# WATER SUPPLY INVESTIGATION FOR THE CITY OF RYDER, NORTH DAKOTA


by

Steve W. Pusc



North Dakota Ground-Water Studies
Number 98
North Dakota State Water Commission
David Sprynczynatyk, State Engineer

Prepared by the
North Dakota State Water Commission

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## INTRODUCTION

In April of 1990, the city of Ryder contacted the State Water Commission concerning dangerously low water levels in their city production well. An investigation was subsequently conducted by the State Water Commission to determine the condition of their present water supply and to identify possible alternative water sources. Two of the main recommendations resulting from that investigation were: 1). to initiate a observation program for the city of Ryder's production well including water levels, water use, pumping rate and precipitation and 2). to conduct test drilling, water sampling and water level measurements in a 3 to 4 mile radius of Ryder to determine if there are locations in either the Ryder aquifer or the Ryder Ridge aquifer with sufficient saturated thickness to support a low yield well. The purpose of this report is to summarize the results of the test drilling and observation effort and to outline alternatives available to the city of Ryder.

## LOCATION OF STUDY AREA

The area of this ground-water investigation is located in the southwestern corner of Ward County, North Dakota (fig. 1). Specifically the area covers the area in and around the city of Ryder, North Dakota, in Townships 151 and 152, Range 86 West(fig. 1)

## METHODS OF STUDY

Hydrogeologic investigation of the Ryder area was accomplished by test drilling at 9 sites, installing 11 observation wells and measuring and recording depth to water in the 11 new observation wells and in the existing Ryder city production well. Additional work included: (1) a complete review and assembly of all existing data and literature and (2) ground-water samples for chemical analyses.

Test holes were drilled with a Failing model 1250 forward hydraulic mud rotary drill rig owned by the NDSWC. Observation wells were constructed using 2 inch diameter polyvinyl chloride (PVC) casing with 5 or 10 foot long PVC screens.

Pairs of observation wells were constructed specifically for this investigation to determine the vertical distribution of water levels and water quality in the area.

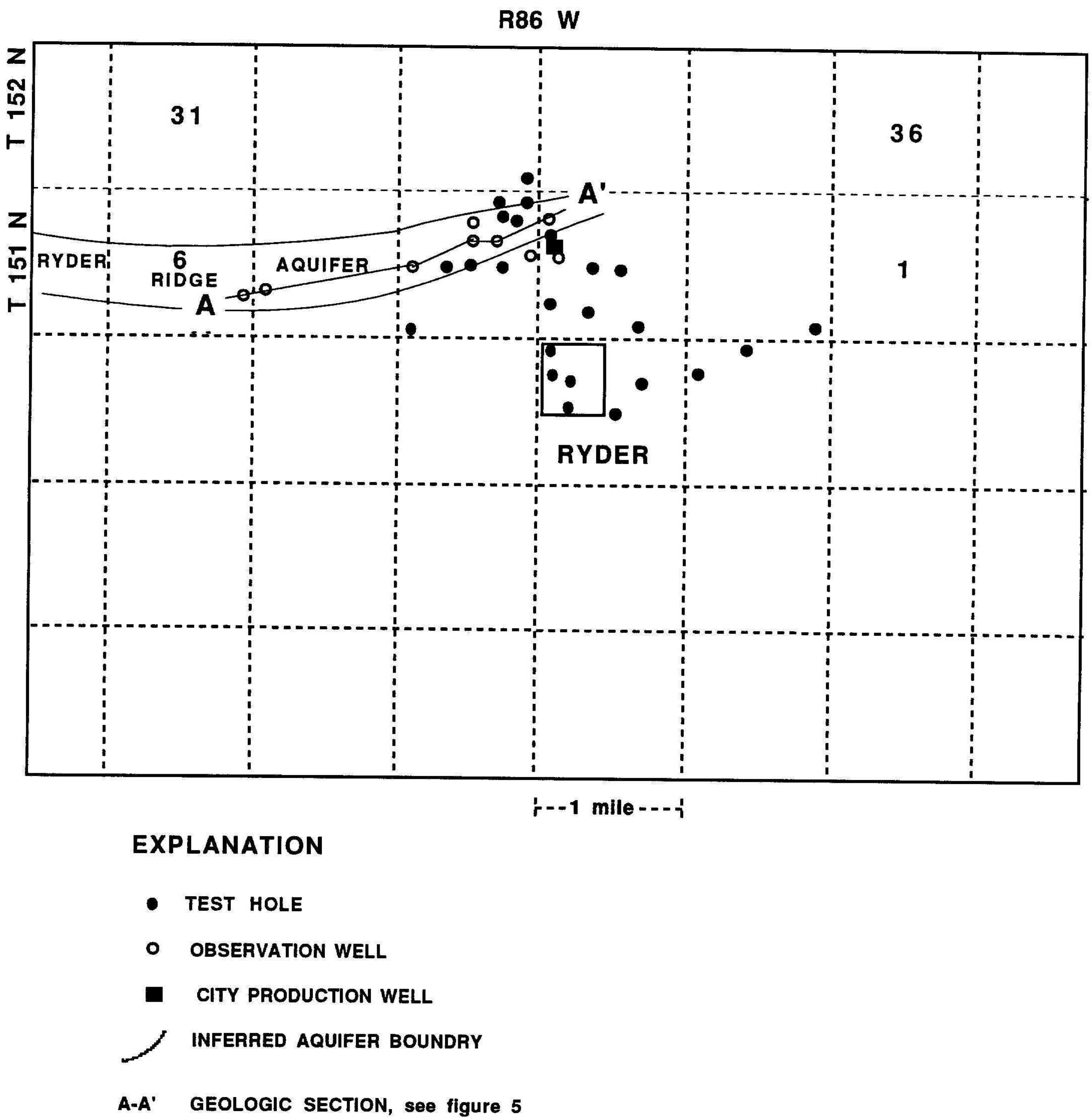


FIGURE 1. Location of test holes, observation wells, the city of Ryder production well and the inferred boundries of the Ryder Ridge aquifer in the vicinity of Ryder, North Dakota

Construction of the observation well pairs involved the drilling of an initial deep test hole to determine the stratigraphy at the site. Once the stratigraphy at the site was known, the number and depth of observation wells required could be determined. The initial deep test hole also served as a hole for the deep observation well. After drilling was completed, 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. High solids bentonite 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. After the grout settled, additional grout was used to fill the annular space to 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 compressed 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.

Samples of drill cuttings were collected and visually analyzed on a continuous basis throughout the drilling process. Resistivity and spontaneous potential logs were run in most of the NDSWC test holes. Copies of the geophysical logs are available for inspection in the office of the NDSWC. Locations of all test holes and observation wells are presented on figure 1. Pertinent data at each test hole site are presented in Appendix 1.

