County of St. Paul No. 19

Part of the North Saskatchewan River Basin
Parts of Tp 055 to 062, R 03 to 13, W4M
Regional Groundwater Assessment

Prepared for

In conjunction with

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration | Administration du rétablisseme agricole des Prairies

Canada

Prepared by
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HYDROGEOLOGICAL CONSULTANTS LTD.

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Date ______________________________

PERMIT NUMBER: P 385

The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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1 PROJECT OVERVIEW

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

How a County takes care of one of its most precious resources - groundwater - reflects the future wealth and health of its people. Good environmental practices are not an accident. They must include genuine foresight with knowledgeable planning. Implementation of strong practices not only commits to a better quality of life for future generations, but 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 County toward the management of the groundwater resource, which is a key component of the well-being of the County, and is a guide for future groundwater-related projects**

1.1 About This Report

This report provides an overview of (a) the groundwater resources of the County of St. Paul No. 19, (b) the processes used for the present project and (c) the groundwater characteristics in the County.

Additional technical details are available from files on the CD-ROM provided with this report. The files include the geo-referenced electronic groundwater database, 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 A.

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 the Appendix.

Appendix B provides a complete list of files included on the CD-ROM.

Appendix C includes the following water well information:

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

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

1.2 The Project

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

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

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

This report represents Modules 2 and 3.

1.3 Purpose

This project is a regional groundwater assessment of the County of St. Paul No. 19. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the County.**

The regional groundwater assessment includes:

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

Under the present program, the groundwater-related data for the County of St. Paul No. 19 have been assembled. Where practical, the data have been digitized. These data are then being used in the regional groundwater assessment for the County.

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1 See glossary
2 See glossary

2 INTRODUCTION

2.1 Setting

The County of St. Paul No. 19 is situated in east-central Alberta. This area, part of the Alberta Plains region, exists within the drainage area of the North Saskatchewan River drainage basin. The area includes some or all of townships 055 to 062, ranges 03 to 13, west of the 4th Meridian.

Most of the County boundaries follow township or section lines. The exception is the western part of the southern boundary, which is the North Saskatchewan River. The ground elevation varies between 550 and 670 metres above mean sea level (AMSL). The topographic surface generally decreases from the west to the east.

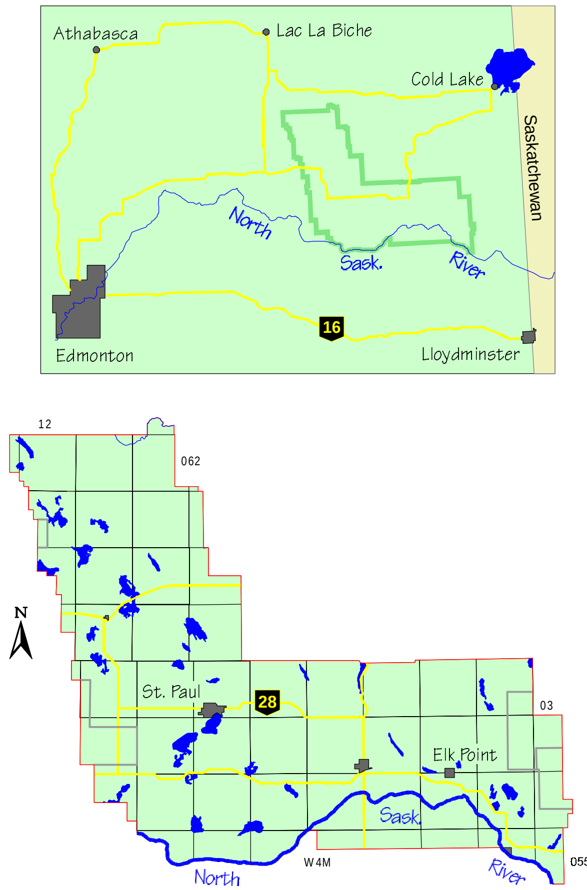

Figure 1. Index Map

2.2 Climate

The climate of the County is a Dfb based on the Köppen classification. This means a climate of a cold-snowy forest with no distinct dry season and cool summers. The mean annual precipitation at the Elk Point Climatological Station measures 435.9 millimetres (mm), based on data from 1961 to 1990. For the same time interval, the maximum annual precipitation reached 563 mm, and the minimum was 292 mm. Between 1961 and 1990, the annual temperature averaged 1.1 degrees C. The potential evapotranspiration for the area is more than 50 centimetres per year (Hackbarth, 1975).

2.3 Background Information

Currently in the County of St. Paul, there are 5,116 water wells in the groundwater database. Based on a rural population of 6,300, there are three water wells per family of four. The domestic or stock water wells vary in depth from less than 1 metre to 152.4 metres below ground level. Lithologic details are available for 3,164 water wells.

Data for casing diameter are available for 1,865 water wells, with 427 indicated as having a diameter of more than 300 mm and 1,438 having a diameter of less than 300 mm. The casing diameters of less than 300 mm are for drilled water wells, of which 65% were drilled before 1980. The water wells with a diameter of greater than 300 mm are mainly bored water wells.

Before 1980, plastic casing was used in 0.4% of the water wells. From the beginning of 1980 to the end of 1989, 35% of the water wells were completed with plastic casing. This figure has risen to 96% since the beginning of 1990.

Water wells not used for domestic needs must be licensed. At the end of 1996, 82 groundwater diversions were licensed. The total maximum authorized diversion from these 82 water wells is 1,494 cubic metres per year; 81 percent of the authorized groundwater diversion is allotted for agricultural use. The Town of St. Paul obtains its water from the North Saskatchewan River and is the only community in the County that is not using groundwater.

Little or no groundwater is available in the northern and eastern parts of the County. In these areas the upper bedrock, the Lea Park Formation, is primarily shale with no significant amount of fracturing. The surficial[3] deposits may contain sand and gravel layers. However, the sand and gravel deposits occur as pockets and are therefore not identifiable on a regional scale.

The total dissolved solids in the groundwater are generally less than 2,000 milligrams per litre (mg/L). Groundwaters from the surficial deposits are chemically hard with a high dissolved iron content. Groundwaters from the bedrock aquifers 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 1.0 mg/L.

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

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

[3] See glossary

3 TERMS

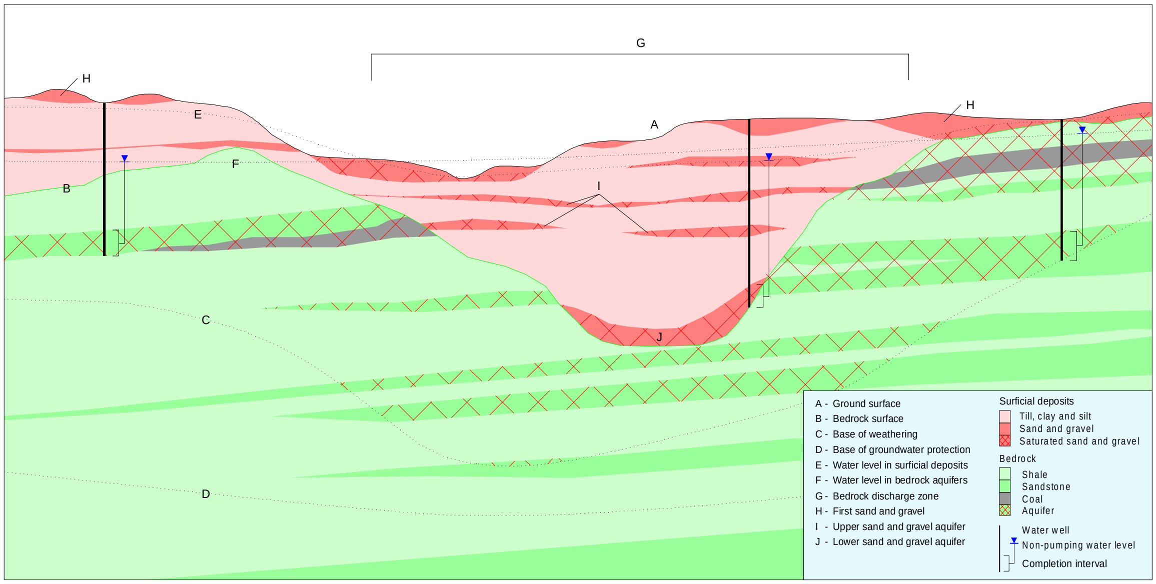

Figure 2. Generalized Cross-Section (for terminology only)

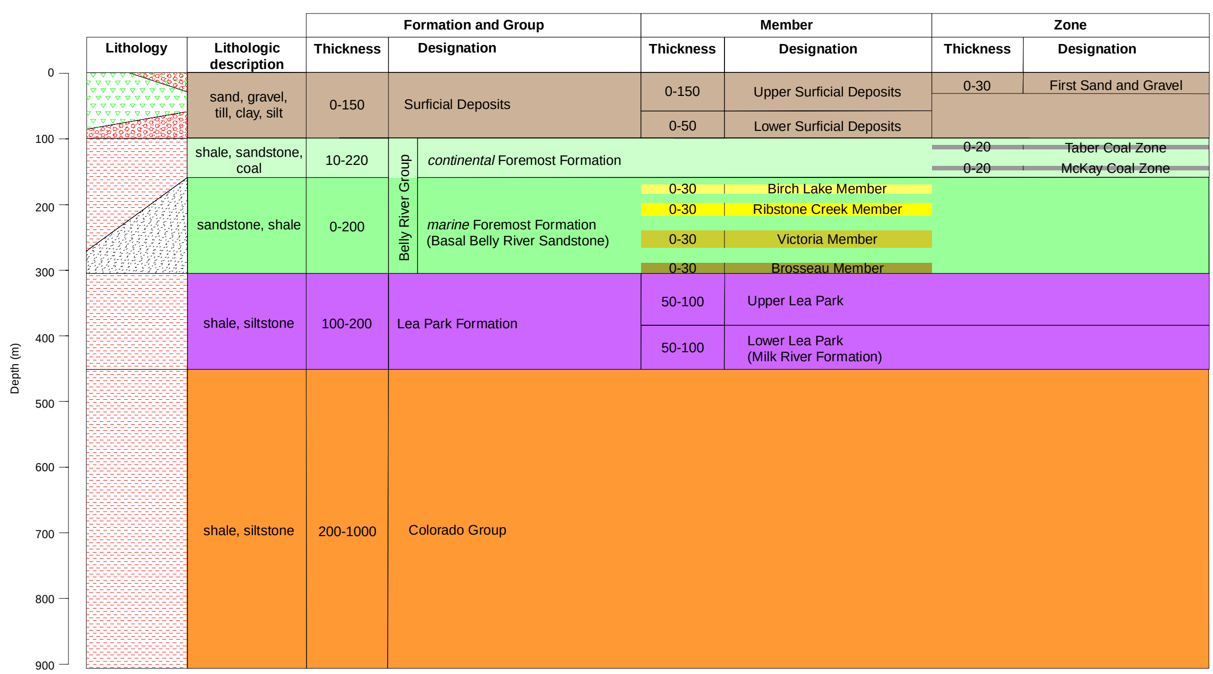

Figure 3. Geologic Column

4 METHODOLOGY

4.1 Data Collection and Synthesis

The AEP groundwater database is the main source of groundwater data available. 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 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 TM coordinate system. This means that a record for the SW ¼ of section 05, township 058, range 09, W4M, would have a horizontal coordinate with an Easting 232886 and a Northing 5984513, 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[4] and apparent yield[5] 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[6]. 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

[4] For definitions of Transmissivity, see glossary
[5] See glossary
[6] 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[7] 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 the 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 on the basis of 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 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 1. Risk of Groundwater Contamination Criteria

7 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 non-pumping water level and the elevation of the top of the aquifer are combined to determine the available drawdown[8]. 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 figurers 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

Where possible, files are available in more than one format.

[8] See glossary

5 AQUIFERS

5.1 Background

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

The thickness of the surficial deposits varies from less than 20 to more than 140 metres. 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 it is not saturated, it is not an aquifer. The top of the surficial aquifers has been determined from the non-pumping water level 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. Many of the water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few 100 mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the County, 67% 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 majority of the water wells completed in bedrock aquifers within the County have casing diameters of less than 200 millimetres.

The upper bedrock includes part of the Belly River Group and the Lea Park Formation. The Belly River Group has a maximum thickness of 150 metres and includes both the *continental* and *marine* facies[9] of the Foremost Formation.

The Lea Park Formation is the upper bedrock over approximately 50% of the County. The Lea Park Formation is mainly composed of shale, which is a fine-grained deposit that without fracturing has a very low permeability and cannot transmit significant quantities of groundwater to water wells. Hydrogeologists refer to the very low permeability rocks as aquitards[10]; they are unsuitable for the development of groundwater supplies, even for single-family needs.

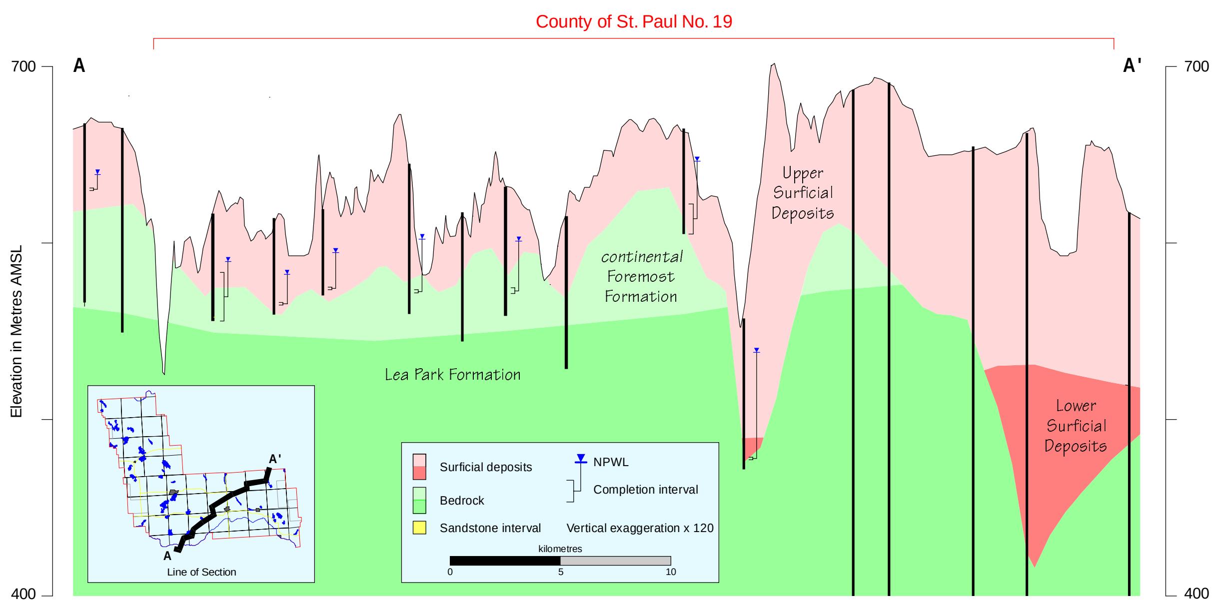

Figure 4. Cross-Section A – A'

9 See glossary
10 See glossary

5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. This includes pre-glacial materials, which were deposited before glaciation, and drift, materials deposited directly by or indirectly during glaciation. The lower surficial deposits include the pre-glacial and some transitional sediments 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 can be 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”.

The total thickness of the surficial deposits ranges from less than 20 to more than 140 metres. The maximum thickness occurs in association with the Buried Beverly Valley, which is north of the Town of St. Paul. Over the majority of the County, the surficial deposits are less than 100 metres thick.

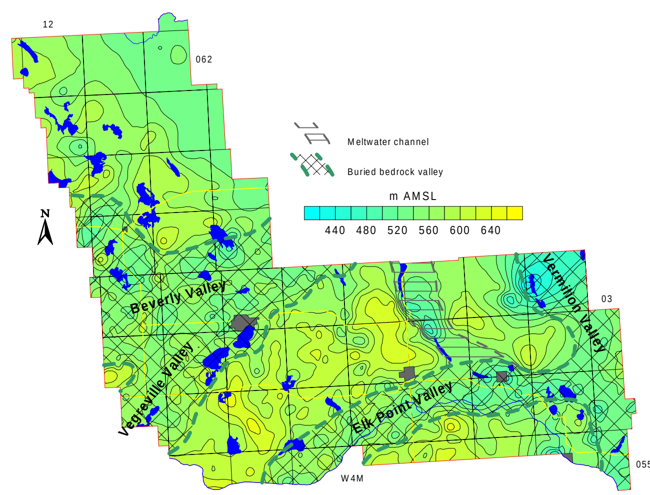

Figure 5. Bedrock Topography

The lower surficial deposits are composed mostly of fluvial[11] and lacustrine[12] deposits. The total thickness of the lower surficial deposits can be up to 100 metres. If the elevation of the top of the lower surficial deposits is approximately 540 metres AMSL, an elevation that corresponds closely to the top of the Muriel Lake Formation (Andriashek, 1985), the lower surficial deposits can be expected under approximately 20% of the County. The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits can directly overlie the bedrock surface in the buried bedrock valleys referred to as the Buried Beverly Valley and the Buried Vermilion Valley. The lowest sand and gravel deposits are of fluvial origin and are usually no more than a few metres thick.

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[11] See glossary
[12] See glossary

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits of meltwater origin, which occur as isolated pockets. The thickness of the upper surficial deposits can be up to 120 metres. The greatest thickness of upper surficial deposits occurs in the areas of the buried bedrock valleys. These valleys include the Buried Beverly, Vegreville, Elk Point, and Vermilion Valleys, plus the deeply incised meltwater channel northeast of Elk Point.

Sand and gravel deposits can occur throughout the entire unconsolidated section. The combined thickness of all sand and gravel deposits as a function of the total thickness of the surficial deposits has been determined. Over approximately 5% of the County, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. The areas where the sand and gravel thickness is more than 50% of the total thickness of the surficial deposits are all in the southern part of the County, with most of the areas associated with buried bedrock lows.

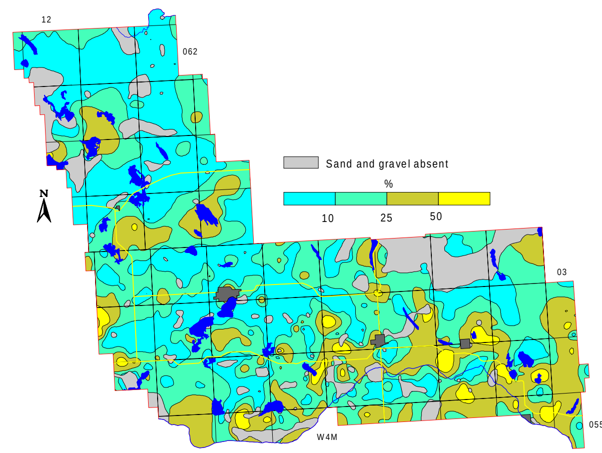

Figure 6. Amount of Sand and Gravel in Surficial Deposits

5.2.2 Sand and Gravel Aquifer(s)

The main source of groundwater in the County is aquifers in the surficial deposits. The particular aquifer used is in a large part dictated by the aquifers present. Some water wells are completed in aquifers in the lower surficial deposits and some are completed in aquifers in the upper surficial deposits.

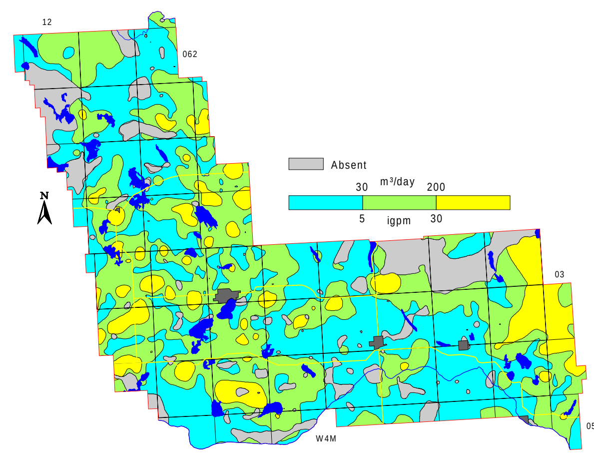

Figure 7. Apparent Yield from Water Wells completed through Sand and Gravel Aquifer(s)

The adjacent map shows the water well yields that are expected in the County based on the surficial aquifers that have been developed. Based on these data, water well yields of more than 200 m³/day can be expected in parts of the County, most notably in the eastern part. Over a significant part of the County, water well yields can be less than 30 m³/day. One of the noteworthy points of the adjacent map is the "patchy" nature of the expected yields. The patchy appearance of the yield map indicates the lack of continuity of the individual aquifers. The higher values for water well yields are more frequently located in the middle part of the County, where the general trend of the Buried Beverly and Vermilion Valleys can be seen.

