UNITED STATES DEPARTMENT OF THE INTERIOR O. L. Chapman, Secretary.

GEOLOGICAL SURVEY W. E. Wrather, Director

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GEOLOGY AND GROUND-WATER HYDROLOGY OF THE HEART RIVER IRRIGATION PROJECT AND THE DICKINSON AREA, NORTH DAKOTA

By

Paul C. Tychsen

WITH A SECTION ON THE MINERAL QUALITY OF WATERS OF THE HEART RIVER PROJECT

By

Herbert A. Swenson

Compiled as part of program of Interior Department for development of the Missouri River Basin.

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GEOLOGY AND GROUND-WATER HYDROLOGY OF THE HEART RIVER IRRIGATION PROJECT AND THE DICKINSON AREA, NORTH DAKOTA

By Paul C. Tychsen

ABSTRACT

The Heart River irrigation project, in southwestern North Dakota, lies in the Missouri Plateau section of the Great Plains physiographic province, which extends from the Missouri escarpment to and beyond the western border of the State. The area ranges in altitude from 1,620 to 2,275 feet and locally has strong relief.

The floor of the Heart River Valley is underlain by alluvial deposits of Quaternary age. In the westernmost part of the area, the Fort Union formation of Paleocene (Tertiary) age forms the valley sides, but in a downstream direction the Cannonball and Ludlow formations, here undifferentiated, also of Paleocene age, crop out in the valley sides and underlie progressively broader areas of the upland surface. The Hell Creek formation of Upper Cretaceous age appears above stream level only in the stretch of the valley between the center of T. 136 N., R. 85 W., and the northeastern part of T. 137 N., R. 84 W. Glacial drift, which once covered the whole area, now has been almost entirely removed by erosion except for scattered boulders on the uplands. The Cannonball and Ludlow unit and the Fort Union formation yield moderate supplies of ground water, and the river alluvium yields more abundant supplies. At the present rate of withdrawal and with normal precipitation there is little danger of seriously depleting the supply. In 1946 the average depth to water in observation wells in the Heart River Valley was 19 feet, whereas the depth to water in observation wells in the upland averaged 30 feet.

The Dickinson area is small and is about 45 miles upstream from the Heart River irrigation project. Ground-water levels in the Dickinson municipal well field have declined considerably within recent years, but the impounding of Heart River water is expected to insure a more adequate water supply for the town.

Samples of ground water from four wells in the lower Heart River Valley were analyzed to determine the present mineral character of the waters in this region. Waters from shallow and deep wells in the Dickinson area were analyzed to assist in determining the practicability of furthur utilization of ground water as a public supply. A map showing

areas of the least-mineralized ground water in the Dickinson area is presented and the need of further exploratory work is discussed.

INTRODUCTION

Location of the Area

The Heart River, a tributary of the Missouri River, is located in southwestern North Dakota and flows in a generally east and northeast direction through parts of Stark, Grant, and Morton Counties to its confluence with the Missouri River near Mandan. The investigation covered the lower 120 miles of the course of the Heart River, and also a 9-mile portion of the Heart River Valley near Dickinson. (See fig. 1.)

Methods Used in this Investigation

The principal field work upon which this report is based was done by the writer during June, July, and August, 1946. Geologic mapping of reconnaissance nature was done to determine the relation of the geologic formations to ground-water supplies. An inventory of all existing wells in the area was made, and all available pertinent information regarding them was collected. In addition, periodic measurements of water-level fluctuations were made in representative wells. In general, altitudes of the measuring points of the wells situated in the upland areas were determined by altimeter and those along the river valley were taken from topographic maps. To obtain control as accurate as possible on altimeter altitudes, frequent checks were made on established bench marks. In some places where the bench marks were widely scattered, temporary bench marks were established by altimeter.

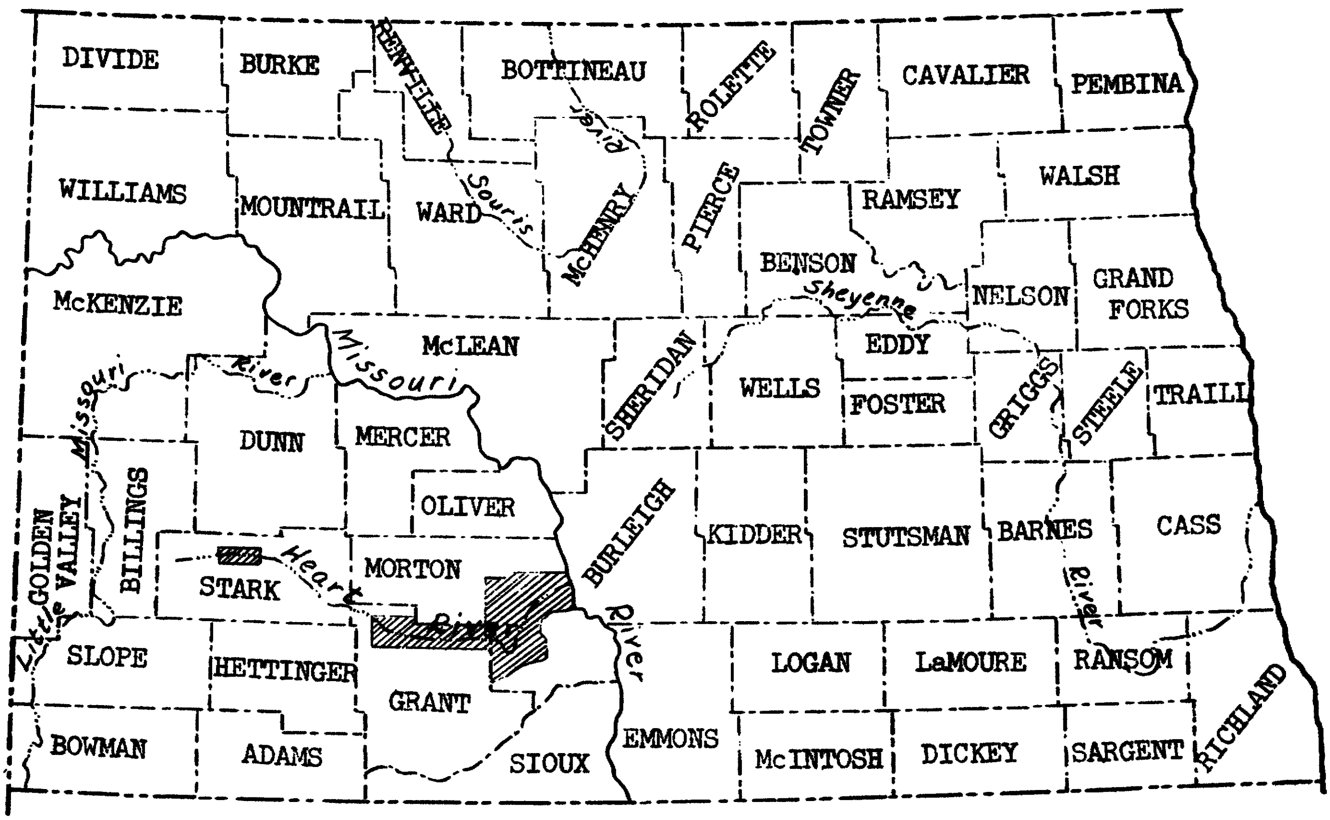

Figure 1.--Index map of North Dakota showing areas covered by present report.

Well-Numbering System

The well numbers used in this report show the location of the wells according to the General Land Office survey of the area. The number of a well is always given according to the following formula: Township - Range - Section - 160-acre tract within that section - and the 40-acre tract within the quarter section. Where two or more wells are located within a 40-acre tract, the wells are numbered serially according to the order in which they were visited or inventoried. The 160-acre and 40-acre tracts are designated a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. (See fig. 2.)

Bibliography

The Geological Survey of the United States Department of the Interior and the North Dakota State Geological Survey have published several reports concerning parts of the Heart River area. These have been drawn upon to some extent, and are listed below along with certain other publications to which reference is made in this report.

Leonard, A. G., U. S. Geol. Survey Geol. Atlas, Bismarck folio (no. 181), 1911.

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Flint, R. F., Glacial geology and the Pleistocene epoch, John Wiley and Sons, 1945.

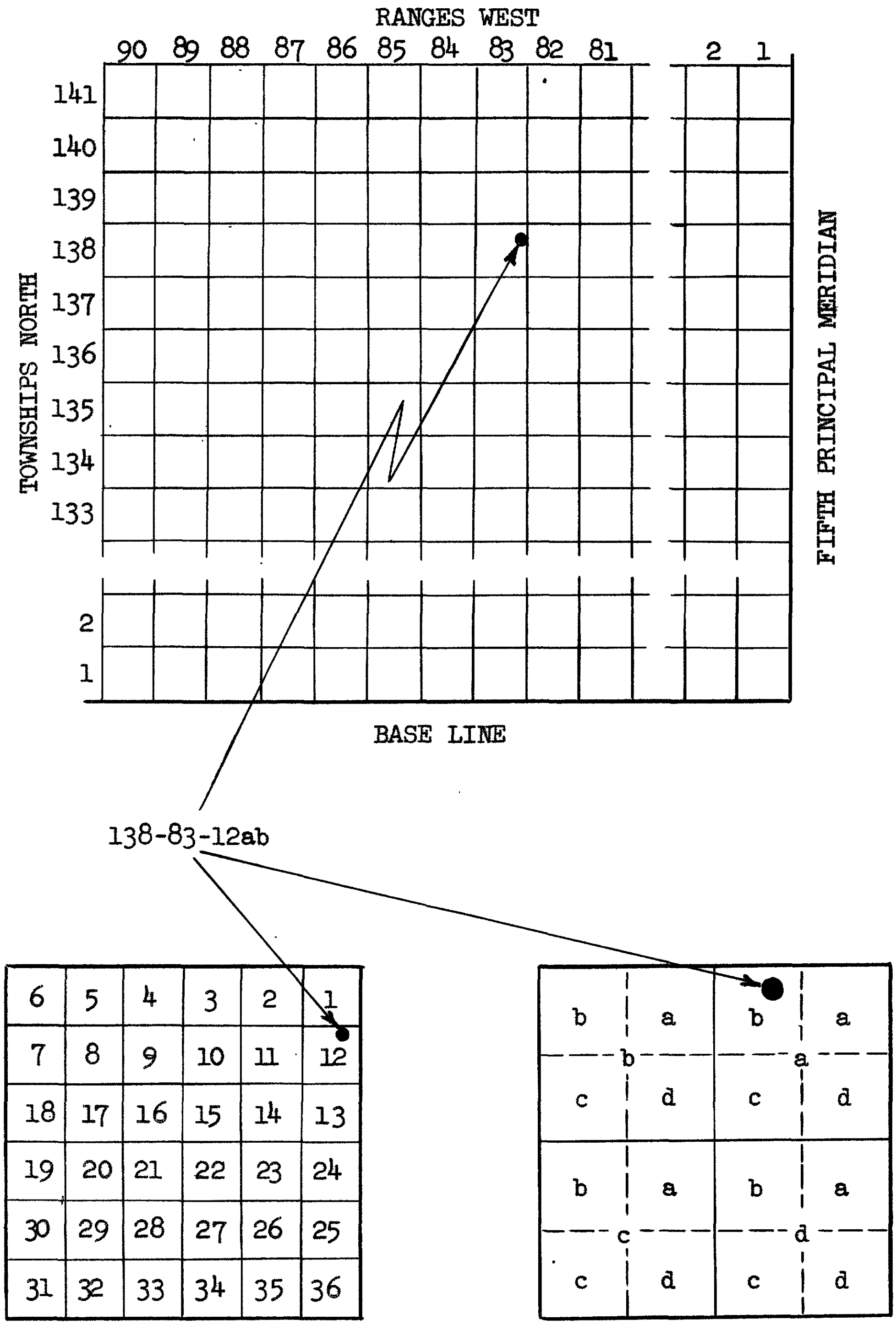

Figure 2.--Sketch illustrating well-numbering system.

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

Published geologic maps by W. M. Laird for the southern part of Morton County, by E. E. Tisdale for the Heart Butte quadrangle, and by E. T. Hancock for the New Salem lignite field have been freely used by the writer in supplementing his field investigations.

In cooperation with the North Dakota Geological Survey and the North Dakota State Water Conservation Commission, the Federal Survey has maintained a program of water-level measurements in selected wells throughout the State since 1937. The measurements through 1945 have been published in Geological Survey Water-Supply Papers 840, 845, 886, 908, 938, 946, 988, 1018, and 1025.

Acknowledgments

This study is one of a series being made by the Geological Survey as part of the program of the Interior Department for the development of the Missouri River Basin.

The study of the geology and occurrence of ground water was under the general supervision of O. E. Meinzer, geologist in charge of the Division of Ground Water (now Ground Water Branch) until his retirement on December 1, 1946; since that date the work has been under the general supervision of the present geologist in charge, A. N. Sayre. The investigation was under the direct supervision of both G. H. Taylor, regional engineer in charge of ground-water studies in the Missouri River Basin, and G. A. LaRocque, Jr., district engineer.

The quality-of-water studies were under the general direction of S. K. Love, chief of the Quality of Water Branch, and under the immediate supervision of P. C. Benedict, district engineer in charge of quality-of-water investigations in the Missouri River Basin. Analyses of samples were made by J. G. Connor, J. M. Stowe, H. A. Swenson, and L. L. Thatcher.

LOWER HEART RIVER AREA

Geography and Drainage

The part of the Heart River Basin covered by this report extends from the northeast corner of T. 136 N., R. 90 W., in a general east direction across northern Grant County and thence northeast through Morton County to Mandan, a distance of 120 river miles (or 50 air-line miles.) The relief is strongly marked, and the altitude ranges from 2,275 feet in the uplands to 1,620 feet at the confluence of the Heart and Missouri Rivers near Mandan. The lower Heart River area is shown in some detail on the geologic map (pl. 1).

