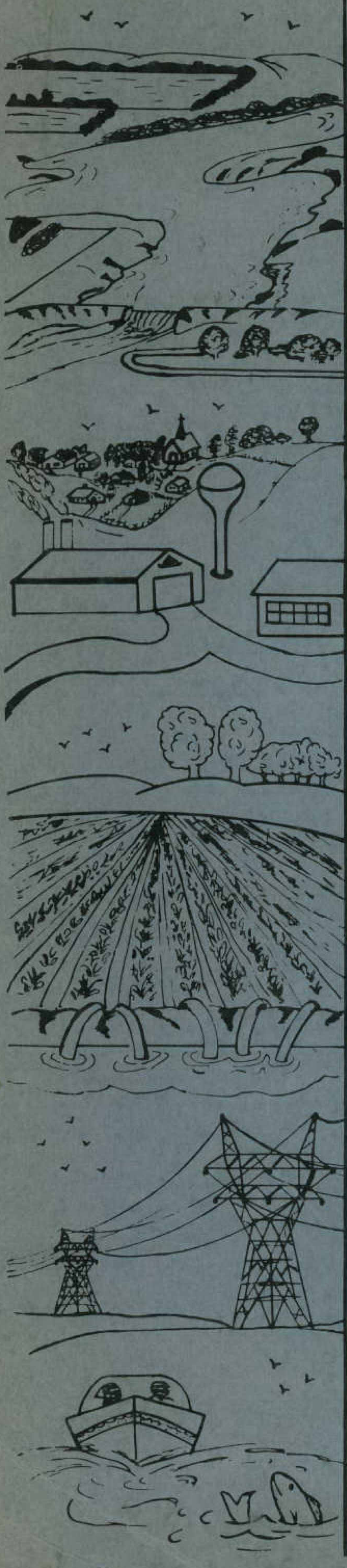


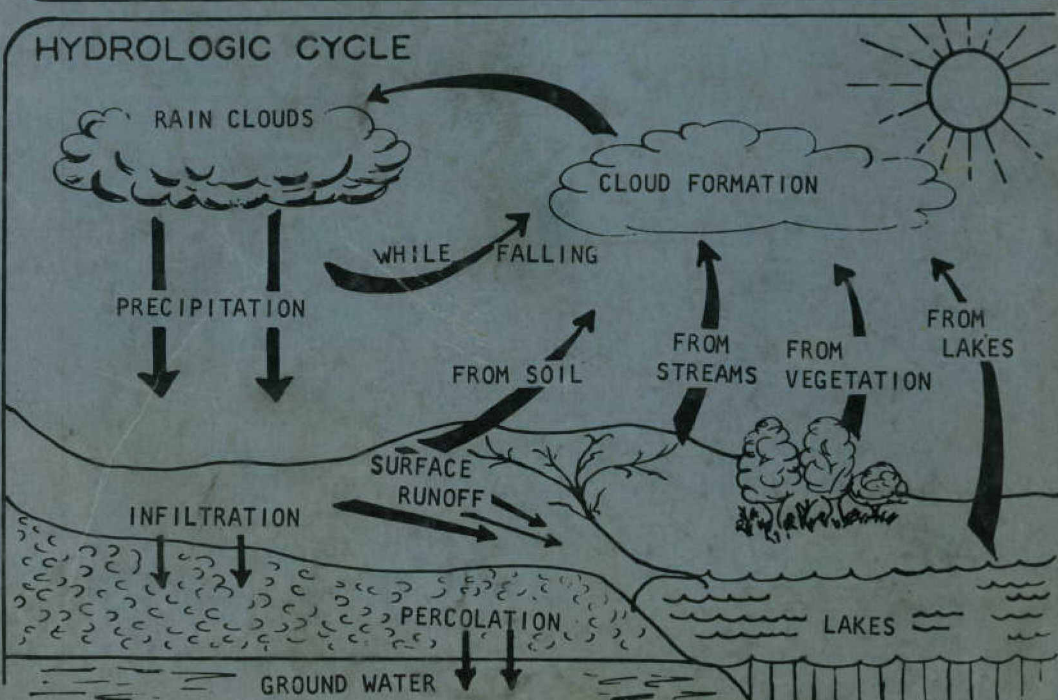
GROUND-WATER SURVEY OF THE RUGBY AREA
PIERCE COUNTY, NORTH DAKOTA
N.D.S.W.C. PROJECT NO. 1341

NORTH DAKOTA GROUND WATER STUDIES
NO. 62

By
Larry L. Froelich, Geologist

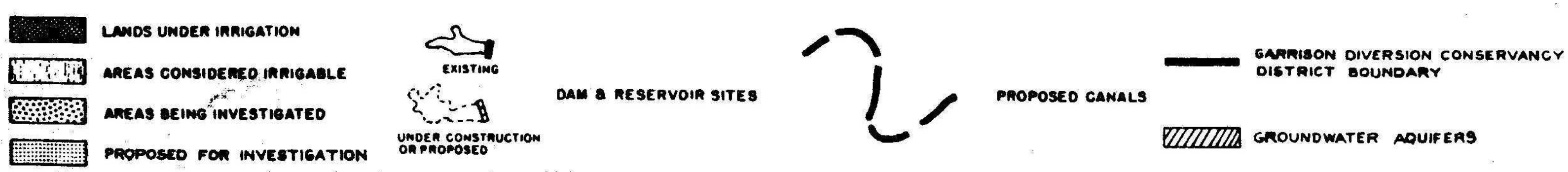
PUBLISHED BY
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
1301 STATE CAPITOL, BISMARCK, NORTH DAKOTA

1965



NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN



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PIERCE COUNTY, NORTH DAKOTA

INTRODUCTION

Purpose and Scope

In October of 1963 the State Water Commission entered into an agreement with the City of Rugby to conduct a ground-water survey of the Rugby area. Preliminary planning began early in 1964 and actual field work began about the middle of May. The purpose of this survey was to locate an adequate supply of good quality water to be used for a municipal supply.

The survey consisted of a selected well inventory, test drilling and observation well installation, collection of water samples for chemical analyses, the compilation of available existing data and a geohydrologic interpretation of the area. The study was under the direct supervision of the author. Test drilling was done by Lewis and Lanny Knutson. A pumping test was performed on a well drilled by Fred Simpson of Bisbee, North Dakota, following the conclusion of the test drilling program. Chemical analyses of water samples were performed by the State Laboratories Department, Bismarck.

The author is deeply indebted to Mr. Morris Greig and Mr. Liston Grider, Rugby well drillers, whose data and information assisted materially in the interpretation of ground-water conditions in the area. Special acknowledgements are due Mr. Raymond Hanson, Chairman of the Rugby Water Council, Mr. Virgil Hoium, Treatment Plant Manager, Members of the City Council and Mr. Fred Simpson for their fine cooperation.

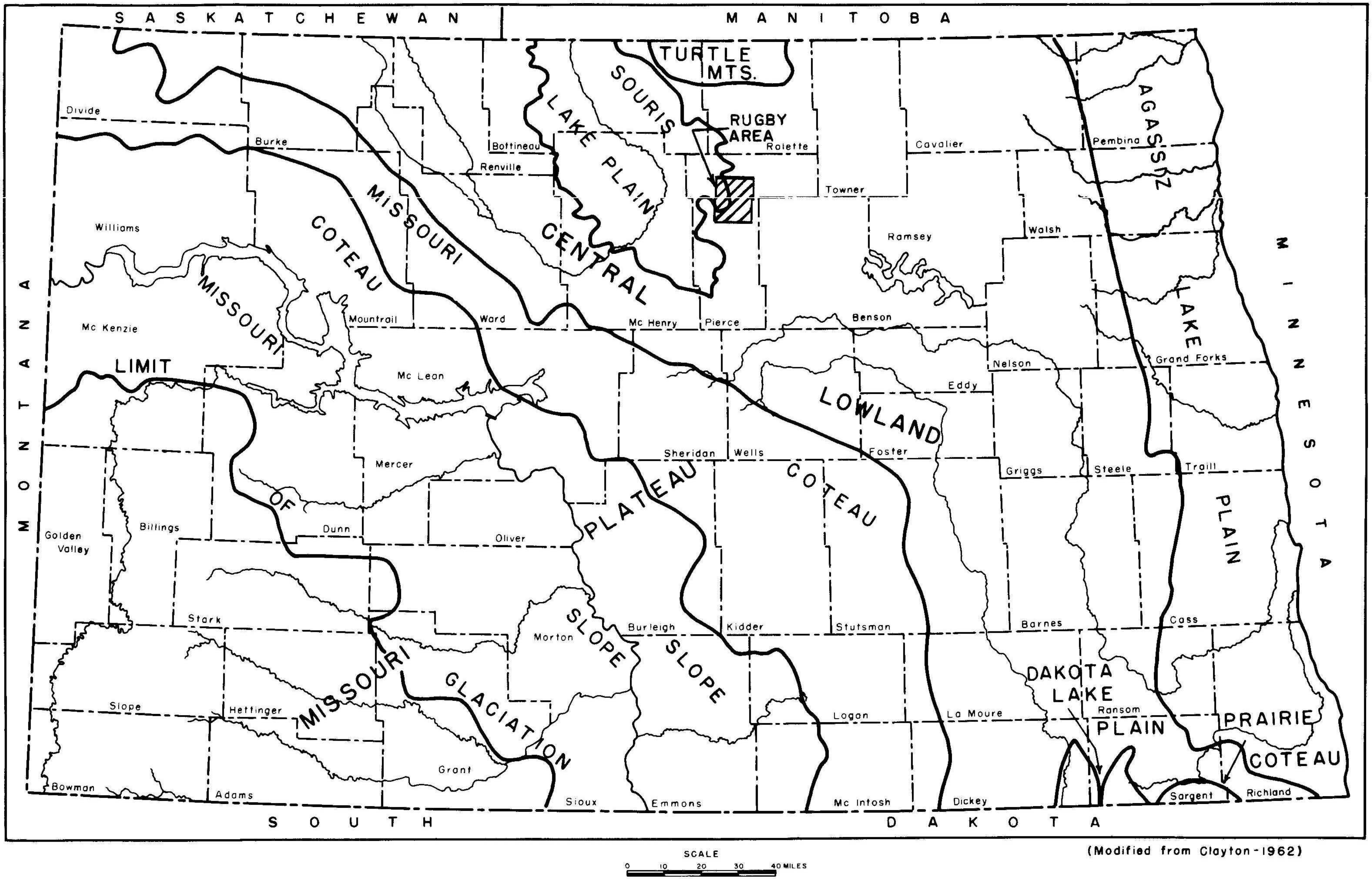

FIGURE I--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC PROVINCES AND LOCATION OF THE RUGBY AREA

Location and General Features

The Rugby area, as described in this report, consists of approximately 120 square miles which includes the western two-thirds of Township 156 North, Range 72 West, all of Township 156 North, Range 73 West and Township 157 North, Range 72 West and the eastern two-thirds of Township 157 North, Range 73 West. A portion of Section 31, Township 157 North, Range 71 West was included in the report as a result of additional test drilling connected with this survey. The entire area is located in the Central Lowland Physiographic Province of North Dakota as shown in figure 1. The northwestern portion of the Rugby area is in the Souris Lake Plain, a topographic feature of the Central Lowlands. Surface elevations vary from 1495 feet above sea level on the west-central edge of the area to 1695 feet in the hills four miles north of Rugby.

The drainage of the Souris Lake Plain in the Rugby area is poorly integrated and consists of a few intermittent streams. The remainder of the area is essentially self-contained and is typified by undulating topography; the lower portions containing lakes, potholes, or sloughs in which runoff from the surrounding land collects.

Rugby, the geographical center of North America, has an estimated (1965) population of 3,500. It is the only population center in the area. Rugby is located on U. S. Highway 2 and State Highway 3 and is served by the Great Northern Railroad. Climatological data of the U. S. Weather Bureau at Rugby shows the average temperature to be 42.6°F based on a 16-year record through 1963. Average precipitation based on a 35-year record through 1963 is 15.73 inches (U. S. Department of Commerce, 1964). Dryland farming and, to a lesser extent, dairying, are the major occupations in the area.

Present Water Supply

The present (1965) Rugby water supply is obtained from four wells located in the northern part of the City. Three previously used city wells have been abandoned. City wells 4 and 5 are located on the corner of 2nd Street NW and 3rd Avenue NW. Both were drilled to a depth of 70 feet by McCarthy Well Company in 1954. Both are 16 inches in diameter, set with 12-foot screens, and gravel packed. Well 4 is equipped with a Jacuzzi submersible pump, well 5 with a Layne turbine. The initial capacity of the two wells was approximately 600 gallons per minute (North Dakota State Department of Health files). City wells 6 and 7, located on the corner of 2nd Avenue NW and 2nd Street NW, were drilled to a depth of 68 feet by Liston Grider in 1958 and 1961 respectively. Both are 10 inches in diameter, set with 10-foot perforated casing, and equipped with Fairbanks-Morse turbines. The initial capacity of both wells was approximately 400 gpm (North Dakota State Department of Health files).

The aquifer in which the four city wells are developed consists of from 22 to 26 feet of poorly sorted sand and gravel. Although the areal extent of the aquifer is not known, it is the general consensus of local well drillers that it is confined to the northern part of the city and may be localized to within an area of 6 acres. Numerous private wells drilled throughout the city attest to this figure.

For the past ten years the water level of the city aquifer has been steadily declining. Early in January, 1965, the decline began to seriously affect the pumping rate of the city wells. In November, 1964, the capacity of the four wells pumping simultaneously was about 375 gpm. By January, 1965, the capacity was about 325 gpm; in February it had lowered to a rate of 260 gpm, and in March pumping had to be restricted to 10 to 12 hours a day at a rate of 180 to 220 g.p.m.; most of the water being pumped from wells 4 and 5 (Virgil Hoium, personal communication).

Well 7 was shut down in January when it began pumping intermittently, probably due to incrustation of the perforated casing. The water levels in Wells 4 and 5 were below the top of the screen while the wells were being pumped. Well 6 could not be measured but the water level is believed to have also been below the top of the perforated casing. The steady decline of the water level indicates the aquifer is being gradually dewatered. If the present rate of dewatering continues without significant spring recharge, the aquifer may not be capable of yielding sufficient water to meet municipal demands by the Summer of 1965.

Table 1 lists the monthly water usage, in gallons, as recorded at the water treatment plant since 1959. The figures include losses, city use, and metered water throughout the water supply system. A gradual increase in water consumption can be seen from 1959 through 1963. The decrease of 8,478,300 gallons from 1963 to 1964 may be due to the unseasonably cool and wet weather during 1964 and a reported malfunction in the recording equipment at the treatment plant (Virgil Hoium, personal communication).

