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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
RESTON, VA. 22092

GROUND-WATER AVAILABILITY IN THE BELCOURT AREA, ROLETTE COUNTY, NORTH DAKOTA

Open-File Report 75-104

Prepared in cooperation with the
U.S. Public Health Service

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By P. G. Randich

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Bismarck, North Dakota

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SELECTED FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

A dual system of measurements--English units and the International System (SI) of units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

Multiply English units	By	To obtain SI units
Acres	0.4047	hectares (ha)
Acre-feet (acre-ft)	1,233	cubic metres (m^3)
	1.233×10^{-6}	cubic kilometres (km^3)
Feet	.3048	metres (m)
Gallons	3.785	litres (l)
Gallons per day (gal/d)	3.785×10^{-3}	cubic metres per day (m^3/d)
Gallons per minute (gal/min)	.06309	litres per second (l/s)
Inches	2.54	centimetres (cm)
Miles	1.609	kilometres (km)
Square miles (mi^2)	2.590	square kilometres (km^2)

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ABSTRACT

Test drilling and geologic data indicate that there are two potential aquifers in the Belcourt, N. Dak. area capable of supplying a sufficient quantity of ground water for the city of Belcourt. The Fox Hills aquifer, located about 3 miles (4.8 kilometres) west of Belcourt, could yield a sufficient quantity, as much as 500,000 gallons per day (1,900 cubic metres per day), of ground water for Belcourt, but the quality is unsuitable for a public supply. The Shell Valley aquifer, located about 5 miles (8 kilometres) southwest of Belcourt, appears to contain the quantity and quality of ground water required for the city of Belcourt municipal supply.

INTRODUCTION

Purpose and Scope

At the request of the U.S. Public Health Service, the U.S. Geological Survey is conducting a ground-water study in the Belcourt, N. Dak. area. The purpose of the study is to locate a suitable ground-water supply for the city of Belcourt, N. Dak.

The ground-water study is being conducted in two phases. Phase 1 consists of a reconnaissance of the geology and hydrology

of the area, test drilling, sample description, electric logging, observation-well installation, water sampling for chemical analyses, and preparation of a report describing the major findings and recommendations. The selection of a ground-water source will be based on the results of phase 1.

Phase 2 consists of well construction, aquifer testing and analyses, and water sampling and analyses. The objectives of phase 2 are to determine proper well spacing and long-term adequacy of the ground-water source selected.

This report is the result of phase 1 of the study.

Location of the Area and Present Water Supply

The city of Belcourt has a population of about 1,900 and is located in northeastern Rolette County, north-central North Dakota (fig. 1). The study area consists of about 96 mi^2 (249 km^2) in and near the Turtle Mountain Indian Reservation.

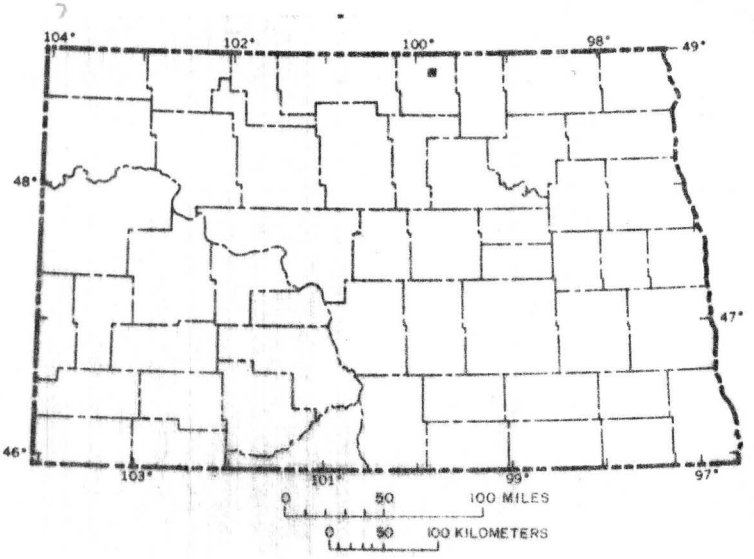

FIGURE 1.--Location of study area.

The present (1973) municipal water supply is obtained from Belcourt Lake located 2 miles (3 km) north of Belcourt. Present usage is about 225,000 gal/d (850 m^3/d). Future needs may be as much as 500,000 gal/d (1,900 m^3/d). There are many private wells in the area, which range in depth from about 20 to 400 feet (6 to 122 m) (U.S. Public Health Service, written commun., 1973), and supply water for domestic and livestock uses. Many of these wells produce only small quantities of poor quality water.

Well- and Test-Hole Numbering System

The well- and test-hole numbering system used in this report is illustrated in figure 2 and is based upon the location of the well or test hole within the grid established by the U.S. Bureau of Land Management's survey of the area. The first numeral denotes the township north of a base line; the second numeral denotes the range west of the fifth principal meridian; and the third numeral denotes the section in which the well or test hole is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections (10-acre or 5-ha tracts). Consecutive terminal numerals are added if more than one well is located within a given 10-acre (4-ha) tract. Thus, well 162-069-15DAA is in the NE¼NE¼SE¼ sec. 15, T. 162 N., R. 69 W. Similarly, well 162-069-08DCD2 is the second well located in the SE¼SW¼SE¼ sec. 8, T. 162 N., R. 69 W.

