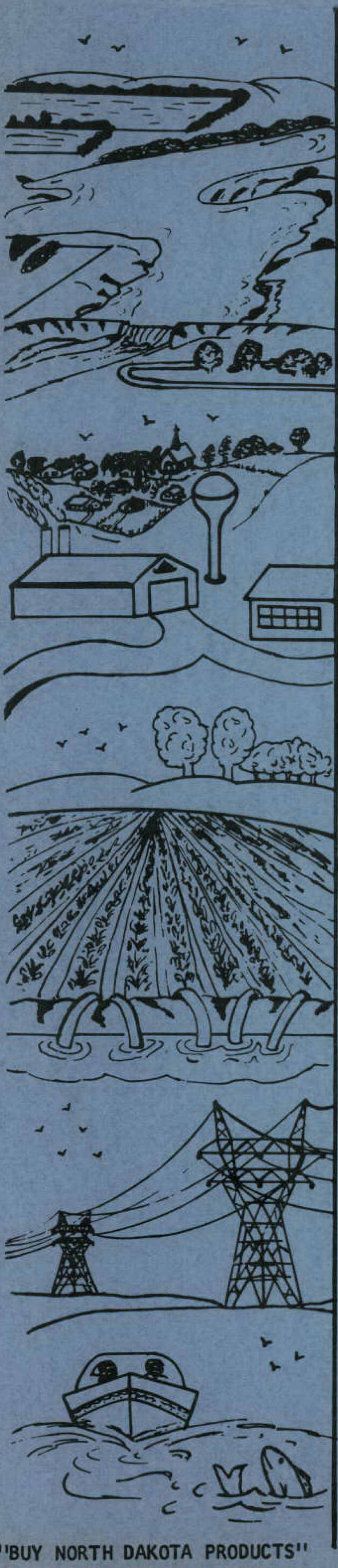

"BUY NORTH DAKOTA PRODUCTS"

GEOLOGY AND GROUND WATER RESOURCES OF THE HETTINGER AREA ADAMS COUNTY, NORTH DAKOTA

By
C. J. Robinove
Geologist, Geological Survey
United States Department of the Interior

NORTH DAKOTA GROUND WATER STUDIES
NO. 24

Prepared by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission, and the North Dakota Geological Survey

PUBLISHED BY
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
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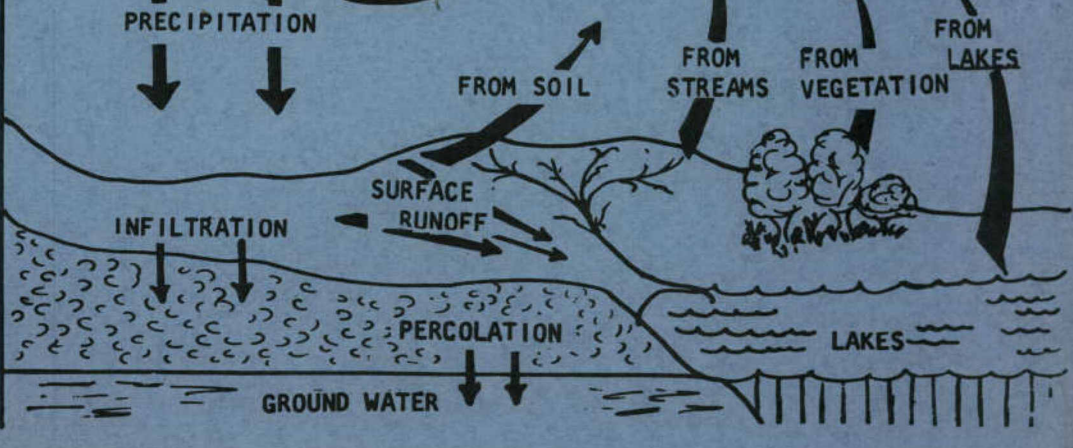

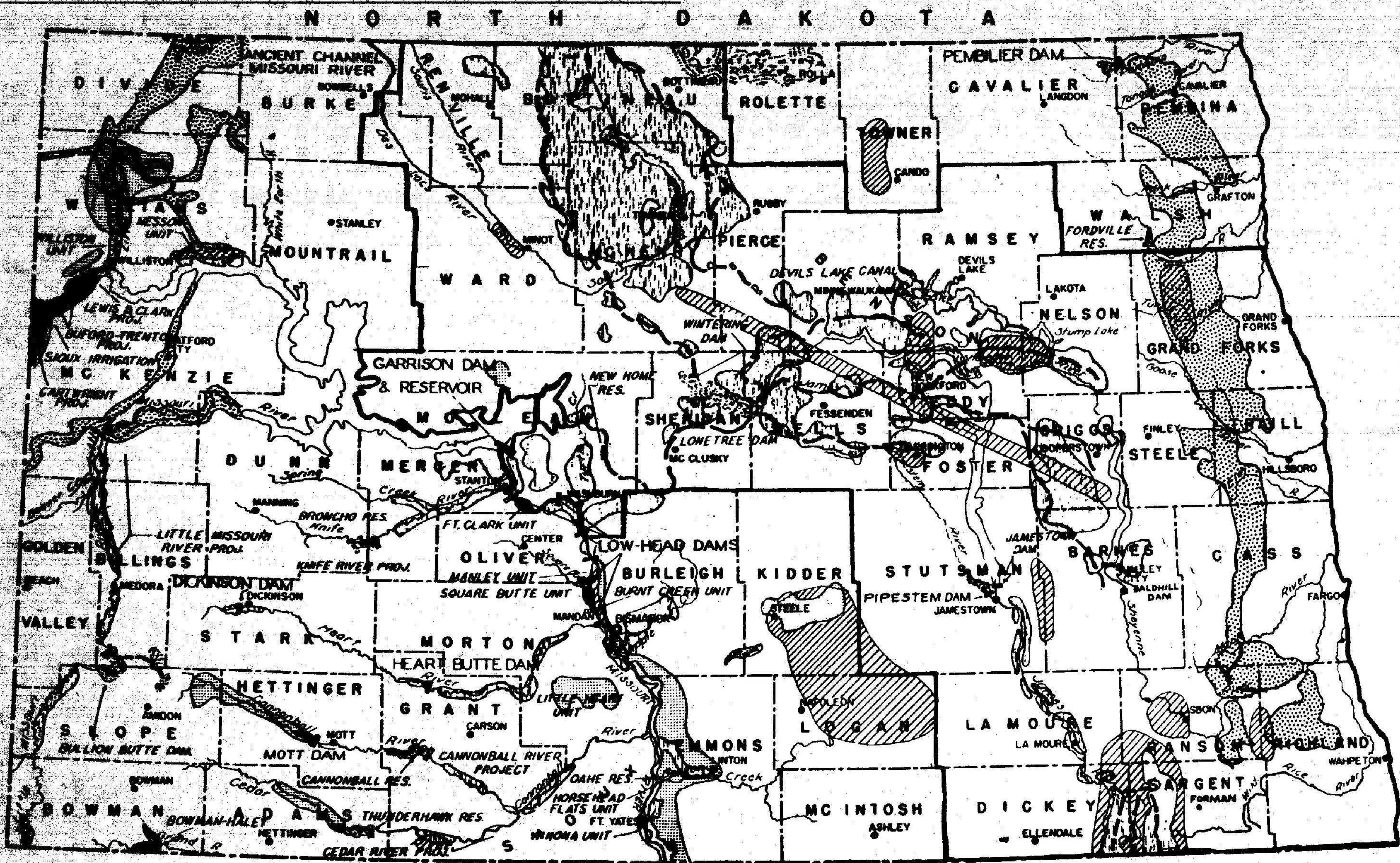

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

- LANDS UNDER IRRIGATION
- AREAS CONSIDERED IRRIGABLE
- AREAS BEING INVESTIGATED
- PROPOSED FOR INVESTIGATION

DAM & RESERVOIR SITES: EXISTING; UNDER CONSTRUCTION OR PROPOSED

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GEOLOGY AND GROUND-WATER RESOURCES OF THE HETTINGER AREA ADAMS COUNTY, NORTH DAKOTA

By
C. J. Robinove

ABSTRACT

The area described in this report includes 216 square miles in Tps. 129 and 130 N., Rs. 95, 96, and 97 W., in southwestern North Dakota. The city of Hettinger (1950 population, 1,762) is in the south-central part of the area.

The Hettinger area is in the unglaciated section of the Missouri Plateau. Thin deposits of Quaternary alluvium are present in the valley of Flat Creek. The Tongue River member of the Fort Union formation lies at the surface throughout most of the area. Underlying the Tongue River member are the Ludlow and Cannonball members of the Fort Union formation, the Hell Creek formation, and the Fox Hills sandstone. The Pierre shale, Niobrara formation, Benton shale, and Dakota sandstone underlie the Fox Hills sandstone.

Domestic and stock water is obtained from the Tongue River member. Wells range in depth from a few feet to more than 200 feet, and generally produce adequate amounts of hard water. Five wells that tap the Fox Hills sandstone at depths ranging from 900 to 1,200 feet supply water to the city of Hettinger. Water from the Fox Hills sandstone is soft but has a high fluoride content. No water is obtained from the alluvium in the stream valleys nor from the Pierre shale, Niobrara formation, Benton shale, and Dakota sandstone.

INTRODUCTION

Location and General Features of the Area

The Hettinger area as described in this report comprises 216 square miles (6 townships) in southern Adams County, N. Dak. (See fig. 1). The city of Hettinger (1950 population, 1,762), in the south-central part of the area, is served by U. S. Highway 12 and a branch of the Chicago, Milwaukee, St. Paul, and Pacific Railroad running east and west. State Highway 8 runs north from its junction with U. S. Highway 12 about 7 miles east of Hettinger. The town of Bucyrus (1950 population,111) is about 8 miles northwest of Hettinger on U. S. Highway 12.

The average annual precipitation at Hettinger, based on a 48-year record by the United States Weather Bureau, is 14.55 inches. The average annual temperature, for the same period of record, is 43°F.

Adams County is in the unglaciated section of the Missouri Plateau, a division of the Great Plains physiographic province. This province is characterized in the Dakotas by rolling uplands and buttes that generally are capped with resistant sandstone, and by interbutte depressions in softer rocks; the depressions are covered, in places, with a veneer of sediments eroded from the buttes and, in turn, contribute sediments to the terraced river valleys (Fenneman 1931, p. 66[1/]).

Purpose and Scope of the Investigation

A study of the geology and ground-water resources of Adams County, N. Dak., is being made by the United States Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the North Dakota Geological Survey. The study is one of a series of investigations in the State and this report is No. 24 in the series. The purpose of these investigations is to study the surface and subsurface geology, and to determine the occurrence, movement, discharge

1/See "Literature Cited" at the end of this report.