Table 1 -- Monthly water usage as recorded
at the Rugby treatment plant since 1959

	1959	1960	1961	1962	1963	1964
January	3,503,800	3,522,900	3,963,400	4,153,700	4,512,000	5,130,800
February	2,999,200	3,164,900	3,229,700	4,225,600	4,406,300	4,644,100
March	3,697,000	3,755,100	3,478,700	4,691,300	5,064,300	4,681,300
April	3,504,400	3,578,000	3,817,100	4,321,600	4,578,500	4,192,500
May	4,398,000	4,081,000	4,735,500	4,282,400	5,239,600	4,806,900
June	5,235,500	4,727,800	7,811,500	4,678,500	4,855,600	4,838,600
July	5,574,700	6,839,000	5,533,500	5,462,700	6,979,700	5,493,300
August	5,420,800	4,859,900	6,811,800	6,325,900	6,107,800	5,304,400
September	3,734,500	4,053,000	3,689,000	5,467,300	6,135,400	4,315,600
October	3,511,800	4,126,000	4,058,600	5,012,000	5,975,900	3,968,600
November	3,347,000	3,606,900	3,676,700	4,823,700	5,285,800	4,142,000
December	3,735,800	3,910,600	4,131,700	4,355,800	5,149,800	4,297,300
Annual Total	48,662,500	50,227,100	54,937,200	57,800,600	64,295,700	55,817,400

Wells 4, 5, 6, and 7 have provided sufficient water to meet municipal demands up to the present time (March 1965). The major problem, and the reason this study was instigated, is the poor quality of the water being used. Raw water from the city wells is highly mineralized, contains excessive sulfates and iron, and is extremely hard. A treatment plant was built in 1957 to enhance the quality of the water. Soda ash and lime are introduced into the raw water to soften it and eliminate the iron. Although this is accomplished successfully the sodium concentration is built up in the process. Since low-sodium water is a requisite for persons on salt-free diets, Rugby doctors and the State Department of Health strongly recommended that better quality water be sought for the municipal supply. It is presently costing the city 40 to 50 cents to treat 1,000 gallons of the raw well water.

Water storage facilities in Rugby consist of a 50,000 gallon overhead reservoir located near the corner of 1st Street NW and Main Avenue and a 180,000 gallon reservoir at the treatment plant located at the north end of 4th Avenue NW. Water mains and laterals, as well as sewage facilities, are adequately distributed throughout the city. The sewage plant and lagoon are located southwest of the city limits.

Previous Investigations

A general study of the geology and ground-water resources of Pierce County was made by Simpson (1929,pp. 187-189) in which he discusses water-bearing strata in the county. Abbott and Voedisch (1938,pp. 70-71) include chemical analyses of two of the older city wells.

McCarthy Drilling Company drilled 8 or 10 test holes for Rugby in 1949 or 1950 in an attempt to locate a water supply for the city. All holes were drilled within the city limits. No suitable aquifers were encountered.

Lemke (1960) discusses broad regional geologic features of the Rugby area in his study of the Souris River area.

The State Department of Health (1964) lists chemical analyses from 3 city wells and from the tap at the treatment plant in their compilation of chemical analyses of municipal water supplies in North Dakota.

Well-numbering System

The well-numbering system used in this report, illustrated in figure 2, is based on the location of the well or test hole in the Federal system of rectangular surveys of public lands. The first number denotes the township north and the second number denotes the range west, both referred to the Fifth principal meridian and base line; the third number denotes the section in which the well or test hole is located. The letters a, b, c, and d designate respectively the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). Thus well 157-73-15daa would be located in the NE¼ NE¼ SE¼ Section 15, Township 157 North, Range 73 West. Consecutive terminal numerals are added if more than one well is located in a 10-acre tract.

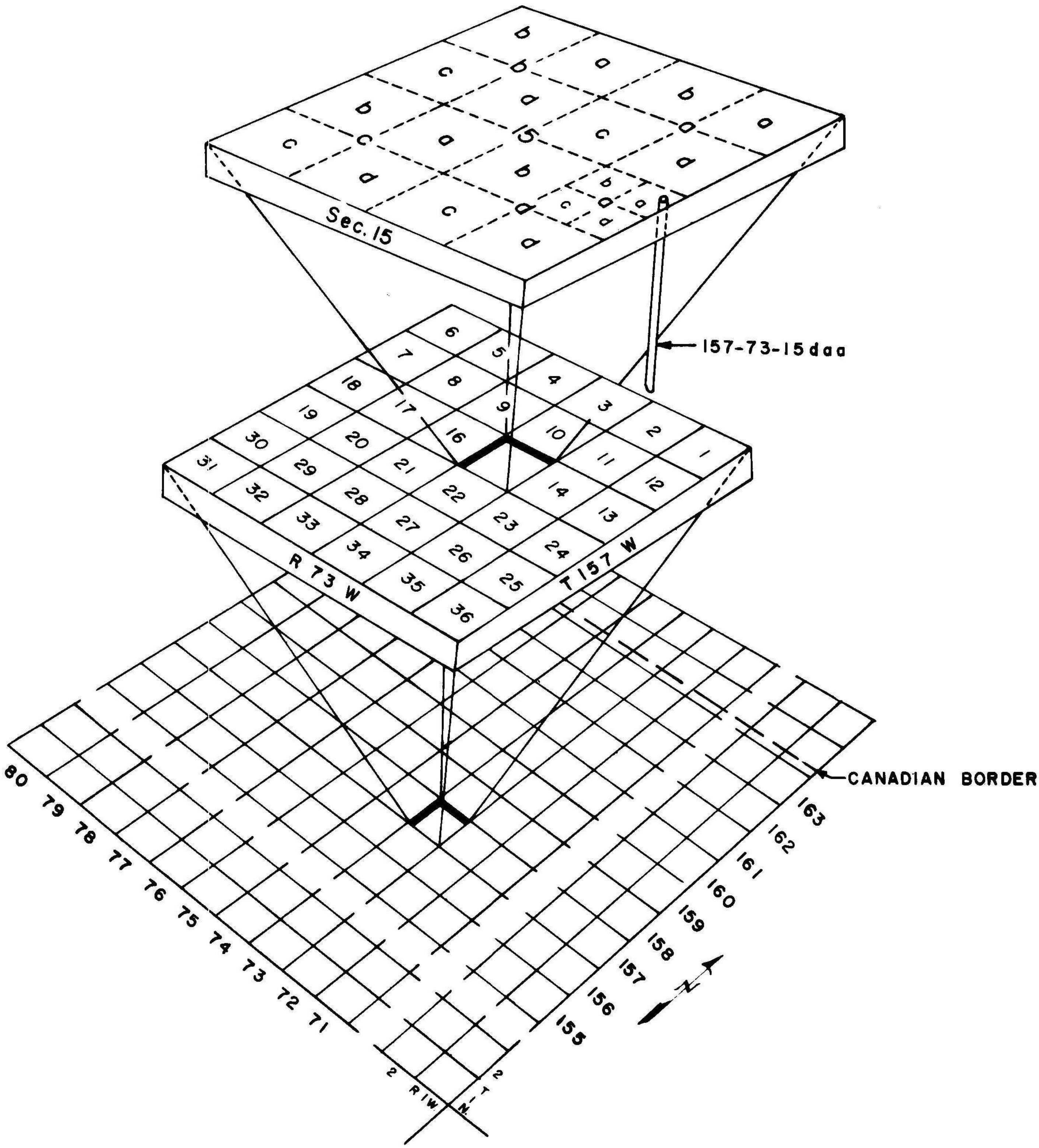

FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

GEOLOGY AND OCCURRENCE OF GROUND WATER

Contrary to the popular belief that ground water occurs in "veins" or underground rivers and lakes, scientific investigations have proven that nearly everywhere, at varying depths, the porous material composing the earth's crust is saturated with water. It is the geologic structure and composition of the material that determines whether water can be withdrawn in sufficient quantity for an intended purpose from a well penetrating the material. Since the occurrence of ground water is dependent upon geologic relationships, the two must be examined simultaneously to determine the availability of ground water in any given area.

Bedrock

Surficial deposits in the Rugby area consist entirely of material which accumulated during and after Pleistocene glaciation. The glacial deposits, in turn, are underlain by approximately 5000 feet of consolidated sedimentary rocks. Composed essentially of shale, sandstone, limestone and dolomite, these rocks represent formations of the Ordovician, Silurian, Devonian, Mississippian and Cretaceous Systems of geologic time.

Two formations of the Cretaceous System, the Pierre Shale and the Fox Hills Formation, were encountered during test drilling. Formations below the Pierre Shale were not considered in this survey because of their depth and the tendency to contain highly mineralized water. The "Dakota Sandstone", an extensively utilized aquifer in southeastern North Dakota, may be encountered at a depth of approximately 1850 feet in the Rugby area. The formations of the Dakota Group may attain a thickness of approximately 300 feet at Rugby (Inferred from N.D.G.S. Circulars 30, 107, 126, and 149).

Pierre Shale--The Pierre Shale was encountered in test holes 1, 24, 25 and 26 (Figure 3, Table 5). In test holes 24, 25 and 26, it was overlain by 36 to 74 feet of glacial deposits; whereas in test hole 1, it was overlain by 82 feet of glacial deposits and 223 of younger sedimentary rocks believed to represent the Fox Hills Formation. The altitude on the upper surface of the Pierre Shale in test holes 24, 25 and 26 was 1498, 1489 and 1460 feet, respectively. In test hole 1 the Pierre Shale was encountered at 1273 feet above sea level. This displacement of approximately 200 feet is anomalous because the Fox Hills Formation, at all known exposed and traceable contacts, is found to conformably overlie the Pierre Shale.

The material described as Pierre Shale in this report consists of hard, brittle, fissile, noncalcareous, olive black shale. The upper few feet of the shale was usually found to be highly fractured. Drilling time is considerably reduced in the Pierre Shale, as compared to overlying deposits, because of its tightly consolidated nature.

Local drillers report several wells have been developed in the Pierre Shale, especially in the southern part of the Rugby area. The wells, usually 4 to 6 inches in diameter, produce small quantities of soft moderately mineralized and sometimes salty water. Recharge is from overlying materials, but, due to the low permeability of the shale, the wells are generally limited to a capacity of 3 or 4 gpm. Water in shale wells is usually under low hydrostatic pressure.

Fox Hills Formation--Consolidated strata overlying the Pierre Shale, and tentatively ascribed to the Fox Hills Formation, were encountered in all but test holes 24, 25 and 26 (Figures 3, 4a and 4b, Table 5). The strata consist of light gray to olive gray shale interbedded with or overlain by sandstone and siltstone. Carbonaceous material (decayed vegetation), limestone concretions and bentonite (volcanic ash) were observed in several test holes. No fossils were found in the test hole cuttings to establish the age of these strata.

Apparently the Fox Hills Formation in the Rugby area consists of two separate members; an upper sandstone member and a lower shale member. The noncalcareous sandstone is generally fine-to medium-grained and dark greenish gray in color. Although it contains variable amounts of clay, it is usually soft and friable. It consists almost entirely of grains of quartz, feldspar, glauconite, lignite and mica which are commonly subrounded. In places the upper member is interbedded with gray shale and contains thin sandstone and siltstone strata (See Table 5). The lower member is essentially a soft, massive, silty shale, usually light-to medium-gray in color. Although quite uniform, it does contain variable amounts of silt and very fine sand. Varying from slightly to moderately calcareous, the shale also contains thin lenses or layers of light blue, noncalcareous bentonite. Even though the lower member is tightly consolidated, the drilling rate in it is much faster than in the Pierre Shale.

The anomaly involving an approximate 200-foot displacement between the upper surface of the Pierre Shale in test hole 1, northeast of Rugby, and test holes 24, 25, and 26, southwest of Rugby, may have at least three possible explanations. First there is the possibility of geologic structure in the bedrock. Secondly the lower member of the Fox Hills Formation as ascribed herein may, in actuality, be the Pierre Shale. Thirdly because no fossils were found to positively identify the strata above the Pierre Shale as the Fox Hills

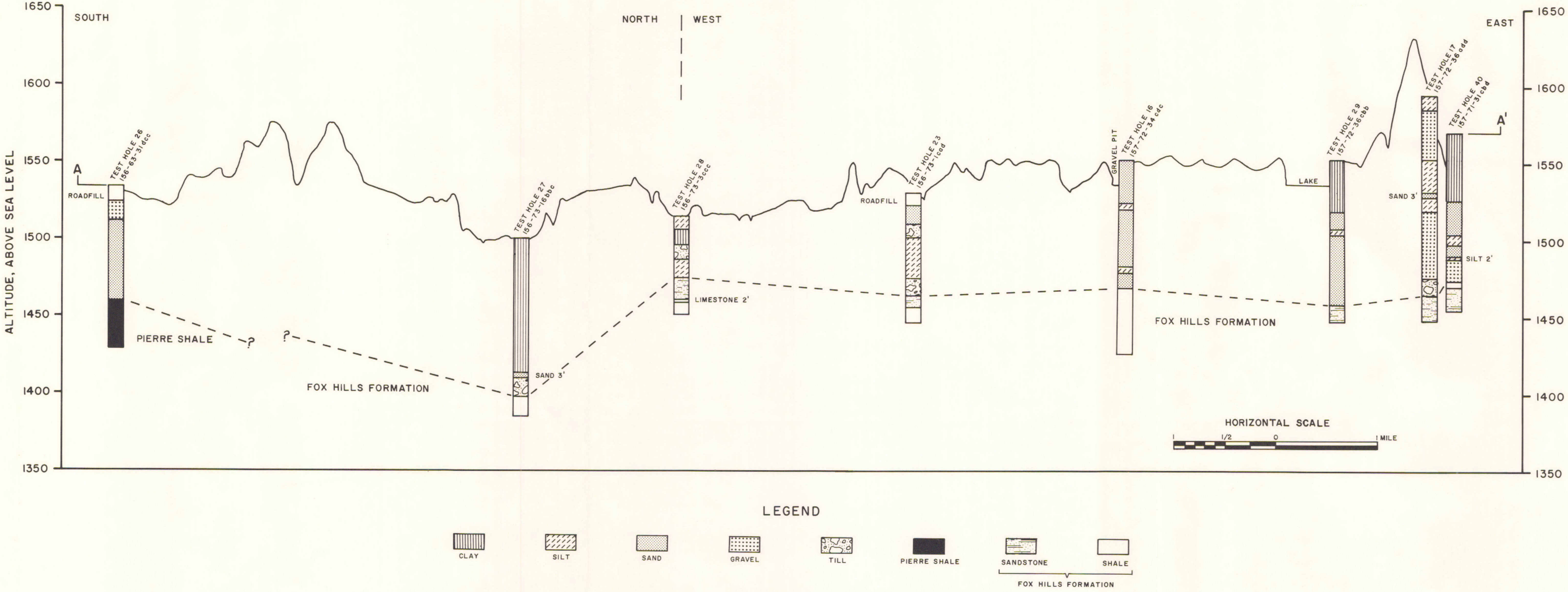

FIGURE 4a--GEOLOGIC CROSS-SECTION A-A'
(LOCATION OF SECTION A-A' SHOWN IN FIGURE 3)