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits have not been differentiated based on aquifers in the upper or lower surficial deposits. The main reason for not separating the chemical analysis results into the different aquifers is the lack of control. The majority of the chemical analysis results are not associated with water wells that have water well drilling reports. Consequently, it is not known from which aquifer the water sample has been obtained. However, all available chemical analysis results have been used; otherwise, only 15% of the available chemical analyses could be used.

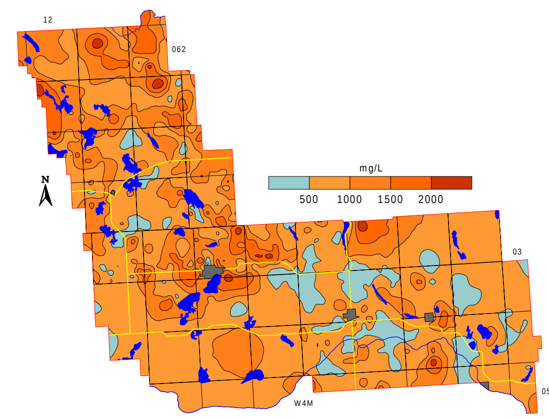

Figure 8. Total Dissolved Solids in Groundwater from Surficial Deposits

The other justification for not separating the analyses was that there appeared to be no major chemical difference between groundwater from the upper and 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 total dissolved solids from less than 500 to more than 1,000 mg/L. Most of the groundwaters from the northern part of the County have concentrations of dissolved solids in excess of 1,000 mg/L. The majority of the groundwaters from the southern part of the County have total dissolved solids of less than 1,000 mg/L. All of the groundwater from the surficial deposits is expected to have concentrations of dissolved iron of greater than 1 mg/L.

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

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. These aquifers typically occur above an elevation of 540 metres AMSL. The saturated sand and gravel deposits are not continuous and are expected over approximately 80% of the County.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is in part a function of the elevation of the non-pumping water level associated with the upper surficial deposits and in part a result of the depth to the bedrock surface. Since the non-pumping water level 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. The main exception occurs close to major topographic features, where the surficial deposits can be thick but, because of the large topographic relief, the surficial deposits drain more easily and the Aquifer can be very thin or absent. This phenomenon is apparent in areas close to the North Saskatchewan River Valley.

While the sand and gravel deposits of 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 ten metres thick in some areas, but over the majority of the County, is less than five metres thick or is absent. Most of the greater thickness in the Upper Sand and Gravel Aquifer occurs in the southwestern and eastern parts of the County.

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 long-term yield of the water wells is limited. The yield map shows that, in less than 10% of the County, higher short-term yields can be expected. The main area of high short-term yields is in the eastern part of the County. The long-term yields for water wells completed in this Aquifer are expected to be mainly less than 30 m³/day. Where the upper 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.

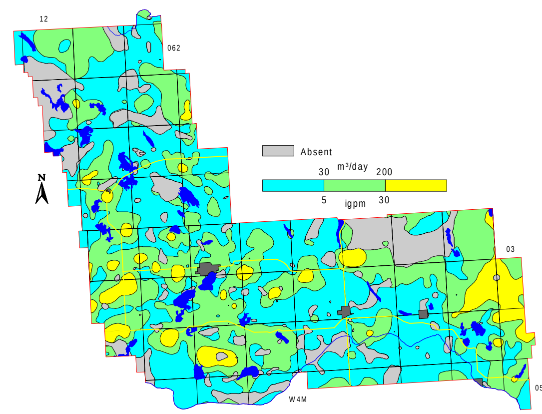

Figure 9. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deepest of the pre-glacial linear bedrock lows of the Buried Beverly and Vermilion Valleys. The Lower Sand and Gravel Aquifer may be a continuous aquifer in the Buried Beverly Valley, where the thickness of the sand and gravel deposits may reach ten metres. In all, the Aquifer occupies less than 20% of the County.

5.2.4.1 Apparent Yield

Water wells completed in the Lower Sand and Gravel Aquifer may have yields in excess of 100 m³/day. The highest yields are expected in townships 059 and 060, ranges 09 to 11, W4M. In this area, the projected long-term yield from individual water wells could be more than 300 m³/day. The Lower Sand and Gravel Aquifer is absent from the majority of the County.

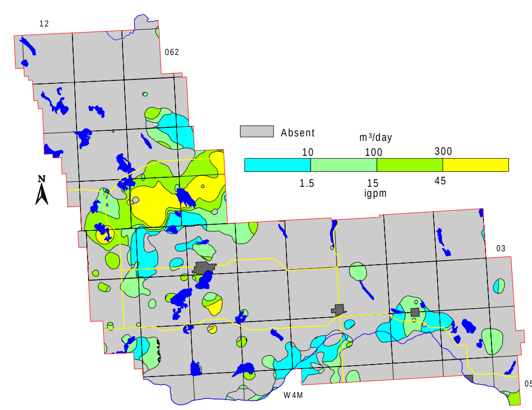

Figure 10. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock includes the Lea Park Formation and parts of the Belly River Group. The Belly River Group in the area of the County has a maximum thickness of 150 metres and includes both the *continental* and *marine* facies of the Foremost Formation.

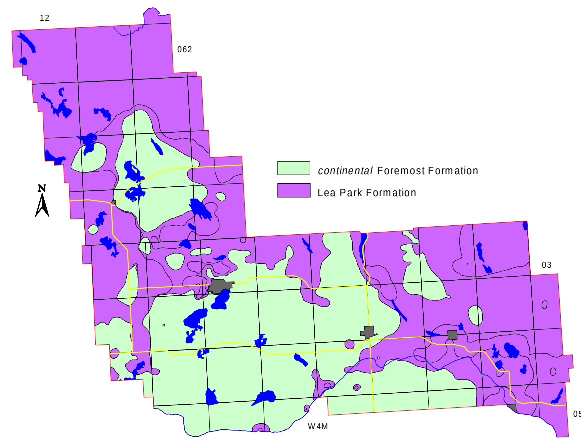

Figure 11. Bedrock Geology

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 most of the County, the *continental* Foremost Formation is close to the bedrock surface, has been fractured or weathered and can be a significant aquifer.

In the County, the *marine* Foremost Formation, an offshore deposit, includes patches of the Victoria Member. The Victoria Member is a fine-grained sandstone and siltstone less than ten metres thick, which occurs in relatively small isolated areas that cover less than a few tens of square kilometres. The largest area where the Victoria Member is present is in the western part of the County.

The Lea Park Formation underlies the Foremost Formation and has two parts. The upper part is primarily a shale deposit, with minor amounts of fine-grained sandstone, siltstone and bentonite. The bentonite is both a cementing agent for some of the sandstone and siltstone deposits and an individual sedimentary layer. The upper Lea Park Formation is less than 100 metres thick and is the uppermost bedrock under most of the northern and eastern parts of the County. Unless fractured or weathered, the upper Lea Park is an aquitard.

The lower part of the Lea Park Formation is primarily shale and is 60 to 110 metres thick. Unless fractured or weathered, the lower Lea Park, which underlies the entire County, is an aquitard. This part of the Lea Park Formation is equivalent to the Milk River Formation.

A regional lineament analysis using DEM maps indicates that a group of collapsed structures may be present within the County. The collapsed structures occur in a northwest-southeast trending zone that passes through the eastern and northern parts of the County. In these areas, blocks of the Foremost Formation may have subsided a few tens of metres and the Lea Park Formation may be fractured. These conditions could be responsible for anomalous hydraulic conductivity values attributed to the Lea Park Formation.

5.3.2 Aquifers

The groundwater database has 574 records that indicate the top of the completion interval for a water well or water test hole is below the bedrock surface. Of these 574 records, 125 have sufficient data to calculate apparent yields. In addition to these water wells, there have been 48 water test holes that have been abandoned, presumably as "dry holes". A distribution of these records shows that most of the dry holes have been in the southern and southeastern parts of the County. In these areas, the upper bedrock is the Lea Park Formation or, if the upper bedrock is the *continental* Foremost Formation, it is either thin or drained.

The producing water wells mainly occur within the area underlain by either the *continental* Foremost Formation or the Victoria Member of the *marine* Foremost Formation. Some of the bedrock water wells are completed in areas where the Lea Park Formation is indicated as being the uppermost bedrock. The water wells completed where the upper bedrock is the Lea Park Formation are not indicative of the normal hydrogeological conditions for the Lea Park Formation. These water wells, which are indicated as being completed in the Lea Park Formation, may be completed in the Foremost Formation and are not identified as such because of inadequate stratigraphic control, or there may be local fracturing in the Lea Park Formation.

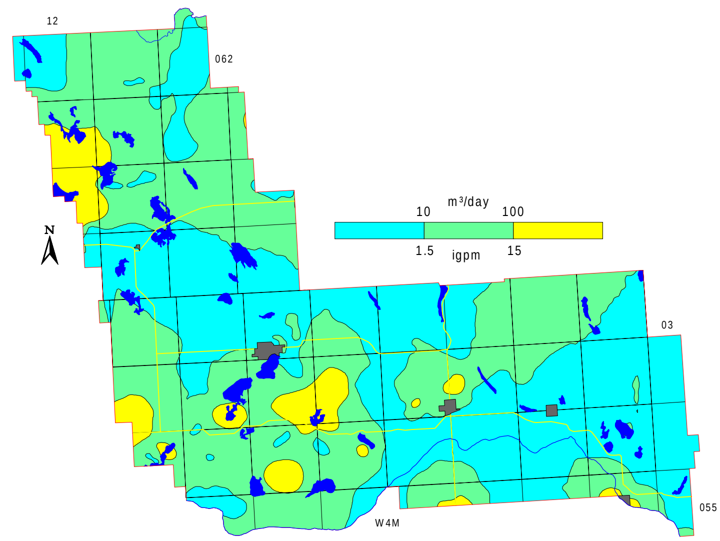

Figure 12. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

5.3.2.1 Chemical Quality of Groundwater

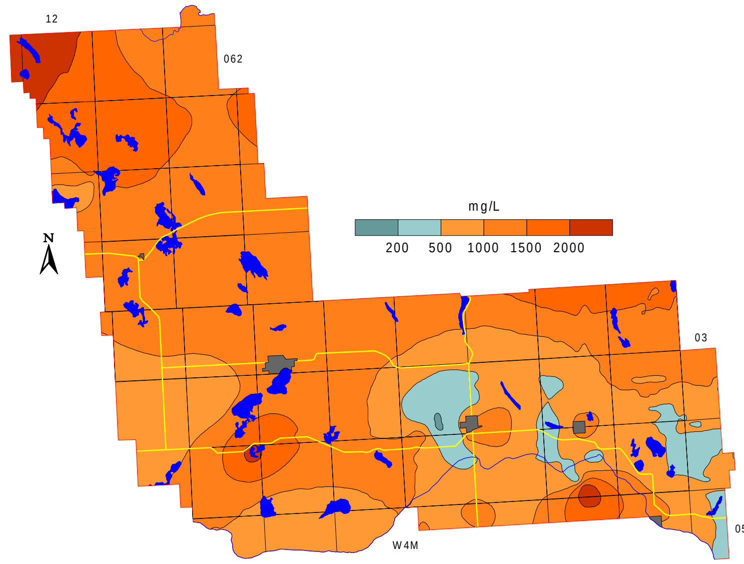

Figure 13. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The total dissolved solids (TDS) concentrations in the groundwater from the upper bedrock aquifers range from 300 to 3,000 mg/L. In more than 50% of the area, TDS values range from 1,000 to 2,000 mg/L. The values remain less than 1,000 mg/L in the eastern part of the County.

The low TDS areas west and east of Elk Point correspond to locations where lows in the bedrock surface, resulting from meltwater channels, are present. In the northwestern part of the County, where the upper bedrock is the Lea Park Formation, the TDS concentrations are expected to exceed 2,000 mg/L. The higher TDS values southwest of the Town of St. Paul occur in an area where the upper bedrock is the *continental* Foremost Formation. A relationship between TDS and sulfate concentrations shows that when TDS values exceed 1,200 mg/L, the sulfate concentration exceeds 400 mg/L.

The Piper tri-linear plots show that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are a sodium-bicarbonate type.

5.3.3 *Continental* Foremost Aquifer

The *continental* Foremost Aquifer is part of the *continental* Foremost Formation, which underlies approximately two thirds of the County. However, there are only eight water wells completed in the *continental* Foremost Aquifer north of township 058. The majority of the water wells completed in the *continental* Foremost Aquifer are south of the Town of St. Paul.

5.3.3.1 Depth to Top

The depth to the top of the *continental* Foremost Aquifer is mostly less than 100 metres. The largest area where the top of the *continental* Foremost Aquifer is more than 100 metres below ground level is in township 059, range 10, W4M, north of the Buried Beverly Valley.

5.3.3.2 Apparent Yield

The projected long-term yields for individual water wells completed through the *continental* Foremost Aquifer vary from less than 50 to more than 100 m³/day. The higher yields are mainly in the central part of the County, south and east of the Town of St. Paul. This area is on the south side of the Buried Beverly Valley and also is an area where the depth to the top of the Lea Park Formation is at its greatest. The higher yield areas appear to be related to weathering or fracturing.

The low-yield area between the towns of Elk Point and St. Paul corresponds to an area where the *continental* Foremost Aquifer is more than 50 metres thick but where there appears to be little or no fracturing or weathering of the *continental* Foremost Formation.

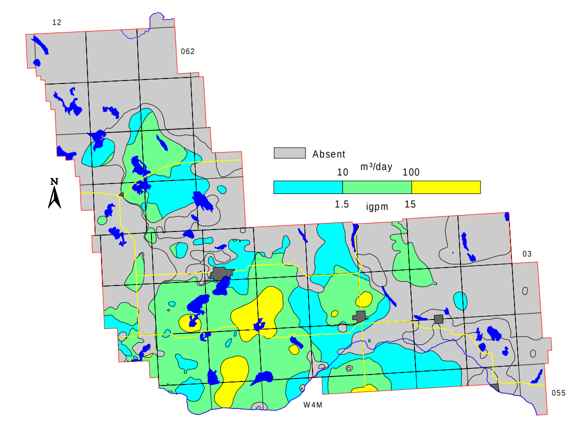

Figure 14. Apparent Yield for Water Wells Completed through* continental *Foremost Aquifer

5.3.3.3 Quality

The Piper tri-linear plots 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 concentration ranges from less than 500 to over 2,000 mg/L in the *continental* Foremost Aquifer. The groundwaters with a TDS of less than 500 mg/L occur west and north of the Town of Elk Point. Groundwaters with a TDS of over 1,000 mg/L can be expected in the central part of the area in townships 056 and 057, ranges 09 and 10, W4M. When TDS values exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

Very few chemical analysis results indicate a fluoride concentration above 1.0 mg/L.

The chloride concentration of the groundwater from the *continental* Foremost Aquifer ranges from less than 10 to over 100 mg/L. In the central part of the County, the chloride concentration is less than 10 mg/L, while in the northern and southern parts of the County, higher chloride concentrations occur.

5.3.4 Lea Park "Aquitard"

The Lea Park Formation is mostly composed of shale with only minor amounts of bentonitic sandstone present in some areas. Generally the Lea Park Formation is an aquitard. Since there are water wells completed in the Lea Park, the designation "aquitard" is being used to indicate that the Lea Park Formation can be permeable under special conditions. These conditions would include weathering and/or fracturing. The adjacent map shows that water wells completed in the Lea Park Formation are expected to have lower yields in the western and southern parts of the County. The control points in the northeastern and southeastern parts of the County are locations where the projected long-term yields for existing water wells exceed 30 m³/day, with some water wells having projected yields of several hundred cubic metres per day.

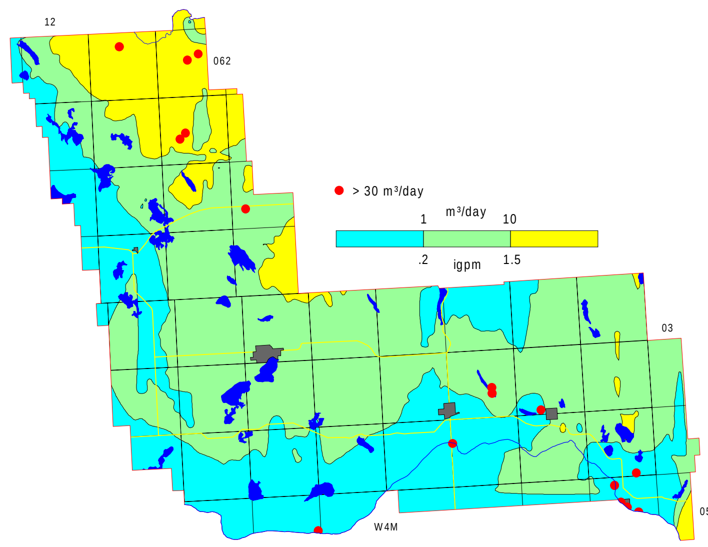

Figure 15. Apparent Yield for Water Wells Completed through Lea Park "Aquitard"

The existence of water wells completed in the Lea Park Formation is an anomalous condition based on the geology of the Formation. The high projected yields could be the result of collapsed structures and fracturing associated with the collapse process. It is also possible for the collapsed blocks to contain some of the Foremost Formation, which together with a high degree of fracturing and weathering, could be responsible for high transmissivity values and hence the high projected water well yields.

The TDS of the groundwater from the Lea Park Formation can be more than 3,000 mg/L. In the southern part of the County, near the North Saskatchewan River, the TDS concentration is less than 1,000 mg/L. These lower values are a result of the "flushing" of the aquifer by short, active groundwater flow systems. In the northern part of the County, the TDS are greater than 1,000 mg/L because of slower, longer groundwater flow paths.

6 GROUNDWATER BUDGET

Estimation of the groundwater budget for the sand and gravel aquifers and the bedrock aquifers requires different methods. This is because recharge to and discharge from the bedrock aquifers is mainly through the surficial deposits while most of the recharge to and discharge from the surficial deposits is from the land surface.

6.1 Aquifers in Surficial Deposits

The groundwater in the surficial deposits is the net result of recharge to and discharge from these deposits. The recharge is mainly from precipitation, although some groundwater enters the surficial deposits from the underlying bedrock. The discharge includes losses to bedrock aquifers, discharge from springs, evapotranspiration, and discharge from water wells. The change in the quantity of groundwater in the surficial deposits is apparent from the change in the water level associated with individual aquifers within the surficial deposits. Often these water-level changes are measured and recorded in water wells intended specifically for that purpose; these water wells are referred to as observation water wells. When a graph of the changes with time is prepared, it is referred to as a hydrograph.

6.1.1 Hydrographs

There are two observation water wells in the County where water levels are being measured and recorded with time. These observation water wells are part of the AEP groundwater-monitoring network. One of the observation water wells is in the west-central part of the County in 12-12-059-11 W4M (AEP Obs WW No. 392). This observation water well is completed in the Lower Sand and Gravel Aquifer in the depth interval from 120 to 128 metres below ground level. Water-level measurements are available from this observation water well from 1993 to 1996. Over this time frame, there has been a general decline in the water level of 0.3 metres.

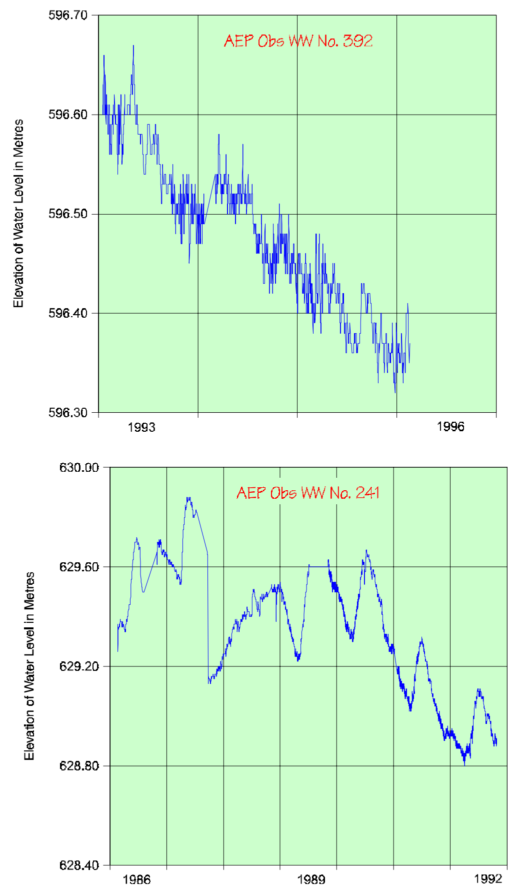

Figure 16. Hydrographs 392 and 241

The second observation water well is in the southern part of the County in 08-34-055-06 W4M (AEP Obs WW No. 241). The observation water well is 36.0 metres deep and is completed partially through the Upper Sand and Gravel Aquifer and partially through the upper bedrock, which is the *continental* Foremost Formation. Water levels were measured and recorded in this observation water well between 1986 and 1992. In 1987, there appears to be a discontinuity in the water-level record. Late in the year, the water level shows a decline of more than 0.5 metres in a day. Undoubtedly, this change was a result of re-calibration of the recording equipment. In late 1989, part of the water-level record is missing. Because of these breaks, it is difficult to determine what has been happening to the water level over the seven years of record. However, between 1990 and 1992, the water level did decline slightly more than 0.4 metres.

