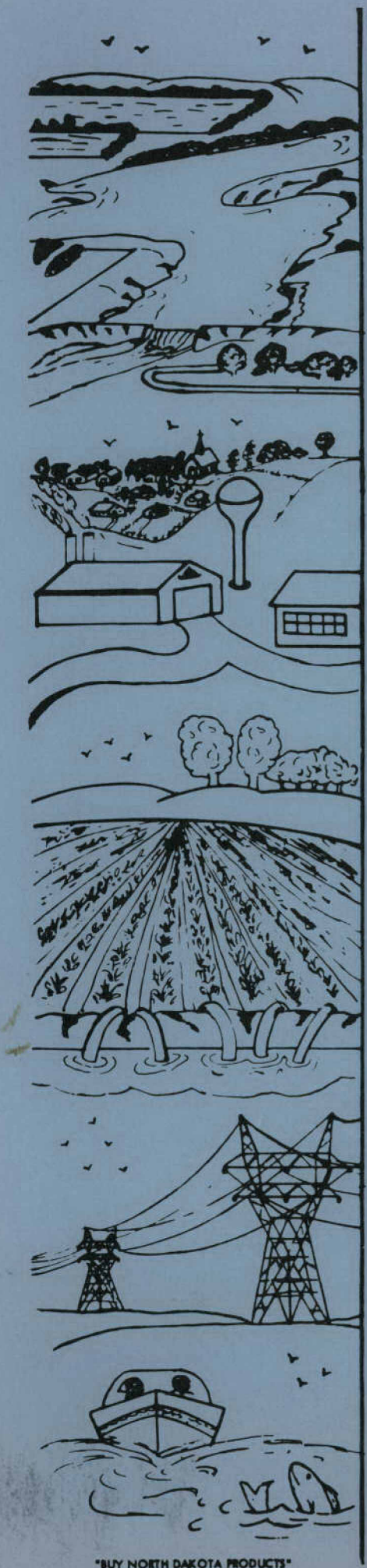

"BUY NORTH DAKOTA PRODUCTS"

Ground-Water Resources of the Ellendale Area Dickey County, North Dakota

North Dakota Ground-Water Studies
No. 75

By
Charles E. Naplin
Ground-Water Geologist

Published By
North Dakota State Water Commission
State Office Building
900 Boulevard
Bismarck, North Dakota 58501

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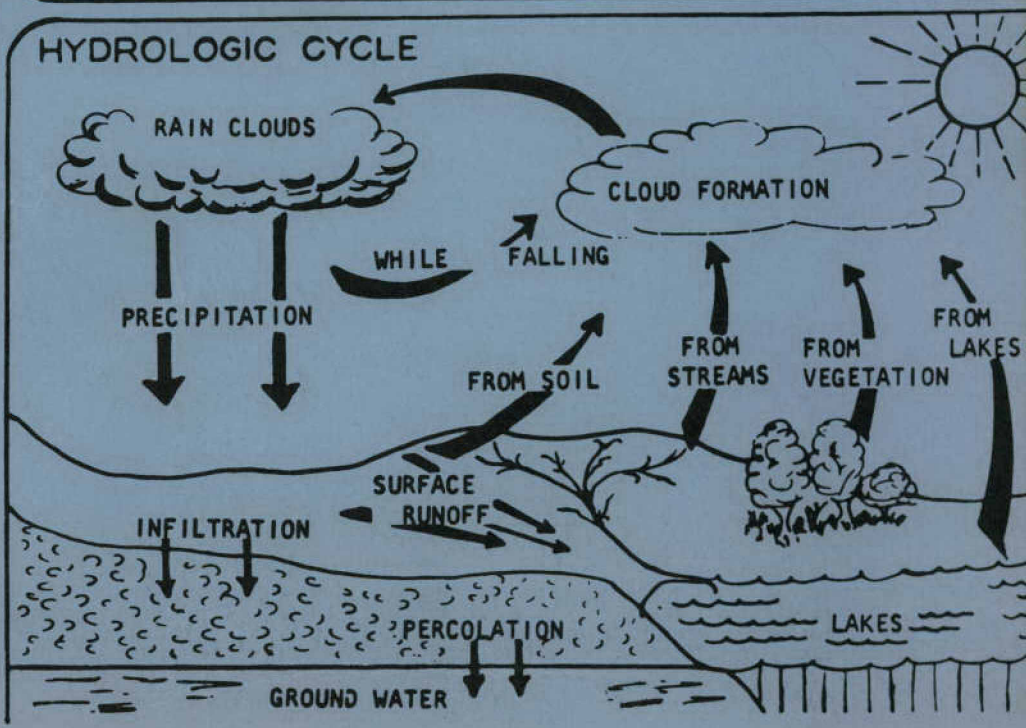

GROUND-WATER RESOURCES OF THE ELLENDALE AREA

DICKEY COUNTY, NORTH DAKOTA

SWC Project No. 750

By

Charles E. Naplin, Ground-Water Geologist
North Dakota State Water Commission

NORTH DAKOTA GROUND-WATER STUDIES NO. 75

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DICKEY COUNTY, NORTH DAKOTA

INTRODUCTION

PURPOSE AND SCOPE

In the spring of 1968 the Ellendale City Council requested the North Dakota State Water Commission conduct a ground-water survey for the city. As a result this study was undertaken to determine the potential of the existing municipal water supply (1968), and to further investigate ground-water availability in the Ellendale area.

Field work consisted of subsurface exploration by test drilling, collection of selected water samples for chemical analyses, the periodic measurement of water levels in observation wells, and an aquifer test. The drilling and associated field work were under direct supervision of the author. Lewis Knutson and Hugh Jacobson accomplished the test drilling using a hydraulic-rotary drilling machine. Chemical analyses were performed by Garvin Muri, State Water Commission chemist, at the North Dakota State Laboratories Department. The aquifer test was conducted under the supervision of R. W. Schmid, ground-water hydrologist, with assistance from Robert McAdoo. Special acknowledgement is extended to former Mayor Earl H. Redlin, Mayor Art Raymond, and city water plant manager, Mr. Art Schlenker, for information concerning city wells and water facilities.

LOCATION AND GENERAL FEATURES

The Ellendale area described in this report consists of 198 square miles including all or portions of Tps. 129 and 130 N., Rs. 61, 62 and 63 W. The study area is located in south-central Dickey County and is within the Central

Lowland physiographic province of North Dakota (fig. 1). Relief in the area is gently rolling with surface elevations ranging from 1,359 feet to 1,520 feet above sea level. The regional slope is toward the east.

The average annual temperature at Ellendale is 42.6° F. based on a 71-year period of record (U. S. Department of Commerce, 1969). The average annual precipitation for the same period of record is 19.11 inches.

Ellendale, (1970 population 1,517), is essentially an agricultural community. It is served by branch lines of the Burlington Northern Railroad. Motor transportation to the city is provided by State Highway 11 and U. S. Highway 281.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report, as illustrated in figure 2, is based upon the location of the well in the Federal system of rectangular surveys of public lands. The first number denotes the township north of the base line that passes laterally through the middle of Arkansas; the second number denotes the range west of the fifth principal meridian; 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 section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). Consecutive terminal numerals are added if more than one well is located in a 10-acre tract. Thus well 130-63-15daa is in the NE¼NE¼SE¼ sec. 15, T. 130 N., R. 63 W.

PRESENT WATER SUPPLY

The city of Ellendale derives its water supply from three wells (pl. 1). City well 1 (129-62-18bbb$_1$) was drilled in 1957 and is 30 feet deep. City

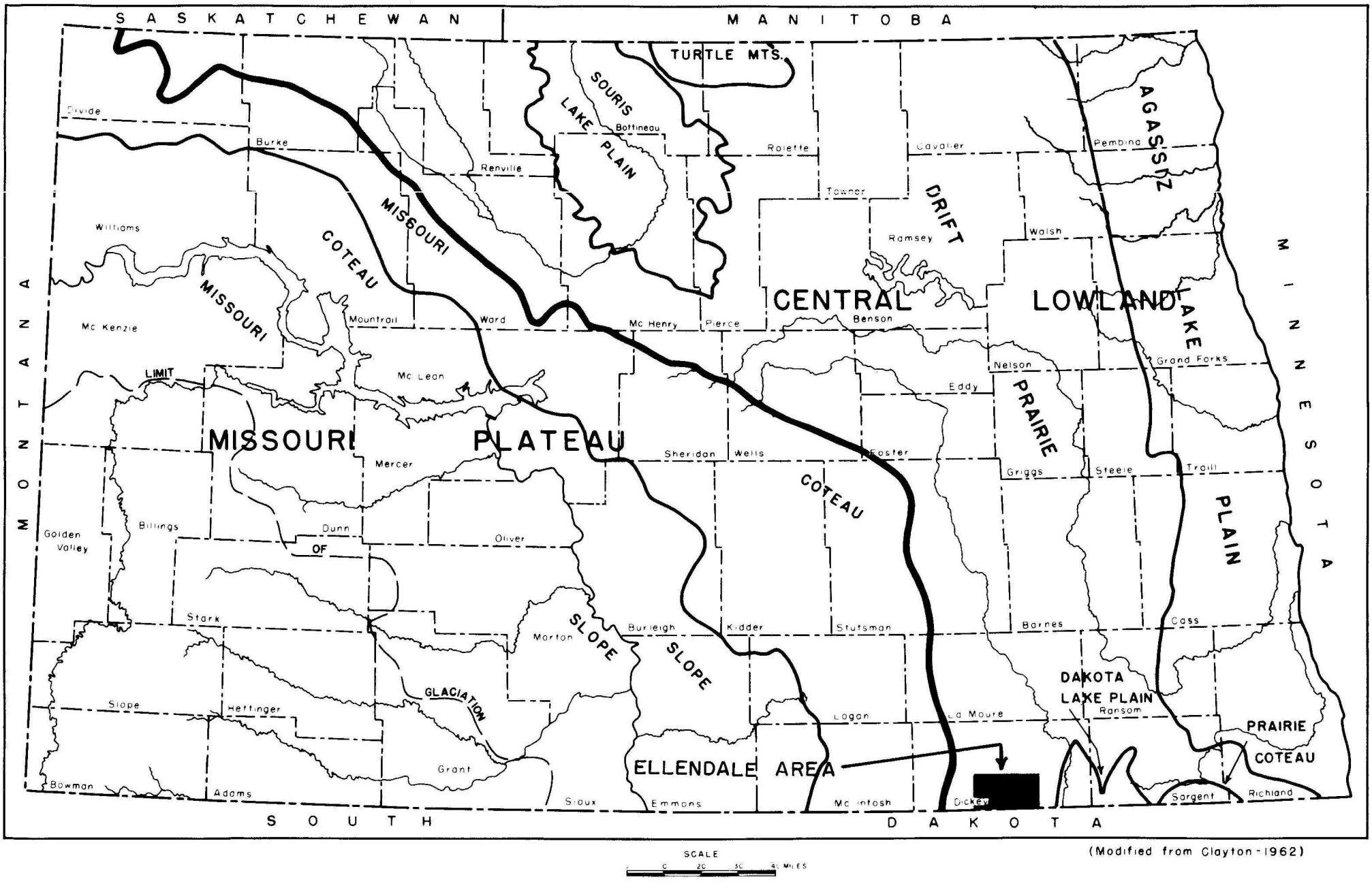


FIGURE I--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC PROVINCES AND LOCATION OF THE ELLENDALE AREA

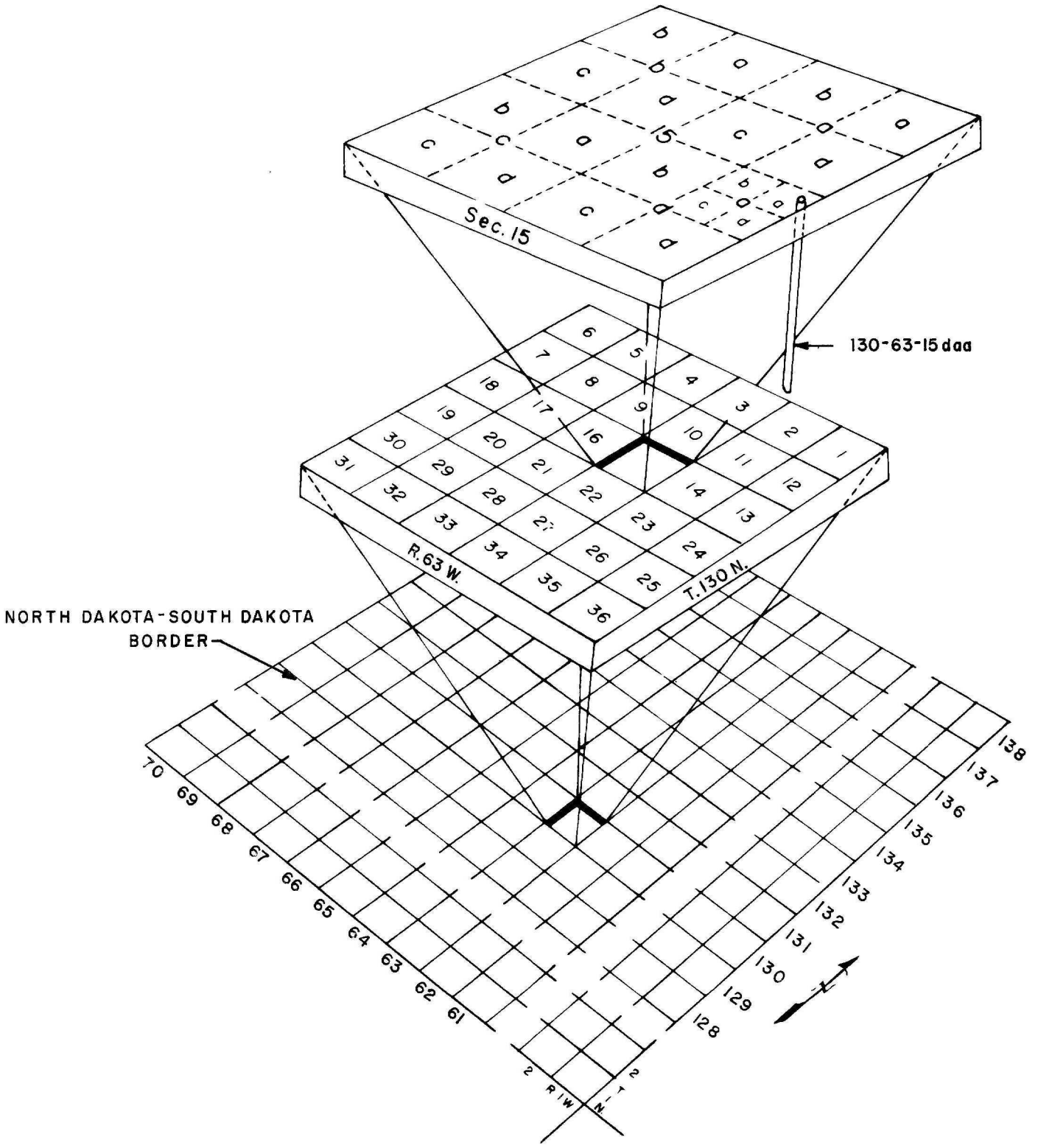


FIGURE 2--SYSTEM OF NUMBERING WELLS, TEST HOLES, AND SPRINGS

well 2 (129-62-18bbc) is 29 feet in depth and was drilled in 1959. Both wells are 12 inches in diameter and are completed in the lower 10 feet with V-slot well screen. Both are located in a discontinuous sand and gravel deposit on the east side of Dry Branch Creek. Water is chlorinated at the well sites and pumped to a treatment plant for removal of iron and manganese. City well 3 (129-63-12cba), completed in an aquifer of the Dakota artesian system, is 1,083 feet in depth and is located within the city limits. Ordinarily city well 3 is used only for emergencies. During the fall of 1970 city wells 1 and 2 were pumped at a combined rate of 100 gpm (gallons per minute) and this water was then mixed with water from city well 3, also being pumped at a rate of 100 gpm (Art Schlenker, oral communication, 1970).

Average annual water consumption in 1964 was about 123,000 gpd (gallons per day), but during certain times of the year consumption would be as high as 200,000 gpd (Lindvig, 1965). Using 123,000 gpd as the average daily consumption, this would approximate 140 acre-feet per year. However, the city is now using more water and daily consumption is probably 160,000 gpd, and may exceed 300,000 gpd during periods in the summer months when demand is great (Art Schlenker, oral communication, 1970). At 160,000 gpd the average annual consumption is about 180 acre-feet per year.

Because of low water levels in city wells 1 and 2 in 1959, a clay core was constructed across Dry Branch Creek in the southern part of sec. 24, T. 129 N., R. 63 W. (pl. 1). The purpose of the clay core was to prevent the downstream movement of ground water and, thereby, cause the water table along Dry Branch Creek to rise. A rise in the water table did not occur, and in 1961 a dam was completed on top of the clay core in order to establish a reservoir. With a spillway elevation of 1,412 feet the reservoir

has a storage capacity of 246 acre-feet. The clay core and dam were financed jointly by the North Dakota State Water Commission and the city of Ellendale.

PREVIOUS INVESTIGATIONS

An unpublished ground-water survey for the city was conducted by the North Dakota State Water Commission in cooperation with the U. S. Geological Survey in 1957. The investigation consisted of test drilling, installation of observation wells, collection of water samples, and a pumping test conducted on a well located in the vicinity of city well 1. The North Dakota State Water Commission conducted an additional ground-water investigation of the Ellendale area under the supervision of Milton O. Lindvig (1965).

GEOLOGY AND GROUND-WATER CONDITIONS

The occurrence of ground water in any area is directly related to the physical structure of underlying rocks. In the Ellendale area more than a thousand feet of sedimentary rocks underlie the mantle of glacial drift. These rocks consist of limestone, sandstone, and shale (table 1). Shale is the predominant bedrock lithology.

BEDROCK

Test drilling during this investigation encountered the Pierre Formation below the glacial drift in about the western half of the study area, while the Niobrara Formation was found to underlie the remainder (fig's. 3, 4, and 5).

Table 1 -- STRATIGRAPHIC COLUMN OF THE ELLENDALE AREA

Millions of Years Ago	Era	System	Group	Formation	Lithology
Present	Cenozoic	Quaternary		Glacial Drift	Boulder clay (till), sand and gravel, cobbles, boulders
2-3		Tertiary			
70	Mesozoic	Cretaceous	Montana	Pierre	Shale
			Colorado	Niobrara	Calcareous shale
				Carlile	Shale
				Greenhorn	Calareous shale, limestone
				Belle Fourche	Shale, bentonite
			Dakota	Mowry	Shale, bentonite
				Newcastle	Sandstone
				Skull Creek	Shale
135				Fall River-Lakota	Sandstone, shale
	Paleozoic	Ordovician	Big Horn	Red River	Limestone, dolomite
			Winnipeg	Roughlock ?	Sandstone
				Icebox ?	Shale
500				Black Island	Sandstone
	Cryptozoic	Precambrian			Igneous and metamorphic crystalline rocks
5000					

(Revised from Strassberg, 1954)

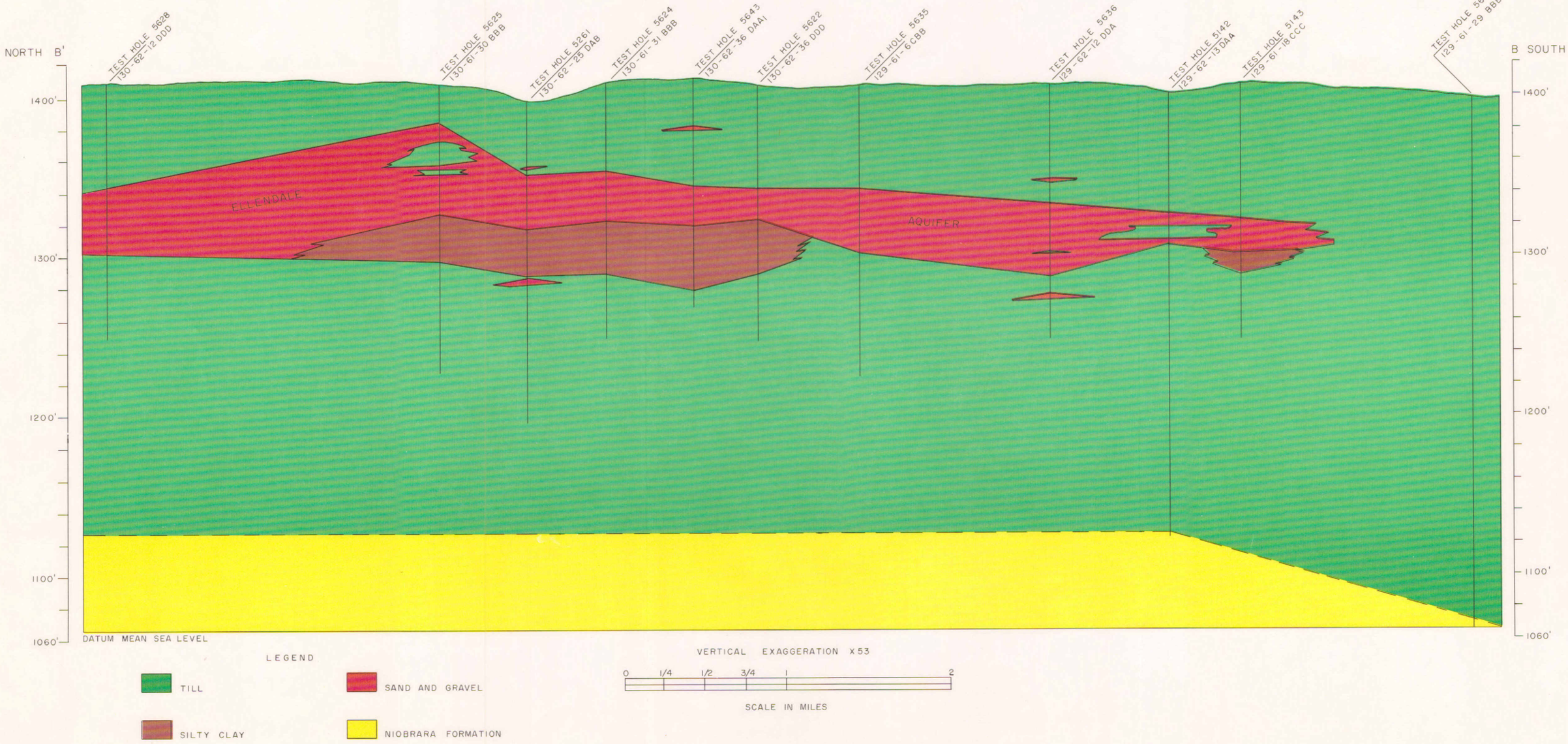


FIGURE 4 -- GEOLOGIC CROSS SECTION B-B'

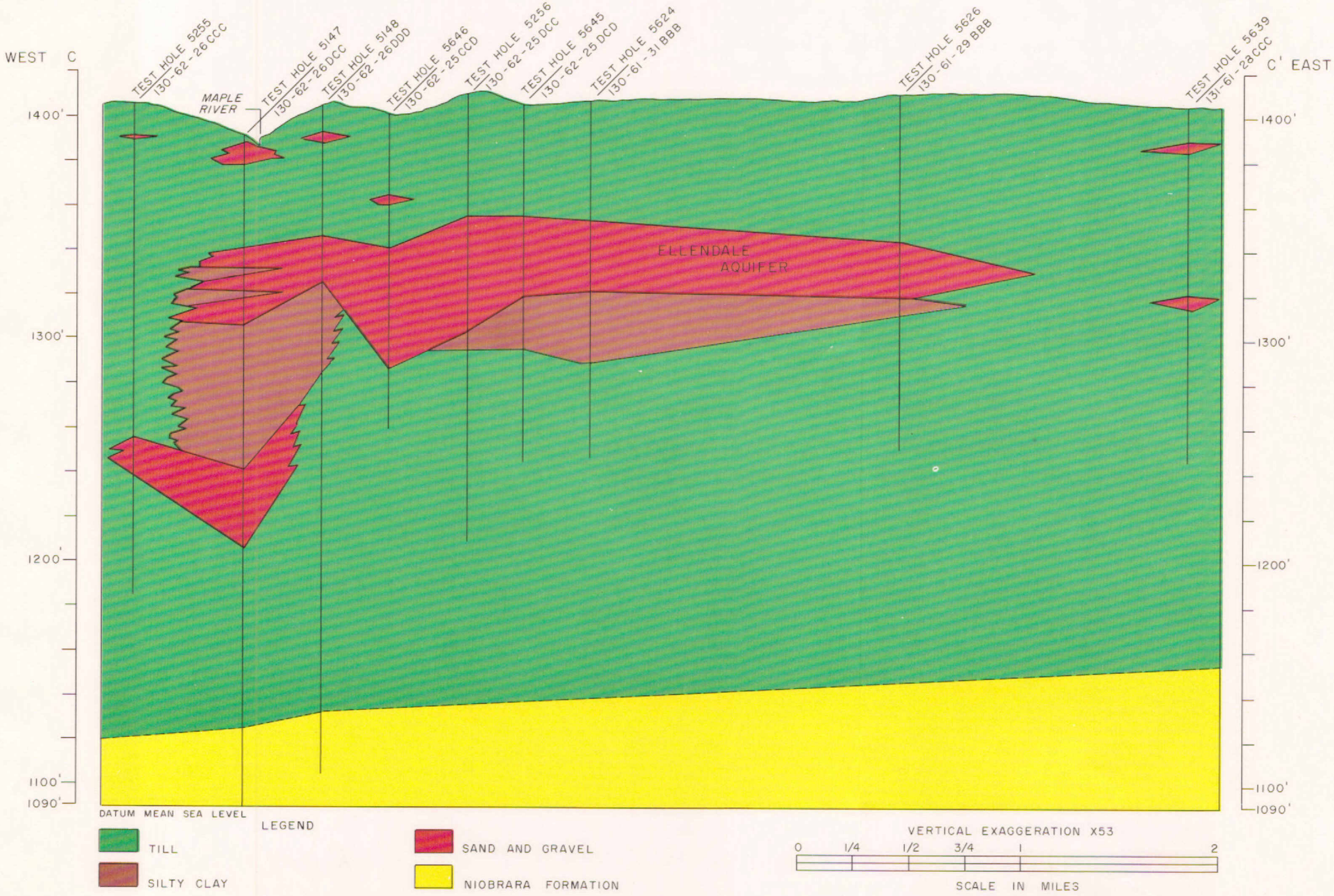


FIGURE 5-- GEOLOGIC CROSS SECTION C-C'

Drill cuttings of the Pierre Formation indicated a hard medium-dark-gray to grayish-black, noncalcareous shale. Samples of the Niobrara Formation show a moderately hard, grayish-brown, slightly calcareous to calcareous shale containing numerous small white specks. Shale of either formation is considered relatively impermeable and will not readily yield water to wells. However, in some areas the Pierre Formation may be fractured to a depth of several feet in its upper horizon and will yield small quantities of water to large-diameter wells. In the Pheasant Lake area seven miles west of Ellendale, for instance, there are several wells completed in the Pierre Formation.

The Pierre Formation was encountered at elevations ranging from 1,291 feet above mean sea level in test hole 5117 (129-62-8ddd) to 1,452 feet in test hole 5114 (130-63-32aaa). Mean sea level elevations to the top of the Niobrara Formation ranged from 1,055 feet in test hole 5140 (129-62-22aab) to 1,181 feet in test hole 5630 (130-62-15bbb).

Formations of the Colorado and Dakota Groups, all of Cretaceous age, underlie the Niobrara (table 1). The Colorado Group consists primarily of relatively impermeable shales, whereas, the Dakota Group is comprised of several permeable sandstones that are capable of yielding water to wells. Several formations of Ordovician age underlie the Cretaceous system in this area. Formations of the Big Horn and Winnipeg Groups consist of sandstone, limestone, dolomite, and shale. The more permeable sandstones and limestones will yield water to wells. However, all permeable formations of the Cretaceous and Ordovician systems commonly contain waters that are highly mineralized.

GLACIAL DRIFT

Glacial drift refers to stratified or unstratified material deposited directly or indirectly by glacial action. The surface of the glacial drift in the Ellendale area is ground moraine, which is a landform of low relief and gently undulating topography. It is entrenched in places by Maple River, Dry Branch and Sewer Branch Creeks, and their intermittent tributaries.

Till and associated sand and gravel deposits

Most glacial drift in the Ellendale area is composed of till. Till is an unconsolidated, unstratified, heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders. Glacial deposition of these materials occurred with little or no transportation by water. Till is colloquially termed "blue clay" when it is encountered below the water table. When it occurs above the water table it becomes weathered by the processes of leaching and oxidation and is commonly referred to as "yellow clay." Till in the Ellendale area ranges in thickness from 32 feet in test hole 5114 (130-63-32aaa) to 329 feet in test hole 5642 (129-61-29bbb).

Clay and silt, the two predominant constituents of till, are extremely fine grained, relatively impermeable, and will not readily yield water to wells. Numerous thin lenses of sand and gravel commonly are associated with till, however. These lenses characteristically are local in areal extent and yield small quantities of water to wells.

Outwash

Sand and gravel deposited by melt water streams beyond active glacial ice is termed outwash. Deposits of this type occur along Sewer Branch and Dry Branch Creeks and the Maple River.

Test drilling suggests the surficial outwash deposits along Dry Branch Creek are not continuous (fig. 6). The sand and gravel deposit in which city wells 1 and 2 are completed varies considerably in thickness and extends over an area of approximately 26 acres. Known thicknesses of sand and gravel range from 10 feet in test hole 5173 ($129\text{-}62\text{-}18bbb_3$) to 24 feet in test hole 5172 ($129\text{-}62\text{-}18bbb_4$), but as much as 26 feet of gravel was reported at city well 1 ($129\text{-}62\text{-}18bbb_1$).

Subsurface data indicate a buried outwash deposit exists east of the Maple River in the Ellendale area. Test drilling indicates it extends over an area of about 17 square miles in portions of Tps. 129 and 130 N., Rs. 61 and 62 W. (fig. 7). However, the deposit probably extends over a much larger area than indicated in this report. Figures 3, 4, and 5 illustrate the buried outwash stratigraphically in cross section.

Sand and gravel encountered during test drilling ranges in thickness from 5 feet in test hole 5630 (130-62-15bbb) to 58 feet in test hole 5637 (129-61-17bbb). Test hole 5147 (130-62-26dcc) penetrated several small intervals of sand and a thick sequence of silty and sandy clay before gravel was encountered.

The grain size of water-bearing materials ranges from silt to very coarse-grained sand to coarse sandy gravel. Grain-size distribution varies considerably from one location to another but generally materials become more fine grained toward the flanks of the deposit. Materials are moderately to well sorted and the degree of roundness of individual grains ranges from angular to rounded.