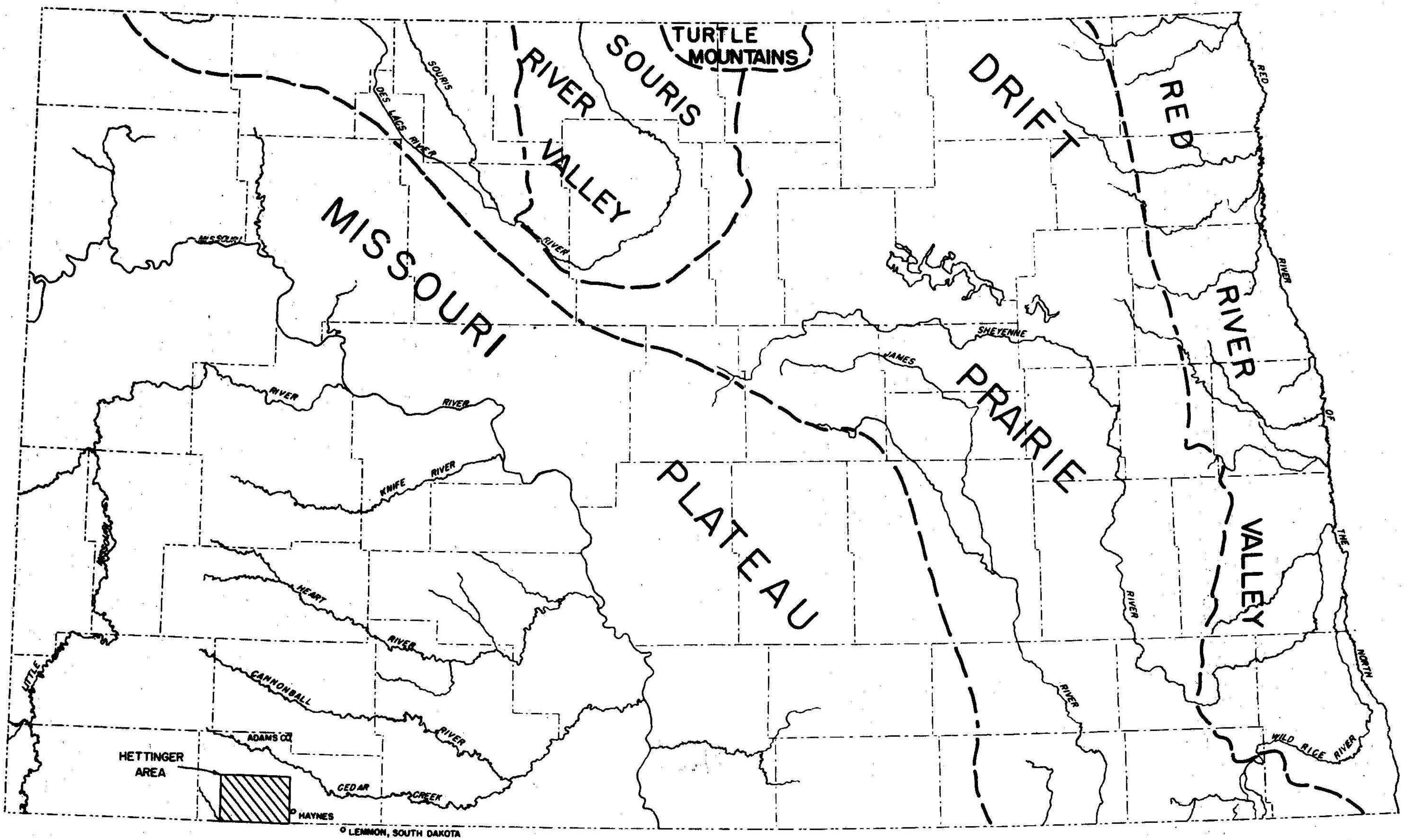


FIGURE I

MAP SHOWING PHYSIOGRAPHIC PROVINCES IN NORTH DAKOTA (MODIFIED AFTER SIMPSON) AND LOCATION OF THE HETTINGER AREA.

recharge, quantity, and quality of the ground water available for all purposes, including municipal, domestic, irrigation, and industrial. The most critical current need is an adequate and perennial water supply for many towns and small cities throughout the State. Therefore,countywide studies are begun in the vicinity of towns that request the help of the State Water Conservation Commission and the State Geologist to locate suitable ground-water supplies. Progress reports, such as this one, are prepared before the completion of the general studies so that current data may be available for use in connection with immediate problems.

The work done during this investigation consists of (1) an inventory of wells and springs in the area, (2) test drilling, (3) determination of the land-surface elevations of the test holes by aneroid barometer, (4) collection of and mineral analysis of water samples from wells and springs, (5) a pumping test of the Fox Hills sandstone, and (6) a study of the available data.

Previous Investigations and Acknowledgments

The first detailed geologic mapping in the Hettinger area probably was by E Russell Lloyd (1914) as a part of a study of the lignite resources of a larger area. His geologic map includes the southeastern township of the area. Simpson (1929, p. 63-65) has discussed the geology and ground-water resources of Adams County, and Abbott and Voedisch (1938) have discussed the chemical quality of the water supply of Hettinger.

This investigation was made under the direct supervision of J. W. Brookhart, district geologist of the Ground Water Branch of the Geological Survey, Grand Forks, N. Dak.

Mayor Alvin Cors and members of the Hettinger City Council were most helpful during the investigation. Sterling Norbeck and Alfred Jacobson, well drillers, generously furnished information about wells in the area.

Present Water Supplies and Future Needs

Rural Water Supplies

Water in the rural parts of the Hettinger area is used principally for domestic and livestock needs. The commonest type of well is drilled, 4 to 6 inches in diameter and generally less than 200 feet deep; most, but not all, were reported to be adequate and to produce a perennial water supply. A few shallow dug or bored wells furnish water for farm use, but several were reported to produce inadequate amounts of water or to become dry during drought years. No difficulty is expected in future development of ground water for farm use in the Hettinger area.

Municipal Water Supplies

The city of Hettinger obtains water from five wells producing from depths between about 800 and 1,200 feet below land surface. The yield from each well ranges from 40 to 60 gpm (gallons per minute) depending on the drawdown in the well. The water is pumped in a closed system directly into the mains or water tower. Two of the wells were formerly owned by the Chicago, Milwaukee, St. Paul, and Pacific Railroad and were purchased by the city of Hettinger in 1955, to supplement the water obtained from the three other city-owned wells. The railroad wells formerly obtained water from two aquifers. The upper aquifer, which lies between depths of about 286 and 400 feet below the land surface, yields water that is objectionable because it has a brown color, due to dissolved organic material from lignite beds in the aquifer, and tends to stain enamel fixtures and laundry. The city of Hettinger installed sleeves in the well casings of the two railroad wells in an attempt to seal the upper aquifer. The lower aquifer is the same as that tapped by the three other city-owned wells.

The three original city wells did not produce sufficient water to meet peak demands and to provide fire protection. Thus, the use of water was necessarily restricted during the summers of 1953, 1954, and 1955. The additional water from the former railroad wells has temporarily satisfied the demand for water, but an increase in population or water use, or both, may again result in a water shortage in the future.

Well-Numbering System

The well-numbering system used in this report is illustrated in figure 2 and is based upon the location of the well within the United States Bureau of Land Management's survey of the area. The first numeral denotes the township north of the base line; the second numeral denotes the range west of the fifth principal meridian, and the third numeral denotes the section in which the well is located. The letters a, b, c, and d designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections (10-acre tracts). Consecutive terminal numerals are added when more than one well occurs within a 10-acre tract. Thus, well 129-95-8ccc is in the southwest quarter of the southwest quarter of the southwest quarter of sec. 8, T. 129 N., R. 95 W. Similarly, well 130-95-30dcb2 is the second well inventoried in the northeast quarter of the southwest quarter of the southeast quarter of sec. 30, T. 130 N., R. 95 W.

GEOLOGIC HISTORY

Thick sections of sedimentary rocks underlie the Dakota sandstone to relatively great depths. The formations are not discussed in this report because they are not considered to be sources of water supply in the area.

Cretaceous period.--The area that is now the northern Great Plains was covered during most of Cretaceous time by a vast sea in which the sediments of the Dakota,

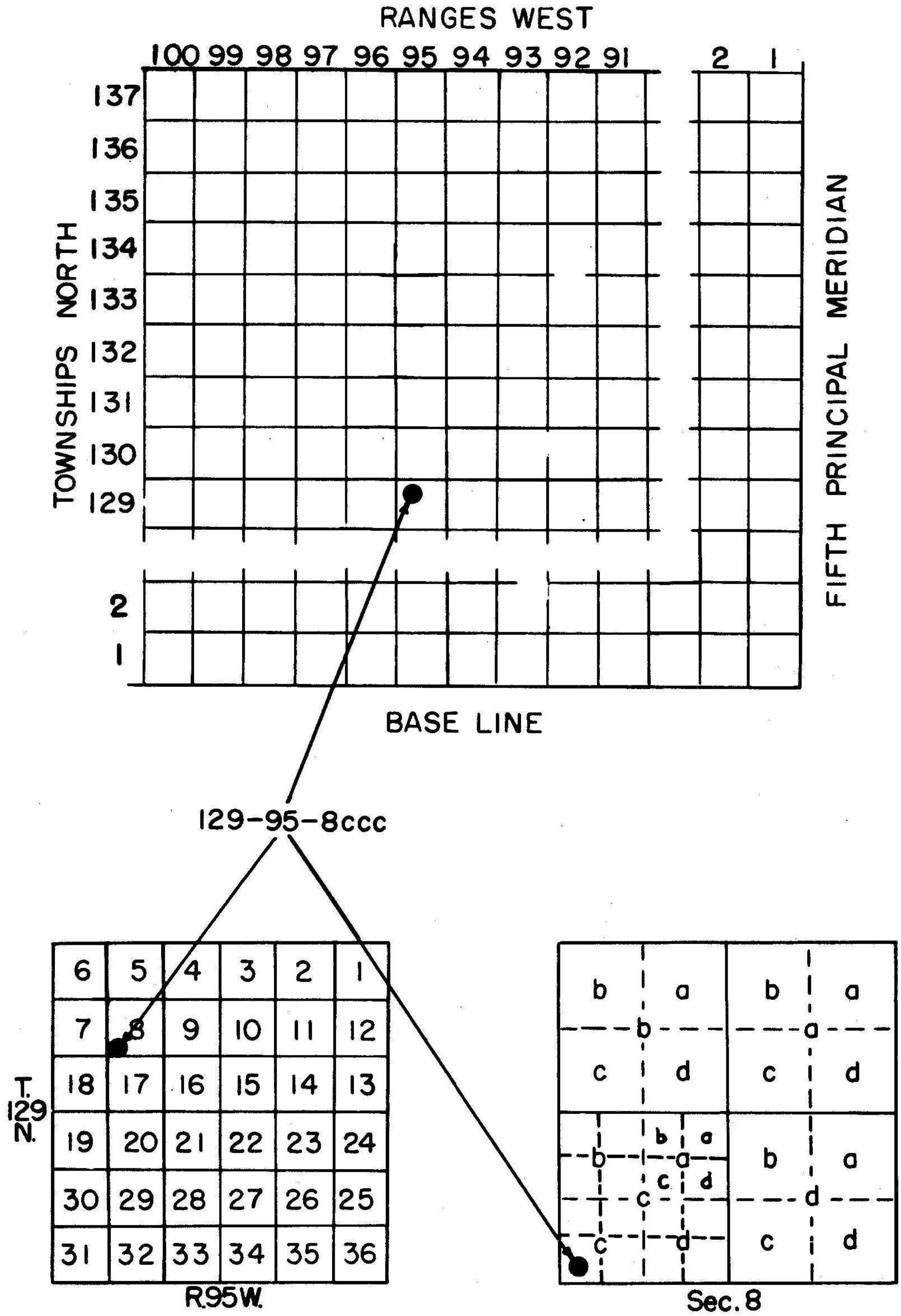


Figure 2. --Sketch illustrating well-numbering system.

Benton, Niobrara, Pierre, and Fox Hills formations were deposited. The sediments of the Dakota sandstone were deposited as the Cretaceous sea advanced over the land and they include both terrestrial and marine sediments. The other Upper Cretaceous formations, except the Hell Creek, are very uniform in lithology over wide areas, indicating that the marine conditions under which they were deposited probably were very uniform. During the retreat of the sea in Late Cretaceous time, terrestrial sandstone, shale, and lignite were deposited over the marine sediments and formed the Hell Creek formation (Laird and Mitchell, 1942).

Tertiary period.--Another marine invasion, though not as extensive or long lasting as the Cretaceous invastion, occurred in Paleocene time. The sandstone and shale of the Cannonball member of the Fort Union formation were deposited in this sea. The Cannonball member becomes progressively thinner westward and grades into and interfingers with the terrestrial Ludlow member of the Fort Union formation, which was deposited on the western shore of the Cannonball sea. The sea then withdrew from the Great Plains and the terrestrial Tongue River member of the Fort Union formation was deposited. The Tongue River member is similar to lithology to the Ludlow member but it overlies both the Ludlow and the Cannonball members. It is the most widely distributed surficial formation in southwestern North Dakota (Laird and Mitchell, 1942).