The Heart River for a time was a tributary of the Cannonball River. This is indicated by the wide, gently sloping, alluvial-floored valley which extends from secs. 31 and 32, T. 136 N., R. 84 W., to sec. 36, T. 134 N., R. 82 W., and connects the valley of the Heart River with the valley of the Cannonball River. The floor of this connecting valley is more than 100 feet higher than the present floor of the Heart River Valley and its bordering bluffs on the east and northeast are continuous with those along the present valley. It is not known whether this abandoned valley represents the original course of the Heart River or whether it was a temporary course during a part of Pleistocene time when the lower end of the Heart River Valley may have been blocked by the advance of an ice sheet.

A. G. Leonard has divided the Heart River Basin into three broad divisions, consisting of (a) the immediate river valley, characterized by a very productive alluvial soil and ranging from a quarter of a mile to 1½ miles in width; (b) the rolling upland prairie, characterized by isolated buttes and boulder-covered ridges with the basal sandstone beds of the Fort Union formation at shallow depth; and (c) stream-dissected "badlands," representative of shales of the Cannonball and Ludlow formations, undifferentiated, and suitable only for grazing purposes. Numerous small, intermittent side streams have cut gullies into the soft sandy shales of the Cannonball and Ludlow unit as far back as a mile from the valley bottom lands. Typical examples of such badland topography are found in the S½ T. 136 N., R. 85 W., and are particularly evident on aerial photographs of the region.

The upland areas adjoining the Heart River bottom lands favor rapid runoff with slight absorption or evaporation of the rain water. There is little vegetation in the drainage basin to retard runoff, and consequently flash floods commonly follow heavy rains during the summer.

Climate

The climate is characterized by long, cold winters and short, warm summers, typical of plateau regions. The mean annual precipitation at Bismarck[1] is 16.40 inches. The precipitation is heaviest during May, June, and July, and it declines throughout the summer and fall, reaching a minimum in December, January, and February. The mean monthly precipitation at Bismarck over a 70-year period is as follows:

Mean monthly precipitation, in inches, at Bismarck, North Dakota (From U. S. Weather Bureau).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0.45	0.46	0.92	1.51	2.27	3.37	2.26	1.82	1.32	0.92	0.57	0.53	16.40

Summary of Stratigraphy

The bedrock formations of the lower Heart River area are nearly horizontal or have only a gentle regional dip to the north. The only bedrock formations exposed are the Hell Creek formation of Upper Cretaceous age, and the Cannonball and Ludlow formations, undifferentiated, and Fort Union formation of Paleocene (Tertiary) age. Proper differentiation of the Cretaceous and Tertiary formations of this region has long been a vexing problem in stratigraphy, and the scope of this paper precludes expressing the various opinions offered.

1 Annual meteorological summary, U. S. Dept. Commerce, Weather Bur., Bismarck, N. Dak., 1945.

The classification accepted by the U. S. Geological Survey is used in this paper and is as follows:

Quaternary

Alluvium, outwash, and glacial till and boulder deposits

Tertiary (Paleocene)

Fort Union formation

Cannonball and Ludlow formations, undifferentiated

Cretaceous (Upper Cretaceous)

Hell Creek formation

Fox Hills sandstone

Pierre shale

Niobrara formation

Dakota sandstone

The Cannonball and Ludlow formations, undifferentiated, and the Fort Union formation form steep escarpments along the sides of the river valley, dividing the possible irrigable lands into small detached areas. A few feet of sandy shale which is believed to belong to the Hell Creek formation has been mapped by W. M. Laird[2] and is exposed along the banks of the Heart River in Tps. 136 and 137 N., Rs. 84 and 85 W. The formation has no importance as a water-bearing material and for this reason is not considered in detail in the present paper. The surface deposits consist of scattered patches of weathered bouldery glacial drift, and the alluvial deposits along the Heart River Valley and its tributary streams.

2 Laird, W. M., and Mitchell, R. H., The geology of the southern part of Morton County, North Dakota: North Dakota Geol. Survey Bull. 14, 1942.

Water-bearing Formations

Cannonball and Ludlow Formations, Undifferentiated

The Cannonball and Ludlow formations, undifferentiated, lie at the surface throughout most of the east half of Morton County and form the upland area immediately bordering the river bottom lands in northeastern Grant County. At the west end of the area the Cannonball and Ludlow unit is composed of massive dark-colored sandstone, shale, and clay, and contains thin beds of lignite. Traced eastward, it changes in character, and in the vicinity of Mandan it is composed largely of dark shale. The contact between the Cannonball and Ludlow unit and the overlying Fort Union formation was found to be conformable and marked by a gradational change of lithology. The contact disappears beneath the land surface near the west edge of sec. 11, T. 136 N., R. 89 W.[3] The following detailed section of the Cannonball and Ludlow formations, undifferentiated, was measured in the river bank in the NW$\frac{1}{4}$ sec. 18, T. 138 N., R. 82 W.

Section of the Cannonball and Ludlow formations, undifferentiated, in NW$\frac{1}{4}$ sec. 18, T. 138 N., R. 82 W.

	Feet
Residual soil, sandy, weathered, dark	4.0
Sandstone and shale, fine-grained, intercalated, buff-colored	5.0
Sandstone and shale, thin-bedded, buff-colored	4.0
Shale, gray	3.0
Sandstone	1.0
Sandstone and shale, intercalated	1.0
Shale, gray	.7
Sandstone and shale, intercalated, light-colored	.7
Shale, gray, fine-textured	.5
Shale, sandy, light-colored	1.0

3 Tisdale, E. E., The geology of the Heart Butte quadrangle: North Dakota Geol. Survey Bull. 13, p. 7, 1941.

Section of the Cannonball and Ludlow formations, undifferentiated, in NW $\frac{1}{4}$ sec. 18, T. 138 N., R. 82 W.--Continued

	Feet
Shale, gray..	.5
Sand and clay, intercalated....................................	.5
Shale, sandy...	3.5
Concretion zone, lenticular....................................	2.0
Talus slope down to river level................................	7.6

In a report on the New Salem lignite field, Morton County, Hancock[4] described the following generalized section of the Cannonball and Ludlow units:

Section of the Cannonball and Ludlow formations, undifferentiated, containing possibly a part of the Hell Creek, measured in a cut bank on the north side of Heart River in sec. 10, T. 138 N., R. 83 W.

	Feet
Top of Cannonball and Ludlow unit	
6. Partly concealed, but the few exposures indicate soft gray sandy shale..	75
5. Sandstone, brown, very hard and resistant, forming a well-defined shelf; in places very fossiliferous, containing marine shells................................	4
4. Sandstone, yellow, soft, unconsolidated.................	15
3. Sandstone, similar to 1................................	43
2. Sandstone, similar to 1, but the belt is of lighter color..	45
1. Sandstone, fine-grained, soft, unconsolidated, consisting of yellowish-brown bands alternating with darker bands and containing lenticular masses of sandstone. The entire mass has a characteristic somber hue. (Part of this may be the Hell Creek formation)...................	115
	297

Wells encountering fairly thick sections of soft sandstone in the Cannonball and Ludlow unit can be expected to yield about 7 to 10 gallons of water a minute. The water is generally hard but is suitable for all domestic uses. If a well fails to encounter sandstone beds in the unit,

[4] Hancock, E. T., The New Salem lignite field, Morton County, N. Dak.: U. S. Geol. Survey Bull. 726, pp. 9-10, 1921.

small supplies of mineralized water may be obtained from sandy shale.

Gravity-type springs issuing from the sandstone and lignite beds of the Cannonball and Ludlow unit are numerous in many coulees and shallow valleys of intermittent streams that border the river valley. Water from these springs often supplements supplies that are obtained from wells, and at two farms spring water is piped into the house and used for domestic purposes. Owners reported that the spring flow is nearly constant throughout the year regardless of the amount of precipitation.

All the springs observed were of the gravity-seepage type. The maximum flow reported was 6 to 7 gallons a minute, issuing from a spring located on the north side of the river opposite well 136-85-15cc. The flow of this spring was reported to have been about 15 gallons a minute in 1940. The springs probably are supplied by seepage from different ground-water horizons and issue at exposed contacts between sandstone and shale strata. Locations of springs that were visited or reported are shown on the geologic map (pl. 1).

Irrigation water placed upon the river-bottom lands and on flat bench lands underlain by the Cannonball and Ludlow unit will probably raise the water table considerably, and the amount of seepage from springs will be increased. The sandstone beds of the Cannonball and Ludlow unit underlying the bench lands should be capable of storing large quantities of water that reaches them from irrigation.

Fort Union Formation

The name Fort Union was first used by F. V. Hayden in 1861 to designate the group of strata containing lignite beds in the area near Fort Union, eastern Montana. The formation is now known to extend over large parts of eastern Montana and North Dakota and adjoining parts of South Dakota, Wyoming, and Canada.

The Fort Union formation conformably overlies the Cannonball and Ludlow unit. It extends over most of Grant County and occupies large detached areas in the southwestern part of Morton County. The formation consists chiefly of light-colored interbedded sandstone and shale and thin beds of lignite, and it offers sharp contrast to the dark shale and sandstone of the Cannonball and Ludlow unit. In many places throughout the uplands the lignite has been burned and has baked the overlying shale into a conspicuous red scoria. However, evidence of such burning was not observed along the Heart River Valley. The scoria is found capping the hills and bluffs in the upland area north of the river and is extensively used for road surfacing.

The basal 100 feet of the Fort Union formation consists of massive light buff-colored sandstone with a considerable admixture of silt and clay, and it also contains numerous large lenticular concretions. The formation is well exposed along the river bluffs in the western part of the area. The concretions, ellipsoidal in shape and up to 20 or 25 feet in length, are well displayed near the proposed Heart Butte dam site.

Tisdale[5] reports the cementing medium of these lenticular masses to be chiefly calcium carbonate.

Throughout the proposed reservoir area, the river has cut nearly vertical cliffs into the basal sandstone of the Fort Union formation. The sandstone is exposed, for the most part, along the bluffs bordering the river lowlands, and the surrounding upland surfaces consist of light-colored intercalated shale and sandstone containing lignite and scoria.

Hard light-gray or yellow quartzitic stones having highly polished surfaces and containing numerous cylindrical holes were found associated with the Fort Union formation. These fine-grained rocks were particularly abundant on the slopes of the uplands. Their wide distribution throughout the area underlain by the Fort Union indicates their possible origin from several different horizons within the formation.

E. E. Tisdale, who has done considerable work in the immediate area, has determined the altitude of the contact of the Fort Union formation with the Cannonball and Ludlow unit to be 2,011 feet at a bluff in the SW$\frac{1}{4}$ sec. 21, T. 136 N., R. 88 W. The altitude of the contact in Morton County, about 28 miles east of this area, averages 2,100 feet. A typical section examined by Tisdale[6] in sec. 21, T. 136 N., R. 88 W., showed the following sequence of strata, in which the geologic names have been modified to conform to the present usage:

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5 Tisdale, E. E., The geology of the Heart Butte quadrangle: North Dakota Geol. Bull. 13, p. 11, 1941.

6 Tisdale, E. E., op. cit., pp. 8-9.

Section of Fort Union formation and the Cannonball and Ludlow formations, undifferentiated, in the SW¼ sec. 21, T. 136 N., R. 88 W.

	Feet	Inches
Fort Union formation		
Sand, light-gray, argillaceous, with much cross bedding. Weathers buff. Contains some spherical marcasite concretions up to 1 inch in diameter. Exposed to top of bluff...............	71	0
Cannonball and Ludlow formations, undifferentiated		
Shale, brown to black, with limonitic material, somewhat silty. Some small marcasite concretions..	4	7
Sand, greenish-gray, fine-grained, argillaceous, and limonitic shale concretions................	4	7
Sand, greenish-gray, and thin lenses of dark-gray and brownish-colored shale, marcasite concretions, and small selenite crystals. Sand pinches out in places to leave shale for nearly entire thickness...............................	14	0
Sand, gray, fine-grained, interbedded with brown carbonaceous shale............................	7	0
Shale, gray, with some greenish-gray sand lenses and sandstone concretions, thin-bedded; most of sand near the base of the bed.................	8	10
Shale, dark-gray, silty near the bottom, more sandy near the top, bluish-gray color when wet.	7	7
	117	7

Laboratory studies by Tisdale on 18 samples of sandstone from the Fort Union formation within this area showed the "sand" to range in texture from a coarse silt to medium sand. Numerous samples were found to contain an appreciable amount of calcium carbonate, and quartz and feldspar were found to be the most abundant minerals. The studies indicated that the source rock of the Fort Union formation may be of metamorphic origin and may not be far from the Heart Butte area. The reader is referred to Tisdale's publication for a detailed discussion of the mechanical and mineral analyses of the samples.

The principal water-bearing beds in the Fort Union formation are the sandstones. These are separated by layers of shale, which hinder vertical movement of water from one sandstone bed to another and in some places serve as confining beds, producing artesian conditions. As is true of the Cannonball and Ludlow unit, the yields of wells that draw water from the sandstones of the Fort Union are small to moderate. Ground water developed from the lignite beds within the Fort Union formation is generally brown in color, soft, and has a disagreeable taste. Weathered residual and wash materials on the gentle slopes of the upland yield moderate amounts of water to shallow dug wells.

