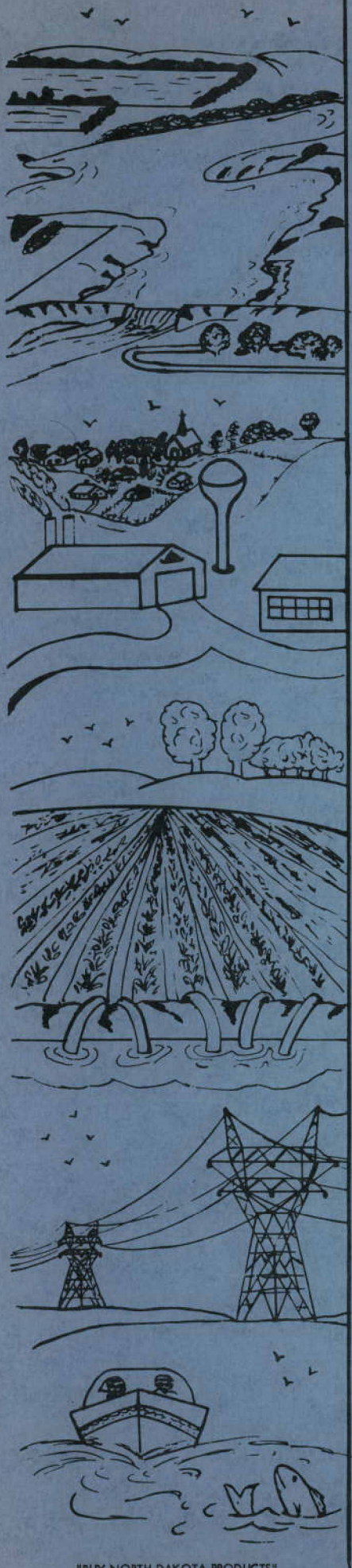


"BUY NORTH DAKOTA PRODUCTS"

GROUND WATER IN THE VICINITY OF DICKINSON, STARK COUNTY, NORTH DAKOTA

SWCC PROJECT NO. 748

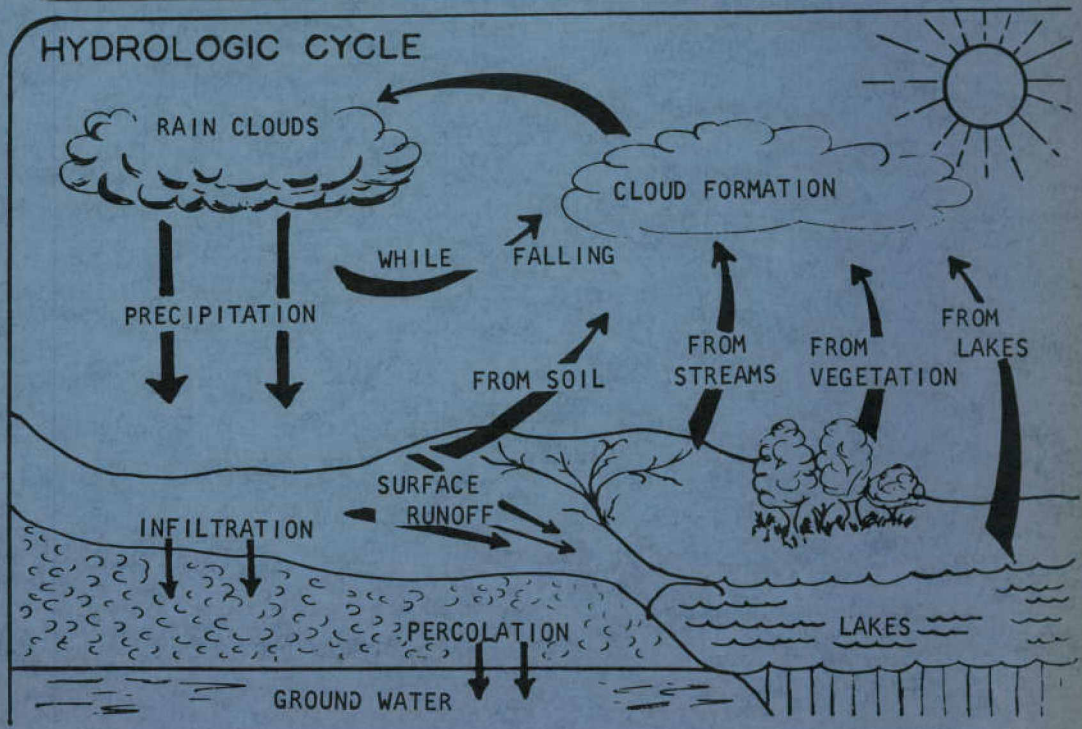
BY
R. W. SCHMID, GEOLOGIST

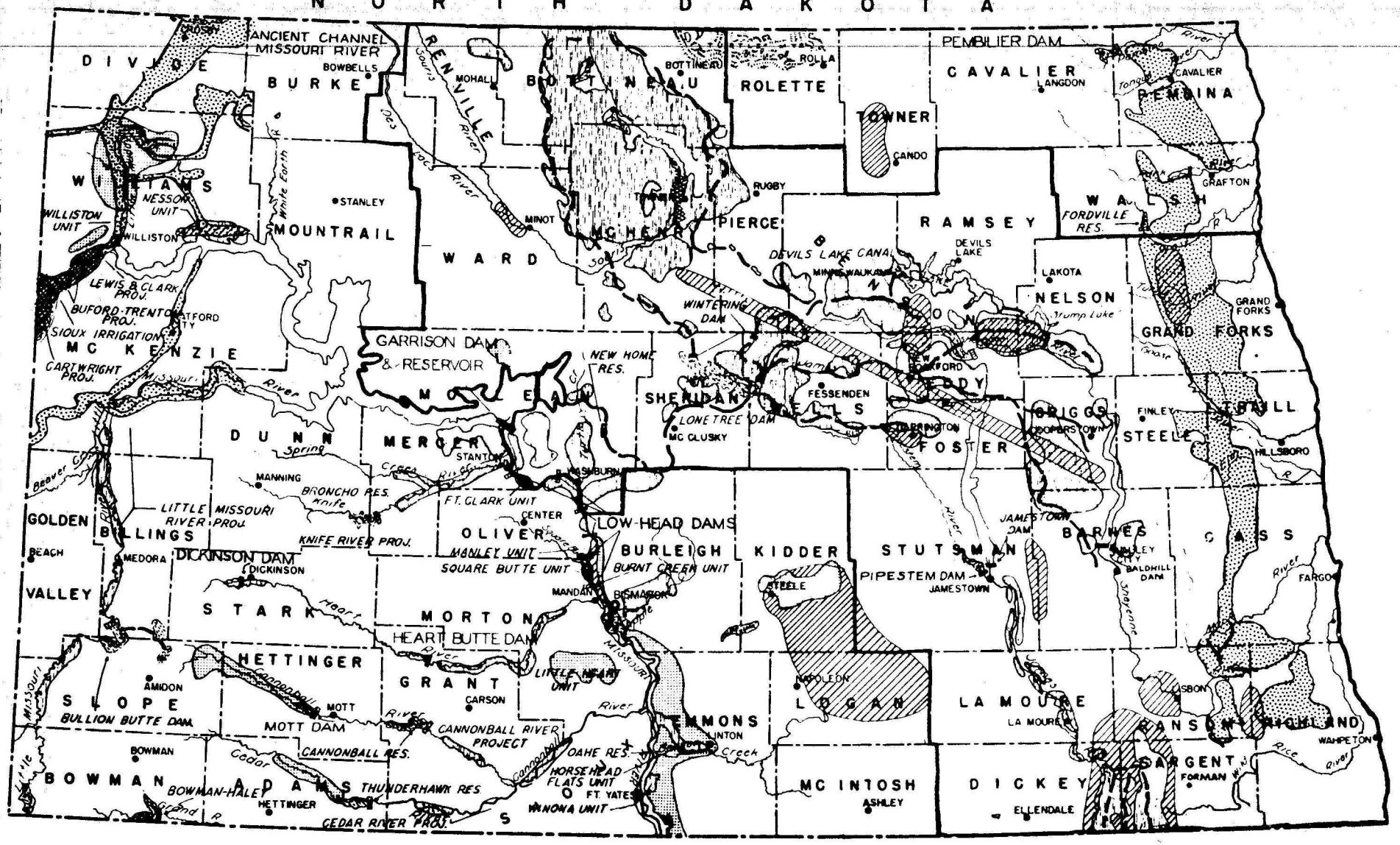
NORTH DAKOTA GROUND WATER STUDIES

NO. 51

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

1963





NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

WATER RESOURCES DEVELOPMENT PLAN

LANDS UNDER IRRIGATION

AREAS CONSIDERED IRRIGABLE

AREAS BEING INVESTIGATED

PROPOSED FOR INVESTIGATION

EXISTING

UNDER CONSTRUCTION OR PROPOSED

DAM & RESERVOIR SITES

PROPOSED CANALS

GARRISON DIVERSION CONSERVANCY DISTRICT BOUNDARY

GROUNDWATER AQUIFERS

Gov. William L. Guy
CHAIRMAN
OSCAR LUNSETH
VICE CHAIRMAN
MILO W. HOISVEEN
SECRETARY AND STATE ENGINEER
RICHARD P. GALLAGHER
MATH DAHL
WILLIAM W. CORWIN
EINAR H. DAHL
HENRY J. STEINBERGER

NORTH DAKOTA STATE WATER CONSERVATION COMMISSION

NEWS RELEASE

April 8, 1963

Water Commission Releases Dickinson and Bottineau Groundwater Study Reports

Groundwater study reports of the Bottineau and Dickinson areas were released today by the State Water Conservation Commission.

The reports contain geologic maps, logs of test holes drilled, chemical analyses, test boring location maps, and an analysis of the geology and hydrology of the areas.

An aquifer with good potential as a source of good quality water for Dickinson was located, according to the report. An aquifer is defined as a water-bearing bed of earth, gravel, or porous stone which contains and transmits ground water. Roger W. Schmid, Commission Geologist, is author of the Dickinson report. The City of Dickinson has expressed a desire to proceed with a pump test which would provide them with a safe water withdrawal record of the field. The test would be conducted under the direction of the State Water Conservation Commission.

Ground water is available in adequate quantity in the Bottineau area according to the report entitled "Investigation of Ground Water Conditions in the Bottineau Area". Larry L. Froelich, Commission Geologist, is author of the Bottineau report.

Copies of both reports are available from the Commission office 1301 State Capitol, Bismarck, North Dakota.

NORTH DAKOTA
STATE WATER CONSERVATION COMMISSION

1301 STATE CAPITOL — CAPITOL 3-8000, EXT. 41

BISMARCK, NORTH DAKOTA

WATER RESOURCES DEVELOPMENT CREATES WEALTH

LETTER OF TRANSMITTAL

RE: Groundwater Study Reports

We are enclosing a copy of a groundwater study report published by the State Water Conservation Commission because of your interest in such reports released by this office.

Should you desire further information regarding this report, feel free to contact the State Water Conservation Commission office in Bismarck.

Sincerely yours,

Milo W. Hoisveen

Milo W. Hoisveen
Engineer-Secretary

MWH:hs

Mimeo #160

GROUND WATER IN THE VICINITY OF DICKINSON, STARK COUNTY, NORTH DAKOTA
SWCC PROJECT NO. 748

By
R. W. Schmid, Geologist

NORTH DAKOTA GROUND WATER STUDIES NO. 51

Published By
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
1301 State Capitol, Bismarck, North Dakota

-1963-

CONTENTS

	Page
INTRODUCTION	1
WELL-NUMBERING SYSTEM	2
PHYSIOGRAPHY AND GEOLOGY	3
HYDROLOGY	4
WATER QUALITY	5
RECOMMENDATIONS	6
REFERENCES	34

BASIC DATA TABLES
AND ILLUSTRATIONS

		Page
Table 1.	Chemical Analyses of Water From the Dickinson Area	8
2.	Water Quality Standards	10
3.	Logs of Test Holes	11

		Following Page
Figure 1.	Physiographic Provinces of North Dakota and Location of Dickinson Area	1
2.	Sketch Illustrating Well-Numbering System	1
3.	Map of Dickinson Area Showing Test Holes and Water Sample Locations	2
4.	Geologic Map of Dickinson Area	3
5.	Map of Aquifer Area Northwest of Dickinson	4
6.	Cross-section A-A'	5
7.	Cross-section B-B'	5
8.	Cross-section C-C'	5

GROUND WATER IN THE VICINITY OF DICKINSON STARK COUNTY, NORTH DAKOTA

INTRODUCTION

Dickinson, population 9,971 (1960 census), is in northcentral Stark County. The City is served by a main line of the Northern Pacific Railroad, U. S. Highway 10 and State Highway 22. Dickinson is located near the center of the 270 square mile study area (figures 1 and 3).

