Leduc County

Part of the North Saskatchewan River Basin
Parts of Tp 047 to 051, R 21 to 28, W4M and R 01 to 04, W5M
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

Canada

Prepared by
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Our File No.: **98-130**

February 1999
(Revised December 1999)

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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 Leduc County toward the management of the groundwater resource, which is a key component toward 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 Leduc County, (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 to be provided with the final version of 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 as page-size drawings 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;
3) a flow chart showing the licensing of a groundwater diversion under the new Water Act; and
4) 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. The new Water Act was proclaimed 10 Jan 1999.

Appendix E provides a list of water wells recommended for field verification.

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 Leduc County. 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

Leduc County is situated in central Alberta. This area is part of the Alberta Plains region. The County is within the North Saskatchewan River basin; a part of the County's northern boundary is the North Saskatchewan River. The other County boundaries follow township or section lines. The area includes parts of the area bounded by township 051, range 04, W5M in the northwest and township 047, range 21, W4M in the southeast.

Regionally, the topographic surface varies between 640 and 940 metres above mean sea level (AMSL). The lowest elevations occur in the North Saskatchewan River Valley in the northern part of the County and the highest are in the southwestern part of the County as shown in Figure 1.

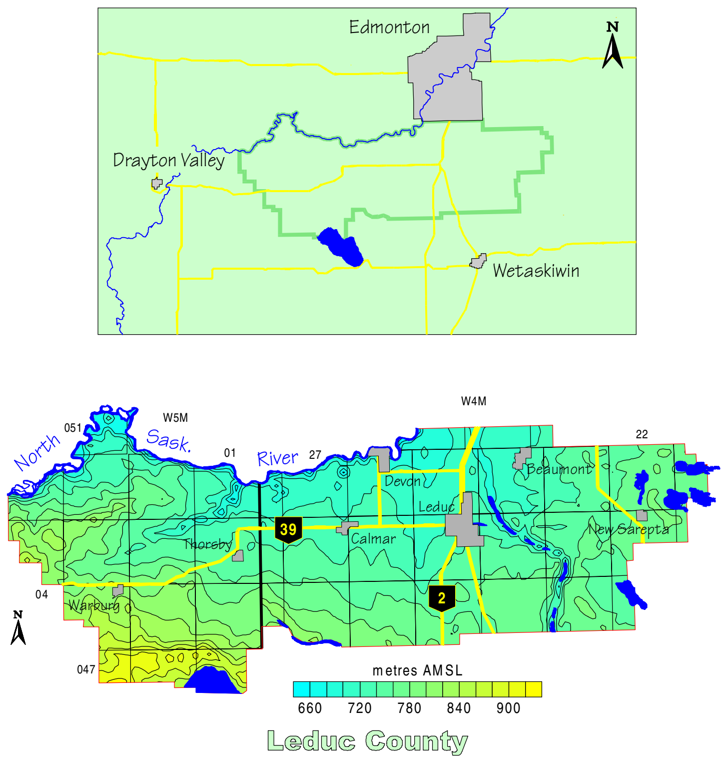

Figure 1. Index Map

2.2 Climate

Leduc County lies within the Dfb climate boundary. 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 both the Low Boreal Mixedwood region and the Aspen Parkland region. Increased precipitation and cooler temperatures, resulting in additional moisture availability influence this vegetation change.

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.

The mean annual precipitation averaged from three meteorological stations within the County measured 473 millimetres (mm), based on data from 1938 to 1993. The mean annual temperature averaged 2.5 °C, with the mean monthly temperature reaching a high of 16.2 °C in July, and dropping to a low of -13.6 °C in January. The calculated annual potential evapotranspiration is 508 millimetres.

2.3 Background Information

There are currently records for 5,922 water wells in the groundwater database for the County. Of the 5,922 water wells, 5,362 are for domestic/stock purposes. The remaining 560 water wells were completed for a variety of uses, including industrial, investigation, observation and municipal. Based on a rural population of 12,361, there are two domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from 0.91 metres to 209.1 metres below ground level. Lithologic details are available for 3,093 water wells.

Data for casing diameters are available for 2,322 water wells, with 2,193 indicated as having a diameter of less than 275 mm and 129 having a diameter of more than 450 mm. The casing diameters of greater than 450 mm are mainly bored or dug water wells and those with a surface casing diameter of less than 275 mm are drilled water wells. The majority of large-diameter water wells occur along a northwest-southeast-trending area from the northern to the southern border through the Village of Thorsby. These water wells are in an area where the upper bedrock is either the Battle or Whitemud formations or the Lower Scollard.

Steel, galvanized steel and plastic represent 99% of the materials that have been used for surface casing in drilled water wells over the last 40 years in the County. Steel and galvanized steel were the main casing types until the start of the 1990s, when plastic casing became the dominant type.

Galvanized steel surface casing was used in 3% of the new water wells in the early 1960s. By the early 1970s, galvanized steel casing was being used in 55% of the water wells. From 1975 onward, there was a general decrease in the percentage of water wells using galvanized steel, with the last reported use in October 1993.

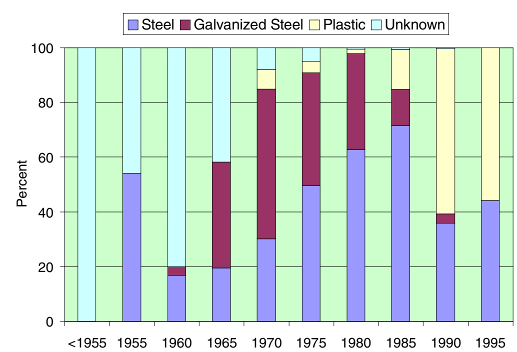

Figure 2. Surface Casing Types used in Drilled Water Wells

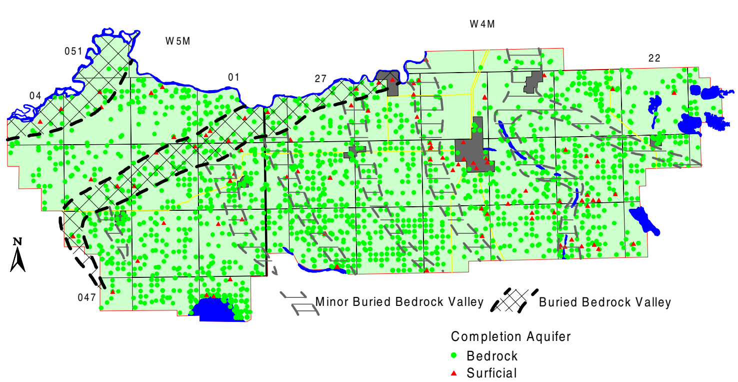

Figure 3. Location of Water Wells

There are 2,590 water well records with sufficient information to identify the aquifer 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 126. The adjacent map shows that these water wells occur in most areas throughout the County. Approximately 80% of the water wells completed in surficial aquifers have a completion depth of less than 30 metres.

The remaining 2,464 water wells have the top of their completion interval deeper than the top to the bedrock surface. From Figure 3, it can be seen that water wells completed in bedrock aquifers occur over most of the County.

Water wells not used for domestic needs must be licensed. At the end of 1996, 180 groundwater diversions were licensed in the County. Of the 180 licensed groundwater users, 155 are for agricultural purposes, and the remaining 25 are for industrial, municipal, diversion, domestic and other purposes. The total maximum authorized diversion from the water wells associated with these licences is 2,978 cubic metres per day (m^3/day); 44% percent of the authorized groundwater diversion is allotted for agricultural use. The largest potable groundwater diversion licensed within the County is for the Village of New Sarepta, having a diversion of 179.2 m^3/day. The largest licensed industrial groundwater diversions within the County are for three saline water source wells; the largest of these saline diversions is in 14-03-049-01 W5M; this saline water source well is completed at a depth of 1,300 metres below ground surface.

The adjacent table shows a breakdown of the 180 licensed groundwater diversions by the aquifer in which the water well is completed. Even though three saline water source wells are licensed, these supplies no longer need to be licensed. The highest licensed diversions are for water wells completed in the Lower Lacombe Aquifer; the majority of the Lower Lacombe groundwater is used for industrial purposes.

	Licensed Groundwater Users (m^3/day)						
Aquifer	Agricultural	Industrial	Municipal	Diversion	Domestic	Other	Total
Upper Sand and Gravel	0	0	0	0	0	34	34
Lower Sand and Gravel	3	0	0	0	0	0	3
Upper Lacombe	29	0	0	0	0	0	29
Lower Lacombe	156	358	0	0	0	0	514
Haynes	239	0	243	0	20	0	502
Upper Scollard	132	0	0	54	0	0	186
Lower Scollard	157	0	0	0	5	0	162
Upper Horseshoe Canyon	369	0	0	0	44	0	413
Middle Horseshoe Canyon	212	24	243	0	0	0	479
Lower Horseshoe Canyon	0	0	0	0	0	0	0
Saline Source Wells	0	436	0	0	0	0	436
Unknown	10	95	115	0	0	0	220
Total	1,307	913	601	54	69	34	2,978

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the water requirement for livestock for the County is in the order of 12,250 m^3/day, which is nine times the amount of the groundwater diversion licensed for agricultural purposes.

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.

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 1,500 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. Less than 20% of the chemical analyses indicate a fluoride concentration above 1.5 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 provided by the Alberta Energy and Utilities Board (EUB), a depth to the Base of Groundwater Protection can be determined. This depth, for the most part, would be the maximum drilling depth for a water supply well.

Over approximately 80% of the County, the depth to the Base of Groundwater Protection is more than 300 metres. There are only a few areas where the depth to the Base of Groundwater Protection is less than 200 metres; these areas are mainly west of range 02, W5M as shown on the adjacent map.

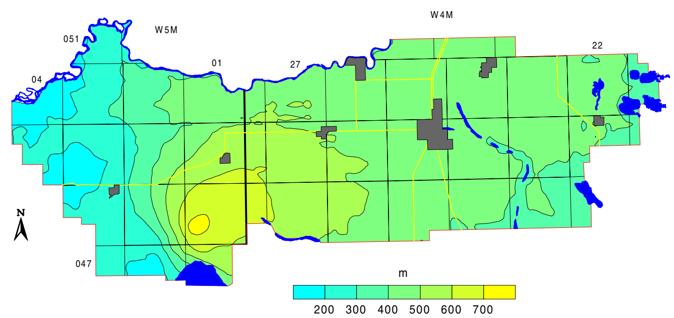

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are sixteen 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 for licensed diversions have been difficult to obtain from AEP, in part because of the failure of the licensee to provide the data. Within the County, however, there is one groundwater monitoring project operated by Mow-Tech Ltd. from which meaningful water-level data can be obtained.

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

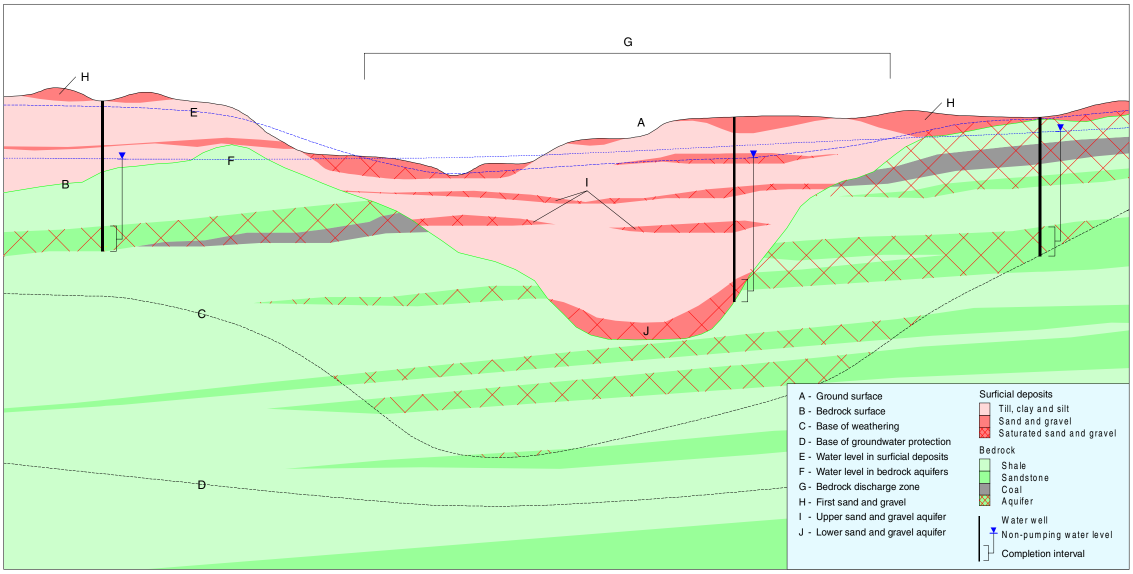

Figure 5. Generalized Cross-Section (for terminology only)

Lithology	Lithologic Description	Group and Formation: Thickness (m)	Group	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
	sand, gravel, till, clay, silt	<40		Surficial Deposits	<40	Upper	<20	First Sand and Gravel
					<30	Lower		
	sandstone, shale, coal	<200	Paskapoo Formation	Lacombe Member	0-70	Upper		Upper Sandstone
								Middle Sandstone
								Lower Sandstone
					30-70	Lower		Lower Lacombe Coal Zone
	sandstone, shale, coal			Haynes Member	20-60			
	shale, sandstone, siltstone, coal	60-220	Edmonton Group	Scollard Formation	60-150	Upper	<2	Upper Ardley Coal Zone
							~20	Ardley Coal Zone (main seam)
							<1	Nevis Coal Seam
					20-80	Lower		
	shale, claystone, tuff, bentonite	~25		Battle Formation	<0.3	Kneehills Member		
	shale, siltstone, sandstone	5-10		Whitemud Formation				
	shale, sandstone, coal, bentonite, limestone, ironstone	300-380		Horseshoe Canyon Formation	~100	Upper		
					~100	Middle		
					<10	Drumheller Member		
					~170	Lower		
	shale, sandstone, siltstone	60-120		Bearpaw Formation				

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. However, unlike other areas in the Province, duplicate water well IDs are not a problem in the County.

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. This situation has been improved for Leduc County. Prairie Farm Rehabilitation Administration (PFRA) has re-positioned 5,787 water wells within the County using aerial photographs and subdivision plans. These coordinates are provided with the records on the CD-OM.

The present project uses the 10TM coordinate system. This means that a record for the SE ¼ of section 24, township 049, range 27, W4M, would have a horizontal coordinate with an Easting of 79,352 metres and a Northing of 5,896,100 metres, the centre of the quarter section. If the water well has been positioned by PFRA, the location will be more accurate, possibly within several 10s of metres of the actual location. 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 interval.

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. When calculating the apparent long-term yield, values for effective or aquifer transmissivity are used, if available.

The 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.

Values for apparent transmissivity, apparent yield and hydraulic conductivity are calculated from the DST summaries. Also, the DST summaries are used to obtain water level elevations.

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.

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. Even when only limited data are available, grids are prepared. However, the data from these grids must be used with extreme caution because the gridding process can be unreliable.

4.3.1 Risk Criteria

The main source of groundwater contamination involves activities on or near the land surface. The risk of contamination 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.

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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 outline and the thickness of the geological unit. The thickness of the porous and permeable part(s) of the geological unit 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 to the cross-section from the digitally prepared surfaces.

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 as poster-size drawings forwarded with this report. The cross-sections also are in Appendix A, and are included on the CD-ROM; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

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

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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 20 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 40 metres. The Buried Beverly and Warberg (sic*) valleys are the main southwest-northeast-trending linear bedrock lows in the County. The Buried Beverly Valley and the North Saskatchewan River occupy the same linear bedrock low at the northwestern border of the County. Strawberry Creek and the Buried Warburg Valley, an extension of the Buried Stony Valley (Carlson, 1967), occupy the same linear bedrock low in the northwest-central part of the County. Cross-section A-A' passes across the Buried Warburg Valley and shows the surficial deposits being up to 40 metres thick within the Valley.

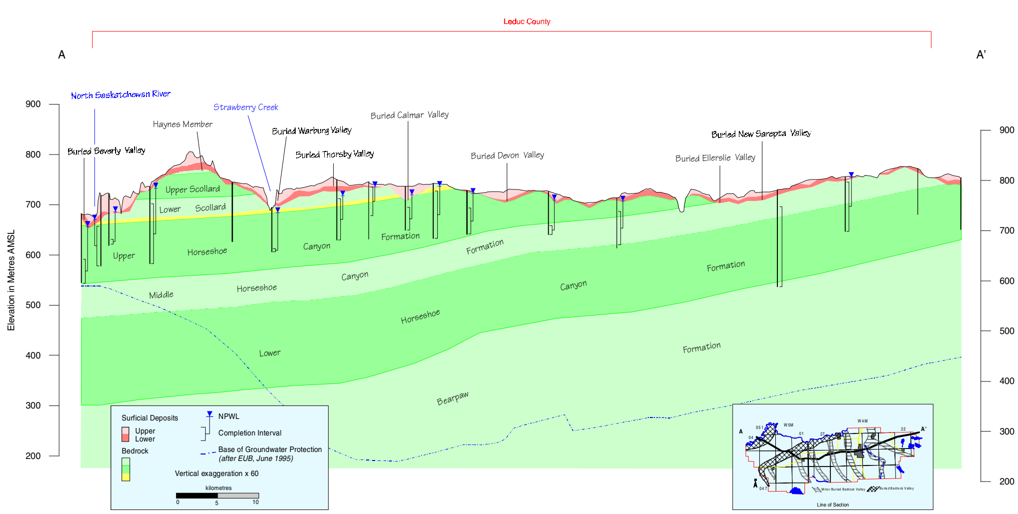

Figure 7. Cross-Section A - A'

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 that are less than 15 metres deep. The base of the surficial deposits is the bedrock surface.

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* Carlson, 1970; to be spelled like the Village of Warburg in the report and on figures, hereinafter.

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 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, casing diameter information is available for 62 of the 126 water wells completed in the surficial deposits; 20 of these have a casing diameter of more than 450 millimetres, and are assumed to be bored or dug 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 are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, although 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 2,464 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. Within the County, casing diameter information is available for 1,874 of the 2,464 water wells completed in the bedrock aquifers. Of these 1,874 water wells, 99% have surface casing diameters of less than 275 mm and these bedrock water wells have been mainly completed with either a slotted liner or as open hole. There were 21 bedrock water wells that were completed with a water well screen. Records from 17 of these 21 bedrock water wells indicated the presence of coal in the screened interval.

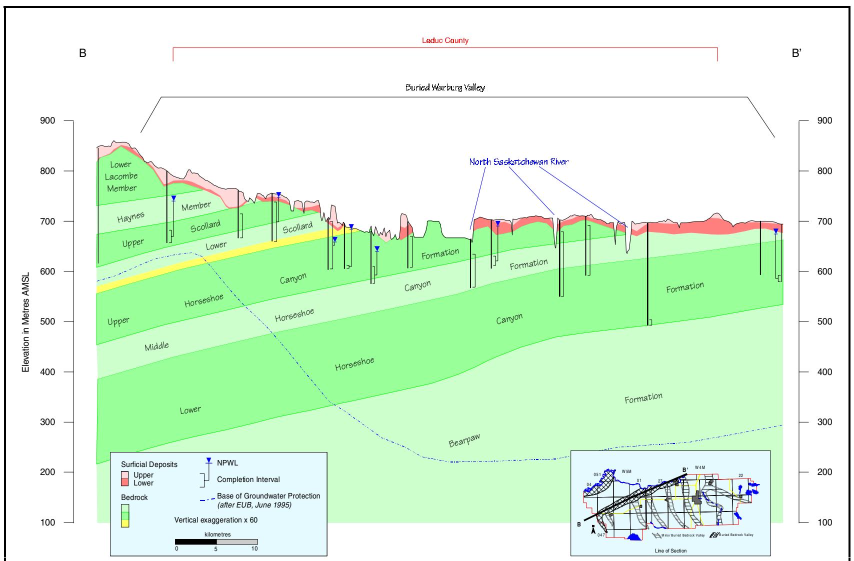

Figure 8. Cross-Section B - B'

The upper bedrock includes the Paskapoo, Scollard and Horseshoe Canyon formations (Figure 8). In the County, the Paskapoo Formation consists of the Lacombe and Haynes members. The Bearpaw Formation underlies the Lower Horseshoe Canyon Formation and is a regional aquitard[9].

8 See glossary
9 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[10] and lacustrine[11] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The upper surficial deposits include the more traditional glacial deposits of till[12] and meltwater deposits. In the County, pre-glacial materials are expected to be present in association with parts of the Buried Beverly and Warburg 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”.

Over the majority of the County, the surficial deposits are less than 20 metres thick. The exceptions are mainly in association with the linear bedrock lows where the deposits can have a thickness of more than 40 metres. The main southwest-northeast-trending linear bedrock lows in the County have been designated as the Buried Beverly and Warburg valleys, as shown on the following map.

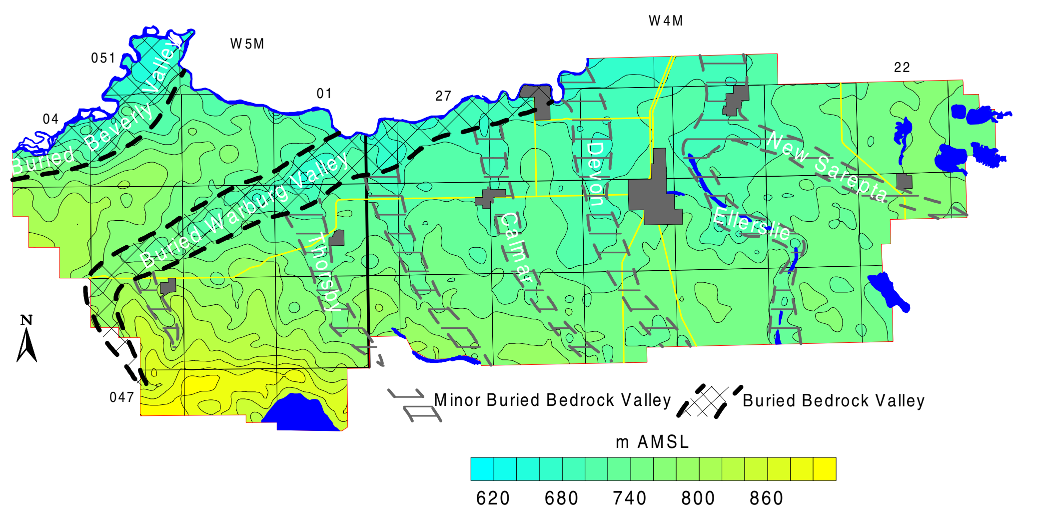

Figure 9. Bedrock Topography

10 See glossary
11 See glossary
12 See glossary

The Buried Beverly Valley coincides with the North Saskatchewan River in the northwestern part of the County in townships 050 and 051, ranges 03 and 04, W5M. The Valley is approximately six to nine kilometres wide with local bedrock relief being less than 60 metres. Sand and gravel deposits can be expected in association with this bedrock low, but the thickness of the sand and gravel deposits is expected to be mainly less than 15 metres.

The Buried Warburg Valley originates near the Town of Warburg, trends from southwest to northeast and coincides with the North Saskatchewan River in townships 050 and 051, ranges 25 to 28, W4M. The Valley is approximately four kilometres wide, with local relief being less than 80 metres. Sand and gravel deposits associated with the linear bedrock lows can be expected to be mainly less than 15 metres thick.

In addition to the Buried Beverly and Warburg valleys, there are minor buried bedrock valleys shown on the bedrock topography map. These lows trend southeast to northwest in the County, and are tributaries to the Buried Warburg and Stony valleys. The most significant of these tributaries are the Buried Thorsby, Calmar, Devon, Ellerslie and New Sarepta valleys.

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur over most of the northern half of the County. The total thickness of the lower surficial deposits is mainly less than 15 metres, but can be more than 25 metres in the Buried Warburg Valley. 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 Beverly and Warburg valleys. The lowest sand and gravel deposits are of fluvial origin, are usually less than five metres thick and may be discontinuous.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. The thickness of the upper surficial deposits is mainly less than 20 metres. The greatest thickness of upper surficial deposits occurs mainly in association with the northwest-southeast-trending linear bedrock lows; there are several areas in the County where these deposits are not present.

Sand and gravel deposits can occur throughout the surficial deposits. The total thickness of sand and gravel deposits is generally less than ten metres but can be more than 15 metres in the areas of the linear bedrock lows.

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over less than 15% of the County, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. The areas where the sand and gravel percentages are more than 50% are mainly associated with the linear bedrock lows.

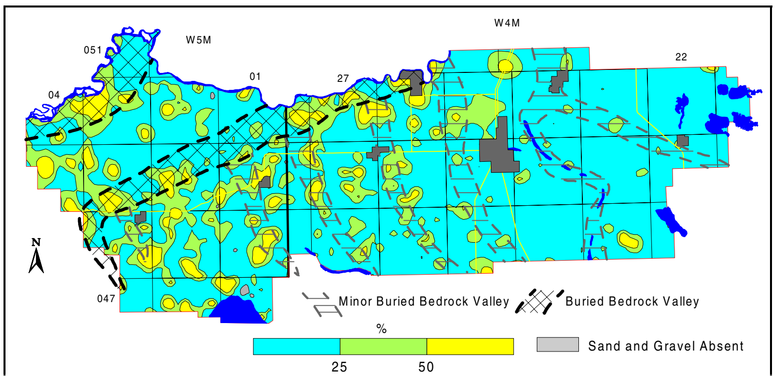

Figure 10. Amount of Sand and Gravel in Surficial Deposits

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, 81 water wells are completed in aquifers in the lower surficial deposits and 593 are completed in aquifers in the upper surficial deposits. This number of water wells is nearly four times the number determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location.

The majority of the water wells completed in the upper surficial deposits are mainly in the southeast–northwest-trending linear bedrock lows as shown in Figure 11. A large number of the water wells completed in the lower surficial deposits are located along the Buried Warburg Valley.

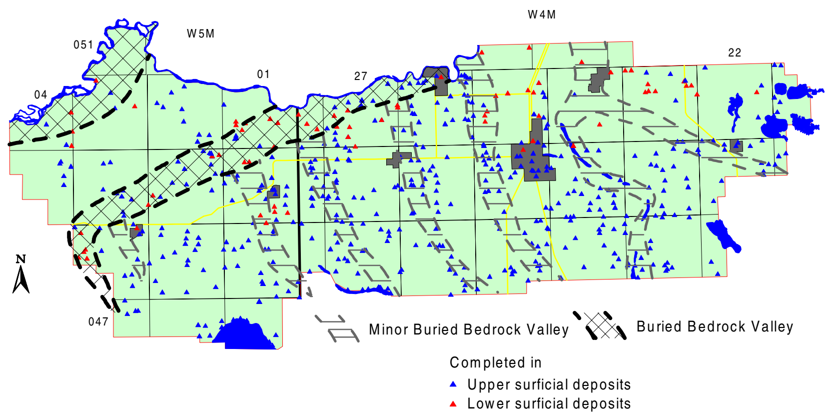

Figure 11. Water Wells Completed in Surficial Deposits

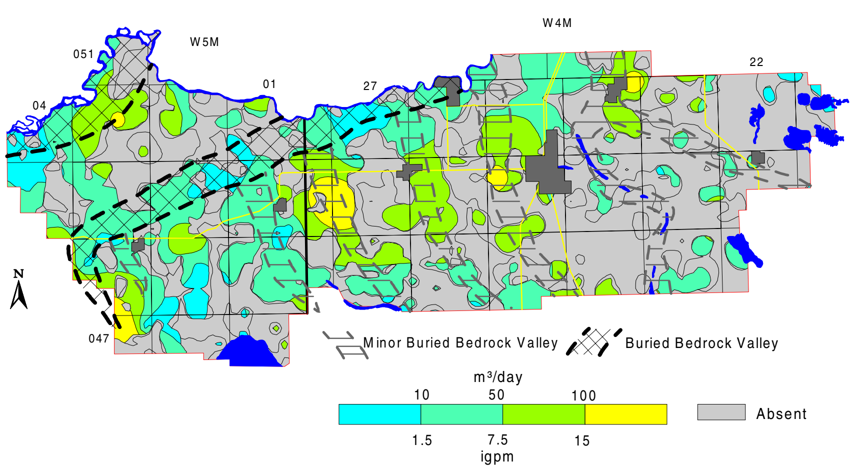

Figure 12. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

The adjacent map shows expected yields for water wells completed in aquifers in sand and gravel aquifers(s), based on the aquifers that have been developed by existing water wells. These data show that water wells with yields of less than 50 m³/day from sand and gravel aquifer(s) can be expected in most areas of the County where the sand and gravel aquifer(s) are present. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with the minor buried bedrock valleys. Over approximately 60% of the County, the sand and gravel deposits are not present, or if present, are not saturated.

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 data that can be attributed to the Lower Sand and Gravel Aquifer. This is in part related to the number of control points from this Aquifer, which is in part related to the limited areal extent of the lower 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 and lower sand and gravel aquifers. The groundwaters from these aquifers are generally chemically hard and high in dissolved iron. In the adjacent municipalities of Brazeau and Parkland, chemical hardness concentrations in the groundwaters from the surficial deposits are mainly more than 200 mg/L; in Leduc County, the chemical hardness values of the groundwaters are mainly less than 200 mg/L.