Depth to water measurements were recorded on a monthly basis in the 11 observation wells (Appendix 2). Water levels were measured with steel tapes, electronic well sounders, and one continuous recorder.

A continuous float type water level recorder was also installed in the Ryder city production well (fig. 1).

Water samples for chemical analysis were collected from all of the observation and production wells in the study area. The water sampling procedure involved the collection of 500 milliliters (ml) of raw water, 500 ml of filtered water and 500 ml of filtered and acidified (nitric acid) water. Samples from selected wells were also sampled for selected trace metals. Field measurements of specific conductance and water temperature were also made. Water temperature was, however, measured at land surface and does not represent an in situ temperature. The pH was measured in the laboratory.

State Water Commission observation wells were sampled using two methods; pumping with a gas squeeze bladder pump or by bailing with a PVC point source bailer. Water samples were obtained from the city supply well by using the existing pump.

Sampling with a bailer or gas squeeze pump involved the removal of at least three casing volumes of water to introduce formation water into the well. After evacuating at least three casing volumes of water, either the well was pumped further with the gas squeeze pump or a variable capacity PVC point source bailer was lowered to just above the bottom of the well screen. Bailing and/or pumping continued until enough water was secured for the sample. Water chemistry data are presented in Appendix 3 of this report.

## LOCATION NUMBERING SYSTEM

Wells and test holes presented on Figure 1 are numbered according to a system based on the location in the public land classification of the United States Bureau of Land Management (fig. 2). 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 151-86-04ADD is located in the SE1/4 SE1/4 NE1/4 of Section 4, Township 151 North, Range 86 West (fig. 2). Consecutive terminal numerals are added if more than one well is located in a 10-acre tract.

## PRESENT WATER SUPPLY

Water for municipal purposes is pumped from shallow sand and gravel deposits of the Ryder aquifer about 1/2 mile north of the city ( fig. 1,, SW 1/4 NW 1/4 of section 3). In this area, the city has one well which is 19 feet deep ( measured from the top of the casing; well is 15 feet deep from the original land surface (fig. 3). The well, installed in November of 1962, is constructed of 3, six foot long sections of concrete pipe, 84 inches in diameter. The bottom 4 feet of the lower section of pipe consists of porous

