REGIONAL GROUNDWATER ASSESSMENT OF POTABLE GROUNDWATER IN COUNTY OF WARNER No. 5, ALBERTA

Prepared for:

County of Warner No. 5

Prepared by:

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Executive Summary

The County of Warner No. 5 is located in southern Alberta, bordering the Canada / United States boundary. The County area includes part of the region between townships 001 to 008 and ranges 11 to 21, W4M. The topography is gently rolling and is cut by deep, meltwater-eroded coulees. The Milk River is a major surface water feature that crosses the southernmost area of the County. The climate in the County is continental arid.

This regional groundwater assessment has been based primarily on information available from the groundwater database of Alberta Environment Groundwater Information Centre. There are currently 2,244 water well records for the County Area in the GIC database, with approximately one third of them relating to wells installed prior to 1950. The records indicated that 63.2% of the wells would be expected to be used for domestic and stock purposes, 14.7% for industrial purposes, 0.7% for municipal purposes, 0.6% for irrigation purposes and 6% for investigations and monitoring purposes, while 14.8% did not indicate a specific use. It is unknown how many of these wells may still be active.

At the end of 2000, there were 35 groundwater allocations[1] within the County and 28 of these could be linked to the Alberta Environment database. The total maximum authorized diversion associated with these allocations was 877,645 m^3/year, roughly 2,405 m^3 per day (367 igpm), although actual usage could be less. Licensed allocations included agricultural (25.1%), commercial (0.1%), industrial (4.2%), municipal (69.2%) and recreational (1.4%). The surficial deposits provide groundwater for the majority of the allocations (85%), followed by the Milk River aquifer (6.5%), the Oldman Formation (2.6%) and the Foremost Formation (1.3%).

The geology in the County of Warner is characterized by a series of bedrock subcrops that expose different formations (Milk River, Pakowki, Foremost, Oldman, and Bearpaw) as the topmost bedrock. The Milk River Formation is the oldest, while the Bearpaw is the youngest. The formations are generally shallower in the southern portion of the County and become deeper to the west and north. The Bearpaw Formation is only present in the area of the Milk River Ridge. The Pakowki and Bearpaw Formations are mostly shales and have poor groundwater potential. Water wells, therefore, have been completed primarily into the Milk River, Foremost and Oldman Formations. South of Milk River Ridge lies the pre-glacial Whiskey Valley which follows to some extent the present-day Milk River. The in-filled Whiskey Valley is an important aquifer south of the Town of Milk River.

1 There are 25 licenses. Each license may specify more than one allocation for different water uses.

The surficial deposits comprise the materials above the bedrock surface which have been deposited through several stages of glaciation in southern Alberta. These materials consist of a mixture of rock and mineral particles ranging in grain size from clay to sand, with pebbles. Sand and gravels layers in glacial deposits form the main aquifers in such deposits.

Yields for wells completed into surficial deposits are generally low and probably in the range of 10 to 30 m^3/day (1.5 to 4.5 igpm). Many bored or dug wells would be expected to have low yields. Yields of 30 to 100 m^3/day (4.5 to 15 igpm) would be expected from localized sand and gravel deposits, while higher yields may be expected for wells completed in alluvial sands and gravels of present day rivers or buried sands and gravels (e.g., Whiskey Valley Aquifer).

Yields for wells completed in the Oldman and Foremost Formations would generally be expected to be lower than 10 m^3/day (1.5 igpm). Local yields of 10 to 30 m^3/day are more common in the Foremost Formation than in the Oldman Formation. Yields for wells in the Milk River Aquifer would be expected to be in the range of 10 to 70 m^3/day (1.5 to 10.5 igpm). Local yields in areas with high transmissivities could be in the range of 230 to 830 m^3/day (35 to 125 igpm).

The groundwater quality in both the surficial deposits and bedrock aquifers is quite variable. Groundwater from the surficial deposits is expected to be hard to very hard and have total dissolved solids higher than 700 mg/L. Bedrock groundwater, on the other hand, is moderately soft, but is more mineralized with total dissolved solids generally exceeding 1,450 mg/L. Softer groundwater is generally present in the Milk River Aquifer.

Piezometric levels in the Milk River Aquifer have shown little change in the past 50 years in the southern area of the County, however, declines of 15 to 30 m were present in the northeast part of the County where high producing wells are present. In the Foremost and Oldman Formations there has been generally no documented evidence of depletion. Water wells in surficial deposits are subject to climatic conditions and, as such, water levels will vary seasonally and the well may become dry during drought periods.

The Alberta Environment GIC database had several limitations that included: the lack of complete information in a water well record, the simplification of the coordinate system used to locate the water wells (center of ¼ section or LSD), the distribution of the data and the lack of adequate tests for aquifer parameters. For the County of Warner, in particular, the database had very few records. For the next level of study the database needs updating, and more information is required from existing, as well as new, water wells. It is recommended that a water well network database be established for the County, based exclusively on field verified data. As a first step, 343 water well records with sufficient data have been identified for potential inclusion into this network, if the respective water wells are still active.

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1.0 Project Overview

Stantec Consulting Ltd. was retained by County of Warner No. 5 to conduct a regional groundwater assessment of potable groundwater in the County of Warner No. 5. Financial assistance for this project was provided by Prairie Farm Rehabilitation Administration (PFRA) and County of Warner No. 5.

1.1 OBJECTIVES

The objectives of this regional groundwater assessment were to:

- Conduct a comprehensive review of the groundwater resources in County of Warner No. 5 to:
  - identify the geological formations and aquifers in both the surficial deposits and bedrock;
  - define the extent of the geological formations and aquifers;
  - describe the quality and quantity of groundwater associated with each aquifer;
  - assess groundwater use and possible effects on the aquifers.
- Provide a series of user-friendly, digitally prepared maps to illustrate the hydrogeological characteristics and available information (i.e., expected groundwater yield and quality, expected well depth, degree of protection, etc.) for each potential aquifer beneath the study area.
- Provide GIS ready shape files and databases that contained "added value" water well data that would allow for future updating.

1.2 SCOPE OF WORK

The scope of work for this project was outlined in the terms of reference dated November 10, 2000 and is summarized as follows:

TASK 1 Collect and review available data for surficial and bedrock potable-water aquifers above the Base of Groundwater Protection. Review and filter data from existing databases (i.e., GIC [1] and licensing well databases) and add value fields to the existing data;

TASK 2 Conduct hydrogeologic mapping and prepare a series of digital maps compatible with ArcView (shape) files;

[1] *GIC* refers to the Alberta Environment Groundwater Information Centre Water Well Records database.

