Special Areas 2, 3 and 4, and M.D. of Acadia

Part of the Red Deer, and the South and North Saskatchewan River Basins
Parts of Tp 019 to 037, R 01 to 18, W4M
Regional Groundwater Assessment

Prepared for

Special Areas

M.D. of ACADIA #34

In conjunction with

Agriculture and Agri-Food Canada
Prairie Farm Rehabilitation Administration

Agriculture et Agroalimentaire Canada
Administration du rétablisseme agricole des Prairies

Canada

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Our File No.: **99-101**

March 2000

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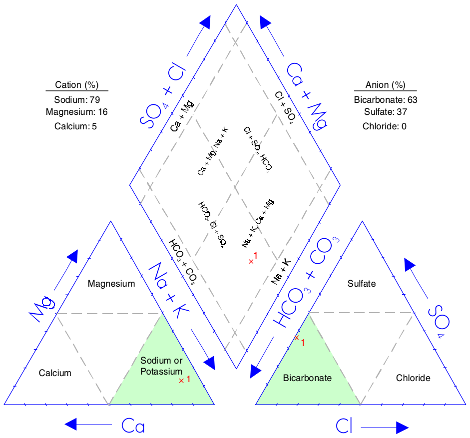
Glossary

Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer
Available Drawdown	in a confined aquifer, the distance between the non-pumping water level and the top of the aquifer in an unconfined aquifer (water table aquifer), two thirds of the saturated thickness of the aquifer
Deltaic	a depositional environment in standing water near the mouth of a river
Dewatering	the removal of groundwater from an aquifer for purposes other than use
Evapotranspiration	a combination of evaporation from open bodies of water, evaporation from soil surfaces, and transpiration from the soil by plants (Freeze and Cherry, 1979)
Facies	the aspect or character of the sediment within beds of one and the same age (Pettijohn, 1957)
Fluvial	produced by the action of a stream or river
Friable	poorly cemented
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
km	kilometre
Kriging	a geo-statistical method for gridding irregularly-spaced data (Cressie, 1990)
Lacustrine	fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits
Lithology	description of rock material
Lsd	Legal Subdivision
m	metres
mm	millimetres
m^2/day	metres squared per day
m^3	cubic metres
m^3/day	cubic metres per day
mg/L	milligrams per litre
Obs WW	Observation Water Well



Piper Tri-Linear Diagram

Piper tri-linear diagram	a method that permits the major cation and anion compositions of single or multiple samples to be represented on a single graph. This presentation allows groupings or trends in the data to be identified. From the Piper tri-linear diagram, it can be seen that the groundwater from this sample water well is a sodium-bicarbonate-type. The chemical type has been determined by graphically calculating the dominant cation and anion. For a more detailed explanation, please refer to Freeze and Cherry, 1979
Rock	earth material below the root zone
Surficial Deposits	includes all sediments above the bedrock
Thalweg	the line connecting the lowest points along a stream bed or valley; *longitudinal profile*
Till	a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders
Transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer
Water Well	a hole in the ground for the purpose of obtaining groundwater; “work type” includes test hole, chemistry, deepened, well inventory, federal well survey, reconditioned, reconstructed, new, old well-test
Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer Apparent Yield: based mainly on apparent transmissivity Long-Term Yield: based on effective transmissivity
AE	Alberta Environment
AMSL	above mean sea level
DEM	Digital Elevation Model
DST	drill stem test

EUB	Alberta Energy and Utilities Board
GCDWQ	Guidelines for Canadian Drinking Water Quality
NPWL	non-pumping water level
NSR	North Saskatchewan River
PFRA	Prairie Farm Rehabilitation Administration
TDS	Total Dissolved Solids
WSW	Water Source Well or Water Supply Well

I. Project Overview

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

How a municipality 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. Municipalities with genuine foresight, knowledgeable planning, and sound practices provide better quality of life to future generations and a solid base for increased economic activity **Though this report’s scope is regional, it is a first step for Special Areas 2, 3, and 4 (Special Areas), and the M.D. of Acadia (M.D.) in managing their groundwater. It is also a guide for future groundwater-related projects.**

A. Purpose

This project is a regional groundwater assessment of Special Areas and the M.D. prepared by Hydrogeological Consultants Ltd. (HCL) with financial assistance from Prairie Farm Rehabilitation Administration (PFRA). The regional groundwater assessment provides the information to assist in the management of the groundwater resource within Special Areas and the M.D. Groundwater resource management involves determining the suitability of various areas in Special Areas and the M.D. 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 Special Areas and the M.D.**

The regional groundwater assessment will:

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

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

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[1] See glossary

[2] See glossary

B. The Project

This regional study should only be used 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 - Report
Module 4 - Groundwater Query
Module 5 - Familiarization Session

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

C. About This Report

This report provides an overview of (a) the groundwater resources of Special Areas and the M.D., (b) the processes used for the present project, and (c) the groundwater characteristics in Special Areas and the M.D.

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

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

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

Appendix C includes the following:

1) a procedure for conducting aquifer tests with water wells[3]
2) a table of contents for the Water (Ministerial) Regulation under the new Water Act
3) a flow chart showing the licensing of a groundwater diversion under the new Water Act
4) additional information.

The Water (Ministerial) Regulation deals with the wellhead completion requirement (no more water-well pits), the proper procedure for abandoning unused water wells and the correct procedure for installing a pump in a water well. The new Water Act was proclaimed 01 Jan 1999.

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

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[3] See glossary

II. Introduction

A. Setting

Special Areas 2, 3, and 4, and the M.D of Acadia are situated in southeastern Alberta. This area is part of the Alberta Plains region. Special Areas and the M.D are within the Red Deer, and the South and North Saskatchewan river basins. A part of the southern border in Special Areas 2 and 3, and the M.D. of Acadia is the Red Deer River; the South Saskatchewan River is the southeastern border of Special Areas 2. The other boundaries follow township or section lines. The study area includes parts of the area bounded by township 037, range 18, W4M in the northwest and township 019, range 01, W4M in the southeast. An overlay showing additional cultural details is in the pocket of this report.

Regionally, the topographic surface varies between 580 and 1,040 metres above mean sea level (AMSL). The lowest elevations occur in the Red Deer River Valley and the highest are in the vicinity of the Town of Hanna as shown in Figure 1 and page A-5.

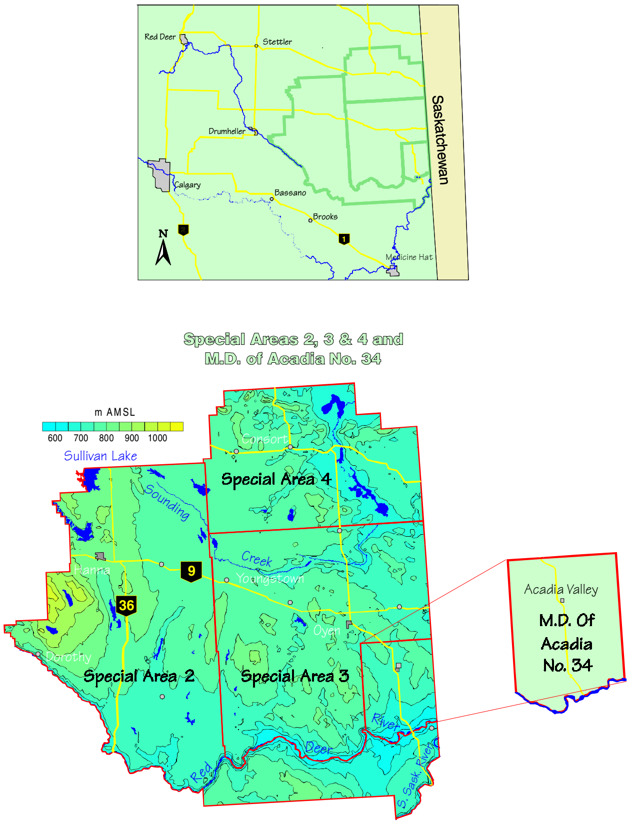

Figure 1. Index Map

B. Climate

Special Areas 2, 3, 4 and the M.D. of Acadia lie within a semiarid Bsk climate. In a Bsk climate, there is a lack of moisture. This means the mean annual potential evapotranspiration[4] exceeds the mean annual precipitation. This classification is based on potential evapotranspiration values determined using the Thornthwaite method (Thornthwaite and Mather, 1957), combined with the distribution of natural ecoregions in the area. The ecoregions map (Strong and Leggatt, 1981) shows that Special Areas and the M.D. are located in the Mixed Grass region, a transition between Aspen Parkland and Dry Mixed Grass ecoregions.

The mean annual precipitation averaged from six meteorological stations within the project area measured 337 millimetres (mm), based on data from 1941 to 1993. The annual temperature averaged 2.3 °C, with the mean monthly temperature reaching a high of 17.6 °C in July, and dropping to a low of -15.7 °C in January. The calculated annual potential evapotranspiration is 461 millimetres.

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[4] See glossary

C. Background Information

1) Numbers, Types and Depths of Water Wells

There are currently records for 8,079 water wells in the groundwater database for Special Areas and the M.D. Of the 8,079 water wells, 7,128 are for domestic/stock purposes. The remaining 951 water wells were completed for a variety of uses, including municipal, industrial, irrigation and observation. Based on a rural population of 6,289 (Phinney, 1999), there are five domestic/stock water wells per family of four. The domestic or stock water wells vary in depth from 0.6 metres to 260 metres below ground level. Details for lithology[5] are available for 3,333 water wells.

2) Numbers of Water Wells in Surficial and Bedrock Aquifers

There are 2,512 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 top of bedrock are water wells completed in surficial aquifers. Of the 2,512 wells for which aquifers could be defined, 1,080 are completed in surficial aquifers, with 70% having a completion depth of less than 30 metres. The adjacent map shows that the majority of the water wells completed in the surficial deposits occur in the eastern half of the project area, and frequently in the vicinity of linear bedrock lows.

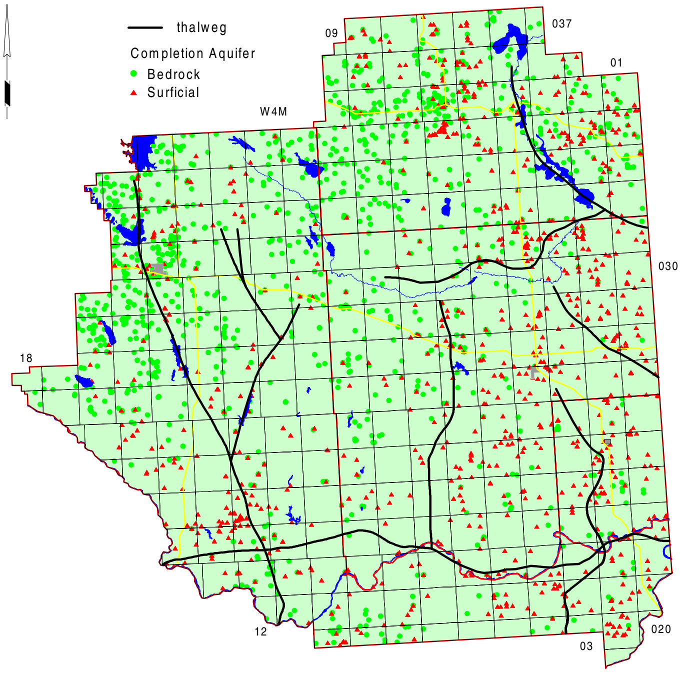

Figure 2. Location of Water Wells

The 1,432 water wells that have the top of their completion interval below the top of the bedrock are referred to as bedrock water wells. From Figure 2, it can be seen that water wells completed in bedrock aquifers occur mainly in the northern and western parts of Special Areas.

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[5] See glossary

3) Casing Diameter and Types

Data for casing diameters are available for 3,594 water wells, with 2,000 (56%) indicated as having a diameter of less than 275 mm and 1,594 having a diameter of more than 300 mm. The casing diameters of greater than 300 mm are mainly bored or dug water wells and those with a surface-casing diameter of less than 275 mm are usually drilled water wells. More than 80% of the large-diameter water wells were completed before 1950.

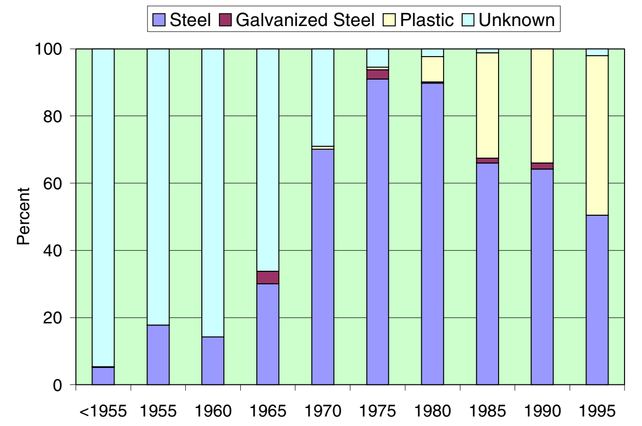

Figure 3. Surface Casing Types used in Drilled Water Wells

In Special Areas and the M.D., steel, galvanized steel and plastic represent 99% of the materials that have been used for surface casing in drilled water wells over the last 40 years. Until the 1960s, the type of surface casing used in drilled water wells was mainly undocumented. Steel casing was in use in the 1950s and is still being used in 51% of the water wells being drilled in Special Areas and the M.D. in the 1990s. Steel and galvanized steel were the main casing types until the start of the 1980s, at which time plastic casing started to replace the use of steel and galvanized steel casings.

Galvanized steel surface casing was used in a maximum of 4% of the new water wells from the 1950s to the early 1990s. Galvanized steel was last used in April 1991.

4) Requirements for Licensing

Water wells not used for household use and providing groundwater with total dissolved solids (TDS) of less than 4,000 milligrams per litre (mg/L) must be licensed. At the end of 1996, 288 groundwater allocations were licensed in the project area. Of the 288 licensed groundwater users, 229 are for agricultural purposes, and the remaining 59 are for municipal, industrial, diversion, domestic and other purposes. The total maximum authorized diversion from the water wells associated with these licences is 11,935 cubic metres per day (m^3/day), of which 39% is for diversion purposes, 25% is allotted for agricultural use, 22% is allotted for industrial use, and 12% is allotted for municipal use. The remaining 2% of the water wells have been licensed for domestic and other uses as shown in Table 1 on the following page.

The largest licensed groundwater allocation within the project area is for Manalta Coal Ltd., having a “diversion” of 4,400 m^3/day. When a groundwater use is listed as “diversion”, the activity is usually related to dewatering[6] activities. The largest licensed industrial groundwater allocation within Special Areas and the M.D. is for a water source well completed in the Oldman Aquifer in 16-25-027-02 W4M owned by Talisman Energy Inc., having an allocation of 432 m^3/day. The largest potable groundwater diversion licensed within Special Areas and the M.D. is for the Village of Consort, having a diversion of 259 m^3/day. The Village of Consort has four licences, for a total allocation of 590 m^3/day. The remaining licences for municipal purposes are for the villages of Cereal, Empress and Veteran, and the M.D. of Acadia.

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[6] See glossary

The following table shows a breakdown of the 288 licensed groundwater allocations by the aquifer in which the water well is completed. The largest total licensed allocations are in the Lower Horseshoe Canyon and Upper Surficial aquifers; the majority of the groundwater is used for "diversion" and agricultural purposes.

	Licensed Groundwater Users* (m³/day)							
Aquifer**	Agricultural	Industrial	Municipal	Diversion	Domestic	Other	Total	Percentage
Upper Surficial	1,168	0	673	0	9	23	1,873	16
Lower Surficial	110	0	0	0	155	0	265	2
Upper Horseshoe Canyon	82	0	27	0	0	5	114	1
Middle Horseshoe Canyon	43	0	0	0	0	0	43	0
Lower Horseshoe Canyon	327	18	0	4,646	0	0	4,991	42
Bearpaw	671	5	47	0	0	0	723	6
Oldman	349	746	482	0	5	0	1,582	13
Birch Lake	9	55	0	0	0	0	64	1
Ribstone Creek	9	0	0	0	0	0	9	0
Victoria	0	509	0	0	0	0	509	4
Saline	0	1,103	0	0	0	0	1,103	9
Unknown	218	205	236	0	0	0	659	6
Total	2,986	2,641	1,465	4,646	169	28	11,935	100
Percentage	25	22	12	39	2	0	100	

* - data from AE ** - identification of Aquifer by HCL

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the water requirement for livestock for Special Areas only is in the order of 35,740 m³/day. Ninety-eight percent of the required water has been licensed by Alberta Environment (AE). Groundwater provides 2,986 m³/day and surface water provides 32,208 m³/day.

5) Groundwater Chemistry and Base of Groundwater Protection

Groundwaters from the surficial deposits are expected to be chemically hard with a high dissolved iron content. The Total Dissolved Solids (TDS) concentrations in the groundwaters from the upper bedrock in the project area are generally less than 2,000 mg/L. Groundwaters from the bedrock aquifers frequently are chemically soft with generally low concentrations of dissolved iron. The chemically soft groundwater is high in sodium concentration. Less than 10% of the chemical analyses indicate a fluoride concentration above 1.5 mg/L.

The minimum, maximum and average concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the upper bedrock in Special Areas and the M.D. have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in Table 2. Of the five constituents compared to the GCDWQ, the average values of TDS, sodium, and sulfate concentrations exceed the guidelines.

	Range for Special Areas and M.D. in mg/L			Recommended Maximum Concentration
Constituent	Minimum	Maximum	Average	GCDWQ
Total Dissolved Solids	14.0	8350	1713	500
Sodium	3.0	2690	544	200
Sulfate	1	5187	606	500
Chloride	1.0	2340	65	250
Fluoride	0.02	2.39	0.62	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives

GCDWQ - Guidelines for Canadian Drinking Water Quality, Sixth Edition
Minister of Supply and Services Canada, 1996

Table 2. Concentrations of Constituents in Groundwaters from Upper Bedrock Aquifer(s)

Alberta Environment defines the Base of Groundwater Protection as the elevation below which the groundwater is expected to have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, and the elevation of the Base of Groundwater Protection provided by the Alberta Energy and Utilities Board (EUB), a depth to the Base of Groundwater Protection can be determined. These values are gridded using the Kriging[7] method to prepare a Base of Groundwater Protection surface. This surface is then used throughout the project area. The depth to the Base of Groundwater Protection, for the most part, would be the maximum drilling depth for a water well for agricultural purposes or for a potable water supply. If a water well is completed below the Base of Groundwater Protection with the total dissolved solids of the groundwater exceeding 4,000 mg/L, then the groundwater use does not require licensing by AE.

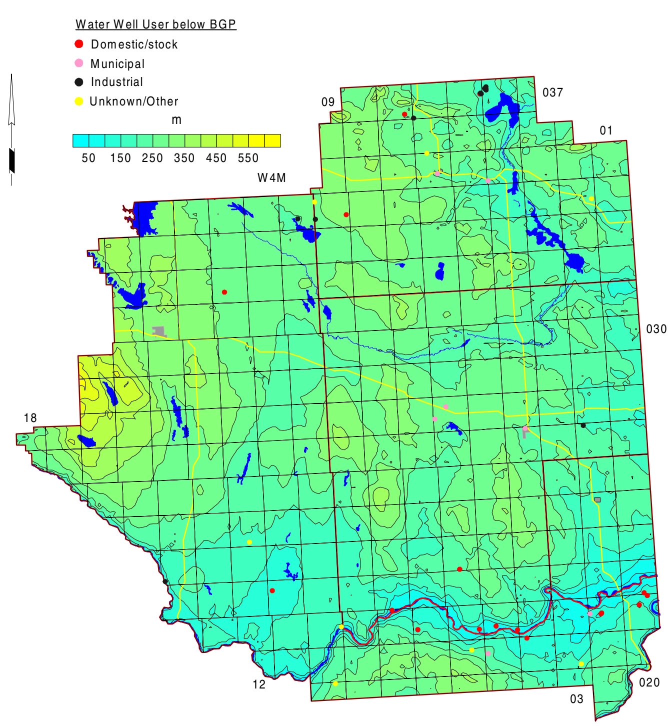

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

There are 46 water wells that have a completion depth below the Base of Groundwater Protection. Many of these water wells are located within a few kilometres of the Red Deer River. Of the 46 water wells, 19 are used for domestic/stock purposes, 12 for industrial purposes, seven for municipal purposes and for eight, the use is unknown or other. Chemistry data are available for only nine water wells, with TDS exceeding 4,000 mg/L in four wells.

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 19 AE-operated observation water wells within Special Areas, and none within the M.D. of Acadia. Additional data can be obtained from some of the licensed groundwater diversions. In the past, the data for licensed diversions have been difficult to obtain from AE, 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 Special Areas and the M.D. is too few to provide a reliable groundwater budget (see section 6.0). 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.

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[7] See glossary

III. Terms

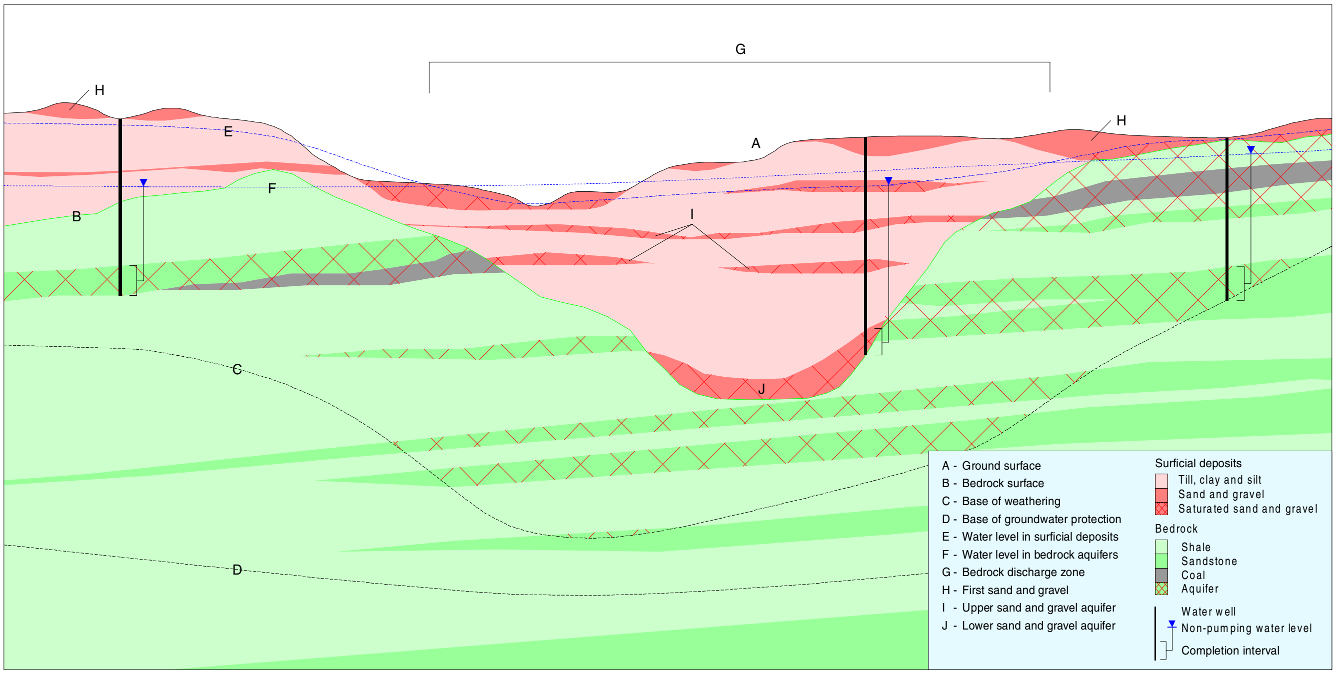

Figure 5. Generalized Cross-Section (for terminology only)

Figure 6. Geologic Column

IV. Methodology

A. Data Collection and Synthesis

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

1) water well drilling reports
2) aquifer test results from some water wells
3) location of some springs
4) water well locations determined during water well surveys
5) chemical analyses for some groundwaters
6) location of flowing shot holes
7) location of structure test holes
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 present database for the project area contains approximately 400 duplicate water well IDs.

The AE groundwater database uses a land-based system with only a limited number of records having a value for ground elevation. The locations for records usually include a quarter section description; a few records also have a land description that includes a Legal Subdivision (Lsd). For digital processing, a record location requires a horizontal coordinate system. In the absence of an actual location for a record, the record is given the coordinates for the centre of the land description. This situation has been improved for Special Areas and the M.D. Prairie Farm Rehabilitation Administration (PFRA) and HCL have repositioned 3,208 water wells within Special Areas and the M.D. using a Global Positioning System (GPS) instrument. These coordinates are provided with the records on the CD-ROM.

The present project uses the 10TM coordinate system. This means that a record for the NW ¼ of section 23, township 024, range 09, W4M, would have a horizontal coordinate with an Easting of 268,860 metres and a Northing of 5,661,368 metres, the centre of the quarter section. If the water well has been positioned by PFRA as a result of field verification, the location will be more accurate, possibly within ten metres of the actual location. Once the horizontal coordinates are determined for a record, a ground elevation for that record is obtained from the 1:20,000 Digital Elevation Model (DEM) from the Resource Data Division of AE.

At many locations within the project area, more than one water well is completed at one legal location. Digitally processing this information is difficult. To obtain a better understanding of the completed depths of water wells, a digital surface was prepared representing the minimum depth for water wells and a second digital surface was prepared for the maximum depth. Both of these surfaces are used in the groundwater query on the CD-ROM. When the maximum and minimum water well depths are similar, there is only one aquifer that is being used.

After assigning spatial control for the ground location for 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
5) depth to the top and bottom of completion intervals.

Also, where sufficient information is available, values for apparent transmissivity[8] and apparent yield[9] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. Since the regional hydrogeology map was published in 1979 (Borneuf, 1979), 223 values for effective transmissivity have been added to the groundwater database.

The EUB well database includes records for all of the wells drilled by the oil and gas industry. The information from this source includes:

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

Values for apparent transmissivity, apparent yield 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 (pages 42-44). 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.

B. 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
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.

The values for the elevation of the top and bottom of individual geological units at specific locations help to determine the spatial distribution of the individual surfaces. Establishment of a surface distribution digitally requires preparing a grid. The inconsistent quality of the data necessitates creating a representative sample set

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[8] For definitions of Transmissivity, see glossary
[9] For definitions of Yield, see glossary

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.

C. Hydrogeological Parameters

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

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

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of these parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid. Even when only limited data are available, grids are prepared. However, the data from these grids must be used with extreme caution because the gridding process can be unreliable.

1) Risk Criteria

The main source of groundwater contamination involves activities on or near the land surface. The risk of groundwater contamination is high when the near-surface materials are porous and permeable and low when the materials are less porous and less permeable. The two sources of data for the risk analysis include (a) a determination of when sand and gravel is or is not present within one metre of the ground surface, and (b) the surficial geology map. The presence or absence of sand and gravel within one metre of the land surface is based on a geological surface prepared from the data supplied on the water well drilling reports. The information available on the surficial geology map is categorized, based on relative permeability. The information from these two sources is combined to form the risk assessment map. 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 3. Risk of Groundwater Contamination Criteria

D. 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 established. This process provides both the outline and the thickness of the geological unit.

Grids must also be combined to allow the calculation of projected long-term yields for individual water wells. The grids related to the elevation of the NPWL and the elevation of the top of the aquifer are combined to determine the available drawdown[10]. The available drawdown data and the transmissivity values are used to calculate values for projected long-term yields for individual water wells, which are completed in a specific aquifer.

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

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

Once the technical details of a cross-section are correct, the drawing file is moved to the software package CorelDRAW! for simplification and presentation in a hard-copy form. This report includes these cross-sections and poster-size drawings. As well, both Appendix A and the CD-ROM contain the cross-sections; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

E. Software

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

- Acrobat 4.0
- ArcView 3.1
- AutoCAD 14.01
- CorelDRAW! 8.0
- Microsoft Office 2000
- Surfer 7.0

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[10] See glossary

V. Aquifers

A. Background

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

1) Surficial Aquifers

Surficial deposits in Special Areas and the M.D. are mainly less than 50 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 100 metres. The Buried Calgary Valley is the main east-west-trending linear bedrock low in Special Areas and the M.D. The Red Deer River and the Buried Calgary Valley occupy the same linear bedrock low at the southern border of Special Area 3 and the M.D. of Acadia (buried bedrock valley extents overlay in report pocket). Cross-section A-A' is west to east along the Buried Calgary Valley, and shows the thickness of the surficial deposits varying from less than ten to more than 100 metres.

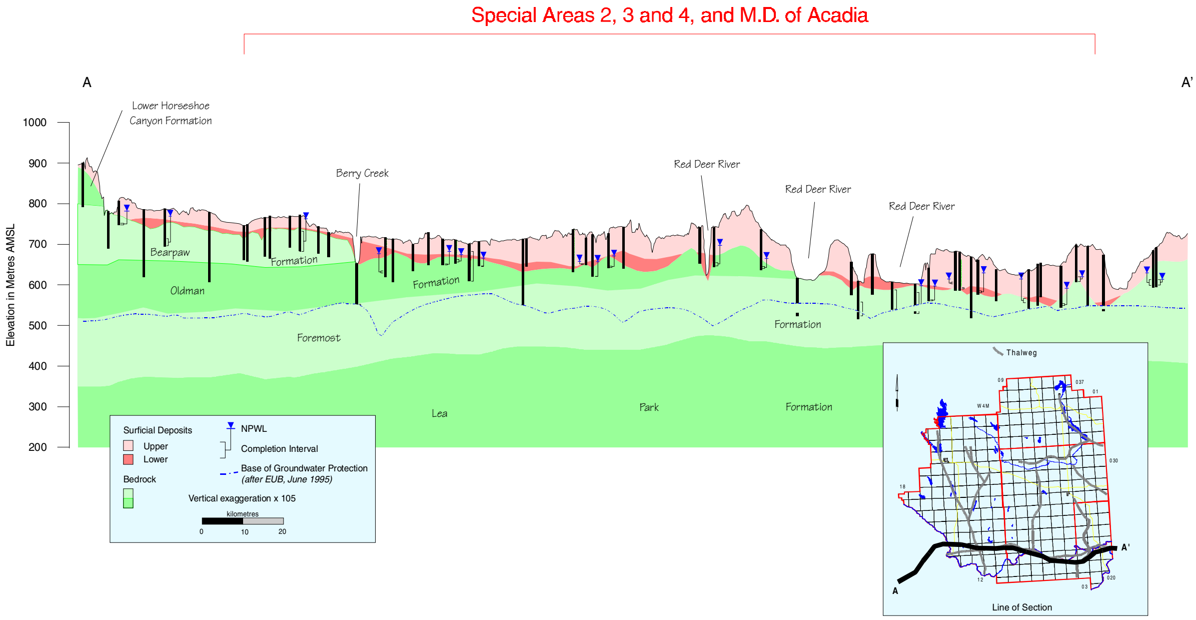

Figure 7. Cross-Section A - A'

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

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some 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 project area, casing-diameter information is available for 647 of the 1,080 water wells completed in the surficial deposits; 251 of these have a casing diameter of more than 300 millimetres, and are assumed to be bored or dug water wells.

2) Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface and above the Lea Park Formation. Some of this bedrock contains saturated rocks with sufficient permeability to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, although some of the sandstones are friable[11] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft.

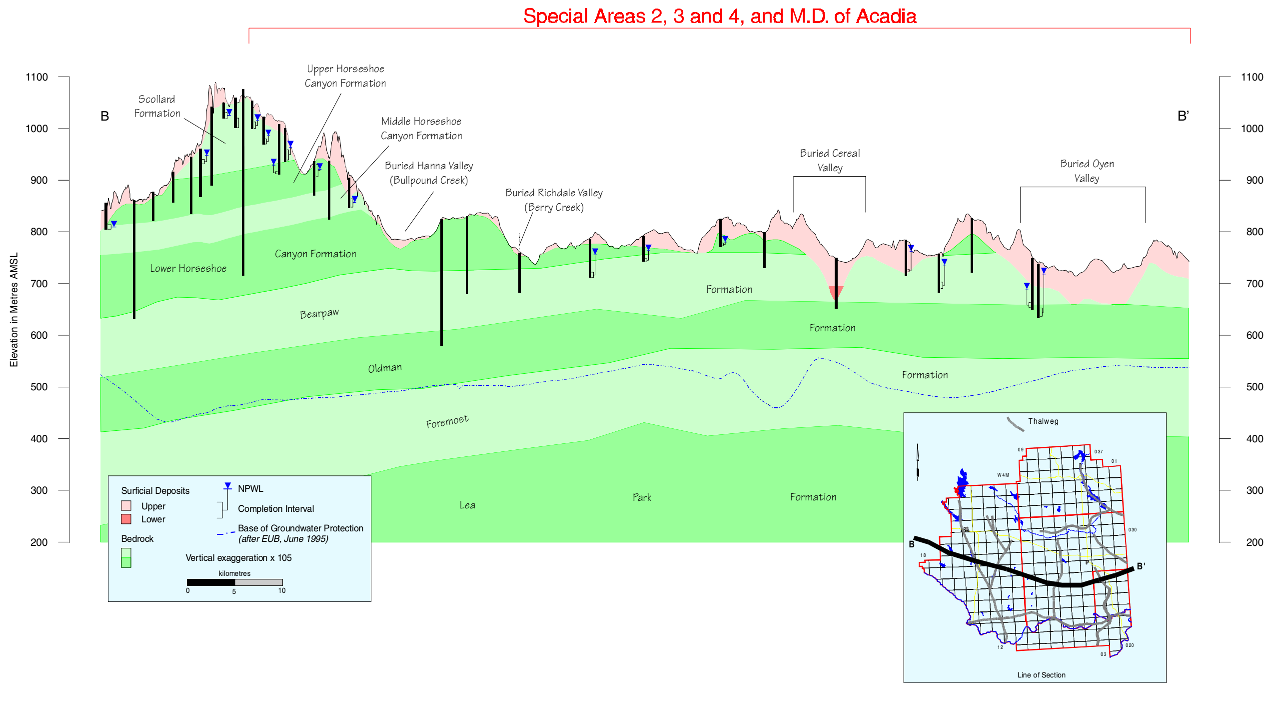

Figure 8. Cross-Section B - B'

The data for 1,432 water wells show that the top of the water well completion interval is below the top of bedrock, indicating that the water wells are completed in at least one bedrock aquifer. Within the project area, casing-diameter information is available for 1,220 of the 1,432 water wells completed below the top of bedrock. Of these 1,220 water wells, 98% have surface-casing diameters of less than 300 mm and these bedrock water wells have been mainly completed with either a screen or as open hole.

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[11] See glossary

The upper bedrock includes the lower part of the Paskapoo Formation, the Edmonton Group, the Bearpaw Formation and the Belly River Group (page A-8). The Lea Park Formation underlies the Belly River Group and is a regional aquitard[12].

B. Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. This includes pre-glacial materials, which were deposited before glaciation, and materials deposited directly or indirectly by glaciation. The *lower surficial deposits* include pre-glacial fluvial[13] and lacustrine[14] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[15] and meltwater deposits.

1) Geological Characteristics

While the surficial deposits are treated as one hydrogeological unit, they consist of three individual units. When present, the sand and gravel deposits of the lower surficial deposits are the first unit; these deposits are mainly saturated. The second and third units are associated with the sand and gravel deposits in the upper surficial deposits. The sand and gravel deposits in the upper surficial deposits occur mainly as pockets. The second unit is the saturated part of these sand and gravel deposits; the third unit is the unsaturated part of these deposits. (See Figure 5 for a graphical depiction of the above description). While the unsaturated deposits are not technically an aquifer, they are significant as they provide a pathway for liquid contaminants to move downward into the groundwater. Because of the significance of the shallow sand and gravel deposits, they have been mapped where the tops of these deposits are present within one metre of the ground surface; these shallow deposits are referred to as the "first sand and gravel".

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on the adjacent map. There are numerous linear bedrock lows shown on the bedrock topography map. The lowest elevation of the linear bedrock low is the thalweg; the thalwegs for the linear bedrock lows in the present report are named mainly as per Carlson, 1969.

Over the majority of the project area, the upper surficial deposits are less than 30 metres thick (page A-11). The exceptions are mainly in association with the linear bedrock lows where the deposits can have a thickness of more than 50 metres. The main linear bedrock low in the project area has been designated as the Buried Calgary Valley, as shown on the adjacent bedrock topography map. This Valley trends east while occupying the present-day Red Deer River Valley. The Buried Calgary Valley is approximately 15 to 40 kilometres wide, with local relief being up to 100 metres.

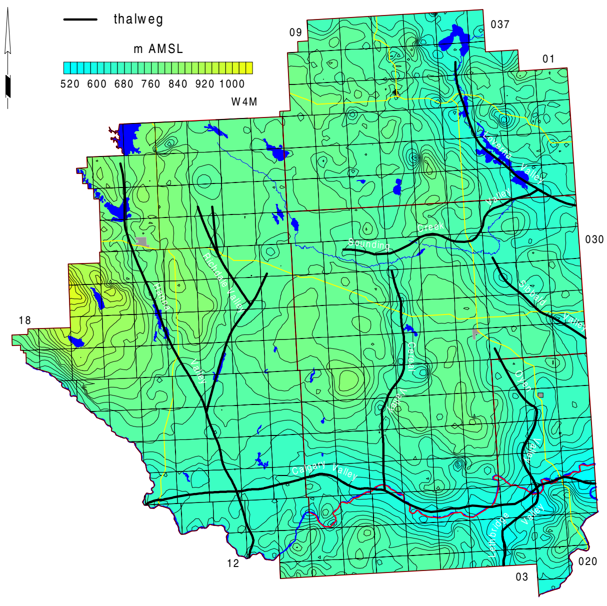

Figure 9. Bedrock Topography

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[12] See glossary
[13] See glossary
[14] See glossary
[15] See glossary

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur over more than 15% of the project area, in association with linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than 20 metres, but can be up to 50 metres in the areas of linear bedrock lows. The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally be expected to directly overlie the bedrock surface in the Buried Calgary Valley. The lower sand and gravel deposits are of fluvial origin, are usually less than five metres thick and may be discontinuous.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits, which are expected to occur mainly as isolated pockets. The greatest thickness of the upper surficial deposits is mainly in association with the linear bedrock lows; there are several areas in the project area where the upper surficial deposits are not present.

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

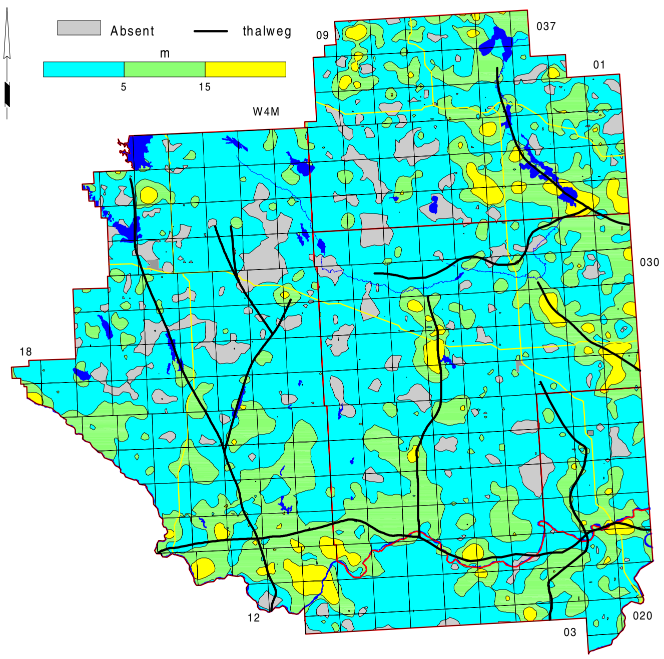

Figure 10. Thickness of Sand and Gravel Deposits

The combined thickness of all sand and gravel deposits has been determined as a function of the total thickness of the surficial deposits. Over approximately 5% of the project area, the sand and gravel deposits are more than 50% of the total thickness of the surficial deposits. One area where the sand and gravel percentages are higher is in association with the Buried Calgary Valley. The other areas where sand and gravel deposits constitute more than 50% of the total thickness of the surficial deposits may be in areas where linear bedrock lows exist but have not been identified due to a shortage of accurate bedrock control points.

2) Sand and Gravel Aquifer(s)

One source of groundwater in the project area includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. From the present hydrogeological analysis, 148 water wells are completed in aquifers in the lower surficial deposits and 3,239 are completed in the upper surficial deposits. This number of water wells is three times the number determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the expected elevation of the bedrock surface at the same location, then the water well is designated as a water well completed in an aquifer in the surficial deposits.

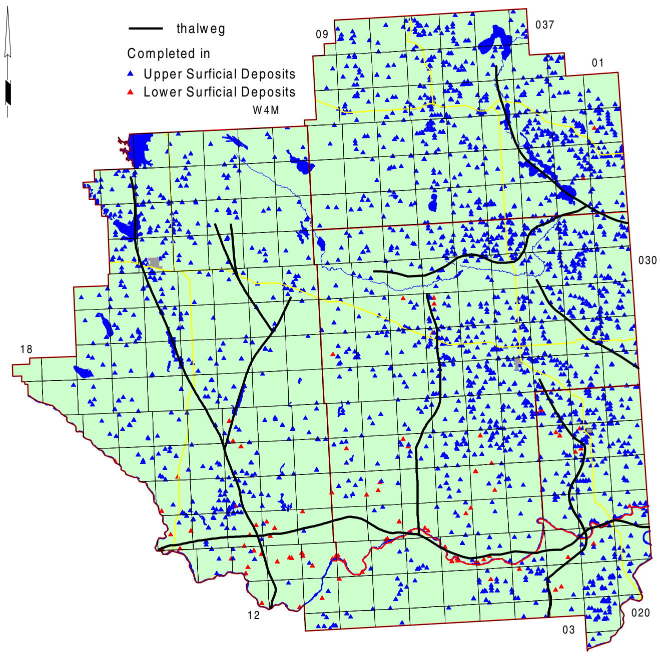

Figure 11. Water Wells Completed in Surficial Deposits

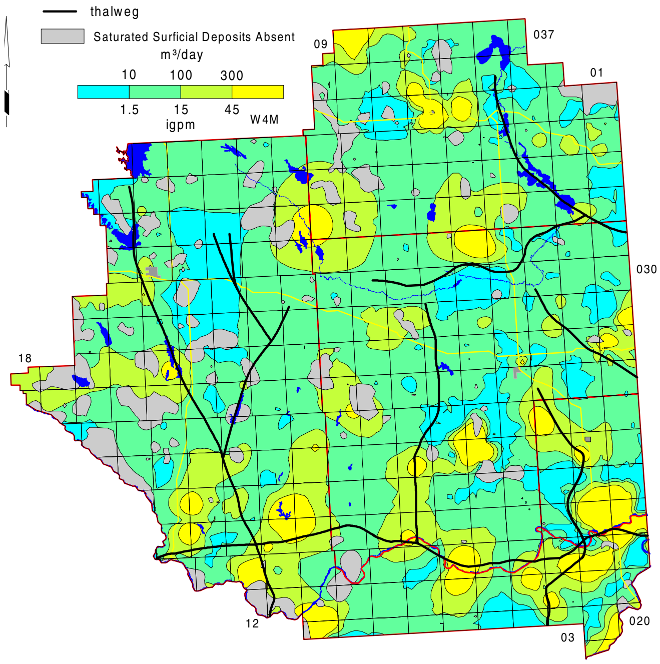

Figure 12. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

The water wells completed in the upper surficial deposits occur throughout the project area, but are mainly concentrated in the eastern half of the area, as shown in Figure 11. The majority of the water wells completed in the lower surficial deposits are located along the Buried Calgary Valley.

a) Water Well Yields

The adjacent map shows expected yields for water wells completed in aquifers in the sand and gravel aquifer(s) based on the aquifers that have been developed by existing water wells. These data show that water wells with yields of less than 100 m³/day from sand and gravel aquifer(s) can be expected in most areas of the project area. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with linear bedrock lows. In 15% of the project area, the surficial deposits are not saturated.

b) Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits have not been differentiated based on aquifers in the upper or lower surficial deposits. The main reason for not separating the chemical analysis results into the different aquifers is the lack of data that can be attributed to the Lower Sand and Gravel Aquifer. This is in part related to the number of control points from this Aquifer, which is in part related to the limited areal extent of the lower surficial deposits.

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

The groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate with some sodium-bicarbonate-type waters; approximately 60% of the groundwaters from surficial deposits have a TDS of more than 1,000 mg/L. The groundwaters with TDS of less than 500 mg/L occur mainly in the western and eastern parts of the project area. The nitrate + nitrite (as N) concentrations in the groundwaters from the surficial deposits exceed the maximum acceptable concentrations (MAC) of 10 mg/L mainly in the northern part of the project area. Groundwaters from the surficial deposits are expected to have dissolved iron concentrations of more than 1 mg/L.

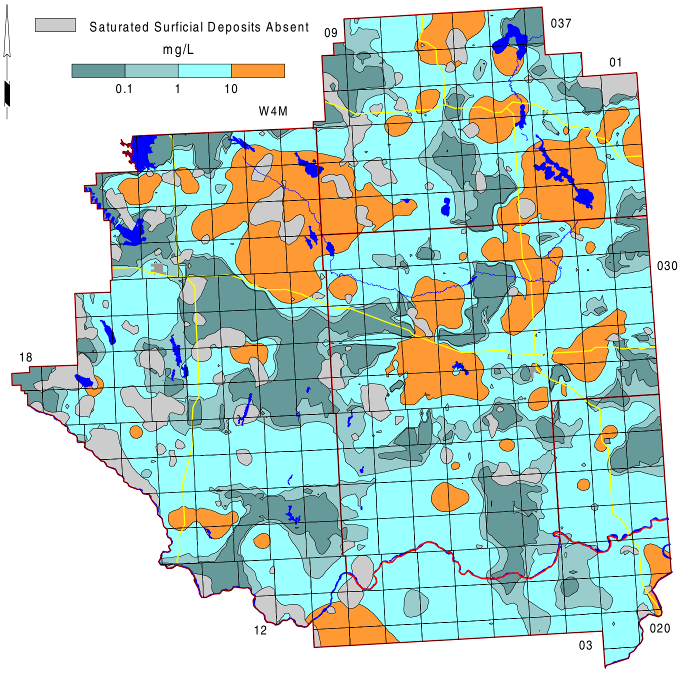

Figure 13. Nitrate + Nitrite (as N) in Groundwater from Surficial Deposits

	Range for Special Areas and M.D. in mg/L			Recommended Maximum Concentration
Constituent	Minimum	Maximum	Average	GCDWQ
Total Dissolved Solids	105	7316	1444	500
Sodium	2	1762	235	200
Sulfate	0	4379	585	500
Chloride	0	2217	22	250
Nitrate + Nitrite (as N)	0	157	6.5	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives

GCDWQ - Guidelines for Canadian Drinking Water Quality, Sixth Edition
Minister of Supply and Services Canada, 1996

Table 4. Concentrations of Constituents in Groundwaters from Surficial Deposits

Although the majority of the groundwaters from surficial deposits are bicarbonate-type waters, there are groundwaters with sulfate as the main anion. The groundwaters with elevated levels of sulfate generally occur in areas where there are elevated levels of total dissolved solids. There are very few groundwaters from the surficial deposits with appreciable concentrations of the chloride ion and in most of the project area, the chloride ion concentration is less than 100 mg/L.

The minimum, maximum and average concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) in the groundwaters from water wells completed in the surficial deposits in the project area have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in the table above. Of the five constituents that have been compared to the GCDWQ, the average values of TDS, sodium and sulfate concentrations exceed the guidelines.

3) Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated upper surficial deposits. These aquifers can directly overlie or be close to the bedrock surface or they can be close to the land surface. Saturated sand and gravel deposits in the upper surficial deposits are not usually continuous but are expected over approximately 90% of the project area.

a) Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the upper surficial deposits; and (2) the depth to the bedrock surface. Since the non-pumping water-level surface in the surficial deposits tends to be a subdued replica of the bedrock surface, the thickness of the Upper Sand and Gravel Aquifer tends to be directly proportional to the thickness of the surficial deposits.

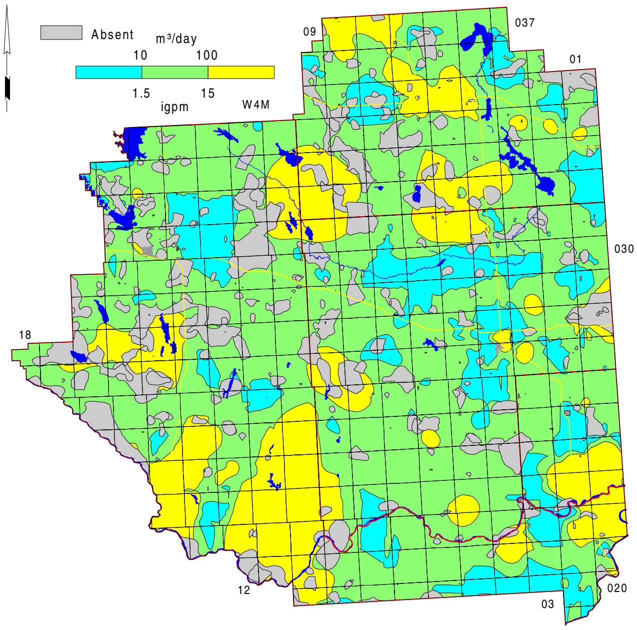

Figure 14. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

While the sand and gravel layers in the upper surficial deposits are not continuous, the Upper Sand and Gravel Aquifer includes all of the aquifers present in the upper surficial deposits. The Upper Sand and Gravel Aquifer is more than 50 metres thick in a few areas, but over the majority of the project area where the Upper Sand and Gravel Aquifer is present, it is less than 30 metres thick; in about 10% of the project area, the Aquifer is absent. Most of the greater thickness in the Upper Sand and Gravel Aquifer occurs in the areas of linear bedrock lows.

b) Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of water wells with high yields; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the apparent yields of the water wells are limited. The apparent yields for water wells completed in this Aquifer are expected to be mainly between ten and 100 m^3/day. Where the Upper Sand and Gravel Aquifer is absent and where the yields are low, the development of water wells for the domestic needs of single families may not be possible. From this Aquifer, and construction of well into the underlying bedrock may be the only alternative, provided yields and quality are suitable.

The Village of Consort operates a water supply well for municipal purposes in 13-33-035-06 W4M that is completed in the Upper Sand and Gravel Aquifer. This water supply well is currently licensed to divert 259 m^3/day. Chemical data from this water supply well indicate a TDS of 1,415 mg/L, a chloride concentration of 14 mg/L, a sulfate concentration of 209 mg/L, and a nitrate + nitrite (as N) of 2.8 mg/L.

The M.D. of Acadia operates a water supply well in 02-06-026-01 W4M that is completed in the Upper Sand and Gravel Aquifer. An aquifer test conducted in 1977 indicated a long-term yield of 350 m^3/day (UMA, 1978). This water supply well is currently licensed to divert 195 m^3/day.

4) Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the lowest part of the pre-glacial linear bedrock lows. The thickness of the sand and gravel deposits is mainly less than 30 metres. The Lower Sand and Gravel Aquifer is mostly restricted to the linear bedrock lows in the project area.

a) Apparent Yield

Apparent yields for water wells completed in the Lower Sand and Gravel Aquifer range from less than ten m^3/day to more than 300 m^3/day. The highest yields are expected in the Buried Calgary and Oyen valleys.

The M.D. of Acadia operates a water supply well for domestic purposes in 14-08-025-02 W4M that is completed in the Lower Sand and Gravel Aquifer. This water supply well is currently licensed to divert 155 m^3/day.

A water well was drilled in 1987 for Dinosaur Provincial Park in SW 07-021-11 W4M, south of the Red Deer River and outside the project area. This water well is completed in the Lower Sand and Gravel Aquifer and has a projected long-term yield of 160 m^3/day

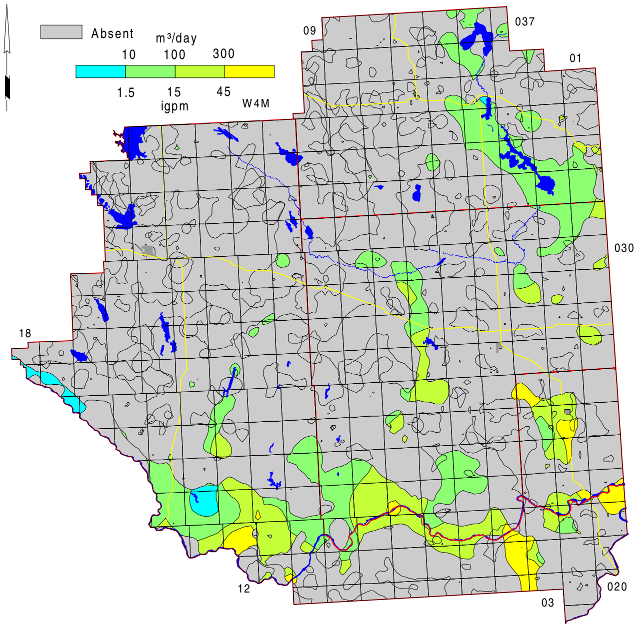

Figure 15. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

A groundwater sample was collected from the M.D. of Acadia water supply well in August 1992. Chemical data from the sampling indicate the groundwater has a TDS of 1,977 mg/L, a chloride of 56 mg/L, a sulfate concentration of 509 mg/L, and a manganese concentration of 0.47 mg/L (CAESA, March 1995). The GCDWQ recommended maximum concentration for manganese is 0.05 mg/L.

A groundwater sample was collected from the Dinosaur Provincial Park 1987 Water Well. Chemical data from the sampling indicate the groundwater has a TDS of 778 mg/L, a chloride concentration of 32 mg/L, a sulfate concentration of 33 mg/L, and a nitrate + nitrite (as N) of <0.2 mg/L (HCL, September 1987).

C. Bedrock

1) Geological Characteristics

The upper bedrock in Special Areas and the M.D. includes the Paskapoo Formation, the Edmonton Group, the Bearpaw Formation and the Belly River Group. The adjacent bedrock geology map has been prepared in part from the interpretation of geophysical logs related to oil and gas activity.

The Paskapoo Formation consists of cycles of thick, tabular sandstones, siltstone and mudstone layers (Glass, D. J. [editor], 1990). The Paskapoo Formation is the upper bedrock in parts of townships 029 and 030, range 16, W4M. The maximum thickness of the Paskapoo Formation can be 800 metres, but in the project area, the thickness is less than 30 metres. The Paskapoo Formation consists of the Dalehurst, Lacombe and Haynes members (Demchuk and Hills, 1991); in the project area, only the Haynes Member is present. There will be no direct review of the Paskapoo Aquifer in the body of this report; however, structure-contour maps are included in Appendix A, and on the CD-ROM.

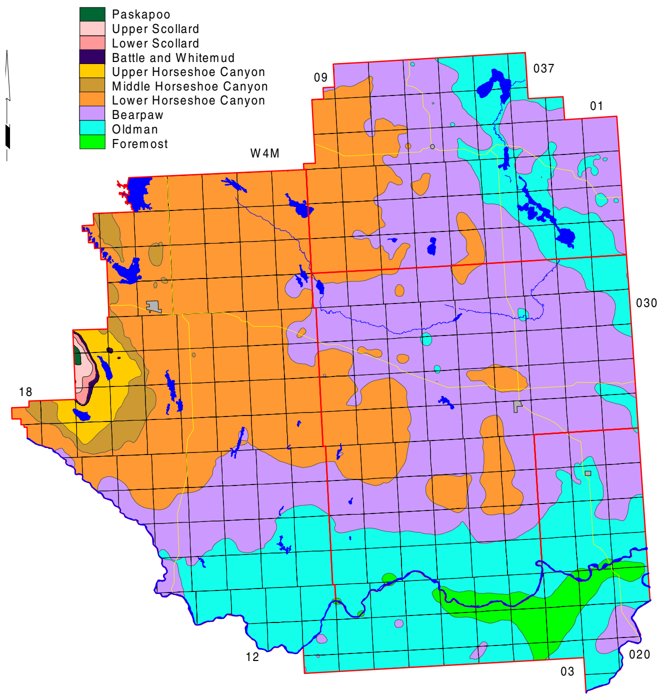

Figure 16. Bedrock Geology

The Edmonton Group consists of fresh and brackish-water deposits of fine-grained sandstone and silty shale, thick coal seams, and numerous bentonite beds (Carrigy, 1971). The Edmonton Group includes the Scollard, Battle, Whitemud and Horseshoe Canyon formations. The Edmonton Group is the upper bedrock in the western part of the project area. The thickness of the Edmonton Group varies from 300 to 500 metres, but in the project area, the thickness is less than 350 metres. In the project area, the Scollard, Battle, Whitemud and Upper Horseshoe Canyon formations have limited importance and there will be no direct review of these aquifers in the body of this report. However, some maps associated with the Edmonton Group are included in Appendix A and on the CD-ROM. Because the Battle and Whitemud formations are thin, they are included as part of the Upper Horseshoe Canyon Formation and are not shown separately except on the bedrock geology map.

The Horseshoe Canyon Formation consists of deltaic[16] and fluvial sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be finer grained. The lower 60 to 70 metres and the upper 30 to 50 metres of the Horseshoe Canyon Formation can include coarser grained sandstone deposits.

The Bearpaw Formation is the upper bedrock in most of the east-central part of the project area and is generally less than 100 metres thick in the project area. The Bearpaw Formation consists of marine shale, siltstone and minor sandstone layers except in some areas where the thickness of the sandstone layers can be significant. The Bearpaw Formation "represents the final widespread marine unit in the Western Canada Foreland Basin"

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[16] See glossary

(Catuneanu et al, 1997). The border between the bottom of the Bearpaw Formation and the uppermost part of the Belly River Group was used as a geological marker in the e-log interpretation.

The Belly River Group in the project area has a maximum thickness of 300 metres and includes the Oldman and Foremost formations. The Foremost Formation includes the marine facies[17] within the project area. The Oldman Formation is present under most of the project area, but subcrops mainly in the southern and northeastern parts of the project area and has a maximum thickness of 130 metres. The Oldman Formation is composed of sandstone, siltstone, shale and coal deposited in a continental environment. The Oldman Formation is composed of three parts: (a) the Comrey, (b) the Upper Siltstone and (c) the 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 *marine* Foremost Formation is less than 180 metres thick and is positioned between the overlying Oldman Formation and the underlying Lea Park Formation. In the *marine* Foremost Formation, individual members have been identified. The members include both sandstone and shale units. For the present project, the individual members are identified by the designation given to the sandstone members, with the underlying shale member being considered as the shale facies of the sandstone member. For example in this report, the Birch Lake Member includes the Birch Lake Member (a sandstone deposit) and the underlying shale deposit. Eastward, the sandstone layers of individual members grade into marine shale deposits. In the project area, due to the limited data available for the members underlying the Birch Lake Member, this report will include a discussion on the Birch Lake Member only. Structure-contour maps for the underlying members are included in Appendix A, and on the CD-ROM.