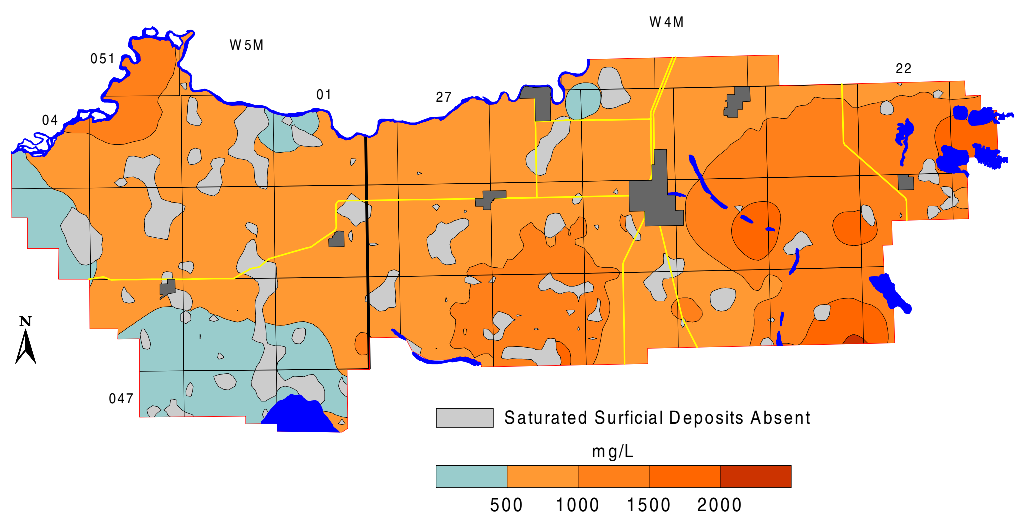

Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

The groundwaters from the surficial deposits are generally calcium-magnesium-bicarbonate-type waters; however, in Leduc County sodium-bicarbonate-type waters dominate, with 70% of the groundwaters having a TDS of less than 1,000 mg/L. The groundwaters with lower TDS values occur in the western part of the County. Groundwaters from the surficial deposits are expected to have dissolved iron concentrations of greater than 1 mg/L.

Although the majority of the groundwaters from surficial deposits are sodium-bicarbonate-type waters in the County, there are groundwaters from the surficial deposits with calcium as the main cation; there are also groundwaters with significant concentrations of the sulfate ion. The groundwaters with elevated levels of sulfate generally 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 30 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. Typically, these aquifers directly overlie or are close to the bedrock surface. Saturated sand and gravel deposits are not continuous but are expected over approximately 25% of the County.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the upper surficial deposits; and (2) 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 is more than 15 metres thick in a few areas, but over the majority of the County, is less than five metres thick; in over 65% of the County, the Aquifer is absent. Most of the greater thickness in the Upper Sand and Gravel Aquifer occurs in the areas of the northwest-southeast-trending linear bedrock lows.

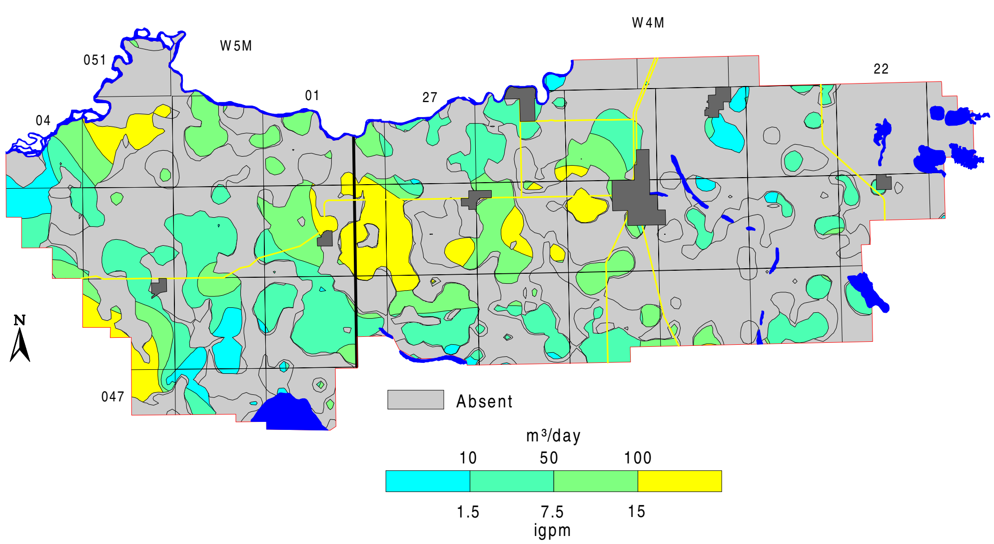

Figure 14. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

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 occur mainly as hydraulically discontinuous pockets, the apparent yields of the water wells are limited. The apparent yields for water wells completed in this Aquifer are expected to be mainly less than 100 m³/day. 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.

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 thickness of the Lower Sand and Gravel Aquifer is mainly less than five metres. The Lower Sand and Gravel Aquifer is mostly restricted to the Buried Beverly and Warburg valleys in the County.

5.2.4.1 Apparent Yield

Apparent yields for water wells completed in the Lower Sand and Gravel Aquifer range from less than 10 m³/day to more than 30 m³/day. The highest yields are expected in the northern part of the County in association with a linear bedrock low, in the vicinity of the Town of Beaumont.

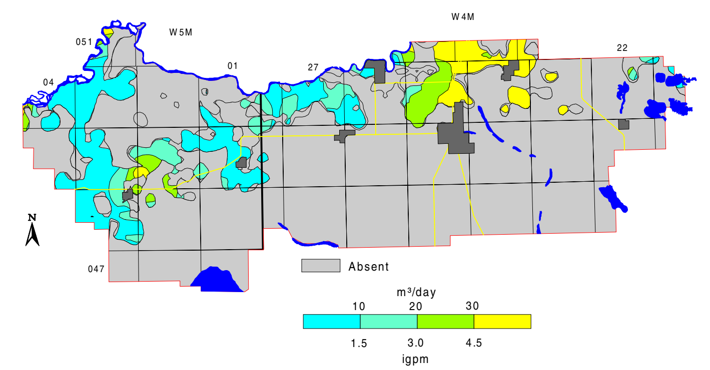

Figure 15. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County is the Paskapoo Formation and the Edmonton Group. The Paskapoo Formation consists of cycles of thick, tabular sandstones, siltstone and mudstone layers (Glass, D. J. [editor], 1990). The Edmonton Group consists of fresh and brackish-water deposits of fine-grained sandstone and silty shale, thick coal seams, and numerous bentonite beds (Carrigy, 1971). The maximum thickness of the Paskapoo Formation can be 800 metres, but in the County, the thickness is from 0 to 200 metres. The thickness of the Edmonton Group varies from 400 to 480 metres. The Edmonton Group in the County includes the Scollard, Battle, Whitemud and Horseshoe Canyon formations.

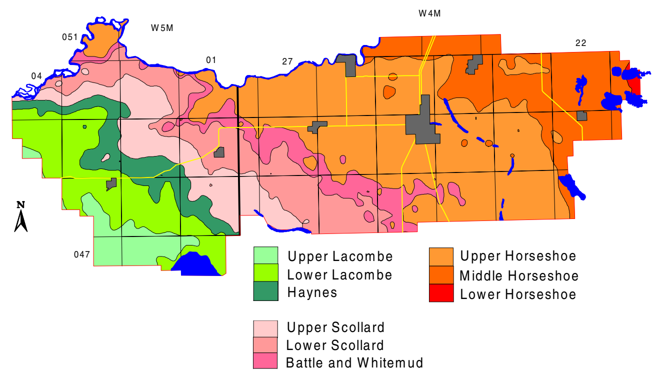

Figure 16. Bedrock Geology

The Paskapoo Formation is the upper bedrock and subcrops in the southwestern quarter of the County. The Paskapoo Formation in central Alberta consists of the Dalehurst, Lacombe and Haynes members (Demchuk and Hills, 1991); in Leduc County, the Dalehurst Member is not present.

The Lacombe Member is the upper bedrock in the western part of the County and subcrops in parts of townships 047 to 050, ranges 01 to 04, W5M. The Lacombe Member has a maximum thickness of 140 metres and has two separate designations: Upper and Lower. The Upper Lacombe Member is mostly composed of shale interbedded with sandstone and has a maximum thickness of 70 metres. The Lower Lacombe Member is composed of sandstone and coal layers. In the middle of the Lower Lacombe Member, there is a coal zone, which can be up to five metres thick. The Lower Lacombe Member has a maximum thickness of 70 metres.

The Haynes Member subcrops in the western part of the County, in parts of townships 048 to 050, ranges 01 to 04, W5M and underlies the Lower Lacombe Member. The Haynes Member has a maximum thickness of 60 metres and is composed mainly of sandstone with some siltstone, shale and coal.

The Scollard Formation underlies the Haynes Member and subcrops in the western part of the County. The Scollard Formation has a maximum thickness of 120 metres within the County and has two separate designations: Upper and Lower. The Upper Scollard consists mainly of sandstone, siltstone, shale and coal seams or zones. Two prominent coal zones within the Upper Scollard are the Ardley Coal (up to 20 metres thick) and the Nevis Coal (up to 3.5 metres thick). The bottom of the Nevis Coal Seam is the border between the Upper and Lower Scollard. The Lower Scollard has a maximum thickness of 50 metres and is composed mainly of shale and sandstone.

Beneath the Scollard Formation are two formations having a maximum thickness of 30 metres; the two are the Battle and Whitemud formations. The Battle Formation is composed mainly of claystone, tuff, shale and bentonite, and includes the Kneehills Member, a 2.5- to 30-cm thick tuff bed. The Whitemud Formation is composed mainly of shale, siltstone, sandstone and bentonite. The Battle and Whitemud formations are significant geologic markers, and were used in the preparation of various geological surfaces within the bedrock. Because of the ubiquitous nature of the bentonite in the Battle and Whitemud formations, there is very little significant permeability within these two formations.

The Horseshoe Canyon Formation is the lower part of the Edmonton Group and is the upper bedrock in the eastern half of the County. The Horseshoe Canyon Formation has a maximum thickness of 350 metres and has three separate designations: Upper, Middle and Lower. The Upper Horseshoe Canyon, which can be up to 100 metres thick, is the uppermost bedrock in the east-central part of the County immediately east of the area where the Scollard Formation subcrops. The Middle Horseshoe Canyon, which is up to 70 metres thick, subcrops in the northeastern part of the County. The Lower Horseshoe Canyon, which is up to 170 metres thick, subcrops in a small part of township 050, range 21, W4M in the extreme northeastern corner of the County.

The Horseshoe Canyon Formation consists of deltaic[13] and fluvial sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of limestone and ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be finer grained. The lower 60 to 70 metres and the upper 30 to 50 metres of the Horseshoe Canyon Formation can include coarser grained sandstone deposits.

The Bearpaw Formation underlies the Horseshoe Canyon Formation and is in the order of 80 metres thick within the County. The Bearpaw Formation includes transgressive, shallow marine (shoreface) and open marine facies[14] deposits. In Leduc County, the Bearpaw Formation is composed mainly of shale and as such is a regional aquitard. Because the Bearpaw Formation is an aquitard, there will be no direct review of the Bearpaw Formation in the text of this report.

5.3.2 Aquifers

Geological Unit	No. of Water Wells
Upper Lacombe	95
Lower Lacombe	616
Haynes	240
Upper Scollard	289
Lower Scollard	395
Upper Horseshoe Canyon	1,897
Middle Horseshoe Canyon	830
Lower Horseshoe Canyon	58
Other	829
Total	5,249

Table 2. Completion Aquifer

Of the 5,922 water wells in the database, 2,464 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 5,249 from 2,464. 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 5,249 bedrock water wells, 4,420 have been assigned a specific geologic unit. The bedrock water wells are mainly completed in the Upper and Middle Horseshoe Canyon aquifers and the Lower Lacombe Aquifer, as shown in the table above.

13 See glossary
14 See glossary

There are 676 records for bedrock water wells that have apparent yield values; this constitutes 13% of all bedrock water wells. In the County, water well yields in the upper bedrock aquifer(s) are mainly less than 50 m³/day. The few areas of higher yields that are indicated on the adjacent figure are sporadic in the County. These higher yields may be a result of increased permeability that has resulted from the weathering process.

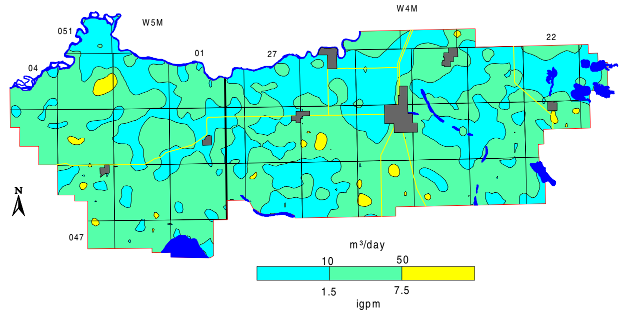

Figure 17. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

All of the bedrock water wells with apparent yield values can be assigned to aquifers associated with specific geologic units. 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 Values for Apparent Yields	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Upper Lacombe	35	8	17	10
Lower Lacombe	220	74	117	29
Haynes	60	14	29	17
Upper Scollard	95	16	53	26
Lower Scollard	95	54	34	7
Upper Horseshoe Canyon	62	10	50	2
Middle Horseshoe Canyon	98	30	60	8
Lower Horseshoe Canyon	11	4	3	4
Totals	676	210	363	103

Table 3. 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 200 to more than 2,000 mg/L. The TDS values of more than 1,500 mg/L are mainly east of range 24, W4M.

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 concentrations exceed 400 mg/L. The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 100 mg/L in more than 90% of the County.

In 85% of the County, the fluoride ion concentration in the groundwater from the upper bedrock aquifer(s) is less than 1.5 mg/L.

The Piper tri-linear diagrams[15] (see Appendix A) show that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

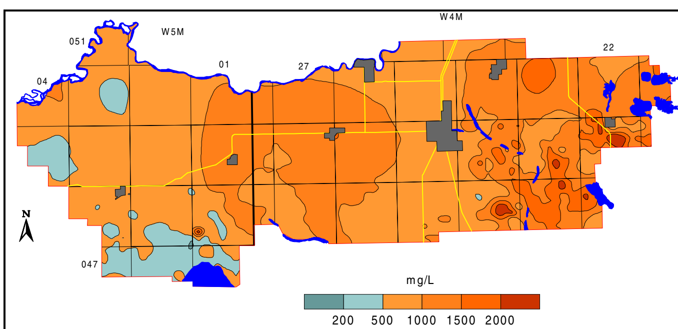

Figure 18. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

[15] See glossary

5.3.4 Upper Lacombe Aquifer

The Upper Lacombe Aquifer comprises the porous and permeable parts of the Upper Lacombe Member that subcrops under the surficial deposits in parts of townships 047 to 049, ranges 01 to 04, W5M in the southwestern part of the County. The thickness of the Upper Lacombe Member is mainly between 20 and 60 metres but varies from less than 20 metres at the northeastern extent to 80 metres in the southwestern part of the County.

5.3.4.1 Depth to Top

The depth to the top of the Upper Lacombe Member is a function of the thickness of the surficial deposits, which ranges from less than 10 metres to more than 20 metres.

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Lacombe 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 in ranges 03 and 04, W5M.

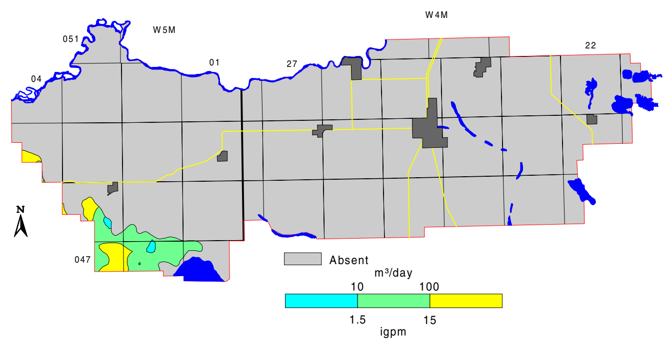

Figure 19. Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer

5.3.4.3 Quality

The groundwaters from the Upper Lacombe Aquifer are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are expected to be mainly less than 500 mg/L, with higher values mainly in townships 047 to 049, ranges 02 to 04, W5M. The sulfate concentrations are generally less than 100 mg/L. The chloride concentrations of the groundwaters from the Upper Lacombe Aquifer range from less than 4 to a high of 13 mg/L.

5.3.5 Lower Lacombe Aquifer

The Lower Lacombe Aquifer comprises the porous and permeable parts of the Lower Lacombe Member. The Lower Lacombe Aquifer subcrops in the southwestern part of the County and underlies the Upper Lacombe Aquifer. The thickness of the Lower Lacombe Member is mainly between 40 and 80 metres.

5.3.5.1 Depth to Top

The depth to the top of the Lower Lacombe Member varies from less than 20 metres below ground level at the northeastern extent of the Member to more than 80 metres in the southwestern part of the County.

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Lacombe Aquifer are mainly between 10 and 100 m³/day. The adjacent map indicates that apparent yields of more than 100 m³/day are expected at the eastern extent of the Member in township 048, range 02, W5M.

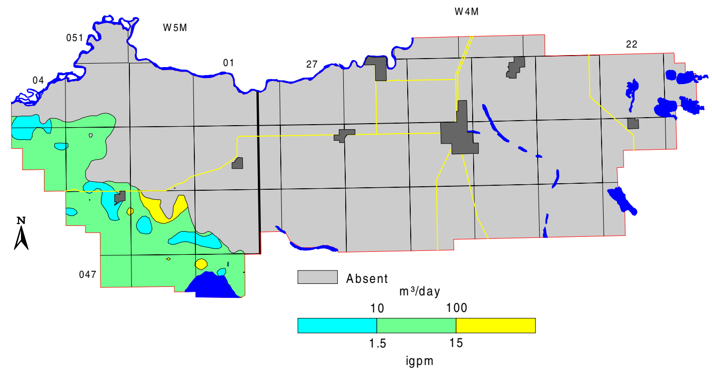

Figure 20. Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer

Two Talisman Energy Inc. (Talisman) water source wells in 16-34-047-02 W5M are authorized to divert a total of 360 m³/day (Hydrogeological Consultants Ltd. (HCL), 1999). The water source wells are completed in the Lower Lacombe Aquifer. An extensive aquifer test with the two water source wells in 1989 (HCL, 1989) indicated an effective transmissivity of 25 m²/day and a corresponding storativity of 0.0016.

5.3.5.3 Quality

The groundwaters from the Lower Lacombe Aquifer are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are mostly between 500 and 750 mg/L. The higher values are in the southwestern corner of the County. The sulfate concentrations are generally less than 100 mg/L. Chloride concentrations in the groundwaters from the Lower Lacombe Aquifer range from less than 4 to more than 10 mg/L.

The groundwaters from the Talisman water source wells are sodium-bicarbonate-types. Between 1970 and 1997, five groundwater samples were collected from the two water source wells in the Lower Lacombe Member (HCL, May 1998). The TDS concentrations ranged from 500 to 800 mg/L, sulfate concentrations ranged from below the detection limit to 5 mg/L, and chloride concentrations ranged from 15 to 47 mg/L.

5.3.6 Haynes Aquifer

The Haynes Aquifer comprises the porous and permeable parts of the Haynes Member. The Haynes Member underlies the Lower Lacombe Member and subcrops under the surficial deposits in the western part of the County. The thickness of the Haynes Member is mainly between 30 and 50 metres but varies from less than 10 metres at the northeastern extent to 60 metres in the southwestern part of the County.

5.3.6.1 Depth to Top

The depth to the top of the Haynes Member is variable, ranging from less than 20 metres at the northeastern extent to more than 140 metres in the southwestern part of the County.

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Haynes Aquifer range from less than 10 to more 100 m³/day. The areas where water wells with higher yields are expected are mainly where the Haynes Member subcrops under the surficial deposits and would be most subjected to weathering processes.

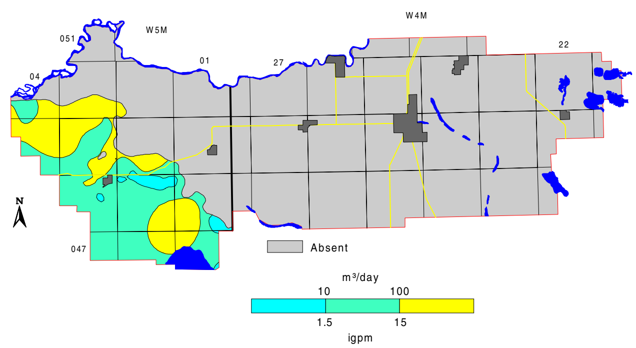

Figure 21. Apparent Yield for Water Wells Completed through Haynes Aquifer

An aquifer test conducted with the Fred Kostyk Lawn Water Well completed in the Haynes Aquifer and drilled in NE 23-048-02 W5M in 1981 (HCL, January 1998) indicated a long-term yield in excess of 11.5 m³/day based on a transmissivity of 19.2 m²/day and a pumping rate of 8 litres per minute.

Additional data for the Haynes Aquifer are available for a water source well in the Alder Flats area, southwest of the County, in 01-17-045-07 W5M (HCL, 1995). An extended aquifer test indicated a long-term yield of 45 m³/day based on an effective transmissivity of 0.25 m²/day.

5.3.6.3 Quality

The groundwaters from the Haynes Aquifer are mainly a bicarbonate type (see CD-ROM). The TDS concentrations are mostly between 500 and 750 mg/L. The sulfate concentrations are generally less than 100 mg/L. Chloride concentrations in the groundwaters from the Haynes Aquifer are mainly less than 10 mg/L. Groundwater from the Fred Kostyk Lawn Water Well (HCL, January 1998) is a sodium-bicarbonate-type, has a TDS concentration of 627 mg/L, a sulfate concentration of 53 mg/L and a chloride concentration of 3.4 mg/L. Groundwater from the Alder Flats area water source well (HCL, 1995), which is completed in the Haynes Aquifer, has a TDS concentration of 1,245 mg/L, a sulfate concentration of 1 mg/L and a chloride concentration of 360 mg/L; the Alder Flats water source well is 382 metres deep.

5.3.7 Upper Scollard Aquifer

The Upper Scollard Aquifer comprises the porous and permeable parts of the upper part of the Scollard Formation that underlies the Haynes Member in the westernmost part of the County, and subcrops under the surficial deposits where the Haynes Member has been eroded. The thickness of the Upper Scollard Formation increases to the southwest and can reach 80 metres in the southwestern part of the County.

5.3.7.1 Depth to Top

The depth to the top of the Upper Scollard is variable, ranging from less than 20 metres at the northeastern extent to more than 200 metres in the southwestern corner of the County.

5.3.7.2 Apparent Yield

The apparent yields for water wells completed through the Upper Scollard Aquifer range from less than 10 to more than 100 m³/day, with 17% of the values being between 200 and 700 m³/day.

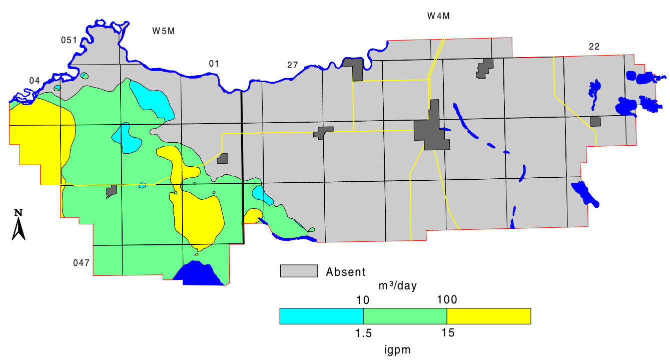

Figure 22. Apparent Yield for Water Wells Completed through Upper Scollard Aquifer

5.3.7.3 Quality

The groundwaters from the Upper Scollard Aquifer are mainly a sodium-bicarbonate type. The TDS concentrations in groundwaters from the Upper Scollard Aquifer are mainly less than 1,000 mg/L. The sulfate concentrations are mainly less than 100 mg/L. Chloride concentrations in the groundwaters from the Upper Scollard Aquifer range from less than 4 to more than 10 mg/L.

5.3.8 Lower Scollard Aquifer

The Lower Scollard Aquifer comprises the porous and permeable parts of the lower part of the Scollard Formation that underlies the Upper Scollard Aquifer, and subcrops under the surficial deposits in the western part of the County. The thickness of the lower part of the Scollard Formation is mainly between 30 and 40 metres but varies from less than 10 metres at the northeastern extent to more than 40 metres in the southwestern part of the County.

5.3.8.1 Depth to Top

The depth to the top of the Lower Scollard is variable, ranging from less than 20 metres at the northeastern extent to more than 280 metres in the southwestern part of the County.

5.3.8.2 Apparent Yield

The apparent yields for water wells completed through the Lower Scollard Aquifer are significantly less than the yield of water wells completed through the Upper Scollard Aquifer. Fifty-seven percent of the values for apparent yield for the water wells completed in the Lower Scollard Aquifer are less than 10 m³/day. The adjacent map shows the higher yields toward the western edge of the County. However, these values are a result of the gridding procedure used to process a limited number of data points. The number of data points is limited in the western part of the County, due to the increased depth of burial. It is expected that the yields for water wells completed in the Lower Scollard Aquifer in the western part of the County will be less than 50 m³/day.

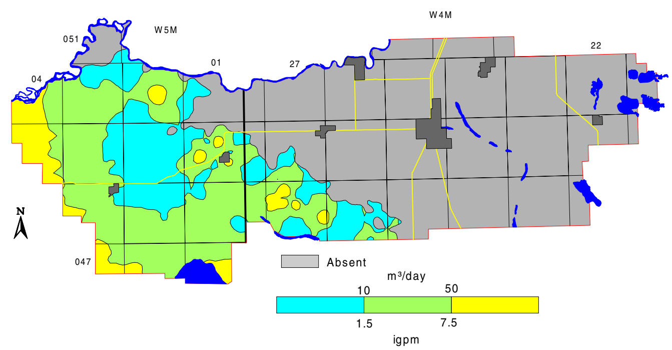

Figure 23. Apparent Yield for Water Wells Completed through Lower Scollard Aquifer

5.3.8.3 Quality

There are two water well records in the database with sufficient information to determine the chemical type of groundwaters from the Lower Scollard Aquifer. The groundwaters from the Lower Scollard Aquifer are a sodium-bicarbonate-type. There are 12 water well records in the database that have TDS, chloride and sulfate values for water wells completed through the Lower Scollard Aquifer. The TDS concentrations in groundwater from the Lower Scollard Aquifer range from less than 750 to more than 1,000 mg/L. The higher TDS values are in the southwestern part of the County. The sulfate concentrations in the groundwaters from the Lower Scollard Aquifer are mainly less than 100 mg/L. The two small areas on the map (see CD-ROM) that indicate sulfate concentrations of more than 100 mg/L are a result of the gridding procedure used to process data from adjacent counties. The chloride concentrations in the groundwaters from the Lower Scollard Aquifer range from less than 4 to more than 10 mg/L.

5.3.9 Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Upper Horseshoe Canyon Formation that underlies the Scollard Formation, and subcrops under the surficial deposits in 40% of the County. The thickness of the Upper Horseshoe Canyon Formation increases to the southwest and can reach more than 100 metres in the western part of the County.

5.3.9.1 Depth to Top

The depth to the top of the Upper Horseshoe Canyon Formation is variable, ranging from less than 20 metres at the eastern extent to more than 300 metres in the extreme southwestern corner of the County.

5.3.9.2 Apparent Yield

The apparent yields for water wells completed through the Upper Horseshoe Canyon Aquifer range from less than 10 to more than 100 m³/day; sixty-nine percent of the apparent yield values that are available are between 10 and 50 m³/day. The lower yields presented in the western part of the County, and shown on the adjacent map, could be a result of the gridding procedure used to process a very limited number of data points due to the depth of burial. The areas where water wells with higher yields are expected are mainly where the Upper Horseshoe Canyon Formation subcrops under the surficial deposits and would be most subjected to weathering processes.

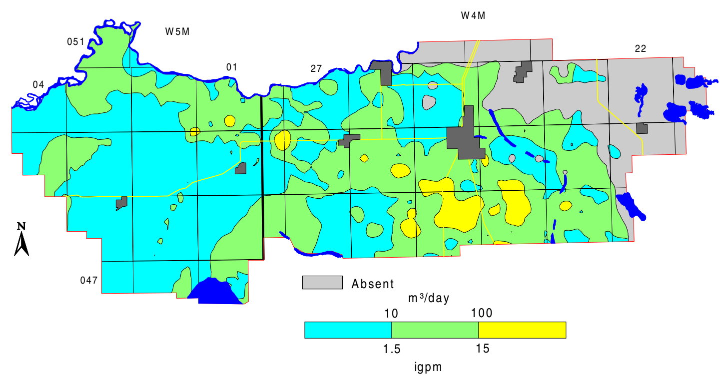

Figure 24. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer

An extended aquifer test conducted with the Village of Calmar's Water Test Hole 80-6, drilled in 07-25-049-07 W5M and completed in the Upper Horseshoe Canyon Aquifer (MLM, 1980), indicated a long-term yield of more than 100 m³/day based on a transmissivity of 85 m²/day.

5.3.9.3 Quality

The groundwaters from the Upper Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types. The TDS concentrations in groundwaters from the Upper Horseshoe Canyon Aquifer are mainly less than 1,500 mg/L. The higher TDS values are in ranges 23 and 24, W4M. The sulfate concentrations are mainly less than 500 mg/L. Chloride concentrations in the groundwaters from the Upper Horseshoe Canyon Aquifer are mainly less than 250 mg/L.

Chemistry data were not available for the Village of Calmar water test hole completed in the Upper Horseshoe Canyon Aquifer.

5.3.10 Middle Horseshoe Canyon Aquifer

The Middle Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Middle Horseshoe Canyon Formation which subcrops under the surficial deposits in the northeastern part of the County. The thickness of the Middle Horseshoe Canyon Formation increases to the west and can reach more than 70 metres in the western part of the County. In general terms, the permeability of the Middle Horseshoe Canyon Aquifer is very low. Higher local permeability can be expected when the depth of burial is less than 100 metres and weathering processes have occurred.

5.3.10.1 Depth to Top

The depth to the top of the Middle Horseshoe Canyon Formation is variable, ranging from less than 50 metres in the eastern part of the County to more than 350 metres in the southwestern part of the County.

5.3.10.2 Apparent Yield

The apparent yields for water wells completed through the Middle Horseshoe Canyon Aquifer range from less than 10 to more than 100 m³/day. However, 82% of the values for apparent yield are less than 50 m³/day. The lower yields presented in the north-central third of the County could be a result of the gridding procedure used to process a very limited number of data points due to the depth to the top of the Formation. The areas where water wells with higher yields are expected are mainly at the eastern extent of the Aquifer where the Middle Horseshoe Canyon Formation subcrops under the surficial deposits and would be most subjected to weathering processes.