Simpson[7], in his report on the geology and ground-water resources of North Dakota, describes ground water derived from the Fort Union formation as follows:

> The waters from the Fort Union formation may be divided into two classes. One class comprises the waters from wells less than 100 feet deep, which are hard and contain calcium, magnesium, and bicarbonate as the predominating radicles. These waters are very similar to the waters from the drift, alluvial deposits, and other overlying deposits. The second class comprises waters from wells more than 100 feet deep, which are soft and contain sodium and bicarbonate or sodium and sulphate as the predominating radicles.

Owners of wells drilled in the Fort Union formation in T. 136 N., R. 83 W., reported the same conditions that Simpson described. In the N½ sec. 22, a well 86 feet deep yields hard water, and a well 298 feet deep yields a plentiful supply of soft water. Both wells obtain water from the Fort Union formation and are located within 50 yards of each other. Well owners in sec. 28 of the same township also reported that similar differences exist between the shallow and the deep water. Possibly the presence of lignite beds may cause the water from the deeper wells to be

7 Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 36, 1929.

softer.

Gravity-type seepage springs are common in the Fort Union formation and issue from beds of fine-grained sandstone and lignite in the bluffs bordering the river bottom lands. All the springs observed, however, had only slight seepage-type flows.

Glacial Deposits

Throughout the Heart River Basin, erosion has removed practically all the glacial drift and has left behind only scattered boulders and deposits of very coarse gravel. These deposits have little or no importance as water-bearing material and are not considered in detail in this report. Many glacial boulders more than 1½ feet in diameter were observed. The largest boulder seen, located in sec. 4, T. 137 N., R. 83 W., was approximately 14 by 9 by 5 feet in dimensions. All the boulders examined were of granitic rock.

Alluvium

Alluvial deposits along the Heart River Valley consist of roughly sorted silt, sand, and gravel derived from the glacial drift and from the Fort Union formation and the Cannonball and Ludlow unit of the surrounding upland. The drift was originally transported from the front of the melting ice sheet and deposited by the overloaded streams along the river valley. Former flood plains thus remain as terraces and are present in secs. 30, 33, and 34, T. 139 N., R. 81 W., and in sec. 25, T. 139 N.,

R. 82 W. The terraces, which are underlain by gravel, border upon the present-day alluvium. They are 5 to 15 feet higher than the present flood plain.

Throughout the Heart River Valley the surface alluvium consists of gray fine sandy silt. Deposits of coarse gravel in the present stream bed are concentrated at curves throughout the river's course, but are thin and limited in areal extent. Hand-auger holes bored into the alluvium in sec. 8, T. 136 N., R. 85 W., close to the river bank, showed that the fine sandy silt extends down to a depth of about 3 feet, grading into coarse sand and gravel. Owners of wells that have been dug in the alluvium near the outer edge of the valley reported sand and gravel deposits at depths of about 20 feet beneath the land surface.

The driller's log of a well drilled in 1943 at the North Dakota State Training School, near Mandan, shows that the alluvium there is about 55 feet thick. The log shows the character of the underlying Cannonball and Ludlow unit to a depth of 349 feet.

Log of well at State Training School in N½ sec. 33, T. 139 N., R. 81 W., near Mandan, North Dakota.

	Thickness (feet)	Depth (feet)
Alluvium		
Clay, yellow	20	20
Quicksand and gravel	30	50
Clay, light-blue	5	55
Cannonball and Ludlow formations, undifferentiated		
Sandstone, fine-grained	2	57
Shale, black	23	80
Sandstone, blue, with water	5	85
Rock	½	85½
Sandstone, blue, with water	19	104½
Shale, brown	4	108½
Lignite	½	109

Log of well at State Training School in N½ sec. 33, T. 139 N., R. 81 W., near Mandan, North Dakota--Continued

	Thickness (feet)	Depth (feet)
Cannonball and Ludlow formations, undifferentiated --Continued		
Sandstone, blue, with water	15	124
Shale and sandstone	25	149
Shale, blue	40	189
Sandstone, blue, with water	11	200
Rock	2	202
Sandstone, blue, with water	7	209
Rock	1	210
Sandstone, blue, with water	19	229
Shale, blue	10	239
Sandstone, blue, with water	20	259
Shale	10	269
Sandstone, blue	30	299
Shale, blue, and sandstone	50	349

The light-blue clay at a depth of 50 to 55 feet, underlying quicksand and gravel, probably is the lowest part of the alluvium. It is of interest to note that the water-bearing beds in the Cannonball and Ludlow unit are reported to be blue sandstone beds that occur between impermeable strata of rock and clay, giving rise to several water-bearing zones.

The total thickness of the stream deposits on the east side of the Missouri River Valley at Bismarck, as revealed in drillings by the Union Pacific Railroad, ranges from 50 to 125 feet. Numerous test holes drilled by the Bureau of Reclamation in sec. 13, T. 136 N., R. 89 W., at the Heart Butte dam site, indicate that the alluvial deposits extend to a depth of about 20 feet beneath the bed of the Heart River. (See pl. 1.)

The test holes indicate that the thickness of the alluvium differs considerably from place to place. Generally, the thinnest deposits are (1) where the alluvium pinches out against the Fort Union formation at the outer edges of the river valley and (2) directly beneath the river channel. The maximum thickness of the alluvium, as revealed by the test holes, is about 45 feet, at a location near the outer edge of the valley. Interbedded soft light-gray sandstone and dark-gray clay shale underlie the alluvium throughout the dam-site area. Similar conditions probably exist throughout the Heart River Valley.

The river alluvium provides an extensive reservoir for storage of ground water, especially within the coarser gravel deposits. Throughout the valley the water table is comparatively close to the surface and shallow dug wells provide adequate supplies for domestic needs. However, the surficial deposits of silt and muddy sand contain an abundance of decayed organic material, and ground water derived from them is generally of poor quality and taste. At greater depths the sand and gravel deposits provide larger supplies of water of better quality. Most of the existing wells penetrating the alluvium can be pumped dry, showing that they have small yields, but they refill readily. In general, waters from the alluvial deposits are of better quality than those from other formations.

Depth to Ground Water

In the summer of 1946 the measured depth to the water table or piezometric surface ranged from a few feet to 64 feet. The average measured depth to the water table in the alluvial deposits along the Heart River bottom lands was 19 feet, whereas the measured depth to the piezometric surface of water in the aquifers of the bedrock formations underlying the upland area averaged 30 feet. Along the former course of the Heart River, a strip characterized by alluvial deposits and trending in a southeasterly direction through T. 136 N., R. 84 W., the depth to ground water averaged about 45 feet. The water table and piezometric surface lack much of the irregularity common to the land surface. In the valley bottom lands the altitude of the water table approximates that of the river surface, and it is reported that the fluctuations of the water table closely follow the rise and fall of the river.

In general, the ground water in the river alluvium moves toward the river and down the valley. The prevalence of shale and clay shale in the Cannonball and Ludlow unit and in the Fort Union formation hinders or prevents vertical circulation between water-bearing beds of alluvium in the river bottom lands and the sandstones in the formations underlying the upland areas. Within the river alluvium, however, which has a large storage capacity, ground water is able to circulate both vertically and horizontally.

Water within the river alluvium is derived directly from rainfall on the exposed alluvium and indirectly through seepage from the surrounding uplands, and from the river during high stages. Ground-water discharge in the form of springs and seeps along the bluffs bordering the valley is small, and presumably there is movement of ground water into the river alluvium at the contact between the alluvium and the Cannonball and Ludlow unit or the Fort Union formation.

During flood periods the water surface of the river rises considerably above the water table in the adjoining alluvium and the stream becomes influent; that is, river water percolates into the adjacent alluvium and raises the water table. During dry periods the river falls below the level of the adjacent water table and the stream becomes effluent; that is, water percolates from the alluvium into the river.

Subsurface flow of ground water from the former channel of the Heart River in T. 136 N., R. 84 W., into the present river channel is indicated by the elevation of the water table along the former channel for a distance of about 2 miles south from the sharp bend of the river. The bottom of the old channel, forming a depression about 2 miles in width, rises gradually for a distance of about 2 miles south of the river bend, and upon attaining an elevation of 125 feet above the present river bed it descends toward the south, so that a divide separates the drainage of Louse Creek from that of Heart River.[8] The former channel probably forms an extensive ground-water storage area. Owners of shallow wells located in the area report adequate water supplies, and two deep wells drilled in the W½ sec. 15, T. 135 N., R. 84 W., encountered sand containing abundant ground-water supplies at depths of 75 and 86 feet, respectively.

Irrigation of the flood plains and terraces will cause the water table to rise and the flow of ground water toward the river to increase.

The water levels in key observation wells throughout North Dakota declined an average of 1.13 feet from 1937 through 1940.[9] Excessive

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8 Leonard, A. G., North Dakota Geol. Survey 6th Bienn. Rept., p. 32, 1912.

9 Meinzer, O. E., Wenzel, L. K., and others, Water levels and artesian pressure in observation wells in the United States in 1940, part 3, Northcentral States: U. S. Geol. Survey Water-Supply Paper 908, p. 4, 1942.

rainfall during 1941 raised ground-water levels in the Heart River Valley to their highest level since the beginning of the measurements in 1937, and the heavy precipitation during June 1943 raised the ground-water levels to their highest stage since the first water-level measurements were made. The record of ground-water fluctuations indicates that the lowest stages generally have been reached during February and March, and the highest stages during June and July.

In the future, ground-water levels in the river alluvium will depend largely on the regulated flow of the river; ground-water levels in irrigated areas will depend in part on the amount of seepage from irrigation water spread on the land; and ground-water levels in nonirrigated areas will continue to depend largely on the amount and distribution of precipitation.

Periodic measurements of the depth to water in observation wells in the Heart River Valley were begun in May 1946. Records of the measurements made through 1948 are given in table 5, page 49.

Utilization of Ground Water

Nearly all the public and domestic water supplies throughout the area are obtained from wells. Information concerning the use of water from 86 wells and 2 springs in the lower Heart River Valley was obtained and is listed in table 6, page 52. Of the total wells inventoried, 26 were either temporarily or permanently abandoned as of 1946. The use of the remaining wells was as follows: 6 were used for domestic supply, 38 for domestic and stock water, and 17 for livestock only.

DICKINSON AREA

Previous Studies

Studies have been made by the United States Bureau of Reclamation in the vicinity of Dickinson to determine the practicability of impounding the water of the Heart River for municipal, industrial, and irrigation use. The quantity and quality of water thus impounded would be adequate to supply the potential demand, allowing for moderate growth of population. When necessary, water from the present city wells can be used to supplement the river supply.

During the period from March 27 to May 6, 1944, A. L. Greenlee and T. G. McLaughlin, of the Geological Survey, and K. C. Lauster, acting director of the Division of Sanitary Engineering of the North Dakota State Department of Health, made a quantitative study of the ground-water resources of the Dickinson area. The results of their examination were published in 1946.[10] In the summary of their report which follows, the numbers of the city wells have been converted to conform to the numbering system used in this report, as shown in the following table. As all the city wells are located in T. 139 N., R. 96 W., they will be referred to in the text only by the section, quarter-section, and quarter-quarter-section figures.

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

Numbers of City Wells at Dickinson

Well no., (McLaughlin and Greenlee)	Well no., this report	Well no., (McLaughlin and Greenlee)	Well no., this report
1	139-96-3bb1	4	139-96-3bb6
2	3bb2	5	4ac1
3	3bb3	6	4ac2
3A	3bb4	7	4bd1
3B	3bb5	7A	4bd2

Geography and Drainage

The area studied (see fig. 6, p. 44) lies along the Heart River immediately south of Dickinson and includes the Dickinson city wells located in the NE$\frac{1}{4}$ sec. 3 and the N$\frac{1}{2}$ sec. 4, T. 139 N., R. 96 W.

Extending across Stark County from west to east, the Heart River Valley within the Dickinson area is characterized by broad deposits of alluvium and by low terraces. The only remnants of the deposits left by the ice sheet are a few scattered boulders, and the topography is largely the result of stream action on the soft horizontal beds of the Fort Union formation. The drainage system is mature, and the upland surface is characterized by gently rolling hills which grade into low, flat-lying terraces within the river valley. The annual precipitation averages about 15 inches.

Geologic Formations and Their Water-Bearing Properties

The sedimentary deposits that crop out within the Dickinson area consist of alluvial material of Quaternary age, and soft massive buff-colored sandstone and shale of the Fort Union formation of Tertiary age.

Immediately underlying these deposits are subsurface strata which include beds of Tertiary and latest Cretaceous age.

Subsurface Formations

Formations believed to be present in the subsurface of the area include, from youngest to oldest, the Cannonball and Ludlow formations, undifferentiated, of Paleocene age, and the Hell Creek formation, Fox Hills sandstone, Pierre shale, Niobrara formation, and Dakota sandstone, of Upper Cretaceous age. The Fox Hills sandstone is the most likely of these formations to contain an adequate supply of water and should be encountered by the drill at a depth between 1,000 and 1,300 feet.[11] However, test drilling would be required to evaluate its usefulness. The Dakota sandstone, also capable of producing moderate amounts of water, should be reached about 5,100 feet below the surface, or about 2,700 feet below sea level.[12] Waters of the Dakota sandstone, however generally are highly mineralized, and the great depth of this sandstone prohibits its economical development as a source of supply.

Fort Union Formation

Within the Dickinson area the Fort Union formation is the surface rock along both sides of the valley and underlies the alluvium of the valleys and terraces. The exposures of the Fort Union consist of massive

11 McLaughlin, T. G., and Greenlee, A. L., op. cit., p. 13.
12 Ballard, Norval, Regional geology of Dakota basin: Am. Assoc. Petreleum Geologists Bull., vol. 26, p. 1568, 1942.

buff-colored sandstone, clay shale, and thin beds of lignite. A typical exposure in the southern part of sec. 15, T. 139 N., R. 97 W., just north of the road, shows 43 feet of massive buff-colored sandstone containing a lignite bed 2 feet thick about 12 to 14 feet below the top of the section. Numerous lenticular masses, 2 feet or more thick and 10 to 15 feet long, are also common in the formation. Samples of material from test holes show that the soft sandstone and shale extend to a depth of at least 200 feet. Test holes drilled by the United States Bureau of Reclamation in sec. 8, T. 139 N., R. 96 W., indicate that a compact blue sandstone, probably of the Fort Union formation, underlies the Heart River Valley at depths of 20 feet or more below the land surface. (See fig. 3.)