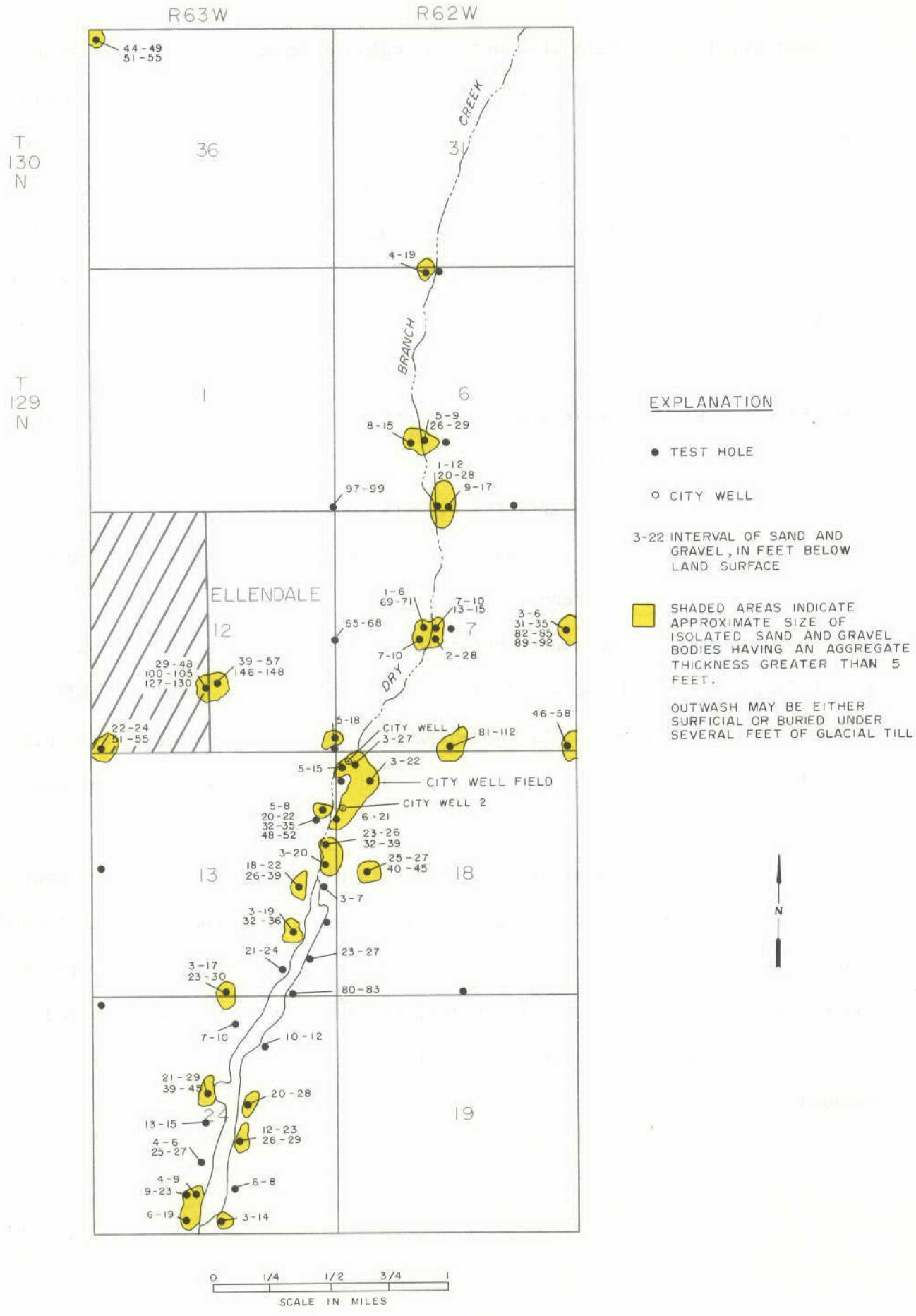


FIGURE 6-- OUTWASH DEPOSITS ALONG DRY BRANCH CREEK

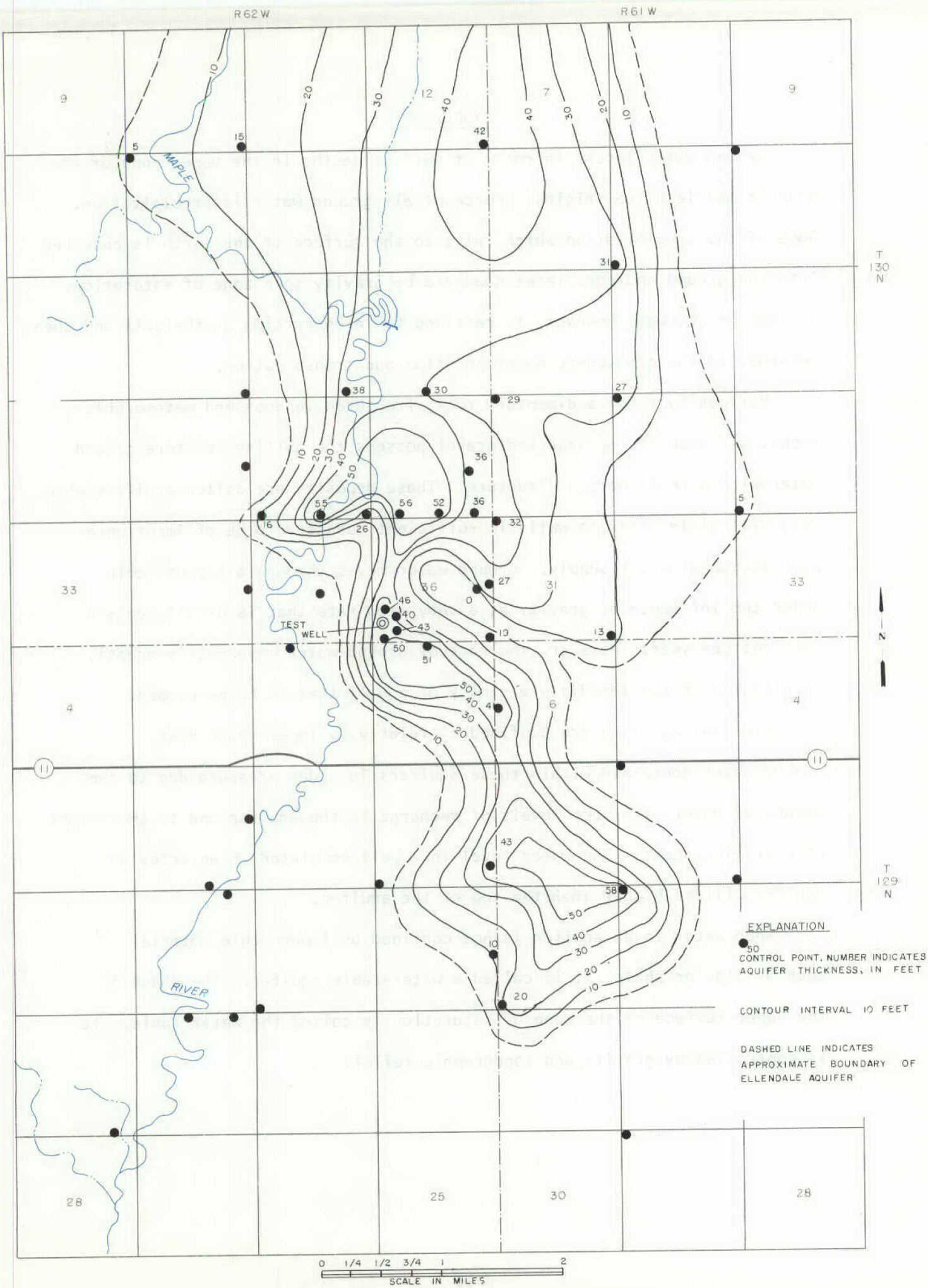


FIGURE 7--LOCATION AND THICKNESS OF ELLENDALE AQUIFER

HYDROLOGY

Ground water occurs in rocks at various depths in the upper zone of the earth's mantle. The original source of all ground water is precipitation. Some of the precipitation which falls to the surface of the earth is absorbed into the ground and percolates downward by gravity to a zone of saturation. A large percentage, however, is retained for a short time by the soil and then returned to the atmosphere by evaporation and transpiration.

Various types of sedimentary rock, fractured igneous and metamorphic rocks, and deposits of sand and gravel possess the ability to store ground water within their porous structure. These deposits are called aquifers when they will yield water to wells in sufficient quantity to be of importance as a source of water supply. Ground water moves through a porous media under the influence of gravity at a very slow rate that is usually only a few feet per year. However, the rate of ground-water movement is greatly accelerated in the immediate vicinity of a well that is being pumped.

Artesian aquifers are confined by relatively impermeable beds. Ground water contained within these aquifers is under pressure due to the weight of water at higher levels of recharge in the aquifer and to the weight of overlying rocks. The water level in a well completed in an artesian aquifer will be higher than the top of the aquifer.

When water in an aquifer is not confined by impermeable material such as clay or shale, it is called a water-table aquifer. The shape of the upper surface of the zone of saturation is called the water table. It is controlled by gravity and topographic relief.

Water enters an aquifer (recharge) by the direct absorption of precipitation. Water leaves an aquifer (discharge) by evaporation from soils, lakes, ponds, and streams, by seepage to streams, and by springs. Discharge also occurs through transpiration of plants and by the pumping of wells. Fluctuation in water levels corresponds to recharging or discharging conditions. A rise in the water level of a well indicates the rate of recharge is greater than the rate of discharge. Consequently, a decline in water level suggests that the rate of discharge exceeds the rate of recharge.

DAKOTA ARTESIAN SYSTEM

In the Ellendale area sandstone formations of the Dakota Group comprise an artesian aquifer system that provides a source of water to many farm wells and city well 3. Ground water contained in the Dakota Group aquifers is under considerable hydrostatic pressure. In many cases the pressure is high enough to lift a column of water in a well above the land surface resulting in a flowing well. In 1908 a well was drilled to a depth of 1,363 feet for the city of Ellendale and reportedly flowed at a rate of 800 gpm. A gage pressure of about 196 psi (pounds per square inch) was registered at land surface (Simpson, 1929). Theoretically this artesian pressure was of sufficient magnitude to lift a column of water about 452 feet above land surface. Over a period of many years the original artesian head in this area has been largely depleted. Wells no longer flow at their original rate and several have ceased to flow.

DRY BRANCH OUTWASH DEPOSIT

The outwash deposits located along Dry Branch Creek are discontinuous and, therefore, are not hydraulically connected (fig. 6). Test drilling indicates that the deposit of sand and gravel in which city wells 1 and 2 are completed occupies an area of about 26 acres, but does not extend under the creekbed. Therefore, recharge to this deposit occurs only from direct precipitation

on the aquifer and when the level of Dry Branch Creek is high enough for water to enter the outwash body. Periods of recharge are irregular and occur primarily during the annual spring thaw and sporadically throughout the summer months from heavy rainfall. The median annual runoff over the 28-square-mile drainage area of Dry Branch Creek is approximately 10 acre-feet per square mile (Glover, 1964). Recharge to the Dry Branch outwash is but a small percentage of the average median runoff of 280 acre-feet because much water is lost to evaporation, seepage, transpiration, and low flows.

Figure 9 shows a typical yearly fluctuation in the water table of the Dry Branch outwash in which the city well field is located. From late March to early May the rate of recharge exceeds the rate of discharge and the water table rises. However, as soon as the period of spring runoff is over the water table begins a continuous decline, with the lowest level occurring in March prior to the spring thaw. Even during periods of moderate to heavy precipitation in the months of May, June and July, water levels indicate the removal of water by pumping exceeds the influx of water by precipitation and runoff.

The volume of available ground water in the Dry Branch sand and gravel deposit can be calculated by multiplying the 26 acres of areal extent times a 20-foot average saturated thickness times the average specific yield estimated to be 0.06 ($26 \times 20 \times 0.06 = 31.2$ acre-feet). It should be emphasized that 31.2 acre-feet is only an average figure and is subject to wide variation depending upon the amount of seasonal precipitation and the degree and duration of pumping. The annual water requirement for Ellendale in 1971 is estimated at 180 acre-feet, therefore, the Dry Branch outwash is not capable of providing enough water to the city without continuous recharge.

The numerous small outwash deposits shown in figure 6 all have a very limited ground-water storage capacity. Therefore, only small yields can be expected from the Dry Branch outwash deposits. An individual outwash body would only yield a sufficient quantity of water to domestic or stock wells.

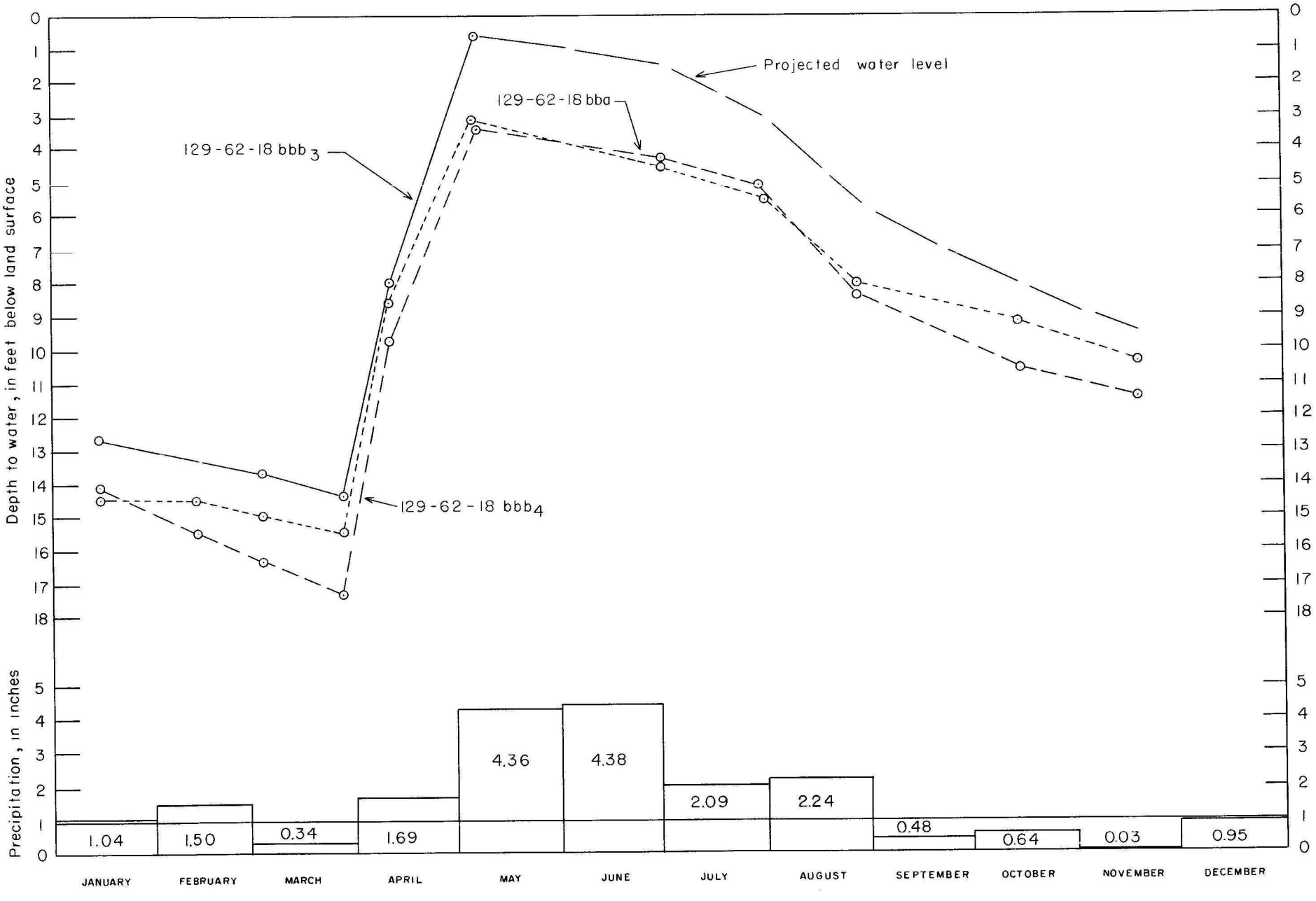


FIGURE 8 -- WATER-LEVEL FLUCTUATIONS IN DRY BRANCH OUTWASH DEPOSIT AND PRECIPITATION AT ELLENDALE DURING 1969

ELLENDALE AQUIFER

The buried outwash deposit east of the Maple River is here named the Ellendale aquifer. Figure 7 shows the thickness and areal extent of the Ellendale aquifer as defined by test drilling. Ground water contained in the aquifer is under artesian pressure.

Water-level elevations in the Ellendale aquifer range from about 1,395 to 1,397 feet above mean sea level. Flows can be expected at elevations below 1,395 feet mean sea level. Test hole 5147 (130-62-26dcc) was originally completed as an observation well and flowed at a rate of approximately 30 gpm at an elevation of 1,390 feet mean sea level. The well was plugged and abandoned after a water sample had been recovered.

Figure 9 indicates very little annual fluctuation in water levels throughout the aquifer. A small increase in water level occurs in late spring and early summer indicating the aquifer is receiving some recharge through the surrounding till and probably from deposits outside the study area. This hydrograph suggests that the aquifer acheives a state of hydrologic equillibrium in fall and winter months when recharge is about equal to discharge. It also indicates the aquifer extends over a relatively large area and is not readily affected by periods of below normal precipitation.

An aquifer test was conducted during July 1970 using an 8-inch-diameter well located 6 miles east and 1 mile north of Ellendale ($130\text{-}62\text{-}36ccb_3$). The well was completed from 59 to 99 feet below land surface with a 6-inch-diameter, 0.012-inch V-slot well screen. The test was started July 23 and a pumping rate of 310 gpm was maintained for 5 days. Water levels were measured in 23 observation wells and the test well. Drawdown ranged from 0.03 foot in observation well 5629 (130-62-10ddd) to 44.38 feet in the test well ($130\text{-}62\text{-}36ccb_3$).

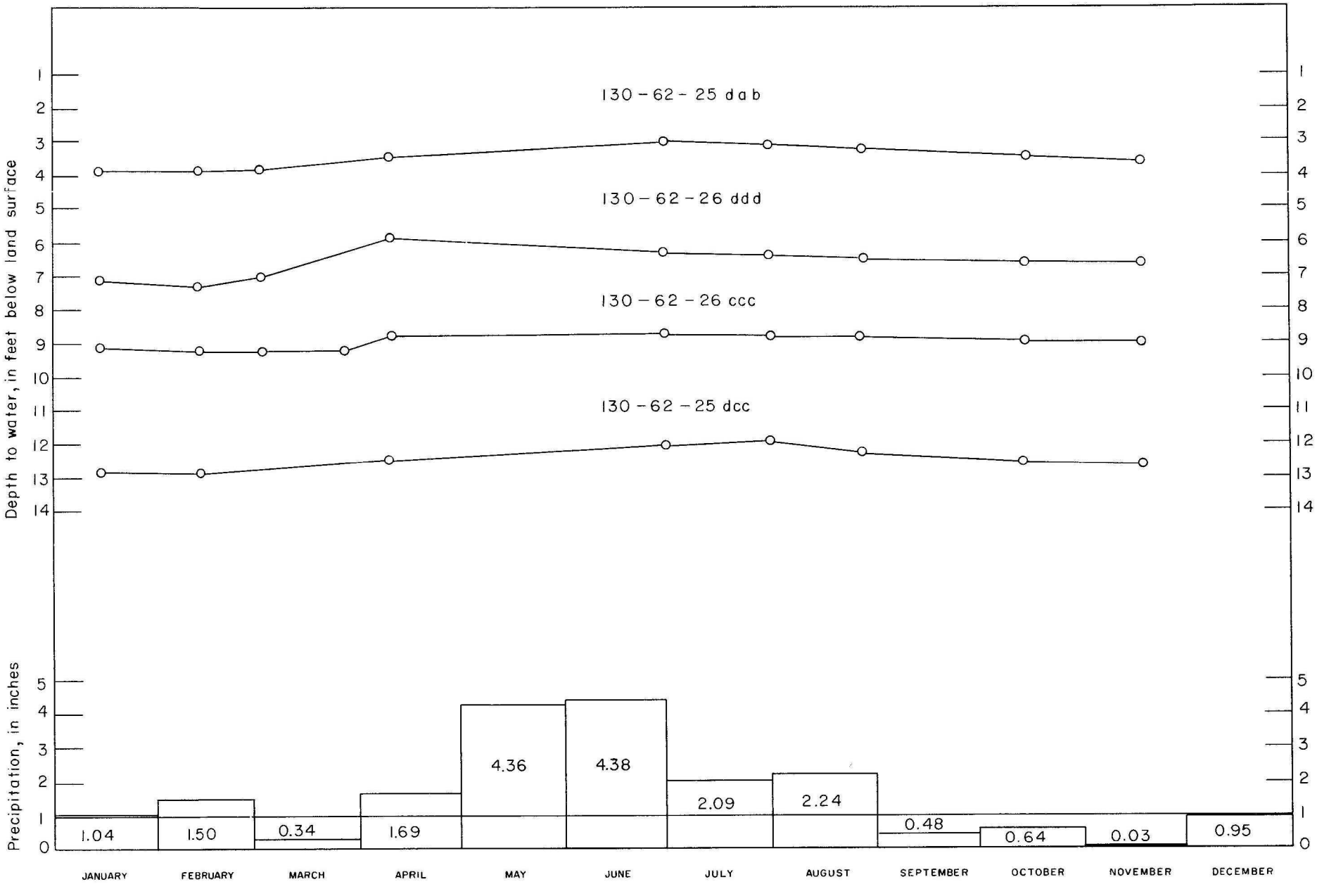


FIGURE 9 -- WATER-LEVEL FLUCTUATIONS IN ELLENDALE AQUIFER AND PRECIPITATION AT ELLENDALE FOR 1969

Figure 10 shows static water-level conditions in the aquifer before pumping was started. Water-level decline monitored in observation wells after 5 days of pumping are shown in figure 11. Ground-water movement was toward the test well site and occurred as the hydraulic pressure was reduced in the aquifer by pumping the test well. Figure 12 graphically illustrates drawdown and recovery for selected observation wells versus time.

Interpretation of aquifer-test data indicates a coefficient of transmissibility of 25,000 gpd/ft. (gallons per day per foot of aquifer width under a hydraulic gradient of 100 percent). A coefficient of storage of 0.0004 can be expected for an average section of aquifer.

The specific capacity of a well, discharge divided by the drawdown, is controlled by hydrologic characteristics of the aquifer and well construction, but is primarily determined by grain size and the permeability of aquifer materials. The specific capacity of the test well was determined to be 6.98 gpm/foot of drawdown. The production well was completed in predominantly fine-to medium-grained sand that contained a large percentage of silty clay. Clay lenses and interstitial clay in aquifer bodies reduce premeability and will adversely affect the specific capacity of a well.

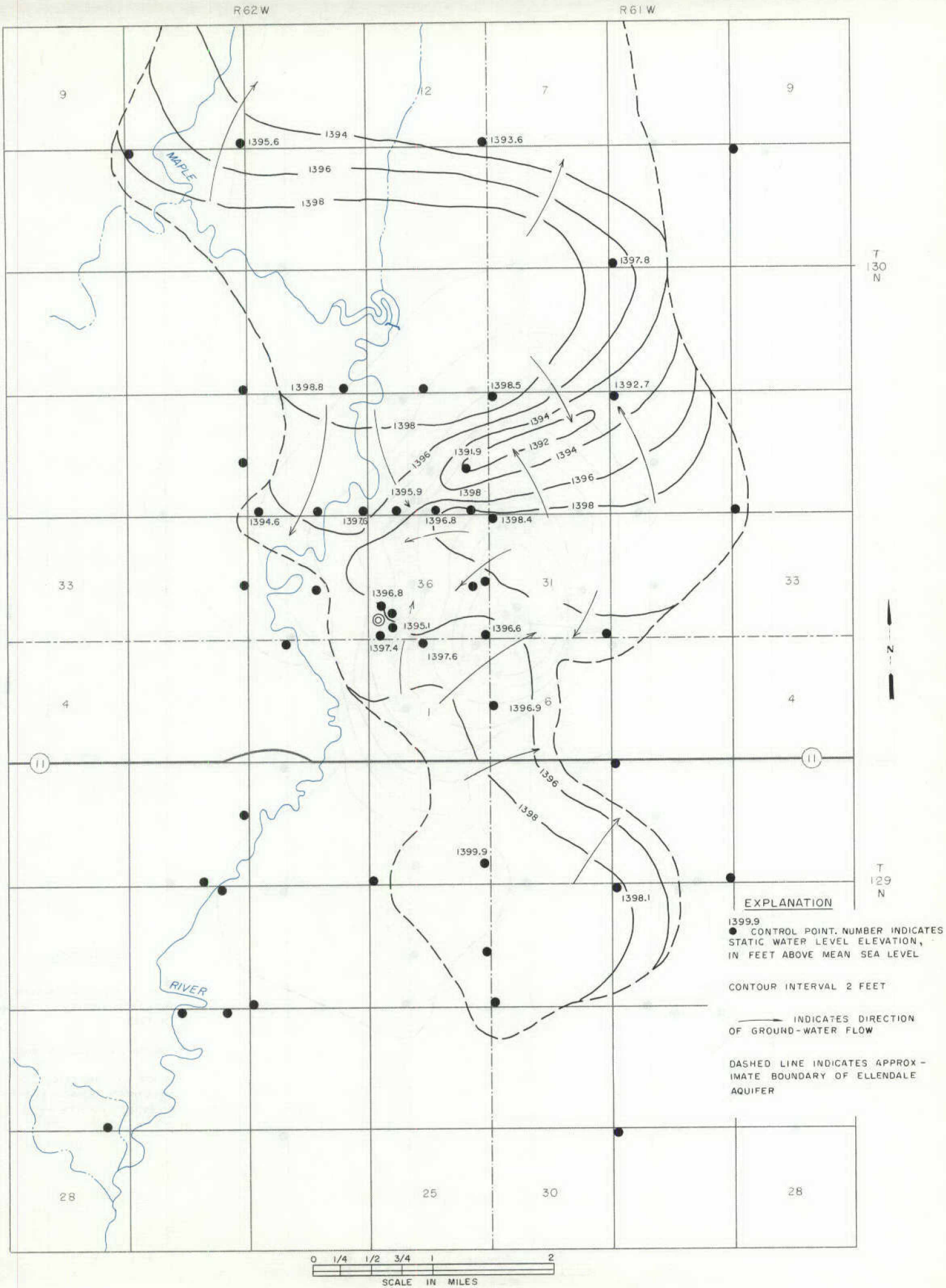


FIGURE 10-- WATER LEVELS IN ELLENDALE AQUIFER JULY 1970

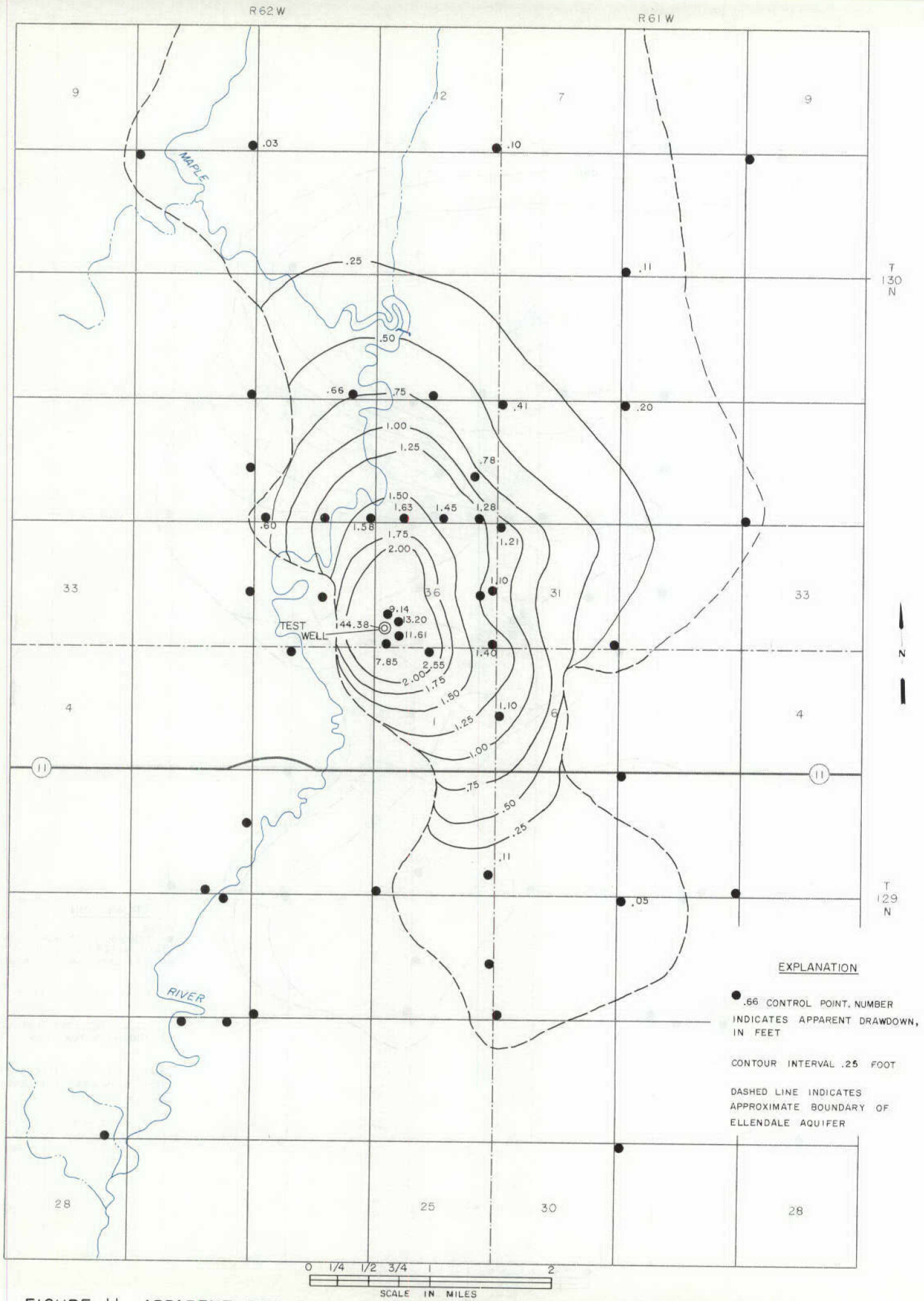


FIGURE 11--APPARENT DRAWDOWN AFTER 5 DAYS PUMPING OF TEST WELL AT 310 G.P.M.

