County of Two Hills No. 21

Part of the North Saskatchewan River Basin
Parts of Tp 052 to 057, R 06 to 15, W4M
Regional Groundwater Assessment

Prepared for

In conjunction with

Agriculture and Agri-Food Canada	Agriculture et Agroalimentaire Canada
Prairie Farm Rehabilitation Administration	Administration du rétablisseme agricole des Prairies

Prepared by
hydrogeological consultants ltd.
1-800-661-7972
Our File No.: **97-101**

October 1998
(Revised November 1999)

PERMIT TO PRACTICE
HYDROGEOLOGICAL CONSULTANTS LTD.

Signature ______________________________

Date ______________________________

PERMIT NUMBER: P 385

The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

1 PROJECT OVERVIEW

"Water is the lifeblood of the earth." - Anonymous

How a County takes care of one of its most precious resources - groundwater - reflects the future wealth and health of its people. Good environmental practices are not an accident. They must include genuine foresight with knowledgeable planning. Implementation of strong practices not only commits to a better quality of life for future generations, but also creates a solid base for increased economic activity. **This report, even though it is regional in nature, is the first step in fulfilling a commitment by the County of Two Hills No. 21 toward the management of the groundwater resource, which is a key component of the well-being of the County, and is a guide for future groundwater-related projects.**

1.1 About This Report

This report provides an overview of (a) the groundwater resources of the County of Two Hills No. 21, (b) the processes used for the present project and (c) the groundwater characteristics in the County.

Additional technical details are available from files on the CD-ROM provided with this report. The files include the geo-referenced electronic groundwater database, maps showing distribution of various hydrogeological parameters, the groundwater query, and ArcView files. Likewise, all of the illustrations and maps from the present report, plus additional maps, figures and cross-sections, are available on the CD-ROM. For convenience, poster-size maps and cross-sections have been prepared as a visual summary of the results presented in this report. Copies of these poster-size drawings have been forwarded with this report, and are included in Appendix D.

Appendix A features page-size copies of the figures within the report plus additional maps and cross-sections. An index of the page-size maps and figures is given at the beginning of Appendix A.

Appendix B provides a complete list of maps and figures included on the CD-ROM.

Appendix C includes the following:

1) a procedure for conducting aquifer tests with water wells;
2) a table of contents for the Water Well Regulation under the Environmental Protection and Enhancement Act; and
3) additional information.

The Water Well Regulation deals with the wellhead completion requirement (no more water-well pits), the proper procedure for abandoning unused water wells and the correct procedure for installing a pump in a water well.

1.2 The Project

It must be noted that the present project is a regional study and as such the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at given locations.

The present project is made up of five parts as follows:

Module 1 - Data Collection and Synthesis
Module 2 - Hydrogeological Maps
Module 3 - Covering Report
Module 4 - Groundwater Query
Module 5 - Training Session

This report and the accompanying maps represent Modules 2 and 3.

1.3 Purpose

This project is a regional groundwater assessment of the County of Two Hills No. 21. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the County.**

The regional groundwater assessment includes:

- identification of the aquifers[1] within the surficial deposits[2] and the upper bedrock;
- spatial definition of the main aquifers;
- quantity and quality of the groundwater associated with each aquifer;
- hydraulic relationship between aquifers; and
- identification of the first sand and gravel deposits below ground level.

Under the present program, the groundwater-related data for the County have been assembled. Where practical, the data have been digitized. These data are then being used in the regional groundwater assessment for the County.

[1] See glossary
[2] See glossary

2 INTRODUCTION

2.1 Setting

The County of Two Hills No. 21 is situated in east-central Alberta. This area is part of the Alberta Plains region. The County exists within the North Saskatchewan River basin. The Vermilion River flows in the south-central part of the County. Part of the northern boundary of the County is the North Saskatchewan River. The other boundaries follow township or section lines. The area includes some or all of townships 052 to 057, ranges 06 to 15, west of the 4th Meridian.

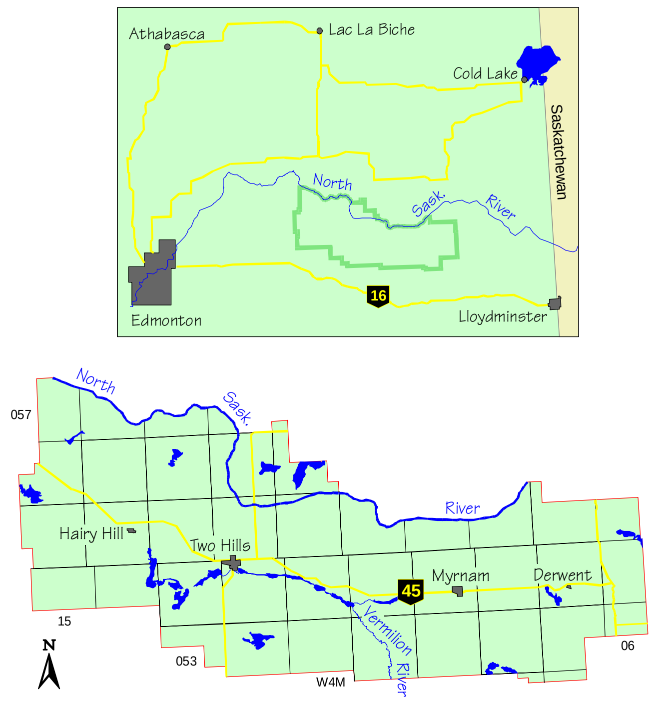


Figure 1. Index Map

Regionally, the ground elevation varies between 530 and 740 metres above mean sea level (AMSL), with the lowest elevation occurring in the North Saskatchewan River Valley.

2.2 Climate

The County lies within the transition zone between a humid, continental Dfb climate and a semiarid Bsk climate. This classification is based on potential evapotranspiration values determined using the Thornthwaite method (Thornthwaite and Mather, 1957), combined with the distribution of natural ecoregions in the area. The ecoregions map (Strong and Legatt, 1981) shows that the County is located in the Aspen Parkland region, a transition between boreal forest and grassland environments.

A Dfb climate consists of long, cool summers and severe winters. The mean monthly temperature drops below –3 °C in the coolest month, and exceeds 10 °C in the warmest month. A Bsk climate is characterized by its moisture deficiency, where mean annual potential evapotranspiration exceeds the mean annual precipitation.

The mean annual precipitation averaged from four meteorological stations within the County measured 414 millimetres (mm), based on data from 1961 to 1993. The mean annual temperature averaged 2.0 °C, with the mean monthly temperature reaching a high of 16.5 °C in July, and dropping to a low of -15.3 °C in January. The calculated annual potential evapotranspiration is 521 millimetres.

2.3 Background Information

There are currently records for 3,629 water wells in the groundwater database for the County. Of the 3,629 water wells, 2,036 are for domestic/stock purposes. The remaining 1,593 water wells were completed for a variety of uses, including municipal, industrial and observation purposes. Based on a rural and hamlet population of 2,753, there are three domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from less than two metres to 366 metres below ground level. Lithologic details are available for 1,723 water wells.

Data for casing diameters are available for 1,524 water wells, with 591 having a diameter of more than 330 mm and 933 having a diameter of less than 220 mm. The casing diameters of greater than 330 mm are mainly bored water wells and those with casing diameters of less than 220 mm are drilled water wells.

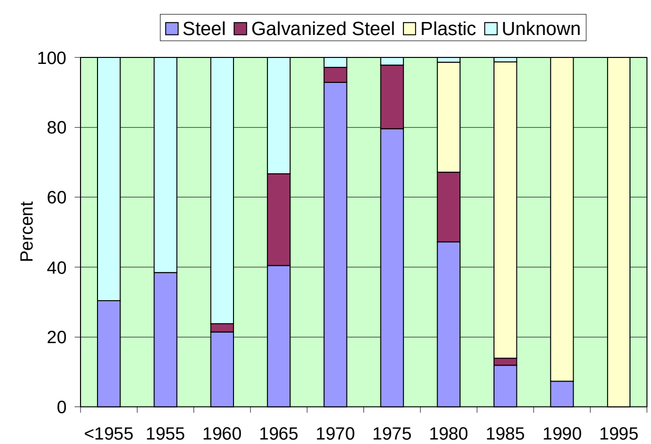


Figure 2. Surface Casing Types used in Drilled Water Wells

Steel, plastic and galvanized steel represent 99% of the materials that have been used for surface casing over the last 40 years in water wells completed in the County. From before 1955 to the mid-1960s, the surface casing used was unknown in the majority of the water wells drilled. Steel casing was in use in the 1950s and in 93% of the water wells being drilled in the early 1970s. From the early 1970s to the 1990s, the use of steel casing has declined. Galvanized steel surface casing was used in 2% of the new water wells in the early 1960s. By the mid-1960s, galvanized steel casing was being used in 26% of the water wells, more than at any other time. The last reported use of galvanized steel was in August 1988. Plastic casing was used for the first time in August 1980. The percentage of water wells with plastic casing has increased and in the mid-1990s, plastic casing was used in 93% of the water wells drilled in the County.

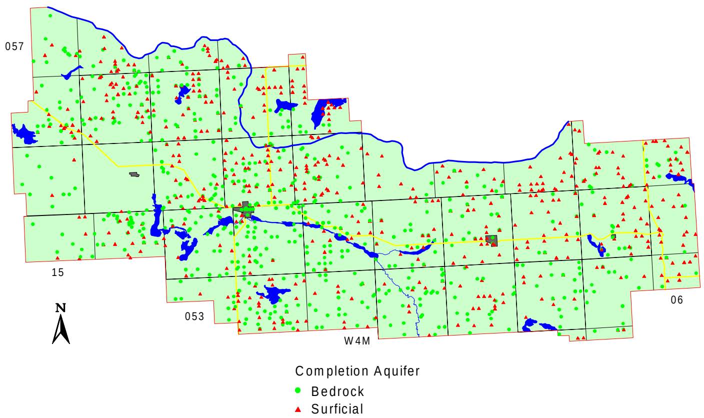


Figure 3. Location of Water Wells

There are 1,347 water well records with sufficient information to identify the aquifers in which the water wells are completed. The water wells that were not drilled deep enough to encounter the bedrock, plus water wells that have the bottom of their completion interval above the bedrock surface, are water wells completed in surficial aquifers. The number of water wells completed in aquifers in the surficial deposits is 655. The adjacent map shows that these water wells occur over most of the County. Approximately 80% of the water wells completed in the surficial aquifers have a completion depth of less than 40 metres and 20% have a completion depth of more than 40 metres. The remaining 692 water wells have the top of their completion interval deeper than the depth to the bedrock surface. From Figure 3, it can be seen that water wells completed in bedrock aquifers occur over most of the County.

Although there are 120 water wells located in township 055, range 14, W4M, sufficient information to identify the completion aquifers was not available.

Water wells not used for domestic needs must be licensed. At the end of 1996, 79 groundwater diversions were licensed in the County. The total maximum authorized diversion from these 79 water wells is 2,450 cubic metres per day (m³/day); 38% of the authorized groundwater diversion is allotted for agricultural use. The largest licensed groundwater diversion within the County, of 274 m³/day, is for the Two Hills Lions Club in 01-31-054-12 W4M. This water supply well is completed at a depth of 24.99 metres below ground surface in the Lower Sand and Gravel Aquifer.

The adjacent table shows a breakdown of the 79 licensed groundwater diversions by the aquifer in which the water well is completed. The highest diversions are for licensed water wells completed in the Milan Aquifer, of which most of the groundwater is used for agricultural purposes, and the Lower Sand and Gravel Aquifer. The majority of the licensed water wells completed in the Lower Sand and Gravel Aquifer are used for municipal purposes. There is only one water well in the County that has been licensed for industrial purposes and the licensed diversion is 3 m³/day. A detailed discussion of the individual aquifers can be found later in this report.

Aquifer	Licensed Groundwater Diversions (m³/day) Agricultural	Industrial	Municipal	Other	Total
Upper Sand and Gravel	0	0	0	0	0
Lower Sand and Gravel	44	0	456	274	774
continental Foremost	129	0	21	0	150
Milan	650	0	142	0	792
marine Foremost	14	3	0	0	17
Ribstone Creek	36	0	115	0	151
Victoria	52	0	514	0	566
Total	925	3	1,248	274	2,450

Table 1. Licensed Groundwater Diversions

At many locations within the County, more than one water well is completed at one legal location. Digitally processing this information is difficult. To obtain a better understanding of the completed depths of water wells, a digital surface was prepared representing the minimum depth for water wells and a second digital surface was prepared for the maximum depth. Both of these surfaces are used in the groundwater query on the CD-ROM. When the maximum and minimum water well depths are similar, there is only one aquifer that is being used. The areas where the greatest differences between the minimum and maximum depth occur most often are where water wells completed in aquifers in the surficial deposits are most common.

Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. The total dissolved solids (TDS) concentrations in the groundwaters from the upper bedrock in the County are generally less than 1,000 milligrams per litre (mg/L). Groundwaters from the bedrock aquifers frequently are chemically soft with generally low concentrations of dissolved iron. The chemically soft groundwater is high in sodium concentration. Approximately 3% of the chemical analyses indicate a fluoride concentration above 1.0 mg/L.

Alberta Environmental Protection (AEP) defines the Base of Groundwater Protection as the elevation below which the groundwater is expected to have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, the bedrock surface and the Base of Groundwater Protection, a depth to the Base of Groundwater Protection can be determined. This depth would be for the most part the maximum drilling depth for a water supply well. Over approximately 15% of the County, the depth to the Base of Groundwater Protection is more than 150 metres. There is also approximately 15% of the County where the depth to the Base of Groundwater Protection is less than 50 metres.

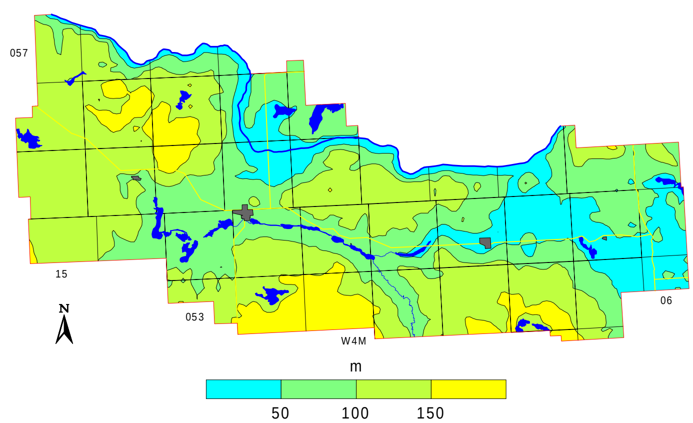


Figure 4. Depth to Base of Groundwater Protection

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, data are available from four AEP-operated observation water wells within the County. Additional data can be obtained from some of the licensed groundwater diversions. In the past, these data have been difficult to obtain from AEP, in part because of the failure of the licensee to provide the data.

However, even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget. The most cost-efficient method to collect additional groundwater monitoring data would be to have the water well owners measuring the water level in their own water well on a regular basis.

3 TERMS

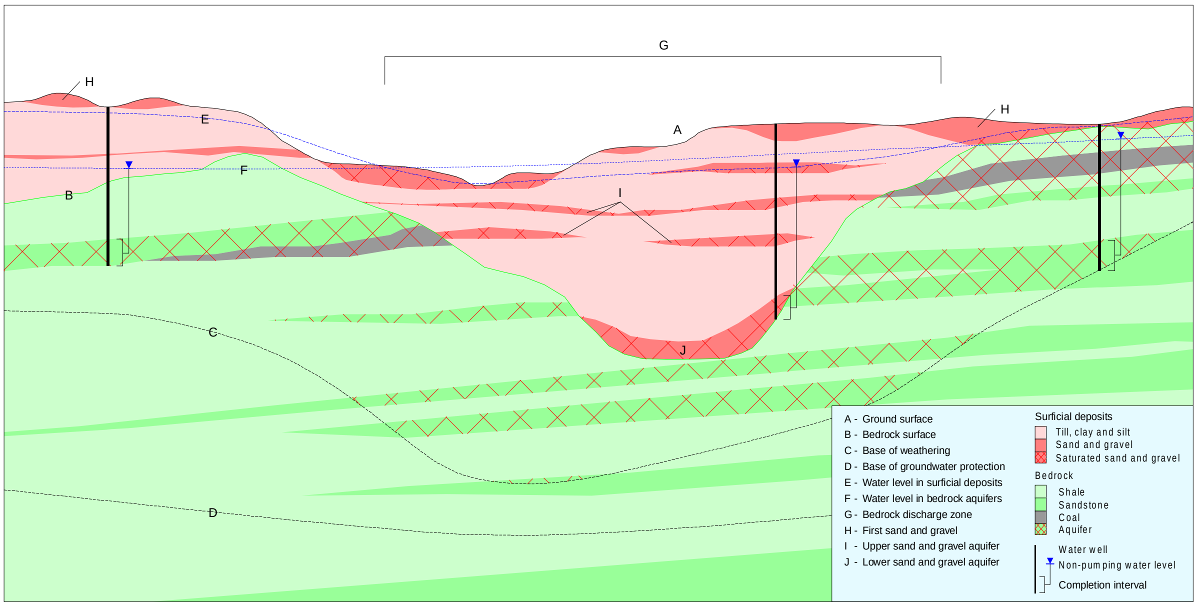


Figure 5. Generalized Cross-Section (for terminology only)

Depth (m)	Lithology	Lithologic Description	Group and Formation: Thickness (m)	Group	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
0		sand, gravel, till, clay, silt	<70		Surficial Deposits	<70	Upper	<30	First Sand and Gravel
						<30	Lower		
100		sandstone, siltstone, shale, coal	40-80	Belly River Group	Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone
						<20	Upper Siltstone Member		
						8-20	Comrey Member		
		shale, sandstone, coal	10-220		*continental* Foremost Formation			<20	Taber Coal Zone
200								<20	McKay Coal Zone
		sandstone, shale	<200		*marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		Milan Aquifer
						<30	Ribstone Creek Member		
300						<30	Victoria Member		
						<30	Brosseau Member		
400		shale, siltstone	100-200		Lea Park Formation	50-100	Upper		
500						50-100	Lower		

Figure 6. Geologic Column

4 METHODOLOGY

4.1 Data Collection and Synthesis

The AEP groundwater database is the main source of groundwater data. The database includes the following:

1) water well drilling reports;
2) aquifer test results from some water wells;
3) location of some springs;
4) water well locations determined during water well surveys;
5) chemical analyses for some groundwaters;
6) location of flowing shot holes;
7) location of structure test holes; and
8) a variety of data related to the groundwater resource.

The main disadvantage to the database is the absence of quality control. Very little can be done to overcome this lack of quality control in the data collection, other than to assess the usefulness of control points relative to other data during the interpretation. Another disadvantage to the database is the lack of adequate spatial information.

The AEP groundwater database uses a land-based system with only a limited number of records having a value for ground elevation. The locations for records usually include a quarter section description; a few records also have a land description that includes a Legal Subdivision (Lsd). For digital processing, a record location requires a horizontal coordinate system. In the absence of an actual location for a record, the record is given the coordinates for the centre of the land description.

The present project uses the 10TM coordinate system. This means that a record for the SE ¼ of section 31, township 054, range 12, W4M would have a horizontal coordinate with an Easting of 214,318 metres and a Northing of 5,952,985 metres, the centre of the quarter section. Once the horizontal coordinates are determined, a ground elevation is obtained from the 1:20,000 Digital Elevation Model (DEM) from the Resource Data Division of AEP.

After assigning spatial control to the records in the groundwater database, the data are processed to determine values for hydrogeological parameters. As part of the processing, obvious keying errors in the database are corrected.

Where possible, determinations are made from individual records for the following:

1) depth to bedrock;
2) total thickness of sand and gravel;
3) thickness of first sand and gravel when present within one metre of ground surface;
4) total thickness of saturated sand and gravel; and
5) depth to the top and bottom of completion intervals.

Also, where sufficient information is available, values for apparent transmissivity[3] and apparent yield[4] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. The apparent transmissivity results are then used to estimate a value for hydraulic conductivity[5]. The conductivity values are obtained by dividing the apparent transmissivity by the completion interval. To obtain a value for regional transmissivity of the aquifer, the hydraulic conductivity is multiplied by the effective thickness of the aquifer based on nearby e-log information. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity.

The Alberta Energy & Utilities Board (EUB) well database includes records for all of the wells drilled by the oil and gas industry. The information from this source includes:

1) spatial control for each well site;
2) depth to the top of various geological units;
3) type and intervals for various down-hole geophysical logs; and
4) drill stem test (DST) summaries.

Unfortunately, the EUB database contains very little information from above the base of groundwater protection. Because the main interest for a groundwater study comes from data above the base of groundwater protection, the data from the EUB database have limited use.

Values for apparent transmissivity and hydraulic conductivity are calculated from the DST summaries.

Published and unpublished reports and maps provide the final source of information to be included in the new groundwater database. The reference section of this report lists the available reports. The only digital data from publications are from the Geological Atlas of the Western Canada Sedimentary Basin (Mossop and Shetsen, 1994). These data are used to verify the geological interpretation of geophysical logs but cannot be distributed because of a licensing agreement.

4.2 Spatial Distribution of Aquifers

Determination of the spatial distribution of the aquifers is based on:

1) lithologs provided by the water well drillers;
2) geophysical logs from structure test holes;
3) wells drilled by the oil and gas industry; and
4) data from existing cross-sections.

The identification of aquifers becomes a two-step process: first, mapping the tops and bottoms of individual geological units; and second, identifying the porous and permeable parts of each geological unit in which the aquifer is present.

After obtaining values for the elevation of the top and bottom of individual geological units at specific locations, the spatial distribution of the individual surfaces can be determined. Digitally, establishment of the distribution of a surface requires the preparation of a grid. The inconsistent quality of the data

[3] For definitions of Transmissivity, see glossary
[4] For definitions of Yield, see glossary
[5] See glossary

necessitates creating a representative sample set obtained from the entire data set. If the data set is large enough, it can be treated as a normal population and the removal of extreme values can be done statistically. When data sets are small, the process of data reduction involves a more direct assessment of the quality of individual points. Because of the uneven distribution of the data, all data sets are gridded using the Kriging[6] method.

The final definition of the individual surfaces becomes an iterative process involving the plotting of the surfaces on cross-sections and the adjusting of control points to fit with the surrounding data.

The porous and permeable parts of the individual geological units have been mainly determined from geophysical logs.

4.3 Hydrogeological Parameters

Water well records that indicate the depths to the top and bottom of their completion interval are compared digitally to the spatial distribution of the various geological surfaces. This procedure allows for the determination of the aquifer in which individual water wells are completed. When the completion interval of a water well cannot be established unequivocally, the data from that water well are not used in determining the distribution of hydraulic parameters.

After the water wells are assigned to a specific aquifer, the parameters from the water well records are assigned to the individual aquifers. The parameters include non-pumping (static) water level (NPWL), transmissivity and projected water well yield. The total dissolved solids, chloride and sulfate concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers.

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of these parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid.

4.3.1 Risk Criteria

The main source of groundwater contamination involves activities on or near the land surface. The risk is high when the near-surface materials are porous and permeable and low when the materials are less porous and less permeable. The two sources of data for the risk analysis include (a) a determination of when sand and gravel is or is not present within one metre of the ground surface, and (b) the surficial geology map. The presence or absence of sand and gravel within one metre of the land surface is based on a geological surface prepared from the data supplied on the water well drilling reports. The information available on the surficial geology map is categorized based on relative permeability. The information from these two sources is combined to form the risk assessment map. The criteria used in the classification of risk are given in the table above.

Surface Permeability	Sand or Gravel Present To Within One Metre Of Ground Surface	Groundwater Contamination Risk
Low	No	Low
Moderate	No	Moderate
High	No	High
Low	Yes	High
Moderate	Yes	High
High	Yes	Very High

Table 2. Risk of Groundwater Contamination Criteria

---

[6] See glossary

4.4 Maps and Cross-Sections

Once grids for geological surfaces have been prepared, various grids need to be combined to establish the extent and thickness of individual geological units. For example, the relationship between an upper bedrock unit and the bedrock surface must be determined. This process provides both the aquifer outline and the aquifer thickness. The aquifer thickness is used to determine the aquifer transmissivity by multiplying the hydraulic conductivity by the thickness.

Grids must also be combined to allow the calculation of projected long-term yields for individual water wells. The grids related to the elevation of the NPWL and the elevation of the top of the aquifer are combined to determine the available drawdown[7]. The available drawdown data and the transmissivity values are used to calculate values for projected long-term yields for individual water wells, completed in a specific aquifer.

Once the appropriate grids are available, the maps are prepared by contouring the grids. The areal extent of individual parameters is outlined by masks to delineate individual aquifers. Appendix A includes page-size maps from the text, plus additional page-size maps and figures that support the discussion in the text. A list of maps and figures that are included on the CD-ROM is given in Appendix B.

Cross-sections are prepared by first choosing control points from the database along preferred lines of section. Data from these control points are then obtained from the database and placed in an AutoCAD drawing with an appropriate vertical exaggeration. The data placed in the AutoCAD drawing include the geo-referenced lithology, completion intervals and NPWLs. Data from individual geological units are then transferred from the digitally prepared surfaces to the cross-section.

Once the technical details of a cross-section are correct, the drawing file is moved to the software package CorelDRAW! for simplification and presentation in a hard-copy form. These cross-sections are presented in this report and in Appendix A, are included on the CD-ROM, and are in Appendix D in a page-size format.

4.5 Software

The files on the CD-ROM have been generated from the following software:

- Microsoft Professional Office 97
- Surfer 6.04
- ArcView 3.1
- AutoCAD 14.01
- CorelDRAW! 8.0
- Acrobat 3.0

[7] See glossary

5 AQUIFERS

5.1 Background

An aquifer is a porous and permeable rock that is saturated. If the NPWL is above the top of the rock unit, this type of aquifer is an artesian aquifer. If the rock unit is not entirely saturated and the water level is below the top of the unit, this type of aquifer is a water-table aquifer. These types of aquifers occur in one of two general geological settings in the County. The first geological setting is the sediments that overlie the bedrock surface. In this report, these are referred to as the surficial deposits. The second geological setting includes aquifers in the upper bedrock. The geological settings, the nature of the deposits making up the aquifers within each setting, the expected yield of water wells completed in different aquifers, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

5.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than 40 metres thick, except in areas of linear bedrock lows where the thickness of surficial deposits can exceed 60 metres. The Buried Vegreville and Elk Point valleys are the two main linear bedrock lows in the County. The Buried Vegreville Valley is present in the western third of the County and trends generally from southwest to northeast. The Buried Elk Point Valley is present in the eastern third of the County and also trends from southwest to northeast. Cross-section A-A' passes across both the Buried Vegreville and Elk Point valleys, and shows the thickness of the surficial deposits as being mainly from 40 to 60 metres.

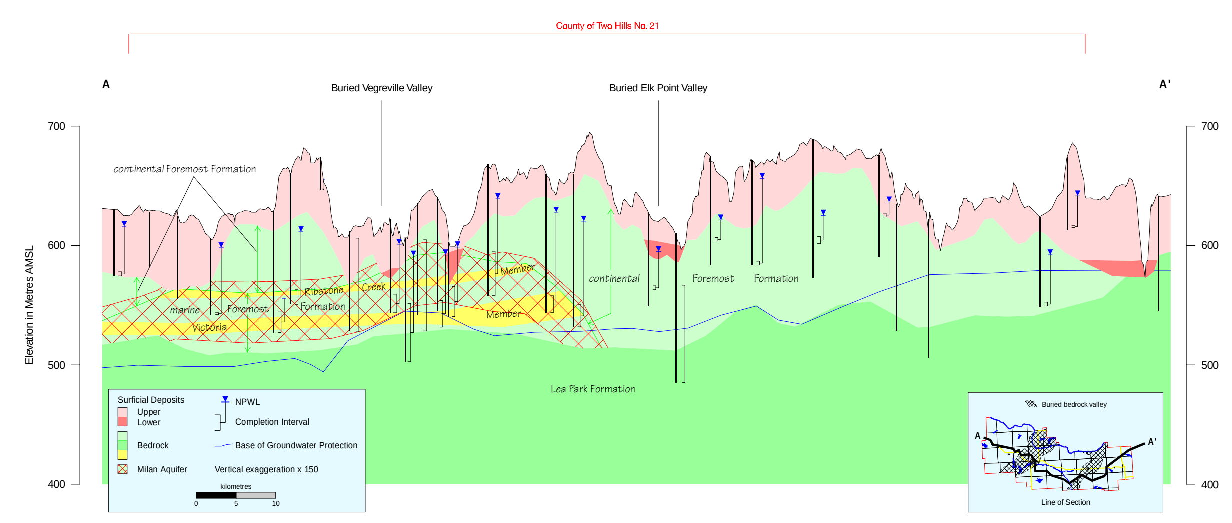


Figure 7. Cross-Section A - A'

The main aquifers in the surficial materials are sand and gravel deposits. In order for a sand and gravel deposit to be an aquifer, it must be saturated; if not saturated, a sand and gravel deposit is not an aquifer. The top of the surficial aquifers has been determined from the NPWL in water wells less than 15 metres deep. The base of the surficial aquifers is the bedrock surface.

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some of the water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the County, 52% of the water wells completed in the surficial deposits have a casing diameter of greater than 330 millimetres or no reported diameter for the surface casing, and are assumed to be dug or bored water wells.

5.1.2 Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface. Some of this bedrock contains porous, permeable and saturated rocks that have a structure that is permeable enough for the rock to be an aquifer. Water wells completed in bedrock aquifers usually do not require water well screens, though some of the sandstones are friable[8] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft. The data for 692 water wells show that the top of the water well completion interval is below the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. Of these 692 water wells, more than 90% have surface casing diameters of less than 220 mm and 25% of these bedrock water wells have been completed with water well screens.

The upper bedrock includes parts of the Belly River Group. The Lea Park Formation underlies the Belly River Group as shown in Figure 8. The Belly River Group has a maximum thickness of 250 metres and includes parts of the Oldman Formation and both the *continental* and *marine* facies[9] of the Foremost Formation. The *marine* Foremost Formation is divided into shale and sandstone members. In the County, the sandstone units include the Ribstone Creek, Victoria and Brosseau members. The upper part of the *marine* Foremost Formation is included in the Milan Aquifer. In the County, the Lea Park Formation is a regional aquitard[10].

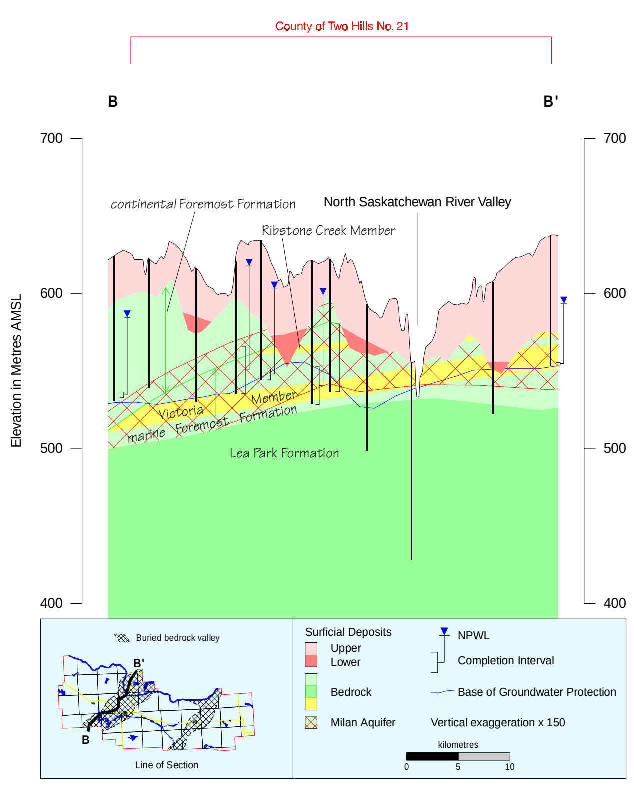


Figure 8. Cross-Section B - B'

8 See glossary
9 See glossary
10 See glossary

5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. This includes pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly by glaciation. The lower surficial deposits include pre-glacial fluvial[11] and lacustrine[12] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The upper surficial deposits include the more traditional glacial deposits of till and meltwater deposits. In the County, pre-glacial material would be expected to be mainly present in association with the Buried Vegreville and Elk Point valleys.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeological unit, they consist of three hydraulic parts. The first is the sand and gravel deposits of the lower surficial deposits, the second is the saturated sand and gravel deposits of the upper surficial deposits and the third is the sand and gravel close to ground level, which is usually unsaturated. The sand and gravel deposits in the upper part of the surficial deposits can extend above the upper limit of the saturation zone and because they are not saturated, they are not an aquifer. However, these sand and gravel deposits are significant since they provide a pathway for liquid contaminants to move downward into the groundwater. Because of the significance of the shallow sand and gravel deposits, they have been mapped where they are present within one metre of the ground surface and are referred to as the “first sand and gravel”.

