Smoky Lake Region

Part of the North Saskatchewan River Basin
Parts of Tp 057 to 064, R 11 to 19, W4M
Regional Groundwater Assessment

Prepared for

COUNTY OF SMOKY LAKE

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
hydrogeological consultants ltd.
1-800-661-7972
Our File No.: **97-103**

September 1998
(Revised November 1999)

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1 PROJECT OVERVIEW

“Water is the lifeblood of the earth.” - Anonymous

How a Region 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 creates a solid base for increased economic activity. **This report, even though it is preliminary in nature, is the first step in fulfilling a commitment by the Region toward the management of the groundwater resource, which is a key component of the well-being of the Region, and is a guide for future groundwater-related projects.**

1.1 About This Report

This report provides an overview of (a) the groundwater resources of the Smoky Lake Region, (b) the processes used for the present project and (c) the groundwater characteristics in the Region.

Additional technical details are available from files on the CD-ROM provided with this report. The files include the geo-referenced electronic groundwater database, grid files used to prepare 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 page-size copies are included in Appendix D.

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

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

Appendix C includes the following:

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

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

1.2 The Project

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

The present project consists 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 represents Modules 2 and 3.

1.3 Purpose

This project is a regional groundwater assessment of the Smoky Lake Region. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the Region. Groundwater resource management involves determining the suitability of various areas in the Region 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 Region.**

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 Smoky Lake Region have been assembled. Where practical, the data have been digitized. These data are then being used in the regional groundwater assessment for the Region.

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[1] See glossary
[2] See glossary

2 INTRODUCTION

2.1 Setting

The Smoky Lake Region is situated in central Alberta. This area is part of the Alberta Plains region. The Smoky Lake Region includes the County of Smoky Lake No. 13, the Buffalo Lake and Kikino Metis settlements, and all of White Fish Lake I.R. 128 and Saddle Lake I.R. 125. The Region exists within the North Saskatchewan River basin. The majority of the southern boundary of the Region is the North Saskatchewan River. The area includes some or all of townships 057 to 064, ranges 11 to 19, west of the 4th Meridian.

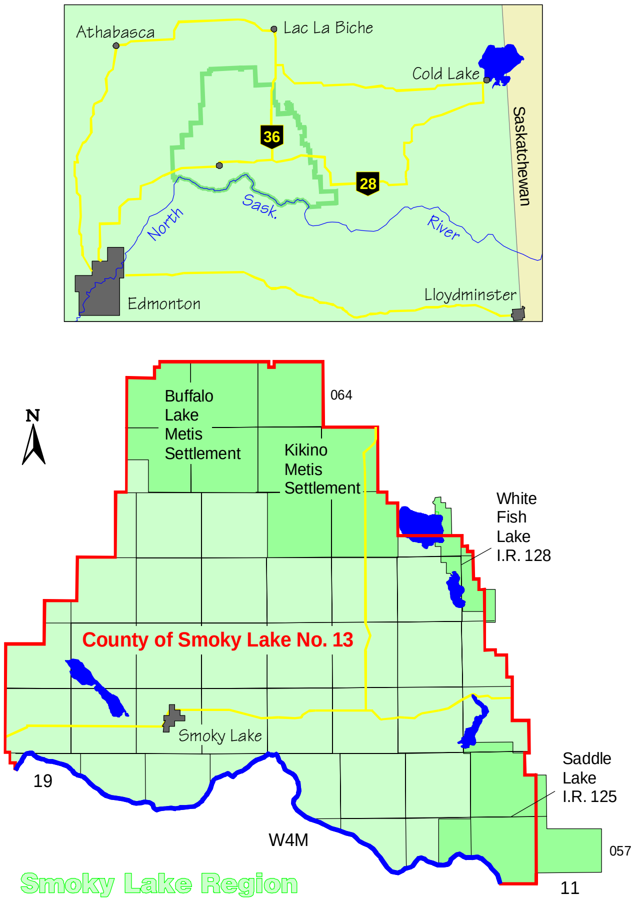


Figure 1. Index Map

The Region boundaries follow township or section lines. The exception is the southern boundary. The ground elevation varies between 535 and 735 metres above mean sea level (AMSL). The topographic surface generally decreases toward the northern and southern parts of the Region.

2.2 Climate

The Smoky Lake Region 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 Region is located in both the Low Boreal Mixedwood region and the Aspen Parkland region. This vegetation change is influenced by increased precipitation and cooler temperatures, resulting in additional moisture availability.

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 445 millimetres (mm), based on data from 1958 to 1993. The mean annual temperature averaged 1.7 °C, with the mean monthly temperature reaching a high of 16.4 °C in July, and dropping to a low of -14.8 °C in January. The calculated annual potential evapotranspiration is 507 millimetres.

2.3 Background Information

There are currently records for 3,201 water wells in the groundwater database for the Smoky Lake Region. Of the 3,201 water wells, 2,496 are located outside the Settlements and the Indian Reserves. Of the 3,201 water wells, 2,576 are for domestic/stock purposes. The remaining 625 water wells were completed for a variety of uses, including municipal, observation and industrial purposes. Based on a rural population of 2,782, not including the population from the Settlements and the I.R.s, there are 3.7 water wells per family of four. The domestic or stock water wells vary in depth from less than one metre to 152 metres below ground level. Lithologic details are available for 1,857 water wells.

Data for casing diameter are available for 1,403 water wells, with 481 indicated as having a diameter of more than 350 mm and 922 having a diameter of less than 350 mm. The casing diameters of less than 350 mm are for drilled water wells and water wells with a diameter of greater than 350 mm are mainly bored water wells.

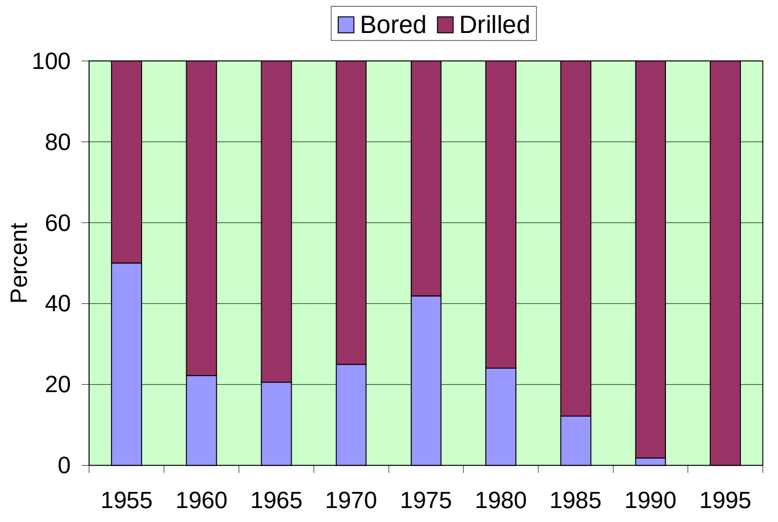


Figure 2. Relationship between Drilled and Bored Water Wells

There has been a gradual decline in the percentage of bored water wells completed within the Smoky Lake Region from the early 1950s to 1995. The only time when there was a rise in the percentage was during the 1970s. From 1970 to 1974, 50% of the bored water wells were drilled by one contractor; from 1975 to 1979, 30% were drilled by another contractor and 30% by a third contractor.

Steel, plastic and galvanized steel represent 90% of the materials that have been used for surface casing over the last 40 years in water wells completed in the Region. The most common material is steel. Steel casing was used in the 1950s and is still being used today. Approximately 37% of the water wells are reported as having steel surface casing. The next most common material is plastic. Plastic casing is used in 31% of the water wells. The first reported use of plastic casing in the Region was in June 1980. In the 1990s, nearly 90% of the water wells have been completed with plastic casing. Over the last 40 years, galvanized steel was used in 22% of the water wells. However, the last reported use of galvanized steel was in March 1994.

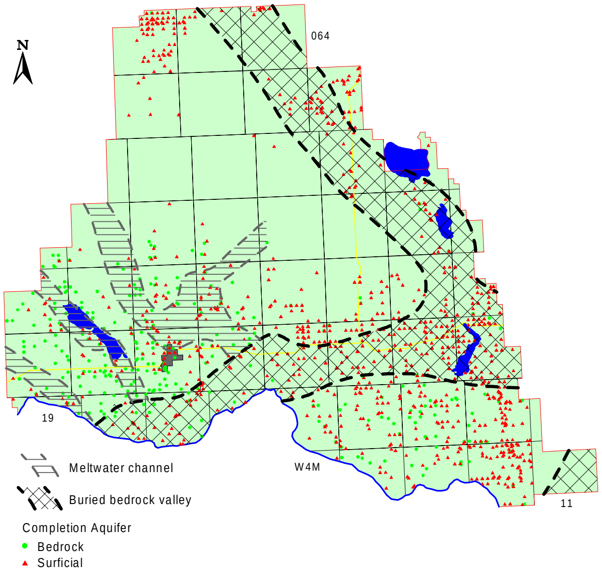


Figure 3. Location of Water Wells

There are 1,511 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 1,200. The adjacent map shows that these water wells are mainly in the southeastern part of the Region and in the two Settlements.

The remaining 311 water wells have the top of their completion interval deeper than the depth to the bedrock surface. From the adjacent map, it can be seen that water wells completed in bedrock aquifers occur mainly in the southwestern part of the Region and do not tend to occur in the areas underlain by buried bedrock valleys or meltwater channels.

There are large areas of the Region where there are few, if any, water wells. For example, there are no records for water wells in Tp 062, R 17, and Tp 063, R 16, W4M and only one or two water wells in Tp 061, R 14 and 15, W4M, and Tp 062, R 15 and 16, W4M.

Water wells not used for domestic needs must be licensed. At the end of 1996, 29 groundwater diversions were licensed in the Region. The total maximum authorized diversion from these 29 water wells is 1,273 cubic metres per day (m^3/day); 59 percent of the authorized groundwater diversion is allotted for agricultural use. The largest licensed groundwater diversion within the Region is 669.4 m^3/day for the Town of Smoky Lake; this water well is completed in the Lower Sand and Gravel Aquifer.

At many locations within the Region, 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 surface was prepared representing the minimum depth for water wells and a second 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, the impression is that only one aquifer is being used. The area where the greatest differences between the minimum and maximum depth occur most often is in areas where water wells completed in aquifers in the surficial deposits are most common.

The total dissolved solids in the groundwater in the Region are generally less than 2,000 milligrams per litre (mg/L). Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. 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. Very few 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, a depth to the Base of Groundwater Protection can be determined. This depth would be for the most part the maximum drilling depth for a water supply well. Over approximately 70% of the Region, the depth to the Base of Groundwater Protection is more than 100 metres. The area where the depth to the Base of Groundwater Protection is less than 20 metres is mainly in the northeastern part of the Region.

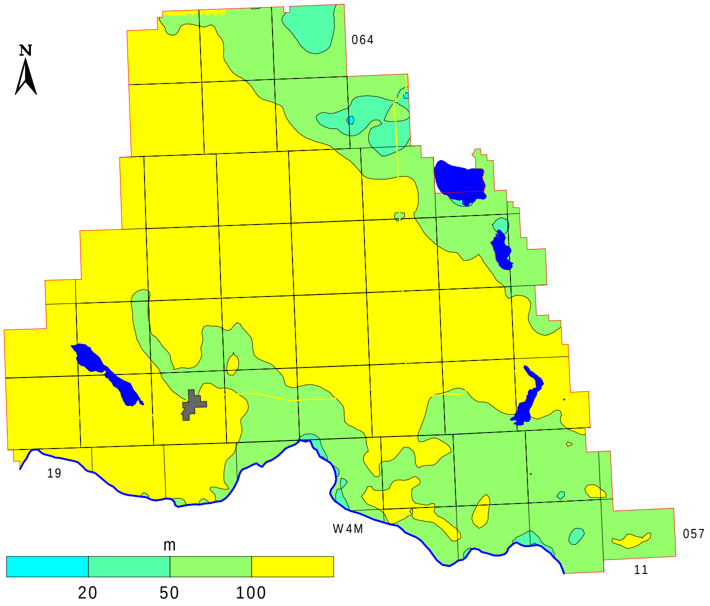


Figure 4. Depth to Base of Groundwater Protection

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are no data available from **Alberta Environmental Protection-**operated observation water wells within the Smoky Lake Region. Additional data can be obtained from some of the licensed groundwater diversions. In the past, these data have been difficult to obtain from AEP, in part because of the failure of the licensee to provide the data. **However, even with the available sources of data, the number of water-level data points relative to the size of the Region 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

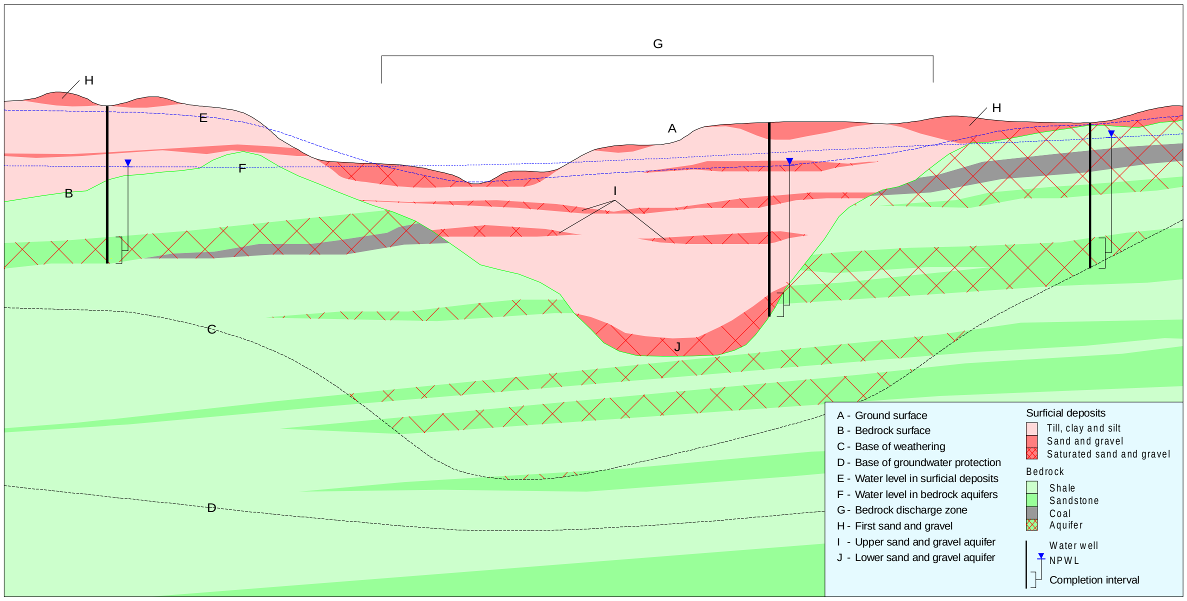
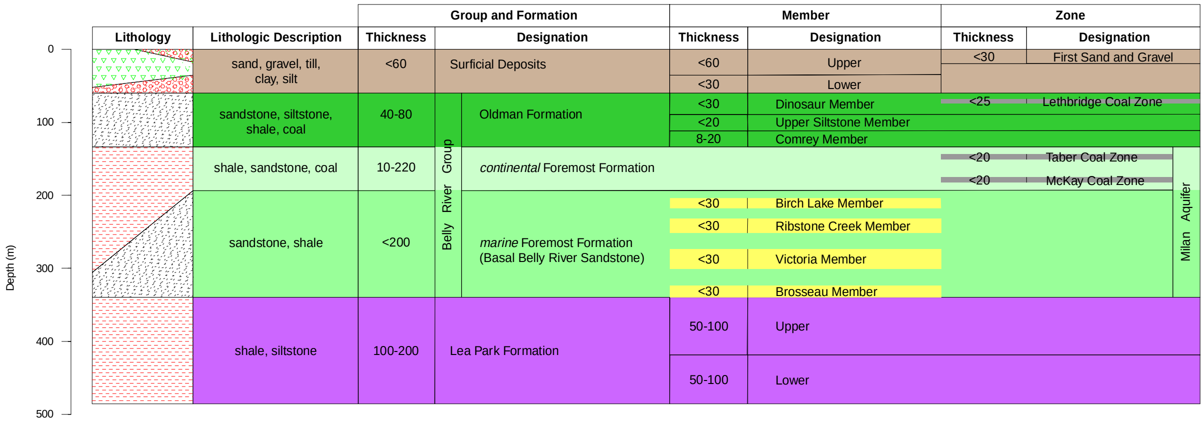


Figure 5. Generalized Cross-Section (for terminology only)



Lithologic Description	Group and Formation Thickness	Group	Group and Formation Designation	Member Thickness	Member Designation	Zone Thickness	Zone Designation	
sand, gravel, till, clay, silt	<60		Surficial Deposits	<60	Upper	<30	First Sand and Gravel	
				<30	Lower			
sandstone, siltstone, shale, coal	40-80	Belly River Group	Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone	
				<20	Upper Siltstone Member			
				8-20	Comrey Member			
shale, sandstone, coal	10-220		*continental* Foremost Formation			<20	Taber Coal Zone	Milan Aquifer
						<20	McKay Coal Zone	
sandstone, shale	<200		*marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member			
				<30	Ribstone Creek Member			
				<30	Victoria Member			
				<30	Brosseau Member			
shale, siltstone	100-200		Lea Park Formation	50-100	Upper			
				50-100	Lower			

Figure 6. Geologic Column

4 METHODOLOGY

4.1 Data Collection and Synthesis

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

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

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

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

The present project uses the 10-degree Transverse Mercator (10TM) coordinate system. This means that a record for the NW ¼ of section 28, township 059, range 17, W4M, would have a horizontal coordinate with an Easting of 163,689 metres and a Northing of 5,998,631 metres, the centre of the quarter section. Once the horizontal coordinates are determined, a ground elevation is obtained from the 1:20,000 Digital Elevation Model (DEM) from the Resource Data Division of AEP.

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

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

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

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

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

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

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

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

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

4.2 Spatial Distribution of Aquifers

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

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

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

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

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

4.3.1 Risk Criteria

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

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

Table 1. Risk of Groundwater Contamination Criteria

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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 aquifer outline and the aquifer thickness. The aquifer thickness is used to determine the aquifer transmissivity by multiplying the hydraulic conductivity by the thickness.

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

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 non-pumping water levels. Data from individual geological units are then transferred from the digitally prepared surfaces to the cross-section.

Once the technical details of the 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 Appendix A, are included on the CD-ROM, and are in Appendix D in a page-size format.

4.5 Software

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

- Microsoft Professional Office 97
- Surfer 6.04
- ArcView 3.0a
- 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 Region. 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 nature of the water wells, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

5.1.1 Surficial Aquifers

Surficial deposits in the Region are mainly less than 60 metres thick, except in areas of linear bedrock lows where the thickness of surficial deposits can exceed 100 metres. The Buried Beverly Valley is one of the main linear lows. This linear low is present in the southern third of the Region and trends west to east. Cross-section A-A’ passes through the Buried Beverly Valley and shows the surficial deposits being more than 100 metres thick within the Valley. The present-day North Saskatchewan River has eroded down into the *marine* Foremost Formation in the southern part of the Region.

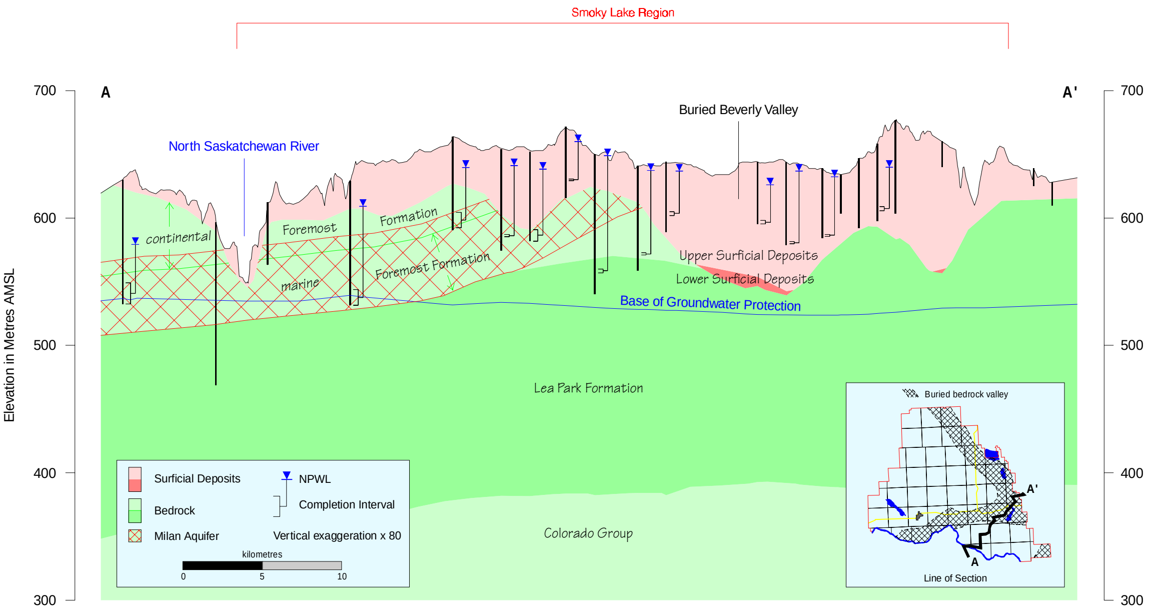

Figure 7. Cross-Section A - A'

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

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some of the water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they can be completed in low-permeability aquifers, these water wells would not generally 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 Region, 27% of the water wells completed in the surficial deposits have a casing diameter of greater than 350 millimetres or no reported diameter for the surface casing, and are assumed to be dug or bored water wells.

5.1.2 Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface. Some of this bedrock contains porous, permeable and saturated rocks that have a structure that is permeable enough for the rock to be an aquifer. Water wells completed in bedrock aquifers usually do not require water well screens and the groundwater is usually chemically soft. The data for 311 water wells indicate that the top of the water well completion interval is below the top of the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. Of these 311 water wells in the database, 246 have values for surface casing diameter. Of the 246 water wells, 95% have casing diameters of less than 350 millimetres and 52% of these water wells have been completed with water well screens.

The upper bedrock includes parts of the Belly River Group and the Lea Park Formation (Figure 8). The Belly River Group has a maximum thickness of 250 metres and includes the lowest part of the Oldman Formation and both the *continental* and *marine* facies[8] of the Foremost Formation. In the Smoky Lake Region, the Lea Park Formation is a regional aquitard[9]. The upper part of the *marine* Foremost Formation is included in the Milan Aquifer.

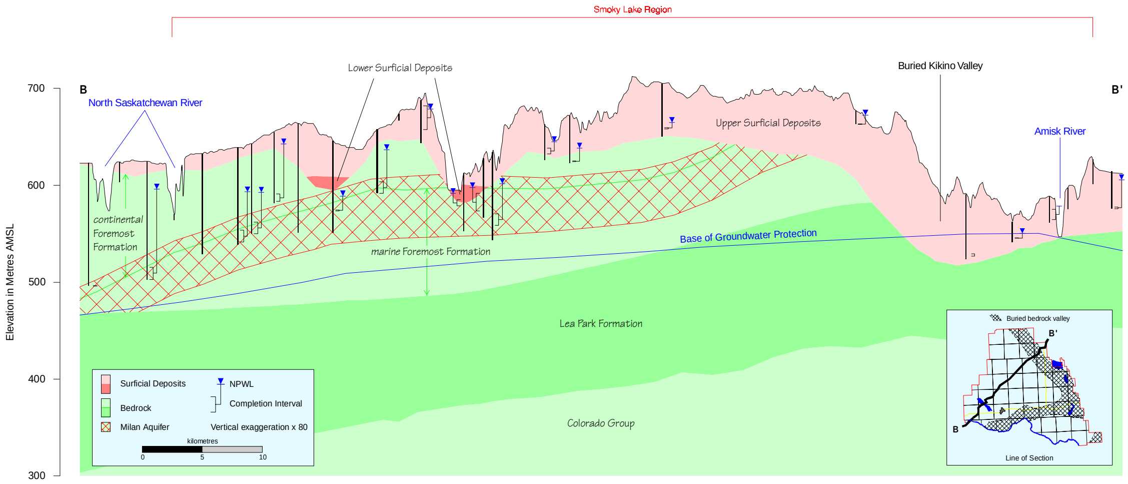

Figure 8. Cross-Section B - B'

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[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 drift, materials deposited directly by or indirectly during glaciation. The lower surficial deposits include the pre-glacial and some transitional sediment deposited as the glaciers advanced. The upper surficial deposits include the more traditional glacial deposits of till and meltwater deposits.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeological unit, they consist of two hydraulic parts. One hydraulic part includes sand and gravel aquifers associated with major linear lows in the bedrock surface and are part of the lower surficial deposits. The second hydraulic unit includes sand and gravel deposits that are not necessarily associated with major linear lows in the bedrock surface and are in the upper part of the surficial deposits. 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 mechanism 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 Region, the surficial deposits are less than 60 metres thick. The exceptions are mainly in association with the linear bedrock lows where the deposits can have a thickness of more than 100 metres. The two most significant linear bedrock lows have been designated as the Buried Beverly Valley and the Buried Kikino Valley. The Buried Beverly Valley is in the southern part of the Region as shown on the adjacent map. The Valley trends from southwest to east, extending from the valley of the present-day North Saskatchewan River to the east side of the Region, where it joins the Buried Kikino Valley. The Buried Beverly Valley is approximately 6 to 9 kilometres wide, with local bedrock relief being less than 60 metres. Sand and gravel deposits can be expected in association with this bedrock low, with the thickness of the sand and gravel deposits expected to be mainly less than 30 metres.

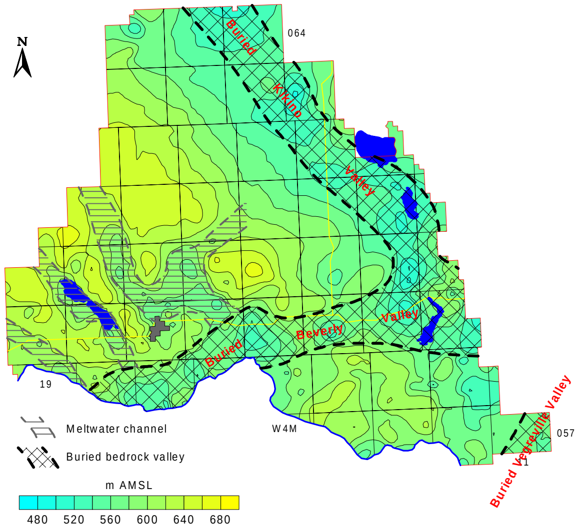

Figure 9. Bedrock Topography

The second linear bedrock low, the Buried Kikino Valley, trends from northwest to southeast along the eastern edge of the Region, joining the Buried Beverly Valley in the southeastern part of the Region. The Buried Kikino Valley is approximately 9 kilometres wide, with local relief being less than 60 metres. Sand and gravel deposits associated with this linear bedrock low can be expected to be less than 30 metres thick.

