WATER SUPPLY INVESTIGATION FOR THE RAMSEY RURAL WATER PROJECT PORTIONS OF BENSON, RAMSEY, EDDY AND NELSON COUNTIES, NORTH DAKOTA

by

Steve W. Pusc

North Dakota Ground-Water Studies
Number 100
North Dakota State Water Commission
David Sprynczynatyk, State Engineer

Prepared by the
North Dakota State Water Commission
In cooperation with the
Ramsey County Water Resources District

ND State Water Commission

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INTRODUCTION

General statement

In February of 1991, the Ramsey County Water Resource District contacted the North Dakota State Water Commission requesting a brief summary of the ground-water resources of northeastern Benson County. The Water Resource District is exploring the area for the location of a well field to serve their proposed Ramsey County Rural Water Project.

In March of 1991, a report summarizing the ground-water resources of northeastern Benson county was completed(Pusc, 1991). On April 10, 1991, the report was presented at a meeting of the Ramsey County Water Resource Board. The main conclusions from the report were as follows:

"Based on an analyses of the available data, it appears that the area as specified as an alternative water source for the Ramsey Rural Water District warrants further examination. Aquifers in the area of interest (Spiritwood aquifer near Warwick and Warwick aquifer) have sufficient saturated thickness, large enough areal extent, favorable water level responses, good to excellent water quality and favorable recharge characteristics to consider the area for further development. Additional drilling and testing would be needed ,however, to sufficiently identify an area capable of sustaining the long term appropriation of good quality ground water."

At the April 10, 1991 meeting, the Ramsey County Water Resource Board requested that the State Water Commission prepare a proposal for the detailed investigation of the Spiritwood and Warwick aquifers in northeastern Benson county with special emphasis on selecting an area that will serve the long term water quantity and quality needs of the Ramsey County Rural Water Project. A proposal was completed and submitted in June of 1991.

A cost sharing agreement between the Ramsey County Water Resources District and the North Dakota State Water Commission was entered into in July of 1991, for the purpose of a survey, investigation and study of the Spiritwood and Warwick Aquifers in portions of Ramsey, Benson and Nelson Counties. The investigation consisted of five parts: 1). preliminary planning, 2). test drilling and observation well construction, 3). water quality sampling and analyses, 4). surveying for elevation control and 5). report preparation. The purpose of this report is to describe the work conducted, summarize the data collected, provide an interpretation of the ground-water conditions and to provide recommendations for the development of a water supply to serve the proposed rural water system.

Estimated water requirements

The Ramsey Rural Water feasibility study calls for an initial demand of 500,000 to 1,000,000 gallons per day or 560 to 1,120 acre-feet per year. The proposal calls for the construction of a 600 gpm transmission pipe line. A continuos pumping rate of 600 gpm would produce 967.8 acre-feet over an entire year.

Description of study area

The area of this ground-water investigation is located along the southeastern edge of the Devils Lake Basin in northeastern North Dakota (figures 1 and 2). The Devils Lake basin is a 3,800 square mile closed basin which is a non contributing part of the Red River of the North drainage (figure 1).

Specifically, the Ramsey Rural Water study area is located in an area that covers portions of northeastern Benson county, southeastern Ramsey county, western Nelson county and northeastern Eddy county (figure 3). The Sheyenne River is the southern boundary of this ground-water investigation (figures 1, 2 and 3).

Topography and Drainage

The study area is located on the topographic divide between East Devils Lake to the northwest and the Sheyenne River to the south (figure 2). The area is characterized by a range of steep hills to the north (Devils Lake Mountain and Blue Mountain), a gently rolling to flat area in the center and steep valley walls overlooking the Sheyenne River. Several small tributaries to the Sheyenne river drain portion of the study area. Tolna coulee is the largest of these tributaries (figure 3). Elevations range from 1590 feet at the crest of Devils Lake Mountain to 1355 feet along the Sheyenne River (figure 2).

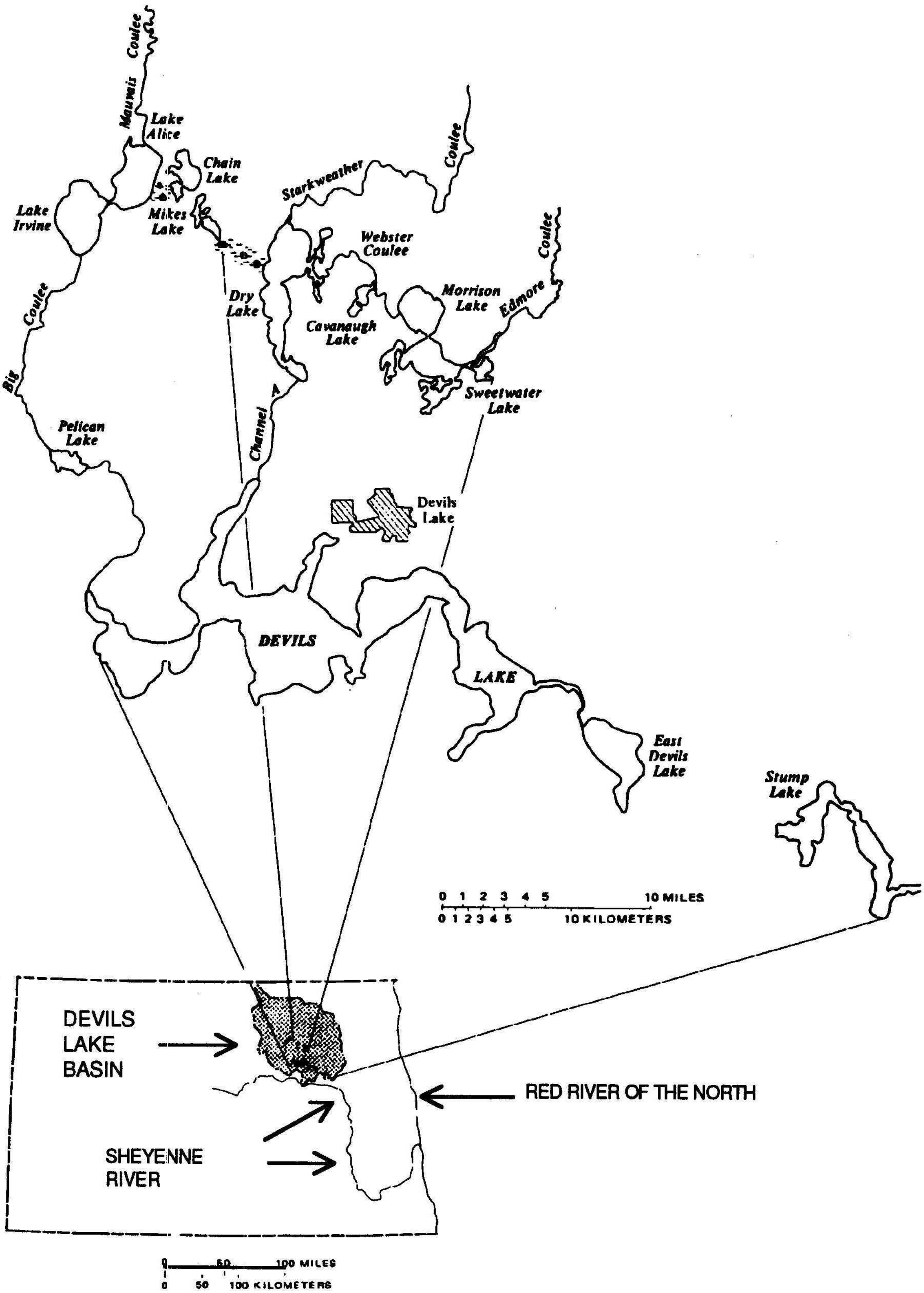


FIGURE 1. Location of the Devils Lake Basin, North Dakota (modified from Ryan and Wiche, 1988)

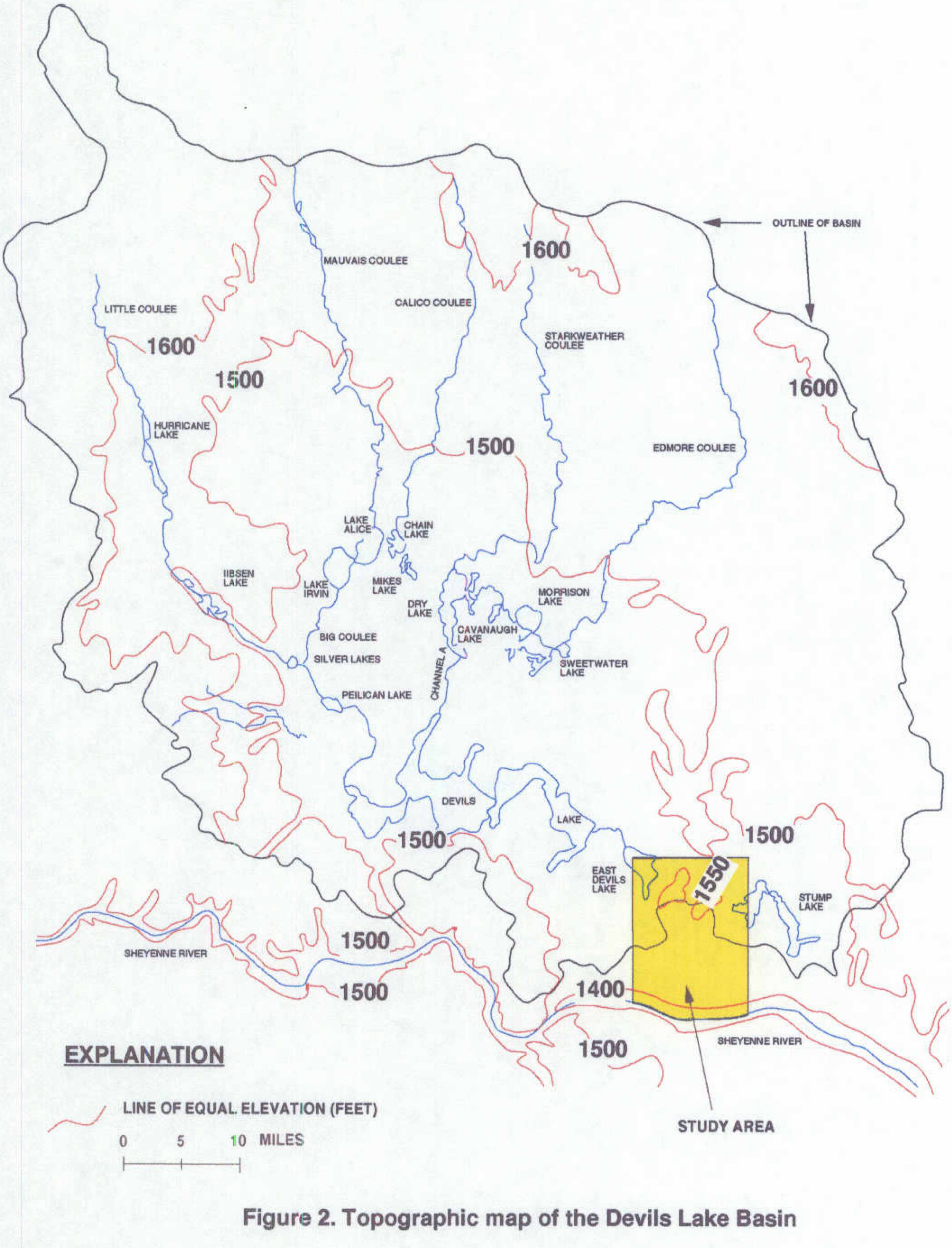


Figure 2. Topographic map of the Devils Lake Basin

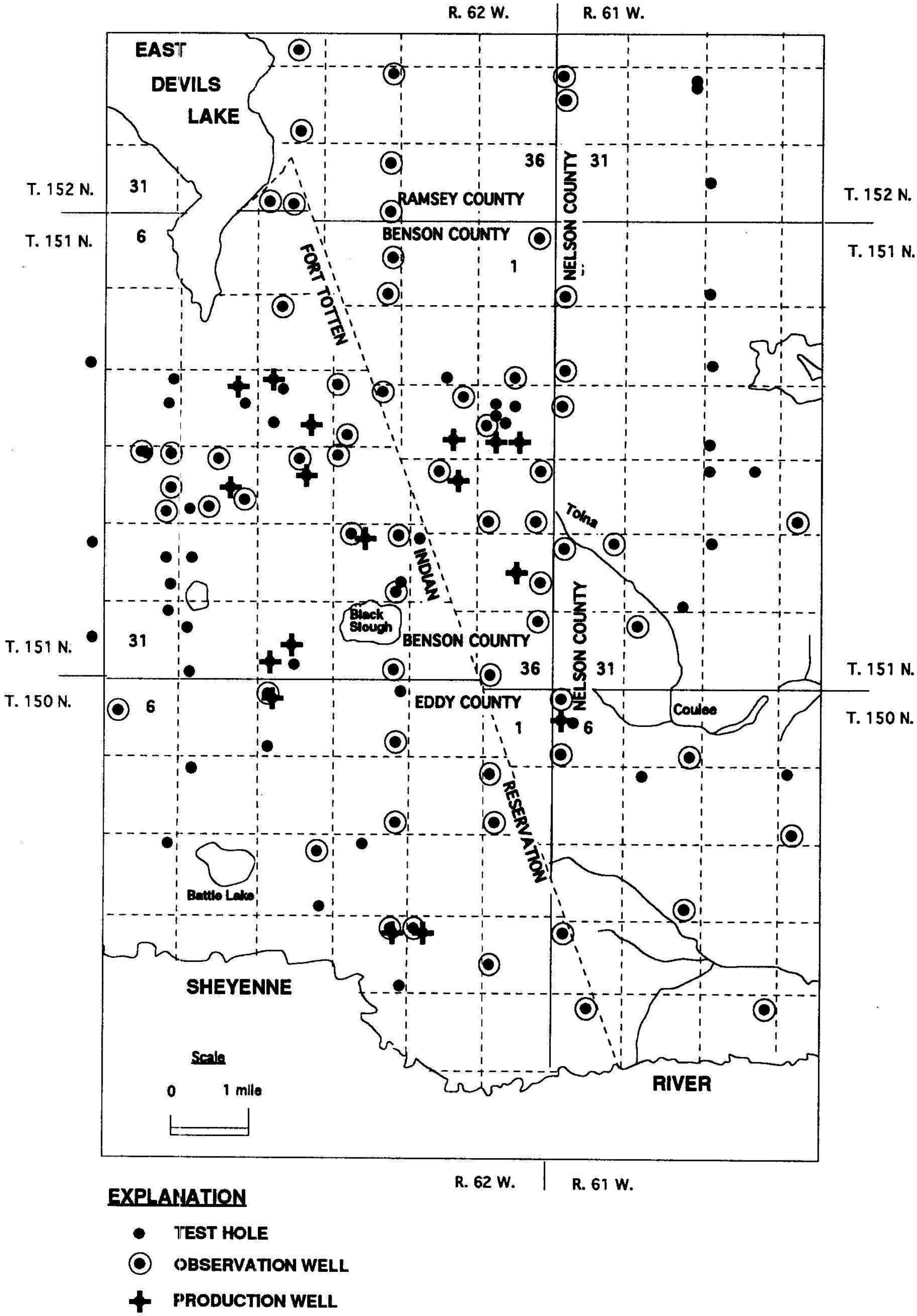


FIGURE 3. LOCATION OF TEST HOLES, OBSERVATION WELLS AND PRODUCTION WELLS IN THE RAMSEY RURAL WATER STUDY AREA

Previous Investigations

Paulson and Akin (1964) described the ground-water resources of the Devils Lake area. The primary purpose of their investigation was to determine whether or not an adequate supply of potable water could be obtained from ground water in the region to serve the city of Devils Lake. A discussion of the Warwick aquifer is included in their report.

The North Dakota State Water Commission (NDSWC), in cooperation with the United States Geological Survey (USGS), the North Dakota Geological Survey (NDGS), and various County Water Management Districts conducted ground-water surveys of Benson and Pierce Counties, Ramsey County, Eddy and Foster County and Nelson and Walsh Counties. The Part I's, Geology, are comprehensive investigations of the surficial geology and general discussions of the subsurface geology (Bluemle, 1965, Bluemle, 1973, Carlson, 1975 and Hobbs, 1987). The Part II's, Basic Data, includes inventories of test holes, well logs, water level measurements and chemical analyses (Downey, 1971, Hutchinson, 1977, Randich, 1971 and Trapp, 1966). The Part III's, Ground-Water Resources, present general evaluations of the water yielding potential and chemical quality of major bedrock, glacial drift and alluvial aquifers in the various counties (Downey, 1973, Hutchinson, 1980, Randich, 1977 and Trapp, 1968).

A water budget investigation of Devils Lake, conducted by the NDSWC and the U.S.G.S., describes the hydrogeology of a large portion of the Devils Lake Basin (Pusc, 1992). The Ramsey Rural Water Study Area is included in this discussion.

Methods of Study

Hydrogeologic investigation of the Ramsey Rural Water study area was accomplished by test drilling at 9 sites, installing 16 observation wells and measuring and recording depth to water in the 16 new observation wells. Other data collected included: (1) measuring water levels in 59 existing observation wells and (2) collecting and analyzing ground-water samples from all the observation wells and from select irrigation and municipal wells in the area. Locations of the test holes, observation wells, irrigation wells and municipal wells are presented in figure 3.

Test holes were drilled with a Failing 1250 forward mud rotary drilling rig owned by the NDSWC. Lithologies were described and geophysical logs made. Pertinent data for these test holes and observation wells are presented in Table 1. Observation well construction is described below.

Nests of observation wells were constructed specifically for this study to aid in determining vertical ground-water flow and chemistry. The observation wells were constructed of either 1 $^{1}/_{4}$ inch or 2 inch diameter polyvinyl chloride (PVC) casing with 5 or 10 foot long PVC screens. Construction of the observation well nests involved the drilling of an initial test hole through the glacial drift and into the shale bedrock. Information from the initial test hole was used to determine the number and depth of the other observation wells that were required at each site. The initial test hole also served as a hole for the deepest observation well. First, the desired length of casing and screen were inserted into the test hole. Silica sand was then placed around the screen using a tremie pipe. After sand packing, the tremie pipe was lifted so that the bottom of the tremie pipe was above the top of the sand pack. Neat cement grout was then injected down the tremie pipe and upward in the annular space. This process continued until the grout overflowed around the casing at land surface. The grout was allowed to "set" and then the observation wells were slugged with a small quantity of fresh water and pumped with air for development. Subsequent observation wells were completed at each nest site by moving the drilling rig ahead 15 to 20 feet and drilling the next hole.

Depth to water measurements were recorded on a monthly basis in the new and existing observation wells. Water levels were measured with chalked steel tapes. Depth to water data are presented in Table 2.

Third order differential leveling was used to establish the elevation to mean sea level of each observation well. The elevations at the top of the casing and at land surface were determined to the nearest 0.01 foot. This information, along with the water level data, were used to construct water level maps and hydrographs.

Water samples were collected from all of the observation wells and from selected irrigation and municipal wells. The water sampling procedure involved the collection of 500 milliliters (ml) of raw water, 500 ml of filtered water, 500 ml of filtered and acidified (nitric acid) water and 500 ml of filtered and double acidified water. The samples were analyzed for major anion and cation concentrations and selected trace elements. Chemical analyses were performed at the North Dakota State Water Commission Lab. Chemical analyses of ground water from selected wells in the area are presented in Table 3.

Location numbering system

Wells and test holes presented on figure 3 are numbered according to a system based on the location in the public land classification of the United States Bureau of Land Management (figure. 4). 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 is located. Letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter section (10 acre tract). For example, well 153-64-04ADD is in the SE1/4 SE1/4 NE1/4 Section 4, Township 153 North, Range 64 West (figure. 4). Consecutive terminal numerals are added if more than one well is located in a 10-acre tract.

