GROUND WATER SUPPLY PROBLEMS IN THE SANBORN AREA
BARNES COUNTY, NORTH DAKOTA

BY

C. J. HUXEL, JR.

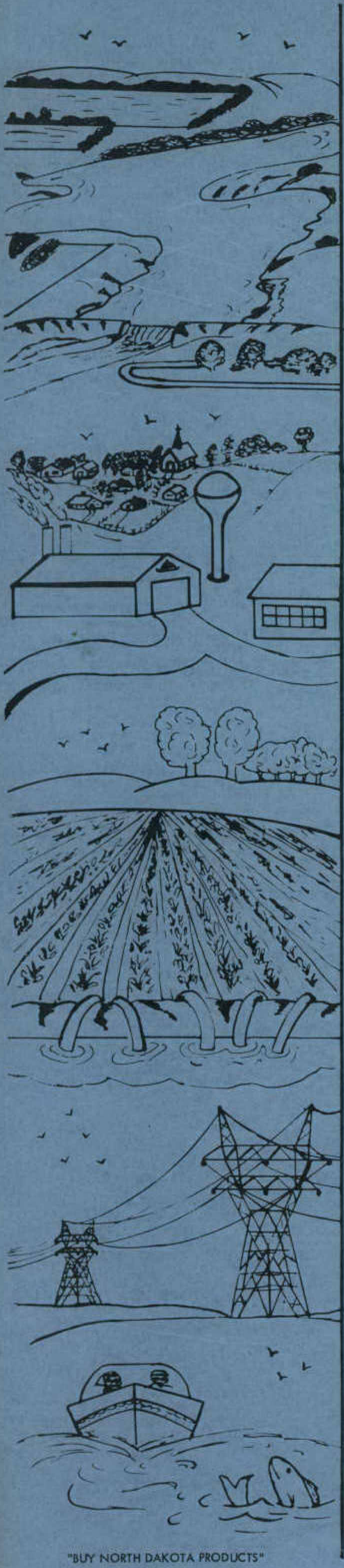
GEOLOGICAL SURVEY
UNITED STATES DEPARTMENT OF THE INTERIOR

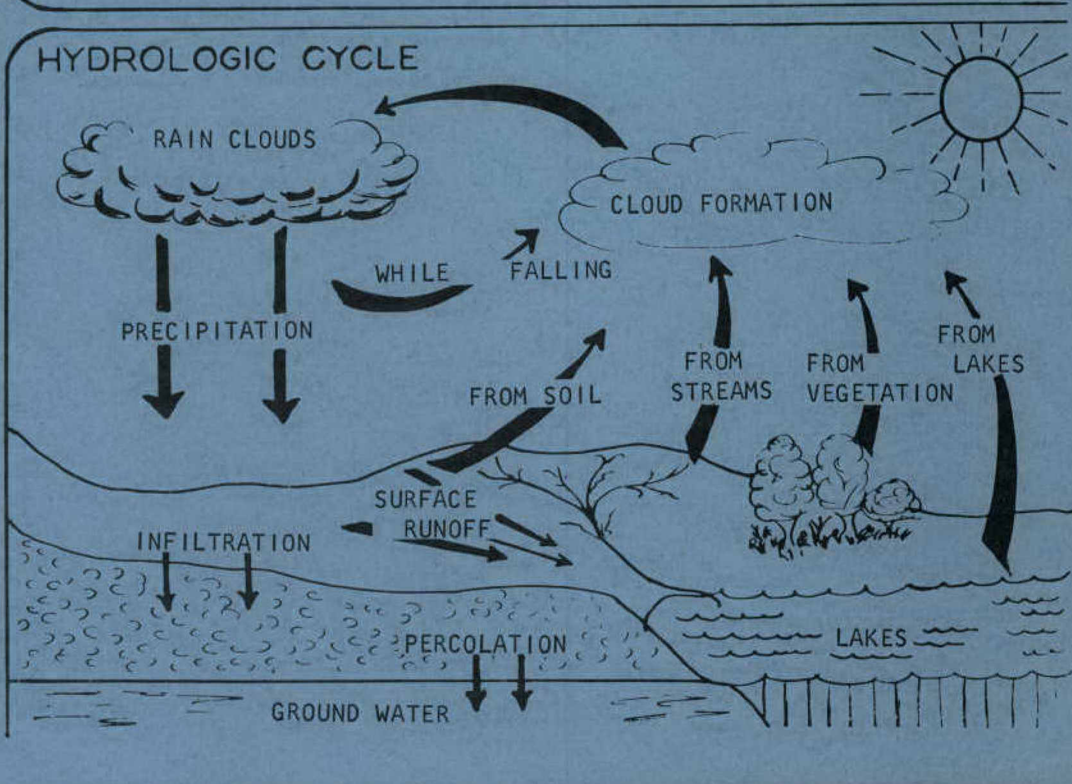
NORTH DAKOTA GROUND WATER STUDIES

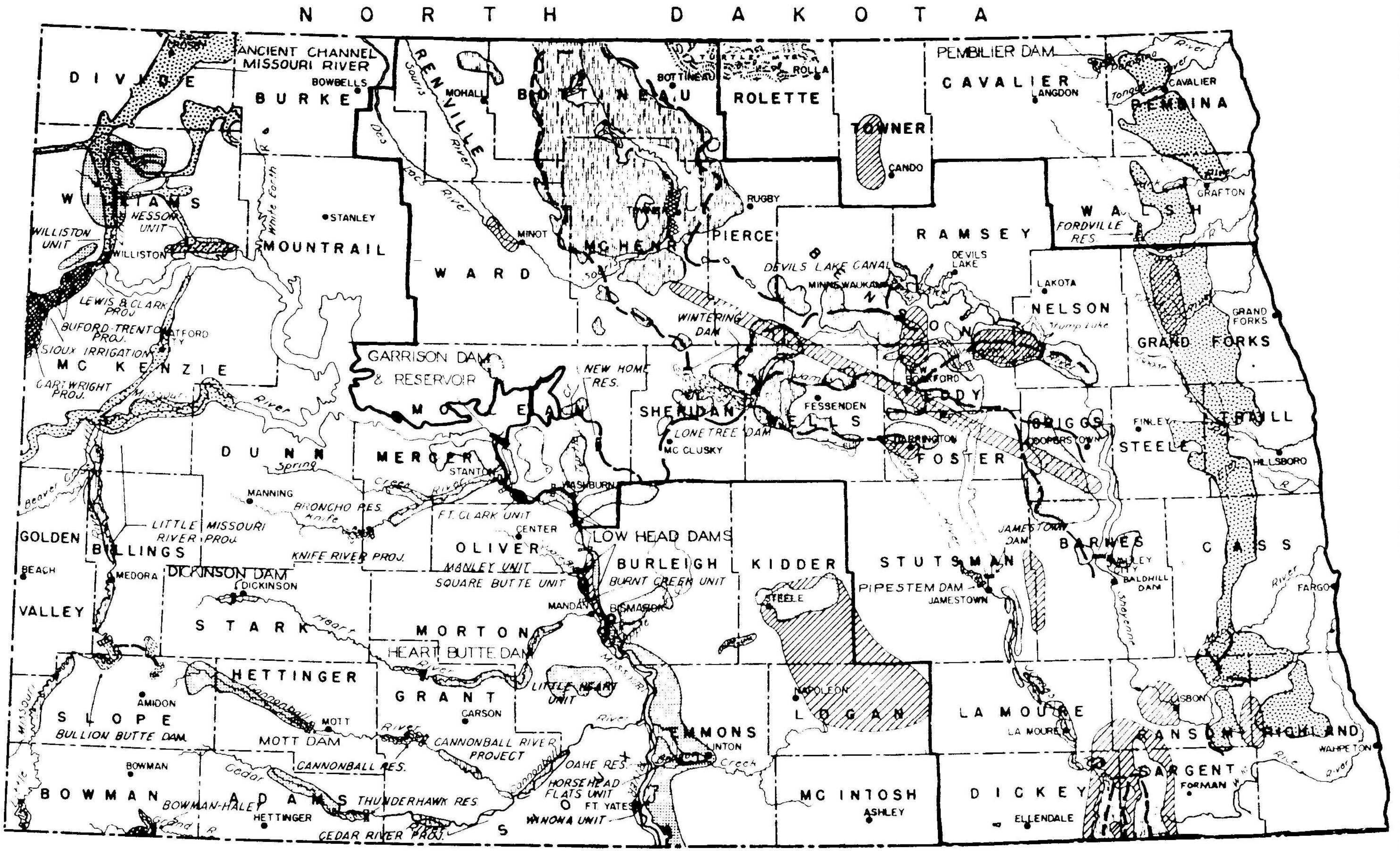
NO.32

PUBLISHED BY
NORTH DAKOTA STATE WATER CONSERVATION COMMISSION
1301 STATE CAPITOL, BISMARCK, NORTH DAKOTA
IN COOPERATION WITH
U. S. GEOLOGICAL SURVEY

1961







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

GROUND WATER SUPPLY PROBLEMS IN THE
SANBORN AREA
BARNES COUNTY, NORTH DAKOTA

BY

C. J. Huxel, Jr.

Geological Survey
United States Department of the Interior

NORTH DAKOTA GROUND WATER STUDIES

NO. 32

Published By
North Dakota State Water Conservation Commission
1301 State Capitol, Bismarck, North Dakota
In Cooperation With
U. S. Geological Survey

1961

CONTENTS

	Page
Introduction	1
Geohydrology	3
Bedrock	3
Glacial drift	4
Drift aquifers and their properties	5
Quality of water	7
Present water-supply problems	10
Present municipal-supply facilities	10
Pollution problem	11
Summary and conclusions	12
References	21

ILLUSTRATIONS

Facing page

Figure 1. Maps showing the location of wells, test holes, the test-hole sections, and the area underlain by Unit B in the Sanborn area.......... 2

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

3. Test-hole sections in the Sanborn area......... 5

TABLES

Page

1. Chemical analyses of ground water.............. 8

2. Recommended maximum limits of selected chemical constituents in drinking water............... 10

3. Logs of test holes............................ 15

GROUND-WATER SUPPLY PROBLEMS IN THE SANBORN AREA, BARNES COUNTY, NORTH DAKOTA

By
C. J. Huxel, Jr.

INTRODUCTION

The village of Sanborn, population 263 (1960 census), located 2 miles north of U. S. Interstate Highway No. 94 in west-central Barnes County, is typical of many small rural North Dakota municipalities.

