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OPEN-FILE REPORT 85-UR

GROUND WATER INVESTIGATION FOR THE SIOUX RURAL WATER SYSTEM AND THE CITY OF HAYTI, SOUTH DAKOTA

by

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1997

CONTENTS

FIGURES

TABLES

INTRODUCTION

This investigation was conducted from June 29 through October 25, 1983, by the South Dakota Geological Survey, a program within the Department of Environment and Natural Resources, at the request of the Sioux Rural Water System and the city of Hayti, South Dakota. The purpose of the investigation was to assist the city of Hayti and the Sioux Rural Water System in evaluating their options regarding a new ground water supply. This report contains the results of the investigation that was conducted in two areas: an area north, east, and southeast of the city of Hayti, and an area north and west of the city of Castlewood, South Dakota (fig. 1). The request for an investigation was initiated in response to problems that were affecting, or could potentially affect, the Hayti city wells and the Sioux Rural Water System wells.

BACKGROUND

On January 20, 1983, an above ground gasoline spill occurred in the city of Hayti in which 4,151 gallons of gasoline were released. The Hayti city wells and the Sioux Rural Water System wells are drilled into a shallow aquifer and on January 22, 1983, it was confirmed that the gasoline had reached the water table in this aquifer. At the time of the gasoline spill, the Sioux Rural Water System had two wells that were located approximately 700 feet downgradient from the spill. Consequently, this gasoline spill created an immediate concern.

Another problem encountered by the city of Hayti was a brackish water intrusion into the city wells. Hayti is located directly east of Lake Marsh and the city and the lake are both located on outwash terrain. Water quality data collected from the municipal water system indicate that the total dissolved solids, sulfate, and hardness concentrations have increased drastically over time. Further investigation showed that heavy pumping of the municipal wells had induced recharge from Lake Marsh. With the city wells contaminated, it would be likely that the rural water wells (approximately 1,200 feet north of the city wells) may eventually suffer the same degradation in water quality. This brackish water intrusion into the municipal well system created another ground water contamination problem for the city and rural water system.

METHODS AND PROCEDURES

Drilling and Well Installation

Drilling for this project began June 29, 1983, and concluded October 25, 1983. All test holes were advanced using the mud rotary drilling method. Eighty-two test holes were drilled, 53 of which were cased with 2-inch diameter polyvinyl chloride casing and screen for use as monitoring wells (fig. 1). Of the 53 monitoring wells installed for this investigation, 45 wells were installed in the Big Sioux aquifer and 8 wells were installed in the Prairie Coteau aquifer. Lithologic logs for test holes and monitoring wells are on file at the South Dakota Geological Survey.

Water Level Measurements

The depths to water in the monitoring wells were measured on 26 occasions (tables 1, 2, and 3) to the nearest 0.01 foot. Measurements were made using a fiberglass tape measure with a concave shaped device on the end that makes an audible sound upon impact with the water.

Water Sampling and Analysis

Water samples were collected from 39 monitoring wells installed for this investigation and from 2 surface water locations. Of the 39 monitoring wells sampled, 33 wells were installed in the Big Sioux aquifer and 6 wells were installed in the Prairie Coteau aquifer. All water quality analyses were performed by the South Dakota Geological Survey Basic and Analytical Studies Laboratory. All well development and sampling information are on file at the South Dakota Geological Survey.

HYDROGEOLOGIC SETTING

General Geology

The surficial geology of Hamlin County is derived primarily from glaciation. The result of this glaciation was the deposition of material referred to as glacial drift composed of till and outwash. Till consists of a heterogeneous mixture of boulders, gravel, sand, clay, and silt. The till matrix is composed predominantly of clay and silt. Outwash consists primarily of sand and gravel that has been washed, sorted, and deposited by flowing meltwater. Varying amounts of less permeable materials (silt and clay) may be dispersed throughout the outwash matrix. These sand and gravel deposits (outwash) are often important aquifers.

Big Sioux Aquifer

Outwash deposits along the Big Sioux River and its tributaries comprise the Big Sioux aquifer. The Big Sioux aquifer is primarily an unconfined, surficial aquifer composed of sand and gravel (outwash). The predominant grain size of the aquifer material ranges from fine sand to very coarse gravel. Ground water recharge is thought to be primarily from downward percolation of precipitation or, in some areas, excess irrigation. Surface water may also infiltrate into the aquifer when surface water elevations are higher than adjacent ground water elevations.

Prairie Coteau Aquifer

Kume (1985) describes the Prairie Coteau aquifer in the study area as follows:

> Buried beneath till and within the thick layer of glacial drift that blankets the area are numerous lenticular bodies of outwash. Many of these deposits are included in what is herein named the Prairie Coteau aquifer. Generally, those outwash deposits buried beneath 30 feet or

> more of till and not otherwise part of a surface or near-surface aquifer, and not part of the Altamont aquifer at the base of the drift, are included in the Prairie Coteau aquifer.

By Kume's definition, the Prairie Coteau aquifer consists of several layers of sand and gravel that are separated by, and enclosed in, till. This definition creates a problem, however, because the definition does not consider or define individual aquifers within the Prairie Coteau. The understanding of the physical system comprising Kume's Prairie Coteau aquifer is limited. It is, therefore, difficult to predict water availability and water quality for long-term use in each layer of the Prairie Coteau aquifer.

RESULTS OF INVESTIGATION

Hayti Area

Big Sioux Aquifer

In the Hayti area (fig. 2), the Big Sioux aquifer is a surficial, unconfined aquifer composed of fine sand to medium gravel and underlies portions of the study area. The sand and gravel unit ranges in thickness from 11 feet (R2-83-160; about 1.5 miles north of Hayti) to 61 feet (R2-83-145; about 2 miles southeast of Hayti). Saturated thickness of the Big Sioux aquifer on October 17, 1983, ranged from 7.5 feet (R2-83-150; about 1.75 miles north of Hayti) to 51 feet (R2-83-145).

Water samples were collected from 14 monitoring wells installed in the Big Sioux aquifer for this investigation in the Hayti area. Table 4 and figure 3 indicate that the quality of water in the Big Sioux aquifer is variable in the Hayti area. In water collected from monitoring wells, total dissolved solids ranged in concentration from 384 to 3,925 milligrams per liter (mg/L), hardness ranged from 316 to 2,563 mg/L, sulfate ranged from 52 to 2,520 mg/L, and iron ranged from <0.05 to 11.7 mg/L. Nitrate-nitrogen plus nitrite-nitrogen (referred to here as simply nitrate) concentrations ranged from less than 0.05 to 4.12 mg/L (fig. 4). These nitrate concentrations are low and indicate that nitrate contamination was not a concern in the Big Sioux aquifer in this area.

Ground water showing the best water quality was found just north of the city of Hayti in section 21 (fig. 3). In water collected from monitoring wells in this area, total dissolved solids ranged in concentration from 384 to 516 mg/L, hardness ranged from 316 to 368 mg/L, and sulfate ranged from 52 to 87 mg/L. Iron concentrations were elevated in water collected from some monitoring wells and ranged from 0.18 to 1.98 mg/L.

The poorest quality ground water was found north of Lake Marsh, west of the city of Hayti. Water collected from monitoring well R2-83-161 (fig. 2) had a total dissolved solid concentration of 3,925 mg/L, a hardness concentration of 2,563 mg/L, a sulfate concentration of 2,520 mg/L, and an iron concentration of 11.7 mg/L. Another monitoring well located north of Lake Marsh (R2-83-162) also had elevated concentrations of total dissolved solids, hardness, and sulfate. These concentrations indicate a brackish-type water. Generally, brackish waters are too saline to be potable.

Surface Water and Ground Water Interaction

The water quality of Lake Marsh is poor. Water collected from the lake (table 4 and fig. 3) had a total dissolved solids concentration of 6,320 mg/L, a hardness concentration of 3,300 mg/L, and a sulfate concentration of 4,160 mg/L. These concentrations indicate that water in Lake Marsh is brackish. The water quality of the small lake just north of Lake Marsh (table 4 and fig. 3) is also poor and can also be considered brackish. The facts that Lake Marsh and the Big Sioux aquifer are located in the same outwash unit and have similar water quality are evidence for a good hydraulic connection between Lake Marsh and the Big Sioux aquifer in this area.

