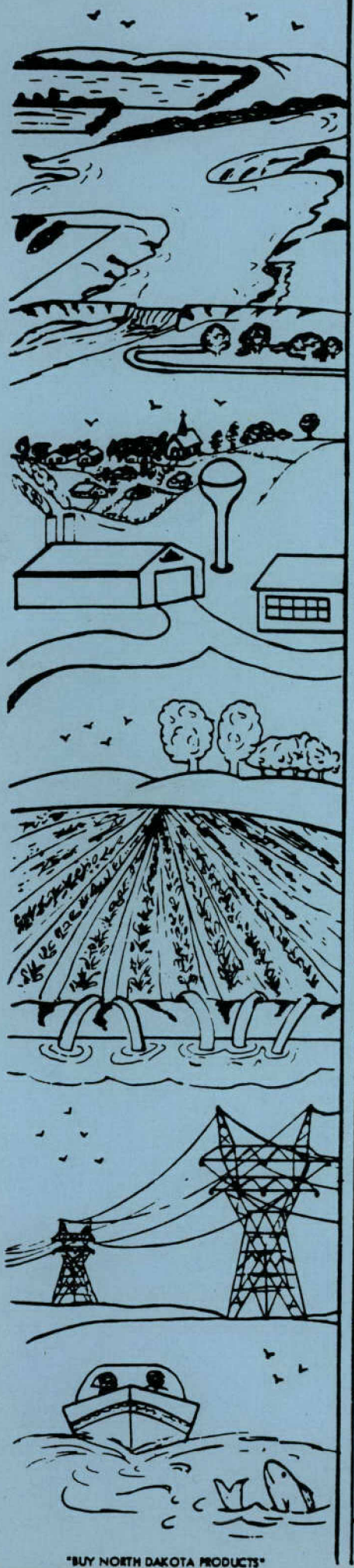


"BUY NORTH DAKOTA PRODUCTS"

Report of

NORTH DAKOTA STATE WATER COMMISSION

State Office Building

BISMARCK, NORTH DAKOTA

58501

GEOHYDROLOGY OF THE WASHBURN-WILTON AREA

BURLEIGH AND McLEAN COUNTIES, NORTH DAKOTA

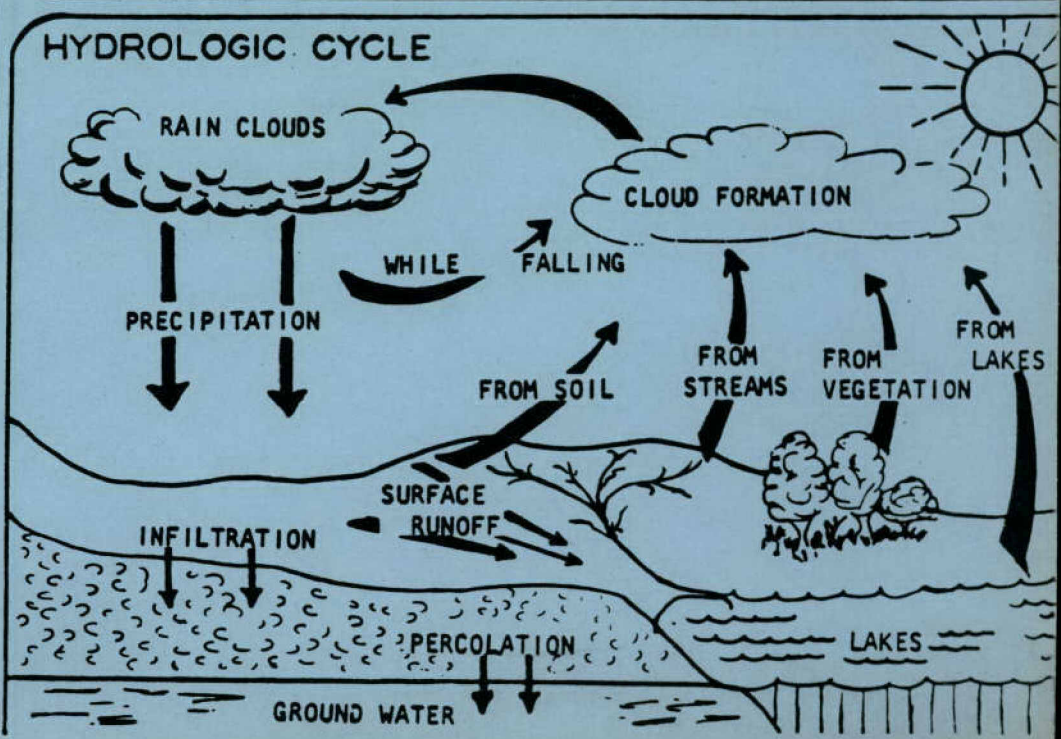
SWC PROJECTS NOS. 812 AND 1596

NORTH DAKOTA GROUND-WATER STUDIES

NO. 81

By
Charles E. Naplin
Ground-Water Geologist

-1979-



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State Office Building
900 Boulevard
Bismarck, North Dakota 58501

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GEOHYDROLOGY OF THE WASHBURN-WILTON AREA
BURLEIGH, McLEAN, AND OLIVER COUNTIES, NORTH DAKOTA

SWC Project Nos. 812 and 1596

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Charles E. Naplin, Ground-Water Geologist

INTRODUCTION

PURPOSE AND SCOPE

In the spring of 1973 the Washburn and Wilton City Councils passed resolutions requesting that the North Dakota State Water Commission conduct ground-water investigations for their respective cities. Requests for the studies were approved for Wilton on March 30, 1973 and for Washburn on September 5, 1973. The investigation consisted of data collected in two phases. Initial field work was conducted for Wilton during March and April, 1973 and additonal work was completed for Washburn in October and November, 1973.

A geohydrologic investigation of the area was accomplished by test drilling, installing observation wells, collecting water samples for chemical analysis, measuring water levels, and inventorying selected private wells. The basic data and information from additional sources was compiled and evaluated during December 1973 and January 1974.

ACKNOWLEDGEMENT

The test drilling was accomplished by Lewis Knutson using the state-owned hydraulic rotary drilling machine. All field work was under direct supervision of the author. Chemical analyses were performed by Garvin Muri, State Water Commission chemist, at the North Dakota State Laboratories Department in Bismarck. Special acknowledgement is extended

to Mayors James Stroup, Washburn, and Paul Bartholomew, Wilton, for their cooperation and assistance during this investigation.

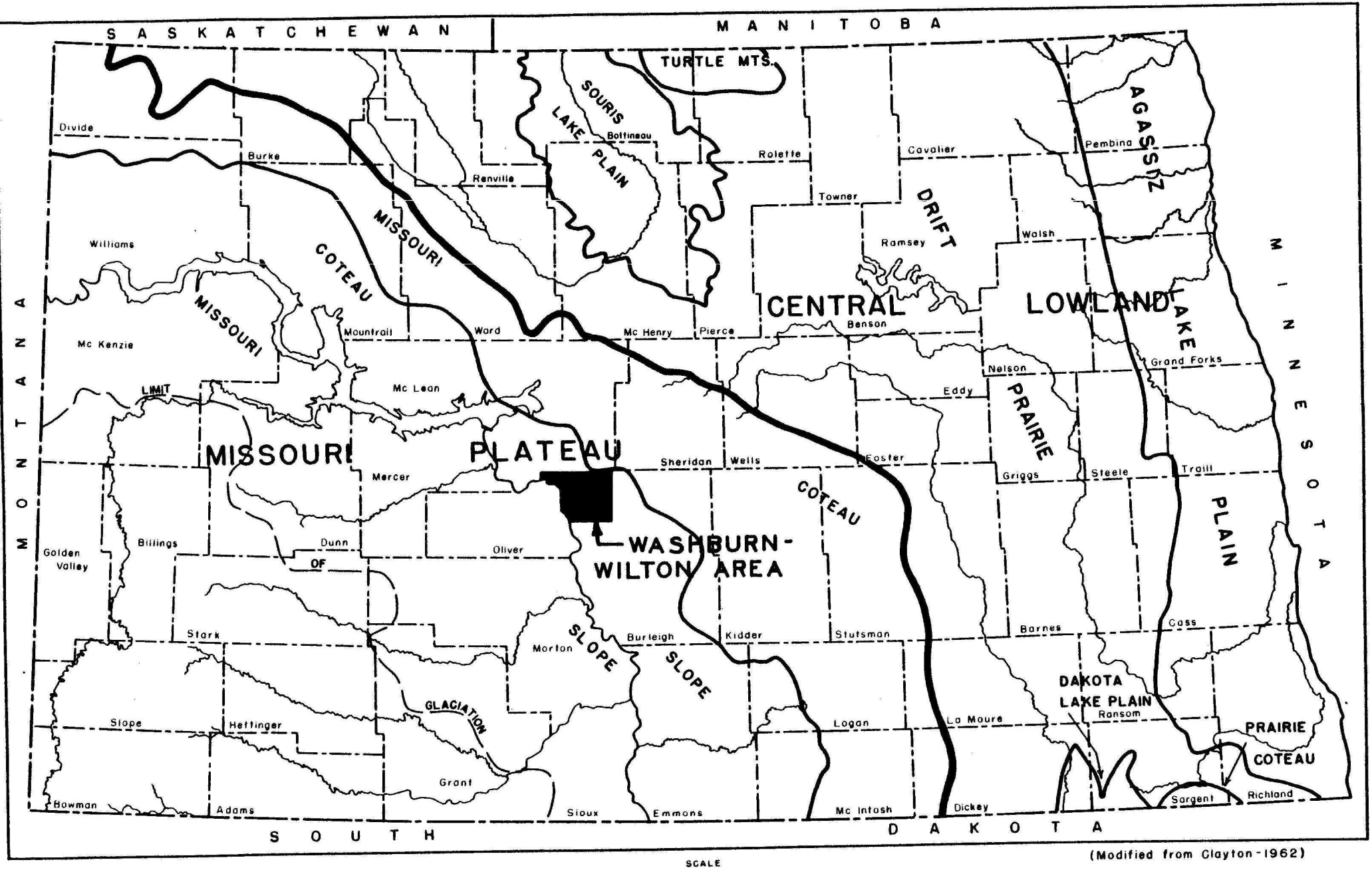
LOCATION AND GENERAL FEATURES

The study area is located in portions of northwestern Burleigh, southern McLean, and northeastern Oliver Counties and is within the Coteau Slope division of the Missouri plateau physiographic province of North Dakota (fig. 1). Geohydrologic data collected during this study and interpolated from previous investigations describe a 178 square mile area that includes all or portions of Townships 142, 143, and 144 North, Range 79, 80, 81, and 82 West (pl. 1).

Climatological data, based on a 32-year period of record at the National Weather Service station located 25 miles south of Wilton at Bismarck, shows the average annual temperature to be 42.2°F. Average annual precipitation for the same period of record was 15.15 inches (National Weather Service, 1971).

The Washburn-Wilton area is characterized by well-drained hilly topography. The major drainages in the study area are Turtle, Painted Woods, and Yanktonai Creeks. All of these flow into the Missouri River. Surface elevations range from less than 1,650 feet near the Missouri River to 2,230 feet southwest of Wilton.

Washburn (1970 population 804) and Wilton (1970 population 695) are agricultural communities. U.S. Highway 83, State Highway 200-A, and a branch line of the Soo Line Railroad serve the city of Washburn. Wilton is served by U.S. Highway 83, State Highway 36, and branch lines of the Soo Line and Burlington Northern railroads.



(Modified from Clayton-1962)

SCALE
0 10 20 30 40 MILES

FIGURE 1--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC PROVINCES AND LOCATION OF THE WASHBURN-WILTON AREA

PREVIOUS INVESTIGATIONS

The geology and ground-water resources of Burleigh, McLean, and Oliver Counties were described in general terms by Simpson (1929). His report lists an inventory of typical private and municipal wells and a few chemical analyses. Simpson concentrated on describing the bedrock geology of the Fort Union Group and discusses several springs that issue from lignite beds exposed along the Missouri Valley.

A more detailed ground-water study of the Wilton area was also conducted for the city by Simpson in 1929 (written communication, 1929). He discussed several wells which tap bedrock aquifers from depths of 40 to 60 feet and from depths of 150 to 200 feet. The best quality water found was assoicated with beds of lignite and sandstone which occur above a depth of 200 feet. At that time Wilton was using five wells located within the city limits and completed in a 25 to 30 foot bed of sandstone. These wells ranged from 170 to 175 feet in depth and were completed with 6-inch diameter open-end casing. Water levels in the city wells were more than 120-feet below the land surface and cylinder-type pumps were required to lift water to the surface. Simpson reported well yields of 3 to 3½ gpm (gallons per minute) per well but the wells had a tendency to pump sand and muddy water. They were not screened or perforated.

Ground-water surveys of Burleigh, McLean, and Oliver Counties have been conducted on a cooperative basis with the North Dakota State Water Commission, U.S. Geological Survey, and the North Dakota Geological Survey. These reports consist of three parts each. Part 1, Geology is a description of the bedrock and glacial geology. Part 2, Basic Data is a tabulation of test hole and well logs, an inventory of wells, water-

level measurements, and chemical analyses. Part 3, Ground-Water Resources is an evaluation of the water-yielding potential and chemical quality of major aquifers in the bedrock and glacial drift. These publications provide general analysis of the county ground-water resources and contain much useful information which is beneficial to domestic, agricultural, municipal, and industrial water users.

PRESENT WATER SUPPLIES

City of Washburn

The City of Washburn obtains its water supply from the Missouri River. Water is treated and chlorinated at the pumping plant located adjacent to the river on the west side of town. Washburn uses between 22.5 and 24.5 million gallons of water per year (Klausing, 1974).

Municipal pumping facilities are adequate at the present (1974) time but future population growth may require expansion of the existing plant. It has been reported that traces of sediment appear in the city water during the spring when the Missouri is at a high level, indicating that the municipal treatment facilities are not adequate. The North Dakota State Health Department now requires that municipalities using river water as a source of public supply employ adequate sedimentation and filtration facilities. Therefore, the city of Washburn may find it necessary to modernize their treatment plant or develop an alternate source of water supply.

City of Wilton

Wilton obtains its water supply (1974) from three wells located about one-half mile east of town. These wells are completed in a silty, fine-grained sandstone bed of the Sentinel Butte Formation (Fort Union

Group) and have a combined yield of 37 gpm. It is estimated that the city currently uses about 12.1 million gallons of water per year (Klausing, 1974).

The city's original water supply was provided by several wells located on the south side of town. These wells were completed in a sandstone bed of the upper Tongue River Formation at depths ranging from 170 to 175 feet. Because of diminished well yields and poor water quality the old well field was abandoned in the early 1950's. In 1953, three wells were drilled east of town and in 1959 two additional wells were added to the existing well field. However, well construction problems caused the latter two wells to pump an excessive amount of sand and they were abandoned. Low well yields and an increasing demand for water have made it necessary for the city to seek assistance in developing an additional source of ground-water supply.

WELL-NUMBERING SYSTEM

The wells and test holes listed in Table 3 are numbered according to a system based on the location in the public land classification of the United States Bureau of Land Management (fig. 2). The first numeral denotes the township north of a base line, the second numeral denotes the range west of the fifth principal meridian, and the third numeral denotes the section in which the well is located. The letters A, B. C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). For example, well 144-81-15DAA is in the NE¼NE¼SE¼ Section 15, Township 144 North, Range 81 West. Consecutive terminal numerals are added if more than one well is located in a 10-acre tract.

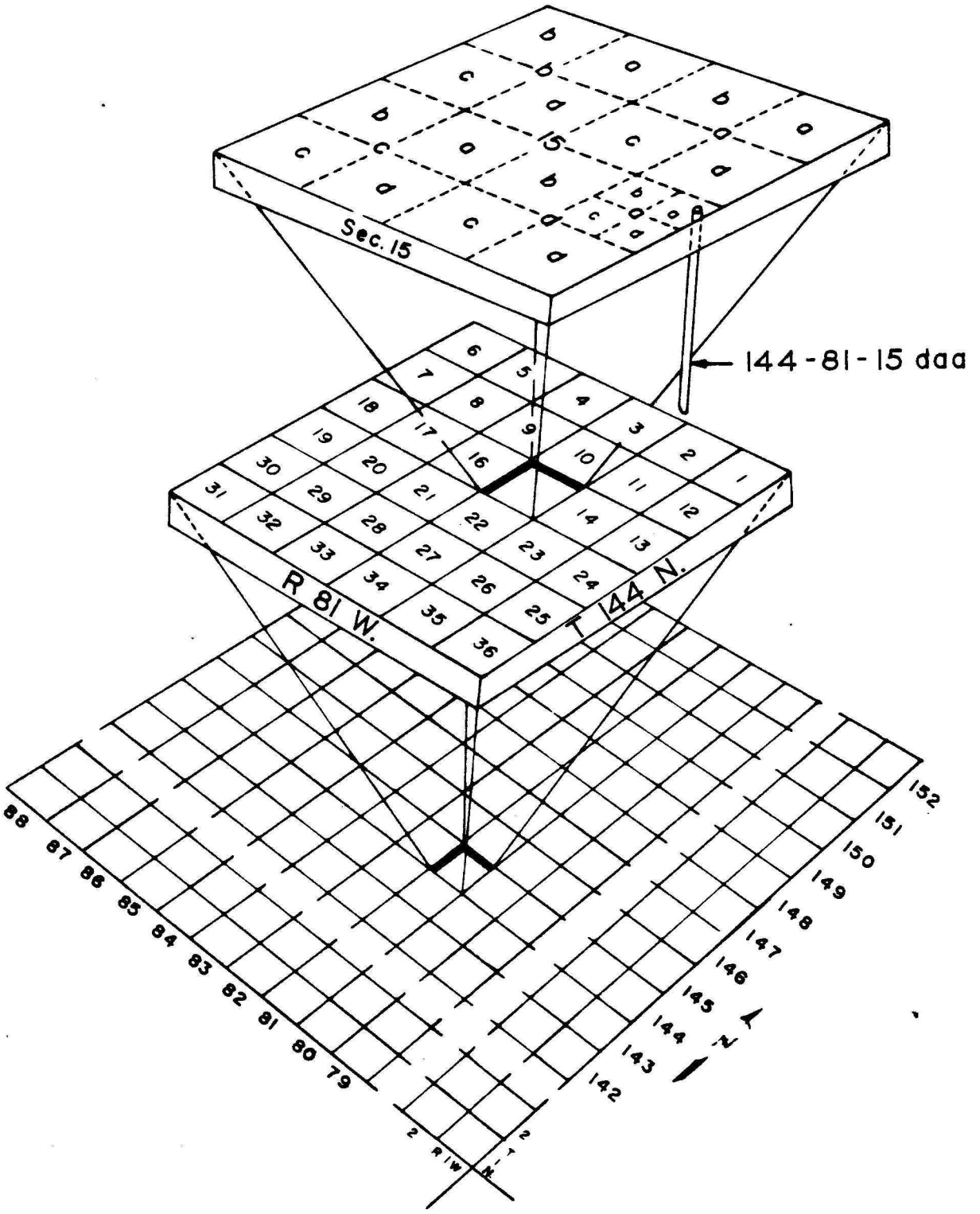


FIGURE 2--SYSTEM OF NUMBERING WELLS AND TEST HOLES.

DEFINITION OF TERMS

Aquifer -- a permeable deposit that contains sufficient saturated material that will yield significant quantities of water to wells.

Artesian Aquifer -- an aquifer in which water is under sufficient pressure to rise above the top of the aquifer.

Bedrock -- semiconsolidated rock underlying glacial and alluvial deposits of pleistoncene and/or Holocene age.

Discharge -- the removal or loss of water from an aquifer or the flow of water into a stream.

Evapotranspiration -- the process by which water is returned to the atmosphere through direct evaporation from water or land surfaces and by transpiration of vegetation.

Flowing well -- a well in an artesian aquifer having sufficient head to discharge water at land surface.

Glaciofluvial deposits -- sediments deposited by streams flowing from a glacier.

Ground water -- water in the zone saturation.

Ground-water movement -- the movement of ground water in the zone of saturation.

Hydraulic gradient -- slope of water table or potentiometric surface in either feet per foot or in feet per mile.

Infiltration -- the movement of water from the surface towards the zone of saturation.

Lacustrine deposits -- sediments formed in a lake environment.

Observation well -- a well from which hydrologic data are measured and recorded.

Permeable rock -- a rock that has a texture permitting water to move through it under ordinary pressure differential.

Potentiometric surface -- the imaginary horizon formed by the head in a artesian aquifer.

Recharge -- the addition of water to the zone of saturation.

Storage -- the quantity of water contained in openings in the zone of saturation.

Under flow -- the downstream movement of ground water through the permeable deposits beneath a stream.

Water table -- the upper surface of the zone of saturation where the hydrostatic pressure is equal to atmospheric pressure. The configuration of the water table commonly is a subdued expression of the land surface.

Zone of saturation -- the zone below the water table.

WATER QUALITY

All natural water occuring on the earth's surface or underground contains dissolved minerals. As it falls to the earth's surface, precipitation begins to dissolve mineral matter. As it infiltrates, this water continues to dissolve minerals. Dissolved minerals in ground water vary in type and concentration depending upon the composition and solubility of rocks encountered, the length of time the water is in contact with the rocks, and the amount of carbon dioxide and soil acids in the water. Water which has been underground for a long time, or which has travelled a long distance from the recharge area, usually contains more dissolved mineral matter than water which has been underground for a short time or is withdrawn close to a recharge area.

Dissolved mineral constituents are reported in milligrams per liter (mg/l). A milligram per liter is one thousandth (0.001) of a gram of dissolved material per liter of solution. Hardness is usually reported in milligrams per liter, but may be converted to grains per U. S. gallon (gr/gal) by dividing milligrams per liter by 17.12.

Table 1 lists the various constituents of water for a domestic or municipal water supply in North Dakota. Results of chemical analyses for wells in the study area are listed in Table 2.

BASIC HYDROLOGIC CONCEPTS

All ground water of economic importance is derived from precipitation. After the precipitation falls to the earth's surface, part is returned to the atmosphere by evaporation, some runs into streams, and the remainder percolates into the ground. Much of the water which sinks into the ground is held temporarily in the soil and then is returned to the atmosphere by evapotranspiration. The remainder percolates downward to the zone of saturation to ground water.

Ground water moves under the influence of gravity from areas of recharge to areas of discharge. The movement of ground water is generally very slow being only a few feet per year. The rate of movement is governed by the permeability of the deposits through which the water moves and by the hydraulic gradient. Gravel and well-sorted, medium to coarse sand are usually very permeable. Fine-grained materials such as silt, clay and shale have low permeabilities and act as confining barriers restricting the free movement of ground water into or out of more permeable rocks.

Table 1 -- Dissolved chemical constituents in water -- their effects upon usability and recommended concentration limits for domestic and municipal water supplies in North Dakota.

Constituent or Parameter	Effects of dissolved constituents on water use	Suggested limits for drinking water in North Dakota[1]	U.S. Public Health Service recommended limits for drinking water[2]
Silica (SiO_2)	No physiological significance		
Iron (Fe)	Concentrations over 0.1 mg/l will cause staining of fixtures. Over 0.5 mg/l may impart taste and colors to food and drink.		0.3 mg/l
Manganese (Mn)	Produces black staining when present in amounts exceeding 0.05 mg/l		0.05 mg/l
Calcium(Ca) and Magnesium (Mg)	Calcium and magnesium are the primary causes of hardness. High concentrations may have a laxative effect on persons not accustomed to this type of water.		
Sodium (Na)	No physiological significance except for people on salt-free diets. Does have an effect on the irrigation usage of water.		
Potassium (K)	Small amounts of potassium are essential to plant and animal nutrition.		
Bicarbonate (HCO_3) and Carbonate (CO_3)	No definite significance, but high bicarbonate content will impart a flat taste to water.		
Sulfate (SO_4)	Combines with Calcium to form scale. More than 500 mg/l tastes bitter and may be a laxative	0-300 mg/l - low 300-700 mg/l - high over-700 mg/l - very high	250 mg/l
Percent Sodium and Sodium Adsorption Ratio (SAR)	Indicate the sodium hazard of irrigation water.		
Chloride (cl)	Over 250 mg/l may impart a salty taste, greatly excessive concentrations may be physiologicaiiy harmful. Humans and animals may adapt to higher concentrations.		250 mg/l
Flouride (F)	Flouride helps prevent tooth decay within specified limits. Higher concentrations cause mottled teeth.	Limits of 0.9 mg/l to 1.5 mg/l	Recommended limits depend on average of daily temperatures. Limits range from 0.6 mg/l at 32°C. to 1.7 mg/l at 10°C.
Nitrate (NO_3)	Over 45 mg/l can be toxic to infants. Larger Concentrations can be tolerated by adults. More than 200 mg/l may have a deleterious effect on livestock health		45 mg/l
Boron (B)	No physiological significance. Greater than 2.0 mg/l may be detrimental to many plants		
Total dissolved solids	Persons may become accustomed to water containing 2,000 mg/l or more dissolved solids.	0-500 mg/l - low 500-1400 mg/l average 1400-2500 mg/l high over 2500 mg/l very high	500 mg/l
Hardness (as $CaCo_3$)	Increases soap consumption, but can be removed by a water-softening system.	0-200 mg/l - low 200-300 mg/l average 300-450 mg/l high over 450 mg/l very high	
pH	Should be between 6.0 and 9.0 for domestic consumption		
Specific Conductance	An electrical indication of total dissolved solids measured in micromhos per Centimeter at 25°C. Used primarily for irrigation analyses.		

1. Schmid, R. W., 1965, Water Quality Explanation: North Dakota State Water Commission, unpublished report, File No. 989.
2. U.S. Public Health Service, 1962, Public Health Service Drinking Water Standards: U.S. Public Health Service, Pub. No. 956, 61 p.

TABLE 2--Continued

(Analytical results are in milligrams per liter except where indicated)

AQUIFERS Owner or Designation	Location	Depth of Well (feet)	Temp(°C)	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	Land Surface Elevation (feet above mean sea level)
LOST LAKE AQUIFER																										
T.H. 3898	143-81-2BCC1	34	7	11-6-69	29	1.80		82	19	19	4.3	339		45		0.2			367	285	7	13	0.5	583	8.1	1710
T.H. 3897	-2BCC2	258	9	11-6-69	33	0.12		43	8.9	443	4.6	1180	8	91		0.8			1250	144		87	16	2080	8.3	1710
T.H. 8950	-3ADB	83	7	11-2-73	24	2.90	0.62	89	21	22	5.4	380		28	5.1	0.3	2.0		387	310		13	0.5	624	7.7	1700
T.H. 8939	-3BAA	163	8	10-29-73	26	3.50	0.32	96	22	160	6.3	622		150	23	0.6	1.8	0.43	796	330		51	3.8	1240	7.9	1703
T.H. 8933	-3BBB	42	6.5	11-6-73	25	8.90	0.60	59	27	180	6.0	549		170	21	0.4	1.0		726	260		59	4.9	1090	7.8	1710
T.H. 8932	-4ADD1	173	6.5	10-26-73	28	2.00	0.14	47	15	200	6.7	616		68	33	0.8	0.9	0.43	705	180		70	6.5	1120	8.0	1720
T.H. 8932-A	-4ADD2	263	7	10-29-73	22	2.20	0.16	34	13	300	5.5	748	12	59	80	1.1	1.9	0.56	899	140		82	11	1460	8.4	1720
T.H. 2695	-4BDA	160		7-24-67	24	1.10		61	23	323	6.8	911		117	69	1.1		0.48	1070	246		73	8.9	1690	8.0	1680
L. Chesworth	-4DBC	35	8	7-3-68	18		0.03	98	26	41	6.6	378		137	3.9	0.2	2.5	0.10	519	353	43	20	0.9	789	7.8	1700
T.H. 8940	-5AAD	40	7	10-30-73	19	2.90	0.72	150	55	380	7.4	997		510	34	0.5	0.4	0.17	1650	600		58	6.7	2360	7.6	1665
T.H. 8941	-5ADD1	83	6	10-31-73	24	6.10	0.36	75	27	340	7.5	1010		35	140	0.8	0.4	1.10	1160	300		71	8.5	1900	7.8	1666
T.H. 8941-A	-5ADD2	183	7	10-31-73	21	2.70	0.12	44	22	400	7.4	1060		62	140	0.8	1.0	0.90	1170	200		81	12	1940	7.9	1666
T.H. 8942	-5DDB	80	6	11-1-73	26	9.50	0.18	130	52	280	8.4	1000		270	30	0.7	0.3	0.47	1300	540		53	5.2	1930	7.7	1660
T.H. 2694	-16DBB	51	9	8-24-67	23	5.10		57	51	236	6.7	813		168	21	0.2	1.5	1.40	971	354		59	5.5	1800	8.0	1661
T.H. 4110	144-80-19ABA	258	8	8-20-70	22	2.50	0.02	70	30	359	7.3	873		338	20	0.6	0.3	0.56	1280	297		72	9.0	1910	7.9	1765
NDGS 64	144-81-25ADA	18	7.5	5-9-68	34	0.74	0.45	70	57	418	13	1010		475	34			0.59	1600	408		68	9.0	2280	8.1	1715
T.H. 8946	-32BCD	50	7	11-2-73	22	24.0	0.46	120	46	360	6.4	1020		370	14	0.5	0.4	0.26	1470	490		61	7.1	2100	7.7	1660
T.H. 8945	144-82-22AAB1	183	6	11-7-73	22	1.50	0.16	59	18	530	7.6	1360		79	130	0.7	1.0	0.56	1440	220		83	16	2300	7.7	1665
T.H. 3729	-23DDD	200	9	7-8-69	20	2.40		18	3.9	607	4.8	1380		95	107	0.9	1.0	1.30	1480	61		95	34	2410	8.1	1670
MISSOURI RIVER AQUIFER																										
Western 4-H Camp	144-82-16AD	90	6	10-29-73	19	43.0	0.42	190	67	430	6.4	1090		750	16	0.5	5.8	0.09	2070	750		55	6.8	2810	7.5	1670
T.H. 8943	-16ADA	30	6	11-5-73	17	2.90	0.68	97	33	550	6.4	1090		630	8	0.4	1.0	0.65	1880	380		76	12	2650	7.9	1665
T.H. 2697	-17AAD1	41		7-25-67	19	2.70		52	31	546	6.4	1010		602	6.3	0.9	1.5	0.26	1760	259		82	15	2530	8.0	1670
T.H. 8944	-17AAD2	40	6	11-14-73	21	9.30	0.30	150	60	510	6.7	1210		700	10	0.5	1.0	0.17	2060	620		64	8.9	2820	7.6	1660
T.H. 8945-A	-22AAB2	70	7	11-7-73	23	9.0	0.66	140	41	220	10	959		190	18	0.4	1.0	0.09	904	520		47	4.2	1450	7.3	1665
T.H. 2688	-23BBB	38	9	7-18-67	15	5.3		96	27	94	8.7	578		69	9.3	0.7	0.6		585	352		36	2.2	979	7.5	1665
MINOR DRIFT AQUIFERS																										
H. Renner	142-79-32BAA	62	7	9-18-63	7.1	9.20				129	14	570		1050	6.0	0.7	1.5		2004	1250	786	18	1.7	2422	7.5	
M. Triske	142-80-4BAA	40	7.5	4-24-73	19	0.04	0.07	167	108	64	6.4	473		555	19	0.2	2.4		1250	860	472	14	0.9	1630	7.1	2070
T.H. 3895	143-80-8AAA	78		5-7-70	25	1.0		194	49	209	7.6	432		787	7.7	0.2	0.6	0.30	1500	688	334	40	3.5	1950	7.8	1890
T.H. 4105	143-81-24DDA	38	7.5	8-24-70	20	1.0		73	25	721	5.3	903		1100	6.7	0.4	0.1	0.57	2410	287		84	19	3300	7.9	1780
L. Jennings	144-80-28BCB1	47	7.5	6-26-68	24			91	26	331	11	789		361	37	0.2	23.0	0.54	1260	336		67	7.8	1910	7.9	1780
SURFACE WATER																										
SPRING (Lignite Source)	142-79-6AAA		11	4-24-73	14	1.80	0.66	368	183	54	14	271		1480	11		1.0	0.56	2350	1670	1450	7	0.6	2560	7.3	2110
Missouri River (City of Washburn)	144-82-14CDD		8	10-29-73	7.1	0.25	0.01	51	23	58	3.6	188		180	12	1.0	1.0	0.13	430	220	66	36	1.7	671	8.0	1660

TABLE 2--CHEMICAL ANALYSES

(Analytical results are in milligrams per liter except where indicated)

AQUIFERS / Owner or Designation	Location	Depth of Well (feet)	Temp(°C)	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	Land Surface Elevation (Feet above mean sea level)
SENTINEL BUTTE FORMATION																										
T. H. 8611	142-80-2 DDD_1	82	8	5-3-73	22	1.50	2.00	215	94	36	6.9	561		453	29	0.2	1.0	0.39	1170	923	463	8	0.5	1550	7.9	2115
City of Wilton 2	143-80-35 DAA_1	100	8	4-24-73	11	0.06	0.64	126	47	3.7	4.4	426		181	2.9	0.1	1.0	0.09	595	509	160	2	0.1	879	7.4	2165
City of Wilton 1	-35 DAD	92	7	4-23-68	18	0.13		109	27	4.1	3.7	428		46	0.8	0.1			401	385	34	2	0.1	759	7.7	2160
City of Wilton 1	-35 DAD	92	8	4-23-73	16	1.00	0.60	104	38	4.4	3.5	432		69	1.8	0.1	1.0		464	415	61	2	0.1	708	7.5	2160
E White	-36 BCC	110	8.5	7-2-68	8.7			56	15	1.2	3.2	241		10	2.4		6.1		206	203	6	1	0	393	8.1	2160
City of Wilton 3	-36 CBB	102	7.5	4-23-68	9.3	0.15		76	17	1.5	3.7	271		41	3.0	0.1		0.10	291	261	39	1	0	488	7.9	2180
City of Wilton 3	-36 CBB	102	7	4-24-73	7.9	0.08	0.24	82	27	1.4	3.5	308		70	5.8		1.0		355	315	62	1	0	565	7.6	2180
UPPER TONGUE RIVER FORMATION																										
T. H. 8617	142-80-1 CBB	144	7	4-24-73	9.1	0.36	0.14	104	56	114	7.7	624		243	3.6	0.1	1.0	0.34	867	492		33	2.2	1280	7.2	2120
M. Backman	-2 CCC	255	8	4-24-73	13	1.10	0.20	164	99	73	9.1	781		290	3.4	0.1	1.0	0.21	1050	816	175	16	1.1	1510	6.9	2160
P. Garowski	-12 BBC	140	7	4-24-73	8.6	1.30	0.14	63	37	143	12	609		116	2.6	0.1	4.6	0.21	655	310		49	3.5	1050	7.3	2115
M. Backman	143-79-30 CCA	80	7	4-24-73	8.4	0.36	0.40	233	116	115	12	717		702	5.2		4.6	0.26	1620	1060	472	19	1.5	2010	7.2	2080
A. Gregoryk	143-80-21 CCC	120	7.5	4-24-73	11	2.00	0.28	158	85	106	7.9	745		342	6.2	0.1	1.0	0.21	1080	744	133	23	1.7	1580	7.0	2035
A. Duma	-32 ADA	80	8	4-24-73	8.3	0.32	0.02	53	27	209	6.4	546		265	4.4	0.1	4.4	0.64	804	243		64	5.8	1270	7.4	2030
T.H. 8605	-33 ADD	169	10.5	4-3-73	9.7	0.04	0.22	42	20	388	9.7	623	24	502	6.9	0.2	1.0	0.64	1320	188		81	12	1930	8.5	2045
LOWER TONGUE RIVER FORMATION																										
M. Backman	143-79-30 CCA_2	265	8	4-24-73	10	0.87	0.02	4.8	1.9	465	2.4	848	5	344	6.8	0.6	0.7	0.69	1290	20		98	45	1940	8.3	2080
G. Cleveland	143-80-17 DDD	220	8.5	7-1-68	9.8	2.40		5.4	3.5	454	2.4	952	7	180	17	0.7		0.47	1140	28		97	37	1780	8.3	1980
H. Stewart	-34 ADD	210	10.5	7-2-68	4.4	0.24		5.1	2.1	366	2.5	747	15	185	1.6	0.5		0.34	936	21		97	35	1460	8.3	2190
N. Duma	-34 CCB	300	8.5	4-25-73	13	0.14	0.05	3.8	0.6	437	1.8	954	10	126	31	0.6	2.0	0.56	1080	12		98	55	1680	8.4	2100
CANNONBALL FORMATION																										
B. Hall	144-80-22 ADD	220	10	6-27-68	22	0.28		4.8	1.9	508	2.2	1140	18	10	117	0.5	1.0	2.10	1210	20		98	49	2030	8.3	1860
HELL CREEK FORMATION																										
T. Krush	142-80-1 BDB	570	9	4-24-73	14	1.50	0.01	5.4	0.6	568	3.5	1310		27	134	0.7	1.0	1.0	1470	16		98	62	2250	8.1	2140
P. Patrick	143-80-16 CCB_1	530	12.5	7-1-68	8.6	0.38		4.6	1.6	598	2.3	1170		4.2	249	0.6		2.7	1420	18		98	61	2370	8.1	1980
L. Frankland	143-81-24 CDA	350	10.5	7-3-68	8.1	0.08		4.8	1.9	635	2.4	1220		3.5	277	0.7	1.0	2.0	1540	20		98	62	2480	8.2	1820
FOX HILLS FORMATION																										
T.H. 1984	142-81-4 ABC	435		8-62	12	0.15		4.9	2.2	761	2.1	1140		1.8	517	2.3	0.3	2.7	1870	21		99	72	3180	8.1	1666
T. H. 8610	143-80-32 CCC	600	10	4-10-73	8.6	0.32	0.08	4.9	2.2	657	2.8	1240	25	8.2	296	1.0	1.0	2.4	1680	21		98	62	2760	8.5	1955

The water level in a well fluctuates in response to recharge to and discharge from the aquifer. Land surface loadings and atmospheric pressure changes cause minor water level fluctuations in confined aquifer. Pumping a well causes the water level to decline. The water level surface surrounding the well will resemble a cone and is referred to as the "cone of depression". Water-level drawdown is the difference between static and pumping levels. The degree of drawdown is controlled by the hydraulic properties of the aquifer, the physical characteristics of the well, and the rate and duration of pumping. Continuous withdrawal of water from an aquifer by pumping will cause a decrease in the rate of natural discharge, an increase in the rate of recharge, and/or a reduction of the volume of water in storage.