In addition to the Buried Beverly and Kikino valleys, the Buried Vegreville Valley passes below the eastern part of the Saddle Lake I.R. 125 in parts of township 057, range 11, W4M.

Four other linear bedrock lows are shown on the bedrock topography map. All of these lows are in the southwestern part of the Region and are indicated as being of meltwater origin. However, because sediments associated with the lower surficial deposits are indicated as being present in these linear bedrock lows, it is possible that the bedrock lows were originally tributaries to the Buried Beverly Valley drainage system.

The lower surficial deposits are composed mainly of fluvial[10] and lacustrine[11] deposits. Lower surficial deposits occur over approximately 20% of the Region, in association with linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than 20 metres, but ranges from 20 to more than 60 metres in parts of the Buried Beverly and Kikino valleys. The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally be expected to directly overlie the bedrock surface in the Buried Beverly and Kikino valleys. The lowest sand and gravel deposits are of fluvial origin and are usually less than 10 metres thick.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till plus sand and gravel deposits of meltwater origin. The thickness of the upper surficial deposits is mainly less than 40 metres. The greatest thickness of upper surficial deposits occurs mainly in association with the Buried Kikino Valley.

Sand and gravel deposits can occur throughout the entire unconsolidated section. The total thickness of sand and gravel deposits is generally less than 30 metres but can be more than 30 metres in the areas of the buried bedrock lows and meltwater channels.

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 50% of the Region, the sand and gravel deposits are more than 25% of the total thickness of the surficial deposits. The areas where the greatest percentage of sand and gravel tend to occur are in the southwestern part of the Region where linear bedrock lows are present.

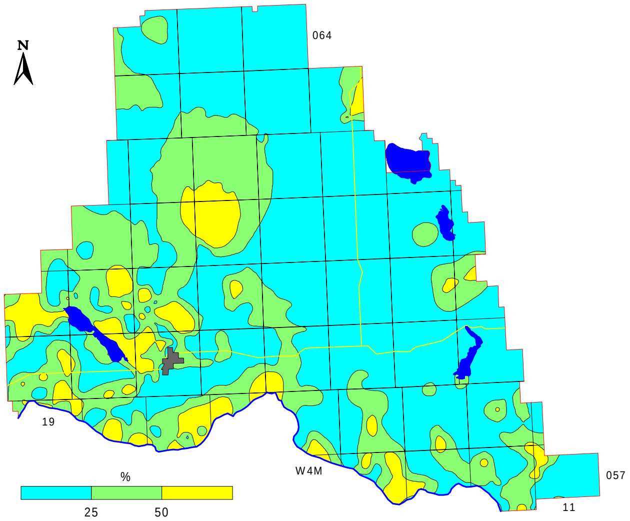

Figure 10. Amount of Sand and Gravel in Surficial Deposits

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[10] See glossary
[11] See glossary

5.2.2 Sand and Gravel Aquifer(s)

One significant source of groundwater in the Region 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, 166 water wells are completed in aquifers in the lower surficial deposits and 2,388 are completed in aquifers in the upper surficial deposits. This number of 2,554 water wells completed in aquifers in the surficial deposits is more than double the number of water wells determined to be completed in aquifers in the surficial deposits, based on lithology given on the water well drilling reports.

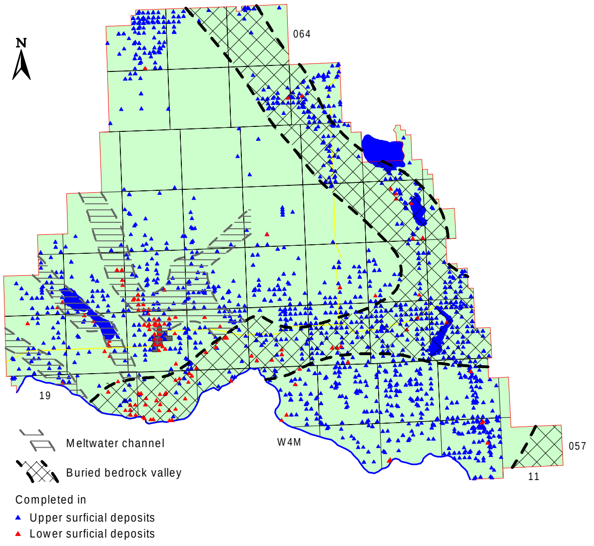

Figure 11. Water Wells Completed in Surficial Deposits

The majority of the water wells completed in the upper surficial deposits are located in the southern half of the Region, as shown on Figure 11. The majority of the water wells completed in the lower surficial deposits are located along the Buried Beverly Valley or in the meltwater channel north of the Town of Smoky Lake.

The adjacent map shows water well yields that are expected in the Region, based on surficial aquifers that have been developed by existing water wells. These data show that water wells with yields of more than 100 m³/day in the sand and gravel aquifer(s) can be expected mainly in the Buried Beverly Valley and in 40% of the southeastern portion of the Region. Over the majority of the Region, water wells completed in the sand and gravel aquifer(s) would be expected to mainly have long-term yields of less than 100 m³/day.

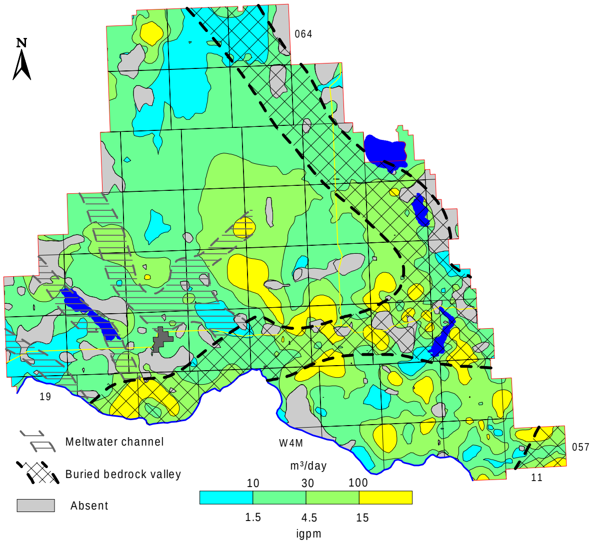

Figure 12. Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

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

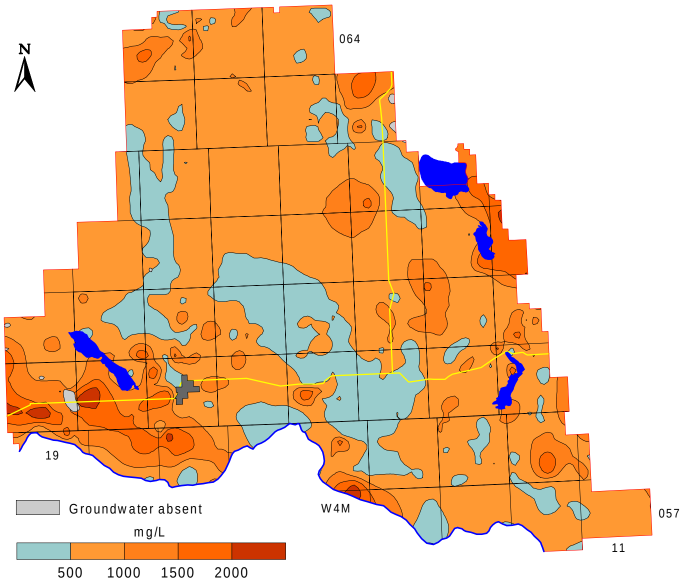

Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

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

The groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate-type waters, with 70% of groundwaters having total dissolved solids (TDS) of less than 1,000 mg/L. The groundwaters with a TDS of more than 1,500 mg/L occur mainly in the southwestern and eastern parts of the Region. All of the groundwaters from the surficial deposits are expected to have concentrations of dissolved iron of greater than 1 mg/L. The chemical analyses results for groundwater samples collected from water test holes completed near the Hamlet of Spedden (PFRA, 1990) in the Upper Sand and Gravel Aquifer, indicated TDS concentrations of more than 1,000 mg/L and a hardness of in the order of 600 mg/L.

Groundwater from the Town of Smoky Lake Recreation Complex Water Well completed in the Upper Sand and Gravel Aquifer has a TDS of 425 mg/L and a chemical hardness of 248 mg/L. The groundwater from WSW No. 1 in NW 28-059-17 W4M, which is completed in the Upper Sand and Gravel Aquifer, has a TDS of 300 and a chemical hardness of 255 mg/L.

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

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. These aquifers typically occur above an elevation of 600 metres AMSL in the western part of the Region and above an elevation of 540 metres AMSL in the eastern part of the Region. The saturated sand and gravel deposits are not continuous and are expected over approximately 85% of the Region.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is in part a function of the elevation of the non-pumping water-level surface associated with the upper surficial deposits and in part a result of the depth to the bedrock surface. Since the non-pumping water-level surface 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 10 metres thick in the Buried Beverly and Kikino valleys and meltwater channels, but over the majority of the County, is less than 10 metres thick or absent.

5.2.3.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of water wells with high yields; however, because the sand and gravel deposits 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.

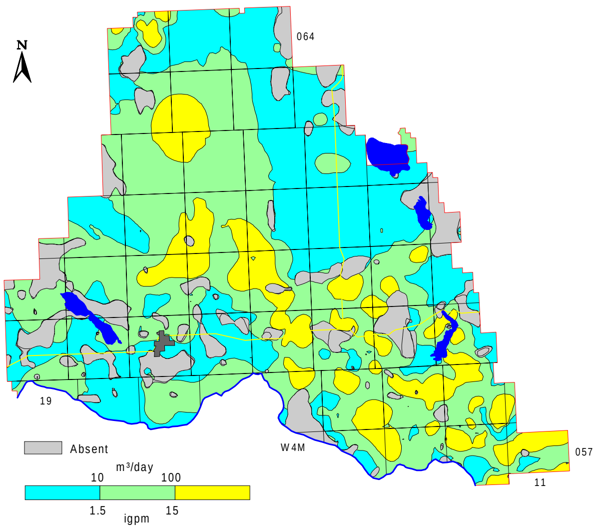

Figure 14. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

A groundwater study conducted for AEP (Hydrogeological Consultants Ltd., 1974) determined a long-term yield of 110 m³/day for the Town of Smoky Lake Recreation Complex Water Supply Well completed in the Upper Sand and Gravel Aquifer. A second water supply well completed in the Upper Sand and Gravel Aquifer northwest of the Town has provided more than 400 m^3/day for the last 14 years with no adverse effect on the water level in the Aquifer.

A groundwater study conducted for the Saddle Lake Indian Reserve (Hydrogeological Consultants Ltd., 1977) determined a long-term yield of 85 m³/day for the Reserve's Water Supply Well No. 2 completed in the Upper Sand and Gravel Aquifer.

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deepest part of the pre-glacial linear bedrock lows. The Lower Sand and Gravel Aquifer is present in 20% of the County, with a thickness of mainly less than 10 metres.

5.2.4.1 Apparent Yield

Water wells completed in the Lower Sand and Gravel Aquifer have yields that range from less than 10 to more than 100 m³/day. The highest yields are expected in the Buried Beverly and Kikino valleys. In these areas, the projected long-term yields from individual water wells could be more than 100 m³/day.

Water supply wells for the Town of Smoky Lake have also been completed in the Lower Sand and Gravel Aquifer. At least one of the water supply wells was completed within the Town's limits and one other is located in NE 29-059-17 W4M. The transmissivity value determined for the Aquifer at each location is in the order of 75 m²/day; the projected long-term yield for each of the water wells is less than 100 m^3/day.

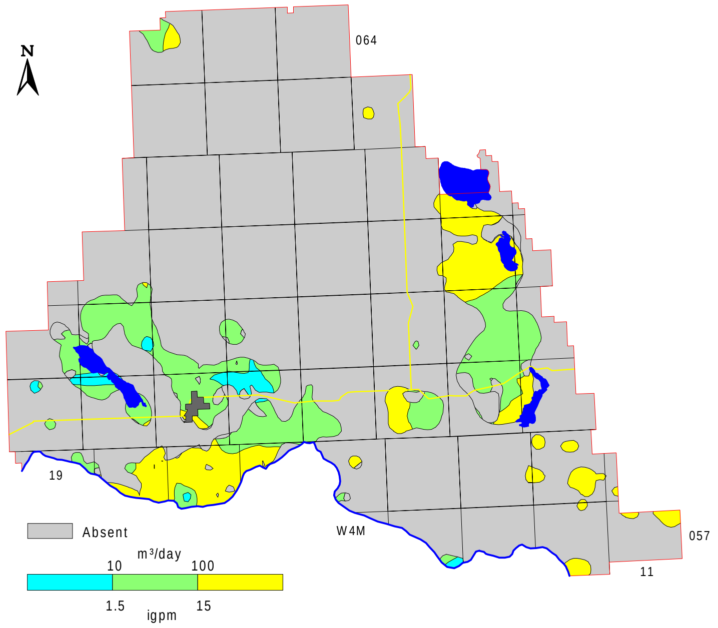

Figure 15. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock includes parts of the Belly River Group and the Lea Park Formation.

The Belly River Group in the Region has a maximum thickness of 250 metres and includes the lowest part of the Oldman Formation, and both the *continental* and *marine* facies of the Foremost Formation.

The uppermost part of the Belly River Group is the Oldman Formation. This Formation occurs as outliers within the area of the *continental* Foremost Formation in portions of townships 059, 060 and 061, ranges 17, 18 and 19, W4M. The Oldman Formation has a maximum thickness of 15 metres within the Region.

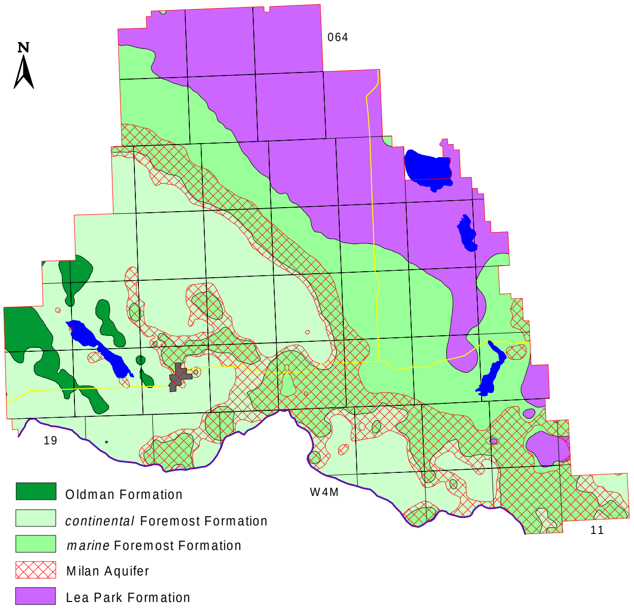

Figure 16. Bedrock Geology

The *continental* Foremost Formation underlies the Oldman Formation in the southwestern half of the Region; in the northeastern half of the Region, the *continental* Foremost Formation has been completely eroded. The *continental* Foremost Formation, a backshore deposit, consists mainly of shale deposits with minor amounts of sandstone present. Coal zones occur within the *continental* Foremost Formation, with the main ones referred to as the McKay and the Taber Coal Zones. There are also minor amounts of ironstone, a chemical deposit, in the *continental* Foremost Formation. Where the *continental* Foremost Formation is close to the bedrock surface, it can be fractured or weathered and can have significant local permeability.

Beneath the *continental* Foremost Formation is the *marine* Foremost Formation, which has a maximum thickness of 60 metres within the Region. To the south and east of the Smoky Lake Region, the *marine* Foremost Formation includes up to five sandstone members. The Smoky Lake Region is close to the western extent of the *marine* Foremost Formation. In this area, the sandstone members tend to thicken and the intervening shale layers become thin. With this change, distinguishing between the individual sandstone members is not possible. Even though the individual members cannot be distinguished, the sandstone occurrence is a significant aquifer and has been designated the "Milan Aquifer". The top of the Milan Aquifer can extend up to 10 metres into the overlying *continental* Foremost Formation and occupies up to 40 metres of the upper *marine* Foremost Formation. The westward extent of the Milan Aquifer coincides with the position where the Basal Belly River Sand can be distinguished. In the Smoky Lake Region, the Milan Aquifer is present under the southwestern half of the Region and subcrops in the central-southwestern part of the Region.

In the Smoky Lake Region, the Lea Park Formation is composed mainly of shale and as such is a regional aquitard. Between the Lea Park Formation and the Milan Aquifer there is the lower part of the *marine* Foremost Formation, which can be up to 30 metres thick. The lower part of the *marine* Foremost Formation has been included with the Lea Park Formation since the distinction between the two is difficult to make in the area.

5.3.2 Aquifers

Of the 3,201 water wells in the database, 311 were defined as being completed in bedrock aquifers. This designation is based on the top of the completion interval being below the bedrock surface. Of these 311 water wells, the length of their completion interval as a percentage of the completed depth of the water well varies between 0% and 96%, with 80% of the water wells having a completion interval that is less than one-quarter of their total depth.

Bedrock Aquifer	Number
Oldman	1
continental Foremost	273
marine Foremost	323
Lea Park	36
Total	633

Table 2. Completion Aquifer

In order to make use of additional information within the groundwater database, it was assumed that water wells with no completion interval data would 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 from 311 to 733. With the use of geological surfaces that were determined from the interpretation of geophysical logs, it has been possible to assign 633 of the 733 water wells completed in bedrock aquifers to specific aquifers based on their completion intervals. The results show that 94% of the bedrock water wells are completed in the *continental* Foremost and *marine* Foremost aquifers as shown in the table above; the remaining 100 bedrock water wells are completed in more than one aquifer and have not been assigned a specific bedrock aquifer. The number of water wells that are completed in the *marine* Foremost Aquifer also include the water wells that are completed in the Milan Aquifer. Of the 36 water-well records that are designated as the Lea Park Aquitard, 24 were indicated as dry or abandoned, and 10 records are for chemistries; however, there is no certainty that the groundwater is from the Lea Park Aquitard.

There are 117 records for bedrock water wells that have apparent yield values. In the Smoky Lake Region, water well yields can be expected to be mainly less than 100 m³/day in the Upper Bedrock Aquifer(s). The areas of higher yields are mainly south of township 061, W4M. These higher yields may be a result of increased permeability that has resulted from the weathering process. The higher yields in township 060, ranges 12 and 13, W4M, indicated on the adjacent figure, are mainly suspect. This area in the east-central part of the Region is one where the Lea Park is the upper bedrock and water well yields would be expected to be less than 10 m^3/day.

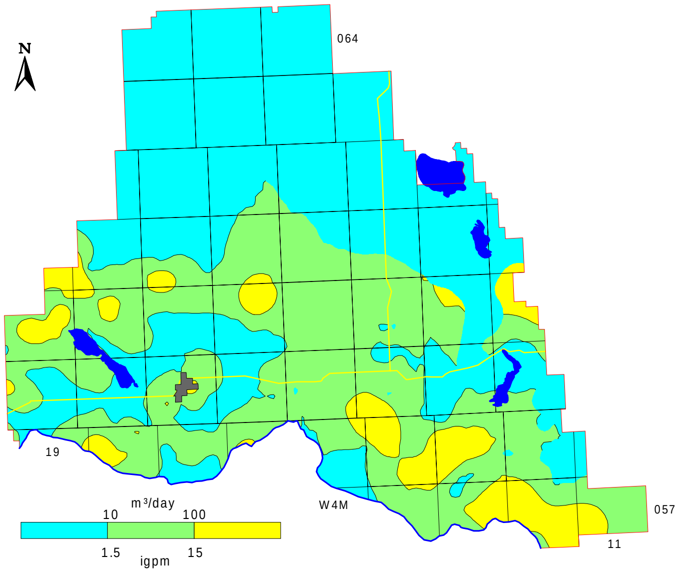

Figure 17. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 114 apparent yield values that can be assigned to a specific bedrock aquifer. The number of water wells with apparent yields that are completed in the *marine* Foremost Aquifer also include the values that are included in the Milan Aquifer. The majority of the water wells completed in bedrock aquifers have apparent yields that are less than 100 m³/day, as shown in the adjacent table.

		Number of Water Wells with Apparent Yields		
Aquifer	No. of Water Wells with Apparent Yields	<10 m³/day	10 to 100 m³/day	>100 m³/day
Oldman	0	#N/A	#N/A	#N/A
continental Foremost	59	31	18	10
marine Foremost	55	11	22	22
Totals	114	42	40	32

Table 3. Apparent Yields of Bedrock Aquifers

5.3.3 Chemical Quality of Groundwater

The TDS concentrations in the groundwater from the upper bedrock aquifer(s) range from less than 500 to more than 2,000 mg/L. In approximately 40% of the Region, TDS values are less than 1,000 mg/L. However, there are very few areas where the TDS values are less than 500 mg/L. The lower TDS groundwaters occur in a 20-kilometre northwest-southeast trending band starting in township 061, range 19, W4M.

A relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifer(s) exceed 1,300 mg/L, the sulfate concentration exceeds 400 mg/L.

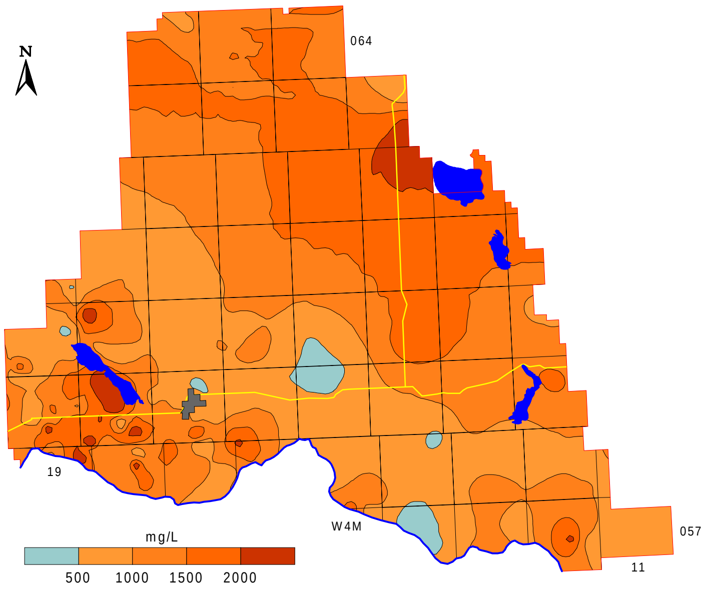

Figure 18. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The Piper tri-linear diagrams show that all chemical types of groundwater occur in the upper bedrock aquifer(s). However, the majority of the groundwaters are a sodium-bicarbonate type.

Fluoride concentrations in the groundwater from the upper bedrock aquifer(s) are mainly less than 1.0 mg/L.

5.3.4 *Continental* Foremost Aquifer

The *continental* Foremost Aquifer is the porous and permeable parts of the *continental* Foremost Formation which subcrops under the southwestern part of the Region. The thickness of the *continental* Foremost Formation increases to the southwest and can reach more than 100 metres in the southwestern part of the Region. In general terms, the permeability of the *continental* Foremost Aquifer is very low. Higher local permeability can be expected when the depth of burial is less than 100 metres and fracturing or weathering has occurred.

5.3.4.1 Depth to Top

The depth to the top of the *continental* Foremost Formation is variable, ranging from less than 20 to more than 60 metres. The largest area where the top of the *continental* Foremost Formation is more than 60 metres below ground level is along the northeastern edge of the Formation.

5.3.4.2 Apparent Yield

The projected long-term yields for water wells completed through the *continental* Foremost Aquifer are mainly between 10 and 100 m^3/day. The higher yields mainly occur in township 060, ranges 16 to 19, W4M. The impression is that the higher yields may be related to a west-east trending sandstone channel within the *continental* Foremost Formation. It is unlikely that this trend is a result of weathering. The other higher yield area may be related to geologic processes or weathering or fracturing.

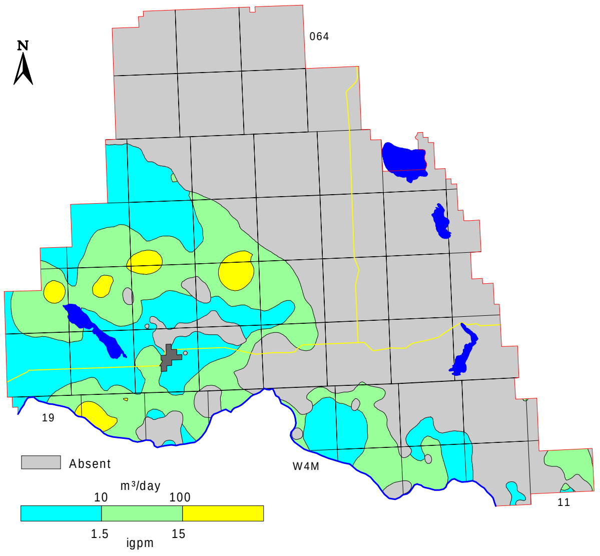

Figure 19. Apparent Yield for Water Wells Completed through continental Foremost Aquifer

5.3.4.3 Quality

The Piper tri-linear diagrams show that all chemical types of groundwater occur in the *continental* Foremost Aquifer. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

The TDS concentrations in the groundwater from the *continental* Foremost Aquifer range from less than 500 to more than 2,000 mg/L, but are mainly less than 1,000 mg/L. The higher values of TDS are mainly in the southwestern part of the Region, in township 058 and 059, ranges 18 and 19, W4M. The lower values of TDS occur in the southeastern part of the Region. When TDS values exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

Chloride concentrations in the groundwater from the *continental* Foremost Aquifer are mainly less than 100 mg/L. One exception is along the southwestern border of the Region. In this area, chloride concentrations can exceed 250 mg/L.