Quaternary period.--Alluvium derived from the erosion of the Tertiary sediments was deposited in the stream valleys. It consists of clay with small amounts of sand and gravel and is fairly thin in the Hettinger area.

PRINCIPLES OF OCCURRENCE OF GROUND WATER

Essentially allground water is derived from precipitation. Rain or melted snow enters the ground by direct penetration or by percolation from streams and lakes that lie above the water table. Ground water generally moves laterally from area of recharge to areas of natural discharge.

Ground water is discharge by evaporation from lakes and ponds, by plan transpiration, by evaporation from the land surface in areas where the water table is near the land surface, by seepage to streams and by pumping or flow from wells.

Any rock formation or stratum that will yield water in sufficient quantity to be important as a source of supply is called an "aquifer" (Meinzer,1923, p.52). Water moving in an aquifer from recharge to discharge areas may be considered to be in "transient storage".

The amount of water that a rock can hold is limited by its porosity. Unconsolidated material, such as clay, sand, and gravel, generally is more porous than consolidated rocks, such as sandstone and limestone; however, consolidated rocks in some areas are highly porous. The capacity of an aquifer to yield water by gravity drainage may be much less than indicated by its porosity, because part of the water is held in the pore spaces by molecular attraction between the water and the rock particles; the smaller the pores, the greater the proportion of water that will be held. The amount of water, expressed in percentage of a cubic foot, that will drain by gravity from 1 cubic foot of an aquifer is called the "specific yield" of the aquifer.

If the water is an aquifer is not confined by overlying impervious strata the water is under water-table conditions, and can be obtained from storage in the aquifer by gravity drainage--that is, by lowering the water level as in the vicinity of a pumped well.

Water is under artesian conditions if it is confined in the aquifer by an overlying impermeable stratum. Under these conditions, hydrostatic pressure will cause the water in a well, or other conduit penetrating the aquifer, to rise above the top of the aquifer, and the aquifer yields water as the water level in the well is lowered. However, the aquifer remains saturated; it yields water because the water expands and because the aquifer is compressed as the pressure is decreased. Gravity drainage does not occur under normal artesian conditions.

The volume of water that is released from storage in a unit volume of an aquifer when the water level in the aquifer lowers a unit distance is indicated by the "coefficient of storage". Under water-table conditions it is essentially equal to the specific yield, but under artesian conditions it is very much smaller than the specific yield.

Material in which the pore spaces are relatively large, as in coarse gravel, offers little resistance to the movement of water, and the material has a "high permeability". However, material in which the pore spaces are small, as in clay or shale, may offer great resistance to the movement of water, such material has "low permeability". Permeability is expressed quantitatively, for field use, as the number of gallons of water per day that will pass through a cross-sectional area of 1 square foot under unit, or 100-percent, hydraulic gradient at the temperature of the local ground water.

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

The water-yielding potential of an aquifer is governed by its permeability or transmissibility, by its volume, and by its ability to store and release water. Recharge to the aquifer also must be adequate if the water-supply development is to last indefinitely, because even a small rate of withdrawal will deplete the water in storage unless it is replenished by recharge. Aquifers of high permeability, but small in areal extent and completely enclosed in relatively impermeable material, have been pumped nearly dry in a comparatively short time, to the detriment and disappointment of those concerned. The rather high initial yield of a well may give an erroneous impression that a great volume of water will be available from the aquifer indefinitely. Thus, before a ground-water development is made, sufficient test drilling should be done and pumping tests made to determine the water-yielding capabilities of and the recharge to the aquifer being considered.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Table 1 shows a stratigraphic section of the geologic formations that underlie the Hettinger area, and their water-bearing properties. Formations older than the Dakota are not shown in the table or discussed in this report.

Dakota Sandstone

The Dakota sandstone comprises sandstone and shale beds of Early Cretaceous age. In the Hunt Oil-Zach Brooks No. 1 State oil test well (129-104-16bb) in Bowman County, about 55 miles west of Hettinger, the top of the Dakota sandstone is reported to be 4,676 feet below the land surface. The total thickness of the Dakota sandstone in this well is reported (Petroleum Inf. Co., 1954) to be 379 feet.

No wells have been drilled to the Dakota sandstone in the Hettinger area because of its great depth and because of the probability that water from the formation is too highly mineralized for municipal or domestic use.

Benton Shale, Niobrara Formation, and Pierre Shale

Gray shales of the Benton, Niobrara, and Pierre formations form most of the Upper Cretaceous formations in North Dakota. The top of the Pierre shale is about 1,200 feet below the land surface at Hettinger. In the Western Natural Gas No. Traux-Traer test well (132-102-13db) in Bowman County, about 40 miles west of Hettinger, the total thickness of the Pierre, Niobrara, and Benton formations is reported (Petroleum Inf. Co. 5-13-54) to be 3,813 feet.

No wells in the Hettinger area obtain water from these formations; they will yield only meager amounts of water to individual wells anywhere in the State. The shales, although they may be saturated, do not yield water readily to wells.

Fox Hills Sandstone

The Fox Hills sandstone overlies the Pierre shale and is about 900 feet below the land surface at Hettinger, no samples of the sandstone were available for study. However, its total thickness is reported to be 320 feet at Elk Butte in sec. 15, T. 20 N., R. 27 W., Corson County, S. Dak., about 55 miles southeast of Hettinger (Laird and Mitchell, 1942, p.6). The formation consists of a basal zone of crossbedded and partly concretionary sandstone, a middle zone of interbedded sandstone and shale, and an upper zone of light-gray sandstone. Marine fossils are abundant in the Fox Hills sandstone and indicate that the sediments were deposited in an oceanic environment.

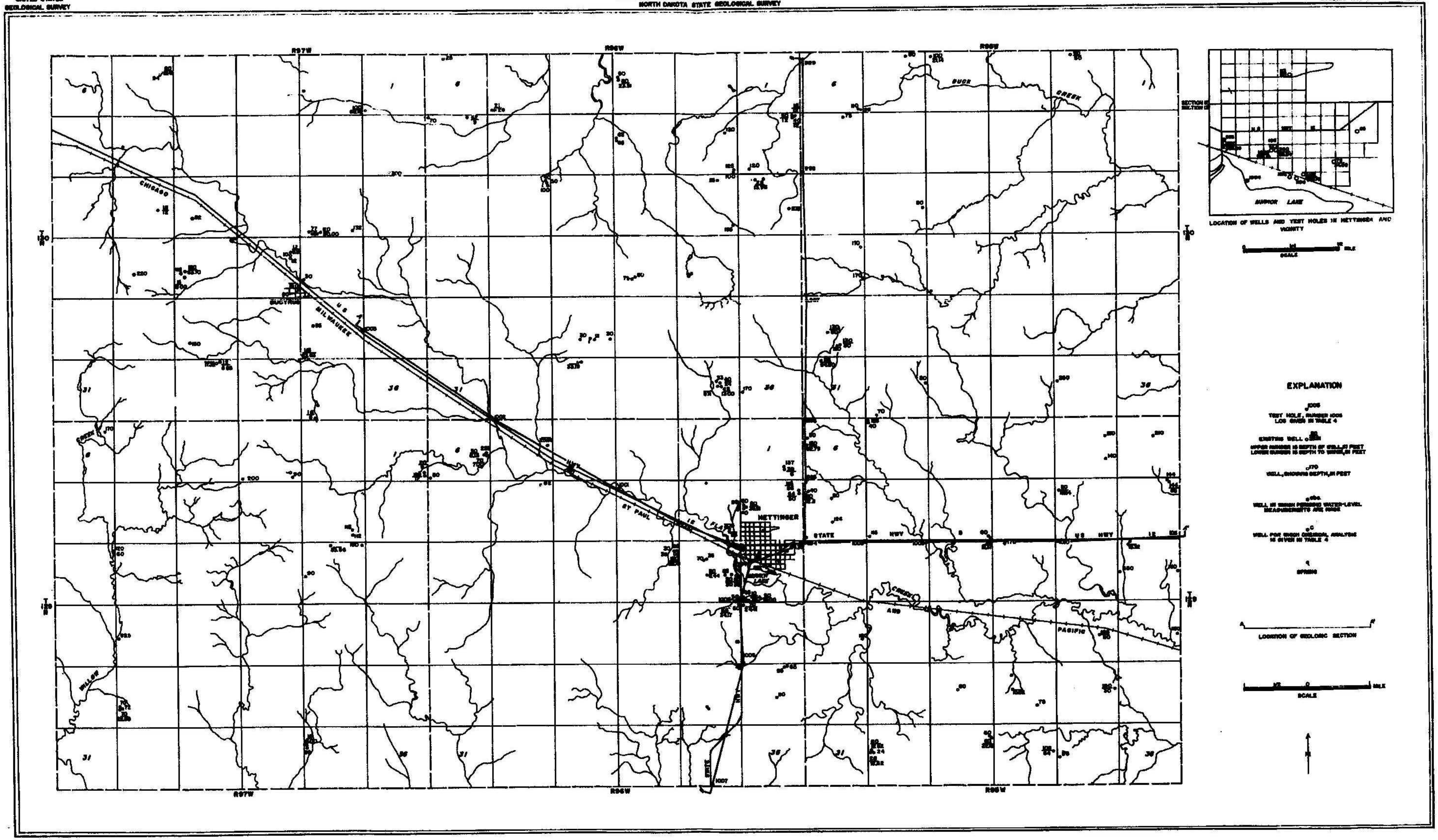
No test hole drilled during the investigation reached the Fox Hills sandstone. However, the log of well 129-96-13bdd2 shows interbedded sands and clays between 892 and 1,192 feet that probably belong to the Fox Hills sandstone.

The casings of the Hettinger municipal wells, including the former railroad wells, are perforated opposite the sandstone beds of the Fox Hills sandstone. The formation is an artesian aquifer and the static water level is about 335 feet below the land surface. The different sand beds may have different artesian pressures, and the formation may not act as a single hydrologic unit, at least during short periods of pumping. A well at Lemmon, S. Dak., tapping the Fox Hills sandstone was reported to produce 60 gpm with 180 feet of drawdown. The casing in this well was perforated at 700 and 940 feet below the land surface. A well drilled several years later was perforated only in the 940-foot sand and produced 100 gpm with approximately the same drawdown.[2/] Thus, the lower water-bearing zone probably is under greater pressure than the upper zone, and perforating the well casing opposite both zones allows water to move from the lower to the upper zone, with a consequent loss of water from and pressure in the lower zone.

2/Sterling Norbeck, personal communication, 1954

TABLE 1.--Geologic Formations and Their Water-Bearing Properties

Era	System	Formation	Character of rocks	Thickness (feet)	Approximate depth (feet below lsd)	Water Supply
Cenozoic	Quaternary	Alluvium	Clay, gravel	0-20	Surficial deposits in stream valleys	Variable
	Tertiary	Fort Union formation	Sandstone, shale, lignite	350-600	Surficial deposits	Will yield small amounts throughout area; water generally is hard.
Mesozoic	Cretaceous	Hell Creek formation	Sandstone and shale	100-575	500-900	Not an aquifer in the area.
		Fox Hills sandstone	Sandstone and some shale	320 ±	900	Yields moderate amounts of soft water.
		Pierre shale	Shale	1,800 ±	1,200	None
		Niobrara formation	Shale	200 ±	3,000	None
		Benton shale	Shale	1,000 ±	3,200	None
		Dakota sandstone	Sandstone, shale	200 ±	4,200	Water-bearing in eastern N. Dak. but not tapped in or near area.

