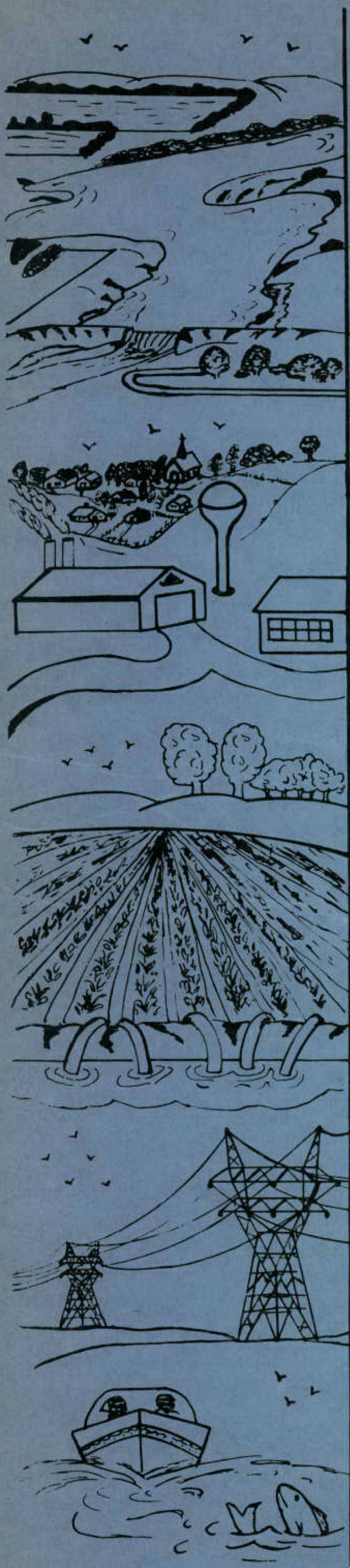


GROUND-WATER SURVEY OF THE SHEYENNE AREA

EDDY COUNTY, NORTH DAKOTA

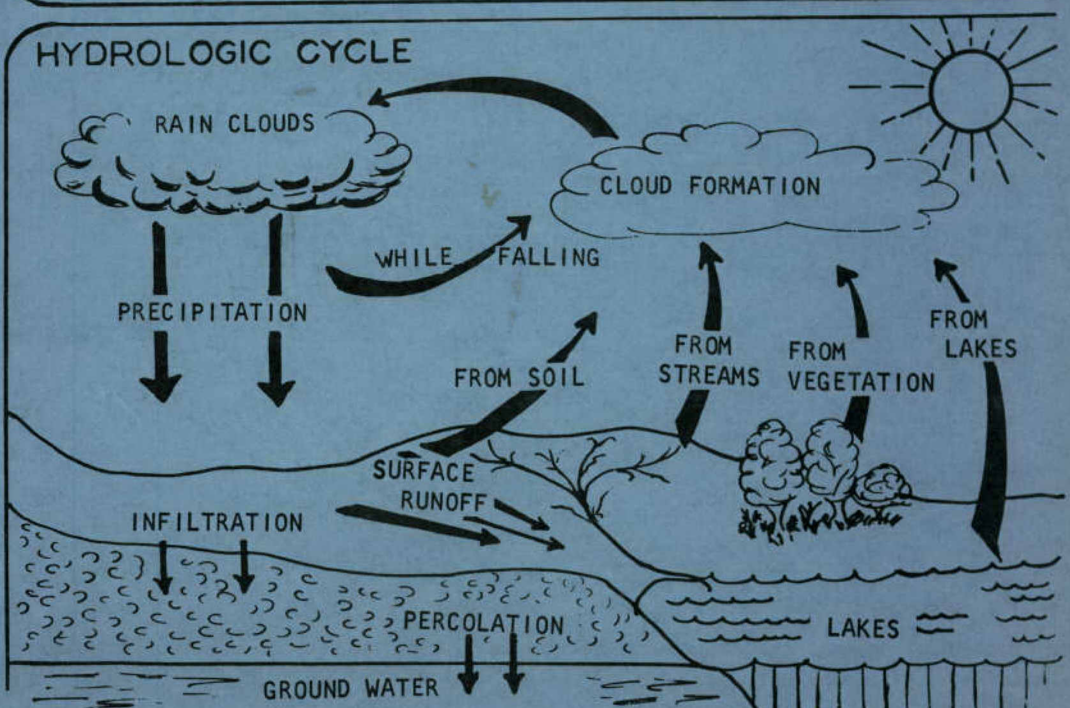
N. D. S. W.C.C. PROJECT NO. 802

NORTH DAKOTA GROUND WATER STUDIES NO. 60

By
Larry L. Froelich, Geologist

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

1964



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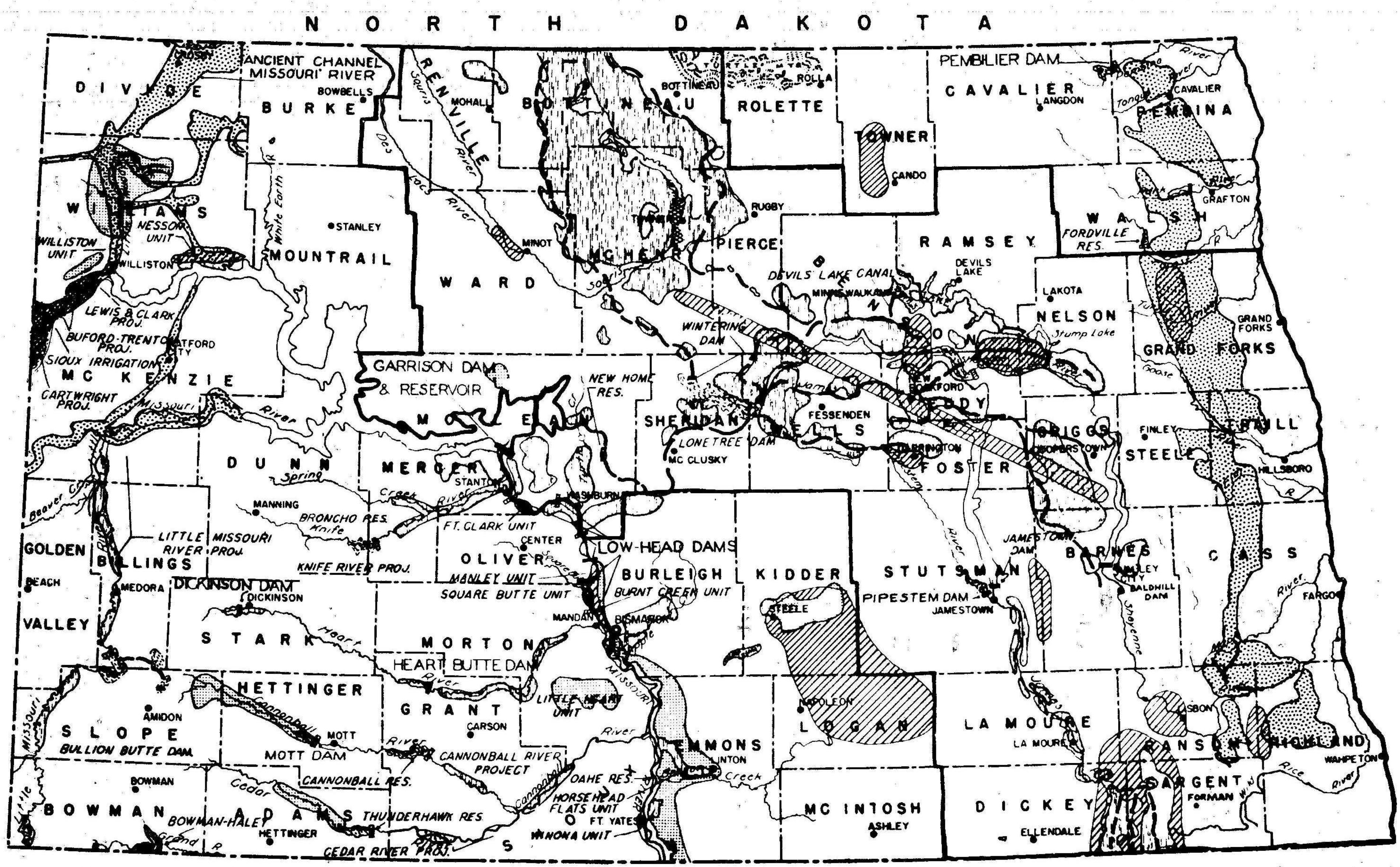

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

LANDS UNDER IRRIGATION

AREAS CONSIDERED IRRIGABLE

AREAS BEING INVESTIGATED

PROPOSED FOR INVESTIGATION

EXISTING

UNDER CONSTRUCTION OR PROPOSED

DAM & RESERVOIR SITES

PROPOSED CANALS

GARRISON DIVERSION CONSERVANCY DISTRICT BOUNDARY

GROUNDWATER AQUIFERS

GROUND-WATER SURVEY OF THE SHEYENNE AREA
EDDY COUNTY, NORTH DAKOTA

NORTH DAKOTA STATE WATER COMMISSION PROJECT NO. 802

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GROUND-WATER SURVEY OF THE SHEYENNE AREA

EDDY COUNTY, NORTH DAKOTA

INTRODUCTION

Purpose and Scope

At the request of the village of Sheyenne, the North Dakota State Water Commission, in October 1963, conducted a ground-water survey in the vicinity of Sheyenne. The purpose of the survey was to locate an additional supply of water for the village.

The survey consisted of a selected well inventory, collection of water samples for chemical analyses, test drilling and observation well installation, one preliminary pumping test, compilation of 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. Chemical analyses were performed at the State Laboratories, Bismarck.

Special acknowledgements are due to Mr. Vernon Hansen for his fine cooperation. His generosity in information, time, labor, and materials is greatly appreciated. Norman Stai, well driller, and Paul Wold of the Bureau of Reclamation, Bismarck, were very helpful in furnishing logs and other data.

Location and general features

The Sheyenne area, as described in this report, consists of 16 square miles in T. 150 N., R. 66 W. in northwestern Eddy County. It is included in the Central Lowland physiographic province of North Dakota as shown in Figure 1.

