STATE OF SOUTH DAKOTA
Nils Boe, Governor

SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Special Report 40

GROUND-WATER SUPPLY FOR THE CITY OF WAUBAY, SOUTH DAKOTA

by
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Science Center
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Errata

p. 13 Figure 7, first sentence following explanation. Add (in feet) to end of sentence.

p. 15 Sixth paragraph, last sentence. "Municipal" is misspelled.

p. 18 Figure 8, bottom of map. R. 53 W. to the west should be R. 54 W.

p. 23 Test Hole No. 9. The location should be 122-54-33abbd.

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INTRODUCTION

Present Investigation

This report contains the results of a special investigation conducted by the South Dakota Geological Survey from June 6 to July 10, 1966, in and around the city of Waubay, Day County, South Dakota (fig. 1), for the purpose of assisting the city in locating a future water supply.

Waubay now obtains its water from one well that is 200 feet deep that produces water from a buried glacial outwash sand and gravel. The well production of 85 gallons per minute is inadequate much of the year, and the water has a high iron and manganese content.

A survey of the ground-water possibilities was conducted in the Waubay area and covered 56 square miles. This survey included the preparation of a generalized geologic map, the drilling of 56 test holes, the collection of 15 water samples for analysis, a well interview of all wells within the study area and obtaining electric logs of 9 test holes. As a result of this survey, it was determined that further development of the city's present source of water is advisable. Three more aquifers were located which may also provide an adequate water supply for the city.

The field work and preparation of this report were performed under the supervision of Lynn S. Hedges, Ground-Water Geologist, and Fred V. Steece, Research Geologist. The aid and cooperation of the residents in and around Waubay, especially City Auditor D. D. Rebelske, is greatly appreciated.

Location and Extent of Area

The city of Waubay is located in northeastern South Dakota in Day County and has a population of 851 (1960 census). The area covered in this report is in the Coteau des Prairies division of the Central Lowland physiographic province (fig. 1).

Climate

The climate is continental temperate with large daily fluctuations in temperature. The average daily temperature is 43.0 degrees F. and the average annual precipitation is 20.52 inches at the U. S. Weather Bureau Station at Watertown 32 miles southeast of Waubay.

Topography and Drainage

The topography westward from the end-moraine crest east of Waubay (fig. 2) is characterized by a combination of knobs and kettles with low broad sags containing lakes, and former watercourses as represented by the surface outwash (fig. 2). Drainage is nonintegrated and all small streams empty into local lakes or sloughs. This type of topography and drainage is typical of youthful glacial drift.

The topography east of the end-moraine crest (fig. 2) is gently undulating and contains only a few closed depressions. The drainage is mostly integrated. This type of topography is generally more typical of older glacial drift.

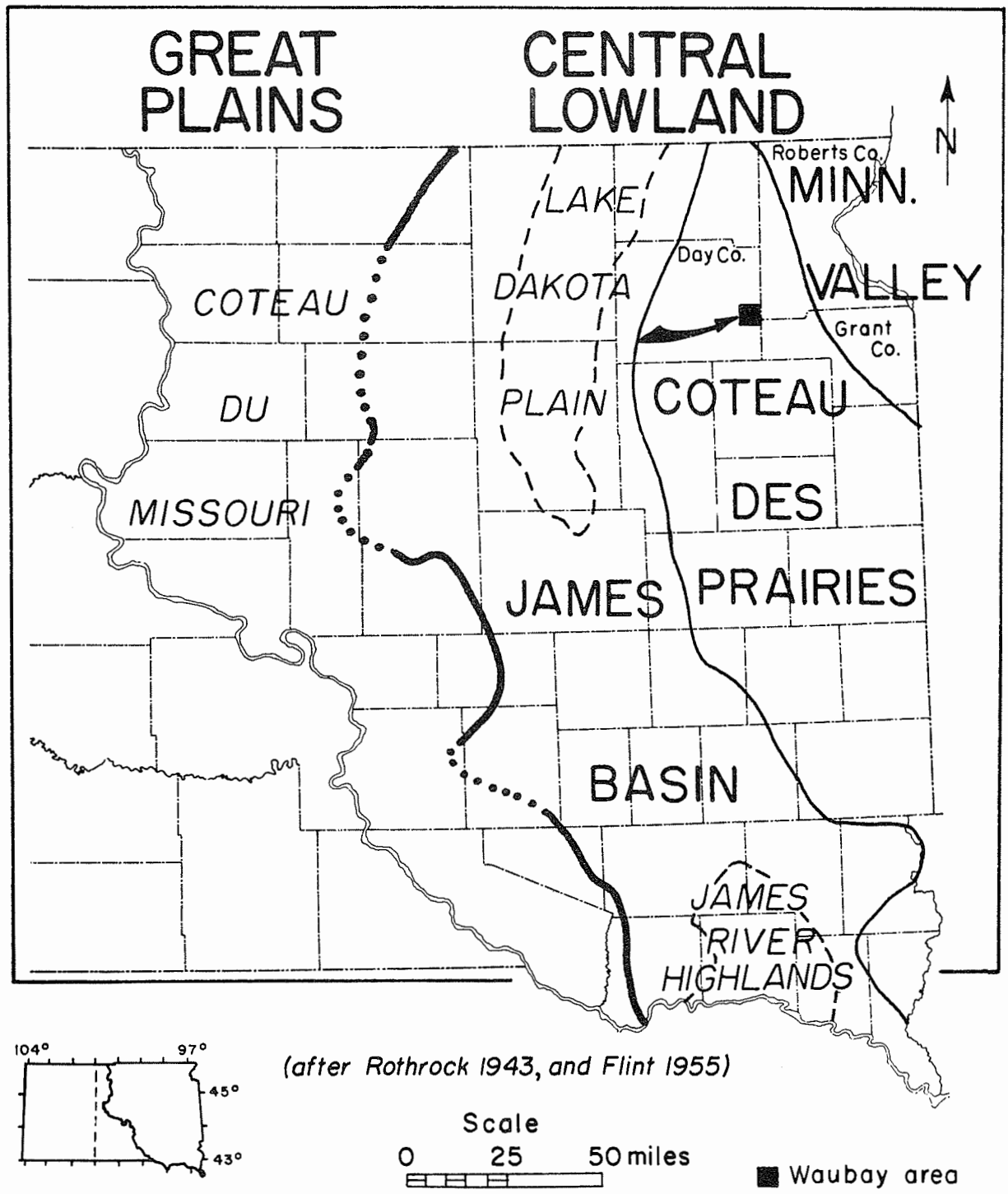


Figure I. Map showing location of the Waubay area and the major physiographic divisions of eastern South Dakota.

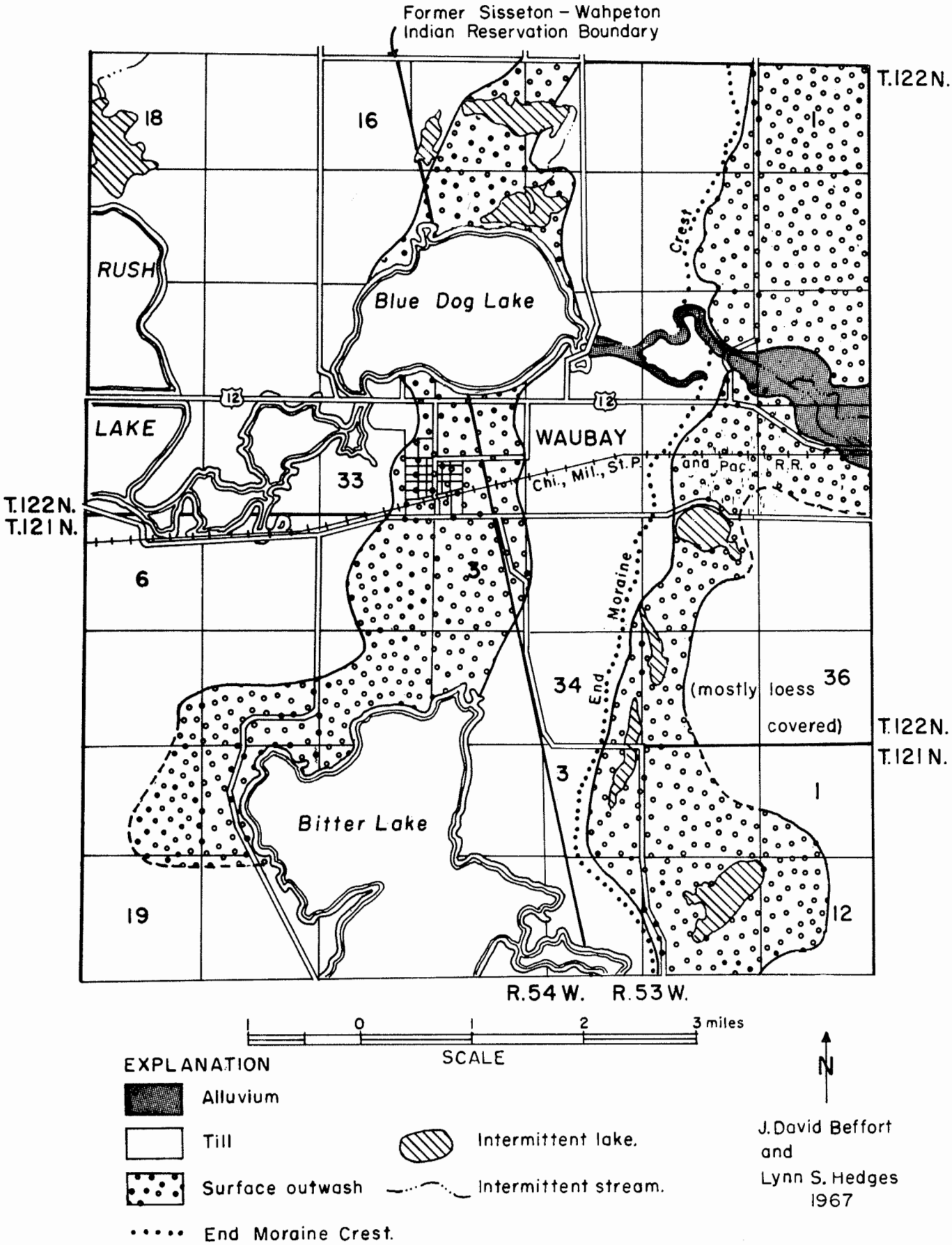


Figure 2. Generalized geologic map of the Waubay area.