TASK 3 Conduct a hydrogeological evaluation and prepare a concise report summarizing the assessment, yet describing in sufficient detail the maps prepared, the geologic/hydrogeologic framework and the available groundwater resources. Draft report to be provided for review;

TASK 4 Prepare a query program to extract selected information from the database;

TASK 5 Review draft report and GIS compatible digital files (carried out by PFRA and the County of Warner No. 5);

TASK 6 Provide a final presentation and training session for County of Warner No. 5 staff, councillors and guests;

TASK 7 Provide Report, Maps, Data and Query; and

TASK 8 Provide compact disk (CD) with the groundwater database, GIS, and Adobe Acrobat files.

1.3 LIMITATIONS

This regional groundwater assessment should be used only as a general guide. Local variations in several of the aquifer and geological properties/parameters described in this report are to be expected.

This report was prepared using generally accepted professional standards for this type of assessment and is based on the best information available at the time of the assessment. This report was prepared on the basis of existing information supplied previously by third parties in various contexts. Stantec did not independently verify this information, and makes no warranty or representation regarding the accuracy or completeness of the information.

This assessment is of a regional nature and local variations/deviations from the interpretation provided in this report are to be expected. **A detailed local study is required to verify hydrogeological conditions at specific sites/locations.**

Stantec, PFRA and the County of Warner No. 5 accept no responsibility for any claims or damages, if any, suffered by any party as a result of decisions made, or actions taken, based on this report or the information presented herein.

1.4 THIS REPORT

This report documents the work described in section 1.2 as per the requirements of Task 3. This report and additional maps are presented in Adobe Acrobat format in the accompanying CD-ROM. A set of posters has been prepared and was provided with this report.

Appendix A: Provides a list of water wells recommended for field verification

Appendix B: Provides a list of maps and figures included in the CD-ROM

Appendix C: Provides page size copies of the posters provided with this report

2.0 Introduction

2.1 SETTING

The County of Warner is located in southern Alberta, bordering the Canada / United States boundary. The County area includes part of the region between townships 001 to 008 and ranges 11 to 21, W4M, as shown in Figure 2.1a and 2.1b.

Most of the County area is located within the Alberta High Plains. Ground surface elevations vary from 900 m AMSL[2] in the northeast to 1,250 m AMSL in the south-west, along the Milk River Ridge. Along the south border, elevations range from 1,060 m AMSL to 1,220 m AMSL. Figure 2.2 shows the surface topography for the County.

The topography of the plains is gently rolling and is cut by deep, meltwater-eroded coulees. Three drainage systems are present in the County area. North and east of Wrentham, surface water drains toward Chin Lakes and Chin Coullee. The northwest area of the County (Raymond, Stirling and the northern slopes of Milk River Ridge) and the area south and east of Wrentham drain into Etzikom Coulee, which drains into Pakowki lake (a closed lake[3]). The creeks from the southern and eastern slopes of Milk River Ridge and the area south and east of Warner drain into the Milk River. The Verdigris Coulee is a major drainage feature which drains into the Milk River. Figure 2.1b illustrates some of the surface water drainage features.

2.2 CLIMATE

The climate in the County area is continental arid, generally characterized by long hot summer days and cold winter. On average, daily temperatures would be expected to be in the range of -14.8ºC to -0.3ºC in January (the coldest month), and 10ºC to 26.5ºC in July (the warmer month). Extreme temperatures could reach -43ºC during the winter, and 41ºC during the summer.

Mean annual precipitation would be expected to be in the range of 350 mm to 400 mm based on data from three weather stations near the County: Lethbridge, Foremost and Aden. A fourth weather station in Cardston had annual mean precipitation of 547 mm.

[2] m AMSL - metres above mean sea level
[3] a closed lake has no outlets and is located in a topographic low.

2.3 BACKGROUND

2.3.1 Number, Type and Depth of Water Wells.

There are currently 2,244 water well records, for the County Area, in the Alberta Environment GIC database. The records indicated that 1,420 (63.2%) wells are used for domestic and stock purposes, 330 (14.7%) for industrial purposes, 15 (0.7%) for municipal purposes, 13 (0.6%) for irrigation purposes and 136 (6%) for investigations and monitoring purposes, while 332 (14.8%) did not indicate a specific use. It is unknown how many of these wells may still be active.

The depth of the wells vary from 1 m to 342 m for domestic, stock, municipal and irrigation wells, and the majority of industrial wells. Thirty-one industrial wells and 14 wells with unknown use have depths that range from 500 m to 1,270 m and these wells are believed to have been used for oil and gas explorations, as they extend well beyond the bottom of the Milk River Formation. Depths for investigation and monitoring wells are generally in the range of 5 to 140 m.

The majority of the wells had depths shallower than 100 m and did not show any trends with well depth across the County. Wells with depths between 100 m and 350 m showed a slight trend of being deeper toward the north. This trend is associated with wells completed into the Milk River Aquifer, which becomes deeper toward the north.

A total of 898 records had detailed geological information. Chemistry data was available for 584 wells. There were 41 records related to springs in the GIC database, however, there was no information on flow rates. Borneuf (1983) listed 14 springs within the County with 10 of them located in the southwestern part of the County[4] and 4 of them in the southern part[5,6]. According to Borneuf, flow rates for these springs were mostly in the order of 0.08 L/sec with two springs yielding 0.28 and 0.38 L/sec.

2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 1,970 water well records with sufficient information to define whether the wells are completed in the surficial deposits or bedrock. Of these, 605 wells are completed in surficial deposits, and 1,365 in bedrock.

Figure 2.3 shows that both surficial and bedrock wells are presented throughout the County area. Wells completed in surficial deposits are generally shallower than 20 m, as only 25% of these wells are completed at depths that range from 20 m to 61 m

[4] Townships 1 to 5, ranges 17 to 20.
[5] Townships 1 and 2, ranges 13 and 15.
[6] The springs listed by Borneuf (1983) were also included in the GIC database.

(maximum depth on record for surficial wells). Over 50% of surficial wells on record were constructed prior to 1950.

2.3.3 Drilling Methods, Casing Diameter and Type

Figure 2.4 shows the distribution of casing type for 1,120 water well records. Although 590 records have no indication of casing type, the majority of the wells appear to be constructed of steel. Steel is likely mostly used because the main aquifer, the Milk River, is quite deep. Plastic casings, which are relatively new material, have been used only for monitoring wells with diameter equal to, or smaller than, 50 mm, except for one well with a diameter of 140 mm that was used for domestic and stock purposes. It is worth noting that out of 590 records without a listed casing type, 187 were hand dug, and 371 were older than 1950[7].

