STATE OF SOUTH DAKOTA
Nils Boe, Governor

SOUTH DAKOTA STATE GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 32

GROUND WATER SUPPLY FOR THE CITY OF IPSWICH, SOUTH DAKOTA

by
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INTRODUCTION

Present Investigation

This report contains the results of a special investigation by the South Dakota State Geological Survey from July 16 to August 14, 1964, in and around the city of Ipswich, Edmunds County, South Dakota (fig. 1), for the purpose of assisting the city in locating future water supplies. Ipswich now receives its water from two artesian wells which do not supply the quantity and quality of water needed by the community. The two wells have a combined flow of about 50 gallons per minute and produce water from the Dakota sandstones at a depth of about 1,200 feet and 1,550 feet. Both wells are located within the city limits (fig. 2). At present the city has a combined storage capacity of 130,000 gallons which in addition to the well capacity is inadequate much of the year.

A survey of the ground water possibilities was made of a 100 square mile area around the city, and consisted of geologic mapping, a well inventory, and the drilling of 62 auger holes to an average depth of 63 feet, and the taking of 12 water samples for analysis.

As a result of this survey it was found that there were two possibilities for future development of ground water supplies at Ipswich. The first is further development of the present supply from the Dakota Group. The second possibility is in the shallow glacial aquifer running north-south about 3½ miles east of the city.

The field work and preparation of this report were performed under the supervision of Lynn S. Hedges, staff ground water geologist. The drillers on the project were Keith Hansen, Aldean Fickbohm, and Mike Fresvik. Nat Lufkin of the State Geological Survey and the State Chemical Laboratory analyzed the water samples.

The cooperation of the residents of Ipswich and the surrounding area, especially Mayor Henry Beck, and Joe Nigg, Sr., Superintendent of Water Works, is greatly appreciated.

Location and Extent of Area

The city of Ipswich is located in north-central South Dakota in Edmunds County, and has a population of 1,131 (1960 census). The area is in the James Basin of the Central Lowland physiographic province (fig. 1).

Climate

The climate is continental temperate with large daily and seasonal fluctuations in temperature. The average daily temperature is 43.7° F. at the U. S. Weather Bureau Station in Aberdeen, 26 miles east of Ipswich. The average annual precipitation is 19.14 inches at the U. S. Weather Bureau Station at Aberdeen.

In 1963 the total precipitation was 24.52 inches and as of August 31, 1964, the area had received 21.95 inches of precipitation at the U. S. Weather Bureau Station at Ipswich. Total precipitation for 1964 was 23.02 inches at Ipswich.

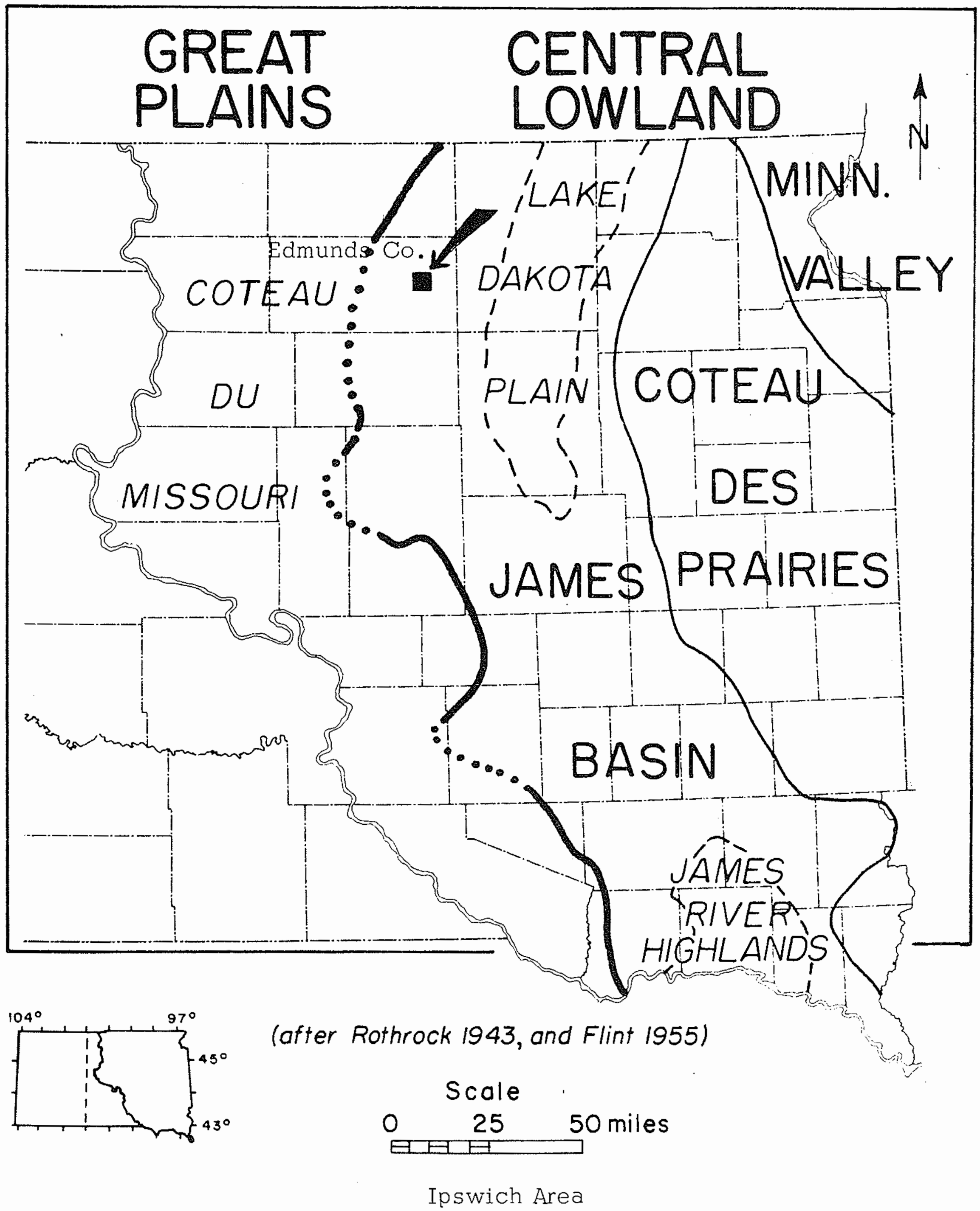
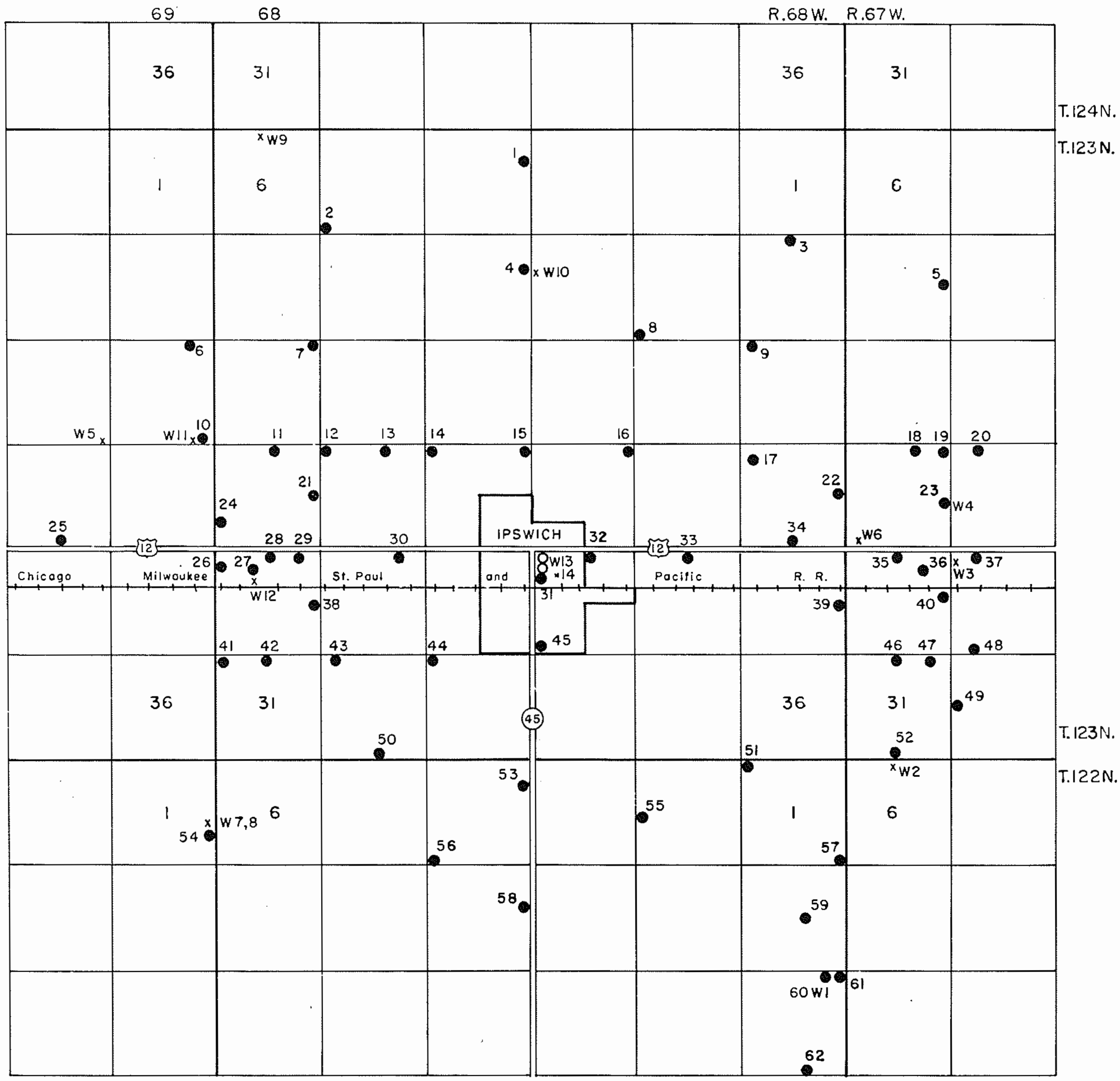