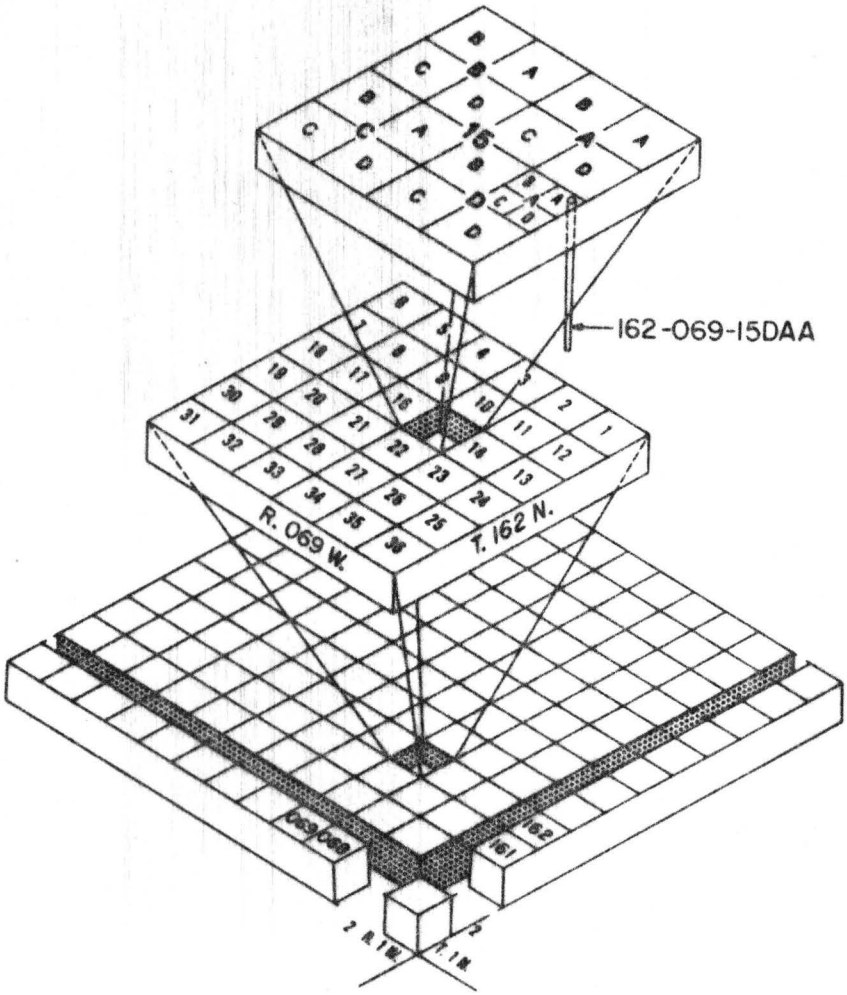

FIGURE 2.--System of numbering wells and test holes.

Previous Studies

A general study of the geology and ground-water resources of Rolette County was made by Simpson (1929). A ground-water reconnaissance of the Rolla-St. John area was made by Brookhart and Powell (1961). Municipal ground-water studies were made for Rolla (Schmid, 1964) and for St. John (Froelich, 1967). The geology of Rolette County was described by Deal (1971).

GEOLOGY AND OCCURRENCE OF GROUND WATER

Bedrock Formations

Consolidated rocks underlying the glacial drift in the Belcourt area are termed bedrock. The youngest of these rocks are of Cretaceous and Tertiary age[1] (table 1). The following formations are described from oldest to youngest.

Pierre Formation.--The top of the Pierre Formation underlies glacial deposits in the eastern part of the area at an altitude of about 1,550 feet (470 m) above mean sea level and in the western part at about 1,500 feet (460 m). Silty lenses and fractures in the upper part of the formation may yield small quantities of water to wells.

[1]The stratigraphic nomenclature used in this report is that of the North Dakota Geological Survey and does not necessarily follow the usage of the U.S. Geological Survey.

Fox Hills Formation.--The Fox Hills Formation is a moderately productive aquifer west of Belcourt where it contains a sandstone bed as much as 56 feet (17 m) thick (162-071-26BAA1). This sandstone generally occurs at altitudes between 1,650 and 1,750 feet (500 and 530 m). Wells in this aquifer were reported to yield from 10 to 100 gal/min (0.63 to 6.3 l/s) (U.S. Public Health Service, written commun., 1973).

Hell Creek Formation.--The Hell Creek Formation was not identified during drilling in the Belcourt area, but may be present in the northwestern part of T. 162 N.

Cannonball and Tongue River Formations.--The Cannonball and Tongue River Formations were not identified during test drilling in the Belcourt area. These formations are present above an altitude of 1,800 feet (549 m) west and north of the Belcourt area (Deal, 1971, p. 12).

Glacial Drift

Glacial drift was fully penetrated by 19 test holes in the Belcourt area (table 2). Thickness of the drift ranged from 113 to 430 feet (34 to 131 m) and averaged 241 feet (73 m). The drift, which consists of about 90 percent till and 10 percent glaciofluvial silt, sand, gravel, and cobbles, is divided into (1) till and associated sand and gravel deposits, (2) ice-contact deposits, and (3) surficial-outwash deposits.

Till and associated sand and gravel deposits.--Till is used in this report both as a genetic and descriptive term indicating an unsorted, unstratified, cohesive mixture of particles ranging in size from clay to boulders. Till may contain relatively thin isolated deposits of glaciofluvial sand and gravel (pl. 2). Till has a low hydraulic conductivity, but a well developed in the interbedded sand and gravel generally yields 1 to 20 gal/min (0.06 to 1.3 l/s).

Several sand and gravel deposits occur above and below a buried oxidized zone in the Belcourt area (pl. 2, sec. A-A'), but they are not thick enough to be considered a potential aquifer for the city of Belcourt.

Ice-contact deposits.--Ice-contact deposits consist mostly of stratified silt, sand, and gravel deposited in contact with melting glacial ice. Three test holes (162-070-20AAB, 162-070-08DAA1, and 162-070-15BAB1) drilled through ice-contact deposits penetrated several sand beds capable of yielding moderate to large quantities of water (table 2). However, test holes drilled several hundred feet from these sites showed the ice-contact deposits to be absent or very thin. Although they are generally thin and local, some ice-contact deposits probably could be used as a supplemental water source for the city of Belcourt.

Surficial-outwash deposits.--Surficial-outwash deposits, consisting mostly of sand and gravel, underlie plains and narrow valleys in parts of the Belcourt area. These deposits

were penetrated by eight test holes--four test holes in the Wolf Creek valley and four in the Shell valley outwash (pl. 1). Thickness of surficial outwash in the Wolf Creek valley ranged from 17 to 25 feet (5 to 8 m) and averaged 20 feet (6 m). In the Shell valley outwash, the thickness ranged from 31 to 35 feet (9 to 11 m) and averaged 33 feet (10 m). Neither the quantity nor quality of the ground water in the surficial outwash in the Wolf Creek valley appears adequate for the city of Belcourt municipal supply.

The Shell valley outwash appears to be the best potential source of ground water in the Belcourt area. Based on estimates of average porosity, thickness, and areal extent, the Shell Valley aquifer contains about 5,000 acre-feet of water per square mile (0.002 km^3/km^2). About half of this amount would be available to wells. The water levels are about 9 feet (3 m) below land surface, and water movement through the unconfined deposits appears to follow the topographic gradient to the southwest (pl. 2, sec. B-B'). Recharge is derived from precipitation percolating through surface materials. Some recharge may be derived from Wolf Creek during spring runoff or seasonal rains. Most of the time, however, there is no flow in Wolf Creek.

The area underlain by surficial-outwash deposits, designated the Shell Valley aquifer in this report, is considered the most feasible for development during phase 2 of this study (pl. 1). It is about 5 miles (8 km) southwest of Belcourt and is about 200 feet (60 m) lower in altitude than Belcourt.