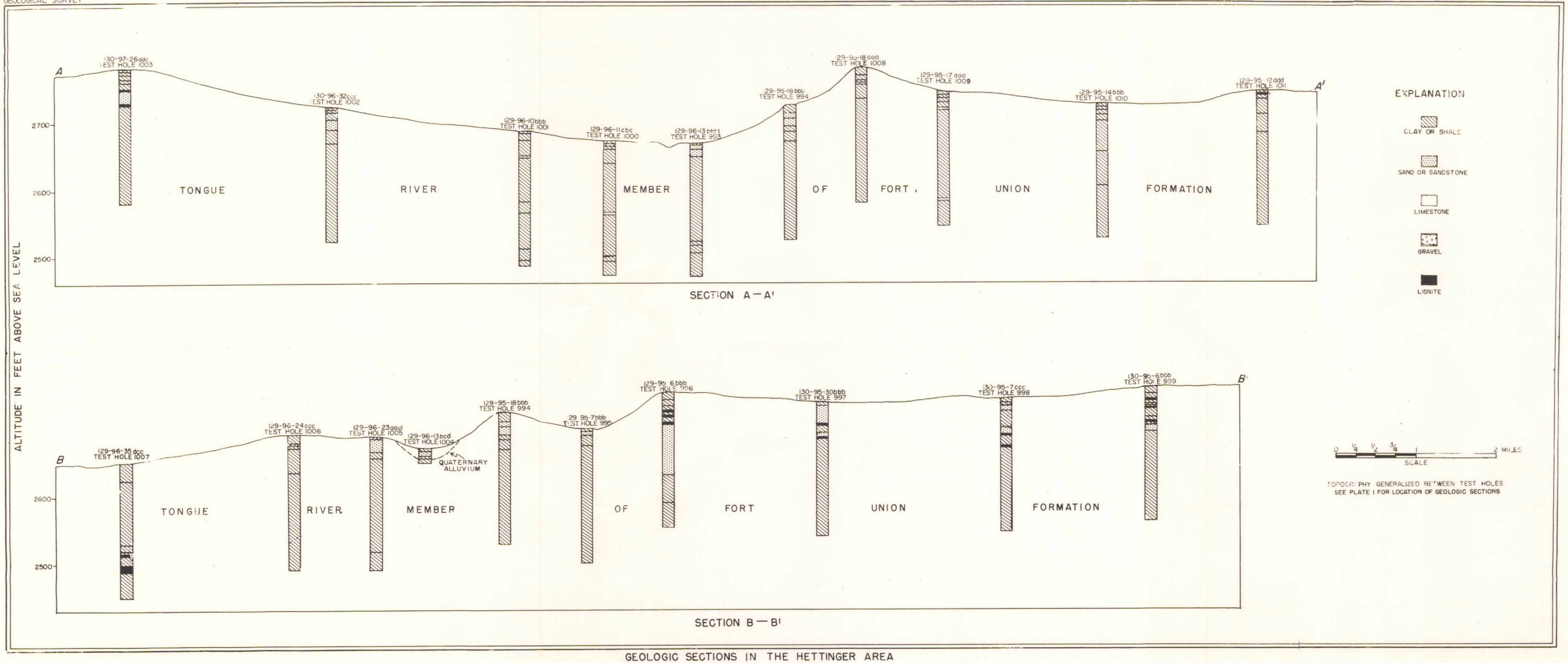


MAP OF HETTINGER AREA, ADAMS COUNTY, NORTH DAKOTA, SHOWING LOCATION OF WELLS, SPRINGS, TEST HOLES, AND GEOLOGIC SECTIONS

UNITED STATES
GEOLOGICAL SURVEY

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
NORTH DAKOTA STATE GEOLOGICAL SURVEY

NORTH DAKOTA GROUND-WATER
STUDIES NO. 24 PLATE 2



GEOLOGIC SECTIONS IN THE HETTINGER AREA

An aquifer test was made at the site of the Hettinger municipal wells, but because of obstructions between the pump columns and casings, the drawdown could be measured in only one well. The drawdown in this well did not follow a normal pattern and therefore the coefficients of storage and transmissibility of the aquifer could not be determined. The situation of differential head that exists in the Fox Hills sandstone at Lemmon,S. Dak. may occur here also and may be responsible for the abnormal drawdown measurements. A drawdown of about 40 feet was measured in city well 129-96-13bdd1 after the railraod wells had pumped for 2 hours. The static water level in this well was reported to be 305 feet below the land surface when it was drilled in 1936; the static level was 335 feet below the land surface in the fall of 1954.

The static water level in one former railroad well is reported to have been 211 feet below the land surface, and its drawdown to have been 166 feet,when it was drilled in 1937. The static level in the other former railroad well is reported to have been 220 feet below the land surface,and its drawdown to have been 172 feet, when drilled in 1940. The difference in static water levels of the wells from 1937 to 1955 is about 115 feet. This difference may represent a decline in head due to pumping since the original development of the well field, interference from other pumped wells when the recent measurements were made, or an incomplete recovery to the static level after pumping had ceased. Interference of new with existing wells can be prevented or diminished by locating the new wells far enough from the present well field to prevent or minimize the intersection of their respective cones of depression.

Hell Creek Formation

The Hell Creek formation consists of gray bentonitic shale and sandstone, lignite, lignitic shale,and concretions. It does not crop out in the Hettinger area but is exposed in Bowman and Slope Counties, about 45 miles west of Hettinger, and near the Missouri River, about 60 miles east of Hettinger.

Logs of the former railraod wells at Hettinger provide the only geologic data about formations that underlie the Fort Union formation in the Hettinger area, and the formational contacts cannot accurately be identified from the logs. However, the Hell Creek formation is assumed to underlie the area.

The sandstone and lignite beds of the Hell Creek formation will yield small amounts of water, but probably no more than shallower formations will yield. The only wells that penetrate the Hell Creek formation in the Hettinger area are the municipal and former railroad wells. The brown water formerly obtained from the railroad wells may be from the Hell Creek formation or shallower beds. The original municipal wells do not produce water from the Hell Creek formation.

Fort Union Formation

The Fort Union formation of Tertiary age comprises three members: the basal Cannonball and Ludlow members and the Tongue River member.

Outcrops of the Cannonball member, which consists of fine-grained sandstone and shale, have been mapped in the Flat Creek valley near Haynes, N. Dak. (Lloyd, 1914). The member probably is not more than 150 feet thick in the eastern part of the Hettinger area and is progressively thinner toward the west where it interfingers with and is replaced by the Ludlow member. The Cannonball member is of marine origin and the Ludlow member is terrestrial; the contact between the two members represents the shoreline of the Paleocene sea in which the Cannonball member was deposited.

The Ludlow member consists of sand, shale, lignite, and lignite shale. It is progressively thicker toward the west and eventually replaces the Cannonball member.

The Tongue River member constitues the surficial deposits in most of the Hettinger area. The total thickness of the Tongue River member is about 300 feet where it is completly exposed outside the Hettinger area. Post-Oligocene erosion probably removed some of the member in the area. During the investigation 19 test holes, toatling 3,578 feet in depth, were drilled in the Tongue River member; 3,309½ feet of the drilling was in clay, 228½ feet in sand or sandstone, 26 feet in lignite, 9 feet in limestone, and 5 feet in gravel. The sand or sandstone and lignite beds generally are small in areal extent and thin, and many probably are completely enclosed by clay beds.

A stratigraphic section of the beds of the Tongue River member, exposed in a small bute in T. 23 N., R. 12 E., sec. 23, Perkins County, S. Dak. is as follows:

Description	Thickness (feet)
Sandstone, fine-grained, buff, thin-bedded	2
Siltstone, gray, thin-bedded, with 1" to 4" beds of rusty-brown siltstone which is more resistant to weathering than the gray siltstone; sandy ironstone concretions	25
Siltsone, gray, yellow, purple, very thin-bedded; 1" zone at base contains many plant fragments	4
Siltstone, gray; 3" brown sandy zone at bottom, slightly oxidized at top; many plant fragments	3
Lignite, clayey and sandy, with yellow stains................	1
Shale, brown to purple, fissile, jointed; plant fragments....	8
Shale, sandy, and thin-bedded lignite, brittle; weathers to a reddish-brown color................................	6
Lignite, and lignitic yellow shale, thin-bedded, brittle.....	6
Shale, plastic, light-gray; very fractured thin zones of iron concretions; leaf fragments; yellow stains on joint planes. Base not exposed................................	15
Total	70

Logs of test holes drilled in the Tongue River member are given in table 3.

Adequate water for farm use is available from sandstone and lignite beds in the Fort Union formation at most places in the Hettinger area. However, many wells must be drilled to depths of nearly 200 feet before sufficient quantities of water are obtained. A few deep wells in the formation were reported to be inadequate, and some shallow dug or bored wells were reported to become dry during drought years. Several springs yieldwater for livestock. The measured flow from spring 130-96-23c was approximately 15 gpm in May 1955.

Whether any wells in the area obtain water from the Cannonball or Ludlow members could not be definitly established. The water-bearing characteristics of those members probably are similar to those of the shallower Tongue River member.

Water that is withdrawn by wells from the sand and lignite beds must be replaced if a perennial supply of water is to be maintained. Recharge is from precipitation in the form of rain or melted snow that seeps into the ground and thence through the clay layers into the sand and lignite beds. All the rocks below the water table are saturated, but only the sand and lignite beds are sufficiently permeable to yield water in quantities adequate for domestic and farm use. The sand and gravel beds are not continuous (see pl. 2), and predicting the depth and thickness of an aquifer is extremely difficilt or impossible without prior knowledge of the subsurface geology at or very near the point in question. Wells of the same depth only a short distance apart may produce greatly different quantities of water because one may tap a sand or lignite bed while the other may be entirely in clay.

The lenticular nature of the aquifers is illustrated by test holes 995 and 996 (see pl. 2). Test hole 995 penetrated only a few feet of soft sandstone near the land surface and bottomed in clay at a depth of 200 feet; test hole 996, only a mile away, penetrated three lignite beds and a thick bed of clayey sand within 125 feet of the land surface. Much more water could be obtained from a well at test hole 996 than from a well near test hole 995. If a quantity of water larger than that normally needed for domestic and stock use is required, the characteristics of the water-bearing materials should be determined by drilling test holes before drilling production wells.

Quaternary Alluvium

Fourteen feet of alluvium was penetrated in test hole 1004 (129-96-13bcd) in the Flat Creek valley at Hettinger. The alluvium consisted of clay and some sand and gravel.

No wells obtain water from the alluvium. The saturated thickness of the alluvium depends upon the stage of Flat Creek and Mirror Lake; if the water level in the lake declines, the water level in wells in the alluvial deposits will drop, and wells would go dry. Adequate quantities of water for municipal use probably could not be obtained from these deposits.

QUALITY OF THE GROUND WATER

Principles of Water Quality

Ground water dissolves a part of the soluble menerals in the rocks as it moves through an aquifer. The amount of mineral dissolved is governed by the amount and kind of soluble materials in the aquifer and by the length of time the water is in contact with them. Therefore, water that has been stored underground a long time or that has traveled a great distance through an aquifer generally is more highly mineralized than water relatively near the recharge area, provided the aquifer is of homogeneous mineral composition.

The following is a partial list of chemical substances for which the U. S. Public Health Service (1946) has specified maximum concentration limits in drinking water used on common carriers in interstate traffic. These standards for drinking water have been recommended by the American Water Works Association for all public water supplies.

Chemical constituent	Maximum concentration may be permitted (parts per million)
Dissolved solids	500 (1,000 if better water is not available)
Chloride (Cl)	250
Sulfate (SO_4)	250
Magnesium (Mg)	125
Fluoride (F)	1.5
Iron and manganes (Fe ≠ Mn)	0.3

Excessive amounts of nitrate in ground water may indicate organic contaminatio Water containing more than about 44 ppm of nitrate also may cause cyanosis when fed to infants (Comly, 1945; Silverman, 1949). Fluoride in drinking water in concentrations of 0.8 to 1.5 ppm is known to prevent or lessen the incidence of dental caries (tooth decay) in children. Higher concentrations, however, may cause mottling of teeth (California State Water Pollution Control Board, 1952, p. 257).

Practically all ground wter contains calcium and magnesium, which cause hardness of varying degree depending upon the concentration of these constituents. Hardness in water is undesirable, especially in water used for washing, because it increases soap consumption. Water having a hardness of about 100 ppm as $CaCO_3$ generally is considered to be moderately hard; water having a hardness of 100 to 200 ppm usually can be softened economically.