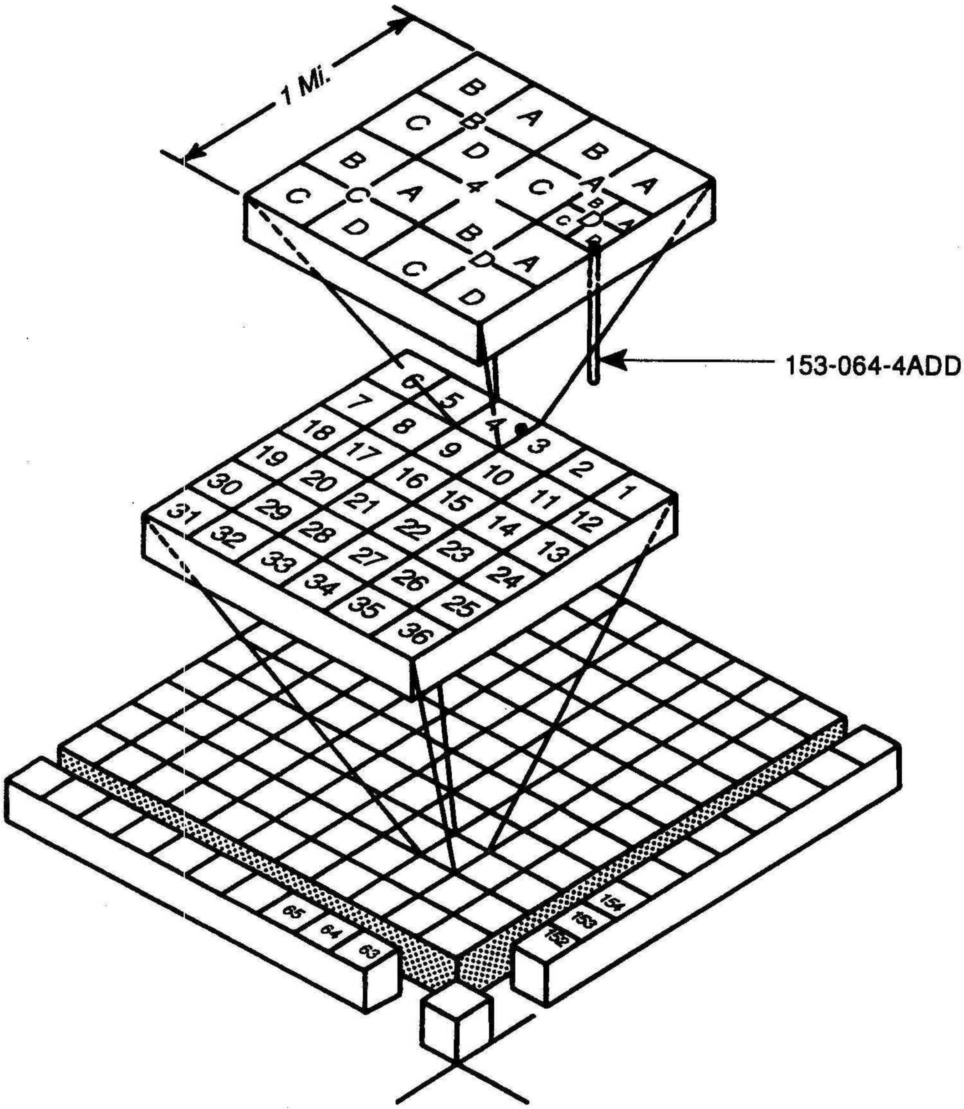


FIGURE 4. Location Numbering System

GEOLOGIC SETTING

General Geology

A detailed discussion of the basin wide geology is beyond the scope of this water supply investigation. The reader is referred to the references at the end of this text if more detail on the geologic setting is needed.

In the Ramsey Rural Water Study area, the major land forms include outwash deposits, ground moraine, end moraine, and lake deposits(figure 5). The Warwick glacial outwash deposit, which consists mainly of sand and gravel, overlies most of the study area (figure 5)

Ground moraine deposits, as shown in figure 5, are composed mainly of low permeability glacial till. In the study area, ground moraine occurs as scattered deposits within the Warwick outwash deposits.

End moraine deposits, also composed mainly of glacial till, occur in the area occupied by Devils Lake Mountain and Blue Mountain (North Viking Moraine, figure 5). Topographically, end moraines are areas of high relief with hummocky tops (knob and kettle).

Lake deposits, composed mainly of laminated clay and silt, occur around the perimeters of East Devils Lake and Stump Lake (figure 5).

Bedrock

Shale of the Pierre Formation directly underlies glacial drift over most of the Devils Lake Basin. The surface of the bedrock immediately underlying the glacial drift is a result of a complex sequence of geologic events. Ancient rivers (Cannonball) and glacial diversion channels (Starkweather) carved deep valleys into the Pierre Shale (figure 6). These valleys were formed at different times and cross one another in a complicated manner making the subsurface geology very complex (Hobbs, 1987). Sand and gravel deposited within these ancient drainage networks comprise the major buried valley aquifers in the area (figure 7). Later, glaciers moving across the area

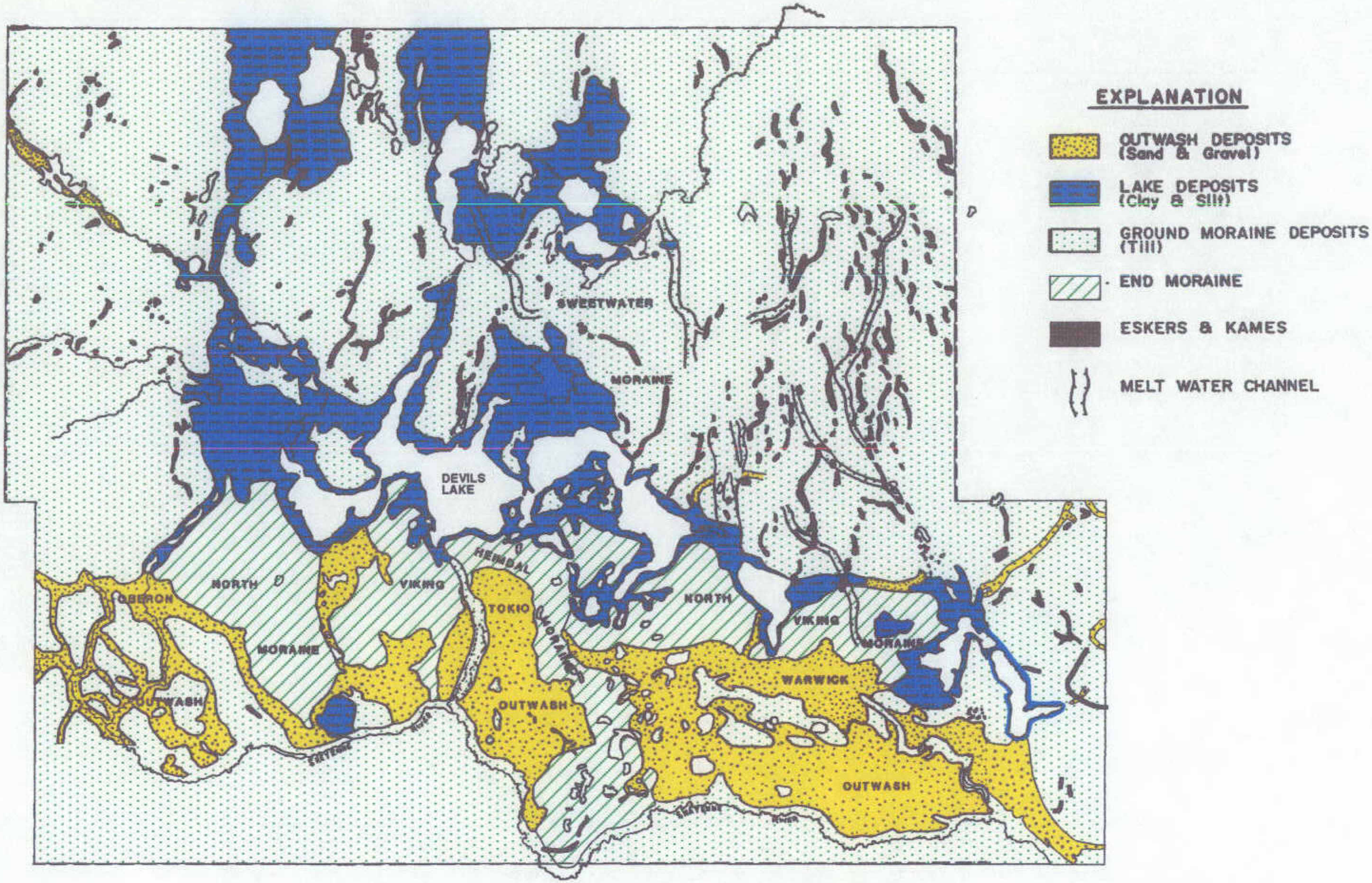


FIGURE 5. Generalized surfical geologic map of the Devils Lake area, Portions of Benson, Ramsey, Nelson and Eddy Counties (Modified from Paulson, 1964, Bluemle, 1965, Bluemle, 1973, Carlson, 1975, Clayton, 1980A & B, and Hobbs, 1987

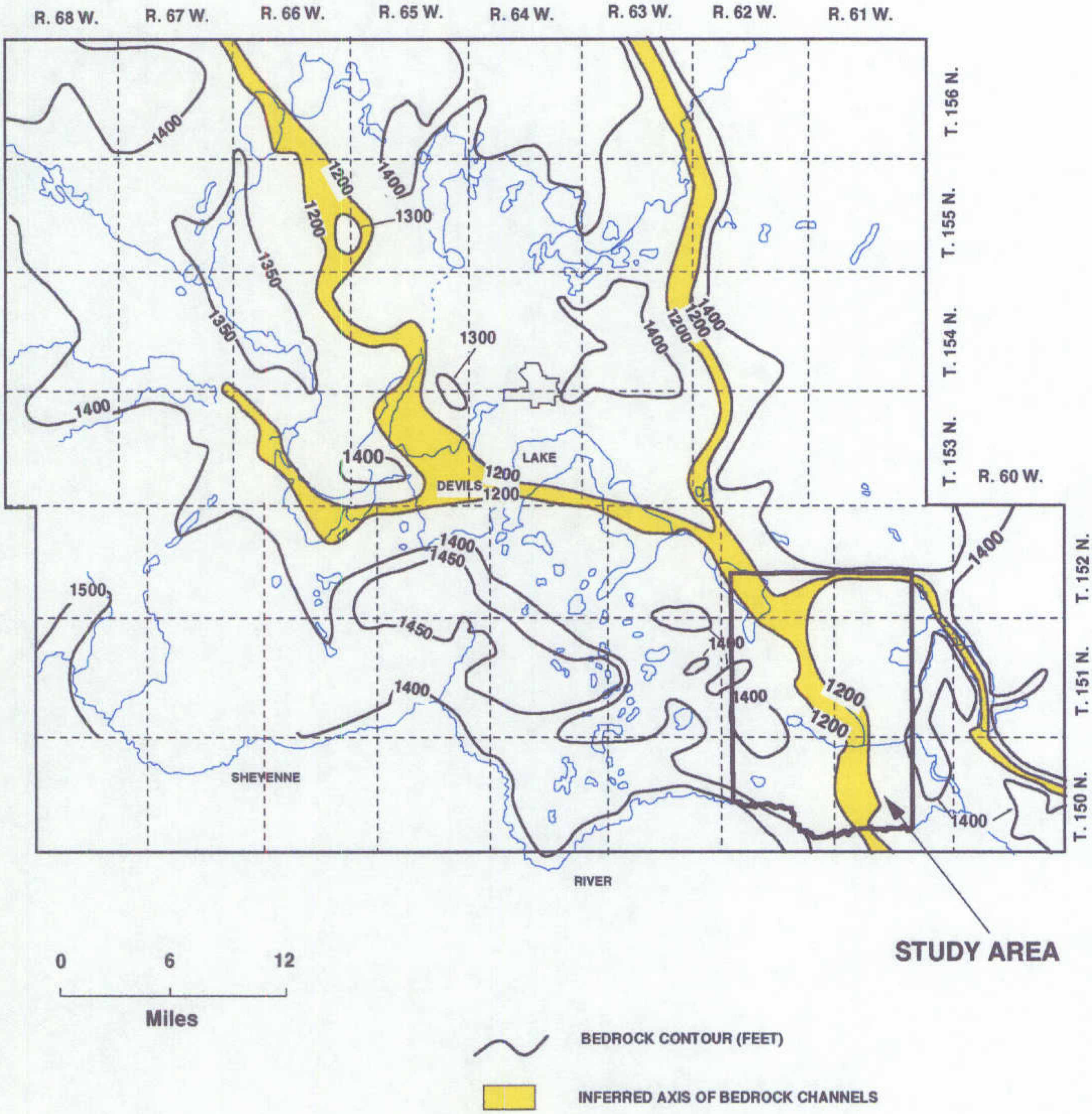


Figure 6. Structure contours of the top to the Pierre Shale, Devils Lake Area

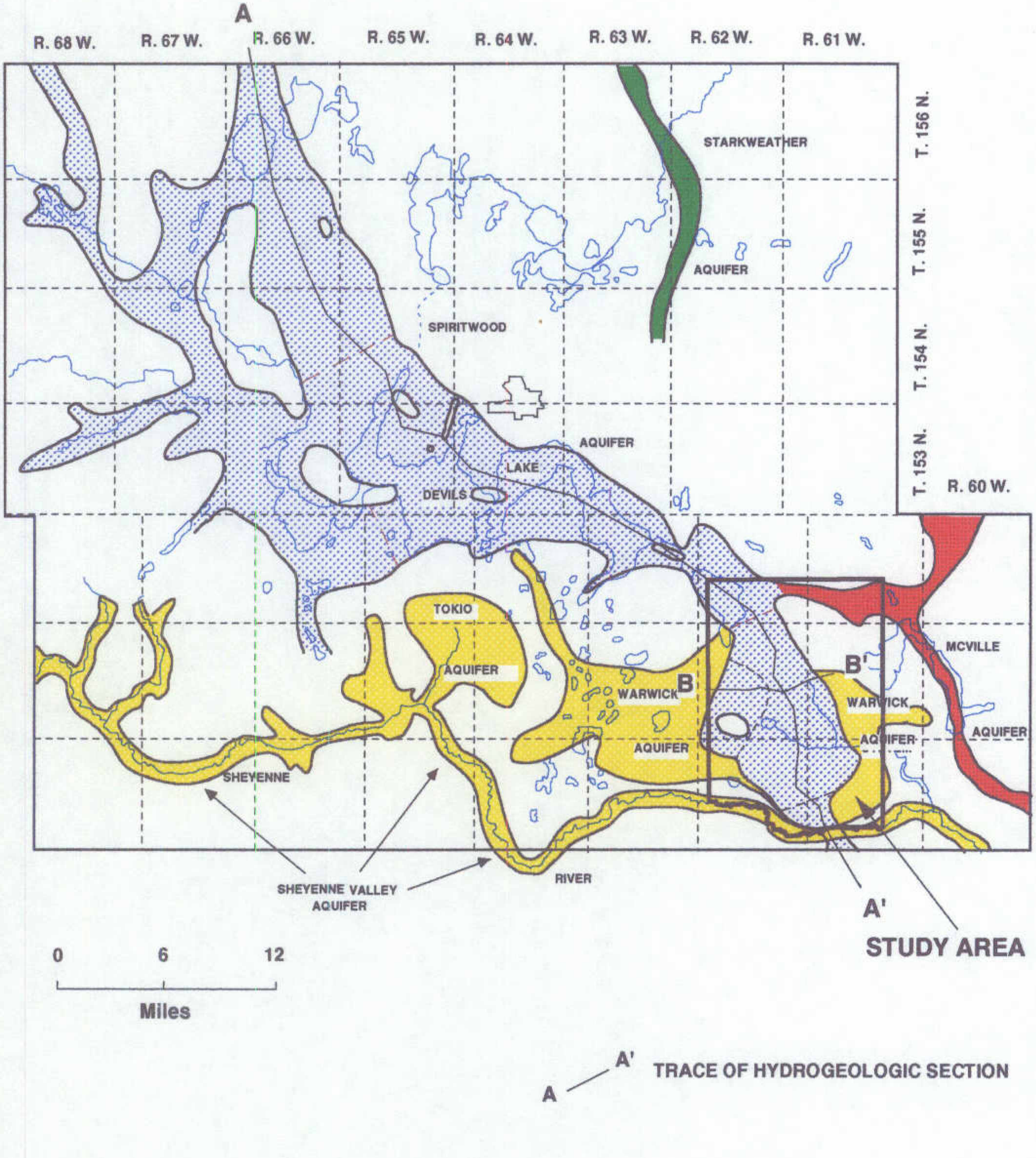


Figure 7. Major aquifers in the Devils Lake area

deposited successive sequences of glacial drift and lacustrine deposits on top of the ancient river valley sediments. Note that the Ramsey Rural Water Project study area overlies a portion of the largest bedrock valley in the Devils Lake area (figure 6, elevation 1200 feet).

Major aquifers

The Ramsey Rural Water study area overlies two potential ground-water sources, the Warwick aquifer and the Spiritwood aquifer system (figure 7), (Paulson, 1964, Trapp, 1966, Downey, 1973, Hutchinson, 1980, Randich, 1977 and Pusc, 1992).

Warwick aquifer

The Warwick aquifer is a shallow unconfined aquifer that consists of unconsolidated sand and gravel of the Warwick outwash deposit (figures 5 and 7). Saturated thickness of the Warwick aquifer ranges from 10 to 200 feet and averages 74 feet (Randich, 1977). In a large portion of the area, the Warwick aquifer overlies the Spiritwood aquifer system (figures 7, 8 and 9). Test drilling in extreme northeastern Benson county revealed that the Warwick aquifer is generally 20 to 50 feet thick, however there are areas where the Warwick extends down to 160 feet. The city of Devils Lake obtains ground water in an area where the Warwick aquifer is in places 100 to 200 feet thick (Randich, 1977).

Spiritwood aquifer system

The Spiritwood aquifer system, in the Ramsey Rural Water study area, is in reality part of an extensive buried valley aquifer complex. Statewide, the Spiritwood aquifer system extends from the Canadian border in Towner County, southeastward to the South Dakota border in Sargent county (NDSWC, 1986).

The Spiritwood aquifer system, in the Devils Lake area, has been subdivided into 5 aquifer segments (Randich, 1977, Hutchinson, 1980 and Pusc, 1992, figure 10). Three of the aquifer segments occurring in the Ramsey Rural Water study area are (figure 11): 1). the Spiritwood aquifer near Devils Lake, 2). the Spiritwood aquifer near Warwick and 3). the Spiritwood near the Sheyenne River. Total length of the Spiritwood aquifer system in the Ramsey Rural Water study area is about 13 miles (figure 11).