Data Point Numbering System

Data collection points are located in accordance with the United States Bureau of Land Management's system of land subdivision. The first numeral of a point designation indicates the township; the second, the range; and the third, the section in which the point is situated. Lowercase letters after the section number indicate location within the section: 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. The letters a, b, c, and d are assigned in a counterclockwise direction, beginning in the northeast corner of each tract. For example, test hole 11 (fig. 3), 122-54-33 adcc is located in the $SW\frac{1}{4}SW\frac{1}{4}$ $SE\frac{1}{4}NE\frac{1}{4}$ sec. 33, T. 122 N., R. 54 W.; this method of designation is shown in figure 4.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits of the Waubay area are chiefly the result of glaciation late in the Pleistocene Epoch. Glacial deposits which are collectively termed drift, can be broadly divided into till and outwash sediments.

Till consists of clay and silt-size particles randomly mixed with sand, pebbles and boulders, and was deposited by the glacial ice. A linear ridge of till built at the margin of a glacier is an end moraine and marks the position where the rate of ice flow and ice melting was in equilibrium. Thus, till is built into a ridge in much the same manner as a pile of debris is built at the end of a conveyer belt. Over much of the western two-thirds of the study area the till and an accompanying end moraine were deposited by the last glacial advance (fig. 2). In the southeast part of the study area till was deposited by an earlier ice sheet; however, most of this till is presently covered with windblown silt or loess (fig. 2).

Outwash sediments consist chiefly of sand and pebbles with minor amounts of silt and clay, and were deposited by meltwater streams from the wasting glacier. In the Waubay area the outwash sediments exhibit two topographic forms: (1) rolling to undulating, and (2) nearly level. The undulating outwash topography has been collapsed, that is, the sand and gravel was deposited on or against ice and literally collapsed when the ice melted away thus leaving an irregular topography. The nearly level outwash was deposited in a topographic low much as streams deposit material today. On figure 2 these two topographic forms of outwash have not been differentiated. If a large outwash deposit is buried beneath till or other sediments, it is referred to as a buried outwash; small lenticular deposits of sand and gravel outwash are called stratified sand lenses.

Alluvium consists mostly of silt- and clay-size particles with minor amounts of sand and gravel, deposited by recent streams since the retreat of the glaciers. Alluvium is present along the small stream entering the east end of Blue Dog Lake (fig. 2).

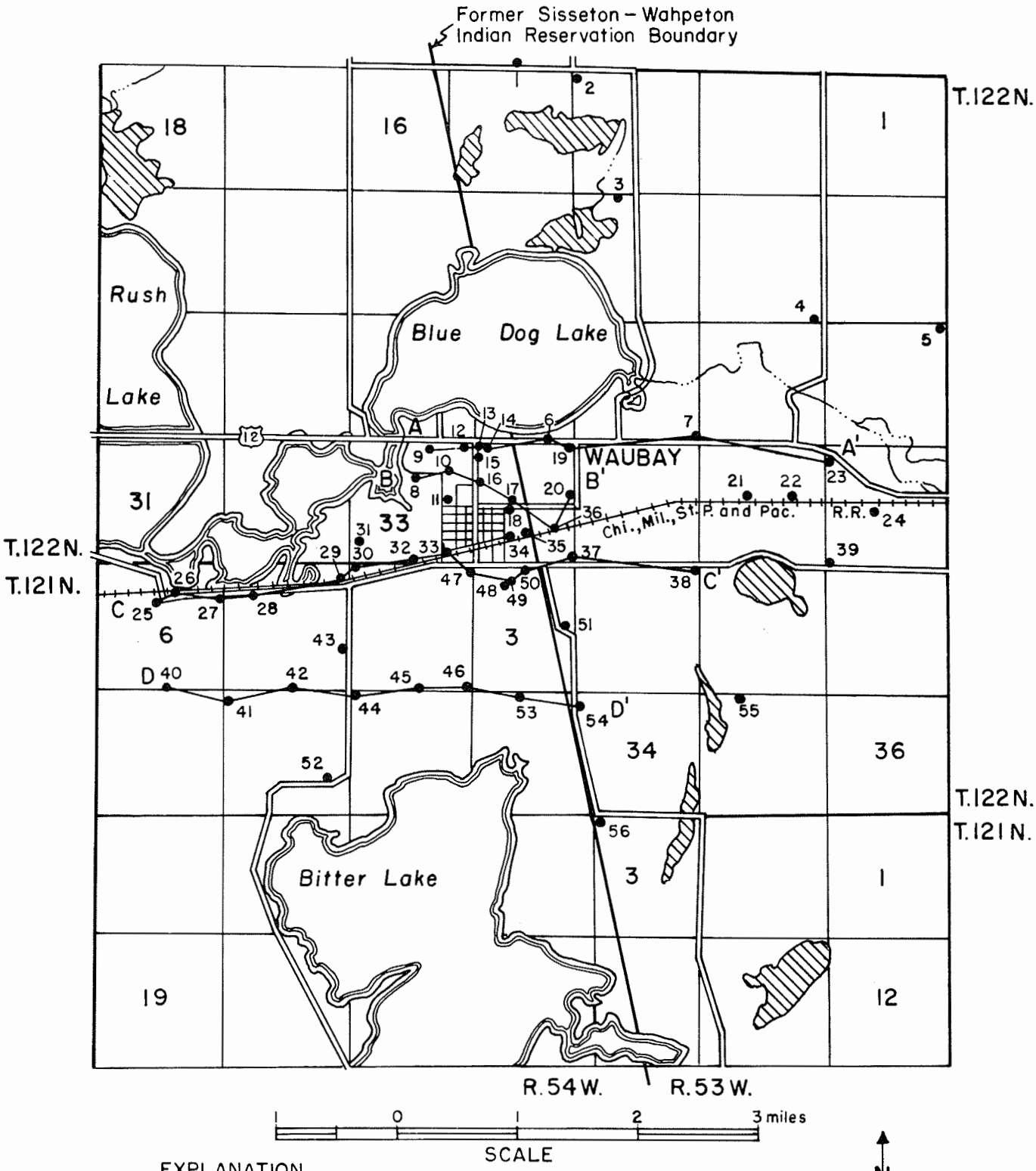


Figure 3. Map showing location of test holes in the Waubay area.

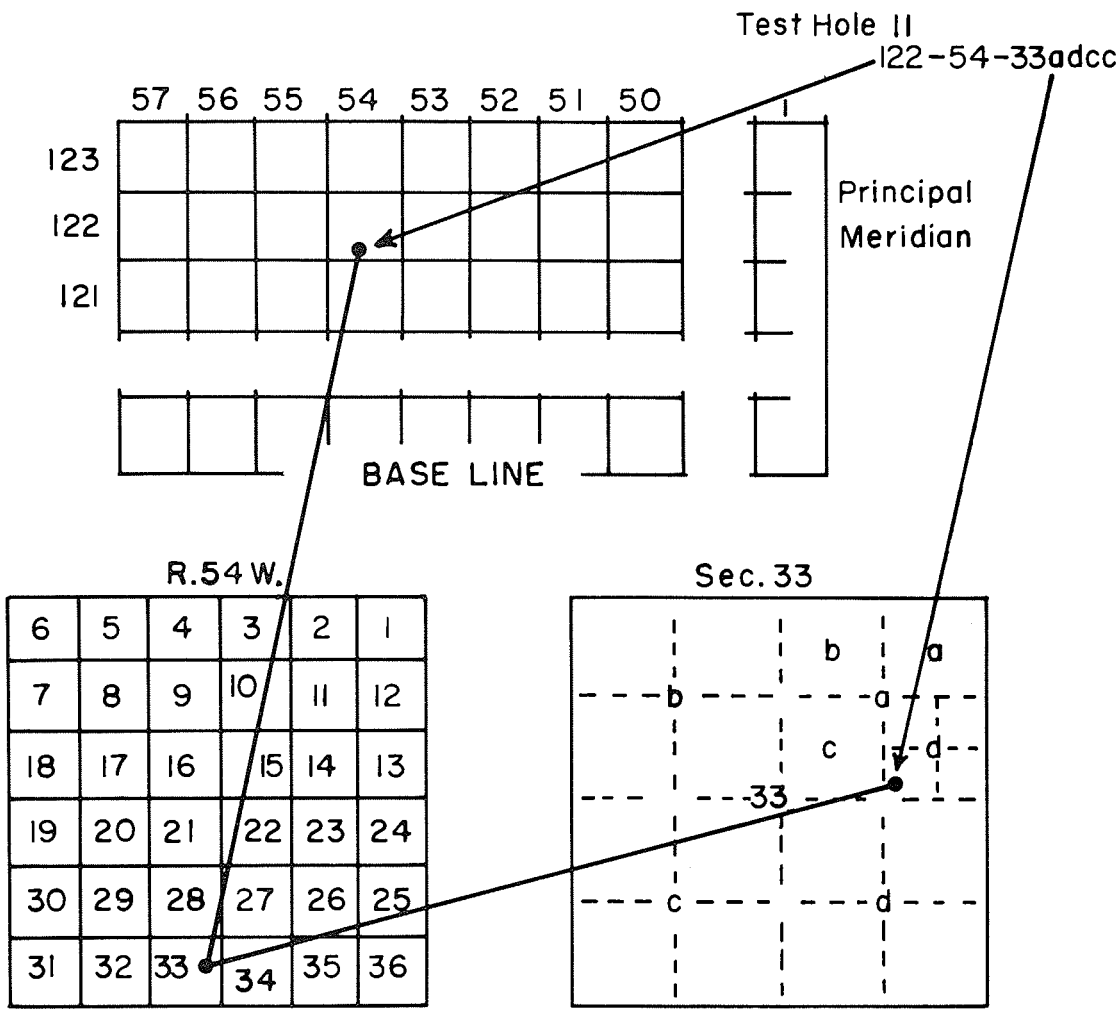


Figure 4. Data point numbering system.