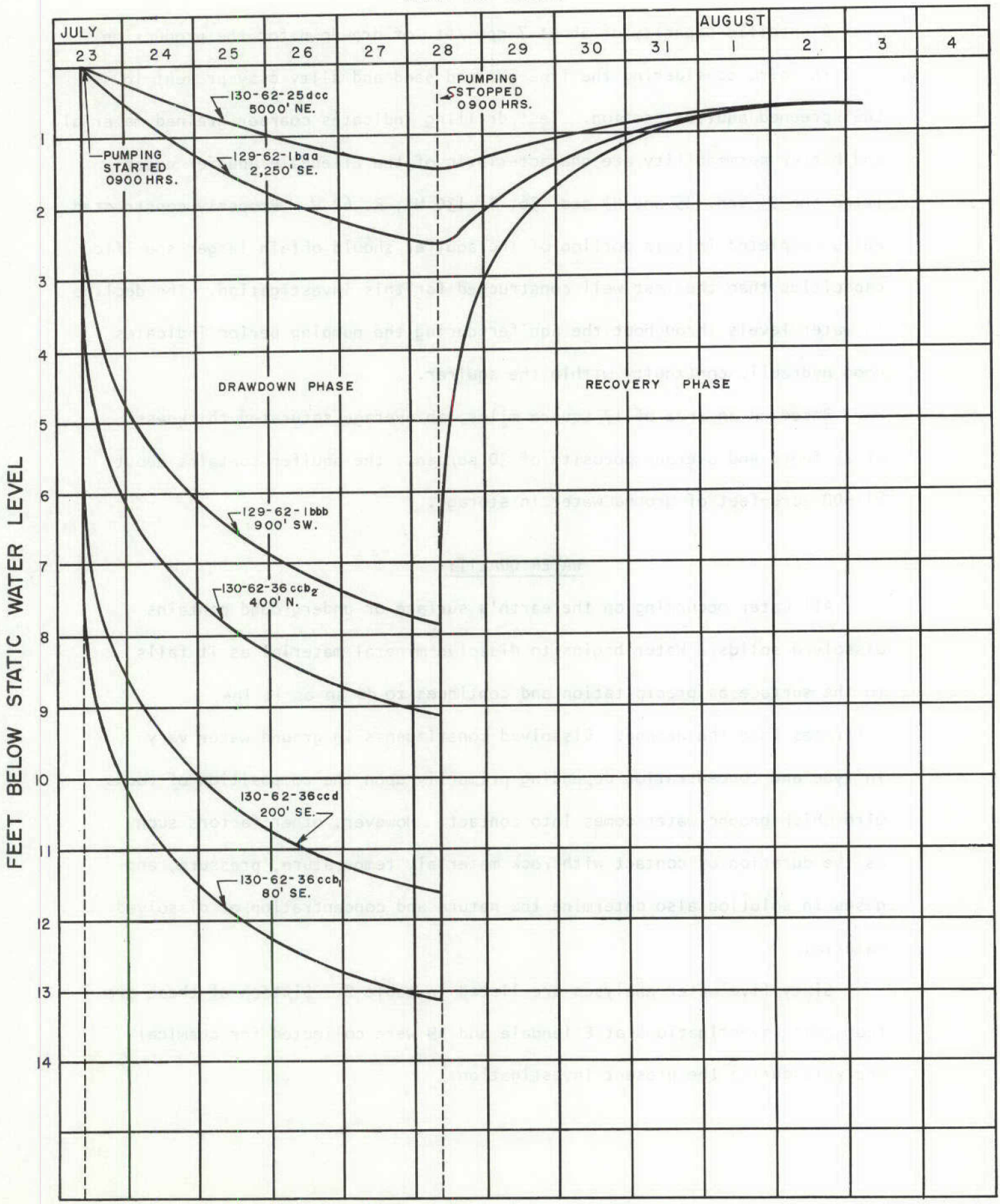


FIGURE 12--DRAWDOWN AND RECOVERY OF SELECTED OBSERVATION WELLS

A specific capacity of about 7 gpm./ft. of drawdown for the production well is fair, considering the fine-grained sand and silty clay present in the screened aquifer section. Test drilling indicates coarser grained material and better permeability are characteristic of the Ellendale aquifer underlying the S½ sec. 25 and N½ sec. 36, T. 130 N., R. 62 W. Properly constructed wells completed in this portion of the aquifer should obtain larger specific capacities than the test well constructed for this investigation. The decline in water levels throughout the aquifer during the pumping period indicates good hydraulic continuity within the aquifer.

Based on an area of 17 square miles, an average saturated thickness of 25 feet, and average porosity of 30 percent, the aquifer contains about 81,600 acre-feet of ground water in storage.

WATER QUALITY

All water occurring on the earth's surface or underground contains dissolved solids. Water begins to dissolve mineral material as it falls to the surface as precipitation and continues to do so as it infiltrates into the ground. Dissolved constituents in ground water vary in type and concentration depending primarily upon the composition of rocks with which ground water comes into contact. However, other factors such as the duration of contact with rock material, temperature, pressure, and gases in solution also determine the nature and concentration of dissolved material.

Sixty-five water analyses are listed in table 2. Sixteen of these are from past investigations at Ellendale and 49 were collected for chemical analysis during the present investigation.

TABLE 2—CHEMICAL ANALYSES

(Analytical results in parts per million except as indicated)

AQUIFERS Owner or Designation	Location	Depth of Well (feet)	Temp(°F)	Date of Collection	(SiO_2)	(Fe)	(Mn)	(Ca)	(Mg)	(Na)	(K)	(HCO_3)	(CO_3)	(SO_4)	(Cl)	(F)	(NO_3)	(B)	Total Dissolved Solids	Total Hardness as $CaCO_3$	Total Hardness Noncarbonate	Percent Sodium	SAR	Specific Conductance	pH
ORDOVICIAN ROCKS																									
Black Island Formation	129-63 14 bad	1738	—	2-11-64	—	0.90	—	92	24	1254		195	0.0	1850	685	1.9	0.0	—	3730	330	170	—	—	5500	8.0
DAKOTA ARTESIAN SYSTEM																									
City Well 3 *	129-63 12 cba	1083	—	—	28	0.50	—	29	9.8	993		591	—	435	939	3.2	6.2	—	2777	114	—	—	—	—	—
TILL-ASSOCIATED DEPOSITS																									
Test Hole 750-3	129-62 7 cdd	83	—	5-27-64	18	0.20	—	96	40	427	14	556	0.0	581	197	0.9	30	0.90	1770	405	—	61	9.2	2600	8.1
——	19 aab	118	—	5-15-64	22	4.60	—	71	24	646	16	843	0.0	456	375	0.7	2.0	0.73	2220	275	—	83	17	3090	7.9
——	129-63 12 ccg	34	—	5-28-64	22	0.24	—	374	114	248	18	432	0.0	1030	387	0.8	2.0	0.00	2720	1410	1050	27	2.9	3240	7.8
Test Hole 750-1	12 dbc	44	—	5-28-64	21	0.26	—	176	68	554	17	563	0.0	1300	84	1.0	40	0.50	2760	720	259	62	8.8	3480	8.1
Ruben Meidinger	34 baa	48	—	8-28-68	21	0.20	0.81	1020	499	665	47	739	0.0	2110	230	0.5	444	0.73	7670	4600	3990	24	4.3	10100	7.5
DRY BRANCH OUTWASH																									
——	129-62 7 abb	14	—	2-11-64	18	0.44	—	178	94	152	7.8	439	0.0	677	100	0.5	1.0	0.95	1520	830	470	28	2.3	2030	8.1
——	7 bcd	40	—	2-11-64	18	0.17	—	141	70	41	7.0	244	0.0	267	122	0.4	1.14	0.00	940	640	440	12	0.7	1480	8.0
——	7 cab	40	—	2-11-64	21	0.26	—	109	86	92	4.0	386	0.0	380	92	0.6	4.0	0.83	1030	625	309	31	1.6	1520	8.1
Test Hole 1177	$7ccc_2$	18	—	7-22-57	—	1.30	—	—	—	—	—	—	—	267	96	—	—	—	948	495	—	—	—	—	7.7
Test Hole 1176	7 dbb	28	—	7-11-57	—	0.70	—	—	—	—	—	—	—	244	96	—	—	—	945	500	—	—	—	—	7.9
City Well 1 *	$18bbb_1$	30	—	10-16-59	—	1.70	—	160	77	200		580	0.0	550	75	Trace	0.0	—	1643	716	—	—	—	—	7.2
City Well 1 *	$18bbb_1$	30	—	'62 or 63	—	4.10	—	298	91	134		476	0.0	850	112	0.2	0.0	—	1961	1120	—	—	—	—	7.0
City Well 1	$18bbb_1$	30	48	5-7-68	20	2.20	0.97	174	59	108	11	355	0.0	526	69	0.3	1.0	0.15	1250	679	388	25	1.8	1580	7.8
City Well 1	$18bbb_1$	30	48	9-5-68	19	4.00	1.90	204	64	134	12	412	0.0	621	94	0.2	0.0	0.24	1440	775	437	27	2.1	1890	7.6
City Well 1	$18bbb_1$	30	47	12-10-68	23	2.60	1.40	216	79	125	12	414	0.0	610	101	0.2	0.0	0.19	1440	863	523	24	1.9	1880	7.5
City Well 1	$18bbb_1$	30	45	2-13-69	23	6.60	1.70	232	75	128	12	400	0.0	635	126	0.1	2.5	0.23	1440	890	562	24	1.9	1970	7.5
City Well 1	$18bbb_1$	30	46	3-5-69	24	4.90	—	224	68	124	11	395	0.0	616	116	0.1	2.5	0.19	1430	841	—	24	—	1890	7.5
City Well 1	$18bbb_1$	30	46	4-10-69	21	4.20	1.80	278	91	129	12	416	0.0	810	109	0.1	1.6	0.30	1730	1070	729	21	1.7	2170	7.7
City Well 1	$18bbb_1$	30	58	7-1-69	21	0.58	1.20	186	55	114	12	433	0.0	501	73	0.1	1.0	0.07	1200	691	336	26	1.9	1640	7.8
City Well 2 *	18 bbc	29	—	'62 or '63	—	5.00	—	286	103	148		488	0.0	850	152	0.3	0.0	—	2027	1140	—	—	—	—	7.3
City Well 2	18 bbc	29	—	1-18-65	16	6.60	—	326	108	188	15	464	0.0	1050	152	0.2	0.0	0.35	2180	1260	881	24	2.3	2610	7.1
City Well 2	18 bbc	29	45	11-30-66	21	1.70	—	150	61	155	13	444	0.0	393	139	0.2	0.2	0.47	1170	625	261	35	2.7	1720	7.9
City Well 2	18 bbc	29	46	5-7-68	19	4.00	1.80	244	94	217	12	543	0.0	740	214	0.3	2.0	0.34	1960	995	550	32	3.0	2490	7.6
City Well 2	18 bbc	29	49	9-5-68	18	5.00	2.50	270	96	196	13	508	0.0	866	181	0.0	0.0	0.34	2040	1070	653	28	2.6	2580	7.4
City Well 2	18 bbc	29	46	12-10-68	21	2.40	2.40	296	114	220	14	537	0.0	875	242	0.1	0.0	0.31	2130	1210	770	28	2.8	2790	7.2
City Well 2	18 bbc	29	46	2-13-69	19	5.50	2.90	320	119	223	14	543	0.0	965	239	0.0	1.0	0.31	2170	1290	644	27	2.7	2920	7.5
City Well 2	18 bbc	29	46	3-5-69	21	8.80	—	331	110	229	13	546	0.0	963	240	0.1	2.5	0.23	2290	1280	—	—	—	2870	7.4
City Well 2	18 bbc	29	45	4-10-69	20	5.60	3.10	360	124	231	13	532	0.0	1080	231	0.0	0.2	1.20	2180	1410	974	26	2.7	3000	7.5
City Well 2	18 bbc	29	57	7-1-69	18	0.12	1.20	170	66	144	11	492	0.0	462	110	0.1	1.0	0.15	1250	695	292	31	2.4	1790	7.7
Test Hole 5133	129-63 13 dab	35	46	8-26-68	23	2.50	0.22	448	127	1030	22	415	0.0	1470	550	0.3	0.0	1.00	5220	1640	1300	57	11	7190	7.6
Test Hole 5166	$24cba_1$	20	46	9-5-68	18	0.90	1.30	416	195	404	9.4	911	0.0	1200	547	0.1	0.0	0.29	3550	1840	1090	32	4.1	4490	7.7
ELLENDALE AQUIFER																									
Test Hole 5635	129-61 6 cbb	100	47	5-12-70	31	0.03	0.58	150	28	174	13	509	0.0	430	17	0.1	2.5	0.52	1080	489	72	43	3.4	1540	7.9
Test Hole 5637	17 bbb	110	48	5-13-70	29	1.60	0.32	209	63	23	7.5	469	0.0	449	19	0.1	2.5	0.26	1040	780	395	6	0.4	1390	7.7
Test Hole 5634	129-62 1 baa	80	47	5-12-70	31	0.05	1.40	132	27	133	11	500	0.0	285	23	0.2	1.0	0.60	855	440	30	39	2.8	1300	8.0
Test Hole 5650	1 bbb	83	48	5-19-70	30	0.44	1.90	135	24	151	10	328	0.0	401	55	0.2	1.0	0.60	1010	437	143	42	3.1	1440	7.8
Test Hole 5636	12 ddd	90	48	5-12-70	32	0.00	0.66	150	28	255	13	587	0.0	568	6.0	0.2	1.0	0.86	1300	490	9	52	5.0	1850	7.9
Test Hole 5627	130-61 17 ccc	103	44	5-7-70	31	0.20	0.13	166	29	152	12	459	0.0	477	19	0.2	0.1	0.60	1100	535	159	38	2.9	1640	7.9
Test Hole 5626	29 bbb	80	44	5-7-70	31	0.00	1.10	130	23	179	11	506	0.0	379	18	0.2	0.0	0.56	1010	419	4	47	3.8	1480	7.9
Test Hole 5625	30 bbb	80	43	5-6-70	30	1.00	0.11	122	28	132	10	432	0.0	339	13	0.2	0.8	0.37	879	420	66	40	2.8	1280	7.7
Test Hole 5624	31 bbb	80	43	5-6-70	30	0.00	0.84	154	28	181	12	488	0.0	465	18	0.2	2.5	0.82	1110	501	101	43	3.5	1580	7.8
Test Hole 5629	130-62 10 ddd	100	45	5-7-70	30	0.05	1.00	130	29	250	13	442	0.0	422	142	0.3	2.5	0.63	1210	445	83	54	5.2	1860	7.8
Test Hole 5628	12 ddd	100	45	5-7-70	30	0.00	0.95	76	19	98	8.3	403	0.0	141	6.4	0.3	2.5	0.26	554	270	0	43	2.6	875	7.9
Robert Miller	24 ddd	24	46	1-14-69	24	0.05	0.02	230	84	34	10	476	0.0	286	97	0.1	1.88	0.23	1230	919	529	7	0.5	1710	7.8
Test Hole 5261	25 dab	60	45	12-11-68	30	0.00	1.30	141	24	154	11	484	0.0	342	18	0.2	0.0	0.70	952	451	54	42	3.2	1380	7.7
Test Hole 5256	25 dcc	100	46	12-10-68	28	0.00	1.50	161	27	133	11	347	0.0	444	42	0.2	0.0	0.62	1020	515	230	35	2.6	1420	8.0
Test Hole 5255	26 ccc	160	45	12-9-68	29	0.27	0.66	152	33	205	12	432	0.0	413	131	0.2	0.0	0.85	1210	515	161	46	3.9	1780	7.9
Test Hole 5147	26 dcc	180	46	8-28-68	30	0.16	0.02	134	16	168	12	389	0.0	417	41	0.2	0.2	0.68	1030	399	80	47	3.7	1460	7.6
Test Hole 5147	26 dcc	180	44	9-6-68	27	0.03	0.88	133	20	170	11	397	0.0	421	41	0.2	0.0	0.59	1030	414	88	46	3.6	1460	7.5
Test Hole 5148	26 ddd	70	46	8-30-68	26	0.14	1.30	133	21	172	12	404	0.0	426	37	0.2	0.0	0.73	1040	420	89	46	3.6	1460	7.7
Test Hole 5647	$36ccb_1$	80	48	5-19-70	32	0.20	1.20	132	23	163	11	367	0.0	429	47	0.2	0.0	0.67	1020	424	123	45	3.4	1460	7.8
Test Hole 5649	$36ccb_2$	83	49	5-19-70	31	0.18	1.40	142	23	151	11	374	0.0	434	43	0.2	0.0	0.67	1030	448	141	42	3.1	1450	7.8
Test Well	$36ccb_3$	100	45	7-23-70	28	0.18	1.10	142	25	165	10	368	0.0	431	43	0.4	1.0	0.52	1010	456	154	43	3.4	1470	7.7
Test Well	$36ccb_2$	100	46	7-24-70	29	0.22	1.10	141	23	164	11	368	0.0	431	43	0.4	2.5	0.60	1010	447	145	44	3.4	1460	7.6
Test Well	$36ccb_2$	100	46	7-25-70	27	0.12	1.20	139	18	165	10	372	0.0	431	44	0.4	0.0	0.36	1030	421	116	45	3.5	1480	7.5
Test Well	$36ccb_3$	100	46	7-26-70	27	0.50	1.20	139	18	162	10	368	0.0	429	45	0.4	0.0	0.27	968	420	118	45	3.4	1470	7.5
Test Well	$36ccb_2$	100	46	7-27-70	27	0.07	1.20	138	20	162	10	374	0.0	431	45	0.3	0.0	0.30	959	428	121	44	3.4	1460	7.5
Test Well	$36ccb_2$	100	46	7-28-70	27	0.00	1.20	138	21	164	10	372	0.0	427	45	0.4	1.0	0.36	1060	431	126	45	3.4	1470	7.4
Test Hole 5649	36 ccd	83	48	5-19-70	31	0.12	1.30	135	22	159	11	366	0.0	428	48	0.2	0.0	0.78	1030	426	126	44	3.4	1460	7.7
Test Hole 5622	36 ddd	80	45	5-5-70	31	0.00	0.40	144	26	221	11	551	0.0	455	26	0.3	1.0	0.86	1160	465	13	50	4.5	1680	7.8
SURFACE WATER																									
Maple River	129-62 15 aab	—	65	8-27-68	8.2	0.26	0.01	81	52	190	17	496	0.0	294	114	0.3	0.0	0.44	1020	415	8	49	4.0	1590	7.5
Dry Branch Res.	129-63 24 acd	—	62	9-3-68	22	0.00	0.02	138	147	324	24	132	6.8	792	561	0.1	0.0	0.24	2240	950	830	42	46	3180	8.5
Dry Branch Res.	24 cdd	—	32	12-11-68	20	0.16	0.05	188	209	411	32	272	0.0	1000	700	0.2	0.0	0.31	2810	1330	1110	39	4.9	3970	8.0
Slough		—	32	12-11-68	24	0.10	0.67	136	100	411	63	1200	38	504	69	0.6	0.0	0.16	1990	750	—	52	6.5	2730	8.5

* Chemical analysis by the North Dakota State Health Department, Bismarck, North Dakota

The following summary gives the significance of selected constituents of water for a domestic or municipal water supply in North Dakota (Schmid, 1965):

Silica (SiO_2)

Silica has no physiological or esthetic significance.

Iron (Fe)

Over 0.3 ppm (parts per million) iron may cause staining of laundry fixtures, and over 0.5 ppm may be tasted by persons unaccustomed to water with a high iron content. Iron removal systems are available.

Manganese (Mn)

Manganese produces black staining when present in amounts exceeding 0.05 ppm.

Calcium (Ca) and Magnesium (Mg)

Calcium and Magnesium are the primary causes of hardness. Over 125 ppm magnesium may have a laxative effect on persons unaccustomed to this type of water.

Sodium (Na)

No physiological or esthetic significance results from the presence of sodium except for persons on salt-free diets. It does have an effect on irrigation usage of water.

Potassium (K)

Small amounts of potassium are essential to plant and animal nutrition.

Bicarbonate and Carbonate (HCO_3 and CO_3)

These constituents have no definite significance in natural water; there are, however, certain standards to be maintained in water-treatment plants. A water with high bicarbonate content will tend to have a flat taste.

Sulfate (SO_4)

A 250 ppm limit for sulfate is set by the U. S. Public Health Service, however, a survey by the North Dakota State Health Department indicates no laxative effect is noticed until sulfates reach 600 ppm. Over 750 ppm, there is generally a laxative effect. The following is a classification established by the North Dakota State Department of Health:

0 - 300 ppm	Low
300 - 700 ppm	High
Over 700 ppm	Very high

Chloride (Cl)

Over 250 ppm chloride may have a salty taste to persons unaccustomed to high concentrations. Humans and animals may become accustomed to high concentrations.

Flouride (F)

Flouride is believed to prevent decay in children's teeth within the limits of 0.9 to 1.5 ppm in North Dakota. Higher concentrations may cause mottled teeth.

Nitrate (NO_3)

Over 45 ppm nitrate can be toxic to infants, much larger contentrations can be tolerated by adults. Nitrate in excess of 200 ppm may have a deleterious effect on livestock health.

Boron (B)

Boron has no physiological or esthetic significance.

Total Dissolved Solids

A limit of 500 to 1,000 ppm of total dissolved solids is set by the U. S. Public Health Service, but persons may become accustomed to water containing 2,000 ppm or more total dissolved solids. The following is a classification established by the North Dakota State Department of Health Survey:

0 - 500 ppm	Low
500 - 1,400 ppm	Average
1,400 - 2,500 ppm	High
Over 2,500 ppm	Very high

Hardness

Hardness increases soap consumption but can be removed by a water-softening system. The following is a general hardness scale established by the North Dakota State Department of Health:

0 - 200 ppm (as $CaCo_3$)	Low
200 - 300 ppm	Average
300 - 450 ppm	High
Over 450 ppm	Very high

pH

Should be between 6.0 and 9.0 for domestic consumption.

Percent Sodium; Sodium Adsorption Ratio, Specific Conductance

Are all factors used in determining irrigation feasibility.

Ground water in sandstones of the Dakota Group is generally described as being saline. Water from city well 3 is a sodium-chloride type which contains 2,777 ppm total dissolved solids, 993 ppm sodium and potassium, and 939 ppm chloride.

Iron content is 0.50 ppm but the water is treated to reduce this concentration. Dakota water can be treated through a process of desalinization to remove most of the dissolved solids, but present desalinization costs are high.

The quality of ground water in the Dry Branch surficial outwash varies considerably throughout the year. Concentrations of dissolved minerals are greater in the fall and winter months because of the migration of poorer quality water from surrounding glacial till into the deposit. In the spring and summer, ground water in the outwash deposit becomes diluted when surface runoff infiltrates into the porous material and the concentration of dissolved minerals is diminished accordingly.

Water in the Dry Branch outwash is a calcium-sodium-sulfate type water. Total dissolved solids range from 940 to 5,220 ppm and averaged 1,811 ppm. Sulfate and hardness averaged 710 ppm and 969 ppm, respectively. The dissolved iron content ranged from 0.12 to 8.80 ppm and manganese concentrations are substantial enough to require treatment and removal.

Ground water in the Ellendale aquifer is of the sodium-sulfate-bicarbonate type. Total dissolved solids ranged from 554 to 1,300 ppm and averaged 1,033 ppm. Sulfate ranged from 141 to 568 ppm. Hardness averaged 472 ppm as calcium carbonate. Dissolved iron ranged from 0 to 1.60 ppm and manganese ranged from 0.02 to 1.90 ppm.

SUMMARY AND CONCLUSIONS

The Ellendale area studied during this investigation consists of 198 square miles in south-central Dickey County and is situated within the Central Lowland physiographic province of the Interior Plains. The average annual precipitation is 19.11 inches and the average temperature is 42.6° F. Maximum

relief is about 160 feet. Drainage occurs through south-flowing Sewer Branch and Dry Branch Creeks and Maple River.

Greater than 1,000 feet of sedimentary rocks underlie the area with the predominant lithology being shale. Sandstones of the Dakota and Winnipeg Groups yield highly mineralized water to wells. Outwash deposits of sand and gravel occur at random along Dry Branch Creek, but are not significant aquifers.

The Ellendale aquifer is a buried outwash deposit of sand and gravel that extends over a known area of 17 square miles. This deposit is capable of yielding over 300 gpm to an individual well completed in an average section of the aquifer. Recharge to the aquifer occurs through surrounding till and probably from deposits outside the study area. The Ellendale aquifer contains about 81,600 acre-feet of ground water in storage, based on an average porosity of 30 percent, and an average saturated thickness of 25 feet. Water quality does not change appreciably and is of the sodium-sulfate-bicarbonate type. Dissolved iron does not exceed accepted standards in most cases, but treatment for manganese may be required.

This investigation has shown that the Dry Branch outwash deposits do not have sufficient areal extent or the recharge capability necessary to provide the city of Ellendale with an adequate supply of water. Water from the Dakota artesian system is highly mineralized and would require costly treatment to enhance its quality. Subsurface data, an aquifer test, and water quality suggest that the Ellendale aquifer is more than capable of providing the city with an adequate supply of good quality water.

TABLE 3 - WATER LEVELS IN OBSERVATION WELLS

Depth to water, in feet below or (+) above land surface

Test hole 5635 129-61-6cbb

Date	Water Level
May 13, 1970	9.59
July 23	9.06
August 3	9.79
December 11	9.18

Test hole 5637 129-61-17bbb

Date	Water Level
May 13, 1970	42.88
July 23	41.91
December 11	42.02

Test hole 5634 129-62-1baa

Date	Water Level
May 13, 1970	5.61
July 23	6.36
August 3	7.06
December 11	6.42

Depth to water, in feet below or (+) above land surface

Test hole 5650 129-62-1bbb

Date	Water Level
July 23, 1970	+ 0.44
August 3	+ 0.21

Test hole 5636 129-62-12dda

Date	Water Level
May 13, 1970	6.51
July 23	7.10
December 11	7.30

Test hole 5151 129-62-18bba

Date	Water Level
September 3, 1968	12.04
December 10	14.03
December 11	14.02
January 14, 1969	14.35
February 13	14.48
March 5	14.96
March 27	15.42
April 10	9.42
May 5	3.10

Depth to water, in feet below or (+) above land surface

Test hole 5151 129-62-18bba (Continued)

Date	Water Level
July 1, 1969	4.54
July 31	5.48
August 27	7.90
October 14	9.15
November 18	10.31
April 24, 1970	9.15
May 19	7.40
December 11	9.50

Test hole 5173 129-62-18bbb$_3$

Date	Water Level
September 5, 1968	10.05
December 10	11.74
December 11	11.75
January 14, 1969	12.56
March 3	13.65
March 27	14.35
April 10	8.05
May 5	0.56
April 24, 1970	4.05
May 19	4.10

Depth to water, in feet below or (+) above land surface

Test hole 5172 129-62-18bbb$_4$

Date	Water Level
September 5, 1968	12.65
December 10	13.92
December 11	13.87
January 1, 1969	14.01
February 13	15.40
March 3	16.17
March 27	17.20
April 10	9.70
May 5	3.20
July 1	4.24
July 31	5.41
August 27	8.31
October 14	10.53
November 18	11.37
January 1, 1970	10.69
February 26	10.67
April 24	6.20
May 19	8.30
December 11	8.40

Test hole 5133 129-63-13dab

Date	Water Level
September 5, 1968	10.00

Depth to water, in feet below or (+) above land surface

Test hole 5166 129-63-24cda$_1$

Date	Water Level
September 5, 1968	5.50
December 10	4.43
January 14, 1969	4.93
February 13	5.13
July 1	2.00
July 31	3.22
August 27	4.33
October 14	4.96
November 18	4.80
April 24, 1970	1.83

Test hole 5627 130-61-17ccc

Date	Water Level
May 13, 1970	17.17
July 23	17.20
August 3	17.46
December 11	17.65

Test hole 5626 130-61-29bbb

Date	Water Level
May 13, 1970	17.06

Depth to water, in feet below or (+) above land surface

Test hole 5626 130-61-29bbb (Continued)

Date	Water Level
July 23, 1970	17.32
August 3	17.67
December 11	17.70

Test hole 5625 130-61-30bbb

Date	Water Level
May 13, 1970	8.88
July 23	9.53
December 11	8.00

Test hole 5624 130-61-31bbb

Date	Water Level
May 13, 1970	9.19
July 23	9.65
August 3	10.30
December 11	9.90

Test hole 5629 130-62-10ddd

Date	Water Level
May 13, 1970	19.12

Depth to water, in feet below or (+) above land surface

Test hole 5629 130-62-10ddd (Continued)

Date	Water Level
July 23, 1970	19.35
August 3	19.46
December 11	19.65

Test hole 5628 130-62-12ddd

Date	Water Level
May 13, 1970	16.19
July 23	16.40
August 3	16.58
December 11	16.80

Test hole 5631 130-62-23ddc

Date	Water Level
May 13, 1970	10.79
July 23	11.15
August 3	11.82

Test hole 5646 130-62-25ccd

Date	Water Level
July 23, 1970	5.08

Depth to water, in feet below or (+) above land surface

Test hole 5646 130-62-25ccd (Continued)

Date	Water Level
August 3, 1970	5.77
December 11	6.40

Test hole 5261 130-62-25dab

Date	Water Level
December 11, 1968	4.00
January 14, 1969	3.90
February 13	3.96
March 3	3.88
April 10	3.57
July 1	3.17
July 31	3.28
August 27	3.38
October 14	3.60
November 18	3.73
April 24, 1970	3.75
May 13	3.79
July 23	4.12
August 3	4.71
December 11	4.45

Depth to water, in feet below or (+) above land surface

Test hole 5256 130-62-25dcc

Date	Water Level
December 11, 1968	13.08
January 14, 1969	12.85
February 13	12.90
April 10	12.55
July 1	12.10
July 31	12.00
August 27	12.36
October 14	12.54
November 18	12.70
April 24, 1970	12.60
May 13	12.52
July 23	13.20
August 3	13.86
December 11	13.45

Test hole 5645 130-62-25dcd

Date	Water Level
July 23, 1970	8.03
August 3	8.73
December 11	8.31

Depth to water, in feet below or (+) above land surface

Test hole 5255 130-62-26ccc

Date	Water Level
December 11, 1968	9.32
January 14, 1969	9.25
February 13	9.30
March 3	9.25
March 27	9.25
April 10	8.84
July 1	8.80
July 31	8.90
August 27	8.92
October 14	9.05
November 18	9.15
April 24, 1970	9.10
May 13	9.24
July 23	10.35
August 3	10.34
December 11	9.80

Test hole 5148 130-62-26ddd

Date	Water Level
August 30, 1968	7.30
December 11	7.08
January 14, 1969	7.10

Depth to water, in feet below or (+) above land surface

Test hole 5148 130-62-26ddd (Continued)	
Date	Water Level
February 13	7.30
March 3	7.05
April 10	5.94
July 1	6.44
July 31	6.50
August 27	6.59
October 14	6.78
November 18	6.85
April 24, 1970	6.85
May 13	6.96
July 23	7.40
August 3	8.11
December 11	7.60

Test hole 5647 130-62-36ccb$_1$	
Date	Water Level
July 23, 1970	4.25
August 3	4.87

Depth to water, in feet below or (+) above land surface

Test hole 5649 130-62-36ccb$_2$

Date	Water Level
July 23, 1970	4.19
August 3	4.73

Test hole 5648 130-62-36ccd

Date	Water Level
July 23, 1970	4.92
August 3	5.53

Test hole 5622 130-62-36ddd

Date	Water Level
May 13, 1970	8.14
July 23	9.39
August 3	10.13
December 11	9.59

TABLE 4 - LOGS OF TEST HOLES

The following test hole logs are a summary of data from the driller's logs, geologist's sample descriptions, and the resistivity and potential electric logs.