The 1989, 1990, 1991, and 1992 water-level changes in the AEP Obs WW No. 241 show a typical annual fluctuation in water level. This change includes a rise in the water level in late spring/early summer and then a decline in the water level from mid-summer to late-spring/early-summer of the following year. In 1989 and 1990, the rise in water level was more than 0.4 metres; in 1991 and 1992, the rise was approximately 0.3 metres. The rise in water level in late spring/early summer occurs after the frost has left the ground.

6.1.2 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is one to four cubic kilometres. This volume is based on an areal extent of 3,200 square kilometres and a saturated sand and gravel thickness of four 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).

Because the sand and gravel deposits are mainly confined aquifers, the change in water level in the aquifer remains a function of the storativity of the aquifer rather than the porosity. The storativity values for the sand and gravel range from 8.9×10^{-4} to 2.2×10^{-4}. Based on a storativity value of 5×10^{-4}, and an available drawdown[13] of 20 metres, a total volume of available groundwater from the confined aquifer is 0.03 cubic kilometres.

If the decline in water level in the AEP Obs WW No. 392 were representative of the entire County, the 0.3-metre decline in three years would represent a 480,000 m^3 decrease in the volume of groundwater in the aquifers. This decrease would be 1.6% of the estimated available groundwater from the sand and gravel aquifers without using the groundwater stored in the aquifer proper. The decrease in the volume of groundwater represented by the water-level decline could be a result of either a decrease in recharge or an increase in discharge.

The groundwater in the Lower Sand and Gravel Aquifer in the Buried Beverly Valley flows from west to east. Based of an average transmissivity of 30 m^2/day, a gradient of 0.004, and an average valley width of ten kilometres, total estimated flow for the Buried Beverly Valley is 1,200 m^3/day.

6.1.3 Recharge/Discharge

The hydraulic relationship between the groundwater in the sand and gravel aquifer and the groundwater in the bedrock aquifer is given by the non-pumping water levels 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.

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[13] See glossary

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

The hydraulic gradient between the surficial deposits and the bedrock aquifers has been determined by subtracting the non-pumping water levels in the surficial deposits from the non-pumping water levels in the bedrock. The bedrock recharge classification 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 area classified as a bedrock discharge area is one 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 area.

The adjacent map shows that over more than 80% of the County there is a downward hydraulic gradient between the surficial deposits and the bedrock aquifers. The main area where there is an upward hydraulic gradient is associated with buried valleys or meltwater channels that have been incised into the bedrock. The largest area of upward hydraulic gradient is in the Buried Beverly Valley north of the Town of St. Paul. This area is approximately the size of four townships and in this area, groundwater from the bedrock could recharge the sand and gravel aquifers in the surficial deposits.

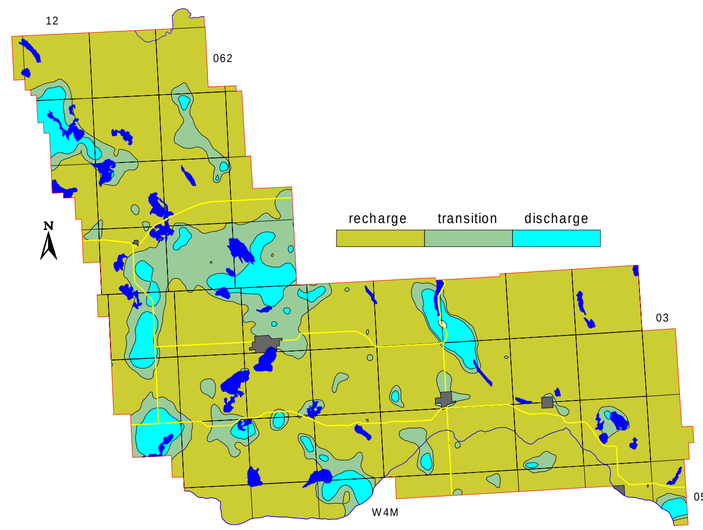

Figure 17. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

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

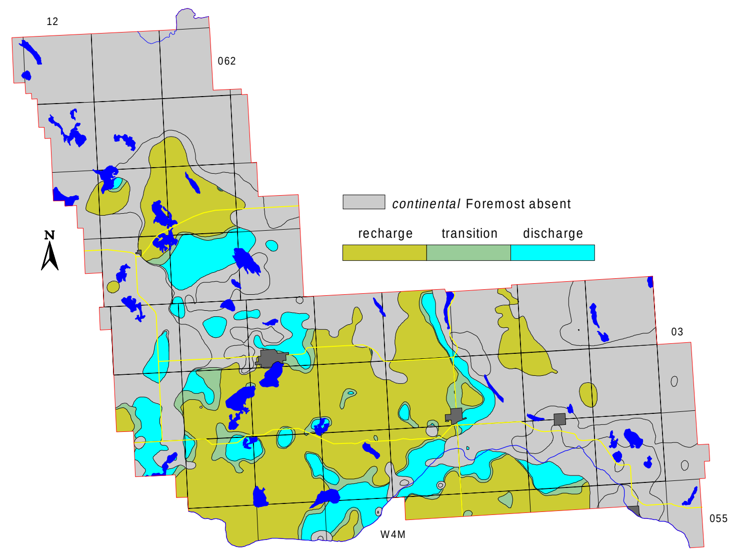

Figure 18. Recharge/Discharge Areas between Surficial Deposits and continental Foremost Aquifer

One area where an estimate of groundwater recharge to the bedrock has been attempted is south of the Town of St. Paul. In this area the upper bedrock is the *continental* Foremost Formation. The non-pumping water level indicates that most of the groundwater flows to the north or south of an east-west divide. The water-level map for the *continental* Foremost Aquifer shows that the hydraulic gradient is in the order of four metres per kilometre to the north of the divide and approximately the same to the south. With an average transmissivity for the Aquifer of 5 m²/day and an Aquifer width of 60 kilometres, the flow through the Aquifer would be 600 m³/day. Because there would be a similar set of conditions south of the divide, the total flow through the *continental* Foremost Formation near St. Paul would be 1,200 m³/day. This means that half of the groundwater is flowing toward the North Saskatchewan River Valley, and the other half of the groundwater is flowing toward the Buried Beverly and Vegreville Valleys.

No attempt has been made to estimate the flow through any other part of the *continental* Foremost Formation or any of the other bedrock aquifers.

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, the necessary action must be taken to minimize the risk of groundwater contamination.

The potential for groundwater contamination is based on the concept that the easier it is for a liquid contaminant to move downward, the easier it is for the groundwater to become contaminated. In areas where there is groundwater discharge, liquid contaminants cannot enter the groundwater flow systems to be distributed throughout the area. 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 3,164 records in the area of the County with lithology descriptions, 443 have sand and gravel within one metre of ground level. In the remaining 2,721 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 2. Risk of Groundwater Contamination Criteria

The Risk of Groundwater Contamination map shows that, over 35% of the County, there is a high or very high risk of the groundwater being contaminated. These areas would be considered the least desirable ones for groundwater 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 does not affect groundwater quality.

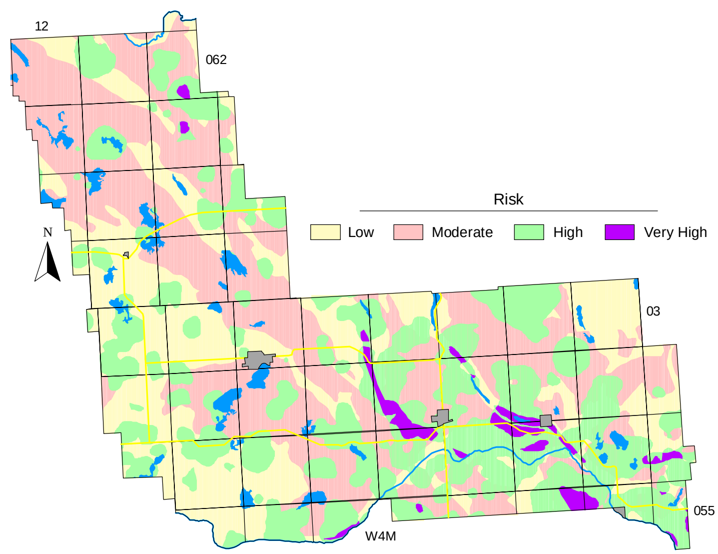

Figure 19. Risk of Groundwater Contamination

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.

In addition to the quality of the information in the database, there is only a limited understanding of the distribution of individual geological units, both in the bedrock and the surficial deposits. The complexity of the depositional environment and a limited amount of subsurface control exacerbate the problem of trying to develop digital surfaces. The best example of this is the indication of significant yields for water wells completed in the Lea Park Formation, which is generally thought of as an aquitard. This anomaly can only be explained by conducting a detailed investigation of the local conditions. This would require a detailed program involving geophysical techniques and test drilling. Because of the broad nature of the condition, a study would need to be completed to better define the anomaly and provide direction for a field program.

Another area of concern is the determination of a groundwater budget. Two observation water wells are totally inadequate to obtain meaningful values 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.

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 (2 hours of pumping and 2 hours of recovery) should be performed with the water well to obtain a realistic estimate for the transmissivity of the aquifer in which the water well is completed.
3. Water samples should be collected for chemical analysis after 5 and 115 minutes of pumping, and analyzed for major and minor ions.

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

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

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

Groundwater is a renewable resource and it must be managed.

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10 GLOSSARY

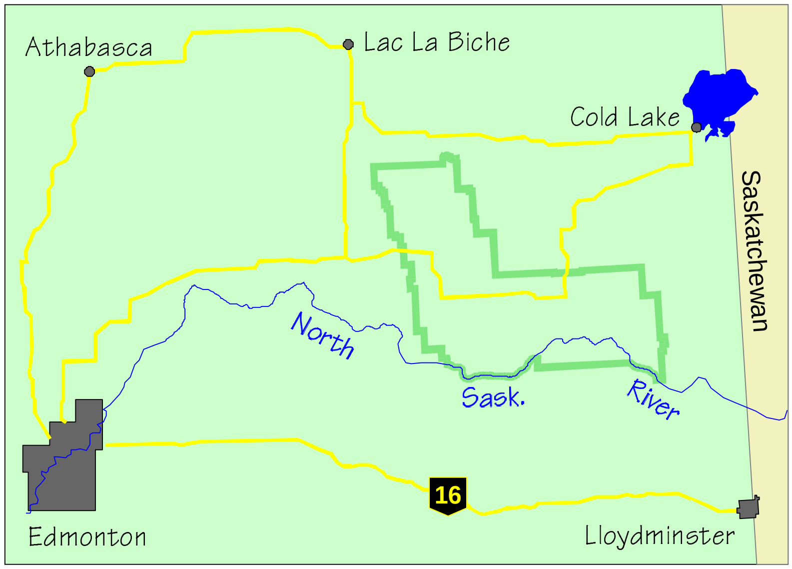
Apparent Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer.
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells 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.

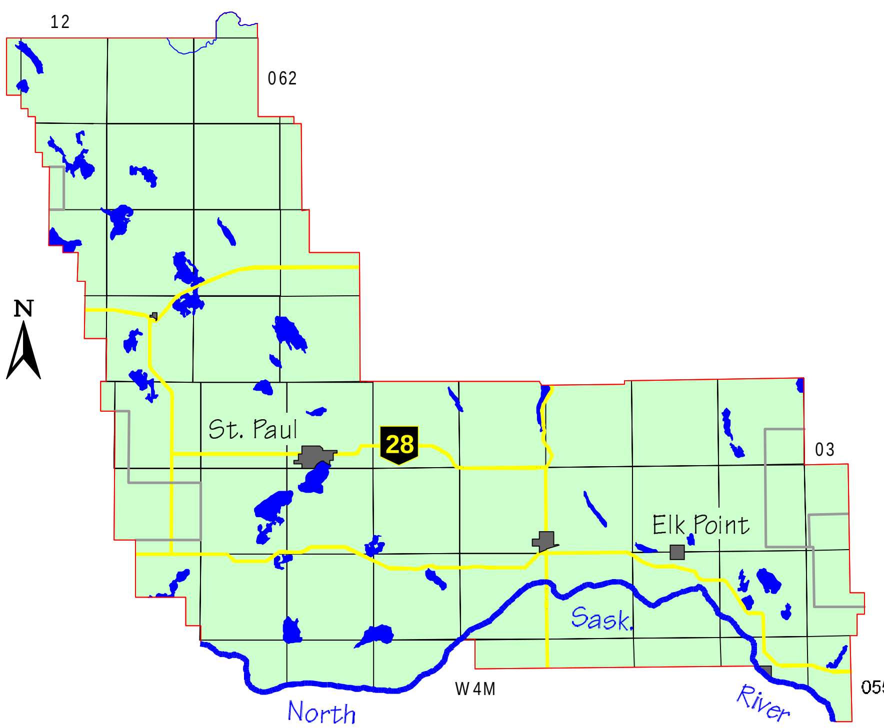
COUNTY OF ST. PAUL NO. 19

Appendix A

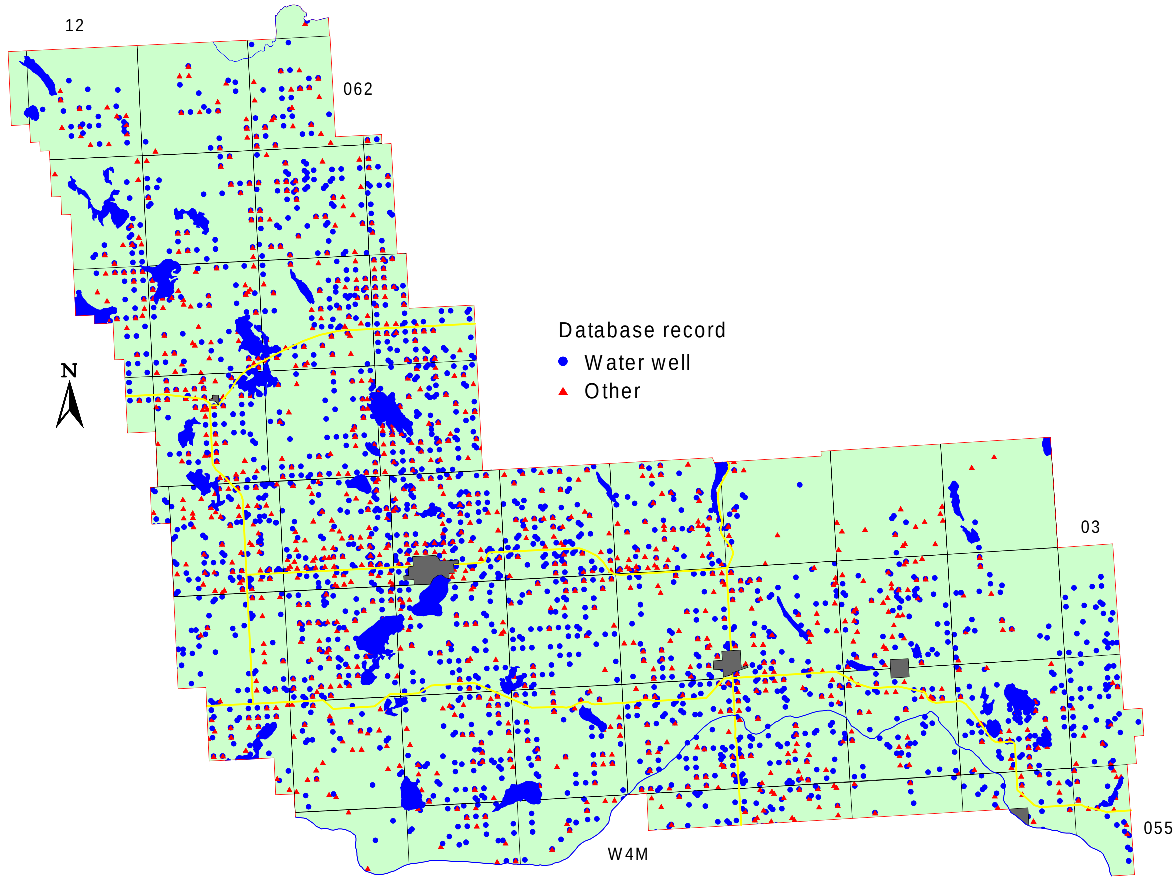
HYDROGEOLOGICAL MAPS AND DIAGRAMS

Index Map

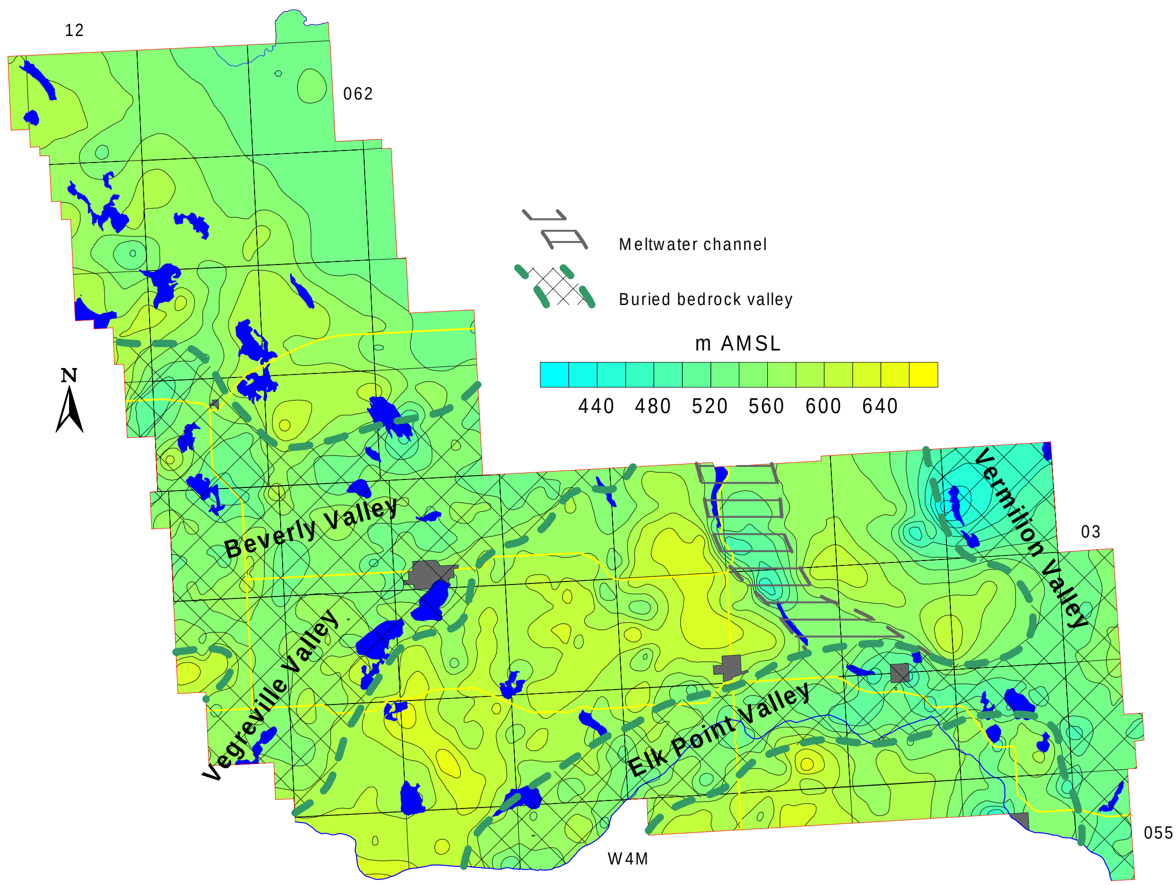

Athabasca
Lac La Biche
Cold Lake
Saskatchewan
North
Sask.
River
Edmonton
16
Lloydminster