Alluvium

Alluvial deposits in the Belcourt area consist of clay, silt, sand, and gravel. They occur in shallow depressions, sloughs, lakes, and in valleys of perennial and intermittent streams. Because the deposits are relatively thin and contain small quantities of water they are not considered to be a reliable source of water for Belcourt.

QUALITY OF WATER

The chemical analyses of water samples collected during this study and previous studies provided data on the chemical quality of the ground water in the Belcourt area. These analyses are listed in table 3.

Water for drinking purposes is frequently evaluated for suitability by comparing the concentration of various constituents with the following minimum standards recommended by the U.S. Public Health Service (1962):

Constituent	Concentrations in milligrams per litre (mg/l)
Iron (Fe)	0.3 [300 micrograms per litre (µg/l)]
Manganese (Mn)	.05 (50 µg/l)
Sulfate (SO_4)	250
Chloride (Cl)	250
Fluoride (F)	.6-1.7
Nitrate (NO_3)	45
Dissolved solids	500

Chemical analyses of 18 ground-water samples from the Belcourt area (table 3) indicate that concentrations of iron, manganese, sulfate, and dissolved solids in most aquifers exceed minimum drinking-water standards. Highest concentrations were found in the samples of ground water from bedrock formations; lower concentrations were found in samples from sand and gravel deposits in the till and alluvium; and lowest concentrations were found in samples from ice-contact and outwash deposits.

CONCLUSIONS

Phase 1 of the study showed that there are two potential aquifers in the Belcourt area capable of supplying a sufficient quantity of ground water for the city of Belcourt. The first aquifer is located about 3 miles (5 km) west of Belcourt (near test hole 22, pl. 1), and consists of about 56 feet (17 m) of sandstone. Although it may provide the required quantity of water, the quality of the water does not meet minimum U.S. Public Health Service (1962) requirements.

The second aquifer is located about 5 miles (8 km) southwest of Belcourt near test holes 18, 19, and 20 (pl. 1). This aquifer consists of about 30 feet (9 m) of sand and gravel in the Shell valley outwash. The Shell Valley aquifer appears to contain the quantity and quality of ground water required for the city of Belcourt (pl. 1).

Aquifer testing and related work proposed for phase 2 of this study could be performed near section lines bordering the south and east sides of the SE¼ sec. 3, T. 161 N., R. 71 W. (pl. 1).

Phase 2 will consist of the following:

1. Observation-well installation at 10 sites using 1¼-inch (3.2-cm) pipe with 3-foot (1-m) No. 18-slot screen for the purpose of collecting aquifer-test data. The wells would range from 30 to 50 feet (9 to 15 m) in depth. Total drilling probably would not exceed 500 feet (152 m).
2. Installation and development of a 6-inch (15-cm) diameter test well with 10 feet (3 m) of 5- to 6-inch (13- to 15-cm) diameter No. 35-60-slot screen between 25 and 35 feet (8 and 11 m) below land surface.
3. Pumping the test well at a constant rate of about 200 gal/min (12.6 l/s) for 72 hours and discharging the water through a pipeline into Wolf Creek.
4. Collection and analysis of water samples.
5. Monitoring water-level declines and recovery in the test well and observation wells during and after pumping.
6. Removal of all wells not needed by the U.S. Public Health Service for future use.
7. Analysis of aquifer-test data and preparation of the final report.

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U.S. Public Health Service, 1962, Public health drinking water standards: U.S. Public Health Service Pub. no. 956, 61 p.

TABLE 1.--Generalized section of the geologic units and their water-yielding and water-quality characteristics in the Belcourt area

Erathem	System	Series	Geologic unit	Estimated thickness (ft)	Character	Water-yielding and water-quality characteristics
Cenozoic	Quaternary	Holocene	Alluvium	15	Detrital deposits (chiefly stream) in valleys. Sand, silt, clay, and gravel; generally stratified and oxidized.	Yields small water supplies for domestic and livestock. Water high in iron content and hard.
		Pleistocene (In order of water-bearing potential)	Surficial-outwash deposits	50	Unconsolidated sand and gravel with a little silt. Of glaciofluvial origin. Occur in plains and associated melt-water drainage channels.	Yields of about 300 gal/min are likely where relatively thick sand and gravel beds occur. Fine-grained beds yield smaller quantities of water. Water is generally low in dissolved solids and of a calcium bicarbonate type.
			Ice-contact deposits	50	Unconsolidated stratified silt, sand, and gravel of glaciofluvial origin. Occur as kames, eskers, or similar glacial features. Small areal extent.	Yields relatively moderate supplies (25 to 50 gal/min) of water where areal extent and saturated thickness are sufficient. Water is generally of a calcium to magnesium bicarbonate type.
			Till and associated sand and gravel deposits	450	Unconsolidated, unsorted clay to boulders. Locally contains glaciofluvial silt, sand, and gravel. Sand and gravel deposits frequently occur as surficial and buried zones of oxidized sediment.	May yield very small quantities of water, but the supply, especially from shallow dug wells, is undependable in long dry periods. Isolated bodies of sand and gravel occur within the till. These yield relatively small supplies (1 to 20 gal/min), but steady withdrawals are limited because recharge from surrounding till is slow.
	Tertiary	Paleocene	Tongue River Formation	100	Light-tan, yellow, and white sandstone and sandy gray limonitic shale. Terrestrial. Contains lignite beds in places.	Yields moderate quantities of water at most places. Water from lignite frequently is brown.
			Cannonball Formation	250	Light- to dark-brownish-gray shaly sandstone and dark marine shale.	Yields moderate quantities of water at most places. Generally water is high in sulfate.
Mesozoic	Cretaceous	Upper Cretaceous	Hell Creek Formation	200	Somber-gray bentonitic shale, siltstone, and fine sandstone. Sometimes lignitic in the upper part. Concretions of manganosiderite and marcasite.	Yields moderate quantities of water generally of a sodium bicarbonate sulfate type.
			Fox Hills Formation	300	Grayish-green marine sandstone, siltstone, and shale. Ferruginous.	Yields as much as 100 gal/min from sandstone. Locally contains water under confined conditions. Generally a sodium bicarbonate type.
			Pierre Formation	900	Bluish-gray to dark-gray marine shale. Fossiliferous. Contains many concretions and some silty lenses.	Generally not considered as a source of water for wells in the study area.