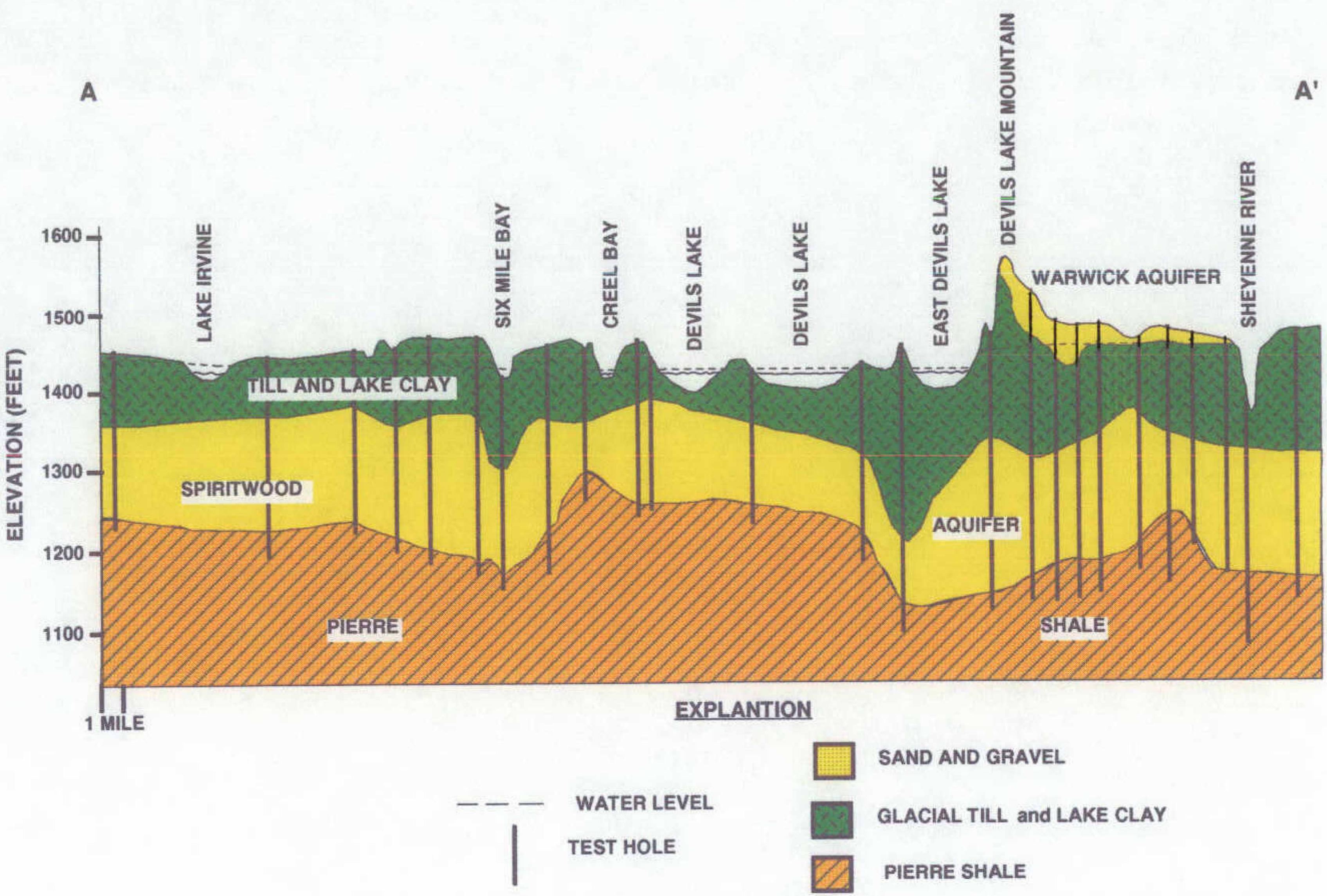


FIGURE 8. HYDROGEOLOGIC SECTION ALONG THE MAIN CHANNEL OF THE SPIRITWOOD AQUIFER SYSTEM

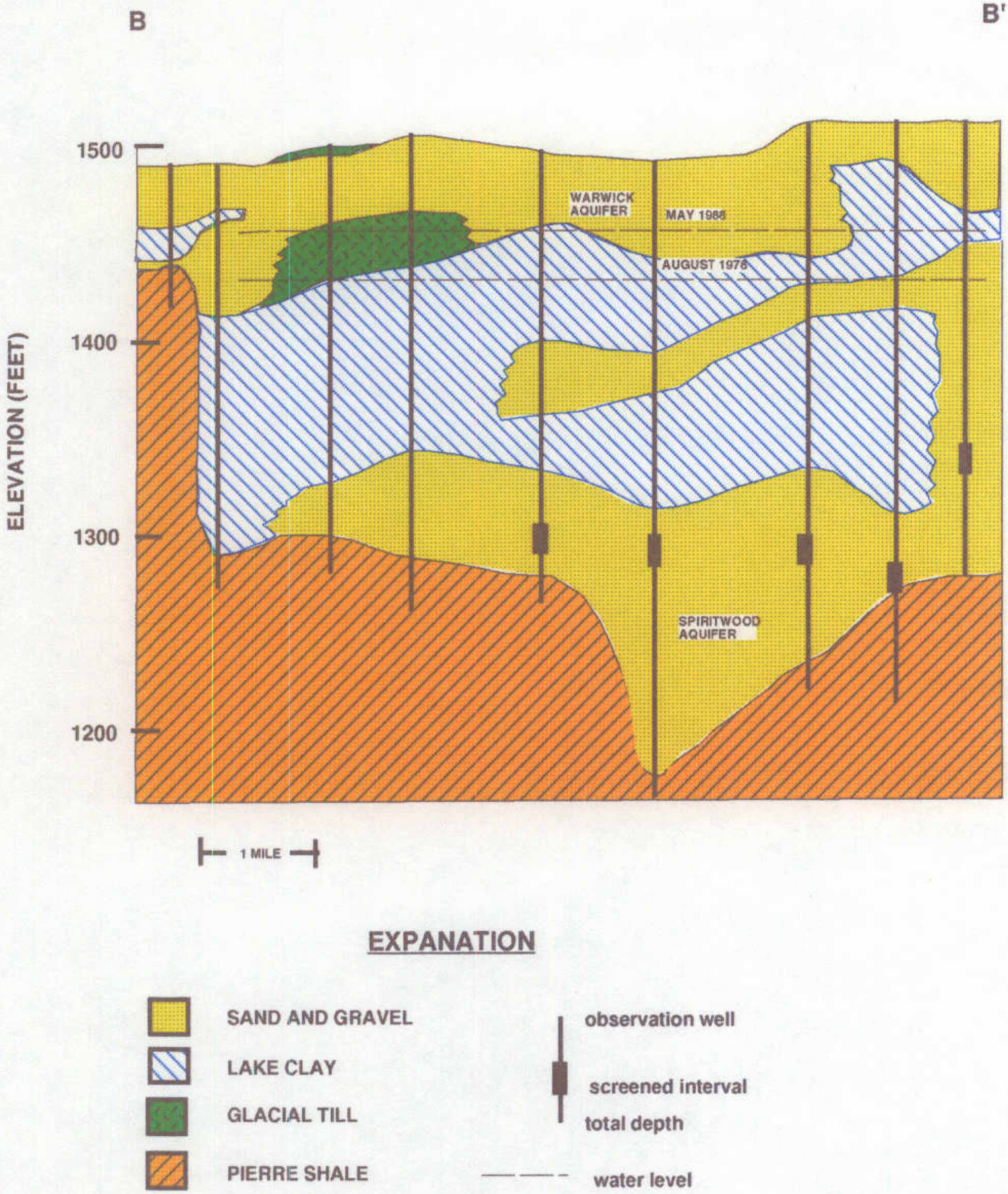


FIGURE 9. Hydrogeologic section showing the Warwick and Spiritwood aquifers, northeastern Benson County

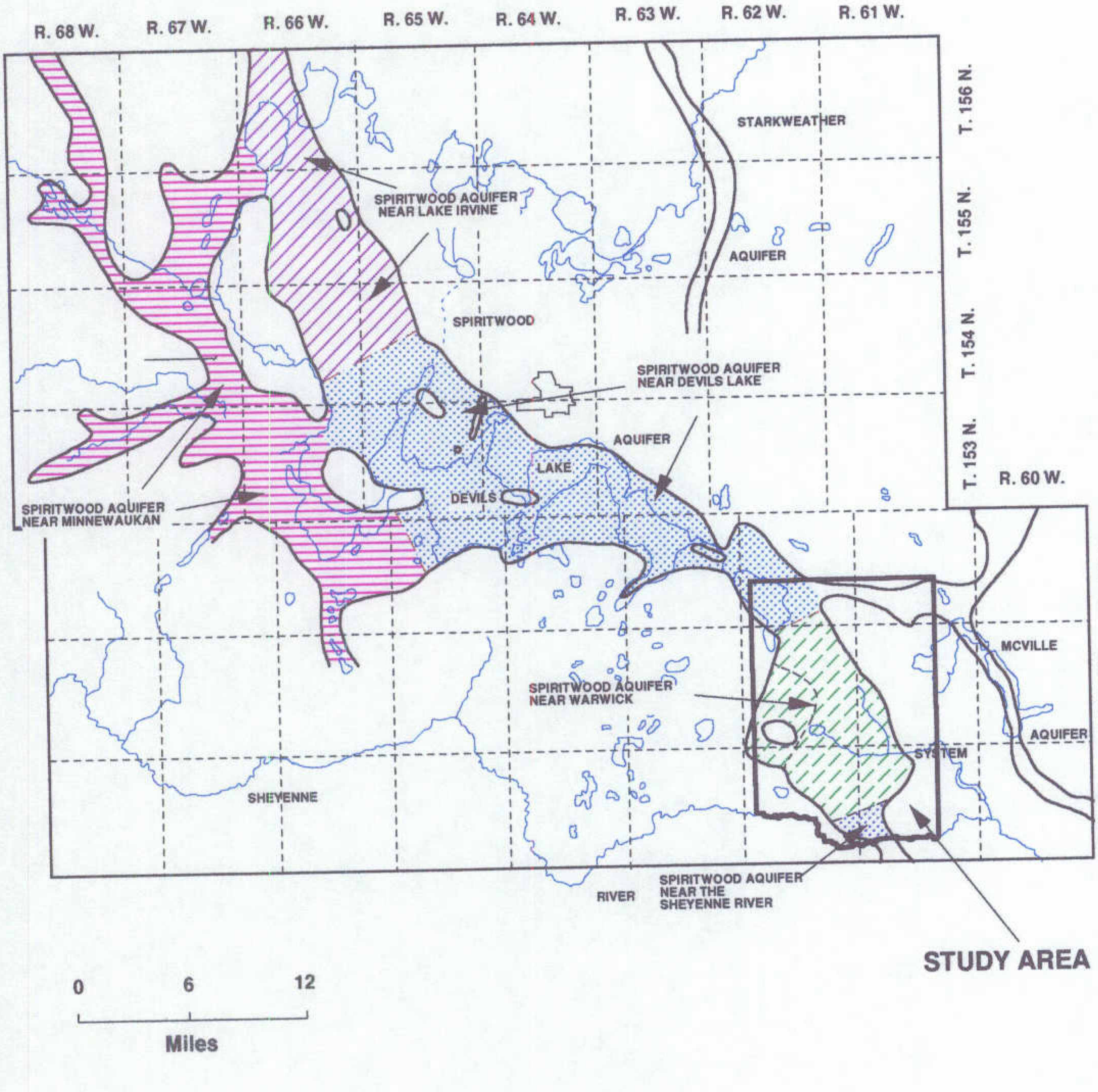


FIGURE 10. SUBDIVISIONS OF THE SPIRITWOOD AQUIFER SYSTEM IN THE DEVILS LAKE AREA

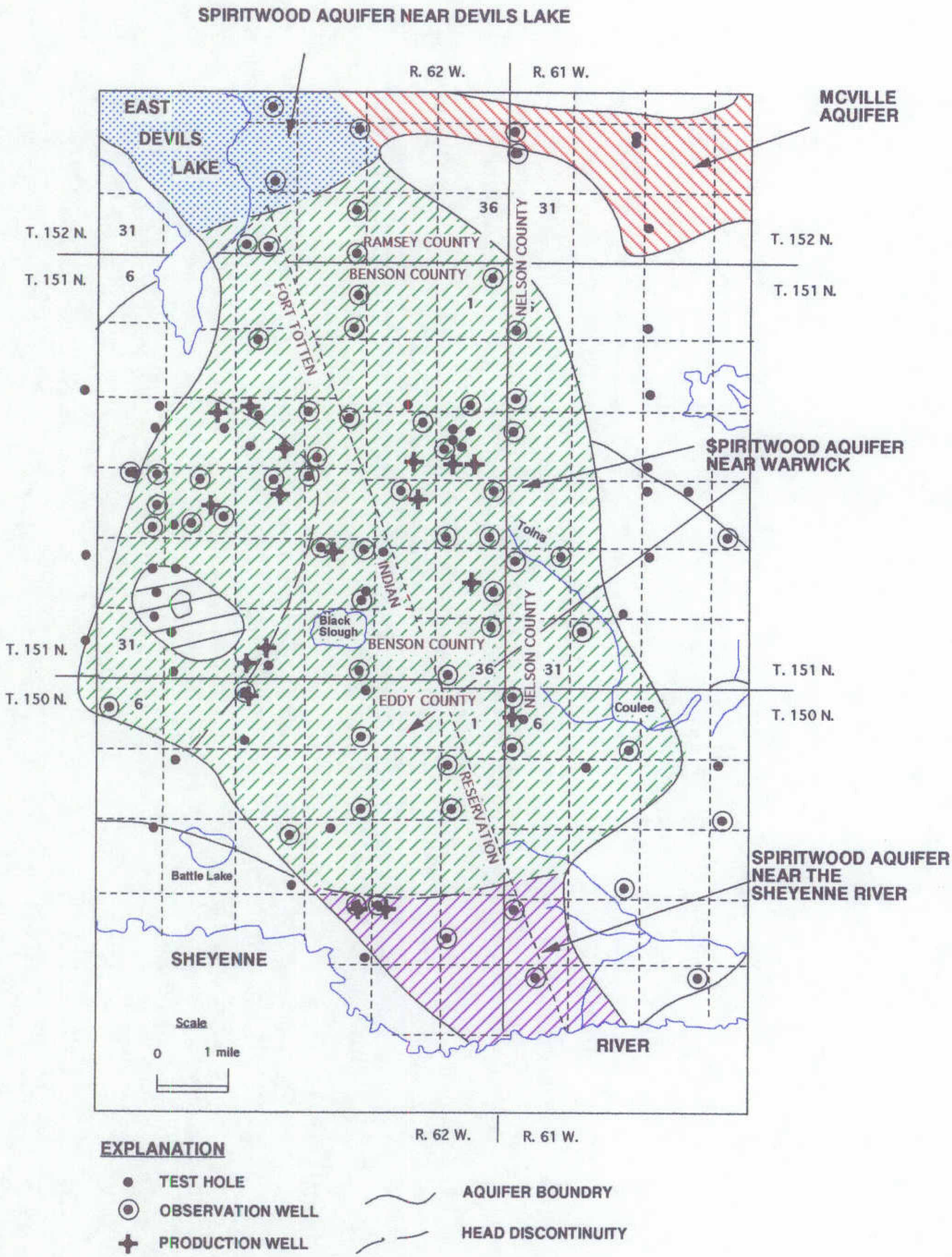


FIGURE 11. SUBDIVISIONS OF THE SPIRITWOOD AQUIFER SYSTEM IN THE RAMSEY RURAL WATER STUDY AREA

Spiritwood aquifer near Devils Lake

In the Ramsey Rural Water Study area the Spiritwood aquifer near Devils Lake varies from 38 feet thick on the bedrock channel flanks to as much as 95 feet thick just east of East Devils Lake (figures 9 and 12). In this area, the Spiritwood aquifer near Devils Lake is about 3 miles wide and intersects with the McVille aquifer to the east (figures 7 and 11).;

Spiritwood aquifer near Warwick

The Spiritwood aquifer near Warwick includes that portion of the Spiritwood aquifer system that is overlain primarily by outwash deposits of the Warwick aquifer (figures 5 and 7). As shown in figure 11, the area varies from 3 to 8 miles wide, is about 9 to 10 miles long and covers approximately 60 square miles.

Test drilling in northeastern Benson County (area of interest) revealed that the Spiritwood aquifer near Warwick ranges from 30 feet thick on the bedrock channel flanks to as much as 184 feet thick southeast of east Devils Lake (figures 8, 9 and 12). According to driller's logs, there are areas where the overlying Warwick aquifer extends to a depth of about 160 feet, suggesting that there may be locations where the Warwick and Spiritwood aquifers are a continuous aquifer unit. Based on the geology of the area the Spiritwood aquifer near Warwick probably receives leakage from the overlying Warwick aquifer.

Transmissivity of the Spiritwood aquifer near Warwick ranges from 5,600 to 16,600 ft^2/day (Randich, 1977 and Johnson, 1979). The Storage coefficient ranges from 2.38×10^{-4} to 7.07×10^{-4} indicating confined conditions. Currently there are several large capacity wells in the area that produce between 500 to 1,000 gpm from the Spiritwood aquifer near Warwick.

Based on an areal extent of about 60 square miles, a mean thickness of 100 feet, and an estimated specific yield of 15 percent, approximately 580,000 acre-feet of water is available from storage from the Spiritwood aquifer near Warwick.

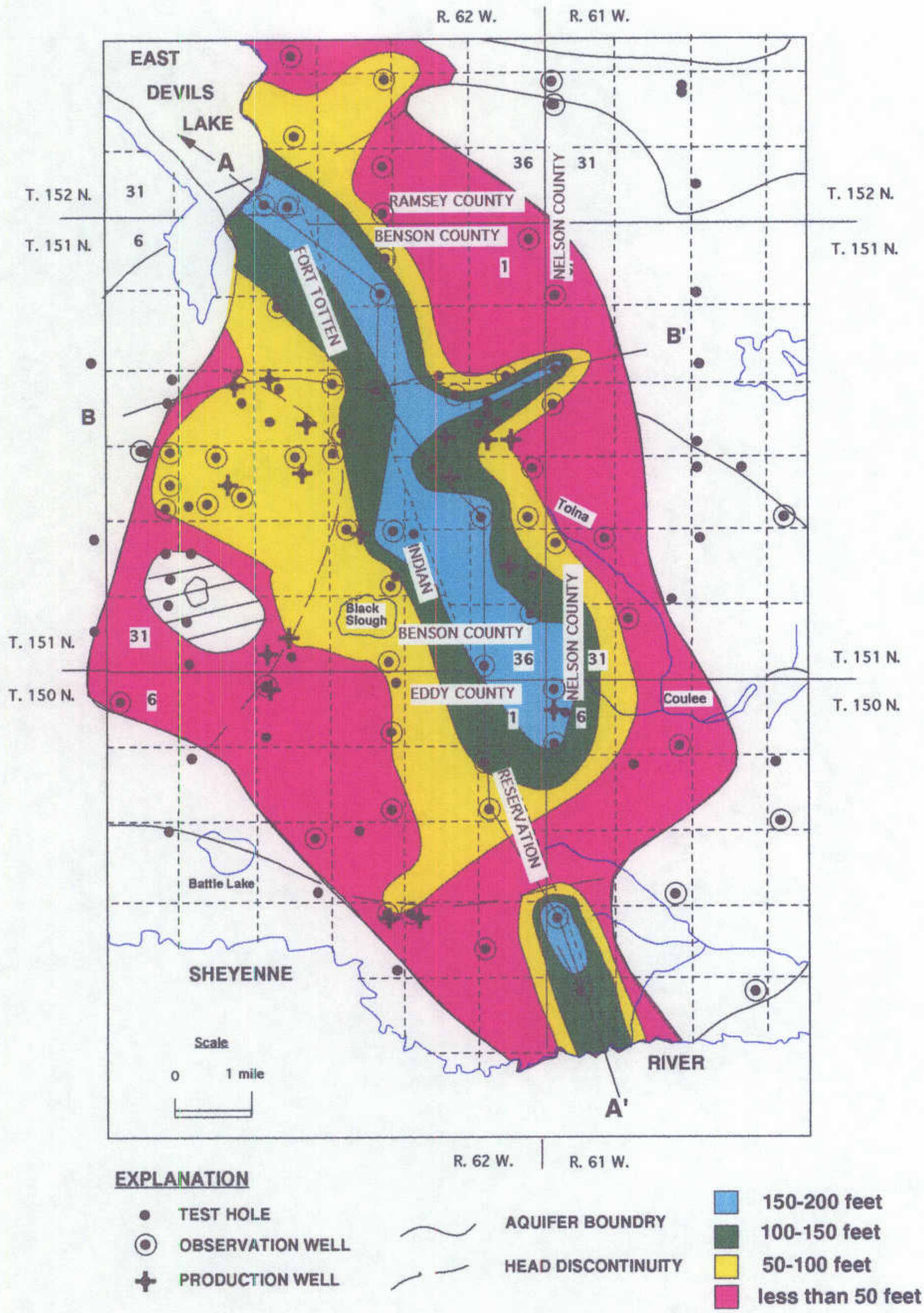


FIGURE 12. Thickness of the Spiritwood aquifer system in the Ramsey Rural Water Study Area

Spiritwood aquifer near the Sheyenne River

In this area the Spiritwood aquifer becomes rather narrow, 1 to 2 miles wide and varies from 22 feet to 160 feet thick (figures 8 and 12). The main portion of the aquifer occurs in a depth interval ranging from 130 to 300 foot. Note also that water levels in the Spiritwood aquifer near the Sheyenne River are 75 to 80 feet lower than water levels in the Spiritwood aquifer near Warwick (figure 8). This water level discontinuity is a result of a thinning and narrowing of the aquifer system in this area.

GROUND-WATER RESOURCES

Existing Development

Currently there are 13 approved water permits in the Ramsey Rural Water study area (figure 13). Twelve of those permits are approved for the irrigation of 2983.4 acres of land using 4315.0 acre-feet of ground water. Total approved pumping rate for irrigation is 14,000 gallons per minute. The City of Tolna holds a permit in this area that allows them to appropriate 54 acre-feet of ground water at 200 gallons per minute for municipal purposes(figure 13).

Since 1976, reported water use has varied from 400 and 500 acre-feet per year in 1976, 1981 and 1987 to over 1500 acre-feet per year in 1988 and 1989 (figure 14). Reported water use of over 1500 acre-feet per year represents only about 1/3 of the total amount approved in the area (4369 acre-feet). As of 1990, a total of 2,225 acres were reported to be under irrigation in northeastern Benson county (figure 13). In addition, the Devils Lake Sioux Tribe appears to be irrigating about 800 acres, putting the total amount of land under irrigation at over 3000 acres.

Spiritwood aquifer system

Water levels

Water levels in the Spiritwood aquifer vary depending on which segment of the aquifer system is examined (figure 15). Water levels in the Spiritwood aquifer near Devils Lake are slightly higher than and fluctuate in a manner similar to Devils Lake (figure 15). Depth to water in this segment of the aquifer can vary from only a few feet below or slightly above land surface.

Water levels in the Spiritwood aquifer near Warwick currently vary from 20 to 30 feet below land surface (table 2). Depth to water in a well located on the crest of Devils Lake Mountain is in excess of 130 feet below land surface. Inspection of the hydrologic sections in figures 8 and 9 reveal that the water level in the Spiritwood aquifer rises 100 feet over the top of the aquifer indicating that the aquifer is under confined conditions.