The water-supply problem facing Sanborn is that of obtaining a sufficient quantity of good-quality water to satisfy local domestic needs. The problem is complicated by pollution of existing ground-water resources. Pollution has increased in Sanborn because closely spaced private sewage-disposal systems are operated where water is obtained from wells tapping a shallow aquifer that has restricted circulation.

An investigation of ground-water conditions was begun in the spring of 1960 by the U.S. Geological Survey in cooperation with the North Dakota State Water Conservation Commission. The purposes of the study are to examine the ground-water resources available in a 20-square-mile area surrounding Sanborn and to describe the specific conditions that contribute to the water-supply problems of the village. As part of a continuing Statewide program of water-resources investigations, some of the data contained in this report will be included also in a future, more comprehensive investigation covering all of Barnes County. Moreover, the information given here will be of use to the residents of Sanborn and may contribute to the understandingof similar problems in other areas.

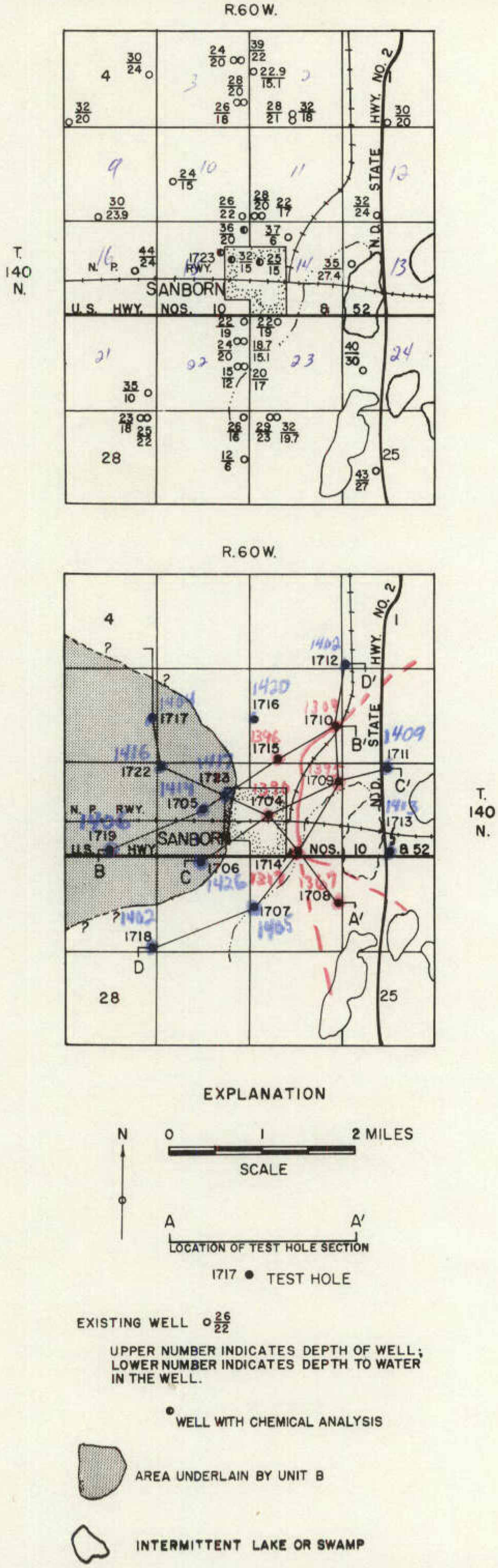


FIG. 1. MAPS SHOWING THE LOCATION OF WELLS, TEST HOLES, THE TEST HOLE SECTIONS, AND THE AREA UNDER LAIN BY UNIT B IN THE SANBORN AREA.

An inventory was made of all existing wells in the report area outside of the Sanborn boundaries, special attention being given to depths of wells and depths to water in wells. The well-location map (fig. 1) summarizes these data. Some wells within the village limits also were canvassed. Chemical analyses were made of water from three private wells and one test hole in the area (table 1). Data on subsurface geology were obtained by drilling 18 test holes with a rotary drilling rig owned by the North Dakota State Water Conservation Commission. The locations of these holes are recorded on figure 1. A total of 1,058 feet was logged during the drilling (table 3). The altitude above mean sea level at each test hole was determined with a Paulin altimeter, using first- and second-order U.S. Coast and Geodetic bench marks.

The well-numbering system used in this report is based upon the public land classification of the U.S. Bureau of Land Management and is illustrated in figure 2. The first numeral denotes the township north of the base line, the second numeral the range west of the fifth principal meridian, and the third 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 NE$\frac{1}{4}$SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 15, T. 140 N., R. 60 W. Consecutive terminal numerals are added if more than one well is recorded within a 10-acre tract.