Figure 1.--Major Physiographic Divisions of Eastern South Dakota, and Location of the Ipswich Area.

Figure 2. Data Map of the Ipswich Area.



EXPLANATION

1 ● Auger test hole

O W13 City well and water sample

60 ● W1 Auger test hole with water sample

x W6 Farm well with water sample

Number following (W) designating water sample corresponds to analyses number in Table I.

Scale
0 1/2 1 2 3 Miles

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Topography and Drainage

The topography of the Ipswich area is a gently undulating surface with many closed depressions containing sloughs. East of Ipswich about 4 miles the topography becomes slightly more undulating.

Several small intermittent creeks flow eastward and ultimately empty into the James River. The abundance of small eastward-flowing creeks in the area is due to the general eastward slope of the west flank of the James Basin.

Well-Numbering System

Wells in this report are numbered in accordance with the U. S. Bureau of Land Management's system of land subdivision. The first numeral of a well designation indicates the township, the second the range, and the third the section in which the well is situated. Lower case letters after the section number indicate the well location within the section. The letters a, b, c, d, are assigned in a counterclockwise direction, beginning in the northeast corner of each tract. The first letter denotes the 160-acre tract, the second the 40-acre tract, the third the 10-acre tract, and the fourth the $2\frac{1}{2}$-acre tract. Auger Test Hole 33 (fig. 2), 123-68-26abbb is located in the NW$\frac{1}{4}$NW$\frac{1}{4}$NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 26, T. 123 N., R. 68 W.; the method of designation is shown in Figure 3.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Ipswich area are chiefly the result of glaciation late in the Pleistocene Epoch. The glacial deposits, collectively termed drift, can be divided into till and outwash.

Till consists of a jumbled mixture of clay, silt, sand, pebbles, and boulders transported and deposited directly by the ice itself.

Outwash material, which consists primarily of sands and gravels with varying amounts of silt and clay, was deposited by meltwater streams from the wasting glaciers, and may be covered with as much as 4 feet of alluvium. Buried outwash deposits, with the exception of small sand and gravel lenses, are lacking in the mapped area.

Alluvial material has been deposited along the intermittent streams (fig. 4) since the retreat of the glaciers. The alluvium consists of clay and silt with minor amounts of fine to medium sand. There are several deposits of alluvium in the Ipswich area, but most of them are too small to be a mappable geologic feature.

Subsurface Bedrock

There are no bedrock outcrops in the area studied. However, stratified rocks of Cretaceous age lie beneath the surface deposits. The Pierre Shale lies directly beneath the glacial drift and is underlain in descending

