Hydrogeology
of the
Lost Lake Aquifer System
In The Wilton-Washburn Area
McLean County
North Dakota

By
Allen E. Comeskey

North Dakota Ground-Water Studies
Number 93
North Dakota State Water Commission
Vernon Fahy, State Engineer

1988

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MCLEAN COUNTY NORTH DAKOTA

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INTRODUCTION

STATEMENT OF PURPOSE

On October 10, 1985 the city of Wilton and the State Water Commission entered into agreement to conduct a study to locate a supplemental water supply. Wilton's present system is inadequate to neither meet peak demands nor to supply the city's treatment facility at its designed capacity.

The goals of the study were to better characterize the deposits of the Lost Lake aquifer in the vicinity of Wilton's well field and to ascertain the variability and distribution of the chemical quality of the water.

LOCATION

Wilton is located in the southeast corner of McLean County. Wilton's well field, which is completed in the Lost Lake aquifer, is located about 8 miles northwest of the city in Sections 2 and 3, Township 143 North, Range 81 West (fig. 1). Test drilling was conducted in Sections 2, 3, and 4, Township 143 North, Range 81 West; and Section 35, Township 144 North, Range 81 West.

PREVIOUS INVESTIGATIONS

Two recent investigations have dealt specifically with the Lost Lake aquifer. Klausing (1974) drilled 18 test holes in or around the aquifer from 1966 to 1970. On pages 38 through 39 of the McLean County Ground–Water Study, part III, he discusses the location, areal extent, nature of the sediments, water levels, and water quality. The configuration of the buried valley is represented on plate 1, the aquifer boundaries on plate 2, and geologic cross–sections on plate 3.

Naplin (1979) conducted additional drilling during the 1973 field season and better characterized a portion of the aquifer in which Wilton completed its production wells. On

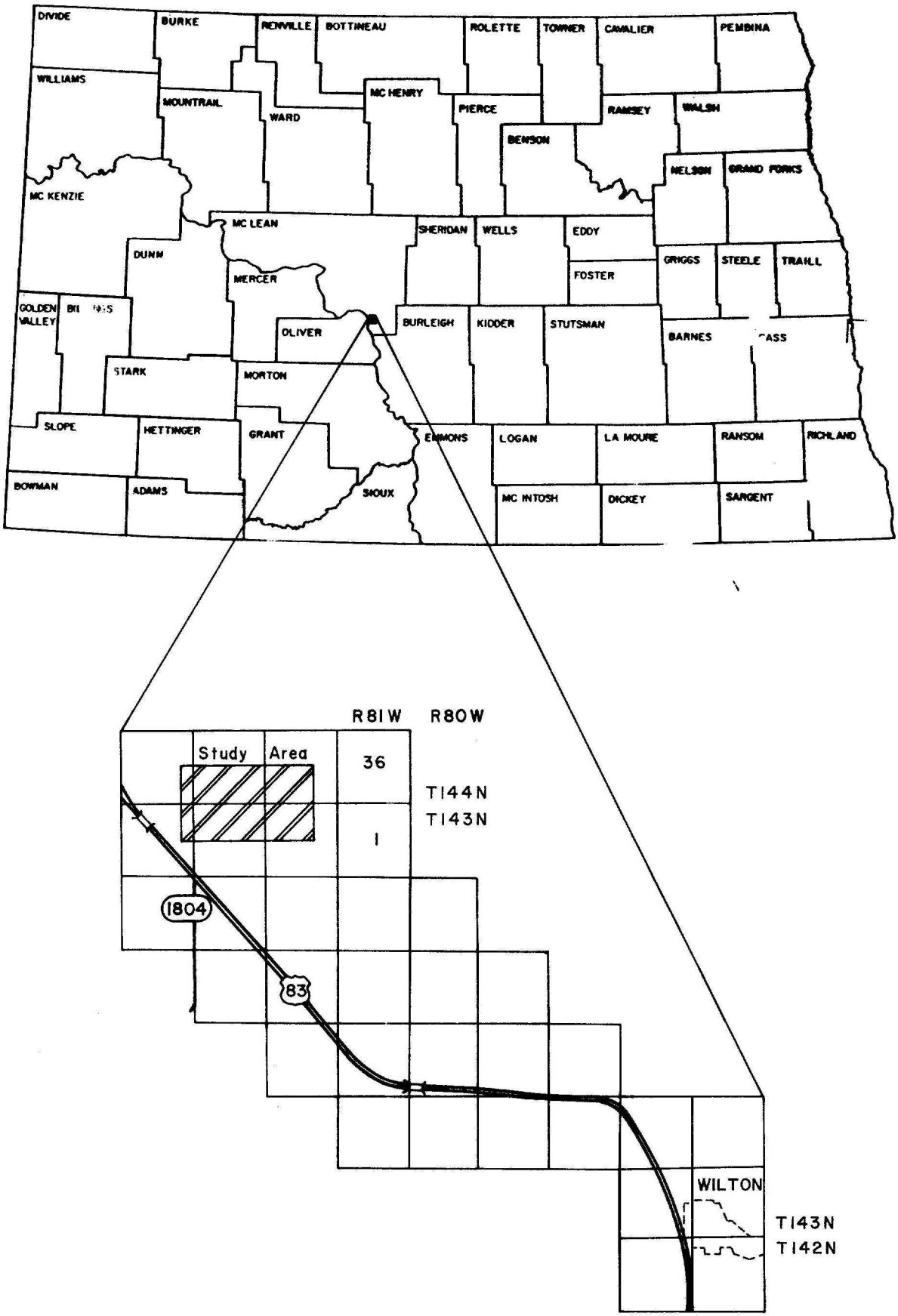

FIGURE 1.-Study Area Location.

pages 26 through 29 of North Dakota Ground–Water Studies No. 81 he describes the lithology, thickness, hydrologic properties, and water quality. Aquifer boundaries and the potentiometric surface are depicted in figure 5. Table 2 contains analysis of the chemical quality of the water. Geologic cross–sections of the Lost Lake aquifer are presented on plate 2.

LOCATION NUMBERING SYSTEMS

The system for denoting the location of a test hole or observation well is based on the federal system of rectangular surveys of public land. The first and second numbers indicate Township North and Range West of the 5th Principal Meridian and base line (fig. 2). The third number indicates the Section. The letters A, B, C, and D designate respectively the northeast, northwest, southwest, and southeast quarter Section (160 acre tract), quarter–quarter Section (40 acre tract) and quarter–quarter–quarter Section (10 acre tract). Therefore a well denoted by 143–081–04AAA would be located in NE1/4 NE1/4 NE1/4 of Section 04, Township 143 North, Range 81 West. Consecutive terminal numbers are added if more than one well is located in a 10 acre tract, for example, 143–81–02BBB$_1$ and 143–81–02BBB$_2$.

PRESENT WATER SUPPLY

Wilton's present production wells are located at 143–81–02BCC and 143–81–03ADD. Well #1 (143–81–02BCC) is 55 feet deep, constructed of 8 inch–diameter casing and screened from 25 to 35 and from 50 to 55 feet. Well #2 (143–81–03ADD) is 85 feet deep, constructed of 12 inch–diameter casing and is screened from 65 to 85 feet. Wilton holds water permit #2173 which authorizes the withdrawal of 200 acre–feet per year at a rate of 400 gallons per minute. The water treatment plant is designed to operate at 200 gallons per minute. Wilton used an average of 77 acre–feet per year from 1975 to 1983. The wells are alternately pumped at one week intervals at about

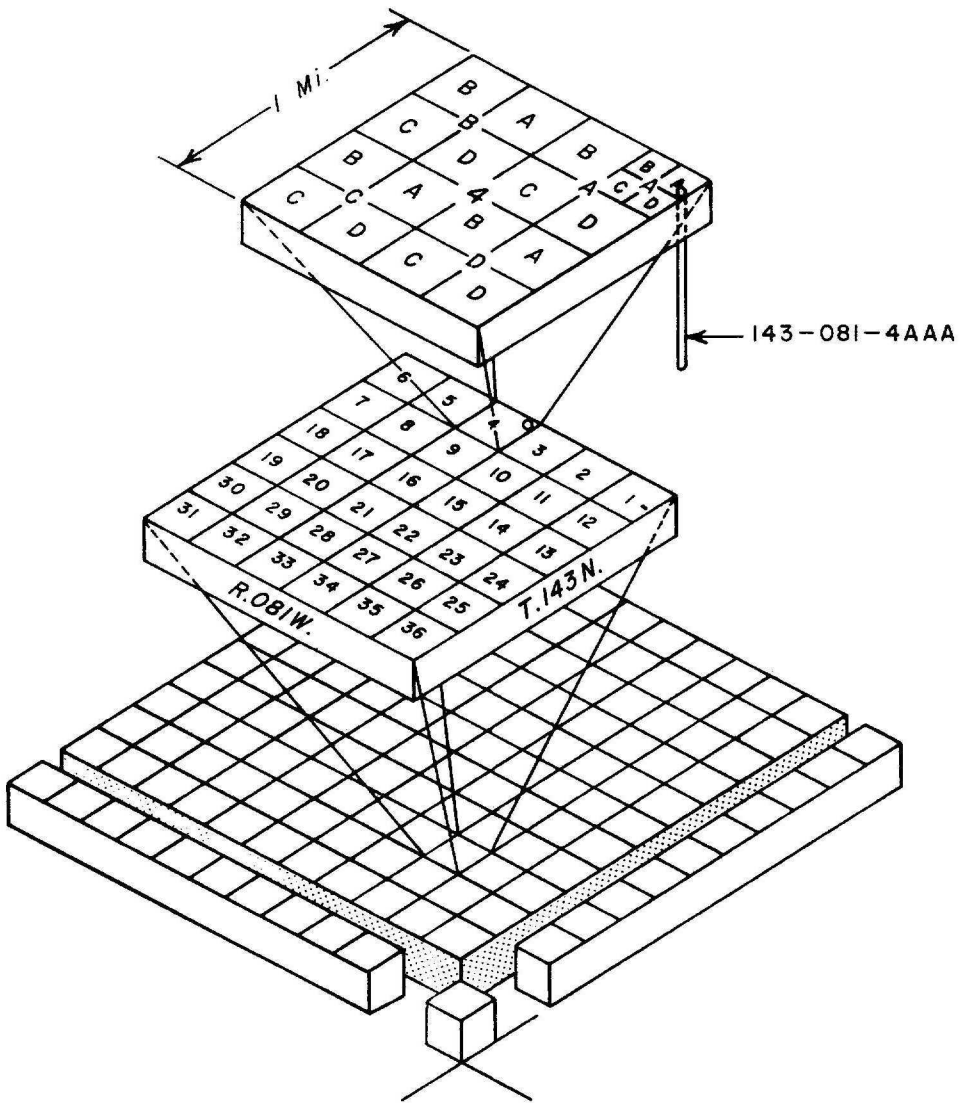

FIGURE 2.-Location Numbering System.

120 and 140 gallons per minute respectively. Rodney Peterson of the city of Wilton says both production wells are experiencing substantial water level declines and require the one week intervals to recover. Neither well can sustain the 200 gallons per minute needed to operate the treatment plant at capacity. The 120 to 140 gallons per minute presently produced cannot meet Wilton's peak demands during the summer months.

ACKNOWLEDGEMENTS

Special thanks are due Rodney Peterson and Merton Hansen of the city of Wilton for their assistance and information and to Joseph Denault, Tod DeMontigny, Kent Rood, and William Sawiki for permission to conduct exploratory drilling on their properties.

METHODS

The study was accomplished by means of: 1) test drilling, which includes the recording of lithologic logs and borehole geophysical logs, and observation well construction; 2) water sample collection and analysis; and 3) water level monitoring.

Test drilling was conducted on August 8 and November 1 through 15, 1985 and May 2 through June 6, 1986. Twenty–six locations were drilled totaling 6,956 feet (a map showing the locations of all test holes is found on plate 1). Twenty–one observation wells were constructed. Water samples were collected on December 4 and 5, 1985 and June 6 through 9, 1986. Water levels were measured December 1985 through January 1986 and June 13 through July 10, 1986.

Test drilling was accomplished by the forward mud–rotary method generally using a 4 3/4 inch bit. Lithologic logs are written records of the materials encountered by the drill and are based on samples obtained from the drilling mud. These are compiled by the geologist. Geophysical logs are graphs of the electrical properties of the materials penetrated by the bore hole. The lithologic and geophysical logs have been included in the appendix. Observation wells provide access to the water contained in the aquifer by means

of 1 1/4 inch diameter pvc pipe and 1 1/4 inch pvc well screen of various slot sizes. Water samples were obtained by air lifting the water from the wells with air lines inserted into the wells and connected to portable compressors. These samples are sent to the State Water Commission Laboratory for analysis. Results of the analyses are found in table 3. The significance of these results are found in table 4 in the appendix. Water levels are obtained by inserting a steel tape into the well and measuring depth to water. Continuous water level recorders were also installed on selected wells. Water level data is included with the test hole logs in the appendix.

HYDROGEOLOGY

The Lost Lake aquifer system is associated with a buried valley. The valley is filled with fluvial silt, sand, and gravel; lacustrine clay and silt; glacial till; and ice contact deposits. Southwest of the study area it intersects the Painted Woods Creek aquifer which both Klausing (1974) and Naplin (1979) considered to be hydraulically connected to it. Northeast of the study area it extends into Sheridan County.

Naplin (1979) interpreted the sediments of the Lost Lake aquifer to be continuous but interrupted by a large lens of silt and clay to the northeast. Additional drilling revealed that locally it is several units composed of coarse sediments interbedded in silt and clay and having a limited hydraulic connection.

This study identified five distinct aquifer units within the study area as follows: 1) a surficial unit, 2) a shallow confined unit in which production well #1 is completed, 3) a shallow confined unit in which production well #2 is completed, 4) an intermediate confined unit, and 5) a deep confined unit.

The surficial unit ranges from 5 to 40 feet thick (fig. 3). It is composed of very coarse sand and gravel up to one inch in diameter. Grains are rounded and composed of carbonates and silicates. At higher elevations it is unsaturated and oxidized. Portions of this deposit are confined by clay or till.

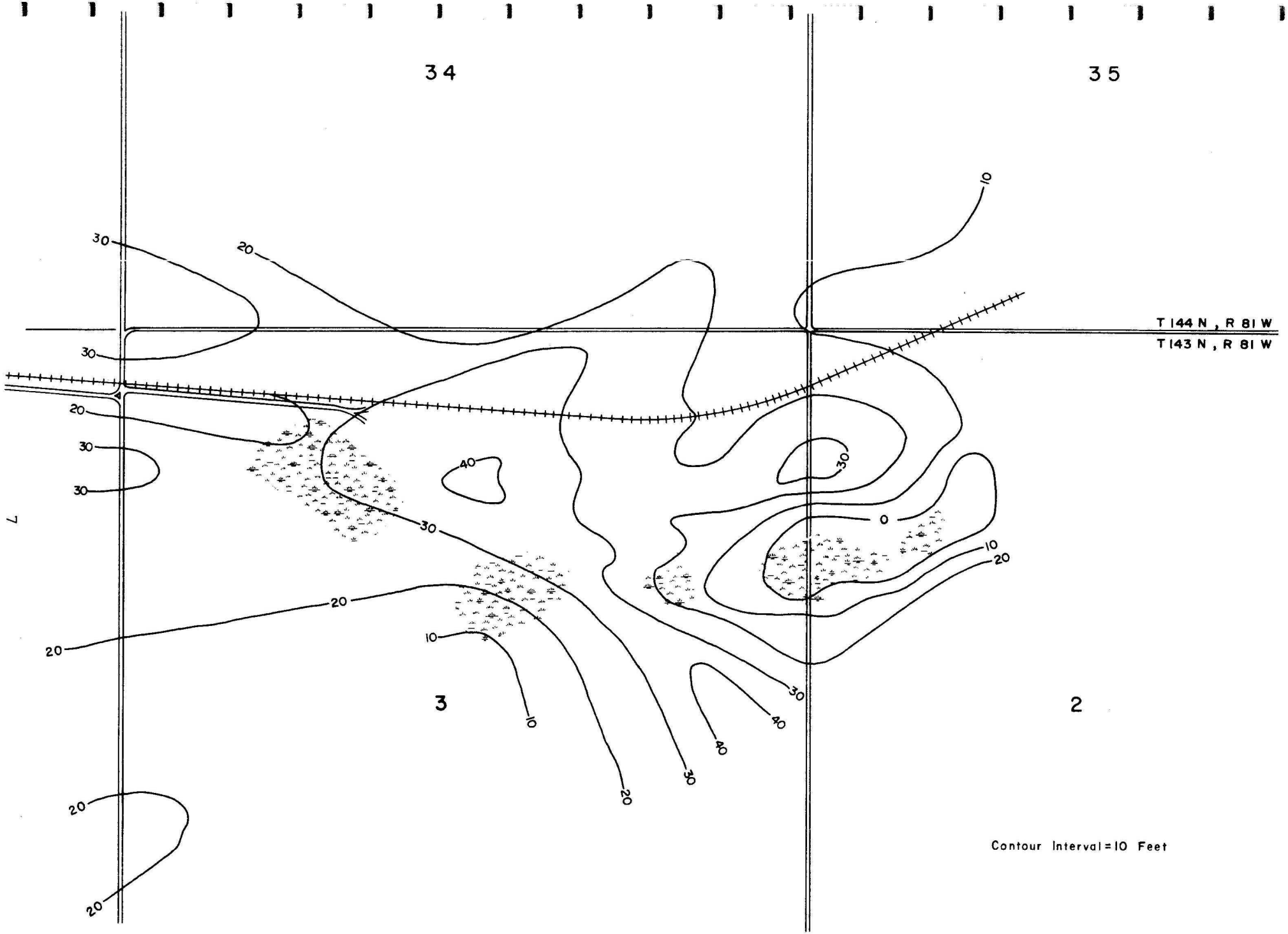

FIGURE 3 - Thickness of surficial aquifer.

These sediments may be collapsed outwash, being deposited on stagnant ice and then draped over the land surface as glacial ice melted out from under them (plate 2, unit A). This would account for the variability in thickness and its location on hills and slopes. The sediment may be discontinuous, resulting in isolated patches of limited areal extent. These isolated patches may not contain enough water to support development of a water supply.

The shallow confined unit in which production well #1 is completed ranges from 19 to 80 feet thick (fig. 4). Depth to the aquifer ranges from 7 to 27 feet. It is about 1,600 feet long and 800 feet wide.

It is composed of fine sand to coarse gravel with predominantly fine and medium sand. Grains are rounded and composed of quartz. The aquifer is isolated, being enclosed in silt and clay (plate 2, cross–section D–D' and H–H', unit B). This may imply an origin as an ice contact deposit left as the glacial ice melted.

The shallow confined unit in which production well #2 is completed ranges from 52 to 57 feet in thickness and is interbedded with silt and clay (plate 2, cross–section H–H', unit C). Depth to the aquifer ranges from 48 to 63 feet. It is about 500 feet long and 500 feet wide (fig. 5). It is composed of fine sand to coarse gravel with predominantly medium to very coarse sand. Grains are rounded and composed of carbonates with some silicates. It, too, is an isolated deposit enclosed in silt and clay which may imply an ice contact origin.

The intermediate confined aquifer is from 50 to 149 feet thick (fig. 6). Depth to the aquifer ranges from 98 to 177 feet. Within the study area it is about 6,600 feet long and 1,000 to 3,700 feet wide. It is composed of fine to very coarse sand with predominantly very coarse sand. Grains are rounded and composed of quartz. The sediments lie directly on bedrock and are enclosed in silt and sandy clay (plate 2, unit D). The origin of the deposit may be either fluvial or an asker deposited in a lacustrine environment as suggested by its sinuous nature and the adjacent silt and clay.