Casing diameters on record range from 38 mm to 2,440 mm. Casing diameters greater than 275 mm accounted for 25% of the records, and were generally hand dug, or bored, wells. Casing diameters smaller than 275 mm accounted for 75% and were mostly drilled wells. Typical casing diameters were 152 mm (257 wells, mostly prior to 1950), 141 mm (154 wells, mostly post 1960) and 1,220 mm (157 wells, mostly prior to 1950). Many of old wells completed in the Milk River Aquifer are of small diameter (50 or 75 mm) which makes it difficult for sealing these wells.

Figure 2.5 shows the distribution of drilling methods used to install the wells. Hand dug methods account for 26% of the wells, while drilled methods account for 57% of the wells. All hand dug wells on record were installed prior to 1960. Drilling is currently the preferred method for water well installation in the County. Most hand dug and bored wells are completed in surficial deposits, while drilled wells are completed in bedrock. Screened wells represent a very small proportion of either surficial or bedrock wells. The majority of the wells have perforated casing.

Figure 2.6 shows the distribution of water wells by the reported year of installation. There were 1,555 of 2,244 records with completion date. Periods of high activity were notably 1910 to 1930 and 1970 to 1990. Agra E&E (1998) reported that several wells were drilled in the late 1980’s under the Alberta Government drought assistance program. It is possible that installation of water supply pipelines from the mid 1980’s to early 1990’s may have contributed to the general decline of new water wells in the 1990’s. Another possibility for this decline is that the GIC database may not have been fully updated with all water well records that were submitted to AENV in the late 1990’s.

[7] Only 466 records out of 590 had data for completion date. Therefore, 371 of the 466 records (80%) were older than 1950.

2.3.4 Licensed Water Wells

According to current legislation[8], approvals are not required for water wells which supply less than 1,250 m^3/year of groundwater for household[9] use. Wells which supply in excess of 1,250 m^3/year for household use, or wells supplying groundwater for any other use (e.g., agricultural, municipal, commercial, industrial, recreational) will generally require a license or approval[10].

At the end of 2000, there were 35 groundwater allocations[11] within the County and 28 of these could be linked to the Alberta Environment database. The total maximum authorized diversion associated with these allocations was 877,645 m^3/year, although actual usage could be less. Licensed allocations included agricultural (25.1%), commercial (0.1%), industrial (4.2%), municipal (69.2%) and recreational (1.4%). Table 2.1 shows the distribution of the allocations by use and aquifer.

Table 2.1 Maximum Annual Groundwater Allocations for Licensed Wells (m^3)

Formation	No. of Allocations	Agricultural	Commercial	Industrial	Municipal	Recreational	Total
Surficial Deposits	17	163,430			573,590	12,330	**749,350**
Oldman	3	22,810					**22,810**
Foremost	3		860		10,610		**11,470**
Milk River	11	33,900			23,115		**57,015**
Manville (?)	1			37,000			**37,000**
Total	**35**	**220,140**	**860**	**37,000**	**607,315**	**12,330**	**877,645**

1. Allocation amounts from Alberta Environment
2. Identification of formation by Stantec

The surficial deposits provide groundwater for the majority of the allocations (85%), followed by the Milk River Aquifer (6.5%), the Oldman Formation (2.6%) and the Foremost Formation (1.3%). The Alberta Environment records showed a license for a deep well (850 m) which is probably completed into the Manville Formation. Groundwater from the Manville Formation is not considered usable groundwater[12].

The largest license allocations are for municipal use: one for the Milk River East group of wells (175,020 m^3/year) and another for the Milk River West/Warner West group of wells (382,400 m^3/year).

[8] *Water Act*, S.A. 1996, c. W-3.5 and *Water (Ministerial) Regulations* A.R. 205/98 (proclaimed in force January 1, 1999).
[9] Household means one or more individuals living in a single, private and detached dwelling place.
[10] Use of groundwater with concentration of total dissolved solids exceeding 4,000 mg/L does not require a licensel. Other exemptions may apply.
[11] There are 25 licenses. Each license may specify more than one allocation for different water uses.
[12] Groundwater with less than 4,000 mg/L of total dissolved solids is considered *usable* groundwater by Alberta Environment.

If the total licensed allocation of 877,645 m^3 per year were fully utilized it would correspond to an average usage of 2,405 m^3 per day (367 igpm).

2.3.5 Base of Groundwater Protection

Base of Groundwater Protection, as defined by Alberta Environment , is the elevation below which groundwater would be expected to have more than 4,000 mg/L of total dissolved solids. Groundwater with less than 4,000 mg/L of total dissolved solids are considered *usable groundwater*. Alberta Environment does not investigate usable groundwater below a depth of 600 m from ground level (EUB, 1995).

In the context of water wells, the Base of Groundwater Protection represents the likely maximum depth of drilling at any location, as groundwater below that depth is expected to be very poor (TDS > 4,000 mg/L). Drilling beyond that depth for the purposes of completing a water well is not recommended.

Elevations of the Base of Groundwater Protection are provided by the Alberta Energy and Utilities Board (EUB). The deepest formation with usable groundwater is the Milk River Formation for most of the County, and the Belly River Formation[13] in the western portion of the County. Reference well data are available for most of the townships north of township 003, however, there is a lack of references wells in the southeastern area of the County.

Based on the elevation of the Base of Groundwater Protection provided by the EUB and ground elevations, a depth to the Base of Groundwater Protection was calculated. These data were contoured and are presented in Figure 2.8. In the central and northern area of the County, the depth to the Base of Groundwater Protection ranges from 140 m below ground level (BGL) to slightly over 400 m BGL. In the southeastern portion of the County, where there are no reference wells, the Base of Groundwater Protection would be 15 m below the base of the Milk River Formation.

Figure 2.9 shows the Depth to the Base of Groundwater Protection derived by incorporating the EUB data, where they are available, with the interpreted base of the Milk River Aquifer for the southeastern portion of the County. This modified Depth to the Base of Groundwater Protection is also indicated in the geological cross sections (refer to Figures 4.3 and 4.4 and CDROM). Based on Figure 2.9, the depth to the Base of Groundwater Protection would range from 80 m BGL to 410 m BGL.