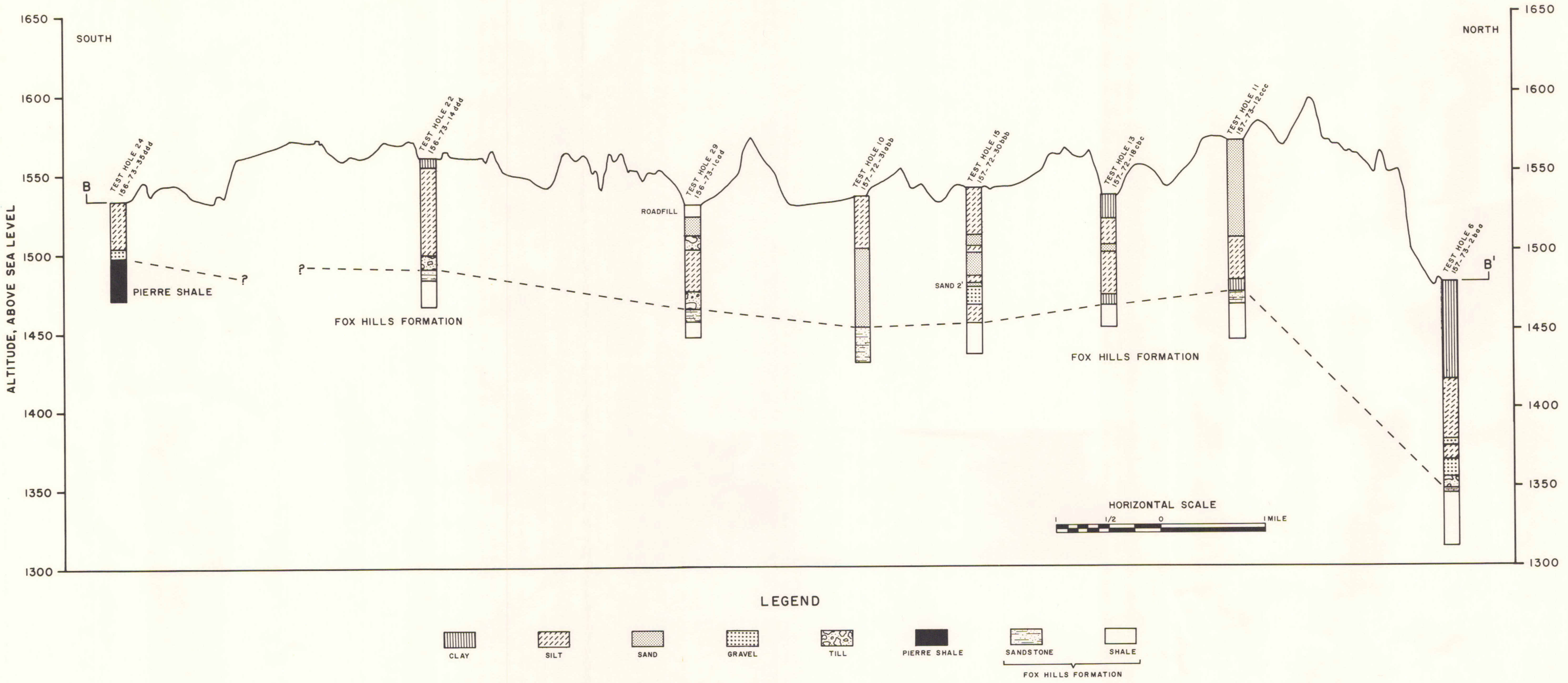

FIGURE 4b--GEOLOGIC CROSS SECTION B-B'

(LOCATION OF SECTION B-B' SHOWN IN FIGURE 3)

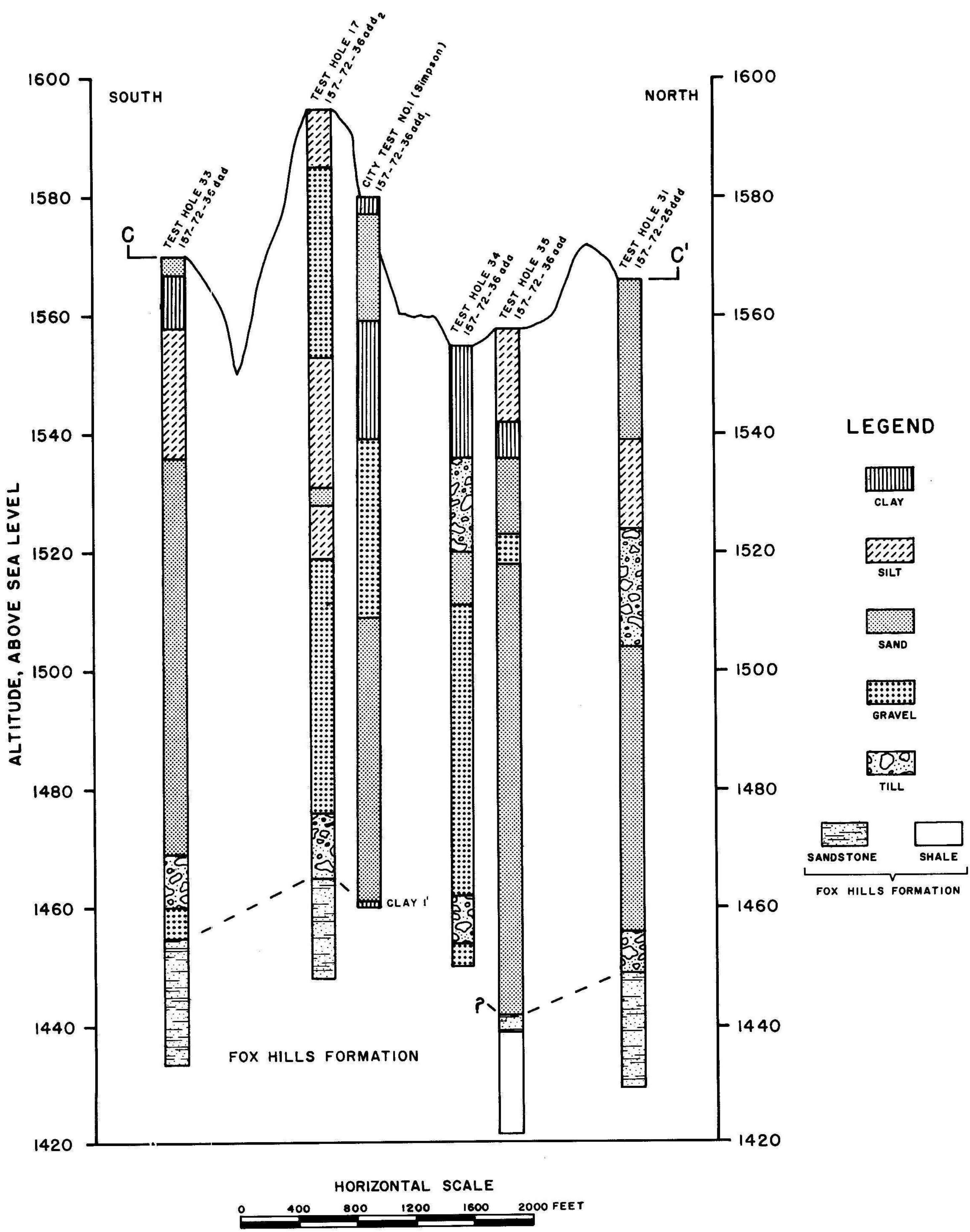

FIGURE 4c -- GEOLOGIC CROSS-SECTION C-C'

(LOCATION OF SECTION C-C' SHOWN IN FIGURE 3)

Formation, it is possible that the formation may have been deposited after Cretaceous time and may not be the Fox Hills Formation at all.

The type of geologic structure which possibly exists in the Rugby area cannot be determined with present available data nor is it within the scope of this report to discuss the problem. Two possibilities, however, are a fault between test holes 24, 25, and 26 and test hole 1 or a syncline with its axis somewhere north of test hole 1. A fault having the upthrown side to the south would account for the Pierre Shale at a lower altitude in test hole 1, however, the existence of a fault with a displacement of 200 feet in this area seems unlikely based on available data. A syncline with the strata dipping towards the north in the Rugby area would seem more probable and would also account for the Pierre Shale being lower in test hole 1. Lemke (1960, pp. 104-108) discusses direct evidence of structure of Upper Cretaceous and Tertiary rocks in the Souris River and adjacent areas along with problematical and indirect inference of structure in North Dakota and Saskatchewan and Manitoba, Canada. He made no specific mention of the Rugby area, however.

If the shale, herein ascribed to the lower member of the Fox Hills Formation, is the Pierre Shale, the altitude of its upper surface in test hole 1 would be 1461 feet, corresponding favorably with the altitude of 1460 feet on the Pierre Shale in test hole 26. It is conceivable that local geologic conditions during the deposition of the Pierre Shale and Fox Hills Formation could have resulted in facies changes within the formation, however, it seems unlikely that such a pronounced lithologic change involving 188 feet of shale would occur in so short a distance (approximately 9 miles).

In the event geologic structure is absent in the Rugby area, the sediments younger than the Pierre Shale must have been deposited on an erosional surface of the Pierre Shale. If such is the case, the younger sediments encountered during test drilling are probably not the Fox Hills Formation because of the apparent unconformity between these sediments and the Pierre Shale.

The nearest outcrop of Fox Hills sediments known to the author is located approximately 27 miles southeast of Rugby along the east shore of Buffalo Lake in the NW$\frac{1}{4}$ Section 12, Township 152 North, Range 72 West. Here, exposed in a roadcut, indurated glauconitic sandstone strata are bowed up in the form of an anticline. Fossils, especially HALYMENITES MAJOR, characterizes the Fox Hills sediments at this site. Although more highly oxidized and iron-stained, the sandstone strata at Buffalo Lake closely resemble that encountered in the Rugby area.

Because of the similarity of the sandstone strata at Buffalo Lake and that in the Rugby area, the upper member of the sediments above the Pierre Shale are herein ascribed to the Fox Hills Formation. Owning to the geologic structure in the bedrock observed at Buffalo Lake, it is not impractical to assume some type of geologic structure also exists in the Rugby area. If the upper member is Fox Hills as assumed, the light gray shale overlying the olive black Pierre Shale must either be Pierre Shale or the Fox Hills Formation. Because there is such a pronounced lithologic change between the light gray shale and typical Pierre Shale, it has been ascribed to the lower member of the Fox Hills Formation in this report.

The lower member of the Fox Hills Formation is not an aquifer in the Rugby area, and because of the very fine-grained nature of the deposit it does not readily yield water to wells. The upper member where present, however, constitutes a significant ground-water reservoir. Locally termed "black sand," wells penetrating significant thicknesses of the sand are reported to have yielded 26 gpm for a short period. Wells, generally 4" in diameter, yield adequate and reliable quantities of water for ordinary domestic and stock-watering demands from the upper member. Many farmers throughout the Rugby area favor this water to that of overlying glacial aquifers because it is generally softer. As in the Pierre Shale, the water in the upper member is also under low hydrostatic pressure. There are no wells, either in the Pierre Shale or the upper member of the Fox Hills Formation, that are known to be flowing in the Rugby area.

Glacial Drift

All unconsolidated materials overlying the Pierre Shale and/or the Fox Hills Formation in the Rugby area are collectively termed glacial drift. There are, however, recent deposits of windblown silt and sand and stream-deposited alluvium occurring within the area. These recent deposits are generally too thin to constitute a significant source of ground-water supply.

The thickness of glacial drift encountered during test drilling varied from 36 to 171 feet and averaged about 86 feet. The drift unconformably overlies the upper surface of the bedrock which usually varies from an altitude of 1450 to 1500 feet. Bedrock valleys were discovered at the sites of test holes 27 (156-73-16bbc) and 6 (157-73-2abb) (Figures 3, 4a and 4b). These valleys probably contained tributaries to a major preglacial drainage system.

The glacial geology of North Dakota is extremely complex and not yet fully understood. Based on available data, however, it is believed the majority of glacial drift in the Rugby area is the result of deposition by the Souris Lobe of the Mankato Substage of the Wisconsin Stage of Pleistocene Glaciation. How many lobes of earlier glacial advances which may have crossed the area is not known.

During Mankato time, nearly all glaciers advanced across the State from the northeast. One exception was the Souris Lobe which flowed up the Souris River valley from the northwest. The linear ridges concentrated south of Rugby (See Figure 5) indicate the direction of ice movement in the Rugby area.

The Souris Lobe extended very little beyond the Rugby area. Its limits are indicated by a lobate belt of hilly topography known as the Martin Moraine. This moraine trends due south from the southeast edge of the Turtle Mountains (See Figure 1) through Rolette County, through Range 70 and 71 of Township 147 and 148 of Pierce County, and into Benson County to a point near Long Lake approximately 6 miles south of the Village of Pleasant Lake. From Long Lake the moraine swings southwestward through southern Pierce County and into Sheridan County where it comes in contact with the Missouri Coteau which it borders northwestward into southeastern Ward County.

The Martin Moraine indicates the maximum advance of the Souris Lobe. Lemke (1960, p. 116) states, ". . . a total thickness of more than 1,000 feet of ice is indicated for the glacial Lake Souris area at the time of maximum advance of the Mankato Substage."

As the Souris Lobe passed over the Rugby area it eroded irregularities on the bedrock surface and altered or removed previously deposited glacial material. In some test holes a tightly compacted material composed of silt, sand, pebbles and occasionally cobbles embedded in a blue-gray clayey matrix was encountered overlying bedrock. This material, called till, is a result of deposition by ice with no sorting by water. Occasionally, water-laid sand and gravel is encountered within or underlying the till. This till is uncommon throughout the area and is believed to have been deposited prior to the advance of the Souris Lobe.

The majority of glacial deposits and their attendant topographic features are the result of accumulation as the ice of the Souris Lobe melted. Apparently the ice of the Souris Lobe did not retreat from the Rugby area in an orderly fashion. Rather, it seems to have stagnated and melted in place.

Material which had been incorporated into the glacial ice during its advance was deposited in various ways. Where the material was dumped with little or no sorting by meltwater, hills composed essentially of till were formed. These topographic features are termed end moraine or recessional moraine (See Figure 5). Ice contact deposits are topographically similar to end moraines but consist of sorted and stratified sediments which accumulated on or within masses of melting stagnant ice. Where meltwater channels were established among or away from the deteriorating blocks of ice, outwash deposits of sorted sand and gravel were formed. However, if the meltwater was ponded, lacustrine silt and clay accumulated. Some of the outwash deposits and lacustrine silt and clay are combined and shown as the stratified drift plain in figure 5.

As the terminus of the Souris Lobe melted and receded towards the northwest, the meltwater from the ice was confined between the ice front and the Martin Moraine. A large lake, called glacial Lake Souris, was created. Glacial Lake Souris deposits are found up to an altitude of about 1540 feet in the Rugby area, however, the water level of the lake may have risen to 1570 feet or more during its early stage.

As the melting continued, Lake Souris eventually drained into the James and Sheyenne River basins through a series of diversion channels in southern McHenry and Pierce Counties. With the final retreat of the Souris Lobe, natural drainage toward the north was re-established and the water of glacial Lake Souris emptied into the Hudson Bay drainage system.

End Moraines--End moraines are confined to the southeastern part of the Rugby area. As previously mentioned, end moraines are topographic features of variable lithologic composition which were dumped, in place, at the terminus of a mass of ice. They are characterized by a conspicuous hummocky surface of higher relief than the surrounding plain.

End moraines are usually composed of glacial till. In the Rugby area, however, the till of the Souris Lobe appears to have been derived from stratified silt and sand. Therefore the till lacks the pebbles, cobbles and boulders which are so commonly associated with other end moraines in the State. The significance of this may be that while other glacial advances encroached across the State from the northeast over granite and indurated limestone terrain, the Souris Lobe passed over soft shale and sandstone terrain and probably over previously deposited stratified drift.

Till, because of its generally heterogeneous nature, constitutes a poor aquifer. Even though the till of the Souris Lobe appears to be more permeable than till of other glacial advances, it is doubtful if a well developed in it would yield any large quantity of water. Generally associated with the till, however, are water-laid sand and gravel deposits which may yield sufficient and reliable quantities of water for ordinary domestic or stock demands. Because of generally limited aerial extent, these deposits may become dewatered if large quantities of water are continuously pumped from the aquifer.