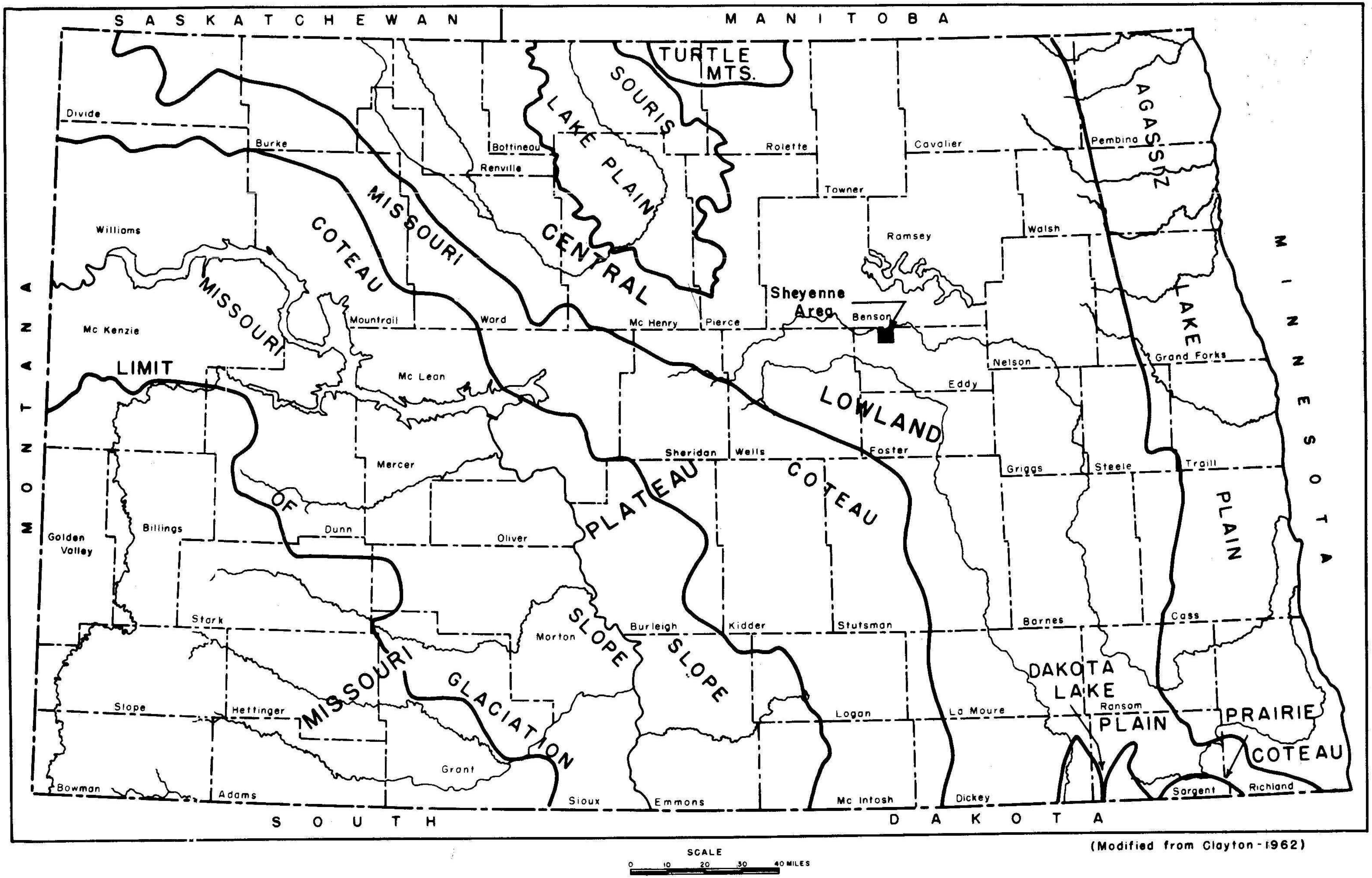


FIGURE I--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC UNITS AND LOCATION OF THE SHEYENNE AREA

Topographically the area varies from the knobby range of hills in the southern and eastern parts of the area to the essentially flat-bottomed floodplain of the Sheyenne River in the northern part of the area. Elevation varies from 1670 feet above sea level in the southeast to about 1410 feet, which is the usual surface water level in the Sheyenne River.

The entire area is within the drainage basin of the Sheyenne River, however, an integrated drainage system has not developed. The one intermittent stream in the area, which heads in the swampy area southwest of Sheyenne, drains into Warsing Lake. The main water supply to this man-made lake, however, is from springs. Erosion in recent time has contributed little to the present topography.

Dryland farming is the major occupation in the Sheyenne area. The Bureau of Reclamation irrigated 118.3 acres on a development farm immediately west of Sheyenne from 1956 to 1960. The Sheyenne Sand and Gravel Company, located approximately 1½ miles northwest of Sheyenne employs several men.

Sheyenne, population 423 in 1960, is the only town in the area. It is located on U. S. Highway 281 and is served by the Northern Pacific Railway. Climatological data are not available for Sheyenne, however, the U. S. Weather Bureau maintains weather stations at several towns in this part of the State. Records from the 1962 annual summary of the Weather Bureau show the average annual temperature and precipitation for the following: Devils Lake -- 38.8° F and 16.98 inches; Maddock -- 39.5° F and 16.54 inches; Fessenden -- 40.0° F and 17.27 inches; Carrington -- 39.2° F and 17.46 inches. In 1962 McHenry recorded an average of 38.2° F and 21.20 inches with Sykeston and Warwick recording 19.55 and 26.85 inches of precipitation respectively.

Present Water Supply

The present water supply (1964) for the village of Sheyenne is obtained from a well previously owned by the Northern Pacific Railway Company. The well is 25 feet deep and approximately 24 feet in diameter. The well was originally dug to provide water for steam-powered locomotives.

Prior to the installation of water and sewage facilities in 1959, shallow private wells provided the water supply for residents of Sheyenne. Now the water supply is chlorinated at the pumphouse in the southwest corner of the village and pumped to a 50,000 gallon overhead storage reservoir from whence it is distributed in mains to the residents. Sewage is disposed of in a 46 acre waste stabilization pond located approximately one-quarter mile east of the village.

Normally the village well provides adequate water to meet demands. No statistics are available on water consumed in the village, but Mr. Vernon Hansen (1963, personal communcation) estimated average winter and spring consumption of about 36,000 to 37,000 gallons per day and summer and fall consumption up to 42,000 gallons per day.

In the late summer of 1963 the water level in the village well declined below the source of water supplying the well, thus creating a water shortage and instigating this study. In the meantime, however, to alleviate the water shortage, the well was artificially recharged by pumping water from the Sheyenne River to the site of the well and allowing it to percolate into the sandy soil. The pump, formerly installed by the Bureau of Reclamation for irrigating a portion of the development farm immediately west of Sheyenne, was located on the south bank of the Sheyenne River near the Sheyenne Sand and Gravel Company. From this point the water was lifted 80' to the northwest corner of the $NE\frac{1}{4}NW\frac{1}{4}$ of section 8 through a 1,550 foot long 12" welded steel pipeline. From this point water flowed by gravity through a series of irrigation ditches to an infiltration pond constructed near the village well. Water was pumped for a period of two weeks after which the natural water level in the well rose sufficiently to meet the water demand.

Previous Investigations

A general study of the geology and ground-water resources of Eddy County was made by Simpson (1929, p. 127-129) in which he discusses water-bearing strata of the county. Abbott and Voedisch (1938, p. 56-57) include a chemical analyses of water from a well in Sheyenne in their report on municipal ground-water supplies.

The Sheyenne area is located in the south central portion of the area studied by Tetrick (1949). The topography, stratigraphy, and glacial features of the area are discussed in his report along with his observations of sand and gravel deposits and ground-water resources.

Much valuable hydrologic data are included in the annual reports (1956-1960) on North Dakota Development Farms prepared by the Bureau of Reclamation. The 1956 report contains the first report on the Sheyenne Development Farm and includes information on history, soils, irrigation features, special studies, ground-water levels, and agricultural statistics of the farm.

The North Dakota State Department of Health (1964) includes a chemical analyses of the chlorinated municipal water supply of Sheyenne in their compilation of North Dakota municipal waters.

An investigation of ground-water resources of Foster-Eddy Counties was begun in 1962 and is presently in progress. The investigation is scheduled for completion in 1966.

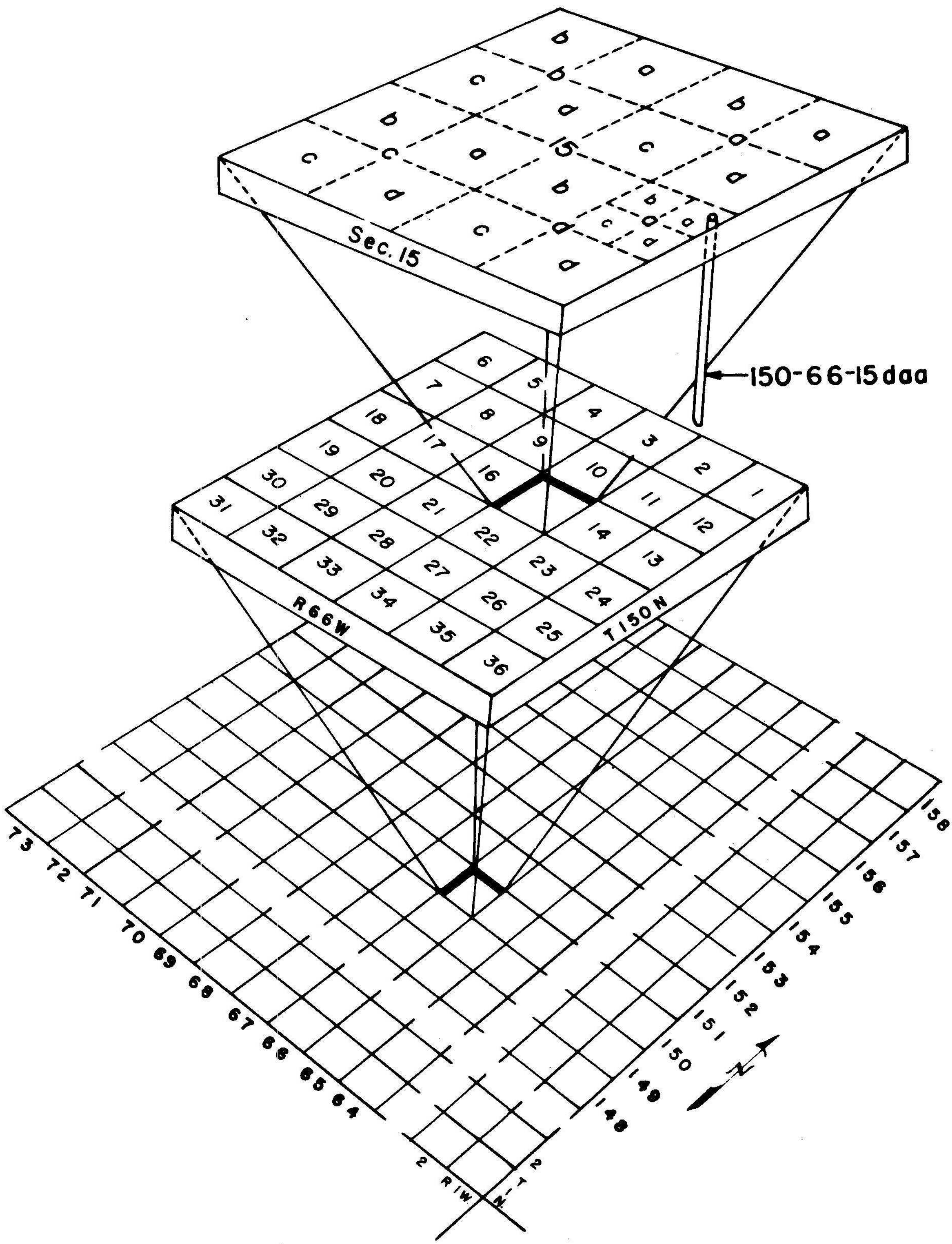


FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

Well-numbering System

The well-numbering system used in this report, illustrated in Figure 2, is based on the location of the well 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 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 if more than one well is located in a 10-acre tract. Thus well 150-66-15daa would be located in the NE$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 15, Twp. 150 N., Rge. 66 W.

GEOLOGY

Geologic information was gained from previously existing geologic reports and maps, soils maps, aerial photographs, topographic maps, test hole logs, and observation of conditions as they exist in the Sheyenne area.

Pierre Shale

The Pierre Shale is the only bedrock formation which crops out or underlies all glacial or glaciofluvial deposits in the area. All test holes encountered the shale at relatively shallow depths.