In most of the area, the top of the Foremost Formation coincides with the Base of Groundwater Protection. A map showing the depth to the Base of Groundwater Protection is given on page 6 of this report, in Appendix A, and on the CD-ROM.

The present breakdown of the Foremost Formation would not be possible without identifying a continuous top for the Lea Park Formation. The top of the Lea Park Formation represents a geologic time border between the marine environment of the Lea Park Formation and the mostly continental environment of the Foremost Formation.

The top of the Lea Park Formation is the bottom of the higher resistivity layer that occurs within a few metres below a regionally identifiable bentonite marker, as shown in the adjacent e-log. This marker occurs approximately 100 metres above the Milk River shoulder.

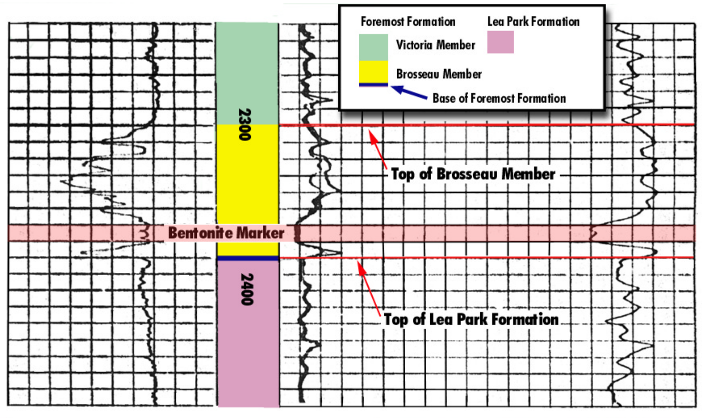

Figure 17. E-Log showing Base of Foremost Formation

The Lea Park Formation is mostly composed of shale, with only minor amounts of bentonitic siltstone present in some areas. Regionally, the Lea Park Formation is an aquitard. Because the Lea Park Formation is an aquitard, there will be no direct review of the Lea Park Aquitard in the body of this report. However, structure-contour maps associated with the Lea Park Aquitard are included in Appendix A and on the CD-ROM.

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[17] See glossary

2) Aquifers

Of the 8,079 water wells in the database, 1,432 were defined as being completed below the top of bedrock. This designation is based on the top of the completion interval being below the top of bedrock. However, at least a reported completion depth is available for the majority of water wells and assigning the water wells to specific geologic units is possible only if the completion interval is identified. In order to make use of additional information within the groundwater database, it was assumed that if the total drilled depth of a water well was more than ten metres below the top of a particular geological unit, the water well was assigned to the particular geologic unit. With this assumption, it has been possible to designate the aquifer of completion for 4,455 additional water wells. There are 1,735 water wells that have been identified as being completed in bedrock aquifers above the Middle Horseshoe Canyon Formation or below the Birch Lake Member, or in more than one bedrock aquifer.

Geological Unit	No. of Water Wells
Middle Horseshoe Canyon	83
Lower Horseshoe Canyon	1,250
Bearpaw	1,656
Oldman	997
Birch Lake	166
Other	453
Multiple Completions	1,282
Total	5,887

Table 5. Completion Aquifer

The bedrock water wells are mainly completed in the Bearpaw, Lower Horseshoe Canyon and Oldman aquifers, as shown in the adjacent table. More than 20% of the bedrock water wells are likely to have multiple completions.

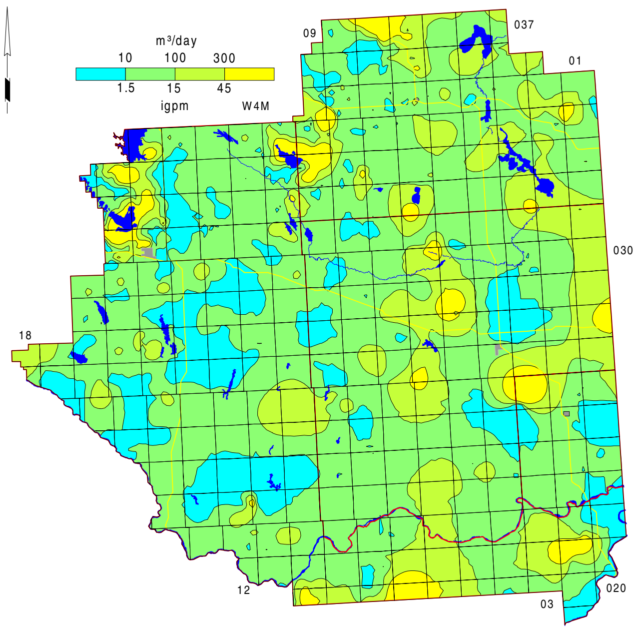

Figure 18. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 1,257 records for bedrock water wells that have apparent yield values, 21% of all bedrock water wells. The water well yields in the upper bedrock aquifer(s) varies throughout the project area, but are mainly between ten and 100 m³/day. The water well yields of greater than 100 m³/day are scattered throughout the project area, but are scarcer west of range 08. The exceptions are the extreme northwestern part of the project area and near Kirkpatick Lake, in townships 033 and 034, ranges 09 and 10, W4M. In these areas water wells with yields of greater than 300 m³/day occur. The higher yield areas may identify areas of increased permeability resulting from the weathering process.

Aquifer	No. of Water Wells with Values for Apparent Yield	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Middle Horseshoe Canyon	49	7	33	9
Lower Horseshoe Canyon	401	112	211	78
Bearpaw	351	84	207	60
Oldman	374	31	248	95
Birch Lake	23	0	13	10
Totals	1,198	234	712	252

Table 6. Apparent Yields of Bedrock Aquifers

Of the 1,257 water well records with apparent yield values, 1,198 have been assigned to aquifers associated with the specific geologic units that are being discussed in this report. Fifty-nine percent or 712 of the water wells completed in the bedrock aquifers have apparent yields that range from ten to 100 m³/day, and 21% or 252 have apparent yields that are more than 100 m³/day, as shown in the table above.

3) Chemical Quality of Groundwater

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 to more than 3,000 mg/L. Approximately 55% of these groundwaters have a TDS content of more than 1,500 mg/L. The groundwaters with a TDS content of more than 3,000 mg/L occur mainly in the eastern two thirds of the project area.

The relationship between TDS and sulfate concentrations shows that when TDS values in the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L. Approximately 50% of the sulfate values are more than 500 mg/L. The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 100 mg/L in more than 80% of the project area.

In 90% of the project area, the fluoride ion concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 1.0 mg/L.

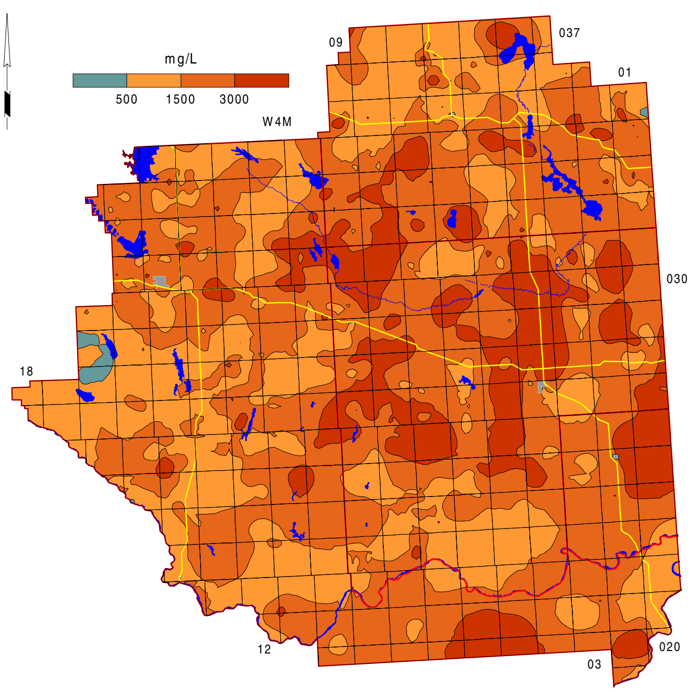

Figure 19. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The Piper tri-linear diagrams [18] (see Appendix A) show that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types. There are some groundwaters from the upper bedrock aquifer(s) in which calcium and magnesium are the main cations. These groundwaters are usually from aquifers that are close to the bedrock surface.

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[18] See glossary

4) Middle Horseshoe Canyon Aquifer

The Middle Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Middle Horseshoe Canyon Formation. The Middle Horseshoe Canyon Formation subcrops in the western part of the project area. The thickness of the Middle Horseshoe Canyon Formation increases to the west and can be more than 50 metres at the western edge of Special Areas. In general terms, the permeability of the Middle Horseshoe Canyon Aquifer is very low. Higher local permeability can be expected where weathering processes have been active.

a) Depth to Top

The depth to the top of the Middle Horseshoe Canyon Formation is variable, ranging from less than 20 metres in the area of subcrop to more than 180 metres in townships 029 and 030, range 16, W4M. The Middle Horseshoe Canyon Formation is mainly less than 60 metres below ground level and is a reflection of the thickness of the surficial deposits.

b) Apparent Yield

The apparent yields for water wells completed through the Middle Horseshoe Canyon Aquifer range from less than 10 to more than 300 m³/day. However, 75% of the 49 values for apparent yield are less than 50 m³/day.

The areas where water wells with higher yields are expected are mainly in the northwestern corner of Special Areas. The higher water well yields occur because the Middle Horseshoe Canyon Formation in Special Areas subcrops under the surficial deposits and the Aquifer is affected by weathering processes. The yields of water wells completed in the Middle Horseshoe Canyon Aquifer are higher than the yields of water wells completed in areas where the Middle Horseshoe Canyon Aquifer does not subcrop.

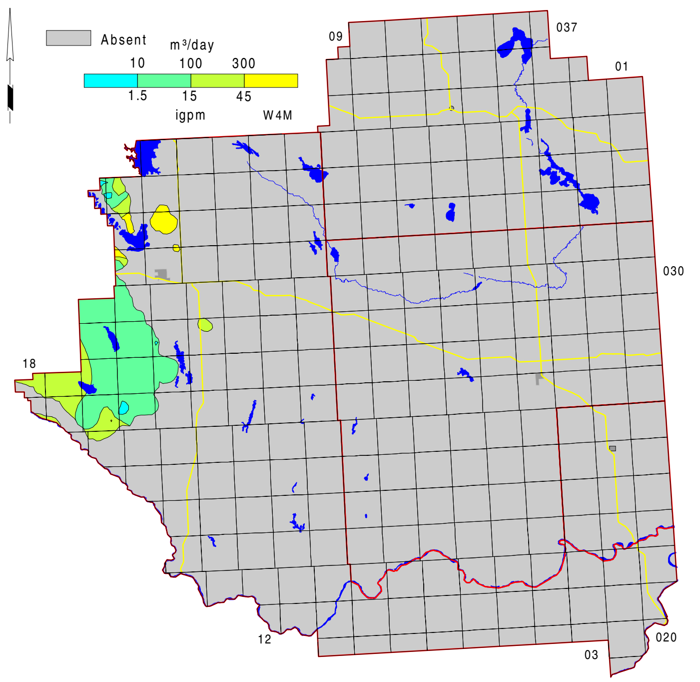

Figure 20. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer

An extended aquifer test conducted with a water test hole in NW 25-027-17 W4M completed in the Middle Horseshoe Canyon Aquifer indicated a long-term yield of 90 m³/day. A second water test hole drilled 280 metres north of the NW 25 water test hole is also completed in the Middle Horseshoe Canyon Aquifer. However, there is no direct hydraulic continuity between the aquifers in which the two water test holes are completed and the long-term yield of the second water test hole is 50 m³/day (HCL, July 1997).

c) Quality

The groundwaters from the Middle Horseshoe Canyon Aquifer are a sodium-bicarbonate type (see CD-ROM), with TDS mainly between 1,000 and 1,500 mg/L. The sulfate concentrations are expected to be mainly less than 500 mg/L and chloride concentrations from the Middle Horseshoe Canyon Aquifer in the project area are expected to be mainly less than 10 mg/L.

5) Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Lower Horseshoe Canyon Formation, which underlies the northwestern part of the project area. The thickness of the Lower Horseshoe Canyon Formation increases to the west and can reach more than 140 metres in the western parts of Special Areas. In general terms, the permeability of the Lower Horseshoe Canyon Aquifer is very low. Higher local permeability can be expected where weathering processes have occurred.

a) Depth to Top

The depth to the top of the Lower Horseshoe Canyon Formation is variable, ranging from less than 20 to more than 220 metres below ground level and is a reflection of the thickness of the surficial deposits.

b) Apparent Yield

The apparent yields for individual water wells completed through the Lower Horseshoe Canyon Aquifer range mainly from ten to 100 m³/day, with 20% of the values being more than 100 m³/day. The areas where water wells with higher yields are expected may have been subjected to weathering processes.

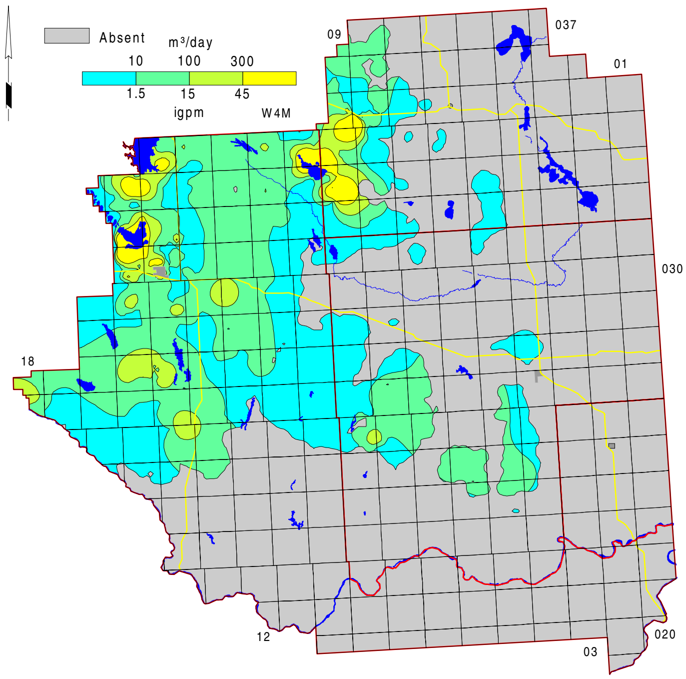

Figure 21. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

c) Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are sodium-bicarbonate or sodium-sulfate types (see CD-ROM), with TDS mainly between 1,000 and 2,000 mg/L. The sulfate concentrations that are less than 500 mg/L are mainly in the western part of the project area. When TDS values in the groundwaters from the Lower Horseshoe Canyon Aquifer exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

The chloride concentrations of the groundwaters from the Lower Horseshoe Canyon Aquifer can be expected to be mainly less than 100 mg/L.

6) Bearpaw Aquifer

The Bearpaw Aquifer comprises the porous and permeable parts of the Bearpaw Formation, which underlies the project area in most of townships 024 to 037, W4M. The structure contours show the Formation being mostly less than 110 metres thick.

a) Depth to Top

The depth to the top of the Bearpaw Formation is mainly less than 50 metres below ground level where the Formation subcrops. In the northern part of the M.D. of Acadia, the Bearpaw Formation is the uppermost bedrock. Where the Paskapoo Formation is the upper bedrock in the western part of Special Areas, the depth to the top of the Bearpaw Formation can be more than 350 metres.

b) Apparent Yield

The apparent yields for individual water wells completed through the Bearpaw Aquifer are mainly in the range of 10 to 100 m³/day, with less than 20% of the values being more than 100 m³/day. The lower yield values presented in the western part of the project area could be a result of the gridding procedure used to process a limited number of data points. The areas where water wells with higher yields are expected are mainly where the Bearpaw Formation subcrops under the surficial deposits and would most be subjected to weathering processes. The Bearpaw Formation is present only in the northern half of the M.D. and water-well yields are expected to be mainly less than 100 m³/day.

An example of a high yielding water well where the Bearpaw Formation does not subcrop is a water well drilled near Kirkpatrick Lake in 16-34-033-09 W4M for Mapco Inc. This water well is completed at an elevation below the Bulwark Sandstone and is indicated as having a long-term yield of 1,500 m³/day (HCL, March 1972).

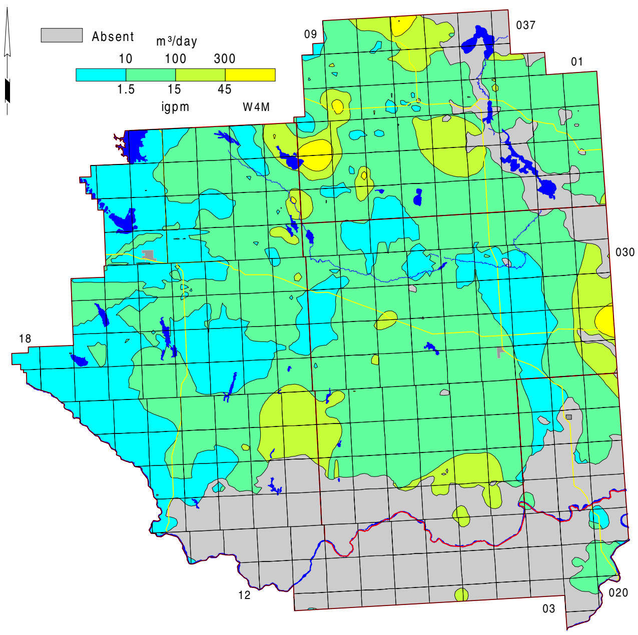

Figure 22. Apparent Yield for Water Wells Completed through Bearpaw Aquifer

c) Quality

The groundwaters from the Bearpaw Aquifer are mainly a sodium-sulfate type (see CD-ROM). The TDS concentrations are mainly more than 1,000 mg/L. The areas where TDS concentrations of more than 2,000 mg/L are expected are mainly where the Bearpaw Formation subcrops under the surficial deposits; in these areas, the sulfate concentrations are mainly more than 500 mg/L. Chloride concentrations in the groundwaters from the Bearpaw Aquifer mainly range from 10 to 100 mg/L. There are some areas in the northwestern part of Special Areas where the chloride concentration is expected to be more than 250 mg/L. The values of chloride concentration of greater than 250 mg/L in the northwestern part of the project area are a result of the gridding procedure used to process a limited number of data points. In the entire project area, 15% of the chloride concentration values exceed 250 mg/L.

The TDS concentration in the groundwater from a water well completed in the Bearpaw Aquifer near Kirkpatrick Lake was 1,424 mg/L; the sulfate concentration was 690 mg/L and the chloride concentration was 10 mg/L (HCL, March 1972).

7) Oldman Aquifer

The Oldman Aquifer comprises the porous and permeable parts of the Oldman Formation. The Oldman Formation subcrops in the southern quarter of the project area, in the vicinity of the Buried Calgary Valley. The Oldman Formation also subcrops in a small area of the northeastern part of the project area, in the vicinity of the Buried Loverna Valley. The thickness of the Oldman Formation is generally less than 90 metres.

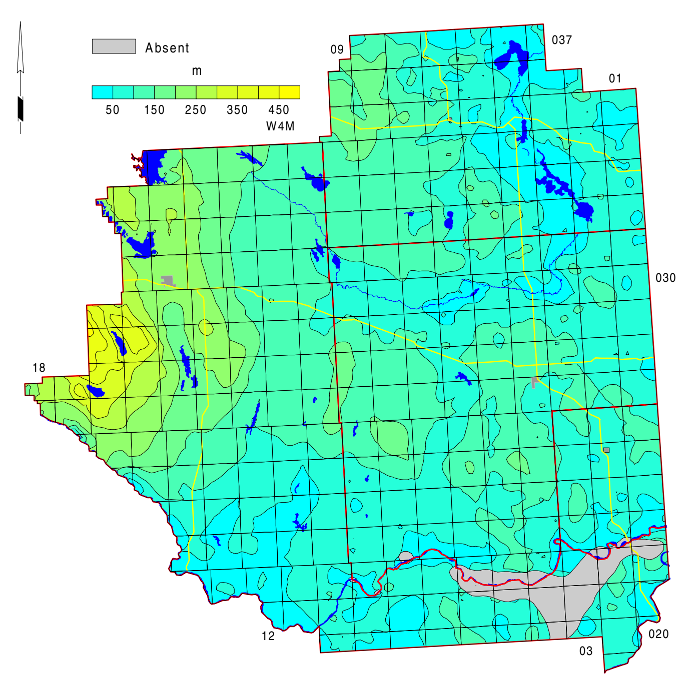

Figure 23. Depth to Top of Oldman Formation

a) Depth to Top

The depth to the top of the Oldman Formation ranges mainly less than 50 metres below ground level in some of the southern and northeastern parts of the project area where the Oldman Formation subcrops. In the southern part of the M.D. of Acadia, the Oldman Formation is the uppermost bedrock. In the western part of the project area where the Oldman is below the Paskapoo Formation, the depth to the top of the Oldman Formation can be more than 450 metres. In the western part of the project area, the Base of Groundwater Protection coincides with the base of the Oldman Formation. A map showing the depth to the Base of Groundwater Protection is given on page 6 of this report, in Appendix A, and on the CD-ROM.

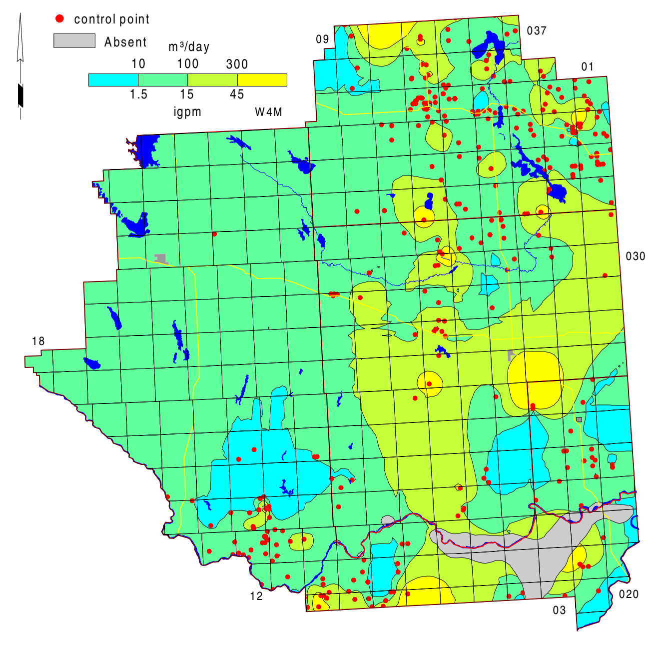

Figure 24. Apparent Yield for Water Wells Completed through Oldman Aquifer

b) Apparent Yield

Most of the water wells completed in the Oldman Aquifer are in the northeastern and southern parts of Special Areas. Throughout the remainder of the project area, there are very few water wells that have been completed in the Oldman Aquifer. The apparent yield for individual water wells completed through the Oldman Aquifer range mainly between 10 and 100 m³/day. However, the large expanse of yields of less than 100 m³/day in the western part of the project area may be a reflection of the limited amount of data rather than the hydraulic properties of the Aquifer.

The control point in 11-31-031-12 W4M reflects the data from an aquifer test conducted with a water test hole for Best Pacific Resources Ltd. The water test hole drilled in July 1996 was completed from 236.5 to 250.0 metres below ground level in a sandstone layer close to the base of the Oldman Aquifer (HCL, Dec 1998). In September 1999, the water test hole was subsequently licensed as a water source well to divert 80 m³/day.

An extended aquifer test conducted with a water test hole completed in the Oldman Aquifer for the Village of Consort has a long-term yield of 250 m³/day (Pretula, 1981). The Village is licensed to divert up to 330 m³/day from three water supply wells completed in the Oldman Aquifer in 15-035-06 W4M.

c) Quality

The groundwaters from the Oldman Aquifer are mainly a sodium-sulfate type (see CD-ROM). The TDS concentrations are mainly more than 1,000 mg/L. The sulfate concentrations are mainly more than 500 mg/L in the eastern part of the project area. Chloride concentrations in the groundwaters from the Oldman Aquifer are mainly less than 250 mg/L in the eastern part of the project area. The TDS and chloride concentrations in the western part of the project area tend to be higher because of the depth of burial of the Oldman Formation.

The groundwater from the Best Pacific water source well is a sodium-chloride type water with TDS of 3,257 mg/L; the sulfate concentration was less than 1 mg/L and the chloride concentration was 1,821 mg/L (HCL, December 1998).

The TDS concentration in the groundwater from a Village of Consort water supply well completed in the Oldman Aquifer was 1,230 mg/L; the sulfate concentration was 10 mg/L and the chloride concentration was 124 mg/L (Pretula, 1981). The chemical data from a second groundwater sample collected and analyzed in 1986 indicated no significant changes in the chemical quality of the groundwater quality had occurred over five years.

8) Birch Lake Aquifer

The Birch Lake Aquifer comprises the porous and permeable parts of the Birch Lake Member. Structure contours have been prepared for the top and bottom of the Member, which underlies all of the project area. The structure contours show the Member is generally less than 80 metres thick.

a) Depth to Top

The depth to the top of the Birch Lake Member ranges from less than 50 metres below ground level where the Member subcrops in the vicinity of the Buried Calgary Valley to more than 550 metres below ground level in the west-central part of the project area.

b) Apparent Yield

There are 23 apparent yield control points in the project area from the groundwater database. More than 40% of the control points for individual water wells completed through the Birch Lake Aquifer have apparent yields of more than 100 m^3/day. However, all of the control points are from areas where the depth to the top of the Member is less than 200 metres. In areas where the depth of burial is more than 200 metres, water well yields may be less than 100 m^3/day. Also, in the western part of the area, the Birch Lake Aquifer is part of a continental sequence of sediments and water-well yields would be more variable and mainly less than 50 m^3/day.

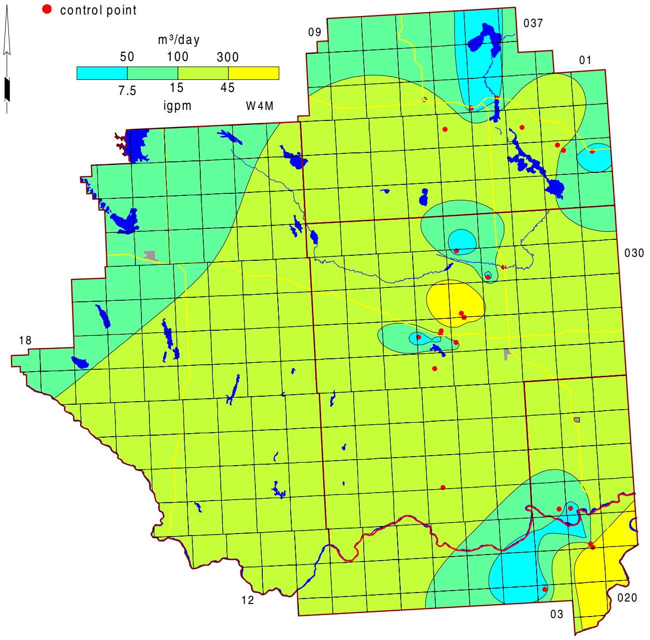

Figure 25. Apparent Yield for Water Wells Completed through Birch Lake Aquifer

c) Quality

The groundwaters from the Birch Lake Aquifer have no dominant chemical type; however, sodium is the main cation (see CD-ROM). The TDS concentrations for groundwaters from the Birch Lake Aquifer range from less than 1,000 to more than 2,000 mg/L. The lower values of TDS occur mainly in the western part of the project area, which could be a result of the gridding procedure used to process a limited number of data points. When TDS values in the groundwaters from the Birch Lake Aquifer exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

The chloride concentrations of the groundwaters from the Birch Lake Aquifer range from less than 10 to more than 250 m^3/day; more than 60% of the control points have chloride concentrations of more than 250 mg/L.

VI. Groundwater Budget

A. Hydrographs

There are 19 locations in the project area where water levels are being measured and recorded with time. These sites are observation water wells (Obs WWs) that are part of the AE regional groundwater-monitoring network. These 19 Obs WWs are in ten different parts of the project area as shown on the adjacent map. Five of the hydrographs discussed in the text below are included in Appendix A; hydrographs for the other 14 AE Obs WWs are included on the CD-ROM.

Water-level data are available from 19 observation water wells. Of the 19 data sets, 17 extend over a time interval of eight to 14 years, with the remaining two records being for 32 years. There is no obvious trend in the water-level fluctuations in all of the AE observation water wells. The type of water-level fluctuations has been placed in seven groups as shown in the table below.

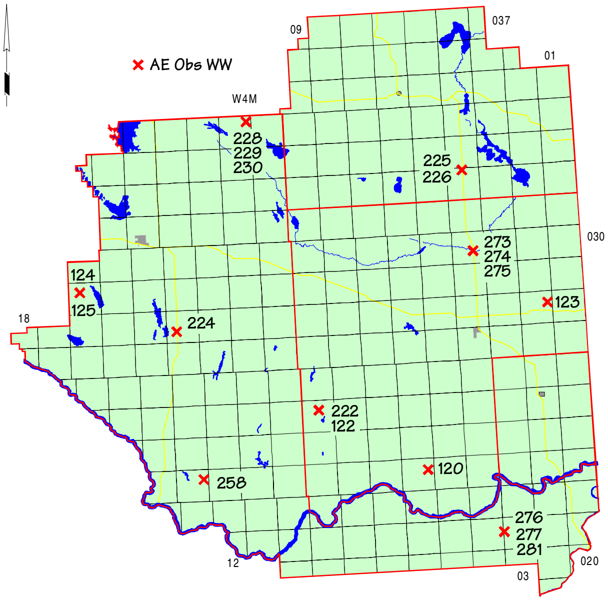

Figure 26. Observation Water Well Locations

Number of	General Description of	Type of Aquifer	
Data Sets	Water-level Change	Bedrock	Surficial
2	Unreliable record	1	1
8	Not much change	2	6
3	General decline	2	1
2	Annual fluctuation	1	1
2	Multi-year fluctuation	1	1
1	Recovering	0	1
1	Rising	1	0

Table 7. Water-Level Fluctuations in AE Obs WWs

The eight data sets indicated in the adjacent table with *not much change* in water level generally have fluctuations of less than 0.25 metres over the entire length of the record.

Two observation water wells, AE Obs WW Nos. 225 and 274, are completed in aquifers in the bedrock. AE Obs WW No. 225 is completed in the Oldman Aquifer and AE Obs WW No. 274 is completed in the Birch Lake Aquifer. There has been a *general decline* in water level in these two observation water wells. The Obs WWs are located in the eastern part of the study area and are less than 30 kilometres apart. There is no apparent reason for the water-level declines, which are between 0.5 and 0.6 metres. The only other recorded water-level decline is in AE Obs WW No. 281 (see CD-ROM), completed in surficial deposits near the Red Deer River; this decline is 0.4 metres over the nine years of the water-level record.

The water levels in two observation water wells, AE Obs WW Nos. 229 and 230, show a “typical” *annual fluctuation* as illustrated in the adjacent graph. The water level rises in late spring/early summer and then declines until the next late spring/early summer. This type of fluctuation is associated with recharge to the aquifer as the frost leaves the ground, with there being no recharge during the remainder of the year. When there is no recharge, the water level gradually declines. Both of the observation water wells are at the same site near Kirkpatrick Lake in the northwestern part of the study area.

The water-level records that show a *multi-year fluctuation* involve a water-level change of less than one metre. This condition occurs in AE Obs WW Nos. 123 and 273 (see CD-ROM) in the east-central part of the study area; these observation water wells are less than 30 kilometres apart. The reason for the multi-year changes is not understood.

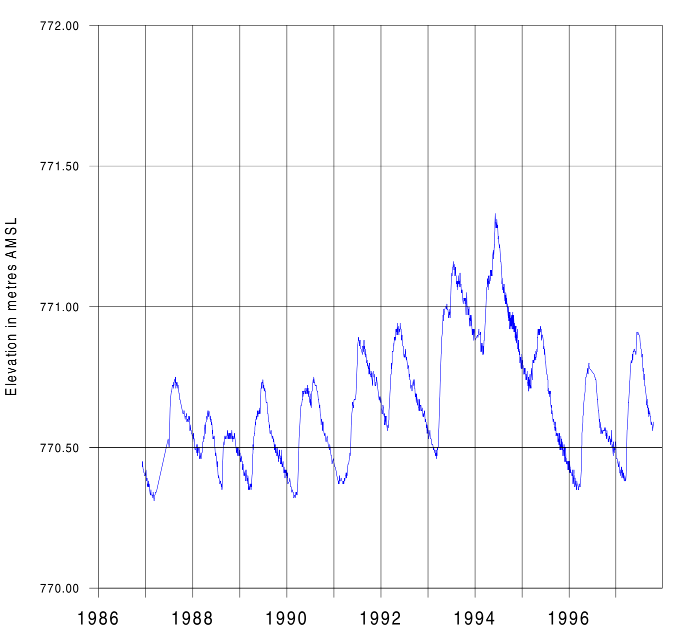

Figure 27. AE Obs No. 229 - Hydrograph

The water-level record in AE Obs WW No. 224 (see CD-ROM) that is designated in Table 7 as *recovering* is close to the Hamlet of Sheerness and may be responding to a cessation of pumping at a nearby site. After the water level recovered, there was *not much change*.

AE Obs WW No. 125 (see CD-ROM) located at the western limit of the study area and completed in a bedrock aquifer was the only location where a *rise* in water level was recorded over the entire monitoring interval. The water-level rise is close to one metre over 32 years. Half of the water-level rise occurred between 1970 and 1976.

In a 25-township area that includes townships 027 to 031, ranges 03 to 07, W4M, there are records for 76 water wells that are completed at a depth of greater than 90 metres. These water wells are mainly completed in the Oldman Aquifer and have a value for NPWL. Of the 76 water wells, 34 were completed before 1975 and 42 were completed after 1974. The elevations of the NPWLs in the 42 water wells drilled after 1974 are between 30 metres higher and 84 metres lower than the elevations of the non-pumping water levels in the water wells drilled before 1975. Unfortunately, there is no more than one water level associated with each water well. The adjacent map shows the result of subtracting the elevations of the water levels in the post-1974 water wells from the pre-1975 water-level elevations. This water-level decline may be a result of limited recharge to the bedrock aquifers.

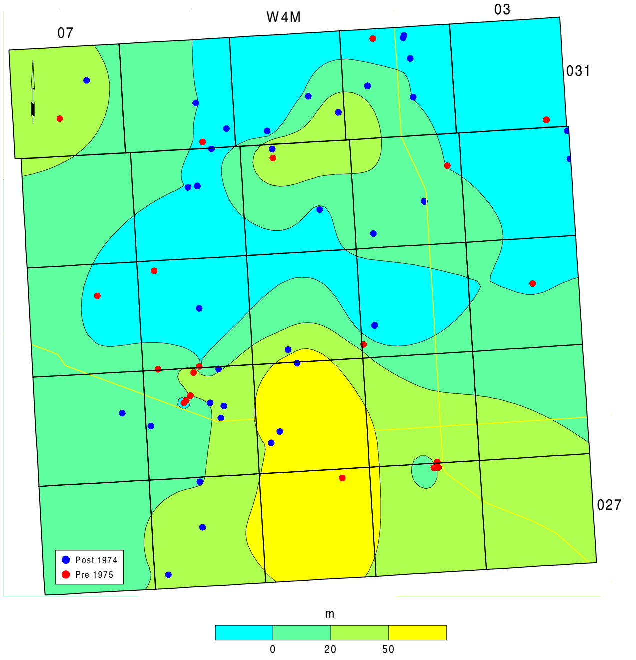

Figure 28. Water-Level Lowering in the Oldman Aquifer

B. Groundwater Flow

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

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

Aquifer/Area	Transmissivity (m^2/day)	Hydraulic Gradient	Width (km)	General Direction of Flow	Volume (m^3/day)	Aquifer Volume (m^3/day)	Authorized Diversion (m^3/day)
Upper Surficial						31,000(1)	1,873
Buried Calgary Valley						600	265
	57	0.001	14.4	east	570		
Lower Horseshoe Canyon						3500	4,991
Western area	3.5	0.003	48	west	420		
	3.5	0.009	48	east	1575		
Eastern part	3.5	0.004	52.8	west	770		
	3.5	0.004	52.8	east	770		
Bearpaw						3300	723
Western area	2	0.003	57.6	west-south-west	288		
	2	0.004	57.6	East-northeast	480		
Central area	5	0.001	153.6	west	800		
	5	0.001	153.6	east	800		
Eastern area - Northern part	6	0.002	19.2	west	180		
	6	0.003	19.2	east	309		
Eastern area - Southern part	2	0.002	38.4	west	160		
	2	0.004	38.4	east	274		
Oldman						1500	1,582
West flow	2.5	0.002	67.2	southwest	280		
	2.5	0.002	67.2	northwest	350		
East flow	2.5	0.003	38.4	northeast	240		
	2.5	0.002	38.4	southeast	200		
	2.5	0.004	38.4	north	400		
Birch Lake						900	64
	2.8	0.002	96	westerly	448		
	2.8	0.002	96	easterly	448		
Ribstone Creek						1400	9
	8	0.002	56	easterly	933		
	8	0.001	56	westerly	467		

(1) HCL, May 1996

The data provided in the above table indicate there is more groundwater flowing through two of the seven individual bedrock aquifers than has been authorized to be diverted from the individual aquifer. For the Oldman Aquifer, the authorized diversion slightly exceeds the calculated flow through the aquifer. In the case of the Lower Horseshoe Canyon Aquifer, the authorized diversion is approximately 50% more than the calculated flow through the Aquifer. The calculations of flow through individual aquifers as presented in the above table are very approximate and are intended only as a guide for future investigations.

1) Quantity of Groundwater

The adjacent water-level map has been prepared from water levels associated with water wells completed in aquifers in the surficial deposits. These water levels were used for the calculation of the saturated thickness of surficial deposits. In areas where the elevation of the water-level surface is below the bedrock surface, the surficial deposits are not saturated. The water-level map for the surficial deposits shows a general flow direction toward the Red Deer River and Sounding Creek, with the lowest water-level elevations occurring along the Red Deer River.

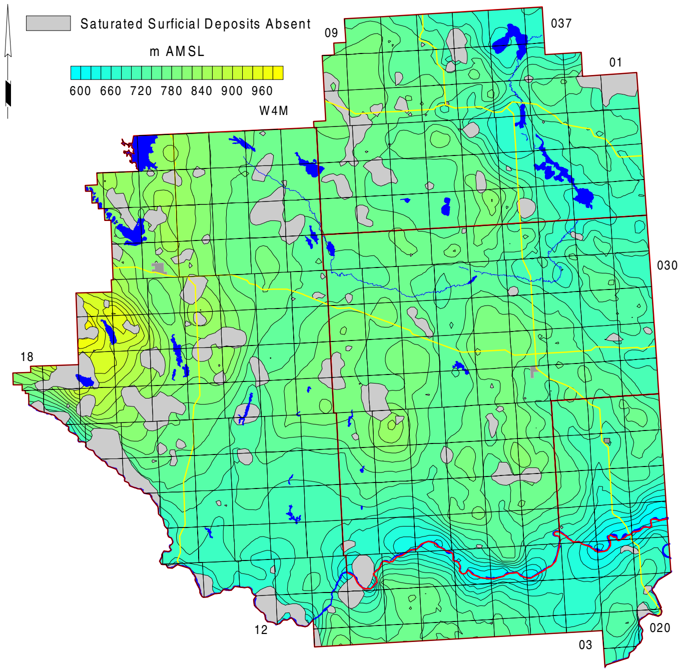

Figure 29. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

2) Recharge/Discharge

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

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

a) Surficial Deposits/Bedrock Aquifers

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

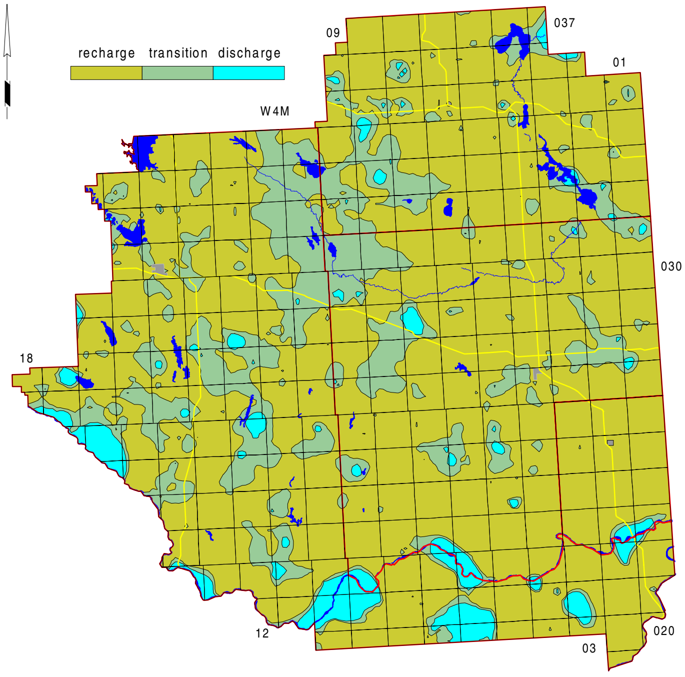

Figure 30. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

The adjacent map shows that, in more than 70% of the project area, there is a downward hydraulic gradient (i. e. recharge) from the surficial deposits toward the upper bedrock aquifer(s). Areas where there is an upward hydraulic gradient from the bedrock to the surficial deposits are mainly in the vicinity of the Buried Calgary Valley, with local discharge along some segments of Berry Creek and the lower reaches of Sounding Creek, including around Sounding Lake. The remaining parts of the project area are areas where there is a transition condition.

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

b) Bedrock Aquifers

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

The hydraulic relationship between the surficial deposits and the Bearpaw Aquifer indicates that in more than 75% of the project area where the Bearpaw Aquifer is present, there is a downward hydraulic gradient (i. e. recharge). Discharge areas for the Bearpaw Aquifer are mainly associated with the edge of the Aquifer. The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers indicates there is also mainly a downward hydraulic gradient.

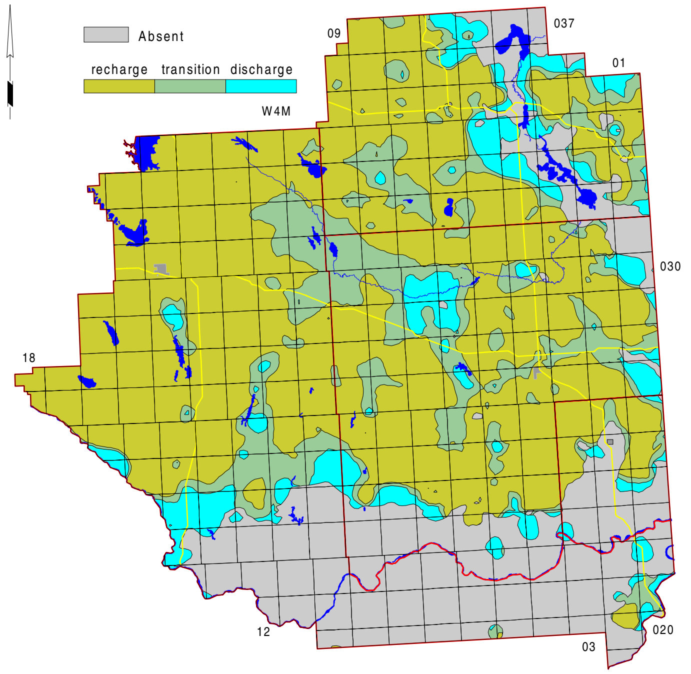

Figure 31. Recharge/Discharge Areas between Surficial Deposits and Bearpaw Aquifer

VII. Potential For Groundwater Contamination

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

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

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

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

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

To identify the areas where sand and gravel can be expected within one metre of the ground surface, all groundwater database records with lithologies were reviewed. From a total of 4,909 records in the project area with lithological descriptions, 1,618 have the top of a sand and gravel deposit present within one metre of ground level. In the remaining 3,291 records, the first sand and gravel is deeper or not present. This information was gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.

1) Risk of Groundwater Contamination Map

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

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

Table 8. Risk of Groundwater Contamination Criteria

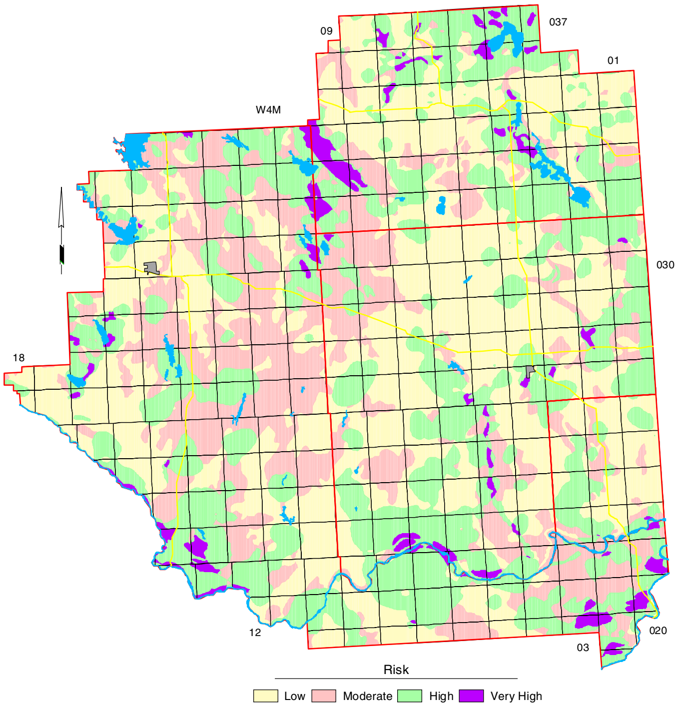

Figure 32. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that, in 35% of the project area, there is a high or very high risk for the groundwater to be contaminated. These areas would be considered the least desirable ones for a development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that contaminants will not affect groundwater quality.

VIII. Recommendations

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

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

The quality of the data in the groundwater database is affected by two factors: a) the technical training of the persons collecting the data, and b) the quality control of the data. The possible options to upgrade the database include the creation of a “super” database, which includes only verified data. The first step would be to field-verify the 432 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. Even though the water wells for which Special Areas or the M.D. has responsibility do not satisfy the above criteria, it is recommended that they be field verified, water levels be measured, a water sample collected for analysis, and a short aquifer test be conducted. A list of at least some of the Special Areas and M.D.-operated water wells are also included in Appendix E. An attempt to update the quality of the entire database is not recommended.

In general, the elevation of the Base to Groundwater Protection may be too shallow along stretches of the Red Deer River. It is recommended that the elevation of the Base of Groundwater Protection be reviewed by EUB and AE in the study area, specifically along the Red Deer River and the other areas indicated on Figure 4 (Page 7) where the water wells are completed below the Base of Groundwater Protection.

In the bedrock, there are indications that a useable aquifer in the western part of the study area may be present in parts of the Oldman Aquifer. The top of the Oldman Formation varies between 100 and 500 metres below ground level in the western part of the project area. In 31-031-12 W4M, the main sandstone unit was encountered at 236 metres. This Aquifer would represent the maximum depth that can be considered for the development of groundwater supplies for traditional agricultural purposes. Because of the depth of the Aquifer, it would not normally be developed because of the cost and the risk of not encountering a suitable groundwater supply. Therefore, a test-drilling program could be considered to evaluate the Oldman Aquifer in areas where only limited groundwater supplies are available from shallower aquifers. The purpose of the program would be to determine the parameters of the Oldman Aquifer and the chemical quality of the groundwater from the Aquifer to assist local residents in determining if an attempt should be made to develop a groundwater supply from the Oldman Aquifer.

While there are a few areas where water-level data are available, on the overall, there are an insufficient number of water levels to set up a groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View and in Flagstaff County, 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.

A second approach to obtain water-level data would be to conduct a field survey to identify water wells not in use that could be used as part of an observation network. Special Areas or M.D. personnel and/or local residents could measure the water levels in the water wells regularly. Because of the apparent lowering of the water level in the Oldman Aquifer in the Oyen area as shown in Figure 28 (Page 33), it is recommended that some water wells in this area be included in a groundwater monitoring program.

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

Before an attempt is made to upgrade the level of interpretation provided in this report and the accompanying maps and groundwater query, it is recommended that all water wells for which water well drilling reports are available be subjected to the following actions (see pages C-2 to C-4):

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

A list of 432 water wells that could be considered for the above program is given in Appendix E.

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. One method of obtaining uniformity would be to have the water well drilling reports submitted to the AE Resource Data Division in an electronic form. The money presently being spent by AE and PFRA to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

An effort should be made to form a partnership with the petroleum industry. The industry spends millions of dollars each year collecting information relative to water wells. Proper coordination of this effort could provide significantly better information from which future regional interpretations could be made. Special Areas 2, 3 and 4, and the M.D. of Acadia could accomplish this by 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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X. Conversions

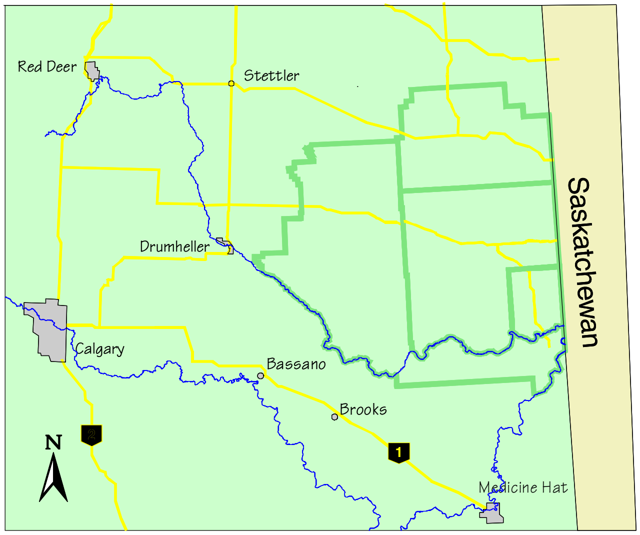
Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	square metres (m^2)
square metres (m^2)	10.763 910	square feet (ft^2)
square metres (m^2)	0.000 001	square kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	parts per million (ppm)
ppm	0.998 859	mg/L
mg/L	1.001 142	ppm
Volume (capacity)		
acre feet	1233.481 838	cubic metres
cubic feet	0.028 317	cubic metres
cubic metres	35.314 667	cubic feet
cubic metres	219.969 248	gallons (UK)
cubic metres	264.172 050	gallons (US liquid)
cubic metres	1000.000 000	litres
gallons (UK)	0.004 546	cubic metres
imperial gallons	4.546 000	litres
Rate		
litres per minute (lpm)	0.219 974	UK gallons per minute (igpm)
litres per minute	1.440 000	cubic metres/day (m^3/day)
igpm	6.546 300	cubic metres/day (m^3/day)
cubic metres/day	0.152 759	igpm

SPECIAL AREAS 2, 3 AND 4, AND M.D. OF ACADIA

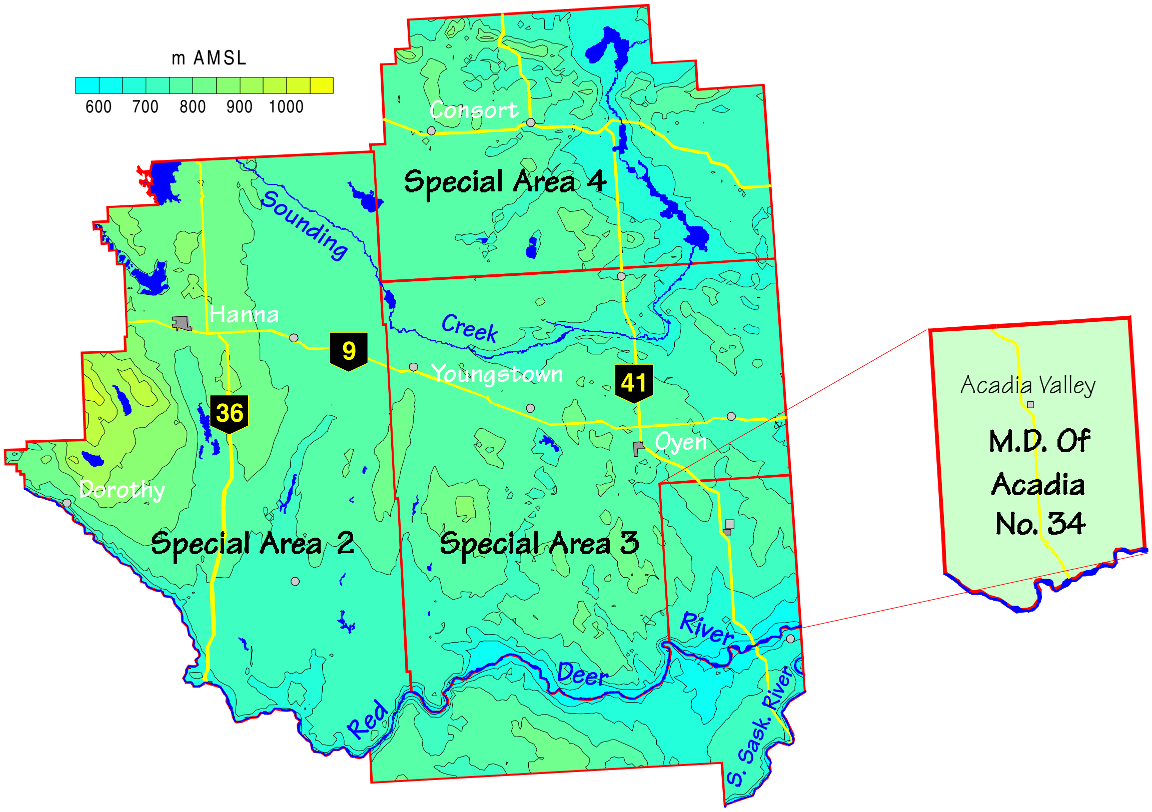
Appendix A

HYDROGEOLOGICAL MAPS AND FIGURES

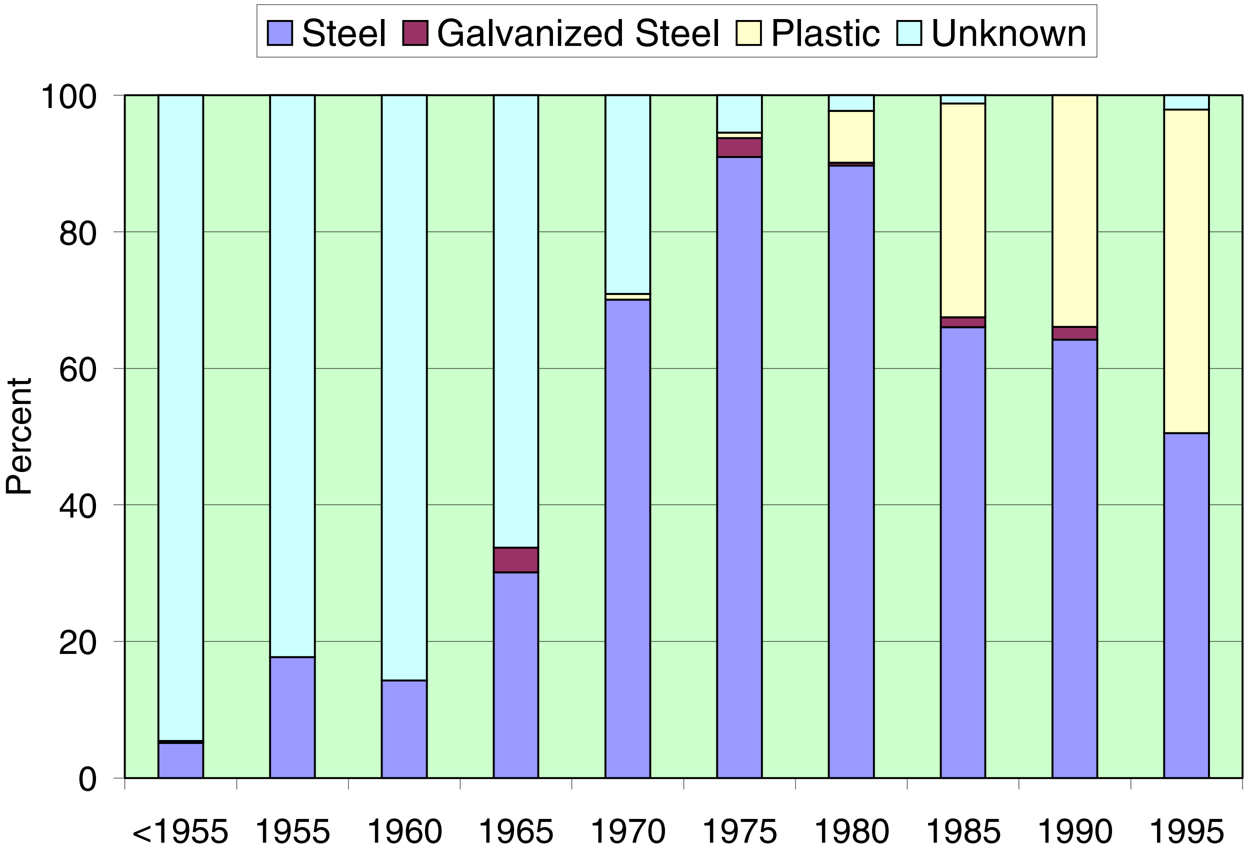
Index Map



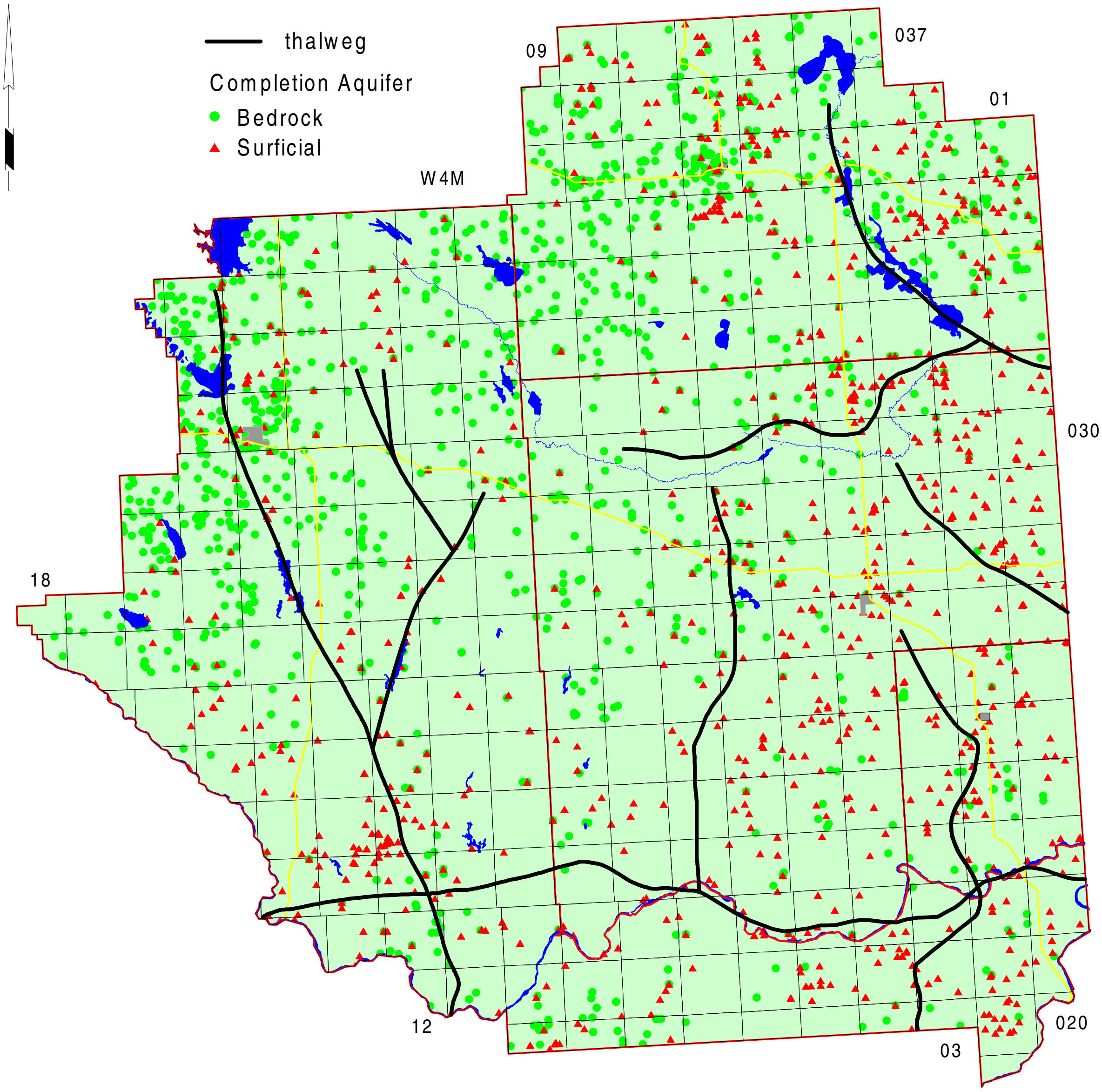
Special Areas 2, 3 & 4 and M.D. of Acadia No. 34