12
062
N
St. Paul
28
03
Elk Point
Sask.
055
W4M
North
River

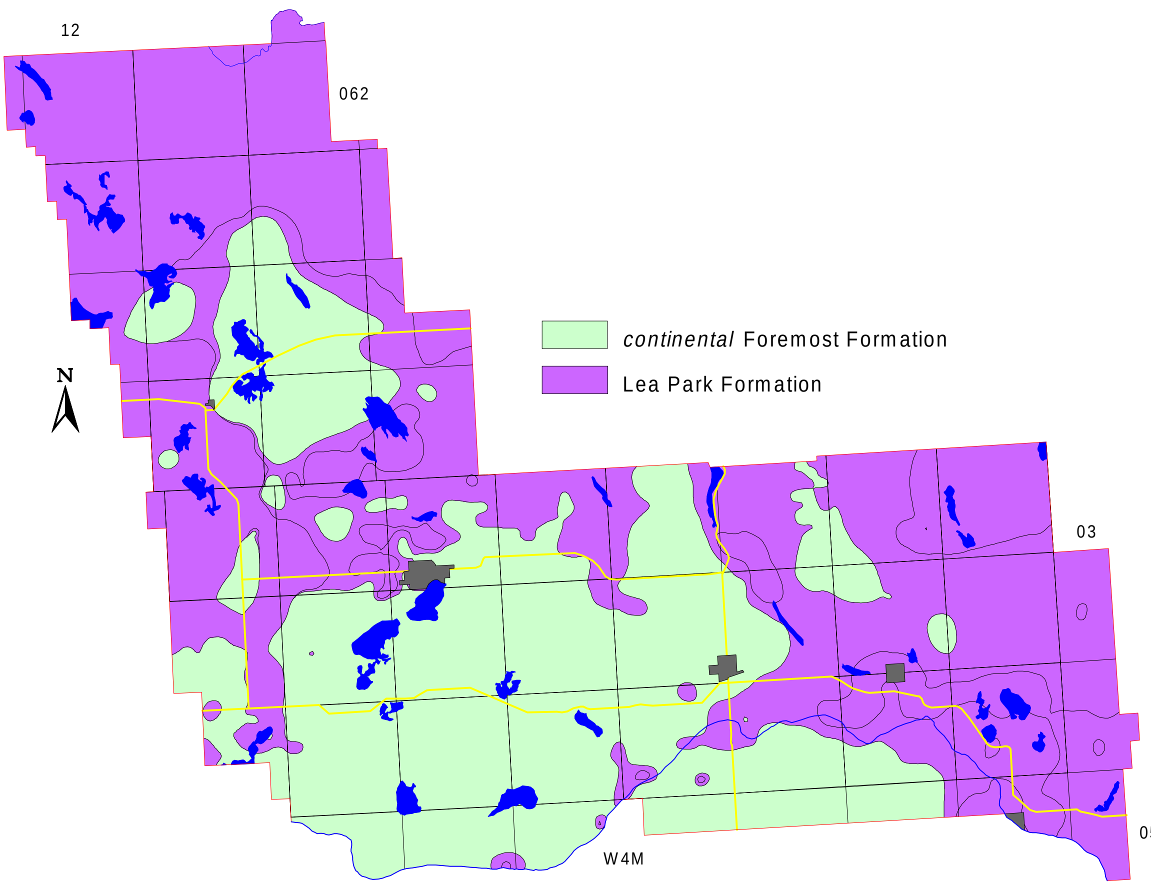
Location of Water Wells

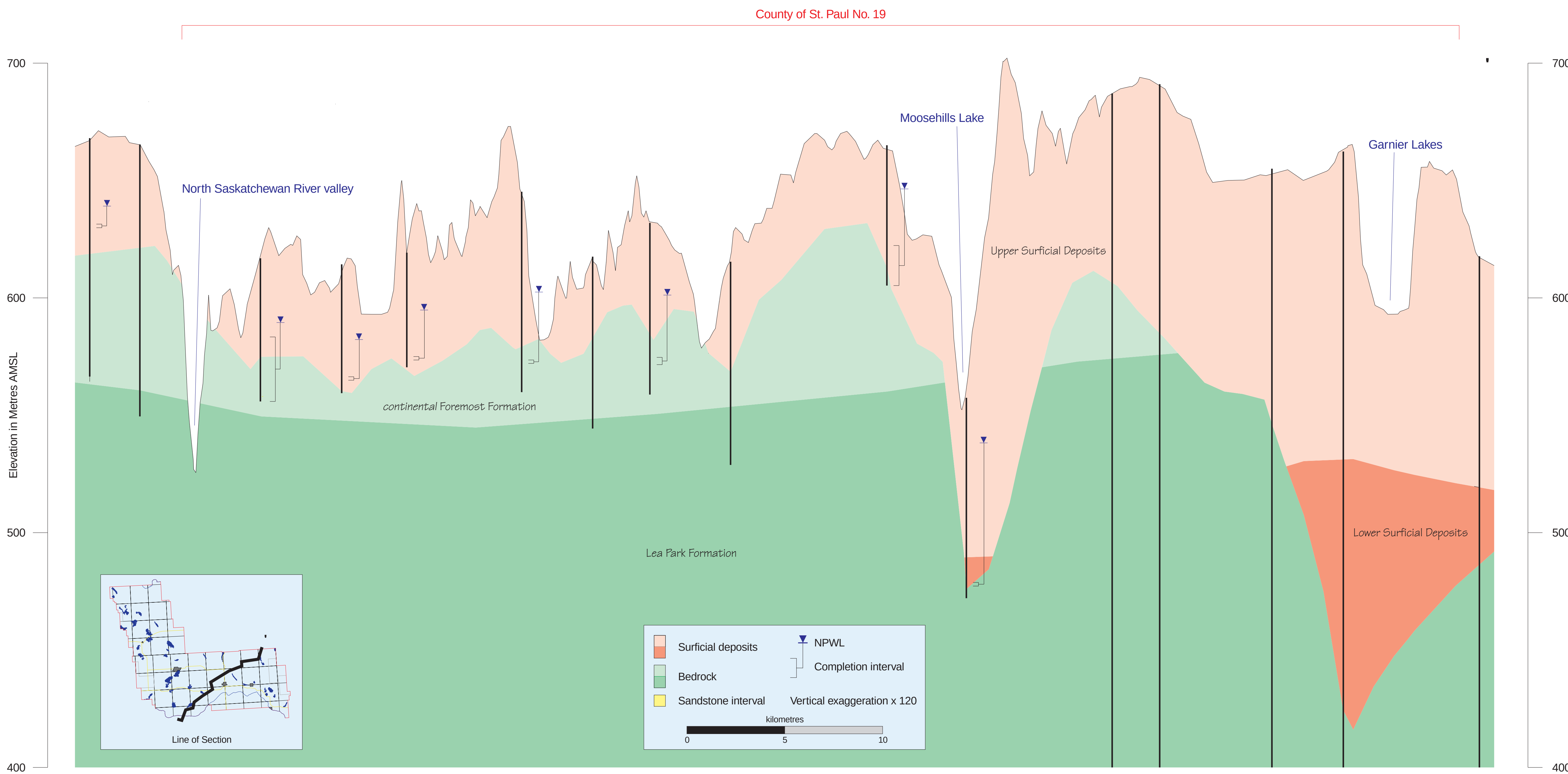


Bedrock Topography

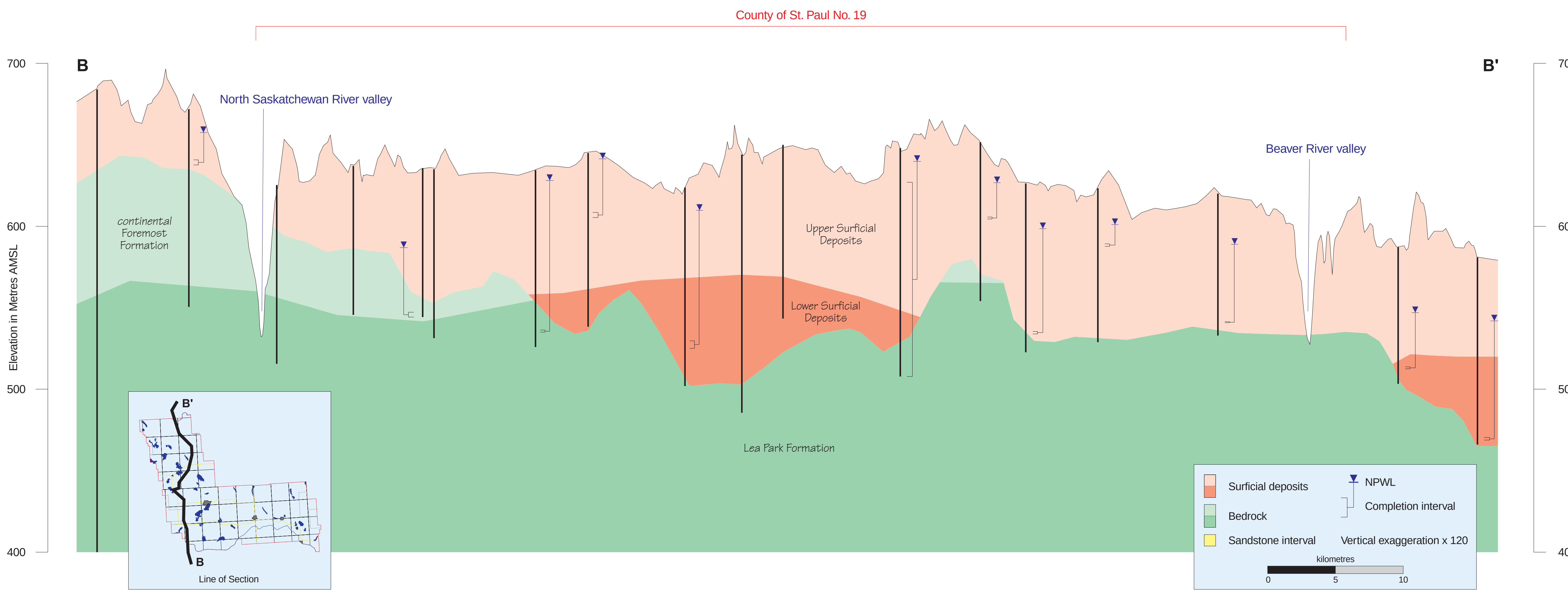


Bedrock Geology





Cross-Section A - A'



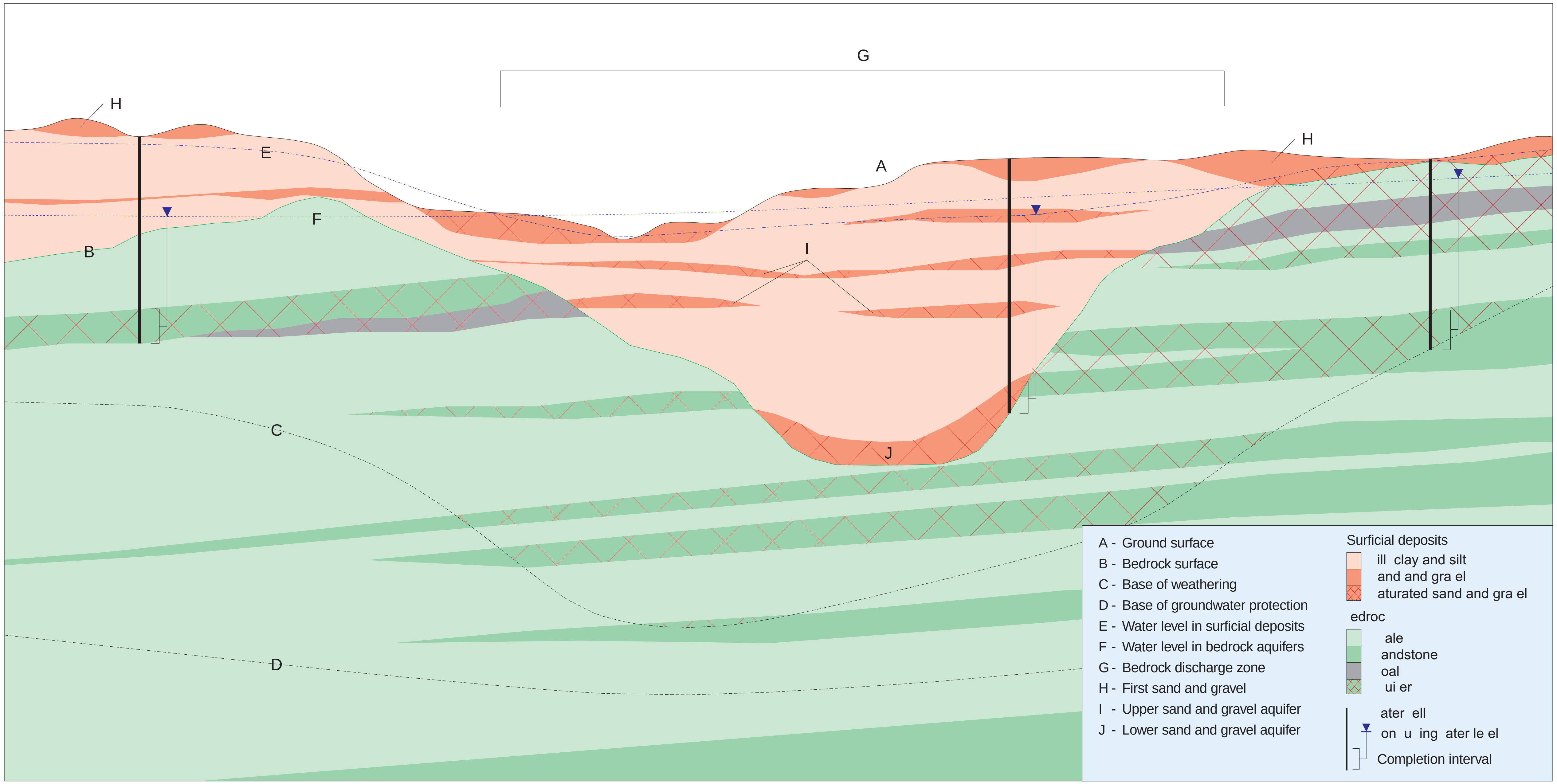
Cross-Section B - B'

hydrogeological consultants ltd.

Lithologic description	Formation and Group Thickness	Formation and Group Designation	Member Thickness	Member Designation	Zone Thickness	Zone Designation
sand, gravel, till, clay, silt	0-150	Surficial Deposits	0-150	Upper Surficial Deposits	0-30	First Sand and Gravel
			0-50	Lower Surficial Deposits		
shale, sandstone, coal	10-220	Belly River Group: *continental* Foremost Formation			0-20	Taber Coal Zone
					0-20	McKay Coal Zone
sandstone, shale	0-200	Belly River Group: *marine* Foremost Formation (Basal Belly River Sandstone)	0-30	Birch Lake Member		
			0-30	Ribstone Creek Member		
			0-30	Victoria Member		
			0-30	Brosseau Member		
shale, siltstone	100-200	Lea Park Formation	50-100	Upper Lea Park		
			50-100	Lower Lea Park (Milk River Formation)		
shale, siltstone	200-1000	Colorado Group				

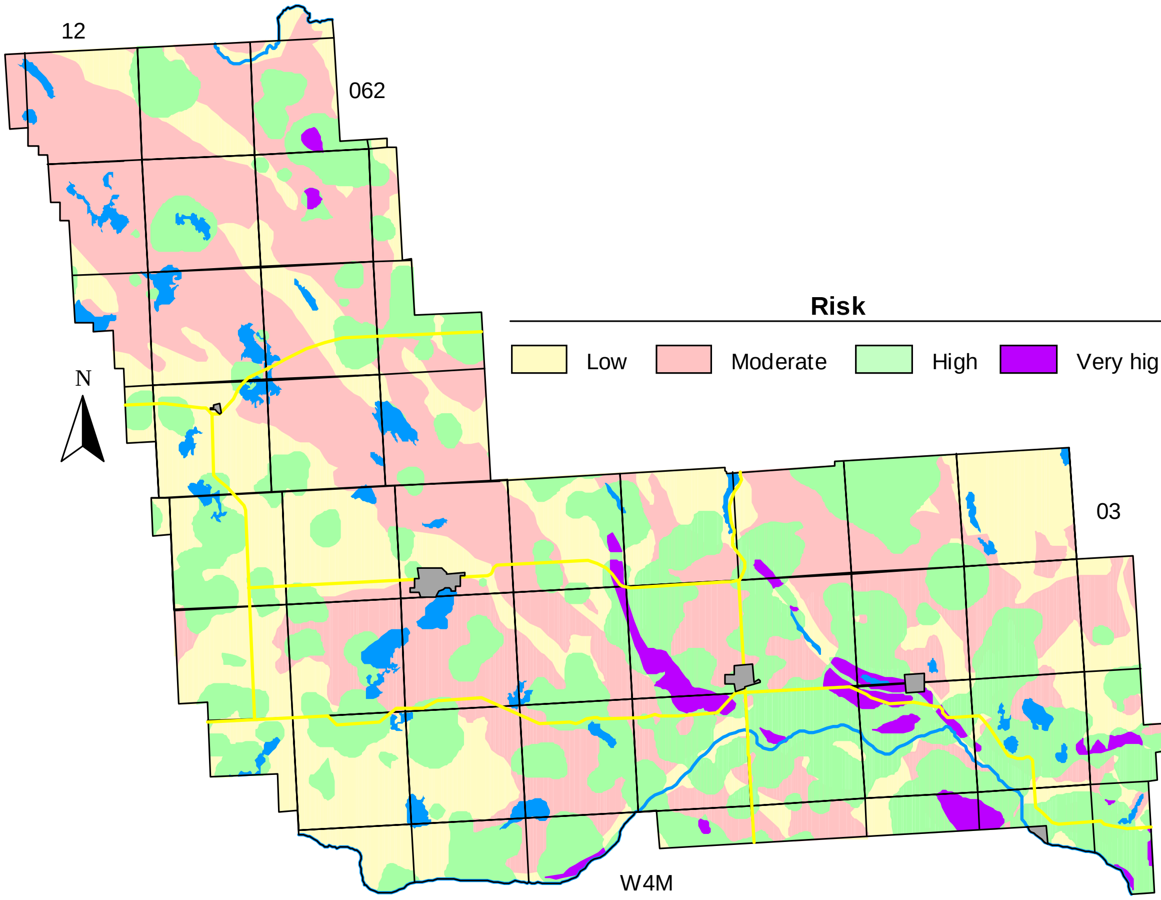
Depth (m): 0, 100, 200, 300, 400, 500, 600, 700, 800, 900

Geologic Column

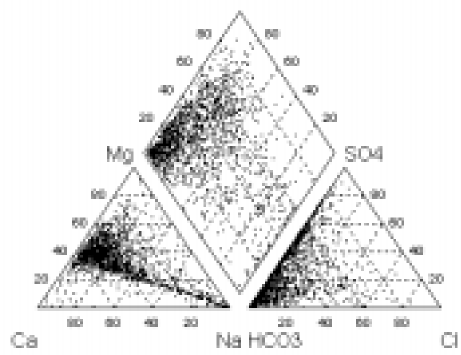


Generalized Cross-Section
(for terminology only)