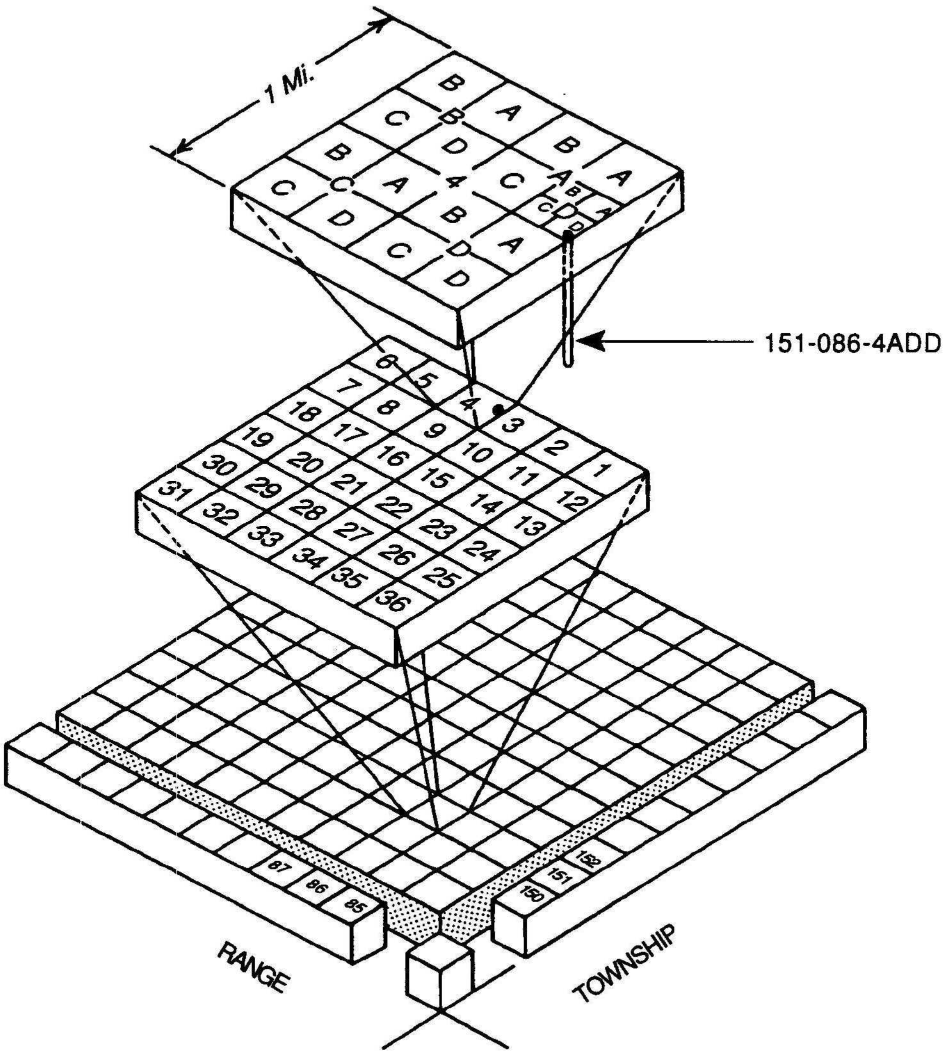


**Figure 2. Location-numbering system.**

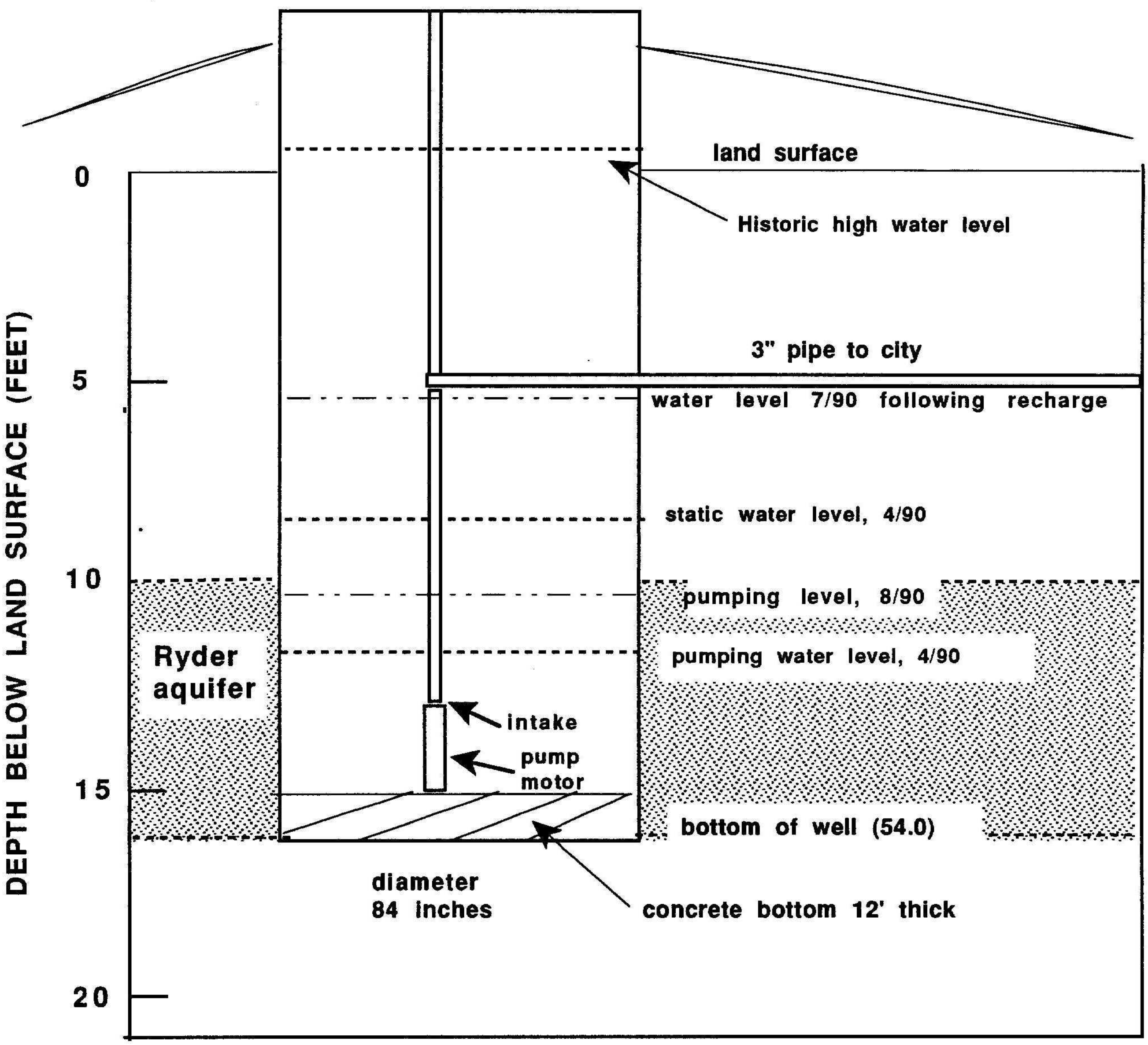


Figure 3. City of Ryder production well and Ryder aquifer

concrete to allow water from the aquifer to enter the well. At the well site, sand and gravel of the Ryder aquifer occurs from 10 to 16.5 feet below land surface ( bls) and is only 6.5 feet thick.

The city of Ryder is presently using about 15,000 to 17,000 gallons of ground water per day. The pump in the well produces about 30 to 40 gallons per minute. Raw water is chlorinated in the well and then pumped directly into the city distribution system.

Historic water level records for the area are limited. At the time the city well was constructed (1962), water levels in the Ryder aquifer ranged from 3 to 4 feet bls. Available drawdown in the city of Ryder well, at the time of well construction (1962), was 9 to 10 feet above the pump intake. The highest water level in the city well appears to have been about .5 feet above land surface as evidenced by the highest water stain in the well (fig. 3). The recent dry cycle and pumping by the city of Ryder has, at times lowered the water level in the well below the top of the aquifer indicating that the aquifer has fluctuated between confined and unconfined conditions (fig. 3). Since the city well was constructed (1963-1990), there has been about a 40 to 50 % loss in the amount of available drawdown(static height of water above the pump intake).

Recently measured water levels in the city well have fluctuated from 11.8 feet bls during April 1990 testing of the well to 5.30 feet bls on July 30, 1990 (fig. 4). Abundant rainfall in April, May and part of July ( 10 to 12 inches) resulted in recharge to the Ryder aquifer with water levels rising about 3 feet (figs. 3 & 4). Since the end of July, however, there has been virtually no precipitation and water levels have started to decline from the combined effects of evapotranspiration and pumping (fig. 4). As of August 14, 1990, the pumping level in the well was 10.34 feet bls.(figs. 3 & 4). At a pumping level of 10.34 feet there is only 2.66 feet of water above the pump intake and 4.66 feet of water in the well(figs. 3 & 4).

Since the end of July, water levels in the city well have declined at a rate of about 2 feet/month (fig. 4). In the absence of recharge, water levels will continue to decline from the combined effects pumping and evapotranspiration. If this downward rate of decline continues and if no significant recharge occurs the remainder of this