This surface water/ground water connection is also evidenced by the brackish water intrusion from Lake Marsh into the Hayti city wells. As stated previously, both the city of Hayti and Lake Marsh are located on outwash terrain. The total dissolved solids, hardness, and sulfate concentrations have increased drastically over time in the municipal water system. Further investigation showed that the heavy pumping of the municipal wells had induced recharge from Lake Marsh.

Prairie Coteau Aquifer

The Prairie Coteau aquifer is a buried and confined aquifer composed of medium sand to medium gravel and underlies the eastern portion of the study area. Locations of wells installed in this aquifer are shown on figure 2. Generally, the sand and gravel unit is located 82 to 137 feet below ground and ranges in thickness from 9 feet (CO-83-134) to 44 feet (CO-83-133).

Water samples were collected from six monitoring wells installed in the Prairie Coteau aquifer for this investigation in the Hayti area. Table 4 and figure 5 indicate that the quality of water in the Prairie Coteau aquifer is variable in this area. In water collected from monitoring wells, total dissolved solids ranged in concentration from 529 to 4,000 mg/L, hardness ranged from 509 to 1,901 mg/L, sulfate ranged from 251 to 2,380 mg/L, and iron ranged from <0.05 to 0.34 mg/L.

Castlewood Area

Big Sioux Aquifer

In the Castlewood area (fig. 6), the Big Sioux aquifer is a surficial, unconfined aquifer composed of fine sand to medium gravel and underlies portions of the study area. The sand and gravel range in thickness from 9 feet (CO-83-109) to 36 feet (CO-83-100). Saturated thickness of the Big Sioux aquifer on October 11 and 16, 1983, varied from 9 feet (CO-83-109) to 36 feet (CO-83-100).

Water samples were collected from 19 monitoring wells installed in the Big Sioux aquifer for this investigation in the Castlewood area (table 4). Table 4 and figure 7 indicate that the quality of water in the Big Sioux aquifer is generally good in this area. In water collected from monitoring wells, total dissolved solids ranged in concentration from 330 to 1,225 mg/L, hardness ranged from 243 to 839 mg/L, sulfate ranged from 69 to 348 mg/L, and iron ranged from <0.05 to 0.85 mg/L.

In July 1983, nitrate concentrations ranged from <0.05 to 60 mg/L (table 4 and fig. 8). For reference, the drinking water standard for public water systems is 10 mg/L for nitrate (U.S. Environmental Agency, 1994). Of the 19 monitoring wells sampled for this study, 5 wells had nitrate concentrations above 10 mg/L. As shown on figure 8, the elevated nitrate concentrations are not found in one specific area.

POSSIBLE AREAS FOR FURTHER INVESTIGATION

Big Sioux Aquifer – Hayti Area

An area southeast of Hayti in the central portion of the east half of sec. 35, T. 114 N., R. 53 W. (fig. 3) may warrant further investigation. At monitoring well R2-83-146 (fig. 2), the thickness of the sand and gravel is 36 feet and the saturated thickness on October 17, 1985, was 25.3 feet. Water collected from this monitoring well had a hardness concentration of 502 mg/L, a sulfate concentration of 280 mg/L, an iron concentration of <0.05 mg/L, and a nitrate concentration of <0.05 mg/L. It should be noted, however, that poorer ground water quality does exist in the area (fig. 3).

Prairie Coteau aquifer – Hayti area

An area that may contain sufficient saturated thickness of the Prairie Coteau aquifer for development of wells is east of Hayti in the southeast quarter of sec. 23, T. 114 N., R. 53 W. and in the northeast quarter of sec. 26, T. 114 N., R. 53 W. (fig. 5). At monitoring wells CO-83-136 and CO-83-137 (fig. 2), the sand and gravel unit was found to be 26 and 27 feet thick, respectively. Because the Prairie Coteau aquifer is confined, the entire sand and gravel unit is saturated. However, the quality of water in the aquifer is not as good as that in the Big Sioux aquifer described previously.

As shown on figure 5, water quality varies from the north end of the recommended area (CO-83-136) to the south end of the recommended area (CO-83-137). Generally, water collected from monitoring well CO-83-136 is of better quality than water collected from well CO-83-137. Water collected from these two monitoring wells had total dissolved solids concentrations of 529 mg/L and 1,360 mg/L, respectively, hardness concentrations of 509 mg/L and 1,107 mg/l, respectively, and sulfate concentrations of 251 mg/L and 780 mg/L, respectively. Iron concentrations were <0.05 mg/L in water collected from both monitoring wells. There was no other well in the Prairie Coteau aquifer that had water quality as good as the quality in well CO-83-136 (fig. 5).

Big Sioux Aquifer – Castlewood Area

Three recommended areas west and north of Castlewood (fig. 7) may warrant further investigation. In these areas, the thickness of the sand and gravel ranges from 18 feet (CO-83-121) to 36 feet (CO-83-100). The saturated thickness of the Big Sioux aquifer on October 11 and 16, 1985, ranged from 18 feet (CO-83-121) to 36 feet (CO-83-100). Water collected from monitoring wells in these areas (CO-83-100, CO-83-102, and CO-83-121) had total dissolved solids concentrations ranging from 370 to 462 mg/L, hardness ranging from 271 to 324 mg/L, sulfate ranging from 74 to 136 mg/L,

iron ranging from <0.05 to 0.08 mg/L, and nitrate ranging from <0.05 to 5.7 mg/L. It should be noted, however, that poorer quality ground water does exist in the area (figs. 7 and 8).

GENERAL COMMENTS

If the Big Sioux aquifer is considered for development of a new water supply, it must be kept in mind that this aquifer is vulnerable to surface sources of contamination. The existing water quality problems at Hayti are evidence of this. Although the quality of water in the areas identified for possible further investigation may be currently acceptable for municipal use, there is no guarantee that the quality might not degrade either by inducement of surrounding poorer quality water due to water withdrawal from municipal wells or by land use practices over the aquifer.

Prior to the installation of a production well, further test drilling should be performed in the area of interest to verify the extent and thickness of the aquifer. The installation of additional wells for the testing of water quality would also be useful in documenting aquifer conditions. If the city of Hayti or the Sioux Rural Water System should decide to develop a wellfield in any of the described areas, it is suggested that an aquifer test be conducted to assist in estimating long term water yield from the aquifer. Recommendations on the pumping rate and well spacing will be based on the results of the aquifer test. Water samples should also be collected during the aquifer test for complete chemical analysis.

As of February 1997, the Sioux Rural Water System is utilizing water produced from three wells (Doug Anderson, Sioux Rural Water System, personal communication, 1997). Two wells are located in sec. 34, T. 115 N., R. 52 W., and one well is located in sec. 3, T. 114 N., R. 52 W. The wells are installed in the Big Sioux aquifer. The Sioux Rural Water System has also received a permit for four additional wells in sec. 34, T. 115 N., R. 52 W. The four new wells will also be installed in the Big Sioux aquifer. On June 13, 1994, the city of Hayti joined the Sioux Rural Water System.

REFERENCES

Kume, J., 1985, *Water resources of Deuel and Hamlin Counties, South Dakota*: U.S. Geological Survey, Water-Resources Investigations Report 84-4069, 53 pp.

U.S. Environmental Protection Agency, 1994, *Drinking water regulations and health advisories*: November 1994.

Figure 1. Location of the study area.