Ice-Contact Deposits--Ice-contact deposits are topographically similar to end moraines. The lithology, however, is more variable than end moraines and, in most cases, completely unpredictable. Flint (1957, p. 146) explains the characteristics of ice-contact deposition.

"Whether accumulation takes place upon, against, or underneath the wasting terminal zone of the glacier, it is likely to be sporatic and irregular, with no intervening distance to smooth out diurnal and seasonal differences in rate of melting and release of sediment. The same site may successively see a rushing stream, a quiet pool, a small avalanche of boulders, and actual overriding by ice, folding or faulting the layers of sediment or smearing till upon them. Ice is likely to melt out from beneath the accumulating sediment, or from a supporting position beside it causing sagging, collapse, slumping, and earth flow. In such a place anything can happen, and it usually does."

The sporatic and irregular nature of accumulation, even within a localized area, is clearly evident by comparison of logs from test holes 17, 31 through 40 and Simpson Test No. 1 (Figures 3,4c, and 5, Table 5). Lithologic variations apparently are quite pronounced even within a few tens of feet, indicating the deposits are collapsed masses of drift which accumulated upon or within stagnating ice and were let down as the ice melted.

The most common constituents of the ice-contact deposits appear to be sand and gravel which may be extremely poorly-sorted to exceptionally well-sorted, or any combination thereof. Associated with the sand and gravel is lake clay and silt and occasionally till. Clay, silt, and till may occur as thin lenses in a borehole or make up the entire lithology above bedrock.

Throughout the Rugby area are found numerous ice-contact features not necessarily associated with the larger collapsed ice-contact deposits. These features include kames, eshers, crevasse fillings, and kettles (Figure 5). Kames are mound-like hills composed essentially of sand and gravel deposited in openings in or on stagnating ice and left in place as the ice melted. Eshers are essentially the same, but were deposited by streams of meltwater which flowed under, within, or upon the ice. They are in the form of narrow sinuous ridges. Short, sometimes linear, ridges similar in composition to kames and eshers are attributed to crevasse fillings. A kettle is a depression or basin in glacial drift, formed by the melting of a block of ice that was partly or wholly buried in the drift. Sloughs and lakes occupy the majority of kettles in the Rugby area.

The linear ridges south of Rugby may be classified as ice-contact features also, but they are probably constructional rather than depositional features. It is believed these ridges were formed as the Souris Lobe moved over the area rather than deposited as the ice melted. Geologic conditions which caused their creation are not clear but general consensus is they are a drumlinoidal feature (See Lemke, 1960, pp. 59-66). In the Rugby area these ridges consist essentially of stratified drift, mainly sand and silt.

Ice-contact deposits are usually a source of ground water, however, the only reliable method of determining whether or not enough water for any intended purpose is available at any particular site is to drill a well and pump it. The specific yield of the well will depend on the depth and thickness of the aquifer, its aerial extent and the degree of hydrologic connection to an available recharge area. Moderately large yields, such as those required for municipal use, industry, or irrigation, will also depend on the type of well construction.

The ice-contact deposits, as a whole, are generally moderately to highly permeable and will allow rapid infiltration of precipitation. They are usually found in areas of self-contained drainage and very little runoff. Springs and seepage areas are commonly associated with the ice-contact deposits. These are discharge areas for the infiltrated water that has reached the water table or has been intercepted by impermeable material above the zone of saturation preventing it from reaching the water table.

Stratified Drift Plain Deposits--The stratified drift plain delineated on figure 5 is a nearly level to gently undulating plain composed of stratified clay, silt, sand, gravel, and till. Judging from test hole data it appears the deposits of the stratified drift plain accumulated as the Souris Lobe crossed the area and also as it retreated from the area. The presence of numerous kettles and an extensive blanket of silt throughout the plain suggests the surficial deposits accumulated exclusively during the recessional stage in a shallow lacustrine environment.

Till is the least common constituent of the stratified drift plain. It generally occurs overlying the bedrock, suggesting it may have been deposited as the Souris Lobe passed over the area. The till of the Souris Lobe is generally very sandy and can easily be distinguished from the more clayey till which probably was deposited during an earlier glacial advance. Till also occurs occasionally at the surface and included within lacustrine sediments. In neither instance do they attain thickness much over 20 feet and probably are not extensive. It is believed these deposits of till accumlated in much the same manner as the material in the end moraines, but on a much smaller scale.

Sand and gravel deposits are found associated with till or completely independent of it. When well-sorted, the deposits can be assumed to have been deposited by melt-water streams; where unassorted, they may have accumulated in conditions similar to ice-contact deposition.

Lacustrine silt and clay are the most common sediments encountered throughout the stratified drift plain and may attain thicknesses of over 50 feet. Significant thicknesses such as 84 feet in test hole 9

(157-72-20ccc) suggest the lake must have endured for quite some time, since the rate of sedimentation in a lacustrine environment is usually quite low. However, if one considers the volume of silt and clay which must have been incorporated into a mass of ice possibly over 1000 feet thick and then released as the ice melted into a fairly local basin, one can perceive how the rate of sediment accumulation would be many times greater than under normal conditions.

Ground-water conditions are variable within the stratified drift plains. Farm wells encountering sand and/or gravel deposits generally supply sufficient water for domestic or stock needs. However, instances are reported where sand and gravel was limited or missing and much difficulty was experienced in developing a well. Sometimes several wells had to be drilled before one yielding 2 or 3 gpm was located.

Where a significant thickness of permeable material is encountered it may be possible to obtain a moderately large supply of water. An example would be test hole 16 (157-72-34cbc) (See Figures 3 and 4a, Table 5). In this area the sand appears to be fairly extensive, but may be completely surrounded by silt. The silt has a very high porosity but, because of the high specific retention, would yield water slowly. Once a well developed in the permeable sand began pumping, the sand would be recharged slowly but continuously by gravity flow from the silt.

Outwash--Outwash is defined as stratified drift deposited by meltwater streams, beyond active glacier ice. Outwash deposits, sorted sand and gravel, occur buried at various depths in association with other sediments (Table 5) and at the surface as shown in figure 5.

Some of the buried outwash may have been deposited in front of the Souris Lobe, or earlier lobes as they crossed the Rugby area. These deposits were subsequently overridden by the ice and are overlain by till or other sediments which accumulated as the ice melted.

The surficial outwash deposits are confined in definite meltwater channels which contained meltwater streams during the wasting of the Souris Lobe or they may occupy an area of less definite boundaries if the sand and gravel accumulated on the ice and collapsed as the ice melted from beneath.

Irregardless of the mode of deposition, the outwash deposits consist almost entirely of sorted sand and gravel with only minor amounts of silt and clay. They are moderately to highly permeable and are a good supply source for wells providing domestic and stock requirements. It is possible that collapsed outwash, usually associated with ice-contact deposits, would yield sufficient water for controlled irrigation or municipal use. Outwash associated with till, however, has a tendency to be lenticular and discontinuous and will be dewatered by continuous pumping. Dugouts for stock watering purposes are common in the outwash in the meltwater channels and most contain water throughout the year.

If a well is to be drilled into outwash for moderate or large quantities of water, the immediate area should be first investigated by test drilling and a pumping test performed on a pilot well. There are several locations in the Rugby area that have possibilities for development providing the quality of the water is not an important factor.

Lacustrine Deposits--Perhaps the only ice-contact deposits in the Rugby area which will not function as an aquifer are those associated with kettles. These depressions contained lakes in which clay and silty clay accumulated as the Souris Lobe melted. The lakes have been considerably reduced in size since Pleistocene time, and now occupy the lowest part of the depression or have disappeared completely. Intermittent lakes, sloughs or perennially soft, spongeous ground now occupy the majority of the area where the larger lakes once stood.

The lacustrine deposits which now occupy the kettles are characterized by flat topography and are essentially impermeable. Spring runoff into these low areas remains to be evaporated or transpired by vegetation. Very little runoff infiltrates to the ground-water table. In fact it is the combination of impermeable lacustrine deposits and ground-water seepage from surrounding more permeable deposits that keeps these areas saturated.

Lacustrine deposits are not a source of supply to wells in the Rugby area. However, because of the highly saturated nature of the clay, dugouts in this material provide sufficient water for livestock. Farm wells must depend on buried outwash or the bedrock for a water supply.

Glacial Lake Souris Deposits--Lake Souris was an ice-marginal lake that enlarged northwestward as the ice front receded in that direction. Lake Souris deposits in the Rugby area accumulated from the meltwater discharge directly off the ice front and inwash from areas exposed above the lake level.

The lake bed has a flat surface with a maximum altitude of 1540 feet in the Rugby area. However, the author believes that glacial Lake Souris reached an altitude of 1570 feet or more during its early stage and, therefore, it is presumed that the lacustrine clay and silt and much material in the stratified drift plain accumulated contemporaneously with the Lake Souris deposits.

Clay and silt are the predominant lithology of the Lake Souris deposits. However, where the lake bordered ice-contact deposits, sand, which washed into the lake from the ice-contact deposits, interfingers with the clay and silt and extends an unknown distance into the lake deposits. The thickness of the Lake Souris deposits is variable, the maximum thickness encountered being 100 feet in test hole 6 (157-73-2baa).

Local well drillers have reported considerable difficulty in developing even low yield farm wells throughout the Souris Lake Plain. This is understandable since the silt and clay deposits are practically impermeable. However, wells, drilled near the ice-contact deposits and which penetrate interfingering sand deposits, are reported to yield adequate farm supplies. Where this sand is absent, buried outwash or the upper member of the Fox Hills Formation must be sought for the water supply.

WATER QUALITY

Ground water in the Rugby area is primarily of meteoric origin. Meteoric water, water precipitated as rain or snow, contains only small amounts of dissolved mineral matter. As soon as it reaches the earth, however, the water begins to react with the minerals of the soil and rocks it comes in contact with. The amount and character of the mineral matter dissolved by meteoric water depends upon the chemical composition and physical structure of the rocks with which it has been in contact, the temperature, the pressure, the duration of contact, and the material already in solution. The solvent action of the water is assisted by carbon dioxide in solution which is derived from the atmosphere and organic processes in the soil through which the water passes.

Quality of shallow water, in general, varies with the quantity; where abundant the water is commonly potable, where scanty it is commonly mineralized. Extent of mineralization, in general, varies directly with depth; deeper bedrock waters being usually more highly mineralized than shallow waters. Deep artesian water is usually highly mineralized. Shallow water is, however, more likely to be polluted from surface sources.

The purity of water as regards the sanitary conditions must be determined by inspection of the source and its surroundings and by bacteriological examination of the water. The condition of a water as regards pollution may change so quickly that the results of an examination at one time do not necessarily bear any relation to the purity of the water at another time. The mineral constituents, on the other hand, are fairly constant in water from a given source, unless the source is a stream that carries different quantities of dissolved material at different stages.

The quality of water for public supply and domestic use is commonly evaluated in relation to standards of the United States Public Health Service for drinking water. The standards, adopted in 1914 to protect the health of the traveling public, were revised several times in subsequent years. The latest revision by the U. S. Public Health Service (1962), is, in part, as follows:

Table 2 - - Drinking water standards of the U. S. Public Health Service

	parts per million
Iron (Fe)	.3
Magnesium (Mg)	125
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	1.5
Nitrate (NO_3)	45
Dissolved Solids	500

Fifteen water samples were collected for chemical analysis in connection with this survey. The analyses, along with seven analyses from previous publications, are included in table 3. All samples, with the possible exception of well 156-73-9adc$_1$, were recovered from glacial drift aquifers.

By comparison of table 2 and table 3 it should be realized that water supplies from wells in the Rugby area may contain excessive concentrations of one or more chemical constituents. A water sample from a questionable well may be collected in a tightly sealed quart jar and sent to the State Laboratories Department or State Department of Health in Bismarck for analysis. The chemical analysis of a domestic

TABLE 3 - CHEMICAL ANALYSES

(analytical results in parts per million except as indicated)

Location	Well Depth (Feet)	Aquifer	Date of Collection	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids: Sum	Dissolved solids: Residue on evaporation at 180° C	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption-ratio	Specific conductance (micromhos at 25° C)	pH
156-73-1b/1 City of Rugby	52	Gravel	5-16-21	-	25	9.1	94	31	32		298	0	145	18	-	.50	-	-	510	362	-	-	-	-	-
156-73-1bba$_1$ Rugby Creamery	60	Sand & Gravel	9- 8-64	50°F	20	2.3	214	69	68	10	463	0	495	61	.3	.00	0.0	1170	1220	820	441	15	1.0	1640	7.4
156-73-1cbc Charles Hamilton	46	Sand	9-10-64	54°F	21	.10	57	20	16	5.1	270	0	39	3.4	.4	0.0	0.0	295	305	226	5	13	.5	505	7.4
156-73-1cca Rugby High School	42	Dark Sand	9- 8-64	64°F	19	.08	74	28	17	5	260	0	113	5.4	.3	8.0	0.0	398	406	300	87	11	.4	658	7.3
156-73-9adc$_1$ Harold Ostrom, Jr.	70	Sand	9- 9-64	48°F	23	.63	19	7.8	157	6.8	489	0	29	3.9	.4	1.0	0.0	489	490	80	0	79	7.6	797	7.5
156-73-31dcc Test Hole 26	60	Sand	6- 5-64	48°F	29	.11	54	14	53	5.3	285	7	58	5.0	.2	7.0	0.0	373	396	192	0	37	1.7	571	8.4
157-72-18bcc Test Hole 12	38	Gravel	6- 1-64	46°F	18	1.2	332	2032	3780	96	1200	0	15,800	244	1.7	0.0	1.3	22,900	25,800	9170	8200	47	-	19,600	8.0
157-72-31abb Test Hole 10	80	Sand	5-28-64	47°F	22	.38	122	32	724	13	474	0	1,480	62	.9	30	0.5	2720	2850	435	47	78	15	3610	8.2
157-72-31/2 City of Rugby	57	Gravel	-	-	34	1.8	152	51	32	-	370	-	301	40	.2	1.3	-	-	871	604	-	-	-	-	-
157-72-31/2 City of Rugby (park)	27	Gravel	-	-	27	.7	78	31	53	-	310	-	168	14	.6	1.3	-	-	477	334	-	-	-	-	-
157-72-31ddc/3 City well #3	68	Gravel	-	-	--	2.5	256	90	173	-	473	0	863	36	Trace	0	-	-	1492	1012	-	-	-	1870	7.3
157-72-31ddc/3 City well #4	70	Gravel	-	-	--	8.3	392	165	500	-	693	0	2,000	45	Trace	0	-	-	2750	1660	-	-	-	3440	7.0
157-72-31ddc/3 City well #5	70	Gravel	-	-	--	3.7	300	87	145	-	512	0	925	34	Trace	0	-	-	1586	1110	-	-	-	1980	7.1
Tap water/3	--	Gravel	-	-	--	0.0	24	29	400	-	183	24	963	47	1.1	0	-	-	1670	180	-	-	-	2820	8.3
Rugby Treatment Plant Raw water	--	Sand & Gravel	9-10-64	48°F	22	2.5	284	95	205	16	517	0	1,050	38	.4	0	0.0	1970	1980	1100	677	28	2.7	2400	7.4
Rugby Treatment Plant Treated water	--	Sand & Gravel	9-10-64	50°F	10	0.2	32	12	558	14	248	18	1,030	45	.8	0	0.0	1840	1860	130	0	89	21	2520	8.8
157-72-34cbc Test Hole 16	80	Sand	6- 2-64	48°F	22	.48	80	92	820	11	858	0	1,500	86	.9	0.0	1.7	3030	3220	580	0	75	15	3970	8.2
157-72-36add$_1$ * Simpson Test #1	119	Sand & Gravel	1-20-65	44°F	22	.15	34	18	30	5.8	218	0	38	3.0	.2	0.0	0.0	258	270	157	0	28	1.0	443	7.3
157-72-36add$_1$ ** Simpson Test #1	119	Sand & Gravel	1-21-65	44°F	23	.31	36	18	31	6.1	231	0	40	3.5	.2	0.0	0.0	272	273	166	0	28	1.0	464	7.4
157-72-36add$_2$ Test Hole 17	120	Gravel	6- 2-64	48°F	21	.20	60	17	34	5.2	317	0	34	6.0	.3	9.0	.5	343	357	222	0	24	1.0	560	8.2
157-73-10acc Clinton Hamilton	31	Sand	9-10-64	46°F	18	.18	109	49	12	8.8	408	0	159	11	.4	0.0	0.0	568	574	475	141	5	.2	890	7.3
157-73-25abb J. M. Anderson	60	Detrital Lignite	9- 8-64	48°F	24	3.0	51	19	104	11	376	0	119	8.8	.5	2.0	0.0	527	532	206	0	51	3.2	830	7.4

/1 Simpson, 1929
/2 Abbott & Voedisch, 1938
/3 North Dakota State Department of Health, 1964

* Beginning of pumping test
** After 26 hours of pumping

water supply will ordinarily include the determination of total hardness, dissolved solids, alkalinity, pH, and the presence of iron, sulfates and chlorides. Each agency will briefly discuss the chemical characteristics of the water sample and, in some instances, make recommendations.