TABLE 2.--Lithologic logs of wells and test holes in the Belcourt area

EXPLANATION

Lsd, land surface datum MP, measuring point

161-071-02AAA
Test hole 16
Altitude 1,805 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Gravel, fine to very coarse; cobbles	12	12
	Sand, medium to very coarse, gravelly	6	18
	Till, olive-gray; sand and gravel lenses at 37-38, 45-46, 75-76, and 150-153 ft	138	156
	Till, olive-gray, sandy; very tight in places; fairly loose and sandy to 220 ft	96	252
Fox Hills Formation(?):			
	Shale, light-gray, silty, smooth; leached appearance	10	262
	Shale, dark-brownish-gray, tight, silty	18	280

161-071-02BBC
Test hole 18
Altitude 1,785 feet

Glacial drift:			
	Clay, medium-gray, silty to sandy	12	12
	Gravel, medium to coarse, sub-rounded; about 60 percent carbonates, 30 percent shale, and 10 percent granitics and quartz	23	35
	Sand, medium to coarse, gravelly	10	45
	Till, olive-gray, silty	7	52
	Gravel, medium, sandy	1	53
	Till, olive-gray, silty; sand and gravel lenses at 57-58, 63-64, 70-72, and 95-96 ft	54	107
	Till, olive-gray, silty; interbedded with thin lenses of sand; some cobbles and boulders	51	158

161-071-02BBC, Continued

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Till, light-gray, sandy, silty; leached appearance	14	172
	Till, medium-dark-gray, silty; some boulders	43	215
Fox Hills Formation(?):			
	Shale, dark-brownish-gray, bentonitic; interbedded with lenses of siltstone	25	240

161-071-04DDC
Test hole 20
Altitude 1,740 feet

Glacial drift:			
	Gravel, fine to coarse	10	10
	Silt, olive-gray	4	14
	Sand, fine to coarse	6	20
	Clay, olive-gray, silty	4	24
	Gravel, medium to coarse, sandy	11	35
	Sand, silty to clayey	5	40

Note: Installed 25 ft of 1¼-inch plastic pipe, No. 18-slot screen 24-30 ft. MP top of casing 1.00 ft above lsd. Water level 8 ft below lsd.

161-071-10BBB
Test hole 19
Altitude 1,742 feet

Glacial drift:			
	Topsoil, brownish-black, sandy	2	2
	Gravel, medium to coarse, subrounded; about 60 percent carbonates, 20 percent shale, and 20 percent granitics and quartz	14	16
	Sand, medium to coarse, gravelly	6	22
	Gravel, fine to medium, sandy	9	31
	Till, olive-gray; interbedded with lenses of very sandy clay	51	82
	Till, olive-gray, silty	42	124

161-071-10BBB, Continued

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Till, medium-gray, silty----------	17	141
	Till, dark-gray, silty; interbedded with lenses of sandy clay-------	47	188
Fox Hills Formation(?):			
	Shale, medium-gray; interbedded with lenses of brown sandy siltstone----------	52	240

Note: Installed 25 ft of 1¼-inch plastic pipe, No. 18-slot screen 24-30 ft. MP top of casing 1.00 ft above lsd. Water level 8 ft below lsd. Pumped for water sample.

162-069-06BAB
Test hole 6-797
Altitude 1,862 feet
(Log from Schmid, 1964)

Glacial drift:			
	Soil----------	1	1
	Till, moderate yellowish brown, calcareous, oxidized----------	25	26
	Gravel, granule to pebble, sandy, angular to rounded, poorly sorted----------	2	28
	Till, olive gray, calcareous------	7	35
	Sand, medium to very coarse, gravelly, angular to rounded, unsorted----------	1	36
	Till, olive-gray, calcareous------	3	39
	Gravel, granule to pebble, sandy, rounded, unsorted----------	3	42
	Till, olive gray, calcareous------	5	47
	Till, grayish olive, calcareous, partially oxidized (probably reworked oxidized till)---------	4	51
	Till, light olive brown, calcareous, oxidized----------	43	94
	Gravel, granule to pebble, subangular to rounded----------	5	99
	Till, olive gray, calcareous (sandy, granule to pebble, gravel from 103 to 106 ft)------	20	119

162-069-06BAB, Continued

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Till, light olive brown, calcareous, oxidized	15	134
	Till, light olive gray, calcareous, partially oxidized	12	146
Undifferentiated bedrock:			
	Silt, light olive brown, clayey, calcareous, oxidized	11	157
	Silt, greenish gray, clayey, calcareous	5	162
	Sand, bluish gray, very fine to fine, silty, calcareous	4	166
	Sandstone, bluish gray, calcareous	2	168

162-069-18AAA
Test hole 160
Altitude 1,830 feet
(Log from Schmid, 1964)

Glacial drift:			
	Soil	1	1
	Till, yellow, oxidized	11	12
	Till, gray	2	14
	Sand, medium to very coarse, gravelly	5	19
	Till, gray	18	37
	Sand, medium to very coarse, gravelly	2	39
	Till, brown to gray, partially oxidized	31	70
	Till, gray	43	113
Undifferentiated bedrock:			
	Silt, gray, sandy	20	133
	Shale, gray	17	150

162-069-18BBB
Test hole 4-797
Altitude 1,855 feet
(Log from Schmid, 1964)

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Gravel, granule to pebble, sandy, subangular to rounded	2	2
	Till, moderate yellowish brown, calcareous, oxidized	10	12
	Till, olive gray, calcareous	20	32
	Till, dusky yellowish brown to olive black, calcareous, partially oxidized (may be reworked oxidized till)	19	51
	Sand, clayey, rounded quartz	1.5	52.5
	Till, moderate yellowish brown, calcareous, oxidized	10.5	63
	Gravel, granule to pebble, sandy, subangular to rounded	4	67
	Till, moderate yellowish brown, calcareous, oxidized	33	100
	Till, olive gray, calcareous	7	107
	Gravel, granule to cobble, sandy, very angular to rounded	18	125
	Till, olive gray, calcareous	12	137
	Till, light olive brown, calcareous, oxidized	21	158
	Till, olive gray	10	168
	Sand, clayey to gravelly	8	176
	Till, olive gray, calcareous	112	288
Pierre shale:			
	Shale, dark greenish gray, silty, noncalcareous	16.5	304.5

162-069-18DDD
Test hole 171
Altitude 1,836 feet
(Log from Schmid, 1964)

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Soil	1	1
	Till, yellow, oxidized	17	18
	Sand, medium to very coarse, gravelly	21	39
	Till, gray	17	56
	Till, brown, oxidized	15	71
	Till, gray (finer grained from 144 to 189 feet)	118	189
	Sand, gravelly	1	190
	Till, gray	6	196
Undifferentiated bedrock:			
	Shale, gray	14	210