Grain-size classification is C. K. Wentworth's scale from Pettijohn (1957).

Elevations are based on mean sea level datum as represented on and interpreted from the Ellendale, Ellendale South, Savo Northwest, and Silverleaf, U. S. Geological Survey topographic maps.

Test holes are called observation wells when they have been completed as wells with $1\frac{1}{4}$ inch diameter plastic casing. Well depth and the screened aquifer interval are so designated.

Explanation of Lithologic Symbols


Gravel or sand and gravel


Till


Silty clay


Shale

129-61-6cbb
Test Hole 5635
Elevation 1406 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, pebbly, brownish-black	1	1
	Clay, silty, moderately sandy, pebbly, cobbles, moderate yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	16	17
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	48	65
	Sand, occasional thin clay lenses, very fine-to medium-grained (mostly fine-grained), subangular to rounded, moderately well-sorted	41	106
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	74	180

Observation well
Depth 100 feet
Screened interval 97-100 feet

129-61-8bbb
Test Hole 5651
Elevation 1420 feet

Glacial Drift:			
	Topsoil, silty, clayey, sandy, brownish-black	1	1
	Clay, silty, moderately sandy, pebbly, cobbles, boulders, dusky yellow to moderate yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	18	19
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	2	21
	Gravel, clayey, fine to coarse, angular to subrounded, poorly sorted, oxidized	3	24
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, cohesive, slightly plastic, calcareous (till)	91	115
	Clay, very silty, sandy, olive-gray, occasional light olive-gray laminations, cohesive, plastic, calcareous (glaciofluvial sediment)	30	145
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	15	160

129-61-17aaa
Test Hole 5638
Elevation 1390 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, silty, sandy, pebbly, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, cobbles, boulders, dusky-yellow to moderate-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till) ----------	23	24
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	156	180

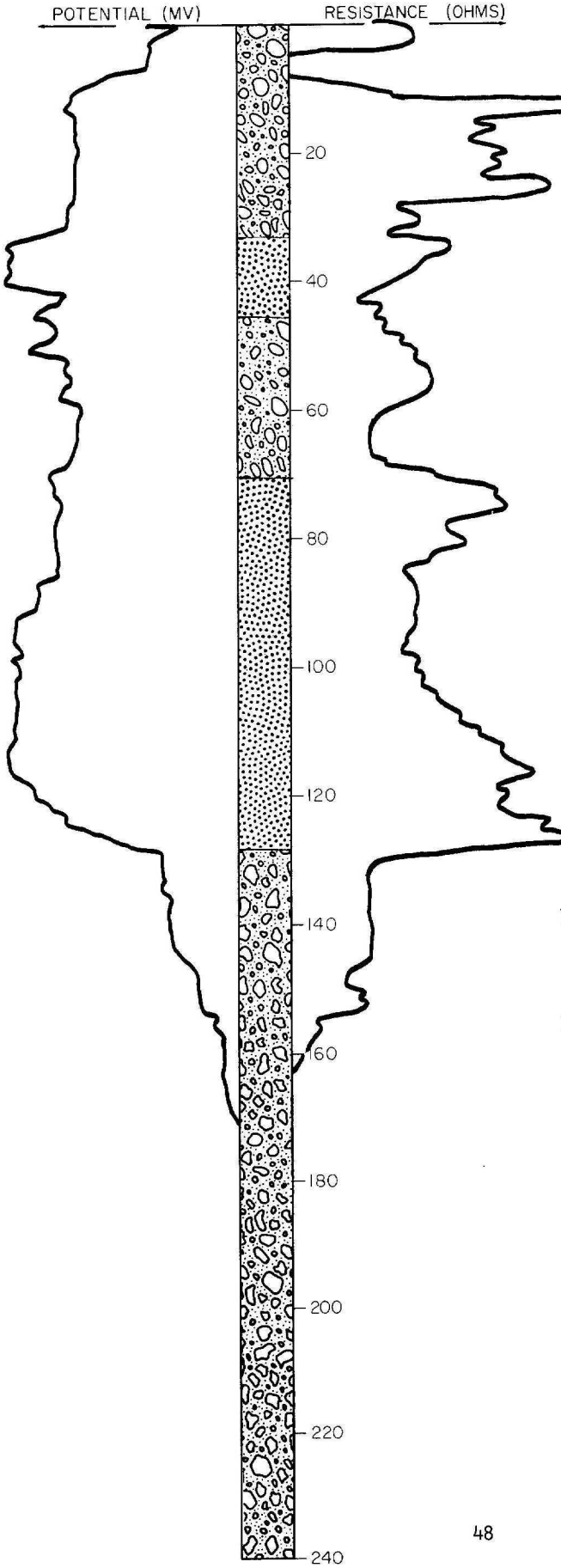
TEST HOLE 5637

LOCATION: 129-61-17bbb

DATE DRILLED: May 1970

ELEVATION: 1440
(FT, MSL)

DEPTH: 340
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, sandy pebbly, brownish-black.

1-33 Clay, silty, moderately sandy, pebbly, gravel lenses, cobbles, boulders, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till).

33-45 Sand, moderately gravelly, fine- to very coarse-grained, (mostly coarse-grained), subangular to rounded, fair sorting, mostly quartz and carbonates, some shale, oxidized.

45-70 Clay, silty, sandy, pebbly, occasional gravel lenses, cobbles, boulders, olive-gray, moderately cohesive, slightly plastic, calcareous (till).

70-83 Gravel, moderately sandy, fine to coarse, (mostly medium-to coarse), some cobble-sized material, angular to sub-rounded, fair sorting, approximately 15-25 percent shale, 30-40 percent carbonates, 15-25 percent granitics, metamorphics, slightly lignitic, taking water rapidly.

83-119 Sand, slightly gravelly, fine- to very coarse-grained, (mostly medium-to very coarse-grained), subangular to rounded, moderately well sorted, approximately 20-30 percent shale, remainder portion mostly quartz and feldspar, very lignitic, taking some water.

119-128 Gravel, moderately sandy, fine to coarse, cobbles, angular to rounded, moderately well-sorted, taking some water.

128-331 Clay, silty, slightly sandy, pebbly, cobbles, boulders, occasional thin gravel lenses, olive-gray, cohesive, moderately plastic (till).

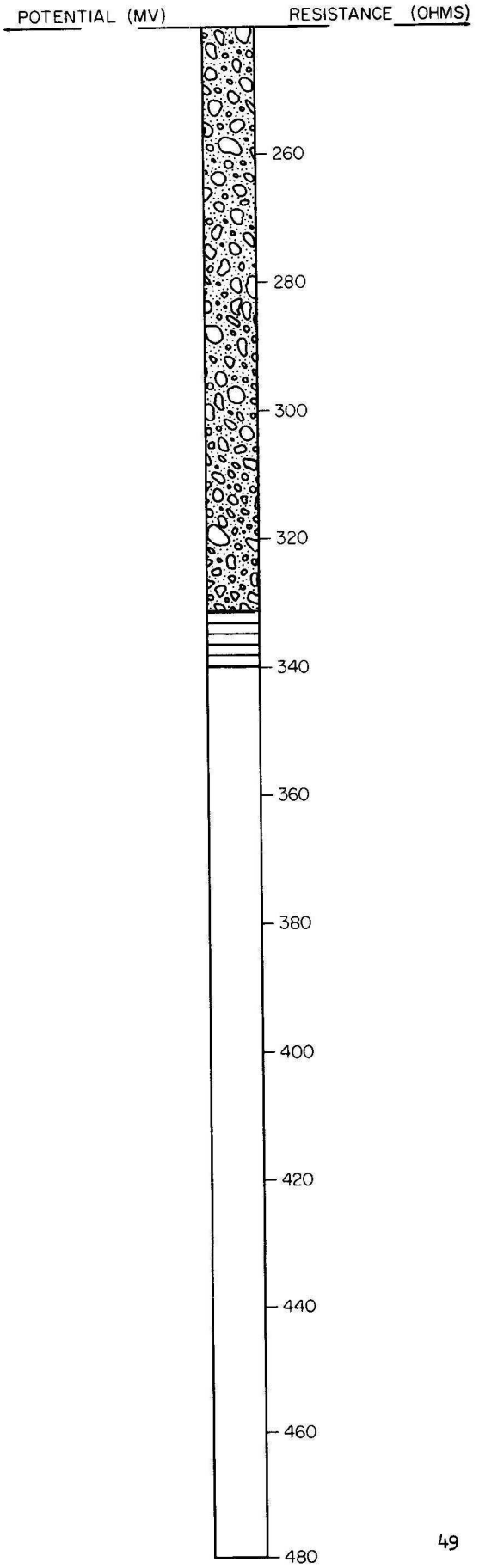
TEST HOLE 5637 (cont.)

LOCATION: 129-61-17bbb

DATE DRILLED: May 1970

ELEVATION: 1440
(FT, MSL)

DEPTH: 340
(FT)



DESCRIPTION OF DEPOSITS

Niobrara Formation

331-340 Shale, siliceous, brownish-gray to brownish-black, indurated, occasional small white specks, a few dark-brown concretions, calcareous.

Observation well
Depth 110 feet
Screened interval 107-110 feet

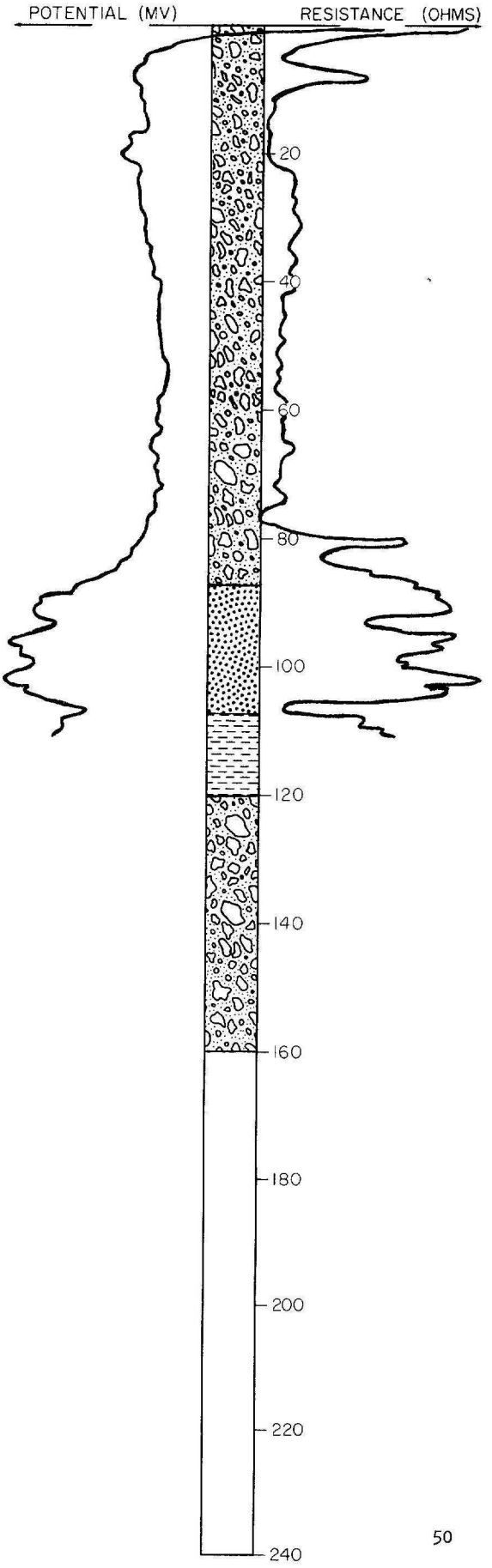
TEST HOLE 5143

LOCATION: 129-61-18ccc

DATE DRILLED: August 1968

ELEVATION: (FT, MSL) 1407

DEPTH: (FT) 160



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, slightly sandy, clayey, black.

1-14 Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till).

14-87 Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous, occasional thin sand lenses (till).

87-107 Sand, slightly silty, interbedded with very silty clay, very fine to medium-grained, angular to subrounded, moderately well-sorted, predominantly quartz with some shale and carbonates.

107-120 Clay, very silty, thinly interbedded with very fine to fine grained sand, olive-gray to light-olive-gray, laminated, calcareous (glaciofluvial sediment).

120-160 Clay, silty, pebbly, olive-gray, cohesive, slightly to moderately plastic, calcareous (till).

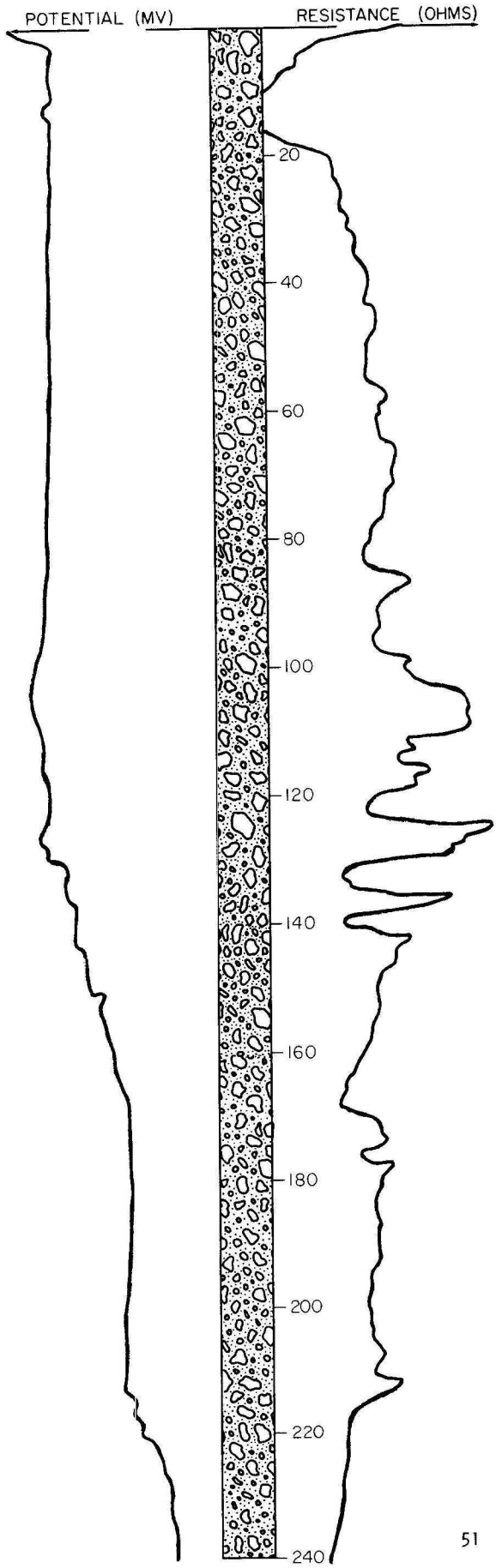
TEST HOLE 5642

LOCATION: 129-61-29bbb

DATE DRILLED: May 1970

ELEVATION: 1398
(FT, MSL)

DEPTH: 331
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-4	Road fill, clay, silt, sand pebbles, dusky-yellow to dark-yellowish-brown.
4-21	Clay, silty, moderately sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till).
21-325	Clay, silty, slightly sandy, pebbly, cobbles, boulders, occasional thin gravelly, sand lenses, olive-gray, cohesive, moderately plastic, calcareous (till).
325-326	Boulder, granite, very hard.
326-329	Clay, silty, slightly sandy, pebbly, cobbles, olive-gray, cohesive, slightly plastic, calcareous (till).

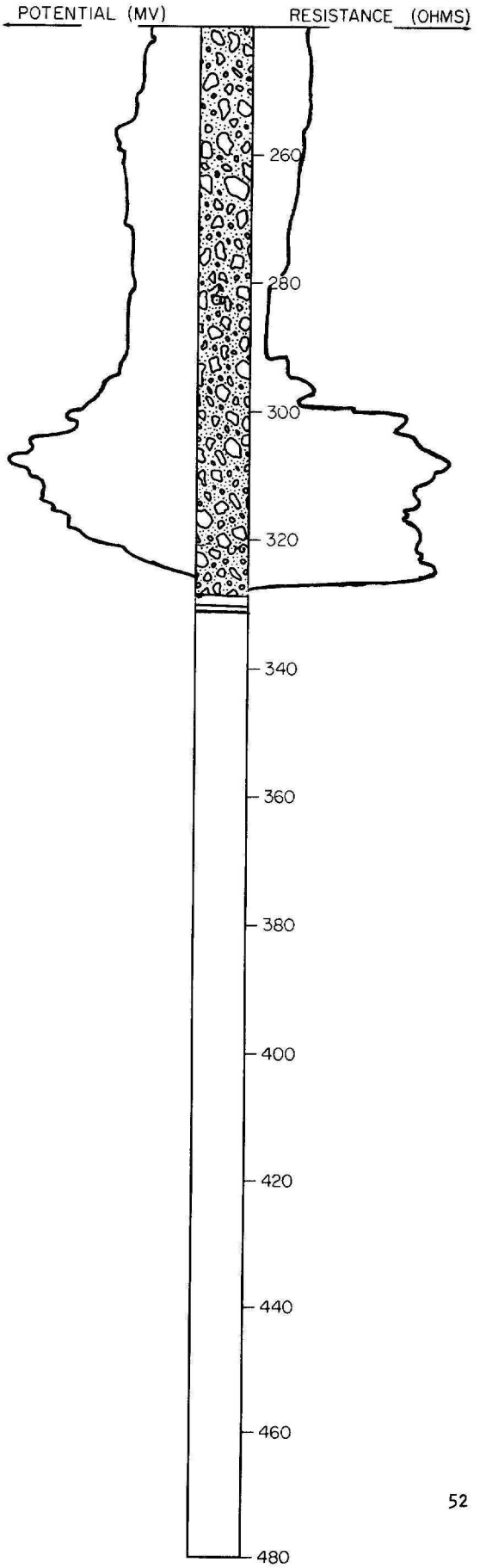
TEST HOLE 5642 (cont.)

LOCATION: 129-61-29bbb

DATE DRILLED: May 1970

ELEVATION: 1398
(FT, MSL)

DEPTH: 331
(FT)



DESCRIPTION OF DEPOSITS

Niobrara Formation

329-331 Shale, siliceous, grayish-black to brownish-black indurated, bedded, slightly calcareous, a few small white specks.

129-62-1baa
Test Hole 5634
Elevation 1404 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, sandy, pebbly, brownish-black	1	1
	Clay, silty, moderately sandy, pebbly, cobbles, boulders, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)	13	14
	Clay, silty, slightly sandy, pebbly, a few cobbles and boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	40	54
	Sand, occasional thin clay lenses, very fine-to coarse-grained, (mostly medium-grained), subangular to rounded, well-sorted, approximately 15-25 percent shale, remaining portion mostly quartz and feldspar, some carbonates, slightly lignitic, "clean looking" samples	43	97
	Clay, very silty, gravelly, olive-gray, very plastic, slightly cohesive, calcareous (glaciofluvial sediment)	3	100
	Sand, slightly clayey, very fine-to medium-grained, subangular to rounded, moderately well-sorted, mostly quartz, some shale	8	108
	Clay, very silty, moderately sandy, olive-gray, occasional-light olive-gray laminations very plastic, slightly cohesive, calcareous (glaciofluvial sediment)	11	119
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	35	154
	Gravel, fine to coarse, angular to subrounded, poorly sorted, mostly carbonates, some shale and granitics	3	157
	Clay, silty, pebbly, slightly sandy, olive-gray, cohesive, plastic, calcareous (till)	3	160

Observation well
Depth 80 feet
Screened interval 77-80 feet

129-62-1bbb
Test Hole 5650
Elevation 1397 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, silty, sandy, pebbly, boulders, brownish-black	1	1
	Clay, silty, moderately sandy, pebbly, cobbles, boulders, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	15	16
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, cohesive, moderately plastic, calcareous (till)	51	67
	Sand, very fine-to medium-grained, (mostly medium-grained), sub-angular to rounded, well-sorted, mostly quartz and feldspar, approximately 15-25 percent shale, some carbonates, lignitic	25	92
	Clay, very silty, sandy, olive-gray a few light-olive-gray laminations slightly cohesive, plastic, calcareous (glaciofluvial sediment)	4	96
	Sand, occasional thin silty, sandy, clay lenses, very fine-to medium-grained, subangular to rounded, well-sorted, mostly quartz, some shale, lignitic	25	121
	Clay, silty, slightly sandy, pebbly cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	19	140

Observation well
Depth 83 feet
Screened interval 77-83 feet

129-62-2bab
Test Hole 5257
Elevation 1400 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, clayey, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic oxidized (till)	21	22
	Clay, silty, very slightly sandy, pebbly, a few cobbles, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	18	40
	Clay, silty, numerous sand lenses, gravelly, olive-gray, cohesive, plastic, calcareous (till)	70	110
	Clay, silty, slightly sandy, pebbly, a few thin lenses of sandy gravel, moderately cohesive to cohesive, moderately plastic, calcareous (till)	90	200

129-62-6baa$_1$
Test Hole 5159
Elevation 1432 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, slightly sandy, pebbly, brownish-black ----------	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	14	15
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous (till) ----------	45	60

129-62-6baa$_2$
Test Hole 5158
Elevation 1420 feet

Glacial Drift:			
	Topsoil, silty, sandy, pebbly, brownish-black ----------	1	1
	Clay, silty, slightly sandy, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till) ----------	3	4
	Sand, slightly gravelly, medium to very coarse-grained, angular to subrounded, moderately well-sorted, approximately 60-70 percent quartz, remainder mostly shale, carbonates and granitics, oxidized upper 10 feet of section ----------	15	19
	Clay, silty, pebbly, olive-gray, moderately plastic, calcareous (till) ----------	21	40

129-62-6cac
Test Hole 5165
Elevation 1415 feet

Glacial Drift:			
	Topsoil, silty, clayey, black ------	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	7	8
	Sand, slightly gravelly, fine to very coarse-grained, angular to subrounded, fair to moderate sorting, approximately 60-70 percent quartz, remainder mostly carbonates, shale and lignite ----------	7	15
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	25	40

129-62-6cad$_1$
Test Hole 5163
Elevation 1428 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, pebbly, clayey, brownish black	1	1
	Clay, silty, slightly sandy, pebbly, a few cobbles, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	20	21
	Clay, silty, slightly pebbly, olive-gray, cohesive, moderately, plastic, calcareous (till)	19	40

129-62-6cad$_2$
Test Hole 5164
Elevation 1415 feet

Glacial Drift:			
	Topsoil, silty, clayey, black	1	1
	Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	4	5
	Sand, very fine to coarse-grained, angular to subrounded, moderately well-sorted, predominantly quartz and shale, small percent carbonates	4	9
	Clay, silty, slightly sandy, pebbly, olive-gray, very fine-grained sand from 16-17 feet, moderately cohesive, moderately plastic, calcareous (till)	17	26
	Sand, silty, clayey, fine to medium-grained, moderately well-sorted, subangular to subrounded, mostly carbonates and granitics	3	29
	Clay, silty, pebbly, olive-gray, cohesive, plastic, calcareous (till)	11	40

129-62-6ccc
Test Hole 5118
Elevation 1477 feet

Glacial Drift:			
	Topsoil, sandy, silty, clayey, brownish-black	1	1
	Clay, sandy, silty, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	19	20

129-62-6ccc (cont.)
Test Hole 5118
Elevation 1447 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, pebbly, olive-gray to medium-dark-gray, cohesive, plastic to moderately plastic, calcareous (till) ----------	77	97
	Sand, clayey, silty, medium-to coarse-grained, poorly sorted, angular to subrounded, mostly quartz and carbonates, moderate amount of detrital lignite ----------	2	99
	Clay, silty, pebbly, a few cobbles, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous (till) ----------	41	140
Pierre Formation:			
	Shale, moderately siliceous, grayish-black to black, moderately indurated, noncalcareous, occasional thin light-olive-gray bentonitic laminations ----------	20	160

129-62-6cdd$_1$
Test Hole 5162
Elevation 1418 feet

Glacial Drift:			
	Topsoil, sandy, silty, pebbly, brown-	1	1
	Clay, sandy, silty, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	$8\frac{1}{2}$	$9\frac{1}{2}$
	Gravel, slightly silty, sandy (approximately 25-35 percent medium to very coarse-grained, subangular to subrounded sand), fine to coarse (mostly fine to medium), angular to subrounded, fair sorting, mostly limestone, dolostone and shale, some light colored granitics and chalcedony ----------	$7\frac{1}{2}$	17
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	23	40

129-62-6cdd2
Test Hole 5119
Elevation 1417 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, silty, sandy, clayey, black-	1	1
	Sand, slightly gravelly, fine to very coarse-grained, angular to subrounded, moderately well-sorted, approximately 60-70 percent carbonates with some quartz, shale, granitics, oxidized to 5 feet ----------	11	12
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, plastic (till) ----------	8	20
	Sand, very clayey, silty, slightly gravelly, medium to very coarse-grained, angular to subrounded, poorly sorted, mostly carbonates and shale ----------	8	28
	Clay, silty, slightly sandy, pebbly, gravelly lower 15 to 20 feet of section, olive-gray, moderately cohesive, plastic, calcareous, lignitic (till) ----------	78	106
Pierre Formation:			
	Shale, slightly siliceous, medium-dark-gray to grayish-black, moderately indurated, non-calcareous, occasional thin light-olive-gray bentonitic laminations, a few thin limestone concretions lower 3 to 4 feet of section ----------	14	120

129-62-6dcd
Test Hole 750-5
Elevation 1425 feet

Glacial Drift:			
	Clay, silty, sandy, brownish-yellow, oxidized, moderately cohesive, slightly plastic, calcareous (till) ----------	16	16
	Clay, silty, sandy, pebbly, a few boulders, olive-gray, moderately cohesive, slightly plastic, calcareous, lignitic (till) ----------	76	92
	Clay, as above with shale fragments, cohesive, dark-olive-gray, non-calcareous, limestone boulder from 99 to 103 feet (till) -------	24	116
Pierre Formation:			
	Shale, dark-greenish-gray, brittle, fissile ----------	4	120

129-62-7acc
Test Hole 5121
Elevation 1432 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, sandy, silty, clayey, dark yellowish-brown	1	1
	Clay, silty, very slightly sandy, pebbly, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)	15	16
	Clay, silty, slightly sandy, pebbly, occasional cobbles, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous, lignitic (till)	107	123
Pierre Formation:			
	Shale, slightly siliceous, medium-dark-gray to grayish-black, moderately indurated, noncalcareous, occasional light-olive-gray bentonitic laminations	17	140

129-62-7add
Test Hole 5122
Elevation 1430 feet

Glacial Drift:			
	Topsoil, sandy, silty, pebbly, dark-yellowish-brown	1	1
	Clay, very sandy, silty, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	2	3
	Sand, silty, medium to coarse-grained, angular to subrounded, fair sorting, approximately 60-70 percent quartz, remainder shale and carbonates, oxidized	3	6
	Clay, moderately sandy, silty, pebbly, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)	12	18
	Clay, slightly sandy, silty, pebbly, dark-yellowish-brown to olive-gray, moderately cohesive, moderately plastic, calcareous (till)	13	31
	Sand, slightly gravelly, interbedded with thin lenses of olive-gray clay, medium to coarse-grained, angular to subrounded, moderately well-sorted, predominantly shale and lignite, some carbonates	4	35
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	47	82

129-62-7add (cont.)
Test Hole 5122
Elevation 1430 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Gravel, sandy (approximately 20-30 percent medium to very coarse-grained, subangular to sub-rounded sand), fine to coarse, angular to rounded, fair sorting, predominantly shale and lignite, <5 to 10 percent carbonates	3	85
	Clay, slightly to moderately sandy, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	4	89
	Sand, gravelly, (approximately 30-40 percent fine, angular to sub-rounded shale gravel) fine to coarse-grained, angular to subrounded, moderately well-sorted, 50-60 percent quartz, remainder shale, lignite, limestone and dolostone	3	92
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous, a few cobbles (till)	22	114
Pierre Formation:			
	Shale, slightly siliceous, medium-dark-gray to grayish-black, non-calcareous, non-fractured, moderately indurated	6	120

129-62-7bdd$_1$
Test Hole 5150
Elevation 1412 feet

Glacial Drift:			
	Topsoil, sandy, pebbly, silty, black	1	1
	Clay, slightly sandy, silty, pebbly moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	6	7
	Gravel, slightly sandy, fine to medium, angular to subrounded, poorly sorted, mostly carbonates and granitics, oxidized	3	10
	Clay, silty, sandy, pebbly, olive-gray, moderately cohesive, plastic (till)	3	13
	Sand, medium to very coarse-grained, subangular, subrounded, moderately well-sorted, mostly quartz and shale, some carbonates	2	15
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till)	25	40

129-62-7bdd$_2$
Test Hole 5120
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, clayey, silty, slightly sandy, black	1	1
	Gravel, slightly sandy, interbedded with moderate-yellowish-brown clay, fine to coarse, angular to subrounded, fair sorting, predominantly carbonates, some granitics and shale	5	6
	Clay, moderately sandy, silty, pebbly, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)	5	11
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive to moderately cohesive, plastic, calcareous (till)	58	69
	Sand, very fine-to medium-grained, angular to subrounded, fair sorting, mostly quartz and shale, some detrital lignite, poor samples	2	71
	Clay,slightly sandy, silty, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till)	9	80

129-62-7cab
Test Hole 5149
Elevation 1415 feet

Glacial Drift:			
	Topsoil, sandy, silty,clayey, brownish-black	1	1
	Clay, slightly sandy, silty, pebbly, moderate-yellowish-brown, cohesive, slightly plastic, oxidized (till)	6	7
	Gravel, slightly sandy, fine to coarse, angular to subrounded, poorly sorted, oxidized, mostly carbonates and light colored granitics, very little shale	3	10
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till)	30	40

129-62-7cbb
Test Hole 5123
Elevation 1440 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, sandy, pebbly, silty, dark yellowish-brown	1	1
	Clay, sandy, very slightly gravelly, silty, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)	20	21
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive to cohesive, plastic, calcareous (till)	44	65
	Sand, slightly gravelly, fine to coarse-grained, angular to sub-rounded, moderately well-sorted, approximately 50-60 percent quartz, remainder shale and carbonates	3	68
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, plastic (till)	12	80