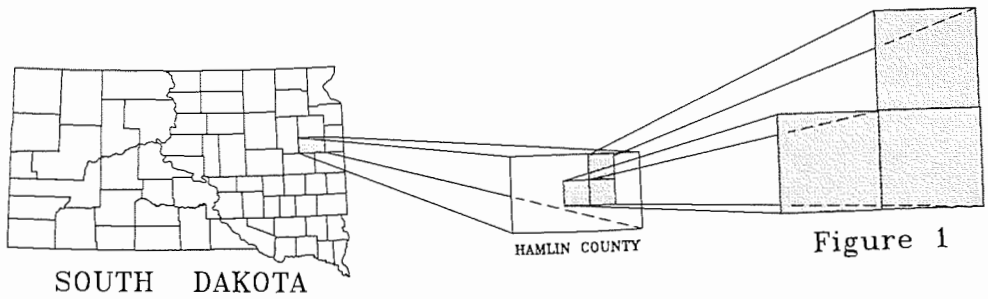
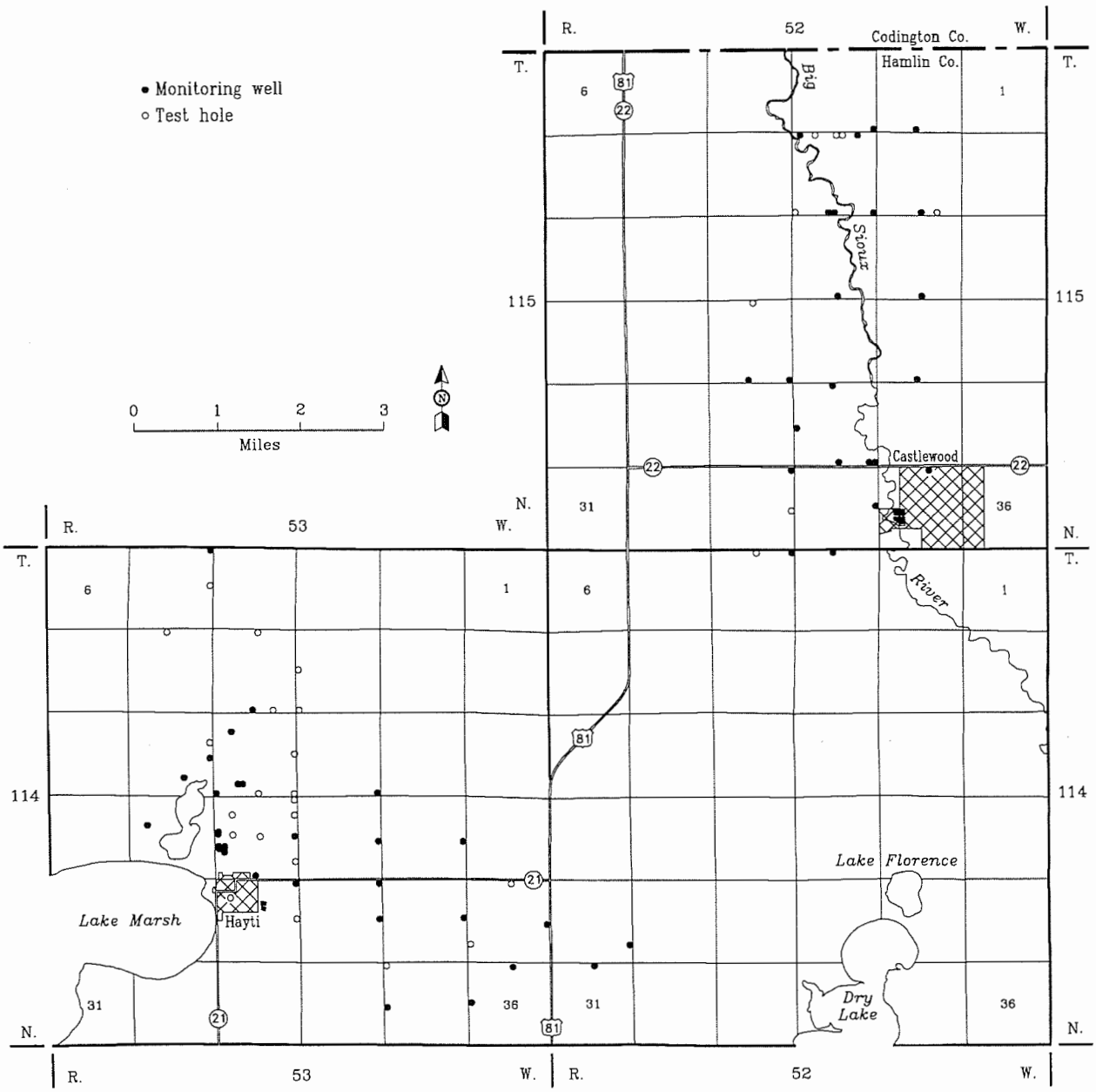
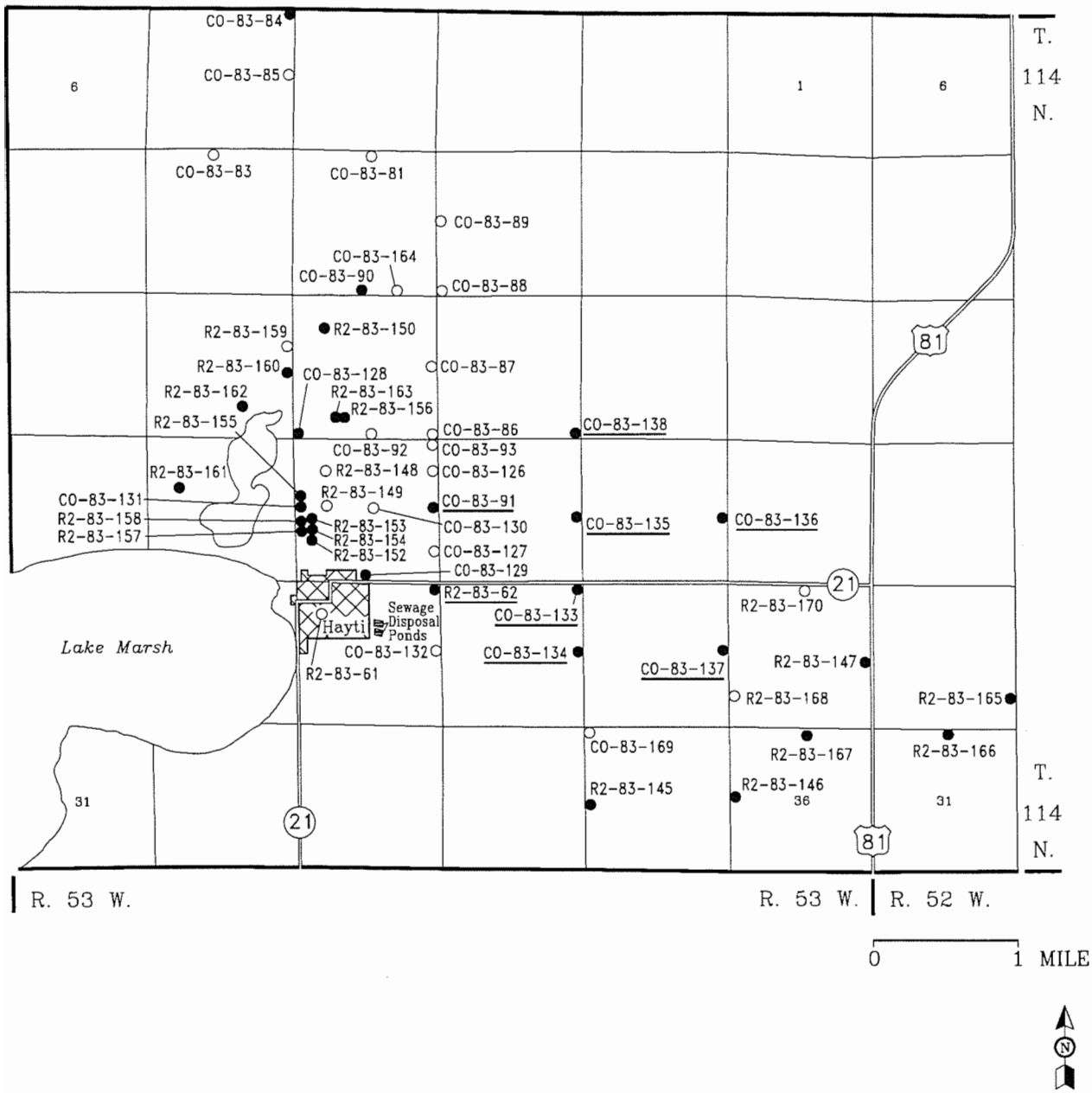