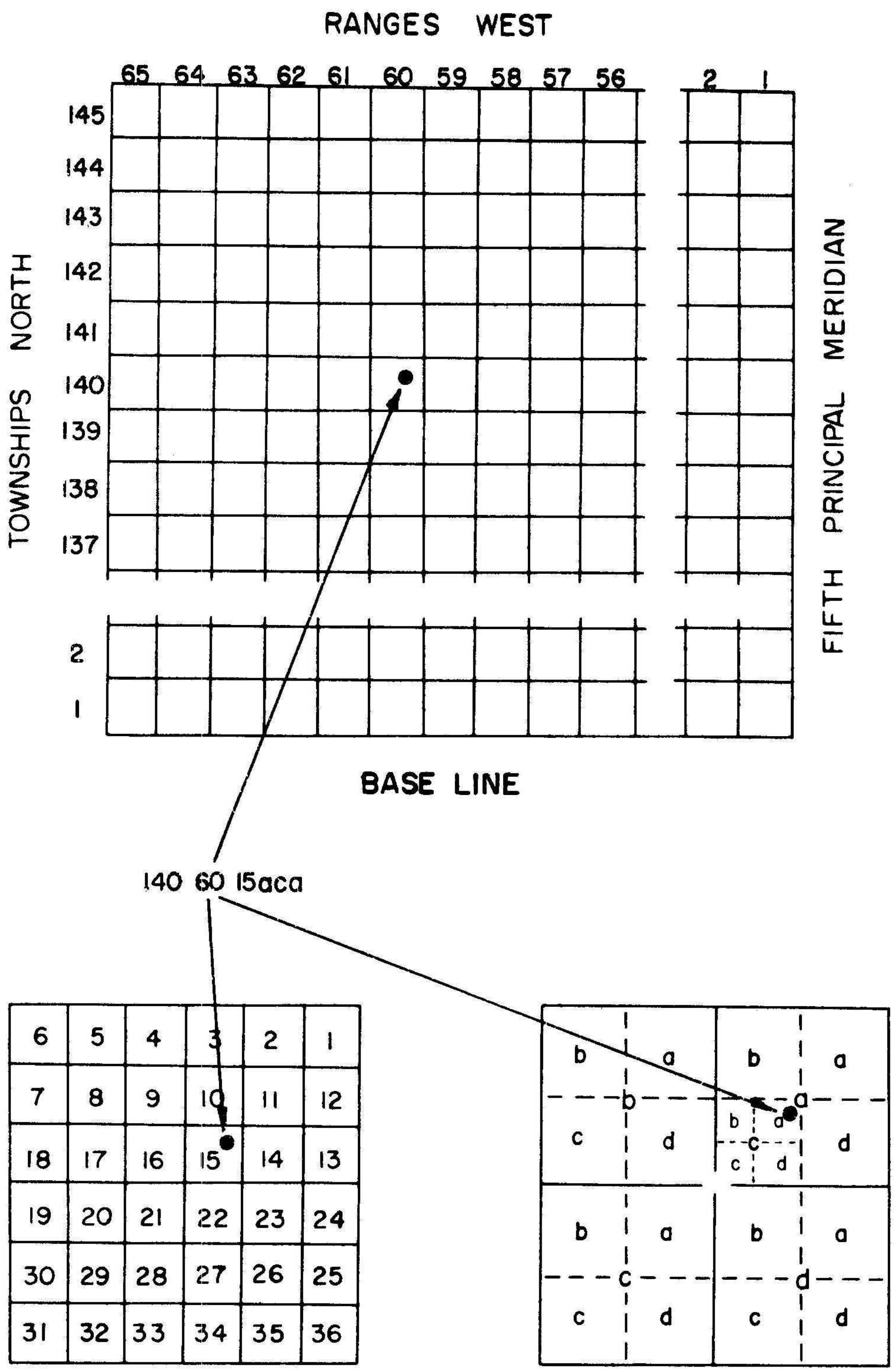


Figure 2 -- Sketch illustrating well-numbering system

GEOHYDROLOGY

Surface materials in this part of North Dakota consist mostly of glacial drift deposited from continental ice sheets during late phases of Pleistocene glaciation. The Sanborn area is located on low-relief ground moraine deposited at the proximal (iceward) edge of the northwest-southeast-trending Kensal-Oakes end moraine. End and ground moraine are composed largely of material called glacial till, a pebbly to bouldery clay. The topography of the ground moraine is gentle and even; relief seldom exceeds 15 feet per square mile. The topography of the end moraine, on the other hand, is rough and hummocky, its relief usually exceeding 30 feet per square mile. Except for a few shallow deposits of sand and gravel adjacent to and within small valleys, the soil in the Sanborn area consists entirely of slightly weathered glacial till.

The area is drained by two shallow gravel-bottomed valleys that represent former glacial melt-water channels. These valleys, which carry water only after heavy rains or thaws, and their associated gravel deposits, are poorly defined and are insignificant as sources of ground-water supply.

Bedrock.--A bedrock formation called the Pierre shale of Late Cretaceous age, lies directly under the glacial drift in the Sanborn area and in most of North Dakota east of the 100th meridian. The Pierre, referred to locally as slate, is a compact, smooth-textured, slightly brittle blue-gray clay. It is easily recognized and distinguished from glacial till in drill cuttings.

Information obtained from test drilling shows that the bedrock surface is considerably higher in the Sanborn area than it is a few miles to the west. The altitude of the top of the Pierre shale at locations 5 and 8 miles west and northwest of Sanborn averages 1,323 and 1,261 feet above sea level, respectively; it is about 1,395 feet above sea level in the Sanborn area. Thus Sanborn is on a local bedrock high.

The depth to bedrock in test holes 1710 and 1714 is greater than that in adjacent holes; this suggests that a buried channel may be cut into the bedrock surface. The logs of these test holes, however, show no sand and gravel deposits associated with the channel or depression in the bedrock surface. In some buried channels, water-bearing deposits are present; therefore, additional exploration in the channel or depression noted above might result in the locating of a small aquifer.

The Pierre shale is relatively impermeable and does not yield water readily to wells. It does, however, influence the chemical quality of water in drift aquifers directly overlying it.