129-62-7ccc$_1$
Test Hole 750-2
Elevation 1415 feet

Glacial Drift:			
	Topsoil, black	1	1
	Clay, silty, sandy, brownish-yellow, moderately cohesive, calcareous, oxidized (till)	13	14
	Clay, silty, sandy, pebbly, interbedded with thin coarse-grained sand lenses, olive-gray, moderately cohesive, moderately plastic, slightly calcareous, lignitic (till)	77	91
	Clay, sandy, pebbly, olive-gray, cohesive, moderately calcareous (till)	18	109
Pierre Formation:			
	Shale, dark blackish-gray, indurated, noncalcareous	11	120

129-62-7ccc$_2$
Test Hole 1177
Elevation 1415 feet

Glacial Drift:			
	Topsoil, black	1	1
	Clay, yellow	4	5
	Gravel, fine to medium, much shale	6	11
	Gravel, coarse, much shale, some cobbles	7	18

Observation well
Depth 18 feet

129-62-7cdd
Test Hole 750-3
Elevation 1435 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, sandy, occasional boulders, brownish-yellow, slightly cohesive, moderately plastic, calcareous (till)	23	23
	Clay, silty, sandy, a few boulders, olive-gray, moderately cohesive, slightly plastic, moderately calcareous (till)	58	81
	Gravel, sandy, fine to coarse, poorly sorted, subangular to subrounded, mostly limestone, shale and granitics	2	83
	Sand, interbedded with clay lenses from 95 to 112 feet, medium to very coarse-grained, moderately well-sorted, subangular to subrounded, mostly shale, granitics and limestone, some lignite	29	112
	Clay, silty, sandy, olive-gray, cohesive, moderately calcareous (till)	19	131
Pierre Formation:			
	Shale, dark-blackish-gray, indurated, non-calcareous	9	140

Observation well
Depth 83 feet

129-62-7dbb
Test Hole 1176
Elevation 1434 feet

Glacial Drift:			
	Topsoil, black	2	2
	Gravel, fine to coarse	26	28
	Clay, gray, gravelly (till)	2	30

Observation well
Depth 28 feet

129-62-7ddd
Test Hole 750-4
Elevation 1430 feet

Glacial Drift:			
	Clay, silty to sandy, brownish-yellow, moderately cohesive, oxidized (till)	16	16

129-62-7ddd (cont.)
Test Hole 750-4
Elevation 1430 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Clay, silty, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till)	30	46
	Sand, gravelly, coarse-to very coarse-grained, moderately well-sorted, subangular, 50-60 percent shale, remainder limestone and granitics	12	58
	Clay, silty, sandy, pebbly, olive-gray, moderately plastic, highly calcareous, detrital shale fragments from 93 to 137 feet (till)	79	137
Pierre Formation:			
	Shale, dark-blackish-gray, indurated, noncalcareous	13	150

129-62-8bba
Test Hole 750-6
Elevation 1430 feet

Glacial Drift:			
	Topsoil, black	1	1
	Clay, silty, sandy, pebbly, brownish-yellow, slightly cohesive, moderately calcareous, a few boulders (till)	20	21
	Sand, gravelly, coarse-grained, moderately sorted, subangular to subrounded, mostly limestone and granitics, some shale, oxidized	13	34
	Clay, silty, olive-gray, moderately cohesive, plastic, highly calcareous (till)	7	41
	Gravel, slightly sandy, fine to medium, subangular to subrounded, moderately sorted, mostly shale, limestone and granitics	5	46
	Clay, silty, sandy, olive-gray, moderately cohesive, plastic, moderately calcareous (till)	5	51
	Gravel, slightly sandy, fine to medium, subangular to subrounded, moderately sorted, approximately 50 percent shale, remainder limestone and granitics	2	53
	Clay, silty, sandy, olive-gray, moderately cohesive, plastic, moderately calcareous (till)	30	83
	Sand, medium-to coarse-grained, moderately sorted, subangular to subrounded, mostly limestone and shale, some granitics	7	90
	Clay, sandy, olive-gray, moderately cohesive, slightly plastic, moderately calcareous (till)	38	128
Pierre Formation:			
	Shale, dark-blackish-gray, indurated, noncalcareous	7	135

129-62-8cdd
Test Hole 5116
Elevation 1422 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, sandy, silty, clayey, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown to dark-yellowish-brown, cohesive to moderately cohesive, moderately plastic, oxidized (till)	13	14
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive to cohesive, moderately plastic to plastic, calcareous (till)	46	60
	Gravel, sandy (approximately 20-30 percent medium-to very coarse-grained, angular to subrounded sand), fine to coarse, angular to subrounded, fair sorting, mostly carbonates, some shale and light colored granitics	3	63
	Clay, silty, pebbly, olive-gray, cohesive to moderately cohesive, moderately plastic, calcareous (till)	53	116
	Clay, silty, slightly gravelly, a few cobbles, pebbly, olive-gray, cohesive to moderately cohesive, moderately plastic, calcareous (till)	24	140

129-62-8ddd
Test Hole 5117
Elevation 1417 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, silty, sandy, clayey, black-	1	1
	Clay, slightly to moderately sandy, pebbly, silty, dusky-yellow to moderate - yellowish-brown, slightly to moderately cohesive, plastic, oxidized (till)	14	15
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	62	77
	Sand, medium-to coarse-grained, poorly sorted, poor samples	1	78
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	31	109
	Gravel, slightly sandy, angular to subrounded, poorly sorted, fine to coarse, mostly carbonates, some shale and lignite	2	111
	Clay, silty, sandy, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till)	15	126

129-62-8ddd (cont.)
Test Hole 5117
Elevation 1417 feet

Formation	Lithology	Thickness (feet)	Depth
Pierre Formation:			
	Shale, grayish-black to medium-dark-gray, slightly siliceous, non-calcareous, non-fractured, moderately indurated ----------	14	140

129-62-10add
Test Hole 5138
Elevation 1379 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, clayey, black ----------	1	1
	Clay, slightly sandy, silty, pebbly, moderate-yellowish-brown, to dark-yellowish-brown, moderately cohesive, plastic, oxidized (till) ----	9	10
	Gravel, slightly sandy, fine to medium, angular to subrounded, poorly sorted, mostly quartz and carbonates, some shale and granitics ----------	3	13
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till) -------	20	33
	Sand, fine-to medium-grained, moderately well-sorted, mostly quartz, some shale and carbonates ---------	3	36
	Clay, silty, slightly sandy, occasionally interbedded with gravel lenses, olive-gray, moderately cohesive, plastic to moderately plastic, calcareous, lignitic (till) ----------	124	160

129-62-10dcd
Test Hole 5136
Elevation 1378 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, pebbly, black ----------	1	1
	Clay, very silty, moderately sandy, pebbly, moderate-yellowish-brown to dark-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till) ---------	12	13
	Sand, gravelly (approximately 15-30 percent fine, angular to subangular gravel), medium-to very coarse-grained, angular to subrounded, moderately well-sorted, approximately 50-60 percent quartz, remainder shale, light and dark colored granitics and carbonates ----------	7	20

129-62-10dcd (cont.)
Test Hole 5136
Elevation 1378 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	40	60
	Clay, silty, occasionally interbedded with thin, poorly sorted gravel lenses, pebbly, a few cobbles, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous (till)	20	80
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive to cohesive, plastic, calcareous (till)	120	200
	Clay, silty, pebbly, thinly interbedded with lenses of poorly sorted clayey and silty medium-grained sand, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	106	306
Niobrara Formation:			
	Shale, grayish-brown with numerous moderate-brown concretions, a few white specks, slightly siliceous, thinly laminated, indurated, slightly calcareous	14	320

129-62-12bbb
Test Hole 5621
Elevation 1395 feet

Glacial Drift:			
	Topsoil, silty, sandy, clayey, grayish-black	1	1
	Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	18	19
	Clay, silty, slightly sandy, pebbly, a few cobbles, olive-gray, moderately cohesive, plastic, calcareous (till)	38	57
	Gravel, very sandy, some cobbles, fine to coarse, angular to rounded, mostly carbonates, some granitics-	1	58
	Clay, silty, slightly sandy, pebbly, numerous cobbles and boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	22	80
	Clay, same as above, but without cobbles and boulders (till)	55	135
	Clay, silty, very sandy, sand occurs as lenses, olive-gray, cohesive, very plastic, calcareous (till)	20	155

129-62-12bbb (cont.)
Test Hole 5621
Elevation 1395 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Clay, silty, slightly sandy, pebbly olive-gray, cohesive, plastic, calcareous (till) ----------	8	163
	Sand, fine-to medium-grained, sub-angular to subrounded, fair sorting, mostly quartz and carbonates -----	3	166
	Clay, silty, slightly sandy, pebbly, a few cobbles and boulders, olive-gray, cohesive, moderately plastic, calcareous (till) ----------	138	304
	Gravel, cobbles and boulders, fine to coarse, angular, poorly sorted, mostly carbonates and shale, some granitics ----------	2	306
Niobrara Formation:			
	Shale, grayish-brown to brownish-black, occasional small white specks, slightly calcareous, indurated ----------	14	320

129-62-12ccc
Test Hole 5641
Elevation 1400 feet

Glacial Drift:			
	Topsoil, silty, sandy, clayey, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, a few cobbles, moderate-yellowish-brown, slightly plastic, moderately cohesive, oxidized (till) ----------	20	21
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, cohesive moderately plastic, calcareous (till) ----------	80	101
	Gravel, moderately sandy, fine to coarse, (mostly fine to medium), angular to subangular, moderately well-sorted, mostly quartz, granitics and metamorphics, some shale and carbonates, taking some water ----	5	106
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	24	130

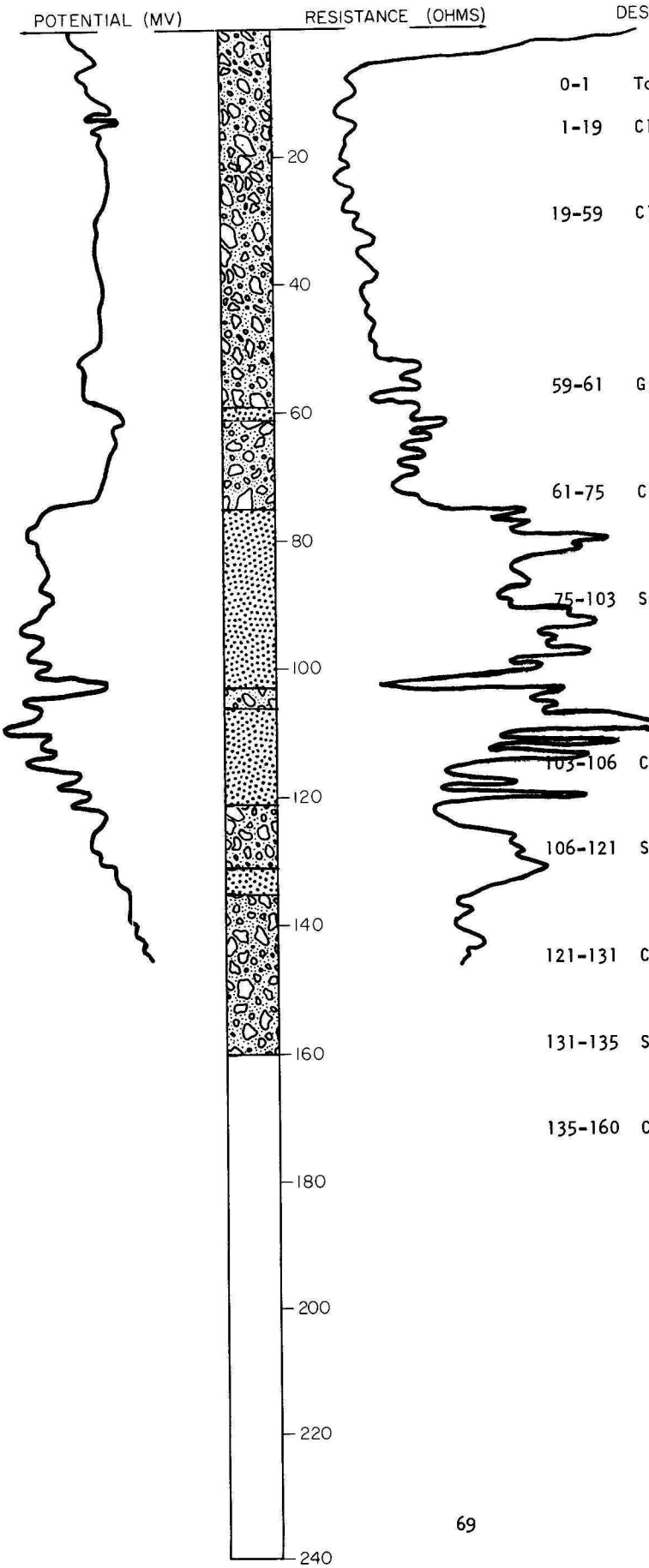
TEST HOLE 5636

LOCATION: 129-62-12dda

DATE DRILLED: May 1970

ELEVATION: 1407
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, sandy, brownish-black.

1-19 Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till).

19-59 Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

59-61 Gravel, slightly sandy, fine to coarse, subangular to rounded, fair sorting, mostly carbonates, some shale and granitics.

61-75 Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

75-103 Sand, very fine-to medium-grained, subangular to rounded, well-sorted, approximately 15-25 percent shale, remaining portion mostly quartz and feldspar, lignitic.

103-106 Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

106-121 Sand, fine-to coarse-grained, (mostly fine-to medium-grained), angular to rounded, moderately well-sorted, mostly quartz and feldspar, some shale.

121-131 Clay, silty, slightly sandy, pebbly, cobbles, olive-gray, cohesive, plastic, calcareous (till).

131-135 Sand, fine-to coarse-grained, moderately well-sorted, angular to rounded, mostly quartz and feldspar, some shale.

135-160 Clay, silty, moderately sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

Observation well
Depth 90 feet
Screened interval 87-90 feet

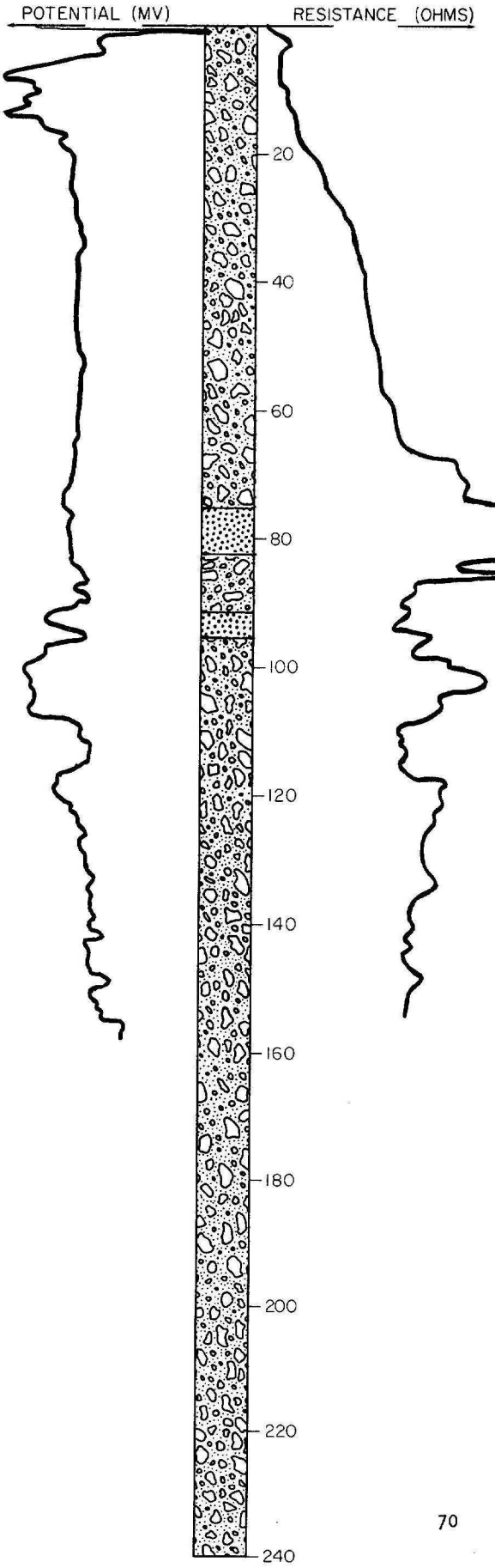
TEST HOLE 5142

LOCATION: 129-62-13daa

DATE DRILLED: August 1968

ELEVATION: (FT, MSL) 1402

DEPTH: (FT) 280



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Topsoil, silty, slightly sandy, clayey, brownish-black.
1-14	Clay, silty, very slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till).
14-75	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive to moderately cohesive, plastic, calcareous, occasional cobbles (till).
75-76	Cobbles, mostly light colored granitics.
76-82	Sand, very slightly gravelly, medium to very coarse-grained, subangular to subrounded, fair sorting, predominantly quartz and granitics, small percent shale and lignite.
82-86	Clay, silty, pebbly, occasional cobbles, olive-gray, moderately cohesive, moderately plastic, calcareous (till).
86-87	Boulder, granite, reddish-to pinkish-white.
87-91	Clay, silty, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till).
91-95	Sand, silty, clayey, fine-to coarse-grained, subangular to subrounded, fair sorting, mostly quartz and shale, some carbonates.
95-120	Clay, silty, pebbly, moderately sandy, olive-gray, cohesive to moderately cohesive, plastic, calcareous (till).
120-275	Clay, slightly to moderately sandy, silty, pebbly, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous, occasional gravelly lenses (till).

TEST HOLE 5142 (cont.)

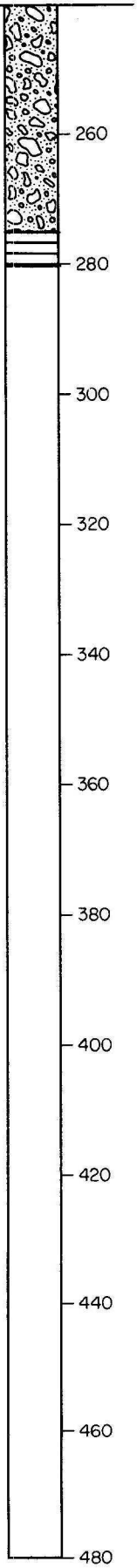
LOCATION: 129-62-13daa

DATE DRILLED: August 1968

ELEVATION: 1402
(FT, MSL)

DEPTH: 280
(FT)

POTENTIAL (MV) RESISTANCE (OHMS)



DESCRIPTION OF DEPOSITS

Niobrara Formation

275-280 Shale, grayish-brown with a few white specks and moderate-brown concretions, indurated, very slightly calcareous, parting visible.

129-62-14ccc
Test Hole 5141
Elevation 1381 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, sandy, silty, clayey, brownish-black	1	1
	Clay, moderately sandy, silty, pebbly, dusky-yellow to moderate-yellowish-brown, slightly to moderately cohesive, plastic, oxidized (till)	7	8
	Sand, silty, clayey, slightly gravelly, fine-to very coarse-grained, angular to subrounded, poorly sorted, oxidized, mostly quartz and carbonates, some shale	3	11
	Clay, sandy, silty, pebbly, dark-yellowish-brown, moderately cohesive, moderately plastic, calcareous, oxidized (till)	6	17
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive to moderately cohesive, plastic, calcareous, occasional thin gravel lenses	48	65
	Sand, very fine-to coarse-grained, angular to rounded, well-sorted, mostly quartz with moderate amount of shale and carbonates	5	70
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till)	6	76
	Sand, very fine-to medium-grained, subangular to rounded, moderately well-sorted, mostly quartz, some shale and carbonates	2	78
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous, a few cobbles (till)	82	160

129-62-15aab
Test Hole 5137
Elevation 1378 feet

Glacial Drift:			
	Topsoil, sandy, slightly pebbly, silty, brownish-black	1	1
	Clay, moderately sandy, silty, pebbly, moderate-yellowish-brown to dark-yellowish-brown, moderately cohesive, moderately plastic, calcareous, oxidized (till)	6	7
	Sand, slightly gravelly, medium-to very coarse-grained, angular to subrounded, poorly sorted, oxidized, mostly quartz and carbonates, some shale	8	15

129-62-15aab (cont.)
Test Hole 5137
Elevation 1378 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, slightly sandy, silty, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till) -------	59	74
	Clay, silty, interbedded with poorly sorted sandy gravel, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) --	142	216
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive to cohesive, plastic, calcareous (till) ----------	74	290
Niobrara Formation:			
	Shale, grayish-brown with numerous brown concretions, very slightly siliceous, thinly laminated, slightly calcareous, a few white specks, dark brown film on drilling mud, indurated ----------	30	320

129-62-18bba
Test Hole 5151
Elevation 1420 feet

Glacial Drift:			
	Topsoil, silty, sandy, pebbly, black ----------	1	1
	Clay, very sandy, silty, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till) ---------	2	3
	Gravel, very clayey (clay occurs as matrix material, could be classified as gravelly till), fine to very coarse, angular to subrounded, poorly sorted, mostly carbonates and shale, some light colored granitics ----------	7	10
	Sand, interbedded with thin sand lenses, very fine-to medium-grained, subangular to subrounded, moderately well-sorted, approximately 60-70 percent quartz, some shale and carbonates ----------	10	20
	Gravel, slightly sandy, fine to coarse, angular to subrounded, fair sorting, approximately 50 percent carbonates and 50 percent shale and light colored granitics ----------	2	22
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	3	25
	Sand, very fine-to medium-grained, subangular to subrounded, moderately well-sorted, mostly shale with moderate amount of quartz ---	1	26
	Clay, silty, slightly sandy, pebbly, a few cobbles, olive-gray, slightly to moderately cohesive, plastic, calcareous (till) ----------	80	106

129-62-18bba (cont.)
Test Hole 5151
Elevation 1420 feet

Formation	Lithology	Thickness (feet)	Depth
Pierre Formation:			
	Shale, medium-dark-gray to grayish-black, moderately indurated, non-calcareous, occasional light-olive-clay bentonitic laminations ------	14	120

Observation well
Depth 22 feet
Screened interval 19-22 feet

129-62-18bbb$_2$
Test Hole 5152
Elevation 1415 feet

Glacial Drift:			
	Topsoil, silty, clayey, sandy, black ----------	1	1
	Clay, silty, very slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic oxidized (till) ----------	7	8
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	32	40

129-62-18bbb$_3$
Test Hole 5173
Elevation 1413 feet

Glacial Drift:			
	Topsoil, silty, sandy, pebbly, brownish-black ----------	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	4	5
	Gravel, sandy (approximately 20-30 percent medium-to very coarse-grained sand), fine to medium, angular to subrounded, fair sorting, mostly granitics and carbonates with some shale -------	10	15
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	25	40

Observation well
Depth 15 feet
Slotted interval 10-15 feet

129-62-18bbb4
Test Hole 5172
Elevation 1417 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, gravelly, sandy, silty, brown	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	2	3
	Sand, slightly gravelly, medium- to very coarse-grained, angular to subrounded, moderately well-sorted, mostly quartz and light colored granitics, some carbonates and shale	24	27
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	13	40

Observation well
Depth 25 feet
Screened interval 22-25 feet

129-62-18bcb
Test Hole 5131
Elevation 1412 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, sandy, brownish-black	1	1
	Clay, slightly to moderately sandy, silty, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive to cohesive, plastic, oxidized (till)	5	6
	Gravel, sandy (approximately 35-45 percent fine-to very coarse-grained, angular to subrounded shale sand), fine to medium, angular to subrounded, moderately well-sorted, approximately 50-60 percent shale, remainder carbonates and granitics	15	21
	Clay, silty, sandy, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till)	39	60

129-62-18bcd
Test Hole 5125
Elevation 1428 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, sandy, silty, clayey, brownish-black	1	1
	Clay, slightly to moderately sandy, silty, pebbly, moderate-		

129-62-18bcd (cont.)
Test Hole 5125
Elevation 1428 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	yellowish-brown to dark-yellowish brown, moderately cohesive, plastic, oxidized (till)	19	20
	Clay, silty, sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	5	25
	Sand, very fine-to medium-grained, angular to rounded, well-sorted, approximately 70-80 percent quartz, remainder shale, carbonates and lignite	2	27
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	13	40
	Gravel, slightly sandy, fine to coarse, angular to subrounded, fair sorting, mostly shale and carbonates, some light colored granitics	5	45
	Clay, silty, sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till)	15	60

129-62-18dcc
Test Hole 750-7
Elevation 1431 feet

Glacial Drift:			
	Topsoil, black	1	1
	Clay, silty, pebbly, a few boulders, grayish-yellow, moderately cohesive, moderately plastic (till)	18	19
	Clay, silty, sandy, pebbly, olive-gray, moderately cohesive, slightly plastic, moderately calcareous (till)	39	58
	Clay, silty, sandy, pebbly, olive-gray, moderately cohesive, plastic, moderately calcareous (till)	47	105
	Clay, very silty, very sandy, a few boulders, olive-gray, very slightly cohesive, moderately calcareous (till)	12	117
Pierre Formation:			
	Shale, greenish-gray, non-calcareous, indurated	13	130

129-62-21ddd
Test Hole 5144
Elevation 1385 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, sandy, clayey, brownish-black	1	1
	Clay, very silty, sandy, dusky-yellow, poor samples	1	2
	Gravel, slightly to moderately sandy, fine to coarse, angular to subrounded, mostly shale and carbonates, some granitics, slightly oxidized	5	7
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, plastic to moderately plastic, calcareous, lignitic (till)	133	140

129-62-22aab
Test Hole 5140
Elevation 1377 feet

Glacial Drift:			
	Topsoil, silty, clayey, slightly sandy, black	2	2
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)	13	15
	Clay, silty, slightly sandy, pebbly, occasionally interbedded with thin lenses of poorly sorted, fine to coarse, carbonate gravel, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous (till)	85	100
	Clay, silty, moderately sandy, a few cobbles, interbedded occasionally with medium to coarse, unsorted, carbonate gravel, olive-gray, moderately cohesive, slightly to moderately plastic, calcareous (till)	222	322
Niobrara Formation:			
	Shale, moderately siliceous, light-olive-gray to medium-gray, very calcareous, indurated, numerous white specks, laminated	18	340

129-62-22baa
Test Hole 5139
Elevation 1378 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, slightly sandy, clayey, brownish-black ----------	1	1
	Clay, sandy, silty, pebbly, moderate-yellowish-brown to dark-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) -	12	13
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till) -------	25	38
	Sand, fine-to very coarse-grained, angular to rounded, moderately well-sorted, approximately 50-60 percent shale and 40-50 percent quartz, small percent carbonates -	4	42
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	10	52
	Sand, fine-to coarse-grained, angular to subrounded, fair sorting, mostly shale, some quartz, lignite and carbonates ----------	3	55
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	100	155
	Gravel, interbedded with clay, fine to medium, angular to subrounded, poorly sorted, mostly carbonates, some granitics and shale ---------	2	157
	Clay, silty, slightly gravelly, sandy, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	23	180

129-62-28dcd
Test Hole 5145
Elevation 1382 feet

Glacial Drift:			
	Topsoil, silty, pebbly, clayey, brownish-black ----------	1	1
	Clay, silty, sandy, gravelly, dusky-yellow to moderate-yellowish-brown, slightly to moderately cohesive, plastic, oxidized (till) ----------	1	2
	Gravel, sandy (approximately 25-35 percent medium-to very coarse-grained, angular to subrounded sand), fine to coarse, angular to subrounded, poorly sorted, interbedded with very silty clay, mostly carbonates and granitics, oxidized ----------	8	10
	Clay, silty, slightly to moderately sandy, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till) ----------	65	75

129-62-28dcd (cont.)
Test Hole 5145
Elevation 1382 feet

Formation	Lithology	Thickness (feet)	Depth
Pierre Formation:			
	Shale, grayish-brown to dusky-brown, occasional moderate-brown concretions, indurated, non-calcareous, a few white specks ---	25	100

129-62-29ccc
Test Hole 5146
Elevation 1409 feet

Glacial Drift:			
	Topsoil, silty, sandy, clayey, black ----------	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish brown, moderately cohesive, moderately plastic, oxidized (till) ----------	17	18
	Sand, very fine-to medium-grained, subrounded, fair sorting, mostly quartz, some shale ----------	5	23
	Clay, silty, slightly sandy, occasional pebbles, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	68	91
Pierre Formation:			
	Shale, grayish-black, indurated, thinly interbedded with layers of light-olive-gray bentonitic shale, occasional thin yellowish-gray limestone concretions ----------	29	120

129-63-2aaa
Test Hole 5115
Elevation 1450 feet

Glacial Drift:			
	Topsoil, slightly sandy, silty, clayey, brownish-black ----------	1	1
	Clay, slightly sandy, silty, clayey, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	14	15

129-63-2aaa (cont.)
Test Hole 5115
Elevation 1450 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, pebbly, olive-gray, cohesive, plastic to moderately plastic, calcareous (till) -------	81	96
	Gravel, slightly sandy, fine to coarse, angular to subrounded, fair sorting, mostly carbonates, some shale and granitics ---------	1	97
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately plastic, cohesive, calcareous (till) ------	5	102
	Gravel, fine to coarse, angular to subrounded, fair sorting, mostly carbonates, some shale and granitics ----------	2	104
	Clay, silty, pebbly, olive-gray to medium-dark-gray, cohesive, moderately plastic, calcareous (till) ----------	12	116
Pierre Formation:			
	Shale, slightly siliceous, medium-dark-gray to grayish-black, moderately indurated, noncalcareous, occasional thin light-olive-gray bentonitic laminae ----	24	140

129-63-2dda
Test Hole 1175
Elevation 1450 feet

Glacial Drift:			
	Clay, yellow, fine to coarse gravel (till) ----------	16	16
	Clay, sandy, gray (till) ----------	10	26
	Clay, gray, fine to medium gravel, lignitic (till) ----------	44	70
	Clay, gray, fine to medium shale pebbles, lignitic (till) --------	23	93
	Sand, fine to coarse, some lignite -	5	98
	Clay, gravelly, pebbly, gray (till)-	33	131
Pierre Formation:			
	Shale ----------	9	140

129-63-10dab
Test Hole 1174
Elevation 1462 feet

Glacial Drift:			
	Clay, brown ----------	5	5
	Clay, gravelly, yellow (till) ------	11	16
	Clay, gravelly, pebbly, gray (till)-	10	26

129-63-10dab (cont.)
Test Hole 1174
Elevation 1462 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Sand, fine to coarse	2	28
	Clay, sandy, gravelly, pebbly, gray (till)	42	70
	Clay, gravelly, pebbly, gray (till)-	23	93
Pierre Formation:			
	Shale	17	110

129-63-11add
Test Hole 1173
Elevation 1454 feet

Glacial Drift:			
	Topsoil, black	2	2
	Clay, gravelly, yellow (till)	9	11
	Clay, blue	3	14
	Sand, gravelly, coarse, mostly shale, some lignite	5	19
	Clay, gravelly, pebbly, gray (till)-	71	90