The Pierre Shale consists essentially of a uniformly fine-textured, dark bluish gray or greenish gray, argillaceous marine shale which was deposited during Late Cretaceous time. Where exposed and weathered, such as the road cuts immediately north of Sheyenne, where U. S. Highway 281 descends into the

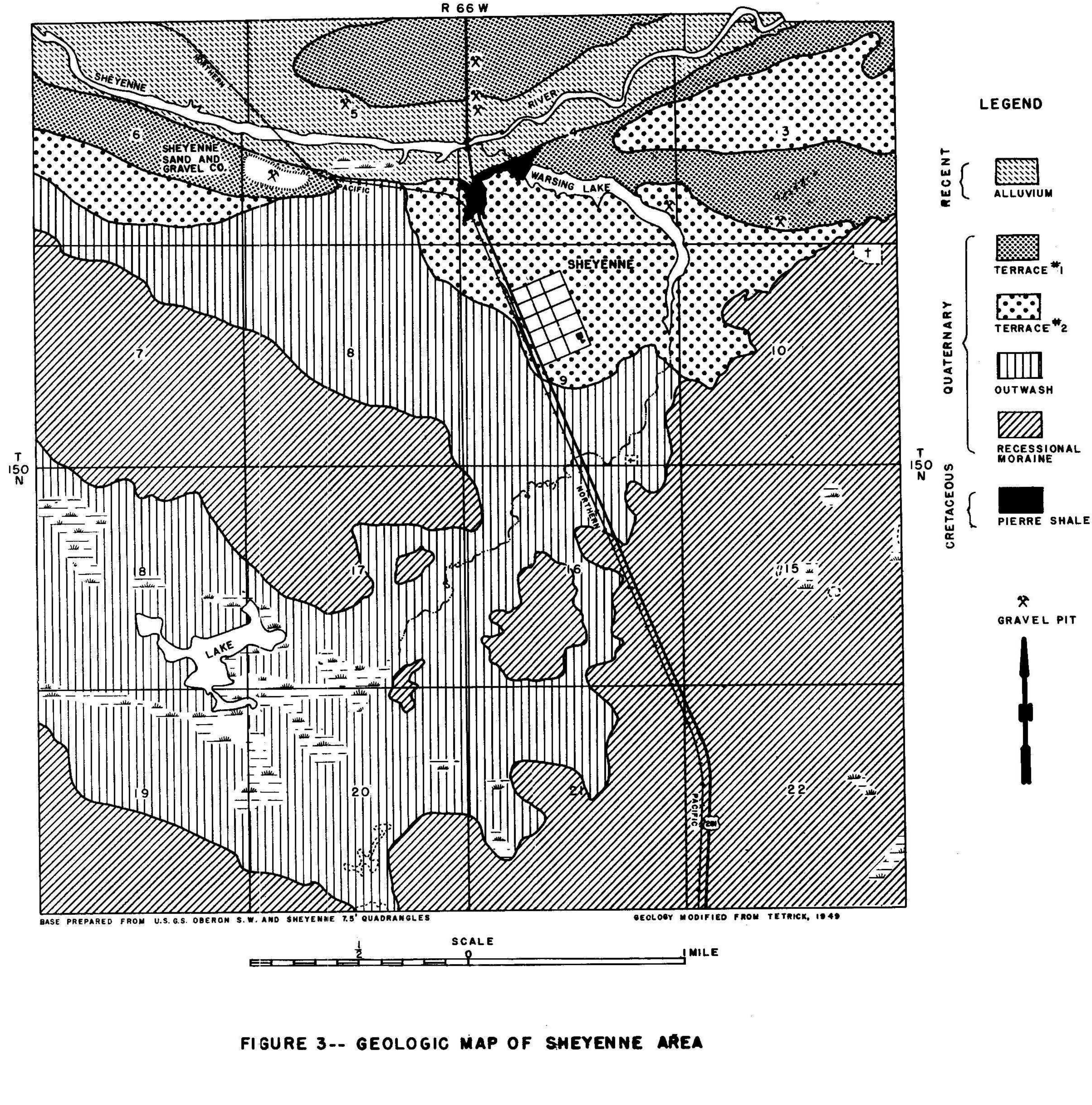


FIGURE 3-- GEOLOGIC MAP OF SHEYENNE AREA

Sheyenne River Valley (Figure 3), the shale appears as a medium-gray clay characterized by polygonal mud-crack forms.

The Sheyenne River has cut a narrow valley into the Pierre Shale to a depth of at least 130 feet. However, as much as 80 feet of this cut has been refilled by river deposits. Outside the valley the surface of the shale appears to be gently to moderately undulating plain, now overlain by glacial and glaciofluvial deposits.

The summary of the Calvert Exploration Co.-State #1 oil test drilled in the NE$\frac{1}{4}$NE$\frac{1}{4}$ section 8, Twp. 150 N., Rge. 65 W., approximately 6 miles east of Sheyenne, indicates formations below the Pierre Shale are included in the following geologic systems -- Cretaceous, Jurassic, Mississippian, Devonian, Silurian, Ordovician, and Precambrian. Precambrian granite was encountered at a depth of 3,860'. Surface elevation at the site is 1,550' above sea level. The Dakota Sandstone, an extensive water-bearing formation, was encountered at a depth of 1,574 feet.

Recessional Moraines

The only glacial deposits exposed in the Sheyenne area are recessional moraines. These moraines are characterized by knob and kettle topography and are the result of a standstill of glacial ice which allowed material to be deposited along the terminal edge of the ice. The material composing the moraines is a dark gray, heterogeneous mixture of clay, silt, sand, pebbles, cobbles, and boulders, collectively termed till. The clay and silt has been derived from the Pierre Shale and other Cretaceous clays and shales, most of which has been incorporated into the till from local areas over which the ice passed. The limestone and granitic cobbles and boulders were derived from areas in Canada where the ice sheet originated.

The recessional moraine in the southern and eastern part of the Sheyenne area (Figure 3) is part of an extensive morainal complex known as the Heimdal Moraine. The isolated moraine, trending southeast through section 7 and continuing into section 17, is also part of the Heimdal Moraine but has been separated from the main moraine by erosion by glacial meltwaters. Evidence of erosion is indicated by the subdued topography on the isolated moraine as compared to the rugged topography of the main part of the Heimdal Moraine, which is also higher in elevation.

Outwash

Outwash was deposited in the Sheyenne area during the retreat of the glaciers from the area. Waters derived from the melting glaciers established a course through the glacial deposits, eroding and reworking the materials, and eventually depositing the sorted sediments in meltwater channels, or broad outwash plains.

The outwash in the Sheyenne area is essentially a channel deposit consisting of silt, reworked till, sand, and fine gravel. The silt and reworked till is concentrated in a band extending southeast from the isolated moraine previously described, to the main part of the Heimdal Moraine (Figure 3). In other words those parts of sections 16, 17, 20, and 21 which would be covered if the isolated moraine was continuous at the surface to the southeast. Small 'islands' of undisturbed till are found in this area and are marked by numerous boulders at the surface in spots where they occur. Sand and fine gravel are found in the remainder of the area shown as outwash in Figure 3. The sand and gravel is well-sorted and attains thicknesses of up to 40 feet.

Terraces

Following the deposition of outwash and the final retreat of the glaciers, the Sheyenne River began to entrench into the surficial materials. Three stages of river development are exposed in the Sheyenne area and are indicated by two separate terraces and alluvium in the floodplain of the Sheyenne River.

The two well-formed and distinct bench-like terraces are shown in Figure 3. Terrace No. 2 was deposited first and approximates an elevation of 1480 feet above sea level. Terrace No. 1 is found at an elevation of about 1460'. The terraces were deposited during the early stages of development of the Sheyenne River when the volume of water was much greater than the present day Sheyenne River ever carries, even during maximum flood stage. This large amount of water was due to melting of glaciers, mainly to the northwest of the Sheyenne area.

The terrace deposits overlie the Pierre Shale in the eastern half of the Sheyenne area and glacial till in the western half. They may attain a thickness of 30 feet or more but average about 20 feet. The material of the terraces varies widely in size, however, the vertical distribution of any size is relatively uniform in any one section. Terrace No. 2 above the Sheyenne Sand and Gravel Company is not being presently mined because it is predominately sand with very little gravel. Terrace No. 1, on which the sand and gravel company is located contains the variation of sizes required by a company which washes sand and gravel for marketing.

Alluvium

The present day Sheyenne River is only a few feet wide except during flood stage. The floodplain varies from one-fourth to over one-half mile wide.

The original valley, measured across the top at Sheyenne, is two miles wide and illustrates the difference between the ancestral Sheyenne River and the present stream.

Recent alluvium in the floodplain of the Sheyenne River consists of silt and sand. Thickness of the alluvium is variable but generally less than 10 feet. Below the alluvium are found outwash deposits consisting essentially of sand or gravel. This outwash was deposited in the channel of the Sheyenne River as the supply of water from the northwest began to decrease and the river no longer had the capability to transport the coarser materials. About 70 feet of outwash was encountered in a test hole near the Sheyenne Sand and Gravel Company in the valley of the Sheyenne River. The material is generally well-sorted, however, occasional layers of silt and clay were encountered.

Figure 4 is a map of the Sheyenne area which shows the location of test holes and wells used in the interpretation of ground-water conditions in the area. It also shows the location of geologic cross-sections which are illustrated in Figures 5a, b, and c. These cross-sections show the configuration of the surface, subsurface conditions as they exist at each test hole or well, and the nature of the material encountered at each site. Table 3 in the back of the report contains a record of the test holes and wells. Table 4 consists of logs of the test holes and wells and includes a description of the materials which were penetrated.

OCCURRENCE OF GROUND WATER

Water-bearing characteristics of the geologic units

Pierre Shale

Any formation or strata that yields water to wells is called an aquifer. The Pierre Shale in the Sheyenne area could be considered a weak aquifer.

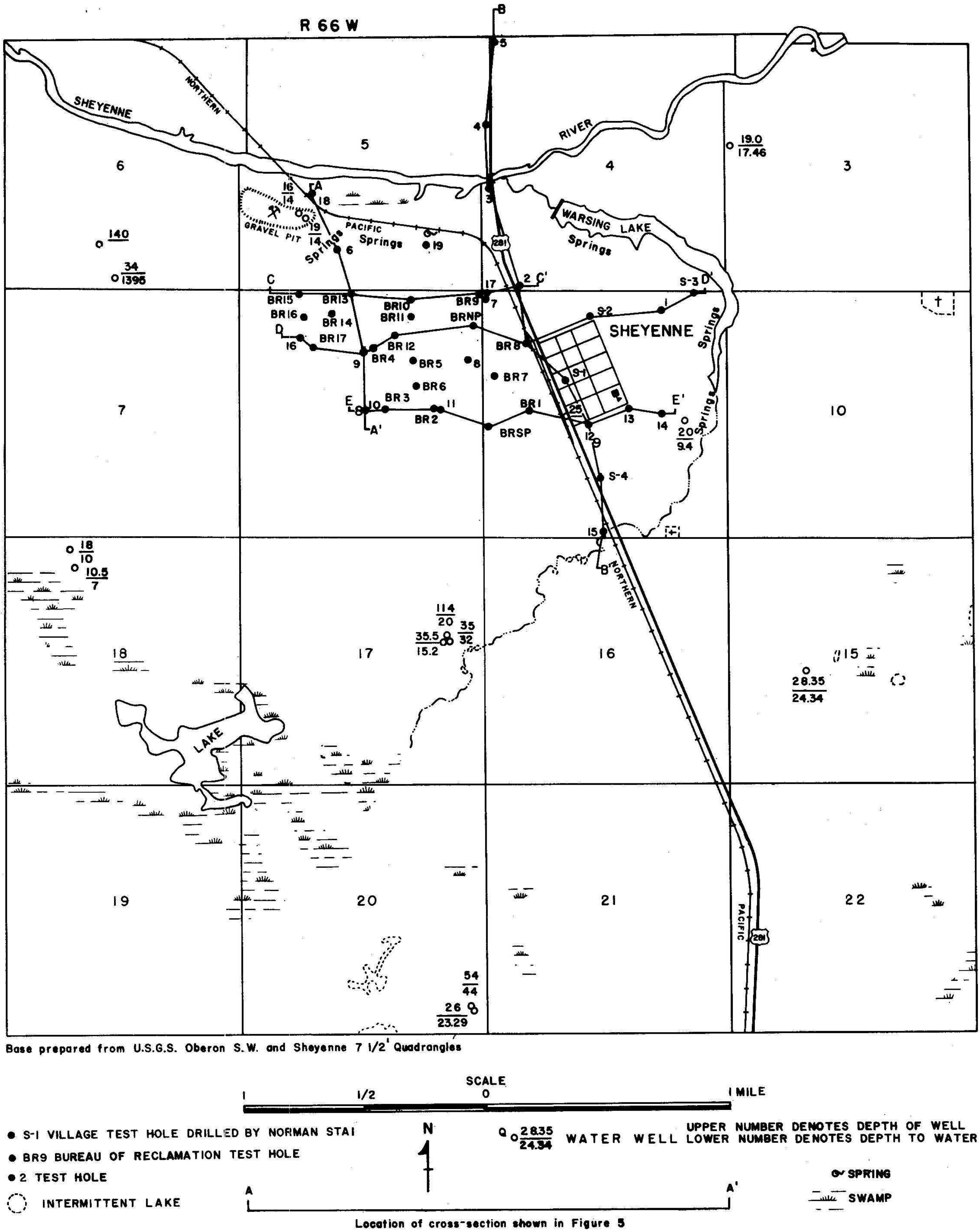


FIGURE 4--MAP OF THE SHEYENNE AREA SHOWING LOCATION OF SELECTED WELLS, TEST HOLES AND GEOLOGIC CROSS-SECTIONS.