Glacial drift.--The cover of glacial drift thins correspondingly as the altitude of the bedrock surface increases from west to east. The thickness of the drift in test holes in the Sanborn area averages 46 feet, whereas 4 to 8 miles northwest of Sanborn it averages 212 feet.

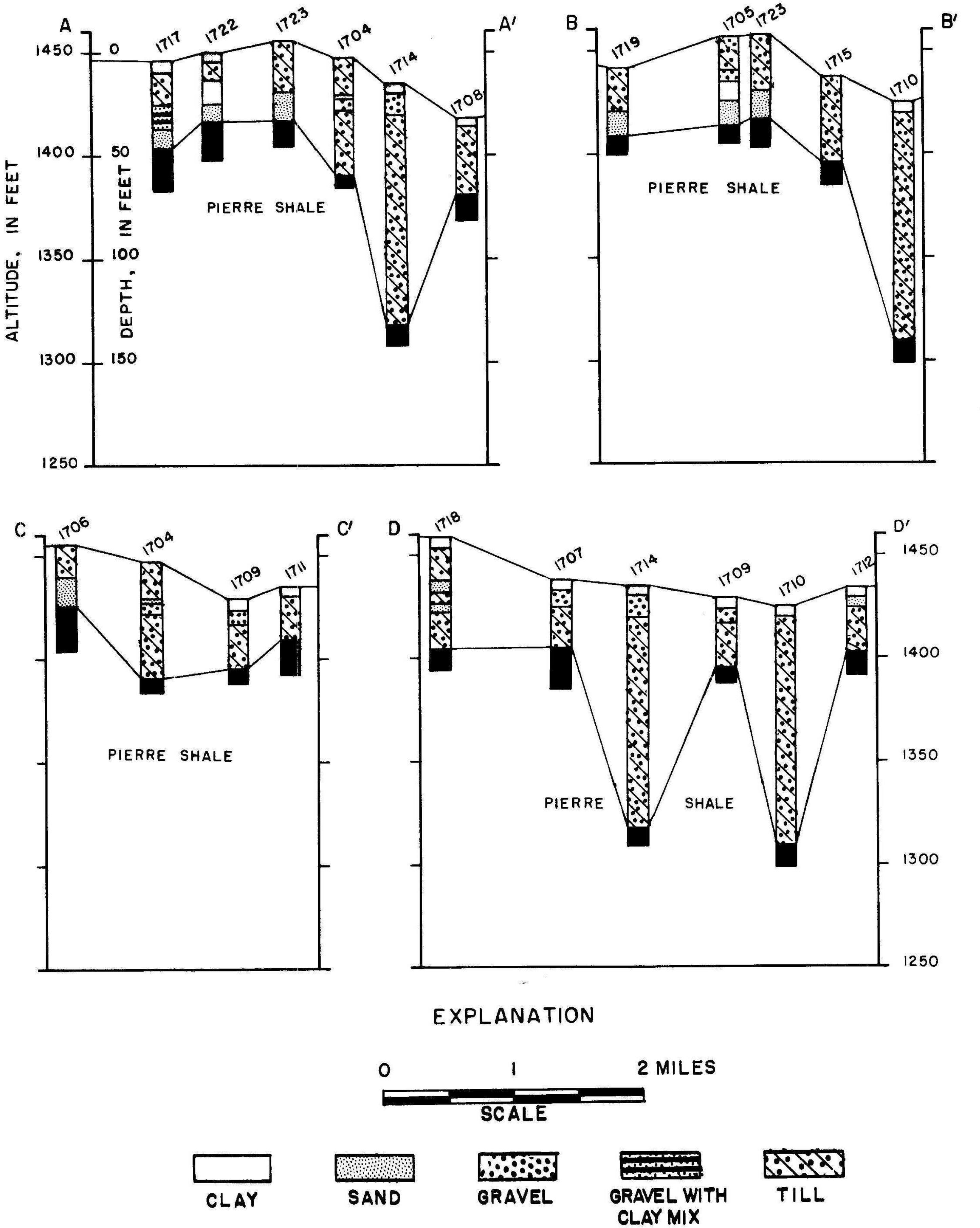


FIG. 3 **TEST HOLE SECTIONS IN THE SANBORN AREA**

The materials composing the drift may be broadly classified into two major types: (1) glacial till and (2) glaciofluvial deposits. The till, which makes up the major part of the drift cover, was deposited directly by the ice. It is a poorly sorted, sandy to gravelly cohesive, plastic blue clay; it also contains many boulders. As a result of chemical weathering within 15 to 20 feet of the land surface, the till ordinarily becomes less cohesive and acquires a yellow to brown color. Till is too nearly impermeable to constitute a good source of ground water for wells.

Glaciofluvial deposits consist of silt, sand, gravel, and larger rocks that were laid down by melt water flowing on top of, within, or in front of the glacial ice. They may occur at the land surface, as does the sand and gravel associated with the small melt-water valleys in the Sanborn area. More often, however, they are found as lenses and sheets of sand and gravel buried within the body of the till. When such deposits are saturated, they readily yield water to wells. The test-hole sections across the area (fig. 3) illustrate the known relations between the various glaciofluvial deposits penetrated during test drilling.