GEOLOGY

PREGLACIAL ROCKS

The Washburn-Wilton area is located on the eastern side of the Williston Basin and is underlain by more than 8,000 feet of sedimentary rock ranging from Cambrian to Tertiary in age (Bluemle, 1971). All bedrock formations have a regional westerly dip and thicken in that direction. These sedimentary rocks consist of alternating beds of claystones, siltstone, sandstones, shales, limestones, and evaporites which were deposited millions of years ago. This investigation is concerned only with the Upper Cretaceous and Tertiary rocks which underlie the study area.

Data compiled from test drilling, surface geology, and topographic maps were used to construct the generalized bedrock map of the Washburn-

Wilton area (fig. 3). The bedrock surface is shown on this map as it would appear if all the overlying glacial drift were removed. There are two prominent features on the map. The first is the outlier of the Sentinel Butte Formation. This outlier underlies a topographic high. The second is the narrow band of the Hell Creek Formation. This band is located in a preglacial valley of the Knife River which was entrenched into the upper Hell Creek Formation.

The Fox Hills Formation is a marine sequence of interbedded claystone, siltstone, and sandstone as substantiated by test holes 8610 (142-80-32CCC) and 1984 (142-81-4ADC). The top of the Fox Hills at Wilton is about 750 feet below the land surface (1,400 feet mean sea level). Four lithologic units within the formation are identifiable at Wilton. They correspond to beds defined by Kume and Hanson (1965) in Burleigh County (pl. 2). A bed of very fine- to fine-grained, semi-consolidated, bluish-gray sandstone occurs in the upper part of the formation. This bed is probably the Colgate member of the Fox Hills Formation which underlies much of western North Dakota. In the Wilton area this sandstone bed is about 30 feet thick. A lower bed of sandstone and interbedded claystone can also be identified in the Fox Hills. This bed is more than 50 feet thick and is probably equivalent to the Timber Lake Member which crops out in Emmons County (Feldman, 1972). Total thickness of the Fox Hills in the study area may exceed 300 feet.

The Hell Creek Formation directly overlies the Fox Hills and is slightly more than 200 feet in thickness. Alternating beds of brownish- to greenish-gray claystone, sandstone, and shale comprise the formation. The sandstone beds are thin and may be discontinous.

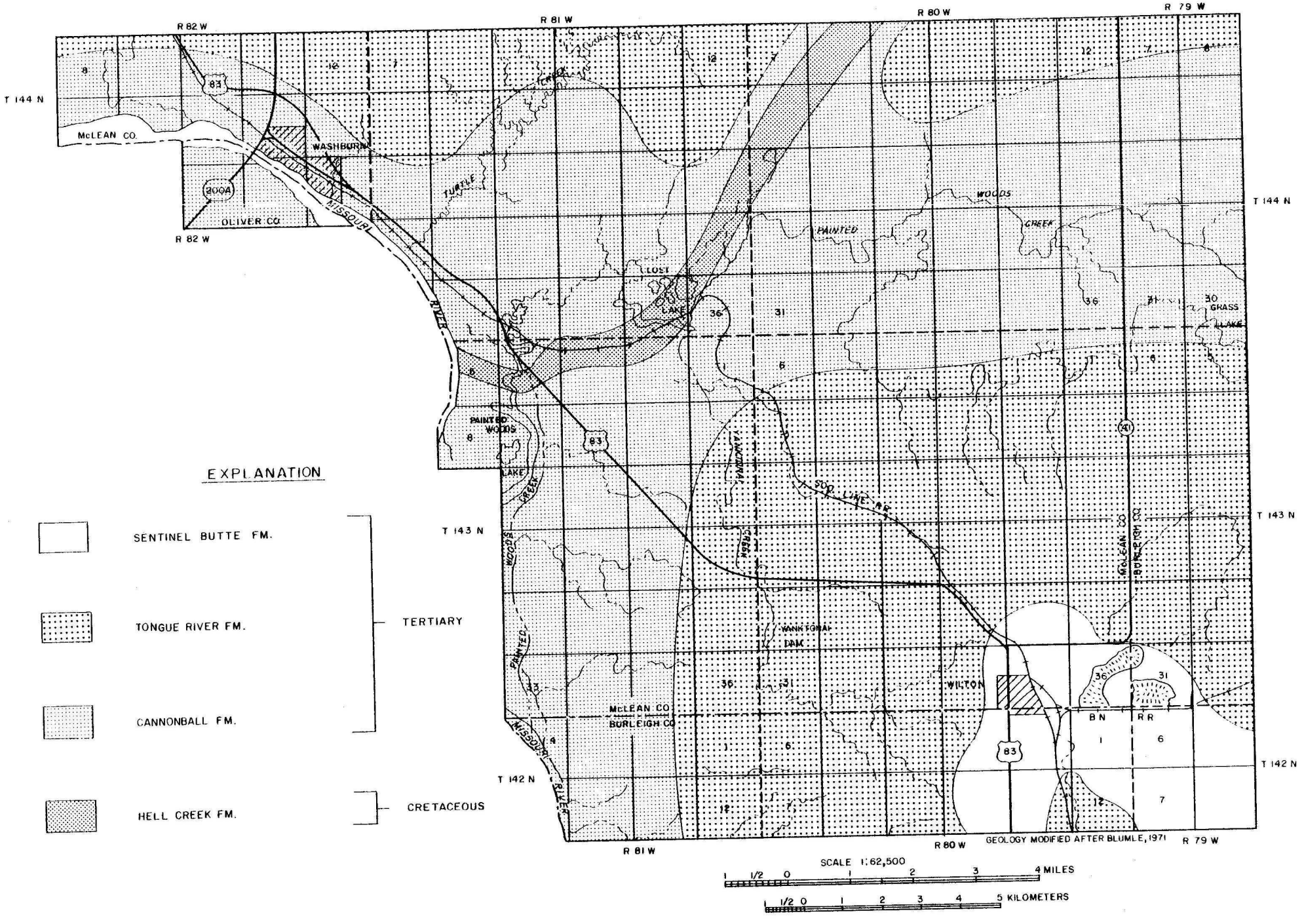


FIGURE 3--BEDROCK GEOLOGIC MAP OF THE WASHBURN-WILTON AREA

Medium- to brownish-gray, sandy claystones of the Cannonball Formation overlie the Hell Creek. The Cannonball is a marine unit which contains numerous limestone concretions and thin beds of limey, highly calcareous sandstone. The Cannonball is more than 200 feet thick in the study area.

Continental deposits of the Tongue River Formation directly overlie the Cannonball. It consists of a basal, fine-grained sandstone unit overlain by interbedded claystone, siltstone, sandstone, and lignite. Near Wilton the basal sandstone has an average thickness of about 30 feet and can be easily distinguished in the subsurface (pl. 2). Subsurface data indicate that the formation exceeds 200 feet in thickness near Wilton where erosion has not altered the original section.

Test drilling for this study and correlation of geologic maps of McLean County, indicate that in the southeast portion of the study area an outlier of the Sentinel Butte Formation overlies the Tongue River (fig. 3). Previous authors (Royse, 1967 and Carlson, 1973) used three criteria to define the Tongue River-Sentinel Butte contact: (1) color, (2) a lignite horizon in the uppermost portion of the Tongue River, and (3) the presence of a basal sandstone in the Sentinel Butte. The first two criteria could not be determined from subsurface data, but a basal sandstone unit could be traced on electric logs and identified from drill cuttings. The basal sandstone is silty and very fine- to medium-grained. It is semi-consolidated, fossilliferous, and bluish-gray in color.

Siltstone, sandy claystone, and lignite beds constitute the upper Sentinel Butte Formation near Wilton. A 10-foot bed of lignite was

penetrated in test hole 8614 (142-80-1AAB) located about one mile east of Wilton and south of the abandoned coal mine. This lignite is probably an extension of the coal bed which was mined in this vicinity during the early 1900's. The Sentinal Butte Formation ranges in thickness from about 25 feet to more than 100 feet.

GLACIAL DEPOSITS

During the Pleistocene Epoch, the Washburn-Wilton area was subjected to several periods of glaciation: the deposits laid down by this activity are as much as 282 feet thick. The thickest section of glacial drift occurs in the preglacial Knife River valley located east of Washburn (pl. 2). Ground moraine, characterized by gently rolling topography, is the predominant glacial landform in the area. However, along the Missouri River valley the glacial drift is thin or has been removed by erosion.

Glacial drift in the study area consists of till and glaciofluvial deposits. Till, an unsorted mixture of clay, silt, sand, pebbles, cobbles, and boulders was deposited by direct ablation and wasting of glacial ice with little or no sorting action by water. Above the water table it is yellowish-brown in color, indicating that the clay minerals have been oxidized by chemcial weathering. Below the water table it is generally olive gray in color. About 70 percent of the land surface in the Washburn-Wilton area is till. Till usually has thin, lenticular, discontinuous deposits of sand or gravel associated with it.

Glaciofluvial deposits overlie about 20 percent of the study area. These consist generally of sand and gravel which have been sorted and stratified by glacial melt water. The valleys of the Missouri River,

Painted Woods, Yanktonai Creeks, and the preglacial Knife River are partially filled with glaciofluvial sand and gravel deposits. Those deposits constitute glacial drift aquifers (fig 4).

The glaciofluvial deposits which were presented by test holes in the valleys of the Missouri River and its tributaries are generally overlain by alluvial clays and silts of post-glacial origin. These alluvial sediments are thin and generally unsaturated in the study area.

GROUND WATER IN THE BEDROCK

AQUIFERS IN THE UPPER CRETACEOUS ROCKS

The Fox Hills and Hell Creek Formations are important bedrock aquifers in most of western North Dakota. Both formations underlie the Washburn-Wilton area, but relatively few wells have been completed in the sandstone beds of these units. Chemical analyses of water from selected wells in the study area are listed in Table 2.

Fox Hills Formation

Thickness and Lithology - Drill cuttings indicated that the Fox Hills consisted of 55 feet of fine- to medium-grained, greenish-gray, glauconitic sandstone (pl. 2). An observation well was completed to a depth of 435 feet and reportedly had a flow rate of 50 gpm.

Drill cuttings and electric and gamma ray logs taken from test holes 8610 (143-80-32-CCC) indicate that the Fox Hills Formation consists of 184 feet of interbedded sandstone, claystone, and siltstone (pl. 2). Twenty-eight feet of very fine- to fine-grained, bluish-gray sandstone was penetrated from at depth of 576 to 604 feet. An observation well was completed to a depth of 600 feet in this section. Test hole 8610

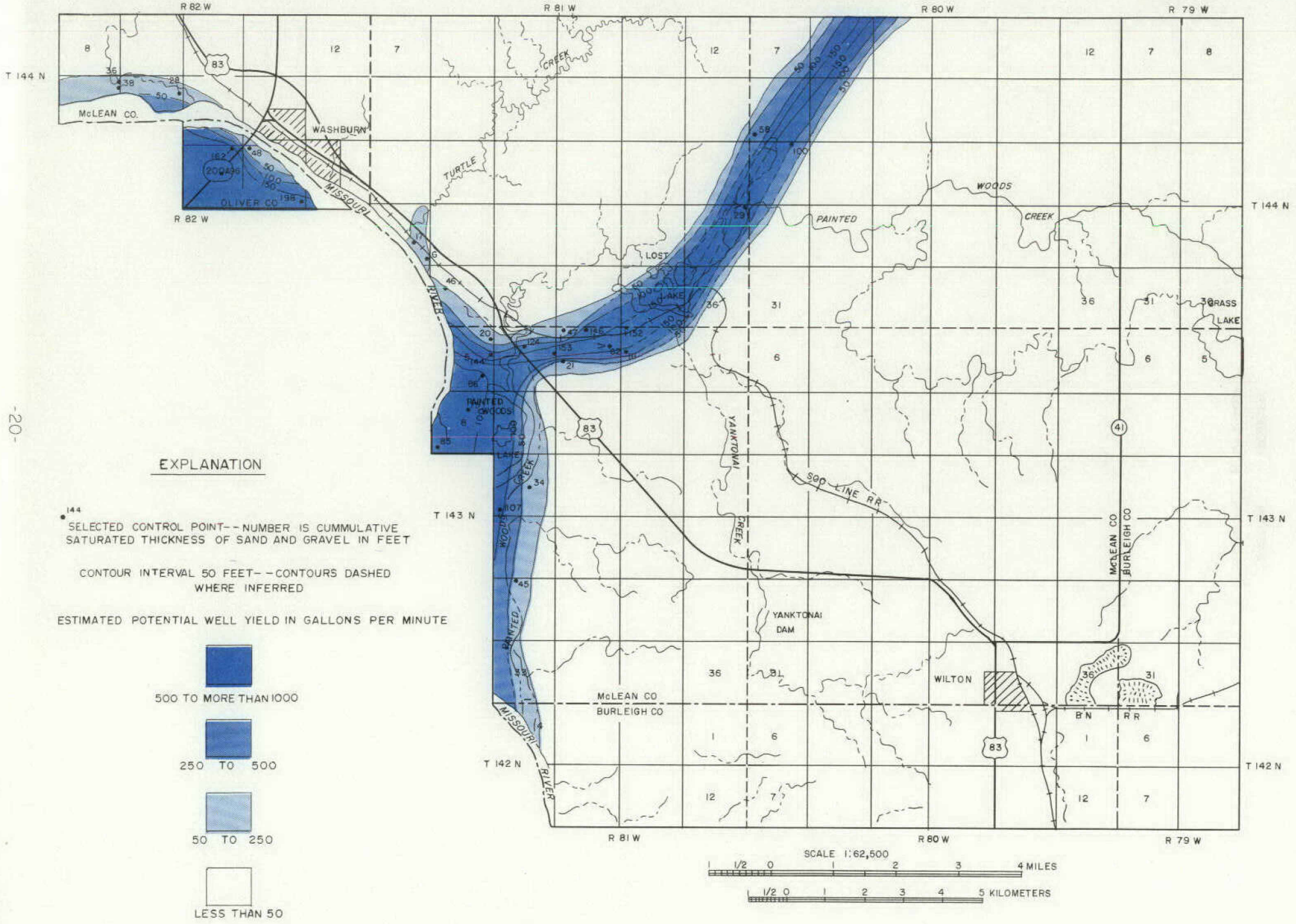


FIGURE 4 -- LOCATION, THICKNESS, AND ESTIMATED POTENTIAL YIELD OF THE LOST LAKE AND MISSOURI RIVER AQUIFERS

penetrated also 56 feet of sandstone interbedded with claystone from a depth of 660 to 716 feet. The upper and lower sandstones encountered in test hole 8610 are probably the Colgate and Timber Lake members of the Fox Hills.

Hydraulic Properties - Data on the potentiometric surface of the Fox Hills aquifer in McLean County indicate that the hydraulic gradient slopes to the east (Klausing, 1974). The interpolation of water-level data indicates that the elevation of the potentiometric surface of the Fox Hills aquifer at Wilton would be about 1,720 feet. Therefore, assuming a surface elevation of 2150 feet, the static water level in an 800 foot well at Wilton would be more than 400 feet below land surface. Wells completed in the Fox Hills Formation at Washburn at elevations below 1760 feet may flow.

Well yields from the Fox Hills are generally low. Specific capacities for Fox Hills wells in Mercer and Oliver Counties (Croft, 1970) range from less than 0.1 to 0.6 gpm per foot of drawdown. An average specific capacity for the aquifer would be about 0.25 gpm per foot. Therefore, the drawdown in a 50 gpm well at Wilton would be about 200 feet resulting in a 600 feet pumping water level.

Water Quality Water from wells at 143-80-32CCC and 142-81-4ADC is a very soft, sodium bicarbonate type which contains dissolved solids of 1680 and 1870 mg/l (milligrams per liter). Flouride content may exceed the limits recommended by the U.S. Public Health Service (table 1). The high sodium concentration makes this water undesirable for watering lawns or gardens.

Hell Creek Formation

Thickness and Lithology -Test holes 1984 (142-81-4ADC) and 8610 (143-80-32CCC) penetrated 235 feet and 206 feet of Hell Creek, respectively. The formation consists of interbedded claystone, siltstone, sandstone, and shale. Several beds of clayey, fine-grained, greenish-gray, glauconitic sandstone were encountered but no observation wells were installed. The thickest sandstone bed was penetrated between 424 and 448 feet in test hole 8610. The top of the Hell Creek at Wilton is about 1,625 feet above mean sea level.

Hydraulic Properties Reported water levels from domestic wells completed in the Hell Creek at 143-80-16CCB and 143-81-24CDA indicate a potentiometric surface elevation of about 1,780 feet. The potentiometric surface for the Hell Creek at Wilton would be approximately 1,760 feet.

Well yields in the Hell Creek are similar to those of the Fox Hills. Domestic wells completed in the formation commonly yield a few gallons per minute, but fully penetrating, properly constructed wells will have higher yields.

Water Quality Three water samples from the Hell Creek in the study area indicate a sodium bicarbonate water very similar in quality to Fox Hills. Dissolved solids ranged from 1,420 to 1,540 mg/l and the water is very soft. Flouride is within recommended limits. A high sodium content makes the water undesirable for irrigation.

AQUIFERS IN TERTIARY ROCKS

Wilton's city wells and numerous domestic and stock wells tap sandstones of the Sentinel Butte and Tongue River Formation. The Sentinel Butte underlies only a small portion of the area and is a minor

aquifer. The Tongue River underlies about 50 percent of the study area and is an important bedrock aquifer.

Cannonball Formation

With the exception of test hole 1984 (142-81-4ADC) which penetrated about 80 feet of very fine-grained, clayey sandstone. Test drilling and well inventory data did not indicate any significant sandstone beds in the Cannonball Formation. However, existing data indicates that the Cannonball is not a significant aquifer in this area. A well at 144-80-22ADD taps the Cannonball Formation at a depth elevation of 220 feet and yields a sodium bicarbonate type water which has total dissolved solids concentration of 1210 mg/l.

Tongue River Formation

Thickness and Lithology Test drilling indicates the Tongue River Formation at Wilton contains both upper and lower sandstone beds which can be distinguished as separate hydrologic units by differences in water levels and chemical quality. The basal sandstone is common to the Tongue River Formation in most of western North Dakota. In the Washburn-Wilton area it can be recognized from drill cuttings and on electric logs. The sandstone is clayey, very fine- to fine-grained, and light-gray to bluish-gray in color. It ranges in thickness from a few feet to as much as 56 feet in test hole 8608 (143-79-31AAA). The basal sandstone crops out about six miles west of Wilton along the Missouri Valley.

The upper Tongue River sandstone is lenticular and variable in thickness. It is generally clayey, very fine- to fine-grained, carbonaceous, lignitic, and may be fossilferous. The sandstone is bluish-gray to

brownish-gray in color. It ranges in thickness from a few feet to as much as 50 feet in test hole 8610 (143-80-32CCC).

Hydraulic Properties Water levels in observation wells completed in the upper and lower Tongue River sandstone indicate that ground water movement is downward through the Formation. Data also suggests that the potentiometric surfaces of both the upper and lower aquifers slope eastward and westward from the topographic bedrock high at Wilton.

Well yields are low, due to the fine-grained material and to interstitial clay and silt which substantially reduce permeability. A 4-inch diameter observation well at 142-80-1CBB was completed in the upper Tongue River sandstone. The well was screened from 139 to 144 feet with 5 feet of 3-inch diameter No. 8 slot (0.008 inch) screen which has sandpacked. It was pumped with a submersible pump at about 6 gpm. The specific capacity was estimated at about 0.1 gpm per foot of drawdown. Anticipated yields for properly constructed wells in the Tongue River sandstones at Wilton will probably not exceed 20 gpm per well.

Water Quality Water samples from four wells completed in the basal sandstone indicate the water is a sodium bicarbonate type which averages 1,112 mg/l dissolved solids. It is high in sodium and very soft. Concentrations of boron and flouride are high.

Seven water samples from wells in the upper Tongue River sandstone indicate that the water may be either a calcium-magnesium bicarbonate or a sodium bicarbonate type. The water is generally quite hard and contains variable concentrations of iron and sulfate.

Sentinel Butte Formation

Thickness and Lithology Data from 17 test holes indicate that in the Wilton area the Sentinel Butte Formation consist of interbedded claystone,

siltstone, sandstone, and lignite. The basal sandstone is usually interbedded with claystone, and ranges in thickness from four feet in test holes 8627 (143-80-35ADC) to 52 feet in test hole 8613 (142-80-1BBB). The sandstone is silty and clayey. It is very fine- to medium-grained and semi-consolidated to loose. Its color is light-gray to bluish-gray. Often a sandy, greenish-gray, bentonitic claystone directly overlies the sandstone bed.

Hydraulic Properties - Wilton's city wells are completed in the basal Sentinel Butte at depths ranging from 92 to 102 feet. The combined pumping rate of three wells used by the city is 37 gpm. Drill cuttings and electric logs show the basal sandstone in the vicinity of the city well field to be very lenticular and interbedded with claystone. About one mile southeast of Wilton the Sentinel Butte sandstone is less clayey, coarser-grained, and not as interbedded with claystone. However, anticipated well yields in this area probably would not exceed 15 to 20 gpm per well.

Water level data show that basal Sentinel Butte aquifer is recharged primarily by precipitation. The overlying glacial drift is very sandy permitting the rapid infiltration of snowmelt and rainfall.

Water Quality Seven water samples from the Sentinel Butte aquifer show the water to be generally of good quality and of the calcium bicarbonate type. Dissolved solids range from 206 to 1,170 mg/l averaging 497 mg/l. The water is hard. Iron and manganese concentrations are within accepted limits, except for a water sample at 142-80-2DDD which indicated 1.50 mg/l iron and 2.0 mg/l manganese.

GROUND WATER IN THE GLACIAL DRIFT

Glaciofluvial deposits of sand and gravel which partially fill buried valleys of the Missouri River and the preglacial Knife River are important glacial drift aquifers in the Washburn-Wilton area. Data obtained during this investigation and interpolated from existing reports and maps (Klausing, 1974) were used to evaluate the geohydrologic characteristics of the Lost Lake and Missouri River aquifers.

Glaciofluvial deposits which underlie the Missouri River floodplain have been called the Painted Woods aquifer by Klausing (1974), and the Missouri River aquifer by Croft (1973). Missouri River aquifer will be used in this report due to the geographical proximity to the Missouri River and because of the similar water quality and hydrologic characteristics of the flood plain deposits.

Figure 4 shows the location, thickness, and estimated potential yield of the Lost Lake and Missouri River aquifers. The direction of ground-water movement is indicated on figure 5. Geologic sections of the Lost Lake and Missouri River aquifers are represented on plate 2.

Lost Lake Aquifer

Thickness and Lithology The Lost Lake aquifer is a buried preglacial river channel which underlies about 7 square miles of the study area (fig. 4). The aquifer consists of interbedded clay, silt, sand, gravel, and till. Water-bearing sand and gravel ranges in cumulative thickness from 21 feet in test hole 8936 (143-81-3CBB) to 153 feet in test hole 8932 (143-81-4ADD). The clastic materials range in size from fine sand to coarse gravel and are generally well-sorted. Fine to coarse, clayey gravel is commonly found overlying the bedrock surface in the buried valley (pl. 2). Loss of circulation during test drilling indicates that permeabilities are high.

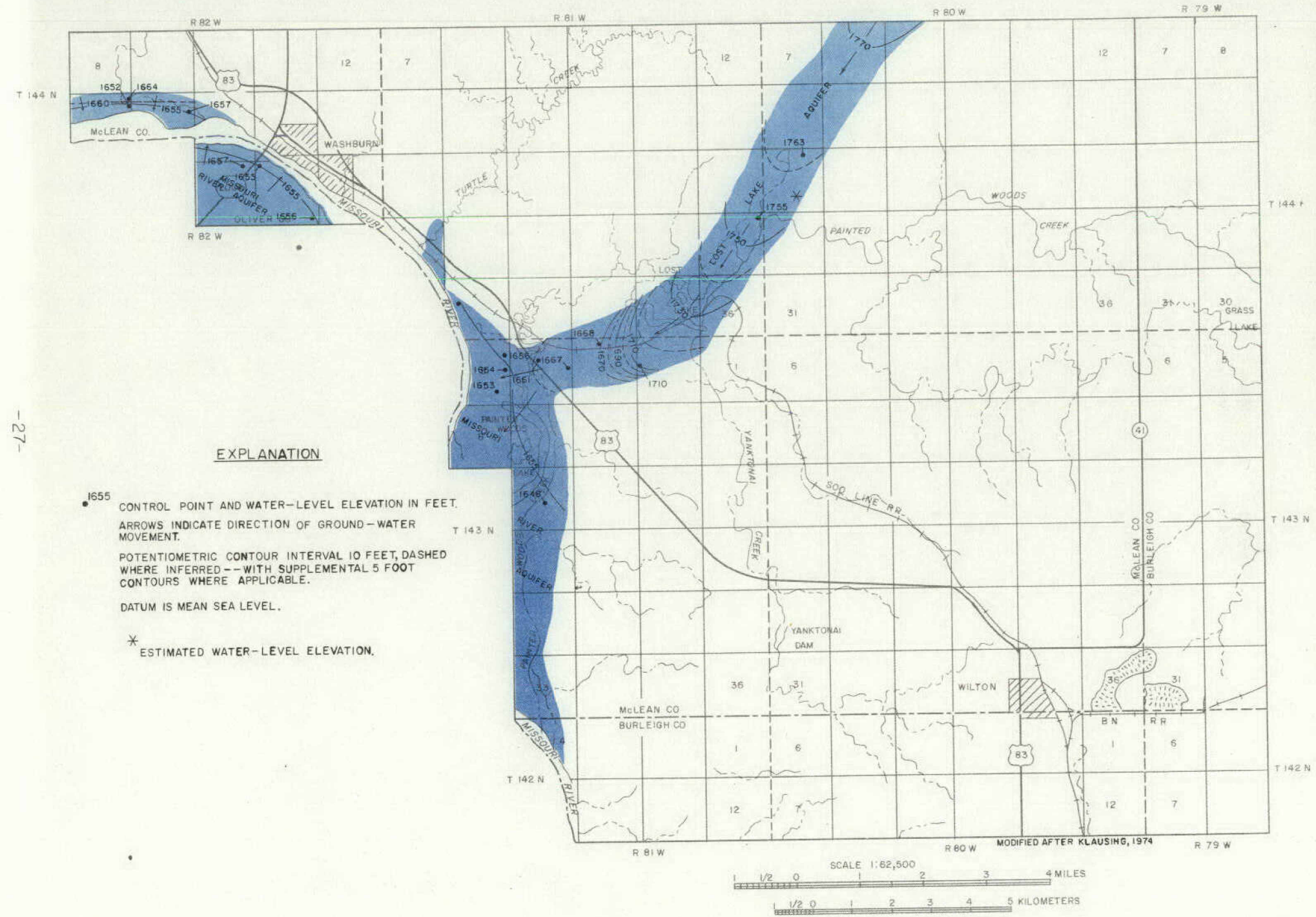


FIGURE 5--MAP SHOWING DIRECTION OF GROUND-WATER MOVEMENT IN THE LOST LAKE AND MISSOURI RIVER AQUIFERS

Geologic sections B-B', C-C', and D-D' show cross-sectional views drawn at right angles to the horizontal axis of the aquifer. Southwest of Lost Lake a large, lenticular-shaped body of silty clay divides the aquifer into an upper and a lower unit. Water-level and water quality data show that the clay body forms a semi-impermeable boundary between aquifer units. However, to the northeast, in the vicinity of test holes 4110 (144-80-19ABA), and north of the Painted Woods Lake area in the Missouri River valley the aquifer consists of only one unit (E-E' on pl. 2).

Hydraulic Properties Water levels in observation wells range from above the land surface (flowing wells) to more than 48 feet below the land surface. Aquifer materials in the buried valley are under artesian pressure, but southwest of Lost Lake localized water-table conditions may exist in the upper aquifer unit. The general direction of ground-water movement is toward the Missouri River valley (fig. 5).

The Lost Lake aquifer is recharged by infiltration through surrounding glacial drift and by upward seepage through underlying bedrock. Discharge from the aquifer occurs as leakage into adjacent bedrock, glacial drift, and the Missouri River aquifer. The upper unit may discharge locally into Painted Woods Creek.

Aquifer test data are not available on the Lost Lake aquifer, however, based on the grain-size and the thickness of clastic materials yields exceeding 1000 gpm may be possible from a properly constructed well.

Water Quality - Nineteen water samples from the Lost Lake aquifer indicate that the water may be either a sodium bicarbonate or a calcium bicarbonate type. Generally, wells completed in the lower aquifer unit will yield

sodium bicarbonate water and wells tapping the upper unit will yield calcium bicarbonate water. There appears to be a mixing of waters between the Lost Lake and Missouri River aquifers north of Painted Woods Lake where these deposits overlie each other and are hydraulically connected.

Dissolved solids ranged from 367 mg/l to 1650 mg/l and averaged 1065 mg/l. The water is soft to very hard. Concentrations of iron and manganese usually exceed recommended limits and will require treatment to remove them for municipal or domestic use. Locally, sulfate exceeds the 250 mg/l limit set by the U.S. Public Health Service (table 1).

Water quality in the upper unit of the aquifer is superior to that of the lower unit, and is best in Secs. 2 and 3, Township 143 North, Range 81 West. Good quality water in this area is partially due to the rapid infiltration of precipitation down through surficial sands and gravel. Water quality is also influenced by the previously mentioned lenticular body of silty clay, which functions as a confining bed and prevents the upward migration of poorer quality water from the lower aquifer unit. Water from the upper unit of the Lost Lake aquifer is very similar in quality to the Missouri River water at Washburn and water in the Sentinel Butte Formation at Wilton (table 2).

Missouri River Aquifer

Thickness and Lithology In the study area the Missouri River aquifer underlies about 6 square miles of the Missouri valley. The aquifer consists of interbedded glaciofluvial clay, silt, sand, and gravel thinly overlain by alluvial clays and silts. Sand and gravel comprising the aquifer ranges in thickness from 28 feet in test hole 8943 (144-82-

16ADA) to 198 feet in test hole 3729 (144-82-23DDD). Clastic materials range in size from fine sand to very coarse gravel. They are highly permeable.

The deposit is thickest across the Missouri River southwest of Washburn. This is due to the influence of the buried preglacial Knife River valley which underlies the surficial floodplain deposits of the Missouri River. Subsurface data indicate that the aquifer consists of nearly 200 feet of sand and gravel in this area.

Hydraulic Properties Water levels in the Missouri River aquifer are generally within 10 feet of land surface. They fluctuate in response to changes in the stage of the Missouri River and in the amount of annual precipitation (Klausing, 1974)

The aquifer is recharged by the infiltration of precipitation, underflow from the Lost Lake aquifer, and leakage from surrounding bedrock. Ground water is discharged by underflow to the Missouri River, evapotranspiration and by pumping. The general direction of ground water movement is toward the Missouri River (fig. 5).

Aquifer test data for a well (143-81-29BBB[1]) located outside the study area on the Missouri floodplain shows the aquifer to be highly premeable and capable of yields exceeding 1000 gpm from an individual well (Klausing, 1974). This well, owned by the South McLean Mutual Aid Association, is 107 feet in depth, 12 inches in diameter, and screened from 82 to 107 feet. It was pumped at a rate of 1,180 gpm had a specific capacity of 106 gpm per foot of drawdown.

Water Quality Dissolved solids for six water samples ranged from 585 mg/l to 2,070 mg/l. The water is very hard, generally high in sulfate,

and a sodium bicarbonate type. Concentrations of iron and manganese exceed recommended limits.

Minor Drift Aquifers

Thickness and Lithology Deposits of sand and gravel, in the valleys of Painted Woods and Yanktonai Creeks, and lenses of sand and gravel, associated with till, constitute aquifers which are capable of providing small quantities of ground water to domestic and stock wells in the study area. Permeable materials range in saturated thickness from a few feet to as much as 33 feet in test hole 4105 (143-81-24DDA). Sand and gravel deposits in Painted Woods and Yanktonai Creeks are highly variable in thickness and may, in places, be discontinuous.

Hydraulic Properties Water levels generally fluctuate in response to the amount and frequency of precipitation and surface runoff along Painted Woods and Yanktonai Creeks. Ground-water movement is downstream toward the Lost Lake area. Evaluation of water-level data indicates that these deposits are not hydraulically connected to the Lost Lake aquifer.

Water Quality - Five water samples indicate a calcium or sodium sulfate type water ranging from 1,250 mg/l to 2,410 mg/l dissolved solids. Dissolved iron and manganese concentrations may exceed limits recommended by the U.S. Public Health Service.

SUMMARY AND CONCLUSIONS

Data collected and evaluated during this investigation describe a 178 square mile area surrounding the cities of Washburn and Wilton including portions of Burleigh, McLean, and Oliver Counties. The area is situated within the Coteau Slope division of the Missouri Plateau

physiographic province of North Dakota. The average temperature is 42.4°F. and the average annual precipitation is 15.15 inches.