The average annual precipitation recorded by the U. S. Weather Bureau Station at Dickinson from 1892 to 1960 was 15.50 inches. Most of the precipitation occurs during the growing season. The mean annual temperature for the same period was 40.7°F.

This study was made by the North Dakota State Water Conservation Commission during August of 1962 for the purpose of locating additional water supplies for Dickinson. The City now obtains its municipal water supply from Edward Arthur Patterson Lake, locally known as the Dickinson Reservoir, and a number of wells located within the City limits in the northern part of Dickinson.

The wells and reservoir produce insufficient amounts of water during peak demands. Water from the reservoir has to be treated extensively because of algae and colloidal bentonite in the reservoir. The wells, some more than 30 years old, have been pumped much harder than natural recharge replenishes the supply and are therefore uneconomical due to high pumping costs and low output.

Simpson (1929) briefly discussed the ground water resources of Stark County in a general study of the whole state. McLaughlin and Greenlee (1946) reported on the ground water and geology at Dickinson in North Dakota Ground

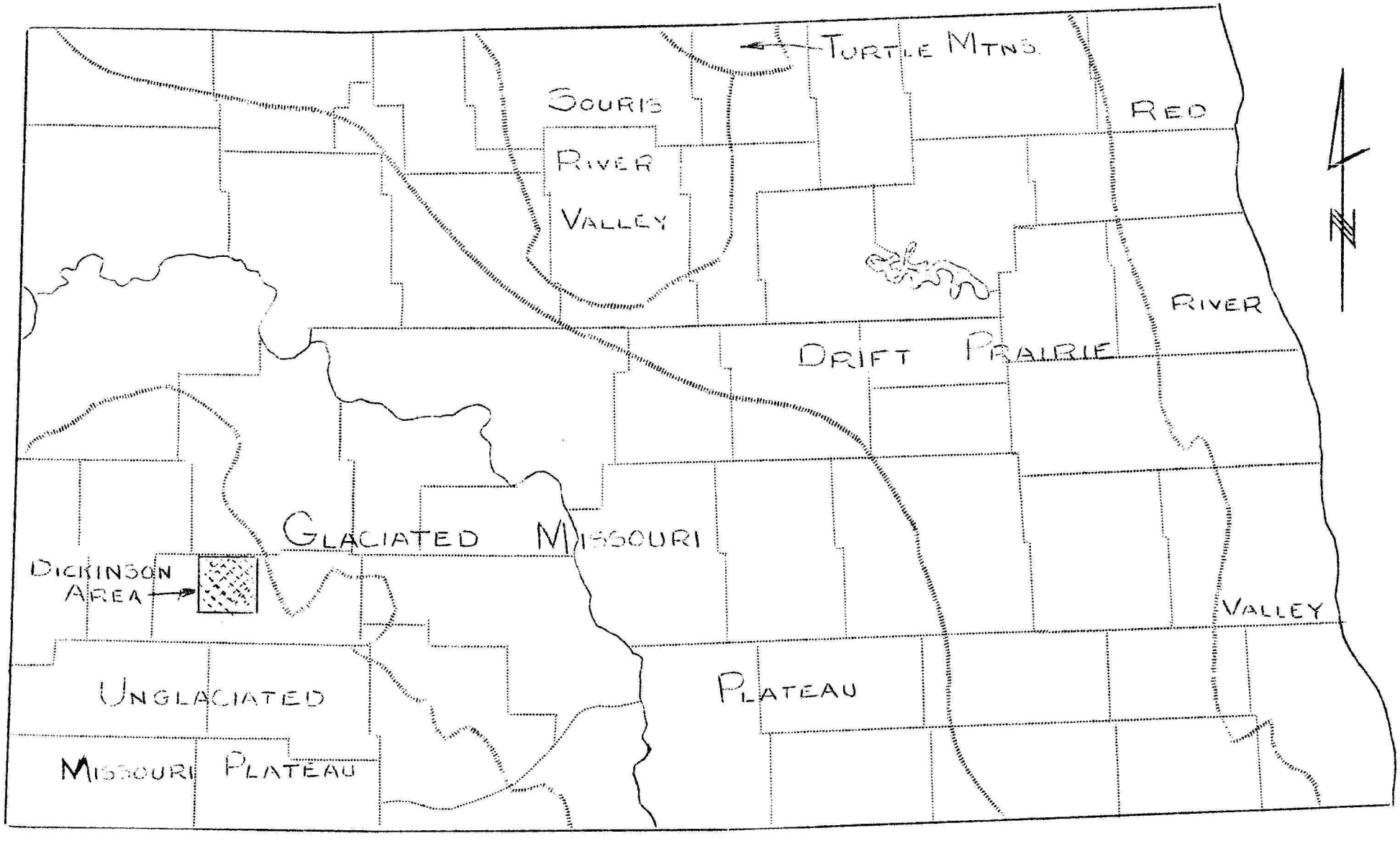


FIGURE I. PHYSIOGRAPHIC PROVINCES IN NORTH DAKOTA AND LOCATION OF THE DICKINSON AREA (Modified from Simpson, 1929)

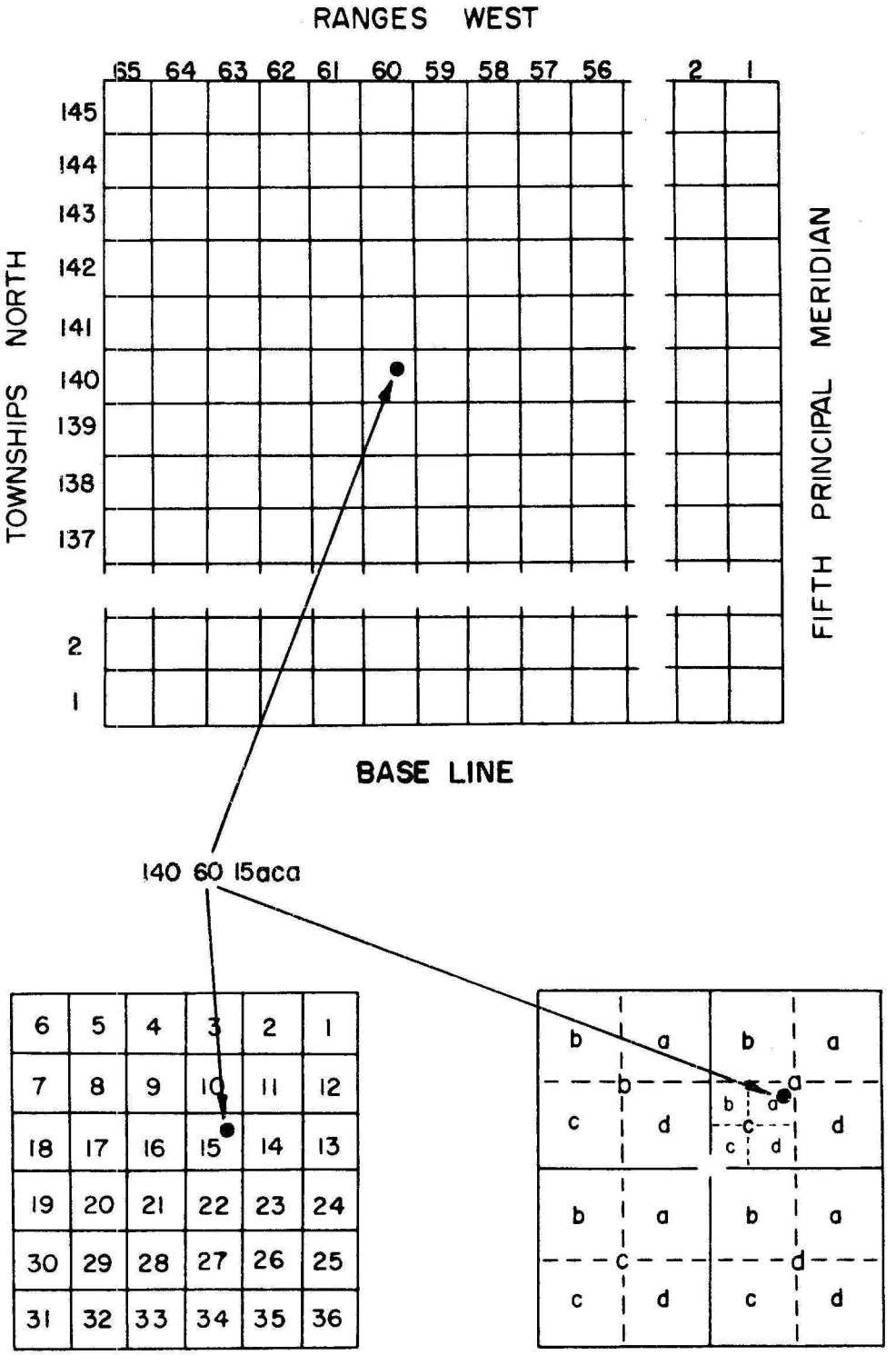


Figure 2 -- Sketch illustrating well-numbering system

Water Studies No. 3. The Chamber of Commerce (1947) of Dickinson released a report on the "Water Supply Problem" of Dickinson.

The cooperation of City officials, City engineer Mike Cuskelly, local well drillers and residents of the area was of considerable assistance to this project. The fieldwork, including the well inventory and supervision of most of the test drilling, was done by Larry L. Froelich, Geologist, North Dakota State Water Conservation Commission.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is illustrated in figure 2 and is based upon the location of the well within the grid established by the U. S. Bureau of Land Management's survey of the area. The first numeral denotes the township north of the base line which extends laterally across the middle of Arkansas; the second numeral denotes the range west of the fifth principal meridian, and the third numeral denotes the section in which the well is located. The letters a, b, c, and d, designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections (10-acre tracts). Thus, well 140-60-15aca is in the NE¼SW¼NE¼ of Sec. 15, T. 140 North, R. 60 W. Similarly, well 139-96-6aaa is the well located in the NE¼NE¼NE¼ of Sec. 6, T. 139 North, R.96 W.