Subsurface Bedrock

No bedrock is exposed in the Waubay area; however, general information from well logs extrapolated to the Waubay area indicate the presence of stratified sedimentary rocks of Cretaceous age underlying the glacial deposits. These rocks in descending order are the Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone and Graneros Shale, and the Dakota Formation (official designation of this unit recently changed by the South Dakota Geological Survey, Schoon, 1965).

The Pierre Shale consists of light- to dark-gray fissile shale with many thin bentonite beds and concretionary layers. The thickness of the Pierre in this area is variable, ranging between 300 and 600 feet and has an average thickness of about 350 feet.

The Niobrara Marl is mainly light- to dark-gray marl which contains numerous white microscopic specks, thin impure bentonite beds, and is about 75 feet thick in this area.

The Carlile Shale is about 200 feet thick in this area and consists chiefly of gray fissile shale and may contain thin interbedded sands and impure limestone.

The Greenhorn Limestone has a thickness of about 50 feet in the Waubay area, and is composed of light- to dark-gray fragmental limestone and light- to dark-gray marl and marly shale. The limestone is dense and easily recognized both in well cuttings and in mechanical well logs.

The Graneros Shale is chiefly a siliceous shale, but is locally sandy. The Graneros is about 220 feet thick in the Waubay area.

The Dakota Formation consists of fine to coarse, non-cemented to cemented sandstone and interbedded shale. The thickness of this unit is highly variable throughout the State but is about 200 feet thick in this area.

Granite of Precambrian age probably underlies the Dakota Formation in the Waubay area.

OCCURRENCE OF GROUND WATER

Principles of Occurrence

Ground water is defined as water contained in the voids or openings of rock or sediments below the water table; therefore, the water table marks the upper surface of the saturated zone of the water-bearing formation. The common belief that water occurs in "veins" which crisscross the area in a disconnected maze is not true, as water occurs nearly everywhere below the surface. The depth of a water supply is dependent upon the water table which is not a static level, but fluctuates, and in a general way reflects the surface topography. The water table ranges from a few feet to many tens of feet below the surface; in the Waubay area it ranges from 3 to 33 feet below the surface.

The amount of water which is contained in a reservoir rock or aquifer is controlled by the porosity and permeability of the rock. Porosity refers to the number of voids in a rock, and is expressed in the ratio of pore

space to the total volume of rock. Porosity is dependent upon (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 which has been removed by percolating ground water. Sands and gravels usually have porosities that range from 20 to 40 percent, depending on the above conditions; whereas, sandstones have porosities of 15 to 25 percent. Sandstones have lower porosities because of their higher degree of compaction and cementation.

Permeability is 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, while a material that is high in porosity but in which the pores are not connected will have a low permeability. Therefore, it can be seen that while porosity and permeability are related, they are not synonymous.

Nearly all ground water is derived from precipitation. Rain or melting snow either percolates directly downward to the water table and becomes ground water, or drains off as surface water. Surface water either evaporates, escapes to the ocean by streams, or percolates downward to the ground-water table. In general, ground water moves laterally down the hydraulic gradient, and is said to be in transient storage.

Recharge is the addition of water to an aquifer, and is accomplished in three ways: (1) by downward percolation of precipitation from the ground surface, (2) by downward percolation from surface bodies of water, (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 by plants, (2) by seepage upward or laterally into surface bodies of water, (3) by lateral underflow of water in transient storage, and (4) by pumping from wells.

Ground Water in Alluvium

Alluvium is present in the small stream which empties into the east end of Blue Dog Lake (fig. 2). This alluvium is porous and may contain large amounts of water where it is below the water table, but because of low permeability and limited extent does not readily yield large amounts of water.

Ground Water in Glacial Deposits

As stated earlier, glacial deposits can be divided into till and outwash. Till, because of its unsorted nature and resultant low permeability, usually does not yield water readily; however, outwash is generally a good source of water because of its high porosity and permeability.

In the Waubay area there are four glacial aquifers which may be considered for future development for a municipal water supply. These aquifers are composed of glacial outwash sand and gravel and hereafter will be referred to as the surface outwash, the upper buried outwash, the lower buried outwash and the basal sand and gravel.

Surface Outwash

A surface outwash is present in a strip one-half to one and one-half miles wide extending from the northern edge of the study area north of Blue Dog Lake southward to Bitter Lake (fig. 2). Another surface outwash is present east of the end-moraine crest (fig. 2).

That part of the surface outwash south of Blue Dog Lake and west of the end-moraine crest (fig. 2) has received the most emphasis during this study. Figure 5 shows the distribution, saturated thickness and best area for ground-water development in the surface outwash. In this area the surface outwash has a saturated thickness ranging from 0 to 126 feet (fig. 5). On figure 5 the margins of the surface outwash generally are farther east and west of the surface outwash margins shown on the generalized geologic map (fig. 2). This is due to the presence of a mantle of till as much as 25 feet thick covering the surface outwash along much of its margin. However, that part of the surface outwash covered by till is certainly in hydrologic continuity with the uncovered part as indicated in the cross sections on figure 6a and b. Within the margins of the surface outwash on figure 2 as much as 12 feet of overburden may locally cover the sand and gravel. These deposits consist of small unmapped patches of loess, alluvium, or silty and clayey portions of the outwash. In general, the upper 30 to 40 feet of the surface outwash consists of medium sand to gravel and the lower part is finer grained and contains more clay and silt.

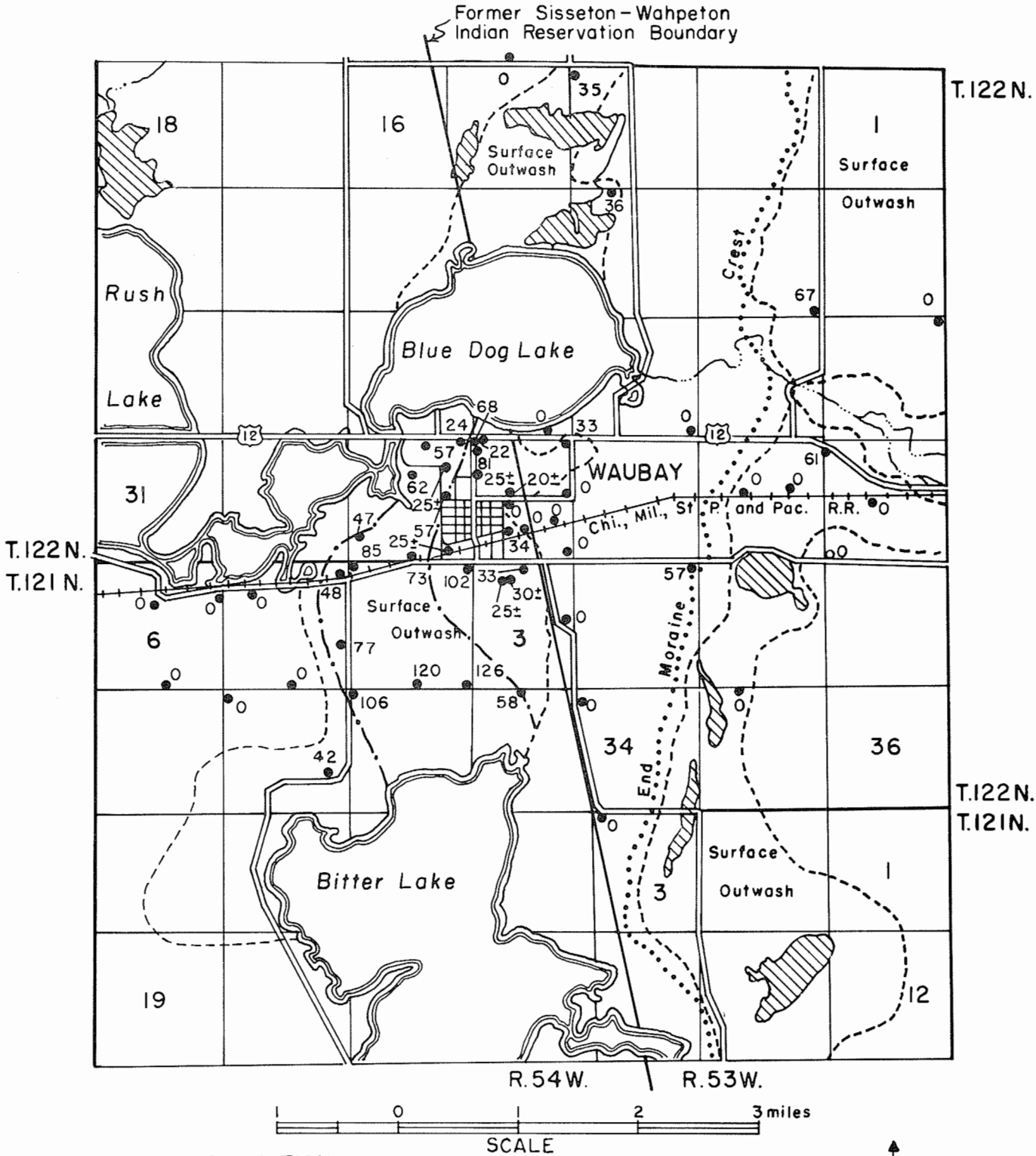
The area best suited for further investigation in the surface outwash trends north-south along the west edge of town (fig. 5). That part of the surface outwash to the east is more erratic in distribution, thickness and lithology and does not have the direct and nearly continuous hydraulic connection to the lakes as does the western portion of the surface outwash.

Much of the surface outwash east of the end-moraine crest is thin and unsaturated; however, near the creek entering the east edge of Blue Dog Lake as much as 67 feet of saturated sand and gravel was penetrated (test hole 4). Thus, that area along the creek and east of the end-moraine crest may be considered a potential ground-water source pending additional test data.

North of Blue Dog Lake the saturated portion of the surface outwash is at least as much as 36 feet thick (fig. 5). This thickness is probably sufficient to provide an adequate quantity of water; however, more testing would have to be done to determine the extent and capabilities of this aquifer.

