County of Thorhild No. 7

Part of the North Saskatchewan River Basin
Townships 058 to 063, Ranges 18 to 23, 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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"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 Thorhild No. 7, (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 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 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 Module 3.

1.3 Purpose

This project is a regional groundwater assessment of the County of Thorhild No. 7. The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the County.**

The regional groundwater assessment includes:

- Identification of the aquifers[1] within the surficial deposits and the upper bedrock[2];
- 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 Thorhild No. 7 have been assembled. Where practical, the data have been digitized. These data are then being used in the regional groundwater assessment for the County.

1 See glossary
2 See glossary

2 INTRODUCTION

2.1 Setting

The County of Thorhild No. 7 is situated in central Alberta. This area is part of the Alberta Plains region. The County exists within the North Saskatchewan River basin. The southeastern boundary of the County is the North Saskatchewan River. The area includes some or all of townships 058 to 063, ranges 18 to 23, west of the 4th Meridian.

The County boundaries follow township or section lines. The exception is the southeastern boundary. The ground elevation varies between 580 and 710 metres above mean sea level (AMSL). The topographic surface generally decreases toward the southern part of the County.

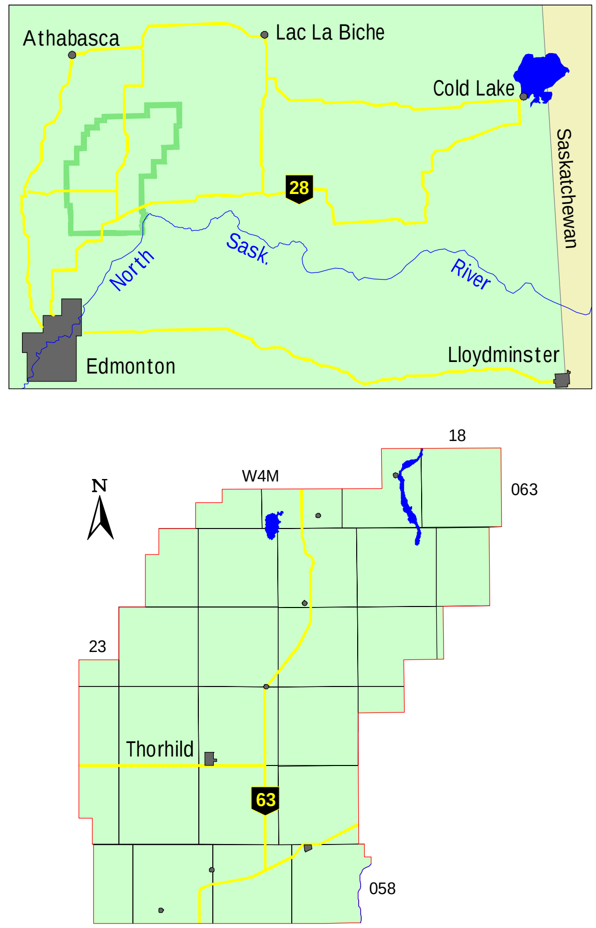

Figure 1. Index Map

2.2 Climate

The climate of the County is a Dfb based on the Köppen classification. This is characteristic of a humid continental climate with long, cool summers and severely cold winters. The mean annual precipitation at the Newbrook Climatological Station measures 507 millimetres (mm), based on data from 1961 to 1979. For the same time interval, the maximum annual precipitation reached 691 mm, and a minimum of 374.4 mm. The annual potential evapotranspiration for the area was calculated to be 490 millimetres, 17 millimetres less than the mean annual precipitation (Borneuf, 1975). Between 1961 and 1979, the annual temperature averaged 0.6 °C. The mean annual temperature reached a maximum of 2.5° C in 1976, and a minimum of -0.7 °C in 1965.

2.3 Background Information

There are currently records for 2,101 water wells in the groundwater database for the County of Thorhild. Of the 2,101 water wells, 1,737 are for domestic/stock/irrigation purposes. The remaining 364 water wells were completed for a variety of uses, including municipal, observation and industrial purposes. Based on a rural population of 2,901, there are nearly two water wells per family of four. The domestic or stock water wells vary in depth from less than 2 metres to 457 metres below ground level. Lithologic details are available for 1,255 water wells.

There are 636 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 177. The adjacent map shows that these water wells are mainly east of Highway 63 and south of Highway 18.

The remaining 459 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 over most of the County. However, water wells completed in bedrock aquifers are not common in range 21 south of Thorhild nor in the extreme northern part of the County west of Long Lake.

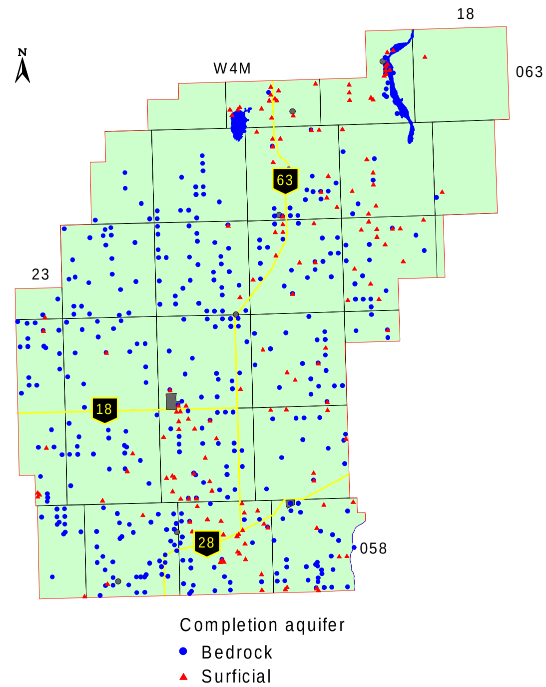

Figure 2. Location of Water Wells

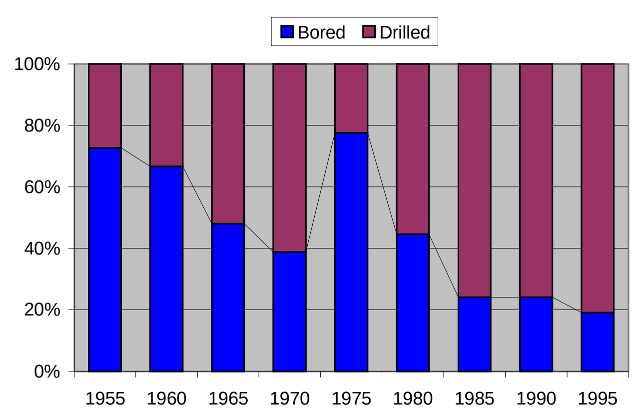

Figure 3. Relationship between Drilled and Bored Water Wells

Data for casing diameter are available for 675 water wells, with 265 indicated as having a diameter of more than 350 mm and 410 having a diameter of less than 200 mm. The casing diameters of less than 200 mm are for drilled water wells and water wells with a diameter of greater than 350 mm are mainly bored water wells.

There has been a gradual decline in the percentage of bored water wells completed within the County of Thorhild from the early 1950s to 1995. The only time when there was a rise in the percentage was in the 1970s.

There are five different materials that have been used for surface casing over the last 40 years in water wells completed in the County. The most common material is steel. Steel casing was used in the 1950s and is still being used today. Approximately 50% of the water wells are reported as having steel surface casing. The next most common material is galvanized steel. However, the last reported use of galvanized steel was in July 1993. Plastic casing is used in 16% of the water wells. The first reported use of plastic casing in the County was in July 1973. In the 1990s, slightly more than 50% of the water wells have been completed with plastic casing.

Water wells not used for domestic needs must be licensed. At the end of 1996, 84 groundwater diversions were licensed in the County. The total maximum authorized diversion from these 84 water wells is 571 cubic metres per day (m³/day); 71 percent of the authorized groundwater diversion is allotted for agricultural use. The largest licensed groundwater diversion within the County is 54.1 m³/day for Alberta Mineral Extraction Inc.; their water well is completed in a sand and gravel aquifer associated with the Buried Egremont Valley.

At many locations within the County, more than one water well is completed at one legal location. Digitally processing this information is difficult. To obtain a better understanding of the completed depths of water wells, a 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 wells depths are similar, the impression is that there is only one aquifer that is being used. Over approximately 50% of the County, the difference between the maximum and minimum depth is less than 5 metres. The area where the greatest differences between the minimum and maximum depth occur most often is the north-central part of the County and in areas where water wells completed in aquifers in the surficial deposits are most common.

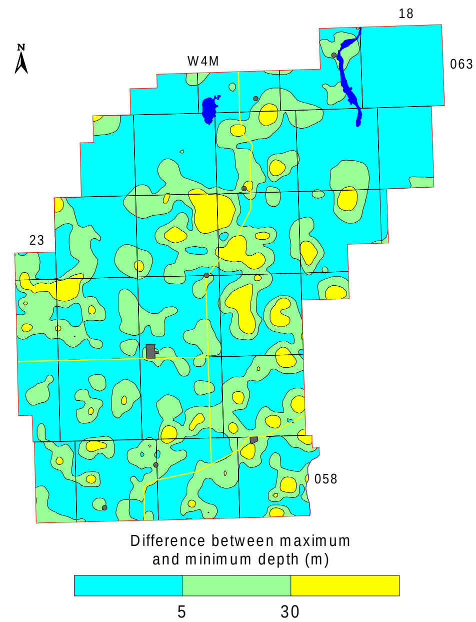

Figure 4. Depth of Existing Water Wells

The total dissolved solids in the groundwater in the County 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 1.0 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, there are no data available from the one **Alberta Environmental Protection** (AEP)-operated observation water well within the County of Thorhild. Additional data can be obtained from some of the licensed groundwater diversions. In the past, these data have been difficult to obtain from AEP, in part because of the failure of the licensee to provide the data. **However, even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget. The most cost-efficient method to collect additional groundwater monitoring data would be to have the water well owners measuring the water level in their own water well on a regular basis.**

3 TERMS

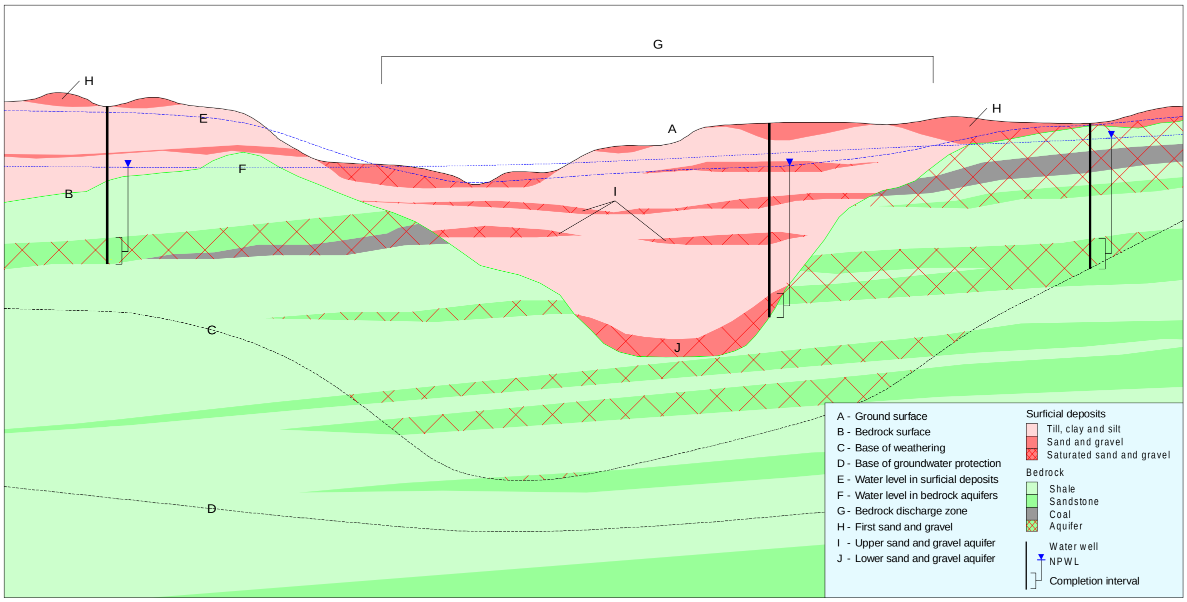

Figure 5. Generalized Cross-Section (for terminology only)

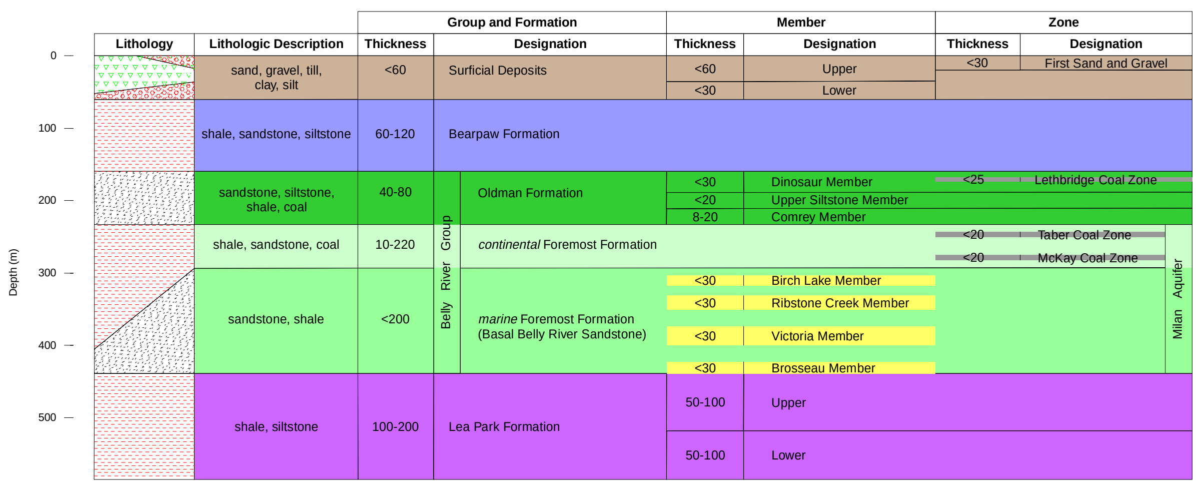

Figure 6. Geologic Column

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 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 TM coordinate system. This means that a record for the SE ¼ of section 06, township 060, range 21, W4M, would have a horizontal coordinate with an Easting 122,212 metres and a Northing 5,999,632 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

[3] For definitions of Transmissivity, see glossary
[4] 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 method.

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

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

4.3 Hydrogeological Parameters

Water well records that indicate the depths to the top and bottom of their completion interval are compared digitally to the spatial distribution of the various geological surfaces. This procedure allows for the determination of the aquifer in which individual water 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, 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 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 adjacent table.

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

Table 1. Risk of Groundwater Contamination Criteria

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. 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

5 AQUIFERS

5.1 Background

An aquifer is a porous and permeable rock that is saturated. If the non-pumping water level 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

Surficial deposits in the County are mainly less than 40 metres thick, except in areas of linear bedrock lows where the thickness of surficial deposits can exceed 80 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 not saturated, a sand and gravel deposit 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 hundred mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the County, 46% of the water wells completed in the surficial deposits have a casing diameter of greater than 200 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 459 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 459 water wells in the database, 280 have values for surface casing diameter. Of the 280 water wells, 82% have casing diameters of less than 200 millimetres.

The upper bedrock includes the lowest part of the Bearpaw Formation, parts of the Belly River Group and some of the Lea Park Formation. The Bearpaw Formation is the uppermost bedrock along the west-central part of the County. The Belly River Group has a maximum thickness of 250 metres and includes the Oldman Formation and both the *continental* and *marine* facies[6] of the Foremost Formation. The Oldman Formation is the upper bedrock and subcrops under the surficial deposits in the western two-thirds of the County. The *continental* Foremost Formation subcrops under the surficial deposits in the northeastern one-third of the County except where the *marine* Foremost Formation subcrops in the extreme northeastern part of the County. The Lea Park Formation underlies the Belly River Group and is a regional aquitard[7].

The bedrock geology map also shows the Milan Aquifer subcropping in the northeastern part of the County.

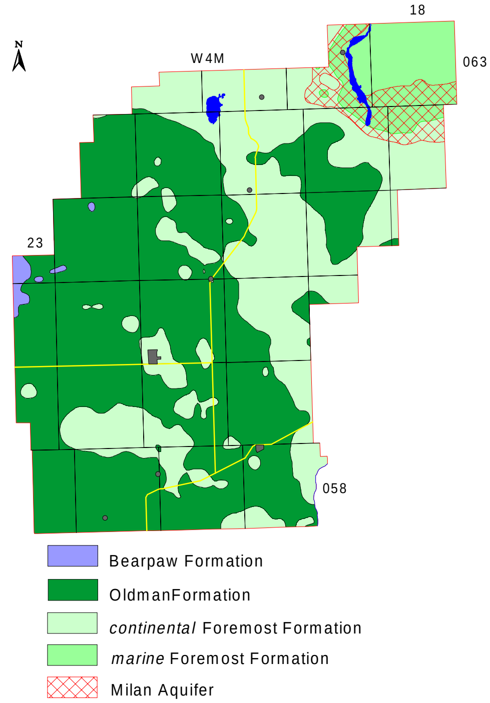

Figure 7. Bedrock Geology

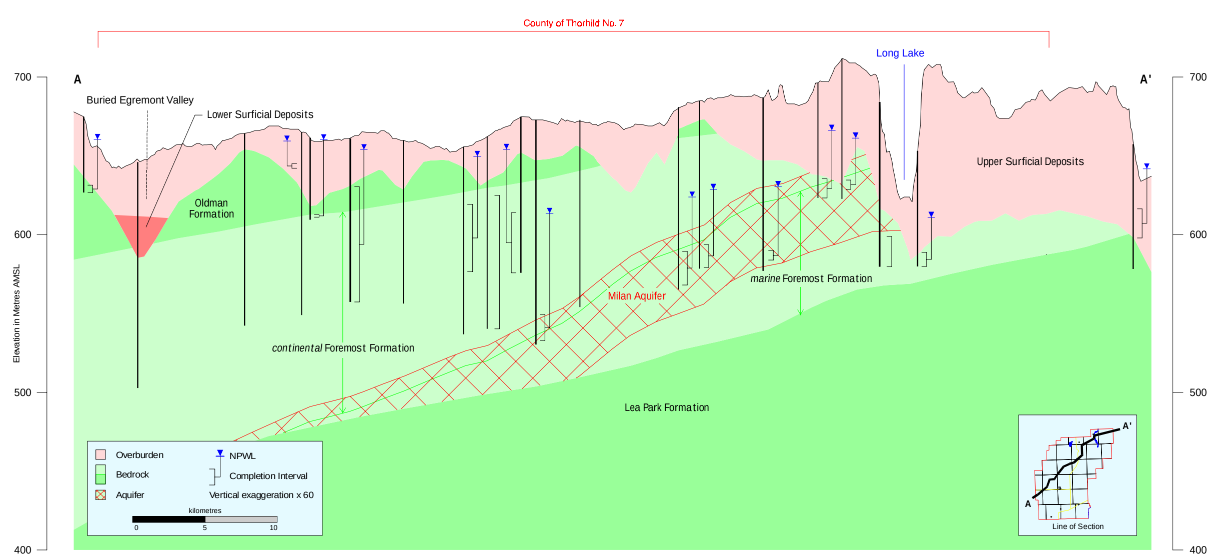

Figure 8. Cross-Section A - A'

6 See glossary
7 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 not 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 County, the surficial deposits are less than 40 metres thick. The exceptions in thickness are mainly in association with linear lows in the bedrock surface. The most significant linear bedrock low has been designated as the Buried Egremont Valley, which is approximately 10 kilometres south of the Village of Thorhild and is shown on the adjacent map. The Buried Egremont Valley trends from the northwest to the southeast and is a tributary valley to the Buried Beverly Valley, which is immediately south of the County of Thorhild. In the Buried Egremont Valley, surficial deposits can be more than 80 metres thick.

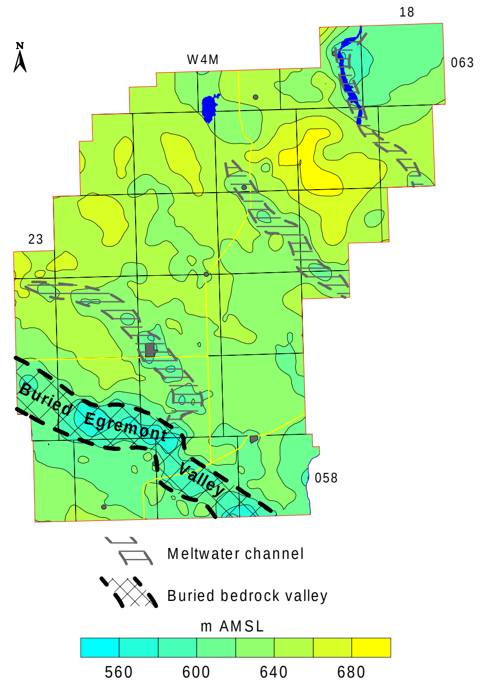

Figure 9. Bedrock Topography

The surficial deposits include two depositional environments. One depositional environment occurs in the lower part of the surficial deposits. The lower surficial deposits are mostly of fluvial[8] and lacustrine[9] origin. The elevation of the top of the lower surficial deposits is approximately 610 metres AMSL. This change in depositional environment could correspond to the top of the Muriel Lake Formation (Andriashek, 1985). The maximum thickness of the lower surficial deposits in the County is 25 metres, which occurs mainly in the southern and northeastern part of the County. The lowest part of the lower surficial deposits can include pre-glacial sand and gravel deposits.

8 See glossary
9 See glossary

The sand and gravel deposits that directly overlie the bedrock surface in the Buried Egremont Valley are part of the lower surficial deposits. The lowest sand and gravel deposits are of fluvial origin and are usually no more than a few metres thick (CAESA, 1996). There are only a few areas in the County, other than the Buried Egremont Valley, where lower surficial deposits are expected. One area is near Long Lake in Tp 063, R 19, W4M. However, the actual bedrock surface in the Long Lake area may be different from what is indicated on cross-section A-A' (Figure 8), due to the paucity of data available for the northeastern part of the County. Also, this bedrock low and others in the County may be a result of meltwater action and therefore would be considered part of the depositional environment that is attributed to the upper surficial deposits.

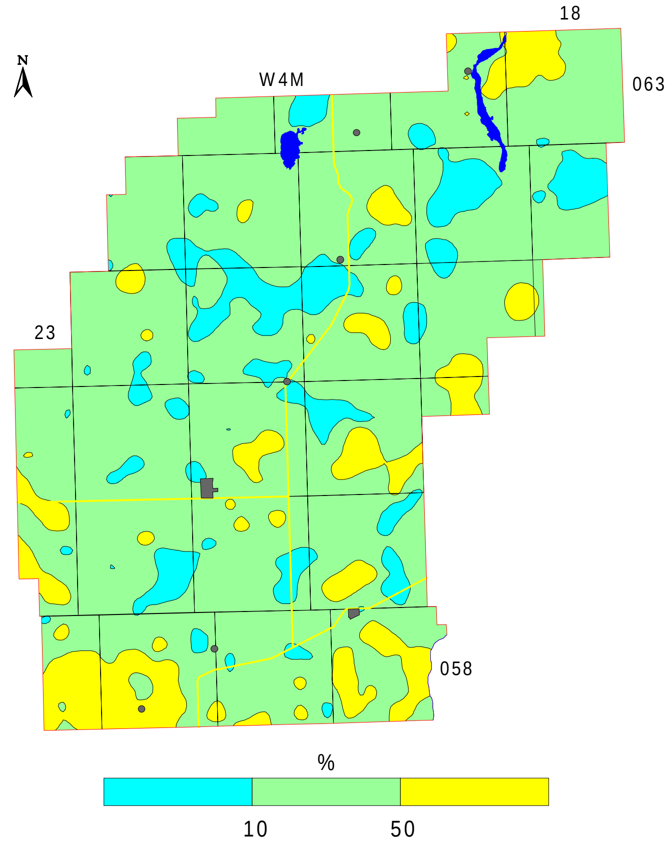

Figure 10. Amount of Sand and Gravel in Surficial Deposits

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include clay and till, and sand and gravel deposits of meltwater origin. The thickness of the upper surficial deposits is mainly less than 40 metres.

Sand and gravel deposits can occur throughout the entire unconsolidated section. 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 10% of the County, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. These areas are not associated with the areas of greatest thickness of surficial deposits.

5.2.2 Sand and Gravel Aquifer(s)

One source of groundwater in the County includes aquifers in the surficial deposits. The actual aquifer that is developed is usually dictated by which aquifer is present.

The adjacent map shows water well yields that are expected in the County, based on surficial aquifers that have been developed by existing water wells. Based on these data, water well yields of more than 100 m³/day in the sand and gravel aquifer(s) can be expected in less than 5% of the County. Over the majority of the County, water wells completed in the sand and gravel aquifer(s) would be expected to mainly have long-term yields of less than 10 m³/day. The higher values for water well yields are more frequently located in the southwestern part of the County.

A groundwater study conducted by PFRA for the County of Thorhild (CAESA, 1996) determined a long-term yield of more than 130 m³/day for a water test hole completed within the Buried Egremont Valley.