Figure 1



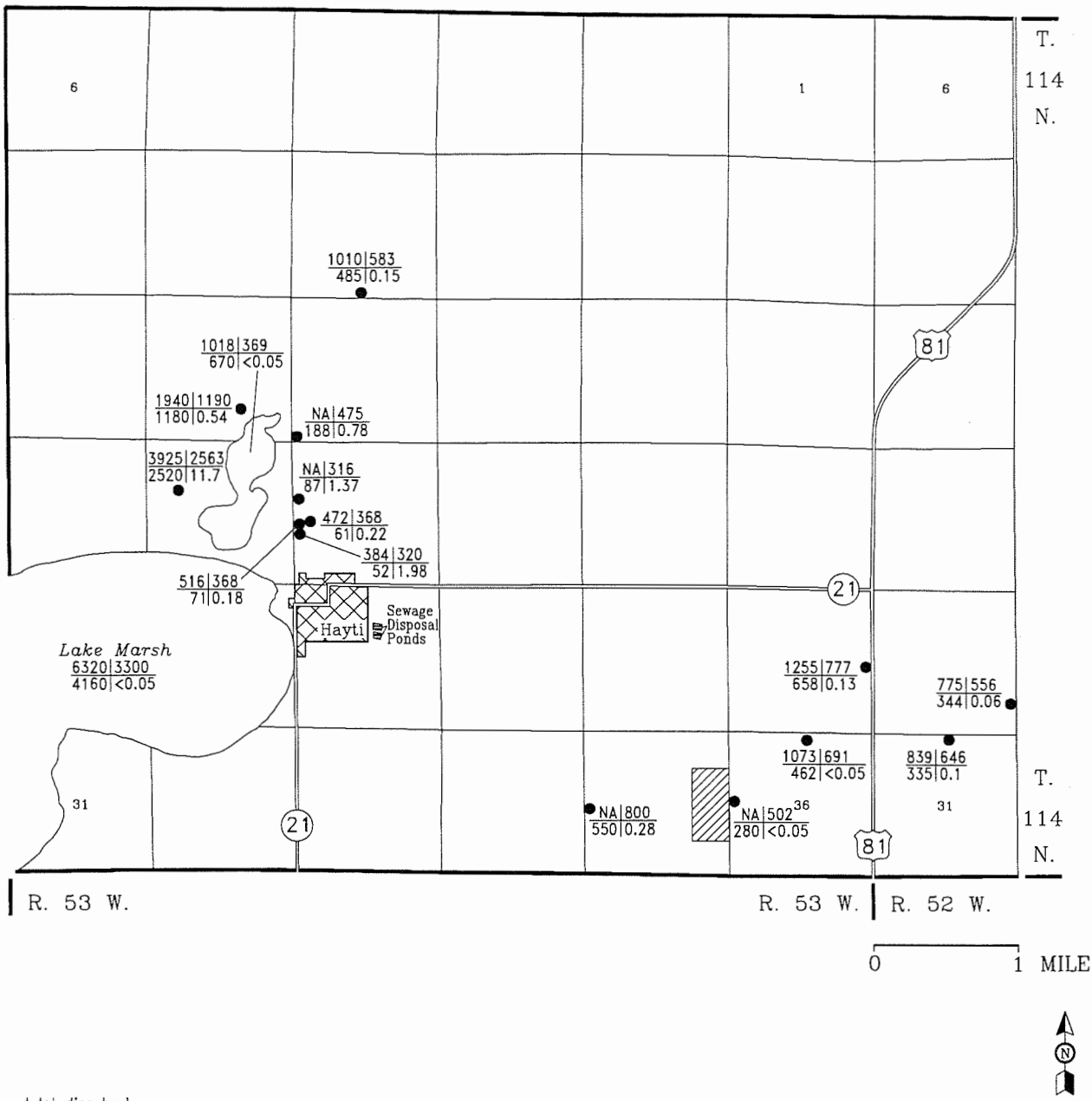


CO-83-134 ● Monitoring well

CO-83-169 ○ Test hole

Letters and numbers are the South Dakota Geological Survey test hole or well identifier. An underline indicates that the well was installed in the Prairie Coteau aquifer. All other wells were installed in the Big Sioux aquifer.

Figure 2. Locations of test holes and monitoring wells in the Hayti area.

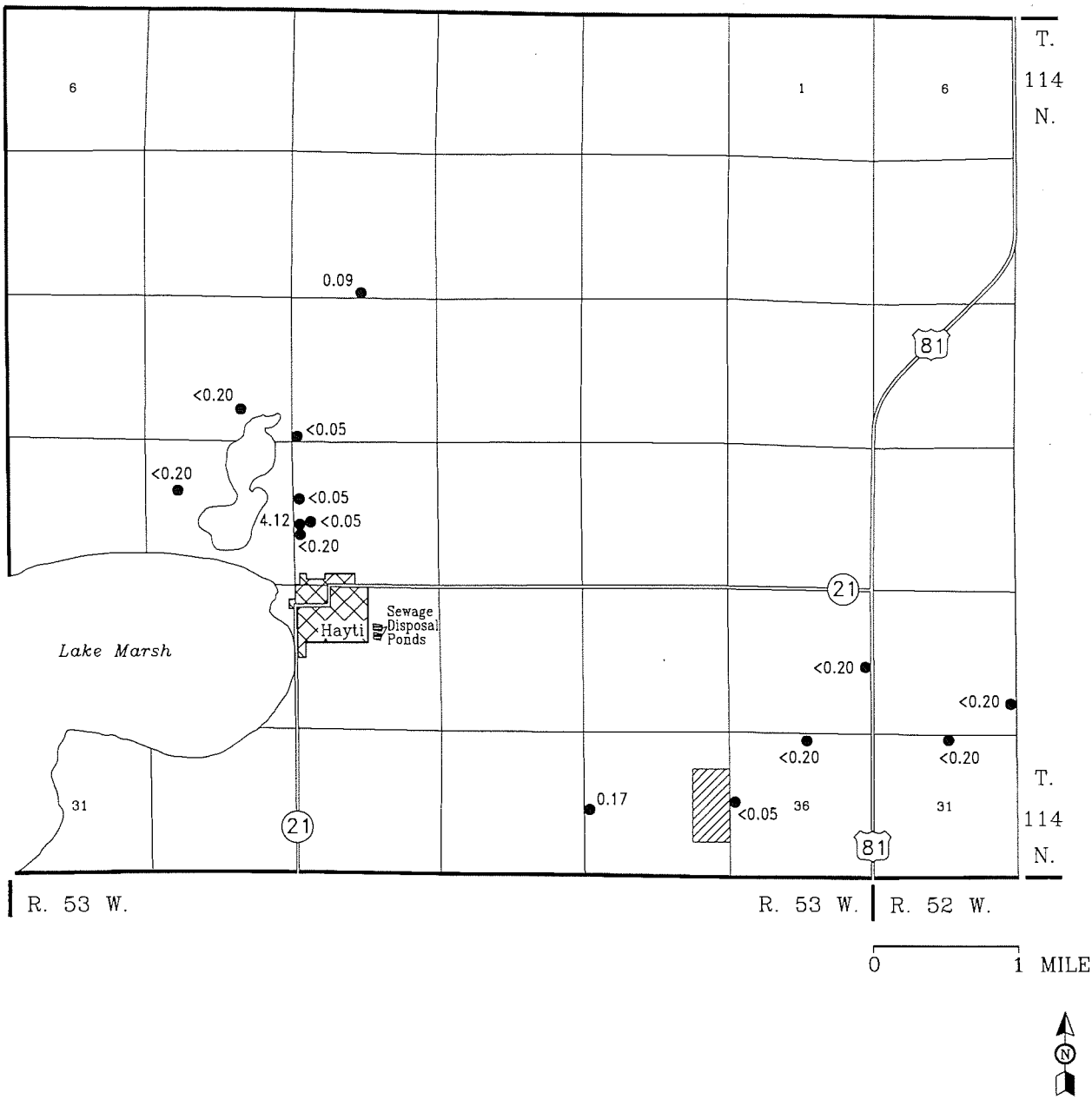


total dissolved solids
hardness
NA|502
280|<0.05
sulfate
iron

Monitoring well. Numbers are concentrations in milligrams per liter. The letters NA indicate that the parameter was not analyzed.

Possible area in the Big Sioux aquifer for further investigation.

Figure 3. Selected water quality parameters and concentrations in the Big Sioux aquifer and Lake Marsh in the Hayti area.



0.09● Monitoring well. Number is nitrate concentration in milligrams per liter.

