STATE OF SOUTH DAKOTA
Archie Gubbrud, Governor

STATE GEOLOGICAL SURVEY
Allen F. Agnew, State Geologist

SPECIAL REPORT 22

WATER SUPPLY FOR THE CITY OF BERESFORD

by
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Science Center
University of South Dakota
Vermillion, South Dakota
June, 1962

Supplement, June 1, 1963

In the original conclusions and recommendations of this report, it was recommended that the city of Beresford do further testing along the Brule Creek aquifer in the SW$\frac{1}{4}$ sec. 14, T. 95 N., R. 50 W. and the NW$\frac{1}{4}$ sec. 23, T. 95 N., R. 50 W.

This testing was done in the spring of 1963 by the Thrope Drilling Company of Des Moines, Iowa, and the water in the aquifer was found to be of much poorer quality than that indicated by the samples collected by the South Dakota Geological Survey crew the previous summer (samples 1-7, Table 1). This discrepancy is probably due to faulty water sample collection procedures on the part of the South Dakota Geological Survey crew. Samples 1-6 were collected from very shallow farm wells (20-30 feet) and Sample 7 also from a shallow depth of 30 feet in Test Hole No. 15 (In Table 1, sample 7 is shown to come from a depth of 80 feet which is incorrect; that is the depth of the test hole--the water sample was pumped from a depth of 30 feet).

The aquifer at the above recommended sites is about 70-80 feet deep and the samples collected by the Thrope Drilling Company were taken from a depth of about 60 feet. The water from this 60-foot depth is of very poor quality (comparable to water samples 8-14, Table 1). This probably means that the water collected from the shallow wells by the State Geological Survey reflected recent recharge by rainfall in the immediate area rather than the true quality of the water in the aquifer from depths at which it would be pumped.

At the present time (June 1, 1963), additional testing is being done by the City of Beresford farther north along the Brule Creek aquifer where a better quality of water was indicated in the original State Geological Survey study.

Merlin J. Tipton
Assistant State Geologist

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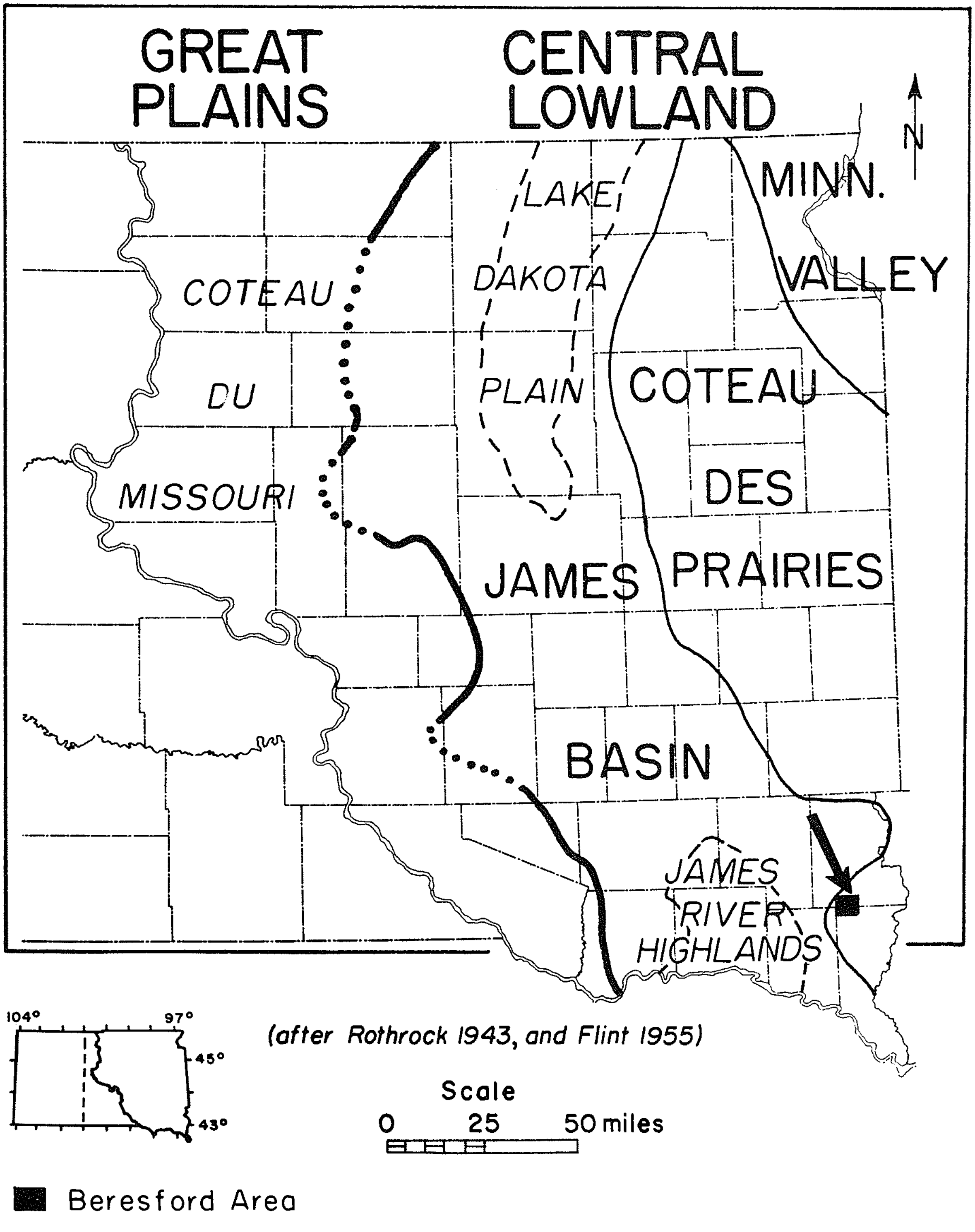
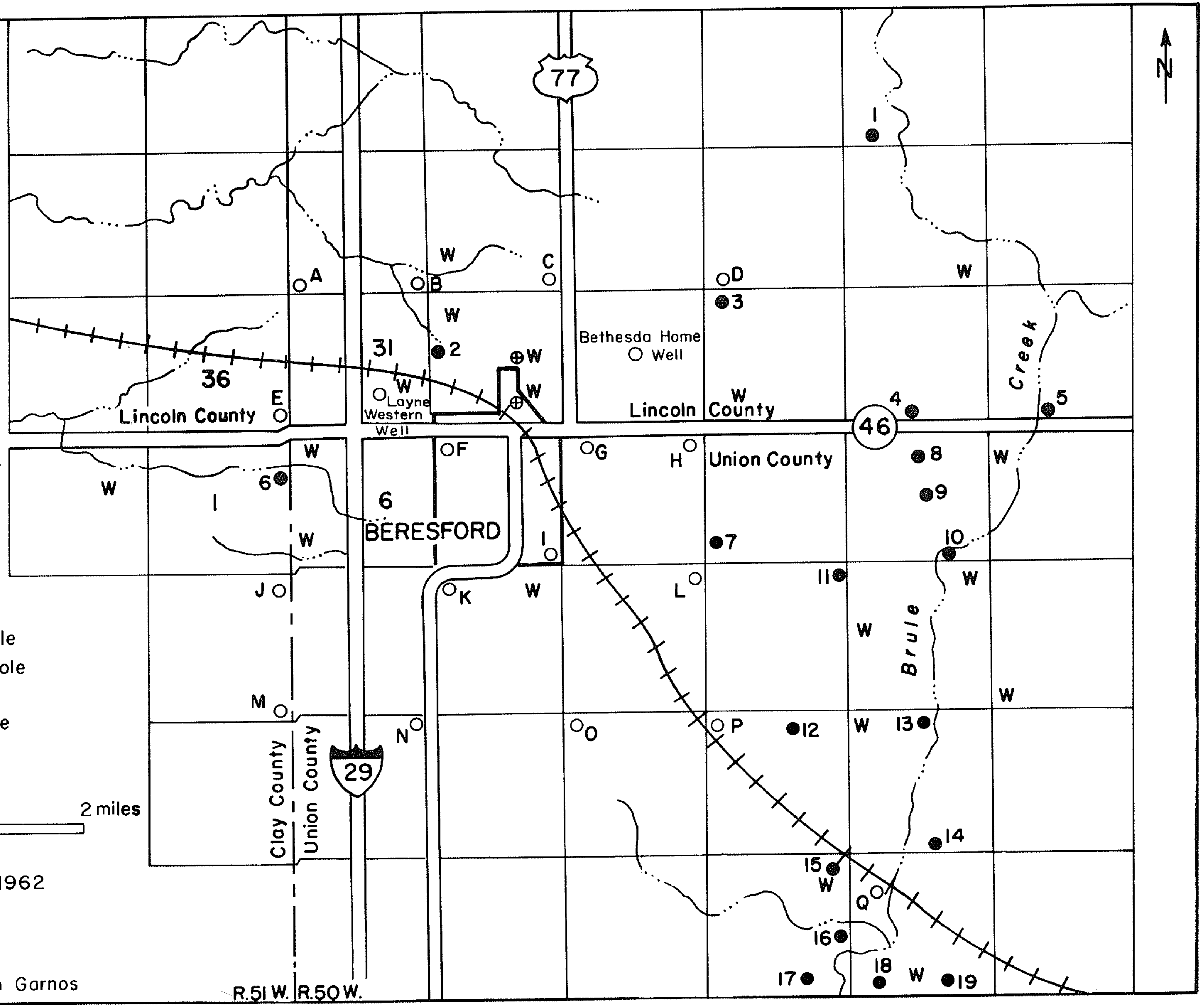