Surface Casing Types used in Drilled Water Wells

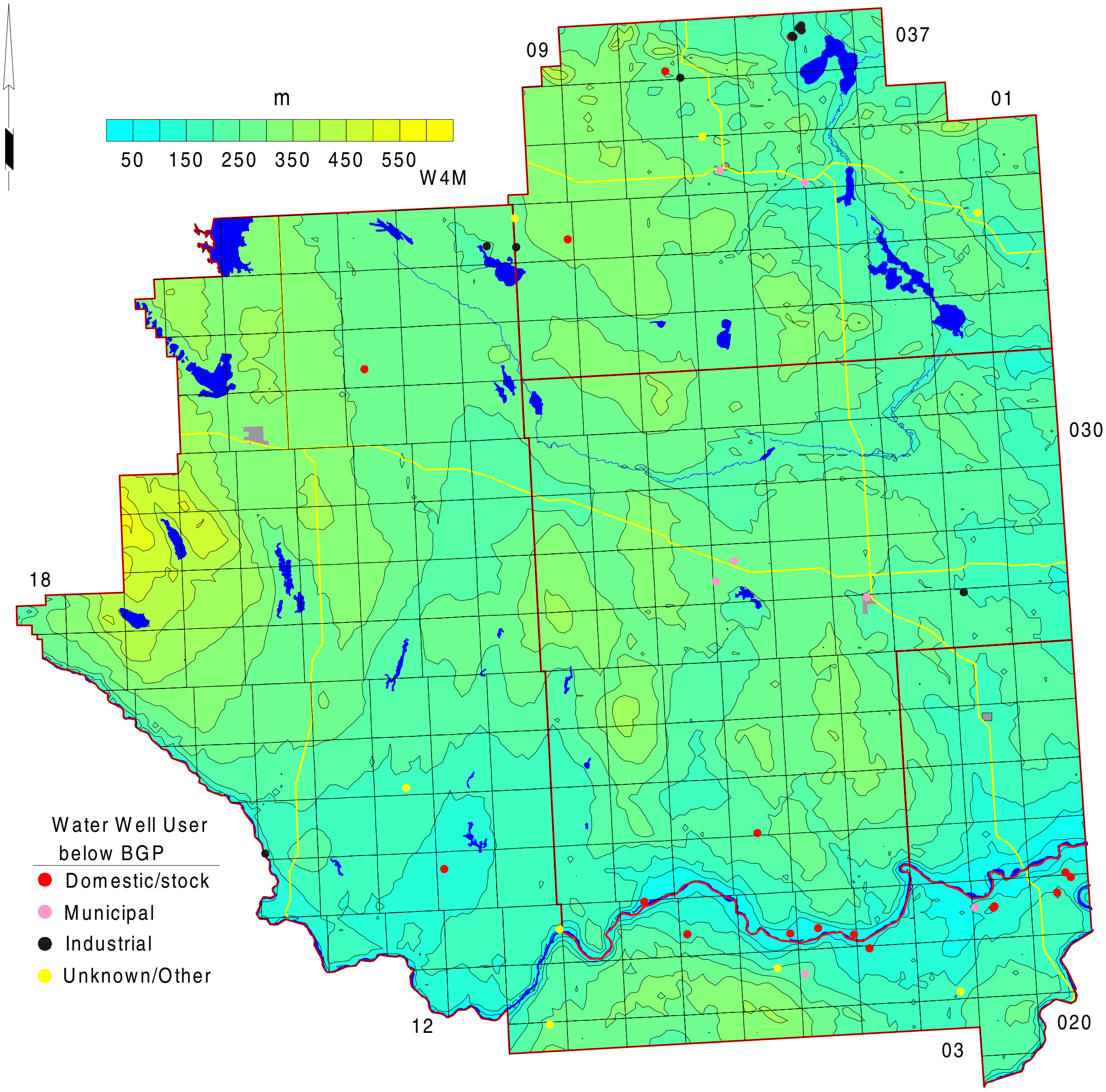


Location of Water Wells



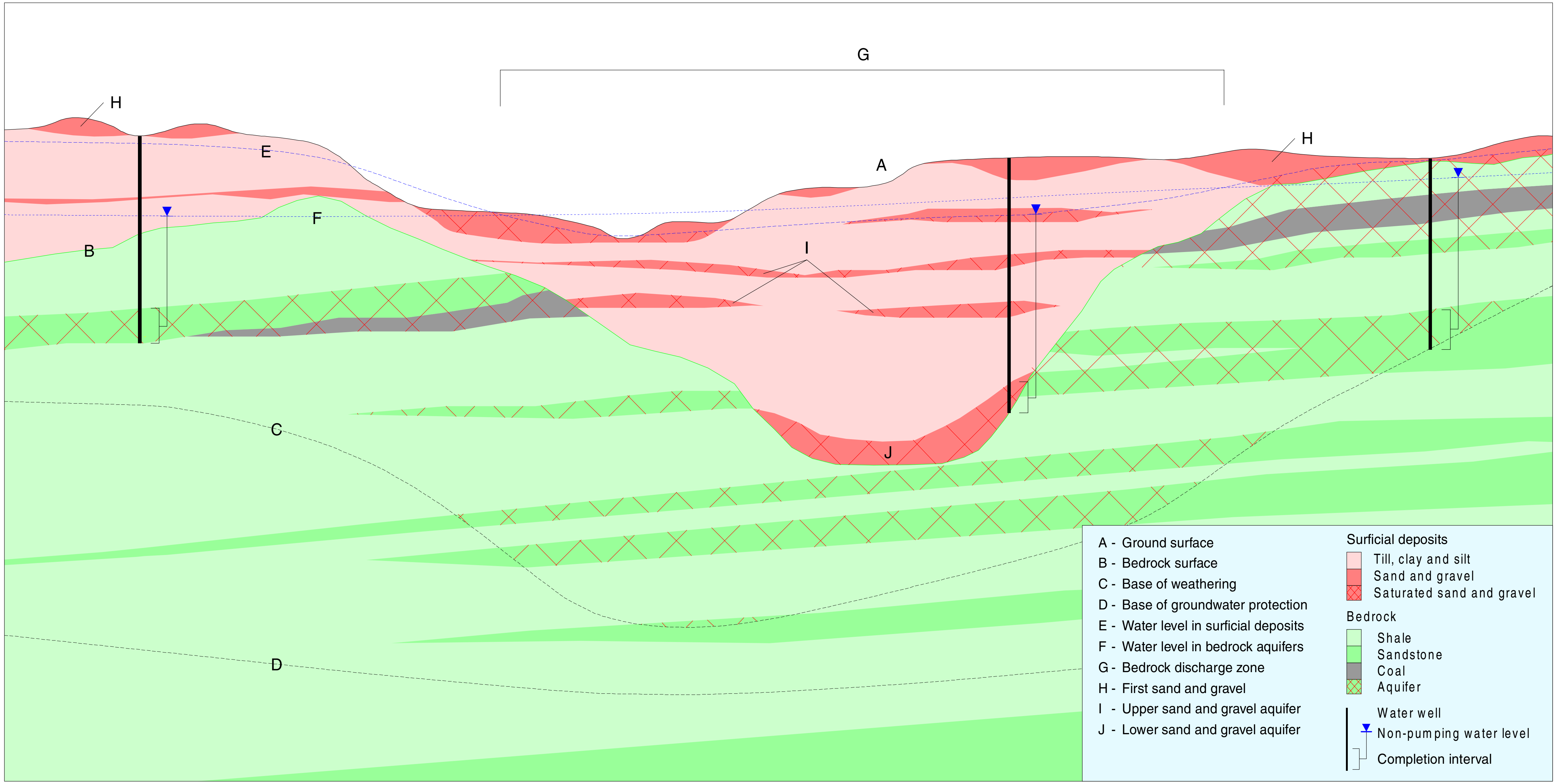
Depth to Base of Groundwater Protection

(after EUB, 1995)



Generalized Cross-Section

(for terminology only)

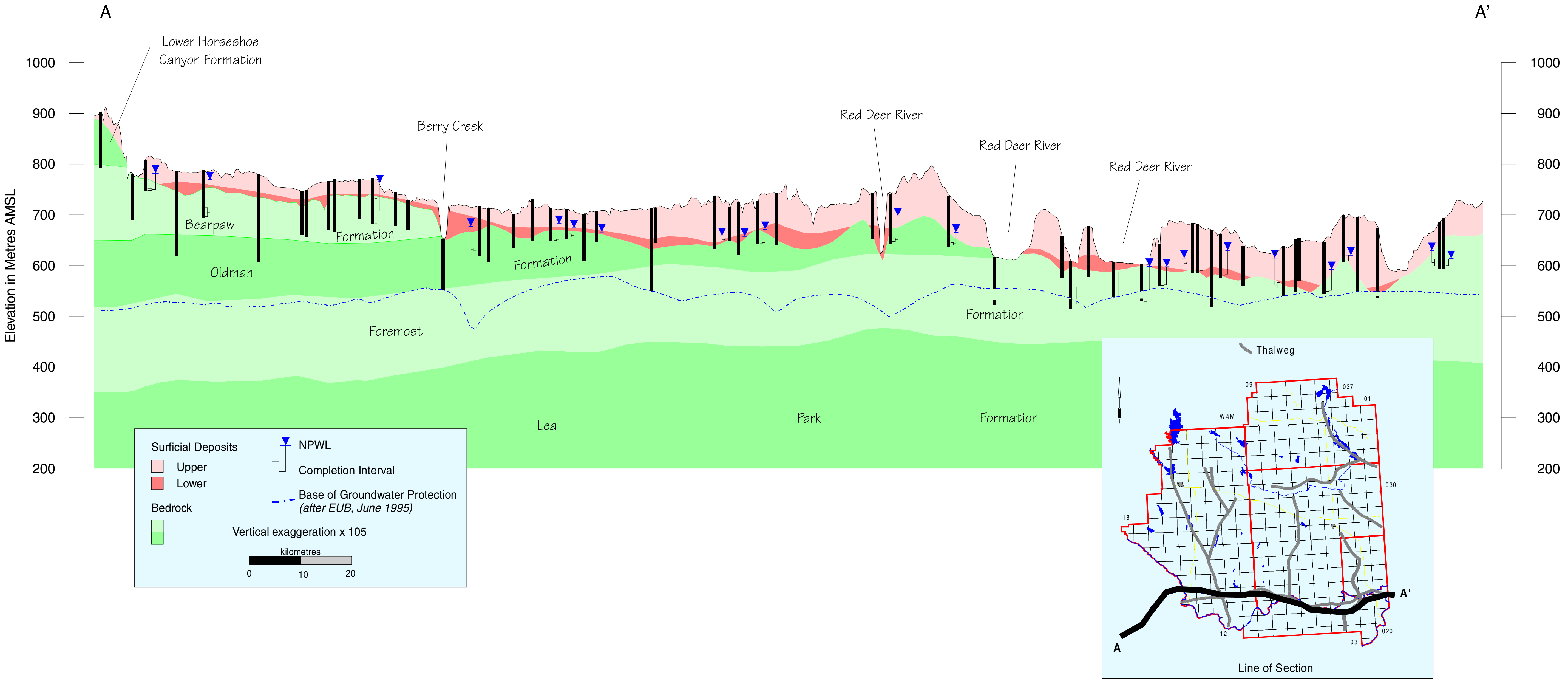


Geologic Column

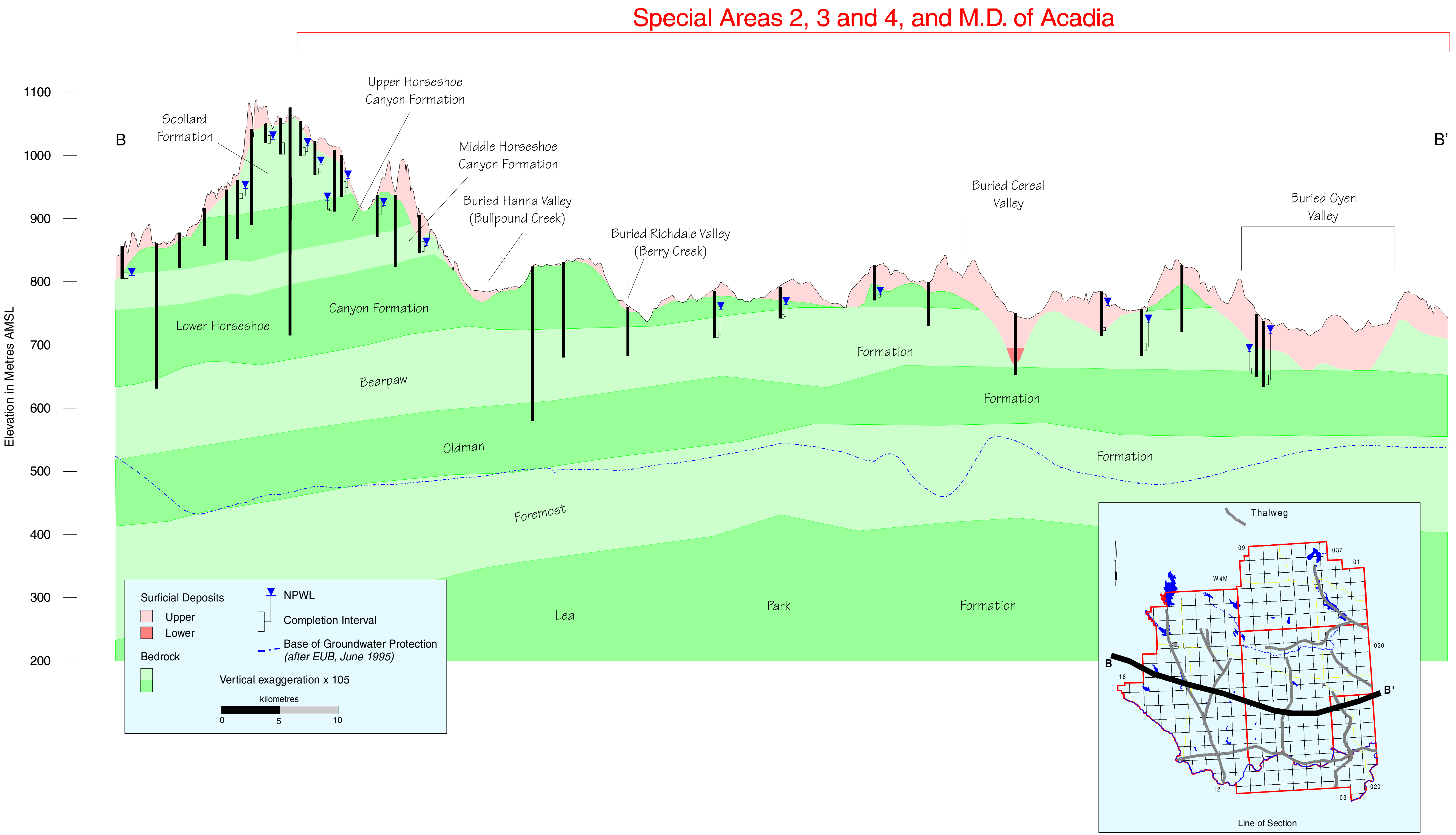
Lithologic Description	Group and Formation				Member			Zone	
	Average Thickness (m)	Group		Designation	Average Thickness (m)	Designation		Average Thickness (m)	Designation
sand, gravel, till, clay, silt	<140			Surficial Deposits	<140	Upper		<30	First Sand and Gravel
					<50	Lower			
sandstone, shale, coal	<800			Paskapoo Formation	>300	Dalehurst Member			Obed-Marsh Coal Zone
									Lower Dalehurst Coal Zone
					100-250	Lacombe Member	Upper	Upper	Upper Sandstone
									Middle Sandstone
									Lower Sandstone
					30-100		Lower	Lower	Lower Lacombe Coal Zone
					20-100	Haynes			
shale, sandstone, coal	60-150	Edmonton Group		Scollard Formation	40-100	Upper		<2	Upper Ardley Coal Zone
								~20	Ardley Coal Zone (main seam)
								<1	Nevis Coal Seam
					20-60	Lower			
shale, clay, tuff	~25			Battle Formation	<0.3	Kneehill Member			
	5-10			Whitemud Formation					
shale, sandstone, coal, bentonite, limestone, ironstone	300-380			Horseshoe Canyon Formation	~100	Upper			
					~100	Middle			
					~170	Lower			
shale, sandstone, siltstone	60-120			Bearpaw Formation					
sandstone, siltstone, shale, coal	<300	Belly River Group	40-130	Oldman Formation		Dinosaur Member		<25	Lethbridge Coal Zone
						Upper Siltstone Member			
						Comrey Member			
sandstone, shale			<200	Foremost Formation	<70	Birch Lake Member			Taber Coal Zone
					<60	Ribstone Creek Member			
					<70	Victoria Member			McKay Coal Zone
					0-30	Brosseau Member			
shale, siltstone				Lea Park Formation	100-200				

Cross-Section A - A'

Special Areas 2, 3 and 4, and M.D. of Acadia

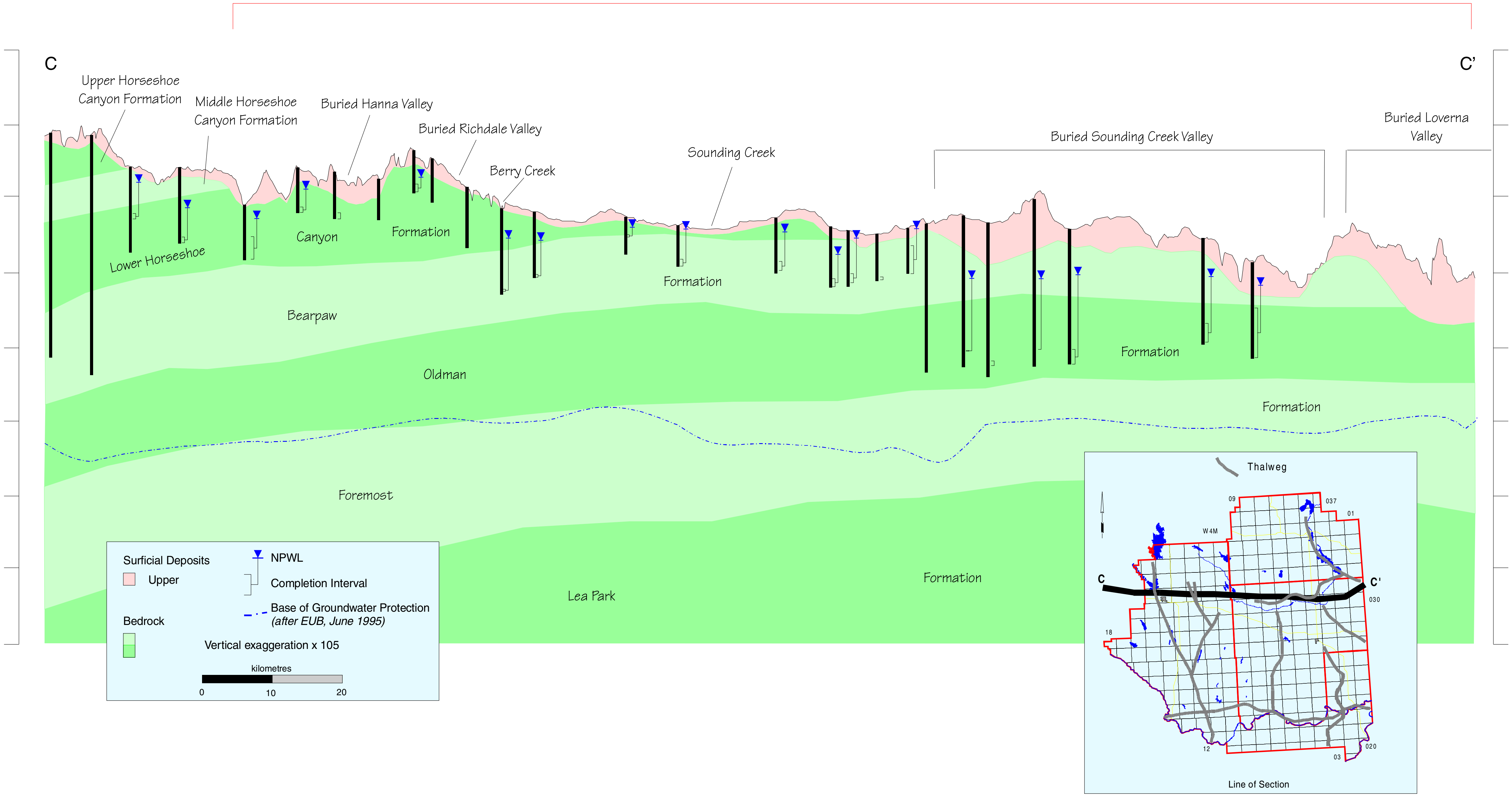


Cross-Section B - B'

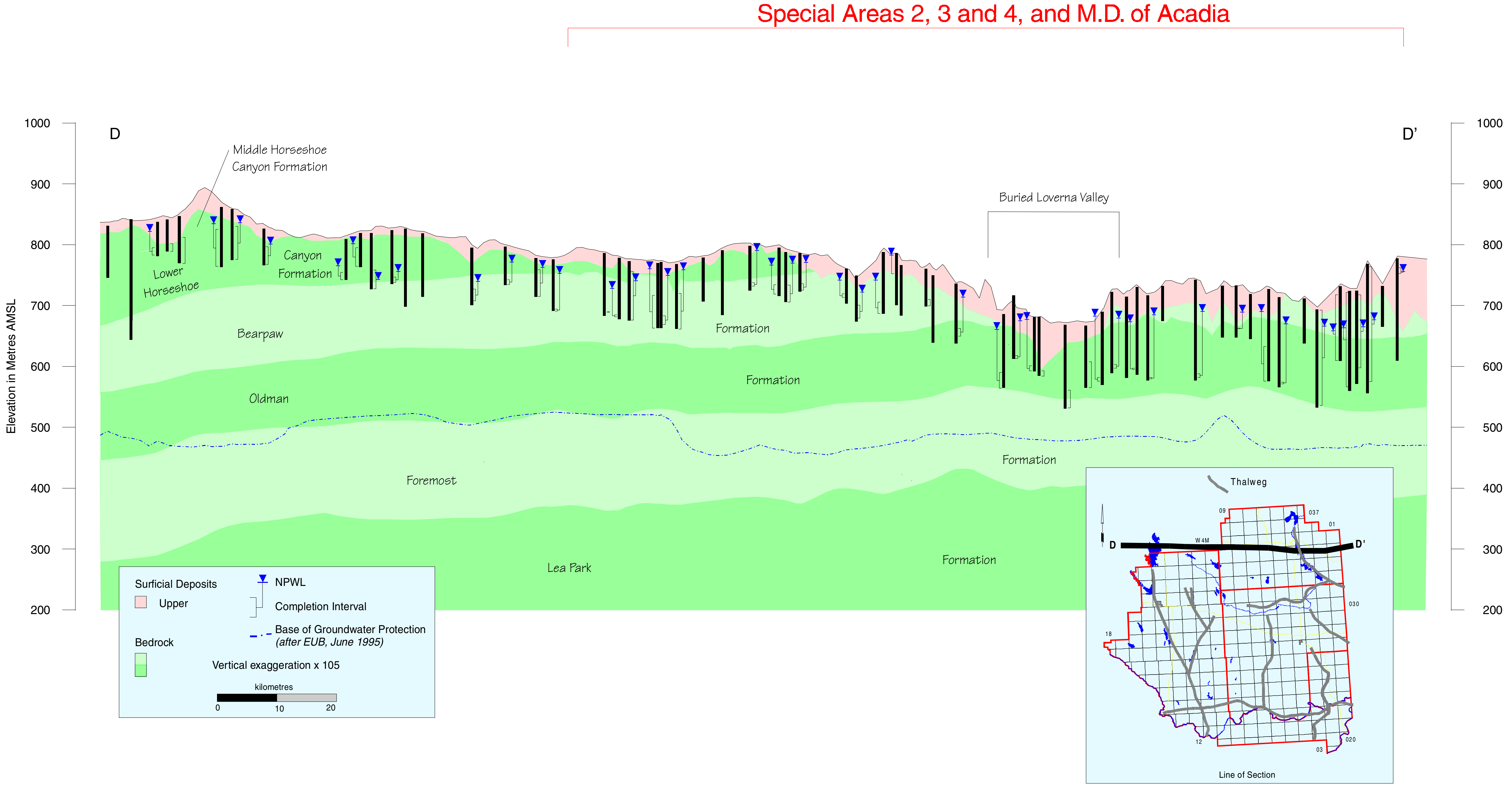


Cross-Section C - C'

Special Areas 2, 3 and 4, and M.D. of Acadia

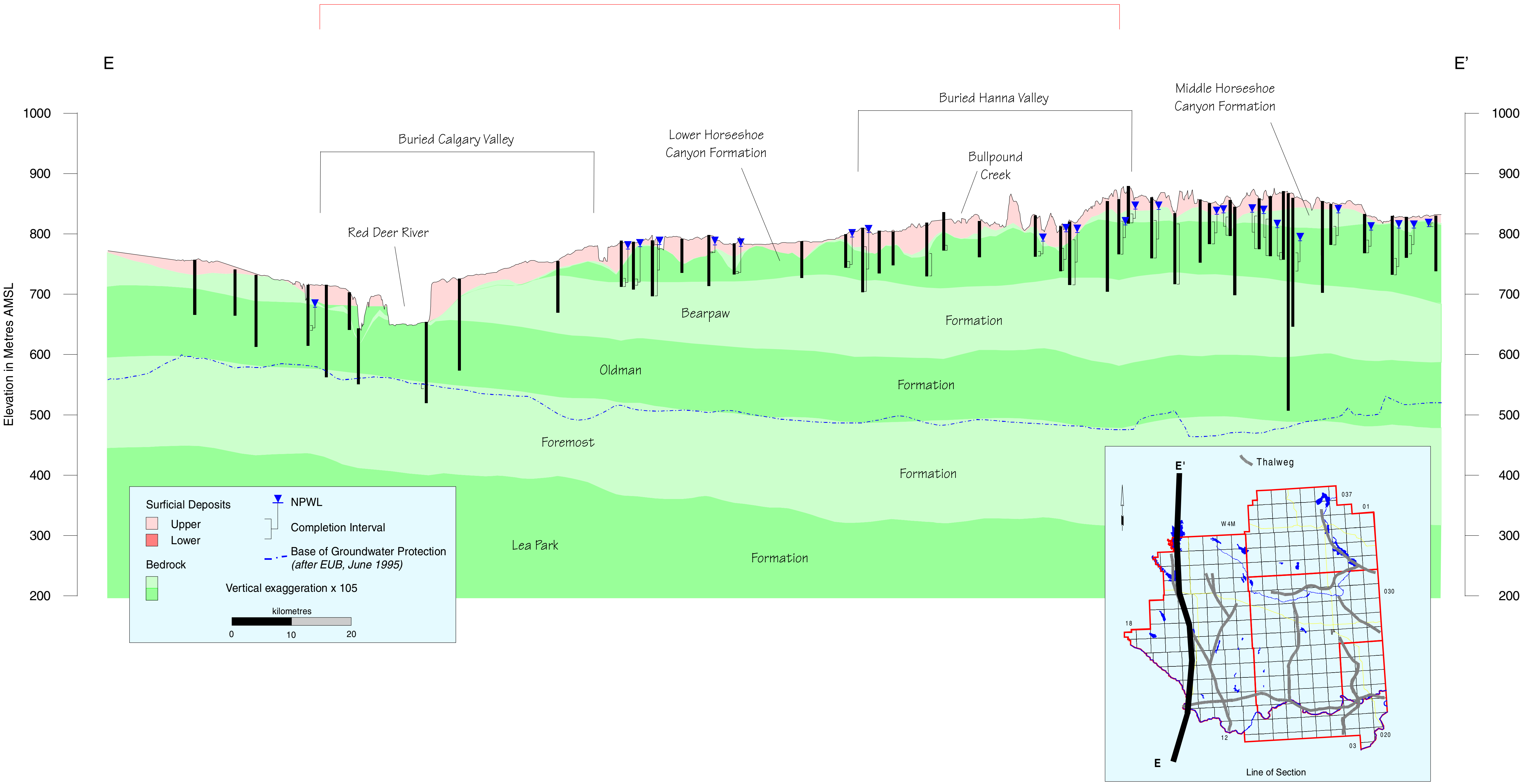


Cross-Section D - D'



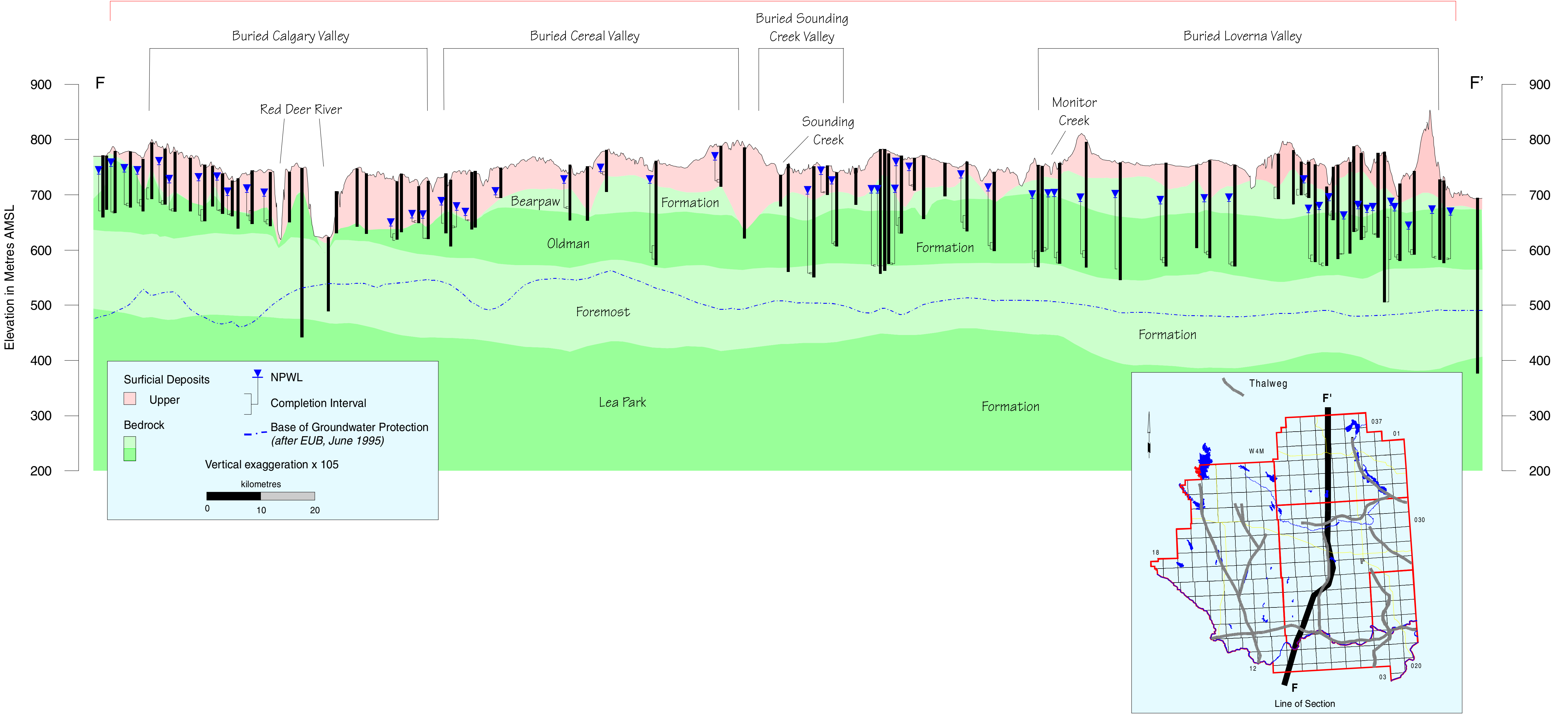
Cross-Section E - E'

Special Area 2, 3 and 4, and M.D. Of Acadia



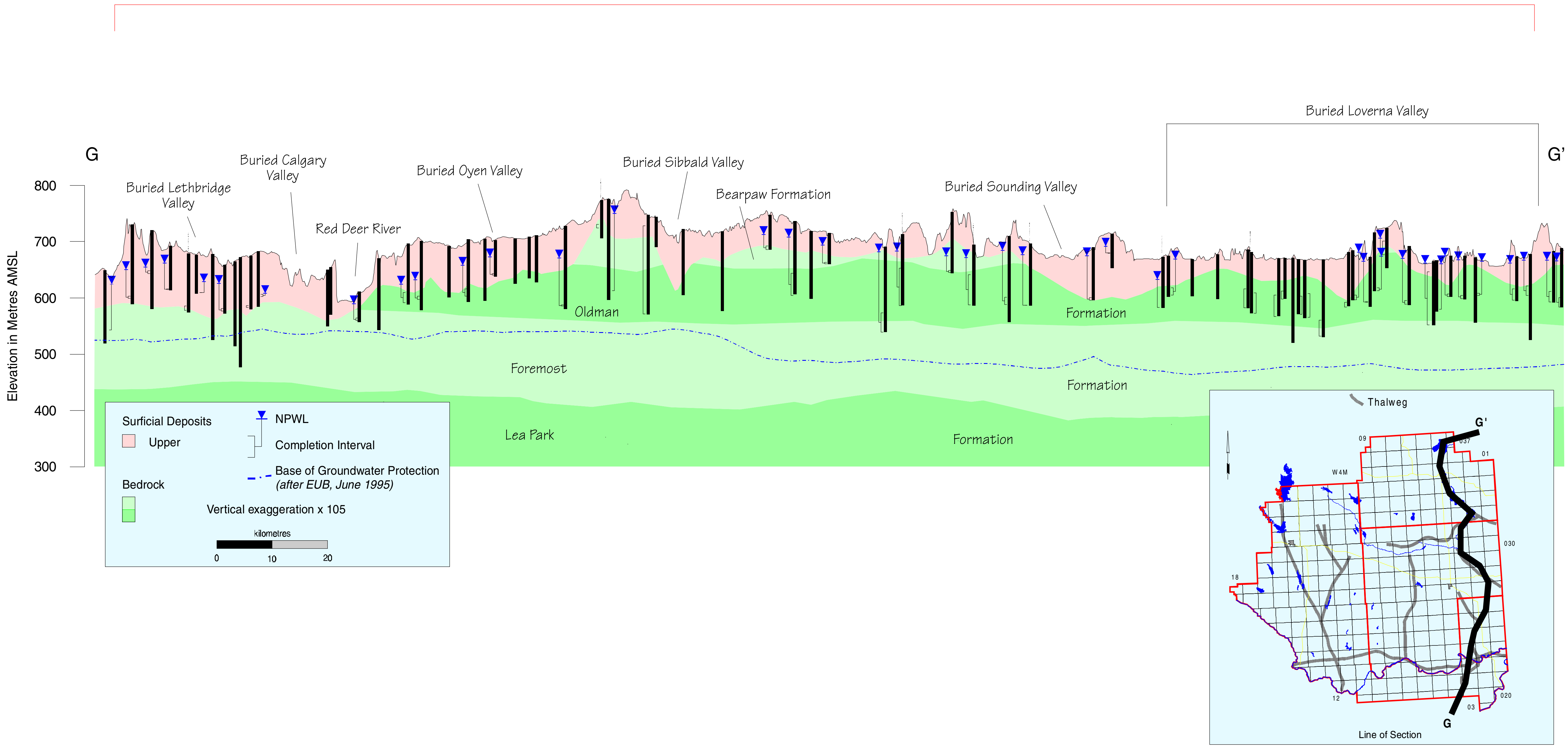
Cross-Section F - F'

Special Areas 2, 3 and 4, and M.D. of Acadia

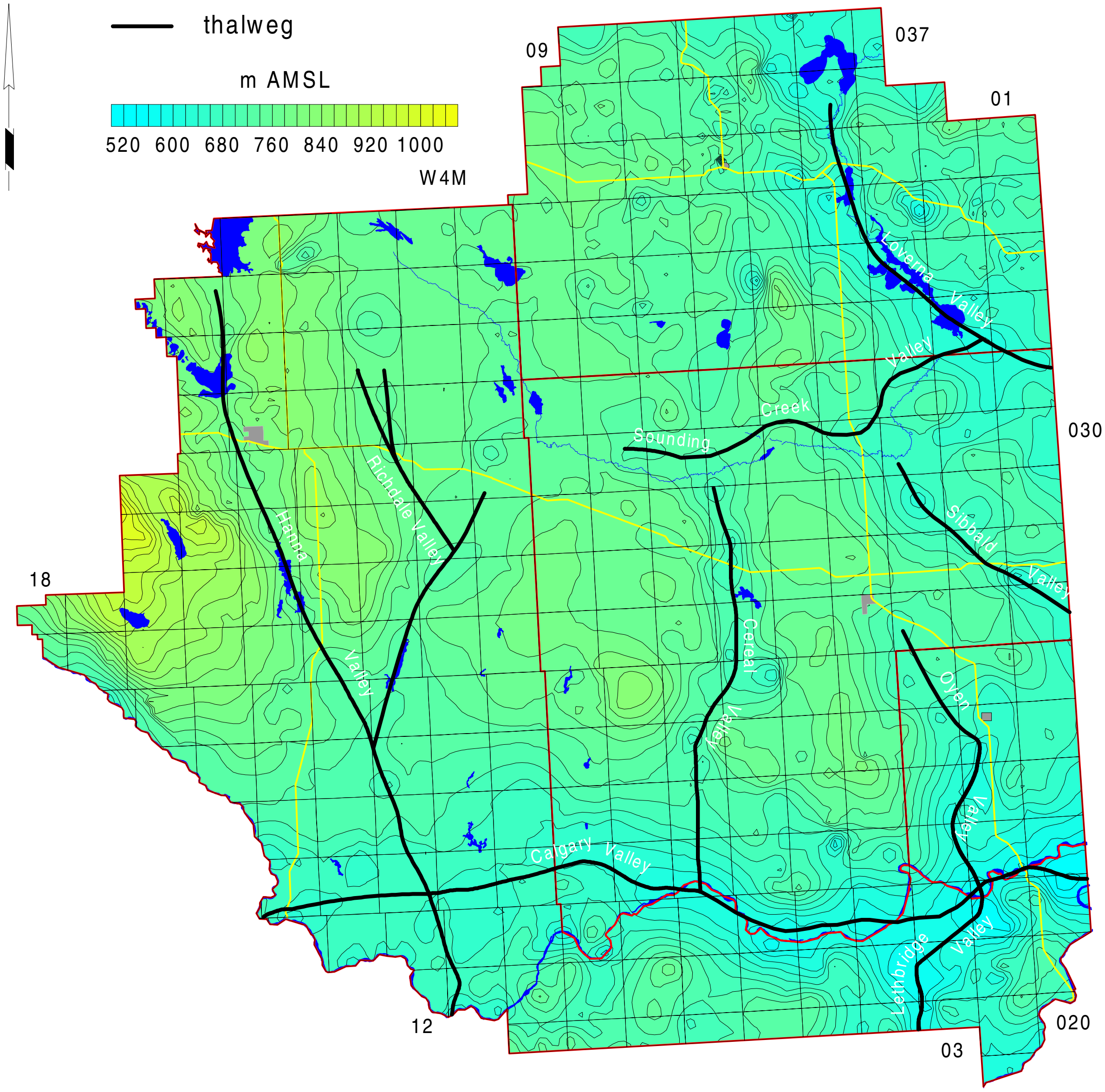


Cross-Section G - G'

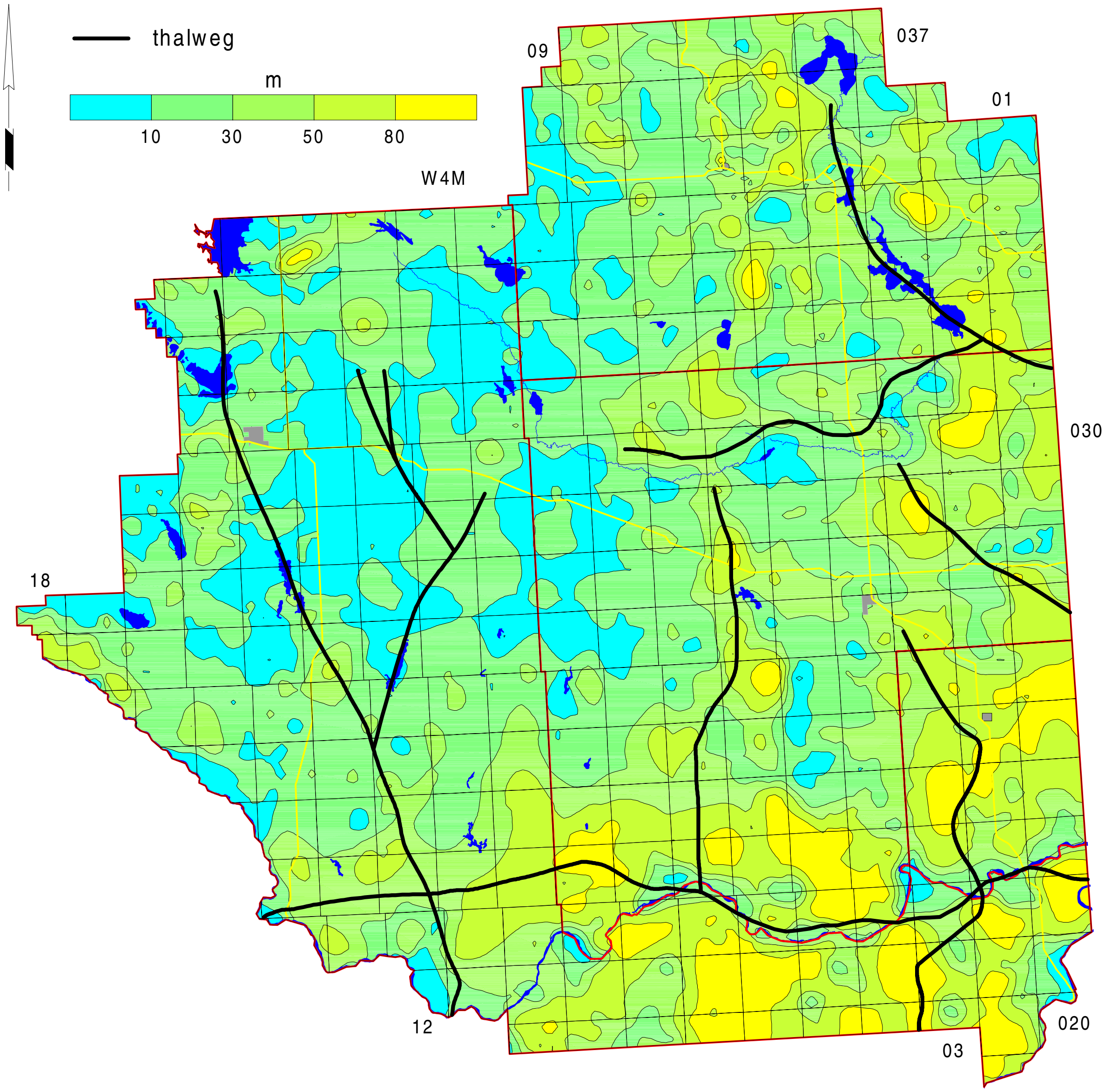
Special Areas 2, 3 and 4, and M.D. of Acadia



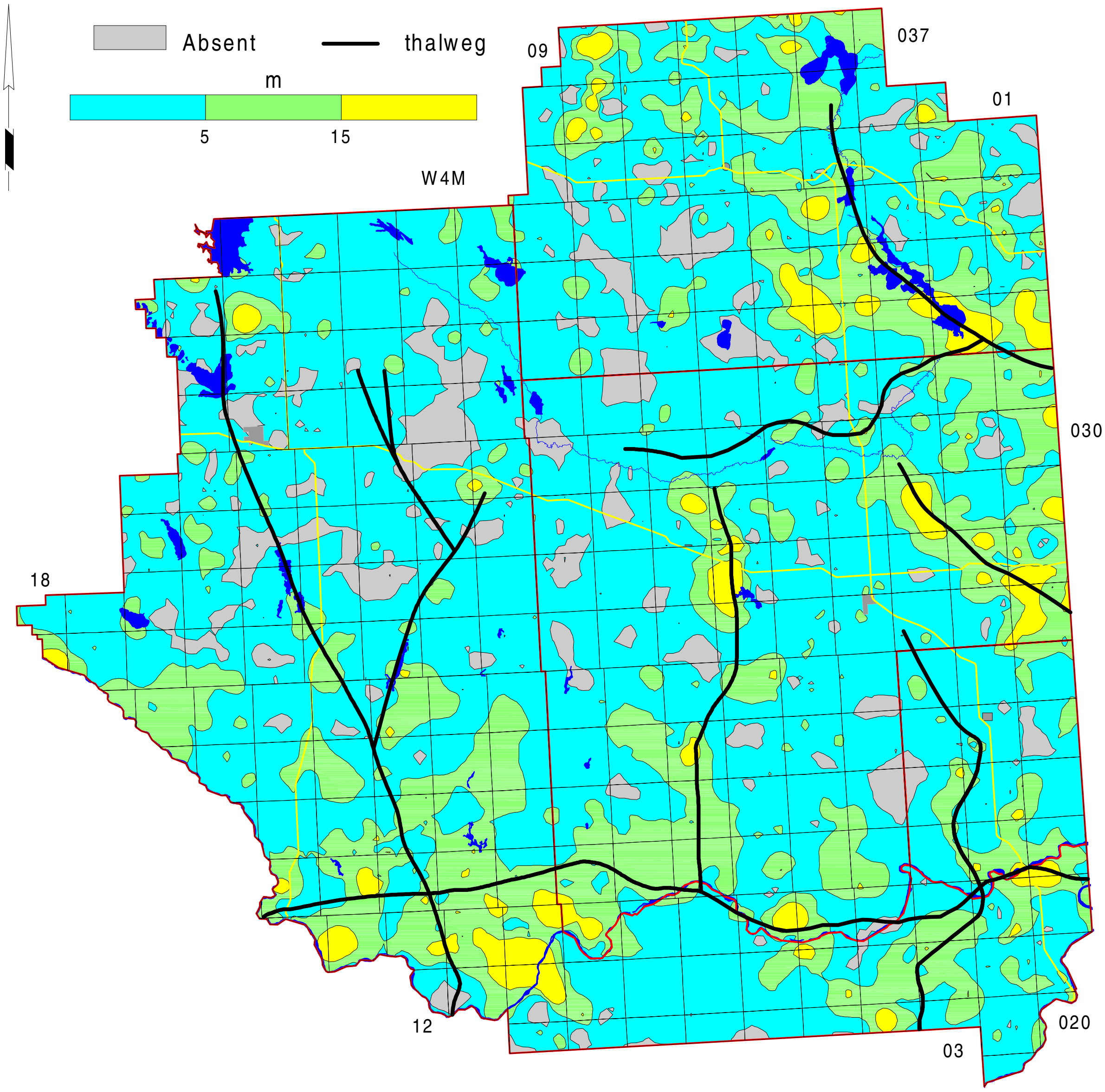
Bedrock Topography



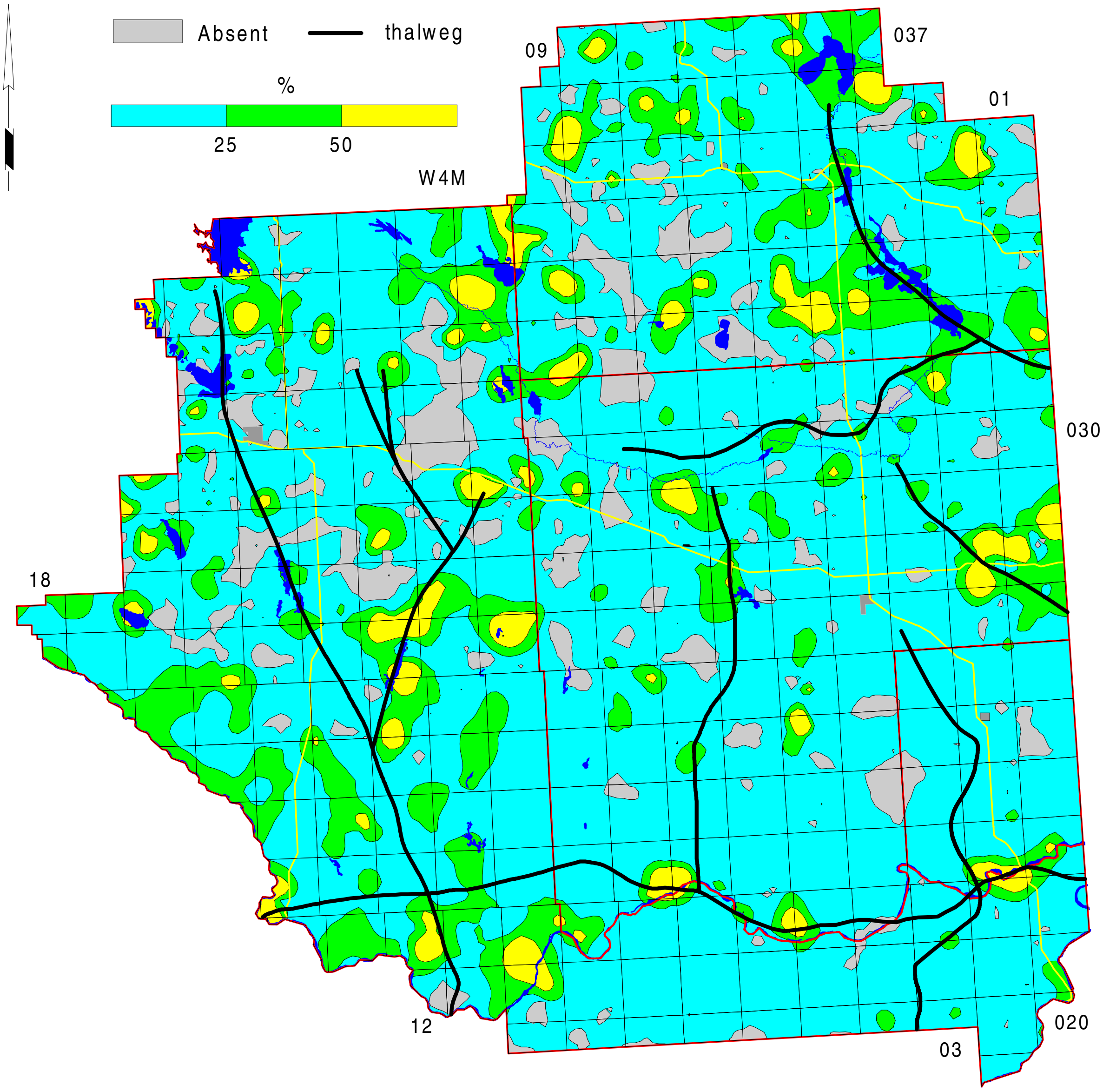
Thickness of Surficial Deposits



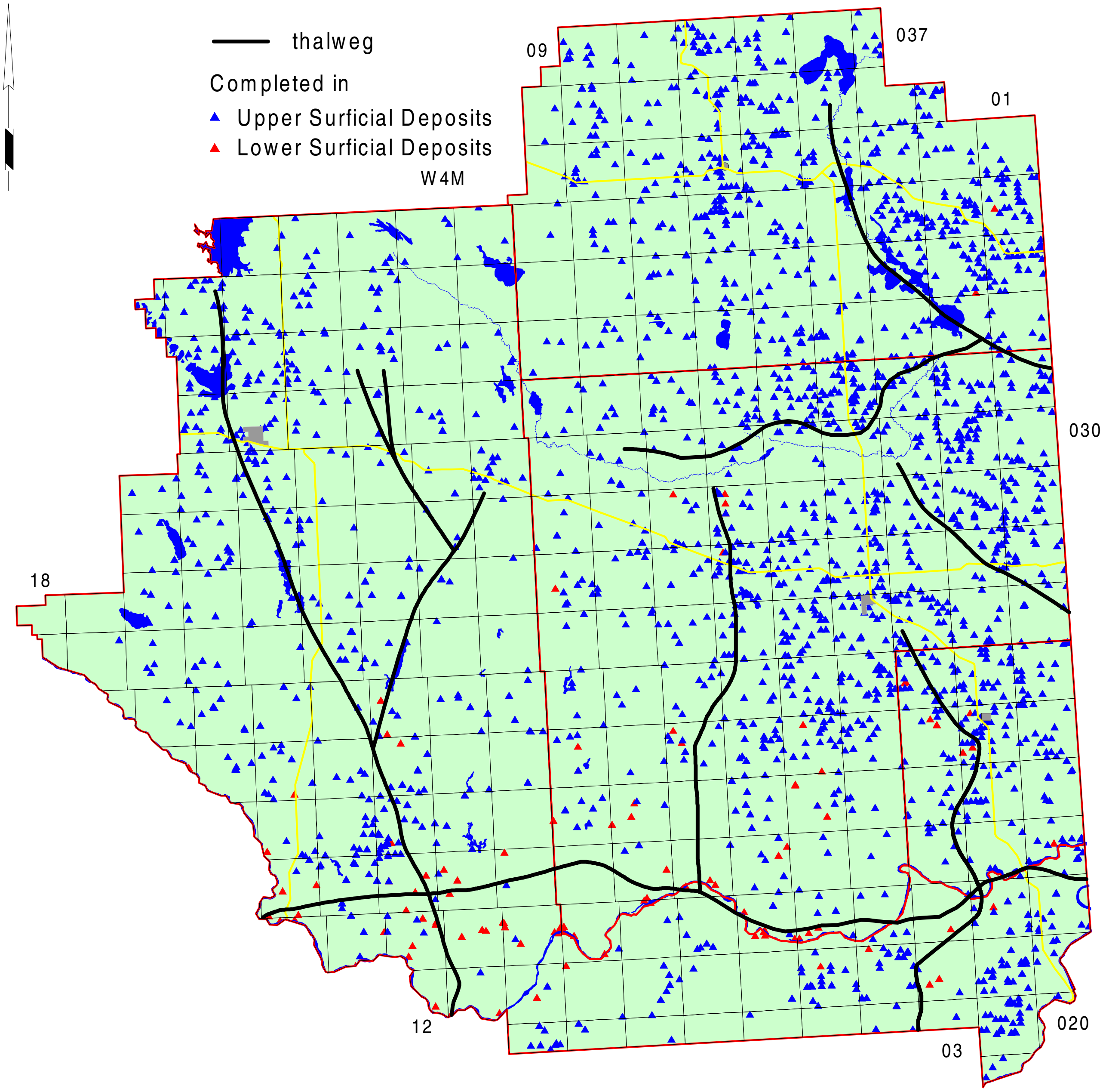
Thickness of Sand and Gravel Deposits



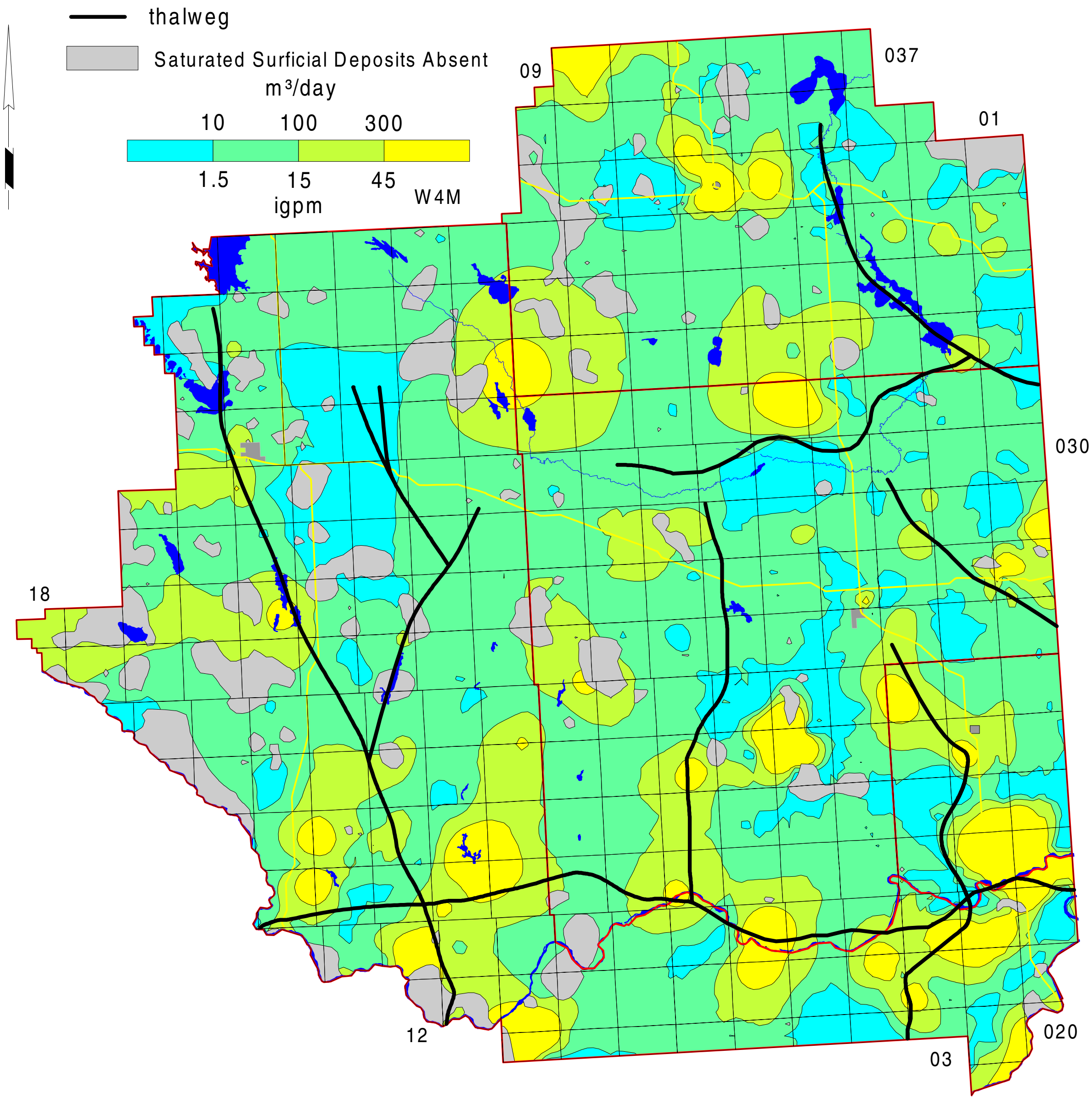
Amount of Sand and Gravel in Surficial Deposits