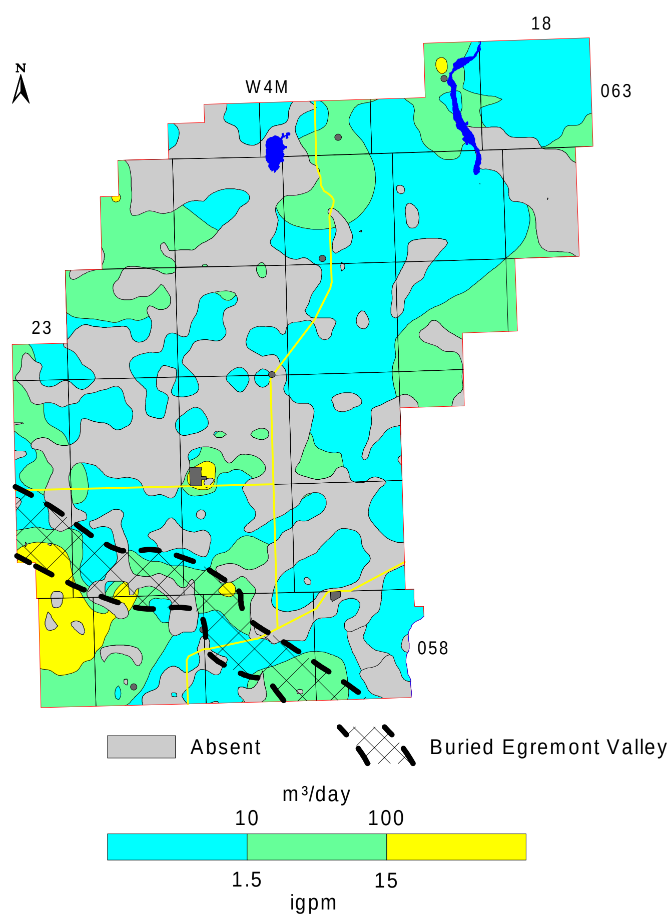

Figure 11. Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)

5.2.3 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.

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.

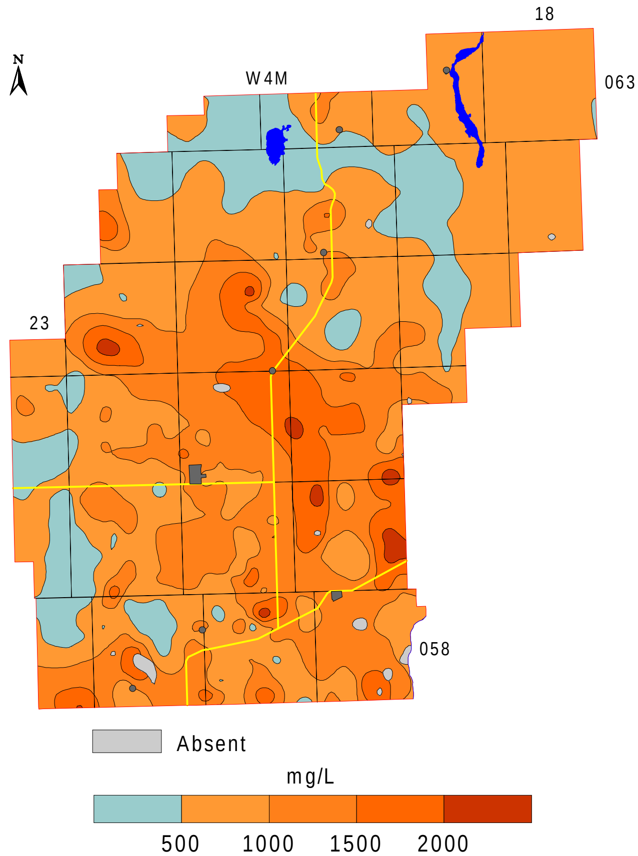

Figure 12. Total Dissolved Solids in Groundwater from Surficial Deposits

The groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate-type waters, with 60% of groundwaters having total dissolved solids (TDS) of less than 1,000 mg/L. The groundwaters with a TDS of more than 2,000 mg/L occur mainly in the central part of the County. All of the groundwaters from the surficial deposits are expected to have concentrations of dissolved iron of greater than 1 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 with appreciable concentrations of the chloride ion and in most of the County the chloride ion concentration is less than 100 mg/L.

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County includes the lowest part of the Bearpaw Formation and part of the Belly River Group. The Lea Park underlies the Belly River Group.

The Bearpaw Formation is the upper bedrock in the western portion of the County, present mainly in townships 060 and 061, range 23, W4M. "The Bearpaw Formation consists of marine shale, siltstone and minor sandstone, and represents the final widespread marine unit in the Western Canada Foreland Basin" (Catuneanu et al, 1997). The Bearpaw Formation is generally less than 25 metres thick in the County and is not treated as an aquifer for the County of Thorhild.

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

The Oldman Formation is the upper bedrock in the western two-thirds of the County. There are also subcrops of the Oldman Formation that occur as outliers within the area of the *continental* Foremost Formation. The Oldman Formation has a maximum thickness of 50 metres within the County and is composed of sandstone, siltstone, shale and coal deposited in a continental environment. The Oldman Formation is the upper part of the Belly River Group and is composed of three parts: the Comrey, the Upper Siltstone and Dinosaur members. The uppermost part of the Dinosaur Member is the Lethbridge Coal Zone. Sandstone is predominant in the Comrey Member, the Upper Siltstone is mainly siltstone, and the Dinosaur Member includes shale and coal deposits.

The *continental* Foremost Formation underlies the Oldman Formation in the southwestern half of the County and subcrops under the surficial deposits in most of the northeastern half of the County; only in the northeastern corner of the County has the *continental* Foremost Formation 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. Underlying the *continental* Foremost Formation is the *marine* Foremost Formation, which includes up to five sandstone members, and has a maximum thickness of 80 metres within the County.

The upper part of the *marine* Foremost Formation is present in the area. However, the sandstones making up the *marine* Foremost Formation cannot always be separated into individual members that are identified east and south of the County of Thorhild. This situation occurs because the sandstone members of the *marine* Foremost Formation thicken and the intervening shale layers thin toward the western edge of the *marine* facies. 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 extends up to 10 metres into the overlying *continental* Foremost Formation and can occupy the upper 40 metres of the *marine* Foremost Formation. The westward extent of the Milan Aquifer coincides with the position where the Basal Belly River Sand can be distinguished. In the County of Thorhild, the

Milan Aquifer is present under the northeastern two-thirds of the County and subcrops in the northeastern part of the County (Figure 7).

5.3.2 Aquifers

In general, water wells in the bedrock aquifers in the County of Thorhild can be expected to provide only limited quantities of groundwater. The adjacent map shows water well yields that are expected based on the upper bedrock aquifers that have been developed. For approximately half of the County, water wells completed in bedrock aquifers have apparent yields of more than 10 m³/day.

The producing water wells mainly occur within the area where either the Oldman, Foremost Aquifer or Milan Aquifer are present. Some of the bedrock water wells are completed in areas where the *continental* Foremost Formation is indicated as being the upper bedrock.

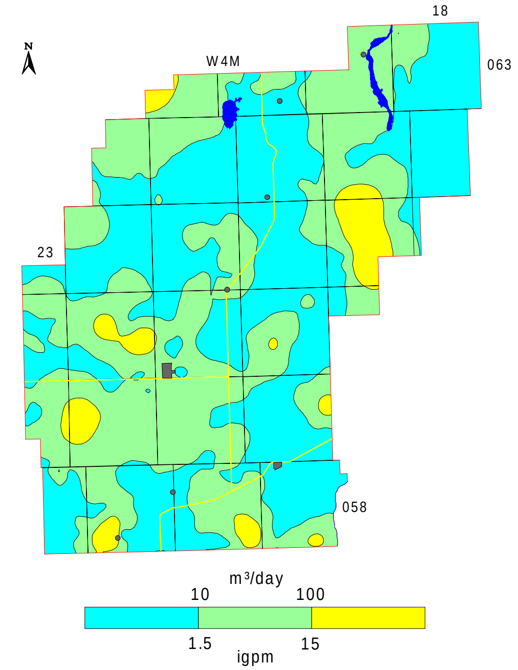

Figure 13. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer

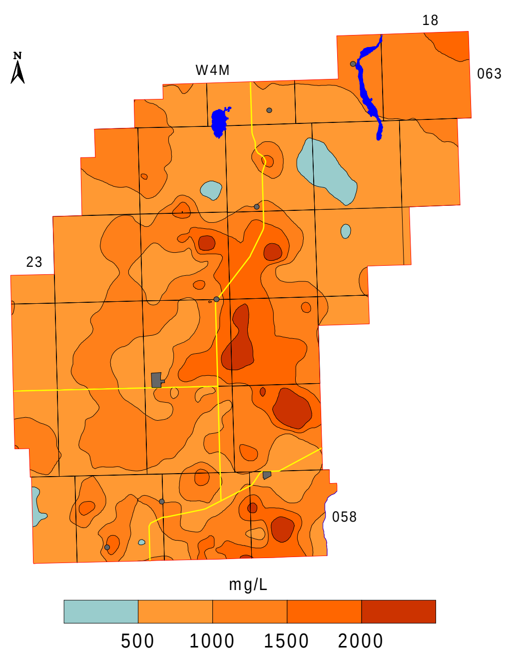

Figure 14. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer

5.3.3 Chemical Quality of Groundwater

The TDS concentrations, in the groundwater from the upper bedrock aquifers, range from less than 500 to more than 2,000 mg/L. In more than 50% of the area, TDS values are less than 1,000 mg/L.

A relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifers exceed 1,200 mg/L, the sulfate concentration exceeds 400 mg/L.

The Piper tri-linear diagrams show that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are a sodium-bicarbonate type. The analyses that show a sodium-bicarbonate type groundwaters are from water wells in the western, northwestern and northern parts of the County.

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

5.3.4 Oldman Aquifer

The Oldman Aquifer is part of the Oldman Formation that underlies the southwestern half of the County. The thickness of the Oldman Formation is generally less than 50 metres; in the majority of the northeastern part of the County, the Oldman Formation has been eroded.

5.3.4.1 Depth to Top

The depth to the top of the Oldman Formation increases generally to the west. In the areas where the Oldman Formation subcrops, the depth to the top of the Formation depends on the thickness of the surficial deposits. In these areas, the depth can be less than 20 metres. In the western part of the County, where the Oldman is below the Bearpaw Formation, the depth to the top of the Oldman Formation is more than 40 metres.

5.3.4.2 Apparent Yield

The projected long-term yields are variable for individual water wells completed in the Oldman Aquifer and range from less than 10 m³/day to more than 100 m³/day. The areas where water wells with higher yields are expected are mainly in the southern half of the County. However, there are several areas where the Oldman Aquifer has been eroded, such as around the Village of Thorhild and in the vicinity of the Buried Egremont Valley. In the northern and western parts of the County, yields for water wells completed in the Oldman Aquifer are expected to be less than 10 m³/day.

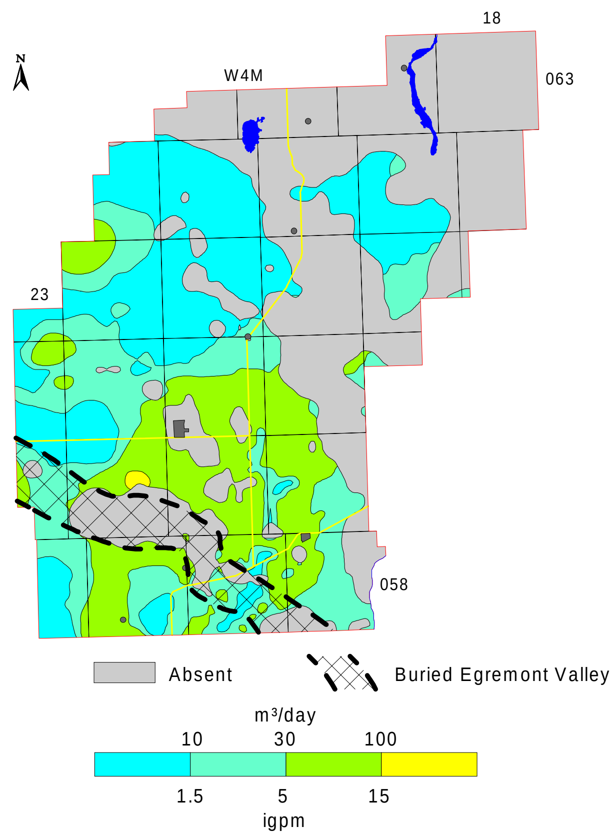

Figure 15. Apparent Yield for Water Wells Completed through Oldman Aquifer

5.3.4.3 Quality

The TDS concentrations for groundwater from the Oldman Aquifer range from less than 500 to more than 2,000 mg/L. The higher values of TDS occur in the extreme southeastern part of the County. The lower concentrations of TDS are in the northern and southwestern parts of the County. When TDS values in the groundwater from the Oldman Aquifer exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

The chloride concentration of the groundwater from the Oldman Aquifer can be expected to be less than 100 mg/L. The lowest values are expected in the western and northern parts of the County.

5.3.5 *Continental* Foremost Aquifer

The *continental* Foremost Aquifer is part of the *continental* Foremost Formation and subcrops under the northeastern part of the County. The thickness of the *continental* Foremost Aquifer increases to the southwest and can reach a thickness of 160 metres in the southwestern part of the County. 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.

5.3.5.1 Depth to Top

The depth to the top of the *continental* Foremost Aquifer is variable, ranging from less than 20 to more than 100 metres. The largest area where the top of the *continental* Foremost Aquifer is more than 80 metres below ground level is in the vicinity of the Buried Egremont Valley.

5.3.5.2 Apparent Yield

The projected long-term yields for water wells completed through the *continental* Foremost Aquifer are mainly less 30 m³/day. The higher yields are mainly south of the Village of Thorhild in close proximity to the Buried Egremont Valley. These higher yields may be related to a combination of geologic processes: fluvial-derived sandstone channels and weathering or fracturing. Higher water well yields may be expected in the northern part of the County. However, the higher yields in the northern part of the County may be mapping anomalies caused by the absence of data.

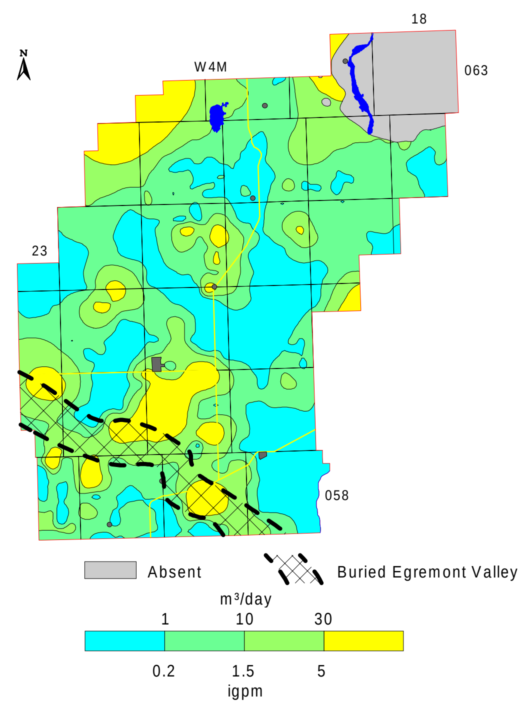

Figure 16. Apparent Yield for Water Wells Completed through continental Foremost Aquifer

5.3.5.3 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 groundwater from the *continental* Foremost Aquifer range from less than 500 to more than 2,000 mg/L. The higher values of TDS tend to be east of Highway 63 and occur in close proximity to the eastern subcrop edge of the Oldman Formation. 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. The exceptions include a 10-kilometre wide band extending from Tp 062, R 22, W4M down to Tp 059, R 20, W4M and in the southwestern part of the County. In these two areas, chloride concentrations can exceed 250 mg/L.

5.3.6 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 in one aquifer because the individual sandstone members, which can be identified to the east and south of the County, are not generally discernible within the County. 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 County of Thorhild.

5.3.6.1 Depth to Top

The depth to the top of the Milan Aquifer is a function of the depth to the stratigraphic border between the *continental* and *marine* facies of the Foremost Formation and the topographic surface. 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 northeastern part of the County, in the Long Lake area, to more than 240 metres toward its western extent.

5.3.6.2 Apparent Yield

The projected long-term yields for individual water wells completed in the Milan Aquifer are mainly less than 100 m³/day. The adjacent map includes 12 values within the County. Eight of the 12 values are between 18 and 51 m³/day. The remaining four values vary between 134 and 4,420 m³/day. The very high value, which is not included in the analysis, is for a water well in Tp 059, R 20, W4M. The water well is 120 metres deep and the water level is approximately 25 metres lower than another water well completed in the Milan Aquifer less than five kilometres north.

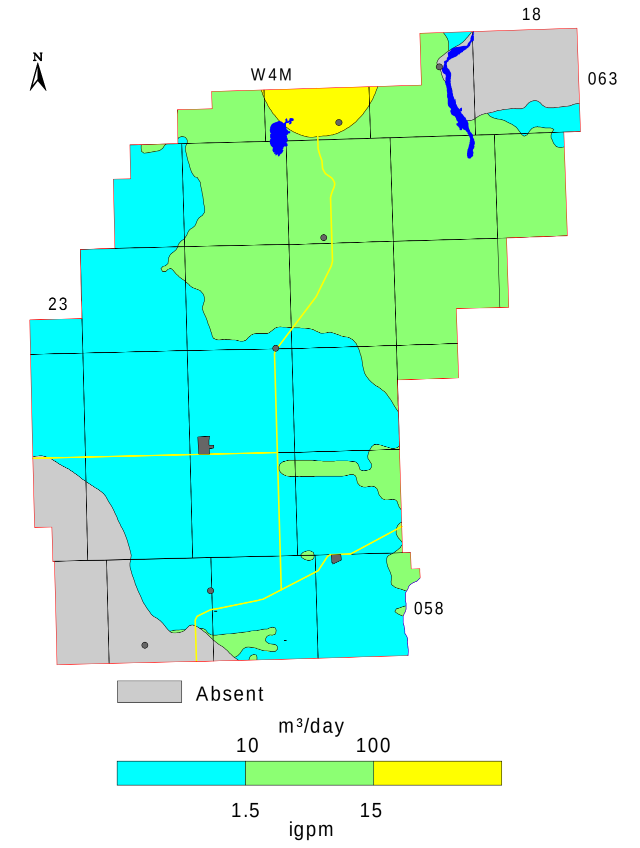

Figure 17. Apparent Yield for Water Wells Completed through Milan Aquifer

5.3.6.3 Quality

Groundwaters from the Milan Aquifer are mainly bicarbonate- or chloride-type waters. Within the County there are results available from nine chemical analyses. The results indicate that, within the majority of the County, the TDS are expected to be in the order of 1,000 to 1,500 mg/L. However, the results from the *marine* Foremost Formation indicate that TDS values can exceed 1,500 mg/L in the extreme southeastern corner of the County.

Chloride concentrations of more than 250 mg/L can be expected in the groundwater from the Milan Aquifer throughout the western and southern parts of the County, where the Aquifer is present. Where the Milan Aquifer subcrops, chloride concentrations are generally less than 100 mg/L. The large extent of the area where chloride concentrations are greater than 250 mg/L is based on very few data points on a regional scale. When the chloride ion concentrations in the groundwaters from the Milan Aquifer are combined with the chloride ion concentrations in the groundwaters from the *marine* Foremost Formation, groundwaters with chloride concentrations of greater than 250 mg/L are only expected in the area south of Tp 060. This situation is best illustrated by the chloride ion concentration shown for the *marine* Foremost Formation.

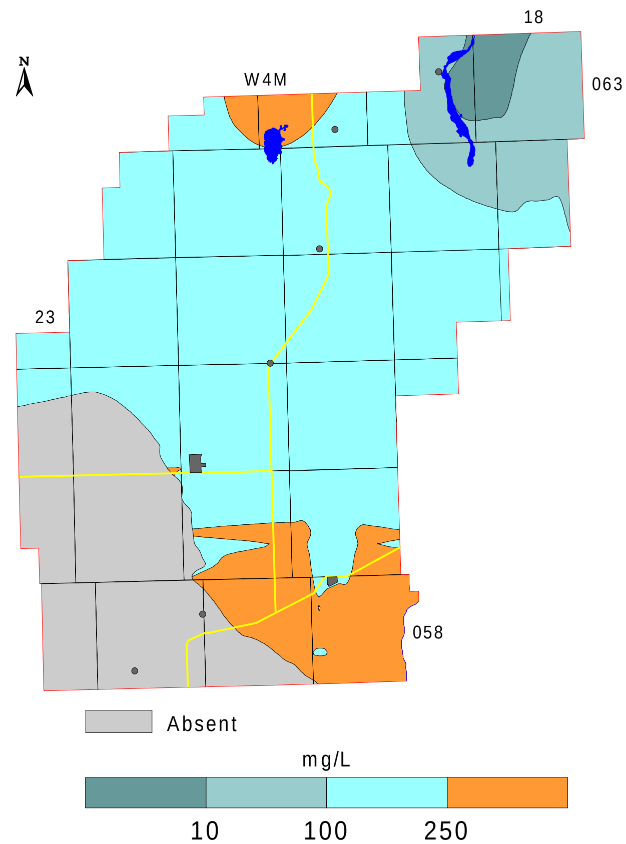

Figure 18. Chloride in Groundwater from marine Foremost Aquifer

In general terms, the deeper the Milan Aquifer is below ground level, the lower the yields and the higher the TDS and chloride ion concentrations. The Aquifer could be developed for domestic supplies in the northern two-thirds of the County, except in the extreme northeastern part of the County where the Aquifer is not present. In the southeastern part of the County, groundwater from the Aquifer would have limited uses without treatment because of the high TDS and high concentrations of the chloride ion; in the southwestern part of the County, the Aquifer is absent.

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 County. The aquifers include the surficial deposits as one hydraulic unit, the Buried Egremont Valley, the Oldman Aquifer, 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)
Surficial Deposits	1	0.002	50	Southeast	100
Buried Egremont Valley	20	0.002	5	Southeast	200
Oldman	5	0.002	25	South	250
continental Foremost	2	0.004	50	South/Southeast	400
Milan	5	0.002	30	Northwest/Southeast	300

The recharge to these aquifers would not be restricted to the County of Thorhild.

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 0.2 to 1.5 cubic kilometres. This volume is based on an areal extent of 2,100 square kilometres and a saturated sand and gravel thickness of two metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

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

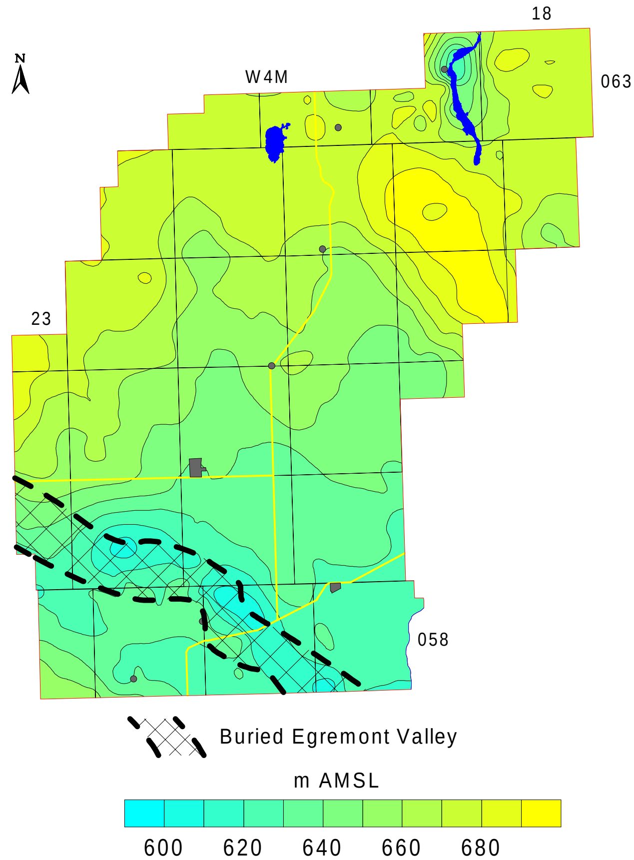

Figure 19. Non-Pumping Water-Level Surface in Surficial Deposits

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.