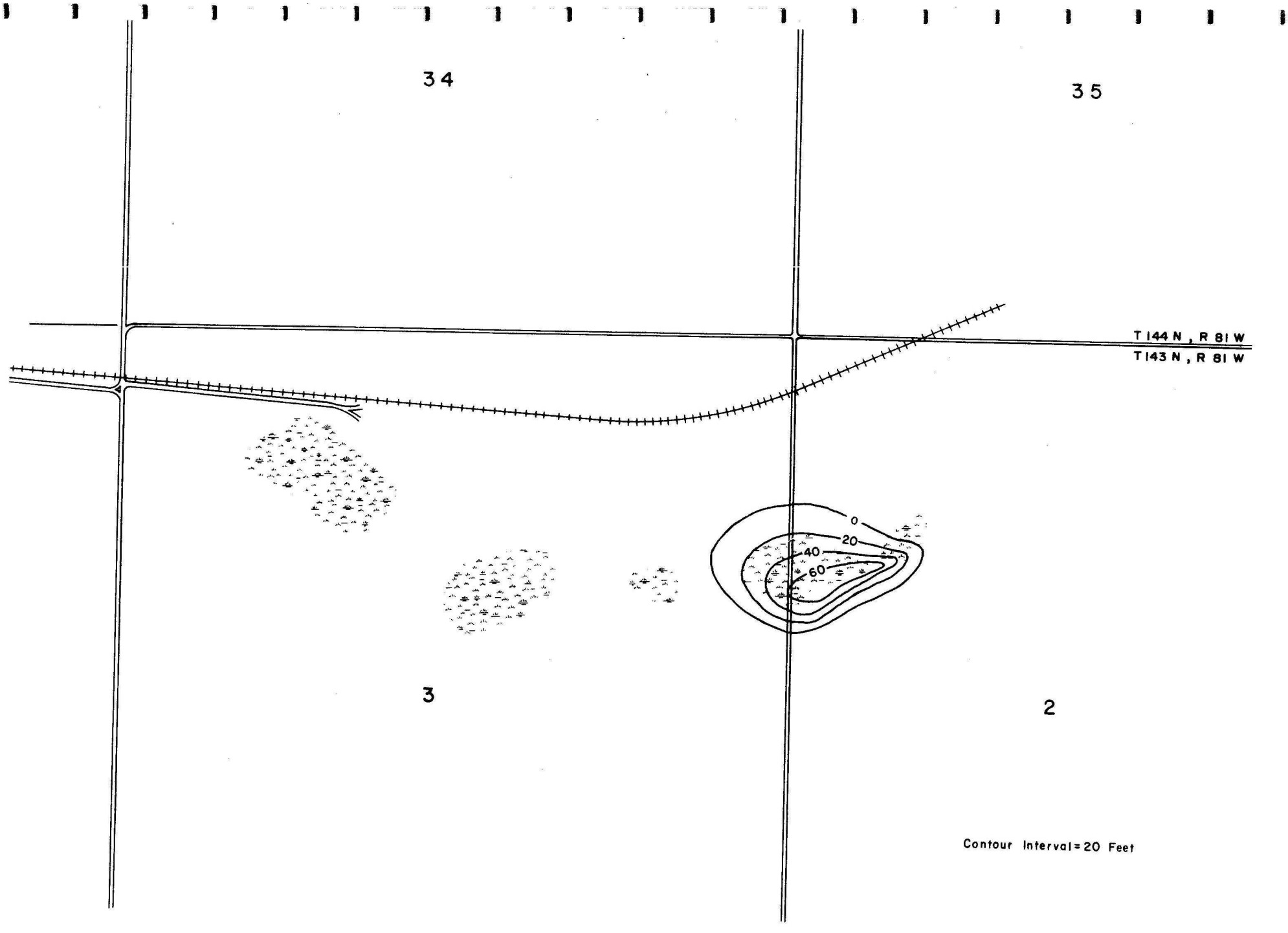

FIGURE 4 -Thickness of shallow confined aquifer 1.

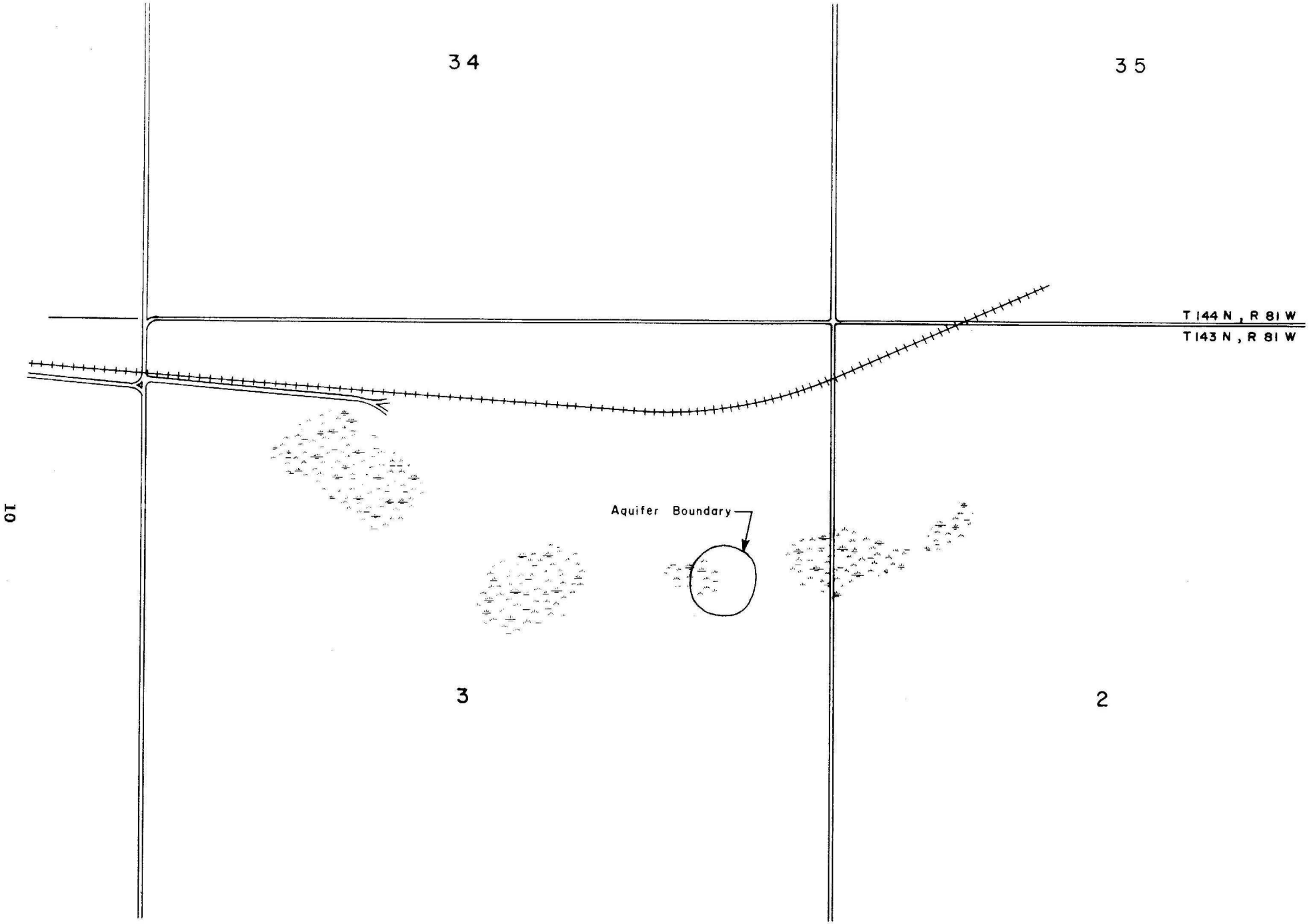

FIGURE 5 - Boundary of shallow confined aquifer 2.

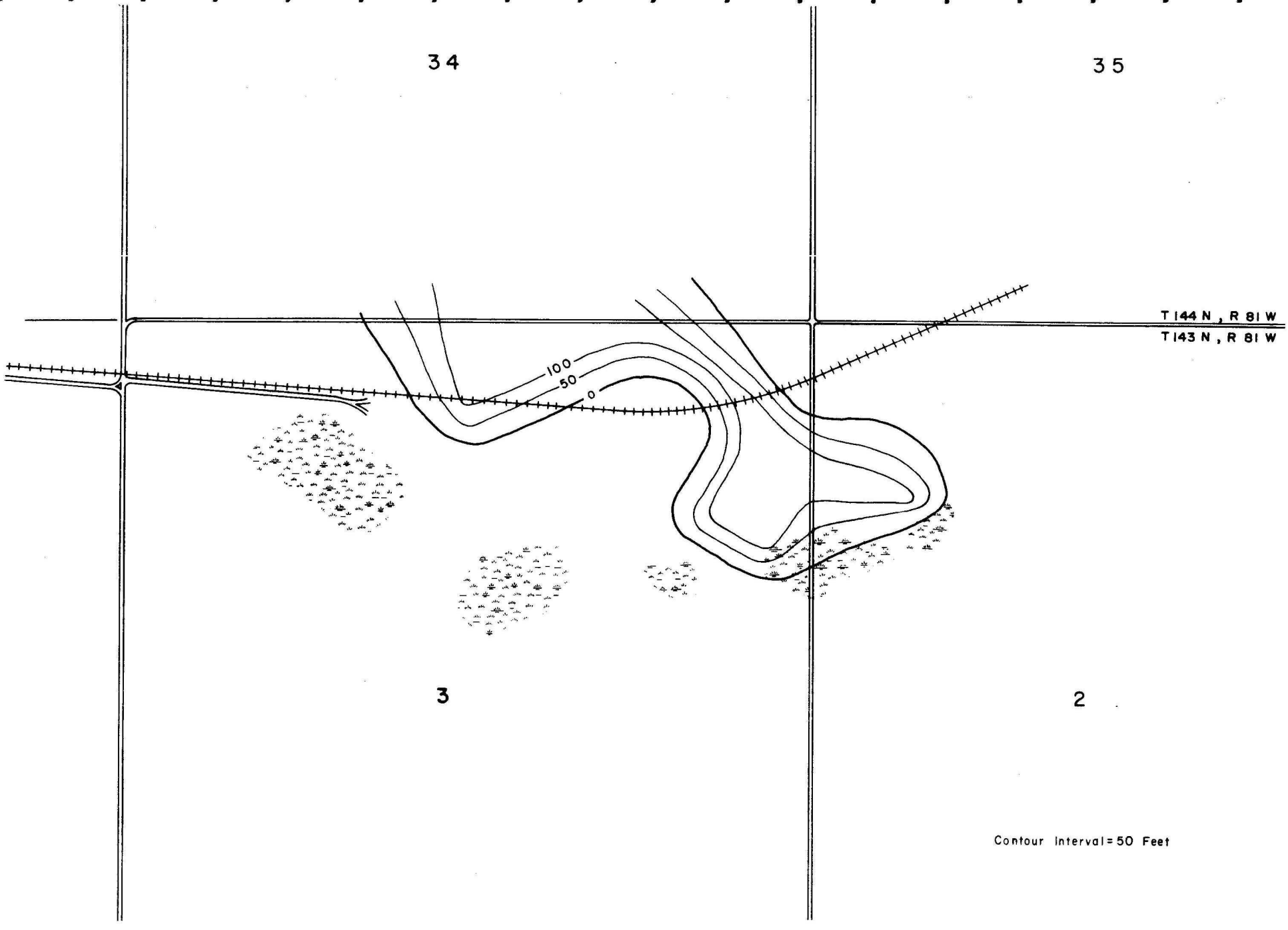

FIGURE 6 - Thickness of intermediate confined aquifer.

The deep confined aquifer occupies the deepest part of the buried valley where it is incised into bedrock and overlain by silt and clay (plate 2, unit E). It is not continuous along the long axis of the valley but has been truncated by low permeability sediments, effectively dividing it into two separate sections (fig. 7). Thickness ranges from 9 to 42 feet. The eastern portion is about 3,400 feet long and 400 feet wide. The western portion is about 2,300 feet long and 1,500 feet wide. It is composed of very coarse sand and coarse gravel with predominantly medium to coarse gravel. Grains are angular to rounded and composed predominantly of carbonates with some detrital lignite and silicates. The probable origin of the deposit is a preglacial fluvial sediment as suggested by the lack of shield silicates.

WATER LEVELS

One observation well is completed in the surficial aquifer. Observation well 11738 has a water level elevation of 1,685.41 feet. Depth to water is 7.18 feet and the aquifer has a saturated thickness of 29 feet.

Four observation wells are completed in the shallow confined aquifer in which production well #1 is completed. Observation well 3898 was completed in 1973 before the production well was constructed. On October 29, 1973 the water level elevation was 1,697.7 feet. On January 16, 1986 the water level elevation was 1,687.41 feet. This is a decline of about 10 feet.

Water level elevations range from 1,688.11 feet in the east to 1,687.17 feet near the production well on January 20, 1986. Gradients are toward the production well at about .3 feet per mile from the west to about 9.2 feet per mile from the east (fig. 8).

There is also an upward vertical gradient. Observation well 11731 is screened from 60 to 65 feet and has a water level elevation of 1,688.11 feet. Observation well 3898 is screened from 31 to 34 feet and has a water level elevation of 1,687.17 feet.

Production well #1 was pumped for 20 hours at 120 gallons per minute on January

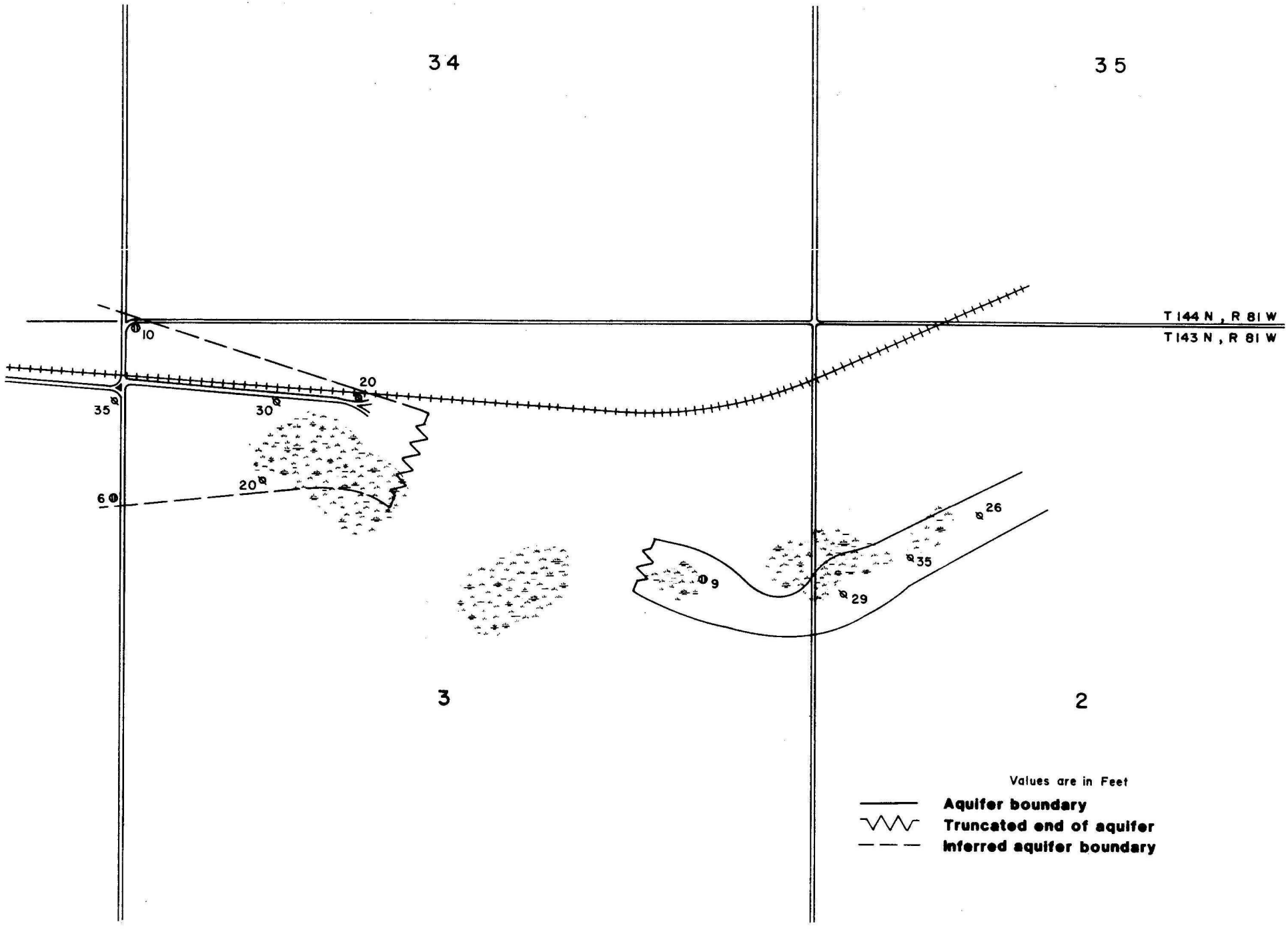

FIGURE 7 - Boundary and thickness values of deep confined aquifer.

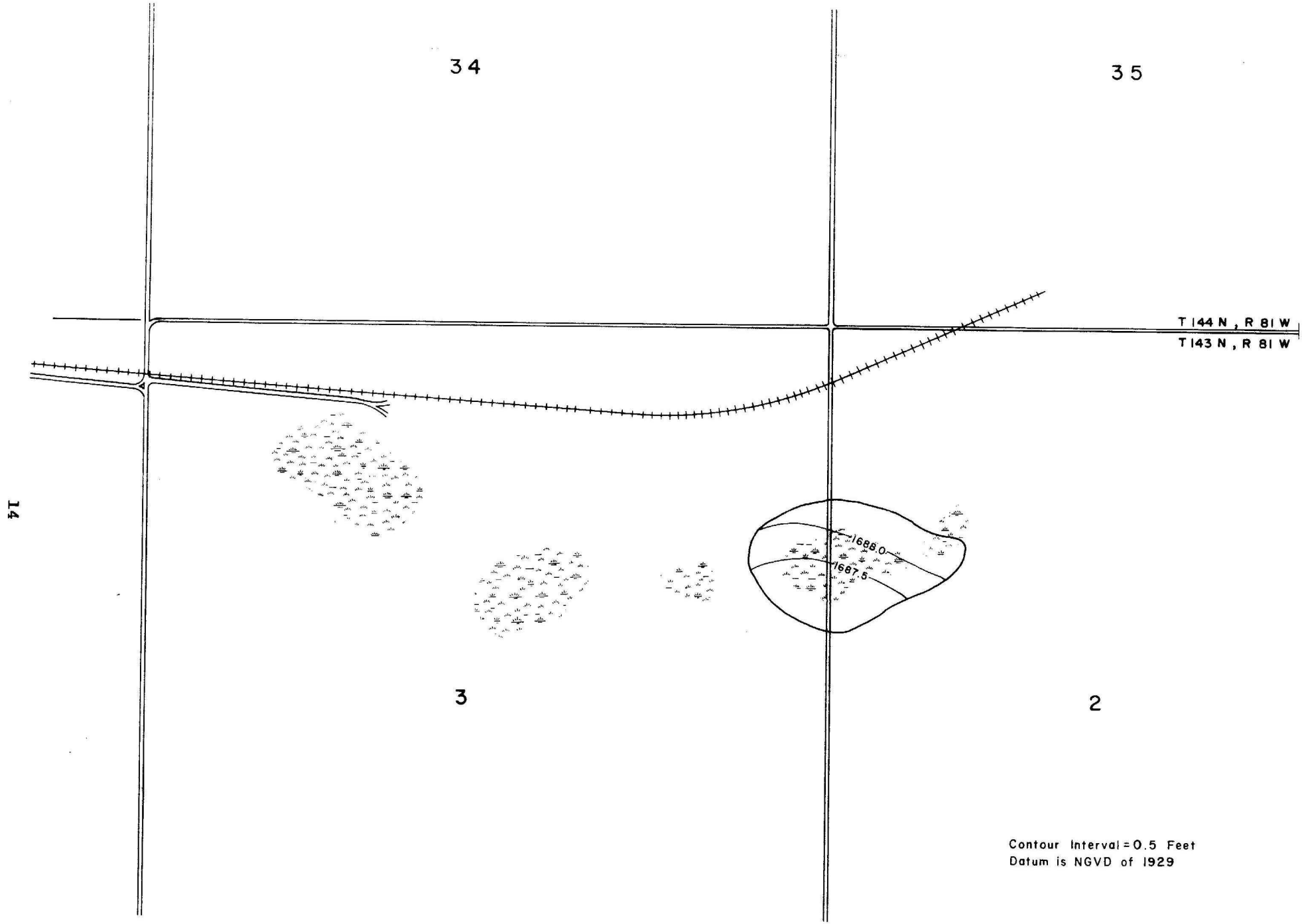

FIGURE 8 – Potentiometric surface of shallow confined aquifer.

20, 1986. On January 21, 1986 all observation wells were measured to determine which water levels had responded to the pumping. The water level in the production well was also measured to determine the amount of drawdown it is experiencing and how well it recovers. Water levels in observation wells 3898, 11722, 11615, 11731, and 8949 responded to the pumping.

Table 1 displays the declines of water levels observed at each well. On January 22, 1986 the water level in city well 1 had recovered 11.5 feet.

Table 1. – Water Level Declines After 20 Hours Pumping of City Well 1

Well	Distance from Production Well (ft.)	Decline (ft)
11615	740	0.10
11731	470	0.30
8949	2000	0.32
11722	540	0.41
3898	140	1.80
City well 1		12.43

One observation well is completed in the shallow confined unit in which production well #2 is completed. On November 14, 1973 the water level elevation was 1693.49 feet. On November 9, 1985 the water level elevation was 1654.41 feet. This is a decline of about 39 feet.

Production well #2 was also pumped for 20 hours at 140 gallons per minute on March 4, 1986. Water levels were measured on March 5, 1986. The water level in well 8950 was the only one affected though its response was obscured by barometric pressure changes and snow melt.