5.3.5 Milan Aquifer

The Milan Aquifer is used to designate the sandstone beds that occur near the western limit of the *marine* Foremost Formation. The sandstone beds are included as one aquifer because the individual sandstone members, which can be identified to the east and south of the Region, are not generally discernible within the Region. The Milan Aquifer includes up to 40 metres of the *marine* Foremost Formation and up to 10 metres of the overlying *continental* Foremost Formation. On the CD-ROM, the *marine* Foremost Aquifer and the Milan Aquifer are presented separately. However, for the most part the two aquifers are the same within the Smoky Lake Region.

5.3.5.1 Depth to Top

The depth to the top of the Milan Aquifer is a function of the depth to the stratigraphic border between the *continental* and *marine* facies of the Foremost Formation and the topographic surface. From the Figure 8 cross-section, it can be seen that the dip of the continental/marine interface of the Foremost Formation is much steeper than the general dip of the individual formations. The depth to the top of the Milan Aquifer ranges from less than 20 metres in the vicinity of the Town of Smoky Lake to more than 100 metres toward its western extent.

5.3.5.2 Apparent Yield

The projected long-term yields for individual water wells completed in the Milan Aquifer are mainly less than 100 m³/day. The higher yields tend to be in water wells located along the southern part of the Region in townships 057, 058 and 059. A follow-up study (Hydrogeological Consultants Ltd, 1993) to a study conducted by PFRA for the Village of Warspite (PFRA, 1991) indicated a long-term yield of in the order of 400 m³/day for a water supply well completed in the Milan Aquifer.

A study for the Town of Smoky Lake (Hydrogeological Consultants Ltd, 1975) indicated a long-term yield of 75 m³/day for a water well completed in the Milan Aquifer.

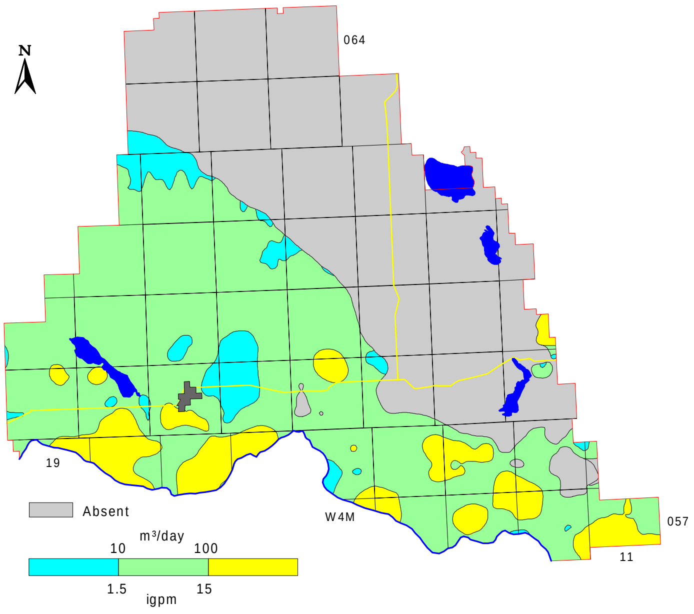

Figure 20. Apparent Yield for Water Wells Completed through Milan Aquifer

5.3.5.3 Quality

Groundwaters from the Milan Aquifer are mainly sodium-bicarbonate- or sodium-sulfate-type waters. The TDS concentrations in the groundwater are expected to be less than 1,000 mg/L east of range 18, and including the Town of Smoky Lake, and more than 1,000 mg/L west of range 17. At the Village of Warspite (Tp 059, R 18, W4M), three separate sandstone layers are included in the Milan Aquifer. Groundwaters from the upper two sandstone layers have TDS values of in the order of 850 mg/L, sulfate concentrations of between 250 and 300 mg/L and chloride concentrations of 10 mg/L (PFRA, 1991). The groundwater from the lower aquifer has a TDS value of 1,400 mg/L, a sulfate concentration of less than 30 mg/L and a chloride concentration of 365 mg/L (Hydrogeological Consultants Ltd., 1993).

Regionally, chloride concentrations of more than 250 mg/L can be expected in the groundwater from the Milan Aquifer over more than 15% of the Region. Chloride values of less than 10 mg/L can be expected in the vicinity of the Town of Smoky Lake and in the southeastern part of the Region.

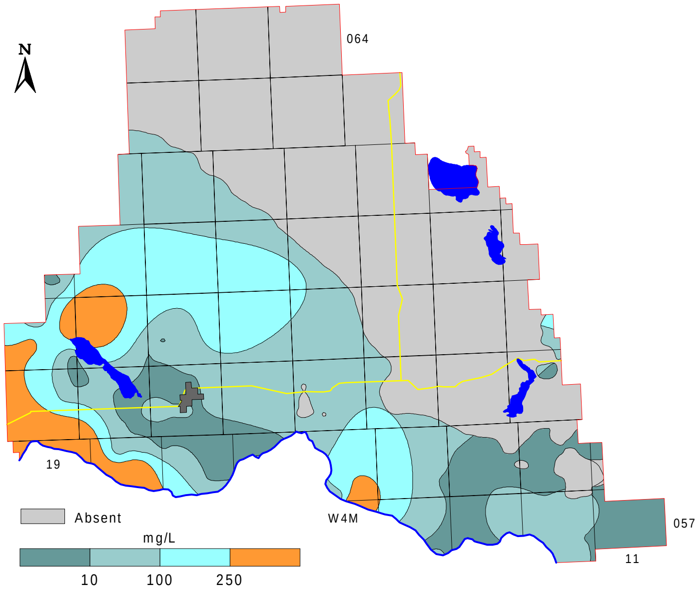

Figure 21. Chloride in Groundwater from Milan Aquifer

6 GROUNDWATER BUDGET

6.1 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are presently available. One indirect method of measuring recharge is to determine the quantity of groundwater flowing through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow 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 of the width for the aquifer. For the present program, the flow has been estimated for those parts of the various aquifers within the Region. The aquifers include the surficial deposits as one hydraulic unit, the Buried Beverly Valley, the *continental* Foremost Aquifer, and the Milan Aquifer.

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

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Authorized Diversion (m^3/day)
Surficial Deposits	10	0.004	60	South	2400	185
Buried Beverly Valley	28	0.003	10	East	850	706
Continental Foremost	7	0.003	40	South	850	0
Milan Aquifer	9	0.003	40	South	1100	299

The flow through the Lower Sand and Gravel Aquifer associated with the Buried Beverly Valley is inconclusive. The value in the above table assumes that flow is along the length of the Aquifer. The water-level map indicates that flow in the Aquifer is westward from R 15 and eastward from R 14 in Tp 059, W4M. The Authorized Diversion refers to the amount of groundwater that can be diverted under licences issued by AEP.

A second method to establish recharge is to monitor water levels in an aquifer close to a groundwater diversion point. Some data are available from the Town of Smoky Lake water supply wells completed in the Upper Sand and Gravel Aquifer. Between 1984 and 1996, there has been groundwater production of up to 299,000 cubic metres per year (820 m^3/day) from the Upper Sand and Gravel Aquifer with no adverse effect on the water level in the Aquifer. Therefore, it can be concluded that recharge to the aquifer is offsetting the present diversion. A detailed analysis would be required to understand the nature of the recharge.

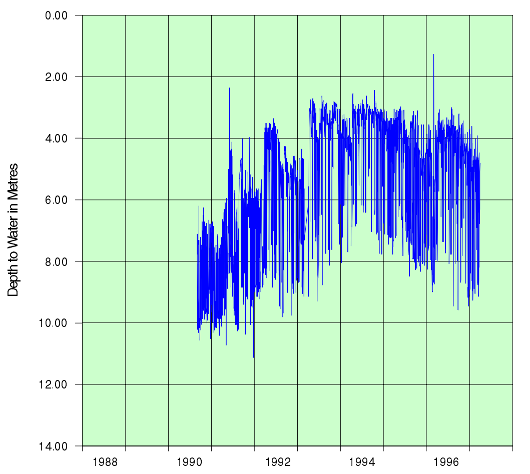

Figure 22. Water-Level Summary – Upper Sand and Gravel Aquifer

6.1.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 1 to 6 cubic kilometres. This volume is based on an areal extent of 4,000 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).

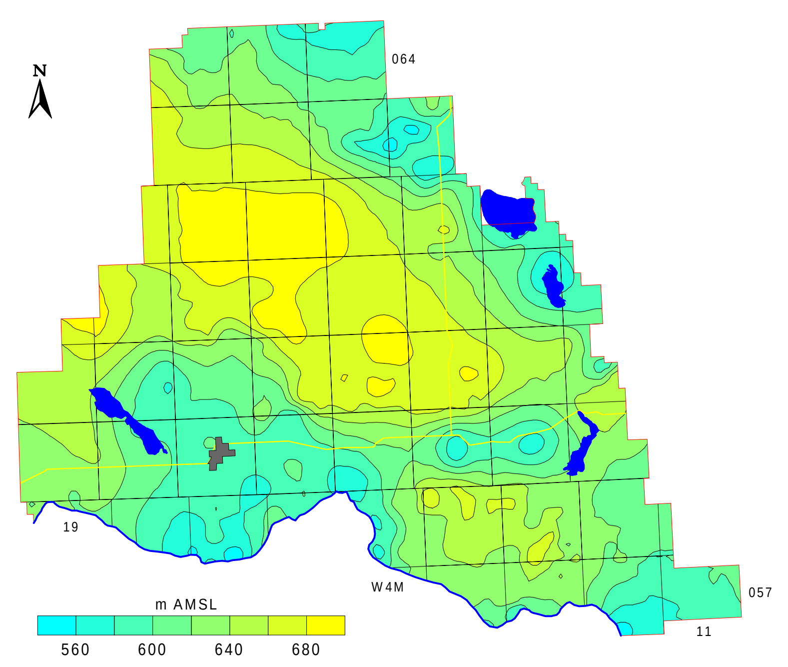

Figure 23. Non-Pumping Water-Level Surface in Surficial Deposits

The adjacent water-level map has been prepared by considering all water wells completed in aquifers in the surficial deposits, except in the vicinity of the buried valleys. In the vicinity of the Buried Beverly and Kikino valleys, only the water levels from water wells completed in the deeper sand and gravel deposits have been included.

6.1.2 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.

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

6.1.2.1 Surficial Deposits/Bedrock Aquifers

The hydraulic gradient between the surficial deposits and the bedrock aquifers has been determined by subtracting the non-pumping water-level surface for all water wells in the surficial deposits from the non-pumping water-level surface associated with all water wells completed in bedrock aquifers. The recharge classification on the adjacent map 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. 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.

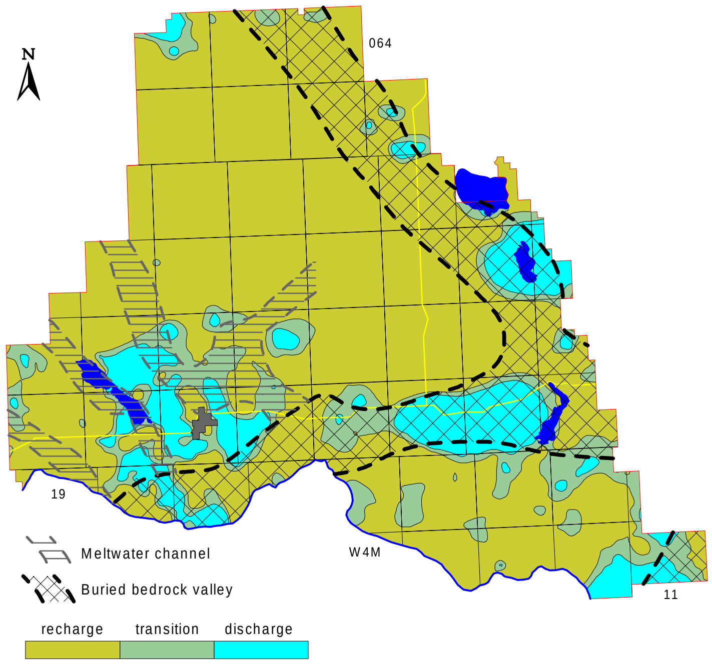

Figure 24. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

The map above shows that in more than 80% of the Region there is a downward hydraulic gradient between the surficial deposits and the upper bedrock aquifers. Areas where there is an upward hydraulic gradient, discharge from the bedrock, are mainly associated with lows in the bedrock surface. The remaining parts of the Region are areas where there is a transition condition.

Because of the paucity of data, a meaningful calculation of the volumes of groundwater entering and leaving the surficial deposits is not possible.

6.2 Bedrock Aquifers

Recharge to the bedrock aquifers within the Region takes place from the overlying surficial deposits and from flow in the aquifer from outside the Region. The recharge/discharge maps show that generally for most of the Region, there is a downward hydraulic gradient from the surficial deposits to the bedrock. If the flow of 2,000 m^3/day through the two main bedrock aquifers is maintained by recharge from the surficial deposits, and since the two main aquifers occupy an area of 2,000 square kilometres, the average recharge to the bedrock aquifers would need to be 1 m^3 per square kilometre per year. This quantity of water would be significantly less than 0.01% of the annual precipitation.

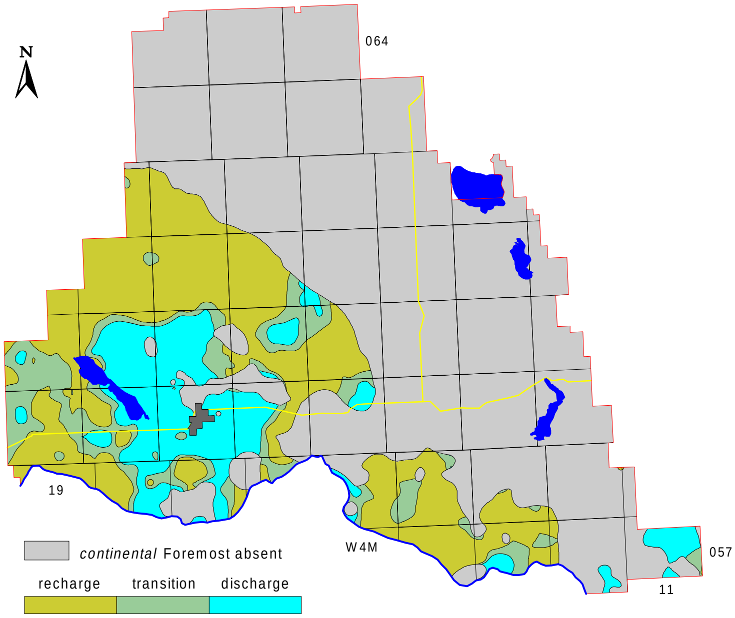

Figure 25. Recharge/Discharge Areas between Surficial Deposits and continental Foremost Aquifer

The hydraulic relationship between the surficial deposits and the *continental* Foremost Aquifer indicates that in 40% of the Region where the *continental* Foremost is present, there is an upward hydraulic gradient. This discharge area is mainly present in the area of bedrock lows. The presence of a discharge area at the eastern extent of a formation is not uncommon; this does not appear to be the situation for the *continental* Foremost Aquifer, probably as a result of the paucity of data.

The hydraulic relationship between the surficial deposits and the Milan Aquifer shows a similar situation to the *continental* Foremost Aquifer but of a lesser magnitude due to the paucity of data.

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 spreading of fertilizers, pesticides, herbicides and manure. The spreading of highway salt can also degrade groundwater quality.

When activities occur that do or can 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, then 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. When there are 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 2,190 records in the area of the Region with lithology descriptions, 472 have sand and gravel within one metre of ground level. In the remaining 1,718 records, the first sand and gravel is deeper or not present. This information was then gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.

7.1.1 Risk of Contamination Map

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

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

Table 4. Risk of Groundwater Contamination Criteria

The Risk of Groundwater Contamination map shows that, in less than 30% of the Region, there is a high or very high risk of the groundwater being contaminated. These areas would be considered the least desirable ones for development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that groundwater contamination would not affect groundwater quality.

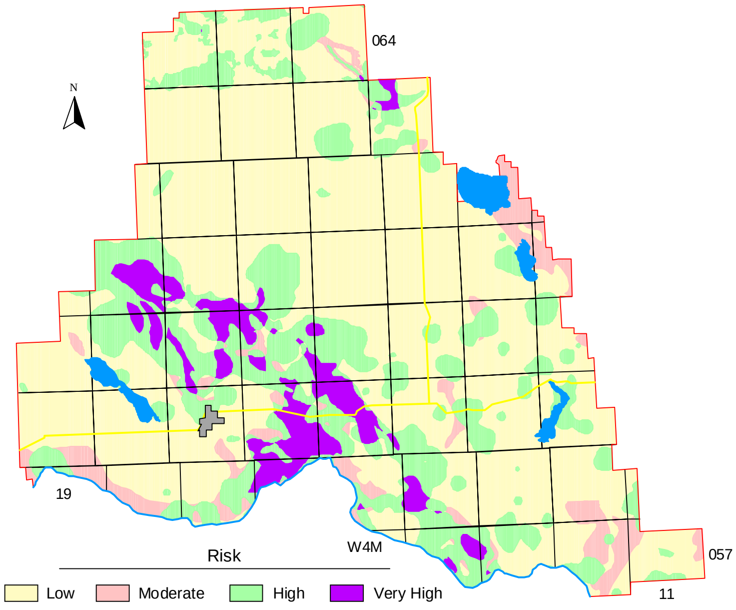

Figure 26. Risk of Groundwater Contamination

8 RECOMMENDATIONS

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

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

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

The results of the present study indicate that the only readily identifiable aquifer in the surficial deposits is the sand and gravel deposit associated with the linear bedrock lows and even these aquifers cannot be delineated with any degree of confidence due to the limited amount of data. In order to understand the relationship between the Buried Beverly and Kikino valleys, it is recommended that a test-drilling program or possibly a surface geophysical program be completed in the vicinity of the Village of Vilna (Tp 059, R 13, W4M). If water test holes are drilled, casing and screens should be installed to allow for the measuring of water levels. At the present time there are insufficient data to understand the directions of flow in the Lower Sand and Gravel Aquifer associated with the Buried Beverly Valley.

There are indications that significant aquifers may be present in the bedrock. These include the Milan Aquifer and sandstone channels in the *continental* Foremost Formation. However, detailed studies would need to be completed to map either of these aquifers in detail. A study of the Milan Aquifer could be attempted using the available water well drilling reports and the 3D Analyst program that works with ArcView. A study of the sandstone channels in the *continental* Foremost Formation could be attempted using geophysical logs from the oil industry.

The Milan Aquifer could be developed for domestic supplies in the southern part of the Region. It is recommended that a test-drilling program be completed to evaluate the significance of this Aquifer in the Smoky Lake Region where the depth to the base of the Milan Aquifer can be in the order of 150 metres.

Another area of concern is the determination of a groundwater budget. There are no observation water-well data to obtain water levels for the groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View, water well owners are being provided with a tax credit if they accurately measure the water level in their water well once per week for a year. A pilot project indicated that approximately five years of records are required to obtain a reasonable data set. The cost of a five-year project involving 50 water wells would be less than the cost of one drilling program that may provide two or three observation water wells.

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

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

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

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

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

An effort should be made to form a partnership with the petroleum industry. The industry spends millions of dollars each year collecting information relative to water wells. Proper coordination of this effort could provide significantly better information from which future regional interpretations could be made. This could be accomplished by the Region 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

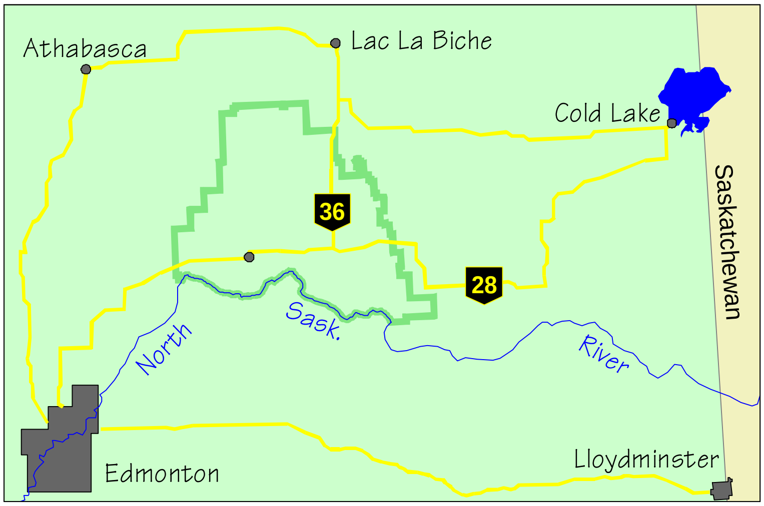
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities.
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer.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

SMOKY LAKE REGION

Appendix A

HYDROGEOLOGICAL MAPS AND FIGURES

Index Map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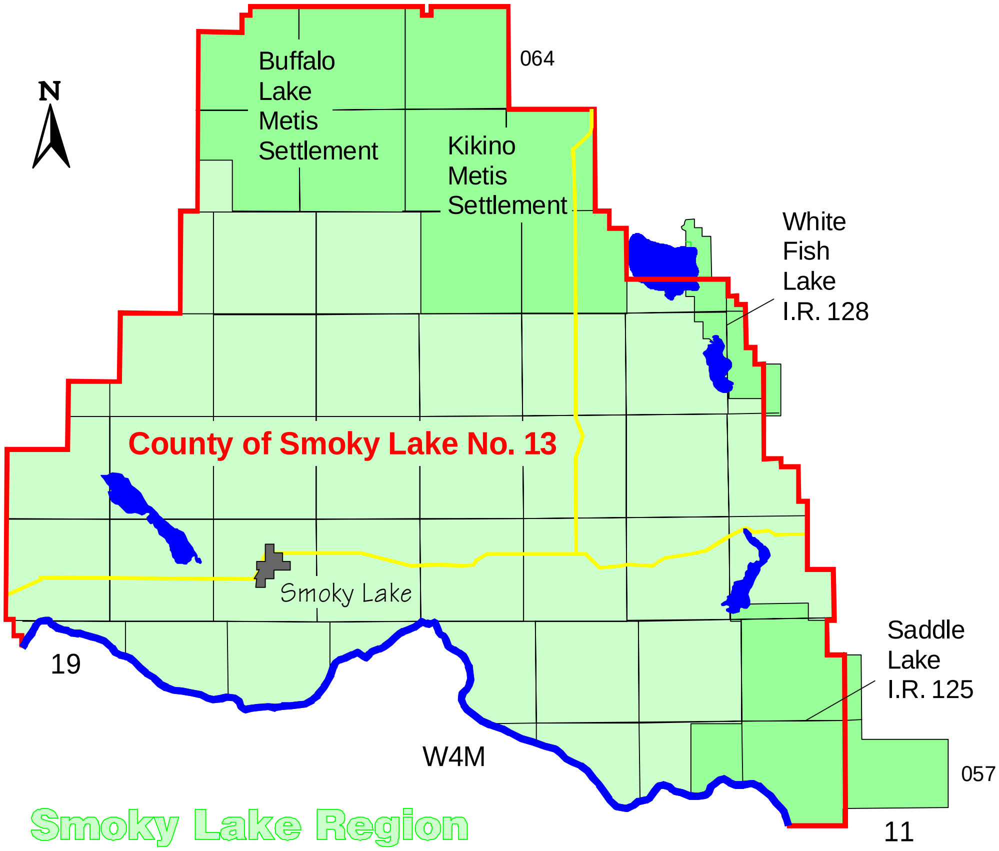
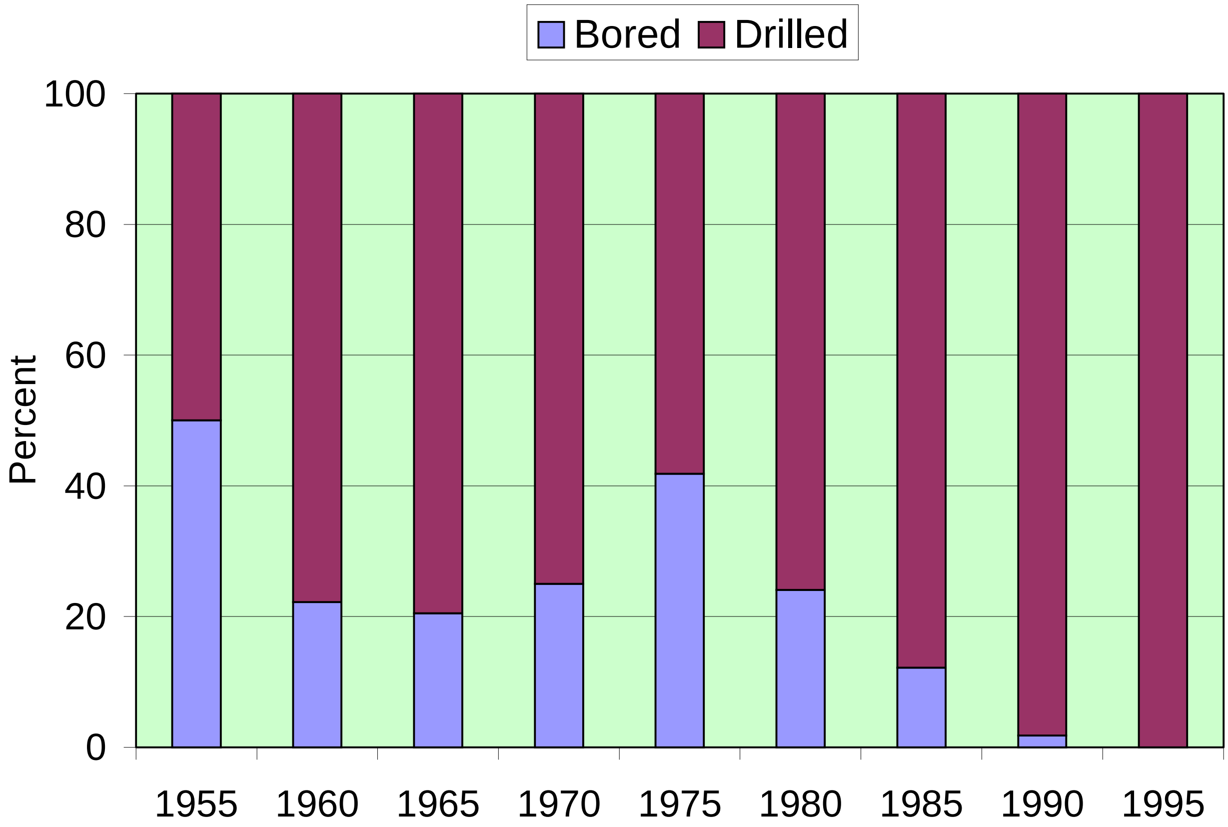
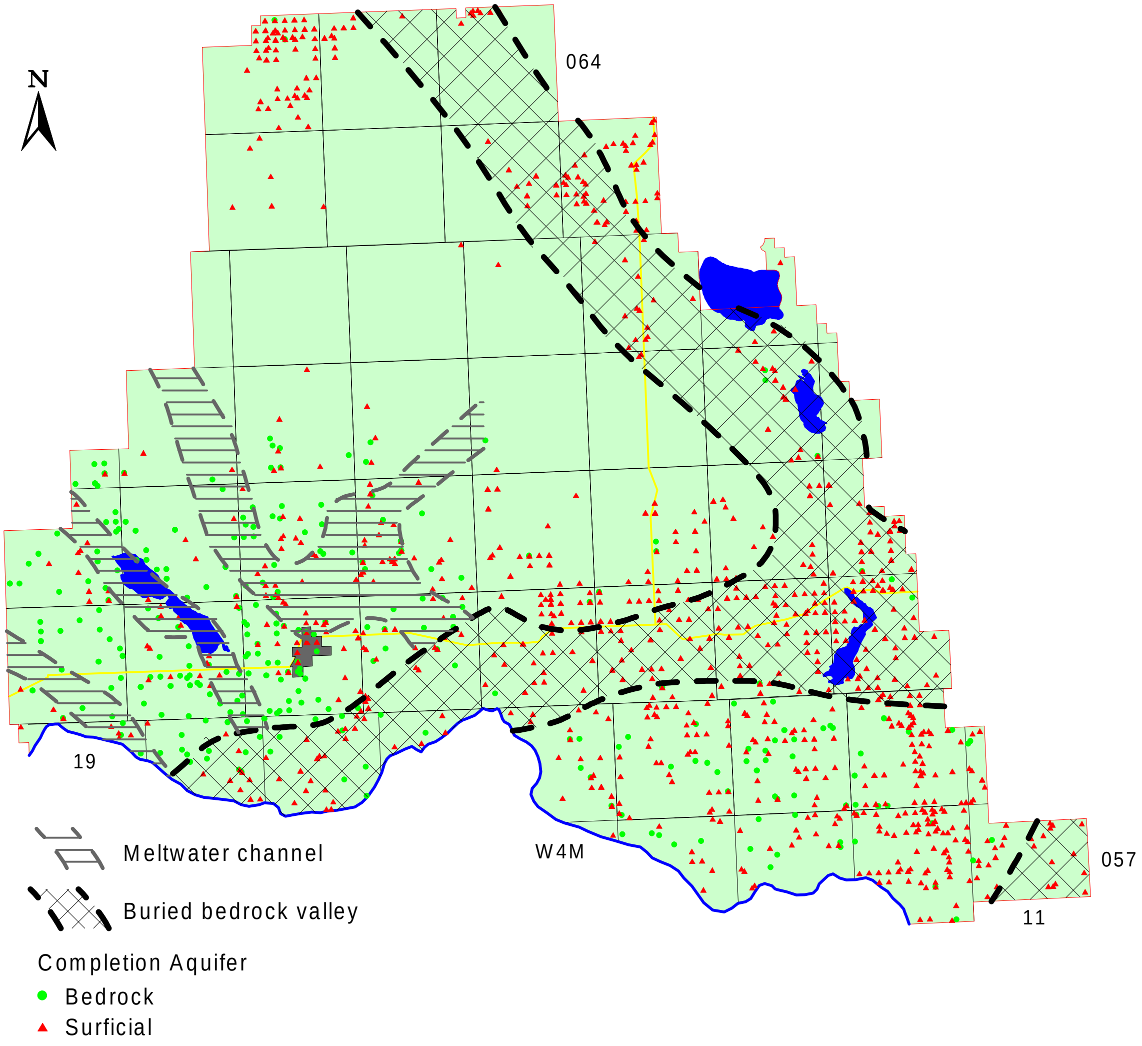
Lac La Biche
Cold Lake
Saskatchewan
36
28
North
Sask.
River
Edmonton
Lloydminster


