Lacombe County

Part of the Red Deer River Basin
Tp 038 to 041, R 21 to 28, W4M & Tp 038 to 041, R 01 to 04, W5M
Regional Groundwater Assessment

Prepared for:

In conjunction with:

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration | Administration du rétablisseme agricole des Prairies

Canada

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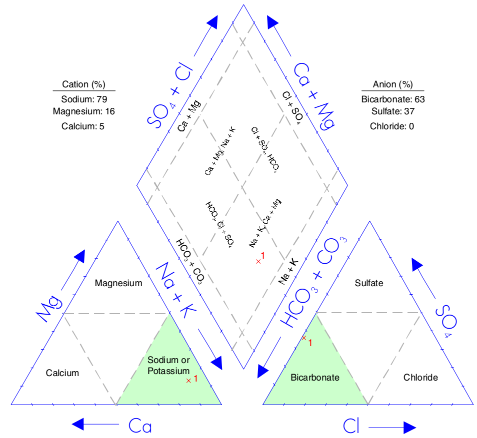
Glossary

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
Borehole	includes all “work types” except springs
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)
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 — 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



Piper Tri-Linear Diagram

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” as defined by AENV 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

AENV — 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
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 County takes care of one of its most precious resources - groundwater - reflects the future wealth and health of its people. Good environmental practices are not an accident. They must include genuine foresight with knowledgeable planning. Implementation of strong practices not only commits to a better quality of life for future generations, but also creates a solid base for increased economic activity. **Though this report's scope is regional, it is a first step for Lacombe County in managing their groundwater. It is also a guide for future groundwater-related projects.**

A. Purpose

This project is a regional groundwater assessment of Lacombe County 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 the County. Groundwater resource management involves determining the suitability of various areas in the County for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the County.**

The regional groundwater assessment 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 possible groundwater depletion areas associated with each upper bedrock aquifer.

Under the present program, the groundwater-related data for the County have been assembled. Where practical, the data have been digitized. These data are then being used in the regional groundwater assessment for Lacombe County.

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 eight parts as follows:

Task 1 - Data Collection and Review
Task 2 - Hydrogeological Maps, Figures, Digital Data Files
Task 3 – Hydrogeological Evaluation and Preparation of Report
Task 4 - Groundwater Information Query Software
Task 5 – Review of Draft Report and GIS Data Files
Task 6 – Report Presentation and Training Session
Task 7 – Provision of Report, Maps, Data Layers and Query
Task 8 – Provision of Compact Disk for Sale to General Public.

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

C. About This Report

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

Additional technical details are available from files on the CD-ROM to be provided with the final version of this report. The files include the geo-referenced electronic groundwater database, maps showing distribution of various hydrogeological parameters, the groundwater query, ArcView and ArcExplorer 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) interpretation of chemical analysis of drinking water
5) 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 10 Jan 1999.

Appendix D includes page-size copies of the poster-size figures provided with this report.

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

[3] See glossary

II. Introduction

A. Setting

Lacombe County is situated in south-central Alberta. Most of this area is part of the Alberta Plains region. The County is within the Red Deer River basin; a part of the County's southeastern boundary is the Red Deer River. The other County boundaries follow township or section lines. The area includes parts of the area bounded by township 038, range 04, W5M in the southwest and township 041, range 21, W4M in the northeast.

Regionally, the topographic surface varies between 740 and 1,100 metres above mean sea level (AMSL). The lowest elevations occur mainly in the eastern part of the County and the highest are in the western parts of the County as shown on Figure 1 and page A-2. The area is well drained by numerous streams.