Upper Buried Outwash

The upper buried outwash trends east-west along the south side of Blue Dog Lake and may be present in the subsurface under the lake and north of the lake. The location of this aquifer and its thickness is shown in figure 7 and its relationshop to the other aquifers is shown on the cross sections (fig. 6a and b). This aquifer is found at depths ranging between 20 and 190 feet although the general range is about 100 to 180 feet. The thickness of the outwash is from 10 to 100 feet but averages about 80 feet along the north



EXPLANATION

33 Test hole showing saturated thickness of sand and gravel in feet; a plus or minus (±) following the number indicates that the figures are estimated.

Boundary of saturated surface outwash.

Best area for development.

Intermittent lake.

Intermittent stream.

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Figure 5. Saturated thickness and distribution of the surface outwash.

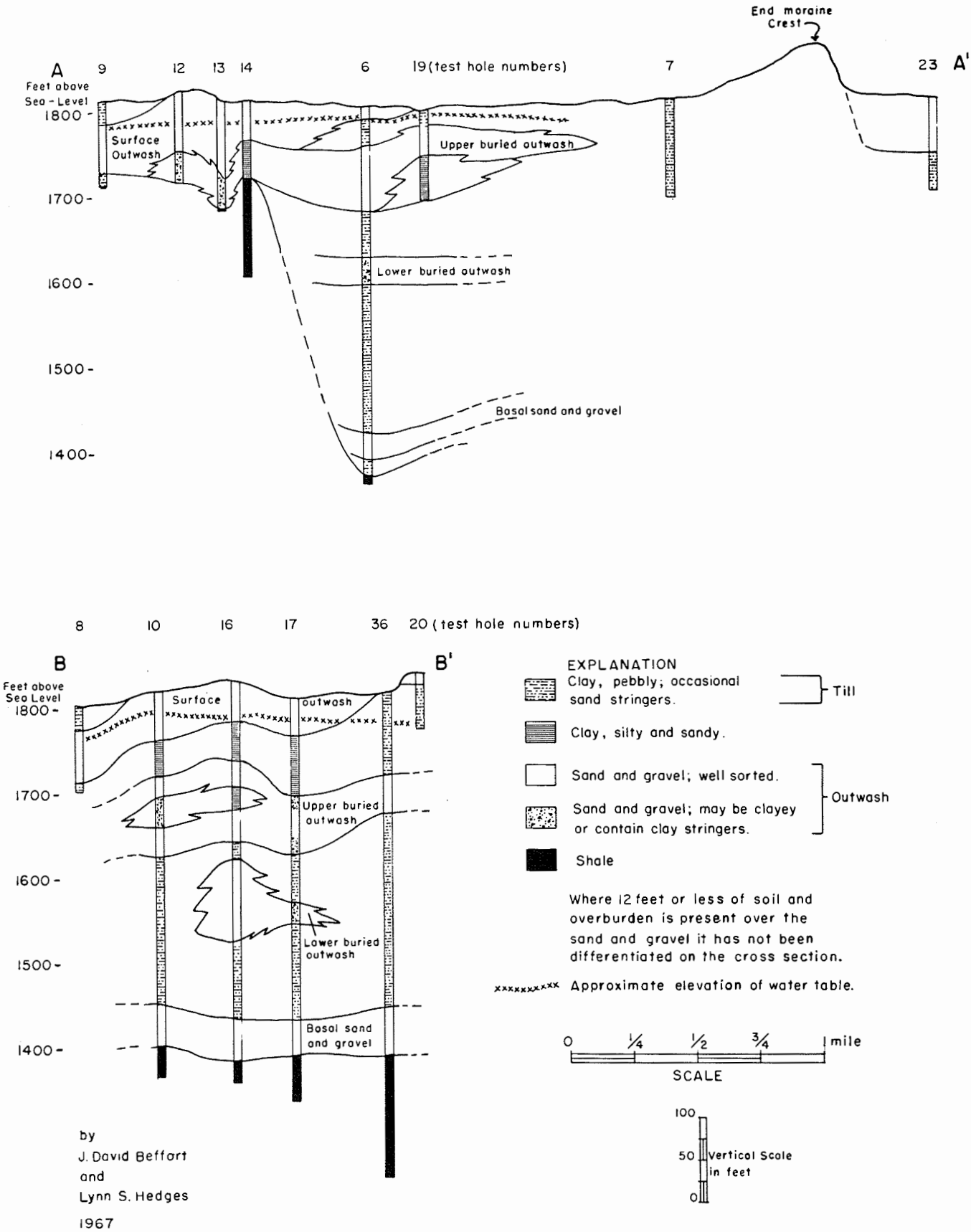

Figure 6a. Cross sections showing the relationship of the aquifers in the Waubay area. (See figure 3 for location of cross-sections.)

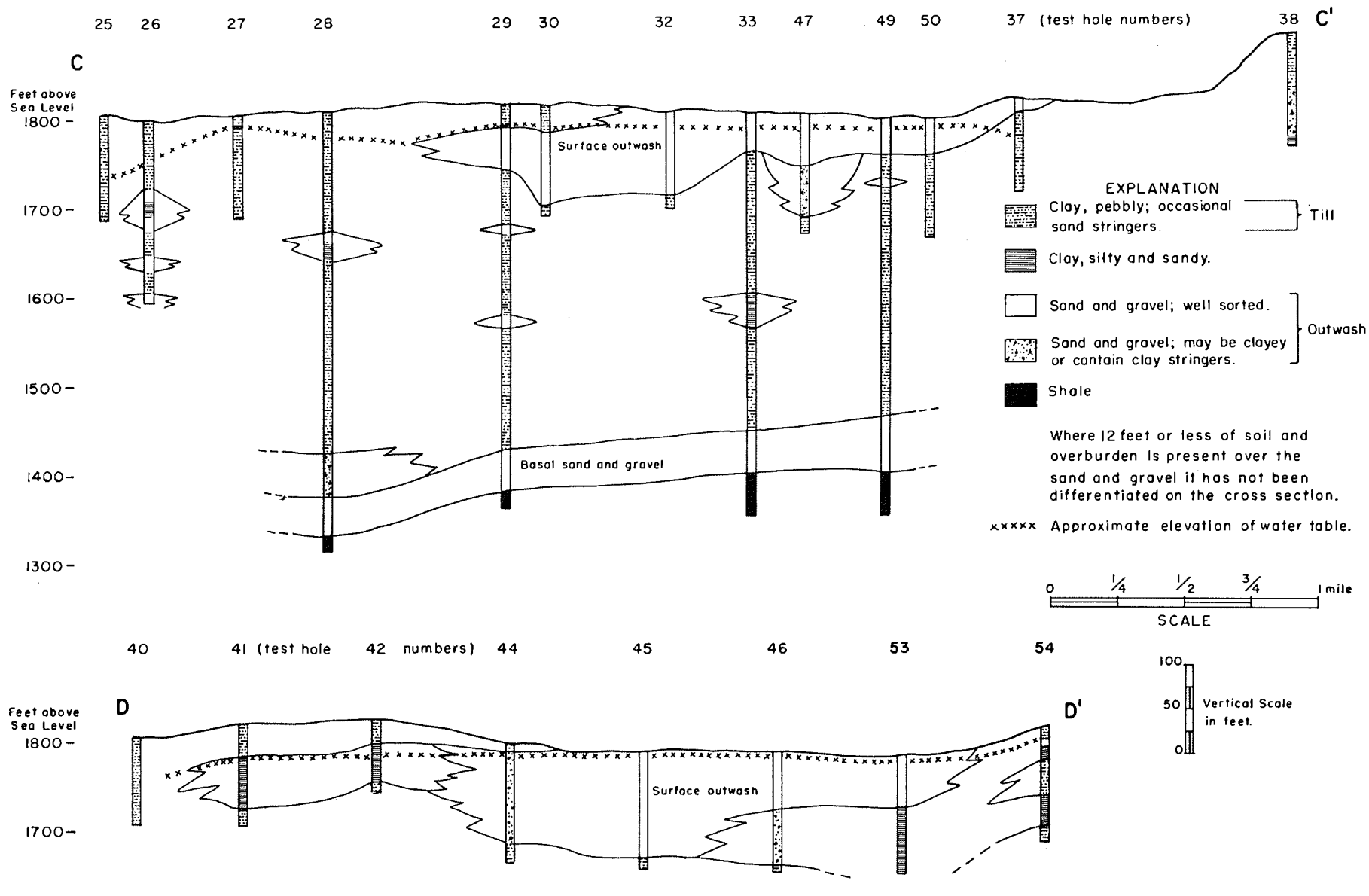

Figure 6b. Cross sections showing the relationship of the aquifers in the Waubay area. (See figure 3 for location of cross-sections.)