There are seven observation wells completed in the intermediate confined aquifer. Water level elevations on April 10, 1986 ranged from 1660.73 feet at 11729 to 1658.74 feet

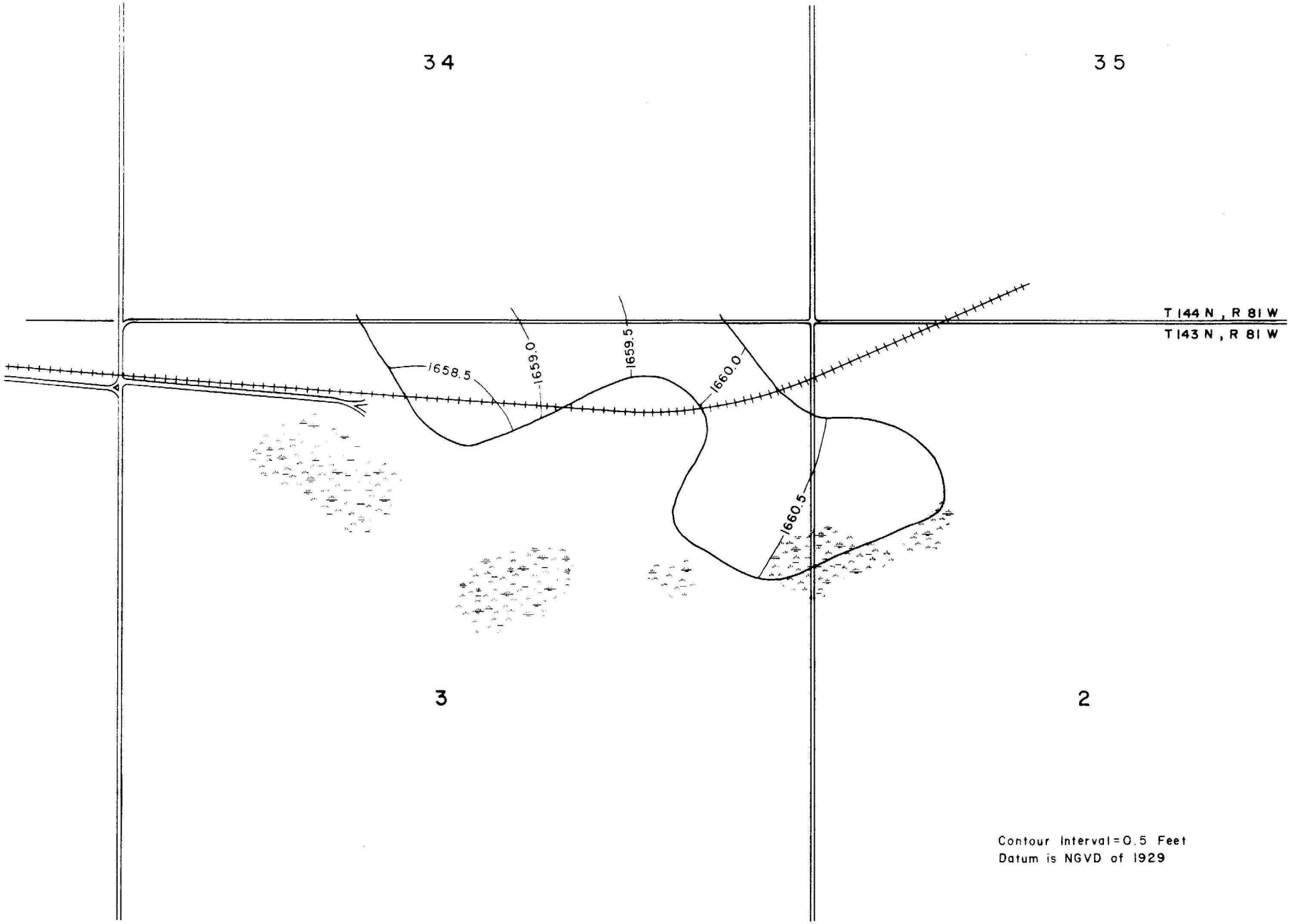

FIGURE 9 - Potentiometric surface of intermediate confined aquifer.

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6   245 10   Hydrogeology of the Lost Lake Aquifer in the Wilton-Washburn
  area, McLean County, North Dakota / ǂc by Allen E. Comeskey.
7   260      Bismarck, N.D. (900 East Boulevard, Bismarck 58505) : ǂb North
  Dakota State Water Commission, ǂc 1988.
8   300      iv, 62 p. : ǂb ill., maps ; ǂc 28 cm.
9   440  0   North Dakota ground-water studies, ǂv no. 93
10  500      1 map & 1 chart folded leaves in ǂe pocket.
11  504      Includes bibliographical references (p. 25).
12  590      DOES NOT CIRCULATE.  MATERIAL MUST BE USED AT THE NORTH DAKOTA
  STATE WATER COMMISSION TECHNICAL REFERENCE LIBRARY.  REQUESTS FOR
  PHOTOCOPIES WILL BE ACCEPTED BY THE NORTH DAKOTA STATE LIBRARY.
13  650  0   Hydrogeology ǂz North Dakota ǂz McLean County
14  650  0   Groundwater ǂz North Dakota ǂz McLean County.
15  710 1    North Dakota State Water Conservation Commission.
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at 8939. The gradient is towards the west at about 2.9 feet per mile (fig. 9).

At location 143–081–02BBCB observation wells 11732 and 11733 are screened from 225 to 230 feet and 158 to 163 feet, respectively. On January 22, 1986 the water level elevations were 1,660.63 feet and 1,660.55 feet respectively indicating a slight upward vertical gradient.

The United States Geological Survey has been monitoring the water level in observation well 8939 since 1978. Water level elevations have naturally fluctuated from about 1,660.5 feet to 1,663 feet (fig. 10). These fluctuations do not appear to be related to the amount of precipitation received in the area (fig. 11).

The Painted Woods Golf Club in Washburn has its irrigation well completed in this aquifer at 143–081–03BAAD. This well was constructed in 1983 and was used during the 1984 and 1985 seasons. In 1984 the golf course pumped 50.1 acre–feet and in 1985 it pumped 36.3 acre–feet at a rate of 300 gallons per minute. Effects of the pumping are reflected in the water levels in observation well 8939 (143–081–03BAA, fig. 10). Water levels declined about 3.5 feet during the 1984 pumping season and recovered to the pre–pumping level. Water levels declined about 5.5 feet during the 1985 pumping season. Recovery is not as complete as from the 1984 season resulting in a deficit of about 1.5 feet. It appears that the effects of the pumping are superimposed on a natural trend of declining water levels. Since there are about 122 feet of available drawdown, the maximum water level decline represents only 4.5% of what is available.

Continuous water level recorders were installed on observation wells 8939, 11770, 11739, 11732, and 11733 from June 13 through 20 and July 2 through 10, 1986. The extent and degree of the impact of the pumping of the golf course irrigation well was observed through the aquifer and surrounding sediments. Table 2 presents representative declines of water levels during pumping at various distances from the irrigation well.

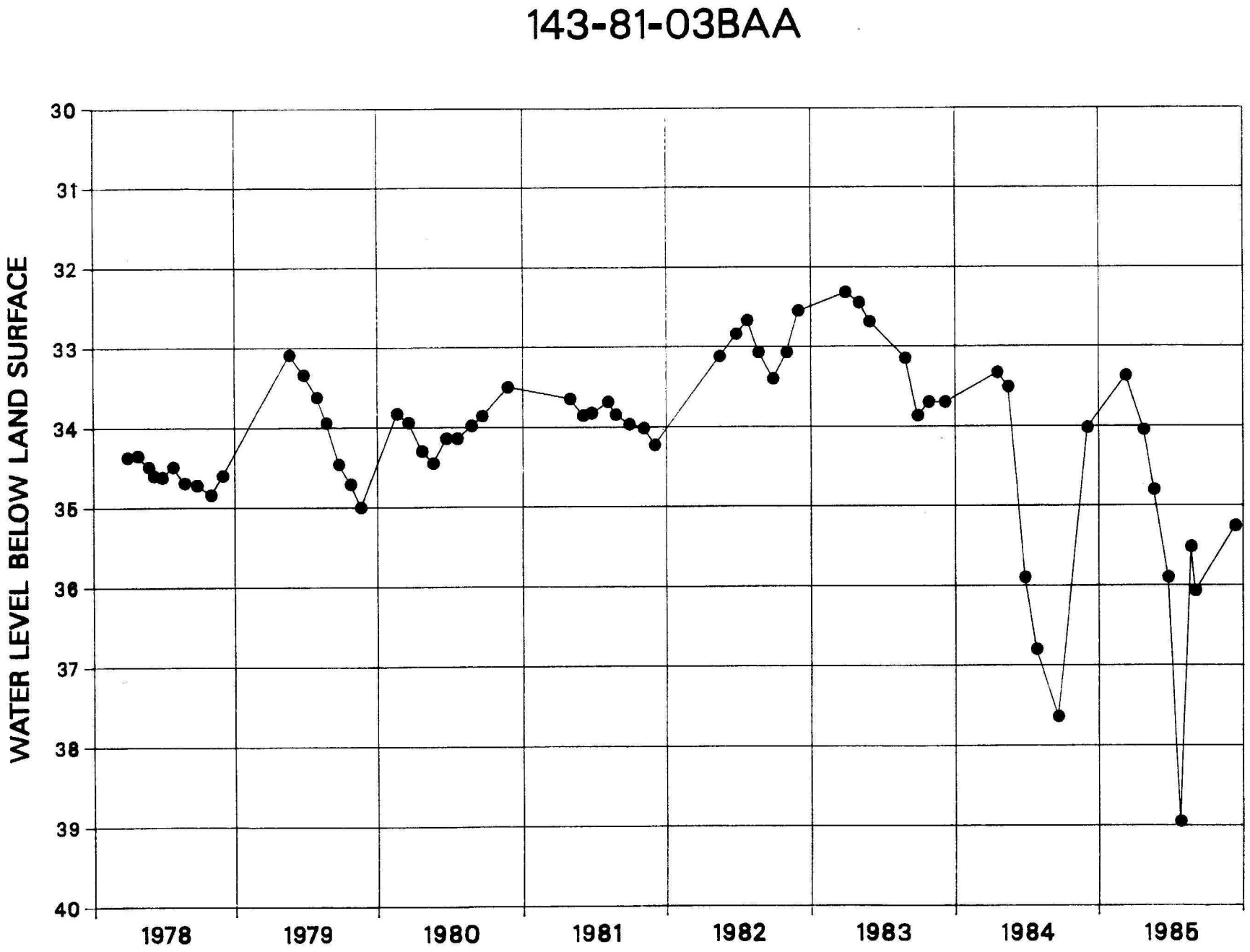

FIGURE 10 - Water level fluctuations at 143-081-03BAA

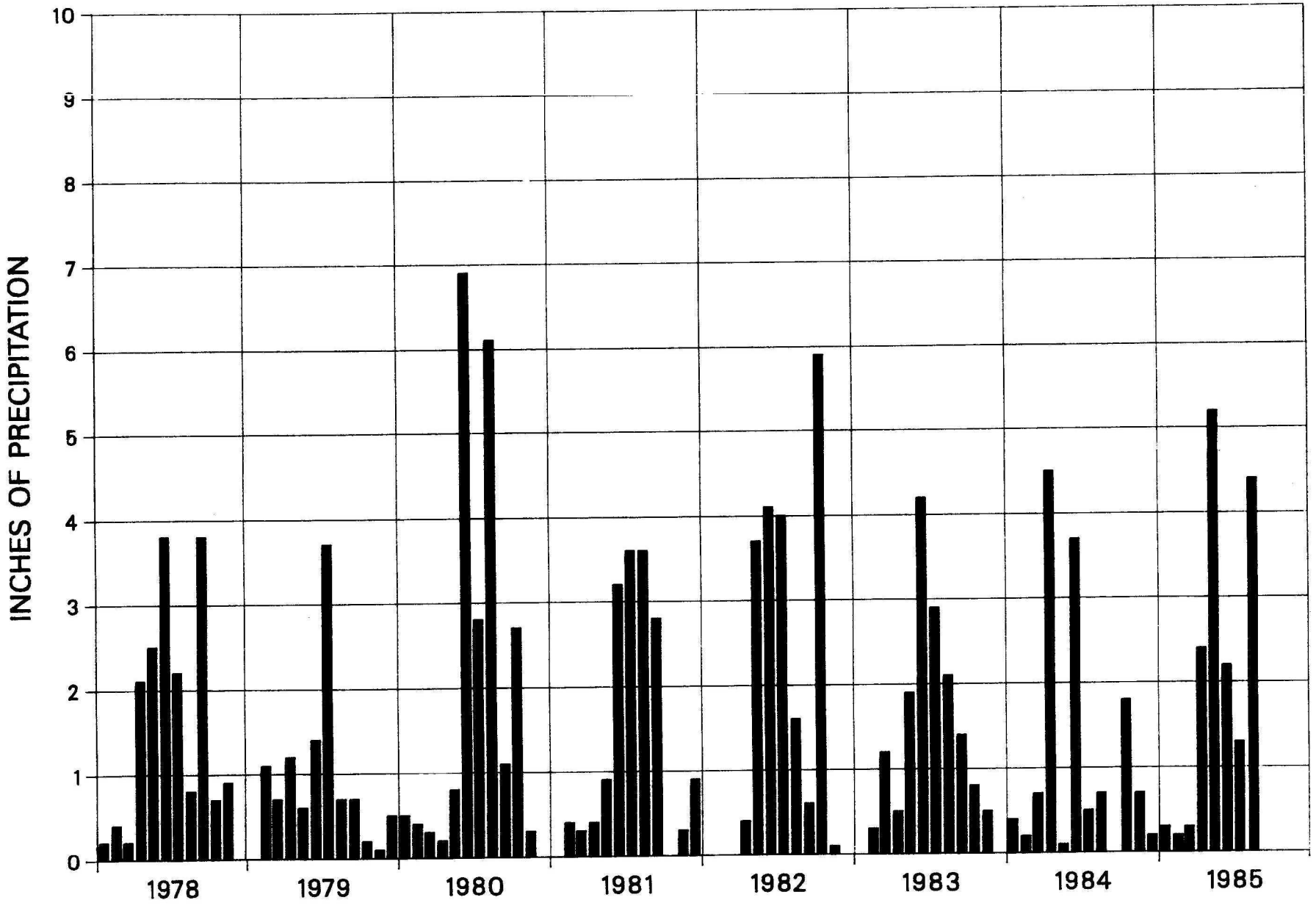

FIGURE 11 - Precipitation at Wilton

Table 2. – Drawdown in Intermediate Confined Aquifer
During Pumping of Painted Woods Golf Course Irrigation Well

Pumping Period	Well	distance from prod. well (ft.)	Drawdown (ft.)
June 16 through 18	8939	600	3.2
	11770	1500	2.1
	11769	800	2.8
July 5 through 9	8939	600	3.4
	11733	2800	1.6

Water level declines due to pumping of the irrigation well were less than anticipated, possibly indicating leakage from the surrounding sediments. Table 2 also compares the water level changes in well 11769 with changes in 8939. Well 11769 is completed in the silty and sandy clays that envelope the intermediate confined aquifer. A continuous record water level recorder was also installed on 11769 to detect effects from pumping of the irrigation well. Even though the coarse sediments that comprise the intermediate confined aquifer are of limited areal extent, water available for withdrawal will be supplemented by leakage from the surrounding sediments.

Water level elevations are noted beside the observation wells completed in the deep confined aquifer on figure 12. Water level elevations of the eastern portion range from 1708.85 to 1706.22 feet. The gradient is roughly to the west at about 11.4 feet per mile. Water level elevations of the western portion range from 1668.2 to 1658.1 feet. The gradient is roughly to the west or northwest at about 12.8 feet per mile. There is about a 38 foot difference between water level elevations of the two sections of aquifer.

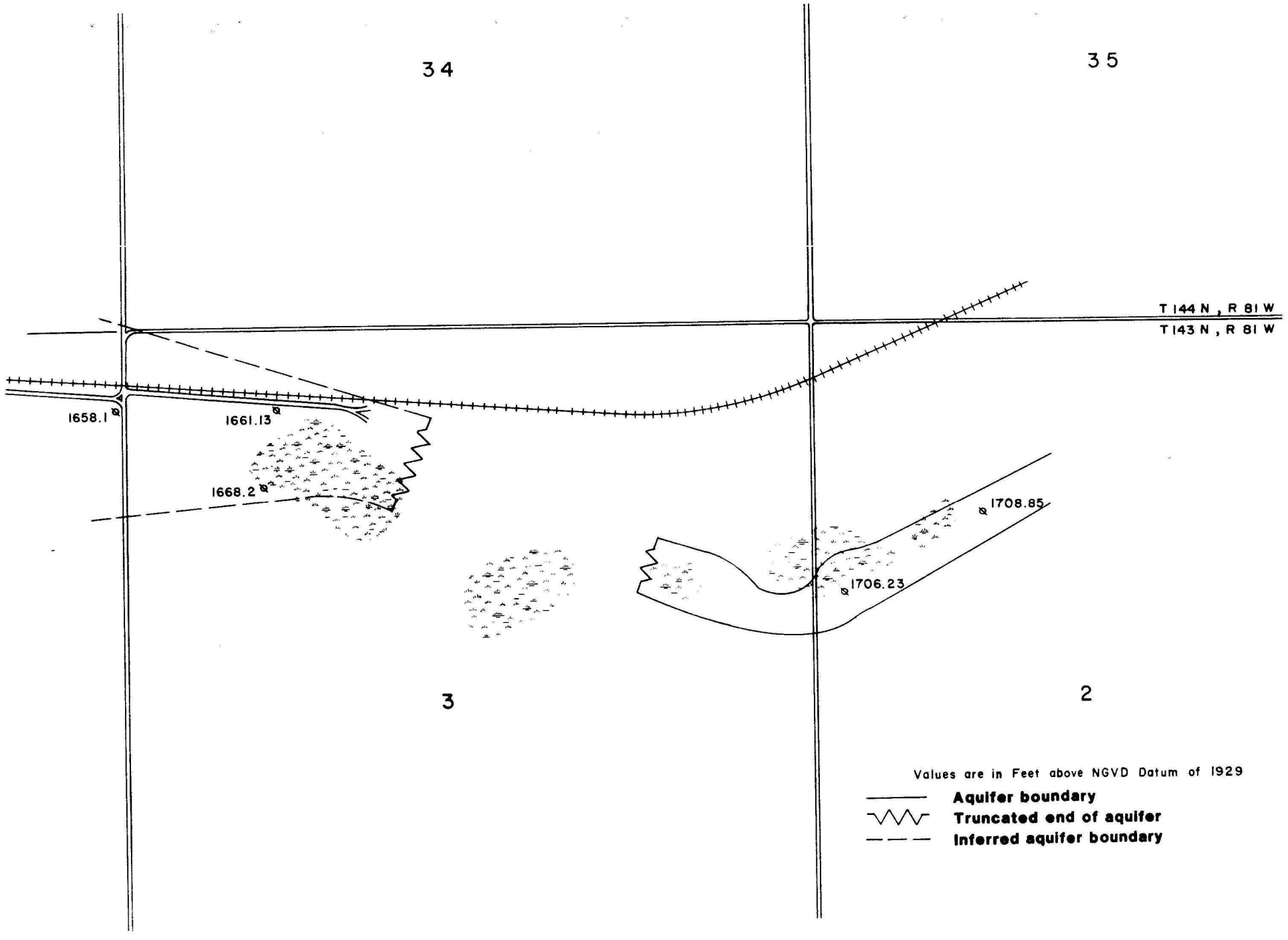

FIGURE 12 - Water levels of deep confined aquifer.

WATER QUALITY

Water of the surficial aquifer as represented by a sample from well 11738 is sodium bicarbonate type. Total dissolved solids are 742 milligrams per liter (table 3). Hardness is 380 milligrams per liter. There are also isolated near surface sand units. Observation well 11725 is completed in one of these. A sample from this well contains 1,950 milligrams per liter total dissolved solids. The isolated nature is a major factor resulting in the more mineralized water. It is likely that other isolated deposits would contain water of similar quality.

Water of the shallow confined aquifer in which production well #1 is completed ranges from a calcium to sodium bicarbonate type. Total dissolved solids range from 367 to 1,220 milligrams per liter. Hardness ranges from 280 to 350 milligrams per liter.

Water quality is vertically stratified. Water derived directly from precipitation forms a layer above more mineralized water found at depth. Within 40 feet of the surface the water is a calcium bicarbonate type. Total dissolved solids are 381 milligrams per liter. At 60 feet the water is a sodium bicarbonate type. Total dissolved solids are 1,220 milligrams per liter. Production well #1 is screened from 25 to 35 feet and 50 to 55 feet. Water from the production well appears to be a blend of the two types of water and the concentration of total dissolved solids is 700 milligrams per liter.

Water from the shallow confined aquifer in which production well #2 is completed is a calcium bicarbonate type. Total dissolved solids range from 593 to 796 milligrams per liter. Hardness ranges from 310 to 340 milligrams per liter.

Water quality in the intermediate confined aquifer is a sodium bicarbonate type. Total dissolved solids range from 821 to 1,310 milligrams per liter. Hardness ranges from 67 to 370 milligrams per liter.

Water quality within the intermediate confined aquifer is variable both vertically and laterally. Observation wells 11732 and 11733 are screened from 225 to 230 feet and 158 to 163 feet respectively at location 143–081–02BBCB. Total dissolved solids were 1,310

and 1,210 milligrams per liter respectively. The greatest concentration of dissolved solids is encountered at 143–081–02BBCB from well 11732. The lowest concentration of dissolved solids was encountered at 143–081–03BAA at 821 milligrams per liter from well 8939.

Water from the deep confined aquifer is a sodium bicarbonate type. Total dissolved solids range from 781 to 1,300 milligrams per liter. Hardness ranges from 144 to 340 milligrams per liter. Water quality is generally better in the western portion of the aquifer.

PRODUCTION WELL #3

Based on the findings of this study, Production well #3 was located at 143–081–03ABB. It was drilled and constructed from October 2 to 19, 1987. After completion, a 24 hour pump test was conducted from October 20 to 21.