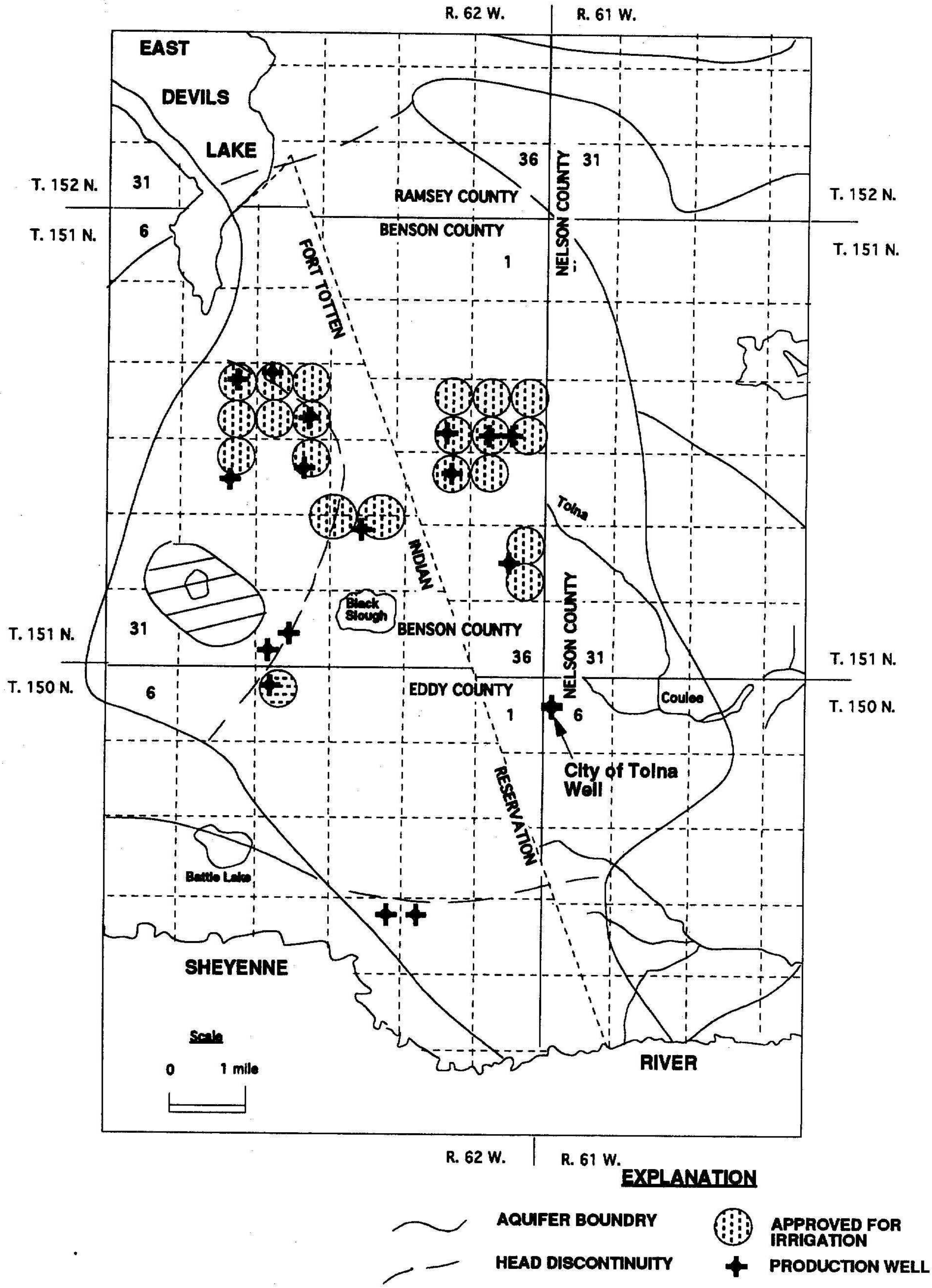


FIGURE 13. GROUND-WATER DEVELOPMENT IN THE RAMSEY RURAL WATER STUDY AREA

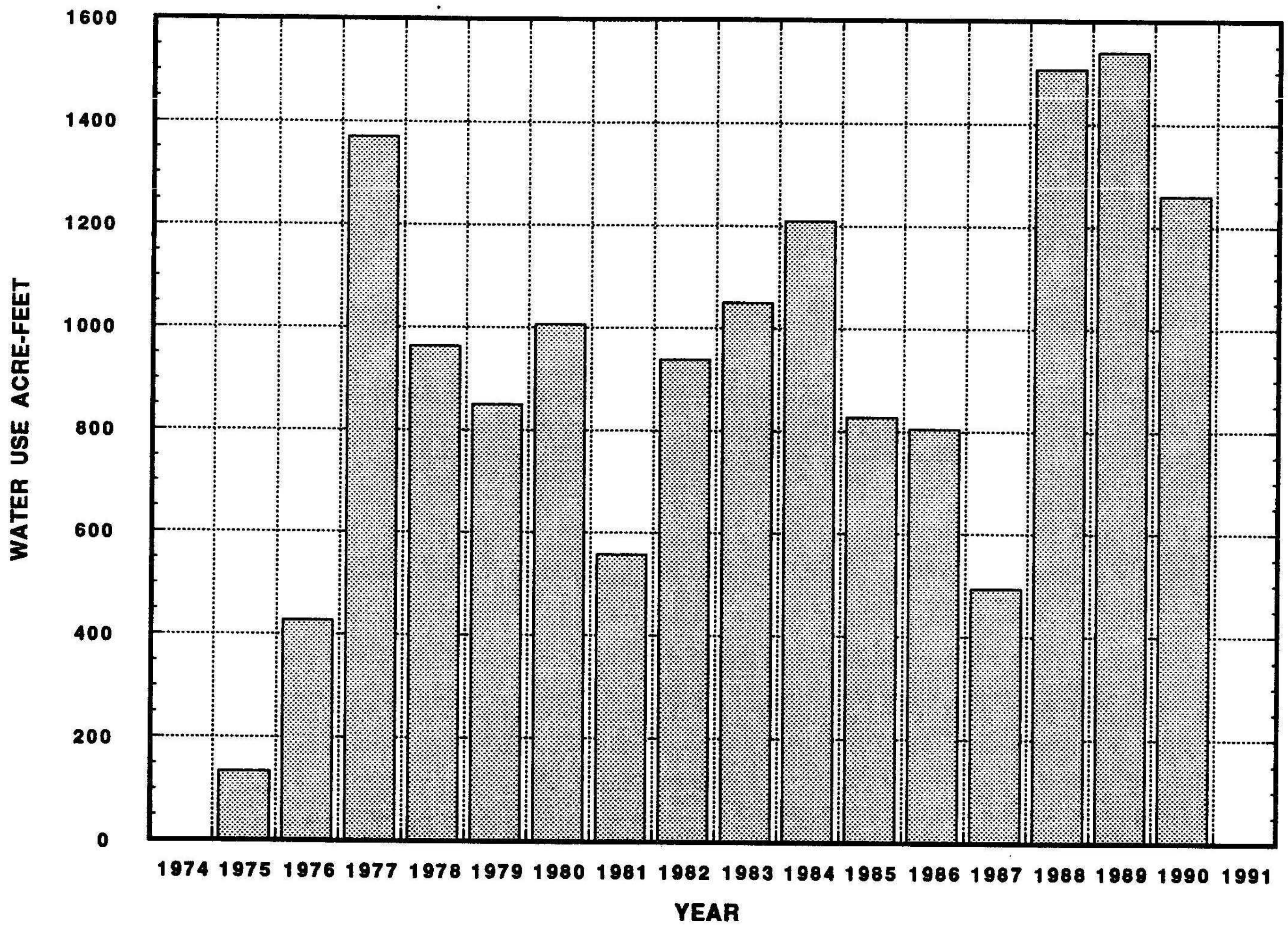


FIGURE 14. REPORTED WATER USE FOR THE SPIRITWOOD AQUIFER IN NORTHEASTERN BENSON COUNTY, NORTH DAKOTA

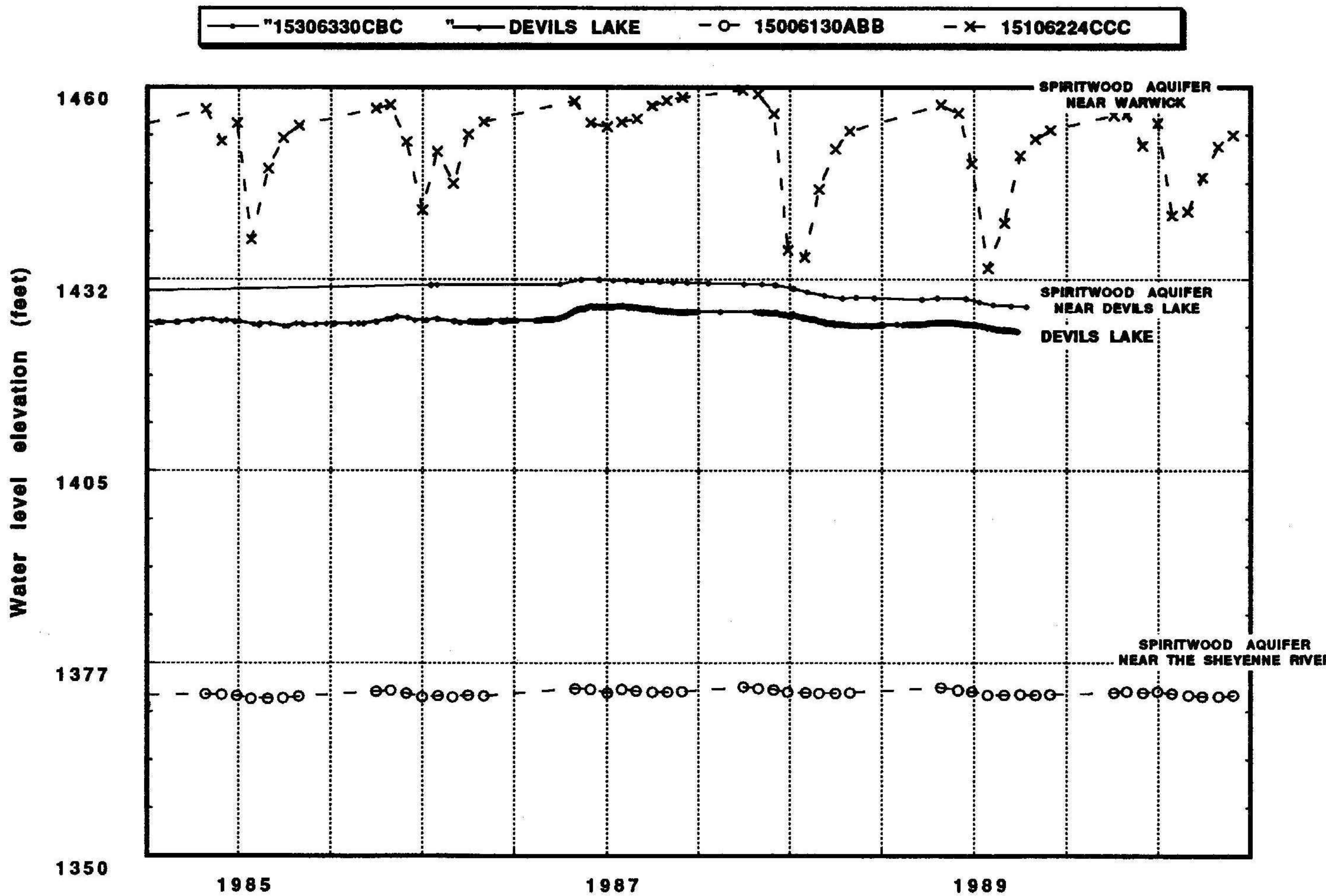


Figure 15. Water levels in the Spiritwood aquifer system in the Devils Lake area, North Dakota (1985-1990)

Water levels in the Spiritwood aquifer near Warwick have fluctuated in response to changing climate patterns and variations in irrigation pumping (figures 15 16 and 17). During the summer months, water levels in the area decline as a result of the irrigation pumping. Water levels recover during the fall, winter and early spring months. Maximum drawdown has been about 20 feet during a typical irrigation season (figures 15 and 16). The recorded low water level was approximately 1430 feet above mean sea level in August of 1978 (drawdown due to irrigation). Currently there is over 100 feet of available drawdown (drawdown to top of aquifer) in the Spiritwood aquifer near Warwick (figures 8, 9 and 17).

Since 1977, two distinct water level trends have been recorded for the Spiritwood aquifer near Warwick. From 1977 through 1988 water levels generally rose at a rate of 1/2 foot per year (figures 16 and 17). Since 1988, water levels have decreased at a rate of 1/2 foot per year. This response is due to changing water use patterns (brought on by changing climatic conditions) in the area. Also, water levels in the Spiritwood aquifer near Warwick may be adjusting slightly to fluctuations in the height of the regional discharge area (Devils Lake, figures 15 and 16).

Water levels in the Spiritwood aquifer near the Sheyenne River are considerably lower than water levels in the other segments of the aquifer system (figure 15). In this area the water levels fluctuate in response to the height of the Sheyenne River.

Ground-water movement

A map illustrating the natural direction of ground-water flow for the Spiritwood aquifer system from East Devils Lake to the Sheyenne River is presented in figure 18. Note that a ground-water divide occurs in Township 151, Range 61, with the resulting ground-water flow in the Spiritwood aquifer both northwest towards East Devils Lake and southeast towards the Sheyenne River (figures 8 and 18). A second ground-water divide occurs just south and east of the first divide with the resulting ground-water flow towards the Sheyenne River and Tolna Coulee. In this particular area the Sheyenne River, Devils Lake, and Tolna Coulee serve as natural discharge areas for the Spiritwood aquifer system. During the irrigation season, this natural flow pattern is disrupted resulting in some ground-water movement towards the various pumping centers in the area (figure 19).

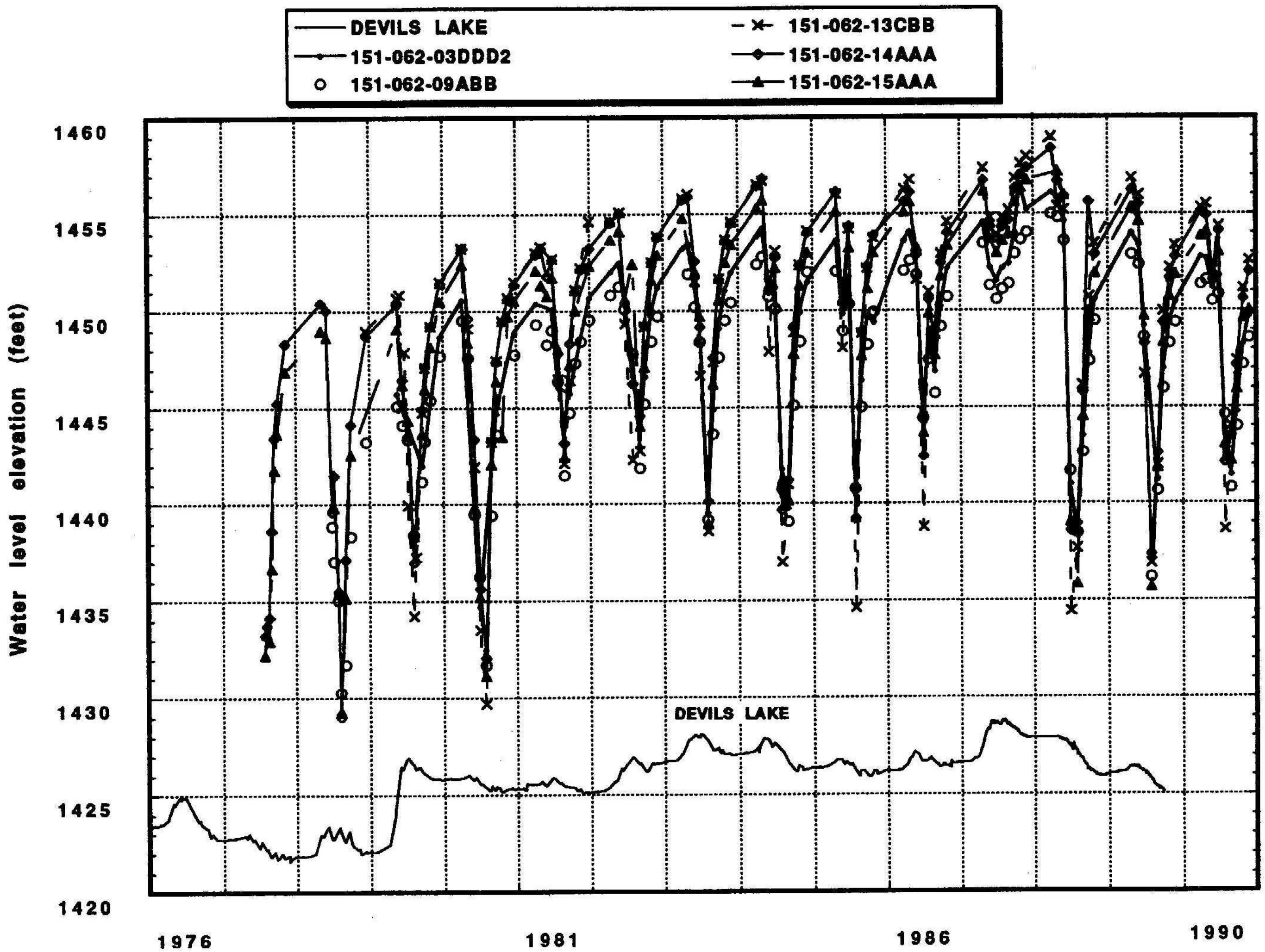


Figure 16. Water levels in the Spiritwood aquifer near Warwick, northeastern Benson county and southwestern Ramsey county,North Dakota (1976-1990)

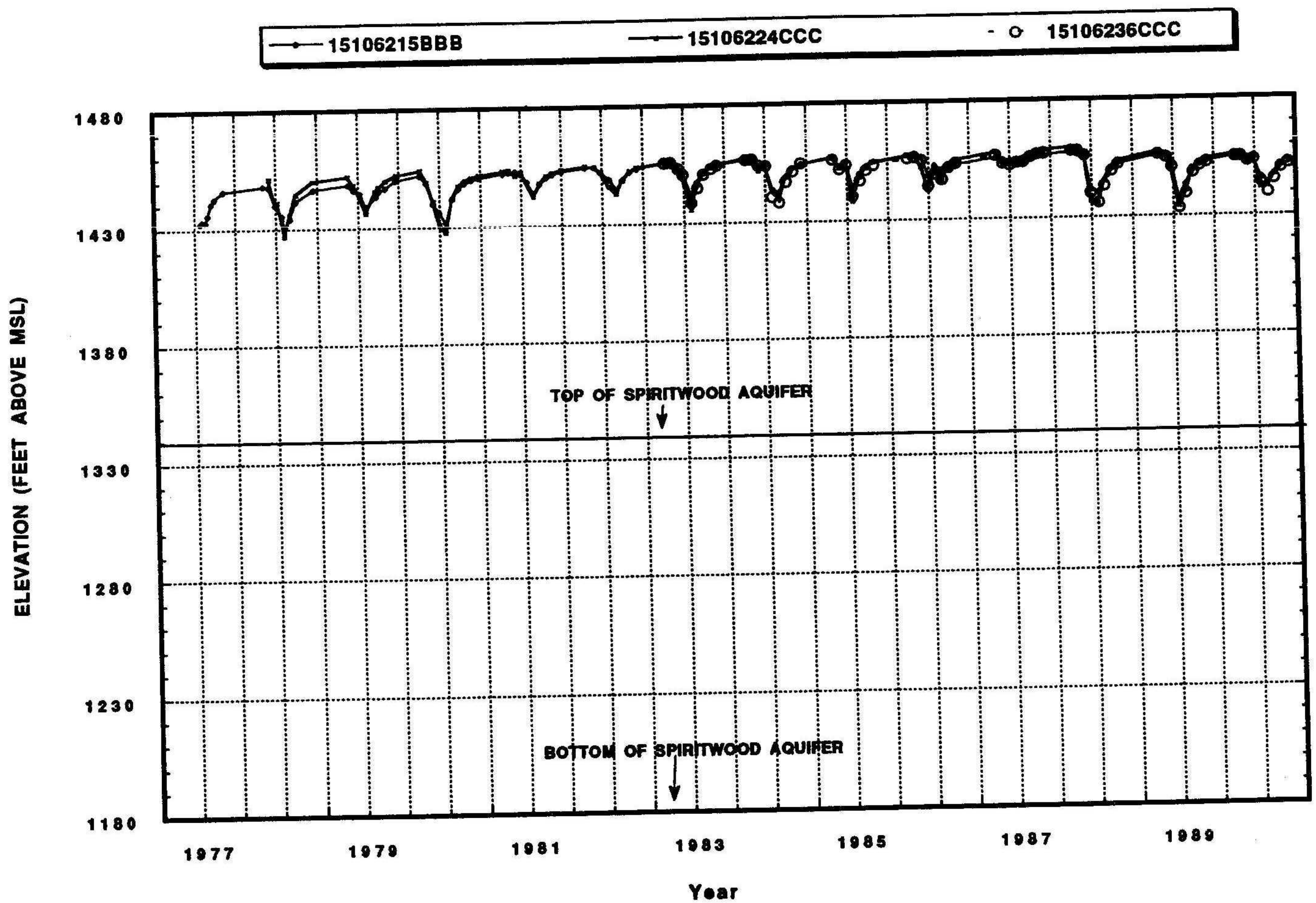


FIGURE 17. COMPARISION OF WATER LEVELS IN THE SPIRITWOOD AQUIFER TO THICKNESS OF THE SPIRITWOOD AQUIFER IN THE RAMSEY RURAL WATER STUDY AREA

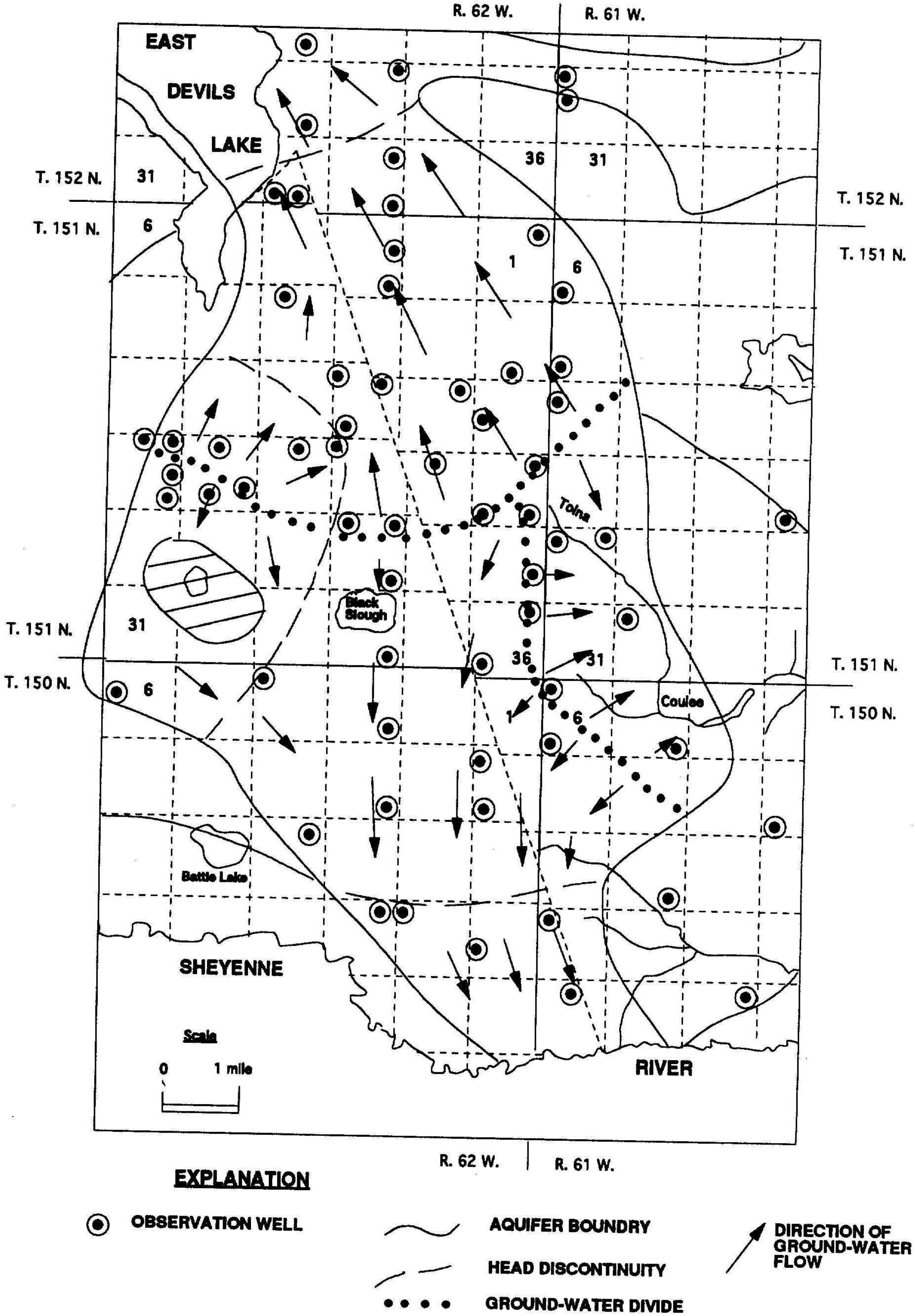


FIGURE 18. DIRECTION OF GROUND-WATER FLOW IN THE SPIRITWOOD AQUIFER SYSTEM UNDER NATURAL CONDITIONS.

