Pressure Head Fluctuations of the Fox Hills-Hell Creek Aquifer in the Knife River Basin, North Dakota

PHOTO BY MERLYN SKALEY

By
Rex P. Honeyman
Hydrologist

Water Resources Investigation No. 44
North Dakota State Water Commission
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North Dakota State Water Commission
Office Memo

To: Project File #1442
From: Rex Honeyman, Hydrologist
Subject: Pressure Head Fluctuations of the Fox Hills-Hell Creek Aquifer in the Knife River Basin, North Dakota
Date: May 30, 2007

Introduction:

Under North Dakota Century Code §61-20-06, the State Engineer is responsible for monitoring decline, fluctuations, and permanence of artesian flowing aquifers. Once each decade the State Engineer selects representative wells to monitor the overall pressure head change and water quality of the Fox Hills-Hell Creek aquifer in western North Dakota. The results are published in three reports. One report compiles the pressure head results from wells in Billings, Golden Valley, and Slope Counties, a second report compiles the pressure head results from wells in McKenzie County and a third report which is covered in this document compiles the pressure head results from wells within the Knife River Basin in Oliver, Mercer, and Dunn Counties (Figure 1).

The purpose of the above listed studies is to promote conservation of water supplies and in doing so slow the decline in pressure head in the Fox Hills-Hell Creek aquifer, which is a valuable resource in western North Dakota. Many stockman, domestic users, municipalities and industrial users depend on the Fox Hills-Hell Creek aquifer for their water supply. Municipal water use from the aquifer has steadily declined from the mid 1990s and into the new millennium due to the advent of the Southwest Pipeline which is continually supplying more and more water users with Lake Sakakawea water (Figure 2). Industrial water use from the Fox Hills-Hell Creek aquifer fluctuates throughout the historical record (Figure 2). This fluctuation can be attributed to fluctuation in oil activity in western North Dakota, which uses fresh water for desalinization in oil wells.

The aquifer is referred to as the Fox Hills-Hell Creek aquifer, because it straddles the boundary between the marine Fox Hills Formation and the overlying

Figure 1 -- Location of study area

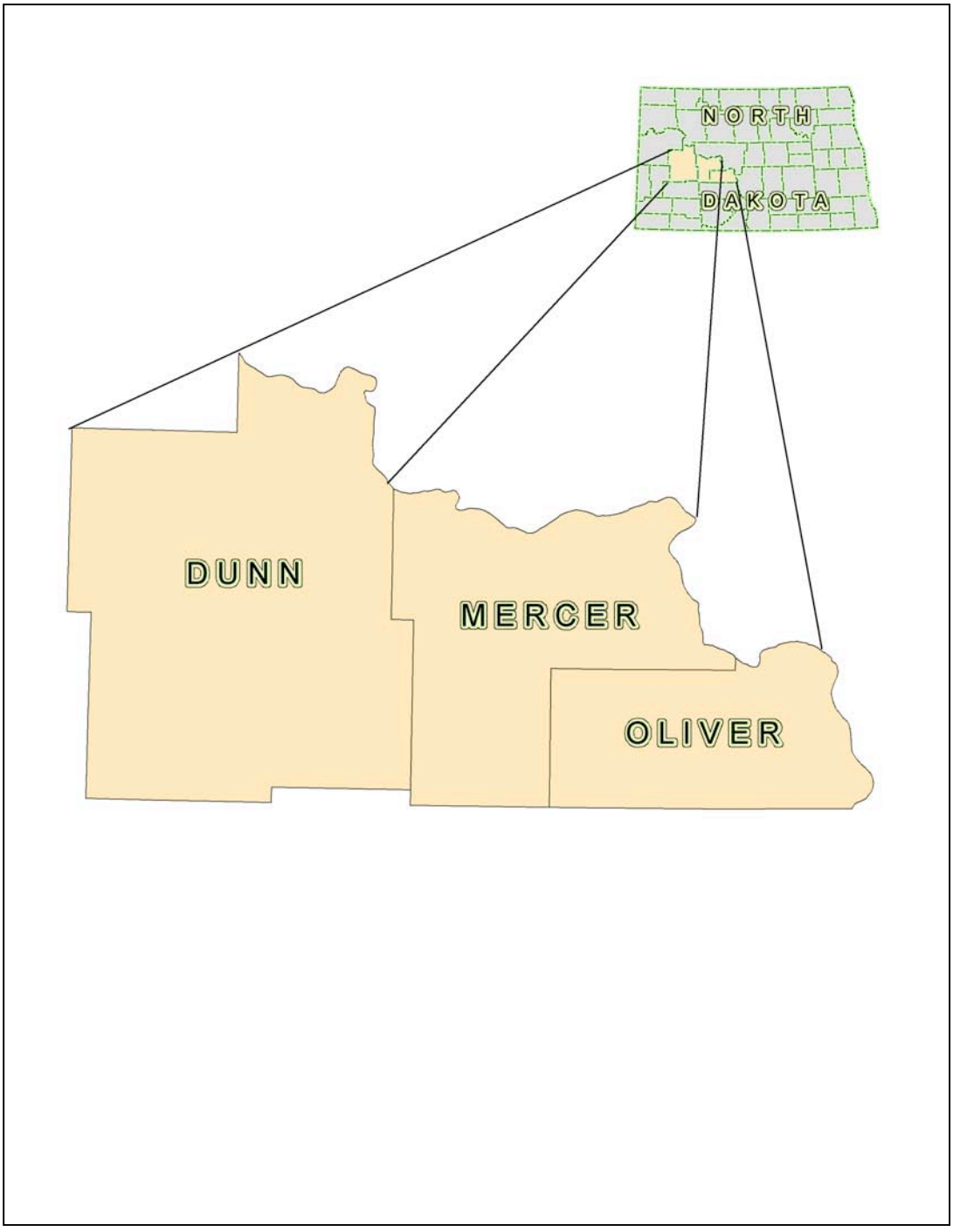
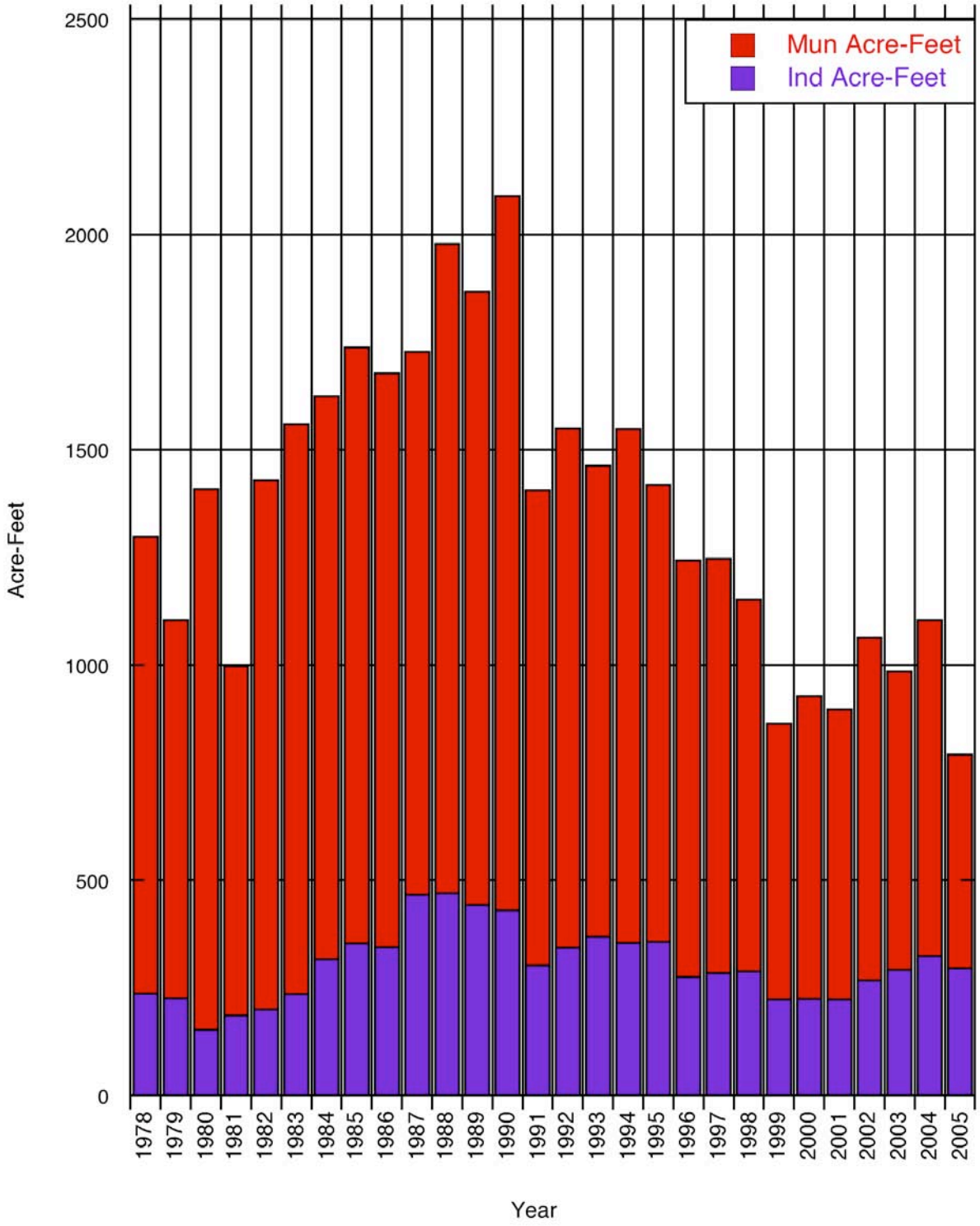


Figure 2 -- Total reported water use from the Fox Hills aquifer for municipal and industrial purposes in North Dakota



non-marine Hell Creek Formation. It was formed from sand deposits on beaches and river deltas along a sea receding to the east. The offshore deposits, with occasional marine fossils, are included in the Fox Hills Formation, while the back-beach and river flood plain landform deposits are included in the Hell Creek Formation. The somewhat unwieldy long name is often shortened to the Fox Hills aquifer. This report will refer to the Fox Hills-Hell Creek aquifer as the Fox Hills aquifer. Any references made to the Hell Creek aquifer throughout this report is referring to the middle or upper Hell Creek Formation. The pressure head of the Hell Creek aquifer is typically much less than what is measured in deeper portions of the Hell Creek Formation that is hydraulically connected to the Fox Hills aquifer.

The Fox Hills Formation underlies the western half of North Dakota as illustrated in Figure 3. Recharge to the aquifer likely occurs in areas where the Fox Hills Formation is at or near the surface in southwestern North Dakota, northwestern South Dakota, southeastern Montana, and northeastern Wyoming (Figure 3). Well depths in the Fox Hills aquifer range from just below land surface in southwestern North Dakota to over 2,000 feet below land surface in northeastern Billings County, southeastern McKenzie County, and western Stark County (Figure 4).

The pressure heads (water levels above the top of the aquifer) in the Fox Hills aquifer decline when the discharge is greater than the recharge. Recharge to the Fox Hills aquifer is very small and is easily exceeded by the discharge, which occurs mainly in the form of withdrawal of water from wells.

In September of 2005, nine flowing wells in the Knife River Basin and 1 flowing well in the Little Missouri basin were monitored within the study area. The locations of these domestic/stock and municipal wells are illustrated in Figure 5. Pressure head measurements were made on 9 wells, while water quality analysis was collected from all 10 wells. The pressure head measurements were made to continue monitoring the rate of pressure head decline in the Fox Hills aquifer in an area where flowing wells discharge water from the aquifer. Many of the wells have been monitored since the 1960s and 1970s. The 10 domestic, stock, and municipal wells monitored in 2005 were

Figure 3 -- Extent of the Fox Hills Formation in North Dakota

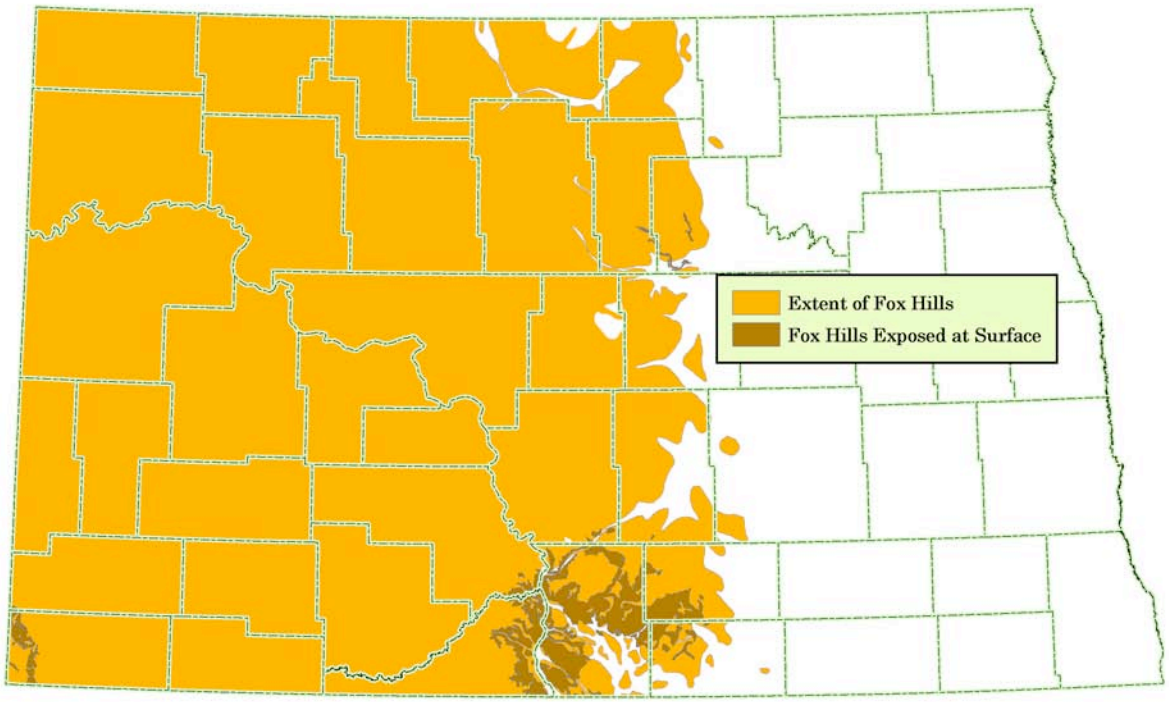


Figure 4 -- Average well depth of the Fox Hills aquifer based on screened intervals of 356 Fox Hills wells in North Dakota

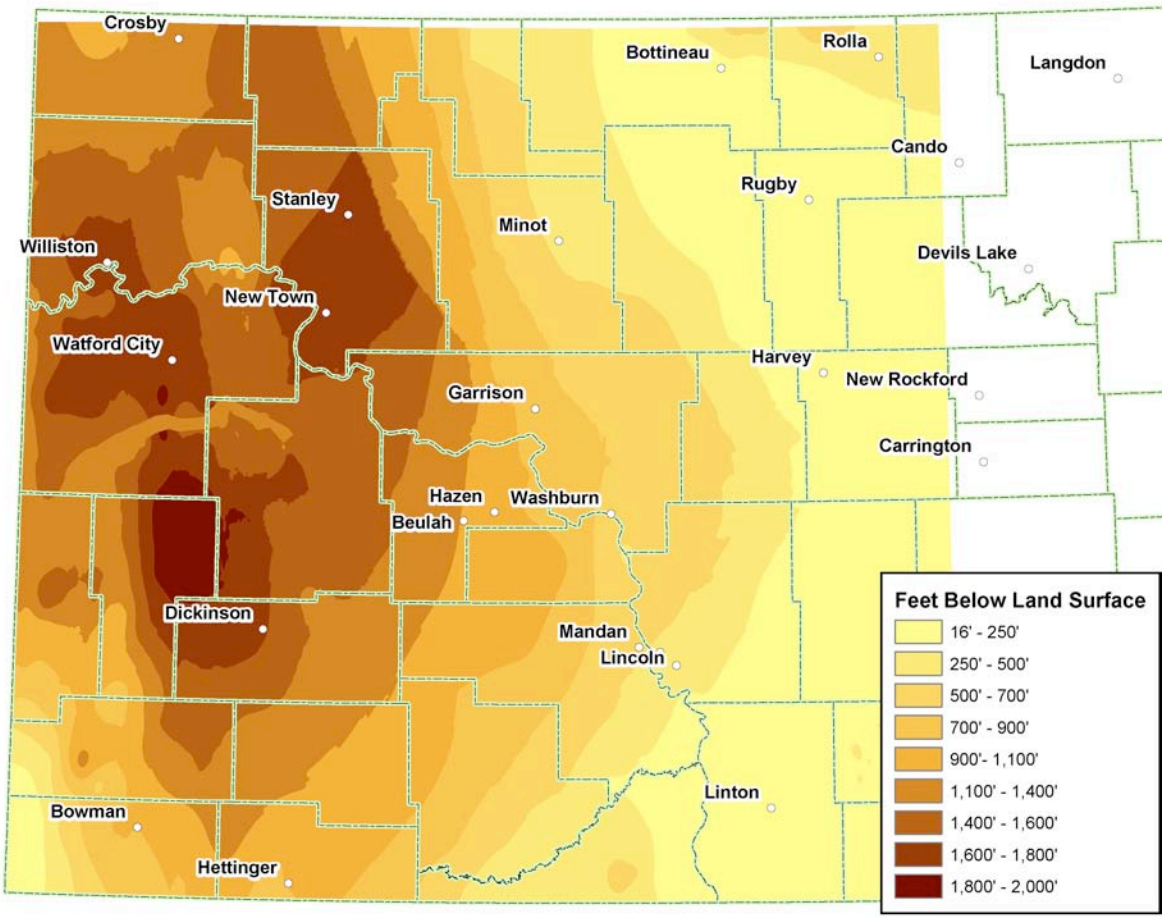
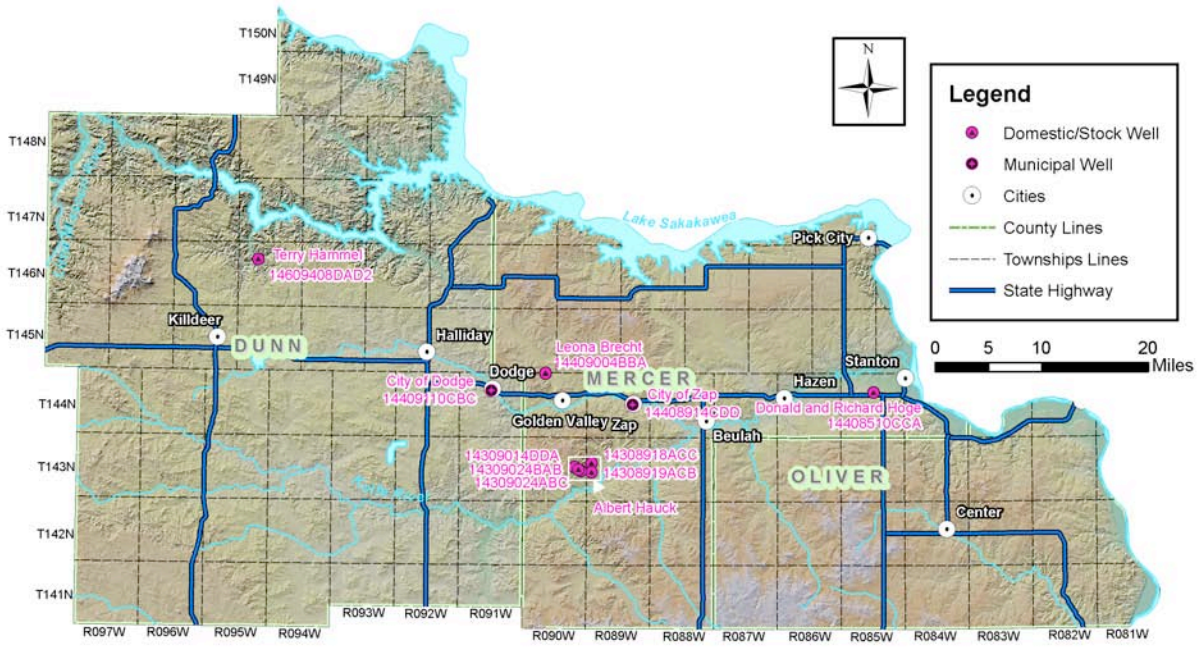