162-070-06DAA
Test hole 5
Altitude 2,020 feet

Glacial drift:			
	Topsoil, brownish-black	1	1
	Till, moderate-yellowish-brown, sandy, calcareous, oxidized	23	24
	Till, medium-gray, sandy, calcareous	39	63
	Till, olive-gray; occasional cobbles and boulders	27	90
	Boulder, granite	1	91
	Till, olive-gray, calcareous	12	103
	Till, olive-gray; gravelly in places	21	124
	Till, olive-gray; interbedded with thin lenses of sandy gravel; occasional cobble or boulder	79	203
	Till, olive-gray, calcareous; occasional cobble or boulder	33	236
	Till, moderate-yellowish-brown, sandy, gravelly, iron-stained, oxidized	16	252

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Gravel, medium to coarse, sandy, subrounded to rounded; about 50 percent detrital shale, 30 percent carbonates, and 20 percent granitics and sandstones (oxidized Fe)----------	4	256
	Till, medium-gray, gravelly-------	3	259
	Gravel, fine to coarse, subrounded to rounded; about 20 percent coarse sand, 30 percent detrital shale, and 30 percent carbonates; remainder granitics and sandstones----------	8	267
	Till, olive-gray, gravelly to sandy----------	16	283
	Boulder, granite----------	-	283

162-070-08DAA1
Test hole 8
Altitude 2,020 feet

Glacial drift:			
	Gravel, reddish-brown, fine to medium, oxidized----------	2	2
	Till, yellowish-brown, sandy, oxidized----------	14	16
	Till, medium-dark-gray; some very thin lenses of gravel----------	71	87
	Sand, fine to medium, subrounded; predominantly carbonates and shale----------	9	96
	Clay, olive-gray, silty----------	3	99
	Sand, fine to medium, subrounded--	3	102
	Clay, olive-gray, silty----------	3	105
	Sand, fine to medium, subrounded to rounded; carbonates, shale, and granitics----------	7	112
	Clay, olive-gray----------	5	117
	Sand, fine to medium, subrounded to rounded; carbonates, shale, and granitics----------	13	130

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Till, olive-gray, sandy----------	20	150
	Boulder, limestone----------	1	151
	Till, olive-gray, sandy----------	4	155
	Boulder, limestone----------	1	156
	Till, olive-gray, sandy to gravelly----------	11	167
	Boulder----------	1	168
	Sand, medium to coarse, subrounded to rounded; about 25 percent medium gravel; mostly carbonates and shale----------	14	182
	Till, yellowish-brown, sandy; about about 50 percent sand----------	25	207
	Till, olive-gray; occasional thin lenses of sand and gravel-------	43	250
	Till, olive-gray, sandy; more gravelly till than above--------	25	275
	Till, medium-gray, sandy----------	20	295
	Till, dark-gray, tight----------	31	326
Fox Hills Formation(?):			
	Siltstone, greenish-gray, clayey--	14	340
	Sandstone, greenish-gray, very fine to fine, indurated---------	6	346
	Sandstone, greenish-gray, fine, unconsolidated----------	7	353
	Shale, greenish-gray, silty-------	7	360

Note: Installed 175 ft of 1¼-inch plastic pipe, No. 18-slot screen 174-180 ft. MP 1.00 ft above lsd. Water level 68 ft below lsd. Pumped for water sample.

162-070-08DAA2
Test hole 9
Altitude 2,020 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Gravel, fine to coarse, oxidized; mostly carbonates, shale, and granitics	18	18
	Till, medium-gray, silty; boulder at 93 ft	76	94
	Sand, fine to medium, clayey	3	97
	Boulder	1	98
	Till, medium-gray, very silty	20	118
	Sand, fine to coarse, silty to clayey, subrounded, fairly tight	13	131
	Boulder, sandstone	1	132
	Till, olive-gray, silty	3	135
	Boulder, limestone	1	136
	Till, olive-gray, silty to sandy	6	142
	Gravel, fine to coarse, sandy; interbedded with thin lenses of silty clay	4	146
	Till, olive-gray, sandy	14	160
	Till, olive-gray, gravelly to bouldery	13	173
	Till, olive-gray; interbedded with lenses of sandy gravel	5	178
	Boulder, dolomite	1	179
	Till, yellowish-buff, sandy, oxidized	26	205
	Boulder, granite	1	206
	Till, medium-gray, tight; older till	14	220

162-070-11BAA
Test hole 8-797
Altitude 2,000 feet
(Log from Schmid, 1964)

Glacial drift:			
	Fill	6	6
	Sand, medium to very coarse, gravelly	6	12
	Till, moderate yellowish brown, calcareous, oxidized	6	18
	Till, olive-gray, calcareous	45	63

162-070-12CCC
Test hole 162
Altitude 1,945 feet
(Log from Schmid, 1964)

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Soil	1	1
	Till, yellow, oxidized	18	19
	Till, gray	20	39
	Sand, gravelly	3	42
	Till, gray	48	90
	Till, brown, partially oxidized (may be reworked oxidized till)	8	98
	Till, gray	14	112
	Till, yellow, oxidized	55	167
	Till, gray	76	243
Undifferentiated bedrock:			
	Clay, light gray	30	273
	Shale, gray	17	290

162-070-12DDD
Test hole 161
Altitude 1,850 feet
(Log from Schmid, 1964)

Glacial drift:			
	Soil	1	1
	Till, yellow, oxidized	7	8
	Sand, medium to very coarse, gravelly	6	14
	Till, gray	17	31
	Sand, medium to very coarse, gravelly	9	40
	Till, gray	10	50
	Till, yellow, oxidized	32	82
	Till, gray	21	103
	Gravel, granule to pebble, sandy	25	128
	Till, gray	13	141
	Till, yellow, oxidized	19	160
	Till, gray	130	290
Pierre shale:			
	Shale, gray	30	320

162-070-14BBB
Test hole 163
Altitude 1,985 feet
(Log from Schmid, 1964)

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Soil----------	4	4
	Till, yellow, oxidized----------	7	11
	Till, gray----------	3	14
	Gravel, granule to pebble, sandy--	13	27
	Till, gray----------	129	156
	Till, brown, partially oxidized (may be reworked oxidized till)-	12	168
	Till, gray----------	7	175
	Till, yellow, oxidized----------	42	217
Undifferentiated:			
	Silt, gray, clayey to sandy, could be till or bedrock----------	23	240