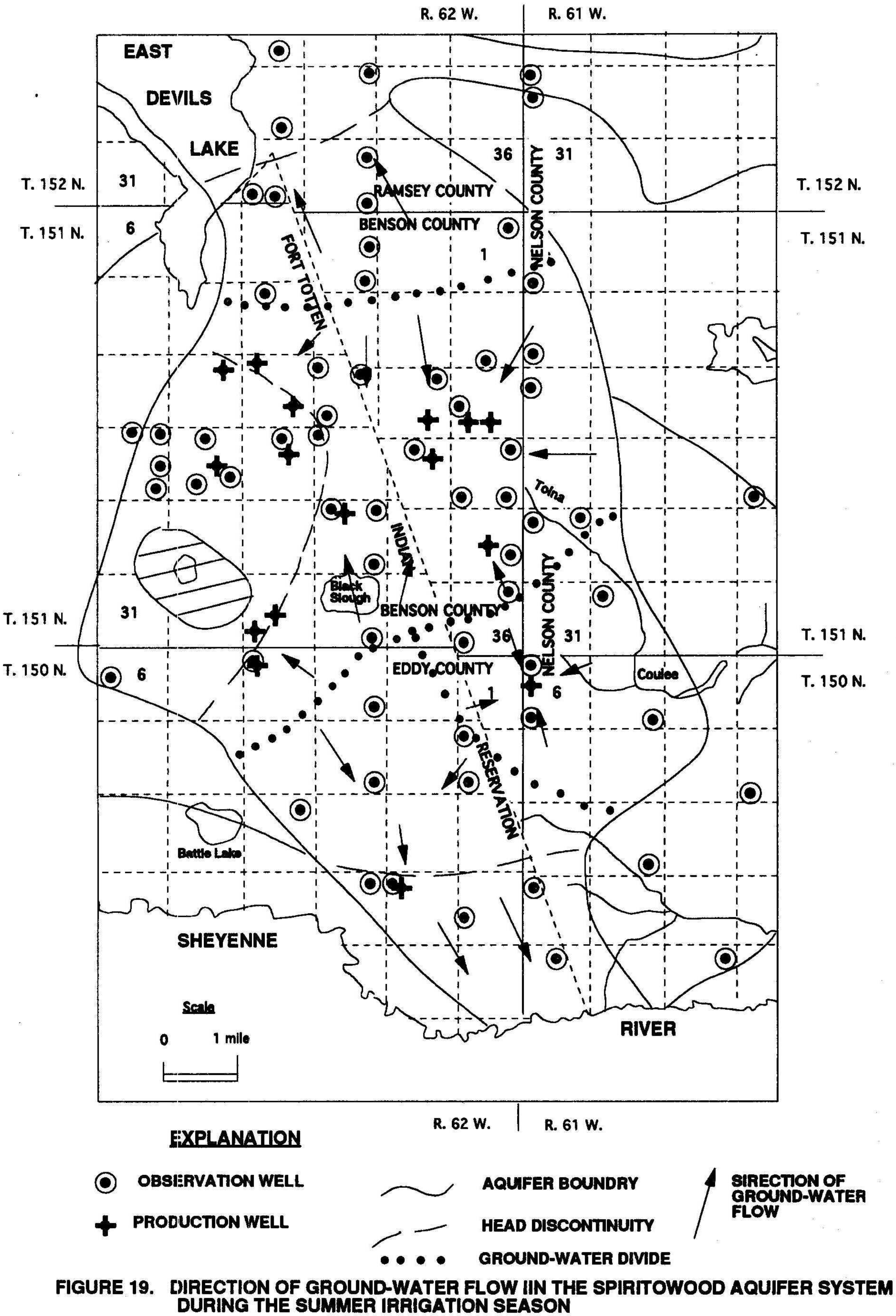


FIGURE 19. DIRECTION OF GROUND-WATER FLOW IIN THE SPIRITOWOOD AQUIFER SYSTEM DURING THE SUMMER IRRIGATION SEASON

GROUND-WATER QUALITY

Warwick aquifer

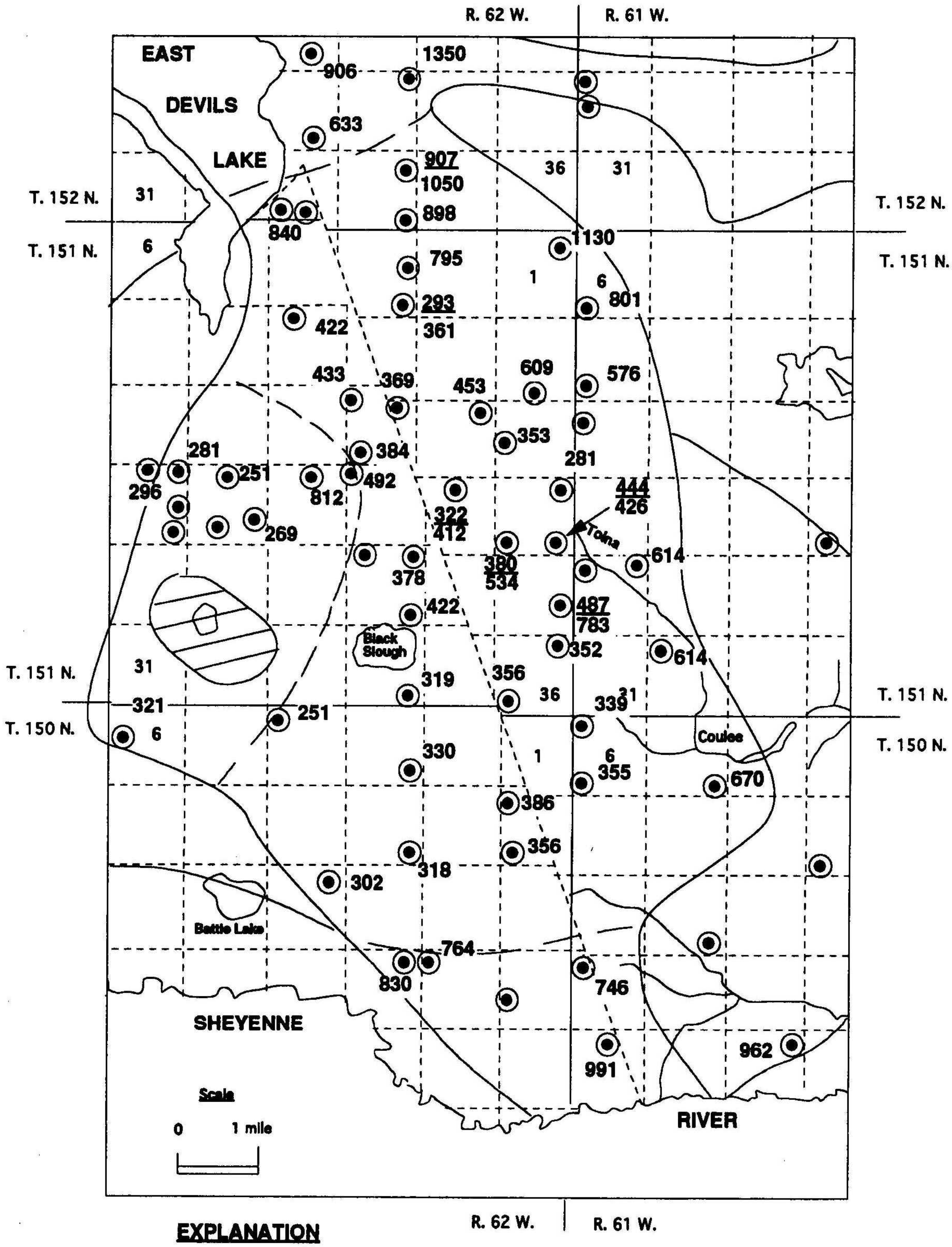
Ground-water in the Warwick aquifer is primarily a calcium bicarbonate type. Total dissolved solids concentrations ranged from 200 to 600 mg/l and averaged less than 300 mg/l. As stated by Randich, 1977, "Generally, the aquifer (Warwick) contains some of the best quality ground water available in North Dakota." A detailed discussion of the various chemical constituents in water from the Warwick aquifer is not included in this discussion due to the thin saturated thickness of the Warwick aquifer in the Ramsey Rural Water Study Area.

Spiritwood aquifer

Analysis of ground-water samples from the Spiritwood aquifer system indicate that the quality of water varies considerably throughout the extent of the buried valley complex. Sodium and calcium are the predominant cations and bicarbonate and sulfate are the predominant anions.

Spiritwood aquifer near Warwick

Water analyzed from the Spiritwood aquifer system near Warwick has the lowest total dissolved solids concentrations of any of the Spiritwood samples (figure 20). Ground water from this segment of the aquifer system is generally a calcium-bicarbonate type near the central part of the aquifer, while the sodium-bicarbonate type predominates near the valley flanks. Dissolved solids range from 200 to 1000 mg/l with the bulk of the samples in the 200 to 600 mg/l range (figure 20). In general, ground water from the Spiritwood aquifer near Warwick is highest in dissolved solids concentrations near the discharge areas (Devils Lake , Tolna Coulee and the Sheyenne River). Dissolved solids concentrations are lowest near the central part of the buried valley, and in those areas where the Warwick aquifer overlies the Spiritwood aquifer. It appears that good quality, low total dissolved solids water is moving down from the Warwick aquifer and recharging the Spiritwood aquifer in the area (Cline and Pusc, 1990). The relatively short flow paths from recharge to discharge area in this portion of the Spiritwood Aquifer also aids in keeping the water low in total dissolved solids concentrations (figure 8). Hardness of the ground water from the Spiritwood aquifer



EXPLANATION

- OBSERVATION WELL
- 321 TOTAL DISSOLVED SOLIDS, mg/l
- <u>322 TOP OF AQUIFER</u>
  412 BASE OF AQUIFER
- AQUIFER BOUNDRY
- HEAD DISCONTINUITY

FIGURE 20. DISTRIBUTION OF TOTAL DISSOLVED SOLIDS CONCENTRATION OF WATER SAMPLED FROM THE SPIRITWOOD AQUIFER SYSTEM, mg/l

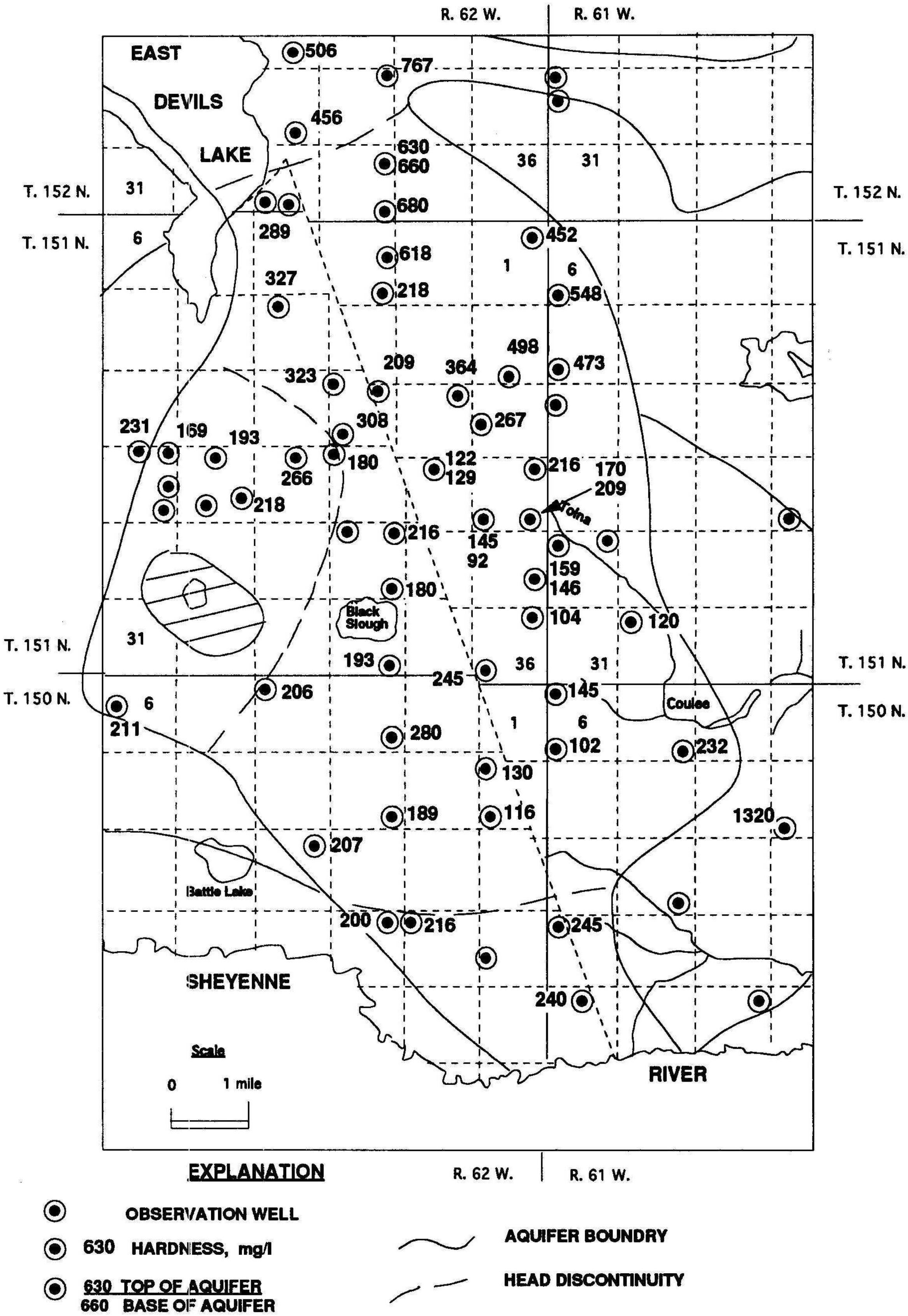


FIGURE 21. DISTRUBUTION OF HARDNESS CONCENTRATION OF WATER SAMPLED FROM THE SPIRITWOOD AQUIFER SYSTEM, mg/l

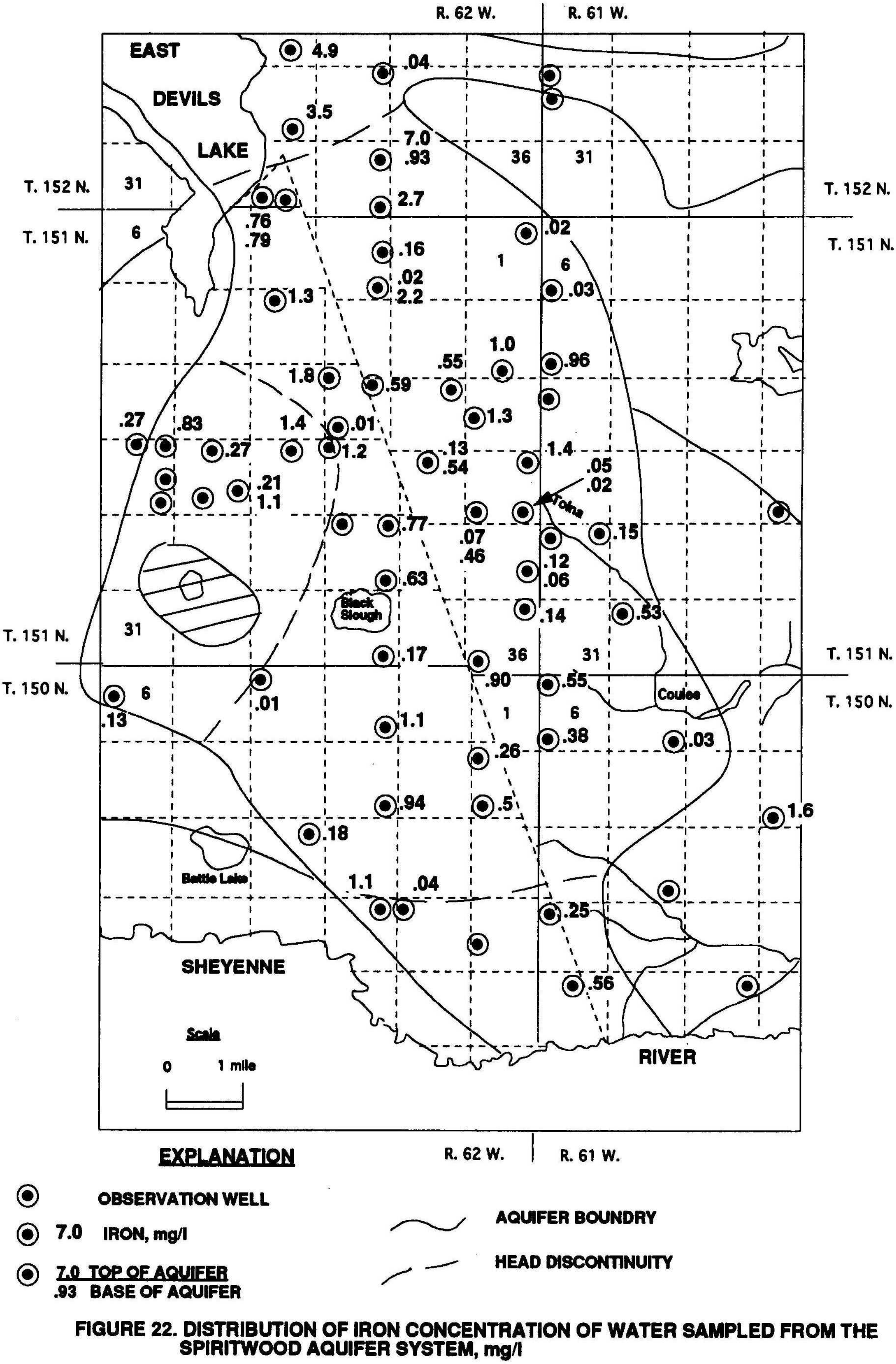
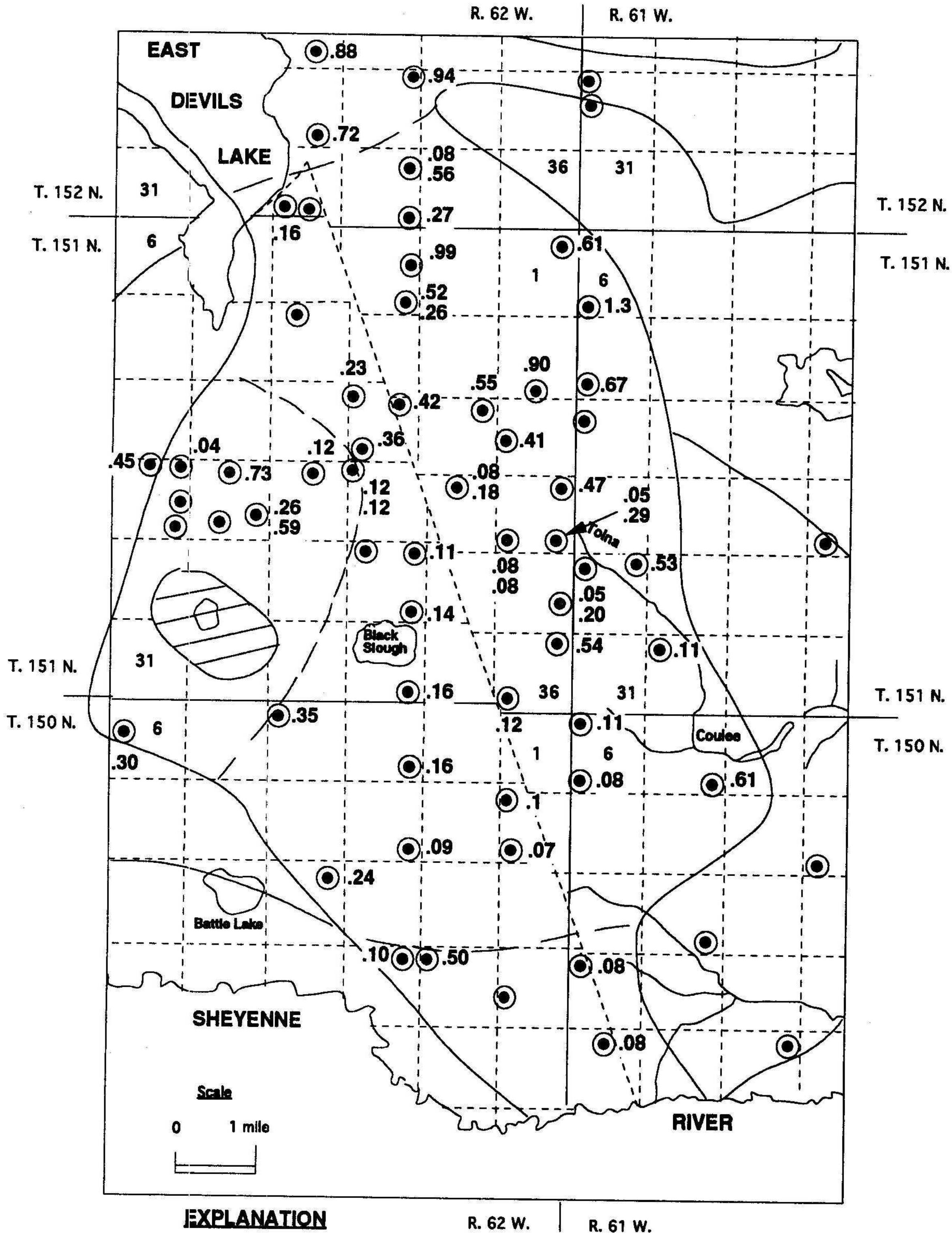