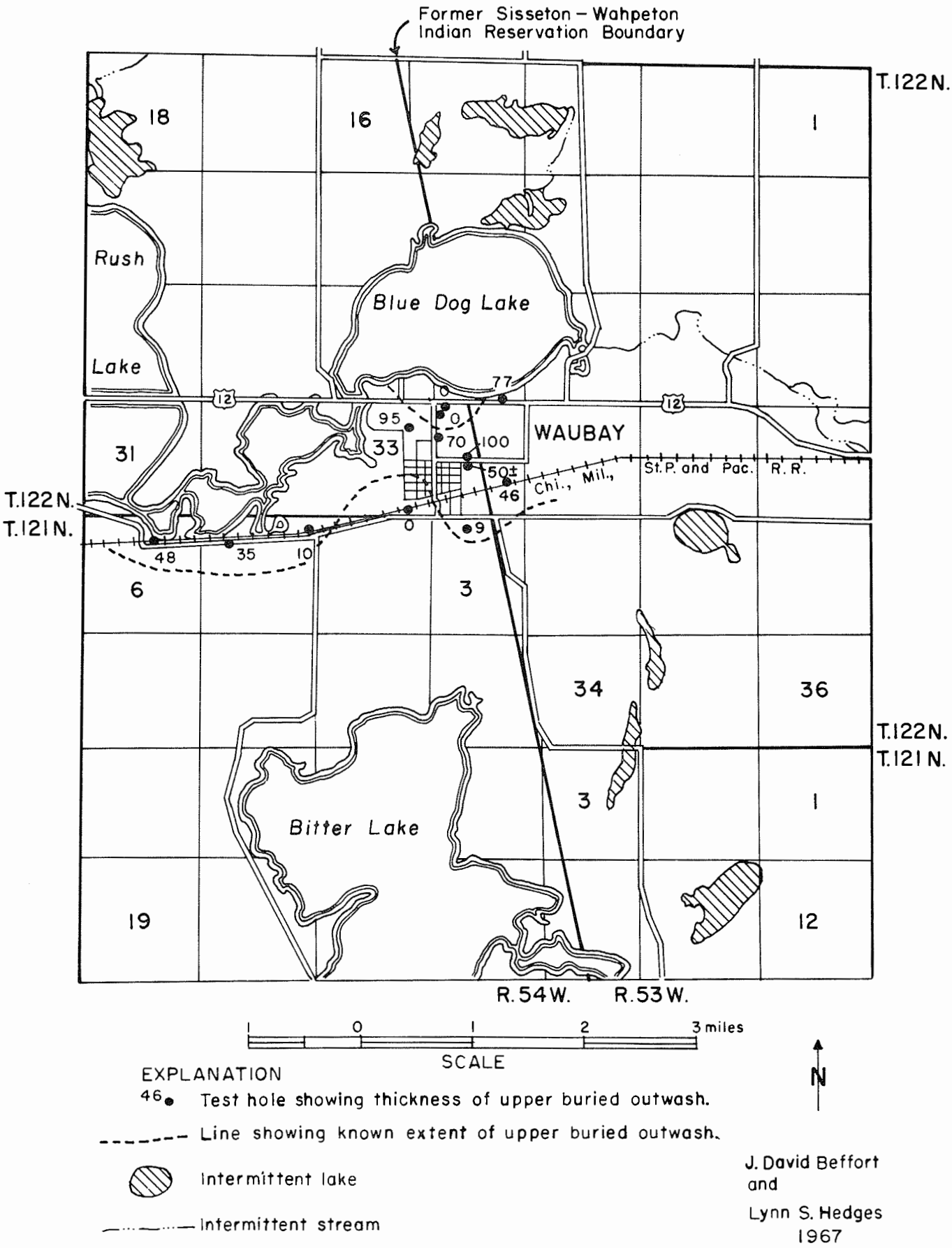

Figure 7. Map showing distribution and thickness of the upper buried outwash.

edge of Waubay. The lithology of the outwash varies from a uniform fine to medium sand to a fine to medium gravel. Test hole 14 one-half mile north of town penetrated Pierre Shale at a depth of 90 feet (cross section A-A', fig. 6a) and test hole 33 on the southwest corner of town contained no upper buried outwash, thus restricting the width of the aquifer to less than 1 mile in this area. The best area for development in this aquifer would be in a line along test holes 10, 16, and 17 where the aquifer is 70 to 100 feet thick, but far enough south of test hole 14 so that possible interference from the bedrock high is minimized.

Lower Buried Outwash

The lower buried outwash has 90 feet of clean, medium to coarse gravel in test hole 16 (cross section B-B', fig. 6a). Other test holes nearby, such as test holes 6, 17, and 33 show thin sand or gravelly stringers at the same horizon. Still other nearby tests (10, 36 and 49) show no aquifer at this horizon. Thus, the extent of this aquifer seems quite restricted. Thorough testing of this aquifer should be done before considering it as a permanent water supply for the city.

The surface outwash, the upper buried outwash and probably the lower buried outwash represent a complex system of cut and fill episodes in the Waubay area during the Pleistocene Epoch. Thus, in places the lower part of the surface outwash may be in contact with the upper buried outwash; the same relationship could also hold true for the upper and lower buried outwash aquifers. A re-interpretation of test holes 6 and 19 in cross section A-A' (fig. 6a) will illustrate this concept. The upper buried outwash in test hole 19 could be correlated with the surface outwash in test hole 6. Considering the close proximity of the two test holes, it is almost certain that the upper buried outwash in test hole 6 would be in contact with the surface outwash now present in both test holes. More examples could be given; however, the point is made that some degree of hydraulic continuity is probably present between the surface and upper buried outwash. This same concept holds true for the upper and lower buried outwash although the hydraulic connection may be less direct. Much more testing would be required to learn the precise interrelationship of the three aquifers but the basic idea presented above is believed to be true.

Basal Sand and Gravel

The basal sand and gravel aquifer is present at depths ranging from 335 to 430 feet and has a nearly uniform thickness of about 45 feet. All deep tests in the area penetrated this aquifer except test hole 14 which penetrated a bedrock high. This aquifer would probably yield an adequate supply of water for the city; however, a thorough testing would be required to determine the quantity and quality of water available.

Ground Water in Bedrock

Some subsurface formations yield sufficient water for domestic purposes but in most cases it is of poorer quality than the water from the surficial deposits, or does not produce sufficient quantity for larger capacity wells. The Dakota Formation is the only bedrock in this area which may have the potential for a municipal supply.

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.

Table 1 is a comparison of water analyses from the Waubay area and the State modified Public Health Standards for drinking water and figure 8 shows the location of the water samples. Of the 16 water analyses shown in table 1 (neglecting the water from Bitter Lake, sample N) 4 samples exceeded the recommended limits in magnesium, iron and total solids; one (out of 6 tests) exceeded the limits for manganese; and none exceeded the limits in chlorides, nitrogen or fluoride (the last two had only 6 tests each). All samples have hard water, only the degree of hardness varies. In this area sulfate, iron, manganese and total solids are most important when considering water quality and thus are the only constituents that will be discussed.

Water from the surface outwash is represented by samples C, F, I, K, L and Q (table 1 and fig. 8). In the one sample tested no manganese was found. Only a trace of iron was found except sample Q which had 0.06 parts per million. The sulfate content is generally moderate and total solids exceeded the recommended limits in only two samples, and then by only a small margin. Thus, the water from the surface outwash should generally be very well suited for a municipal supply.

Water samples B, E, H and J are probably from the upper part of the upper buried outwash. These samples have all constituents within the recommended limits except two which are high in iron. Thus, unless a high iron content is present, water from the upper buried outwash should also be well suited for a municipal supply.

The lower buried outwash is represented by sample D (table 1). The water from this aquifer is high only in iron and should be adequate for a minicipal water supply.

Water samples were not available from the basal sand and gravel or the Dakota Formation; however, general knowledge and experience indicates that the quality would be inferior to any of the above-mentioned aquifers.

Table 1.--Chemical analyses of water samples from the Waubay area.

Sample	Source	Parts Per Million											
		Calcium	Sodium	Magnesium	Chlorides	Sulfate	Iron	Manganese	Nitrogen	Fluoride	pH	Hardness $CaCO_3$	Total Solids
A	***	---	---	50	250	500*	0.3	0.05	10.0	0.9-1.7**	---	---	1000*
B	BO?	85		17	none	trace	none					280	504
C	SO	77	5	11	none	14	none	none	1.2	none		240	306
D	BO	104	20	42	4	171	2.5	0.4	0.3	0.4	7.4	439	629
D_1	BO	104	20	41	4	160	0.5	0.0	0.0	0.4	7.4	429	595
E	BO	117	15.6	50	trace	150	0.3	none	1	0.2		496	796
F	SO?	157		40	none	258	trace				7.7	540	720
G	SL?	85		32	trace	156	trace				8.0	340	526
H	BO	78	15.6	42	1	44	0.7	none	2	0.2		368	482
I	SO	128		86	56	360	trace				7.3	680	1078
J	BO	78	14	2.9	none	104	none	none	0.2	none		313	452
K	SO	132		39	30	216	none				7.8	490	772
L	SO	200		74	40	529	trace				7.6	800	1210
M	SL	160		44	10	432	10.0				7.4	580	965
N	****	56?		1150?	450		trace					4800	8800?
O	SL?	197		56	20	550	5(+)					720	1445
P	SL?	184		41	18	480	trace					630	1183
Q	SO	97		52	26	180	0.06					465	885

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

** Optimum

*** BO, Upper buried outwash (except Sample D from lower buried outwash); SO, surface outwash; SL, sand lense

**** Water from Bitter Lake

Samples B, E, H and J were analyzed by the State Chemical Laboratory in Vermillion.
Samples D and D_1 analyzed by the State Department of Health at Pierre.
The remaining samples were analyzed by the State Geological Survey in Vermillion.