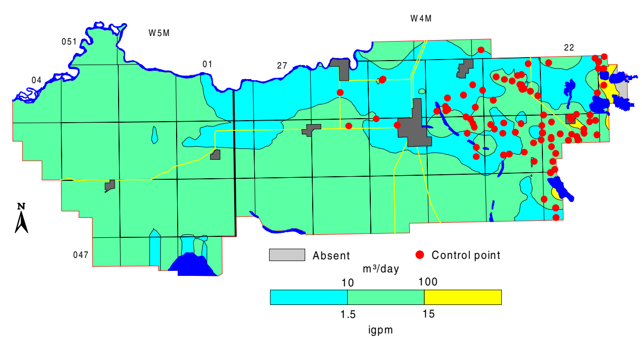

Figure 25. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer

An extended aquifer test was conducted with the Village of New Sarepta's Water Test Hole (WTH) No. 6-81 in SW 34-049-22 W4M was completed in the Middle Horseshoe Canyon Aquifer (Tokarsky, 1981). The long-term yield for this water test hole is more than 300 m³/day. The high projected long-term yield may be a result of the weathering processes, increasing the local transmissivity of the Aquifer.

5.3.10.3 Quality

The groundwaters from the Middle Horseshoe Canyon Aquifer are mainly sodium-bicarbonate or sodium-sulfate types, with TDS mainly between 1,000 and 1,500 mg/L. The sulfate concentrations are generally less than 500 mg/L and chloride concentrations are mainly less than 100 mg/L. The groundwaters from WTH No. 6-81 are a sodium-bicarbonate type. Two groundwater samples from Water Test Hole 6-81 while completed in the Middle Horseshoe Canyon Aquifer (Tokarsky, 1981) had TDS concentrations of 757 and 826 mg/L, sulfate concentrations of 68 and 73 mg/L and chloride concentrations of 3 and 4 mg/L.

All of the chemical parameter maps exhibit lower values in the western part of the County as a result of the gridding process using limited data control.

5.3.11 Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Lower Horseshoe Canyon Formation which subcrops under the surficial deposits in a small area in the extreme northeastern part of the County. The thickness of the Lower Horseshoe Canyon Formation increases to the west and can reach more than 160 metres in the western part of the County. In general terms, the permeability of the Lower Horseshoe Canyon Aquifer is very low. Higher local permeability can be expected when the depth of burial is less than 100 metres and weathering processes have occurred. In the eastern two-thirds of the County, the Lower Horseshoe Canyon Formation is above the Base of Groundwater Protection.

5.3.11.1 Depth to Top

The depth to the top of the Lower Horseshoe Canyon Formation is variable, ranging from less than 50 metres in the northeastern part of the County to more than 550 metres in the southwestern part of the County.

5.3.11.2 Apparent Yield

There are 14 values available for the apparent yields for water wells completed in the Lower Horseshoe Canyon Aquifer. Of these 14 values, three are from drill stem tests, which are the westernmost control points on the adjacent figure. The control points in Tp 050, R 21, W4M all have apparent yields of greater than 100 m³/day.

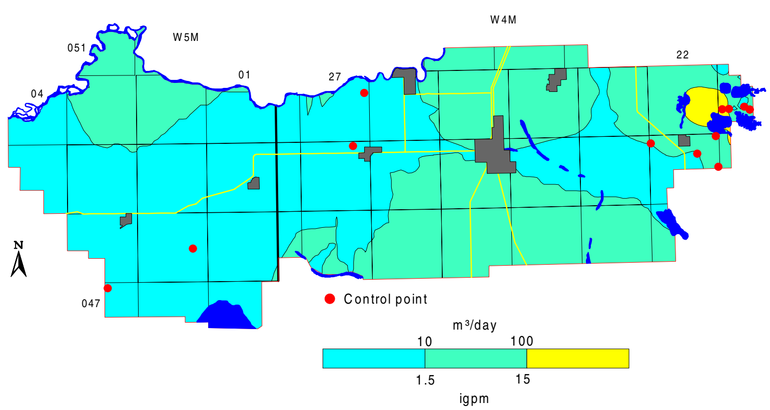

Figure 26. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

In general terms, the yields from the Lower Horseshoe Canyon Aquifer can be more than 1,000 m³/day where the aquifer has been subjected to weathering processes, to less than 10 m³/day where the depth of burial is significant and less weathering has occurred.

5.3.11.3 Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are sodium-bicarbonate or sodium-sulfate types, based on the information provided on five water well records in the database. From these and the few partial chemical analyses results available, the concentrations of TDS are mainly less than 1,500 but range from 500 to more than 2,000 mg/L, the sulfate values are mainly between 100 and 500 mg/L and the chloride concentrations are mainly less than 250 mg/L.

All of the chemical parameter maps exhibit lower values west of range 24, W4M (see CD-ROM) as a result of the gridding process using limited data control.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are sixteen locations in the County where water levels are being measured and recorded with time. These sites are observation water wells (Obs WWs) that are part of the AEP regional groundwater-monitoring network. These sixteen Obs WWs are in four main areas of the County. Of the sixteen Obs WWs, thirteen are in the vicinity of the Village of Warburg (six in 12-10-048-03 W5M, seven in 14-04-048-02 W5M), and the remaining three are in 02-18-049-23 W4M (Rollyview), 10-26-049-25 W4M (Leduc) and 08-36-050-26 W4M (Devon). Water-level measurements are available for the Rollyview Obs WW but are of limited use, and are not presented in the report.

The water-level fluctuations in AEP Obs No. 320 in 14-04-048-02 W5M have been compared to the summer precipitation measured at the Calmar weather station; the comparison is shown in the adjacent graph. The observation water well is 9.1 metres deep and is completed in the Upper Lacombe Aquifer. The summer precipitation includes the total precipitation measured in May, June, July and August of each year. The comparison shows that the water-level fluctuation reflects the changes in summer precipitation. The highest peaks in water level occur in 1986, 1990 and 1991. These peaks correspond to three of the four highest years of summer precipitation. The water-level fluctuations show two water peaks for most years. The first peak would be associated with recharge when the frost leaves the ground and the second coincides with the end of the growing season. The low water level at the start of each year is a result of no recharge to the groundwater flow system during the time of ground frost.

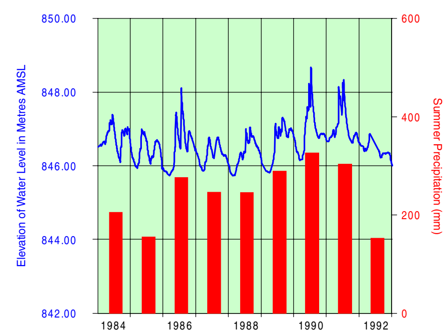

Figure 27. Summer Precipitation vs Water Levels in AEP Obs WW No. 320

There are six other AEP Obs WWs in 14-04-048-02 W5M, completed in aquifers ranging from the Lower Lacombe to the Upper Horseshoe Canyon. The water-level measurements for AEP Obs WW No. 344, completed at a depth of 244 metres below ground level in the Upper Horseshoe Canyon Aquifer, are available from 1983 to 1988 but are of limited use. However, the schematic drawing of the drilling log for Obs WW No. 344 was used to show the completion intervals for six of the seven AEP Obs WWs in 14-04-048-02 W5M (see Appendix A). The hydrographs for AEP Obs WW Nos. 315, 319 and 317 completed in the Lower Lacombe Aquifer also show water-level peaks that can be related to the precipitation peaks in 1986, 1990 and 1991. However, the water level in AEP Obs WW No. 316, completed at a depth of 125 metres in the Haynes Aquifer, shows no relationship to the precipitation peaks.

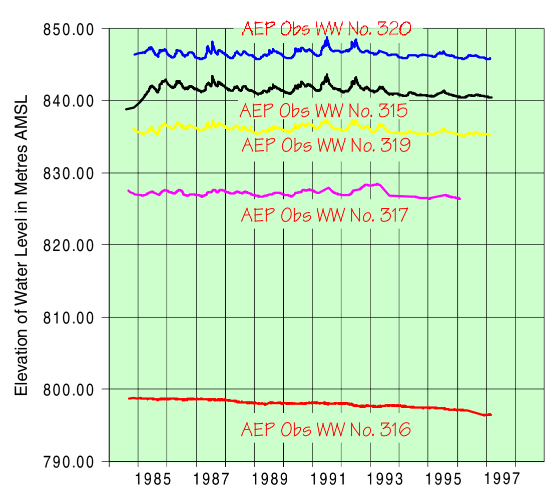

Figure 28. Hydrographs - AEP Observation Water Wells

Similar trends were also noted for the AEP observation water wells in 12-10-048-03 W5M. At this location, there are six observation water wells completed in aquifers from the Upper Surficial Deposits down to the Lower Scollard. The main difference in the water-level fluctuations between these observation water wells and the observation water wells in 14-04-048-02 W5M is only the observation water wells completed in the Upper Surficial Deposits and in the Upper Lacombe Aquifer appear to have a direct correlation with precipitation. This means that at the 12-10 location, the effects of precipitation cannot be observed below a depth of 25 metres while at the 14-04 site, the effects of precipitation are evident to a depth of 65 metres.

AEP Obs WW No. 156 in 08-36-050-26 W4M near Devon is completed at a depth of 10.7 metres in the Upper Surficial Deposits. The water levels in Obs WW No. 156 declined one metre from 1960 to 1970, rose three metres from 1970 to 1974, and rose another metre from 1974 to 1996 (see Appendix A). The water-level fluctuations in Obs WW No. 156 appear to be in response to groundwater users that stopped using groundwater in the mid-1970s.

AEP Obs WW No. 153 in 10-26-049-25 W4M is within the City of Leduc and is completed at a depth of 22.1 metres below ground level in the Middle Horseshoe Canyon Aquifer. The water levels in Obs WW No. 153 rose one metre from 1957 to 1972 (Appendix A). From 1972 to 1974, the water level sharply declined approximately two metres. The closest water well to this observation water well in the AEP groundwater database and drilled before 1972 is a domestic water well in NE 25-049-25 W4M. The domestic water well was drilled in 1968 and is completed in the Upper Horseshoe Canyon Aquifer. Whether this water well had an impact on the water level in the observation water well cannot be determined. However, the water-level decline between 1972 and 1973 does show the effects of groundwater diversion in the general vicinity of the observation water well.

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 laterally through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and 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 those parts of the various 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 lateral groundwater flow through the individual bedrock aquifers can be summarized as follows:

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	(m^3/day)	Flow (m^3/day)	Diversion (m^3/day)
Upper Lacombe						3,000	29
	34	0.008	6	Northwest	2,000		
	34	0.006	4	Southeast	1,000		
Lower Lacombe						3,000	514
	12	0.010	21	Northeast	3,000		
Haynes						1,000	502
	13	0.003	19	Northwest	1,000		
Upper Scollard						300	186
	5	0.003	27	Northwest	300		
Lower Scollard						600	162
	2	0.006	24	Northeast	300		
	2	0.006	24	Northwest	300		
Upper Horseshoe Canyon						600	413
	3	0.004	24	Northwest	300		
	3	0.003	35	North	300		
Middle Horseshoe Canyon						100	479
	1	0.003	29	Northwest	100		
Lower Horseshoe Canyon						100	0
	1	0.003	29	Northwest	100		

The data provided in the above table indicates there is more groundwater flowing through the individual bedrock aquifers than has been authorized to be diverted from each aquifer, except for the Middle Horseshoe Canyon Aquifer. The calculations of flow through individual aquifers as presented in the above table are very approximate and are intended as a guide for future investigations. Because a significant aquifer cannot be delineated in the surficial deposits, no attempt has been made to calculate the flow through either the Upper Sand and Gravel or the Lower Sand and Gravel aquifers.

6.2.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.2 to 1 cubic kilometres. This volume is based on an areal extent of 800 square kilometres and a saturated sand and gravel thickness of five 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 from water levels associated with water wells completed in aquifers in the surficial deposits. These water levels were used for the calculation of the saturated thickness of surficial deposits. In areas where the elevation of the water-level surface is below the bedrock surface, the surficial deposits are not saturated. The water-level map for the surficial deposits shows a general flow direction toward the Buried Warburg, Devon and Ellerslie valleys; in the extreme northwestern part of the County, the flow is toward the North Saskatchewan River.

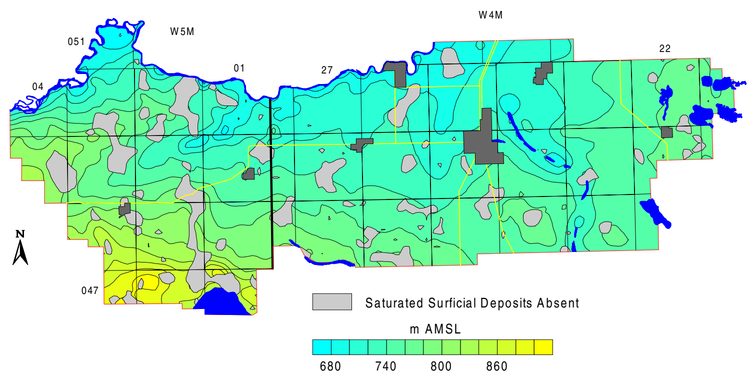

Figure 29. Non-Pumping Water-Level Surface in Surficial Deposits

6.2.2 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. In areas where the surficial deposits are unsaturated, the extrapolated water level for the surficial deposits is used.

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.

6.2.2.1 Surficial Deposits/Bedrock Aquifers

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 the 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 50% of the County, there is a downward hydraulic gradient from the surficial deposits toward the upper bedrock aquifer(s). Areas where there is an upward hydraulic gradient from the bedrock to the surficial deposits are mainly in the vicinity of the group of lakes that coincide with the Buried Ellerslie Valley. The remaining parts of the County are areas where there is a transition condition.

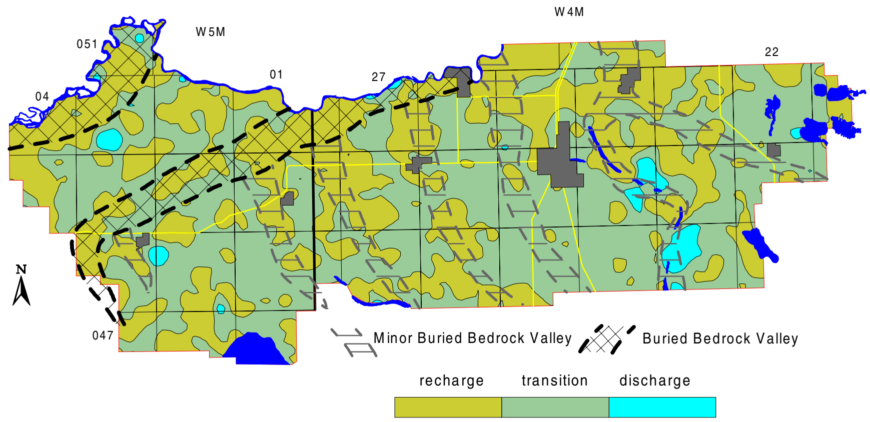

Figure 30. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

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

6.2.2.2 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 aquifers. 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.

The hydraulic relationship between the surficial deposits and the Upper Horseshoe Canyon Aquifer indicates that in more than 60% of the County where the Upper Horseshoe Canyon Aquifer is present, there is a downward hydraulic gradient. Discharge areas for the Upper Horseshoe Canyon Aquifer are associated with the edge of the Aquifer and the group of lakes that coincide with the Buried Ellerslie Valley. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers, with the exception of the Lacombe aquifers, indicates there is mainly a downward hydraulic gradient.

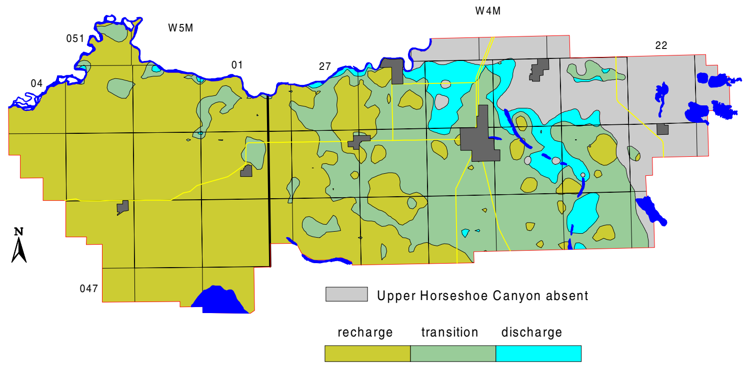

Figure 31. Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer

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 3,498 records in the area of the County with lithological descriptions, 178 have sand and gravel within one metre of ground level. In the remaining 3,320 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 Groundwater 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 - Top 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 4. Risk of Groundwater Contamination Criteria

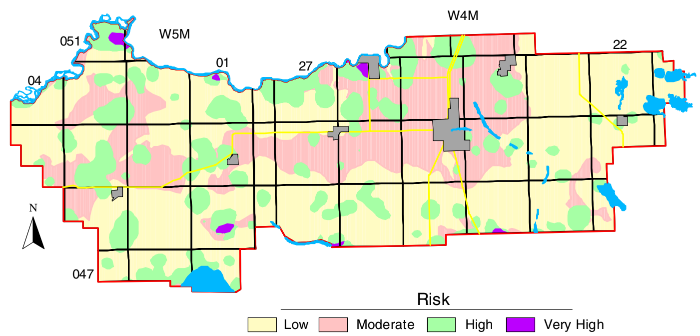

Figure 32. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that, in less than 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.

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 includes only verified data. The first step would be to field-verify the 16 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. 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.

The results of the present study indicate that the only readily identifiable aquifers in the surficial deposits are the sand and gravel deposits associated with the lows in the bedrock surface. The most noteworthy bedrock lows include the Buried Warburg Valley and the minor buried bedrock valleys.

While there are a few areas where water-level data are available, on the overall, there are an insufficient number of water levels to set up a 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, 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. Another municipality, Flagstaff County, is currently in the process of setting up a regional groundwater-monitoring program.

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 (see also pages C-2 to C-4):

1. The horizontal location of the water well should be determined within 10 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.

A list of 16 water wells that could be considered for the above program is given in Appendix E.

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 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.

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10 GLOSSARY

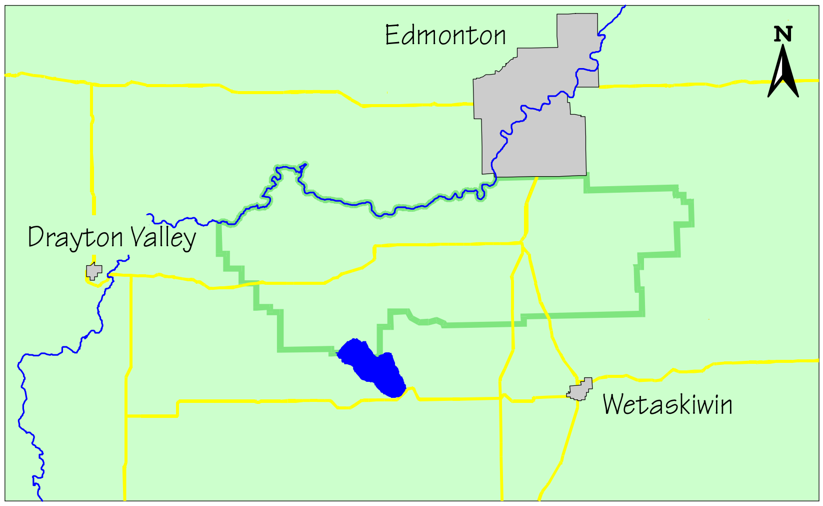
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities.
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer.
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.
Deltaic	a depositional environment in standing water near the mouth of a river.
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.
Piper tri-linear diagram	a method that permits the major cation and anion compositions of single or multiple samples to be represented on a single graph. This presentation allows groupings or trends in the data to be identified.
Surficial Deposits	includes all sediments above the bedrock.
Till	a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders.
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.

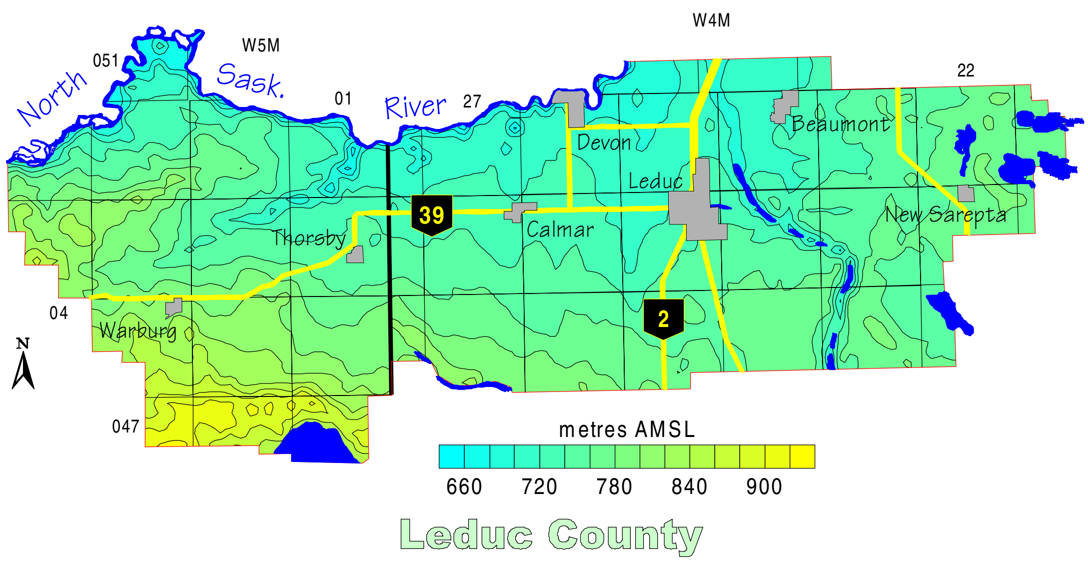
LEDUC COUNTY

Appendix A

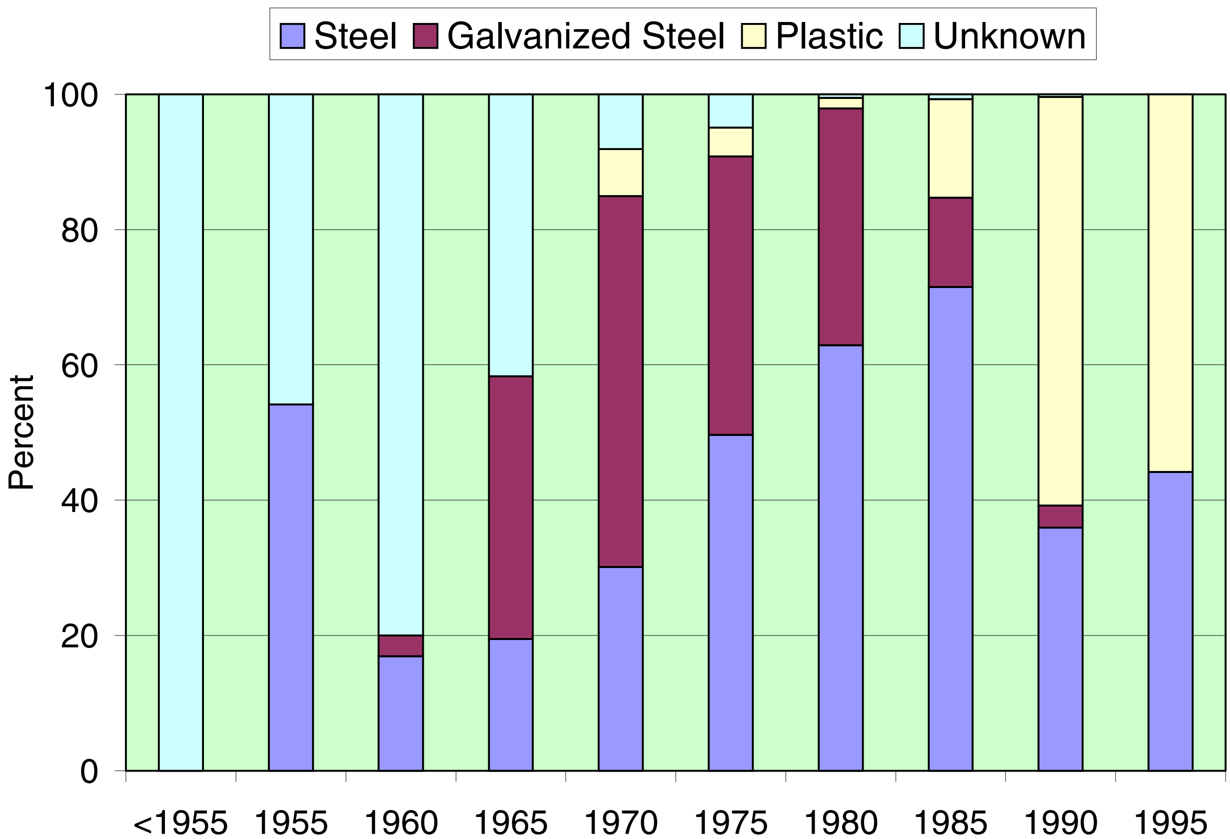
HYDROGEOLOGICAL MAPS AND FIGURES

Index Map

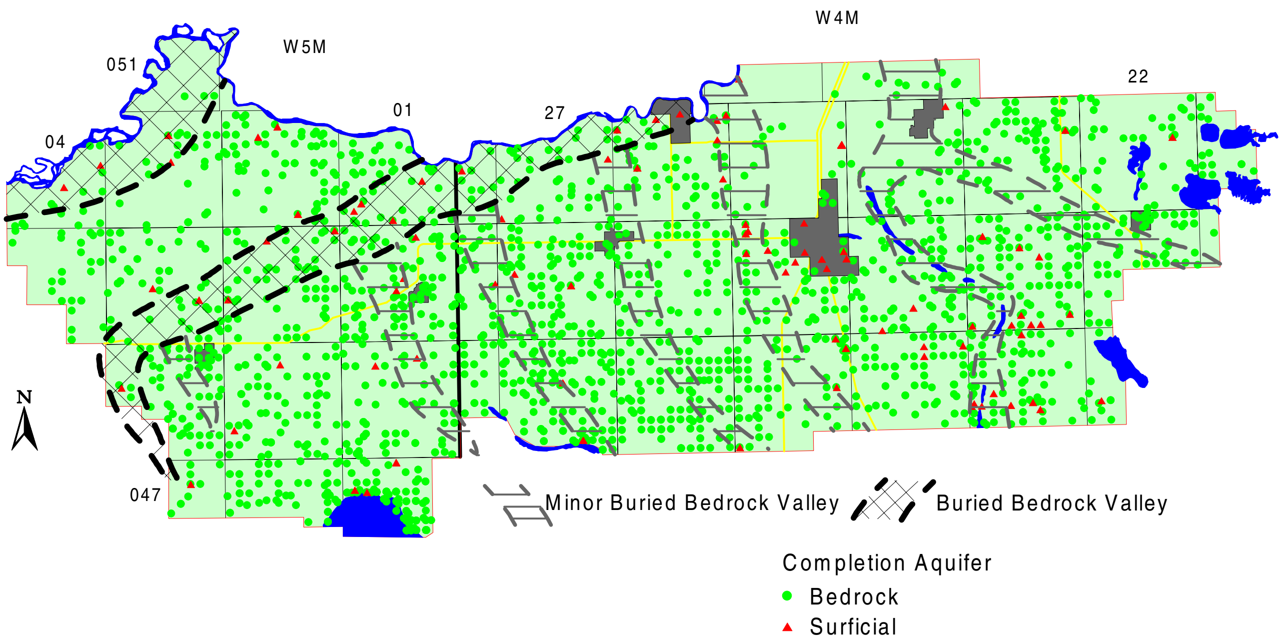

Edmonton
N
Drayton Valley
Wetaskiwin


W4M
W5M
051
North
Sask.
01
River
27
22
Devon
Beaumont
Leduc
39
Thorsby
Calmar
New Sarepta
04
Warburg
N
2
047
metres AMSL
660
720
780
840
900
Leduc County

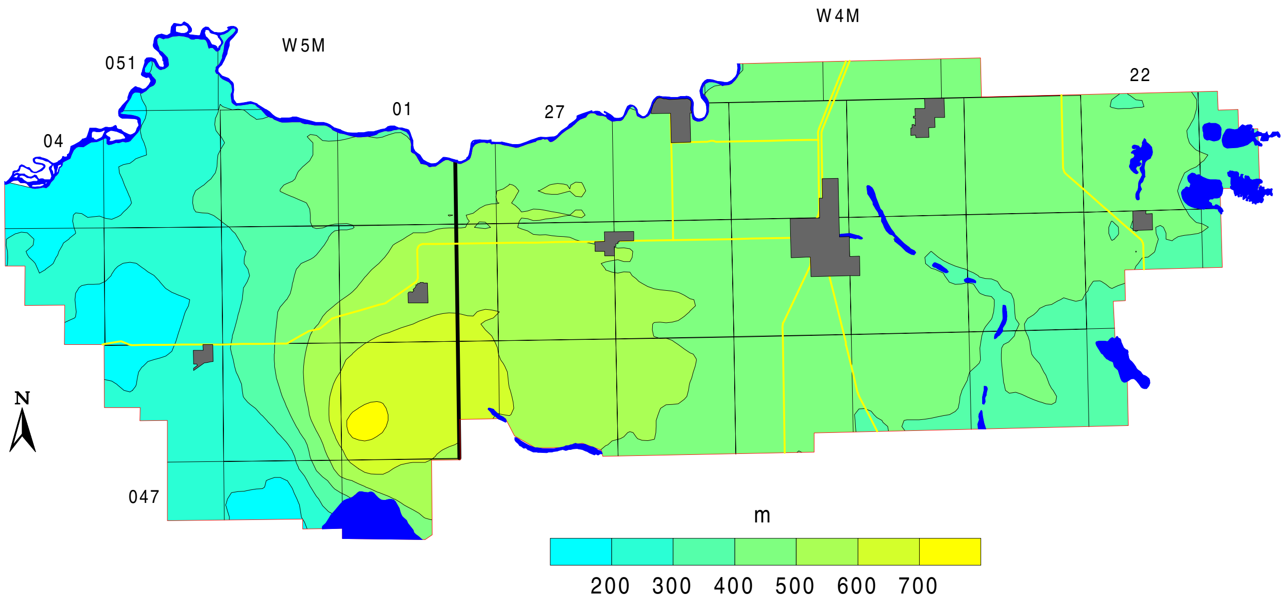
Surface Casing Types used in Drilled Water Wells