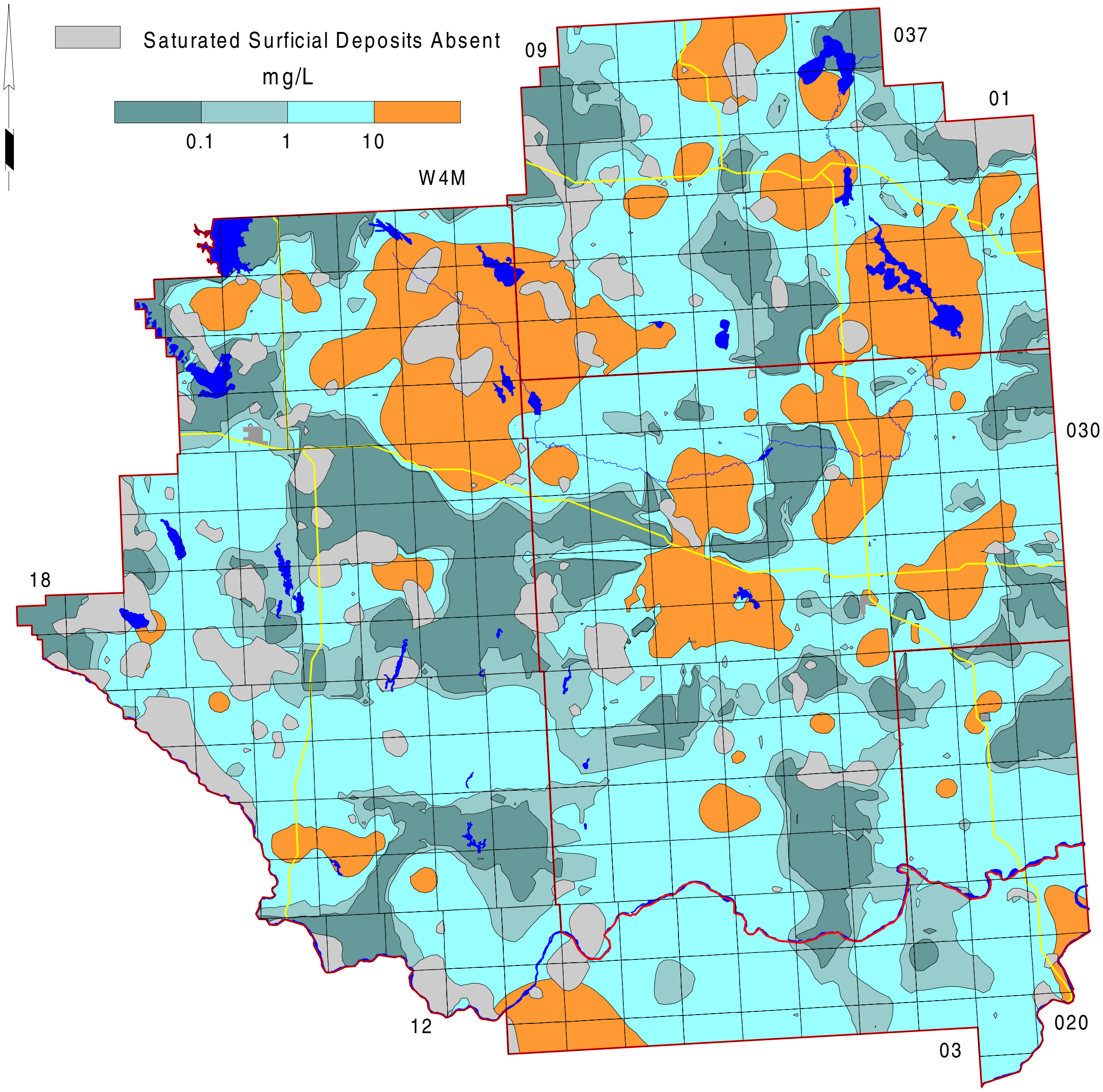
Water Wells Completed in Surficial Deposits



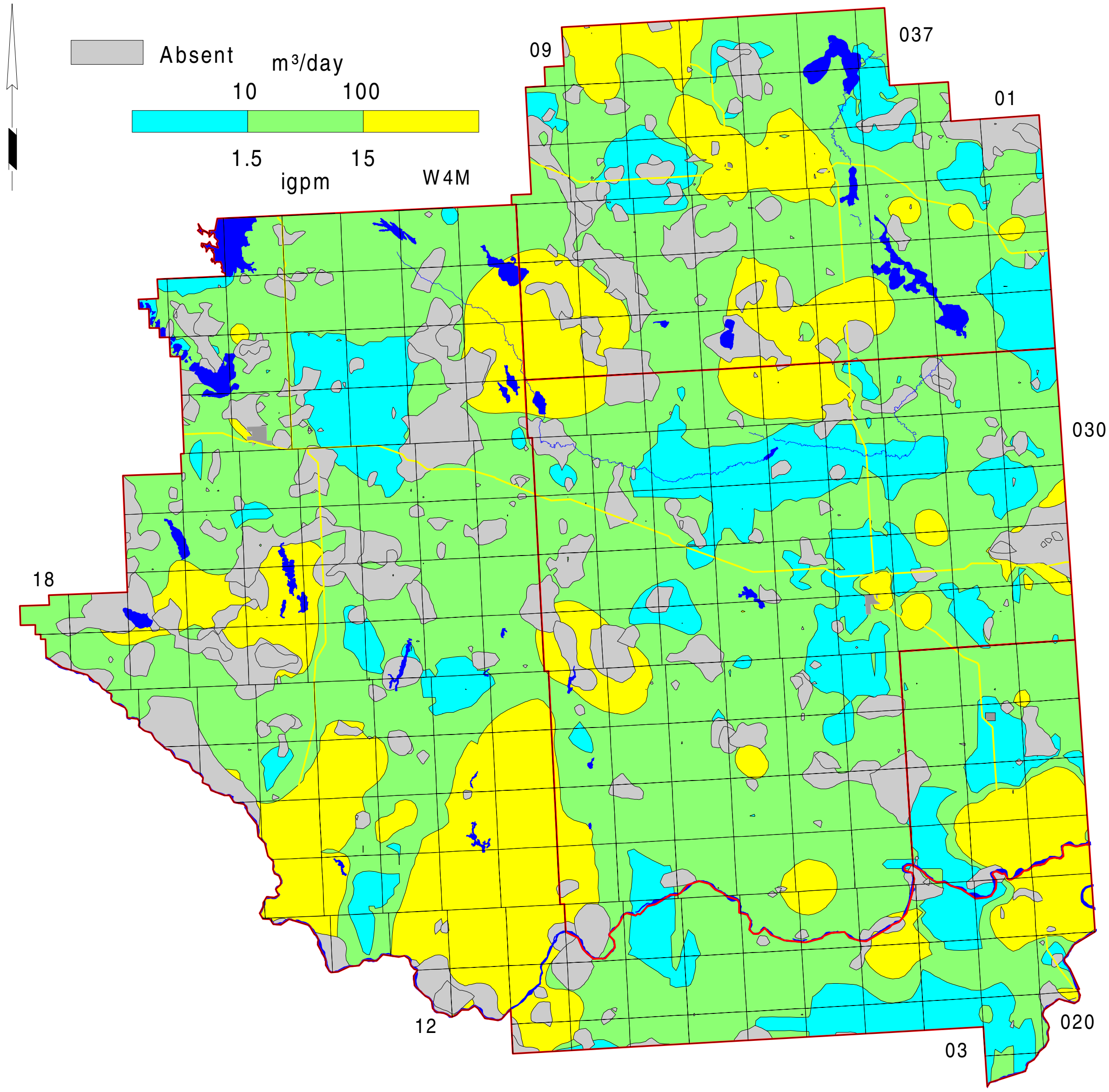
Apparent Yield for Water Wells Completed in Surficial Deposits



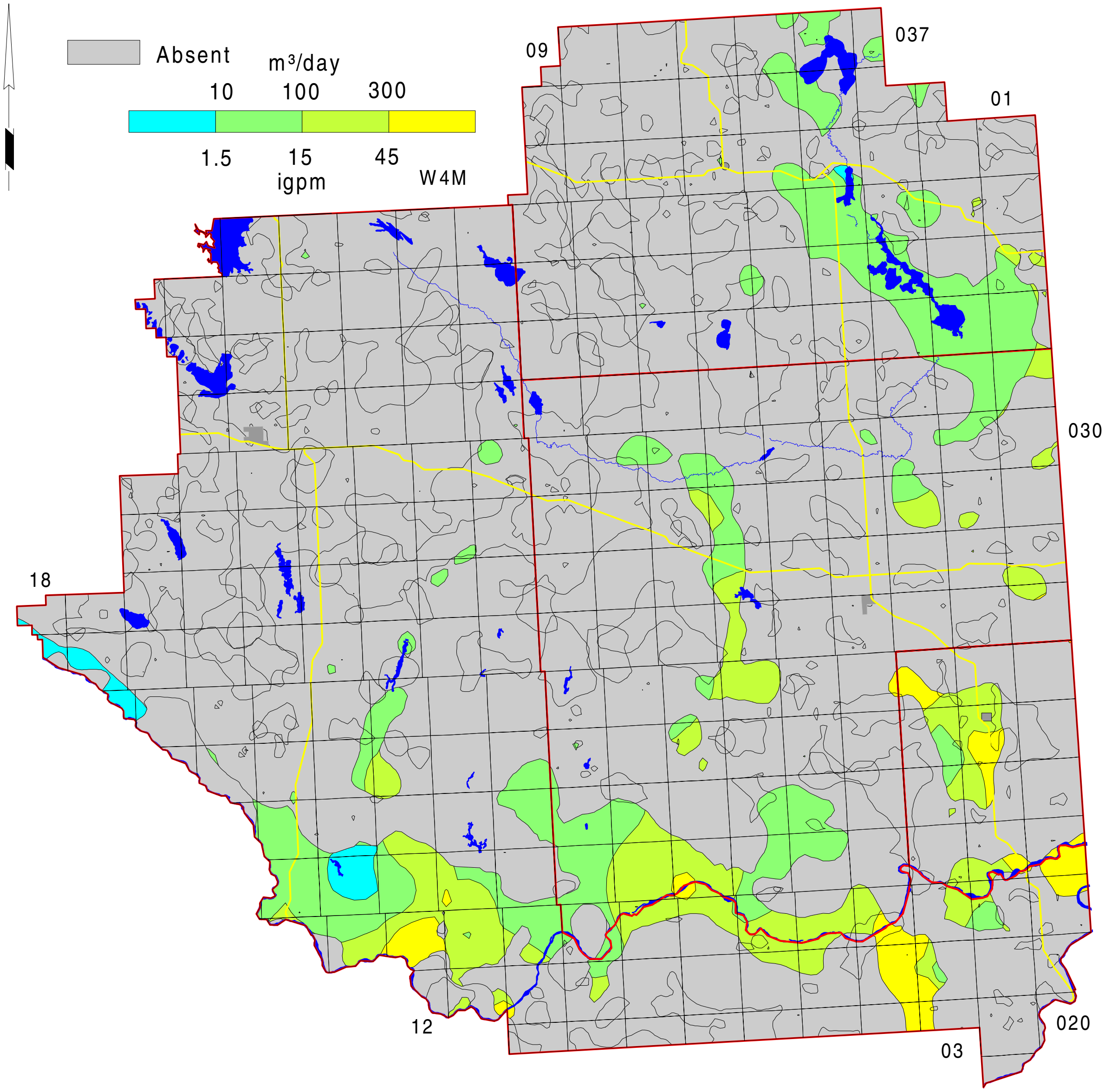
Nitrate + Nitrite (as N) in Groundwater from Surficial Deposits



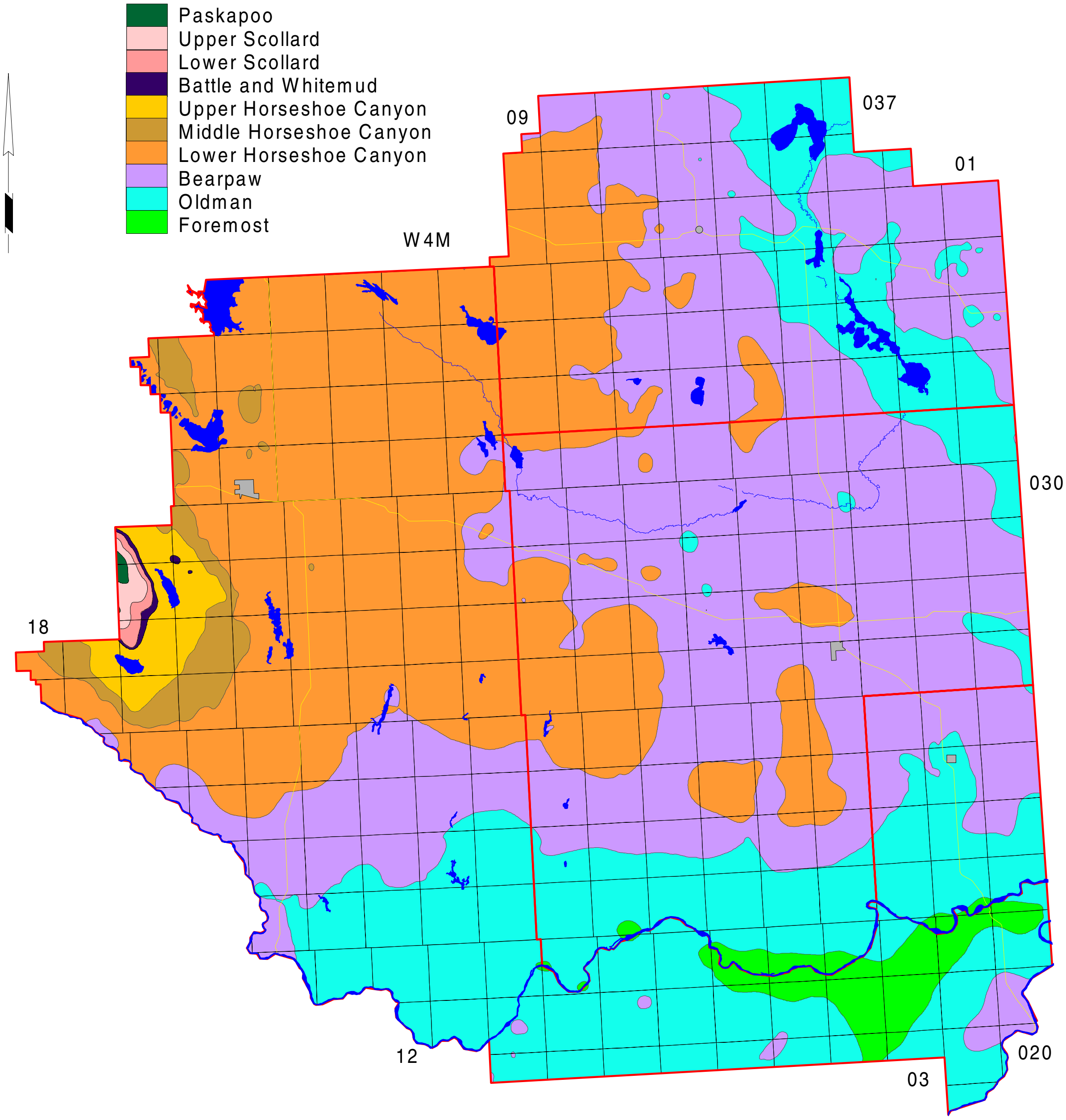
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



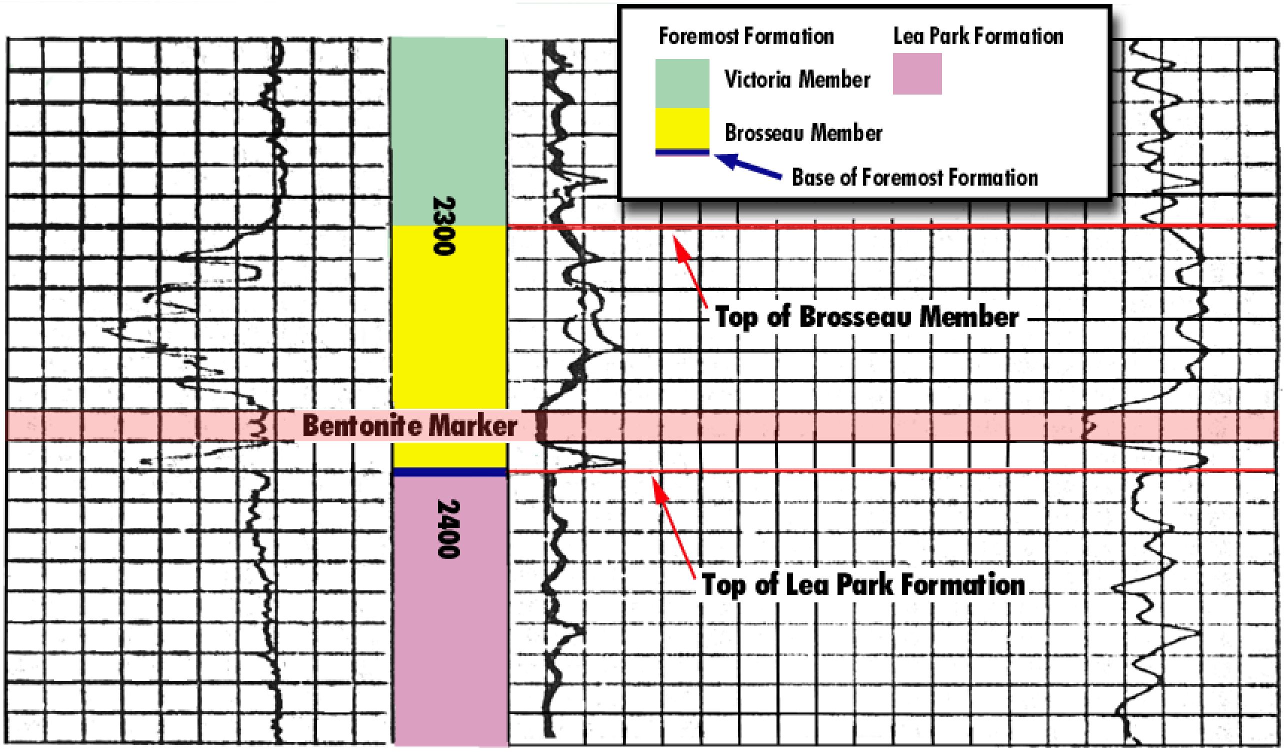
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



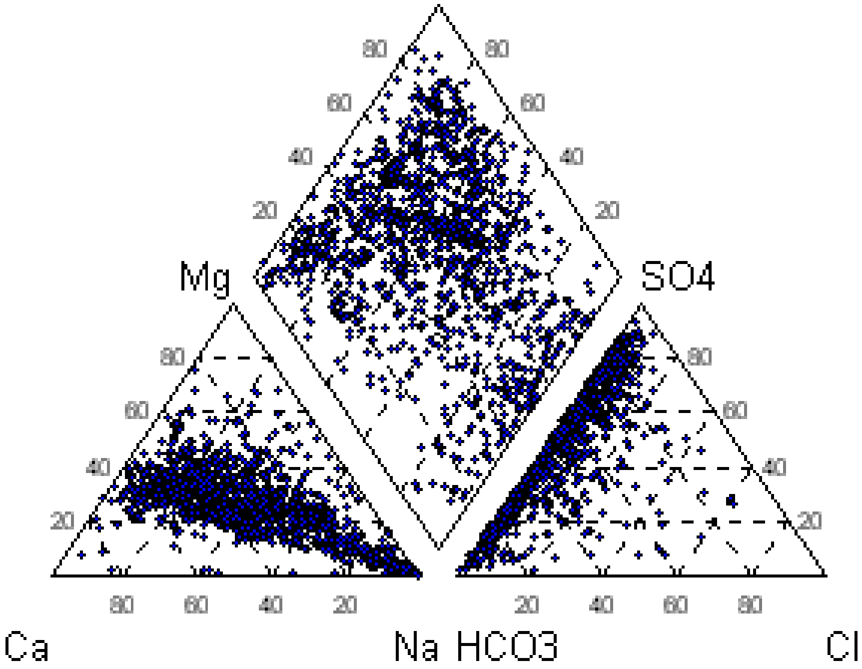
Bedrock Geology



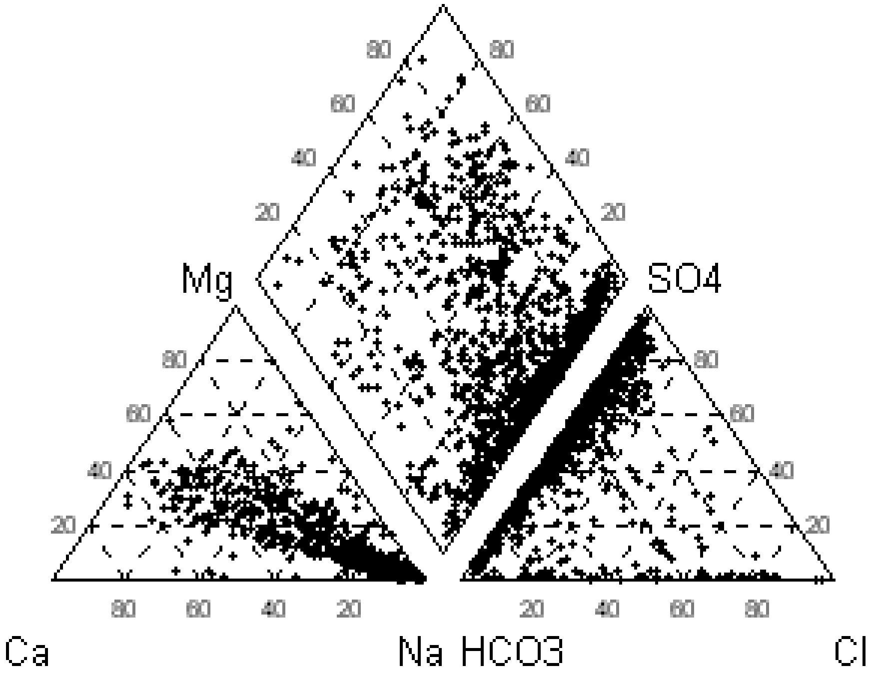
E-Log Showing Base of Foremost Formation



Piper Diagrams

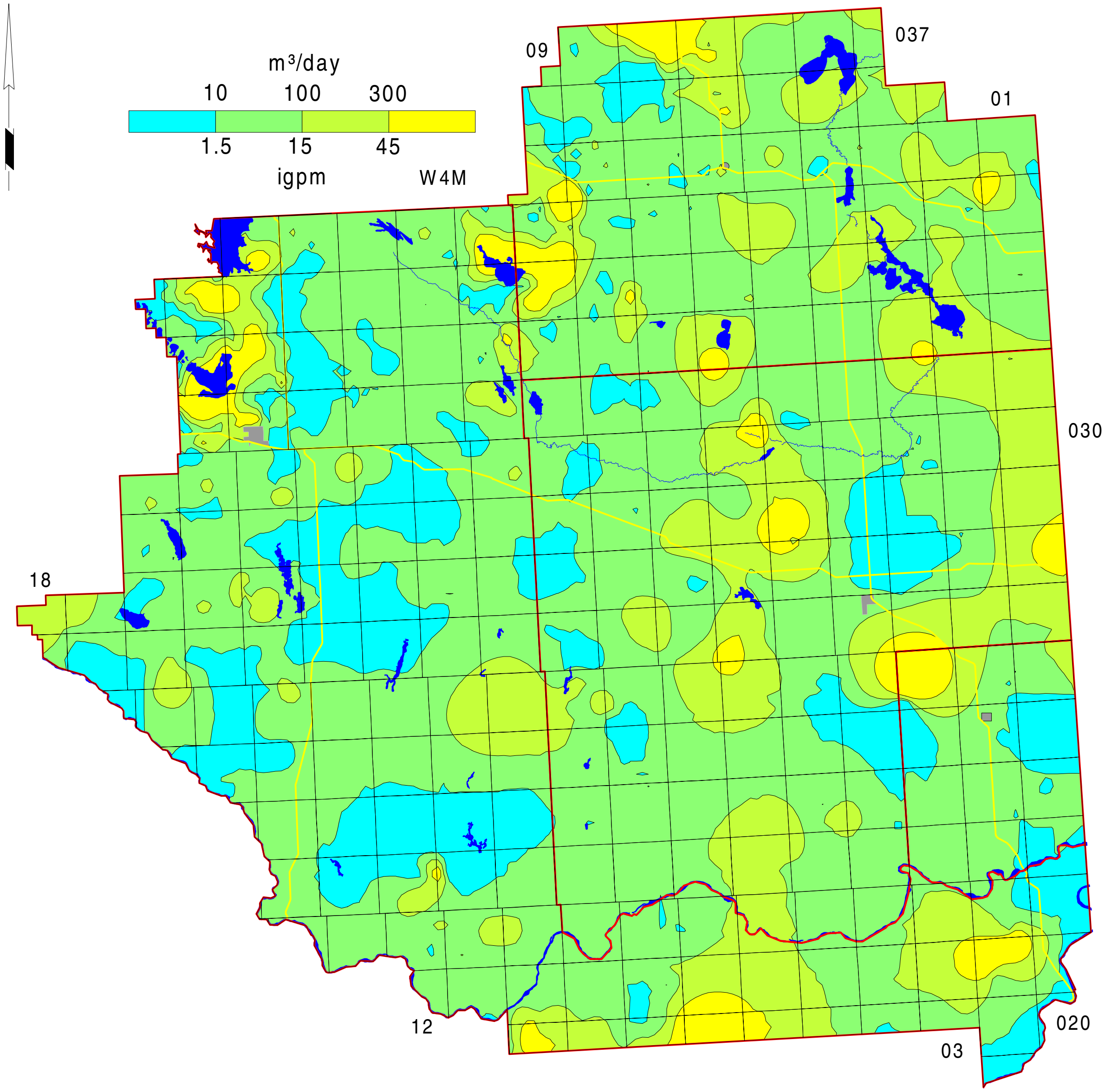


Surficial Deposits

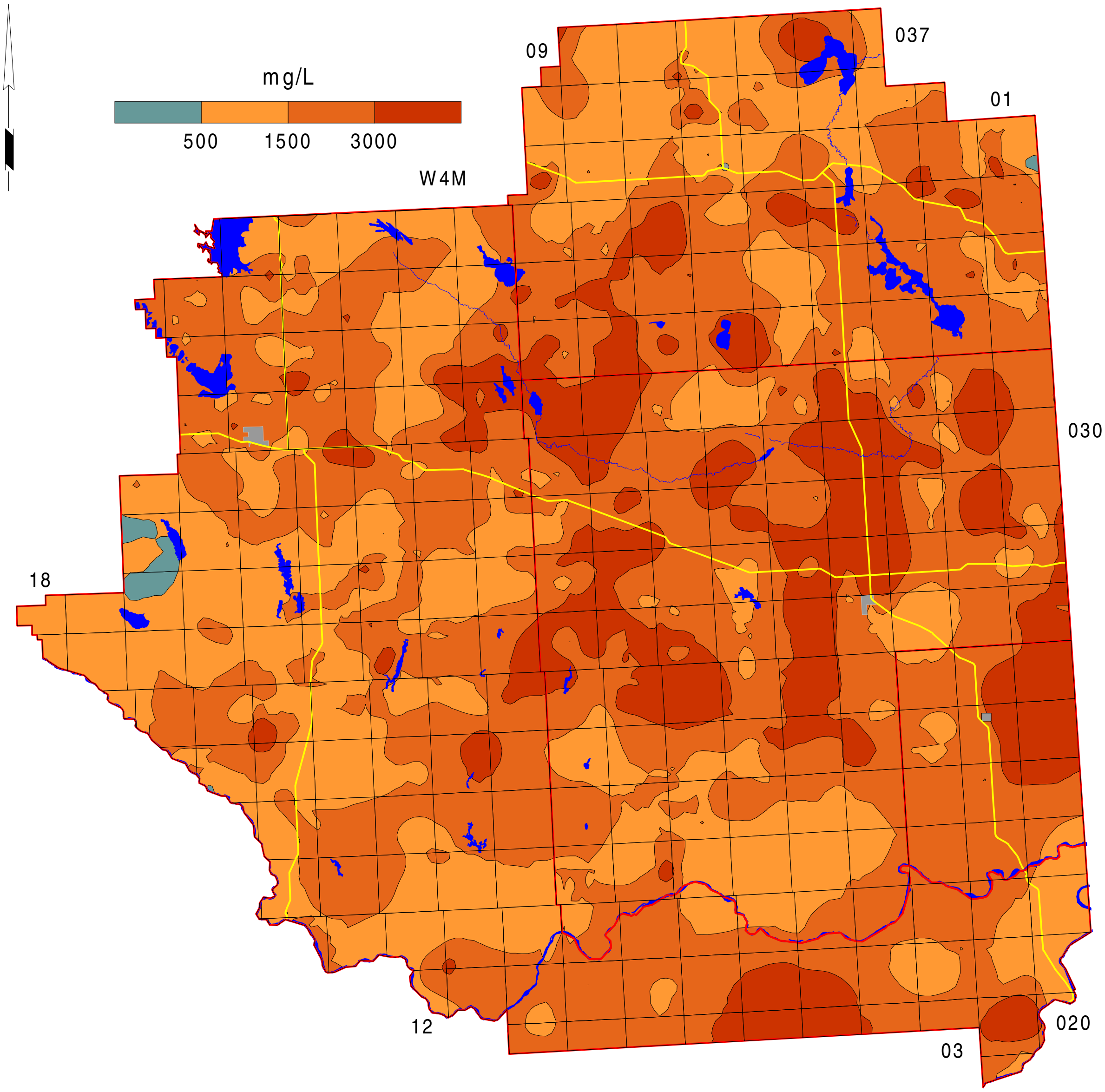


Bedrock Aquifers

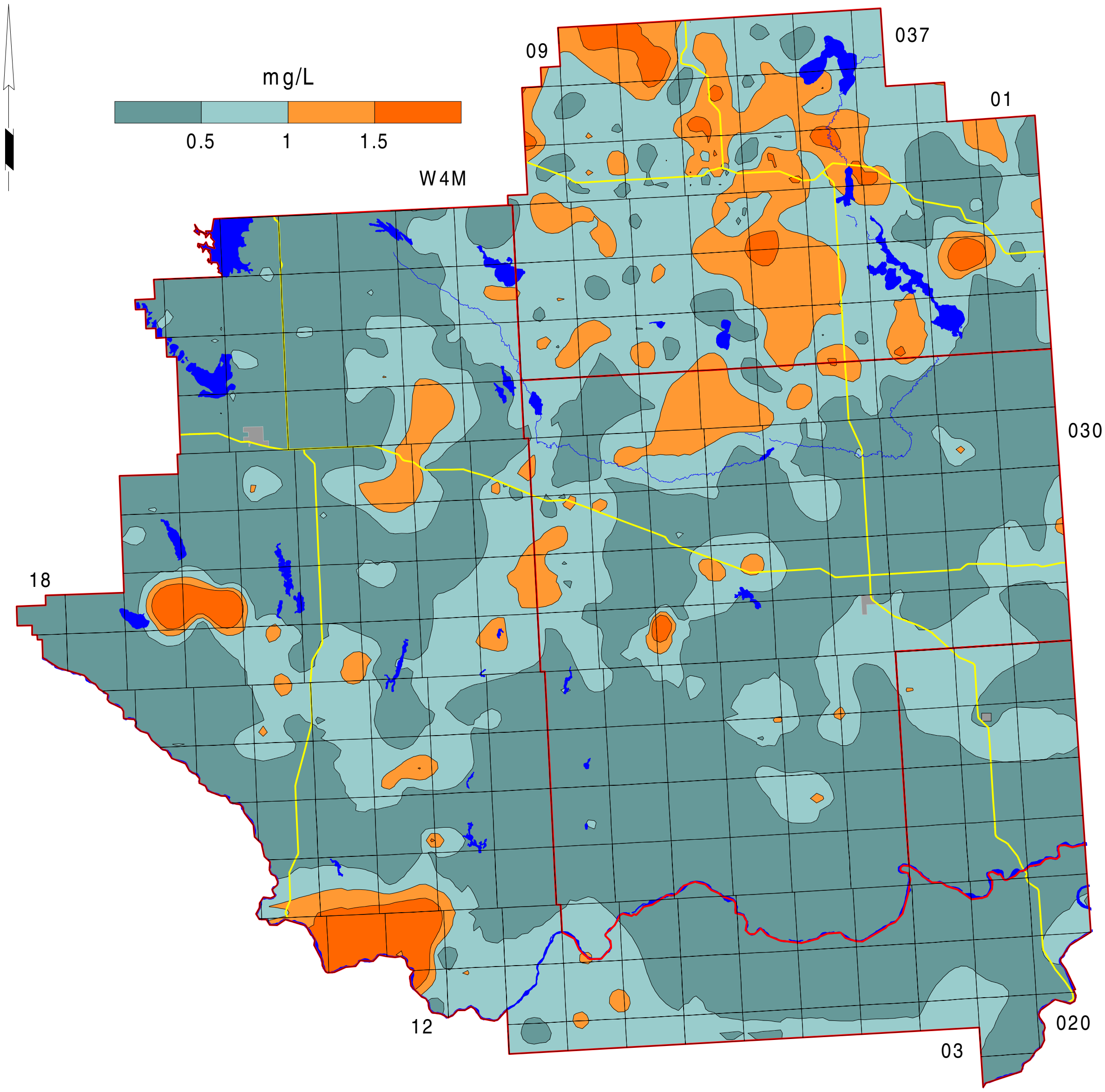
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



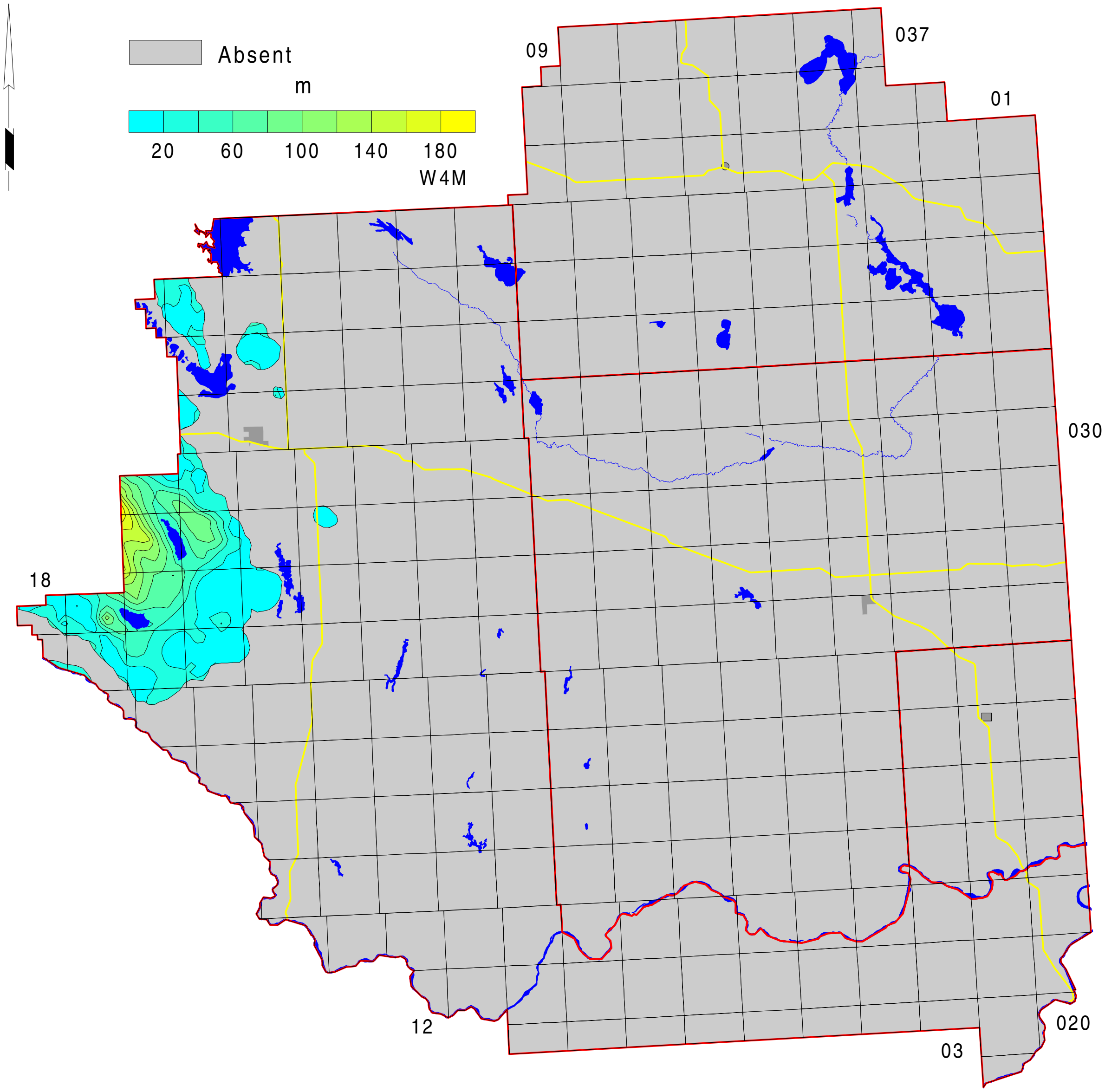
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



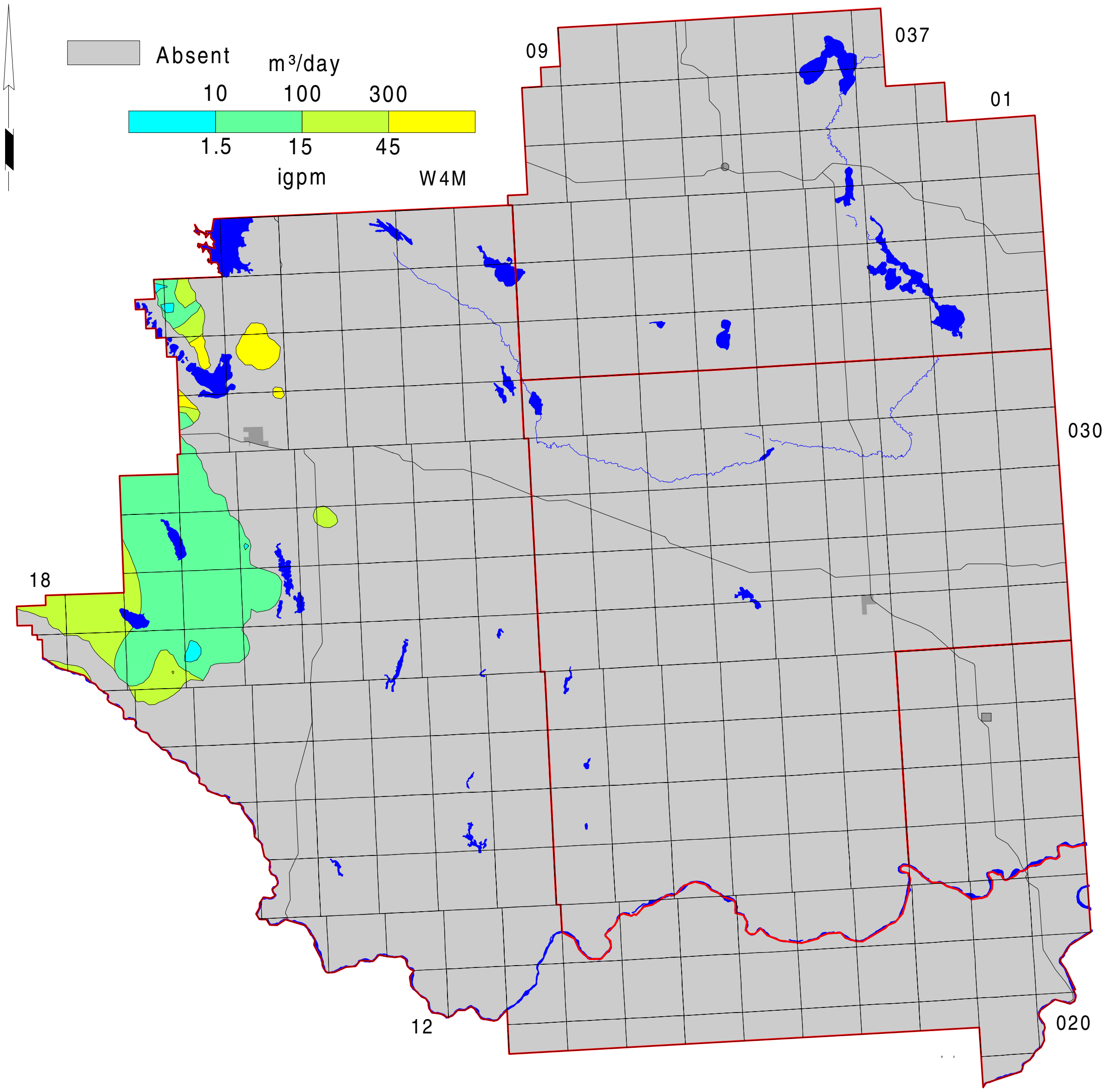
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



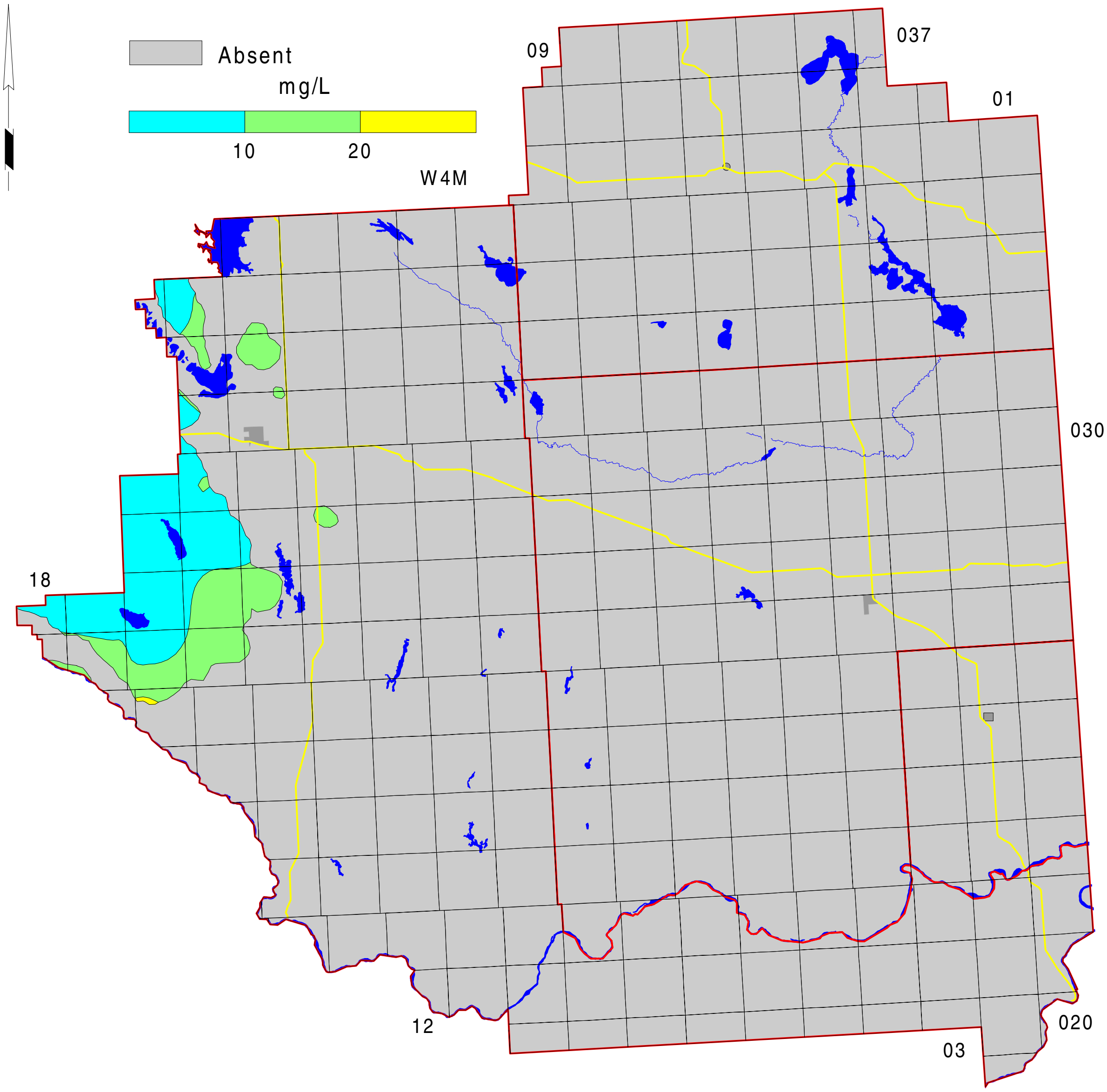
Depth to Top of Middle Horseshoe Canyon Formation



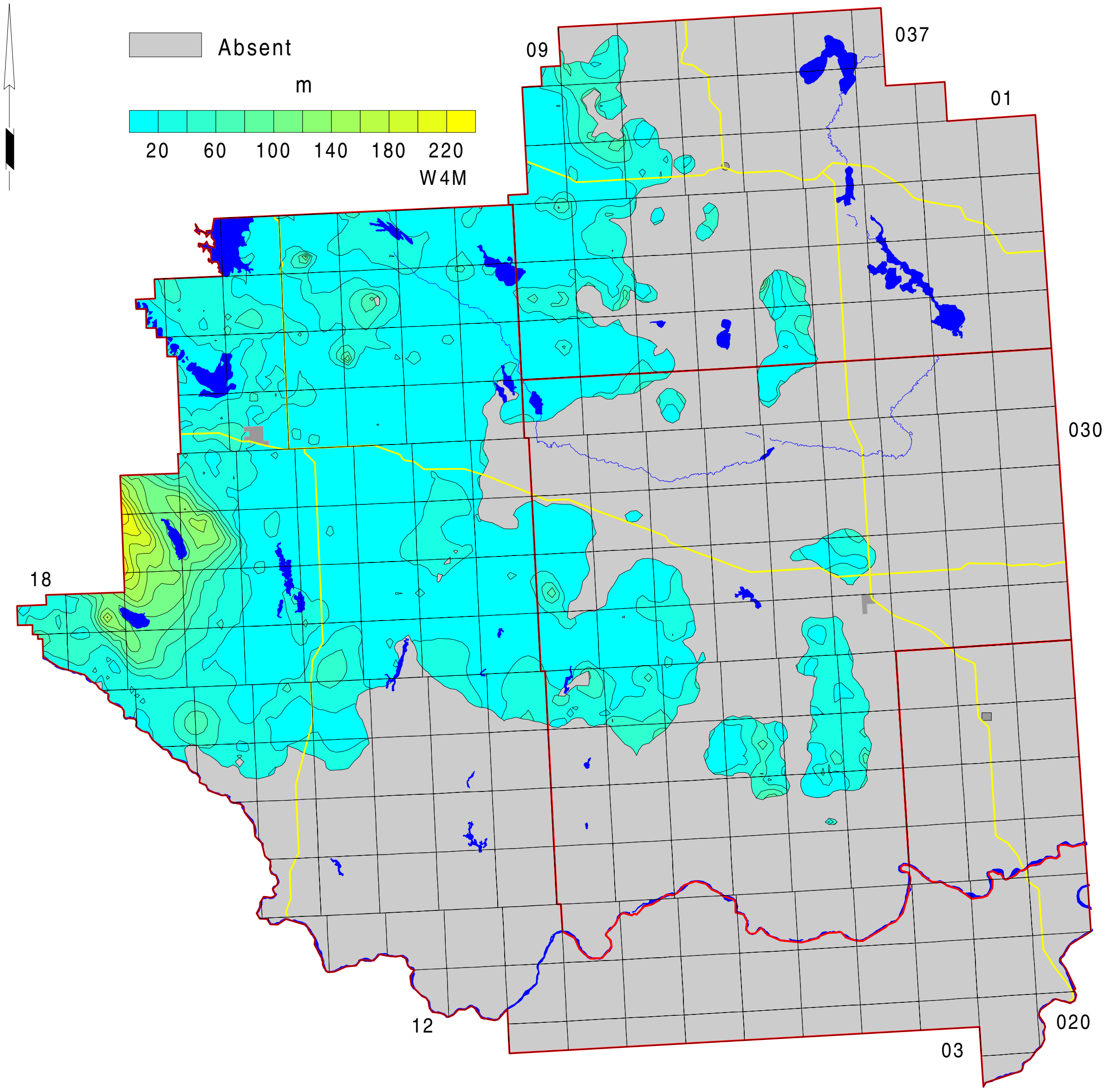
Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer



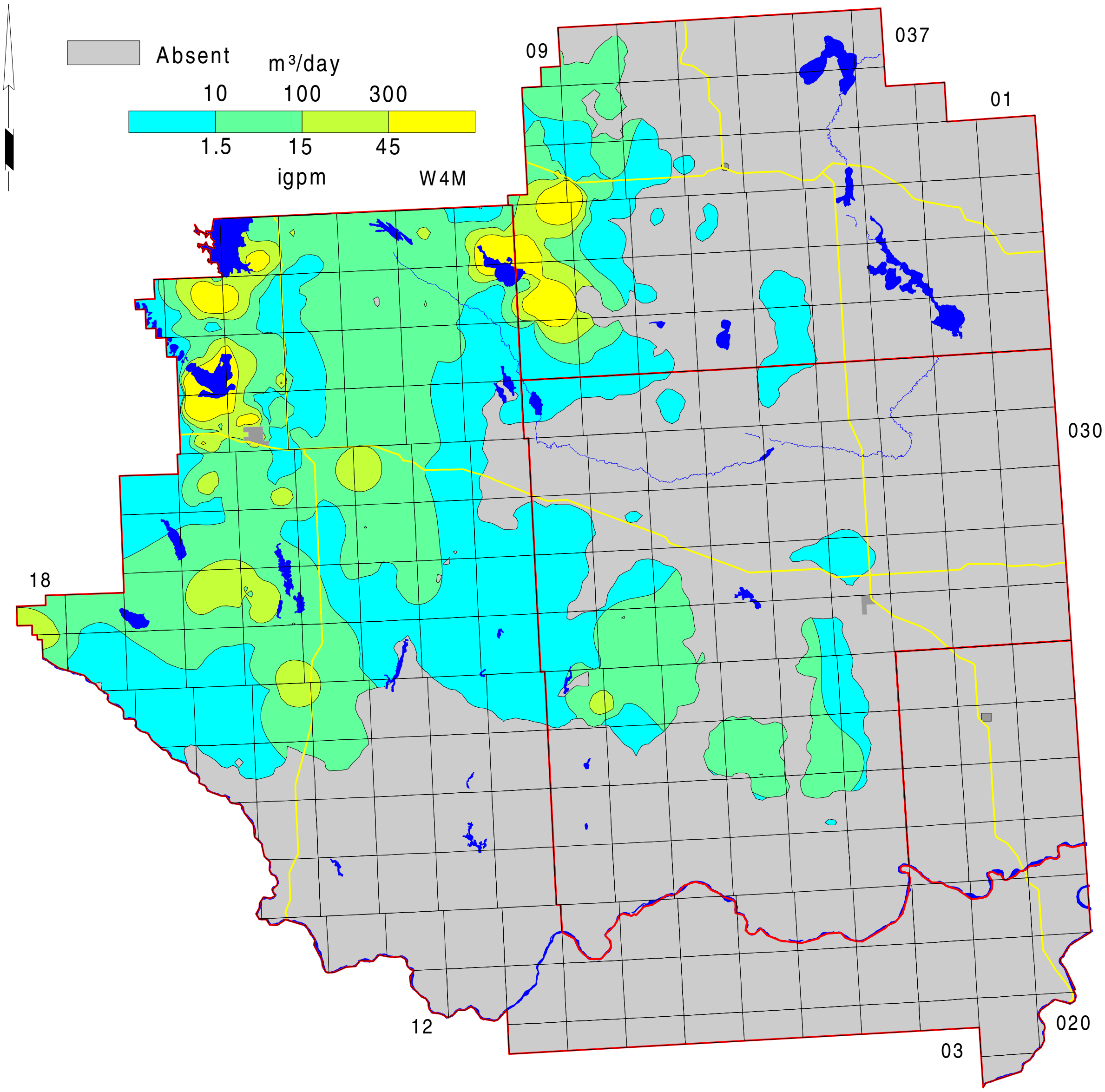
Chloride in Groundwater from Middle Horseshoe Canyon Aquifer



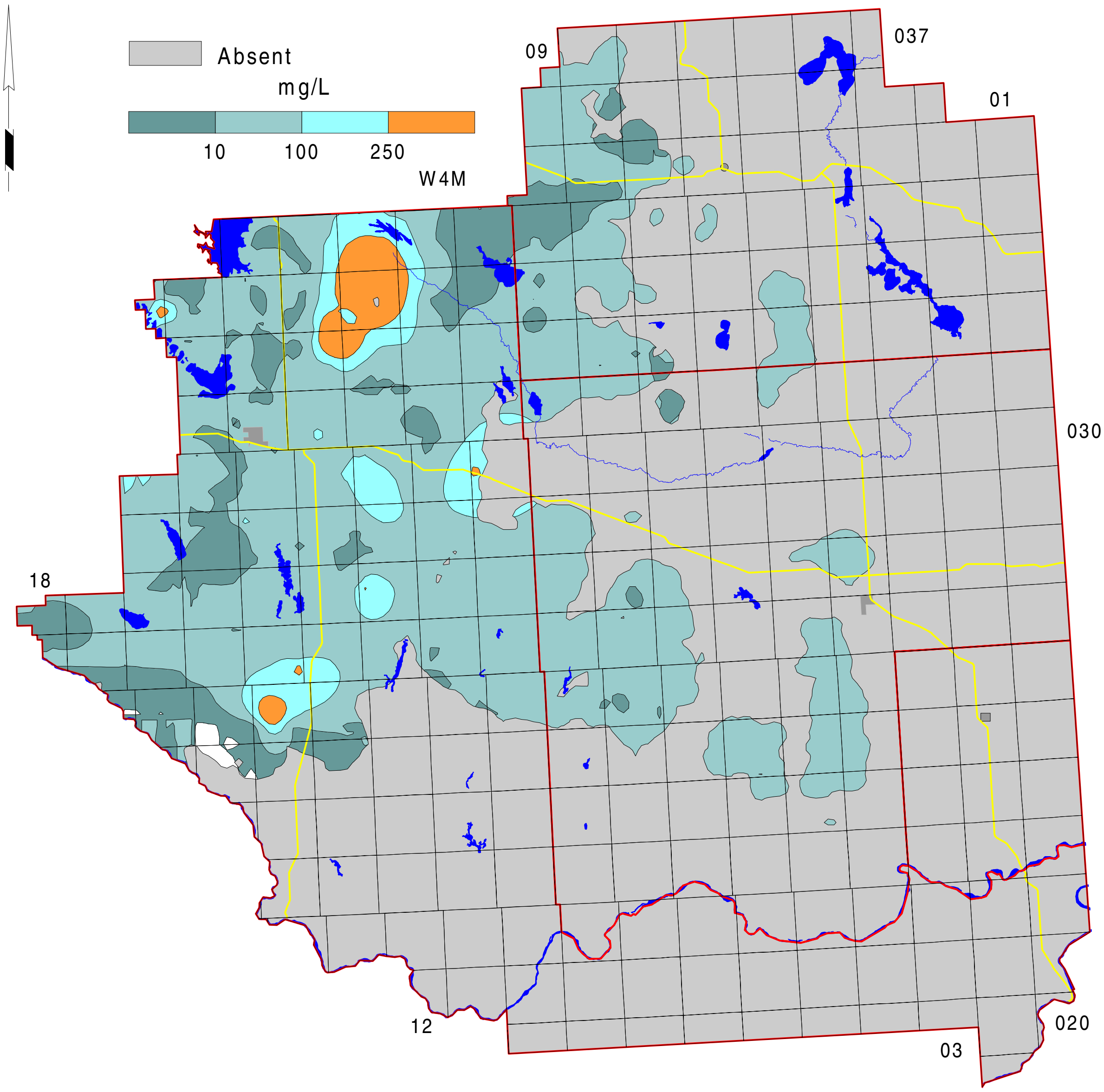
Depth to Top of Lower Horseshoe Canyon Formation