▨ Possible area in the Big Sioux aquifer for further investigation.

Figure 4. Nitrate concentrations in the Big Sioux aquifer in the Hayti area.

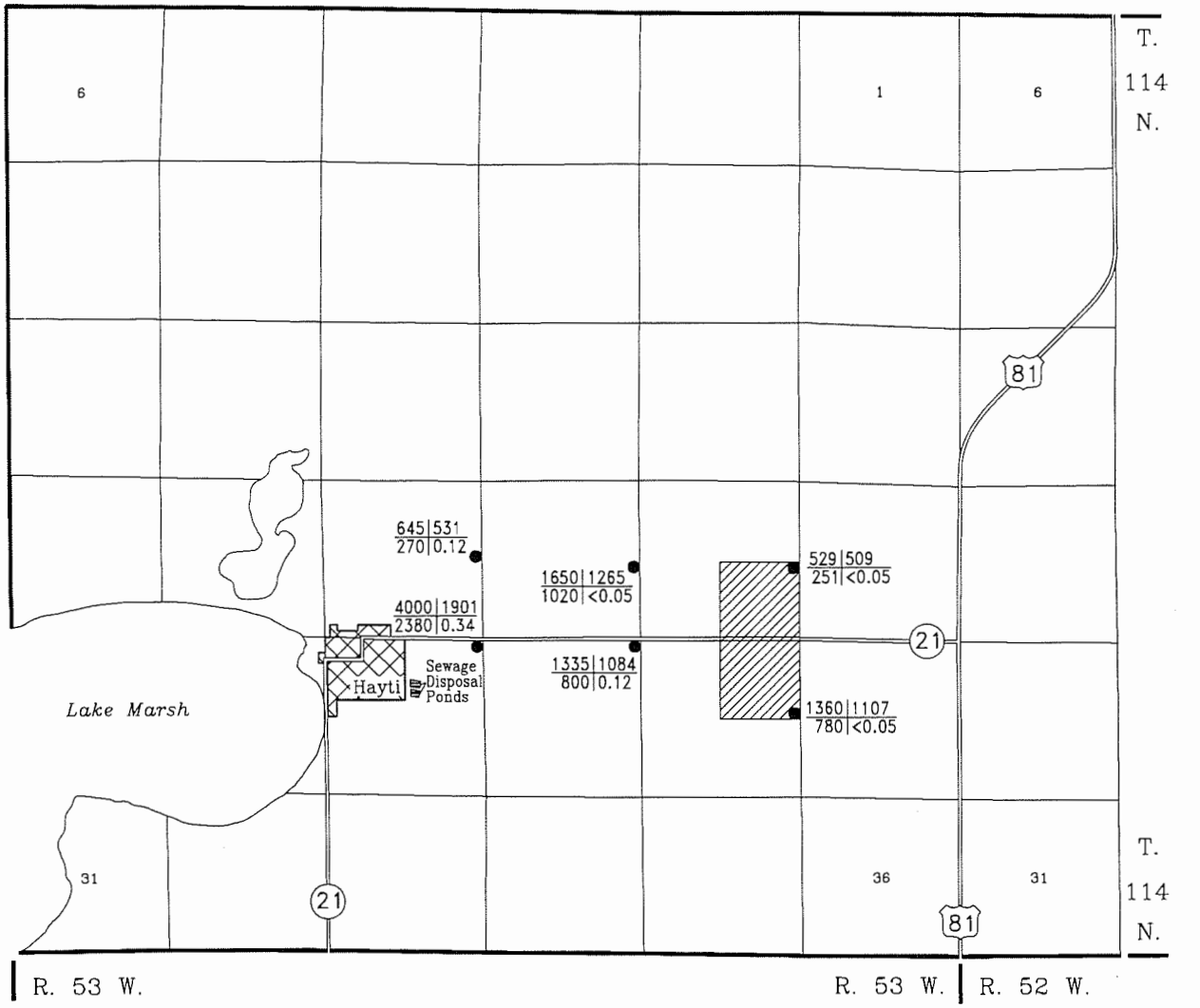


Figure 5. Selected water quality parameters and concentrations in the Prairie Coteau aquifer in the Hayti area.

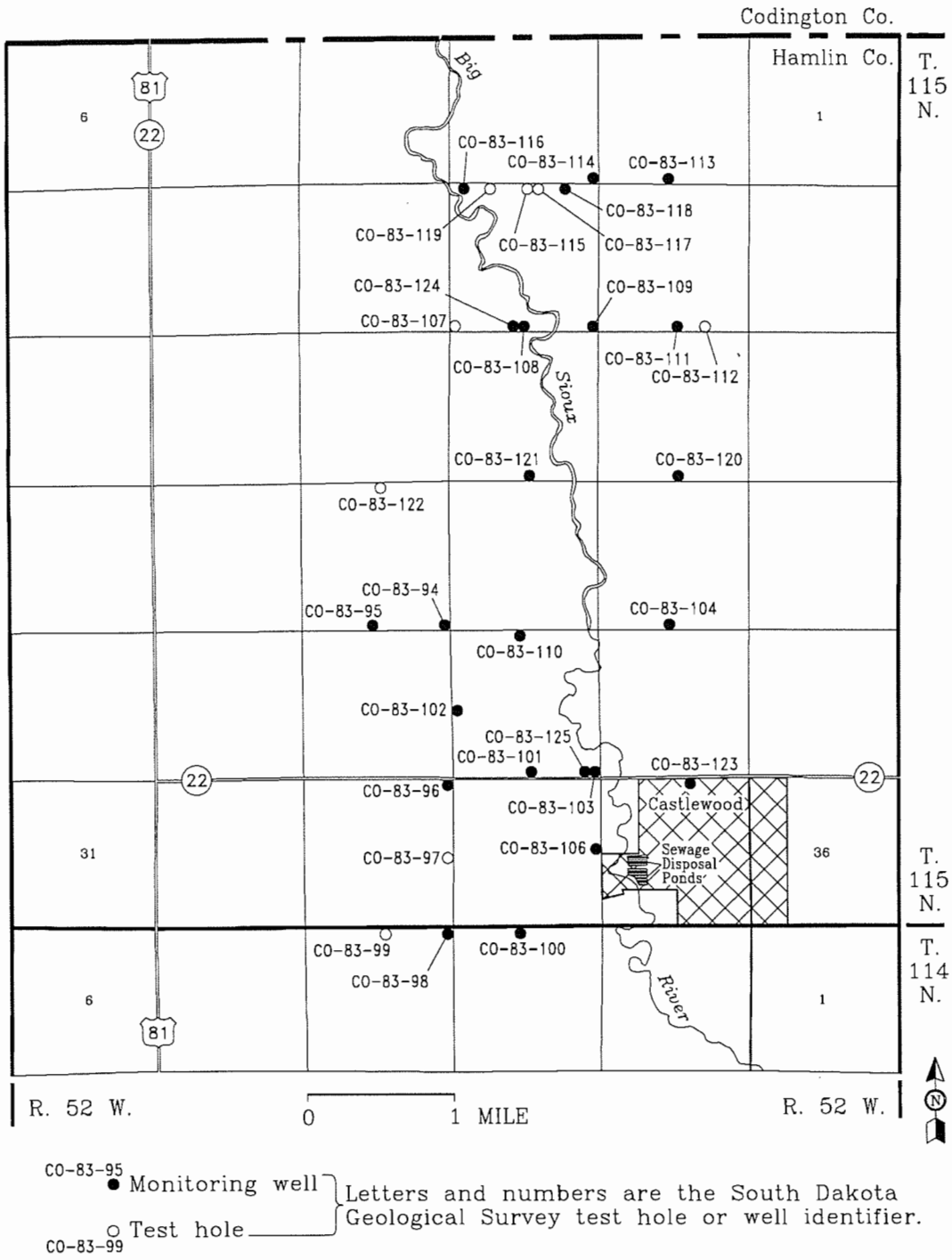


Figure 6. Locations of test holes and monitoring wells in the Castlewood area.