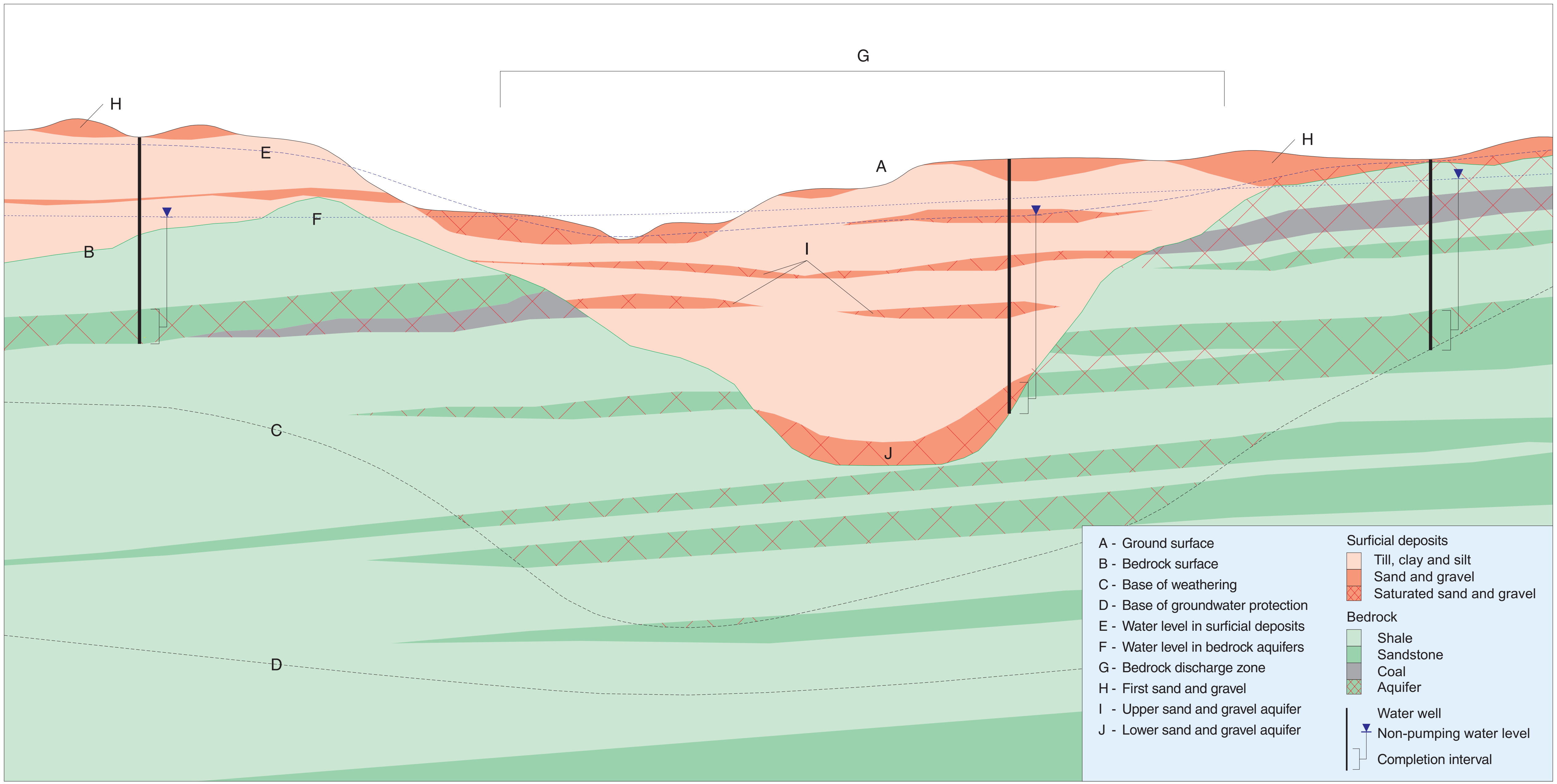


Location of Water Wells



Depth to Base of Groundwater Protection

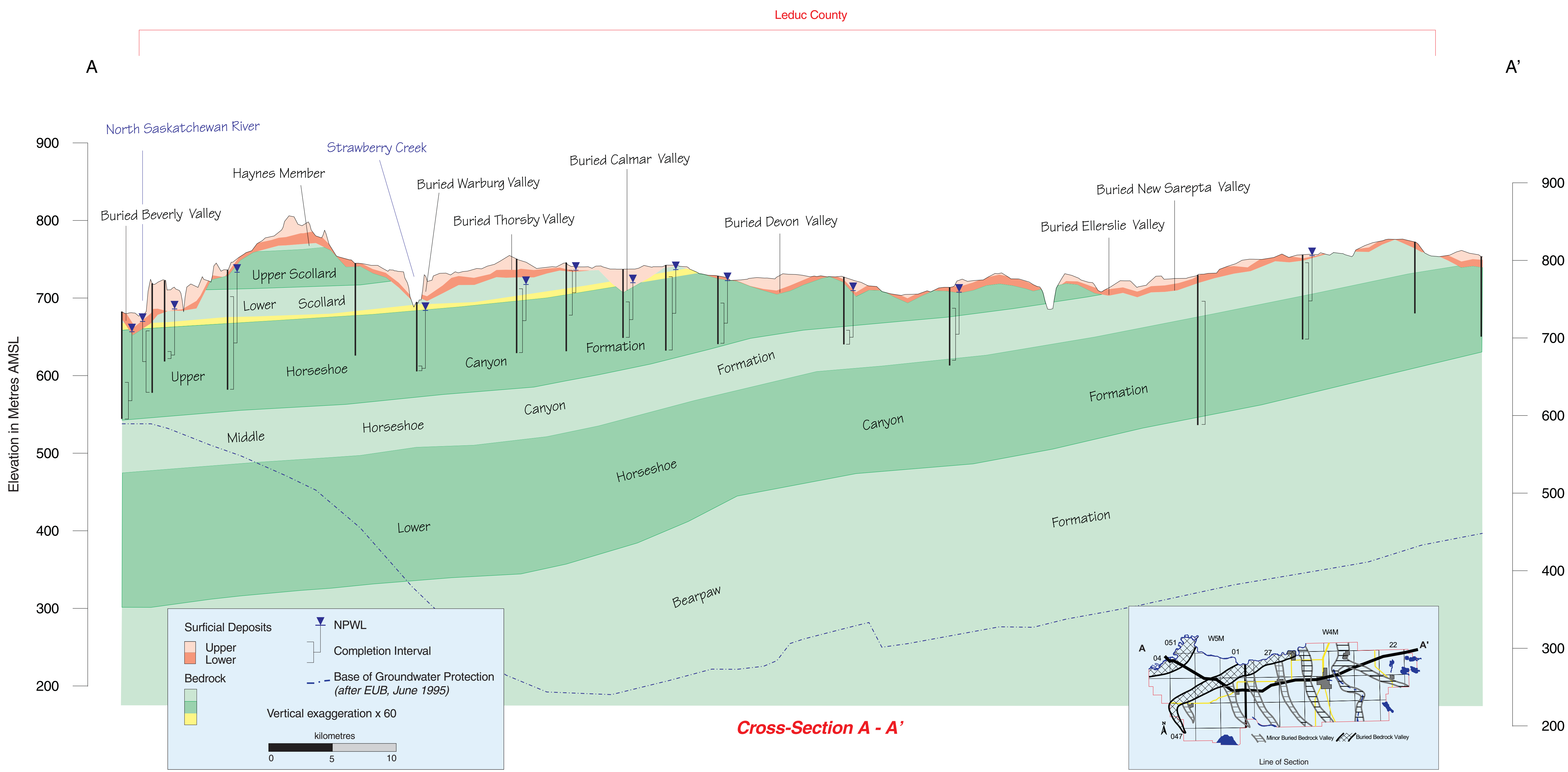




Generalized Cross-Section
(for terminology only)

Lithology	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	<40	Surficial Deposits	<40	Upper	<20	First Sand and Gravel
				<30	Lower		
	sandstone, shale, coal	<200	Paskapoo Formation: Lacombe Member	0-70	Upper		Upper Sandstone
							Middle Sandstone
							Lower Sandstone
				30-70	Lower		Lower Lacombe Coal Zone
	sandstone, shale, coal		Paskapoo Formation: Haynes Member	20-60			
	shale, sandstone, siltstone, coal	60-220	Edmonton Group: Scollard Formation	60-150	Upper	<2	Upper Ardley Coal Zone
						~20	Ardley Coal Zone (main seam)
						<1	Nevis Coal Seam
				20-80	Lower		
	shale, claystone, tuff, bentonite	~25	Edmonton Group: Battle Formation	<0.3	Kneehills Member		
	shale, siltstone, sandstone	5-10	Edmonton Group: Whitemud Formation				
	shale, sandstone, coal, bentonite, limestone, ironstone	300-380	Edmonton Group: Horseshoe Canyon Formation	~100	Upper		
				~100	Middle		
				<10	Drumheller Member		
				~170	Lower		
	shale, sandstone, siltstone	60-120	Bearpaw Formation				

Geologic Column



Cross-Section A - A'

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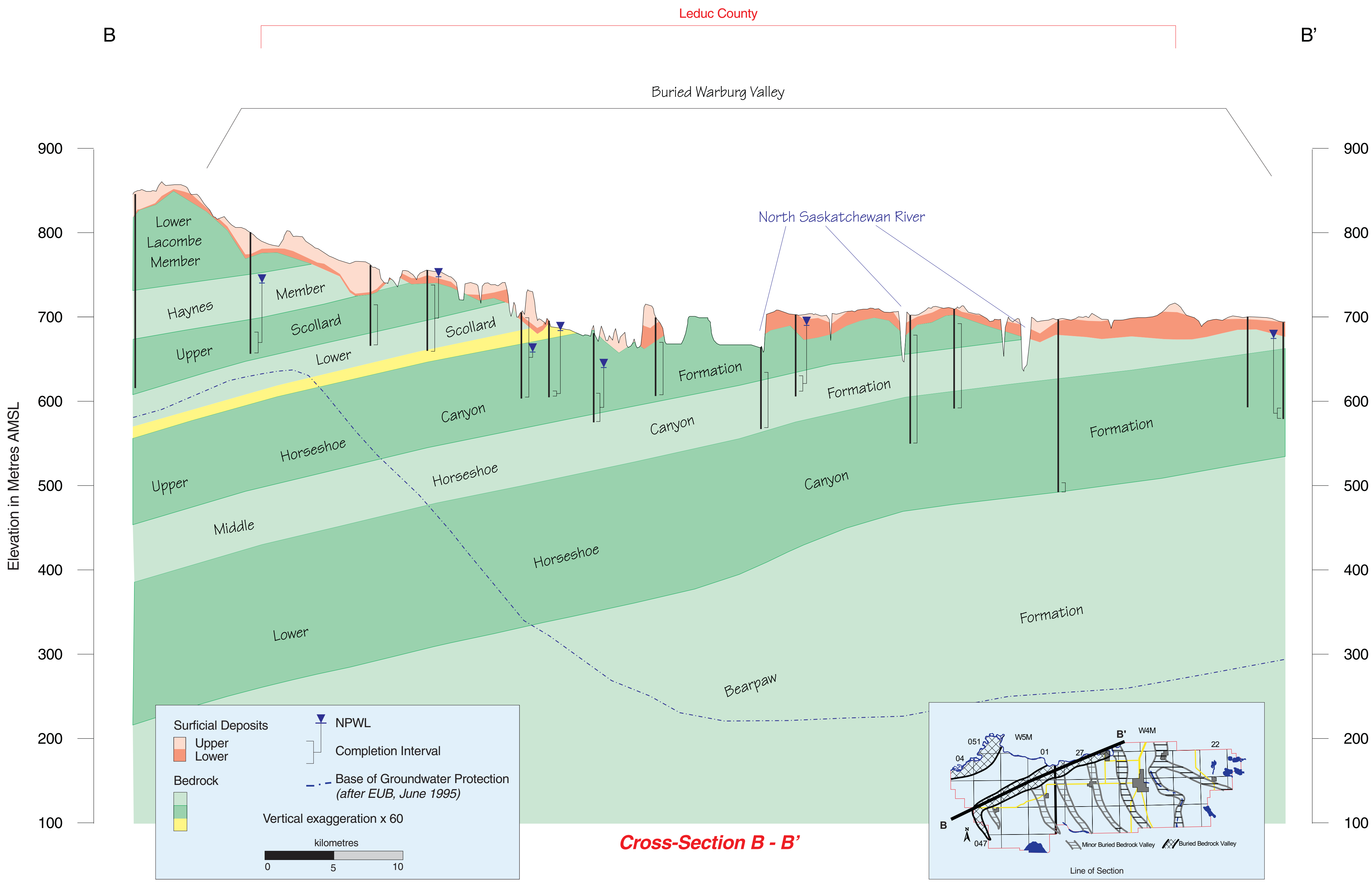
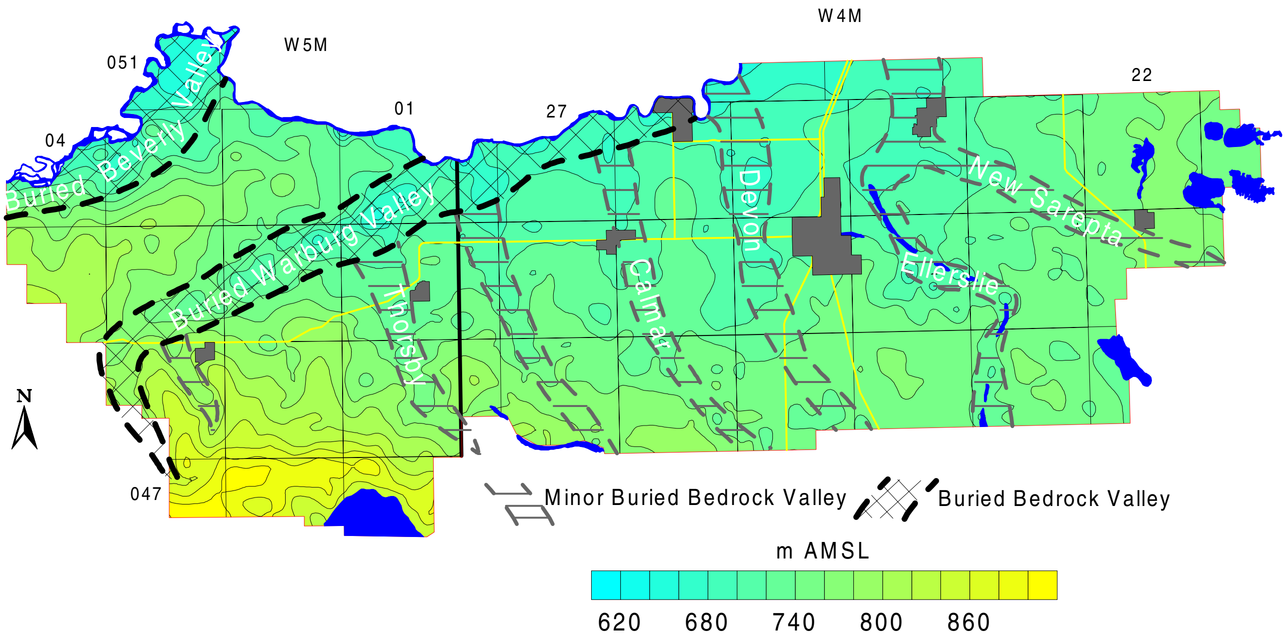
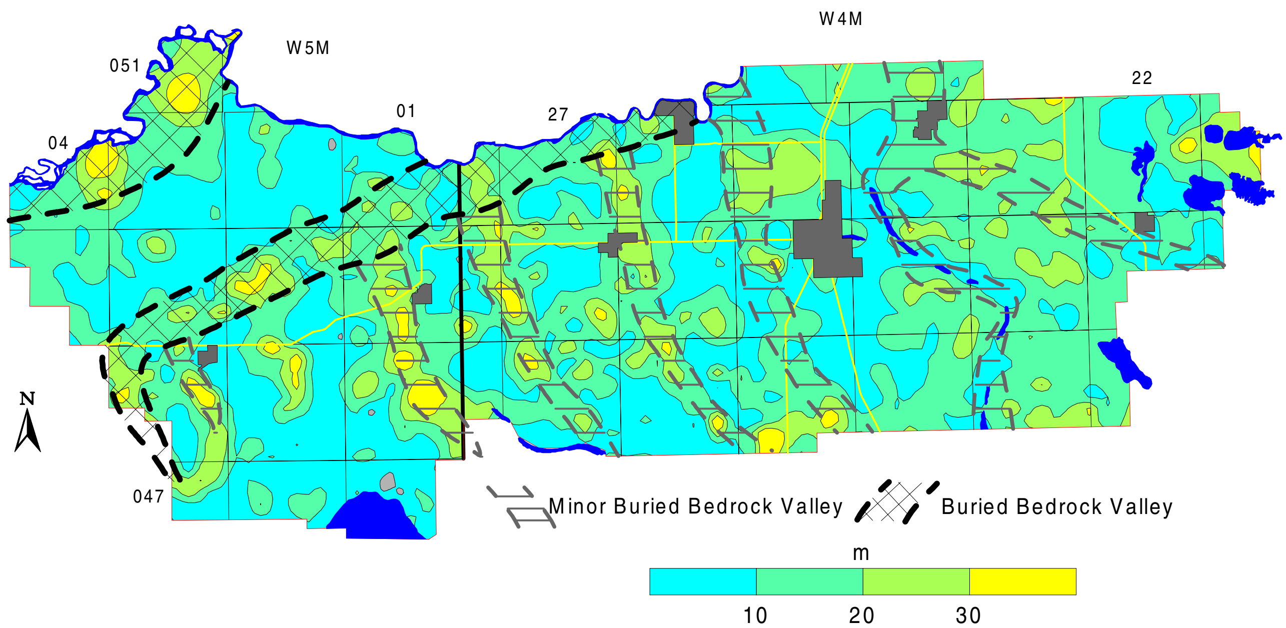


Cross-Section B - B'

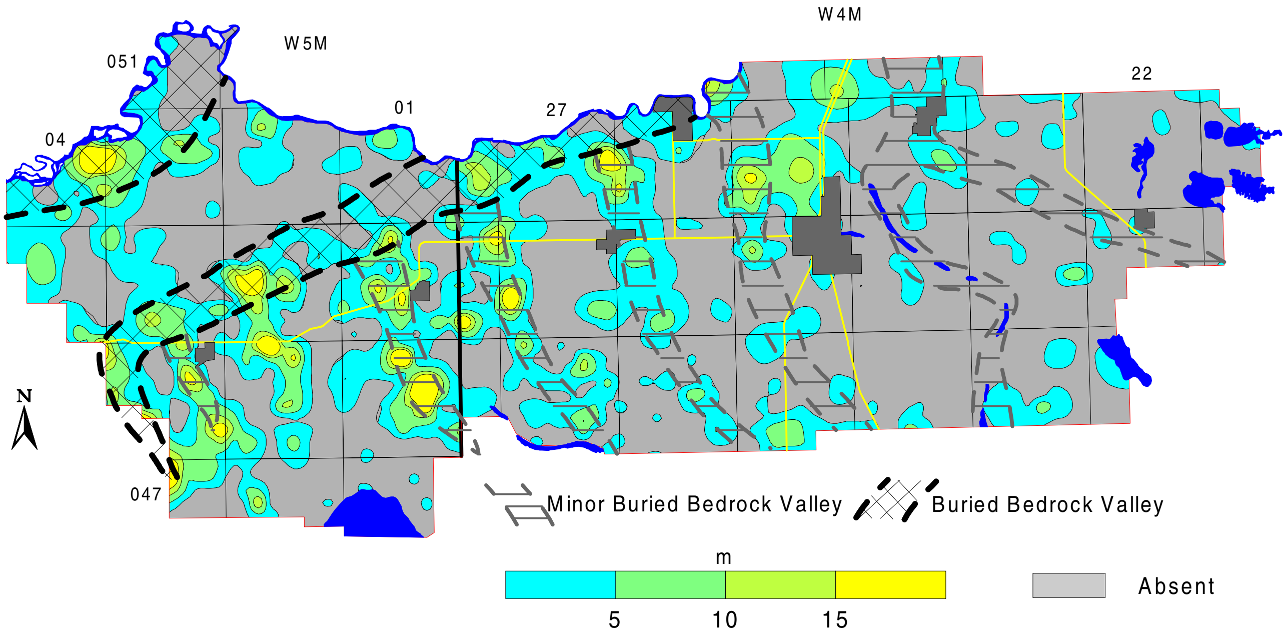
Bedrock Topography



Thickness of Surficial Deposits



Thickness of Sand and Gravel Aquifer(s)



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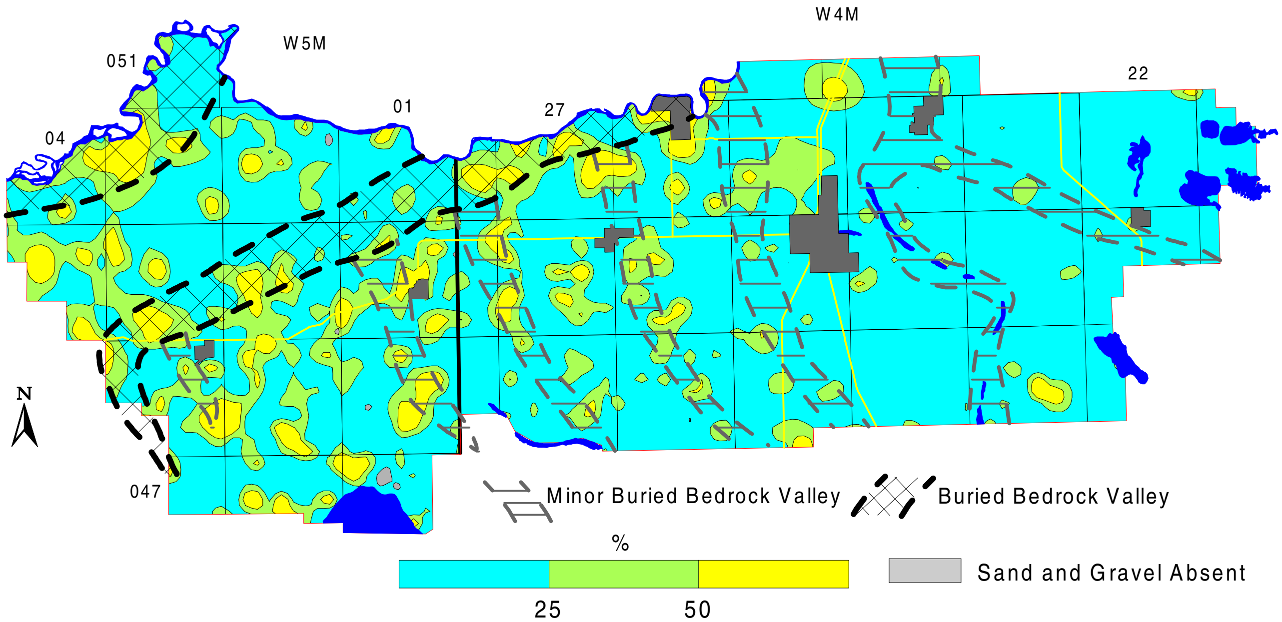
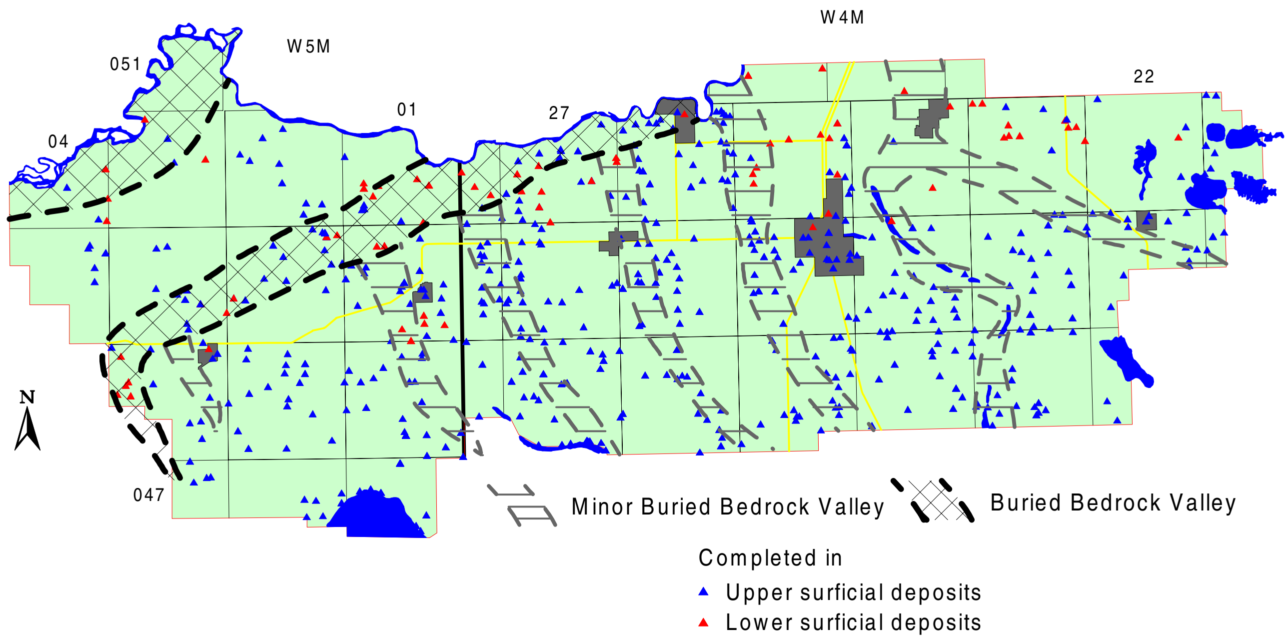
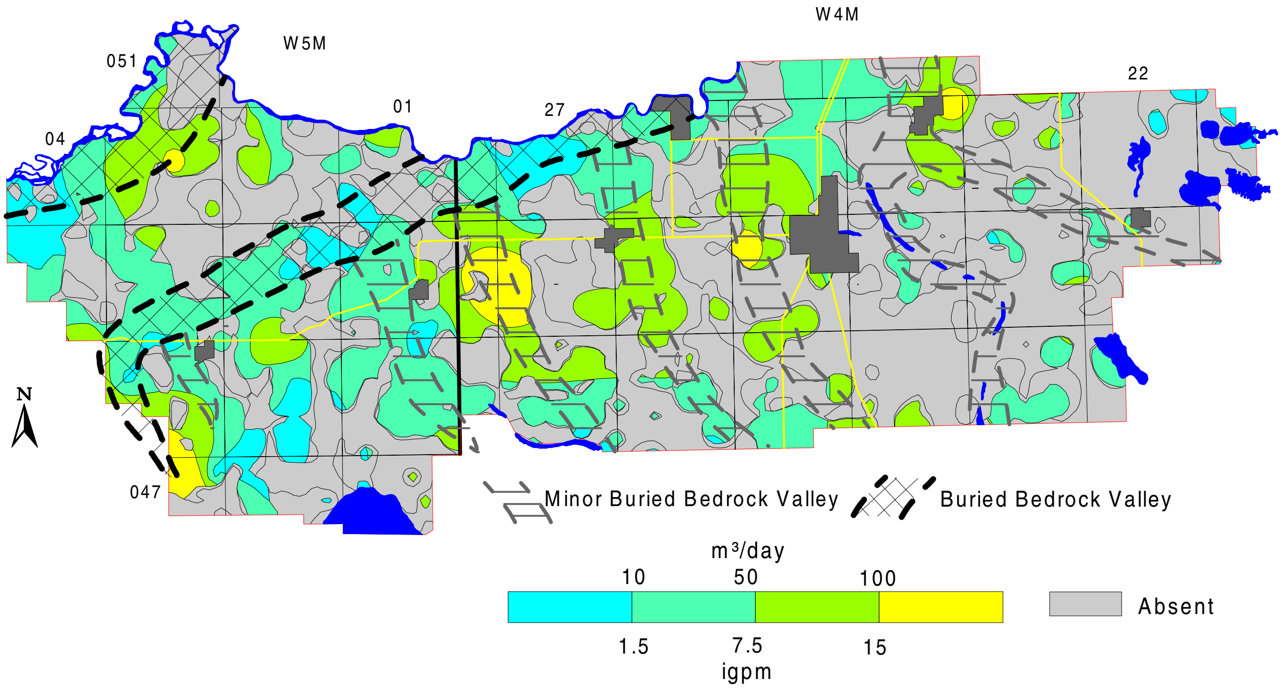
Amount of Sand and Gravel in Surficial Deposits



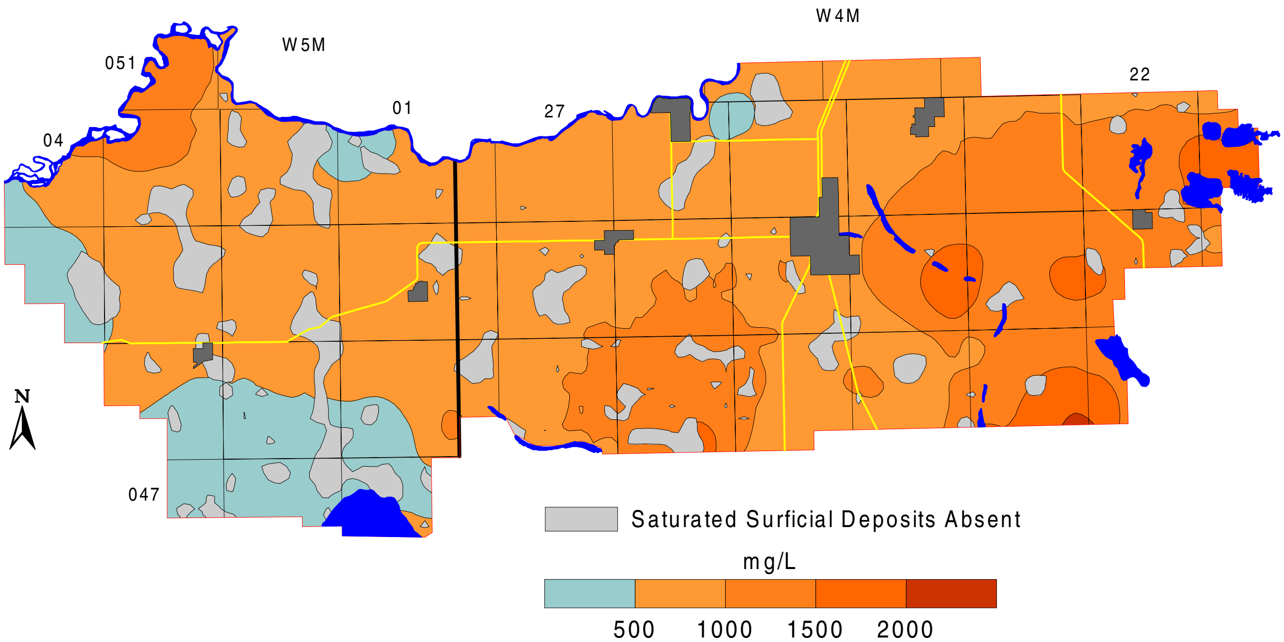
Water Wells Completed in Surficial Deposits