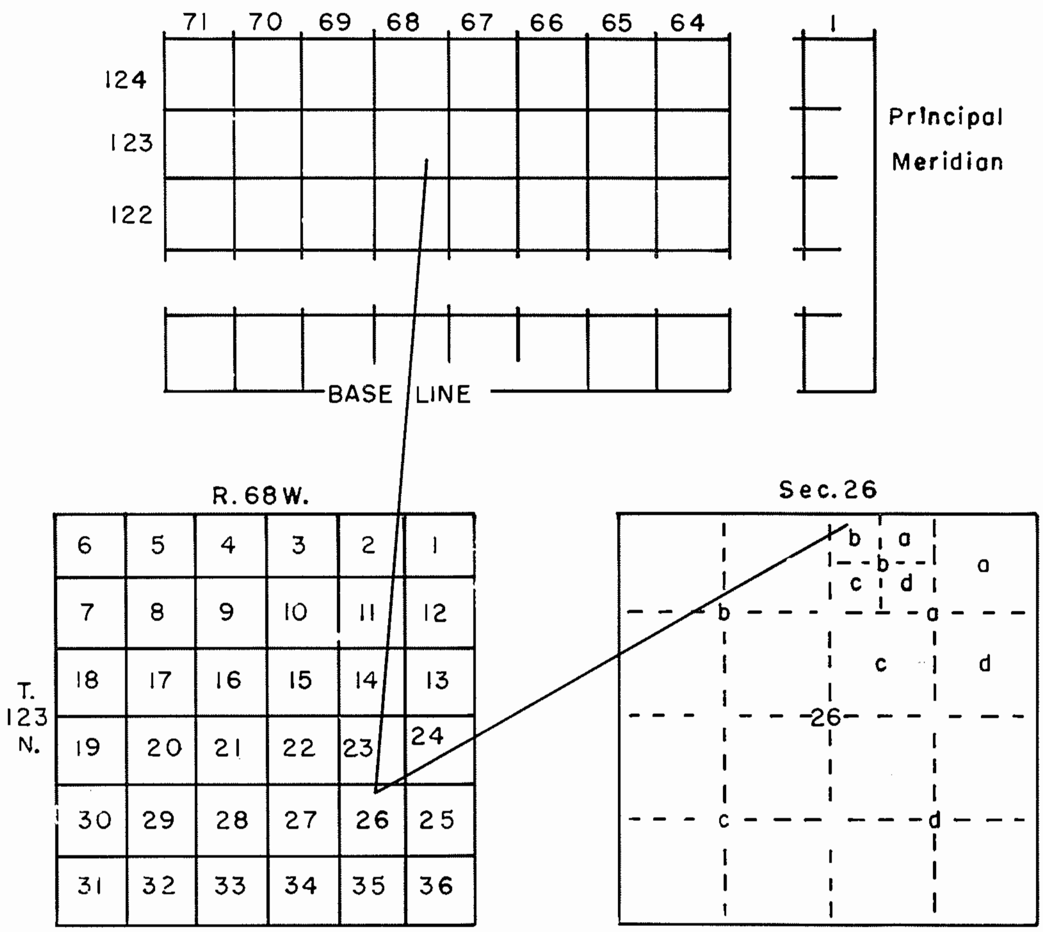
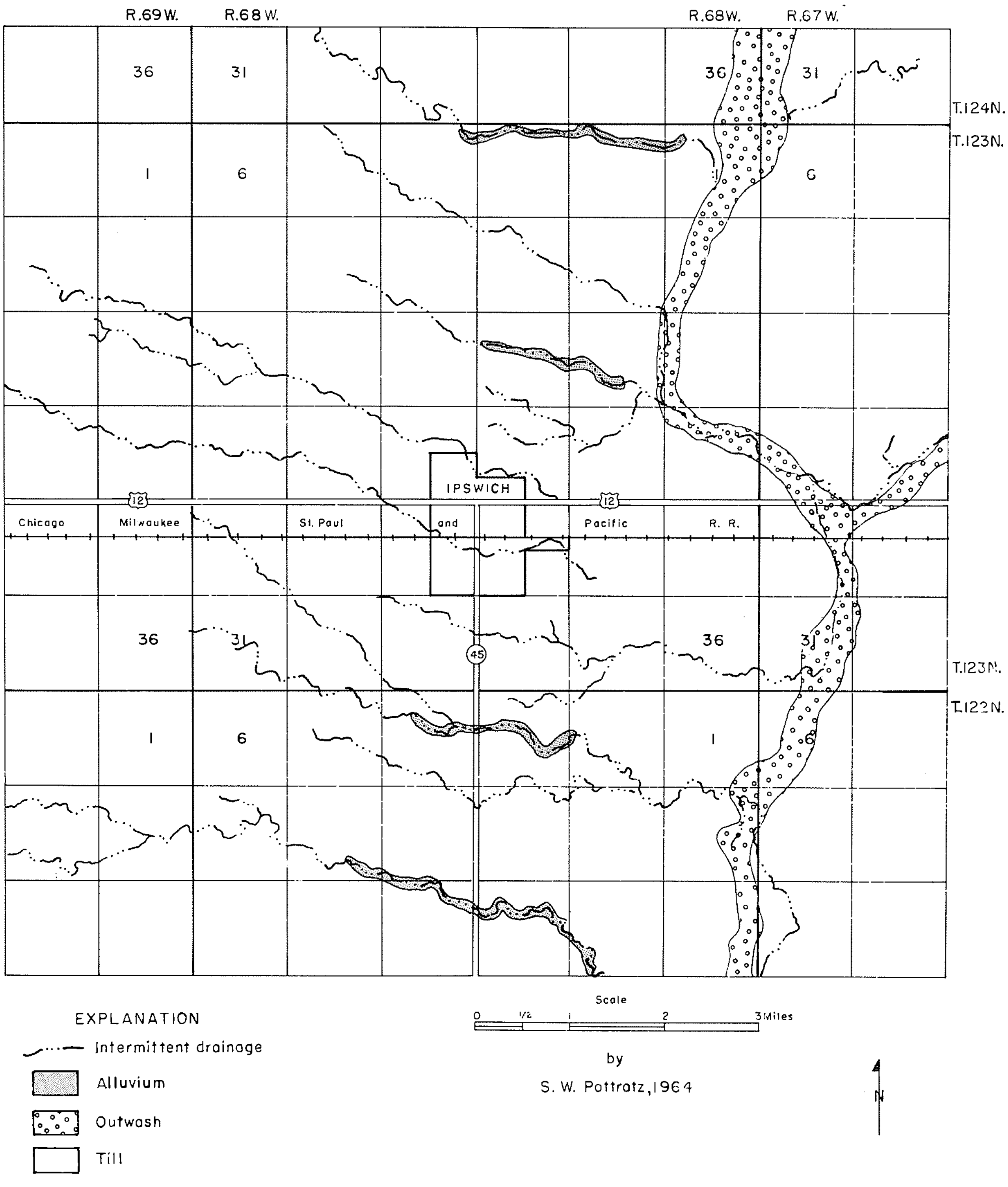


Figure 3 Well-Numbering System

Figure 4. Generalized Geologic Map of the Ipswich Area.



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order by the Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Group.

The Pierre Shale is the bedrock directly underlying the glacial drift in this area. The configuration of the Pierre surface is shown in Figure 5. The bedrock surface has a general easterly slope from an elevation of about 1,550 feet at the western margin of the area studied, to about 1,400 feet at the east. A small valley in the bedrock is indicated about $2\frac{1}{2}$ miles west of the city; however, it is apparently too small to be traced without detailed drilling.

The Pierre has a thickness of about 500 feet in the Ipswich area, and consists of light-gray fissile shale with bands of iron concretions.

The Niobrara Marl consists of approximately 130 feet of light to medium blue-gray shale which contains numerous microscopic white calcareous specks.

The Carlile Shale is medium- to dark-gray bentonitic shale with pyrite concretions and layers of fine, brown siltstone. This formation has a thickness of about 300 feet.

The Greenhorn Limestone is about 50 feet thick and consists of a hard layer of white to cream limestone containing numerous fossil fragments. The limestone is overlain, and possibly underlain, by a layer of dark-gray shale containing numerous small white calcareous specks.

The Graneros Shale is hard light- to dark-gray siliceous shale having a thickness of approximately 300 feet.

An interpolation of the information from an oil test in Brown County about 23 miles to the northeast (Oil Hunters #1 Raetzman), and an oil test in Walworth County 45 miles west of Ipswich (Peppers #1 State) indicates the Dakota Group has a thickness of about 500 feet at Ipswich. The Dakota Group probably consists of an upper unit of thin-bedded sandstones and shales about 320 feet thick. Underlying this is a shale unit about 60 feet thick. This shale unit overlies another sandstone and shale unit which may be up to 100 feet thick. In Ipswich, the upper sandstone and shale unit would lie about 1,200-1,500 feet below the surface. The lower sandstone and shale unit would lie about 1,550-1,650 feet below the surface.

The meager data available indicates there may be as much as 500 feet of Paleozoic sediments underlying the lower sandstone unit of the Dakota Group. These rocks would probably consist mostly of limestones and shales with minor amounts of sandstone.