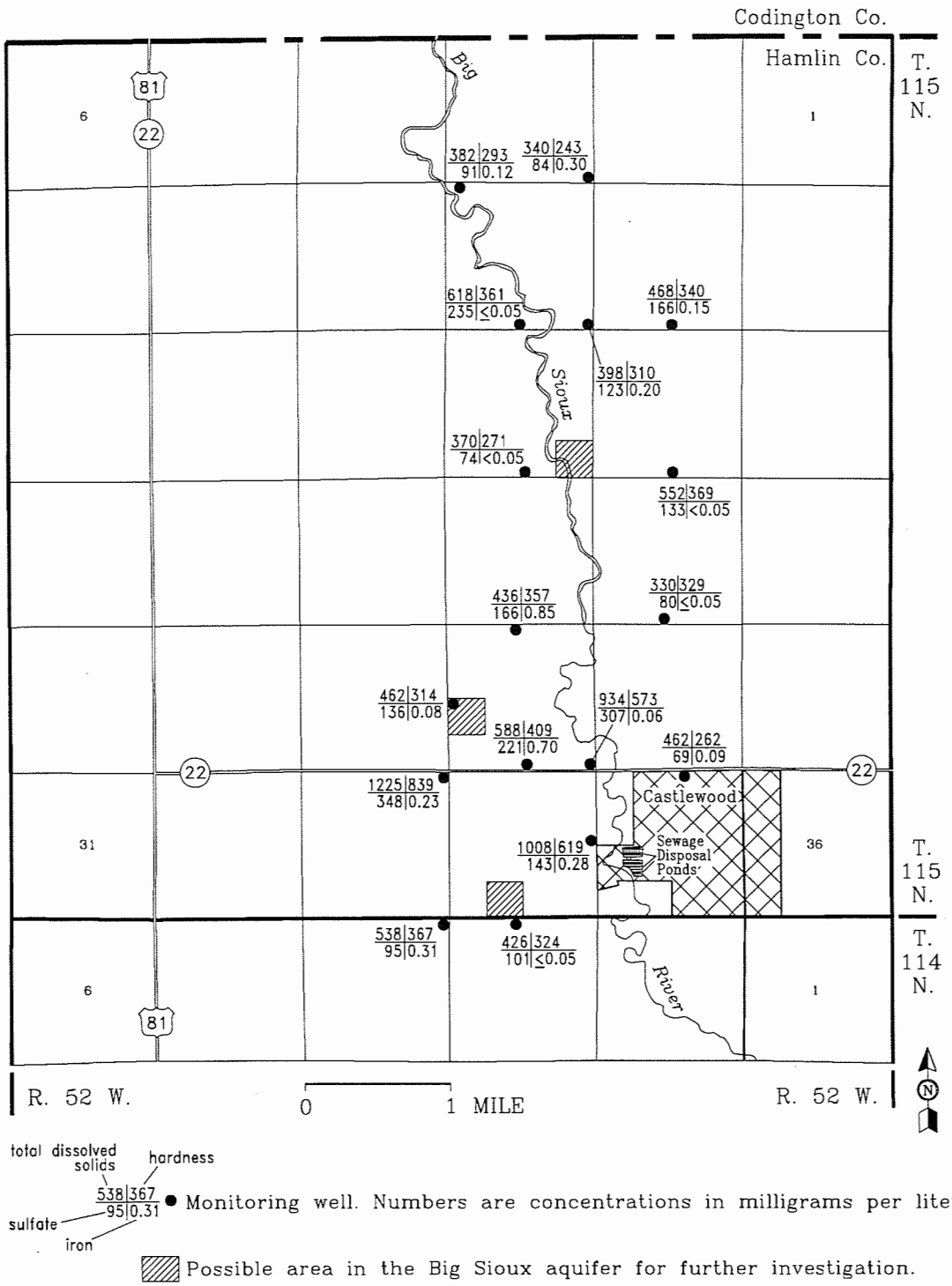
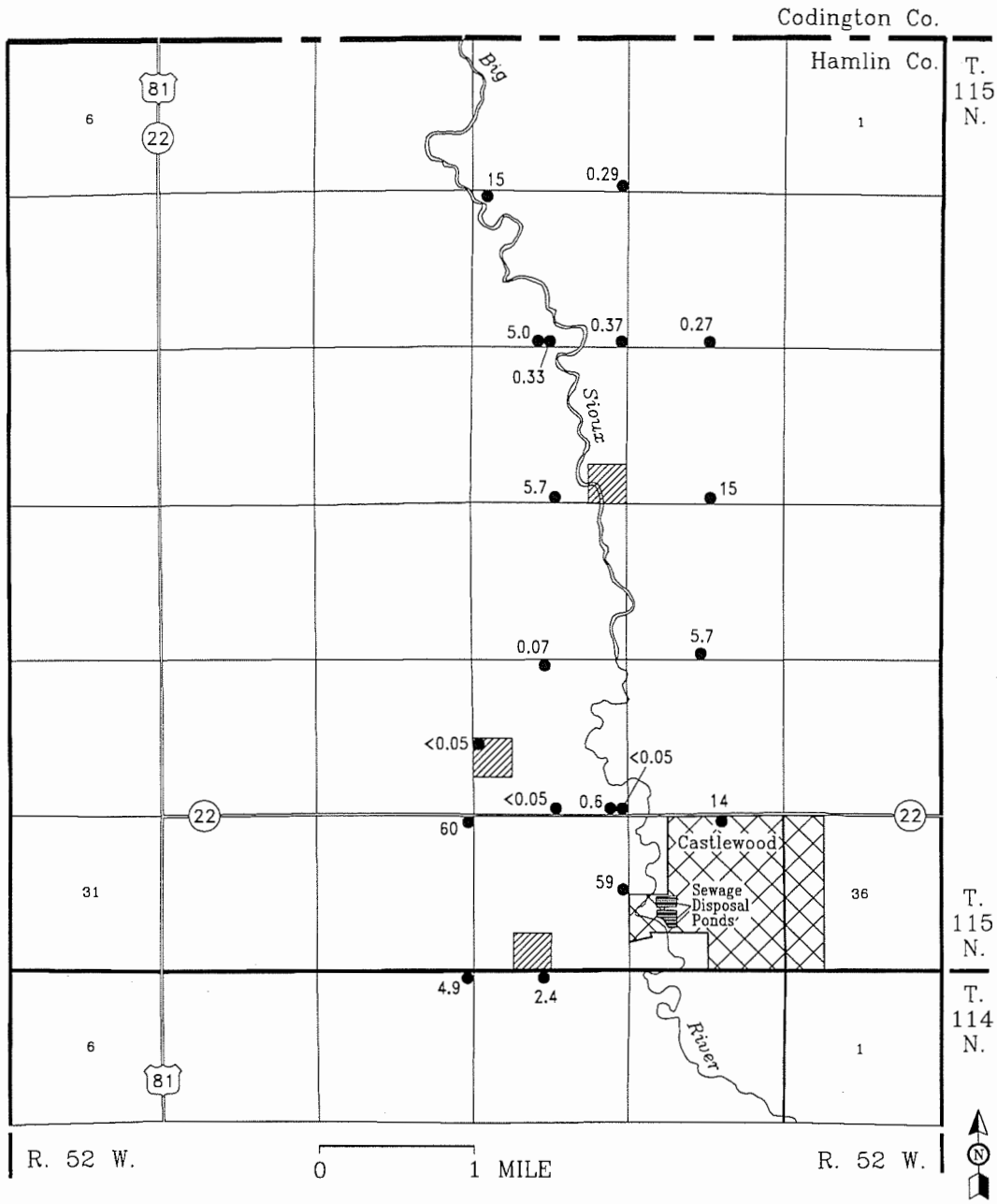


Figure 7. Selected water quality parameters and concentrations in the Big Sioux aquifer in the Castlewood area.



2.4 ● Monitoring well. Number is nitrate concentration in milligrams per liter.

▨ Possible area in the Big Sioux aquifer for further investigation.

Figure 8. Nitrate concentrations in the Big Sioux aquifer in the Castlewood area.