FIGURE 22. DISTRIBUTION OF IRON CONCENTRATION OF WATER SAMPLED FROM THE SPIRITWOOD AQUIFER SYSTEM, mg/l



EXPLANATION

OBSERVATION WELL

.08 MANGANESE, mg/l

.08 TOP OF AQUIFER
.56 BASE OF AQUIFER

AQUIFER BOUNDRY

HEAD DISCONTINUITY

FIGURE 23. DISTRIBUTION OF MANGANESE CONCENTRATION OF WATER SAMPLED FROM THE SPIRITWOOD AQUIFER SYSTEM, mg/l

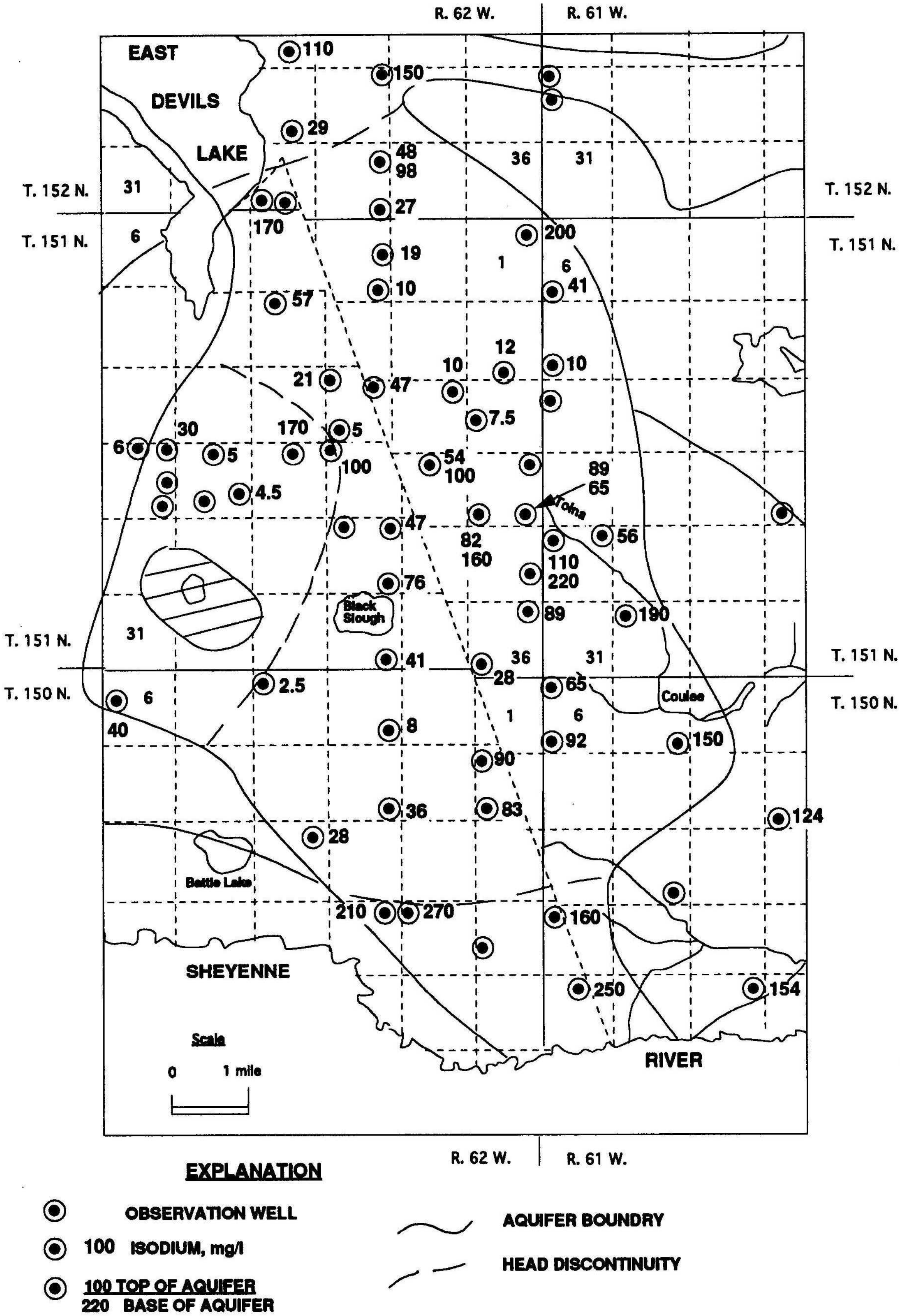


FIGURE 24. DISTRUBUTION OF SODIUM CONCENTRATION OF WATER SAMPLED FROM THE SPIRITWOOD AQUIFER SYSTEM, mg/l

near Warwick ranges from 100 to 500 mg/l (figure 21). Iron concentrations range from .01 to 1.8 mg/l (Figure 22). Manganese varies from .04 to .9 mg/l (figure 23) while sodium levels range from 2.5 to 220 mg/l (figure 24).

Spiritwood aquifer near the Sheyenne River

Ground water in the Spiritwood aquifer near the Sheyenne River (discharge area) is very similar to ground water in the Spiritwood aquifer near Warwick except that the total dissolved concentrations are higher (figure 20). The ground water also tends to be a sodium-bicarbonate type instead of a calcium-bicarbonate type. Drinking water standards for sodium, sulfate, iron and hardness were exceeded in most of the samples from this portion of the aquifer (Figures 21, 22, 23 and 24 and tables 3 and 4).

Spiritwood aquifer near Devils Lake

Ground water in the Spiritwood aquifer near Devils Lake is also high in dissolved solids concentrations (figure 20, 1000 to 2000 mg/l). Waters with high total dissolved solids concentrations were expected because Devils Lake is the regional ground water discharge area and as such, flow path length and travel time would tend to concentrate the chemicals in the discharge areas. Drinking water standards for sodium, sulfate, iron and hardness were exceeded in most of the samples from this portion of the aquifer (Figures 21, 22, 23 and 24 and tables 3 and 4).

SUMMARY AND RECOMMENDATIONS

The area under investigation contains two significant aquifer systems: 1). the Warwick aquifer and 2). the Spiritwood aquifer system. The Warwick aquifer is a shallow unconfined aquifer that covers most of the study area. In a large portion of the area the Warwick aquifer overlies and provides recharge to the Spiritwood aquifer system. Saturated thickness of the Warwick aquifer varies from less than 10 feet to as much as 150 to 200 feet in those areas where the Spiritwood and Warwick aquifers are one continuous unit. Because of the highly variable saturated thickness of the Warwick aquifer in the specific study area, it is concluded that it does not represent the most desirable ground-water source for the Ramsey Rural Water system.

The Spiritwood aquifer system is a buried valley type aquifer system that is generally under confined conditions. In the study area the aquifer is divided into the Spiritwood aquifer near Devils Lake, the Spiritwood aquifer near Warwick, and the Spiritwood aquifer near the Sheyenne River. On the basis of the available data, the Spiritwood aquifer near Warwick has the highest potential for development. The Spiritwood aquifer near Warwick is generally 100 feet thick but can be as much as 184 feet thick. This segment of the aquifer is 9 to 10 miles long, as much 8 miles wide and covers approximately 60 square miles. Irrigation and municipal wells completed into the Spiritwood aquifer near Warwick yield between 500 to 1000 gpm. Ground water from the Spiritwood aquifer near Warwick is a calcium-sodium-bicarbonate type with total dissolved solids ranging from 200 to 600 mg/l. Treatment and removal of iron, manganese, and hardness may however be desirable. In addition, the Spiritwood aquifer near Warwick is bounded by poorer quality to the east (edge of aquifer), north (Spiritwood aquifer near Devils Lake) and south (Spiritwood aquifer near the Sheyenne River). Better quality water occurs to the west. Additional pumping in the area may cause some change in the water quality. It is uncertain if leakage from the Warwick and ground-water movement from the west will continue to keep the water low in total dissolved solids or if poorer quality water will begin to move from the north, south and east.

Based on an analysis of the available data, it appears that the Spiritwood aquifer near Warwick has sufficient saturated thickness (100 to 200 feet), large enough areal extent (60 square miles), minor water level fluctuations, good to excellent water quality and favorable recharge characteristics to support the withdrawal of an additional 1000 acre-feet of water per year . In general the best area for development is along the axis of the Spiritwood aquifer where the maximum saturated thickness occurs. The area selected should be near the center of the aquifer in order maximum the potential for long term withdrawals of good quality water. The area that is most favorable for development is in a band running from just northwest of the city of Tolna's production well (NW 1/4 section 6, T. 150 N., R. 61 W.) to just south east of the old school house in section 23, T. 151 N., R. 62 W.

Once sites are selected, several test holes should be drilled and observation wells constructed to determine the site specific geology and saturated thickness of the aquifer. Formation samples should also be collected for sieve analyses and screen design. Additional water samples should also be analyzed to determine the ground-water quality in the proposed well field area. Any new production wells should be tested to determine the productivity and hydraulic characteristics of the Spiritwood aquifer in the area. Based on the available data the proposed production wells will probably be 175 to 250 feet in depth.

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TABLE 1 Records of wells and test holes

151-061-06CCC

NDSWC 12805

Date Completed:	7/24/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	250	Source of Data:	
Screened Interval (ft):	223-228	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1505

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	Yellowish brown, silty, sandy with pebbles, iron stained, oxidized till	1-27
CLAY	olive gray, silty, sandy with pebbles, till, shale gravel from 44-48 feet	27-68
CLAY	olive gray, stiff, drills smooth and slow	68-169
SAND & GRAVEL	fine sand to coarse gravel, drills fast, choppy, taking water, 30% shale, 10% lignite, remainder igneous	169-191
CLAY	olive gray, sandy	191-198
SAND & GRAVEL	sandy from 198-221 then coarser from 221-237, taking water, rocky at bottom, changed to rock bit	198-237
SHALE	black, greasy, some brittle fragments (Pierre shale)	237-250

151-062-01AAD

NDSWC 12808

Date Completed:	7/30/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	220	Source of Data:	
Screened Interval (ft):	178-183	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1495

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	yellowish brown, silty, sandy with pebbles, oxidized till	1-18
CLAY	olive gray, silty sandy with pebbles, till	18-63
CLAY	olive gray, slightly silty, sticky, drills slow	63-135
CLAY	gray to black, harder than above	135-157
GRAVEL	sandy, 20-40% shale, medium sand to coarse gravel, well rounded to subrounded, drills fast to choppy, taking water	157-193
SHALE	black, greasy, clayey (Pierre shale)	193-198
SHALE	black, brittle, angular fragments	198-220

151-062-03ADDA

NDSWC 12804

Date Completed:	7/23/91	Well Type:	2 INCH ABS
Depth Drilled (ft):	400	Source of Data:	
Screened Interval (ft):	350-355	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1575

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	yellowish brown, silty, oxidized clay	1-16
CLAY	yellowish brown, silty sandy with pebbles, oxidized till	16-26
SAND & GRAVEL	oxidized	26-30
TILL	oxidized	30-32
GRAVEL	oxidized	32-52
TILL	oxidized	52-54
CLAY	olive gray, silty sandy with pebbles, interbedded with sand and gravel, till	54-82
CLAY	olive gray, silty, sticky	82-182
CLAY	black, sticky, hole boots off, losing circulation	182-250
CLAY	black, with fragments of shale, Pierre?, some black greasy organics	250-292
GRAVEL	coarse with coarse to very coarse sand, some lignite fragments, 20-30% shale, ran out of drill stem	292-400

151-062-23ABB
NDSWC 5283

Date Completed:	5/12/78	Well Type:	2 INCH ABS
Depth Drilled (ft):	320	Source of Data:	
Screened Interval (ft):	228-231	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1477.2

Lithologic Log

Unit	Description	Depth (ft)
SAND	fine to coarse sand, mostly medium sand, well sorted, sub angular to rounded, mostly quartz (40%), also some carbonates, shale, and lignite, coarse bed of lignitic sand at 35 feet, oxidized zone ends at 26 feet, taking water, mixed mud at 60 feet	0-58
GRAVEL	sandy, fine to coarse gravel, mostly fine gravel, fine to coarse sand, moderately sorted and rounded, mostly shale gravel (390% to 40%)	58-66
SILT	clayey, sandy, light to dark gray clay, medium to coarse sand interbedded	66-74
SILT	very clayey, very poor return, medium to dark gray, 80% silt	74-93
CLAY	medium to dark gray, very plastic and compact	93-100
CLAY	silty, sandy, pebbles, dark gray, fine to coarse sand and pebbles, till	100-118
CLAY	silty, medium dark gray, very compact, moderately plastic	118-136
SAND	fine to very coarse, mostly medium sand, fairly well sorted, very coarse sand is mostly lignite, fine to medium sand is mostly quartz,	136-176
SAND	as above, mostly coarse to very coarse, some fine gravel, abundant shale pebbles, slightly plastic, taking water	176-277
CLAY	shale, silty, medium light to dark gray with some brownish gray, tight, cohesive, brittle, calcareous, Niobrara formation, bedrock	277-320

151-062-23ABB2

NDSWC 12810A

Date Completed:	7/31/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	160	Source of Data:	
Screened Interval (ft):	148-153	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1475

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	very fine to medium, well sorted, iron stained, oxidized, taking water	1-19
SAND	very fine to coarse, unoxidized, well rounded, becomes very coarse with depth, 10% fine gravel, taking water	19-45
GRAVEL	sandy, pea to marble size shale gravel, taking lots of water mixed 1 bag of mud	45-66
GRAVEL	interbedded with silty clay	66-76
CLAY	olive silty	76-135
SAND	gravely, medium sand to coarse gravel	135-160

151-062-23ABB3

NDSWC 12810B

Date Completed:	7/31/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	60	Source of Data:	
Screened Interval (ft):	48-53	Principal Aquifer :	Warwick
Casing size (in) & Type:		L.S. Elevation (ft)	1475

Lithologic Log

Unit	Description	Depth (ft)
see log for 23 ABB2		0-0

151-062-24CCC

NDSWC 5292

Date Completed:	5/11/78	Well Type:	2 INCH ABS
Depth Drilled (ft):	320	Source of Data:	
Screened Interval (ft):	258-261	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1481.2

Lithologic Log

Unit	Description	Depth (ft)
SAND	gravely, fine to coarse sand, fine gravel, mostly medium sand, well sorted, angular to rounded, oxidized	0-14
GRAVEL	sandy, fine to coarse gravel, fine to coarse sand, mostly medium gravel, mostly shale, fair to well sorted, rounded to slightly angular	14-21
CLAY	silty, sandy, medium plastic, dark gray clay, fine to medium sand (15%)	21-25
CLAY	light to dark gray, very plastic, compact	25-71
SAND	very fine to medium, mostly fine sand, very well sorted, mostly quartz, some lignite fragments	71-92
SAND	coarse sand with layers of lignite	92-94
CLAY	silty, dark gray, clay, 10 to 20 % silt, very plastic and cohesive, very compact at 135 feet	94-142
SAND	very fine to medium sand, mostly fine sand, very well sorted	142-150
SAND AND CLAY	interbedded, fine sand and gray clay, moderately compact	150-162
SAND	coarse lignitic sand interbedded with dark gray clay	162-172
SAND	as above, interbedded, more lignite	172-181
SAND	fine to medium, mostly medium, well sorted, subrounded	181-187
GRAVEL	sandy, fine to medium gravel, medium to coarse sand, mostly fine gravel, mostly quartz, shale and carbonates, some lignite, moderately well sorted, subrounded, bed of medium gravel, lignite fragments at 250 feet, some clay layers at 290 feet	187-300
CLAY	silty, dark gray clay, very compact, plastic (Niobrara) bedrock	300-320

151-062-24CCC2

NDSWC 12807A

Date Completed:	7/25/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	160	Source of Data:	
Screened Interval (ft):	148-153	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1475

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	very fine to fine, oxidized	1-18
SAND	unweathered gravely	18-22
CLAY	olive gray, till	22-31
CLAY	olive gray, silty	31-71
SAND	fine, lignitic	71-92
CLAY	silty, gray	92-138
SAND	very fine to medium, lignitic, drills fast, taking water	138-160

151-062-24CCC3

NDSWC 12807B

Date Completed:	7/25/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	30	Source of Data:	
Screened Interval (ft):	18-23	Principal Aquifer :	Warwick
Casing size (in) & Type:		L.S. Elevation (ft)	1475

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	very fine to fine, oxidized	1-18
GRAVEL	coarse, unweathered, pea to marble size	18-23
CLAY	olive gray, silty, sandy with pebbles, till	23-30

151-062-24DDC1

NDSWC 12806A

Date Completed:	7/25/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	240	Source of Data:	
Screened Interval (ft):	218-223	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1485

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
GRAVEL	coarse, pea to marble size, iron stained, oxidized, lots of unweathered sand and gravel from 15-23 feet, taking water	1-23
CLAY	olive gray, silty, sandy with pebbles, poorly sorted till layer of sand and gravel from 32-37 feet	23-37
CLAY	very silty, olive gray drills smooth and fast	37-48
CLAY	less silty, drills slower, olive gray	48-67
SAND	very fine to fine, lots of lignites, and shale	67-90
CLAY	olive gray, very hard	90-143
SAND	very fine to fine, drills fast lignitic, taking water, layer of clay from 58-61 feet	143-161
SAND	very fine to very coarse, drills choppy and fast, lignitic, taking water	161-185
GRAVEL	coarse sand to pea gravel, well rounded to subrounded, lots of lignites and shales	185-231
SHALE	black, hard, may be fractured, bedrock, (Pierre shale)	231-240

151-062-24DDC2

NDSWC 12806B

Date Completed:	7/25/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	160	Source of Data:	
Screened Interval (ft):	148-153	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1485

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND & GRAVEL	oxidized	1-24
CLAY	olive gray, silty, sandy, with pebbles, till	24-36
CLAY	olive gray	36-68
SAND	very fine to fine	68-79
CLAY	olive gray, silty	79-84
SAND	very fine, lignitic	84-91
CLAY	gray, hard	91-143
SAND	very fine to medium, lots of lignites	143-160

151-062-24DDC3

NDSWC 12806C

Date Completed:	7/25/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	28	Source of Data:	
Screened Interval (ft):	18-23	Principal Aquifer :	Warwick
Casing size (in) & Type:	.	L.S. Elevation (ft)	1485

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND & GRAVEL	iron stained, oxidized	1-24
CLAY	olive gray, silty, sandy, with pebbles, till	24-28

151-062-25DAA1

NDSWC 12809A

Date Completed:	7/30/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	240	Source of Data:	
Screened Interval (ft):	218-223	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1485

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
GRAVEL	iron stained, sandy, oxidized, taking water	1-15
GRAVEL	unoxidized, sandy, coarse sand to pea to marble size gravel, taking water	15-21
CLAY	olive gray, silty, sandy with pebbles, rocky, till	21-37
CLAY	olive gray, sticky, drills slow	37-47
SAND	very fine to fine	47-61
CLAY	olive gray, silty	61-142
SAND	very fine to fine, drills fast, drills as if interbedded with clay	142-172
GRAVEL	sandy, 30% shale, drills very choppy, taking water, coarse sand to pea gravel, well rounded to subrounded	172-231
SHALE	black, brittle, with bentonite fragments, (Pierre shale)	231-240