Of the 2,064 water wells with completed depth data, there were 132 records where the well depths were greater than the depth to the Base of Groundwater Protection, as interpolated from Figure 2.9. Forty-five were for oil/gas investigations, 43 were for industrial purposes[14], and the remaining 44 were completed in the Milk River Aqui

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[13] Includes Oldman and Foremost Formations
[14] These records did not have lithologic logs and a formation could not be assigned to them.

fer[15]. For these wells completed into the Milk River Aquifer, the differences in depths are mostly attributed to inaccurate ground elevations associated with the water wells[16] and also to the fact that several wells are drilled into the shales of the Colorado Group to confirm the end of the Milk River Formation. The shales of the Colorado Group have no groundwater supply potential.

Six wells[17], used for domestic and/or stock purposes, had completion depths significantly below the Base of Groundwater Protection. Since these wells are completed into the Milk River Formation, because of their location and depth, it is possible that the water well records have an incorrect location. The available completion data for these wells do not seem to match the geology in the vicinity of the well.

2.3.6 Groundwater Level Data

Continuous water level measurements are available for 8 observation wells operated by Alberta Environment and 6 observation wells in the Whiskey Valley. Of the 8 Alberta Environment observation wells, 4 are near Milk River (3 in surficial deposits and 1 in Milk River Aquifer), 2 are near Warner (in Foremost Formation), and 2 are immediately east of the County area (in Milk River Aquifer). A summary of the observation wells is presented in Table 5.1 in Section 5. Non-pumping water levels are also discussed in Section 5.

2.3.7 Groundwater Chemistry

The groundwater quality in both the surficial deposits and bedrock aquifers is quite variable. Groundwater from the surficial deposits is expected to be hard to very hard[18] and have total dissolved solids higher than 700 mg/L. Bedrock groundwater, on the other hand, is moderately soft, but is more mineralized with total dissolved solids expected to be generally higher than 1,450 mg/L. Softer groundwater is generally present in the Milk River Aquifer.

Tables 2.2 and 2.3 present a summary of groundwater chemistry for surficial deposits and bedrock aquifers. The *Guidelines for Canadian Drinking Water Quality - GCDWQ* (Health Canada, 1996) have also been included. In groundwater from the surficial deposits, sulphate and sodium concentrations were generally higher than the *Guidelines* in 50% of the cases. Concentrations of total dissolved solids (TDS) exceeded the *Guidelines* in the majority of the cases.

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15 These records were deemed to be completed in the Milk River Aquifer based on their completion interval, depth, available lithologic logs and additional information.
16 The GIC database locates the wells in the center of the quarter-sections or LSD, as discussed in section 3.1.
17 The WELLID's for these wells are:164388, 165635, 165795, 165796, 196222, 196406, 202655, and 221013.
18 Degrees of Hardness are as follows: very soft (0-30), soft (30-60), moderately soft (60-120), hard (120-180) and very hard (>180)

Table 2.2 Summary of Groundwater Chemistry: Surficial Deposits

Parameter	Minimum	Maximum	25%-tile	50%-tile	75%-tile	90%-tile	GCDWQ
Hardness	10	4,750	219	450	873	1,411	
TDS	86	16,800	704	1,317	2,631	4,196	500 AO[19]
Sulphate	2.2	11,280	137	450	1,207	2,116	500 AO
Chloride	2	631	9	20	63	148	250 AO
Fluoride	0.05	6.1	0.18	0.27	0.43	0.67	1.5 MAC[20]
Nitrate+Nitrate-N	0.05	126	0.5	2.3	10.5	39	10 MAC
Sodium	3	3,609	59	209	525	825	200 AO

• Units are mg/L. Hardness expressed as $CaCO_3$
• %-tile - percentile

Table 2.3 Summary of Groundwater Chemistry: Bedrock Formations

Parameter	Minimum	Maximum	25%-tile	50%-tile	75%-tile	90%-tile	GCDWQ
Hardness	1	6,400	24	82.5	348	889	
TDS	2	22,668	1,444	2,128	2,970	4,726	500 AO
Sulphate	1	12,240	143	502	1,124	2,280	500 AO
Chloride	1	2,516	22	57	132	442	250 AO
Fluoride	0.08	10.4	0.35	0.66	1.44	2.84	1.5 MAC
Nitrate+Nitrate-N	0.05	1,089	0.5	1.40	5.55	22.2	10 MAC
Sodium	4.6	5,356	447	680	916	1,318	200 AO

• Units are mg/L. Hardness expressed as $CaCO_3$
• %-tile - percentile

In bedrock aquifers, concentrations of total dissolved solids and sodium are higher than the *Guidelines* in the majority of the cases, while sulphate is higher than the *Guidelines* in 50% of the cases. Fluoride concentrations are higher in bedrock aquifers than in the surficial deposits, with a large proportion of the elevated values occurring in the Milk River Aquifer.

[19] Asthetic Objectives (AO) are provided for parameters that, although they pose no adverse effects to human health, could impart the appearance or palatability of the water. For example, sodium is an important element for the body functions and the body has very effective methods to control the levels of sodium. At sodium concentrations of 175 to 185 mg/L, the taste of drinking water becomes offensive (Health Canada, 1996).

[20] Maximum Acceptable Concentrations (MAC) have been established for certain substances that are known or suspected to cause adverse effects on health. Each MAC was derived to safeguard health assuming lifelong consumption of drinking water containing the substance at that concentration (Health Canada, 1996).

Nitrate plus nitrite concentrations were lower than the *Guidelines* in 75% of the cases for both surficial deposits and bedrock aquifers. There are, however, several cases with high nitrates, which reached a maximum of 126 mg/L-N in the surficial deposits and 1,089 mg/L-N in bedrock (Foremost Formation).

It is important to note that the GIC records provide little information on how the samples were taken and how representative of actual aquifer conditions they would be (for example, some samples may have been collected after treatment). Additional water quality data would be available from the local Health Unit but could not be assessed because of client confidentiality.