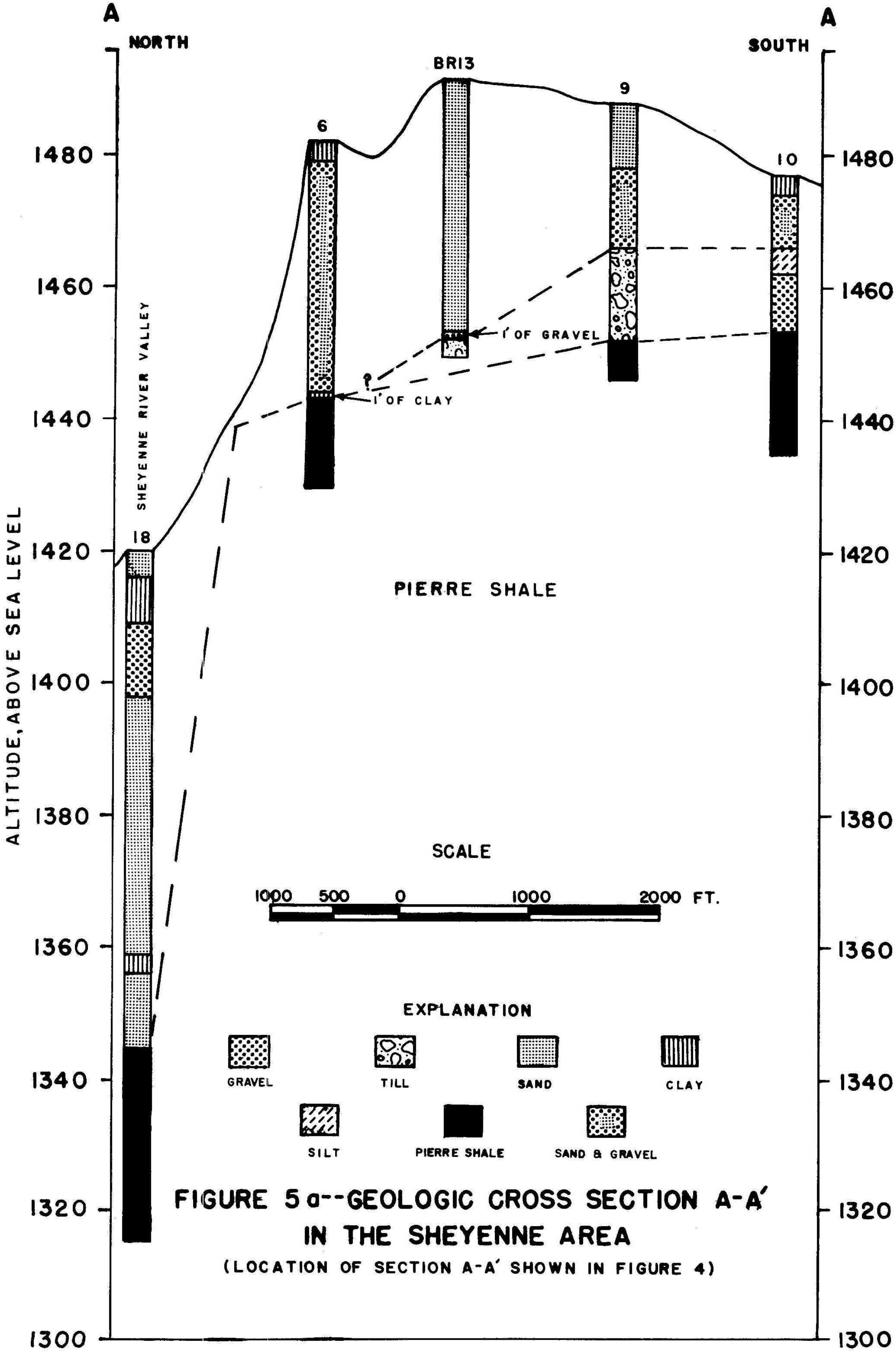


FIGURE 5a--GEOLOGIC CROSS SECTION A-A' IN THE SHEYENNE AREA

(LOCATION OF SECTION A-A' SHOWN IN FIGURE 4)

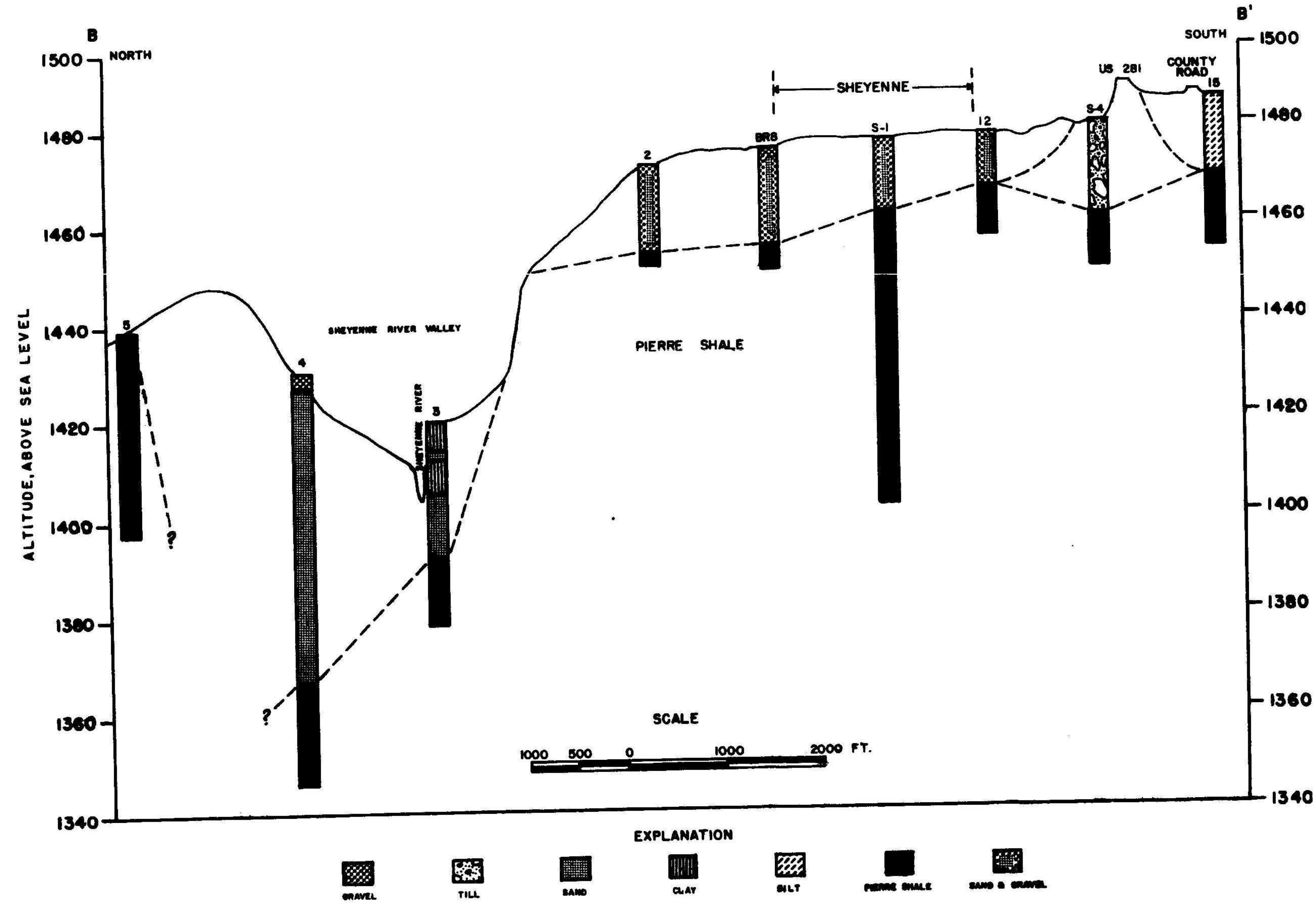


FIGURE 5b--GEOLOGIC CROSS SECTION B-B' IN THE SHEYENNE AREA

(LOCATION OF SECTION B-B' SHOWN IN FIGURE 4)