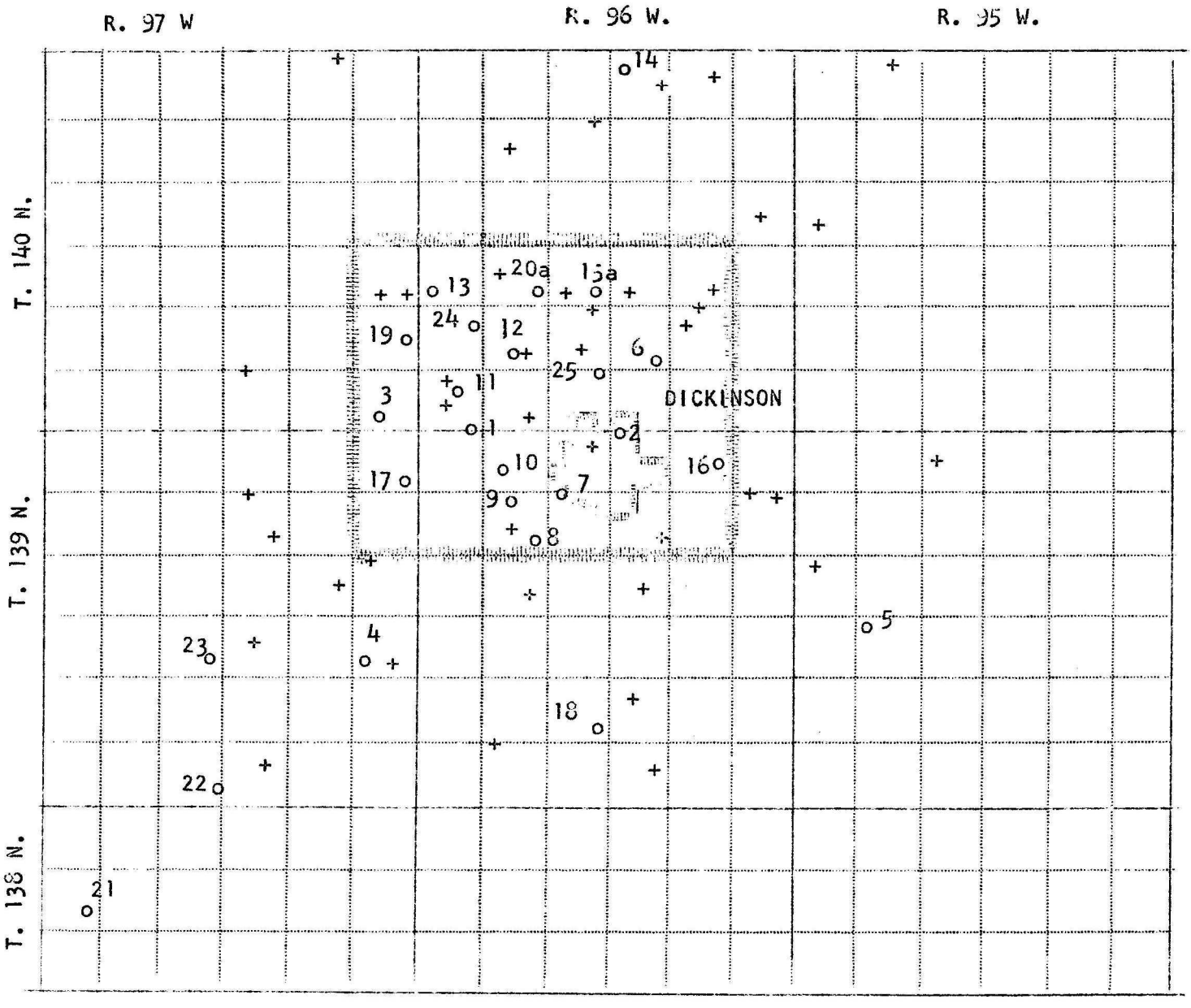


FIGURE 3. MAP OF DICKINSON AREA SHOWING TEST HOLES AND WATER SAMPLE LOCATIONS

PHYSIOGRAPHY AND GEOLOGY

Dickinson is located in the unglaciated Missouri Plateau Section of the Great Plains Province (Fenneman,1931). The rolling prairie and abrupt buttes in the area are the result of erosion by the Heart River and its tributaries.

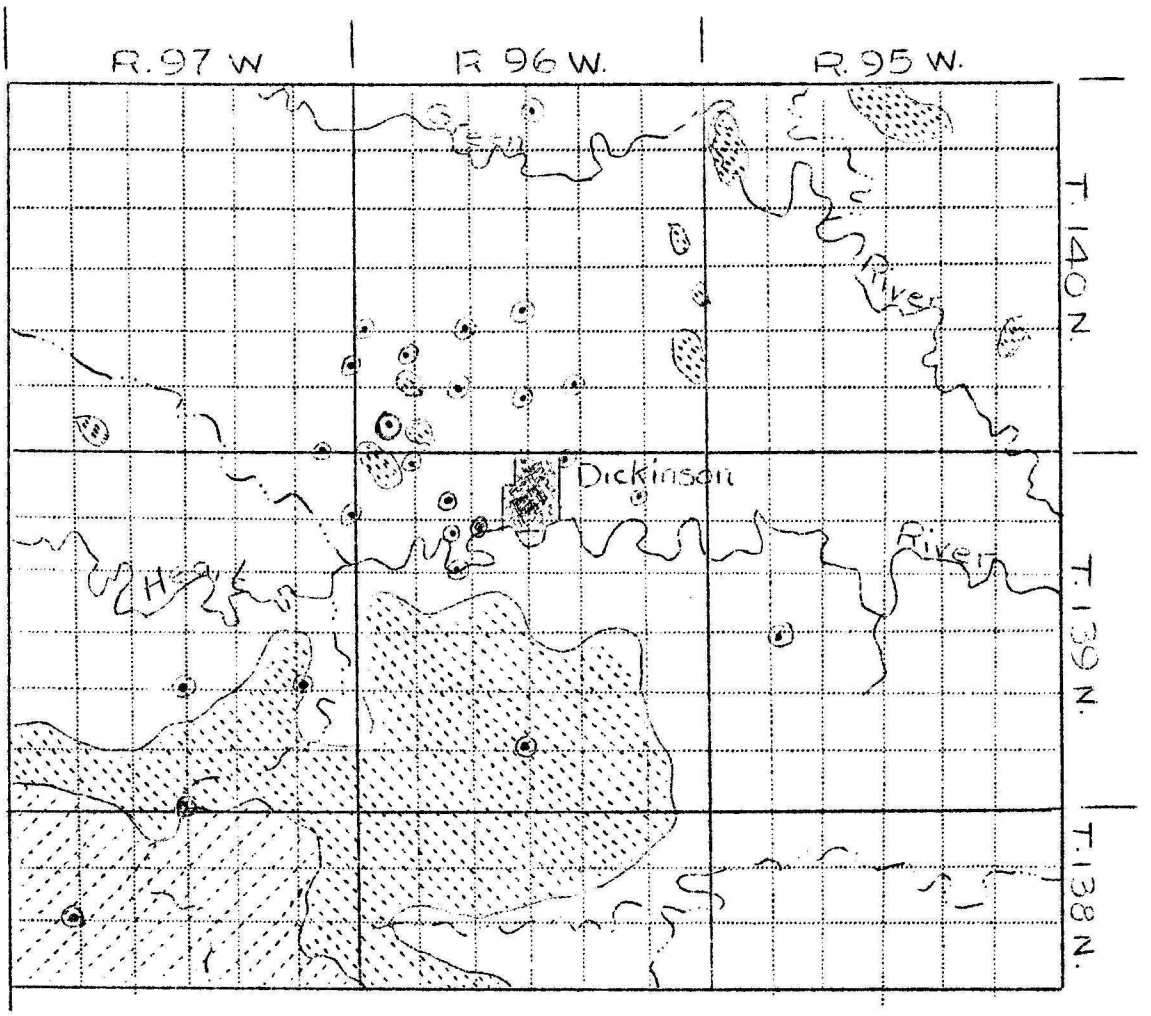
Elevations in the area range from less than 2300 feet above sea level in the Heart River Valley on the east side of the area to more than 2800 feet in the southwest corner of the area. The areal relief is therefore over 500 feet. Local relief ranges from less than 20 feet per mile up to as much as 290 in less than a mile at Davis Butte northeast of Dickinson.

The Tongue River Formation of Paleocene age is the oldest formation exposed in the area. This formation, of the Fort Union Group, consists of clay, shale, silt, sand, sandstone, and lignite. The Tongue River Formation, penetrated in all test holes, underlies the entire area and makes up the greatest percentage of the surface area (figure 4). The sand and lignite of this formation are important aquifers in the area.

The Golden Valley Formation of Eocene age consists of sand, silt,shale, and clay that is generally lighter in color than the underlying Tongue River sediments. Davis Butte northeast of Dickinson is an example of the sediments of this formation. Sand strata of the Golden Valley Formation, particularly near the base of the formation, are important aquifers in the area southwest of Dickinson (test holes 21 and 22-748).

In the southwest corner of the study area the White River Formation of Oligocene age overlies the erosional surface of the Golden Valley Formation. This formation (test hole 21-748) consists of sand, clay, siltstone, and sandstone. The "haystack" buttes in the Little Badlands are capped by erosion re-

FIGURE 4. GEOLOGIC MAP OF THE DICKINSON AREA
(from Hansen, 1956)



Oligocene Age:
White River Formation

Eocene Age:
Golden Valley Formation

Paleocene Age:
Tongue River Formation

0.3 " = 1 Mile

⊙ Indicates test hole location - for number see Figure 2.

sistant bentonitic clays (Holland, 1957). The basal sand of this formation could be an important aquifer to the farms and ranches in the area.

Erosion taking place since the deposition of the formations outlined above has formed the present topography. In some areas there are small amounts of alluvial material. Alluvium on hills and slopes, such as the gravel on the north side of the Green River, is probably of Pleistocene age and is usually above the water table. Alluvium in valleys, such as the flood plain of the Heart River, is probably Pleistocene and/or Recent. Valley alluvium is generally too thin to provide any substantial amounts of water.

Hydrology

Water bearing strata were encountered in nearly all test holes (table 3). The most promising ground water aquifer encountered during the study lies northwest of Dickinson between Highways 10 and 22 (figure 5). This area extends north to approximately the Heart-Green River drainage divide which is also the probable location of the ground water divide between the two rivers. The entire recharge area of this aquifer has not been delineated.

The area around test holes 11-748 and 1-748 (figure 6) has the best quality water (analyses 140-96-31bd and ca). The sand in these locations extends from the surface or near surface to a depth of 70 to 85 feet; the lower 50 to 55 feet of which is saturated. This sand is fine to medium and contains very little clay. The permeability should be considerably better than at the present city wells.

Test holes 20A-748 and 24-748 (figure 7) were predominantly sand to depths of 210 and 135 feet respectively; the former contains about 200 feet of

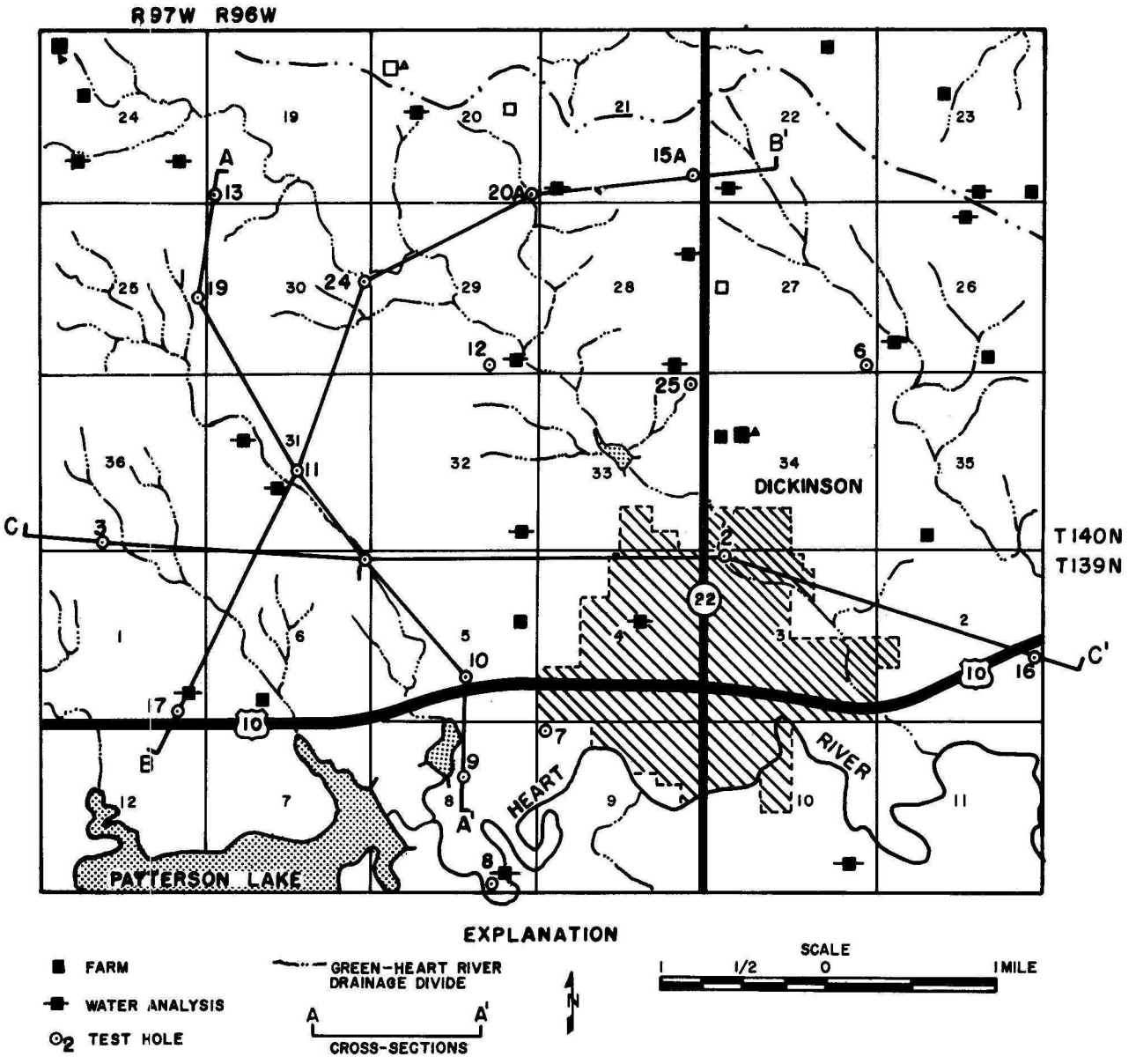


FIGURE 5--MAP OF AQUIFER AREA NORTHWEST OF DICKINSON

saturated sand. The sand in this part of the aquifer is quite clayey, therefore, the aquifer is less permeable in this area. Water quality in the vicinity of 20A-748 is fair (analysis 140-96-21cc).