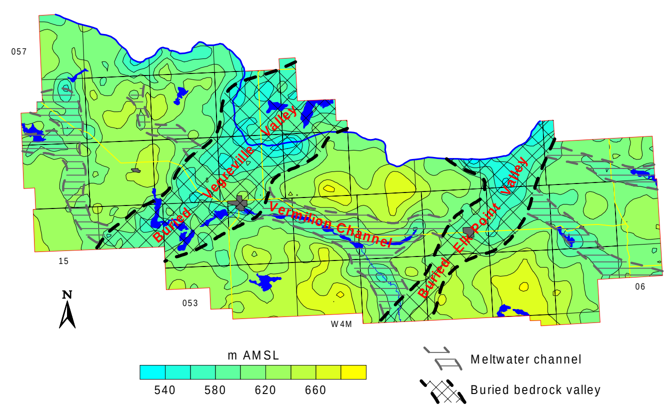


Figure 9. Bedrock Topography

Over the majority of the County, the surficial deposits are less than 40 metres thick. The exceptions are mainly in association with the linear bedrock lows where the deposits can have a thickness of more than 60 metres. The two most significant linear bedrock lows in the County have been designated as the Buried Vegreville Valley and the Buried Elk Point Valley. The Buried Vegreville Valley is in the western third of the County as shown on the adjacent map. The Buried Vegreville Valley trends from southwest to northeast, is approximately 8 to 16 kilometres wide within the County and has a local bedrock relief of less than 60 metres. Sand and gravel deposits can be expected to be present in association with this bedrock low, but the thickness of the sand and gravel deposits is expected to be mainly less than 30 metres. The Two Hills Lions Club is licensed to use 274 m³/day of groundwater from a water supply well completed in the Lower Sand and Gravel Aquifer associated with the Buried Vegreville Valley.

The second linear bedrock low, the Buried Elk Point Valley, trends from southwest to northeast in the eastern third of the County. The Buried Elk Point Valley is approximately four to ten kilometres wide, with local relief being less than 60 metres. Sand and gravel deposits can be expected to be present in association with this bedrock low, with the thickness of the deposits expected to be less than 30 metres.

11 See glossary
12 See glossary

There are other linear bedrock lows shown on the bedrock topography map. The majority of these lows trend northwest to southeast in the County and are indicated as being of meltwater origin. The Vermilion Channel is one of these linear bedrock lows. However, there are indications that the Lower Sand and Gravel deposits occupy at least parts of this linear bedrock low. If they are Lower Sand and Gravel deposits, it is possible that the meltwater channel occupies a pre-glacial channel.

The lower surficial deposits are composed mainly of fluvial and lacustrine deposits. Lower surficial deposits occur over approximately 20% of the County, in association with linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than 20 metres, but ranges from less than 10 to more than 30 metres in parts of the Buried Vegreville and Elk Point valleys. The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally be expected to directly overlie the bedrock surface in the Buried Vegreville and Elk Point valleys. The lowest sand and gravel deposits are of fluvial origin and are usually less than 10 metres thick.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till plus sand and gravel deposits of meltwater origin. The thickness of the upper surficial deposits is mainly less than 30 metres. The greatest thickness of upper surficial deposits occurs mainly in association with the Buried Vegreville Valley.

Sand and gravel deposits can occur throughout the entire unconsolidated section. The total thickness of sand and gravel deposits is generally less than ten metres but can be more than 20 metres in the areas of the buried bedrock lows and meltwater channels.

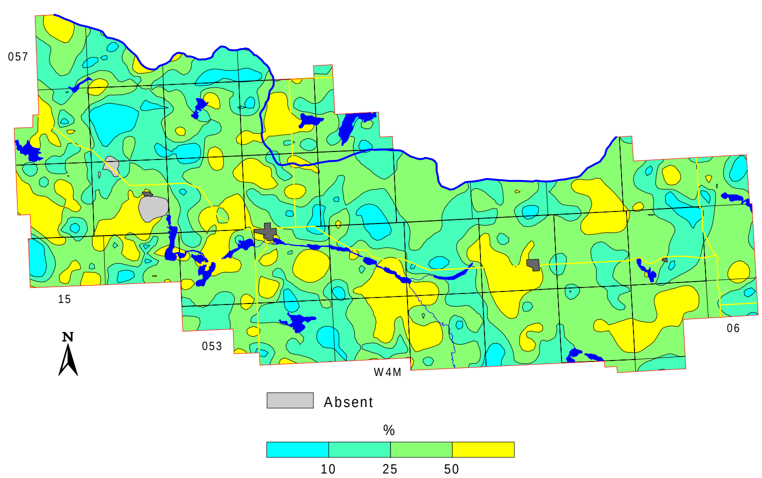


Figure 10. Amount of Sand and Gravel in Surficial Deposits

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 25% of the County, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits.

5.2.2 Sand and Gravel Aquifer(s)

One source of groundwater in the County includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. From the present hydrogeological analysis, 204 water wells are completed in aquifers in the lower surficial deposits and 1,711 are completed in aquifers in the upper surficial deposits. This number of 1,915 water wells completed in aquifers in the surficial deposits is nearly three times the number of water wells determined to be completed in aquifers in the surficial deposits based on lithologies given on the water well drilling reports.

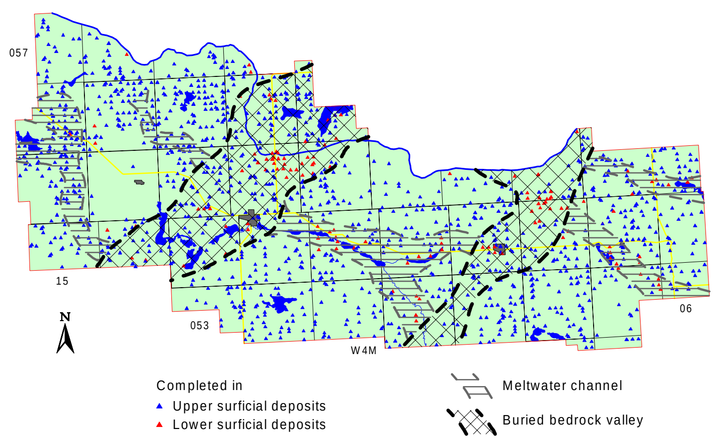


Figure 11. Water Wells Completed in Surficial Deposits

The water wells completed in the upper surficial deposits are located throughout the County, as shown in Figure 11. The majority of the water wells completed in the lower surficial deposits are located along the Buried Vegreville and Elk Point valleys and bedrock lows of meltwater origin.

The adjacent map shows water well yields that are expected in the County, based on surficial aquifers that have been developed by existing water wells. These data show that water wells with yields of more than 100 m³/day from sand and gravel aquifer(s) can be expected in more than 30% of the County. The most notable areas where yields of more than 100 m³/day are expected are mainly in the Buried Vegreville Valley. Over the majority of the County, water wells completed in the sand and gravel aquifer(s) would be expected to mainly have long-term yields of from 10 to 100 m³/day.

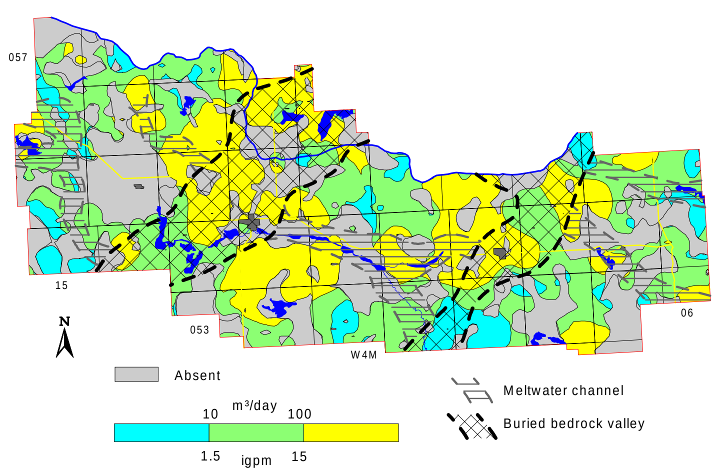


Figure 12. Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits have not been differentiated based on aquifers in the upper or lower surficial deposits. The main reason for not separating the chemical analysis results into the different aquifers is the lack of control. Because of the limited areal extent of the lower surficial deposits, almost all of the analysis results are from the upper surficial deposits.

The other justification for not separating the analyses was that there appeared to be no major chemical difference between groundwaters from the upper or lower sand and gravel aquifers. The groundwaters from these aquifers are generally chemically hard and high in dissolved iron.

The groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate-type waters, with 80% of groundwaters having a TDS concentration of less than 1,000 mg/L. The groundwaters with a TDS of more than 1,500 mg/L occur in the western part of the County. Groundwaters from the surficial deposits are expected to have concentrations of dissolved iron that are greater than 1.0 mg/L. Groundwater from a water test hole completed in the Lower Sand and Gravel Aquifer associated with the Vermilion Channel has a TDS of 531 mg/L, a dissolved iron concentration of 1.0 mg/L and a hardness of 416 mg/L. Chloride concentrations were below 0.7 mg/L (Hydrogeological Consultants Ltd., 1996 [in progress]).

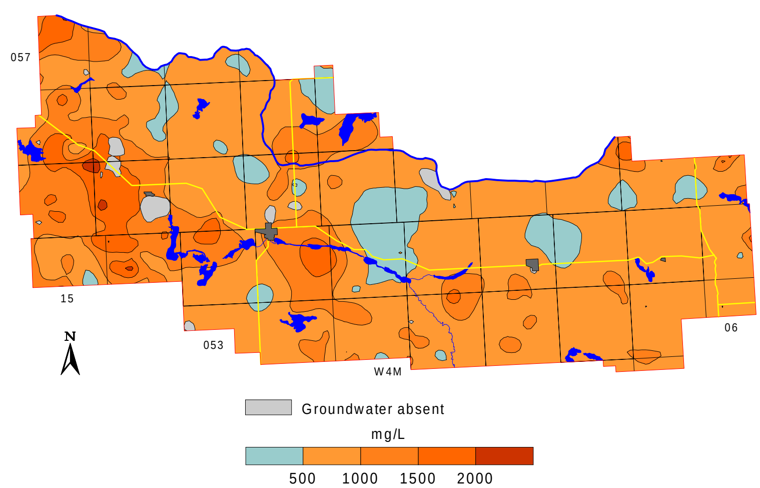


Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

Although the majority of the groundwaters are calcium-magnesium-bicarbonate-type waters, there are groundwaters from the surficial deposits with sodium as the main cation; there are also groundwaters with significant concentrations of the sulfate ion. The groundwaters with elevated levels of sulfate occur in areas where there are elevated levels of total dissolved solids. There are very few groundwaters from the surficial deposits with appreciable concentrations of the chloride ion and in most of the County, the chloride ion concentration is less than 100 mg/L.

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. These aquifers typically occur above an elevation of 580 metres AMSL. Saturated sand and gravel deposits are not continuous but are expected over approximately 80% of the County.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is in part a function of the elevation of the non-pumping water-level surface associated with the upper surficial deposits and in part a result of the depth to the bedrock surface. Since the non-pumping water-level surface in the surficial deposits tends to be a subdued replica of the bedrock surface, the thickness of the Upper Sand and Gravel Aquifer tends to be directly proportional to the thickness of the surficial deposits.

While the sand and gravel deposits in the upper surficial deposits are not continuous, the Upper Sand and Gravel Aquifer includes all of the aquifers present in the upper surficial deposits. The Upper Sand and Gravel Aquifer can be up to 20 metres thick in a few areas, but over the majority of the County, is less than ten metres thick; over 20% of the County, the Aquifer is absent. Most of the greater thickness in the Upper Sand and Gravel Aquifer occurs in the areas of linear bedrock lows.

5.2.3.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of water wells with high yields. However, because the sand and gravel deposits can occur as hydraulically discontinuous pockets, the long-term yields of the water wells are usually less than 100 m³/day. One exception would be the water well completed in 23-055-11 W4M in the Rannach Pasture. The aquifer test conducted with the water well indicated a long-term yield of 600 m³/day (Hydrogeological Consultants Ltd., January 1996). Where the Upper Sand and Gravel Aquifer is absent and where the yields are low, the development of water wells for the domestic needs of single families may not be possible.

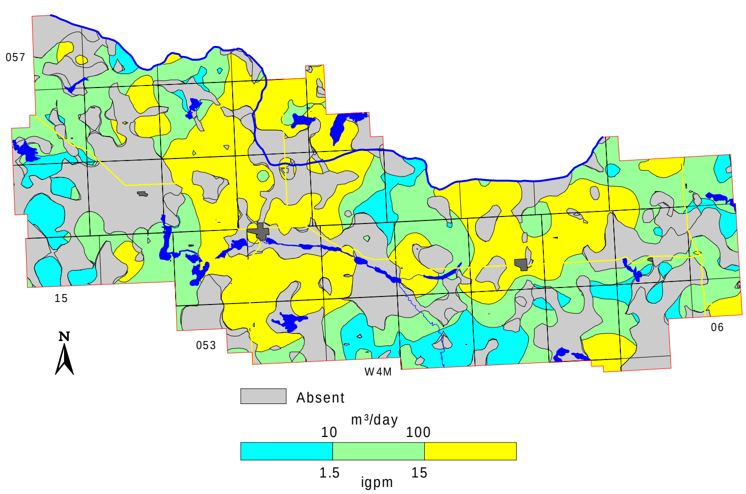


Figure 14. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deepest part of the pre-glacial linear bedrock lows. The Lower Sand and Gravel Aquifer is not continuous in the Buried Vegreville Valley and the thickness is mostly less than five metres. The Lower Sand and Gravel Aquifer is mainly restricted to parts of the Buried Vegreville and Elk Point valleys. Sand and gravel deposits occur overlying the bedrock surface in the Vermilion Channel below an elevation that coincides with the top of the lower surficial deposits. It is possible that the Vermilion Channel is occupying a pre-glacial valley and that the sand and gravel deposits are of pre-glacial origin. The sand and gravel deposits overlying the bedrock surface within the Vermilion Channel are not identified as lower sand and gravel deposits on the adjacent map.

5.2.4.1 Apparent Yield

Water wells completed in the Lower Sand and Gravel Aquifer are expected to have yields between 10 and 100 m³/day but may have yields in excess of 100 m³/day. The highest yields are expected in the Buried Vegreville and Elk Point valleys.

The Town of Two Hills has completed at least some of its water supply wells in the Lower Sand and Gravel Aquifer associated with the Buried Vegreville Valley. The projected long-term yield from one of the Town of Two Hills water supply wells is in excess of 2,500 m³/day (Geoscience Consulting Ltd., 1980).

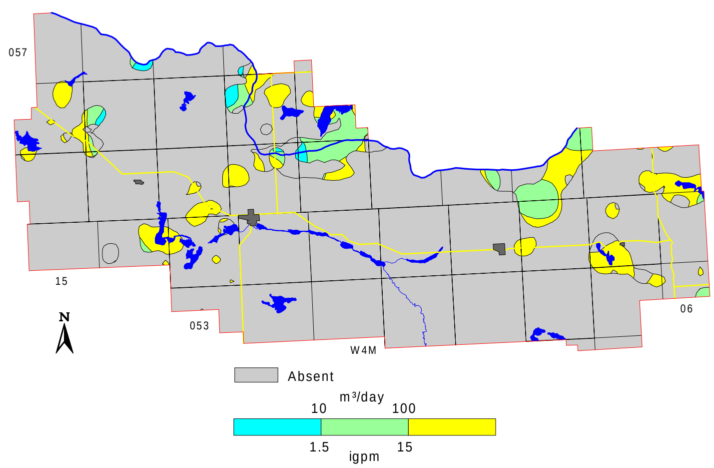


Figure 15. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer was encountered by a water test hole drilled for Highland Feeders. An extensive aquifer test with the water test hole showed that the short-term yield from the water test hole would be in the order of 250 m³/day. However, the Lower Sand and Gravel Aquifer at this location is of limited areal extent and the projected long-term yield from the water test hole is 35 m³/day (Hydrogeological Consultants Ltd., 1998 [in progress]).

Extensive aquifer testing has been conducted with water test holes drilled for Alberta Agri-Ethanol Co. Ltd. east of the Town of Two Hills. Fifteen of sixteen water test holes encountered sand and gravel deposits that are associated with a linear bedrock low that is referred to as the Vermilion Channel. At this time, it is not known if these are Lower Sand and Gravel deposits that were reworked by meltwater processes or are meltwater deposits associated with the upper surficial deposits. Extensive aquifer tests with water test holes completed in the sand and gravel aquifer indicated a long-term supply of approximately 500 m³/day (Hydrogeological Consultants Ltd., 1996 [in progress]).

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County includes parts of the Belly River Group. The Lea Park Formation underlies the Belly River Group.

The Belly River Group in the County has a maximum thickness of 150 metres, and includes parts of the Oldman Formation and both the *continental* and *marine* facies of the Foremost Formation.

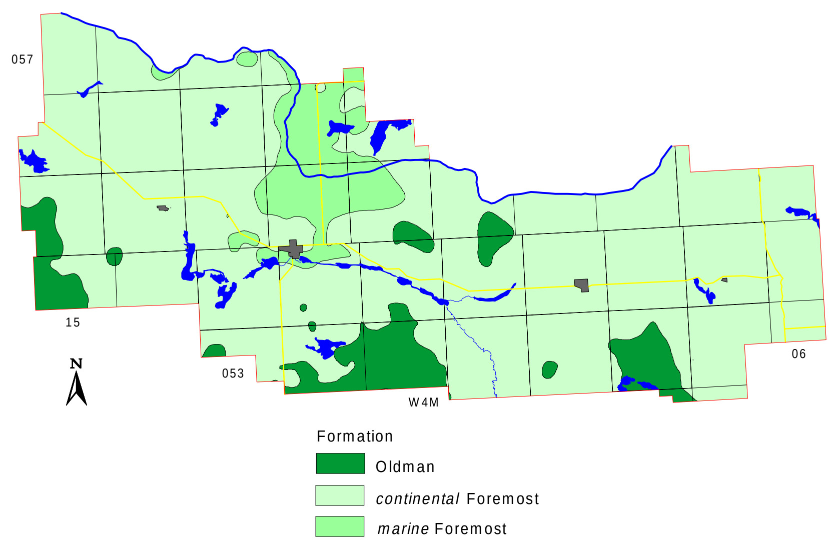


Figure 16. Bedrock Geology

The uppermost part of the Belly River Group is the Oldman Formation. Within the County only the lower part of the Oldman Formation is present and it forms the upper bedrock in a few areas in the southern part of the County. The Oldman Formation within the County has a maximum thickness of 30 metres and is composed of sandstone, siltstone, shale, and coal deposits of the Comrey and Upper Siltstone members.

The *continental* Foremost Formation underlies the Oldman Formation and subcrops under the surficial deposits in the majority of the County; it has a maximum thickness of 140 metres within the County. The *continental* Foremost Formation, a backshore deposit, consists mainly of shale deposits with minor amounts of sandstone present. Coal zones occur within the *continental* Foremost Formation, with the main ones referred to as the McKay and the Taber coal zones. There are also minor amounts of ironstone, a chemical deposit, in the *continental* Foremost Formation. Where the *continental* Foremost Formation is close to the bedrock surface, it can be fractured or weathered and can have significant local permeability.

The *marine* Foremost Formation has a maximum thickness of 80 metres within the County and underlies the *continental* Foremost Formation in the western half of the County. The *marine* Foremost Formation subcrops as the upper bedrock in the north-central part of the County, mainly in townships 055 and 056, ranges 11 and 12, W4M.

In parts of eastern Alberta the *marine* Foremost Formation can be separated into individual sandstone and shale members. However, close to the upper part of the *marine* Foremost Formation, and particularly toward the western extent, the sandstones making up the *marine* Foremost Formation cannot always be separated into individual members. This situation occurs because the sandstone members of the *marine* Foremost Formation thicken and the intervening shale layers thin toward the top and the western extent of the marine facies. Even though the individual members cannot be distinguished, the sandstone occurrence can be a significant aquifer and has been designated the "Milan Aquifer". The top of the Milan Aquifer extends up to ten metres into the overlying *continental* Foremost Formation and can occupy the upper 40 metres of the *marine* Foremost Formation. The westward extent of the Milan Aquifer coincides with the position where the Basal Belly River Sand can be distinguished. The Milan Aquifer is present in the western half of the County under the *continental* Foremost Formation but does not subcrop anywhere in the County.

In the County of Two Hills, the Milan Aquifer occupies almost the entire *marine* Foremost facies. The Ribstone Creek and Victoria members have been shown on the cross-sections (Figures 7 and 8) and maps have been prepared for the two members. The maps are presented on the CD-ROM. Also, there is a discussion for the Ribstone Creek and Victoria members. However, the main discussion for these members in this report is included in the section for the Milan Aquifer. In the query, the Ribstone Creek and Victoria members are only identified when outside the area of the Milan Aquifer.

The Lea Park Formation is mostly composed of shale, with only minor amounts of bentonitic sandstone present in some areas. Regionally, the Lea Park Formation is an aquitard.

5.3.2 Aquifers

Of the 3,629 water wells in the database, 692 were defined as being completed in bedrock aquifers. This designation is based on the top of the completion interval being below the bedrock surface. The completion depth is available for the majority of water wells. In order to make use of additional information within the groundwater database, it was statistically determined that water wells typically have completion intervals equivalent to one quarter of their completed depth. This relationship was used to increase the number of water wells identified as completed in bedrock aquifers to 1,812 from 692. With the use of geological surfaces that were determined from the interpretation of geophysical logs, it has been possible to assign the water wells completed in bedrock aquifers to specific aquifers based on their completion intervals. Of the 1,812 bedrock water wells, 1,674 could be assigned a specific aquifer. The bedrock water wells are mainly completed in the *continental* Foremost Aquifer, as shown in the table above. The total of 50 given for the number of water wells completed in the *marine* Foremost Aquifer does not include water wells completed in the individual members of the *marine* Foremost Aquifer; however, the 50 water wells do include water wells completed through more than one member. The discussions related to specific aquifers, later in this report, do not include the *marine* Foremost Aquifer or the Lea Park Aquitard due to the paucity of data available for these geological units in the County. However, maps associated with these geological units are included on the CD-ROM.

Bedrock Aquifer	No. of Water Wells
Oldman	40
continental Foremost	1217
Milan	212
marine Foremost	50
Ribstone Creek Member	55
Victoria Member	76
Lea Park	24

Table 3. Completion Aquifer

There are 338 records for bedrock water wells that have apparent yield values. In the County, water well yields can be expected to be mainly less than 100 m³/day. The areas of higher yields that are indicated on the adjacent figure are mainly in the central part of the County. These higher yields may be a result of increased permeability that has resulted from the weathering process in association with the Buried Vegreville and Elk Point valleys.

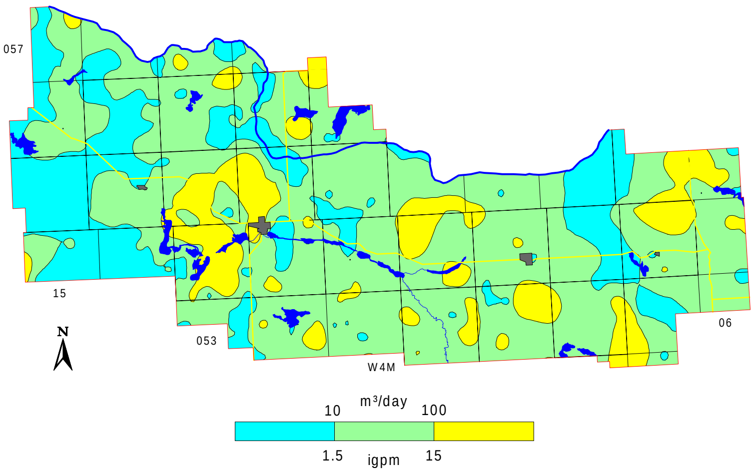


Figure 17. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 335 apparent yield values that can be assigned to a specific bedrock aquifer. The majority of the water wells completed in the bedrock aquifers have apparent yields that range from 10 to 100 m³/day, as shown in the table below.

Aquifer	No. of Water Wells with Apparent Yields	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Oldman	4	2	1	1
continental Foremost	268	67	133	68
Milan	11	4	4	3
marine Foremost	1	0	0	1
Ribstone	18	9	7	2
Victoria	33	9	20	4
Totals	335	91	165	79

Table 4. Apparent Yields of Bedrock Aquifers

5.3.3 Chemical Quality of Groundwater

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 to more than 2,000 mg/L. In more than 60% of the area, TDS values are less than 1,000 mg/L, with a few areas having TDS concentrations of less than 500 mg/L. The higher values are expected in the western 20% of the County, as can be seen on the adjacent figure.

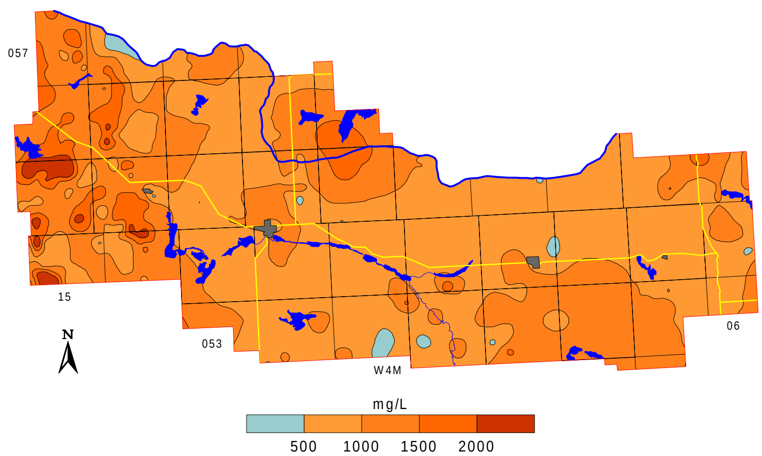


Figure 18. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentration exceeds 400 mg/L. The majority of the sulfate concentrations are less than 500 mg/L. The higher values are expected mainly in the central and western parts of the County. The chloride concentration in groundwater from the upper bedrock aquifer(s) is less than 100 mg/L in 20% of the County.

In 95% of the County, the fluoride ion concentration in the groundwater from the upper bedrock aquifer(s) is less than 1.0 mg/L.

The Piper tri-linear diagram (see Appendix A and CD-ROM) shows that all chemical types of groundwater occur in the upper bedrock aquifer(s). However, the majority of the groundwaters are sodium-bicarbonate types.

5.3.4 Oldman Aquifer

The Oldman Aquifer comprises the porous and permeable parts of the Oldman Formation and underlies less than 200 square kilometres, mainly in the southern part of the County. The thickness of the Oldman Aquifer in the County is mainly less than 30 metres.

5.3.4.1 Depth to Top

The depth to the top of the Oldman Formation is mainly between 10 and 30 metres except in the southern part of the County, where it can be greater than 30 metres.

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed in the Oldman Aquifer are mainly less than 100 m³/day. The adjacent map includes four values within the County. Three of the four values are less than 20 m³/day and the fourth value is more than 350 m³/day.

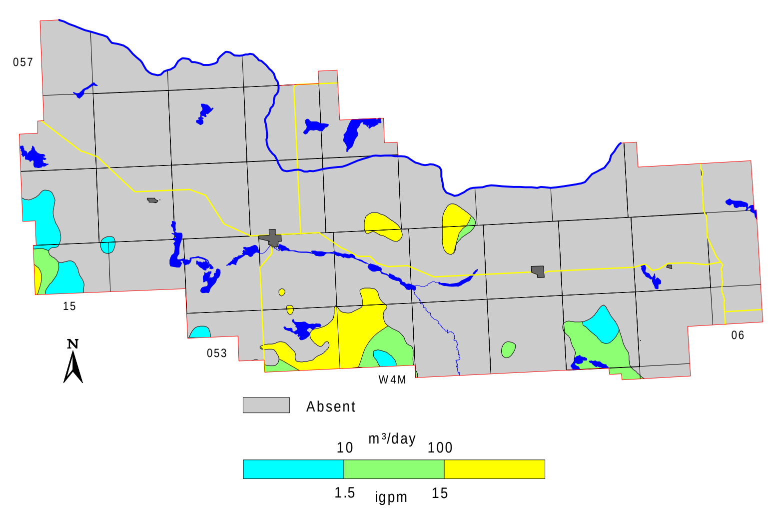


Figure 19. Apparent Yield for Water Wells Completed through Oldman Aquifer

5.3.4.3 Quality

There are seven water well records in the database with sufficient information to determine the chemical type of groundwaters from the Oldman Aquifer. The groundwaters are mainly a sodium-sulfate type. TDS concentrations are expected to be mainly less than 1,000 mg/L. The sulfate concentrations are mainly less than 500 mg/L except in the western part of the County where the sulfate concentrations are expected to exceed 500 mg/L. Chloride concentrations in the groundwater from the Oldman Aquifer are mainly between 10 and 100 mg/L.

5.3.5 *Continental* Foremost Aquifer

The *continental* Foremost Aquifer comprises the porous and permeable parts of the *continental* Foremost Formation and subcrops in the majority of the County. The thickness of the *continental* Foremost Formation varies from less than 20 metres at the edge of the subcrop to more than 120 metres in the southern part of the County. The thickness of the *continental* Foremost Formation decreases in the vicinity of the North Saskatchewan and the Vermilion river valleys as a result of erosional processes. The *continental* Foremost Aquifer does not include the lower ten metres of the Formation, which is the Milan Aquifer.

5.3.5.1 Depth to Top

The depth to the top of the *continental* Foremost Formation is variable, ranging from less than 20 metres in the areas closely corresponding to the areas where the thickness of the surficial deposits is less than 20 metres, to more than 60 metres.

5.3.5.2 Apparent Yield

The projected long-term yields for individual water wells completed in the *continental* Foremost Aquifer are mainly between 10 and 100 m³/day. The adjacent map indicates that apparent yields of more than 100 m³/day are expected mainly east of range 11, W4M. The higher yields in these areas are a reflection of the greater thickness and not the higher permeability of the aquifer materials.

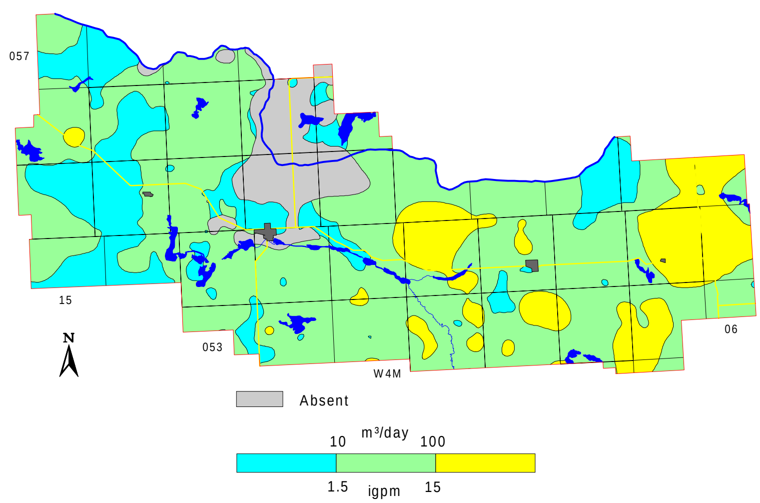


Figure 20. Apparent Yield for Water Wells Completed through continental Foremost Aquifer

5.3.5.3 Quality

The Piper tri-linear diagram shows the majority of the groundwaters to be sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are expected to be in the order of 500 to 1,500 mg/L. The higher values are expected to be in the western part of the County. When TDS values exceed 1,300 mg/L, the sulfate concentrations exceed 400 mg/L. The sulfate concentrations are mainly below 500 mg/L. Chloride concentrations in the groundwater from the *continental* Foremost Aquifer are mainly less than 250 mg/L.

5.3.6 Milan Aquifer

The Milan Aquifer is used to designate a zone that occurs near the top and the western limit of the *marine* Foremost Formation and includes the lower part of the *continental* Foremost Formation. The sandstone beds are included as one aquifer because the individual sandstone members are not generally discernible throughout. The Milan Aquifer includes up to 40 metres of the *marine* Foremost Formation and up to ten metres of the overlying *continental* Foremost Formation. On the CD-ROM, the *marine* Foremost Aquifer and the Milan Aquifer are presented separately. However, for the most part the two aquifers are the same within the County.

5.3.6.1 Depth to Top

The depth to the top of the Milan Aquifer is a function of the depth to the stratigraphic border between the *continental* and *marine* facies of the Foremost Formation and the topographic surface. The depth to the top of the Milan Aquifer ranges from less than 50 metres to more than 150 metres.

5.3.6.2 Apparent Yield

The Milan Aquifer is present in the western half of the County. The apparent yields for individual water wells completed in the Milan Aquifer are mainly less than ten m³/day. The lower yields occur in the northern two-thirds of the area occupied by the Milan Aquifer within the County. Water well yields are expected to be mainly between 10 and 100 m³/day in the southern third of the Aquifer. The higher yields of more than 100 m³/day tend to be in water wells located in township 054, range 14, W4M. An extended aquifer test conducted with a water test hole completed in the Milan Aquifer (Hydrogeological Consultants Ltd., 1998 [in progress]) indicated a long-term yield of 630 m³/day.

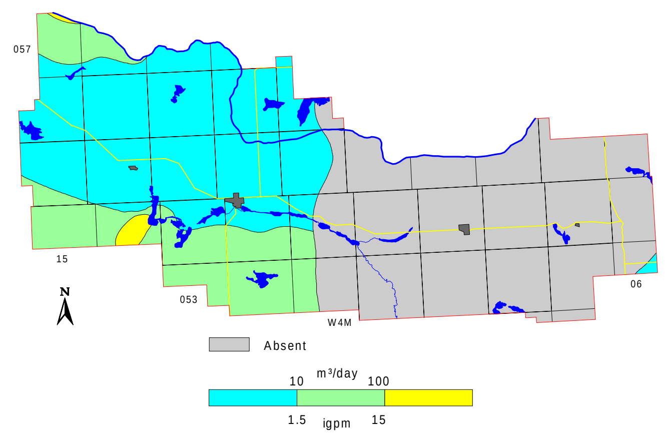


Figure 21. Apparent Yield for Water Wells Completed through Milan Aquifer

5.3.6.3 Quality

The Piper tri-linear diagram shows the majority of the groundwaters are sodium-bicarbonate or sodium-chloride types (see CD-ROM). The TDS concentrations are expected to be mainly less than 2,000 mg/L. The higher values are expected to be in the western part of the County. The sulfate concentrations range mainly from 100 to 500 mg/L.