Dickinson obtains its present water supply from the Fort Union formation, the soft sandstone and lignite beds of which afford good storage reservoirs for ground water. Numerous springs issue from the lignite beds, particularly on the slopes of valleys and in coulees. A constant spring flow, filling a 2½-inch pipe, was observed in the NE¼ sec. 7, T. 139 N., R. 95 W. Moderate to large supplies are furnished by wells deriving their water from the sandstone beds.

Although large amounts of water are found in the lignite beds, the water generally contains considerable organic material and has the dark-brown color typical of waters occurring in lignite. The Lehigh Briquette Company, at Lehigh, pumps approximately 30,000 gallons of such water a day. The superintendent reported the altitude of the original ground-water level at the plant to be 2,330 feet, which was several feet above the river level. During the summer of 1946, however, the elevation of the water

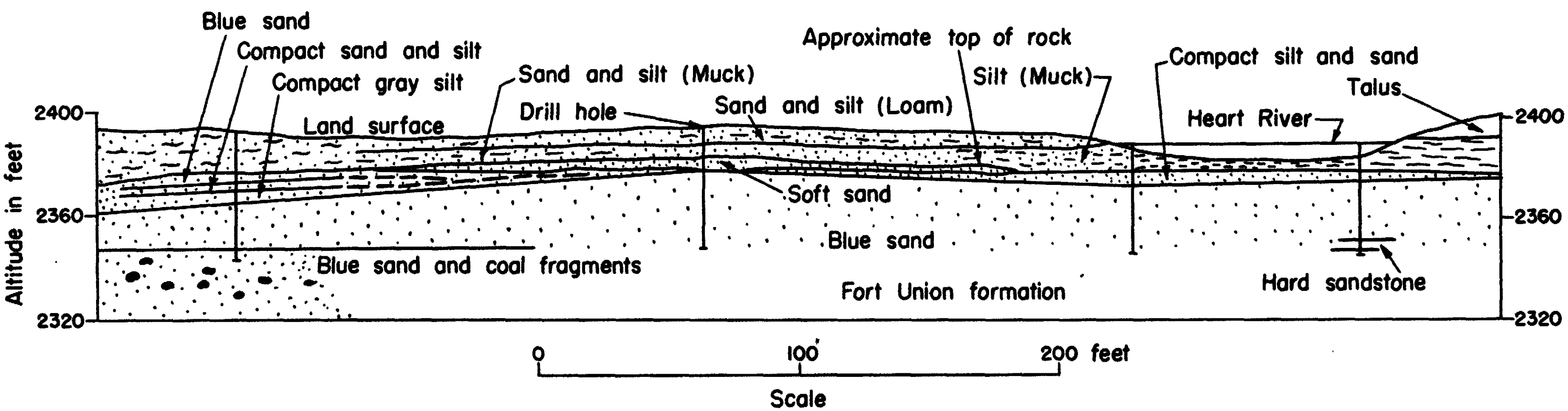

Figure 3.—Section across Heart River Valley in sec. 8, T.139 N., R.96 W., showing geology and profile of land surface (after U.S. Bureau of Reclamation)

level was reported as being nearly the same as that of Heart River, indicating a decline due to draft on the ground-water supply.

The sandstones of the Fort Union formation are fine-grained, containing varying amounts of clay and shale. McLaughlin and Greenlee found them to have high porosity but low specific yield and transmissibility, and estimated that the water-bearing beds would have to be at least 30 feet thick to justify their development as a source of municipal water supply. Test drilling is necessary to locate areas of adequate thickness because the beds differ greatly in thickness from place to place.

Alluvium

The surficial alluvium consists of fine sandy to silty material, which grades downward to coarse gravel and sand overlying the Fort Union formation. The alluvium underlies the valleys to a considerable depth and the terraces to differing but lesser depths. A large pit in the NE$\frac{1}{4}$ sec. 12, T. 139 N., R. 97 W., exposes 5$\frac{1}{2}$ feet of coarse gravel overlying fine-grained sandstone. The alluvial deposits are widespread, store large amounts of water, and yield adequate supplies of ground water for farm and household needs.

Ground-water levels in the municipal well field at Dickinson, located about 6,000 feet north of Heart River in the NW$\frac{1}{4}$ sec. 3, and the N$\frac{1}{2}$ sec. 4, T. 139 N., R. 96 W., have declined rapidly in recent years, resulting in a decreased yield. (See fig. 4.) At the time of construction of wells 3bb1, 3bb2, 3bb3, between 1928 and 1930, the water level had declined from a probable original depth of 42 feet below the land surface

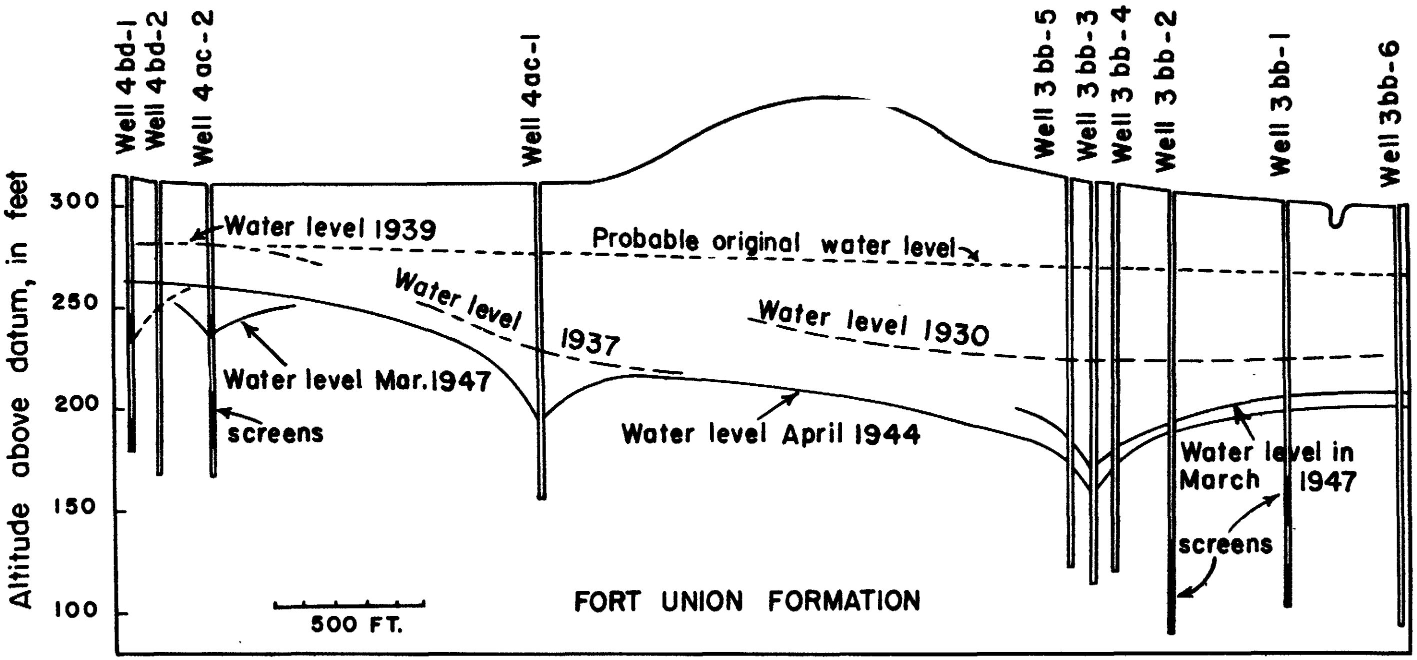

Figure 4.– Section through well field at Dickinson, N. Dak., showing fluctuations of water level (after McLaughlin and Greenlee).

to 83 feet at well 3bb1 and 87 feet at well 3bb3. The depths to water in wells 3bb1 and 3bb3 in April 1944 were 105 and 129 feet, respectively. The average total decline of water level in the east half of the well field has been about 80 feet. The water level in the vicinity of wells 4ac2 and 4bd1 declined about 19 feet between 1934 and 1944.[13]

The ground-water level in March 1947 indicated some recovery in the eastern part of the well field, however, and a continued decline in the western part. It is probable that the water level has reached or soon will reach an equilibrium position and will not decline much more at the present rate of pumping.

Depth to Ground Water

The depth to water below land surface in 11 wells measured in September 1946 ranged from 17.53 to 59.10 feet. (See table 6, p. 52). This range does not include a depth to water of 101.65 feet which was measured in well 139-96-3bb4 and which was produced by the pumping of wells in the Dickinson well field.

Fluctuations of Ground-Water Levels

Time was not available during the field season of 1946 for work other than the establishment of observation wells in the Dickinson area. Except for measurements of the water level in the Dickinson well field, all measurements of the water level made through 1948 are given in table 5, page 49.

13 McLaughlin, T. G., and Greenlee, A. L., op. cit., p. 5.

Since early in 1944 water-level records have been maintained on wells 3bb4 and 4bd2 to insure a continuous record of the water level on both sides of the well field. Nearby wells were pumping at the time of each measurement, so that the levels do not generally represent static water levels in the well field. Representative measurements of the water level in each well are listed below:

139-96-3bb4.

Water level in feet below measuring point

Date	Water level	Date	Water level	Date	Water level
Apr. 14, 1944	129.50	Jan. 10, 1945	141.53	Aug. 10, 1946	132.92
June 10	129.20	Feb. 10	132.55	Sept. 10	103.55
Aug. 10	143.87	Nov. 10	136.22	Jan. 10, 1947	130.04
Nov. 10	140.65	July 10, 1946	113.45	Mar. 25	134.43
Dec. 10	139.92				

139-96-4bd2.

Water level in feet below measuring point

May 28, 1944	48.82	Nov. 10, 1944	65.72	Jan. 10, 1945	61.28
June 10	66.20	Dec. 10	56.20	25	54.68
Aug. 10	68.82				

Well 3bb4 is an abandoned well and well 4bd2 is a test well drilled in 1944. Measurements of the water level in the abandoned well indicate a net lowering of 5.23 feet during the period from June 10, 1944, to March 25, 1947. The test well showed a net lowering of 5.86 feet between the first and last measurements recorded.

McLaughlin and Greenlee found that, despite the lowering of the water level in the east half of the well field, a few wells obtained small quantities of water at relatively shallow depths. These wells probably penetrate perched water bodies upheld by beds of impermeable clay shale. Test hole 3bb5 encountered water between depths of 51 and 53 feet.

Pumping Tests

Pumping tests were made on wells 3bb3 and 4bdl during the investigation of McLaugnlin and Greenlee, and the reader is referred to their report for a detailed discussion. Well 3bb3 was pumped continuously for 49 hours at an average rate of 105 gallons a minute and well 4bdl was pumped for 44.5 hours at 130 gallons a minute. When pumps in the eastern part of the field were stopped, prior to the test on well 3bb3, the water level rose rapidly for a few hours, but the rate of recovery gradually decreased, so that after 2 or 3 days the rate of rise was only a few hundredths of a foot a day, indicating that the water level was approaching a static condition on a large cone of depression.[14]

The pumping tests were made to determine the transmissibility of the water-bearing beds. Expressed in gallons a day through each section of the beds penetrated by the wells 1 mile wide and the full saturated thickness of the aquifers, for each foot per mile of hydraulic gradient, the transmissibility was found to be 8,500 gallons a day per foot at well 3bb3 and 4,500 gallons a day per foot at well 4bdl.

Conclusions

Approximately 40 wells and test holes were drilled in the vicinity of Dickinson during the period up to 1944 and most of them were abandoned because of inadequate supplies of water of suitable quality. Wells

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14 McLaughlin, T. G., and Greenlee, A. L., op. cit., p. 19.

penetrating the river alluvium are suitable for individual farm use and may yield adequate supplies for municipal use but further testing of this possibility is necessary. Sandstone beds underlying the Dickinson area have been found to differ greatly both in thickness and transmissibility. Most of the test wells have been abandoned because the water-bearing sandstone contained too much clay.

Impounding of the Heart River water has accordingly been suggested as the most feasible solution to the problem of the municipal water supply, and to furnish necessary water for irrigation. Although the studies made thus far are not exhaustive, they indicate that this plan may be the most practicable for the development of adequate water supplies.

MINERAL QUALITY OF THE WATERS

By Herbert A. Swenson

Nature of Study

This section of the report briefly describes the mineral quality of ground water at four points in the lower Heart River Valley, and discusses in more detail the character of the ground water in the Dickinson area, approximately 45 miles upstream from the Heart River irrigation project.

Composition of Ground Waters

All ground waters contain variable amounts of mineral constituents in solution, derived in part from rocks and soils through which the waters percolate. Rain water which contains, in solution, carbon dioxide from the air and from organic acids in the soil, acts vigorously on rock particles, especially limestones, dolomites, and feldspars, decomposing them and forming new compounds of calcium, magnesium, sodium, and potassium. Pure water will dissolve only about 20 parts per million of calcium carbonate and about 28 parts per million of magnesium carbonate, but water containing carbon dioxide will dissolve many hundred parts per million of these substances.