Test hole 17-748 (figure 7) contained many separate sand lenses which are probably a southern extension of the aquifer. A nearby water analysis (139-97-1dd) showed excellent quality; however, it is not known if all the lenses contain the same type of water. On the northern edge of the aquifer only 55 feet of sand was encountered in test hole 13-748 (figure 6) but the water from a nearby farm (140-97-24dd) was of excellent quality.

The eastern portion of the area shown on figure 5 has very poor quality water (analyses 140-96-22cc through 140-96-29dd). The better quality water farther west is probably a result of the more direct recharge of that area. Since ground water collects mineral constituents while moving from area of recharge to area of discharge the water in the eastern part of the area is more mineralized than that in the west. The sand strata in this eastern area (test holes 2, 12, 15A, and 25-748) is of rather low permeability because of the high clay content of the sand strata. The present city wells are also in this same area of low permeability and poor water quality (analysis 139-96-4ac).

Water Quality

Most of the 42 samples analyzed (table 1) were taken from farm wells as a part of the field work for this study; 13 of the analyses were taken from previous publications and North Dakota State Department of Health records. The data indicates that water quality in the Dickinson area is variable and the water quality standards (table 2) indicate that many of the samples are beyond

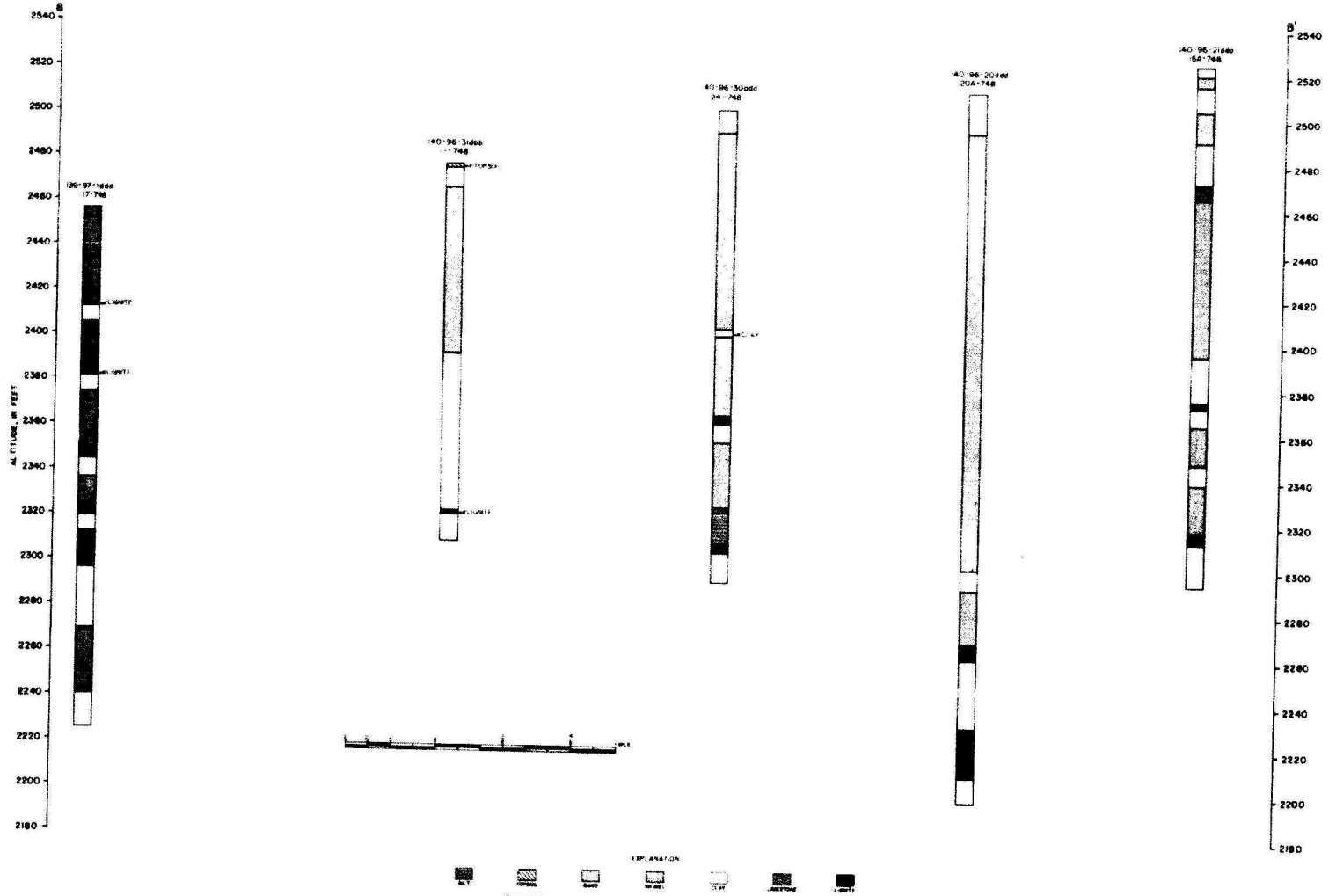


FIGURE 7.--GEOLOGIC SECTION B-B' IN THE DICKINSON AREA

LOCATION OF SECTION SHOWN IN FIGURE 5.

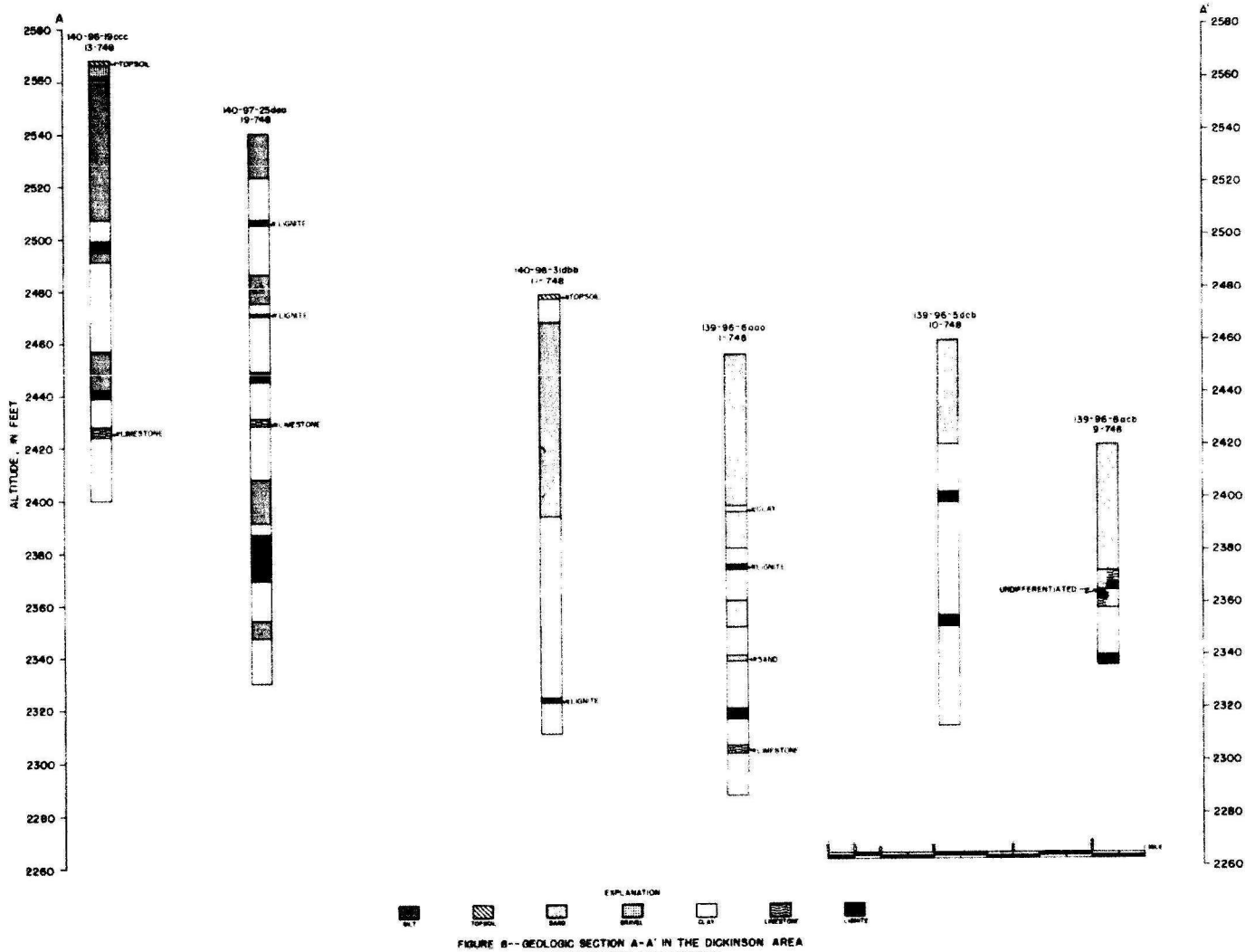


FIGURE 8--GEOLOGIC SECTION A-A' IN THE DICKINSON AREA

(LOCATION OF SECTION SHOWN IN FIGURE 81

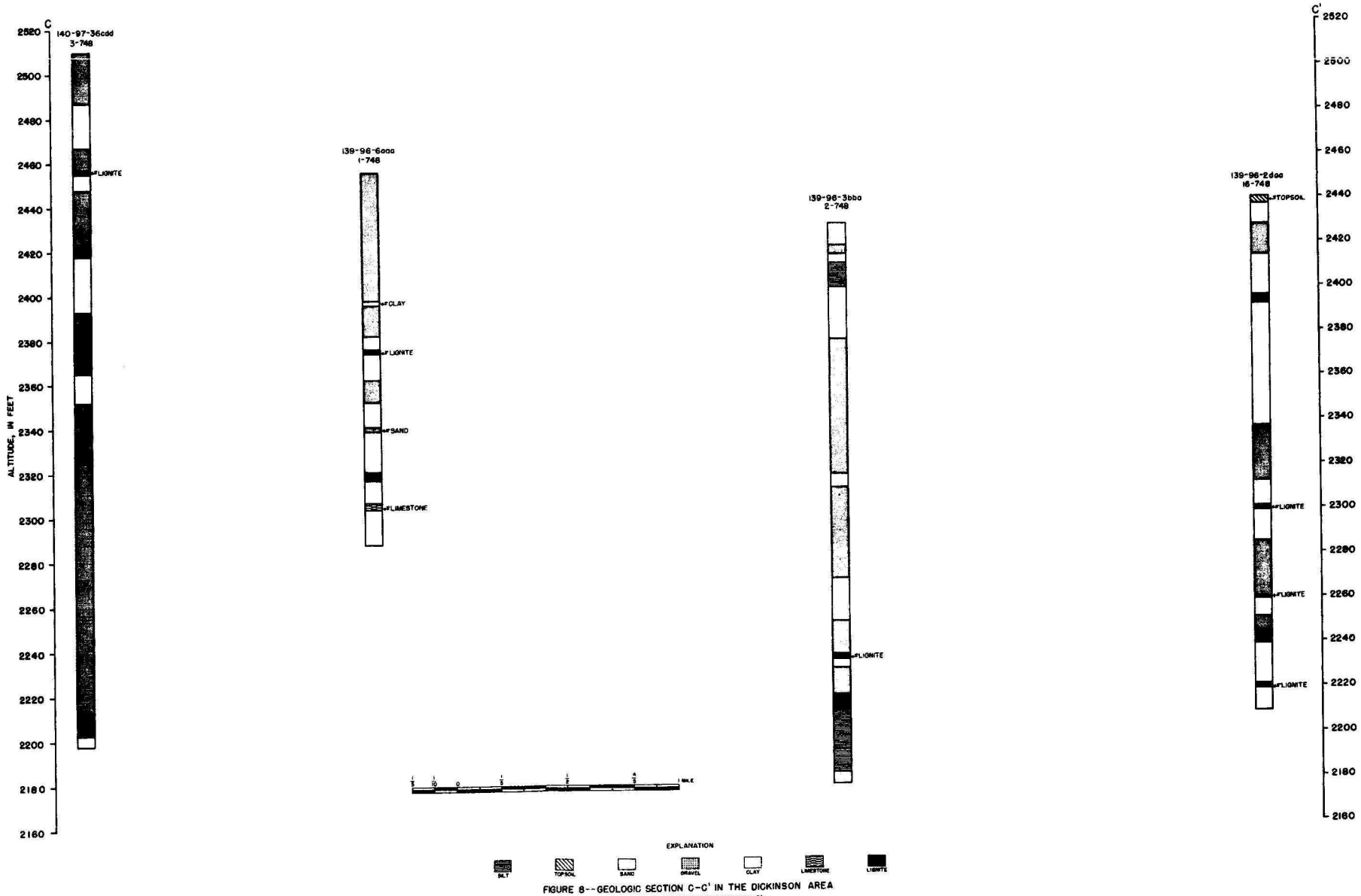


FIGURE 8--GEOLOGIC SECTION C-C' IN THE DICKINSON AREA

(LOCATION OF SECTION SHOWN IN FIGURE 5)