The well is 212 feet deep. It is constructed of 165 feet of 12.75 inch O.D. steel casing weighing 49.56 pounds per lineal foot. Fifty feet of 11 inch O.D. #24 slot, stainless steel wire wrap screen is welded to the bottom of the casing. The screened interval is from 162 to 212 feet below land surface. The screen was sand packed with sand and backfilled to 76 feet below land surface with unsorted gravel. Development consisted of airlifting and jetting. Following development, grout was emplaced from 50 to 76 feet, isolating the surficial aquifer from the intermediate confined aquifer. It was then backfilled to surface with gravel.

PUMP TEST

A 24 hour pump test was conducted for well #3 on October 20 and 21, 1987. The well was pumped at about 317 gallons per minute. Drawdown and recovery were recorded for the production well and continuous record water level recorders were installed on observation wells 11771 and 11733. After 24 hours 97.35 feet of drawdown were recorded. The specific capacity is 3.3 gallons per minute per foot of drawdown. The transmissivity is

calculated from the production well data at 3,086 ft^2/day.

SUMMARY AND CONCLUSIONS

The Lost Lake aquifer system occupies a buried valley that trends northeast from the Missouri River south of Washburn, through southeastern McLean County into Sheridan County. Sediments filling the buried valley are composed of fluvial silt, sand, and gravel; lacustrine clay and silt; glacial till; and ice contact deposits. Five aquifer units were identified within these sediments. They are as follows: 1) a surficial unit, 2) two shallow confined units, 3) an intermediate confined unit, and 4) a deep confined unit.

Wilton's present production wells are completed in the two shallow confined units. These will not support any further development due to their limited area extent. Remaining units have characteristics both favorable and unfavorable to development of a municipal supply. The surficial unit, though possessing superior quality water, may be too discontinuous to provide adequate quantity. The deep unit, though possessing adequate quantity, was lacking acceptable quality water. The intermediate confined unit has water with quality compatible with the needs of the city and has the areal extent and saturated thickness to support the development of a municipal supply.

Water quality within the intermediate confined unit varies both laterally and vertically, the lower dissolved solids occurring in the vicinity of 143–081–03BAA, and generally lower dissolved solids occurring near the top of the aquifer. The Painted Woods Golf Course irrigation well is located at 143–081–03BAAD and water levels will decline in its vicinity when being pumped. Siting a production well will be a compromise between utilizing the better quality water found in the vicinity of 143–081–03BAA and minimizing interference from pumping of the irrigation well. By screening only the upper portion of the aquifer, thus reducing the available drawdown to the top of the screen, the additional water level decline caused by pumping of the irrigation well will be more significant and should be considered.

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APPENDIX

TEST HOLE LOGS

Grain size determination is based on the Wentworth (1922) size scale. Color description is based on the Geological Society of America (1963) rock color chart. Geophysical logs are single point resistance.

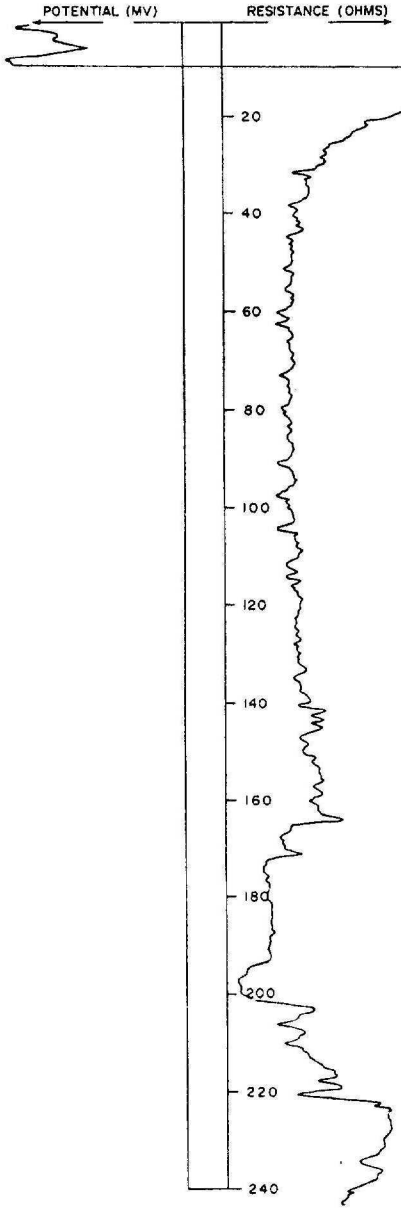
TEST HOLE 11723

LOCATION: 143-81-02BACB

DATE DRILLED: 11/4/65

ELEVATION: approx. 1710 (FT, MSL)

DEPTH: 240 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 -11 Sand and gravel, coarse sand to gravel ¼" dia., predom. very coarse sand, oxid.

11-150 Silt, clayey, oxid. to 15' (fluvial)

150-169 Sand, fine, very clayey

169-195 Clay, olive gray, silty, sandy, a few pebbles (till)

Hell Creek Formation

195-240 Sandstone, very fine grain, interbedded with claystone and lignite

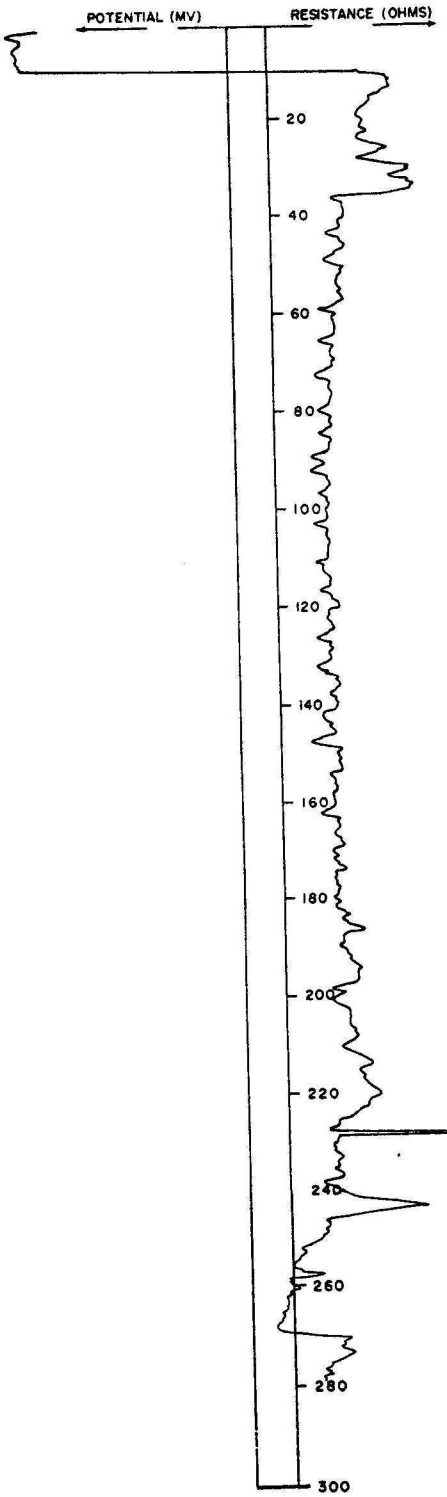
TEST HOLE 11724

LOCATION: 143-81-02BACC$_1$

DATE DRILLED: 11/4/85

ELEVATION: (FT, MSL) approx. 1702

DEPTH: (FT) 280



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 15 Clay, slightly silty, oxid. to 9' (lacustrine)

15 - 22 Silt, brown to black, carbonaceous, slightly clayey

22 - 35 Sand and gravel, coarse sand to gravel ¼" dia., predom. very coarse sand, subrounded to rounded

35 -207 Silt, slightly clayey, oxid. to 48', below 170' some interbedded fine sand

207-242 Sand, very fine grain, clayey

242-244 Gravel

244-251 Clay, olive gray, silty, sandy, pebbly (till)

Hell Creek Formation

251-280 Claystone, brownish gray, tight, interbedded lignite

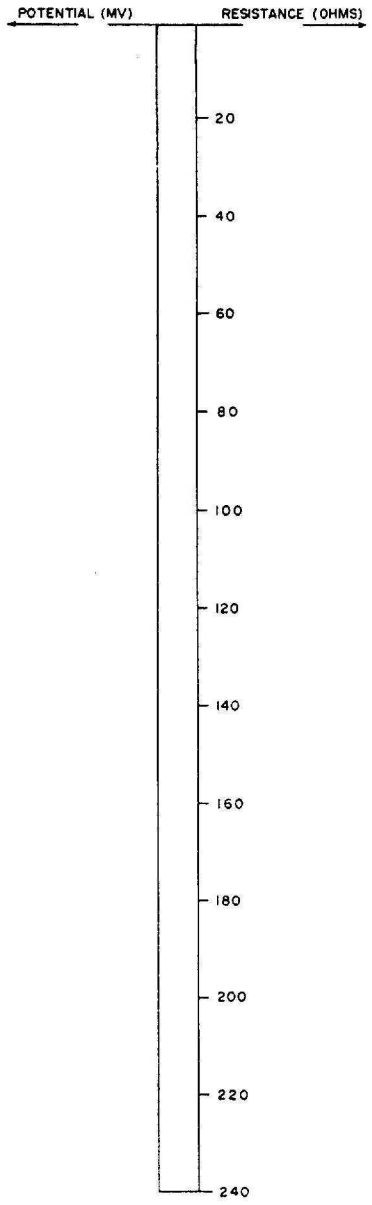
TEST HOLE 11725

LOCATION: 143-81-02BACC$_2$

DATE DRILLED: 11/4/85

ELEVATION (FT, MSL): 1702.6

DEPTH (FT): 43



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 16 Clay, black to gray

16 - 22 Silt, brown, clayey, slightly carbonaceous

22 - 40 Sand and gravel, coarse sand to gravel 1" dia., predom. very coarse sand and fine gravel, subrounded to rounded

40 - 43 Silt, yellow brown, slightly clayey

Observation Well

Depth: 40'
S.I.: 35'- 40'

Water Level

12/4/85	8.45
1/16/86	8.58
1/20/86	8/57
1/21/86	8.59
1/22/86	8.58
2/18/86	8.61
2/20/86	8.63
3/4/86	8.41
3/5/86	8.39
4/10/86	7.6
4/22/86	7.36

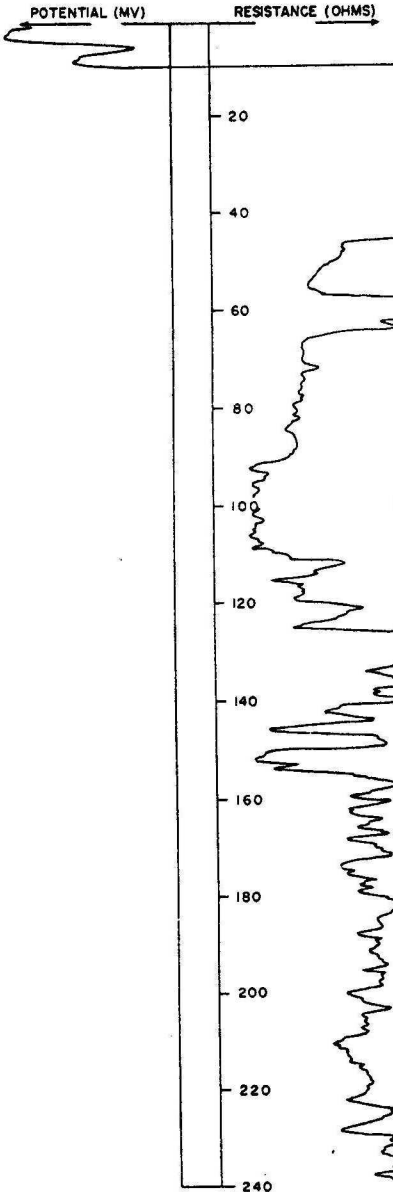
TEST HOLE 11732

LOCATION: 143-81-02BBCB$_1$

DATE DRILLED: 11/6/85

ELEVATION: 1731.9 (FT, MSL)

DEPTH: 236 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 4 Sand, coarse, oxid.

4 - 8 Silt, dark yellowish orange, clayey, oxid.

8 -14 Sand, coarse sand to fine gravel, predom. very coarse sand

14 -20 Silt, yellowish orange, oxid.

20 -32 Sand, fine grading to coarse by 30'

32 -47 Gravel, coarse sand to gravel 1" dia., predom. gravel ¼"-½" dia., rounded, oxid.

47-100 Clay, olive gray, silty, sandy, gravelly (till)

100-124 Clay, olive gray (lacustrine)

124-234 Sand, fine to med., rounded, grading to coarse sand by 200' some interbedded clay

Hell Creek Formation

234-236 Claystone, brown, tight, waxy

Observation Well

Depth: 230'

S.I.: 225'-230'

Water Level

12/4/85	71.78
1/16/86	71.10
1/20/86	71.12
1/21/86	71.22
1/22/86	71.27
2/18/86	71.12
2/20/86	71.11
3/4/86	70.93
3/5/86	71.00
4/10/86	71.39
7/2/86	73.22

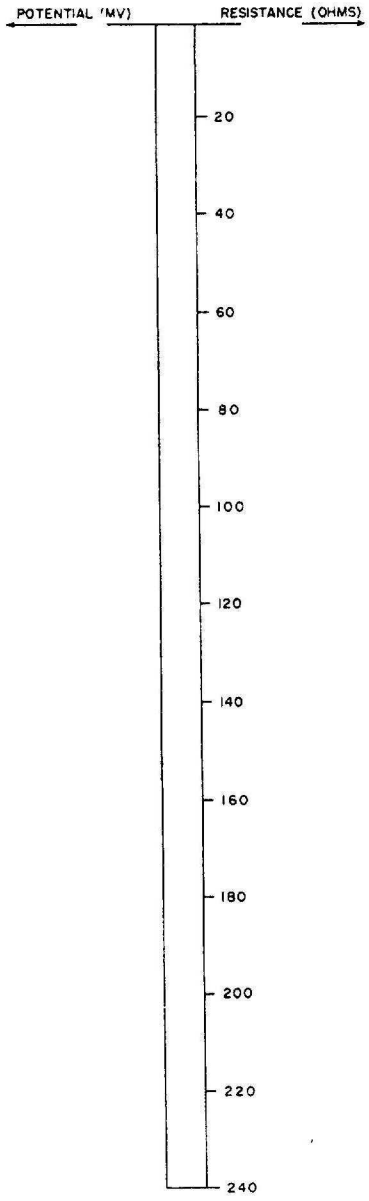
TEST HOLE 11733

LOCATION: 143-81-02BBCB$_2$

DATE DRILLED: 11/6/85

ELEVATION: 1732.4
(FT, MSL)

DEPTH: 165
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 10 Clay, dark yellowish orange, silty, oxid.

10 - 32 Sand, fine to coarse

32 - 40 Gravel, coarse sand to 1" dia. predom. ¼" dia., rounded, oxid.

40 - 46 Sand, coarse, oxid. to 44'

46 - 61 Clay, olive gray, silty, pebbly (till)

61 - 66 Gravel

66 -101 Clay, olive gray, silty, pebbly (till)

101-125 Clay, olive gray, silty

125-165 Sand, fine to coarse, predom. medium, rounded, interbedded clay to 153'

Observation Well

Depth: 163'
S.I.: 158'- 163'

Water Level

12/5/85	72.94
1/16/86	71.67
1/20/86	71.70
1/20.86	71.82
1/22/86	71.85
2/18/86	71.68
2/20/86	71.79
3/4/86	71.56
3/5/86	71.60
4/10/86	71.98
6/3/86	74.40
6/19/86	74.97
7/2/86	73.84
7/2/86	73.81
7/3/86	73.63
7/10/86	74.65

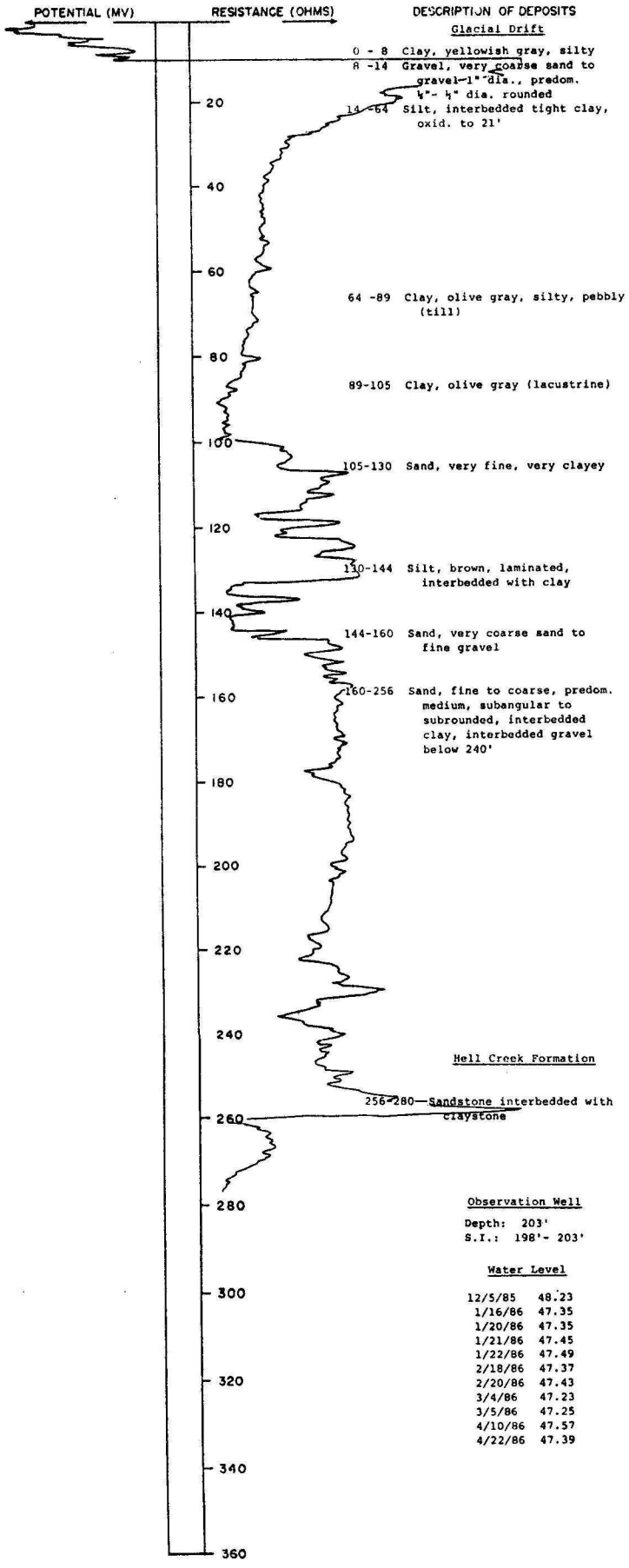
TEST HOLE 11727

LOCATION: 143-81-02BCAB

DATE DRILLED: 11/4/85

ELEVATION: 1708.3 (FT, MSL)

DEPTH: 280 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 8 Clay, yellowish gray, silty

8 -14 Gravel, very coarse sand to gravel-1" dia., predom. ¼"- ¼" dia. rounded

14 -64 Silt, interbedded tight clay, oxid. to 21'

64 -89 Clay, olive gray, silty, pebbly (till)

89-105 Clay, olive gray (lacustrine)

105-130 Sand, very fine, very clayey

130-144 Silt, brown, laminated, interbedded with clay

144-160 Sand, very coarse sand to fine gravel

160-256 Sand, fine to coarse, predom. medium, subangular to subrounded, interbedded clay, interbedded gravel below 240'

Hell Creek Formation

256-280 Sandstone interbedded with claystone

Observation Well

Depth: 203'
S.I.: 198'- 203'

Water Level

12/5/85	48.23
1/16/86	47.35
1/20/86	47.35
1/21/86	47.45
1/22/86	47.49
2/18/86	47.37
2/20/86	47.43
3/4/86	47.23
3/5/86	47.25
4/10/86	47.57
4/22/86	47.39

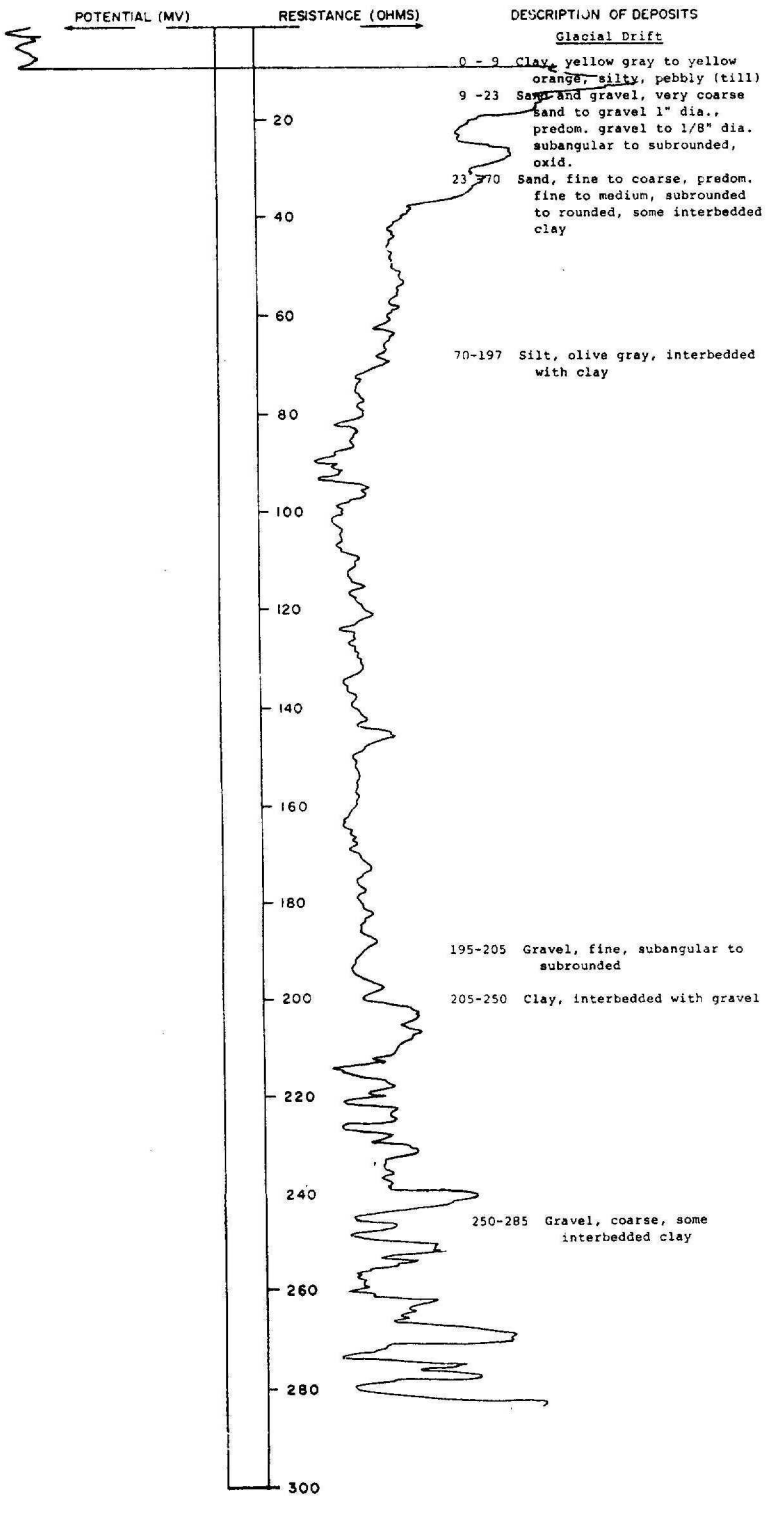
TEST HOLE 11730

LOCATION: 143-81-02DCAC$_1$

DATE DRILLED: 11/5/85

ELEVATION: approx. 1702 (FT, MSL)

DEPTH: 285 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 9 Clay, yellow gray to yellow orange, silty, pebbly (till)

9 -23 Sand and gravel, very coarse sand to gravel 1" dia., predom. gravel to 1/8" dia. subangular to subrounded, oxid.