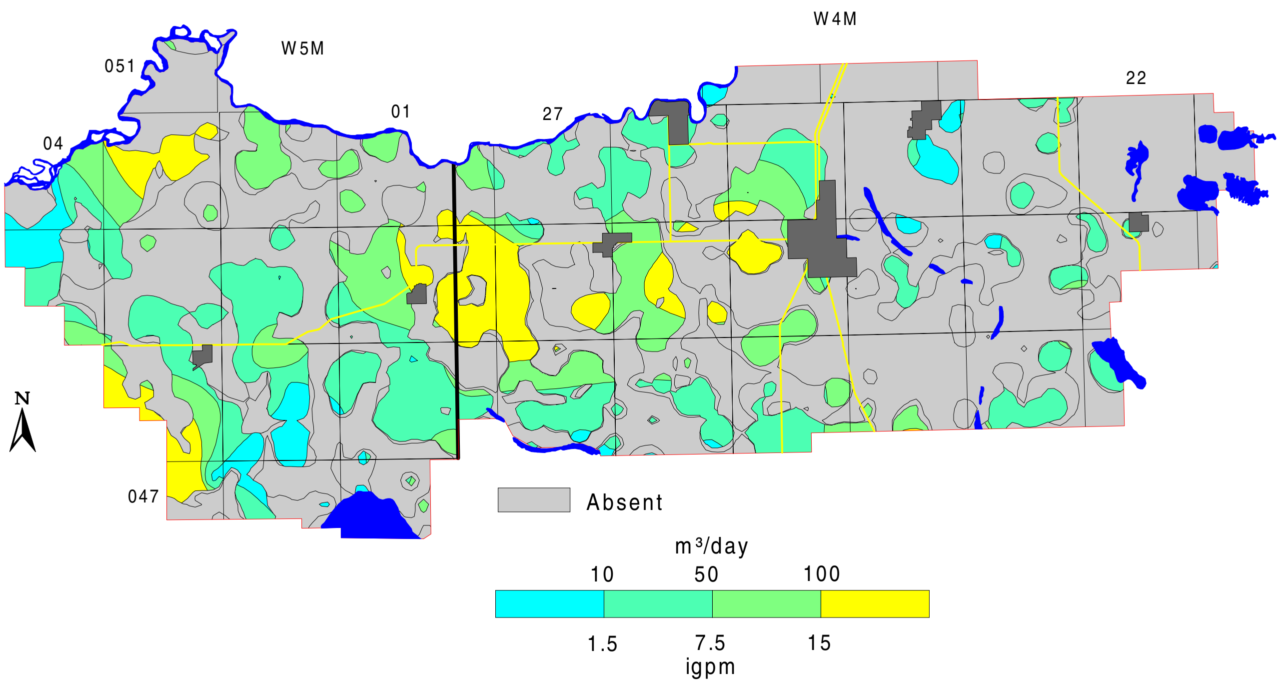
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



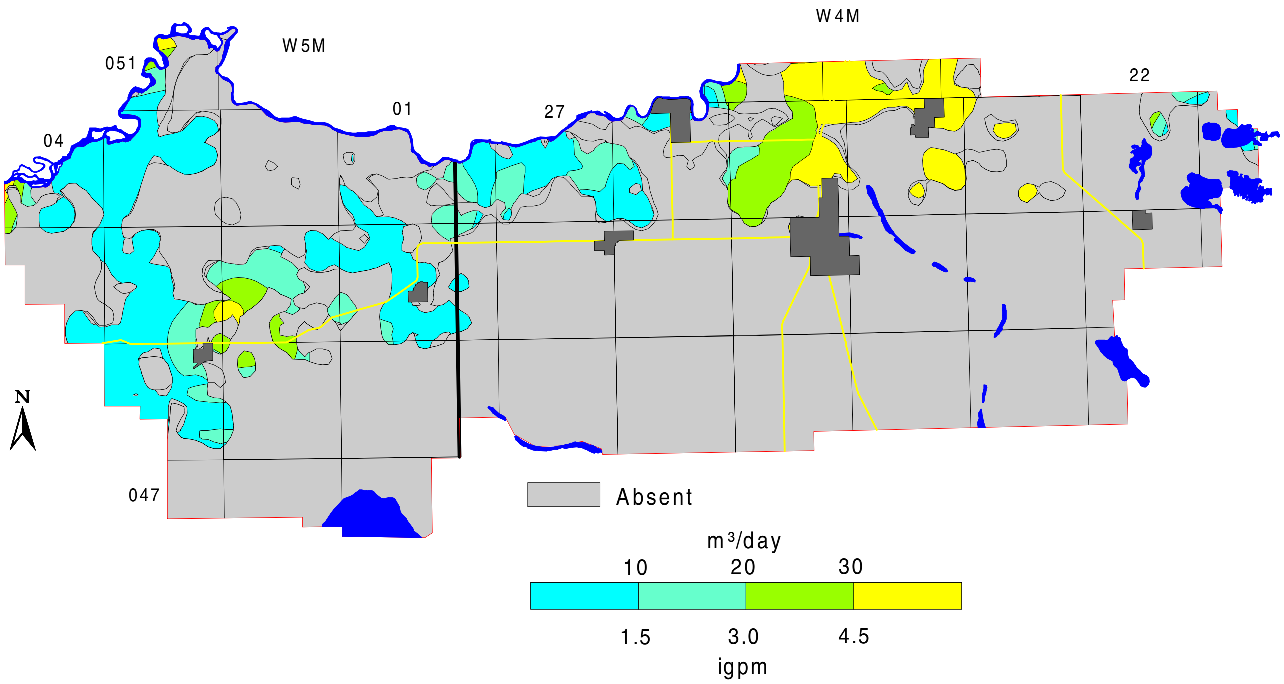
Total Dissolved Solids in Groundwater from Surficial Deposits



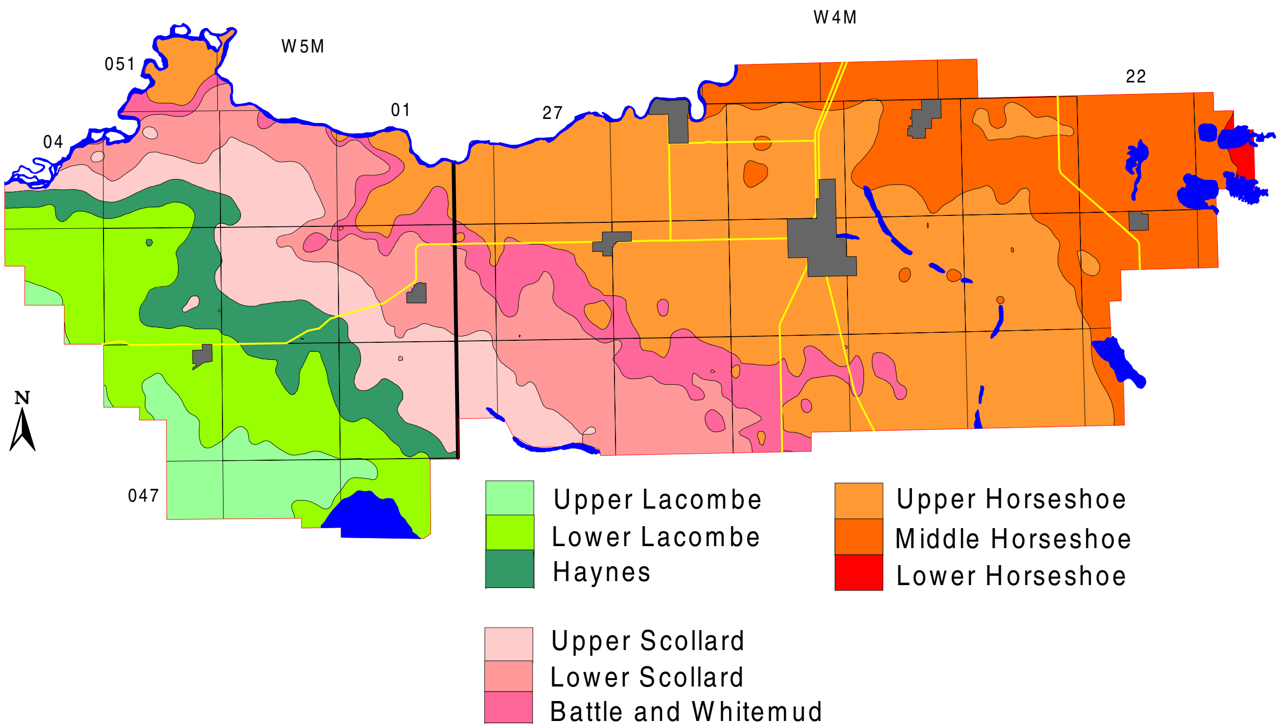
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



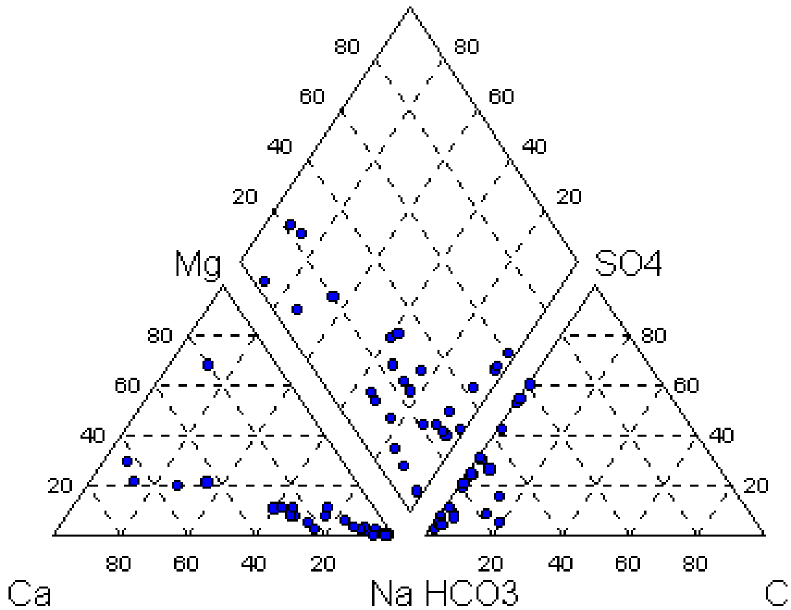
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



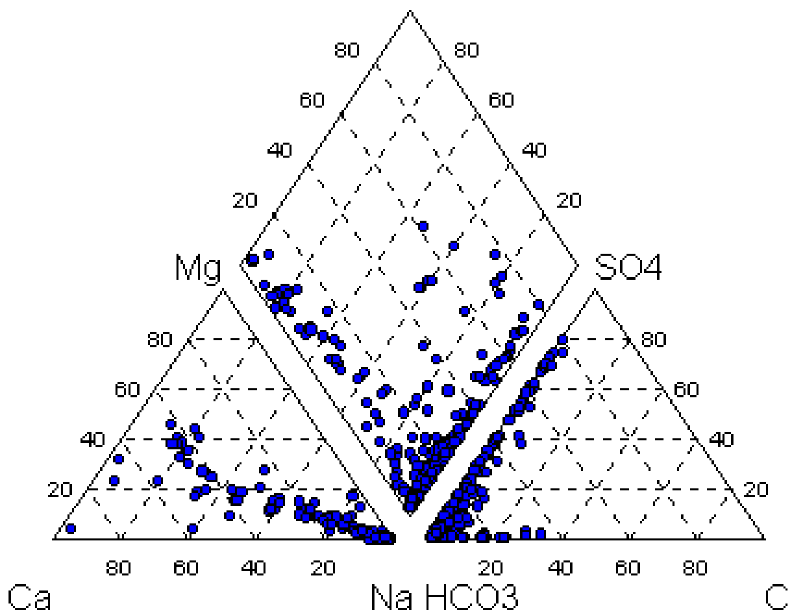
Bedrock Geology



Piper Diagrams



Surficial Deposits



Bedrock Aquifers

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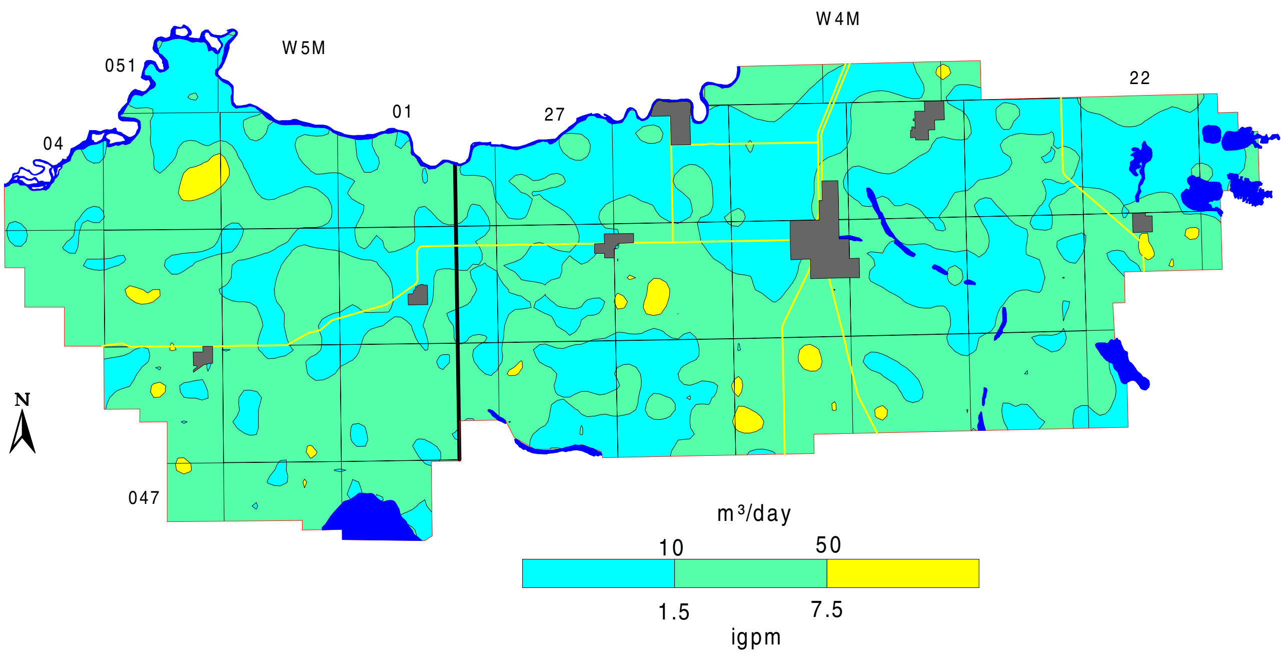
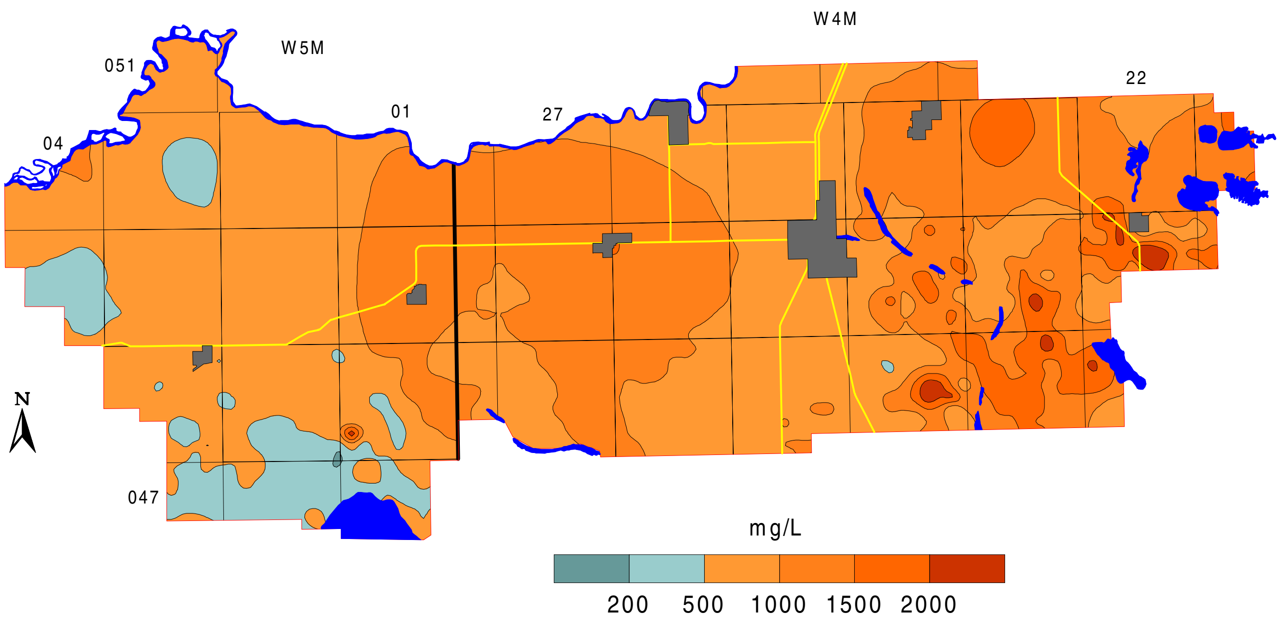
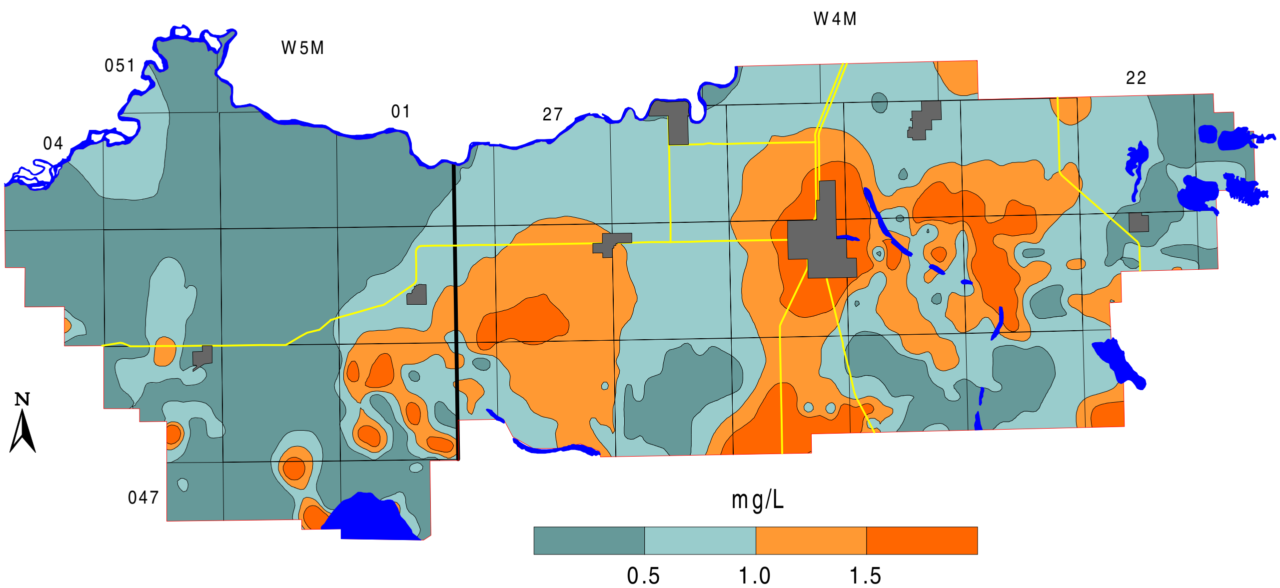
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



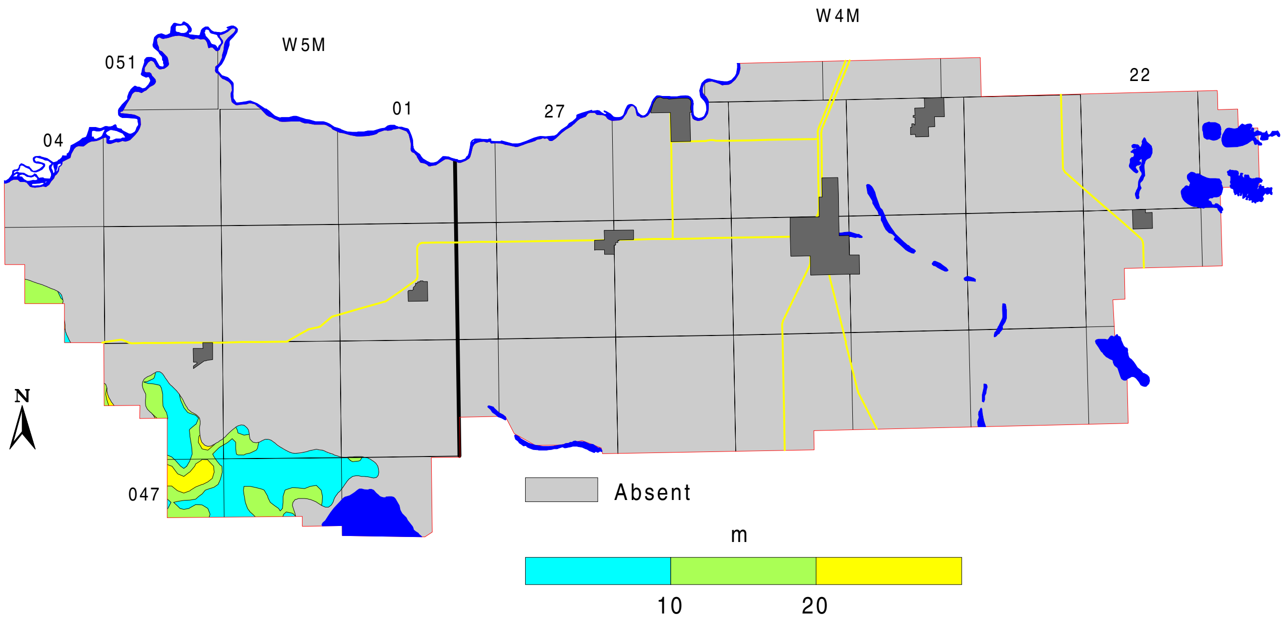
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



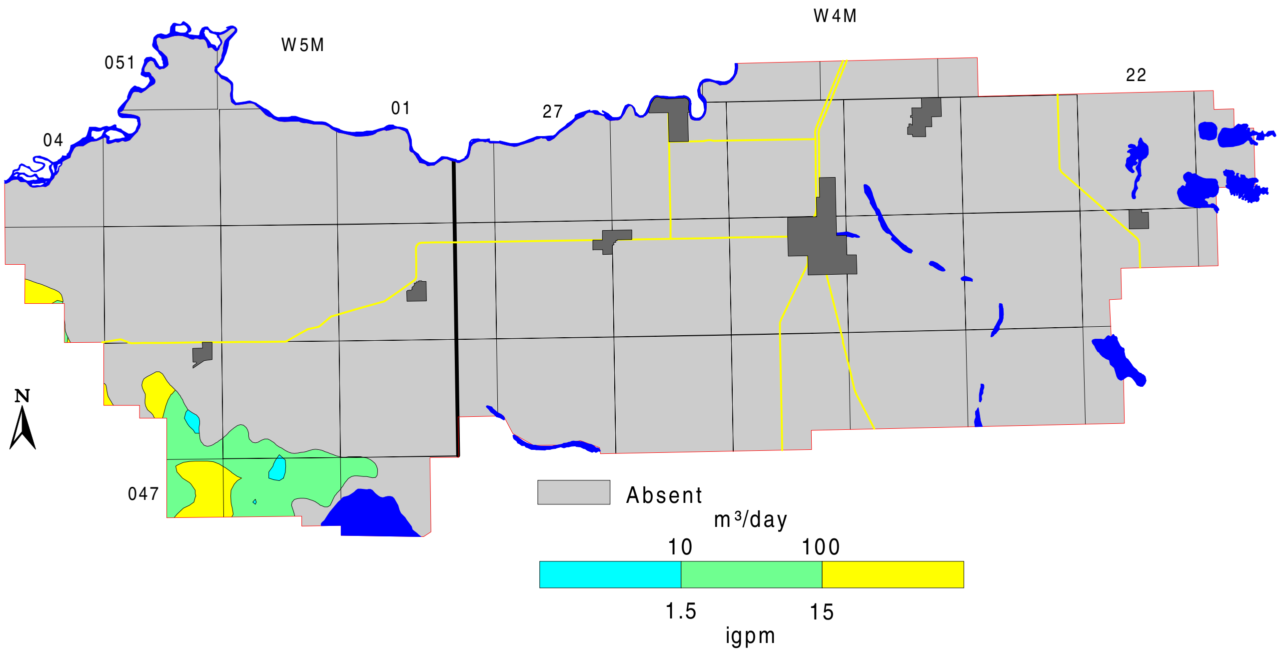
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



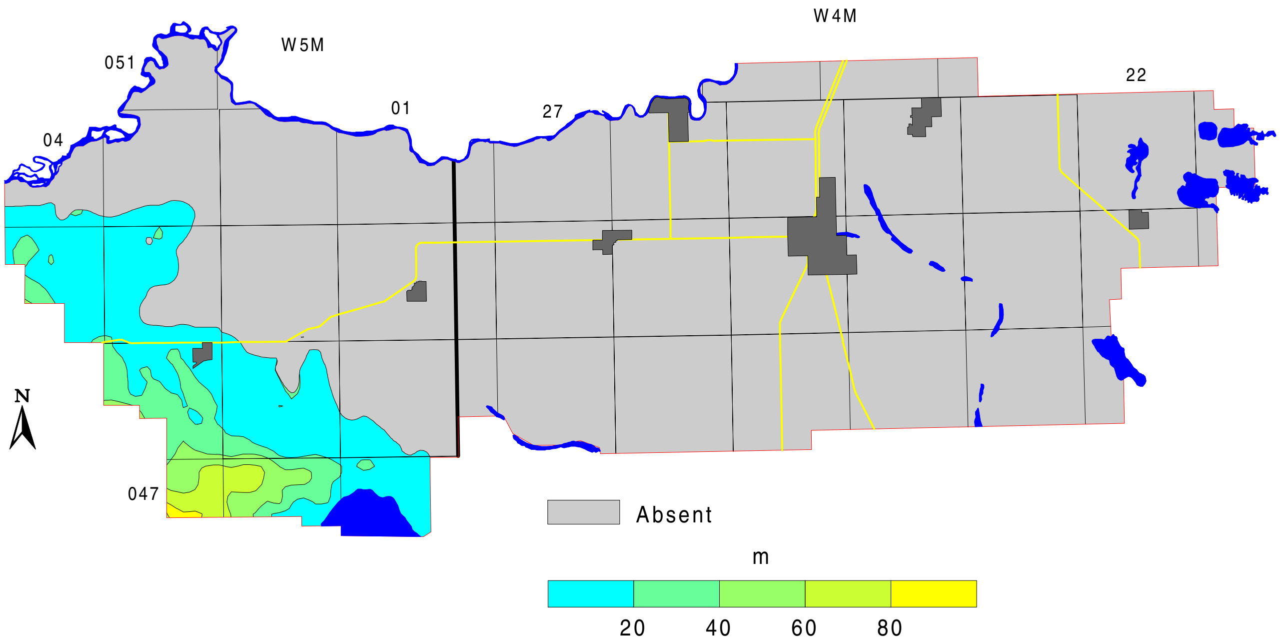
Depth to Top of Upper Lacombe Member



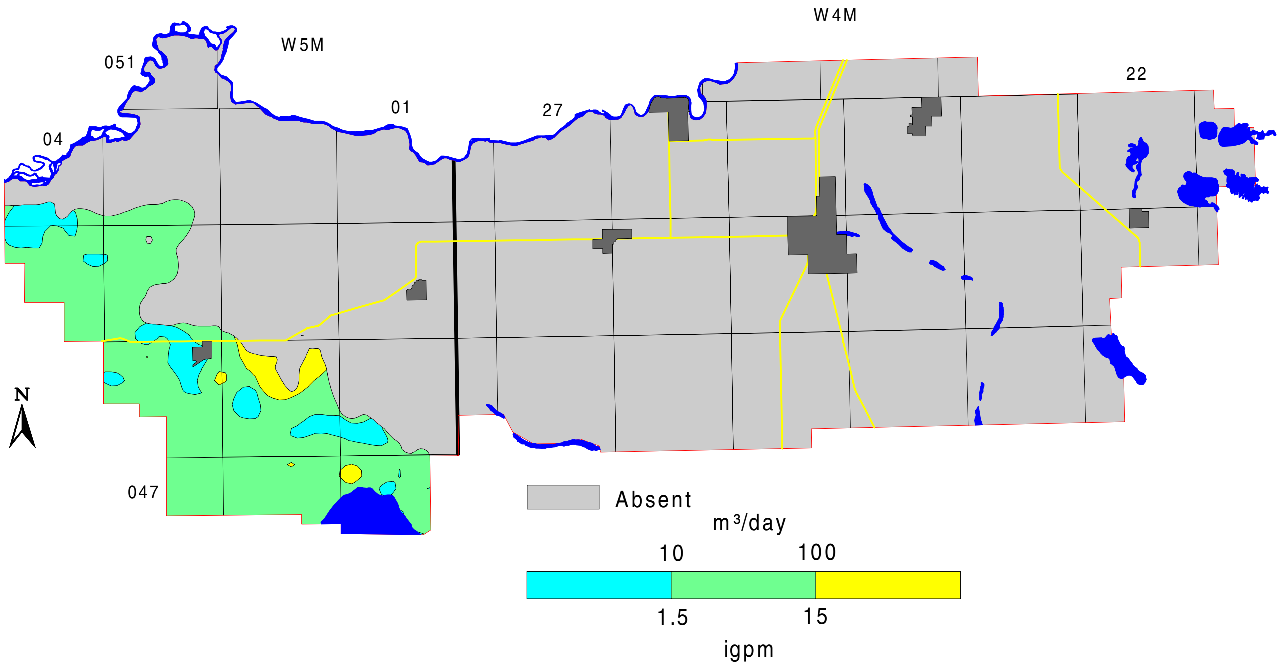
Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer