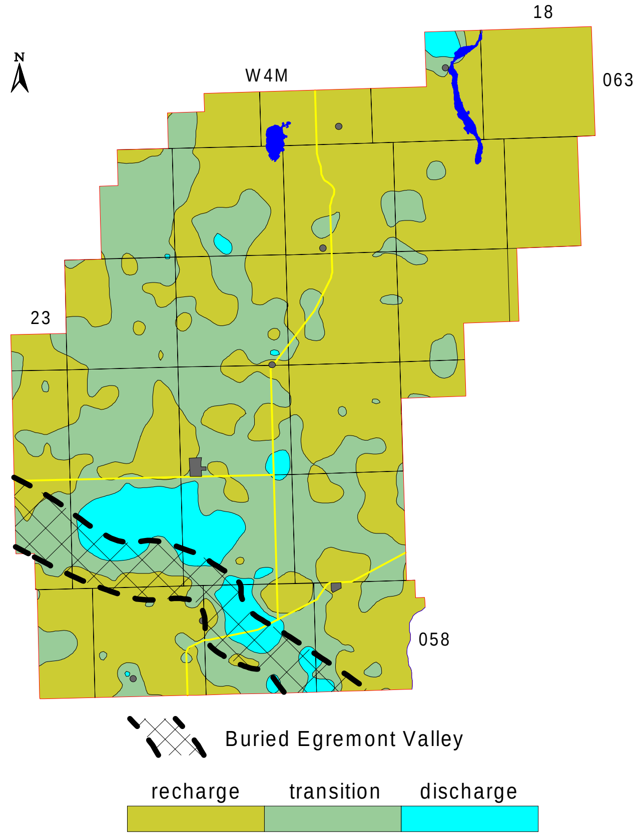

Figure 20. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer

The adjacent map shows that in more than 60% of the County there is a downward hydraulic gradient between the surficial deposits and the upper bedrock aquifers. Areas where there is an upward hydraulic gradient are mainly associated with lows in the bedrock surface. This appears to be the situation in the southwestern part of the County, where the Buried Egremont Valley is present. The other parts of the County where there is either transition or discharge may indicate the presence of meltwater channels.

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 and from flow in the aquifer from outside the County. The recharge/discharge maps show that generally for most of the County, there is a downward hydraulic gradient from the surficial deposits to the bedrock. 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.

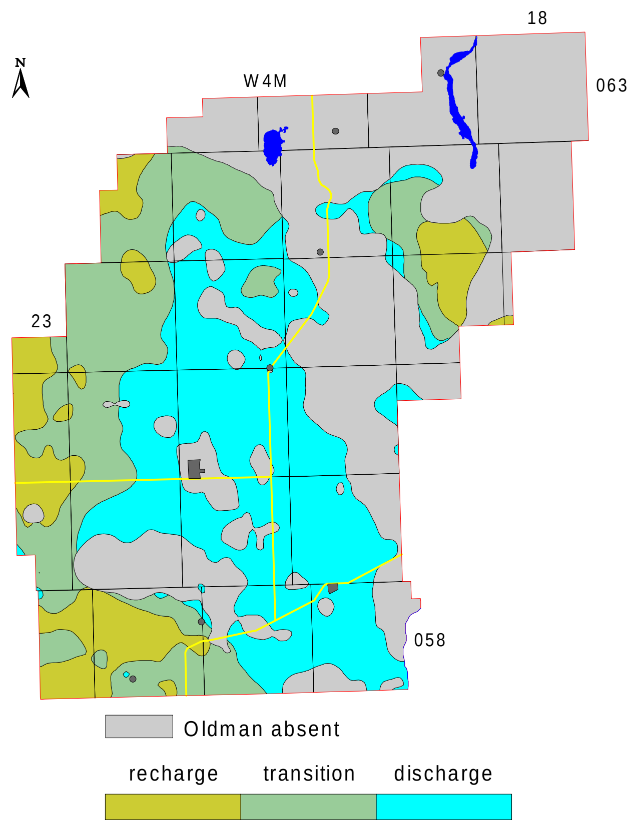

Figure 21. Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer

The hydraulic relationship between the surficial deposits and the Oldman Aquifer indicates that in 50% of the County where the Oldman is present, there is an upward hydraulic gradient. The presence of a discharge area at the eastern extent of a formation is not uncommon; what is uncommon in this situation is the size of the area where the upward hydraulic gradient exists. Since the main flow in the Aquifer is toward the south, the upward hydraulic gradient over the large area may be a result of the lower permeability in the surficial deposits.

The recharge/discharge configuration for the *continental* Foremost Formation and the surficial deposits shows discharge from the bedrock in the general area of the Buried Egremont Valley. The extensive areas of transitional flow suggest that meltwater valleys or sandstone channels in the bedrock may be present. All of the transmissivity values of greater than 9 m²/day occur in the transitional area of the *continental* Foremost Formation.

The hydraulic relationship between the surficial deposits and the Milan Aquifer shows that throughout almost all of the County there is a downward hydraulic gradient.

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 1,255 records in the area of the County with lithology descriptions, 130 have sand and gravel within one metre of ground level. In the remaining 1,125 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 Top Within One Metre Of Ground Surface	Groundwater Contamination Risk
Low	No	Low
Moderate	No	Moderate
High	No	High
Low	Yes	High
Moderate	Yes	High
High	Yes	Very High

Table 2. Risk of Groundwater Contamination Criteria

The Risk of Groundwater Contamination map shows that, in less than 25% of the County, there is a high or very high risk of the groundwater being contaminated. These areas would be considered the least desirable ones for 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.

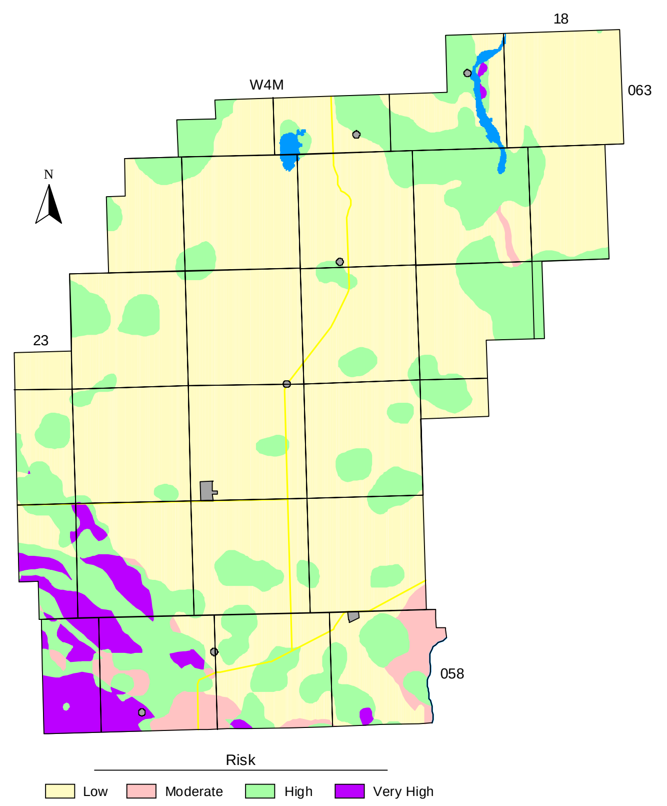

Figure 22. Risk of Groundwater Contamination

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 Buried Egremont Valley, identified by PFRA in 1995 (CAESA, 1996). 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.

The Milan Aquifer could be developed for domestic supplies in the northern two-thirds of the County. However, in the southwestern part of the County, the Aquifer is absent and in the southeastern part of the County, the groundwater would have limited uses without treatment because of the high TDS and high concentrations of chloride ion. It is recommended that a test-drilling program be completed to evaluate the significance of this Aquifer in the County of Thorhild. The program could involve areas where only limited groundwater supplies are available from shallower aquifers; one such area could be northeast of Thorhild where little or no groundwater is available from upper bedrock aquifers.

Sandstone channels exist within the *continental* Foremost Formation. However, because of the regional nature of the present study, identification of individual channels is not possible. Therefore, it is recommended that all existing geophysical logs available for the areas where the *continental* Foremost Formation is present be interpreted in an attempt to delineate where the sandstone channels are expected. After the channels have been delineated, a test-drilling program should be completed to evaluate the method as a means of identifying the location of significant aquifers within the *continental* Foremost Formation.

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 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

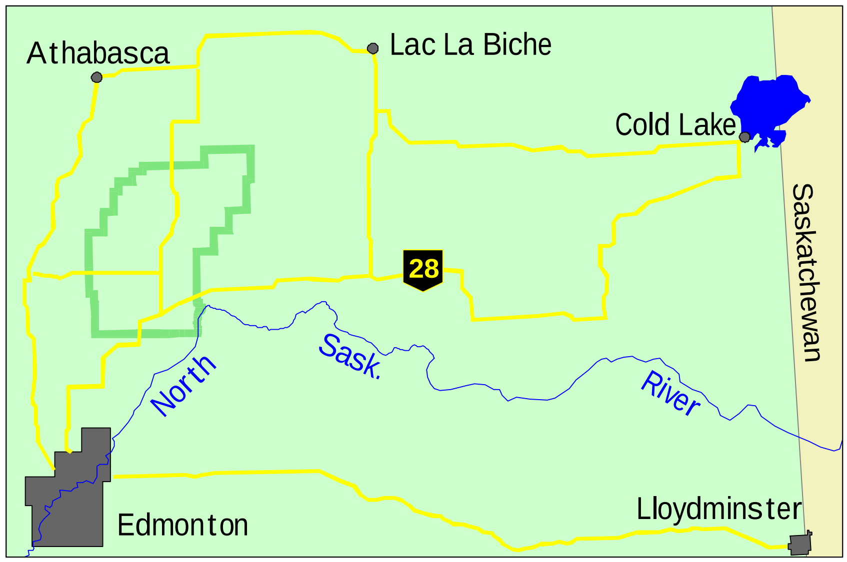
Apparent Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer.
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells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

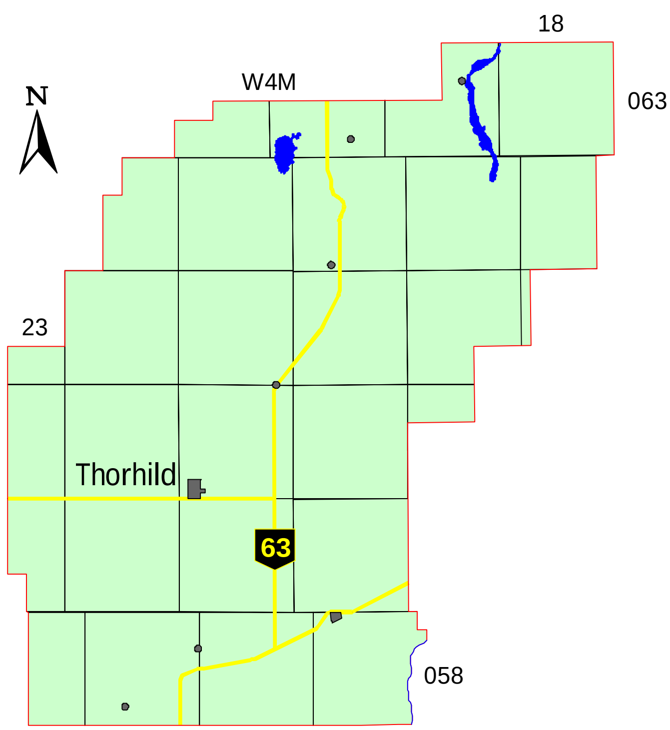
COUNTY OF THORHILD NO. 7

Appendix A

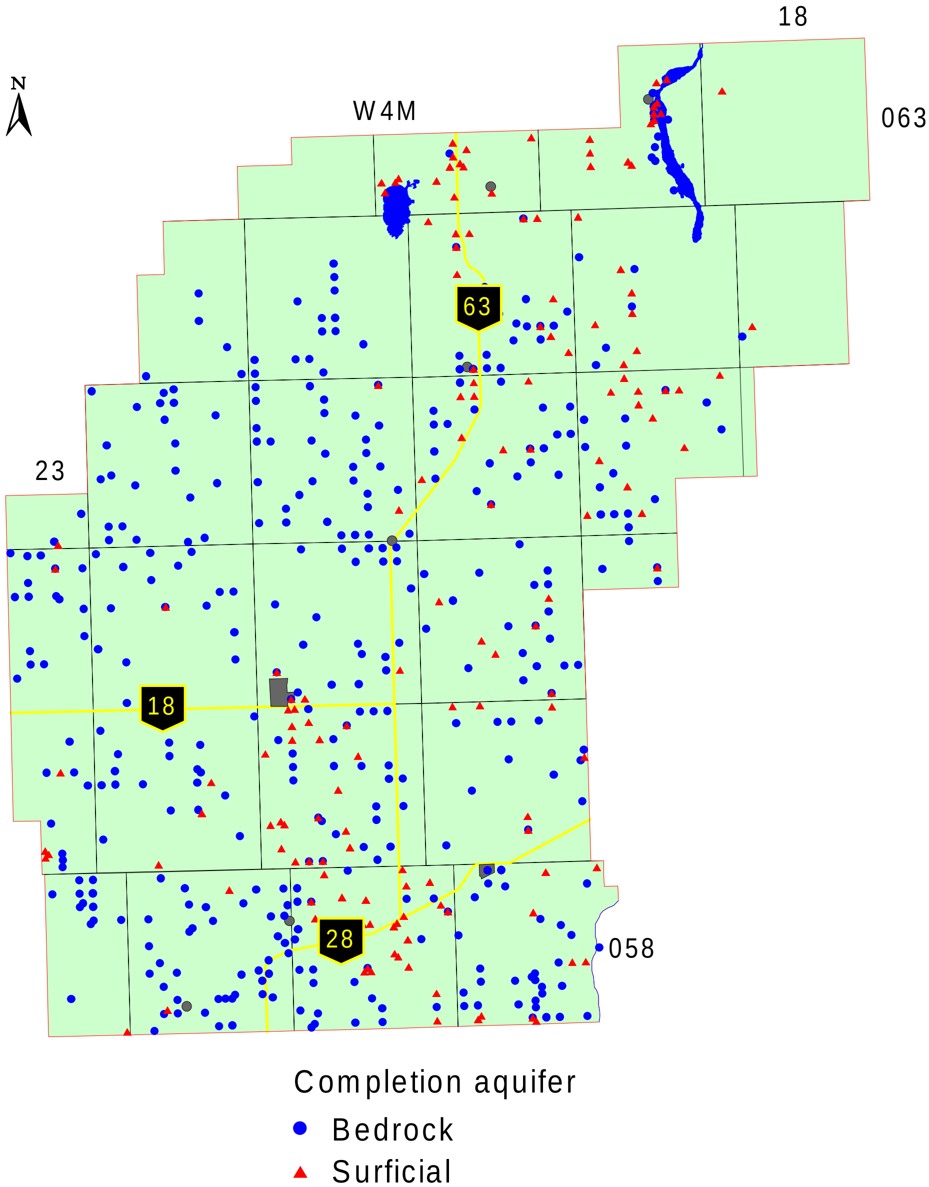
HYDROGEOLOGICAL MAPS AND FIGURES

Index Map

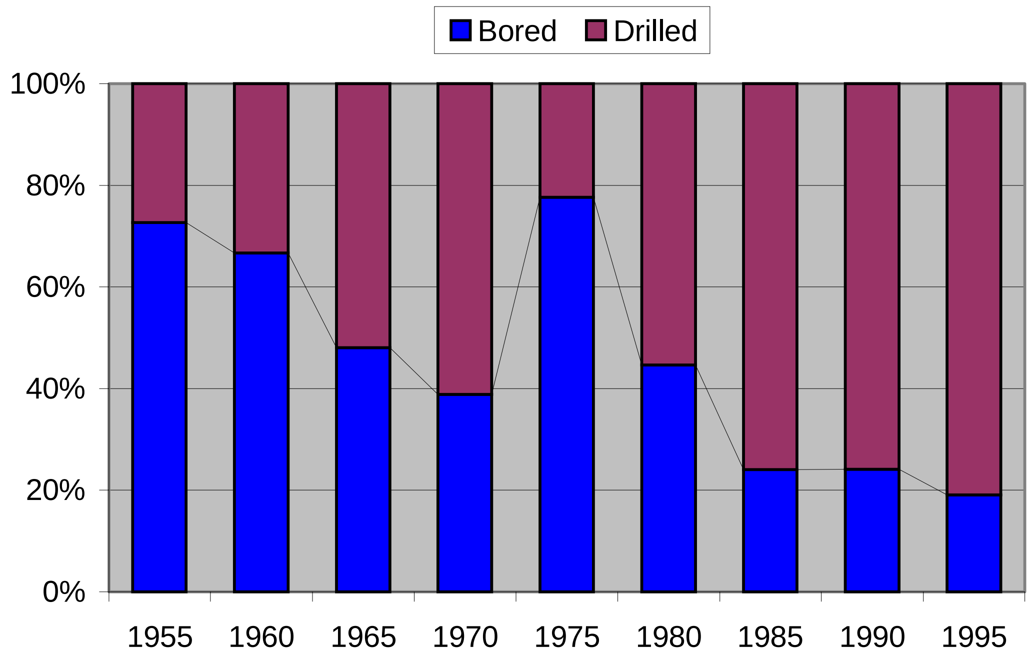

Athabasca
Lac La Biche
Cold Lake
Saskatchewan
28
North
Sask.
River
Edmonton
Lloydminster


18
W4M
N
063
23
Thorhild
63
058

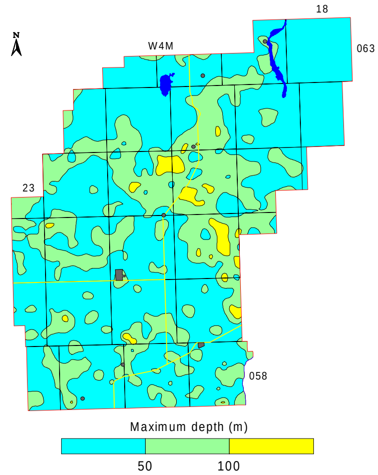
Location of Water Wells

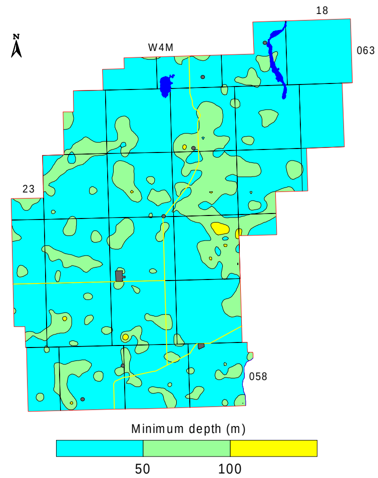


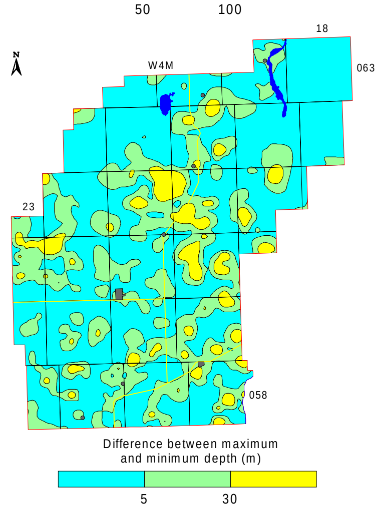
Relationship between Drilled and Bored Water Wells

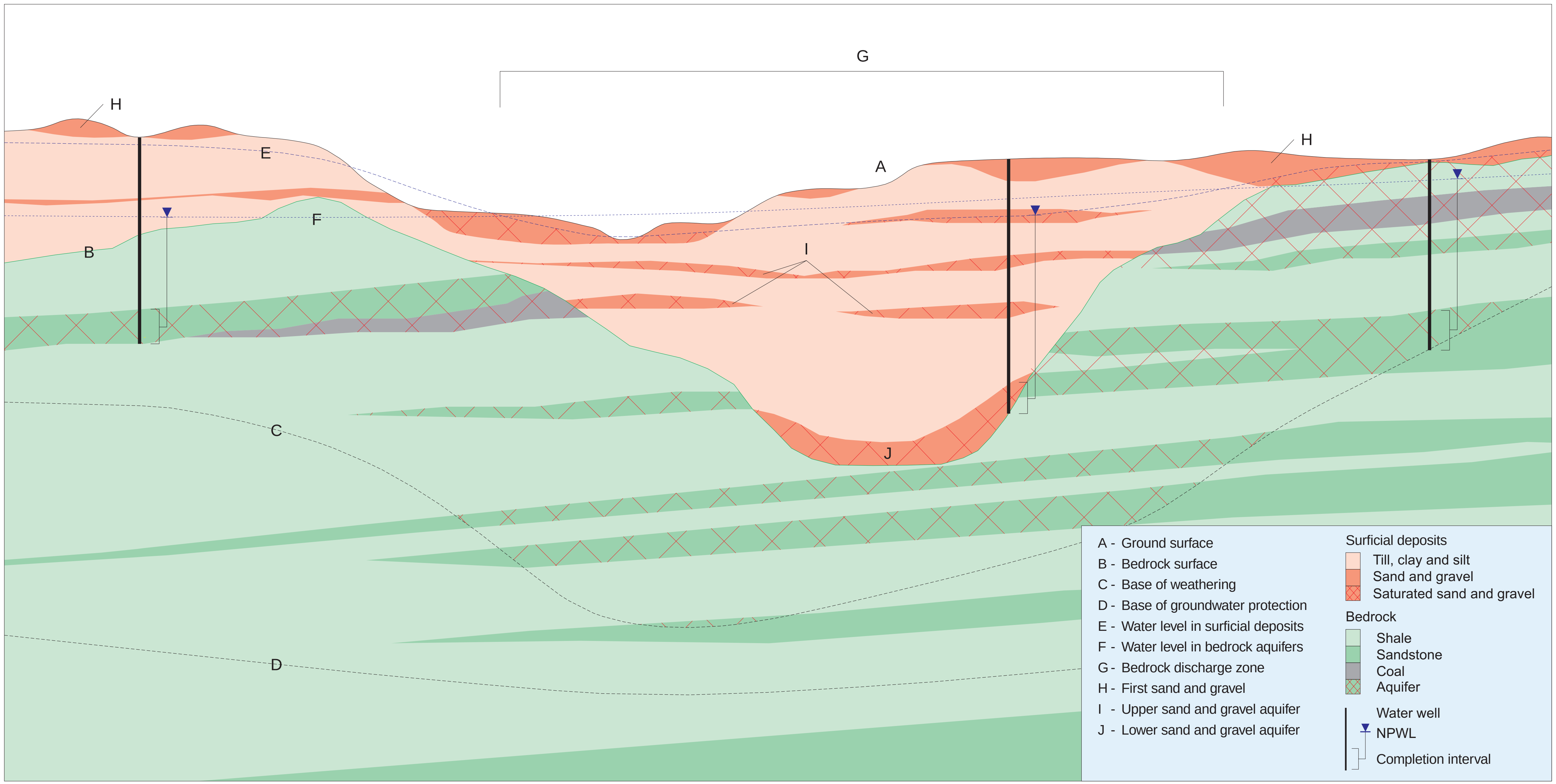


Depth of Existing Water Wells









Generalized Cross-Section

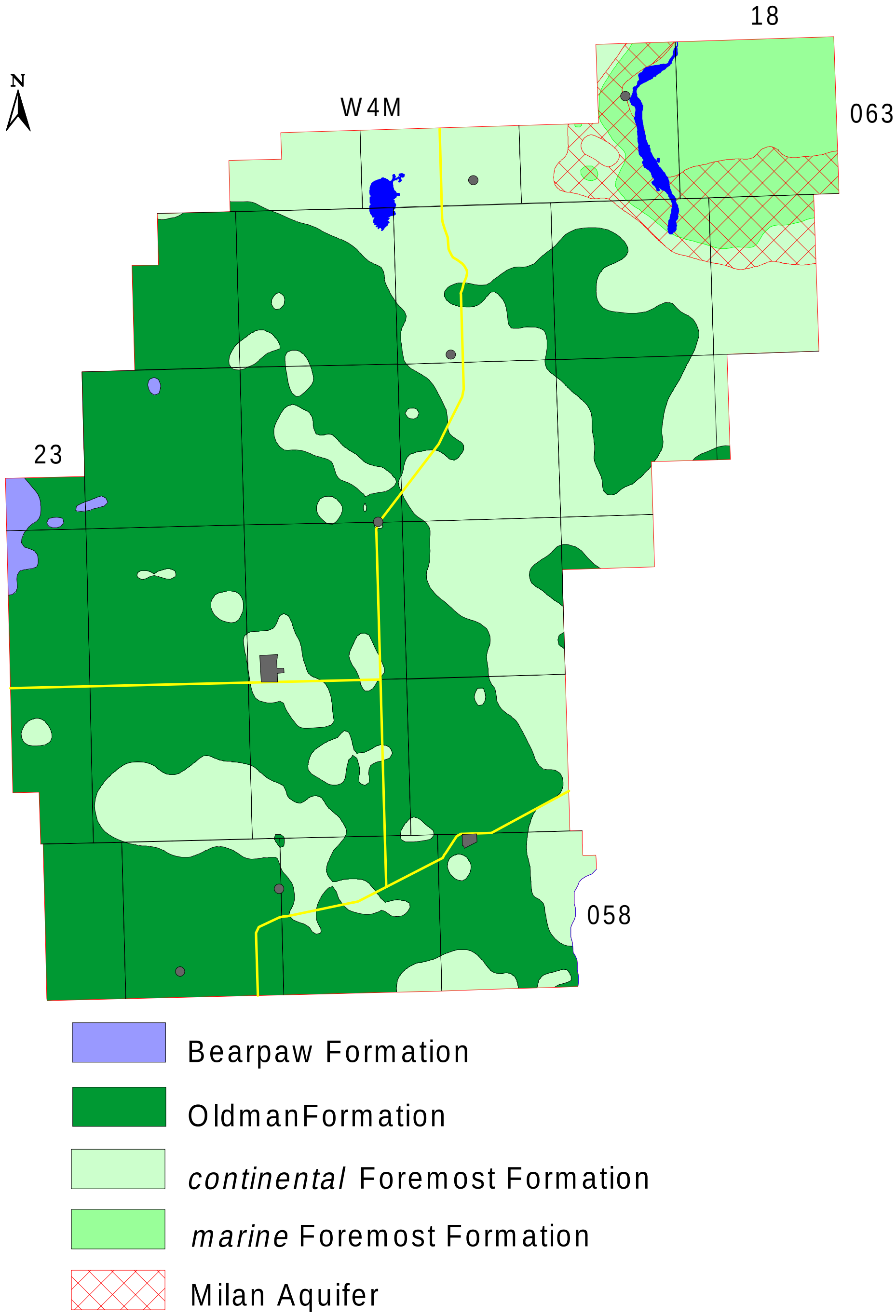
(For terminology only)