23 -70 Sand, fine to coarse, predom. fine to medium, subrounded to rounded, some interbedded clay

70-197 Silt, olive gray, interbedded with clay

195-205 Gravel, fine, subangular to subrounded

205-250 Clay, interbedded with gravel

250-285 Gravel, coarse, some interbedded clay

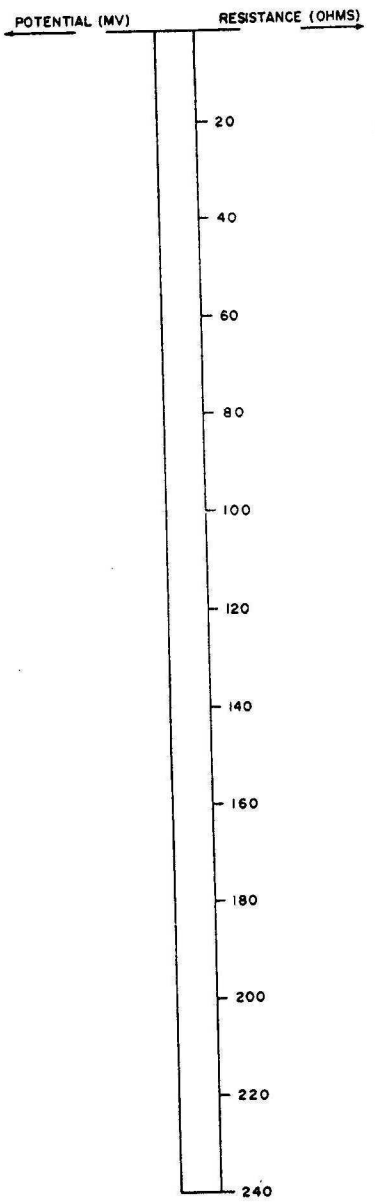
TEST HOLE 11731

LOCATION: 143-81-02BCAC$_2$

DATE DRILLED: 11/6/85

ELEVATION: 1702.3
(FT, MSL)

DEPTH: 75
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 7 Clay, gray, mottled, oxid.
7 -20 Sand and gravel, very coarse sand to gravel, 1" dia., subangular to rounded
20 -67 Sand, fine to very coarse, predom. medium and coarse, subrounded
67 -75 Silt, clayey

Observation Well

Depth: 65'
S.I.: 60'- 65'

Water Level

12/4/85	13.91
1/16/86	14.11
1/20/86	14.19
1/21/86	14.49
1/22/86	14.60
2/18/86	14.93
2/20/86	14.67
3/4/86	14.10
3/5/86	13.98
4/10/86	11.28
7/2/86	14.62

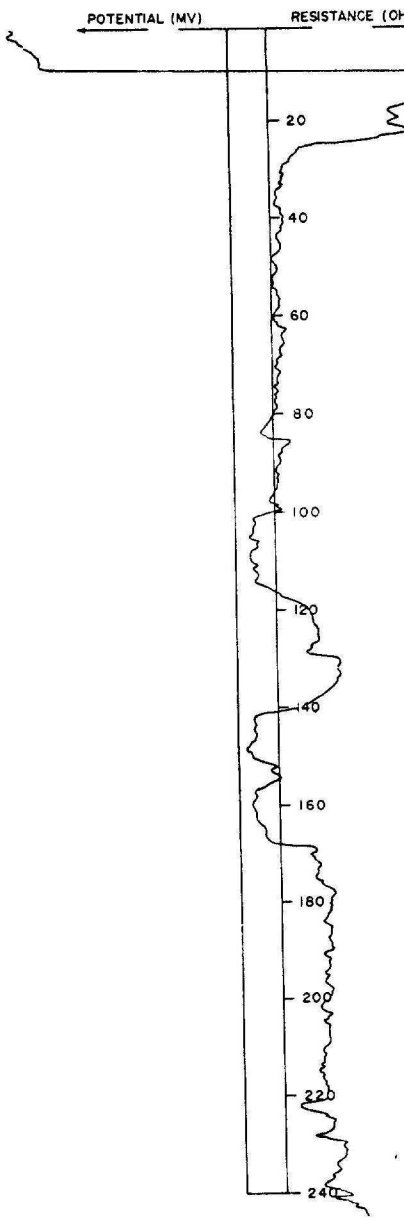
TEST HOLE 11721 and 11722

LOCATION: 143-81-02BCBC1&2

DATE DRILLED: 11/1/85

ELEVATION: 1701.4 and 1701.5 (FT, MSL)

DEPTH: 240 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 6 Clay, oxid. to 4'

6 -15 Sand and gravel, fine sand to gravel ¼" dia.

15 -25 Sand, fine to coarse, predom. fine and medium, subrounded

25 -70 Clay, olive gray, silty (fluvial)

70-101 Clay, olive gray, pebbly, tight (till)

101-126 Clay, olive gray, tight, waxy (lacustrine)

126-139 Sand, very fine to fine, very clayey

139-151 Clay, olive gray (lacustrine)

151-160 Clay, olive gray, silty, pebbly (till)

160-165 Clay, olive gray (lacustrine)

165-216 Sand, fine to fine gravel, predom. medium to coarse, clayey to 180'

Hell Creek Formation

216-240 Sandstone, fine grain, angular, interbedded claystone and lignite

Observation Well
Depth: 203'
S.I.: 198'- 203'

Water Level

12/4/85	41.21
1/16/86	40.54
1/20/86	40.59
1/21/86	40.69
1/22/86	40.71
2/18/86	40.57
2/20/86	40.65
3/4/86	40.42
3/5/86	40.48
4/10/86	40.81
4/22/86	40.58
7/2/86	42.65

Observation Well
Depth: 23'
S.I.: 18'-23'

Water Level

12/4/85	13.22
1/16/86	13.39
1/20/86	13.48
1/21/86	13.89
1/22/86	13.93
2/18/86	14.21
2/20/86	13.91
3/4/86	13.24
3/5/86	12.99
4/10/86	9.70
4/22/86	9.63
7/2/86	14.02

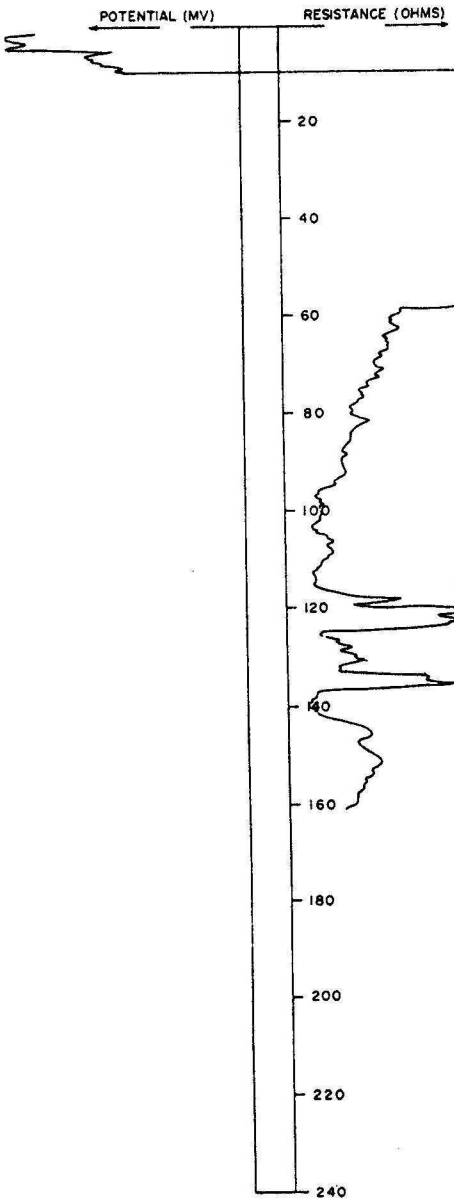
TEST HOLE 11728 and 11729

LOCATION: 143-81-02BCCB1&2

DATE DRILLED: 11/5/85

ELEVATION: approx. 1729.2 (FT, MSL)

DEPTH: 160 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 -12 Silt, brown, clayey, interbedded gravel

12 -23 Gravel, very coarse sand to gravel, 2" di., predom. gravel ¼" dia., rounded, oxid.

23 -40 Silt, yellowish orange, clayey, oxid. to 38'

40 -60 Sand, very fine to fine, subangular to subrounded

60 -84 Clay, olive gray, very silty

84 -97 Clay, olive gray, silty, pebbly (till)

97-117 Clay, olive gray, very plastic (lacustrine)

117-122 Gravel, detrital lignite

Hell Creek Formation

122-160 Claystone, brownish gray, interbedded with fine grain sandstone

Observation Well
Depth: 53'
S.I.: 48'- 53'

Water Level

12/4/86	38.58
1/16/86	38.82
1/20/86	38.72
1/21/86	38.80
1/22/86	38.75
2/18/86	38.90
2/20/86	38.93
3/4/86	38.94
3/5/86	38.98
4/10/86	39.19

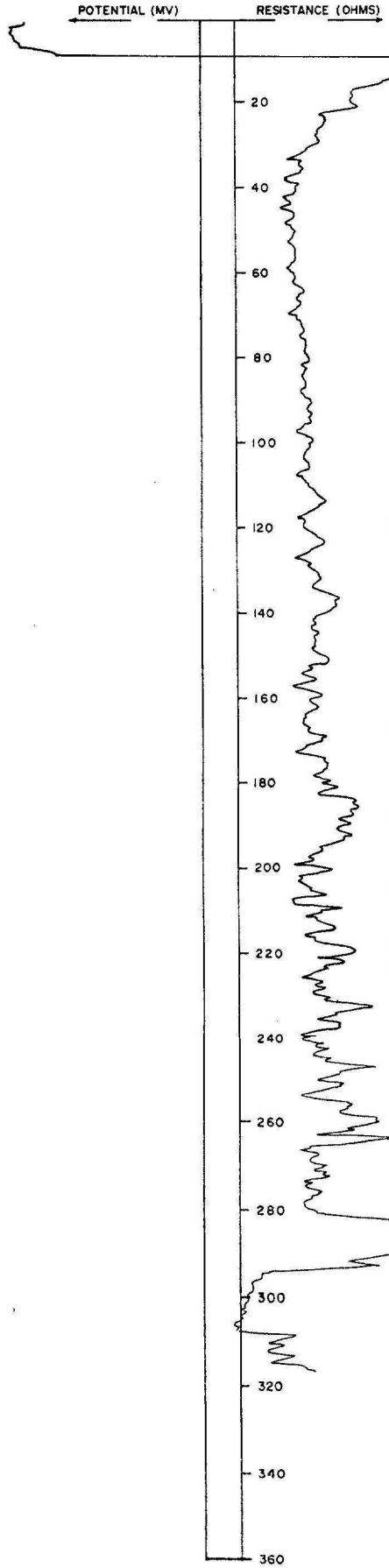
TEST HOLE 11726

LOCATION: 143-81-02BDBC

DATE DRILLED: 11/4/85

ELEVATION: (FT, MSL) 1705.1

DEPTH: 300 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 10 Clay, yellowish gray, silty, ~~gravelly~~ (till)

10 - 22 Sand and gravel, coarse sand to gravel ¼" dia., predom. very coarse sand, subrounded to rounded

22 -120 Silt, olive gray, clayey

120-170 Sand, very fine grain, very clayey

170-192 Sand, fine to medium, some interbedded clay

192-209 Sand, very clayey, interbedded with clay

209-214 Sand and gravel, predom. very coarse sand and fine gravel, subangular, some interbedded clay

214-232 Clay, sandy

232-274 Sand and gravel, as above, grading to coarse gravel by 264'

Hell Creek Formation

274-300 Claystone, brown, silty

Observation Well
Depth: 273'
S.I.: 268'- 273'

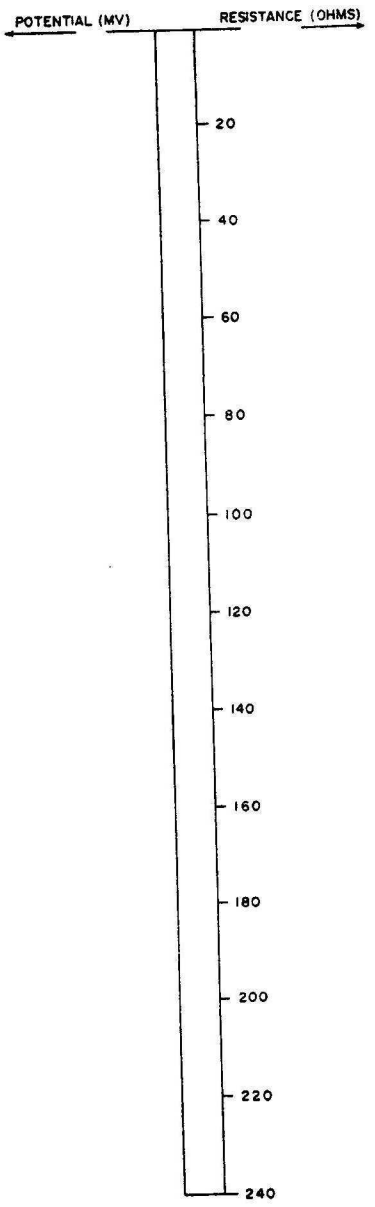
TEST HOLE 11614

LOCATION: 143-81-02CBB

DATE DRILLED: 8/13/85

ELEVATION: approx. 1745 (FT, MSL)

DEPTH: 80 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 10 Sand and gravel, fine sand to fine gravel, predom. coarse and very coarse sand, subrounded to rounded, oxid.

10 - 22 Sand, very fine to medium, predom. fine to medium, subangular to rounded

22 - 42 Silt, slightly to moderately clayey, oxidized to 35'

42 - 56 Clay, olive gray, slightly pebbly, interbedded gravel (till)

Hell Creek Formation

56 - 61 Siltstone, greenish gray, clayey

61 - 80 Sandstone, greenish gray, fine grain, well sorted

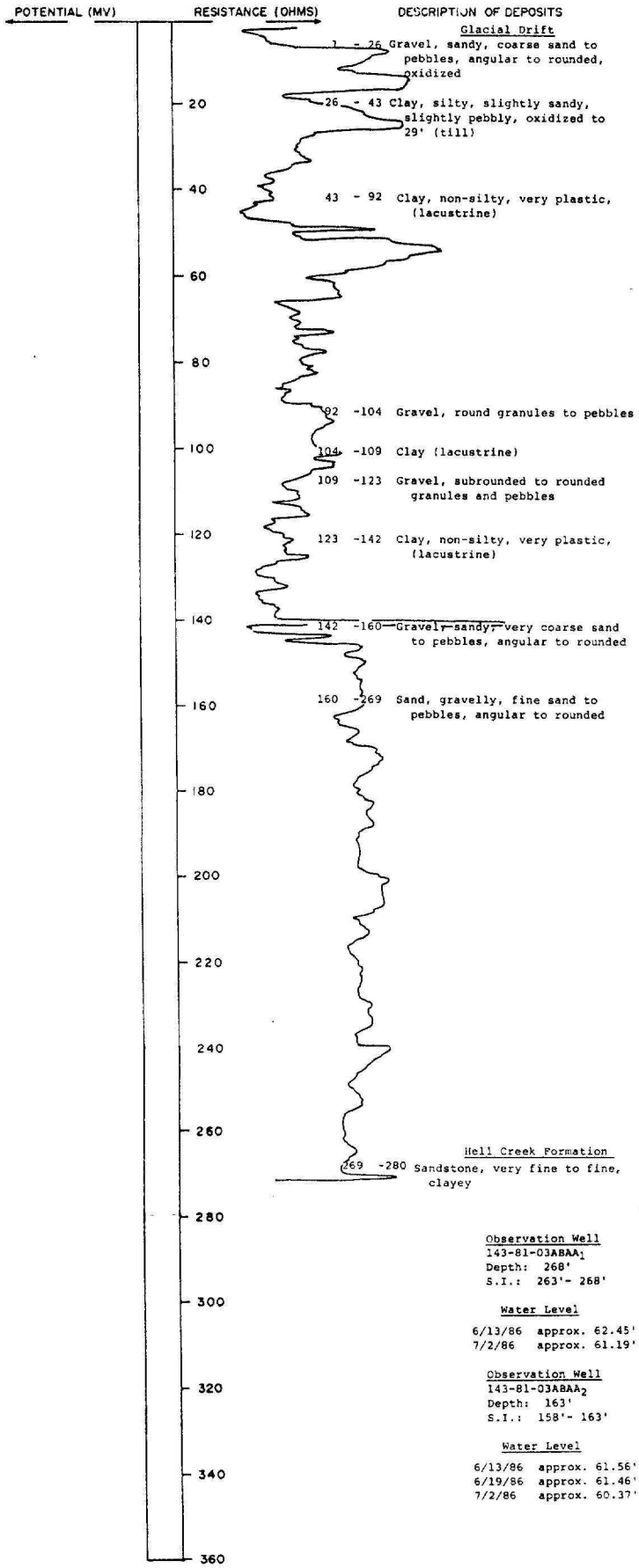
TEST HOLE 11770

LOCATION: 143-81-03ABAA

DATE DRILLED: 6/4/86

ELEVATION: Approx. 1730 (FT, MSL)

DEPTH: 280 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

1 - 26 Gravel, sandy, coarse sand to pebbles, angular to rounded, oxidized

26 - 43 Clay, silty, slightly sandy, slightly pebbly, oxidized to 29' (till)

43 - 92 Clay, non-silty, very plastic, (lacustrine)

92 -104 Gravel, round granules to pebbles

104 -109 Clay (lacustrine)

109 -123 Gravel, subrounded to rounded granules and pebbles

123 -142 Clay, non-silty, very plastic, (lacustrine)

142 -160 Gravel, sandy, very coarse sand to pebbles, angular to rounded

160 -269 Sand, gravelly, fine sand to pebbles, angular to rounded

Hell Creek Formation

269 -280 Sandstone, very fine to fine, clayey

Observation Well
143-81-03ABAA$_1$
Depth: 268'
S.I.: 263'- 268'

Water Level

6/13/86 approx. 62.45'
7/2/86 approx. 61.19'

Observation Well
143-81-03ABAA$_2$
Depth: 163'
S.I.: 158'- 163'

Water Level

6/13/86 approx. 61.56'
6/19/86 approx. 61.46'
7/2/86 approx. 60.37'

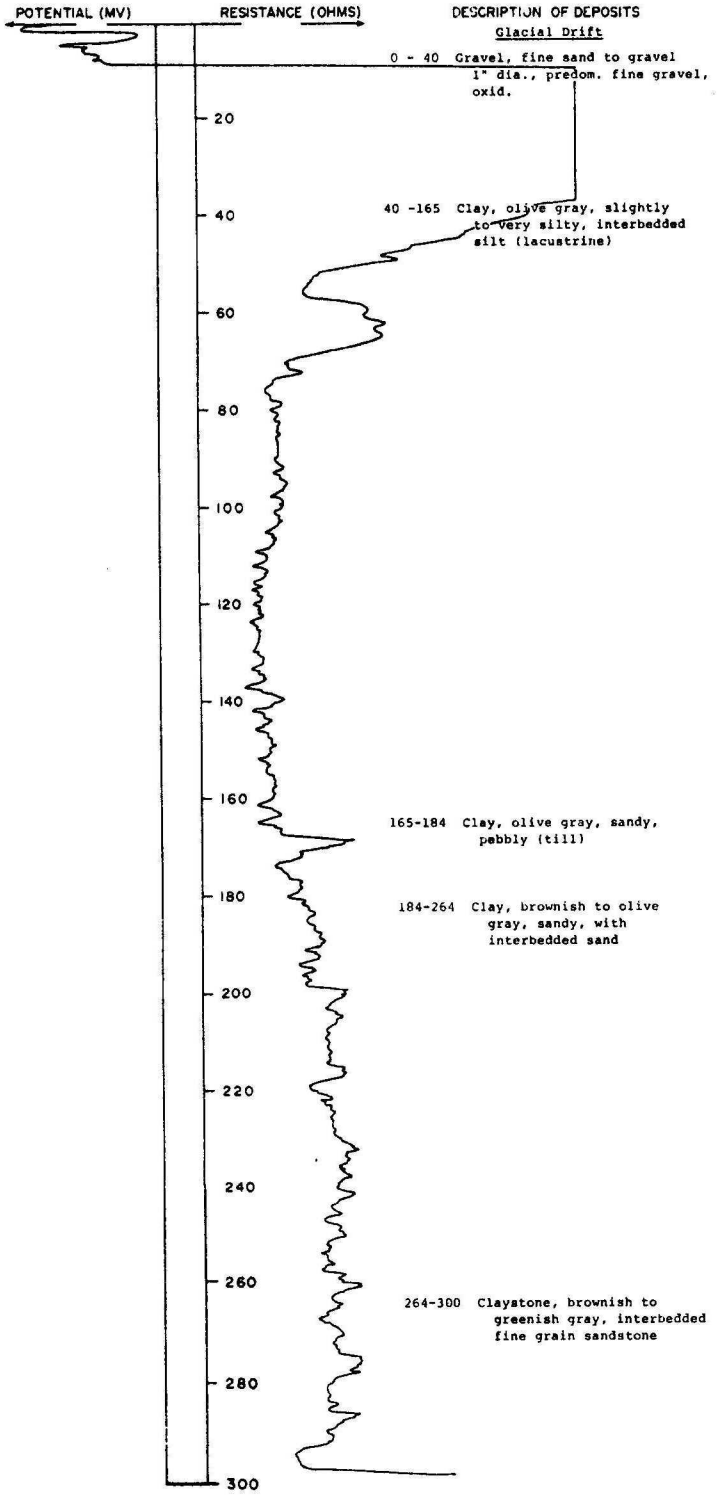
TEST HOLE 11736

LOCATION: 143-81-03ABCC

DATE DRILLED: 11/13/85

ELEVATION: (FT, MSL) approx. 1730

DEPTH: 300 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 40 Gravel, fine sand to gravel 1" dia., predom. fine gravel, oxid.