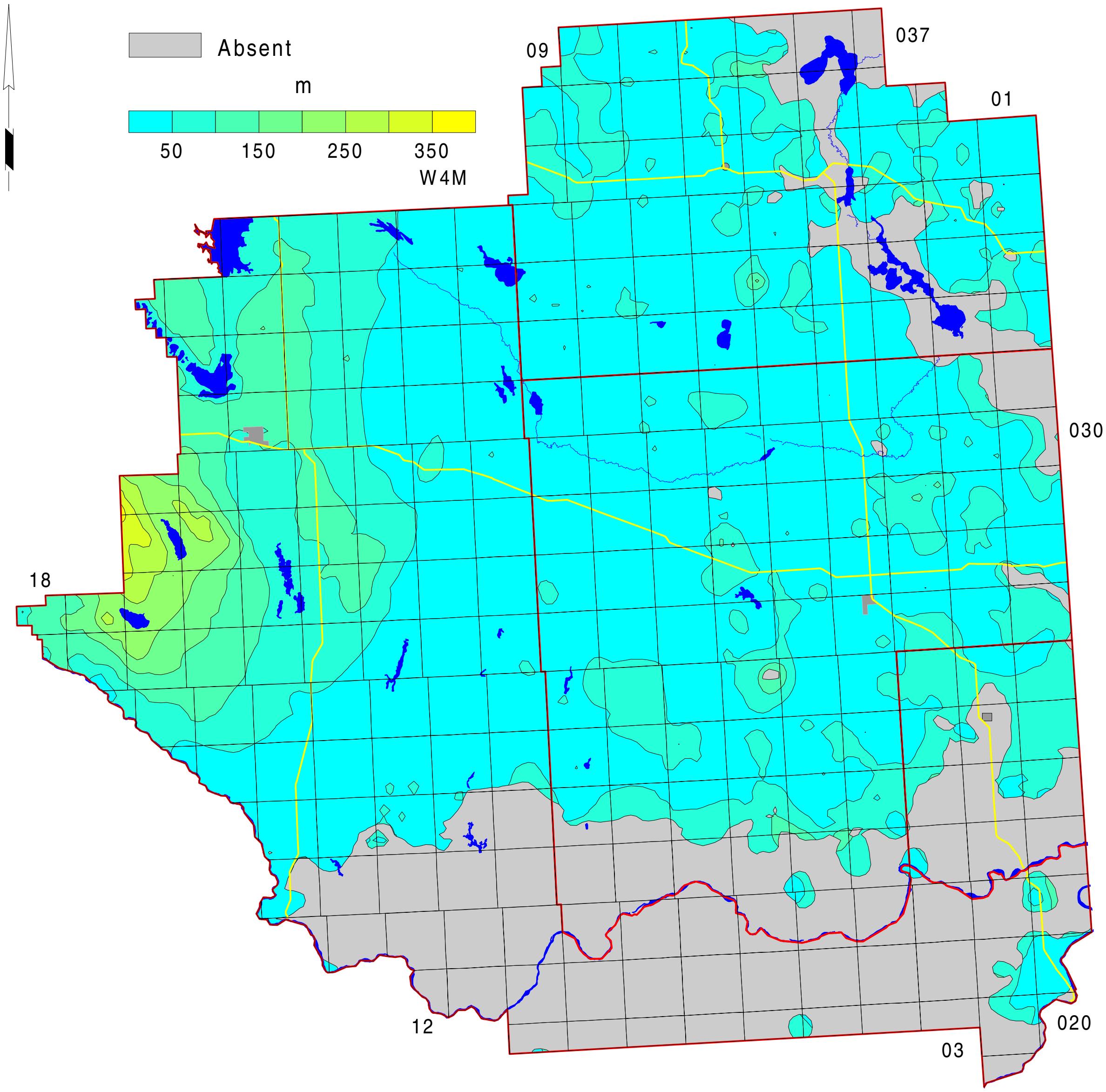
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer



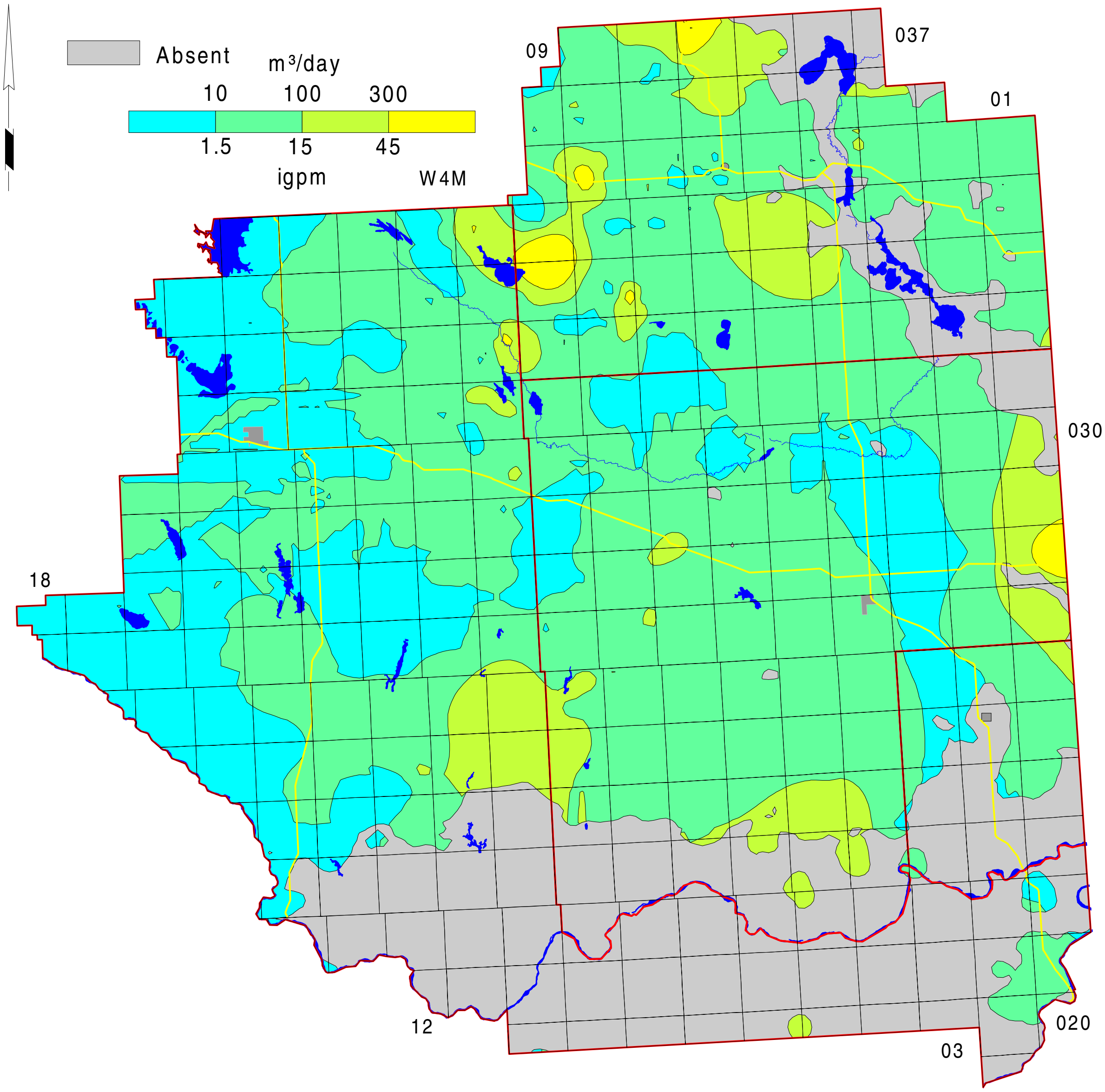
Chloride in Groundwater from Lower Horseshoe Canyon Aquifer



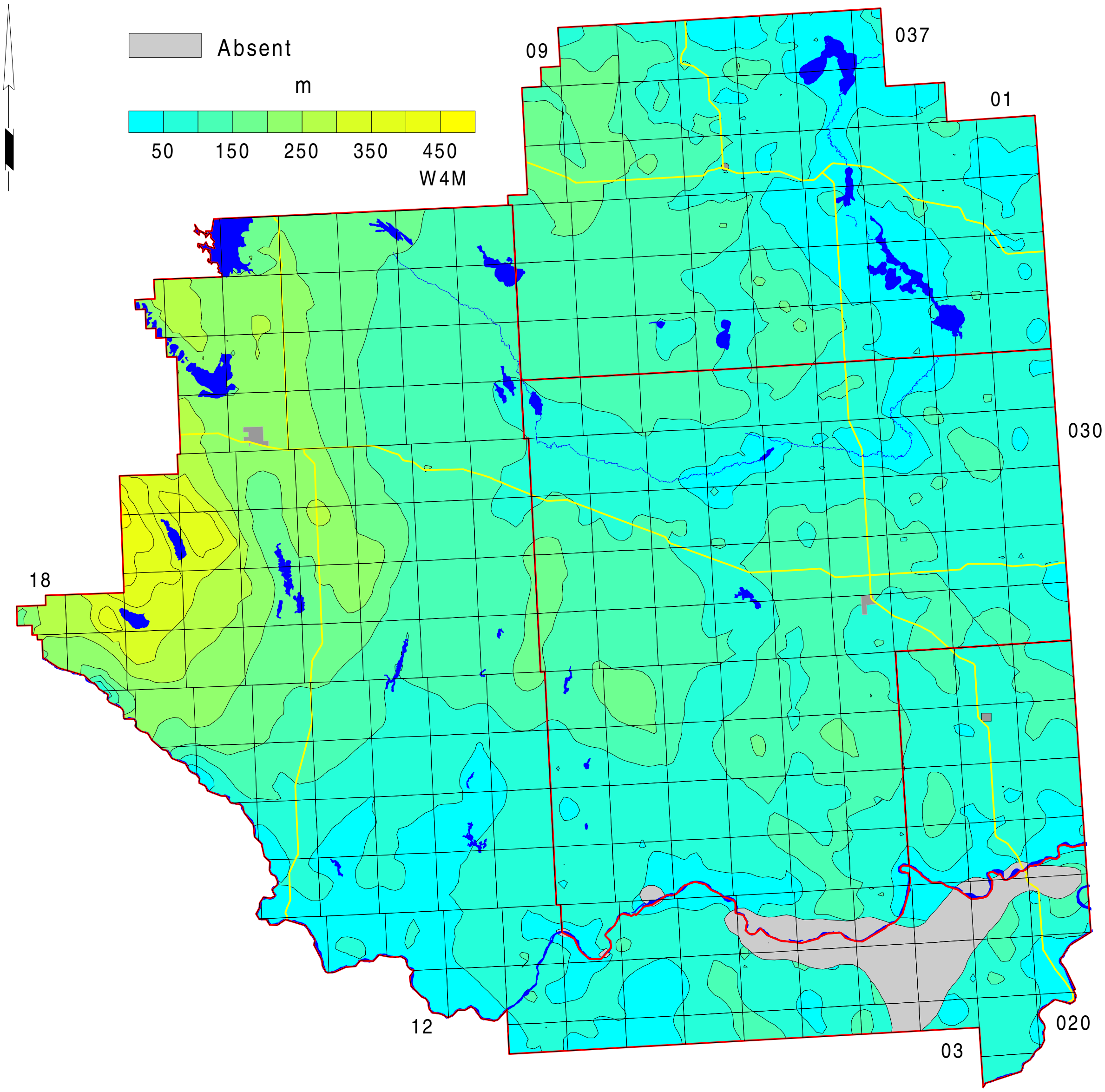
Depth to Top of Bearpaw Formation



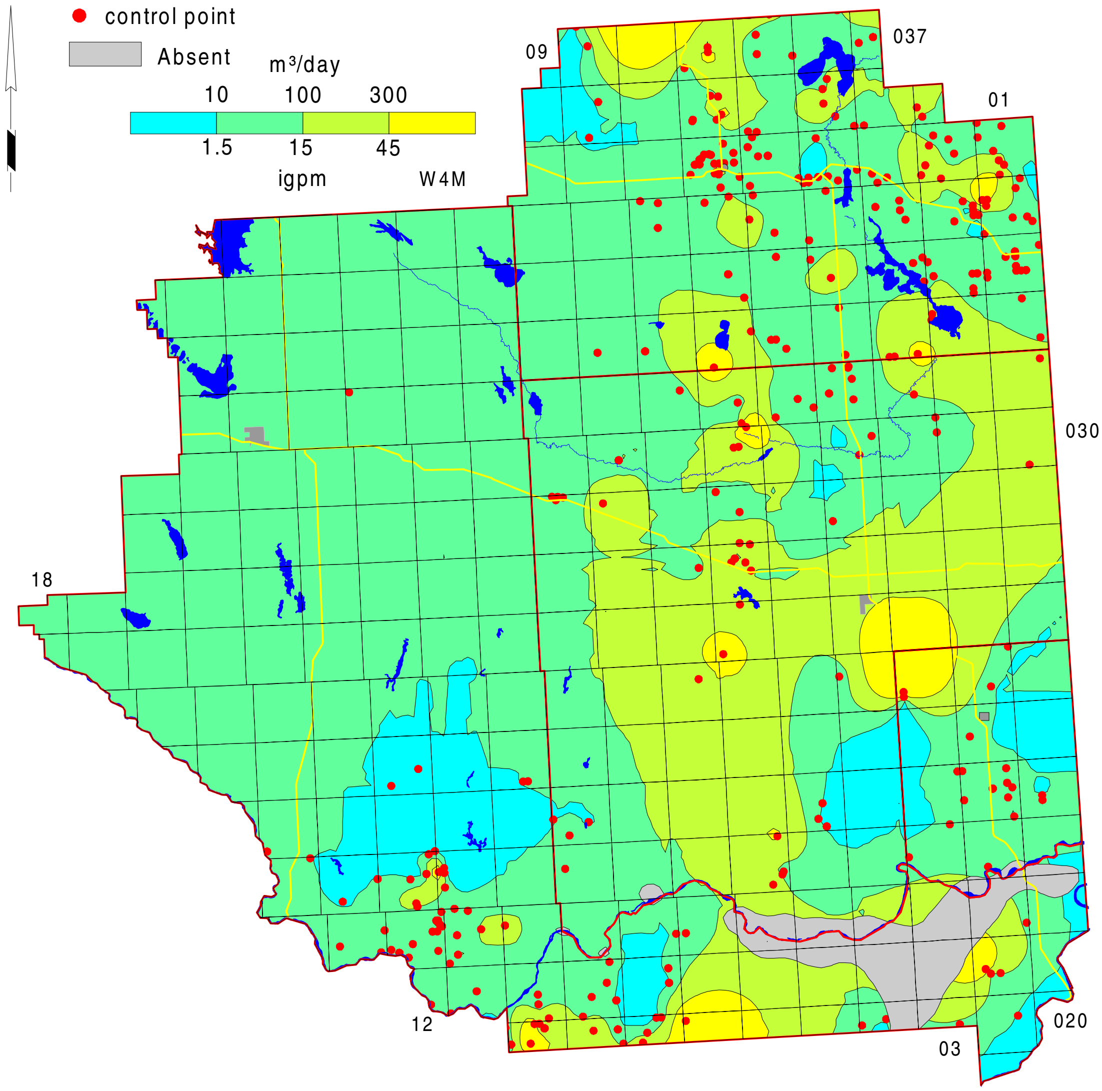
Apparent Yield for Water Wells Completed through Bearpaw Aquifer



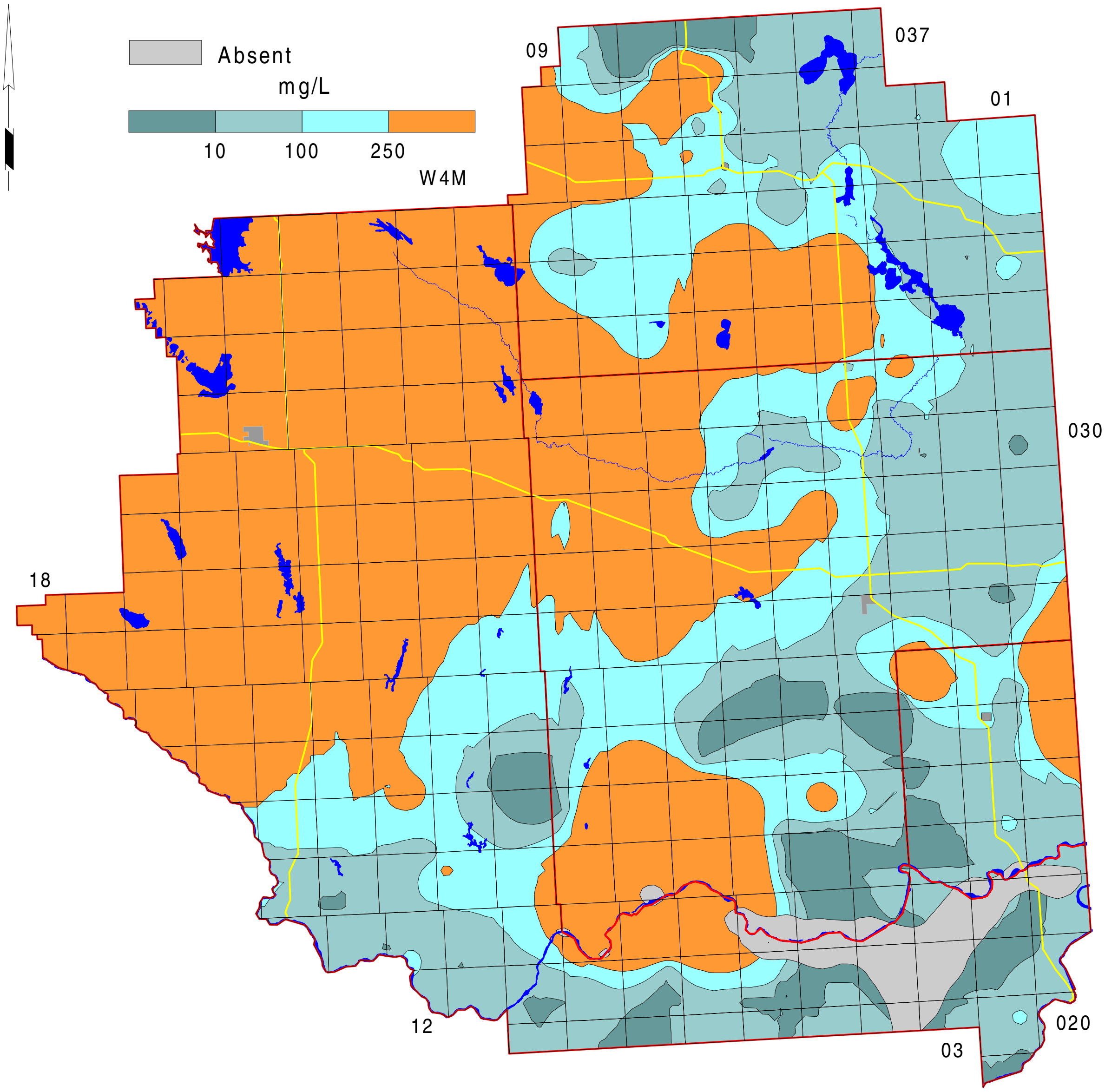
Depth to Top of Oldman Formation



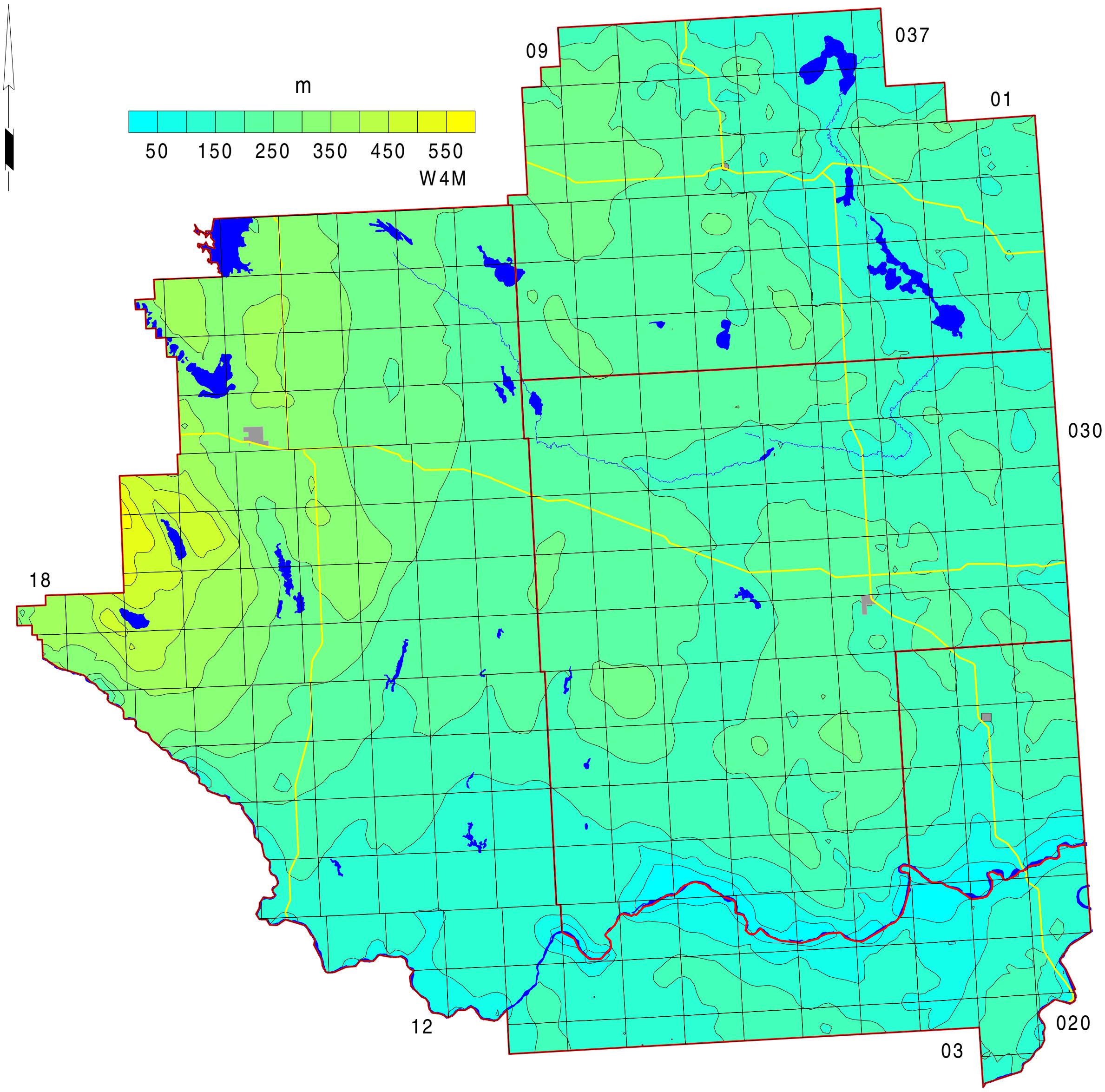
Apparent Yield for Water Wells Completed through Oldman Aquifer



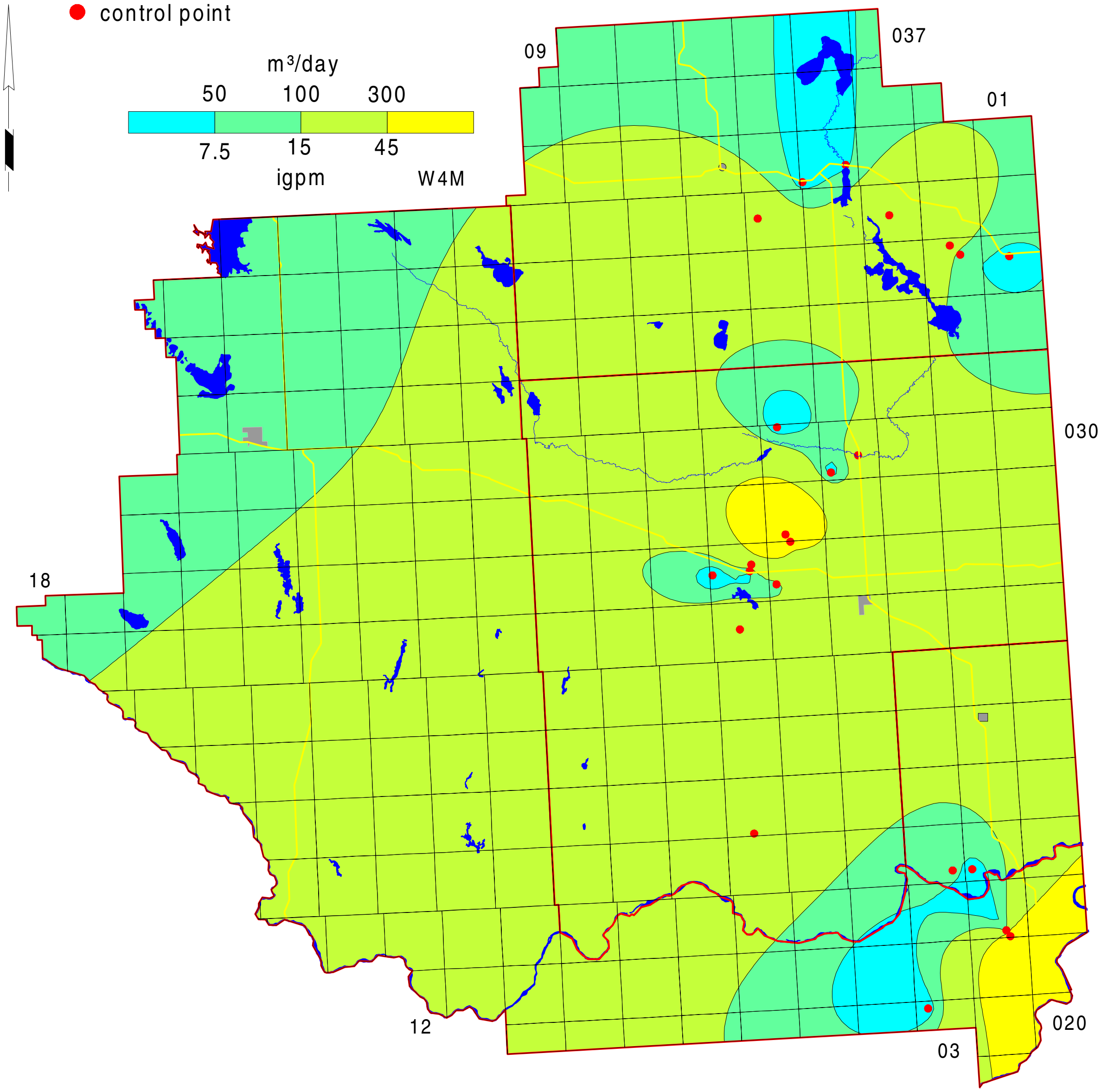
Chloride in Groundwater from Oldman Aquifer



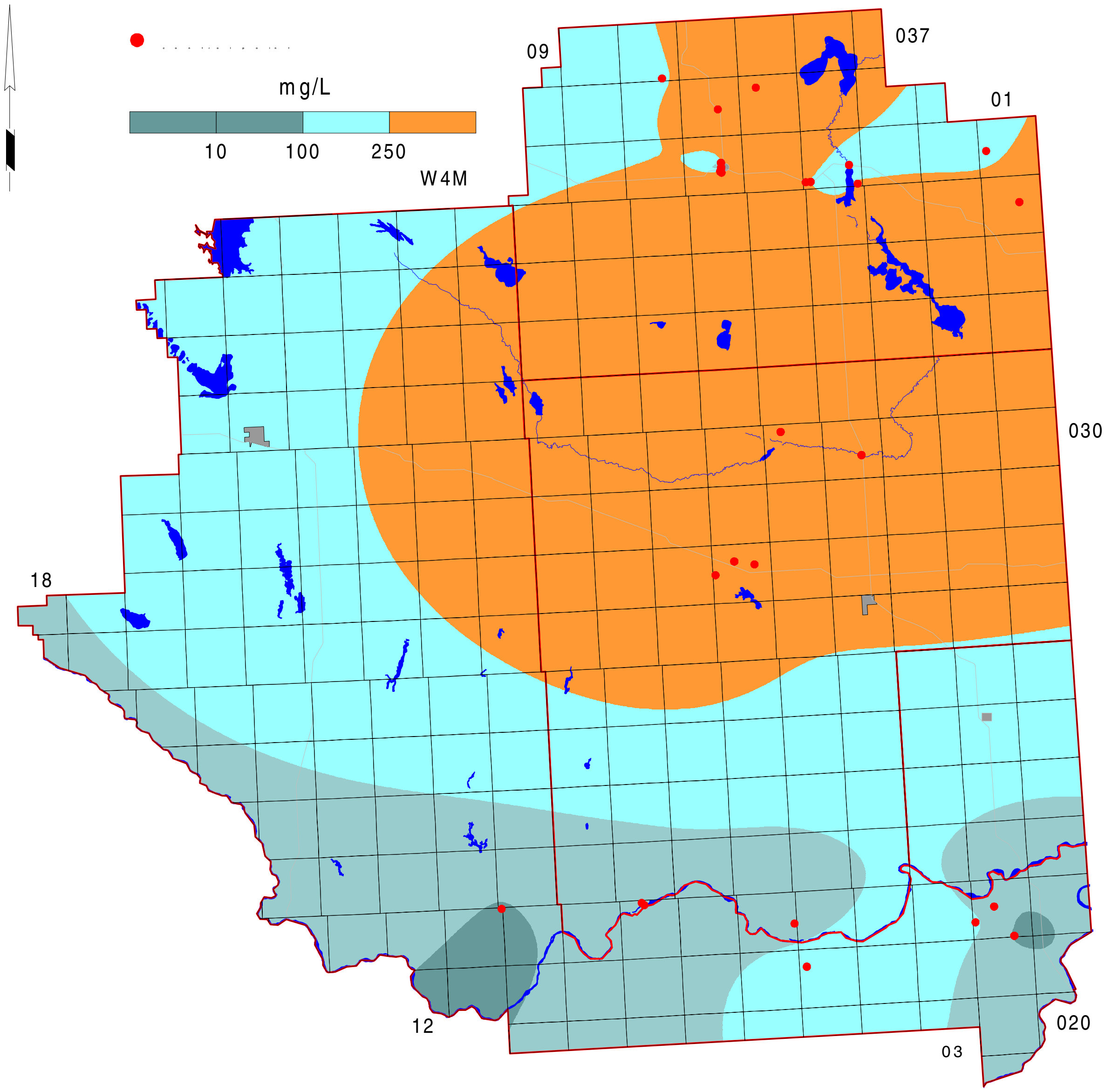
Depth to Top of Birch Lake Member



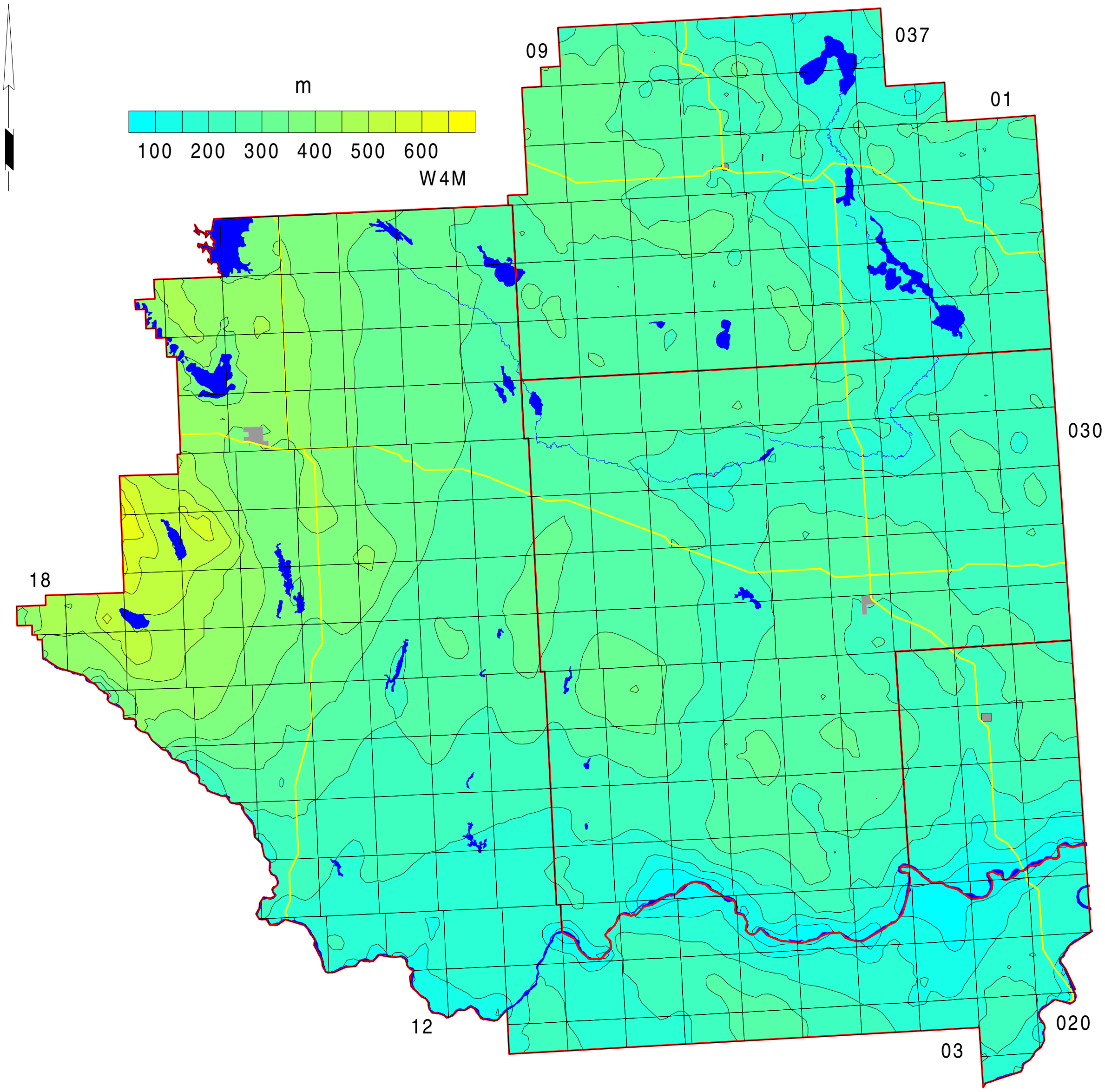
Apparent Yield for Water Wells Completed through Birch Lake Aquifer



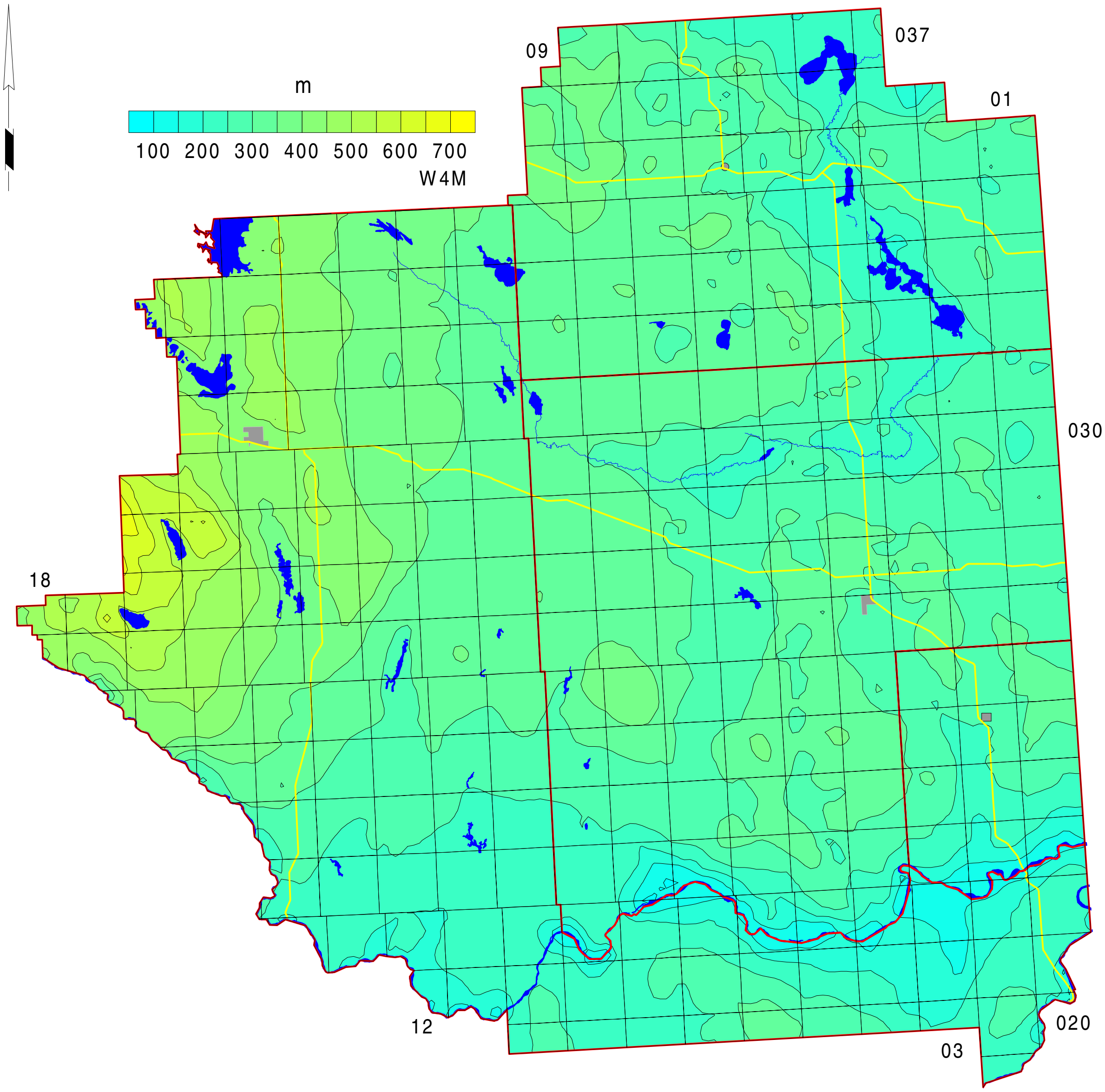
Chloride in Groundwater from Birch Lake Aquifer



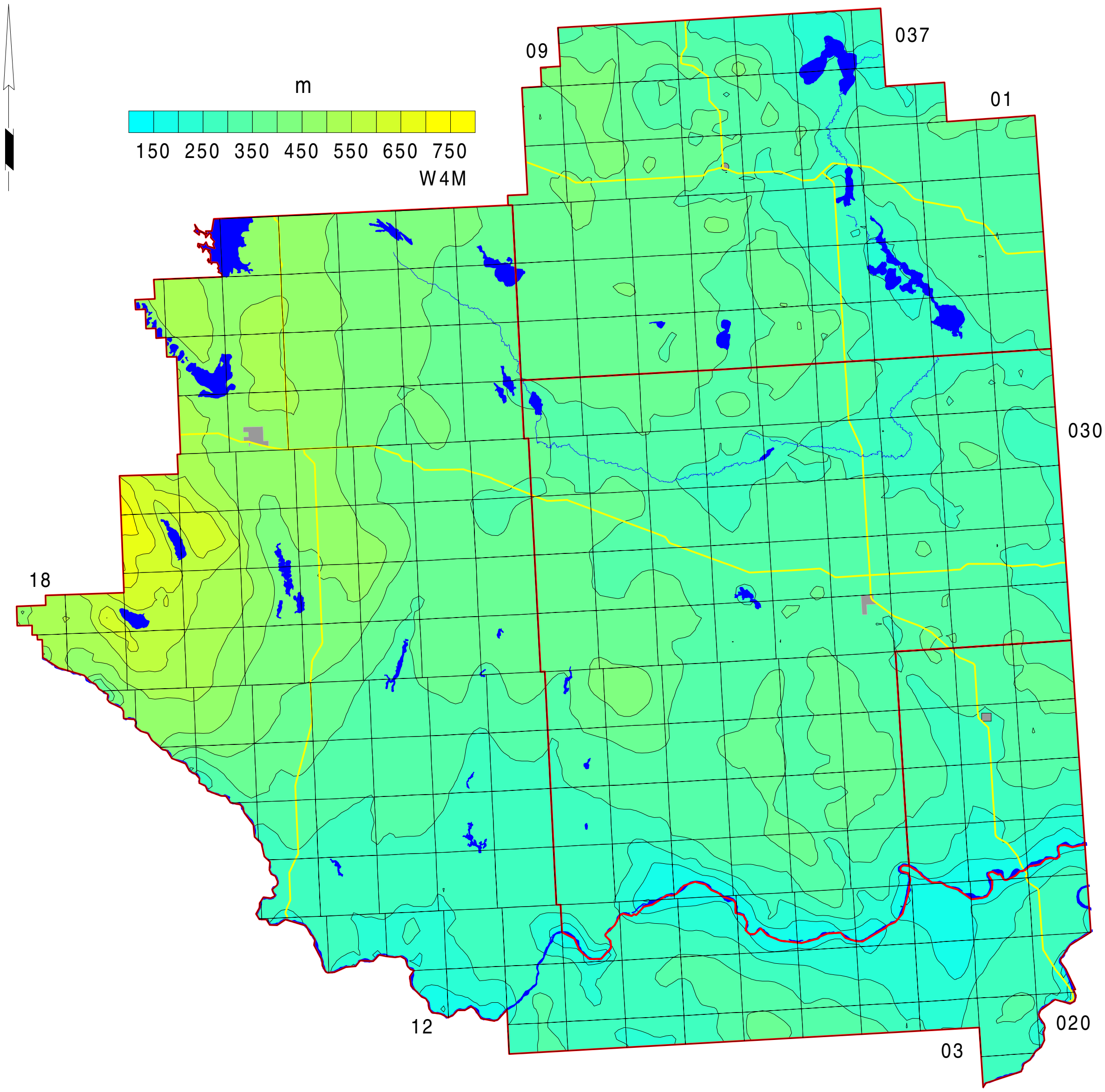
Depth to Top of Ribstone Creek Member



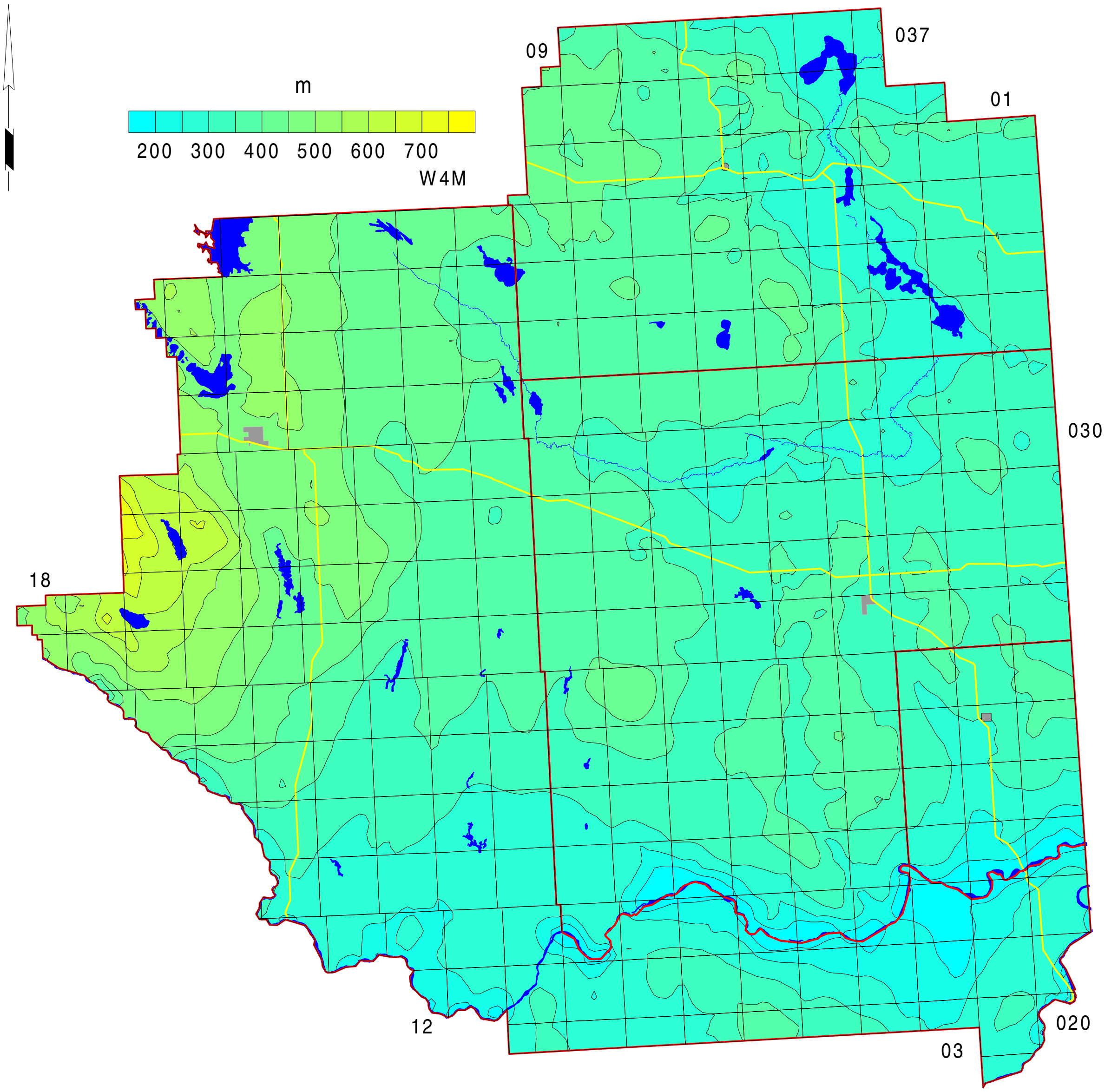
Depth to Top of Victoria Member



Depth to Top of Brosseau Member



Depth to Top of Lea Park Formation



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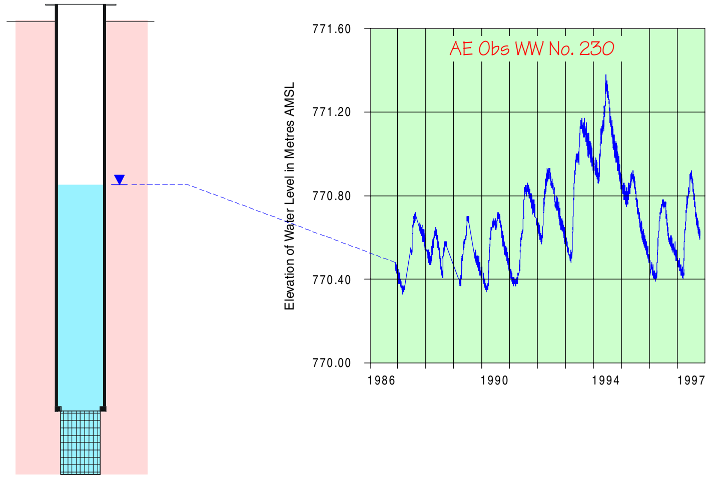
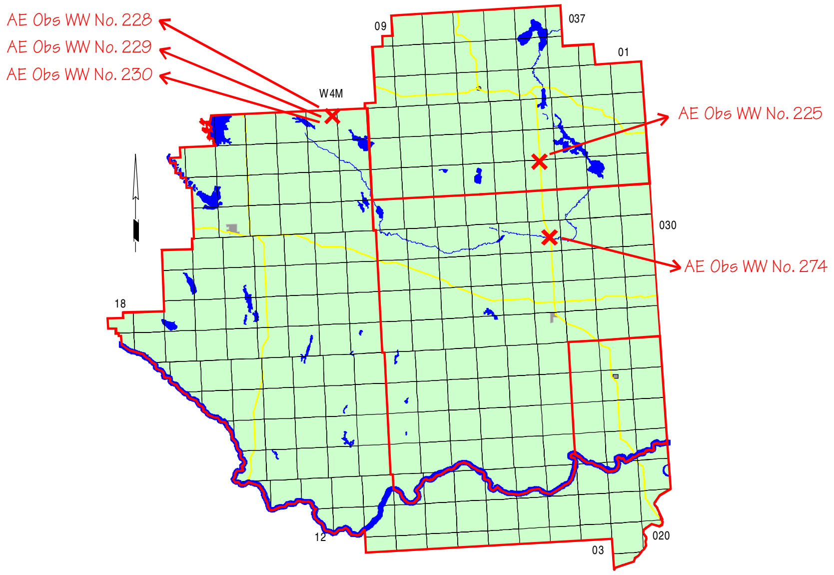
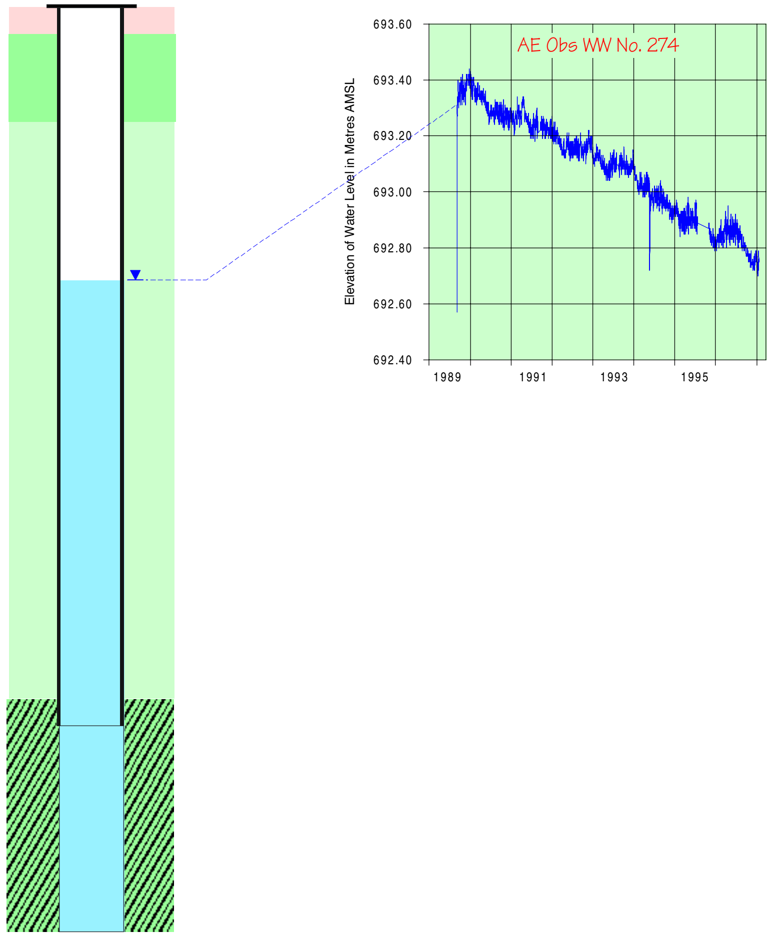
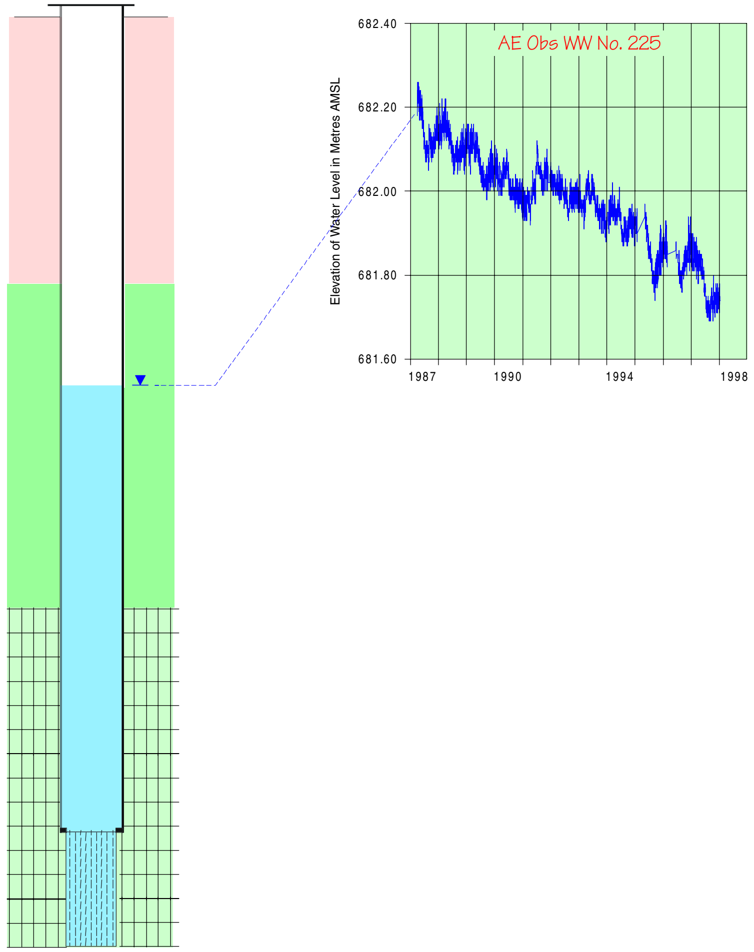
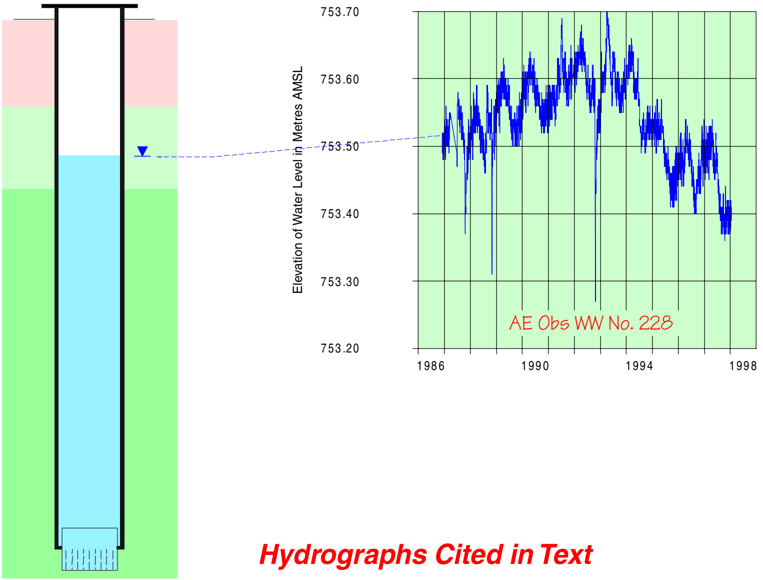


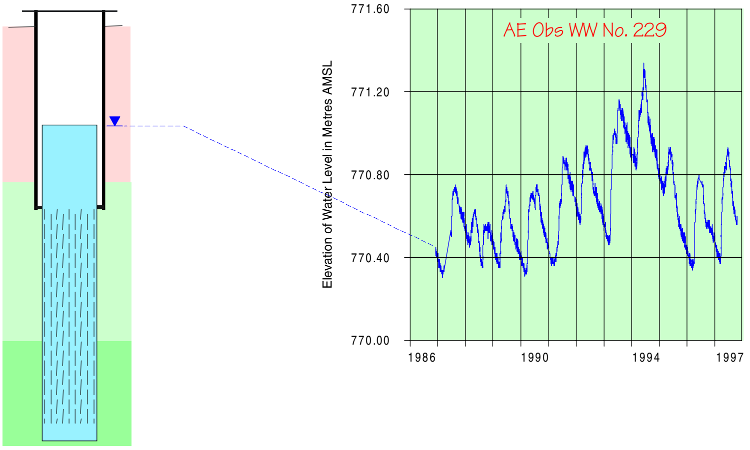






- ▼ Non-Pumping Water Level
- 🟥 Upper Surficial Deposits
- 🟩 Lower Horseshoe Canyon Member
- 🟩 Bearpaw Member
- ▦ Oldman Member
- ▨ Birch Lake Member