Figure I. Major Physiographic Divisions of Eastern South Dakota and Location of the Beresford area

Figure 2.
Data Map of the
Beresford Area



Explanation
1 ● — Auger test hole
A ○ — Rotary test hole
⊕ — City well
W — Water Sample

Scale
0 1/2 1 2 miles

by
G. K. Baker, 1962

drafted by Elizabeth Garnos

Climate

The climate is continental temperate, with large daily fluctuations in temperature. The mean annual temperature is 47.8 degrees F., and the average annual precipitation is 25 inches at the U. S. Weather Bureau Station in Canton, 17 miles northeast of the city of Beresford.

Topography and Drainage

The topography of the area is youthful glacial moraine--rolling hills and valleys with knobs and kettles. The city of Beresford lies on a topographic high; consequently, the streams in the area drain away from the city in all directions. These streams eventually reach the Vermillion River about ten miles to the west, or Brule Creek about five miles east of Beresford.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Beresford area are chiefly the result of glaciation in the Pleistocene Epoch. These glacial deposits, collectively termed drift, can be divided into till and outwash sediments. Till consists of a jumbled mixture of clay, silt, sand, pebbles and boulders, carried and deposited by the ice itself. The outwash material, which consists primarily of sands and gravels, was deposited by meltwater streams from the wasting glaciers. A surface outwash deposit occurs along Brule Creek (fig. 3) in the eastern part of the mapped area. A buried outwash (fig. 3) covered by as much as 175 feet of drift (Test Hole D, Appendix B) is present in the central part of the mapped area.

Alluvium has been locally deposited on the glacial deposits by recent streams since the retreat of the glaciers, and consists of silt and clay with minor amounts of sand. Although not mapped as such, as much as 20 feet of alluvium covers the surface outwash along Brule Creek.

Subsurface Bedrock

Stratified rocks of Cretaceous age lie beneath the surficial deposits in the Beresford area. The surficial deposits in the western and southern parts of the mapped area are underlain by the Niobrara Formation, and the surficial deposits in the remainder of the area are underlain by the Carlile Formation. The Carlile underlies the Niobrara where the Niobrara has not been removed. The Carlile is underlain in descending order by the Greenhorn and Graneros Formations and the Dakota Group.

The Niobrara Formation consists of light to medium blue-gray shale which contains numerous microscopic white calcareous specks.

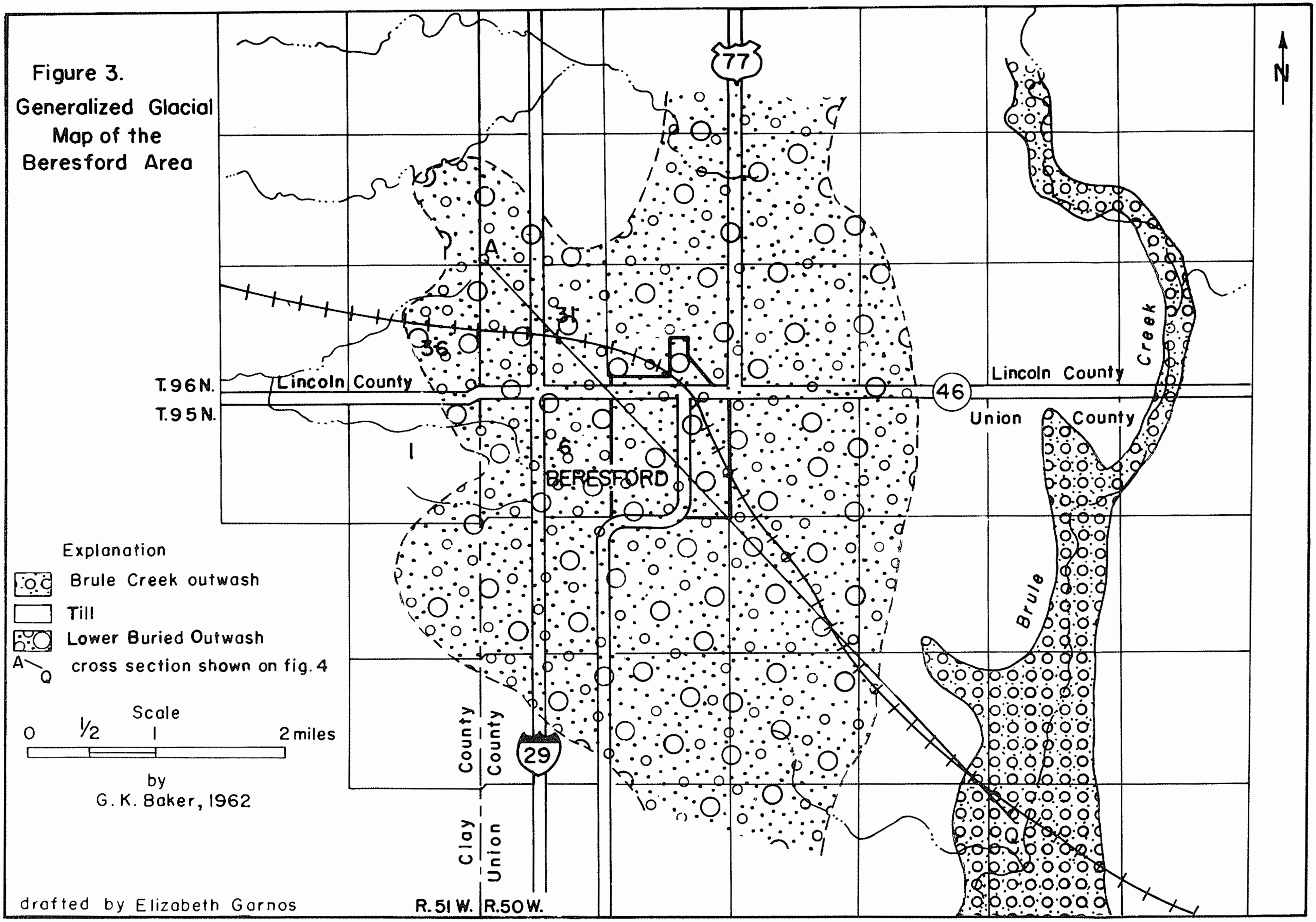


Figure 3. Generalized Glacial Map of the Beresford Area

The Carlile Formation is medium- to dark-gray bentonitic shale with pyrite concretions and layers of fine brown siltstone. The uppermost part of the Carlile Formation in the southern part of the mapped area is a sandy unit referred to as the Codell Member. This member is an aquifer which yields sufficient water for domestic needs only, in the Beresford area.