the permissible concentrations. These concentrations are only recommended limits, however, and in actual practice less than $\frac{1}{4}$ of the analyses could be classified as unusable. The best samples are the two analyses from 140-96-31, on the other hand 140-96-26ca was the worst sample taken. This latter quality of water is permissible for cattle, sheep and horses, but exceeds the recommended level for humans, poultry and swine. The best two analyses (140-96-31) were said to be "unusually good quality water" by the State Laboratories Department.

Recommendations

If the individual test holes and water analyses discussed in the two previous sections are viewed as a group there is one locality where further investigations should begin; this is Section 31 of Township 140 North, Range 96 West. The sand aquifer, while not thick, is quite permeable and the water analyses are excellent. Since there is only about 50 feet of saturated sand, under water table conditions, this location should be tested to determine the quantity of water that may be obtained from wells in the immediate area.

A pumping test in the area would provide an estimate of permissible pumping rates. Ideally a new well should be drilled and completed to city specifications for this purpose since most domestic and stock wells aren't constructed for the high capacities necessary in a city well. A pumping test could be performed by using an existing well; this however would probably give incomplete data.

It is possible that a pumping test in the 140-96-31 area would indicate that this area is incapable of producing sufficient water for Dickinson. In such a case the area toward test holes 24-748 and 20A-748 should be further

investigated. Although the sand is less permeable in this area there is a much greater thickness of saturated aquifer. Additional wells could also be drilled between test hole 11-748 and Dickinson if a further need became apparent.

Although the recharge area of this aquifer is not completely defined it is quite possible that improved practices of land use and road design to reduce surface runoff and increase recharge to the aquifer could make a noticeable improvement in the long range production of the aquifer. Increased recharge would also keep the poorer quality water from the east from moving into the heavily pumped area.

TABLE 1.-------

Analyses in parts per million except pH

Location	Sample Source	Depth (feet)	Source of Analysis a/	Date	Iron Fe	Calcium Ca	Magnesium Mg
139-95-4cb	Anton Wanner	121	State	8-17-62	1.2		
139-95-18ba	Angilo Messina	105	State	8-17-62	0.9		
139-96-4ac	City of Dickinson	154	USGS	7-18-47	0.05	9.0	7.0
139-96-8dd	T.H. 8-748, flow	357	State	9- 4-62	3.9		
139-96-10dd	Brown	120	USGS	7-18-47	0.05	107	59
139-96-12ab	Dickinson Riding Stables	25	USGS	7-18-47	0.05	215	120
139-96-12bb	S. L. Carroll	60	USGS	10- 6-46	0.3	82	49
139-96-27bd	L. J. Krank	130	State	8-17-62	1.2		
139-96-34da	W. P. Schmidt	65	State	8-17-62	1.7		
139-97-1dd		50	USGS	7-18-47	0.05	64	46
139-97-10ba	M. R. Hellman	52	State	9- 4-62	0.9		
139-97-10dd		40	USGS	7-18-47	0.05	325	113
139-97-13bb		34	USGS	7-18-47	0.25	57	24
139-97-14da		40	USGS	7-18-47	0.05	313	97
139-97-22ca	G. F. Weiler	12-15	State	8-17-62	0.2		
139-97-24dc	George Roller	48	State	8-17-62	1.7		
139-97-34ac	J. P. Clarys	18	State	8-17-62	0.2		
140-95-5bd	Ludwig Barta	25	State	8-17-62	1		
140-95-18cd	Roland Svihl	90	State	8-17-62	0.3		
140-96-2da	Joe Vrona	25	State	8-17-62	0.2		
140-96-3ad	J. A. Hondhl	40	State	8-17-62	0.2		
140-96-8ca	Jacob Kaintz	150	State	9- 4-62	2.8		
140-96-9aa	Ester Fisher	35	State	8-17-62	3.0		
140-96-13ca	Vince Ridl	150	Health	5- 4-59		22.6	13.0
140-96-13ca	Vince Ridl	87	Health	5- 4-59		75.0	51.6
140-96-20bc	Jack Ehrmantraut	135	State	8-31-62	2.2		
140-96-21cc	Frank Wock	75	State	12- 5-62	1.1		
140-96-22cc			State	12- 5-62	3.6		
140-96-23dc	U.S. Air Force #1	176	Health	2-28-61	1.6	196	19
140-96-26ab	U.S. Air Force #2	178	Health	2-28-61	5.2	80	56
140-96-26cc	Wilbert Hewson	40	State	8-31-62	2.2		
140-96-28ad	Louie Pribyl	165	State	8- 4-62	1.0		
140-96-28dd	A. J. Schwindt	100	State	12- 5-62	1.0		
140-96-29dd	Ludwig Filipi	89	State	9- 4-62	7.9		
140-96-31bd	Paul Frenzel	40	State	12- 5-62	0.1		
140-96-31ca	J. J. Kadrmas	65	State	8-31-62	0.3		
140-96-32dd	Experiment Station	85	State	12- 5-62	0.2		

Chemical Analyses of Water From the Dickinson Area

Sodium Na	Bicarbonate $CaCO_3$ b/	Sulphate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3	Total Hardness $CaCO_3$	Total Dissolved Solids c/	pH
	444	297	2		Trace	110	942	7.9 @ 30°C
	504	155	22		Trace	110	800	8.0 @ 30°C
574	729	528	7	0.2	.5	51	1600	8.4
	520	266	8		Absent	20	1206	8.6 @ 25°C
508	574	1020	12	0.2	1.2	510	2070	7.1
245	404	1100	10	0.5	1.5	1030	1980	7.3
	703	1660	9.6	0.8	0.8	406	3200	7.8
	588	333	8		Absent	40	1142	8.0 @ 30°C
	180	86	4		Absent	190	326	7.6 @ 30°C
66	332	133	14	0.7	12	349	566	7.1
	516	699	16		12	720	1660	7.3 @ 25°C
178	443	1140	12	0.1	18	1276	2080	7.1
89	314	109	6	0.4	.3	241	481	7.4
134	331	970	95	0.4	1.2	1180	1850	7.3
	260	183	14		12	350	626	7.9 @ 30°C
	268	219	8		Absent	170	629	7.6 @ 30°C
	352	241	26		24	350	824	7.6 @ 30°C
	616	317	12		Trace	550	1156	7.2 @ 30°C
	244	171	83		305	620	1240	7.5 @ 30°C
	148	137	73		Absent	320	562	7.6 @ 30°C
	380	344	68		183	670	1506	7.6 @ 30°C
	816	234	6		Trace	20	1264	7.8 @ 25°C
	268	315	6		Trace	300	760	7.0 @ 30°C
1017	557	1665	12.6	1.2	Trace	110	3427	7.7
1325	68	570	17.6		Trace	400	932	5.7
	344	58	4		Trace	290	435	6.9 @ 25°C
	436	258	Absent		Absent	564	855	7.1 @ 23°C
	368	1373	14		3	1120	2480	7.2 @ 23°C
180	376	550	3		4.4	570	1424	
178	142	650	3		4.4	430	1154	
	344	3201	42		122	1170	4990	6.7 @ 25°C
	784	407	4		Absent	24	1502	7.8 @ 25°C
	608	828	32		92	610	2070	7.5 @ 23°C
	380	726	6		Absent	810	1510	7.1 @ 25°C
	80	91	Absent		18	120	195	7.1 @ 23°C
	192	80	6		Trace	170	299	7.1 @ 25°C
	420	275	Absent		Trace	360	858	7.3 @ 23°C

TABLE 1. continued

Analyses in parts per million except pH

Location	Sample Source	Depth (feet)	Source of Analysis a/	Date	Iron Fe	Calcium Ca	Magnesium Mg
140-97-2aa	E. L. Rambousek	25	State	8-31-62	0.3		
140-97-24cc	Louis Zahradnik	58	State	8-31-62	0.3		
140-97-24dd	J. V. Ridl & Sons	40	State	12- 5-62	0.1		
140-97-34bb	Norman Zander	36	State	9- 4-62	0.5		

a/ Analyses done by the State Laboratories Department (State), U. S. Geological Survey (USGS), or the North Dakota State Department of Health (Health)

b/ USGS and Health analyses converted from HCO_3

c/ Health TDS are obtained by summation of ions while State TDS are obtained by evaporation, the latter method is more reliable.

Chemical Analyses of Water From the Dickinson Area

Sodium Na	Bicarbonate $CaCO_3$ b/	Sulphate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3	Total Hardness $CaCO_3$	Total Dissolved Solids c/	pH
	440	622	20	73	73	460	1460	7.2 @ 25°C
	348	388	16		12	610	1020	7.2 @ 25°C
	220	152	8		24	264	382	7.4 @ 23°C
	504	458	8		Trace	470	1176	7.2 @ 25°C

Chemical Analyses of Water From the Dickinson Area

Sodium Na	Bicarbonate $CaCO_3$ b/	Sulphate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3	Total Hardness $CaCO_3$	Total Dissolved Solids c/	pH
	440	622	20	73	73	460	1460	7.2 @ 25°C
	348	388	16		12	610	1020	7.2 @ 25°C
	220	152	8		24	264	382	7.4 @ 23°C
	504	458	8		Trace	470	1176	7.2 @ 25°C

Chemical Analyses of Water From the Dickinson Area

Sodium Na	Bicarbonate $CaCO_3$ b/	Sulphate SO_4	Chloride Cl	Fluoride F	Nitrate NO_3	Total Hardness $CaCO_3$	Total Dissolved Solids c/	pH
	440	622	20	73	73	460	1460	7.2 @ 25°C
	348	388	16		12	610	1020	7.2 @ 25°C
	220	152	8		24	264	382	7.4 @ 23°C
	504	458	8		Trace	470	1176	7.2 @ 25°C

TABLE 2.--Water Quality Standards
From North Dakota State Department of Health
Sanitary Engineering Services

Characteristic	Permissible Concentrations (Parts per million except pH)	Objections To Excessive Concentrations
Iron (Fe)	0.3	Esthetic Staining of Laundry
Magnesium (Mg)	125	Possible Laxative Effect
Sodium (Na)	250	Possible Physiological Effect
Sulphates (SO_4)	250	Possible Laxative Effect
Chloride (Cl)	250	Possible Laxative Effect
Fluoride (F)	1.5	Mottled Teeth
Nitrate (NO_3)	43.4	Possible Physiological Effect (toxic to infants)
Total Solids	1000-1500	Possible Laxative Effect
pH	Less than 10.6	Possible Laxative Effect

TABLE 3--Logs of Test Holes

The following test hole logs are a composite of information from the driller's log, the geologist's sample description, and the resistivity and potential electric logs.

Color nomenclature, from Goddard, et. al. (1951), indicates the color of wet samples.