Figure 5 -- Domestic and livestock wells monitored in 2006 - well owners and well names



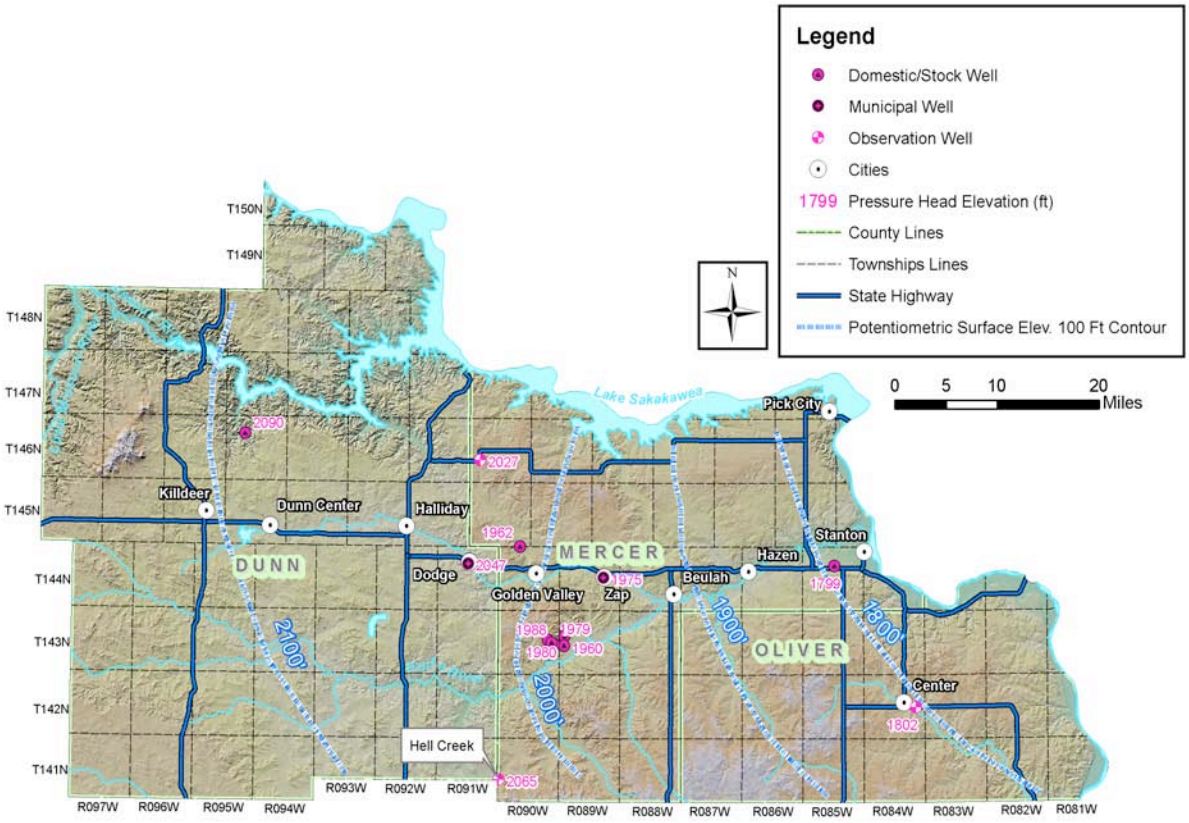
also monitored in 1984 and in 1994. Nine wells are located in low-lying areas along the valleys of Spring Creek, Knife River, and their tributaries where the land surface elevation is lower than the pressure head of the aquifer. One stock well, 146-094-08DAD2, is located in the valley of a Little Missouri River tributary. Pressure heads in three observation wells are measured annually and have been included within this report. The location of the 3 observation wells is shown in Figure 6.

Well information:

For each well visited the following information was compiled and included in the appendix of this report:

- Date the well was completed
- Land surface elevation
- Depth drilled
- Screened interval
- Purpose of well
- Casing diameter and material
- Source of information
- Well owner
- Owner's address
- Well location (a detailed description to aid in finding the well)
- Any available well completion information
- Description of the above ground portion of the well
- 2005 well discharge, or flow rate
- Description of pressure head recovery following well shut in
- Remarks
- Lithologic log of the well, where available
- Table showing the long term pressure head measurements

Figure 6 -- 2006 potentiometric surface map of the Fox Hills aquifer



- Table of 2005 shut in time vs. pressure head readings
- Well hydrographs
- Photographs of the well in 2005
- Water quality analyses

The following is a list of working papers and materials compiled during this study and previous studies, but are not included within the report:

- Highway map
- Atlas map
- Topographic map
- Photographs (1984 and 1994)
- County study well information
- Well driller's report
- Graph of shut in time vs. pressure head recovery (1984 and 1994)
- Previous hydrographs, for brochure, etc.
- Well run sheet
- 1994 and 2005 field notes
- 1994 and 2005 water quality analysis
- Brochure titled: *Flowing Well Pressure Changes in the Knife River Area* (1985 - Updated in 1995 & 2007)

Aquifer pressure head:

The elevation of the pressure head of the Fox Hills aquifer, as measured in the wells visited in 2005, is shown in Figure 6. The potentiometric surface slopes to the east, from an elevation of 2,100 feet in central Dunn County to an elevation of 1,800 feet in eastern Oliver County, for a hydraulic gradient of approximately 5.3 feet per mile. The equipotential lines are curved, concave on the east side, possibly because of lower pressure heads in the area of the flowing wells in the Knife River basin.

Pressure head decline rate:

During the 1994 to 2005 period, the rate of change in pressure head in the 9 flowing wells and 3 observation wells ranged from -3.9 to +1.4 feet per year with an average decline of 0.8 feet per year (Table 1). The previous decade (1984 to 1994) had an average decline rate of 0.6 feet per year. The average rate of decline measured prior to 1984 in the Knife River Basin was 0.8 feet per year. Figure 7 illustrates the areal distribution of the current rate of decline for the 1994 to 2005 period and the previous rate of decline for the 1984 to 1994 period.

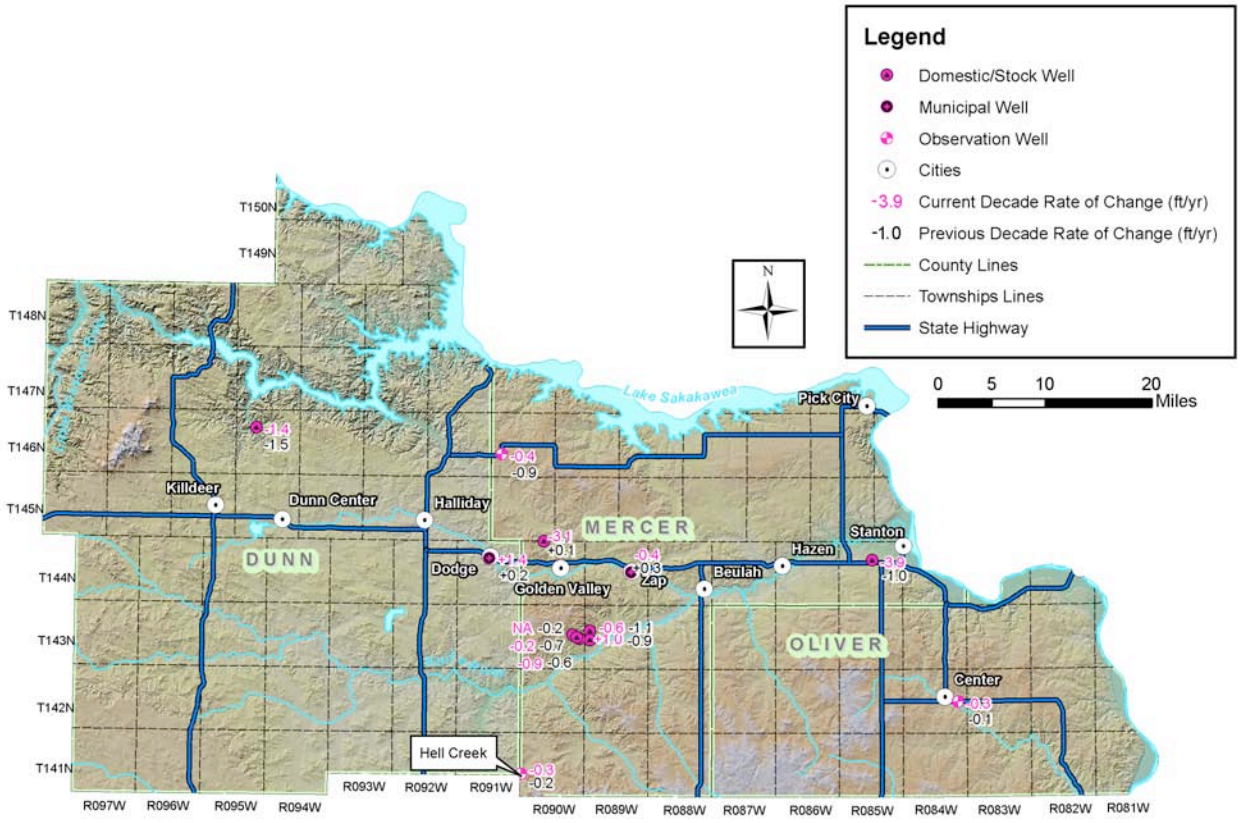
Table 1 -- Pressure head rate of change based on the 1994 and 2005 measurements

Well Location	Aquifer	Purpose	Pressure head rate of change (ft/yr)	Flow rate (gpm)
141-090-19CCD	Hell Creek	Observation Well	-0.3	NA
142-084-24BBA	Fox Hills	Observation Well	-0.3	NA
143-089-18ACC	Fox Hills	Domestic/Stock Well	-0.6	5
143-089-19ACB	Fox Hills	Domestic/Stock Well	+1.0	4
143-090-14DDA	Fox Hills	Domestic/Stock Well	NA	20
143-090-24ABC	Fox Hills	Domestic/Stock Well	-0.9	6
143-090-24BAB	Fox Hills	Domestic/Stock Well	-0.2	2
144-085-10CCA	Fox Hills	Domestic/Stock Well	-3.9	30
144-089-14CDD	Fox Hills	Municipal Well	-0.4	15
144-090-04BBA	Fox Hills	Domestic/Stock Well	-3.1	1
144-091-10CBC	Fox Hills	Municipal Well	+1.4	12
146-090-20CCC	Fox Hills	Observation Well	-0.4	NA
146-094-08DAD2	Fox Hills	Domestic/Stock Well	-1.4	15

No measurements could be made on stock well, 143-090-14DDA, which now has a pump installed in the well. In 1994, this well had a pressure head of 4.5 feet above land surface. Based on the pressure head decline rates, the pressure head in this well would likely be near land surface.

Two wells had pressure head increases from the 1994 to the 2005 measurements. The first well with a pressure head increase is the City of Dodge municipal well 144-091-10CBC. The well was used as the city's municipal source until 1995, after which the city began to obtain its municipal water supply from the Southwest Pipeline. The city had an average reported water use of 14.5 acre-feet per year from 1985 to 1994, equivalent to a constant well discharge rate of 9 gallons

Figure 7 -- Rate of pressure head change in the Fox Hills aquifer



per minute. As water flowed from the well for municipal purposes, a local cone of pressure relief formed and expanded as pumping continued. In 1994 when the previous pressure head measurement was taken, the cone of pressure relief was near its maximum extent prior to cessation of pumping in 1995. After pumping ceased, the local cone of pressure relief began to recover, which explains the 1.4 feet per year increase in pressure head in municipal well 144-091-10CBC. The second well is stock well, 143-089-19ACB, which showed a recovery of 1.0 foot per year since 1994. In 1994, the well was flowing into a water tank prior to the pressure head measurement, but was shut in 2005. The increase in pressure head from 1994 to 2005 is likely due to the recovery of the cone of pressure relief that existed in 1994.

The remaining 10 wells had pressure head declines over the last decade. The City of Zap experienced some of the same conditions that the City of Dodge did in switching from a Fox Hills well to an alternative water supply. Based on the 1984 to 1994 monitoring events, the City of Zap well 144-089-14CDD indicated a recovery rate of 0.3 foot per year. The well had been the city's municipal source until late 1984, six months after the 1984 pressure measurement was made. The city reported annual water use that averaged 40 acre-feet per year from l978-1983, equivalent to a constant well discharge rate of 25 gallons per minute. The Zap municipal well (144-089-14CDD) has not been used with any regularity since the city switched to an alternative source in late 1984. The pressure head recovery between 1984 and 1994 in the well is likely due to the local recovery of the cone of pressure relief formed from many years of pumping. After the well fully recovered sometime after 1994, pressure heads began to decline reflecting the overall aquifer decline. In 2005, the rate of change from 1994 was -0.4 feet per year. Based on the current pressure head decline rates (Figure 7) and the current pressure head above land surface (Figure 8), estimates of when each well monitored will stop flowing were made and are shown in Figure 9.