Location of Water Samples

A	South Dakota Department of Health Standards	
B	T. Stretz	122-53-15dbbd
C	E. Shea	122-54-27ccdc
D	Waubay City Well (South)	
D_1	Waubay City Well (North)	
E	A. Nelson	122-54-34bdcc
F	C. Holman	122-53-21dbba
G	L. Richard	122-53-22bccc
H	E. Manska	121-54-4bacb
I	M. Jorgenson	121-54-4cbbb
J	Test Hole 48	121-54-3bbda
K	J. Yunker	121-54-3baaa
L	H. Herren	122-53-28aaac
M	C. Jones	121-54-7bbba
N	Bitter Lake	
O	J. Theil	122-53-34cbba
P	Wm. Leimkuhl	121-54-19bbbd
Q	L. Acker	121-54-34ccda

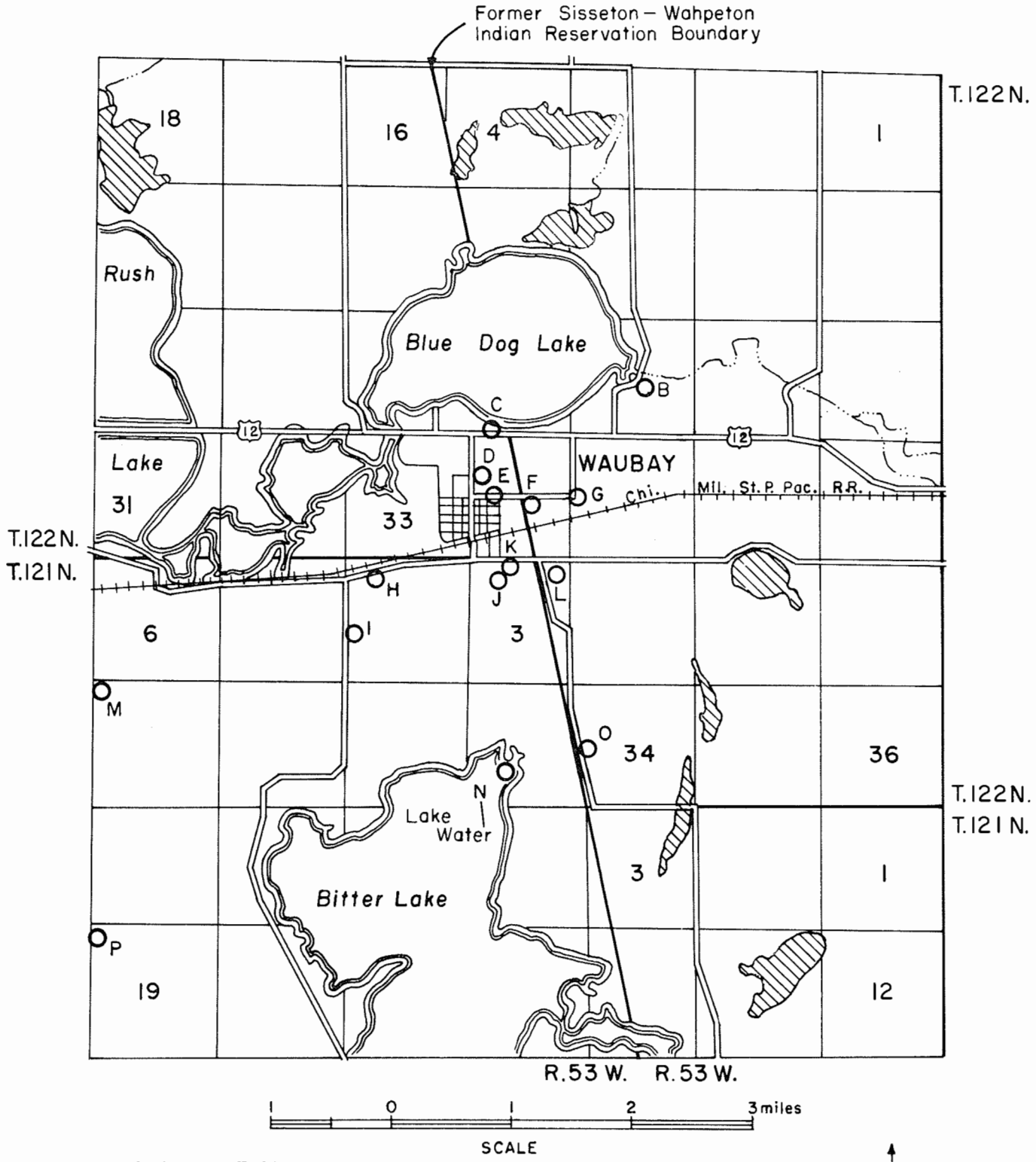

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Figure 8. Map showing location of water samples in the Waubay area.

CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the city of Waubay test for future water supplies from the upper buried outwash from which the city supply is currently being obtained. Further testing should be done near and in line with test holes 10, 16, and 17 (fig. 3). Wells completed in this aquifer would obtain water between 95-195 feet deep. The only drawback to this source is the possible high iron content.

The surface outwash aquifer would probably be as good in quality and quantity as water from the upper buried outwash. This aquifer is generally exposed at the surface and probably has a direct hydraulic connection to Blue Dog Lake. These factors would allow rapid recharge from precipitation and seepage of surface water. These same factors, however, would allow more rapid fluctuation of water levels during dry periods and would make this aquifer more susceptible to contamination and pollution. Wells completed in this aquifer would only have to be 50-120 feet deep. The best locations to investigate near town would be in the vicinity of test holes 8, 9, 30, or 32 (fig. 3) where 57 to 85 feet of aquifer was penetrated. The main drawback to this aquifer is its distance from the present distribution system.

If both of the two previous recommendations fail to produce the desired quantity and quality of water, further tests could be made in the surface outwash north of Blue Dog Lake. Tests could also be made east of the end-moraine crest in the surface outwash in the lower buried outwash at test hole 16, in the basal sand and gravel, or in the Dakota Formation.

When the city decides to install a new well or wells, an additional testing program should be carried out to determine the thickness and extent of the aquifer. On the basis of these tests a site should be picked and a test well installed and test pumped. The test pumping should be conducted by licensed engineers and should have a duration of at least 72 hours. It is suggested that the city officials contact a commercial drilling company licensed by the State of South Dakota to drill the well. The State Water Resources Commission should be consulted with regard to obtaining a water right and well permit, 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 water system.

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Schoon, R. A., 1965, The Dakota Formation of South Dakota: S. Dak. Acad. Sci. Proc. 44, p. 72-79.

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 Test Holes in the Waubay Area

Test Hole No. 1
Location: 123-53-33dccc
SDGS Auger
Elevation: 1859 feet
Depth to Water: dry

0- 3	Topsoil
3-14	Clay, dark-brown, moist, some sand and a few pebbles
14-30	Clay, yellow-brown
30-40	Clay, brown, many large pebbles

* * * *

Test Hole No. 2
Location: 122-53-3bbbb
SDGS Auger
Elevation: 1850 feet
Depth to Water: Not measured

0- 2	Topsoil
2- 9	Clay, brown, 30% sand
9-15	Sand, brown, few large pebbles, moist
15-45	Gravel, brown, medium to coarse, trace of clay
45-80	Sand, gray, fine, 40% clay; brown 65-80
80-95	Clay, brown, sandy 80-90; pebbles 90-95

* * * *

Test Hole No. 3
Location: 122-53-10baba
SDGS Auger
Elevation: 1816 feet
Depth to Water: 19 feet

0- 2	Topsoil
2- 9	Clay, dark-brown, pebbly and large rocks, moist
9-55	Sand, brown; medium-grained and clayey 9-19; medium to coarse 19-45; fine to medium and clayey 45-55
55-80	Clay, brown, 40% medium sand

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Test Hole No. 4
Location: 122-53-11dddd
SDGS Auger
Elevation: Not taken
Depth to Water: 8 feet

0- 8	Clay, black and pebbly
8- 75	Sand, gray, medium; high clay content 8-25 feet; brown 25-55 feet
75- 85	Clay; gray and medium sand 75-82 feet; brown and pebbly 82-85 feet

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Test Hole No. 5
Location: 122-53-13aaaa
SDGS Auger
Elevation: Not taken
Depth to Water: 59 feet (?)

0- 2	Topsoil
2- 7	Gravel, brown, clay and sand mixed
7-100	Clay, brown, pebbly; gray 17-26 feet; brown and pebbly 26-59; brown and sandy 59-100 feet

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Test Hole No. 6
Location: 122-53-16dccd
SDGS Rotary
Elevation: 1812 feet
Depth to Water: Not measured

0- 2	Topsoil
2- 15	Gravel
15- 47	Clay, gray, and sand stringers
47- 80	Gravel, medium to coarse
80-124	Sand
124-195	Clay, gray, gravel stringers 163-195
195-210	Gravel and clay stringers
210-385	Clay, gray; thin gravel stringers 210-240, rocky 360-375
385-419	Gravel
419-445	Pierre Shale

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Test Hole No. 7
Location: 122-53-15dddd
SDGS Auger
Elevation: 1819 feet
Depth to Water: Not measured

0- 1	Topsoil
1-115	Clay, brown to 12 feet; gray 12-115 feet; pebbles 12-65 and 107-115; much fine sand 65-107

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Test Hole No. 8
Location: 122-54-33bdac
SDGS Auger
Elevation: 1808 feet
Depth to Water: Not measured

0- 3	Topsoil
3- 28	Clay, yellow-brown to 21 feet; gray 21-28; pebbly
28- 90	Sand, gray, medium 28-65, coarse 65-90; clay decreases downward
90-100	Clay, gray, pebbly

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Test Hole No. 9
Location: 112-54-33abbd
SDGS Auger
Elevation: 1819 feet
Depth to Water: 27 feet

0- 1	Topsoil
1- 27	Clay, brown, pebbly to 18 feet; much medium to coarse sand 18-27
27- 84	Sand, brown to 40 feet, gray 40-84, medium to coarse, clay content decreases downward
84-100	Clay, gray, pebbly

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Test Hole No. 10
Location: 122-54-33aacc
SDGS Rotary
Elevation: 1826 feet
Depth to Water: Not measured

(continued on next page)

Test Hole No. 10--continued

0- 2	Topsoil
2- 8	Clay, light-brown
8- 58	Gravel
58-100	Silt and clay interbedded, gray
100-140	Gravel
140-153	Sand and gravel; some silt and clay
153-195	Gravel, medium
195-370	Clay, gray, silty; rock 210-211
370-423	Gravel, clayey 385-395, 410-415
423-455	Pierre Shale

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Test Hole No. 11
Location: 122-54-33adcc
SDGS Auger
Elevation: 1811 feet
Depth to Water: 22 feet

0- 3	Topsoil
3- 22	Clay, brown, very sandy
22- 79	Sand, brown, fine 22-30, medium to coarse 30-79; clay decreasing downward
79-100	Clay, gray, pebbly

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Test Hole No. 12
Location: 122-54-33aaab
SDGS Auger
Elevation: 1829 feet
Depth to Water: 36 feet

0- 1	Topsoil
1-110	Sand, brown to 45 feet, gray 45-70, brown 88-110; fine 1-29 and 88-110; clayey

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Test Hole No. 13
Location: 122-54-34bbba
SDGS Auger
Elevation: 1817 feet
Depth to Water: 22 feet

(continued on next page)

Test Hole No. 13--continued

0- 3	Topsoil
3- 7	Clay, gray and fine sand
7- 90	Sand, brown to 60 feet; rocky 18-22 feet; medium to coarse, coarseness increasing downward
90-123	Sand, gray, fine to medium, clayey
123-125	Pierre Shale (?)