The Greenhorn Formation consists of a hard layer of white to cream limestone containing numerous fossil fragments.

The Graneros Formation is hard light- to dark-gray siliceous shale.

The Dakota Group consists chiefly of fine to coarse light-colored sandstones interbedded with gray shales.

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 may evaporate or drain to the sea by 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, and is accomplished in three main ways: (1) by downward percolation of water from the ground surface, (2) by the downward percolation of water from surface bodies such as lakes and streams, and (3) by lateral underflow of water in transient storage.

Discharge, or the removal of ground water from an aquifer, is accomplished in four main ways: (1) by evaporation and transpiration from plants, (2) by seepage upward or laterally into surface bodies of water as by springs, (3) by lateral underflow of water in transient storage, and (4) by pumping of wells.

The amount of water that is contained in the rock is controlled by the porosity and permeability of the rock. Porosity is a measure of the amount of voids in a rock and is expressed in the ratio of pore space to the total volume of rock.

Porosity is dependent on: (1) the shape and arrangement of individual particles, (2) the degree of sorting of the particles, (3) the degree of cementation and compaction of the particles, and (4) the amount of material that has been removed by percolating ground water. Sands and gravels usually have porosities of 20-40 percent, whereas sandstones have porosities of 15-25 percent. Sandstones have lower porosities owing to their higher degree of compaction and cementation.

Permeability is a measure of the rate at which a fluid will pass through a material. A material that has a high percentage of interconnected pores likewise has a high permeability, whereas a material in which the pores are not connected will have low permeability, although it may have high porosity. Therefore, it can be seen that porosity and permeability are not synonymous but are nevertheless related.

Ground Water in Alluvium

Alluvium exists along the smaller unnamed drainages in the Beresford area and on Brule Creek. The alluvium would not provide a source of water for the city of Beresford because of the low permeability of the deposit. This low permeability is due to the small size of the particles which make up the alluvium.

Ground Water in Glacial Deposits

Till does not yield water readily because of its highly unsorted nature and low porosity and permeability. Outwash, on the other hand, is a good source of ground water because of its high porosity and permeability.

Several outwash deposits occur in the Beresford area. A surface outwash deposit occurs along Brule Creek (fig. 3) in the eastern part of the mapped area. This outwash is locally more than 85 feet thick (Test Hole 14, Appendix A), and is covered with 5-20 feet of alluvium. The outwash sediments consist of coarse sand and pea-sized gravel, below the present valley of Brule Creek. The large areal extent and thickness, the good permeability and porosity, and the good quality of the water make this outwash deposit a good aquifer. Auger Test Holes 1,5,9,10,12, 13,14,15,16,18, and 19 (Appendix A and fig. 2), and Rotary Test Q (Appendix B and fig. 2) penetrated the Brule Creek outwash.

Two buried outwash deposits occur in the central part of the mapped area. The upper buried outwash (fig. 4), thin and discontinuous, is not adequate as an aquifer for a city; however, it is adequate locally for farm use.

The lower buried outwash (fig. 3, 4, and 5) consists of coarse sand to pea-sized gravel, and varies in thickness from a few feet to more than 100 feet. The two thickest parts of this lower buried outwash occur on the southern edge of Beresford and one mile northeast of the city (fig. 5). This outwash, covered by as much as 155 feet of drift, is probably continuous to the north and south of the city of Beresford, but pinches out to the east and west.

Like the Brule Creek outwash, the lower buried outwash has good porosity and permeability, but unlike the Brule Creek outwash, the quality of water is poor. All of the Geological Survey rotary test holes with the exception of Q (Appendix B) penetrated this aquifer.

Figure 4 is a northwest-southeast cross-section which infers the extent of the lower buried outwash and shows its inferred relationship to the Brule Creek outwash.

Ground Water in Bedrock

The Niobrara Formation is a known water producer in some areas of the State. In the western part of the mapped area most of the farm wells produce from this formation. These wells in the "chalk rock" range in depth from 40 to 135 feet below the surface.

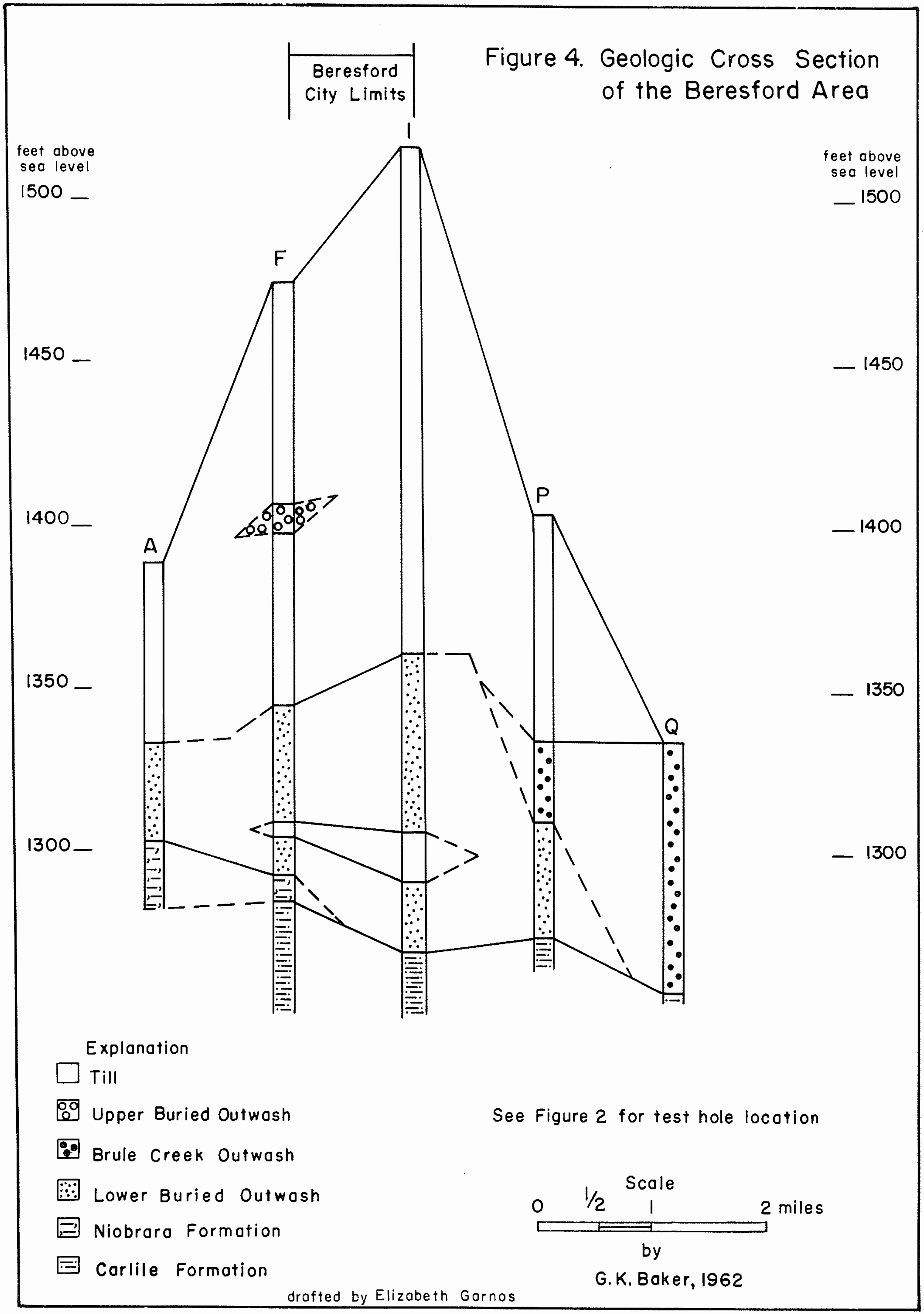
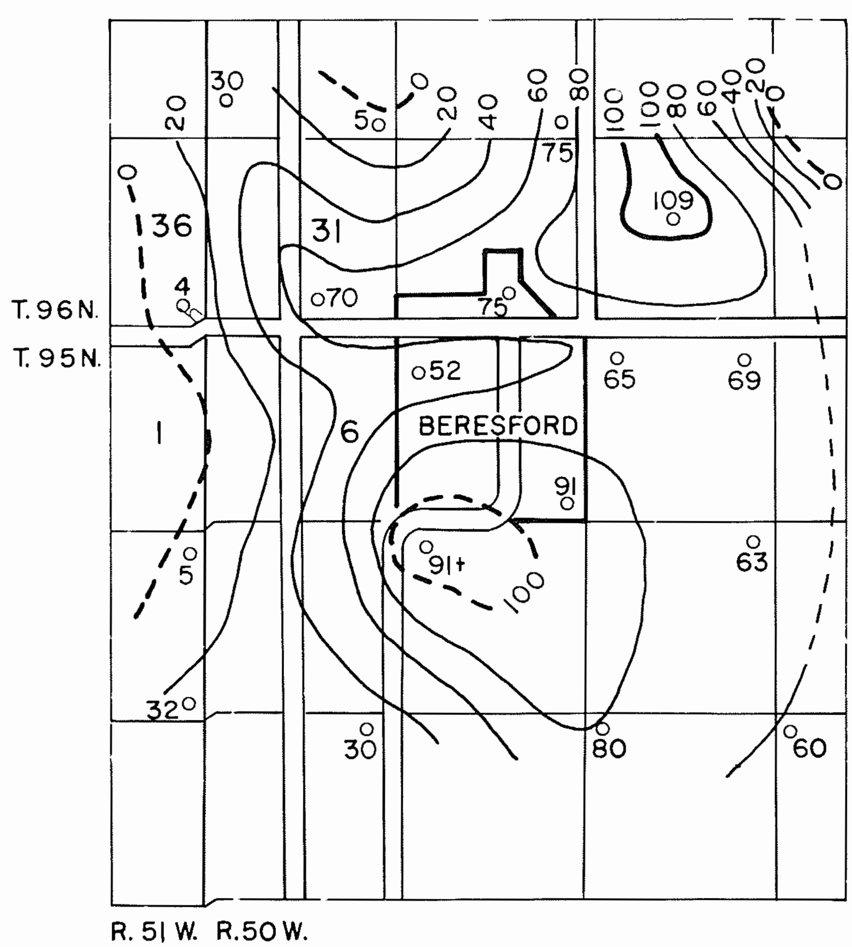