Chloride concentrations in the groundwater from the Milan Aquifer are mainly less than ten mg/L in the northeastern two-thirds of the Aquifer but exceed 250 mg/L in the southwestern third of the Aquifer. Chloride concentrations in excess of 1,000 mg/L were typical in the groundwaters from the water test holes completed in the Milan Aquifer in sections 16 and 24, township 054, range 14, W4M (Hydrogeological Consultants Ltd., 1998 [in progress]).

5.3.7 *Marine* Foremost Aquifer

There is no detailed discussion for the *marine* Foremost Aquifer in this report; however, maps for this Aquifer are provided on the CD-ROM.

5.3.8 Ribstone Creek Aquifer

The Ribstone Creek Aquifer comprises the porous and permeable parts of the Ribstone Creek Member. Structure contours have been prepared for the top and bottom of the Member, which underlies 70% of the western half of the County. The structure contours show the Member being mostly less than ten metres thick. However, because of the local hydrogeological setting, the Ribstone Creek Aquifer is mainly incorporated into the Milan Aquifer and the amount of information for the Ribstone Creek Aquifer interval is very limited. The Groundwater Query does not include information for the Ribstone Creek Aquifer, only the Milan Aquifer.

5.3.8.1 Depth to Top

The depth to the top of the Ribstone Creek Member is mainly less than 100 metres below ground level, but can be more than 120 metres in the northwestern part of the County.

5.3.8.2 Apparent Yield

The apparent yields for individual water wells completed through the Ribstone Creek Aquifer are mainly less than 100 m³/day. Water wells with higher yields are expected at the northeastern edge of the Aquifer.

A study for the Town of Two Hills indicated a long-term yield of 130 m³/day for a water supply well completed in the Ribstone Creek Aquifer (Geoscience Consulting Ltd., 1976).

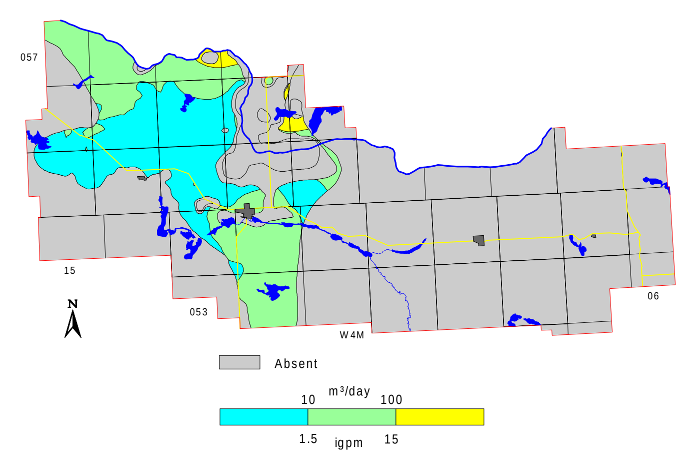


Figure 22. Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer

5.3.8.3 Quality

There were six water well records in the database with sufficient information to determine the chemical type of groundwaters from the Ribstone Creek Aquifer; the groundwaters are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are expected to be mainly less than 1,500 mg/L. The higher values are expected to be in the northwestern part of the County, and in the vicinity of the Town of Two Hills. The sulfate concentrations range mainly from 100 to 250 mg/L. Chloride concentrations in the groundwater from the Ribstone Creek Aquifer are mainly less than 100 mg/L, but are expected to exceed 250 mg/L in the northwestern part of the County.

Groundwater from the Ribstone Creek Aquifer from a Town of Two Hills water supply well has a TDS value of in the order of 1,000 mg/L, a sulfate concentration of more than 250 mg/L and a chloride concentration of 20 mg/L (Geoscience Consulting Ltd., 1976).

5.3.9 Victoria Aquifer

The Victoria Aquifer comprises the porous and permeable parts of the Victoria Member. Structure contours have been prepared for the top and bottom of the Member, which underlies the western half of the County. The structure contours show the Member as being mostly less than 15 metres thick. However, because of the local hydrogeological setting, the Victoria Aquifer is mainly incorporated into the Milan Aquifer. The amount of information for the Victoria Aquifer interval is very limited. The Groundwater Query includes information for the Victoria Aquifer over a very small area where it is not included in the Milan Aquifer; otherwise, the Victoria Aquifer interval is included in the Milan Aquifer.

5.3.9.1 Depth to Top

The depth to the top of the Victoria Member is mainly less than 140 metres below ground level. The greatest depth is in the areas along the southern edge of the County.

5.3.9.2 Apparent Yield

The apparent yields for individual water wells completed through the Victoria Aquifer are mainly in the range of 10 to 100 m³/day. The areas where water wells with higher yields are expected are mainly near the Town of Two Hills and the areas to the north.

A study for the Town of Two Hills indicated a long-term yield of 300 m³/day for a water supply well completed in the Victoria Aquifer (Geoscience Consulting Ltd., 1976).

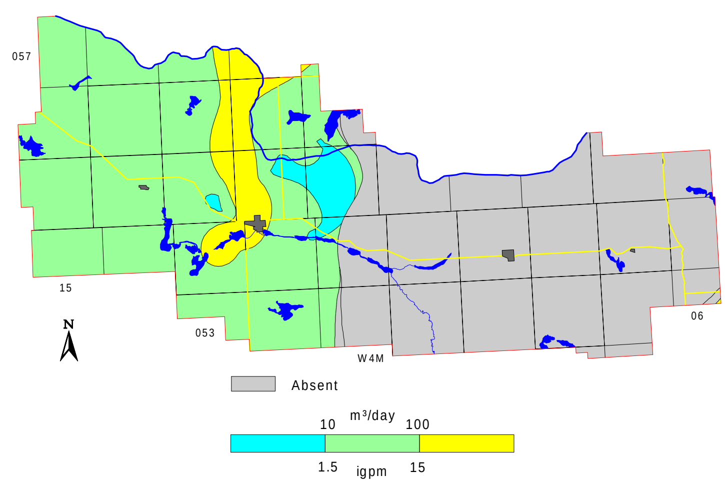


Figure 23. Apparent Yield for Water Wells Completed through Victoria Aquifer

5.3.9.3 Quality

There are four water well records in the database with sufficient information to determine the chemical type of groundwaters from the Victoria Aquifer; they are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are expected to be mainly less than 1,500 mg/L. The higher values are expected to be in the northwestern and northeastern parts of the Aquifer. The sulfate concentrations range mainly from 100 to 500 mg/L. Chloride concentrations in the groundwater from the Victoria Aquifer are mainly less than 100 mg/L, but exceed 250 mg/L in the western part of the County.

5.3.10 Lea Park Aquitard

The Lea Park Formation is composed mainly of shale and has a very low permeability. In most of the area, the top of the Lea Park Formation coincides with the Base of Groundwater Protection. A map showing the depth to the Base of Groundwater Protection is given on page 6 of this report, in Appendix A, page A – 6, and on the CD-ROM.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are five observation water wells in the County where water levels are being measured and recorded with time. Four sites are observation water wells (Obs WWs) that are part of the AEP regional groundwater-monitoring network. Two of the four AEP Obs WWs are located in the vicinity of the Town of Two Hills: Obs WW No. 173 is in 12-32-054-12 W4M and Obs WW No. 174 is in 05-11-054-13 W4M; Obs WW No. 270 is in 15-22-055-12 W4M south of the Hamlet of Duvernay and Obs WW No. 240 is in NW 07-055-06 W4M northeast of the Village of Derwent. Their hydrographs are shown in the adjacent figure. The other groundwater monitoring site is a part of the Highland Feeders Limited facility.

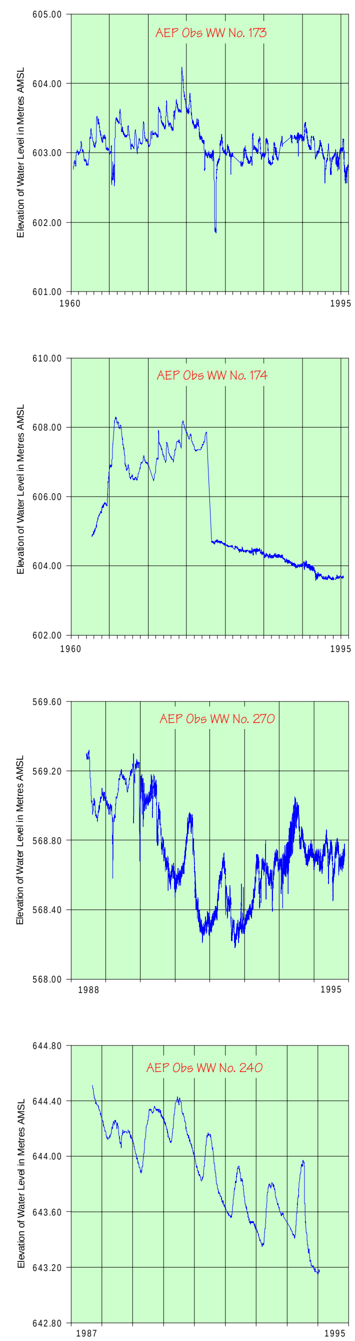


Figure 24. Hydrographs - AEP Observation Water Wells

AEP Obs WW No. 173 is completed open hole at a depth from 30.5 to 76.2 metres below ground level in the Milan Aquifer. This observation water well is located approximately 30 metres from the Town of Two Hills WSW No. 4 (Geoscience Consulting Ltd. 1976), which is completed in the Ribstone Creek Aquifer interval of the Milan Aquifer. The hydrograph shows that water levels generally rose a total of one metre between 1960 and 1974. From 1974 to 1978 the water declined approximately one metre. Between 1978 and 1995 the general water level has not changed more than one half a metre. There are annual fluctuations in the water level, with rises in the spring and fall and declines in the winter and summer and an overall annual fluctuation of approximately 30 cm. The water-level decline in 1965 was not in response to pumping from WSW No. 4 since the water supply well did not exist until 1968. However, the water-level decline in 1978 may have been interference from the pumping of WSW No. 4. The observation water well is no longer part of the AEP Observation Water Well Network.

AEP Obs WW No. 174 is completed at a depth of 54.9 metres below ground level in the Milan Aquifer. This hydrograph has two distinct parts. Between 1962 and 1977, the water level fluctuates as much as two metres over several months and the water level generally rises more than two metres. In late 1977 and early 1978, the water level declines more than two metres. After this decline, the water level fluctuates a matter of a few centimetres and generally declines for 18 years. The 18-year decline is in the order of one metre. The hydrograph does not show any annual fluctuation. The change in character of the hydrograph in 1978 indicates a significant change in local use of groundwater or a change in the observation water well itself.

The third AEP Obs WW completed in the Milan Aquifer is AEP Obs WW No. 270. This observation water well is located in 15-22-055-12 W4M and is completed with a water well screen, with the bottom of the screen 20.6 metres below ground level. The monitoring of the water level in this observation water well began in 1988. Over the eight years of record, the water level shows an annual fluctuation that indicates the influence of municipal use. The lowest water level occurs in late summer/early fall with the highest water level in late spring/early summer. The annual fluctuations are less than one metre. In 1990 and 1991, there is a general decline in the water level followed by a general rise during 1993 and 1994. The change in water level between 1988 and 1995 is similar to the water-level change observed in Obs WW No. 173 over the same time interval.

AEP Obs WW No. 240 is completed at a depth of 26.0 metres below ground level in NW 07-055-06 W4M. This observation water well is completed with a water well screen in the *continental* Foremost Aquifer. Water-level data are available from 1987 to early 1995. The hydrograph shows a typical annual fluctuation, with a rise in water level in late spring/early summer, followed by a gradual decline until the late spring/early summer of the following year. Over the eight years of record, the water level has declined approximately one metre.

The Highland Feeders Limited water supply wells in Tp 054, R 14, W4M are completed in the Milan Aquifer. The water supply wells have been used to divert 650,000 cubic metres of groundwater from 1992 to 1997. The W. Sawchuk Domestic Water Well (Dom WW), located less than 1.6 kilometres from the Highland Feeders Limited facility, is completed in the *continental* Foremost Aquifer. This Dom WW is used as an observation water well by Highland Feeders Limited. Even though there was a significant change in water level in early 1995, the change is not related to the diversion by Highland Feeders Limited (Hydrogeological Consultants Ltd., June 1998).

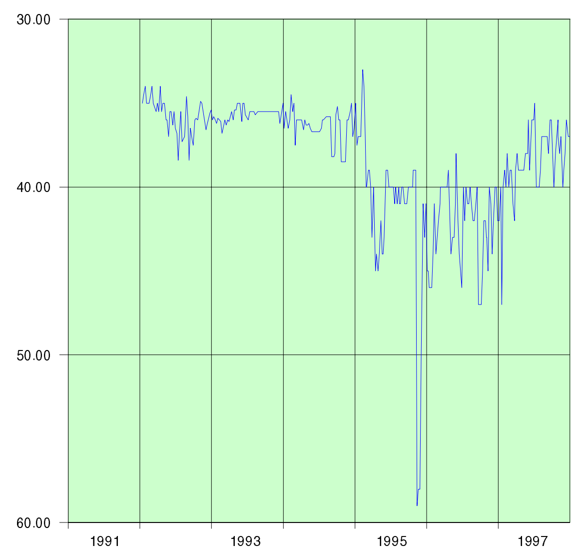


Figure 25. Water-Level Summary - W. Sawchuk Dom WW

6.2 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the County. One indirect method of measuring recharge is to determine the quantity of groundwater flowing through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer, and that the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow through an aquifer must be averaged and estimated. To determine the flow requires a value for the average transmissivity of the aquifer, an average hydraulic gradient and an estimate for the width of the aquifer. For the present program, the flow has been estimated for aquifers within the County.

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer. Based on these assumptions, the estimated groundwater flow through the individual aquifers can be summarized as follows:

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Authorized Diversion (m^3/day)
Surficial Deposits					800	
Vermilion Channel and Buried Elk Point Valley	10	0.003	8	South/North	200	
Vermilion Channel and Buried Elk Point Valley	15	0.005	8	North	600	
Buried Vegreville Valley					900	774
	20	0.003	15	Northeast	900	
continental Foremost					1,300	150
east of Two Hills	7	0.004	40	North	1,150	
west of Two Hills	4	0.001	40	East	150	
Milan Aquifer					750	792
	5	0.003	50	Northeast	750	
Ribstone Creek					300	151
	5	0.002	30	Northeast	300	
Victoria					800	566
	10	0.002	40	Northeast	800	

The above table indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers. However, because of the very approximate nature of the calculation of the quantity of groundwater flowing through the individual aquifers, more detailed work is required to more precisely determine the flow through the aquifers.

6.3 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.4 to 2.4 cubic kilometres. This volume is based on an areal extent of 2,700 square kilometres and a saturated sand and gravel thickness of three metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared by considering water wells completed in aquifers in the surficial deposits. The map shows the highest level of groundwater in surficial deposits, and this level was used for the calculation of saturated surficial deposits and for calculations of recharge/discharge areas.

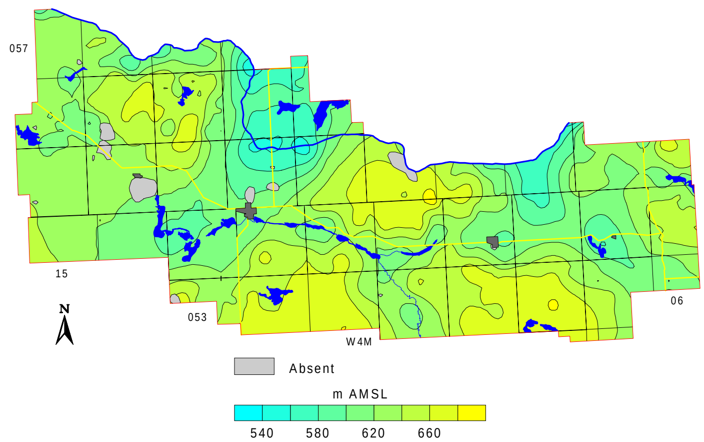


Figure 26. Non-Pumping Water-Level Surface in Surficial Deposits

6.4 Recharge/Discharge

The hydraulic relationship between the groundwater in the surficial deposits and the groundwater in the bedrock aquifers is given by the non-pumping water-level surface associated with each of the hydraulic units. Where the water level in the surficial deposits is at a higher elevation than the water level in the bedrock aquifers, there is the opportunity for groundwater to move from the surficial deposits into the bedrock aquifers. This condition would be considered as an area of recharge to the bedrock aquifers and an area of discharge from the surficial deposits. The amount of groundwater that would move from the surficial deposits to the bedrock aquifers is directly related to the vertical permeability of the sediments separating the two aquifers.

When the hydraulic gradient is from the bedrock aquifers to the surficial deposits, the condition is a discharge area from the bedrock aquifers, and a recharge area to the surficial deposits.

6.4.1.1 Surficial Deposits/Upper Bedrock Aquifer(s)

The hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) has been determined by subtracting the non-pumping water-level surface associated with all water wells completed in upper bedrock aquifer(s) from the non-pumping water-level surface determined for all water wells in the surficial deposits. The recharge classification on the map below includes those areas where the water level in the surficial deposits is more than five metres above the water level in the upper bedrock aquifer(s). The discharge areas are where the water level in the surficial deposits is more than five metres lower than the water level in the bedrock. When the water level in the surficial deposits is between five metres above and five metres below the water level in the bedrock, the area is classified as a transition.

The adjacent map shows that in more than 90% of the County there is a downward hydraulic gradient, recharge to the upper bedrock aquifer(s). Areas where there is an upward hydraulic gradient, or discharge from the bedrock, are very few, and are mainly in the vicinity of lows in the bedrock surface. The remaining parts of the County are areas where there is a transition condition.

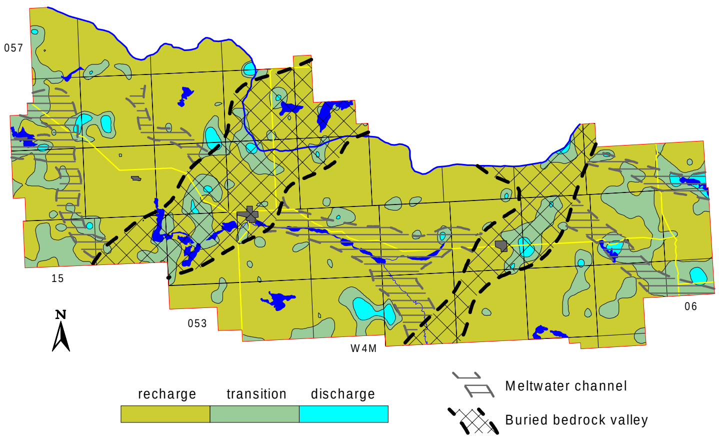


Figure 27. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

Because of the paucity of data, a calculation of the volumes of groundwater entering and leaving the surficial deposits has not been attempted.

6.4.1.2 Bedrock Aquifers

Recharge to the bedrock aquifers within the County takes place from the overlying surficial deposits and from flow in the aquifer from outside the County. The recharge/discharge maps show that generally for most of the County, there is a downward hydraulic gradient from the surficial deposits to the bedrock, i.e. recharge to the bedrock. On a regional basis, calculating the quantity of water involved is not possible because of the complexity of the geological setting and the limited amount of data. However, because of the generally low permeability of the upper bedrock materials, the volume of water is expected to be small.

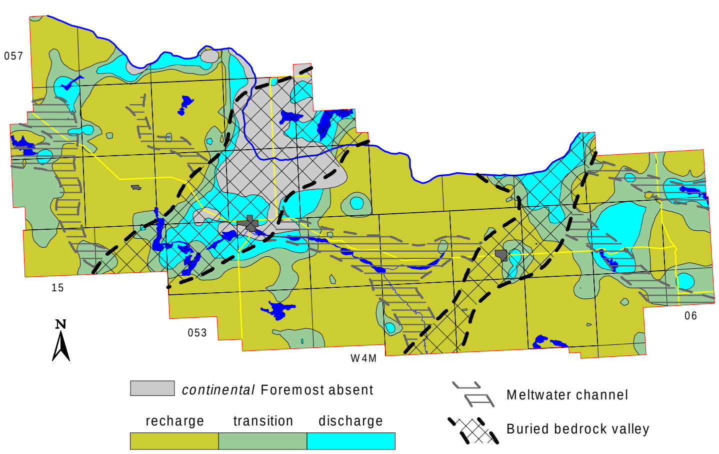


Figure 28. Recharge/Discharge Areas between Surficial Deposits and* continental *Foremost Aquifer

The hydraulic relationship between the surficial deposits and the *continental* Foremost Aquifer indicates that in the 70% of the County where the *continental* Foremost Aquifer is present, there is a downward hydraulic gradient. Discharge and transition areas for the *continental* Foremost Aquifer and the remainder of the bedrock aquifers present in the County are either in or adjacent to the bedrock lows.

7 POTENTIAL FOR GROUNDWATER CONTAMINATION

The most common sources of contaminants that can impact groundwater originate on or near the ground surface. The contaminant sources can include leachate from landfills, effluent from leaking lagoons or from septic fields, and petroleum products from storage tanks or pipeline breaks. The agricultural activities that generate contaminants include the spreading of fertilizers, pesticides, herbicides and manure. The spreading of highway salt can also degrade groundwater quality.

When activities occur that can or do produce a liquid which could contaminate groundwater, it is prudent (from a hydrogeological point of view) to locate the activities where the risk of groundwater contamination is minimal. Alternatively, if the activities must be located in an area where groundwater can be more easily contaminated, the necessary action must be taken to minimize the risk of groundwater contamination.

The potential for groundwater contamination is based on the concept that the easier it is for a liquid contaminant to move downward, the easier it is for the groundwater to become contaminated. In areas where there is groundwater discharge, liquid contaminants cannot enter the groundwater flow systems to be distributed throughout the area. In groundwater recharge areas, low-permeability materials impede the movement of liquid contaminants downward. Therefore, if the soils develop on a low-permeability parent material of till or clay, the downward migration of a contaminant is slower relative to a high-permeability parent material such as sand and gravel of fluvial origin. Once a liquid contaminant enters the subsurface, the possibility for groundwater contamination increases if it coincides with a higher permeability material within one metre of the land surface.

To determine the nature of the materials on the land surface, the surficial geology map prepared by the Alberta Research Council (Shetsen, 1990) has been reclassified based on the relative permeability. The classification of materials is as follows:

1. high permeability - sand and gravel;
2. moderate permeability - silt, sand with clay, gravel with clay, and bedrock; and
3. low permeability - clay and till.

To identify the areas where sand and gravel can be expected within one metre of the ground surface, all groundwater database records with lithologies were reviewed. From a total of 1,928 records in the area of the County with lithological descriptions, 274 have sand and gravel within one metre of ground level. In the remaining 1,654 records, the first sand and gravel is deeper or not present. This information was gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.

7.1.1 Risk of Contamination Map

The information from the reclassification of the surficial geology map is the basis for preparing the initial risk map. The depth to the first sand and gravel is then used to modify the initial map and to prepare the final map. The criteria used for preparing the final Risk of Groundwater Contamination map are outlined in the adjacent table.

Surface Permeability	Sand or Gravel Present To Within One Metre Of Ground Surface	Groundwater Contamination Risk
Low	No	Low
Moderate	No	Moderate
High	No	High
Low	Yes	High
Moderate	Yes	High
High	Yes	Very High

Table 5. Risk of Groundwater Contamination Criteria

The Risk of Groundwater Contamination map shows that, in 25% of the County, there is a high or very high risk of the groundwater being contaminated. These areas would be considered the least desirable ones for a development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that groundwater contamination would not affect groundwater quality.

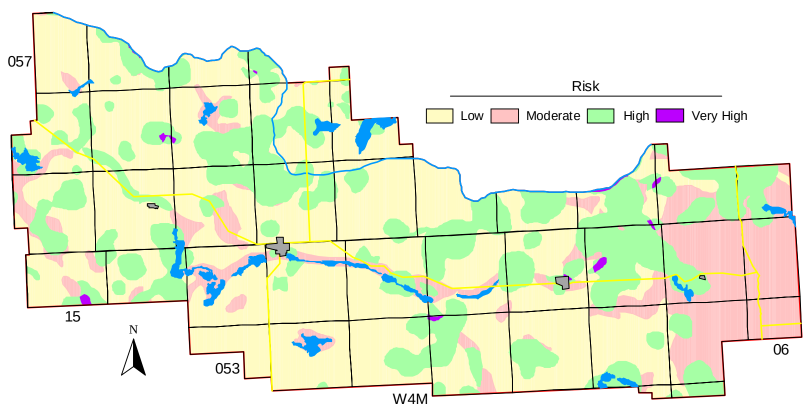


Figure 29. Risk of Groundwater Contamination

8 RECOMMENDATIONS

The present study has been based on information available from the groundwater database. The database has three problems:

1) the quality of the data;
2) the coordinate system used for the horizontal control; and
3) the distribution of the data.

The quality of the data in the groundwater database is affected by two factors: a) the technical training of the persons collecting the data, and b) the quality control of the data. The possible options to upgrade the database include the creation of a “super” database, which would include only verified data. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. An attempt to update the quality of the entire database is not recommended.

There is a shortage of lithologic information for township 055, range 14, W4M. There is not one control point for the bedrock surface in the entire township. Additional data are required to better define the bedrock surface and aquifers present.

The present analysis has shown that the groundwater flow through the aquifers is more than the amount authorized for diversion by AEP. However, because this analysis is based on a regional study, the results should be considered no more than an indication. It is recommended that a detailed study be completed to assess the volume of groundwater flowing through at least the *continental* Foremost Formation. The study would need to obtain all of the data for individual water wells authorized to divert groundwater from the *continental* Foremost Aquifer, document the quantity of groundwater being diverted, establish the water-level trends, and evaluate the hydraulic parameters for the Aquifer. The best method to analyze the data would be through the use of a computer model study.

One of the main shortages of data for the determination of a groundwater budget is water levels as a function of time. There are only four AEP observation-water-well data sources in the County from which to obtain water levels for the groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View, for example, water well owners are being provided with a tax credit if they accurately measure the water level in their water well once per week for a year. A pilot project indicated that approximately five years of records are required to obtain a reasonable data set. The cost of a five-year project involving 50 water wells would be less than the cost of one drilling program that may provide two or three observation water wells.

In general, for the next level of study, the database needs updating. It requires more information from existing water wells, and additional information from new ones.

Before an attempt is made to upgrade the level of interpretation provided in this report and the accompanying maps and groundwater query, it is recommended that all water wells for which water well drilling reports are available be subjected to the following actions:

1. The horizontal location of the water well should be determined within ten metres. The coordinates must be in 10TM NAD 27 or some other system that will allow conversion to 10TM NAD 27 coordinates.
2. A four-hour aquifer test (two hours of pumping and two hours of recovery) should be performed with the water well to obtain a realistic estimate for the transmissivity of the aquifer in which the water well is completed.
3. Water samples should be collected for chemical analysis after 5 and 115 minutes of pumping, and analyzed for major and minor ions.

In addition to the data collection associated with the existing water wells, all available geophysical logs should be interpreted to establish a more accurate spatial definition of individual aquifers.

There is also a need to provide the water well drillers with feedback on the reports they are submitting to the regulatory agencies. The feedback is necessary to allow for a greater degree of uniformity in the reporting process. This is particularly true when trying to identify the bedrock surface. The water well drilling reports should be submitted to the AEP Resource Data Division in an electronic form. The money presently being spent by AEP and Prairie Farm Rehabilitation Administration (PFRA) to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

An effort should be made to form a partnership with the petroleum industry. The industry spends millions of dollars each year collecting information relative to water wells. Proper coordination of this effort could provide significantly better information from which future regional interpretations could be made. This could be accomplished by the County taking an active role in the activities associated with the construction of lease sites for the drilling of hydrocarbon wells and conducting of seismic programs.

Groundwater is a renewable resource and it must be managed.

9 REFERENCES

Carrigy, M. A. 1971. Lithostratigraphy of the Uppermost Cretaceous (Lance) and Paleocene Strata of the Alberta Plains. Research Council of Alberta. Bulletin 27.

Currie, D. V. and N. Zacharko. 1976. Hydrogeology of the Vermilion Area, Alberta. Alberta Research Council. Report 75-5.

Geoscience Consulting Ltd. March 1976. Evaluation of Water Supply. Two Hills, Alberta. Prepared for Alberta Environment.

Geoscience Consulting Ltd. November 1980. Water Well Test Drilling Program. Two Hills, Alberta. August-September, 1980. Prepared for the Town of Two Hills.

Hackbarth, D. A. 1975. Hydrogeology of the Wainwright Area, Alberta. Earth Sciences Report No. 75-1. Alberta Research Council.

Hydrogeological Consultants Ltd. November 1991. Highland View Farms Ltd. Vegreville Area. 1991 Aquifer Testing Program. NW 27-054-14 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. August 1993. Highland View Farms Ltd. Vegreville Area. 1993 Aquifer Testing Program. NW 26-054-14 W4M. Unpublished Contract Report.

Hydrogeological Consultants Ltd. January 1997. Highland Feeders Limited. Vegreville Area. SW 34-054-14 W4M. 1996 Groundwater Evaluation. Unpublished Contract Report.

Hydrogeological Consultants Ltd. June 1998. Highland Feeders Limited. Vegreville Area. Tp 054, R 14, W4M. 1997 Annual Groundwater Monitoring Report. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Highland Feeders Limited. Vegreville Area. Tp 054, R 14, W4M. 1998 Groundwater Program. Unpublished Contract Report (in progress).

Hydrogeological Consultants Ltd. October 1995. TDI Projects Inc. Alberta Agri Ethanol Ltd. Two Hills Area. 04-055-11 W4M. Groundwater Prognosis. Unpublished Contract Report.

Hydrogeological Consultants Ltd. January 1996. Alberta Agri-Ethanol Co. Ltd. Two Hills Area. 04-055-11 W4M. Groundwater Exploration Phase. Unpublished Contract Report.

Hydrogeological Consultants Ltd. Alberta Agri-Ethanol Co. Ltd. Two Hills Area. Tp 054, R 11 W4M. 1996 Vermilion Lakes Aquifer Investigation. Unpublished Contract Report (in progress).

Mossop, G. and I. Shetsen (co-compilers). 1994. Geological Atlas of the Western Canada Sedimentary Basin. Produced jointly by the Canadian Society of Petroleum Geology, Alberta Research Council, Alberta Energy, and the Geological Survey of Canada.

Osachuk, T. N. Patrick. August 1994. County of Two Hills #21. CAESA Drilling Summary Assessment. PFRA, Earth Sciences Division. Edmonton, AB. Unpublished Report.

Ozoray, G., M. Dubord and A. Cowen. 1990. Groundwater Resources of the Vermilion 73E Map Area, Alberta. Alberta Environmental Protection.

Pettijohn, F. J. 1957. Sedimentary Rocks. Harper and Brothers Publishing.

Shetsen, I. 1990. Quaternary Geology, Central Alberta. Produced by the Natural Resources Division of the Alberta Research Council.

Strong, W.L. and K. R. Legatt, 1981. Ecoregions of Alberta. Alta. En. Nat. Resour., Resour. Eval. Plan Div., Edmonton as cited in Mitchell, Patricia and Ellie Prepas (eds.). 1990. Atlas of Alberta Lakes. The University of Alberta Press. Page 12.

Thornthwaite, C. W. and J. R. Mather. 1957. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance. Drexel Institute of Technology. Laboratory of Climatology. Publications in Climatology. Vol. 10, No. 3, P. 181-289.

Toop, David C. 1995. Groundwater Supply Evaluation: County of Two Hills. Regarding: Alberta Agri-Ethanol Co. Ltd. Development Proposal. Prairie Farm Rehabilitation Administration Earth Sciences Division. Edmonton, AB. Unpublished Contract Report.