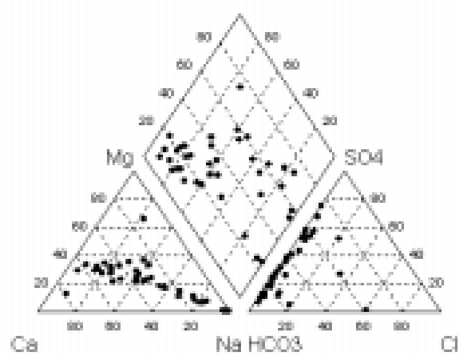
Risk of Groundwater Contamination



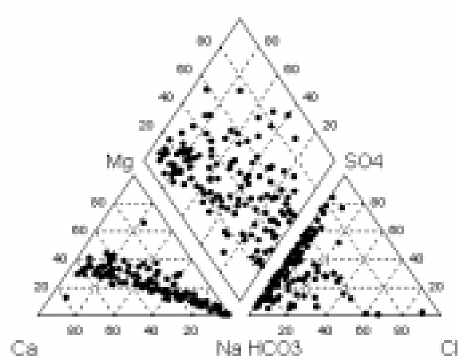
Piper Diagrams



Surficial Deposits

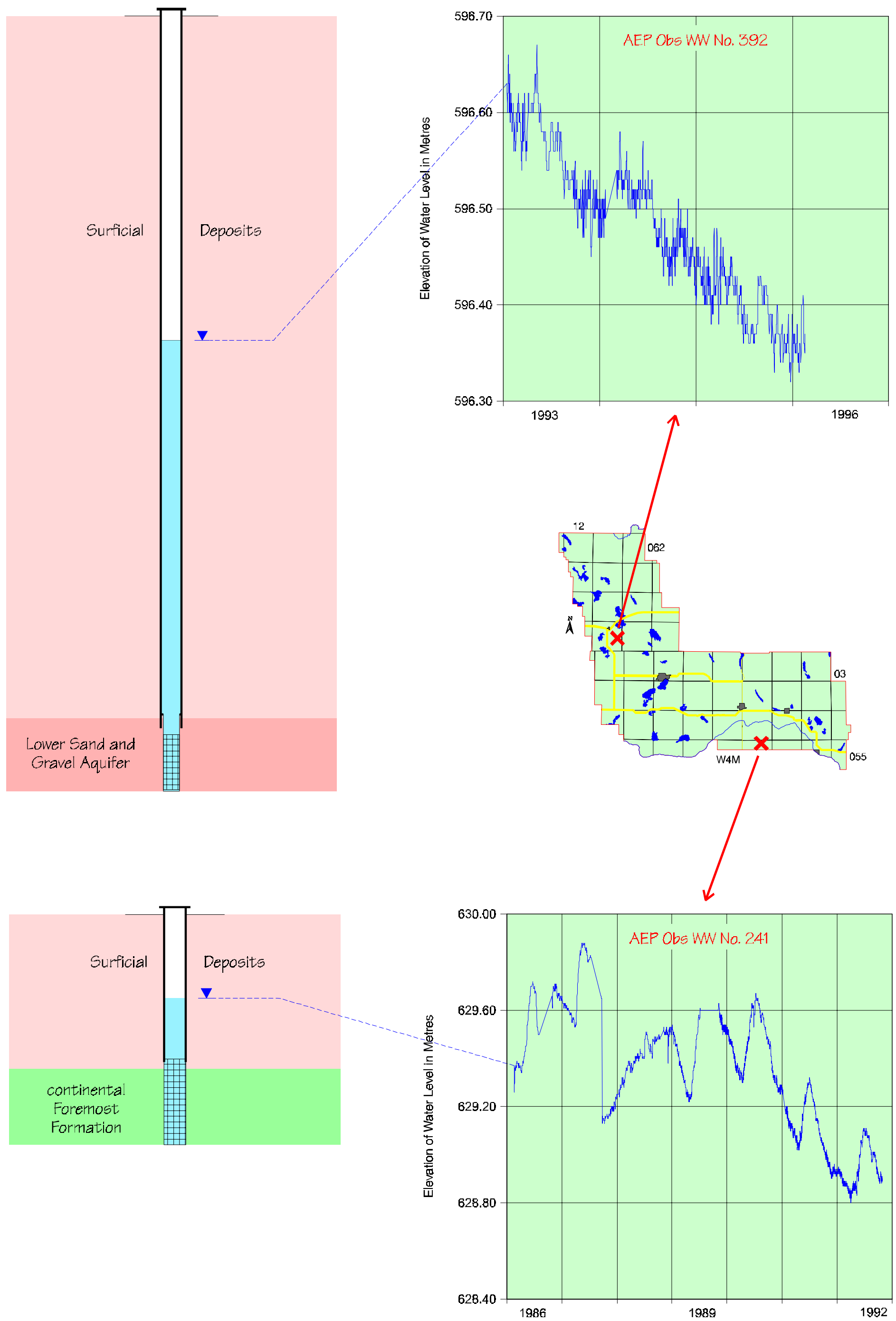


***continental* Foremost Aquifer**

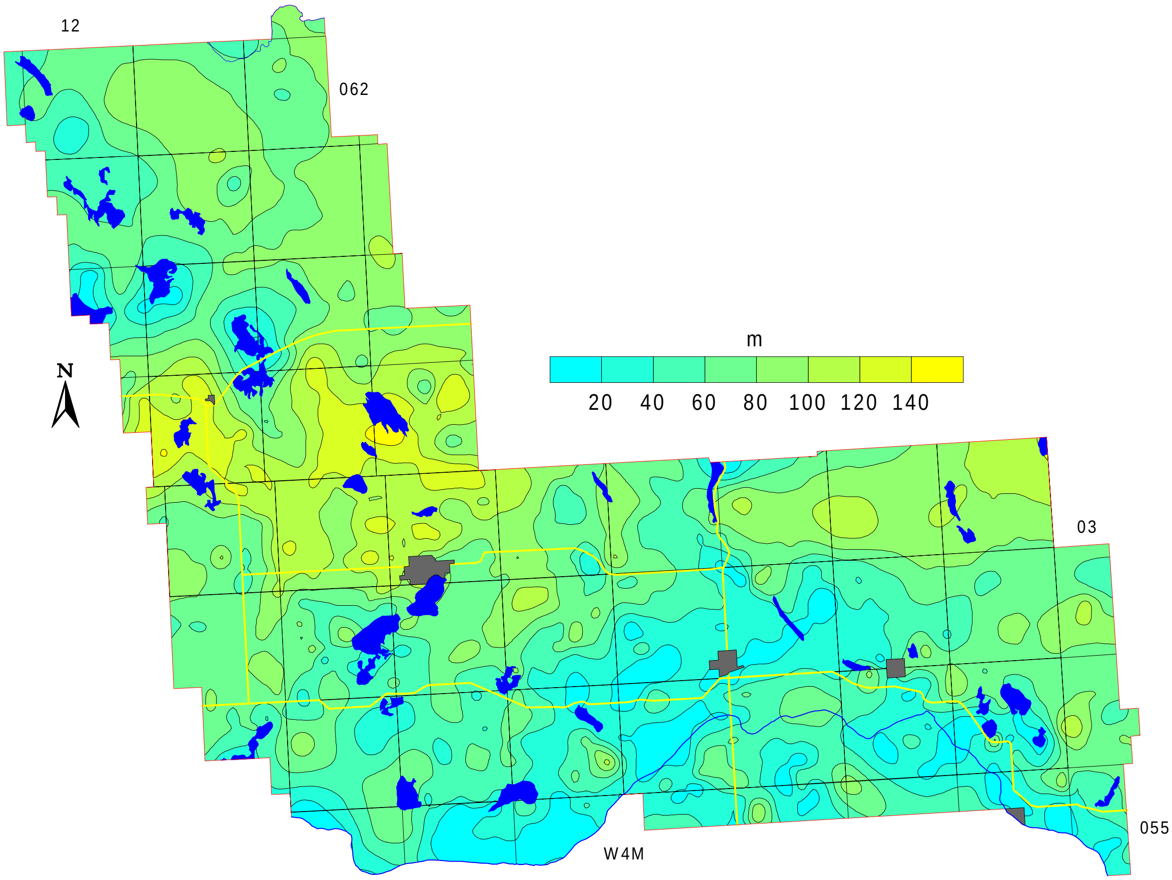


Upper Bedrock Aquifer(s)

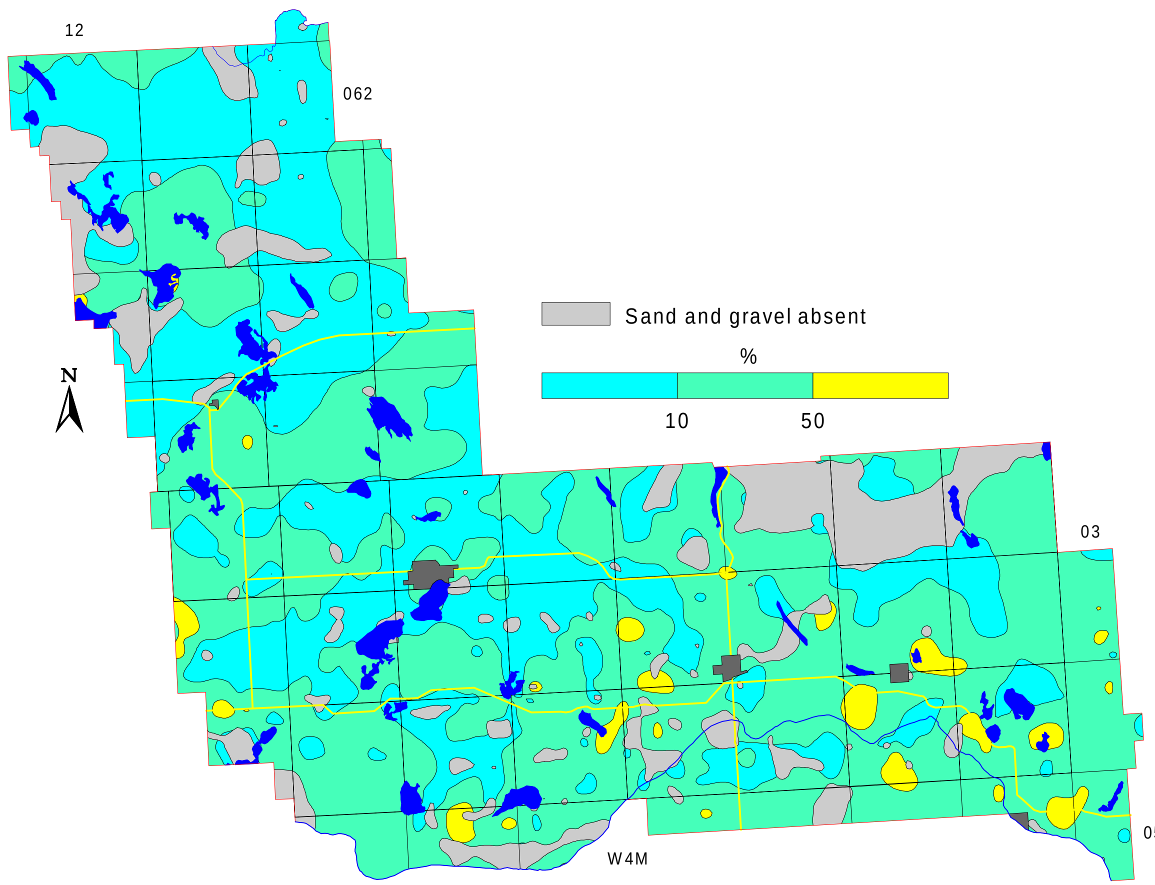
Hydrographs – AEP Observation Water Well Nos. 392 and 241



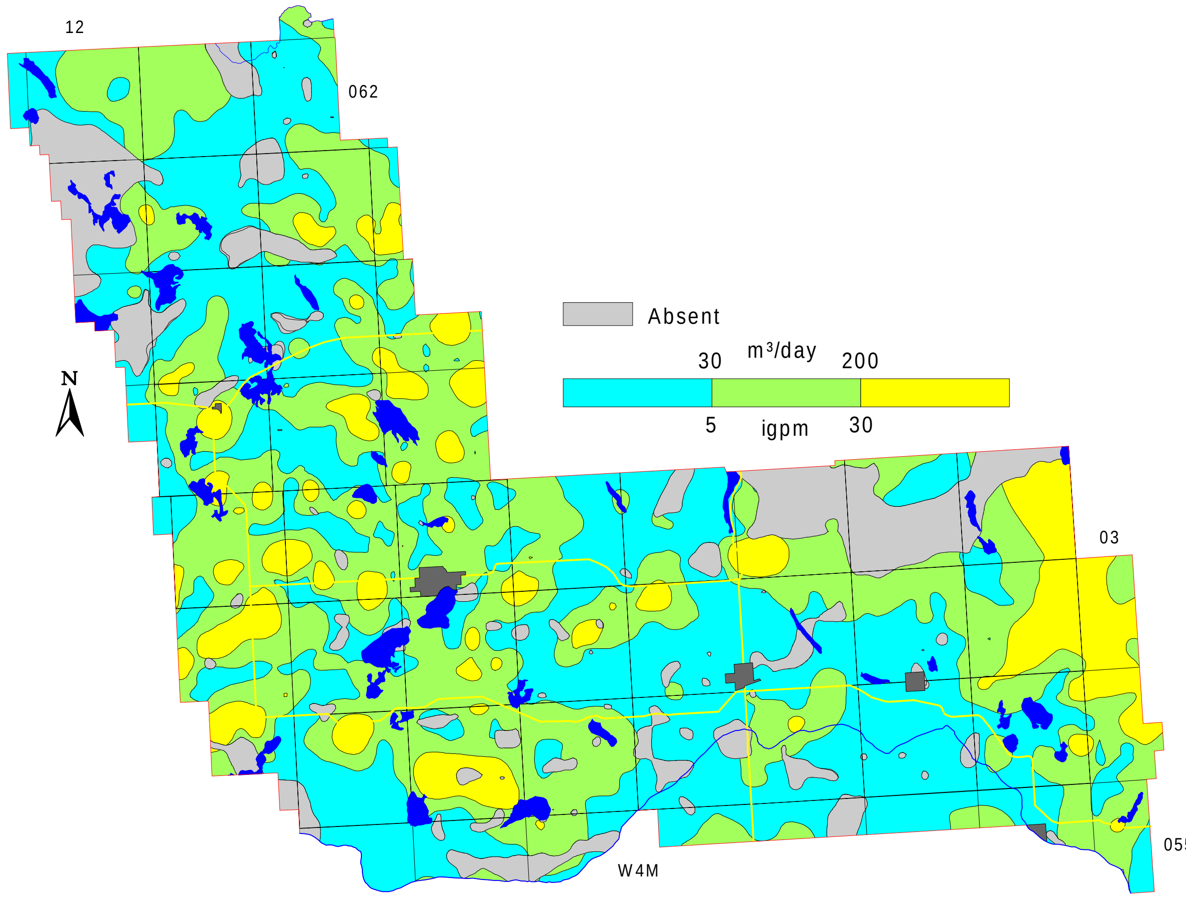
Thickness of Surficial Deposits



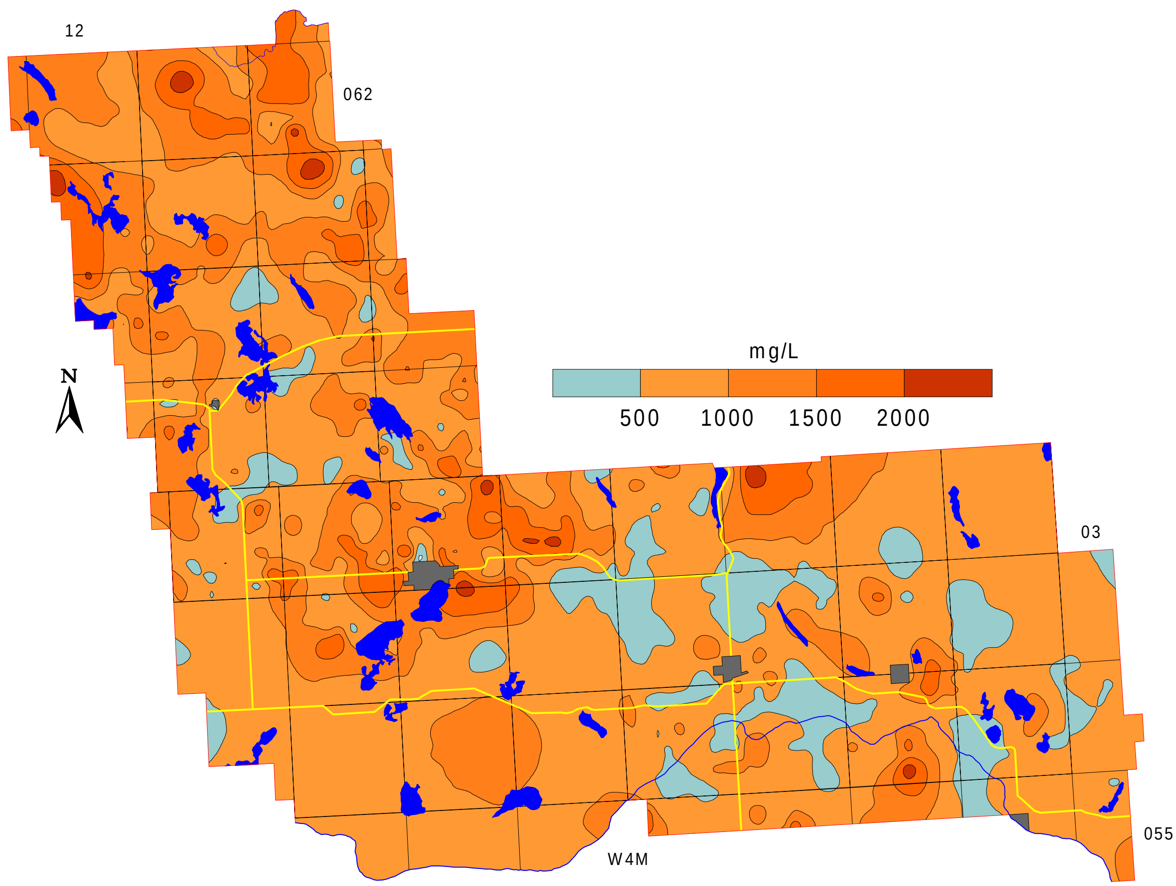
Amount of Sand and Gravel in Surficial Deposits



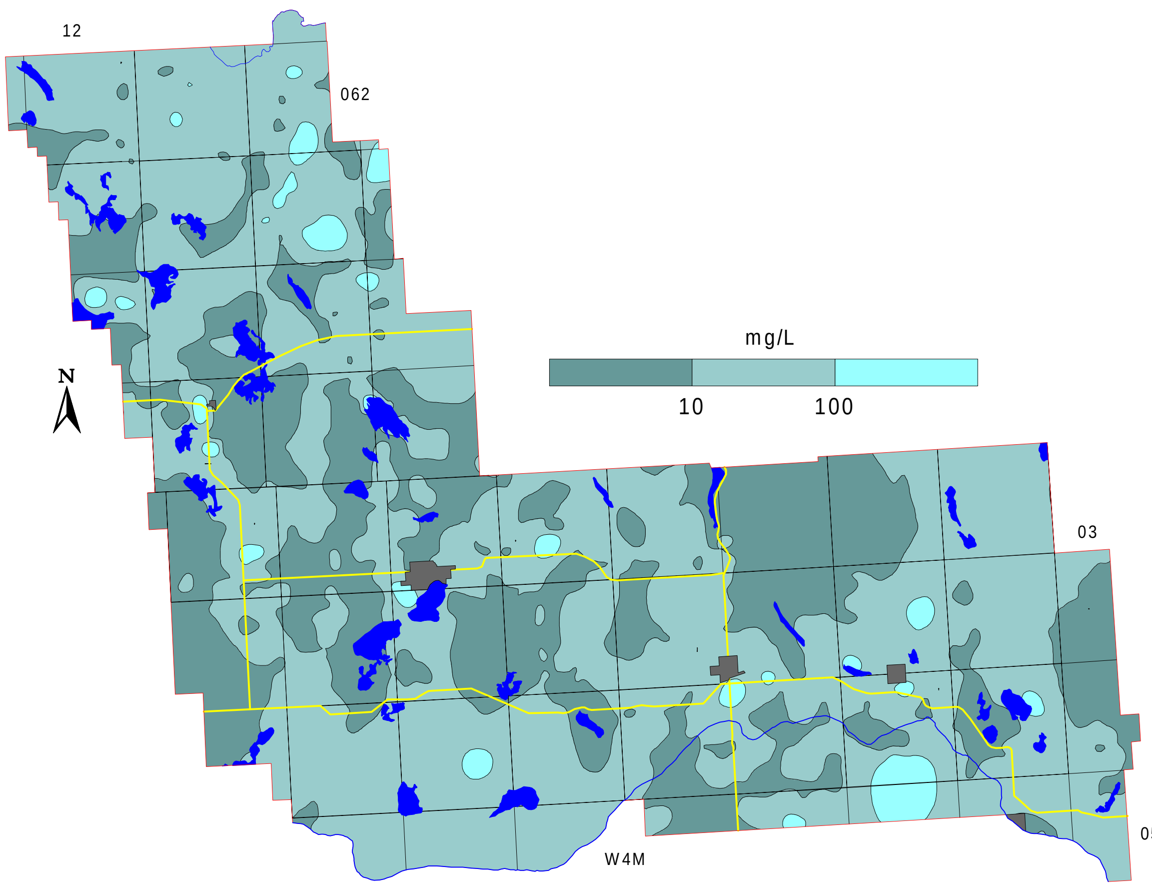
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