Table 1. Water levels in monitoring wells installed in the Big Sioux aquifer in the Hayti area

Well name	Date	Depth to water below casing top (feet)	Casing top elevation above mean sea level (feet)	Water elevation above mean sea level (feet)
CO-83-165	11/03/83	14.30	1687.6	1673.30
	06/04/85	10.70		1676.90
	10/17/85	9.95		1677.65
R2-83-166	11/03/83	19.10	1697.6	1678.50
	06/04/85	16.18		1681.42
	10/17/85	15.50		1682.10
CO-83-84	07/08/83	18.80	1694.0	1675.20
	06/05/85	2.38		1691.62
	10/17/85	0.70		1693.30
CO-83-90	07/07/83	20.80	1708.5	1687.70
	06/05/85	19.05		1689.45
	10/17/85	18.90		1689.60
R2-83-150	11/02/83	16.40	1692.3	1675.90
	06/05/85	15.17		1677.13
	10/17/85	14.75		1677.55
R2-83-163	11/02/83	7.40	1682.0	1674.60
	06/05/85	16.56		1665.44
	10/17/85	16.03		1665.97
CO-83-128	09/21/83	27.50	1702.2	1674.70
	06/05/85	24.78		1677.42
	10/17/85	24.70		1677.50
R2-83-156	11/03/83	7.36	1682.0	1674.64
	06/05/85	5.20		1676.80
	10/17/85	4.80		1677.20
R2-83-160	11/02/83	6.30	1680.2	1673.90
	06/05/85	5.19		1675.01
	10/17/85	5.04		1675.16
R2-83-162	10/24/83	11.90	1687.3	1675.40
	06/05/85	5.31		1681.99
	10/18/85	9.10		1678.20
R2-83-161	11/02/83	12.10	1682.0	1669.90
	06/05/85	9.80		1672.20
	10/17/85	9.67		1672.23
CO-83-131	10/20/83	30.60	1702.2	1671.60
	06/05/85	27.85		1674.35
	10/17/85	27.92		1674.28
R2-83-155	10/20/83	30.90	1702.1	1671.20
	06/05/85	27.80		1674.30
	10/17/85	27.87		1674.23

Table 1 - continued.

Well name	Date	Depth to water below casing top (feet)	Casing top elevation above mean sea level (feet)	Water elevation above mean sea level (feet)
R2-83-157	11/02/83	10.20	1682.6	1672.40
	06/05/85	6.54		1676.06
	10/18/85	6.82		1675.78
R2-83-158	11/02/83	9.95	1686.9	1676.95
	06/05/85	7.50		1679.40
	10/17/85	6.30		1680.60
R2-83-153	11/02/83	13.96	1681.9	1667.94
	06/05/85	10.68		1671.22
	10/17/85	10.50		1671.40
R2-83-154	11/02/83	13.96	1682.0	1668.04
	06/05/85	10.67		1671.33
	10/17/85	10.49		1671.51
R2-83-152	11/02/83	25.70	1702.1	1676.40
	06/05/85	21.95		1680.15
	10/17/85	21.71		1680.39
CO-83-129	08/05/83	16.90	1691.8	1674.90
	06/04/85	15.74		1676.06
	10/17/85	14.95		1676.85
R2-83-147	11/04/83	14.20	1692.0	1677.80
	06/04/85	12.69		1679.31
	10/17/85	12.04		1679.96
R2-83-145	10/20/83	20.40	1687.4	1667.00
	06/04/85	18.27		1669.13
	10/17/85	18.44		1668.96
R2-83-167	11/03/83	14.60	1691.2	1676.60
	06/04/85	12.46		1678.74
	10/17/85	12.02		1679.18
R2-83-146	10/20/83	17.20	1687.4	1670.20
	06/04/85	15.58		1671.82
	10/17/85	15.08		1672.32

Table 2. Water levels in monitoring wells installed in the Prairie Coteau aquifer in the Hayti area

Well name	Date	Depth to water below casing top (feet)	Casing top elevation above mean sea level (feet)	Water elevation above mean sea level (feet)
CO-83-138	09/21/83	71.00	1757.4	1686.40
	06/05/85	67.67		1689.73
	10/17/85	67.10		1690.30
CO-83-91	07/07/83	34.50	1722.8	1688.30
	06/05/85	26.00		1696.80
	10/17/85	24.59		1698.21
CO-83-135	08/05/83	85.00	1747.0	1662.00
	06/05/85	60.27		1686.73
	10/17/85	59.70		1687.30
CO-83-136	08/04/83	39.05	1722.4	1683.35
	06/05/85	35.62		1686.78
	10/17/85	35.05		1687.35
CO-83-137	08/05/83	19.60	1697.6	1678.00
	06/05/85	15.66		1681.94
	10/17/85	15.10		1682.50
CO-83-133	08/04/83	42.90	1727.6	1684.70
	06/05/85	39.47		1688.13
	10/17/85	38.88		1688.72
CO-83-134	09/21/83	13.68	1692.0	1678.32
	06/05/85	10.94		1681.06
	10/17/85	10.44		1681.56
R2-83-62	06/30/83	40.10	1717.1	1677.00
	06/04/85	17.98		1699.12
	10/17/85	17.15		1699.95

Table 3. Water levels in monitoring wells installed in the Big Sioux aquifer in the Castlewood area

Well name	Date	Depth to water below casing top (feet)	Casing top elevation above mean sea level (feet)	Water elevation above mean sea level (feet)
CO-83-100	11/04/83	4.80	1681.6	1676.80
	06/03/85	3.28		1678.32
	10/11/85	3.28		1678.32
CO-83-98	07/20/83	14.03	1692.5	1678.47
	06/03/85	12.28		1680.22
	10/16/85	11.05		1681.45
R2-83-113	07/26/83	18.40	1712.2	1693.80
	06/03/85	16.22		1695.98
	10/16/85	15.30		1696.90
CO-83-114	07/26/83	3.90	1691.6	1687.70
	06/03/85	1.68		1689.92
	10/16/85	0.00		1691.60
CO-83-118	07/27/83	10.00	1701.6	1691.60
	06/03/85	7.93		1693.67
	10/16/85	6.35		1695.25
CO-83-116	07/27/83	9.90	1696.9	1687.00
	06/03/85	7.85		1689.05
	10/16/85	7.70		1689.20
CO-83-108	07/25/83	7.40	1697.1	1689.70
	06/03/85	5.79		1691.31
	10/16/85	5.90		1691.20
CO-83-124	09/20/83	8.90	1696.8	1687.90
	06/03/85	6.24		1690.56
	10/16/85	5.45		1691.35
CO-83-109	07/25/83	4.50	1692.1	1687.60
	06/03/85	3.79		1688.31
	10/16/85	2.70		1689.40
CO-83-111	07/25/83	7.80	1697.3	1689.50
	06/03/85	6.36		1690.94
	10/16/85	4.74		1692.56
CO-83-120	08/02/83	7.40	1686.8	1679.40
	06/03/85	6.27		1680.53
	10/16/85	5.42		1681.38
CO-83-121	08/02/83	6.10	1687.1	1681.00
	06/03/85	4.21		1682.89
	10/16/85	3.82		1683.28
CO-83-95	07/20/83	15.10	1702.6	1687.50
	06/03/85	14.11		1688.49
	10/16/85	13.61		1688.99

Table 3 - continued.

Well name	Date	Depth to water below casing top (feet)	Casing top elevation above mean sea level (feet)	Water elevation above mean sea level (feet)
CO-83-94	07/20/83	12.40	1691.8	1679.40
	06/03/85	12.17		1679.63
	10/16/85	11.58		1680.22
CO-83-104	07/26/83	8.40	1687.0	1678.60
	06/03/85	6.41		1680.59
	10/16/85	5.27		1681.73
CO-83-110	07/20/83	6.40	1681.8	1675.40
	06/03/85	4.31		1677.49
	10/16/85	4.01		1677.79
CO-83-102	07/26/83	9.80	1686.2	1676.40
	06/03/85	7.43		1678.77
	10/16/85	7.47		1678.73
CO-83-101	07/26/83	5.50	1681.4	1675.90
	06/03/85	3.75		1677.65
	10/16/85	3.00		1678.40
CO-83-103	07/26/83	9.30	1687.0	1677.70
	06/03/85	8.25		1678.75
	10/16/85	7.94		1679.06
CO-83-125	09/20/83	8.95	1687.2	1678.25
	06/03/85	8.23		1678.97
	10/16/85	7.91		1679.29
CO-83-96	07/20/83	11.60	1692.3	1680.70
	06/03/85	9.26		1683.04
	10/16/85	9.14		1683.16
CO-83-106	07/26/83	6.30	1676.8	1670.50
	06/03/85	5.75		1671.05
	10/16/85	5.44		1671.36
CO-83-123	08/03/83	8.40	1692.0	1683.60
	06/03/85	6.80		1685.20
	10/16/85	6.93		1685.07