The Washburn-Wilton area is located on the eastern side of the Williston Basin and is underlain by more than 8,000 feet of sedimentary rocks. This investigation was concerned only with upper Cretaceous and Teritary rocks which are potential aquifers in this area. These bedrock aquifers are: 1) Fox Hills, 2) Hell Creek, 3) Tongue River, 4) Sentinel Butte Formations.

The Fox Hills and Hell Creek Formations consist of interbedded claystone, siltstone, sandstone, and shale. Wells tapping sandstone beds of up to 56 feet in thickness will yield small quantities of water. The predominantly sodium bicarbonate type water contained in sandstones of both the Fox Hills and Hell Creek Formations is very similar. Dissolved solids content ranged from 1,680 to 1,870 mg/l in the Fox Hills and from 1,420 to 1,540 mg/l in the Hell Creek. Properly constructed wells tapping sandstones of the Fox Hills and Hell Creek may yield as much as 50 gpm.

The Tongue River and Sentinel Butte Formations consist of interbedded claystone, siltstone, sandstone, shale, and lignite. Two sandstone beds in the Tongue River Formation are important aquifers in the study area. A basal sandstone bed in the Sentinel Butte Formation yields water to municipal wells at Wilton. Sandstones of the Tongue River and Sentinel Butte contain sodium and calcium bicarbonate type water. Dissolved solids content ranged from 655 to 1,620 mg/l in the Tongue River and 206 to 1.170 mg/l in the Sentinel Butte. Properly constructed wells tapping these sandstones may yield as much as 20 gpm.

Glaciofluvial deposits of sand and gravel have the greatest potential for ground-water development in the Washburn-Wilton area. The Lost Lake

and Missouri River aquifers occupy buried valleys and are capable of yielding more than 1000 gpm to properly constructed, fully penetrating wells.

The Lost Lake aquifer consists of interbedded clay, silt, sand and gravel which may exceed 150 feet in thickness. Southwest of Lost Lake the aquifer consists of an upper and a lower unit which are differentiated according to water-level and chemcial quality data.

Water from the Lost Lake aquifer is generally of the sodium bicarbonate type. However, in Sections 2 and 3, Township 143 North, Range 81 West calcium bicarbonate water is found assoicated with the deposits of the upper aquifer unit. Dissolved solids range from 367 to 1,650 mg/l and the water is generally hard. Dissolved iron and manganese usually exceed recommended limits and the treatment for the removal of these constituents will be required.

Deposits of the Missouri River aquifer consist of interbedded clay, silt, sand, and gravel which may exceed 190 feet in thickness. The aquifer is generally confined by alluvium and is under artesian pressure. An aquifer test using an existing irrigation well (143-81-29BBB1) has shown that this aquifer is capable of yielding more than 100 gpm.

The water is a sodium bicarbonate type with a dissolved solids range from 585 to 2,070 mg/l. Concentrations of sulfate, iron, and manganese generally exceed recommended limits.

Minor drift aquifers in the study area are associated with Painted Woods and Yanktonai Creeks or occur as isolated lenses of sand and gravel within the till. They are capable of yielding small quantities of water to domestic and stock wells. Dissolved solids may exceed 2,000 mg/l. The water is generally of the calcium sulfate type.

The results of this study show that Wilton has two possible alternatives for solving their water supply problem.

The first alternative is to drill additional wells about one mile southeast of the city into sandstones of either the Sentinel Butte or Tongue River Formations where subsurface data indicates greater aquifer thickness. However, due to the low permeabilities of the sandstones, at least five wells would be required to provide the city with an additional 100 gpm supply. Future population growth and increased demand would require the installation of additional wells.

Secondly, the city could develop a well field in the upper Lost Lake aquifer located in Sections 2 or 3, Township 143 North, Range 81 West, about 8 miles northwest of town. A single well completed in this aquifer could produce 200 gpm satisfying the city's present and future water requirements. It would be advisable to install two wells in the Lost Lake aquifer, then one well can be maintained for emergencies on a standby basis. Water quality in the upper unit of the Lost Lake aquifer is very similar to that of the city's present water supply, but facilities for the treatment to remove dissolved iron and manganese would be required.

Washburn's water supply facilities are adequate at the present time. However, new surface water treatment and filtration requirements set by the North Dakota State Department of Health may require modification of the city's existing water facilities.

As an alternative to a surface water treatment plant, the city could develop a well field in the upper Lost Lake aquifer located about five miles southeast of town. Water quality in the upper Lost Lake aquifer is essentially equivalent to that of the Missouri River water currently being used by the city, but iron removal facilities would be required.

TABLE 3 -- LOGS OF TEST HOLES

The following logs of test holes and wells are summaries of data from driller's logs, geologist's sample description, resistivity, spontaneous potential, and gamma ray logs. Color descriptions are of wet samples and are based upon color standards of the National Research Council (Goddard and others, 1948). Grand-size classification is C.K. Wentworth's scale from Pettijohn (1957).

Test holes are called observation wells when they have been completed with 1½-inch or 4-inch diameter plastic casing and screened at the bottom. Well depths, screened intervals (S.I.), and water levels, with date of measurement, are so designated. Water levels are in feet below land surface. Elevations, based on mean sea level datum, were interpolated from topographic maps published by the U.S. Geological Survey.

The test holes listed in table 3 with numbers between 8604 and 8952 were drilled as part of this investigation. The other numbered test holes were drilled by the North Dakota State Water Commission prior to this study. Logs of unnumbered test holes and wells were provided by the individual or agency shown in the heading of the log.

TABLE 3 -- Explanation of Lithologic Symbols

Clay

Sandstone

Till

Claystone or Siltstone

Silt

Shale

Sand

Limestone

Gravel

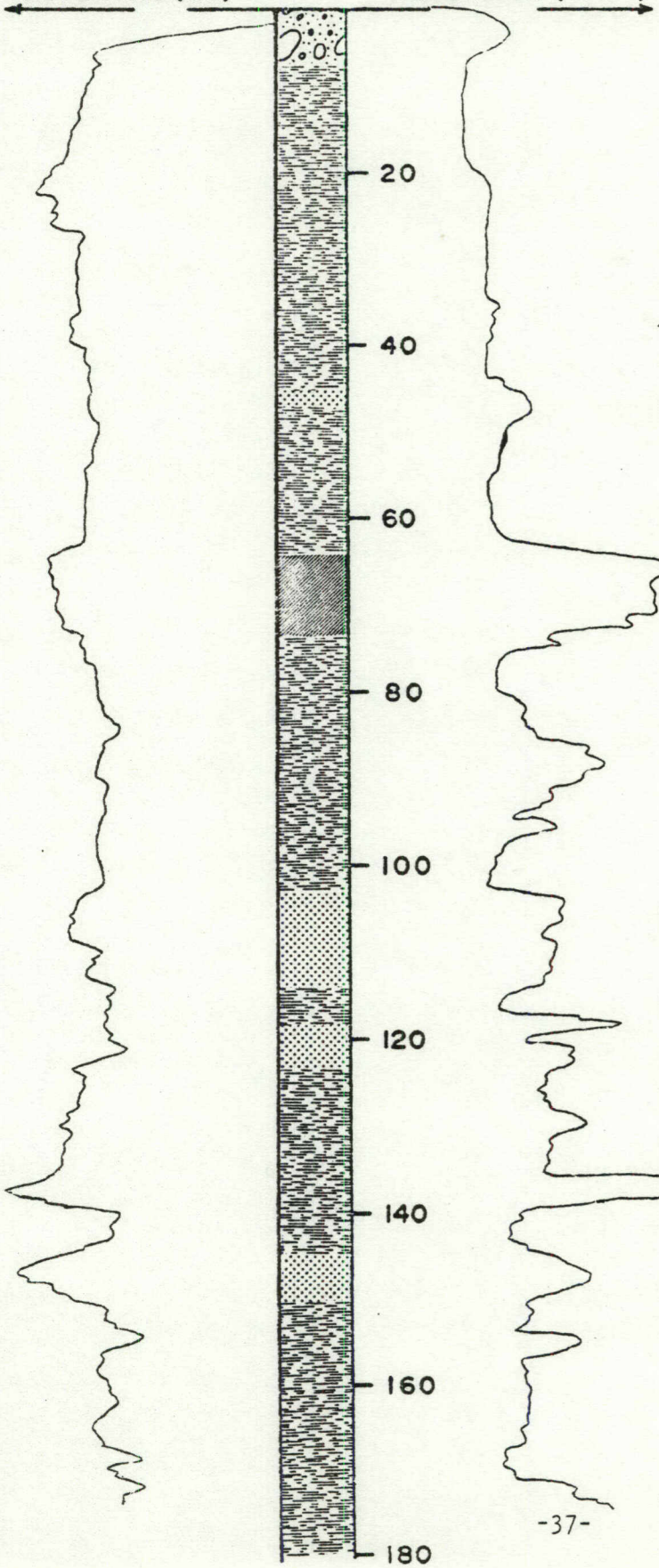
Lignite

LOCATION: 142-80-1AAB

DATE DRILLED: April, 1973

ELEVATION: 2155
(FT, MSL)

DEPTH: 180
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-7 Clay, silty, very sandy, pebbly, yellowish-brown, oxidized (till).

Sentinel Butte Formation

7-45 Claystone, silty, grayish-yellow, calcareous, partially oxidized, a few thin lignite stringers.

45-47 Sandstone, very fine to medium, medium-bluish-gray, subangular, semi-consolidated.

47-64 Siltstone, siliceous, clayey, dark-greenish-gray, noncalcareous.

64-74 Lignite, black, brittle, some thin, brownish-gray, carbonaceous shale bedding.

74-103 Siltstone, siliceous, clayey, medium-light-gray, some greenish-gray bentonitic clay.

Tongue River Formation

103-114 Sandstone, clayey, very fine to fine, light-bluish-gray.

114-118 Claystone, silty, brownish-gray.

118-123 Sandstone, very clayey, very fine to fine, medium-light-gray.

123-145 Siltstone, siliceous, clayey, medium gray with dark-greenish-gray mottling, slightly calcareous.

145-150 Sandstone, silty, very fine to medium, light-bluish-gray, noncalcareous.

150-180 Siltstone, siliceous, clayey, medium-light-gray, some brownish-gray bedding, a few thin lignite stringers.

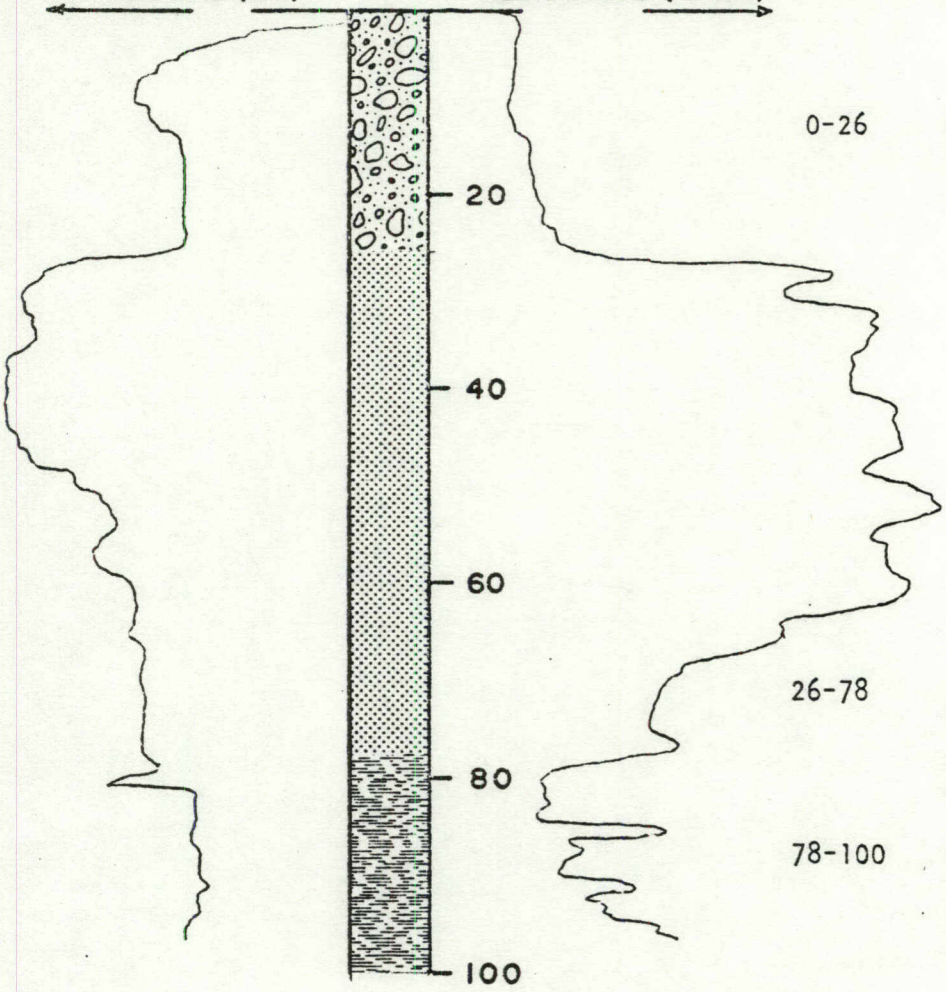
NDSWC 8613

LOCATION: 142-80-1BBB

DATE DRILLED: April, 1973

ELEVATION: 2150
(FT, MSL)

DEPTH: 100
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-26 Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).

Sentinel Butte Formation

26-78 Sandstone, silty, some clay, very fine to fine, yellowish-brown, loose, subangular to subrounded, oxidized, lignitic.

78-100 Siltstone, siliceous, medium-light-gray, some thin, brownish-gray carbonaceous shale bedding, calcareous.

Observation Well
Depth 76 feet
S.I. 73-76 feet
Water level 67.43 feet

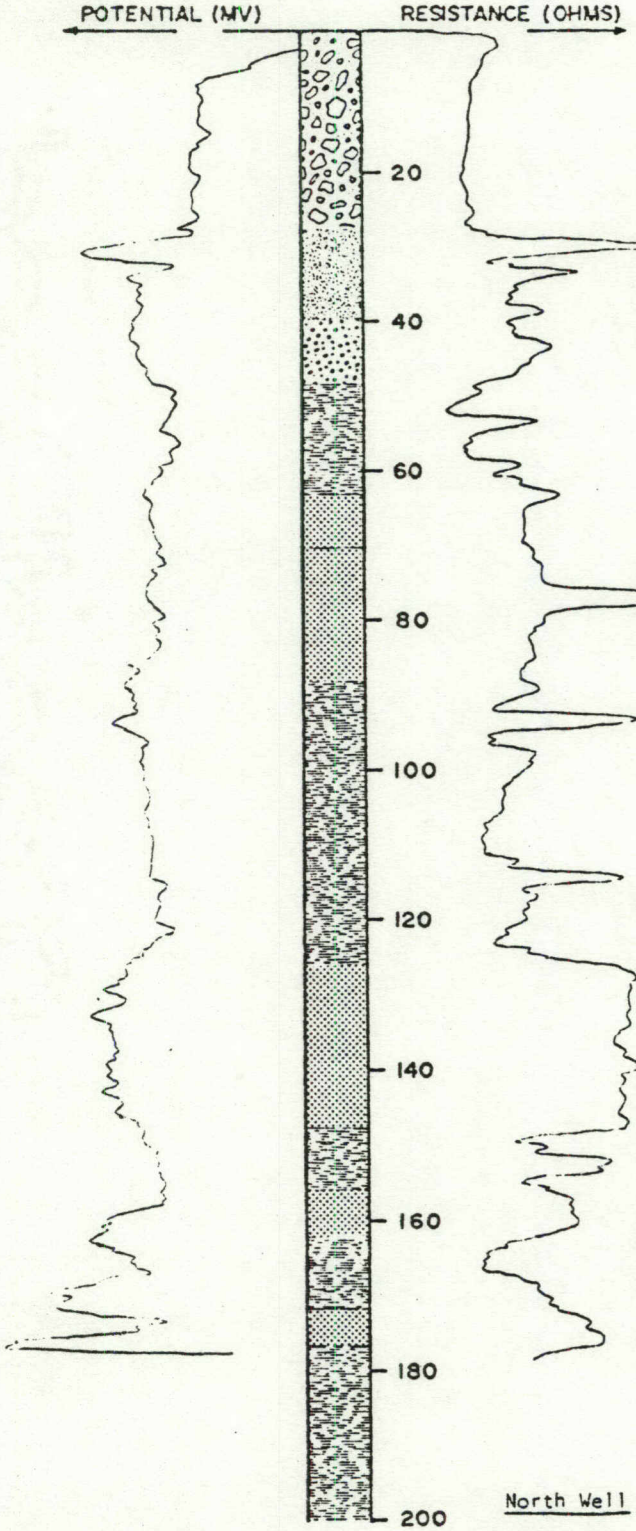
NDSWC 8617

LOCATION: 142-80-1CBB

DATE DRILLED: April, 1973

ELEVATION: 2120
(FT, MSL)

DEPTH: 200
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-27	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).
27-32	Silt, clayey, yellowish-brown, oxidized.
32-40	Silt, clayey, sandy, olive gray, soft, highly calcareous.
40-48	Sand, silty, clayey, fine to medium, dark-yellowish-brown, oxidized.

Sentinel Butte Formation

48-63	Claystone, silty, medium gray, lignite stringers, calcareous.
63-70	Sandstone, about 30 percent clay, very fine to fine, light-brownish-gray, subangular, consolidated.
70-88	Sandstone, about 30 percent clay and silt, very fine to medium, medium-bluish-gray, semi-consolidated to loose, subangular, micaceous, fossil shells.

Tongue River Formation

88-126	Claystone, medium gray to light-brownish-gray.
126-148	Sandstone, very clayey, very fine to fine, light-brownish-gray, fossil shells.
148-156	Claystone, silty, brownish-gray, thin lignite stringers.
156-162	Sandstone, clayey, very fine to fine, brownish-gray, consolidated.
162-172	Claystone, silty, brownish-gray.
172-177	Sandstone, silty, clayey, fine, medium-light-gray.
177-200	Siltstone, siliceous, medium-light-gray, calcareous.

Observation Wells

North Well

Well diameter 4 inches
Depth 144 feet
S.I. 139-144 feet
Water level 73.43 feet
Measured 11-14-73

South Well

Well diameter 1¼ inches
Depth 144 feet
S.I. 138-144 feet
Water level 71-97 feet
Measured 11-14-73

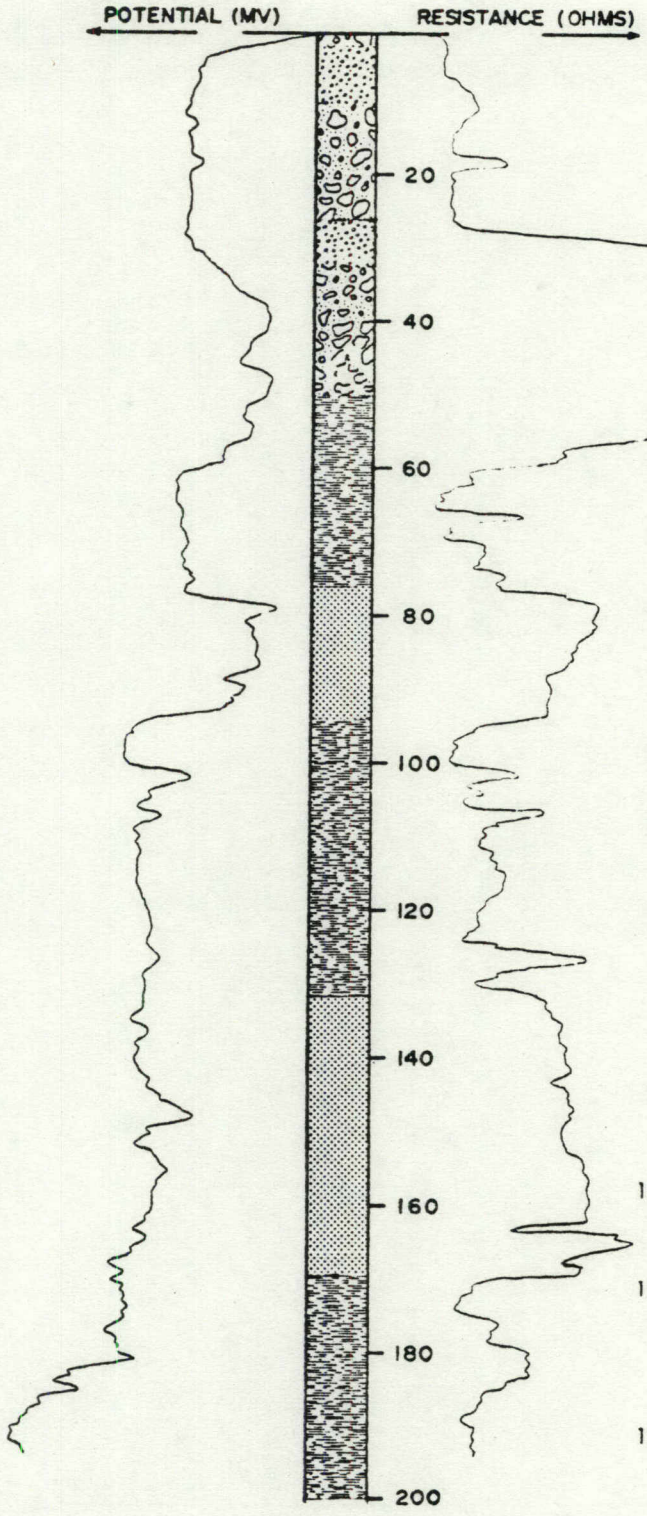
NDSWC 8630

LOCATION: 142-80-1CDD

DATE DRILLED: May, 1973

ELEVATION: (FT, MSL) 2140

DEPTH: (FT) 200



DESCRIPTION OF DEPOSITS

Glacial Drift

0-2	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).
2-10	Sand, slightly clayey, fine to medium, oxidized.
10-26	Clay, silty, pebbly, yellowish-brown, oxidized (till).
26-32	Sand, clayey, fine to medium, oxidized.
32-50	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).

Sentinel Butte Formation

50-62	Siltstone, clayey, sandy, yellowish-brown, oxidized.
62-76	Siltstone, medium-light-gray, some thin brownish-gray carbonaceous shale beds, calcareous.
76-94	Sandstone, slightly clayey, very fine to medium, medium-bluish-gray, loose, friable.

Tongue River Formation

94-100	Claystone, silty, brownish-gray, thin, dark brown carbonaceous shale bedding.
100-132	Siltstone, slightly sandy, clayey, medium-light-gray, thin lignite stringers.
132-170	Sandstone, clayey, silty, very fine to fine, medium-light-gray to light-bluish-gray, semi-consolidated, a few thin claystone beds and lignite stringers.
170-200	Siltstone, siliceous, medium-light-gray, brownish-gray to dark brown shale bedding, thin lignite stringers.

142-80-2ABB
City of Wilton Test well 1
(Log by C. A. Simpson and Son)

Geologic source	Material	Thickness (feet)	Depth (feet)
	Topsoil	1	1
	Brown clay and rock	6	7
	Yellow clay	20	27
	Blue clay	25	52
	Hardpan and rock	5	57
	Slightly gravelly clay	23	80
	Sandy clay	22	102
	Coal	5	107
	Sandy gray clay	1	108
	Fine loose sand	5	113
	Soft gray clay	29	142
	Coal and brown clay	3	145
	Blue shale	17	162
	Coal	1	163
	Gray shale	40	203
	Dark shale with little coal	17	220

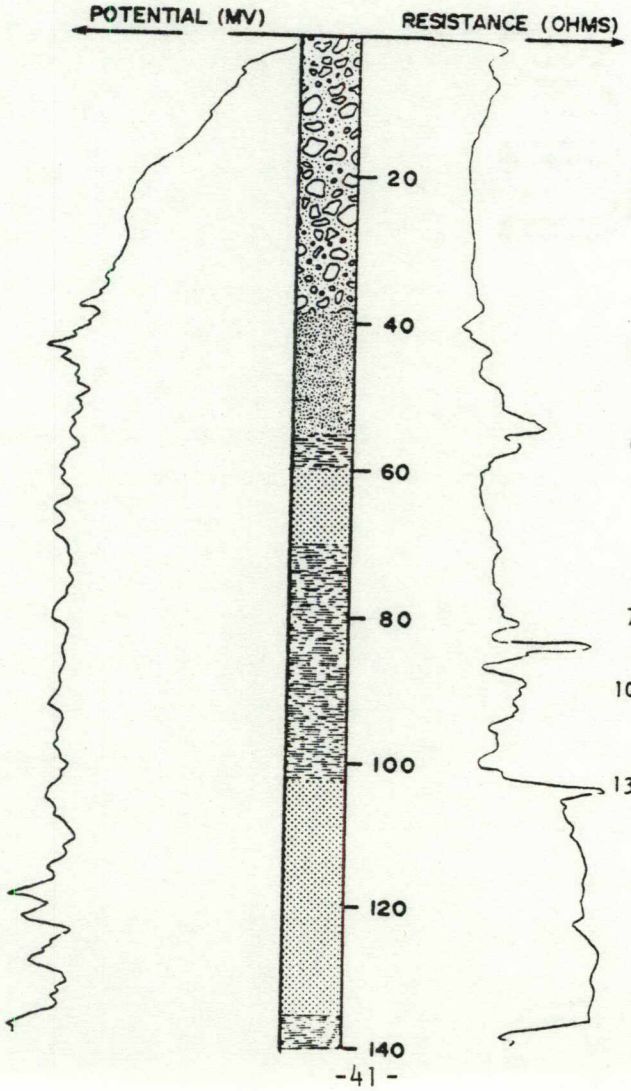
NDSWC 8633

LOCATION: 142-80-20CD

DATE DRILLED: May, 1973

ELEVATION: 2120
(FT, MSL)

DEPTH: 140
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-38 Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).

38-55 Silt, very sandy, gravelly sand lenses, yellowish-brown, oxidized.

Sentinel Butte Formation

55-60 Claystone, siliceous, sandy, medium gray to greenish-gray, bentonitic, calcareous.

60-70 Sandstone, clayey, silty, very fine to fine, medium-bluish-gray, fossiliferous, semi-consolidated.

Tongue River Formation

70-102 Siltstone, siliceous, clayey, light gray, highly calcareous.

102-136 Sandstone, clayey, silty, very fine to fine, light-bluish-gray, consolidated.

136-140 Siltstone, clayey, medium gray, thin brownish-gray, carbonaceous shale bedding.

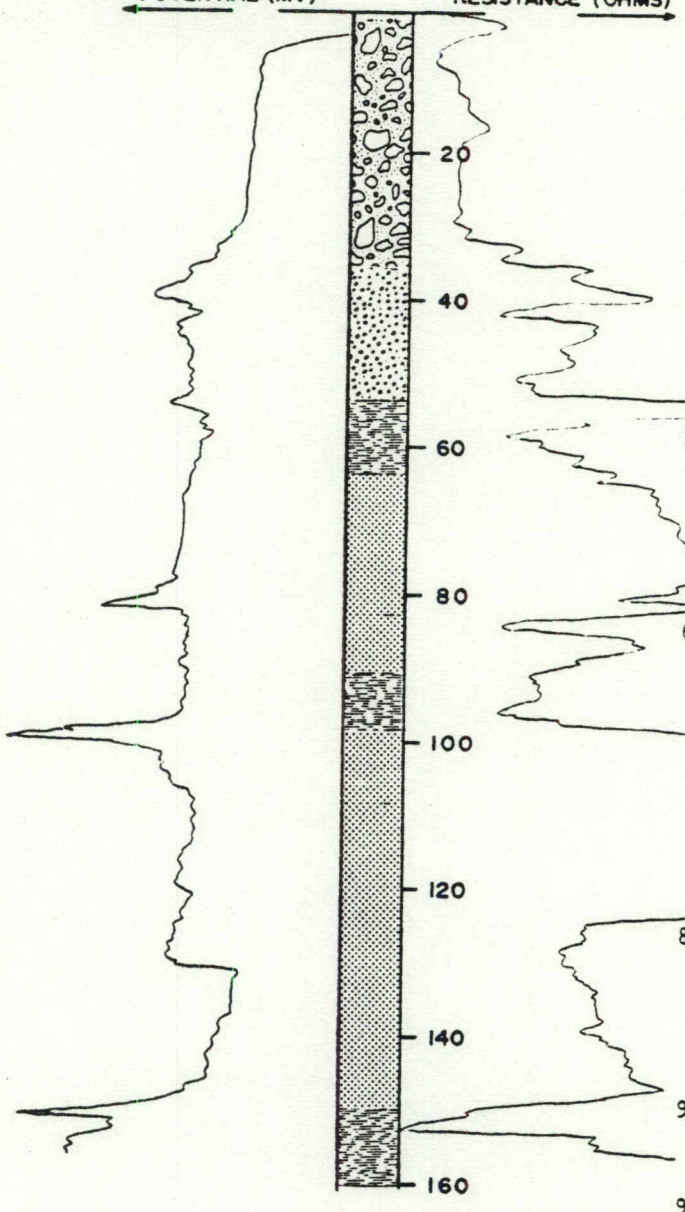
NDSWC 8611

LOCATION: 142-80-2DDD

DATE DRILLED: April, 1973

ELEVATION: 2115
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, sand, pebbly loam, grayish-black.

1-35 Clay, sandy, silty, pebbly, yellowish-brown, oxidized (till).

35-53 Sand, very clayey, fine to coarse, well-oxidized, moderately well-sorted.

Sentinel Butte Formation

53-63 Claystone, silty, sandy, medium-dark-gray with dark-yellowish-brown mottling, partially oxidized.

63-82 Sandstone, slightly clayey, very fine to medium, dark-greenish-gray, semi-consolidated to loose, friable, lignitic.

82-90 Sandstone, silty, clayey, very fine to fine, medium-light-gray, consolidated, friable, calcareous.

Tongue River Formation

90-98 Siltstone, clayey, siliceous, medium-light-gray, highly calcareous.

98-108 Sandstone, silty, clayey, very fine, medium-light-gray, consolidated lignitic, calcareous.

108-150 Sandstone, slightly clayey, very fine to fine, medium-bluish-gray, semi-consolidated to loose, friable, taking water.

150-160 Claystone, silty, light-brownish-gray, occasional thin lignite stringers, carbonaceous.

Observation Well
Depth 82 feet
S.I. 77-82 feet
Water level 43.53 feet
Measured 11-14-73

142-80-3AAA
NDSWC 1985

Elevation: 2170.9 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Till, moderate-yellowish-brown, lignite fragments, highly-calcareous, oxidized	7	7
Sentinel Butte Formation:			
	Clay, moderate-yellowish-brown, silty, cohesive, oxidized	4	11
	Clay, dusky-yellow, silty, cohesive, calcareous	7	18
	Clay, dusky-yellowish-brown, silty, cohesive, oxidized	4	22
	Lignite, hard, sharp fragments	4	26
	Clay, medium-bluish-gray, silty, indurated, lignite smears	11	37
	Sand, medium-bluish-gray, very fine, silty, lignite and mica flakes	14	51
	Clay, medium-bluish-gray, silty, cohesive, lignite flecks, highly-calcareous	8	59
	Lignite, hard	3	62
	Clay, light-bluish-gray, silty, minor lignite flecks	3	65
	Lignite, hard	½	65½
	Clay, pale-blue-green, slightly-silty	7½	73
	Clay, light-olive-gray, silty, cohesive, highly-calcareous	2	75
	Silt, brownish-black, cohesive, abundant lignite fragments, highly-calcareous	6	81
	Clay, dark-greenish-gray, silty, indurated, calcareous	16	97
	Clay, greenish-gray, silty, indurated, white calcareous layers	9	106
	Lignite	1	107
	Silt, light-olive-gray, clayey, lignite flecks, calcareous	11	118
	Sandstone, olive-gray, very hard, indurated, calcareous	1	119
Tongue River Formation:			
	Silt, olive-gray, clayey, very fossiliferous, calcareous	19	138
	Lignite	1	139
	Silt, olive-black; sand, very fine	6	145
	Silt, grayish-blue-green, clayey, occasional lignite chips	7	152
	Sand, very fine, clayey, calcareous	4	156
	Clay, light-olive-gray, silty, lignite fragments, calcareous	7	163
	Lignite	1	164
	Sand, light-olive-gray, lignitic	58	222
	Silt, olive-gray to olive-black, very clayey	3	225

142-80-11ADD
NDSWC 8632
Elevation 2095 feet
Drilled May, 1973

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, sandy, pebbly, yellowish-brown, oxidized (till)	33	33
	Clay, silty, pebbly, olive gray, (till)	11	44
	Sand, clayey, thin layers of olive gray laminated silt, very fine to coarse, well-sorted, very lignitic, gravelly lower 3 feet	18	62
Tongue River Formation:			
	Claystone, silty, medium-light-gray, calcareous	18	80
	Limestone, dark gray, hard	3	83
	Siltstone, clayey, thin bluish-gray sandstone interbeds, lignite stringers, highly calcareous	49	132
	Sandstone, silty, very fine to fine, medium-light-gray, consolidated	5	137
	Siltstone, siliceous, clayey, medium-light-gray, lignite stringers	23	160

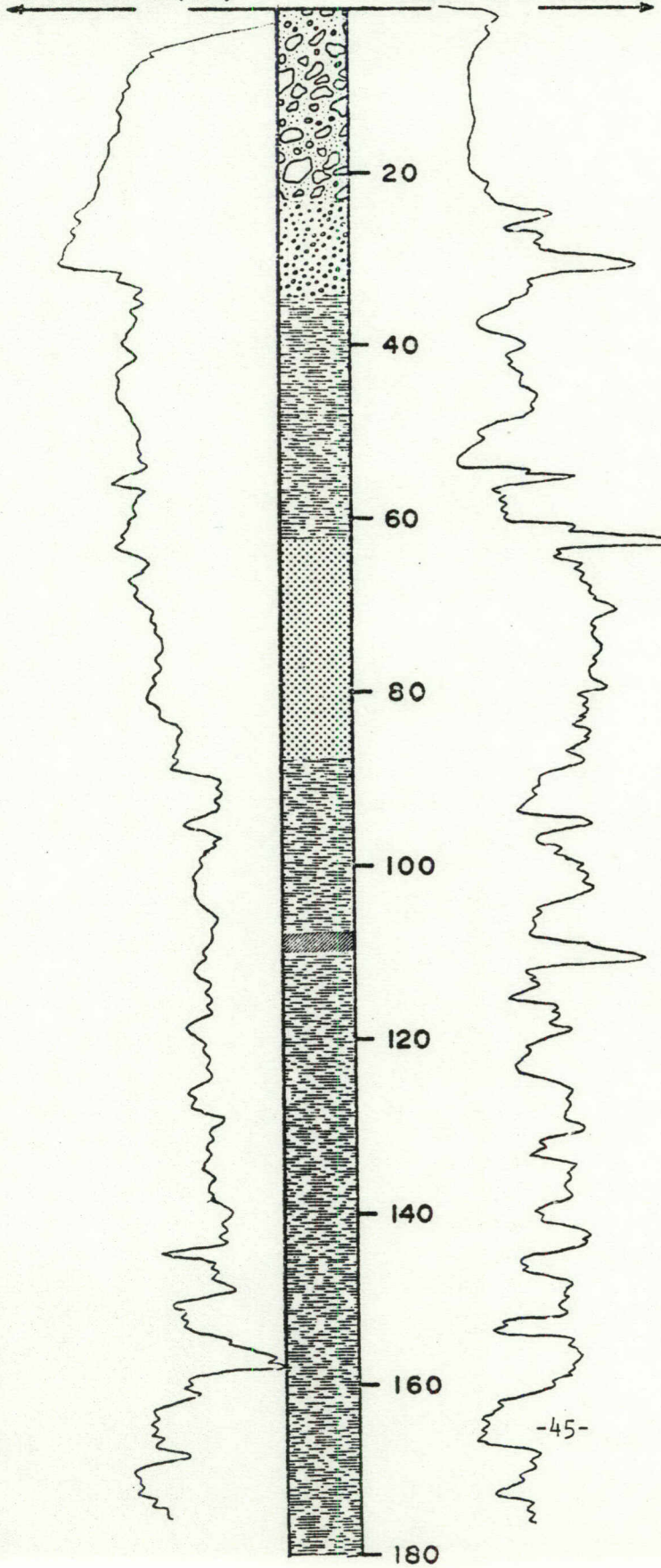
NDSWC 8631

LOCATION: 142-80-12AAD

DATE DRILLED: May, 1973

ELEVATION: 2130
(FT, MSL)

DEPTH: 180
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-23 Clay, sandy, silty, pebbly, yellowish-brown, oxidized (till).