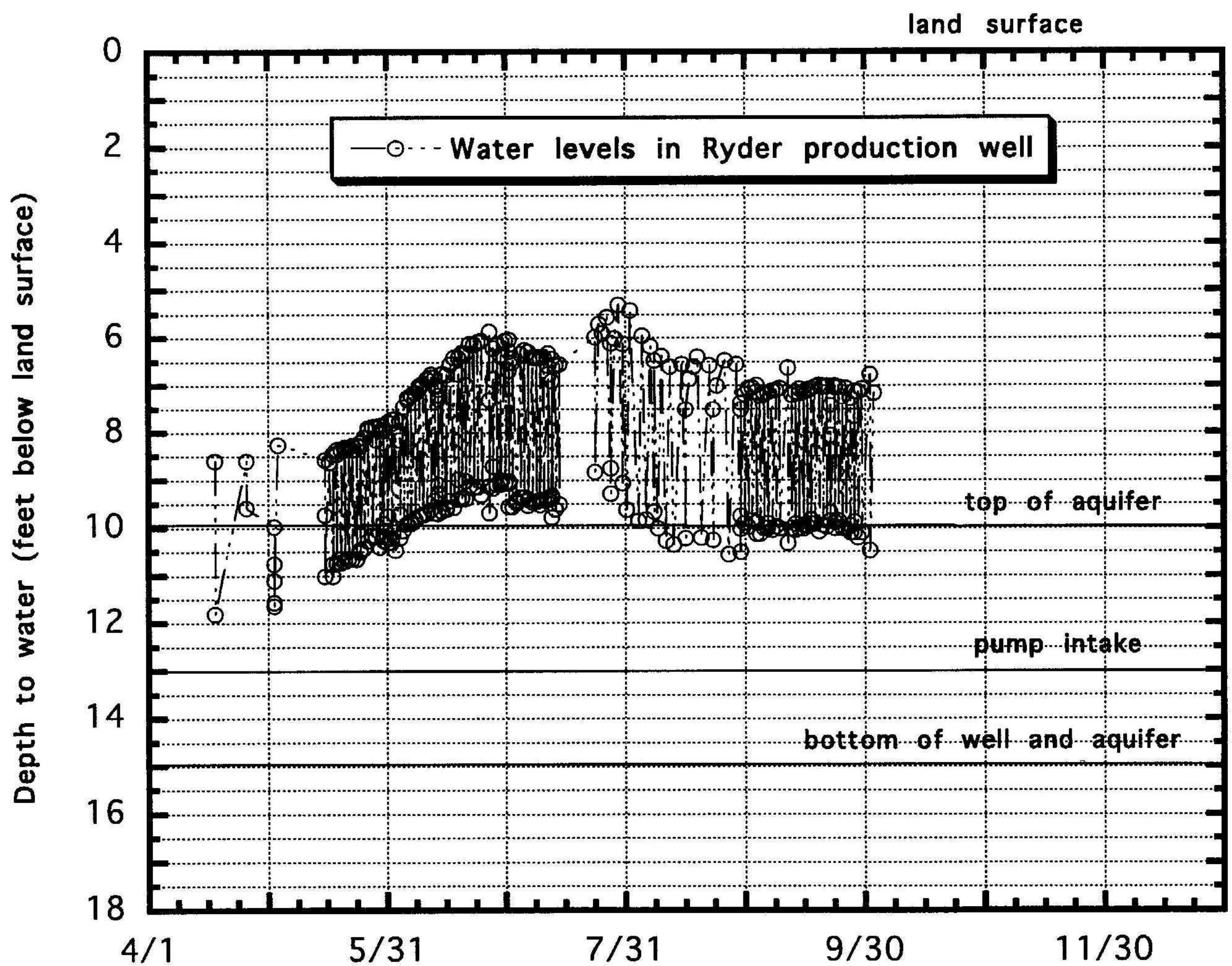


Figure 4. Water levels in the city of Ryder Production Well

summer or fall, the city could again be facing a serious water shortage by as early as the end of September(fig. 4).

Water quality for samples obtained from the city of Ryder's production well are summarized in table 1.

**TABLE 1 WATER QUALITY, RYDER PRODUCTION WELL**

| **CONSTIT.** | **1980** | **1985** | **5/03/90** | **6/18/90** |
|---|---|---|---|---|
| **TDS** | 856 | 690 | 1040 | 1330 |
| **Ca** | 109 | 83 | 120 | 150 |
| **Mg** | 97 | 100 | 110 | 140 |
| **Na** | 61 | 34 | 59 | 65 |
| **SO4** | 556 | 209 | 460 | 660 |
| **Cl** | 32 | 18 | 15 | 24 |
| **NO3** | 0 | | 1.0 | 1 |
| **Fe** | 0.2 | 0.4 | 1.1 | .54 |
| **Mn** | 0.12 | 0.11 | 0.70 | .75 |
| **Hardness** | 668 | 618 | 753 | 530 |

Note that the 1985 sample is of the best quality with TDS concentration only 690 mg/l. The most recent sample obtained on May 3, 1990 reveals that the concentrations of most chemical constituents have increased. Total dissolved solids concentration has increased to 1330 mg/l. It appears that with the reduced recharge and lower water level, ground water of poorer quality is being drawn towards the city well. All of the samples reveal that ground water from the Ryder aquifer is hard with elevated concentrations of iron (Fe), and manganese (Mn).

## RYDER RIDGE AQUIFER

Recent test drilling was conducted in the area to determine the areal extent of the Ryder Ridge aquifer in the vicinity of Ryder. The Ryder Ridge aquifer is a narrow deposit of sand and gravel which extends from near Ryder, North Dakota, westward into Mountrail County (fig. 1 ) (Pettyjohn and Hutchinson, 1971). The aquifer averages 700 feet in width and near Ryder can be seen as a distinct ridge which rises about 40 feet above the surrounding terrain. At a test hole site about 2 miles northwest of Ryder, the Ryder Ridge aquifer consists of an upper unit (56 to 74 feet bls) and a lower unit (86 to 100 feet bls) (fig. 5). At a test hole site about 1/4 mile west of the city well, the Ryder Ridge aquifer occurs form 55 to 74 feet bls (upper unit) and 84 to 114 feet bls (lower unit). About 1/8 mile north of the city well the Ryder Ridge aquifer occurs as an