Thus, ground waters may dissolve sodium and potassium from feldspars; calcium from limestones and gypsum; magnesium from dolomite and magnesian silicates; iron from magnetite, hematite, or limonite; and silica from quartz. As a result, ground waters differ greatly in the kind and amount of mineral solids which they carry in solution, and upon this fact depends the usefulness of the water for one purpose or another. The quantity of mineral matter which a ground water dissolves depends not only on the solvent action of rain water, but also on the exposed grain area of the rocks through which the water moves, the underground temperature and pressure, and the rate at which the water moves through the rock formation or unconsolidated materials.

The relation of rock material to dissolved mineral content of the waters is important. Sands and gravels consisting chiefly of silica may yield a water of low mineralization. Water-bearing sands and gravels in semiarid or arid climates, however, often contain large amounts of alkaline or calcareous materials. Some sands and gravels contain soluble mineral grains or other soluble impurities which will dissolve in the water filtering through them.

Fine-grained materials, such as clay, expose considerable surface to solution, and the waters in them may be more strongly mineralized than those in sands and gravels. Waters obtained from boulder clay are often quite hard and sometimes contain traces of hydrogen sulfide.

Waters in sandstones and indurated shales may be more highly mineralized than waters in the materials mentioned above, because they contain more cementing materials, such as calcium sulfate or calcium carbonate, than do sands and clays. Where water moves rapidly through these rocks, however, it may dissolve relatively little mineral matter.

Limestones provide more soluble constituents than any of the other rocks mentioned, as calcium carbonate dissolves rather easily in water containing carbon dioxide. Waters leaching limestone, chalk, or similar rocks will almost certainly be hard.

Quality of Ground Water

Heart River Irrigation Project

Ground waters from four shallow dug wells in the lower Heart River Valley in Morton County were sampled for chemical analysis. Alluvial deposits yield water to two of these wells, and one well taps the Fort

Union formation and the other the Cannonball and Ludlow unit. Well depths range from 17.6 to 60 feet. The two wells tapping the alluvium yield the more highly mineralized waters. Results of chemical analyses for ground waters sampled in the lower valley are given in table 1.

In view of the few well waters sampled, the character of the water from aquifers in the lower valley can be indicated only in a very general way. The concentration of dissolved solids in the two waters pumped from alluvial deposits exceeds the average for 16 waters from such deposits reported by Simpson[15] for the entire State. Well 137-84-1dd, tapping the alluvium, yields a water in which sodium and bicarbonate account for much of the dissolved solids, although this water with a hardness of 312 parts per million would not be considered soft. Water from well 138-83-14ab, also drawing from alluvial deposits, contains considerable sulfate and is very highly mineralized and hard.

The single samples of water from the Fort Union formation and the Cannonball and Ludlow formations undifferentiated are similar in both concentration and composition, the Fort Union yielding a water slightly more mineralized than that of the Cannonball and Ludlow unit. The water from the Fort Union contained more sulfate than bicarbonate.

Analytical results in equivalents per million are shown diagrammatically in figure 5. The four well waters sampled in this part of the Heart River Valley are used entirely for domestic and stock purposes.

15 Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 32, 1929.

Table 1.--Chemical analyses of ground waters in the lower Heart River Valley, N. Dak. Sept. 1946
(Parts per million)

Well number	Depth in feet	pH	Specific conductance K x 10^5 at 25° C.	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na) and Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Non-carbonate	Percent sodium
Alluvium																
137-84- 1dd	17.6	7.6	206	0.2	64	37	382	886	266	95	1.6	0.2	1290	312	0	73
138-83-14ab	28.9	7.4	337	.1	458	111	324	808	1130	327	.1	2.0	2760	1600	936	31
Fort Union formation																
137-84-10cc	47.4	7.3	154	.1	140	68	133	413	530	20	.1	.0	998	629	290	32
Cannonball and Ludlow formations, undifferentiated																
138-82-10ac	60	7.3	122	.5	92	55	126	527	177	42	.0	67	868	456	24	38

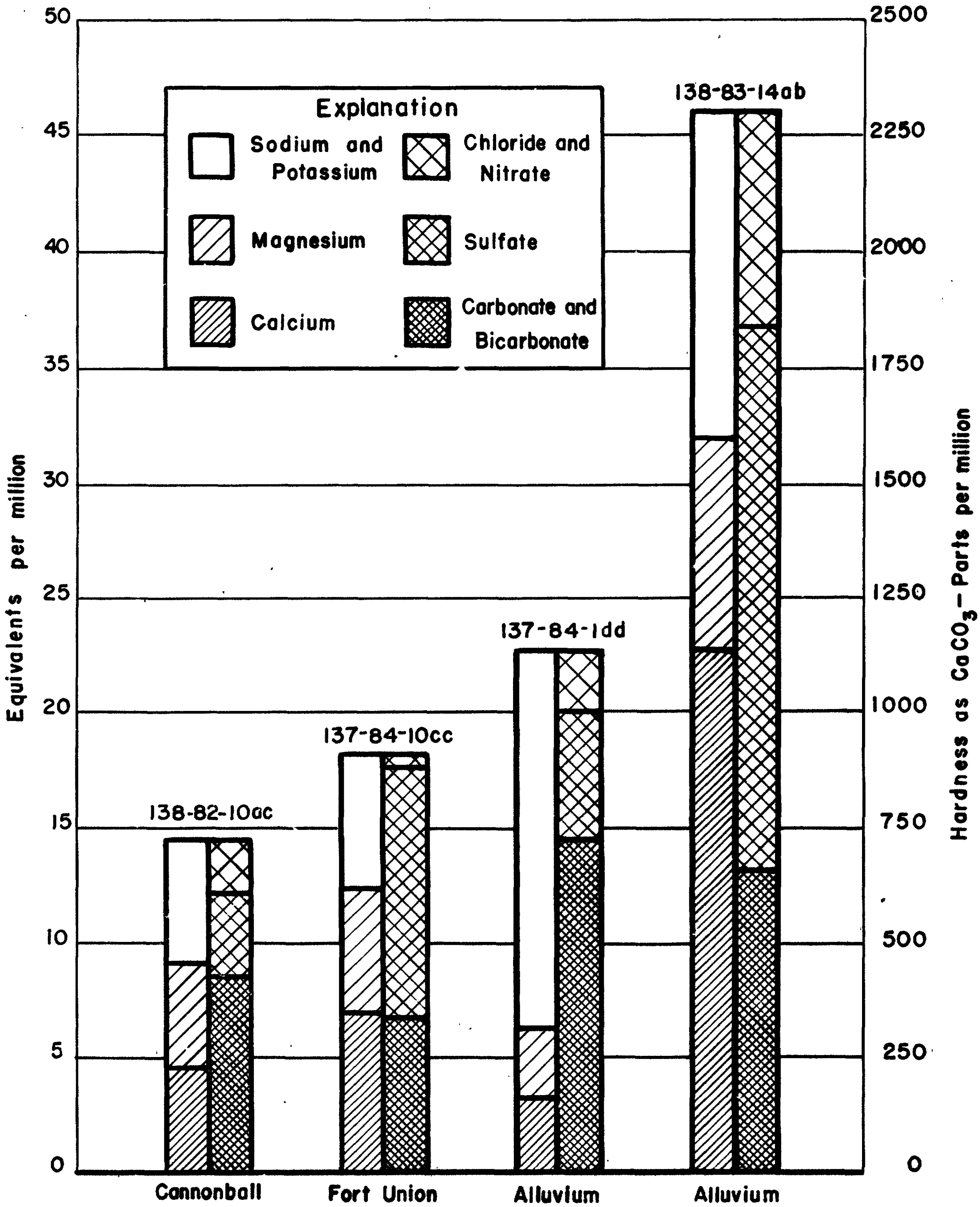


Figure 5. – Graphic representation of chemical analyses of ground waters, lower Heart River Valley

Dickinson Area

The quality of the ground water within and near the city of Dickinson was determined at the request of the Bureau of Reclamation as part of a study to determine the practicability of developing an adequate ground-water supply for municipal use. Detailed information on the mineral character of the water was needed before further consideration could be given to additional ground-water supplies for meeting the needs of the city.

A total of 38 well waters were sampled for chemical analysis. These samples are ground waters recovered from the alluvium and from the blue sands and other beds of the Fort Union formation. A map of the Dickinson area showing locations of wells sampled and sections in which ground water of relatively low mineral content exists is shown in figure 6. Results of chemical analyses of well waters sampled are given in table 2.

Waters from alluvial deposits

Five ground waters from alluvial deposits were selected for complete chemical analyses. Values in percent for both salinity and alkalinity are given in table 3, with dissolved solids arranged in order of increasing concentration.

Palmer[16] pointed out that nearly all terrestrial waters have the two general properties of salinity and alkalinity. Salinity results from salts such as sodium chloride or calcium sulfate which are not appreciably hydrolyzed, and alkalinity can be attributed to free alkaline

16 Palmer, Chase, The geochemical interpretation of water analyses: U. S. Geol. Survey Bull. 479, p. 11, 1911.

Table 2.--Chemical analyses of ground waters in the Dickinson area, N. Dak.
(Parts per million)

Well number	Date of collection	Depth in feet	pH	Specific conductance K x 10^5 at 25° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness: Total	Hardness: Noncarbonate	Percent sodium
								Alluvium											
139-96- 3cd	8- 1-47	30	-	542	-	-	-	-	-	-	206	-	375	-	-	-	-	-	-
3dc	8- 1-47	40	-	192	-	-	-	-	-	-	578	-	38	-	-	-	-	-	-
8ac	8- 1-47	15	-	95.1	-	-	-	-	-	-	340	-	5.0	-	-	-	-	-	-
8bd	8- 1-47	20	-	79.8	-	-	-	-	-	-	366	-	33	-	-	-	-	-	-
8ca	8- 1-47	20	-	83.9	-	-	-	-	-	-	420	-	2.0	-	-	-	-	-	-
8cb	7-18-47	33	7.3	57.3	18	0.20	41	17	69	11	376	14	9.0	0.2	0.2	333	172	0	27
8dc	8- 1-47	34	-	157	-	-	-	-	-	-	428	-	9.0	-	-	-	-	-	-
9ba	8- 1-47	-	-	113	-	-	-	-	-	-	360	-	8.0	-	-	-	-	-	-
9da	8- 1-47	30	-	298	-	-	-	-	-	-	94	-	18	-	-	-	-	-	-
11cb1	8- 1-47	60-80	-	65.0	-	-	-	-	-	-	336	-	3.0	-	-	-	-	-	-
11cb2	8- 1-47	-	-	324	-	-	-	-	-	-	868	-	58	-	-	-	-	-	-
11cc	8- 1-47	40	-	198	-	-	-	-	-	-	408	-	21	-	-	-	-	-	-
12ab	7-18-47	25	7.3	234	20	.05	215	120	245	10	505	1,100	10	.5	1.5	1,980	1,030	616	34
12cc	8- 1-47	-	-	371	-	-	-	-	-	-	650	-	15	-	-	-	-	-	-
139-97-10dd	7-18-47	40	7.1	232	13	.05	325	113	178	7.6	554	1,140	12	.1	18	2,080	1,276	822	23
13bb	7-18-47	34	7.4	74.1	16	.25	57	24	89	7.6	392	109	6.0	.4	.3	481	241	0	44
14da	7-18-47	30	7.3	295	25	.05	313	97	134	11	413	970	95	.4	1.2	1,850	1,180	841	20

Fort Union formation

139-96- 2cc	8- 1-47	140	-	80.0	-	-	-	-	-	-	446	-	10	-	-	-	-	-	-
3bb1	8- 1-47	191	-	172	-	-	-	-	-	-	704	-	7.0	-	-	-	-	-	-
3bb2	8- 1-47	196	-	176	-	-	-	-	-	-	698	-	7.0	-	-	-	-	-	-
3bb3	8- 1-47	182	-	172	-	-	-	-	-	-	690	-	6.0	-	-	-	-	-	-
4ac1	7-18-47	154	8.4	226	12	.05	9.0	7.0	[illegible]	[illegible]	911	528	7.0	.2	.5	1,600	51	0	95
4ac2	8- 1-47	135	-	152	-	-	-	-	-	-	644	-	6.0	-	-	-	-	-	-
4ca	8- 1-47	60	-	261	-	-	-	-	-	-	472	-	21	-	-	-	-	-	-
8cd	8- 1-47	131	-	209	-	-	-	-	-	-	666	-	7.0	-	-	-	-	-	-
10dd	7-18-47	120	7.1	267	11	.05	107	59	508	12	671	1,020	12	.2	1.2	2,070	510	0	68
12bb	10- 6-46	60	7.8	415	-	.30	82	49	949		878	1,660	9.6	.8	.8	3,200	406	0	84
14bb	8- 1-47	-	-	269	-	-	-	-	-	-	1,160	-	6.0	-	-	-	-	-	-
15bb	8- 1-47	-	-	224	-	-	-	-	-	-	298	-	10	-	-	-	-	-	-
15db1	8- 1-47	-	-	224	-	-	-	-	-	-	898	-	6.0	-	-	-	-	-	-
15db2	8- 1-47	-	-	239	-	-	-	-	-	-	1,010	-	7.0	-	-	-	-	-	-
16aa	8- 1-47	-	-	206	-	-	-	-	-	-	364	-	12	-	-	-	-	-	-
16bb	8- 1-47	30	-	323	-	-	-	-	-	-	742	-	13	-	-	-	-	-	-
17ad	8- 1-47	-	-	173	-	-	-	-	-	-	188	-	8.0	-	-	-	-	-	-
139-97- 1dd	7-18-47	50	7.1	79.9	14	.05	64	46	66	14	414	133	14	.7	12	566	349	10	28
140-96-32dd	8- 1-47	75	-	128	-	-	-	-	-	-	522	-	10	-	-	-	-	-	-
33dc	8- 1-47	-	-	72.1	-	-	-	-	-	-	408	-	6.0	-	-	-	-	-	-
35cd	8- 1-47	200	-	223	-	-	-	-	-	-	781	-	6.0	-	-	-	-	-	-