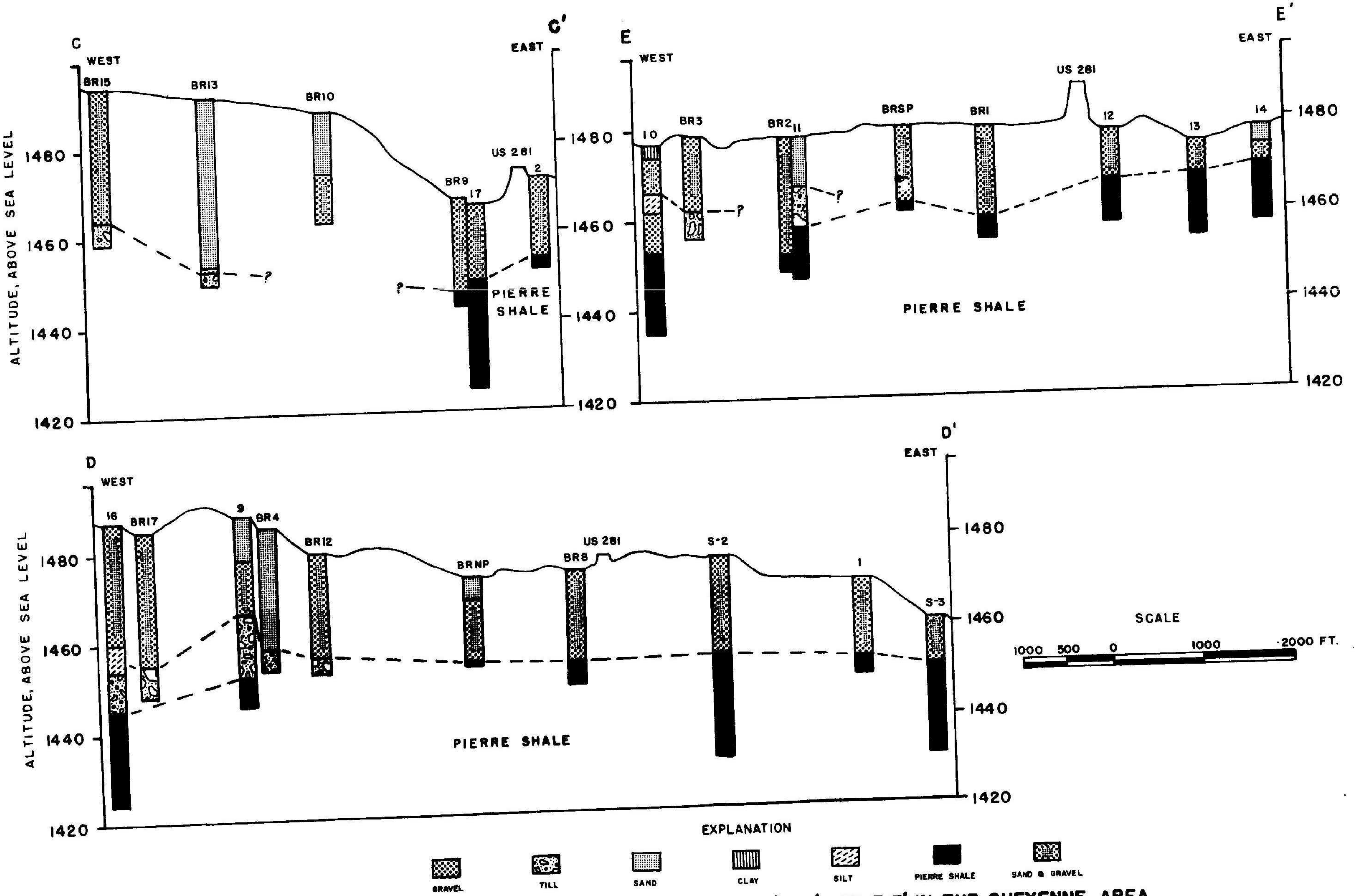


FIGURE 5c--GEOLOGIC CROSS SECTIONS C-C', D-D' AND E-E' IN THE SHEYENNE AREA

(LOCATION OF SECTIONS C-C', D-D' AND E-E' SHOWN IN FIGURE 4)

Because the formation is composed primarily of clay, water is held in the material and released very slowly to a well penetrating it. Nearly all wells in the Pierre Shale recover water from fractured shale near the top of the formation or from sandy layers within it. Yields from such wells are small and generally nondependable. Waters found beneath the Pierre Shale are not generally suitable for a municipal supply.

Recessional Moraines

The recessional moraines in the Sheyenne area also constitute a weak aquifer. Till, the material of which the moraines are made up, consists essentially of clay and silt, and does not readily release water. Most wells drilled in moraine deposits tap sand or gravel pockets included in the till. Sand and gravel readily release water to a well, but the yield depends upon the thickness and lateral extent of the sand or gravel. Some wells, usually 12 to 18 inches in diameter, supply enough water for stock or domestic uses, whereas others are of the 'bucket in the morning, bucket in the evening' type. It is not uncommon for farms located in the morainal areas to have a cistern in which rainwater is stored for domestic use. In some instances water is hauled from wells located outside the morainal areas.

Outwash

The outwash area shown in Figure 3, with the exception of portions of sections 16, 17, 20, and 21, can be considered a very good aquifer. Shallow wells, often less than 30 feet deep, are practically assured of a good water supply. Small diameter driven sandpoint wells, in most cases, will supply demands for ordinary domestic or stock uses.

Those parts of sections 16, 17, 20, and 21 in which the outwash consists of silt and reworked till contain a poor aquifer and, in fact, the material actually blocks the natural subsurface drainage to the northeast, thus creating the sloughs and lake in sections 17, 18, 19, and 20. The outwash in the southwest corner of section 17, in sections 18 and 19, and in the northwest corner of section 20 are underlain by sand and gravel and probably constitutes a source of water capable of supplying the requirements of the village of Sheyenne. The area was not thoroughly investigated, however, because of the distance from the village. It is conceivable that water from this area could be utilized in recharging the city well field by constructing a trench or drainage ditch from the lake to the near vicinity of the well, a distance of approximately 2½ miles.

Terraces

The river terraces, along with the outwash sand and gravel, furnish the only reliable source of ground water in the area. Because of the limited thickness of the terrace deposits in places, wells generally penetrate the entire thickness of terrace sand and gravel and bottom out on the upper surface of the Pierre Shale or glacial till. Some of the older hand dug wells were dug a few feet deeper into the shale or till in order to create a reservoir for water storage during periods of low water levels.

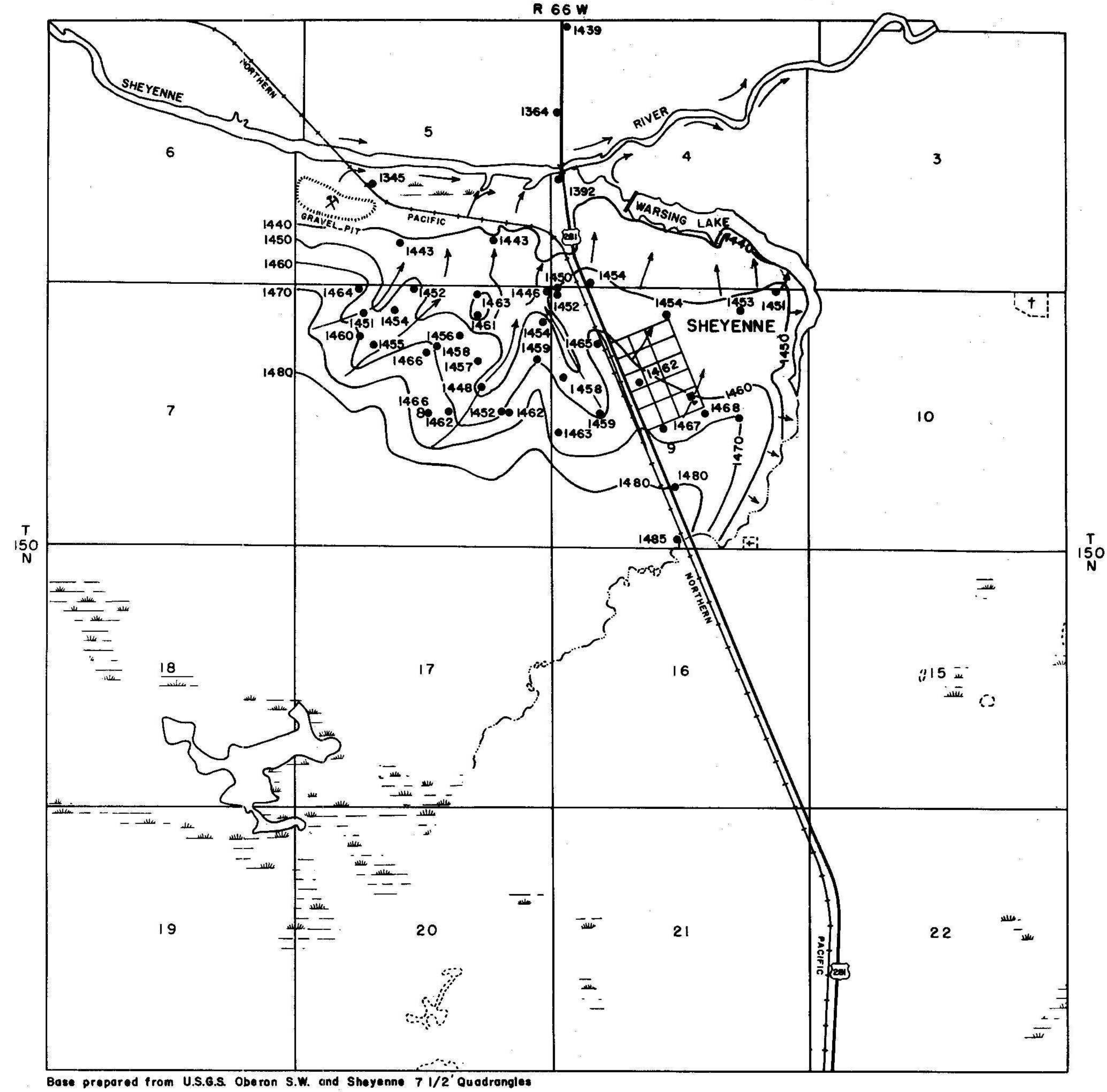
Because the surface of the shale and till underlying the terrace and outwash deposits is undulating, a buried "swell and swale" topography exists. The swales naturally contain greater thicknesses of saturated sand and gravel. Such being the case, a well dug in a swale would have a greater saturated area to draw from than a well located on a swell.

In connection with this study, it was determined that the present village well is located on a swell with a shale surface elevation of 1470 feet. West of the well and trending in a northwesterly direction is a swale (Figure 6). In the extreme corner of section 8 the bedrock surface is at 1450 feet, a difference of 20 feet in elevation from this point to the well. At this point there was approximately 6 feet more of saturated sand and gravel than at the well site.

On April 1-3, 1959, personnel of the U. S. Geological Survey conducted an aquifer test on the prospective city supply well for the village of Sheyenne. The well was pumped for a period of 24 hours at an average rate of 60 gpm (gallons per minute) after which it was shut off. Calculations involving data collected during the test indicate the aquifer has a coefficient of transmissibility (a measure of the ability of the aquifer to transmit water) of about 7,000 gallons per day per foot. In other words for each foot of drawdown in a well being pumped, the well will produce 7,000 gallons of water per day. Six feet of drawdown will therefore produce 42,000 gallons per day, the average amount of water required by the village of Sheyenne during normal summer months.

Alluvium

Alluvium in the floodplain of the Sheyenne River is generally too fine or shallow to constitute a source of water supply for Sheyenne. However, underlying the alluvium are outwash sand and gravel which contain a source of water virtually untapped in the Sheyenne area. Significant amounts of sand and gravel were encountered in test holes 4 and 18 (Figure 4). A well at either site would be capable of producing the amount of water needed by the village. Test drilling indicates the outwash deposits are variable in nature



Base prepared from U.S.G.S. Oberon S.W. and Sheyenne 7 1/2' Quadrangles

SCALE

1 1/2 0 1 MILE

● 1450 TEST HOLE OR OBSERVATION WELL NUMBER DENOTES ELEVATION ABOVE SEA LEVEL. SEE FIGURE 4--FOR WELL OR TEST HOLE DESIGNATION.

↗ DIRECTION OF GROUND WATER FLOW

N

—1460— CONTOUR AT BASE OF AQUIFER

FIGURE 6--POSSIBLE CONFIGURATION OF SURFACE UNDERLYING SAND AND GRAVEL DEPOSITS NEAR SHEYENNE.

and perhaps discontinuous. In the event a production well were to be drilled into this outwash, a pilot well should be drilled first and a pumping test performed in order to determine hydrologic characteristics of the aquifer.

Recharge

Ground-water recharge in the Sheyenne area is dependent entirely on precipitation. Rainfall or snow melt on the permeable outwash and terrace deposits is absorbed easily and quickly. The capacity to absorb moisture is very low in the morainal areas and thus most precipitation runs off and infiltrates into the outwash or terraces.

Ground water infiltrates downward through the earth until it reaches the water table. The water table is a surface below which all sediments are saturated. The water table in the outwash and terrace deposits is a result of build up of ground water which has been prevented from percolating deeper into the earth by the essentially impermeable Pierre Shale or till. When ground water reaches the water table, therefore, it moves laterally, due to the force of gravity, to points of lower elevation and eventually to a discharge area.

As can be seen in Figure 6, the direction of lateral ground water movement near Sheyenne is in a northerly direction toward the Sheyenne River. The lateral movement of ground water in this area is continuous and because of the high permeability of the sand and gravel it is quite rapid. Therefore, unless the outwash and terraces are recharged by precipitation there is a steady decline of the water table and in the event of a prolonged drouth, many wells may go dry.