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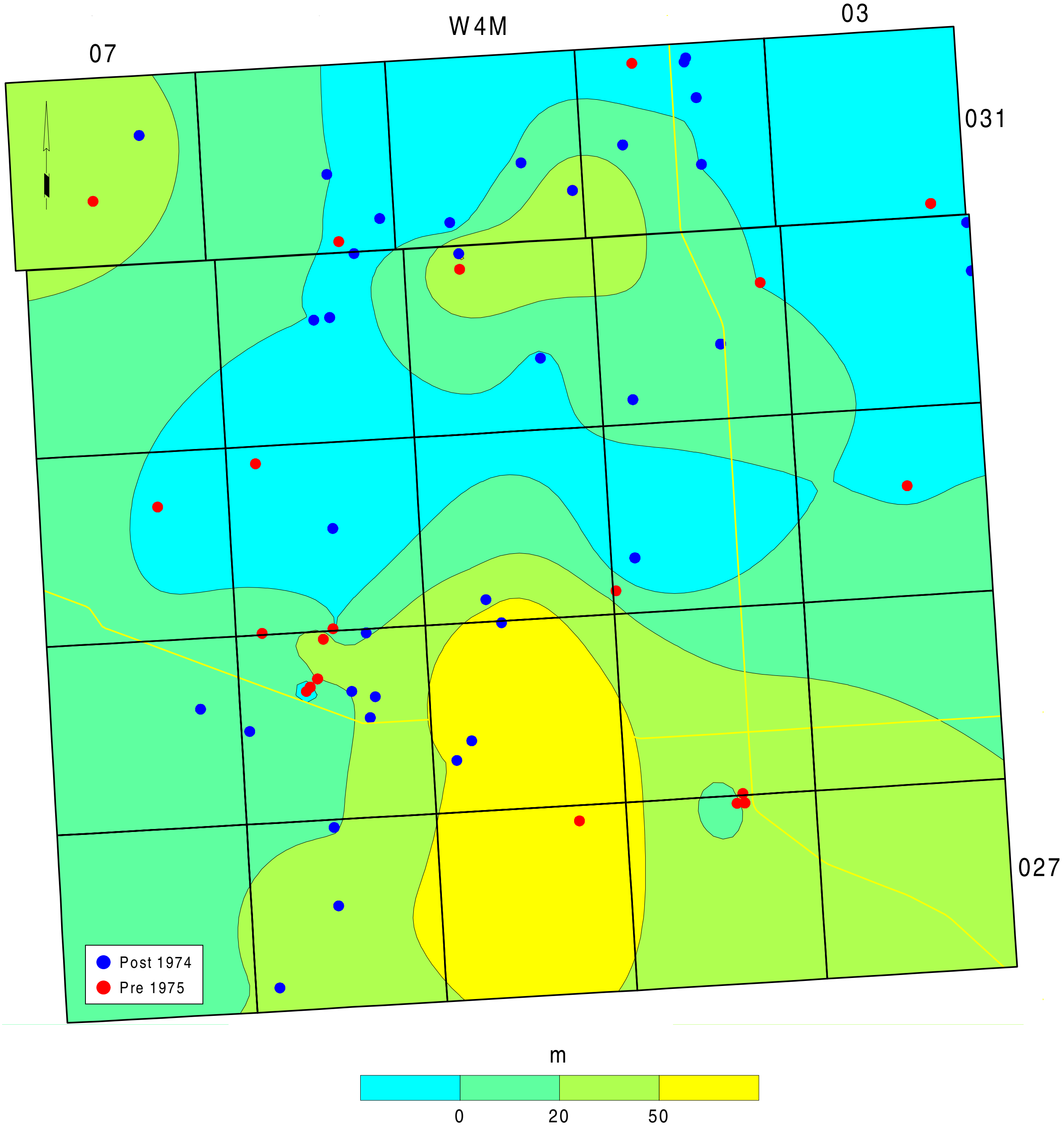
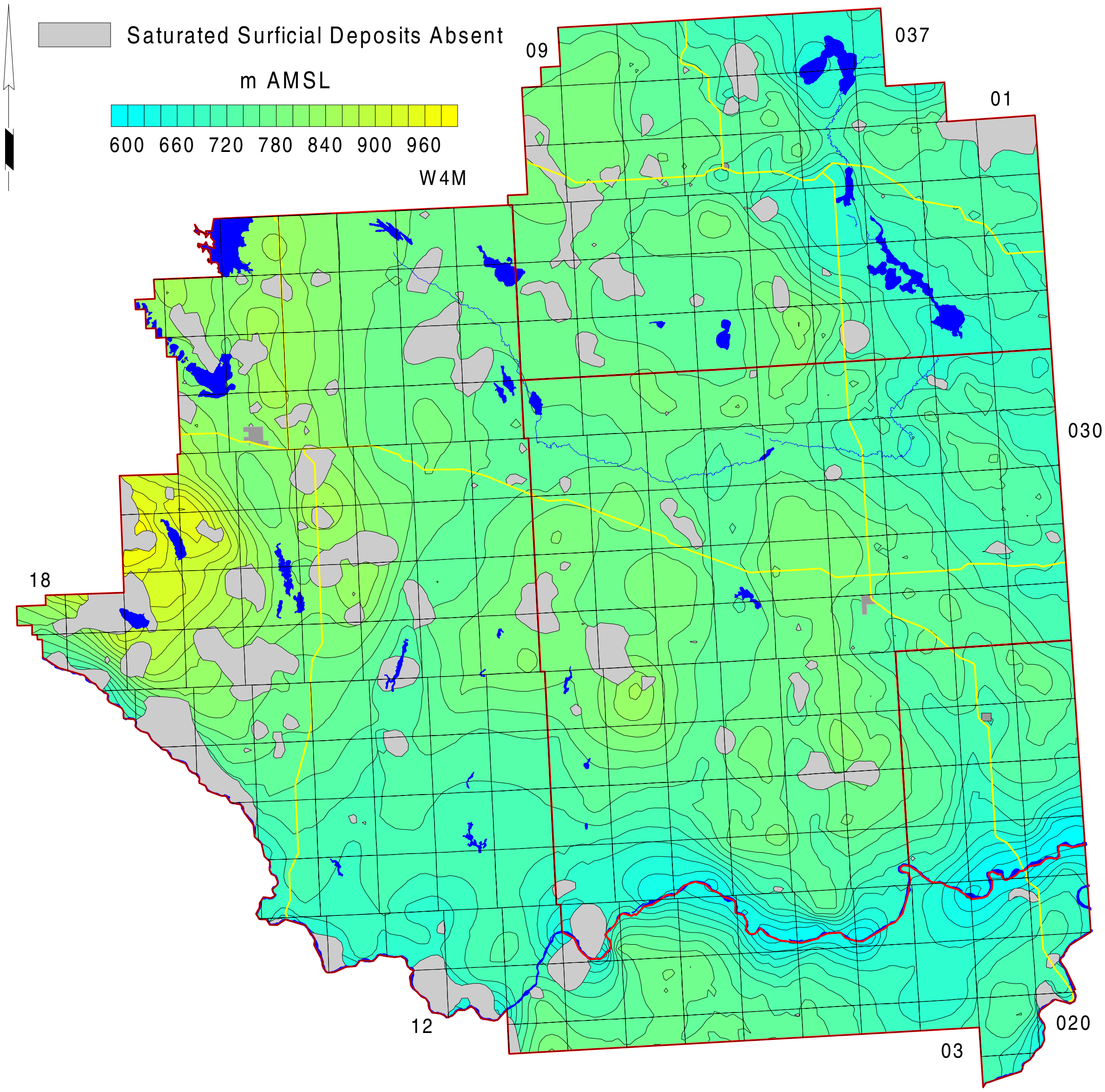
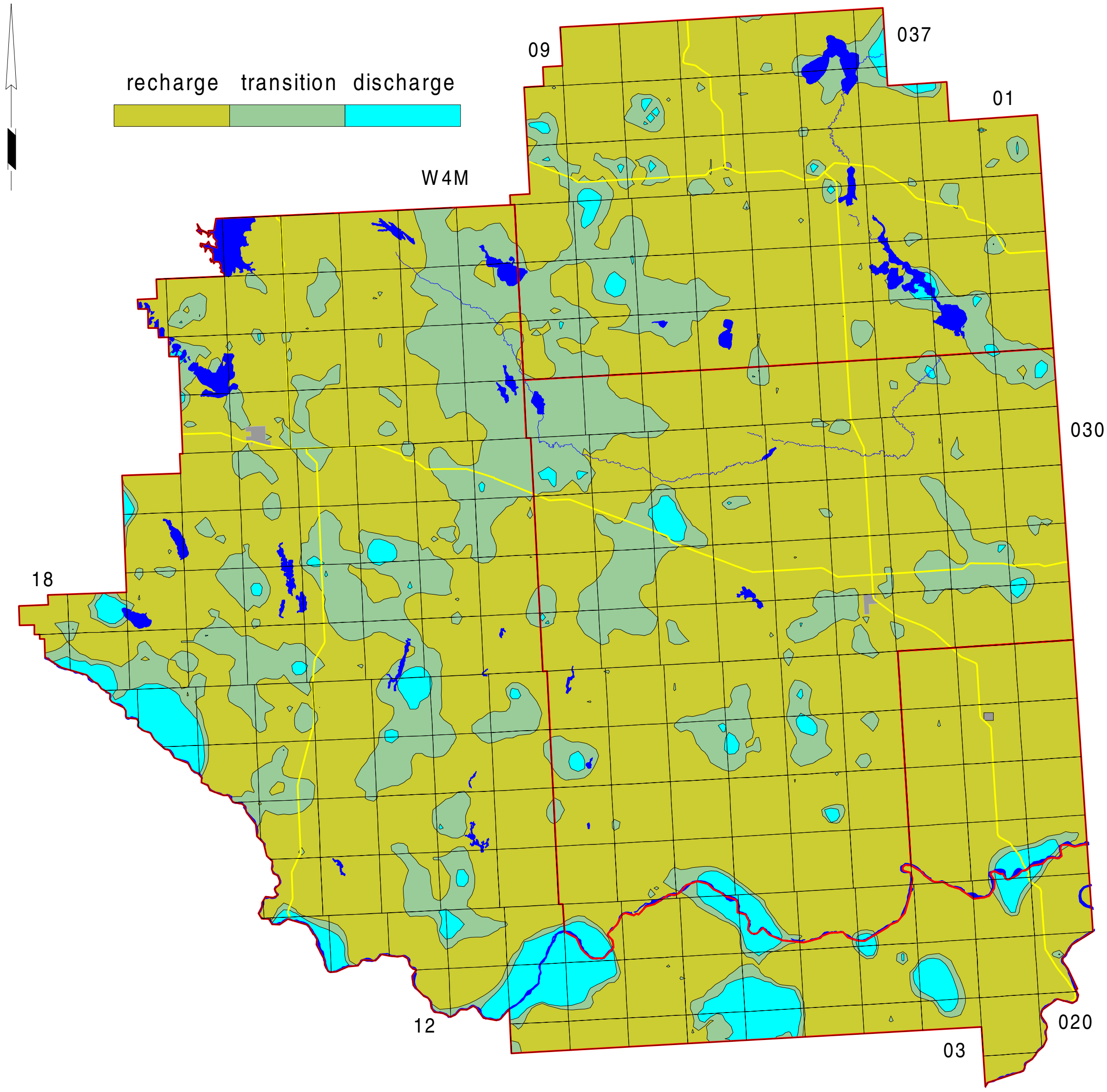
Water-Level Lowering in the Oldman Aquifer



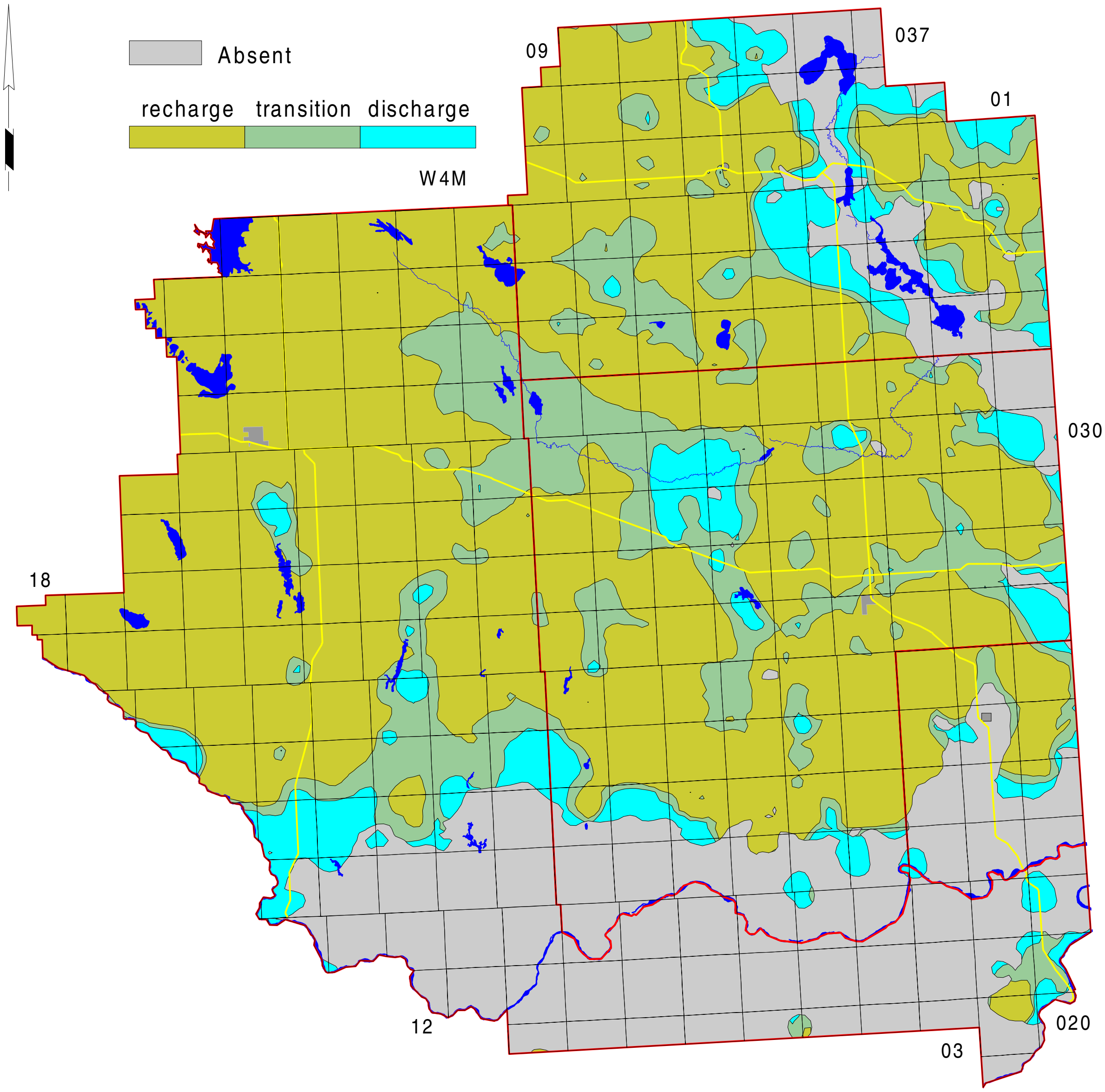
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



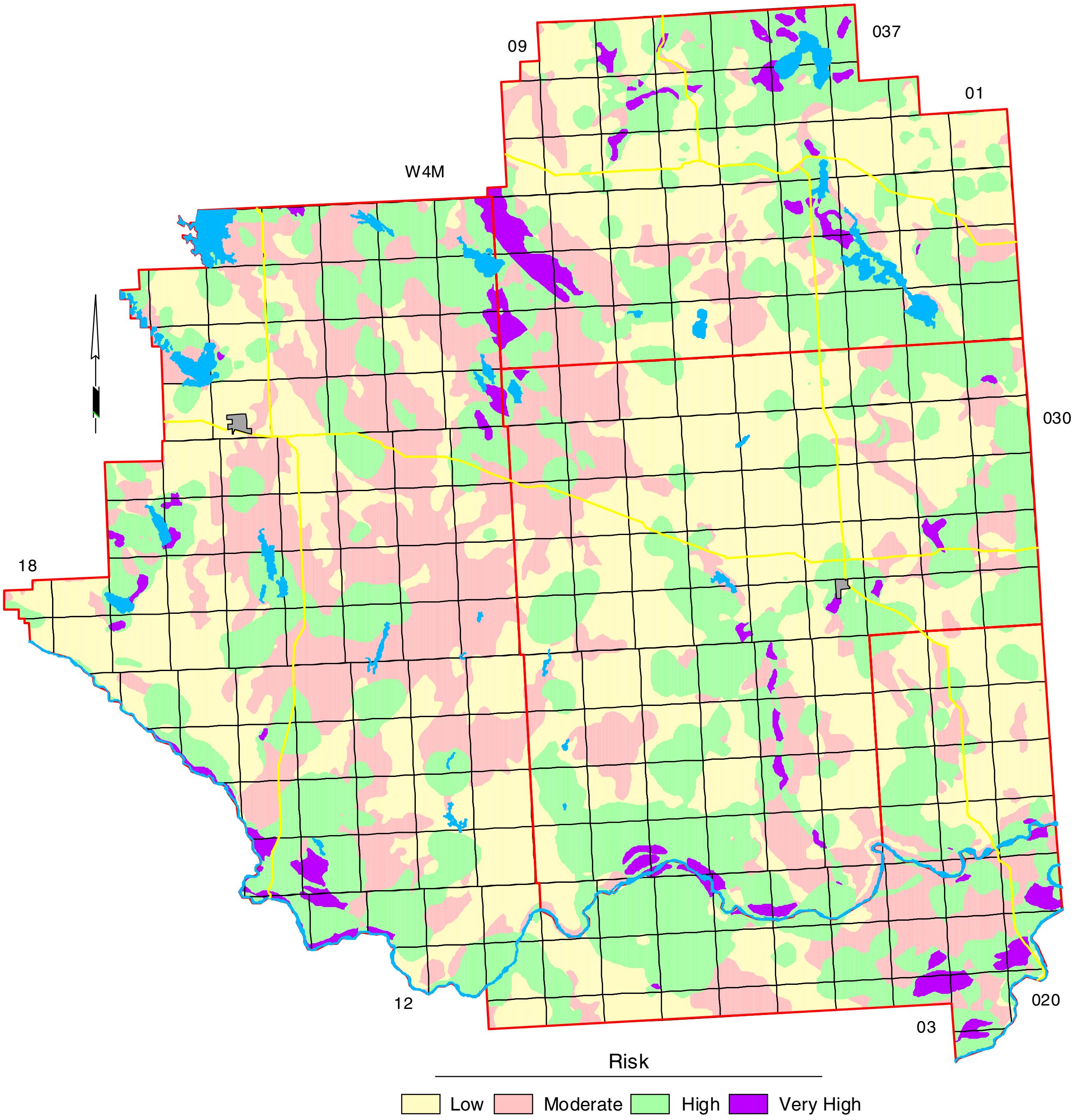
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



Recharge/Discharge Areas between Surficial Deposits and Bearpaw Aquifer



Risk of Groundwater Contamination



SPECIAL AREAS 2, 3 AND 4, AND M.D. OF ACADIA

Appendix B

MAPS AND FIGURES ON CD-ROM

A) Database
B) ArcView Files
C) Query
D) Maps and Figures
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Cross-Section C - C'
Cross-Section D - D'
Cross-Section E - E'
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Cross-Section G - G'
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Depth to Top of Upper Scollard Formation
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Chloride in Groundwater from Lower Horseshoe Canyon Aquifer
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Chloride in Groundwater from Bearpaw Aquifer
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Recharge/Discharge Areas between Surficial Deposits and Bearpaw Aquifer

i) Oldman Formation

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Non-Pumping Water-Level Surface - Oldman Aquifer
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Chloride in Groundwater from Birch Lake Aquifer
Piper Diagram - Birch Lake Aquifer
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k) Ribstone Creek Member

Depth to Top of Ribstone Creek Member
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l) Victoria Member

Depth to Top of Victoria Member
Structure-Contour Map - Top of Victoria Member

m) Brosseau Member

Depth to Top of Brosseau Member
Structure-Contour Map - Top of Brosseau Member

n) Lea Park Formation

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

4) Hydrographs and Observation Water Wells

Hydrographs Cited in Text
Hydrographs in Bigstone Area
Hydrograph in Buffalo Area
Hydrographs in Cavendish Area
Hydrograph in Cessford Area
Hydrographs in Hand Hills Area
Hydrographs in Kirkpatrick Area
Hydrographs in Monitor Area
Hydrograph in Sheerness Area
Hydrograph in Sibbald Area
Hydrographs in Sounding Creek Area
Water-Level Lowering in the Oldman Formation

SPECIAL AREAS 2, 3 AND 4, AND M.D. OF ACADIA

APPENDIX C

GENERAL WATER WELL INFORMATION

Domestic Water Well Testing

Purpose and Requirements

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

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

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

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

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

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

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

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

Groundwater samples should be collected as soon as possible after the start of pumping and within 10 minutes of the end of pumping. Initially only the groundwater samples collected near the end of the pumping interval need to be submitted to the accredited laboratory for analysis. All samples must be properly stored for transportation to the laboratory and, in the case of the bacteriological analysis, there is a maximum time allowed between the time the sample is collected and the time the sample is delivered to the laboratory. The first samples collected are only analyzed if there is a problem or a concern with the first samples submitted to the laboratory.

Procedure

Site Diagrams

These diagrams are a map showing the distance to nearby significant features. This would include things like a corner of a building (house, barn, garage etc.) or the distance to the half-mile or mile fence. The description should allow anyone not familiar with the site to be able to unequivocally identify the water well that was tested. In lieu of a map, UTM coordinates accurate to within five metres would be acceptable. If a hand-held GPS is used, the post-processing correction details must be provided.

Surface Details

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

Groundwater Discharge Point

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

Water-Level Measurements

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

If water levels are obtained using a transducer and data logger, the serial numbers of both transducer and data logger are needed and a copy of the calibration sheet. The additional information required is the depth the transducer was set and the length of time between when the transducer was installed and when the calibration water level was measured, plus the length of time between the installation of the transducer and the start of the aquifer test. All water levels must be measured at least to the nearest 0.01 metres.

Discharge Measurements

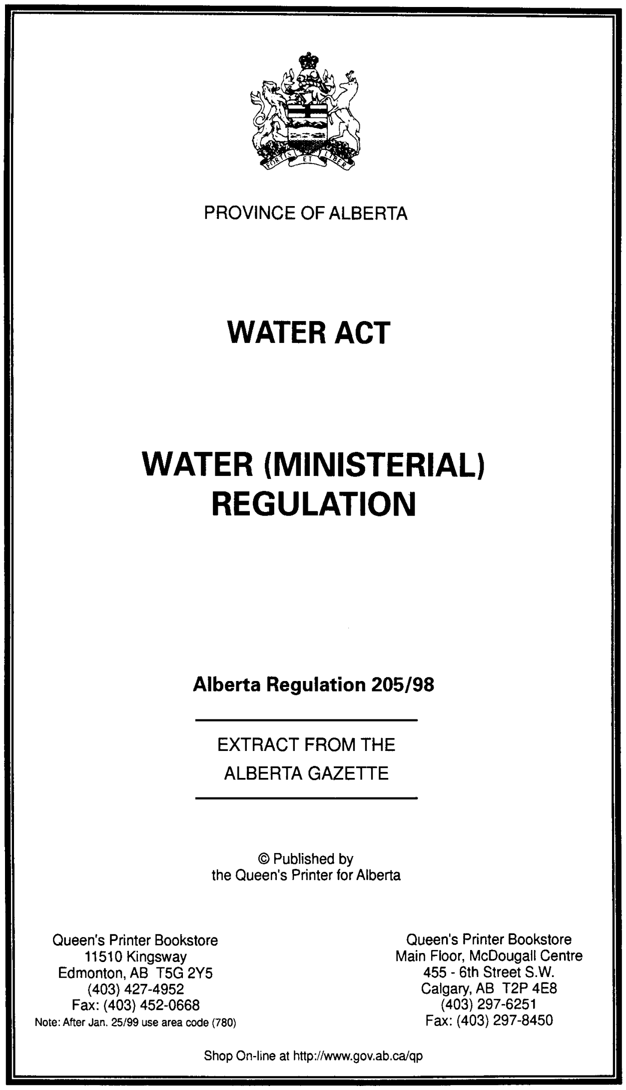
Type of water meter used. This could include such things as a turbine or positive displacement meter. How were the readings obtained from the meter? Were the readings visually noted and recorded or were they recorded using a data logger?

Water Samples

A water sample must be collected between the 4- and 6-minute water-level measurements, whenever there is an observed physical change in the groundwater being pumped, and 10 minutes before the end of the planned pumping interval. Additional water samples must be collected if it is expected that pumping will be terminated before the planned pumping interval.

Water Act –

Water (Ministerial) Regulation



PROVINCE OF ALBERTA

WATER ACT

WATER (MINISTERIAL) REGULATION

Alberta Regulation 205/98

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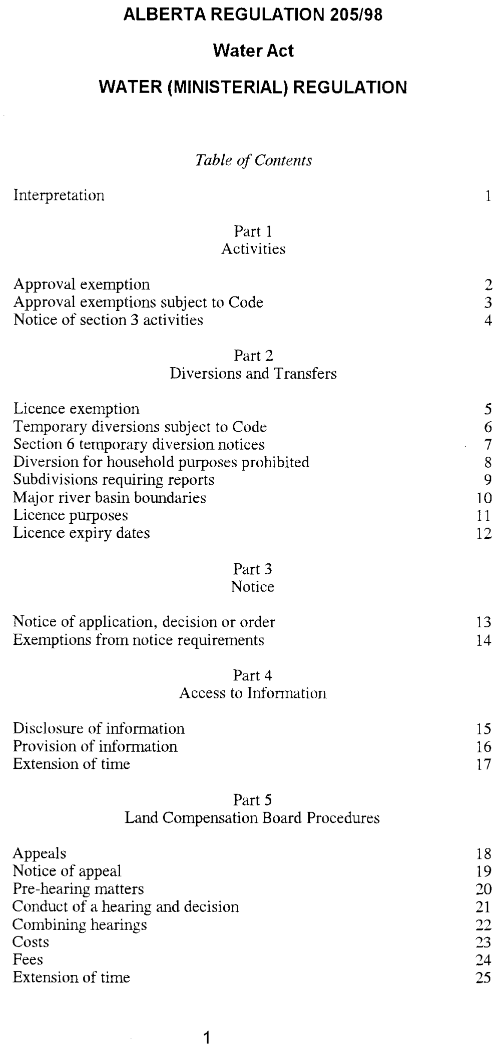

ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

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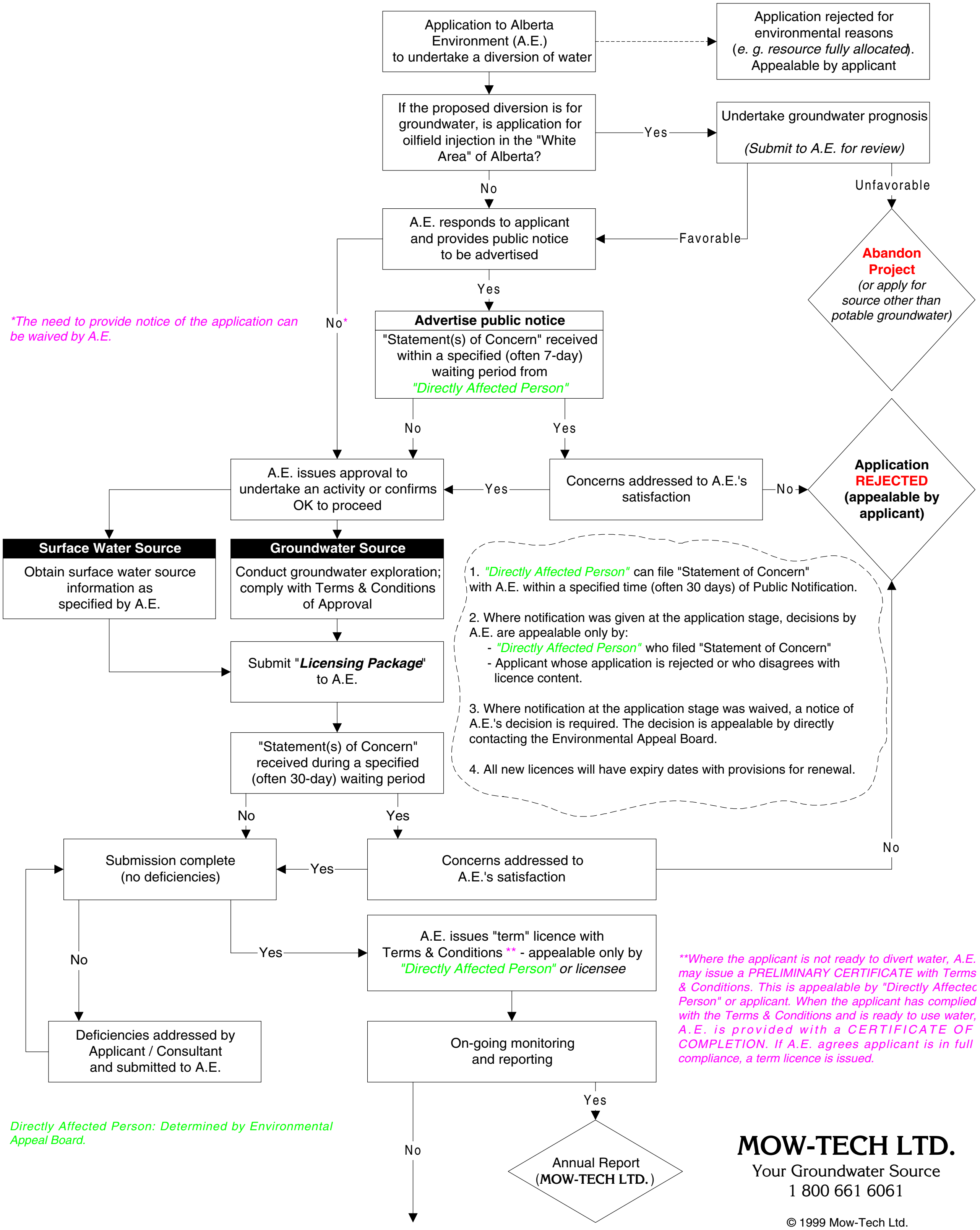
Water Act - Flowchart



**The need to provide notice of the application can be waived by A.E.*

1. "Directly Affected Person" can file "Statement of Concern" with A.E. within a specified time (often 30 days) of Public Notification.

2. Where notification was given at the application stage, decisions by A.E. are appealable only by:
   - "Directly Affected Person" who filed "Statement of Concern"
   - Applicant whose application is rejected or who disagrees with licence content.

3. Where notification at the application stage was waived, a notice of A.E.'s decision is required. The decision is appealable by directly contacting the Environmental Appeal Board.

4. All new licences will have expiry dates with provisions for renewal.

***Where the applicant is not ready to divert water, A.E. may issue a PRELIMINARY CERTIFICATE with Terms & Conditions. This is appealable by "Directly Affected Person" or applicant. When the applicant has complied with the Terms & Conditions and is ready to use water, A.E. is provided with a CERTIFICATE OF COMPLETION. If A.E. agrees applicant is in full compliance, a term licence is issued.*

Directly Affected Person: Determined by Environmental Appeal Board.

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1 800 661 6061

*This flow chart was developed by Mow-Tech Ltd. and is provided as a guide **only** to Alberta's new **Water Act**. Mow-Tech Ltd. accepts no responsibility for the information provided.*

Additional Information

VIDEOS

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

BOOKLET

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

ALBERTA ENVIRONMENTAL PROTECTION

WATER WELL INSPECTORS

Jennifer McPherson (Edmonton: 780-427-6429)

GEOPHYSICAL INSPECTION SERVICE

Edmonton: 780-427-3932

COMPLAINT INVESTIGATIONS

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

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

Carl Mendosa (Edmonton: 780-492-2664)

UNIVERSITY OF CALGARY – Department of Geology and Geophysics - Hydrogeology

Larry Bentley (Calgary: 403-220-4512)

FARMERS ADVOCATE

Paul Vasseur (Edmonton: 780-427-2433)

PRAIRIE FARM REHABILITATION ADMINISTRATION

Dave Seitz (Hanna: 403-854-4448)

LOCAL HEALTH DEPARTMENTS

SPECIAL AREAS 2, 3 AND 4, AND M.D. OF ACADIA

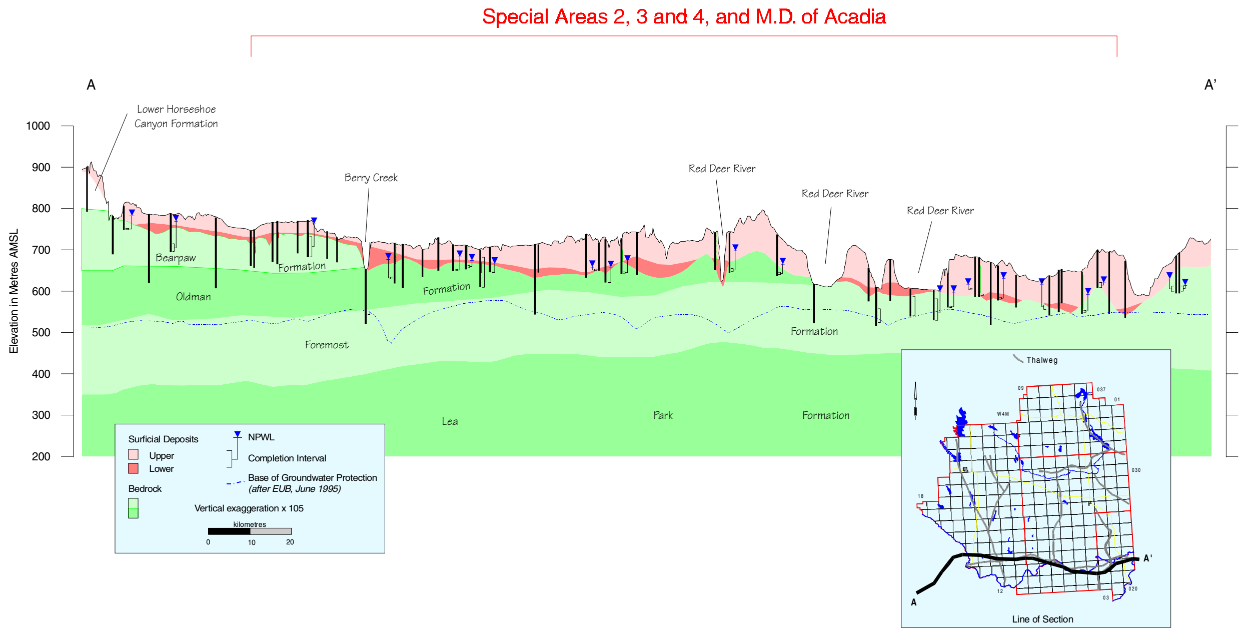
Appendix D

Maps and Figures Included as Large Plots

Cross Sections

Cross-Section A - A'

Special Areas 2, 3 & 4 and M.D. of Acadia No. 34
Cross-Section A - A'



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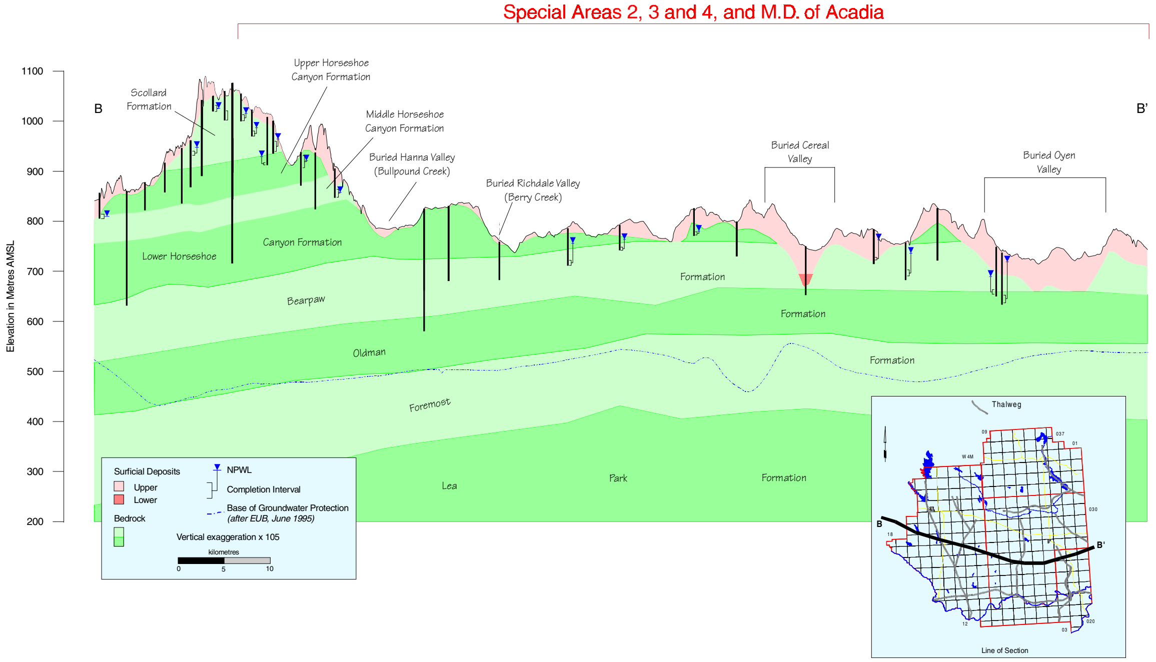
Cross-Section B - B’

Special Areas

Special Areas 2, 3 & 4 and M.D. of Acadia No. 34
Cross-Section B - B'



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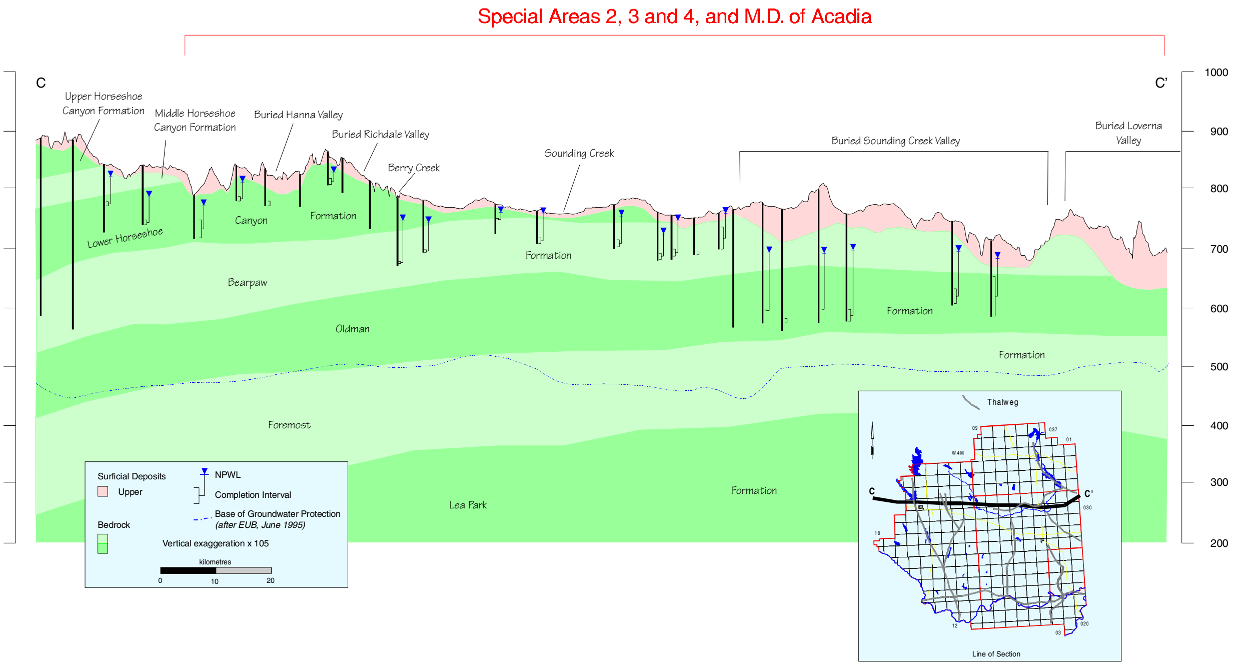
Cross-Section C - C'

Special Areas 2, 3 & 4 and M.D. of Acadia No. 34
Cross-Section C - C'



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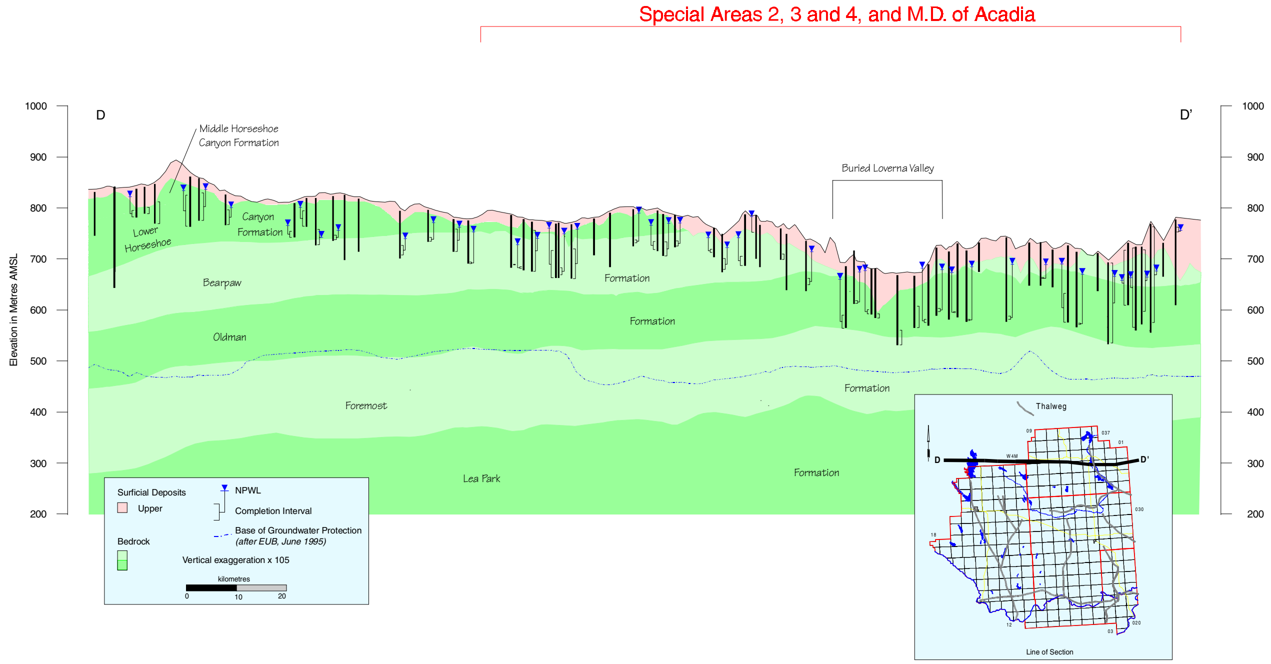
Cross-Section D - D’

Special Areas 2, 3 & 4 and M.D. of Acadia No. 34
Cross-Section D - D'



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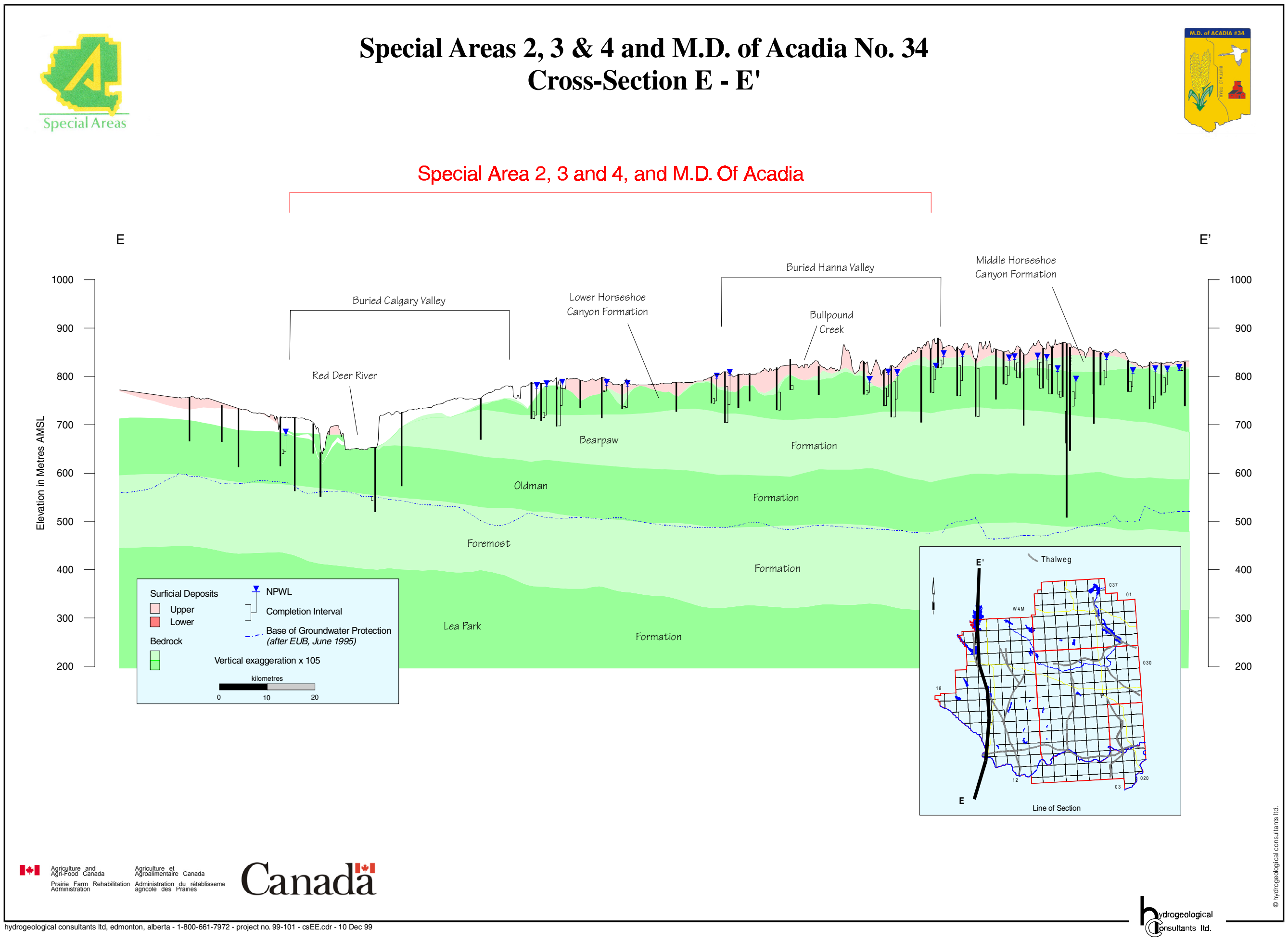
Cross-Section E - E'



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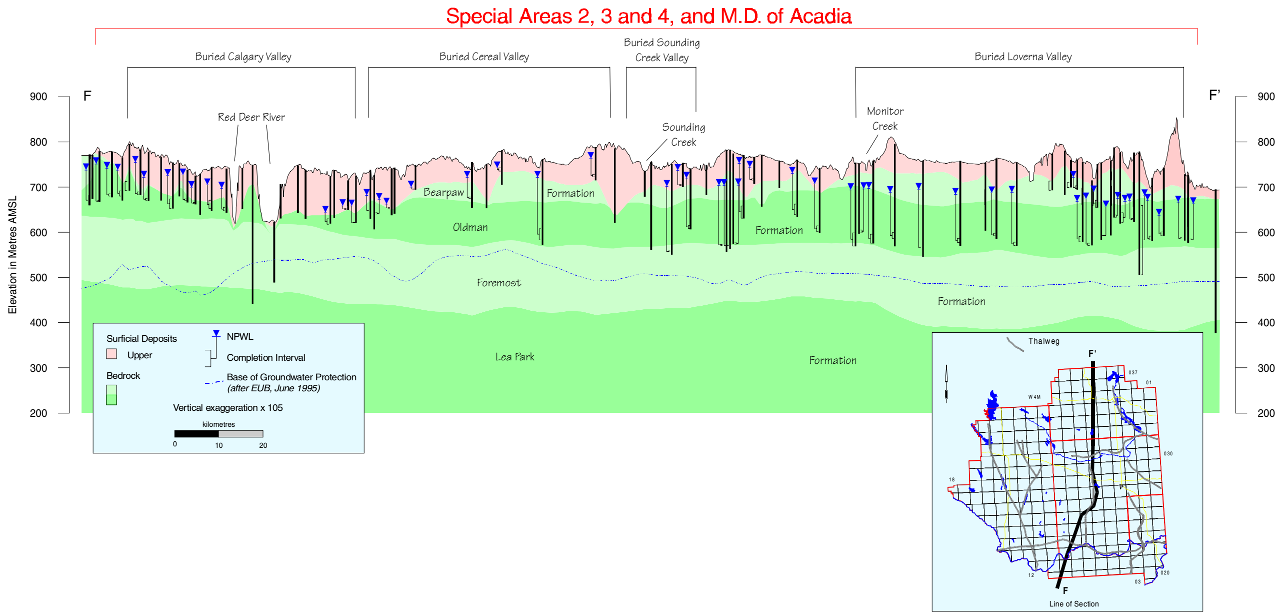
Cross-Section F - F'

Special Areas 2, 3 & 4 and M.D. of Acadia No. 34
Cross-Section F - F'



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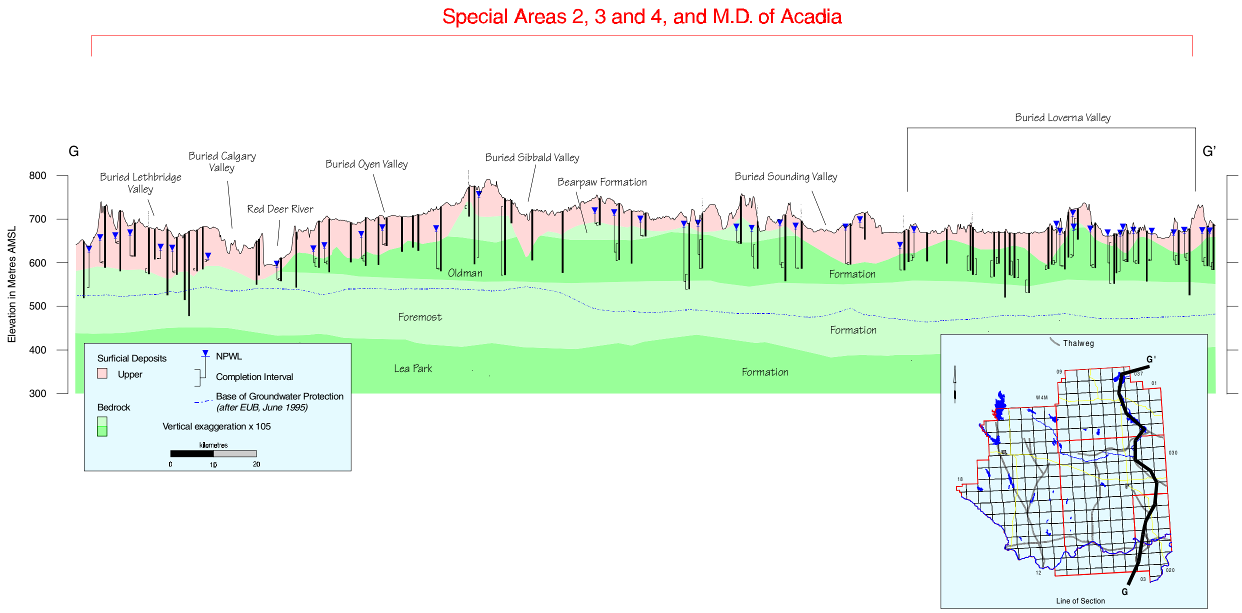
Cross-Section G - G’

Special Areas 2, 3 & 4 and M.D. of Acadia No. 34
Cross-Section G - G'



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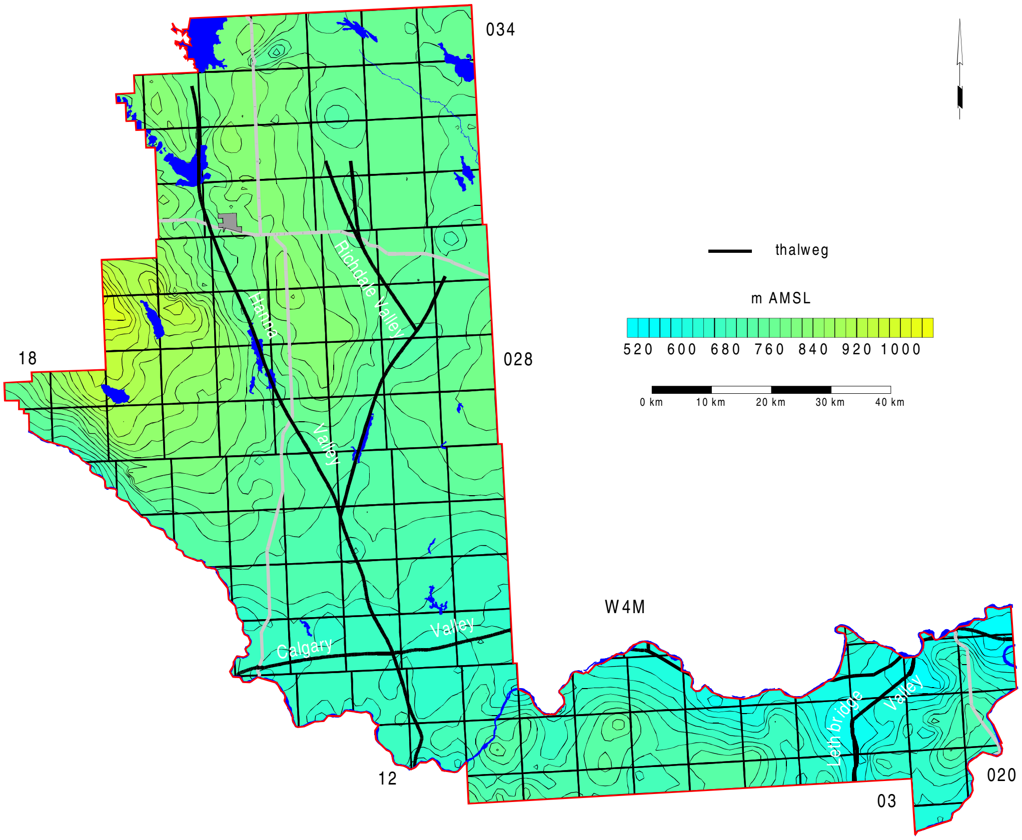
Special Area 2

Bedrock Topography

Special Areas

Special Area 2
Bedrock Topography



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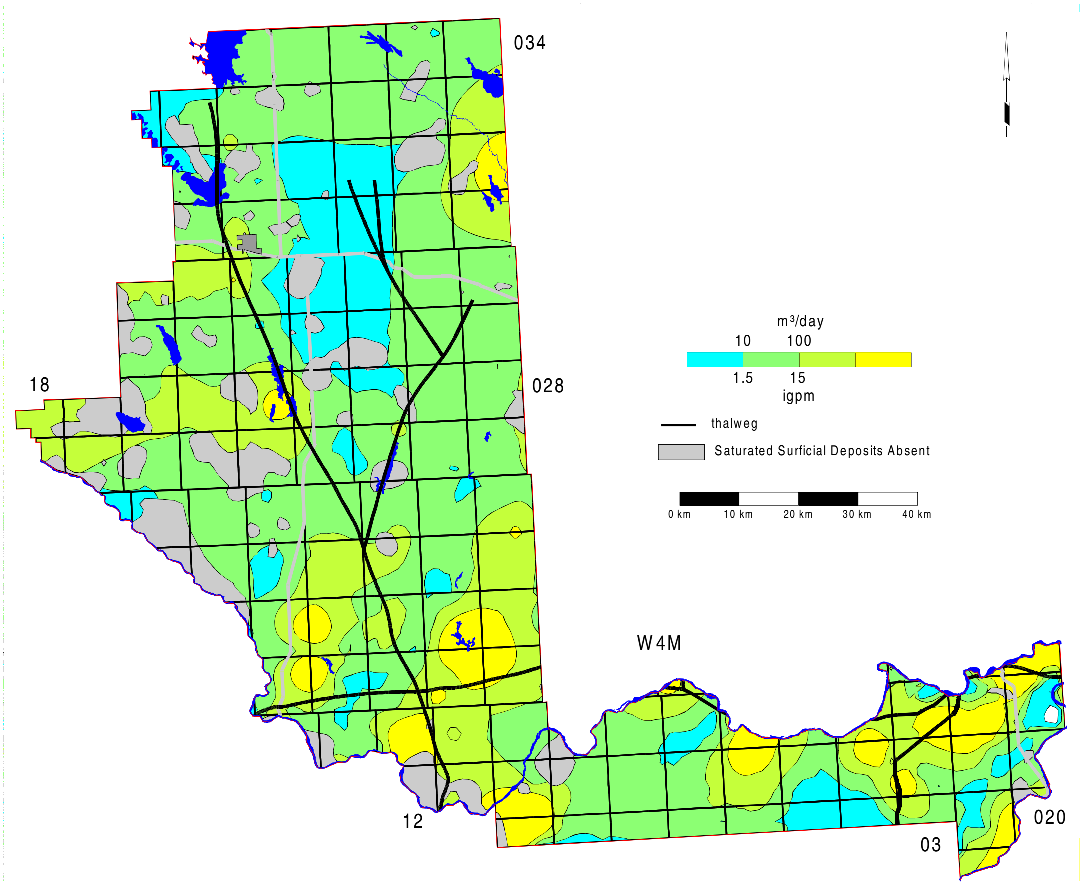
Apparent Yield for Water Wells Completed in Surficial Aquifer(s)

Special Areas

Special Area 2
Apparent Yield for Water Wells Completed in Surficial Aquifer(s)



GROUNDWATER CONSUMPTION

Goundwater Purpose (1) (2)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household

(2) traditional agriculture use as defined in the Water Act

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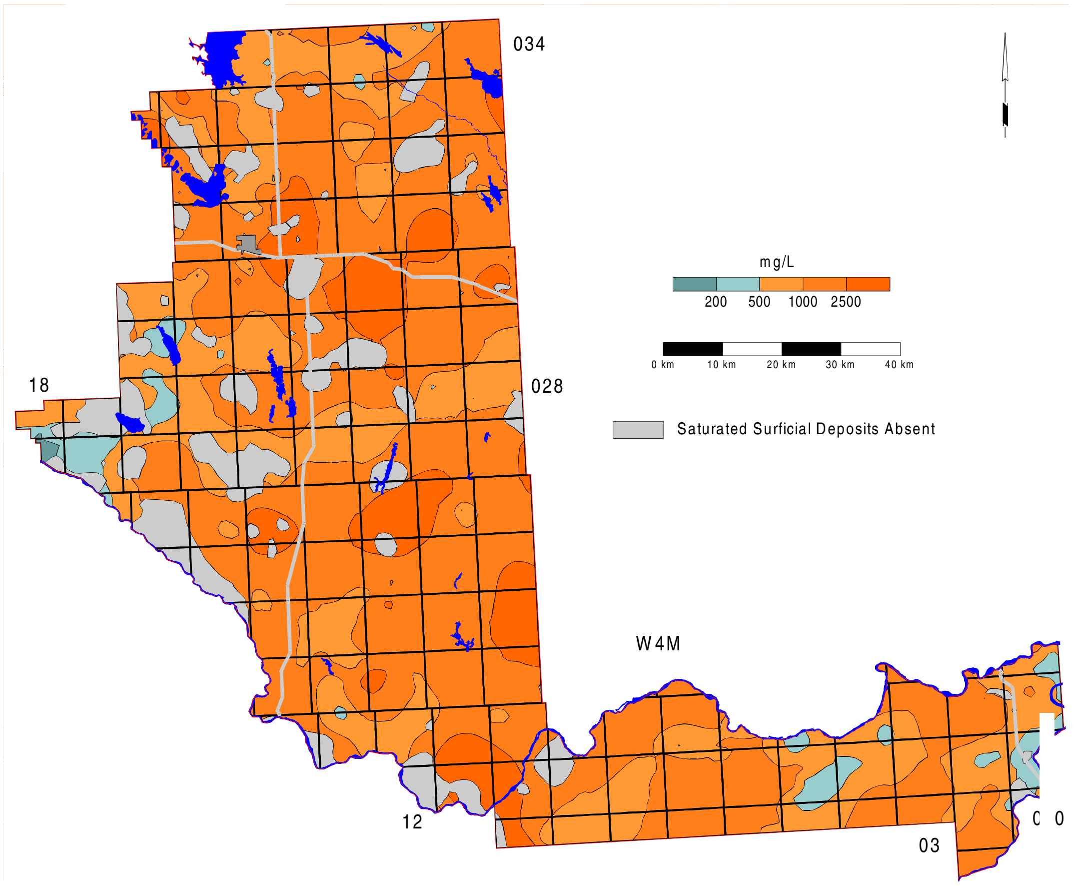
Total Dissolved Solids in Groundwater from Surficial Aquifer(s)