Figure 8 -- Pressure head of the Fox Hills aquifer in feet above the land surface

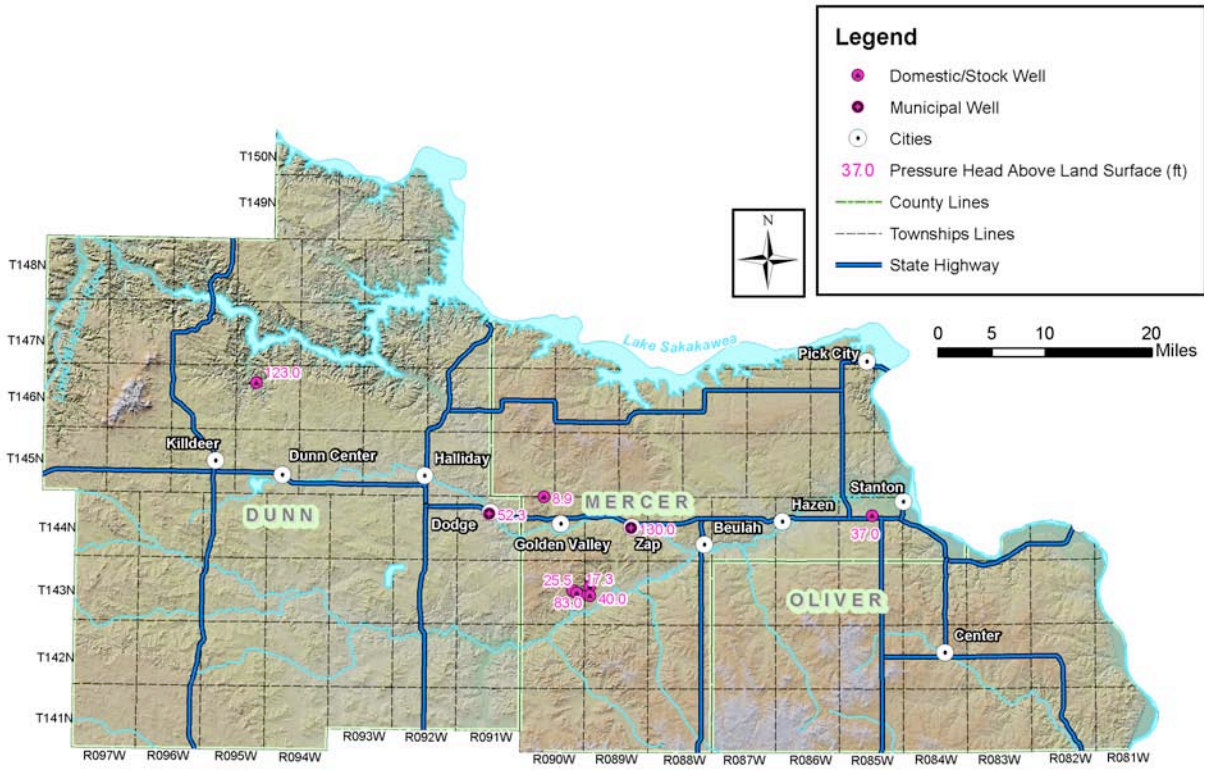
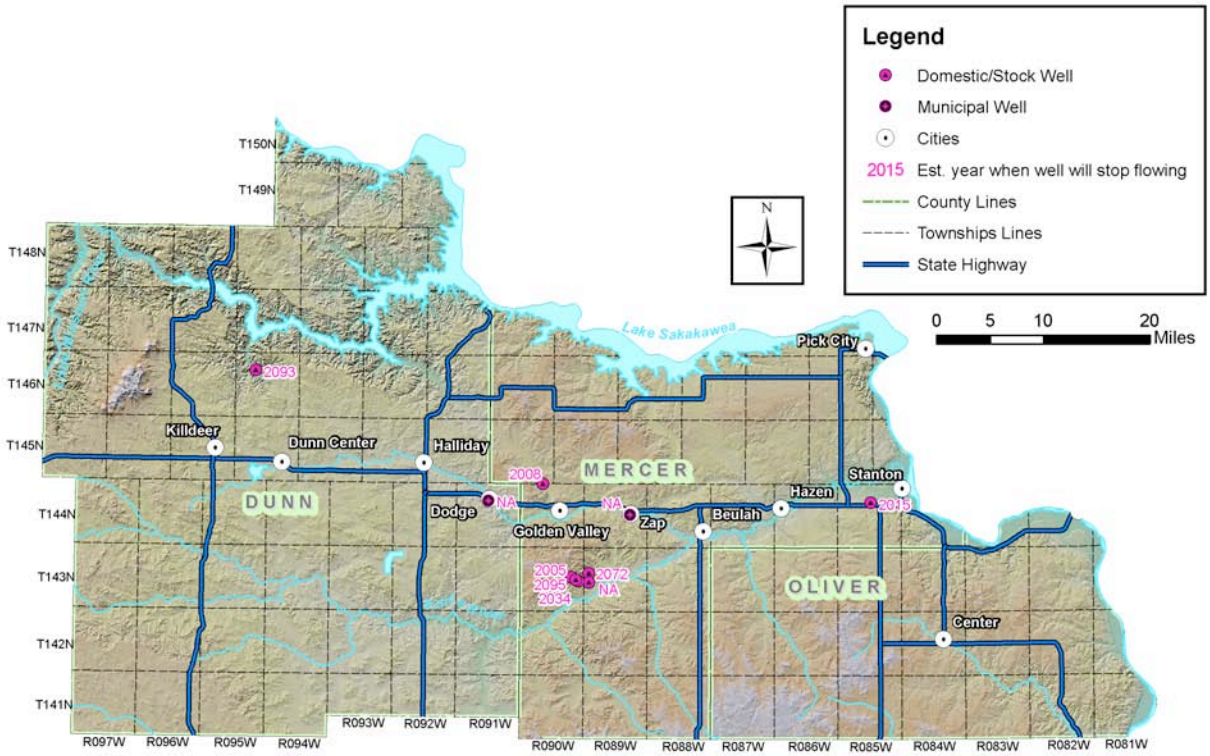


Figure 9 -- The estimated year when flowing wells will cease to flow



Flow rate:

At the time of the 2005 pressure head measurements, the rate at which the wells were discharging water was measured before the wells were shut in. All the flowing wells were equipped with valves for regulating the rate of flow. The flow rates range from 3 to 30 gallons per minute with an average rate of 10 gallons per minute (Table 1). The three observation wells have pressure heads below land surface and therefore have no flow rate. The feet of pressure head recovery between the first and last pressure measurement are listed in Table 2. The lack of pressure head recovery in most wells when they are shut in suggests water may be leaking through a corroded well casing.

Table 2 -- Pressure head recovery between the first and last measurements after the well was shut-in

Well	Recovery (feet)	Shut-in Time (minutes)
143-089-18ACC	10.0	120
143-089-19ACB	7.0	60
143-090-14DDA	3.0	35
143-090-24ABC	3.0	60
143-090-24BAB	4.0	60
144-085-10CCA	8.0	120
144-089-14CDD	5.0	30
144-090-04BBA	3.9	60
144-091-10CBC	6.3	120
146-094-08DAD2	0.0	20

Water Quality:

Water samples were collected for chemical analysis from all 10 flowing wells and one observation well visited in 2005. Concentrations of some of the selected dissolved minerals are shown in Table 3 and Figure 10. Chemical analyses indicate the water is predominantly a sodium-bicarbonate type that generally has less dissolved constituents than water in the overlying formations (Figure 10).

Table 3 also lists the maximum contaminant level (MCL) and the secondary maximum contaminant level (SMCL) defined by the United States Environmental Protection Agency (EPA). MCLs are primary standards that are legally enforceable standards that apply to public water systems. Primary standards protect public health

Figure 10 -- Major dissolved constituents in samples collected from the Fox Hills aquifer in September 2005

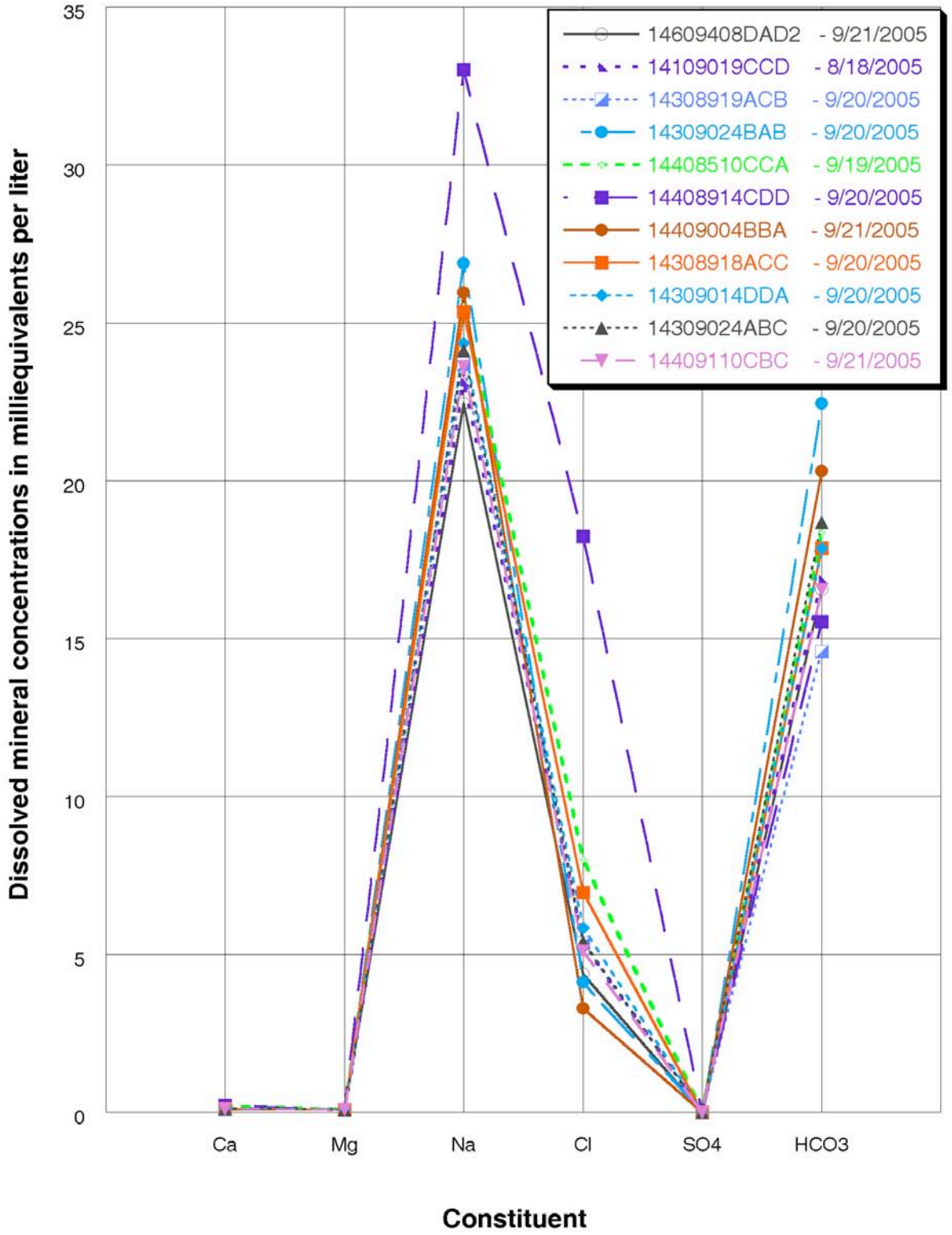


Table 3 -- Concentrations of selected ions and total dissolved solids in sampled wells

Location	Screened Interval	Date Sampled	Sodium (mg/L)	Fluoride (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	TDS (mg/L)
141-090-19CCD	1142-1142	8/18/2005	532	4.9	1030	190	1310
143-089-18ACC	1380	9/20/2005	583	4.95	1090	247	1390
143-089-19ACB	1280	9/20/2005	545	5.22	890	190	1270
143-090-14DDA	1361-1445	9/20/2005	560	5.23	1090	207	1330
143-090-24ABC	0-0	9/20/2005	555	5.18	1140	192	1340
143-090-24BAB	1280	9/20/2005	618	2.49	1370	146	1450
144-085-10CCA	900-900	9/19/2005	587	4.21	1120	284	1440
144-089-14CDD	1241-1281	9/20/2005	759	4.22	948	647	1880
144-090-04BBA	1265-1265	9/21/2005	597	2.79	1240	117	1330
144-091-10CBC	1450-1575	9/21/2005	543	5.42	1010	181	1230
146-094-08DAD2	1660-1730	9/21/2005	516	5.57	1010	155	1180
MCL	N/A	N/A	N/A	4.0	N/A	N/A	N/A
SMCL	N/A	N/A	N/A	2.0	250	250	500

by limiting the levels of contaminants in drinking water. SMCLs are non-enforceable recommended standards and are not considered a health hazard. Most of the water samples collected and analyzed for this study exceed the MCL for fluoride (Table 3). According to the EPA, elevated levels of fluoride can cause bone disease (pain and tenderness of the bones); children may get mottled teeth. Ground water in the Fox Hills aquifer almost always exceeds SMCL for total dissolved solids (TDS) and bicarbonate and occasionally exceeds the SMCL for chloride.

The concentrations of TDS decreased in 2005 when compared to the previous samples collected in 1994. However, the results of water quality samples are very similar to the previous decade. There is an average 6% decrease in TDS in samples collected in 2005 versus 1994. When comparing samples collected in 1994 to samples collected in 1987 or prior, there was an average 0.5% decrease in concentrations of TDS.

Temporal variations in water quality may be attributed to the amount of water pumped prior to sample collection, differences in sampling protocol between sampling events, and casing failure in wells. However, there is no relationship between the amount of water withdrawn from the Fox Hills aquifer and its water chemistry.

Most of the wells were flowing prior to the field visit, which allowed for the collection of representative samples from the aquifer. The length of time the wells had

been flowing prior to sampling is unknown. However, the two municipal wells 144-089-14CDD and 144-091-10CBC and a stock well, 143-089-19ACB had been shut in for an extended period of time prior to the field visit, so collecting a fresh water sample from the aquifer in a timely manner was not possible. Depending on the flow rate of the well and the depth of the well, it could take any where from a few hours to several days to evacuate enough water to remove a full casing volume. A full casing volume of water was not evacuated prior to sampling observation wells, which have a pressure head below the land surface. Variations in pumping time prior to sampling could cause variations in the water quality, because representative samples may not always be obtained.

Failed well casings could also cause temporal variations in water quality. This would allow poorer quality water from overlying formations, to mix with the Fox Hills aquifer water. In this situation, the analysis will indicate that the water quality of the Fox Hills aquifer is deteriorating when in fact the well is deriving some of its water from other formations.

In general, the concentration of total dissolved solids increases to the east within the study area, away from the recharge area. The full suite of water quality information is included in the Appendix under each individual well.

Summary:

The pressure heads (water levels above the top of the aquifer) in the Fox Hills aquifer decline when the discharge is greater than the recharge. Recharge to the Fox Hills aquifer is very small and is easily exceeded by the discharge, which occurs mainly in the form of withdrawal from wells.

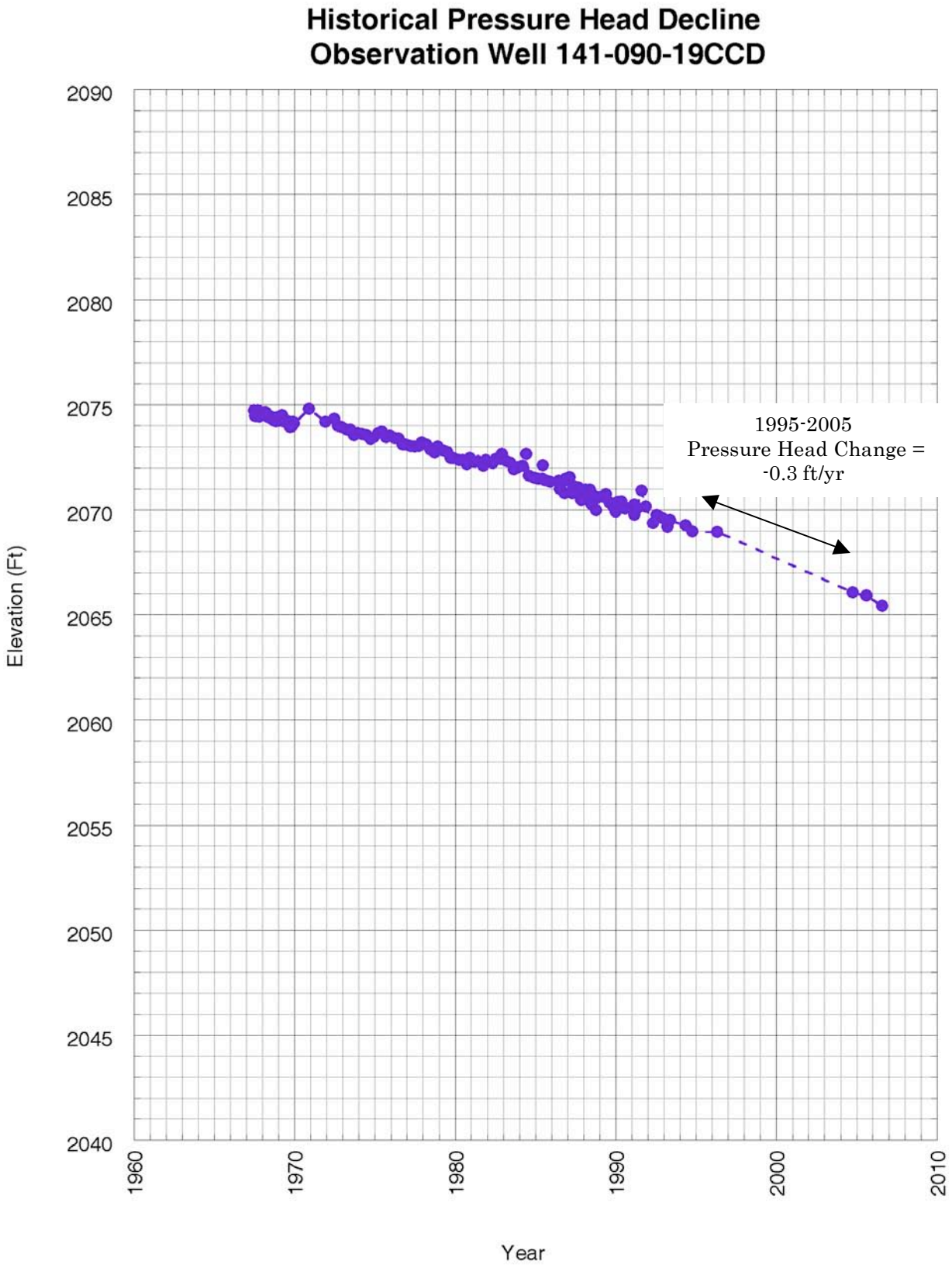
The pressure head in the Fox Hills wells in the Knife River Basin continues to decline at an average rate of 0.8 feet per year. The 1984 to 1994 decade had an average decline rate of 0.6 feet per year. The average rate of decline measured prior to 1984 in the Knife River Basin was 0.8 feet per year. The overall potentiometric surface slopes to the east, which follows the general surface landscape. The hydraulic gradient is approximately 5.3 feet per mile.

The water quality from samples collected in 2005 reflects slightly better water quality than the samples collected in 1994. There is an average 6% decrease in total dissolved solids (TDS) in samples collected in 2005 versus 1994. When comparing samples collected in 1994 to samples collected in 1987 or prior, there was an average of 0.5% decline in concentrations of TDS. There is no relationship between the amount of water withdrawn from the Fox Hills aquifer and its water chemistry. Temporal variations in water quality may be attributed to the amount of water pumped prior to sample collection, differences in sampling protocol between sampling events, and casing failure in wells. Most of the water samples collected and analyzed for this study exceeded the Maximum Contaminant Level for fluoride. According to the EPA, elevated levels of fluoride can cause bone disease (pain and tenderness of the bones); children may get mottled teeth. Total dissolved solids and bicarbonate exceeded the Secondary Maximum Contaminant Levels (SMCL) established by the EPA. Occasionally chloride exceeded the SMCL. SMCLs are not considered a health hazard.