Water containing large amounts of sodium, in relation to the total cation concentration, is undesirable for irrigation because the soil tends to become impermeable with its prolonged use. The sodium reduces the permeability by closing the pores of the soil and impairing drainage. The impairment of drainage in turn tends to raise the concentration of sodium in the soil (California State Water Pollution Control Board, 1952, p. 357).

Dakota Sandstone

No wells penetrate the Dakota sandstone in the Hettinger area. Water from the formation in eastern North Dakota is highly mineralized, and in places it contains as much as 20,000 ppm of dissolved solids. It is probable that the water is highly mineralized in the Hettinger area also.

Fox Hills Sandstone

Analyses of two samples of water from the Fox Hills sandstone are given in table 2. The water is slightly saline (1,070 and 1,100 ppm of dissolved solids), but is soft and suitable for laundry use. The fluoride concentration is high, the concentration of dissolved solids is greater than 1,000 ppm, and the water should not be used regularly as drinking water by children. The percent sodium, the ratio of sodium to the principal cations (sodium, potassium, calcium, and magnesium)- all concentrations being expressed in equivalents per million - is large (97-99 percent). Therefore, the water is not suitable for irrigation or lawn watering; however, it is acceptable for some domestic uses.

Fort Union Formation

Analyses of five samples of water from the Fort Union formation are included in table 2. Four samples are from wells and one is from a spring.

Well 129-96-4cac produces water from a lignite bed; the water has a high amount of dissolved organic material, which gives it an objectionable brown color and a tendency to stain enamel fixtures and laundry. The water has a high fluoride concentration and is very soft.

The water from spring 130-96-23c is very hard, high in iron and sulfate, and objectionable for laundry use, although its content of dissolved solids is relatively low.

Well 129-96-13bl (400? feet deep) produced water that is high in iron, moderate in dissolved solids, and soft.

Water from well 129-96-13b2 (30 feet deep) is the least mineralized of all the waters analyzed. The content of dissolved solids is relatively low, but the water is hard. Many well owners in the rural parts of the Hettinger area report that water from wells as deep as 200 feet is hard.

SUMMARY

Most of the ground water used in the Hettinger area is obtained from two aquifers: the Tongue River member of the Fort Union formation yields water to the shallow domestic and farm wells, and the Fox Hills sandstone yields water to the municipal wells at Hettinger. Adequate water for farm and domestic use generally is available from sand and lignite beds of the Tongue River member, but in many places several water-bearing beds must be tapped by a well to obtain sufficient water. More water can be pumped from the Fox Hills sandstone in the area, but new wells will need to be far enough from existing wells to assure a minimum of interference.

Water from the Tongue River member generally is hard but is suitable for domestic and stock purposes. Water from the Fox Hills sandstone is soft and, except for a high fluoride content, is suitable for general domestic use.

ANALYSES OF GROUND WATER
per million)

Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation)	Hardness as $CaCO_3$
412	2	956	41	12	33	5	4	1,090	10
130	21	556	..	1,360	156	...	17	3,290	1,940
418	1.8	604	95	45	130	3.5	6	1,100	9
423	....	894	..	24	128	3.2	.3	1,070	28
316		849	0	42	12	...	2.0	854	55
7.7		307	0	14	2.0	...	3.1	274	263
16	6.8	215	..	316	T	.1	T	750	455

TABLE 2.--CHEMICAL
(Parts

Aquifer: FH, Fox Hills sandstone; FU, Fort Union formation
Lig, lignite; Sd, sand; Ss, sandstone
Chloride: T, trace

Location number	Owner or name	Date of collection	Depth of well (feet)	Aquifer		Iron (Fe)	Calcium (Ca)	Magnesium (Mg)
				Formation	Material			
129-96								
4cac	Alfred Rose 1/	11-22-54	450	FU	Lig	1.9	...	2.4
13bac3	Adams County Creamery 1/	11-22-54	106	FU	Sd	.19	161	373
13bbb2	Hettinger 1/	11-22-54	1,180	FH	Ss	0.7	...	2.2
13	do 2/	1936?	1,152?	FH	Ss		2.4	4.5
13b1	do 3/	7-23-21	400?	FU	Sd	1.3	12	6.1
13b2	O. T. Peterson 3/	7-23-21	30	FU	Sd	.20	56	30
130-96								
23c	Tom Clement 1/	5-26-55	Spring	FU	Lig	2.6	99	50

1/Analysis by North Dakota State Laboratories Dept.
2/Abbott and Voedisch, 1938.
3/Simpson, 1929.

Depth of well and depth to water: Measurements are given in feet, tenths, and hundredths; reported depths are given in feet.

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

Remarks: Statements on adequacy, quality, and suitability are as reported by users.

Location no.	Owner or name	Depth of well (feet)	Diameter (inches)	Type of well	Date completed	Depth to water (feet) below land surface)
129-95						
1acb	Gaylord Olson	210	...	Dr	1950	......
2adb	Mrs. C. Olson	150	6	Dr	....	......
2dac	Gaylord Olson	140	...	Dr	....	......
5bbb1	L. R. McNeil	40	...	Dr	1946	......
5bbb2	do	125	...	Dr	....	......
6bbb	Test hole 996	200	5	Dr	1955	......
6bcb	Bob Simonson	90	6	Dr	....	......
6bcc	Albert Beckman	130	24	...	....	112.79
7bbb	Test hole 995	200	5	Dr	1955	......
7bbc1	L. Seamonds	90	4	Dr	....	32.8
7bbc2	do	40	6	Dr	....	......
7bda	C. Remington	80	...	Dr	....	......
7cad	Jim Massad	126	...	Dr	1943	......
7ccc	Eric Eneberg	...	6	Dr	....	......
8ccc	Lloyd T. Meller	115	4½	Dr	....	......
9ddd1	G. Zimmerman	60	6	Dr	....	......
9ddd2	do	26	...	Du	....	15.37
11bbc	Hilma Peterson	80	...	Dr	....	19.34
12aab1	O. Nottviet	144	4	Dr	1941	85
12aab2	do	144	4	Dr	....	......
12ddd	Test hole 1011	200	5	Dr	1955	......
13bba1	A. Steinbach	...	6	Dr	....	......
13bba2	do	...	6	Dr	....	15.32
13cbb	John Gustin	160	6	Dr	....	......
13daa	do	160	...	Dr	....	......
14bbb	Test hole 1010	200	5	Dr	....	......

Use of water: D, domestic; Ind, industrial; Irr, irrigation; PS, public supply; S, stock, T, test hole; U, unused.

Aquifer: FH, Fox Hills sandstone; FU, Fort Union formation; Lig, lignite; Sd, sand; Ss, sandstone.

Date of measurement	Use of water	Aquifer: Formation	Aquifer: Material	Elevation of land surface	Remarks
.....	S	...	..	.....	Water soft, adequate.
.....	S	..	..	.....	Water inadequate, unfit for laundry.
.....	D,S	..	..	.....	Water rusty; adequate.
.....	D	..	..	.....	Water hard.
.....	S,Irr.	..	..	.....	Water medium hard.
.....	T	..	..	2,758	See log.
.....	D,S	..	..	.....	Water adequate but rusty; unfit for laundry.
10- 4-54	D,S	..	..	.....	Water hard; adequate.
.....	T	..	..	2,703	See log.
10- 4-54	S	..	..	.....	Water hard; adequate.
.....	D	..	..	.....	Well goes dry after yielding about 100 gal under steady pumping.
.....	D	..	..	.....	Water hard; adequate, but unfit for laundry.
.....	D	..	..	.....	Water medium hard;adequate. See log.
.....	D,S	..	..	.....	Water hard; well easily pumped dry.
.....	D,S	..	..	.....	Well goes dry during heavy pumping Water hard, rusty.
.....	D,S	..	..	.....	Water medium hard;adequate.
10- 5-54	D,S	..	..	.....	Water hard, rusty. Temp. measured 58°F.
10- 5-54	D,S	..	..	.....	Water hard, rusty; adequate.
1954	S	..	..	.....	Water adequate.
.....	D	..	..	.....	Water adequate.
.....	T	..	..	2,756	See log.
.....	D	..	..	.....	Water hard.
10- 6-55	U	..	..	.....	
.....	D,S	..	..	.....	Water soft; adequate.
.....	S	..	..	.....	Water adequate.
.....	T	..	..	2,728	See log.

Location no.	Owner or name	Depth of well (feet)	Diameter (inches)	Type of well	Date completed	Depth to water (feet below land surface)
129-95 (Cont.)						
15bba	Ray Anderson	170	5½	Dr	1928	.....
17aaa	Test hole 1009	200	5	Dr	1955	.....
18aaa	Test hole 1008	200	5	Dr	1955	.....
18bbb	Test hole 994	200	5	Dr	1955	.....
19daa	E. Stinberg	160	6	Dr	....	.....
23dba	Jacob Maier	165	...	Dr	1949	80
24daa	Ray Brown	150	4	Dr	....	.....
26add	Billy G. Olson	180	...	Dr	....	30
27bac	Bertha Sand	...	6	Dr	....	.....
27bdc	do	...	6	Dr	....	10.82
27dbd	Paul Gordon	78	6	Dr	....	.....
28bdd	W. Bentsen	80	6	Dr	....	.....
32bcc1	L. Manning	60	5	Dr	1952	12.52
32bcc2	do	24	6	B	....	.....
32bcc3	do	28	24	B	1910	12.52
33aad1	George Leonard	60	...	Dr	....	.....
33aad2	do	60	24	Du	....	22.72
34add	Oscar Gordon	106	6	Dr	....	54
35cbb	Paul Gordon	93	4	Dr	....	.....
129-96						
1dca1	Freda Zimmerman	137	6	Dr	1938	.....
1dca2	do	39	...	Dr	1945	6
4cac	Alfred Rose	450	6	Dr	....	.....
5add	....	...	6	...	....	25.89
6ccc	H. Erickson	50	...	Dr	....	.....
6daa1	John Herm	225	6	Dr	....	.....
6daa2	do	30	6	Dr	....	8.13
6daa3	do	70	6	Dr	....	7.00
8aab	Robert Gilman	62	6	Dr	....	.....
10bbb	Test hole 1001	200	5	Dr	....	.....
11add1	W. Hansen	80	6	Dr	....	.....
11add2	do	...	6	Dr	....	.....
11baa	Hettinger Airport	...	6	Dr	1930	.....

Date of measurement	Use of Water	Aquifer: Formation	Aquifer: Material	Elevation of land surface	Remarks
.....	D,S	..	..	.....	Water hard; adequate.
.....	T	..	..	2,746	See log.
.....	T	..	..	2,783	See log.
.....	T	..	..	2,727	See log.
.....	S	..	..	.....	Water adequate.
1949	D,S	..	..	.....	Water adequate; little alkali.
.....	D,S	..	..	.....	Water adequate.
1954	D,S	..	..	.....	Water hard; adequate.
.....	D,S	..	..	.....	Water medium hard; adequate.
10- 6-54	S	..	..	.....	Water adequate; some alkali.
.....	S	..	..	.....	Water adequate.
.....	D,S	..	..	.....	Water medium hard; adequate.
10- 6-54	S	FU	Sd	.....	Depth may be less due to filling with sand.
.....	D	..	..	.....	Water medium hard; inadequate.
10- 6-54	U	..	..	.....	
.....	D,S	..	..	.....	Water soft; adequate.
10- 6-54	U	..	..	.....	
1948	...	..	..	.....	Well dries up with steady pumping; iron in water, medium hard.
.....	...	..	..	.....	See log.
.....	S	..	..	.....	Water adequate.
1949	D	..	..	.....	Water level may rise above basement floor.
.....	D,S	FU	Lig	.....	Brown water. Chemical analysis.
10- 7-54	U	..	..	.....	
.....	S	..	..	.....	Water adequate.
.....	S	..	..	.....	Well pumps dry. Water very hard, some rust and alkali.
10- 9-54	D	..	..	.....	Well pumps dry after yielding 30 gals., but has fast recovery.
10- 9-54	U	..	..	.....	
.....	D,S	..	..	.....	Water adequate; hard, rusty,alkali.
.....	T	..	..	2,689	See log.
.....	D,S	..	..	.....	Water hard; adequate.
.....	S	..	..	.....	Well pumps 5 gpm; hard.
.....	Ind,D	..	..	.....	Water hard; adequate.