The sodium concentration of ground water was carefully noted throughout the investigation. The presence of sodium in water may affect persons suffering heart, kidney, or circulatory ailments. When a strict sodium-free diet is recommended, any water should be tested and persons so affected should rely on their physician's advice. Water, especially water that has been softened, should be analyzed for sodium when a precise rate of individual sodium intake is recommended. Because individual intake of sodium varies, no recommended limit for sodium is established.

TEST DRILLING AND PUMPING TEST ANALYSIS

Since the primary purpose of this survey was to locate an adequate supply of good quality water, all test holes encountering a potential aquifer during the initial phase of test drilling were developed as observation wells and water samples were collected for chemical analysis. The initial phase of test drilling included test holes 1 through 29. The chemical analyses indicated two potential aquifers containing exceptionally good quality water. They are at the sites of test hole 17 (157-72-36add$_2$) and test hole 26 (156-73-31dcc) (See Figure 3, Tables 3, 4, and 5).

Because test hole 17 is nearer to Rugby than test hole 26, test holes 30, 31 and 32 were drilled in an effort to delineate the aquifer north of test hole 17. The aquifer was absent at the site of test hole 30, however, 48 feet of sand was encountered in test hole 31. The sand was encountered at an altitude of 1504 feet as compared to 1519 feet at the top of the aquifer in test hole 17 (See Figure 4c). Unfortunately an observation well was not installed from which water levels and chemical analyses from test holes 17 and 31 could be compared, therefore making it difficult to determine whether or not the aquifer in test hole 31 was hydraulically connected to that in test hole 17. The most valuable information gained from the three test holes was the discovery of 27 feet of surface sand in test hole 30 and 25 feet in test hole 31. A preliminary soils map of Pierce County, prepared by the Department of Soils of the Agricultural Experiment Station located at North Dakota State University in Fargo, shows a fairly extensive outwash plain including and toward the northeast of test holes 31 and 32. If the surface sand encountered in test holes 31 and 32 is continuous and hydraulically connected to the outwash to the northeast, conditions favoring a recharge area of several hundred acres are indicated for the aquifer encountered in test holes 17 and 31.

On the basis of the above test hole and quality water data, it was recommended to the City Council that a pilot well be developed and pumped in the vicinity of test holes 17 and 31. The Council, however, wisely elected to have more test holes drilled in order to determine the feasibility of drilling the pilot well. A supplemental agreement with the State Water Commission resulted in the drilling of test holes 33 through 40 around the site of test hole 17 (See Figure 3, Table 5).

All supplemental test holes, with the exception of test holes 36 and 39, encountered variable but significant thicknesses of saturated sand and gravel. The combination of all test hole data in the area indicated an irregular surface on the bedrock which is in turn, overlain by extremely variable glacial ice-contact lithology. Although variable, the ice-contact deposits consisted essentially of sand and gravel (Figure 4c), therefore indicating some degree of hydraulic connection. It was then decided by the City Council that a pilot well would be feasible, even though consideration was given to the fact that areas of no flow in the vicinity of test holes 36 and 39 could be expected.

The firm of C. A. Simpson and Son, Bisbee, was contracted to drill the pilot well. The 8-inch well was completed with a 10-foot Number 20 slot Johnson screen from 109 to 119 feet. The well is believed to have penetrated the full thickness of aquifer. It was naturally developed. A sieve analysis of the material in the section screened showed approximately 90% to be medium sand or coarser. Approximately 20% was very coarse sand and gravel. The well is located 320 feet north of test hole 17.

The pilot well was completed in December of 1964, however, inclement weather prevented pumping until the latter part of January, 1965, at which time Milton Lindvig, Ground-water Engineer for the State Water Commission, and the author, assisted by Mr. Fred Simpson, conducted a pumping test. The well was pumped at a rate of 190 gpm for 48 hours. The static water level of 44.86 feet lowered 3.50 feet within 5 minutes of pumping, but after 48 hours there had been but a total of 4.61 feet of drawdown. A total of 1.02 feet drawdown was observed in test hole 17. The specific capacity of the pumped well was about 41 gpm per foot of drawdown, however, the transmissibility varied from 39,500 gal./day/ft. to 132,000 gal./day/ft. (Lindvig, February 26, 1965, unpublished report). Transmissibility is the rate of flow of water in gallons per day through a vertical strip of aquifer 1 foot wide and extending the full saturated height under a hydraulic gradient of 100 per cent at a temperature of 60°F.

An accurate analysis of the pumping test is limited because the pumping rate was too low to achieve complete analytical data. Mechanical difficulties prevented a higher pumping rate. However, two interesting hydrologic characteristics were noted by Lindvig during the test. After about 900 minutes of pumping, the slope of the curve formed by drawdown data increased for both wells. The increase in slope is believed to indicate that the cone of depression formed by the pumped well encountered a no-flow boundary. After 1900 minutes the curve slope decreased sharply. Lindvig attributes this to discharge water from the well percolating into and recharging the aquifer. This decrease was not noted in test hole 17 which is uphill from the discharge area. Based on the data collected during the test, Lindvig feels no single well should be expected to yield more than 400 gpm and suggests a spacing of 1000 feet between wells.

RECOMMENDATIONS

Test drilling, water quality and pumping test data were presented in detail on March 1, 1965 in the office of the State Engineer in Bismarck to Mr. Raymond Hanson, Chairman of the Rugby City Council, Mr. Niel Liming, Council Member, Mr. Virgil Hoium, Treatment Plant Manager, and Mr. Paul Wold, Rugby City Engineer. They, in turn, discussed the matter with the City Council that evening and a decision to expand test drilling to determine recharge conditions to the aquifer resulted. The test drilling, to be done in May of 1965, will undoubtably be advantageous although another pumping test performed on the pilot well at a rate of 500 to 600 gpm, plus the installation of strategically located observation wells, would probably yield substantially more valuable data.

Final recommendations, naturally, cannot be made pending the results of the proposed test drilling, however, in lieu of the situation in the present city well field, it would seem advisable that the City of Rugby be prepared to have another source of water available for municipal use by the Summer or Fall of 1965. Since the area around test hole 17 is the only tested area which does contain good quality water, and apparent indications are that the quantity needed for the municipal supply is also available, it is recommended that progress be directed towards that source in the very near future.

TABLE 4 -- Records of Wells and Test Holes

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

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

Type of well: Dr, drilled; Du, dug; Dv, driven; Bo, Bored; g.p.m., Gallons per minute; g.p.d., Gallons per day.

Use of water: D, domestic; U, unused; PS, public supply; S, stock; T, test hole; Ind, industry; Obs., Observation well.

C. A. - Chemical analysis

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date Completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
156-72-3bcb	Peter J. Hornstein	93	4	Dr	1960	16	1960	D,S	Shale	1561	5 gpm
156-72-4dcc	Test Hole 19	199	4 3/4	Dr	6- 3-64	-	-	T	-	1615	See log
156-72-8bba	Nel Bickler	48	4	Dr	-	8	-	D	Shale	1555	4 gpm, hard
156-72-8ccc	Lincoln School	91	4	Dr	1958	20	1958	D	-	1558	-
156-72-10aaa	Test Hole 18	126	4 3/4	Dr	6- 2-64	9.12	6- 8-64	T	Gravel	1570	See log
156-72-16ccc	Test Hole 20	105	4 3/4	Dr	6- 3-64	20.83	6- 8-64	T	Sand & Gravel	1560	See log
156-72-33bbb	Test Hole 21	73	4 3/4	Dr	6- 3-64	15.12	6- 8-64	T	Gravel	1567	See log
156-73-1b1/	City of Rugby	52	96 x 24	Du &Dv	-	40	-	PS	Gravel	-	C.A.
156-73-1bba$_1$	Rugby Creamery	60	8	Dr	1940	30	-	Ind.	Sand & Gravel	1560	C.A., 50,000 gpd
156-73-1bba$_2$	Rugby Creamery	60	8	Dr	1954	30	-	U	Sand & Gravel	1560	Needed cleaning, 9-8-64
156-73-1cab	Test Hole 23	84	4 3/4	Dr	6- 3-64	4.33	6- 8-64	T	Sand	1530	See log
156-73-1cbc	Charles Hamilton	46	3	Dr	1958	20	1958	D	Sand from 35 to 55 feet	1550	C.A.
156-73-1cca	Rugby High School	42	4 1/4	Dr	1961	11	1961	PS	Dark Sand from 30 to 40 feet	1550	C.A., 25 gpm

1/ Simpson, 1929
2/ Abbott & Voedisch, 1938

TABLE 4 -- Records of Wells and Test Holes - Continued

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date Completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
156-73-2ccc	Bureau of Reclamation Obs. Well 77B	23	2	Dr	-	8.2 12.9 12.47	7-23-52 2-26-53 4-16-64	Obs.	Till	1530	-
156-73-3ad	Pig Factory	46	4	Dr	11- -63	12	11- -63	S	Gravel from 38 to 46 ft.	1530	2 ft. draw-down pump-ing 12 gpm 4 days
156-73-3ccc	Test Hole 28	64	4 3/4	Dr	6- 8-64	-	-	T	-	1515	See log
156-73-6dac	James Witt	48	18	Dr	1944	38	1944	S	'black muck'	1516	Alkaline, cistern for house
156-73-7bcb	Darwin Kinney	44	24	Bo	7- -64	23	1964	D,S	Gravel	1507	Colored, not used for drinking
156-73-9adc$_1$	Harold Ostrem, Jr.	70	4	Dr	-	-	-	S	Sand	1542	C.A.
156-73-9adc$_2$	Harold Ostrem, Jr.	66	4	Dr	1956	-	-	D	Sand	1545	Hard
156-73-10aba	John Lavik	86.3	4	Dr	-	33.2	-	D,S	Sand	1542	3 gpm
156-73-11aab	Rugby Livestock Sales	65	4 1/4	Dr	1961	20	1961	Ind.	Gravel	1540	8 gpm
156-73-13aaa	Sivert H. Jelle	89	4	Dr	1953	20	1953	D,S	Coarse Sand	1562	Hard
156-73-14ddd	Test Hole 22	94	4 3/4	Dr	6- 3-64	15.04	6- 8-64	T	-	1560	See log
156-73-16aa	Erdel Lavik	72	4	Dr	1957	20	1957	D, S	Gravel	1534	Hard
156-73-16bbc	Test Hole 27	115	4 3/4	Dr	6- 4-64	-	-	T	-	1500	See log
156-73-18bdd[1/]	H. J. Tion	75	-	Dr	-	-	-	-	Fine sand at 40 feet	1520	-
156-73-24bbb	Dr. Lynn Lunde	165	4	Dr	10-6-64	30	10-6-64	D	Shale	1550	4 gpm; see log
156-73-24ccc	Christensen Twp.Hall	88	4	Dr	1957	22	1957	PS	Shale & sand	1570	10 gpm
156-73-25bab[1/]	Henry Gunderson	400	-	-	-	dry	-	-	-	1571	No water
156-73-26dbb	Hans Dahl	91	4	Dr	1954	60	1954	D,S	Gravel from 83 to 91	1565	10 gpm, soft

TABLE 4 -- Records of Wells and Test Holes - Continued

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date Completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
156-73-28bdd	Lawrence Grove	-	4	Dr	1954	43	1954	D,S	Shale	1563	8 gpm, hard
156-73-28dac	Sigfreid Grove	110	4	Dr	1953	8	1953	D,S	Fine white sand	1571	4 gpm, soft
156-73-28dda	Bethel Luthern Church	95	4	Dr	1964	50	1964	PS	Hard shale & gravel	1574	6 gpm
156-73-31dcc	Test Hole 26	60	1 1/4	Dr	6- 4-64	4.15	6- 8-64	Obs.	Sand from 22 to 74	1534	C.A.,See log
156-73-34bbb	Test Hole 25	73	4 3/4	Dr	6- 4-64	13.05	6- 8-64	T	Gravel from 20 to 31	1540	See log
156-73-35ddd	Test Hole 24	63	4 3/4	Dr	6- 4-64	-	-	T	Gravel from 31 to 37	1534	See log
157-71-31baa	Test Hole 32	115½	4 3/4	Dr	9-23-64	-	-	T	-	1565	See log
157-71-31bcc	Test Hole 36	105	4 3/4	Dr	10-14-64	-	-	T	-	1560	See log
157-71-31cbb	Test Hole 37	86	4 3/4	Dr	10-14-64	-	-	T	-	1565	See log
157-71-31cbd	Test Hole 40	115½	4 3/4	Dr	10-15-64	-	-	T	-	1570	See log
157-72-3ccc$_1$	Bryce Jordan	38	24 to 2	Du & Dv	-	20	-	D,S	Sand	1573	Hard
157-72-3ccc$_2$	Bryce Jordan	92	4	Dr	1951	-	-	D,S	Sand	1573	
157-72-3dad	Bryce Jordan	91	4	Dr	1953	18	1953	D,S	60ft. of clean dark sand	1581	3 gpm, hard
157-72-7cad	Obert Blessum Sand & Gravel Pit	76	4	Dr	1963	21	1963	Ind.	Black sand and gravel from 75 to 76	1630	25 gpm, soft
157-72-10aad	Test Hole 3	84	4 3/4	Dr	5-26-64	-	-	T	Gravel from 55 to 59	1565	See log
157-72-11add	Oden Anderson	65	4	Dr	1955	16	1955	D,S	Gravel and hard shale	1572	8 gpm, soft
157-72-16abb	Lester Blessum	95	4	Dr	1950	50	1950	S	Sand	1600	4 gpm, hard
157-72-17bcc	Test Hole 7	84	4 3/4	Dr	5-27-64	16.83	6- 9-64	T	Sand from 25 to 41	1574	See log