Appendix -- Well Information

141-090-19CCD

Date Completed:	04/19/67	*Purpose:*	Observation Well
L.S. Elevation (ft):	2080'	*Well Type:*	4"Steel
Depth Drilled (ft):	1790'	*Aquifer:*	Hell Creek (Fox Hills?)
Screened Interval (ft):	1142' - 1142'	*Source:*	Mann Drilling
Owner:	NDSWC		
Address:	Bismarck		
Well Location:	Located about 1200 feet east of gravel road (still west of some scattered trees), about 80 feet north of the trail, in a tilled field.		
Completion:	Drilled 200+ feet of Pierre Fm. Reamed, cased and developed. Open hole completion at 1142 feet in sandy Hell Creek Fm., 90 feet above Colgate Member of the Fox Hills Fm. (1230-1364), as indicated by gamma & resistivity logs. The 1987-1994 decline rate of 0.2 feet/year and the pressure head elevation are as expected for the Fox Hills-Hell Creek aquifer.		
Wellhead description: (casing & plumbing)	The measuring point is about 0.6 feet above the small concrete pad,		
Remarks:			


Historical Pressure Head Decline
Observation Well 141-090-19CCD
Elevation (Ft)
2090
2085
2080
2075
2070
2065
2060
2055
2050
2045
2040
1960
1970
1980
1990
2000
2010
Year
1995-2005
Pressure Head Change =
-0.3 ft/yr

Lithologic Log

(Logged by Henry Trapp, Larry Froelich, & Tony Mann)

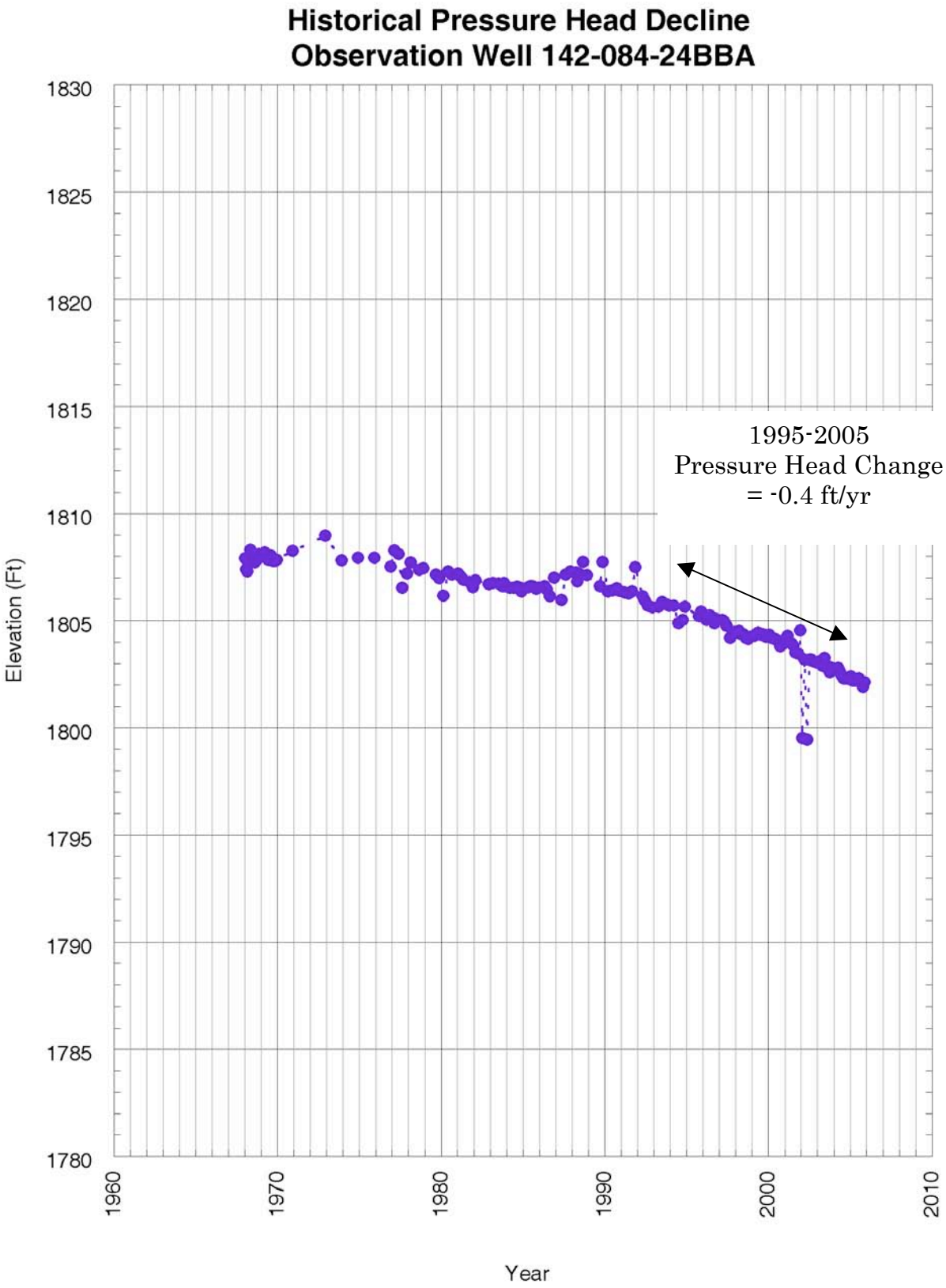
Unit	Description	Depth (ft)
SAND	Fine to medium grained, silty (glacial drift)	0-36
SANDSTONE	Fine grained, silty, lignite 56-60 (Sentinel Butte Fm.)	36-68
CLAYSTONE	Light olive gray, silty, sandy, lignitic 163-170	68-182
SANDSTONE	Fine grained	182-235
CLAYSTONE	Silty	235-264
SANDSTONE	Clayey, silty	264-418
SILTSTONE	Grayish olive, clayey	418-490
SANDSTONE	Fine to medium grained (Basal Tongue River Fm.)	490-520
CLAYSTONE	Light olive, silty (Ludlow Fm. maybe Cannonball)	520-790
SANDSTONE	Clayey, silty (still Ludlow or Cannonball Fm.)	790-892
SILTSTONE	Light olive gray, clayey (Hell Creek Fm.)	892-980
SANDSTONE	Silty, clayey	980-1212
SILTSTONE	Clayey	1212-1230
SANDSTONE	Dark greenish gray, fine grained, silty, clayey (Fox Hills Fm. - Colgate Member)	1230-1364
SILTSTONE	Grayish olive, sandy (lower Fox Hills Fm.)	1364-1564
SHALE	Dark greenish gray, sandstone (?), (Pierre Fm.)	1564-1790

Water Quality

Location	141-090-19CCD
County	Mercer
Screened Interval	1142'-1142'
Aquifer	Hell Creek
Purpose	Observation Well
Date Sampled	08/18/05
Time Sampled	16:12:00
Yield (gpm)	10
Field Temp(C)	13.60
Lab pH	8.75
Field Conductivity (um/cm)	2120
Lab Conductivity (um/cm)	2310
Total Dissolved Solids (mg/L)	1310
Calcium (mg/L)	3.10
Magnesium (mg/L)	<1
Potassium (mg/L)	2.3
Sodium (mg/L)	532.0
Fluoride (mg/L)	4.90
Bicarbonate (mg/L)	1030
Carbonate (mg/L)	74.0
Sulfate (mg/L)	<0.3
Chloride (mg/L)	190.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	<0.09
Iron (mg/L)	0.105
Manganese (mg/L)	<0.01
Hardness(mg/L)	12.0
Sodium Adsorption Ratio (SAR)	67.2
Residual Sodium Carbonate (Equiv/L)	19.0
Percent Sodium	98.7

142-084-24BBA

Date Completed:	11/29/67	*Purpose:*	Observation Well
L.S. Elevation (ft):	2006'	*Well Type:*	4"Steel
Depth Drilled (ft):	1295'	*Aquifer:*	Fox Hills
Screened Interval (ft):	966' - 966'	*Source:*	Mann Drilling Co.
Owner:	NDSWC		
Address:	Bismarck		
Well Location:	Located on hill one mile east of Center, about 700 feet east of section line trail, south of highway, about 20 feet north of 100 feet highway right of way line.		
Completion:	Open end completion, cemented with 180 bags cement		
Wellhead description: (casing & plumbing)	Four inch well extends 3.4 feet above ground, USGS uses 2.0 feet as the MP height.		
Remarks:			


Historical Pressure Head Decline
Observation Well 142-084-24BBA
1830
1825
1820
1815
1810
1805
1800
1795
1790
1785
1780
Elevation (Ft)
1960
1970
1980
1990
2000
2010
Year
1995-2005
Pressure Head Change
= -0.4 ft/yr

Lithologic Log

(logged by Larry Froelich & Tony Mann)

Unit	Description	Depth (ft)
SILTSTONE	Interbedded with claystone, at times lignitic, sandier 160-215, 340-418, 422-484 (Tongue River Formation). (An interpretation of the county study interpretation).	0-484
SILTSTONE	Sand between 517-520, 595-620, 696-707, fine grained (Cannonball-Ludlow Formations, undifferentiated)	484-707
SANDSTONE	Fine to medium sand between 945-1000 feet, (Colgate Member), underlain by siltstone and claystone (Fox Hills Formation)	945-1202
SHALE	Silty, olive gray (Pierre Formation)	1202-1295

Water Quality

Location	142-084-24BBA
County	Oliver
Screened Interval	966'-966'
Aquifer	Fox Hills
Purpose	Observation Well
Date Sampled	08/22/68
Time Sampled	00:00:00
Yield (gpm)	5
Field Temp(C)	
Lab pH	8.6
Field Conductivity (um/cm)	
Lab Conductivity (um/cm)	2820
Total Dissolved Solids (mg/L)	1670
Calcium (mg/L)	4.2
Magnesium (mg/L)	1.3
Potassium (mg/L)	2.5
Sodium (mg/L)	684
Fluoride (mg/L)	3.5
Bicarbonate (mg/L)	1170
Carbonate (mg/L)	38
Sulfate (mg/L)	4.6
Chloride (mg/L)	343
Hydroxide (mg/L)	
Nitrate(mg/L)	0
Iron (mg/L)	0.32
Manganese (mg/L)	0.01
Hardness (mg/L)	16
Sodium Adsorption Ratio (SAR)	74
Residual Sodium Carbonate (Equiv/L)	
Percent Sodium	99

143-089-18ACC

Date Completed:	08/01/64	*Purpose:*	Stock Well
L.S. Elevation (ft):	1920'	*Well Type:*	2"Steel
Depth Drilled (ft):	0'	*Aquifer:*	Fox Hills
Screened Interval (ft):	0' - 1380'	*Source:*	Bandy Drilling Co.

Owner: Lois Wanner and Adam Wanner

Address: 1700 County 5, Golden Valley, ND 58541

Well Location: Well is located along north-south fence line 150 feet east of fork in creek/draw, south side of creek.

Completion: Only available information is that in the county study & Rip's notes

Wellhead description: (casing & plumbing) Pipe extends 2.4 feet above ground, and goes to stock tank.

Remarks:

Shut in time vs. pressure head: 2005 measurements

Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	30.00	31.00	31.50	32.00	32.50	33.00	33.50	34.00	34.50	35.00

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)	36.00	36.25	36.75	37.00	37.50	38.00	38.50	39.00	39.50	40.00

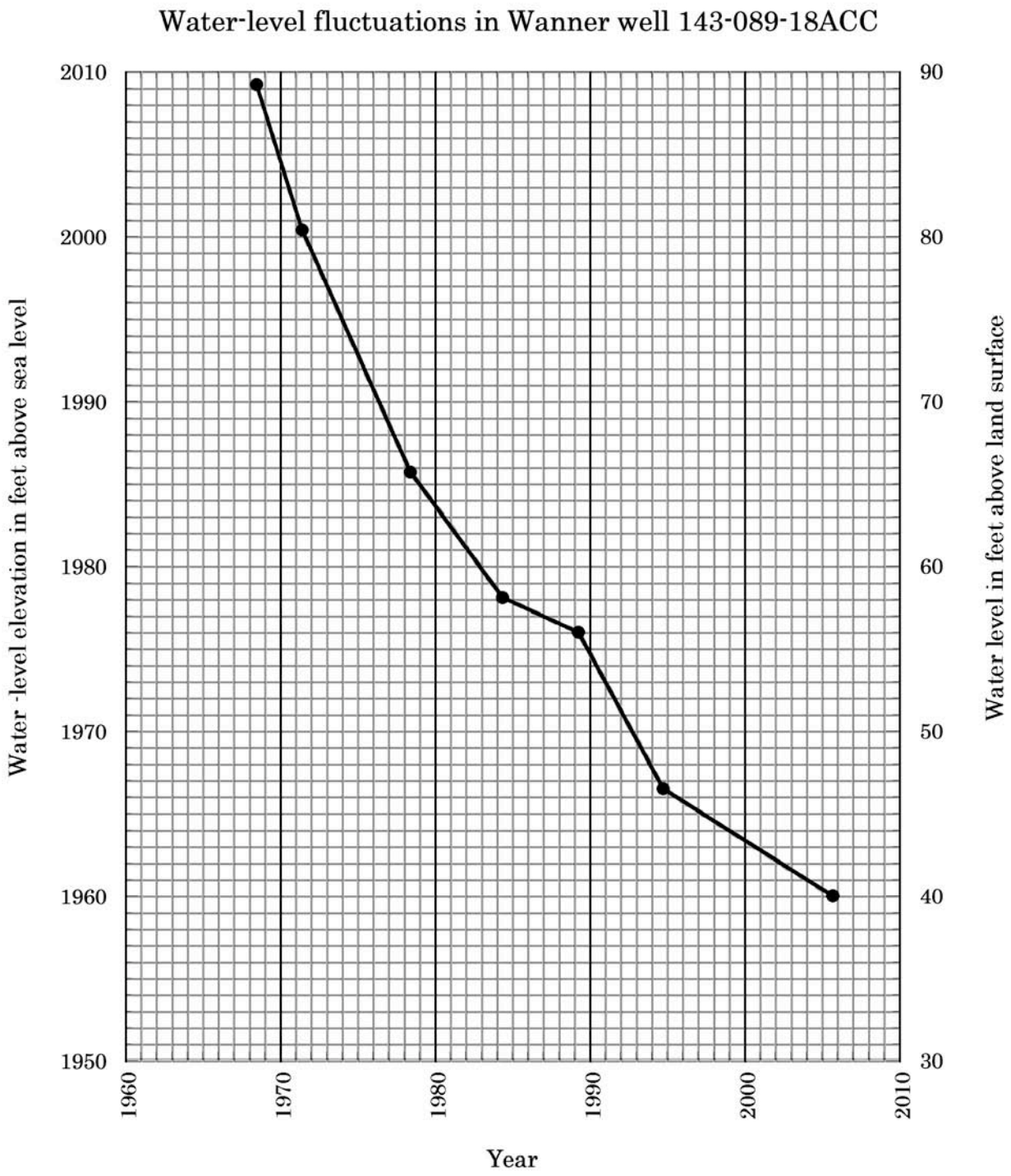
Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
07/68		60	89.2		Mack Croft
06/07/71		60	80.4	-3.0	Mack Croft
07/07/78		175	65.7	-2.1	Dave Ripley
05/15/84		120	58.1	-1.3	Allen Comeskey
04/18/89		120	56	-0.42	Allen Comeskey
09/30/94		120	46.5	-1.75	Alan Wanek
09/20/05	7.5	120	40.0	-0.6	Merlyn Skaley

Lithologic Log

(Bandy Drilling Co.)

Unit	Description	Depth (ft)
TOPSOIL	Surface soil is written on log, possibly glacial drift, or zone of oxidization.	0-12
LIGNITE		12-19
SHALE	Blue	19-105
SHALE	Blue (the County Study interpretation of Bandy's log described 0-105 feet as Sentinel Butte Fm. and 105-520 feet as Tongue River Formation)	105-221
SHALE	Blue, rock at 221-225, 246-249, lignite at 305-314	221-520
SANDSTONE	520-523 indurated	520-554
SHALE	Blue, rock at 619-622 (the County Study interpretation is Cannonball or Ludlow Formation between depths of 554 feet and 850 feet.)	554-680
SAND	And shale	680-762
SHALE	Blue	762-849
SAND	Rock (indurated zone) 849-850, and shale (Co. Study has 850 as the top of the Hell Creek (?) Formation.)	849-950
SHALE	Blue	950-1245
SANDSTONE		1245-1320
SHALE	Blue	1320-1333
SANDSTONE	The County Study interpretation of the log does not note the Fox Hills Formation, but 1245 feet depth would be a good formation top.	1333-1380


Water-level fluctuations in Wanner well 143-089-18ACC
Water -level elevation in feet above sea level
2010
2000
1990
1980
1970
1960
1950
Water level in feet above land surface
90
80
70
60
50
40
30
1960
1970
1980
1990
2000
2010
Year

Water Quality

Location	143-089-18ACC
County	Mercer
Screened Interval	0'-1380'
Aquifer	Fox Hills
Purpose	Stock Well
Date Sampled	09/20/05
Time Sampled	17:15:00
Yield (gpm)	7.6
Field Temp(C)	20.80
Lab pH	8.40
Field Conductivity (um/cm)	2210
Lab Conductivity (um/cm)	2440
Total Dissolved Solids (mg/L)	1390
Calcium (mg/L)	2.53
Magnesium (mg/L)	<1
Potassium (mg/L)	2.0
Sodium (mg/L)	583.0
Fluoride (mg/L)	4.95
Bicarbonate (mg/L)	1090
Carbonate (mg/L)	16.0
Sulfate (mg/L)	<0.3
Chloride (mg/L)	247.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	0.09
Iron (mg/L)	0.040
Manganese (mg/L)	<0.01
Hardness(mg/L)	10.0
Sodium Adsorption Ratio (SAR)	78.4
Residual Sodium Carbonate (Equiv/L)	18.0
Percent Sodium	99.0

Lois Wanner and Adam Wanner well at 143-089-18CCC

143-089-19ACB

Date Completed:	00/00/00	*Purpose:*	Stock Well
L.S. Elevation (ft):	1897'	*Well Type:*	2"Steel
Depth Drilled (ft):	0'	*Aquifer:*	Fox Hills
Screened Interval (ft):	0' - 1280'	*Source:*	

Owner: Albert Hauck

Address: RR1, Box 22, Golden Valley, ND 58541
Farmstead 9 miles south of Golden Valley at 143-90-24BA

Well Location: Well is located 100 feet north of creek and 500 feet east southeast (down gradient) of trail.