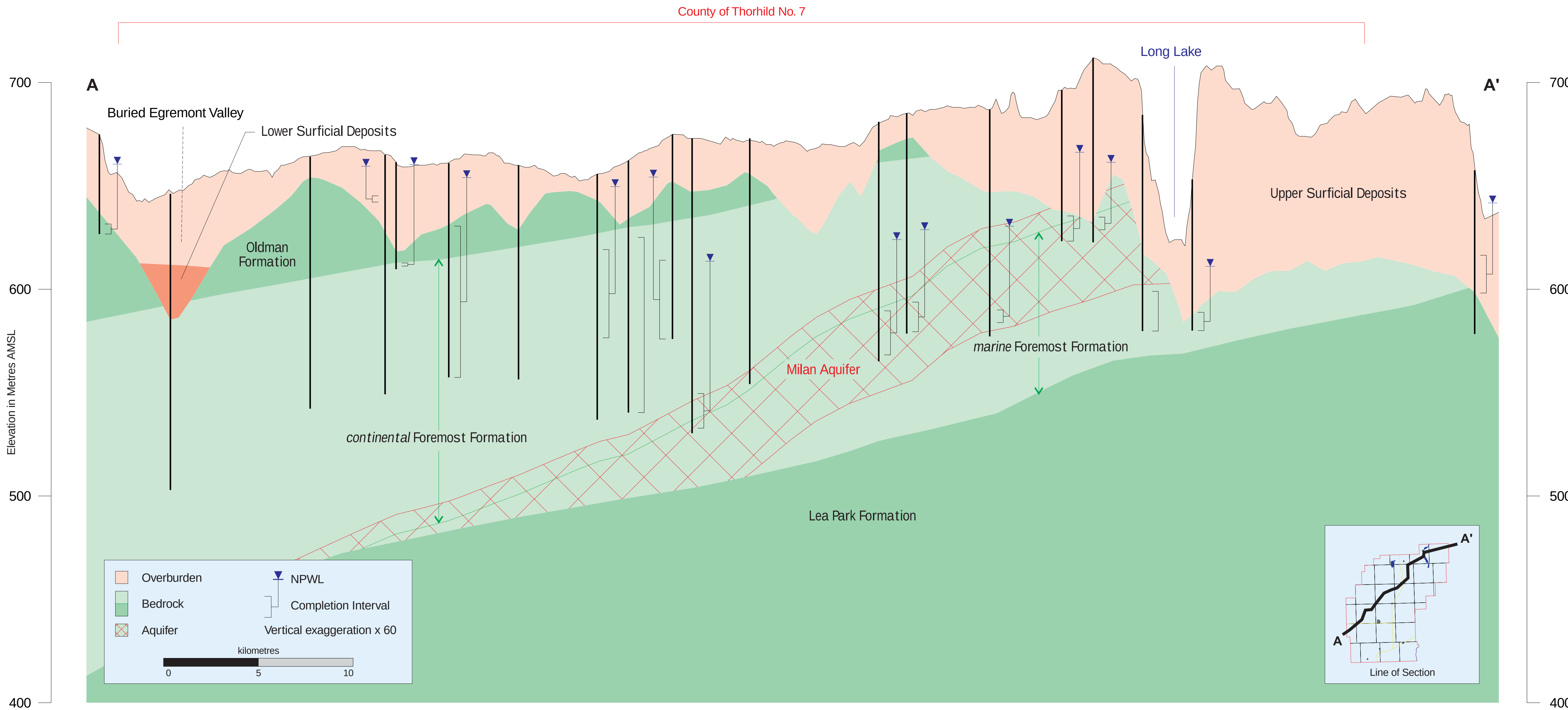
Lithology	Lithologic Description	Group and Formation: Thickness	Group and Formation: Designation	Member: Thickness	Member: Designation	Zone: Thickness	Zone: Designation
	sand, gravel, till, clay, silt	<60	Surficial Deposits	<60	Upper	<30	First Sand and Gravel
				<30	Lower		
	shale, sandstone, siltstone	60-120	Bearpaw Formation				
	sandstone, siltstone, shale, coal	40-80	Belly River Group — Oldman Formation	<30	Dinosaur Member	<25	Lethbridge Coal Zone
				<20	Upper Siltstone Member		
				8-20	Comrey Member		
	shale, sandstone, coal	10-220	Belly River Group — *continental* Foremost Formation			<20	Taber Coal Zone (Milan Aquifer)
						<20	McKay Coal Zone (Milan Aquifer)
	sandstone, shale	<200	Belly River Group — *marine* Foremost Formation (Basal Belly River Sandstone)	<30	Birch Lake Member		Milan Aquifer
				<30	Ribstone Creek Member		
				<30	Victoria Member		
				<30	Brosseau Member		
	shale, siltstone	100-200	Lea Park Formation	50-100	Upper		
				50-100	Lower		

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

Geologic Column

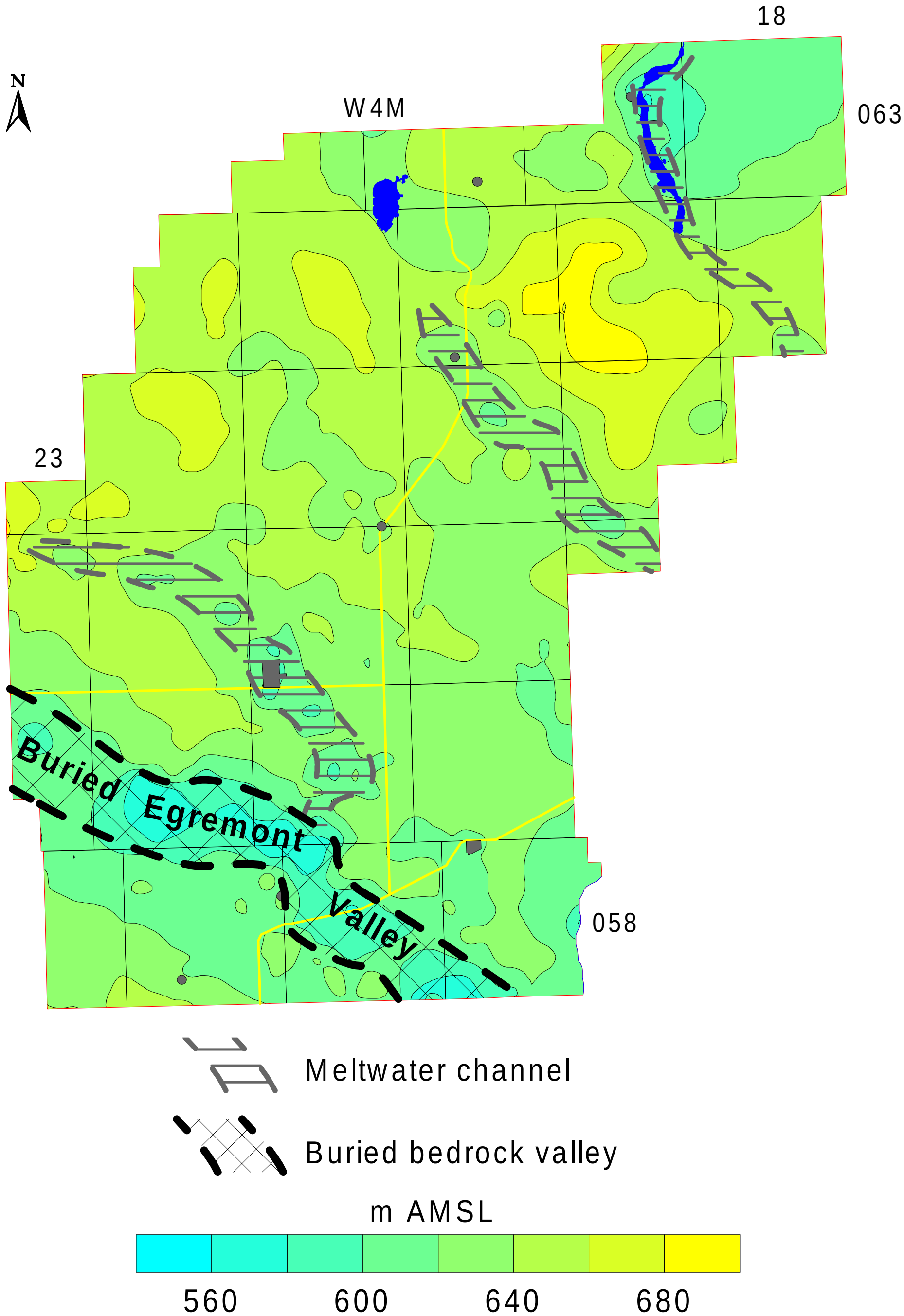
Bedrock Geology



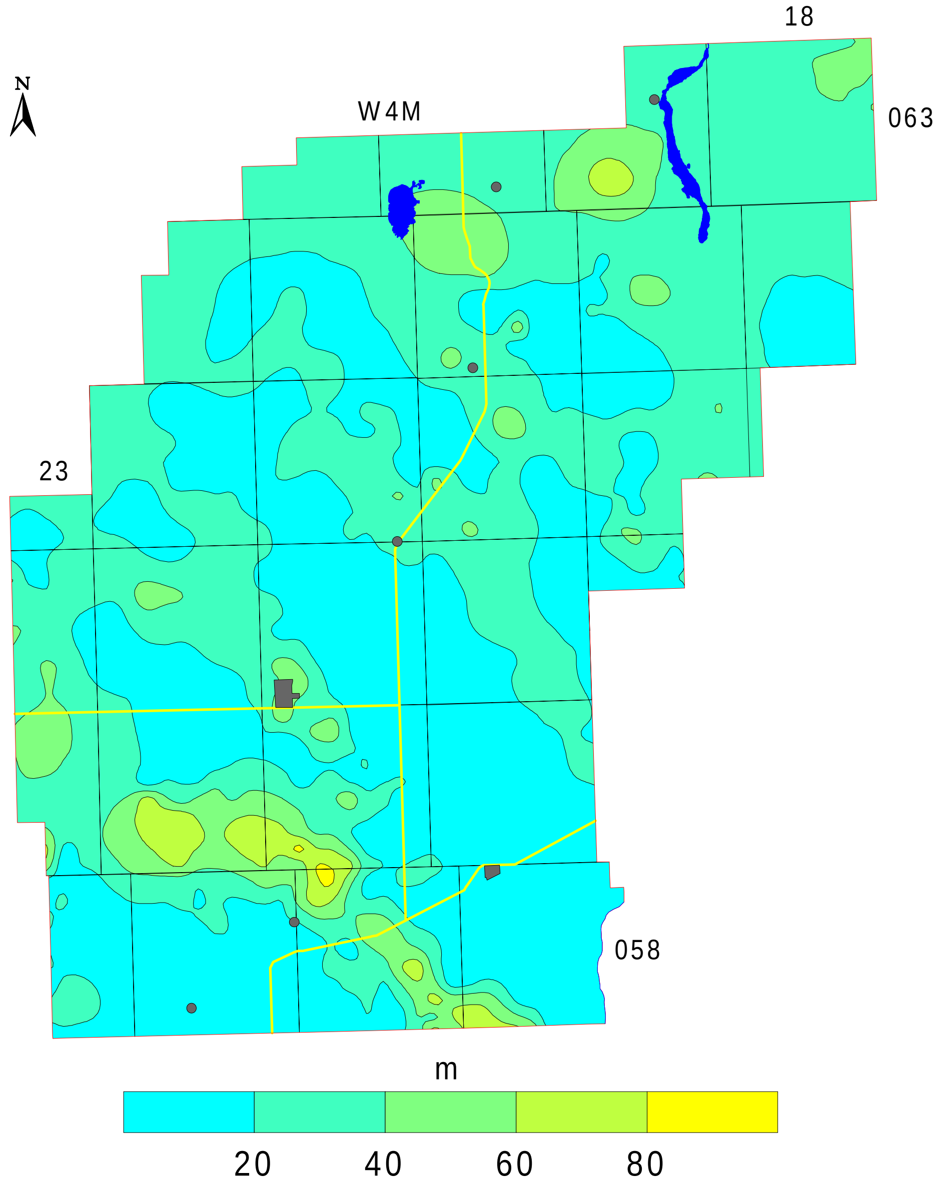


Cross-Section A - A'

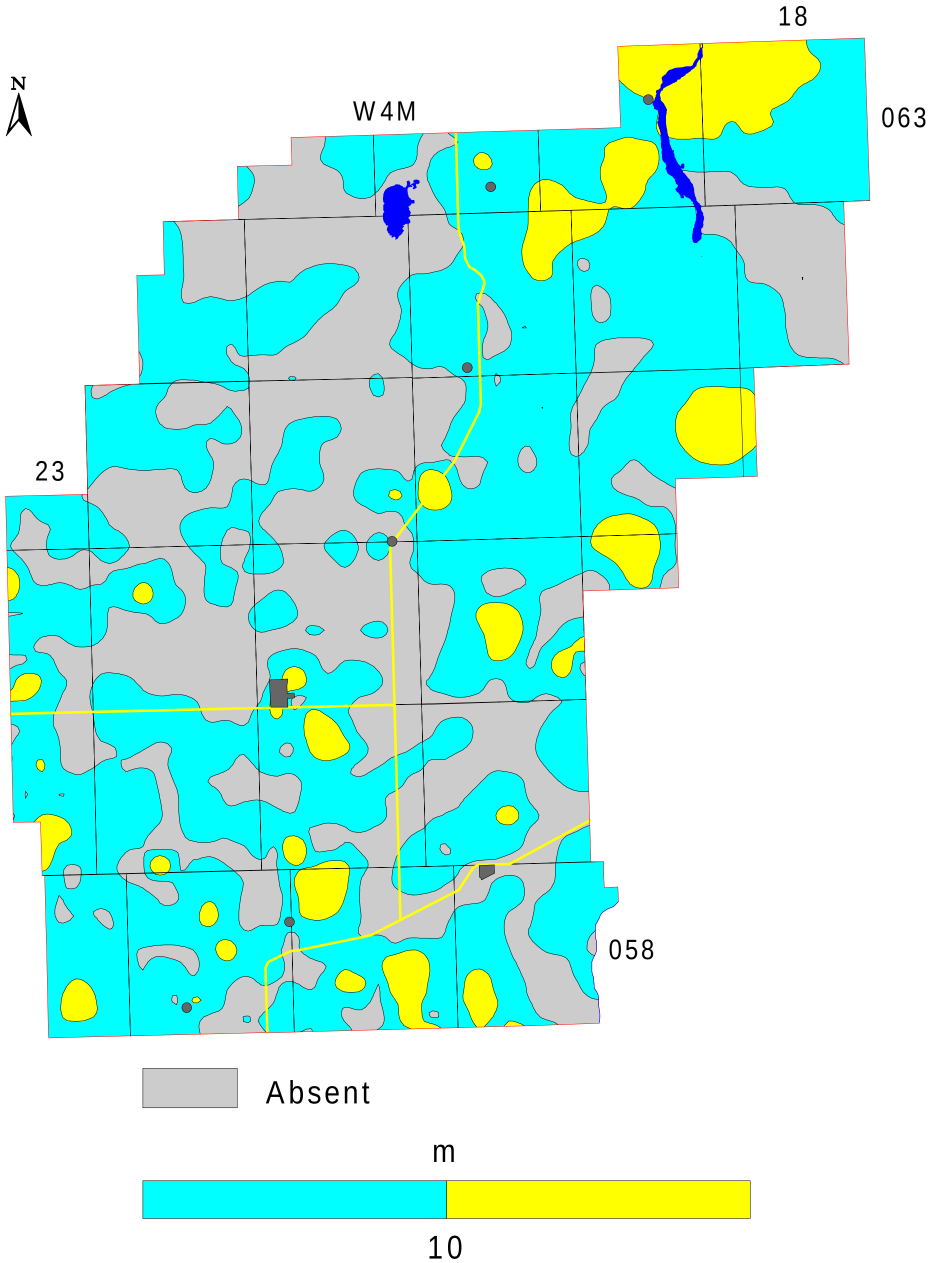
Bedrock Topography



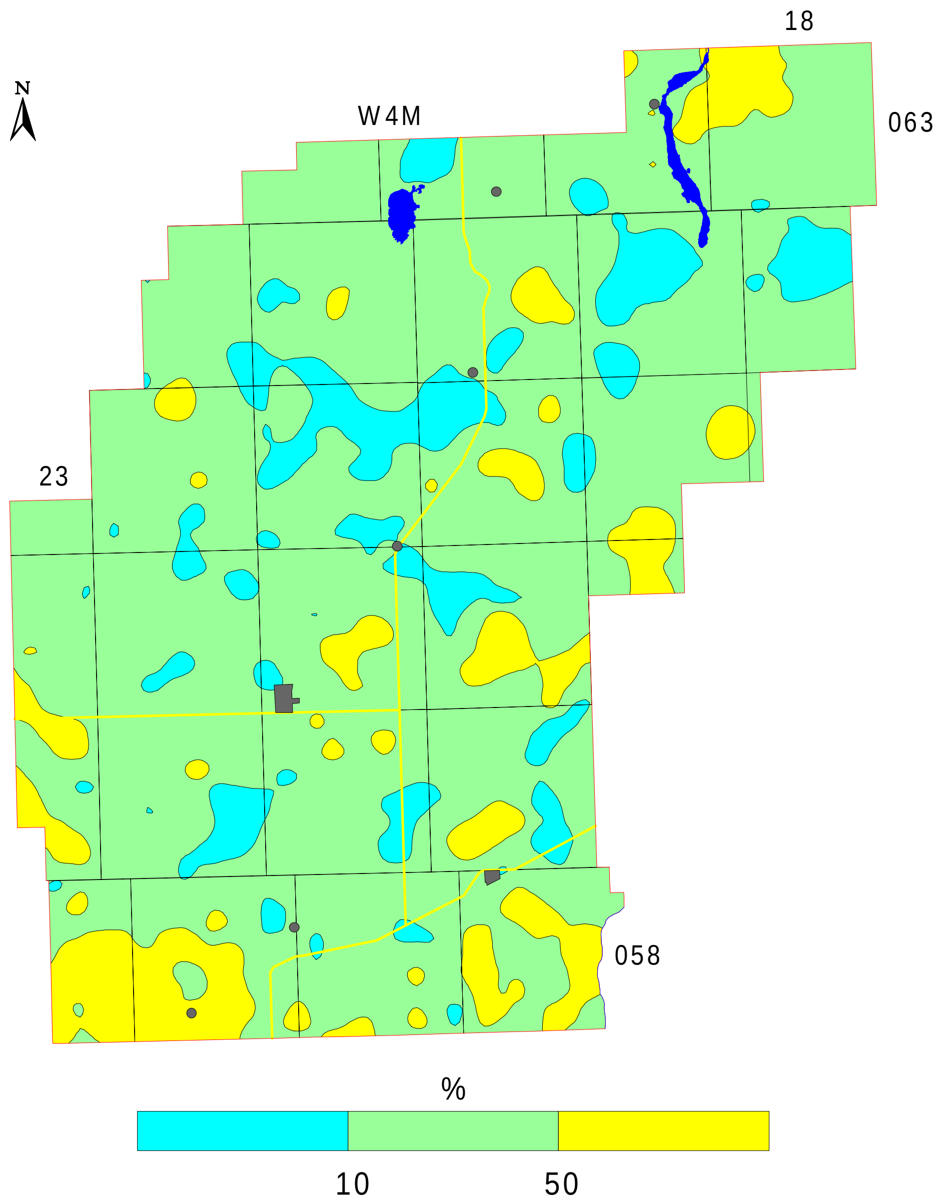
Thickness of Surficial Deposits



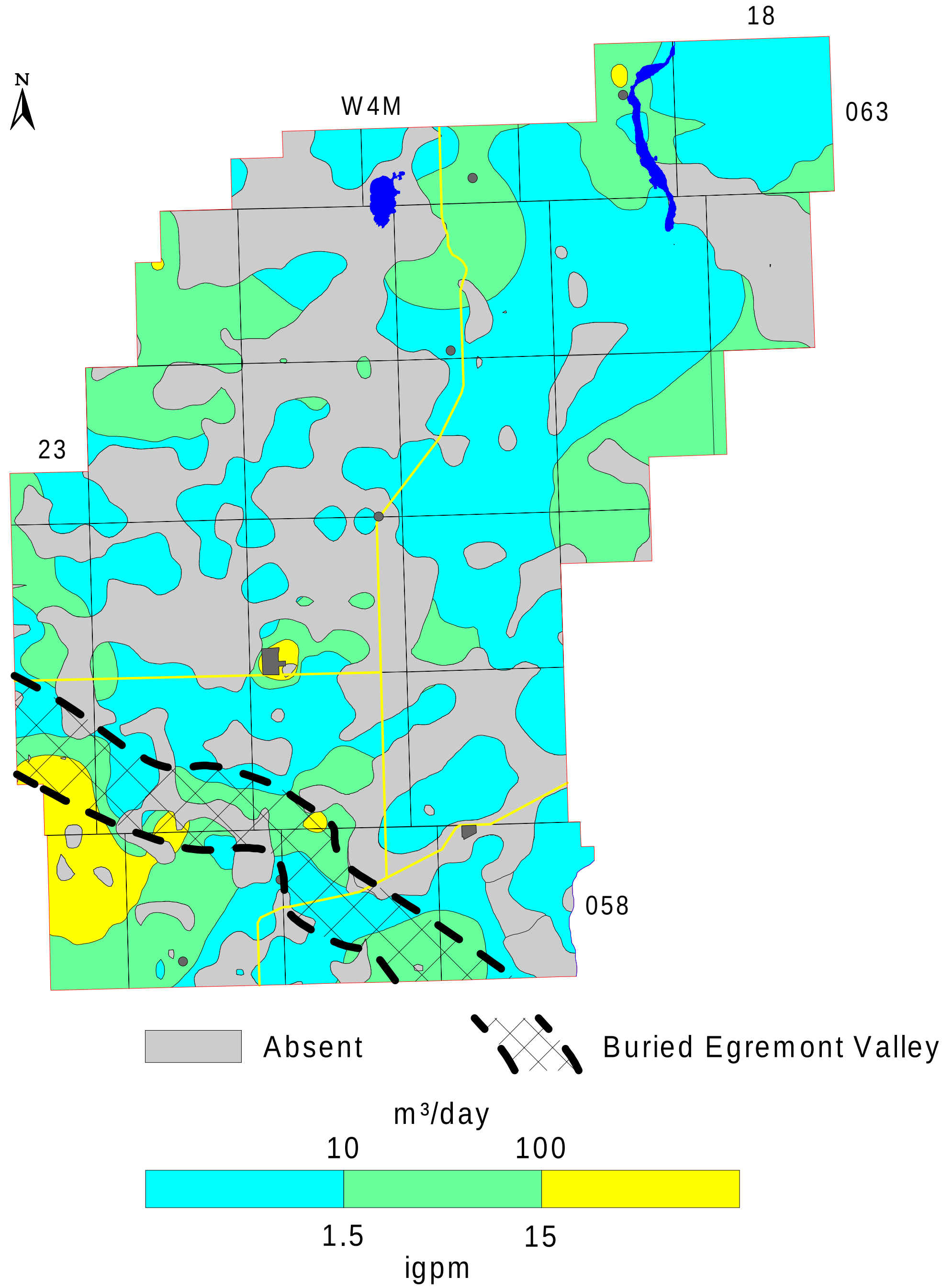
Thickness of Sand and Gravel Aquifer(s)