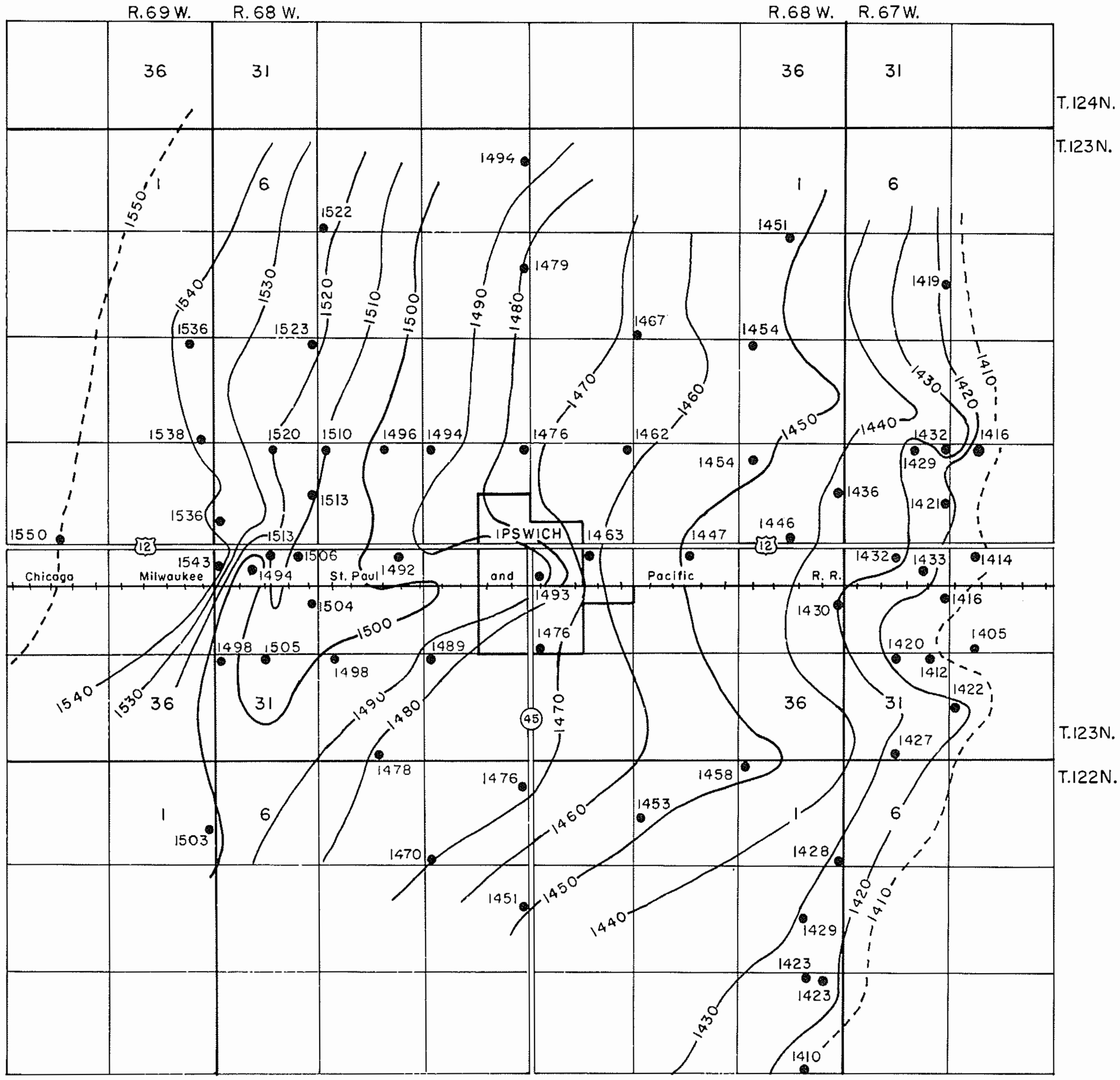
OCCURRENCE OF GROUND WATER

Principles of Occurrence

Contrary to popular belief, ground water does not occur in "veins" that criss-cross the land at random. Instead it can be shown that water occurs nearly everywhere beneath the surface, but at varying depths. The top of this zone of saturation is known as the water table.

Nearly all ground water is derived from precipitation. Rain or melting snow either percolates downward to the water table and becomes ground water, or drains off as surface water. Surface water may percolate downward and become ground water, or it may evaporate or drain to the sea by

Figure 5. Map showing Configuration of Buried Surface of Pierre Shale in the Ipswich Area.



EXPLANATION

● Test showing elevation above sea level of the Pierre Shale surface.

Contour line showing equal elevation above sea level.

Contour interval 10 feet.

Scale: 0 — 1/2 — 1 — 2 — 3 Miles

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means of streams. In general, ground water moves laterally down the hydraulic gradient, and is in transient storage.

Recharge is the addition of water to an aquifer (water-bearing material) and is accomplished in a number of ways: (1) by downward percolation of precipitated water from the land surface, (2) by downward percolation from surface bodies of water such as lakes and streams, and (3) by lateral movement of water in transient storage.

Discharge of ground water from a water-bearing material is accomplished in four main ways: (1) by evaporation and transpiration of plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral movement of water in transient storage, and (4) by pumping.

The amount of water which can be stored in a saturated material is equal to the amount of voids or pore spaces in that material. A measurement of the capability of a material to store water (or any other liquid) is called porosity. Porosity depends entirely on the shape and arrangement of the particles in a material, and is not affected by size. Sands and gravels usually have porosities of 20-40 percent, whereas sandstones normally have porosities of 15-25 percent; this lower porosity of sandstones is due to closer packing and to cementation of the particles.

Permeability is the rate at which a fluid will pass through a substance. If the pore spaces of a material are connected, the permeability of that material will be high. If the pore spaces are not connected, the permeability will be low. Thus, a material may have high porosity and still not yield water readily because of low permeability. Sands and gravels, however, tend to have both high porosity and high permeability. Thus, the geologist is not concerned with finding a "vein" when looking for a good water supply. Because water occurs almost everywhere in the ground, he is searching instead for a sand or gravel or another similarly porous and permeable deposit that lies beneath the water table.

Ground Water in Alluvium

Alluvium is present in small patches along several of the intermittent streams in the Ipswich area (fig. 4). This alluvium may contain large amounts of water where it is below the water table, but because of its low permeability it does not yield water readily. The alluvium along the intermittent drainage $2\frac{1}{4}$ miles south of town was test-drilled (Test Hole 53), but the deposits are thin, are of limited areal extent, and too fine to support a city water supply.

Ground Water in Glacial Deposits

As was stated earlier, glacial deposits can be divided into till and outwash. Till, because of its unsorted nature and the larger amount of clay, usually does not yield water readily. Outwash, on the other hand, is a good source of ground water because of its high porosity and high permeability.

The only outwash deposit near Ipswich which might be suitable for a city supply is located in the valley about 4 miles east of the city and trending north-south (fig. 4). Following is a list of the test holes drilled in the valley showing the amount of saturated sand and gravel encountered in each one.

Test Hole	Saturated Sand and Gravel
3	25
9	20
17	12
22	0
35	11
36	18
37	27
40	0
47	25
49	20
52	5
57	35
59	31
60	31
61	7

The saturated sand and gravel in this valley varies from 0 (Test Holes 22 and 40) to 35 feet (Test Hole 57) in thickness and is quite variable in texture. It may consist of fine sand with up to 50 percent silt and clay (Test Hole 57) to a fine gravel containing low amounts of clay (Test Hole 36). The sand and gravel may vary laterally in a short distance in both texture and thickness, as illustrated by comparison of Test Holes 60 and 61.

Those test holes showing the greatest thickness of saturated sand and gravel may not necessarily be the most desirable areas for ground water development, since many of them show that the aquifer contains a large percentage of silt and clay. The most promising areas for ground water development would be in those areas where 10 feet or more of saturated, clean, well-sorted sand and/or gravel occurs, such as in Test Holes 17, 36, and 60.

It was stated earlier that in 1963 and 1964 the precipitation in the Ipswich area was above normal. Since no records of shallow ground water fluctuations are available for this area, the effect of the above-normal precipitation on the ground water levels cannot be determined. However, it should be pointed out that the above-normal precipitation could result in a higher water table in the surface outwash than normal. This, of course, would mean that during years of normal or below-normal precipitation, the saturated thickness of sand and gravel in the surface outwash might be less than indicated by the present study.

Ground Water in Bedrock

The sandstones of the Dakota Group supply water to many wells in the Ipswich area, including the present city wells. These sandstones are at a depth of about 1,200-1,550? feet in the Ipswich area, and their waters are under artesian pressure which causes many wells in the area to flow.

Most of the bedrock wells in the Ipswich area are completed in the upper sandstone and shale unit. Only three wells are known which may be producing from the lower sandstone and shale unit. These are the Joe Webber well (123-68-4dddd), the Jean Hammrick well (123-68-30daaa), and Ipswich City Well #1.

The recharge for these Dakota sandstones in South Dakota is said to come from the Rocky Mountains or the Black Hills, where they crop out at a much higher elevation than in the Ipswich area. The overlying Cretaceous shales provide the impervious material that confines the water to the sandstones.

It was mentioned earlier that up to 500 feet of sediments may be present below the Dakota Group. Abundant supplies of water often can be obtained from these rocks; however, no information is available concerning these rocks in the Ipswich area. In addition, the quality of water obtained from these rocks is generally similar to, or poorer than, the water obtained from the Dakota Group.

Quality of Ground Water

Precipitated water is nearly pure before it reaches the ground; however, all ground water contains minerals which are obtained: (1) from the atmosphere, (2) from soil and underlying deposits as the water percolates downward to the water table, and (3) from deposits below the water table in which the water is circulating. In general it can be said that the more minerals a water contains, the poorer its quality. The water in the Dakota sandstones is generally of a poorer quality than that in the outwash deposits.

Table 1 is a comparison of the various waters in the Ipswich area with the present city water (samples 13 and 14) and with the Public Health Standards for drinking water (sample A). It can be seen that both present city wells exceed the South Dakota modified Public Health Standards in magnesium, sulfates, iron, manganese, fluorides, and total solids. The hardness is also quite high, although there are no limits set by the Public Health Standards. It should be noted that City Well #2, which obtains its water from about 1,200 feet has considerably less hardness than City Well #1, which obtains its water from about 1,550 feet.