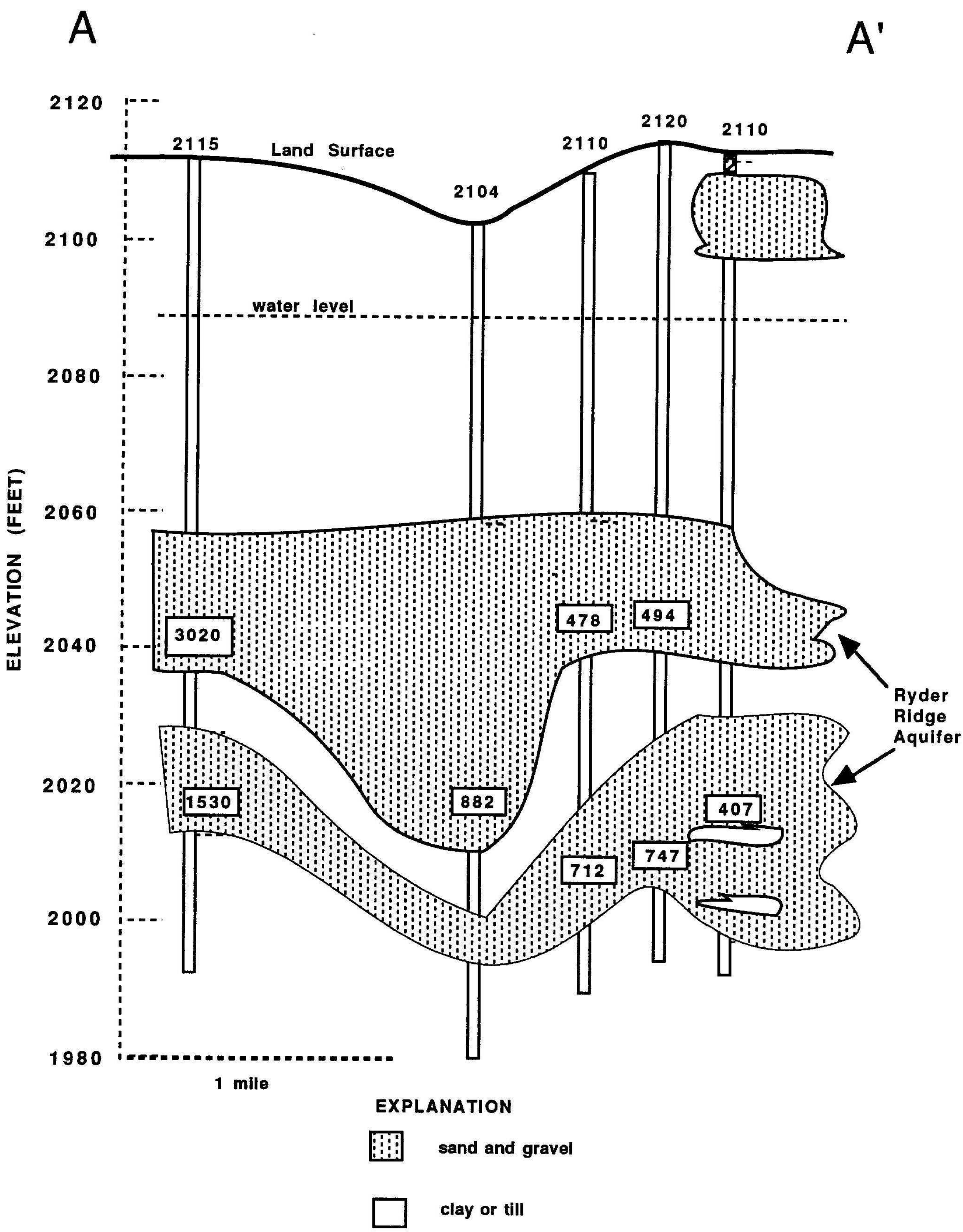


Figure 5. Geologic section along the axis of the Ryder Ridge aquifer and distribution of total dissloved solids

interbedded sequence of sand, gravel and clay from 60 to 115 feet bls (fig. 5). Thickness of the Ryder Ridge aquifer varies from 15 to 40 feet. In the vicinity of Ryder, the Ryder Ridge aquifer is at least 2 miles long. In general, about 40 to 60 feet of clay and/or till overlies and confines the Ryder Ridge aquifer. Water levels in the Ryder Ridge aquifer vary from 11 to 26 feet bls(fig. 5).

In July of 1990, the North Dakota State Water Commission sampled and analyzed ground water from the observation wells completed in the Ryder Ridge aquifer. Water from the aquifer can be classified as a calcium bicarbonate type near Ryder to a calcium-sodium sulfate type about 2 miles northwest of Ryder. The concentrations of total dissolved solids ranged from 407 mg/l just north of the Ryder city well to 3020 mg/l about 2 miles west of the city Ryder (fig. 5). Calcium concentrations varied from 81 mg/l in well 03bbc to 370 mg/l in 06daa2. Sodium ranged from 18 mg/l to 400 mg/l. Sulfate concentrations varied from 40 mg/l in well 03bbc to 1600 mg/l in well 06daa2. Hardness ranged from 305 mg/l to 1582 mg/l. Iron concentrations ranged from .1 mg/l to 11mg/l, and manganese ranged from .92 mg/l to 4.3 mg/l. Generally, ground water from the Ryder Ridge aquifer is of best quality in the upper unit of the aquifer and at the observation well site 1/8 miles north the city of Ryder well.

## SUMMARY AND CONCLUSIONS

The city of Ryder currently obtains water for municipal purposes from a single large diameter shallow well (15 feet) constructed in the Ryder aquifer. Based on the available data, the Ryder aquifer is shallow, arealy discontinuous, and has limited saturated thickness. The recent drought resulted in almost 3 years of no recharge to the Ryder aquifer. Before the rains of 1990, evapotranspiration and pumping by the city of Ryder was removing water from ground-water storage, resulting in a water level decline. Following are several summary statements concerning the Ryder aquifer and the impacts that the drought and municipal pumping have had.

1). The Ryder aquifer, near the city of Ryder municipal well, is only 4 to 8 feet thick and covers less than 1 square mile. Because of the limited size of the aquifer in the vicinity of the city well, the amount of ground water available locally from storage is rather small. In addition, Ryder's present well fully penetrates the Ryder aquifer so it not possible to deepen the well in the hope of screening more aquifer material.

2). Water use during the course of this study has been about 15,000 to 17,000 gallons per day. The pump in the well had been producing 30 to 40 gpm, however that rate has recently dropped off due to encrustation of the pump intake.

3). Historic water level records for the area are limited. At the time (1963) the city of Ryder constructed their well, water levels in the Ryder aquifer ranged from 3 to 4 feet below land surface. Available drawdown in the city of Ryder well, at the time of construction ( 1963), was 9 to 10 feet above the pump intake. The highest water level in the city well appears to have been .5 feet above land surface as evidenced by the highest water stain in the well.

4). Recently measured water levels in the city well have fluctuated from 11.8 feet below land surface during April testing of the well to 5.30 feet on July 30, 1990. Abundant rainfall in April, May and part of July ( 10 to 12 inches) resulted in recharge to the Ryder aquifer with water levels rising about 3 feet. Since the end of July, however, there has been virtually no precipitation and water levels have started to decline from the combined effects of evapotranspiration and pumping. As of August 14, 1990, the pumping level in the well was 10.34 feet below land surface. At a pumping level of 10.34 feet there is only 2.66 feet of water above the pump intake and 4.66 feet of water in the well.

5). Since the end of July, water levels in the city well have declined at a rate of about 2 feet/month. In the absence of recharge, water levels will continue to decline from the combined effects pumping and evapotranspiration. If this downward rate of decline continues and if no significant recharge occurs the remainder of this summer or fall, the city could again be facing a serious water shortage by as early as the end of September(fig. 3).

6). The Ryder aquifer, because of its shallow nature, is very susceptible to variations in climate. The fact that the aquifer is very susceptible to variations in climate also means that the potential for contamination from the surface is very high.

A recent investigation conducted in the vicinity of Ryder revealed the following about the Ryder Ridge aquifer.

1). The Ryder Ridge aquifer is a buried deposit of sand and gravel that occurs in a linear fashion from 2 miles northwest of Ryder to about 1/8 miles north of the present city well. Near the city of Ryder, the Ryder Ridge aquifer occurs as 2 layers of sand and gravel (upper and lower units) which range in thickness from 15 to 40 feet. Within 1/4 mile west or 1/8 mile north of the present city well, the Ryder Ridge aquifer occurs anywhere from 60 to 120 below land surface. Based on test drilling, the aquifer is at least 700 feet wide and 2 miles long. A property designed and constructed well that is screened in a thicker portion of the Ryder Ridge aquifer should yield between 50 and 200 gpm.

2). Water from the Ryder Ridge aquifer can be classified as a calcium bicarbonate type near Ryder to a calcium-sodium sulfate type about 2 miles west of Ryder. The concentrations of total dissolved solids ranged from 407 mg/l just north of the Ryder city well to 3020 mg/l about 2 miles west of the city Ryder. The concentrations of the major chemical constituents were less than the recommended drinking water standards (Cline, 1990), except for elevated levels of iron, manganese and hardness. Generally, ground water from the Ryder Ridge aquifer is of best quality in the upper unit of the aquifer and at the observation well site located 1/8 miles north of the city of Ryder well.