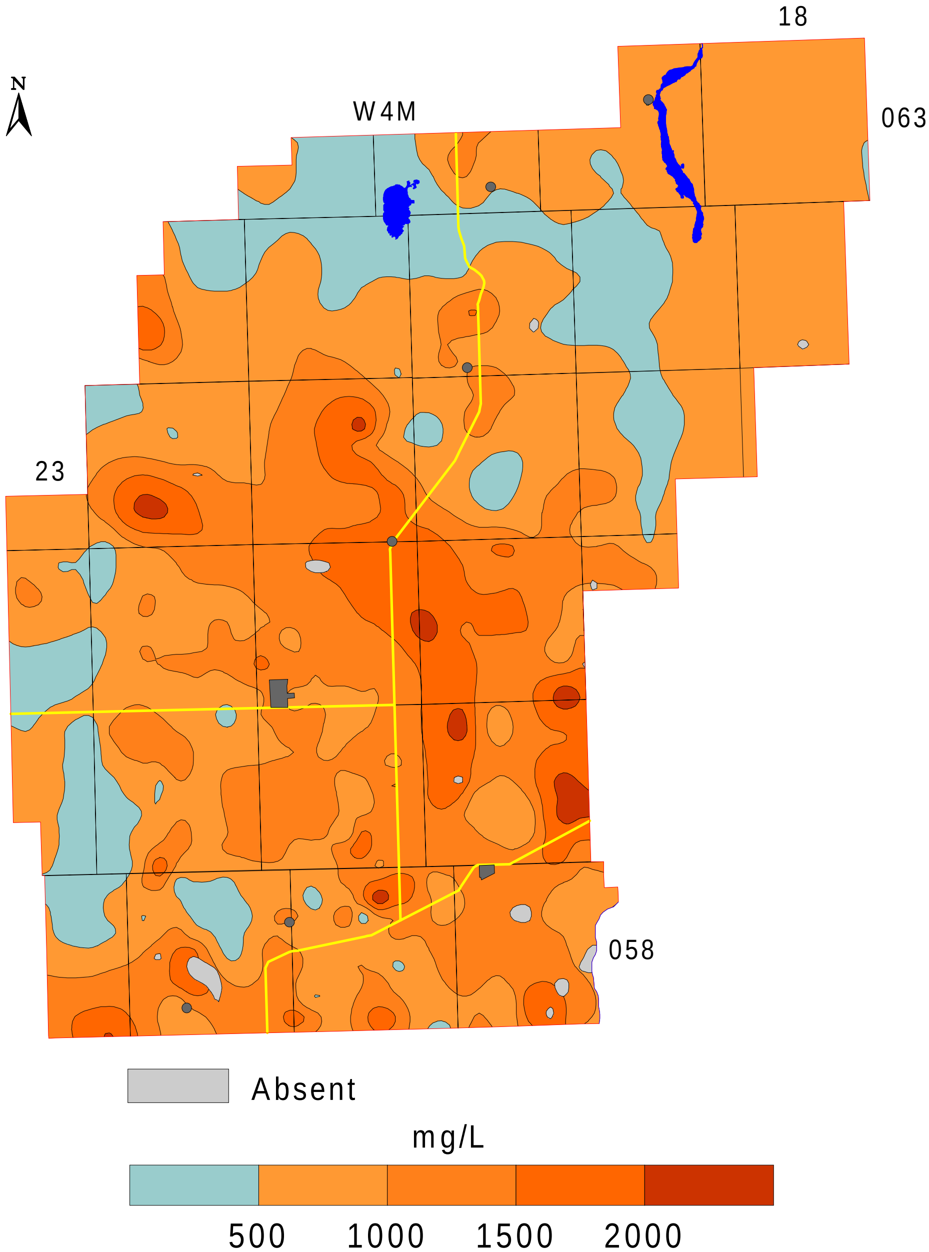
Amount of Sand and Gravel in Surficial Deposits



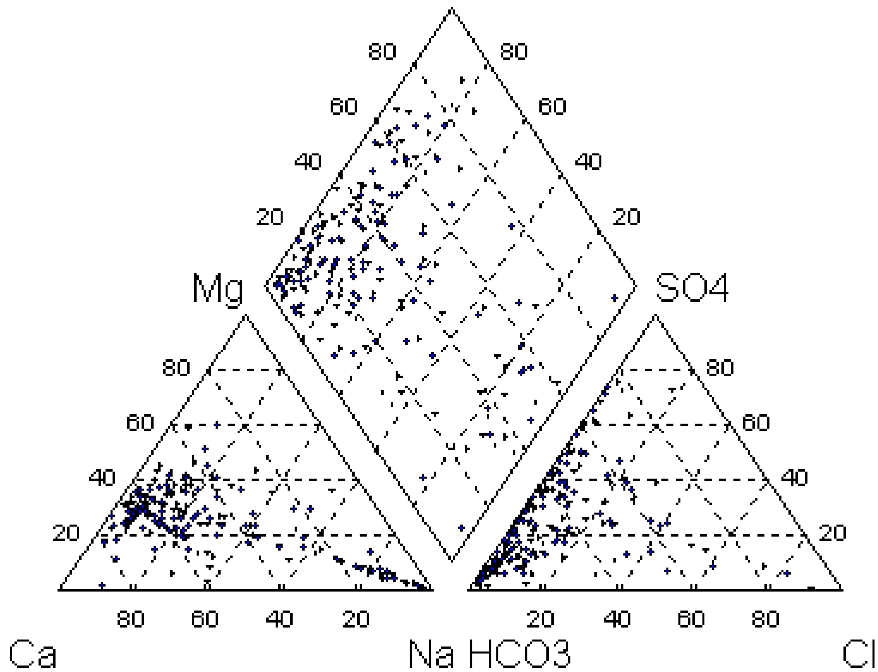
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



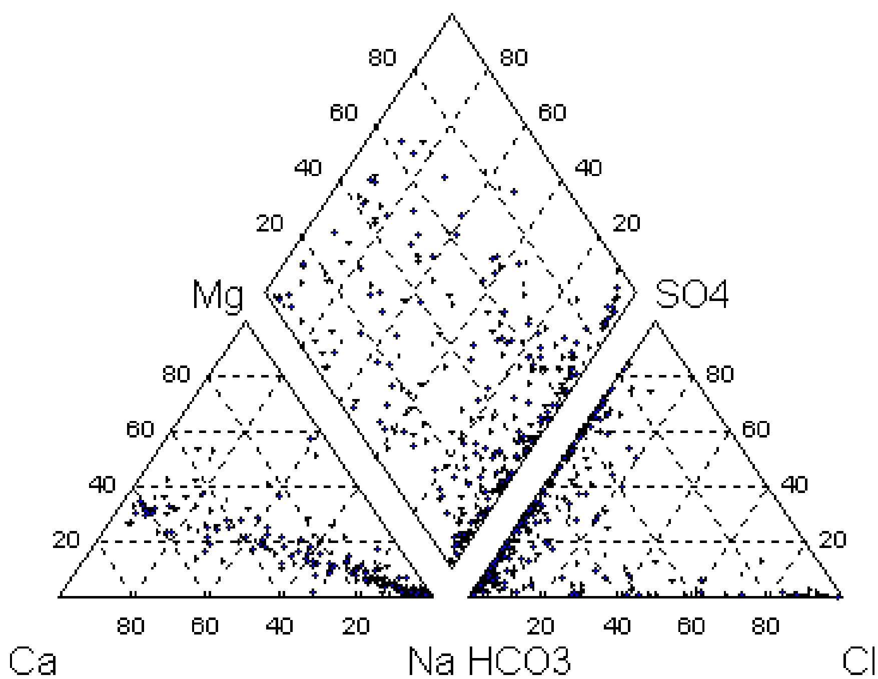
Total Dissolved Solids in Groundwater from Surficial Deposits



Piper Diagrams

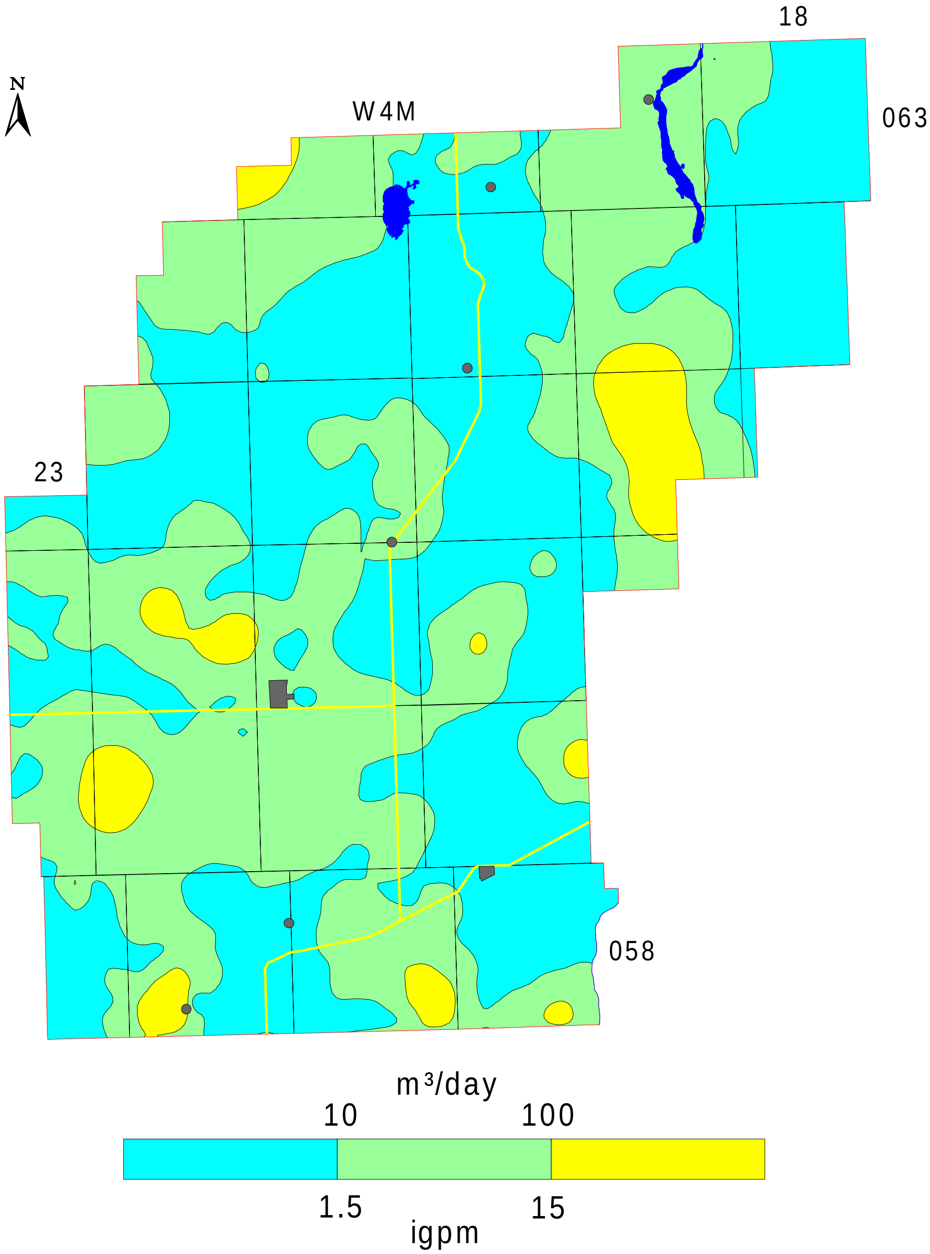


Surficial Deposits

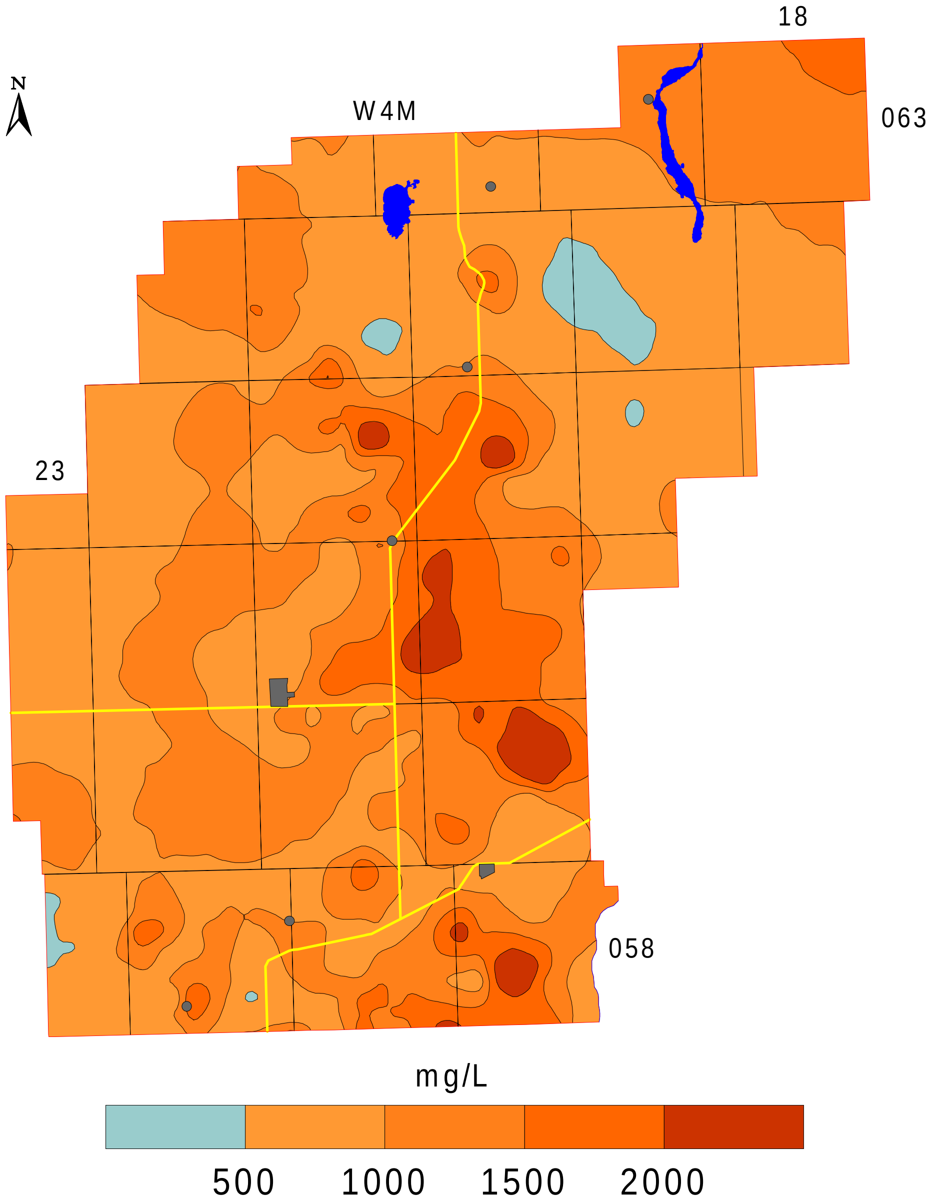


Bedrock Aquifers

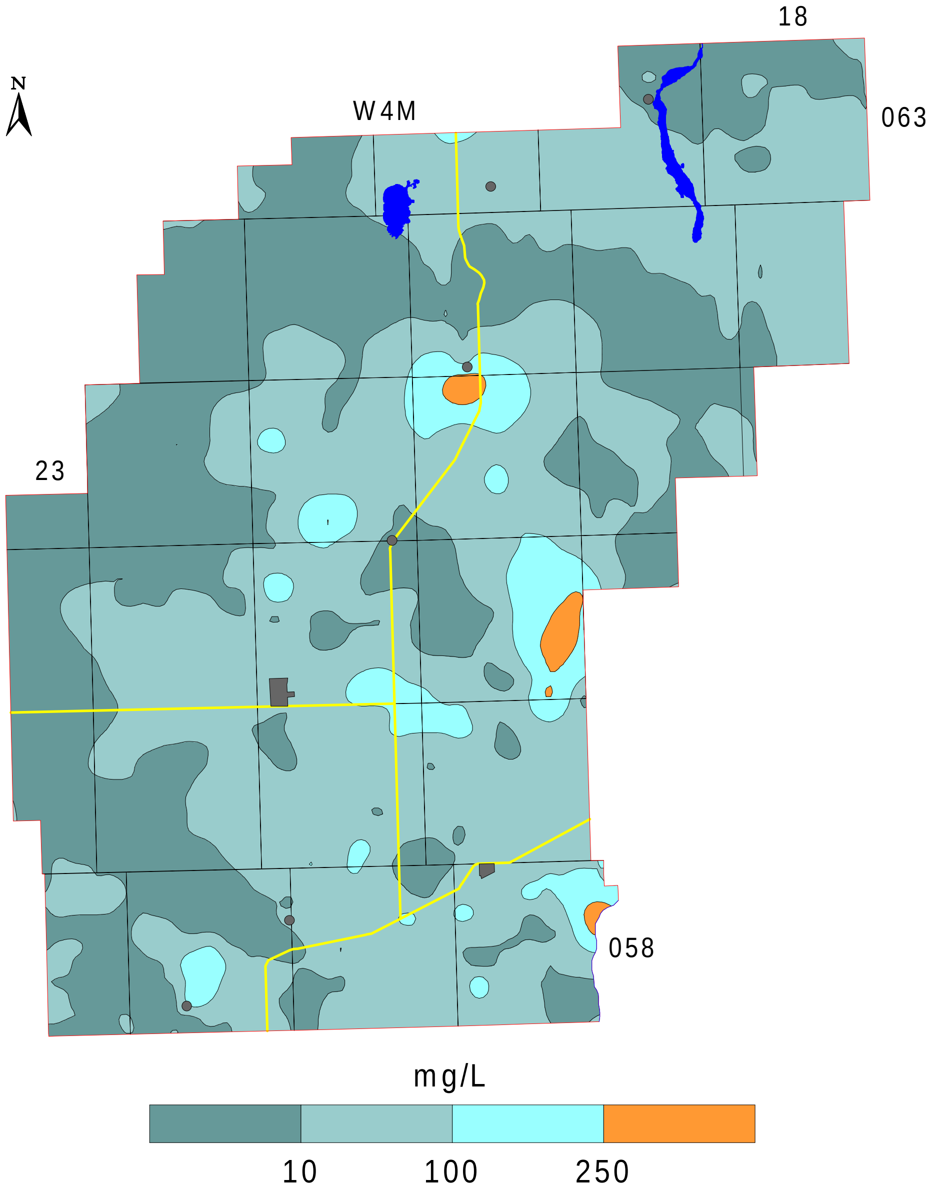
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer



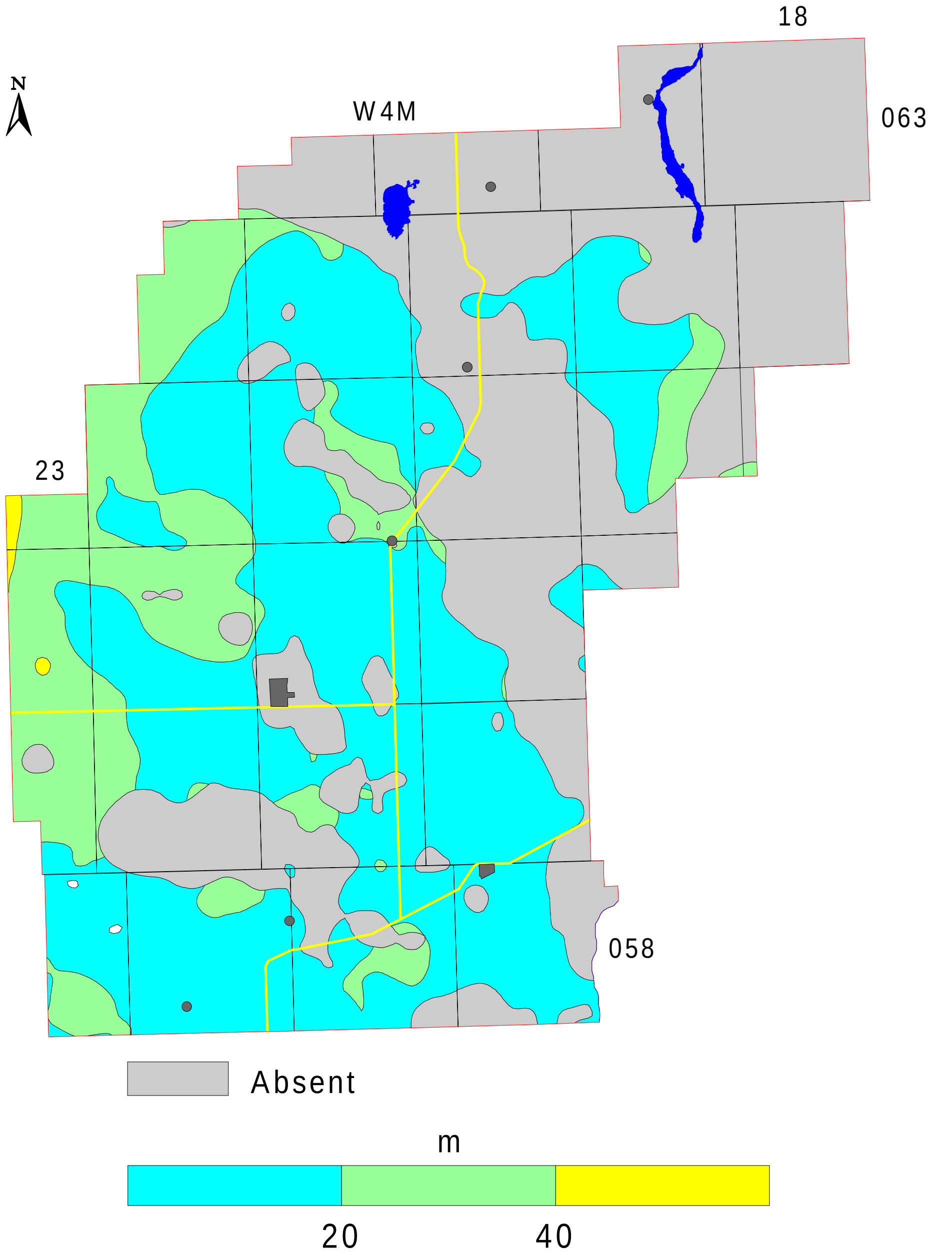
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer



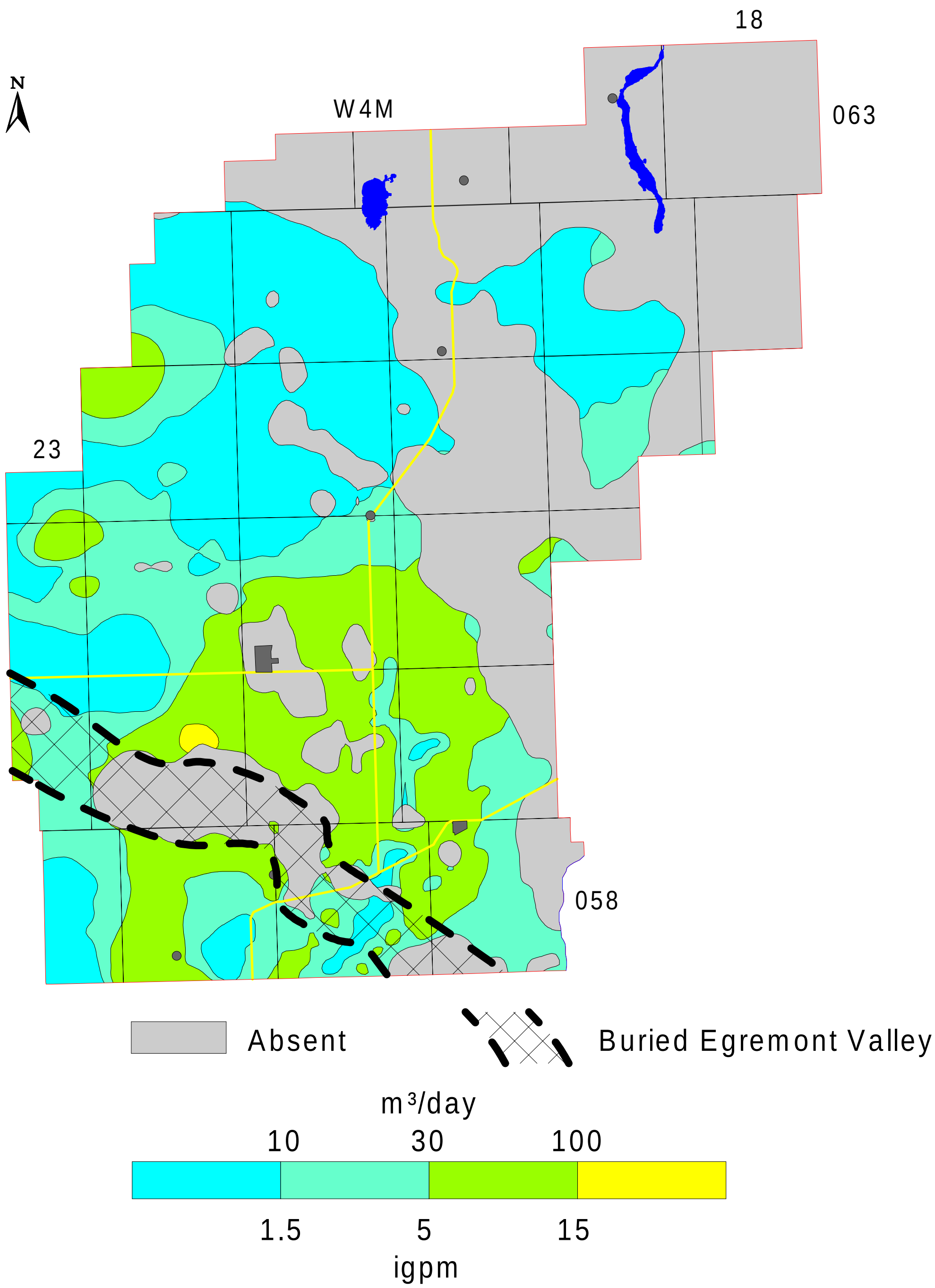
Chloride in Groundwater from Upper Bedrock Aquifer