151-062-25DAA2

NDSWC 12809B

Date Completed:	7/30/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	160	Source of Data:	
Screened Interval (ft):	148-153	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1485

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
GRAVEL	oxidized, iron stained	1-15
GRAVEL	sandy, unweathered	15-21
CLAY	olive gray, silty, sandy with pebbles, till	21-31
CLAY	olive gray	31-46
SAND	fine, lots of lignite	46-61
CLAY	olive gray, silty	61-141
SAND	very fine to medium, drills fast, taking water	141-160

151-062-25DAA3

NDSWC 12809C

Date Completed:	7/31/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	30	Source of Data:	
Screened Interval (ft):	18-23	Principal Aquifer :	Warwick
Casing size (in) & Type:		L.S. Elevation (ft)	1485

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
GRAVEL	iron stained, oxidized, sandy, taking water	1-15
GRAVEL	unweathered, sandy, coarse sand to pea gravel, taking water	15-21
CLAY	olive gray, silty, sandy with pebbles, rocky, poorly sorted, till	21-30

152-062-34AAD1

NDSWC 12802A

Date Completed:	7/22/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	200	Source of Data:	
Screened Interval (ft):	158-163	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1480

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	yellowish brown, iron stained, silty, sandy with pebbles, oxidized till	1-9
TILL	as above, olive gray, unoxidized, layers of coarse sand from 22-26, 27-28, 38-40 and 50-51 feet	9-55
CLAY	olive gray, drills smooth	55-117
SAND	very fine to coarse gravel, well rounded to subrounded, lots of lignite	117-146
GRAVEL	coarse sand to coarse gravel, well rounded to subrounded, drills choppy, taking water	146-175
SHALE	black to gray, brittle (Pierre shale)	175-200

152-062-34AAD2

NDSWC 12802B

Date Completed:	7/23/1	Well Type:	2 INCH PVC
Depth Drilled (ft):	140	Source of Data:	
Screened Interval (ft):	128-133	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1480

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND & GRAVEL	oxidized	1-5
CLAY	yellowish brown, oxidized, silty, sandy with pebbles, till	5-9
CLAY	olive gray, silty, sandy with pebbles, till	9-23
SAND & GRAVEL	fine sand to coarse gravel	23-31
TILL	olive gray, pebbles	31-41
GRAVEL	shale, lignitic	41-46
TILL	olive gray, pebbles	46-54
CLAY	olive gray, silty	54-119
SAND	very fine to fine from 119-128, from 128-140 becomes coarse sand to gravel	119-140

152-062-34DDA

NDSWC 12803

Date Completed:	7/23/91	Well Type:	2 INCH PVC
Depth Drilled (ft):	280	Source of Data:	
Screened Interval (ft):	238-243	Principal Aquifer :	Spiritwood
Casing size (in) & Type:		L.S. Elevation (ft)	1525

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
GRAVEL	iron stained, oxidized	1-4
CLAY	yellowish brown, silty, sandy with pebbles, oxidized till	4-28
CLAY	very silty, oxidized, 41-44 feet oxidized sand	28-44
CLAY	olive gray, silty, sandy with pebbles, unweathered till	44-76
CLAY	very silty, olive gray	76-212
SAND	fine to coarse, drills choppy, taking a little water, mostly quartz and igneous, some shale, lots of lignites	212-224
GRAVEL	coarse sand to fine gravel, well rounded to subrounded, drills real choppy, taking water, rocky, gravel is pea to marble size at 250	224-267
SHALE	black, brittle, (Pierre shale)	267-280

TABLE 2 Water levels in selected wells

150-061-05DDD
Spiritwood Aquifer
LS Elev (msl,ft)=1454.2
SI (ft.)=167-170

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	34.29	1419.91	07/28/91	34.36	1419.84
04/30/91	34.25	1419.95	08/31/91	34.47	1419.73
05/30/91	34.27	1419.93	09/28/91	34.35	1419.85
06/29/91	34.33	1419.87	10/26/91	34.35	1419.85

150-061-06BBB
Spiritwood Aquifer
LS Elev (msl,ft)=1462.7
SI (ft.)=197-203

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	9.03	1453.67	07/28/91	10.87	1451.83
04/30/91	8.66	1454.04	08/31/91	14.31	1448.39
05/30/91	8.93	1453.77	09/29/91	11.14	1451.56
06/29/91	9.63	1453.07	10/26/91	9.22	1453.48

150-061-06CCC2
Spiritwood Aquifer
LS Elev (msl,ft)=1468.01
SI (ft.)=198-203

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	14.40	1453.61	07/28/91	15.93	1452.08
04/30/91	14.14	1453.87	08/31/91	19.53	1448.48
05/30/91	14.22	1453.79	09/28/91	16.65	1451.36
06/29/91	15.09	1452.92	10/26/91	14.74	1453.27

150-061-19BBB
Spiritwood Aquifer
LS Elev (msl,ft)=1459.43
SI (ft.)=175-181

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	86.83	1372.60	07/28/91	87.07	1372.36
04/30/91	86.70	1372.73	08/30/91	87.22	1372.21
05/30/91	86.83	1372.60	09/28/91	87.08	1372.35
06/29/91	86.98	1372.45	10/26/91	87.03	1372.40

150-061-30ABB
Spiritwood Aquifer
LS Elev (msl,ft)=1458.5
SI (ft.)=237-240

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	85.18	1373.32	07/28/91	85.49	1373.01
04/30/91	85.10	1373.40	08/30/91	85.68	1372.82
05/30/91	85.23	1373.27	09/28/91	85.49	1373.01
06/29/91	85.32	1373.18	10/26/91	85.45	1373.05

150-062-03DDD
Spiritwood Aquifer
LS Elev (msl,ft)=1473.19
SI (ft.)=168-173

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	18.99	1454.20	07/28/91	20.09	1453.10
04/30/91	18.77	1454.42	08/30/91	23.19	1450.00
05/30/91	18.64	1454.55	09/28/91	21.10	1452.09
06/29/91	19.52	1453.67	10/26/91	19.27	1453.92

150-062-04BBA
Warwick Aquifer

LS Elev (msl,ft)=1471.5
SI (ft.)=27-42

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	9.03	1462.47	07/28/91	9.61	1461.89
04/30/91	8.86	1462.64	08/30/91	10.27	1461.23
05/30/91	10.07	1461.43	09/28/91	6.76	1464.74
06/30/91	7.39	1464.11	10/26/91	6.68	1464.82

150-062-06BBC
Spiritwood Aquifer

LS Elev (msl,ft)=1470.1
SI (ft.)=123-126

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	6.81	1463.29	07/28/91	4.87	1465.23
04/30/91	6.48	1463.62	08/30/91	5.44	1464.66
05/30/91	6.01	1464.09	09/28/91	4.58	1465.52
06/30/91	5.52	1464.58	10/26/91	4.79	1465.31

150-062-10DDD
Spiritwood Aquifer

LS Elev (msl,ft)=1473.74
SI (ft.)=168-173

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	19.59	1454.15	08/30/91	23.63	1450.11
06/29/91	19.97	1453.77	10/26/91	19.83	1453.91

150-062-12BBB
Spiritwood Aquifer

LS Elev (msl,ft)=1477
SI (ft.)=218-223

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)

150-062-12CCCB
Spiritwood Aquifer

LS Elev (msl,ft)=1472.66
SI (ft.)=198-203

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	18.55	1454.11	08/30/91	23.73	1448.93
06/29/91	19.41	1453.25	10/26/91	19.20	1453.46

150-062-16AAA
Spiritwood Aquifer

LS Elev (msl,ft)=1473.4
SI (ft.)=152-155

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	17.43	1455.97	07/28/91	17.29	1456.11
04/30/91	17.14	1456.26	08/30/91	20.09	1453.31
05/30/91	16.92	1456.48	09/28/91	18.94	1454.46
06/30/91	17.20	1456.20	10/26/91	17.34	1456.06

150-062-22AAC
Spiritwood Aquifer

LS Elev (msl,ft)=0
SI (ft.)=145-160

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)

150-062-23BBB
Spiritwood Aquifer

LS Elev (msl,ft)=1462.2
SI (ft.)=154-178

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	35.27	1426.93
04/30/91	34.91	1427.29
05/30/91	34.73	1427.47
06/29/91	40.56	1421.64
07/28/91	37.54	1424.66
08/30/91	36.79	1425.41
09/28/91	36.00	1426.20
10/26/91	35.50	1426.70

150-062-24CBB
Spiritwood Aquifer

LS Elev (msl,ft)=1462.78
SI (ft.)=158-163

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	88.99	1373.79
04/30/91	88.77	1374.01
05/30/91	88.68	1374.10
06/29/91	88.97	1373.81
07/28/91	88.99	1373.79
08/30/91	89.26	1373.52
09/28/91	89.12	1373.66
10/26/91	89.08	1373.70

151-061-06CCC
Spiritwood Aquifer

LS Elev (msl,ft)=1515
SI (ft.)=223-228

Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	63.86	1451.14
08/31/91	64.13	1450.87
09/29/91	62.85	1452.15
10/25/91	61.78	1453.22

151-061-07CCC
Spiritwood Aquifer

LS Elev (msl,ft)=1512.68
SI (ft.)=178-183

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	56.85	1455.83
04/29/91	55.38	1457.30
05/30/91	55.15	1457.53
06/29/91	55.13	1457.55
07/28/91	55.44	1457.24
08/31/91	55.51	1457.17
09/29/91	55.31	1457.37
10/25/91	54.88	1457.80

151-061-30AAA
Spiritwood Aquifer

LS Elev (msl,ft)=1505.11
SI (ft.)=218-223

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	51.67	1453.44
04/29/91	51.38	1453.73
05/30/91	51.22	1453.89
06/29/91	52.22	1452.89
07/28/91	53.54	1451.57
08/31/91	55.71	1449.40
09/29/91	53.46	1451.65
10/26/91	51.90	1453.21

151-061-30BBB
Spiritwood Aquifer

LS Elev (msl,ft)=1453.2
SI (ft.)=197-200

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	-0.20	1453.40
07/28/91	-0.06	1453.26

151-061-32BBB
Spiritwood Aquifer

LS Elev (msl,ft)=1465.26
SI (ft.)=168-173

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	11.76	1453.50
04/30/91	11.48	1453.78
05/30/91	11.44	1453.82
06/29/91	12.39	1452.87
07/28/91	13.38	1451.88
08/31/91	16.70	1448.56
09/29/91	13.78	1451.48
10/26/91	12.06	1453.20

151-062-01AAD LS Elev (msl,ft)=1496.16
Spiritwood Aquifer SI (ft.)=178-183

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	45.30	1450.86	09/29/91	44.54	1451.62
08/31/91	45.74	1450.42	10/25/91	43.32	1452.84

151-062-03DDA LS Elev (msl,ft)=1608.2
Spiritwood Aquifer SI (ft.)=350-355

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/09/91	158.95	1449.25	10/26/91	156.79	1451.41
09/28/91	158.17	1450.03			

151-062-03DDD1 LS Elev (msl,ft)=1535.2
Warwick Aquifer SI (ft.)=62-65

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/31/91	45.60	1489.60	10/26/91	45.85	1489.35
09/28/91	45.83	1489.37			

151-062-03DDD2 LS Elev (msl,ft)=1535.2
Spiritwood Aquifer SI (ft.)=260-263

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	83.57	1451.63	07/28/91	85.24	1449.96
04/29/91	83.28	1451.92	08/29/91	87.28	1447.92
05/30/91	83.22	1451.98	09/28/91	85.24	1449.96
06/28/91	83.97	1451.23	10/26/91	83.85	1451.35

151-062-09ABB LS Elev (msl,ft)=1494.4
Spiritwood Aquifer SI (ft.)=197-203

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	43.87	1450.53	07/28/91	44.88	1449.52
04/29/91	43.55	1450.85	08/29/91	47.33	1447.07
05/30/91	43.54	1450.86	09/28/91	45.53	1448.87
06/28/91	44.18	1450.22	10/26/91	44.20	1450.20

151-062-12DCC LS Elev (msl,ft)=1511.1
Spiritwood Aquifer SI (ft.)=235-238

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	56.10	1455.00	07/28/91	58.80	1452.30
04/29/91	56.02	1455.08	08/31/91	59.68	1451.42
05/30/91	55.94	1455.16	09/28/91	57.58	1453.52
06/29/91	56.49	1454.61	10/25/91	56.31	1454.79

151-062-13CBB LS Elev (msl,ft)=1496.2
Spiritwood Aquifer SI (ft.)=238-241

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
04/29/91	41.43	1454.77	08/29/91	46.26	1449.94
05/30/91	41.37	1454.83	09/28/91	43.32	1452.88
06/28/91	42.25	1453.95	10/25/91	41.94	1454.26
07/28/91	47.28	1448.92			

151-062-14AAA LS Elev (msl,ft)=1511.5
Spiritwood Aquifer SI (ft.)=218-224

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	57.62	1453.88	07/28/91	61.82	1449.68
04/29/91	57.30	1454.20	08/29/91	61.73	1449.77
05/30/91	57.25	1454.25	09/28/91	59.17	1452.33
06/28/91	58.06	1453.44	10/25/91	57.83	1453.67

151-062-15AAA LS Elev (msl,ft)=1492.1
Spiritwood Aquifer SI (ft.)=197-203

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	39.17	1452.93	07/28/91	41.94	1450.16
04/29/91	38.76	1453.34	08/29/91	43.30	1448.80
05/30/91	38.71	1453.39	09/28/91	40.74	1451.36
06/28/91	39.55	1452.55	10/26/91	39.30	1452.80

151-062-15BBB LS Elev (msl,ft)=1494.9
Spiritwood Aquifer SI (ft.)=198-204

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	40.58	1454.32	07/28/91	44.13	1450.77
04/29/91	40.29	1454.61	08/29/91	46.05	1448.85
05/30/91	40.25	1454.65	09/28/91	43.66	1451.24
06/28/91	40.96	1453.94	10/26/91	42.23	1452.67

151-062-15CCC LS Elev (msl,ft)=1479.1
Warwick Aquifer SI (ft.)=18-21

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	10.77	1468.33	07/28/91	8.43	1470.67
04/30/91	10.70	1468.40	08/29/91	9.11	1469.99
05/30/91	10.49	1468.61	09/28/91	8.93	1470.17
06/28/91	9.29	1469.81	10/26/91	8.95	1470.15

151-062-16BCA LS Elev (msl,ft)=1505
Spiritwood Aquifer SI (ft.)=178-198

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)

151-062-17ABD1 LS Elev (msl,ft)=1500
Spiritwood Aquifer SI (ft.)=178-198

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)

151-062-19AAA LS Elev (msl,ft)=1486
Spiritwood Aquifer SI (ft.)=133-138

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	22.62	1463.38	07/28/91	22.97	1463.03
04/30/91	22.50	1463.50	08/30/91	23.22	1462.78
05/30/91	22.39	1463.61	09/28/91	21.60	1464.40
06/29/91	22.13	1463.87	10/26/91	21.32	1464.68

151-062-19ABB
Warwick Aquifer

LS Elev (msl,ft)=1484.6
SI (ft.)=30-33

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	20.15	1464.45	07/28/91	19.53	1465.07
04/30/91	20.25	1464.35	08/30/91	19.44	1465.16
05/30/91	20.29	1464.31	09/28/91	19.36	1465.24
06/29/91	20.27	1464.33	10/26/91	19.34	1465.26

151-062-19ADD1
Warwick Aquifer

LS Elev (msl,ft)=1482.6
SI (ft.)=33-38

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	19.47	1463.13	07/28/91	18.21	1464.39
04/30/91	19.38	1463.22	08/30/91	18.15	1464.45
05/30/91	19.11	1463.49	09/28/91	18.09	1464.51
06/29/91	18.89	1463.71	10/26/91	17.98	1464.62

151-062-19DDA
Warwick Aquifer

LS Elev (msl,ft)=1468.2
SI (ft.)=40-45

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	7.66	1460.54	07/28/91	5.90	1462.30
04/30/91	6.98	1461.22	08/30/91	6.29	1461.91
05/30/91	6.70	1461.50	09/28/91	5.95	1462.25
06/29/91	6.11	1462.09	10/26/91	5.90	1462.30

151-062-20ABB
Spiritwood Aquifer

LS Elev (msl,ft)=1482.8
SI (ft.)=148-151

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	19.71	1463.09	07/28/91	20.09	1462.71
04/30/91	19.59	1463.21	08/30/91	19.98	1462.82
05/30/91	19.48	1463.32	09/28/91	18.60	1464.20
06/29/91	19.18	1463.62	10/26/91	18.34	1464.46

151-062-20ACA
Not Yet Entered (for aq Aquifer

LS Elev (msl,ft)=1490
SI (ft.)=168-183

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)

151-062-20BDD
Not Yet Entered (for aq Aquifer

LS Elev (msl,ft)=0
SI (ft.)=0-0

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)

151-062-20CDA
Warwick Aquifer

LS Elev (msl,ft)=1476.9
SI (ft.)=78-81

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	14.60	1462.30	10/26/91	12.97	1463.93
09/28/91	13.03	1463.87			

151-062-20DAD1
Spiritwood Aquifer

LS Elev (msl,ft)=1470.5
SI (ft.)=143-146

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	8.12	1462.38
04/30/91	7.92	1462.58
05/30/91	7.58	1462.92
06/29/91	6.77	1463.73
07/28/91	6.77	1463.73
08/30/91	7.24	1463.26
09/28/91	6.62	1463.88
10/26/91	6.44	1464.06

151-062-20DAD2
Warwick Aquifer

LS Elev (msl,ft)=1470.7
SI (ft.)=55-58

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	8.17	1462.53
04/30/91	7.88	1462.82
05/30/91	7.58	1463.12
06/29/91	7.18	1463.52
07/28/91	6.68	1464.02
08/30/91	7.20	1463.50
09/28/91	6.67	1464.03
10/26/91	6.49	1464.21

151-062-21BAA
Spiritwood Aquifer

LS Elev (msl,ft)=1485.5
SI (ft.)=160-166

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	22.66	1462.84
04/30/91	22.48	1463.02
05/30/91	24.09	1461.41
06/29/91	22.37	1463.13
07/28/91	38.10	1447.40
08/30/91	33.09	1452.41
09/28/91	23.89	1461.61
10/26/91	21.19	1464.31

151-062-22BBB2
Spiritwood Aquifer

LS Elev (msl,ft)=1476.3
SI (ft.)=171-177

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	13.57	1462.73
04/30/91	13.30	1463.00
05/30/91	15.97	1460.33
06/28/91	13.49	1462.81
07/28/91	34.89	1441.41
08/29/91	30.91	1445.39
09/28/91	13.27	1463.03
10/26/91	12.06	1464.24

151-062-23ABB
Spiritwood Aquifer

LS Elev (msl,ft)=1477.2
SI (ft.)=228-231

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	22.54	1454.66
04/29/91	22.25	1454.95
05/30/91	22.21	1454.99
06/28/91	23.16	1454.04
07/28/91	28.40	1448.80
08/31/91	27.79	1449.41
09/28/91	24.26	1452.94
10/25/91	22.78	1454.42

151-062-23ABB2
Spiritwood Aquifer

LS Elev (msl,ft)=1476.1
SI (ft.)=148-153

Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	30.18	1445.92
08/31/91	28.59	1447.51
09/28/91	25.08	1451.02
10/25/91	23.59	1452.51

151-062-23ABB3 LS Elev (msl,ft)=1476.5

Warwick Aquifer SI (ft.)=48-53

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	10.95	1465.55	09/28/91	10.87	1465.63
08/31/91	11.23	1465.27	10/25/91	11.04	1465.46

151-062-24AAA LS Elev (msl,ft)=1491.8

Spiritwood Aquifer SI (ft.)=197-203

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	36.49	1455.31	07/28/91	39.77	1452.03
04/29/91	36.21	1455.59	08/31/91	40.72	1451.08
05/30/91	36.17	1455.63	09/29/91	37.96	1453.84
06/29/91	36.88	1454.92	10/25/91	36.64	1455.16

151-062-24CCC LS Elev (msl,ft)=1481.2

Spiritwood Aquifer SI (ft.)=258-261

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	25.99	1455.21	07/28/91	30.72	1450.48
04/30/91	25.70	1455.50	08/31/91	32.19	1449.01
05/30/91	25.67	1455.53	09/29/91	27.83	1453.37
06/29/91	26.58	1454.62	10/25/91	26.26	1454.94

151-062-24CCC2 LS Elev (msl,ft)=1479.5

Spiritwood Aquifer SI (ft.)=148-153

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	32.75	1446.75	09/29/91	29.02	1450.48
08/31/91	32.62	1446.88	10/25/91	27.45	1452.05

151-062-24CCC3 LS Elev (msl,ft)=1479.3

Warwick Aquifer SI (ft.)=18-23

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	8.95	1470.35	09/29/91	9.51	1469.79
08/31/91	9.16	1470.14	10/25/91	9.34	1469.96

151-062-24DDC1 LS Elev (msl,ft)=1484.8

Spiritwood Aquifer SI (ft.)=218-223

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	37.91	1446.89	09/29/91	33.07	1451.73
08/31/91	36.68	1448.12	10/25/91	31.39	1453.41

151-062-24DDC2 LS Elev (msl,ft)=1485.1

Spiritwood Aquifer SI (ft.)=148-153

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	37.27	1447.83	09/29/91	33.74	1451.36
08/31/91	37.09	1448.01	10/25/91	32.15	1452.95