Figure 4. Geologic Cross Section of the Beresford Area

Figure 5. Isopach Map Showing Thickness of the Lower Buried Outwash in the Beresford Area



Explanation

Lines of equal thickness of Lower Buried Outwash; interval 20 feet

o69 Test hole showing thickness of Lower Buried Outwash deposit

Scale

0 ½ 1 2 miles

by
G. K. Baker, 1962

drafted by Elizabeth Garnos

This water is contained in joints and solution cavities along bedding planes in the formation. The quality of this water is somewhat poorer than the present city water.

The Niobrara Formation will continue to supply water to farm wells in the area described; it is doubtful, however, that this formation could supply enough water for the city of Beresford.

Two farm wells northwest of Beresford are in the Greenhorn Limestone (Appendix D). Water is contained in this formation in a similar manner to that in the Niobrara Formation. The Greenhorn does not appear to be a potential aquifer for the city of Beresford.

The two city wells, the Bethesda Home well (1 mile northeast of Beresford) and one farm well in the area studied are presently drawing water from the sandstones of the Dakota Group. Although the Dakota is a State-wide aquifer, it fails to produce enough water to supply the city of Beresford. This aquifer contains water under artesian pressure.

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, the more minerals a water contains, the poorer its quality.

Table 1 shows the chemical properties of various waters in the Beresford area, as compared with the present city water and with the standards for drinking water established by the U. S. Department of Public Health (1961). The two producing city wells (Samples B and C) come within the standards set, being high only in iron and fluoride content. A small amount of fluoride in water is desirable.

Water Samples 1-7 (table 1) were collected from the Brule Creek Outwash. Samples 1, 3, 5, and 7 are of very good quality, whereas Samples 2 and 6 are high in sulfate, magnesium, and total solids and Sample 2 and 7 are high in iron. Sample 4 is of fair quality, being only slightly high in hardness and total solids.

Water Samples 8, 9, and 10 (table 1) are from farm wells believed to be pumping from the upper buried outwash. Samples 9 and 10 are very high in hardness, magnesium, iron, sulfate, and total solids. Sample 8 is high in hardness and total solids. Due to the small volume of outwash and the poor quality of water, the upper buried outwash aquifer is not satisfactory for the city needs.

Water Samples 12, 13, and 14 (table 1) are from farm wells and Sample 11 (table 1) is from the Layne-Western 62-5 well, all of which are believed to be pumping from the lower buried outwash aquifer. The Layne-Western 62-5 well is used by Western Construction Company to supply water for construction on Interstate Highway 29. All samples are extremely high in magnesium, sulfate, hardness, and total solids, and all except Sample 11 are extremely high in iron. Considerable treatment would be necessary to bring this water within the limits established by the U. S. Department of Public Health.

Table 1.--Chemical Analyses of Water Samples from the Beresford Area
(see following page for sample locations)

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magnesium	Chloride	Sulfate	Iron	Manganese	Nitrate	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A		--	--	50	250	500*	0.3	0.05	10	0.9-1.7**	--	--	1000*
B	Dakota	123	143	27	80	383	2.4	0.1	0.0	2.8	7.6	424	954
C	Dakota	115		30	84	391	0.7	0.0	0.0	3.2	7.0	412	960
1	Brule Creek Outwash	62	16	27	0.4	78	0.34	0	0.8	0	7.8	268	402
2	Brule Creek Outwash	408		82	16	972	3.5				7.0	1350	2205
3	Brule Creek Outwash	74	15	39	5	102	0.2	0	1.4	0.2	7.4	345	490
4	Brule Creek Outwash	197		39	8	243	0.4				7.2	640	1170
5	Brule Creek Outwash	212		-30	24	78	0.6				7.4	410	859
6	Brule Creek Outwash	260	28	95	0	819	0.2	2.8	0	0.2	7.0	1041	1616
7	Brule Creek Outwash	100	16	49	0	328	2.2	0	0.2	0.6	7.3	452	688
8	Upper Buried Outwash	520		-121	8	389	0.1				7.6	815	1074
9	Upper Buried Outwash	508		107	8	1118	15.0				6.9	1700	2810
10	Upper Buried Outwash	480		75	8	924	3.8				6.9	1500	2410
11	Lower Buried Outwash	467	98	519	2	2079	0.1	0.8	0.7	0.2	7.0	2300	3718
12	Lower Buried Outwash	452	144	283	4	2114	57	0.3	1.2	0.04	6.9	2295	3942
13	Lower Buried Outwash	351	87	222	0	1661	56	0	0.3	0.2	6.7	1788	2958
14	Lower Buried Outwash	303	140	178	0.7	1513	33	0.3	0.9	0.2	7.0	1490	2718
15	Niobrara	650		94	8	1165	20.0+				6.9	2000	2310
16	Niobrara	635		86	8	1265	0.3				7.0	1930	3010
17	Niobrara	902		-20	8	1410	9.0				6.9	2170	3320

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

** Optimum

Table 1.--Chemical Analyses of Water - continued

Sample No.