N
Buffalo Lake Metis Settlement
Kikino Metis Settlement
064
White Fish Lake I.R. 128
County of Smoky Lake No. 13
Smoky Lake
19
W4M
Saddle Lake I.R. 125
057
11
Smoky Lake Region

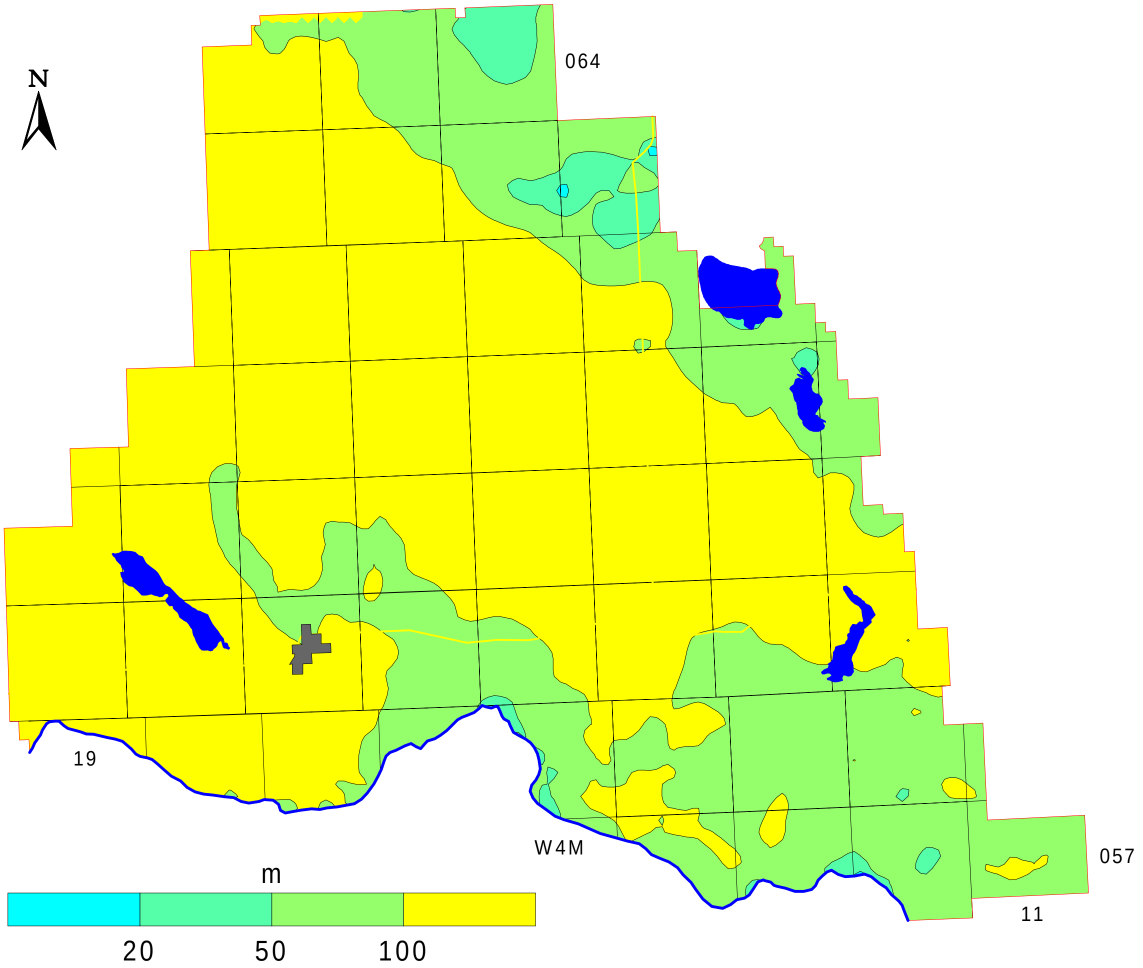
Surface Casing Types used in Drilled Water Wells

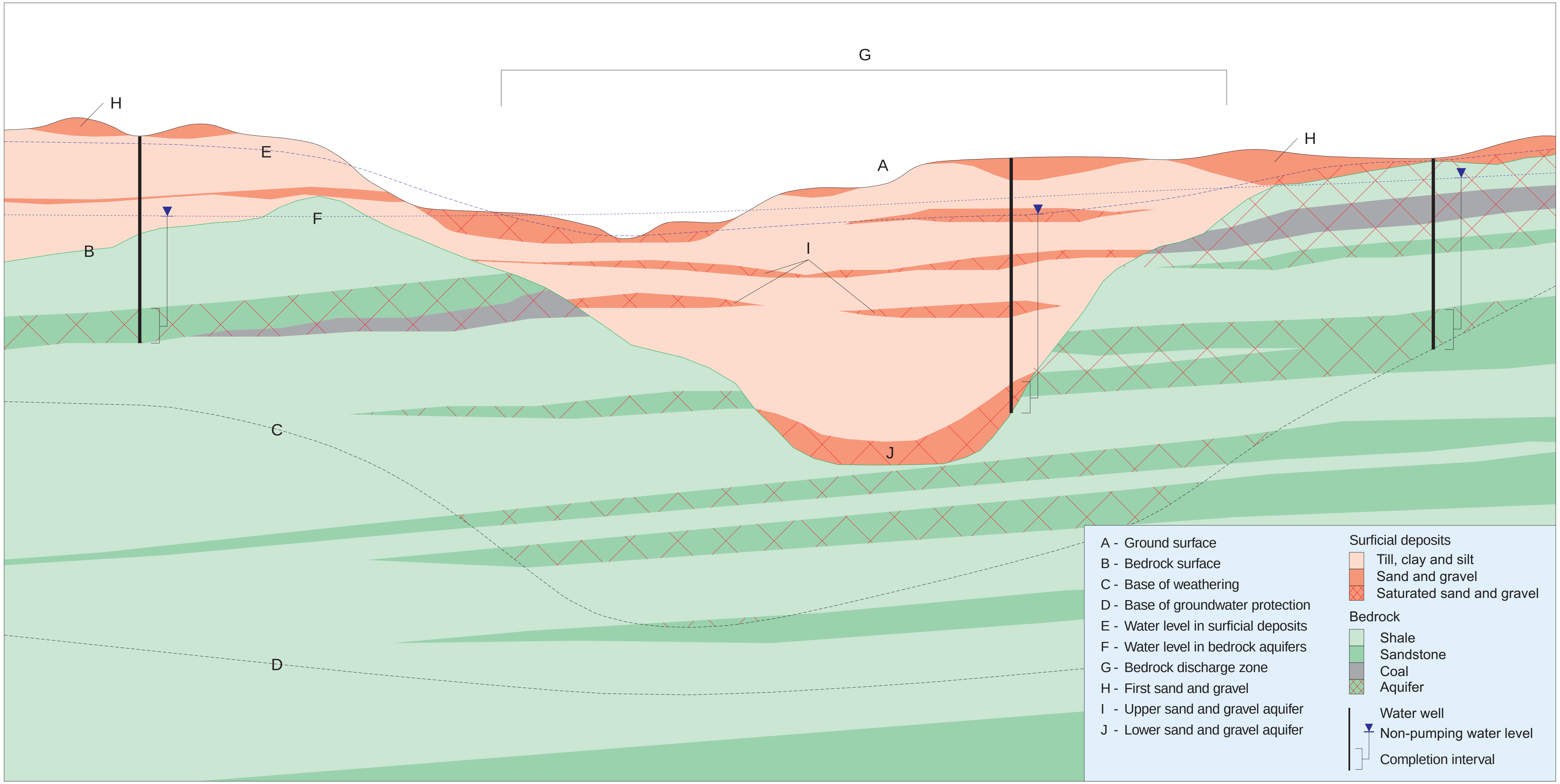


Location of Water Wells



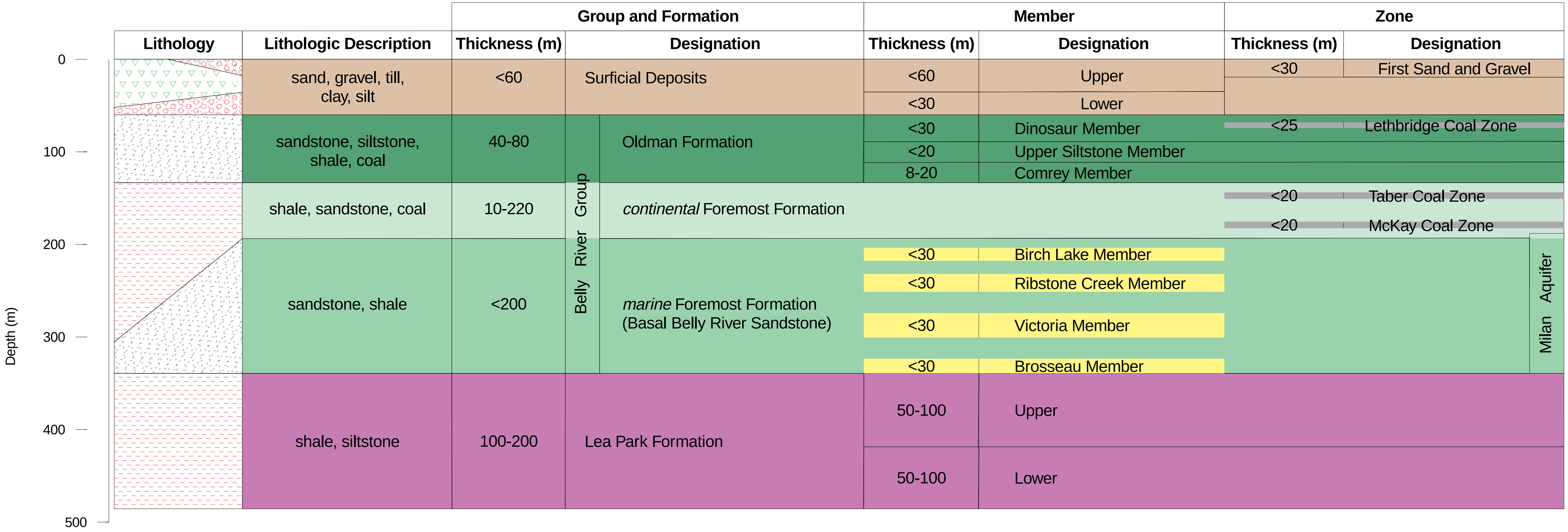
Depth to Base of Groundwater Protection





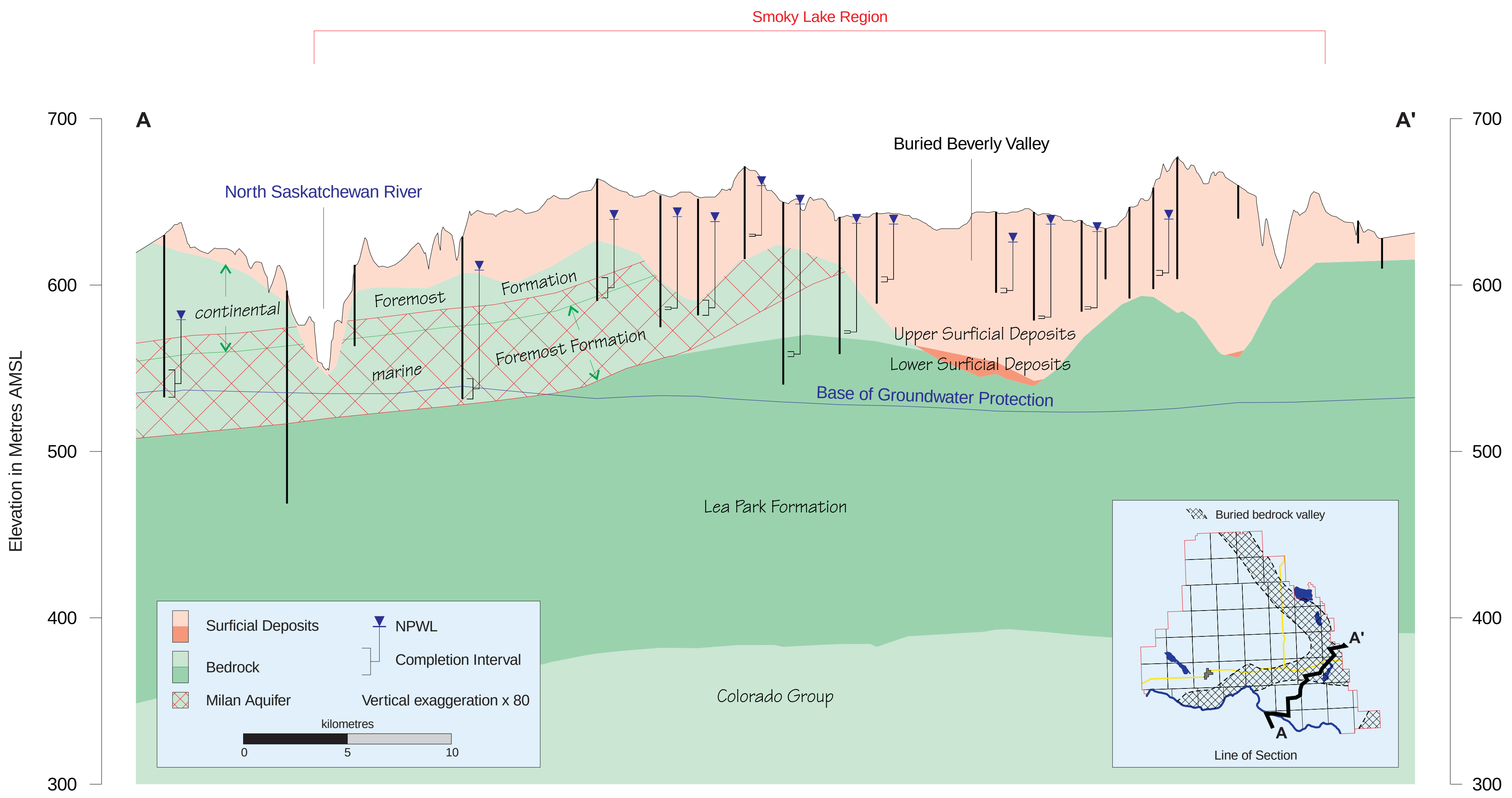
Generalized Cross-Section

(for terminology only)

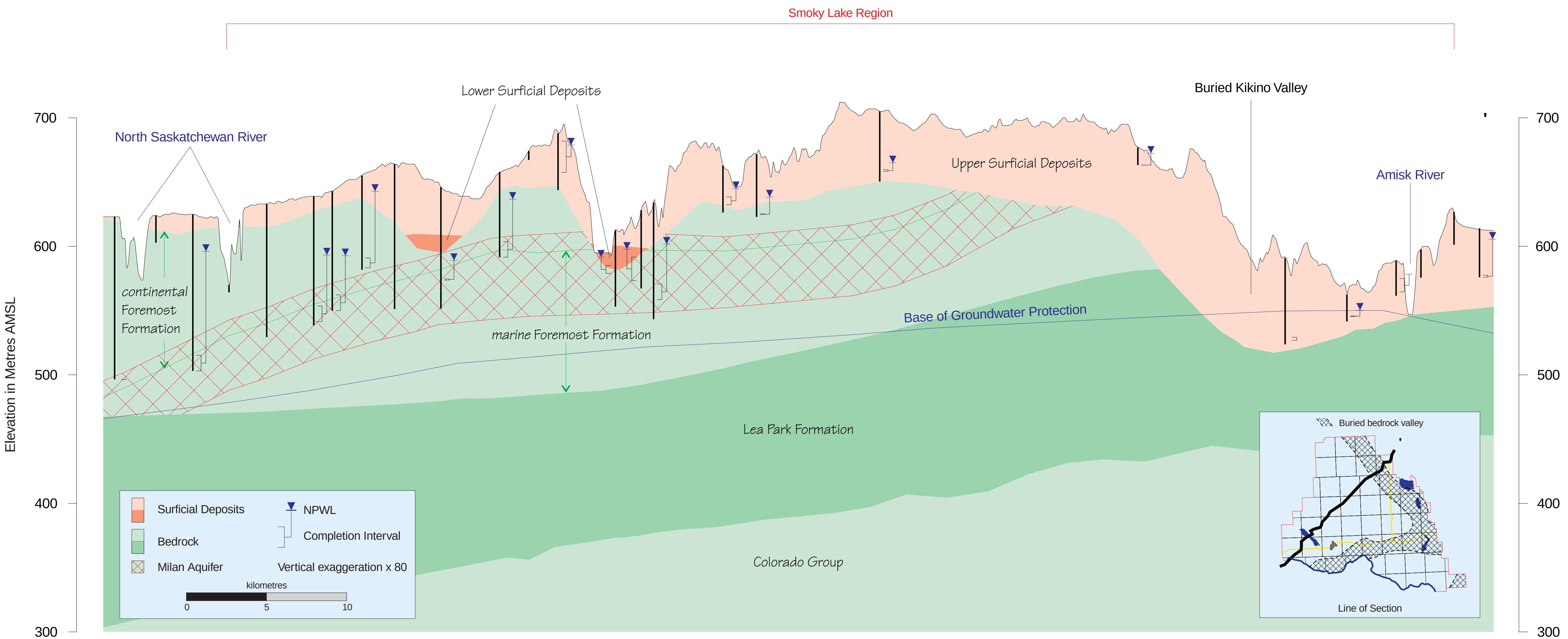


Lithology	Lithologic Description	Group and Formation Thickness (m)	Group and Formation Designation		Member Thickness (m)	Member Designation	Zone Thickness (m)	Zone Designation
	sand, gravel, till, clay, silt	<60	Surficial Deposits		<60	Upper	<30	First Sand and Gravel
					<30	Lower		
	sandstone, siltstone, shale, coal	40-80	Belly River Group	Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone
					<20	Upper Siltstone Member		
					8-20	Comrey Member		
	shale, sandstone, coal	10-220		*continental* Foremost Formation			<20	Taber Coal Zone
							<20	McKay Coal Zone
	sandstone, shale	<200		*marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		Milan Aquifer
					<30	Ribstone Creek Member		
					<30	Victoria Member		
					<30	Brosseau Member		
	shale, siltstone	100-200	Lea Park Formation		50-100	Upper		
					50-100	Lower		

Geologic Column

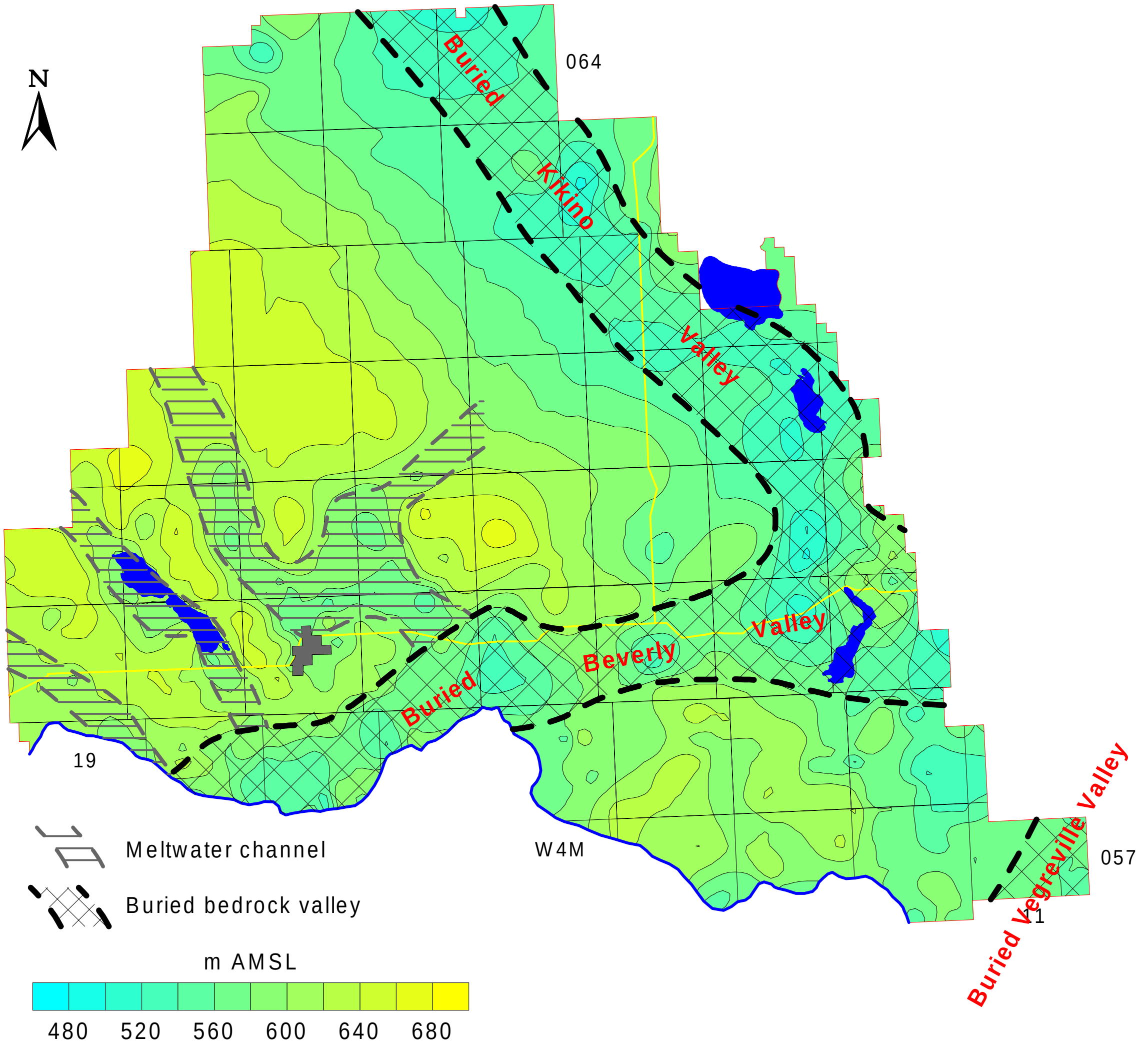


Cross-Section A - A'