Drift aquifers and their properties.--Most of the wells in Sanborn apparently obtain water from the sand and gravel lens recorded in the log of test hole 1704. This lens, which will be referred to hereafter as Unit A, seems to be restricted to the immediate vicinity of Sanborn. Logs of test holes 1705, 1706, 1717, 1719, 1727, and 1723 record the occurrence of another unit consisting of a sheet of glaciofluvial deposits at the base of the till. The materials of this deposit appear to be hydraulically continuous and constitute a single aquifer. This aquifer will be referred to as Unit B, and its approximate areal limits as defined by test drilling are shown on the test-hole location map (fig. 1). Although both are recharged by water percolating down through the overlying weathered till the fact that Unit A is separated from the bedrock by till and that Unit B lies directly on the bedrock, makes it appear unlikely that the 2 units are connected hydraulically. However, this could be confirmed only by a pumping test. Water from Unit B is discharged from a few wells in the western part of Sanborn and from farm wells west of the village.

Thick sand and gravel deposits were found in test holes drilled in eastern Stutsman and western Barnes Counties about 8 miles west of the Sanborn area. These deposits, which are part of a large buried glacial channel, form a potentially productive aquifer. The channel has been traced for 9 miles along the Stutsman-Barnes County line and is known to extend eastward into Barnes County at a point 4 miles north of Urbana, N. Dak. There is no surface indication of the presence of this aquifer, and its position can be determined only by test drilling.

Quality of water.--Partial chemical analyses were made of water from three private wells in the area, and a relatively complete chemical analysis was made of water from test hole 1723 (table 1). Two of the private wells (140-60-15adc and -15aaa) and the test hole (140-60-15aca) yield water from Unit B. The water from the other private well (140-60-14bcc) comes from Unit A. In general the water from all these wells is very hard and slightly saline according to Robinove, Langford, and Brookhart (1958, p. 3). The concentration of sulfates is high -- 374 to 817 ppm (parts per million) -- in all 4 samples, probably indicating the influence of the Pierre shale. Sulfate-reducing bacteria were reported from well 140-60-15adc --- (written communication, L. A. Koehler, State Laboratories Dept., Bismarck, N. Dak., 1960). Under certain conditions these bacteria may convert sulfate salts into hydrogen sulfide, thus imparting an unpleasant taste and odor to the water. The concentration of iron was determined for three of the samples and was high in all of them.

The high degree of mineralization of water in the report area probably results largely from poor circulation within the aquifers. Circulation is inhibited by the presence of clay in the pore spaces of the sand and gravel of the water-bearing units and by the confinement of the aquifers between relatively impermeable bodies of till and bedrock.

TABLE 1.--

Results in parts per million except as indicated

Well number	Owner or name	Depth of well (feet)	Date of collection	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
140-60								
14bcc a/	L. W. Anderson	25	11-15-60	0.3	...	..	...	..
15aaa	Schloessing	36	11-15-60	1.4	...	..	...	..
15aca	Test hole 1723	52	5-25-60	.3	145	72	168	9
15adc	Ray Schmitt	32	10- 1-60	...	...	..	...	..

a/Water treated by softener
b/Includes bicarbonate (HCO_3) as carbonate (CO_3)

Chemical Analyses of Ground Water

Analyses by State Laboratories, Bismarck

Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$ (Calcium, Magnesium)	Dissolved solids (Residue at 180°C)	Calculated from determined constituents	Percent sodium	pH
...	817	392	...	67	...	61	2,140	.....	..	7.7
...	541	59	...	1.3	...	501	1,270	.....	..	7.3
352	643	72	0.5	5.0	0	689	1,490	1,290 b/	11	7.9
...	374	48	...	....	...	564	952	.....	..	7.0

Table 2, adapted from U.S. Public Health Service (1946) drinking water standards recommended for interstate carriers, and from Welsh and Thomas (1960, p. 291, 298), shows a maximum limit of 44 ppm for nitrates. It is reported that water from some wells in this aquifer has nitrate concentrations exceeding this limit. (Oral communication, L. W. Anderson, Chairman, Sanborn Village Council.) This could result from contamination of the aquifer by organic wastes derived from cesspools and septic-tank systems in the village. Samples from well 140-60-15aaa and test hole 1723 (140-60-15aca), near the northern and western borders of Sanborn, do not contain excessive nitrate concentrations, which indicates that at present these wells, in Unit B, are not in an area of contamination. Test hole 1723 has 5.0 ppm nitrate; periodic chemical analysis of water from a well near test hole 1723 should be made to determine whether the nitrate concentration is increasing. Because water that contains nitrate above 44 ppm may cause methemoglobinemia --- a kind of blue-baby disease -- in infants (Silverman, 1949; Welsh and Thomas, 1960, p. 297-298), the high-nitrate content of water from wells in Sanborn is a potentially serious health problem.

Table 2.--Recommended maximum limits of selected chemical constituents in drinking water (U.S. Public Health Service, 1946, Reprint 2697)

Constituent	Recommended limit (ppm)
Iron (Fe) plus manganese (Mn)	0.3
Magnesium (Mg)	125
Chloride (Cl)	250
Fluoride (F)	1.5 a/
Sulfate (SO_4)	250
Nitrate (NO_3)	44
Dissolved solids	500 b/

a/Maximum permissible limit.

b/Dissolved-solids concentration of 1,000 ppm is permitted if water of better quality is not available.

PRESENT WATER-SUPPLY PROBLEMS

Present municipal-supply facilities.--Most of the wells in Sanborn and the surrounding area have been dug or bored and then cased with concrete, tile, wood, or steel pipe. The village has no public water-supply system, although water from a large-diameter dug well next to the city hall is used for fire control. Sanborn also has an earth-banked water reservoir with a capacity of 55,000 gallons.