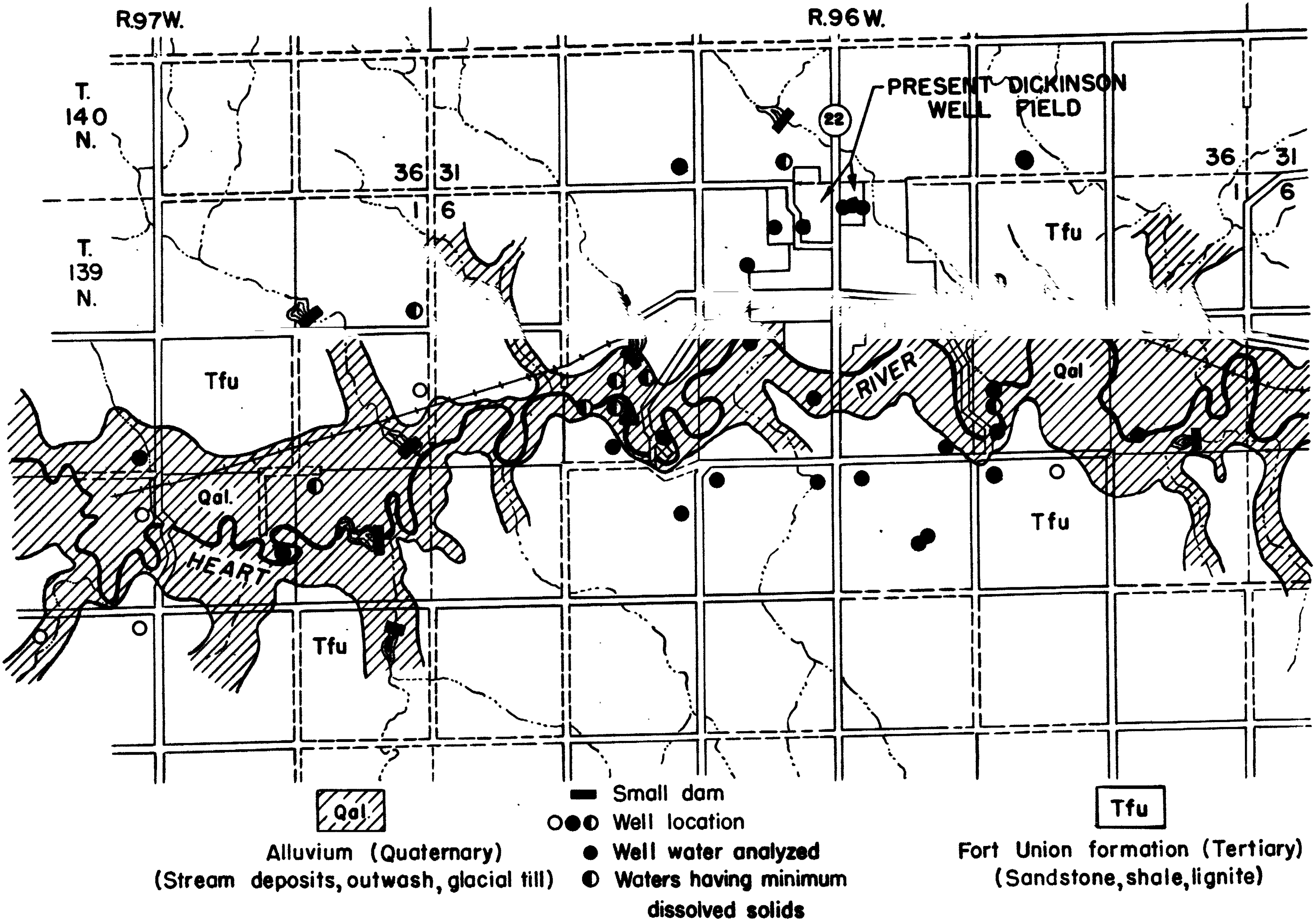


Figure 6.—Map of Dickinson area, North Dakota, showing geology and location of wells

bases produced by the hydrolytic action of water on solutions of bicarbonates and on solutions of salts of other weak acids.

Table 3.--Salinity and alkalinity values for waters from alluvium

Well number	Dissolved solids (parts per million)	Specific cond. K x 10^5 at 25° C.	Percent	
			Salinity	Alkalinity
139-96- 8cb	333	57.3	8.3	91.7
139-97-13bb	481	74.1	27.7	72.3
139-97-14da	1,850	295	77.3	22.7
139-96-12ab	1,980	234	73.7	26.3
139-97-10dd	2,080	232	72.9	27.1

The less-mineralized waters are seen to be those of lower salinity and correspondingly higher alkalinity. The waters from wells 139-96-8cb and 139-97-13bb contain largely bicarbonates of sodium, calcium, and magnesium, as shown in figure 7. Where drainage is poor, the alluvial deposits yield highly mineralized waters, and this may explain the higher concentrations of dissolved solids in the other well waters sampled. Sulfate accounts for 52 to 98 percent of the salinity in waters sampled in this area from alluvial deposits.

Waters from the Fort Union formation

Of the four waters from the Fort Union formation sampled, those of greater mineralization also show higher percentages of salinity. Table 4 gives values for the well waters, arranged in ascending order of

Table 4.--Salinity and alkalinity values for waters from the Fort Union formation

Well number	Dissolved solids (parts per million)	Specific con. K x 10^5 at 25° C.	Percent	
			Salinity	Alkalinity
139-97- 1dd	566	79.9	33.4	66.6
139-96- 4ac1	1,600	226	42.8	57.2
139-96-10dd	2,070	267	66.3	33.7
139-96-12bb	4,300	415	70.8	29.2

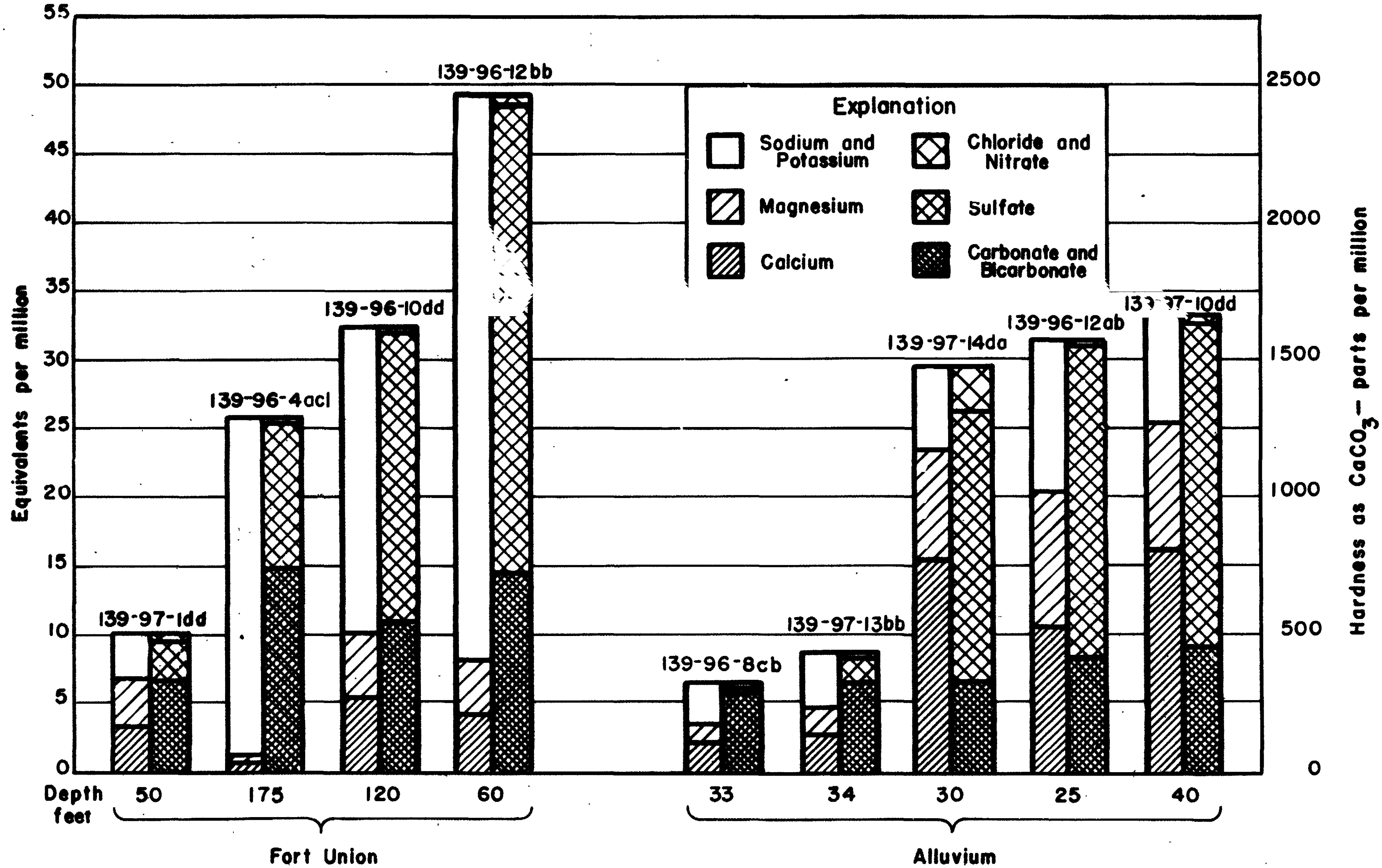


Figure 7.—Graphic representation of analyses of ground waters from the Dickinson area, N. Dak.

dissolved-solids concentration. It will be noted that a reduction in percentage of alkalinity occurs with an increase in dissolved solids. Sulfate accounts for 82 to 99 percent of the salinity in the samples from the Fort Union formation.

As shown in figure 7, sodium comprises most of the total of bases in three of the waters from the Fort Union. The softer waters found in wells 139-96-4ac1, 139-96-10dd, and 139-96-12bb have apparently undergone a change in chemical character. Simpson[17] reasons that alterations in the composition of waters from wells more than 100 feet deep in the Fort Union may be due to the precipitation of calcium and magnesium and carbonate or sulfate from solution; to the formation of bicarbonates through reduction of the original sulfate present in lignite, carbonaceous material, or natural gas; or to base exchange where the waters have given up calcium and magnesium in exchange for sodium. Some of the waters may have dissolved sodium sulfate directly from the rocks with which they came in contact.

Summary

The chemical character of the water in four wells in the lower Heart River Valley has been determined. These analyses will give some indication as to the quality of ground water prior to irrigation of land in this region.

Ground waters from the alluvial deposits and Fort Union formation in the Dickinson area were analyzed to assist in determining the practicability of developing a supplemental water supply for the city of Dickinson.

17 Simpson, H. E., *op. cit.*, p. 36.

Six places in the Dickinson area where the results of chemical analysis show the ground water to be relatively low in mineral content are shown on a map. (See fig. 6, p. 44). The alluvial deposits in the following locations were found to yield waters suitable for a public supply: 139-96-8ac, 8bd, 8ca, 8cb, and 11cb1, and 139-97-13bb. Three samples of water from the Fort Union formation (139-96-2cc, 139-97-1dd, and 140-96-33dc) are considered acceptable as to quality for supplementing the city's water supply. In the Dickinson area both the alluvial deposits and the Fort Union formation yield waters whose mineral content varies appreciably within a short distance. For both aquifers the more dilute waters are characterized by lower percentages of salinity and correspondingly higher percentages of alkalinity. The comparatively softer waters found in deep wells tapping the Fort Union formation have undergone an alteration in composition.

On the basis of the information obtained, the development of an additional and acceptable municipal ground-water supply may be practicable. Further exploration of the quality of water from shallow aquifers in sections 7, 8, 9, 10, and 11, T. 139 N., R. 96 W., and sections 12, 13, and 14, T. 139 N., R. 97 W., is suggested to define accurately the horizontal extent of shallow aquifers yielding the best water. If these areas are then found to be capable of yielding an adequate supply of water, several test holes should be drilled and sustained pumping tests made to measure the quantity and further check the quality under sustained pumping. Shallow aquifers should be thoroughly explored and rejected as not practicable before consideration is given to the Fort Union and underlying formations.

Table 5.--Measurements of water level in observation wells in Grant, Morton, and Stark Counties, North Dakota
[Measurements in feet below land-surface datum]

Grant County

136-85-8aa.

Date	Water level	Date	Water level	Date	Water level
May 24, 1946	25.34	May 19, 1947	23.73	May 6, 1948	24.04
July 11	25.20	July 17	25.02	July 28	25.02
Sept.10	25.80	Oct. 1	25.27	Oct. 19	25.63

136-86-12db.

May 13, 1946	31.15	July 17, 1947	28.12	July 28, 1948	29.91
Aug. 14	31.44	Oct. 1	28.70	Oct. 19	31.04
May 19, 1947	29.79				

136-86-20ac.

May 13, 1946	29.50	July 18, 1947	29.23	July 29, 1948	29.46
July 11	29.52	Oct. 1	29.47	Oct. 19	29.59
May 19, 1947	29.26	May 6, 1948	29.37		

136-87-20dd.

May 15, 1946	14.20	July 18, 1947	14.34	July 29, 1948	15.19
July 11	14.12	Oct. 1	14.30	Oct. 19	16.04
May 20, 1947	14.37	May 6, 1948	14.56		

136-88-18ca.