162-070-15BAB1
Test hole 10
Altitude 2,000 feet

Glacial drift:			
	Topsoil, brownish-black, sandy----	1	1
	Gravel, fine to coarse, sandy, oxidized----------	1	2
	Till, yellowish-brown, sandy, oxidized----------	28	30
	Gravel, medium to coarse, well-rounded----------	2	32
	Till, olive-gray, silty----------	12	44
	Gravel, medium, sandy, rounded----	3	47
	Till, olive-gray, sandy; some cobbles and boulders----------	68	115
	Till, olive-gray, sandy to gravelly----------	32	147
	Gravel, fine to coarse, sandy-----	6	153
	Till, olive-gray; occasional cobbles and boulders----------	44	197
	Till, grayish-brown, sandy to gravelly----------	55	252
	Gravel, fine to coarse, sandy-----	3	255

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Till, olive-gray, silty----------	36	291
	Sand, fine to coarse, rounded-----	4	295
	Till, yellowish-gray to brown, sandy, oxidized; older till-----	17	312
	Sand, fine to medium, silty-------	2	314
	Till, dark-gray, very sandy-------	12	326
Fox Hills Formation(?):			
	Clay, greenish-gray, plastic------	6	332
	Sandstone, grayish-green, very fine to fine, clayey----------	15	347
	Siltstone, grayish-green, semi-consolidated--------------------	13	360

162-070-15BAB2
Test hole 10A
Altitude 2,000 feet

Glacial drift:			
	Topsoil, brownish-black, sandy----	1	1
	Till, yellowish-brown, sandy, oxidized------------------------	29	30
	Gravel, medium to coarse, sandy, rounded------------------------	15	45
	Till, olive-gray, silty----------	15	60

162-070-17AAA
Test hole 11
Altitude 2,009 feet

Glacial drift:			
	Gravel, fine to coarse, subrounded, oxidized; carbonates, granitics, and silicates------------------	12	12
	Sand, fine to coarse, rounded; about 60 percent detrital shale and 30 percent carbonates; interbedded with thin lenses of silty clay----------	29	41
	Till, medium-gray, silty, tight; interbedded thin sand lenses at 72 and 92 ft--------------------	59	100
	Till, olive-gray, silty, tight----	15	115

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Cobbles and boulders	4	119
	Till, medium-gray, silty	38	157
	Gravel, fine to coarse, sandy; saturated	2	159
	Till, dark-gray, sandy	3	162
	Gravel, fine to coarse, sandy	1	163
	Till, olive-gray, gravelly; boulders	25	188
	Till, medium-gray, sandy	17	205
	Till, yellowish-brown, sandy, oxidized; boulders	12	217
	Gravel, fine to medium, silty to sandy; boulders	4	221
	Till, dark-gray, silty, tight	29	250
	Gravel, fine to medium, sandy, silty; saturated	7	257
	Till, dark-gray, silty	13	270
Fox Hills Formation(?):			
	Siltstone, medium-light-gray, bentonitic	18	288
	Shale, light-gray, silty; leached appearance	10	298
	Siltstone, light-gray, sandy, bentonitic	22	320

162-070-18ADD
Test hole 6
Altitude 2,040 feet

Glacial drift:			
	Topsoil, brownish-black	1	1
	Till, moderate-yellowish-brown, clayey; silty in places	2	3
	Clay, medium-light-gray, laminated; iron stains; lignite smears	29	32
	Till, medium-dark-gray, silty	26	58
	Till, olive-gray, silty to sandy; some boulders; occasional gravel lenses	9	67
	Till, olive-gray, very silty	43	110
	Till, olive-gray, very silty to sandy	51	161

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Till, olive-gray, silty to sandy; lignite smears	29	190
	Till, olive-gray, gravelly; occasional cobble or boulder	13	203
	Gravel, fine to medium, sandy	6	209
	Till, olive-gray; interbedded with thin lenses of gravel	25	234
	Gravel, medium, sandy	2	236
	Till, yellowish-brown, oxidized	6	242
	Gravel, medium to coarse, sandy, oxidized	6	248
	Till, yellowish-brown, gravelly, oxidized	10	258
	Till, moderate-yellowish-brown, oxidized; iron stains	18	276
	Gravel, medium to coarse; some clayey till lenses	8	284
	Till, olive-gray, silty	2	286
	Gravel, medium, sandy	7	293
	Till, olive-gray, sandy to gravelly	43	336
	Gravel, fine to medium, sandy	8	344
Fox Hills Formation(?):			
	Clay, medium-bluish-gray, silty to sandy	36	380

162-070-20AAB
Test hole 12
Altitude 1,970 feet

Glacial drift:			
	Gravel, fine to coarse, subangular, oxidized	12	12
	Till, olive-gray, silty	10	22
	Gravel, fine to medium; about 30 percent carbonates, 40 percent shale, 30 percent granitics, etc.; sand lenses 29-32 and 45-47 ft; thin silty clay lenses 73-83 ft	61	83
	Till, brownish-gray, oxidized; some cobbles	47	130

162-070-20AAB, Continued

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Gravel, fine to medium, clayey----	6	136
	Till, olive-gray, silty----------	17	153
	Till, yellowish-brown, sandy, gravelly, oxidized----------	20	173
	Gravel, medium, clayey, angular---	5	178
	Till, medium-gray, silty----------	28	206
	Sand, medium, silty to clayey-----	5	211
	Clay, olive-gray, silty----------	3	214
	Gravel, fine to medium, sandy-----	4	218
	Till, olive-gray, sandy----------	3	221
	Gravel, fine to medium; interbedded with lenses of silty clay-------	10	231
	Till, medium-dark-gray, silty-----	32	263
	Till, dark-gray, sandy----------	10	273
	Gravel, fine to medium, angular---	5	278
	Till, dark-gray, silty----------	4	282
Fox Hills Formation(?):			
	Clay, medium-gray, silty, bentonitic----------	12	294
	Sandstone, medium-gray, fine, indurated----------	5	299
	Siltstone, light-gray, sandy, bentonitic----------	21	320

Note: Installed 70 ft of 1¼-inch plastic pipe, No. 18-slot screen 69-75 ft. MP 1.00 ft above lsd. Water level 14 ft below lsd. Pumped for water sample.