TABLE 3.--RECORDS OF WELLS,

Location no.	Owner or name	Depth of well (feet)	Diameter (inches)	Type of well	Date completed	Depth to water (feet below land surface)
129-96 (Cont.)						
11cbc	Test hole 1000	200	5	Dr	1955	......
11ddb1	State Experiment Farm	200	5	Dr	....	......
11ddb2	do	...	24	Du	....	25.00
12aad1	Geo. P. Mailler	116	6	Dr	1926	56
12aad2	do	54	...	Du	....	50
12bcc1	Carl Muller	60	6	Dr	....	......
12bcc2	do	80	6	Dr	....	36.51
12bcc3	do	40	6	Dr	....	......
12cdc	James Clement	83	5	Dr	....	60
13aaa	Cemetery	...	6	Dr	....	64.33
13aba	Motel Ray	130	5	Dr	....	62.11
13abd	Joe Muth	85	4	Dr	....	......
13aca	Lowell Fitch	75	5	Dr	....	34.00
13b	O. T. Peterson	30	...	Du	....	22.00
13bac1	City of Hettinger	1,050	12	Dr	....	335.10
13bac2	do	300	6	Dr	....	133.54
13bac3	Adams County Creamery	106	6	Dr	....	......
13bbb1	Test hole 993	200	5	Dr	1955	......
13bbb2	City of Hettinger	1,180	12	Dr	....	369.00
13bcd	Test hole 1004	20	5	Dr	1955	......
13bdd1	City of Hettinger	1,182	12	Dr	....	333.75
13bdd2	Chicago, Milwaukee, St. Paul & Pacific RR.	1,192	12	Dr	1936	......
13bdd3	do	1,190	12	Dr	1936	......
13ccc1	Emil Nelson	45	...	Dr	....	......
13ccc2	do	10	6	Dr	....	4.84
13ccc3	Erland Bergland	50	...	Dr	....	19.00
14bda1	Joe Clement	35	6	B	....	......
14bda2	do	70	6	Dr	....	......
14caa	Erland Bergland	50	6	Dr	....	8.44
14dac1	J. Knutson	50	5½	Dr	....	30
14dac2	do	60	5½	Dr	....	30
14dba	Joe Clement	88	5½	Dr	1954	......

Date of measurement	Use of water	Aquifer: Formation	Aquifer: Material	Elevation of land surface	Remarks
.....	T	..	..	2,679	See log.
.....	D	..	..	.....	Water very hard; fairly adequate.
5-24-55	U	..	..	.....	
1954	S	FU	Sd	.....	Water highly mineralized.
1954	D	..	..	.....	Water adequate.
.....	S	..	..	.....	Well pumps dry in 15 minutes. Soft water.
10- 7-54	U	..	..	.....	
.....	D	..	..	.....	Well dries up after pumping 100 gals. Medium hard.
1954	Irr	..	..	.....	
10- 6-54	Irr	..	..	.....	
10-11-54	U	..	..	.....	
.....	D	..	..	.....	Water very hard.
10- 4-54	D	..	..	.....	Water hard; adequate.
7-23-21	D	FU	Sd	.....	Simpson, 1929.
10- 1-54	PS	FH	Ss	.....	
10- 1-54	U	..	..	.....	
.....	Ind	FU	Sd	.....	Chemical analysis.
.....	T	..	..	2,672	See log.
10- 4-54	PS	FH	Ss	.....	Chemical analysis.
.....	T	..	..	2,672	See log.
10- 2-54	PS	FH	Ss	.....	Casing perforated.
.....	PS	FH	Ss Lig	.....	See log.
.....	PS	FH	Ss Lig	.....	do.
.....	D,S	..	..	.....	Water hard, rusty; adequate.
10- 8-54	S	..	..	.....	Well pumps dry after 10 gals.
10- 8-54	D	..	..	.....	Water hard, rusty; adequate.
.....	S	..	..	.....	Well pumps dry easily.
.....	D	..	..	.....	Water hard; adequate.
10- 8-54	U	FU	Sd	.....	
1954	..	..	..	.....	Water hard; alkali, adequate
1954	Irr	..	..	.....	Water hard; some alkali.
.....	S	..	..	.....	Water hard.

TABLE 3.--RECORDS OF WELLS,

Location no.	Owner or name	Depth of well (feet)	Diameter (inches)	Type of well	Date com-pleted	Depth to water (feet below land surface)
129-96 (Cont.)						
14ddd	Erland Bergland	50	6	Dr	....	......
15aad1	O. Osmundson	28	66	Du	....	......
15aad2	do	30	66	Du	....	......
15aad3	do	150	6	Dr	....	13.00
15aad4	do	35	10	Dr	....	......
23aaa1	Test hole 1005	200	5	Dr	1955	......
23aaa2	Erland Bergland	50	6	Dr	....	......
23abb	Didia Moen	65	6	Dr	....	34.17
24bbb	Erland Bergland	70	6	Dr	....	24.41
24ccc	Test hole 1006	200	5	Dr	1955	......
25aba1	Ernest Stinberg	65	6	Dr	....	......
25aba2	do	65	6	Dr	....	......
25dbb	do	80	6	Dr	....	......
26aaa1	L. J. Gustin	...	...	Dr	....	......
26aaa2	do	...	...	Dr	....	......
26aaa3	do	...	...	Dr	....	......
26cad1	P. Ketterling	...	...	Dr	....	......
26cad2	do	...	...	Dr	....	......
35dcc	Test hole 1007	200	5	Dr	1955	......
129-97						
1ddd1	Hubert Erickson	198	4	Dr	....	12
1ddd2	do	20	...	Dr	....	9
3ccc	R. A. Honeyman	200	6	Dr	....	......
3ddc1	Toby Koch	Spring	...	...	....	......
3ddc2	do	90	6	Dr	....	......
6aac	Oscar Opheim	170	6	Dr	....	......
11ddb1	Selmer Holland	115	...	Dr	1943	......
11ddb2	do	112	6	Dr	....	......
14aaa	do	160	...	Dr	....	......
14baa	....	...	36	Du	....	53.66
14cbb	G. Halvorson	90	6	Dr	....	......
18aad1	J. P. Holden	120	5	Dr	....	......
18aad2	do	60	5	Dr	....	......
20cbb	Albert Munson	69.5	4	Dr	....	......

SPRINGS, AND TEST HOLES -- Continued

Date of measurement	Use of water	Aquifer: Formation	Aquifer: Material	Elevation of land surface	Remarks
.....	S	FU	Sd	.....	Water hard; alkali.
.....	D	..	..	.....	Well pumps dry; water hard.
.....	S	..	..	.....	do.
10- 9-54	S	..	..	.....	Water soft; adequate.
.....	S	..	..	.....	Well dries up easily; water hard.
.....	T	..	..	2,692	See log.
.....	S	..	..	.....	Water hard, rusty; adequate.
10- 8-54	D,S	..	..	.....	Water medium hard; adequate.
10- 8-54	S	..	..	.....	Water hard; adequate. See log.
.....	T	..	..	2,694	See log.
.....	D	..	..	.....	Water hard; adequate.
.....	S	..	..	.....	Water medium hard; adequate.
.....	S	..	..	.....	Water soft.
.....	D	..	..	.....	Well dries up under heavy pumping Water medium hard.
.....	S	..	..	.....	Water hard; adequate.
.....	S	..	..	.....	do
.....	D	..	..	.....	Water hard; rusty.
.....	D,S	..	..	.....	Well goes dry after ½ day pumping, water hard.
.....	T	..	..	2,642	See log.
1954	...	..	..	.....	Water hard, alkali; adequate.
1954	...	..	..	.....	
.....	S	FU	Sd	.....	Water soft, adequate.
.....	S	FU	Lig	.....	Water adequate.
.....	D	..	..	.....	Well dries up under heavy pumping, water hard, rusty.
.....	D,S	..	..	.....	Water medium hard; alkali.
.....	D	..	..	.....	Water hard, rusty; adequate.See log.
.....	S	..	..	.....	
.....	S	..	..	.....	Water hard, rusty; adequate.
10- 9-54	...	..	..	.....	
.....	D,S	..	..	.....	Well pumps dry after 200 gals. Water medium hard, alkali.
.....	D,S	..	..	.....	Water hard; adequate.
.....	S	..	..	.....	Water medium hard.
.....	D	..	..	.....	Water hard; adequate.

Location no.	Owner or name	Depth of well (feet)	Diameter (inches)	Type of well	Date completed	Depth to water (feet below land surface)
129-97 (Cont.)						
29cbc1	Henry Jeffers	72	6	Dr	....	......
29cbc2	do	70	...	Dr	....	......
29cbc3	do	70	...	Dr	....	22.69
35bcb1	Leslie Horal	18	40	Du	....	13.00
35bcb2	do	92	6	Dr	....	......
130-95						
2bab	Lee Haag	90	6	Dr	....	50
4bbb	Ellsworth Olson	100	6	Dr	....	21.14
5aba	A. Zimmerman	80	6	Dr	....	......
6bbb	Test hole 999	200	5	Dr	....	......
6ddd1	A. Beckman	110	6	Dr	....	......
6ddd2	do	95	6	Dr	....	......
7aba	Peter Melling	75	6	Dr	....	......
7ccc	Test hole 998	200	5	Dr	1955	......
17daa	M. Zimmerman	80	...	Dr	....	......
19aad	A. Beckman	170	6	Dr	....	......
19dad	do	170	6	Dr	....	......
21ccc	M. Zimmerman	...	6	Dr	....	......
30bbb	Test hole 997	200	5	Dr	1955	......
30caa	Nels Olson	130	6	Dr	....	80
30dcb1	do	130	6	Dr	....	80
30dcb2	do	130	6	Dr	....	......
31bab	H. O. Lundahl	85	6	Dr	....	54.00
32add	J. H. Larson	80	6	Dr	....	......
32ccd	do	70	6	Dr	....	......
35bcc	Joe Ihle	250	6	Dr	....	......

Date of measurement	Use of water	Aquifer: Formation	Aquifer: Material	Elevation of land surface	Remarks
.....	D	..	..	.....	Water hard; adequate.
.....	S	..	..	.....	Water medium hard; adequate.
10- 9-54	S	FU	Sd	.....	Water reported medium hard. See log.
10- 9-54	S	..	..	.....	Well goes dry after 200 gals.
.....	D	..	..	.....	Water medium hard; adequate.
1954	D,S,Irr	..	..	.....	Water hard; adequate.
10- 5-54	D,S	FU	Sd	.....	Water hard, alkali; adequate. See log.
.....	D,S	..	..	.....	Water hard, alkali; adequate.
.....	T	..	..	2,765	See log.
.....	S	..	..	.....	Water adequate.
.....	D	FU	Sd	.....	Water hard; adequate. See log.
.....	S	..	..	.....	Water adequate.
.....	T	..	..	2,749	See log.
.....	D,S	..	..	.....	Water adequate.
.....	S	..	..	.....	
.....	D,S	...	..	.....	Water hard, adequate; alkali.
.....	S	..	..	.....	
.....	T	..	..	2,742	See log.
1954	S	..	..	.....	Water adequate.
1954	D	..	..	.....	Water hard, rusty; adequate.
.....	S	..	..	.....	Water adequate.
10- 4-55	D,S	..	..	.....	Water hard. Dries up quickly under heavy pumping but will recover within 2 hours.
.....	S	..	..	.....	Water hard.
.....	D,S	..	..	.....	Water medium hard; adequate.
.....	D,S	..	..	.....	Water soft.