23-34 Sand, silty, clayey, fine to coarse, well-sorted, light brown, oxidized.

Sentinel Butte Formation

34-48 Siltstone, siliceous, medium-light-gray, calcareous.

48-62 Siltstone, brownish-gray with dark brown, carbonaceous shale bedding, thin lignite stringers.

62-88 Sandstone, clayey, very fine to medium, greenish-gray to medium-bluish-gray, semi-consolidated to loose.

Tongue River Formation

88-108 Claystone, silty, medium-light-gray with brownish-gray, carbonaceous shale bedding, calcareous.

108-110 Lignite, black, brittle.

110-180 Siltstone, siliceous, medium-light-gray, thin sandstone bedding and a few thin lignite stringers.

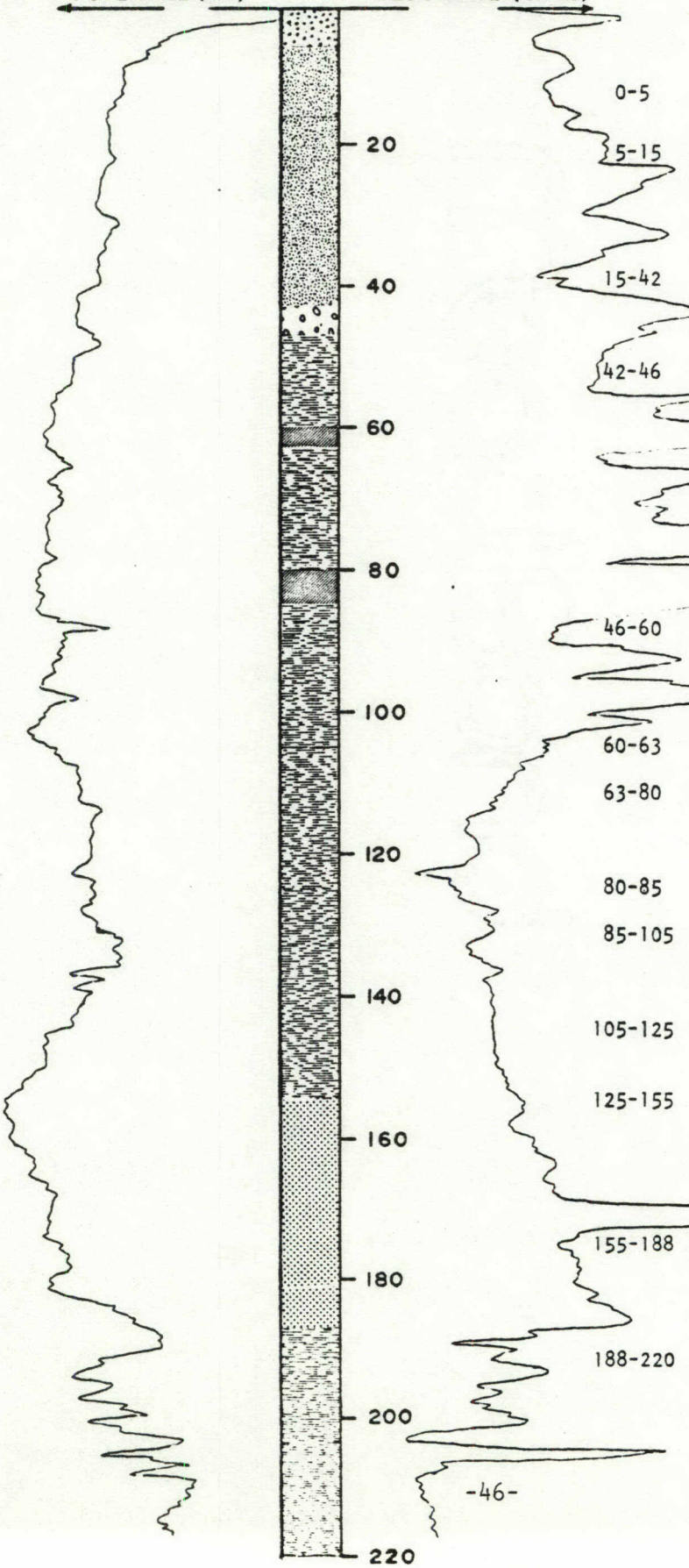
NDSWC 8612

LOCATION: 142-80-12CCD

DATE DRILLED: April, 1973

ELEVATION: 2070
(FT, MSL)

DEPTH: 220
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-5 Sand, silty, medium to very coarse, oxidized.

5-15 Silt, clayey, yellowish-brown, oxidized.

15-42 Silt, clayey, olive gray, thin sand lenses, highly calcareous.

42-46 Gravel, sandy, slightly clayey, fine to coarse, oxidized.

Tongue River Formation

46-60 Siltstone, siliceous, medium light gray, highly calcareous.

60-63 Lignite, black, brittle.

63-80 Claystone, silty, medium-dark-gray to brownish-gray, occasional thin lignite stringers.

80-85 Lignite, black, brittle

85-105 Claystone, silty, brownish-gray, thin lignite stringers, carbonaceous.

105-125 Claystone, silty, brownish-gray, carbonaceous.

125-155 Siltstone, siliceous, medium-light-gray, fossiliferous, some greenish-gray bentonitic clay bedding, slightly calcareous.

155-188 Sandstone, clayey, very fine to medium, medium-bluish-gray, semi-consolidated to consolidated, cemented from 170-172 feet.

188-220 Siltstone and claystone, brownish-gray to medium gray, light-brownish-gray sandstone interbeds, light brown limestone concretions, noncalcareous.

142-81-4ADC
NDSWC #1984

Elevation: 1666.3 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Clay, yellowish-orange, sandy, oxidized -----	4	4
	Gravel, fine to medium, sandy, oxidized -----	3	7
Cannonball Formation:			
	Sand, very fine to fine, silty to clayey, lignite fragments, oxidized ----------	33	40
	Sand, fine, silty to clayey, lignite fragments ----------	13	53
	Sandstone, friable, highly-calcareous -------	5	58
	Sand, fine, silty to clayey, unsorted, abundant lignite and mica, (glauconitic) --	5	63
	Sand, greenish-black, silty, (glauconitic) --	25	88
	Silt, olive-gray, sandy, lignite and mica flakes, slightly-calcareous ----------	1	89
	Limestone, olive-gray, sandy ----------	2	91
	Silt, olive-gray, clayey to sandy, harder than above, slightly-calcareous ----------	26	117
	Sand, olive-gray, abundant lignite and green specks (glauconitic) ----------	2	119
	Limestone, sandy, very hard ----------	4	123
	Silt, olive-gray, sandy, mica flakes --------	13	136
	Sand, grayish-blue-green, very fine to fine, (abundant glauconite) ----------	9	145
Hell Creek Formation:			
	Sand, olive-gray, very silty, lignite and mica flakes ----------	17	162
	Silt, olive-black, clayey, lignite and mica flakes ----------	8	170
	Silt, olive-black, pyrites ----------	18	188
	Silt, light-olive-gray pyrite, mica, and lignite ----------	9	197
	Sand, grayish-blue-green, very fine to medium-angular, abundant green grains (glauconitic) ----------	12	209
	Silt, olive-gray, sandy ----------	6	215
	Sand, light-olive-gray, very fine to medium, green grains, (glauconitic) ----------	19	234
	Shale, greenish-gray, sandy to clayey, lignitic ----------	16	250
	Sand, olive-black, very fine to fine, abundant green grains (glauconite) ----------	13	263
	Sand, clayey, mostly quartz, some mica and greenish grains ----------	5	268
	Limestone, sandy ----------	3	271
	Sand, olive-gray, very fine to medium, clayey ----------	16	287
	Shale, dark-greenish-gray; sand, very fine; mica and lignite flakes, abundant light-bluish to greenish grains ----------	47	334
	Sand, very fine to fine, silty, black and green grains ----------	14	348
	Lignite ----------	5	353
	Shale, olive-gray, silty ----------	11	364
	Shale, greenish-gray, silty to sandy, (glauconitic) ----------	16	380
Fox Hills Formation:			
	Sand, greenish-gray, fine to medium, abundant green and black grains (glauconitic) ----------	15	395
	Sand, greenish-gray, fine to medium clayey, (glauconitic) ----------	5	400
	Sand, greenish-gray, fine to medium, clayey (glauconitic) ----------	35	435

Observation Well
Depth 435 feet
Perforated from 415-435 feet
Flow

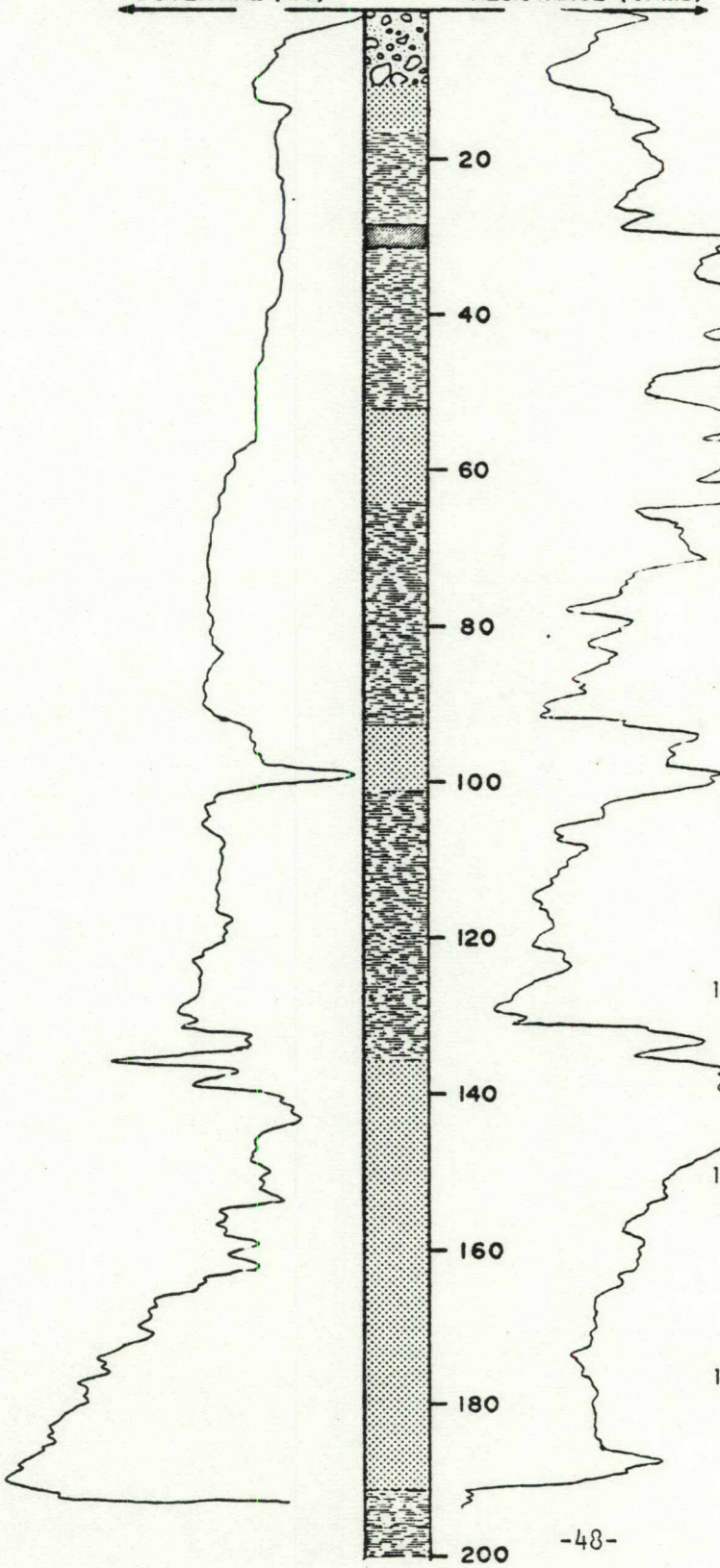
NDSWC 8608

LOCATION: 143-79-31AAA

DATE DRILLED: April, 1973

ELEVATION: 2060
(FT, MSL)

DEPTH: 200
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-10 Clay, silty, pebbly, yellowish-brown, oxidized (till).

Tongue River Formation

10-16 Sandstone, fine, yellowish-brown, thin siltstone bedding, lignite stringers, calcareous.

16-28 Siltstone, clayey, yellowish-brown, sandstone interbeds, oxidized.

28-31 Lignite, black brittle.

31-52 Siltstone, clayey, medium-light-gray, thin sandstone bedding, calcareous.

52-64 Sandstone, clayey, silty, very fine to fine, medium-light-gray, thin claystone bedding.

64-93 Claystone, siliceous, medium gray, brownish-gray carbonaceous shale interbeds, fossiliferous.

93-101 Sandstone, silty, fine, medium-bluish-gray, consolidated.

101-136 Claystone, silty, siliceous, medium-light-gray, brownish-gray, carbonaceous shale interbeds, lignite stringers from 130-135 feet.

136-192 Sandstone, slightly clayey, fine to medium, medium-bluish-gray, loose to consolidated, friable, lignitic.

Cannonball Formation

192-200 Siltstone, siliceous, brownish-gray, noncalcareous.

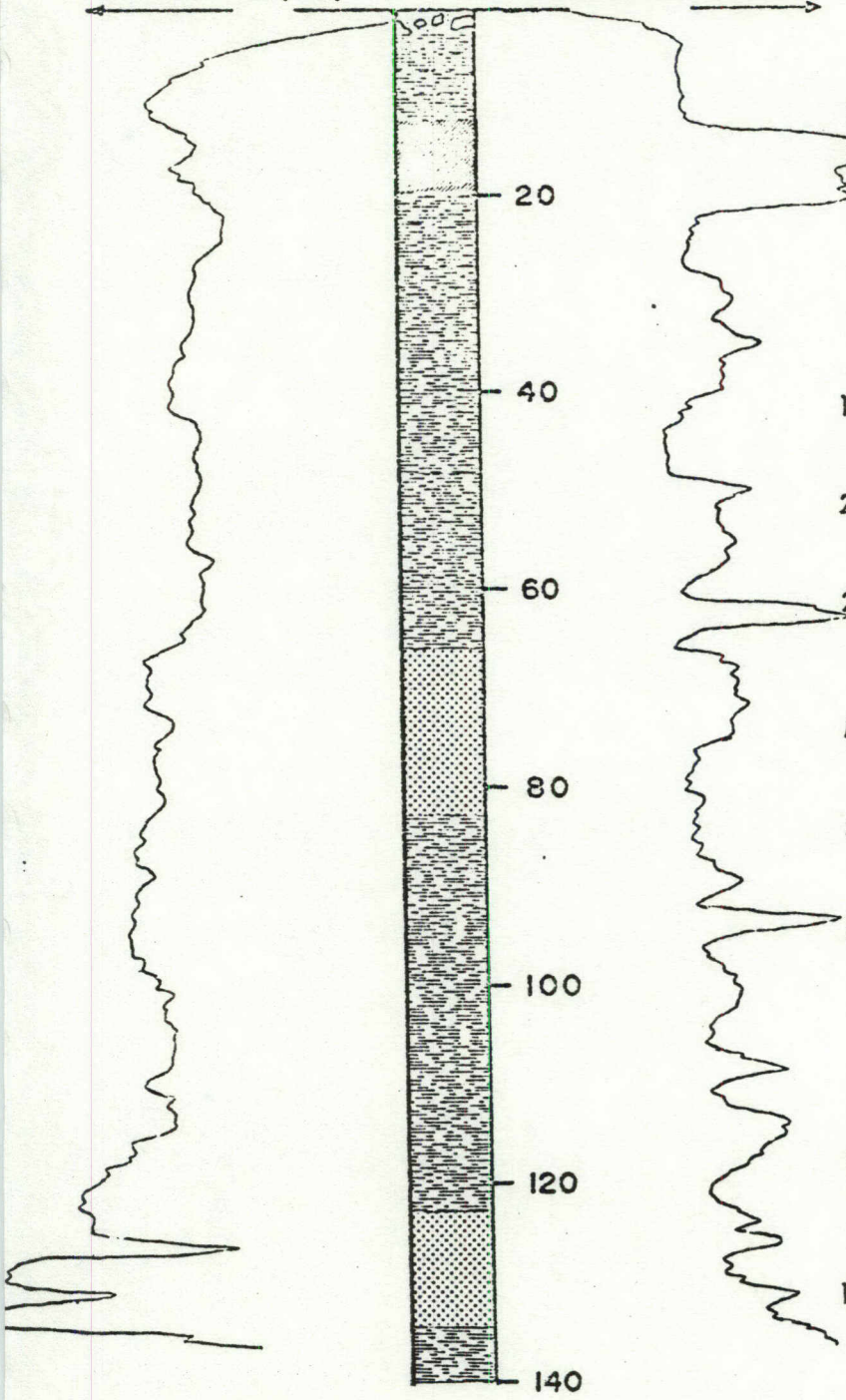
NDSWC 8628

LOCATION: 143-79-31DCC

DATE DRILLED: April, 1973

ELEVATION: 2120
(FT, MSL)

DEPTH: 140
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-3 Clay, silty, sandy, pebbly, yellowish-brown, (till).

Sentinel Butte Formation

3-12 Claystone, silty, yellowish-brown to dusky yellow, oxidized.

12-20 Lignite, black, brittle, fractured, taking water.

20-27 Claystone, greenish-gray, bentonitic.

27-40 Siltstone, siliceous, medium-light-gray, brownish-gray mottling, calcareous.

40-48 Claystone, siliceous, greenish-gray, thin lignite stringers.

48-66 Siltstone, medium gray to light-brownish-gray, calcareous

66-83 Sandstone, clayey, very fine to fine, light-brownish-gray, consolidated.

Tongue River Formation

83-123 Siltstone, siliceous, medium gray, brownish-gray shale bedding, slightly calcareous.

123-135 Sandstone, very clayey, very fine to fine, medium-light-gray to light-brownish-gray, subangular, thin claystone bedding.

135-140 Claystone, silty, medium gray, lignite stringers, calcareous.

Observation well
Depth 20 feet
S.I. 17-20 feet
Water level 10.45 feet
Measured 11-14-73

143-80-2CCB
NDSWC 3894

Elevation: 1914 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, silty, black	1	1
	Silt, clayey, yellowish-gray	2	3
	Clay, silty, yellowish-gray to olive-brown; scattered sand and gravel (till)	16	19
	Clay, silty, sandy, olive-gray; scattered pebbles (till)	13	32
Tongue River Formation:			
	Shale, sandy, carbonaceous, variegated gray, green, and brown; interbedded with fine greenish-gray sand and lignite	28	60

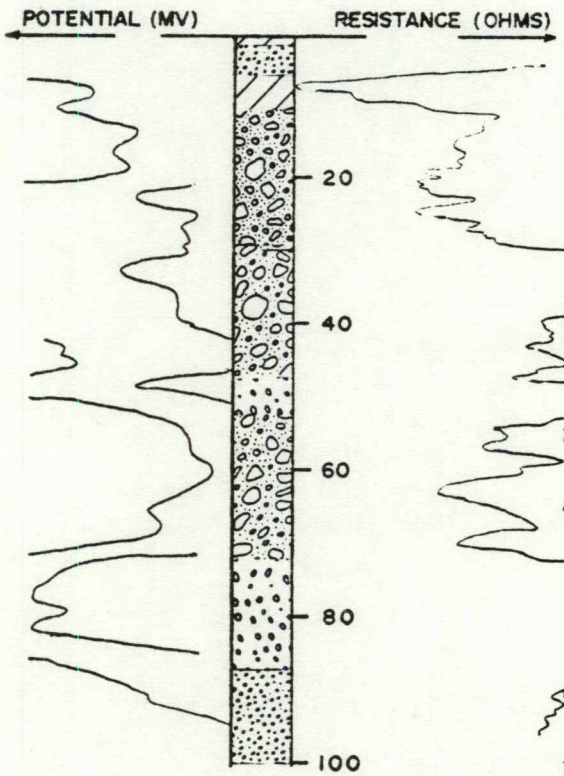
NDSWC 3895

LOCATION: 143-80-8AAA

DATE DRILLED: November, 1969

ELEVATION: (FT, MSL) 1890

DEPTH: (FT) 100



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Clay, sandy, black (topsoil).
1-5	Sand, fine, silty, yellowish-gray.
5-10	Clay, yellowish-brown
10-26	Clay, silty, sandy, pebbly, olive-gray (till).
26-47	Clay, sandy, pebbly, olive-gray; silt and sand lenses (till).
47-52	Gravel, fine to medium, sub-rounded.
52-72	Clay, silty, sandy, pebbly, olive-gray (till).
72-87	Gravel, fine to medium, sandy, subangular to subrounded.

Tongue River Formation

87-100	Sand, very fine to fine, clayey, micaceous, noncalcareous, greenish-gray.

Observation well
Depth 80 feet
S.I. 77-80 feet
Water level 24.91 feet
Measured 11-30-70

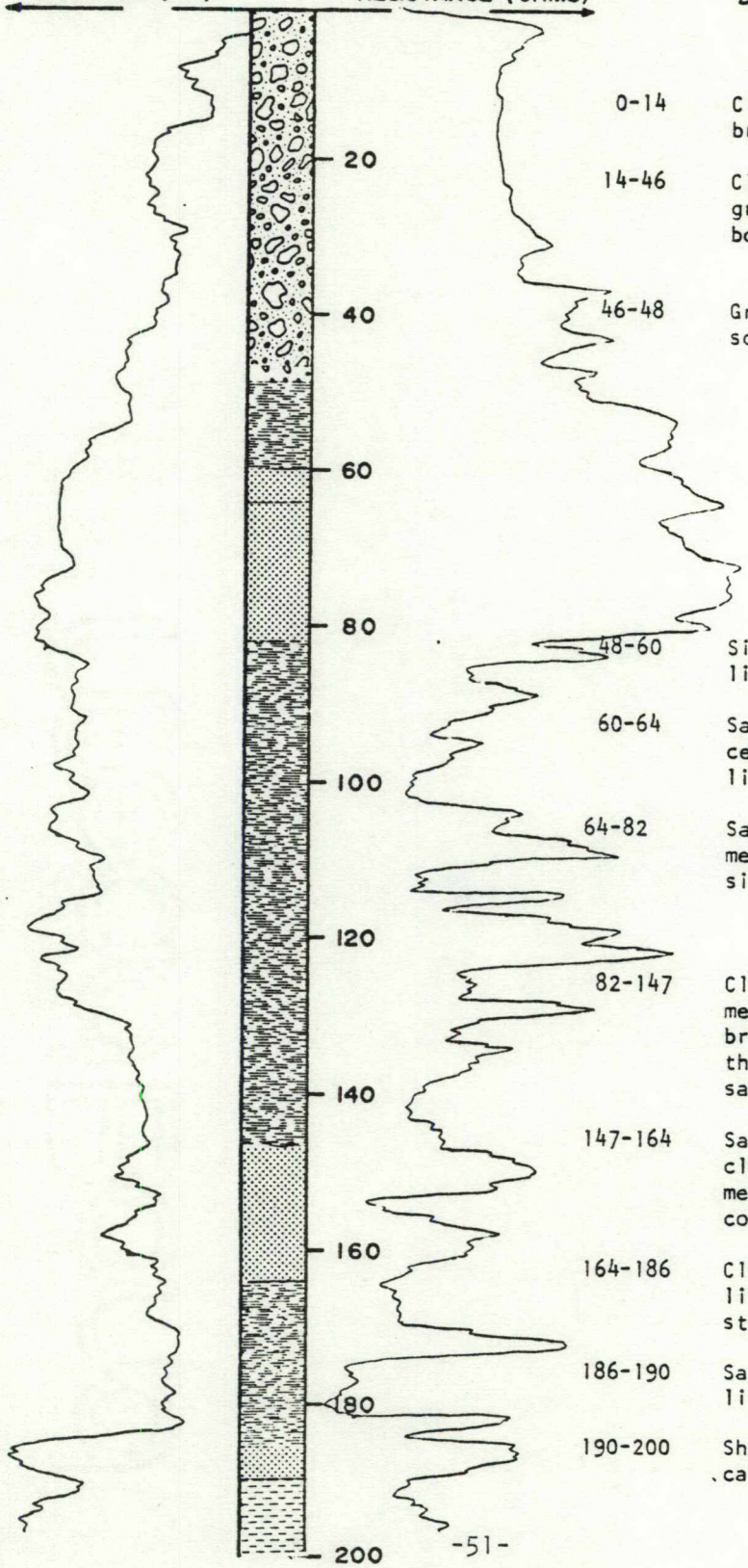
NDSWC 8609

LOCATION: 143-80-22DDD

DATE DRILLED: April, 1973

ELEVATION: 2060
(FT, MSL)

DEPTH: 200
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-14	Clay, sandy, pebbly, yellowish-brown, oxidized (till).
14-46	Clay, sandy, silty, pebbly, olive gray, some reworked bedrock boulders (till).
46-48	Gravel, fine to coarse, poorly sorted, loose.

Tongue River Formation

48-60	Siltstone, siliceous, medium-light-gray, highly calcareous.
60-64	Sandstone, very fine, medium gray, cemented, highly calcareous, lignitic.
64-82	Sandstone, clayey, very fine to medium, medium-bluish-gray, thin siltstone beds, lignitic.
82-147	Claystone, siliceous, medium gray, medium-light-gray siltstone and brownish-gray shale interbeds, thin lignite stringers and thin sandstone beds.
147-164	Sandstone, claystone interbeds, clayey, very fine to medium, medium-bluish-gray, loose to consolidated, lignitic, micaceous.
164-186	Claystone, silty, sandy, medium-light-gray to brownish-gray, limestone concretions.
186-190	Sandstone, fine, brownish-gray, lignitic, consolidated.
190-200	Shale, slightly sandy, dark brown, carbonaceous.

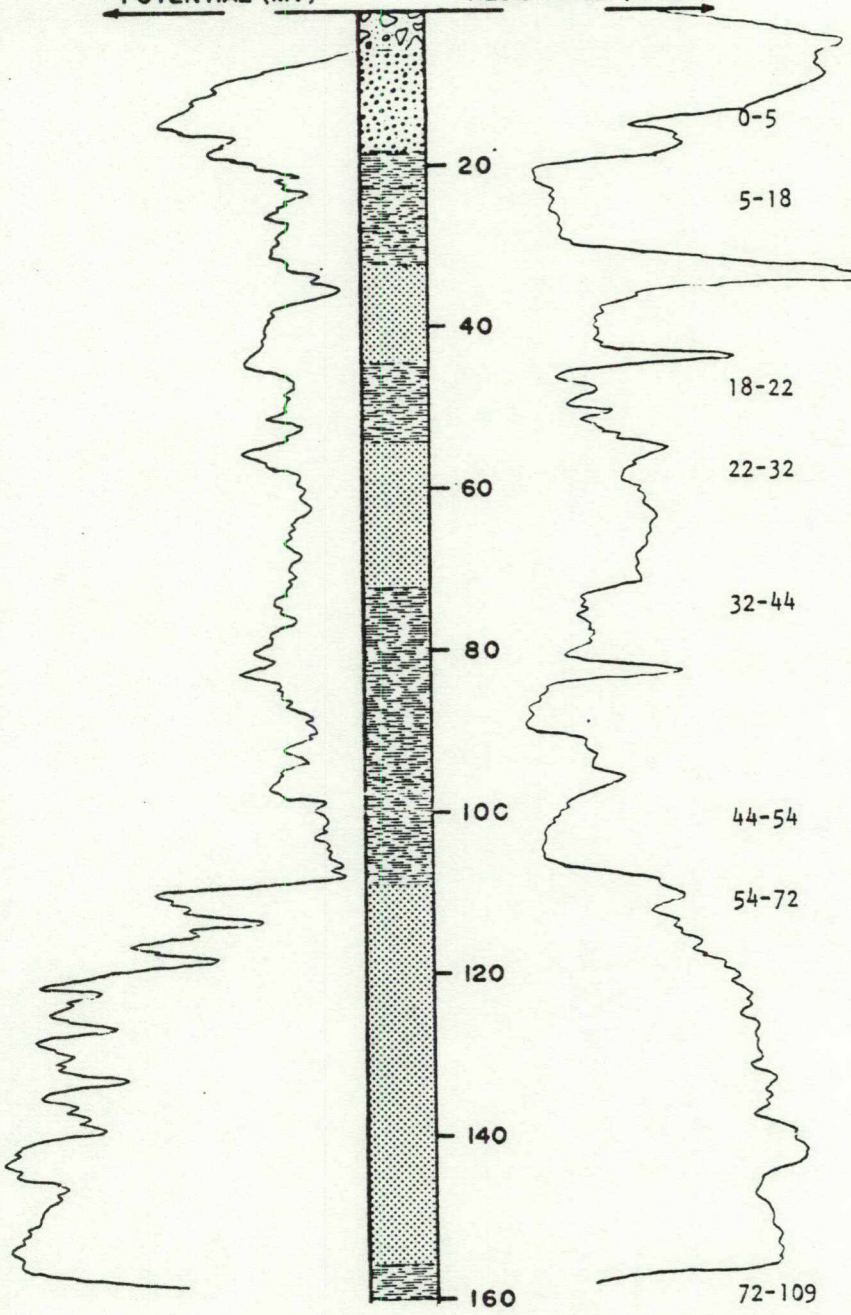
NDSWC 8616

LOCATION: 143-80-26CCC

DATE DRILLED: April, 1973

ELEVATION: 2105
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-5	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).
5-18	Sand, clayey, gravelly, fine to coarse, reworked bedrock sand, lignitic, oxidized.

Sentinel Butte Formation

18-22	Claystone, silty, yellowish-brown, oxidized.
22-32	Siltstone, clayey, siliceous, medium-light-gray to greenish-gray, bentonitic, highly calcareous.
32-44	Sandstone, clayey, light-bluish-gray, very fine to fine, consolidated, friable, cemented from 32-34 feet.

Tongue River Formation

44-54	Siltstone, siliceous, medium-light-gray, highly calcareous.
54-72	Sandstone, clayey, very fine to fine, light-bluish-gray, semi-consolidated, friable, calcareous.
72-109	Siltstone, siliceous, clayey, medium-light-gray, calcareous.
109-156	Sandstone, slightly clayey, very fine to medium, medium-bluish-gray, semi-consolidated, friable, lignitic, taking water rapidly.
156-160	Siltstone, siliceous, medium gray.

Observation well
Depth 154 feet
S.I. 148-154 feet
Water level 101.47 feet
Measured 11-14-73

143-80-26DAD
NDSWC 8615

Elevation 2155 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till)	2	2
	Sand, silty, clayey, medium to coarse, moderate brown, oxidized	2	4
	Clay, silty, pebbly, yellowish-brown, oxidized (till)	4	8
Sentinel Butte Formation:			
	Claystone, silty, yellowish-brown to dusky yellow, oxidized	11	19
	Lignite, black to dark-brownish-black, brittle, fractured, taking water rapidly	7	26
	Claystone, silty, medium-light-gray, calcareous, lost circulation, abandoned hole	14	40

143-80-32AAA
NDSWC 8604

Elevation: 2010 feet

Glacial drift:			
	Gravel, sandy, clayey, fine to coarse, loose, oxidized	4	4
	Clay, very sandy, gravelly, yellowish-brown, well-oxidized (till)	16	20
	Clay, silty, pebbly, olive gray, calcareous (till)	55	75
Tongue River Formation:			
	Siltstone, clayey, sandy, light-gray, non-calcareous	5	80
	Sandstone, clayey, silty, very fine to fine, medium-bluish-gray, consolidated	6	86
	Siltstone, siliceous, medium gray, non-calcareous	20	106
	Sandstone, very fine to medium, dark-greenish-gray, semi-consolidated to loose, friable	8	114
	Claystone, silty, brownish-gray, noncalcareous	12	126
	Sandstone, fine to medium, light-bluish-gray, semi-consolidated, lignitic, micaceous	17	143
	Lignite, black, brittle, fractured, taking water rapidly	3	146
	Shale, silty, sandy, brownish-gray, lignite stringers, noncalcareous	4	150
	Claystone, very sandy, silty, medium-dark-gray to brownish-gray, noncalcareous	35	185
	Sandstone, clayey, fine, dark-greenish-gray, noncalcareous, consolidated, subangular	15	200
Cannonball Formation:			
	Claystone, silty to sandy, medium-dark-gray, to brownish-gray, thin siltstone and dark brown carbonaceous shale interbeds, lignitic, noncalcareous	182	382
	Claystone, siliceous, dark gray, hard, noncalcareous	8	390

Observation well
Depth 138 feet

S.I. 132-138 feet
Water level 97.71 feet
Measured 11-14-73

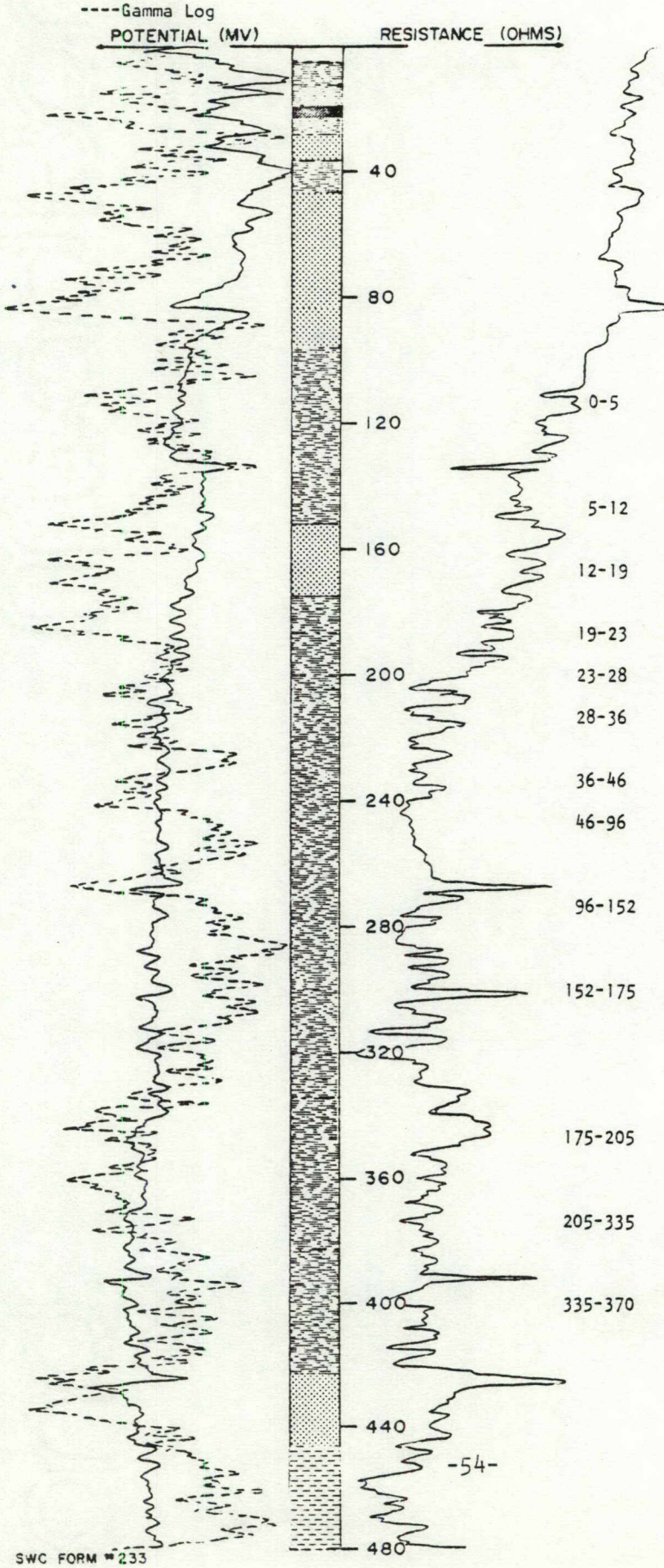
NDSWC 8610

LOCATION: 143-80-32CCC

ELEVATION: 1955 (FT, MSL)

DATE DRILLED: April, 1973

DEPTH: 760 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-5	Road fill.