Pollution problem.--During the past few years water from an increasing number of wells in Sanborn has become contaminated by coliform bacteria. At present (1960) it is estimated that less than 30 percent of the wells in the village yield bacterially safe drinking water, according to Miss L. Irvyne Berg, Public Health Nurse, Barnes County. Records documenting specific wells which have been tested are available at the Barnes County Health Department, Valley City. Repeated flushings of some of the contaminated wells with chlorine or Hilex has failed to eliminate the undesirable bacteria permanently. This shows that the primary aquifer in the village (Unit A) and the material through which it is recharged have become heavily contaminated. In this situation, decontamination measures applied to individual wells are ineffective.

The widespread contamination of Unit A probably results from the infiltration of the aquifer and overlying zone of recharge by effluvia from the many private sewage-disposal systems in Sanborn. Most of these systems employ septic tanks that reduce raw sewage to a liquid state, enabling it to infiltrate more readily into the material surrounding the system. The function and limitations of the septic tank are explained more fully in the following quotation (U.S. Public Health Service, 1957, p. 22):

"Contrary to popular belief, septic tanks do not accomplish a high degree of bacteria removal. Although the sewage undergoes treatment in passing through the tank, this does not mean that infectious agents will be removed; hence, septic-tank effluents cannot be considered safe."

Ordinarily if water containing bacteria percolates through fine-grained sediments, the bacteria are filtered out. However, if percolation is continued over a long period and the filtering medium becomes thoroughly saturated with bacteria-laden liquid, the filtering action is likely to become ineffective. As a result, the zone of contamination will constantly expand and will eventually include any shallow aquifer in its immediate vicinity. If the circulation of ground water in such an aquifer is restricted, the bacteria in the infected recharge to the aquifer will not be eliminated by flushing and filtering. Thus, contamination may become progressively more acute as the uncontaminated water in storage is withdrawn by discharging wells and is replaced by contaminated recharge.

The conditions described above exist in the Sanborn area. This fact is substantiated by the excessive concentration of nitrates reported from some of the wells (Oral communication, Sanborn Village Official) in Sanborn.

SUMMARY AND CONCLUSIONS

In order to evaluate the possibility of developing a municipal water-supply system for Sanborn, three factors concerning the area's ground-water resources have been considered: (1) quantity, (2) chemical quality, and (3) pollution.

Ground-water reserves in the Sanborn area are generally limited. Of the two aquifers discussed in this report, Unit B probably contains more available water in storage than Unit A. It is not possible to compute the permeability or storage capacity of Unit B with the data available; however, a pumping test of a well penetrating the unit would help determine whether or not Units A and B are connected hydraulically. Unit A, in addition to being seriously contaminated by organic wastes, is of such limited areal extent and capacity that it would prove inadequate as a permanent source of ground water for municipal use.

In general, ground water in the Sanborn area is very hard and slightly saline. Salinity is not excessive when compared with most North Dakota water and is not a health hazard. Hardness can be greatly reduced by the application of softening techniques. This is illustrated by the low hardness of water from well 140-60-14bcc in comparison with the water from the other three wells tested in the area (table 1). The water from well 140-60-14bcc had been run through a softener prior to sampling.

Use of water having high concentrations of nitrate by some residents of Sanborn can be avoided by locating future wells outside the area of contamination.

Bacterial pollution of an area's ground-water reservoirs often occurs when inadequate sewage-disposal methods are practiced where certain geohydrologic conditions prevail. These conditions, all of which are found in the Sanborn area, are summarized below.

Natural geohydrologic conditions	Manmade conditions
1. Thin drift cover over the bedrock. 2. Bedrock relatively impermeable. 3. Aquifers in drift are close to the land surface. 4. Ground-water circulation in drift aquifers is restricted. 5. Natural recharge to aquifers is low.	1. Closely spaced private sewage-disposal systems are concentrated in the area overlying the aquifer from which local water supplies from private wells are obtained.

A community that is without a central sewage-disposal system should carefully examine the geologic and hydrologic factors affecting its source or sources of water and then take the necessary steps to safeguard these from contamination. In the case of Sanborn, it would be advisable to locate a proposed municipal well as far as is practical from areas that are now contaminated. Unit B, west of the village, appears to be free of the general contamination found in the immediate vicinity of Sanborn.

TABLE 3.--Logs of Test Holes

140-60-1ccc
Test hole 1712
Altitude 1,434 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	2	2
	Clay, light-gray	3	5
	Sand, coarse, and fine gravel	5	10
	Till, gray; fine and medium gravel, cobbles; shale pebbles	22	32
Pierre shale:			
	Shale, blue-gray	10	42

140-60-9daa
Test hole 1717
Altitude 1,446 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	1	1
	Clay, light-gray	4	5
	Till, brown, oxidized; fine gravel.	16	21
	Gravel, clayey, fine	12	33
	Sand, fine and medium	9	42
Pierre shale:			
	Shale, blue-gray	21	63

140-60-11cbb
Test hole 1716
Altitude 1,440 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	2	2
	Clay, light-gray	4	6
	Till, brown, oxidized; fine gravel.	6	12
	Gravel, fine, and coarse sand	8	20
Pierre shale:			
	Shale, blue-gray	22	42