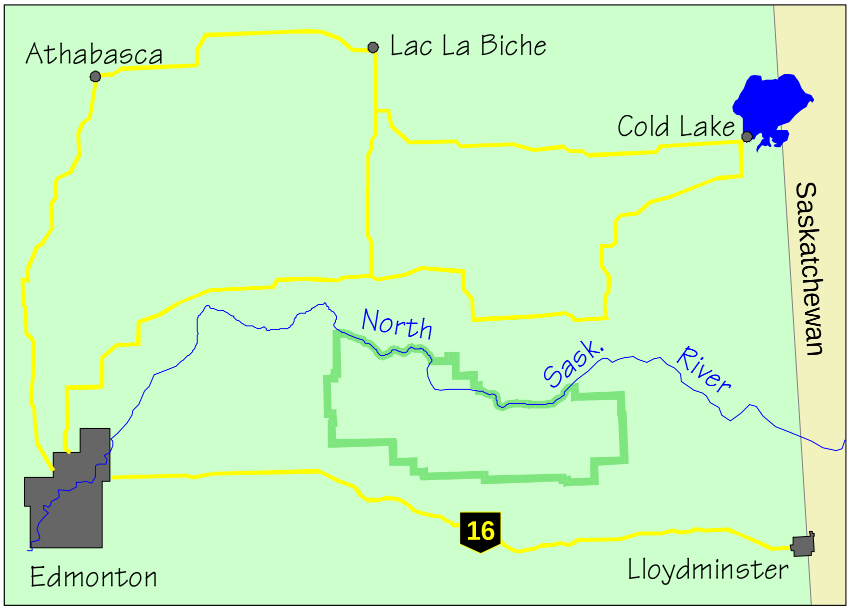
10 GLOSSARY

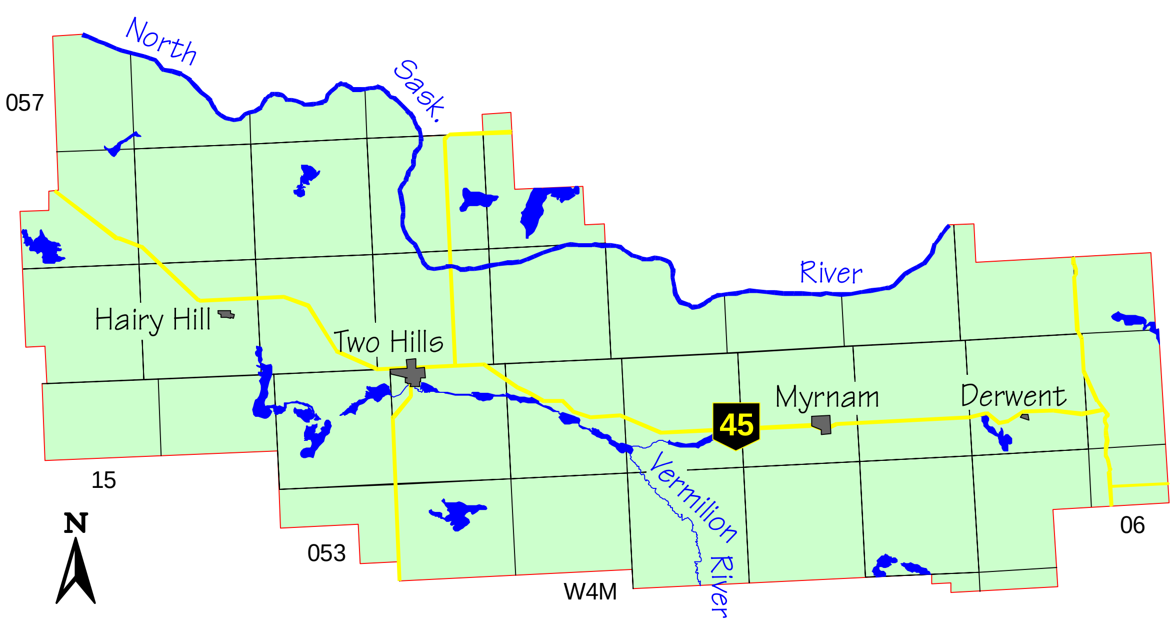
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities.
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer.
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer.
	in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer.
Facies	the aspect or character of the sediment within beds of one and the same age (Pettijohn, 1957).
Fluvial	produced by the action of a stream or river.
Friable	poorly cemented.
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time.
Kriging	a geo-statistical method for gridding irregularly-spaced data.
Lacustrine	fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits.
Surficial Deposits	includes all sediments above the bedrock.
Transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer.
	Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings.
	Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test.
	Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer.
Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer.
	Apparent Yield: based mainly on apparent transmissivity.
	Long-Term Yield: based on effective transmissivity.

COUNTY OF TWO HILLS NO. 21
Appendix A

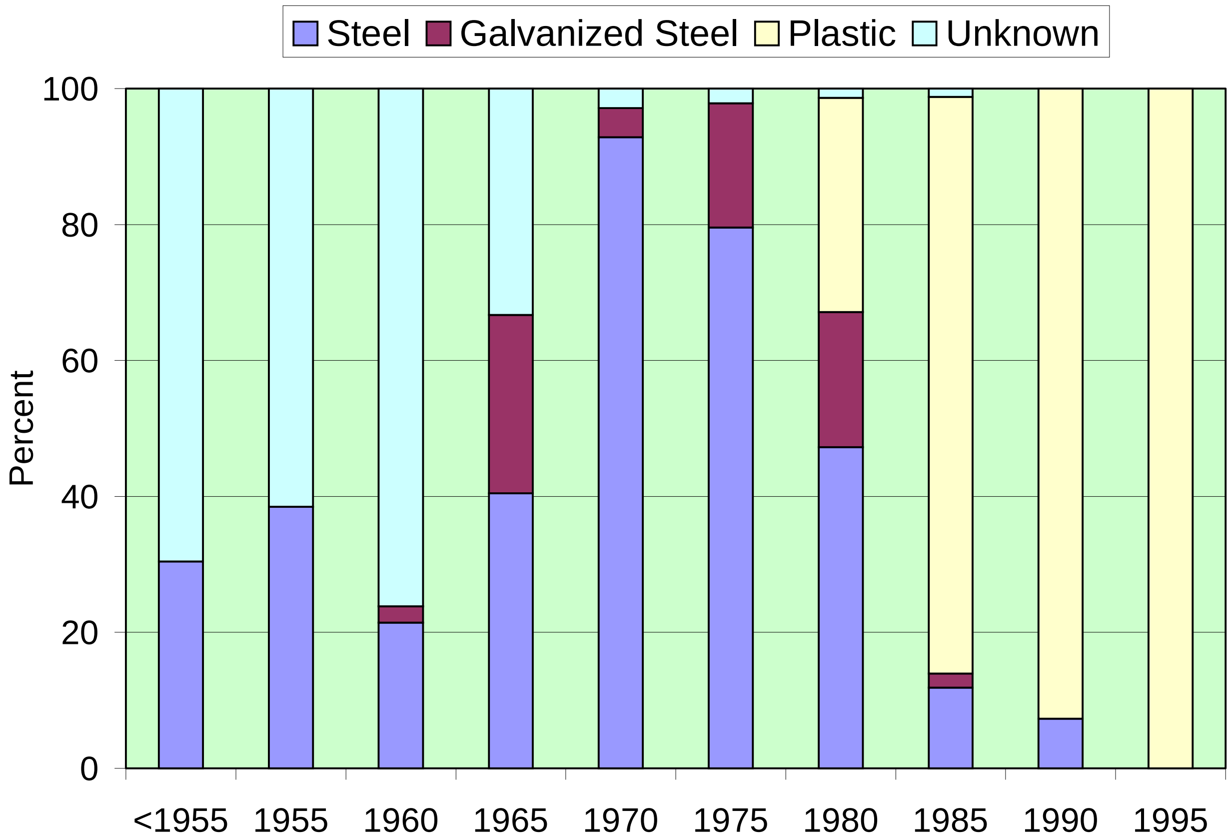
HYDROGEOLOGICAL MAPS AND FIGURES

Index Map

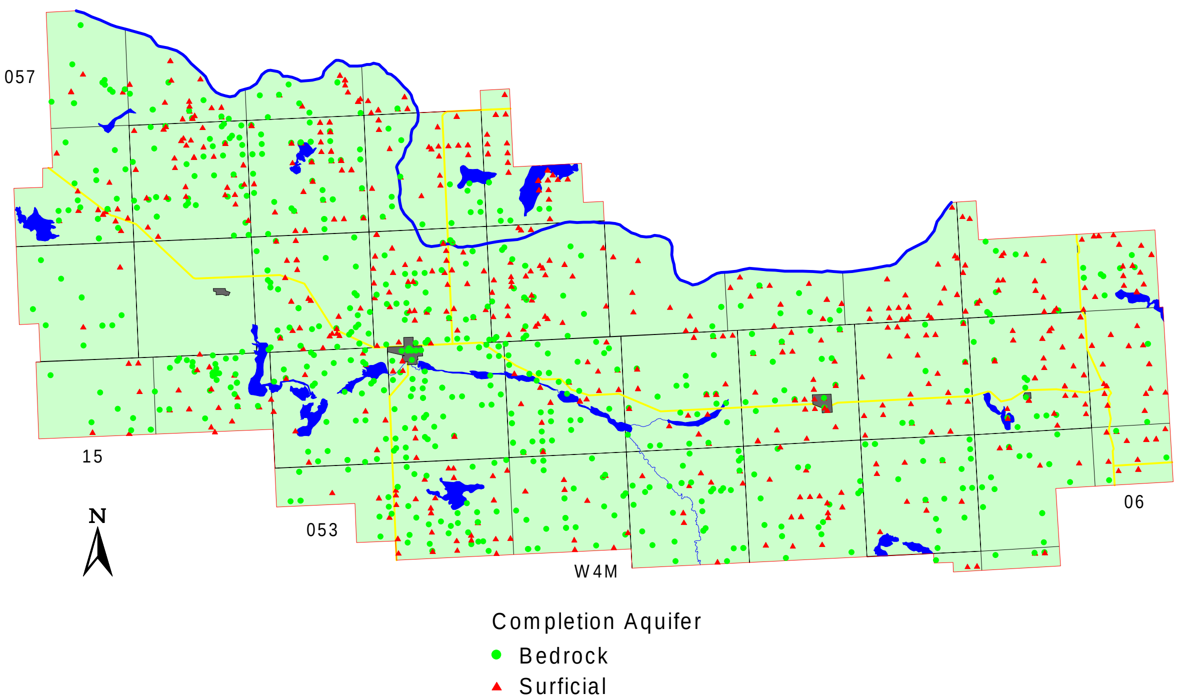

Athabasca
Lac La Biche
Cold Lake
Saskatchewan
North
Sask.
River
16
Edmonton
Lloydminster


North
Sask.
057
River
Hairy Hill
Two Hills
Myrnam
Derwent
45
15
N
053
W4M
Vermilion
River
06

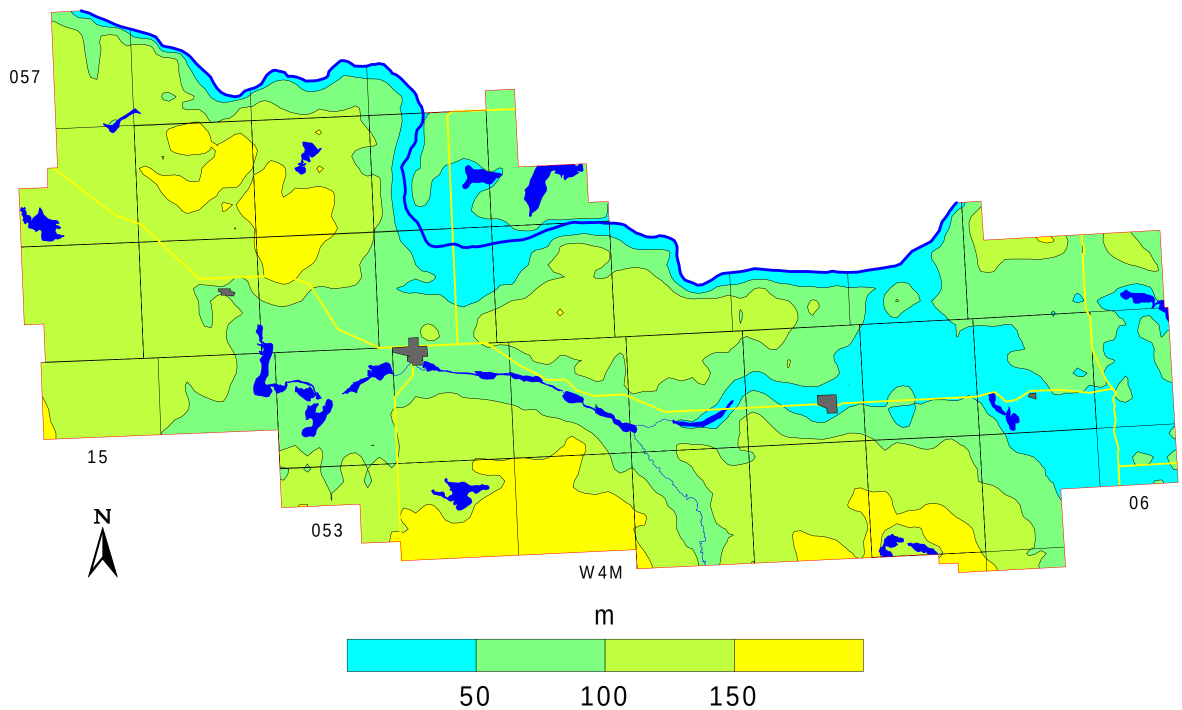
Surface Casing Types used in Drilled Water Wells

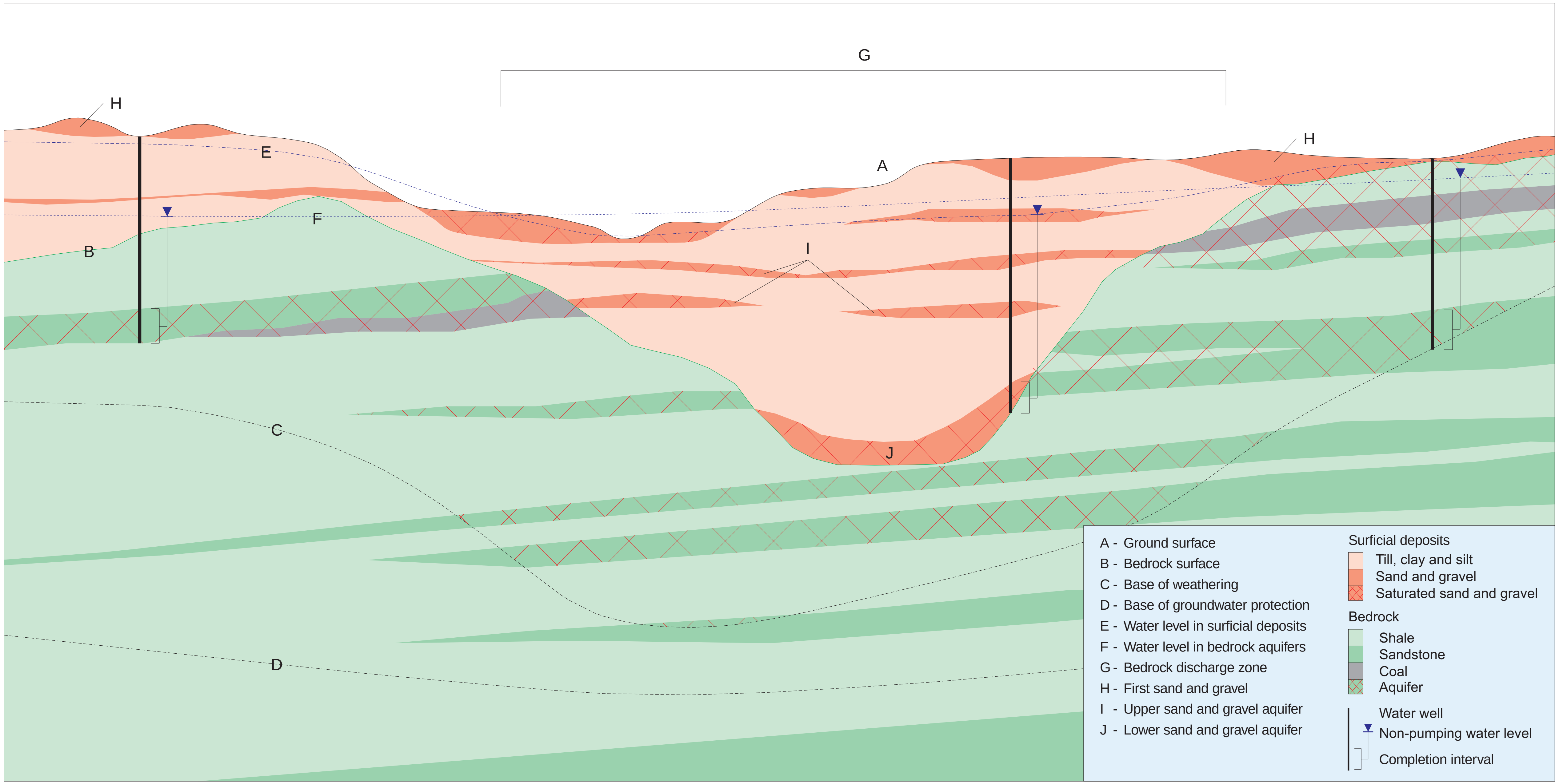


Location of Water Wells



Depth to Base of Groundwater Protection



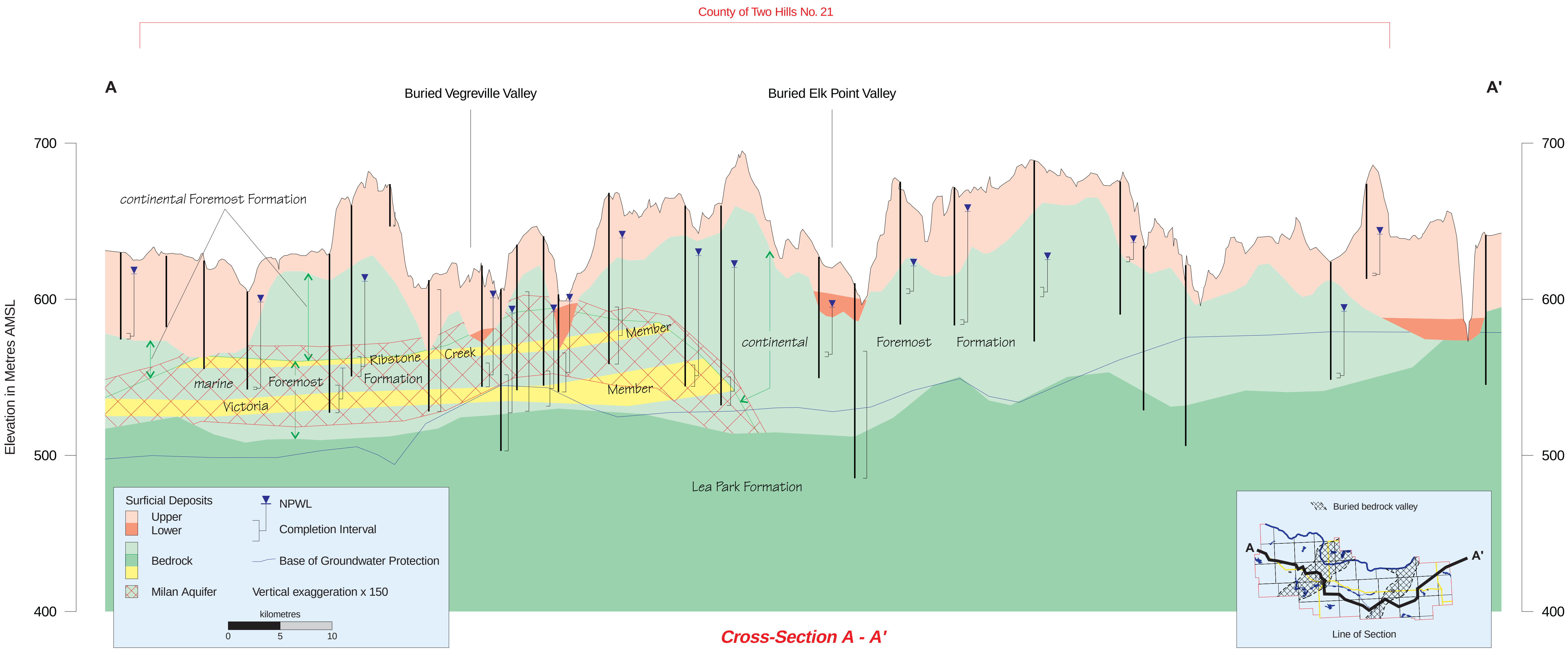


Generalized Cross-Section
(for terminology only)

Depth (m): 0, 100, 200, 300, 400, 500

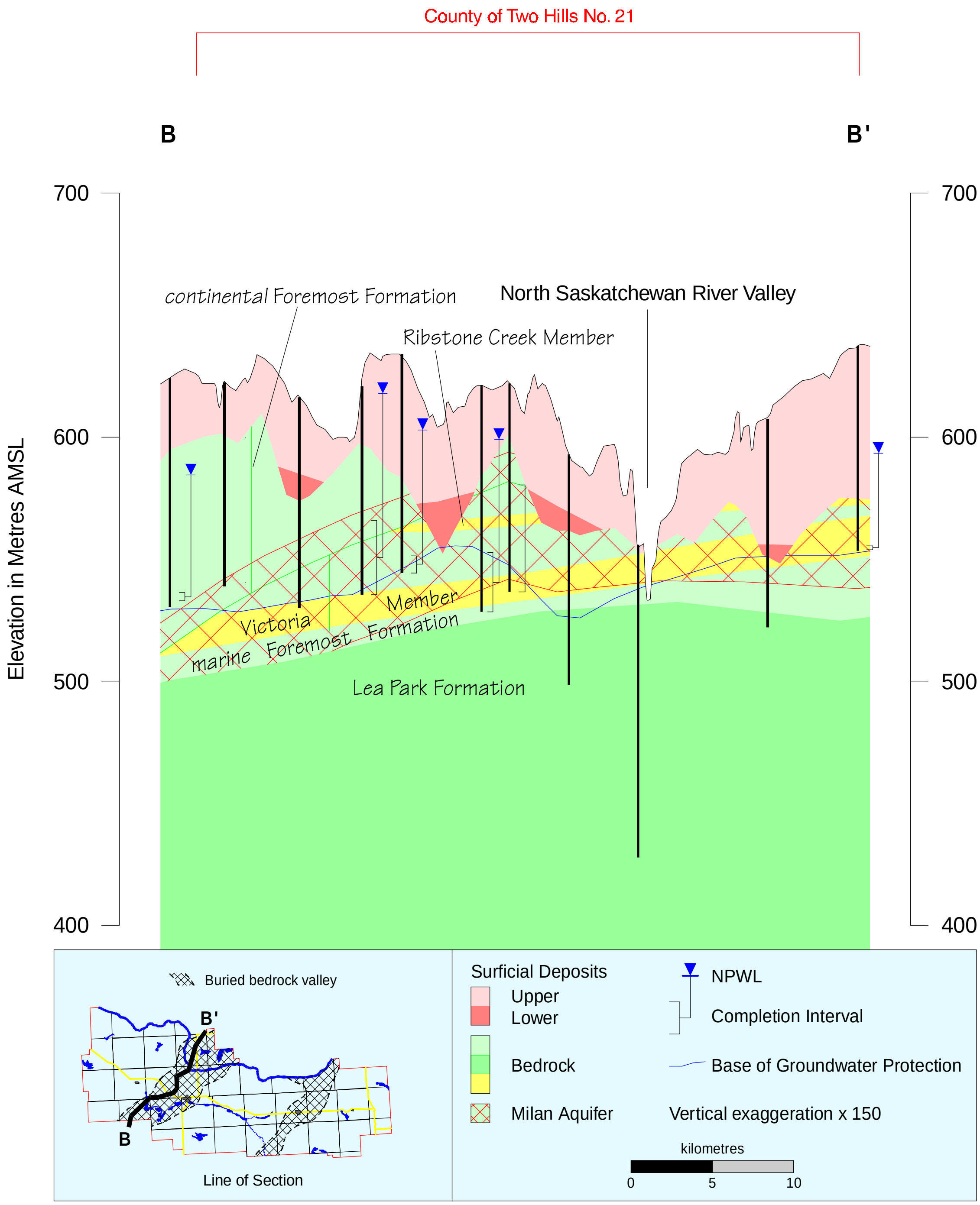
Lithologic Description	Group and Formation: Thickness (m)	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
sand, gravel, till, clay, silt	<70	Surficial Deposits	<70	Upper	<30	First Sand and Gravel
			<30	Lower		
sandstone, siltstone, shale, coal	40-80	Belly River Group – Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone
			<20	Upper Siltstone Member		
			8-20	Comrey Member		
shale, sandstone, coal	10-220	Belly River Group – *continental* Foremost Formation			<20	Taber Coal Zone
					<20	McKay Coal Zone
sandstone, shale	<200	Belly River Group – *marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		Milan Aquifer
			<30	Ribstone Creek Member		
			<30	Victoria Member		
			<30	Brosseau Member		
shale, siltstone	100-200	Lea Park Formation	50-100	Upper		
			50-100	Lower		

Geologic Column

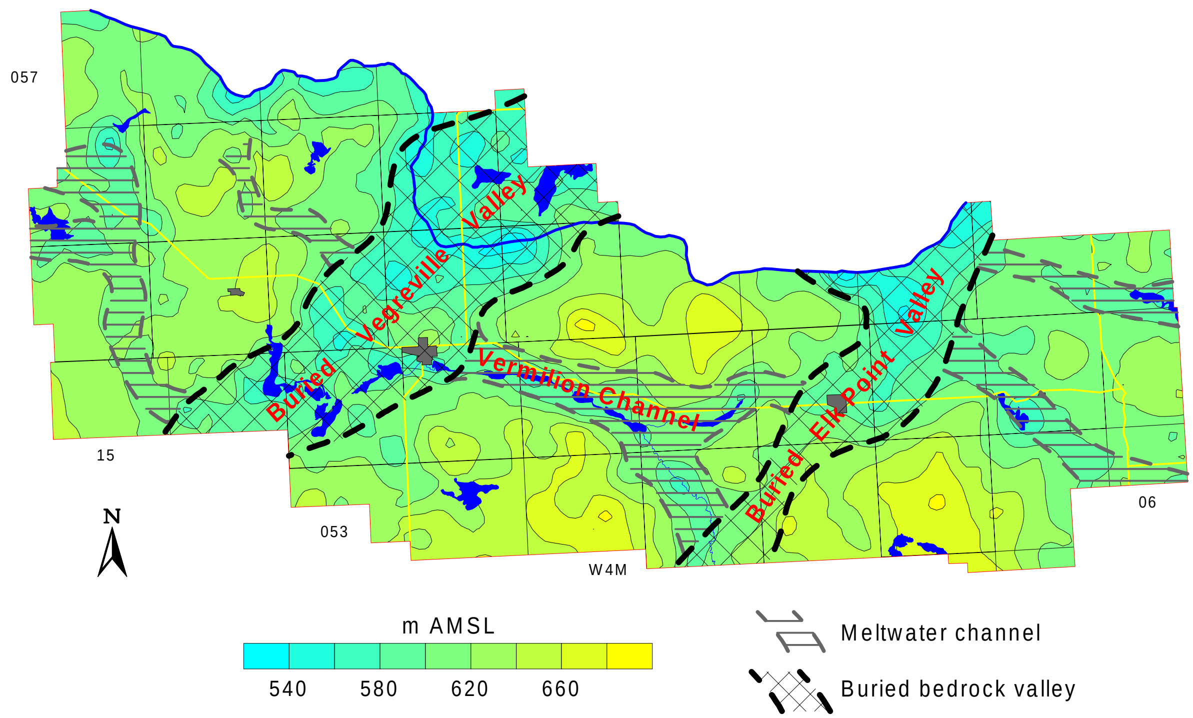


Cross-Section A - A'

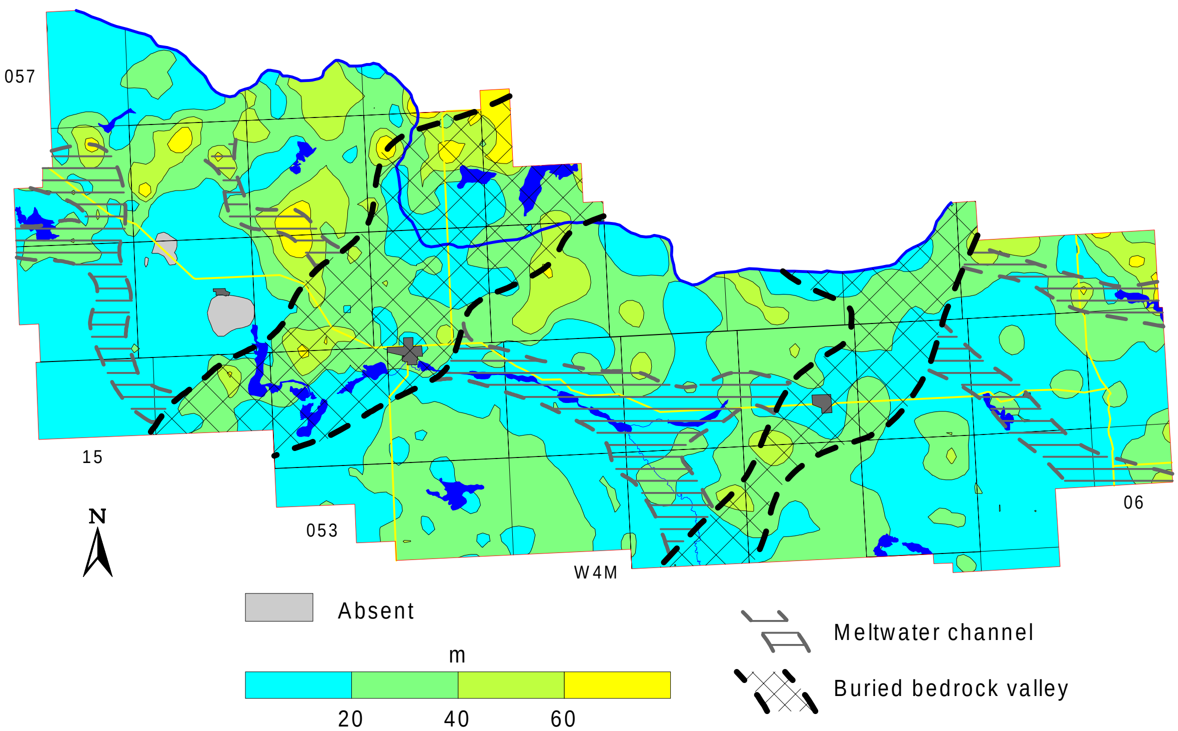
Cross-Section B - B'