129-63-11daa
Test Hole 1167
Elevation 1454 feet

Glacial Drift:			
	Earthfill	3	3
	Clay, yellow	8	11
	Clay, gravelly, yellow (till)	6	17
	Clay, gravelly, pebbly, gray (till)-	4	21
	Sand, gravelly, fine-to medium-grained	9	30
	Clay, gravelly, pebbly, gray (till)-	13	43
	Gravel, fine to medium, mostly shale	3	46
	Clay, gravelly, pebbly, lignitic, gray (till)	32	78
	Gravel, fine to coarse, lignitic	2	80
	Clay, gravelly, lignitic, gray (till)	39	119
Pierre Formation:			
	Shale	11	130

129-63-11dca
Test Hole 1168
Elevation 1443 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, black	2	2
	Clay, gravelly, yellow (till)	9	11
	Gravel, sandy, fine to coarse	13	24
	Clay, gravelly, gray (till)	37	61
	Gravel, fine to coarse, lignitic	4	65
	Clay, gravelly, pebbly, lignitic, gray (till)	48	113
Pierre Formation:			
	Shale	7	120

129-63-12cad
Test Hole 1166
Elevation 1453 feet

Glacial Drift:			
	Topsoil, black	3	3
	Clay, gravelly, yellow (till)	16	19
	Clay, gravelly, pebbly, gray (till)-	10	29
	Sand, gravelly, fine-to coarse-grained, some shale	19	48
	Clay, gravelly, pebbly, lignitic, gray (till)	52	100
	Gravel, sandy, fine to medium	5	105
	Clay, gravelly, gray (till)	22	127
	Sand, fine-to medium-grained	3	130
	Clay, gravelly, lignitic, gray (till)	11	141
Pierre Formation:			
	Shale	19	160

129-63-12ccc
Test Hole 1169
Elevation 1451 feet

Glacial Drift:			
	Clay, gravelly, yellow	22	22
	Gravel, fine to coarse	2	24
	Clay, gravelly, gray (till)	27	51
	Sand, fine-to coarse-grained, abundant shale	4	55
	Clay, gravelly, pebbly, gray (till)-	70	125
Pierre Formation:			
	Shale	5	130

129-63-12dbc
Test Hole 750-1
Elevation 1450 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, black ----------	1	1
	Clay, silty, sandy, brownish-yellow, moderately cohesive, slightly plastic, oxidized (till) ---------	18	19
	Clay, silty, sandy, pebbly, dark-olive-gray, moderately cohesive, slightly plastic (till) ----------	20	39
	Sand, gravelly, very coarse-grained, subangular, moderately well-sorted, mostly limestone and granitics, small percent shale and lignite --	18	57
	Clay, very silty, olive-gray, slightly cohesive, poor samples (till) -	50	107
	Gravel, coarse, subrounded, poor samples ----------	1	108
	Clay, silty, olive-gray, poor samples (till) ----------	15	123
	Sand, very coarse-grained, poor samples ----------	1	124
	Clay, silty, olive-gray, poor samples (till) ----------	2	126
	Clay, silty, olive-gray, lignitic (till) ----------	3	129
	Clay, silty, sandy, olive-gray, calcareous (till) ----------	17	146
	Sand, coarse-grained, subangular, moderately well-sorted, mostly limestone and granitics ----------	2	148
Pierre Formation:			
	Shale, very slightly silty, dark-gray, slightly cohesive, very slightly calcareous ----------	12	160

Observation well
Depth 44 feet

129-63-13aad
Test Hole 5132
Elevation 1416 feet

Glacial Drift:			
	Topsoil, silty, clayey, black ------	1	1
	Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately oxidized (till) ----------	4	5
	Gravel, a few cobbles, very silty, clayey, fine to coarse, angular to subrounded, poorly sorted, mostly carbonates and light-colored, very small percent shale, oxidized ----	3	8
	Clay, slightly sandy, pebbly, olive-gray, moderately cohesive to cohesive, plastic (till) ----------	12	20
	Sand, silty, very fine-to coarse-grained, subangular to subrounded, moderately well-sorted, mostly quartz, some shale and carbonates-	2	22

129-63-13aad (cont.)
Test Hole 5132
Elevation 1416 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, silty, sandy, occasional pebbles, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	10	32
	Gravel, slightly sandy, fine to coarse, angular to rounded, poorly sorted, mostly carbonates, some light-colored granitics and shale, small percent lignite ----------	3	35
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till) -------	13	48
	Sand, silty, clayey, very fine-to medium-grained, subangular, moderately well-sorted, mostly quartz and carbonates ----------	4	52
	Clay, silty, sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -	8	60

129-63-13add$_1$
Test Hole 5130
Elevation 1411 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, clayey, brownish-black ----------	1	1
	Clay, moderately sandy, silty, pebbly, moderate-yellowish-brown to dark-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	7	8
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	15	23
	Sand, very fine-to coarse-grained, angular to rounded, moderately well-sorted, approximately 50-60 percent shale, remainder quartz and carbonates ----------	3	26
	Clay, moderately sandy, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	6	32
	Gravel, sandy (approximately 30-40 percent medium-to very coarse-grained, angular to subrounded sand), fine to medium, angular to subrounded, moderately well-sorted, approximately 60-70 percent shale, remainder carbonates and light colored granitics ----------	7	39
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, plastic, calcareous (till) ----------	21	60

129-63-13add$_2$
Test Hole 5124
Elevation 1410 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, sandy, black -------	1	1
	Clay, slightly sandy, silty, pebbly, moderate-yellowish-brown to dark-yellowish-brown, moderately cohesive, plastic, oxidized (till) -	2	3
	Sand, very fine-to medium grained, angular to subrounded, well-sorted, approximately 70-80 percent quartz, remainder shale, carbonates and lignite, oxidized to 12 feet bls ----------	14	17
	Gravel, sandy, fine to medium, subangular to subrounded, mostly shale and carbonates, some light colored granitics ----------	3	20
	Clay, silty, pebbly, olive-gray, cohesive, plastic (till) ----------	20	40

129-63-13bcc
Test Hole 1170
Elevation 1453 feet

Glacial Drift:			
	Topsoil, black ----------	2	2
	Clay, yellow ----------	14	16
	Clay, gravelly, lignitic, olive-gray (till) ----------	107	123
Pierre Formation:			
	Shale ----------	7	130

129-63-13daa
Test Hole 5129
Elevation 1412 feet

Glacial Drift:			
	Topsoil, silty, clayey, black ------	1	1
	Clay, very silty, slightly sandy, pebbly, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)----------	2	3
	Gravel, slightly sandy, silty, fine to medium, poorly sorted, angular to subrounded, mostly carbonates some shale and granitics, oxidized ----------	4	7
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)----------	53	60

129-63-13dab
Test Hole 5133
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, slightly sandy, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	13	14
	Clay, silty, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till)	4	18
	Sand, very slightly gravelly, fine- to very coarse-grained, angular to subrounded, moderately well-sorted, approximately 50-60 percent shale, remainder carbonates and light-colored granitics	4	22
	Clay, slightly to moderately sandy, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	4	26
	Sand, slightly gravelly, fine-to very coarse-grained, angular to subrounded, moderately well-sorted, approximately 40-50 percent shale, remainder carbonates and light colored granitics, small percent lignite, occasional clay lenses lower 5-6 feet of section	13	39
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately plastic, calcareous (till)	21	60

Observation well
Depth 35 feet
Screened interval 32-35 feet

129-63-13dac
Test Hole 5134
Elevation 1413 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, slightly sandy, black	1	1
	Clay, silty, slightly sandy, moderate-yellowish-brown to dusky-yellow, slightly to moderately cohesive, plastic, oxidized (till)	2	3
	Gravel, silty, slightly clayey, slightly sandy, fine to coarse, angular to subrounded, poorly sorted, mostly carbonates, small percent granitics, oxidized	16	19
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, plastic, calcareous (till)	13	32

129-63-13dac (cont.)
Test Hole 5134
Elevation 1413 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Sand, very fine-to medium-grained, angular to subrounded, moderately well-sorted, mostly quartz and shale	4	36
	Clay, silty, pebbly, olive-gray, cohesive, plastic, calcareous (till)	24	60

129-63-13dad
Test Hole 5128
Elevation 1414 feet

Glacial Drift:			
	Topsoil, silty, clayey, slightly sandy, black	1	1
	Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown to dark-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	11	12
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous (till)	48	60

129-63-13dcc
Test Hole 1172
Elevation 1434 feet

Glacial Drift:			
	Topsoil, black	1	1
	Clay, gravelly, yellow (till)	2	3
	Sand, coarse, gravelly	14	17
	Clay, gravelly, gray (till)	6	23
	Gravel, fine to medium, approximately 2/3 shale	7	30
	Clay, gravelly, gray, lignitic (till)	66	96
Pierre Formation:			
	Shale	4	100

129-63-13dda
Test Hole 5127
Elevation 1412 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, sandy, silty, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown to dark-yellowish-brown, moderately cohesive, moderately plastic, calcareous, oxidized (till)	9	10
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	13	23
	Sand, very slightly gravelly, medium-to coarse-grained, sub-angular to subrounded, fair sorting, approximately 50-60 percent shale, remainder quartz and carbonates	4	27
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	33	60

129-63-13ddb
Test Hole 5135
Elevation 1412 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, slightly sandy, black	1	1
	Gravel, silty, clayey, fine to coarse, poorly sorted, angular to subangular, mostly carbonates and granitics, oxidized	6	7
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	14	21
	Sand, very fine-to fine-grained, subangular to subrounded, moderately well-sorted, mostly quartz and shale, lignitic	3	24
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till)	36	60

129-63-13ddc
Test Hole 5126
Elevation 1412 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, sandy, silty, black -------	1	1
	Clay, silty, slightly to moderately sandy, pebbly, moderate-yellowish-brown to dark-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ---------	3	4
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	76	80
	Gravel, very slightly sandy, fine to coarse, angular to subrounded, moderately well-sorted, mostly carbonates, some shale, granitics and lignite ----------	3	83
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	20	103
Pierre Formation:			
	Shale, medium-dark-gray, to grayish-black, indurated, noncalcareous, non-fractured, occasional thin light olive-gray bentonitic laminae ----------	17	120

129-63-14baa
Test Hole 5153
Elevation 1440 feet

Glacial Drift:			
	Topsoil, silty, clayey, black ------	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	7	8
	Sand, slightly gravelly, medium-to very coarse-grained, angular to subrounded, poorly sorted, mostly quartz and shale, some carbonates, lignitic ----------	4	12
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till) -------	28	40

129-63-24aba
Test Hole 5171
Elevation 1416 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, clayey, black ----------	1	1
	Clay, silty, slightly sandy, pebbly, dusky yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	6	7

129-63-24aba (cont.)
Test Hole 5171
Elevation 1416 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Sand, very fine-to medium-grained, angular to subrounded, moderately well-sorted, mostly quartz, some carbonates, oxidized ----------	3	10
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	30	40

129-63-24abd
Test Hole 5157
Elevation 1416 feet

Glacial Drift:			
	Topsoil, silty, clayey, brownish-black ----------	1	1
	Clay, silty, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	9	10
	Gravel, slightly sandy, silty, fine to coarse, angular to subangular, poorly sorted, mostly light colored granitics and carbonates, oxidized ---------	2	12
	Clay, silty, very slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	28	40

129-63-24acd
Test Hole 5156
Elevation 1422 feet

Glacial Drift:			
	Topsoil, silty, clayey, pebbly, dark-yellowish-brown ----------	1	1
	Clay, silty, very slightly sandy, pebbly, gravelly from 7-9 feet bls, dusky-yellow to moderate-yellowish-brown, slightly to moderately cohesive, moderately plastic, oxidized (till) ---	13	14
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	6	20
	Gravel, slightly sandy, fine to coarse, angular to subrounded, poorly sorted, mostly carbonates and shale, some lignite ----------	8	28
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	12	40

129-63-24bbb
Test Hole 1171
Elevation 1458 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, yellow	14	14
	Clay, gravelly, lignitic, brown (till)	8	22
	Clay, gravelly, a few boulders, gray (till)	103	125
Pierre Formation:			
	Shale	5	130

129-63-24bdd
Test Hole 5170
Elevation 1425 feet

Glacial Drift:			
	Topsoil, silty, clayey, slightly sandy, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, numerous cobbles, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	14	15
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	6	21
	Gravel, sandy (approximately 20-30 percent medium-to very coarse-grained, angular to subrounded sand), fine to coarse, angular to subrounded, fair sorting, mostly carbonates and shale, some light colored granitics	8	29
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	10	39
	Sand, slightly gravelly, medium-to very coarse-grained, angular to subrounded, fair sorting, predominantly shale, some carbonates	6	45
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	15	60

129-63-24caa
Test Hole 5169
Elevation 1415 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, brownish-black	1	1

129-63-24caa (cont.)
Test Hole 5169
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, slightly to moderately cohesive, moderately plastic, oxidized (till) ----------	7	8
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	5	13
	Sand, slightly gravelly, medium-to coarse-grained, angular to subrounded, poorly sorted, mostly granitics, quartz and carbonates -	2	15
	Clay, silty, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till) ----------	23	38
	Sand, fine-to medium-grained, subangular, fair sorting, mostly shale and quartz, poor samples ---	1	39
	Clay, silty, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till) ----------	1	40

129-63-24cad
Test Hole 5168
Elevation 1416 feet

Glacial Drift:			
	Topsoil, sandy, silty, pebbly, brownish-black ----------	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, slightly to moderately cohesive, semi-plastic, oxidized (till) ----------	3	4
	Gravel, silty, clayey, fine to coarse, angular, poorly sorted, oxidized, predominantly carbonates and light colored granitics -	2	6
	Clay, silty, pebbly, dark-yellowish-brown to olive-gray, moderately cohesive, moderately plastic, cohesive, partially oxidized (till) ----------	2	8
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, cohesive (till) ---------	17	25
	Sand, slightly gravelly, medium-to very coarse-grained, angular to subrounded, moderately well-sorted, mostly carbonates and shale, some light colored granitics and lignite ----------	2	27
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	13	40

129-63-24cda$_1$
Test Hole 5166
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, slightly sandy, black	1	1
	Gravel, silty, clayey, slightly sandy, fine to coarse, angular to subangular, fair sorting, mostly carbonates and light colored granitics, some shale, oxidized	8	9
	Sand, very fine-to coarse-grained, angular to subrounded, well-sorted, approximately 75-85 percent quartz, remainder shale, carbonates and lignite	14	23
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	17	40

Observation well
Depth 20 feet
Screened interval 17-20 feet

129-63-24cda$_2$
Test Hole 5167
Elevation 1413 feet

Glacial Drift:			
	Topsoil, silty, clayey, sandy, black	1	1
	Clay, silty, very slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)	3	4
	Gravel, slightly sandy, silty, fine to coarse, angular to subrounded, poorly sorted, oxidized, predominantly carbonates and light colored granitics, small percent shale	5	9
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	31	40

129-63-24cdd
Test Hole D.H. 19
Elevation 1414 feet

Glacial Drift:			
	Topsoil	1	1
	Clay, white	2	3
	Clay, reddish-yellow	3	6
	Sand, gravelly	4	10
	Sand, fine-grained, gray	9	19
	Clay, gravelly, gray (till)	7	26

129-63-24dbb
Test Hole 5155
Elevation 1418 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:	Topsoil, silty, clayey, pebbly, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	4	5
	Gravel, clayey, silty fine to coarse angular to subangular, poorly sorted, mostly granitics and carbonates, oxidized	1	6
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	6	12
	Sand, slightly to moderately silty, very fine-to medium-grained, angular to subrounded, moderately well-sorted, approximately 50-60 percent quartz, remainder mostly shale, small percent carbonates	11	23
	Clay, silty, pebbly, olive-gray, cohesive, plastic (till)	3	26
	Sand, medium-to very coarse-grained, angular to subangular, fair sorting mostly carbonates and quartz, some shale	3	29
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	11	40

129-63-24dcb
Test Hole 5154
Elevation 1420 feet

Glacial Drift:	Topsoil, silty, clayey, black	1	1
	Clay, silty, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	5	6
	Gravel, slightly sandy, silty, fine to coarse, angular to subrounded, poorly sorted, mostly granitics and carbonates, some shale, oxidized	2	8
	Clay, silty, pebbly, olive-gray, cohesive to moderately cohesive, moderately plastic, calcareous (till)	32	40

129-63-24dcc
Test Hole D.H. 15
Elevation 1412 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil	1	1
	Clay, white	1	2
	Clay, yellow	1	3
	Sand and gravel	11	14
	Clay, gravelly, gray (till)	10	24

129-63-27cdc
Test Hole 5178
Elevation 1450 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	10	11
	Clay, silty, pebbly, olive-gray, cohesive, plastic to moderately plastic, calcareous (till)	94	105
	Clay, very silty, light-olive-gray to brownish-gray to olive-gray, slightly cohesive, slightly plastic, calcareous, thinly laminated (glaciofluvial sediment)	20	125
Pierre Formation:			
	Shale, medium-dark-gray to grayish-black, indurated, noncalcareous, non-fractured, occasional light olive-gray bentonitic laminations-	15	140

129-63-27ddd
Test Hole 5177
Elevation 1432 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, pebbly, brownish-black	1	1
	Gravel, silty, slightly sandy, fine to coarse, angular to subangular, fair sorting, mostly carbonates and light colored granitics, some shale, oxidized	7	8
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	62	70
Pierre Formation:			
	Shale, slightly siliceous, medium dark gray to grayish-black, indurated, noncalcareous, non-fractured	10	80

130-61-16bbb
Test Hole 5640
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, sandy, brownish-black	1	1
	Clay, silty, moderately sandy, pebbly, cobbles, boulders, moderate-yellowish-brown, slightly plastic, moderately cohesive, oxidized (till)	10	11
	Clay, silty, slightly sandy, pebbly, occasional thin sand lenses, cobbles, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	129	140

130-61-17ccc
Test Hole 5627
Elevation 1415 feet

Glacial Drift:			
	Topsoil, sandy, silty, clayey, brownish-black	1	1
	Clay, sandy, silty, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	25	26
	Clay, silty, slightly sandy, pebbly, slightly gravelly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	19	45
	Gravel, sandy, fine to coarse, subrounded, fair sorting, mostly carbonates and shale	1½	46½
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till)	10½	57
	Sand, slightly gravelly, fine- to coarse-grained, subangular to rounded, mostly quartz	1	58
	Clay, silty, moderately sandy, pebbly, thin gravel lenses, olive-gray (till)	2	60
	Sand, fine-to coarse-grained, well-sorted, subangular to rounded	2	62
	Clay, silty, moderately sandy, pebbly, slightly gravelly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	10	72
	Sand, slightly gravelly, very fine- to very coarse-grained, (mostly medium-to very coarse-grained), subangular to rounded, well-sorted, approximately 25-35 percent shale, 20-30 percent carbonates, remaining portion mostly quartz, slightly lignitic, "clean-looking" samples-	14	86

130-61-17ccc (cont.)
Test Hole 5627
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, very silty, slightly sandy, olive-gray, slightly cohesive, plastic, calcareous (glaciofluvial sediment) ----------	7	93
	Sand, occasional thin clay lenses, slightly gravelly (fine gravel), very fine-to very coarse-grained, (mostly medium-to coarse-grained), subangular to rounded, well-sorted, mostly quartz and shale, lignitic-	17	110
	Clay, very silty, olive-gray, occa--sional light-olive-gray laminations, slightly cohesive, plastic, calcareous (glaciofluvial sediment) -	12	122
	Clay, silty, slightly sandy, pebbly, gravelly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	156	278
Niobrara Formation:			
	Shale, brownish-black with occasional reddish-brown concretions, indurated, very slightly calcareous, laminated, occasional small white specks -----	22	300

Observation well
Depth 103 feet
Screened interval 97-103 feet

130-61-28ccc
Test Hole 5639
Elevation 1405 feet

Glacial Drift:			
	Topsoil, silty, sandy, clayey, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, slightly plastic, moderately cohesive, oxidized (till) ----------	13	14
	Boulder, granite, very hard --------	1	15
	Gravel, moderately sandy, fine to medium, angular to rounded, fair sorting, approximately 35-45 percent carbonates, some shale, granitics, metamorphics and other siliceous rocks, oxidized throughout ----------	5	20
	Clay, silty, slightly sandy, a few thin gravel lenses, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	65	85
	Gravel, slightly sandy, fine to coarse, angular to rounded, fair sorting,		

130-61-28ccc (cont.)
Test Hole 5639
Elevation 1405 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	approximately 25-35 percent shale, 30-40 percent carbonates, remaining portion mostly granitics, slightly lignitic, taking some water ------	5	90
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, cohesive, plastic, calcareous (till) ----------	70	160

130-61-29bbb
Test Hole 5626
Elevation 1410 feet

Glacial Drift:			
	Topsoil, silty, sandy, pebbly, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, slightly gravelly, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till) ----------	25	26
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, plastic, calcareous (till) ----------	40	66
	Sand, slightly gravelly (fine gravel), very fine-to very coarse-grained, (mostly medium-grained), sub-angular to rounded, well-sorted, approximately 25-40 percent shale, 10-20 percent carbonates, remaining portion mostly quartz and feldspar, slightly lignitic, "clean-looking" samples ----------	27	93
	Silt, moderately clayey, dark-gray, slightly cohesive, very plastic, (glaciofluvial sediment) ---------	7	100
	Clay, silty, slightly sandy, pebbly, slightly gravelly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	60	160

Observation well
Depth 80 feet
Screened interval 77-80 feet

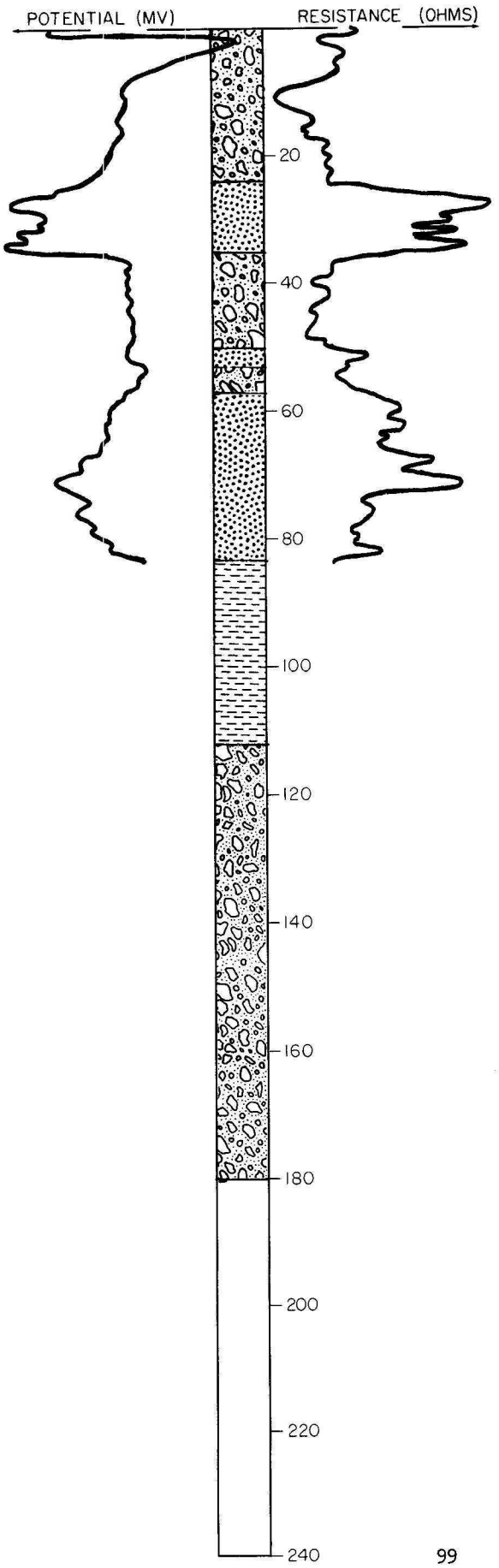
TEST HOLE 5625

LOCATION: 130-61-30bbb

DATE DRILLED: May 1970

ELEVATION: 1408
(FT, MSL)

DEPTH: 180
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Topsoil, silty, sandy, clayey, brownish-black.
1-15	Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till).
15-24	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).
24-35	Sand, moderately gravelly, fine- to very coarse-grained, (mostly medium-to coarse-grained), subangular to subrounded, fair sorting, approximately 25-35 percent shale, 20-30 percent carbonates, remaining portion mostly quartz and feldspar, slightly lignitic.
35-50	Clay, silty, gravelly, moderately sandy, olive-gray, moderately cohesive, moderately plastic, calcareous (till).
50-53	Gravel, moderately clayey, moderately sandy, fine to coarse, angular to subrounded, fair sorting, approximately 35-45 percent carbonates, 20-30 percent shale, remaining portion granitics, metamorphics, and other siliceous rocks.
53-57	Clay, silty, moderately sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).
57-83	Sand, slightly gravelly, very fine- to very coarse-grained, (mostly medium-to very coarse-grained), subangular to rounded, well-sorted, approximately 35-45 percent shale, remaining portion mostly quartz and feldspar, some carbonates, slightly lignitic, "clean-looking" samples, taking water.
83-112	Clay, very silty, olive-gray, occasional light-olive-gray laminations, very cohesive, very plastic, calcareous (glaciofluvial sediment).
112-180	Clay, silty, slightly sandy, pebbly, occasional gravel lenses, moderately cohesive, plastic, calcareous (till).

Observation well
Depth 80 feet
Screened interval 77-80 feet

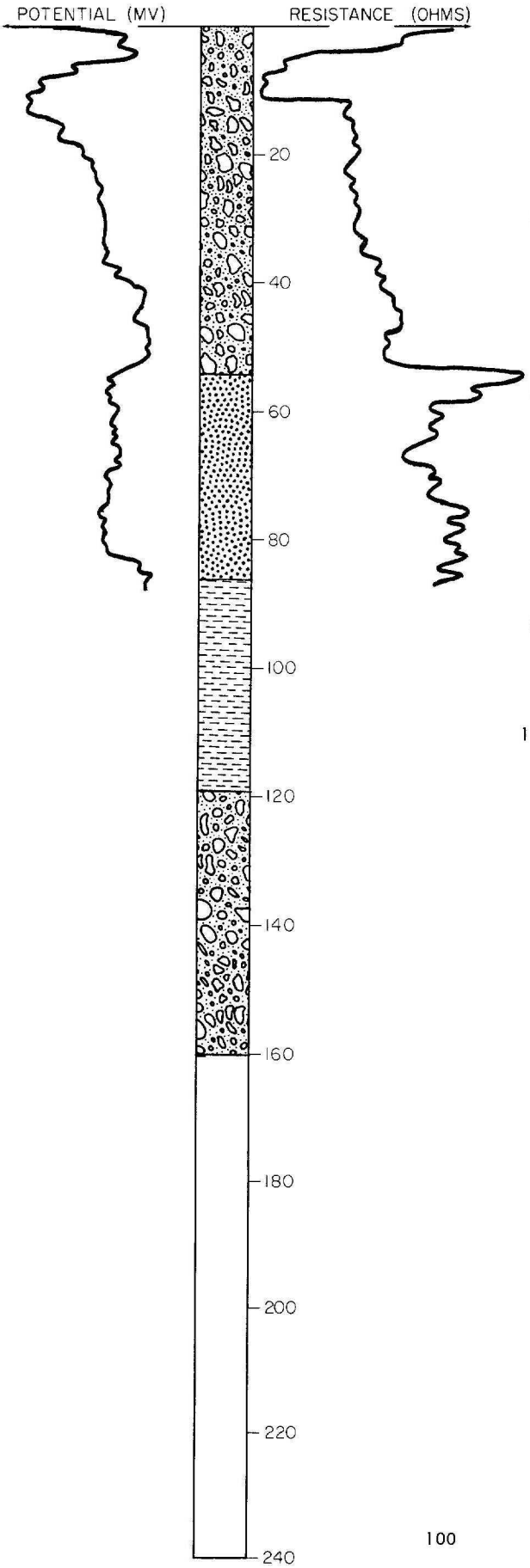
TEST HOLE 5624

LOCATION: 130-61-31bbb

DATE DRILLED: May 1970

ELEVATION: 1408
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, sandy, clayey, brownish-black.

1-27 Clay, silty, moderately sandy, pebbly, dusky-yellow to moderate-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till).

27-54 Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

54-86 Sand, slightly gravelly, (approximately 10-25 percent fine to coarse gravel), fine-to very coarse-grained, (mostly medium- to very coarse-grained), angular to subrounded, moderately well-sorted, approximately 25-45 percent shale, 5-15 percent carbonates, remaining portion mostly quartz and feldspar, taking some water.

86-119 Clay, very silty, olive-gray, occasional light-olive-gray laminations, very plastic, cohesive, calcareous (glaciofluvial sediment).