Completion: Only information is that in the county study, plus the lithologic log on the back of Allen Comeskey's field notes (source unknown).

Wellhead description: (casing & plumbing) Casing and valved pipe extend two feet above ground. Serves stock tank.

Remarks:

Shut in time vs. pressure head: 2005 measurements

Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	76.0	78.0	79.0	80.0	80.0	80.0	81.0	82.0	82.0	82.0

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)	83.0	83.0	83.0	83.0	83.0	83.0				

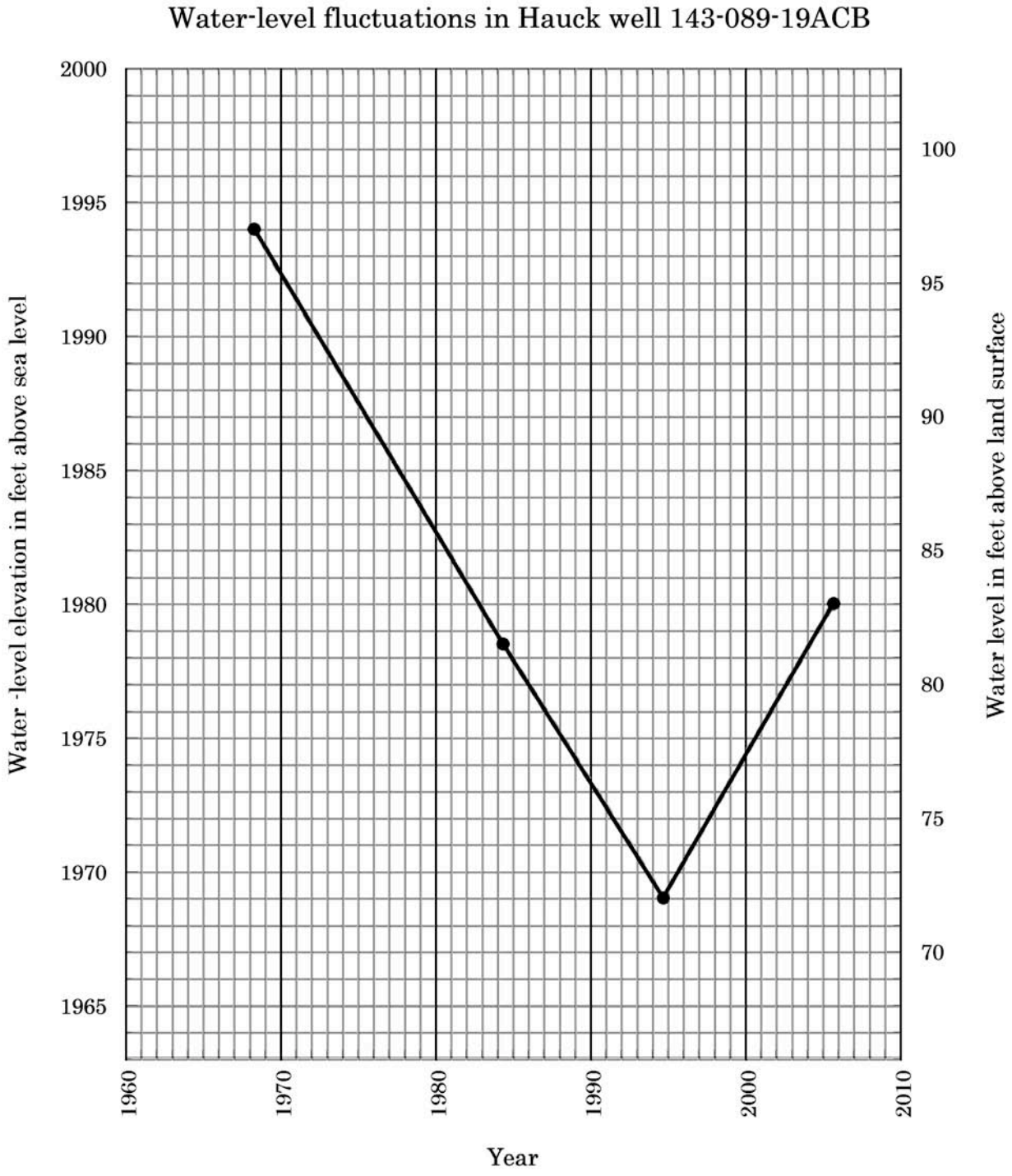
Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
05/68		NA	97.0		Mack Croft
05/16/84		120	81.5	-1.0	Allen Comeskey
09/28/94		120	72.0	-0.9	Alan Wanek
09/20/05	4	60	83.0	+1.0	Merlyn Skaley

Lithologic Log

(from AEC's field notes)

Unit	Description	Depth (ft)
SHALE	Blue	25-71
SAND		71-80
SHALE	Blue, with coal streaks	80-687
SHALE	Blue, indurated (rock) 687-694	687-1115
SAND	& clay streaks	1115-1280


Water-level fluctuations in Hauck well 143-089-19ACB
Water -level elevation in feet above sea level
2000
1995
1990
1985
1980
1975
1970
1965
Water level in feet above land surface
100
95
90
85
80
75
70
1960
1970
1980
1990
2000
2010
Year

Water Quality

Location	143-089-19ACB
County	Mercer
Screened Interval	0'-1280'
Aquifer	Fox Hills
Purpose	Stock Well
Date Sampled	09/20/05
Time Sampled	15:37:00
Yield (gpm)	4
Field Temp(C)	14.20
Lab pH	8.92
Field Conductivity (um/cm)	2040
Lab Conductivity (um/cm)	2280
Total Dissolved Solids (mg/L)	1270
Calcium (mg/L)	<2
Magnesium (mg/L)	<1
Potassium (mg/L)	2.0
Sodium (mg/L)	545.0
Fluoride (mg/L)	5.22
Bicarbonate (mg/L)	890.0
Carbonate (mg/L)	90.0
Sulfate (mg/L)	<0.3
Chloride (mg/L)	190.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	<0.09
Iron (mg/L)	0.540
Manganese (mg/L)	<0.01
Hardness(mg/L)	9.0
Sodium Adsorption Ratio (SAR)	78.5
Residual Sodium Carbonate (Equiv/L)	17.0
Percent Sodium	99.0

Albert Hauck well at 143-089-19ACB

143-090-14DDA

Date Completed:	11/12/74	*Purpose:*	Stock Well
L.S. Elevation (ft):	2000'	*Well Type:*	2"Steel
Depth Drilled (ft):	1453'	*Aquifer:*	Fox Hills
Screened Interval (ft):	1361' - 1445'	*Source:*	James Drilling

Owner:	Albert Hauck
Address:	RR1, Box 22, Golden Valley, ND 58541 Farmstead 9 miles south of Golden Valley at 143-90-24BA
Well Location:	To reach the well, go northwest from the farmstead, cross to the north side of a creek and follow the creek west about 0.4 mile to southerly bend in creek.
Completion:	Four inch casing set to 79 feet, screened interval is perforated pipe, no grouting. AEC had reported leaking in 1984.
Wellhead description: (casing & plumbing)	The well casing extends 2.9 feet above land surface.
Remarks:	

*****Pump installed in well, because pressure head is below land surface*****

Shut in time vs. pressure head: 2005 measurements

Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)										

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)										

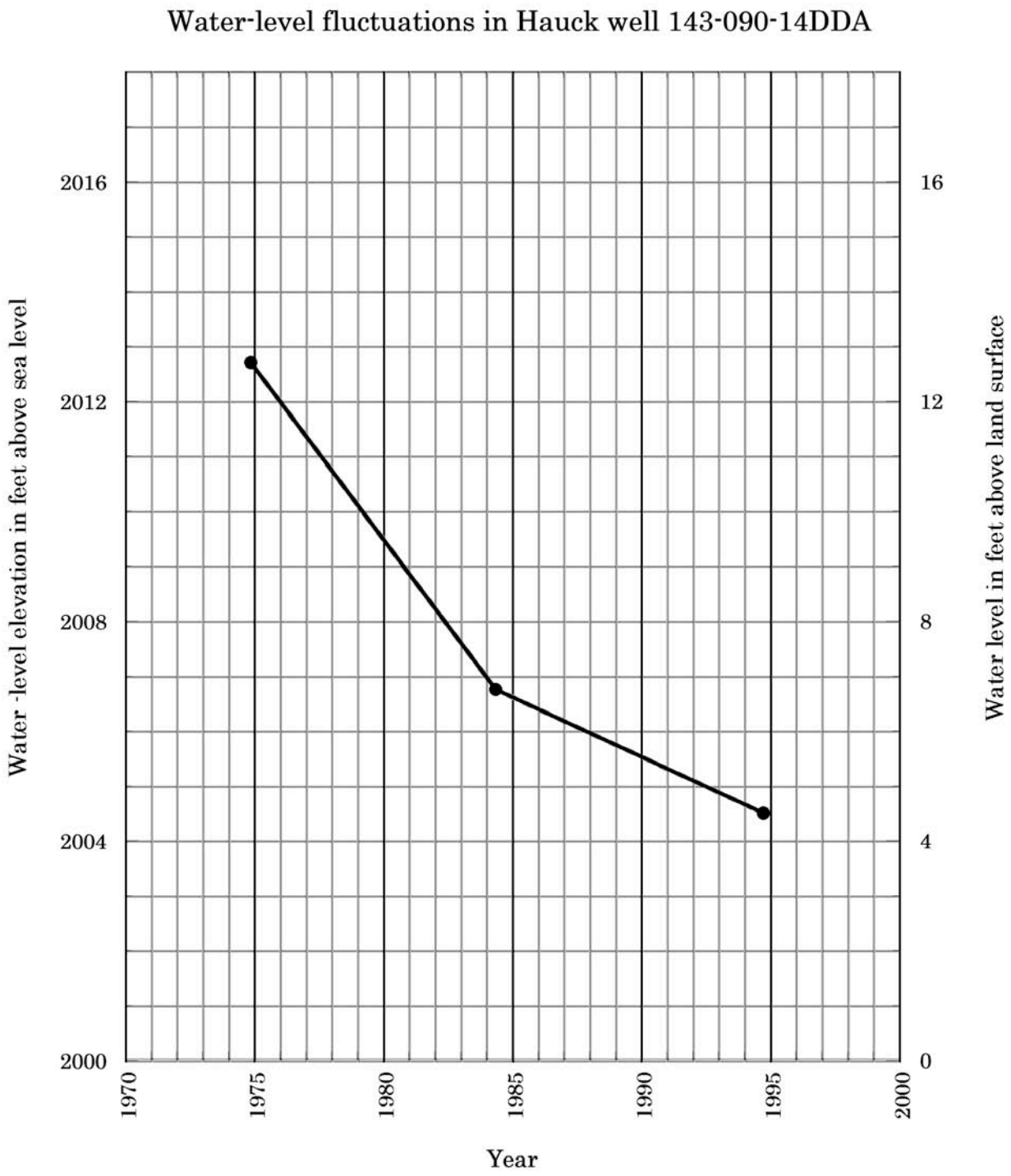
Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
11/74		NA	12		Mack Croft
05/16/84		8	6.75	-0.5	Allen Comesky
09/30/94		30	4.50	-0.2	Alan Wanek

Lithologic Log

(Logged by Henry Trapp, Larry Froelich, & Tony Mann)

Unit	Description	Depth (ft)
SAND	Fine to medium grained, silty (glacial drift)	0-36
SANDSTONE	Fine grained, silty, lignite 56-60 (Sentinel Butte Fm.)	36-68
CLAYSTONE	Light olive gray, silty, sandy, lignitic 163-170	68-182
SANDSTONE	Fine grained	182-235
CLAYSTONE	Silty	235-264
SANDSTONE	Clayey, silty	264-418
SILTSTONE	Grayish olive, clayey	418-490
SANDSTONE	Fine to medium grained (Basal Tongue River Fm.)	490-520
CLAYSTONE	Light olive, silty (Ludlow Fm. maybe Cannonball)	520-790
SANDSTONE	Clayey, silty (still Ludlow or Cannonball Fm.)	790-892
SILTSTONE	Light olive gray, clayey (Hell Creek Fm.)	892-980
SANDSTONE	Silty, clayey	980-1212
SILTSTONE	Clayey	1212-1230
SANDSTONE	Dark greenish gray, fine grained, silty, clayey (Fox Hills Fm. - Colgate Member)	1230-1364
SILTSTONE	Grayish olive, sandy (lower Fox Hills Fm.)	1364-1564
SHALE	Dark greenish gray, sandstone (?), (Pierre Fm.)	1564-1790


Water-level fluctuations in Hauck well 143-090-14DDA
Water -level elevation in feet above sea level
2016
2012
2008
2004
2000
Water level in feet above land surface
16
12
8
4
0
1970
1975
1980
1985
1990
1995
2000
Year

Water Quality

Location	143-090-14DDA
County	Mercer
Screened Interval	1361'-1445'
Aquifer	Fox Hills
Purpose	Stock Well
Date Sampled	09/20/05
Time Sampled	11:08:00
Yield (gpm)	20
Field Temp(C)	12.80
Lab pH	8.45
Field Conductivity (um/cm)	2080
Lab Conductivity (um/cm)	2320
Total Dissolved Solids (mg/L)	1330
Calcium (mg/L)	2.48
Magnesium (mg/L)	<1
Potassium (mg/L)	2.0
Sodium (mg/L)	560.0
Fluoride (mg/L)	5.23
Bicarbonate (mg/L)	1090
Carbonate (mg/L)	23.0
Sulfate (mg/L)	<0.3
Chloride (mg/L)	207.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	0.09
Iron (mg/L)	0.033
Manganese (mg/L)	<0.01
Hardness(mg/L)	10.0
Sodium Adsorption Ratio (SAR)	75.8
Residual Sodium Carbonate (Equiv/L)	18.0
Percent Sodium	98.9

Albert Hauck well at 143-090-14DDA

143-090-24ABC

Date Completed:	00/00/00	*Purpose:*	Stock Well
L.S. Elevation (ft):	1960'	*Well Type:*	2"Steel
Depth Drilled (ft):	NA	*Aquifer:*	Fox Hills
Screened Interval (ft):	NA	*Source:*	

Owner: Albert Hauck

Address: RR1, Box 22, Golden Valley, ND 58541
Farmstead 9 miles south of Golden Valley at 143-90-24BA

Well Location: Located 70 feet south of creek in cattle yard at southeast corner of Hauck farmstead, about 1000 feet from house and about 50 feet east northeast of metal building.

Completion: Not available

Wellhead description: (casing & plumbing) Casing extends about three feet above land surface and runs water into a stock tank.

Remarks:

Shut in time vs. pressure head: 2005 measurements

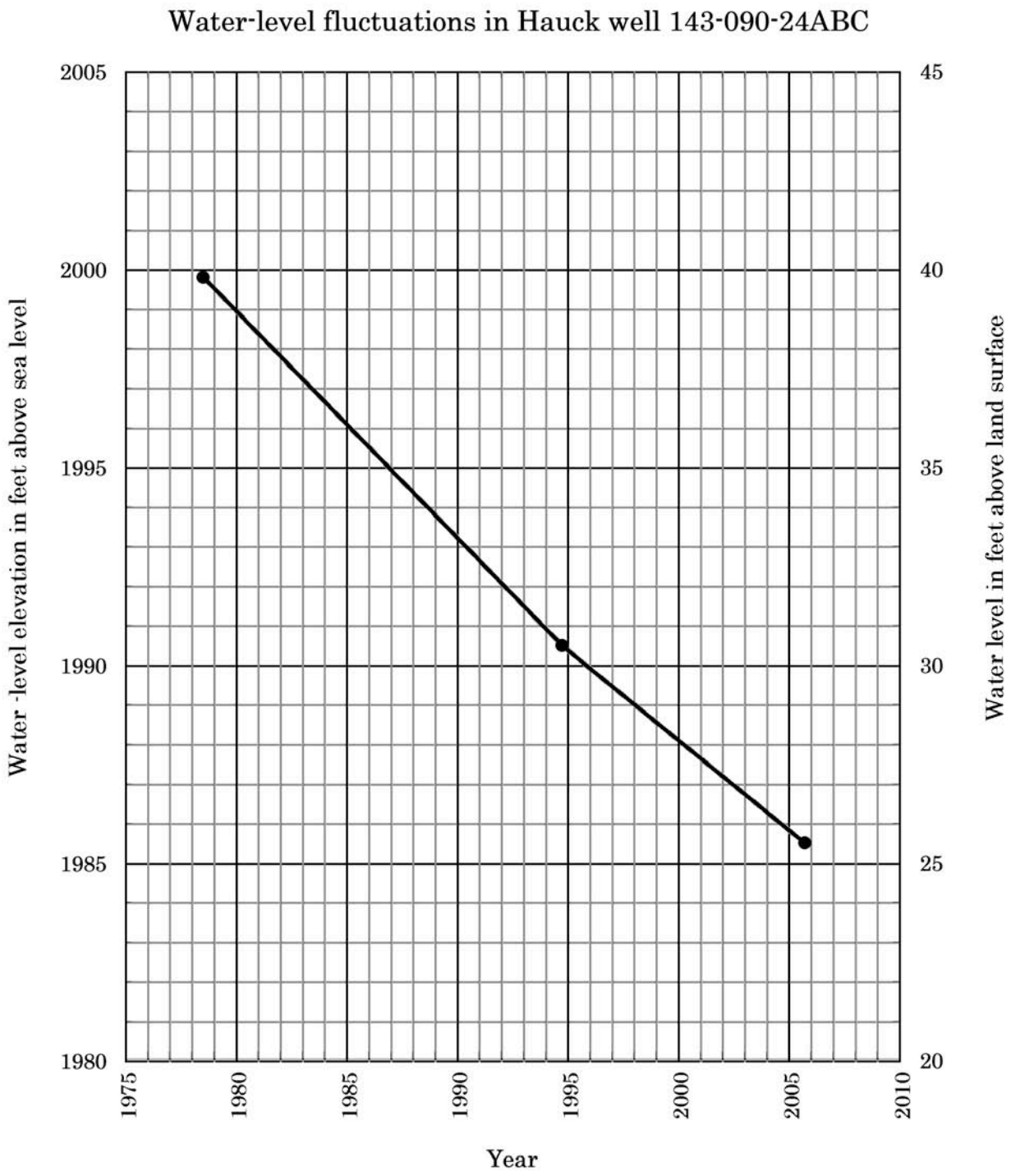
Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	22.50	22.75	23.00	23.00	23.25	23.50	23.75	24.00	24.25	24.50