Recharge to a well in any specific area is dependent upon the material the well is developed in. Recharge to wells developed in the Pierre Shale or till is very slow and a safe yield can be determined only by use. Recharge to wells developed in outwash or terrace deposits is very good and a safe yield of 5 gallons per minute for each foot of saturated sand and gravel can be obtained. This figure was derived from a pumping test performed in connection with this study in the extreme northwest corner of section 9 and from data collected by the U. S. Geological Survey in 1959. No data is available for estimating the safe yield of a well developed in the outwash underlying the river alluvium, however, it would probably be greater than 5 gpm. A pumping test would be necessary to determine a safe yield from this outwash.

Discharge

Ground water is always in the process of movement from areas of recharge to areas of discharge. Most notable of discharge areas in the Sheyenne area are the springs. No attempt has been made to estimate the amount of ground water lost to springs, but the figure would be in millions of gallons per year. As shown in Figure 4, the springs are concentrated along the Sheyenne River valley wall and along Warsing Lake. The springs are the result of the water table intersecting the surface of the land. There is no possible way of preventing this great loss of ground water. The only solution is to dig a well at the site of the spring and pump the water before it is lost to the spring. In areas where there are numerous springs, such as in the southeast quarter of section 5, a series of sandpoint wells would be effective in reducing ground water loss to springs and increasing the water supply for Sheyenne.

Other discharge areas in the Sheyenne area include evaporation from open bodies of water and soil and water consumed by vegetation. These processes are a natural phenomenon and difficult to prevent as far as enhancing a water supply is concerned.

WATER QUALITY

Ground water in the Sheyenne area is of meteroic 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, it begins to react with the minerals of the soil and rocks with which it comes in contact. The amount and character of the mineral matter dissolved by meteoric waters depend upon the chemical composition and physical structure of the rocks with which they have been in contact, the temperature pressure, duration of contact and the material already in solution. The solvent action of the water is assisted by carbon dioxide in solution, derived from the atmosphere and organic processes in the soil through which the water passes.

Quality of shallow ground water, in general, varies inversely with the quantity; where abundant it is commonly potable, where sparse it is commonly highly mineralized. Extent of mineralization, in general, varies directly with depth; deeper bedrock waters being 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 or river 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 (1963), approved by the Secretary of Health, Education and Welfare, are, in part, as follows:

Table 1 -- Drinking water standards of the U. S. Public Health Service

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

Table 2 lists 24 analyses of water samples taken in the Sheyenne area. All samples, with the exception of the last one (150-66-15cab), were taken from outwash or terrace deposits. The water quality from these deposits is very good, but the water is quite hard. All samples indicate the water is suitable for domestic use and irrigation. No analyses of water from the outwash underlying the river alluvium was taken, however, the water should also be of good quality and suitable for a municipal supply.

TABLE 2 — Record of Chemical

(analytical results in parts

Location	Depth of well (feet)	Aquifer	Date of collection	(SiO_2)	(Fe)	(Ca)	(Mg)	(Na)	(K)	(HCO_3)	(CO_3)
150-66-5cac	Spring	Terrace #2	10-25-63	31	.5	56	46	38	8.2	229	9.6
150-66-5cbd	16	Terrace #1	10-25-63	18	.48	46	26	120	10	494	0
150-66-8aaa	22	Terrace #2	1956[1]	--	--	70	17	94	--	250	24
150-66-8aad	20	Terrace #2	1956	--	--	22	22	122	--	49	24
150-66-8aba$_2$	22	Outwash	1956	--	--	62	21	87	--	201	15
150-66-8abc	32	Outwash	1956	--	--	--	--	340	--	506	39
150-66-8abd	27	Outwash	1956	--	--	42	5	53	--	244	6
150-66-8aca	31	Outwash	1956	--	--	56	11	12	--	165	27
150-66-8acc$_2$	23	Outwash	1956	--	--	66	13	7	--	183	15
150-66-8acd	32	Outwash	1956	--	--	12	12	179	--	250	24
150-66-8adc$_1$	30	Outwash	1956	--	--	58	10	14	--	110	9
150-66-8baa$_2$	33	Outwash	1956	--	--	50	12	14	--	110	9
150-66-8bab	48	Outwash	1956	--	--	64	16	7	--	165	0
150-66-8bac	37	Outwash	1956	--	--	56	9	14	--	165	3
150-66-8bba	35	Outwash	1956	--	--	64	16	14	--	177	0
150-66-9 [2]	18-20	Terrace #2	1938(?)	18	3.8	82	39	27	--	283	--
150-66-9bbb$_2$	21	Terrace #2	10-18-63	19	.36	54	37	52	6.0	171	0
150-66-9bbd	25	Terrace #2	1956	--	--	96	17	18	--	195	30
150-66-9bcb	30	Outwash	1956	--	--	46	6	71	--	207	18
150-66-9bcd	25	Outwash	1956	--	--	76	6	37	--	207	3
150-66-9cab	25	Terrace #2	10-25-63	16	.64	56	17	135	15	444	0
150-66-9cab[3]	25	Terrace #2	-	--	0	108	24	50	--	342	38
150-66-9cbb	19	Outwash	1956	--	--	20	4	58	--	55	15
150-66-15cab	28.35	Till	10-21-63	17	.42	240	141	57	10	605	0

1/ All analyses with 1956 dates were performed by Bureau of Reclamation.

2/ Abbott and Voedisch, 1938 (p. 56-57).

3/ North Dakota State Department of Health, 1964 (p. 20-21).

Analyses

per million except as indicated)

(SO_4)	(Cl)	(F)	(NO_3)	(B)	Total dissolved solids	Total hardness as $CaCO_3$	Total hardness noncarbonate	% Sodium	SAR	Specific conductance micromho's/cm	pH
180	26	.2	0	0	522	328	125	20	.9	801	8.4
85	4	.4	1	.10	571	220	0	53	3.5	926	8.0
173	11	--	--	--	--	--	--	0	0	--	8.5
29	18	--	--	--	--	--	--	63.1	4.3	--	8.2
62	4	--	--	--	--	--	--	44.8	2.5	--	8.3
163	28	--	--	--	--	--	--	96.1	23.9	--	8.6
14	0	--	--	--	--	--	--	47.9	2.0	--	8.2
14	0	--	--	--	--	--	--	11.9	2	--	8.2
29	0	--	--	--	--	--	--	6.4	2	--	8.4
86	74	--	--	--	--	--	--	83.0	9.0	--	8.4
86	7	--	--	--	--	--	--	13.0	.4	--	8.2
38	7	--	--	--	--	--	--	14.6	.5	--	8.2
29	0	--	--	--	--	--	--	6.3	.5	--	8.2
10	0	--	--	--	--	--	--	14.6	.5	--	8.3
72	4	--	--	--	--	--	--	11.8	.5	--	8.2
109	21	.4	71	--	522	374	--	--	--	--	--
205	16	.3	20	0	501	284	145	28	1.3	801	8.2
53	11	--	--	--	--	--	--	11.4	.5	--	8.5
72	7	--	--	--	--	--	--	52.5	2.5	--	8.3
101	7	--	--	--	--	--	--	27.1	1.0	--	7.9
115	20	.3	2.0	0	597	212	0	56	4.0	1000	7.6
158	18	Trace	2	--	847	368	--	--	--	1073	8.5
38	--	--	--	--	--	--	--	65.8	1.6	--	8.3
550	148	.6	60	.19	1530	1180	686	9	.7	2196	7.3

The analyses of water recovered from till shows the water to be highly mineralized, very hard, and containing excessive nitrates. High nitrates can cause pathological disorders in the human system and the State Department of Health should be notified when excessive nitrates are discovered. No analyses are available of Pierre Shale waters in the Sheyenne area, however, these waters are commonly highly mineralized and often salty.

RECOMMENDATIONS

The outwash and terrace deposits contain the only reliable source of good quality water in the Sheyenne area. During the course of this survey at least four possible ways of increasing the water supply for Sheyenne were determined.

Ground water stored in portions of sections 17, 18, 19,and 20 could be utilized in recharging the present village well. This could be done by constructing a drainage ditch from the lake (Fig. 3 and 4) to the infiltration pond adjacent to the village well. By proper construction, gravity flow could be obtained and no pumps would be necessary.

A second alternative would be to dig a new village well in the bedrock swale in the extreme northeast corner of section 8. Indications are this is the nearest location to the village that a single well could produce the gallonage of water required by the village. Gallonage could be increased by locating a well at or towards the site of test hole 19 (Figure 4). Pumping test data indicate a safe yield of 5 gpm for each saturated foot of sand and gravel in the outwash and terrace deposits. Therefore, a large diameter well need not be installed. A 4- to 6-inch diameter well with a 4- or 5-foot screen would be just as effective as a large diameter well.

Thirdly, the area north of test hole 19 contains numerous springs which discharge thousands of gallons per month. In order to prevent this loss of ground water and increase the amount of water available for a municipal supply, a series of sandpoint wells, traversing east to west above the springs, could be installed. In effect, by pumping the sandpoint wells, the water level would be lowered and thus decreasing the supply of water to the springs but supplying the water required for municipal use.

In the event that future developments require larger amounts of water than that presently needed or available at Sheyenne, the outwash sand and gravel underlying the alluvium in the Sheyenne River valley should be explored further. It is possible that a well in these deposits could produce from 100 to 400 gallons per minute if the deposits are hydrologically connected.

TABLE 3 -- Records of Wells and Test Holes

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

Type of well: Dr, drilled; Du, dug; Dv, driven; Bo, bored; Au, augered; g.p.m., Gallons per minute.

C. A. - Chemical analysis   P. A. - Partial chemical analysis

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

Use of water: D, domestic; U, unused; PS, public supply; S, stock; T, test hole; O, observation well.

@ - Approximate

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
150-66-3bcc	Unknown	19.0	36	Du	-	17.46	10-21-63	U	-	1472	
150-66-4bbb	Test Hole 5	42	4 3/4	Dr	10-17-63	13.88	10-21-63	T	Shale	1439	See log
150-66-4cbb	Test Hole 3	42	4 3/4	Dr	10-17-63	@3.73	10-21-63	T	Sand	1420	See log
150-66-4ccd	Test Hole 2	21	4 3/4	Dr	10-17-63	@11.33	10-21-63	T	Sand	1472	See log
150-66-4ada	Test Hole 4	84	4 3/4	Dr	10-17-63	@5.17	10-21-63	T	Sand	1430	See log
150-66-5cab	Test Hole 10	105	4 3/4	Dr	10-25-63	4.75	10-25-63	T	Sand	1420	See log
150-66-5cac	Sheyenne Sand & Gravel Company	19	1 1/2	Du	1957	14	-	D	Sand & Gravel	1440	
150-66-5cbd	Sheyenne Sand & Gravel Company	16	1 1/2	Dv	1963	14	-	D	Sand & Gravel	1440	C.A.
150-66-5cda	Test Hole 6	52	1 1/4	Dr	10-17-63	Dry	10-21-63	O	-	1482	See log-plastic pipe installed
150-66-5ddb	Test Hole 19	21	4 3/4	Dr	10-25-63	5.18	10-25-63	T	Sand & Gravel	1455	See log
150-66-6cda	Carl Benson	140±	6"	Dr	-	-	-	S	Shale	1485	Hard, salty
150-66-6cdd	Carl Benson	34	36	Du	1-24-56	13.95	10-22-63	D,S	Sand & Gravel	1495	
150-66-8aaa	Bureau of Reclamation #9 well	22	4	Dr	1955	12.4	3-13-64	O	Sand & Gravel	1467.4	See log, P.A.