TABLE 3.--RECORDS OF WELLS,

Location no.	Owner or name	Depth to well (feet)	Diameter (inches)	Type of well	Date completed	Depth to water (feet below land surface)
130-96						
3bcc1	Vern Carroll	90	...	Dr	....	......
3bcc2	do	80	6	Dr	....	23.91
5ccc	Anna Larson	21	48	Du	....	11.28
6bab	H. Thorsen	25	6	Dr	....	......
7aba	Peter Melling	62	6	Dr	....	9
7bbb	Orville Larson	70	5	Dr	....	......
10bcc1	Henry Stinberg	62	6	Dr	....	......
10bcc2	do	65	24	Dr	....	......
11adb	M. Skogen	130	...	Dr	....	......
11ddd1	do	100	6	Dr	....	......
11ddd2	do	125	6	Dr	....	......
12aaa1	J. Fuglesten	18	4	B	....	12
12aaa2	do	50	6	Dr	....	12
12aaa3	do	40	6	Dr	1952	12
12ccd	Cliff Skogen	120	6	Dr	....	......
13baa	Geo. P. Mailler	...	18	Du	....	......
13bab	C. Larson	28	6	Dr	....	13.96
13dab	G. P. Mailler	...	6	Dr	....	11.18
14aba	Ed Skogen	55	6	Dr	....	......
14dda	do	195	6	Dr	....	......
17aad1	H. Erickson	40	6	Dr	....	......
17aad2	do	50	6	Dr	....	......
17aad3	do	100	6	Dr	....	......
22dac1	G. Stenberg	75	6	Dr	....	......
22dac2	do	80	6	Dr	....	......
23c	Tom Clement	Spring	...	...	....	......
28cad	A. M. Hawkinson	30	6	Dr	....	......
28dad	do	30	...	Dr	....	......
28dbd1	do	91	6	Dr	....	......
28dbd2	do	Spring	...	...	....	......
32ccc	Test hole 1002	200	5	Dr	....	......
33baa1	H. Arndorfer	...	...	Dr	1953	......
33baa2	do	...	6	Dr	....	33.19
35acd1	Gordon McNeil	33	6	Dr	....	......
35acd2	do	40	6	Dr	....	24
35acd3	do	45	...	Du	....	13.00
35acd4	do	...	6	Dr	....	8.71
36cbb	do	170	6	Dr	....	......

Date of measurement	Use of water	Aquifer: Formation	Aquifer: Material	Elevation of land surface	Remarks
.....	D	..	..	.....	Water hard, rusty; adequate.See log.
10- 7-54	S	..	..	.....	Water hard.
10- 7-54	D,S	..	..	.....	Water hard, rusty; adequate
.....	S	..	..	.....	Water hard, adequate.
1954	D	..	..	.....	Water hard; adequate. See log.
.....	S	..	..	.....	Water soft; adequate.
.....	D	FU	Sd	.....	Water hard, rusty; adequate. See log.
.....	S	..	..	.....	Water hard, rusty; adequate.
.....	S	..	..	.....	Water adequate.
.....	D	..	..	.....	Water medium hard.
.....	S	..	..	.....	Water hard, rusty.
1954	D	..	..	.....	Water hard; adequate.
1954	S	..	..	.....	Water adequate.
1954	D	..	..	.....	Water hard; adequate.
.....	D,S	..	..	.....	do.
.....	S	..	..	.....	
10- 7-54	D	..	..	.....	Water hard; adequate.
10- 7-54	S	..	..	.....	
.....	D,S	..	..	.....	Water hard, rusty; adequate.
.....	S	..	..	.....	Water medium hard.
.....	D	..	..	.....	Water hard, rusty; adequate.
.....	S,Irr	..	..	.....	do.
.....	S	..	..	.....	do.
.....	D	FU	Lig	.....	Water hard.
.....	S	FU	Lig	.....	
.....	S	FU	Lig	.....	Measured flow May 26,1955 of about 15 gpm. Chemical analysis.
.....	S	FU	Lig	.....	Water medium hard; adequate.
.....	S	..	..	.....	Water soft.
.....	D	..	..	.....	Water medium hard; adequate.
.....	S	FU	Sd;Lig	.....	Flow estimated to be 1 gpm.
.....	...	..	..	2,723	See log.
.....	D,S	..	..	.....	Water hard, rusty, alkali; adequate.
10- 7-54	S	..	..	.....	do.
.....	D	..	..	.....	Water hard; adequate.
1954	S	..	..	.....	Water medium hard, rusty; adequate.
10- 7-54	U	..	..	.....	
10- 7-54	D	..	..	.....	
.....	S	..	..	.....	Water medium hard; adequate.

TABLE 3.--RECORDS OF WELLS,

Location no.	Owner or name	Depth to well (feet)	Diameter (inches)	Type of well	Date completed	Depth to water (feet below land surface)
130-97						
1ccc	P. N. Stedde	100	6	Dr	....	69.75
2ccb	S. Swenson	...	6	Dr	....	......
5adb1	Joe Uhler	80	6	Dr	....	19.45
5adb2	do	94	...	Dr	....	......
8cba	G. Arneson	...	6	Dr	....	......
12cdd	P. N. Stedde	300	...	Dr	....	......
14cc	Mrs. Halvorson	77	4	Dr	....	......
14cdc	A. Hoffman	80	6	Dr	....	50.00
14ddc	do	132	6	Dr	....	......
16cac	M. Omodt	52	6	Dr	....	......
17dab	do	18	48 x 48	Du	....	12
20ca	Selmer Moen	220	5	Dr	1951	......
21cba1	do	150	4	Dr	1951	63.70
21cba2	do	116	5	Dr	....	......
21cba3	do	15	36	Du	....	8.00
22adb1	John P. Olson	12	48	Du	....	6.91
22adb2	do	10	48	Du	....	......
22adb3	do	12	36	Du	....	....
22dda1	John Moen	...	48	Du	....	15
22dda2	do	80	5	Dr	....	......
23cbc	Chicago, Milwaukee, St. Paul & Pacific RR.	30	...	Du	....	......
26add	Test hole 1003	200	5	Dr	....	......
26bcd	R. A. Honeyman	95	7	Dr	1926	......
28c	do	160	6	Dr	....	......
33aba1	Howard Walch	12	6	B	....	5.85
33aba2	do	...	4	Dr	....	17.32
34aaa	Cameron Stewart	115	5	Dr	....	63.63
35c	Algot Anderson	Spring	...	...	....	......
35ccd	do	16	4	B	....	6

Date of measure-ment	Use of water	Aquifer: Formation	Aquifer: Material	Elevation of land surface	Remarks
10- 8-54	D,S	..	..	......	Water hard, rusty; adequate.
......	D,S	..	..	......	Well dries up after ½ hr. pumping. Water hard.
10- 8-54	D,S	..	..	......	Water hard, rusty; adequate.
......	D	FU	Sd	......	Water hard, rusty; alkali, adequate.
......	D	..	..	......	Water medium hard, rusty; adequate.
......	S	..	..	......	Unable to reach water level with 300' tape.
......	...	..	..	......	Periodic measurements of depth to water.
10- 4-54	U	..	..	......	
......	D,S	..	..	......	Water soft; adequate.
......	S	FU	Sd	......	Water medium soft; adequate.
1954	D	FU	Lig	......	do.
......	S	FU	Sd	......	Bailed at 10 gpm.
6-20-55	D,S	FU	Sd	......	Water very soft.
......	S	FU	Sd	......	Water hard; adequate.
5-20-55	D	FU	Sd	......	Water soft; pumps dry in 1 hour.
10- 8-54	D	..	..	......	Water hard; pumps dry after 200 gals.
......	S	..	..	......	do.
......	S	..	..	......	Water hard; adequate.
1954	D	FU	Sd	......	Water soft; adequate.
......	S	FU	Sd	......	do.
......	D	..	..	......	Water adequate.
......	T	..	..	2,780	See log.
......	D,S	FU	Lig	......	Water hard; adequate.
......	S	FU	Sd	......	Water soft; adequate.
5-17-55	D	FU	Sd	......	Well is in basement of house 4' below land surface. Water rises into basement in spring and well goes dry in August.
5-17-55	S	..	..	......	Water hard; adequate.
......	D,S	..	..	......	Water level measurement made after pumping stopped.
......	...	FU	Sd,Lig	.....	Flow estimated to be 1 gpm;water soft.
1955	S	FU	Lig	......	Water adequate.

TABLE 4.--LOGS OF WELLS AND TEST HOLES

129-95-6bbb
Test hole 996

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, light-gray	8	8
	Clay, gray	10	18
	Clay, dark-gray	6	24
	Lignite	3	27
	Clay, gray, some lignite	5	32
	Lignite	2	34
	Clay, gray	9	43
	Lignite	2	45
	Sand, fine; gray clay; more clay in the lower part	76	121
	Clay, sandy, gray	42	163
	Clay, gray	37	200

129-95-7bbb
Test hole 995

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, brown	3	3
	Sand, fine, silty, gravelly	5	8
	Clay, sandy, yellow	17	25
	Clay, sandy, partly calcareous, light-gray. Hard rock at 51, 73, 124, 170, 191-196 feet; lost circulation of drilling mud between 110 and 120 feet	175	200

129-95-12ddd
Test hole 1011

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, dark-brown	4	4
	Lignite, brown	1	5
	Clay, sandy, light-brown	6	11
	Clay, sandy,very light brown	23	34
	Clay, sandy, light-green	27	61
	Clay, gray; some sand	139	200

129-95-14bbb
Test hole 1010

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, brown	4	4
	Clay, sandy, yellow	5	9
	Clay, yellow	7	16
	Clay, brown	9	25
	Clay, sandy, light-gray	45	70
	Clay, gray, calcareous from 125 to 135 feet	51	121
	Clay, gray; some sand	79	200

129-95-17aaa
Test hole 1009

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, yellow	6	6
	Clay, sandy, yellow; fine gravel	3	9
	Clay, sandy, yellow	7	16
	Clay, yellow	9	25
	Limestone, gray	2	27
	Clay, gray; some sand	133	160
	Limestone, gray	2	162
	Clay, gray; some sand	38	200

129-95-18aaa
Test hole 1008

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, brown	12	12
	Clay, sandy, yellow	8	20
	Clay, yellow	3	23
	Limestone, gray	2	25
	Clay, sandy, yellow	21	46
	Clay, light-gray; some sand	154	200

129-95-18bbb
Test hole 994

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, gray; fine to medium gravel	11	11
	Sand, fine to coarse, very silty	7	18
	Sand, fine to coarse, yellowish-brown; fine gravel	12	30
	Clay, sandy, yellow; shale gravel	9	39
	Clay, sandy, gray	13	52
	Clay, sandy, gray, calcareous. Clay thickness drilling mud. Clay harder and drilling more difficult below 155 feet.	148	200

129-95-35cbb
Paul Gordon
(Log furnished by Alfred Jacobson, well driller, Hettinger, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, white	22	22
	Sand, dry	26	48
	Quicksand	12	60
	Sand	15	75
	Stone	1	76
	Sand	3	79
	Stone	2	81
	Sand	3	84
	No description	9	93

129-96-10bbb
Test hole 1001

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, yellow; fine gravel	2	2
	Clay, sandy, yellow	10	12
	Clay, sandy, gray	23	35
	Sandstone, hard, red	2½	37½
	Clay, gray	71½	109
	Clay, sandy, greenish-gray	11	120
	Clay, gray	54	174
	Clay, sandy, light-gray	18	192
	Clay, gray	8	200

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

129-96-11cbc
Test hole 1000

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, yellow	3	3
	Gravel, fine to medium, silty	5	8
	Clay, sandy, yellow	5	13
	Clay, sandy, greenish-gray. Cored from 30 to 40 feet	20	33
	Clay, gray	73	106
	Limestone, gray, with calcite veins. Cored from 99 to 110 feet	3	109
	Clay, sandy. dark-gray. Cored from 110 to 120 feet	62	171
	Clay, gray; gray shaly limestone. Cored from 172 to 180 feet	9	180
	Clay, gray	20	200

129-96-13bbb1
Test hole 993

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Earth fill	3	3
	Sand, fine to coarse, silty, yellow	6	9
	Sand, fine, silty	11	20
	Clay, light-gray; thickens drilling mud; thinned mud at 80 feet	127	147
	Clay, hard, light-gray; difficult drilling	6	153
	Clay, light-gray	11	164
	Clay, brownish-gray, slightly calcareous; some rounded chert fragments	36	200

129-96-13bcd
Test hole 1004

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium:			
	Clay, brown	3	3
	Sand, fine to coarse; gravel; clay	8	11
	Clay, brown; fine to medium gravel	3	14
Fort Union:			
	Clay, sandy, gray	6	20

129-96-13bdd2
Chicago, Milwaukee, St. Paul & Pacific Railroad
(Driller's log, Norbeck Drilling Co.)