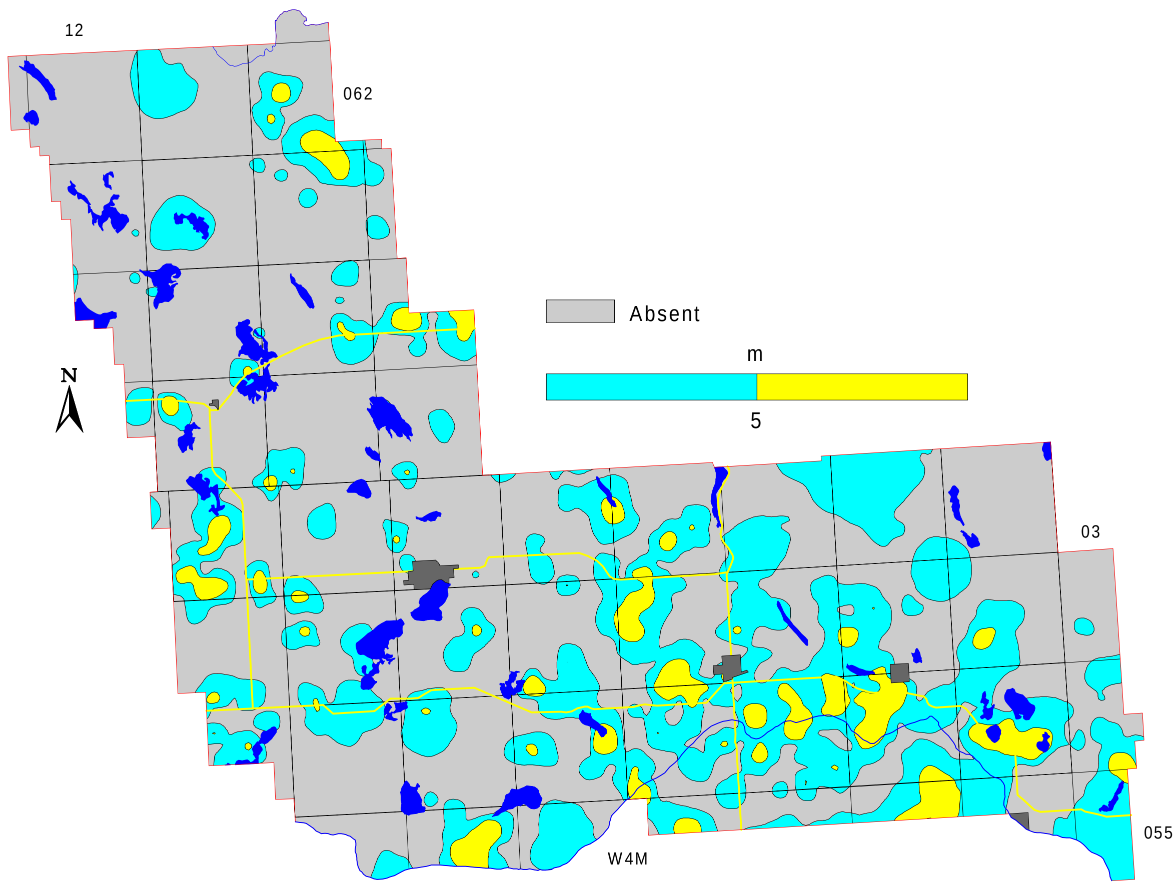
Total Dissolved Solids in Groundwater from Surficial Deposits



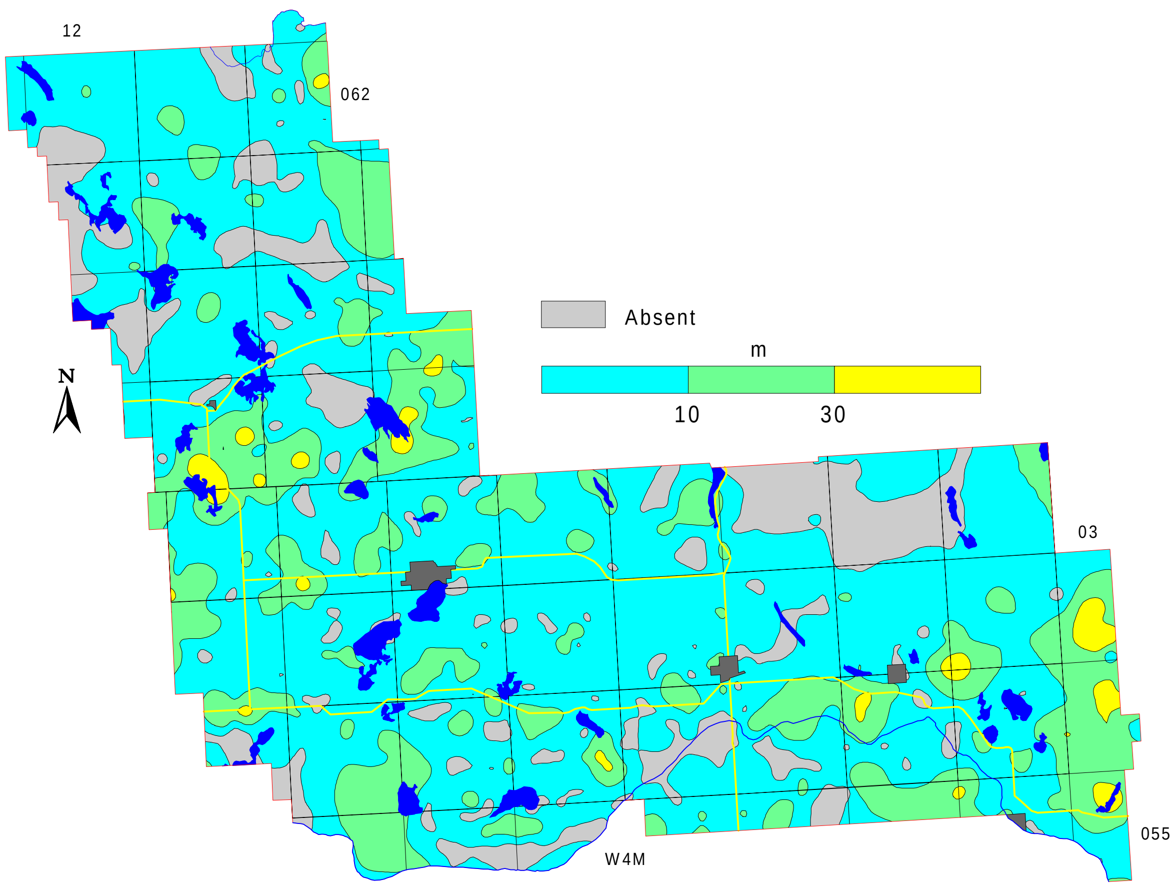
Chloride in Groundwater from Surficial Deposits



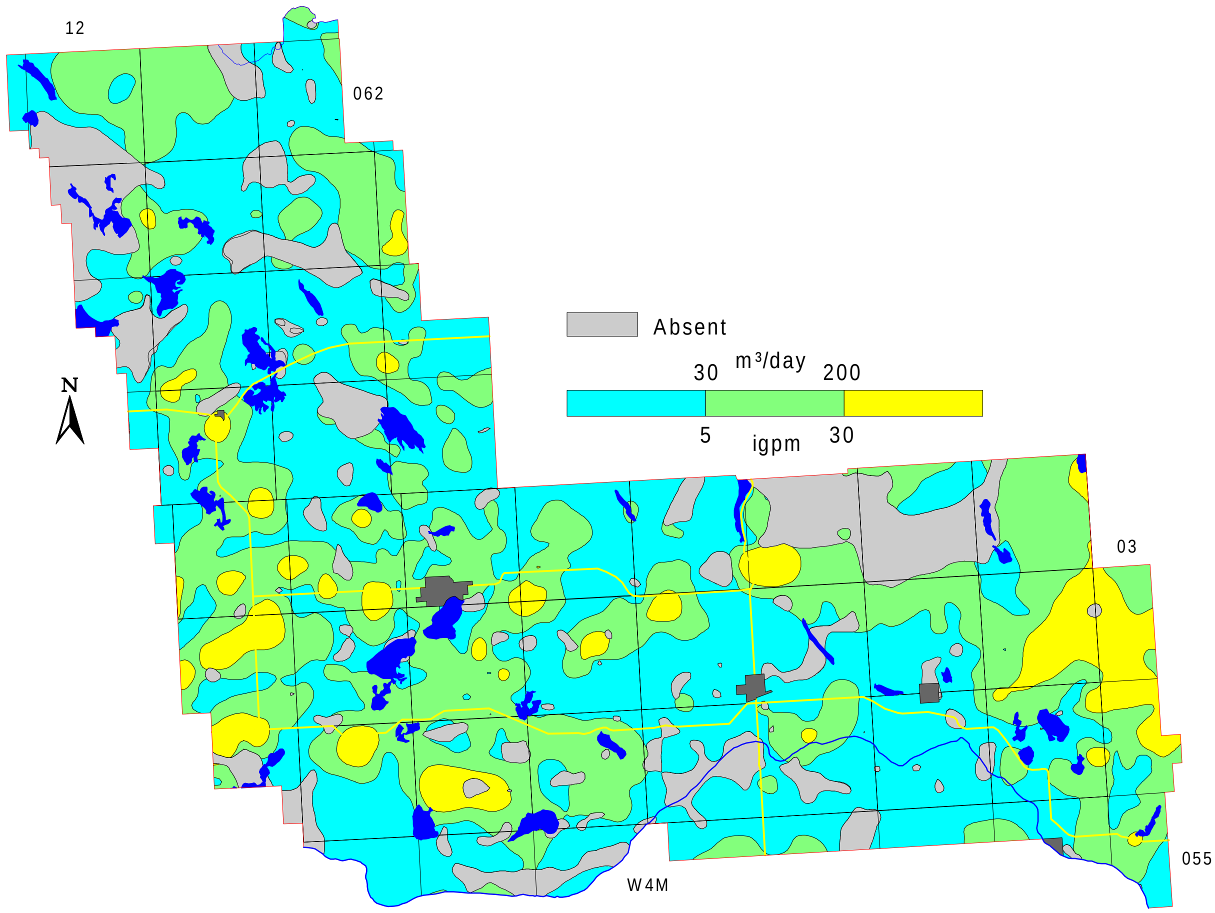
Thickness of First Sand and Gravel



Thickness of Upper Sand and Gravel
(Not all drill holes fully penetrate surficial deposits)

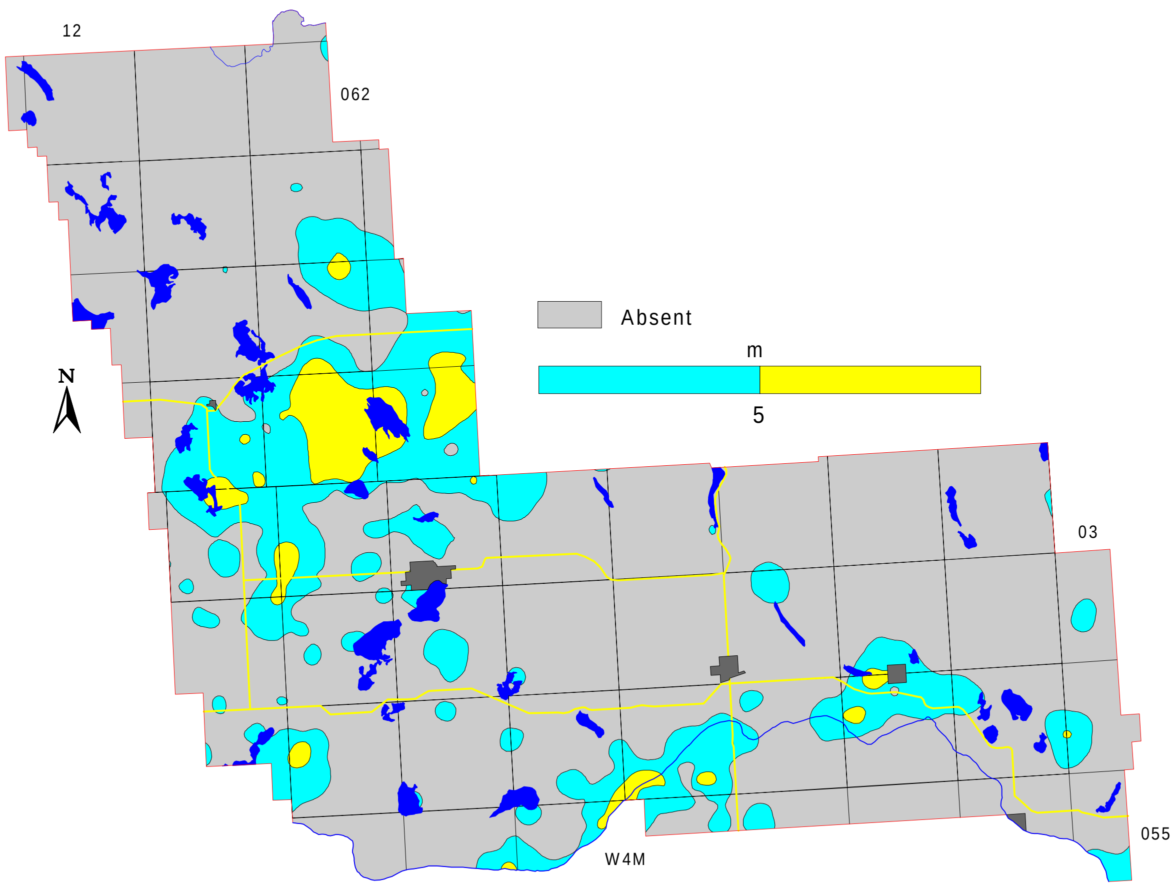


Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

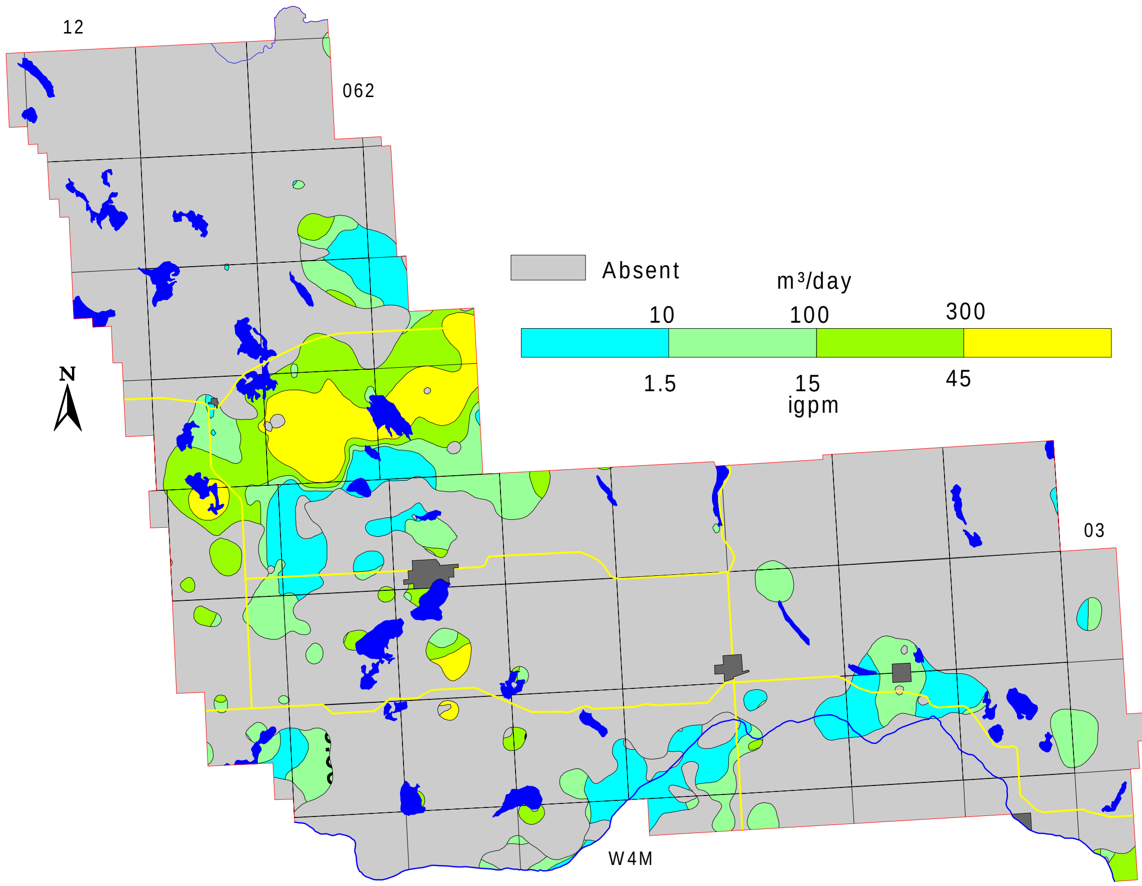


Thickness of Lower Sand and Gravel Aquifer

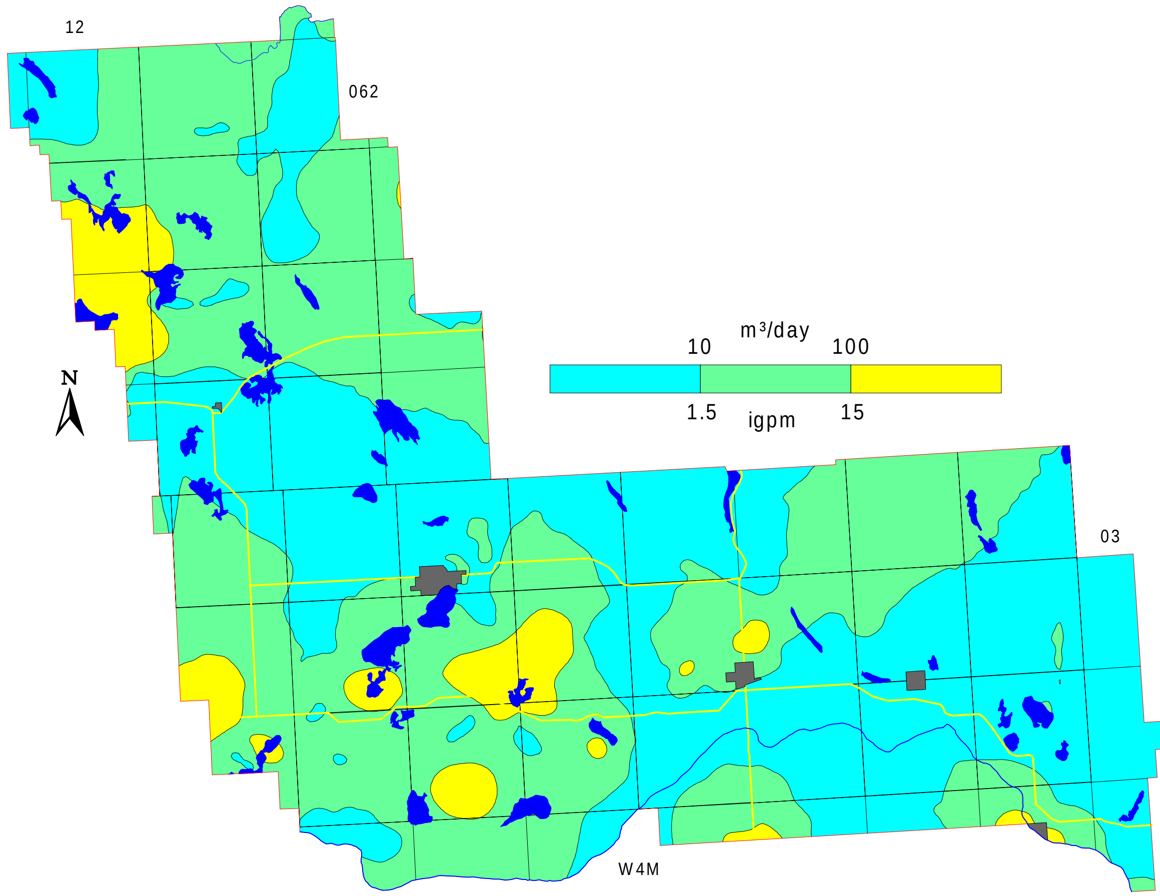
(Not all drill holes fully penetrate surficial deposits)