TABLE 3 -- 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
150-66-8aad	Bureau of Reclamation North Pasture well	20	4	Dr	7-15-59	12.2	7-15-59	O,S	Sand & Gravel	1473.0	3' drawdown after 1 hr. pumping 25 gpm. See log- P.A.
150-66-8aba₁	Bureau of Reclamation #10 well	25	2	Au	11-4-55	Dry	2-11-58	O	-	1487.7	See log; destroyed
150-66-8aba₂	Bureau of Reclamation #11 well	22	2	Dr	1-26-56	17.3	1-26-56	O	Sand & Gravel	1478.7	See log,P.A.
150-66-8abc	Bureau of Reclamation #4 well	32	2	Dr	2-1-56	17.2	2-2-56	O	Sand	1485.1	See log,P.A.
150-66-8abd	Bureau of Reclamation #12 well	27	2	Dr	1-26-56	13.4	2-1-56	O	Sand & Gravel	1479.2	See log,P.A.
150-66-8aca	Bureau of Reclamation #5 well	31	2	Dr	2-8-56	16.6	2-10-56	O	Sand & Gravel	1483.2	See log, P.A.
150-66-8acb	Test Hole 9	42	1 1/4	Dr	10-18-63	@19.57	10-21-63	O	Sand & Gravel	1488	See log,plastic pipe installed but removed
150-66-8acc₁	Test Hole 10	42	4 3/4	Dr	10-18-63	9.54	10-21-63	T	Sand & Gravel	1477	See log
150-66-8acc₂	Bureau of Reclamation #3 well	23	2	Dr	2-9-56	8.8	2-10-56	O	Sand & Gravel	1478.7	See log, P.A.
150-66-8acd	Bureau of Reclamation #6 well	32	2	Dr	5-8-56	7.4	2-10-56	O	Sand	1475.7	See log, P. A.
150-66-8ada	Test Hole 8	31	1 1/4	Dr	10-18-63	Dry to 17.57	10-21-63	O	Sand & Gravel	1480	See log, plastic pipe installed but removed
150-66-8adc₁	Bureau of Reclamation #2 well	30	2	Dr	2-9-56	7.9	2-10-56	O	Sand & Gravel	1477.9	See log, P.A.

TABLE 3 -- Records of Well 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
150-66-8adc$_2$	Test Hole 11	31	4 3/4	Dr	10-18-64	Caved at 7.75'	10-21-63	T	-	1478	See log
150-66-8baa$_1$	Bureau of Reclamation #13 well	42	2	Dr	1-25-56	7.9	1-26-56	0	Sand & Gravel	1491.5	See log, destroyed
150-66-8baa$_2$	Bureau of Reclamation #14 well	33	2	Dr	1-31-56	25.2	2-1-56	0	Sand & Gravel	1492.4	See log, P.A.
150-66-8bab	Bureau of Reclamation #16 well	48	2	Dr	2-7-56	24.2	5-8-56	0	Sand & Gravel	1490.9	See log, P.A.
150-66-8bac	Bureau of Reclamation #17 well	37	2	Dr	2-7-56	17.1	5-8-56	0	Sand & Gravel	1484.7	See log, P.A.
150-66-8bba	Bureau of Reclamation #15 well	35	2	Dr	2-2-56	25.5	2-3-56	0	Sand & Gravel	1494.1	See log, P.A.
150-66-8bbd	Test Hole 16	63	1 1/4	Dr	10-22-63	21.57	10-25-63	0	Sand & Gravel	1487	See log, plastic pipe removed
150-66-9aab	Stai test #3	30	4 1/2	Dr	9-21-63	4.92	10-21-63	T	Sand & Gravel	1461	See log
150-66-9aba	Test Hole 1	21	4 3/4	Dr	10-16-63	@12.04	10-21-63	T	Sand & Gravel	1470	See log
150-66-9acc	Test Hole 13	21	4 3/4	Dr	10-22-63	6.36	10-25-63	T	Sand & Gravel	1475	See log
150-66-9baa	Stai test #2	45	4 1/2	Dr	9-20-63	Caved at 16.34	-	T	-	1476	See log
150-66-9bbb$_1$	Test Hole 17	42	4	Dr	10-23-63	10.90	10-25-63	0,T	Sand & Gravel	1466	See log, 5.2' drawdown pumping 30 gpm for 12 hrs.
150-66-9bbb$_2$	Test Hole 7	21	1 1/4	Dr	10-18-63	14.50	10-21-63	0	Sand & Gravel	1470	See log, C.A.
150-66-9bbd	Bureau of Reclamation #8 well	25	2	Dr	1-19-56	16.3	1-20-56	0	Sand & Gravel	1475.4	See log, P.A.

TABLE 3 -- 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
150-66-9bcb	Bureau of Reclamation #7 well	30	2	Dr	2-10-56	19.7	2-10-56	O	Sand & Gravel	1483.7	See log, P.A.
150-66-9bcd	Bureau of Reclamation #1 well	25	2	Dr	2-10-56	14.0	4-24-56	O	Sand & Gravel	1479.3	See log, P.A.
150-66-9bdb	Stai test #1	75	4 1/2	Dr	9-20-63	11.73	10-21-63	T	Sand & Gravel	1477	See log
150-66-9caa	Test Hole 12	21	4 3/4	Dr	10-22-63	Caved at 8'	-	T	-	1478	See log
150-66-9cab	Village well	25	-	Du	-	-	-	PS	Sand & Gravel	1480	C.A.
150-66-9cbb	Bureau of Reclamation South Pasture well	19	4	Dr	7-20-59	12.8	7-20-59	O,S	Sand & Gravel	1479.7	See log,P.A.
150-66-9cda	Stai test #4	30	4 1/2	Dr	9-21-63	9.28	10-21-63	T	Till	1480	See log
150-66-9cdd	Test Hole 15	31	4 3/4	Dr	10-22-63	-	-	T	-	1485	See log
150-66-9dab	Clifford Lindstrom	20	2	Dv	-	9.4	10-22-63	D,S	Sand	1480	
150-66-9dba	Test Hole 14	21	4 3/4	Dr	10-22-63	8.79	10-25-63	T	Shale(?)	1478	See log
150-66-15cab	Melvin Cook	28.35	36	Bo	-	24.34	10-21-63	D,S	-	1600	C.A.
150-66-17adc$_1$	Art Lillevig	114	6	Dr	-	20	-	S	Shale	1496	Soft,salty
150-66-17adc$_2$	Art Lillevig	35	30	Du	-	32	-	D,S	Sand	1496	Hard
150-66-17adc$_3$	Art Lillevig	35.5	-	Du	-	15.2	10-22-63	D,S	Sand	1496	Hard
150-66-18bab$_1$	Albert Benson	10.5	44	Du	-	7	-	D,S	Sand	1510	Soft
150-66-18bab$_2$	Albert Benson	18	36	Du	-	10	-	S	Shale(?)	1500	Hard
150-66-20ddd$_1$	I.W. Daugherty	26	36	Du	-	23.29	10-22-63	D,S	Sand	1545	Hard
150-66-20ddd$_2$	I. W. Daugherty	54	36	-	-	44	-	S	Till	1545	Hard,alkaline

TABLE 4 — Logs of Test Holes

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 5 150-66-4bbb			
Pierre Shale	Shale fragments, weathered, olive black	3	0	3
	Clay, silty, yellowish gray, soft, slightly plastic, cohesive, noncalcareous; decomposed shale	7	3	10
	Shale, olive black, fissile, brittle, noncalcareous; tight drilling	32	10	42
	Test Hole 3 150-66-4cbb			
Alluvium	Clay, silty, soft, poorly consolidated; many weathered shale fragments	3	0	3
	Clay, light olive gray, soft, plastic, cohesive	3	3	6
	Sand, medium to coarse with pebbles, rounded, poorly sorted	2	6	8
	Clay, olive gray, soft, plastic, cohesive, slight calcareous	4	8	12
	Shale fragments, olive black, loose	3	12	15
	Sand, very fine to fine, silty, olive gray, generally subrounded, moderately well-sorted, slightly calcareous	5	15	20
	Sand, as above, fine to medium	8	20	28
Pierre Shale	Shale, olive black, fissile, brittle, fractured, noncalcareous	14	28	42
	Electric log			

TABLE 4 — Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 2 150-66-4ccd			
Terrace #2				
	Topsoil, sandy loam, black.............	1	0	1
	Sand, medium to very coarse with fine to medium gravel, rusty red, subrounded to rounded, moderately well-sorted...............	9	1	10
	Sand and gravel, as above, becoming coarser with depth..................	8	10	18
Pierre Shale				
	Shale, olive black, slightly hard to brittle, fractured, noncalcareous.	3	18	21
	Test Hole 4 150-66-5ada			
Terrace #1				
	Gravel, fine to coarse, sandy with some clay, rounded, rusty, oxidized..	3	0	3
Alluvium				
	Sand, medium, rounded, well-sorted, oxidized............................	7	3	10
	Sand, medium, dark greenish gray, rounded, well-sorted, slightly calcareous.........................	33	10	43
	Sand, as above, drills fairly tight, possibly clayey in part..............	23	43	66
Pierre Shale				
	Shale, olive black, fissile, brittle, fractured, noncalcareous............	18	66	84

Electric log

TABLE 4 — Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 18 150-66-5cab			
Alluvium				
	Topsoil, gravelly loam, dark brown........................	1	0	1
	Sand, medium, well-sorted, rounded, dark brown..................	3	1	4
	Clay, silty, light olive gray, soft, cohesive, plastic, calcareous; contains inter-bedded sandy layers..........	7	4	11
	Gravel, fine and medium, generally subrounded, moderately sorted, some sand..................	11	11	22
	Sand, medium, gray, subrounded to rounded, very well-sorted; clayey layers from 40 to 50'..	39	22	61
	Clay, silty (?), poor sample return......................	3	61	64
	Sand, light gray, rounded, well-sorted, quartzose, very nice..	11	64	75
Pierre Shale				
	Shale, olive black, indurated, fissile, noncalcareous........	9	75	84
	Shale, as above, very tight drilling....................	21	84	105
	Electric log			
	Test Hole 6 150-66-5cda			
Outwash				
	Topsoil, gravelly loam, dark brown........................	1	0	1
	Clay, silty and sandy, yellowish brown........................	2	1	3
	Sand, medium to coarse, with fine to medium gravel, generally subrounded, moderately sorted, oxidized....................	25	3	28
	Sand, medium to coarse, some gravel, fairly clean..........	10	28	38
	Clay, sandy, high iron content, very heavy stain.............	1	38	39
Pierre Shale				
	Shale, olive gray to greenish gray, moderately soft to slightly hard, shaley partings, noncalcareous	13	39	52

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	Test Hole 19 150-66-5ddb			
Terrace #2				
	Topsoil, silty sandy loam, black......................	3	0	3
	Sand, medium to very coarse and fine gravel, rounded, well-sorted.....................	9	3	12
Pierre Shale				
	Shale, dark greenish gray, slightly hard, plastic, non-calcareous; tight drilling...	9	12	21
	Test Hole #9 well (BR 9) 150-66-8aaa			
Terrace #2				
	Topsoil......................	2	0	2
	Sand with coarse gravel........	19	2	21
Pierre Shale				
	Shale........................	3	21	24
	Bureau of Reclamation North Pasture Well (BR NP) 150-66-8aad			
Terrace #2				
	Sand, fine, brown, dry.........	5	0	5
	Sand, medium, some gravel, dry.	5	5	10
	Sand and gravel, clean, saturated.................	5	10	15
	Sand and gravel, up to $1\frac{1}{2}$" diameter, clean.............	4	15	19
Pierre Shale				
	Shale........................	1	19	20
	Bureau of Reclamation #10 well (BR 10) 150-66-8aba$_1$			
Outwash				
	Topsoil, sandy, black..........	1	0	1
	Sand, fine, tan................	2	1	3
	Sand, fine and medium, brown...	11	3	14
	Sand, coarse, and gravel, fine to medium, brown............	8	14	22
	Sand and gravel, coarse, brown.	3	22	25