162-070-20AAC
Test hole 21
Altitude 1,960 feet

Glacial drift:			
	Gravel, fine to coarse, subrounded to rounded; cobbles; mostly carbonates----------	12	12
	Till, olive-gray, silty to sandy--	26	38
	Till, olive-gray, very sandy, gravelly----------	5	43
	Till, olive-gray, silty----------	27	70
	Gravel, medium; interbedded with thin lenses of silty clay-------	10	80

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Till, olive-gray, silty----------	18	98
	Sand, fine to medium, gravelly-----	1	99
	Till, olive-gray, silty----------	3	102

162-070-29CBC
Test hole 13
Altitude 1,884 feet

Glacial drift:			
	Gravel, fine to medium, oxidized--	4	4
	Sand, very fine to very coarse, oxidized----------	15	19
	Till, olive-gray, silty----------	63	82
	Till, medium-gray, tight----------	10	92
	Till, olive-gray, silty----------	23	115
	Till, olive-gray, sandy to gravelly----------	3	118
	Till, olive-gray; sandy gravel 138-139 ft----------	28	146
	Gravel, fine, sandy----------	2	148
	Till, olive-gray, sandy----------	4	152
Fox Hills Formation(?):			
	Clay, light-gray, silty to sandy; leached appearance----------	32	184
	Shale, medium-gray, silty----------	34	218
	Sandstone, dark-greenish-gray, very fine to medium, clayey----------	12	230
	Siltstone, greenish-gray, semi-consolidated----------	86	316
	Shale, grayish-brown, fissile-----	10	326
	Siltstone, greenish-gray, bentonitic; carbonaceous streaks-----	36	362
Pierre Formation:			
	Shale, dark-gray; some brownish-gray; some lenses are indurated-	74	436
	Shale, bluish-black, siliceous, tight; bentonitic in places (booted up in hole)----------	64	500

162-070-30CCC
Test hole 14
Altitude 1,855 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Gravel, fine to coarse, sandy, subangular to rounded, oxidized-	12	12
	Sand, fine to coarse, subrounded--	5	17
	Clay, medium-gray, silty to sandy-	4	21
	Till, olive-gray; occasional thin lenses of gravel; sandy 51-52, 58-60, and 71-72 ft----------	69	90
	Gravel, fine to medium, sandy; mostly detrital shale----------	3	93
	Till, olive-gray, silty; some cobbles----------	19	112
	Sand, fine to coarse, gravelly, very clayey----------	10	122
	Till, medium-gray, silty----------	5	127
Fox Hills Formation(?):			
	Clay, light-gray, sandy; leached appearance----------	9	136
	Sandstone, grayish-blue, fine to medium----------	6	142
	Siltstone, bluish-gray, sandy to clayey----------	2	144
	Sandstone, grayish-blue, fine to medium, semiconsolidated, friable; flows----------	10	154
	Shale, bluish-gray; interbedded with thin lenses of indurated sandstone----------	6	160

162-071-04ACC
Test hole 4
Altitude 2,160 feet

Glacial drift:			
	Topsoil, brownish-black, sandy----	1	1
	Till, moderate-yellowish-brown, sandy, oxidized; lignite smears-	28	29
	Till, medium-gray, cohesive, silty to sandy----------	13	42
	Till, medium-dark-gray, silty, sandy----------	57	99

162-071-04ACC, Continued

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Gravel, medium to coarse, sandy, clayey	9	108
	Till, olive-gray, silty to sandy; some cobbles and boulders; thin lenses of gravel	40	148
	Till, olive-gray, silty to sandy; occasional cobble or boulder	30	178
	Till, olive-gray; lenses of gravel	12	190
	Till, olive-gray, silty; occasional cobble or boulder	40	230
	Till, dark-gray, silty; occasional boulders	28	258
	Till, dark-gray, silty to gravelly	3	261
	Till, dark-gray, silty; occasional boulders	34	295
	Till, moderate-yellowish-brown, silty, oxidized; iron stains	25	320

162-071-26BAA1
Test hole 22
Altitude 1,965 feet

Glacial drift:			
	Topsoil, brownish-black, sandy	4	4
	Till, yellowish-brown, sandy, silty, oxidized	8	12
	Till, olive-gray, silty	25	37
	Gravel, medium, rounded	1	38
	Till, olive-gray, silty	26	64
	Gravel, medium, sandy; mostly carbonates	3	67
	Till, olive-gray, silty	15	82
	Till, yellowish-brown, sandy, oxidized	12	94
	Gravel, medium, subangular; mostly carbonates	8	102
	Clay, medium-gray, silty	2	104
	Gravel, fine to medium, sandy	3	107
	Till, yellowish-brown, silty, sandy, oxidized	23	130
	Till, dark-brown, very carbonaceous; wood fragments	6	136

162-071-26BAA1, Continued

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift, Continued:			
	Sand, fine to coarse, gravelly----	1	137
	Till, yellowish-brown, sandy, oxidized----------	13	150
	Till, dark-gray, silty----------	25	175
	Sand, medium, gravelly----------	1	176
Hell Creek-Fox Hills Formations(?):			
	Sandstone, dark-grayish-green, very fine, clayey----------	9	185
	Shale, grayish-green, silty-------	27	212
	Sandstone, grayish-green, very fine----------	4	216
	Shale, grayish-green, silty-------	12	228
	Siltstone, greenish-gray, clayey--	16	244
	Sandstone, grayish-green, very fine to fine; indurated in places; lignite chips----------	56	300
	Siltstone, greenish-gray, sandy, cohesive----------	13	313
	Sandstone, greenish-gray, very fine, silty----------	9	322
	Siltstone, greenish-gray----------	4	326
	Sandstone, greenish-gray, very fine----------	4	330
	Siltstone, greenish-gray, sandy; clayey in places----------	20	350
	Shale, dark-greenish-gray, silty--	67	417
Pierre Formation:			
	Shale, dark- to medium-gray, tight----------	43	460
	Shale, medium-gray, silty, bentonitic----------	22	482

162-071-26BAA2
Test hole 22A
Altitude 1,965 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black, sandy----	4	4
	Till, yellowish-brown, sandy, silty, oxidized----------	8	12
	Till, olive-gray, silty----------	25	37
	Gravel, medium, rounded----------	1	38
	Till, olive-gray, silty----------	8	46

162-071-35CDD
Test hole 17
Altitude 1,800 feet

Glacial drift:			
	Gravel, fine to very coarse, oxidized; some cobbles; predominantly carbonates, detrital shale, and igneous pebbles------	30	30
	Sand, medium to coarse; saturated-	5	35
	Till, olive-gray, silty to sandy--	15	50
	Gravel, medium to coarse, sandy---	2	52
	Till, olive-gray; sandy streaks---	13	65
	Sand, coarse, gravelly, silty-----	5	70
	Till, olive-gray, silty; sandy interval 104-108 ft----------	52	122
	Till, olive-gray, very sandy------	12	134
	Till, olive-gray, silty----------	8	142
	Gravel, medium, subrounded--------	4	146
	Till, olive-gray, very sandy------	10	156
	Gravel and cobbles----------	2	158
	Till, olive-gray, sandy----------	4	162
	Cobbles and boulders----------	1	163
	Till, olive-gray, silty----------	11	174
	Cobbles and boulders----------	1	175
	Till, olive-gray, silty; boulders from 180-190 ft----------	15	190