151-062-24DDC3 LS Elev (msl,ft)=1485.1

Warwick Aquifer SI (ft.)=18-23

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/15/91	17.74	1467.36	09/29/91	18.01	1467.09
08/31/91	17.85	1467.25	10/25/91	17.95	1467.15

151-062-25ACD LS Elev (msl,ft)=0

Spiritwood Aquifer SI (ft.)=220-250

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)

151-062-25DAA1 LS Elev (msl,ft)=1482.08

Spiritwood Aquifer SI (ft.)=218-223

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/08/91	30.57	1451.51	09/29/91	30.96	1451.12
08/31/91	34.30	1447.78	10/26/91	29.20	1452.88

151-062-25DAA2 LS Elev (msl,ft)=1482.3

Spiritwood Aquifer SI (ft.)=148-153

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/08/91	31.55	1450.75	09/29/91	31.00	1451.30
08/31/91	34.34	1447.96	10/26/91	29.29	1453.01

151-062-25DAA3 LS Elev (msl,ft)=1482.2

Warwick Aquifer SI (ft.)=18-23

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/09/91	12.62	1469.58	09/29/91	12.68	1469.52
08/31/91	12.61	1469.59	10/26/91	12.15	1470.05

151-062-27AAA1 LS Elev (msl,ft)=1468.4

Warwick Aquifer SI (ft.)=14-16

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	4.29	1464.11	07/28/91	1.33	1467.07
04/30/91	3.03	1465.37	08/31/91	2.16	1466.24
05/30/91	2.05	1466.35	09/28/91	0.39	1468.01
06/29/91	0.39	1468.01	10/25/91	1.08	1467.32

151-062-27AAA2 LS Elev (msl,ft)=1468.6

Spiritwood Aquifer SI (ft.)=198-204

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	13.52	1455.08	07/28/91	18.68	1449.92
04/30/91	13.22	1455.38	08/31/91	21.72	1446.88
05/30/91	13.18	1455.42	09/28/91	15.41	1453.19
06/29/91	14.12	1454.48	10/25/91	13.81	1454.79

151-062-27DDDA
Spiritwood Aquifer

LS Elev (msl,ft)=1464.08
SI (ft.)=188-193

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/29/91	10.69	1453.39
04/30/91	10.38	1453.70
05/30/91	10.34	1453.74
06/29/91	11.33	1452.75
07/28/91	15.03	1449.05
08/31/91	18.30	1445.78
09/28/91	12.70	1451.38
10/26/91	10.92	1453.16

151-062-34DDD
Spiritwood Aquifer

LS Elev (msl,ft)=1466.1
SI (ft.)=167-170

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	12.13	1453.97
04/30/91	11.83	1454.27
05/30/91	11.74	1454.36
06/29/91	12.74	1453.36
07/28/91	14.39	1451.71
08/31/91	17.63	1448.47
09/28/91	14.12	1451.98
10/26/91	12.35	1453.75

151-062-36AAA
Spiritwood Aquifer

LS Elev (msl,ft)=1476.9
SI (ft.)=198-203

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	23.46	1453.44
04/30/91	23.16	1453.74
05/30/91	23.15	1453.75
06/29/91	24.12	1452.78
07/28/91	25.87	1451.03
08/31/91	28.93	1447.97
09/29/91	25.47	1451.43
10/26/91	23.73	1453.17

151-062-36CCC
Spiritwood Aquifer

LS Elev (msl,ft)=1462.3
SI (ft.)=197-203

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/28/91	8.03	1454.27
04/30/91	7.74	1454.56
05/30/91	7.77	1454.53
06/29/91	8.69	1453.61
07/28/91	10.12	1452.18
08/31/91	13.49	1448.81
09/29/91	10.17	1452.13
10/26/91	8.30	1454.00

152-062-07ACA1
Spiritwood Aquifer

LS Elev (msl,ft)=1493.3
SI (ft.)=197-203

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/30/91	51.29	1442.01
06/30/91	50.85	1442.45
08/29/91	51.77	1441.53
10/27/91	51.69	1441.61

152-062-21DBD
Spiritwood Aquifer

LS Elev (msl,ft)=1444.6
SI (ft.)=124-130

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/30/91	1.68	1442.92
06/30/91	1.25	1443.35
08/29/91	2.58	1442.02
10/26/91	1.81	1442.79

152-062-27AAA
Warwick Aquifer

LS Elev (msl,ft)=1450.3
SI (ft.)=138-143

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/30/91	6.36	1443.94
06/30/91	5.84	1444.46
08/29/91	6.47	1443.83
10/26/91	6.15	1444.15

152-062-28DBD
Spiritwood Aquifer

LS Elev (msl,ft)=1444.8
SI (ft.)=137-143

Date	Depth to Water (ft)	WL Elev (msl, ft)
03/30/91	1.39	1443.41
06/30/91	1.04	1443.76
08/29/91	2.54	1442.26
10/26/91	1.97	1442.83

152-062-33CDA1
Spiritwood Aquifer

LS Elev (msl,ft)=1486.8
SI (ft.)=318-323

Date	Depth to Water (ft)	WL Elev (msl, ft)
04/18/91	37.47	1449.33
06/10/91	37.68	1449.12
07/10/91	37.33	1449.47
08/07/91	39.03	1447.77
09/12/91	40.69	1446.11
10/09/91	38.54	1448.26
11/20/91	37.11	1449.69

152-062-33CDA2
Clay Sediments Aquifer

LS Elev (msl,ft)=1486.8
SI (ft.)=45-50

Date	Depth to Water (ft)	WL Elev (msl, ft)
04/18/91	30.04	1456.76
06/10/91	30.07	1456.73
07/10/91	29.69	1457.11
08/07/91	29.44	1457.36
09/12/91	29.09	1457.71
10/09/91	28.48	1458.32
11/20/91	27.30	1459.50

152-062-33CDA3
Spiritwood Aquifer

LS Elev (msl,ft)=1487.1
SI (ft.)=168-173

Date	Depth to Water (ft)	WL Elev (msl, ft)
04/18/91	37.66	1449.44
06/10/91	37.87	1449.23
07/10/91	37.53	1449.57
08/07/91	39.22	1447.88
09/12/91	40.87	1446.23
10/09/91	38.74	1448.36
11/20/91	37.32	1449.78

152-062-33CDA4
Clay Sediments Aquifer

LS Elev (msl,ft)=1487.2
SI (ft.)=133-138

Date	Depth to Water (ft)	WL Elev (msl, ft)
04/18/91	29.79	1457.41
06/10/91	29.84	1457.36
07/10/91	29.75	1457.45
08/07/91	30.74	1456.46
09/12/91	30.44	1456.76
10/09/91	30.03	1457.17
11/20/91	29.51	1457.69

152-062-33CDA5
Till Aquifer

LS Elev (msl,ft)=1487
SI (ft.)=18-23

Date	Depth to Water (ft)	WL Elev (msl, ft)

152-062-33DCB LS Elev (msl,ft)=1484.6

Spiritwood Aquifer SI (ft.)=200-203

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
04/18/91	37.59	1447.01	09/12/91	37.35	1447.25
06/10/91	37.69	1446.91	10/09/91	37.30	1447.30
07/10/91	37.36	1447.24	11/20/91	35.81	1448.79
08/07/91	36.83	1447.77			

152-062-34AAD1 LS Elev (msl,ft)=1460

Spiritwood Aquifer SI (ft.)=158-163

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/08/91	11.13	1448.87	09/28/91	11.83	1448.17
08/31/91	12.75	1447.25	10/26/91	10.56	1449.44

152-062-34AAD2 LS Elev (msl,ft)=1460

Spiritwood Aquifer SI (ft.)=128-133

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/08/91	11.14	1448.86	09/28/91	11.38	1448.62
08/31/91	12.76	1447.24	10/26/91	10.11	1449.89

152-062-34DDA LS Elev (msl,ft)=1530.2

Spiritwood Aquifer SI (ft.)=238-243

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/09/91	81.20	1449.00	09/28/91	81.25	1448.95
08/31/91	82.77	1447.43	10/26/91	79.97	1450.23

Table 3. Chemical analyses of ground-water samples from selected wells

Location	Screened Interval (ft)	Date Sampled	SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	NCH	% Na	SAR	Spec Cond (µmho)	Temp (∞C)	pH
			(milligrams per liter)																					
150-061-05DDD	167-170	07/17/91	33	0.03	0.61	65	17	150	8.1	433	0	160	21	0.3	1	0.52	670	230	0	57	4.3	997	11	
150-061-06BBB	197-203	07/17/91	36	0.55	0.11	35	14	65	4	329	0	13	7.7	0.2	1	0.27	339	150	0	49	2.3	521	7	
150-061-06CCC2	198-203	07/17/91	38	0.38	0.08	25	9.5	92	3.9	334	0	9.1	11	0.3	0.5	0.36	355	100	0	65	4	548	7	
150-061-19BBB	175-181	08/07/91	31	0.25	0.08	57	25	160	7.5	390	0	190	82	0.2	0.2	0.43	746	250	0	58	4.4	1170	9	
150-061-30ABB	237-240	07/17/91	34	0.56	0.08	55	25	250	8.3	458	0	310	73	0.2	8	0.57	991	240	0	68	7	1464	8	
150-062-03DDD	168-173	07/17/91	35	1.1	0.16	79	20	8	2.2	366	0	1.2	2.1	0.2	1	0.01	330	280	0	6	0.2	519	7	
150-062-10DDD	168-173	07/17/91	35	0.82	0.08	48	16	36	3.8	330	0	2.5	4.1	0.2	0.6	0.08	310	190	0	29	1.1	479	7	
150-062-16AAA	152-155	07/17/91	28	0.74	0.21	53	16	27	3.5	316	0	3.3	2.6	0.2	1	0.07	292	200	0	22	0.8	468	9	
150-062-23BBB	154-178	08/06/91	29	0.01	0.02	48	16	200	7.7	442	0	170	66	0.3	5.1	0.47	761	190	0	69	6.3	1167	12	
150-062-24CBB	158-163	08/06/91	37	0.15	0.08	32	12	100	5	372	0	48	4.3	0.2	4.5	0.47	427	130	0	62	3.8	641	9	
151-061-06CCC	223-228	08/15/91	38	0.03	1.3	150	42	41	5.7	475	0	280	4.7	0.2	4.2	0.17	801	550	160	14	0.8	1133	7	
151-061-07CCC	178-183	07/18/91	34	0.96	0.67	130	36	10	3.6	414	0	150	5.1	0.3	1	0.05	576	470	130	4	0.2	816	7	
151-061-30AAA	218-223	07/17/91	38	1.5	0.53	92	36	56	5.4	395	0	180	8.9	0.2	0.4	0.19	614	380	54	24	1.2	860	7	
151-061-32BBB	168-173	07/16/91	37	0.53	0.11	30	11	190	5.5	474	0	70	57	0.4	5.4	0.65	641	120	0	77	7.5	978	6	
151-062-01AAD	178-183	08/15/91	36	0.02	0.61	110	43	200	9.3	601	0	420	14	0.3	1	0.62	1130	450	0	48	4.1	1528	7	
151-062-03DDD1	62-65	07/18/91	29	0.02	0.52	58	26	10	3.8	301	0	14	2.7	0.3	1	0.01	293	250	5	8	0.3	484	9	
151-062-03DDD2	260-263	07/18/91	21	2.2	0.26	85	21	10	2.2	324	0	55	3.7	0.1	1	0.02	361	300	33	7	0.3	575	8	
151-062-09ABB	197-203	08/02/91	32	1.3	0.24	62	20	57	4.8	391	0	43	7.8	0.2	1	0.1	422	240	0	34	1.6	480	8	
151-062-12DCC	235-238	07/16/91	34	1	0.9	140	36	12	3.2	419	0	170	5.1	0.2	1	0.05	609	500	150	5	0.2	837	8	
151-062-13CBB	238-241	07/16/91	38	1.3	0.41	79	17	7.5	1.7	281	0	42	2.1	0.1	0.6	0.02	328	270	37	6	0.2	501	8	
151-062-14AAA	218-224	07/16/91	31	0.55	0.55	100	28	10	2.4	370	0	95	2.3	0.2	1	0.05	453	360	62	6	0.2	693	10	
151-062-15AAA	197-203	07/18/91	34	0.59	0.42	59	15	47	4	331	0	36	5.3	0.2	4.2	0.22	369	210	0	32	1.4	566	6	
151-062-15BBB	198-204	07/18/91	37	1.8	0.23	88	25	21	5.9	401	0	47	3.5	0.2	5.2	0.13	433	320	0	12	0.5	669	7	
151-062-19AAA	133-138	08/01/91	34	0.83	0.04	38	18	30	5.7	279	0	14	1.7	0.2	1	0.3	281	170	0	27	1	400	8	
151-062-19ABB	30-33	08/01/91	30	0.27	0.45	63	18	6	1.6	233	0	59	2	0.1	1	0.01	296	230	40	5	0.2	400	8	
151-062-20ABB	148-151	08/07/91	32	0.27	0.73	61	10	5	1.7	231	0	23	1.7	0.2	1	0.02	251	190	4	5	0.2	380	7	
151-062-20DAD1	143-146	08/07/91	33	1.1	0.26	64	12	4.5	1.8	259	0	15	0.8	0.2	0.3	0.01	261	210	0	5	0.1	398	8	
151-062-20DAD2	55-58	08/07/91	31	0.21	0.59	61	16	4	1.6	257	0	24	2	0.2	1.3	0.01	269	220	8	4	0.1	415	8	
151-062-21BAA	160-166	08/07/91	34	1.4	0.12	72	21	170	7.7	414	0	280	15	0.2	5.8	0.55	812	270	0	57	4.5	1144	8	
151-062-22BBB2	171-177	07/18/91	37	1.2	0.12	44	17	100	5.4	383	0	86	7	0.2	5.1	0.26	492	180	0	54	3.2	733	6	
151-062-23ABB	228-231	07/18/91	31	0.54	0.18	32	12	100	7.3	351	0	29	26	0.2	0.8	0.36	412	130	0	61	3.8	658	7	
151-062-24AAA	197-203	07/16/91	38	1.4	0.47	62	15	13	1.7	269	0	11	4.1	0.2	1	0.02	281	220	0	12	0.4	444	7	
151-062-24CCC	258-261	07/18/91	37	0.46	0.08	23	8.5	160	4.7	391	0	36	65	0.3	5.5	0.5	534	93	0	78	7.2	843	7	
151-062-24CCC2	148-153	08/15/91	36	0.07	0.08	35	14	82	4.7	372	0	13	9.5	0.3	1.7	0.44	380	150	0	54	2.9	603	7	
151-062-24CCC3	18-23	08/15/91	29	0.03	3.2	69	17	4	4.1	315	0	15	0.6	0.1	1	0.02	298	240	0	3	0.1	470	8	
151-062-24DDC1	218-223	08/15/91	38	0.02	0.29	51	20	65	4.7	333	0	73	8.6	0.3	0.7	0.38	426	210	0	40	2	648	8	
151-062-24DDC2	148-153	08/15/91	37	0.05	0.05	40	17	89	4.8	371	0	56	7.5	0.4	8.9	0.7	444	170	0	52	3	669	7	
151-062-24DDC3	18-23	08/15/91	31	0.02	0.11	130	46	5	2.1	338	0	100	29	0.2	120	0.05	630	510	240	2	0.1	980	8	
151-062-25DAA1	218-223	08/08/91	30	0.06	0.2	37	13	220	6	526	0	180	35	0.3	2	0.57	783	150	0	76	7.8	1172	12	
151-062-25DAA2	148-153	08/08/91	35	0.12	0.05	37	16	110	5.3	397	0	69	11	0.4	1.1	0.56	482	160	0	59	3.8	753	12	
151-062-25DAA3	18-23	08/09/91	27	0.01	0.01	110	34	2.5	1.8	299	0	87	21	0.2	72	0.05	503	410	170	1	0.1	771	10	
151-062-27AAA2	198-204	07/18/91	36	0.77	0.11	52	21	47	4.7	361	0	26	8.3	0.2	3.9	0.16	378	220	0	31	1.4	578	7	
151-062-27DDDA	188-193	07/18/91	38	0.63	0.14	44	17	76	5.1	375	0	40	11	0.1	4.4	0.14	422	180	0	47	2.5	635	7	
151-062-34DDD	167-170	07/17/91	32	0.17	0.16	46	19	41	4	330	0	7.8	4.4	0.1	1	0.09	319	190	0	31	1.3	525	8	
151-062-36AAA	198-203	07/16/91	37	0.14	0.54	26	9.5	89	3.7	318	0	14	13	0.3	1	0.39	352	100	0	64	3.9	544	7	
152-062-21DBD	124-130	08/01/91	19	4.9	0.88	130	44	110	7.9	501	0	330	11	0.1	1	0.38	906	510	95	32	2.1	1100	11	
152-062-27AAA	138-143	08/14/91	28	0.04	0.94	190	71	150	12	600	0	550	45	0.3	4.7	0.4	1350	770	270	29	2.4	1782	8	
152-062-28DBD	137-143	08/01/91	31	3.5	0.72	120	38	29	5	407	0	200	4.3	0.2	1	0.14	633	460	120	12	0.6	780	8	
152-062-33CDA1	318-323	08/02/91	34	0.79	0.16	70	28	170	7.5	519	0	260	12	0.2	1	0.3	840	290	0	55	4.3	1000	8	
152-062-33CDA2	45-50	08/02/91	24	5.2	2.8	720	200	28	12	526	0	1300	520	0.1	1	0.13	3070	2600	2200	2	0.2	2000	8	
152-062-33CDA3	168-173	08/02/91	34	0.76	0.08	50	20	31	3.6	313	0	22	4.5	0.2	1	0.21	321	210	0	24	0.9	450	8	
152-062-34AAD1	158-163	08/08/91	32	0.93	0.56	180	51	98	8.1	562	0	380	17	0.1	1	0.28	1050	660	200	24	1.7	1408	9	
152-062-34AAD2	128-133	08/08/91	36	7	0.08	170	50	48	5.9	532	0	320	6.8	0.1	1	0.18	907	630	190	14	0.8	1240	8	
152-062-34DDA	238-243	08/09/91	37	2.7	0.27	190	50	27	6.2	506	0	330	4.2	0.1	1	0.12	898	680	270	8	0.5	1178	8	

Table 4 - - Dissolved chemical constituents in water - - their effects upon usability and recommended concentration limits for domestic and municipal water supplies in North Dakota.

Constituent or Parameter	Effects of dissolved constituents on water use	Suggested limits for drinking water in North Dakota[1]	U.S. Public Health Service recommended limits for drinking water[2]
Silica (SiO_2)	No physiological significance.		
Iron (Fe)	Concentrations over 0.1 mg/l will cause staining of fixtures. Over 0.5 mg/l may impart taste and colors to food and drink.		0.3 mg/l
Manganese (Mn)	Produces black staining when present in amounts exceeding 0.05 mg/l.		0.05 mg/l
Calcium (Ca) and Magnesium (Mg)	Calcium and magnesium are the primary causes of hardness. High concentrations may have a laxative effect on persons not accustomed to this type of water.		
Sodium (Na)	No physiological significance except for people on salt-free diets. Does have an effect on the irrigation usage of water.		
Potassium (K)	Small amounts of potassium are essential to plant and animal nutrition.		
Bicarbonate (HCO_3) and Carbonate (CO_3)	No definite significance, but high bicarbonate content will impart a flat taste to water.		
Sulfate (SO_4)	Combines with Calcium to form scale. More than 500 mg/l tastes bitter and may be a laxative	0-300 mg/l - low 300-700 mg/l - high over-700 mg/l - very high	250 mg/l
Percent Sodium and Sodium Adsorption Ratio (SAR)	Indicate the sodium hazard of irrigation water.		
Chloride (Cl)	Over 250 mg/l may impart a salty taste, greatly excessive concentrations may be physiologically harmful. Humans and animals may adapt to higher concentrations.		250 mg/l
Flouride (F)	Flouride helps prevent tooth decay within specified limits. Higher concentrations cause mottled teeth.	Limits of 0.9 mg/l to 1.5 mg/l	Recommended limits depend on average of daily temperatures. Limits range from 0.6 mg/l at 32°C. to 1.7 mg/l at 10°C.
Nitrate (NO_3)	Over 45 mg/l can be toxic to infants. Larger concentrations can be tolerated by adults. More than 200 mg/l may have a deleterious effect on livestock health.		45 mg/l
Boron (B)	No physiological significance. Greater than 2.0 mg/l may be detrimental to many plants.		
Total dissolved solids	Persons may become accustomed to water containing 2,000 mg/l or more dissolved solids.	0-500 mg/l - low 500-1400 mg/l average 1400-2500 mg/l high over 2500 mg/l very high	500 mg/l
Hardness (as $CaCO_3$)	Increases soap consumption, but can be removed by a water-softening system.	0-200 mg/l - low 200-300 mg/l average 300-450 mg/l high over 450 mg/l very high	
pH	Should be between 6.0 and 9.0 for domestic consumption.		
Specific Conductance	An electrical indication of total dissolved solids measured in micromhos per Centimeter at 25°C. Used primarily for irrigation analyses.		

1. Schmid, R.W., 1965, Water Quality Explanation: North Dakota State Water Commission, unpublished report, File No. 989.
2. U.S. Public Health Service, 1962, Public Health Service Drinking Water Standards: U.S. Public Health Service, Pub. No. 956, 61 p.