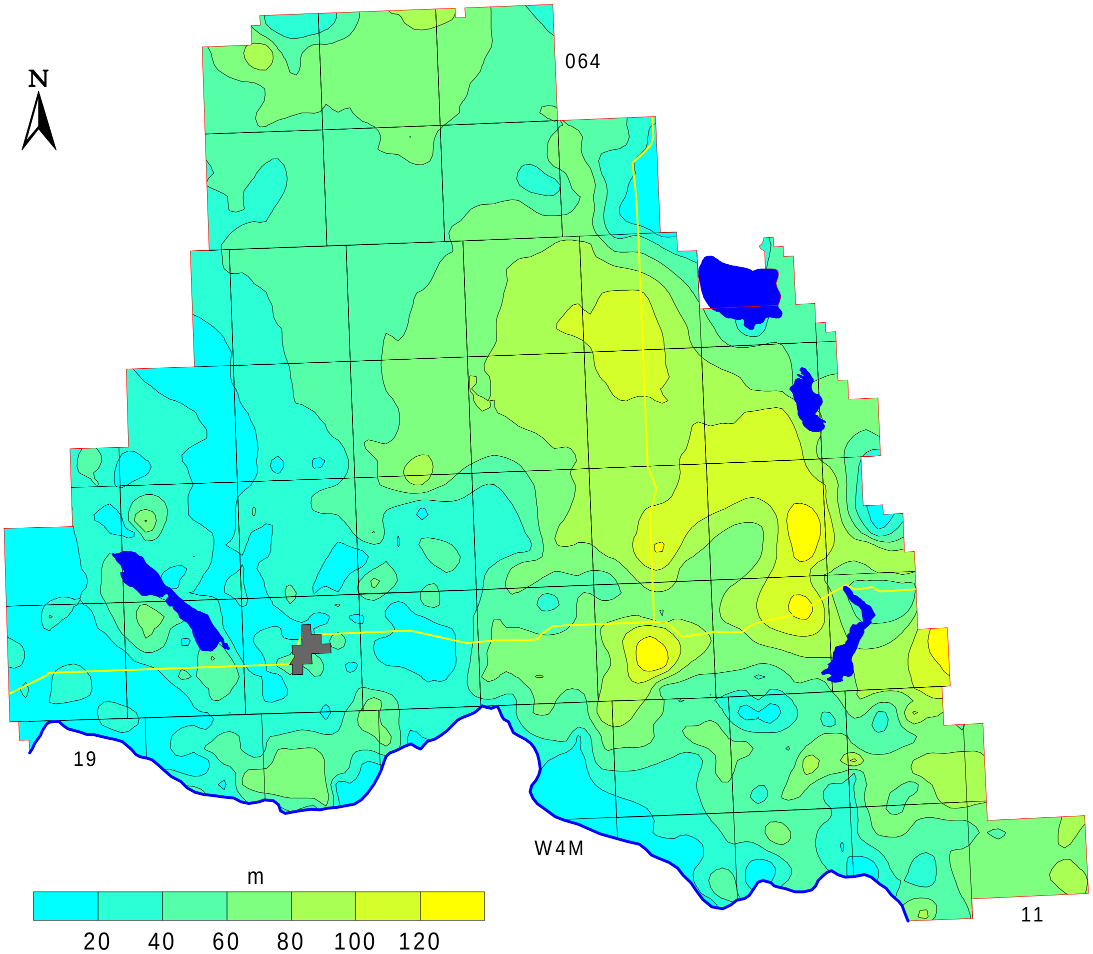


Cross-Section B - B'

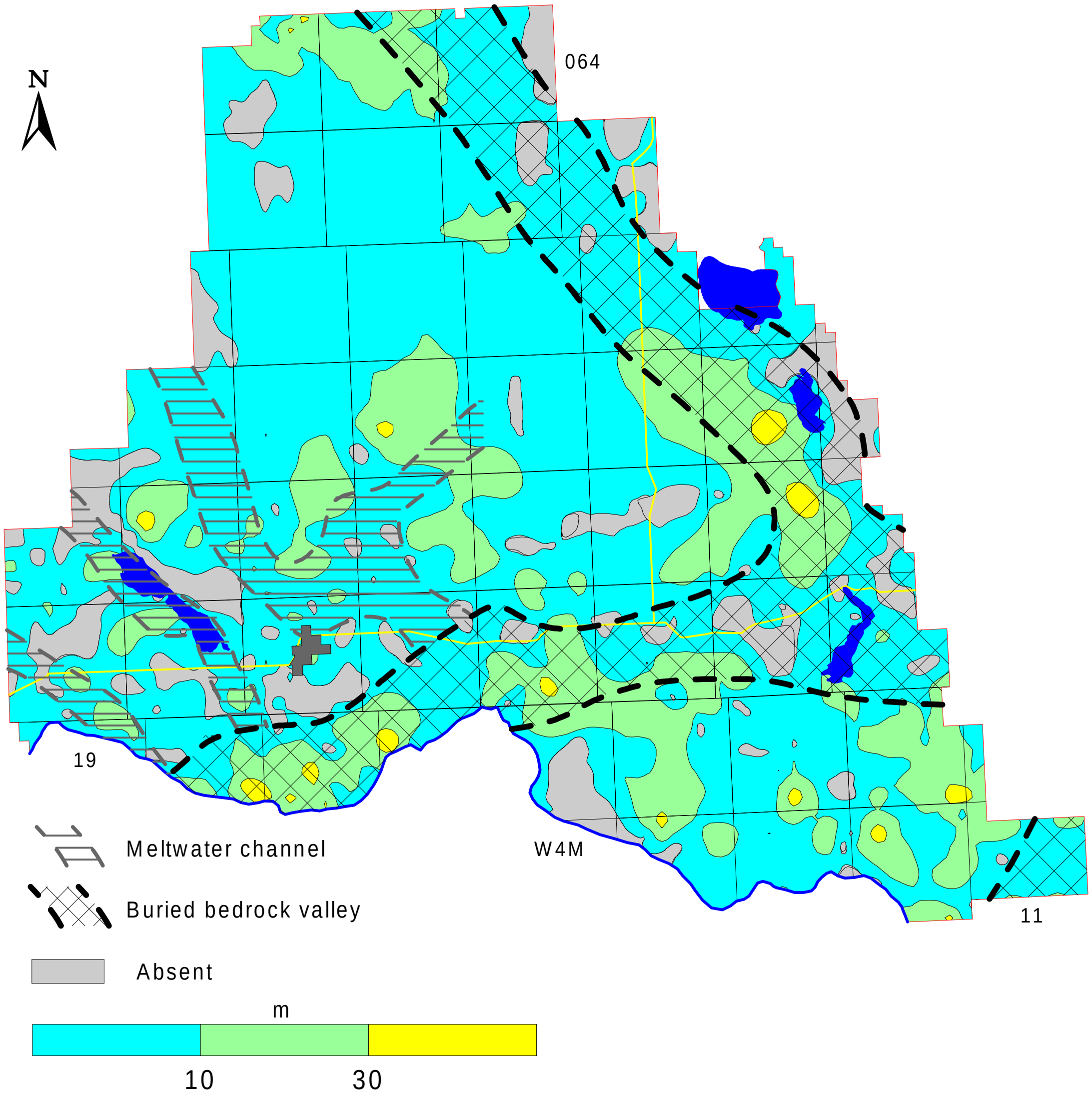
Bedrock Topography



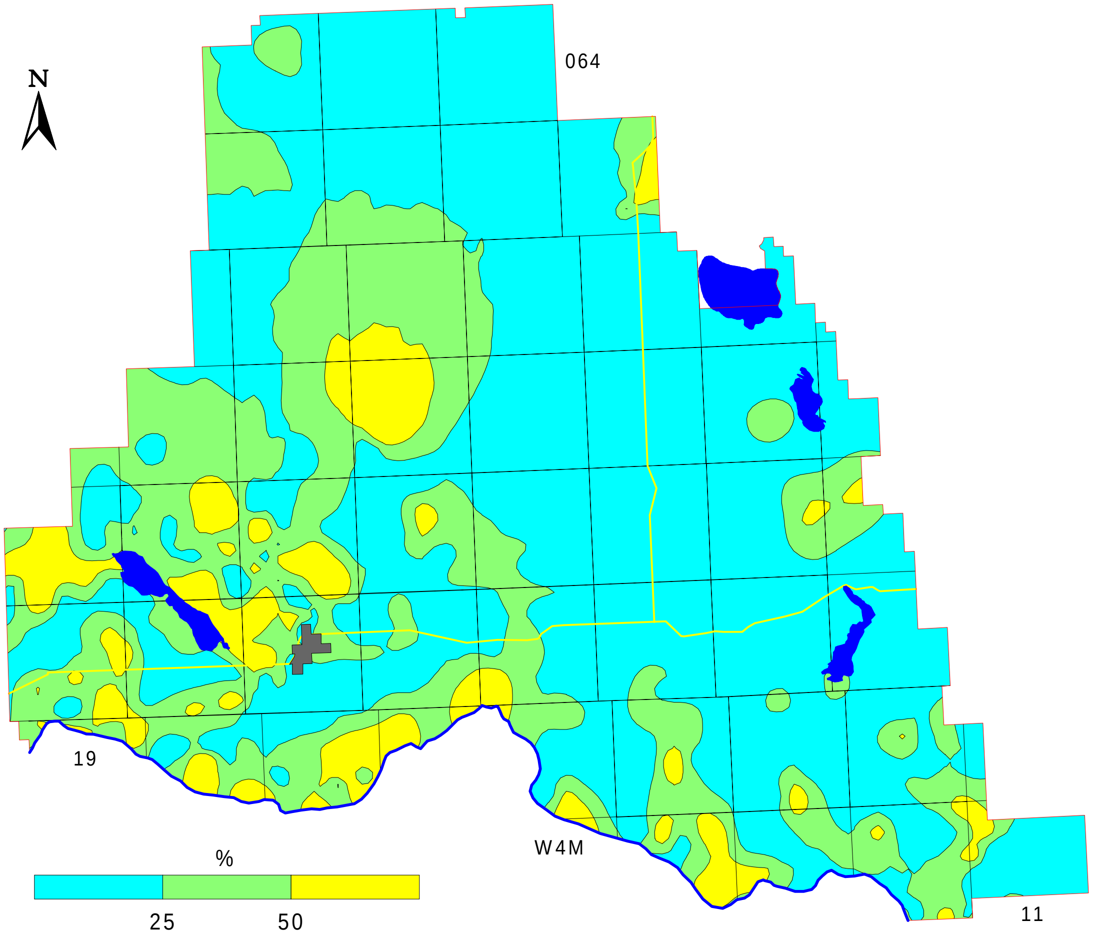
Thickness of Surficial Deposits



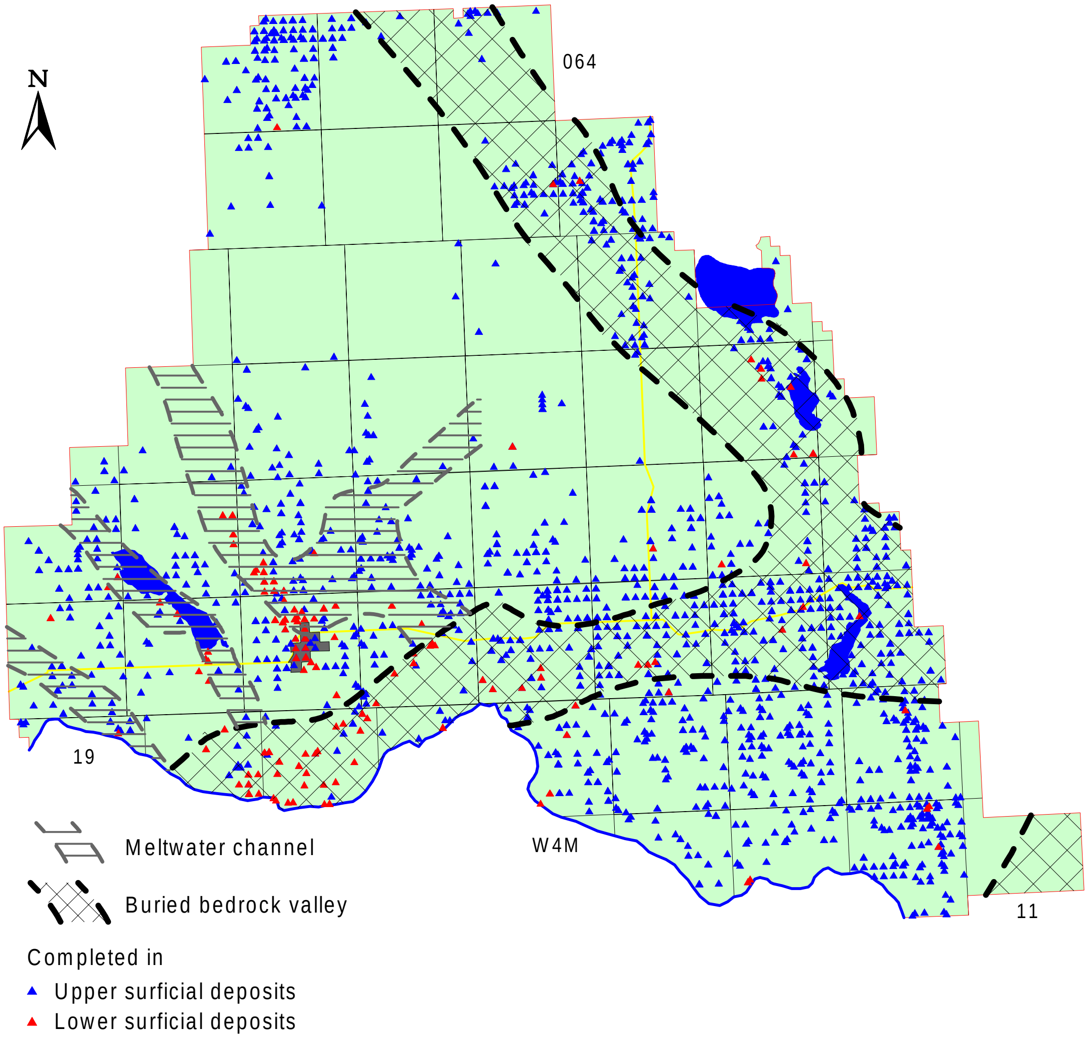
Thickness of Sand and Gravel Aquifer(s)



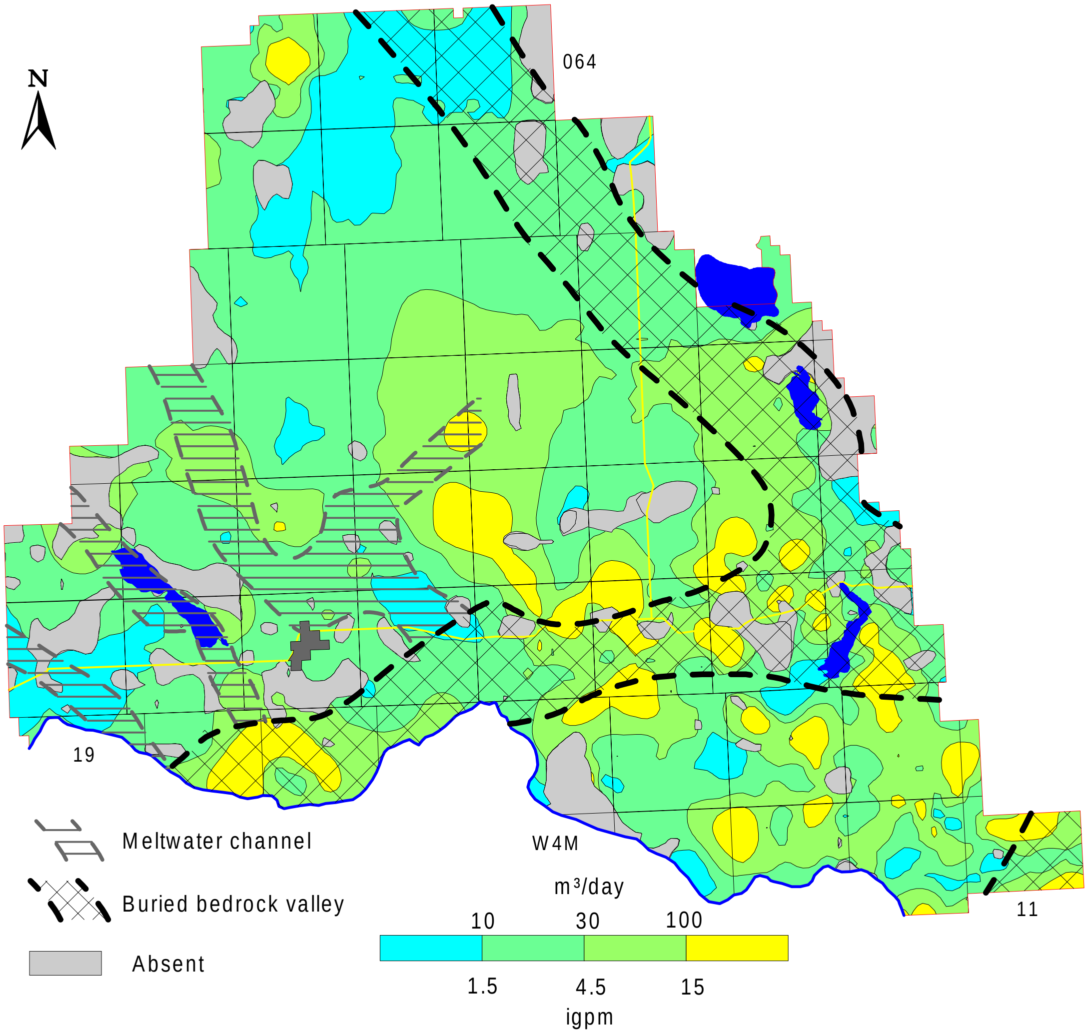
Amount of Sand and Gravel in Surficial Deposits



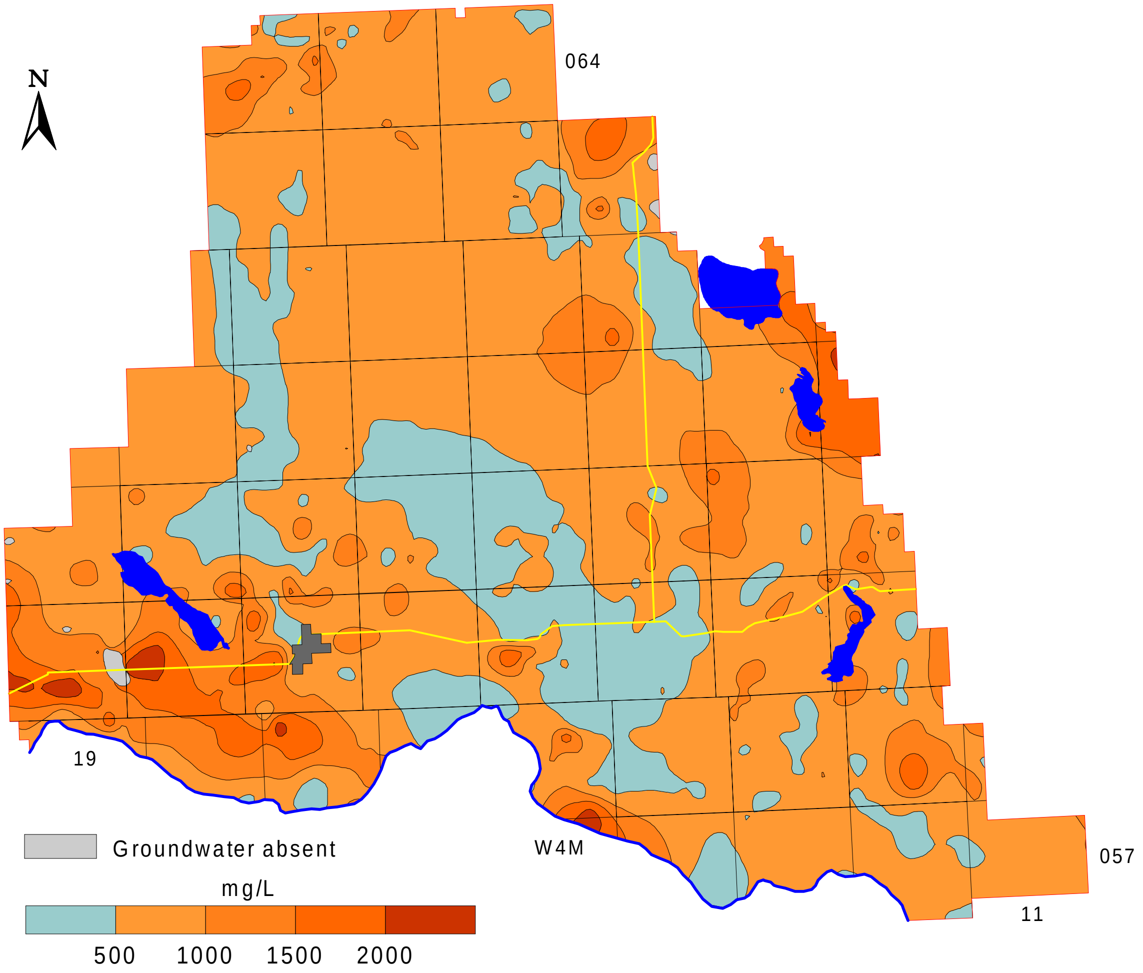
Water Wells Completed in Surficial Deposits



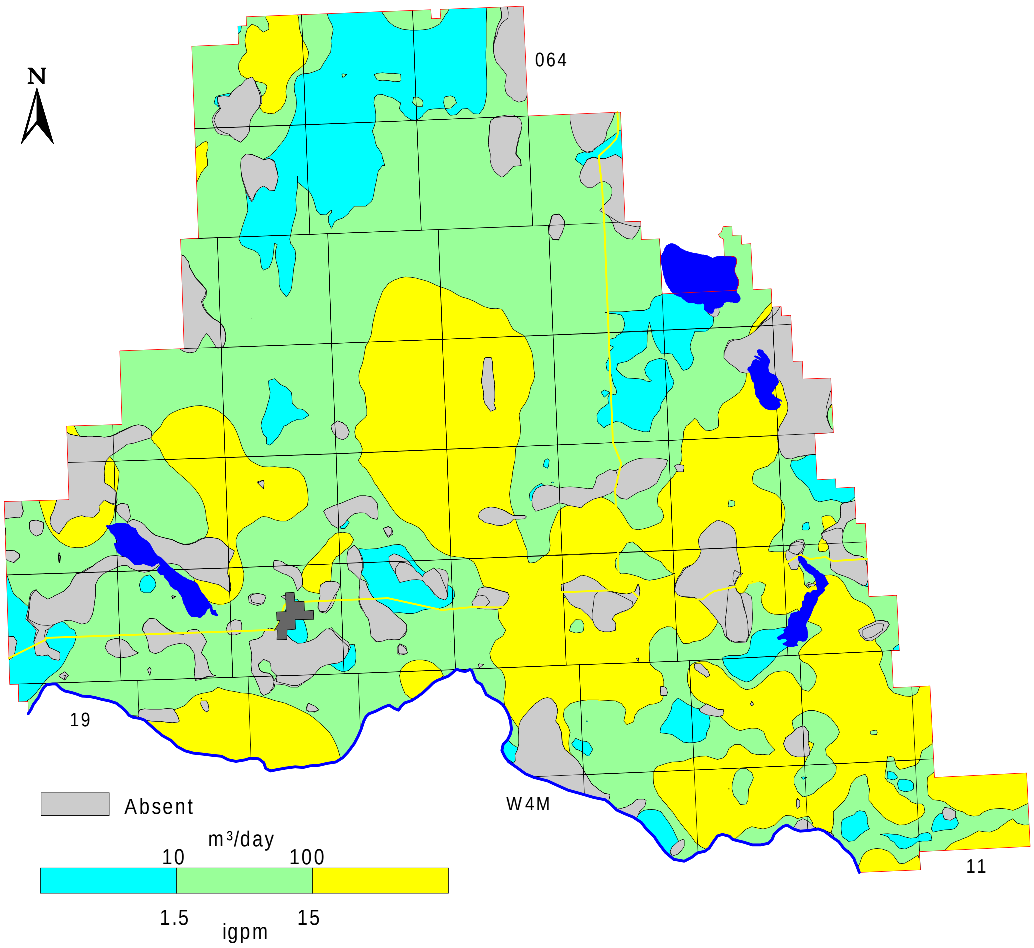
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



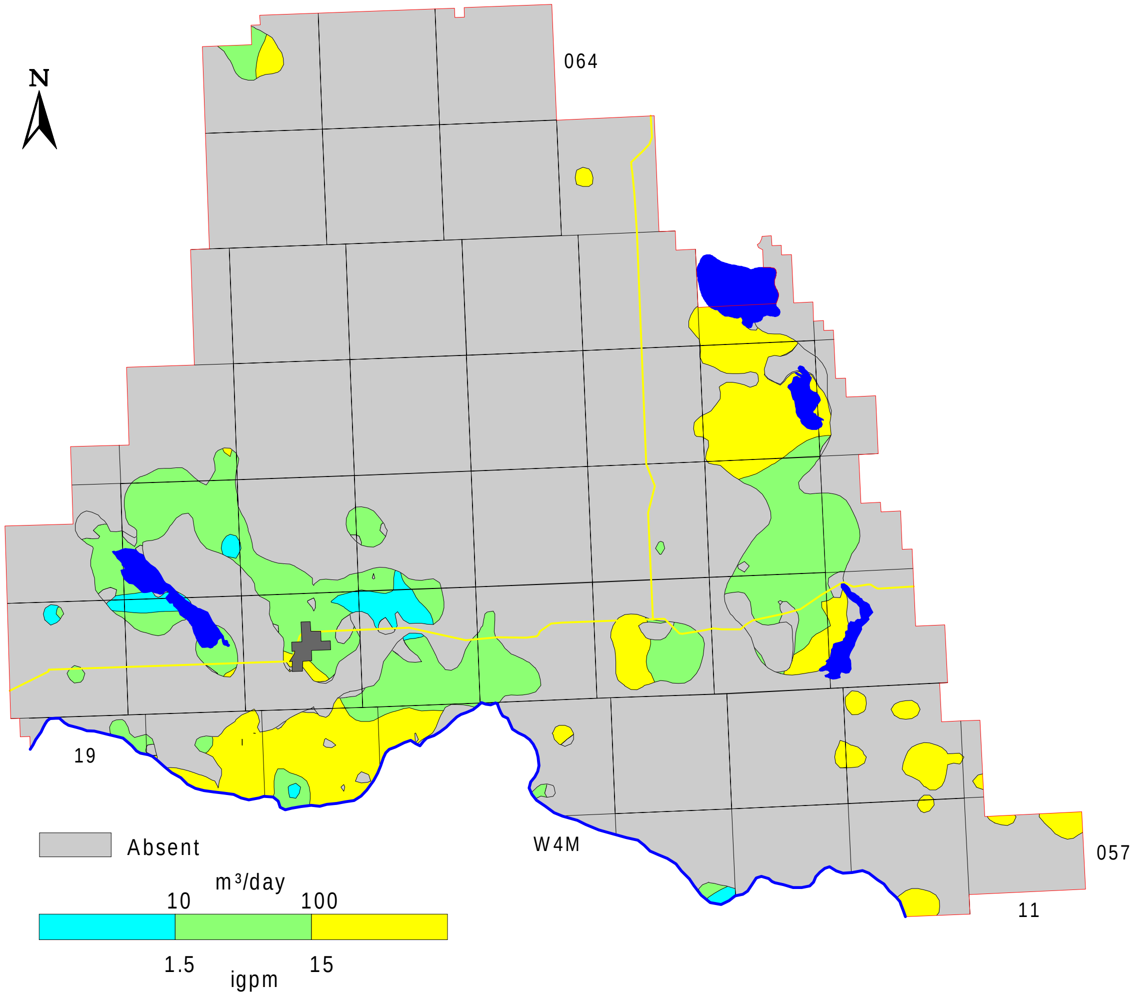
Total Dissolved Solids in Groundwater from Surficial Deposits