The grain size classification is C. K. Wentworth's scale from Truesdell and Varnes (1950).

Elevations were estimated from $7\frac{1}{2}$ minute quadrangle maps with 10 foot contour intervals. Altimeter readings were used where no maps were available (Test holes 21, 22 and 23-748).

Formation	Material	Thickness (feet)	Depth (feet)
	138-97-7ddd T.H.21-748 Elevation 2643 feet		
White River Formation:			
	Silt, pinkish gray, highly calcareous, oxidized.....	16	16
	Silt, light brown, sandy, calcareous.....	4	20
	Siltstone, pale olive, with granular size spherical concretions.....	15	35
	Siltstone, light brown, calcareous.....	4	39
	Clay, pale blue green, slightly calcareous.....	1	40
	Clay, grayish orange pink, slightly calcareous, with sand sized quartz grains.....	25	65
	Clay, very pale orange, slightly calcareous with sand sized quartz grains.....	20	85
	Clay, light greenish gray, slightly calcareous, with sand sized quartz grains	10	95
	Sand, medium to very coarse, clayey (pale blue green) predominantly quartz.....	15	110

TABLE 3 --Logs of Test Holes -- Continued

Formation	Material	Thickness (feet)	Depth (feet)
	138-97-7ddd T.H.21-748 Elevation 2643 feet (continued)		
Golden Valley Formation:			
	Clay, light greenish gray, slightly lignitic	3	113
	Clay, light greenish gray and light olive brown, partially oxidized, slightly lignitic	4	117
	Silt, grayish blue green	15	132
	Clay, variegated (black, brown, purple green etc.)	17	149
	Sand, very fine to fine, subangular, predominantly quartz	46	195
	Sand, fine to coarse, subrounded, predominantly quartz, with some brown shale	29	224
	Silt, greenish gray, with some very fine sand and lignite flecks	22	248
Tongue River Formation:			
	Clay, very light gray with some very fine to medium quartz sand	69	317
	Silt, olive gray, with some lignitic material	43	360
	139-95-20bbb T.H.5-748 Elevation 2495 feet		
Tongue River Formation:			
	Sand, fine, silty, subrounded, predominantly quartz, oxidized	4	4
	Clay, moderate olive brown, silty	6	10
	Sand, clayey, poorly sorted, oxidized	29	39
	Sandstone, fine, calcareous cement, greenish gray	2	41
	Sand, silty, subangular, moderate yellowish brown, oxidized	16	57
	Sandstone, fine, calcareous cement, greenish gray	9	66
	Sand, pale to grayish olive, slightly calcareous, partially oxidized	9	75
	Sand, medium bluish gray	15	90
	Clay, dark greenish gray	10	100
	Lignite	5	105

TABLE 3 --Logs of test holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-95-20bbb T.H. 5-748 Elevation 2495 feet (continued)		
	Clay, dark greenish gray, silty.....	11	116
	Lignite.....	5	121
	Clay, dark greenish gray, silty.....	6	127
	Clay, light greenish gray.....	39	166
	Lignite.....	10	176
	Clay, light greenish gray.....	11	187
	Clay, olive gray.....	14	201
	Sand, fine, greenish gray, predominantly quartz, some mica and lignitic material.	57	258
	Limestone, well indurated.....	2	260
	Sand, fine, greenish gray, predominantly quartz, some mica and lignitic material.	2	262
	Sandstone, fine, greenish gray, with calcareous cement.....	3	265
	Sand, fine, clayey, greenish gray, predominantly quartz.....	53	318
	Clay, olive gray, calcareous.....	4	322
	Limestone, well indurated.....	3	325
	139-96-2daa T.H.16-748 Elevation 2440 feet		
Tongue River Formation:			
	Topsoil, sandy with fragments of concretions.....	3	3
	Clay, light olive gray, silty, oxidized...	9	12
	Sand, fine, silty, dusky yellow subrounded, oxidized.....	14	26
	Clay, light olive gray to olive gray.....	18	44
	Lignite.....	4	48
	Clay, greenish gray.....	10	58
	Clay, olive gray to dark greenish gray, silty.....	45	103
	Sandstone, fine, light greenish gray, calcareous cement.....	2	105
	Sand, fine to medium, dark greenish gray..	3	108
	Sandstone, fine, light greenish gray, calcareous cement.....	2	110
	Sand, fine to medium, dark greenish gray..	18	128
	Clay, light olive gray.....	11	139
	Lignite.....	2	141
	Clay, light olive gray, with lignitic material.....	14	155

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-96-2daa T.H.16-748 Elevation 2440 feet (continued)		
	Sand, fine to medium, clayey, dark greenish gray	25	180
	Limestone, indurated	½	180½
	Lignite	½	181
	Clay, olive gray, silty	8	189
	Limestone, indurated	1	190
	Sand, fine to medium, clayey, dark greenish gray, predominantly quartz	5	195
	Lignite	6	201
	Clay, light olive gray, lignitic material in lower 5 feet	18	219
	Lignite	2	221
	Clay, light olive gray, lignitic material in upper 5 feet	10	231
	139-96-3bba T.H. 2-748 Elevation 2430 feet		
Alluvium:			
	Clay, dusky yellow, silty, calcareous, oxidized	10	10
	Sand, very fine, yellowish olive, slightly calcareous, oxidized	4	14
Tongue River Formation:			
	Clay, yellowish olive, silty, lignitic material, oxidized	4	18
	Silt, yellowish olive gray, partially oxidized	11	29
	Clay, bluish greenish gray with silt, sand and lignitic material	11	40
	Clay, variegated (blue, green, brown and gray) with lignitic material	12	52
	Sand, very fine, clayey, dark greenish gray	16	68
	Sandstone, very fine to fine, calcareous cement, light gray, predominantly rounded frosted quartz	3	71
	Sand, very fine, clayey, dark greenish gray	42	113
	Clay, dark greenish gray, calcareous	6	119
	Limestone, light olive gray, indurated	1	120
	Sand, fine, clayey, greenish gray, lignitic material	40	160

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-96-3bba T.H. 2-748 Elevation 2430 feet (continued)		
	Clay, light olive gray, silty, lignitic material	19	179
	Sand, fine, very clayey, greenish gray	15	194
	Lignite	2	196
	Clay, light olive gray to brownish gray, lignitic material	4	200
	Sand, fine, clayey, greenish gray	12	212
	Lignite	7	219
	Silt, light olive gray, lignitic material	28	247
	Clay, brownish gray, abundant lignitic material	5	252
	139-96-5dcb T.H. 10-748 Elevation 2460 feet		
Tongue River Formation:			
	Sand, fine, light olive gray, predominantly quartz	35	35
	Sand, fine, light olive gray with limonite stains, oxidized	5	40
	Clay, light olive gray	18	58
	Lignite	4	62
	Clay, light olive gray	23	85
	Clay, light olive gray, with lignite seams	20	105
	Lignite	4	109
	Clay, light olive gray, silty	30	139
	Clay, light olive gray	8	147
	139-96-6aaa T.H. 1-748 Elevation 2455 feet		
Tongue River Formation:			
	Sand, fine, clayey, yellowish oxidized	5	5
	Sand, fine, moderate olive brown, predominantly quartz, oxidized	9	16
	Sand as above plus many calcareous grains	8	24
	Sand, fine, medium bluish gray to dark greenish gray, subrounded	34	58

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-96-6aaa T.H. 1-748 Elevation 2455 feet (continued)		
	Clay, light olive gray, silty, calcareous..	2	60
	Sand, fine, bluish greenish gray.....	3	63
	Sand, fine, bluish greenish gray, well sorted subrounded, predominantly quartz..	11	74
	Clay, light olive gray, slightly calcareous	6	80
	Lignite.....	2	82
	Clay, olive gray.....	12	94
	Sand, fine, clayey, light olive gray, slightly calcareous.....	6	100
	Sandstone, fine, light olive gray, slightly calcareous, indurated.....	4	104
	Clay, olive grey to greenish gray, lignitic material.....	11	115
	Sandstone, fine, light olive gray,indurated	2	117
	Clay, olive gray, with lignite and silt....	18	135
	Lignite.....	4	139
	Clay, olive gray, with lignite and silt....	10	149
	Limestone, olive gray, indurated.....	3	152
	Clay, light olive gray.....	16	168
	139-96-8acb T.H.9-748 Elevation 2420 feet		
Alluvium:			
	Topsoil, sandy.....	1	1
	Sand, poorly sorted, moderate yellowish brown, subangular to rounded, composition varied, calcareous, oxidized.....	4	5
Tongue River Formation:			
	Sand, fine, well sorted, subrounded clayey, yellowish brown, oxidized.....	5	10
	Sand, fine, moderate olive brown, calcareous, oxidized.....	25	35
	Sand, fine, clayey, greenish gray.....	13	48
	Undifferentiated - clay, sand, limestone, sandstone and lignite, greenish to brownish gray, thin seams.....	14	62
	Clay, olive gray.....	18	80
	Lignite.....	4	84

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-96-8ddc T.H. 8-748 Elevation 2395 feet		
Alluvium:			
	Sand, fine, brownish gray, moderately sorted, oxidized	4	4
	Sand, fine, clayey, brownish gray, oxidized	7	11
	Sand, fine to medium, well sorted, brownish gray, slightly calcareous, oxidized	2	13
	Gravel, very poorly sorted, brownish gray, angular to subrounded, oxidized	5	18
Tongue River Formation:			
	Clay, olive gray, silty	22	40
	Sand, fine, very clayey, greenish gray	7	47
	Lignite	3	50
	Clay, olive gray, silty	14	64
	Sand, fine, clayey, greenish gray	8	72
	Lignite with interbedded brownish gray clay	8	80
	Lignite	4	84
	Clay, light olive gray, silty	6	90
	Sand, fine, very clayey, dark greenish gray	6	96
	Sand, fine, very clayey, abundant lignitic material, greenish black	10	106
	Sand, fine, clayey, brownish gray	10	116
	Sand, fine, subrounded, some clay, greenish gray	23	139
	Clay, olive gray	8	147
	Lignite	2	149
	Clay, olive gray	9	158
	Lignite	1	159
	Clay, olive gray	21	180
	Lignite	4	184
	Clay, olive gray	4	188
	Lignite	1	189
	Clay, olive gray, some sand	4	193
	Clay, light greenish gray, shard-like quartz particles	13	206
	Sand, fine, brownish olive gray, highly calcareous, predominantly quartz	21	227
	Limestone, brownish gray	3	230
	Silt, olive gray	12	242
	Clay, brownish black to brownish gray, abundant lignitic material	6	248
	Lignite	12	260
	Clay, brownish gray, abundant lignitic material	4	264

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-96-8ddc T.H. 8-748 Elevation 2395 feet (continued)		
	Clay, olive gray, silty.....	20	284
	Sand, fine, clayey, greenish gray predominantly quartz, some lignitic areas	44	328
	Silt, greenish gray.....	17	345
	Sand, fine, clayey, greenish gray, abundant lignitic material.....	12	357
	139-96-9bbb T.H. 7-748 Elevation 2428 feet		
Alluvium:			
	Topsoil.....	1	1
	Gravel, fine to very coarse, poorly sorted calcareous, oxidized.....	3	4
	Sand, fine, well sorted, moderate olive brown, some gravel, oxidized.....	25	29
Tongue River Formation:			
	Sand, fine, clayey, greenish gray, some lignitic material, slightly calcareous...	3	32
	Clay, light olive gray, silty.....	12	44
	Sand, fine, greenish gray, calcareous.....	15	59
	Clay, bluish olive gray.....	6	65
	Lignite.....	2	67
	Clay, light olive gray, silty.....	18	85
	Lignite.....	1	86
	Clay, light olive gray.....	21	107
	Lignite.....	5	112
	Clay, very light olive gray.....	15	127
	Clay, olive gray, lignitic material.....	12	139
	Silt, light greenish gray.....	16	155
	Lignite.....	21	176
	Clay, olive gray.....	13	189
	139-96-28ddd T.H. 18-748 Elevation 2560 feet		
Golden Valley Formation:			
	Clay, light olive gray, very silty to sandy.....	58	58