TABLE 4 -- Records of Wells and Test Holes - Continued

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date Completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
157-72-18bbb	Test Hole 4	84	4 3/4	Dr	5-26-64	2.56	6- 1-64	T	Gravel from 17 to 40	1540	See log
157-72-18bcc	Test Hole 12	38	1 1/4	Dr	5-28-64	3.12	6- 1-64	Obs.	Gravel from 13 to 39	1535	C.A., See log
157-72-18bdd	Test Hole 14	63	4 3/4	Dr	5-28-64	5.70	6- 1-64	T	Sand from 32 to 37	1540	See log
157-72-18cbc	Test Hole 13	84	4 3/4	Dr	5-28-64	1.92	6- 1-64	T	Sand from 32 to 36	1540	See log
157-72-19aaa	Test Hole 8	94½	4 3/4	Dr	5-27-64	5.30	6- 9-64	T	Sand from 54 to 63	1555	See log
157-72-20ccc	Test Hole 9	126	4 3/4	Dr	5-27-64	26.76	6- 9-64	T	Gravel from 104 to 110	1580	See log
157-72-20ddc$_1$	Pete Mattern	80	4	Dr	1946	35	1946	D	Sand	1582	Hard, pumps sand
157-72-20ddc$_2$	Pete Mattern	80	4	Dr	1945	35	1945	S	Gravel	1584	Hard
157-72-21ccc	Test Hole 1	315	4 3/4	Dr	5-25-64	8.25	6- 9-64	T	Sand from 14 to 21	1578	See log
157-72-25ccc	Homer Bell	52	4	Dr	1954	32	1954	D,S	Sand	1565	Slow
157-72-25ddd$_1$	deceased	65	-	Bo	-	-	-	U	Gravel	1572	-
157-72-25ddd$_2$	Test Hole 31	136½	4 3/4	Dr	9-22-64	-	-	T	Sand from 62 to 110	1565	See log
157-72-26bbb	Test Hole 2	84	4 3/4	Dr	5-26-64	4.06	6- 9-64	T	-	1558	See log
157-72-30bbb	Test Hole 15	105	4 3/4	Dr	5-29-64	Flow	-	T	Sand & Gravel from 60 to 74	1540	Plugged, see log
157-72-31abb	Test Hole 10	80	1 1/4	Dr	5-28-64	-	-	Obs.	Sand from 33 to 83	1535	C.A., see log
157-72-31[2/]	City of Rugby	57	72 x 144	Du	-	48	-	PS	Gravel		C.A.
157-72-31[2/]	City Park	27	84 x 96	Du	-	27	-	PS	Gravel		C.A.

TABLE 4 -- Records of Wells and Test Holes - Continued

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date Completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
157-72-31ddc$_1$	Rugby City Well #1	73	30	-	1- 6-38	42	1938	U	Gravel		Abandoned in 1947
157-72-31ddc$_2$	Rugby City Well #2	68	12	Dr	1946	-	-	U	Sand & Gravel		Abandoned in 1954
157-72-31ddc$_3$	Rugby City Well #3	68	10	Dr	1948	-	-	U	Sand & Gravel		Abandoned in 1961
157-72-31ddc$_4$	Rugby City Well #4	70	16	Dr	1954	51	4-10-64	PS	Sand & Gravel	1562	C.A. from 47 to 70
157-72-31ddc$_5$	Rugby City Well #5	70	16	Dr	1954	51	4-10-64	PS	Sand & Gravel	1562	C.A. from 47 to 70
157-72-31ddc$_6$	Rugby City Well #6	68	12	Dr	1958	49	4-10-64	PS	Sand & Gravel	1560	See table 3 from 46 to 68
157-72-31ddc$_7$	Rugby City Well #7	68	12	Dr	1961	49	4-10-64	PS	Sand & Gravel	1560	See table 3 from 46 to 68
157-72-33bac	Mygland Bros.	112	4	Dr	1960	75	1960	D	Muddy Sand and Gravel	1595	2 gpm
157-72-34cbc	Test Hole 16	80	1 1/4	Dr	6- 1-64	19.04	6- 9-64	Obs.	Sand & Gravel	1552	C.A., see log to 83 feet
157-72-35acc$_1$	Paul Hornstein	82	4	Dr	1959	22	1959	D	Black Sand	1564	4 gpm
157-72-35acc$_2$	Paul Hornstein	35	2	Du &Dv	-	-	-	S	Gravel	1562	3 gpm
157-72-36aad	Test Hole 35	136½	4 3/4	Dr	10-12-64	-	-	T	Sand & Gravel	1558	See log from 22 to 115
157-72-36aca	Test Hole 39	147	4 3/4	Dr	10-15-64	-	-	T	-	1575	See log
157-72-36ada	Test Hole 34	105	4 3/4	Dr	10-12-64	-	-	T	Sand & Gravel	1555	See log from 35 to 93
157-72-36adb	Test Hole 38	147	4 3/4	Dr	10-14-64	-	-	T	Sand & Gravel	1585	See log from 26 to 124
157-72-36add$_1$	Rugby Test #1 (Simpson)	119	8	Dr	12-11-64	44.86	1-19-65	T	Sand & Gravel	1580	See log

TABLE 4 -- Records of Wells and Test Holes - Continued

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
157-72-36add$_2$	Test Hole 17	120	1 1/4	Dr	6- 2-64	52.84	6- 9-64	Obs.	Gravel 76 to 119	1595	C.A., See log
157-72-36bbb	Test Hole 30	200	4 3/4	Dr	9-22-64	-	-	T	Sand from 14 to 24	1556	See log
157-72-36cbb	Test Hole 29	105	4 3/4	Dr	6- 8-64	11.82	6- 9-64	T	Sand from 60 to 94	1555	See log
157-72-36dad	Test Hole 33	136½	4 3/4	Dr	10-8-64	-	-	T	Sand from 34 to 101	1570	See log
157-73-2baa	Test Hole 6	161	4 3/4	Dr	5-27-64	Flow	-	T	Gravel from 113 to 124	1481	Plugged, see log
157-73-3ccc	John E. Christenson	92	4	Dr	1961	35	1961	D	Fine Sand	1510	Hard, rusty
157-73-9acc	Leuevich Farmers Elevator	90	6	Dr	1960	10	1960	D	-	1503	Haul water for drinking
157-73-10acc	Clinton Hamilton	31	4	Dr	-	8	-	S	Coarse gray sand	1530	C.A., bailed at 25 gpm
157-73-11cda	Wesley Christensen	93	4	Dr	1964	51	1964	D,S	Medium Sand	1600	12 gpm
157-73-12bbc	Carl Cooper	72	2 1/2	Dr	1959	12	1959	D,S	Sand & Gravel stringers	1572	15 gpm
157-73-12ccc	Test Hole 11	126	4 3/4	Dr	5-28-64	-	-	T	Sand to 62 feet	1570	See log
157-73-14bbb	Rugby Sand & Gravel Co.	27	4	Dr	1957	7	1957	Ind.	Sand	1575	20 gpm
157-73-14bbc	Test Hole 5	94	4 3/4	Dr	5-26-64	-	-	T	Sand & Gravel to 16 ft.	1540	See log
157-73-22add	Tony Brossart	125	4	Dr	1956	-	-	D,S	Sand & Gravel	1528	5 gpm

TABLE 4 -- Records of Wells and Test Holes - Continued

Location No.	Owner	Depth (feet)	Diameter (inches)	Type	Date completed	Depth to water below land surface (feet)	Date of measurement	Use of water	Aquifer	Elevation	Remarks
157-73-23ccb$_1$	J. M. Anderson	100	24 to 18	Bo	-	15	-	S	Gravel	1522	Not too good
157-73-23ccb$_2$	J. M. Anderson	73	24 to 18	Bo	1959	-	-	D,S	Gravel	1522	11 grains hardness. Shale at 73 ft.
157-73-24aaa	Steve Tuchsher	50	4	Dr	-	10	-	U	Black sand	1560	6 gpm, hard
157-73-25abb	J. M. Anderson	60	4	Dr	1954	Flow, 3 gpm	9- 8-64	S	Coarse detrital lignite	1532	C.A., contains iron bacteria

TABLE 5 --Logs of Test Holes

156-72-4dcc
Test Hole 19

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, sandy loam, dark brown......	1	1
	Sand, medium, yellowish brown, well-sorted, subangular to subrounded, slightly calcareous, oxidized.....	28	29
	Sand, fine, silty, yellowish brown, moderately well-sorted, oxidized..	10	39
	Silt, sandy, yellowish gray, soft, friable, oxidized.................	10	49
	Sand, fine, olive gray, well-sorted, generally subrounded..............	8	57
	Silt, sandy, olive gray, soft, friable, poor sample return................	23	80
Lacustrine deposits:			
	Silt, olive gray, soft, moderately cohesive, calcareous................	23	103
	Silt, clayey, olive gray, soft, cohesive, slightly plastic............	40	143
Till:			
	Clay, silty with sand grains and pebbles, olive gray, tightly compacted, slightly hard, cohesive; contains numerous thin gravel layers....................	28	171
Fox Hills Formation:			
	Shale, olive gray, moderately hard, tight and Sandstone, clayey, light greenish gray to dark greenish gray, moderately soft to moderately hard...........	28	199

Electric Log

156-72-10aaa
Test Hole 18

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil, silty clay, black...........	2	2
	Clay, silty, yellowish gray to light gray, heavy iron stains, soft, cohesive, plastic, sticky, oxidized; upper 4 feet cracked or fractured.	20	22
	Clay, silty, olive gray, soft, cohesive, plastic, sticky..................	28	50

TABLE 5 --Logs of Test Holes--cont.

156-72-10aaa
Test Hole 18 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Till:			
	Clay, very sandy with numerous pebbles, olive gray, soft, slightly cohesive	12	62
	Gravel, fine and medium, sandy, thin clayey layers, moderately sorted, subangular to subrounded; drills easy, takes water.................	7	69
	Clay, silty to sandy with pebbles and sand lenses, olive gray, slightly hard, cohesive.....................	36	105
	Clay, silty to sandy with pebbles, olive gray, moderately hard, cohesive	8	113
Fox Hills Formation:			
	Shale, sandy, light olive gray, hard; contains layers of dark greenish gray sandy clay.......................	13	126

Electric Log

156-72-16ccc
Test Hole 20

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil, silty loam, black...........	1	1
	Silt, clayey, yellowish gray to dusky yellow, soft, moderately cohesive, slightly plastic, oxidized........	18	19
	Silt, clayey, with interbedded clay, silt, and sandy clay, olive gray, soft, moderately cohesive to cohesive, slightly to moderately plastic	36	55
Till:			
	Clay, silty with sand grains and pebbles, olive gray, slightly hard, tightly compacted........................	11	66
	Gravel, fine to coarse, moderately sorted; rough drilling, takes water.......	8	74
Fox Hills Formation:			
	Sandstone, fine and medium, clayey, dark greenish gray, moderately soft, moderately loose and friable	19	93
	Shale, sandy, light olive gray to brownish gray, moderately soft, moderately plastic, tight; contains traces of carbonaceous material...	12	105

Electric Log

TABLE 5 --Logs of Test Holes--cont.

156-72-33bbb
Test Hole 21

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil, fine sandy loam, black......	1	1
	Sand, fine, silty with a little clay, brown to gray, loose, 'dirty'.......	12	13
	Silt, clayey to sandy, olive gray, soft, moderately cohesive...............	14	27
Till:			
	Clay, very sandy with pebbles and gravel stringers, olive gray, soft to moderately soft, cohesive, slightly plastic..........................	6	33
	Gravel, fine to medium, sandy, moderately well-sorted, subrounded, clean....	5	38
	Clay, very sandy with pebbles and gravel stringers, olive gray, moderately soft, cohesive, moderately plastic......	17	55
Fox Hills Formation:			
	Sand, fine to medium, clayey, dark greenish gray, well-sorted, subrounded	5	60
	Shale, sandy, light olive gray, moderately soft, cohesive, moderately plastic; contains thin light bluish gray bentonite layers....................	13	73

Electric Log

156-73-1cab
Test Hole 23

Formation	Material	Thickness (feet)	Depth (feet)
	Roadfill............................	8	8
Alluvium:	Sand, fine to coarse, dark gray, moderately well-sorted, subangular to subrounded, saturated............	12	20
Till:			
	Clay, very sandy with pebbles and a few cobbles, olive gray, soft, cohesive, slightly plastic; gravelly	9	29
Lacustrine deposits:			
	Silt, sandy, olive gray, soft, slightly cohesive........................	6	35
	Silt, clayey, olive gray, soft, moderately cohesive, slightly plastic	20	55
Till:			
	Clay, silty to sandy with pebbles and gravel stringers, olive gray, moderately soft to slightly hard, cohesive...........................	11	66

TABLE 5 --Logs of Test Holes--cont.

156-73-1cab
Test Hole 23 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Fox Hills Formation:			
	Sand, fine to medium, clayey, dark greenish gray, slightly friable...	8	74
	Shale, olive gray, moderately soft, plastic..........................	10	84

Electric Log

156-73-3ccc
Test Hole 28

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits:			
	Silt, yellowish gray to dusky yellow, soft, occasional coarse sand grains	9	9
	Clay, very silty, olive gray, soft, smooth, cohesive, plastic.........	10	19
Till:	Clay, very sandy with pebbles, olive gray, cohesive, moderately plastic	9	28
Lacustrine deposits:			
	Silt, clayey, olive gray, soft, slightly crumbly.........................	12	40
Fox Hills Formation:			
	Sand, dark greenish gray, moderately soft, slightly friable.................	14	54
	Limestone, black, indurated..........	2	56
	Shale, silty to sandy, olive gray, soft, moderately plastic...............	8	64

Electric Log

156-73-14ddd
Test Hole 22

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil, silt loam, black............	1	1
	Clay, silty, yellowish gray to dusky yellow, soft, cohesive, plastic, oxidized.........................	5	6
	Silt, clayey, dusky yellow, soft, cohesive, moderately plastic, oxidized	11	17
	Silt, clayey, olive gray, soft, cohesive; some very fine and fine sand, sand content increasing with depth.....	44	61

TABLE 5 --Logs of Test Holes--cont.

156-73-14ddd
Test Hole 22 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Till:			
	Clay, silty to sandy with pebbles and gravel stringers, olive gray, moderately soft to slightly hard, cohesive........................	9	70
Fox Hills Formation:			
	Sand, fine and medium, clayey, dark greenish gray, moderately soft, slightly friable..................	7	77
	Shale, olive gray, moderately soft, plastic; contains streaks of sand.	17	94

Electric Log

156-73-16bbc
Test Hole 27

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits:			
	Clay, dusky yellow, soft, cohesive, plastic, oxidized.................	10	10
	Clay, olive gray, soft, cohesive, plastic	77	87
Till:			
	Sand, medium and coarse, some fine gravel, well-sorted, subangular to subrounded	3	90
	Clay, silty to sandy with pebbles, olive gray, soft, cohesive, tight.......	12	102
Fox Hills Formation:			
	Shale, silty, light olive gray, hard; contains dark greenish gray, moderately soft sandstone strata.....	13	115

No Electric Log

156-73-24bbb
Dr. Lynn Lunde water well
(Log furnished by Fred Simpson)

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil............................	1	1
	Clay, yellow.........................	14	15
	Clay, blue...........................	15	35
	Clay, sandy, blue....................	15	50
	Sand, very clayey....................	10	60
Fox Hills Formation:			
	Clay, sandy, gray....................	30	90
Pierre Shale:			
	Shale..............................	75	165

TABLE 5 --Logs of Test Holes--cont.