40 -165 Clay, olive gray, slightly to very silty, interbedded silt (lacustrine)

165-184 Clay, olive gray, sandy, pebbly (till)

184-264 Clay, brownish to olive gray, sandy, with interbedded sand

264-300 Claystone, brownish to greenish gray, interbedded fine grain sandstone

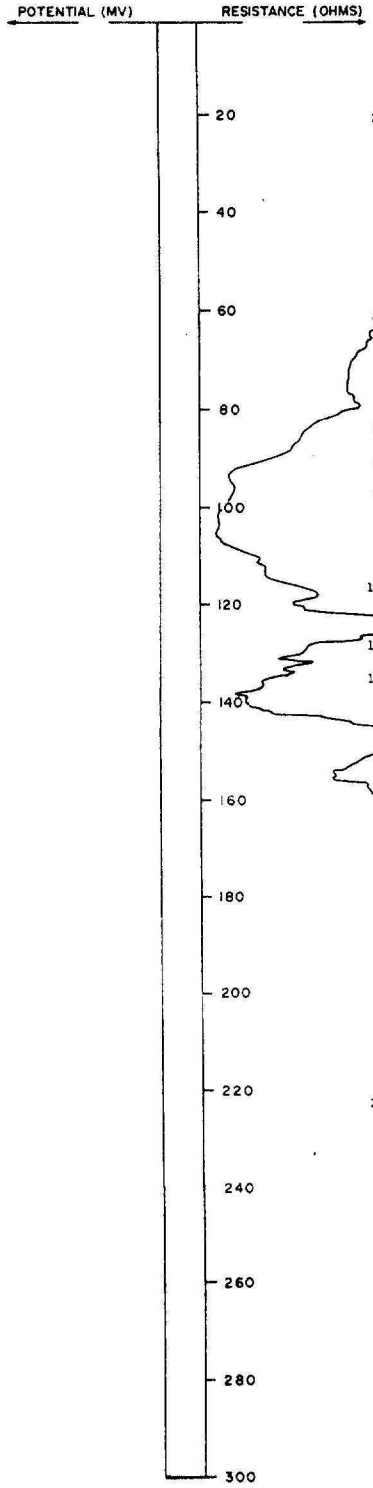
TEST HOLE 11772

LOCATION: 143-81-03ABDA

DATE DRILLED: 6/6/86

ELEVATION: (FT, MSL) Approx. 1720

DEPTH: (FT) 270



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 21 Gravel, very coarse sand, pebbly, subangular to rounded, lacustrine and igneous, oxidized

21 - 84 Clay, silty, sandy, pebbly, soft, plastic, oxidized to 24 feet, interbedded gravel (till)

84 - 86 Clay, non-silty, very plastic, olive gray (lacustrine)

86 - 94 Clay, silty, sandy, pebbly (till)

94 -117 Clay, non-silty, very plastic, olive gray (lacustrine)

117 -126 Sand, very coarse, angular to rounded, lacustrine, interbedded clay

126 -139 Clay, as above

139 -230 Sand, very fine to fine, angular, very clayey, interbedded clay, slightly carbonaceous

230 -270 Sand, clayey, gravelly, angular to rounded, interbedded lacustrine, lignite, and scoria gravel

Observation Well
Depth: 163'
S.I.: 158'- 163'

Water Level
7/2/86 approx. 54.32'

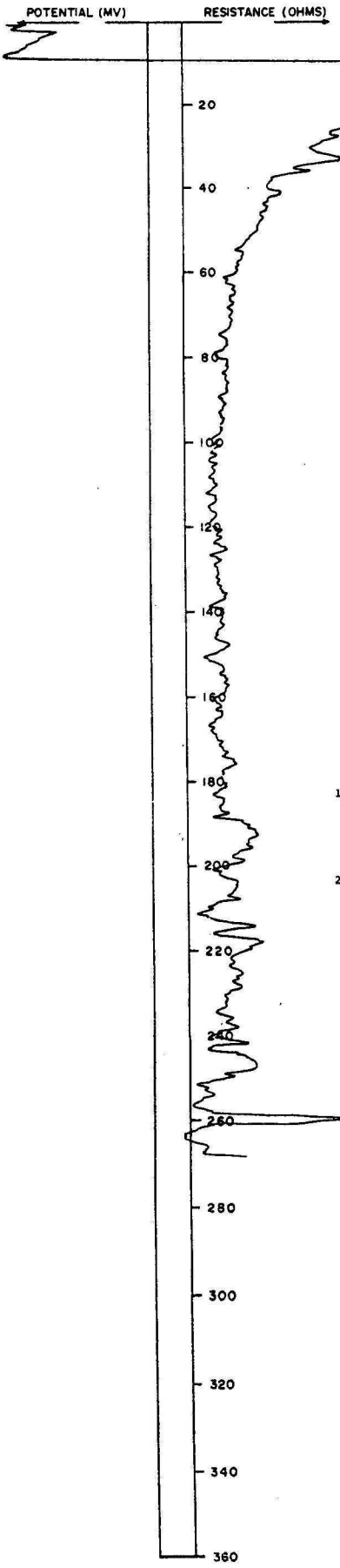
TEST HOLE 11738

LOCATION: 143-81-03ACAC

DATE DRILLED: 11/13/85

ELEVATION: 1692.6 (FT, MSL)

DEPTH: 270 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 -36 Sand and gravel, coarse sand to gravel 1" dia., predom. very coarse sand and fine gravel, subangular to rounded, oxid. to 14'

36-185 Clay, olive gray, silty, laminations of light gray silt

185-206 Sand, very clayey interbedded silt

206-252 Clay, sandy, interbedded till and coarse sand

Hell Creek Formation

252 -261 Sandstone, greenish gray, fine grain, well sorted, clayey

261 -270 Claystone, silty

Observation Well
Depth: 36'
S.I.: 31'- 36'

Water Level

12/4/85	7.0
1/16/86	7.18
1/20/86	7.16
1/21/86	7.13
1/22/86	7.18
2/18/86	7.25
3/4/86	6.88
3/5/86	6.85
4/10/86	6.70
7/2/86	6.70

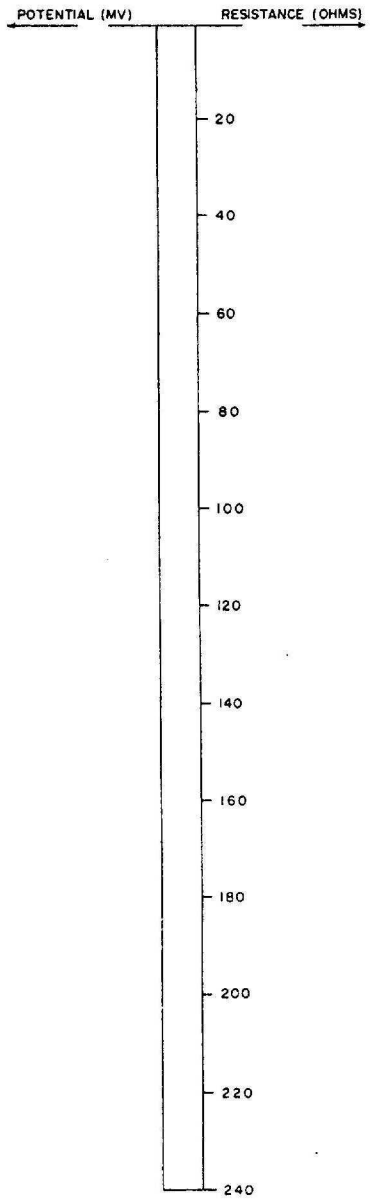
TEST HOLE 11737

LOCATION: 143-81-03ACCC

DATE DRILLED: 11/3/85

ELEVATION: approx. 1720 (FT, MSL)

DEPTH: 80 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 7 Silt, black, carbonaceous

7 -12 Sand and gravel, predom. fine gravel, rounded, oxid.

12 -23 Clay, silty, oxid. to 16'

23 -56 Clay, olive gray, sandy, pebbly (till)

Hell Creek Formation

56 -80 Sandstone, fine grain, interbedded siltstone

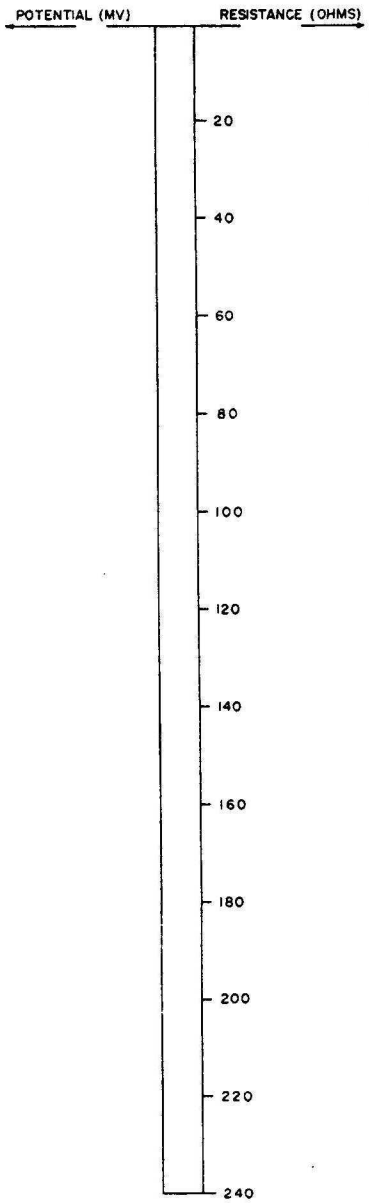
TEST HOLE 11615

LOCATION: 143-81-03ADA$_1$

DATE DRILLED: 8/13/85

ELEVATION: 1704.7 (FT, MSL)

DEPTH: 100 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 5	Sand, fine, oxid.
5 -11	Clay,d ark gray, carbonaceous
11 -18	Sand, fine to coarse; predom. medium, subangular to subrounded
18 -31	Sand and gravel, coarse sand to gravel ¼" dia. subrounded to rounded
31-100	Silt, dark gray, clayey, interbedded, very fine sand

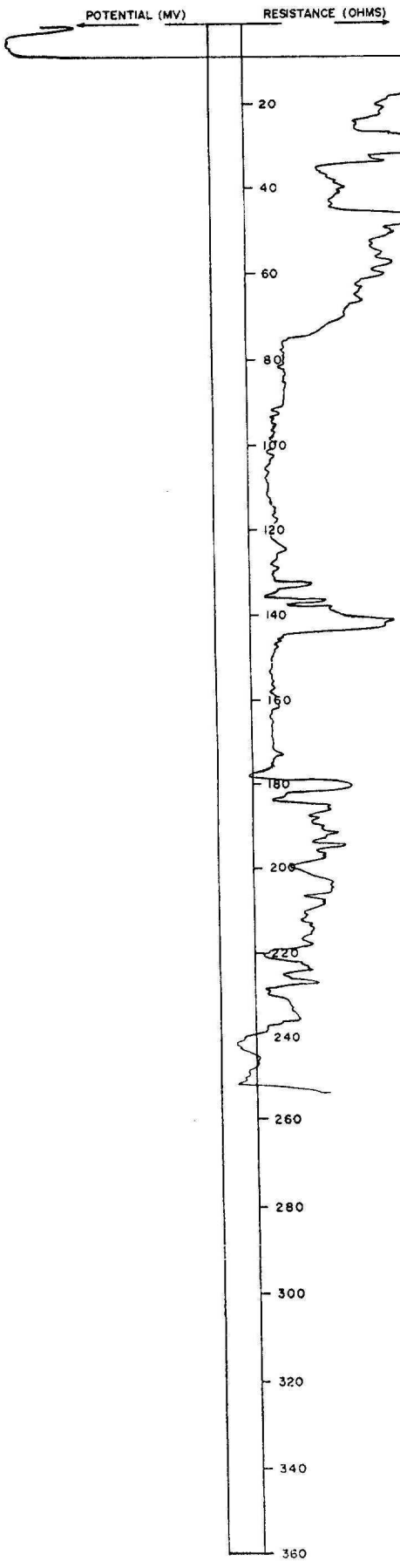
TEST HOLE 11735

LOCATION: 143-81-03ADAD$_2$

DATE DRILLED: 11/12/85

ELEVATION: 1702.0 (FT, MSL)

DEPTH: 260 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 5 Sand and fine gravel, oxid.

5 -11 Clay, olive gray

11 -22 Silt, olive gray, clayey and sandy

22 -34 Sand, fine to coarse

34 -41 Silt, clayey

41 -60 Sand, fine to coarse, predom. medium

60-130 Clay, olive gray, silty, interbedded with clayey silt

130-177 Clay, olive gray, silty, sandy, cobbly (till)

177-227 Sand and gravel, very coarse sand to gravel ¼" dia.- predom. gravel to 1/8" dia. grading to medium and coarse sand by 200', interbedded clay

Hell Creek Formation

227-236 Claystone, silty

236-243 Sandstone

243-260 Claystone, brown, waxy

Observation Well

Depth: 183'
S.I.: 177'- 183'

Water Level

12/4/85	41.44
1/16/86	41.44
1/20/86	41.14
1/21/86	41.19
1/22/86	41.27
2/18/86	41.14
2/20/86	41.09
3/4/86	41.01
3/5/86	40.97
4/10/86	41.51
7/2/86	43.22

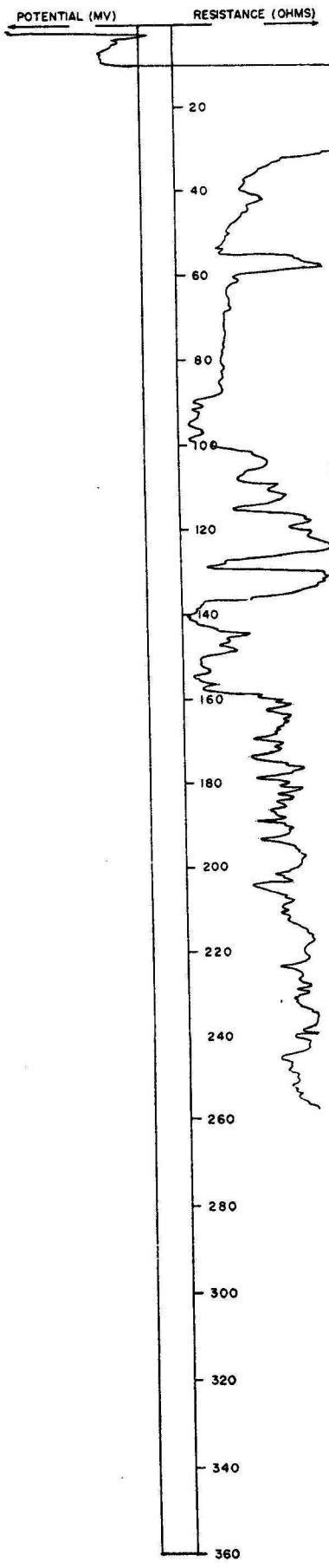
TEST HOLE 11739

LOCATION: 143-81-03ADBA

DATE DRILLED: 11/4/85

ELEVATION: 1714.8 (FT, MSL)

DEPTH: 260 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 17 Sand and gravel, coarse sand to gravel-¼" dia., predom. very coarse sand and fine gravel to 1/8" dia., angular to rounded; predom. sub-angular to subrounded, quartz, carbonates, and shale, oxid.

17 - 20 Silt, dark yellowish orange, clayey, oxid.

20 - 42 Clay, dark yellowish orange to olive gray, slightly silty, oxid. to 26'

42 - 94 Clay, olive gray, silty, sandy, pebbly, soft (till)

94-120 Clay, olive gray, plastic, waxy, interbedded silt and sand (lacustrine)

120-133 Sand, fine grain, well sorted, angular, clay lens 124'-126'

133-155 Clay, olive gray, plastic (lacustrine)

155-234 Sand, medium sand to fine gravel, predom. medium and coarse sand with lignite gravel, gravelly at 233'

Hell Creek Formation

234-260 Sandstone, greenish gray, fine grain, well sorted, interbedded claystone and lignite

Observation Well
Depth: 183'
S.I.: 178'- 183'

Water Level

12/4/85	54.67
1/16/86	54.00
1/20/86	54.02
1/21.86	54.08
2/18/86	54.02
3/4/86	53.88
3/5/86	53.90
4/10/86	54.48
6/13/86	57.01
7/2/86	56.10

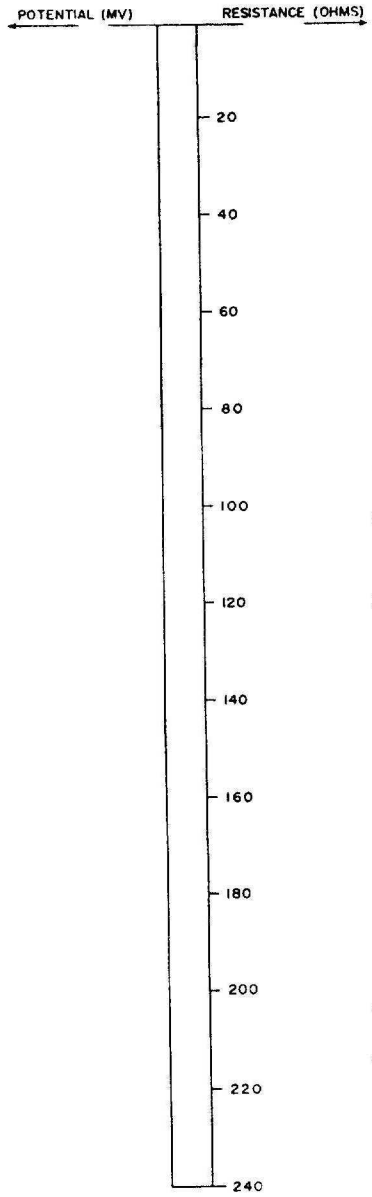
TEST HOLE 11740

LOCATION: 143-81-03ADBD$_2$

DATE DRILLED 11/14/85

ELEVATION (FT, MSL): approx. 1700

DEPTH (FT): 240



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 8 Gravel interbedded with silty clay

8 -11 Sand and gravel, very coarse sand to gravel ¼" dia., rounded, oxid.