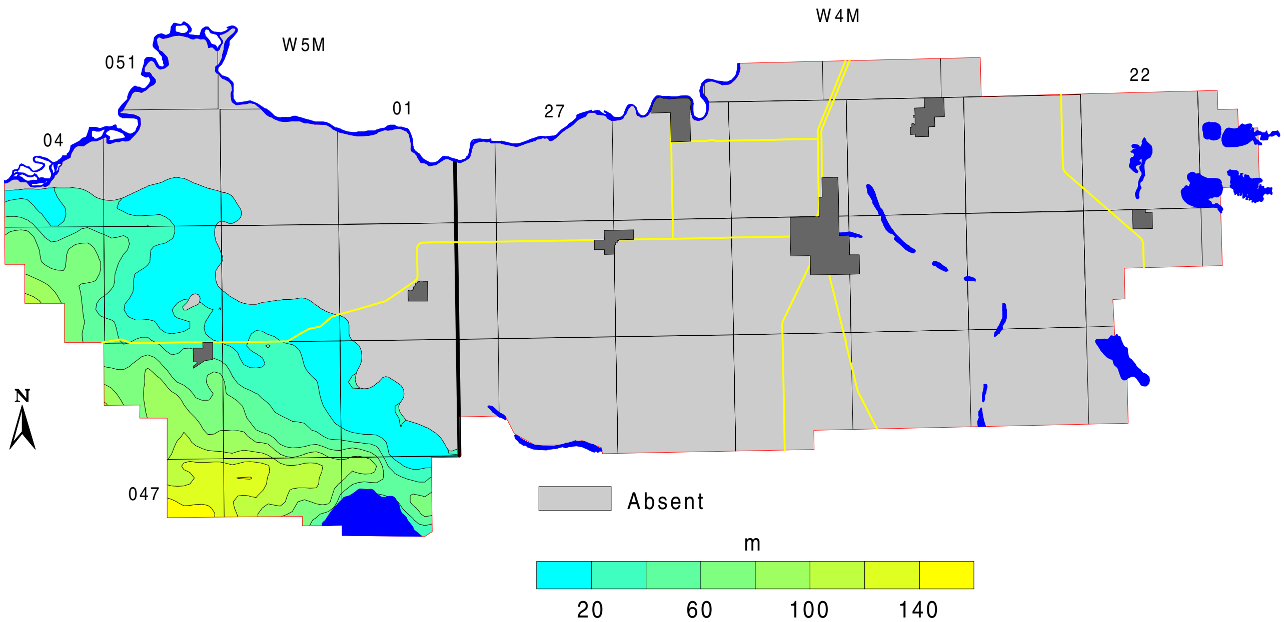
Depth to Top of Lower Lacombe Member



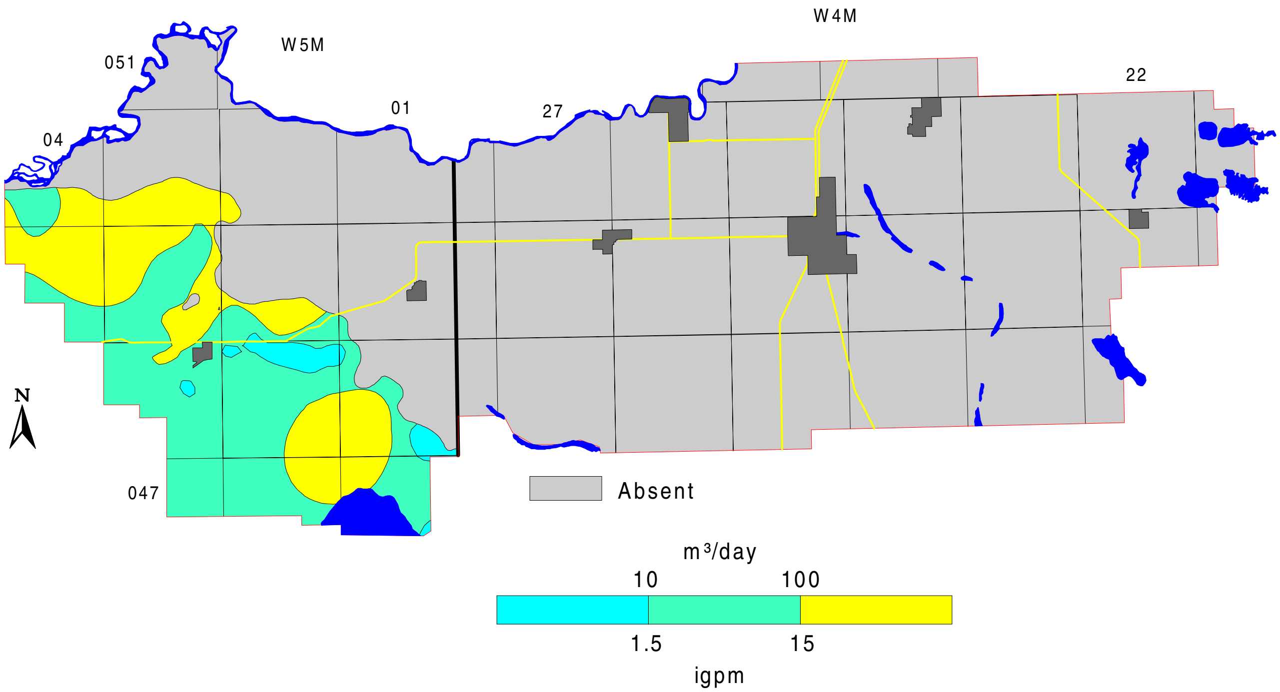
Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer



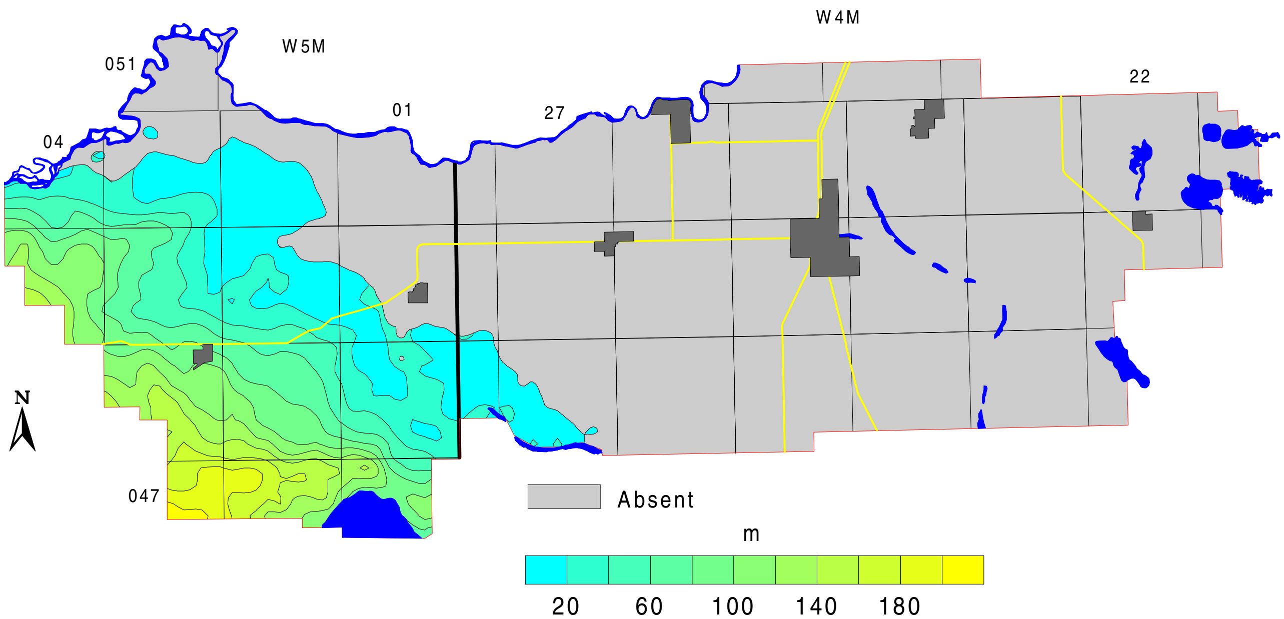
Depth to Top of Haynes Member



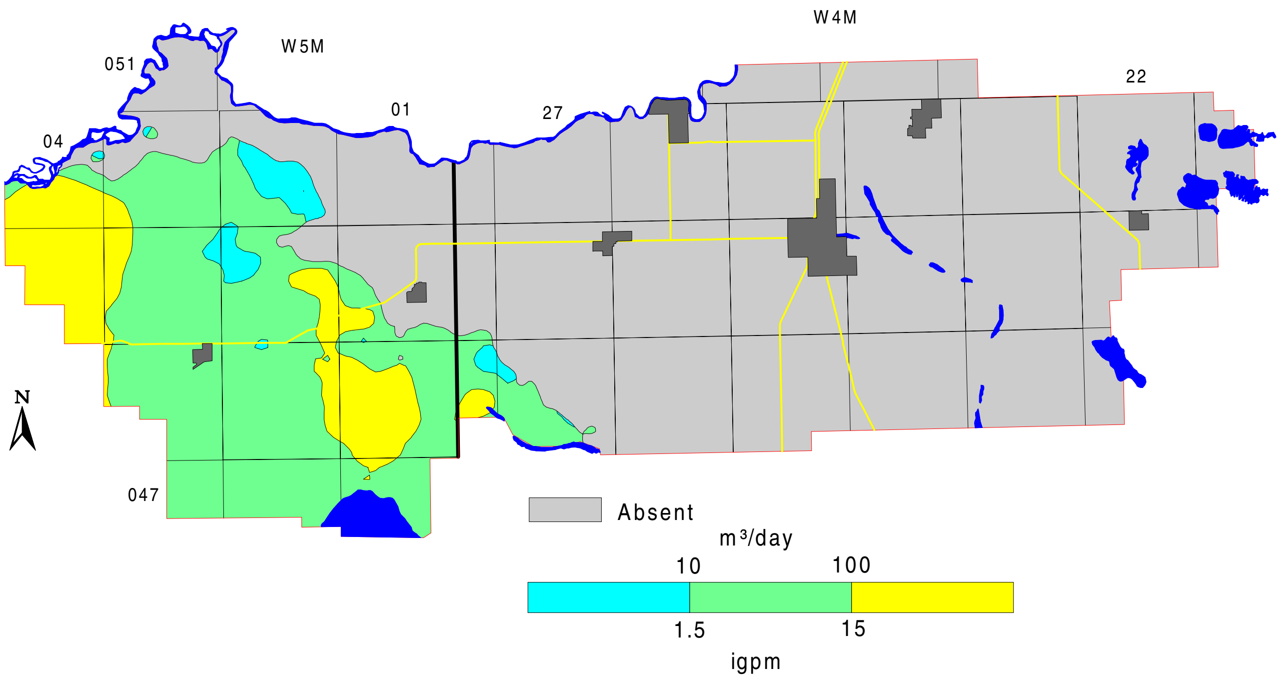
Apparent Yield for Water Wells Completed through Haynes Aquifer



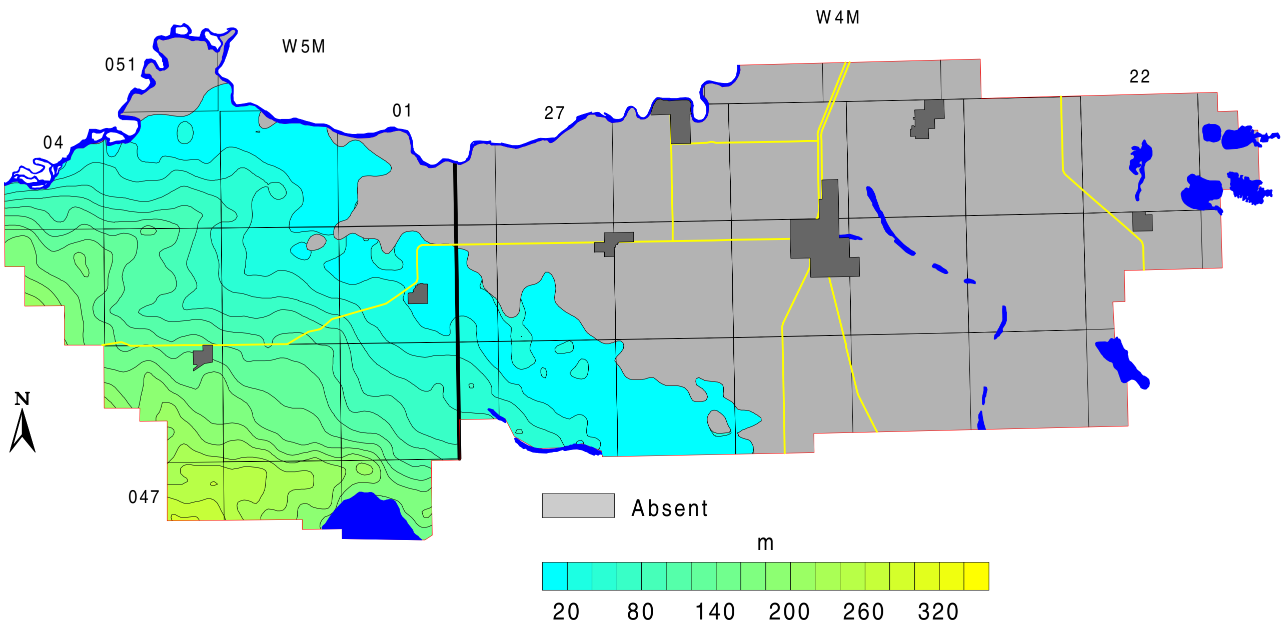
Depth to Top of Upper Scollard



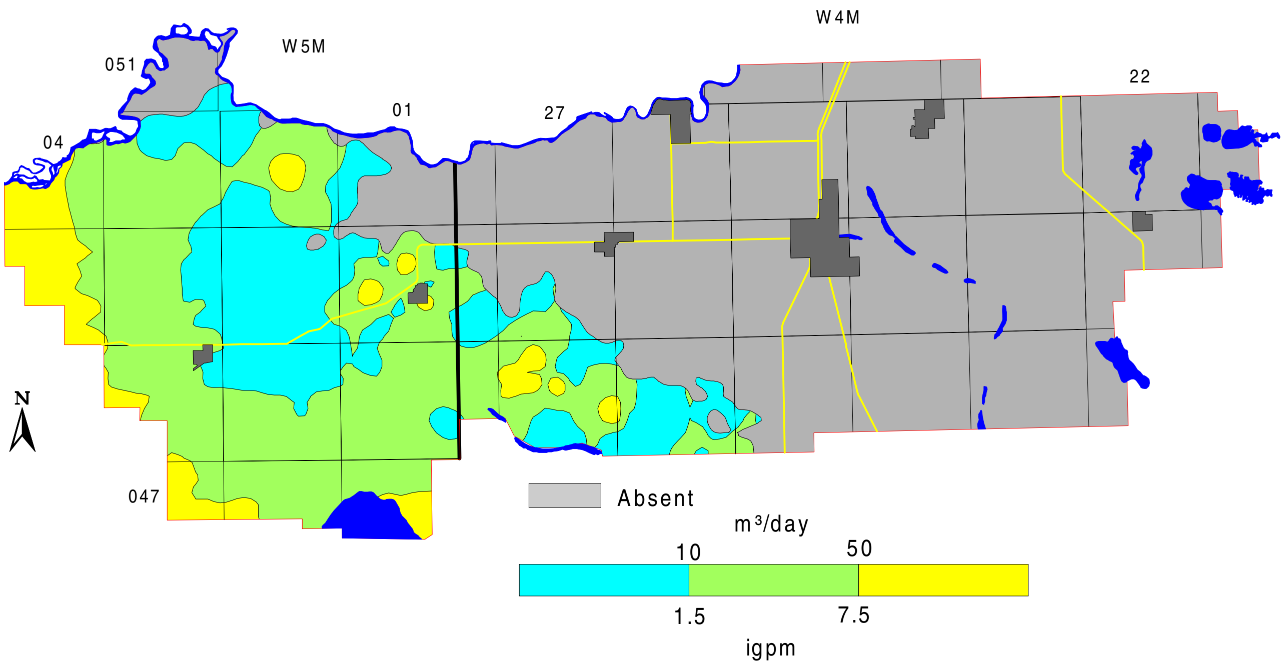
Apparent Yield for Water Wells Completed through Upper Scollard Aquifer



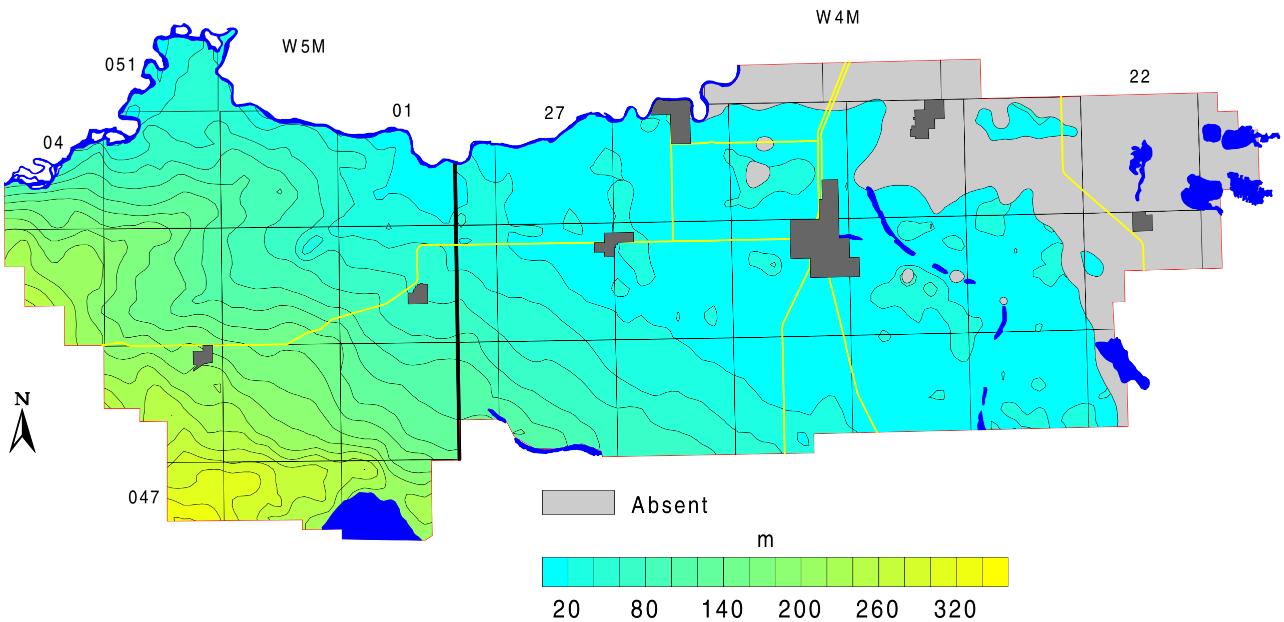
Depth to Top of Lower Scollard



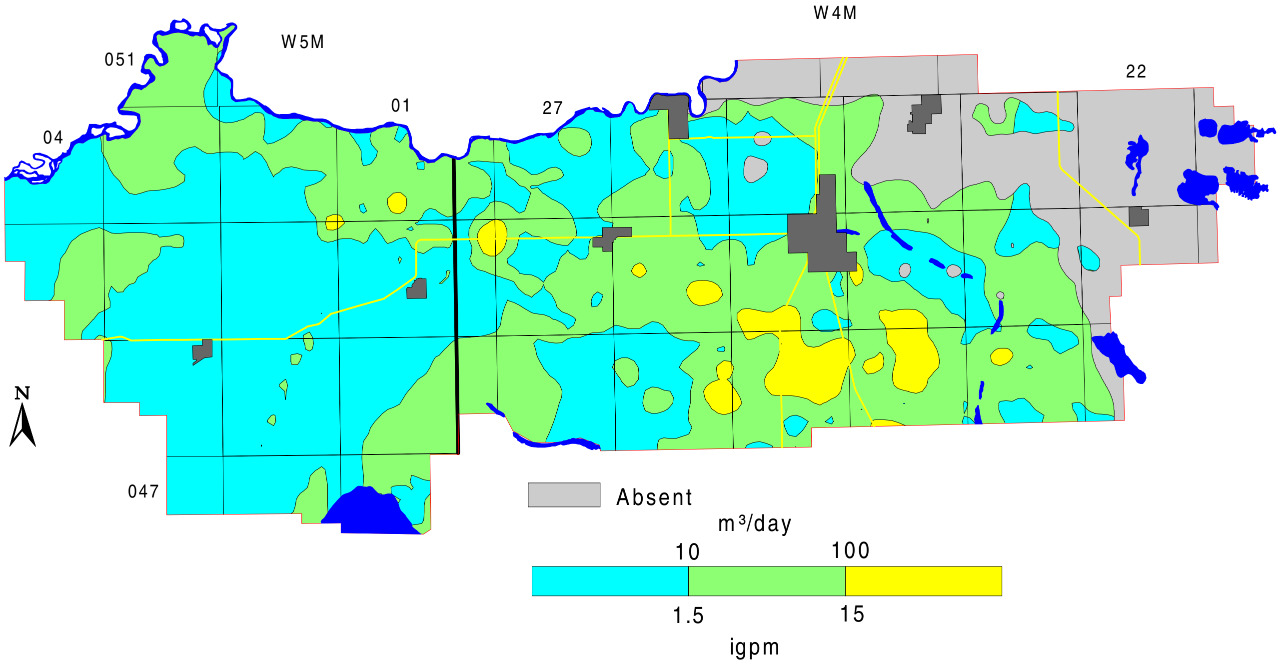
Apparent Yield for Water Wells Completed through Lower Scollard Aquifer



Depth to Top of Upper Horseshoe Canyon Formation



Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer



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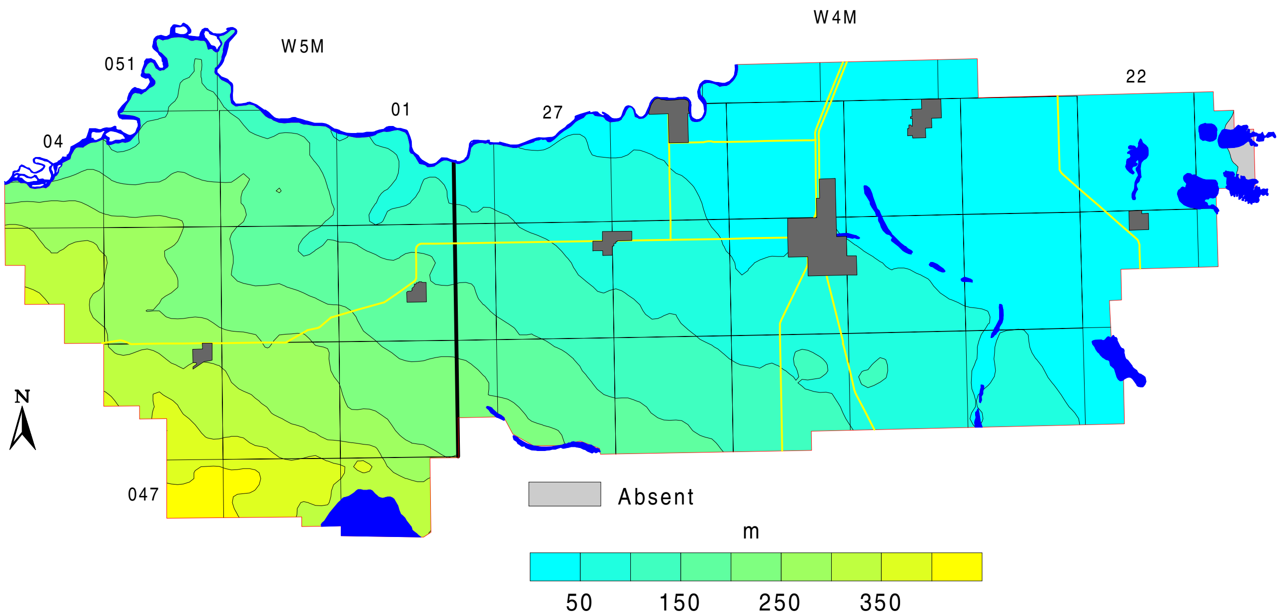
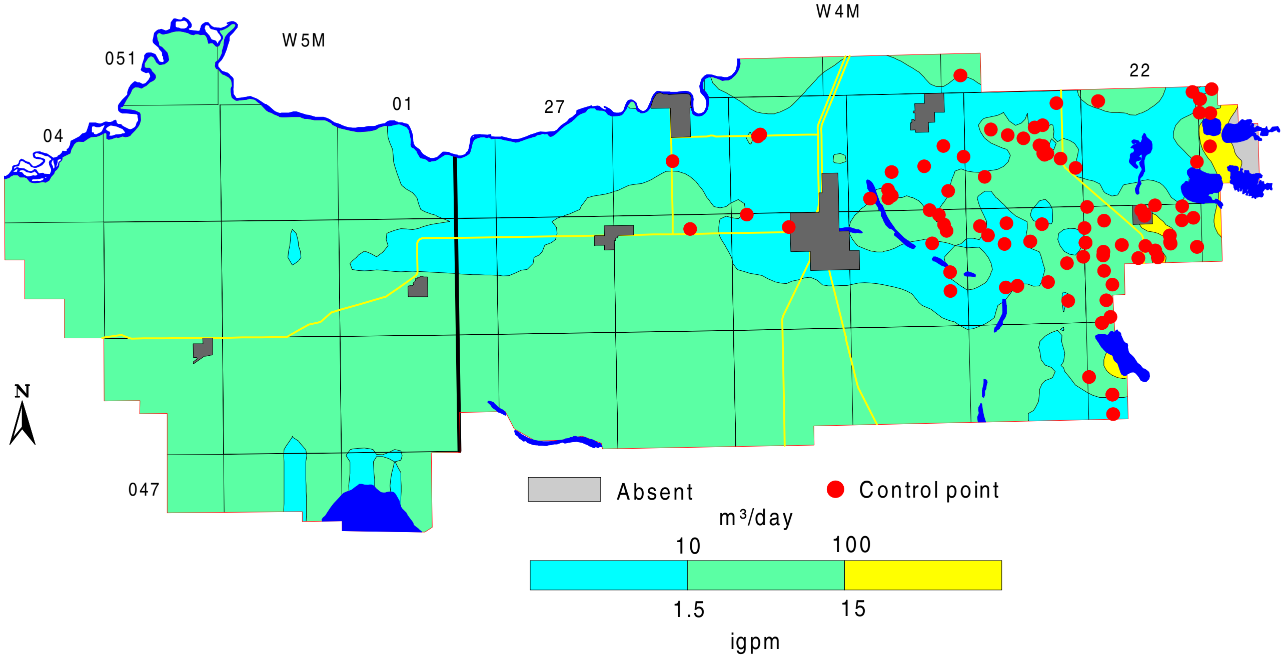
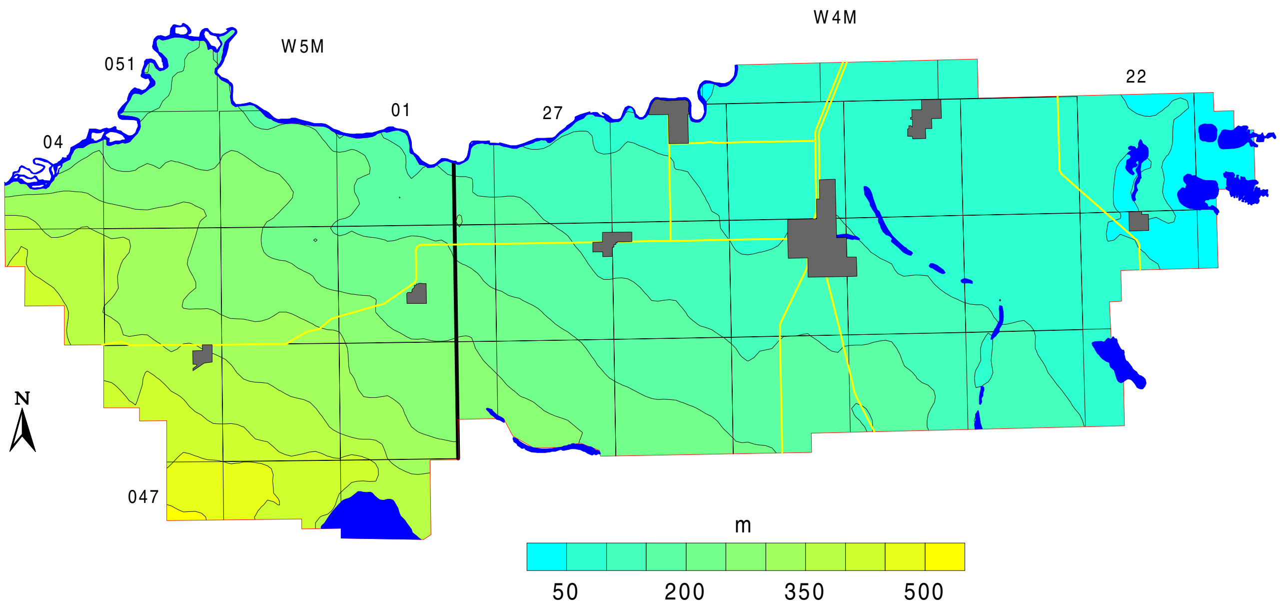
Depth to Top of Middle Horseshoe Canyon Formation



Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer



Depth to Top of Lower Horseshoe Canyon Formation



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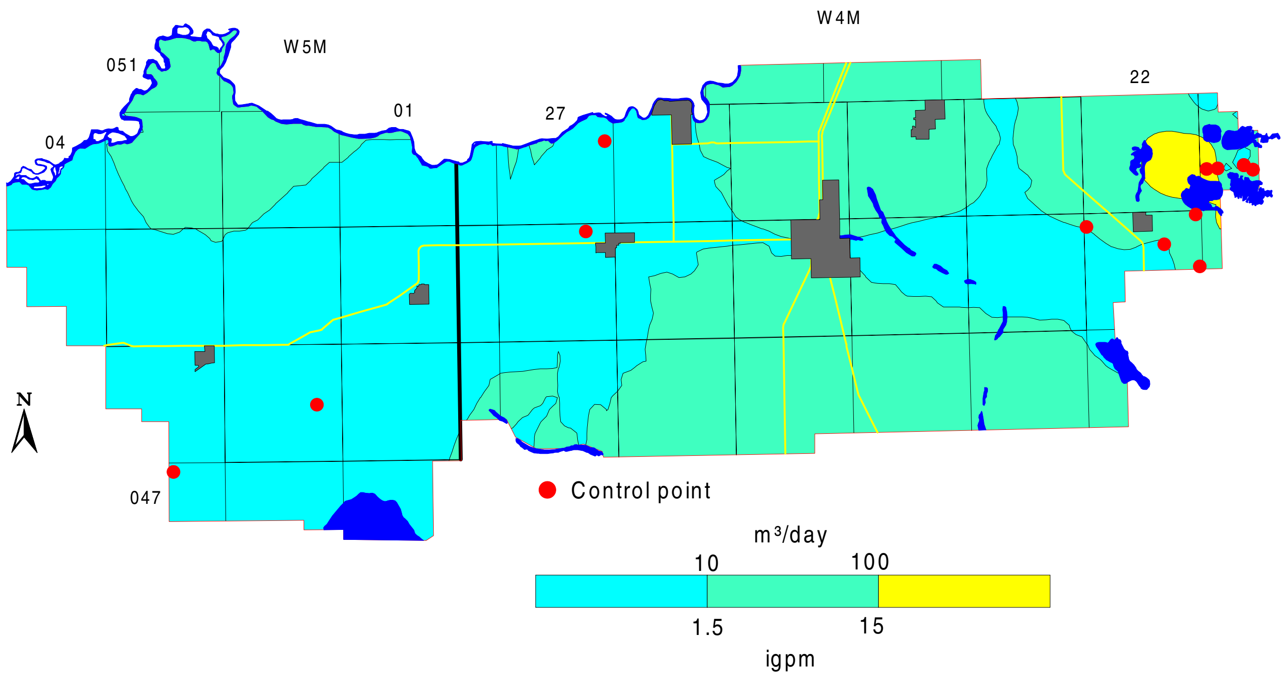
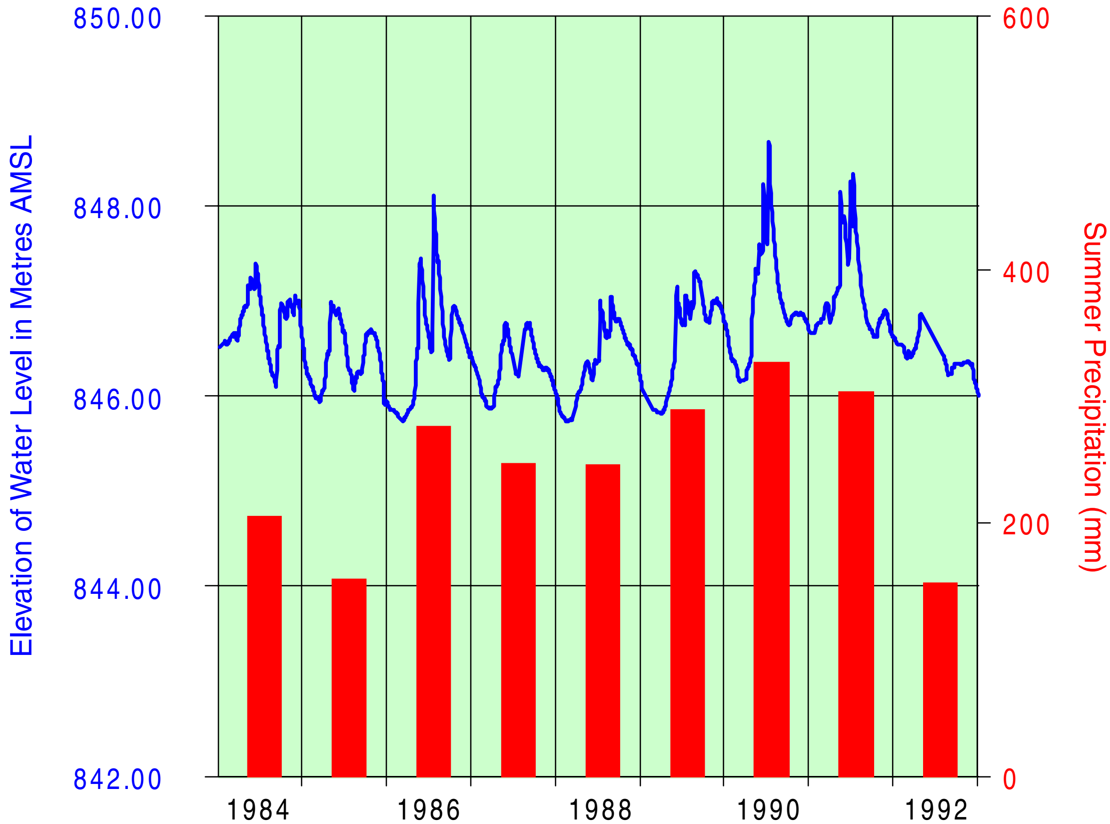
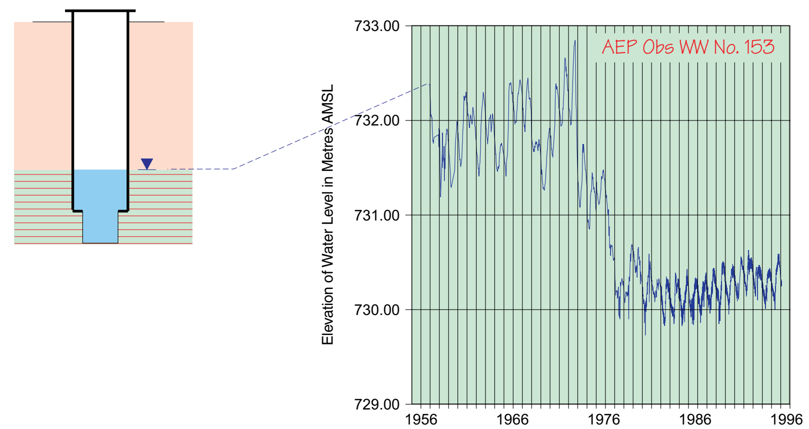
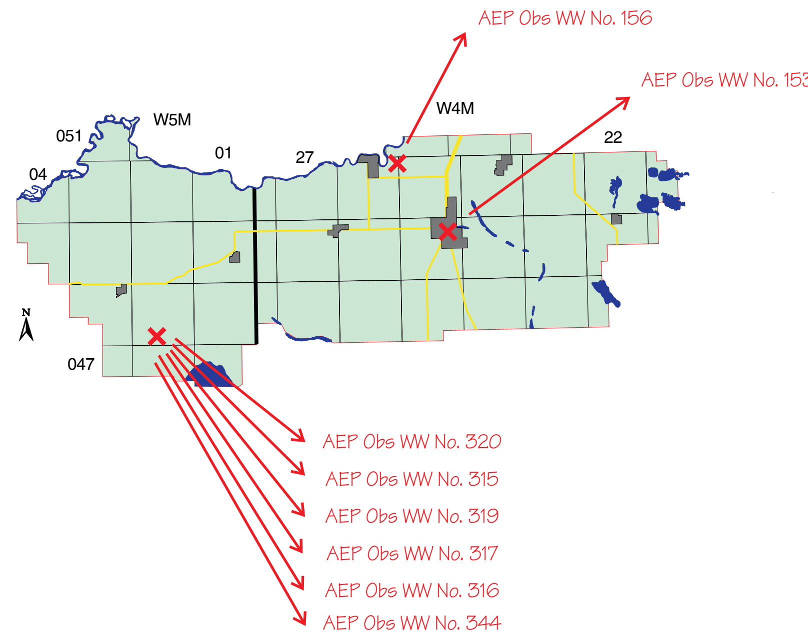
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

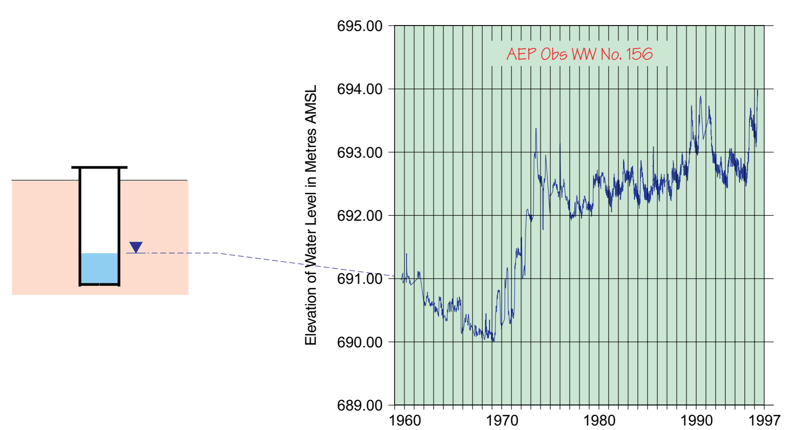


Summer Precipitation vs Water Levels in AEP Obs WW No. 320

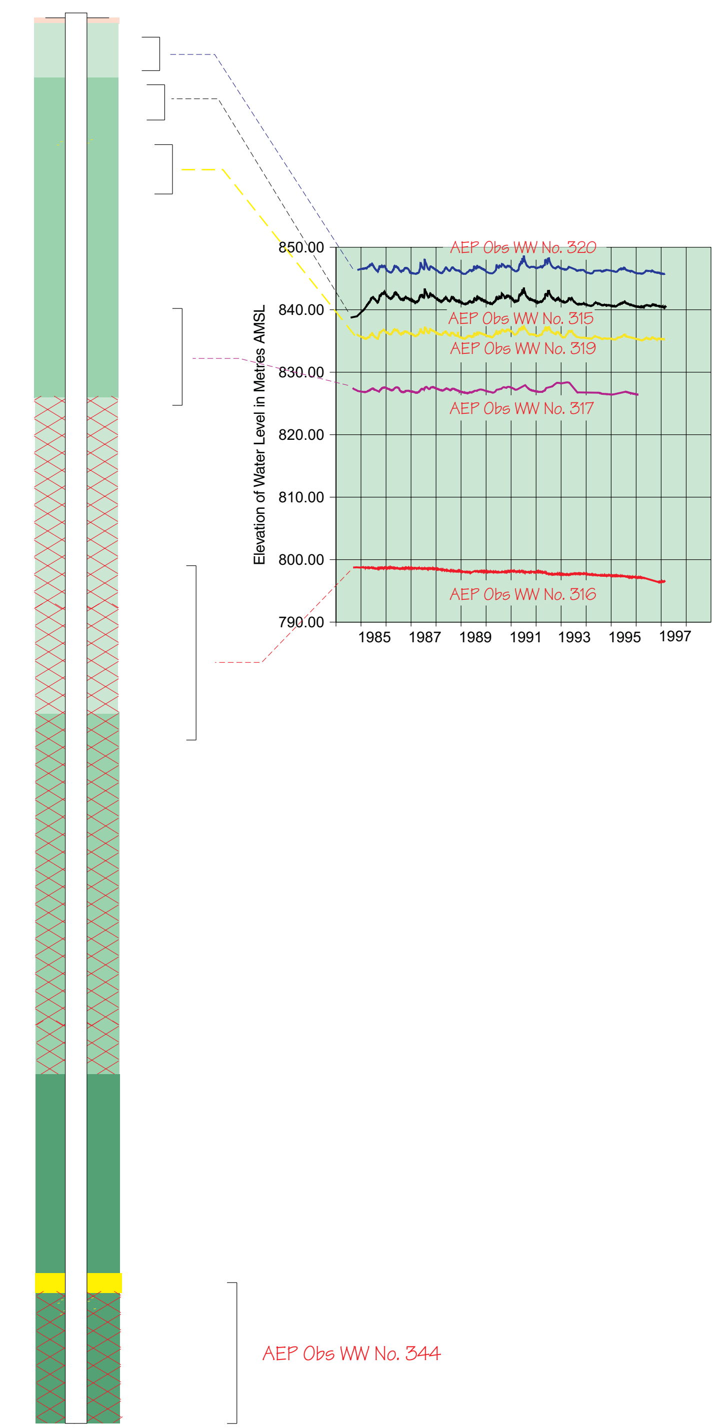






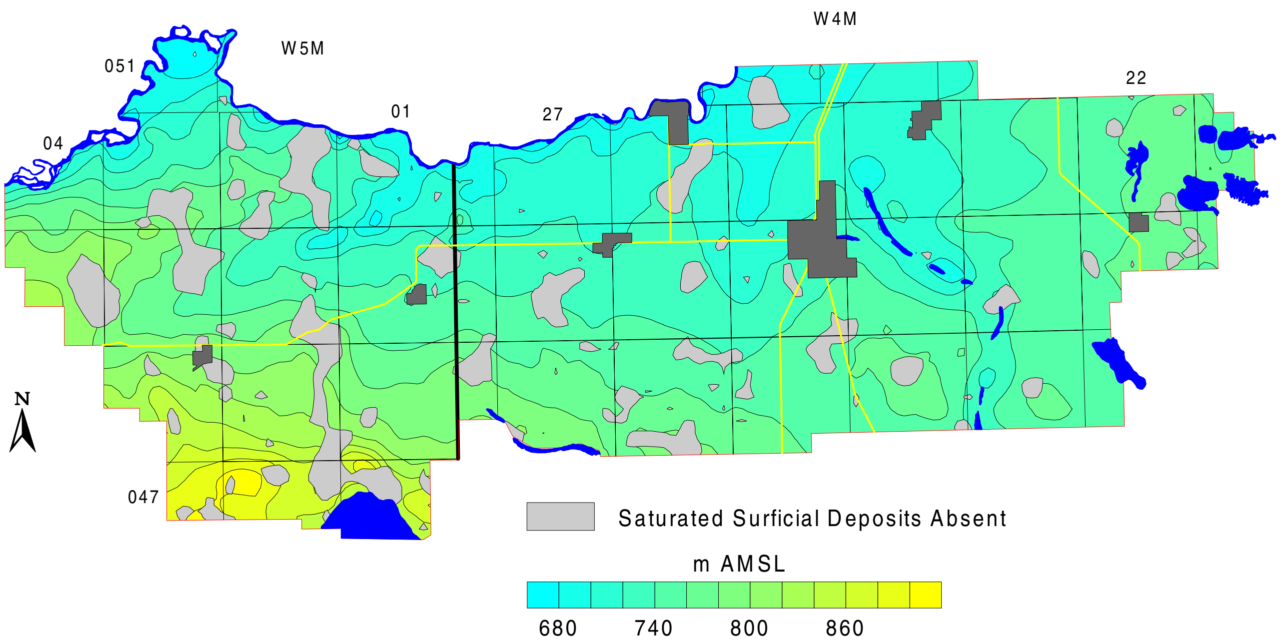


- Non-Pumping Water Level
- Completion Interval
- Upper Surficial Deposits
- Upper Lacombe Member
- Lower Lacombe Member
- Haynes Member
- Upper Scollard
- Lower Scollard
- Battle and Whitemud formations
- Upper Horseshoe Canyon Formation
- Middle Horseshoe Canyon Formation

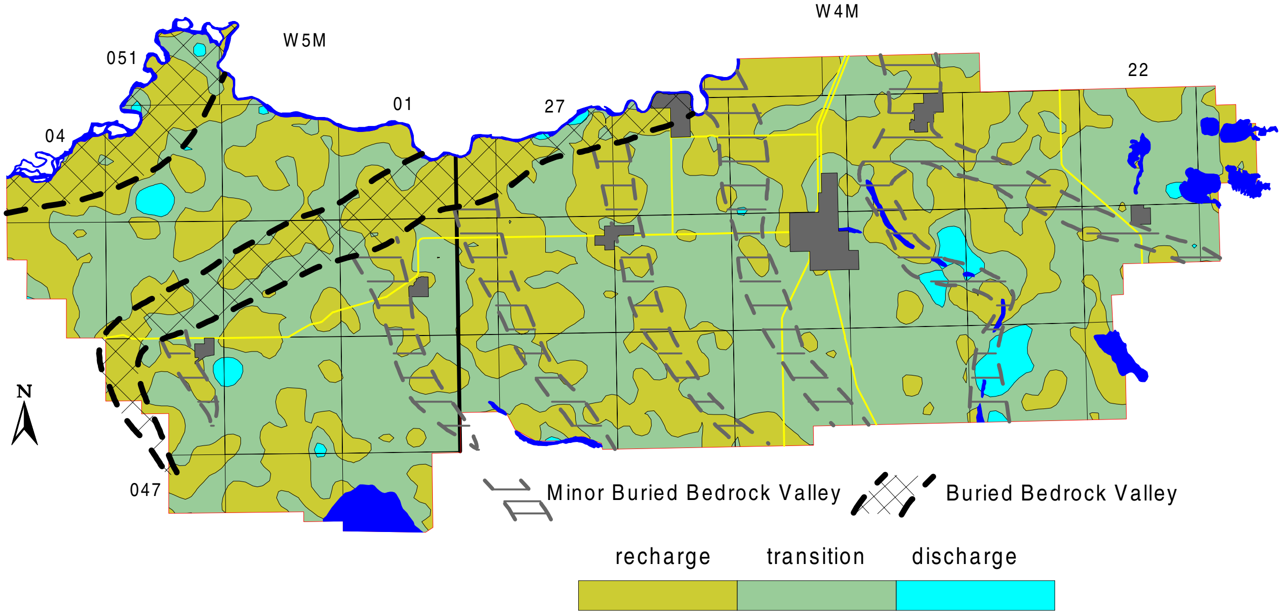


Hydrographs - AEP Observation Water Wells

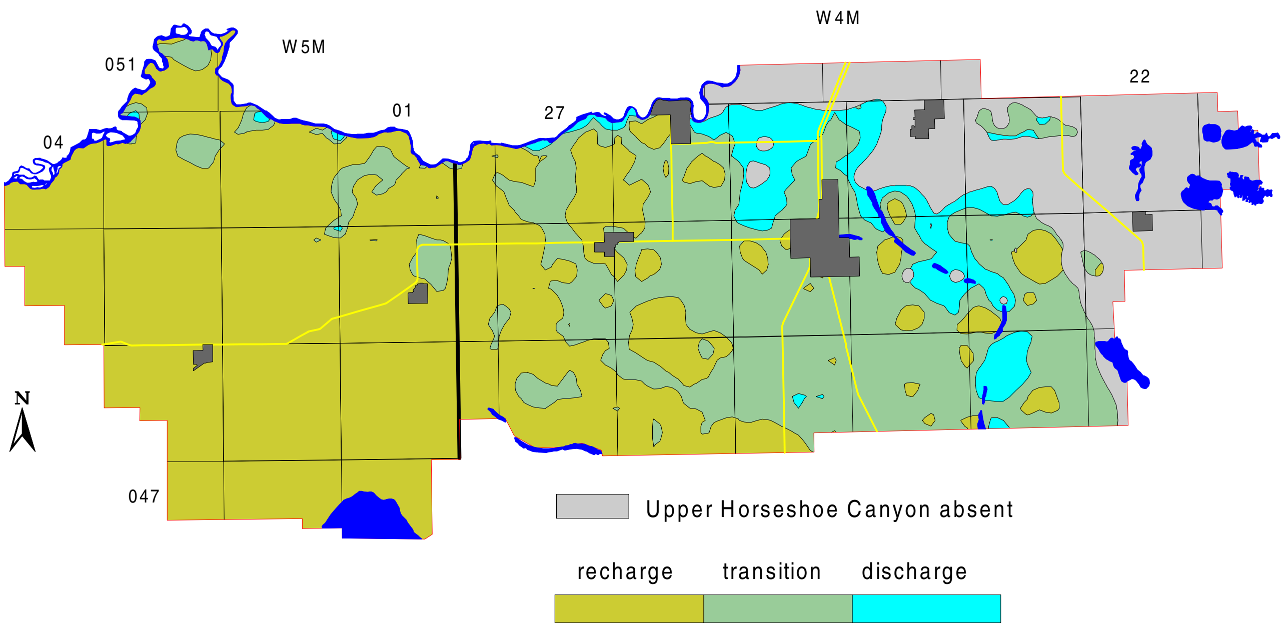
Non-Pumping Water-Level Surface in Surficial Deposits



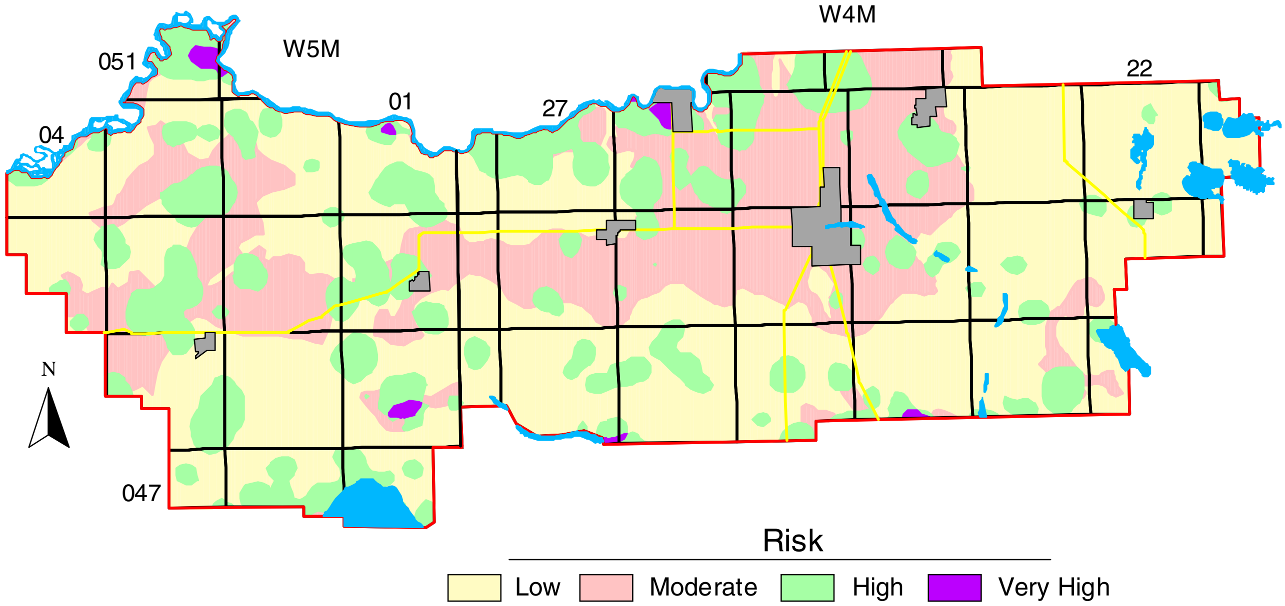
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



Recharge/Discharge Areas between Surficial Deposits and Upper Horseshoe Canyon Aquifer



Risk of Groundwater Contamination



LEDUC COUNTY

Appendix B

MAPS AND FIGURES ON CD-ROM

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

1) General

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Depth to Base of Groundwater Protection
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Bedrock Geology
Cross-Section A - A'
Cross-Section B - B'
Geologic Column
Generalized Cross-Section (for terminology only)
Risk of Groundwater Contamination
Relative Permeability
Summer Precipitation vs Water Levels in AEP Obs WW No. 320
Hydrographs - AEP Observation Water Wells
Water Wells Recommended for Field Verification

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Total Hardness of Groundwater from Surficial Deposits
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Thickness of First Sand and Gravel
First Sand and Gravel - Saturation

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a) General

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

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

d) Lower Scollard Aquifer

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

e) Upper Horseshoe Canyon Aquifer

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

f) Middle Horseshoe Canyon Aquifer

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

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

h) Bearpaw Aquitard

- Depth to Top of Bearpaw Aquitard
- Structure-Contour Map - Top of Bearpaw Aquitard

LEDUC COUNTY
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 10 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 4- and 6-minute water-level measurements, whenever there is an observed physical change in the groundwater being pumped, and 10 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)-(q) of the Environmental Protection and Enhancement Act.

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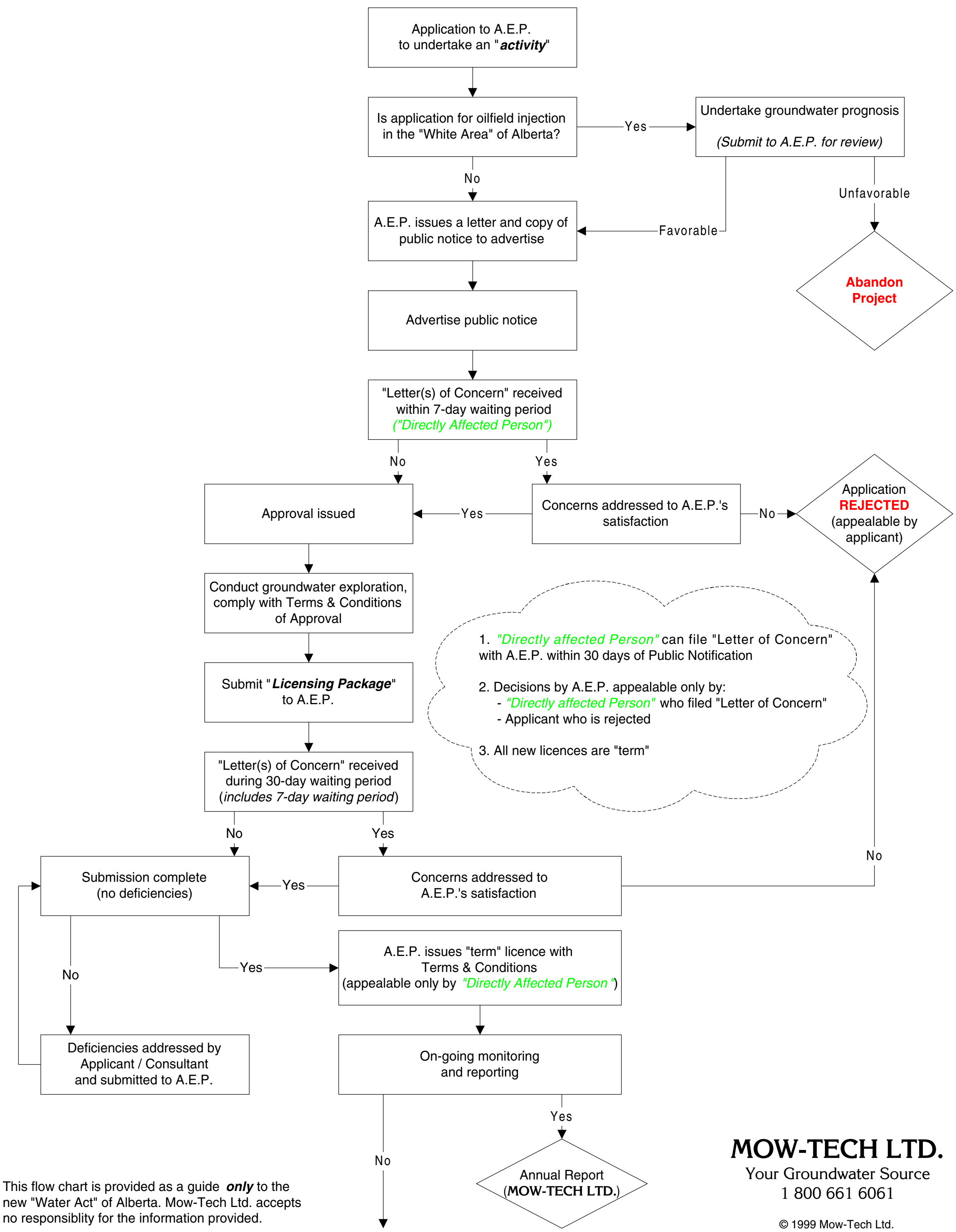

This flow chart is provided as a guide *only* to the new "Water Act" of Alberta. Mow-Tech Ltd. accepts no responsiblity for the information provided.