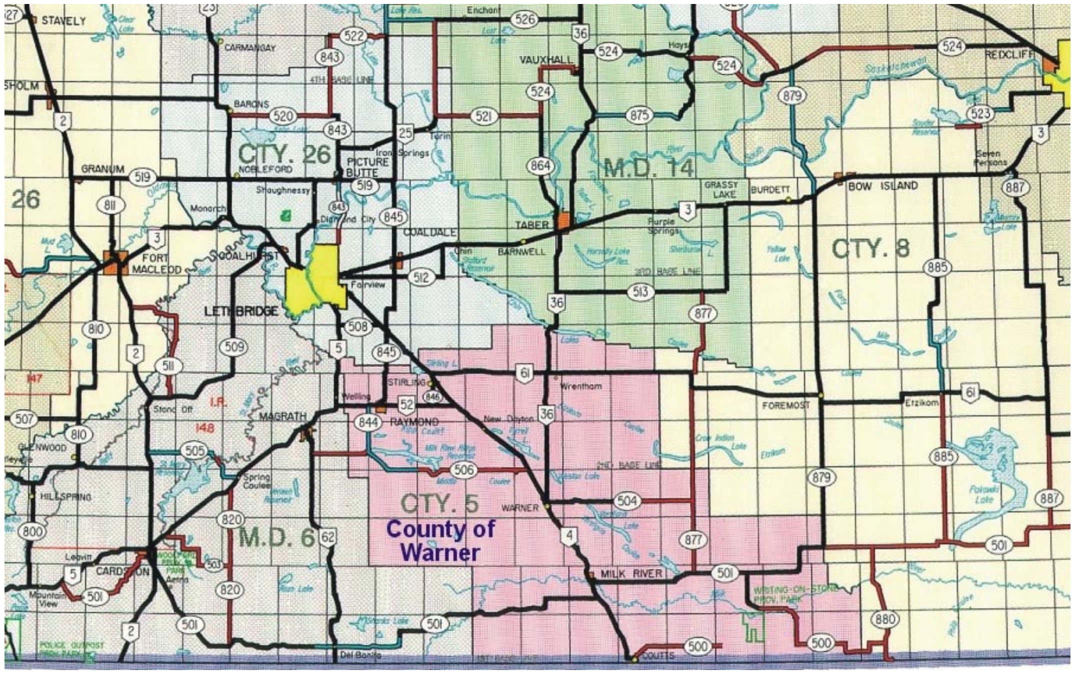
Note:

Tables 2.2 and 2.3 make use of the percentile concept to convey information about the frequency and relative distribution of a particular chemical parameter.

For example, TDS concentrations in groundwater from surficial deposits (Table 2.2) range from 86 to 16,800 mg/L. However, the column labeled 90%-tile (90 percentile) indicates that 90% of the records had TDS concentration lower than 4,196 mg/L. In other words, groundwater with TDS concentrations exceeding 4,196 mg/L represented only 10% of the number of records.

Likewise, in 50% of the cases, groundwater from surficial deposits had TDS concentrations lower than 1,317 mg/L (as indicated in the column labeled 50%-tile), and in 75% of the cases, TDS concentrations were lower that 2,631 mg/L. Only 25% of the records indicated groundwater with TDS concentrations lower than 704 mg/L.

Figure 2.1a Site Location



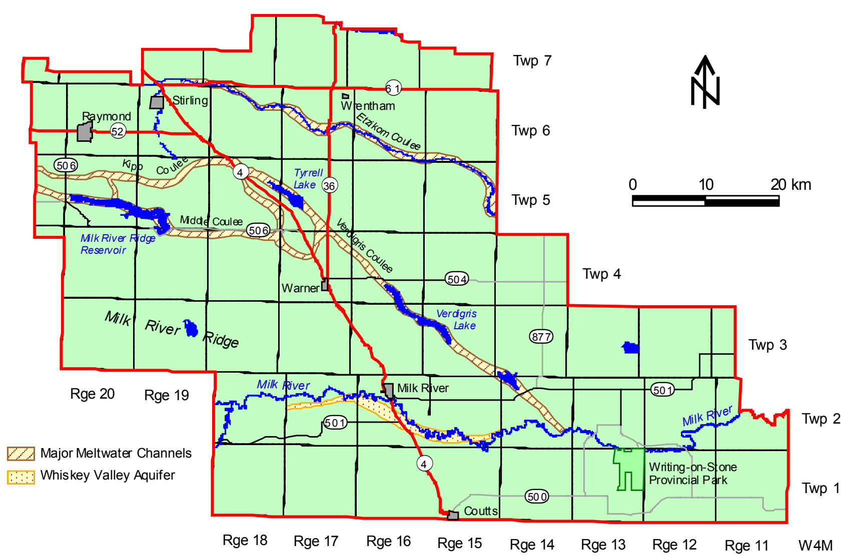


Figure 2.1b County of Warner No. 5

Figure 2.2 Surface Topography

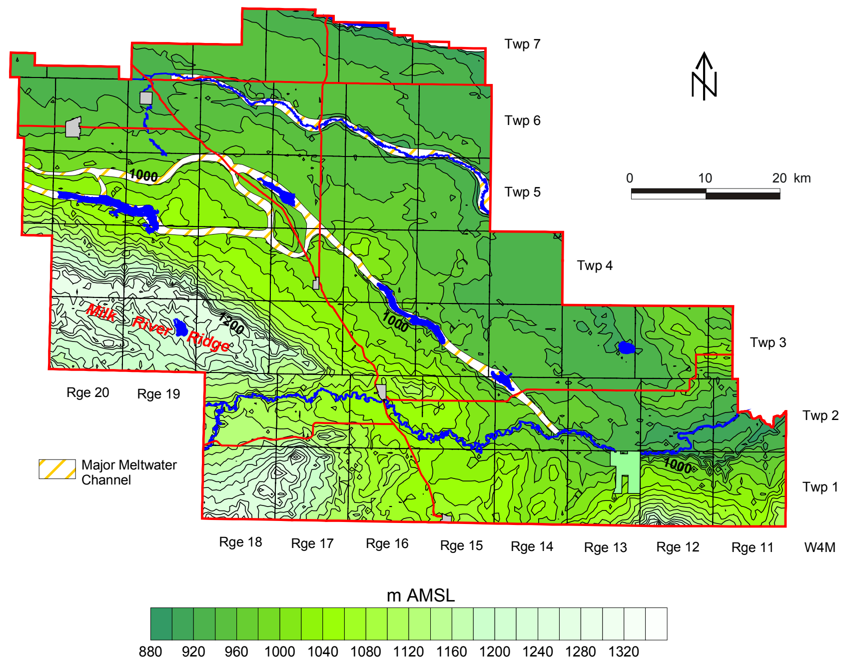
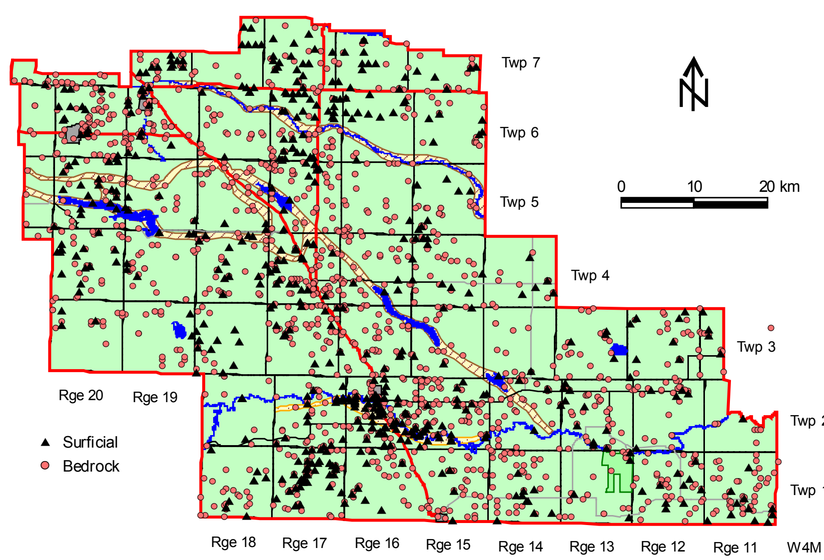