A. U. S. Department of Public Health Drinking Water Standards (1961)

B. Beresford City Well No. 1

C. Beresford City Well No. 2

1. H. Young farm, SW$\frac{1}{4}$ sec. 12, T. 95 N., R. 50 W.

2. C. Olson farm, NW$\frac{1}{4}$ sec. 14, T. 95 N., R. 50 W.

3. F. Farley farm, SW$\frac{1}{4}$ sec. 23, T. 95 N., R. 50 W.

4. M. Jantgaard farm, NW$\frac{1}{4}$ sec. 1, T. 95 N., R. 50 W.

5. C. Erickson farm, NE$\frac{1}{4}$ sec. 11, T. 95 N., R. 50 W.

6. P. Hustrulid farm, NW$\frac{1}{4}$ sec. 11, T. 95 N., R. 50 W.

7. State Geological Survey Test Hole No. 15 at 80 feet

8. W. Reirson farm, SE$\frac{1}{4}$ sec. 26, T. 96 N., R. 50 W.

9. G. Kennedy farm, SW$\frac{1}{4}$ sec. 29, T. 96 N., R. 50 W.

10. P. Vogeli farm, SW$\frac{1}{4}$ sec. 34, T. 96 N., R. 50 W.

11. Layne-Western 62-5 Well, SE$\frac{1}{4}$ sec. 31, T. 96 N., R. 50 W.

12. M. Ende farm, NW$\frac{1}{4}$ sec. 32, T. 96 N., R. 50 W.

13. R. Jensen farm, NW$\frac{1}{4}$ sec. 6, T. 95 N., R. 50 W.

14. J. Dolan farm, NE$\frac{1}{4}$ sec. 8, T. 95 N., R. 50 W.

15. Foose farm, NE$\frac{1}{4}$ sec. 2, T. 95 N., R. 51 W.

16. H. Neilsen farm, NE$\frac{1}{4}$ sec. 15, T. 95 N., R. 51 W.

17. H. Welch farm, SW$\frac{1}{4}$ sec. 6, T. 95 N., R. 50 W.

Samples B and C were analyzed by the State Department of Public Health

Samples 1,3,6,7,11,12,13 and 14 were analyzed by the State Chemical Laboratory, Vermillion

Samples 2,4,5,8,9,10,15,16 and 17 were analyzed by the State Geological Survey field kit, Vermillion

Water Samples 15, 16, and 17 (table 1) were collected from farm wells pumping from the Niobrara Formation. Samples 15 and 16 are high in magnesium and very high in hardness, sulfate, and total solids content, whereas Sample 17 is very high in sulfate, hardness, and total solids. Owing to the small quantity and poor quality of the water, wells in the Niobrara Formation would not be suitable for the city of Beresford.

CONCLUSIONS AND RECOMMENDATIONS

It is suggested that the city of Beresford has two possible sources besides the present Dakota aquifer from which to draw its future water supplies.

The first aquifer, the lower buried outwash (fig. 3), lies beneath the city, the thickest part occupying the SW$\frac{1}{4}$ sec. 5, T. 95 N., R. 50 W., and the NW$\frac{1}{4}$ sec. 8, T. 95 N., R. 50 W. (fig. 5). At this location, the thickness of the water-saturated sand and gravel varies from 80 to 100 feet. A sufficient amount of water could probably be pumped from this aquifer to meet the future needs of the city; however, the quality of the water is very poor (table 1, samples 11, 12, 13, and 14). Considerable and potentially expensive treatment would have to be given to this water to bring it within the drinking water standards (table 1) set by the U. S. Department of Public Health. Furthermore, pipes and pumps subjected to this water would need periodic repair or replacement.

The second aquifer is the surface outwash along Brule Creek (fig. 3). The most favorable part of this aquifer lies in the SW$\frac{1}{4}$ sec. 14, T. 95 N., R. 50 W., and the NW$\frac{1}{4}$ sec. 23, T. 95 N., R. W. Here the water-saturated sand and gravel varies in thickness from 61 to more than 85 feet (Test Holes 14 and 15, Appendix A and Test Hole Q, Appendix B). The water collected and tested in the vicinity (table 1, samples 3 and 7) is of a good quality. Pipes and pumps subjected to this water would require a minimum of repair. A sufficient amount of water could probably be pumped from this aquifer to supply the future needs of the city of Beresford. To pump water from this aquifer to the base of the water tower in the city would require a lift of more than 160 feet over a distance of approximately four miles.

It is recommended that after deciding which of the two aquifers is best suited for the city, that several test holes be drilled in the above recommended locations to determine the extent and thickness of the aquifer. On the basis of these test holes, a location may be picked and a test well put in and test-pumped. This test-pumping should be conducted by licensed engineers for a minumum of 72 hours. These tests are extremely important to determine if the aquifer is continuous, and also to determine what capacity and type of permanent well should be constructed.

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 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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Flint, R. F., 1955, Pleistocene Geology of Eastern South Dakota: U. S. Geol. Survey, Prof. Paper 262, fig. 1.

Rothrock, E. P., 1943, A Geology of South Dakota, Pt. 1: The Surface: S. Dak. Geol. Survey Bull. 13, pl. 2.

U. S. Public Health Service, 1961, Drinking water standards: Am. Water Works Assoc. Jour., v. 53, no. 8, p. 935-945.

APPENDIX A

Logs of Auger Test Holes in the Beresford Area

(for location see figure 2)

Test Hole No. 1
Surface elevation: not measured
Depth to water: 15 feet

0- 2	topsoil
2-14	clay, yellow-brown
14-29	clay, yellow-brown, sandy
29-48	sand, fine grained, clayey

* * * * * *

Test Hole No. 2
Surface elevation: not measured
Depth to water: 5 feet

0-29	clay, yellow-brown
29-59	clay, blue
59-63	drilled like coarse gravel

* * * * * *

Test Hole No. 3
Surface elevation: not measured
Depth to water: 11 feet

0- 2	topsoil
2-19	clay, yellow-brown, boulders
19-58	clay, blue, boulders

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Test Hole No. 4
Surface elevation: not measured
Depth to water: 9 feet

0- 9	topsoil
9-14	drilled like gravel
14-49	alluvium

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Test Hole No. 5
Surface elevation: not measured
Depth to water: 2 feet

0-1	topsoil
1-16	till, sandy, silty, clayey
16-25	sand, silty
25-39	gravel
39-59	no cuttings, drilled like gravel

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Test Hole No. 6
Surface elevation: not measured
Depth to water: 11 feet

0- 4	topsoil
4-11	clay, brown, some sand
11-57	clay, blue, some sand

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Test Hole No. 7
Surface elevation: not measured
Depth to water: 16 feet

0- 5	topsoil
5-14	clay, yellow
14-19	clay, yellow, silty, sandy
19-49	clay, yellow, sandy to pebbly

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Test Hole No. 8
Surface elevation: not measured
Depth to water: 9 feet

0-16	alluvium, black
16-20	till
	unable to drill deeper

* * * * * *

Test Hole No. 9
Surface elevation: not measured
Depth to water: 16 feet

0- 4	topsoil
4-16	clay, black
16-25	silt, brown, clayey
25-59	silt, yellow, sandy
59-68	sand, fine grained
68-89	sand, medium to coarse grained
	did not reach bottom of sand

* * * * * *

Test Hole No. 10
Surface elevation: not measured
Depth to water: 8 feet

0- 5	topsoil
5-19	clay, sandy
19-44	no cuttings
44-63	sand, coarse grained, clay matrix

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Test Hole No. 11
Surface elevation: not measured
Depth to water: 9 feet

0- 2	topsoil
2-26	clay, yellow
26-30	clay, gray, silty
30-39	clay, yellow, silty
39-59	clay, yellow, silty, sandy

* * * * * *

Test Hole No. 12
Surface elevation: not measured
Depth to water: 20 feet

0- 5	topsoil
5-79	clay, sandy
	amount of sand increased from 5 foot to 79 foot.

* * * * * *

Test Hole No. 13
Surface elevation: not measured
Depth to water: 12 feet

0-12	topsoil
12-25	silt, sandy to pebbly
25-74	sand, medium to coarse grained

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Test Hole No. 14
Surface elevation: not measured
Depth to water: 8 feet

0- 2	topsoil
2-29	silt, sandy
29-114	sand, medium to coarse grained
	did not reach bottom of sand

* * * * * *

Test Hole No. 15
Surface elevation: not measured
Depth to water: 12 feet

0-10	topsoil
10-19	silt, very sandy
19-42	sand, medium to coarse grained
42-80	gravel
80-	Carlile Shale

* * * * * *

Test Hole No. 16
Surface elevation: not measured
Depth to water: 7 feet

0- 2	topsoil
2- 7	clay, black
7-14	clay, blue
14-19	silt, sandy
19-83	sand, coarse grained
83-88	clay, blue (Carlile Shale?)