Water samples 1, 2, and 3 (table 1) are from the surface outwash about 4 miles east of Ipswich. These samples indicate the water in this aquifer is generally of a much better quality than the present city supply. Samples 1 and 2 exceed the Public Health Standards in iron, and sample 2 has 10 ppm nitrate, which is the maximum concentration according to the Public Health Standards. Although this water is still "hard", the hardness concentration is much lower than the present city supply.

Samples 4-12 are from sand lenses in the glacial deposits or from the till. The samples indicate the water quality is generally poor and is quite variable.

Table 1.--Chemical analyses of water samples from the Ipswich area. (See fig. 2 and next page for sample locations.)

Sample	Source	Parts Per Million (ppm)											
		Calcium	Sodium	Magne-sium	Chlorides	Sulfate	Iron	Manga-nese	Nitrate	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A		---	---	50	250	500*	0.3	0.05	10.0	0.9-1.7**	----	----	1000*
1	Surface Outwash	75	30	28	51	105	1.0	None	None	0.6	7.75	303	502
2	Surface Outwash	82	48	36	160	65	3.4	None	10.0	0.4	7.7	354	758
3	Surface Outwash	66	45	24	25	147	0.2	None	1.2	0.6	7.7	261	522
4	Sand lens or clay	500		317		1650	2.0				7.55	2250	3250
5	Sand lens or clay	252		156	750	457	0.18				7.4	1270	2204
6	Sand lens or clay	122		262	675	486	0.25				7.5	1380	3350
7	Sand lens or clay	482		316	295	1262	0.40				7.6	2500	4040
8	Sand lens or clay	200		36	54	308	6				7.3	650	1482
9	Sand lens or clay	68		12	1545	Trace	0.45				7.5	208	3800
10	Sand lens or clay	762		1192	4600	2335	Trace				7.35	6800	15,800
11	Sand lens or clay	56		24	600	243	1.3				7.5	240	2620
12	Sand lens or clay	58		16	2	19	4.0				7.4	212	347
13	Dakota Group	359	137	80	53	1264	1.0	0.1	None	3.4	7.6	1226	2261
14	Dakota Group	237	304	69	60	1257	1.0	0.2	None	3.0	7.5	878	2167

* modified for South Dakota by the State Department of Health (written communication, February 5, 1962)

** optimum

Location of Water Samples

A	U. S. Public Health Standards for Drinking Water
1	SDSGS Test Hole #60, 122-68-13abba
2	Wallis Knie, 122-67-6baaa
3	David Hales, 123-67-29bbbc
4	SDSGS Test Hole #23, 123-67-19dada
5	Lester Ernst, 123-67-30daaa
6	Peter Krokosh, 123-67-19cccd
7	J. Blank, 122-69-1daad
8	J. Blank, 122-69-1daad
9	George Dammer, 123-68-6baaa
10	Don Jones, 123-68-10bcbc
11	Jake Volk, 123-69-13dddc
12	Unknown, 123-68-30bdbd
13	City Well #1 (1,550 feet)
14	City Well #2 (1,200 feet)

Samples 1, 2, and 3 analyzed by State Chemical Laboratory in Vermillion; samples 13 and 14 by State Department of Health in Pierre; other samples by the State Geological Survey in Vermillion.

As mentioned in an earlier section of this report, the precipitation in the Ipswich area was above normal in 1963 and 1964. Precipitated water is generally of a better quality than ground water, and most of the recharge to the surface outwash is from direct infiltration of precipitation. Therefore, with the above-normal recharge to this aquifer during 1963 and 1964, the water samples collected during this study could show a better quality than what normally is found during periods of normal or below-normal precipitation.

CONCLUSIONS AND RECOMMENDATIONS

The city of Ipswich has two possibilities for development of a municipal water supply from ground water sources. The first possibility is further development of their present supply from the sandstones of the Dakota Group. Their present city wells are $1\frac{1}{2}$ to 2 inches in diameter with an unknown amount of screen or perforated casing. A larger diameter well properly constructed and installed with a pump should provide an adequate quantity of water for the city. Several water analyses in the area suggest the possibility of one or possibly several zones in the Dakota Group which may contain water of a better quality than the present supply.

If the city should decide to develop their present supply of water from the Dakota Group, a new, large diameter well should be drilled completely penetrating the Dakota Group. Different zones should then be tested for quality and quantity, the final well design and construction being determined from the results of the testing.

The second possibility the city has for a ground water supply is from the surface outwash trending north-south about 4 miles east of town (fig. 4). Test holes in this area indicate up to 35 feet of saturated sand and/or gravel. Water analyses from test holes and existing farm wells indicate a quality of water considerably better than the present supply.

That segment of the outwash from Highway 12 and southward to Test Hole 60 appears to be the best area for possible development. If the city decides to test this area for future water supplies, tests should begin near Test Holes 36 and 60. These areas should be tested to determine the extent of saturated sand and gravel, and to determine the quantity and quality of water available.

Due to the limited area of the surface outwash and apparent restricted recharge, the long-term yield to any single well would probably be small. For this reason it is suggested that if the city would decide to obtain their water supply from the surface outwash that several low capacity wells might, over a period of time, perform better than one or two large capacity wells. In considering development of the shallow glacial aquifer, the cost of a pipeline and installation and maintenance of several shallow wells are factors the city will certainly wish to consider.

If, after test drilling, well sites are chosen, test wells should be installed and test pumped. This test pumping should be conducted by licensed engineers and should be run for a minimum of 72 hours to determine yield, draw down, recovery, and quality of water in the aquifer.

It is suggested that the city contact a commercial drilling company licensed by the State of South Dakota to test-drill the areas recommended. The city officials should consult the State Water Resources Commission with regard to obtaining a water right and a permit to drill a city well, and the State Department of Public Health with regard to the biological and chemical suitability of the water. A consulting engineering firm licensed in South Dakota should be hired to design the well and the water system.

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Rothrock, E. P., 1943, A geology of South Dakota, Part I: The surface: S. Dak. Geol. Survey Bull. 13, pl. 2.

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APPENDIX A

Logs of Test Holes in the Ipswich Area

(Test hole numbers correspond to numbers on data map, Figure 2.)

Test Hole 1
Elevation: 1,536 feet
Location: 123-68-4adaa
Depth to water: 34 feet

0- 4	clay, black, moist
4-13	clay, brown, pebbly, moist
13-34	clay, gray, pebbly, moist
34-42	clay, gray
42-44	Pierre Shale

* * * * *

Test Hole 2
Elevation: 1,604 feet
Location: 123-68-5cccc
Depth to water: 27 feet

0- 8	clay, dark brown, pebbly, moist
8-16	clay, buff, pebbly, moist
16-27	clay, gray, pebbly, moist
27-39	water with some fine sand, no sample augered
39-82	clay, gray, pebbly, moist
82-84	Pierre Shale

* * * * *

Test Hole 3
Elevation: 1,499 feet
Location: 123-68-12baaa
Depth to water: 9 feet

0- 9	clay, dark brown, pebbly, moist
9-14	sand, buff, coarse, saturated
14-34	sand, gray, fine to medium
34-48	clay, gray, pebbly, silty, moist
48-49	Pierre Shale

* * * * *

Test Hole 4
Elevation: 1,542 feet
Location: 123-68-9adaa
Depth to water: dry hole

0- 4	fill dirt in ditch
4-24	clay, buff, pebbly, moist
24-63	clay, gray, pebbly, moist
63-69	Pierre Shale

* * * * *

Test Hole 5
Elevation: 1,476 feet
Location: 123-67-7addd
Depth to water: 9 feet

0- 9	clay, buff, pebbly, moist
9-23	clay, brown, sand (20%), saturated
23-30	clay, gray, saturated, rock at 23 feet
30-34	clay, gray, fine sand (20%), saturated
34-57	clay, gray, saturated
57-59	Pierre Shale

* * * * *

Test Hole 6
Elevation: 1,623 feet
Location: 123-69-13abaa
Depth to water: 54 feet

0- 4	clay, light gray, few pebbles, moist
4- 9	clay, buff, pebbly, moist
4-14	clay, brown, pebbly, moist
14-54	clay, gray, pebbly, moist
54-79	sand, fine, silty, saturated, much water with some rock
79-87	clay, gray, silty, saturated
87-89	Pierre Shale