119-160 Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

Observation well
Depth 80 feet
Screened interval 77-80 feet

130-61-31ddd
Test Hole 5623
Elevation 1418 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, moderately sandy, brownish-black	1	1
	Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, slightly cohesive, plastic, oxidized (till)	30	31
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	19	50
	Sand, slightly clayey, fine-to coarse-grained, (mostly fine-to medium-grained), subangular to rounded, moderately well-sorted, mostly quartz and shale, some carbonates, lignitic	5	55
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, plastic (till)	10	65
	Sand, clayey, very fine-to medium-grained, fair sorting, subrounded, very "dirty-looking" samples, lignitic	4	69
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	19	88
	Sand, slightly gravelly, very fine- to very coarse-grained, subangular to rounded, moderately well-sorted, mostly quartz and shale, lignitic-	4	92
	Clay, very silty, olive-gray to medium-dark-gray, occasional light-olive-gray laminations, very plastic, cohesive, calcareous (glaciofluvial sediment)	41	133
	Clay, silty, slightly sandy, pebbly, gravelly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	144	277
Niobrara Formation:			
	Shale, silty, grayish-brown to brownish-black, indurated, occasional small white specks, slightly calcareous	23	300

130-62-10ddd
Test Hole 5629
Elevation 1415 feet

Glacial Drift:			
	Topsoil, silty, sandy, clayey, brownish-black	1	1
	Clay, silty, moderately sandy, pebbly, cobbles, boulders, moderate-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till)	23	24

130-62-10ddd (cont.)
Test Hole 5629
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Clay, silty, slightly sandy, occasional thin gravel lenses, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	50	74
	Sand, clayey, fine-to medium-grained, subangular to rounded, poorly sorted ----------	2	76
	Clay, silty, moderately sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous, (till) ----------	8	84
	Clay, silty, sandy, pebbly, numerous gravelly, sand lenses, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	7	91
	Sand, silty, clayey, very fine-to coarse-grained, (mostly fine-to medium-grained), subangular to rounded, poorly to moderately well-sorted, approximately 10-20 percent shale, remaining portion mostly quartz, lignitic ----------	15	106
	Clay, silty, slightly sandy, pebbly, occasional gravel lenses, a few cobbles, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	18	124
	Gravel, sandy, fine to medium, angular to subrounded, poorly sorted -----	4	128
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till) -------	32	160

Observation well
Depth 100 feet
Screened interval 97-100 feet

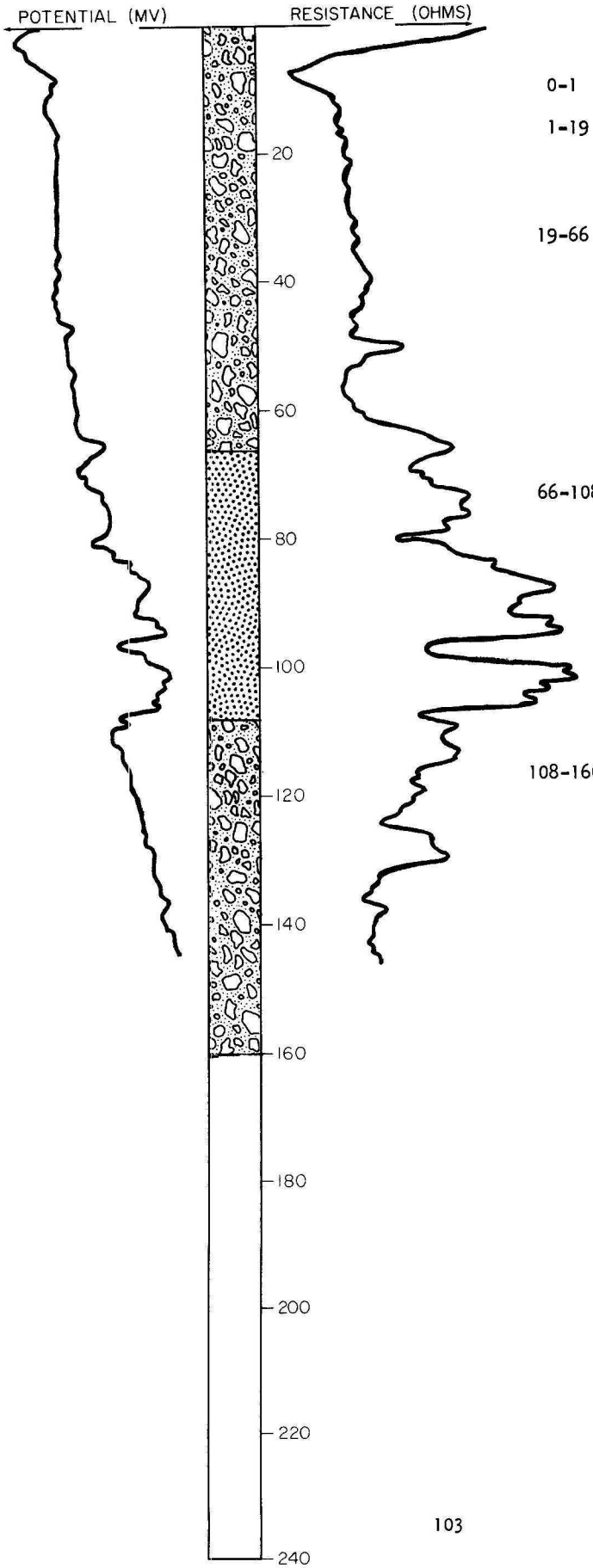
TEST HOLE 5628

LOCATION: 130-62-12ddd

DATE DRILLED: May 1970

ELEVATION: 1410
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, sandy, silty, clayey, brownish-black.

1-19 Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till).

19-66 Clay, silty, slightly sandy, occasional thin sand lenses, pebbly, olive-gray, moderately cohesive, plastic, calcareous (till).

66-108 Sand, slightly gravelly (fine gravel), fine-to very coarse-grained, (mostly medium-to coarse-grained), subangular to rounded, well-sorted, approximately 25-35 percent shale, remainder mostly quartz, feldspar, and carbonates.

108-160 Clay, silty, slightly sandy, pebbly, gravelly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

Observation well
Depth 100 feet
Screened interval 97-100 feet

130-62-15bbb
Test Hole 5630
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, sandy, brownish-black	1	1
	Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	11	12
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	66	78
	Sand, very silty, clayey, very fine- to medium-grained, (mostly fine-grained), subangular to rounded, fair sorting, mostly quartz and shale, lignitic	5	83
	Clay, silty, slightly sandy, pebbly, occasional cobbles and boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	151	234
Niobrara Formation:			
	Shale, siliceous, brownish-black to grayish-black, occasional small white specks and brownish concretions, moderately to slightly calcareous, indurated, bedded	26	260

130-62-22ddd
Test Hole 5259
Elevation 1407 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, slightly sandy, silty, clayey, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	18	19
	Clay, silty, sandy, pebbly, olive-gray to medium-dark-gray, cohesive, moderately plastic, moderately calcareous (till)	181	200

130-62-23ddc
Test Hole 5631
Elevation 1410 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, sandy, brownish-black	½	½

130-62-23ddc (cont.)
Test Hole 5631
Elevation 1410 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Clay, silty, slightly to moderately sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ---	16½	17
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	53	70
	Sand, moderately gravelly, very fine- to coarse-grained, (mostly fine-to medium-grained), subangular to rounded, well-sorted, approximately 15-25 percent shale, remaining portion mostly quartz and feldspar -------	38	108
	Clay, very silty, occasional thin sand lenses, olive-gray, occasional light-olive-gray laminations, very plastic, slightly cohesive, calcareous (glaciofluvial sediment)--	31	139
	Clay, silty, slightly sandy, pebbly, gravelly, olive-gray, cohesive, moderately plastic, calcareous (till) ----------	41	180

Observation well
Depth 80 feet
Screened interval 77-80 feet

130-62-24cdd
Test Hole 5260
Elevation 1415 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, sandy, clayey, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ---	24	25
	Gravel, slightly clayey, silty, sandy, (approximately 25-45 percent fine- to very coarse-grained, angular to subrounded sand), fine to coarse, angular to subrounded, fair sorting, approximately 20-30 percent shale, 30-45 percent carbonates, remainder mostly light-colored granitics, oxidized ----------	30	55
	Clay, silty, slightly sandy, pebbly, a few cobbles, occasional thin gravel lenses, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	25	80
	Silt, moderately sandy, olive-gray to dark-greenish-gray, slightly cohesive, plastic, calcareous, silt fraction washing out, poor samples --------	35	115
	Clay, silty, slightly sandy, pebbly, occasional thin gravel lenses, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	85	200

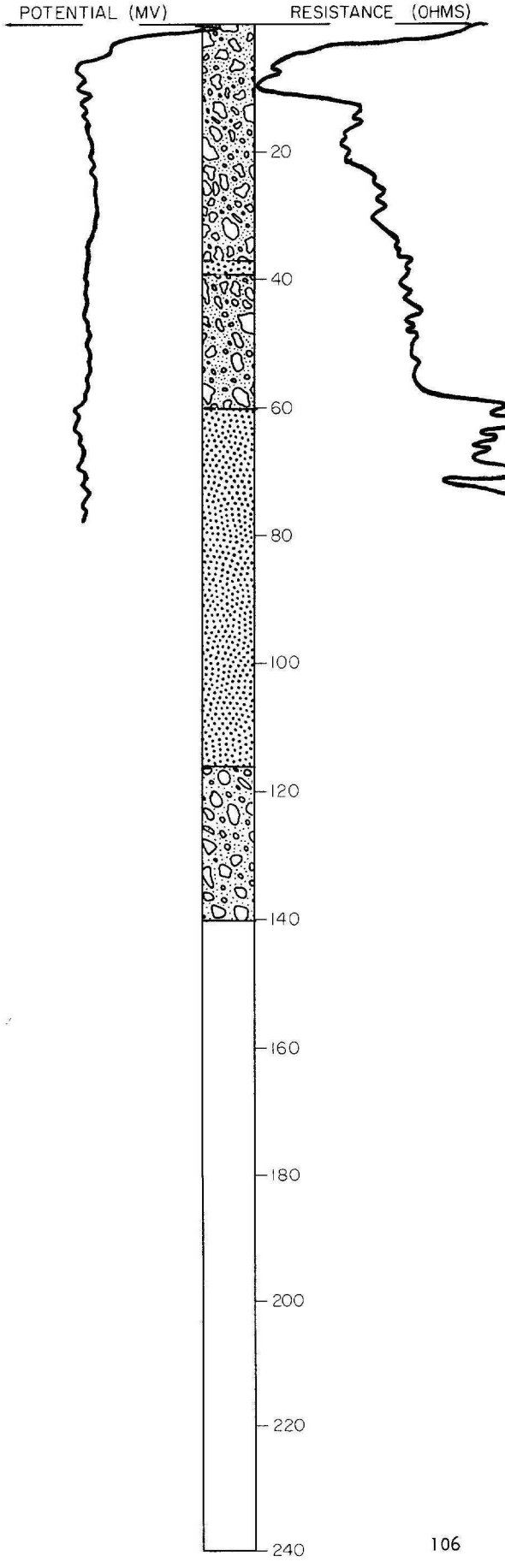
TEST HOLE 5646

LOCATION: 130-62-25ccd

DATE DRILLED: May 1970

ELEVATION: 1401
(FT, MSL)

DEPTH: 140
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Topsoil, silty, sandy, pebbly, brownish-black.
1-16	Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till).
16-37	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).
37-39	Sand, fine-to coarse-grained, subangular, moderately well-sorted.
39-60	Clay, silty, moderately sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).
60-116	Sand, very slightly gravelly, occasional thin clay lenses lower 30 feet of section, very fine-to very coarse-grained, (medium-to very coarse-grained from 60-80 feet and fine-to medium-grained from 80-116 feet), subangular to rounded, well-sorted, approximately 15-20 percent shale, remaining portion mostly quartz and feldspar, slightly lignitic, "clean-looking" samples, taking some water.
116-140	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till).

Observation well
Depth 70 feet
Screened interval 67-70 feet

130-62-25dab
Test Hole 5261
Elevation 1396 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, sandy, silty, clayey, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till) ----------	14	15
	Clay, silty, sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till) ----------	25	40
	Gravel, moderately sandy, slightly silty, fine to medium, angular to subrounded, fair sorting, mostly shale and carbonates, some granitics ----------	2	42
	Clay, silty, moderately sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)-	3	45
	Sand, gravelly (approximately 15-30 percent fine to medium, angular to subrounded gravel), fine-to very coarse-grained, moderately well-sorted, approximately 30-50 percent shale, 15-20 percent carbonates, remainder quartz, light colored granitics, chalcedony and small percent lignite --------	25	70
	Gravel, sandy (approximately 25-45 percent fine-to very coarse- grained, subangular to subrounded sand), fine grading to coarse, angular to rounded, fair sorting, approximately 30-40 percent shale, 20-30 percent light colored granitics, remainder mostly carbonates, small percent lignite ----------	11	81
	Clay, very silty, olive-gray to dark-greenish-gray with light-olive-gray laminations, very plastic, calcareous (glaciofluvial sediment) ---------	29	110
	Gravel, slightly sandy, fine to medium, angular to subrounded, poorly sorted, mostly carbonates and light colored granitics, some shale ----------	4	114
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous, occasional thin gravel lenses ----------	86	200

Observation well
Depth 60 feet
Screened interval 57-60 feet

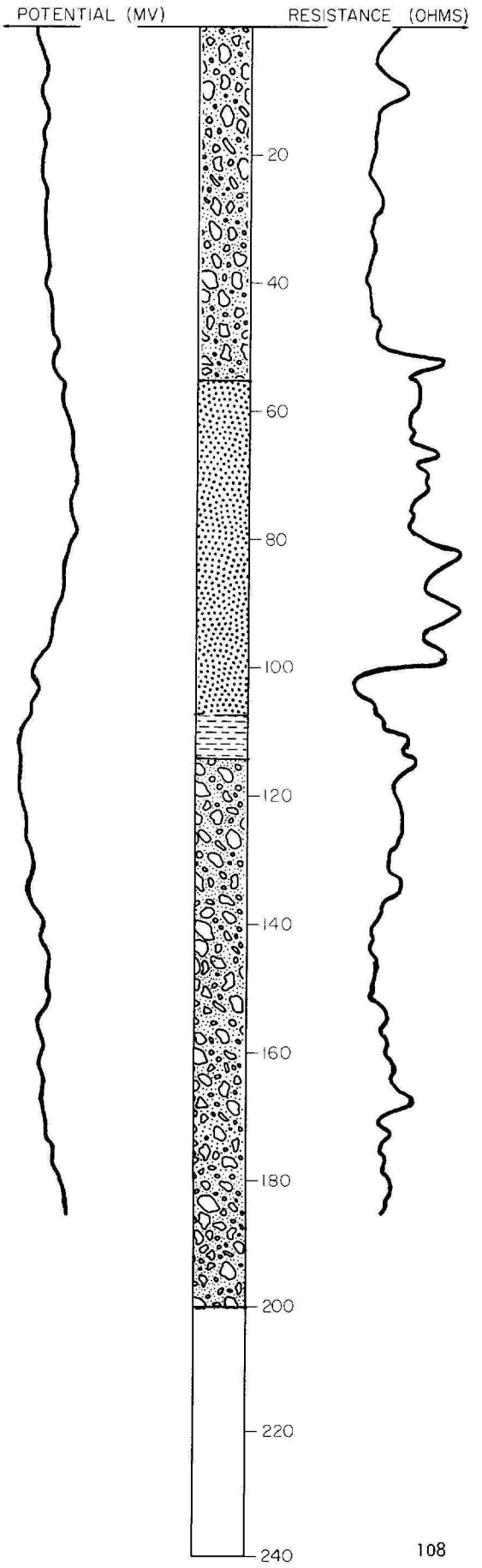
TEST HOLE 5256

LOCATION: 130-62-25dcc

DATE DRILLED: December 1968

ELEVATION: 1410
(FT, MSL)

DEPTH: 200
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, slightly sandy, silty, clayey, brownish-black.

1-12 Clay, silty, slightly sandy, pebbly, very slightly gravelly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till).

12-55 Clay, silty, slightly sandy, numerous pebbles, olive-gray to medium dark-gray, moderately cohesive, moderately plastic, calcareous (till).

55-107 Sand, slightly silty, very slightly gravelly, very fine- to very coarse-grained, sub-angular to rounded, moderately well-sorted, approximately 30-40 percent shale, 40-50 percent quartz, remainder mostly carbonates, taking water.

107-114 Silt, slightly clayey, olive-gray to dark-greenish-gray, slightly cohesive, slightly plastic, silt fraction washing out, poor samples (glaciofluvial sediment).

114-200 Clay, silty, slightly sandy, pebbly, occasional thin gravel lenses, olive-gray, cohesive, slightly plastic, calcareous (till).

Observation well
Depth 100 feet
Screened interval 97-100 feet

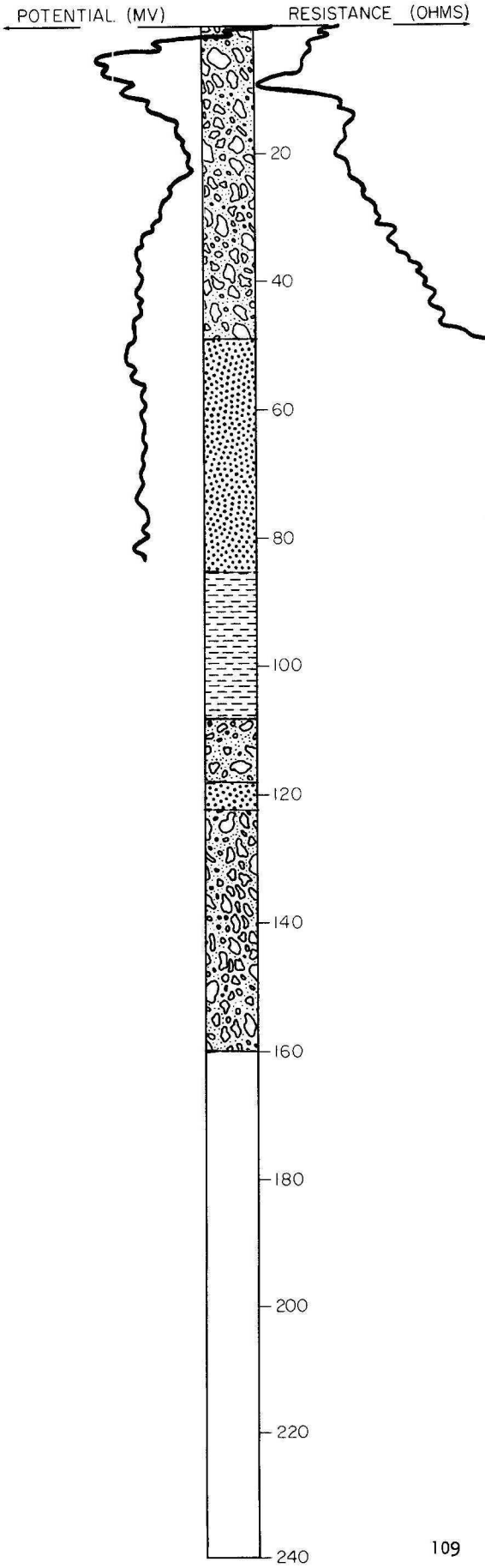
TEST HOLE 5645

LOCATION: 130-62-25dcd

DATE DRILLED: May 1970

ELEVATION: 1406
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, sandy, pebbly, brownish-black.

1-14 Clay, silty, moderately sandy, pebbly, dusky-yellow to moderate-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till).

14-49 Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

49-58 Gravel, sandy, fine to coarse, (mostly fine to medium), subangular to rounded, moderately well-sorted, approximately 15-25 percent shale, 30-40 percent carbonates, remaining portion granitics, metamorphics, and other siliceous rocks, slightly lignitic, taking some water.

58-85 Sand, slightly gravelly, fine- to very coarse-grained, (mostly medium-to very coarse-grained), subangular to rounded, well-sorted, approximately 20-30 percent shale, remaining portion mostly quartz and feldspar, some carbonates, lignitic, "clean-looking" samples, taking some water.

85-108 Clay, very silty, moderately sandy, olive-gray, occasional light-olive-gray laminations, very plastic, slightly cohesive, calcareous, (glaciofluvial sediment).

108-118 Clay, silty, moderately sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

118-122 Sand, moderately gravelly, fine- to very coarse-grained, (mostly coarse-to very coarse-grained), angular to subrounded, moderately well-sorted, mostly quartz and carbonates, some shale.

122-160 Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

Observation well
Depth 70 feet
Screened interval 67-70 feet

130-62-26ccc
Test Hole 5255
Elevation 1405 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, slightly sandy, brownish-black ----------	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ---	13	14
	Sand, very clayey, slightly, gravelly, angular to subangular, fair sorting, medium-to very coarse-grained, mostly quartz and granitics, some carbonates, oxidized --	1	15
	Clay, silty, slightly sandy, pebbly, occasional thin gravel lenses, a few cobbles, olive-gray, cohesive to moderately cohesive, plastic, moderately calcareous (till)-	135	150
	Gravel, sandy (approximately 25-35 percent medium-to very coarse-grained sand), a few clay lenses, fine to medium, angular to rounded, fair sorting, approximately 50-60 percent carbonates, remainder mostly shale and light colored granitics, a few conglomerate pebbles and lignite, taking water ---	16	166
	Clay, silty, slightly sandy, pebbly, numerous thin gravel lenses, a few cobbles, olive-gray, moderately plastic, calcareous (till)--	54	220

Observation well
Depth 160 feet
Screened interval 157-160 feet

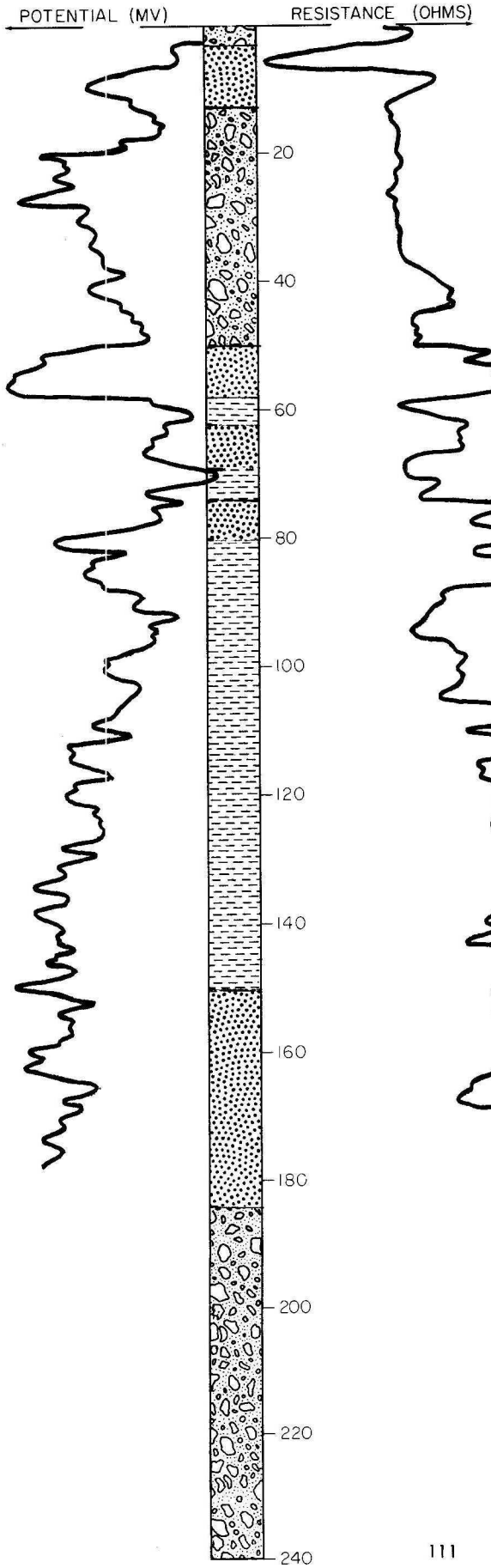
TEST HOLE 5147

LOCATION: 130-62-26dcc

DATE DRILLED: August 1968

ELEVATION: 1390
(FT, MSL)

DEPTH: 300
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, slightly sandy, pebbly, black.

1-3 Clay, very silty, moderately sandy, moderate-yellowish-brown to dark-yellowish-brown, slightly cohesive, slightly plastic, oxidized (till).

3-13 Sand, slightly gravelly, interbedded with clay lenses, fine- to very coarse-grained, angular to subrounded, poorly sorted, mostly shale and quartz.

13-50 Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

50-58 Sand, very silty, interbedded with clay lenses, very fine-to fine-grained, subangular to subrounded, well-sorted, predominantly quartz and shale, <20 percent carbonates.

58-62 Clay, extremely silty, slightly sandy, olive-gray to medium-dark-gray, slightly cohesive, semi-plastic, very calcareous, silt fraction washing out (glaciofluvial sediment).

62-69 Sand, silty, thinly interbedded with clay, very fine-to fine-grained, subangular to rounded, moderately well-sorted, mostly quartz and shale, some carbonates, taking water.

69-74 Clay, very silty, moderately sandy, brownish-gray, slightly cohesive, semi-plastic, silt fraction washing out (glaciofluvial sediment).

74-80 Sand, clayey, silty to extremely silty, very fine-to medium-grained, subangular to subrounded, moderately well-sorted, mostly shale and quartz, <30 percent carbonates.

80-150 Clay, extremely silty, interbedded with very fine-to coarse-grained sand throughout section, olive-gray to medium-dark-gray, slightly cohesive, samples washing out (glaciofluvial sediment).

150-169 Gravel, sandy, slightly silty, slightly clayey, (approximately 25-35 percent medium-to very coarse-grained, subangular to subrounded sand), fine to coarse, becomes more coarse with depth, angular to subrounded, moderately well-sorted, approximately 60-70 percent shale, remainder carbonates, granitics and lignite, rapidly taking water.

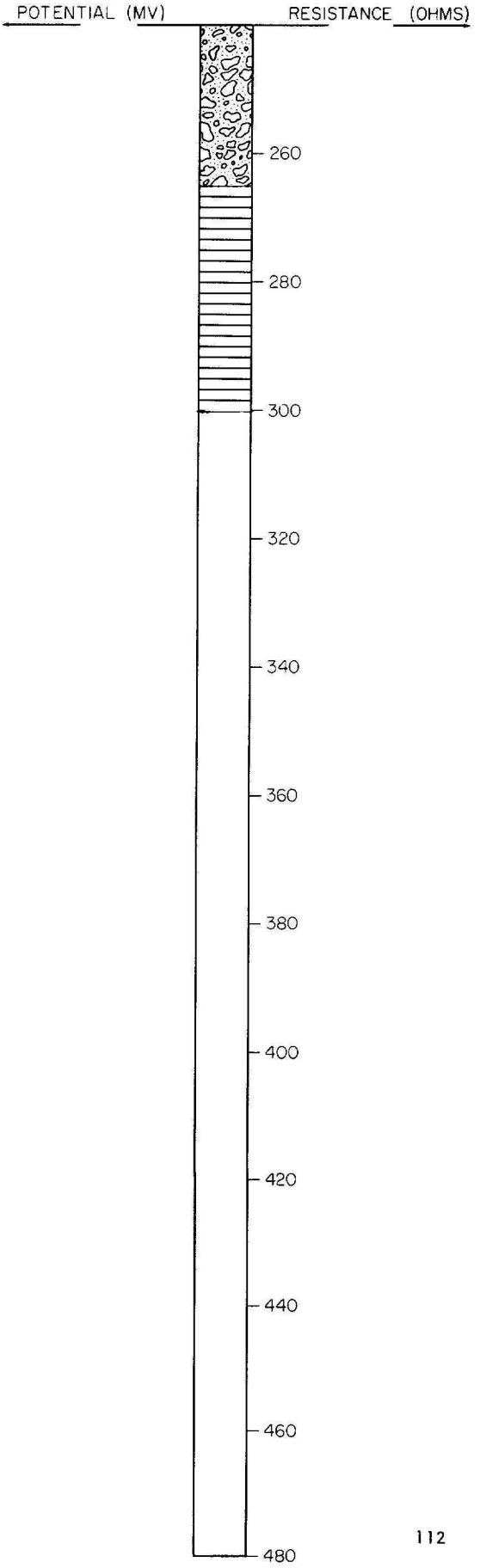
TEST HOLE 5147 (cont.)

LOCATION: 130-62-26dcc

DATE DRILLED: August 1968

ELEVATION: 1390
(FT, MSL)

DEPTH: 300
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift (Cont.)

169-184 Gravel, sandy (approximately 20-30 percent coarse-to very coarse-grained, angular to sub-rounded sand), fine to coarse, subangular to subrounded, well-sorted, approximately 65-75 percent carbonates, remainder shale and granitics, some lignite, taking water.

184-265 Clay, silty, pebbly, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous (till).

Niobrara Formation

265-300 Shale, grayish-brown with numerous moderate-brown concretions, numerous white specks, slightly calcareous, indurated, laminated.

Observation well
Depth 180 feet
Screened interval 177-180 feet

Flowing well - plugged and abandoned 9-6-68

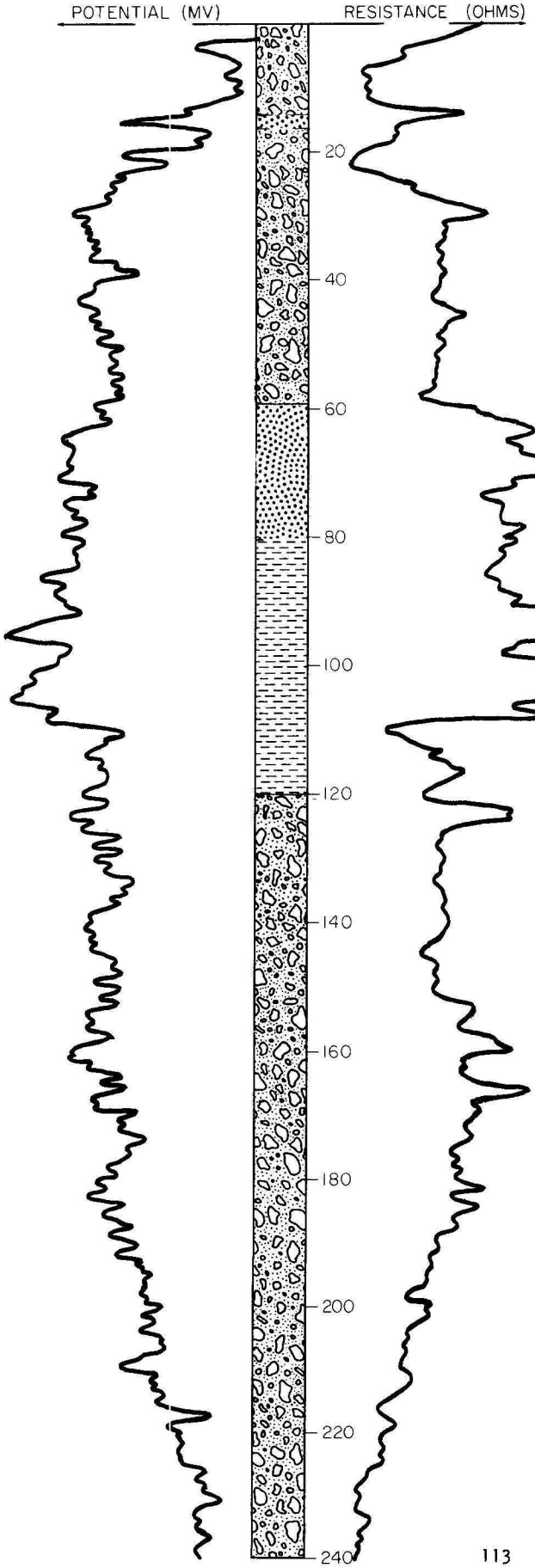
TEST HOLE 5148

LOCATION: 130-62-26ddd

DATE DRILLED: August 1968

ELEVATION: 1405
(FT, MSL)

DEPTH: 300
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Topsoil, silty, slightly sandy, clayey, dark-yellowish-brown.
1-14	Clay, very silty, sandy, pebbly, dusky-yellow to moderate-yellowish-brown, slightly to moderately cohesive, plastic, oxidized (till).
14-16	Sand, silty, clayey, fine-to coarse-grained, angular to subrounded, fair sorting, mostly shale and quartz, poor samples.
16-59	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till).
59-72	Gravel, sandy, (approximately 25-35 percent medium-to very coarse-grained subangular to subrounded sand), fine to coarse, angular to subrounded, fair sorting, approximately 60-70 percent carbonates, remainder shale and light colored granitics, very small percent lignite, taking water.
72-80	Gravel, sandy, interbedded with lenses of silty clay, fine to medium, poorly sorted, angular to subangular, taking some water.
80-120	Silt, slightly clayey, interbedded with lenses of very fine-to medium-grained, subangular to rounded, predominantly quartz sand, taking some water, silt and clay washed out, poor samples (glaciofluvial sediment).
120-272	Clay, silty, pebbly, occasional gravel lenses, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous (till).