* * * * * *

Test Hole No. 17
Surface elevation: not measured
Depth to water: 10 feet

0- 6	topsoil
6-16	clay, blue
16-49	clay, blue, sandy
49-73	till, pebbly

* * * * * *

Test Hole No. 18
Surface elevation: not measured
Depth to water: 6 feet

0- 6	topsoil
6-69	sand, coarse grained
69-89	clay, blue (Carlile Shale?)

* * * * * *

Test Hole No. 19
Surface elevation: not measured
Depth to water: 5 feet

0- 7	topsoil, yellow, clayey
7-68	sand, very coarse grained
68-77	clay, blue (Carlile Shale?)

* * * * * *

APPENDIX B

Logs of Rotary Test Holes in the Beresford Area

(for location see figure 2)

Test Hole No. A
Surface elevation: 1389 feet

0- 55	clay, buff and light gray, more or less oxidized entire interval
55- 85	sand, very coarse, gravel, pea-size
85-100	Niobrara Chalk

* * * * *

Test Hole No. B
Surface elevation: 1409 feet

0- 55	clay, buff, sandy
55- 60	gravel, coarse, very hard drilling
60- 65	clay, buff, sandy
65- 70	sand, medium to coarse grained
70- 87	clay, gray, very little sand or silt
87-125	clay, light gray and light pink
125-130	sand, coarse to granular
130-160	clay, white (Niobrara Chalk)
160-170	shale, medium gray, very fat (Carlile Shale)

* * * * * *

Test Hole No. C
Surface elevation: 1467 feet

0- 55	clay, buff to brown, sandy
55- 95	clay, white to light gray, sandy
95-125	clay, light pink, in part silty
125-200	sand, medium to granular

* * * * * *

Test Hole No. D
Surface elevation: 1463 feet

0- 18	clay, buff, silty
18- 55	clay, gray, silty
55- 60	sand, coarse, gravelly
60-155	clay, dark gray, very silty
155-175	clay, greenish-gray, silty
175-190	sand, very coarse grained to granular, much greenstone
190-200	Carlile Shale

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Test Hole No. E
Surface elevation: 1426 feet

0-45	clay, buff, sandy
45-60	clay, dark gray, sandy
60-62	silt, clay, bright orange
62-66	sand, coarse, gravel, pea-size
66-96	Niobrara Chalk, weathered

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Test Hole No. F
Surface elevation: 1476 feet

0- 28	clay, buff, sandy with few sand streaks
28- 50	clay, gray, sandy
50- 70	clay, silty
70- 77	sand, medium to coarse to pea-size gravel
77- 80	clay, gray, sandy
80- 95	clay, buff, waxy, silty
95-130	clay, light pinkish, silty, waxy
130-166	sand, medium grained
166-170	clay, light pink
170-182	sand, medium grained
182-190	Ash ?, Niobrara Chalk ?
190-225	shale, black, clayey, silty (Carlile Shale)

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Test Hole No. G
Surface elevation: 1504 feet

0- 18	clay, buff, sandy
18- 35	clay, gray, sandy, pebbly
35- 55	clay, gray, sandy, silty
55- 70	clay, olive green, silty, in part pebbly
70- 73	silt, bright orange, clayey
73- 85	clay, light greenish-gray, silty, sandy
85-120	clay, gray, silty, sandy
120-155	clay, light pink, silty
155-220	sand, coarse to granular
220-225	shale, medium gray, plastic (Carlile Shale)

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Test Hole No. H
Surface elevation: 1491 feet

0- 45	clay, buff, sandy
45- 48	clay, yellow to brick red
48- 65	clay, gray, sandy
65- 70	sand, coarse to granular
70- 90	clay, gray, sandy
90- 95	clay, light blue, very fat
95-105	gravel, pea-size, mostly carbonate granules
105-120	clay, light green, silty
120-143	clay, light pink to light brown, very fat
143-212	sand, medium to coarse grained, 50 % granular
212-225	Carlile Shale

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Test Hole No. I
Surface elevation: 1517 feet

0- 25	clay, buff, sandy, pebbly
25- 58	clay, gray, sandy
58- 62	clay, light green, silty
62- 66	silt
66- 80	clay, light tan, silty
80- 90	clay, buff, silty, sandy, pebbly
90-107	silt ?, no cuttings
107-115	clay, silty, white
115-118	clay, silty, sandy
118-125	clay, light maroon, very fat
125-155	clay, pink
155-210	sand
210-225	clay, pink and white
225-246	sand
246-265	Carlile Shale

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Test Hole No. J
Surface elevation: 1433 feet

0- 5	gravel, pea-size, sand
5- 35	clay, buff, sandy
35- 80	clay, gray, sandy, pebbly
80- 96	gravel and sand, poorly sorted
96-102	clay, light green, sandy
102-135	clay, light pink, silty
135-140	silt and sand
140-160	Niobrara Chalk
160-	Carlile Shale

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Test Hole No. K
Surface elevation: 1497 feet

0- 30	clay, buff, sandy, pebbly
30- 40	clay, gray, sandy, pebbly
40- 64	clay, gray, silty, fine sand incorporated
64- 80	clay, bright orange, silty, sandy
80- 92	clay, gray, sandy, pebbly
92- 93	clay, buff, sandy
93- 95	clay, gray, waxy
95-100	sand, medium to coarse grained
100-122	clay, buff, sandy
122-139	clay, light pink, poor cuttings
139-230	sand, medium to coarse grained
	lost circulation at 230 feet, abandoned hole

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Test Hole No. L
Surface elevation: 1450 feet

0- 8	sand, very fine grained, clayey, (loess ?)
8- 18	clay, light gray, very silty
18- 26	clay, buff, sandy, pebbly
26- 40	clay, gray, sandy, pebbly
40- 42	sand, coarse to granular
42- 50	clay, gray, sandy
50- 51	clay, black, sandy
51- 77	clay, gray, sandy
77- 84	clay, light greenish-gray, silty
84-102	clay, pink, silty
102-165	sand, medium to coarse grained, in part granular
165-170	Carlile Shale

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Test Hole No. M
Surface elevation: 1468 feet

0- 45	clay, buff, sandy
45- 52	clay, gray, sandy
52- 58	clay, buff, sandy
58- 63	sand, gravel, poorly sorted
63- 69	clay, buff, sandy
69- 75	clay, gray, sandy
75- 94	clay, pink, silty
94-126	sand and pea-sized gravel
126-140	Niobrara Chalk

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Test Hole No. N
Surface elevation: 1514 feet

0- 30	clay, buff, sandy
30- 55	clay, green, sandy
55-125	silt ?, light buff to orange
125-137	sand
137-150	clay, pink, silty
150-180	sand and gravel
180-215	clay, white and light pink, sandy
	lost circulation at 215 feet, abandoned hole

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Test Hole No. O
Surface elevation: 1513 feet

0- 35	clay, light buff, chocolate-brown, and light gray, sandy
35- 65	silt, dark buff, clayey
65- 78	clay, greenish-gray, sandy
78- 88	sand, coarse grained, very clayey
88-120	clay, gray, sandy, pebbly
120-122	sand, coarse grained to pea-sized gravel
122-152	clay, pink, very fat
152-175	sand, medium to coarse grained, in part pea-sized gravel
175-178	clay, pink, very sandy
178-232	sand, medium to coarse grained, in part pea-sized gravel
232-233	shale, gray (Carlile Shale)

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Test Hole No. P
Surface elevation: 1406 feet

0- 31	clay, buff, very sandy
31- 35	clay, gray, silty
35- 39	clay, buff, sandy
39- 70	clay, gray, sandy
70- 95	gravel, pea-size to nut size, much limestone
95-130	sand, medium to coarse grained
130-140	Carlile Shale