May 15, 1946	14.20	July 18, 1947	14.34	July 29, 1948	15.19
July 11	14.12	Oct. 1	14.30	Oct. 19	16.04
May 20, 1947	14.37	May 6, 1948	14.56		

Morton County

136-84-32bd.

May 10, 1946	29.45	July 17, 1947	29.34	July 28, 1948	29.52
July 9	29.50	Oct. 1	29.91	Oct. 19	29.85
May 16, 1947	29.24	May 10, 1948	28.99		

Table 5.--Measurements of water level in observation wells--Continued.

Morton County--Continued

137-84-1dd.

Date	Water level	Date	Water level	Date	Water level
May 7, 1946	12.30	May 16, 1947	11.50	July 28, 1948	11.82
July 8	12.44	July 17	10.78	Oct. 19	12.73
Sept.17	13.19	May 10, 1948	10.64		

137-84-10cc.

May 28, 1946	32.14	May 16, 1947	31.93	May 10, 1948	31.92
July 8	32.02	July 17	32.07	July 28	31.97
Sept.17	32.19	Sept.30	32.10	Sept.19	32.11

138-82-5ba.

May 8, 1946	15.15	May 19, 1947	14.70	July 17, 1947	18.37
July 3	15.28				

138-82-5da.

Sept. 7, 1946	20.55	Sept.30, 1947	18.53	July 28, 1948	17.48
May 16, 1947	16.10	May 4, 1948	15.20	Oct. 19	19.05
July 17	13.99				

138-82-18bd.

July 3, 1946	18.88	Sept.30, 1947	17.68	July 28, 1948	18.18
May 19, 1947	18.24	May 4, 1948	17.72	Oct. 19	19.46
July 17	17.41				

138-83-14ab.

May 8, 1946	23.00	May 16, 1947	21.36	May 4, 1948	20.02
July 3	22.68	July 17	22.17	July 28	22.48
Sept.17	22.43	Sept.30	22.60	Oct. 19	24.32

Table 5.--Measurements of water level in observation wells--Continued.

Morton County--Continued

139-82-34db.

Date	Water level	Date	Water level	Date	Water level
May 6, 1946	36.35	May 16, 1947	37.59	May 4, 1948	34.08
July 5	35.71	July 17	36.76	July 28	32.34
Sept.17	35.74	Sept.30	35.43	Sept.19	33.40

Stark County

139-96-12bb.

Sept.21, 1946	52.80	Oct. 2, 1947	51.34	July 29, 1948	51.22
May 22, 1947	51.71	May 5, 1948	50.37	Oct. 20	50.98
July 16	47.53				

139-96-14ab.

Sept.21, 1946	59.10	Oct. 2, 1947	59.04	July 29, 1948	51.22
May 22, 1947	51.71	May 5, 1948	50.37	Oct. 20	50.98
July 16	47.53				

139-97-14da.

Sept.13, 1946	23.90	Oct. 2, 1947	22.81	July 29, 1948	23.02
May 22, 1947	22.32	May 5, 1948	23.46	Oct. 20	23.45
July 16	11.58				

Table 6.--Records of wells in Grant, Morton, and Stark Counties, North Dakota

Well number[1]	Owner or tenant	Type of well[2]	Depth of well (feet)[3]	Diameter of well (inches)	Type of casing[4]	Character of water-bearing material[5]	Method of lift[6]	Use of water[7]	Measuring point: Description[8]	Measuring point: Height above land surface (feet)	Measuring point: Altitude above mean sea level (feet)	Depth to water level below measuring point (feet)[9]	Date of measurement	Chemical analysis[10]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
					Grant County									
135-85- 2ad	-	B	-	24	W	Ss	Cy,H	N	Bp	1.0	2,028	41.85 41.85	7-10-46 9- 2-46	-
135-87- 6ac	J. Adler	Du	43	48	W	Ss	Cy,W,G	D,S	Bp	.6	2,140	41.24 41.40	5-23-46 7-11-46	-
12aa	V. C. Lonie	B	42.8	6	C	Ss	Cy,W,G	D,S	Bp	1.0	2,165	33.00 35.20	5-24-46 8-19-46	-
136-85- 4bc	-	Dr	66	5	P	S	Cy,W	D,S	L	-	-	51	9- 5-46	-
8aa	-	B	37.9	24	W	S	Cy,H	O	Bp	2.0	1,841	27.34	5-24-46	-
12bb	-	Du	-	36	C	Ss	Cy,W	S	Bp	1.4	2,098	31.37 27.00	5-28-46 7-10-46	-
15ad	R. Dawson	Sp	-	-	-	S,Sh	F	S	-	-	-	-	-	-
15cc	do.	Du	16.2	36	W	S,Cl	Cy,H	S	Tco	.2	1,816	14.50 14.90	5-13-46 7-11-46	U
25da	-	B	40.5	24	W	S,G	Cy,H,W	D,S	Bp	.3	1,820	21.95 22.70	5-10-46 7- 9-46	-
26ab	-	Dn	22	2	P	S,G	Cy,H	D	L	-	1,813	18	7-11-46	-

136-85-34ac	D. Zeisen	B	85	18	N	Ss	Cy,H,W	D	Bp	.85	2,142	63.87	5-27-46	-
												62.44	7-10-46	
136-86- 2cc	B. Baumeister	B	65	24	N	Ss	Cy,H,W	D,S	Bp	.5	2,075	63.90	5-27-46	-
12db	-	B	34.7	30	W	S	Cy,H	O	Bp	.3	1,848	31.45	5-13-46	-
14ac	A. Mortenson	Du	13.6	24	P	S	-	N	Tca	1.4	1,847	11.60	5-13-46	U
												12.20	8-14-46	
15ba	T. Mortenson	Du	19.7	36	W	S	Cy,H	D,S	Bp	.7	1,862	19.00	5-13-46	-
												19.45	8-14-46	
18aa	R. Feland	Du	14	36	W	Ss,G	Cy,H	D	Bp	.9	1,935	10.05	5-24-46	-
												11.10	7-11-46	
19bc	J. Bader	Du	12.9	36	C	Ss	Cy,H	D,S	Bp	2.5	2,052	8.40	5-24-46	-
												8.55	7-11-46	
20ac	C. E. Johnson	B	32	24	W	S	Cy,H,W	S,O	Bp	1.0	1,897	30.50	5-13-46	-
29ab	L. Handegaard	Du	-	48	C	S,G	Cy,G	S	Bp	.2	1,883	18.02	8-28-46	-
34ba	-	Du	33.6	48	W	Ss	Cy,H	N	Bp	.6	2,100	27.25	5-24-46	-
												27.30	8-15-46	
												27.40	8-30-46	
136-87-14dd	-	Du	56.7	36	P	Ss	-	N	Tcu	.3	2,104	Dry	5-24-46	-
												Dry	7-11-46	
18ad	-	Du	35.1	36	N	Ss	-	N	Tco	.0	1,905	Dry	5-23-46	-
												Dry	7-11-46	
20dd	-	Du	17.2	48	C	S	Cy,H,G	S,O	Bp	.5	1,940	14.7	5-15-46	-
22bc	-	Du	62.0	48	C	S,G	Cy,W	D,S	Bp	1.0	2,085	45.30	8-21-46	-
22dd	-	Sp	-	-	P	Ss	F	S	-	-	-	-	-	-
26ba	L. W. Livermore	Du	7.8	24	W	S	Cy,H	S	Tco	.3	1,932	3.9	5-15-46	U
												5.72	7-11-46	
28db	A. J. Heinz	Du	19.8	48	W	S,Cl	Cy,H	S	Bp	.9	1,946	18.85	5-15-46	-
												18.95	7-11-46	
33cc	R. A. Bay	Du	13.7	48	C	Ss	H	D,S	Tcu	1.1	2,097	10.42	5-23-46	-
136-88- 8aa	M. Kolmann	Du	10.1	48	C	S	Cy,H	D,S	Bp	1.1	2,015	7.84	5-29-46	-
												8.40	7-16-46	

See footnotes at end of table.

Table 6.--Records of wells in Grant, Morton, and Stark Counties, North Dakota--Continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
							Grant County--Continued							
136-88-14db	M. Schmidt	B	35.3	24	W	Ss	Cy,H	D,S	Bp	0.3	2,107	30.74	5-23-46	-
												29.58	7-11-46	
15cd	-	Du	10.8	36	N	S	-	N	L	-	1,975	Dry	5-29-46	-
18ca	-	Du	30.2	48	W	S	Cy,H	D,O	Tcu	.0	2,040	28.1	5-21-46	-
19dc	W. F. Sellner	Du	15.0	30	C	S	-	N	Tcu	.8	2,000	13.03	8-21-46	-
26cb	A. Ulrich	Du	-	48	W	S	Cy,H	D,S	Bp	.2	1,975	22.10	5-22-46	-
												23.06	7-25-46	
34dc	J. Bakos	Du	34	36	C	Ss	Cy,W,H	D,S	Bp	.0	2,040	29.70	5-22-46	-
												29.60	8-23-46	
136-89- 7ab	F. Taylor	Du	17.2	48	W	G	Cy,H	D	Tcu	1.0	-	15.35	5-21-46	-
												15.42	7-16-46	
9bd	A. Koehler	Du	22.2	48	W	S,G	Cy,G	S	Bp	1.0	-	19.95	5-21-46	U
												20.20	7-16-46	
11dd	R. Swift	Du	15.2	36	W	S,G	Cy,W	S	Tcu	-	2,023	9.65	5-21-46	-
24da	-	Du	17.0	36	W	Ss	-	N	Tcu	.3	1,970	14.85	5-22-46	-
												16.32	7-16-46	
							Morton County							
135-84- 4cc	W. Anderson	Dr	-	5	P	S	Cy,W	D,S	Bp	.9	1,876	27.10	10- 3-46	-
												30.55	5-16-47	
												32.71	7-17-47	
4dd	E. Lundstrom	B	45.0	18	W	S	Cy,G	D,S	Bp	.5	1,874	41.50	10- 3-46	-
8aa	M. Martin	B	60	18	W	S	Cy,H	D,S	Tco	1.1	1,870	48.06	10- 3-46	-
8da	-	B	-	-	W	-	Cy,H	D,S	Tco	-	-	85.8	10- 3-46	-
20ad	-	B	70	24	W	S	Cy,W,H	D,S	Tco	.7	1,890	62.16	10- 3-46	-
28bb	Gusteen	Du	65	36	W	S	Cy,W	D,S	Bp	.4	1,866	46.75	10- 3-46	-
136-83-19ad	S. S. Hopfauf	B	45	24	W	-	Cy,W,G	D,S	Tco	.9	2,150	15.94	9-21-46	-
136-84- 3bc	-	B	47.5	24	W	S	-	N	Tco	.0	1,860	Dry	5-11-46	-
												Dry	7- 9-46	

136-84- 4ad	-	Du	14.1	48	W	S	-	N	Tcu	1.7	1,800	Dry	5-10-46	-
												Dry	7- 9-46	
10bb	T. Cronin	Du	32.7	36	W	S,G	Cy,W,H	D,S	Bp	1.2	1,797	30.95	5-11-46	-
												31.25	7- 9-46	
12bb	E. Lundgren	Du	50	36	W	S,Sh	Cy,H	S	Bp	.3	-	41.30	7-19-46	-
13cd	-	B	-	24	P	Ss	Cy,G	S	Tco	1.5	2,072	21.12	9-21-46	-
22bd	-	B	46	24	W	-	Cy,H	D,S	Bp	1.5	-	30.5	5-11-46	-
26cc	-	Du	60.0	36	N	Ss	-	N	L	-	2,042	Dry	9-21-46	-
27aa	C. Pearson	B	42	18	W	S	Cy,H	D,S	Bp	.8	2,022	36.93	9-21-46	-
30aa	-	Du	16.5	36	W	S	-	N	Tcu	.8	1,805	Dry	5-10-46	-
												Dry	7- 9-46	
32bd	H. Bahm	B	36.6	24	W	S	Cy,G	D,S,O	Bp	.8	1,837	30.45	5-10-46	-
												30.50	7- 9-46	
32cd	-	B	27.0	24	W	S	Cy,H	N	Bp	.8	1,852	Dry	5-27-46	-
												Dry	7- 9-46	
137-83- 4aa	M. B. Bard	Du	61.7	48	C	Ss	Cy,H,G	D,S	Tca	.3	2,045	38.20	5- 7-46	-
												40.50	7- 8-46	
137-84- 1dd	T. Stark	Du	17.6	5	C	-	Cy,H	D,S,O	-	-	1,738.38	13.0	5- 7-46	C
10cc	C. Schmitz	B	47.4	24	W	Ss	Cy,G	S,O	Bp	.4	2,198	32.59	5-28-46	C
12bc	-	B	63.9	24	C	Ss	Cy,H	N	Bp	.4	1,842.47	48.65	5- 7-46	-
												48.85	7- 8-46	
22cd	D. Slavick	B	60	24	W	Sh	Cy,G	S	Bp	1.9	2,083	32.23	5-28-46	-
												32.46	7- 8-46	
34aa	O. Zuelich	B	54.0	36	P	Sh	Cy,H	D,S	Bp	.2	1,840	39.65	5-10-46	-
												42.70	7- 8-46	
35ac	-	Dn	-	2	P	S	Cy,H	D,S	L	-	1,763	18	7- 8-46	-
138-81- 4bb	Great Plains Experiment Sta.	Du	28.2	96	W	Ss	N	N	Tcu	1.9	1,716.16	17.82	5-14-46	-
												20.28	8- 1-46	

See footnotes at end of table.