* * * * *

Test Hole 7
Elevation: 1,600 feet
Location: 123-68-18aaaa
Depth to water: dry hole

0- 2	topsoil
2-19	clay, buff, pebbly, moist

(continued on next page)

Test Hole 7--continued

19-24	clay, light gray, pebbly, moist
24-77	clay, gray, pebbly, moist
77-79	Pierre Shale

* * * * *

Test Hole 8
Elevation: 1,525 feet
Location: 123-68-11cccc
Depth to water: dry hole

0-32	clay, brown, pebbly, moist
32-58	clay, gray, pebbly, some rock at 32 feet, moist
58-59	Pierre Shale

* * * * *

Test Hole 9
Elevation: 1,486 feet
Location: 123-68-13bbba
Depth to water: 7 feet

0- 7	clay, buff, moist
7-27	sand, buff, fine, silty, saturated
27-32	clay, silty sand, gray
32-39	Pierre Shale

* * * * *

Test Hole 10
Elevation: 1,628 feet
Location: 123-69-13dddc
Depth to water: 34 feet

0-29	clay, buff, pebbly, moist
29-34	clay, blue, moist
34-90	clay, blue, saturated
90-95	Pierre Shale

* * * * *

Test Hole 11
Elevation: 1,602 feet
Location: 123-68-19abbb
Depth to water: 80 feet

0- 7	clay, buff, pebbly, moist

(continued on next page)

Test Hole 11--continued

7-31	clay, brown, pebbly, moist
31-80	clay, gray, pebbly, moist
80-82	clay, gray, saturated
82-84	Pierre Shale

* * * * *

Test Hole 12
Elevation: 1,592 feet
Location: 123-68-20bbbb
Depth to water: 24 feet

0- 4	clay, dark brown, pebbly, dry
4-24	clay, buff, pebbly, moist
24-34	sand, buff, fine, saturated
34-39	augered medium gravel, much water
39-52	augered much water with fine sand and few medium pebbles
52-73	clay, gray, pebbly, moist
73-82	clay, gray, saturated
82-84	Pierre Shale

* * * * *

Test Hole 13
Elevation: 1,563 feet
Location: 123-68-20abab
Depth to water: 22 feet

0- 7	clay, dark brown, pebbly, moist
7-12	clay, buff, pebbly, moist
12-22	clay, gray, pebbly, moist
22-34	clay, gray, gray sand (50%), saturated
34-67	clay, gray, moist to saturated
67-69	Pierre Shale

* * * * *

Test Hole 14
Elevation: 1,562 feet
Location: 123-68-21bbbb
Depth to water: dry hole

0-24	clay, dark brown to buff, pebbly, dry
24-49	clay, gray, pebbly, dry to moist
49-68	same only more moist
68-69	Pierre Shale

* * * * *

Test Hole 15
Elevation: 1,539 feet
Location: 123-68-21aaaa
Depth to water: dry hole

0-34	clay, buff, pebbly, moist
34-63	clay, gray, pebbly, moist
63-69	Pierre Shale

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Test Hole 16
Elevation: 1,510 feet
Location: 123-68-22aaaa
Depth to water: dry hole

0-22	clay, buff, pebbly, moist
22-29	clay, olive gray, large pebbles, moist
29-48	clay, gray, pebbly, moist
48-53	Pierre Shale

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Test Hole 17
Elevation: 1,487 feet
Location: 123-68-24bbca
Depth to water: 7 feet

0- 3	topsoil
3- 7	gravel, medium, clay (50%), moist
7-19	sand, coarse, gray, saturated
19-33	clay, rocky, moist, many pebbles
33-39	Pierre Shale

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Test Hole 18
Elevation: 1,471 feet
Location: 123-67-19aabb
Depth to water: dry hole

0- 4	clay, olive gray, pebbly, moist
4-19	clay, buff, pebbly, moist
19-42	clay, gray, pebbly, moist
42-44	Pierre Shale

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Test Hole 19
Elevation: 1,470 feet
Location: 123-67-19aaaa
Depth to water: 22 feet

0- 9	clay, buff, pebbly, moist
9-18	clay, dark brown, pebbly, moist
18-22	very hard layer (drilled hard as shale)
22-38	sand, medium, buff clay (50%), saturated
38-39	Pierre Shale

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Test Hole 20
Elevation: 1,473 feet
Location: 123-67-20bbaa
Depth to water: 17 feet

0- 4	clay, dark brown, pebbly, moist
4-17	clay, buff, pebbly, moist
17-29	clay, buff, and fine sand (50%), saturated
29-57	clay, gray, pebbly, moist
57-59	Pierre Shale

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Test Hole 21
Elevation: 1,585 feet
Location: 123-68-19addd
Depth to water: dry hole

0- 4	fill dirt in ditch
4-23	clay, buff, pebbly, moist
23-72	clay, gray, pebbly, moist
72-74	Pierre Shale

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Test Hole 22
Elevation: 1,473 feet
Location: 123-68-24addd
Depth to water: 29 feet

0-19	clay, buff, pebbly, moist
19-29	clay, gray, pebbly, moist
29-34	clay, gray, medium-coarse sand (35%), saturated
34-37	clay, gray, sand (20%), saturated
37-40	Pierre Shale

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Test Hole 23
Elevation: 1,472 feet
Location: 123-67-19dada
Depth to water: 7 feet

0- 7	clay, buff, pebbly, moist
7-22	gravel, fine, clay (10%), saturated
22-29	sand, medium, gray clay, saturated
29-41	clay, gray, medium sand
41-51	clay, gray, pebbly, moist
51-54	Pierre Shale

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Test Hole 24
Elevation: 1,618 feet
Location: 123-68-19cbcc
Depth to water: 24 feet

0- 4	clay, dark brown, pebbly, moist
4-17	clay, buff, pebbly, moist
17-21	clay, gray, pebbly, moist
21-24	sand, fine, saturated
24-77	clay, gray, pebbly, moist to saturated
77-82	clay, gray, pebbly, moist
82-84	Pierre Shale

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Test Hole 25
Elevation: 1,651 feet
Location: 123-69-23dccc
Depth to water: dry hole

0- 14	clay, buff, pebbly, moist
14- 22	clay, brown, pebbly, moist
22-102	clay, gray, pebbly, moist
102-104	Pierre Shale

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Test Hole 26
Elevation: 1,611 feet
Location: 123-68-30bbcc
Depth to water: 44 feet

0-19	clay, buff, pebbly, moist
19-23	clay, brown, pebbly, moist

(continued on next page)

Test Hole 26--continued

23-44	clay, gray, pebbly, moist
44-54	gravel, medium, much silty gray clay, saturated
54-68	clay, gray, many pebbles, saturated
68-69	Pierre Shale

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Test Hole 27
Elevation: 1,566 feet
Location: 123-68-30bdbd
Depth to water: 14 feet

0-14	clay, buff, many pebbles
14-29	clay, buff, medium sand (30%), saturated, many pebbles
29-34	clay, brown, medium-coarse sand (35%)
34-40	gravel, medium-coarse
40-44	clay, brown, some coarse sand, much water
44-54	clay, gray, medium-coarse sand (50%)
54-69	clay, gray, much rock, sand (20%)
69-72	clay, gray, much rock
72-74	Pierre Shale

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Test Hole 28
Elevation: 1,595 feet
Location: 123-68-30abbb
Depth to water: dry hole

0-14	clay, buff, pebbly, moist
14-24	clay, dark brown, pebbly, moist
24-82	clay, gray, pebbly, moist
82-84	Pierre Shale

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Test Hole 29
Elevation: 1,590 feet
Location: 123-68-30aabb
Depth to water: 19 feet

0- 9	clay, buff, pebbly, moist
9-19	clay, dark brown, pebbly
19-22	sand, medium, saturated
22-39	clay, gray, with some medium sand
39-79	clay, gray, pebbly, moist

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Test Hole 29--continued

79-84	same as above only saturated
84-89	Pierre Shale

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Test Hole 30
Elevation: 1,559 feet
Location: 123-68-29aabb
Depth to water: dry hole

0- 9	clay, buff, pebbly, moist
9-14	clay, dark brown, pebbly, moist
14-67	clay, gray, pebbly, moist
67-70	Pierre Shale

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Test Hole 31
Elevation: 1,536 feet
Location: 123-68-27ccbb
Depth to water: dry hole

0- 9	clay, buff, pebbly, moist
9-37	clay, brown, pebbly, moist
37-43	clay, gray, pebbly, moist
43-44	Pierre Shale

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Test Hole 32
Elevation: 1,521 feet
Location: 123-68-27baaa
Depth to water: dry hole

0-39	clay, brown, pebbly, moist
39-58	clay, gray, pebbly, moist
58-64	Pierre Shale

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Test Hole 33
Elevation: 1,501 feet
Location: 123-68-26abbb
Depth to water: 49 feet

0-24	clay, buff, pebbly, moist

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Test Hole 33--continued

24-34	same only many pebbles
34-49	clay, brown, pebbly, moist
49-54	clay, brown, sand (30%), saturated
54-59	Pierre Shale

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Test Hole 34
Elevation: 1,490 feet
Location: 123-68-24cddd
Depth to water: dry hole

0-19	clay, dark brown, pebbly, moist
19-44	clay, gray, pebbly, moist
44-49	clay, gray, very dry (Pierre Shale?)