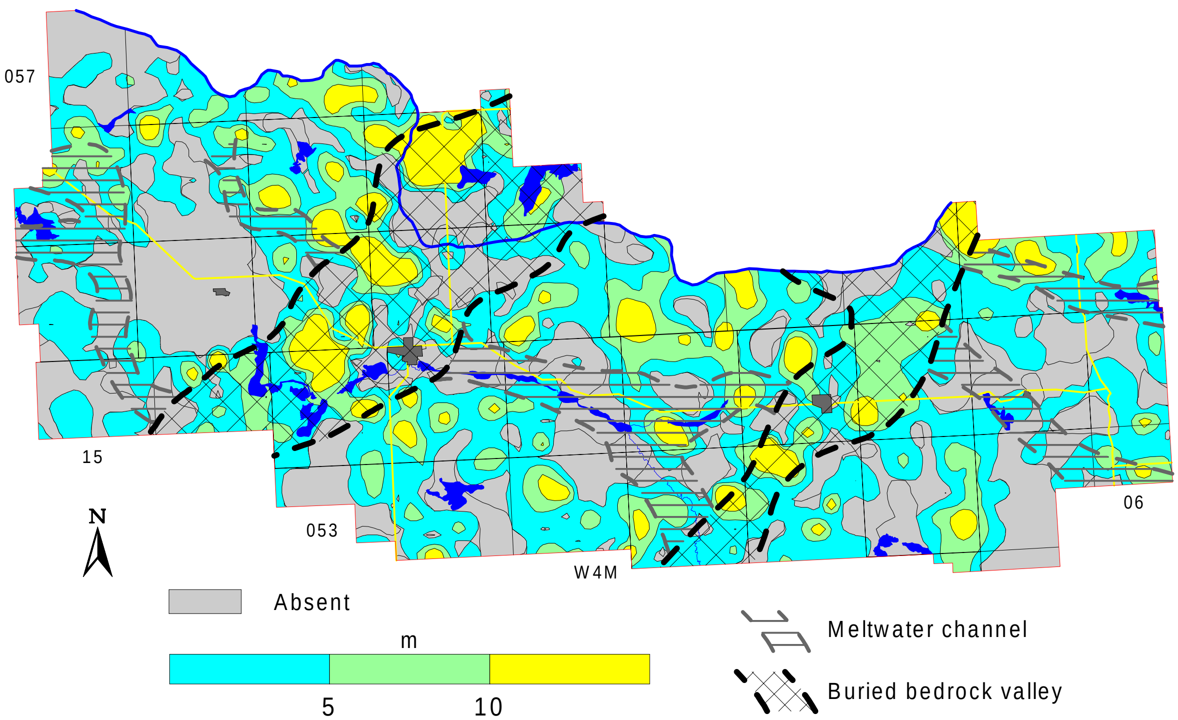
Bedrock Topography



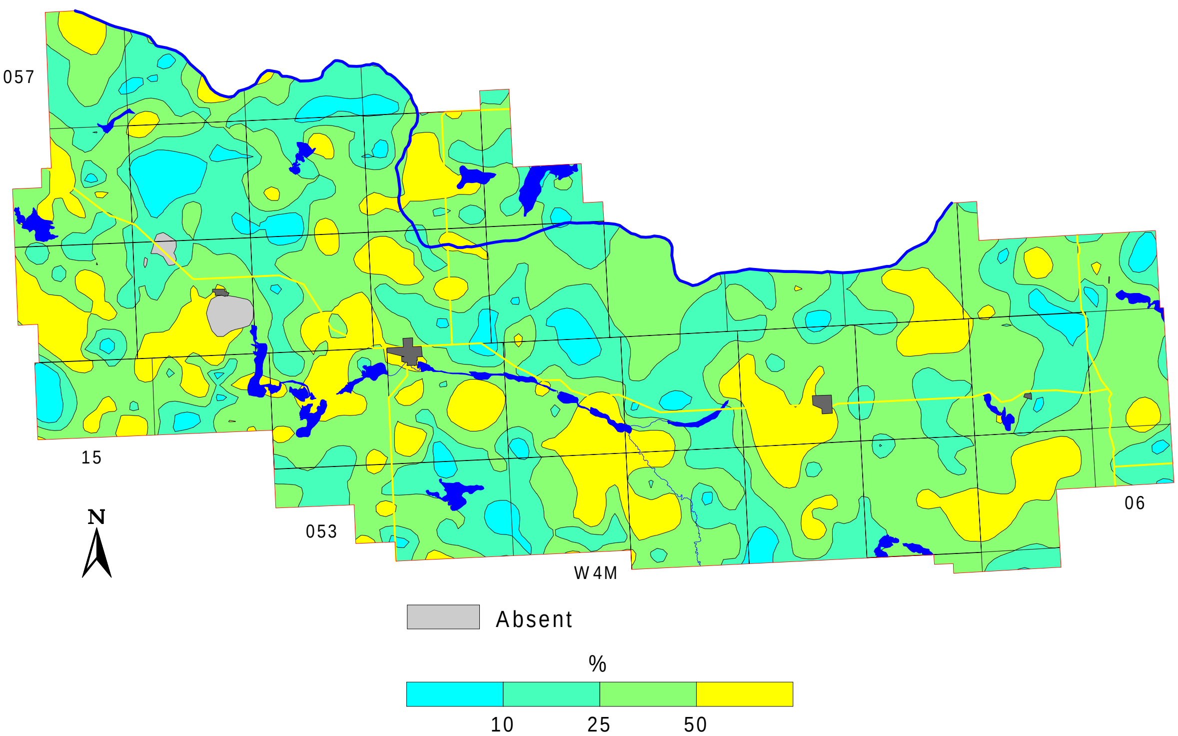
Thickness of Surficial Deposits



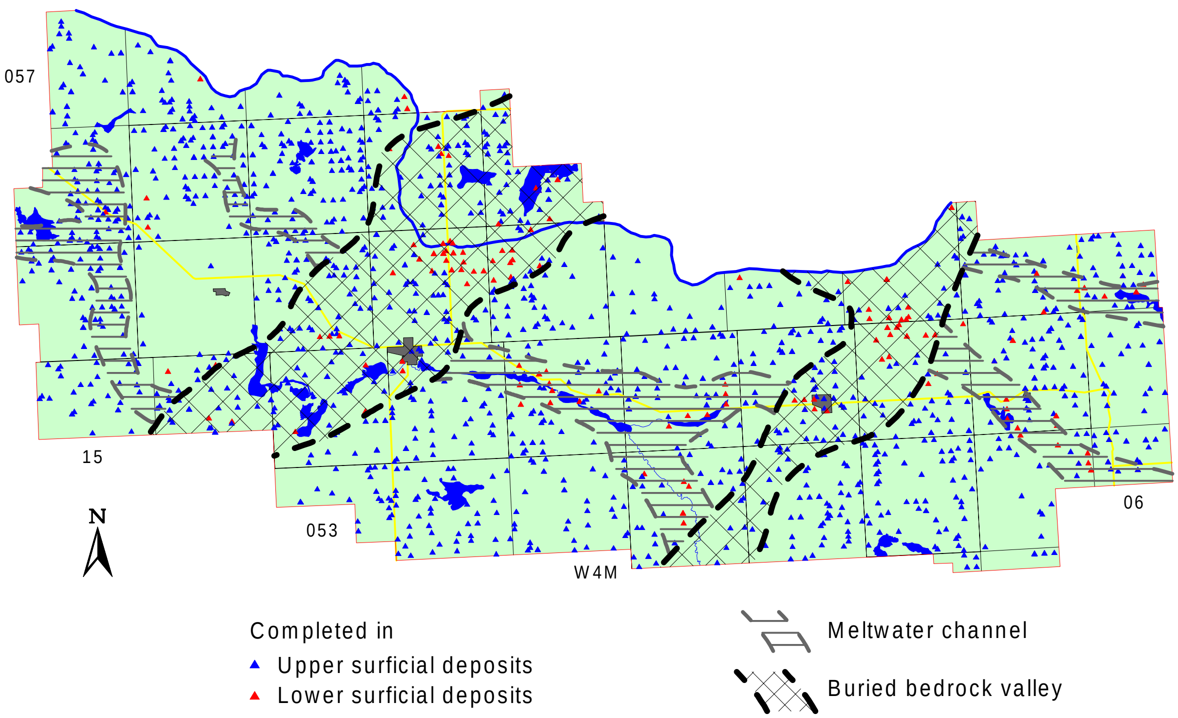
Thickness of Sand and Gravel Aquifer(s)



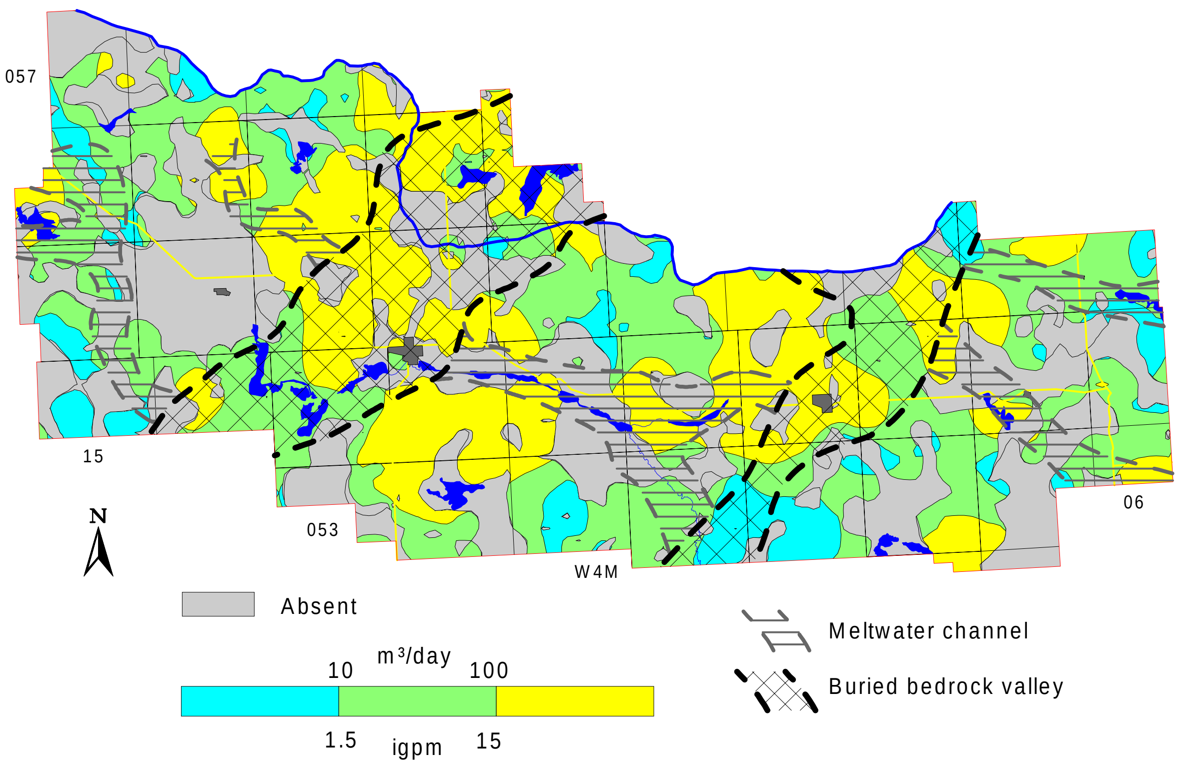
Amount of Sand and Gravel in Surficial Deposits



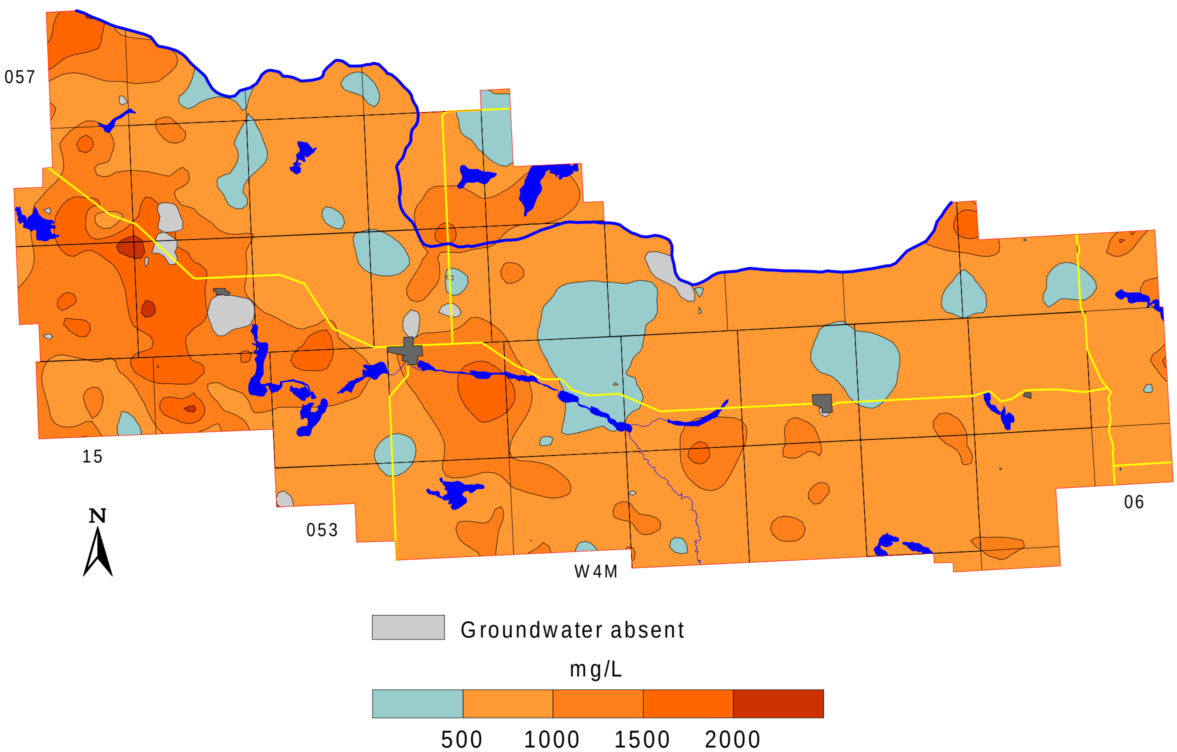
Water Wells Completed in Surficial Deposits



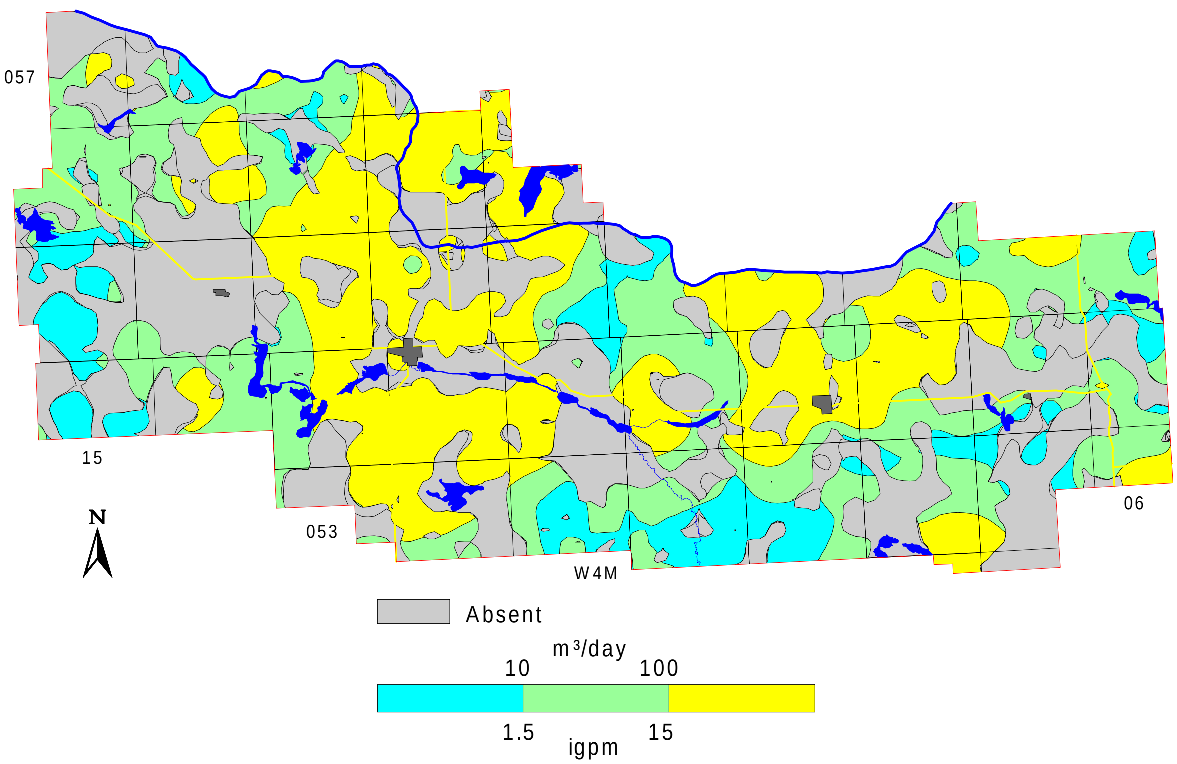
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



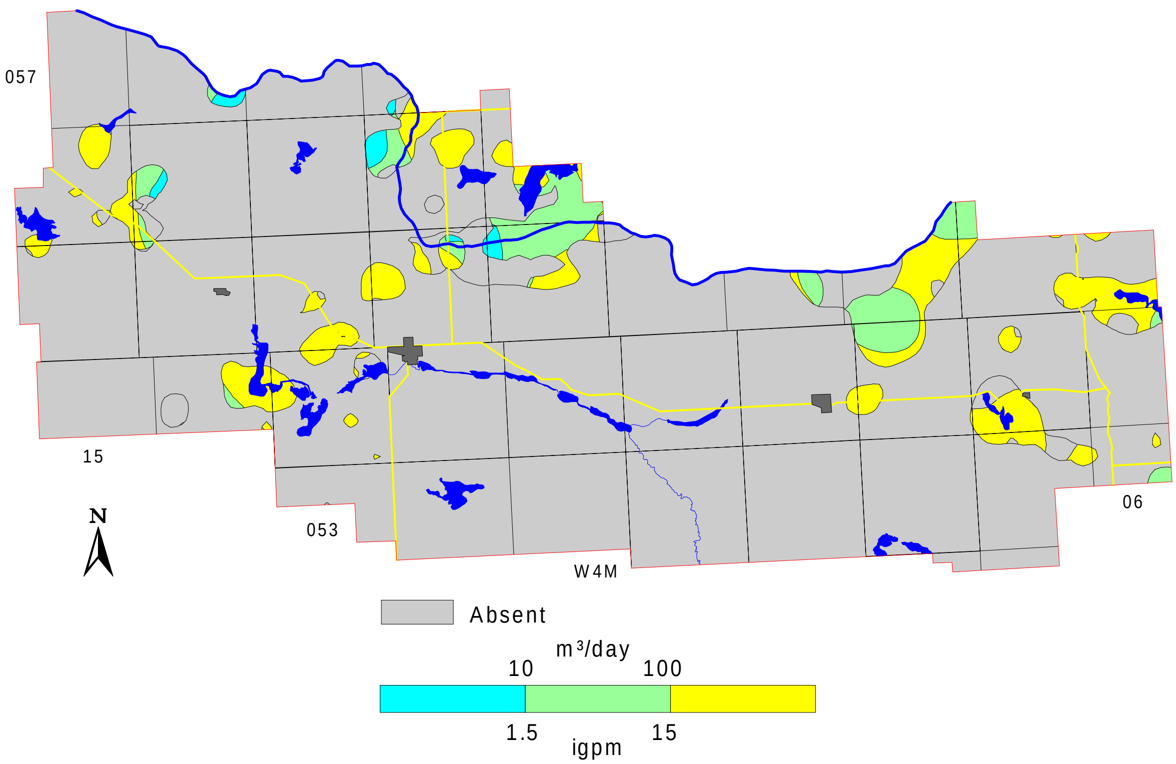
Total Dissolved Solids in Groundwater from Surficial Deposits



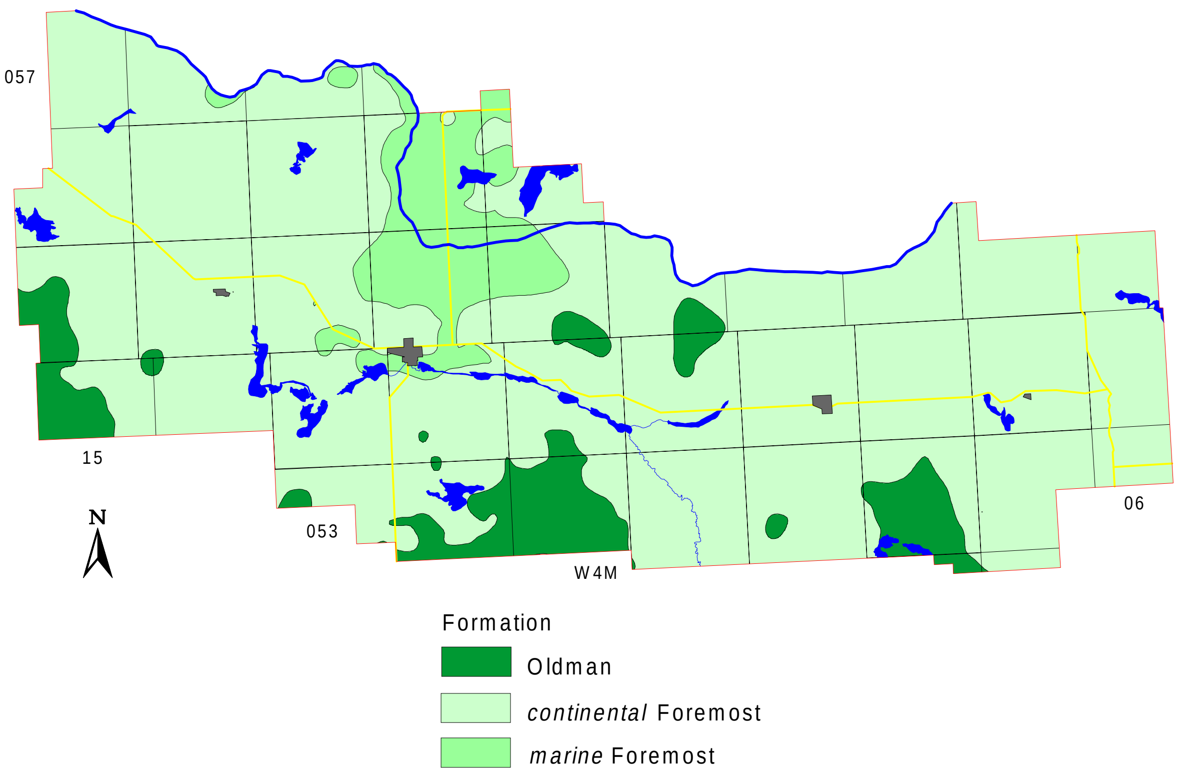
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



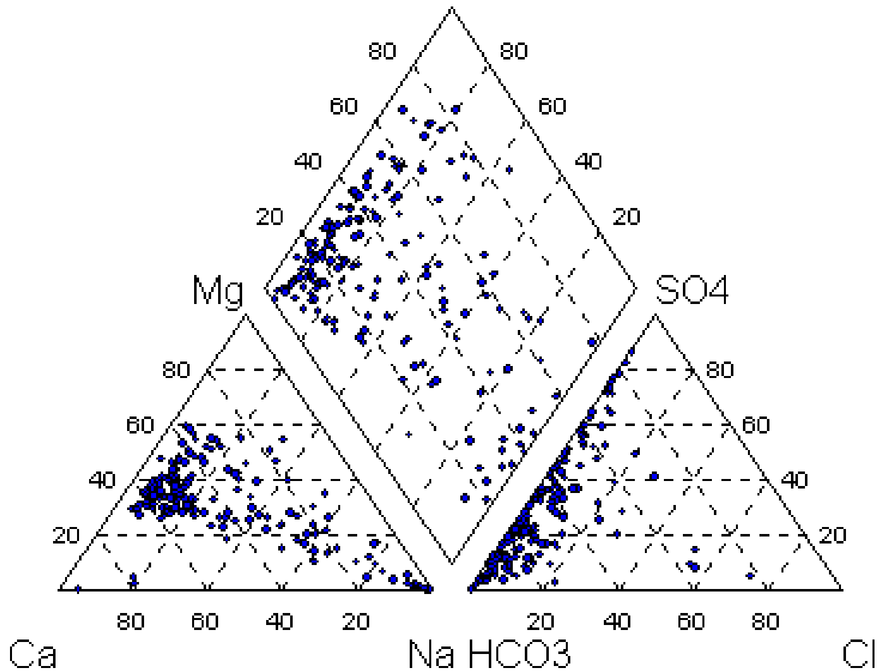
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



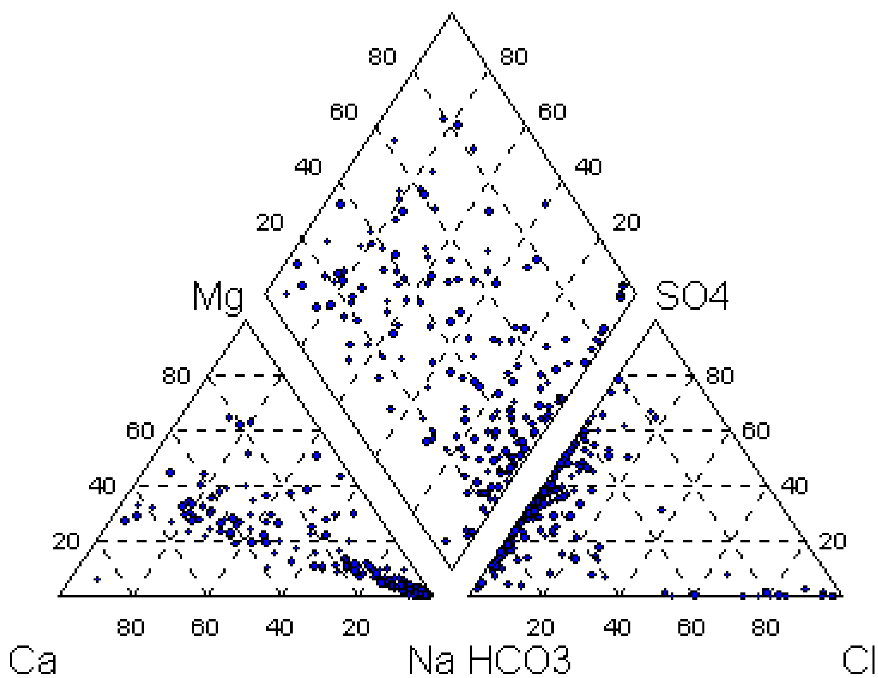
Bedrock Geology



Piper Diagrams

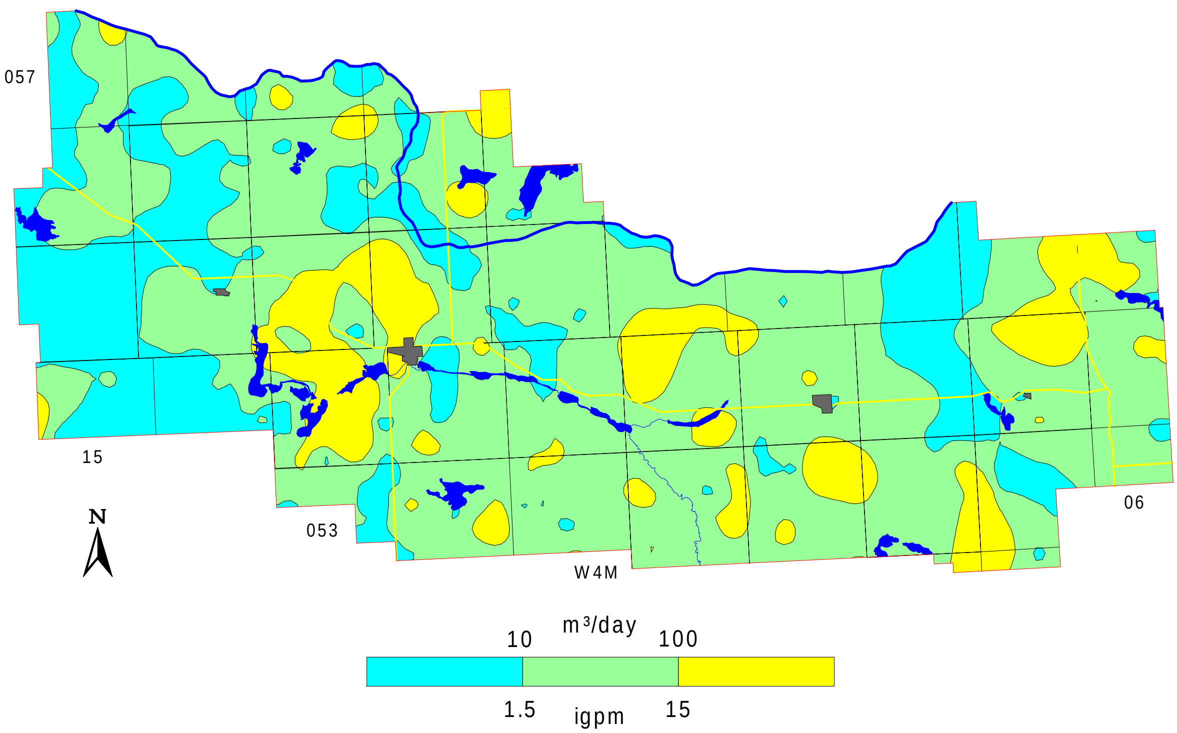


Surficial Deposits

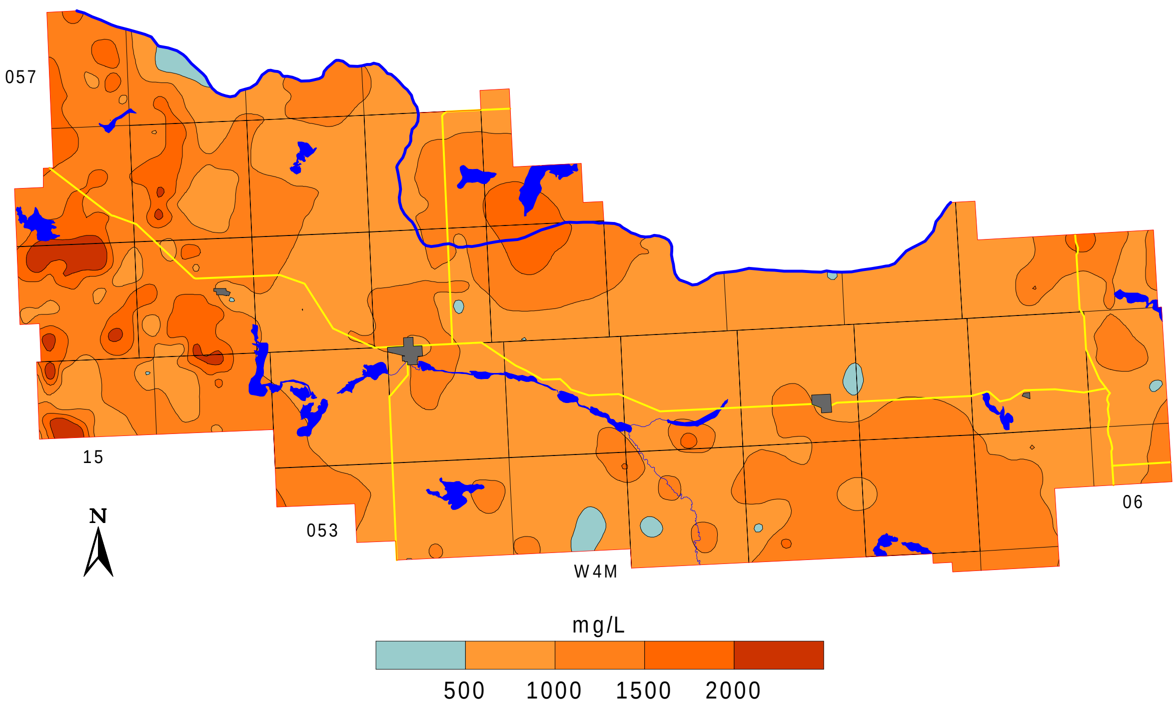


Bedrock Aquifers

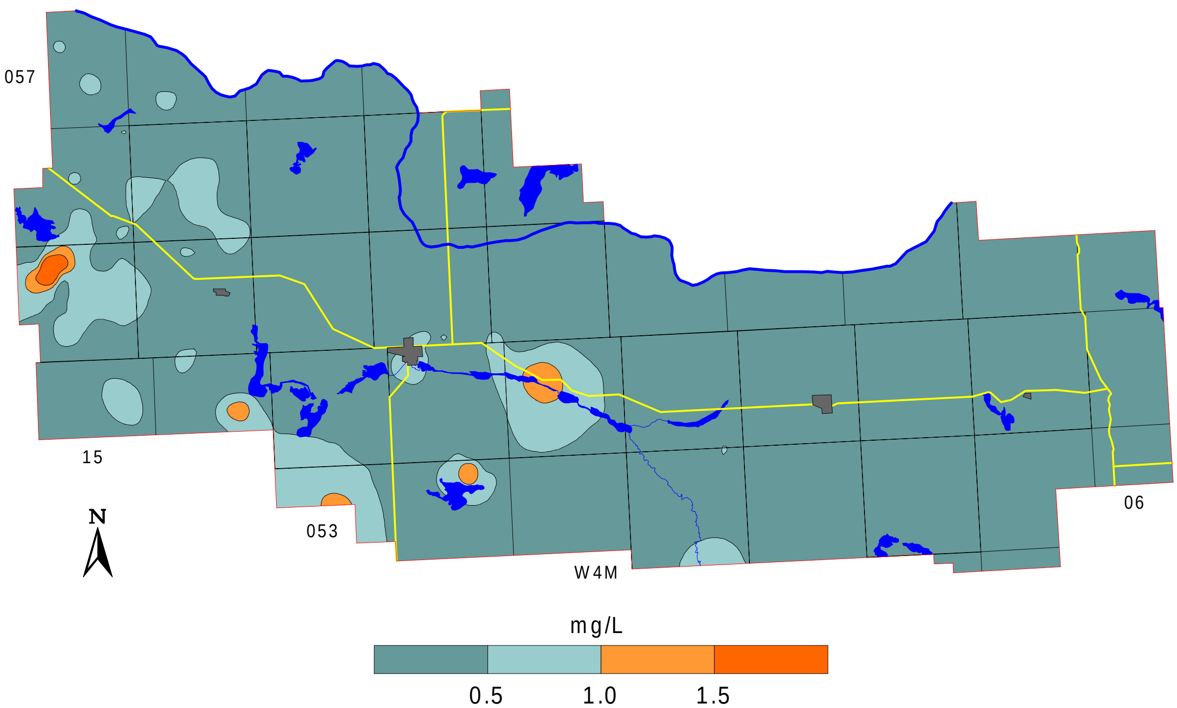
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



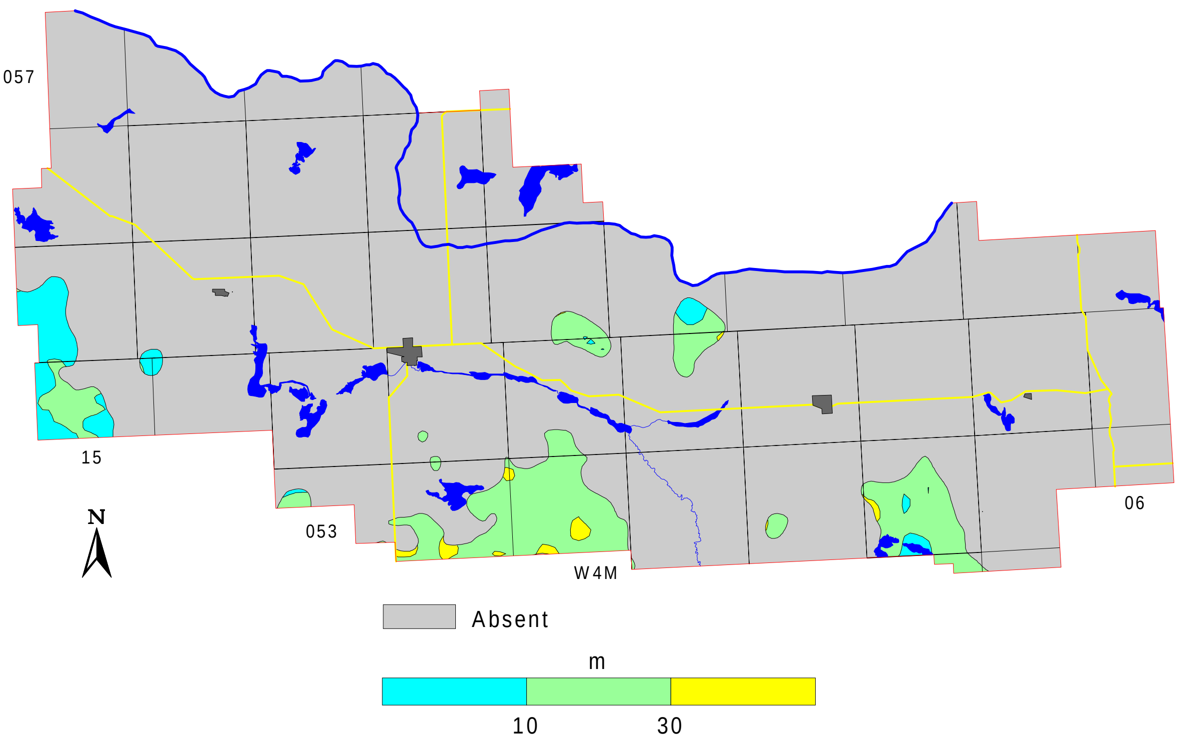
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