11 -63 Clay, olive gray, silty, very carbonaceous 30'- 48'

63 -92 Sand and gravel, coarse sand to gravel ¼" dia., predom. very coarse sand to gravel 1/8" dia., rounded, carbonates and some silicates

92-105 Clay, very sandy

105-120 Sand, fine to coarse, predom. medium to coarse

120-227 Clay, olive gray, silty, interbedded clayey silt and lignite

227-236 Gravel to ¼" dia., rounded, predom. carbonates

Hell Creek Formation

236-240 Claystone, brownish gray

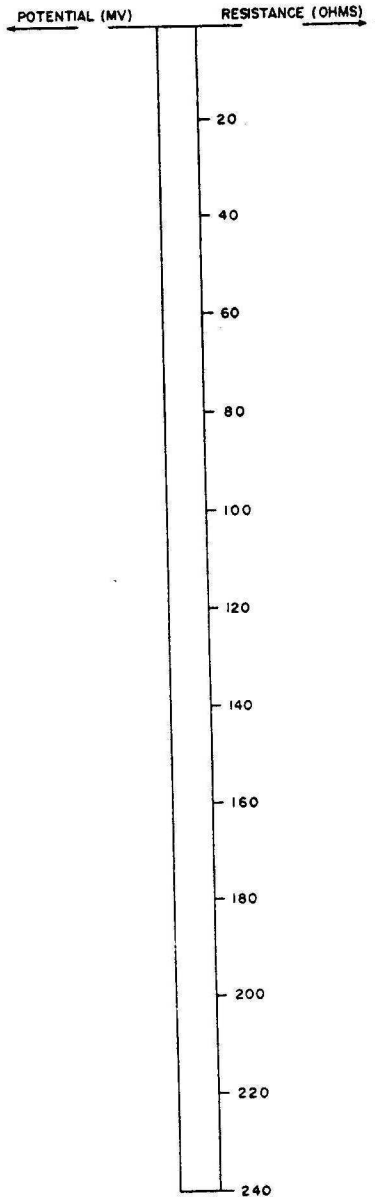
TEST HOLE 11741

LOCATION: 143-81-03ADCD

DATE DRILLED: 11/15/85

ELEVATION: approx. 1740 (FT, MSL)

DEPTH: 80 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 9	Sand and gravel, coarse sand to gravel 1" dia., predom. rounded gravel to ¼" dia. oxid.
9 -32	Sand, coarse, well sorted, rounded
32 -40	Sand and gravel, as above
40 -55	Clay, olive gray, silty, sandy, soft, oxid. 40'- 41' (till)

Hell Creek Formation

55 -70	Claystone, interbedded siltstone
70 -80	Sandstone, greenish gray, fine grain

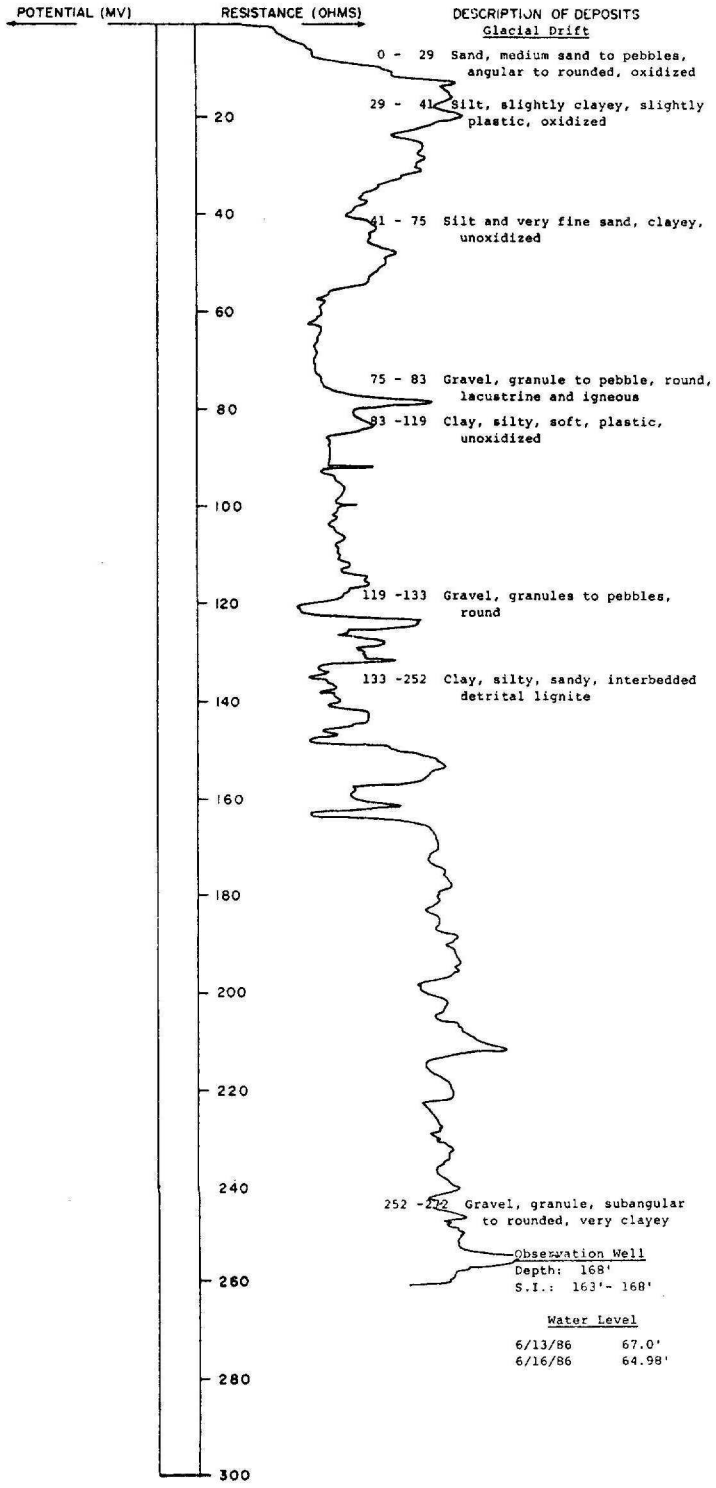
TEST HOLE 11769

LOCATION: 143-81-03BABD

DATE DRILLED: 5/29/86

ELEVATION: (FT, MSL)

DEPTH: 272 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 29 Sand, medium sand to pebbles, angular to rounded, oxidized

29 - 41 Silt, slightly clayey, slightly plastic, oxidized

41 - 75 Silt and very fine sand, clayey, unoxidized

75 - 83 Gravel, granule to pebble, round, lacustrine and igneous

83 -119 Clay, silty, soft, plastic, unoxidized

119 -133 Gravel, granules to pebbles, round

133 -252 Clay, silty, sandy, interbedded detrital lignite

252 -272 Gravel, granule, subangular to rounded, very clayey

Observation Well
Depth: 168'
S.I.: 163'- 168'

Water Level

6/13/86	67.0'
6/16/86	64.98'

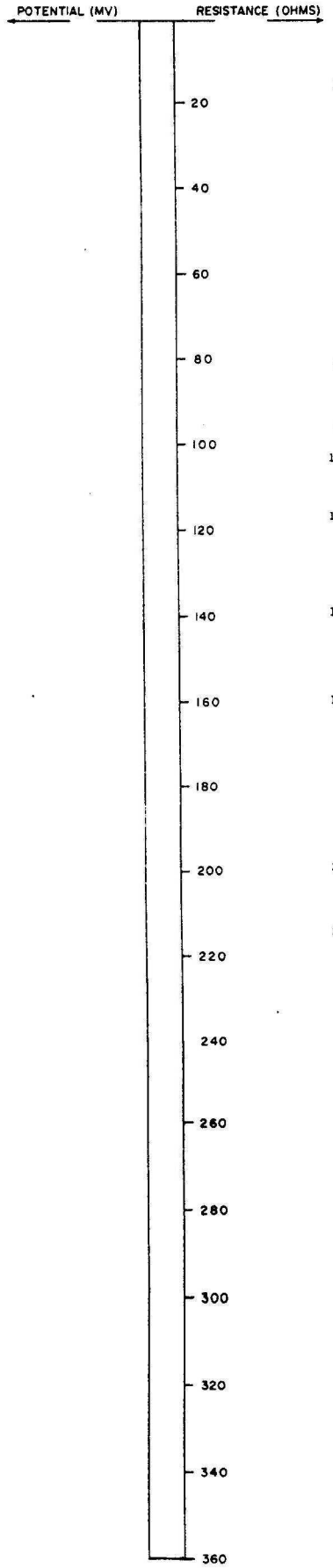
TEST HOLE 11768

LOCATION: 143-81-033BAD

DATE DRILLED: 5/28/86

ELEVATION: (FT, MSL)

DEPTH: 300 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 16 Gravel, very coarse sand to pebbles, angular to rounded, oxdizied

16 - 83 Silt, very clayey, soft, plastic, cohesive, interbedded, gravel, sandy clay, and clay, oxidized to 47 feet

83 - 96 Clay, silty, sandy, pebbly, soft, plastic, cohesive, unoxidized (till)

96 -100 Gravel, very coarse sand to pebbles, angular to round

100 -117 Clay, very silty to non-silty, soft, plastic

117-140 Clay, very sandy, soft, crumbly, interbedded silty clay

140-160 Clay, very silty to very sandy, soft, interbedded detrital lignite

160-201 Sand, clayey, very fine, interbedded detrital lignite

201-215 Clay, carbonaceous, interbedded sandy clay

215-262 Clay, sandy, carbonaceous

262-292 Gravel, coarse pebbles, round lacustrine and quartzite, interbedded clay

Hell Creek Formation

292-300 Sandstone, very fine, clayey

Observation Well

Depth: 268'
S.I.: 263'- 268'

Water Level

7/14/86 approx. 63.87'

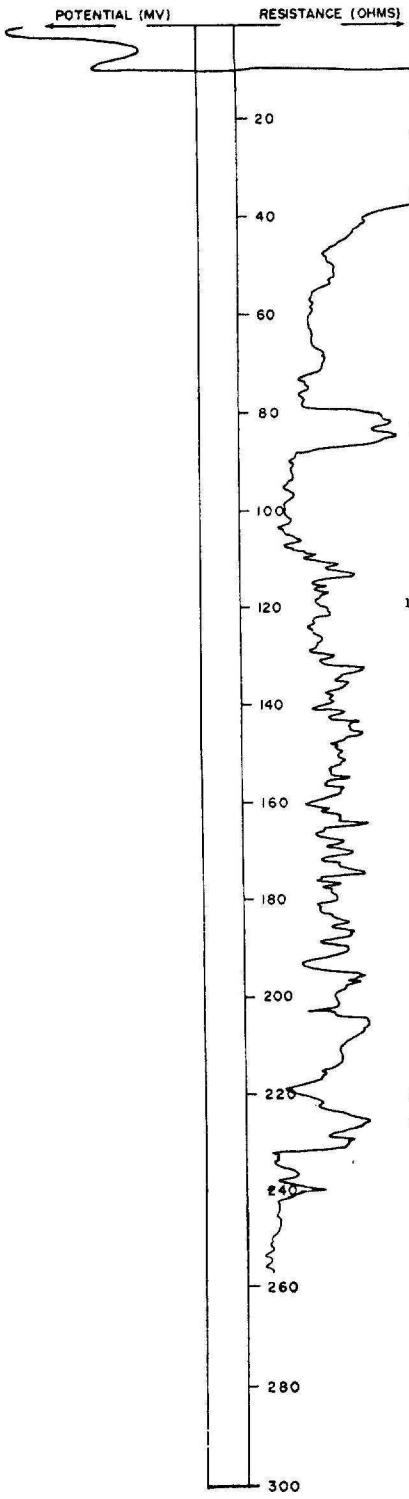
TEST HOLE 11765

LOCATION: 143-81-03BBB3

DATE DRILLED: 5/27/86

ELEVATION: (FT, MSL)

DEPTH: 260 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 6 Silt, very clayey

6 - 9 Gravel, sandy, moderately sandy to pebbles, angular to roun

9 - 25 Sand, gravelly, medium sand to granules, angular to round

25 - 39 Gravel, very coarse sand to pebbles, angular to round

39 - 85 Clay, silty, slightly sandy and pebbly (till)

85 -120 Clay, slightly silty to non-silty, very plastic, very cohesive (lacustrine)

120 -220 Silt, slightly clayey, slightly sandy, very plastic, cohesive, olive gray

220 -230 Sand, very fine to fine, clayey

230 -241 Sand, very fine to medium, very clayey

Hell Creek Formation

241 -242 Sandstone, fine, well indurated

242 -260 Claystone, very sandy, brittle, moderately indurated

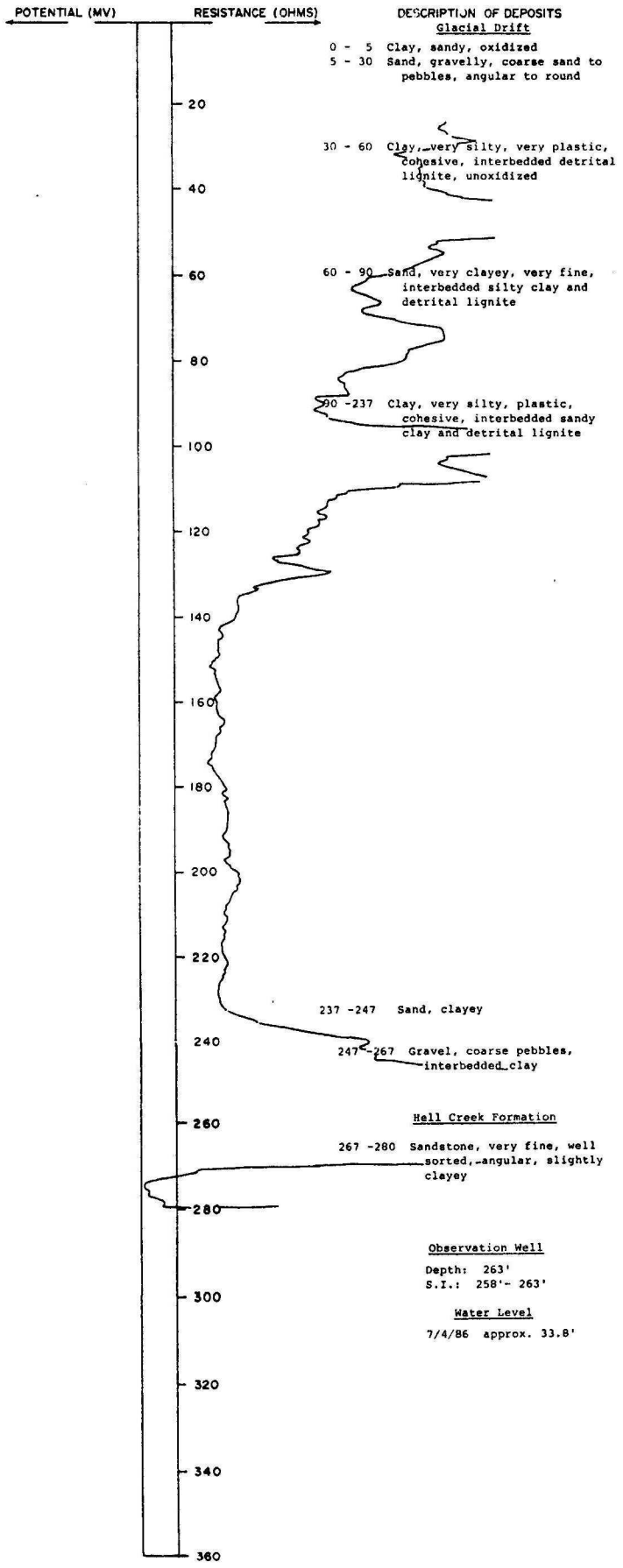
TEST HOLE 11767

LOCATION: 143-81-03BBDD

DATE DRILLED: 5/28/86

ELEVATION: (FT, MSL)

DEPTH: 280 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 5 Clay, sandy, oxidized

5 - 30 Sand, gravelly, coarse sand to pebbles, angular to round

30 - 60 Clay, very silty, very plastic, cohesive, interbedded detrital lignite, unoxidized

60 - 90 Sand, very clayey, very fine, interbedded silty clay and detrital lignite

90 -237 Clay, very silty, plastic, cohesive, interbedded sandy clay and detrital lignite

237 -247 Sand, clayey

247 -267 Gravel, coarse pebbles, interbedded clay

Hell Creek Formation

267 -280 Sandstone, very fine, well sorted, angular, slightly clayey

Observation Well

Depth: 263'

S.I.: 258'- 263'

Water Level

7/4/86 approx. 33.8'

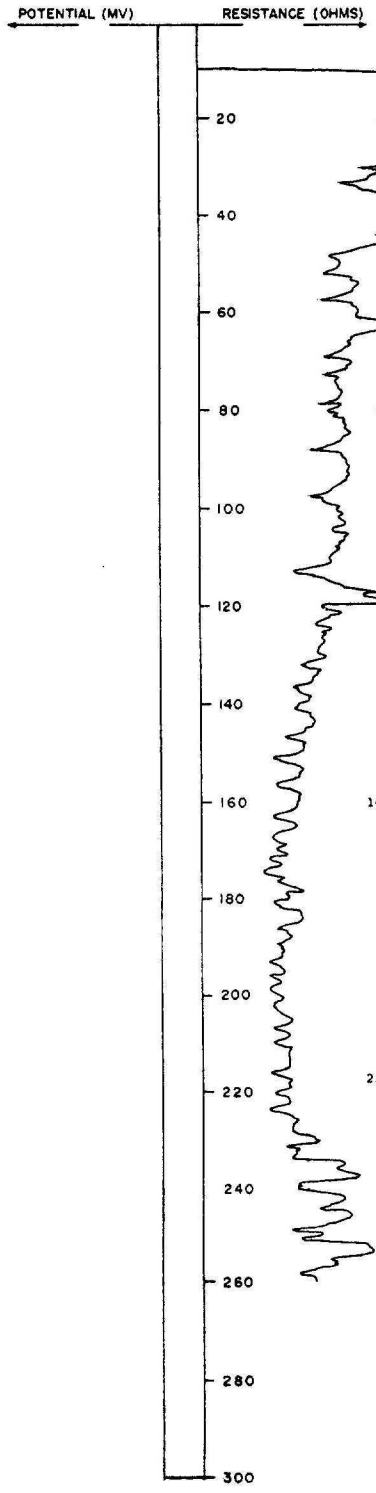
TEST HOLE 11762

LOCATION: 143-81-03CBBB

DATE DRILLED: 5/21/86

ELEVATION: (FT, MSL)

DEPTH: 260 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 6 Sand, gravelly, fine sand to pebbles, angular to round, oxidized

6 - 20 Silt, slightly clayey, slightly cohesive, oxidized

20 - 40 Silt, slightly to very clayey, laminated, interbedded medium sand, oxidized

40 - 80 Silt, very clayey, soft, slightly plastic, interbedded clay

80 -160 Sand, clayey, very fine, interbedded clay, silt, and detrital lignite

160 -235 Clay, slightly silty, plastic, cohesive, interbedded, non-silty clay

Hell Creek Formation

235 -260 Sandstone, very fine to fine, well sorted, angular to subangular

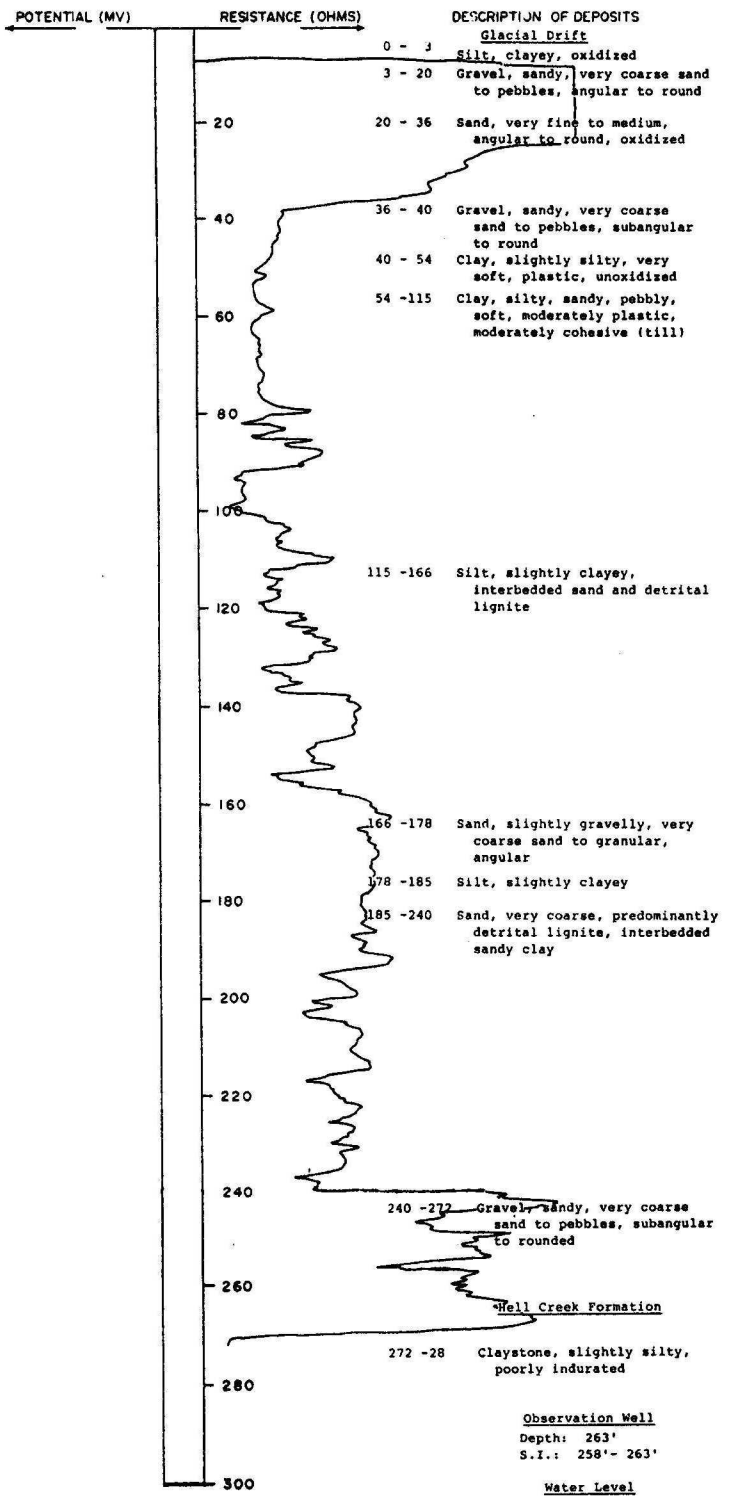
TEST HOLE 11763

LOCATION: 143-81-04AAAD

DATE DRILLED: 5/21/86

ELEVATION: (FT, MSL)