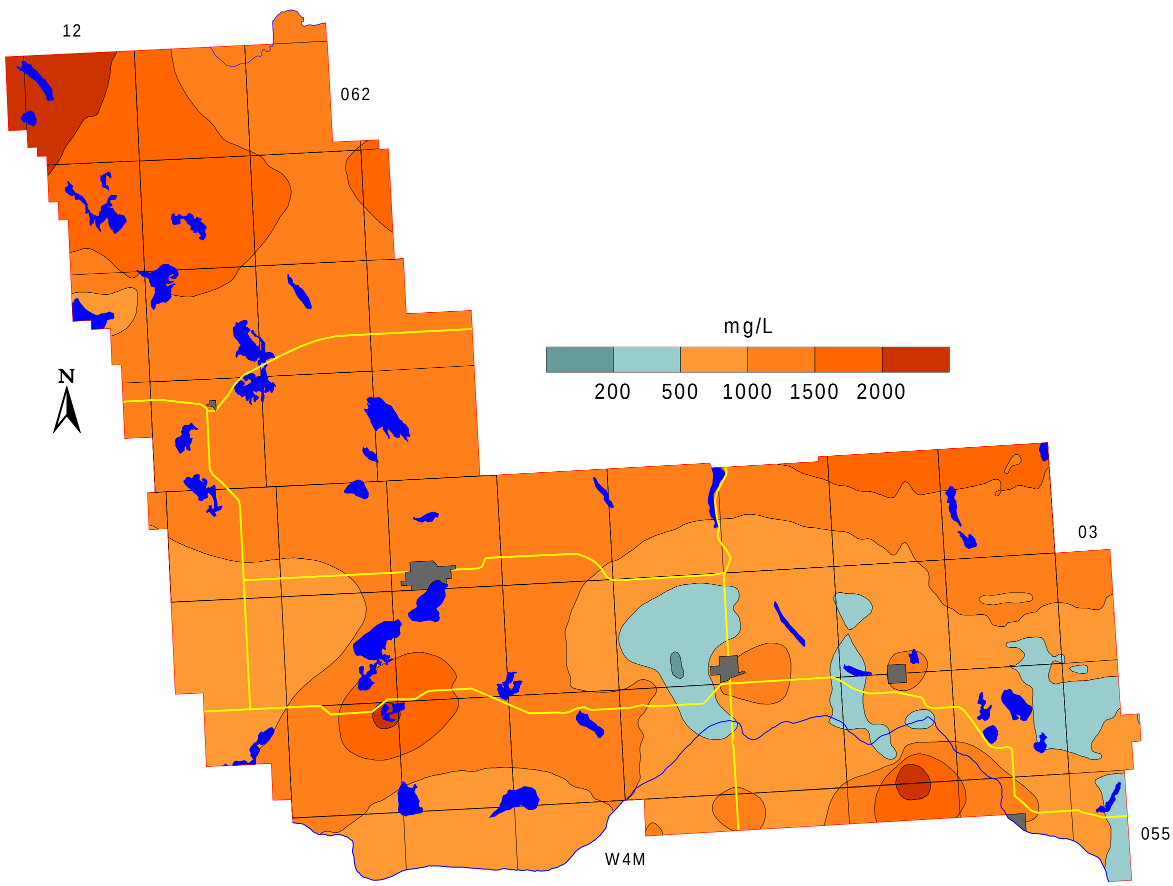
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



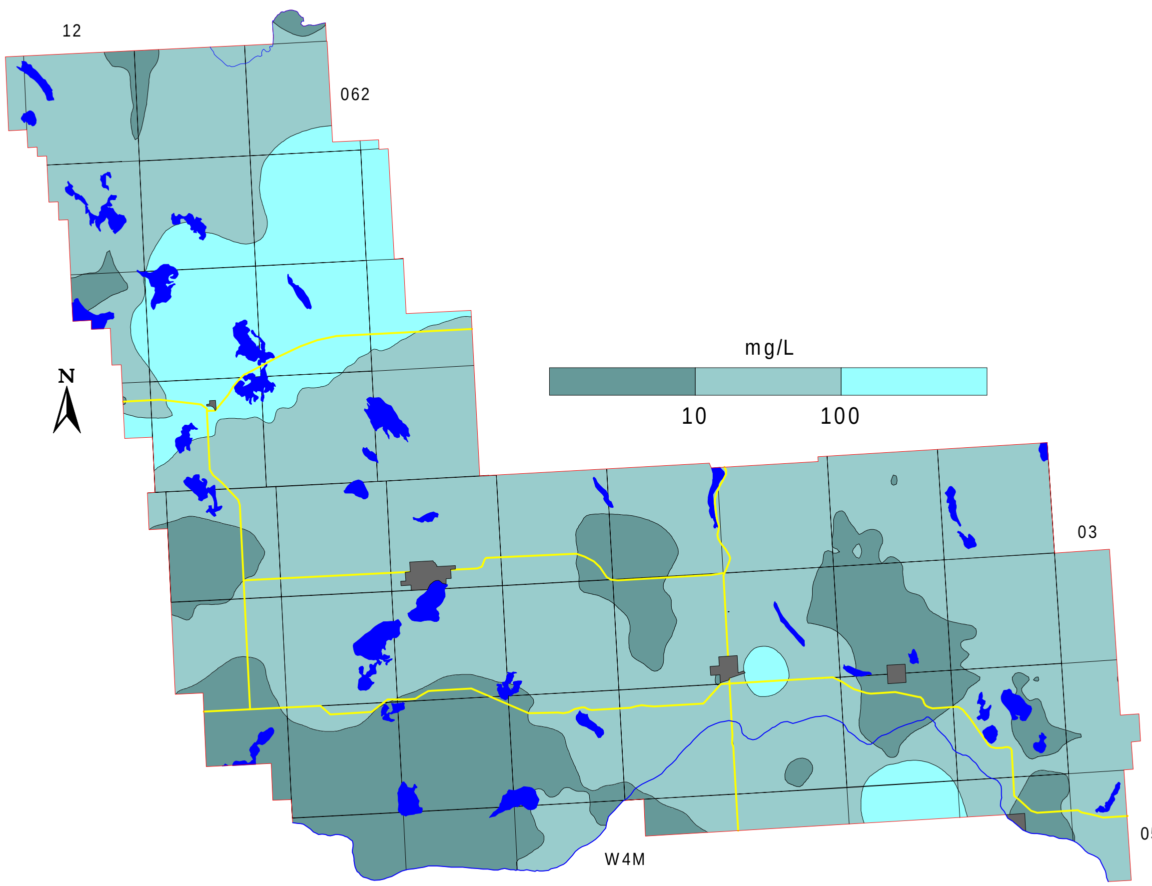
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



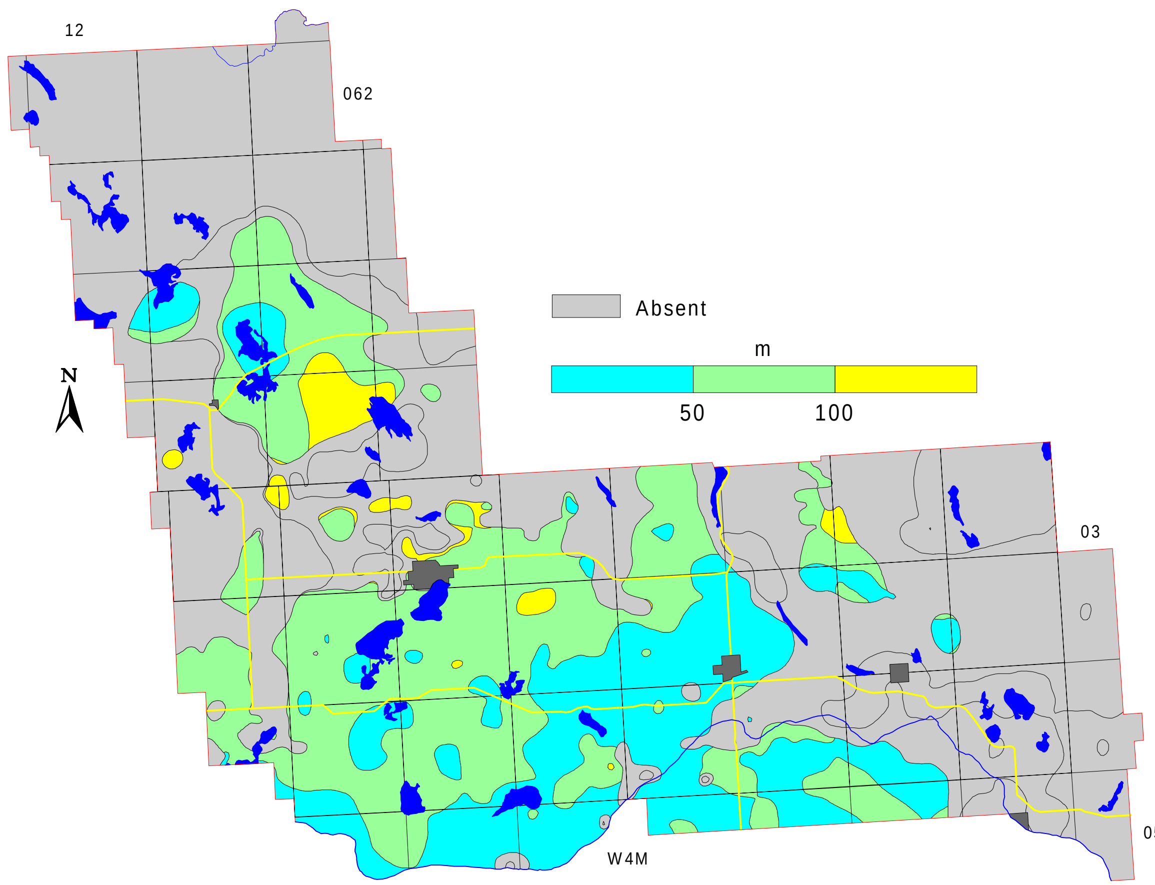
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



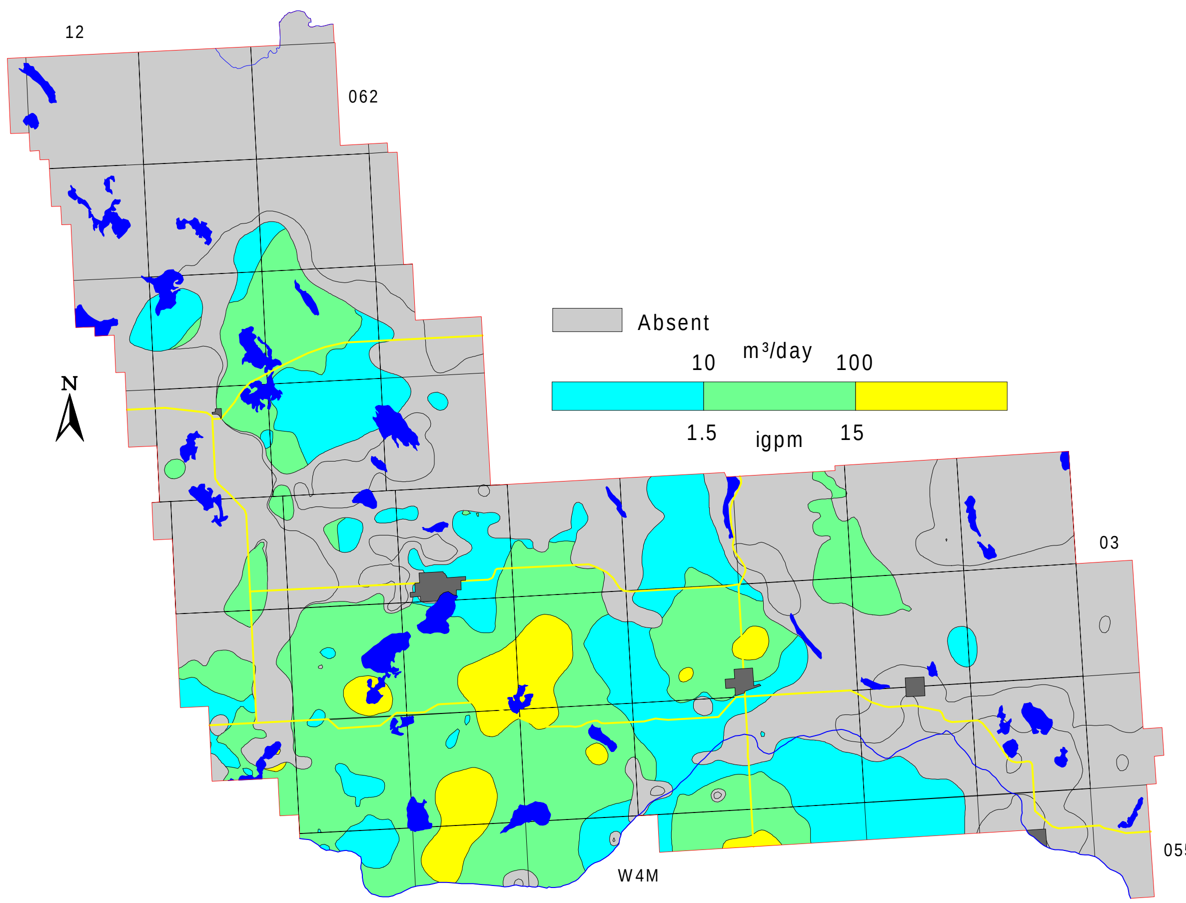
Chloride in Groundwater from Upper Bedrock Aquifer(s)



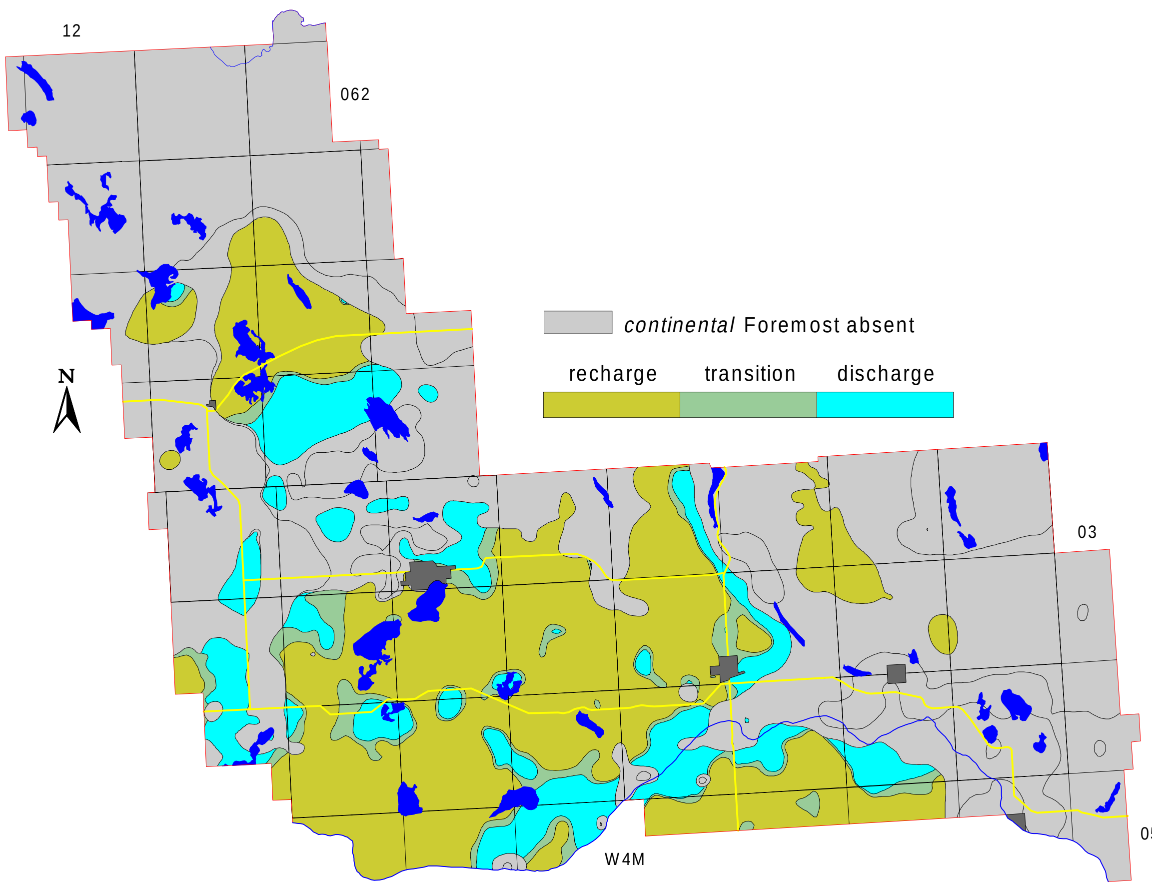
Depth to Top of continental Foremost Formation



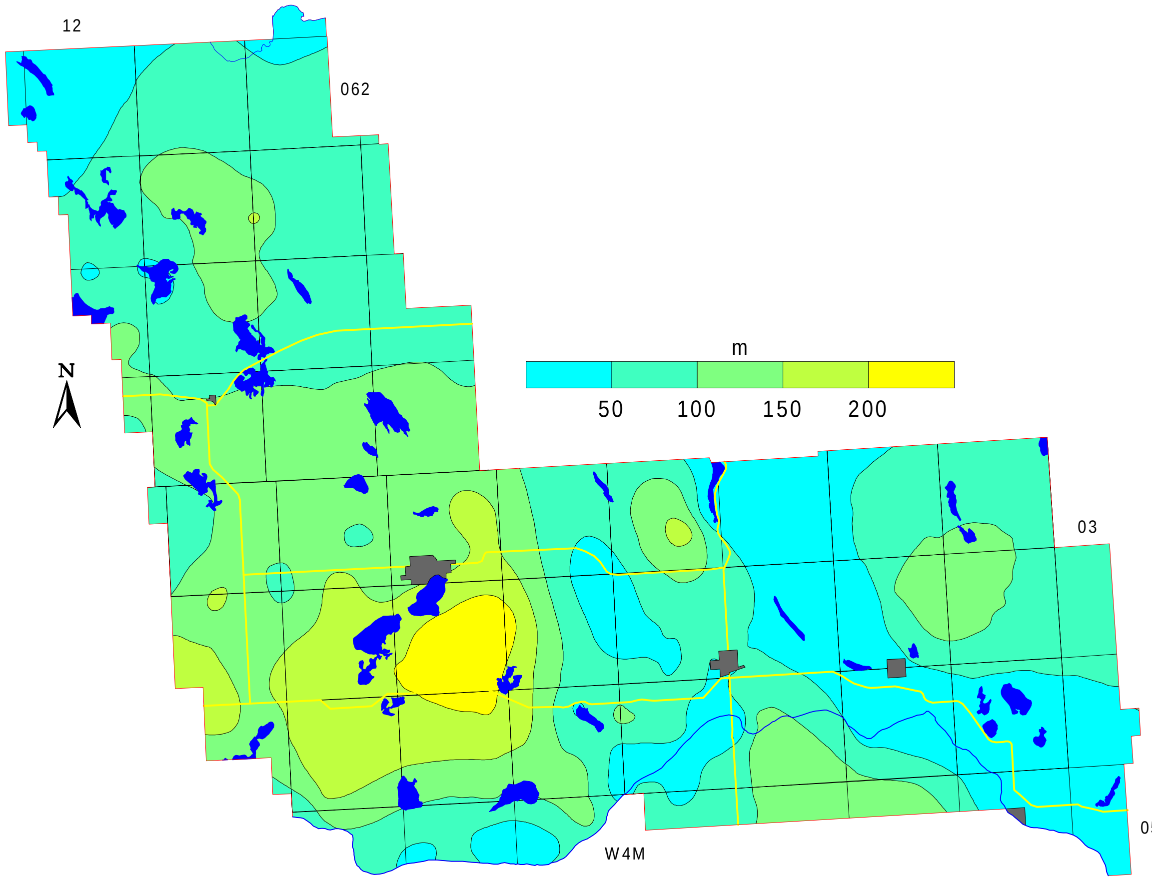
Apparent Yield for Water Wells Completed through continental Foremost Aquifer