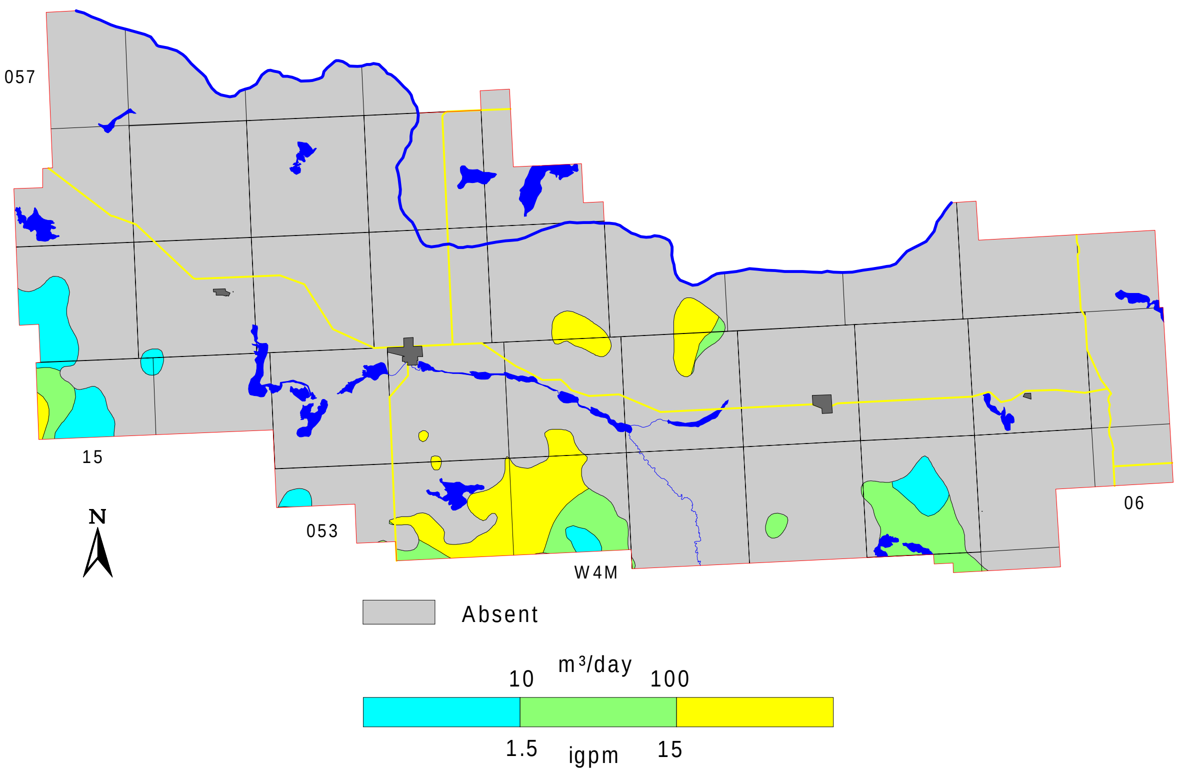
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



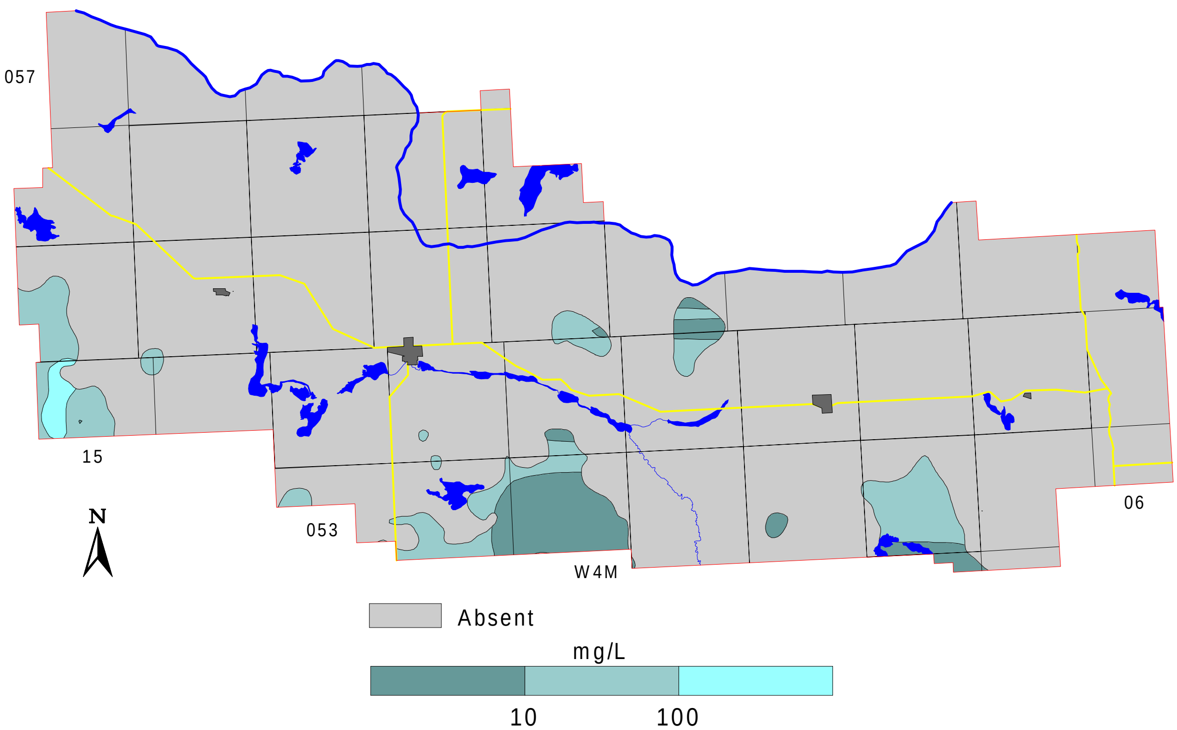
Depth to Top of Oldman Formation



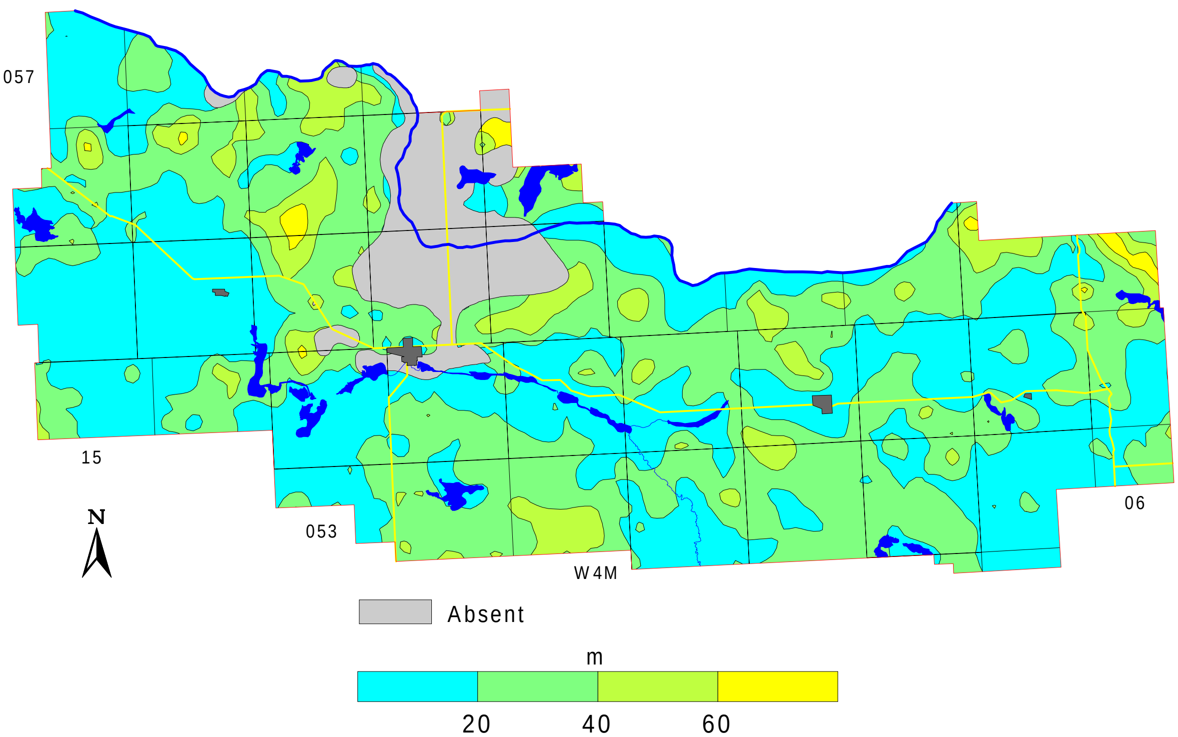
Apparent Yield for Water Wells Completed through Oldman Aquifer



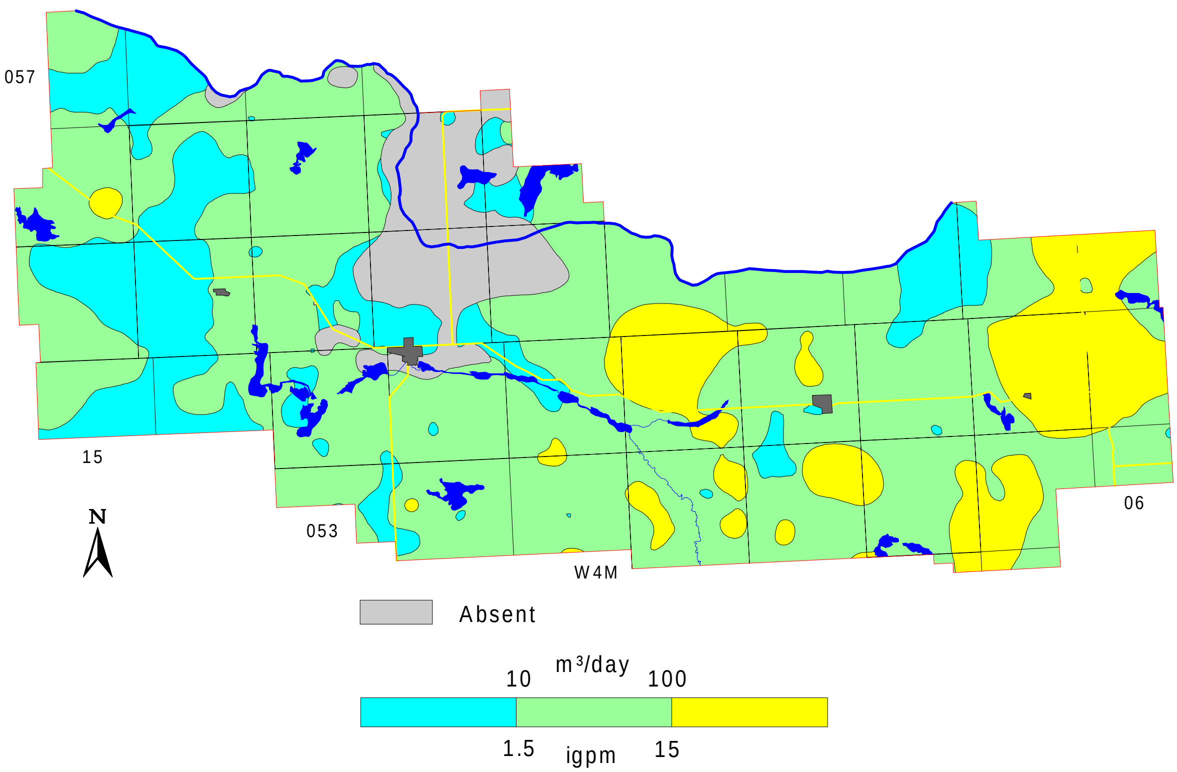
Chloride in Groundwater from Oldman Aquifer



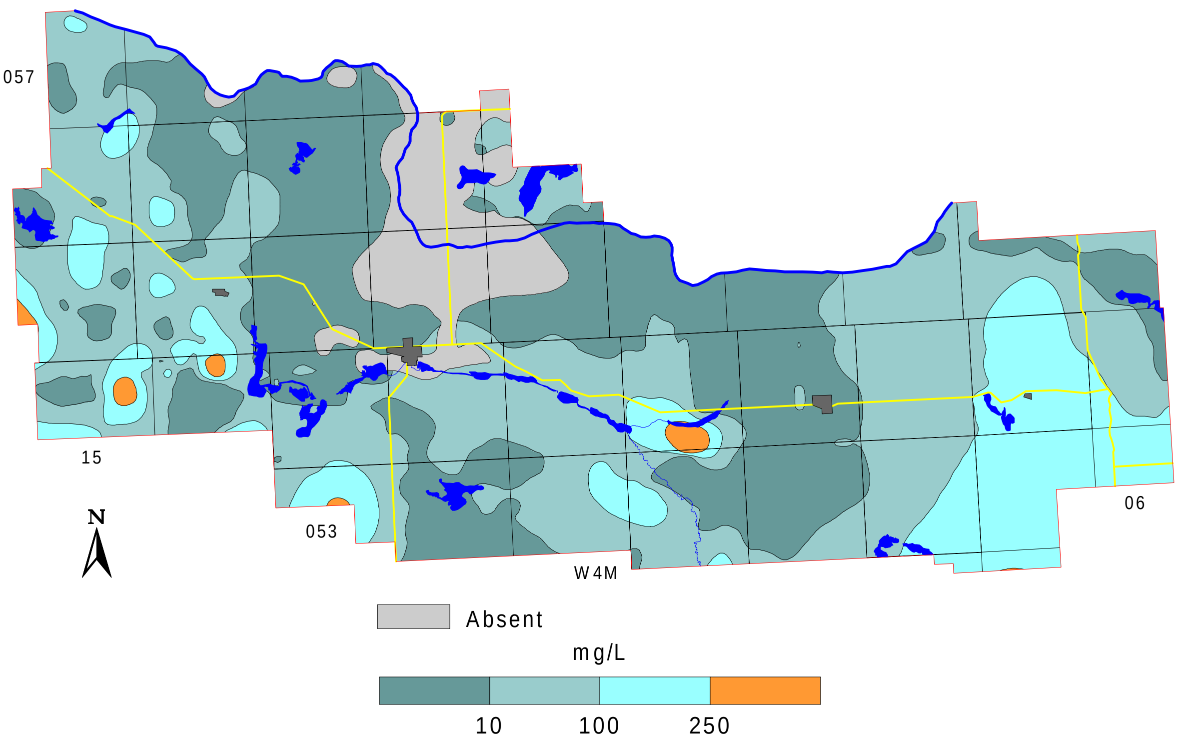
Depth to Top of continental Foremost Formation



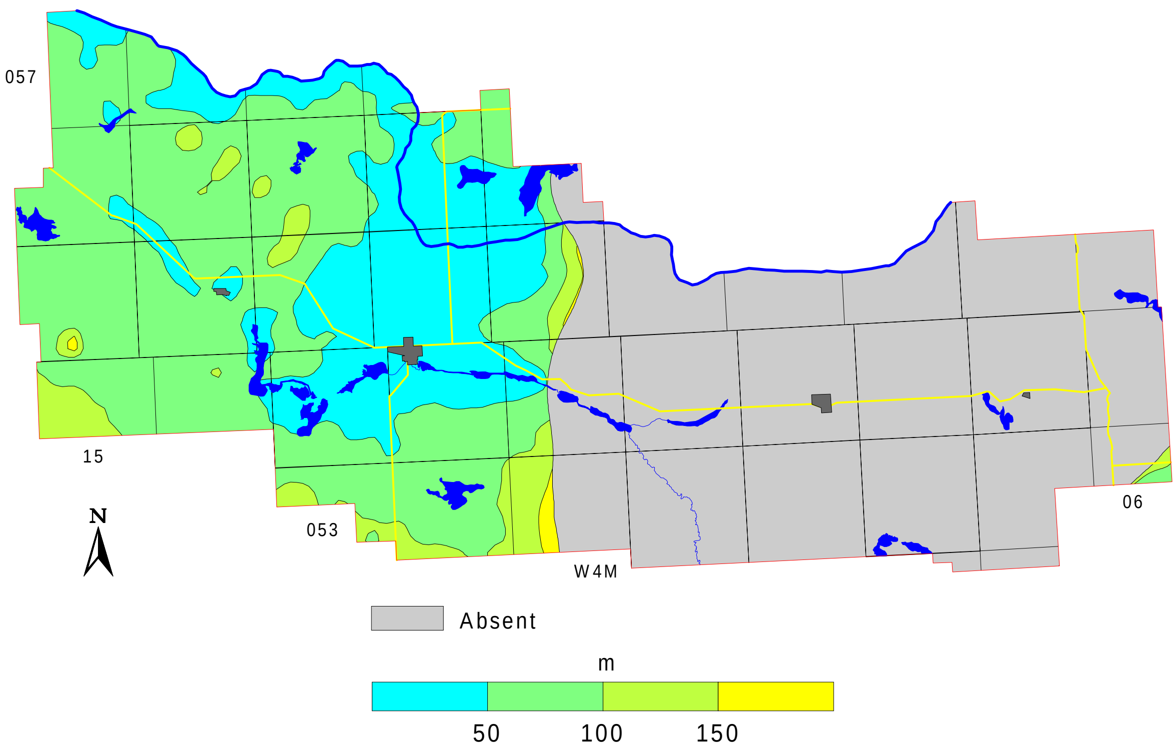
Apparent Yield for Water Wells Completed through continental Foremost Aquifer



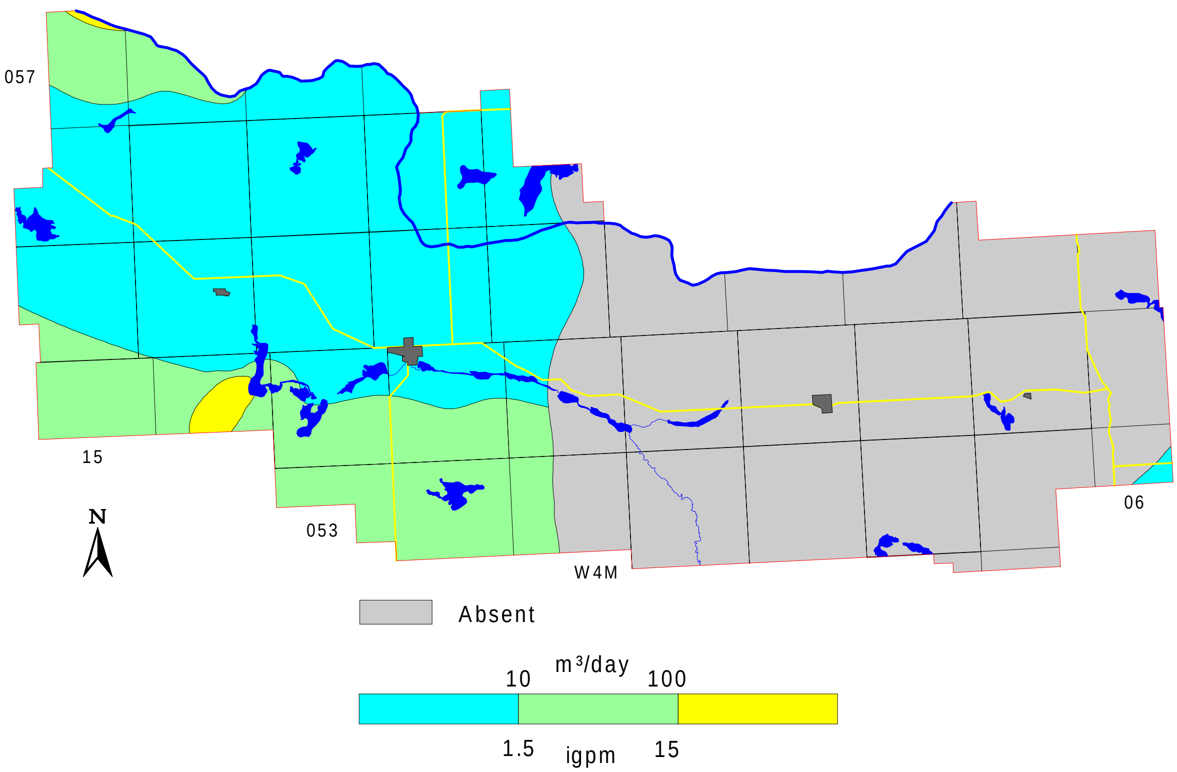
Chloride in Groundwater from continental Foremost Aquifer



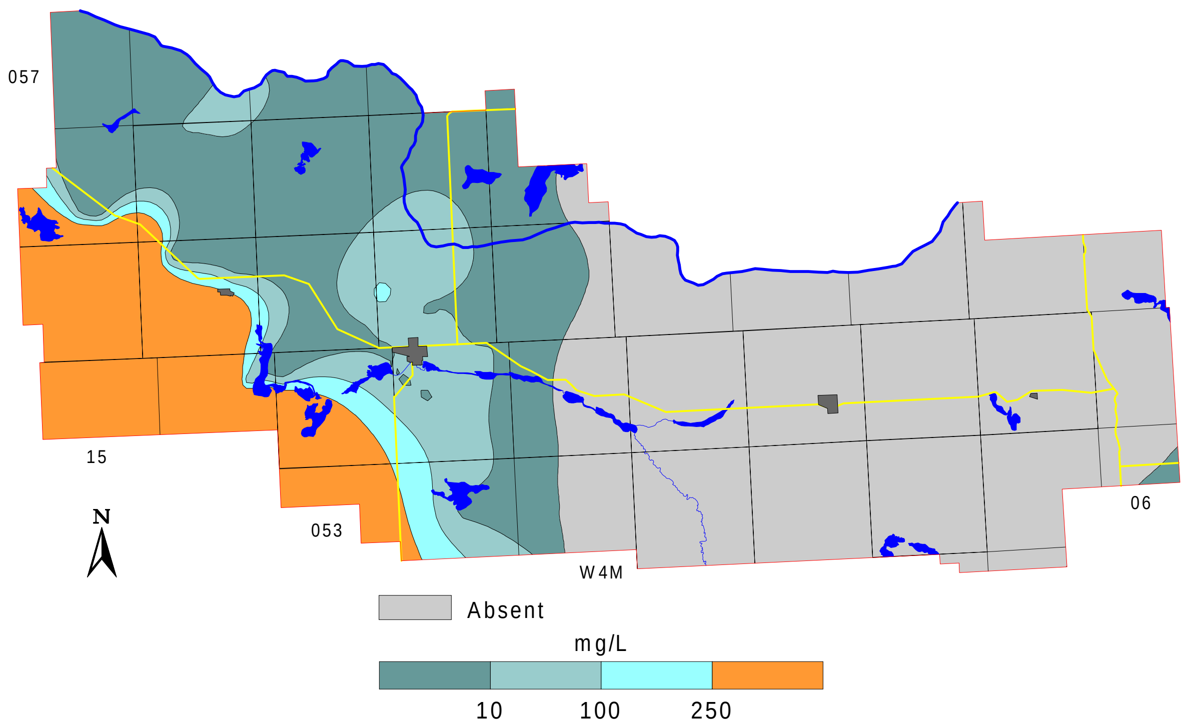
Depth to Top of Milan Aquifer



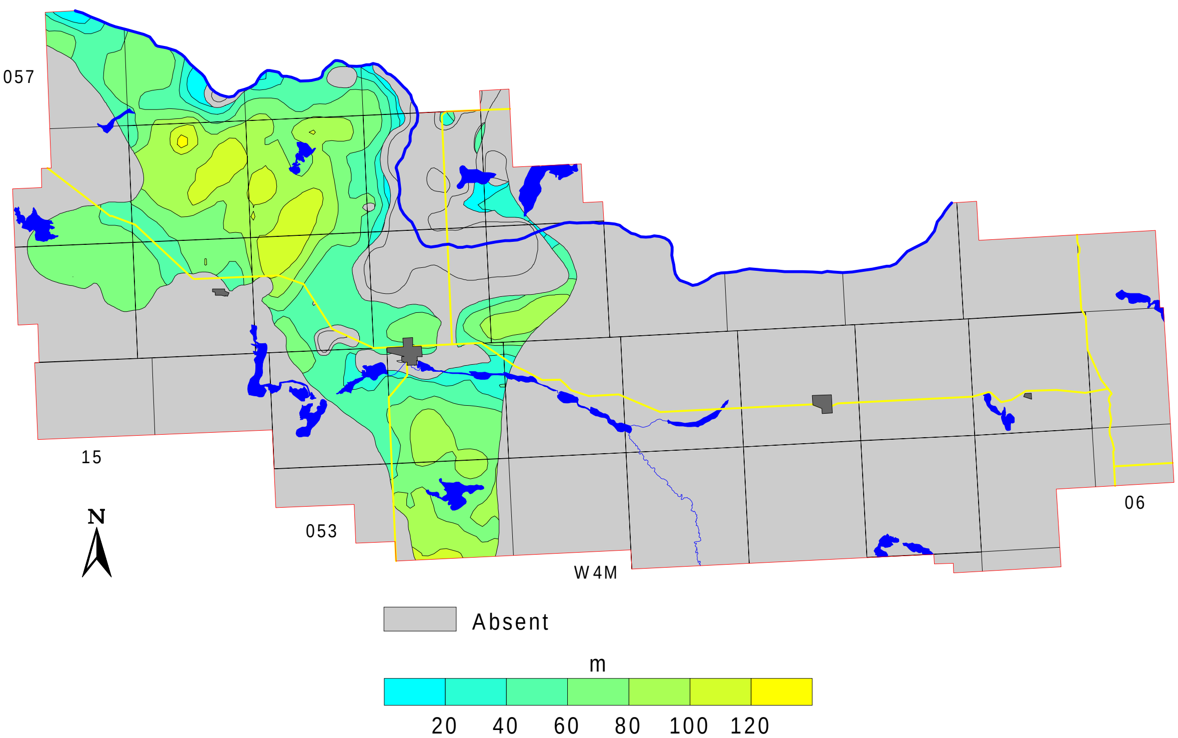
Apparent Yield for Water Wells Completed through Milan Aquifer



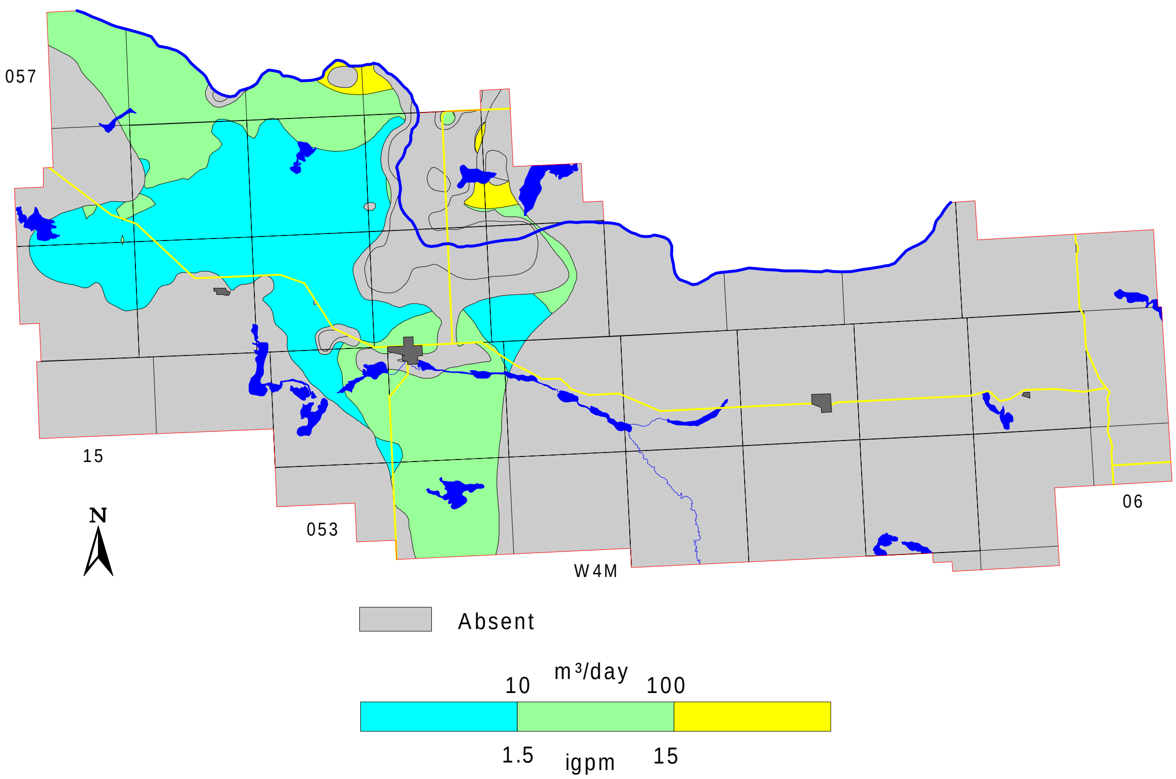
Chloride in Groundwater from Milan Aquifer



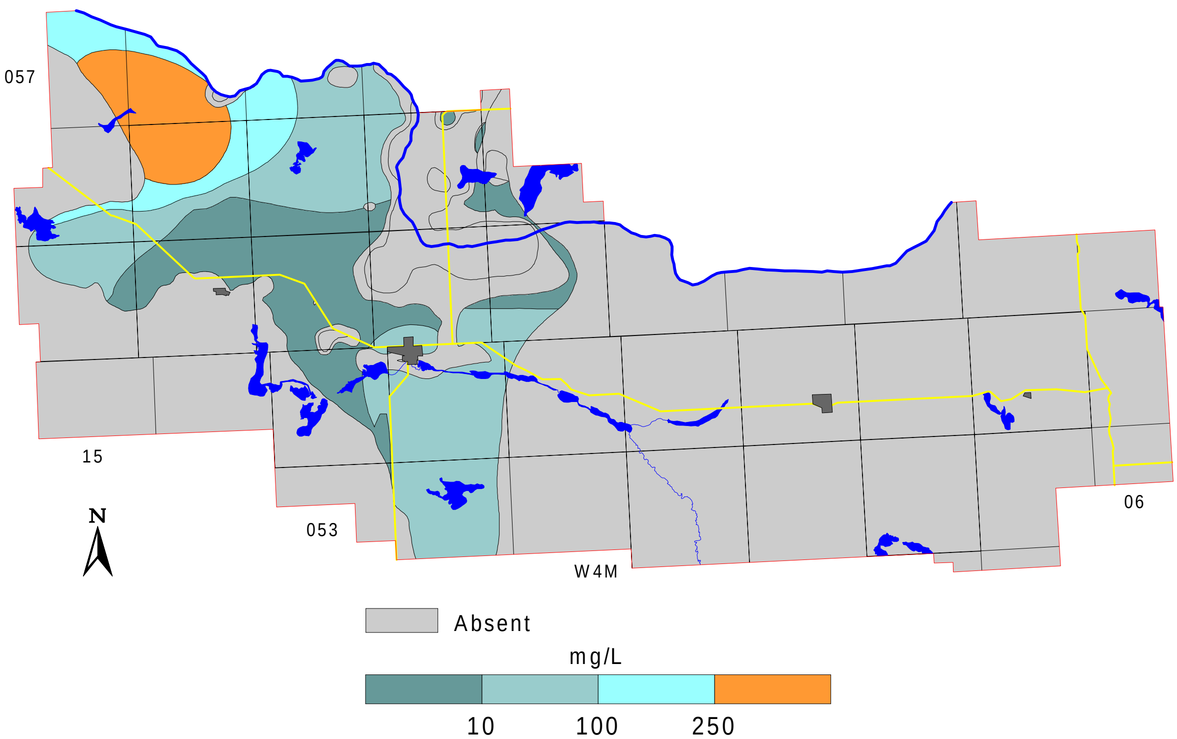
Depth to Top of Ribstone Creek Member



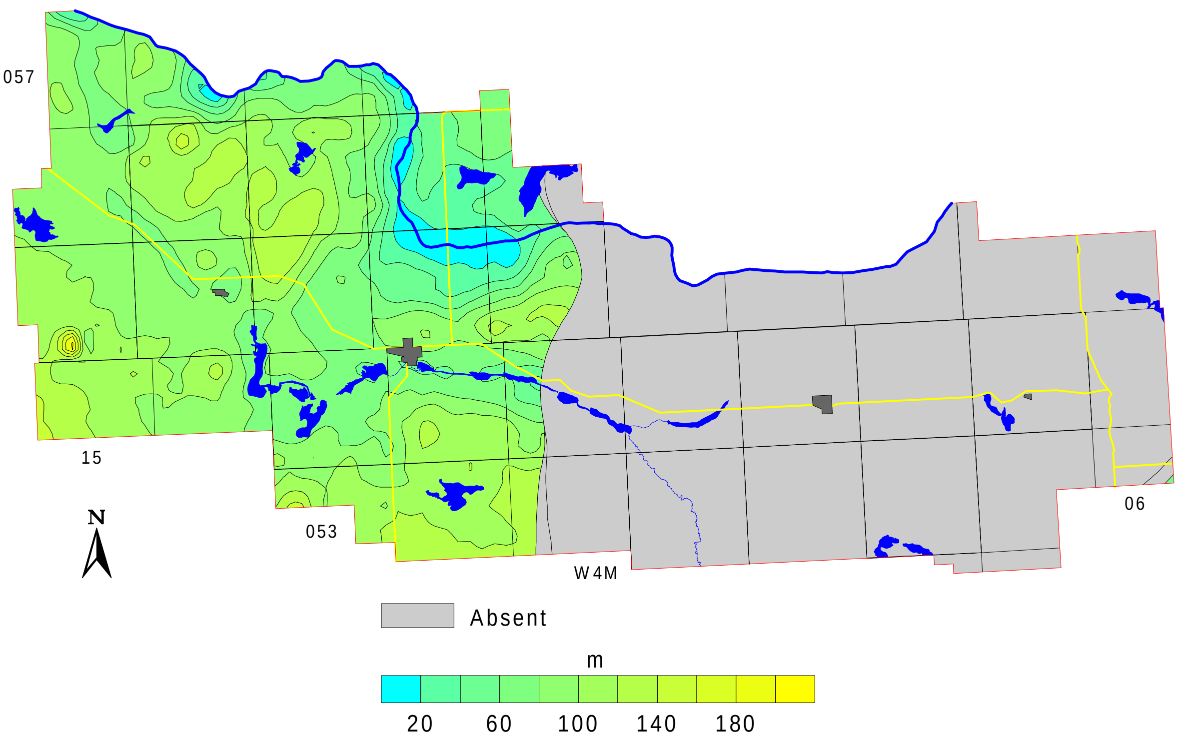
Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer