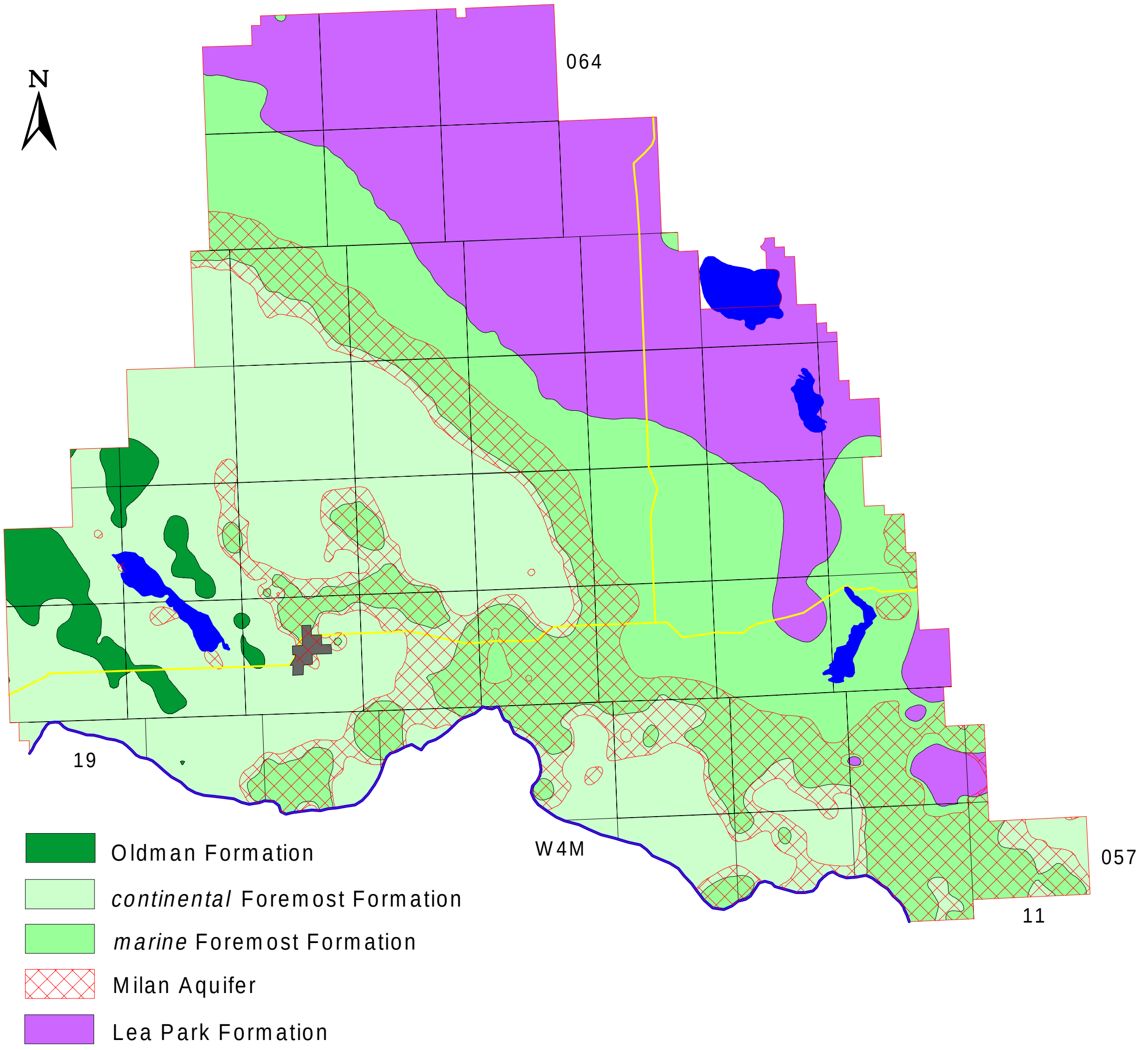
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



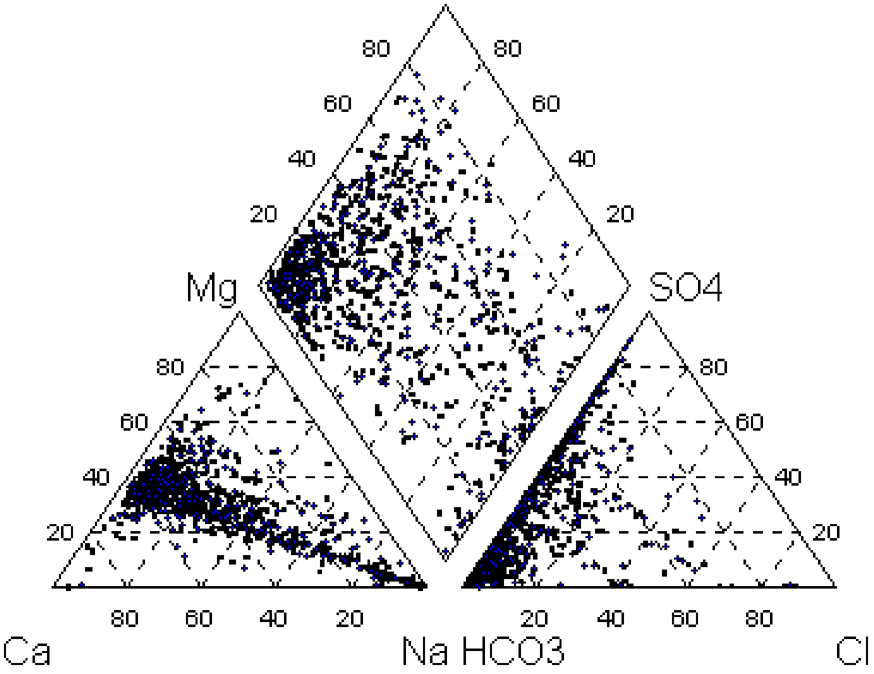
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



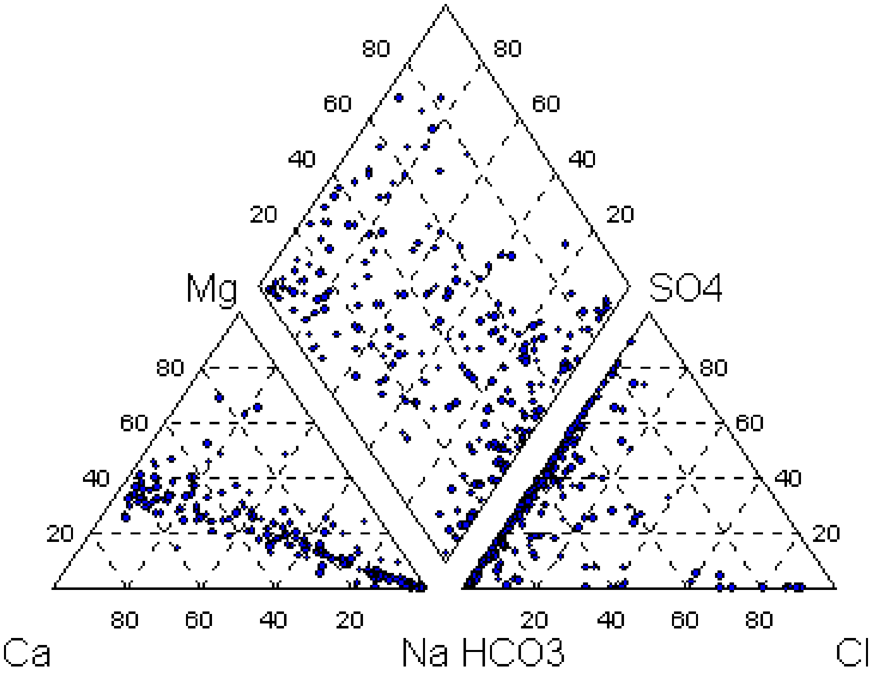
Bedrock Geology



Piper Diagrams

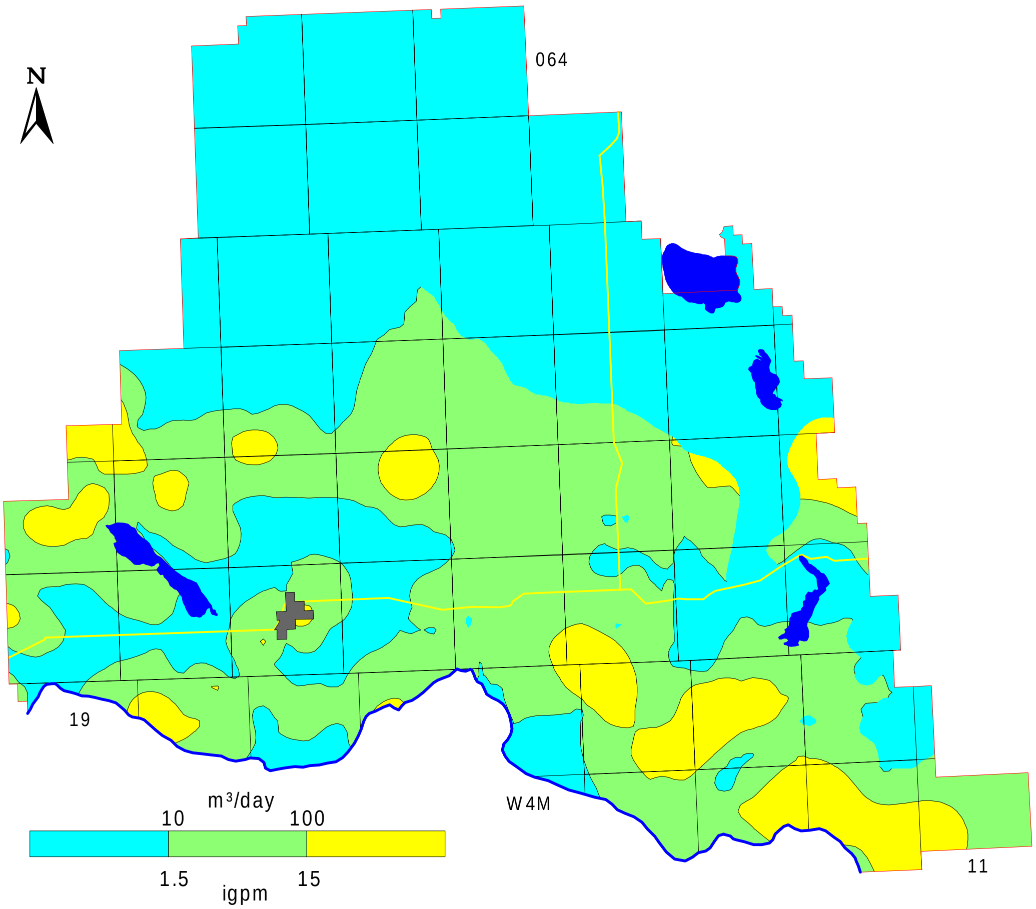


Surficial Deposits

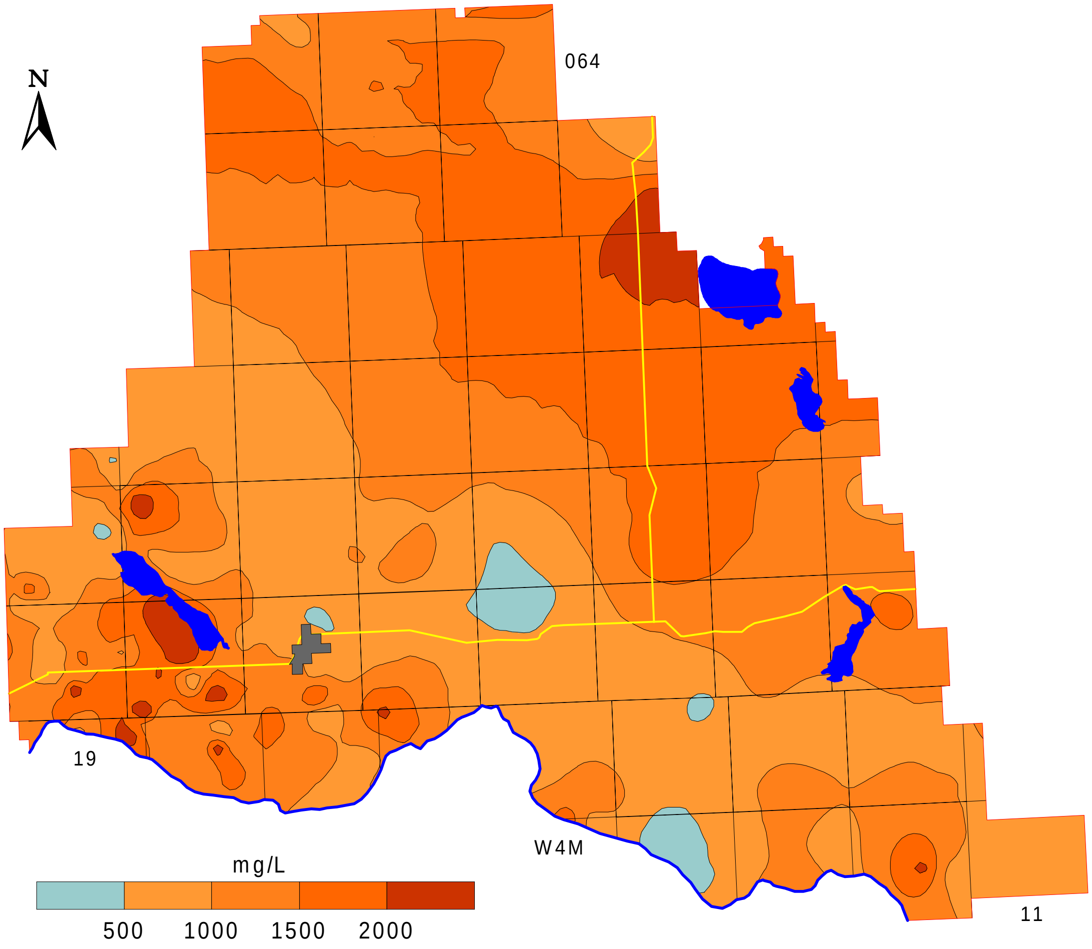


Bedrock Aquifers

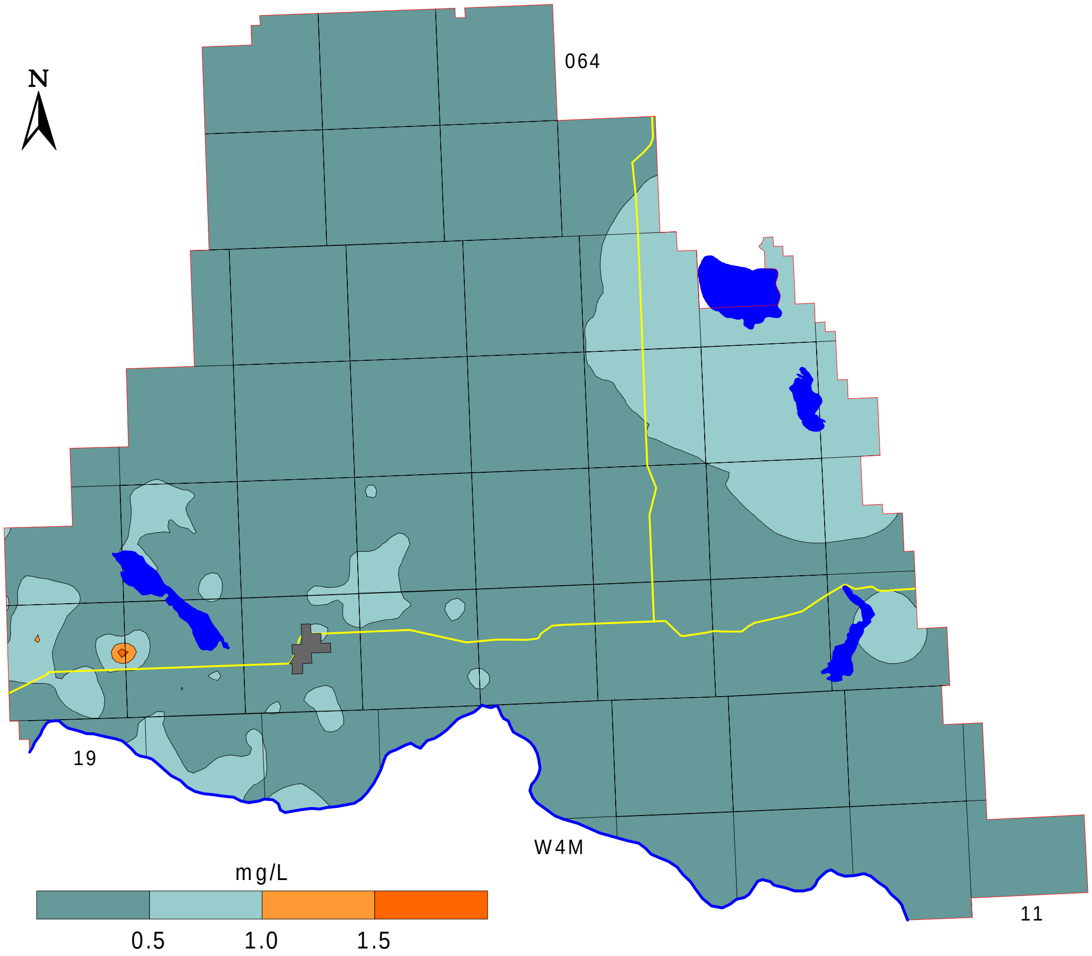
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



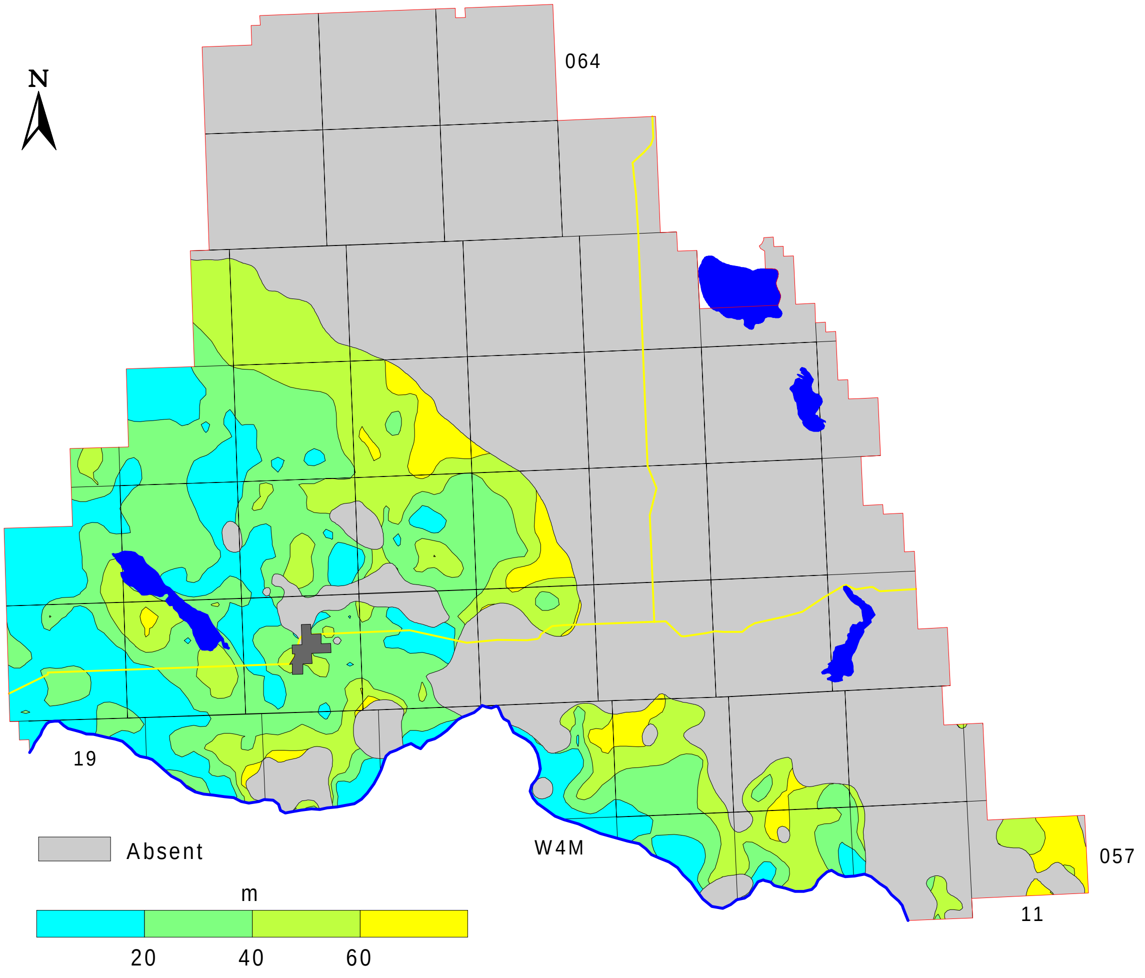
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



Fluoride in Groundwater from Upper Bedrock Aquifer(s)