MOW-TECH LTD.
Your Groundwater Source
1 800 661 6061

Additional Information

VIDEOS

Will the Well Go Dry Tomorrow? (Mow-Tech Ltd.: 1-800 GEO WELL)
Water Wells that Last (PFRA – Edmonton Office: 780-495-3307)
Ground Water and the Rural Community (Ontario Ground Water Association)

BOOKLET

Water Wells that Last (PFRA – Edmonton Office: 780-495-3307)

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UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology

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FARMERS ADVOCATE

Paul Vasseur (Edmonton: 780-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION

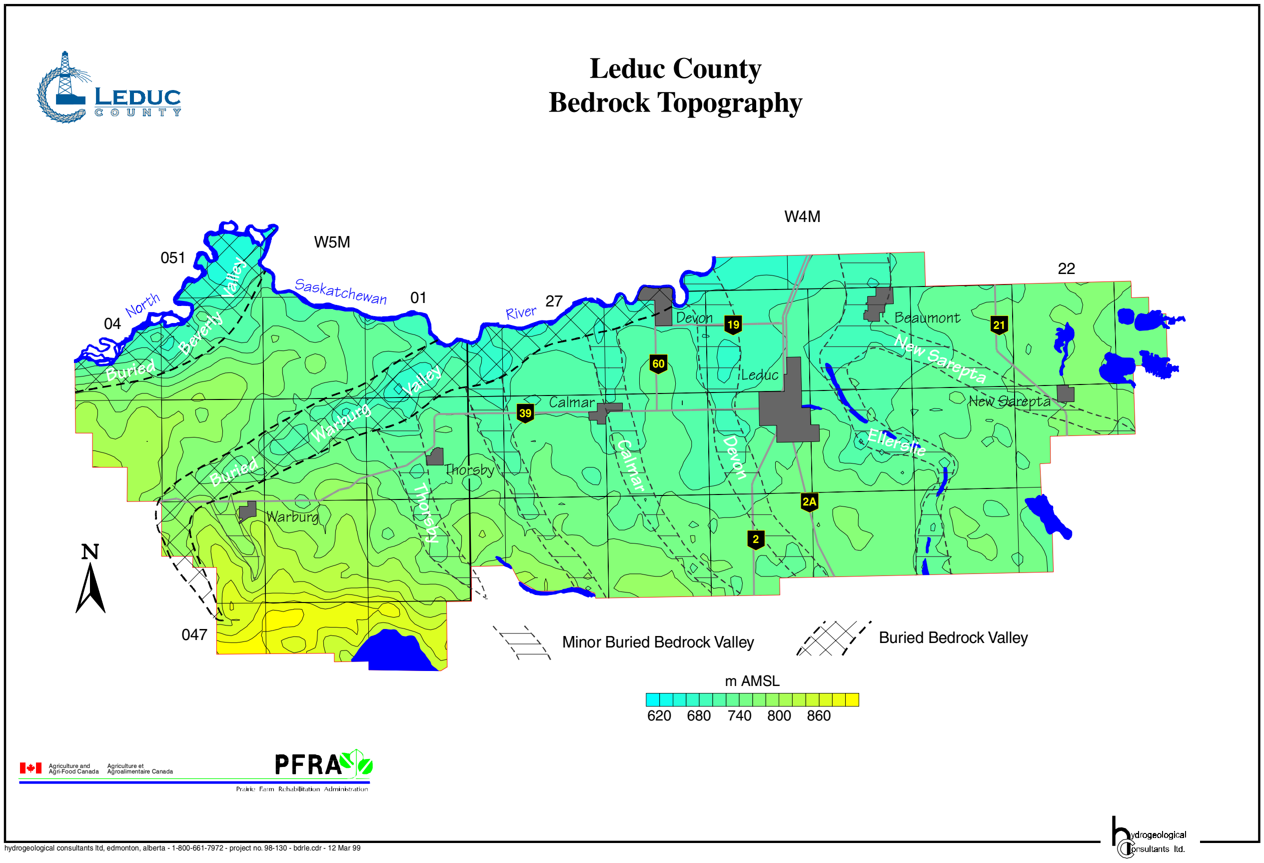
Curtis Snell (Westlock: 780-349-3963)

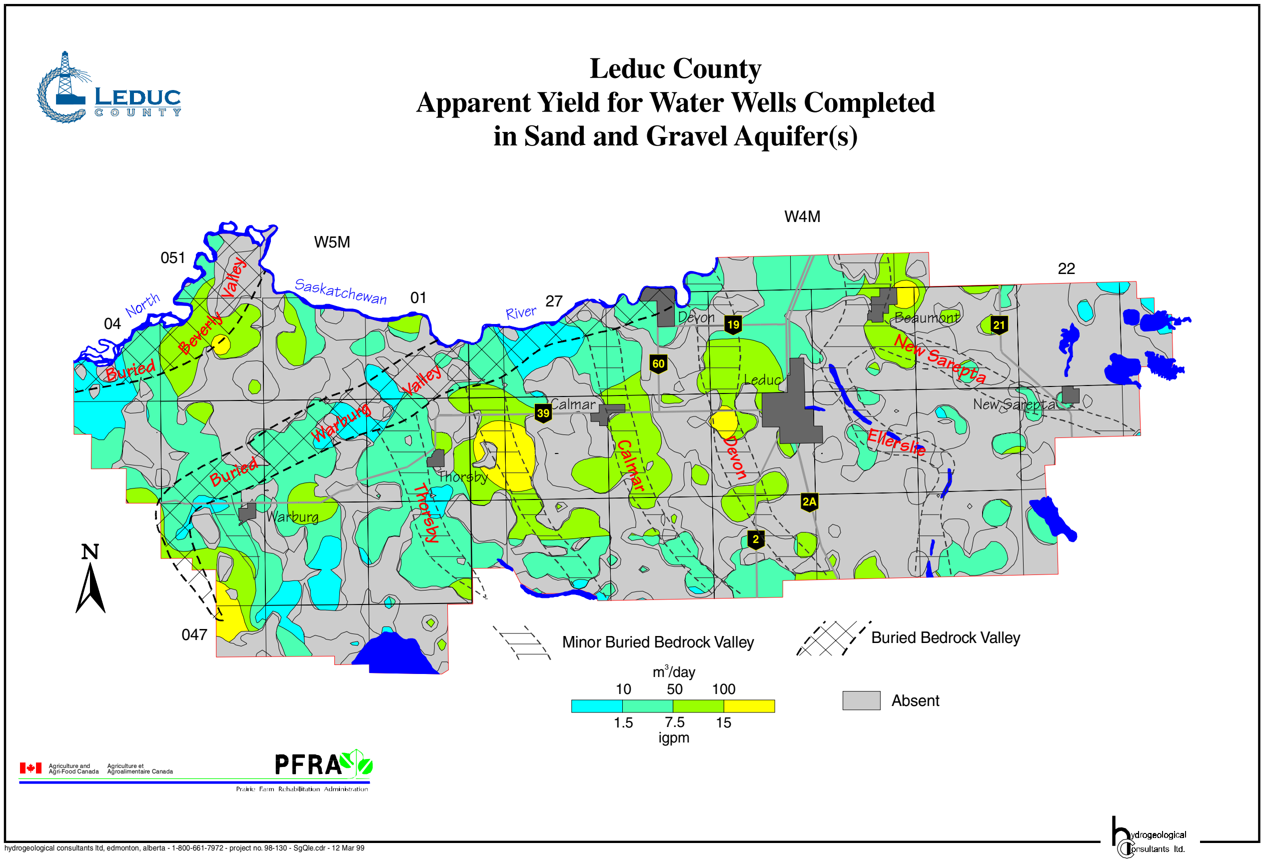
LOCAL HEALTH DEPARTMENTS

LEDUC COUNTY

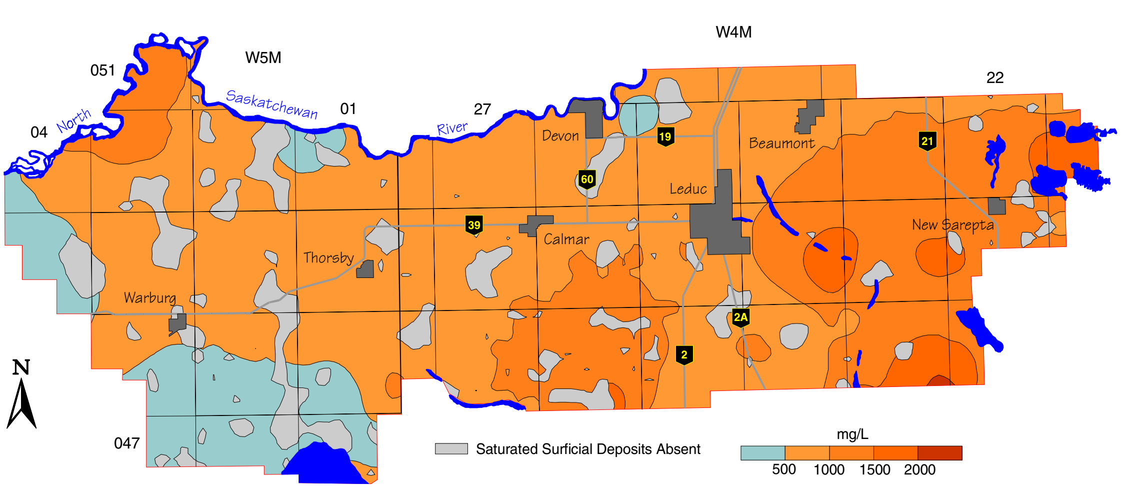
Appendix D

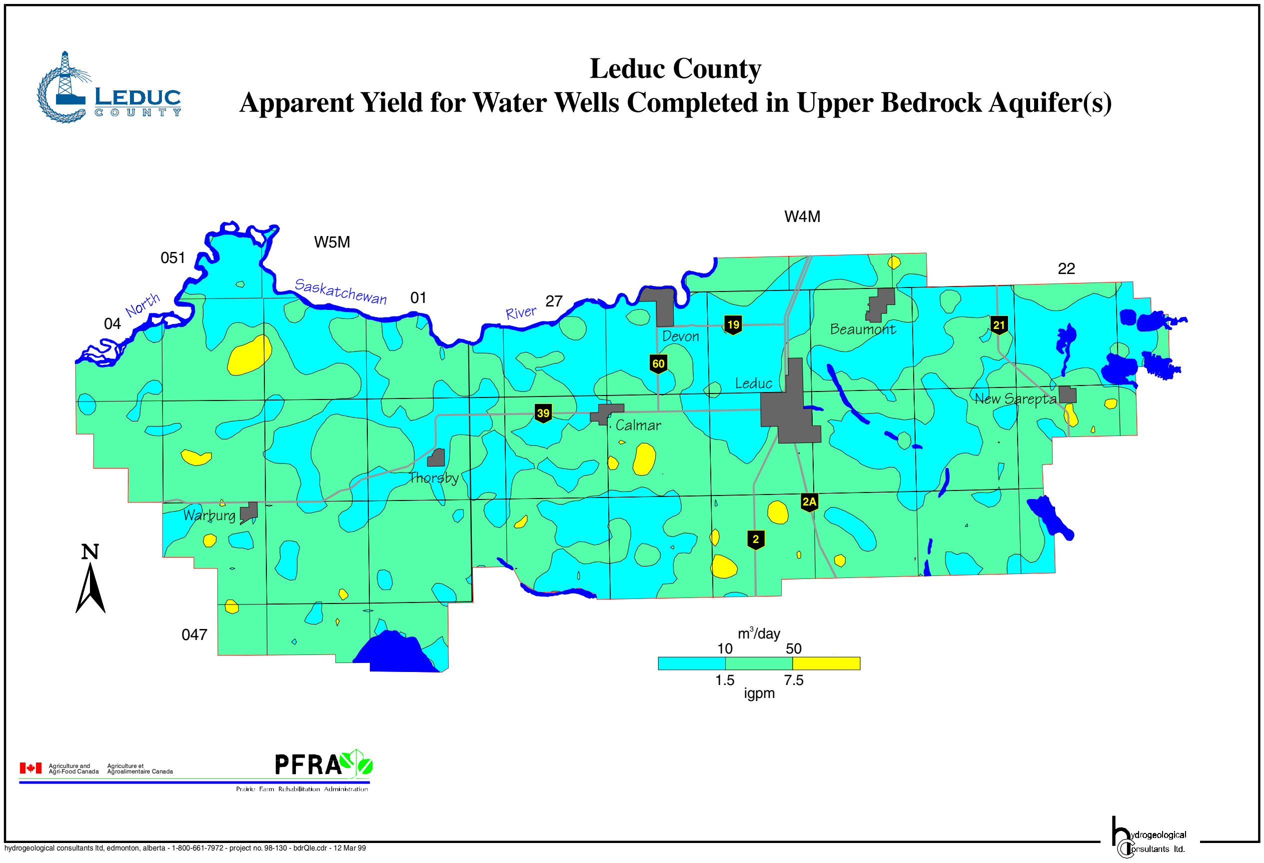
MAPS AND FIGURES INCLUDED AS LARGE PLOTS


Leduc County
Bedrock Topography
LEDUC COUNTY
W5M
W4M
051
04
01
27
22
047
North Saskatchewan River
Buried Beverly Valley
Buried Warburg Valley
Thorsby
Calmar
Devon
New Sarepta
Ellerslie
Beaumont
Leduc
Warburg
19
60
39
21
2A
2
N
Minor Buried Bedrock Valley
Buried Bedrock Valley
m AMSL
620
680
740
800
860
PFRA
Prairie Farm Rehabilitation Administration
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-130 - bdrle.cdr - 12 Mar 99
hydrogeological consultants ltd.


Leduc County
Apparent Yield for Water Wells Completed
in Sand and Gravel Aquifer(s)
W5M
W4M
051
04
01
27
22
047
North Saskatchewan River
Buried Beverly Valley
Buried Warburg Valley
Thorsby
Calmar
Devon
New Sarepta
Ellerslie
Beaumont
Leduc
Warburg
N
Minor Buried Bedrock Valley
Buried Bedrock Valley
m3/day
10 50 100
1.5 7.5 15
igpm
Absent
PFRA
Prairie Farm Rehabilitation Administration
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-130 - SgQle.cdr - 12 Mar 99

Leduc County
Total Dissolved Solids in Groundwater from Surficial Deposits




LEDUC COUNTY
Leduc County
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)
W5M
W4M
051
04
01
27
22
047
North Saskatchewan River
Devon
Beaumont
Leduc
New Sarepta
Calmar
Thorsby
Warburg
19
60
39
21
2A
2
N
m³/day
10
50
1.5
7.5
igpm
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration
hydrogeological consultants ltd.
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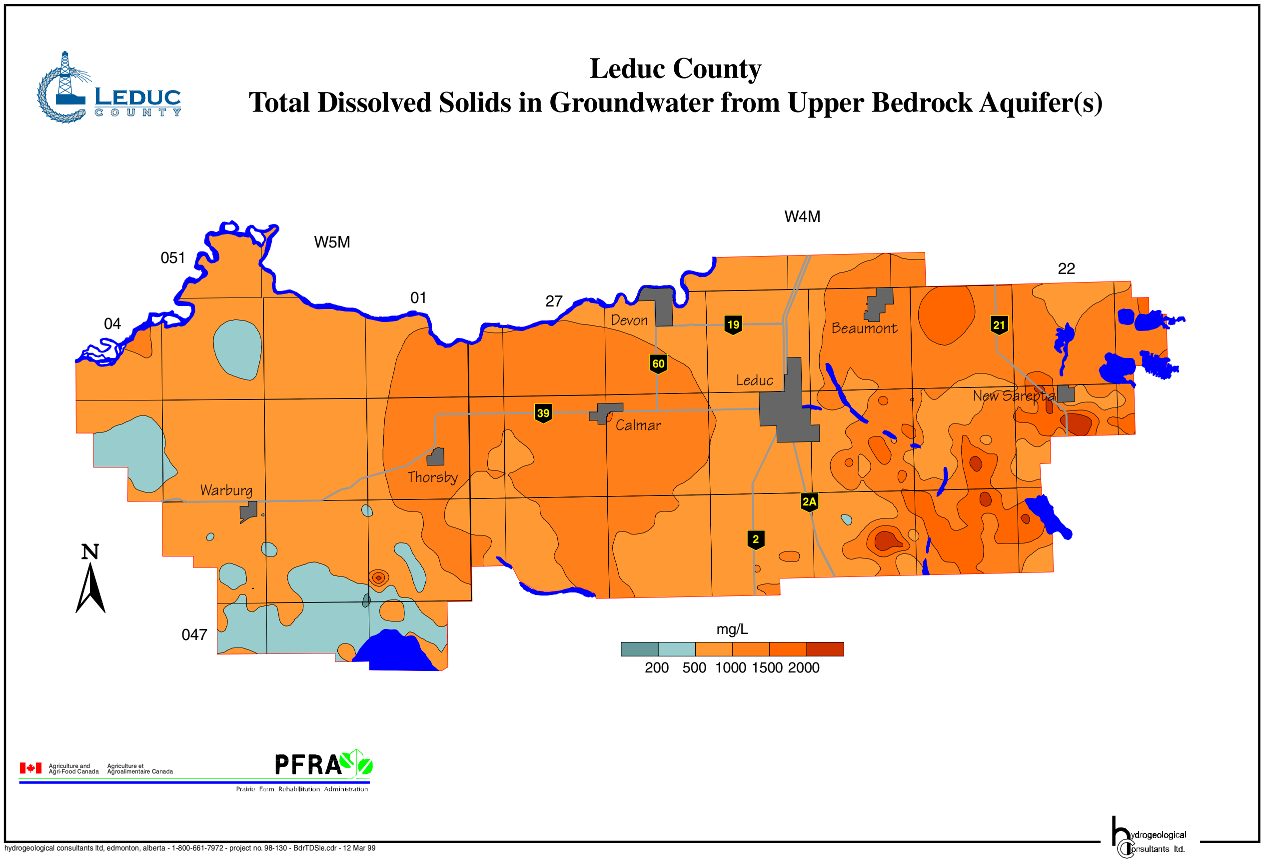
Leduc County
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)
LEDUC COUNTY
W5M
W4M
051
04
01
27
22
047
Devon
Beaumont
Leduc
New Sarepta
Calmar
Thorsby
Warburg
19
60
21
39
2A
2
N
mg/L
200 500 1000 1500 2000
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration
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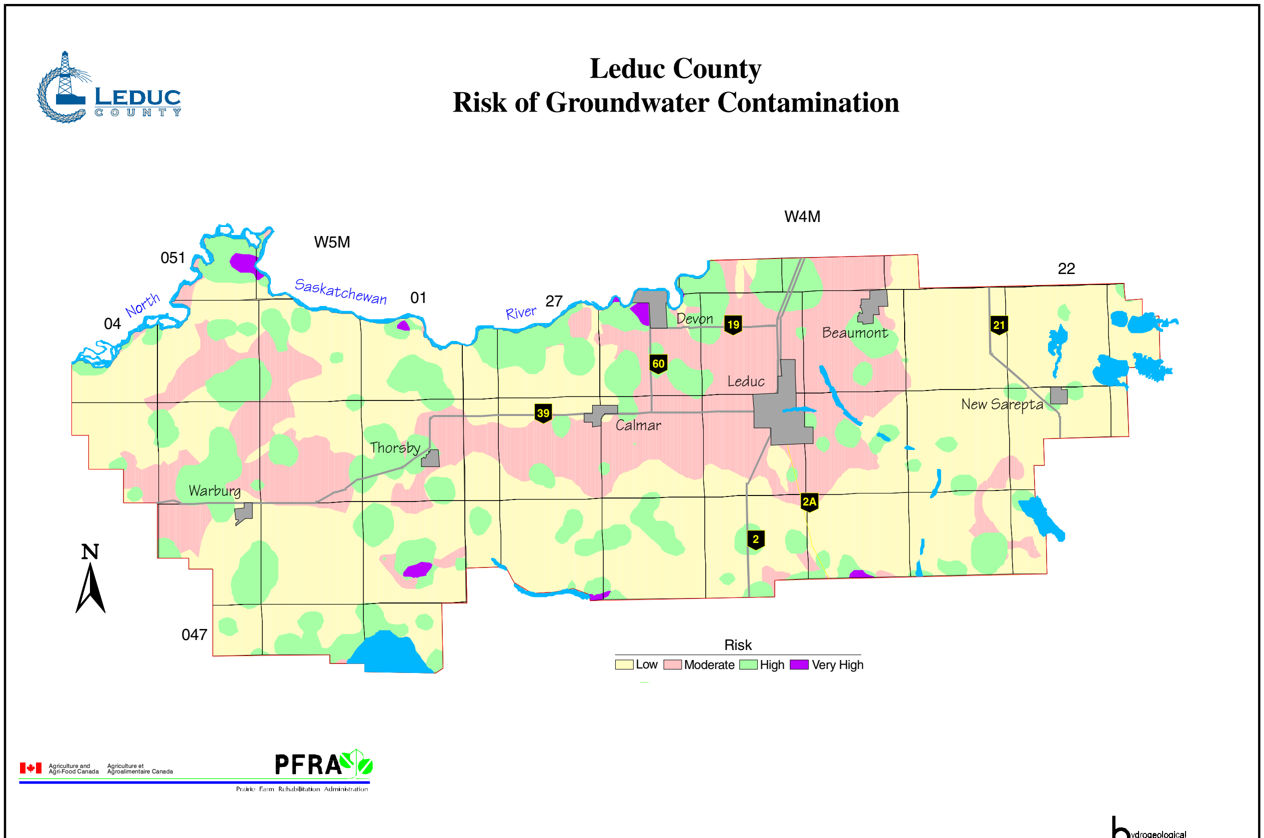

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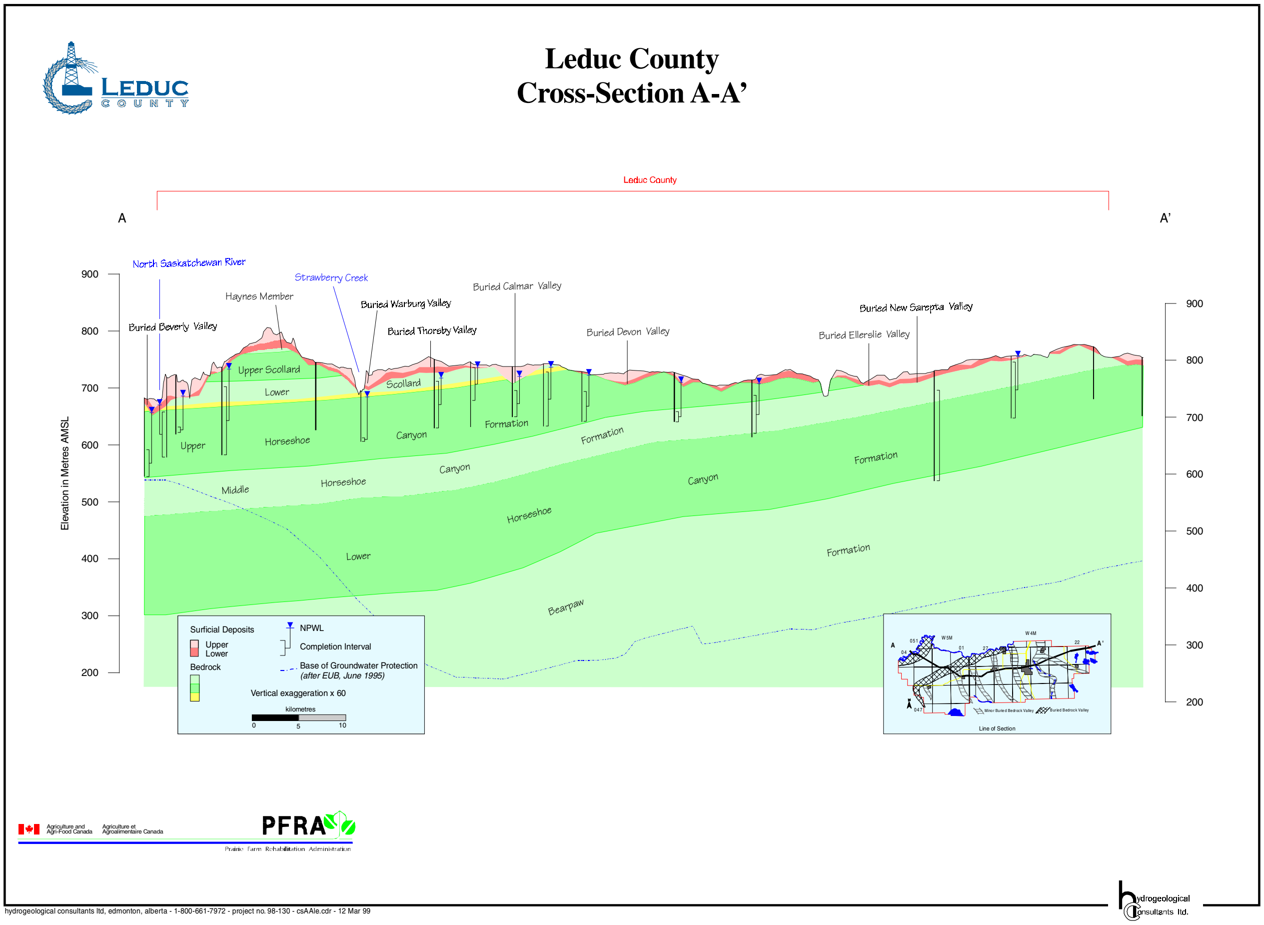
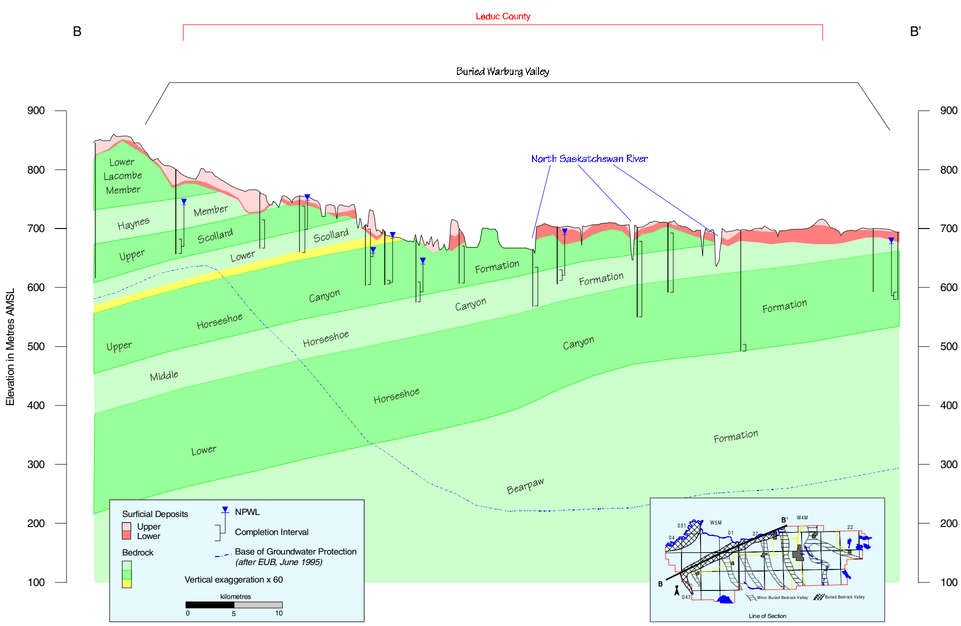

Leduc County
Cross-Section A-A'
Leduc County
A
A'
North Saskatchewan River
Strawberry Creek
Haynes Member
Buried Warburg Valley
Buried Calmar Valley
Buried Beverly Valley
Buried Thorsby Valley
Buried Devon Valley
Buried New Sarepta Valley
Buried Ellerslie Valley
Upper Scollard
Lower
Scollard
Upper
Horseshoe
Canyon
Formation
Middle
Lower
Bearpaw
Elevation in Metres AMSL
Surficial Deposits
Upper
Lower
Bedrock
NPWL
Completion Interval
Base of Groundwater Protection
(after EUB, June 1995)
Vertical exaggeration x 60
kilometres
Line of Section
PFRA
hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 98-130 - csAAle.cdr - 12 Mar 99

Leduc County
Cross-Section B - B'



Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada

PFRA Prairie Farm Rehabilitation Administration

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hydrogeological consultants ltd.

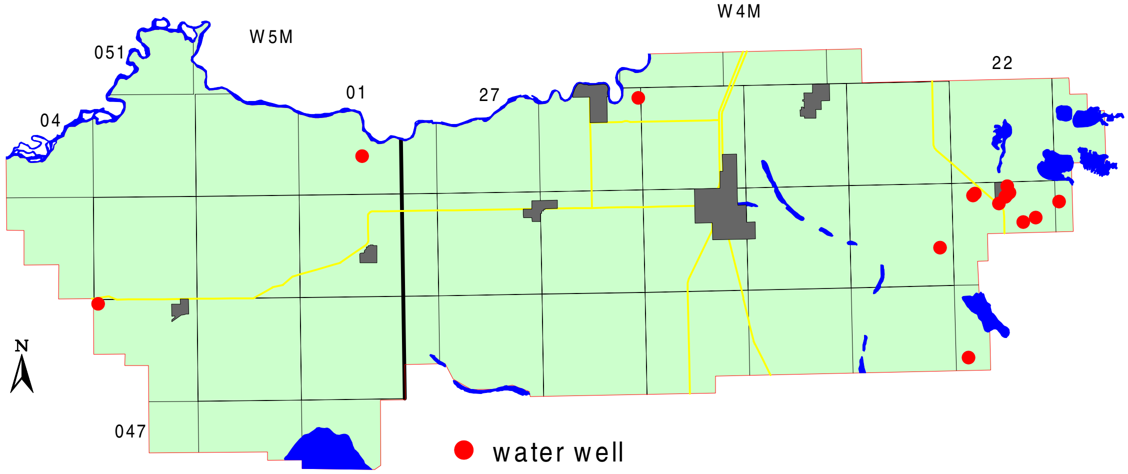
LEDUC COUNTY

Appendix E

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Water Wells Recommended for Field Verification

(details on following page)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Water Well Contractor	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
Helmut Schultz	34-049-22 4	Prier Herbert A	Aug-75	19.2	63.0	6.4	21.0
Agricultural Society	SW 34-049-22 4	Seis-Test	Nov-74	27.4	90.0	3.7	12.0
Sharon Van Drunen	23-049-22 4	Prier Herbert A	Aug-77	18.3	60.0	8.2	27.0
Steve Reminsky	23-049-22 4	Gordon'S Drilling Ltd.	Sep-82	33.5	110.0	12.8	42.0
Ernest Mitchell	NE 28-049-22 4	Holland Drilling Ltd.	Jul-83	22.9	75.0	4.6	15.0
Ron Thomson	SW 32-049-22 4	Big Iron Drilling Ltd.	Apr-82	30.8	101.0	7.6	25.0
Town Of#6 New Sarepta	34-049-22 4	Mcallister Waterwells Ltd.	Apr-81	21.3	70.0	0.3	1.0
Town Of#5 New Sarepta	34-049-22 4	Mcallister Waterwells Ltd.	Apr-81	21.3	70.0	0.3	1.0
R.A. Hickman	NW 34-049-22 4	Papley Drilling	Oct-78	13.7	45.0	4.3	14.0
Maurice Drebert	32-049-22 4	Prier Herbert A	May-71	19.5	64.0	2.3	7.5
Oscar Fengstad	NE 07-048-22 4	Seis-Test	Sep-79	27.1	89.0	4.9	16.0
Henry Bouwman	SE 15-050-01 5	Gordon'S Drilling Ltd.	May-85	9.8	32.0	3.1	10.0
Gregory Best	SW 13-049-23 4	Prier Herbert A	Sep-78	19.2	63.0	10.7	35.0
Rca #26 Devon #1	36-050-26 4	Unknown Driller		10.7	35.0	6.4	21.0
M. Meinczinger	NW 31-048-03 5	Hostyn Drilling Co. Ltd.	May-76	18.3	60.0	1.5	5.0
Teddy Hansen	NW 30-049-21 4	Prier Herbert A	Aug-77	11.3	37.0	3.4	11.0