Figure 2.3 Location of Water Wells



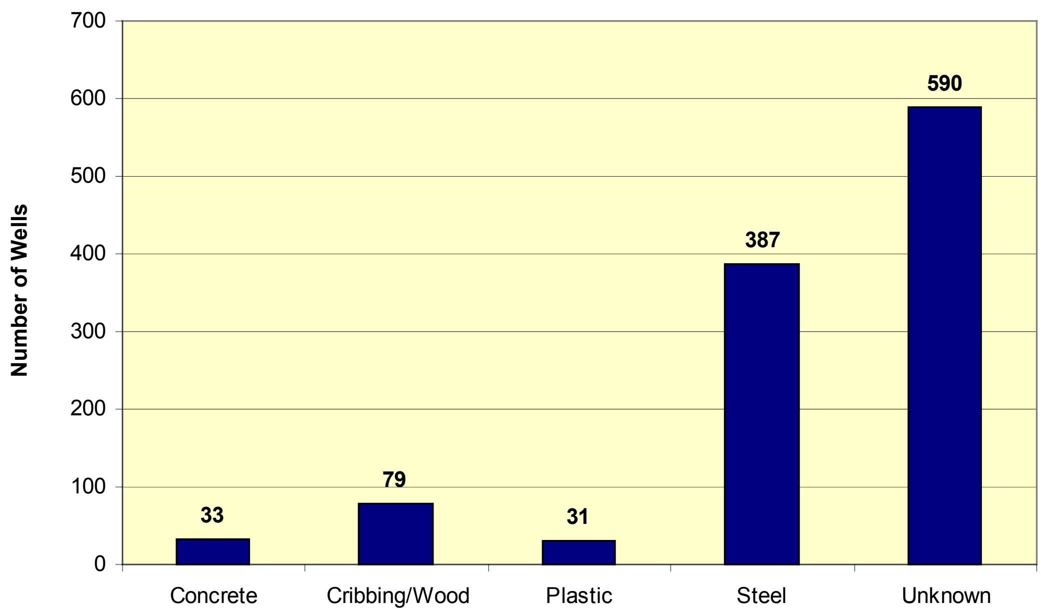


Figure 2.4 Surface Casing Types for Water Wells

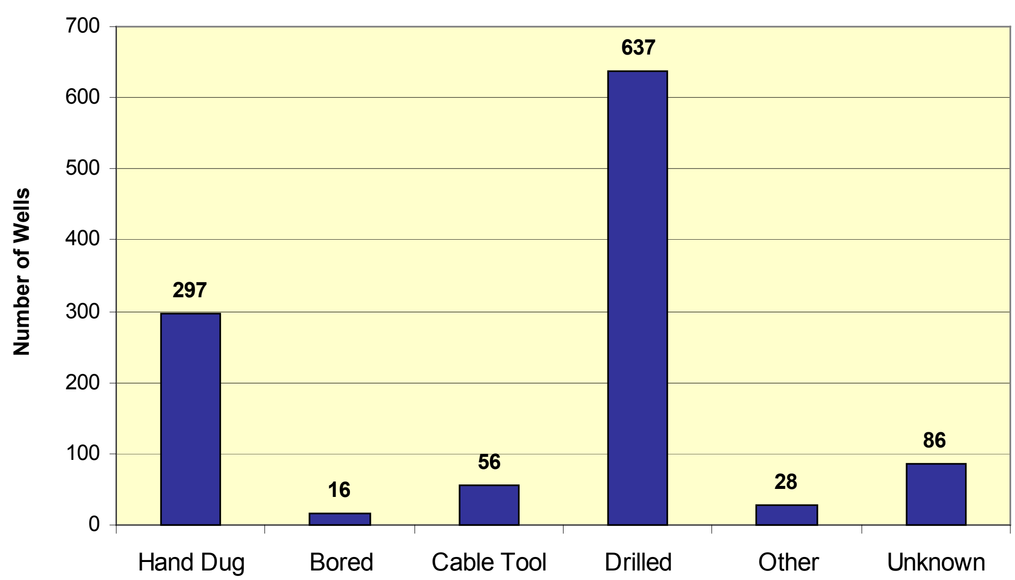


Figure 2.5 Drilling Methods for Water Wells

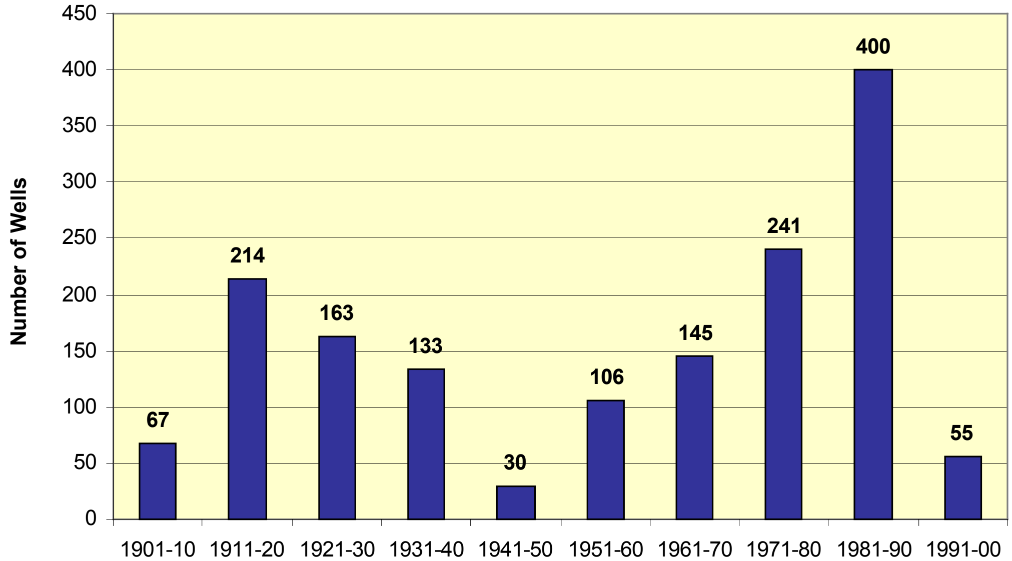


Figure 2.6 Year Water Wells Were Completed

Figure 2.7 Location of Licensed Water Wells

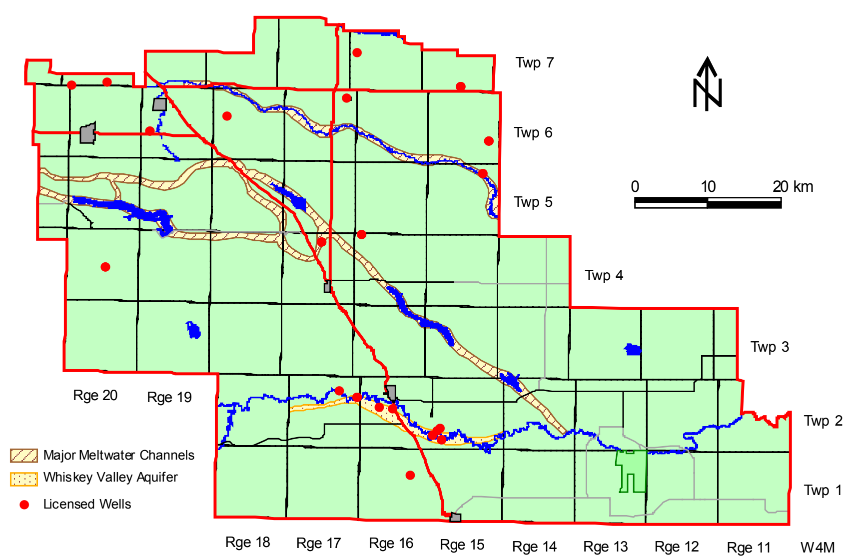


Figure 2.8 Depth to Base of Groundwater Protection (after EUB, 1995)

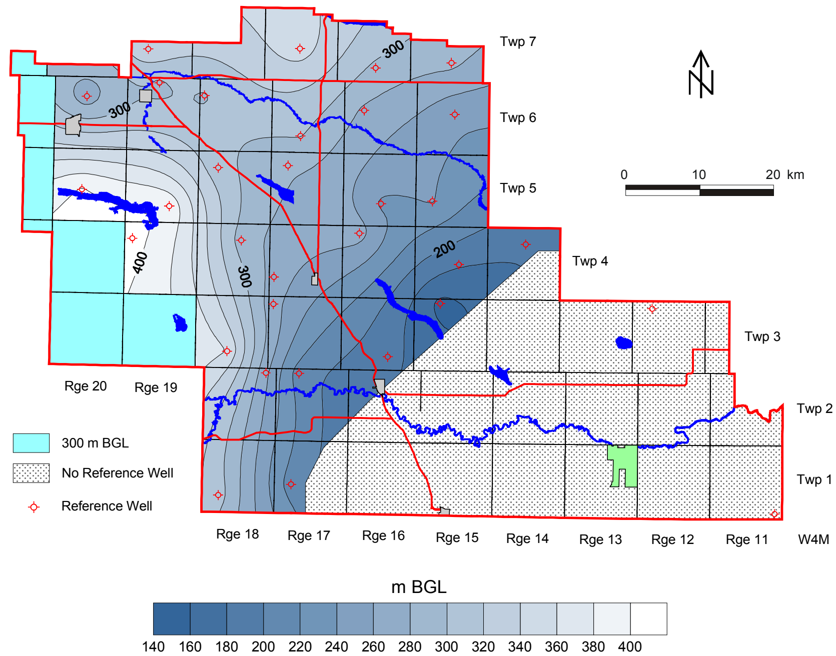
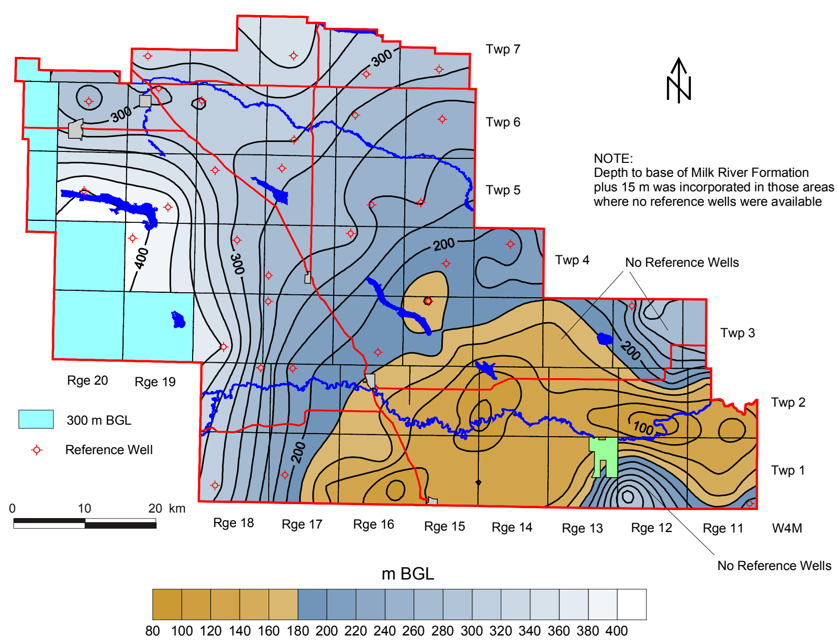


Figure 2.9 Depth to Base of Groundwater Protection (mod. after EUB, 1995) Incorporates Base of Milk River Formation



3.0 Methodology

3.1 DATA COLLECTION AND SYNTHESIS

The main source of data for the groundwater study is the Alberta Environment Groundwater Information Centre (GIC) database. This database contains a variety of information, including:

- Water well drilling reports (e.g., water wells, test holes, observation wells)
- Aquifer test results for some water wells
- Locations of some springs
- Water well locations determined during water well surveys
- Chemical analyses for some water wells
- Location of flowing shot holes
- Location of structure test holes

The GIC database contains two main drawbacks: the absence of quality control and the lack of adequate spatial information. There is not much that can be done about the lack of quality control, except to compare the data to other data deemed to have higher reliability and correct for obvious errors.