Tongue River Formation

5-12	Claystone, sandy, silty, yellowish-brown, oxidized.
12-19	Claystone, silty, medium-light-gray, calcareous.
19-23	Lignite, black, claystone bedding.
23-28	Claystone, sandy, medium gray.
28-36	Sandstone, fine to medium, medium-bluish-gray, consolidated.
36-46	Claystone, clayey, medium gray.
46-96	Sandstone, fine to medium, bluish-gray, thin lignite stringers and claystone bedding.
96-152	Claystone, sandy, brownish-gray, dark brown, carbonaceous shale bedding, lignite stringers.
152-175	Sandstone, clayey, very fine to fine, bluish-gray, consolidated, micaceous.

Cannonball Formation

175-205	Claystone, sandy, medium gray with brownish-gray mottling, yellowish-gray limestone concretions.
205-335	Claystone, silty, sandy, brownish-gray, limestone concretions and sandstone layers.
335-370	Claystone, very sandy, medium gray to brownish-gray, generally non-calcareous.

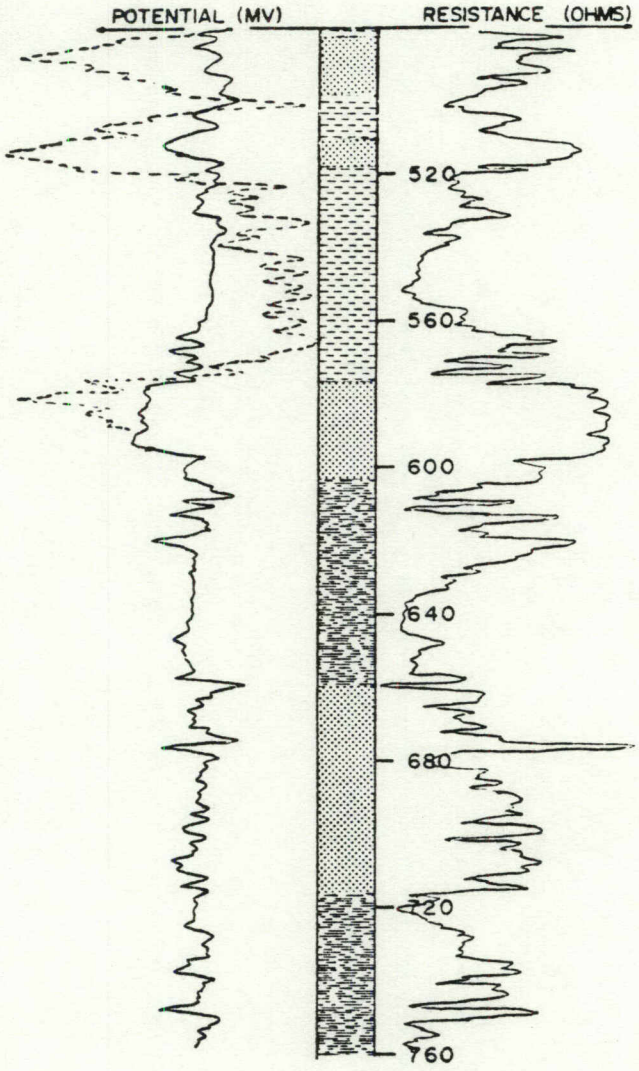
SWC FORM #233

LOCATION: 143-80-32CCC

DATE DRILLED: April, 1973

ELEVATION: 1955
(FT, MSL)

DEPTH: 760
(FT)



DESCRIPTION OF DEPOSITS

Hell Creek Formation

370-424	Claystone, silty, brownish-gray to medium gray, lignitic.
424-448	Sandstone, fine, dark greenish-gray, consolidated, glauconitic, calcareous.
448-482	Shale, brownish-black, carbonaceous, waxy, some thin light-brownish-gray claystone bedding.
482-498	Sandstone, fine to medium, greenish-gray, glauconitic, micaceous.
498-510	Shale, sandy, light-brownish-gray, noncalcareous.
510-518	Sandstone, fine to medium, bluish-gray, slightly glauconitic.
518-576	Shale, slightly sandy, silty, brownish-black with light-brownish-gray siltstone bedding, carbonaceous, waxy.

Fox Hills Formation

576-604	Sandstone, very fine to fine, medium-bluish-gray to brownish-gray, micaceous, semi-consolidated, friable.
604-660	Claystone, silty, light-brownish-gray, thin brownish-black, carbonaceous shale beds, thin light-bluish-gray sandstone interbeds.
660-716	Sandstone, very fine to medium, medium-bluish-gray, glauconitic, micaceous, consolidated, occasional sandy, brownish-gray claystone interbeds.
716-736	Claystone, siliceous, medium gray to dark gray, angular quartz grains, noncalcareous.
736-750	Siltstone, sandy, medium gray, quartz grains, noncalcareous.
750-760	Siltstone, siliceous, grayish-black, hard, brittle, noncalcareous, angular quartz grains.

Observation well
Depth 600 feet
S.I. 588-600 feet
Water level 206.26 feet
Measured 11-14-73

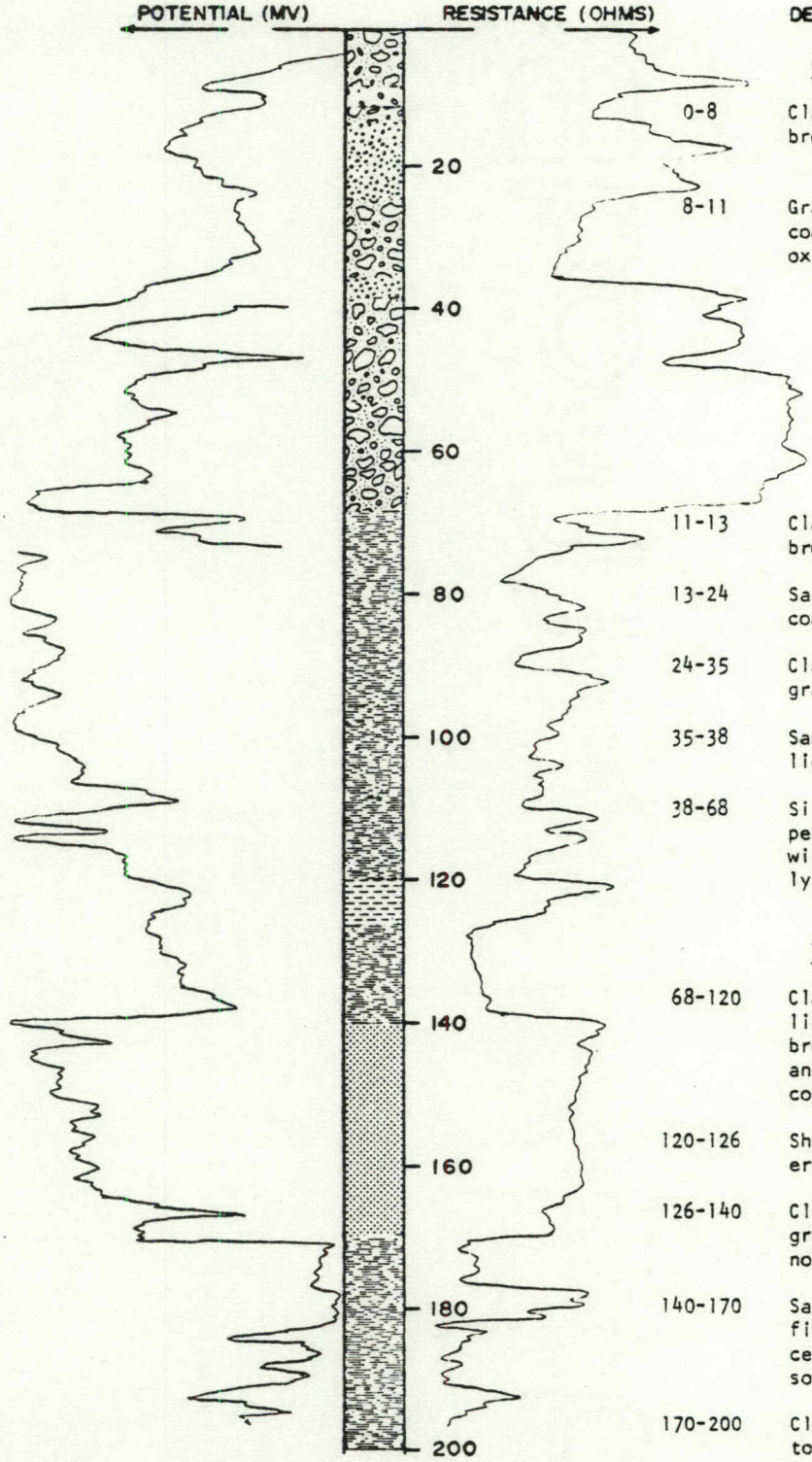
NDSWC 8605

LOCATION: 143-80-33ADD

DATE DRILLED: March, 1973

ELEVATION: 2045
(FT, MSL)

DEPTH: 200
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-8	Clay, sandy, pebbly, yellowish-brown, oxidized (till).
8-11	Gravel, cobbles, clayey, fine to coarse, poorly sorted, loose, oxidized.
11-13	Clay, sandy, pebbly, yellowish-brown, oxidized (till).
13-24	Sand, silty, clayey, medium to coarse, subrounded, oxidized.
24-35	Clay, very silty, pebbly, olive gray, calcareous (till).
35-38	Sand, silty, very fine to medium, lignitic, subrounded.
38-68	Silt, clayey, very sandy, a few pebbles, dark-yellowish-brown with olive gray mottling, partially oxidized (siltill).

Tongue River Formation

68-120	Claystone, siliceous, medium-light-gray to medium gray, dark brown, carbonaceous shale bedding and yellowish-gray, limestone concretions.
120-126	Shale, dark brown, lignite stringers, carbonaceous.
126-140	Claystone, siliceous, greenish-gray to brownish-gray, bentonitic, noncalcareous.
140-170	Sandstone, slightly clayey, very fine to medium, lignitic, micaceous, dark-greenish-gray, consolidated.
170-200	Claystone, silty, brownish-gray to medium-dark-gray, noncalcareous.

Observation well
Depth 169 feet
S.I. 163-169 feet
Water level 107-06 feet
Measured 11-14-73

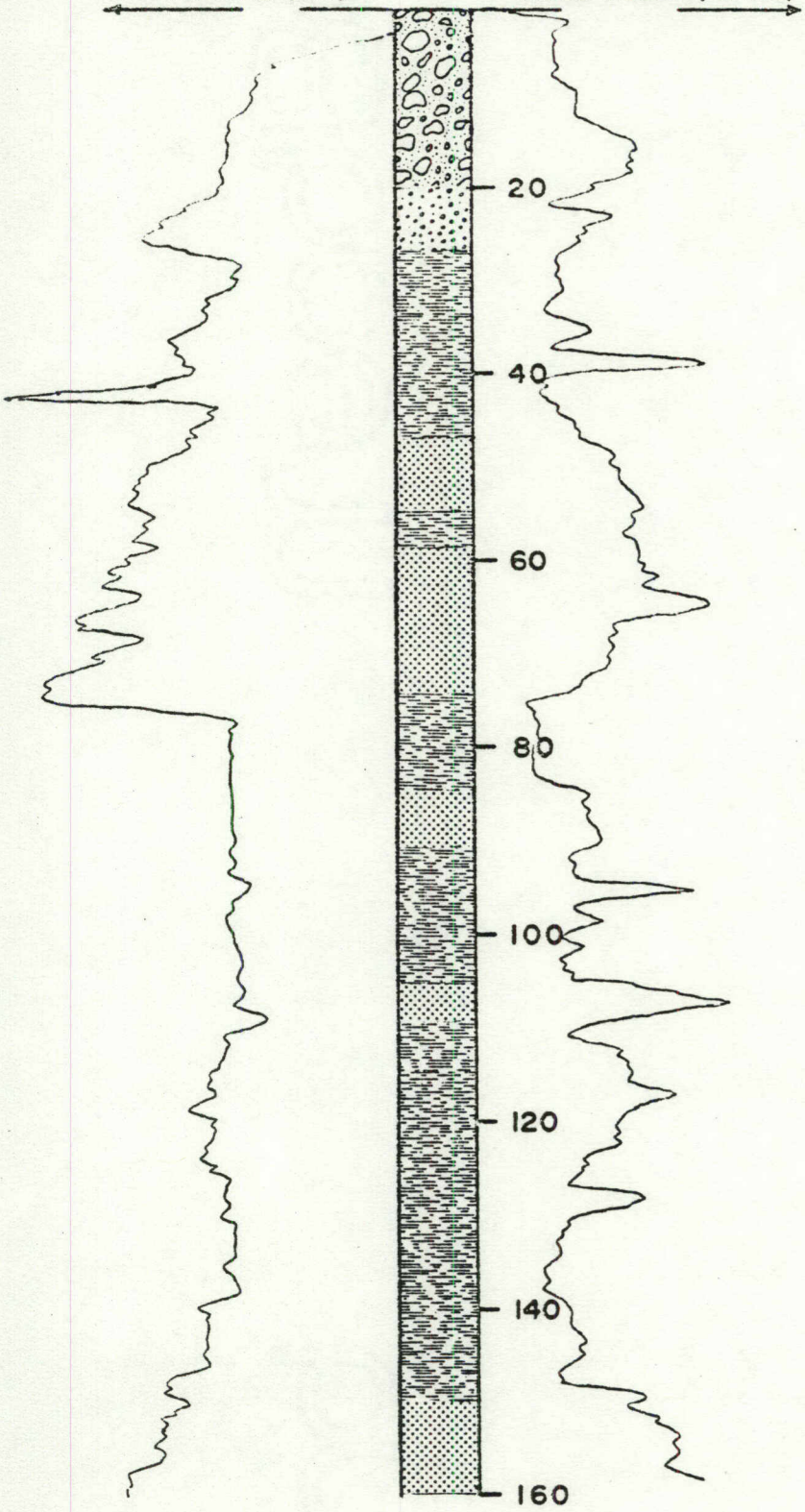
NDSWC 8627

LOCATION: 143-80-35ADC

DATE DRILLED: April, 1973

ELEVATION: 2150
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-20	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).
20-26	Sand, silty, clayey, very fine to medium, oxidized.

Sentinel Butte Formation

26-46	Claystone, silty, sandy, pale-yellowish-brown to medium gray, thin lignite stringers, partially oxidized.
46-54	Sandstone, very clayey, silty, very fine to fine, yellowish-brown, lignitic, oxidized.
54-58	Claystone, siliceous, greenish-gray, bentonitic.
58-74	Sandstone, very clayey, silty, very fine to fine, dark-yellowish brown, consolidated, oxidized.
74-84	Claystone, silty, siliceous, greenish-gray, bentonitic.
84-90	Sandstone, very clayey, very fine to fine, subangular.
90-105	Siltstone, siliceous, medium-light-gray, thin lignite stringer calcareous.
105-109	Sandstone, silty, clayey, very fine to fine, medium-bluish-gray, micaceous, lignitic.

Tongue River Formation

109-150	Siltstone, clayey, siliceous, medium-light-gray to medium-gray, thin brownish-gray shale bedding and thin sandstone layers, slightly calcareous.
150-160	Sandstone, very fine to fine, medium-light-gray, consolidated.

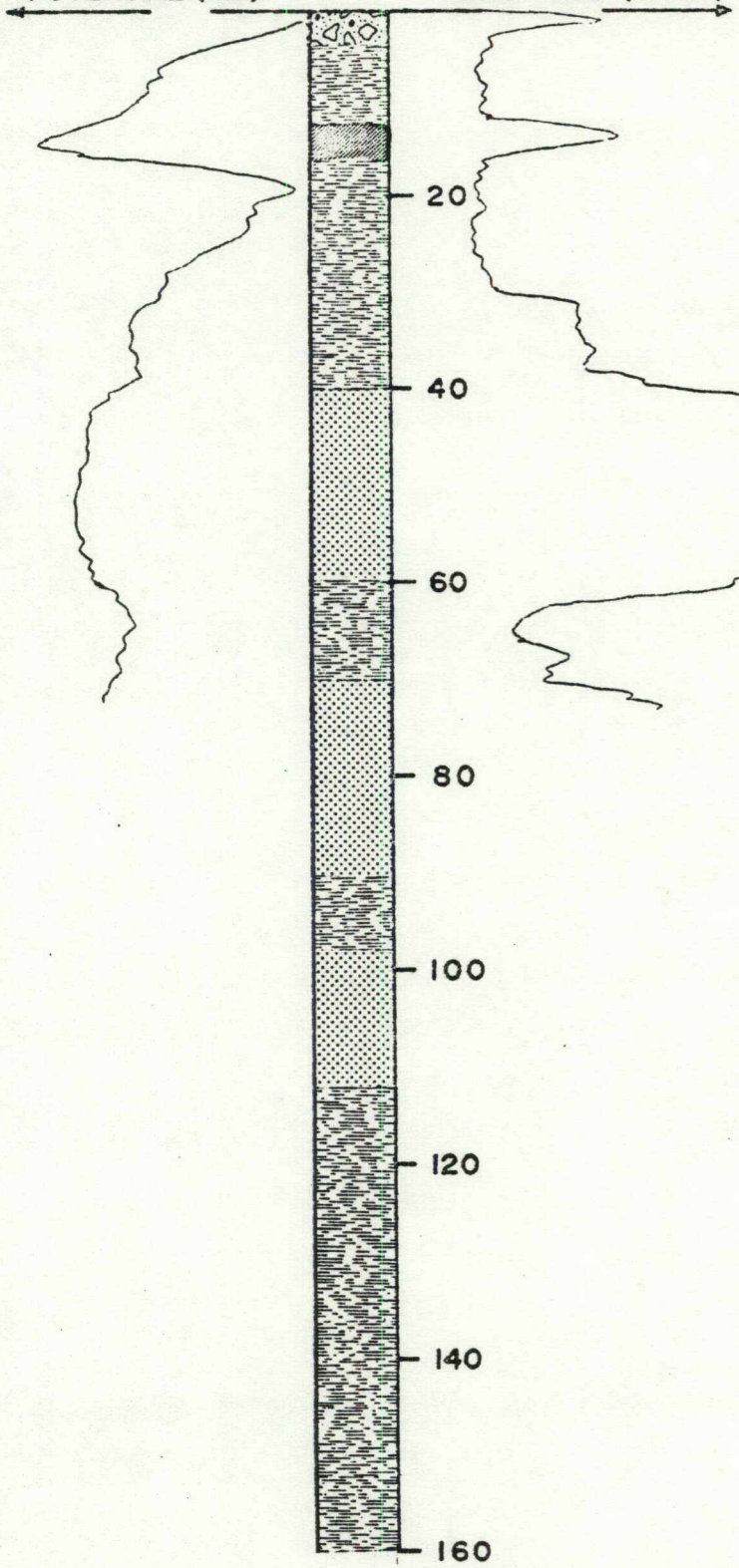
NDSWC 8626

LOCATION: 143-80-35ADD

DATE DRILLED: April, 1973

ELEVATION: 2160
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-4	Clay, silty, pebbly, yellowish-brown, oxidized (till)

Sentinel Butte Formation

4-12	Claystone, silty, yellowish-brown, oxidized.
12-16	Lignite, black, brittle, fractured taking water.
16-40	Claystone, sandy, yellowish-brown to dusky yellow, oxidized.
40-60	Sandstone, clayey, very fine to fine, light-brownish-gray, semi-consolidated to loose, partially oxidized.
60-70	Claystone, silty, sandy, dark-yellowish-brown with light-brownish-gray mottling, slightly calcareous, partially oxidized.
70-90	Sandstone, clayey, very fine to fine, light-brownish-gray, semi-consolidated, partially oxidized.
90-98	Siltstone, clayey, medium-light-gray, calcareous.
98-112	Sandstone, silty, slightly clayey medium-bluish-gray, micaceous, lignitic.

Tongue River Formation

112-160	Siltstone, clayey, siliceous, medium-light-gray, lignite stringers.

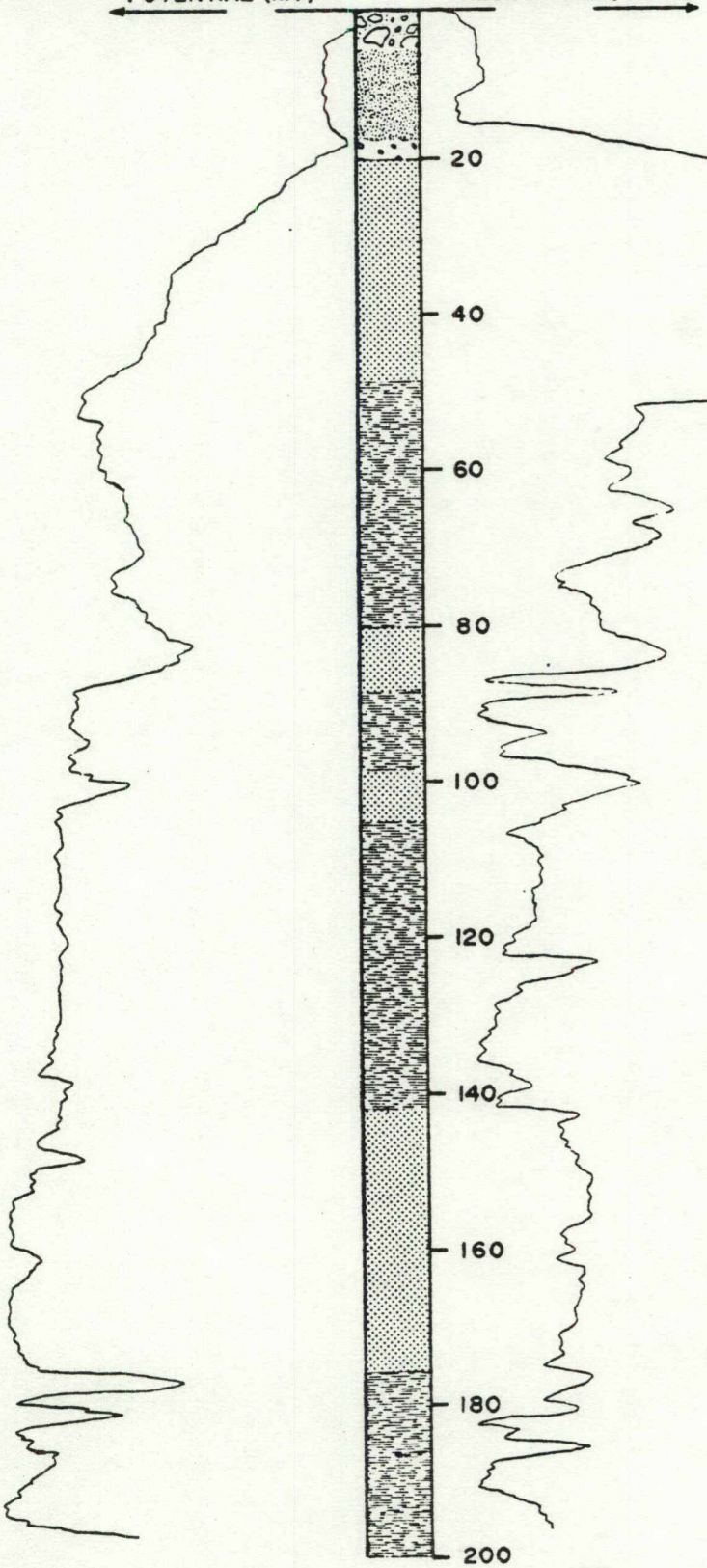
NDSWC 8629

LOCATION: 143-80-35DAA$_1$

DATE DRILLED: April, 1973

ELEVATION: 2145
(FT, MSL)

DEPTH: 200
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-5	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).
5-17	Silt, clayey, pale-yellowish-brown, oxidized.
17-20	Gravel, sandy, fine to coarse, yellowish-brown, oxidized.

Sentinel Butte Formation

20-48	Sandstone, slightly clayey, fine to medium, yellowish-brown, loose to consolidated, lignitic, oxidized.
48-80	Siltstone, sandy, clayey, pale-yellowish-brown, fossiliferous.
80-88	Sandstone, very fine to fine, semi-consolidated to loose, medium-bluish-gray, micaceous, lignitic.

Tongue River Formation

88-98	Siltstone, siliceous, light-brownish-gray, lignite stringers, dark brown, carbonaceous shale bedding.
98-105	Sandstone, slightly clayey, very fine to fine, medium-bluish-gray, consolidated, lignitic, micaceous.
105-142	Siltstone, siliceous, medium-light-gray.
142-176	Sandstone, very clayey, silty, very fine to fine, medium-light-gray, calcareous, consolidated.
176-200	Claystone, sandy, medium gray, thin sandstone layers and dark brown carbonaceous shale beds, thin lignite stringers.

Observation well
Depth 103 feet
S.I. 97-103 feet
Water level 71.92 feet
Measured 11-14-73

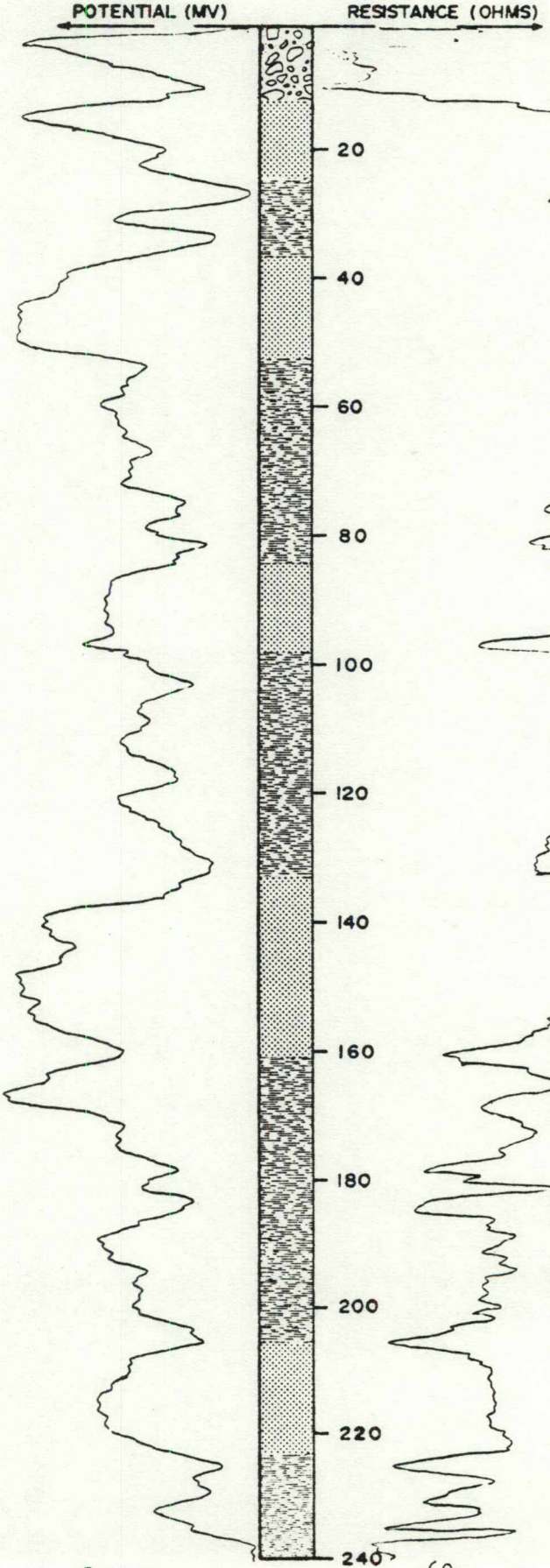
NDSWC 4104

LOCATION: 143-80-350AA$_2$

DATE DRILLED: August, 1970

ELEVATION: 2140
(FT, MSL)

DEPTH: 400
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-3 Silt, sandy, clayey, yellowish-gray (till).

3-12 Clay, silty, sandy, pebbly, olive brown, (till).

Sentinel Butte Formation

12-24 Sandstone, silty, clayey, very fine to fine, dusky-yellow, oxidized.

24-36 Siltstone, sandy, dusky yellow, oxidized.

36-52 Sandstone, silty, clayey, very fine to fine, yellowish-gray, oxidized.

52-84 Claystone, silty, sandy, yellowish-gray with medium-dark-gray mottling, partially oxidized.

84-98 Sandstone, clayey, silty, very fine to fine, dark gray, fossiliferous, lignitic.

SWC FORM # 233 B

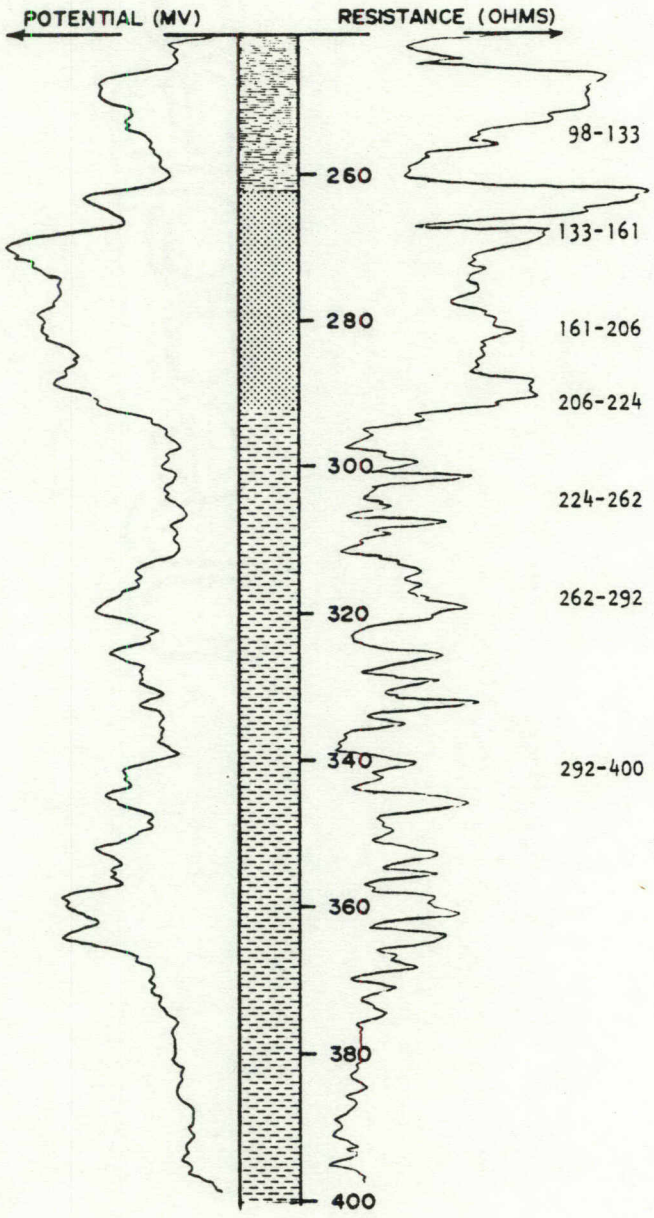
NDSWC 4104 (Continued)

LOCATION: 143-80-35DAA$_2$

DATE DRILLED: August, 1970

ELEVATION: 2140
(FT, MSL)

DEPTH: 400
(FT)



DESCRIPTION OF DEPOSITS

Tongue River Formation

98-133 Siltstone, clayey, medium gray, thin, brownish-gray, carbonaceous shale beds.

133-161 Sandstone, slightly clayey, silty, very fine to fine, greenish-gray, subangular.

161-206 Siltstone, sandy to clayey, brownish-gray, noncalcareous.

206-224 Sandstone, clayey, silty, very fine to fine, medium gray, micaceous.

224-262 Claystone, silty, medium gray, slightly calcareous, siltstone interbeds.

262-292 Sandstone, clayey, silty, fine, medium-bluish-gray to greenish-gray, micaceous, lignitic.

Cannonball Formation

292-400 Shale, silty to sandy, noncalcareous, dark gray to brown.

143-80-35DAA$_3$
City of Wilton Well 2
(Log from C. A. Simpson & Son)

Elevation: 2165 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
	Topsoil	2	2
	Clay, gray	7	9
	Clay, yellow, hard	66	75
	Sandstone	2	77
	Sand and brown clay	7	84
	Clay, gray, sandy	16	100

143-80-35DAA$_4$
City of Wilton Well 4
(Log from Layne-Minnesota Co.)

Elevation: 2165 feet

Topsoil, clay-gravel	20	20
Clay, sandy	15	35
Sand	50	85
Clay, sandy	17	102

143-80-35DAA$_5$
City of Wilton Well 5
(Log from Layne-Minnesota Co.)

Elevation: 2170 feet

Topsoil, gravelly clay	15	15
Coal and clay	10	25
Clay, soft	13	38
Sandstone, hard	2	40
Sand	50	90
Clay, sandy	13	103

143-80-35DAD
City of Wilton Well 1
(Log from C. A. Simpson & Son)

Elevation: 2160 feet

Topsoil	1	1
Clay, yellow	29	30
Clay, yellow, hard	46	76
Sand, clay, hard	8	84
Sand and coal	4	88
Clay, gray, coal	40	128

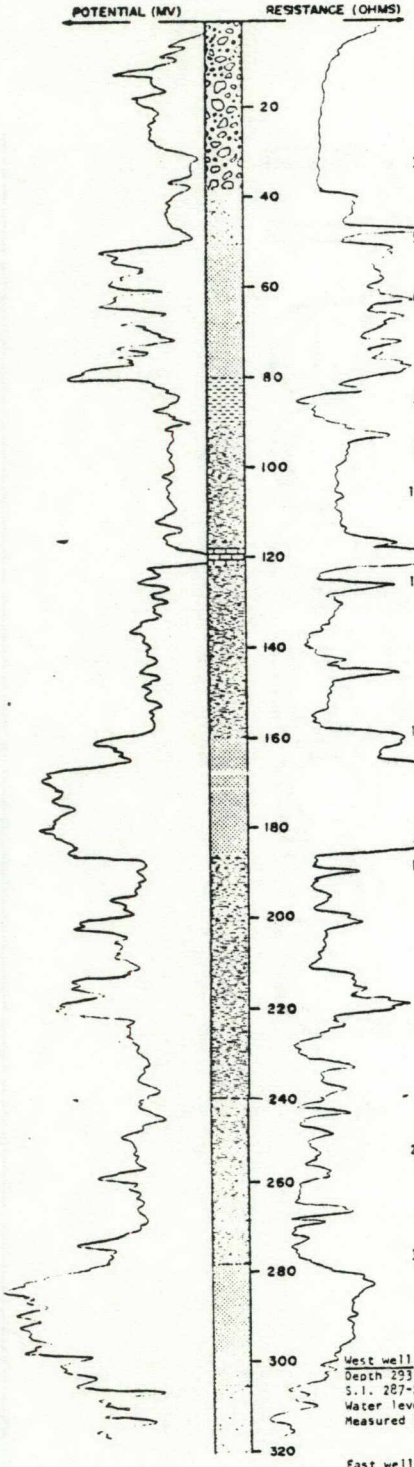
NDSWC 8606

LOCATION: 143-80-35DCD

DATE DRILLED: March, 1973

ELEVATION: 2145 (FT, MSL)

DEPTH: 320 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-38 Clay, very silty, pebbly, yellowish-brown, oxidized (till).