Special Areas

Special Area 2
Total Dissolved Solids in Groundwater from Surficial Aquifer(s)



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Candian Water Quality Guidelines, 1992

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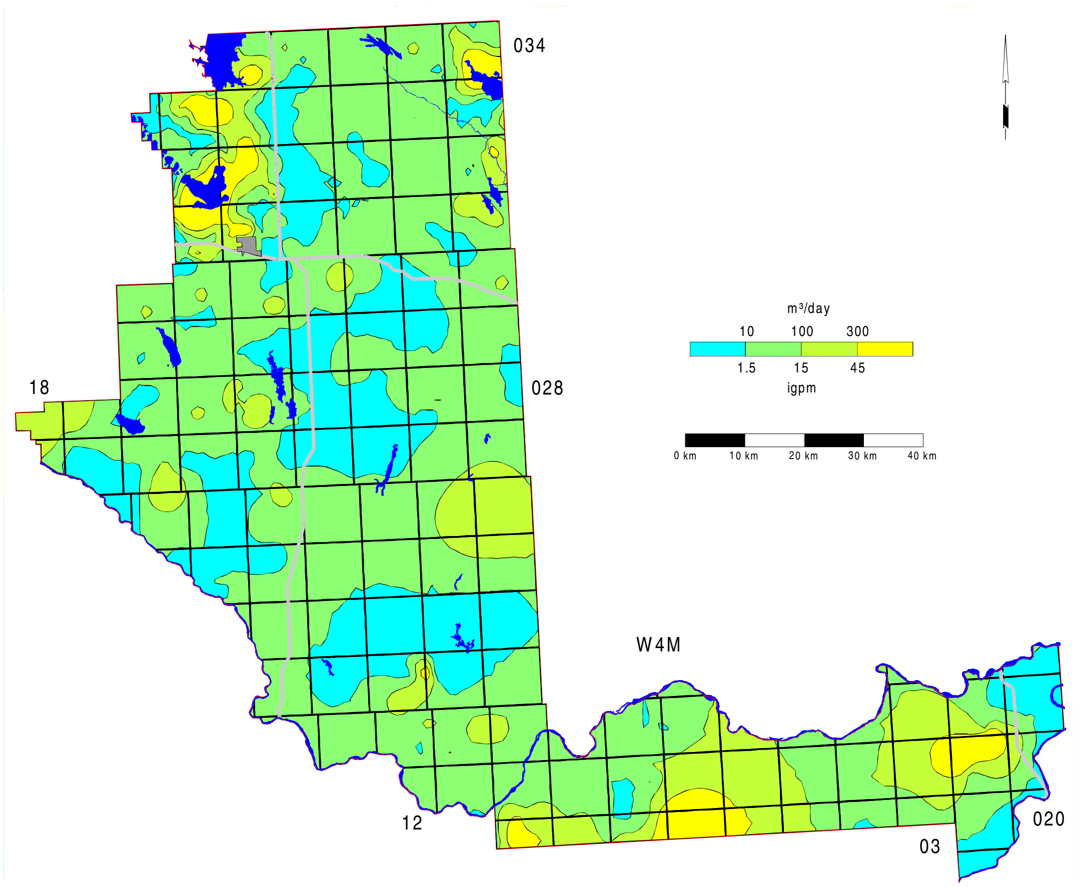
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Special Areas

Special Area 2
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



GROUNDWATER CONSUMPTION

Goundwater Purpose $^{(1)(2)}$	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household
(2) traditional agriculture use as defined in the Water Act

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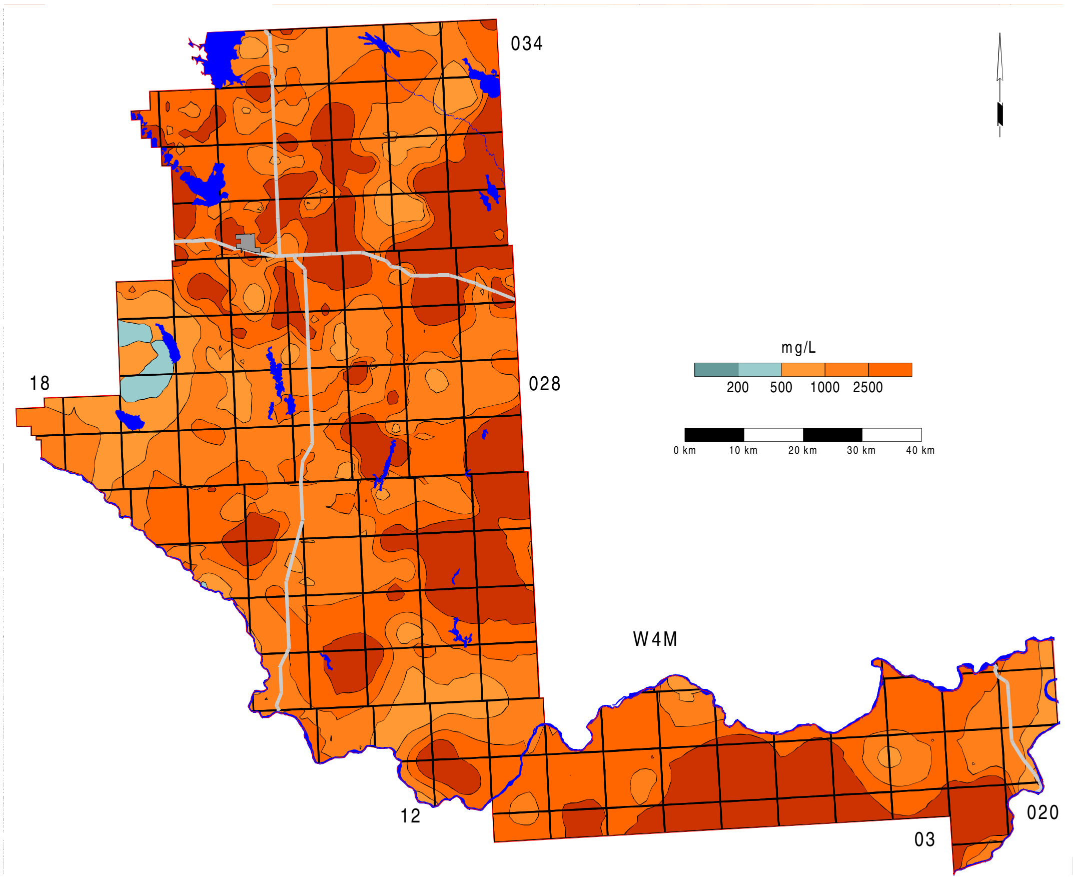
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

Special Area 2
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Candian Water Quality Guidelines, 1992

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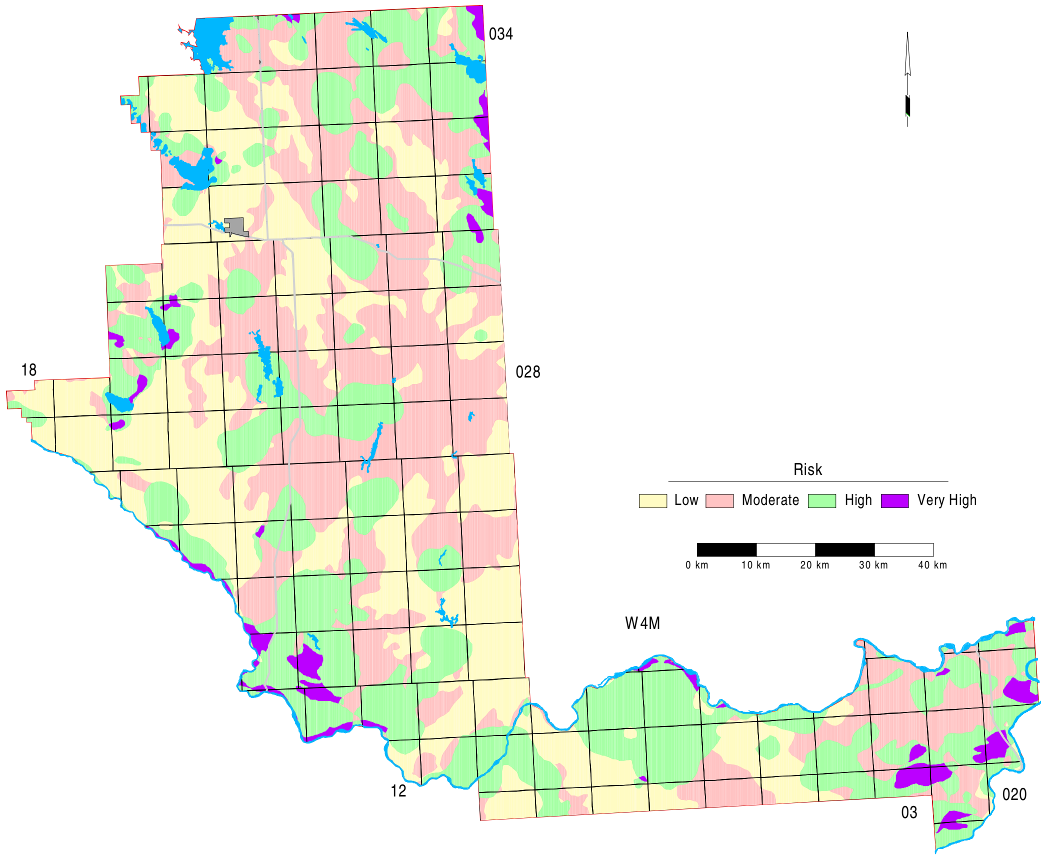
Risk of Groundwater Contamination

Special Areas

Special Area 2
Risk of Groundwater Contamination



Risk of Groundwater Contamination Criteria

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

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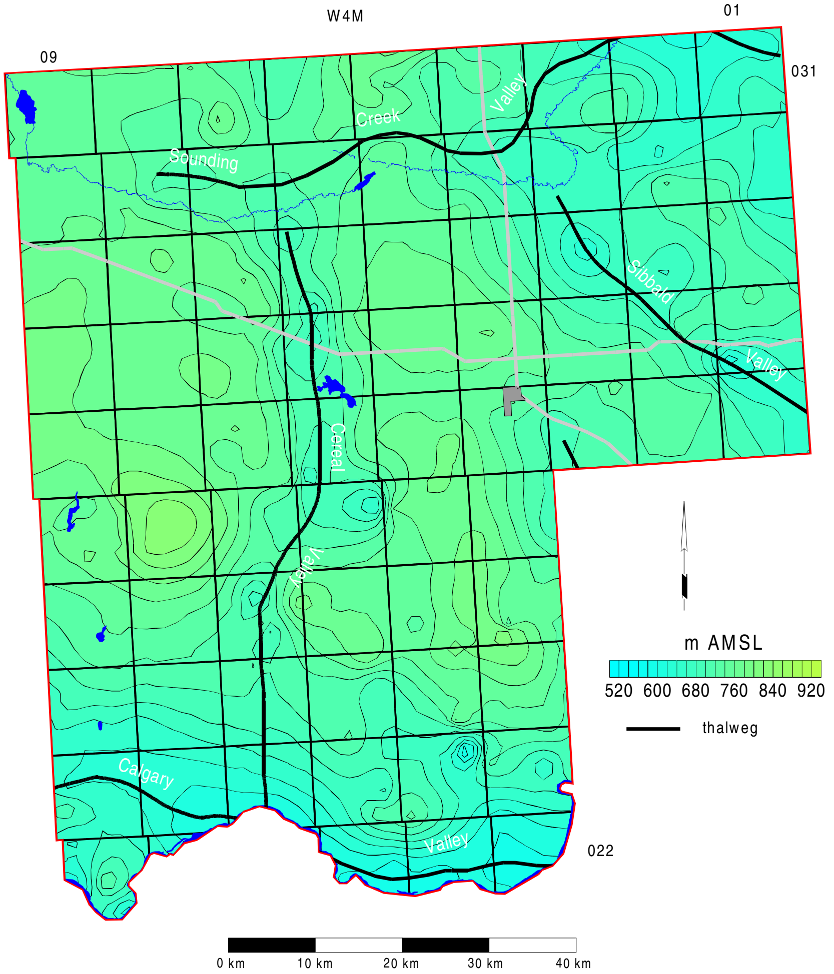
Special Area 3

Bedrock Topography

Special Areas

Special Area 3

Bedrock Topography



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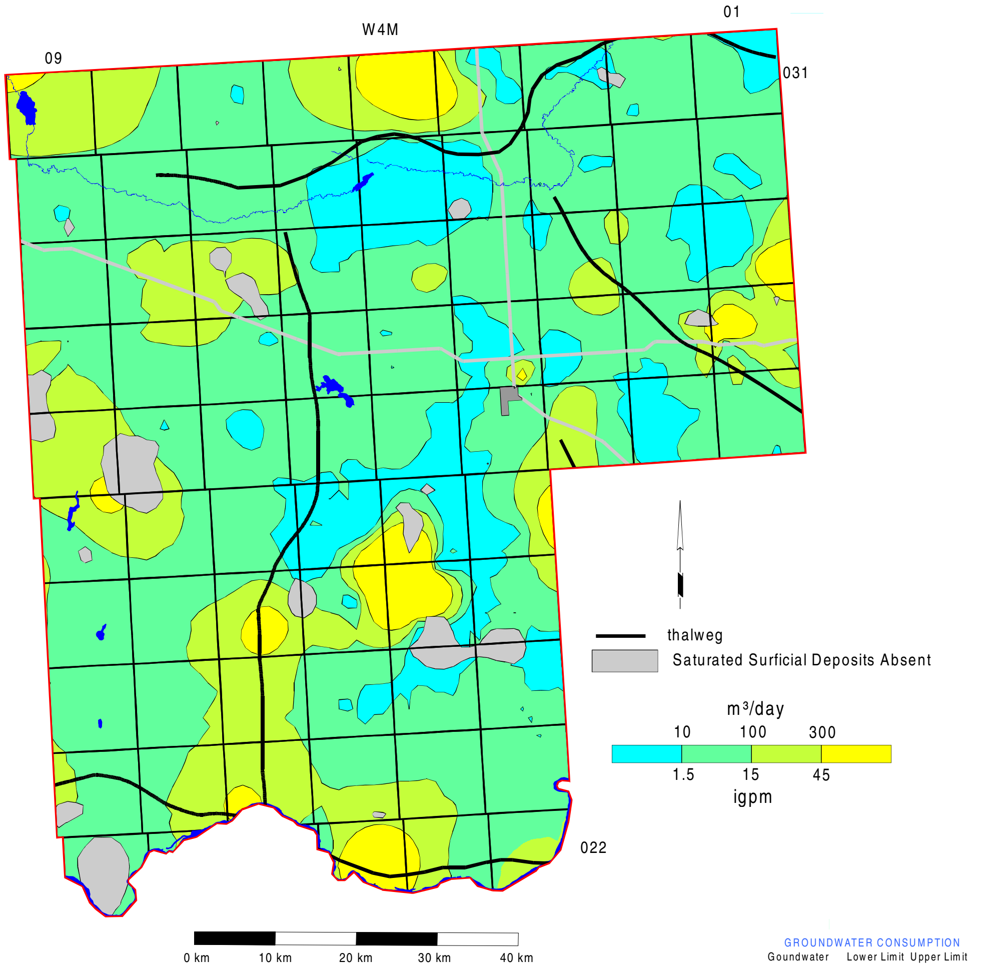
Apparent Yield for Water Wells Completed in Surficial Aquifer(s)

Special Areas

Special Area 3
Apparent Yield for Water Wells Completed in Surficial Aquifer(s)



GROUNDWATER CONSUMPTION

Goundwater Purpose (1) (2)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household
(2) traditional agriculture use as defined in the Water Act

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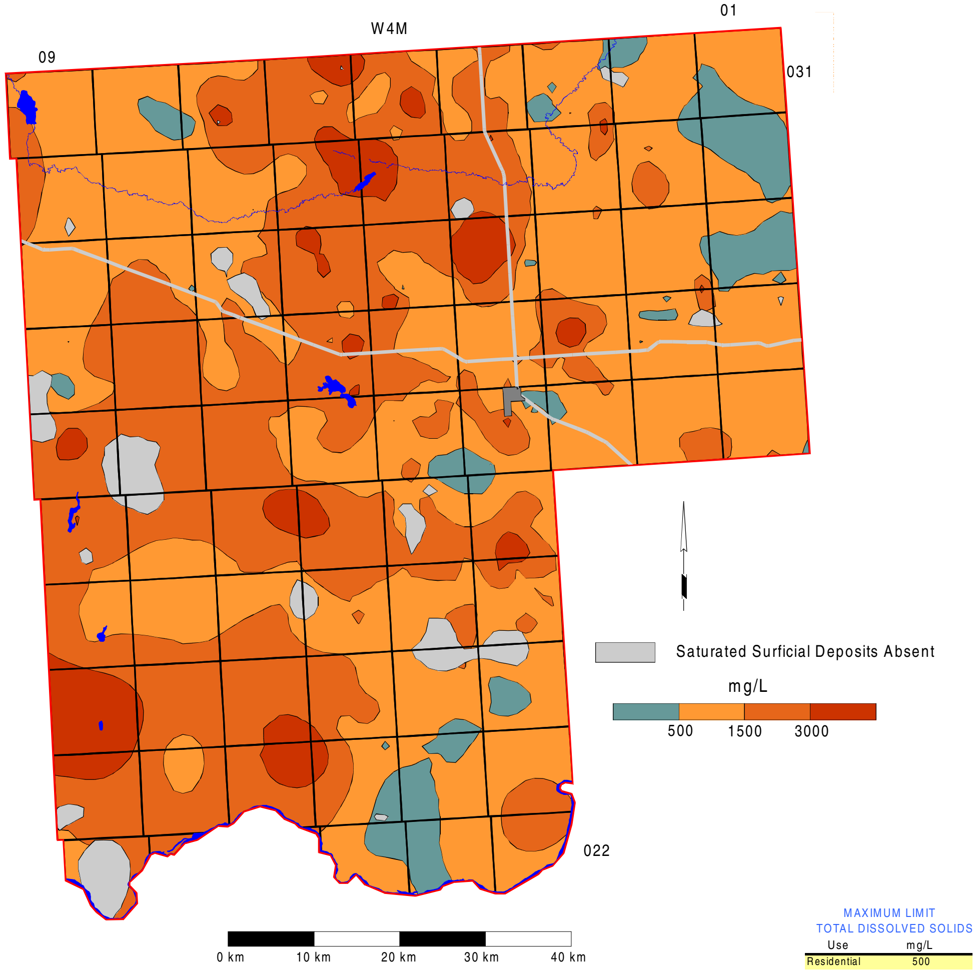
Total Dissolved Solids in Groundwater from Surficial Aquifer(s)

Special Areas

Special Area 3
Total Dissolved Solids in Groundwater from Surficial Aquifer(s)



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Candian Water Quality Guidelines, 1992

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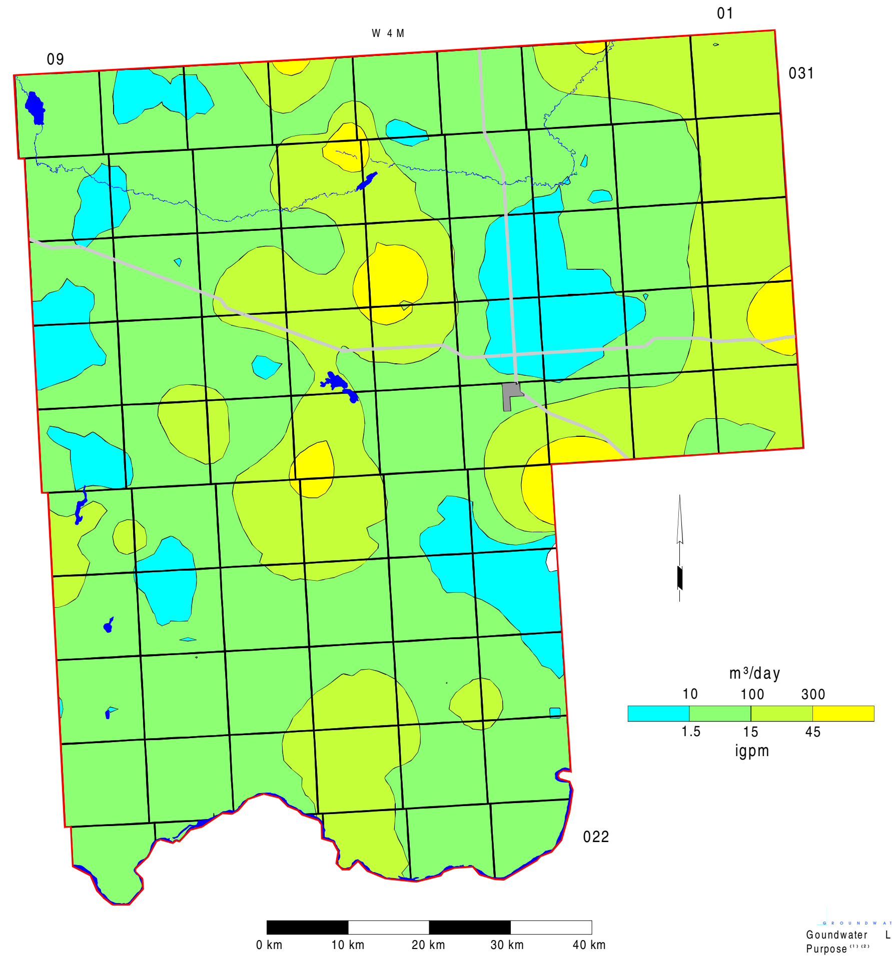
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Special Areas

Special Area 3
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



GROUNDWATER CONSUMPTION

Goundwater Purpose [(1)] [(2)]	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household
(2) traditional agriculture use as defined in the Water Act

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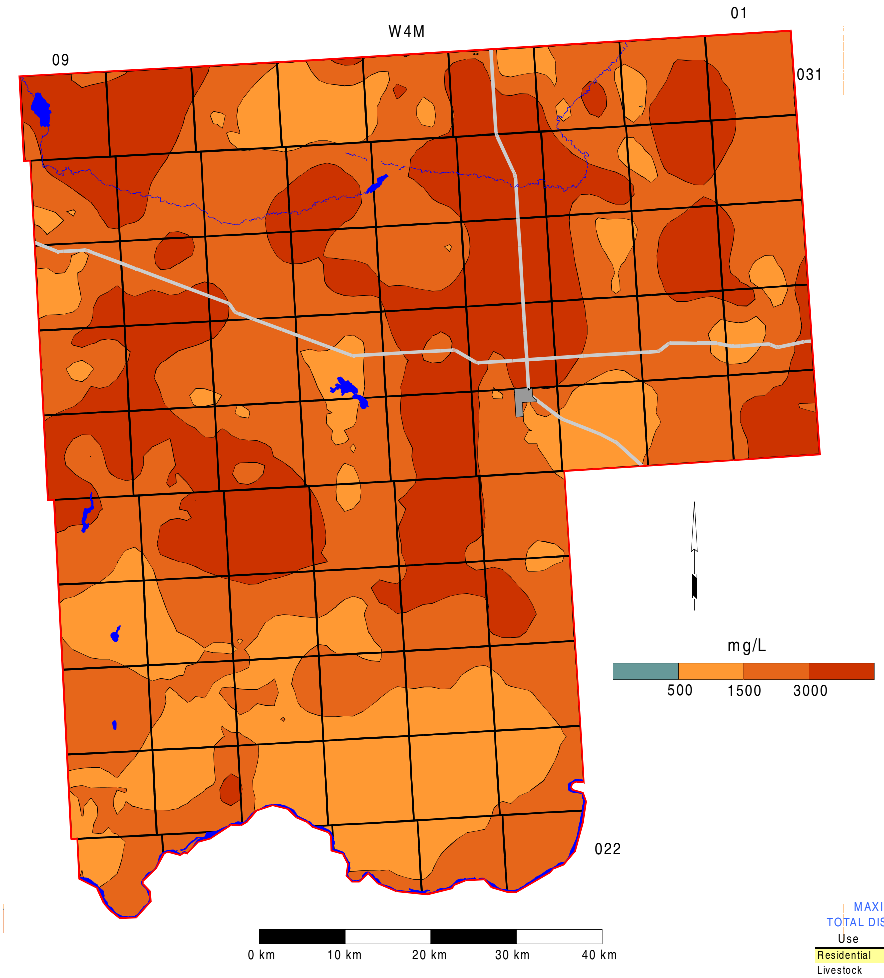
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

Special Areas

Special Area 3
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Candian Water Quality Guidelines, 1992

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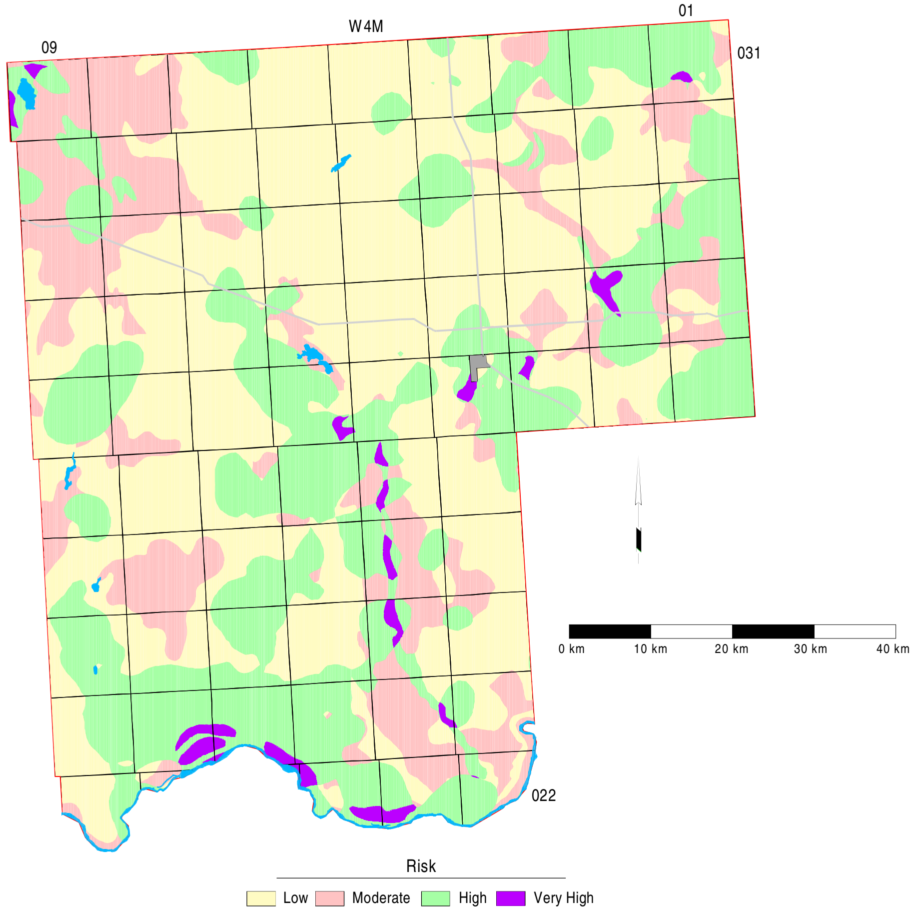
Risk of Groundwater Contamination

Special Areas

Special Area 3
Risk of Groundwater Contamination



Risk of Groundwater Contamination Criteria

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

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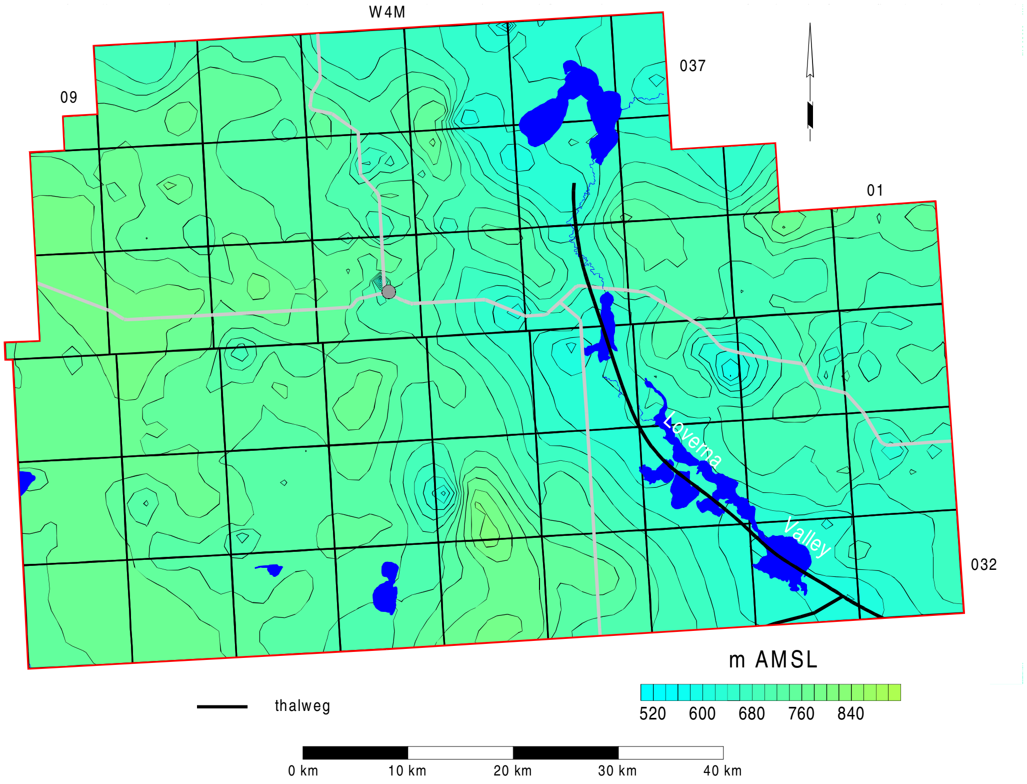
Special Area 4

Bedrock Topography

Special Areas

Special Area 4

Bedrock Topography



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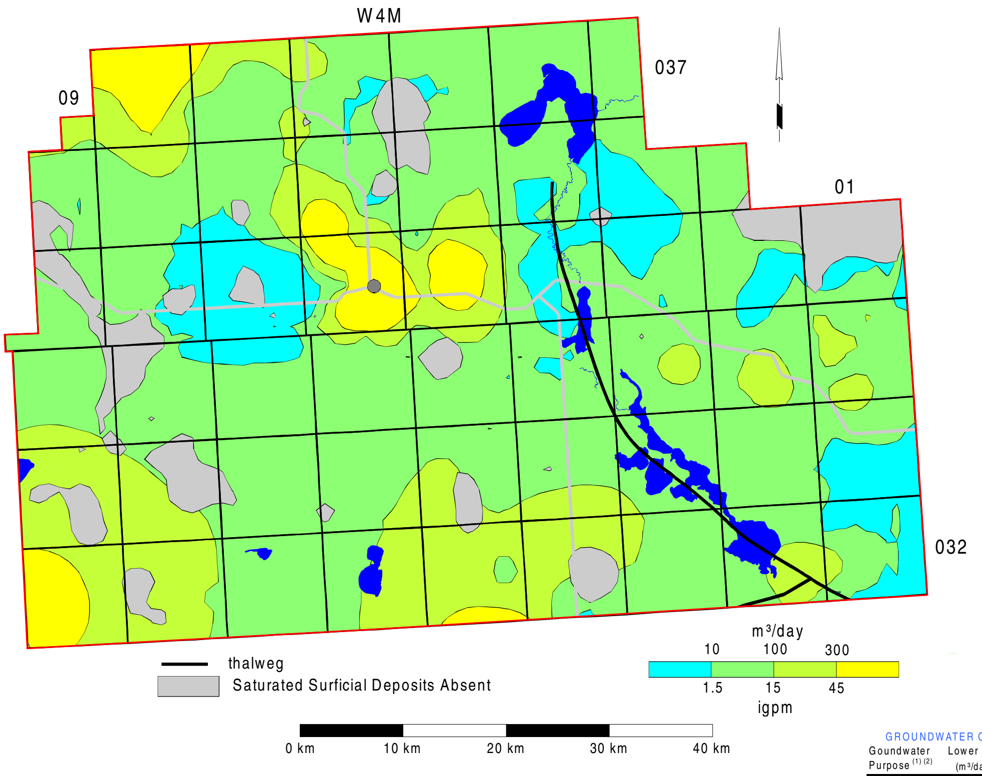
Apparent Yield for Water Wells Completed in Surficial Aquifer(s)

Special Areas

Special Area 4
Apparent Yield for Water Wells Completed in Surficial Aquifer(s)



GROUNDWATER CONSUMPTION

Goundwater Purpose (1) (2)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household
(2) traditional agriculture use as defined in the Water Act

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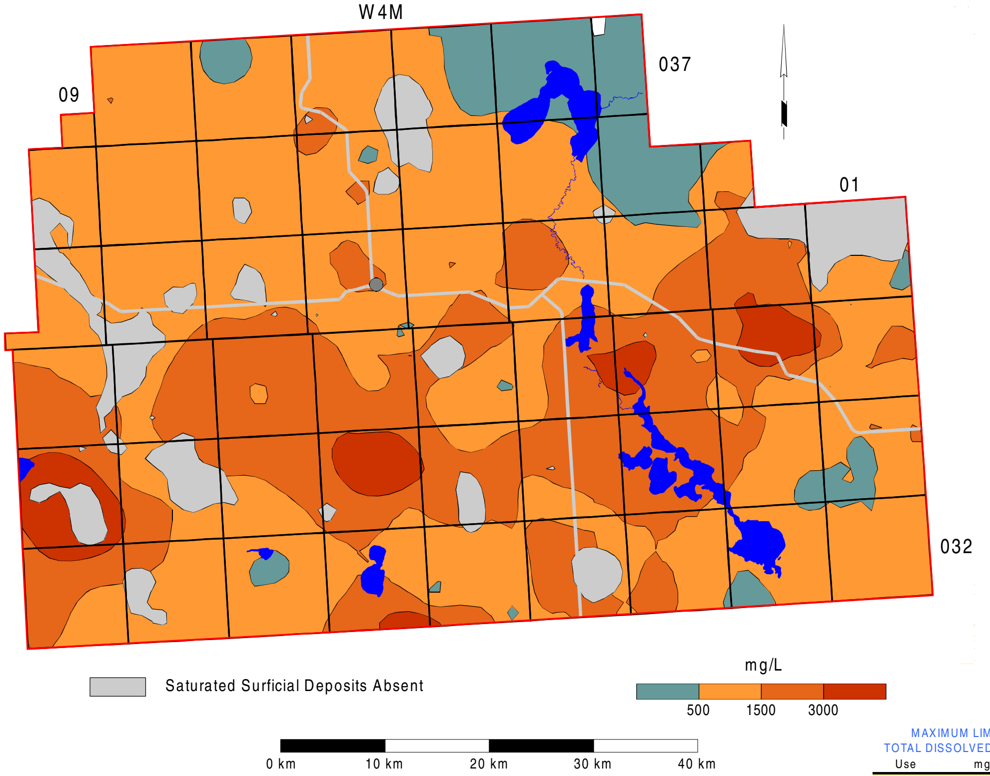
Total Dissolved Solids in Groundwater from Surficial Aquifer(s)

Special Areas

Special Area 4
Total Dissolved Solids in Groundwater from Surficial Aquifer(s)



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Candian Water Quality Guidelines, 1992

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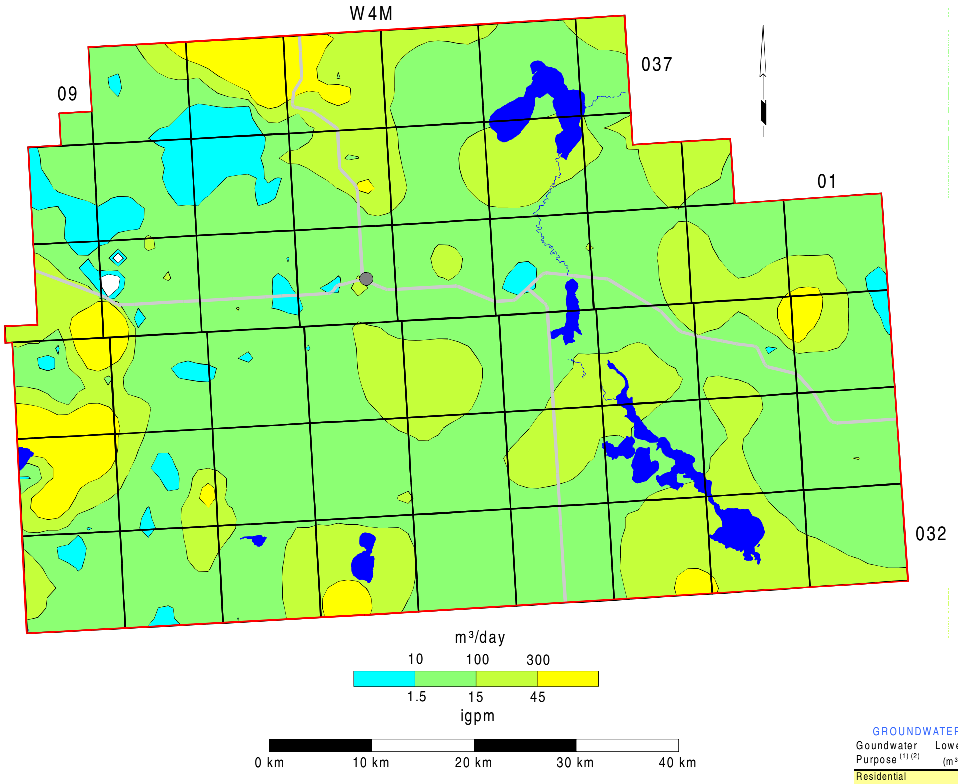
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Special Areas

Special Area 4
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



GROUNDWATER CONSUMPTION

Goundwater Purpose (1) (2)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household
(2) traditional agriculture use as defined in the Water Act

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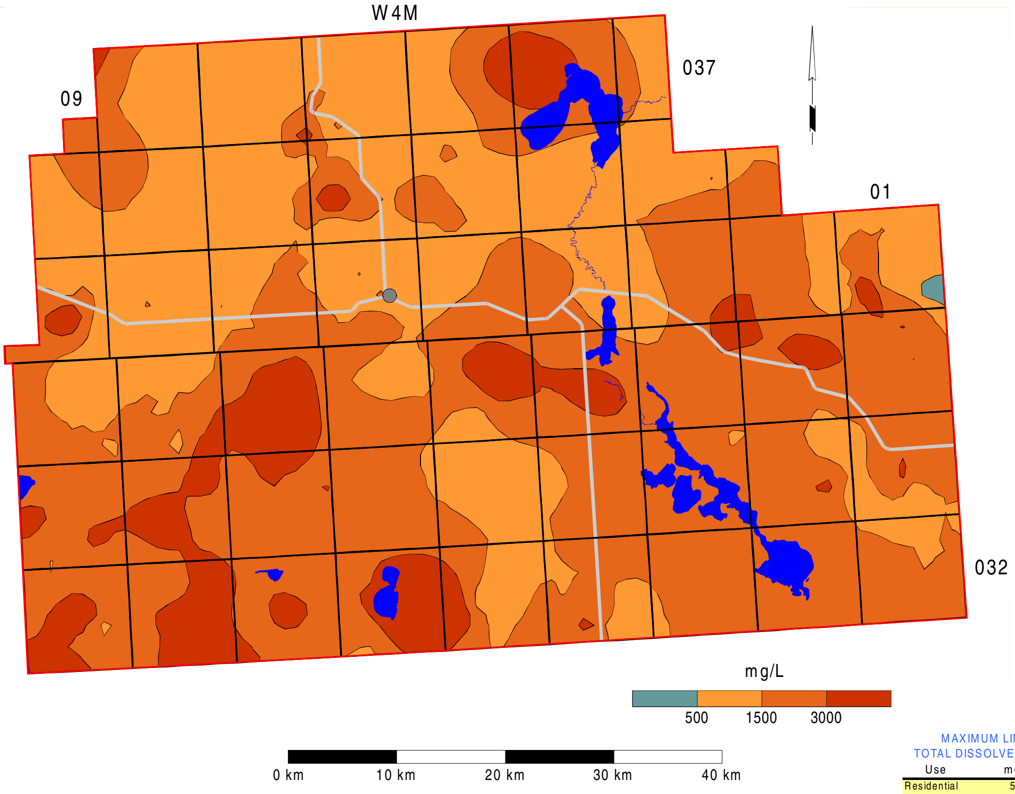
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

Special Areas

Special Area 4
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Candian Water Quality Guidelines, 1992

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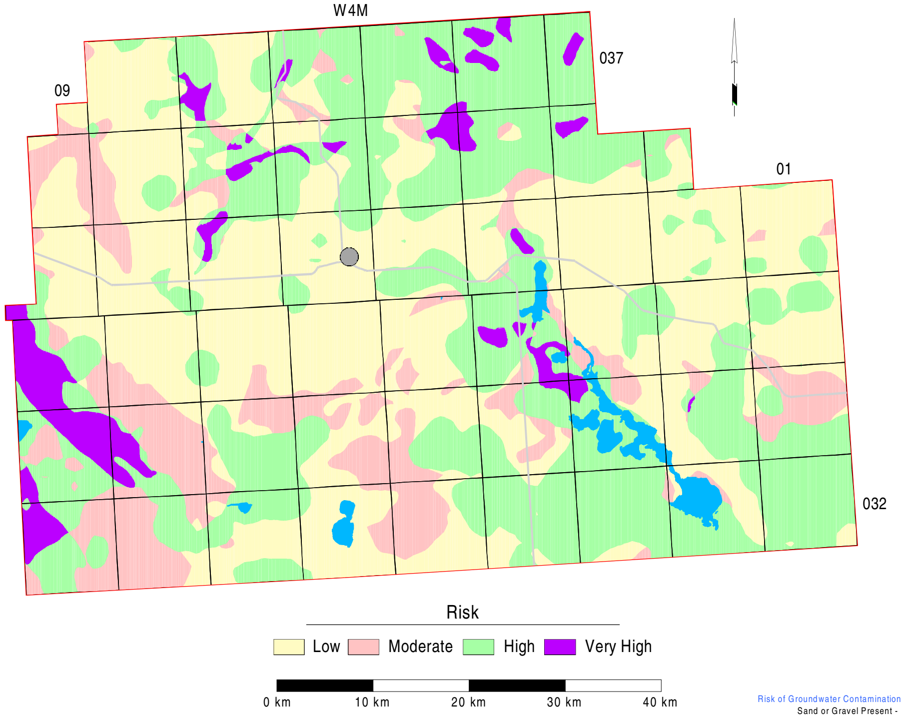
Risk of Groundwater Contamination

Special Area 4
Risk of Groundwater Contamination



Risk of Groundwater Contamination Criteria

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

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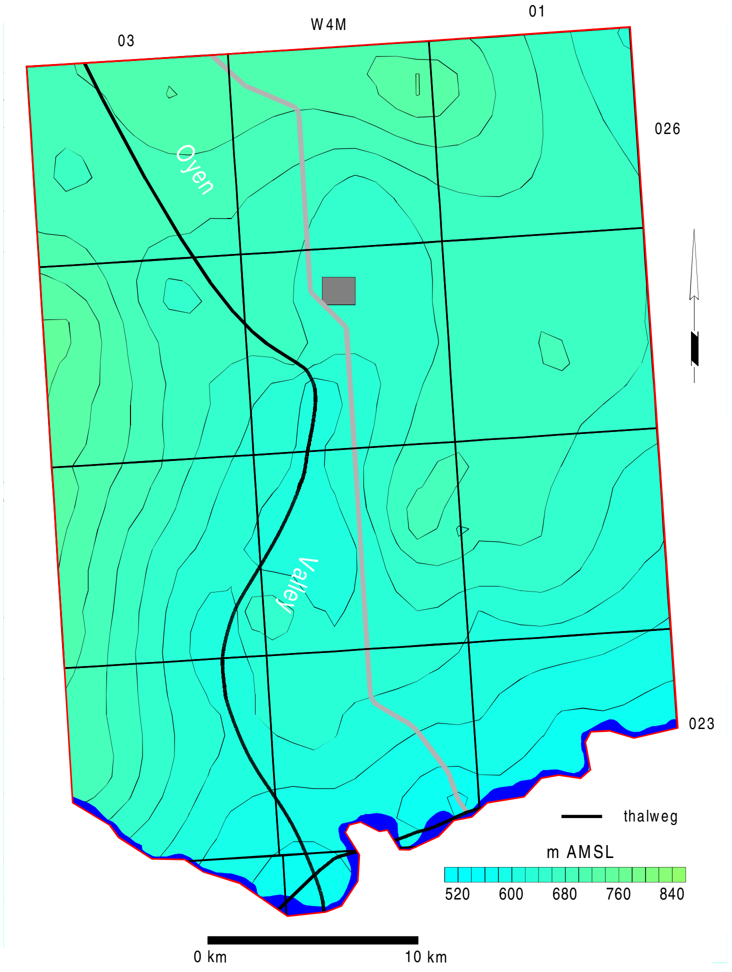
M.D. of Acadia No. 34

Bedrock Topography

M.D. of Acadia No. 34

Bedrock Topography



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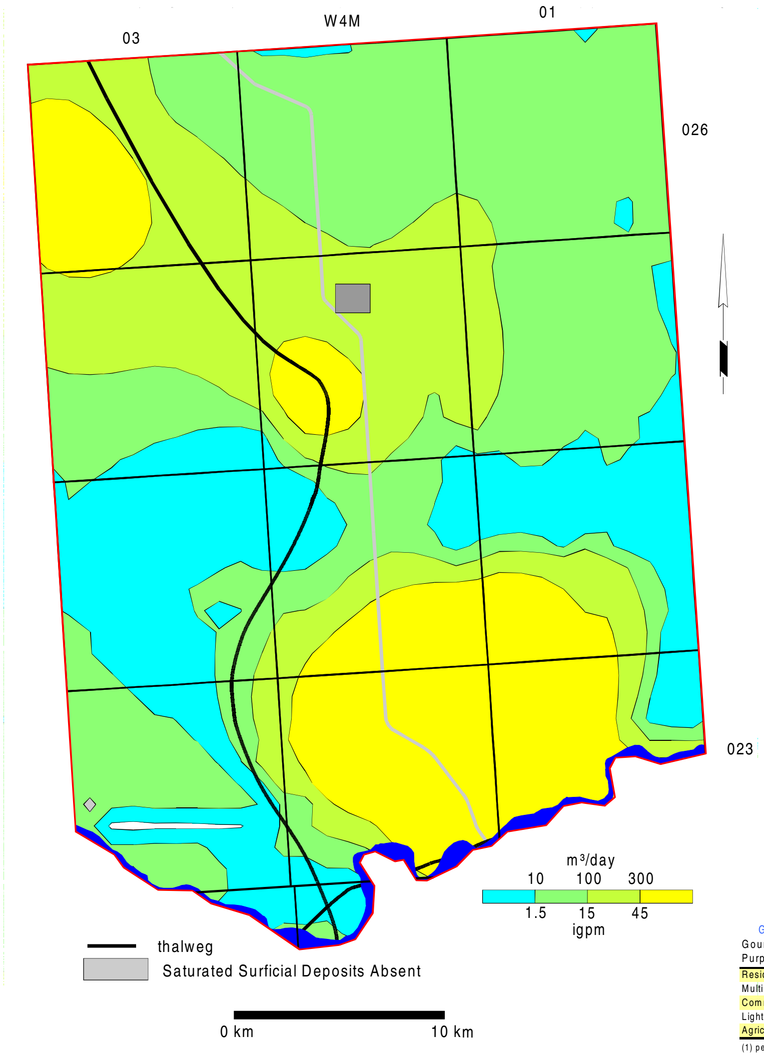
Apparent Yield for Water Wells Completed in Surficial Aquifer(s)

M.D. of Acadia No. 34
Apparent Yield for Water Wells Completed in Surficial Aquifer(s)



GROUNDWATER CONSUMPTION

Goundwater Purpose (1) (2)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household
(2) traditional agriculture use as defined in the Water Act

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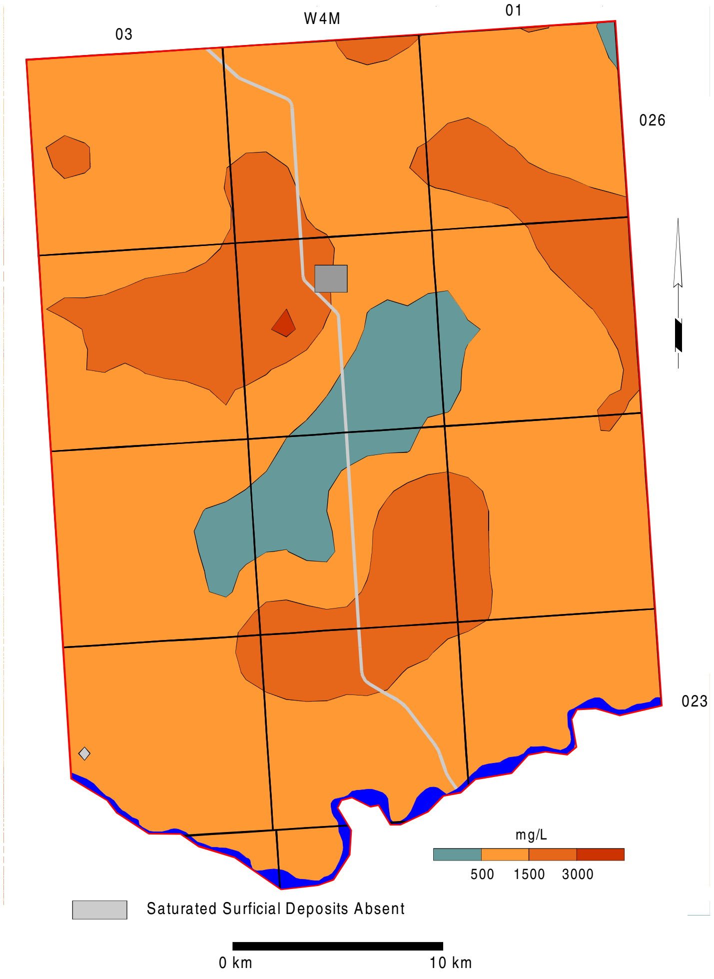
hydrogeological consultants ltd. edmonton, alberta - 1.800.661.7972 - project no. 99-101

Total Dissolved Solids in Groundwater from Surficial Aquifer(s)

M.D. of Acadia No. 34
Total Dissolved Solids in Groundwater from Surficial Aquifer(s)



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Candian Water Quality Guidelines, 1992

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Prairie Farm Rehabilitation Administration

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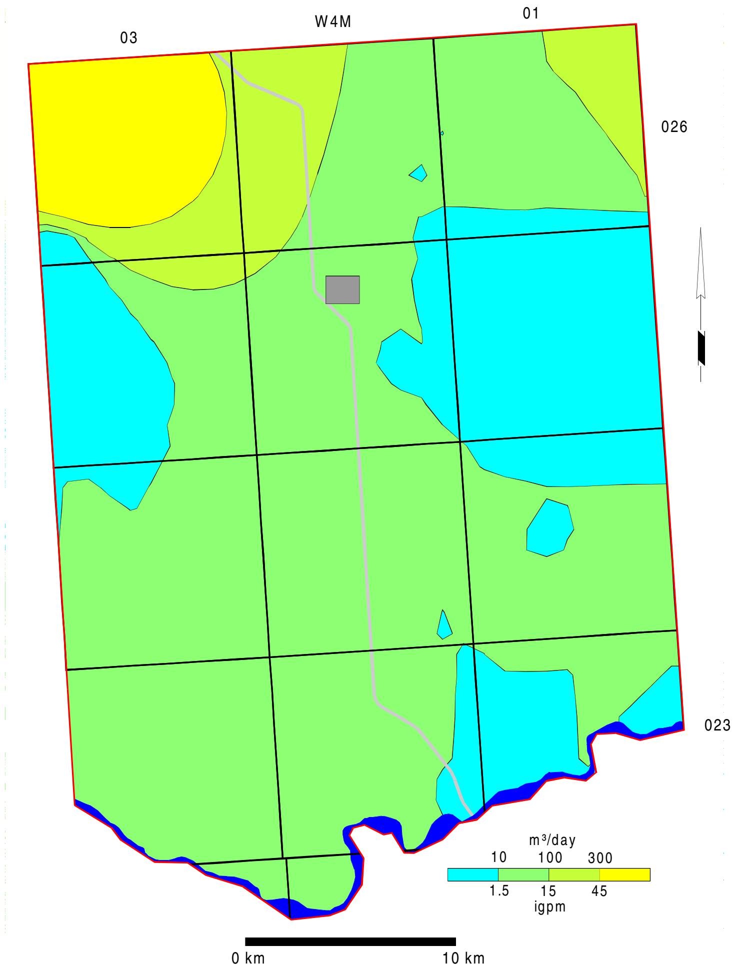
hydrogeological consultants ltd.