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Test Hole No. Q
Surface elevation: 1334 feet

0- 3	Alluvium
3-78	sand, coarse grained, and gravel, pea-size
78-80	Carlile Shale

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APPENDIX C

Log of Layne-Western Well 62-5 and Bethesda Home Well

(for location see figure 2)

Layne-Western Well 62-5

feet	
0- 31	clay, brown, hard; few gravels and boulders
31- 36	clay, gray
36- 60	clay, gray, sticky, fairly hard; trace boulders
60- 61	gravel
61- 62	clay, gray
62- 68	gravel, boulders and clay; hard drilling
68- 85	clay, gray
85- 91	sand and gravel, coarse, buff color
91-101	sand and gravel, coarse; fine sand, buff color
101-105	sand, fine to coarse, buff color
105-106	clay, sandy
106-110	sand, fine to coarse, buff color
110-111	clay, sandy
111-155	sand, fine to coarse, buff color; trace small gravel
155-161	shale, white, chalky

Bethesda Home Well (drilled and logged by the Gus Peck Foundry and Manufacturing Company sometime prior to 1948)

feet	
0- 45	yellow clay with a little surface water
46-100	sandy clay with water
101-165	sand and water
166-195	yellow clay
196-305	sand and water
306-480	shale
481-505	rock
506-640	shale and a few ledges of rock
641-670	dirty sandstone and a little water
671-728	soft sandstone and lots of water
729-731	hard rock
732-740	good hard sandstone
741-746	softer sandstone

APPENDIX D

Table 2.--Records of Wells in the Beresford Area

Well location: Letters stand for quarter section, first number for section, second for township north, third for range west
Type of well: Du, dug; D, drilled
Water-bearing material: o, outwash; ss, sandstone; c, chalk; ls, limestone
Use of water: S, stock; D, domestic

Well Location	Owner or Tenant	Type of Well	Depth of Well (feet)	Geologic Source	Water-Bearing Material	Use of Water
NW-1-95-50	M. Jamtgaard	D	67	Glacial	o	S,D
NW-1-95-50	M. Jamtgaard	D	63	Glacial	o	S,D
SW-2-95-50	N. Erickson	D	125	Glacial	o	S,D
NE-2-95-50	E. Homenadberg	D	85	Glacial	o	S,D
NW-3-95-50	J. Boden	D	40	Glacial	o	S
NE-3-95-50	G. Erickson	D	125	Glacial	o	S
SW-3-95-50	W. Hustrulid	D	100+	Glacial	o	S
SE-3-95-50	L. Jacobsen	D	100	Glacial	o	S,D
NW-3-95-50	O. Olsen	D	90	Glacial	o	S
SE-6-95-50	H. Anderson	D	160	Glacial	o	S
NW-6-95-50	E. Soderstrom	D	100	Glacial	o	S
NW-7-95-50	C. Dohlan	D	139	Glacial	o	S
NW-7-95-50	S. Laustsen	D	185	Niobrara	c	S
SE-7-95-50	O. Tornberg	D	160	Glacial	o	S
NE-8-95-50	J. Dolan	D	180	Glacial	o	S

Appendix D - Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well (feet)	Geologic Source	Water-Bearing Material	Use of Water
NE-8-95-50	A. Jenson	D	175	Niobrara	c	S
SW-8-95-50	L. Muhlenkort	D	125	Glacial	o	S
NW-9-95-50	D. Blumer	D	180			S
NW-9-95-50	C. Jensen	D	150	Glacial	o	S,D
SE-9-95-50	D. Leindberg	D	135	Glacial	o	S
NW-10-95-50	D. Olson	D	130	Glacial	o	S
NE-11-95-50	C. Erickson	D	37	Glacial	o	S,D
NW-11-95-50	P. Hustrulid	D	40	Glacial	o	S
SW-12-95-50	H. Young	D	90	Glacial	o	S,D
SW-12-95-50	H. Young	D	90	Glacial	o	S
NW-13-95-50	C. Cabalka	D	60	Glacial	o	S,D
NW-14-95-50	C. Olson	D	50	Glacial	o	S
SW-15-95-50	W. Heinzman	D	60	Glacial	o	S,D
SW-15-95-50	W. Heinzman	D	32	Glacial	o	S,D
NE-15-95-50	G. Hustrulid	D	50	Glacial	o	S,D
NW-15-95-50	A. Moden	D	94	Glacial	o	S
NW-16-95-50	F. Heinzman	D	80	Glacial	o	S,D
SE-16-95-50	T. Manning	D	90	Glacial	o	S,D
SE-17-95-50	M. Muhlenkort	D	110	Niobrara	c	S
NE-17-95-50	G. Tornberg	D	150	Glacial	o	S

Appendix D - Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well (feet)	Geologic Source	Water-Bearing Material	Use of Water
SW-17-95-50	D. Young	D	160	Glacial	o	S
NE-18-95-50	D. Johnson	D	160	Glacial	o	S
SE-18-95-50	H. Welch	D	90	Niobrara	c	S
SE-18-95-50	D. Westberg	D	582	Dakota	ss	S
NW-19-95-50	M. Muhlenkort	D	155	Glacial	o	S
SE-19-95-50	T. Muhlenkort	D	130	Glacial	o	S
NW-20-95-50	M. Andersen	D	100?	Niobrara	c	S,D
SW-20-95-50	E. Carlson	D	145	Niobrara	c	S
NE-20-95-50	D. Farley	D	75	Glacial	o	S
NW-21-95-50	E. Beinke	D	90	Niobrara	c	S,D
NW-21-95-50	E. Beinke	D	50	Niobrara	c	S,D
SW-21-95-50	E. Fitzgerald	D	112	Niobrara	c	S
SE-21-95-50	E. Fitzgerald	D	92	Niobrara	c	S,D
NW-21-95-50	L. O' Conner	D	120	Niobrara	c	S
NE-22-95-50	W. Heinzman	D	62	Glacial	o	S,D
NE-23-95-50	J. Birgen	D	86	Glacial	o	S,D
SW-23-95-50	F. Farley	Du	15	Glacial	o	S,D
NW-24-95-50	J. Birgen	D	91	Glacial	o	S,D
SW-27-95-50	D. Farley	D	84	Codell	ss	S,D
SW-27-95-50	D. Farley	D	85	Niobrara	c	S,D

Appendix D - Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well (feet)	Geologic Source	Water-Bearing Material	Use of Water
NW-27-95-50	L. Farley	D	57	Niobrara	c	S,D
NW-27-95-50	H. Speich	D	160	Glacial	o	S,D
SW-28-95-50	J. Manning	D	60	Niobrara	c	S,D
NW-28-95-50	J. Wheatly	D	90	Niobrara	c	S
NW-29-95-50	T. Lass	D	100	Niobrara	c	S
SW-29-95-50	T. Muhlenkort	D	40	Niobrara	c	S
SW-36-95-50	H. O'Connell	D	80	Glacial	o	S
SW-1-95-51	F. Lass	D	110	Niobrara	c	S
SE-1-95-51	E. Steward	D	108	Niobrara	c	S
NW-1-95-51	L. Uecker	D	36	Niobrara	c	S
SW-2-95-51	I. Eklund	D	30	Niobrara	c	S
SW-2-95-51	I. Eklund	D	48	Niobrara	c	S
NE-2-95-51	F. Foosh	D	73	Niobrara	c	S
NE-2-95-51	F. Foosh	D	72	Niobrara	c	S
NW-2-95-51	F. Foosh	D	63	Glacial	o	S
NW-3-95-51	A. Norling	D	52	Glacial	o	S,D
NE-3-95-51	A. Sundstrom	D	110	Niobrara	c	S
SW-10-95-51	M. Larson	Du	20	Niobrara	c	S
SE-10-95-51	W. Sundstrom	D	40	Niobrara	c	S
SE-11-95-51	C. Johnson	D	75	Niobrara	c	S