Sentinel Butte Formation

38-50 Claystone, silty, dark-yellowish-brown, yellowish-gray limestone concretions, oxidized.

50-68 Sandstone, very silty and clayey, very fine to fine, yellowish-brown, oxidized.

68-80 Sandstone, clayey, very fine to fine, light-bluish-gray, consolidated.

Tongue River Formation

80-90 Shale, dark brown, carbonaceous, lignite stringers.

90-118 Claystone, sandy, medium gray, fossiliferous .

118-122 Limestone, dark gray, hard.

122-160 Claystone, silty, medium gray, noncalcareous.

160-186 Sandstone, clayey, very fine to fine, medium-light-gray, consolidated, highly calcareous.

186-278 Siltstone and claystone, medium gray to brownish-gray, fossiliferous, noncalcareous.

Tongue River Formation (Continued)

278-305 Sandstone, clayey, fine, medium-bluish-gray, loose to semi-consolidated, friable, lignitic.

Cannonball Formation

305-320 Claystone, silty to sandy, medium gray to brownish-gray, fossiliferous, noncalcareous.

Observation wells

West well
Depth 293 feet
S.I. 287-293 feet
Water level 139.45 feet
Measured 11-14-73

Middle well
Depth 180 feet
S.I. 177-180 feet
Water level 109.35 feet
Measured 11-14-73

East well
Depth 80 feet
S.I. 77-80 feet
Water level 56.22 feet
Measured 11-14-73

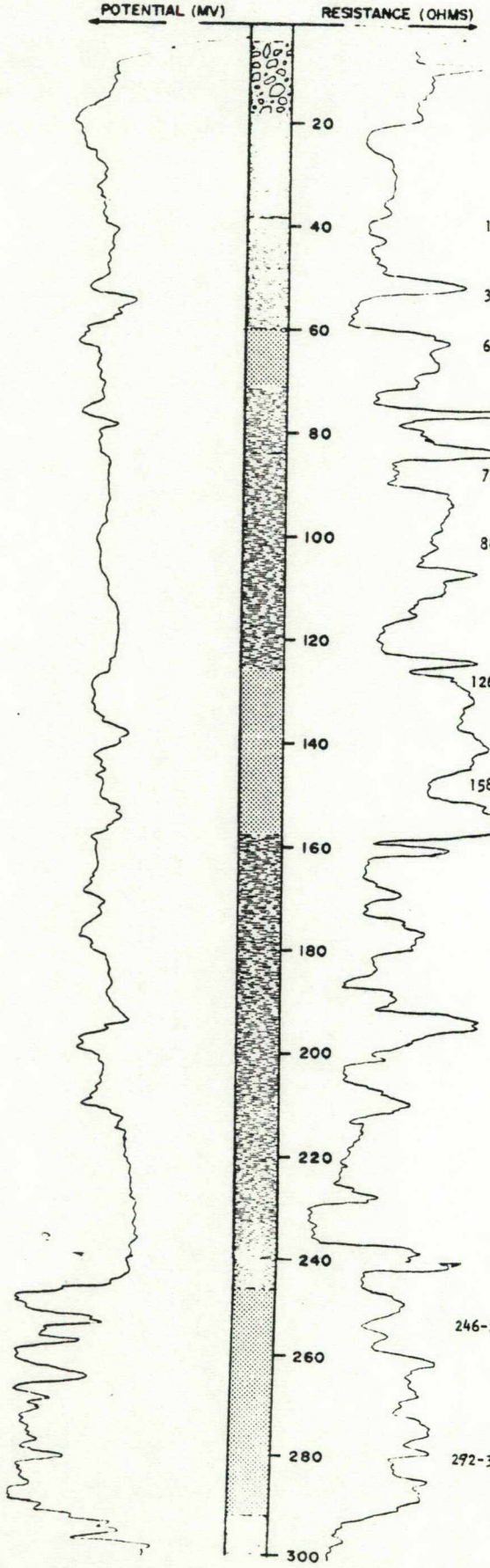
NDSWC 8607

LOCATION: 143-80-36AAB

ELEVATION: 2135
(FT, MSL)

DATE DRILLED: April, 1973

DEPTH: 300
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-3 Road fill.

3-18 Clay, sandy, pebbly, cobbles, yellowish-brown, oxidized (till).

Sentinel Butte Formation

18-38 Claystone, silty, light-gray with yellowish-gray mottling, lignite stringers, oxidized.

38-60 Siltstone, greenish-gray, bentonitic.

60-71 Sandstone, silty, very fine, bluish-gray, consolidated, micaceous.

Tongue River Formation

71-84 Siltstone, sandy, medium-light-gray to dark brown, lignite stringers, carbonaceous.

84-126 Claystone, siliceous, light-gray, lenticular, brownish concretions, noncalcareous.

126-158 Sandstone, clayey, bluish-gray to brownish-gray, consolidated, micaceous, lignitic, claystone interbeds.

158-246 Claystone and siltstone, interbedded, medium gray to brownish-gray, bentonitic, fossiliferous.

246-292 Sandstone, clayey, very fine to medium, bluish-gray to greenish-gray, loose to consolidated, friable.

Cannonball Formation

292-300 Claystone, siliceous, grayish-brown, shaly.

Observation well
Depth 293 feet
S.I. 287-293 feet
Water level 157.09 feet
Measured 11-14-73

143-80-36CBB
City of Wilton Well 3
(Log from C. A. Simpson & Son)

Elevation: 2180 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
	Topsoil	8	8
	Clay, sandy, yellow	83	91
	Sand, dirty, clay lenses	13	104
	Shale, brown	4	108

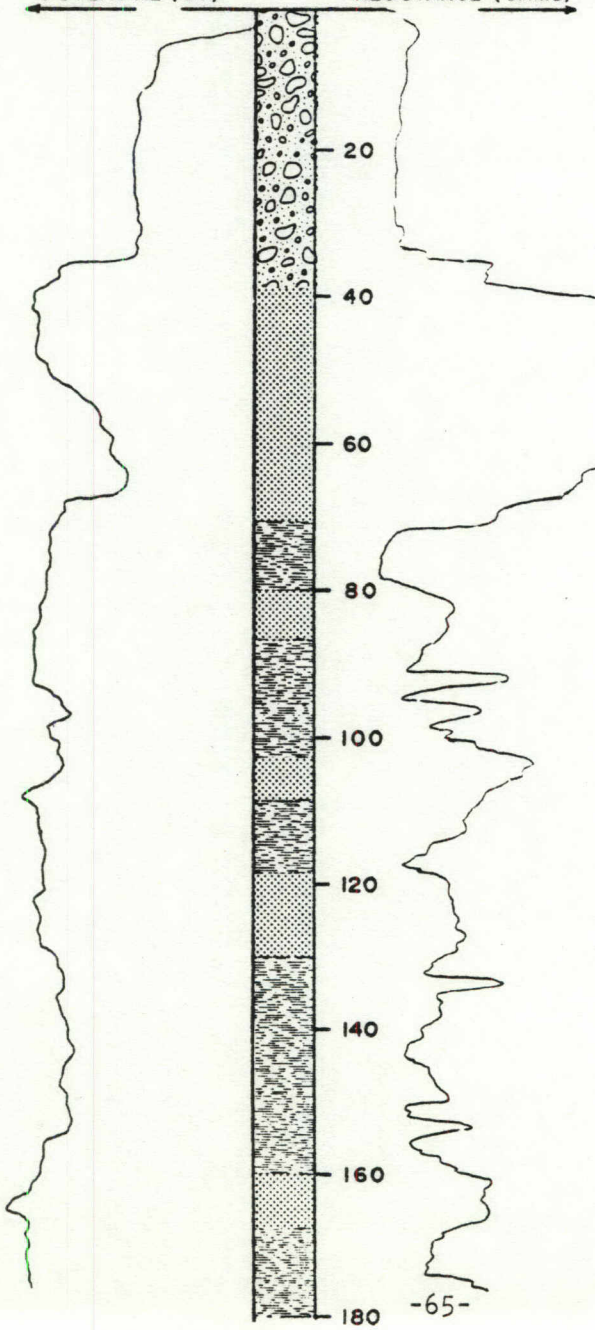
NDSWC 8625

LOCATION: 143-80-36CBC

DATE DRILLED: April, 1973

ELEVATION: (FT, MSL) 2150

DEPTH: (FT) 180



DESCRIPTION OF DEPOSITS

Glacial Drift

0-38 Clay, sandy, silty, pebbly, cobbles, yellowish-brown, oxidized (till).

Sentinel Butte Formation

38-70 Sandstone, clayey, very fine to fine, loose to semi-consolidated, yellowish-brown, oxidized.

70-80 Claystone, silty, greenish-gray, bentonitic.

80-86 Sandstone, clayey, very fine, bluish-gray.

86-102 Siltstone, medium gray, lignite stringers, brownish-gray, carbonaceous shale beds, calcareous.

Tongue River Formation

102-108 Sandstone, bluish-gray, consolidated.

108-118 Siltstone, light gray, calcareous.

118-130 Sandstone, clayey, very fine, light gray consolidated.

130-160 Siltstone, siliceous, medium gray to light-brownish-gray, calcareous.

160-168 Sandstone, clayey, very fine, light-gray, consolidated.

168-180 Siltstone, clayey, light-brownish-gray, calcareous.

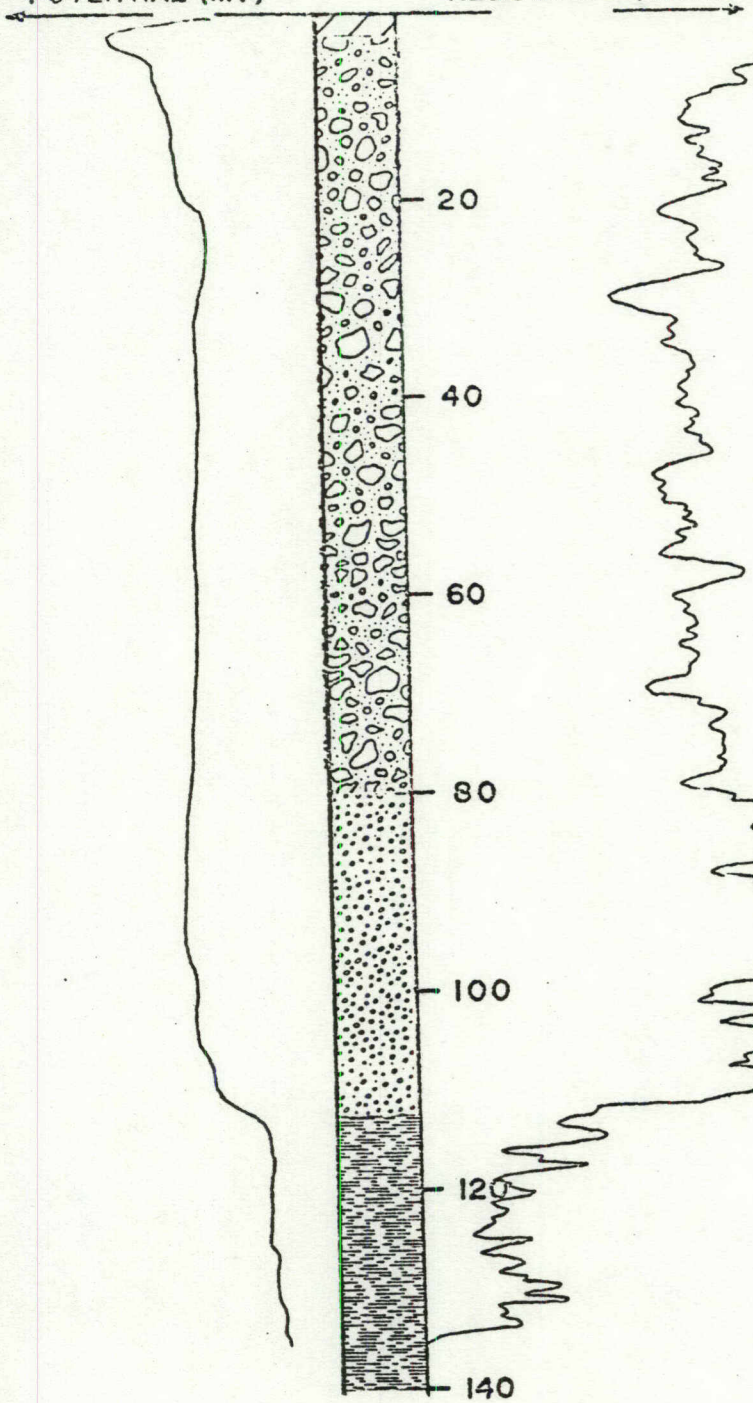
NDSWC 4103

LOCATION: 143-81-1AAA

DATE DRILLED: August 1970

ELEVATION: 1839
(FT, MSL)

DEPTH: 140
(FT)



DESCRIPTION OF DEPOSITS

Glacial drift

0-2 Clay, silty, black (topsoil).

2-5 Silt, clayey, sandy, pebbly, yellowish-gray (till).

5-18 Clay, silty, sandy, pebbly, moderate-olive-brown (till).

18-80 Clay, silty, sandy, pebbly, olive-gray; scattered lignite and isolated sand lenses (till)

80-112 Sand, very fine to fine, silty, subrounded.

Cannonball Formation

112-140 Siltstone, micaceous, carbonaceous, light-gray; interbedded with greenish-gray sandstone.

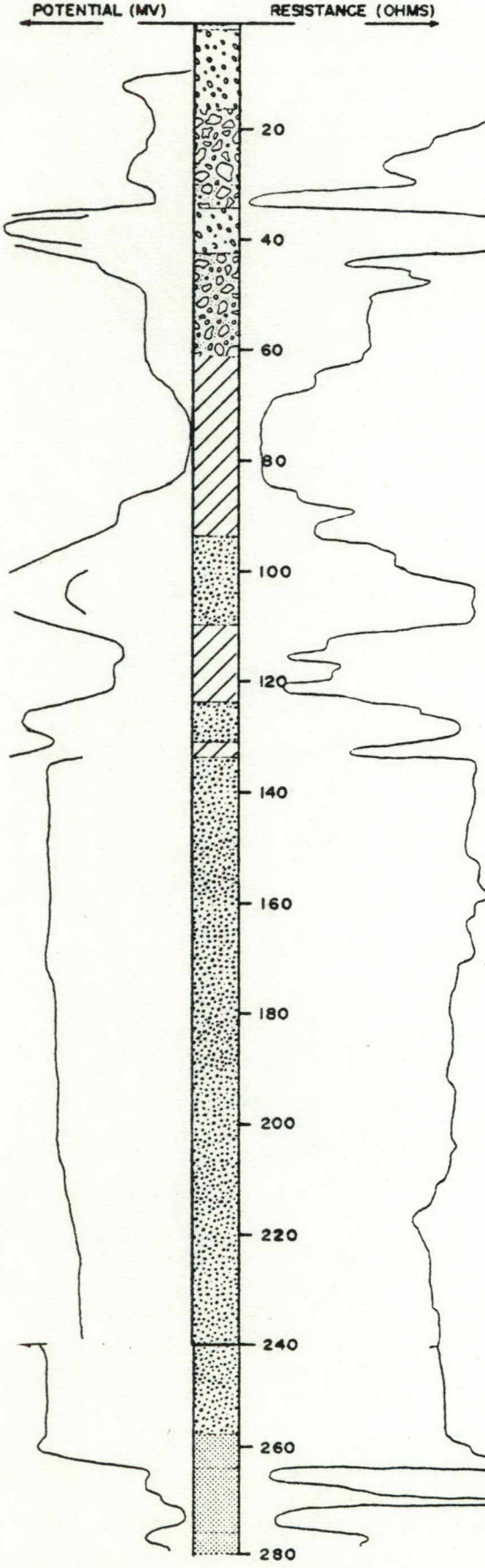
NDSWC 4107

LOCATION: 143-81-28BBB

DATE DRILLED: August 1970

ELEVATION: 1710
(FT, MSL)

DEPTH: 280
(FT)



DESCRIPTION OF DEPOSITS

Glacial drift

0-1	Sand, silty, black (topsoil).
1-16	Gravel, fine to coarse, sandy, subangular to subrounded.
16-30	Clay, silty, sandy, pebbly, light-olive-gray (till).
30-34	Clay, stiff, olive-green.
34-42	Gravel, fine to medium, sandy, subrounded.
42-61	Clay, silty, sandy, pebbly, lignitic, olive-gray; gravelly from 44-48 ft. (till).
61-94	Clay, silty, plastic, olive-gray, laminated (fluvial?).
94-110	Sand, very fine to fine, silty, lignitic, dark-gray.
110-124	Clay, silty, olive-gray, laminated; interbedded with silty clay.
124-131	Sand, very fine to fine, silty, lignitic.
131-134	Clay, silty, plastic, olive-gray.
134-257	Sand, very fine to fine, silty.

Hell Creek Formation

257-264	Sandstone, fine, calcareous, dark-gray.
264-276	Sandstone, fine, clayey, greenish-gray.
276-280	Sandstone, fine, dark-greenish-gray.

143-81-2BBB$_2$
NDSWC 8949

Elevation: 1715 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, sandy, pebbly, yellowish-brown, oxidized (till)	5	5
	Gravel, fine to medium, sandy, oxidized	10	15
	Clay, silty, pebbly, olive gray (till)	13	28
	Sand, fine to coarse	2	30
	Clay, silty, pebbly, olive gray, (till)	5	35
	Gravel, about 20 percent sand, fine to coarse, clay layers, loose	10	45
	Clay, silty, pebbly, olive gray (till)	15	60

Observation well
Depth 40 feet
S.I. 37-40 feet
Water level 35.96 feet
Measured 11-14-73

143-81-2BCC$_1$
NDSWC 3897

Elevation: 1710 feet

Glacial drift:			
	Sand, medium to coarse, gravelly	5	5
	Silt, clayey, sandy, dark-brown	3	8
	Clay, silty, light-gray to bluish-gray	7	15
	Sand, clayey, dark-brownish-gray	2	17
	Clay, silty, plastic, fossiliferous, variegated gray and brown	10	27
	Sand, fine to very coarse; interbedded with fine to medium gravel	38	65
	Sand, fine to coarse	44	109
	Silt, olive-gray; interbedded with fine sand and clay	140	249
	Gravel, fine to coarse, sandy, subangular to subrounded	29	278
Hell Creek Formation:			
	Shale, silty, sandy, hard, carbonaceous, noncalcareous to slightly calcareous, variegated gray, green, and brown	22	300

Observation well
Depth 258 feet
S.I. 252-258 feet
Water level + 0.36 feet
Measured 10-29-73

143-81-2BCC$_2$
NDSWC 3898

Elevation: 1710 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Sand, medium to very coarse, gravelly	5	5
	Clay, silt, and fine sand, fossiliferous, variegated brown, gray, green, and blue; interbedded	28	33
	Sand, medium to coarse, gravelly	7	40

Observation well
Depth 34 feet
S.I. 31-34 feet
Water level 7.30 feet
Measured 10-29-73

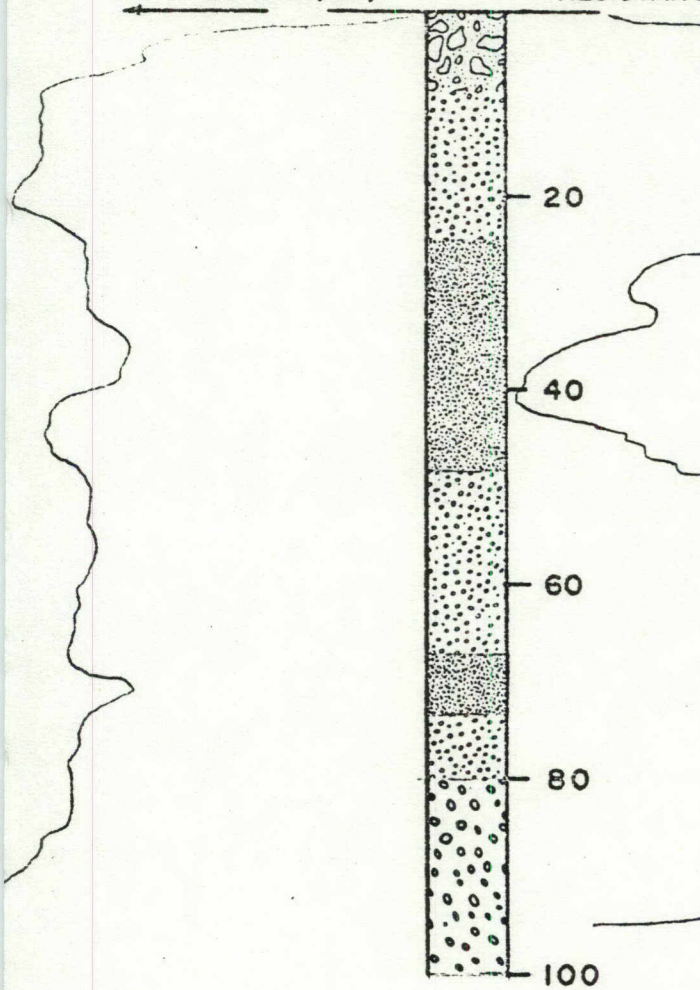
NDSWC 8950

LOCATION: 143-81-3ADB

DATE DRILLED: November, 1973

ELEVATION: 1700
(FT, MSL)

DEPTH: 100
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-8	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).
8-24	Sand, silty, very fine to very coarse, about 20 percent gravel, partially oxidized.
24-48	Silt, sandy, grayish-black to black, carbonaceous, noncalcareous.
48-67	Sand, very fine to very coarse, mostly medium, fair sorting, lignitic.
67-73	Silt, clayey, medium gray, soft,
73-80	Sand, very fine to very coarse, about 30 percent gravel, dark gray, taking water, subrounded.
80-100	Gravel, fine to coarse, about 40 percent sand, subrounded, fair sorting, lignitic, loose, taking water.

Observation well
Depth 83 feet
S.I. 77-83 feet
Water level 7.91 feet
Measured 11-14-73

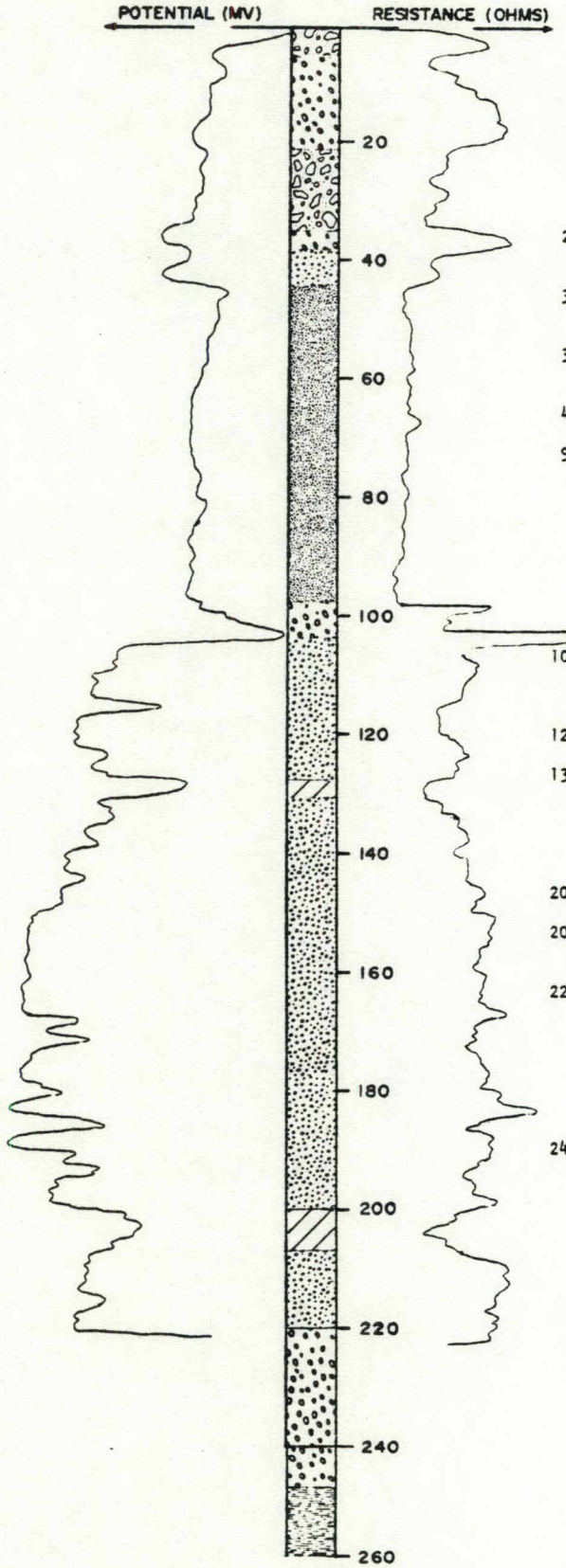
NDSWC 8939

LOCATION: 143-81-3BAA

DATE DRILLED: October, 1973

ELEVATION: 1703
(FT, MSL)

DEPTH: 260
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-5	Clay, sandy, pebbly, yellowish-brown, oxidized (till).
5-21	Gravel, fine to medium, sandy, dark-yellowish-brown, loose, caving, taking water.
21-35	Clay, silty, pebbly, olive gray (till).
35-38	Gravel, fine to coarse, cobbles, clayey.
38-44	Sand, fine to very coarse, clayey, subrounded.
44-98	Silt, sandy, medium gray, soft.
98-104	Gravel, fine to coarse, cobbles, boulders, loose, caving, taking water rapidly.
104-128	Sand, very fine to coarse, mostly medium, subrounded, well-sorted, thin clay layers, lignitic
128-131	Clay, sandy, medium gray, soft.
131-200	Sand, very fine to very coarse, mostly medium to coarse, about 20 percent gravel, subrounded, moderately well-sorted, lignitic, a few clay layers.
200-208	Clay, silty, olive gray, soft.
208-220	Sand, fine to very coarse, thin clay layers, subrounded, lignitic.
220-247	Gravel, fine to coarse, cobbles, angular to well-rounded, fair sorting, some brownish-colored silicates, lignitic.

Hell Creek Formation

247-260	Claystone, sandy, brownish-gray with greenish-gray mottling, non-calcareous.

Observation well
Depth 163 feet
S.I. 157-163 feet
Water level 36.25 feet
Measured 11-14-73

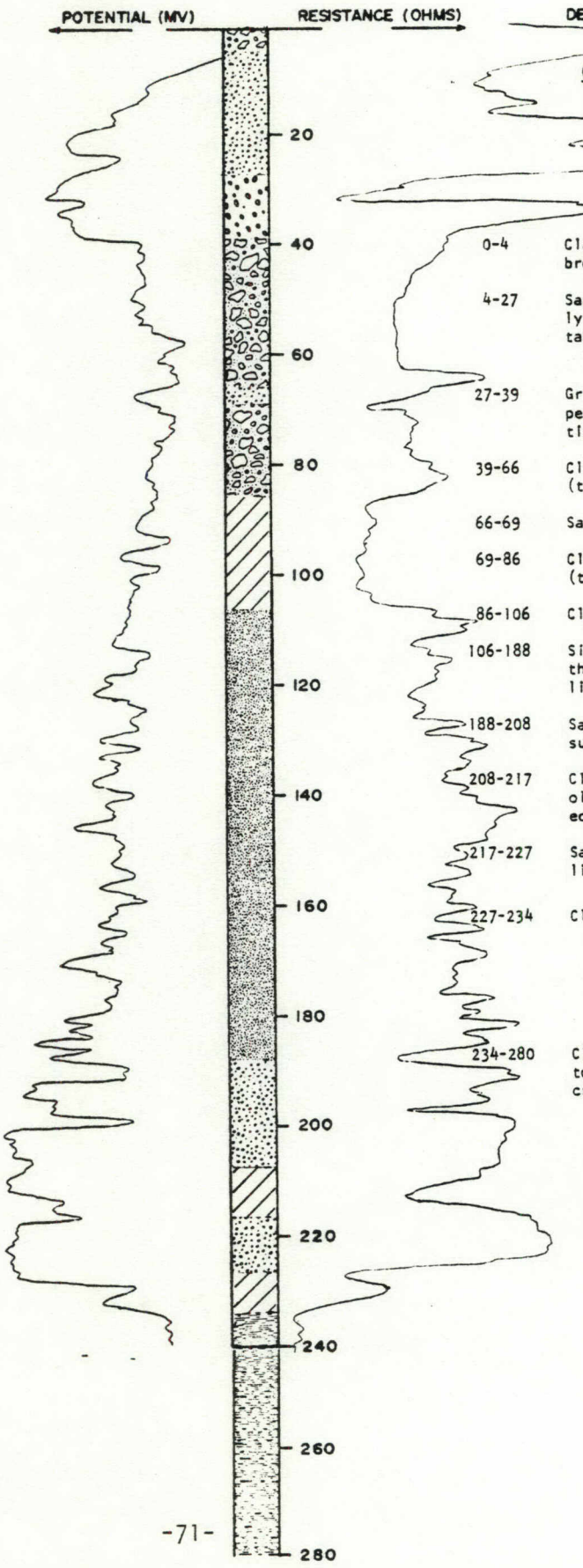
NDSWC 8933

LOCATION: 143-81-3BBB

DATE DRILLED: November 1973

ELEVATION: 1710 (FT, MSL)

DEPTH: 280 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-4	Clay, sandy, pebbly, yellowish-brown, oxidized (till).
4-27	Sand, fine to very coarse, gravelly, oxidized, fair sorting, loose, taking water.
27-39	Gravel, fine to coarse, about 20 percent sand, fair sorting, partially oxidized, taking water.
39-66	Clay, silty, pebbly, olive gray, (till).
66-69	Sand, fine to coarse, subangular.
69-86	Clay, silty, pebbly, olive gray (till).
86-106	Clay, very silty, olive gray.
106-188	Silt, very sandy, medium gray, thin sand layers, soft, detrital lignite chips, highly calcareous.
188-208	Sand, very fine to medium, clayey, subrounded, lignitic.
208-217	Clay, silty, sandy, a few pebbles, olive gray, soft, highly calcareous.
217-227	Sand, fine to medium subangular, lignitic, well-sorted.
227-234	Clay, silty, sandy, brownish-gray.

Hell Creek Formation

234-280	Claystone, sandy, brownish-gray to greenish-gray, limestone, concretions, noncalareous.

Observation well
Depth 42 feet
S.I. 39-42 feet
Water level 21.96 feet
Measured 11-14-73

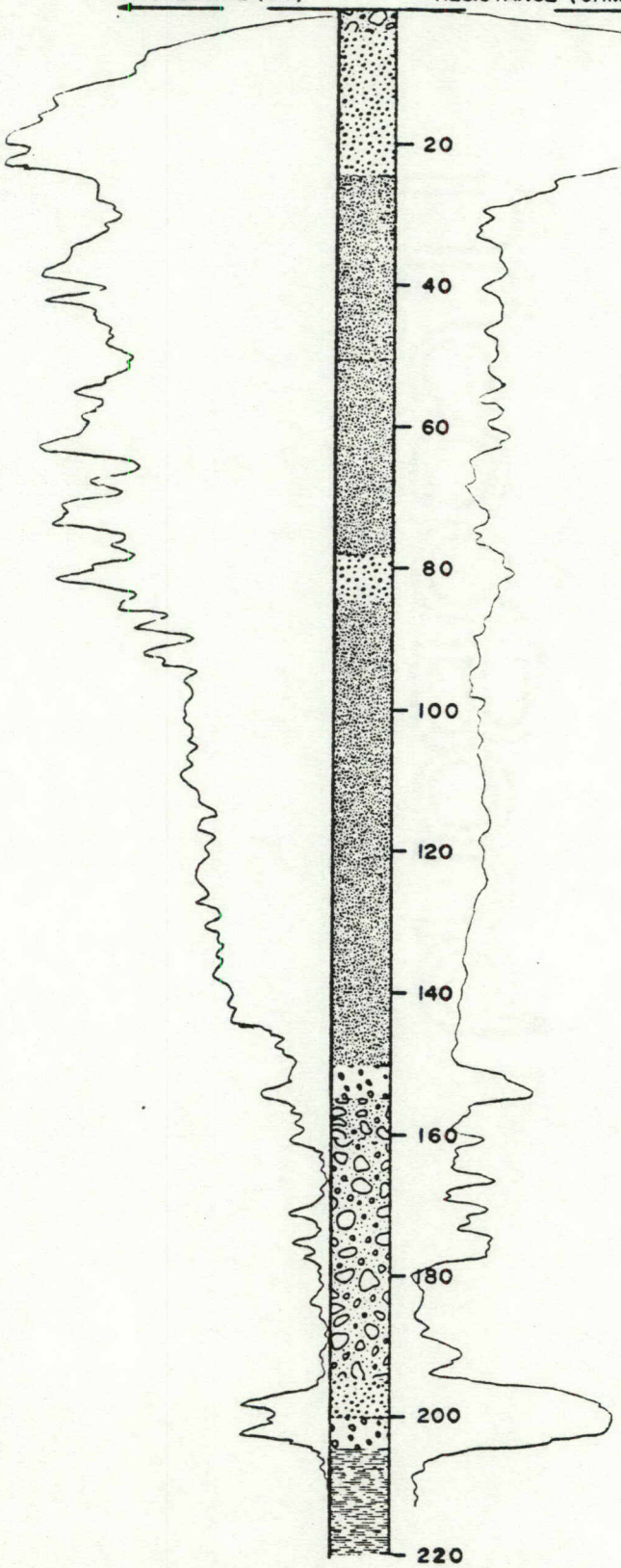
NDSWC 8936

LOCATION: 143-81-3CBB

DATE DRILLED: October, 1973

ELEVATION: 1720
(FT, MSL)

DEPTH: 220
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-3	Clay, sandy, pebbly, gravelly, dusky yellow, oxidized (till).
3-24	Sand, fine to very coarse, gravelly, stained yellowish-brown, loose, taking water, oxidized.
24-50	Silt, sandy, yellowish-brown, soft, oxidized.
50-78	Silt, sandy, olive gray, laminated, soft.
78-84	Sand, very fine to coarse, subrounded, clayey, lignitic.
84-150	Silt, clayey, sandy, olive gray.
150-155	Gravel, sandy, fine to medium, subangular, poorly sorted
155-195	Clay, silty, pebbly, gravelly, olive gray (till).
195-200	Sand, very fine to coarse, mostly coarse, subrounded, well-sorted.
200-205	Gravel, fine to coarse, cobbles, sandy, angular to well-rounded, some brownish-colored silicates.

Cannonball Formation

205-220	Claystone, silty, medium gray, highly calcareous.