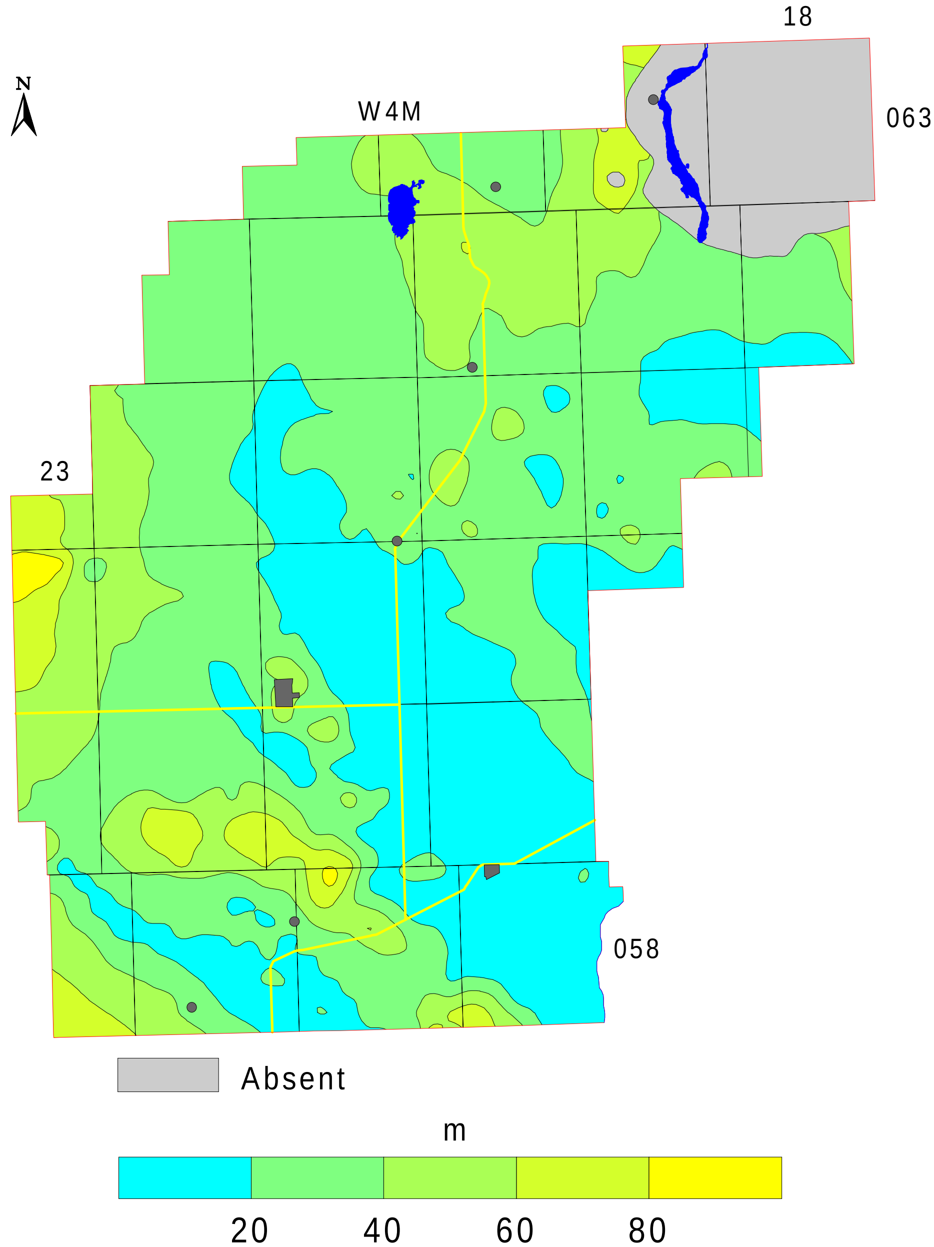
Depth to Top of Oldman Formation



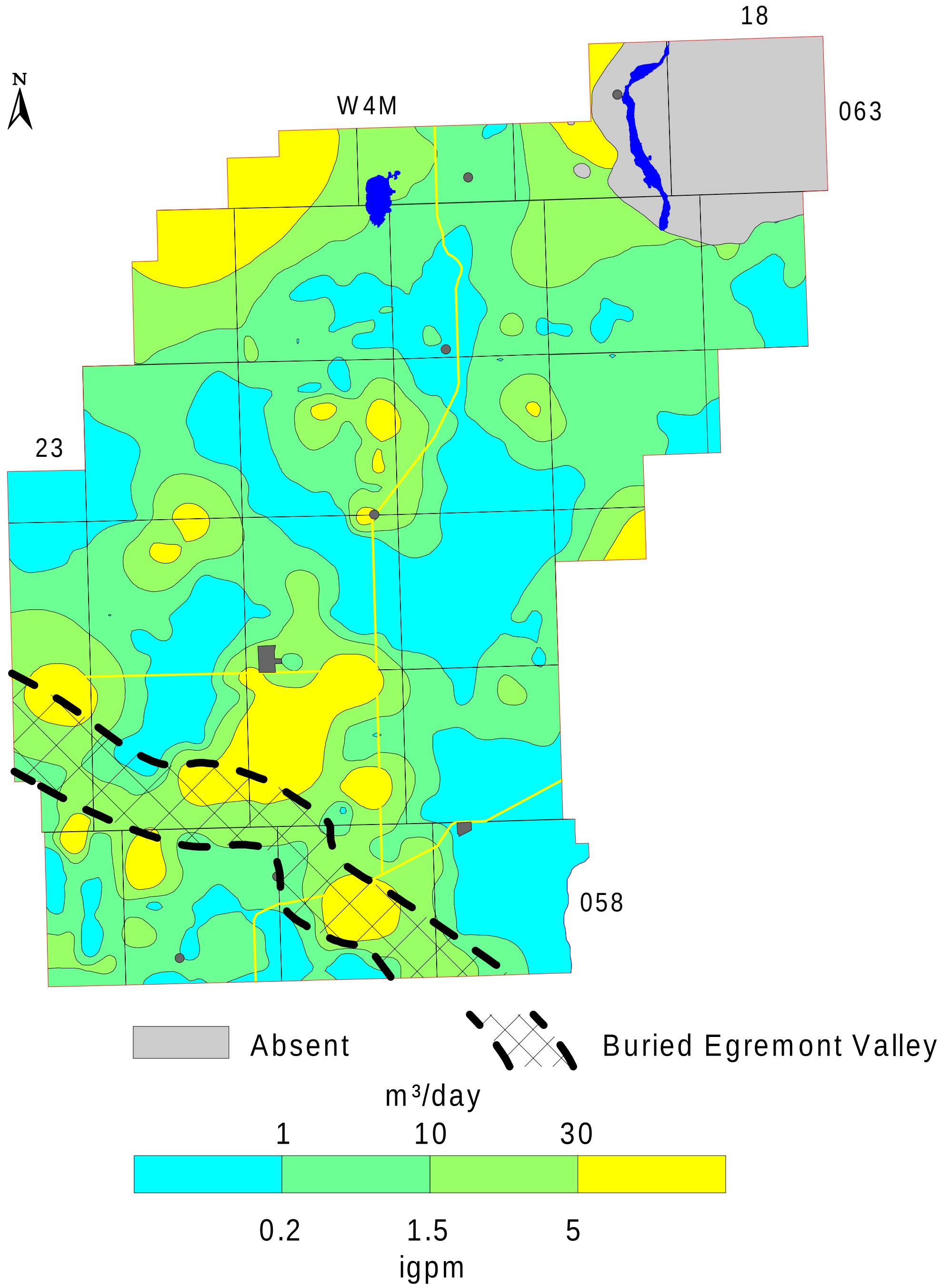
Apparent Yield for Water Wells Completed through Oldman Aquifer



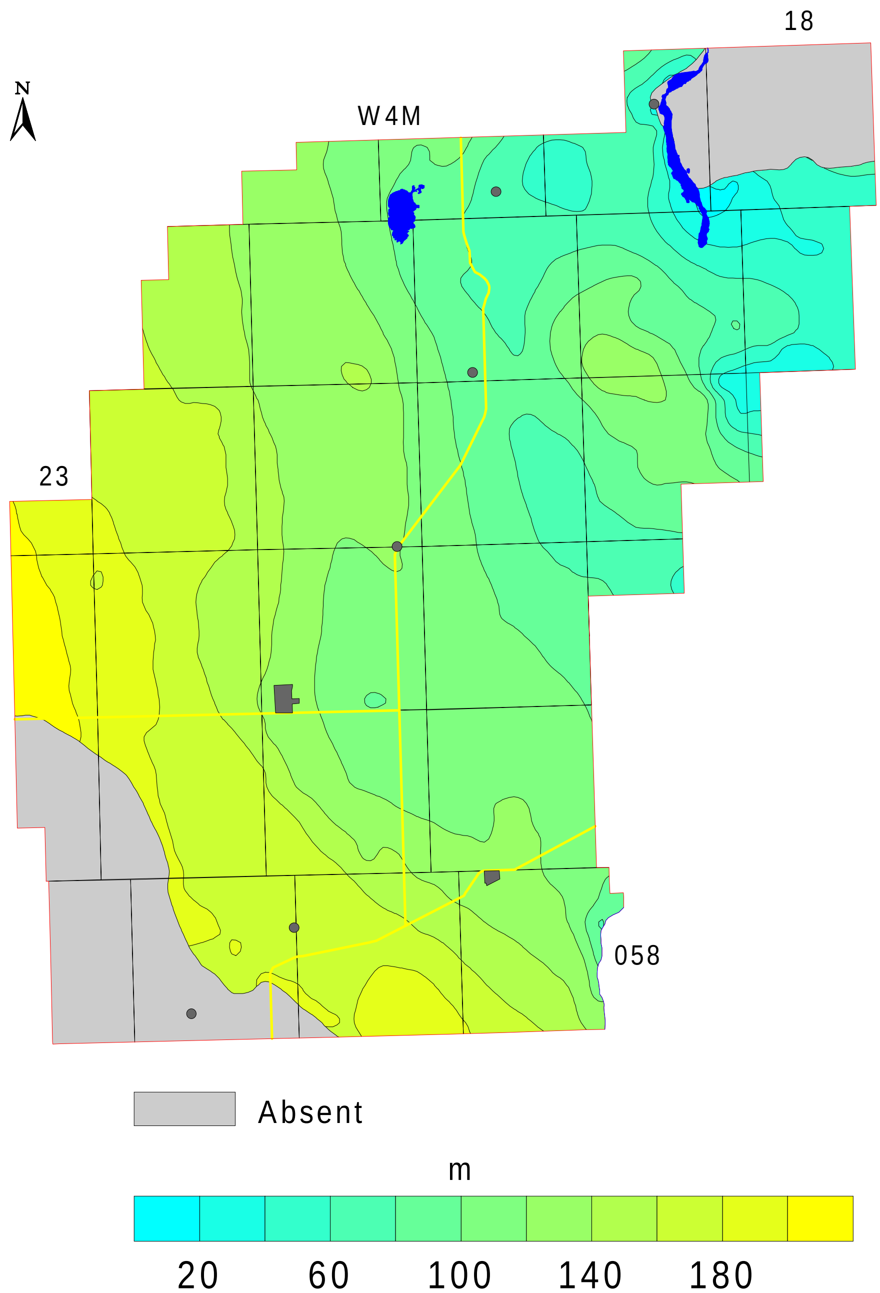
Depth to Top of continental Foremost Formation



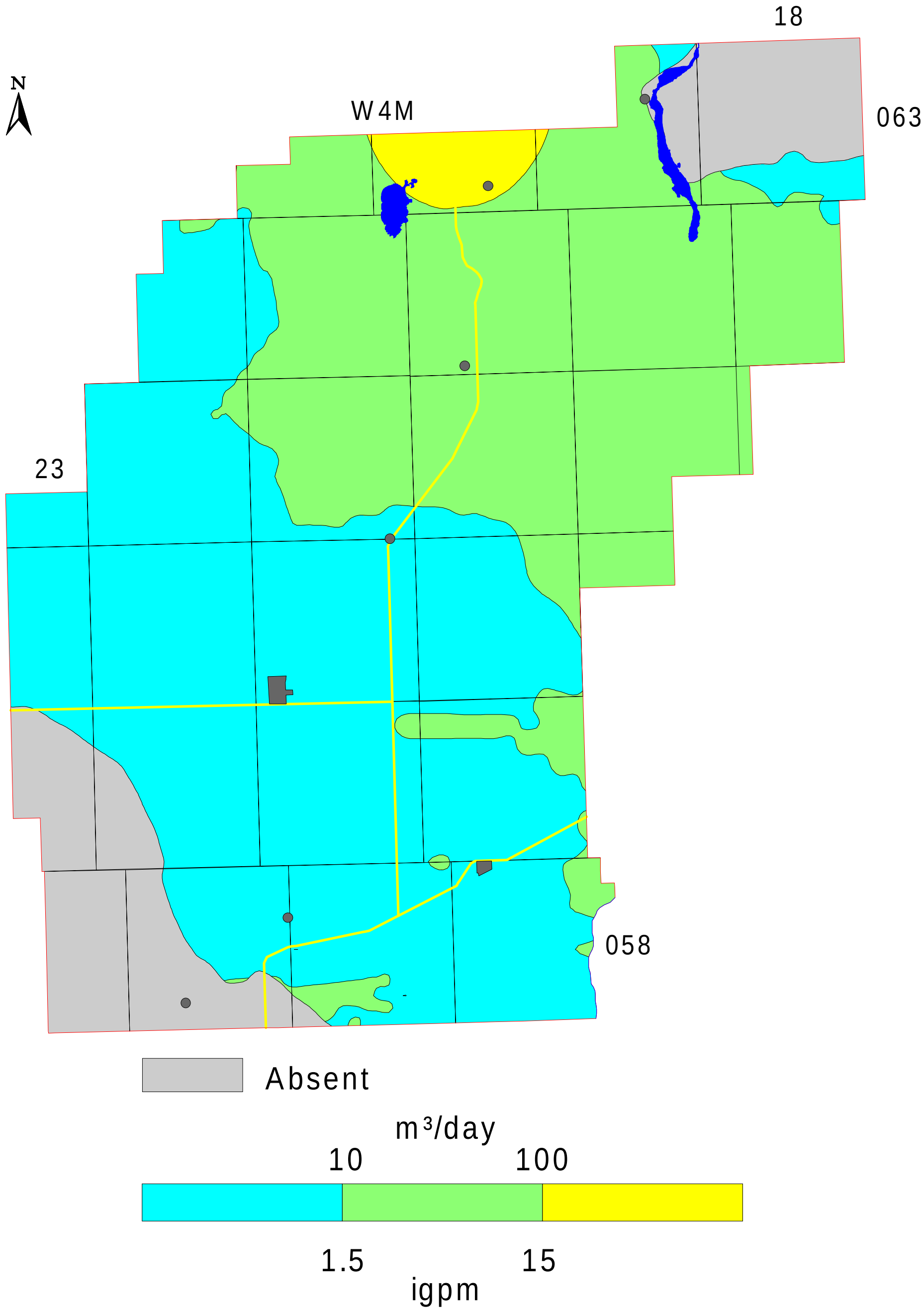
Apparent Yield for Water Wells Completed through continental Foremost Aquifer



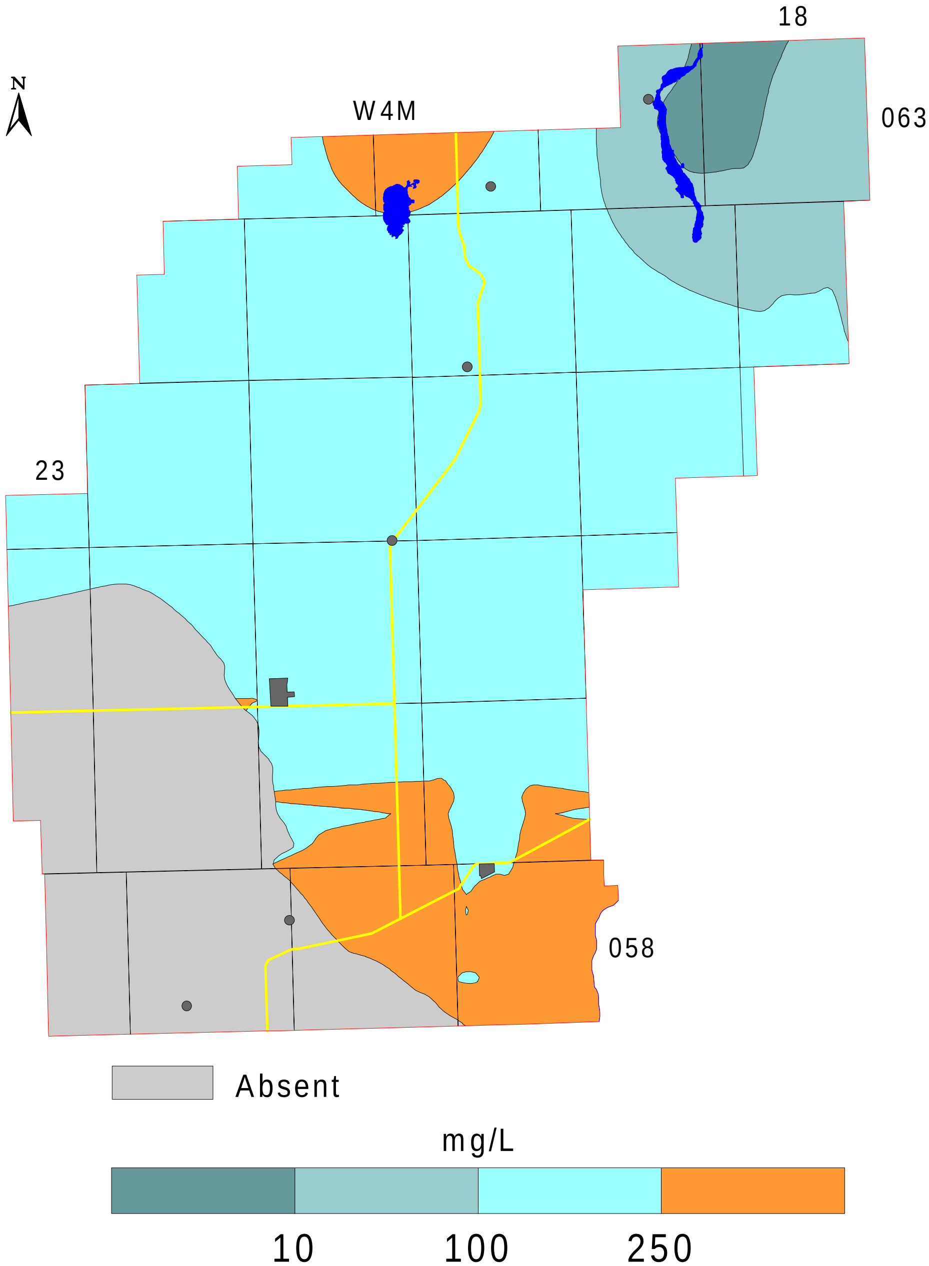
Depth to Top of Milan Aquifer



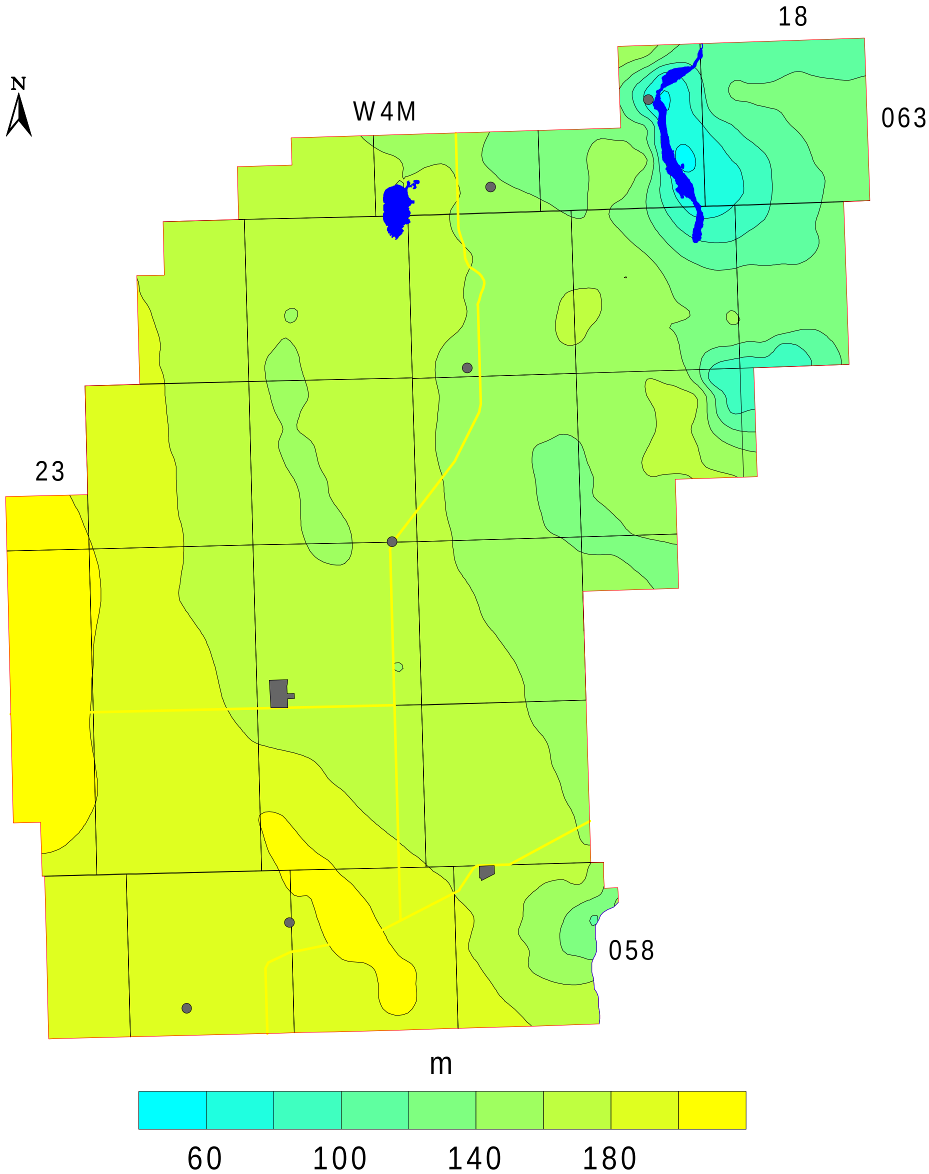
Apparent Yield for Water Wells Completed through Milan Aquifer



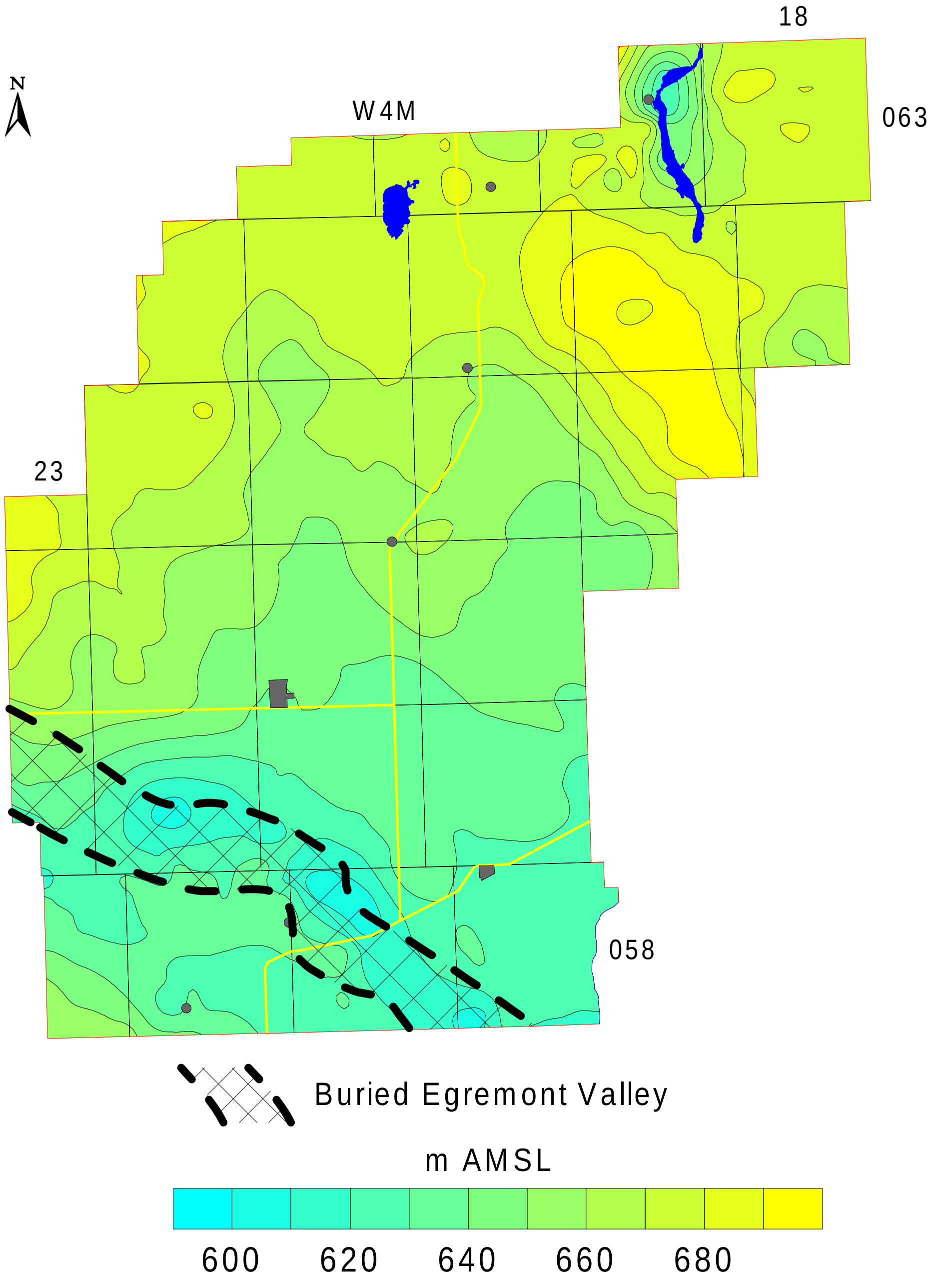
Chloride in Groundwater from marine Foremost Aquifer