156-73-31dc
Test Hole 26

Formation	Material	Thickness (feet)	Depth (feet)
	Roadfill, gravelly clay.............	10	10
Outwash:			
	Gravel, fine and medium, well-sorted, subrounded; takes water..........	12	22
	Sand, fine to coarse, becoming finer with depth, tannish gray to dark greenish gray, well-sorted, subrounded.........................	52	74
Pierre Shale:			
	Shale, olive black, hard, shaley partings, fractured to about 80 feet; tough drilling.............	31	105

Electric Log

156-73-34bbb
Test Hole 25

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, very fine sandy loam, black.	1	1
	Silt, clayey to sandy with sand lenses, dusky yellow, soft, oxidized......	8	9
	Silt, sandy, dusky yellow to moderate olive brown, soft, uniformly sorted	8	17
	Sand, coarse and very coarse with fine to medium gravel, moderately sorted, subangular to subrounded, clean..	15	32
Till:			
	Clay, silty to sandy with gravel stringers, olive gray, moderately soft, cohesive	19	51
Pierre Shale:			
	Shale, olive black, hard, brittle, fissile; tough drilling..................	22	73

Electric Log

156-73-35ddd
Test Hole 24

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Silt, clayey with sand stringers, dusky yellow, soft, loose, oxidized....	9	9
	Silt, clayey, olive gray, soft, cohesive, moderately plastic.......	21	30

TABLE 5 --Logs of Test Holes--cont.

156-73-35ddd
Test Hole 24 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Gravel, fine to coarse, some coarse sand, moderately well-sorted, subangular to subrounded; fairly rough drilling........................	6	36
Pierre Shale:			
	Shale, olive black, hard, brittle, shaley partings..................	27	63

Electric Log

157-71-31baa
Test Hole 32

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Topsoil, silty loam, black..........	1	1
	Clay, silty, dusky yellow, soft.....	5	6
	Sand, fine to medium, moderately well-sorted, subrounded..............	25	31
Lacustrine deposits:			
	Silt, clayey, olive gray, soft......	13	44
Till:			
	Clay, sandy with pebbles and sand stringers, olive gray, moderately soft, moderately cohesive........	40	84
Fox Hills Formation:			
	Shale, silty, light olive gray, soft, with dark greenish gray sandstone strata.........................	31	115

Electric Log

157-71-31bcc
Test Hole 36

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, silt, black................	1	1
	Silt, clayey to gravelly with much sand, yellowish brown, noncohesive, oxidized........................	7	8
	Silt, sandy with pebbles, olive gray to dark greenish gray, soft, cohesive...........................	6	14
	Silt, sandy, greenish gray to olive gray, soft, slightly cohesive....	8	22

TABLE 5 --Logs of Test Holes--cont.

157-71-31bcc
Test Hole 36 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
	Sand, medium to coarse, some gravel, poorly to moderately sorted, angular to subrounded...........	10	32
	Clay, sandy (very fine and fine), olive gray, soft, slightly cohesive	10	42
Ice-contact deposits:			
	Silt, olive gray, slightly hard, cohesive, laminated.................	9	51
	Clay, silty, olive gray, moderately soft, cohesive, slightly plastic.	7	58
	Sand, fine to medium, moderately well-sorted, subangular to subrounded.	6	64
	Silt, clayey, olive gray, moderately soft, cohesive, slightly plastic.	7	71
Till:			
	Clay, silty with pebbles, olive gray, slightly hard, cohesive..........	9	80
Fox Hills Formation:			
	Shale, olive gray, soft, plastic with dark greenish gray, very fine to fine-grained, soft sandstone strata	25	105

Electric Log

157-71-31cbb
Test Hole 37

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, silty loam, black..........	1	1
	Clay, sandy, with interbedded layers of silt and sand, yellowish brown, poorly sorted, highly variable composition, loose to moderately cohesive, oxidized................	17	18
	Sand, medium to very coarse, gravelly, poorly sorted, subangular to subrounded; drills good, takes water	40	58
	Gravel, fine to coarse, poorly sorted, subangular to subrounded; rough drilling, takes much water.......	12	70
	Silt, sandy, olive gray to dark greenish gray, soft, cohesive, laminated..	6	76
Till:			
	Clay, silty with pebbles, olive gray to dark greenish gray, slightly hard, cohesive.......................	6	82

TABLE 5 --Logs of Test Holes--cont.

157-71-31cbb
Test Hole 37 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Fox Hills Formation:			
	Shale, light olive gray, moderately soft, with dark greenish gray, soft, clayey sand......................	3	85
	Sandstone, light greenish gray, indurated, cemented, medium-grained	1	86

Electric Log

157-71-31cbd
Test Hole 40

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, silty loam, black..........	1	1
	Clay, silty to sandy with occasional pebbles and lenses of silt to coarse sand, yellowish brown and light olive gray, soft, crumbly, poorly sorted, oxidized..........	16	17
	Clay, as above, interbedded with lenses of fine sand..................	14	31
	Clay, dark greenish gray, cohesive, slightly hard, tight; 'resembles weathered shale'.................	13	44
	Sand, coarse, gravelly in spots, poorly sorted to well-sorted, subangular to subrounded...................	22	66
	Silt, clayey to sandy, olive gray, moderately soft, cohesive........	7	73
	Sand, coarse, well-sorted, subangular to subrounded...................	7	80
Till:			
	Silt, clayey to sandy with pebbles, olive gray, slightly hard, cohesive....	2	82
	Gravel, fine to coarse, poorly sorted, subangular to rounded...........	14	96
Fox Hills Formation:			
	Siltstone, olive gray, slightly hard, cohesive, noncalcareous..........	4	100
	Sand, clayey, dark greenish gray, moderately soft, slightly friable, 'salt and pepper' appearance.....	15½	115½

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-10aad
Test Hole 3

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Topsoil, very fine sandy loam, black	1	1
	Sand, fine to medium, well-sorted, rusty	3	4
	Clay, silty to sandy, yellowish gray to dusky yellow, soft, slightly cohesive, oxidized........................	11	15
Lacustrine deposits:			
	Clay and silt, olive gray, soft, cohesive, sticky, laminated..........	16	31
Till:			
	Clay, silty to sandy with pebbles and gravel lenses, olive gray, moderately soft, cohesive..................	11	42
Lacustrine deposits:			
	Silt, clayey, olive gray, soft, cohesive	13	55
Outwash:			
	Gravel, fine to coarse, poorly sorted, subrounded; rough drilling........	4	59
Fox Hills Formation:			
	Sandstone, fine to medium, dark greenish gray, soft, friable, noncalcareous	25	84

Electric Log

157-72-17bcc
Test Hole 7

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, sandy loam, black...........	1	1
	Sand, coarse and very coarse with fine gravel, moderately sorted, subrounded, oxidized................	15	16
	Sand, medium and coarse, olive gray, well-sorted, subrounded..........	25	41
Lacustrine deposits:			
	Clay, silty, olive gray, soft, cohesive, plastic...................	9	50
	Silt, olive gray, slightly hard, cohesive, slightly plastic.........	19	69
Fox Hills Formation:			
	Shale, light olive gray, upper 8 feet very sandy, moderately hard, slightly calcareous......................	15	84

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-18bbb
Test Hole 4

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Topsoil, silty loam, black..........	1	1
	Clay, silty to sandy, yellowish gray to dusky yellow, soft, oxidized..	8	9
Ice-contact deposits:			
	Clay, very sandy with occasional pebbles, olive gray, soft, till.....	8	17
	Gravel, fine and medium with medium to coarse sand, moderately sorted, subrounded, clean..................	10	27
	Gravel, fine and medium, sandy to clayey, very poorly sorted, dirty........	13	40
Till:			
	Clay, silty to sandy with pebbles, moderately soft, cohesive, moderately plastic; gravelly in spots.......	11	51
	Sand, medium, well-sorted, clean....	3	54
Fox Hills Formation:			
	Sandstone, dark greenish gray, fine to medium, soft, moderately friable.	11	65
	Shale, sandy (very fine), light olive gray, slightly hard, slightly calcareous; contains zones of dark green, highly glauconitic sand...	19	84

Electric Log

157-72-18bcc
Test Hole 12

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Topsoil, clay loam, black...........	1	1
	Clay, silty to very gravelly, yellowish gray to dusky yellow, unassorted to very poorly sorted, soft, noncohesive..........................	12	13
	Gravel, fine to medium with coarse sand, moderately sorted, subrounded; takes water.....................	26	39
Lacustrine deposits:			
	Silt, clayey, olive gray, moderately soft, cohesive, slightly plastic.	19	58
Fox Hills Formation:			
	Sandstone, clayey, dark greenish gray, moderately soft, moderately friable	15½	73½

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-18bdd
Test Hole 14

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, sandy loam, black..........	1	1
	Sand, fine to coarse, clayey in spots, moderately sorted, subrounded....	16	17
	Silt, olive gray, soft, moderately cohesive; contains occasional gravel stringers......................	15	32
	Sand, medium to coarse, well-sorted, subrounded......................	5	37
	Clay, silty, olive gray, moderately soft, slightly crumbly..........	5	42
Fox Hills Formation:			
	Sandstone, clayey, dark greenish gray, soft, slightly friable...........	7	49
	Shale, clayey, light olive gray, soft, sticky.........................	14	63

Electric Log

157-72-18cbc
Test Hole 13

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Topsoil, clay loam, black...........	1	1
	Clay, silty and sandy, dusky yellow, sorted, soft, noncohesive, oxidized	14	15
	Silt, clayey with gravel stringers and some sand, very gravelly in spots, olive gray, soft, moderately cohesive...........................	17	32
	Sand, medium, olive gray, well-sorted, subrounded......................	4	36
Lacustrine deposits:			
	Silt with layers of fine sand, olive gray, soft, slightly cohesive....	16	52
	Silt, clayey, olive gray, soft, moderately cohesive, slightly plastic	11	63
	Clay, silty, olive gray, soft, cohesive, plastic, slightly sticky.........	7	70
Fox Hills Formation:			
	Shale, light olive gray to olive gray, moderately soft to slightly hard; tight drilling...................	14	84

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-19aaa
Test Hole 8

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Topsoil, silty loam, black..........	1	1
	Clay, silty, dusky yellow, soft.....	8	9
	Sand, medium to coarse with fine gravel, moderately well-sorted, subrounded, clean..........................	11	20
Lacustrine deposits:			
	Clay, silty, olive gray, soft, cohesive	11	31
	Sand, fine and medium, gray, well-sorted, subrounded......................	5	36
	Silt, clayey, olive gray, soft; contains fine sand layers................	18	54
	Sand, fine and medium, silty, olive gray, loose.....................	9	63
	Silt, clayey to sandy, olive gray, soft, moderately cohesive........	6	69
Outwash:			
	Gravel, fine to medium, well-sorted.	4	73
Fox Hills Formation:			
	Shale, sandy, light olive gray, moderately hard; contains layers of noncalcareous, friable, moderately soft, dark greenish gray sandstone	21½	94½

Electric Log

157-72-20ccc
Test Hole 9

Formation	Material	Thickness (feet)	Depth (feet)
Till:			
	Topsoil, very fine sandy loam, black	1	1
	Clay, silty to sandy with pebbles, dusky yellow, soft, slightly cohesive; contains fine sand stringers	19	20
Lacustrine deposits:			
	Silt, clayey, dusky yellow, soft, cohesive, slightly plastic...........	9	29
	Sand, very fine to fine, silty, olive gray, slightly cohesive..........	11	40
	Silt, clayey, olive gray, moderately soft, crumbly to slightly cohesive, highly calcareous................	25	65
	Silt, sandy, olive gray, soft, very slightly to slightly cohesive, laminated; some loose fine sand stringers.......................	39	104

TABLE 5 --Logs of Test Holes--cont.

157-72-20ccc
Test Hole 9 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Gravel, fine to coarse, subrounded, moderately sorted; rough drilling	6	110
Fox Hills Formation:			
	Sandstone, dark greenish gray, clayey, moderately soft, slightly friable and Shale, light olive gray, sandy, moderately hard.....................	16	126

Electric Log

157-72-21ccc
Test Hole 1

Formation	Material	Thickness (feet)	Depth (feet)
Till:			
	Topsoil, very fine sandy loam, black	1	1
	Clay, silty, yellowish gray, soft, slightly cohesive; wave-washed till	4	5
	Clay, silty with pebbles, dusky yellow, soft, cohesive, moderately plastic, oxidized, numerous rusty streaks.	9	14
Lacustrine deposits:			
	Sand, medium, brown to gray, well-sorted, subangular to subrounded.........	7	21
	Clay, sandy, olive gray, soft, moderately cohesive................	7	28
	Silt, olive gray, soft, slightly plastic, uniformly sorted........	16	44
	Clay, olive gray, soft, cohesive, plastic.........................	12	56
Till:			
	Clay, very sandy with pebbles and fine gravel stringers, olive gray, slightly cohesive, nonplastic............	15	71
	Clay, very sandy with lenses of silt and gravel, olive gray, moderately soft, slightly cohesive..........	11	82
Fox Hills Formation:			
	Sandstone, fine to medium, dark greenish gray, well-sorted, subangular, friable, noncalcareous; quartzose with glauconite, lignite, and mica...............	35	117
	Shale, silty to sandy, light olive gray to medium gray, soft to slightly hard, slightly brittle, occasionally bentonitic, slightly calcareous.....	188	305
Pierre Shale:			
	Shale, olive black, moderately hard, brittle, noncalcareous...........	10	315

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-25ddd
Test Hole 31

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, sandy loam, black..........	1	1
	Sand, fine to medium, well-sorted but interbedded with silt and clay lenses	26	27
	Silt, very clayey, grading to sandy, olive gray, soft, slightly cohesive, laminated......................	15	42
Till:			
	Clay, silty to sandy with pebbles, boulders, and lenses of sand and gravel, olive gray, cohesive to loose.........................	20	62
Outwash:			
	Sand, fine to medium, light olive gray, moderately well-sorted, subangular to subrounded............	12	74
	Sand, fine to medium, light olive gray, contains lenses of slightly cohesive clayey sand................	19	93
	Sand, fine to medium, clayey, olive gray, well-sorted, subrounded....	17	110
Till:			
	Clay, silty with sand grains and pebbles, olive gray, moderately soft, cohesive..................	7	117
Fox Hills Formation:			
	Sandstone, fine to medium, clayey, dark greenish gray, moderately soft, well-sorted, subangular to subrounded and Shale, silty, light olive gray, slightly hard, cohesive; tight drilling...	19½	136½

Electric Log

157-72-26bbb
Test Hole 2

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil, silty loam, black.........	1	1
	Clay, dusky yellow, soft, tight, oxidized	5	6
	Clay, silty, moderate olive brown, soft, cohesive, moderately plastic, oxidized	16	22

TABLE 5 --Logs of Test Holes--cont.