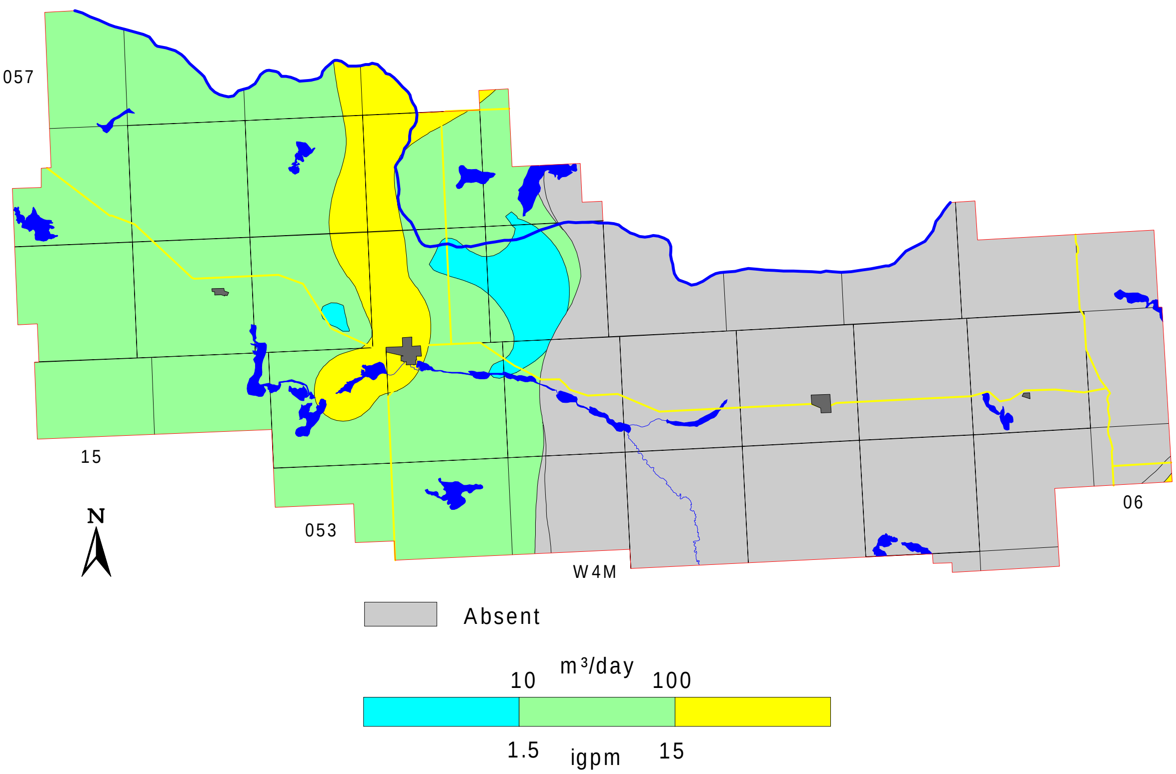
Chloride in Groundwater from Ribstone Creek Aquifer



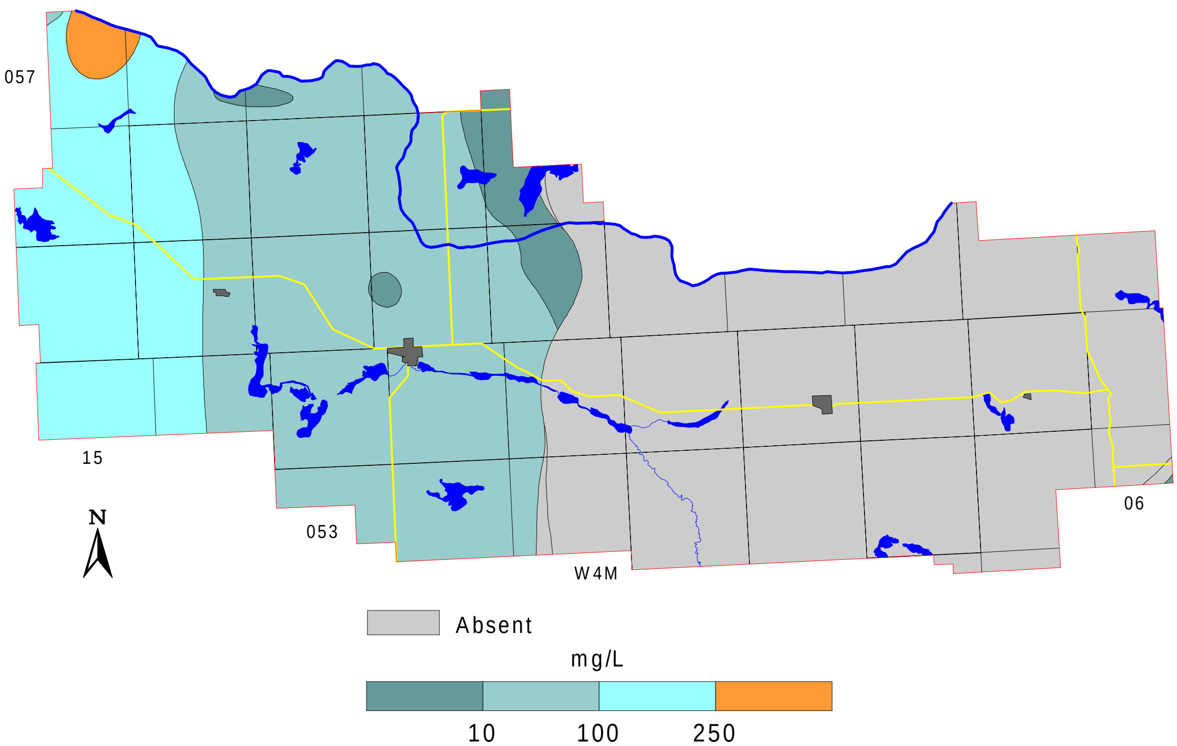
Depth to Top of Victoria Member

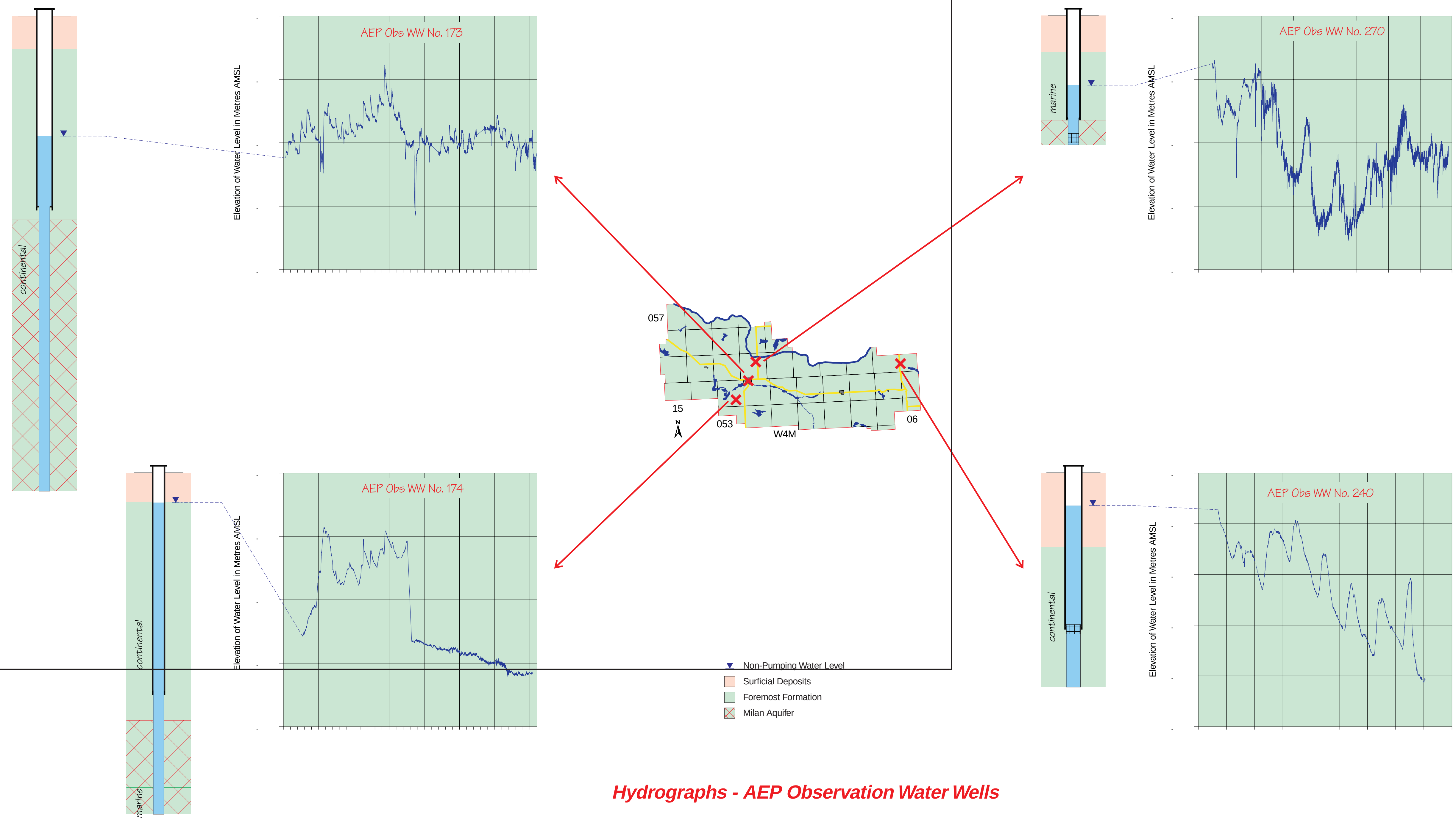


Apparent Yield for Water Wells Completed through Victoria Aquifer



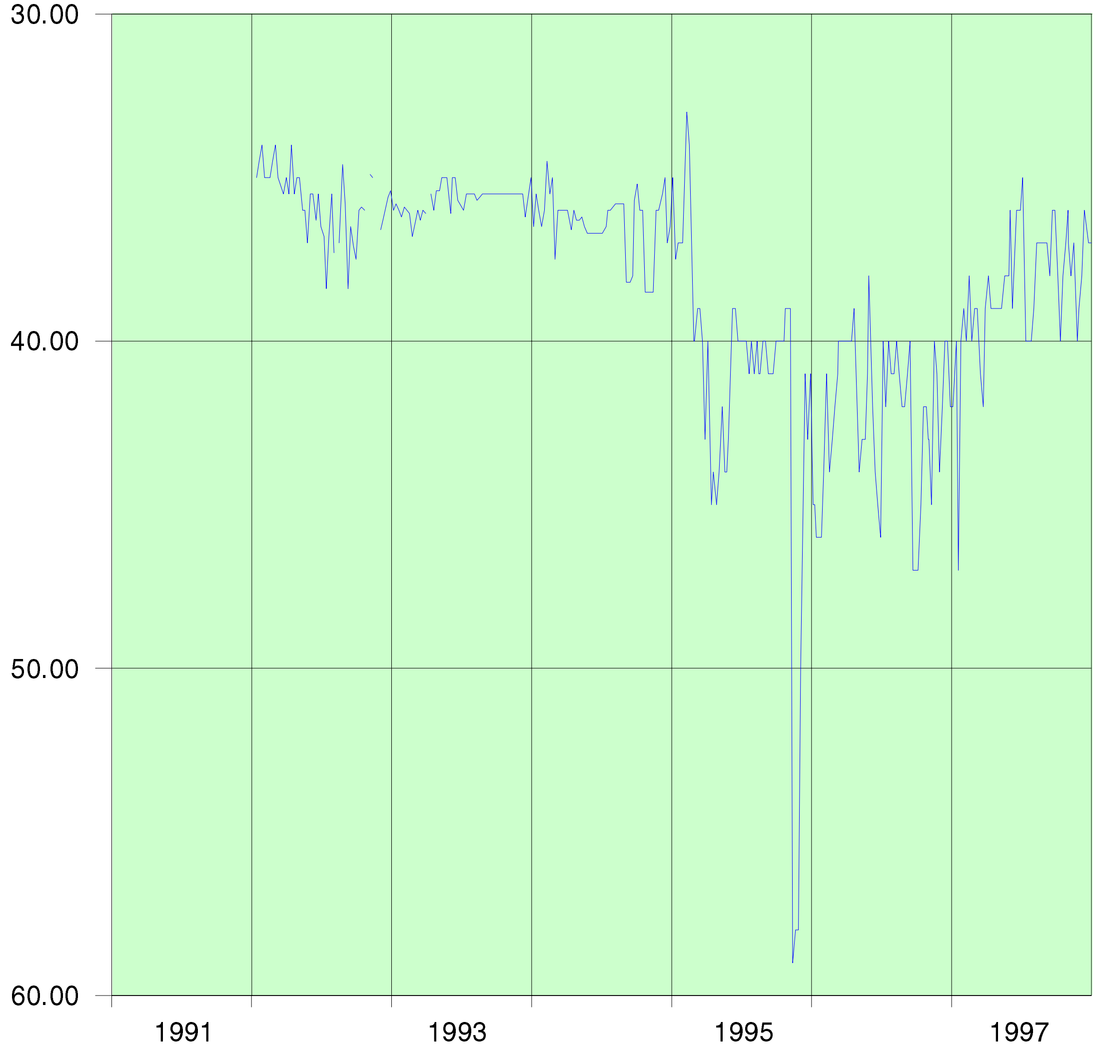
Chloride in Groundwater from Victoria Aquifer



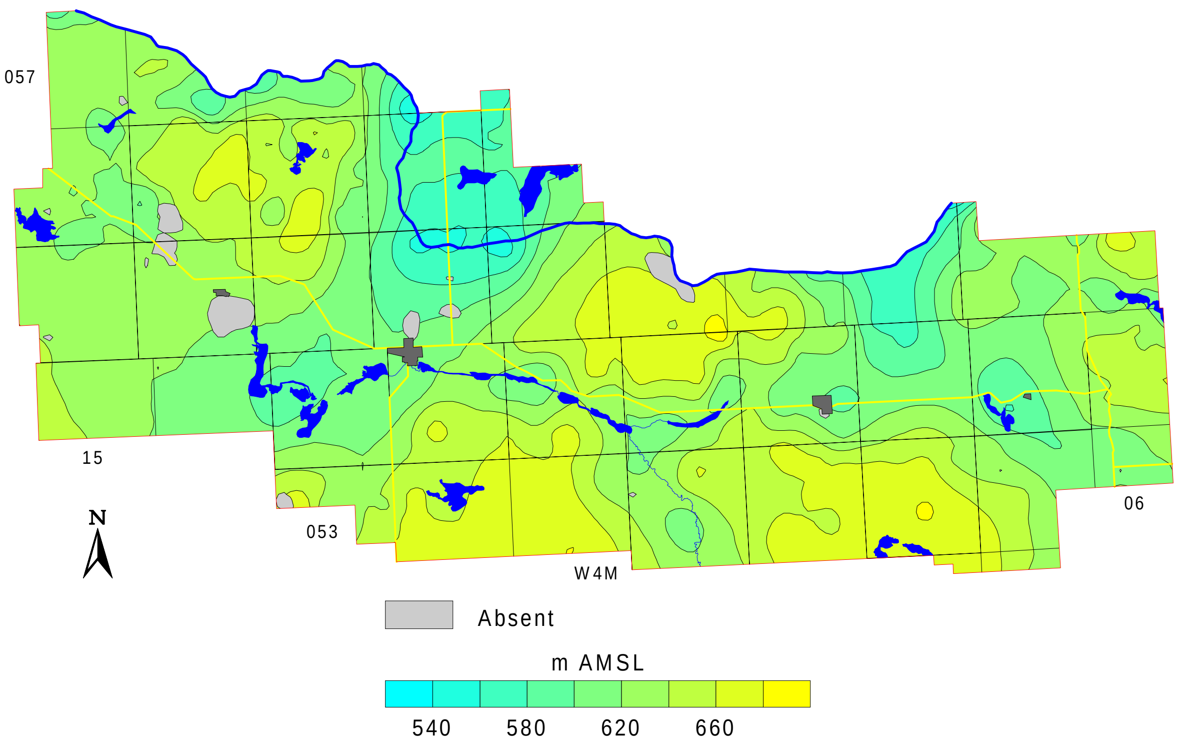


Hydrographs - AEP Observation Water Wells

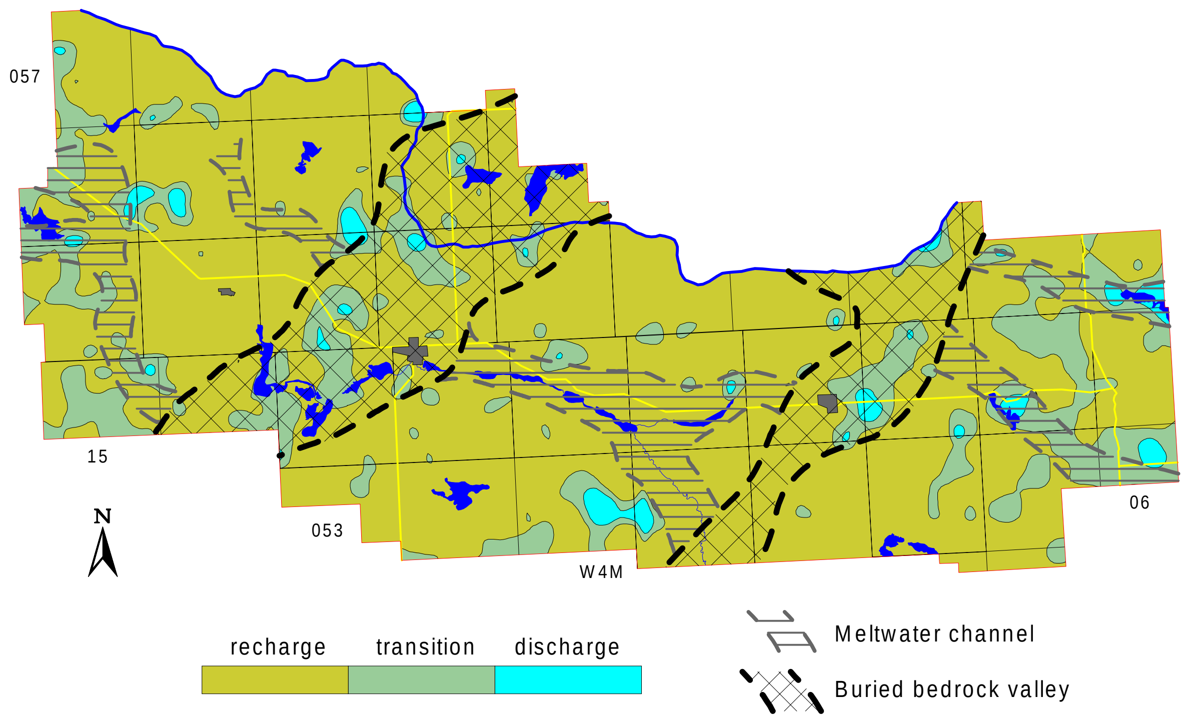
Water-Level Summary - W. Sawchuk Dom WW



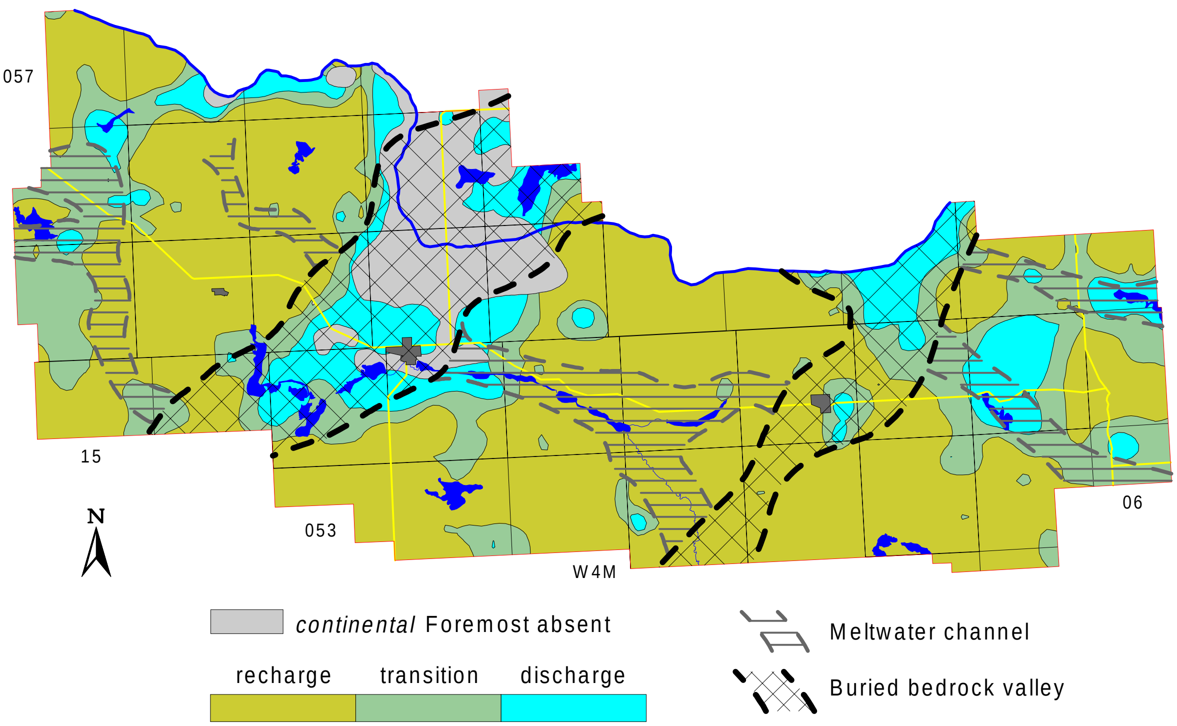
Non-Pumping Water-Level Surface in Surficial Deposits



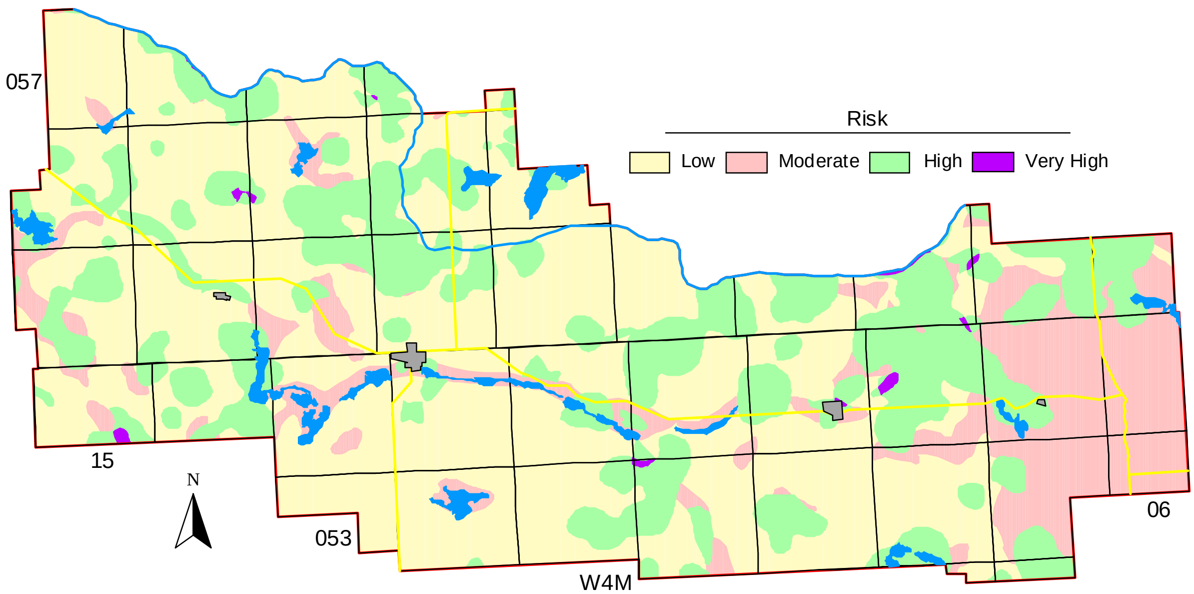
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



Recharge/Discharge Areas between Surficial Deposits and continental Foremost Aquifer



Risk of Groundwater Contamination



COUNTY OF TWO HILLS NO. 21

Appendix B

MAPS AND FIGURES ON CD-ROM

CD-ROM

A) Database
B) ArcView Files
C) Query
D) Maps and Figures

1) General

Index Map
Surface Casing Types used in Drilled Water Wells
Location of Water Wells
Depth of Existing Water Wells
Depth to Base of Groundwater Protection
Bedrock Topography
Bedrock Geology
Cross-Section A - A'
Cross-Section B - B'
Geologic Column
Generalized Cross-Section (for terminology only)
Risk of Groundwater Contamination
Relative Permeability
Hydrographs - AEP Observation Water Wells

2) Surficial Aquifers

a) Surficial Deposits

Thickness of Surficial Deposits
Non-Pumping Water-Level Surface in Surficial Deposits
Total Dissolved Solids in Groundwater from Surficial Deposits
Sulfate in Groundwater from Surficial Deposits
Chloride in Groundwater from Surficial Deposits
Fluoride in Groundwater from Surficial Deposits
Total Hardness of Groundwater from Surficial Deposits
Piper Diagram - Surficial Deposits
Amount of Sand and Gravel in Surficial Deposits
Thickness of Sand and Gravel Aquifer(s)
Water Wells Completed in Surficial Deposits
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)

b) First Sand and Gravel

Thickness of First Sand and Gravel
First Sand and Gravel - Saturation

c) Upper Sand and Gravel

Thickness of Upper Surficial Deposits
Thickness of Upper Sand and Gravel (not all drill holes fully penetrate surficial deposits)
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

d) Lower Sand and Gravel

Structure-Contour Map - Top of Lower Surficial Deposits
Depth to Top of Lower Sand and Gravel Aquifer
Thickness of Lower Surficial Deposits
Thickness of Lower Sand and Gravel (not all drill holes fully penetrate surficial deposits)
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer
Non-Pumping Water-Level Surface in Lower Sand and Gravel Aquifer

3) Bedrock Aquifers

a) General

Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)
Sulfate in Groundwater from Upper Bedrock Aquifer(s)
Chloride in Groundwater from Upper Bedrock Aquifer(s)
Fluoride in Groundwater from Upper Bedrock Aquifer(s)
Total Hardness of Groundwater from Upper Bedrock Aquifer(s)
Piper Diagram - Bedrock Aquifers
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)
Non-Pumping Water-Level Surface in Upper Bedrock Aquifer(s)

b) Oldman Aquifer

Depth to Top of Oldman Formation
Structure-Contour Map - Top of Oldman Formation
Non-Pumping Water-Level Surface - Oldman Aquifer
Apparent Yield for Water Wells Completed through Oldman Aquifer
Total Dissolved Solids in Groundwater from Oldman Aquifer
Sulfate in Groundwater from Oldman Aquifer
Chloride in Groundwater from Oldman Aquifer
Piper Diagram - Oldman Aquifer
Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer

c) *continental* Foremost Aquifer

Depth to Top of *continental* Foremost Formation
Structure-Contour Map - Top of *continental* Foremost Formation
Non-Pumping Water-Level Surface - *continental* Foremost Aquifer
Apparent Yield for Water Wells Completed through *continental* Foremost Aquifer
Total Dissolved Solids in Groundwater from *continental* Foremost Aquifer
Sulfate in Groundwater from *continental* Foremost Aquifer
Chloride in Groundwater from *continental* Foremost Aquifer
Piper Diagram - *continental* Foremost Aquifer
Recharge/Discharge Areas between Surficial Deposits and *continental* Foremost Aquifer
Water-Level Summary - W. Sawchuk Dom WW

d) Milan Aquifer

Depth to Top of Milan Aquifer
Structure-Contour Map - Top of Milan Aquifer
Non-Pumping Water-Level Surface - Milan Aquifer
Apparent Yield for Water Wells Completed through Milan Aquifer
Total Dissolved Solids in Groundwater from Milan Aquifer
Sulfate in Groundwater from Milan Aquifer
Chloride in Groundwater from Milan Aquifer
Piper Diagram - Milan Aquifer
Recharge/Discharge Areas between Surficial Deposits and Milan Aquifer

e) *marine* Foremost Aquifer

Depth to Top of *marine* Foremost Formation
Structure-Contour Map - Top of *marine* Foremost Formation
Non-Pumping Water-Level Surface - *marine* Foremost Aquifer
Apparent Yield for Water Wells Completed through *marine* Foremost Aquifer
Total Dissolved Solids in Groundwater from *marine* Foremost Aquifer
Sulfate in Groundwater from *marine* Foremost Aquifer
Chloride in Groundwater from *marine* Foremost Aquifer
Piper Diagram - *marine* Foremost Aquifer
Recharge/Discharge Areas between Surficial Deposits and *marine* Foremost Aquifer

f) Ribstone Creek Aquifer

Depth to Top of Ribstone Creek Member
Structure-Contour Map - Top of Ribstone Creek Member
Non-Pumping Water-Level Surface - Ribstone Creek Aquifer
Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer
Total Dissolved Solids in Groundwater from Ribstone Creek Aquifer
Sulfate in Groundwater from Ribstone Creek Aquifer
Chloride in Groundwater from Ribstone Creek Aquifer
Piper Diagram - Ribstone Creek Aquifer
Recharge/Discharge Areas between Surficial Deposits and Ribstone Creek Aquifer

g) Victoria Member

Depth to Top of Victoria Member
Structure-Contour Map - Top of Victoria Member
Non-Pumping Water-Level Surface - Victoria Aquifer
Apparent Yield for Water Wells Completed through Victoria Aquifer
Total Dissolved Solids in Groundwater from Victoria Aquifer
Sulfate in Groundwater from Victoria Aquifer
Chloride in Groundwater from Victoria Aquifer
Piper Diagram - Victoria Aquifer
Recharge/Discharge Areas between Surficial Deposits and Victoria Aquifer

h) Lea Park Aquitard

Depth to Top of Lea Park Aquitard
Structure-Contour Map - Top of Lea Park Aquitard

COUNTY OF TWO HILLS NO. 21
Appendix C

GENERAL WATER WELL INFORMATION

Domestic Water Well Testing

Purpose and Requirements

The purpose of the testing of domestic water wells is to obtain background data related to:

1) the non-pumping water level for the aquifer - Has there been any lowering of the level since the last measurement?
2) the specific capacity of the water well, which indicates the type of contact the water well has with the aquifer;
3) the transmissivity of the aquifer and hence an estimate of the projected long-term yield for the water well;
4) the chemical, bacteriological and physical quality of the groundwater from the water well.

The testing procedure involves conducting an aquifer test and collecting of groundwater samples for analysis by an accredited laboratory. The date and time of the testing are to be recorded on all data collection sheets. A sketch showing the location of the water well relative to surrounding features is required. The sketch should answer the question, "If this water well is tested in the future, how will the person doing the testing know this is the water well I tested?"

The water well should be taken out of service as long as possible before the start of the aquifer test, preferably not less than 30 minutes before the start of pumping. The non-pumping water level is to be measured 30, 10, and 5 minutes before the start of pumping and immediately before the start of pumping which is to be designated as time 0 for the test. All water levels must be from the same designated reference, usually the top of the casing. Water levels are to be measured during the pumping interval and during the recovery interval after the pump has been turned off; all water measurements are to be with an accuracy of ± 0.01 metres.

During the pumping and recovery intervals, the water level is to be measured at the appropriate times. An example of the time schedule for a four-hour test is as follows, measured in minutes after the pump is turned on and again after the pump is turned off:

1,2,3,4,6,8,10,13,16,20,25,32,40,50,64,80,100,120.

For a four-hour test, the reading after 120 minutes of pumping will be the same as the 0 minutes of recovery. Under no circumstance will the recovery interval be less than the pumping interval.

Flow rate during the aquifer test should be measured and recorded with the maximum accuracy possible. Ideally, a water meter with an accuracy of better than ±1% displaying instantaneous and total flow should be used. If a water meter is not available, then the time required to completely fill a container of known volume should be recorded, noting the time to the nearest 0.5 seconds or better. Flow rate should be determined and recorded often to ensure a constant pumping rate.