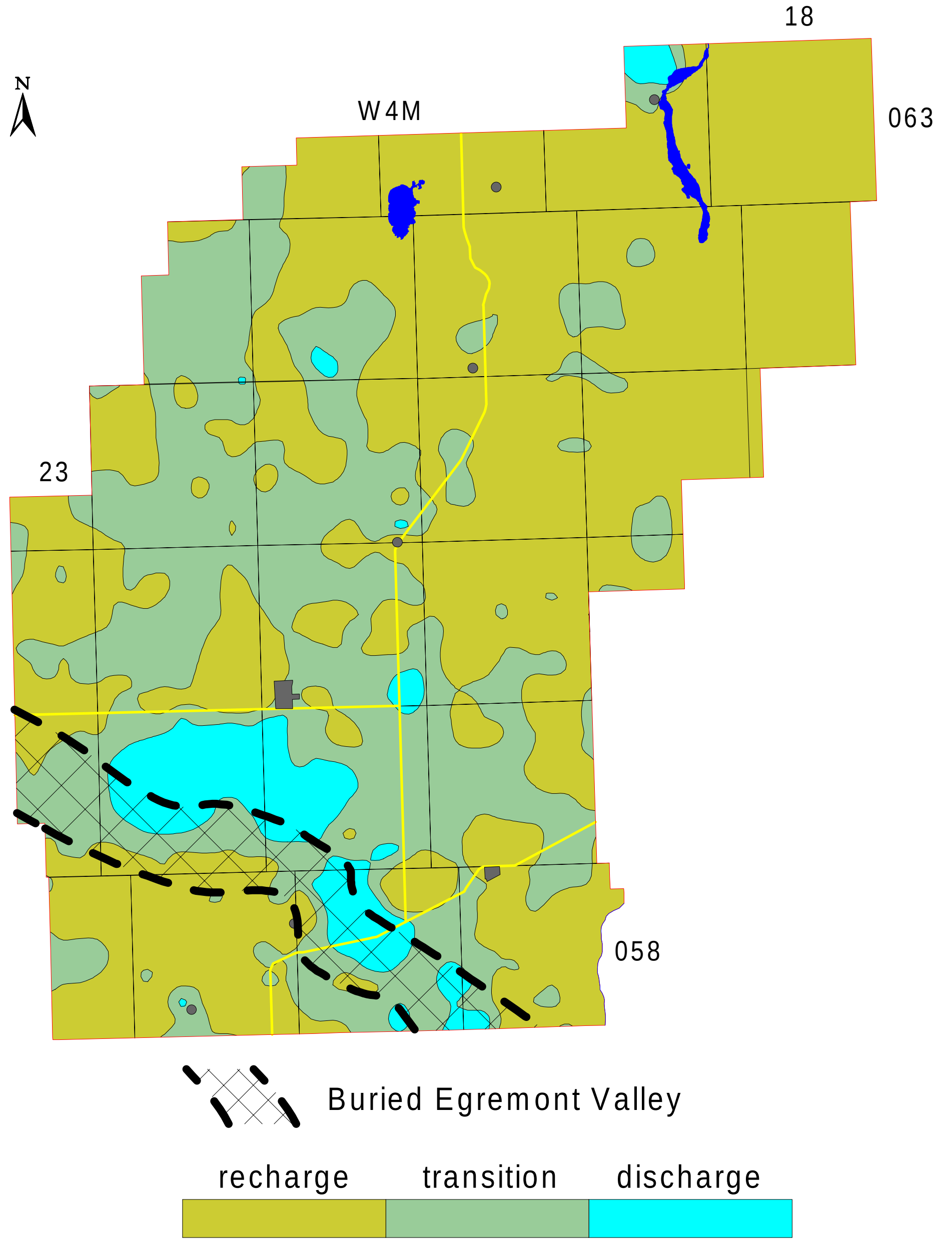
Depth to Top of Lea Park Formation



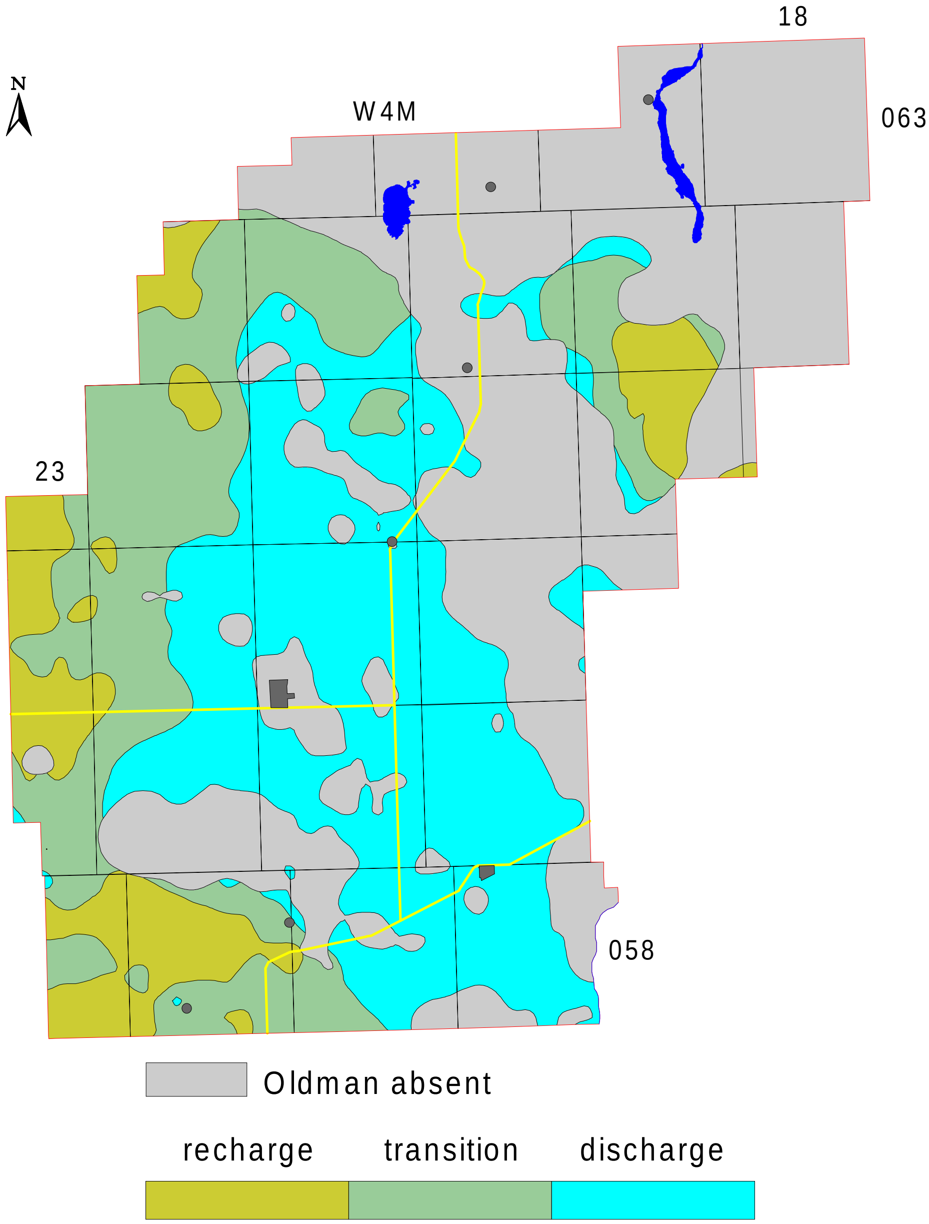
Non-Pumping Water-Level Surface in Surficial Deposits



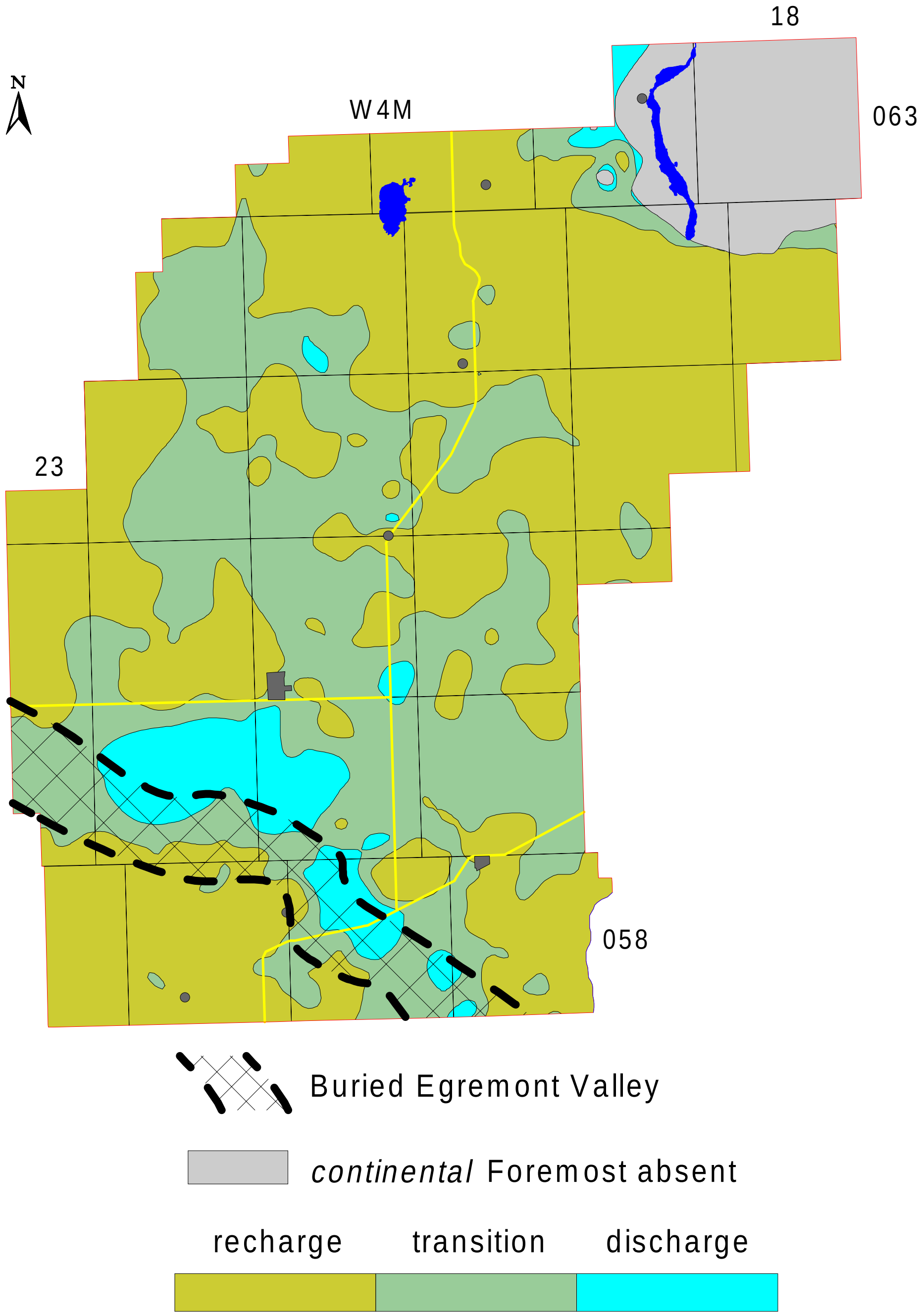
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer



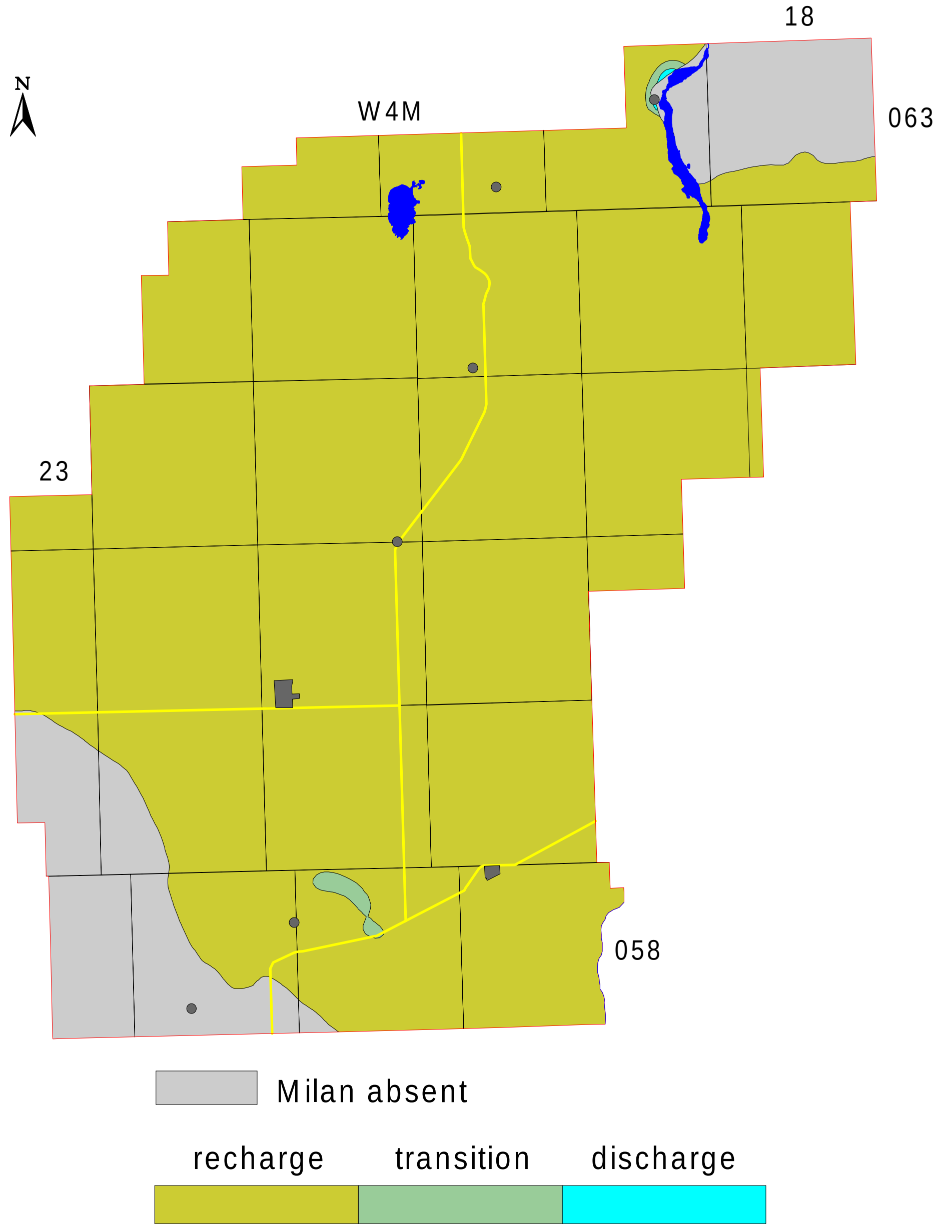
Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer



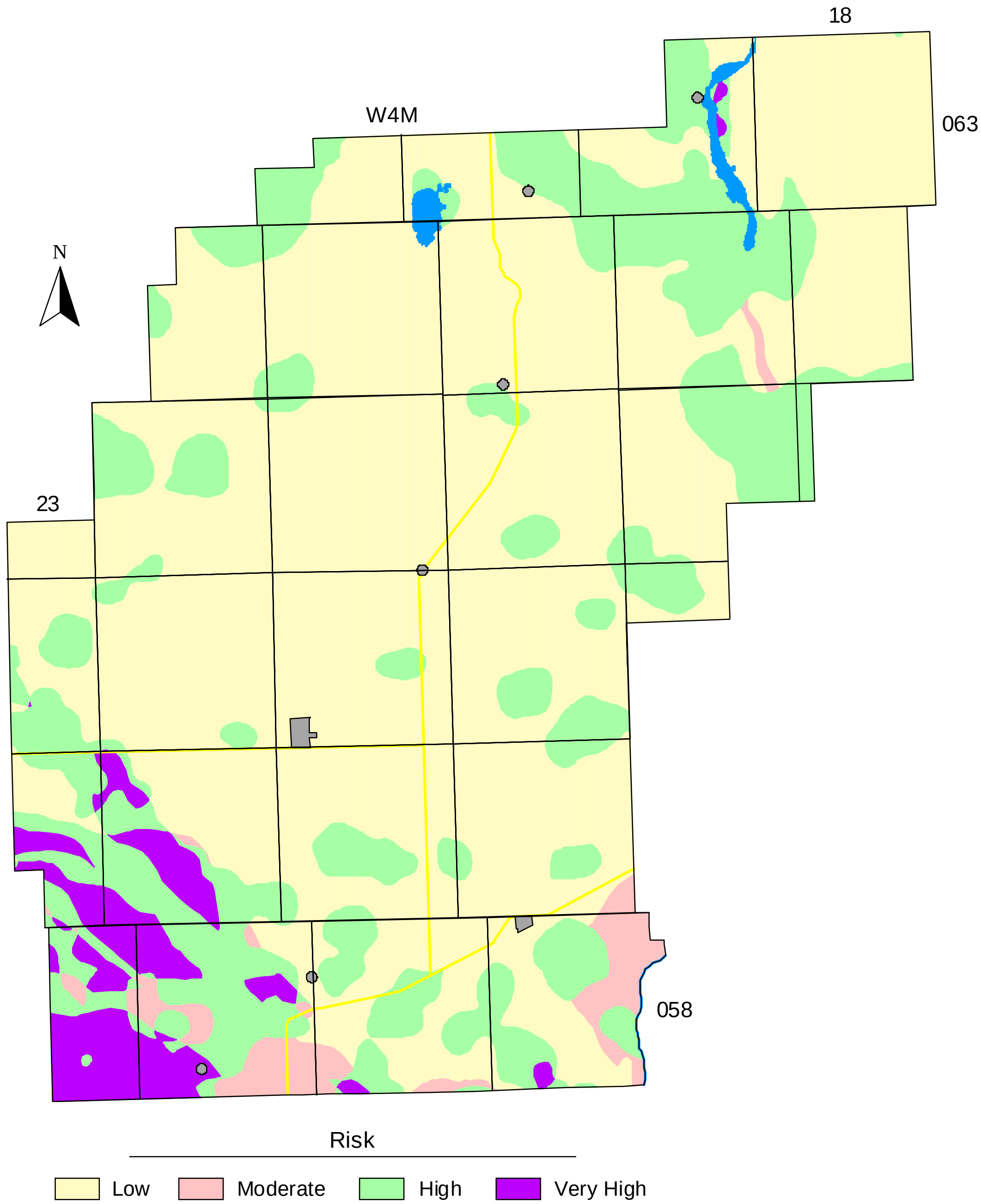
Recharge/Discharge Areas between Surficial Deposits and continental Foremost Aquifer



Recharge/Discharge Areas between Surficial Deposits and Milan Aquifer



Risk of Groundwater Contamination



COUNTY OF LAMONT NO. 30

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
Location of Water Wells
Depth of Existing Water Wells
Bedrock Topography
Bedrock Geology
Cross-Section A - A'
Cross-Section B - B'
Geologic Column
Generalized Cross-Section
Risk of Groundwater Contamination
Relative Permeability

2) Surficial Aquifers

a) Surficial Deposits

Thickness of Surficial Deposits
Amount of Sand and Gravel in Surficial Deposits
Thickness of Sand and Gravel Aquifer
Non-Pumping Water Level in Water Wells Shallower than 15 metres
Non-Pumping Water Level in Surficial Deposits
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer
Total Dissolved Solids in Groundwater from Surficial Deposits
Sulfate in Groundwater from Surficial Deposits
Chloride in Groundwater from Surficial Deposits
Piper Diagram - Surficial Deposits

b) First Sand and Gravel

Thickness of First Sand and Gravel
Saturated First Sand and Gravel

c) Upper Sand and Gravel

Thickness of Upper Surficial Deposits
Thickness of Upper Sand and Gravel
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

d) Lower Sand and Gravel

Depth to Top of Lower Sand and Gravel Aquifer
Structure-Contour Map - Top of Lower Surficial Deposits
Thickness of Lower Surficial Deposits
Thickness of Lower Sand and Gravel Aquifer
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer
Non-Pumping Water Level in Lower Sand and Gravel Aquifer

3) Bedrock Aquifers

a) General

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

b) Bearpaw Aquifer

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

c) Oldman Aquifer

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

d) *continental* Foremost Aquifer

Depth to Top of *continental* Foremost Formation
Structure-Contour Map - Top of continental Foremost Formation
Non-Pumping Water Level - *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 Formation
Recharge/Discharge Areas between Surficial Deposits and *continental* Foremost Aquifer

e) Milan Aquifer

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

f) Lea Park Aquitard

Depth to Top of Lea Park Formation
Structure-Contour Map - Top of Lea Park Formation
Non-Pumping Water Level - Lea Park "Aquitard"
Apparent Yield for Water Wells Completed in Lea Park "Aquitard"
Total Dissolved Solids in Groundwater from Lea Park "Aquitard"

COUNTY OF THORHILD NO. 7

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.

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.