Depth to Top of continental Foremost Formation



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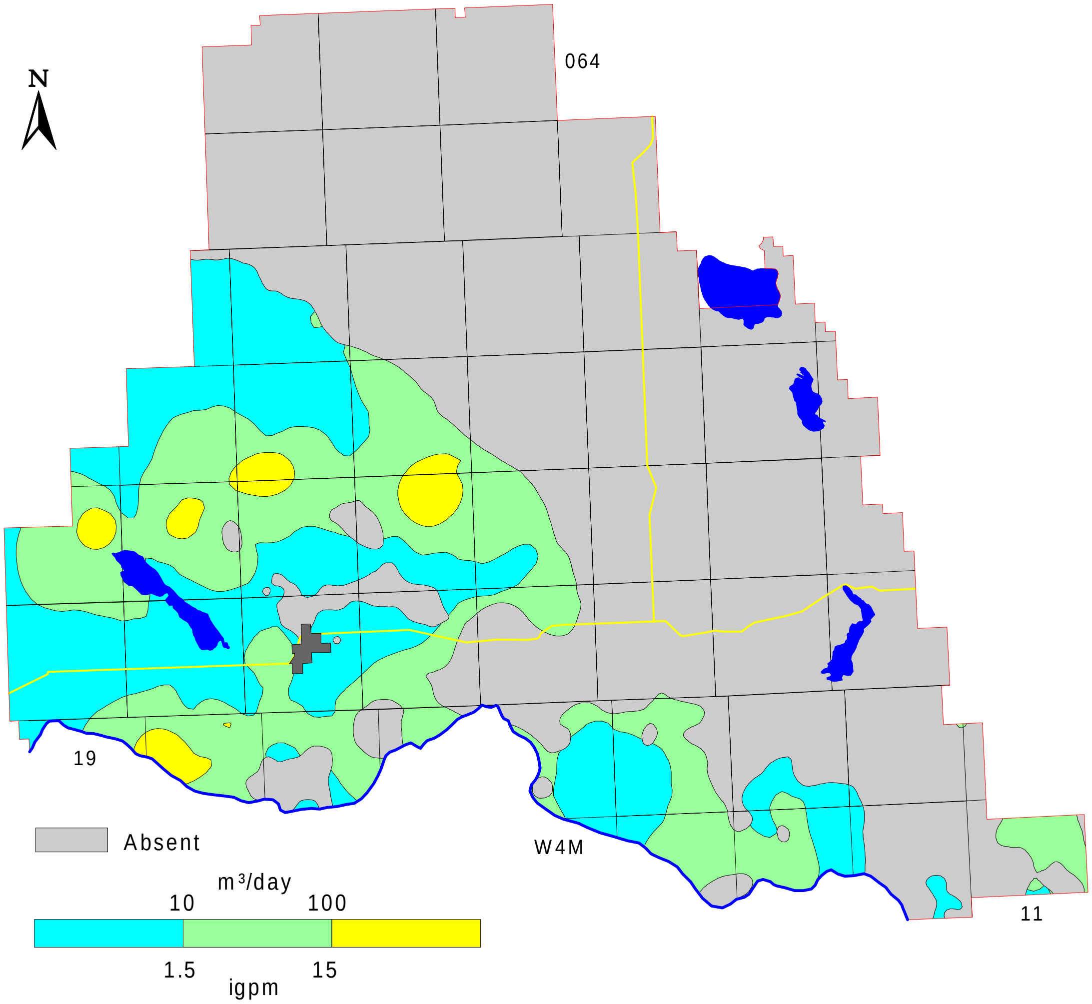
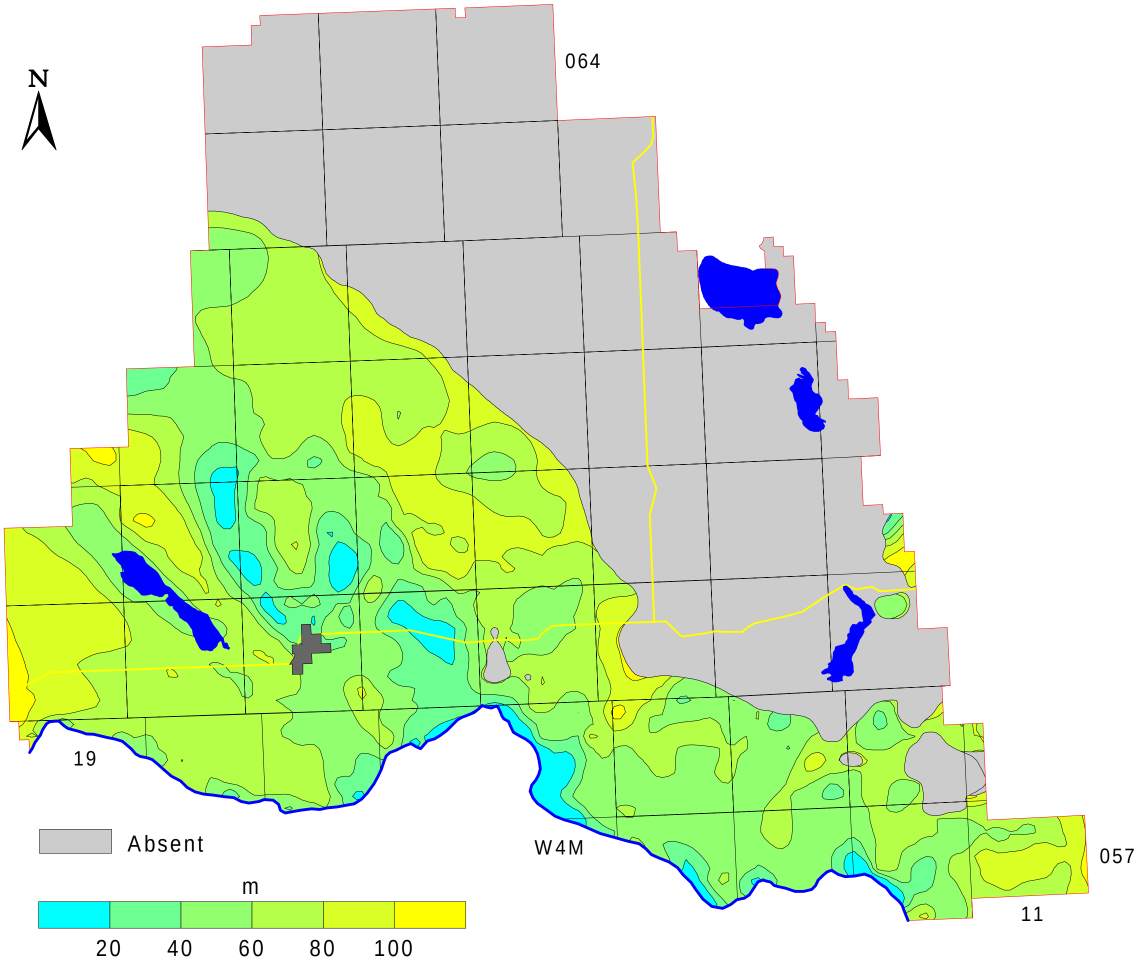
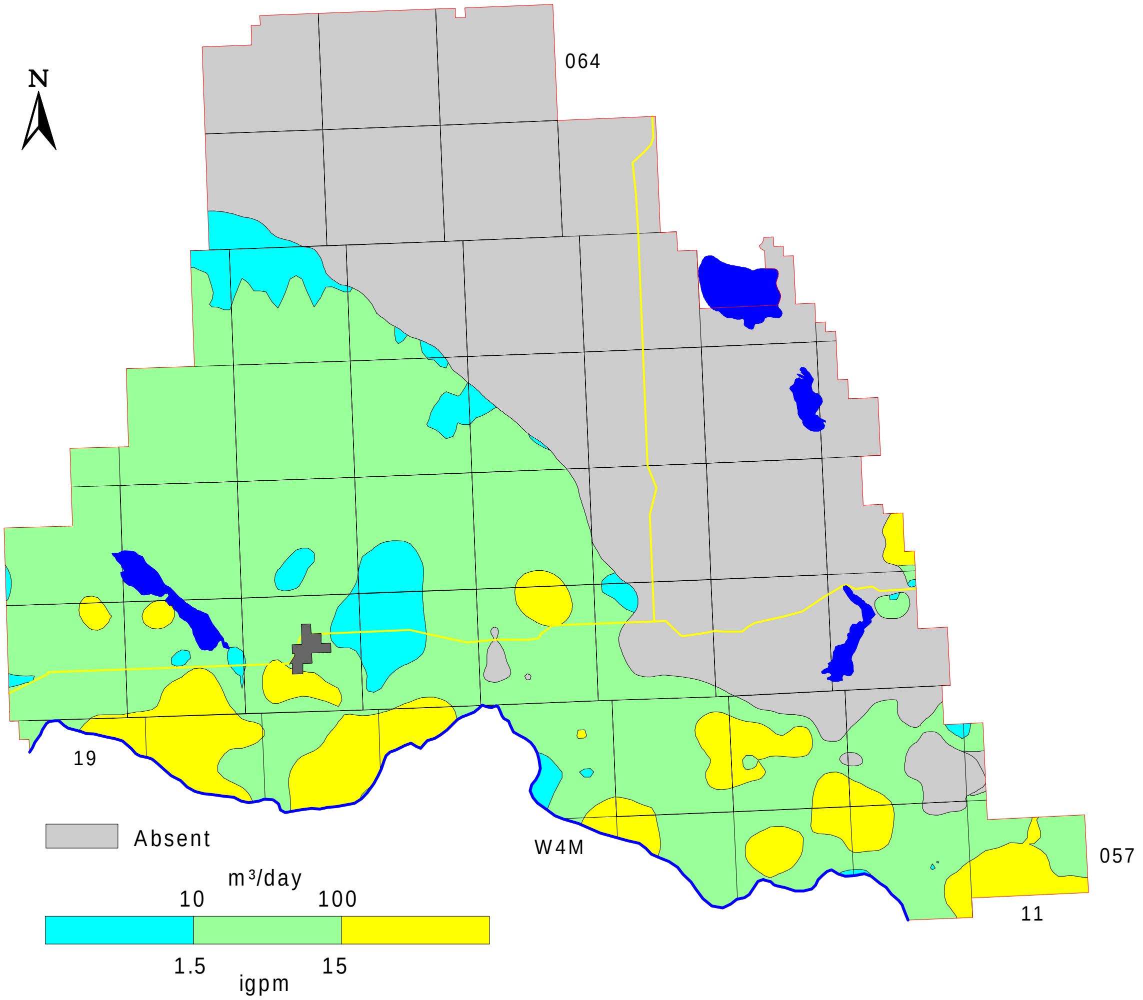
Apparent Yield for Water Wells Completed through continental Foremost Aquifer



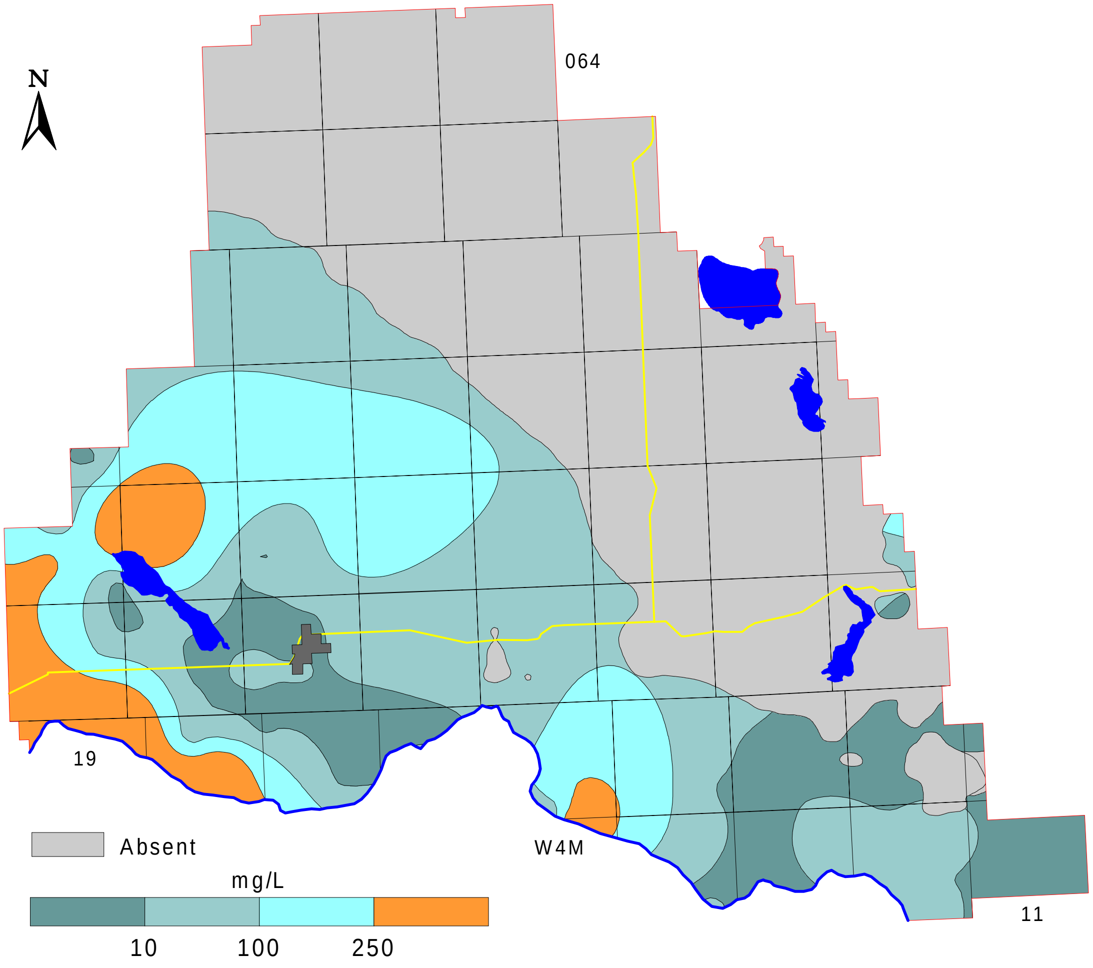
Depth to Top of Milan Aquifer



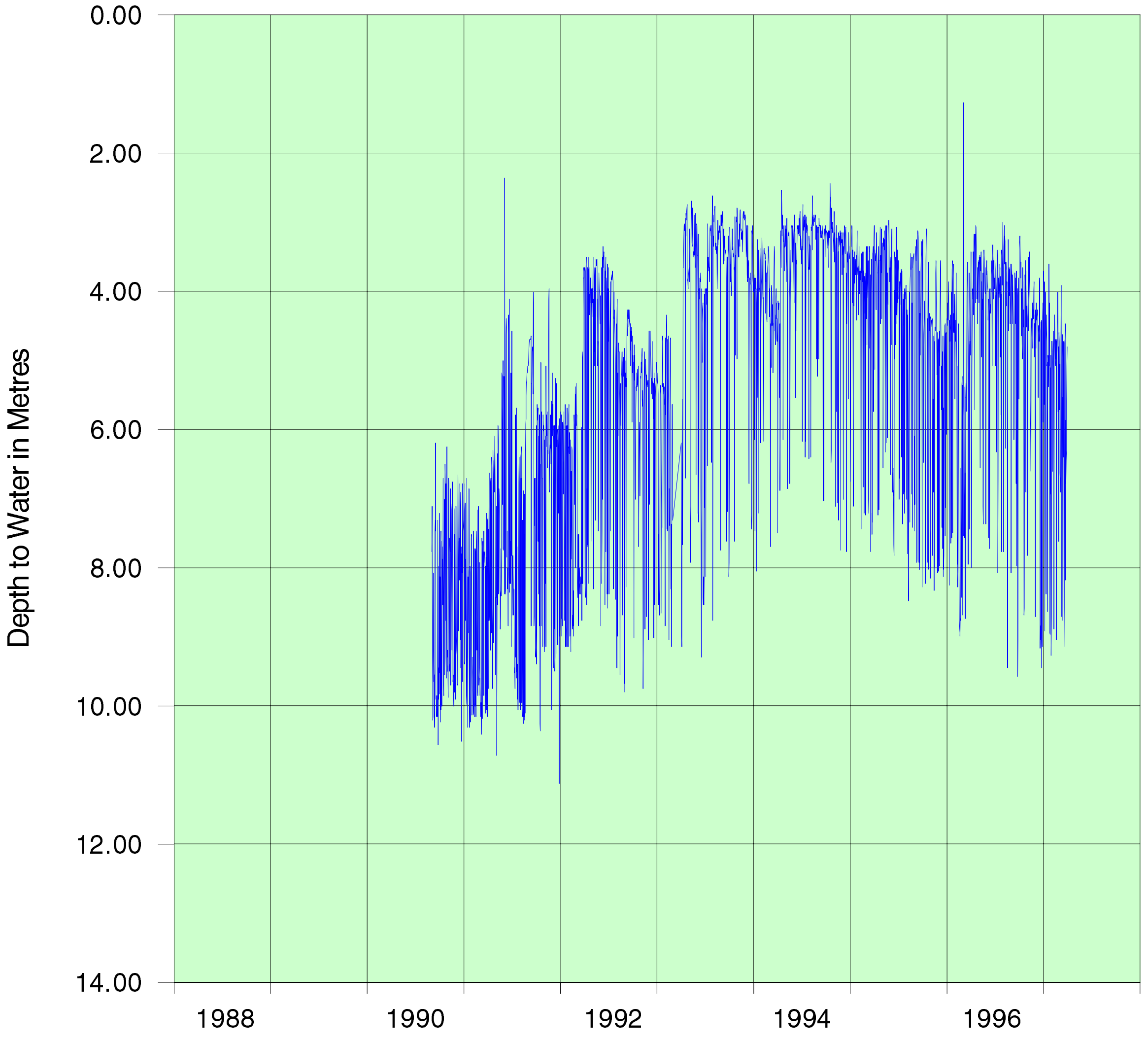
Apparent Yield for Water Wells Completed through Milan Aquifer



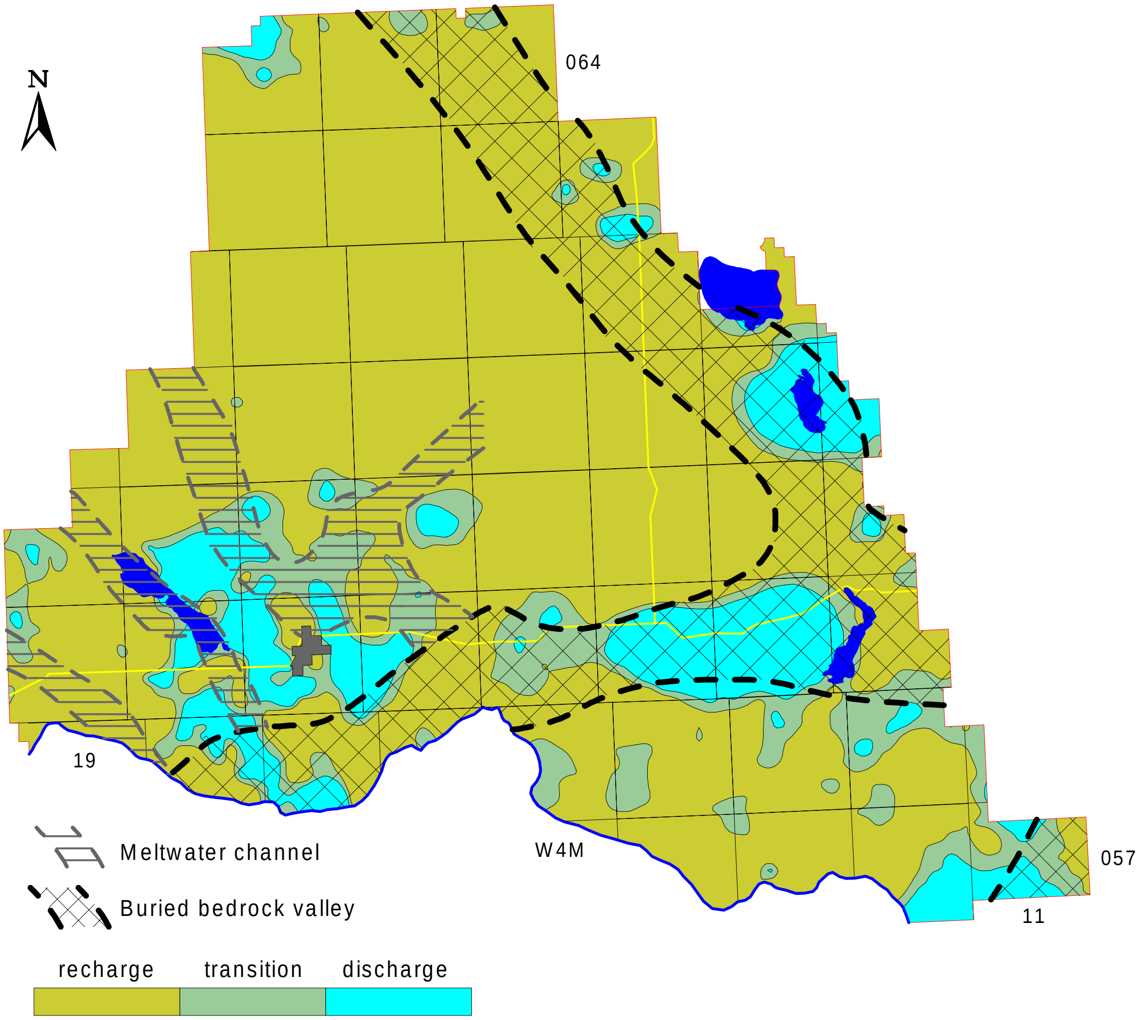
Chloride in Groundwater from Milan Aquifer



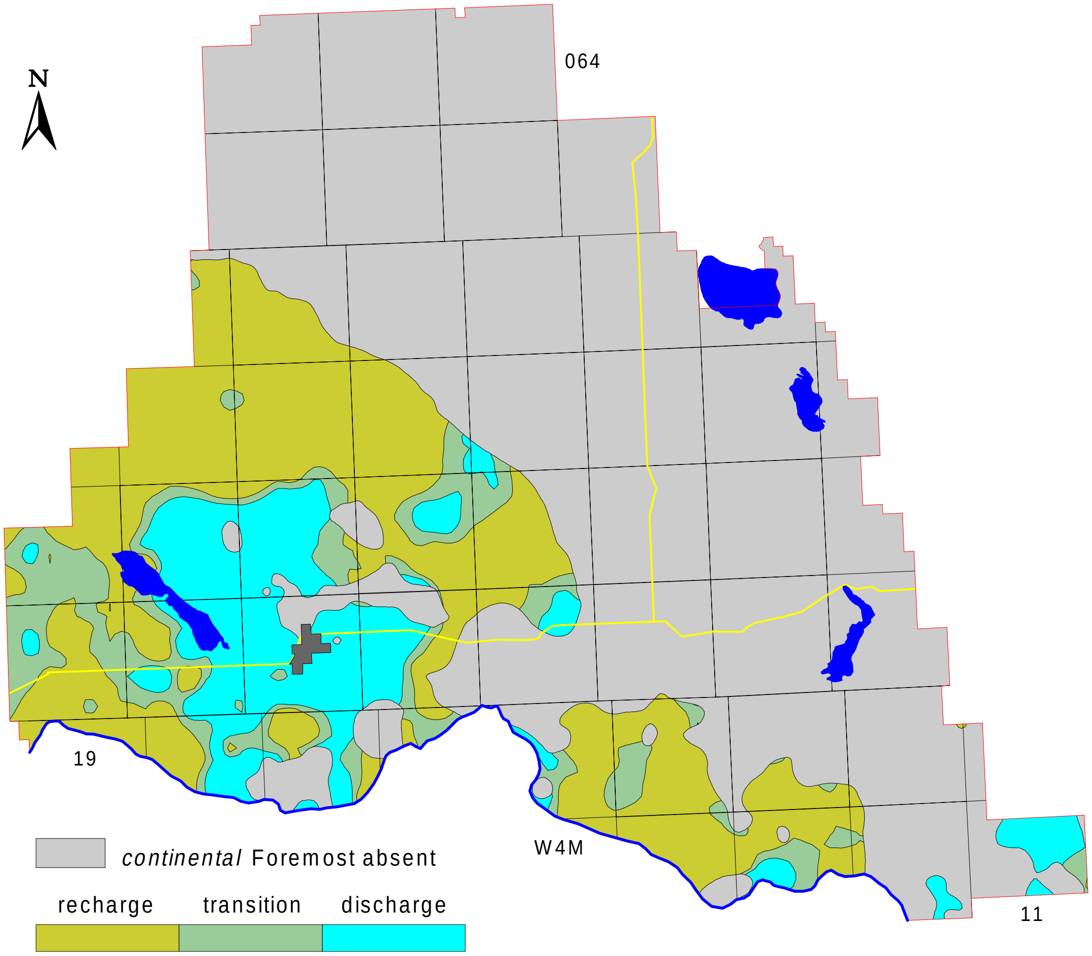
Water-Level Summary – Upper Sand and Gravel Aquifer



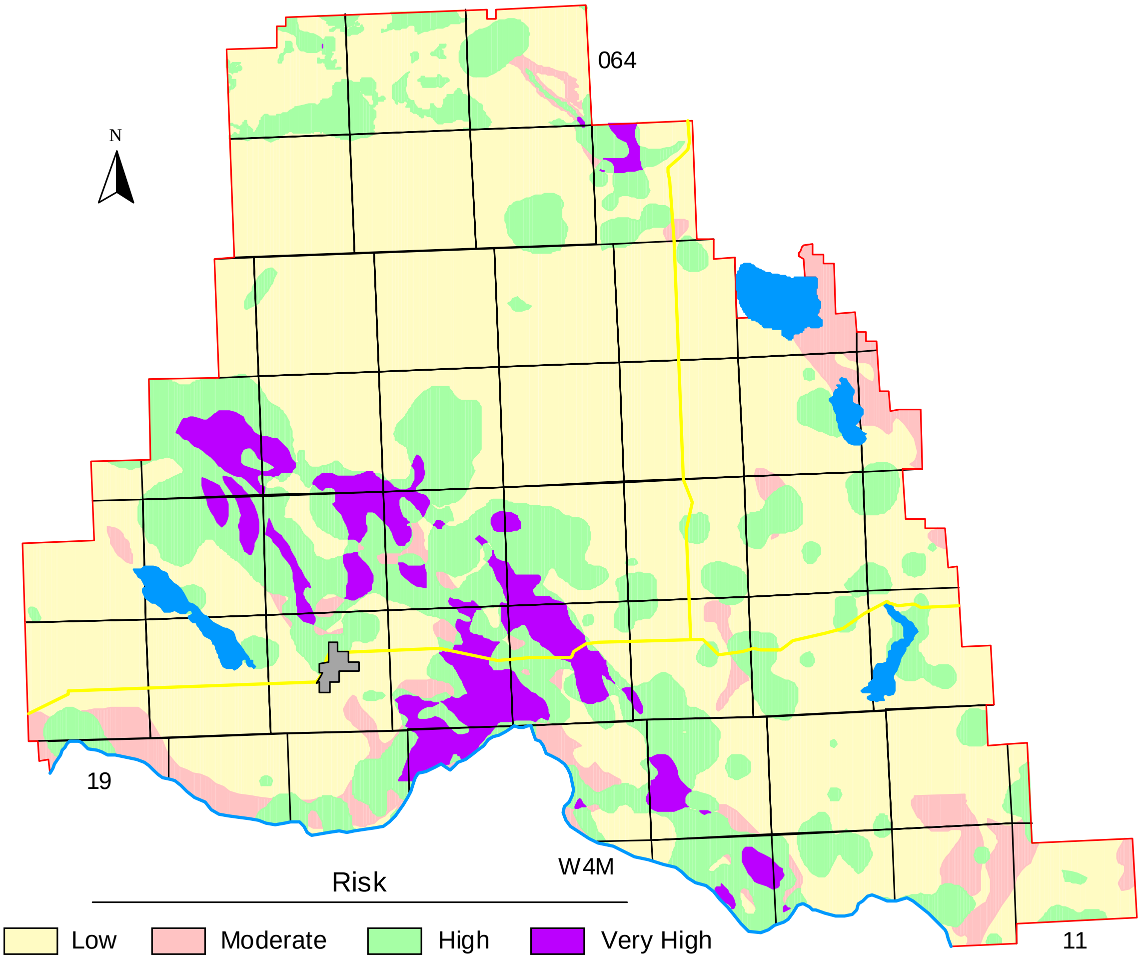
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



Recharge/Discharge Areas between Surficial Deposits and continental Foremost Aquifer



Risk of Groundwater Contamination



SMOKY LAKE REGION

Appendix B

MAPS AND FIGURES ON CD-ROM

CD-ROM

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

1) General

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

2) Surficial Aquifers

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

b) First Sand and Gravel

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

c) Upper Sand and Gravel

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

d) Lower Sand and Gravel

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

3) Bedrock Aquifers

a) General

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

b) Oldman Aquifer

Depth to Top of Oldman Formation
Structure-Contour Map - Top of Oldman Formation
Apparent Yield for Water Wells Completed through Oldman Aquifer

c) *continental* Foremost Aquifer

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

d) *marine* Foremost Aquifer

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

e) Milan Aquifer

Depth to Top of Milan Aquifer
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Apparent Yield for Water Wells Completed through Milan Aquifer
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Piper Diagram - Milan Aquifer
Recharge/Discharge Areas between Surficial Deposits and Milan Aquifer

f) Lea Park Aquitard

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

SMOKY LAKE REGION

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

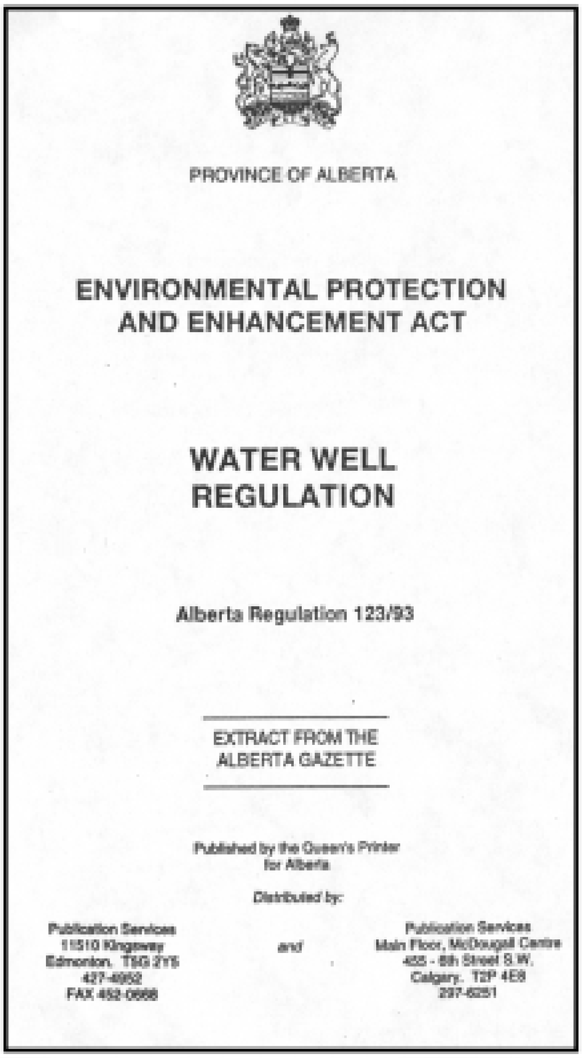
Type of water meter used. This could include such things as a turbine or positive displacement meter. How were the readings obtained from the meter? Were the readings visually noted and recorded or were they recorded using a data logger?