Material	Thickness (feet)	Depth (feet)
Clay, yellow	14	14
Sand, fine	13	27
Clay, yellow	1	28
Clay, yellow	12	40
Clay, blue	40	80
Clay, gray	29	109
Clay, gray, and rock	26	135
Clay, blue	11	146
Clay, blue, and sand rock	15	161
Rock	5	166
Clay, blue	56	222
"Lime rock"	2	224
Clay, blue	10	234
Clay, blue	52	286
Sand	12	298
Clay, blue	58	356
Clay, sandy	22	378
Clay, blue	116	494
Sand; 2 gpm (water)	4	498
Clay, blue	2	500
Sand; 2 gpm (water)	4	504
Clay, hard, blue	18	522
Clay, soft, blue	18	540
Clay, sandy	4	544
Clay, gray	64	608
Clay, gray, and rock	42	650
"Sand rock," hard	3	653
Clay, blue, and rock	122	775
Clay, blue	23	798
Sand; 16 gpm (water)	32	830
Clay, blue	38	868
Clay, blue; and "shell"	4	872
Sand; and hard "sand rock"	4	876
Sand; 6 gpm (water)	4	880
Clay, blue	25	905
Sand	6	911
Sand, and "hard rock"; 9 gpm (water)	17	928
Clay, blue	10	938
Clay, sandy, hard	5	943
Clay, blue	8	951
Sand and clay	6	957
Clay, red	5	962
Clay, gray	46	1,008

129-96-13bdd2 (continued)
Chicago, Milwaukee, St. Paul & Pacific Railroad
(Driller's log, Norbeck Drilling Co.)

Material	Thickness (feet)	Depth (feet)
"Sand rock," hard	1	1,009
Clay, gray	28	1,037
Sand; 6 gpm (water)	8	1,045
Clay, sandy	16	1,061
Sand; 9 gpm (water)	11	1,072
Clay, blue	86	1,158
Sand	13	1,171
"Hard shell"	21	1,192

Well drilled 9-10-1936 to 1-10-1937 by Norbeck Drilling Co., Redfield, S. Dak.

Casing:	0' - 318'	12"
	304' - 795'	10"
	777' - 1,192'	8"

Perforations:

286' - 298'	½" holes, 30 per foot
798' - 830'	" 24 per foot
872' - 880'	" " " "
905' - 928'	" " " "
1,037' - 1,045'	" " " "
1,061' - 1,072'	" " " "
1,158' - 1,171'	" " " "

Static water level when drilled: 211' below land surface.
Pumping level: 377' below land surface with discharge of 60 gpm.

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

129-96-13bdd3
Chicago, Milwaukee, St. Paul & Pacific Railroad
(Driller's log, Norbeck Drilling Co.)

Material	Thickness (feet)	Depth (feet)
Sand, and clay, yellow	16	16
Gravel	3	19
Clay, blue	56	75
Clay, gray	35	110
"Lime rock"	2	112
Clay, blue	47	159
"Lime rock"	4	163
Clay, blue	59	222
Clay, sandy	13	235
Clay, blue	35	270
Clay, brown	18	288
Sand "streaks"; gray clay	11	299
Clay, gray	53	352
"Lime rock"	1	353
Sand "streaks"; gray clay	25	378
Clay, gray	18	396
Sand	3	399
Rock	1	400
Clay, gray	29	429
"Lime rock"	4	433
Clay, gray	43	476
"Lime rock"	2	478
Clay, gray	14	492
Sand	2	494
Clay, gray	55	549
Clay, and "hard shells"	65	614
"Lime rock"	3	617
Clay, gray	12	629
Clay, hard, gray	21	650
"Lime rock"	1	651
Clay, hard, blue	14	665
Clay, sandy	2	667
Clay, gray	52	719
"Lime rock"	2	721
Clay, blue	8	729
Clay, sandy	15	744
Sand	20	764
Clay, sandy	12	776
Clay, sandy	58	834
Coal	5	839
Clay	16	855
Sand	15	870
Clay	6	876

129-96-13bdd3 (continued)
Chicago, Milwaukee, St. Paul & Pacific Railroad
(Driller's log, Norbeck Drilling Co.)

Material	Thickness (feet)	Depth (feet)
Clay	24	900
Sand	34	934
Clay	8	942
"Lime rock"	2	944
Clay	33	977
"Sand streaks"	4	981
Clay, brown	11	992
"Sand streaks"	7	999
Clay, sandy	33	1,032
Sand	4	1,036
"Lime rock"	2	1,038
"Sand streaks"	8	1,046
Sand	11	1,057
Clay, sandy	21	1,078
Sand	14	1,092
"Sand streaks"	15	1,107
Clay	45	1,152
"Lime rock"	2	1,154
Clay	2	1,156
Sand	14	1,170
Clay	20	1,190

Well completed 10-17-1940 by Norbeck Drilling Co., Redfield S. Dak.

Casing:
0' - 344' 12"
327' - 870' 10"
839' - 1,190' 8"

Perforations:
351' - 377') covered by 8" liner
390' - 400')
744' - 830'
900' - 934'
992' - 999'
1,046' - 1,057'
1,078' - 1,092'
1,095' - 1,108'
1,156' - 1,170'

Static water level when drilled: 220 feet below land surface.
Pumping level: 392 feet below land surface with discharge of 72 gpm.

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

129-96-23aaa1
Test hole 1005

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium:			
	Clay, yellow; fine to coarse sand; coarse gravel........................	4	4
Fort Union:			
	Sand, fine silty, yellow................	19	23
	Clay, yellow...........................	4	27
	Clay, sandy, gray......................	5	32
	Clay, sandy, gray; some hard spots. Lost circulation of drilling mud at 150 feet...........................	140	172
	Clay, sandy, light-gray................	28	200

129-96-24bbb
Erland Bergland
(Log furnished by Alfred Jacobson, well driller, Hettinger, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, brown............................	20	20
	Sand, blue; water......................	35	55
	Sand and clay..........................	7	62
	Clay, blue.............................	8	70

129-96-24ccc
Test hole 1006

Formation	Material	Thickness (feet)	Depth (feet)
Alluvium:			
	Clay, sandy, yellow....................	11	11
	Gravel, fine; yellow clay..............	4	15
Fort Union:			
	Silt, sandy, gray......................	4	19
	Clay, sandy, gray......................	37	56
	Clay, gray; some sand. Lost circulation of drilling mud at 150 feet...	144	200

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

129-96-35dcc
Test hole 1007

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, yellowish-brown.........	26	26
	Clay, gray to white..................	95	121
	Clay, sandy, light-gray..............	12	133
	Clay, gray...........................	2	135
	Lignite..............................	2	137
	Clay, gray to brown..................	20	157
	Lignite, and shaly lignite...........	10	167
	Clay, sandy, gray....................	33	200

129-97-11ddb1
Selmer Holland
(Log furnished by Alfred Jacobson,
well driller, Hettinger, N. Dak.)

Fort Union:			
	Clay.................................	40	40
	Sand, gray...........................	30	70
	Sand; water..........................	38	108
	Sand and clay........................	7	115

129-97-29cbc1
Henry Jeffers
(log furnished by Alfred Jacobson,
well driller, Hettinger, N. Dk

Fort Union:			
	Clay.................................	4	4
	"Hardpan"............................	10	14
	Sand, brown..........................	16	30
	Sandstone............................	2	32
	Sand blue............................	4	36
	Sand and clay........................	36	72

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

130-95-4bbb
Ellsworth Olson
(Log furnished by Alfred Jacobson,
well driller, Hettinger, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	"Gumbo"................................	30	30
	Water-bearing material..................	12	42
	Sandstone...............................	2	44
	Sand, blue..............................	31	75
	Sand, blue, water.......................	5	80
	"Main water"............................	5	85
	Sand; water.............................	15	100

130-95-6bbb
Test hole 999

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, yellow.....................	8	8
	Clay, light-brown.......................	8	16
	Lignite, brown..........................	1	17
	Clay, gray..............................	6	23
	Clay, sandy, light-gray.................	5	28
	Clay, brown.............................	1	29
	Lignite, brown..........................	1	30
	Clay, sandy, light-gray.................	14	44
	Clay, sandy, dark-gray..................	5	49
	Lignite, shaly..........................	2	51
	Clay, sandy, gray.......................	4	55
	Sand, fine; gray clay...................	10	65
	Clay, sandy, light-gray; some selenite..	135	200

130-95-6ddd2
Albert Beckman
(Log furnished by Alfred Jacobson,
well driller, Hettinger, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, yellow............................	20	20
	Water-bearing material..................	5	25
	"Tough gumbo"...........................	30	55
	Sand and clay...........................	10	65
	Sand; water.............................	30	95

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

130-95-7ccc
Test hole 998

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, dark-brown.................	4	4
	Silt, sandy, light-brown................	4	8
	Sand, fine to coarse; fine gravel.......	8	16
	Clay, sandy, yellow.....................	26	42
	Sand, fine, gray........................	9	51
	Lignite.................................	2	53
	Clay, light-gray........................	16	69
	Lignite.................................	2	71
	Clay, sandy, gray.......................	129	200

130-95-30bbb
Test hole 997

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, sandy, yellow.....................	4	4
	Sand, fine to medium....................	29	33.
	Lignite, brown. Lost circulation of drilling mud........................	1	34
	Clay, light-brown.......................	11	45
	Sand, fine..............................	6	51
	Lignite, shaly..........................	2	53
	Clay, light- to dark-gray; some sand. Lost circulation of drilling mud from 60 to 70 feet, 70 to 120 feet, and 120 to 195 feet................	147	200

130-96-3bcc1
Vern Carroll
(Log furnished by Alfred Jacobson,
well driller, Hettinger, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	"Hardpan"...............................	4	4
	Sand; water.............................	16	20
	"Tough gumbo"...........................	50	70
	Sand; some water........................	5	75
	Sand and clay...........................	5	80
	Clay....................................	10	90

TABLE 4.--LOGS OF WELLS AND TEST HOLES -- Continued

130-96-7aba
Peter L. Melling
(Log furnished by Alfred Jacobson,
well driller, Hettinger, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Topsoil	4	4
	Clay; water	6	10
	Clay, sticky	5	15
	"Gumbo"	20	35
	Sand; water	27	62

130-96-10bcc1
Henry Stinberg
(Log furnished by Alfred Jacobson,
well driller, Hettinger, N. Dak.)

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Topsoil	3	3
	"Flintstone"	3	6
	Sand, brown	44	50
	Sand; water	12	62

130-96-32ccc
Test hole 1002

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, light-brown	3	3
	Clay, light-brown; fine gravel	4	7
	Clay, yellowish-brown; fine to medium gravel	11	18
	Sand, fine, silty	14	32
	Clay, sandy, gray	22	54
	Clay, gray; some sand. Lost circulation of drilling mud at 120 feet	146	200

130-97-26add
Test hole 1003

Formation	Material	Thickness (feet)	Depth (feet)
Fort Union:			
	Clay, buff	4	4
	Clay, light-gray	5	9
	Clay, reddish-brown; fine sand	7	16
	Clay, buff	5	21
	Clay, light-gray	15	36
	Lignite, black	1	37
	Sand, fine, greenish-gray; some clay	14	51
	Lignite	2	53
	Clay, sandy, gray. Lost circulation of drilling mud from 40 to 70 feet	147	200

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