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)	24.75	25.00	25.00	25.25	25.50	25.50				

Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
07/06/76		62	39.8		Dave Ripley
09/28/94		15	30.5	-0.51	Alan Wanek
09/20/05	6	60	25.5	-0.50	Merlyn Skaley

143-090-24ABC
No Lithologic Log


Water-level fluctuations in Hauck well 143-090-24ABC
Water -level elevation in feet above sea level
Water level in feet above land surface
Year
2005
2000
1995
1990
1985
1980
45
40
35
30
25
20
1975
1980
1985
1990
1995
2000
2005
2010

Water Quality

Location	143-090-24ABC
County	Mercer
Screened Interval	0'-0'
Aquifer	Fox Hills
Purpose	Stock Well
Date Sampled	09/20/05
Time Sampled	13:45:00
Yield (gpm)	6
Field Temp(C)	16.10
Lab pH	8.48
Field Conductivity (um/cm)	2020
Lab Conductivity (um/cm)	2290
Total Dissolved Solids (mg/L)	1340
Calcium (mg/L)	2.42
Magnesium (mg/L)	<1
Potassium (mg/L)	2.1
Sodium (mg/L)	555.0
Fluoride (mg/L)	5.18
Bicarbonate (mg/L)	1140
Carbonate (mg/L)	26.0
Sulfate (mg/L)	<0.3
Chloride (mg/L)	192.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	<0.09
Iron (mg/L)	<0.01
Manganese (mg/L)	<0.01
Hardness(mg/L)	10.0
Sodium Adsorption Ratio (SAR)	75.7
Residual Sodium Carbonate (Equiv/L)	19.0
Percent Sodium	98.9

Albert Hauck well at 143-090-24ABC

143-090-24BAB

Date Completed:	01/01/64	*Purpose:*	Domestic Well
L.S. Elevation (ft):	1962'	*Well Type:*	2"Steel
Depth Drilled (ft):	1300'	*Aquifer:*	Fox Hills
Screened Interval (ft):	0' - 1280'	*Source:*	Bandy Drilling Co.

Owner: Albert Hauck

Address: RR1, Box 22, Golden Valley, ND 58541
Farmstead 9 miles south of Golden Valley at 143-90-24BA

Well Location: The well is located about 200 feet south of the house, north of the rest of the farmstead buildings.

Completion: Information from the county study

Wellhead description: (casing & plumbing) The gage was connected at a faucet on the pipe leading from the well head, about one foot above land surface. Water is piped to a nearby stock tank, but is also piped or pumped to the house, I'm unsure of the plumbing.

Remarks:

Shut in time vs. pressure head: 2005 measurements

Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	13.25	14.00	14.25	14.75	15.00	15.50	15.75	16.00	16.00	16.50

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)	16.50	16.75	16.75	17.00	17.25	17.25				

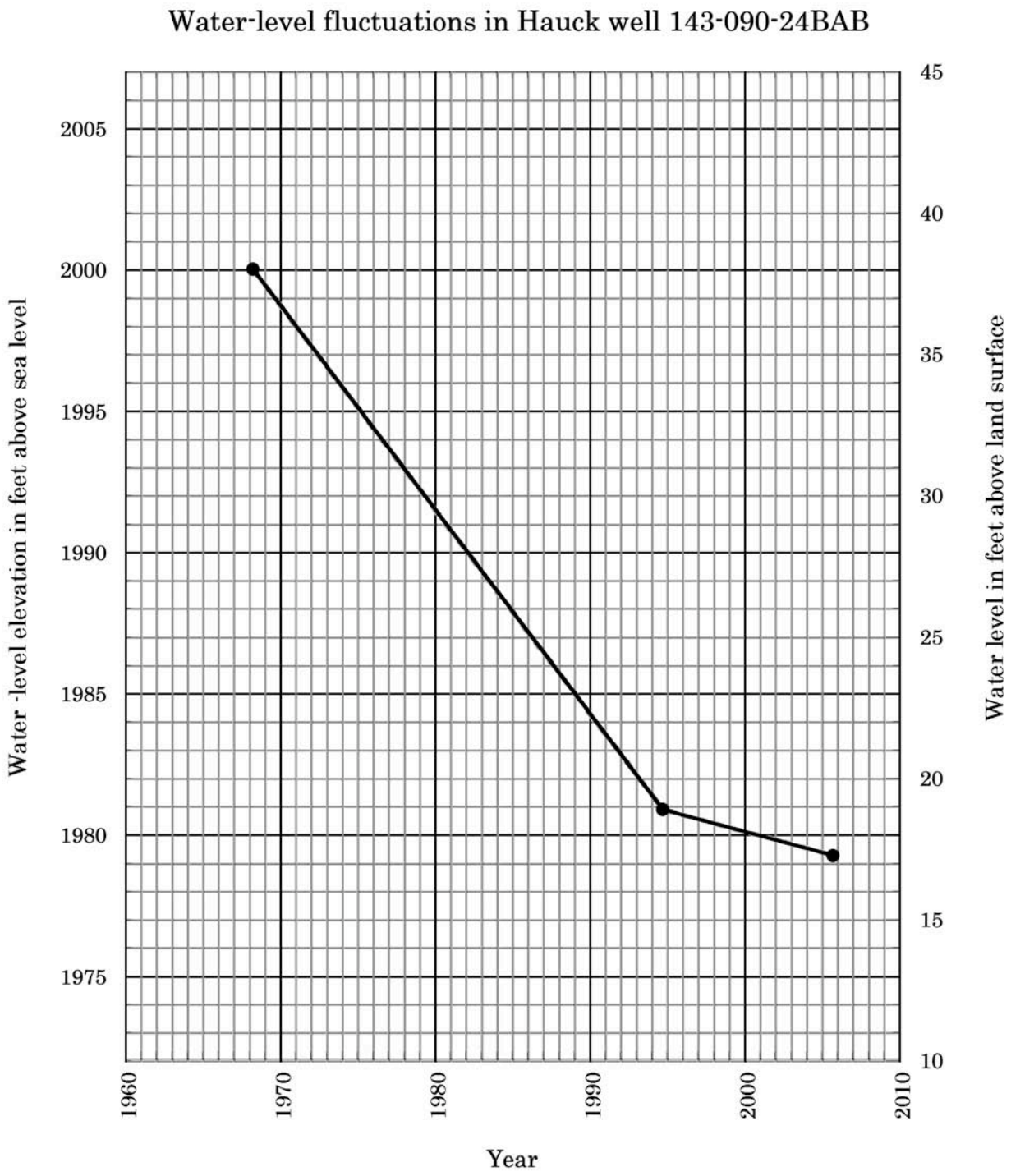
Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
04/68		NA	38		Mack Croft
09/28/94		15	18.9	-0.7	Alan Wanek
09/20/05	2	60	17.25	-0.2	Merlyn Skaley

Lithologic Log

(from Bandy Drilling Co.)

Unit	Description	Depth (ft)
TOPSOIL	Surface soil (from Co. Study, maybe glacial drift)	0-39
SHALE	Blue	39-194
LIGNITE		194-200
SHALE	Blue	200-303
LIGNITE		303-310
SHALE	Blue	310-460
SANDSTONE	Indurated (rock) from 460-464	460-495
SHALE	With coal	495-517
SHALE	Blue	517-562
SANDSTONE		562-575
SHALE	Blue	575-640
SANDSTONE		640-732
SHALE	Blue	732-950
SAND	And shale, rock or indurated zone at 1069-1072	950-1110
SHALE	Blue	1110-1182
SANDSTONE		1182-1207
SHALE	Blue	1207-1240
SANDSTONE		1240-1289
SHALE	Blue	1289-1300


Water-level fluctuations in Hauck well 143-090-24BAB
Water -level elevation in feet above sea level
2005
2000
1995
1990
1985
1980
1975
45
40
35
30
25
20
15
10
Water level in feet above land surface
1960
1970
1980
1990
2000
2010
Year

Water Quality

Location	143-090-24BAB
County	Mercer
Screened Interval	0'-1280'
Aquifer	Fox Hills
Purpose	Domestic Well
Date Sampled	09/20/05
Time Sampled	12:24:00
Yield (gpm)	2
Field Temp(C)	11.00
Lab pH	7.91
Field Conductivity (um/cm)	2190
Lab Conductivity (um/cm)	2540
Total Dissolved Solids (mg/L)	1450
Calcium (mg/L)	3.21
Magnesium (mg/L)	<1
Potassium (mg/L)	2.5
Sodium (mg/L)	618.0
Fluoride (mg/L)	2.49
Bicarbonate (mg/L)	1370
Carbonate (mg/L)	<1
Sulfate (mg/L)	<0.3
Chloride (mg/L)	146.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	0.18
Iron (mg/L)	0.784
Manganese (mg/L)	<0.01
Hardness(mg/L)	12.0
Sodium Adsorption Ratio (SAR)	77.1
Residual Sodium Carbonate (Equiv/L)	22.0
Percent Sodium	98.9

Albert Hauck well at 143-090-24BAB

144-085-10CCA

Date Completed:	01/01/66	*Purpose:*	Stock Well
L.S. Elevation (ft):	1762'	*Well Type:*	2"Steel
Depth Drilled (ft):	900'	*Aquifer:*	Fox Hills
Screened Interval (ft):	900' - 900'	*Source:*	Bandy Drilling

Owner: Donald and Richard Hoge

Address: 19400 15th St. NW, Baldwin, ND 58521

Well Location: Located in pasture NE of corral, about 1/4 mile north & 1/4 mile east of gate at SW corner of section, along highway.

Completion: Open hole completion

Wellhead description: (casing & plumbing) Well discharge point is about 3 feet above land surface. Water discharges into a large, stainless steel, rectangular stock tank.

Remarks:

Shut in time vs. pressure head: 2005 measurements

Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	29.00	29.50	29.50	29.60	30.00	30.25	30.75	31.50	31.90	32.40

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)	33.10	33.40	33.75	34.10	34.90	35.25	35.75	36.00	36.50	37.00

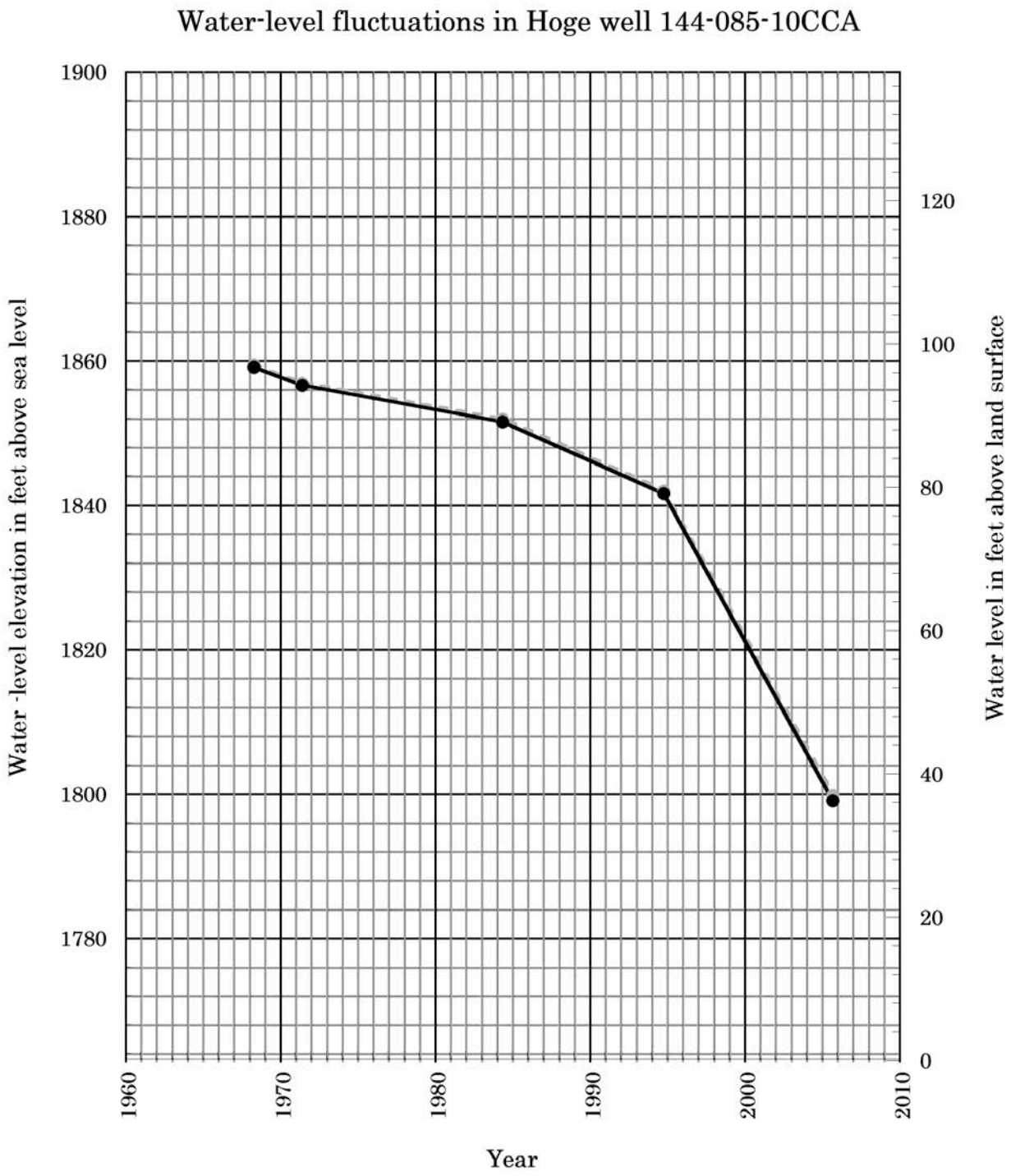
Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
05/68			97.00		
06/03/71			94.50	-0.8	Mack Croft
05/14/84		20	89.45	-0.4	Mack Croft
10/13/94		30	79.50	-0.9	Allen Comeskey
09/19/05	30	120	37.00	-3.89	Merlyn Skaley

Lithologic Log

(from Bandy Drilling)

Unit	Description	Depth (ft)
SOIL	Surface	0-4
SAND		4-10
CLAY	With sand	10-52
SHALE	Sandy, rocks at 105-107, 314-316	52-342
SANDSTONE		342-386
SHALE	Blue	386-438
SANDSTONE		438-446
SHALE	Blue	446-486
SANDSTONE		486-538
SHALE	Blue	538-580
SAND	And shale	580-620
SANDSTONE		620-634
SHALE	Blue	634-646
SANDSTONE		646-692
SHALE	Blue	692-719
SANDSTONE		719-724
SHALE	Blue	724-810
SANDSTONE		810-874
SHALE	Blue	874-900


Water-level fluctuations in Hoge well 144-085-10CCA
Water -level elevation in feet above sea level
1900
1880
1860
1840
1820
1800
1780
Water level in feet above land surface
120
100
80
60
40
20
0
1960
1970
1980
1990
2000
2010
Year

Water Quality

Location	144-085-10CCA
County	Mercer
Screened Interval	900'-900'
Aquifer	Fox Hills
Purpose	Stock Well
Date Sampled	09/19/05
Time Sampled	15:00:00
Yield (gpm)	30
Field Temp(C)	16.10
Lab pH	8.28
Field Conductivity (um/cm)	2180
Lab Conductivity (um/cm)	2530
Total Dissolved Solids (mg/L)	1440
Calcium (mg/L)	3.95
Magnesium (mg/L)	1.0
Potassium (mg/L)	2.8
Sodium (mg/L)	587.0
Fluoride (mg/L)	4.21
Bicarbonate (mg/L)	1120
Carbonate (mg/L)	6.0
Sulfate (mg/L)	<0.3
Chloride (mg/L)	284.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	0.09
Iron (mg/L)	0.042
Manganese (mg/L)	<0.01
Hardness(mg/L)	14.0
Sodium Adsorption Ratio (SAR)	68.2
Residual Sodium Carbonate (Equiv/L)	18.0
Percent Sodium	98.6

Richard and Donald Hoge well at 144-085-10CCA

144-089-14CDD

Date Completed:	01/01/69	*Purpose:*	Municipal Well
L.S. Elevation (ft):	1845'	*Well Type:*	0"Steel
Depth Drilled (ft):	1515'	*Aquifer:*	Fox Hills
Screened Interval (ft):	1241' - 1281'	*Source:*	

Owner:	City of Zap
Address:	P.O. Box 97, Cynthia Zahn (Auditor), Don Horning (City Manager), Clarence Olszewski (Mayor)
Well Location:	Well is located behind (west of) the city auditorium, about 20 feet west of the northwest corner of the building, the old building on the west side of main street, across from city hall and between two bars, Shooters to the south & the Lignite Bar to the north.
Completion:	Well from the county study, no lithologic log
Wellhead description: (casing & plumbing)	Looks like typical private 6" well, faucet about ten feet north of well & hydrant a couple feet farther north.
Remarks:	