TABLE 3.--Logs of Test Holes -- Continued

140-60-11ccd
Test hole 1715
Altitude 1,437 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	2	2
	Till, brown, oxidized; fine gravel.	13	15
	Till, gray; fine and medium gravel; shale pebbles..................	26	41
Pierre shale:			
	Shale, blue-gray..................	11	52

140-60-11dad
Test hole 1710
Altitude 1,425 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	2	2
	Clay, light-gray..................	3	5
	Till, brown, oxidized; fine gravel.	11	16
	Till, gray; fine and medium gravel, cobbles; shale pebbles..........	100	116
Pierre shale:			
	Shale, blue-gray..................	10	126

140-60-13baa
Test hole 1711
Altitude 1,435 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	1	1
	Clay, light-gray..................	4	5
	Till, brown, oxidized; fine gravel.	21	26
Pierre shale:			
	Shale, blue-gray..................	16	42

140-60-13dcc
Test hole 1713
Altitude 1,433 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	1	1
	Till, brown, oxidized; fine gravel	19	20
Pierre shale:			
	Shale, blue-gray	11	31

140-60-14ada
Test hole 1709
Altitude 1,429 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	2	2
	Clay, silty, yellow	4	6
	Gravel, fine and medium	6	12
	Till, gray; fine and medium gravel; shale pebbles	22	34
Pierre shale:			
	Shale, blue-gray	8	42

140-60-14cba
Test hole 1704
Altitude 1,447 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	3	3
	Till, brown, oxidized; fine gravel	15	18
	Sand, fine	2	20
	Gravel, fine	5	25
	Till, gray; fine gravel; shale pebbles	32	57
Pierre shale:			
	Shale, blue-gray	6	63

TABLE 3.--Logs of Test Holes -- Continued

140-60-14dcc
Test hole 1714
Altitude 1,435 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	1	1
	Clay, light-gray	4	5
	Gravel, fine	10	15
	Till, gray; fine and medium gravel, cobbles; shale pebbles	103	118
Pierre shale:			
	Shale, blue-gray	8	126

140-60-15aca
Test hole 1723
Altitude 1,456 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	2	2
	Till, brown, oxidized; fine gravel.	18	20
	Till, gray, fine gravel	5	25
	Sand, fine and medium	6	31
	Sand, fine to coarse	8	39
Pierre shale:			
	Shale, blue-gray	13	52

140-60-15bbb
Test hole 1722
Altitude 1,450 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black	1	1
	Clay, light-gray	4	5
	Till, brown; fine gravel	9	14
	Clay, sandy, gray	11	25
	Sand, fine	9	34
Pierre shale:			
	Shale, blue-gray	18	52

140-60-15bdd
Test hole 1705
Altitude 1,457 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	2	2
	Till, brown, oxidized; fine gravel.	15	17
	Gravel, fine and medium; cobbles...	5	22
	Clay, gravelly, yellow............	4	26
	Clay, silty, gray.................	5	31
	Sand, fine to coarse; shale granules	12	43
Pierre shale:			
	Shale, blue-gray..................	9	52

140-60-16cdd
Test hole 1719
Altitude 1,442 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	2	2
	Till, brown, oxidized.............	10	12
	Till, gray; fine gravel; shale pebbles..........................	9	21
	Sand, fine........................	15	36
Pierre shale:			
	Shale, blue-gray..................	6	42

140-60-21ddd
Test hole 1718
Altitude 1,458 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	2	2
	Clay, light-gray..................	3	5
	Till, brown, oxidized; fine gravel.	9	14
	Till, gray; fine gravel...........	7	21
	Sand, fine........................	6	27
	Till, gray; fine gravel...........	6	33
	Sand, fine and medium.............	4	37
	Till, gray; fine gravel; shale pebbles..........................	19	56
Pierre shale:			
	Shale, blue-gray..................	7	63

TABLE 3.--Logs of Test Holes -- Continued

140-60-22baa
Test hole 1706
Altitude 1,456 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	2	2
	Till, brown, oxidized; fine gravel.	14	16
	Sand, fine........................	14	30
Pierre shale:			
	Shale, blue-gray..................	22	52

140-60-23add
Test hole 1708
Altitude 1,418 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	1	1
	Clay, light-gray..................	3	4
	Till, brown, oxidized; fine gravel.	12	16
	Till, gray; fine and medium gravel; shale pebbles..................	35	51
Pierre shale:			
	Shale, blue-gray..................	12	63

140-60-23cbb
Test hole 1707
Altitude 1,437 ft

Formation	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, black....................	1	1
	Till, brown, oxidized; fine gravel.	4	5
	Gravel, fine and medium...........	7	12
	Till, gray; fine and medium gravel; shale pebbles..................	20	32
Pierre shale:			
	Shale, blue-gray..................	20	52

REFERENCES

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.

Silverman, L. B., 1949, Methemoglobinemia: Report of two cases and clinical review: Journal-Lancet, v. 69, p. 94-97.

U.S. Public Health Service, 1946, Drinking water standards: Public Health Repts., v. 61, no. 11, p. 371-384.

________ 1957, Manual of septic-tank practice: Public Health Service Pub. 526, 85 p.

Welsh, G. B., and Thomas, J. F., 1960, Significance of chemical limits in U.S. Public Health Service drinking water standards: Am. Water Works Assoc. Jour., v. 52, no. 3, p. 289-299.