SWC FORM * 233 B

143-81-3CCB
NDSWC 8935

Elevation: 1705 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Sand, gravelly, fine to very coarse, dark brown, subrounded, oxidized	34	34
	Silt, sandy, dark-yellowish-brown, oxidized	2	36
	Silt, pebbly, sandy, olive gray (till)	9	45
Cannonball Formation:			
	Claystone, sandy, medium gray, calcareous	15	60

143-81-4AAD
NDSWC 8937

Elevation: 1728 feet

Glacial drift:			
	Sand, fine to very coarse, gravelly, yellowish-brown, oxidized, loose, taking water rapidly	34	34
	Silt, sandy, dusky yellow, oxidized	3	37
	Silt, sandy, medium gray, soft	13	50
	Clay, pebbly, olive gray, lost circulation, abandoned (till)	50	100

143-81-4ADA
NDSWC 8938

Elevation: 1725 feet

Glacial drift:			
	Sand, fine to very coarse, gravelly, oxidized, loose, taking water rapidly, caving	28	28
	Silt, yellowish-brown, soft, oxidized	10	38
	Silt, olive gray, soft, lost circulation, abandoned	2	40

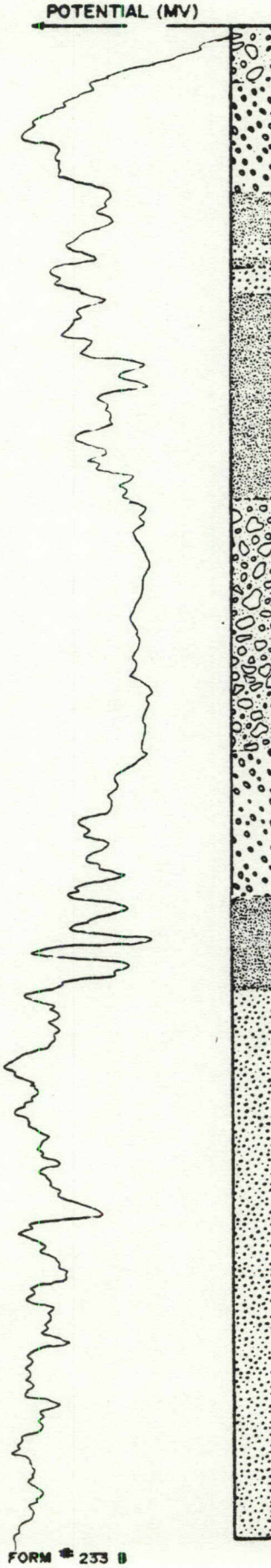
NDSWC 8932

LOCATION: 143-81-4ADD

DATE DRILLED: October, 1973

ELEVATION: 1720
(FT, MSL)

DEPTH: 300
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-9	Clay, sandy, pebbly, dusky yellow, oxidized (till).
9-27	Gravel, fine to coarse, sandy, subangular to rounded, oxidized, taking water.
27-35	Silt, sandy, yellowish-brown, oxidized.
35-37	Sand, very fine to medium, oxidized.
37-39	Silt, sandy, yellowish-brown, soft, oxidized.
39-43	Sand, fine to very coarse, dark-yellowish-brown. well-sorted. oxidized.
43-60	Silt, sandy, olive gray, soft.
60-75	Silt, sandy, medium gray, laminated, soft.
75-115	Clay, pebbly, olive gray, (till).
115-138	Gravel, fine to coarse, sandy, clay layers, cobbles, angular to well-rounded, fair sorting, some brownish silicates, taking water.

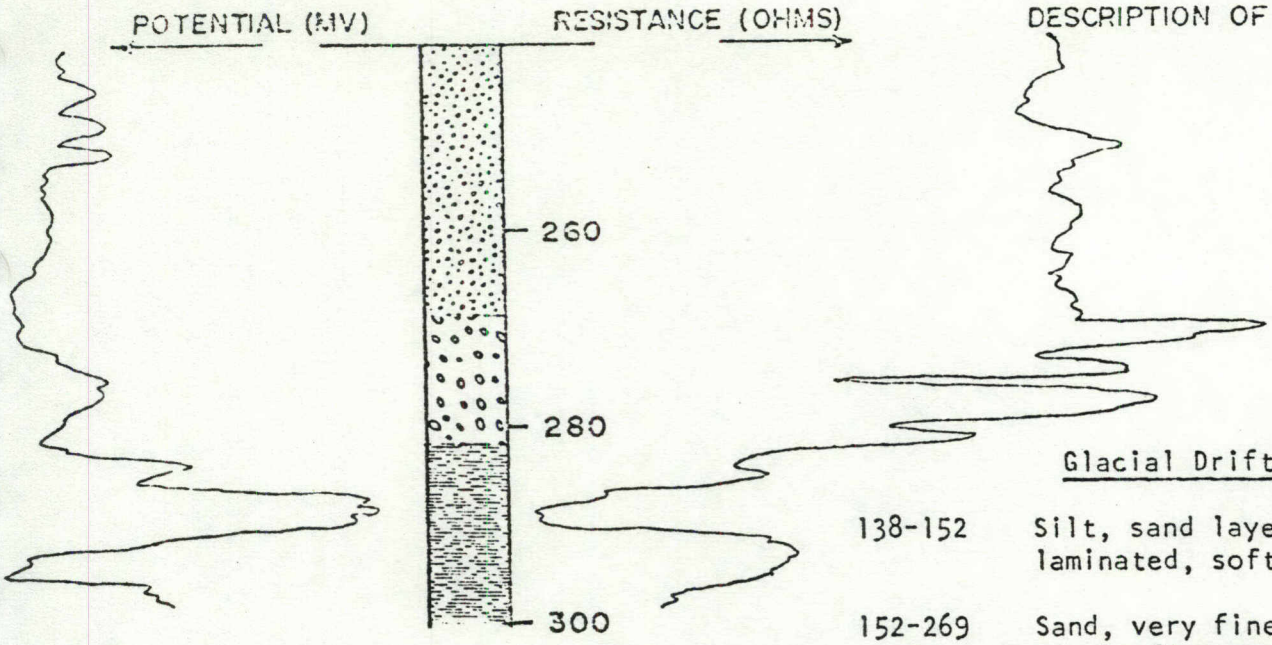
SWC FORM # 233 B

LOCATION: 143-81-4ADD

DATE DRILLED: October, 1973

ELEVATION: 1720
(FT, MSL)

DEPTH: 300
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift (Continued)

138-152 Silt, sand layers, medium gray, laminated, soft.

152-269 Sand, very fine to very coarse, mostly fine to medium, subrounde well-sorted, a few thin clay layers, lignitic, taking water.

269-282 Gravel, fine to coarse, about 3(percent sand, cobbles, fair sor ing, angular to well-rounded, brownish-colored silicates, loo caving slightly, taking water.

Hell Creek Formation

282-300 Claystone, silty, brownish-gray thin greenish-gray sandstone be ding, noncalcareous.

Observation wells

North well	South well
Depth 173 feet	Depth 263 feet
S.I. 167-173 feet	S.I. 257-263 feet
Water level 48.18 feet	Water level 47.44 feet
Measured 11-14-73	Measured 11-14-73

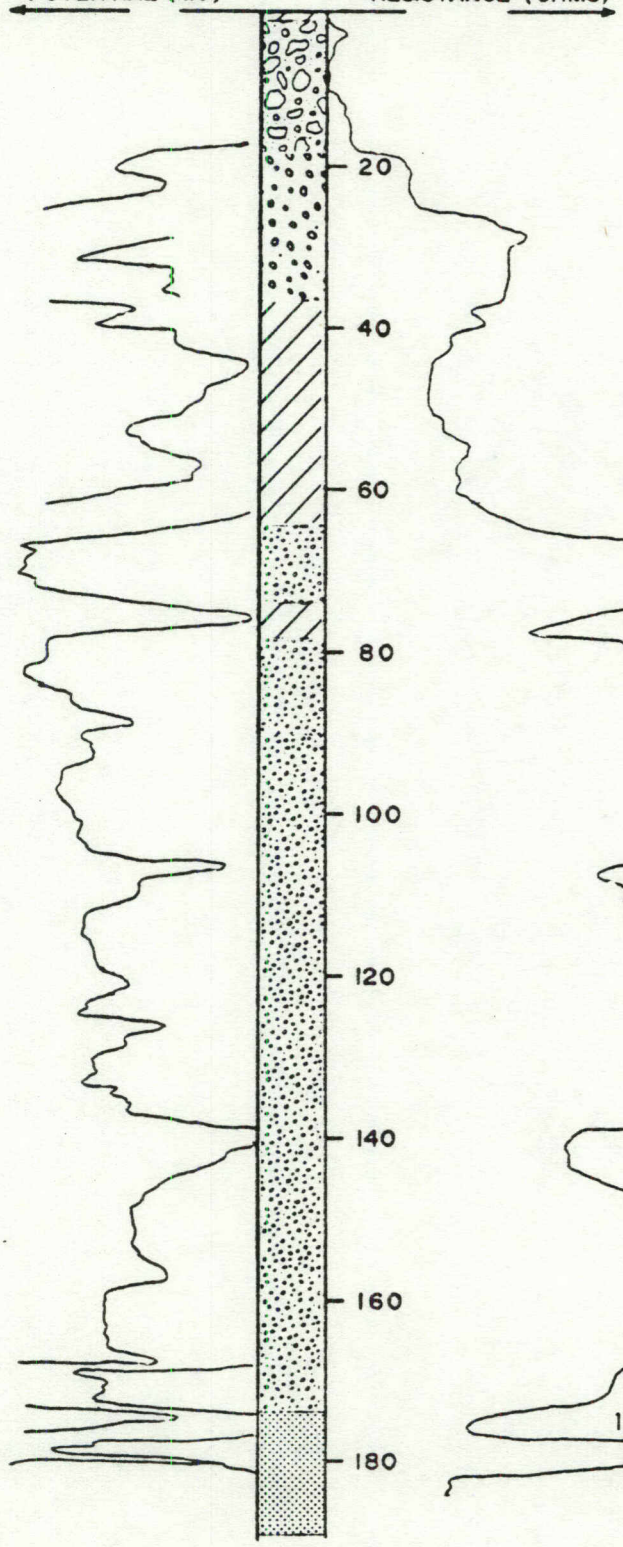
NDSWC 2695

LOCATION: 143-81-4BDA

DATE DRILLED: July 1967

ELEVATION: 1680
(FT, MSL)

DEPTH: 190
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Clay, silty, sandy, grayish-black (topsoil).
1-16	Clay, silty, sandy, light-brown (till).
16-18	Clay, sandy, silty, pebbly, olive-gray (till).
18-36	Gravel, fine to medium, clayey.
36-64	Clay, silty, bluish-gray to olive-brown (lacustrine).
64-74	Sand, very fine to fine, angular to subangular.
74-78	Clay, silty, lignitic, dark-gray to brownish-black (lacustrine).
78-174	Sand, fine to medium, angular to subrounded; clay lenses 104-106 and 139-145 feet.

Cannonball Formation

174-190	Sandstone, fine, calcareous, greenish-gray; interbedded with noncalcareous olive-gray shale.

Observation well
Depth 160 feet
S.I. 157-160 feet
Water level 8.86 feet
Measured 11-14-73

143-81-4CBB
(Log from U.S. Bureau of Reclamation)

Elevation: 1662.7 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, silty, brown; slightly plastic --------	4.4	4.4
	Sand, very fine, silty, loose, brown --------	10.6	15
	Clay, silty, gray to brown, very plastic ----	2.5	17.5
	Sand, very fine, loose, gray ----------	2.5	20
	Silt, gray, compact ----------	2.3	22.3
	Sand, medium, some gravel, gray; small clay seam at 25 feet ----------	7.5	29.8
	Sand, fine, lignitic, loose, gray ----------	5.2	35
	Sand, medium, clean, loose, some gravel, gray ----------	12.6	47.6
	Sand, fine to medium, gravelly, loose, gray; some lignite slack ----------	52.1	99.7
	Sand and gravel, gray ----------	1.5	101.2
	Clay, firm, gray; silt lenses throughout ----	18.8	120

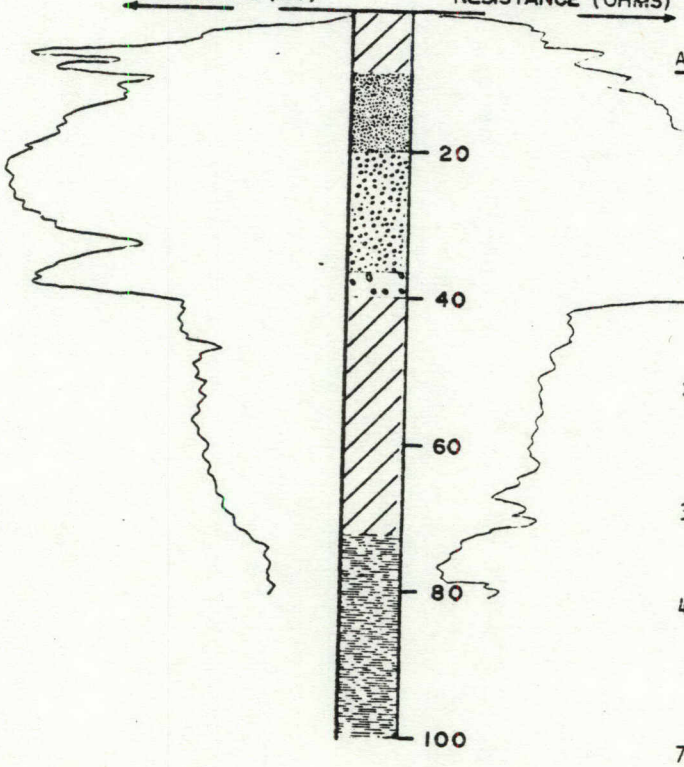
NDSWC 8940

LOCATION: 143-81-5AAD

DATE DRILLED: October, 1973

ELEVATION: 1665
(FT, MSL)

DEPTH: 100
(FT)



DESCRIPTION OF DEPOSITS

Alluvium and glacial drift undifferentiated

0-8 Clay, very silty, yellowish-brown, soft, oxidized.

8-20 Silt, clayey, sandy, olive gray, soft.

20-36 Sand, fine to very coarse, mostly medium to coarse, subrounded, well-sorted, taking water, lignitic.

36-40 Gravel, fine to coarse, sandy, angular to well-rounded, loose, caving.

40-72 Clay, silty, olive gray, plastic, highly calcareous.

Cannonball Formation

72-100 Claystone, sandy, medium gray with brownish-gray and dark-greenish-gray mottling, calcareous.

Observation well
Depth 40 feet
S.I. 37-40 feet
Water level 8.54 feet
Measured 11-1-73

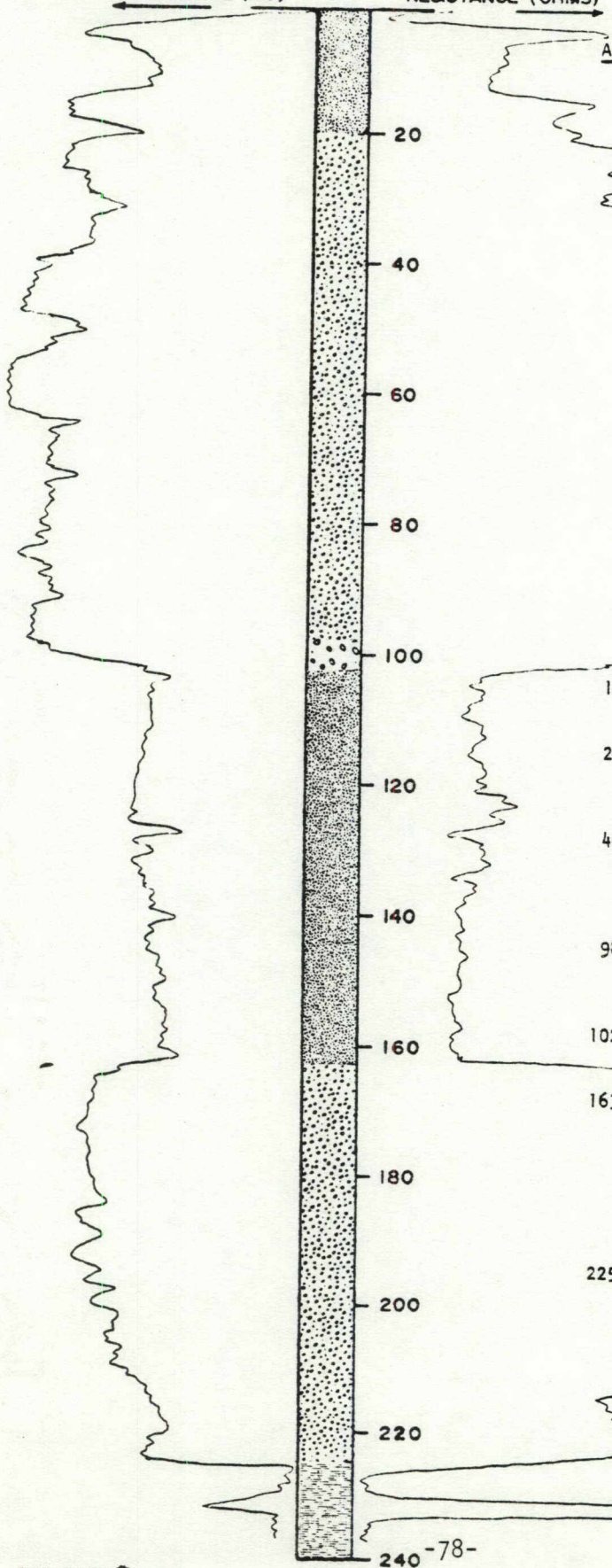
NDSWC 8941

LOCATION: 143-81-5ADD

DATE DRILLED: October, 1973

ELEVATION: 1666
(FT, MSL)

DEPTH: 240
(FT)



DESCRIPTION OF DEPOSITS

Alluvium and glacial drift undifferentiated

0-10 Silt, clayey, yellowish-brown, soft, oxidized.

10-20 Silt, sandy, clayey, olive gray, soft, highly calcareous.

20-40 Sand, thin clayey silt layers, very fine to medium, mostly fine, subrounded, well-sorted, lignitic.

40-98 Sand, clayey silt layers, very fine to very coarse, mostly medium, subrounded, well-sorted lignitic, taking water.

98-102 Gravel, fine to coarse, sandy, subangular to rounded, fair sorting.

102-163 Silt, sandy, clayey, olive gray, soft, detrital lignite.

163-225 Sand, clayey silt layers, very fine to coarse, mostly fine to medium, well-sorted, uniform, taking water.

Hell Creek Formation

225-240 Claystone, silty, brownish-gray, noncalcareous, limestone concretion from 231-232 feet.

Observation wells

East well
Depth 183 feet
S.I. 177-183 feet
Water level 11.15 feet
Measured 12-11-73

West well
Depth 83 feet
S.I. 77-83 feet
Water level 6.35 feet
Measured 12-11-73

SWC FORM # 233 B

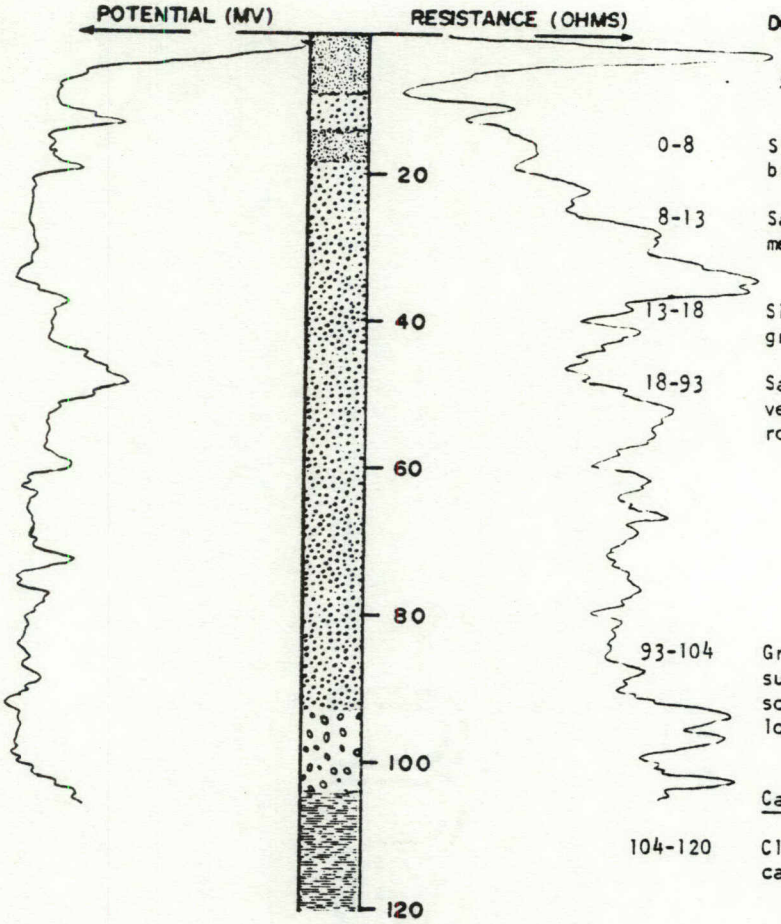
NDSWC 8942

LOCATION: 143-81-5DDB

DATE DRILLED: October, 1973

ELEVATION: (FT, MSL) 1660

DEPTH: (FT) 120



DESCRIPTION OF DEPOSITS

Alluvium and glacial drift undifferentiated

0-8 Silt, sandy, dark yellowish-brown, soft, oxidized.

8-13 Sand, silty, very fine to medium, subrounded.

13-18 Silt, sandy, clayey, olive-gray, soft.

18-93 Sand, thin clayey silt layers, very fine to very coarse, sub-rounded, well-sorted, lignitic.

93-104 Gravel, fine to coarse, sandy, subangular to well-rounded, fair sorting, much detrital lignite, loose, caving.

Cannonball Formation

104-120 Claystone, sandy, medium-gray, calcareous.

Observation Well
Depth 80 feet
S.I. 77-80 feet
Water level 9.75 feet
Measured 11-2-73

143-81-8ACB
(Log from U.S. Bureau of Reclamation)

Elevation: 1665 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, very silty, gray, slightly plastic --	5	5
	Sand, very fine, silty, loose, gray -------	14.8	19.8
	Sand, fine to medium, gravelly from 25-30 feet, lignitic 30-36 feet, gray to brown ----------	20.5	40.3
	Sand and gravel, gray to brown; medium sand and fine to medium gravel ----------	3.4	43.7
	Sand, fine, clayey, gray ----------	1.3	45
	Sand and gravel, silty and lignitic, gray; fine sand and medium to coarse gravel ---	25	70
	Sand, fine to medium, lignitic, gravelly, loose, gray ----------	14.9	84.9
	Clay, firm, silty, gray ----------	2	86.9

143-81-8CCC1
(Log from U. S. Bureau of Reclamation)

Elevation: 1668 feet

Glacial drift:		
Sand, fine, silty, olive-brown; trace of clay	13	13
Sand, fine, silty, olive-brown; silt decreases with depth	10	23
Sand, fine, clayey, gray	7	30
Sand, fine, gray; trace of silt	5	35
Gravel, sandy, silty, loose	15	50
Gravel, trace of coarse sand; boulder at 54 feet	13	63
Boulder	1	64
Sand, medium, loose, gray to brown	6	70

143-81-8CCC2
(Log from U. S. Bureau of Reclamation)

Elevation: 1666 feet

Glacial drift:		
Clay, silty, buff	5	5
Silt, sandy, buff	10	15
Sand, fine to medium, silty, gray	9.1	24.1
Sand, fine to medium, lignitic, loose, gray	14.6	38.7
Sand, medium to coarse, gravelly, lignitic, loose, brown	11.3	50
Sand and gravel, gray; medium sand, medium to coarse gravel	10	60
Sand, fine, silty, loose, gray	10	70
Sand and gravel, gray; sand coarse, gravel fine, thin lignitic layers at 73.6 feet and 93.5 feet	30	100
Clay, silty, firm, gray	7.7	107.7

143-81-10DAD
NDSWC 3896

Elevation: 1770 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, pebbly, dark-brownish-black	1	1
	Silt, clayey, sandy, pebbly, yellowish-gray to dusky-yellow (till)	9	10
	Clay, silty, sandy, pebbly, olive-brown (till)	36	46
	Clay, silty, sandy, pebbly, olive-gray (till)	16	62
Cannonball Formation:			
	Shale, silty, micaceous, brittle, light- to medium-gray	18	80

143-81-11BBB
NDSWC 4106

Elevation: 1768 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy, black	1	1
	Sand, medium to coarse, subangular to subrounded, reddish-brown	25	26
Cannonball Formation:			
	Shale, silty, sandy, hard, carbonaceous, dark-gray	35	61
	Shale, noncalcareous, hard, light-gray	19	80

143-81-14C
(Log from U.S. Bureau of Reclamation)

Elevation: 1663 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, brown; moderately plastic, sand lenses	5	5
	Clay, silty, gray, very plastic	10	15
	Silt, clayey, brown, slightly plastic	8	23
	Sand, fine to medium, loose, poorly graded, gray; clay lenses throughout	17	40
	Sand, medium, loose, poorly graded, gray; some gravel	8	48
	Sand, fine, silty, loose, gray	6	54
	Sand and gravel, buff; fine to medium sand and fine to medium gravel	7.7	61.7
Cannonball Formation:			
	Shale, soft to firm, gray	10.2	71.9

143-81-15BBB
(Log from U.S. Bureau of Reclamation)

Elevation: 1713 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Silt, clayey, gray to brown	4.6	4.6
	Clay, very silty, sandy, gray to brown, slightly plastic	11.4	16
	Clay, plastic, gypsiferous, gray to brown, fine sand and silt lenses throughout	20.5	36.5
Cannonball Formation:			
	Shale, sandy, firm, gray	9.2	45.7

143-81-15CCC
(Log from U.S. Bureau of Reclamation)

Elevation: 1728 feet

Glacial drift:		
Silt, clayey, gray	5	5
Clay, silty, plastic, gray-brown	5	10
Silt, loose, gray	2	12
Gravel, medium, clayey, buff	1	13
Clay, silty, sandy, gray	3	16
Clay, firm, plastic, gray-brown; silt lenses throughout	24.6	40.6
Cannonball Formation:		
Shale, sandy, firm, plastic, gray	20.1	60.7

143-81-16CCC
(Log from U.S. Bureau of Reclamation)

Elevation: 1661 feet

Glacial drift:		
Clay, silty, plastic, brown	4	4
Silt, little clay, plastic, brown	10.7	14.7
Sand, fine, loose, buff	10.3	25
Sand, fine to medium, brown; some fine gravel	10	35
Sand, fine, brown, lignite fragments at 42 feet	13	48
Sand and gravel, medium, loose, brown	4.8	52.8
Clay, silty, gravelly, gray	1.2	54.0
Sand and gravel, coarse, silty	1.3	55.3
Sand, fine, silty, gray; some lignite slack	8.1	63.4
Sand, fine to medium, buff, some fine gravel	21.6	85
Sand, very fine, gray; streaks of silt and lignite slack	5	90
Sand, medium, gravelly, gray; streaks of clay	7.6	97.6
Sand and gravel, silty, loose, gray; medium sand, fine to medium gravel	26.1	123.7
Silt, gravelly, gray	1.3	125
Clay, silty, firm, gray	20	145

143-81-16DBB
NDSWC 2694

Elevation: 1661 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift, undifferentiated:			
	Clay, silty, sandy, moderate-yellowish-brown	14	14
	Clay, silty, sandy, calcareous, grayish-olive to olive-gray; scattered pebbles	6	20
	Sand, fine to medium, gravelly, subangular to rounded	34	54
Cannonball Formation:			
	Shale, noncalcareous, medium-light-gray to moderate-olive-brown; thin sandstone interbeds from 75 to 80 feet	26	80

Observation well
Depth 50 feet
S. I. 47-50 feet
Water level 13.41 feet
Measured 12-11-73

143-81-24DDA1
NDGS auger hole 51

Elevation: 1780 feet

Glacial drift:			
	Silt, sandy, mottled brown	1	1
	Sand, silty, pebbly	3	4
	Sand, coarse, gravelly	2	6
	No sample	11	17

Observation well
Depth 17 feet
Water level 5 feet
Measured 10-67

143-81-24DDA2
NDSWC 4105

Elevation: 1780 feet

Glacial drift:			
	Topsoil, sandy, black	2	2
	Gravel, fine to medium, subrounded, black-	4	6
	Sand, medium to very coarse, subangular to subrounded, dark-gray	14	20
	Gravel, fine to medium, subrounded	4	24
	Clay, plastic, dark-gray; scattered sand	2	26
	Gravel, fine to medium, sandy, subangular to subrounded; isolated clay lenses	14	40
Tongue River Formation:			
	Shale, silty, sandy, carbonaceous, dark-gray	22	62
	Shale, silty, hard, noncalcareous, light-gray	18	80

Observation well
Depth 38 feet
Water level 5 feet
Measured 8-70

143-81-28BAB
(Log from U.S. Bureau of Reclamation)

Elevation: 1657.8 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, silty, slightly plastic, brown ------	6.5	6.5
	Sand, silty, loose, brown ----------	8.1	14.6
	Sand, fine, loose, gray ----------	25	39.6
	Sand and gravel, brown; medium sand and fine to medium gravel ----------	4.1	43.7
	Clay, sandy, plastic, gray ----------	1.3	45
	Boulder ----------	1	46
	Sand and gravel, medium, silty, buff ------	4	50
	Clay, gravelly, plastic, gray; boulders ---	6	56
	Sand, fine, clayey, brown ----------	4	60
	Sand, fine, clayey, gray ----------	7.4	67.4
Cannonball Formation(?):			
	Clay (shale), silty, firm, plastic --------	2.6	70
	Sand, very fine, silty, gray ----------	5.6	75.6
	Clay (shale), silty, firm, very plastic, gray ----------	10.4	86

144-79-29CCB
NDSWC 2050

Glacial drift:			
	Clay, silty, sandy, light-olive-gray ------	5	5
	Gravel, fine to coarse, stained black, unsorted ----------	5	10
	Gravel, sandy, fine to coarse, unsorted ---	10	20
Cannonball Formation:			
	Siltstone, greenish-gray, mica flakes, lignitic, slightly calcareous ----------	10	30

144-80-15DAD
NDSWC 3890

Elevation: 1795 feet

Glacial drift:			
	Topsoil, silty, black ----------	2	2
	Gravel, fine, sandy; interbedded with moderate-yellowish-brown clayey till ----	15	17
	Clay, silty, very sandy, plastic, olive-gray, scattered pebbles (till) ----------	48	65
Cannonball Formation:			
	Sand, very fine, clayey, carbonaceous, green ----------	5	70
	Shale, silty, brittle, medium-light-gray --	10	80

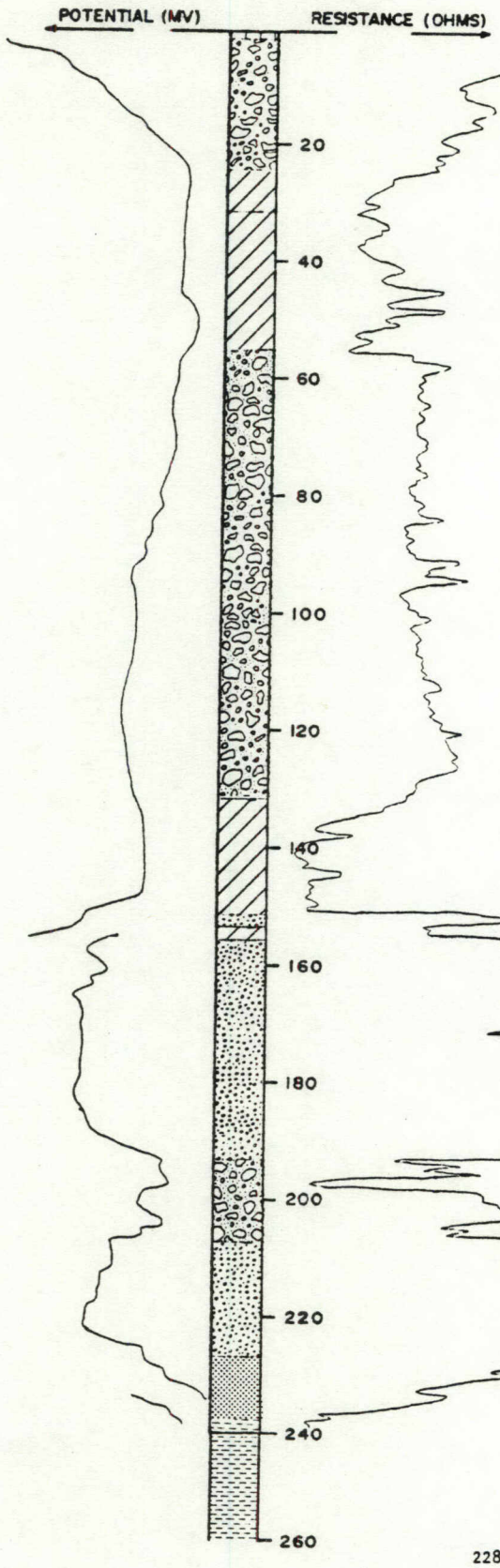
NDSWC 4109

LOCATION: 144-80-18CCC

ELEVATION: 1770
(FT, MSL)

DATE DRILLED: August 1970

DEPTH: 260
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Silt, pebbly, black (top-soil).

1-7 Silt, clayey, sandy, pebbly, yellowish-gray (till).

7-24 Clay, silty, sandy, pebbly, olive-brown (till).

24-31 Clay, plastic, olive-green.

31-55 Clay, silty, olive-gray, laminated (fluvial ?)

55-132 Clay, silty, sandy, pebbly, lignitic, olive-gray (till).

132-152 Clay, plastic, olive-gray; with black oily organic clay laminations.

152-154 Sand, fine, subrounded.

154-156 Clay, silty, plastic, olive-gray.

156-194 Sand, fine to medium, lignitic, subangular to subrounded.

194-208 Clay, silty, olive-gray; interbedded with thin isolated sand and silt lenses (till).

208-228 Sand, coarse, gravelly angular to subrounded.

Hell Creek Formation

228-232 Sandstone, fine, clayey, dark-greenish-gray.

232-238 Sandstone, very fine, clayey, silty, greenish-gray.

238-260 Shale, silty, sandy, carbonaceous, noncalcareous, variegated gray, green, and brown.