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

M.D. of Acadia No. 34
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



GROUNDWATER CONSUMPTION

Goundwater Purpose (1) (2)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential	1.1	3.4
Multi Parcel	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural	17.1	max. available

(1) per household
(2) traditional agriculture use as defined in the Water Act

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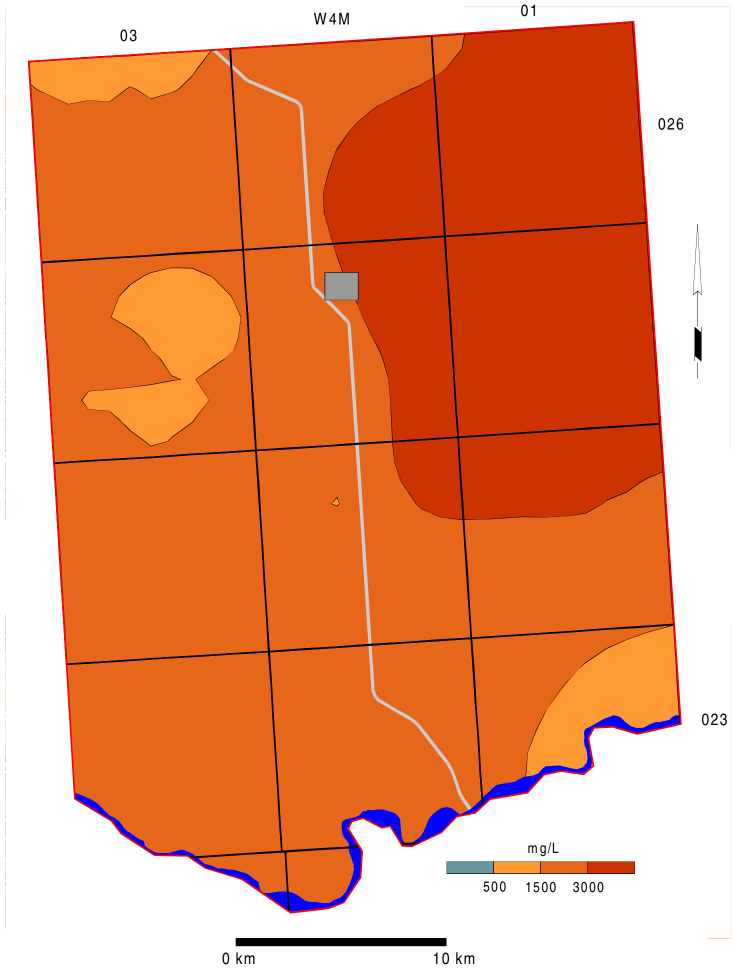
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

M.D. of Acadia No. 34
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

from: Candian Water Quality Guidelines, 1992

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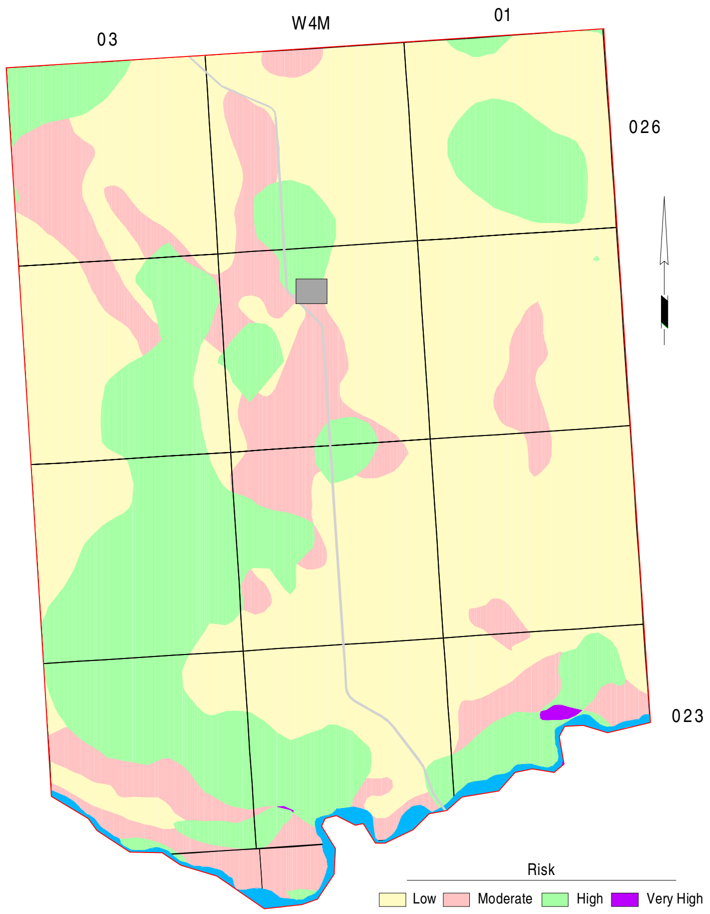
Risk of Groundwater Contamination

M.D. of Acadia No. 34
Risk of Groundwater Contamination



Risk of Groundwater Contamination Criteria

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

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Appendix E

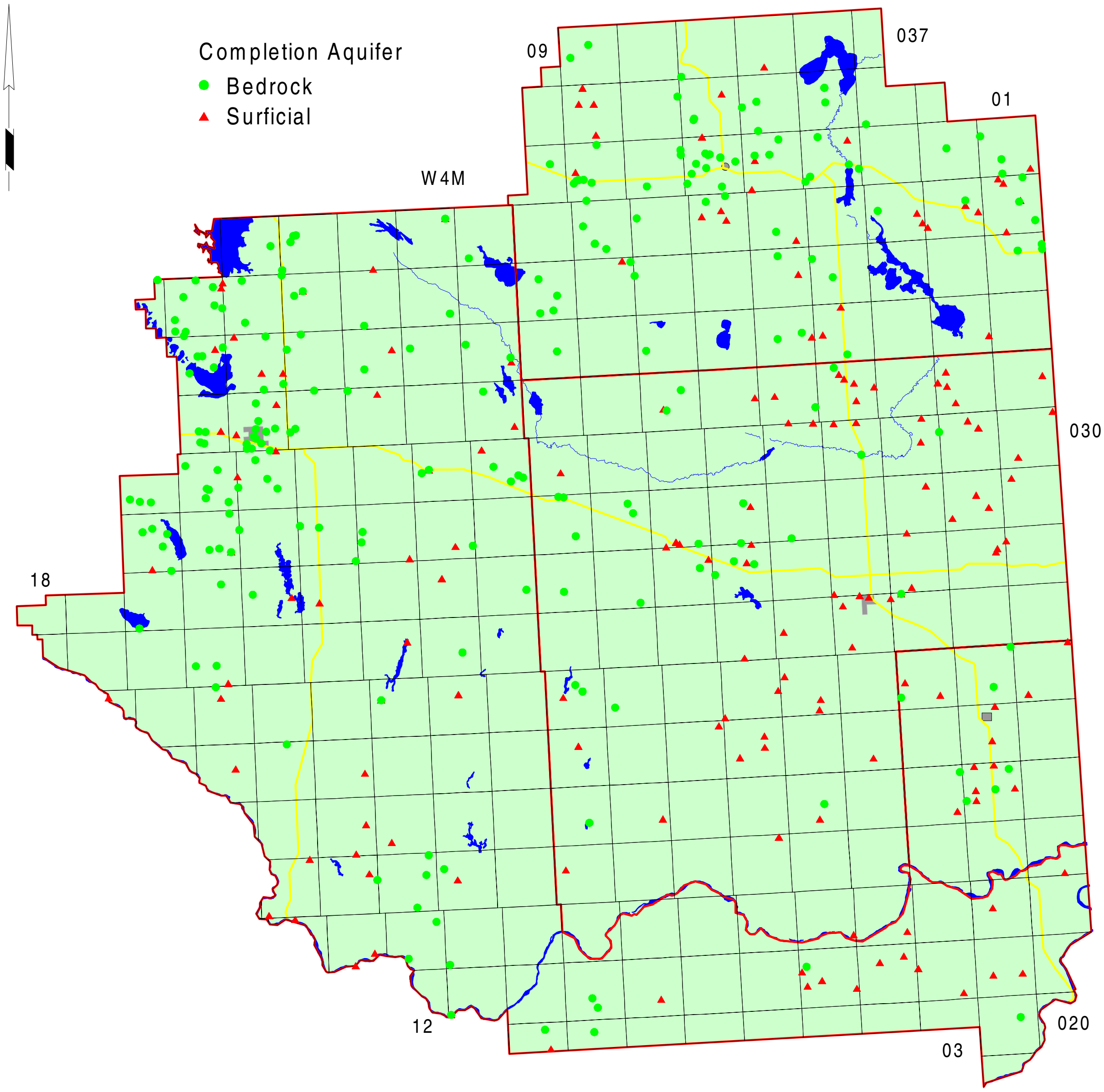
WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

AND

SPECIAL AREAS AND M.D. - OPERATED WATER WELLS

Water Wells Recommended for Field Verification

(details on following pages)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth		NPWL	
				Metres	Feet	Metres	Feet
271098 Alberta, Ltd.	NW-20-034-06 W4M	Upper Surficial	October-81	35.1	115.0	3.0	9.8
62 Bar	NE-07-031-14 W4M	Upper Surficial	April-79	47.6	156.0	14.6	48.0
Abramoff, Mike	SW-07-034-02 W4M	Upper Surficial	June-73	36.6	120.0	30.8	101.1
Acadia Argo Service	NE-34-027-04 W4M	Upper Surficial	July-80	6.7	22.0	1.8	6.0
Acadia Colony	SW-07-026-03 W4M	Bearpaw	August-71	94.5	310.0	59.0	193.5
Acadia Colony	NE-18-026-03 W4M	Lower Surficial	October-74	59.7	196.0	19.0	62.2
Adams, Murray	NW-34-035-08 W4M	Bearpaw	October-82	74.1	243.0	36.0	118.0
Aitken, Doug	SW-05-029-07 W4M	Upper Surficial	October-77	17.7	58.0	15.2	50.0
Alberta Environment	05-19-021-03 W4M	Lower Surficial	November-88	93.9	308.0	47.0	154.3
Alberta Environment	05-19-021-03 W4M	Upper Surficial	November-88	51.5	169.0	44.7	146.5
Alberta Environment	04-25-023-13 W4M	Upper Surficial	November-85	49.4	162.0	20.0	65.6
Alberta Environment	NW-36-023-12 W4M	Oldman	June-78	90.5	297.0	29.3	96.0
Alberta Environment	NE-23-028-02 W4M	Upper Surficial	March-85	34.4	113.0	8.2	26.9
Alberta Environment	04-27-025-09 W4M	Surficial	March-85	35.1	115.0	24.2	79.5
Alberta Environment	04-27-025-09 W4M	Lower Surficial	September-86	35.1	115.0	7.3	24.0
Alberta Environment	08-15-030-04 W4M	Oldman	October-89	65.5	215.0	15.5	50.9
Alberta Environment	13-25-034-11 W4M	Upper Surficial	July-86	11.0	36.0	4.0	13.1
Alberta Environment	09-33-032-04 W4M	Upper Surficial	July-86	45.7	150.0	20.4	67.0
Alberta Environment	13-25-034-11 W4M	Bearpaw	July-86	85.0	279.0	23.2	76.0
Alberta Environment	13-24-028-02 W4M	Upper Surficial	March-85	33.5	110.0	7.7	25.1
Alberta Environment	01-17-028-13 W4M	Upper Surficial	June-86	29.9	98.0	6.7	21.9
Alberta Environment	08-15-030-04 W4M	Oldman	November-88	36.0	118.0	18.7	61.2
Company Ltd.	NW-18-036-05 W4M	Oldman	June-76	95.4	313.0	59.4	195.0
Alberta Recreation & Parks	SW-26-036-06 W4M	Upper Surficial	March-90	15.5	51.0	0.3	1.0
Alberta Transportation	SE-28-031-04 W4M	Surficial	July-80	14.9	49.0	10.7	35.0
Andersen, Ray A.	NE-15-024-05 W4M	Oldman	March-77	145.1	476.0	82.3	270.0
Anderson, Jim	SE-16-028-09 W4M	Bearpaw	August-81	54.9	180.0	18.9	62.0
Anderson, Pete	SE-17-021-02 W4M	Upper Surficial	April-75	23.8	78.0	21.0	69.0
Anderson, William C.	NW-03-031-14 W4M	Lower Horseshoe Canyon	July-73	41.2	135.0	30.5	100.0
Andrus, Doan	NW-34-025-14 W4M	Bearpaw	June-77	24.4	80.0	6.1	20.0
Andrus, Gordon & Phil	SE-18-021-05 W4M	Upper Surficial	September-81	20.7	68.0	15.2	50.0
Annas, Nelson	NE-31-032-14 W4M	Upper Surficial	October-83	31.4	103.0	11.0	36.0
Armstrong, Jim	SE-16-029-15 W4M	Upper Horseshoe Canyon	September-84	48.8	160.0	36.6	120.0
Baier, Theodore J.	SW-30-035-01 W4M	Oldman	December-76	146.6	481.0	56.1	184.0
Baier, Wilfred	NW-09-035-01 W4M	Oldman	March-78	152.4	500.0	33.5	110.0
Barber, Charles	SE-34-035-05 W4M	Bearpaw	September-83	32.0	105.0	8.2	27.0
Barker, Howard	NW-36-030-05 W4M	Upper Surficial	August-84	9.1	30.0	3.1	10.0
Barry, Urben	NW-09-032-12 W4M	Bearpaw	August-79	88.4	290.0	39.3	129.0
Beaudoin, Ed	SW-26-031-07 W4M	Oldman	December-80	182.3	598.0	83.8	275.0
Beck, Ben	SE-22-025-15 W4M	Upper Surficial	October-78	21.3	70.0	8.2	27.0
Beck, Morris	SW-27-029-16 W4M	Upper Horseshoe Canyon	November-76	27.4	90.0	17.7	58.0
Beebe, Delford	NW-17-037-08 W4M	Bearpaw	August-76	95.4	313.0	38.7	127.0
Beier, Ed G.	NE-32-034-01 W4M	Upper Surficial	July-80	18.9	62.0	6.1	20.0
Beier, George	SW-20-034-03 W4M	Oldman	December-85	132.0	433.0	31.4	103.0
Beier, Herman	08-22-034-01 W4M	Upper Surficial	January-48	20.4	67.0	3.1	10.0
Beier, Tony	SW-33-034-01 W4M	Upper Surficial	June-80	36.6	120.0	30.5	100.0
Beier,Elmer	SE-22-034-01 W4M	Birch Lake	September-79	194.5	638.0	54.9	180.0
Bender Estate	SE-02-029-16 W4M	Upper Horseshoe Canyon	August-74	30.5	100.0	15.2	50.0
Benedict, Glen	SE-15-029-15 W4M	Upper Horseshoe Canyon	October-79	29.0	95.0	23.8	78.0
Benner, Harold	SE-18-031-13 W4M	Lower Horseshoe Canyon	May-84	7.0	23.0	4.9	16.0
Berg, Darcy	NW-16-032-05 W4M	Oldman	August-84	134.7	442.0	85.6	281.0
Berg, Marvin	NE-03-026-05 W4M	Upper Surficial	April-81	6.7	22.0	4.9	16.0
Big Stone Com Club	SW-27-026-09 W4M	Bearpaw	April-81	51.8	170.0	32.0	105.0
Bingeman, Mel	SE-27-030-02 W4M	Upper Surficial	September-83	14.3	47.0	4.4	14.5
Bingeman, Melvin	SW-26-030-02 W4M	Upper Surficial	October-85	12.2	40.0	5.2	17.0
Bishoff, Leonard	NW-32-024-02 W4M	Upper Surficial	December-78	9.1	30.0	4.3	14.0

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
Bitz, Vernet	SW-04-029-03 W4M	Upper Surficial	August-84	12.8	42.0	9.1	30.0
Blue, Neil	NE-12-032-02 W4M	Surficial	April-71	93.9	308.0	15.2	50.0
Bodnaruk, Dmitro	SW-10-024-05 W4M	Surficial	March-77	26.8	88.0	16.5	54.0
Bogen, Ivan	SE-32-035-04 W4M	Oldman	July-75	102.7	337.0	21.3	70.0
Bogi, John	SE-03-024-13 W4M	Upper Surficial	June-82	10.1	33.0	3.1	10.0
Bogi, Mike	NE-33-022-14 W4M	Lower Surficial	June-78	15.2	50.0	4.9	16.0
Bogi, Mike	SE-06-023-14 W4M	Lower Surficial	June-78	13.7	45.0	5.2	17.0
Bosh, George	SE-14-035-04 W4M	Birch Lake	October-70	128.0	420.0	18.7	61.3
Bossert, Ervin	SE-05-033-15 W4M	Lower Horseshoe Canyon	June-81	22.9	75.0	15.2	50.0
Bossert, Herb	NE-07-033-15 W4M	Middle Horseshoe Canyon	September-75	30.5	100.0	19.8	65.0
Bowers, George	SE-04-029-07 W4M	Upper Surficial	June-85	7.6	25.0	5.5	18.0
Bowthorpe, J	SW-28-033-09 W4M	Lower Horseshoe Canyon	December-66	32.6	107.0	6.7	22.0
Boyd, Gordon	NE-32-032-13 W4M	Lower Horseshoe Canyon	May-69	41.2	135.0	21.3	70.0
Brumwell, Robert	SE-23-031-01 W4M	Upper Surficial	June-75	42.7	140.0	21.9	72.0
Bullpound Community Club	NW-19-029-14 W4M	Lower Horseshoe Canyon	October-83	21.9	72.0	12.2	40.0
Bunn, Verna	NW-25-022-12 W4M	Oldman	August-79	19.8	65.0	6.4	21.0
Burgemeister, Fred	SW-15-030-15 W4M	Lower Horseshoe Canyon	April-80	43.9	144.0	30.8	101.0
Burgemeister, Garry	SW-15-030-15 W4M	Middle Horseshoe Canyon	December-75	27.4	90.0	14.0	46.0
Burgemeister, Gordon	SW-15-030-15 W4M	Lower Horseshoe Canyon	November-84	41.2	135.0	21.3	70.0
Burnat, Andrea	SE-16-021-09 W4M	Oldman	February-75	62.8	206.0	27.4	90.0
Burnat, Andrew	SW-10-021-09 W4M	Oldman	December-73	68.0	223.0	12.2	40.0
Burnat, Tim & Ted	SW-13-024-08 W4M	Surficial		48.8	160.0	42.7	140.0
Burns, Bill	SW-19-030-14 W4M	Surficial	May-86	36.6	120.0	6.0	19.8
Burrows, Robert	SW-22-030-14 W4M	Lower Horseshoe Canyon	December-81	29.0	95.0	2.7	9.0
Burry Creek School Division	NW-33-026-15 W4M	Lower Horseshoe Canyon	December-77	30.5	100.0	17.1	56.0
Butler, Jack	NE-27-029-08 W4M	Bearpaw	June-80	18.0	59.0	7.0	23.0
Caldwell, Ken T.H # 3	SW-04-034-01 W4M	Upper Surficial	May-88	31.1	102.0	7.3	24.0
Callahan, Don	SE-32-030-14 W4M	Lower Horseshoe Canyon	July-74	18.3	60.0	3.1	10.0
Cameron, H.	SE-20-030-11 W4M	Upper Surficial	September-77	12.5	41.0	4.3	14.0
Cameron, Hugh	SE-20-030-11 W4M	Lower Horseshoe Canyon	September-81	16.2	53.0	9.1	30.0
Campion, Keith	NE-28-031-14 W4M	Lower Horseshoe Canyon	September-82	48.2	158.0	38.1	125.0
Caribe Holdidngs Ltd.	04-15-027-15 W4M	Lower Horseshoe Canyon	July-78	43.3	142.0	20.1	66.0
Carter, Charles H.	NW-03-032-04 W4M	Oldman	January-78	114.3	375.0	27.4	90.0
Cartwright, Ray	NW-35-030-03 W4M	Upper Surficial	June-74	17.7	58.0	13.1	43.0
Caskey, Dale E.	NW-04-029-07 W4M	Surficial	February-77	39.6	130.0	7.6	25.0
Charton Farms Ltd.	SE-18-035-06 W4M	Oldman	July-88	180.4	592.0	106.7	350.0
Chorton Farm (Buxton)	SW-07-035-06 W4M	Bearpaw	November-77	30.5	100.0	12.2	40.0
Chritensen, Norman	NE-26-032-15 W4M	Upper Surficial	November-81	6.7	22.0	1.8	6.0
Cochrane Resources Ltd.	10-02-021-03 W4M	Surficial	October-75	65.8	216.0	16.8	55.0
Cody, Allan	SW-05-028-16 W4M	Upper Horseshoe Canyon	August-83	36.6	120.0	7.6	25.0
Connell, Pat	NE-09-034-05 W4M	Oldman	May-83	164.6	540.0	93.0	305.0
Connors, Lyle	SW-21-023-11 W4M	Lower Surficial	July-83	39.6	130.0	30.5	100.0
Cordell, Trevor	SW-06-028-04 W4M	Upper Surficial	October-81	7.6	25.0	4.6	15.0
Corry, C.	SW-28-033-13 W4M	Upper Surficial	September-66	22.9	75.0	11.9	39.0
Corry, Clifford	SW-28-033-13 W4M	Lower Horseshoe Canyon	January-68	21.9	72.0	12.9	42.3
Corry, Reg.	NW-20-033-13 W4M	Lower Horseshoe	June-82	11.6	38.0	6.7	22.0
Cottenoch, Dave	NE-32-033-14 W4M	Lower Horseshoe Canyon	December-72	32.0	105.0	22.9	75.0
Cruikshank, J.	13-12-029-15 W4M	Upper Surficial	May-79	32.6	107.0	20.5	67.3
Cruikshank, Jim	NW-12-029-15 W4M	Middle Horseshoe Canyon	November-79	42.7	140.0	20.7	68.0
Cruikshank, R.J.	SW-04-031-14 W4M	Lower Horseshoe Canyon	August-76	36.6	120.0	17.7	58.0
Cummings, Bill	NW-12-030-10 W4M	Bearpaw	October-76	36.6	120.0	4.8	15.8
Dalton, Bill	SW-29-031-02 W4M	Upper Surficial	December-80	14.6	48.0	6.1	20.0
Dandell, Eric	SW-12-031-10 W4M	Surficial	August-79	45.7	150.0	5.5	18.0
Deagle, Morris	SW-20-035-06 W4M	Bearpaw	August-74	75.0	246.0	29.0	95.0
Deleff, Harry/Jean	NE-12-035-04 W4M	Oldman	October-85	166.1	545.0	68.0	223.0
Deleff, M.	SW-20-035-05 W4M	Upper Surficial	October-71	30.2		11.0	

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth		NPWL	
				Metres	Feet	Metres	Feet
Devereux, Michael	SW-04-028-03 W4M	Upper Surficial	June-83	15.2	50.0	4.9	16.0
Devine, Ted	SW-06-037-06 W4M	Bearpaw	October-77	46.0	151.0	19.2	63.0
Dick, Paul	SW-10-025-04 W4M	Upper Surficial	October-77	4.9	16.0	3.7	12.0
Dieter, Robert	SE-16-030-15 W4M	Lower Horseshoe Canyon	September-74	32.0	105.0	12.8	42.0
Dillabough, Bruce	SW-11-026-03 W4M	Upper Surficial	October-79	11.6	38.0	2.4	8.0
Dinosaur Provincial Park	SW-07-021-11 W4M	Lower Surficial	August-87	19.8	65.0	4.5	14.8
Doering, Reinhold	NW-36-029-15 W4M	Lower Horseshoe Canyon	April-78	26.5	87.0	20.4	67.0
Doolan, Jim	SE-32-031-04 W4M	Oldman	November-74	141.1	463.0	60.4	198.0
Douglas, Lilian	SE-10-029-11 W4M	Upper Surficial	July-77	12.2	40.0	5.5	18.0
Duff, Majorie M.	SW-22-031-14 W4M	Lower Horseshoe Canyon	April-78	43.9	144.0	18.0	59.0
Duffield, Carl R. Yard Well	SE-27-029-06 W4M	Bearpaw	November-67	30.5	100.0	6.7	22.0
Duffield, Earl	NW-23-029-06 W4M	Upper Surficial	May-81	14.6	48.0	6.4	21.0
Duffield, Raymond	NW-23-029-08 W4M	Lower Horseshoe Canyon	May-81	11.0	36.0	4.9	16.0
Dumaresq Bros Ranch Ltd.	NE-04-037-05 W4M	Lower Surficial		144.5	474.0	79.2	260.0
Dziatkewich, Joe	SE-04-027-06 W4M	Upper Surficial	July-84	14.0	46.0	7.3	24.0
Edwards, George	SE-16-031-15 W4M	Lower Horseshoe Canyon	November-81	54.9	180.0	21.3	70.0
Edwards, Jack	NE-33-029-09 W4M	Bearpaw	July-65	22.9	75.0	13.7	45.0
Ekrol, John	SE-28-037-08 W4M	Oldman	August-77	177.4	582.0	70.1	230.0
Erion, Leo	NE-25-033-15 W4M	Upper Surficial	July-84	13.7	45.0	6.1	20.0
Ertmoed, Elmer	NE-12-021-05 W4M	Upper Surficial	May-75	11.6	38.0	2.4	8.0
Fawcett Clark	SE-28-035-06 W4M	Bearpaw	October-75	68.3	224.1	20.7	67.9
Fawcett, Doug	SE-25-035-07 W4M	Bearpaw	April-76	50.6	166.0	30.5	100.0
Fawcett, Douglas Well #1	NE-25-035-07 W4M	Bearpaw	April-76	42.7	140.0	21.9	72.0
Fecho, Fred	NE-33-031-13 W4M	Lower Horseshoe Canyon	July-80	22.9	75.0	8.2	27.0
Ference, Joe	SE-33-033-05 W4M	Oldman	September-80	183.5	602.0	73.5	241.0
Fitzsimmons, Ivan	NW-34-030-14 W4M	Lower Horseshoe Canyon	March-76	22.9	75.0	14.9	49.0
Flewelling, Gordon	SE-22-034-06 W4M	Upper Surficial	October-75	46.6	153.0	23.8	78.0
Foot, Frank	SW-19-031-02 W4M	Upper Surficial	December-80	12.8	42.0	2.7	9.0
Foot, Frank	SW-19-031-02 W4M	Upper Surficial	December-80	12.8	42.0	2.7	9.0
Fortna, Harold	NE-10-032-14 W4M	Upper Surficial	June-80	10.7	35.0	3.1	10.0
Fowley, Frank	NW-23-020-02 W4M	Oldman	November-73	128.0	420.0	115.8	380.0
Franklin, Clayton	SW-13-031-15 W4M	Upper Surficial	October-75	45.1	148.0	23.8	78.0
Galarneau, Dave	NW-12-032-10 W4M	Upper Surficial	September-81	9.1	30.0	4.3	14.0
Galster, Reinhard	SE-08-030-16 W4M	Upper Horseshoe Canyon	November-77	30.5	100.0	12.2	40.0
Garden Plain Com. Club	NW-31-033-13 W4M	Lower Horseshoe Canyon	April-84	41.2	135.0	21.3	70.0
Garlock, A.	SW-21-030-10 W4M	Bearpaw	May-72	27.4	90.0	4.6	15.0
Garlock, Dave	SW-32-030-10 W4M	Surficial	November-79	30.5	100.0	5.5	18.0
Garlock, Dave	SW-32-030-10 W4M	Upper Surficial	November-78	34.1	112.0	8.5	28.0
Gibson, Bill	NE-36-026-02 W4M	Oldman	August-80	164.0	538.0	26.3	86.4
Gilchrist, Stan	SW-15-030-09 W4M	Upper Surficial		8.5	28.0	4.9	16.0
Gilmer Kieth	NW-08-036-06 W4M	Oldman	September-71	146.9	482.0	75.9	249.0
Gilmer, Keith	NW-08-036-06 W4M	Oldman	September-76	153.3	503.0	75.9	249.0
Gilroyed, Harvey	SE-07-035-04 W4M	Oldman	July-79	103.6	340.0	42.1	138.0
Girletz, Wilf	SE-16-031-07 W4M	Oldman	August-74	210.0	689.0	64.9	213.0
Girletz, Wilf	SW-16-031-07 W4M	Upper Surficial	September-68	10.4	34.0	3.7	12.0
Golby, Lloyd	SE-14-032-10 W4M	Bearpaw	May-74	25.9	85.0	3.7	12.0
Goodbrand, D.	SE-14-028-10 W4M	Bearpaw	May-76	85.3	280.0	41.2	135.0
Gorcak, George	NE-09-035-08 W4M	Lower Horseshoe Canyon	March-83	18.0	59.0	7.9	26.0
Gould Farms Ltd.	SW-27-034-06 W4M	Upper Surficial	September-76	17.4	57.0	8.2	27.0
Gould, Jack	SE-32-034-06 W4M	Oldman	May-80	133.8	439.0	42.1	138.0
Grebinski, Ed	NW-22-032-15 W4M	Lower Horseshoe Canyon	May-83	19.8	65.0	13.1	43.0
Greenfield, George	NE-21-035-05 W4M	Oldman	October-75	143.3	470.0	13.6	44.7
Griffith, Gene	SW-30-029-13 W4M	Lower Horseshoe Canyon	August-80	16.8	55.0	15.2	50.0
Gross, Walter	NE-23-032-12 W4M	Upper Surficial	August-78	7.3	24.0	3.1	10.0
Guenthner, Dave	NE-16-036-04 W4M	Oldman	September-73	72.5	238.0	0.5	1.5

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
Haas, Wallace F.	SE-14-021-02 W4M	Upper Surficial	October-69	18.3	60.0	10.7	35.0
Hadwin Brothers	SE-06-035-05 W4M	Upper Surficial	July-85	54.0	177.0	18.9	62.0
Hager, Nick	SE-25-033-01 W4M	Oldman	May-62	145.7	478.0	33.5	110.0
Hamlet Of Iddesleigh	SE-34-020-10 W4M	Oldman	December-75	95.1	312.0	44.2	145.0
Hamlet Of Monitor	NW-06-035-04 W4M	Birch Lake	July-85	154.5	507.0	9.1	30.0
Handhills #1	04-28-029-16 W4M	Upper Horseshoe Canyon		96.0	315.0	79.5	260.9
Handhills #2	04-28-029-16 W4M	Upper Scollard		39.0	128.0	36.3	119.0
Handhills Lake Club	NE-23-029-16 W4M	Upper Horseshoe Canyon	October-82	36.6	120.0	9.8	32.0
Harvey, R.G.	NW-35-030-14 W4M	Surficial	November-67	28.0	92.0	12.2	40.0
Hayes, A.	SW-20-028-14 W4M	Middle Horseshoe Canyon	November-63	18.3	60.0	11.0	36.0
Hayworth, Wilf	SE-23-032-05 W4M	Oldman	June-79	203.0	666.0	114.3	375.0
Heatherington, Gordon	NE-12-031-05 W4M	Oldman	June-81	123.1	404.0	77.7	255.0
Heck, Arlene	SE-19-029-12 W4M	Lower Horseshoe Canyon	May-82	20.7	68.0	9.8	32.0
Heck, John	NE-23-027-12 W4M	Lower Surficial	May-80	9.1	30.0	3.7	12.0
Heck, John	NE-23-027-12 W4M	Surficial	June-79	21.9	72.0	3.7	12.0
Heck, Richard	··-13-034-02 W4M	Upper Surficial	October-75	12.2	40.0	9.1	30.0
Heeg, Ed	SW-12-024-03 W4M	Upper Surficial	April-75	10.4	34.0	6.7	22.0
Heeg, Edward	SW-12-024-03 W4M	Surficial	April-77	103.6	340.0	68.6	225.0
Helfrich, John	SE-03-023-01 W4M	Upper Surficial	May-75	27.4	90.0	25.6	84.0
Hertz, Ralph	NW-32-030-04 W4M	Upper Surficial	April-70	18.3	60.0	9.1	30.0
High Crest Farms	SE-33-030-02 W4M	Upper Surficial	June-86	22.9	75.0	16.8	55.0
Hok, P.	SW-06-026-06 W4M	Upper Surficial	June-72	36.6	120.0	13.7	45.0
Horner, Brent	SW-13-025-13 W4M	Upper Surficial	September-78	18.3	60.0	15.9	52.0
Houghton, Percy	13-36-023-14 W4M	Upper Surficial	January-40	4.6	15.0	3.4	11.0
Howe, George	SE-12-022-05 W4M	Upper Surficial	May-75	10.7	35.0	3.1	10.0
Hudson'S Bay Oil And Gas	02-08-024-12 W4M	Lower Surficial	June-78	52.4	172.0	7.6	25.0
Huston, Dale	NW-30-028-01 W4M	Upper Surficial	May-83	18.3	60.0	12.2	40.0
Hutchings, Jim	NE-03-035-06 W4M	Oldman	July-84	114.3	375.0	38.1	125.0
Jackson, Henry	SE-12-029-11 W4M	Bearpaw	July-78	36.6	120.0	13.7	45.0
Jackson, T.	NE-10-030-10 W4M	Bearpaw	March-75	45.7	150.0	7.2	23.7
James, Stan	NE-10-031-14 W4M	Lower Horseshoe Canyon	July-71	27.4	90.0	10.7	35.0
Jaques, Roy	NE-33-027-04 W4M	Upper Surficial	June-83	12.8	42.0	4.3	14.0
Jensen, John	SW-30-033-07 W4M	Bearpaw	May-74	31.7	104.0	3.7	12.0
Johnson, Don	NW-36-033-16 W4M	Middle Horseshoe	June-75	41.5	136.0	27.4	90.0
Johnson, Donald	NW-36-033-16 W4M	Middle Horseshoe Canyon	July-80	30.5	100.0	25.6	84.0
Johnston, Vernon	SW-23-025-06 W4M	Upper Surficial	July-76	56.7	186.0	30.5	100.0
Jorgenson, Burt	NE-10-031-04 W4M	Upper Surficial	December-79	9.8	32.0	4.3	14.0
Jorgenson, Gary	NE-22-031-04 W4M	Upper Surficial	May-81	7.9	26.0	4.3	14.0
Kary, Harvey Well#2	NE-03-033-09 W4M	Bearpaw	June-84	54.9	180.0	21.3	70.0
Kautz, Carl	NW-07-031-13 W4M	Lower Horseshoe	May-83	10.1	33.0	3.1	10.0
Kelts, Bud	NE-22-035-06 W4M	Bearpaw	October-81	62.2	204.0	27.0	88.5
Kelts, Doug	NE-26-035-04 W4M	Upper Surficial	November-76	24.4	80.0	18.9	62.0
Kelts, Preston	NE-22-035-06 W4M	Bearpaw	July-80	62.8	206.0	18.3	60.0
Kirriemuir (Sp.Areas # 4)	NW-13-034-03 W4M	Surficial	September-85	163.1	535.0	49.4	162.0
Klassen, E.	NW-20-023-09 W4M	Surficial	December-64	85.3	280.0	76.2	250.0
Knapik, Brent	NW-34-024-02 W4M	Upper Surficial	October-81	4.3	14.0	2.4	8.0
Knapik, Jerry	SW-15-025-02 W4M	Upper Surficial	October-81	9.1	30.0	6.1	20.0
Kotanko, Al	SW-26-035-09 W4M	Lower Horseshoe Canyon	March-83	18.6	61.0	10.3	33.8
Kouppi, Ewalt	NW-04-033-09 W4M	Lower Horseshoe Canyon	May-84	30.5	100.0	10.7	35.0
Kreiser, Brian	NW-34-029-09 W4M	Bearpaw	November-80	19.8	65.0	7.0	23.0
Kroeger, Dale	SE-23-033-05 W4M	Upper Surficial	July-68	56.1	184.0	12.2	40.0
Kroker, Victor	NE-13-031-06 W4M	Upper Surficial	September-83	7.0	23.0	4.0	13.0
Kropinski, Merritt	NE-34-034-06 W4M	Oldman	August-73	152.4	500.0	106.7	350.0
Kuhn, Irwin	NE-10-026-02 W4M	Oldman	March-85	142.6	468.0	56.7	186.0

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth		NPWL	
				Metres	Feet	Metres	Feet
Kulyk, Mike	NE-35-023-06 W4M	Upper Surficial	July-69	7.9	26.0	3.1	10.0
Kulyk, Mike	16-35-023-06 W4M	Upper Surficial	January-52	7.6	25.0	4.9	16.0
Landis, George	SW-28-028-11 W4M	Upper Surficial	September-82	12.8	42.0	3.1	10.0
Landis, George	03-28-028-11 W4M	Upper Surficial	November-81	6.7	22.0	4.6	15.0
Lenfesty, Mark	SE-04-029-16 W4M	Upper Surficial	August-74	15.2	50.0	6.1	20.0
Likness, L.	NE-02-034-05 W4M	Upper Surficial	September-73	16.8	55.0	4.9	16.0
Little Gem Ranches Ltd.	SE-18-032-07 W4M	Oldman	May-74	197.5	648.0	64.6	212.0
Lockhart, Darcy	NE-07-026-08 W4M	Lower Horseshoe Canyon	November-79	50.3	165.0	41.2	135.0
Logan, Bruce	SW-36-025-07 W4M	Upper Surficial	October-82	9.1	30.0	3.7	12.0
Logan, Stan	SW-30-026-05 W4M	Upper Surficial	December-76	45.4	149.0	41.2	135.0
Long, Gordon	SE-19-035-08 W4M	Upper Surficial	October-85	21.6	71.0	4.3	14.0
Loran, Erwin	SW-17-024-02 W4M	Upper Surficial	April-75	10.7	35.0	10.7	35.0
Loyalist Hall Assn.	SW-09-035-07 W4M	Bearpaw	April-79	38.1	125.0	12.2	40.0
Lumsden, Wilfred	SW-30-032-13 W4M	Lower Horseshoe Canyon	January-69	13.1	43.0	8.5	28.0
Machell, Tom & Don	NW-18-028-06 W4M	Birch Lake	October-85	203.6	668.0	61.0	200.0
Mahura, Ted	SW-20-024-02 W4M	Upper Surficial	October-81	10.7	35.0	7.0	23.0
Mahura, Ted J.	SW-20-024-02 W4M	Upper Surficial	July-70	12.5	41.0	11.0	36.0
Mailler, P.	SE-14-030-10 W4M	Bearpaw	May-70	36.6	120.0	5.5	18.0
Malaka, Sylvester	SW-03-034-12 W4M	Upper Surficial	October-82	6.7	22.0	2.4	8.0
Manalta Coal Ltd.	SW-18-029-12 W4M	Lower Horseshoe Canyon	December-79	31.4	103.0	13.4	44.0
Marshall, Thomas A.	SE-09-031-14 W4M	Lower Horseshoe Canyon	April-74	27.4	90.0	6.1	20.0
Martin, Jobe	NE-26-031-14 W4M	Surficial	August-71	48.8	160.0	39.6	130.0
Mashon, Les	NE-28-026-15 W4M	Upper Surficial	August-74	10.7	35.0	8.2	27.0
Mattis, Albert	NW-31-031-12 W4M	Bearpaw	August-66	112.8	370.0	40.5	133.0
Mattis, Glen	NW-31-031-12 W4M	Lower Horseshoe	August-78	11.0	36.0	3.1	10.0
Mcbain, K.	SW-26-025-06 W4M	Upper Surficial	July-72	41.8	137.0	25.9	85.0
Mcbribe, Beatrice	NE-11-022-13 W4M	Surficial	May-85	25.3	83.0	21.3	70.0
Mcbride, J. A.	SE-24-023-13 W4M	Oldman	April-77	64.0	210.0	22.9	75.0
Mcburnie, A.L.	NE-10-021-08 W4M	Upper Surficial	December-79	14.6	48.0	6.1	20.0
Mccallum, M.	03-17-025-06 W4M	Upper Surficial	January-67	14.3	47.0	12.2	40.0
Mcdiarmid, Fred	SE-29-036-08 W4M	Upper Surficial	January-69	54.9	180.0	24.4	80.0
Mckillop, W.	SE-15-024-09 W4M	Oldman	November-76	83.8	275.0	56.1	184.0
Mcnally Bros.	SW-04-029-05 W4M	Bearpaw	November-60	61.9	203.0	12.2	40.0
Miller, Bruce	SE-29-033-15 W4M	Middle Horseshoe Canyon	July-81	22.9	75.0	14.0	46.0
Miller, George	SW-04-035-01 W4M	Oldman	June-86	148.1	486.0	51.8	170.0
Miller, Otto	SW-09-033-14 W4M	Lower Horseshoe Canyon	February-64	61.0	200.0	18.3	60.0
Miller, Steve	NW-35-034-01 W4M	Oldman	November-85	141.7	465.0	43.3	142.0
Mitchell, Dave	SW-33-031-10 W4M	Bearpaw	May-77	54.9	180.0	4.6	15.0
Moench, E.R.	NE-07-030-16 W4M	Lower Scollard	November-69	7.9	26.0	5.5	18.0
Mogck, R.	NE-07-035-08 W4M	Lower Horseshoe	September-61	21.9	72.0	9.8	32.0
Mohr, Albert C.	SE-20-036-05 W4M	Oldman	November-68	157.3	516.0	72.5	238.0
Monkman, Bob	NW-19-021-05 W4M	Upper Surficial	June-78	6.1	20.0	3.7	12.0
Monkman, Rena	NW-16-021-05 W4M	Upper Surficial	May-75	11.3	37.0	9.1	30.0
Morrell, Harold	NE-12-034-03 W4M	Upper Surficial	June-81	37.8	124.0	15.5	51.0
Murphy, Frank	SW-23-034-02 W4M	Upper Surficial	November-75	31.7	104.0	13.1	43.0
Murphy, Frank	NW-23-034-02 W4M	Oldman	May-83	126.2	414.0	53.0	174.0
Murphy, John	NW-05-034-10 W4M	Lower Horseshoe Canyon	March-86	25.3	83.0	2.4	8.0
Muzyka, Bill	NW-23-028-06 W4M	Birch Lake	October-85	213.4	700.0	80.2	263.0
Mygaard, Lloyd #House Well	NE-28-020-09 W4M	Oldman	July-82	73.2	240.0	18.3	60.0
Nelson, Harry G.	NW-20-034-13 W4M	Lower Horseshoe Canyon	June-71	18.3	60.0	10.7	35.0
Nelson, Ivar	NE-35-033-08 W4M	Upper Surficial	June-85	34.1	112.0	12.2	40.0
Nelson, Neil	NW-03-034-08 W4M	Bearpaw	June-81	97.5	320.0	19.8	65.0
Ness Ranches Ltd.	16-18-032-04 W4M	Upper Surficial	January-42	11.0	36.0	6.7	22.0
New Cessford School#Well 2	NW-36-023-12 W4M	Oldman	December-78	54.9	180.0	28.0	92.0
Newton, Dean	SW-24-024-13 W4M	Upper Surficial	July-82	7.0	23.0	4.0	13.0

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
Newton, Jim	NE-36-030-01 W4M	Upper Surficial	August-77	62.8	206.0	28.0	92.0
Nielsen, H.	SW-06-034-13 W4M	Lower Horseshoe Canyon	October-74	9.1	30.0	3.7	12.0
Nielsen, Henry	SW-06-034-13 W4M	Lower Horseshoe	June-73	5.8	19.0	3.1	10.0
Niwa, Bert	SW-22-024-02 W4M	Oldman	August-77	118.6	389.0	76.2	250.0
Norris, Ian	SE-07-029-02 W4M	Upper Surficial	June-79	17.7	58.0	6.1	20.0
North Canadian Oil	SW-28-021-04 W4M	Upper Surficial	July-82	22.9	75.0	14.0	46.0
Nova	NE-26-021-04 W4M	Upper Surficial	July-81	82.3	270.0	65.2	214.0
Olson, Jean	NE-17-031-05 W4M	Upper Surficial	April-77	13.7	45.0	7.6	25.0
Opheim, Laverne	SE-27-028-06 W4M	Upper Surficial	February-77	25.6	84.0	21.3	70.0
Osadczuk, Don	SW-23-020-10 W4M	Upper Surficial	June-79	20.1	66.0	7.3	24.0
Owens, Harry	SE-01-029-13 W4M	Lower Horseshoe Canyon	November-77	13.7	45.0	6.7	22.0
Pahl, Arnold	NE-01-032-14 W4M	Lower Horseshoe Canyon	September-81	32.9	108.0	22.6	74.0
Pahl, Larry	NE-22-032-15 W4M	Lower Horseshoe Canyon	May-83	33.5	110.0	24.7	81.0
Pahl, Packy E.	SW-34-031-12 W4M	Surficial	June-80	11.0	36.0	3.7	12.0
Palynchuk, Paul	NW-35-028-06 W4M	Upper Surficial	February-77	39.0	128.0	21.3	70.0
Parson, Ken	NE-22-026-09 W4M	Bearpaw	December-78	56.4	185.0	30.5	100.0
Parson, L.	NE-22-026-09 W4M	Lower Horseshoe Canyon	January-73	42.7	140.0	33.5	110.0
Peacock Farms	NE-23-028-07 W4M	Oldman	March-85	128.9	423.0	50.3	165.0
Peake, Tom	SW-34-026-17 W4M	Lower Surficial	November-75	19.8	65.0	9.8	32.0
Pearce, O.G.	04-27-026-11 W4M	Upper Surficial	January-63	30.5	100.0	24.4	80.0
Pearce, Orlin	SW-27-026-11 W4M	Upper Surficial	June-80	9.1	30.0	3.7	12.0
Pennington, Dave	SW-14-033-09 W4M	Bearpaw	November-74	61.6	202.0	15.2	50.0
Pfahl, Ivan	SW-26-030-15 W4M	Lower Horseshoe Canyon	April-80	50.3	165.0	29.3	96.0
Pfahl, Lester	SE-09-030-15 W4M	Lower Horseshoe Canyon	February-81	61.0	200.0	29.3	96.0
Pfahl, Lester	SE-09-030-15 W4M	Middle Horseshoe Canyon	February-81	29.0	95.0	13.7	45.0
Pfahl, Lester	SE-09-030-15 W4M	Middle Horseshoe Canyon	October-76	38.1	125.0	25.9	85.0
PFRA	13-33-035-06 W4M	Upper Surficial	August-91	45.7	149.9	10.4	34.3
Powell, Frank	SE-16-031-14 W4M	Lower Horseshoe Canyon	May-78	36.0	118.0	15.4	50.4
Pratt, A.W.	13-17-031-02 W4M	Upper Surficial	January-68	12.2	40.0	5.5	18.0
Preston, Richard	NE-18-030-11 W4M	Bearpaw	November-76	91.4	300.0	33.5	110.0
Proudfoot, Eric	NE-02-028-08 W4M	Lower Horseshoe Canyon	April-84	20.7	68.0	15.2	50.0
Proudfoot, Jim A.	NE-25-028-07 W4M	Upper Surficial	June-80	15.2	50.0	9.5	31.0
Provident Resources	SW-01-029-12 W4M	Upper Surficial	December-76	22.6	74.0	9.1	30.0
Prysiazny, Rose	SW-32-027-04 W4M	Upper Surficial	August-78	6.1	20.0	1.8	6.0
Quaschnick, Marle	NW-03-031-15 W4M	Lower Horseshoe Canyon	July-74	52.4	172.0	36.6	120.0
Quaschnick, Rod	SE-03-032-14 W4M	Lower Horseshoe Canyon	July-84	66.4	218.0	51.8	170.0
Quashnick Bros	SW-10-031-15 W4M	Lower Horseshoe Canyon	June-75	50.3	165.0	36.6	120.0
Radke, W.	NW-14-029-16 W4M	Upper Horseshoe Canyon	July-72	28.7	94.0	18.3	60.0
Rees, Norman	NW-34-033-15 W4M	Lower Horseshoe	July-76	45.1	148.0	19.4	63.6
Ringdahl, J.G.	SW-14-027-11 W4M	Bearpaw	January-68	73.2	240.0	30.5	100.0
Rinker, Henry	SW-12-022-04 W4M	Upper Surficial	April-80	80.8	265.0	68.6	225.0
Robbs, Annette	NE-05-031-14 W4M	Lower Horseshoe Canyon	April-76	38.1	125.0	6.1	20.0
Robbs, Lorne	··-09-031-14 W4M	Lower Horseshoe Canyon	September-64	27.4	90.0	12.2	40.0
Robinson, Emerson	SE-15-031-15 W4M	Lower Horseshoe Canyon	June-77	58.2	191.0	41.5	136.0
Rolls, Won	SE-05-035-08 W4M	Lower Horseshoe Canyon	March-73	25.6	84.0	6.4	21.0
Roseneau, C.	NW-11-029-09 W4M	Bearpaw	April-76	41.2	135.0	22.6	74.0
Rosin, Reinhard	SW-10-030-16 W4M	Upper Horseshoe Canyon	December-75	59.4	195.0	3.1	10.0
Ross, G.	NE-34-030-04 W4M	Upper Surficial	December-65	9.1	30.0	3.7	12.0
Roth, Wallace H.	NE-19-034-07 W4M	Bearpaw	June-80	39.0	128.0	13.1	43.0
Rowden, Larry	SW-18-030-14 W4M	Lower Horseshoe Canyon	January-84	33.5	110.0	6.7	22.0
Rutledge Ranches	SE-21-035-02 W4M	Bearpaw	August-77	25.9	85.0	12.2	40.0
Salik, Pete	SW-03-029-06 W4M	Oldman	May-74	181.4	595.0	55.8	183.0
Scapa Athletic Assoc.	SW-31-033-14 W4M	Upper Surficial	May-83	11.0	36.0	5.2	17.0
Scarff, Tom	NW-11-026-05 W4M	Upper Surficial	February-81	10.4	34.0	3.1	10.0
Schaefer, Mel	NW-29-029-01 W4M	Upper Surficial	July-84	16.8	55.0	12.2	40.0

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet
Schauer, Wes	NW-32-027-03 W4M	Upper Surficial	October-77	30.2	99.0	9.1	30.0
Schauer, Wes	NW-32-027-03 W4M	Bearpaw	October-79	30.5	100.0	7.6	25.0
Scheverman, Clayton W.	NE-34-025-02 W4M	Upper Surficial	June-75	22.9	75.0	20.7	68.0
Schmidt, D.	SW-16-032-15 W4M	Lower Horseshoe Canyon	July-86	22.9	75.0	3.7	12.0
Schober, Herb	··-04-029-07 W4M	Upper Surficial	July-84	14.0	46.0	7.9	26.0
Schultz, Jim	NE-14-032-15 W4M	Lower Horseshoe Canyon	August-77	22.9	75.0	10.7	35.0
Scott, Lucy	NW-22-032-15 W4M	Lower Horseshoe Canyon	May-83	16.8	55.0	10.7	35.0
Senkin, Mike	SE-08-030-01 W4M	Upper Surficial	June-82	31.7	104.0	21.3	70.0
Shadlock, Lawrence	SE-27-028-15 W4M	Middle Horseshoe Canyon	June-79	19.8	65.0	7.5	24.7
Shubert, John L.	SW-24-024-02 W4M	Upper Surficial	May-75	10.7	35.0	5.5	18.0
Shubert, Ron	SE-35-024-02 W4M	Oldman	April-77	141.4	464.0	112.8	370.0
Siepert, Emil	NW-35-032-14 W4M	Lower Horseshoe Canyon	July-82	35.1	115.0	21.3	70.0
Siewert, Garry	NW-01-030-15 W4M	Lower Horseshoe Canyon	February-76	54.9	180.0	39.0	128.0
Siewert, Garry	NW-01-030-15 W4M	Lower Horseshoe Canyon	September-79	54.9	180.0	39.3	129.0
Simkin Gavin	SW-28-035-06 W4M	Oldman	July-84	149.3	489.9	102.4	336.0
Simkin, Gavin	SW-28-035-06 W4M	Oldman	July-84	149.3	490.0	102.4	336.0
Simkin, Robert And John	NE-15-032-09 W4M	Bearpaw	September-77	50.3	165.0	11.6	38.0
Simpson, Ralph	NW-16-035-06 W4M	Bearpaw	September-83	59.4	195.0	20.7	68.0
Slorstad, S.J.	NW-20-026-12 W4M	Bearpaw	May-78	33.5	110.0	10.1	33.0
Slorstad, S.J.	13-20-026-12 W4M	Lower Surficial	January-58	22.6	74.0	9.1	30.0
Smigelski, Ron	NW-26-029-03 W4M	Upper Surficial	October-75	31.7	104.0	10.1	33.0
Smith, Steve	NE-30-030-15 W4M	Middle Horseshoe Canyon	August-79	37.5	123.0	15.2	50.0
Snell Farms Ltd.	NE-05-027-04 W4M	Upper Surficial	October-81	6.7	22.0	1.8	6.0
Spath, Frank	SE-36-024-03 W4M	Oldman	August-77	104.5	343.0	70.1	230.0
Spath, Leo	SW-18-024-02 W4M	Oldman	March-77	76.5	251.0	55.2	181.0
Special Areas	SE-30-021-05 W4M	Birch Lake	December-73	106.7	350.0	137.2	450.0
Special Areas	NW-13-028-14 W4M	Surficial	July-81	49.7	163.0	4.6	15.0
Special Areas #4(Town Well #1)	NE-25-033-01 W4M	Oldman	July-84	147.2	483.0	38.4	126.0
Spence, J. P.	SE-30-023-11 W4M	Oldman	July-75	61.0	200.0	40.8	134.0
Spencer, Art	SE-05-036-05 W4M	Oldman	April-79	152.4	500.0	98.5	323.0
Springside Colony	NE-04-022-13 W4M	Lower Surficial	August-77	12.2	40.0	3.9	12.8
Steveville Dinosaur Park	SW-07-021-11 W4M	Lower Surficial	October-60	18.3	60.0	4.9	16.0
Steveville Dinosaur Park	SW-07-021-11 W4M	Oldman	November-60	19.8	65.0	4.9	16.0
Storch, Norman	SW-20-034-13 W4M	Lower Horseshoe Canyon	September-75	36.6	120.0	22.6	74.0
Storch, Norman P.	SW-20-034-13 W4M	Lower Horseshoe Canyon	July-74	36.6	120.0	22.6	74.0
Sturm, V.	04-21-022-02 W4M	Surficial	April-67	100.6	330.0	79.2	260.0
Suchotzky, A.	NW-09-034-08 W4M	Bearpaw	October-65	53.3	175.0	13.7	45.0
Suchotzky, Alvin E.	NW-09-034-08 W4M	Bearpaw	November-73	50.6	166.0	15.2	50.0
Sulz, H.	04-14-030-14 W4M	Lower Horseshoe Canyon	February-76	21.3	70.0	5.7	18.5
Sutherland, C.H.	NE-18-027-05 W4M	Upper Surficial	November-60	49.7	163.0	12.2	40.0
Symes, Jack	SE-25-036-07 W4M	Bearpaw	September-76	42.1	138.0	17.7	58.0
Symes, Milton	SE-24-031-04 W4M	Upper Surficial	February-81	13.4	44.0	4.3	14.0
T.G. Cattle Co. Ltd	SW-02-027-15 W4M	Upper Surficial	October-75	21.9	72.0	14.3	47.0
Tainsh, Bill	NW-20-035-05 W4M	Bearpaw	August-67	38.1	125.0	7.9	26.0
Tainsh, James	SW-24-035-06 W4M	Bearpaw	October-76	49.1	161.0	19.8	65.0
Tkach, Raymond	NW-03-036-08 W4M	Upper Surficial	March-75	49.1	161.0	23.8	78.0
Todd, Don	SW-12-033-11 W4M	Lower Horseshoe Canyon	June-70	25.9	85.0	4.6	15.0
Tomkins, G.	NE-13-026-06 W4M	Upper Surficial	July-75	44.2	145.0	15.2	50.0
Town Of Oyen Well #2A	08-36-027-04 W4M	Upper Surficial	June-66	7.6	25.0	4.0	13.0
Trevor, Dennis	SW-23-030-03 W4M	Upper Surficial	April-84	5.5	18.0	1.8	6.0
Turnbull, H. W.	SE-20-026-09 W4M	Upper Surficial	October-71	12.5	41.0	2.4	8.0
Tym, Alex	NE-36-033-08 W4M	Bearpaw	July-77	34.8	114.0	4.6	15.0
Ulseth, Dean	SW-20-034-08 W4M	Lower Horseshoe Canyon	June-81	19.2	63.0	5.5	18.0
Unsworth, Cyril	NE-20-034-13 W4M	Lower Horseshoe Canyon	October-81	18.3	60.0	7.3	24.0
Van Sickle, M.	15-36-026-01 W4M	Upper Surficial	January-69	32.9	108.0	15.9	52.0

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth		NPWL	
				Metres	Feet	Metres	Feet
Vanderloht, Irene	SW-09-022-12 W4M	Oldman	May-85	41.5	136.0	18.3	60.0
Village Of Cereal Obs. Well #3	SW-28-028-06 W4M	Birch Lake	June-69	197.2	647.0	60.5	198.6
Village of Consort	13-33-035-06 W4M	Upper Surficial	December-91	48.8	160.0	10.6	34.8
Village Of Veteran	SW-17-035-08 W4M	Bearpaw	December-74	73.2	240.0	21.3	70.0
Village Of Veteran Well #1	SW-17-035-08 W4M	Bearpaw	July-80	66.8	219.0	8.2	27.0
Viste, Albert	SE-09-031-14 W4M	Lower Horseshoe Canyon	June-76	33.5	110.0	8.5	28.0
Viste, Calton	NE-25-032-15 W4M	Lower Horseshoe Canyon	August-78	39.6	130.0	10.4	34.0
Vogel, Albert	12-01-035-01 W4M	Upper Surficial	January-71	6.1	20.0	3.1	10.0
Vogel, Ray	SW-12-034-01 W4M	Oldman	July-80	132.9	436.0	41.0	134.5
Wagstaff, Lloyd	NE-13-032-05 W4M	Upper Surficial	July-84	13.7	45.0	4.3	14.0
Wagstaff, Barry	SE-04-031-05 W4M	Upper Surficial	August-81	13.7	45.0	6.7	22.0
Wainoco Oil & Gass Ltd.	06-06-022-11 W4M	Oldman	July-77	67.1	220.0	36.6	120.0
Walper, Eric #1	NW-19-032-10 W4M	Bearpaw	November-80	48.8	160.0	7.0	23.0
Walton, R.	SW-17-027-15 W4M	Lower Horseshoe Canyon	April-78	48.8	160.0	9.1	30.0
Waters, Harvey	SE-05-031-14 W4M	Lower Horseshoe Canyon	March-83	29.0	95.0	2.1	7.0
Wayne	SE-17-035-08 W4M	Lower Horseshoe Canyon	June-81	19.2	63.0	3.7	12.0
Webb, M.G.	NW-33-036-08 W4M	Upper Surficial	January-69	11.6	38.0	2.4	8.0
Webb, Richard	NW-33-036-08 W4M	Upper Surficial	February-78	14.6	48.0	4.0	13.0
Weich, Ben	SW-04-033-12 W4M	Bearpaw	October-77	89.9	295.0	48.8	160.0
Weich, Bryan	NW-04-033-15 W4M	Lower Horseshoe Canyon	December-79	93.0	305.0	54.9	180.0
Weich, Fred	SW-24-033-15 W4M	Lower Horseshoe Canyon	June-80	34.1	112.0	18.9	62.0
Weich, Kevin	16-19-032-11 W4M	Bearpaw	January-50	48.8	160.0	7.9	26.0
Weich, Rick	NE-06-033-15 W4M	Lower Horseshoe Canyon	June-84	34.8	114.0	25.9	85.0
Wes James & Sons Cattle Lines	SE-09-031-14 W4M	Lower Horseshoe Canyon	November-84	32.0	105.0	10.7	35.0
Westerlund, Doug	SE-25-030-03 W4M	Bearpaw	July-75	25.0	82.0	6.1	20.0
Westerlund, Lloyd	SE-08-031-02 W4M	Upper Surficial	October-77	8.5	28.0	2.4	8.0
Whaley, C.	NE-12-032-14 W4M	Upper Surficial	March-79	12.2	40.0	2.4	8.0
Whaley, John E.	NW-21-029-13 W4M	Lower Horseshoe Canyon	July-64	10.7	35.0	7.3	24.0
White, Craig	NW-05-026-01 W4M	Upper Surficial	April-77	15.2	50.0	4.6	15.0
Wiech, R.	NE-26-033-15 W4M	Lower Horseshoe Canyon	May-80	34.1	112.0	15.5	51.0
Wiechnik, Glen	NW-30-033-04 W4M	Oldman	October-82	100.3	329.0	21.9	72.0
Wiechnik, Jim	NW-16-033-04 W4M	Oldman	June-73	148.7	488.0	27.4	90.0
Williams Ent. (Mark)	NE-23-023-12 W4M	Oldman	September-83	53.3	175.0	34.1	112.0
Williams Enterprises	SE-03-023-12 W4M	Oldman	June-86	65.5	215.0	5.5	18.0
Wilson, Lawrence	NW-28-031-04 W4M	Upper Surficial	May-86	11.3	37.0	4.6	15.0
Wimmer, Herb	NE-13-033-15 W4M	Lower Horseshoe Canyon	February-68	36.6	120.0	21.3	70.0
Wolfert, Alex	NW-13-034-14 W4M	Lower Horseshoe Canyon	June-73	33.5	110.0	26.5	87.0
Woods, Gary	SE-14-029-02 W4M	Upper Surficial	January-83	14.0	46.0	7.0	23.0
Woods, Jeff	SW-22-029-02 W4M	Upper Surficial	April-85	10.7	35.0	1.8	6.0
Worobo, Robert	SE-06-036-03 W4M	Oldman	September-76	168.9	554.0	87.8	288.0
Wraight, Fred	NW-22-036-08 W4M	Upper Surficial	January-67	65.2	214.0	25.9	85.0
Wright, J.	SE-02-029-07 W4M	Bearpaw	October-81	45.7	150.0	24.4	80.0
Wright, Orpha	SE-14-031-14 W4M	Lower Horseshoe Canyon	July-77	28.0	92.0	9.5	31.0
Young, E.	SW-27-033-01 W4M	Oldman	December-73	74.7	245.0	11.9	39.0
Zieffle, Dave	SE-28-036-04 W4M	Oldman	September-73	77.4	254.0	8.2	27.0
Zieffle, Wesley	SE-28-036-04 W4M	Oldman	September-73	76.5	251.0	7.6	25.0

SPECIAL AREAS 2, 3, 4, AND M.D. OF ACADIA-OPERATED WATER WELLS

		Date Water	Completed Depth		NPWL	
Owner	Location	Well Drilled	Metres	Feet	Metres	Feet
M.D. of Acadia #34	15-31-025-01 W4M	Jan-68	8.8	29.0	3.8	12.6
Special Areas	NW-13-028-14 W4M	Jul-81	49.7	163.0	4.6	15.0
Special Areas	SE-30-021-05 W4M	Dec-73	106.7	350.0	137.2	450.0
Special Areas #4(Town Well #1)	NE-25-033-01 W4M	Jul-84	147.2	483.0	38.4	126.0