Shut in time vs. pressure head: 2005 measurements

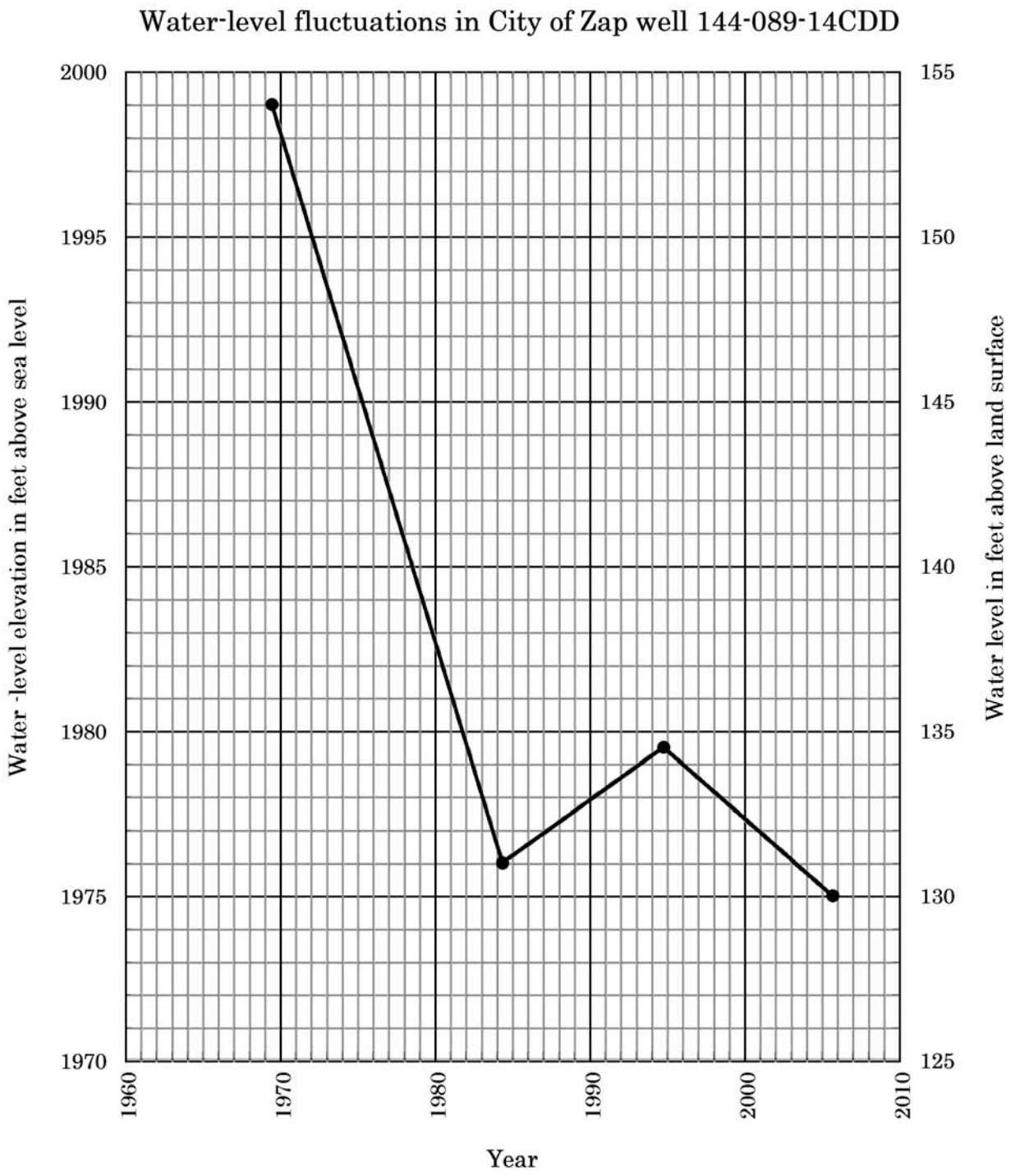
Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	125	126	126	127	127	127	128	128	128	130

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)	130	130								

Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
07/69		NA	154.0		Mack Croft
05/24/84		10	131.0	-1.6	Allen Comeskey
10/11/94		12	134.5	+0.3	Alan Wanek
09/20/05	15	60	130.0	-0.4	Merlyn Skaley

144-089-14CDD
No Lithologic Log


Water-level fluctuations in City of Zap well 144-089-14CDD
Water -level elevation in feet above sea level
Water level in feet above land surface
2000
1995
1990
1985
1980
1975
1970
155
150
145
140
135
130
125
1960
1970
1980
1990
2000
2010
Year

Water Quality

Location	144-089-14CDD
County	Mercer
Screened Interval	1241'-1281'
Aquifer	Fox Hills
Purpose	Municipal Well
Date Sampled	09/20/05
Time Sampled	08:24:00
Yield (gpm)	15
Field Temp(C)	9.80
Lab pH	7.99
Field Conductivity (um/cm)	3090
Lab Conductivity (um/cm)	3460
Total Dissolved Solids (mg/L)	1880
Calcium (mg/L)	4.48
Magnesium (mg/L)	1.0
Potassium (mg/L)	2.9
Sodium (mg/L)	759.0
Fluoride (mg/L)	4.22
Bicarbonate (mg/L)	948.0
Carbonate (mg/L)	<1
Sulfate (mg/L)	<0.3
Chloride (mg/L)	647.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	0.27
Iron (mg/L)	0.827
Manganese (mg/L)	<0.01
Hardness(mg/L)	15.0
Sodium Adsorption Ratio (SAR)	84.3
Residual Sodium Carbonate (Equiv/L)	15.0
Percent Sodium	98.9

City of Zap well at 144-089-14CDD

144-090-04BBA

Date Completed:	07/25/64	*Purpose:*	Stock Well
L.S. Elevation (ft):	1953'	*Well Type:*	2"Steel
Depth Drilled (ft):	1280'	*Aquifer:*	Fox Hills
Screened Interval (ft):	1265' - 1265'	*Source:*	Bandy Drilling Co.

Owner:	Leona Brecht
Address:	Golden Valley, ND 58541
	Two miles north of Golden Valley, well is at farmstead
Well Location:	Located in northwest corner of corral, between metal pole barn and red wood barn, north end of farmstead, tractor tire tank. Water also piped 150 feet south to second tank, near barn. Enter from north
Completion:	No well completion details given on the old style well driller's report
Wellhead description: (casing & plumbing)	Water also piped 150 feet south to second tank, near barn (needs to be shut in). Well extends 2.7 feet above land surface, water runs into a stock tank.
Remarks:	

Shut in time vs. pressure head: 2005 measurements

Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	5.00	5.75	6.25	6.25	6.25	6.5	6.75	7.10	7.25	7.50

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)	8.00	8.90	8.90	8.90	8.90	8.90				

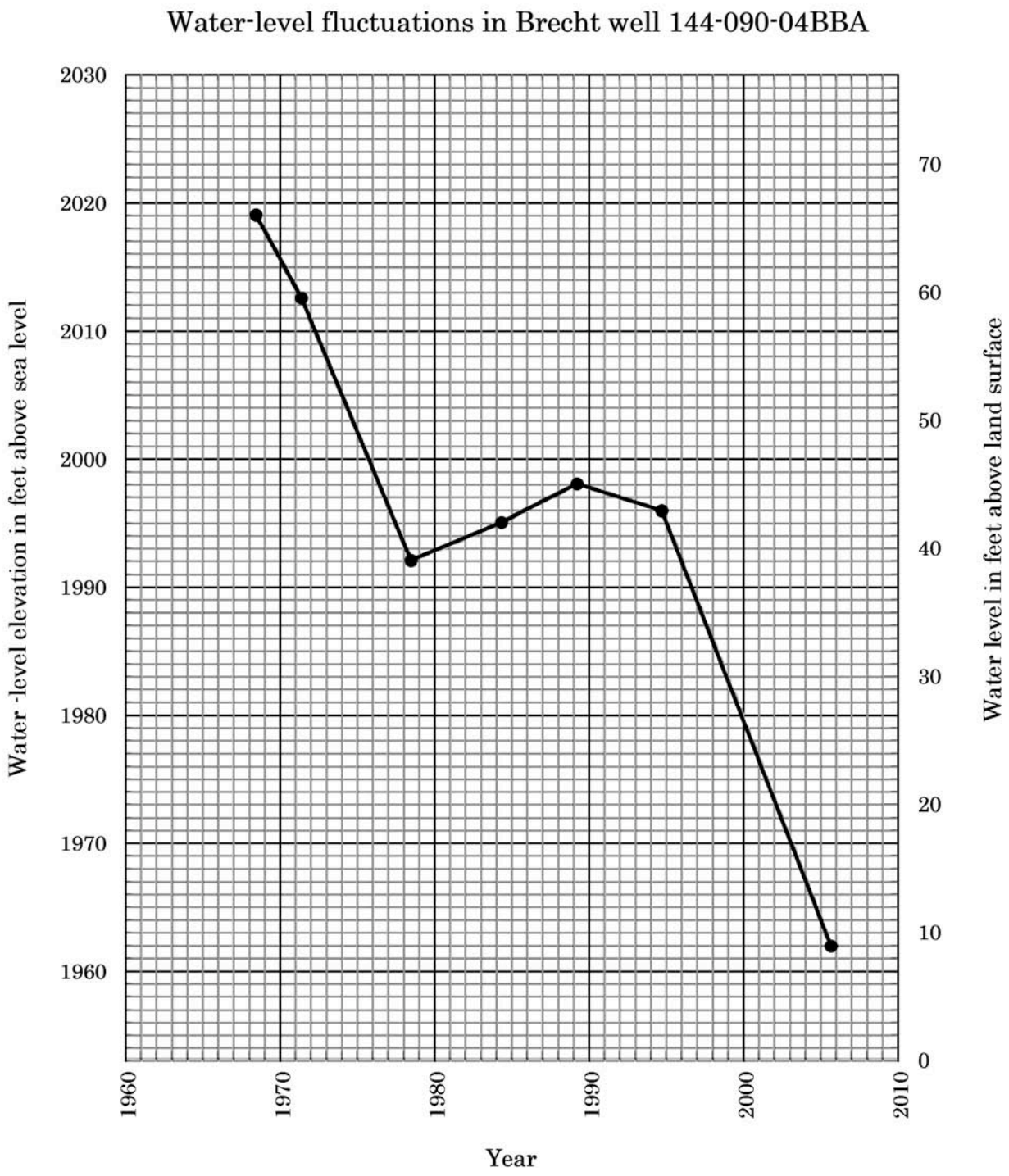
Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
07/68		60	66.0		Mack Croft
06/04/71		60	59.5	-2.2	Mack Croft
07/07/78		47	39.0 (42.6' Corr.)	-2.4	Dave Ripley (leakage)
05/17/84		60	42.0	-0.1	Allen Comeskey
04/18/89		50	45.0	+0.6	Allen Comeskey
10/05/94		60	42.9	-0.5	Alan Wanek
09/21/05	1	60	8.9	-3.1	Merlyn Skaley

Lithologic Log

(from Bandy Drilling Co.)

Unit	Description	Depth (ft)
TOPSOIL	Bandy's driller's log 0-178 feet is surface soil, whatever that means.	0-178
SHALE	Blue	178-270
LIGNITE		270-274
SHALE	Blue	274-338
SANDSTONE		338-360
SHALE	Blue, rock at 585-588	360-590
SANDSTONE		590-639
SHALE	Blue	639-690
SANDSTONE		690-714
SHALE	Blue	714-1035
SANDSTONE		1035-1080
SHALE	Blue	1080-1123
SANDSTONE	Indurated zone (rock) at 1123-1127	1123-1272
SHALE	Blue	1272-1280


Water-level fluctuations in Brecht well 144-090-04BBA
Water -level elevation in feet above sea level
2030
2020
2010
2000
1990
1980
1970
1960
Water level in feet above land surface
70
60
50
40
30
20
10
0
1960
1970
1980
1990
2000
2010
Year

Water Quality

Location	144-090-04BBA
County	Mercer
Screened Interval	1265'-1265'
Aquifer	Fox Hills
Purpose	Stock Well
Date Sampled	09/21/05
Time Sampled	08:10:00
Yield (gpm)	1
Field Temp(C)	13.20
Lab pH	7.39
Field Conductivity (um/cm)	2180
Lab Conductivity (um/cm)	2380
Total Dissolved Solids (mg/L)	1330
Calcium (mg/L)	2.50
Magnesium (mg/L)	<1
Potassium (mg/L)	2.3
Sodium (mg/L)	597.0
Fluoride (mg/L)	2.79
Bicarbonate (mg/L)	1240
Carbonate (mg/L)	<1
Sulfate (mg/L)	<0.3
Chloride (mg/L)	117.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	<0.09
Iron (mg/L)	0.040
Manganese (mg/L)	<0.01
Hardness(mg/L)	10.0
Sodium Adsorption Ratio (SAR)	80.6
Residual Sodium Carbonate (Equiv/L)	20.0
Percent Sodium	99.0

Leona Brecht well at 144-090-04BBA

144-091-10CBC

Date Completed:	11/02/76	*Purpose:*	Municipal Well
L.S. Elevation (ft):	1995'	*Well Type:*	9"Steel
Depth Drilled (ft):	1580'	*Aquifer:*	Fox Hills
Screened Interval (ft):	1450' - 1575'	*Source:*	LTP Enterprises, Inc.

Owner:	City of Dodge (Diane Allmendinger-Mayor) (William Allmendinger - City Manager)
Address:	P.O. Box 96, Dodge, ND 58625
Well Location:	Located behind (50 feet south and 10 feet east of) Dodge city building, which is along the south side of ND highway 200, under a silver painted fiberglass box cover
Completion:	Stainless steel, 35 slot screen
Wellhead description: (casing & plumbing)	Connection for gage off casing, a valve to pump house needs to be turned off.
Remarks:	According to city manager, well once had more flow. This year the flow has increased. Well is no longer used. The well is flushed out for about 10 days 2 times a year

Shut in time vs. pressure head: 2005 measurements

Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	46.00	46.25	46.50	46.75	47.00	47.50	47.75	48.00	48.50	49.00

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)	49.50	50.00	50.10	50.25	50.75	51.00	51.25	51.50	52.00	52.25

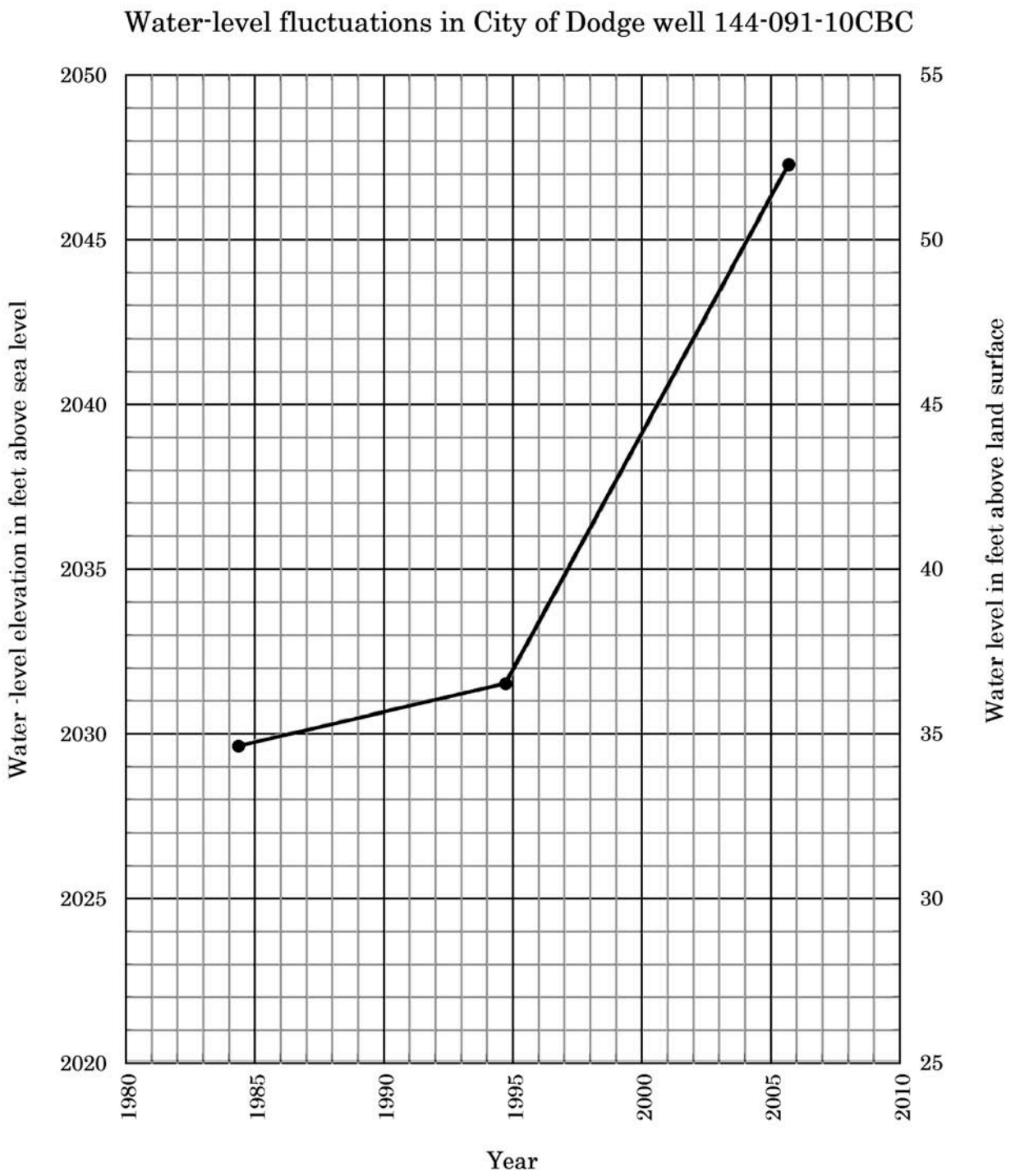
Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
05/24/84		10	34.60		Allen Comeskey
10/05/94		10	36.50	-0.3	Alan Wanek
09/21/05	12	120	52.25	+1.4	Merlyn Skaley

Lithologic Log

(from LTP Enterprises, Inc.)