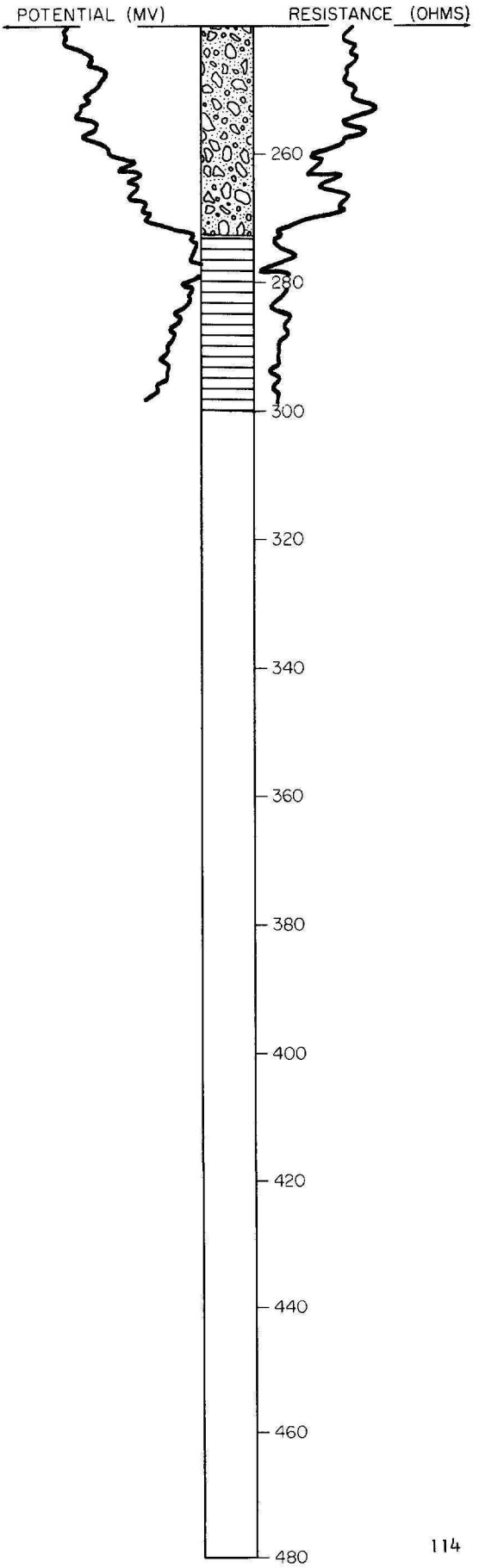
TEST HOLE 5148 (cont.)

LOCATION: 130-62-26ddd

DATE DRILLED: August 1968

ELEVATION: 1405
(FT, MSL)

DEPTH: 300
(FT)



DESCRIPTION OF DEPOSITS

Niobrara Formation

272-300 Shale, brownish-black to dusky-brown with numerous moderate-brown concretions, slightly calcareous, indurated, laminated.

Observation well
Depth 70 feet
Screened interval 67-70 feet

130-62-27daa
Test Hole 5632
Elevation 1410 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, slightly sandy, black	1	1
	Clay, silty, sandy, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	21	22
	Sand, gravelly, fine-to very coarse-grained, subangular, poorly sorted, mostly carbonates, oxidized	3	25
	Clay, silty, slightly sandy, pebbly, cobbles and boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	102	127
	Clay, silty, sandy, very gravelly, numerous cobbles and boulders, olive-gray, cohesive, moderately plastic, calcareous (till)	13	140

130-62-30ddc
Test Hole 5160
Elevation 1420 feet

Glacial Drift:			
	Topsoil silty, pebbly, brownish-black	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	6	7
	Sand, silty, clayey, fine-to coarse-grained, angular to subrounded, poorly sorted, mostly carbonates, some granitics, oxidized	2	9
	Clay, silty, pebbly, dark-yellowish-brown to olive-gray, moderately cohesive, moderately plastic, calcareous (till)	5	14
	Sand, very fine-to medium-grained, angular to subrounded, moderately well-sorted, mostly quartz and shale, small percent carbonates and lignite	5	19
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	21	40

130-62-30ddd
Test Hole 5161
Elevation 1418 feet

Glacial Drift:			
	Topsoil, silty, slightly sandy, pebbly, brownish-black	1	1

130-62-30ddd (cont.)
Test Hole 5161
Elevation 1418 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ---	6	7
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	53	60

130-62-34daa
Test Hole 5633
Elevation 1403 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, sandy, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, a few cobbles, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till) ----------	14	15
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, cohesive, plastic, calcareous (till) ----------	165	180

130-62-35dbd
Test Hole 5258
Elevation 1402 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, sandy, silty, gravelly, brownish-black ----------	1	1
	Gravel, sandy, clayey, silty (approximately 35-45 percent fine-to very coarse-grained, angular to subrounded sand), fine to medium angular to subrounded, approximately 50-60 percent carbonates, remainder light colored granitics, shale and sandstone, oxidized, stratified ----------	19	20
	Sand, gravelly, slightly clayey, (approximately 20-30 percent fine gravel), fine-to very coarse-grained, angular to subrounded, fair sorting, becomes more gravelly with depth, approximately 30-40 percent shale, 40-50 percent quartz, remainder mostly carbonates and granitics ----------	11	31
	Gravel, sandy, very slightly silty and clayey, approximately 15-35 percent sand with sand content decreasing with depth, fine to coarse, angular to subrounded, fair sorting, approximately 60-70		

130-62-35dbd (cont.)
Test Hole 5258
Elevation 1402 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	percent shale, remainder mostly carbonates and granitics ---------	11	42
	Clay, silty, slightly sandy, pebbly, a few cobbles, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	48	90
	Silt, clayey, interbedded with very fine-to medium-grained sand, olive-gray to dark greenish-gray, calcareous, silt fraction washing out (glaciofluvial sediment) -----	59	149
	Clay, silty, slightly to moderately sandy, pebbly, occasional thin gravelly lenses, olive-gray, cohesive, moderately plastic, moderately calcareous (till) --------	51	200

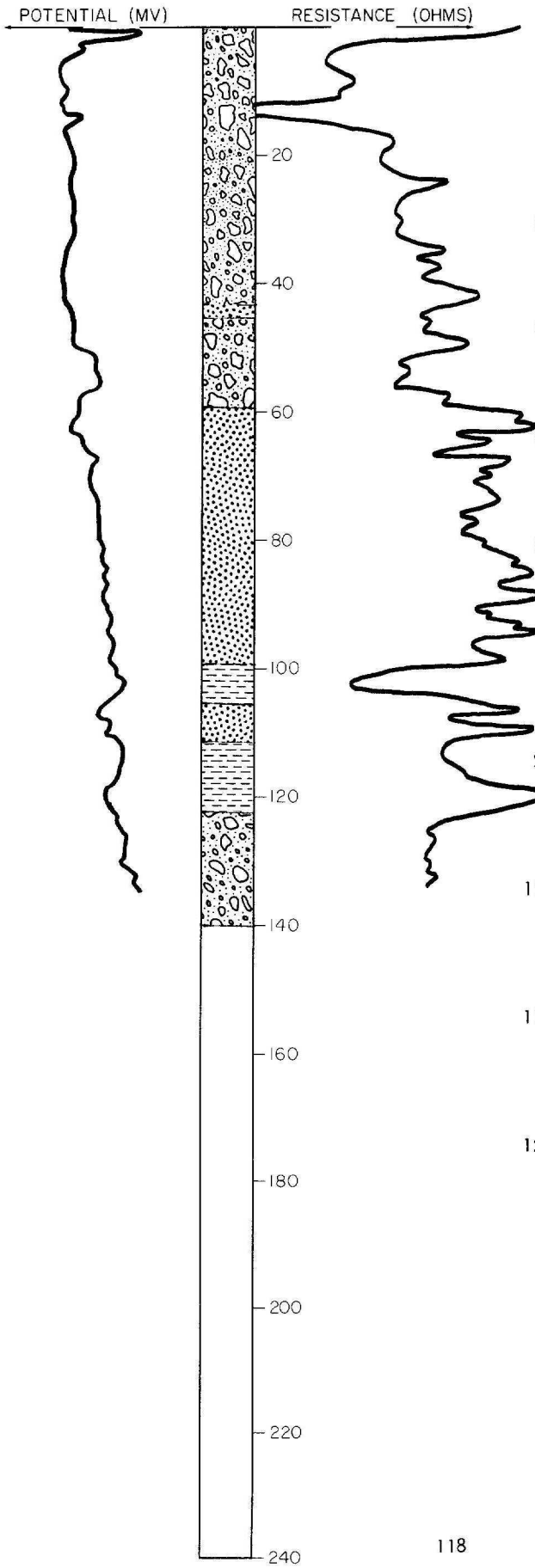
TEST HOLE 5647

LOCATION: 130-62-36ccb$_1$

DATE DRILLED: May 1970

ELEVATION: 1399
(FT, MSL)

DEPTH: 140
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, sandy, clayey, brownish-black.

1-20 Clay, silty, moderately sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, slightly plastic, oxidized (till).

20-43 Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till).

43-45 Gravel, moderately sandy, fine to coarse, (mostly fine), angular to subrounded, poorly sorted, slightly oxidized, mostly carbonates.

45-59 Clay, silty, slightly sandy, pebbly, numerous cobbles and boulders, olive-gray, cohesive, moderately plastic, calcareous (till).

59-99 Sand, very slightly gravelly, (fine gravel), very fine-to very coarse-grained, (mostly medium-to coarse-grained), subangular to rounded, well-sorted, approximately 20-30 percent shale, remaining portion mostly quartz and feldspar, some carbonates, very slightly lignitic, taking some water.

99-105 Clay, very silty, sandy, occasional thin gravel lenses, olive-gray, a few light-olive-gray laminations, slightly cohesive, plastic, calcareous, (glaciofluvial sediment).

105-111 Gravel, silty, occasional silty clay lenses, fine to coarse, subangular to rounded, moderately well-sorted, mostly carbonates, some shale and granitics.

111-122 Clay, very silty, sandy, olive-gray, occasional light-olive-gray laminations, moderately cohesive, moderately plastic, calcareous (glaciofluvial sediment).

122-140 Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till).

Observation well
Depth 80 feet
Screened interval 77-80 feet

130-62-36ccb$_2$
Test Hole 5649
Elevation 1401 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, sandy, clayey, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	18	19
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	24	43
	Sand, slightly gravelly, (mostly fine), fine-to very coarse-grained, (mostly coarse-to very coarse-grained), subangular to rounded, moderately well-sorted ----------	3	46
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, cohesive, slightly plastic calcareous (till) ----------	9	55
	Sand, very fine-to very coarse-grained, (mostly medium-to coarse-grained), subangular to rounded, well-sorted, approximately 20-30 percent shale, remaining portion mostly quartz and carbonates, lignitic ----------	46	101
	Clay, very silty, sandy, occasional thin sandy, gravel lenses, olive-gray, occasional light-olive-gray laminations, plastic, slightly cohesive, calcareous (glacio-fluvial sediment) ----------	12	113
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	27	140

Observation well
Depth 83 feet
Screened interval 77-83 feet

130-62-36ccb$_3$
Test Well
Elevation 1399 feet

Clay, (till) ----------	58	58
Sand, medium-to coarse-grained, (becomes finer with depth) ----------	13	71
Sand, occasional silty clay laminations, very fine-grained --------	17	88
Sand, occasional silty clay lenses, fine-to coarse-grained, (mostly medium-grained), rounded, well-sorted ----------	13	101
Clay, silty, olive-gray ----------	2	103

130-62-36ccb3 (cont.)
Test Well
Elevation 1399 feet

Formation	Lithology	Thickness (feet)	Depth
	Test well completed with 60 feet of 8-inch diameter steel casing and 40 feet of 6-inch diameter, #12 slot screen. Screened interval from 60-100 feet below land surface. Casing and screen pulled and well was abandoned after test.		

130-62-36ccd
Test Hole 5648
Elevation 1400 feet

Glacial Drift:			
	Topsoil, silty, sandy, clayey, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till) ----------	18	19
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	25	44
	Gravel, slightly sandy, silty, fine to coarse, subangular to rounded, fair sorting, mostly carbonates, some shale, granitics, metamorphics, and siliceous rocks ----------	3	47
	Clay, silty, slightly sandy, pebbly, numerous cobbles and boulders, olive-gray, moderately cohesive, moderately plastic calcareous (till) ----------	13	59
	Sand, very slightly gravelly, occasional silty, sandy, clay lenses, very fine-to coarse-grained (mostly medium-grained), subangular to rounded, moderately well-sorted, approximately 25-35 percent shale, remaining portion mostly quartz and feldspar, some carbonates, lignitic ----------	43	102
	Clay, very silty, sandy, occasional thin gravelly, sand lenses, olive-gray, occasional light-olive-gray laminations, cohesive, plastic, (glaciofluvial sediment) ----------	10	112
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	28	140

Observation well
Depth 83 feet
Screened interval 77-83 feet

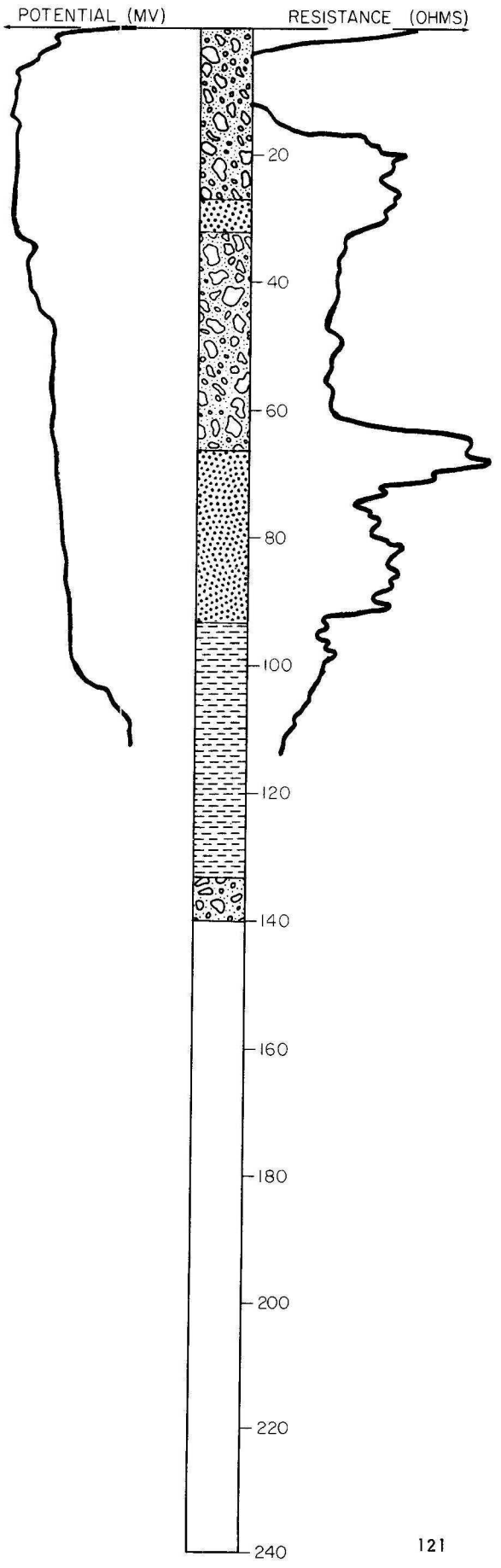
TEST HOLE 5643

LOCATION: 130-62-36daa$_1$

DATE DRILLED: May 1970

ELEVATION: 14·0
(FT, MSL)

DEPTH: 140
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Topsoil, silty, sandy, clayey, brownish-black.
1-17	Clay, silty, moderately sandy, pebbly, cobbles, boulders, moderate-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till).
17-27	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till).
27-32	Sand, slightly gravelly, fine-to very coarse-grained, angular to subrounded, moderately well-sorted, mostly quartz and shale.
32-66	Clay, silty, slightly sandy, pebbly, olive-gray, moderately plastic, moderately cohesive, calcareous (till).
66-70	Gravel, moderately sandy, fine to medium, (mostly fine), angular to rounded, moderately well-sorted, mostly carbonates and shale.
70-93	Sand, occasional thin clay lenses, very fine-to very coarse-grained, (mostly medium-to coarse-grained), subangular to rounded, well-sorted, approximately 15-25 percent shale, 10-20 percent carbonates, remaining portion mostly quartz and feldspar, lignitic.
93-133	Clay, very silty, olive-gray, occasional light-olive-gray laminations, very plastic, cohesive, calcareous (glaciofluvial sediment).
133-140	Clay, silty, slightly sandy, pebbly, olive gray, moderately cohesive, moderately plastic, calcareous (till).

Observation well
Depth 80 feet
Screened interval 77-80 feet

130-62-36daa2
Test Hole 5644
Elevation 1405 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, silty, clayey, sandy, brownish-black ----------	1	1
	Clay, silty, moderately sandy, pebbly, moderate-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till) ----------	13	14
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	15	29
	Sand, moderately gravelly, (fine to coarse gravel), fine-to very coarse-grained, (mostly medium- to very coarse-grained), angular to subrounded, moderately well-sorted, approximately 20-30 percent shale, 15-20 percent carbonates, remaining portion mostly quartz and feldspar, taking some water --	7	36
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	39	75
	Clay, very silty, moderately sandy, olive-gray, occasional light-olive-gray laminations, very plastic, slightly cohesive, calcareous (glaciofluvial sediment) ---------	35	110
	Clay, silty, slightly sandy, pebbly, cobbles, boulders, olive-gray, cohesive, moderately plastic, calcareous (till) ----------	50	160

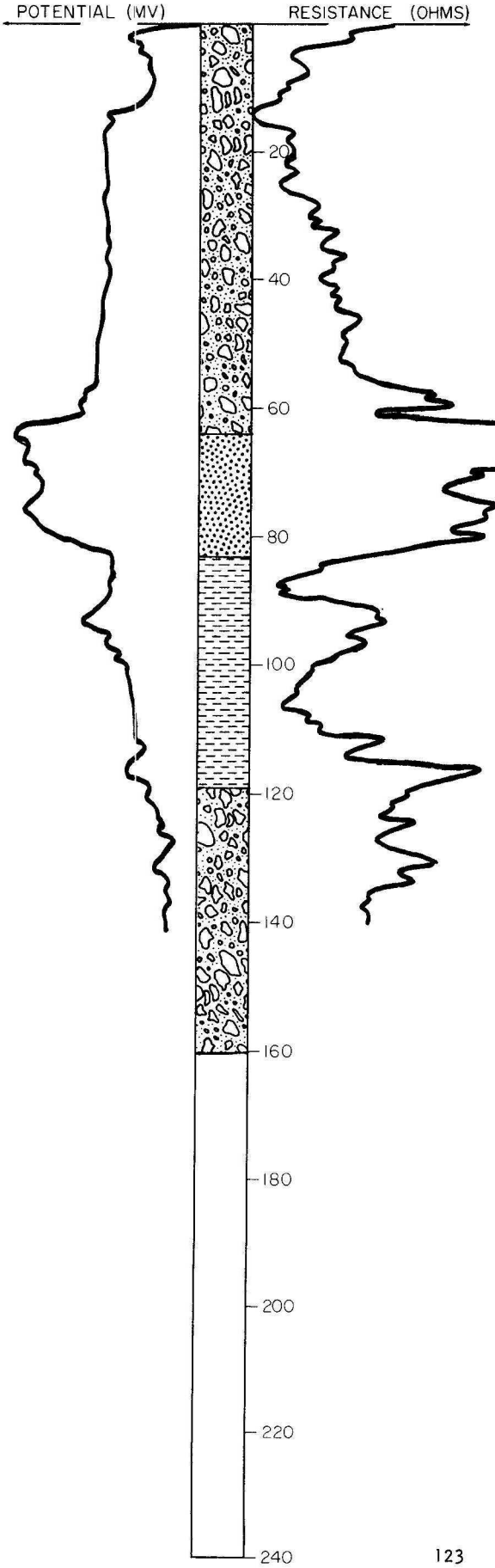
TEST HOLE 5622

LOCATION: 130-62-36ddd

DATE DRILLED: May 1970

ELEVATION: 1406
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, slightly sandy, brownish-black.

1-15 Clay, silty, slightly to moderately sandy, pebbly, moderate-yellowish-brown, slightly cohesive, moderately plastic, oxidized (till).

15-64 Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till).

64-83 Sand, gravelly, fine-to very coarse-grained, subangular to subrounded, moderately well-sorted, approximately 50-60 percent quartz, 10-20 percent shale, 10-20 percent carbonates and siliceous rocks.

83-119 Clay, very silty, olive-gray, occasional light-olive-gray laminations, cohesive, very plastic, calcareous (glacio-fluvial sediment).

119-160 Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till).

Observation well
Depth 80 feet
Screened interval 77-80 feet

130-63-23aaa
Test Hole 5111
Elevation 1467 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, clayey, sandy, silty, brownish-black	1	1
	Clay, moderately sandy, silty, pebbly, moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	14	15
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive to moderately cohesive, plastic to moderately plastic, calcareous (till)	102	117
Pierre Formation:			
	Shale, medium-dark-gray to grayish-black, very slightly siliceous, indurated, noncalcareous, non-fractured	43	160

130-63-25bbb
Test Hole 5112
Elevation 1461 feet

Glacial Drift:			
	Topsoil, silty, clayey, sandy, brownish-black	1	1
	Clay, slightly sandy, silty, pebbly, moderate-yellowish-brown, moderately cohesive, plastic, oxidized (till)	13	14
	Clay, silty, pebbly, olive-gray, moderately cohesive to cohesive, moderately plastic, calcareous (till)	34	48
	Sand, very fine-to fine-grained, subangular to subrounded, fair sorting, mostly quartz, some carbonates	1	49
	Clay, slightly sandy, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till)	9	58
	Sand, very fine-to fine-grained, subangular to subrounded, fair sorting, mostly quartz	2	60
	Clay, silty, very slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till)	64	124
Pierre Formation:			
	Shale, slightly siliceous, medium-dark-gray to grayish-black, indurated, noncalcareous, non-fractured, a few light-olive-gray bentonitic laminations	16	140

130-63-32aaa
Test Hole 5114
Elevation 1484 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Topsoil, sandy, clayey, silty, brownish-black	1	1
	Clay, slightly sandy, silty, occasional pebbles, moderate-yellowish-brown to dark-yellowish-brown, moderately cohesive, plastic, oxidized (till)	21	22
	Clay, sandy, silty, pebbly, olive-gray, moderately cohesive, plastic (till)	10	32
Pierre Formation:			
	Shale, slightly siliceous, medium-dark-gray to grayish-black, moderately indurated, noncalcareous, occasional thin light-olive-gray bentonitic laminations	48	80

130-63-35daa1
Test Hole 5176
Elevation 1450 feet

Glacial Drift:			
	Topsoil, silty, sandy, pebbly, brownish-black	1	1
	Clay, silty, slightly sandy, dusky-yellow to moderate-yellowish-brown, slightly to moderately cohesive, moderately plastic, oxidized (till)	8	9
	Clay, silty, pebbly, olive-gray, cohesive, plastic, calcareous (till)	10	19
	Gravel, fine to medium, angular to subrounded, moderately well-sorted, mostly carbonates and granitics, some shale	3	22
	Clay, silty, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till)	18	40

130-63-35daa2
Test Hole 5174
Elevation 1455 feet

Glacial Drift:			
	Topsoil, silty, sandy, pebbly, brownish-black	1	1
	Clay, silty, pebbly, slightly sandy, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, oxidized (till)	14	15

130-63-35daa$_2$ (cont.)
Test Hole 5174
Elevation 1455 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	4	19
	Sand, very fine-to medium-grained, angular to subrounded, well-sorted, mostly quartz and shale --	6	25
	Gravel, slightly sandy, fine to coarse, angular to subrounded, fair sorting, taking water -------	8	33
	Clay, silty, slightly sandy, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till) -------	7	40

130-63-35dad
Test Hole 5175
Elevation 1452 feet

Glacial Drift:	Topsoil, silty, sandy, clayey, brownish-black -------------------	1	1
	Clay, silty, slightly sandy, pebbly, dusky-yellow to moderate-yellowish-brown, moderately cohesive, moderately plastic, calcareous, oxidized (till) ------------------	13	14
	Clay, silty, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) -------	8	22
	Gravel, slightly sandy, fine to coarse, angular to subrounded, moderately well-sorted, mostly carbonates, some shale and granitics ------------------------	6	28
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------------------------	12	40

130-63-36bbb
Test Hole 5113
Elevation 1457 feet

Glacial Drift:	Topsoil, clayey, sandy, black ------	1	1
	Clay, slightly sandy, silty, pebbly, moderate-yellowish-brown, cohesive to moderately cohesive, moderately plastic, oxidized (till) -	14	15
	Clay, silty, pebbly, olive-gray, cohesive, moderately plastic, calcareous (till) ----------	29	44

130-63-36bbb (cont.)
Test Hole 5113
Elevation 1457 feet

Formation	Lithology	Thickness (feet)	Depth
Glacial Drift:			
	Sand, fine-to coarse-grained, angular to subrounded, moderately well-sorted, mostly carbonates, some shale and lignite ----------	5	49
	Clay, silty, slightly sandy, pebbly, olive-gray, moderately cohesive, moderately plastic, calcareous (till) ----------	2	51
	Gravel, silty, clayey, very slightly sandy, fine to medium, angular to subrounded, fair sorting, mostly carbonates, some granitics and shale, small percent lignite -----	4	55
	Clay, silty, pebbly, olive-gray, moderately cohesive to cohesive, plastic to slightly plastic, calcareous (till) ----------	73	128
Pierre Formation:			
	Shale, slightly siliceous, medium-dark gray to grayish-black, indurated, noncalcareous, nonfractured, a few light-olive-gray bentonitic laminations ------	12	140

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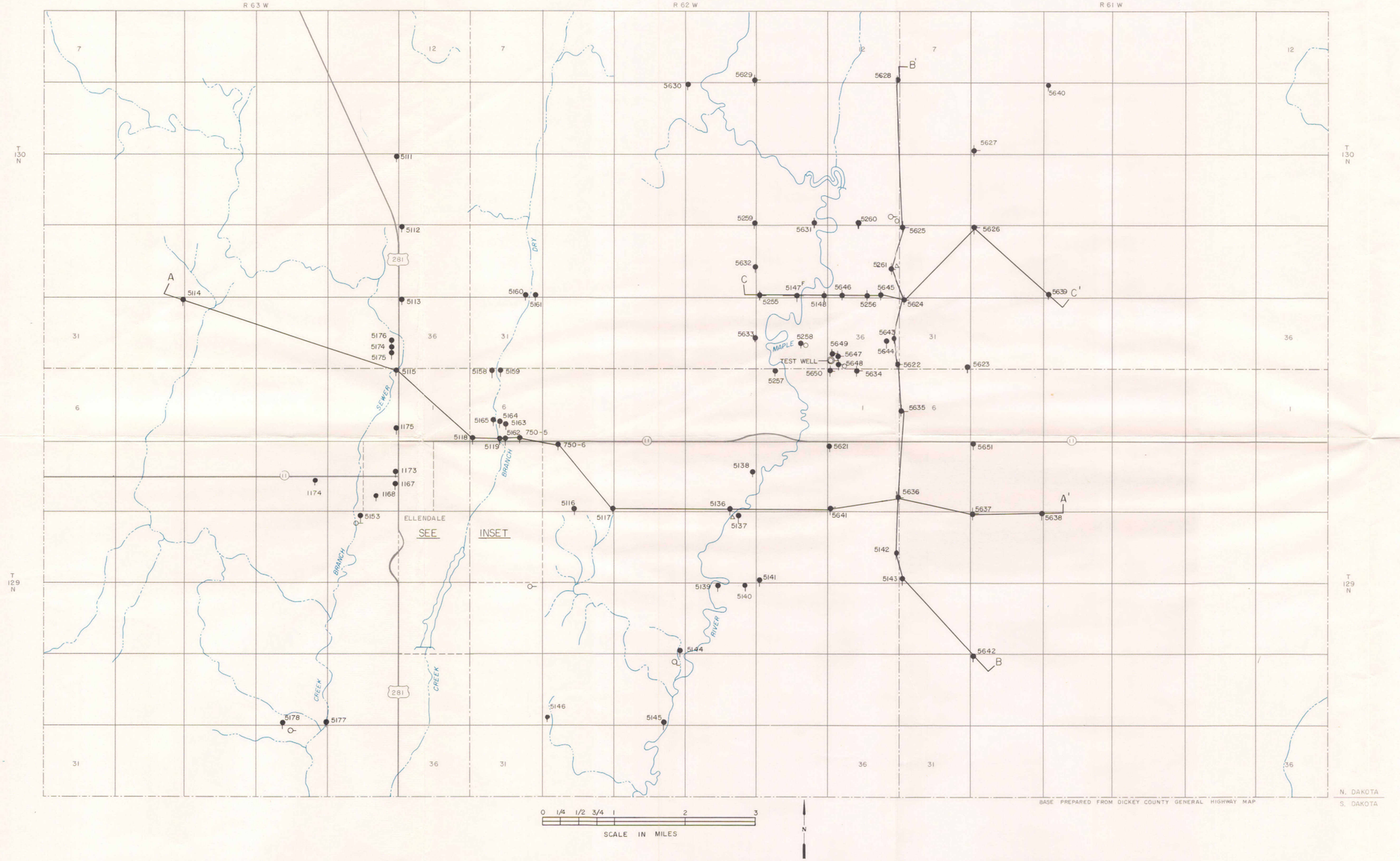

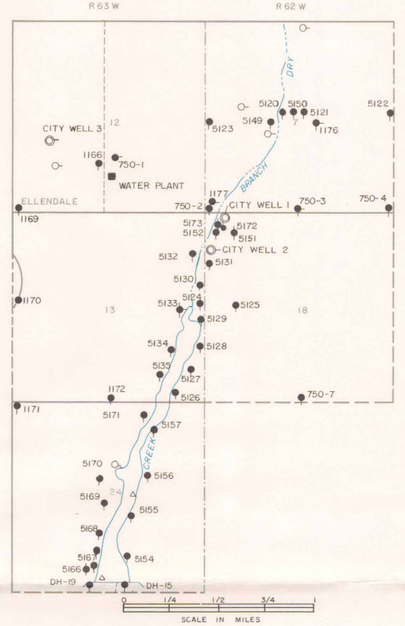

INSET

LEGEND

TEST HOLE AND NUMBER ● 5630

DOMESTIC OR STOCK WELL ○

CITY OR TEST WELL ◎

SPRING Q

GEOLOGIC CROSS SECTION A — A'

MODIFICATIONS USED WITH ABOVE SYMBOLS

WATER-LEVEL MEASUREMENTS IN TABLE 3 ●

LOG IN TABLE 4 ●

CHEMICAL ANALYSIS IN TABLE 2 ●

INDICATES FLOWING WELL ●F

CHEMICAL ANALYSIS OF SURFACE WATER △

PLATE 1 -- MAP OF THE ELLENDALE AREA SHOWING LOCATION OF WELLS, TEST HOLES, AND GEOLOGIC CROSS SECTIONS