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Test Hole 35
Elevation: 1,471 feet
Location: 123-67-30baaa
Depth to water: 13 feet

0- 6	sand, buff, medium, moist
6-13	clay, buff, pebbly, moist
13-24	sand, gray, medium, saturated
24-39	clay, gray, medium sand (30%), saturated
39-44	clay, gray, very dry (Pierre Shale?)

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Test Hole 36
Elevation: 1,470 feet
Location: 123-67-30acaa
Depth to water: 9 feet

0- 3	topsoil, dry, black, silty
3- 9	clay, medium to fine gravel, dry
9-14	gravel, buff, medium, clay (10%), saturated
14-27	gravel, fine, gray clay (10-15%), saturated
27-47	clay, gray, many pebbles, moist, some medium sand
47-49	Pierre Shale

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Test Hole 37
Elevation: 1,462 feet
Location: 123-67-29bbaa
Depth to water: 7 feet

0- 7	clay and sand, buff, moist
7- 9	sand, buff, coarse, clay (10%), saturated
9-34	sand, gray, fine, gray clay (30%), saturated
34-48	clay, gray, fine sand (25%), saturated
48-54	Pierre Shale

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Test Hole 38
Elevation: 1,577 feet
Location: 123-68-30addd
Depth to water: 22 feet

0- 4	clay, olive gray, pebbly, moist
4-17	clay, buff, pebbly, moist
17-22	clay, brown, pebbly, moist
22-31	gravel, fine to medium, clay (10%), saturated
31-41	sand, fine to medium, gray, saturated
41-73	clay, gray, pebbly, moist to saturated
73-74	Pierre Shale

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Test Hole 38A - drilled 10 feet north of Test Hole 38

0-35	clay, pebbly, moist

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Test Hole 38B - drilled 10 feet south of Test Hole 38

0-35	clay, pebbly, moist

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Test Hole 39
Elevation: 1,477 feet
Location: 123-68-25addd
Depth to water: dry hole

0- 2	clay, dark brown, dry
2- 9	clay, gray, very dry
9-14	clay, brown, very dry

(continued on next page)

Test Hole 39--continued

14-24	clay, brown, pebbly, moist
24-47	clay, gray, pebbly, moist
47-49	Pierre Shale

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Test Hole 40
Elevation: 1,463 feet
Location: 123-67-30daaa
Depth to water: 19 feet

0- 9	clay, brown, pebbly, moist
9-19	clay, gray, pebbly, moist
19-42	clay, gray, medium sand (40%), saturated
42-47	clay, gray, pebbly, moist
47-49	Pierre Shale

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Test Hole 41
Elevation: 1,605 feet
Location: 123-68-31bbbc
Depth to water: 47 feet

0- 22	clay, brown, pebbly, dry to moist
22- 47	clay, gray, pebbly, moist, rock at 37 feet
47- 59	rocky, much water with fine to medium sand in it
59- 64	gravel, fine, gray clay (30%), saturated
64- 84	sand, medium, with 20 to 50% gray clay
84- 99	clay, gray, pebbly, moist
99-107	clay, gray, saturated
107-109	Pierre Shale

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Test Hole 42
Elevation: 1,591 feet
Location: 123-68-31baaa
Depth to water: dry hole

0- 4	fill dirt in ditch
4-28	clay, brown, pebbly, moist
28-86	clay, gray, pebbly, moist
86-89	Pierre Shale

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Test Hole 43
Elevation: 1,563 feet
Location: 123-68-32bbab
Depth to water: 54 feet

0- 4	clay, dark brown, pebbly, moist
4-24	clay, buff, pebbly, moist
24-54	clay, gray, pebbly, moist
54-65	clay, gray, saturated
65-70	Pierre Shale

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Test Hole 44
Elevation: 1,546 feet
Location: 123-68-33bbbb
Depth to water: 53 feet (?)

0-19	clay, buff, pebbly, moist
19-24	clay, dark brown, pebbly, moist
24-53	clay, gray, pebbly, moist, augered water at 40 feet
53-57	possibly a saturated sand or sandy clay
57-59	Pierre Shale

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Test Hole 45
Elevation: 1,533 feet
Location: 123-68-27cccc
Depth to water: dry hole

0- 9	clay, buff, pebbly, moist
9-24	clay, dark brown, pebbly, moist
24-57	clay, gray, pebbly, moist
57-59	Pierre Shale

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Test Hole 46
Elevation: 1,472 feet
Location: 123-67-31baaa
Depth to water: 44 feet

0-39	clay, dark brown, pebbly, moist
39-44	clay, gray, pebbly, moist
44-52	clay, gray, sand (15%), saturated
52-53	Pierre Shale

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Test Hole 47
Elevation: 1,464 feet
Location: 123-67-31aaba
Depth to water: 9 feet

0- 4	clay, brown, moist
4- 9	clay, buff, sand (20%), moist
9-14	gravel, medium, buff clay (25%), saturated
14-19	sand, coarse, gray clay (10-15%)
19-34	sand, fine, much clay, saturated
34-52	clay, gray, medium sand (20%), saturated
52-54	Pierre Shale

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Test Hole 48
Elevation: 1,463 feet
Location: 123-67-29ccdc
Depth to water: 22 feet

0- 7	clay, buff, pebbly, moist
7-10	sand, buff, fine, moist
10-12	clay, buff, pebbly, moist
12-22	clay, gray, pebbly, moist
22-39	sand, fine, gray clay, saturated
39-58	clay, gray, pebbly, moist
58-59	Pierre Shale

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Test Hole 49
Elevation: 1,480 feet
Location: 123-67-32cbbb
Depth to water: 12 feet

0- 9	clay, brown, pebbly, dry
9-12	clay, gray, pebbly, dry to moist
12-17	gravel, medium, buff clay (50%), saturated
17-24	sand, coarse (90%), gray clay (10%), saturated
24-32	gravel, medium, gray clay (50%), saturated
32-58	clay, gray, saturated
58-59	Pierre Shale

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Test Hole 50
Elevation: 1,541 feet
Location: 123-68-32dccc
Depth to water: 9 feet

0- 7	clay, brown, pebbly, moist
7- 9	clay, yellow, medium sand (35%)
9-39	clay, gray, saturated, much water
39-63	clay, gray, medium sand (20%), saturated
63-64	Pierre Shale

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Test Hole 51
Elevation: 1,501 feet
Location: 122-68-1bbbb
Depth to water: 38 feet

0- 9	clay, buff, pebbly, moist
9-38	clay, dark brown, pebbly, moist
38-43	sand, olive gray, fine, silty, saturated
43-49	Pierre Shale

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Test Hole 52
Elevation: 1,480 feet
Location: 123-67-31cddd
Depth to water: 9 feet

0- 9	sand, buff, clay, fine, moist
9-14	same only saturated
14-44	clay, gray (75%), fine sand (25%), saturated
44-53	clay, gray, medium sand, saturated
53-59	Pierre Shale