Groundwater samples should be collected as soon as possible after the start of pumping and within ten minutes of the end of pumping. Initially only the groundwater samples collected near the end of the pumping interval need to be submitted to the accredited laboratory for analysis. All samples must be properly stored for transportation to the laboratory and, in the case of the bacteriological analysis, there is a maximum time allowed between the time the sample is collected and the time the sample is delivered to the laboratory. The first samples collected are only analyzed if there is a problem or a concern with the first samples submitted to the laboratory.

Procedure

Site Diagrams

These diagrams are a map showing the distance to nearby significant features. This would include things like a corner of a building (house, barn, garage etc.) or the distance to the half-mile or mile fence. The description should allow anyone not familiar with the site to be able to unequivocally identify the water well that was tested.

In lieu of a map, UTM coordinates accurate to within five metres would be acceptable. If a hand-held GPS is used, the post-processing correction details must be provided.

Surface Details

The type of surface completion must be noted. This will include such things as a pitless adapter, well pit, pump house, in basement, etc. Also, the reference point used for measuring water levels needs to be noted. This would include top of casing (TOC) XX metres above ground level; well pit lid, XX metres above TOC; TOC in well pit XX metres below ground level.

Groundwater Discharge Point

Where was the flow of groundwater discharge regulated? For example was the discharge through a hydrant downstream from the pressure tank; discharged directly to ground either by connecting directly above the well seal or by pulling the pump up out of the pitless adapter; from a tap on the house downstream from the pressure tank? Also note must be made if any action was taken to ensure the pump would operate continuously during the pumping interval and whether the groundwater was passing through any water-treatment equipment before the discharge point.

Water-Level Measurements

How were the water-level measurements obtained? If obtained using a contact gauge, what type of cable was on the tape, graduated tape or a tape with tags? If a tape with tags, when was the last time the tags were calibrated? If a graduated tape, what is the serial number of the tape and is the tape shorter than its original length (i.e. is any tape missing)?

If water levels are obtained using a transducer and data logger, the serial numbers of both transducer and data logger are needed and a copy of the calibration sheet. The additional information required is the depth the transducer was set and the length of time between when the transducer was installed and when the calibration water level was measured, plus the length of time between the installation of the transducer and the start of the aquifer test.

All water levels must be measured at least to the nearest 0.01 metres.

Discharge Measurements

Type of water meter used. This could include such things as a turbine or positive displacement meter. How were the readings obtained from the meter? Were the readings visually noted and recorded or were they recorded using a data logger?

Water Samples

A water sample must be collected between the four- and six-minute water-level measurements, whenever there is an observed physical change in the groundwater being pumped, and ten minutes before the end of the planned pumping interval. Additional water samples must be collected if it is expected that pumping will be terminated before the planned pumping interval.

Environmental Protection and Enhancement Act

Water Well Regulation

PROVINCE OF ALBERTA

ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT

WATER WELL REGULATION

Alberta Regulation 123/93

EXTRACT FROM THE ALBERTA GAZETTE

Published by the Queen's Printer for Alberta

Distributed by:

Publication Services
11510 Kingsway
Edmonton, T5G 2Y5
427-4952
FAX 452-0668

and

Publication Services
Main Floor, McDougall Centre
455 - 6th Street S.W.
Calgary, T2P 4E8
297-6251

Alberta Regulation 123/93

Environmental Protection and Enhancement Act

WATER WELL REGULATION

Filed: April 22, 1993

Made by the Minister of Environmental Protection pursuant to sections 81(1)(a) and (f), 138(a)-(e), (g), (h), (j)-(n) of the Environmental Protection and Enhancement Act.

Table of Contents

Additional Information

VIDEOS

Will the Well Go Dry Tomorrow? (Mow-Tech Ltd.: 1-800 GEO WELL)
Water Wells that Last (PFRA – Edmonton Office: 403-495-3307)
Ground Water and the Rural Community (Ontario Ground Water Association)

BOOKLET

Water Wells that Last (PFRA – Edmonton Office: 403-495-3307)

ALBERTA ENVIRONMENTAL PROTECTION

WATER WELL INSPECTORS

Jennifer McPherson (Edmonton: 403-427-6429)
Colin Samis (Lac La Biche: 403-623-5235)

GEOPHYSICAL INSPECTION SERVICE

Edmonton: 403-427-3932

COMPLAINT INVESTIGATIONS

Blair Stone (Red Deer: 403-340-5310)

UNIVERSITY OF ALBERTA – Department of Earth and Atmospheric Sciences - Hydrogeology

Carl Mendosa (Edmonton: 403-492-2664)

UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology

Larry Bentley (Calgary: 403-220-4512)

FARMERS ADVOCATE

Paul Vasseur (Edmonton: 403-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION

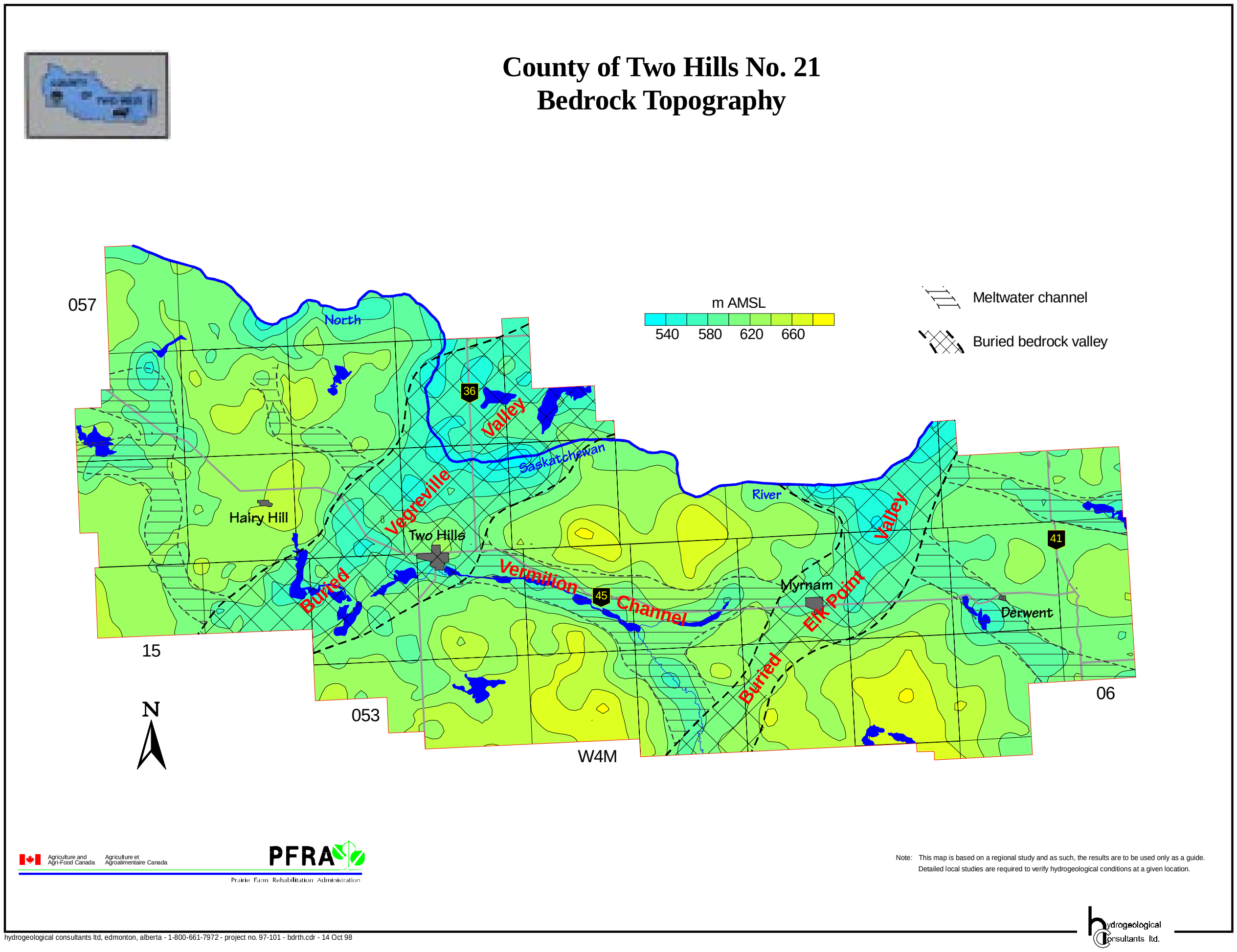
Keith Schick (Vegreville: 403 632-2919)

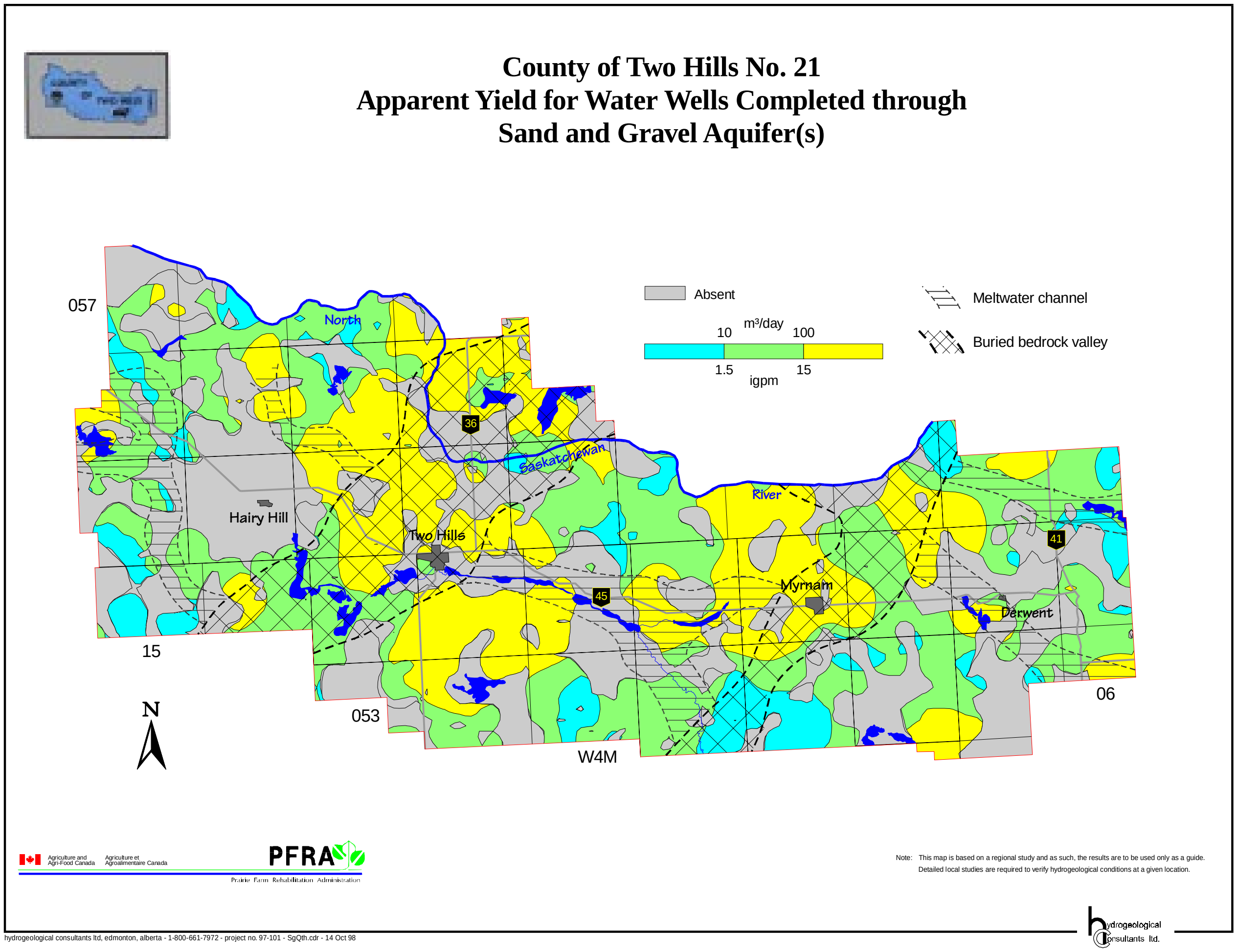
LOCAL HEALTH DEPARTMENTS

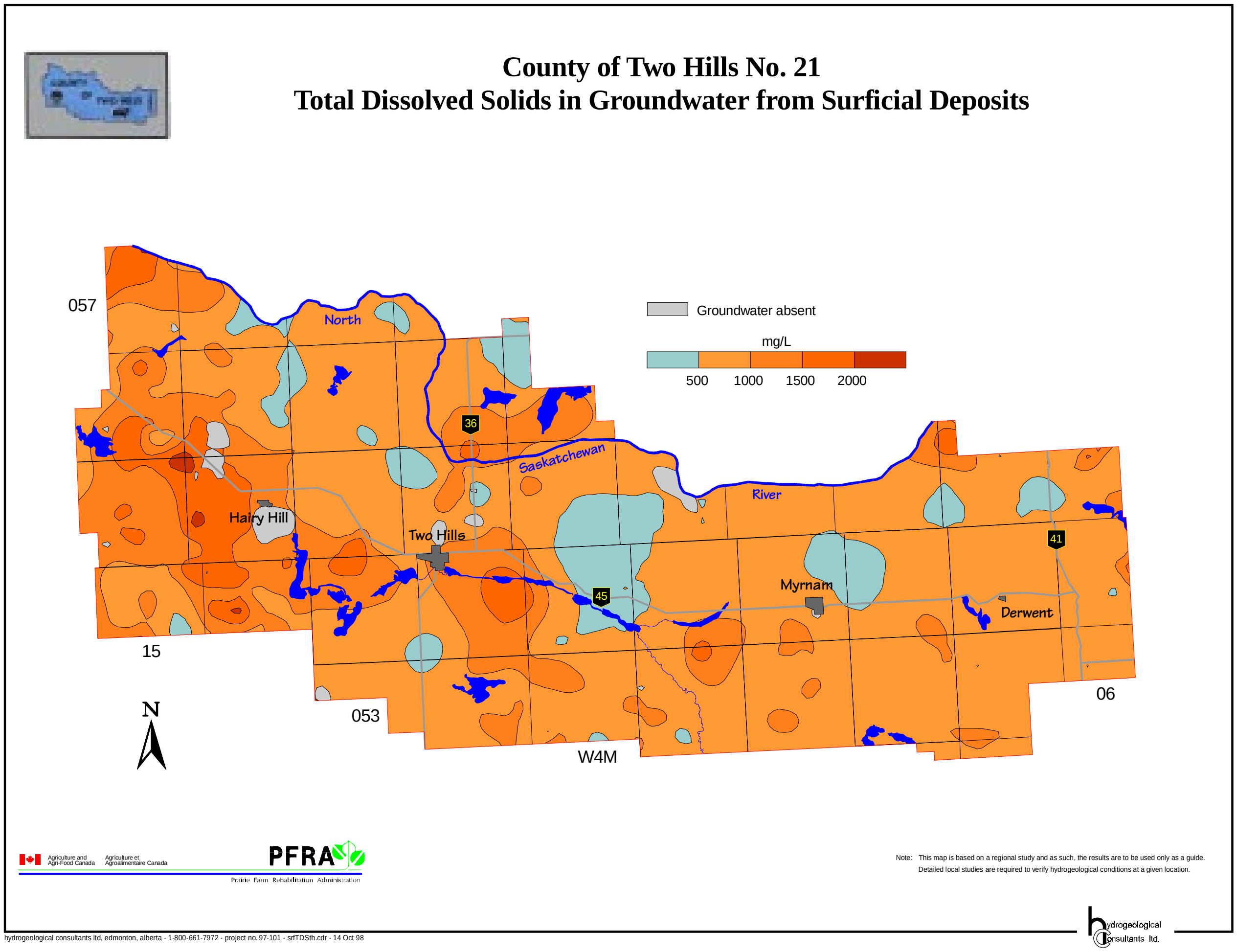
COUNTY OF TWO HILLS NO. 21

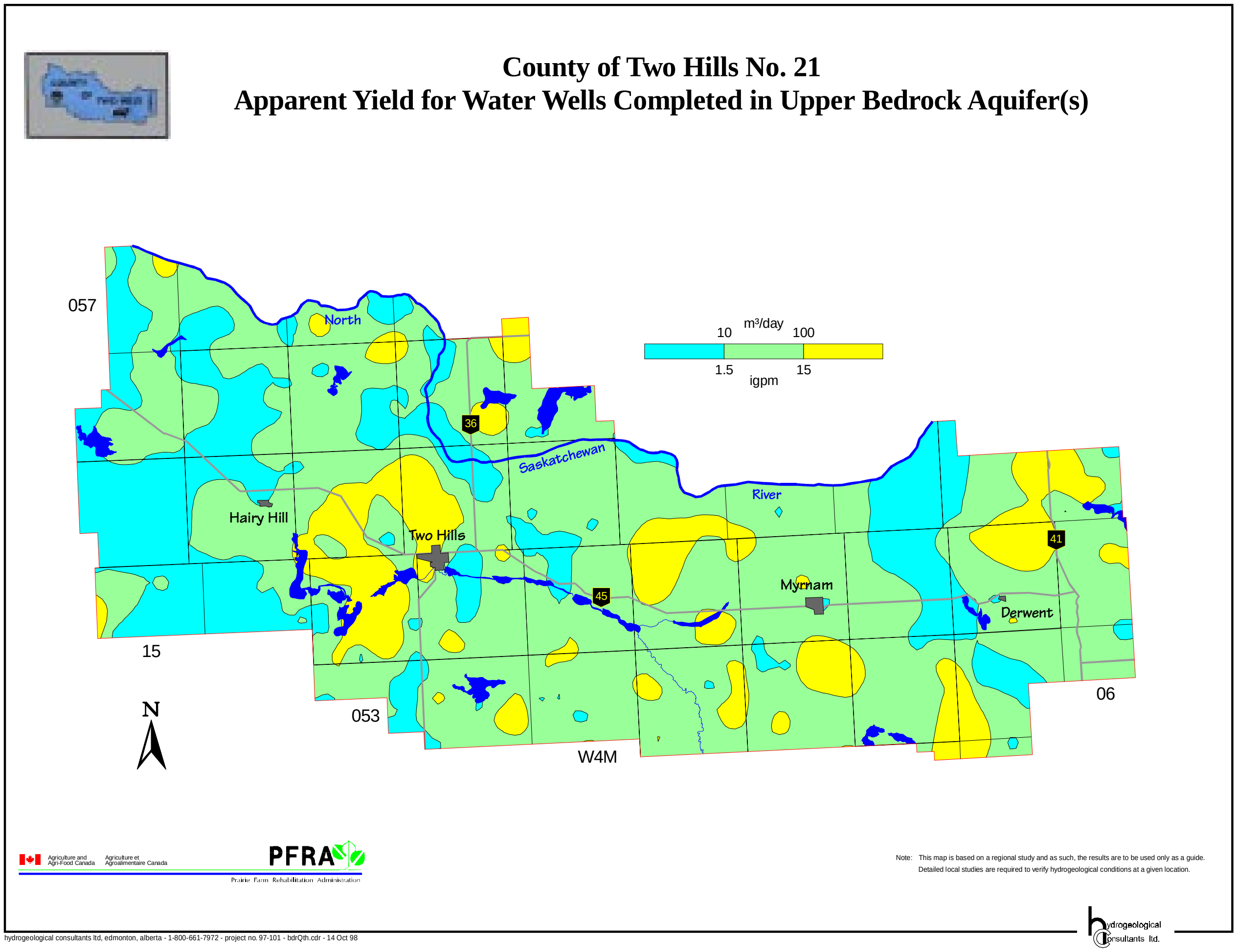
Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

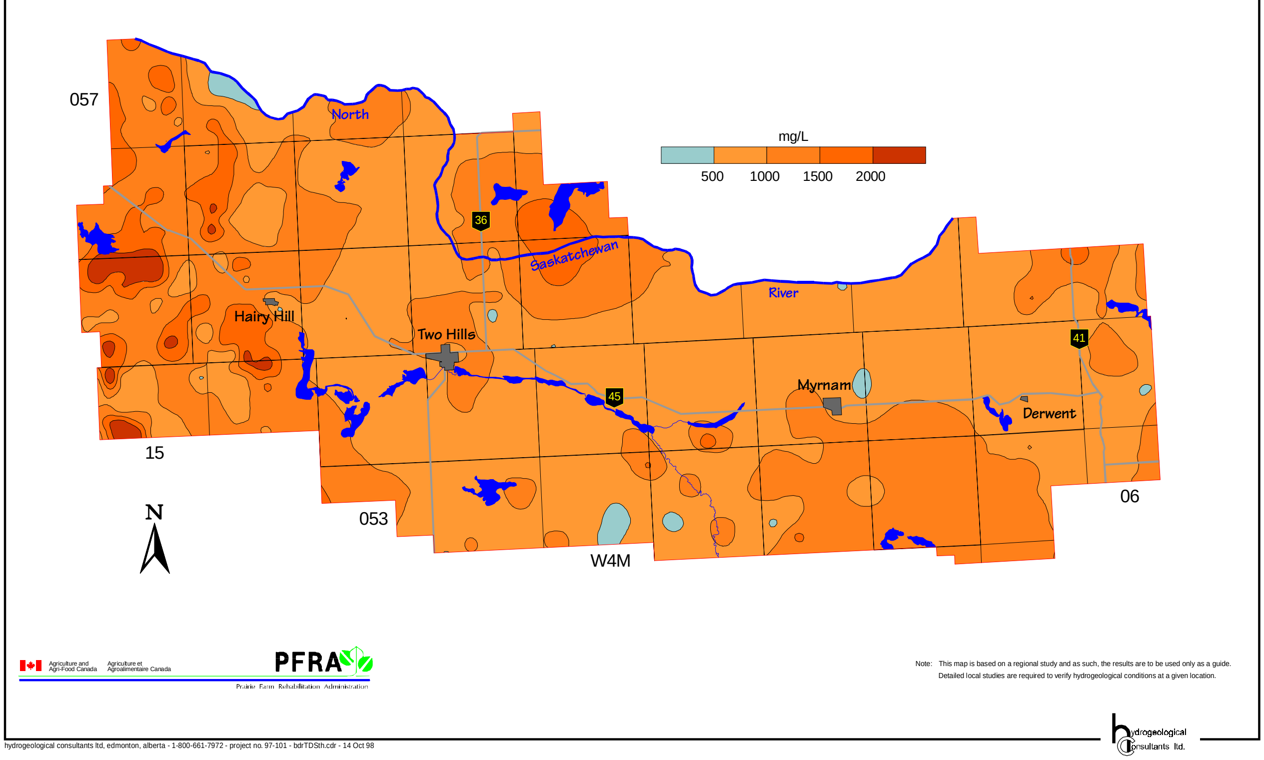

County of Two Hills No. 21
Bedrock Topography
m AMSL
540
580
620
660
Meltwater channel
Buried bedrock valley
057
15
053
W4M
06
North
Saskatchewan
River
Hairy Hill
Two Hills
Myrnam
Derwent
Buried
Vegreville
Valley
Vermilion
Channel
Buried
Elk Point
Valley
36
45
41
N
PFRA
Prairie Farm Rehabilitation Administration
Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-101 - bdrth.cdr - 14 Oct 98
hydrogeological consultants ltd.

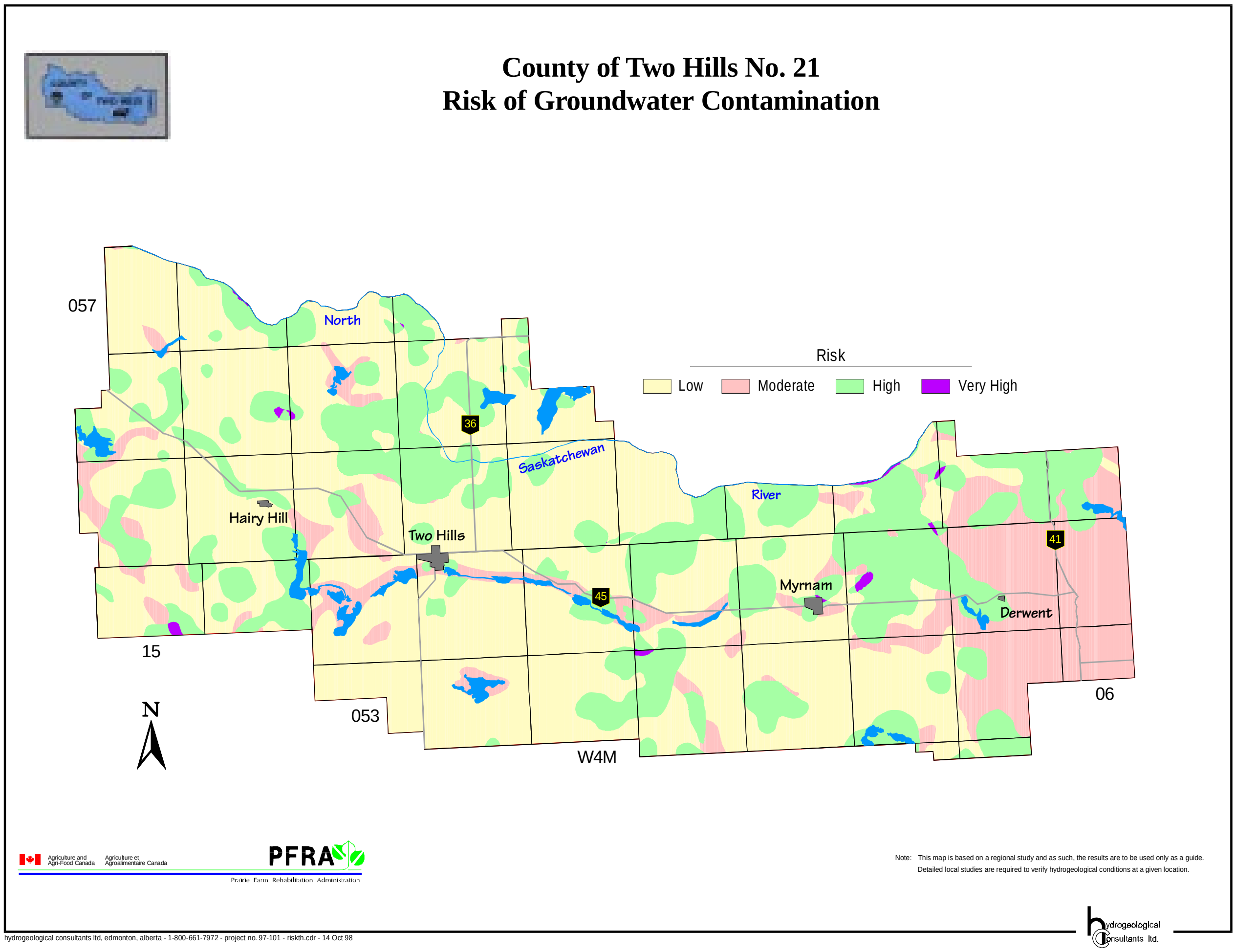

County of Two Hills No. 21
Apparent Yield for Water Wells Completed through
Sand and Gravel Aquifer(s)
Absent
m³/day
10
100
1.5
15
igpm
Meltwater channel
Buried bedrock valley
057
15
053
W4M
06
North
Saskatchewan
River
Hairy Hill
Two Hills
Myrnam
Derwent
36
45
41
N
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration
Note: This map is based on a regional study and as such, the results are to be used only as a guide.
Detailed local studies are required to verify hydrogeological conditions at a given location.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-101 - SgQth.cdr - 14 Oct 98
hydrogeological consultants ltd.

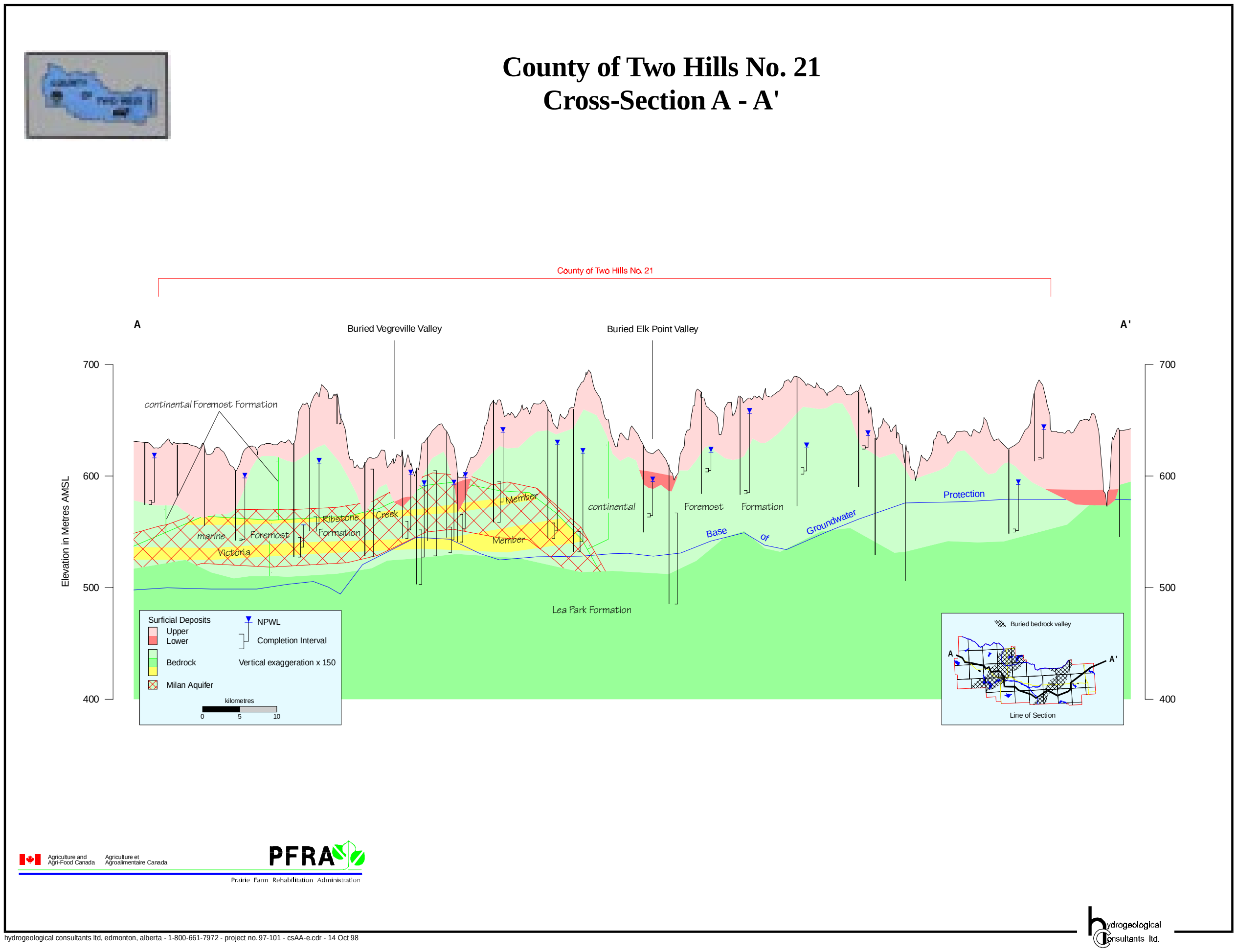

County of Two Hills No. 21
Total Dissolved Solids in Groundwater from Surficial Deposits
Groundwater absent
mg/L
500
1000
1500
2000
057
053
15
06
W4M
N
North
Saskatchewan
River
Hairy Hill
Two Hills
Myrnam
Derwent
36
45
41
PFRA
Prairie Farm Rehabilitation Administration
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-101 - srfTDSth.cdr - 14 Oct 98
hydrogeological consultants ltd.


County of Two Hills No. 21
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)
057
North
Saskatchewan
River
Hairy Hill
Two Hills
Myrnam
Derwent
36
45
41
15
053
W4M
06
N
m³/day
10
100
1.5
15
igpm
PFRA
Prairie Farm Rehabilitation Administration
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-101 - bdrQth.cdr - 14 Oct 98
hydrogeological consultants ltd.

County of Two Hills No. 21
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)




County of Two Hills No. 21
Risk of Groundwater Contamination
Risk
Low
Moderate
High
Very High
057
15
053
06
W4M
N
North
Saskatchewan
River
Hairy Hill
Two Hills
Myrnam
Derwent
36
45
41
PFRA
Prairie Farm Rehabilitation Administration
Note: This map is based on a regional study and as such, the results are to be used only as a guide.
Detailed local studies are required to verify hydrogeological conditions at a given location.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-101 - riskth.cdr - 14 Oct 98
hydrogeological consultants ltd.


County of Two Hills No. 21
Cross-Section A - A'
County of Two Hills No. 21
A
A'
Buried Vegreville Valley
Buried Elk Point Valley
Elevation in Metres AMSL
700
600
500
400
continental Foremost Formation
marine Foremost Formation
Victoria
Birch Lake Member
Ribstone Creek Member
continental Foremost Formation
Base of Groundwater Protection
Lea Park Formation
Surficial Deposits
Upper
Lower
Bedrock
Milan Aquifer
NPWL
Completion Interval
Vertical exaggeration x 150
kilometres
0
5
10
Buried bedrock valley
Line of Section
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration
hydrogeological consultants ltd.
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-101 - csAA-e.cdr - 14 Oct 98

County of Two Hills No. 21
Cross-Section B - B'