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Test Hole No. 14
Location: 122-54-34bbba
SDGS Rotary
Elevation: 1821 feet
Depth to Water: Not measured

0- 2	Topsoil
2- 47	Gravel
47- 90	Clay, silty and interbedded sands
90-207	Pierre Shale

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Test Hole No. 15
Location: 122-54-34bbcb
SDGS Auger
Elevation: 1834 feet
Depth to Water: 34 feet

0- 5	Clay, brown, pebbly
5- 12	Gravel, brown, coarse; mixed with fine sand and clay
12- 28	Sand, brown, medium to coarse, trace of clay and a few large pebbles
28- 34	Gravel, brown, very coarse, some sand
34-115	Sand, brown to 54 feet; gray 54-115 feet; very coarse 34-54, medium 54-115
115-130	Clay, much fine sand; gray 115-120; brown 120-130
130-140	Pierre Shale

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Test Hole No. 16
Location: 122-54-34bcbb
SDGS Rotary
Elevation: 1841 feet
Depth to Water: Not measured

0- 50	Gravel
50- 95	Clay, gray and silt and sand stringers
95-126	Gravel, brown, fine
126-146	Clay, brown to 130 feet, black 130-146
146-190	Gravel, pea-size
190-210	Clay, gray, sand and gravel stringers
210-300	Gravel, medium to coarse
300-400	Clay, gray
400-449	Gravel
449-475	Pierre Shale

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Test Hole No. 17
Location: 122-54-34bcdc
SDGS Rotary
Elevation: 1816 feet
Depth to Water: Not measured

0- 2	Gravel
2- 12	Clay, black to gray
12- 42	Gravel
42- 80	Clay, gray, silty
80- 95	Clay, gray, silty and sandy
95-110	Clay, brown, very silty and sandy
110-182	Sand and gravel; some brown clay 127-140; much coal in cuttings; and wood 155-170
182-200	Clay, gray
200-207	Gravel, coarse
207-380	Clay, gray, sand stringers 240-260 feet
380-422	Gravel (?) or marl and chalk
422-475	Pierre Shale

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Test Hole No. 18
Location: 122-54-34cabb
SDGS Auger
Elevation: 1805 feet
Depth to Water: 58 feet

0- 3	Gravel and rocks
3- 74	Clay, gray-black 3-32, olive-gray 32-48, olive-yellow 48-58, yellow-brown 58-74; pebbly 3-58 and much fine sand 58-74
74-124	Sand, brown, medium silty and clayey
124-135	Clay, gray, very sandy

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Test Hole No. 19
Location: 122-53-21aaaa
SDGS Auger
Elevation: 1806 feet
Depth to Water: 1 foot

0- 1	Topsoil
1- 19	Clay, yellow, trace of sand
19- 52	Sand, yellow-brown, gray at 35 feet; medium to coarse and 25% clay
52-105	Clay, brown, very sandy; layer of rocks encountered at 105 feet

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Test Hole No. 20
Location: 122-53-21addd
SDGS Auger
Elevation: 1847 feet
Depth to Water: 58 feet

0- 1	Topsoil
1- 7	Clay, brown, some fine sand and pebbles
7- 19	Sand, brown, medium, 25% clay
19- 64	Clay, gray to 32 feet, brown 32-64 feet; small pebbles; rock at 64 feet

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Test Hole No. 21
Location: 122-53-23bcdc
SDGS Auger
Elevation: 1852 feet
Depth to Water: 27 feet

0- 4	Topsoil
4- 9	Clay, yellow-brown, small pebbles
9- 11	Gravel, and sand, medium, and clay
11- 27	Clay, brown, small pebbles
27- 45	Sand, brown to 30 feet, then gray, fine to medium
45- 48	Rocks, abandoned hole

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Test Hole No. 22
Location: 122-53-23accd
SDGS Auger
Elevation: Not taken
Depth to Water: 32 feet

0- 1	Topsoil
1- 7	Gravel, brown, and clay
7- 50	Clay, brown, much sand 32-50
50-110	Sand, brown to 55 feet, gray 55-65 feet, brown 65-110 feet; mostly fine, and some clay
110-125	Clay, brown sandy 110-118; pebbly 118-125

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Test Hole No. 23
Location: 122-53-24bbbc
SDGS Auger
Elevation: 1822 feet
Depth to Water: 5 feet

0- 2	Topsoil
2- 5	Gravel, brown
5- 66	Sand, brown to 49 feet, gray 49-66, fine to 30 feet, medium to coarse 30-66 feet
66-110	Clay, olive-gray, many pebbles and rocks

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Test Hole No. 24
Location: 122-53-24bddc
SDGS Auger
Elevation: Not taken
Depth to Water: 30 feet

0- 1	Topsoil
1- 7	Gravel, brown, and clay
7- 30	Clay, brown, and a little fine sand
30-110	Sand, brown to 69 feet, gray 69-79 feet, brown 79-110, fine with some clay
110-140	Clay, brown and sandy 110-129; gray and pebbly 129-140

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Test Hole No. 25
Location: 121-54-6bdaa
SDGS Auger
Elevation: 1808 feet
Depth to Water: Not measured

0- 3	Topsoil
3-120	Clay, gray 3-7 feet, brown 7-22 feet, gray 22-120 feet; pebbly 3-70 feet, fine sand increasing downward 70-109; pebbly 109-120

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Test Hole No. 26
Location: 121-54-6abdb
SDGS Rotary
Elevation: 1802 feet
Depth to Water: Not measured

0- 80	Clay, yellow 0-12 feet, gray 12-80 feet, sand stringers 65-80 feet
80- 93	Gravel and clay stringers
93-110	Clay, gray, silty and gravel stringers
110-125	Gravel, clay stringers
125-137	Clay, gray
137-140	Gravel
140-155	Clay, sandy
155-173	Sand and gravel
173-200	Clay, gray, tough
200-206	Gravel, hit rock at 206 feet and abandoned hole

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Test Hole No. 27
Location: 121-54-6aadd
SDGS Auger
Elevation: 1807 feet
Depth to Water: 9 feet

0- 2	Topsoil
2- 9	Clay, yellow-brown, pebbly
9- 16	Sand, brown, fine to medium, clayey
16-120	Clay, gray; pebbly 16-49 feet, sandy 49-105 feet, pebbly 105-120 feet

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Test Hole No. 28
Location: 121-54-5bbdb
SDGS Rotary
Elevation: 1809 feet
Depth to Water: Not taken

0-135	Clay, yellow to 28 feet, gray 28-135; few thin sand and gravel stringers
135-148	Gravel, coarse
148-170	Clay, gray, gravel stringers 160-170
170-185	Clay, gray, and white chalk or marl (lacustrine?) and greenish-brown clay
185-383	Clay, gray, silty, rocks 215-230, 269-271 and 311 feet
383-395	Sand, and clay
395-435	Clay, silty possibly some sand
435-455	Sand and gravel, clayey
455-480	Gravel, coarse
480-495	Pierre Shale

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Test Hole No. 29
Location: 121-54-aaac
SDGS Rotary
Elevation: 1816 feet
Depth to Water: Not taken

0- 25	Clay, brown
25- 73	Gravel, medium
73-139	Clay, gray
139-142	Gravel
142-165	Clay, gray, gravel stringers
165-168	Gravel
168-240	Clay, gray, brown 172-189
240-253	Gravel
253-390	Clay, gray, maybe brown 310-320 feet
390-435	Gravel, silt and clay interbedded
435-455	Pierre Shale

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Test Hole No. 30
Location: 121-54-4bbbb
SDGS Auger
Elevation: 1815 feet
Depth to Water: 30 feet

(continued on next page)

Test Hole No. 30--continued

0- 2	Topsoil
2- 30	Clay, brown, pebbly
30-115	Sand, brown, fine to medium 30-52 and clayey; coarse and clean 52-115
115-125	Clay, dark-brown and small pebbles

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Test Hole No. 31
Location: 122-54-33ccab
SDGS Auger
Elevation: 1812 feet
Depth to Water: 35 feet

0- 3	Topsoil
3- 35	Clay, yellow-brown to 20 feet, gray 20-35; pebbly
35- 82	Sand, brown, medium 35-60 and coarse 60-82; clay content decreases with depth
82-100	Clay, dark-gray, pebbly

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Test Hole No. 32
Location: 122-54-33dccc
SDGS Auger
Elevation: 1807 feet
Depth to Water: 19 feet

0- 1	Topsoil
1- 16	Sand, brown, medium, clayey
16- 19	Clay, brown, silty
19- 92	Sand, brown to 39 feet, gray 39-92; fine and clayey to 59 feet, coarse and little clay 59-92 feet
92-110	Clay, brown, and much fine to medium sand

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Test Hole No. 33
Location: 122-54-33ddcb
SDGS Rotary
Elevation: 1807 feet
Depth to Water: Not measured

(continued on next page)

Test Hole No. 33--continued

0- 45	Sand and gravel
45- 83	Clay, gray
83-118	Clay, brown to yellow-brown
118-128	Clay, gray
128-181	Clay, yellow-brown, and a few thin sand stringers
181-207	Clay, gray
207-215	Gravel and clay stringers
215-245	Clay, gray and gravel stringers
245-260	Clay, gray and dark-brown cuttings
260-360	Clay, gray, thin gravel stringers 340-360
360-409	Gravel, clayey 360-395; coarse and cleaner 395-409
409-435	Clay, maybe shale
435-455	Pierre Shale

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Test Hole No. 34
Location: 122-54-34cbdd
SDGS Auger
Elevation: 1811 feet
Depth to Water: 26 feet

0- 1	Topsoil
1- 26	Clay, brown and much coarse sand
26- 87	Sand, brown to 82 feet, gray 82-87; very coarse to 82 feet, fine 82-87; clayey
87- 96	Clay, gray, sandy; rock at 96 feet

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Test Hole No. 35
Location: 122-54-34cadd
SDGS Auger
Elevation: 1809 feet
Depth to Water: Not saturated