Table 6.--Records of wells in Grant, Morton, and Stark Counties, North Dakota--Continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
			Morton County--Continued											
138-82- 5ba	G. L. Carlson	Du	20.0	4	T	-	Cy,H	D,S,O	Tcu	0.0	1,684.10	15.15	5- 8-47	-
												15.28	7- 3-46	
												14.70	5-17-47	
												18.37	7-17-47	
5da	A. Larson	Du	23	48	C	S,G	Cy,W,G	D,S,O	Tco	.5	1,685	21.05	9- 7-46	
5db	do.	Du	16.7	48	C	-	-	N	Tco	.6	1,679.28	15.8	5- 6-46	-
												16.36	7- 9-46	
10ac	A. Hendrickson	Du	60	36	C	-	Cy,H	S	Bp	1.7	1,955.75	20.45	5- 6-46	C
												20.67	7- 3-46	
												24.80	9-17-46	
18bd	H. Jankus	Du	21	36	W	-	Cy,H	D,S,O	Tco	.9	1,697	19.78	7- 3-46	-
18cc	C. Hendrickson	Du	26	36	W	-	Cy,H	N	Bp	1.0	1,705	21.65	9- 7-46	-
18dd	-	Du	19.6	48	C	-	Cy,H	N	Bp	.2	1,713.39	17.45	5- 7-46	-
												17.17	7- 3-46	
												17.29	9- 7-46	
21aa	J. Schauss, Sr.	B	48.1	24	W	Ss	Cy,W,H	D,S	Bp	.3	1,882.93	36.80	5-20-46	-
												37.94	7- 3-46	
138-83- 8bb	C. Schiller	B	30	24	W	Ss	Cy,H	D	Bp	.0	1,973	11.95	5-28-46	-
												12.19	7- 3-46	
12ab	J. Jankus	B	48.5	24	N	Ss	Cy,H	D,S	Tco	.4	1,809.37	29.50	5- 8-46	-
												29.77	7- 3-46	
14ab	H. Rask	D	28.9	36	C	S	Cy,H	D,S	Bp	1.2	1,701.67	24.2	5- 8-46	C
												23.88	7- 3-46	
												24.63	9-17-46	
15db	-	Du	46.1	48	W	Ss	-	N	Tco	.0	1,739.00	Dry	5- 8-46	-
												Dry	7- 3-46	
26bd	-	Du	70.5	48	C	Ss	-	N	L	-	1,905	Dry	5- 7-46	-
												Dry	7- 3-46	
30bb	-	B	33.6	24	W	Ss	Cy,H,G	N	Bp	.2	2,030	30.20	5- 8-46	-
												31.40	7- 8-46	
												30.43	9-10-46	

139-81-20dc		Adams	Dr	285	6	P	Ss	Cy,G	D,S	L	-	1,810	55	5-14-46	-
	30bd	-	B	-	6	P	S	Cy,W	D,S	L	-	1,650	22	5-14-46	-
	35cd	G. Behrens	Du	45	36	W	S,G	Cy,H,G	D,S	Bp	.9	1,675.69	41.35	5-14-46	-
													41.59	7-28-46	
139-82-23bd		O. Paine	B	24.1	6	P	S	-	N	Tco	.5	1,675.60	21.14	5- 3-46	-
													21.87	7- 3-46	
	26cc	H. S. Russell	Du	18	84	W	S	Cy,H	S	Bp	.0	1,668.21	17.17	5- 6-46	-
													17.92	7- 5-46	
	34db	-	Du	56.5	48	C	Ss	-	O	Tco	1.0	1,765.00	37.35	5- 6-46	-
	35db	-	Dr	200	6	P	Ss	-	D,S	L	-	-	50	7- 5-46	-
						Stark County									
139-96-	2cc	J. Kausch	Dr	140	5	-	-	Cy,E	-	-	-	-	-	-	P
	3bb1	City of Dickinson	Dr	191.0	20,12	P	Ss	T,E	P	Hp	.88	-	107.20	4- 1-44	-
	3bb2	do.	Dr	196	20,10	P	Ss	T,E	P	Hp	1.0	-	124.59	4- 1-44	-
	3bb3	do.	Dr	182	20,8	P	Ss	T,E	P	Hp	.5	-	128.92	4-14-44	-
	3bb4	do.	Dr	191	8	P	Ss	-	P	Tca	1.9	-	129.50	4-14-44	-
	3bb6	do.	Dr	170	8	P	Ss	Cy,G	P	Hp	1.0	-	97.72	3-31-44	-
	3cd	-	Du	30	48	-	-	H	-	-	-	-	-	-	P
	3dc	G. Clarke	B	40	24	-	-	C,E	-	-	-	-	-	-	P
	4ac1	City of Dickinson	Dr	154.0	20,12	P	Ss	T,E	P	Hp	.6	-	92.14	4- 1-44	-
	4ac2	do.	Dr	135.2	20,12	P	Ss	T,E	P	Hp	.5	-	48.64	5- 5-44	-
	4bd	do.	Dr	140	20,12	P	Ss	T,E	P	Hp	.5	-	51.72	5- 5-44	-
	4ca	V. Meduna	-	60	18	-	-	Cy,H	D	-	-	-	-	-	P

See footnotes at end of table.

Table 6.--Records of wells in Grant, Morton, and Stark Counties, North Dakota--Continued

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
				Stark County--Continued										
139-96- 8ac	Northern Pacific RR	B	15	5	-	S	Cy,H	D	-	-	-	-	-	P
8bd	R. H. Swett	-	20	24	-	S	Cy,E	D	-	-	-	-	-	P
8ca	S. Fitzloff	B	20	24	-	S	C,E	D	-	-	-	-	-	P
8cb	U. S. Government	Dr	-	6	-	S,G	..	-	L	-	2,430	38.48	9-13-46	-
8cd	W. Kesting	Dr	131	5	-	-	C,E	D	-	-	-	-	-	P
8dc	A. Gayda	B	34	24	-	-	C,E	D	-	-	-	-	-	P
9ba	C. Polanski	Du	-	-	-	S	Cy,G	D,S	-	-	-	-	-	P
9da	C. Hulzenbiler	-	30	18	-	-	-	D	-	-	-	15	-	P
10dd	Brown	B	45	24	T	-	-	N	Tca	-	2,514	17.53	9-21-46	-
11cb1	Queen City Packing Co.	Dr	60-80	3	-	-	Cy,H	D	-	-	-	-	-	P
11cb2	do.	Du	-	48	-	-	Cy,E	S,In	-	-	-	-	-	P
11cc	F. Brown, Jr.	-	40	18	-	-	C,E	D	-	-	-	-	-	P
12ab	Dickinson Riding Stables	Du	25	24	W	-	Cy,H	S	L	-	-	20	-	-
12bb	S. L. Carroll	B	68	24	T	-	Cy,W	D,S,O	Tco	2.5	-	55.30	9-21-46	C
12cc	-	-	-	-	-	-	-	D	-	-	-	-	-	P
14ab	F. Johnson	B	81.0	12	C	-	-	O	Tco	.8	2,598	59.90	9-21-46	U
14bb	G. Gress	B	-	24	C	-	Cy,W	S	Tcu	1.0	2,545	48.40	9-21-46	-
15bb	-	Du	-	-	-	-	C,E	D	-	-	-	-	-	P
15db1	J. J. Meyer	Dr	-	-	-	-	Cy,E	D	-	-	-	-	-	P
15db2	do.	Dr	-	-	-	-	Cy,W,E	D	-	-	-	-	-	P
16aa	do.	-	-	-	-	-	C,E	D,S	-	-	-	-	-	P
16bb	Sax Aviation Co.	-	30	18	-	-	C,E	N	-	-	-	-	-	U,P
17ad	-	Du	-	48	-	-	Cy,H	D	-	-	-	-	-	P

Stark County--Continued

139-97- 1dd	-	B	50	30	T	Ss	Cy,W	D,S	Tco	1.0	2,450	34.95	9-11-46	-
10dd	-	Du	40	36	C	S	Cy,W	S	Tco	1.5	2,435	36.36	9-12-46	-
12ad	-	B	40	24	T	Ss	Cy,H	S	Tco	1.2	2,443	27.40	9-12-46	-
13bb	-	B	34.0	24	C	S	Cy,W,S	D,S	L	-	2,419	30	-	-
14da	-	Dr	30	5	P	S	Cy,H	D,O	Bp	.5	2,420	24.40	9-13-46	-
15ad	W. Provotsky	Du	40	24	W	S	Cy,G	D,S	Tco	1.0	2,430	25.70	9-12-46	-
22aa	-	B	65	24	W	Ss	Cy,W	D,S	Tco	.6	2,445	-	-	-
22bb	-	Du	-	36	C	Ss	Cy,H	D,S	Tco	1.0	2,450	22.75	9-12-46	-
140-96-32dd	-	-	75	-	-	-	C,E	-	-	-	-	-	-	P
33dc	-	-	-	18	-	-	-	D	-	-	-	-	-	P
35cd	-	-	200	-	-	-	Cy,E	D	-	-	-	-	-	P

Footnotes:

1 See description of well-numbering system in body of report.

2 B, bored; Dn, driven; Du, dug; Sp, spring.

3 Reported depths below land surface are given in feet; measured depths are given in feet and tenths below measuring points.

4 C, concrete (also brick, tile, or pipe); N, none; P, iron or steel pipe; T, clay tile; W, wood.

5 Cl, clay and sandy clay; G, gravel; S, sand; Sh, shale; Ss, sandstone.

6 Method of lift: C, horizontal centrifugal; Cy, cylinder; F, flow; T, turbine.

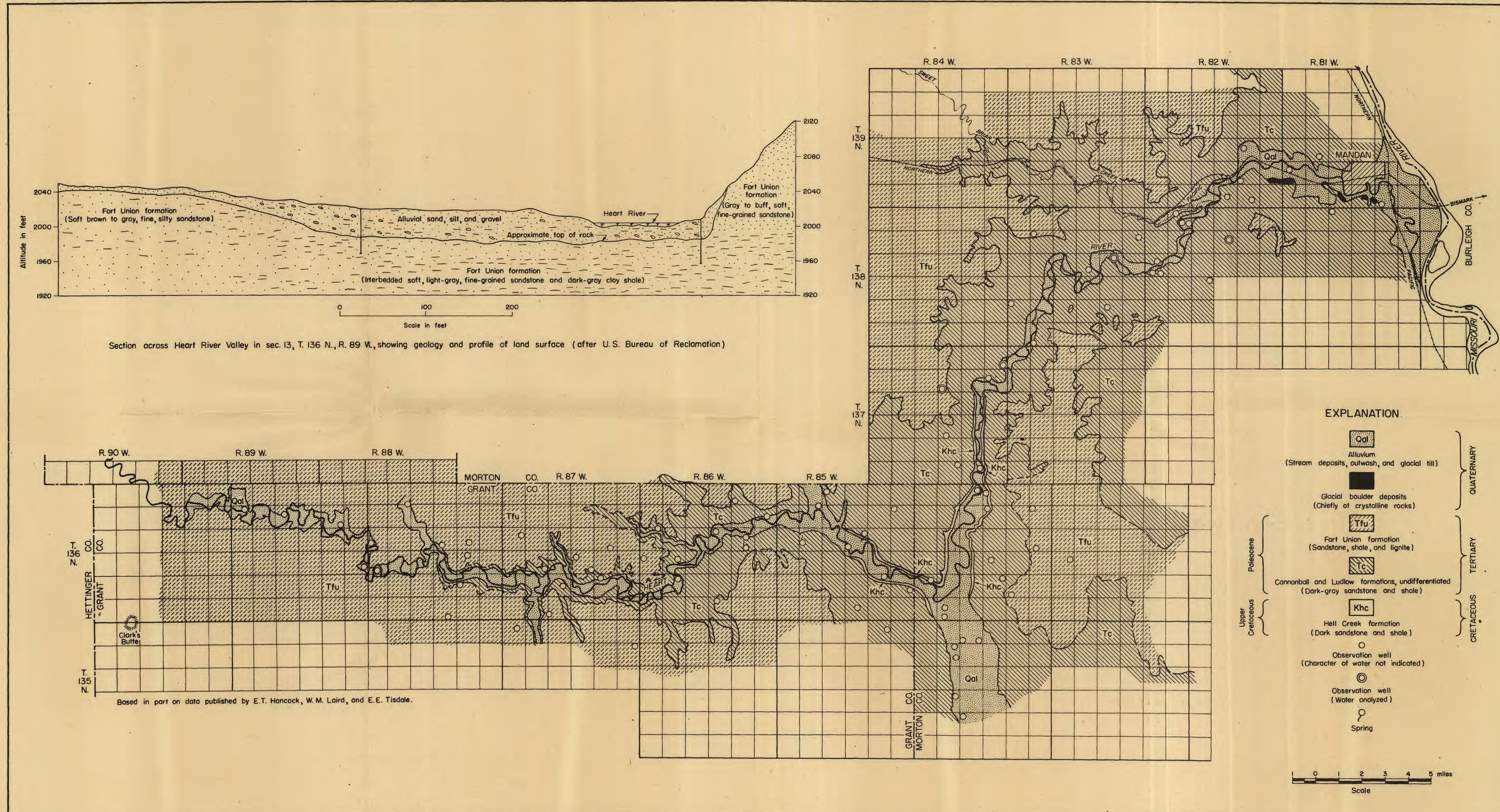
Type of power: E, electric; G, gas engine, H, hand-operated; W, windmill.

7 D, domestic; In, industrial; N, not being used; O, observation; P, public supply; S, stock.

8 Bp, base of pump; Hp, hole in pump base; L, land surface; Tca, top of casing; Tco, top of cover; Tcu, top of curb.

9 Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.

10 P, partial analysis; C, complete analysis; U, reported unfit for domestic use.



GPO D 750

MAP OF THE LOWER HEART RIVER VALLEY, N. DAK., SHOWING GEOLOGY AND LOCATION OF WELLS