In terms of spatial information, a water well record location in the GIC database is generally assigned to the centre of either a quarter section or a Legal Subdivision (LSD). This well location system may lead to a common situation where several well records exist for the same location, although the wells are not physically present at the same location. In these situations, the deepest well record with lithologic information was generally used in the geological interpretation.

In other situations where the topography changes considerably, difficulties in the geological interpretation may arise due to elevation errors. PFRA has re-positioned 623 water wells by geo-corrected orthophoto-mosaics survey and these improved locations were incorporated into the database. Additional data from a Milk River Aquifer well owner survey funded by PFRA and Alberta Environment have provided improved spatial location the wells by the geographic positioning system (GPS). Eighty-nine wells in the County have GPS data and the spatial coordinates were incorporated into the database.

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Ground elevations were obtained from the 1:20,000 Digital Elevation Model (DEM) provided by Altalis via third party license with PFRA. Ground elevations obtained using the GPS survey were not utilized in this study as it was found that the GPS eleva tion data differed considerably from the DEM data, in some cases by more than 20 m.

Where data are available, the following information may be obtained for individual well records:

- Depth to top and bottom of completion interval
- Depth to bedrock
- Thickness of sand and gravel units
- Apparent transmissivity and apparent yield
- Aquifer transmissivity and storativity

The EUB well database includes records for all wells drilled by the oil and gas industry. Information provided by this database include:

- Location of well
- Depth to top of geological units
- Type and intervals for various down-hole geophysical logs
- Drill stem test (DST) summaries

Additional information was obtained from published reports and maps, and is included in the reference section of this report. The Geological Atlas of the Western Sedimentary Basin (Mossop and Shetsen, 1994), contained information on structure elevations and thickness for various geological units in a digital format[21].

The GIS-ready database files and maps were prepared using 1:20,000 base maps geo-referenced to geographic coordinates (latitude and longitude, NAD83). Maps in the report and CDROM are shown in the Universal Transverse Mercator (UTM) projection (NAD83) for Zone 12.

3.2 MAPPING OF AQUIFERS AND FORMATIONS

The geological mapping of aquifers and formations in the County area was based primarily on the following information:

- Lithologs provided by the water well records.
- Data for structure elevation and thickness of formations provided by the Geological Atlas of the Western Sedimentary Basin (Mossop and Shetsen, 1994).
- Data from existing cross-sections (Tokarsky, 1986; Borneuf, 1976; Tokarsky, 1978).

[21] This information is available online at www.ags.gov.ab.ca/AGS_PUB/

The data from the Geological Atlas of the Western Sedimentary Basin provided the basic framework for the definition of the geological formations (refer to Figure 4.1). There were 60 control points with data for the top of the Colorado Group (First White Speckled Shale), 88 for the top of the Milk River Formation and 67 for the top of the Pakowki Formation, within the area defined by townships 001 to 008 and ranges 10 to 22, W4M. These data sets were contoured using the Kriging[22] method to provide the general trend of the geological units. Fourteen cross-sections in an east-west direction and 18 cross-sections in a north-south direction were then prepared to define the top and bottoms of individual geologic units. These cross-sections incorporated available lithology from the water well records and published information such as the Alberta Geological Map (Hamilton et al., 1999).

The final definition of the geological surfaces is an iterative procedure that involved the plotting of the geological surfaces on the cross-sections and the cross-reference with the other cross-sections. The intersections of those NS and EW cross-sections provided the additional control points that were used in the final contour of the surfaces.

The top of each geological unit defined at control points was gridded using the Kriging method and incorporated known boundaries, i.e., top of bedrock, where the unit outcropped. The thickness of each geological unit was also defined at each control point and was then gridded using the Kriging method to generate a contour surface.

Selected cross-sections were finalized for presentation by transferring the data, i.e., ground elevation, top of bedrock, top of formations, well location and completion intervals, and non-pumping water levels, into AutoCad where the data was properly scaled, by applying a vertical exaggeration of 30X, and drawing details were incorporated. The final steps in the cross-section preparation were done with CorelDRAW! which provides a better control for colors and other details in a graphic environment.

3.3 MAPPING OF HYDROGEOLOGICAL PARAMETERS

Water well records that had data on completion, i.e., perforated or screened interval, were compared to the geological surfaces to determine the aquifer/formation in which the well was completed. Only 364 out of 2,244 well records had completion information (i.e, perforation or screen interval). The remainder of the well records that had depth information were assigned to an aquifer/formation based exclusively on the completion depth. In this way, a well record was said to be completed into a particular aquifer/formation if the bottom of the well was within that aquifer/formation interval. This procedure was justified based on the fact that individual aquifers in the Oldman

[22] Kriging is an optimal estimation method that applies to uneven sets, provides statistical inferences on the trends of data set and is an exact interpolator.

and Foremost Formations are difficult to correlate and water wells are generally exposed to several water bearing units within a formation.

After water well records were assigned to specific aquifers/formations, the available data associated with each water well record are assigned to the individual aquifer/formation. These data include: non-pumping water levels, apparent yield, and chemical parameters. Chemical parameters of interest included total dissolved solids, total hardness, sulphate, chloride, fluoride and sodium. Chemical data for a well was averaged when more than one set of analyses was available for the well.

It is important to note that the set of hydrogeological data available for the County of Warner is small and is not evenly distributed on a spatial basis. In a few instances, e.g. apparent transmissivity and apparent yield, contouring of the data was not feasible because of the small number of data points available for each individual formation or aquifer. Another difficulty of small data sets is that few “extreme” values in the data can bias the contours toward this extreme values, suggesting that elevated parameters are present over a larger area than the actual area.

The spatial distribution for these parameters was determined in a similar way as for the geological units. The data was gridded using the Kriging method and contoured. Areas with no data were blanked out. Extreme values of chemical parameters were flagged and removed from the gridding process, as these values were usually singular and did not reflect the regional trend. All data points used in the gridding process were included in the contour maps as black triangles. The data points with extreme values, although not included in the contouring process, were displayed in the contour maps as red circles, for completeness. Whenever two or more data points had the same location, they were averaged to provide one value per location.

In the cases where contouring was not possible, the data was displayed through classed symbols to differentiate the ranges of the data that will be usable to different types of end users.

3.4 SOFTWARE

This report and the files included on the CD-ROM have been generated using the following software:

- Acrobat 4.05
- ArcView 3.2
- AutoCad 14.0
- CorelDRAW 8.0
- Microsoft Office 97
- Surfer 7.0