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-96-28ddd T.H.18-748 Elevation 2560 feet (continued)		
	Clay, yellowish brown, very silty to sandy, oxidized	13	71
	Clay, light olive gray, very silty to sandy, partially oxidized	9	80
	Silt, dark greenish gray, lignitic material grading into		
	Sand, fine to medium, dark greenish gray, micaceous	12	92
Tongue River Formation:			
	Clay, dark greenish gray, silty,micaceous	10	102
	Lignite	2	104
	Clay, olive gray, lignitic material	6	110
	Silt, dark greenish gray, micaceous	6	116
	Clay, olive gray, lignitic material	8	124
	Lignite	10	134
	Sand, fine, dark greenish gray	13	147
	Sand, fine to medium, greenish black, abundant lignitic material	46	193
	Clay, light olive gray, silty	4	197
	Lignite	4	201
	Silt, dark greenish gray, clayey	9	210
	139-97-1ddd T.H.17-748 Elevation 2456 feet		
Tongue River Formation:			
	Sand, fine to medium, moderate olive brown, slightly calcareous, oxidized	7	7
	Sandstone, fine to medium, yellowish gray, calcareous cement, oxidized	4	11
	Sand, fine to medium, moderate olive brown, slightly calcareous, partially oxidized	23	34
	Sand, fine to medium, dark greenish gray, slightly calcareous	9	43
	Lignite	1	44
	Clay, medium gray	7	51
	Sand, fine, very clayey, dark greenish gray	22	73
	Lignite	2	75

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-97-1ddd T.H.17-748 Elevation 2456 feet (continued)		
	Clay, greenish black, abundant lignitic material	7	82
	Sand, fine, clayey greenish gray, calcareous	26	108
	Lignite	4	112
	Clay, light greenish gray to greenish gray lignitic inclusions	8	120
	Sand, fine, clayey, greenish gray, calcareous	17	137
	Clay, variegated (green, white, blue and black), abundant lignitic material	7	144
	Lignite	16	160
	Clay, olive gray	19	179
	Clay, greenish gray, silty	3	182
	Clay, olive green	5	187
	Sand, fine to medium, dark greenish gray, predominantly quartz, micaceous, (197 to 199 indurated, calcareous cement)	29	216
	Clay, olive gray, silty, micaceous, some lignitic material	15	231
	139-97-21ddd T.H.23-748 Elevation 2509 feet		
Tongue River Formation:			
	Sand, very fine, clayey, grayish yellow to dusky yellow, oxidized	15	15
	Clay, dark yellowish orange, oxidized	6	21
	Concretionary zone, claystone	1	22
	Sand, fine to medium, dusky blue green	16	38
	Silt, greenish gray	8	46
	Rock, no sample	1	47
	Clay, olive gray, lignitic material	9	56
	Silt, light olive gray, calcareous	8	64
	Clay, greenish gray to dark greenish gray, sandy, lignitic material	11	75
	Clay, greenish gray, sandy, lignitic material, calcareous	9	84
	Clay, light olive gray, calcareous	3	87

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-97-21ddd T.H.23-748 Elevation 2509 feet (continued)		
	Lignite.....	5	92
	Clay, olive gray to greenish black, silty, some lignitic material.....	13	105
	Undifferentiated Shale, dark greenish gray Shale, olive gray, silty, calcareous Lignite in 105 to 112 zone.....	14	119
	Sand, very fine to fine, clayey, greenish gray, calcareous.....	7	126
	Silt, light olive gray, calcareous.....	4	130
	Sand, very fine, clayey, greenish gray, calcareous.....	6	136
	Sandstone, very fine, calcareous.....	2	138
	Clay, dark greenish gray, calcareous.....	6	144
	Silt, olive gray, calcareous.....	3	147
	Sandstone, fine, calcareous.....	1	148
	Clay, olive gray, calcareous.....	12	160
	Lignite.....	4	164
	Sand, very fine, clayey, dark greenish gray, lignitic material slightly calcareous.....	6	170
	Silt, olive gray, slightly calcareous.....	6	176
	Sand, very fine to fine, clayey, greenish gray, lignitic material, slightly calcareous.....	6	182
	Sand, very fine to medium, clayey medium bluish gray, slightly calcareous.....	10	192
	Clay, olive gray, silty, slightly calcareous, lignitic areas.....	4	196
	Clay, olive black to brownish black, abundant lignite.....	7	203
	Undifferentiated, Silt, olive gray, sandy, calcareous Silt, dark greenish gray, clayey Lignite.....	27	230
	Silt, dark greenish gray to olive gray.....	17	247
	Silt, dark greenish gray, sandy, slightly calcareous.....	5	252
	Sand, very fine, clayey, abundant lignitic material, calcareous.....	21	273
	Sandstone and lignite.....	5	278

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-97-21ddd T.H.23-748 Elevation 2509 feet (continued)		
	Silt, olive gray, lignitic material.....	7	285
	Clay, brownish black, lignite.....	5	290
	Silt, greenish gray to light olive gray, lignitic material.....	5	295
	Silt, light olive gray to yellowish gray...	3	298
	Sand, very fine, clayey, greenish gray, lignitic material, calcareous.....	17	315
	139-97-24ccc T.H. 4-748 Elevation 2475 feet		
Tongue River Formation:			
	Topsoil.....	4	4
	Silt, dusky yellow, calcareous, oxidized...	8	12
	Silt, pale yellowish brown, lignitic material, oxidized.....	4	16
	Silt, grayish orange to dusky yellow, some lignitic material, oxidized.....	12	28
	Silt, medium dark gray, some very fine, dark greenish gray sand.....	30	58
	Sand, very fine, clayey, dark greenish gray, predominantly quartz.....	4	62
	Silt, medium dark gray.....	3	65
	Sand, very fine to medium, medium bluish gray, predominantly quartz.....	21	86
	Claystone, light olive gray, slightly calcareous, well to slightly indurated...	6	92
	Sand, very fine to medium, medium bluish gray, predominantly quartz.....	8	100
	Sandstone, very fine to medium, medium bluish gray, predominantly quartz, highly calcareous cement.....	2	102
	Sand, very fine to medium, medium bluish gray, calcareous.....	10	112
	Sand, very fine to medium, medium bluish gray with lignite.....	6	118
	Clay, olive gray, silty, some lignitic material.....	10	128
	Sand, very fine to fine, silty, light bluish gray to light olive gray.....	7	135

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-97-24ccc T.H. 4-748 Elevation 2475 feet		
	Clay, olive gray, silty with lignite.....	7	142
	Sand, very fine, light olive gray, some lignitic material.....	16	158
	Silt, brownish gray to brownish black with lignitic material and lignite.....	14	172
	Clay, greenish gray, some lignitic material, calcareous.....	23	195
	Silt, light olive gray.....	5	200
	Silt, medium bluish gray, some lignitic material.....	6	206
	Sand, very fine to fine, clayey, greenish gray.....	8	214
	Clay, olive gray, calcareous.....	2	216
	Lignite.....	7	223
	Clay, dark greenish gray, silty, some lignitic material.....	11	234
	Silt, olive black to brownish black, clayey, lignitic material.....	3	237
	Silt, light greenish gray, clayey, some lignitic material.....	4	241
	Silt, greenish gray, clayey.....	5	246
	Claystone, grayish orange, slightly calcareous, well to slightly indurated..	2	248
	Silt, light greenish gray to greenish gray, sandy grading into Sand, very fine to fine, silty.....	57	305
	Lignite and claystone grayish orange, slightly calcareous, well to slightly indurated.....	3	308
	Silt, light olive gray, sandy.....	3	311
	Clay, greenish gray, silty, slightly calcareous.....	5	316
	Silt, greenish gray to olive gray, sandy, lignitic material, calcareous.....	20	336

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-97-33ddd T.H.22-748 Elevation 2536 feet		
Alluvium:			
	Sand, very fine to fine, clayey, predominantly quartz, slightly calcareous.....	2	2
	Silt, brownish gray, clayey to sandy, unsorted, calcareous, oxidized.....	12	14
	Gravel, fine, sandy, unsorted, with pale yellowish brown, highly calcareous, silty, clay, oxidized.....	10	24
	Sand, very fine to coarse, clayey, unsorted, calcareous, oxidized.....	8	32
Golden Valley Formation:			
	Silt, greenish gray, sandy with rocky areas, probably concretions.....	43	75
	Silt, olive gray.....	7	82
	Sand, very fine to medium, clayey, greenish gray to dark greenish gray.....	12	94
	Silt, light olive gray, laminated, slightly calcareous, some lignitic material.....	12	106
	Sand, very fine, clayey, predominantly quartz.....	7	113
	Clay, olive gray, to olive black, silty, laminated, abundant lignitic material....	24	137
	Silt, greenish gray, some lignitic material, calcareous.....	8	145
	Sand, very fine, silty, calcareous.....	16	161
	Clay, dark greenish gray, silty, some lignitic material.....	13	174
	Clay, yellowish gray to olive gray some areas calcareous.....	6	182
	Silt, dark greenish gray, some lignitic material.....	28	210
	Sand, very fine to fine, dark greenish gray, lignitic material.....	39	249
Tongue River Formation:			
	Clay, lignitic, dusky yellowish brown.....	3	252
	Sand, very fine to fine, dark greenish gray, clayey, lignitic material.....	8	260
	Clay, greenish gray, abundant lignitic material.....	5	265
	Clay, dark greenish gray to olive gray, silty.....	4	269

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	139-97-33ddd T.H.22-748 Elevation 2536 feet (continued)		
	Lignite	2	227
	Clay, dark greenish gray, silty	10	281
	Sand, very fine, clayey, greenish gray	14	295
	Lignite	4	299
	Shale, olive gray, calcareous	7	306
	Rock, no samples	1	307
	Silt, grayish blue green to dark greenish gray, lignitic material	12	319
	Rock, no samples	2	321
	Clay, variegated (brown, green, gray, blue etc.), silty, some lignitic material	39	360
	140-96-3bcc T.H.14-748 Elevation 2470 feet		
Tongue River Formation:			
	Sand, fine, clayey, light olive gray, calcareous, oxidized	3	3
	Clay, light olive brown, calcareous	29	32
	Clay, dark greenish gray, silty	1	33
	Sand, fine, clayey, dark greenish gray, calcareous	7	40
	Sandstone, fine, greenish gray, calcareous cement	3	43
	Sand, fine to medium, clayey, dark greenish gray	22	65
	Lignite	5	70
	Clay, greenish gray	6	86
	Lignite	24	110
	Clay, olive gray	10	120
	Clay, greenish gray	9	129
	Sand, fine to medium, clayey, dark greenish gray	71	200
	Sandstone, fine, greenish gray,calcareous.	1	201
	Sand, fine to medium, clayey, olive gray to dark greenish gray, calcareous	21	222
	Silt, light olive gray, clayey,calcareous.	9	231

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	140-96-19ccc T.H.13-748 Elevation 2568 feet		
Alluvium (Pleistocene)	Topsoil	2	2
	Gravel, fine to coarse, sandy, unsorted, subangular, oxidized	4	6
Tongue River Formation:	Sand, fine to medium, clayey, moderate olive brown, calcareous, oxidized	8	14
	Sand, fine to coarse, partially oxidized	47	61
	Clay, light olive gray	8	69
	Lignite	4	73
	Sand, clayey, olive gray, lignitic material	4	77
	Clay, light olive gray, silty	23	100
	Clay, light olive gray, lignite seams	11	111
	Sand, fine to medium, clayey, dark greenish gray, predominantly quartz	15	126
	Lignite	3	129
	Clay, light olive gray	11	140
	Limestone, yellowish gray	4	144
	Clay, light olive gray, silty	24	168
	140-96-20ddd T.H.20A -748 Elevation 2512 feet		
Tongue River Formation:	Clay, dusky yellow, silty, oxidized	2	2
	Clay, light olive gray, very silty, oxidized	16	18
	Sand, fine yellowish olive gray, silty, oxidized	39	57
	Sand, fine to medium, clayey, greenish gray	101	158
	Sand, fine to medium, clayey, greenish gray, with lignite seams	54	212
	Clay, silty, light olive gray, abundant lignitic material	9	221
	Sand, fine to medium, dark greenish gray, silty	24	245
	Lignite	7	252