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

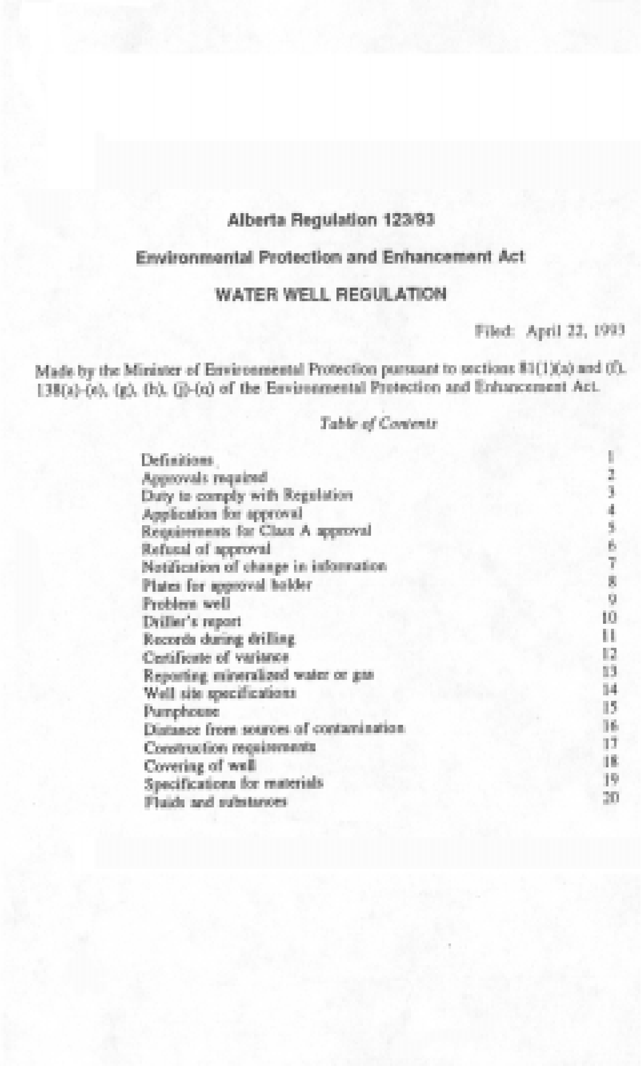
Published by the Queen's Printer
for Alberta

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)-(n) of the Environmental Protection and Enhancement Act.

Table of Contents

Additional Information

VIDEOS

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

BOOKLET

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

ALBERTA ENVIRONMENTAL PROTECTION

WATER WELL INSPECTORS

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

GEOPHYSICAL INSPECTION SERVICE

Edmonton: 403-427-3932

COMPLAINT INVESTIGATIONS

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

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

Carl Mendosa (Edmonton: 403-492-2664)

UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology

Larry Bentley (Calgary: 403-220-4512)

FARMERS ADVOCATE

Paul Vasseur (Edmonton: 403-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION

Keith Schick (Vegreville: 403 632-2919)

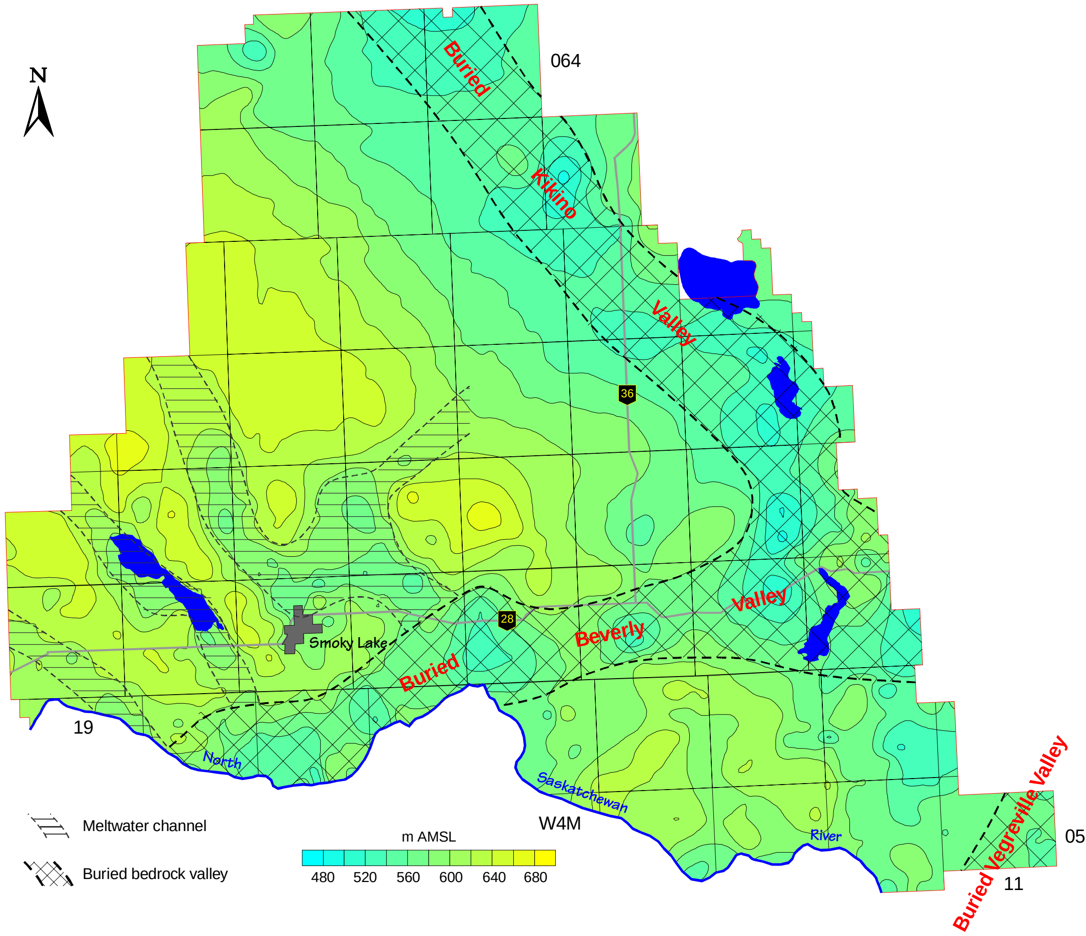
LOCAL HEALTH DEPARTMENTS

SMOKY LAKE REGION

Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

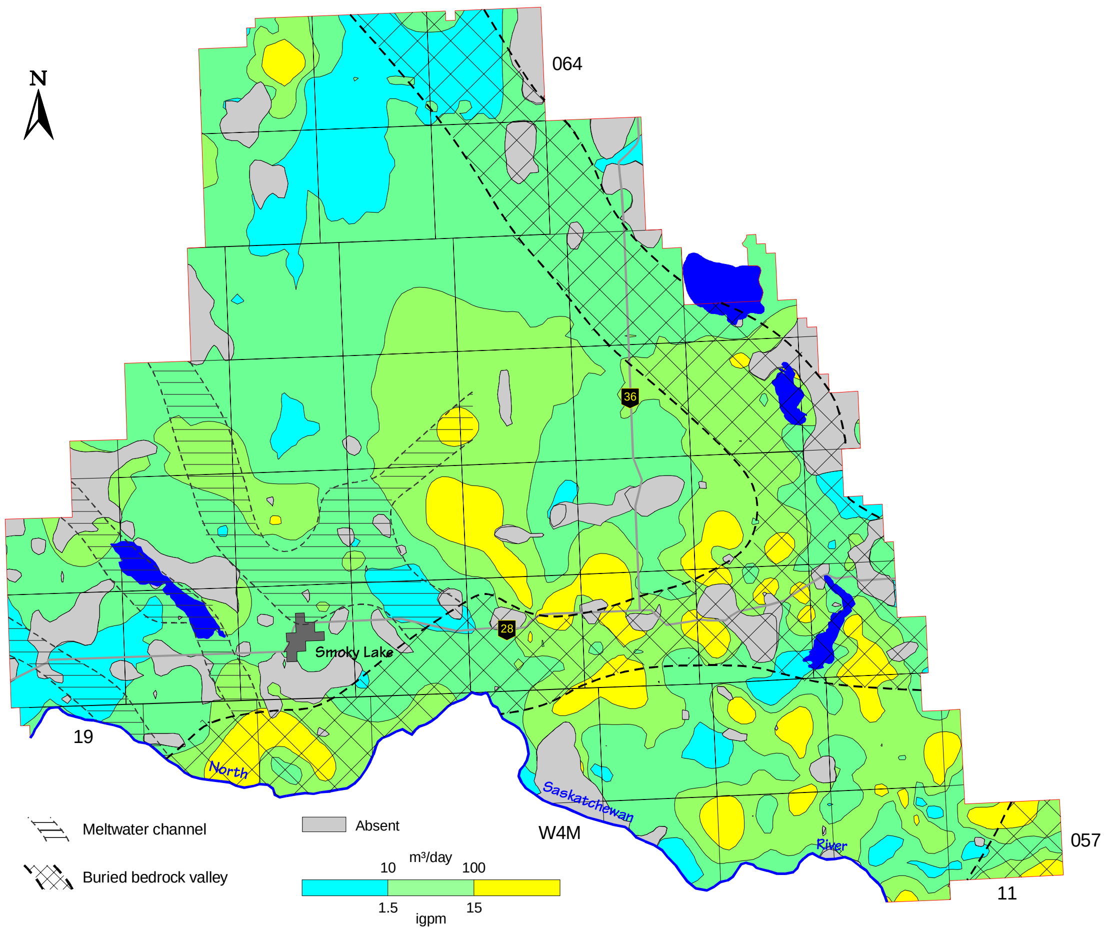
Smoky Lake Region
Bedrock Topography



Note: This map is based on a regional study and as such, the results are to be used only as a guide. Detailed local studies are required to verify hydrogeological conditions at a given location.

hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 96-202 - bdrsl.cdr - 03 Sep 98

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



Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada
PFRA
Prairie Farm Rehabilitation Administration

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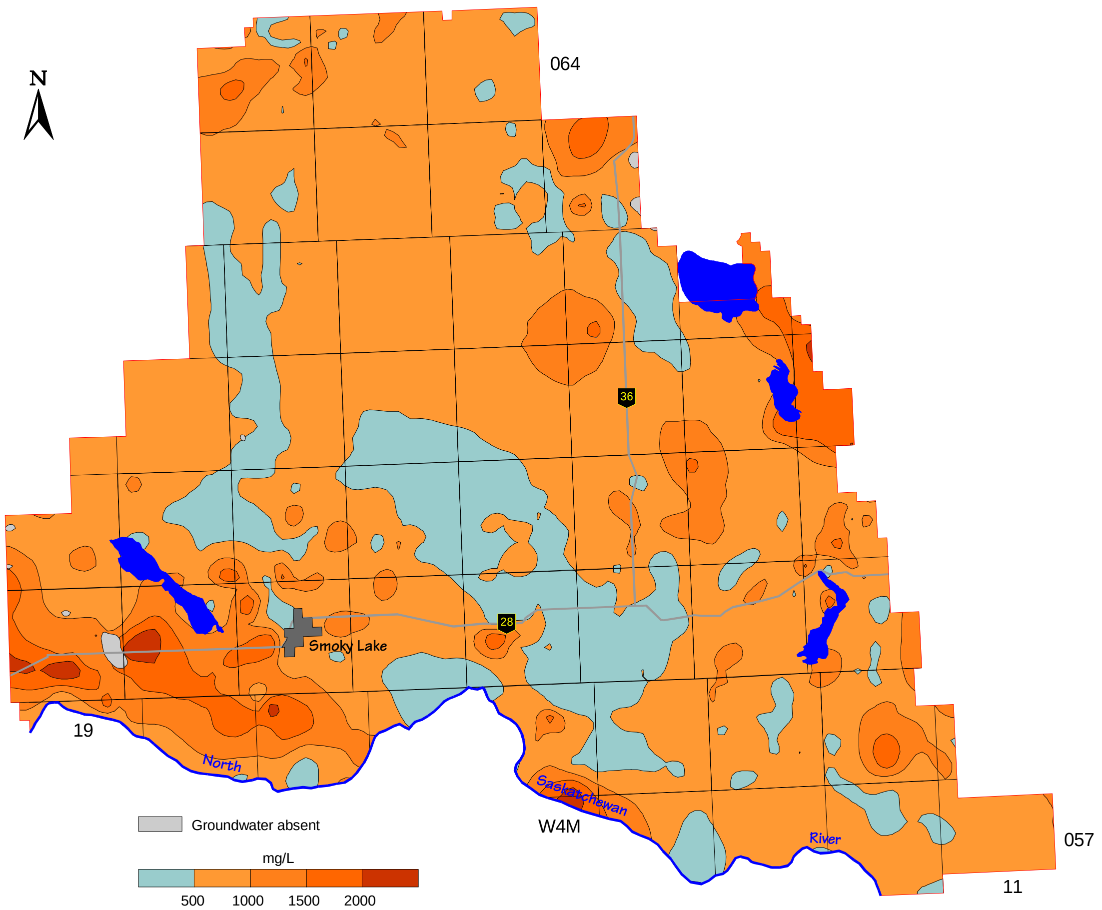
Smoky Lake Region
Total Dissolved Solids in Groundwater from Surficial Deposits



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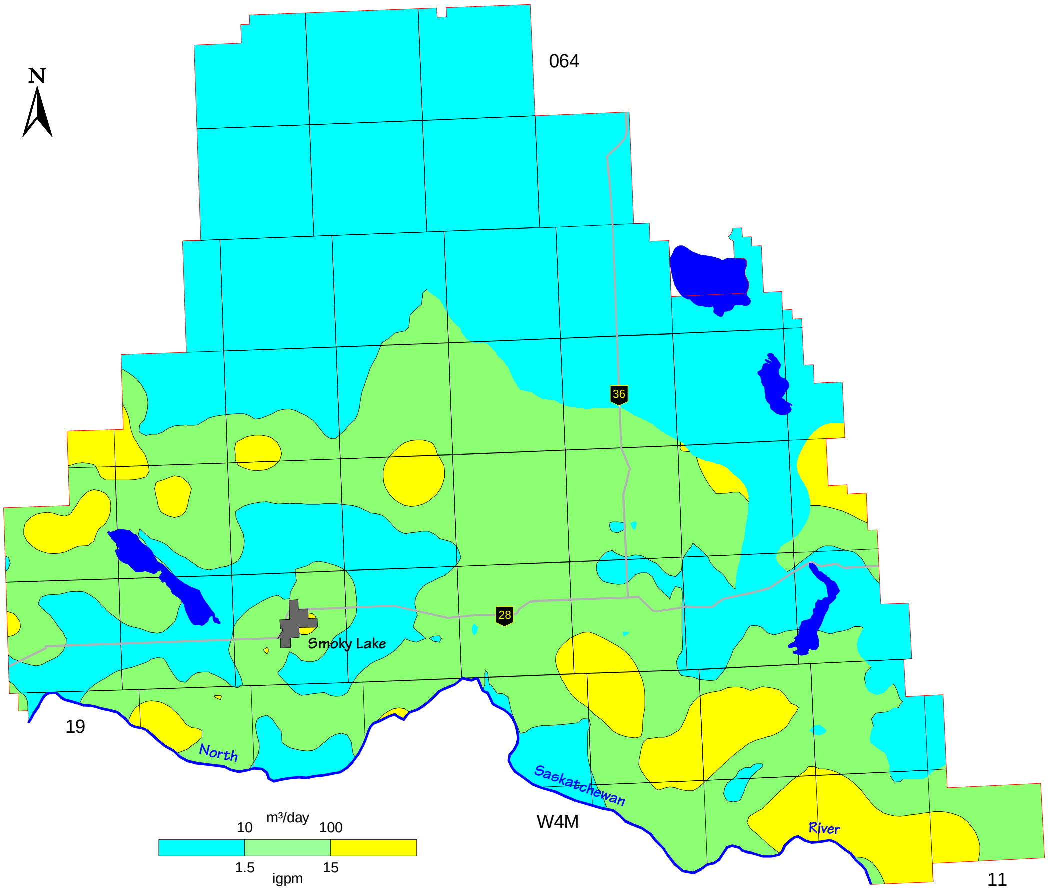
Smoky Lake Region
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



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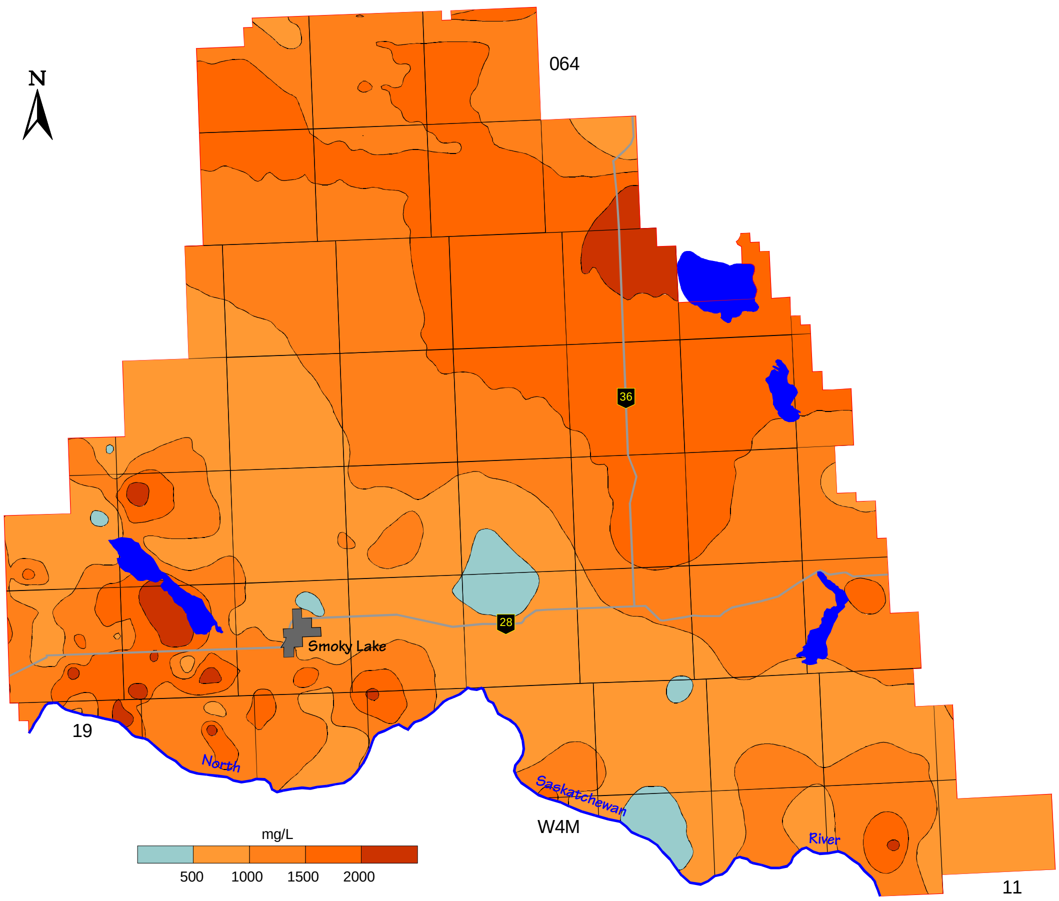
Smoky Lake Region
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



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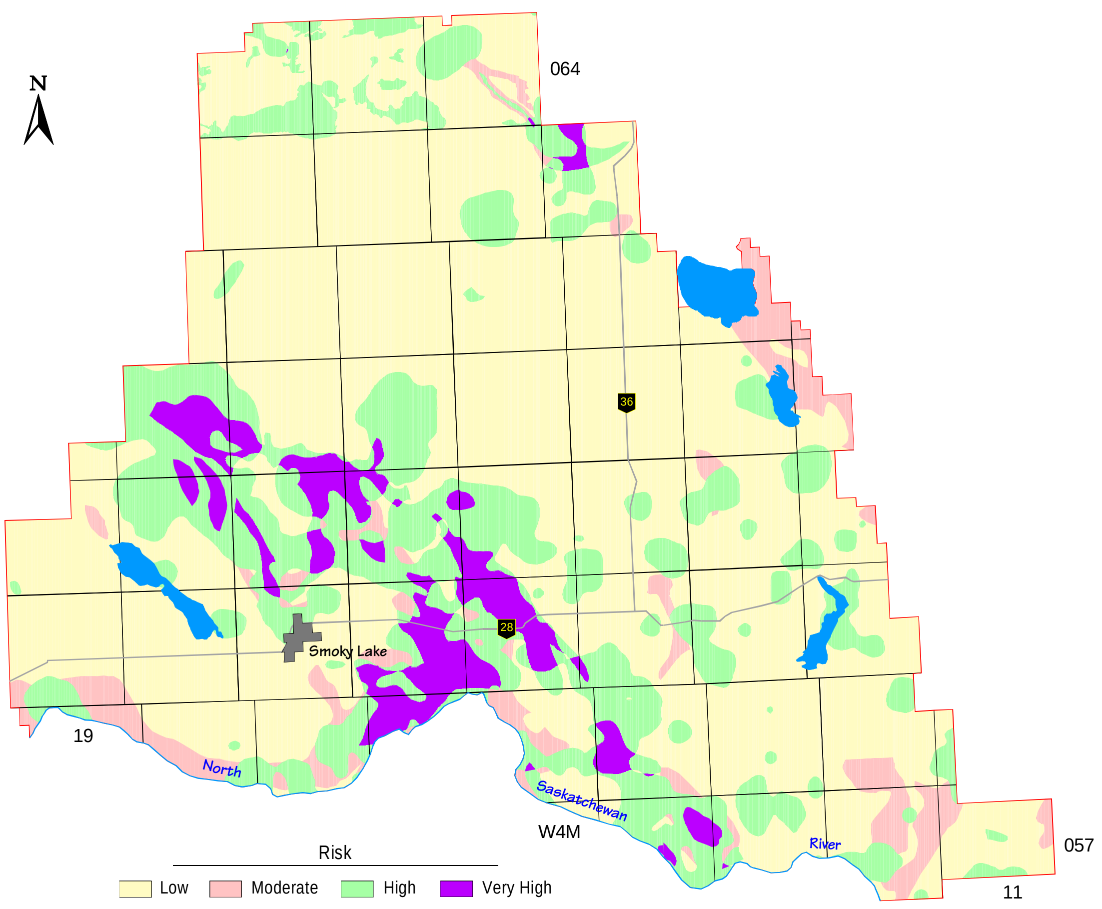
Smoky Lake Region
Risk of Groundwater Contamination



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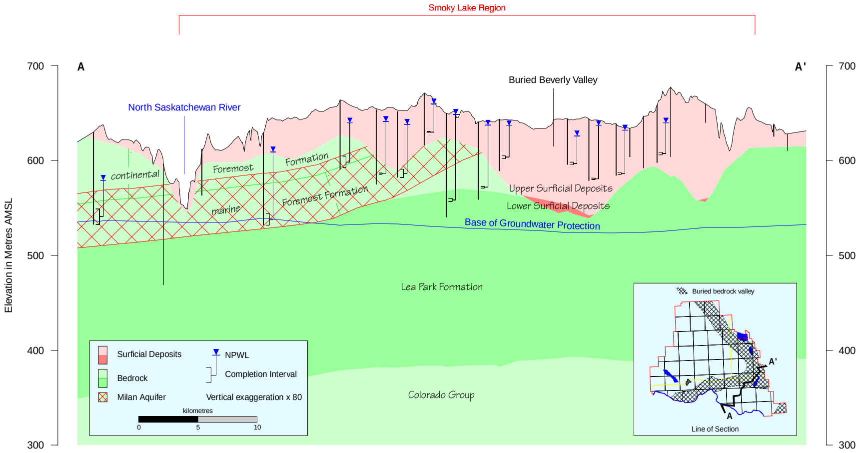
Smoky Lake Region
Cross-Section A - A'



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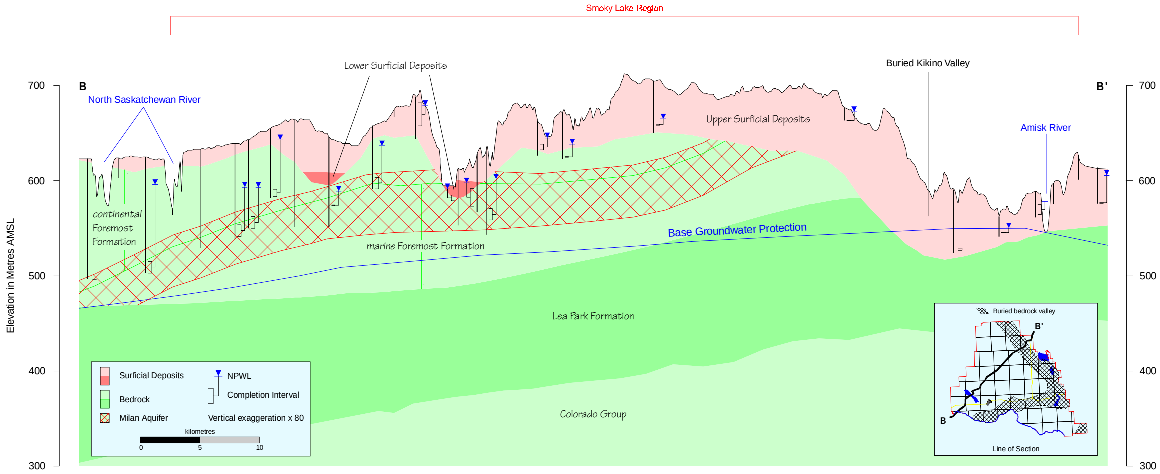
Smoky Lake Region
Cross-Section B - B'



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