## RECOMMENDATIONS

It is obvious that a supplemental water source is needed in the near future to alleviate an inevitable water shortage by the City of Ryder. To this end, the city of Ryder should consider the following:

1). Detailed records need to continue to be kept on the current water supply from the Ryder aquifer (water use per day, pumping rate, length of pumping and nonpumping periods, and water levels at the end of pumping and nonpumping periods). At the present time the city needs to install an inline flow meter to record pumping rate and water use. In addition, a record should be kept on precipitation near the city well and water levels in the slough north and east of the city well. These records are necessary to determine the long term reliability of the current water supply.

2). Because of the limited amount of ground water in storage in the Ryder aquifer, water conservation measures should be in place during times of extended drought to insure a supply of water for the future.

3.) The city may consider setting a lower intake pump in the current well thus adding almost 2 feet to the available drawdown.

4). If the city does develop another water source, the current well should be cleaned to increase its efficiency. Care must be taken however that cleaning does not erode the porous concrete causing a collapse of the well.

5). Based on available data, the Ryder Ridge aquifer appears to have sufficient saturated thickness and large enough areal extent to support a low to medium yield well. The two most promising locations for a new city well are about 1/4 mile west and/or 1/8 mile north of the present city well. The new well would only need to be 60 to 120 feet deep. Any new city well should be tested to determine the productivity and long term reliability of the Ryder Ridge aquifer in this area. Water from the new well could either be used as a supplemental water source or, in the short term, as a source of recharge water to the Ryder aquifer in the vicinity of Ryder's well.

7). Because of the shallow nature of the Ryder aquifer, land use practices should be carefully monitored in the small watershed surrounding the city well. In addition water from the city well should be tested for herbicides and pesticides.

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**APPENDIX 1. LITHOLOGIC LOGS OF TEST HOLES AND WELLS**

**151-086-03BBC**
NDSWC 12617

| | | | |
|---|---|---|---|
| Date Completed: | 6/26/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2110 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 120 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 90-95 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| GRAVEL | sandy, oxidized, fine sand to fine gravel, drills smooth, taking water | 1-15 |
| CLAY | yellowish brown, oxidized | 15-22 |
| SAND | shale pebbles, drills fast, poor return | 22-25 |
| CLAY | olive gray till | 25-32 |
| GRAVEL | | 32-33 |
| CLAY | olive gray, till | 33-54 |
| LIGNITE | with fine sand | 54-56 |
| TILL | olive gray | 56-60 |
| SAND | very fine to medium, 10% lignite | 60-74 |
| SILT | olive gray, very silty with fine sand some clay | 74-82 |
| SAND | very fine to fine, well rounded to subrounded, drills fast | 82-94 |
| GRAVEL | sandy, well rounded to subrounded | 94-97 |
| CLAY | olive gray, silty | 97-101 |
| GRAVEL | sandy | 101-109 |
| CLAY | very silty, drills fast | 109-111 |
| GRAVEL | sandy, very coarse sand to pea gravel, taking water, well rounded to subrounded | 111-115 |
| CLAYSTONE | siltstone, with chunks of sandstone | 115-120 |

## 151-086-03BCB4

NDSWC 12613

| | | | |
|---|---|---|---|
| Date Completed: | 6/25/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2095 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 20 | Aquifer: | Ryder |
| Screened Interval (ft): | 8.5-13.5 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, silty, sandy with pebbles, oxidized till | 1-7 |
| GRAVEL | oxidized | 7-10 |
| GRAVEL | unoxidized, coarse sand to pea gravel, well rounded to subrounded, taking water | 10-14 |
| GRAVEL | layered with till | 14-16 |
| TILL | | 16-20 |

## 151-086-04ABC1

NDSWC 12614

| | | | |
|---|---|---|---|
| Date Completed: | 6/25/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2100 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 120 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 55-60 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, iron stained, silty, sandy with pebbles, oxidized till | 1-22 |
| GRAVEL | sandy, drills fast, taking water, medium sand to pea gravel | 22-25 |
| CLAY | olive gray, silty, sandy with pebbles, till | 25-51 |
| SAND | fine to very coarse, well rounded to subrounded, drills fast, lots of lignite | 51-60 |
| CLAY | olive gray, very silty | 60-65 |
| CLAY | yellowish brown, iron stained, oxidized till | 65-84 |
| CLAY | olive gray, till | 84-116 |
| CLAYSTONE | olive gray, brittle, drills smooth | 116-120 |

## 151-086-04ACA1

NDSWC 12616A

| | | | |
|---|---|---|---|
| Date Completed: | 6/26/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2120 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 120 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 105-110 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| GRAVEL | oxidized, iron stained | 1-5 |
| CLAY | yellowish brown, silty sandy with pebbles, rocky, oxidized till | 5-27 |
| CLAY | olive gray, silty, sandy with pebbles, unweathered till | 27-55 |
| SAND | very fine to medium, well rounded to subrounded, drills smooth, mostly shale, 10% lignites | 55-74 |
| CLAY | olive gray | 74-84 |
| SAND | gravelly, medium to coarse sand with gravel, drills smooth | 84-109 |
| GRAVEL | sandy, medium to coarse sand to pea gravel, drills choppy | 109-114 |
| CLAY | till, picking up bits of sandstone and claystone, bedrock | 114-120 |

## 151-086-04ACA2

NDSWC 12616B

| | | | |
|---|---|---|---|
| Date Completed: | 6/26/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2120 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 80 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 65-70 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| GRAVEL | oxidized | 1-5 |
| CLAY | yellowish brown, oxidized till 22-23 oxidized gravel | 5-26 |
| CLAY | olive gray, silty, very sandy, rocky till | 26-55 |
| SAND | gravelly, see log for 4ACA1 | 55-73 |
| CLAY | olive gray | 73-80 |

**151-086-04ACCB1**

NDSWC 12612A

| | | | |
|---|---|---|---|
| Date Completed: | 6/22/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2110 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 120 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 106-111 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, silty, sandy, with pebbles, oxidized till, 21-24 shale gravel | 1-27 |
| CLAY | olive gray, silty, sandy with pebbles, unweathered till, rocky | 27-52 |
| SAND | very fine to fine, well rounded, drills fast and smooth, composed of shales, limestones and granites | 52-71 |
| SILT | very clayey, olive gray, drills fast | 71-94 |
| GRAVEL | sandy, medium to coarse sand to pea gravel, well rounded to subrounded, drills choppy and rough, taking water, mostly shale, limestone and granites, 10% lignite | 94-114 |
| CLAY | till as above | 113-120 |