Unit	Description	Depth (ft)
TOPSOIL	Black	0-1
CLAY	Brown	1-13
SAND	Fine, brown	13-17
SAND	Fine, brown, layers of clay	17-42
SAND	Fine, blue	42-67
LIGNITE		67-79
CLAY	Blue	79-114
SHALE	Gray, with layers of lignite and periodic limestone boulders (indurated sedimentary layers)	114-322
LIGNITE	Black	322-331
SHALE	Gray, layers of lignite and indurated (limestone from log) layers	331-466
LIGNITE	Black	466-482
SHALE	Gray to black (carbonaceous?, described as lignite shale), with so called limestone boulders	482-1242
SAND	Gray, fine, dirty	1242-1256
SHALE	Gray, with lenses of sand	1256-1265
SHALE	Black (carbonaceous?)	1265-1372
CLAY	Gray	1372-1380
SAND & GRAVEL	Brown ??????	1380-1392
SHALE	Gray	1392-1420
SAND	Gray-black, fine, with periodic hard lenses, usually one foot thick and commonly at about 10 feet intervals	1420-1516
SAND	Gray-black, fine, tighter than above	1516-1540
SAND	Gray-black, with lenses of shale (or shale with lenses of sand)	1540-1550
SHALE	Drills hard	1550-1580


Water-level fluctuations in City of Dodge well 144-091-10CBC
Water -level elevation in feet above sea level
Water level in feet above land surface
Year
2050
2045
2040
2035
2030
2025
2020
55
50
45
40
35
30
25
1980
1985
1990
1995
2000
2005
2010

Water Quality

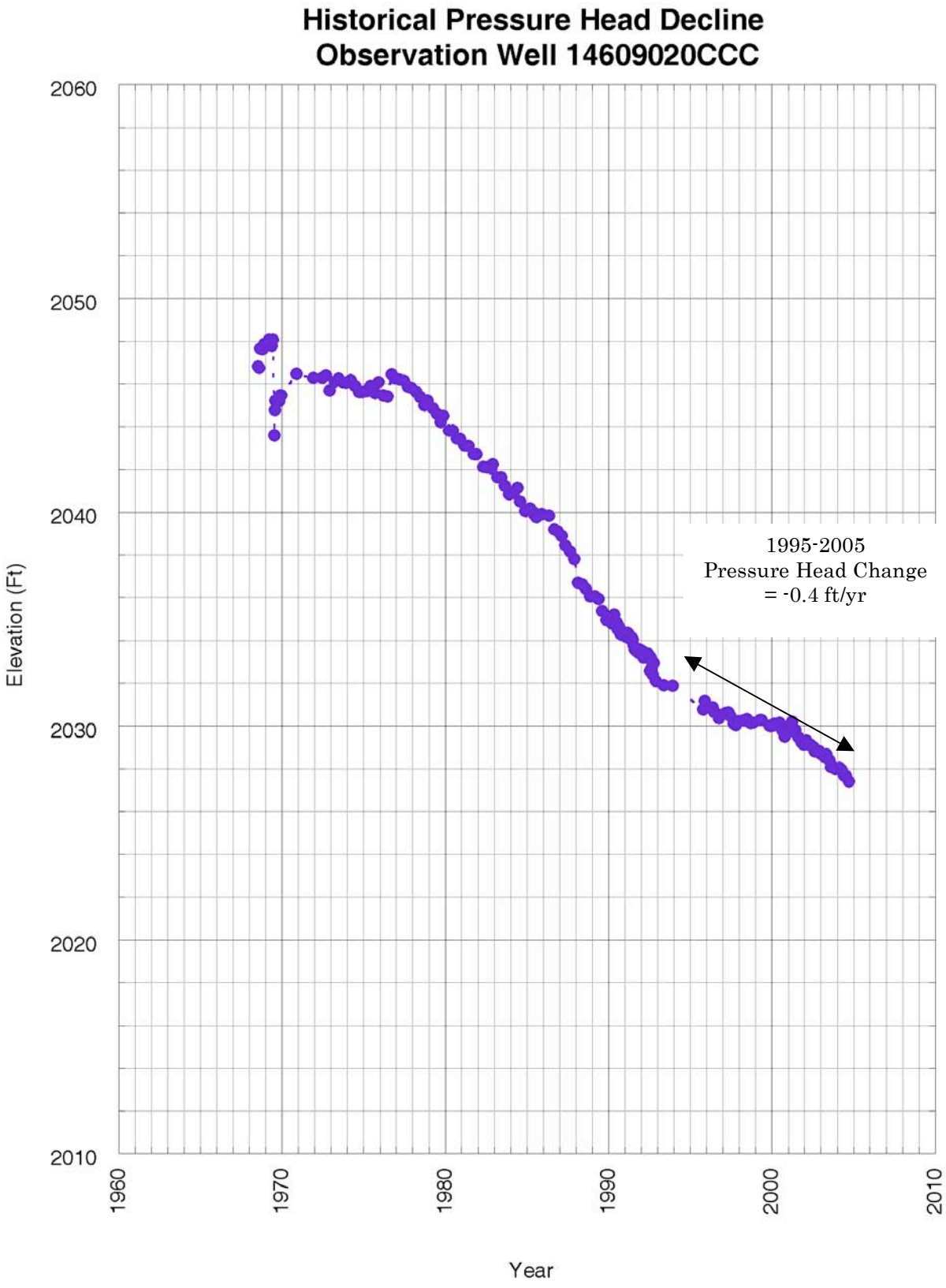
Location	144-091-10CBC
County	Dunn
Screened Interval	1450'-1575'
Aquifer	Fox Hills
Purpose	Municipal Well
Date Sampled	09/21/05
Time Sampled	12:20:00
Yield (gpm)	12
Field Temp(C)	13.80
Lab pH	7.60
Field Conductivity (um/cm)	2000
Lab Conductivity (um/cm)	2200
Total Dissolved Solids (mg/L)	1230
Calcium (mg/L)	2.05
Magnesium (mg/L)	<1
Potassium (mg/L)	1.8
Sodium (mg/L)	543.0
Fluoride (mg/L)	5.42
Bicarbonate (mg/L)	1010
Carbonate (mg/L)	<1
Sulfate (mg/L)	<0.3
Chloride (mg/L)	181.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	<0.09
Iron (mg/L)	0.466
Manganese (mg/L)	<0.01
Hardness(mg/L)	9.0
Sodium Adsorption Ratio (SAR)	77.7
Residual Sodium Carbonate (Equiv/L)	16.0
Percent Sodium	99.0

City of Dodge well at 144-091-10CBC

146-090-20CCC

Date Completed:	06/18/68	*Purpose:*	Observation Well
L.S. Elevation (ft):	2120'	*Well Type:*	4"Steel
Depth Drilled (ft):	1860'	*Aquifer:*	Fox Hills
Screened Interval (ft):	1540' - 1574'	*Source:*	Mann Drilling Co.

Owner:	NDSWC
Address:	Bismarck
Telephone #:	
Well Location:	Located between N-S gravel road and old basement, 70 feet north of E-W section line (trail) and a few feet east of a fence, into a pasture, also about 0.1 mile south of the paved county road.
Completion:	1540 feet of casing cemented with 200 bags of cement
Wellhead description: (casing & plumbing)	Pad for a continuous recorder. Four inch coupling extends about 0.37 feet above the concrete pad.
Remarks:	


Historical Pressure Head Decline
Observation Well 14609020CCC
2060
2050
2040
2030
2020
2010
Elevation (Ft)
1960
1970
1980
1990
2000
2010
Year
1995-2005
Pressure Head Change
= -0.4 ft/yr

Lithologic Log

(Larry Froelich & Tony Mann)

Unit	Description	Depth (ft)
SILTSTONE	Some claystone, sand between 0-96 feet, 168-188 feet (Sentinel Butte Formation). (an added interpretation of the county study interpretation).	0-510
SILTSTONE	With clay, sand between 896-960 (Tongue River Formation).	510-960
SILTSTONE	With clay, sand between 1120-1160, 1200-1219 (Cannonball and Ludlow Formations, undifferentiated).	960-1219
CLAYSTONE	Silty, sandy between 1219-1440 (Hell Creek Formation).	1219-1576
SANDSTONE	Fine to medium grained in 1576-1616 feet (Colgate Member), underlain by clay and sand between 1640-1780 (Fox Hills Formation).	1576-1840
SHALE	Black, fissile (Pierre Formation).	1840-1860

Water Quality

Location	146-090-20CCC
County	Mercer
Screened Interval	1540'-1574'
Aquifer	Fox Hills
Purpose	Observation Well
Date Sampled	11/17/94
Time Sampled	11:30:00
Yield (gpm)	40
Field Temp(C)	15.8
Lab pH	8.67
Field Conductivity (um/cm)	2300
Lab Conductivity (um/cm)	2210
Total Dissolved Solids (mg/L)	1370
Calcium (mg/L)	5
Magnesium (mg/L)	1
Potassium (mg/L)	2.1
Sodium (mg/L)	560
Fluoride (mg/L)	6
Bicarbonate (mg/L)	1100
Carbonate (mg/L)	36
Sulfate (mg/L)	2.5
Chloride (mg/L)	200
Hydroxide (mg/L)	
Nitrate(mg/L)	4.1
Iron (mg/L)	0.06
Manganese (mg/L)	0
Hardness(mg/L)	17
Sodium Adsorption Ratio (SAR)	59
Residual Sodium Carbonate (Equiv/L)	19
Percent Sodium	98

146-094-08DAD2

Date Completed:	10/23/74	*Purpose:*	Stock Well
L.S. Elevation (ft):	1965'	*Well Type:*	1.25"Steel
Depth Drilled (ft):	1730'	*Aquifer:*	Fox Hills
Screened Interval (ft):	1660' - 1730'	*Source:*	Ralph Wold Well Drilling

Owner: Mark and Karol Reddig

Address: 349 98th Avenue NW, Dunn Center, ND 58626

Well Location: Well is located about two miles northwest of the ranch, following a road or trail down into the breaks. The well is just west of where the valley widens, about 100 feet south of the trail, with a tractor tire made into a tank.

Completion: The well was deepened in 1974. It previously had been completed at about 1400 feet depth, in the Hell Creek Fm. The well is reported to be perforated, with the end of the casing left open. The well is reported grouted to 250 feet depth.

Wellhead description: (casing & plumbing) Water discharges into stock tank 1.8 feet above surface (used to discharge into tank at 2.4 feet above surface).

Remarks:

Shut in time vs. pressure head: 2005 measurements

Shut in time (minutes)	1	2	3	4	5	7	9	12	15	20
Pressure head (feet)	123	123	123	123	123	123	123	123	123	123

Shut in time (minutes)	25	30	35	40	50	60	70	80	100	120
Pressure head (feet)										

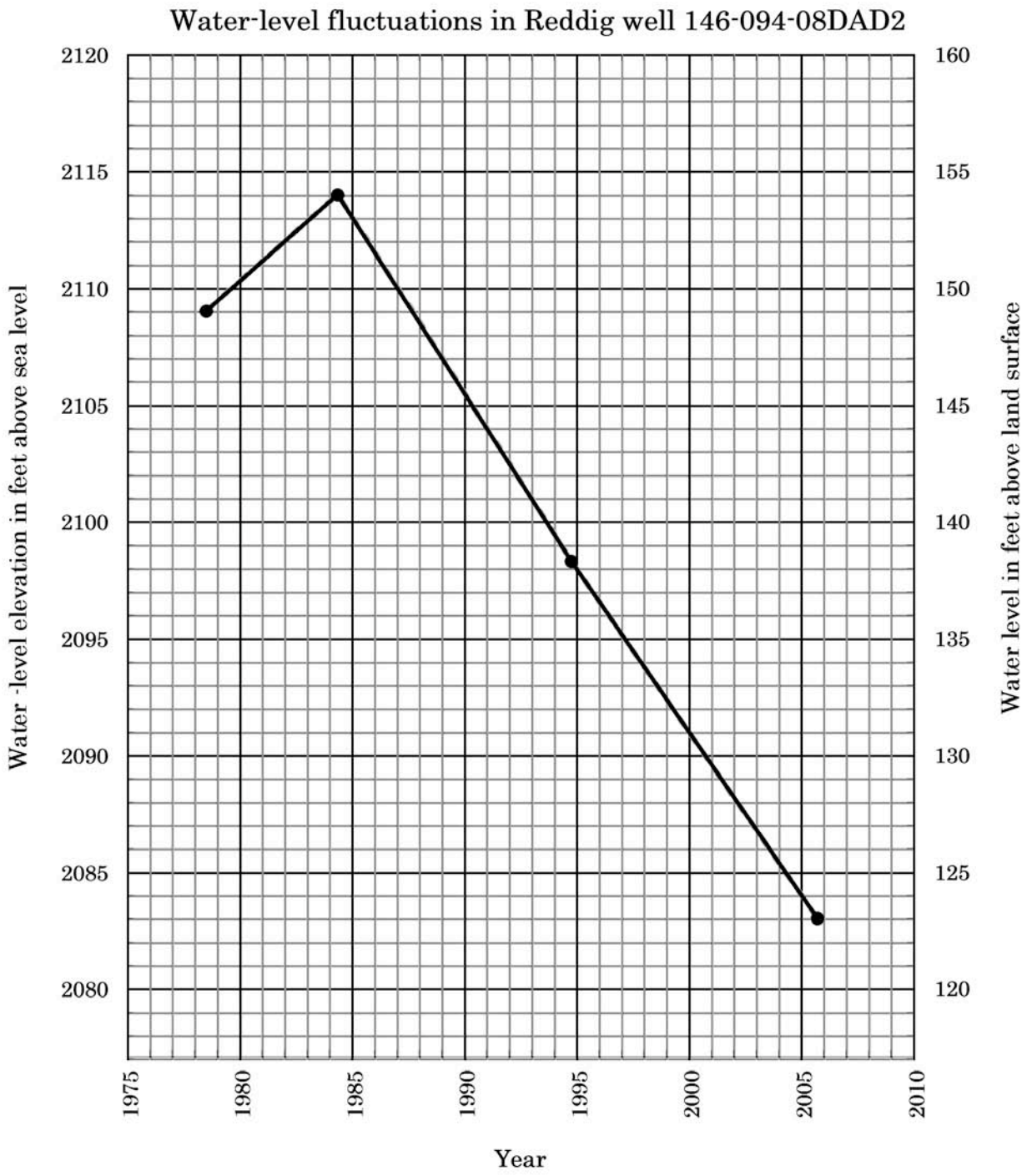
Long term pressure head measurements

Date	Flow rate (gpm)	Shut-in Time (min)	Pressure Head (ft)	Rate of change(ft/yr)	Measurement made by
04/07/78		60	149.0		Dave Ripley
05/18/84		20	154.0	-0.9	Allen Comeskey
10/11/94		30	138.3	-1.5	Alan Wanek
09/21/05	15	20	123.0	-1.4	Merlyn Skaley

Lithologic Log

(from Ralph Wold Well Drilling)

Unit	Description	Depth (ft)
CLAY	Lignite 24-27, 104-109, rock 60-64, 80-82, 180-182, 258-259, 340-343	0-475
SAND		475-595
SHALE		495-610
SAND	Indurated zone (rock) at 610-613	610-665
SHALE	Lignite streaks 702-715	665-715
SAND		715-760
CLAY	Rock 818-820	760-858
SAND		858-875
LIGNITE		875-885
CLAY	Rock at 990-992	885-1090
SAND		1090-1105
SAND	So listed in the county study data, I could not find the original log, probably a log to data base transfer mistake, probably should be clay	1105-1205
LIGNITE		1205-1218
CLAY	Rock 1294-1296	1218-1358
SAND	And water	1358-1404
CLAY	1410 is the bottom of the well as drilled in 1969. The well was deepened 320 feet, to the Fox Hills five years later.	1404-1410
CLAY	Sandy	1410-1440
SHALE		1440-1477
SAND		1477-1495
SHALE	Rock at 1530-1534	1495-1560
SAND	Rock at 1704-1708	1560-1730


Water-level fluctuations in Reddig well 146-094-08DAD2
Water -level elevation in feet above sea level
Water level in feet above land surface
Year
2120
2115
2110
2105
2100
2095
2090
2085
2080
160
155
150
145
140
135
130
125
120
1975
1980
1985
1990
1995
2000
2005
2010

Water Quality

Location	146-094-08DAD2
County	Dunn
Screened Interval	1660'-1730'
Aquifer	Fox Hills
Purpose	Stock Well
Date Sampled	09/21/05
Time Sampled	11:05:00
Yield (gpm)	15
Field Temp(C)	21.3
Lab pH	7.74
Field Conductivity (um/cm)	1963
Lab Conductivity (um/cm)	2100
Total Dissolved Solids (mg/L)	1180
Calcium (mg/L)	<2
Magnesium (mg/L)	<1
Potassium (mg/L)	1.9
Sodium (mg/L)	516.0
Fluoride (mg/L)	5.57
Bicarbonate (mg/L)	1010
Carbonate (mg/L)	<1
Sulfate (mg/L)	<0.3
Chloride (mg/L)	155.0
Hydroxide (mg/L)	<1
Nitrate(mg/L)	<0.09
Iron (mg/L)	<0.01
Manganese (mg/L)	<0.01
Hardness(mg/L)	9.0
Sodium Adsorption Ratio (SAR)	74.3
Residual Sodium Carbonate (Equiv/L)	16.0
Percent Sodium	99.0

Mark and Karol Reddig well at 146-094-08DAD2