157-72-26bbb
Test Hole 2 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Till:			
	Clay, silty to sandy with coarse sand grains and pebbles, olive gray, moderately soft, cohesive, slightly plastic; contains numerous lenses of poorly sorted sand and gravel....	25	47
Fox Hills Formation:			
	Sandstone, fine to medium, dark greenish gray, moderately soft, friable, noncalcareous......................	28	75
	Shale, silty, light olive gray, moderately soft, cohesive; tight drilling....	9	84

Electric Log

157-72-30bbb
Test Hole 15

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil, silty loam, black.........	2	2
	Silt, dusky yellow, soft, noncohesive, oxidized........................	8	10
	Silt, clayey, olive gray, moderately soft, cohesive, slightly plastic; contains occasional gravel lenses.	20	30
	Sand, fine to medium, silty, olive gray, moderately sorted, noncohesive............................	7	37
	Silt, olive gray, moderately soft, moderately cohesive.............	4	41
Outwash:			
	Sand, fine to medium, olive gray, well-sorted in layers, subrounded.....	15	56
	Silt, olive gray, moderately soft, moderately cohesive................	4	60
	Sand, fine to medium, olive gray, well-sorted, subrounded..............	3	63
	Gravel, fine to medium with very coarse sand, poorly sorted, generally subrounded.........................	11	74
Lacustrine deposits:			
	Silt, olive gray, moderately soft, slightly crumbly................	2	76
	Silt, clayey, olive gray, moderately soft, cohesive, slightly plastic.	9	85

TABLE 5 --Logs of Test Holes--cont.

152-72-30bbb
Test Hole 15 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Fox Hills Formation:			
	Shale, silty, moderately soft to moderately hard, light olive gray to olive gray; tight drilling.......	20	105

Electric Log

157-72-31abb
Test Hole 10

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris Deposits:			
	Topsoil, silty clay loam, black.....	3	3
	Silt, clayey, yellowish gray to dusky yellow, soft, noncohesive, oxidized	6	9
	Silt, clayey, olive gray, soft, cohesive, slightly plastic...........	24	33
Outwash:			
	Sand, fine to very coarse, silty to gravelly, poorly sorted, interbedded, subangular to subrounded.........	50	83
Fox Hills Formation:			
	Sandstone, clayey, dark greenish gray, medium-grained moderately soft to hard............................	22	105

Electric Log

157-72-34cbc
Test Hole 16

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Topsoil, gravelly loam, black.......	1	1
	Sand, fine to very coarse with fine gravel, moderately sorted, subangular to subrounded, highly oxidized...	20	21
	Sand, fine to very coarse, moderately well-sorted, subrounded..........	7	28
	Silt, clayey, olive gray, soft, moderately cohesive.................	4	32
	Sand, medium to very coarse, olive gray, well-sorted, generally subrounded; taking water....................	37	69
	Silt, clayey, olive gray, soft, moderately cohesive.......................	4	73
	Sand, fine to very coarse with fine gravel, moderately well-sorted, subrounded	10	83
Fox Hills Formation:			
	Shale, silty, olive gray, soft, crumbly, micaceous, moderately calcareous.	43	126

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-36aad
Test Hole 35

Formation	Material	Thickness (feet)	Depth (feet)
Ice contact deposits:			
	Topsoil, silty loam, black.........	1	1
	Silt, clayey to sandy, dusky yellow, soft, slightly cohesive, oxidized	15	16
	Clay, silty, sandy, and gravelly, dark greenish gray, moderately soft, slightly to moderately cohesive (till).........................	6	22
Outwash:			
	Sand, medium to coarse, well-sorted, subangular to subrounded.........	13	35
	Gravel, fine and medium, sandy, moderately sorted, subrounded.......	5	40
	Sand, medium, well-sorted, subrounded; interbedded but fairly uniform...	52	92
	Sand, medium to very coarse with interbedded lenses of clay, gravel and boulders, very poorly sorted to well-sorted, subangular to rounded	24	116
Fox Hills Formation:			
	Siltstone, sandy, lignitic, dark greenish gray, slightly hard, brittle, noncalcareous..................	3	119
	Shale, sandy, dark greenish gray, moderately soft to slightly hard, cohesive, noncalcareous...........	17½	136½

Electric Log

157-72-36aca
Test Hole 39

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, silty loam, black..........	1	1
	Silt, clay with sand stringers from 20 to 30 feet, dusky yellow, soft, poorly sorted slightly cohesive, oxidized......................	33	34
	Silt, interbedded with silty clay, very fine sand, and detrital shale and lignite, olive gray, moderately soft, sorted in layers, slightly to moderately cohesive.............	50	84
Till:			
	Clay, silty to sandy, olive gray, moderately soft, cohesive; contains occasional shale, limestone, and granite pebbles and boulders.....	45	129

TABLE 5 --Logs of Test Holes--cont.

157-72-36aca
Test Hole 39 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Fox Hills Formation:			
	Shale,sandy, dark greenish gray, slightly hard, moderately cohesive, micaceous, noncalcareous..................	18	147

Electric Log

157-72-36ada
Test Hole 34

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, silty loam, black..........	1	1
	Clay, silty to sandy, dusky yellow to light olive gray, soft, slightly cohesive, oxidized..............	5	6
	Clay, silty, moderate olive brown to olive gray, soft, slightly to moderately cohesive, calcareous, partially oxidized................	13	19
Till:			
	Clay, silty to sandy with pebbles, olive gray to dark greenish gray, moderately soft, moderately cohesive; contains lenses of fine to medium-grained sand	16	35
Outwash:			
	Sand, medium, well-sorted, subangular to subrounded......................	9	44
	Gravel, fine to coarse, sandy, moderately sorted, subangular to subrounded.	22	66
	Gravel, fine and medium with coarse and very coarse sand, moderately well-sorted, generally subrounded.....	27	93
Till:			
	Clay, sandy with pebbles, olive gray to dark greenish gray, soft, cohesive, slightly plastic, slightly calcareous......................	8	101
Outwash:			
	Gravel, very coarse; lost circulating abandoned hole..................	4	105

No Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-36adb
Test Hole 38

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, silty loam, black..........	2	2
	Gravel, fine, sandy, poorly sorted, highly oxidized.................	3	5
	Silt, clayey to gravelly with boulders, light olive gray to olive gray with iron stains, soft to moderately soft, slightly to moderately cohesive, very poorly sorted, partially oxidized	21	26
	Gravel, clayey to sandy with occasional cobbles and boulders, appears to be unassorted but may be lenticular, 'dirty'........................	15	41
Outwash:			
	Sand, coarse but lensed with silty clay, olive gray, moderately sorted, angular to subrounded...........	7	48
	Gravel, fine and medium with coarse and very coarse sand, poorly sorted, angular to subangular...........	8	56
	Sand, medium to coarse, well-sorted, subangular to rounded...........	12	68
	Gravel, fine to coarse, sandy, poorly sorted, subangular to subrounded.	9	77
	Silt, sandy with pebbles and gravel stringers, light olive gray, slightly hard, moderately compacted, cohesive (till).........................	7	84
	Sand, medium to coarse, well-sorted, subangular to subrounded.........	29	113
	Sand, fine to medium,clayey, light olive gray, moderately soft, moderately cohesive.........................	11	124
	Clay, silty to sandy with pebbles, light olive gray, moderately soft, cohesive; contains lenses of silt..........	6	130
Fox Hills Formation:			
	Sandstone, fine to medium, dark greenish gray, moderately soft, cohesive, lignitic and micaceous.............	17	147

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-36add[1]
City Test #1 (Simpson)

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil...........................	1	1
	Clay, yellow......................	2	3
	Sand, clayey......................	2	5
	Sand, yellow......................	11	16
	Sand, clayey......................	5	21
	Clay, yellow......................	17	38
	Clay, gray........................	3	41
Outwash:			
	Gravel, clayey....................	4	45
	Gravel, clayey and sandy..........	9	54
	Gravel, sandy.....................	7	61
	Gravel, clayey and sandy..........	10	71
	Sand, clayey......................	33	104
	Sand, clean, some gravel..........	6	110
	Sand, clayey......................	1	111
	Sand and gravel...................	8	119
	Clay, dark greenish gray, smooth....	1	120

No Electric Log
Log furnished by Fred Simpson

157-72-36add[2]
Test Hole 17

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, silty sand loam, dark brown	1	1
	Silt, clayey to gravelly, dusky yellow, soft, slightly cohesive, oxidized........................	9	10
	Gravel, fine, sandy, moderately sorted, subangular to subrounded, oxidized, dry............................	32	42
Outwash:			
	Silt, clayey with very fine sand, moderate olive brown, soft, slightly cohesive, oxidized..............	10	52
	Silt, clayey, olive gray, soft, moderately cohesive, slightly plastic	12	64
	Sand, fine to medium, olive gray, well-sorted, subrounded..............	3	67
	Silt, clayey, olive gray, soft, moderately cohesive, slightly plastic	9	76
	Gravel, fine and medium, sandy, moderately well-sorted, subrounded; drills easy, takes water......................	43	119

TABLE 5 --Logs of Test Holes--cont.

157-72-36add$_2$
Test Hole 17 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Till:			
	Clay, silty with sand grains, pebbles, and lenses of gravel, olive gray, cohesive, moderately plastic, tightly compacted......................	11	130
Fox Hills Formation:			
	Sandstone, fine to medium, clayey, dark greenish gray, moderately cohesive; contains lenses of olive gray shale and tan limestone................	17	147

Electric Log

157-72-36bbb
Test Hole 30

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil, silty loam, black..........	1	1
	Clay, silty, olive gray, soft, cohesive, moderately plastic, uniformly sorted.........................	5	6
Till:			
	Clay, silty to sandy with pebbles, olive gray, moderately soft, cohesive..	8	14
Outwash:			
	Sand, medium to coarse, gravelly, moderately sorted, subangular to subrounded........................	10	24
	Silt, sandy, interbedded with silty sand, olive gray, soft, slightly to moderately cohesive.............	38	62
Till:			
	Silt, clayey to very sandy with pebbles and lenses of gravel, olive gray, moderately soft, moderately cohesive	24	86
Fox Hills Formation:			
	Shale, silty to sandy, light olive gray to olive gray, moderately soft, moderately cohesive; drills smooth and easy...........................	70	156
	Shale, silty and sandy, light gray to olive black, moderately soft to slightly hard, slightly to moderately cohesive; olive black zones very rich in carbonaceous material (decayed vegetation).....................	44	200

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-72-36cbb
Test Hole 29

Formation	Material	Thickness (feet)	Depth (feet)
Lacustrine deposits:			
	Topsoil, silty clay loam, black.....	2	2
	Clay, silty, yellowish gray to dusky yellow, soft, cohesive, sticky, oxidized.........................	16	18
	Clay, silty, olive gray, soft, smooth, cohesive, plastic, sticky........	16	34
Outwash:			
	Sand, fine, clayey, greenish gray, soft, noncohesive......................	11	45
	Silt, clayey, olive gray, moderately soft, slightly crumbly...........	4	49
	Sand, fine, clayey, olive gray, soft, slightly cohesive; drills fast and easy............................	11	60
	Sand, fine to coarse, light gray, moderately well-sorted, subangular to subrounded, noncohesive..........	21	81
	Sand, coarse, olive gray, well-sorted, subangular to subrounded.........	4	85
	Sand, fine, silty, olive gray, well-sorted, subrounded..............	9	94
Fox Hills Formation:			
	Sandstone, fine, clayey, dark greenish gray, slightly hard, cohesive....	11	105

Electric Log

157-72-36dad
Test Hole 33

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, sandy loam, black..........	1	1
	Sand, medium to coarse, well-sorted.	2	3
	Clay, sandy, dusky yellow, soft, slightly cohesive, poorly sorted, oxidized.........................	9	12
	Silt, clayey to sandy with pebbles, dusky yellow to moderate olive brown, soft, slightly cohesive, poorly sorted, oxidized..........	11	23
	Silt, interbedded with clayey and sandy lenses, pebbly, greenish gray, soft, slightly to moderately cohesive.........................	11	34

TABLE 5 --Logs of Test Holes--cont.

157-72-36dad
Test Hole 33 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Outwash:			
	Sand, medium to coarse, dark greenish gray, well-sorted, subangular to rounded, lignitic................	14	48
	Sand, fine to medium, greenish gray, well-sorted, generally subrounded	16	64
	Sand, very fine and fine, silty, greenish gray, slightly cohesive.	24	88
	Sand, fine, greenish gray, well-sorted, subrounded......................	13	101
Till:			
	Silt, sandy with pebbles, greenish gray to olive gray, moderately soft, cohesive.........................	9	110
	Gravel, fine and medium, sandy, moderately sorted, subrounded.......	5	115
Fox Hills Formation:			
	Sandstone, fine, clayey, dark greenish gray, slightly hard, cohesive, micaceous.......................	21½	136½

Electric Log

157-73-2baa
Test Hole 6

Formation	Material	Thickness (feet)	Depth (feet)
Lake Souris deposits:			
	Topsoil, clay loam, black...........	2	2
	Clay, silty, yellowish gray, soft, oxidized.........................	8	10
	Clay, silty, olive gray, soft, cohesive, plastic, sticky, laminated.	52	62
	Silt, clayey with very fine sand, olive gray, soft, cohesive, plastic, laminated.......................	38	100
Outwash:			
	Gravel, fine to medium with medium to very coarse sand, moderately sorted, subangular to subrounded..........	4	104
	Silt, sandy, very fine to fine, olive gray, soft, cohesive.............	9	113
	Gravel, fine to medium with medium to very coarse sand, moderately sorted, subangular to subrounded..........	11	124
Till:			
	Clay, silty to sandy with pebbles and cobbles, olive gray, moderately soft, cohesive, tightly compacted......	7	131

TABLE 5 --Logs of Test Holes--cont.

157-73-2baa
Test Hole 6 (cont.)

Formation	Material	Thickness (feet)	Depth (feet)
Fox Hills Formation:			
	Sandstone, fine to medium, clayey, dark greenish gray, moderately soft, moderately cohesive................	3	134
	Shale, silty, light olive gray, slightly hard, cohesive; contains greenish gray sandstone strata................	34	168

Electric Log

157-73-12ccc
Test Hole 11

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Topsoil, sandy loam, dark brown.....	2	2
	Sand, medium to very coarse, moderately sorted, subangular to subrounded, oxidized........................	12	14
	Sand, clayey, dusky yellow, soft, slightly cohesive...............	4	18
	Sand, fine to coarse, moderate olive brown to olive gray, moderately sorted, subrounded..............	12	30
	Sand, fine to medium, olive gray, well-sorted, subrounded; clayey in spots	32	62
Lacustrine deposits:			
	Silt, clayey, olive gray, soft to moderately soft, cohesive, slightly to moderately plastic, highly calcareous	27	89
	Clay, olive gray, soft, cohesive, plastic.........................	7	96
Fox Hills Formation:			
	Sandstone, fine to medium, clayey, dark greenish gray, moderately soft with light greenish gray indurated layers	8	104
	Shale, silty, light olive gray to olive gray, moderately soft to slightly hard; contains soft sandstone strata	22	126

Electric Log

TABLE 5 --Logs of Test Holes--cont.

157-73-14bbc
Test Hole 5

Formation	Material	Thickness (feet)	Depth (feet)
Ice-contact deposits:			
	Gravel and small cobbles, sandy, poorly sorted, subrounded, oxidized.....	10	10
	Sand, medium to coarse, gravelly, moderately sorted, subrounded, oxidized	6	16
Lacustrine deposits:			
	Clay, silty, olive gray, cohesive, slightly to moderately plastic...	14	30
	Silt, clayey and sandy, olive gray, soft, slightly to moderately cohesive, interbedded and laminated..	30	60
	Clay, silty, olive gray, soft, cohesive, slightly plastic...........	8	68
	Clay, olive gray, soft, cohesive, plastic..........................	5	73
	Sand, very fine to fine, silty, olive gray, soft, slightly cohesive....	6	79
Fox Hills Formation:			
	Sandstone, dark greenish gray, fine-grained, moderately soft, moderately friable, noncalcareous...........	15	94

Electric Log

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