**151-086-04ACCB2**

NDSWC 12612B

| | | | |
|---|---|---|---|
| Date Completed: | 6/22/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2110 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 80 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 58-63 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, oxidized till | 1-27 |
| CLAY | olive gray, unoxidized till | 27-52 |
| SAND | very fine to fine, becomes more silty from 65-71 feet | 52-71 |
| SILT | very clayey, drills fast | 71-80 |

## 151-086-04ADDA1

NDSWC 12615A

| | | | |
|---|---|---|---|
| Date Completed: | 06/26/90 | Purpose: | Test Hole |
| L.S. Elevation (ft): | | Well Type: | None |
| Depth Drilled (ft): | 100 | | |
| | | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, silty, very sandy, with pebbles, oxidized till | 1-12 |
| GRAVEL | oxidized, medium sand to pea gravel 50% shale, 20% limestone, remainder granites and lignites, taking water | 12-18 |
| GRAVEL | unoxidized, same as above, drills as if coarser, taking water, well rounded to subrounded | 18-22 |
| CLAY | olive gray, silty, sandy with pebbles, till | 22-43 |
| CLAY | silty, olive gray, drills smooth | 43-52 |
| GRAVEL | shale | 52-53 |
| CLAY | yellowish brown, oxidized till | 53-94 |
| CLAY | olive gray, silty, sandy with pebbles, unweathered till | 94-100 |

## 151-086-04ADDA2

NDSWC 12615B

| | | | |
|---|---|---|---|
| Date Completed: | 6/26/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2100 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 28 | Aquifer: | Ryder |
| Screened Interval (ft): | 16-21 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, silty, very sandy oxidized till | 1-13 |
| GRAVEL | iron stained, oxidized | 13-21 |
| CLAY | olive gray, silty, very sandy with pebbles and rocks, till | 21-28 |

**151-086-04CAA**
NDSWC 12611

| | | | |
|---|---|---|---|
| Date Completed: | 06/21/90 | Purpose: | Test Hole |
| L.S. Elevation (ft): | | Well Type: | None |
| Depth Drilled (ft): | 160 | | |
| | | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, very silty, sandy with pebbles, oxidized till | 1-15 |
| CLAY | till as above, olive gray | 15-54 |
| SAND | fine to coarse, mostly fine, drills fast, not taking much water, well rounded to subrounded | 54-62 |
| CLAY | silty, olive gray, sticky | 62-70 |
| CLAY | yellowish brown, oxidized till with gravel layers | 70-112 |
| CLAY | olive gray till | 112-129 |
| CLAY | gray, sandy carbonaceous bedrock | 129-160 |

**151-086-04CBB1**
NDSWC 12607A

| | | | |
|---|---|---|---|
| Date Completed: | 6/20/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2104 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 120 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 78-83 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, iron stained, silty, sandy with pebbles, oxidized till | 1-30 |
| CLAY | olive gray, silty, sandy with pebbles, till | 30-43 |
| SAND | very fine to fine, drills smooth and fast, lignitic, taking a little water layers of clay at 61-61 and 73-74 feet. | 432-74 |
| GRAVEL | sandy, very fine sand to pea gravel, well rounded to subrounded, mostly shale and limestone, some granites and lignites | 74-91 |
| CLAY | brownish silty | 91-101 |
| GRAVEL | rocky, drills rough, interbedded with till | 101-108 |
| CLAY | till as above | 108-120 |

## 151-086-06DAA1

NDSWC 12606A

| | | | |
|---|---|---|---|
| Date Completed: | 6/20/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2100 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 120 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 92-97 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, iron stained, silty sandy with pebbles, rocky till | 1-32 |
| CLAY | olive gray, silty, sandy with small pebbles, till | 32-56 |
| SAND | very fine to fine, well rounded, drills fast, lignites | 56-74 |
| CLAY | olive gray, very silty | 74-86 |
| SAND | very fine to fine, drills smooth | 86-96 |
| GRAVEL | fine sand to pea size gravel, well rounded to subrounded, abundant lignite, gravel is composed of shale, limestone, some granites and lignites, taking water | 96-100 |
| CLAY | brownish, lignitic, some interbedded sand | 100-120 |

## 151-086-06DAA2

NDSWC 12606B

| | | | |
|---|---|---|---|
| Date Completed: | 6/20/90 | Purpose: | Observation Well |
| L.S. Elevation (ft): | 2100 | Well Type: | 2" PVC |
| Depth Drilled (ft): | 80 | Aquifer: | Ryder Ridge |
| Screened Interval (ft): | 59-64 | Source: | NDSWC |

Lithologic Log

| Unit | Description | Depth (ft) |
|---|---|---|
| TOPSOIL | | 0-1 |
| CLAY | yellowish brown, iron stained, silty, sandy with pebbles, oxidized till | 1-32 |
| CLAY | till as above, unoxidized | 32-55 |
| SAND | very fine to fine, drills smooth, abundant shale and lignite | 55-68 |
| CLAY | brownish gray | 68-80 |

**APPENDIX 2. WATER LEVELS IN SELECTED WELLS**

LS = Land surface elevation, obtained from USGS 7 1/2 minute quadrangle maps
SI = Screened Interval, in feet below land surface

**151-086-03BBC**
Ryder Ridge Aquifer

LS Elev (msl,ft)=2110
SI (ft.)=90-95

| Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|
| 01/10/91 | 25.17 | 2086.33 |
| 01/17/91 | 25.20 | 2086.30 |
| 01/22/91 | 27.60 | 2083.90 |
| 01/29/91 | 25.70 | 2085.80 |

**151-086-03BCB4**
Ryder Aquifer

LS Elev (msl,ft)=2095
SI (ft.)=8.5-13.5

| Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|
| 01/10/91 | 11.43 | 2085.82 |
| 01/17/91 | 11.43 | 2085.82 |
| 01/22/91 | 11.41 | 2085.84 |
| 01/29/91 | 11.54 | 2085.71 |

**151-086-04ABC1**
Ryder Ridge Aquifer

LS Elev (msl,ft)=2100
SI (ft.)=55-60

| Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|
| 01/10/91 | 13.60 | 2088.10 |
| 01/17/91 | 13.64 | 2088.06 |
| 01/22/91 | 14.85 | 2086.85 |
| 01/29/91 | 14.13 | 2087.57 |

**151-086-04ACA1**
Ryder Ridge Aquifer

LS Elev (msl,ft)=2120
SI (ft.)=105-110

| Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|
| 01/10/91 | 26.80 | 2094.80 |
| 01/17/91 | 26.83 | 2094.77 |
| 01/22/91 | 28.70 | 2092.90 |
| 01/29/91 | 27.34 | 2094.26 |