0- 3	Gravel
3- 45	Clay, gray to black 3-26 feet, brown 26-45 feet; pebbly

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Test Hole No. 36
Location: 122-53-21dacd
SDGS Rotary
Elevation: 1827 feet
Depth to Water: Not measured

0- 4	Gravel
4- 12	Clay, yellow
12- 37	Clay, gray
37- 97	Clay, yellow; red granite rock at 68 feet
97-143	Sand and gravel; mostly clean gravel 110-143
143-250	Clay, gray
250-260	Clay, brown, very hard and tough
260-358	Clay, gray and brown cuttings mixed
358-363	Gravel, and clay
363-372	Clay, gray
372-430	Gravel, clayey; (Poor sample return from this depth, not much gravel coming up but drills like gravel)
430-575	Pierre Shale, a few marl cuttings and some bentonite

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Test Hole No. 37
Location: 122-53-21dddd
SDGS Auger
Elevation: 1820 feet
Depth to Water: 52 feet

0- 10	Gravel
10- 14	Sand, brown, coarse, clayey
14- 38	Clay, gray, pebbly
38- 52	Clay, brown, pebbly
52-105	Clay, brown, very sandy 52-98 feet and pebbly 98-105

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Test Hole No. 38
Location: 122-53-27aaaa
SDGS Auger
Elevation: 1889 feet
Depth to Water: 58 feet

0- 2	Topsoil
2- 58	Clay, dark-brown, pebbly
58-115	Sand; gray 58-103, brown 103-115; fine and clayey
115-125	Clay, brown, sandy

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Test Hole No. 39
Location: 122-53-24cccc
SDGS Auger
Elevation: 1874 feet
Depth to Water: 72 feet

0- 3	Topsoil
3- 58	Clay, brown, pebbly
58- 72	Clay, dark-gray to black, pebbly
72-140	Clay, gray, much fine to medium sand

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Test Hole No. 40
Location: 121-54-6dccc
SDGS Auger
Elevation: 1806 feet
Depth to Water: Not measured

0-100	Clay, brown to 15 feet, gray 15-100 feet; pebbly

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Test Hole No. 41
Location: 121-54-8bbbc
SDGS Auger
Elevation: 1820 feet
Depth to Water: 36 feet

0- 1	Topsoil
1- 36	Clay, brown to 26 feet, gray 26-36, pebbly
36- 95	Clay, gray, much fine to medium sand
95-115	Clay, gray, pebbly

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Test Hole No. 42
Location: 121-54-5dccc
SDGS Auger
Elevation: 1824 feet
Depth to Water: 40 feet

0- 1	Topsoil
1- 40	Clay, brown, and some fine sand 26-40 feet
40- 70	Clay, gray, silty and fine sand; much medium to coarse sand 59-70
70- 80	Sand, gray, medium clayey; large rock at 80 feet

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Test Hole No. 43
Location: 121-54-5daad
SDGS Auger
Elevation: 1799 feet
Depth to Water: 8 feet

0- 2	Topsoil
2- 24	Sand, brown, medium, some clay
24- 85	Sand, gray, fine to medium, clayey
85-110	Clay, gray, sandy

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Test Hole No. 44
Location: 121-54-9bbbb
SDGS Auger
Elevation: 1799 feet
Depth to Water: 9 feet

0- 9	Clay, brown, trace of medium sand
9- 39	Sand, brown, medium to coarse, very coarse 15-39, some clay
39-115	Sand, gray, fine to medium, clayey
115-135	Clay, gray, pebbly

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Test Hole No. 45
Location: 121-54-4dccc
SDGS Auger
Elevation: 1792 feet
Depth to Water: 2 feet

0- 2	Topsoil
2- 45	Sand, brown, very coarse, some clay
45- 65	Sand, gray, medium to coarse
65-122	Sand, brown, medium to coarse
122-135	Clay, olive-gray, pebbly

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Test Hole No. 46
Location: 121-54-4dddd
SDGS Auger
Elevation: 1790 feet
Depth to Water: 2 feet

0- 2	Topsoil
2- 19	Sand, brown, very coarse to fine gravel, trace of clay
19- 65	Sand, gray, medium to coarse, some clay
65-115	Sand, gray, fine to medium, more clay
115-128	Sand, brown, fine to medium, clayey

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Test Hole No. 47
Location: 121-54-4aaaa
SDGS Auger
Elevation: 1804 feet
Depth to Water: 16 feet

0- 1	Topsoil
1- 4	Gravel, medium
4- 55	Sand, brown, medium
55- 95	Sand, fine to medium
95-118	Sand, brown, fine, clayey
118-135	Clay, gray, pebbly

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Test Hole No. 48
Location: 121-54-3bbda
SDGS Rotary
Elevation: 1795 feet
Depth to Water: Flowing

0- 32	Sand
32- 65	Clay, gray
65- 85	Gravel, brown
85- 90	Rocks
90- 95	Clay, gray

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Test Hole No. 49
Location: 121-54-3bacd
SDGS Rotary
Elevation: 1797 feet
Depth to Water: Not measured

0- 40	Gravel
40- 62	Clay, gray
62- 72	Gravel, brown
72- 93	Clay, brown
93- 95	Gravel, brown
95-220	Clay, gray
220-332	Clay, gray to black, tough
332-399	Gravel, medium and light-gray calcareous cuttings
399-445	Pierre Shale

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Test Hole No. 50
Location: 121-54-3abbb
SDGS Auger
Elevation: 1798 feet
Depth to Water: 7 feet

0- 2	Topsoil
2- 7	Clay, dark-brown, much coarse sand
7- 30	Gravel, brown, and fine to coarse sand
30- 40	Sand, gray, medium to coarse, clayey
40- 79	Clay, gray, much medium sand
79-119	Clay, brown, and much fine sand
119-135	Clay, gray, and fine to medium sand

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Test Hole No. 51
Location: 122-53-28addc
SDGS Auger
Elevation: 1809 feet
Depth to Water: 29 feet

0- 1	Topsoil
1- 14	Clay, brown, pebbly
14- 29	Clay, gray, pebbly
29- 56	Clay, brown to yellow-brown, sandy and pebbles 29-36; much medium sand 36-56
56- 78	Sand, yellow-brown, fine to medium, clayey
78-110	Clay, yellow-brown, sandy

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Test Hole No. 52
Location: 121-54-8dacd
SDGS Auger
Elevation: 1798 feet
Depth to Water: 18 feet

0- 2	Topsoil
2- 18	Clay, yellow-brown, pebbly
18- 39	Sand, brown, medium clayey
39- 60	Sand, gray, fine to medium 39-49, fine 49-60, clayey
60- 65	Clay, gray, much fine sand
65- 75	Clay, gray, pebbly

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Test Hole No. 53
Location: 121-54-10baab
SDGS Auger
Elevation: 1785 feet
Depth to Water: 1 foot

0- 1	Topsoil
1- 21	Gravel, brown, trace of clay
21- 59	Gravel, gray, fine
59- 94	Clay, gray, much medium to coarse sand
94-135	Clay, brown, much medium sand

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Test Hole No. 54
Location: 122-53-34bbbc
SDGS Auger
Elevation: 1817 feet
Depth to Water: 12 feet

0- 1	Topsoil
1- 12	Clay, brown, silty with fine sand
12- 22	Sand, brown, fine to medium, clayey
22- 39	Clay, gray, sandy
39- 79	Clay, gray, pebbly
79- 92	Clay, gray, much fine sand
92-105	Clay, brown, much fine sand
105-112	Clay, gray, much fine sand
112-130	Clay, gray, pebbly

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Test Hole No. 55
Location: 122-53-35babb
SDGS Auger
Elevation: Not taken
Depth to Water: 37 feet

0- 1	Topsoil
1- 37	Clay, brown, pebbly
37-140	Sand, brown, fine; much clay 37-50, less clay 50-130, more clay 130-140

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Test Hole No. 56
Location: 121-53-3bbad
SDGS Auger
Elevation: 1834 feet
Depth to Water: Not measured

0- 1	Topsoil
1- 35	Clay, brown, pebbly
35- 75	Clay, gray, pebbly

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APPENDIX B

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

Geologic source: Buried outwash, BO; Surface outwash, SO; Sand lense, SL; Till, T

Water use: Stock, S; Domestic, D

Name	Location	Depth of Well (ft.)	Geologic Source	Use
W. A. Schultz	120-54-2aaac	80	?	S + D
J. Jost	120-54-6abbb	160	?	S + D
E. Holscher	121-53-2bbcc	40	T	S + D
E. Hinkelman	121-53-3babd	150	BO	S + D
D. Holzerland	121-53-14ccbc	70	?	S + D
E. Holzerland	121-53-24cacc	8	SO?	S + D
D. Leimkuhl	121-53-26abbd	58	?	S + D
J. Yunker	121-54-3baaa	22	SO	S + D
E. Manska	121-54-4bacb	90	BO	D
M. Jorgenson	121-54-4cbbb	20	SO	S + D
O. Jorgenson	121-54-5cccc	160	BO	D
C. Jones	121-54-7bbba	187	SL	S + D
I. Jorgenson	121-54-8aaaa	48	SO	S + D
B. Hawkinson	121-54-10abbb	60	SO	D
W. Leimkuhl	121-54-19bbbd	110	SL?	S + D
L. Acker	121-54-34ccda	22	SO?	S + D
O. Eicht	121-55-24aadb	127	SL?	S + D
A. Weyh	122-53-4aaac	31	SO	S + D

Name	Location	Depth of Well (ft.)	Geologic Source	Use
T. Stretz	122-53-15dbbd	105	BO?	D
C. Holman	122-53-21dbba	38	SO?	S + D
L. Richard	122-53-22bccc	60	SL?	S + D
H. Herren	122-53-28aaac	40	SO	D
P. Tschetter	122-53-28aabc	30	SO	S + D
J. Theil	122-53-34cbba	90	T	S + D
E. Shea	122-54-27ccdc	28	SO	D
G. Long	122-54-31daba	154	SL?	S + D
A. Nelson	122-54-34bdcc	91	BO	S + D