144-80-19ABA
NDSWC 4110

Elevation: 1765 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Sand, fine to coarse, subrounded, yellowish-gray; dry	4	4
	Clay, silty, sandy, dusky-yellow (till)	7	11
	Sand, medium to coarse, subrounded, light-gray	4	15
	Clay, silty, sandy, pebbly, light-olive-gray (till)	12	27
	Clay, silty, sandy, pebbly, olive-gray; lensed with fine to medium lignitic sand (till)	28	55
	Clay, silty, olive-gray; contains light-gray laminations alternating with black organic material	117	172
	Gravel, fine to medium, sandy, angular to subrounded	100	272
Hell Creek Formation(?):			
	Shale, silty, hard, noncalcareous, medium-gray	28	300

Observation well
Depth 268 feet
Slotted 238-268 feet
Water level 2 feet
Measured 8-70

144-80-26BBB1
NDGS auger hole 49

Elevation: 1770 feet

Glacial drift:			
	Sand, coarse, gravelly	6.5	6.5

Observation well
Depth 15 feet
Water level 5 feet
Measured 10-67

144-80-26BBB2
NDSWC 3891

Elevation: 1770 feet

Glacial drift:		
Gravel, fine to coarse, sandy; cobbles and boulders	17	17
Sand, coarse, gravelly, subrounded	6	23
Clay, silty, olive-gray; scattered sand and pebbles (till)	24	47
Gravel, fine to medium, sandy, angular to subrounded	4	51
Cannonball Formation:		
Shale, carbonaceous, medium-gray to brownish-gray; interbedded with silt and sand-	29	80

144-80-26BCB
Test hole 8952

Elevation: 1785 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Gravel, fine to coarse, about 30 percent sand, stained yellowish-brown, loose, caving, taking water rapidly	21	21
	Clay, silty, pebbly, olive gray (till)	39	60
Cannonball Formation:			
	Claystone, sandy, medium gray, calcareous	20	80

144-80-26BCC
NDSWC 3892

Elevation: 1795 feet

Glacial drift:		
Gravel, fine to medium, sandy, angular to subrounded	8	8
Clay, silty, sandy, moderate-olive-brown; scattered pebbles (till)	16	24
Clay, silty, sandy, olive-gray; scattered pebbles (till)	94	118
Cannonball Formation:		
Shale, silty, carbonaceous, brittle, medium- to dark-gray	22	140

144-80-26CCC
NDSWC 3893

Elevation: 1835 feet

Glacial drift:

Silt, clayey, sandy, yellowish-gray to dusky-yellow; scattered pebbles	8	8
Clay, silty, dusky-yellow; scattered sand and pebbles (till)	24	32
Clay, very sandy, silty, olive-gray; scattered pebbles (till)	37	69
Clay, silty, olive-gray; interbedded with very fine to fine loose sand	26	95
Gravel, fine to medium, subangular to subrounded	9	104
Clay, silty, plastic, olive-gray to dark-olive-gray	4	108
Clay, very sandy, plastic, olive-gray; scattered pebbles (till)	36	144
Cannonball Formation:		
Shale, very sandy, brittle, medium-gray to dark-greenish-gray	7	151
Sand, very fine, clayey, light-olive-gray to light-greenish-gray	9	160

144-81-13AAB
NDSWC 3903

Elevation: 1865 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Road fill	4	4
	Gravel, fine to very coarse, cobbles, boulders, sandy, silty clay layers, yellowish-brown, oxidized, loose, caving	39	43
Tongue River Formation:			
	Sandstone, clayey, very fine to fine, greenish-gray, brownish-black, carbonaceous shale bedding, friable, micaceous, noncalcareous	27	70

144-81-13CDC
NDSWC 3901

Elevation: 1865 feet

Glacial drift:		
Clay, silty, sandy, gray	7	7
Gravel, fine to medium, sandy; interbedded with silt and clay	7	14
Clay, silty, sandy, olive-gray; scattered pebbles (till)	6	20
Tongue River Formation:		
Sand, very fine to fine, clayey, micaceous, greenish-gray	20	40

144-81-16DDD
NDSWC 3902

Elevation: 1740 feet

Glacial drift:		
Topsoil, pebbly, dark-brown	1	1
Clay, silty, sandy, dusky-yellow; scattered pebbles (till)	7	8
Clay, silty, sandy, plastic, moderate-olive-brown; scattered pebbles (till)	26	34
Clay, silty, sandy, plastic, olive-gray; scattered pebbles (till)	4	38
Cannonball Formation:		
Sand, very fine to fine, clayey, micaceous, carbonaceous, noncalcareous, greenish-gray	22	60

144-81-25AAA
NDSWC 2864

Elevation: 1715 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, silty, sandy, grayish-black	1	1
	Clay, silty, sandy, dark-gray to dark-greenish-gray	4	5
	Gravel, fine to coarse, angular to subrounded	4	9
	Clay, silty, sandy, calcareous, medium-gray	11	20
	Gravel, fine to coarse, sandy, angular to rounded	16	36
	Clay, silty, calcareous, olive-gray	29	65
	Clay, silty, sandy, calcareous, olive-gray to medium-dark-gray; scattered pebbles (till)	22	87
	Gravel, fine to coarse, sandy, angular to rounded	5	92
	Sand, clayey, silty, olive-gray	8	100

144-81-25ADA
NDGS auger hole 64

Elevation: 1715 feet

Glacial drift:			
	Sand, silty	2.5	2.5
	Sand, medium to coarse, silty, gravelly	12.5	15
	No sample	10	25

Observation well
Depth 18 feet
Water level 4.04 feet
Measured 11-30-70

144-81-26CCB
NDSWC 3900

Elevation: 1700 feet

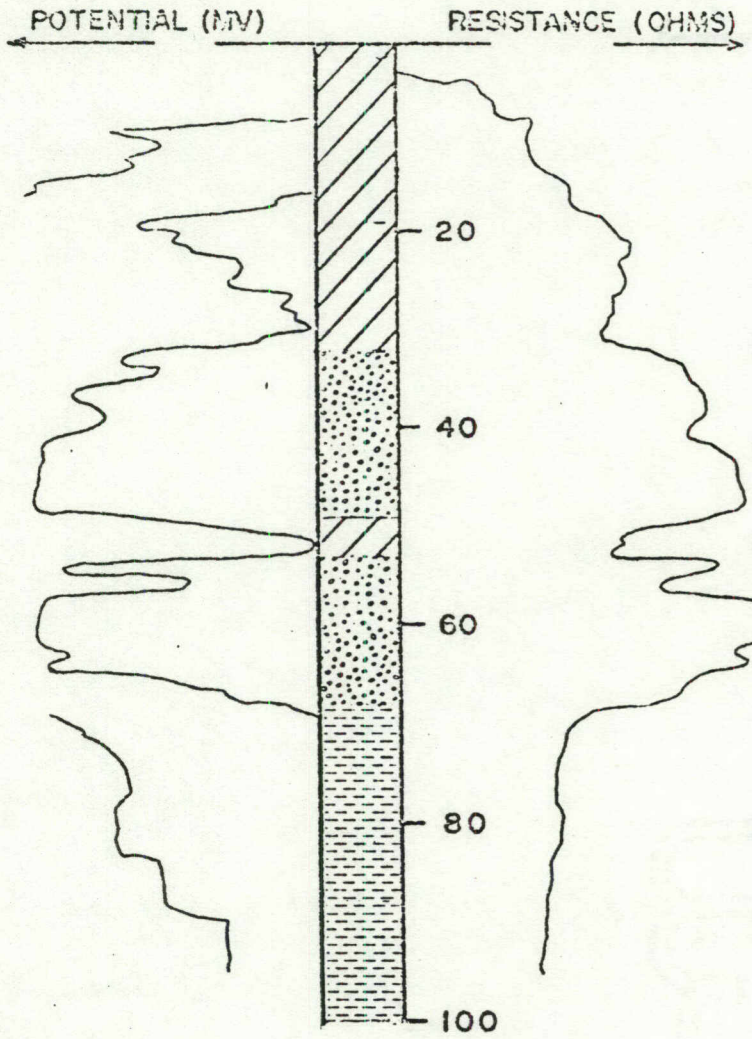
Alluvium:			
	Clay, silt, and clayey sand, gray; interbedded	5	5
	Gravel, fine to medium; interbedded with clay and silt	7	12
Cannonball Formation:			
	Shale, silty, sandy, micaceous, carbonaceous, noncalcareous, variegated gray, and green	28	40

LOCATION: 144-81-30ACC

DATE DRILLED: July 1967

ELEVATION: 1665
(FT, MSL)

DEPTH: 100
(FT)



DESCRIPTION OF DEPOSITS

Alluvium and glacial drift, undifferentiated

0-1	Clay, silty, grayish-black (topsoil).
1-19	Clay, silty, yellowish-brown.
19-32	Clay, silty, sandy, olive-gray to greenish-gray.
32-49	Sand, fine to medium, angular to rounded.
49-53	Clay, silty, olive-gray (lacustrine).
53-68	Sand, coarse, clayey, angular to subrounded.

Cannonball Formation

68-88	Shale, noncalcareous, moderate-brown.
88-100	Shale, calcareous, medium-gray.

144-81-30DBD
NDSWC 8948

Elevation: 1665

Geologic source	Material	Thickness (feet)	Depth (feet)
Alluvium:			
	Sand, very silty, very fine to fine, subrounded, dark brown	20	20
	Sand, clay layers, very fine to medium, subangular, lignitic	9	29
Cannonball Formation:			
	Sandstone, clayey, fine, yellowish-brown with medium gray mottling	9	38
	Sandstone, fine, medium gray, siltstone bedding	22	60

144-81-30DDD
NDSWC 8947

Elevation: 1665

Alluvium:			
	Silt, very sandy, clayey, dark-yellowish-brown, oxidized	10	10
	Sand, silty, very fine to fine, subangular	6	16
Cannonball Formation:			
	Claystone, sandy, silty, medium-light-gray, calcareous	24	40

144-81-32BCD
NDSWC 8946

Elevation: 1660

Alluvium and glacial drift undifferentiated:			
	Silt, very sandy, clayey, dark-yellowish-brown, oxidized	12	12
	Silt, sandy, clayey, olive-gray, soft	7	19
	Sand, clayey silt layers, very fine to coarse, mostly fine to medium, subrounded, well-sorted	9	28
	Sand, fine to very coarse, gravelly, subrounded, well-sorted, taking water	7	35
	Gravel, fine to coarse, sandy, a few clay layers, subangular to well-rounded, loose, caving, taking water	30	65
Cannonball Formation:			
	Claystone, sandy, silty, medium-light-gray, calcareous	15	80

Observation well
Depth 50 feet
S.I. 47-50 feet
Water level
Measured

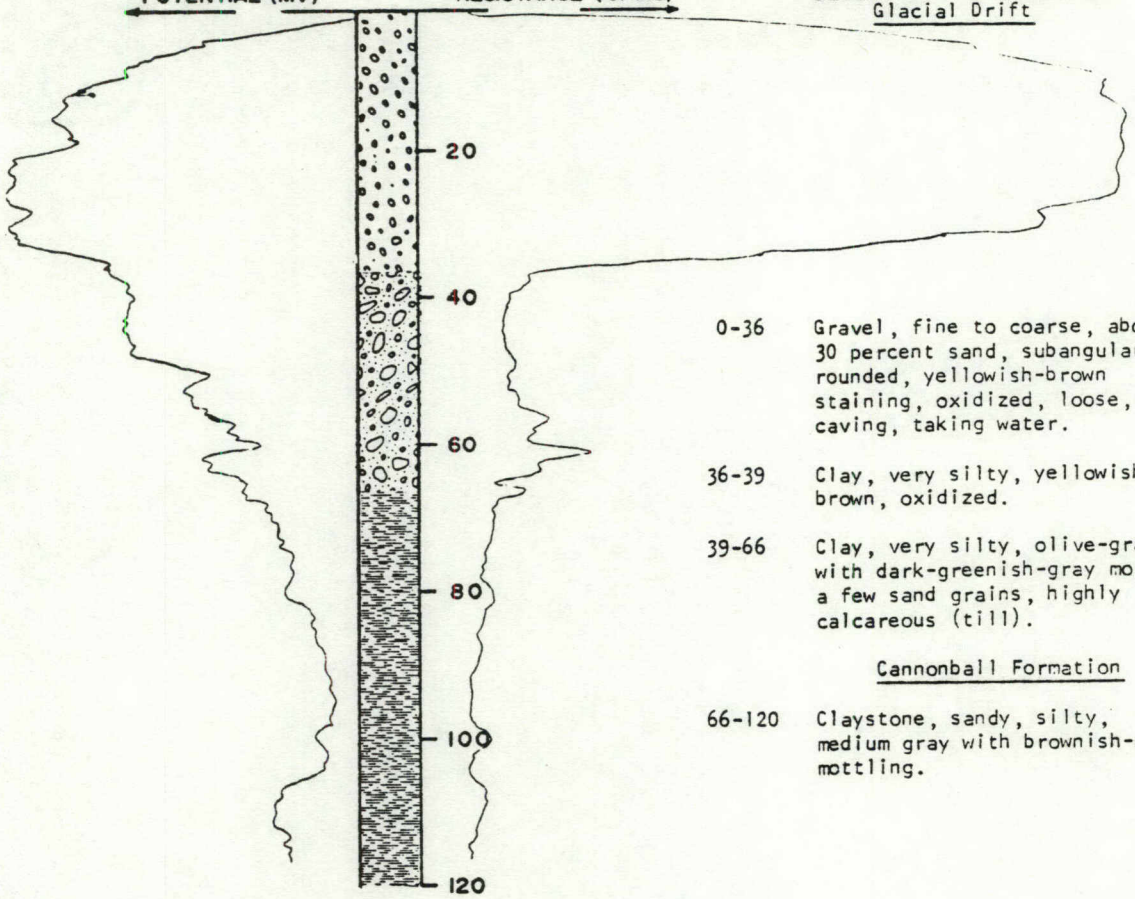
NDSWC 8934

LOCATION: 144-81-34CBB

DATE DRILLED: October, 1973

ELEVATION: 1745
(FT, MSL)

DEPTH: 120
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-36	Gravel, fine to coarse, about 30 percent sand, subangular to rounded, yellowish-brown staining, oxidized, loose, caving, taking water.
36-39	Clay, very silty, yellowish-brown, oxidized.
39-66	Clay, very silty, olive-gray with dark-greenish-gray mottling, a few sand grains, highly calcareous (till).

Cannonball Formation

66-120	Claystone, sandy, silty, medium gray with brownish-gray mottling.

144-81-35CBB
NDSWC 3899

Elevation: 1714 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Gravel, fine to medium, sandy, angular to subrounded; interbedded with moderate-olive-brown silt and clayey sand	16	16
	Clay, silty, plastic, moderate-olive-brown	8	24
	Gravel, fine to medium, subangular to subrounded	15	39
Cannonball Formation:			
	Sand, fine, clayey, yellowish-green	3	42
	Sand, fine, micaceous, carbonaceous, noncalcareous, greenish-gray	9	51
	Shale, silty, sandy, carbonaceous, variegated gray, green, and brown	29	80

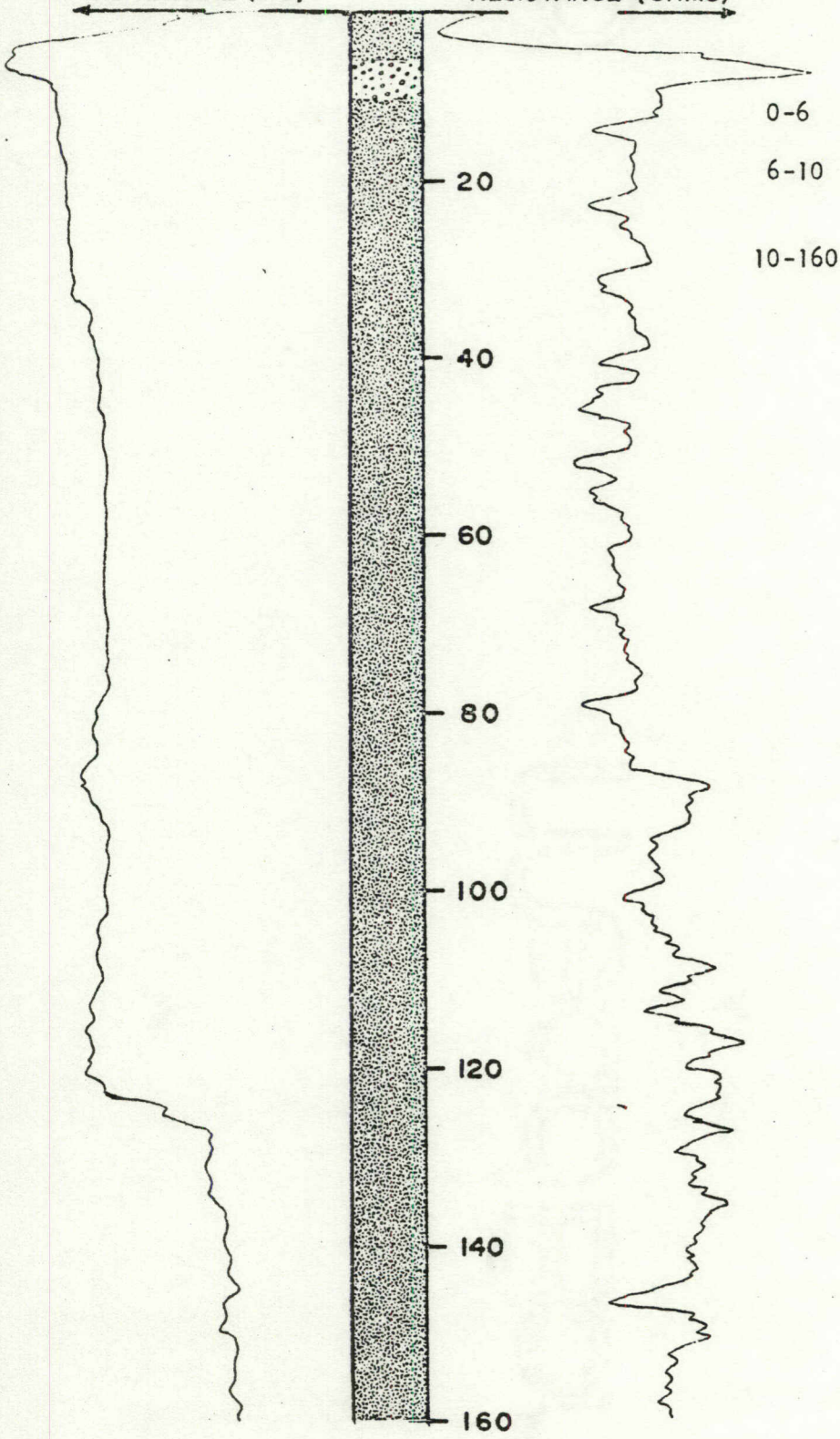
NDSWC 8951

LOCATION: 144-81-35CDD

DATE DRILLED: November, 1973

ELEVATION: 1707
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-6	Silt, sandy, clayey, yellowish-brown, oxidized.
6-10	Sand, fine to coarse, subrounded, oxidized.
10-160	Silt, very sandy, clayey, medium gray, soft, thin sand layers, calcareous.

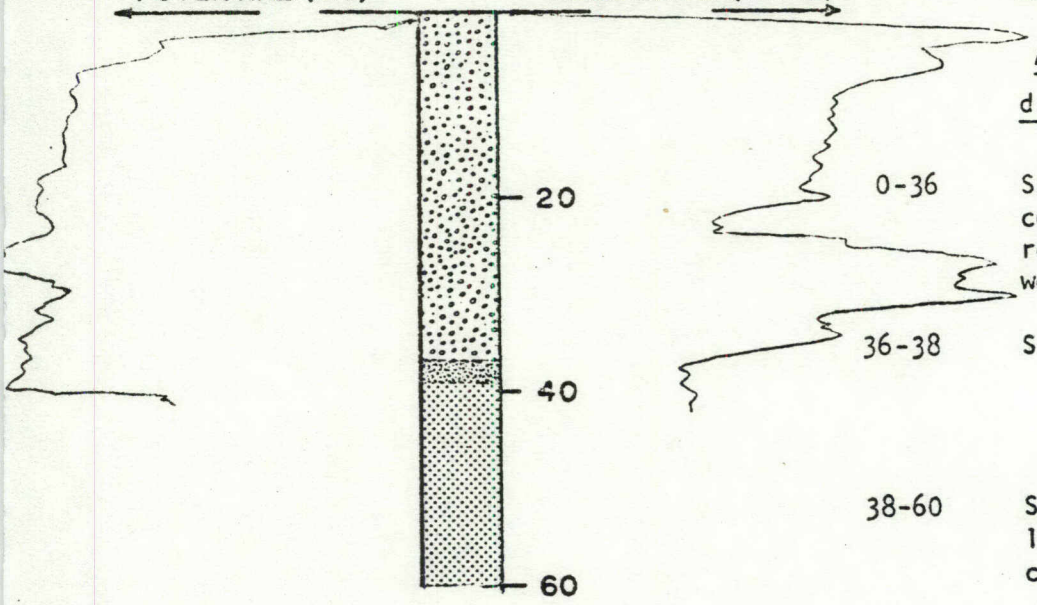
TEST HOLE 8943

LOCATION: 144-82-16ADA

DATE DRILLED: October, 1973

ELEVATION: (FT, MSL) 1665

DEPTH: 60 (FT)



DESCRIPTION OF DEPOSITS

Alluvium and glacial drift undifferentiated

0-36 Sand, silty, very fine to coarse, mostly medium, sub-rounded, dark-yellowish-brown, well-sorted, oxidized, taking wate

36-38 Silt, sandy, olive-gray, soft.

Cannonball Formation

38-60 Sandstone, fine, medium-gray with light-gray bedding, limey, highly calcareous.

Observation well
Depth 30 feet
S.I. - 27-30 feet
Water level 8.06 feet
Measured 12-11-73

144-82-17AAD$_1$

NDSWC 2697

Elevation: 1670 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Alluvium and glacial drift, undifferentiated:			
	Clay, silty, sandy, calcareous, moderate-yellowish-brown	6	6
	Sand, fine to medium, lignitic	28	34
	Gravel, fine to medium, angular to sub-rounded	8	42
Cannonball Formation:			
	Shale, noncalcareous, medium-light-gray	18	60

Observation well
Depth 41 feet
S.I. 38-41 feet
Water level 6 feet
Measured 8-67

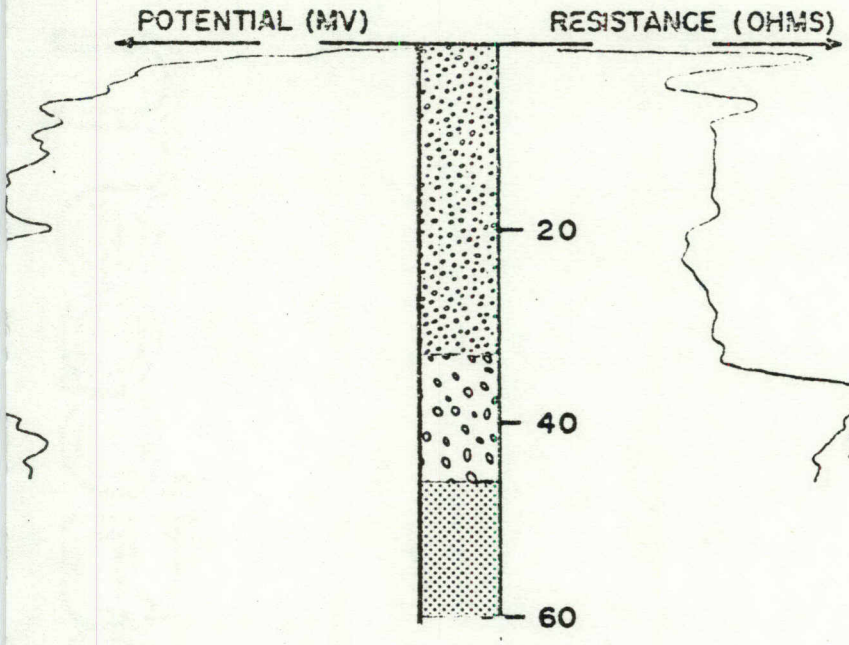
NDSWC 8944

LOCATION: 144-82-17AAD$_2$

DATE DRILLED: October, 1973

ELEVATION: 1660
(FT, MSL)

DEPTH: 60
(FT)



DESCRIPTION OF DEPOSITS

Alluvium and glacial drift undifferentiated

0-33 Sand, slightly clayey, very fine to very coarse, well-sorted, subrounded, dark-yellowish-brown staining, taking water.

33-46 Gravel, fine to coarse, about 30 percent sand, subangular to rounded, well-sorted, taking water, loose.

Cannonball Formation

46-60 Sandstone, clayey, very fine, light gray, highly calcareous, consolidated.

Observation well
Depth 40 feet
S.I. 37-40 feet
Water level 7.53 feet
Measured 12-11-73

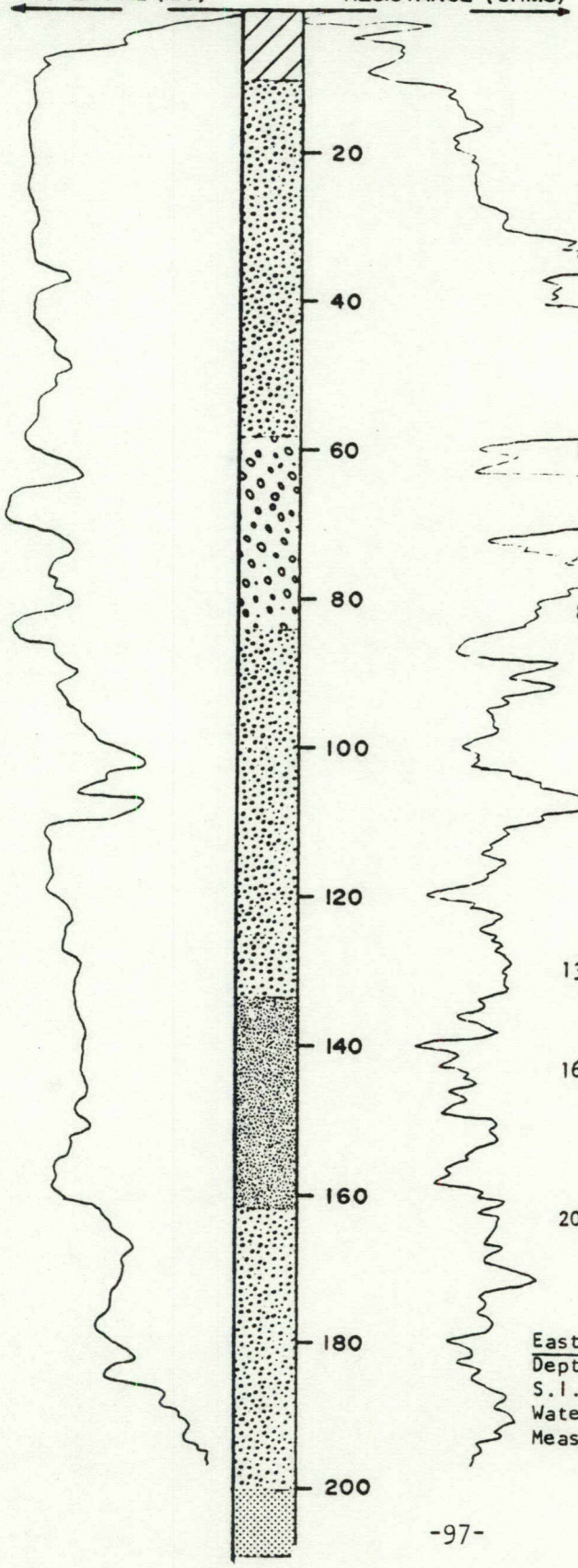
NDSWC 8945

LOCATION: 144-82-22AAB

DATE DRILLED: October, 1973

ELEVATION: 1665 (FT, MSL)

DEPTH: 210 (FT)



DESCRIPTION OF DEPOSITS

Alluvium and glacial drift undifferentiated

0-10	Clay, sandy, silty, dark-yellowish-brown, oxidized.
10-58	Sand, clayey silt layers, very fine to coarse, mostly medium to coarse, subrounded, well-sorted, light brown, taking water, oxidized.
58-84	Gravel, fine to coarse, about 20 percent sand, moderately well-sorted, subangular to well-rounded, taking water, much detrital lignite.
84-134	Sand, clay layers, very fine to very coarse, mostly medium to coarse, subrounded, well-sorted, much lignite.
134-162	Silt, very sandy, clayey, light-olive-gray, soft, highly calcareous.
162-200	Sand, clayey silt layers, very fine to coarse, subrounded, well-sorted, some lignite.

Cannonball Formation

200-210	Sandstone, light-olive-gray, fine, cemented, highly calcareous.

Observation wells

East well	West well
Depth 183 feet	Depth 70 feet
S.I. 177-183 feet	S.I. 67-70 feet
Water level 7.85 feet	Water level 5.14 feet
Measured 11-14-73	Measured 11-14-73

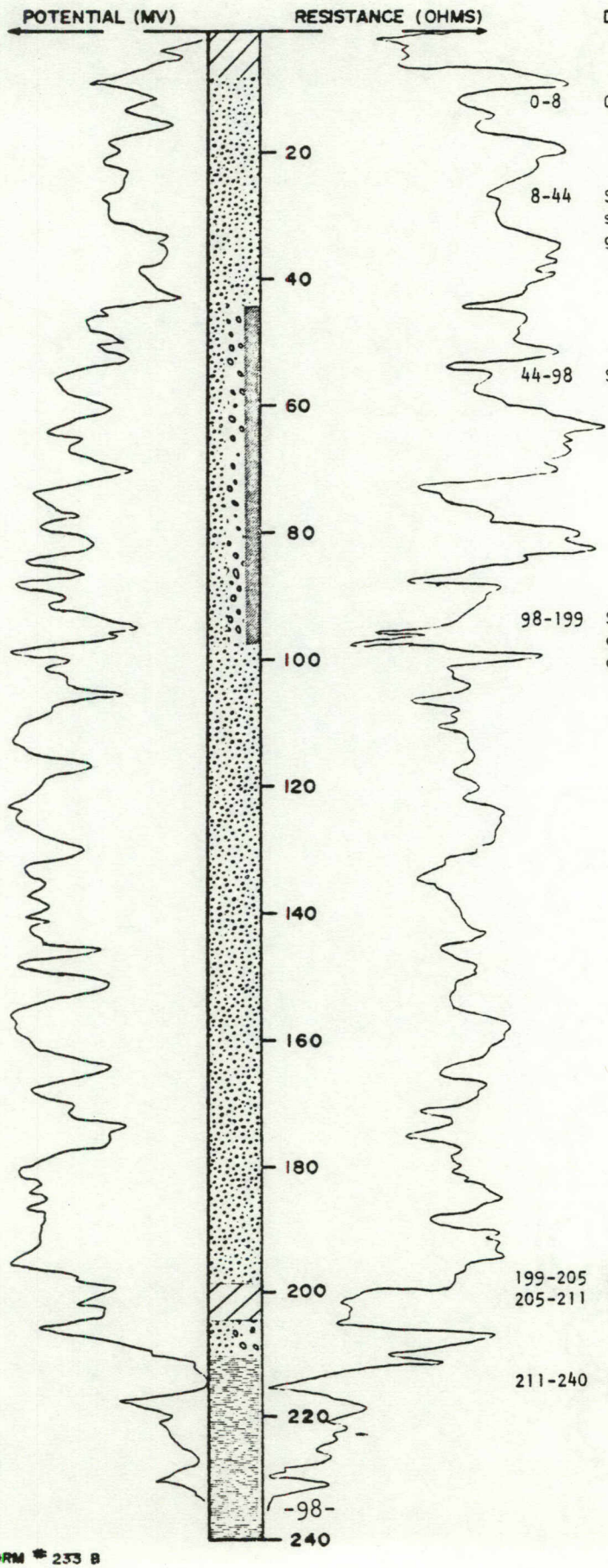
NDSWC 3731

LOCATION: 144-82-22ACC

DATE DRILLED: July, 1969

ELEVATION: (FT, MSL) 1670

DEPTH: (FT) 240



DESCRIPTION OF DEPOSITS

Alluvium

0-8 Clay, silty, yellowish-gray.

8-44 Sand, fine- to coarse-grained, silty, lignitic, carbonaceous, gray.

Glacial drift

44-98 Sand and gravel, lignitic.

98-199 Sand, fine- to coarse-grained; contains a few thin beds of detrital lignite and gravel.

199-205 Clay, silty, olive-gray.

205-211 Sand and gravel.

Cannonball Formation

211-240 Claystone and siltstone, sandy, light-olive-gray.

SWC FORM # 233 B

144-82-23BBB$_1$
NDSWC 2688

Elevation: 1665 feet

Geologic Source	Material	Thickness (feet)	Depth (feet)
Alluvium:			
	Sand, very fine- to medium-grained, clayey, dark-yellowish-brown	25	25
Glacial Drift:			
	Sand, fine- to very coarse-grained, pebbly, lignitic, dark-greenish-gray	24	49
Cannonball Formation:			
	Sandstone, hard	2	51
	Claystone, sandy, silty, dark-greenish-gray-	19	70

Observation well
Depth 38 feet
Water level 12 feet
Measured 8-67
Well destroyed 9-67

144-82-23BBB$_2$
NDSWC 2901

Elevation: 1665 feet

Alluvium:			
	Topsoil, sandy, gravelly, brownish-black	.5	.5
	Clay, very sandy, silty, moderate-yellowish-brown	5.5	6
Glacial Drift:			
	Sand, very fine- to medium-grained	38	44
	Sand, fine- to coarse-grained, pebbly	10	54
Cannonball Formation:			
	Shale, sandy, calcareous, medium-bluish-gray	6	60

Observation well
Depth 51 feet
S.I. 48-51 feet
Water level 10.22 feet
Measured 12-15-66 -99-

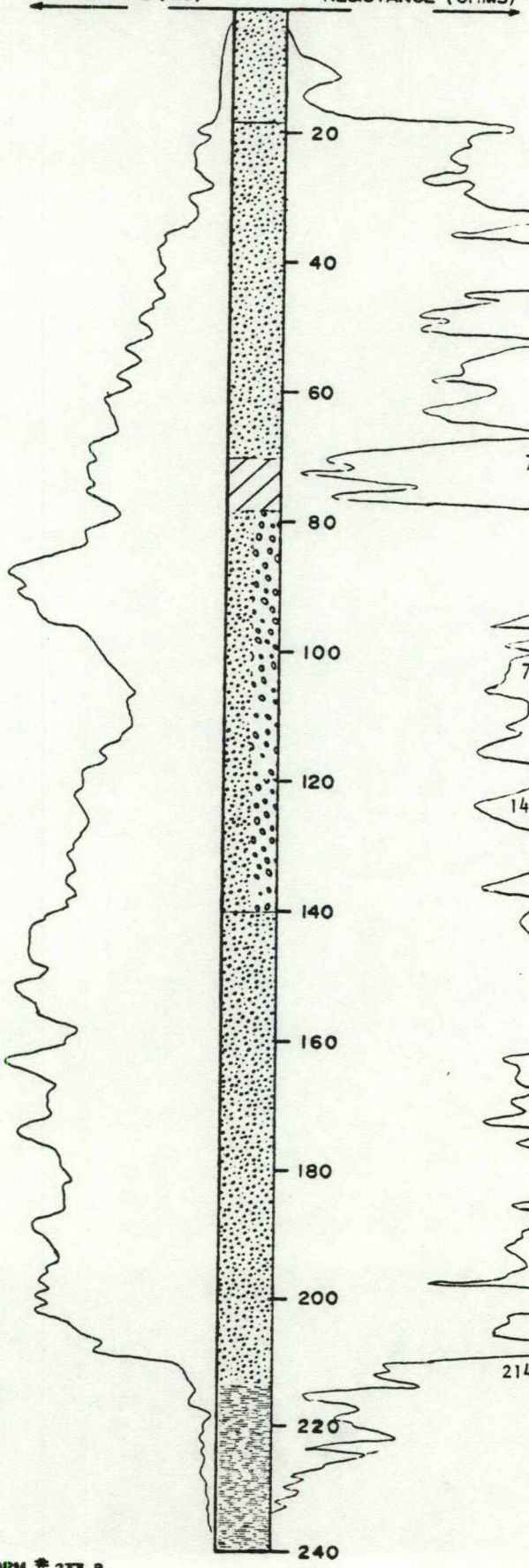
NDSWC 3729

LOCATION: 144-82-23DDD

DATE DRILLED: July, 1969

ELEVATION: (FT, MSL) 1670

DEPTH: (FT) 240



DESCRIPTION OF DEPOSITS

Alluvium

0-18 Sand, fine- to medium-grained, silty, clayey, organic, yellowish-gray.

Glacial drift

18-70 Sand, medium- to coarse-grained, lignitic, light-olive-gray.

70-78 Clay, sandy, silty, carbonaceous.

78-140 Sand and gravel, fine- to coarse-grained, lignitic.

140-214 Sand, medium- to coarse-grained, pebbly, lignitic; thin beds of gravel.

Cannonball Formation

214-240 Claystone, silty, sandy, calcareous, gray.

Observation well
Depth 203 feet
S.I. 197-203 feet
Water level 4 feet
Measured 8-69

SWC FORM # 233 B

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