162-071-36CBC
Test hole 15
Altitude 1,815 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Gravel, coarse, sandy; cobbles and boulders	21	21
	Sand, medium-coarse, gravelly	4	25
	Till, olive-gray, sandy	6	31
	Sand, coarse, gravelly, subangular	5	36
	Clay, medium-gray, silty to sandy	9	45
	Gravel, medium to coarse, sandy; abundant detrital shale	11	56
	Till, olive-gray, sandy	5	61
	Gravel, medium, subrounded	10	71
	Gravel, medium, uniform	5	76
	Clay, olive-gray, silty to sandy	3	79
	Gravel, medium to coarse, sandy, rounded	18	97
	Till, olive-gray, sandy	13	110
	Gravel, medium, rounded	1	111
	Till, olive-gray, silty to sandy	4	115
	Gravel, medium, sandy	1	116
	Till, olive-gray, silty	2	118
	Gravel, medium, sandy	1	119
	Sand, fine to medium, subrounded	1	120

Note: Installed 79.5 ft of 1¼-inch plastic pipe, No. 18-slot screen 78-84 ft. MP 1.50 ft above lsd. Water level 20.9 ft below lsd.

163-070-32DDD
Test hole 7
Altitude 2,062 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, yellowish-brown, sandy---	1	1
	Till, moderate-yellowish-brown, oxidized; thin lenses of gravel-	55	56
	Till, olive-gray, gravelly, sandy-	194	250
	Till, yellowish-gray, very gravelly; cobbles and boulders; mostly carbonates; weathered light-gray bentonitic material--	13	263
	Till, medium-gray, sandy to gravelly, tight; older till-----	37	300
	Till, dark-gray, tight----------	37	337
	Till, dark-gray, sandy----------	11	348
	Till, very dark gray, tight-------	48	396
	Till, dark-gray, sandy; boulder at 405 ft----------	18	414
	Till, dark-gray, tight----------	16	430
Fox Hills Formation(?):			
	Shale, dark-greenish-gray---------	12	442
	Sandstone, greenish-gray, fine to medium, clayey, indurated-------	1	443
	Shale, dark-grayish-black, slightly silty, tight----------	17	460

TABLE 3.--Chemical analyses of ground water from the Shell valley aquifer

Well location	Well number	Depth of well (ft)	Date of sample	Pumping time (hrs)/ rate (gal/min)	Dissolved silica (SiO_2) (mg/l)	Dissolved iron (Fe) (µg/l)	Dissolved manganese (Mn) (µg/l)	Dissolved calcium (Ca) (mg/l)	Dissolved magnesium (Mg) (mg/l)	Dissolved sodium (Na) (mg/l)	Dissolved potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Phosphate ortho dissolved as (P) (mg/l)	Phosphate dissolved ortho (PO_4) (mg/l)	Phosphorus dissolved as (P) (mg/l)	Total alkalinity (as $CaCO_3$) (mg/l)	Dissolved sulfate (SO_4) (mg/l)	Dissolved chloride (Cl) (mg/l)	Dissolved fluoride (F) (mg/l)	Dissolved nitrate (N) (mg/l)	Dissolved boron (B) (µg/l)	Dissolved solids (residue at 180°C) (mg/l)	Hardness (Ca,Mg) (mg/l)	Noncarbonate hardness (mg/l)	Percent sodium	Sodium adsorption ratio	Specific conductance (µmhos/cm 25°C)	pH (units)	Temperature (°C)
161-071-02BCD	27	32	11-06-74	8/6	25	80	590	100	27	23	7.1	327	0.04	0.12	0.05	268	140	4.4	0.1	0.00	110	506	360	93	12	0.5	749	8.1	5.0
161-071-02BDC	28	26	11-06-74	8/3	24	320	520	92	28	14	5.2	321	.03	.09	.04	263	110	3.1	.1	.03	50	447	350	82	8	.3	673	8.0	5.0
161-071-02CBB2	24	41	11-06-74	12/2	24	60	370	98	35	23	5.1	331	.02	.06	.01	271	160	5.3	.1	.03	80	523	390	120	11	.5	780	8.2	5.0
161-071-02CBC1	25	20	11-13-74	12/5	24	20	140	91	48	23	4.1	363	.01	.03	.01	298	170	5.1	.2	1.5	90	566	420	130	10	.5	847	8.0	5.0
161-071-03CCD	34	32	11-05-74	12/5	25	10	20	73	57	14	4.8	360	.05	.15	.01	295	140	4.7	.2	3.3	70	532	420	120	7	.3	808	8.1	5.0
161-071-03CDC1	38	32	11-05-74	10/5	25	10	10	83	50	17	4.9	356	.04	.12	.01	292	150	5.1	.2	2.8	90	529	410	120	8	.4	802	8.1	5.0
161-071-03CDD1	35	39	11-05-74	10/5	22	20	90	78	33	7.5	3.1	249	.05	.15	.03	204	130	4.9	.1	2.9	40	438	330	130	5	.2	649	8.0	5.0
161-071-03CDD4	41	38	11-21-74	4/150	23	20	50	66	27	12	3.3	258	.03	.09	.03	212	83	3.3	.1	3.5	60	364	280	64	9	.3	576	7.8	5.0
161-071-03CDD4	41	38	11-21-74	12/150	23	30	40	65	29	13	3.6	258	.02	.06	.02	212	83	3.4	.1	3.5	50	365	280	70	9	.3	576	7.7	5.0
161-071-03CDD4	41	38	11-22-74	24/120	15	60	60	68	27	15	3.9	260	--	--	--	--	85	2.9	.4	.4	0	352	280	67	10	.4	580	7.8	5.0
161-071-03CDD4	41	38	11-25-74	50/120	23	10	40	65	29	13	3.5	259	.02	.06	.01	212	80	2.3	.1	3.0	50	323	280	69	9	.3	578	7.7	5.0
161-071-03CDD4	41	38	11-27-74	71/120	23	10	30	66	29	13	3.4	260	--	--	.05	213	83	2.3	.1	3.4	80	362	280	71	9	.3	583	7.7	5.0