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Test Hole 53
Elevation: 1,519 feet
Location: 122-68-4aada
Depth to water: 14 feet

0- 4	sand, very silty, very moist
4-14	sand, medium (60%), olive gray clay
14-24	clay, gray, medium sand (45%), saturated
24-43	clay, gray, medium sand (20%), saturated
43-44	Pierre Shale

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Test Hole 54
Elevation: 1,596 feet
Location: 122-69-1dadd
Depth to water: 44 feet

0-24	clay, buff, pebbly, moist
24-44	clay, gray, pebbly, moist
44-74	clay, gray, saturated, medium sand (50%)
74-93	clay, gray, saturated, medium sand (35%)
93-99	Pierre Shale

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Test Hole 55
Elevation: 1,503 feet
Location: 122-68-2cbbb
Depth to water: 24 feet

0- 2	topsoil, black
2- 9	clay, buff, many pebbles, moist
9-14	clay, dark brown, pebbly, moist
14-24	clay, gray, pebbly, moist
24-28	sand, medium, saturated
28-39	clay, gray, pebbly, moist
39-50	clay, gray, pebbly, moist to saturated
50-54	Pierre Shale

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Test Hole 56
Elevation: 1,540 feet
Location: 122-68-4cccc
Depth to water: dry hole

0-19	clay, buff, pebbly, moist
19-23	clay, dark brown, pebbly, moist
23-70	clay, gray, pebbly, moist
70-74	Pierre Shale

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Test Hole 57
Elevation: 1,476 feet
Location: 122-68-1dddd
Depth to water: 9 feet

0- 2	topsoil
2- 9	sand, gray, clean, fine, saturated

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Test Hole 57--continued

9-34	sand, gray, clean, medium, saturated
34-39	sand, gray, fine, clay (20%)
39-44	sand, gray, fine, clay (50%)
44-48	clay, gray, fine sand (25%)
48-54	Pierre Shale

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Test Hole 58
Elevation: 1,524 feet
Location: 122-68-9adda
Depth to water: dry hole

0-10	clay, brown, pebbly, moist
10-17	same, drier
17-19	same with 20% sand
19-29	clay, dark brown, pebbly, moist
29-73	clay, gray, many pebbles, moist, scattered rock from 65-69 feet
73-74	Pierre Shale

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Test Hole 59
Elevation: 1,472 feet
Location: 122-68-12dbab
Depth to water: 3 feet

0- 3	clay, light gray, moist
3-34	sand, coarse, buff, saturated
34-43	clay, gray, moist
43-44	Pierre Shale

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Test Hole 60
Elevation: 1,470 feet
Location: 122-68-13abba
Depth to water: 4 feet

0- 4	sand, fine to medium, clean
4- 9	sand, coarse, clean, saturated
9-29	gravel, fine, clean
29-35	gravel, medium, clean
35-47	clay, gray
47-49	Pierre Shale

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Test Hole 61
Elevation: 1,470 feet
Location: 122-68-13aabd
Depth to water: 3 feet

0- 3	clay, black, silty, moist
3-13	clay, brown, fine sand (30%), silty, saturated
13-26	same only gray
26-27	gravel, medium (70%), gray clay
27-33	sand, medium, saturated
33-37	clay, gray, pebbly, moist
37-47	clay, gray, fine sand and silt (20%), saturated
47-49	Pierre Shale

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Test Hole 62
Elevation: 1,467 feet
Location: 122-68-13dcdc
Depth to water: 4 feet

0- 4	clay, olive-gray, moist
4- 9	sand, fine, and clay (50%), saturated
9-19	clay, gray, coarse sand (40%), saturated
19-34	clay, gray, medium sand (60%), saturated
34-49	same only 30% medium sand
49-57	clay, gray, sand (15%), saturated
57-59	Pierre Shale

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APPENDIX B

Table 2.--Records of wells in the Ipswich area.

Well location: First number stands for township north, second number for range west, third for section, and letters for location in the section.
Type of well: Du, dug; D, drilled; B, bored
Character of material: o, outwash; sl, sand lens; ss, sandstone; t, till
Use of water: D, domestic; S, stock

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Character of Material	Use of Water
122-67-5bbba	Andy Bastian	Du	20	Glacial	t	D, S
122-67-6baaa	Wallis Knie	B	17	Glacial	o	D, S
122-67-7dbab	Leo Theis	D	1350	Dakota	ss	D, S
122-67-32bbbb	Duane Ertz	D	1250	Dakota	ss	D, S
122-68-3daaa	Leroy Gaver	D	1200	Dakota	ss	D, S
122-68-4daaa	Margaret Pfaff	D	1250	Dakota	ss	D, S
122-68-4bdbb	Bert Ertz	D	1300	Dakota	ss	D, S
122-68-5daaa	T. M. Markuson	D	1339	Dakota	ss	D, S
122-68-6aaaa	Robert Markuson	D	1339	Dakota	ss	D, S
122-68-7caaa	Andrew Kraft	D	1400+	Dakota	ss	D, S
122-68-8dbaa	Walter Wietgrefe	D	1300+	Dakota	ss	D, S
122-68-8aabb	Walter Wietgrefe	D	1400	Dakota	ss	S
122-68-11aaab	Mike Schumacher	D	1500	Dakota	ss	D, S
122-69-1daad	J. Blank	Du	40	Glacial	sl	S
122-69-1daad	J. Blank	B	70	Glacial	--	D
122-69-12aadd	Gust Job	B	83	Glacial	sl	D, S
122-69-12ccbb	John Meier	D	1300+	Dakota	ss	D, S

Table 2.--Records of wells--continued

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Character of Material	Use of Water
123-67-8cbbb	Casper Burgod	B	60	Glacial	--	D,S
123-67-18bbbb	Gauer	D	1100-1200	Dakota	ss	D,S
123-67-19cccd	Peter Krokosh	D	1100	Dakota	ss	D,S
123-67-19cccd	Peter Krokosh	Du	20	Glacial	o	D,S
123-67-29bbbc	David Hales	B	16	Glacial	o	D,S
123-67-30daaa	Lester Ernst	Du	10	Glacial	o	D,S
123-68-3bbbc	Clarence Stevens	D	1200	Dakota	ss	D,S
123-68-4dddd	Joe Webber	D	1600	Dakota	ss	D,S
123-68-6baaa	George Dammer	D	80	Glacial	sl	D,S
123-68-8dddd	Jack Dutenhofer	D	1310	Dakota	ss	D,S
123-68-10bcbc	Don Jones	D	60	Glacial	t	S
123-68-11abaa	Byron Jones	D	1280	Dakota	ss	D,S
123-68-12addd	Rubin Bender	D	1280	Dakota	ss	D,S
123-68-14dcdc	Elmer Habeck	D	1300	Dakota	ss	D,S
123-68-15cccc	Connie Miller	D	1400	Dakota	ss	D,S
123-68-16addd	Ed Gillick	D	1200-1300	Dakota	ss	D,S
123-68-20ccdd	Evert Stannard	B	18-20	Glacial	sl	D,S
123-68-20dddd	Charles Sindelar	D	1465	Dakota	ss	D,S
123-68-23dccc	Paul Shoemaker	D	1300	Dakota	ss	D,S
123-68-24dccc	Wesley Stern	D	1300	Dakota	ss	D,S
123-68-24dada	John Dosch	D	1400	Dakota	ss	D,S

Table 2.--Records of wells--continued

Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Character of Material	Use of Water
123-68-29daaa	John Schlepp	D	1100	Dakota	ss	D,S
123-68-30daaa	Jean Hammrich	D	1650	Dakota	ss	D,S
123-68-31cbbb	Art Halsing	D	1200	Dakota	ss	D,S
123-68-32badd	James Pedersen	D	1300	Dakota	ss	D,S
123-68-34bbbb	Ferd Kienow	B	60	Glacial	sl	D,S
123-68-35abbb	Art Semmler	D	1200	Dakota	ss	D,S
123-68-35cddd	Emanuel Semmler	D	1220	Dakota	ss	D,S
123-69-12cddd	Reinhole Kuelber	B	40	Glacial	sl	D,S
123-69-13dddc	Jake Volk	-	100	Glacial	sl	D,S