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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

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

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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)

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PRAIRIE FARM REHABILITATION ADMINISTRATION

Keith Schick (Vegreville: 403-632-2919)

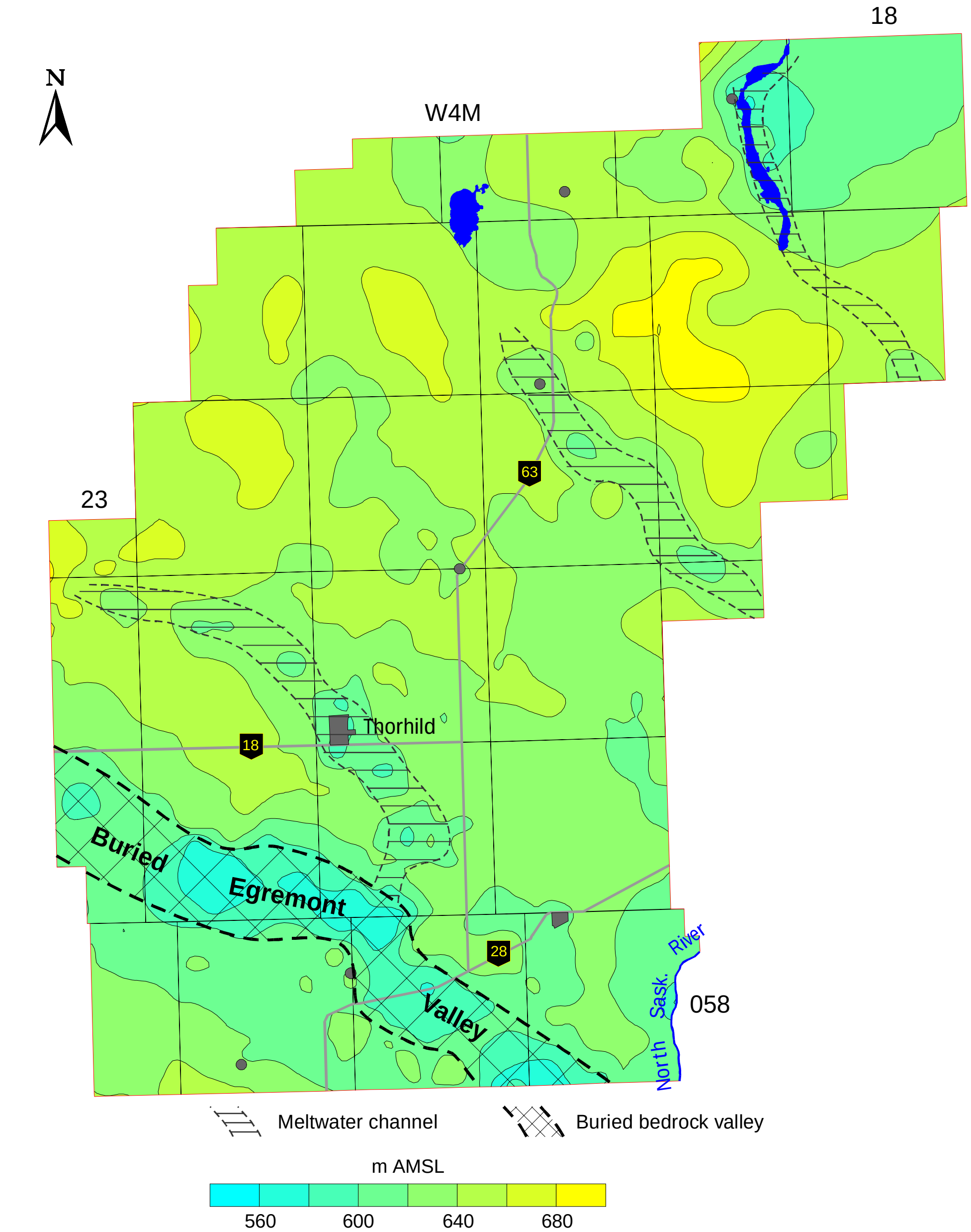
LOCAL HEALTH DEPARTMENTS

COUNTY OF THORHILD NO. 7

Appendix D

MAPS AND FIGURES INCLUDED AS LARGE PLOTS

County of Thorhild No. 7
Bedrock Topography



Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada

PFRA Prairie Farm Rehabilitation Administration

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

hydrogeological consultants ltd, edmonton, alberta - 1-800-661-7972 - project no. 97-161 - bdrt.cdr - 02 Jul 98

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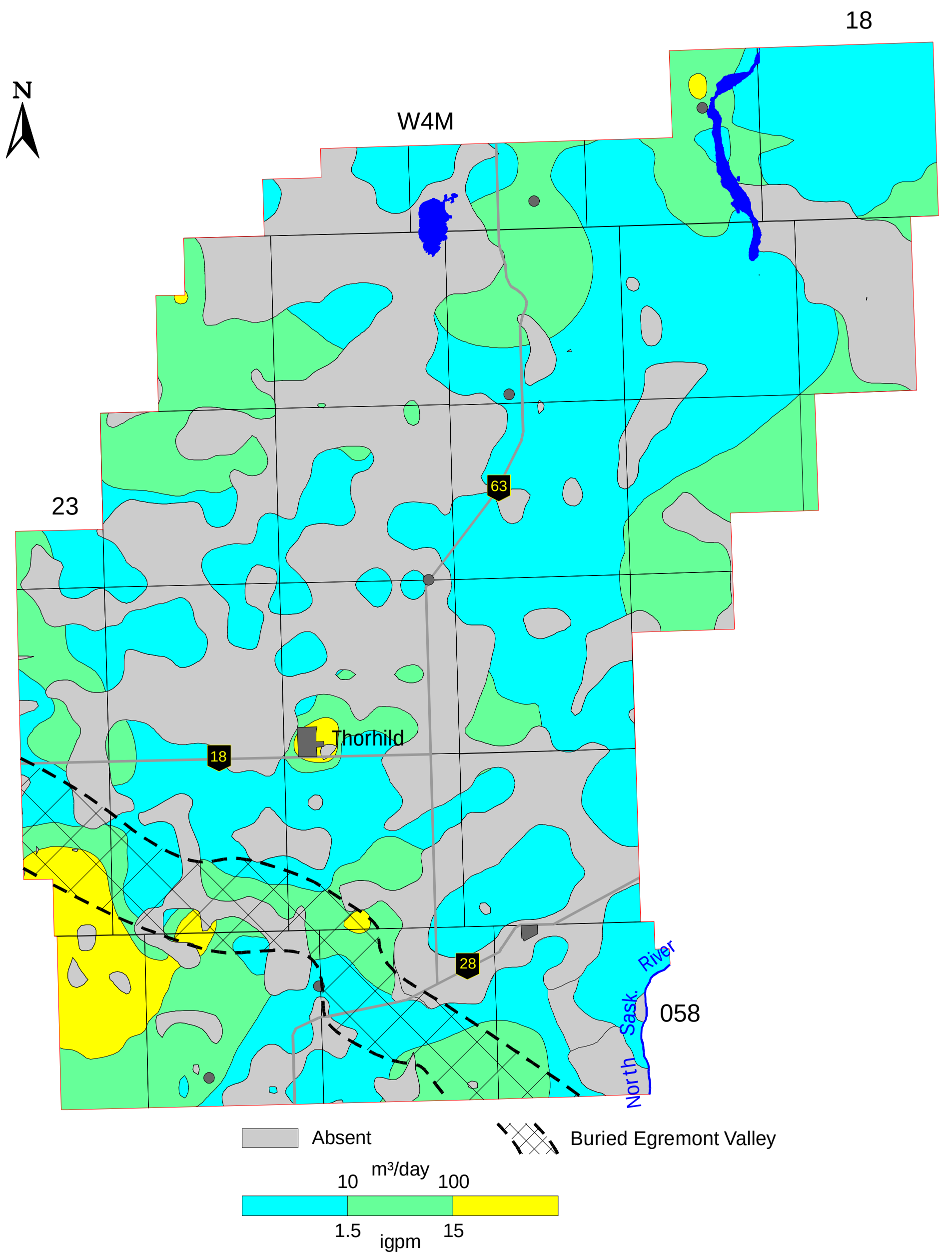
County of Thorhild No. 7
Apparent Yield for Water Wells Completed through Sand and Gravel Aquifer(s)



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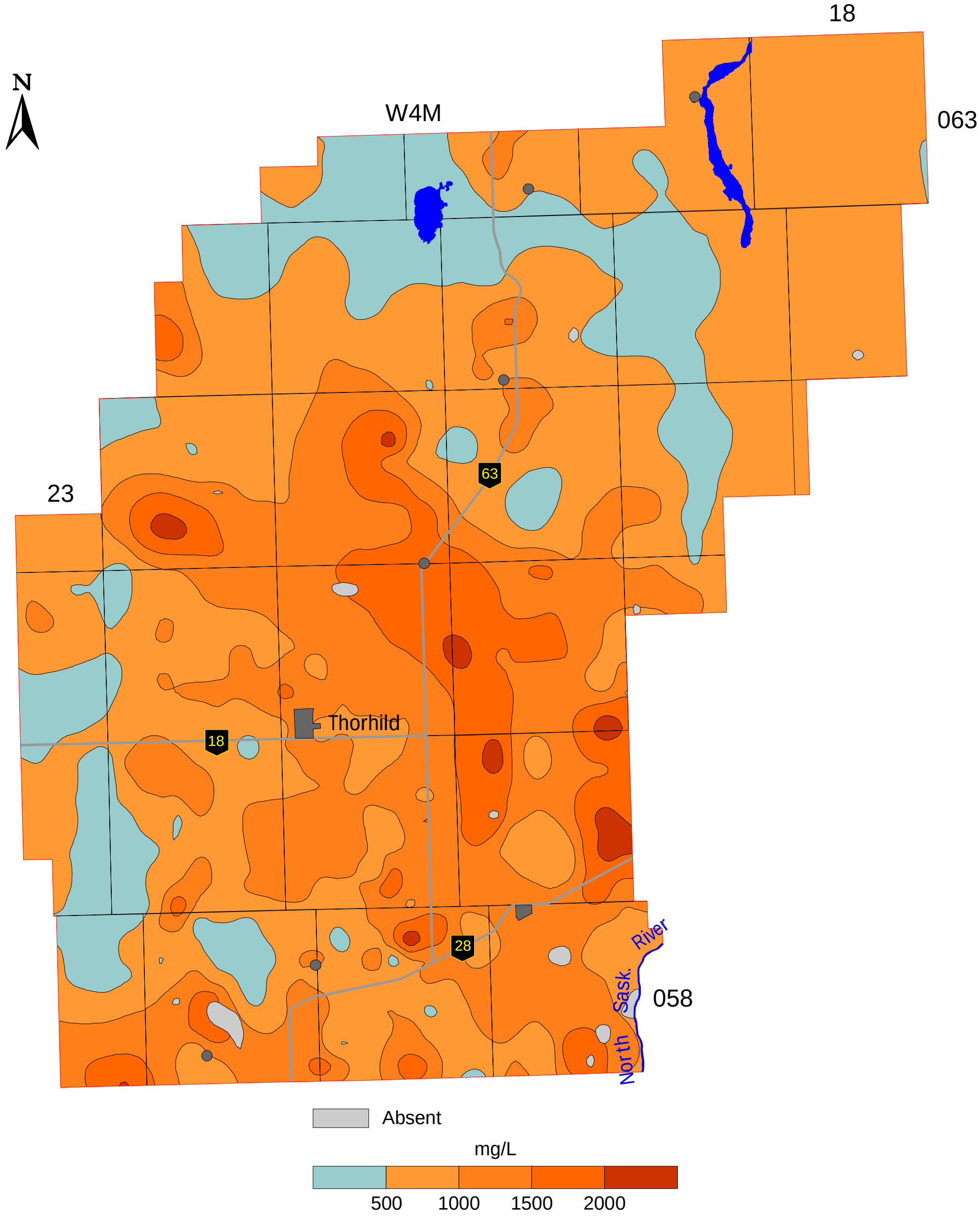
County of Thorhild No. 7
Total Dissolved Solids in Groundwater from Surficial Deposits



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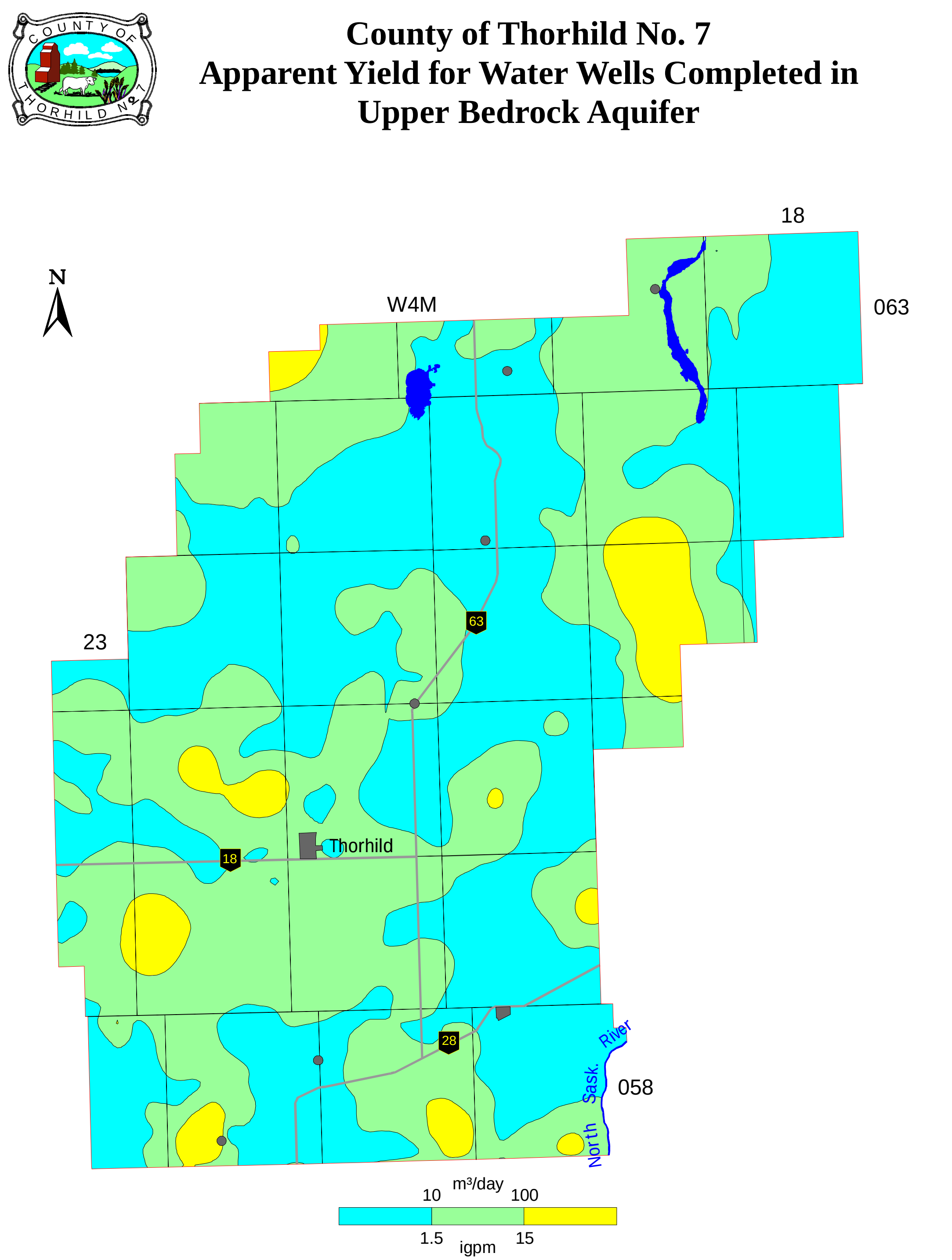
County of Thorhild No. 7
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer



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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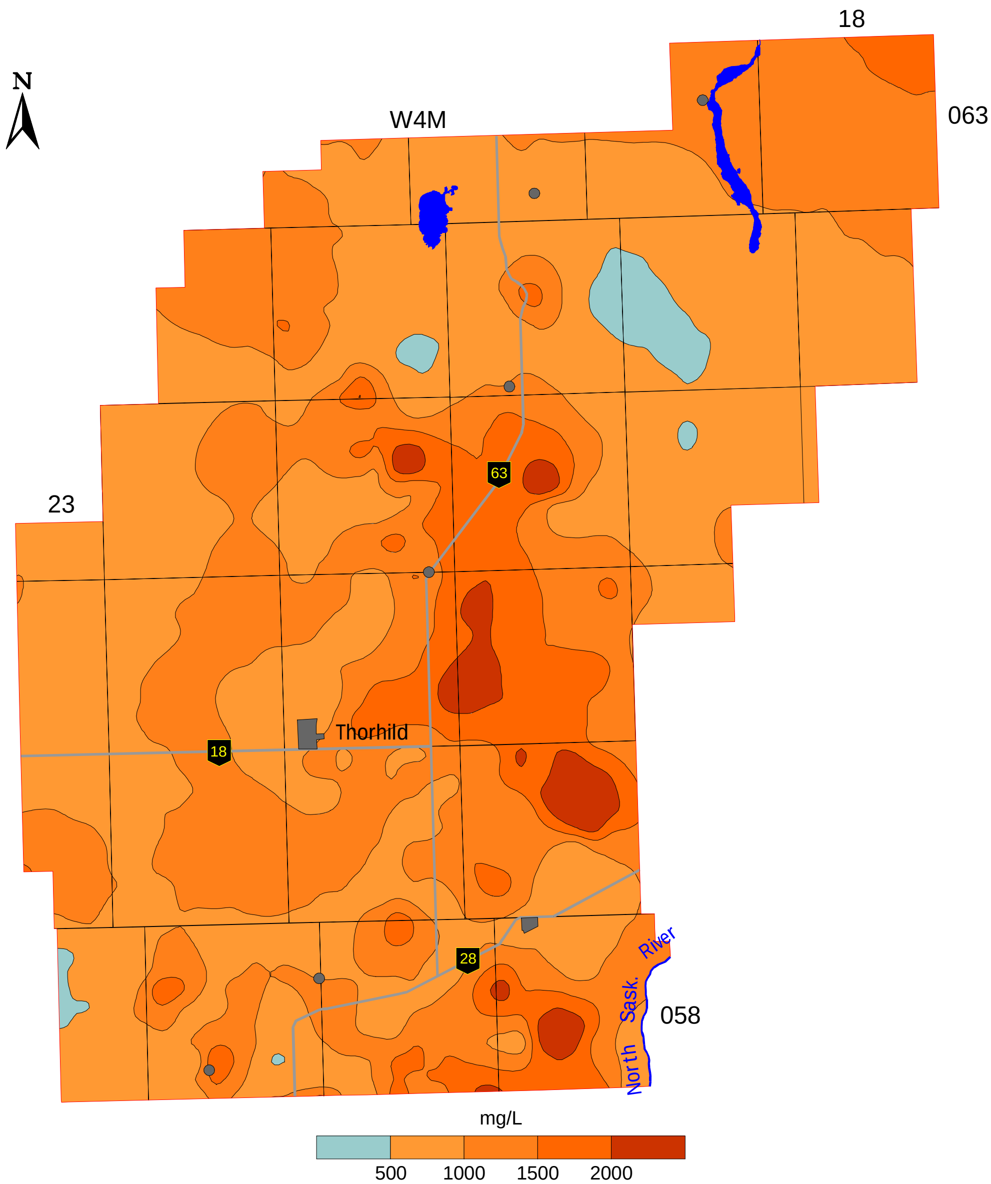
County of Thorhild No. 7
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer



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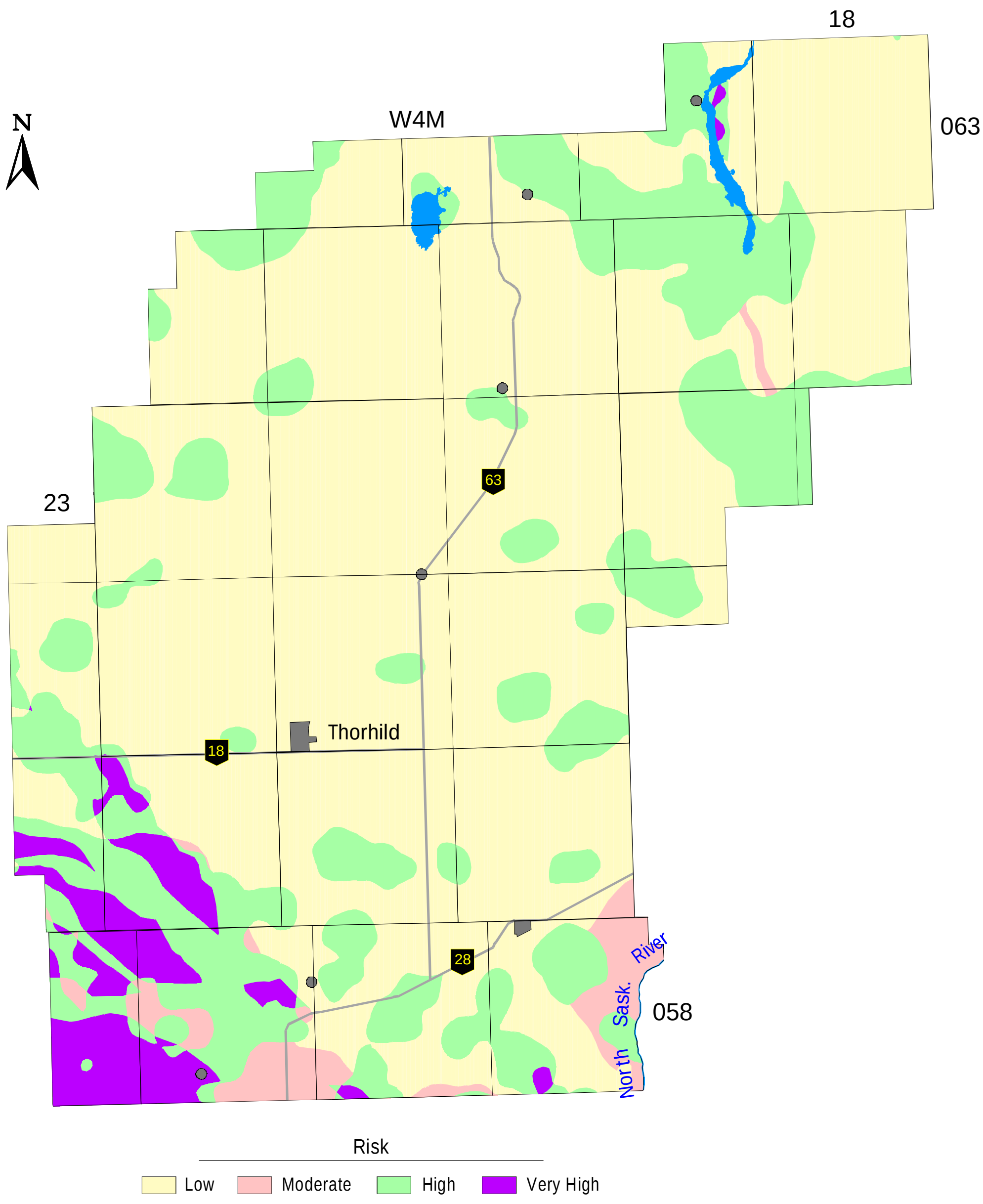
County of Thorhild No. 7
Risk of Groundwater Contamination



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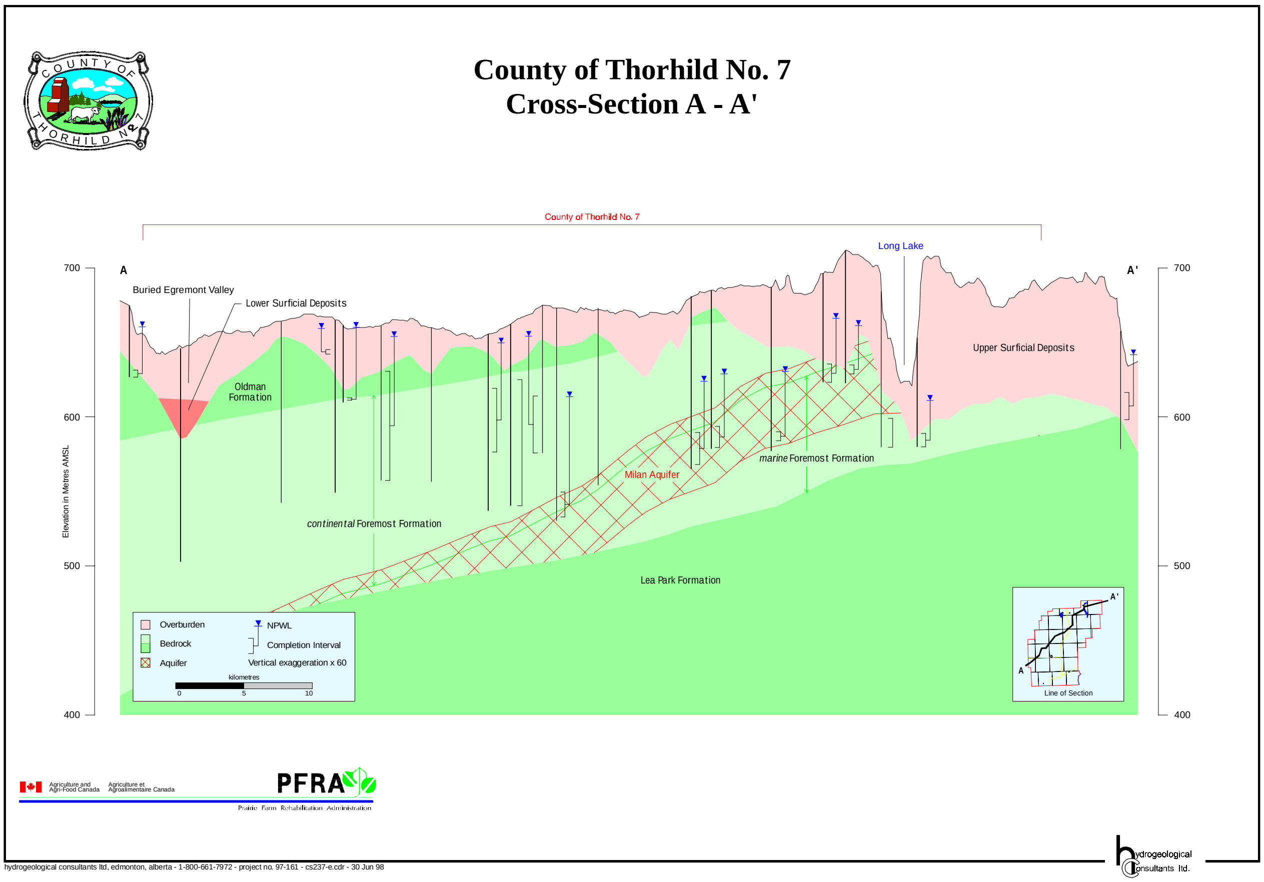
County of Thorhild No. 7
Cross-Section A - A'
County of Thorhild No. 7
Long Lake
A
A'
700
600
500
400
Elevation in Metres AMSL
Buried Egremont Valley
Lower Surficial Deposits
Oldman Formation
Upper Surficial Deposits
marine Foremost Formation
Milan Aquifer
continental Foremost Formation
Lea Park Formation
Overburden
Bedrock
Aquifer
NPWL
Completion Interval
Vertical exaggeration x 60
kilometres
0
5
10
Line of Section
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