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	Bureau of Reclamation #11 well (BR 11) 150-66-8aba2			
Outwash				
	Topsoil........................	1	0	1
	Sand, coarse, gray, and gravel.	17	1	18
Till				
	Till, sandy, gray..............	4	18	22
	Bureau of Reclamation #4 well (BR 4) 150-66-8abc			
Outwash				
	Topsoil........................	1	0	1
	Sand, gray.....................	26	1	27
Till				
	Till, gray.....................	5	27	32
	Bureau of Reclamation #12 well (BR 12) 150-66-8abd			
Outwash				
	Topsoil........................	1	0	1
	Sand and gravel, coarse, gray..	22	1	23
Till				
	Till, sandy, gray..............	4	23	27
	Bureau of Reclamation #5 well (BR 5) 150-66-8aca			
Outwash				
	Topsoil........................	2	0	2
	Sand and gravel, medium, brown.	24.5	2	26.5
Till				
	Till, gray.....................	4.5	26.5	31

TABLE 4 — Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 9 150-66-8acb			
Outwash				
	Topsoil, fine sandy loam, black....	1	0	1
	Sand, fine to coarse, well-sorted, rounded, oxidized...............	9	1	10
	Sand, medium to very coarse with fine gravel, very well-sorted, rounded, clean.................	12	10	22
Till				
	Clay, sandy (very fine and fine) with coarse sand grains, granules, pebbles, and numerous large rocks, olive gray, moderately soft, moderately compacted, cohesive, slightly plastic, calcareous; rough drilling.................	14	22	36
Pierre Shale				
	Shale, dark greenish gray to olive black, moderately soft to slightly hard, mostly massive, some shaley partings, noncalcareous.......................	6	36	42
	Test Hole 10 150-66-8acc1			
Outwash				
	Topsoil, very fine sandy loam, black..........................	1	0	1
	Clay, silty to sandy, yellowish gray, soft.....................	2	1	3
	Sand, fine to very coarse with fine gravel, moderately well-sorted, rounded, oxidized........	8	3	11
Till				
	Silt, olive gray, soft, cohesive, slightly plastic, calcareous....	4	11	15
	Gravel, fine and medium, with interbedded clay...................	9	15	24
Pierre Shale				
	Clay, dark greenish gray, moderately soft, contains many detrital shale fragments, noncalcareous; weathered shale................	4	24	28
	Shale, dark greenish gray, slightly hard, very tight, moderately plastic.......................	14	28	42

Electric log

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Bureau of Reclamation #3 well (BR 3) 150-66-8acc$_2$			
Outwash				
	Topsoil, sandy....................	1.5	0	1.5
	Sand and gravel, medium, brown.....	15.3	1.5	16.8
Till				
	Till, gray, with sand seams........	6.2	16.8	23
	Bureau of Reclamation #6 well (BR 6) 150-66-8acd			
Outwash				
	Topsoil and sand..................	2	0	2
	Sand, fine, silty, brown and gray..	25.5	2	27.5
Till				
	Till, gray........................	4.5	27.5	32
	Test Hole 8 150-66-8ada			
Outwash				
	Topsoil, very fine sandy loam, black.........................	1	0	1
	Sand, medium to very coarse with gravel, moderately sorted, rounded, oxidized......................	20	1	21
Pierre Shale				
	Clay, dark greenish gray, moderately soft, many detrital shale fragments......................	10	21	31

TABLE 4 — Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Bureau of Reclamation #2 well (BR 2) 150-66-8adc$_1$			
Outwash				
	Topsoil, sandy....................	2	0	2
	Sand, medium, brown, and gravel...	24	2	26
Till				
	Till, gray........................	4	26	30
	Test Hole 11 150-66-8adc$_2$			
Outwash				
	Topsoil, silty loam, black........	4	0	4
	Sand, fine to very coarse, sorted, rounded, oxidized.............	7	4	11
Till				
	Clay, silty to sandy with pebbles, olive gray, moderately soft, cohesive, tightly compacted, gravelly and rocky.............	9	11	20
Pierre Shale				
	Shale, dark greenish gray, slightly hard, very tight, noncalcareous.	11	20	31
	Bureau of Reclamation #13 well (BR 13) 150-66-8baa$_1$			
Outwash				
	Topsoil...........................	1	0	1
	Sand, coarse, brown...............	37	1	38
	Gravel, coarse....................	1	38	39
Till				
	Till, gray........................	3	39	42

TABLE 4 — Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Bureau of Reclamation #14 well (BR 14) 150-66-8baa$_2$			
Outwash				
	Topsoil	1	0	1
	Sand, gray, with gravel	27	1	28
	Sand, silty, gray	5	28	33
	Bureau of Reclamation #16 well (BR 16) 150-66-8bab			
Outwash				
	Topsoil	2	0	2
	Sand and coarse gravel	38	2	40
Till				
	Till, gray, with sand seams	5	40	45
Pierre Shale				
	Shale	3	45	48
	Bureau of Reclamation #17 well (BR 17) 150-66-8bac			
Outwash				
	Topsoil	1	0	1
	Sand, medium, brown, and small gravel	29	1	30
Till				
	Till, gray with sand seams	7	30	37
	Bureau of Reclamation #15 well (BR 15) 150-66-8bba			
Outwash				
	Topsoil	2	0	2
	Sand and gravel, gray	28	2	30
Till				
	Till, gray	5	30	35

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	Test Hole 16 150-66-8bbd			
Outwash				
	Topsoil, sandy loam, black........	1	0	1
	Sand, fine to coarse, sorted, rounded, oxidized; some gravel...........	15	1	16
	Sand, fine to coarse with fine gravel, moderately sorted.......	11	16	27
	Silt, olive gray, soft, tight, calcareous....................	6	27	33
Till				
	Silt, clayey and sandy with pebbles and cobbles, olive gray, moderately compacted, calcareous...........	9	33	42
Pierre Shale				
	Shale, dark greenish gray, moderately hard, very tight, noncalcareous..................	21	42	63
	Electric log			
	Stai test #3 (S-3) 150-66-9aab			
Terrace #2				
	Topsoil, sand loam................	1	0	1
	Sand and gravel, medium to coarse.	9	1	10
Pierre Shale (?)				
	Clay, plastic....................	20	10	30
	Test Hole 1 150-66-9aba			
Terrace #2				
	Topsoil, sandy loam, black........	1	0	1
	Sand, medium to very coarse with fine gravel, rusty red, moderately well-sorted, subrounded to well-rounded, oxidized...............	16	1	17
Pierre Shale				
	Shale, olive black, moderately soft to brittle, noncalcareous..	4	17	21

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	Test Hole 13 150-66-9acc			
Terrace #2				
	Topsoil,sandy loam, black.........	1	0	1
	Sand, medium to very coarse with fine gravel, well-sorted, rounded, oxidized......................	6	1	7
Pierre Shale				
	Shale, dark greenish gray, slightly hard, tight, noncalcareous......	14	7	21
	Stai Test #2 (S-2) 150-66-9baa			
Terrace #2				
	Topsoil........................	1	0	1
	Sand and gravel................	21	1	22
Pierre Shale (?)				
	Clay, gray.....................	23	22	45
	Test Hole 17 150-66-9bbb$_1$			
Terrace #2				
	Topsoil, silty loam, black........	2	0	2
	Sand, medium and coarse with fine gravel, sorted, rounded.........	15½	2	17½
Pierre Shale				
	Shale, olive black, tight.........	24½	17½	42
	Test Hole 7 150-66-9bbb$_2$			
Terrace #2				
	Topsoil, silty loam, black........	2	0	2
	Sand, medium to very coarse with fine to medium gravel, well-sorted, rounded......................	16	2	18
Pierre Shale				
	Shale, olive gray to dark greenish gray, moderately soft, moderately plastic, noncalcareous..........	3	18	21

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Bureau of Reclamation #8 well (BR 8) 150-66-9bbd			
Terrace #2				
	Topsoil...........................	2	0	2
	Sand, coarse, gray, and gravel...	18	2	20
Pierre Shale				
	Shale, gray.......................	5	20	25
	Bureau of Reclamation #1 well (BR 1) 150-66-9bcd			
Outwash				
	Topsoil, sandy..................	2	0	2
	Sand, medium, brown, and gravel....................	17.9	2	19.9
Pierre Shale				
	Shale..........................	5.1	19.9	25
	Bureau of Reclamation #7 well (BR 7) 150-66-9bcb			
Outwash				
	Topsoil, sandy..................	2	0	2
	Sand, medium, brown, and gravel....................	24	2	26
Pierre Shale				
	Shale..........................	4	26	30
	Stai test #1 (S-1) 150-66-9bdb			
Terrace #2				
	Topsoil.........................	1	0	1
	Sand and very fine to fine gravel with sand..................	9	1	10
	Gravel with sand..............	5	10	15
Pierre Shale				
	Clay, gray.....................	5	15	20
	Rock ledge.....................	1	20	21
	Clay, gray, plastic............	8	21	29
	Clay with streaks of slate.....	4	29	33
	Clay, plastic..................	23	33	56
	Slate with clay streaks........	4	56	60
	Shale..........................	4	60	64
	Clay, gray.....................	2	64	66
	Shale..........................	9	66	75

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	Depth (feet) To
	Test Hole 12 150-66-9caa			
Terrace #2				
	Topsoil, sandy loam, black........	1	0	1
	Sand, fine to very coarse with fine gravel, sorted, rounded, oxidized......................	10	1	11
Pierre Shale				
	Shale, dark greenish gray, moderately soft to hard, tight, slightly plastic, noncalcareous; contains shaley and pyritic streaks......	10	11	21
	Bureau of Reclamation South Pasture well (BR SP) 150-66-9cbb			
Outwash				
	Sand and a little gravel, clean, dry..........................	15	0	15
	Sand and gravel, clean, wet.......	2	15	17
Pierre Shale				
	Shale..........................	2	17	19
	Stai test #4 (S-4) 150-66-9cda			
Till				
	Topsoil........................	1	0	1
	Clay, sandy, yellow, with cobble stones........................	10	1	11
	Clay, brown, with cobble stones...	2	11	13
	Clay, gray (till)................	6	13	19
Pierre Shale				
	Clay, gray, plastic..............	11	19	30
	Test Hole 15 150-66-9cdd			
Outwash				
	Topsoil, gravelly clay loam,brown.	1	0	1
	Silt, with very fine sand, yellowish gray to dusky yellow, soft, poorly consolidated.................	3	1	4
	Silt, moderate olive brown, soft, fairly cohesive, slightly plastic, calcareous, oxidized. Appears to be uniform with interbedded sandy and gravelly stringers..........	5	4	9

TABLE 4 -- Logs of Test Holes - Continued

Formation	Material	Thickness (feet)	Depth (feet) From	To
	Test Hole 15 150-66-9cdd (continued)			
	Silt, as above, olive gray, unoxidized..................	7	9	16
Pierre Shale				
	Clay, olive black to dark greenish gray, moderately soft, noncalcareous; contains shale fragments, "weathered shale"..	6	16	22
	Shale, dark greenish gray, moderately hard, noncalcareous, tight.......................	9	22	31
	Test Hole 14 150-66-9dba			
Terrace #2				
	Topsoil, sandy loam, black......	2	0	2
	Sand, clayey, yellowish gray....	2	2	4
	Gravel, fine to medium with medium to very coarse sand, rounded, sorted, oxidized.....	4	4	8
Pierre Shale				
	Shale, dark greenish gray, slightly hard, shaley partings, noncalcareous.....................	13	8	21

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