Table 4. Chemical analyses of water samples

Well name	Date collected	Well depth[2]	Conductivity[3]	Parameter[1] with concentration in milligrams per liter											
				Ca	Mg	Na	K	Fe	Mn	SO_4	Cl	F	NO_3-N + NO_2-N	Hardness as $CaCO_3$	TDS
				--	--	--	--	0.3[4]	0.05[4]	250[4]	250[4]	2.4[5]	10[5]	--	500[4]
HAYTI AREA															
Big Sioux aquifer															
R2-83-165	11/03/83	50	1270	132	55	32	5.0	0.06	1.11	344	3	0.47	< 0.20	556	775
R2-83-166	11/03/83	45	1275	163	58	20	5.6	0.1	0.55	335	31	0.28	< 0.20	646	839
CO-83-90	07/08/83	44	999	128	64	75	7.3	0.15	0.49	485	9	0.34	0.09	583	1010
CO-83-128	10/20/83	53	898	108	50	29	3.9	0.78	0.71	188	4	0.26	< 0.05	475	--
R2-83-162	11/02/83	55	2320	330	89	130	12.2	0.54	2.80	1180	13	0.29	< 0.20	1190	1940
R2-83-161	11/02/83	49	4160	690	204	314	21.8	11.7	5.02	2520	15	0.18	< 0.20	2563	3925
R2-83-155	10/20/83	63	619	82	27	16	5.3	1.37	1.39	87	4	0.13	< 0.05	316	--
R2-83-157	11/02/83	45	665	82	28	14	8.4	1.98	2.07	52	3	0.14	< 0.20	320	384
R2-83-158	11/02/83	16	800	93	33	19	4.6	0.18	0.07	71	13	0.25	4.12	368	516
R2-83-153	11/01/83	40	823	93	33	38	14.9	0.22	0.58	61	7	0.10	< 0.05	368	472
R2-83-147	11/04/83	50	1840	191	73	110	5.3	0.13	1.63	658	20	0.57	< 0.20	777	1255
R2-83-145	10/20/83	66	1329	215	64	50	6.8	0.28	1.22	550	9	0.37	0.17	800	--
R2-83-145	11/03/83	66	--	--	--	--	--	0.56	1.28	--	--	--	--	--	--
R2-83-167	11/03/83	45	1600	168	66	80	4.9	< 0.05	1.13	462	15	0.38	< 0.20	691	1073
R2-83-146	10/20/83	38	995	122	48	53	5.7	< 0.05	0.81	280	8	0.31	< 0.05	502	--
R2-83-146	11/03/83	38	--	--	--	--	--	0.08	0.78	--	--	--	--	--	--
Prairie Coteau aquifer															
CO-83-91	07/07/83	123	1040	135	47	32	3.1	0.12	≤ 0.05	270	3	0.28	2.29	531	645
CO-83-135	08/03/83	157	1840	322	112	61	6.5	< 0.05	2.24	1020	13	0.38	0.39	1265	1650
CO-83-136	08/04/83	132	966	128	46	23	4.3	< 0.05	0.78	251	12	0.22	0.23	509	529
CO-83-137	08/04/83	118	1860	275	102	56	5.4	< 0.05	2.08	780	12	0.31	< 0.05	1107	1360
CO-83-137	08/08/83	118	1020	148	53	24	3.6	< 0.05	0.20	355	5	0.14	0.44	588	768
CO-83-133	08/04/83	134	1870	266	102	55	5.0	0.12	1.98	800	12	0.25	0.12	1084	1335
R2-83-62	06/30/83	158	4270	440	195	420	12.5	0.34	1.56	2380	49	0.47	0.25	1901	4000
Surface water															
--	10/12/83	--	1532	141	88	82	20.9	< 0.05	0.06	670	18	0.21	< 0.05	369	1018
--	10/12/83	--	5784	616	428	496	94.4	< 0.05	< 0.05	4160	68	0.17	< 0.05	3300	6320

Table 4 - continued.

Well name	Date collected	Well depth[2]	Conductivity[3]	Parameter[1] with concentration in milligrams per liter											
				Ca	Mg	Na	K	Fe	Mn	SO_4	Cl	F	NO_3-N + NO_2-N	Hardness as $CaCO_3$	TDS
				--	--	--	--	0.3[4]	0.05[4]	250[4]	250[4]	2.4[5]	10[5]	--	500[4]
CASTLEWOOD AREA															
Big Sioux aquifer															
CO-83-100	07/27/83	41	671	87	26	17	4.0	≤ 0.05	0.07	101	6	0.27	2.4	324	426
CO-83-100	11/04/83	41	--	--	--	--	--	0.34	0.07	--	--	--	--	--	--
CO-83-98	07/27/83	37	773	91	34	21	2.3	0.31	0.08	95	5	0.28	4.9	367	538
CO-83-114	07/29/83	25	521	53	27	19	2.2	0.30	0.37	84	6	0.25	0.29	243	340
CO-83-116	07/29/83	27	670	68	30	26	2.7	0.12	0.05	91	27	0.21	15	293	382
CO-83-108	07/28/83	31	974	87	35	71	5.4	≤ 0.05	0.72	235	50	0.40	0.33	361	618
CO-83-124	09/21/83	14	--	--	--	--	--	--	--	--	--	--	5.0	--	--
CO-83-109	07/28/83	23	640	65	36	19	1.6	0.20	0.30	123	6	0.31	0.37	310	398
CO-83-111	07/28/83	25	724	75	37	26	5.6	0.15	0.47	166	11	0.14	0.27	340	468
CO-83-120	08/03/83	20	720	77	43	28	1.6	< 0.05	< 0.05	133	6	0.30	15	369	552
CO-83-121	08/03/83	22	554	64	27	13	2.5	< 0.05	0.13	74	11	0.21	5.7	271	370
CO-83-104	07/28/83	35	697	74	35	21	1.4	≤ 0.05	0.43	80	14	0.27	5.7	329	330
CO-83-110	07/28/83	20	752	82	37	22	2.4	0.85	0.51	166	5	0.26	0.07	357	436
CO-83-102	07/28/83	36	792	68	35	48	6.3	0.08	0.70	136	16	0.24	< 0.05	314	462
CO-83-102	11/04/83	36	--	--	--	--	--	1.20	0.90	--	--	--	--	--	--
CO-83-101	07/28/83	30	959	101	38	50	5.4	0.70	0.80	221	16	0.37	< 0.05	409	588
CO-83-101	11/04/83	30	--	--	--	--	--	0.84	0.80	--	--	--	--	--	--
CO-83-103	07/28/83	21	1260	129	61	55	6.9	0.06	0.80	307	60	0.23	< 0.05	573	934
CO-83-125	09/21/83	14	--	--	--	--	--	--	--	--	--	--	0.6	--	--
CO-83-96	07/28/83	27	2100	209	77	129	6.7	0.23	0.26	348	167	0.33	60	839	1225
CO-83-106	07/27/83	26	1650	139	66	53	91	0.28	0.09	143	71	0.13	59	619	1008
CO-83-106	09/21/83	26	--	--	--	--	--	--	--	--	--	--	64	--	--
CO-83-123	08/03/83	22	691	62	26	46	2.9	0.09	< 0.05	69	26	0.20	14	262	462

[1] **Ca** - calcium; **Mg** - magnesium; **Na** - sodium; **K** - potassium; **Fe** - iron; **Mn** - manganese; **SO_4** - sulfate; **Cl** - chloride; **F** - fluoride; **NO_3-N + NO_2-N** - nitrate-nitrogen + nitrite-nitrogen; **Hardness as $CaCO_3$** - hardness as calcium carbonate; **TDS** - total dissolved solids.

[2] Well depth is presented in feet below casing top.

[3] Conductivity is presented in micromhos per centimeter.

[4] U.S. Environmental Protection Agency (1994). Secondary maximum contaminant levels. Recommended limits.

[5] U.S. Environmental Protection Agency (1994). Maximum contaminant levels. Enforceable limits.