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	140-96-20ddd T.H.20A -748 Elevation 2512 feet (continued)		
	Clay, olive gray to greenish gray, silty, abundant lignitic material.....	25	277
	Clay, olive gray, silty, lignitic material	5	282
	Lignite.....	22	304
	Clay, olive gray, silty.....	11	315
	140-96-21dda T.H.15A-748 Elevation 2525 feet		
Tongue River Formation:			
	Clay, light olive gray, silty, oxidized...	4	4
	Sand, fine, clayey, dusky yellow to moderate olive brown, slightly calcareous, oxidized.....	4	8
	Sandstone, fine, pale olive, calcareous cement, oxidized.....	1	9
	Clay, light olive gray, silty, oxidized...	11	20
	Sand, fine, clayey, dusky yellow to light olive green, slightly calcareous, partially oxidized.....	14	34
	Clay, silty, greenish gray.....	18	52
	Silt, light olive gray to olive gray.....	7	59
	Sand, fine, clayey, dark greenish gray, predominantly quartz.....	4	63
	Sandstone, fine, light greenish gray, calcareous cement.....	2	65
	Sand, fine to medium, clayey, dark greenish gray, predominantly quartz, sandstone from 103' to 107'.....	64	129
	Clay, greenish gray, lignite 149' to 152'.	31	160
	Sand, fine to medium, clayey, greenish gray.....	17	177
	Clay, silty, greenish gray to olive gray, mudstone from 182' to 183'.....	9	186
	Sand, fine to medium, clayey, dark greenish gray.....	21	207
	Lignite.....	5	212
	Clay, light gray, silty.....	19	231

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	140-96-27ddd T.H. 6-748 Elevation 2466 feet		
Tongue River Formation:			
	Clay, silty, yellowish gray, oxidized.....	12	12
	Sand, fine, oxidized.....	4	16
	Clay, olive gray, silty, slightly calcareous.....	4	20
	Clay, olive gray to greenish gray, very silty.....	13	33
	Sandstone, fine, light greenish gray.....	1	34
	Sand, fine, greenish gray, slightly calcareous.....	20	54
	Lignite.....	3	57
	Clay, greenish gray, silty.....	5	62
	Clay, greenish gray, sandy, some lignitic material.....	26	88
	Clay, brownish black, sandy, abundant lignitic material.....	33½	121½
	Sandstone.....	½	122
	Clay, light olive gray.....	11	133
	Lignite.....	2	135
	Sand, fine, clayey, dark greenish gray....	13	148
	Sandstone, light greenish gray, calcareous cement.....	3	151
	Sand, fine, clayey, greenish gray, slightly calcareous.....	6	157
	Clay, olive gray, lignite 162' to 163'....	22	179
	Lignite.....	4	183
	Clay, light greenish gray, lignitic material.....	18	201
	Clay, greenish gray, silty.....	20	221
	Clay, brownish black, silty, abundant lignitic material.....	29	250
	Lignite.....	13	263
	Clay, olive gray, lignitic material.....	33	296
	Silt, dark greenish gray to olive gray, sandy, lignitic material, slightly calcareous.....	22	318
	Sand, very fine to fine, silty, lignitic material, slightly calcareous.....	39	357
	Clay, olive gray, slightly calcareous.....	11	368
	Limestone, light greenish gray.....	2	370
	Clay, light greenish gray, calcareous.....	8	378

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	140-96-29dcd T.H. 12-748 Elevation 2500 feet		
Tongue River Formation:			
	Topsoil	2	2
	Clay, moderate olive brown, silty, oxidized	8	10
	Clay, moderate olive brown, silty, some lignitic material, oxidized	14	24
	Clay, olive gray, lignite 26' to 29'	19	43
	Silt, greenish gray	9	52
	Clay, olive gray to brownish black, lignitic material	4	56
	Lignite, brownish black, lignitic clay 59' to 60'	12	68
	Clay, brownish black, sandy, abundant lignite	16	84
	Sand, clayey, greenish gray	38	122
	Clay, light greenish gray	19	141
	Sand, clayey, greenish gray	25	166
	Clay, olive gray, lignitic seams	27	193
	Lignite	7	200
	Clay, light olive to light greenish gray	10	210
	140-96-30add T.H. 24-748 Elevation 2503 feet		
Tongue River Formation:			
	Clay, yellowish brown, sandy, oxidized	5	5
	Clay, light olive gray, sandy, oxidized	5	10
	Sand, fine to medium, yellowish gray, predominantly quartz, oxidized	15	25
	Sand, fine to medium, moderate olive brown, predominantly quartz, oxidized	15	40
	Sandstone, fine to medium, greenish gray, calcareous cement	2	42
	Sand, fine to medium, bluish gray, predominantly quartz, calcareous	27	69
	Sandstone, fine to medium, greenish gray, calcareous cement	2	71
	Sand, fine to medium, dark greenish gray, predominantly quartz, sandstone 86' to 88'	27	98

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	140-96-30add T. H. 24-748 Elevation 2503 feet (continued)		
	Clay, silty, light olive gray.....	3	101
	Sand, fine to medium, dark greenish gray, predominantly quartz.....	35	136
	Lignite.....	4	140
	Clay, light olive gray, silty.....	8	148
	Sand, fine to medium, dark greenish gray..	5	153
	Sand, fine to medium, dark greenish gray to greenish black, clayey, abundant lignitic material.....	14	167
	Sand, fine to medium, dark greenish gray, clayey.....	10	177
	Silt, olive gray, micaceous.....	16	193
	Lignite.....	4	197
	Clay, light olive gray.....	13	210
	140-96-31dbb T. H.11-748 Elevation 2478 feet		
Tongue River Formation:			
	Topsoil.....	2	2
	Clay, yellowish gray, silty, oxidized.....	9	11
	Sand, fine to medium, silty, light olive gray, predominantly quartz, partially oxidized.....	26	37
	Sand, fine to medium, silty, dark greenish gray, predominantly quartz.....	48	85
	Clay, silty, olive gray to olive black with some thin lignite seams.....	7	92
	Clay, silty, olive gray to olive black with some thin lignite seams also yellowish gray limestone stringers.....	24	116
	Clay, light olive gray to greenish gray...	4	120
	Clay, olive gray, silty.....	12	132
	Clay, greenish gray, silty to sandy.....	15	147
	Clay, greenish gray, silty to sandy, lignitic material.....	5	152
	Clay, light olive gray, silty, lignite 154' to 156'.....	16	168

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	140-96-33aaa T.H.25-748 Elevation 2510 feet		
Tongue River Formation:			
	Clay, yellowish brown, silty, oxidized....	3	3
	Silt, very clayey, yellowish gray, oxidized.....	14	17
	Silt, clayey, yellowish gray, lignitic material, oxidized.....	4	21
	Silt, clayey, olive gray, calcareous.....	9	30
	Sand, fine to medium, dark greenish gray, predominantly quartz, calcareous.....	5	35
	Lignite.....	1	36
	Silt, olive gray, highly calcareous.....	17	53
	Lignite.....	6	59
	Clay, greenish gray.....	15	74
	Clay, olive gray, silty.....	16	90
	Sand, fine to medium, dark greenish gray, predominantly quartz, abundant lignitic material.....	11	101
	Sand, fine, greenish gray.....	21	122
	Sandstone, fine, greenish gray, calcareous cement.....	3	125
	Sand, fine to medium, dark greenish gray, slightly calcareous.....	5	130
	Clay, silty olive gray, lignite 147' to 150'.....	32	162
	Sand, fine, silty to clayey, dark greenish gray.....	12	174
	Lignite.....	2	176
	Clay, brownish olive gray, abundant lignitic material.....	6	182
	Sand, fine to medium, dark greenish gray..	22	204
	Lignite.....	4	208
	Silt, light olive gray, clayey.....	23	231
	140-97-25daa T. H. 19-748 Elevation 2540 feet		
Tongue River Formation:			
	Sand, fine to medium, dark yellowish brown, predominantly quartz, oxidized...	5	5

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	140-97-25daa T. H.19-748 Elevation 2540 feet (continued)		
	Sand, fine to coarse, moderate yellowish brown to moderate olive brown, oxidized	12	17
	Clay, moderate olive brown to light olive gray, oxidized	8	25
	Clay, light olive gray	8	33
	Lignite	2	35
	Clay, silty, dark greenish gray	19	54
	Sandstone, fine, clayey greenish gray, calcareous cement	4	58
	Sand, fine, dark greenish gray, predominantly quartz, calcareous	7	65
	Clay, silty, dark greenish gray, lignitic material	4	69
	Lignite	1	70
	Clay, silty, dark greenish gray, lignitic material	15	85
	Clay, olive gray	6	91
	Lignite	4	95
	Clay, silty, greenish gray, slightly calcareous	14	109
	Limestone, medium bluish gray	3	112
	Clay, olive gray to dark greenish gray	20	132
	Sand, fine, olive gray, predominantly quartz, micaceous, calcareous	17	149
	Clay, light olive gray to olive gray	4	153
	Lignite	18	171
	Clay, silty, olive black to olive gray	15	186
	Sand, fine, greenish gray	7	193
	Clay, olive gray to greenish gray	17	210
	140-97-36cdd T. H. 3-748 Elevation 2510 feet		
Tongue River Formation:			
	Sand, very fine to medium, clayey, moderate yellowish brown, broken concretions	4	4

TABLE 3 --Logs of Test Holes --Continued

Formation	Material	Thickness (feet)	Depth (feet)
	140-97-36cdd T.H. 3-748 Elevation 2510 feet (continued)		
	Sand, very fine to medium, clayey, dusky yellow, predominantly quartz, oxidized	5	9
	Sand, very fine to medium, clayey, grayish olive, predominantly quartz, oxidized	14	23
	Clay, silty, grayish yellow to olive gray, partially oxidized	8	31
	Clay, dark greenish gray, silty	12	43
	Sand, very fine to fine, clayey, greenish gray to dark greenish gray	10	53
	Lignite	2	55
	Clay, silty, dark greenish gray, lignite seams	7	62
	Sand, clayey, dark greenish gray, predominantly quartz, some lignitic material	11	73
	Sand, very fine to fine, clayey,greenish gray	9	82
	Silt, olive gray, lignitic material	6	88
	Lignite	4	92
	Clay, light greenish gray, lignitic seams.	25	117
	Silt, olive gray, lignitic material	11	128
	Lignite	17	145
	Clay, dark greenish gray, silty, lignitic material	13	158
	Silt, greenish gray	22	180
	Sand, very fine to fine, silty greenish gray	15	195
	Sand, very fine, light olive gray, lignitic material	16	211
	Sand, very fine to medium, greenish gray, predominantly quartz	16	227
	Sand, fine to medium, greenish gray, lignitic material	70	297
	Lignite	10	307
	Clay, silty, greenish gray, lignitic material	5	312

REFERENCES

Brant, R. A., 1953, Lignite Resources of North Dakota: U. S. Geol. Survey Circular 226, 78 p.

Caldwell, J. W., 1954, Surface Structure of Western Stark County and adjacent areas of North Dakota: North Dakota Geol. Survey Report of Investigations No. 14.

Dickinson Chamber of Commerce, 1947, Water Supply Problem, Dickinson, North Dakota: City of Dickinson, 46 p.

Fenneman, N. M., 1931,Physiography of Western United States: New York, McGraw-Hall, p. 63-72.

Goddard, et. al., 1951, Rock-Color Chart: distributed by the Geological Society of America, New York, New York.

Hansen, Miller, 1956, Geologic Map of North Dakota: North Dakota Geol. Survey.

Holland, F. D. Jr., 1957, Geologic field trip in the Dickinson area: North Dakota Geol. Survey Misc. Series No. 5, 18 p.

McLaughlin, T. G., and Greenlee, A. L., 1946, Ground Water at Dickinson, North Dakota: North Dakota Ground Water Studies No. 3, 21 p.

Powell, J. E., and Paulson, Q. F., 1961, Geology and ground water resources of the Richardton area, Stark County, North Dakota: North Dakota Ground Water Studies No. 29, 40 p.

Robinove, C. J., Langford, R. H., and Brookhart, J. W., 1958, Saline Water Resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 1428, 72 p.

Simpson, H. E., 1929, Geology and Ground Water Resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 225-228.

Truesdell, P. E. and Varnes, D. J., 1950, Chart correlating various grain-size definitions of sedimentary materials: U. S. Geol. Survey.

Tychsen, P. C., and Swenson, H. A., 1950, Geology and Ground-Water Hydrology of the Heart River Irrigation Project and the Dickinson Area, North Dakota: U. S. Geol. Survey Circ. 34, p. 25-47.