DEPTH: 280 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 3 Silt, clayey, oxidized

3 - 20 Gravel, sandy, very coarse sand to pebbles, angular to round

20 - 36 Sand, very fine to medium, angular to round, oxidized

36 - 40 Gravel, sandy, very coarse sand to pebbles, subangular to round

40 - 54 Clay, slightly silty, very soft, plastic, unoxidized

54 -115 Clay, silty, sandy, pebbly, soft, moderately plastic, moderately cohesive (till)

115 -166 Silt, slightly clayey, interbedded sand and detrital lignite

166 -178 Sand, slightly gravelly, very coarse sand to granular, angular

178 -185 Silt, slightly clayey

185 -240 Sand, very coarse, predominantly detrital lignite, interbedded sandy clay

240 -272 Gravel, sandy, very coarse sand to pebbles, subangular to rounded

Hell Creek Formation

272 -28 Claystone, slightly silty, poorly indurated

Observation Well
Depth: 263'
S.I.: 258'- 263'

Water Level
7/14/86 approx. 56.9'

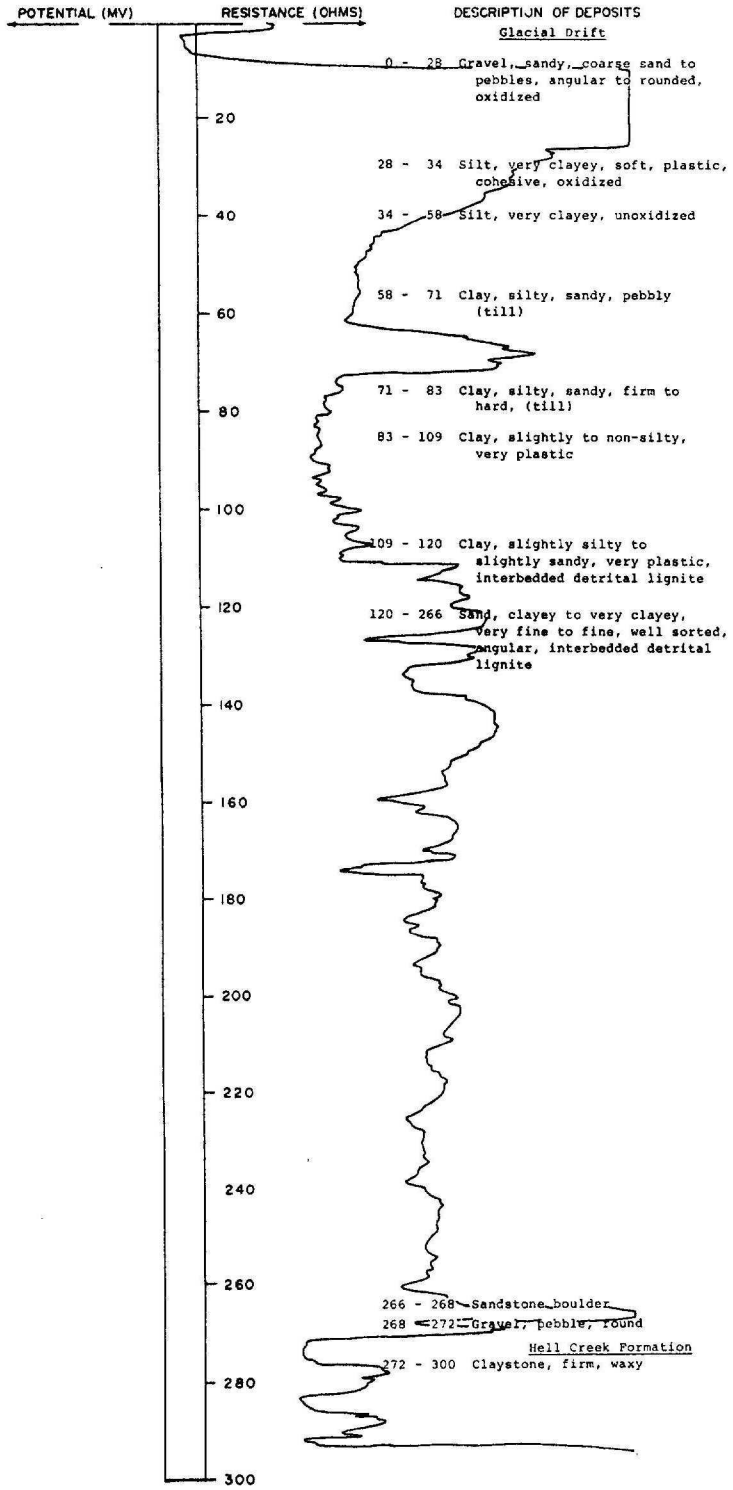
TEST HOLE 11766

LOCATION: 143-81-04ADAA

DATE DRILLED: 5/27/86

ELEVATION: (FT, MSL)

DEPTH: 300 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 - 28 Gravel, sandy, coarse sand to pebbles, angular to rounded, oxidized

28 - 34 Silt, very clayey, soft, plastic, cohesive, oxidized

34 - 58 Silt, very clayey, unoxidized

58 - 71 Clay, silty, sandy, pebbly (till)

71 - 83 Clay, silty, sandy, firm to hard, (till)

83 - 109 Clay, slightly to non-silty, very plastic

109 - 120 Clay, slightly silty to slightly sandy, very plastic, interbedded detrital lignite

120 - 266 Sand, clayey to very clayey, very fine to fine, well sorted, angular, interbedded detrital lignite

266 - 268 Sandstone boulder

268 - 272 Gravel, pebble, round

Hell Creek Formation

272 - 300 Claystone, firm, waxy

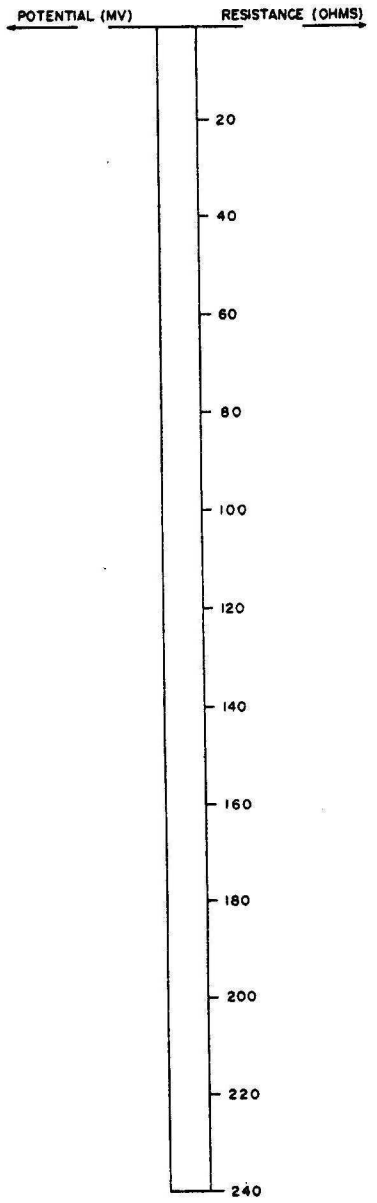
TEST HOLE 11734

LOCATION: 144-81-35CCBB

DATE DRILLED: 11/12/85

ELEVATION: approx. 1720 (FT, MSL)

DEPTH: 140 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0 -12 Gravel, very coarse sand to gravel 2" dia.-predom. ¼ - ½" dia., rounded, oxid.

12 -26 Clay, yellow brown, silty, pebbly, oxid. to 18'

26 -51 Clay, olive gray, silty, interbedded with till

51 -76 Clay, silty, sandy, pebbly (till)

76 -89 Clay (lacustrine)

89 -99 Clay (till) as above

99-113 Silt, clayey

113-116 Clay, silty

Hell Creek Formation

116-140 Claystone, interbedded with sandstone

143-081-02BBB2
Lost Lake aquifer — LS Elev (msl,ft)= 1710.20 — SI (ft)= 37-40

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/14/73	35.96	1674.24
01/16/86	34.15	1676.05
01/20/86	34.10	1676.10
01/21/86	34.42	1675.78
01/22/86	34.37	1675.83
02/18/86	34.29	1675.91
02/20/86	34.37	1675.83
03/04/86	33.90	1676.30
03/05/86	34.29	1675.91
04/10/86	34.16	1676.04
07/02/86	34.26	1675.94

143-081-02BCCB
Lost Lake aquifer — Milton # 1 — SI (ft)= 88-55

Date	Depth to Water (ft)
01/17/86	22.39
01/20/86	22.76
01/21/86	35.19
01/22/86	23.69

143-081-02BCC1
Lost Lake aquifer — LS Elev (msl,ft)= 1705.40 — SI (ft)= 252-258

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/21/79	+1.26	1706.66
06/28/79	+1.94	1707.34
07/31/79	+1.78	1707.18
08/24/79	+1.49	1706.89
09/25/79	+1.18	1706.58
10/25/79	+1.09	1706.49
03/20/80	+1.37	1706.77
04/23/80	+0.86	1706.26
05/21/80	+0.83	1706.23
06/23/80	+0.95	1706.35
07/21/80	+1.01	1706.41
08/21/80	+0.88	1706.28
09/22/80	+1.04	1706.44
04/30/81	+1.21	1706.61
06/02/81	+1.07	1706.47
06/24/81	+0.98	1706.38
08/24/81	+0.86	1706.26
09/28/81	+0.82	1706.22
11/04/81	+0.77	1706.17
12/02/81	+0.66	1706.06
05/18/82	+1.43	1706.83
06/29/82	+1.79	1707.19
07/27/82	+2.00	1707.40
08/25/82	+1.93	1707.33
09/30/82	+1.76	1707.16
05/04/83	+1.76	1707.16
05/31/83	+2.12	1707.52
08/29/83	+1.54	1706.94
09/29/83	+1.17	1706.57
10/27/83	+1.28	1706.68
04/18/84	+1.30	1706.70
05/16/84	+1.62	1707.02
06/27/84	+1.70	1707.10
07/26/84	+1.34	1706.74
09/20/84	+0.92	1706.32
04/10/86	+0.74	1706.14
07/02/86	+0.83	1706.23

143-081-02BCC2
Lost Lake aquifer — LS Elev (msl,ft)= 1705.00 — SI (ft)= 31-34

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
10/29/73	7.30	1697.70	01/21/86	19.64	1685.36
			01/22/86	18.69	1686.31
08/20/85	17.30	1687.70	02/18/86	19.10	1685.90
08/21/85	18.60	1686.40	02/20/86	18.36	1686.64
10/09/85	17.64	1687.36	03/04/86	16.63	1688.37
			03/05/86	17.34	1687.66
01/16/86	17.59	1687.41	04/10/86	13.60	1691.40
01/20/86	17.83	1687.17	07/02/86	18.58	1686.42

143-081-03ADB
Lost Lake aquifer — LS Elev (msl,ft)= 1701.40 — SI (ft)= 77-83

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
11/14/73	7.91	1693.49	01/22/86	45.80	1655.60
			02/18/86	44.32	1657.08
08/21/85	57.87	1643.53	02/20/86	45.05	1656.35
10/09/85	46.99	1654.41	03/04/86	45.40	1656.00
			03/05/86	46.18	1655.22
01/16/86	46.64	1654.76	04/10/86	42.08	1659.32
01/20/86	46.48	1654.92	07/02/86	38.54	1662.86
01/21/86	46.03	1655.37			

143-081-03BAA
Lost Lake aquifer — LS Elev (msl,ft)= 1695.30 — SI (ft)= 157-163

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/14/73	36.25	1659.05
03/30/78	34.37	1660.93
04/26/78	34.35	1660.95
05/24/78	34.49	1660.81
06/06/78	34.60	1660.70
06/28/78	34.62	1660.68
07/26/78	34.49	1660.81
08/24/78	34.69	1660.61
09/25/78	34.72	1660.58
10/31/78	34.84	1660.46
11/30/78	34.60	1660.70
05/22/79	33.09	1662.21
06/27/79	33.34	1661.96
07/31/79	33.62	1661.68
08/24/79	33.94	1661.36
09/25/79	34.46	1660.84
10/25/79	34.71	1660.59
11/20/79	35.00	1660.30
02/20/80	33.83	1661.47
03/20/80	33.94	1661.36
04/23/80	34.30	1661.00
05/21/80	34.45	1660.85
06/23/80	34.14	1661.16
07/21/80	34.14	1661.16
08/26/80	33.98	1661.32
09/22/80	33.86	1661.44
11/25/80	33.50	1661.80
04/30/81	33.65	1661.65
06/02/81	33.86	1661.44
06/24/81	33.83	1661.47
08/05/81	33.69	1661.61
08/24/81	33.85	1661.45
09/28/81	33.97	1661.33
11/04/81	34.02	1661.28
12/02/81	34.23	1661.07
05/18/82	33.12	1662.18
06/29/82	32.84	1662.46
07/27/82	32.67	1662.63
08/25/82	33.07	1662.23
09/30/82	33.40	1661.90
11/03/82	33.07	1662.23
12/01/82	32.55	1662.75
03/30/83	32.32	1662.98
05/04/83	32.45	1662.85
05/31/83	32.69	1662.61
08/29/83	33.15	1662.15
09/29/83	33.87	1661.43
10/27/83	33.70	1661.60
12/07/83	33.70	1661.60
04/18/84	33.33	1661.97
05/16/84	33.51	1661.79
06/27/84	35.90	1659.40
07/26/84	36.80	1658.50
09/20/84	37.64	1657.66
12/04/84	34.02	1661.28
01/16/86	34.86	1660.44
01/20/86	34.87	1660.43
01/21/86	35.00	1660.30
01/22/86	35.03	1660.27
02/18/86	34.87	1660.43
02/20/86	34.94	1660.36
02/25/86	34.72	1660.58
03/04/86	34.74	1660.56
03/05/86	34.81	1660.49
04/10/86	36.56	1658.74
06/05/86	37.44	1657.86
06/13/86	39.23	1656.07
07/02/86	36.92	1658.38
07/10/86	37.78	1657.52

TABLE 3 - CHEMICAL ANALYSES

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

AQUIFERS Owner or Designation	Location	Depth of Well (feet)	Temp(°F)	Date of Collection	(SiO_2)	(Fe)	(Mn)	(Ca)	(Mg)	(Na)	(K)	(HCO_3)	(CO_3)	(SO_4)	(Cl)	(F)	(NO_3)	(B)	Total Dissolved Solids	Total Hardness as $CaCO_3$	Total Hardness Noncarbonate	Percent Sodium	SAR	Specific Conductance	pH
Surficial aquifer																									
SWC #11738	143-81-03ACAC	31-36		12/4/85	24	.05	.47	100	32	130	8.4	655	0	94	22	.2	1.0	.17	742	380	0	42	2.9	1060	8.12
Shallow Confined																									
SWC #11731	143-81-02BCAC$_2$	60-65		12/4/85	28	.16	.17	100	24	320	11	961	0	200	53	.4	1.0	.49	1220	350	0	66	7.4	1800	7.92
11722	143-81-02BCBC$_2$	18-23		12/4/85	26	.93	.46	72	24	23	5.4	344	0	40	3.4	.1	1.0	.14	370	280	0	15	.6	690	8.06
3898	143-81-02BCC$_2$	31-34		11/6/69	29	1.8		82	19	19	4.3		45		0.2				367	285	7	13	16	2080	8.3
Wilton #1	143-81-02BCCB	25-55		1/21/86	24	.18	.34	86	28	130	7.1	537	0	160	19	.18	1.0	.25	700	330	0	46	3.1		8.14
SWC #11615	143-81-03ADA$_1$	26-31		12/4/85	25	.07	.76	76	32	41	11	464	0	44	4.5	.2	1.0	.1	785	320	0	21	1.0	730	8.1
8950	143-81-03ADB	80-83		11/2/73	24	2.9	.62	89	21	22	5.4	380		28	5.1	.3	2.0	.43	796	310	0	13	.5	624	7.7
Wilton #2	143-81-03ADBD	65-85		2/20/86	28	2.2	.60	88	30	63	9.1	479	0	84	13	.1	1.0	.09	593	340	0	28	1.5		7.68
Intermediate																									
SWC #11732	143-81-02BBCB$_1$	225-230		12/5/85	21	.64	.08	29	10	460	6.7	1110	0	31	150	1.2	1.0	1.7	1310	110	0	89	19	2150	8.3
SWC #11733	143-81-02BBCB$_2$	158-163		12/5/85	24	.06	.1	44	18	400	7.5	928	0	1.6	220	1.0	1.0	.63	1210	180	0	82	13	1280	8.24
SWC #11727	143-81-02BCAB	198-203		12/4/85	25	.15	.11	45	16	420	7.0	1030	0	130	94	.6	1.0	.8	1270	180	0	83	14	2000	8.23
SWC #11721	143-81-02BCBC$_1$	198-203		12/5/85	24	.29	.06	37	12	450	7.2	1090	6	86	120	.8	1.0	1.6	1290	140	0	87	17	1750	8.34
SWC #11770	143-81-03ABAA$_1$	263-268		6/9/86	15	.06	.03	15	7	450	3.8	933	36	210	41	.6	1.0	2.3	1240	67	0	93	24		8.7
SWC #11771	143-81-03ABAA$_2$	158-163		6/9/86	24	.06	.51	89	36	260	7.0	817	0	210	34	.3	1.0	.5	1020	370	0	60	5.9		8.19
SWC #11735	143-81-03ADAD$_2$	178-183		12/4/85	24	.05	.25	66	22	370	9.6	960	0	170	67	.5	1.0	.66	1240	260	0	75	10	2050	8.27
SWC #11739	143-81-03ADBA	178-183		12/4/85	25	.18	.18	35	11	450	6.8	1090	0	94	110	.8	1.0	1.5	1290	130	0	87	17	2000	8.3
SWC #8939	143-81-03BAA	157-163		2/25/86	27	.03	.4	69	32	170	9.3	603	0	150	23	.3	1.0	.26	821	300	0	54	4.3	1000	7.9
Painted Woods Golf	143-81-03BAAD	160-190		6/6/86	26	4.6	.46	91	39	230	7.6	809	0	160	46	.4	1.0	.48	974	390	0	56	5.1		7.82
Alluvial Sediments																									
SWC #11772	143-81-03ABDA	158-163		6/9/86	26	1.6	.43	88	30	310	7.2	920	0	150	60	.5	1.0	.51	1130	340	0	66	7.3		8.26
SWC #11769	143-81-03BABD	163-168		6/6/86	25	.17	.34	94	35	180	7.0	695	0	140	31	.4	1.0	.5	825	380	0	50	4.0	1425	8.07
SWC #8932	143-81-04ADD$_1$	260-263		10/25/73	22	2.2	.16	34	13	300	5.5	748	12	59	80	1.1	1.9	.56	911	140	0	82	11	1460	8.4
SWC #8932$_A$	143-81-04ADD$_2$	170-173		10/26/73	23	2.0	.14	47	15	200	6.7	616	0	68	33	.8	.9	.43	697	180	0	70	6.5	1120	8.0
Deep Confined																									
SWC #11726	143-81-02BDBC	268-273		12/4/85	26	.46	.09	41	20	430	7.1	1050	0	160	80	.6	1.0	1.4	1300	190	0	83	14	2250	8.07
SWC #3897	143-81-02BCC$_1$	255-258		11/6/69	33	.12		43	8.9	443	4.5	1180	8	91		.8			1250	144	0	87	16	2080	8.3
SWC #11768	143-81-03BBAD	263-268		6/6/86	29	2.3	.33	84	32	170	6.7	678	0	110	41	.4	.3	.43	781	340	0	51	4	623	8.18
SWC #11767	143-81-03BBDD	258-263		6/6/86	27	.29	.1	43	14	400	6.1	922	14	21	170	.7	.5	1.0	1100	170	0	83	11.3	15	8.41
SWC #11763	143-81-04AAAD	258-263		6/6/86	26	1.4	.18	73	29	270	7.0	819	4	140	57	.5	.2	.65	976	300	0	65	6.8	1520	8.29
Misc.																									
SWC #11725	143-81-02BACC$_2$	35-40		12/4/85	26	4.7	1.1	256	81	230	8.9	699	0	860	57	.3	1.0	.3	1950	1610	1038	34	2.5	2450	7.73

TABLE 4 - 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 physiologically 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.