Appendix D - Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well (feet)	Geologic Source	Water-Bearing Material	Use of Water
SW-11-95-51	C. Sundstrom	D	40	Niobrara	c	S
NW-11-95-51	P. Sundstrom	D	50	Niobrara	c	S
NW-12-95-51	R. Epson	D	120	Niobrara	c	S
NE-12-95-51	L. Klostergaard	D	91	Glacial	o	S
SE-12-95-51	M. Schneider	D	750	Dakota	ss	S
SE-13-95-51	J. Rasmussen	D	120	Niobrara	c	S
NE-13-95-51	A. Smith	D	100	Glacial	o	S
NW-13-95-51	D. Steadman	D	95	Glacial	o	S
NE-13-95-51	J. Welch	D	120	Niobrara	c	S
SW-14-95-51	O. Jacobson	D	63	Niobrara	c	S
NW-14-95-51	E. Larson	D	80	Glacial	o	S
SE-14-95-51	E. Neary	D	108	Niobrara	c	S
NE-14-95-51	H. Nielsen	D	80	Glacial	o	S
NW-15-95-51	A. Larson	Du	20	Niobrara	c	S
SW-15-95-51	C. Larson	Du	20	Niobrara	c	S
NE-15-95-51	H. Nielsen	Du	20	Niobrara	c	S,D
NW-18-95-51	D. Johnson	D	120	Niobrara	c	S,D
NE-21-95-51	Zweifel	D	140	Glacial	o	S
SE-23-95-51	D. Ende	D	104	Niobrara	c	S
SW-23-95-51	D. Ende	D	80	Niobrara	c	S

Appendix D - Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well (feet)	Geologic Source	Water-Bearing Material	Use of Water
NE-23-95-51	G. Twedt	D	90	Niobrara	c	S
SE-24-95-51	M. Birgen	D	80	Niobrara	c	S
NW-24-95-51	H. Johnson	D	125	Niobrara	c	S
NE-24-95-51	M. Muhlenkort	D	120	Niobrara	c	S
SE-25-95-51	M. Birgen	D	120	Glacial	o	S
NE-26-95-51	B. Anderson	D	85	Niobrara	c	S
SE-8-96-50	M. Klostergaard	D	165	Glacial	o	S
SW-16-96-50	J. Paulsen	D	100	Glacial	o	S
SW-17-96-50	G. Peterson	D	100	Glacial	o	S
SE-18-96-50	H. Anderson	D	125	Glacial	o	S,D
SW-18-96-50	O. Tschuty	D	84	Glacial	o	S
SE-19-96-50	D. Anderson	D	125	Glacial	o	S
SE-19-96-50	H. Anderson	D	100	Glacial	o	S
SW-19-96-50	O. Carlson	D	80	Glacial	o	S,D
NE-19-96-50	A. Hybertson	D	120	Niobrara	c	S
SE-20-96-50	J. Dunn	D	100	Niobrara	c	S
NE-20-96-50	G. Ende	D	130	Glacial	o	S
NW-20-96-50	A. Hybertson	D	125	Glacial	o	S,D
SW-20-96-50	V. Sorenson	D	100	Glacial	o	S,D
SE-20-96-50	H. Thompson	D	150	Glacial	o	S

Appendix D - Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well (feet)	Geologic Source	Water-Bearing Material	Use of Water
SW-21-96-50	V. Sorenson	D	100	Glacial	o	S
NW-21-96-50	A. Swanstrom	D	125	Glacial	o	S
SW-22-96-50	R. Graham	D	110	Glacial	o	S
SE-23-96-50	W. Wastell	D	160	Glacial	o	S,D
SE-25-96-50	L. Hagen	Du	15	Glacial	o	S
SE-26-96-50	W. Peierson	D	139	Glacial	o	S
SW-26-96-50	J. Stuessi	D	110	Glacial	o	S,D
NW-26-96-50	J. Voegeli	D	112	Glacial	o	S,D
SW-27-96-50	C. Nelson	D	35	Glacial	o	S
SW-27-96-50	J. Voegeli	Du	34	Glacial	o	S,D
NW-28-96-50	M. Ende	D	120	Glacial	o	S
SW-28-96-50	G. Jensen	D	120	Glacial?	o?	S
NE-28-96-50	L. Kribell	D	93	Codell	ss	S,D
NW-28-96-50	O. Muhlenkort	D	114	Glacial	o	S
SW-28-96-50	C. Nelson	D	165	Glacial	o	S
NE-29-96-50	Anderson	D		Glacial	o	S
SE-29-96-50	B. Dunn	D	90	Niobrara	c	S
NW-29-96-50	G. Kennedy	D	90	Glacial	o	S,D
NE-30-96-50	B. Fillingsness	D	100	Glacial	o	S
SW-30-96-50	H. Lundberg	D	160	Glacial	o	S

Appendix D - Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well (feet)	Geologic Source	Water-Bearing Material	Use of Water
NW-30-96-50	O. Tschuty	D	80	Glacial	o	S
NE-31-96-50	D. Fahlberg	D	90	Glacial	o	S
NW-31-96-50	E. Jensen	D	128	Niobrara	c	S
SE-31-96-50	W. Krause	D	140	Glacial	o	S
SW-31-96-50	H. Sorensen	D	94	Glacial	o	S
NE-32-96-50	M. Ende	D	120	Glacial	o	S
NE-32-96-50	M. Ende	D	80	Glacial	o	S
SW-33-96-50	Bethesda Homes	D	170	Glacial	o	S
SE-33-96-50	Bethesda Homes	D	752	Dakota	ss	S,D
NW-34-96-50	R. Kinkner	D	130	Glacial	o	S,D
SW-34-96-50	B. Nelson	Du	60	Glacial?	o?	S
NE-34-96-50	G. Voegeli	D	140	Glacial	o	S,D
SE-35-96-50	H. O'Connell	D	80	Glacial	o	S,D
SE-36-96-50	L. Voegeli	D	100	Glacial	o	S,D
NE-2-96-51	E. Heglin	D	86	Niobrara	c	S
SE-12-96-51	W. Mckay	D	85	Glacial	o	S
NW-21-96-51	J. Edman	D	27	Glacial	o	S
SE-22-96-51	L. Anderson	D	360	Greenhorn	ls	S
NE-22-96-51	V. Jensen	D	90	Glacial?	o?	S
NE-23-96-51	J. Eide	D	128	Glacial	o	S

Appendix D - Records of Wells--continued

Well Location	Owner or Tenant	Type of Well	Depth of well (feet)	Geologic Source	Water-Bearing Material	Use of Water
NE-23-96-51	W. Kennedy	D	45	Niobrara	c	S,D
NW-23-96-51	A. Ostren	D	40	Niobrara	c	S
SW-23-96-51	A Suing	D	100	Niobrara	c	S
SW-24-96-51	D. Blake	D	90	Glacial?	o?	S
SW-24-96-51	O. Carlson	D	105	Glacial	o	S
NW-24-96-51	W. Kellogg	D	80	Glacial	o	S,D
NE-24-96-51	W. McKay	D	85	Niobrara	c	S
NE-25-96-51	W. Fahlberg	D	131	Glacial	o	S
SE-25-96-51	S. Hanson	D	100	Glacial	o	S
SW-25-96-51	A. Norman	D	100	Niobrara	c	S,D
SE-26-96-51	R. Bonine	D	110	Niobrara	c	S
NW-26-96-51	R. Heglin	D	100	Glacial	o	S,D
NE-26-96-51	R. Kennedy	D	80	Niobrara	c	S,D
NE-27-96-51	L. Anderson	Du	90	Glacial	o	S
NE-27-96-51	D. Kennedy	D	50	Glacial	o	S
NE-34-96-51	J. Wickstrom	D	40	Niobrara	c	S
SE-34-96-51	J. Wickstrom	D	60	Niobrara	c	S,D
SE-35-96-51	E. Carlson	D	225	Greenhorn?	ls	S
NE-35-96-51	P. Carlson	D	75	Niobrara	c	S,D
SW-35-96-51	C. Norling	D	60	Niobrara	c	S
NE-36-96-51	C. Linder	D	65	Niobrara	c	S