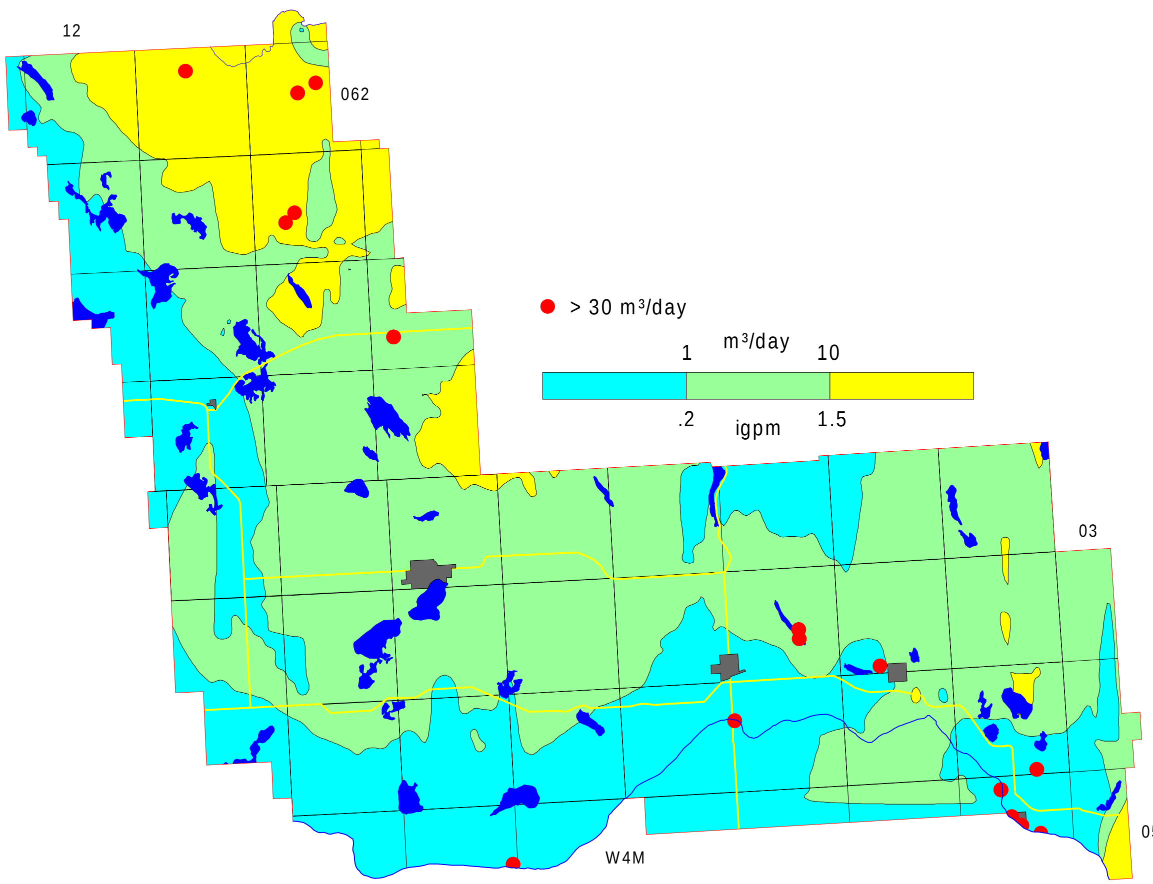
Recharge/Discharge Areas between Surficial Deposits and continental Foremost Aquifer



Depth to Top of Lea Park Formation



Apparent Yield for Water Wells Completed in Lea Park "Aquitard"



COUNTY OF ST. PAUL NO. 19
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 4-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

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

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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)

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Carl Mendosa (Edmonton: 403-492-2664)

UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology

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Paul Vasseur (Edmonton: 403-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION

Dave Seitz (Hanna: (403) 854-4448)

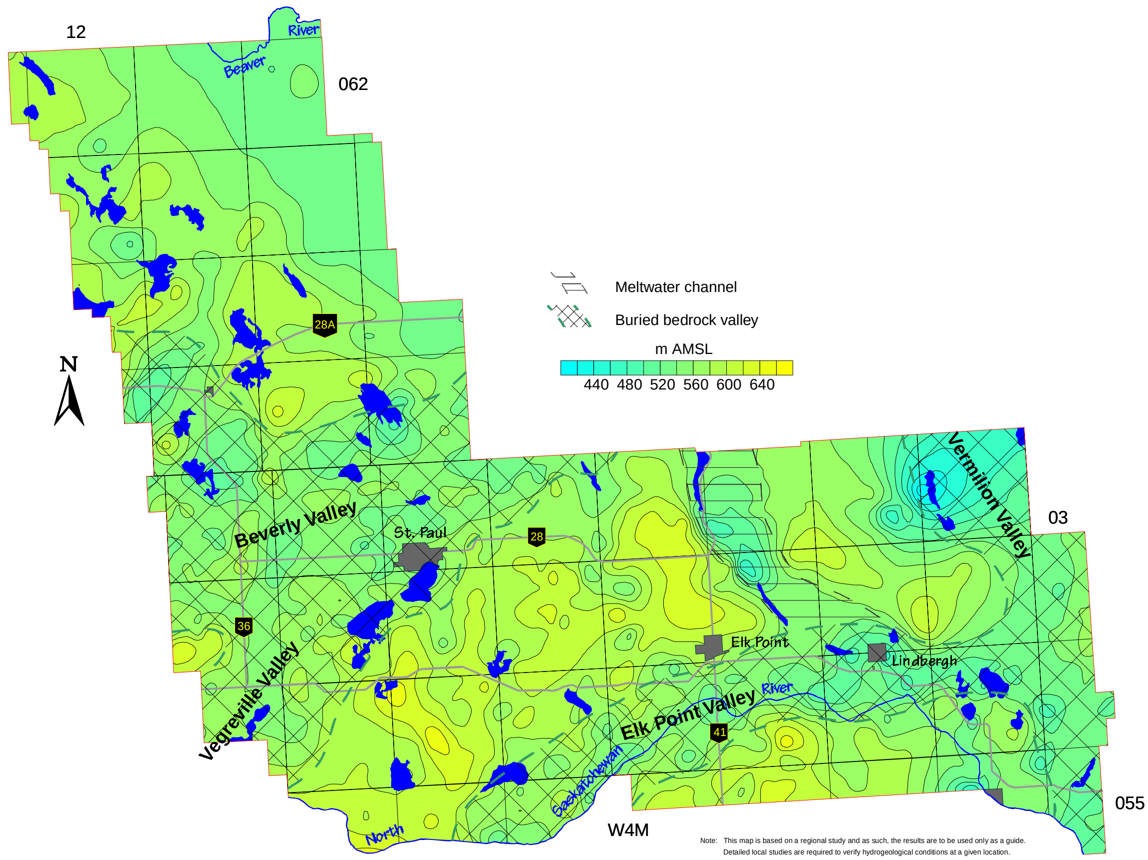
LOCAL HEALTH DEPARTMENTS

COUNTY OF ST. PAUL NO. 19

Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

County of St. Paul No. 19
Bedrock Topography



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Prairie Farm Rehabilitation Administration

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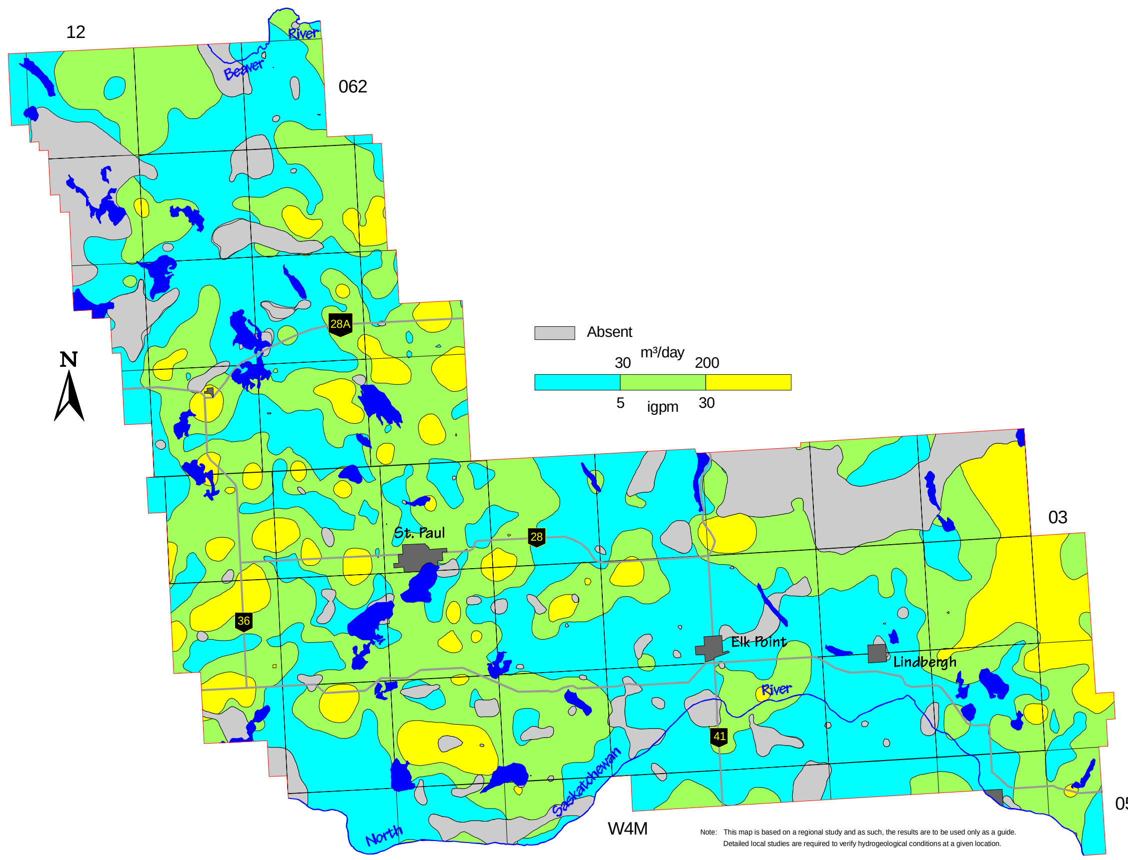
County of St. Paul No. 19
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



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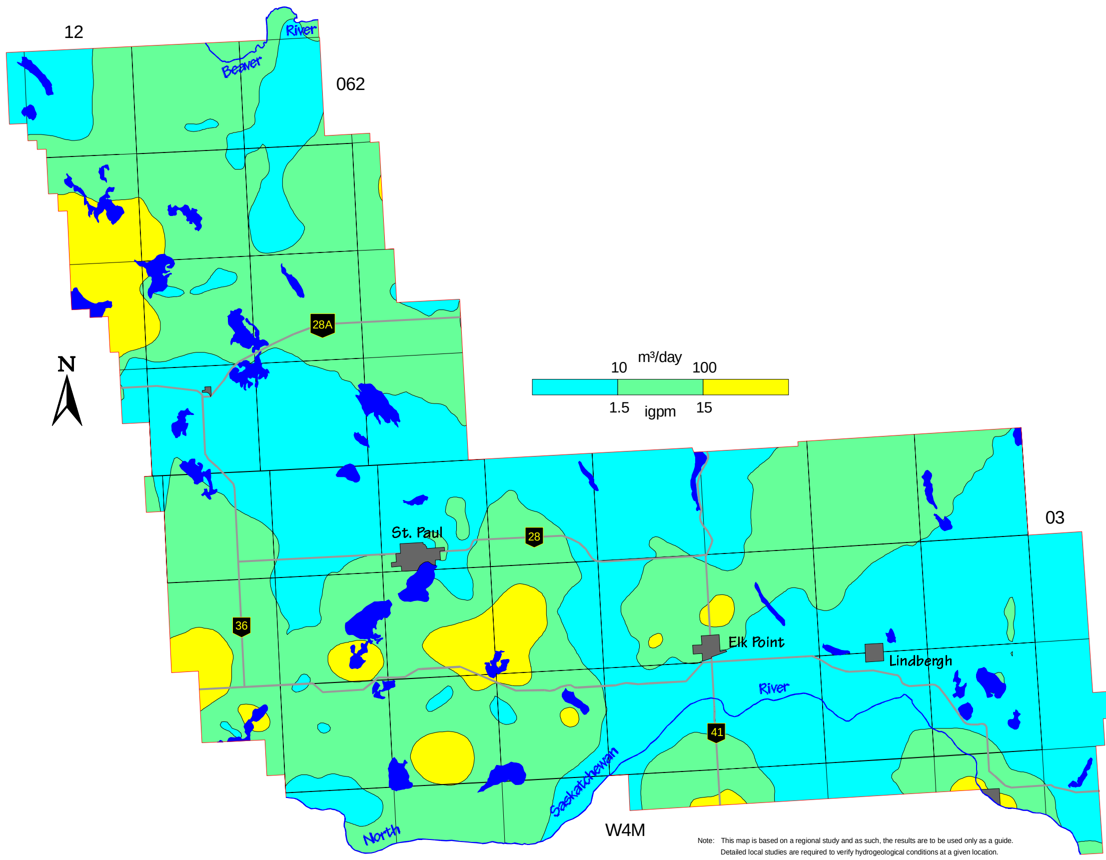
County of St. Paul No. 19
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



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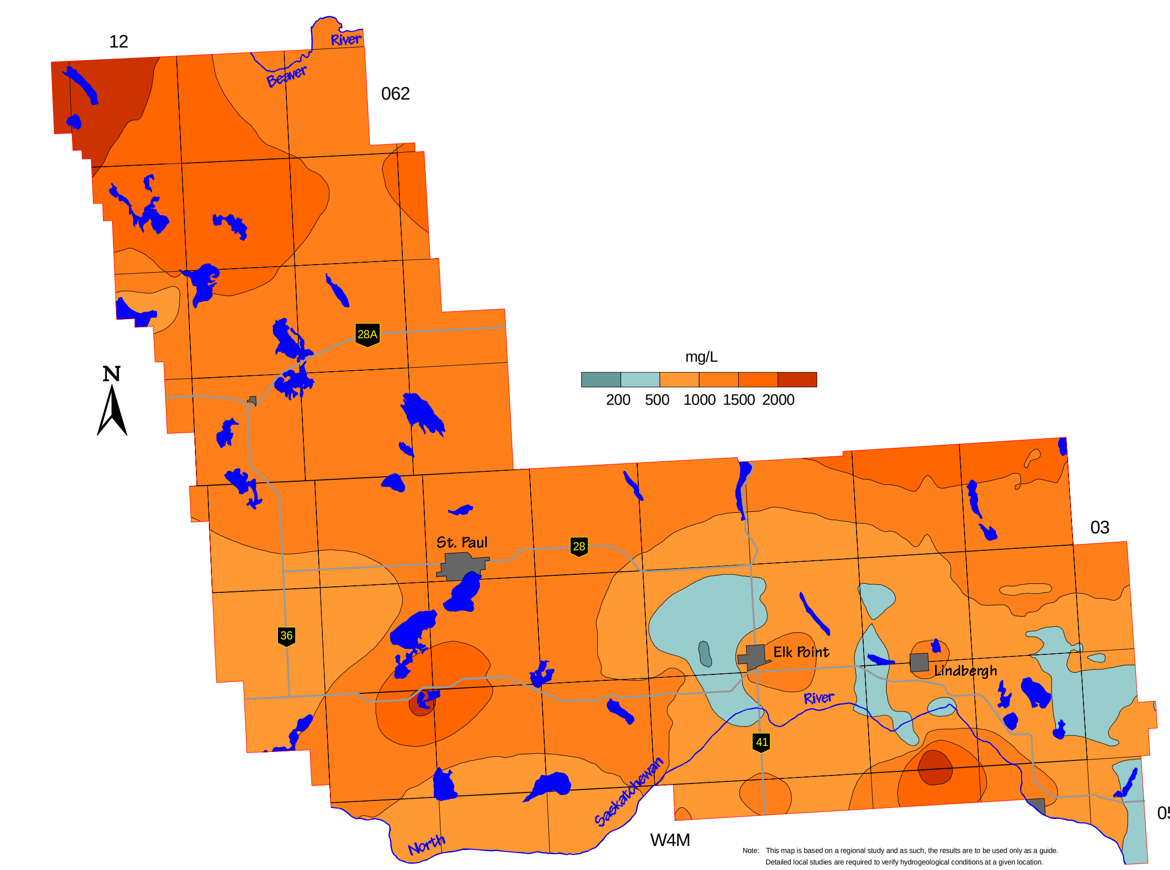
County of St. Paul No. 19
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



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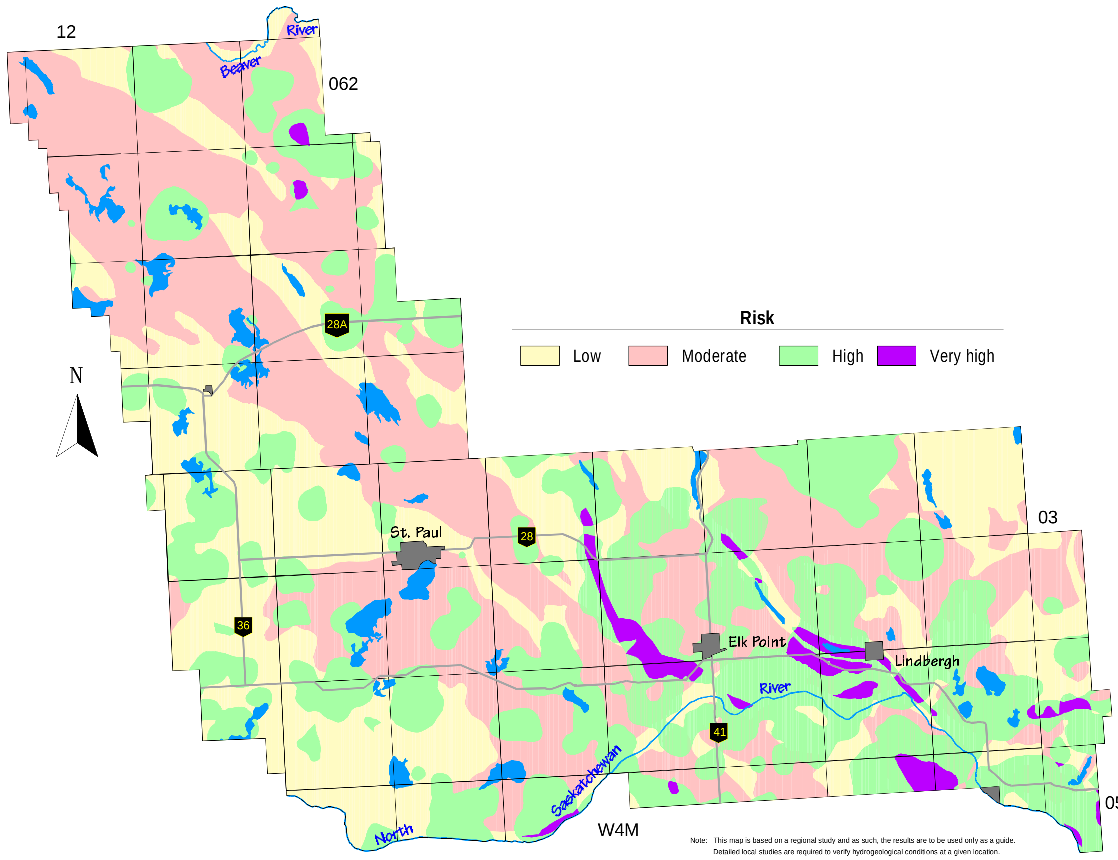
County of St. Paul No. 19
Risk of Groundwater Contamination



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.

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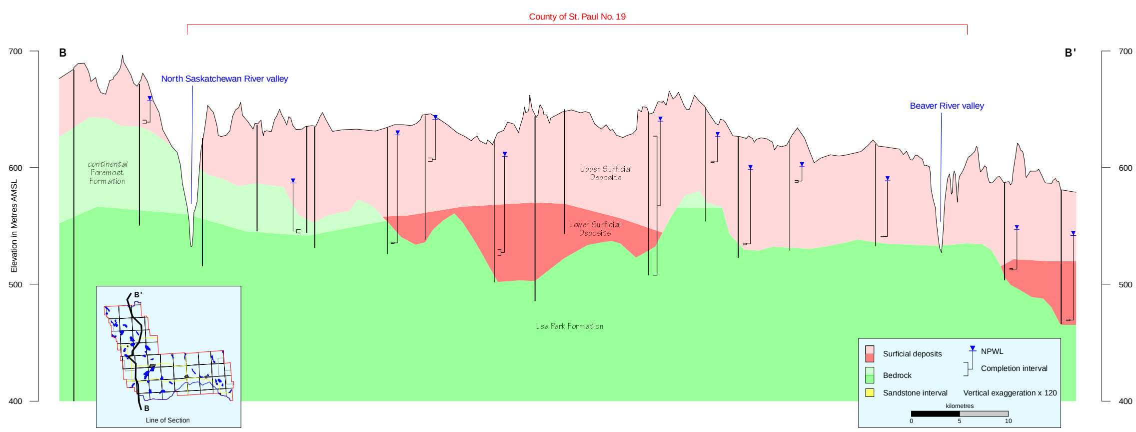
County of St. Paul No. 19
Cross-Section B - B'



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