**151-086-04ACA2**
Ryder Ridge Aquifer

LS Elev (msl,ft)=2120
SI (ft.)=65-70

| Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|
| 01/10/91 | 27.07 | 2094.53 |
| 01/17/91 | 27.10 | 2094.50 |
| 01/22/91 | 28.98 | 2092.62 |
| 01/29/91 | 27.63 | 2093.97 |

**151-086-04ACCB1**
Ryder Ridge Aquifer

LS Elev (msl,ft)=2110
SI (ft.)=106-111

| Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|
| 01/10/91 | 23.81 | 2088.09 |
| 01/17/91 | 23.83 | 2088.07 |
| 01/22/91 | 25.10 | 2086.80 |
| 01/29/91 | 24.40 | 2087.50 |

**151-086-04ACCB2**
Ryder Ridge Aquifer

LS Elev (msl,ft)=2110
SI (ft.)=58-63

| Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|
| 01/10/91 | 23.57 | 2088.03 |
| 01/17/91 | 23.59 | 2088.01 |
| 01/22/91 | 24.77 | 2086.83 |
| 01/29/91 | 24.10 | 2087.50 |

**151-086-04ADDA2** LS Elev (msl,ft)=2100

Ryder Aquifer SI (ft.)=16-21

| Date | Depth to Water (ft) | WL Elev (msl, ft) | Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|---|---|---|
| 01/10/91 | 17.14 | 2084.56 | 01/22/91 | 17.19 | 2084.51 |
| 01/17/91 | 17.16 | 2084.54 | 01/29/91 | 17.31 | 2084.39 |

**151-086-04CBB1** LS Elev (msl,ft)=2104

Ryder Ridge Aquifer SI (ft.)=78-83

| Date | Depth to Water (ft) | WL Elev (msl, ft) | Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|---|---|---|
| 01/10/91 | 13.73 | 2092.22 | 01/22/91 | 14.12 | 2091.83 |
| 01/17/91 | 13.75 | 2092.20 | 01/29/91 | 14.15 | 2091.80 |

**151-086-06DAA1** LS Elev (msl,ft)=2100

Ryder Ridge Aquifer SI (ft.)=92-97

| Date | Depth to Water (ft) | WL Elev (msl, ft) | Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|---|---|---|
| 01/10/91 | 24.20 | 2077.40 | 01/22/91 | 24.22 | 2077.38 |
| 01/17/91 | 24.21 | 2077.39 | 01/29/91 | 24.38 | 2077.22 |

**151-086-06DAA2** LS Elev (msl,ft)=2100

Ryder Ridge Aquifer SI (ft.)=59-64

| Date | Depth to Water (ft) | WL Elev (msl, ft) | Date | Depth to Water (ft) | WL Elev (msl, ft) |
|---|---|---|---|---|---|
| 01/10/91 | 24.81 | 2077.19 | 01/22/91 | 24.80 | 2077.20 |
| 01/17/91 | 24.81 | 2077.19 | 01/29/91 | 24.97 | 2077.03 |

## APPENDIX 3. CHEMICAL ANALYSES OF GROUND WATER

| 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) | | | | | | | | | | | | | | | | | | | | | |
| 151-086-03BBC | 90-95 | 07/03/90 | 27 | 0.99 | 0.92 | 81 | 25 | 25 | 5.4 | 396 | 0 | 40 | 5.1 | 0.3 | 1 | 0.16 | 407 | 310 | 0 | 15 | 0.6 | 665 | 7 | |
| 151-086-03BCB4 | 8.5-13.5 | 07/02/90 | 27 | 2.6 | 0.66 | 110 | 140 | 68 | 24 | 381 | 0 | 640 | 18 | 0.3 | 1 | 0.18 | 1220 | 850 | 540 | 14 | 1 | 1643 | 10 | |
| 151-086-04ABC1 | 55-60 | 07/03/90 | 27 | 0.99 | 1.8 | 110 | 43 | 65 | 7.4 | 456 | 0 | 230 | 6.1 | 0.3 | 1 | 0.34 | 718 | 450 | 78 | 23 | 1.3 | 1061 | 7 | |
| 151-086-04ACA1 | 105-110 | 07/02/90 | 27 | 2 | 1.2 | 84 | 31 | 130 | 7.7 | 462 | 0 | 230 | 4.8 | 0.3 | 1 | 0.24 | 747 | 340 | 0 | 45 | 3.1 | 1136 | 7 | |
| 151-086-04ACA2 | 65-70 | 07/03/90 | 27 | 0.55 | 1.9 | 100 | 32 | 18 | 5.6 | 392 | 0 | 110 | 4.1 | 0.2 | 1 | 0.18 | 494 | 380 | 60 | 9 | 0.4 | 776 | 7 | |
| 151-086-04ACCB1 | 106-111 | 07/02/90 | 27 | 2.4 | 1.2 | 81 | 30 | 120 | 7.8 | 497 | 0 | 190 | 5.6 | 0.3 | 1 | 0.26 | 712 | 330 | 0 | 44 | 2.9 | 1040 | 9 | |
| 151-086-04ACCB2 | 58-63 | 07/02/90 | 27 | 0.1 | 1.6 | 100 | 30 | 19 | 6.1 | 396 | 0 | 92 | 5.3 | 0.3 | 1 | 0.2 | 478 | 370 | 49 | 10 | 0.4 | 772 | 8 | |
| 151-086-04ADDA2 | 16-21 | 07/03/90 | 26 | 0.12 | 0.97 | 79 | 60 | 65 | 8.9 | 380 | 0 | 240 | 9.8 | 0.2 | 1 | 0.11 | 678 | 440 | 130 | 24 | 1.3 | 1050 | 7 | |
| 151-086-04CBB1 | 78-83 | 07/03/90 | 26 | 1.9 | 1.8 | 110 | 43 | 120 | 8 | 454 | 0 | 340 | 5.7 | 0.3 | 1 | 0.28 | 882 | 450 | 80 | 36 | 2.5 | 1235 | 8 | |
| 151-086-06DAA1 | 92-97 | 07/03/90 | 25 | 7.2 | 2.6 | 170 | 69 | 220 | 11 | 593 | 0 | 720 | 12 | 0.2 | 1 | 0.36 | 1530 | 710 | 220 | 40 | 3.6 | 2120 | 7 | |
| 151-086-06DAA1 | 92-97 | 07/04/90 | 25 | 7.2 | 2.6 | 170 | 69 | 220 | 11 | 593 | 0 | 720 | 12 | 0.2 | 1 | 0.36 | 1530 | 710 | 220 | 40 | 3.6 | 2120 | 7 | |
| 151-086-06DAA2 | 59-64 | 07/03/90 | 26 | 11 | 4.3 | 370 | 160 | 400 | 15 | 796 | 0 | 1600 | 39 | 0.2 | 1 | 0.64 | 3020 | 1600 | 930 | 35 | 4.4 | 3770 | 7 | |