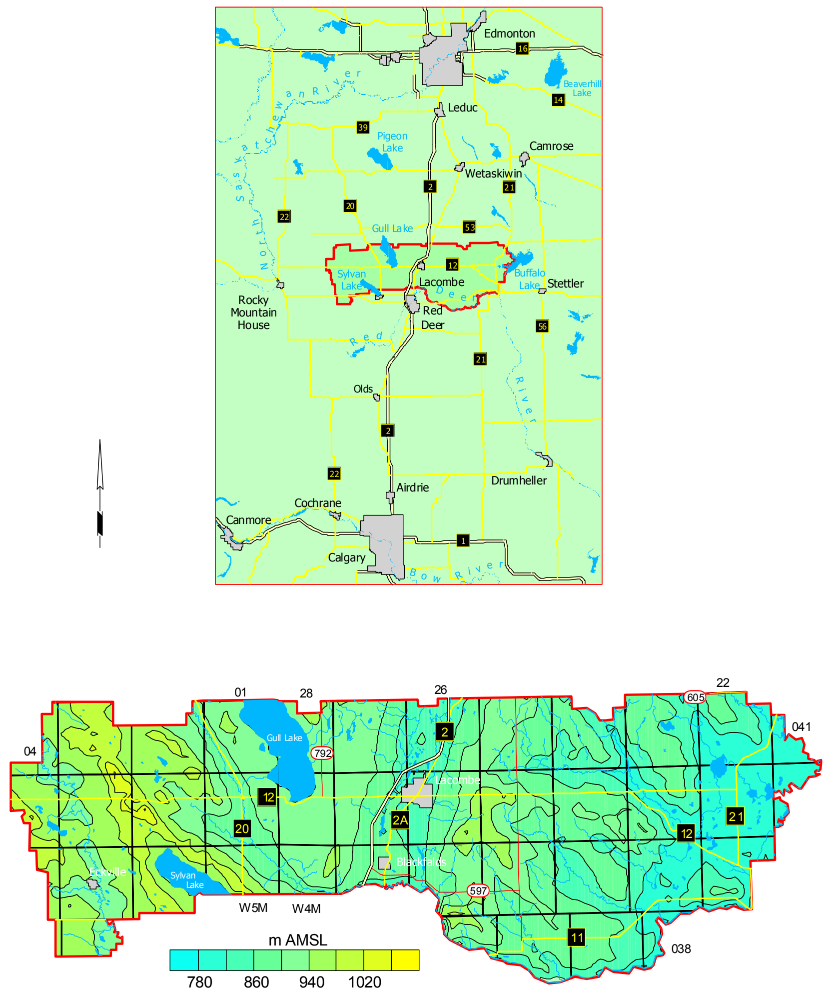


Figure 1. Index Map

B. Climate

Lacombe County lies within the Dfb climate boundary. This classification is based on potential evapotranspiration[4] 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 the County is located in both the Low Boreal Mixedwood region and the Aspen Parkland region. Increased precipitation and cooler temperatures, resulting in additional moisture availability, influence this vegetation change.

A Dfb climate consists of long, cool summers and severe winters. The mean monthly temperature drops below -3° C in the coolest month, and exceeds 10° C in the warmest month.

The mean annual precipitation averaged from five meteorological stations within the County measured 469 millimetres (mm), based on data from 1907 to 1993. The mean annual temperature averaged 2.6° C, with the mean monthly temperature reaching a high of 16.3° C in July, and dropping to a low of -13° C in January. The calculated annual potential evapotranspiration is 508 millimetres.

[4] See glossary

C. Background Information

1) Number, Type and Depth of Water Wells

There are currently records for 7,388 water wells in the groundwater database for the County. Of the 7,388 water wells, 6,505 are for domestic/stock purposes. The remaining 883 water wells were completed for a variety of uses, including industrial, municipal, observation, injection, irrigation, investigation and dewatering. Based on a rural population of 10,081 (Phinney, 1999), there are 2.6 domestic/stock water wells per family of four. It is unknown how many of these water wells may still be active. The domestic or stock water wells vary in depth from 0.30 metres to 241 metres below ground level. Details for lithology[5] are available for 4,898 water wells.

2) Number of Water Wells in Surficial and Bedrock Aquifers

There are 4,357 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 the bedrock are water wells completed in surficial aquifers. Of the 4,357 water wells for which aquifers could be defined, 123 are completed in surficial aquifers, with 65% having a completion depth of more than 20 metres. The adjacent map shows that the water wells completed in the surficial deposits occur throughout the County, frequently in the vicinity of linear bedrock lows. The map also shows a number of water wells located in the two main surface-water bodies. Some of the locations are a result of plotting in the centre of the quarter section; others have the incorrect location.

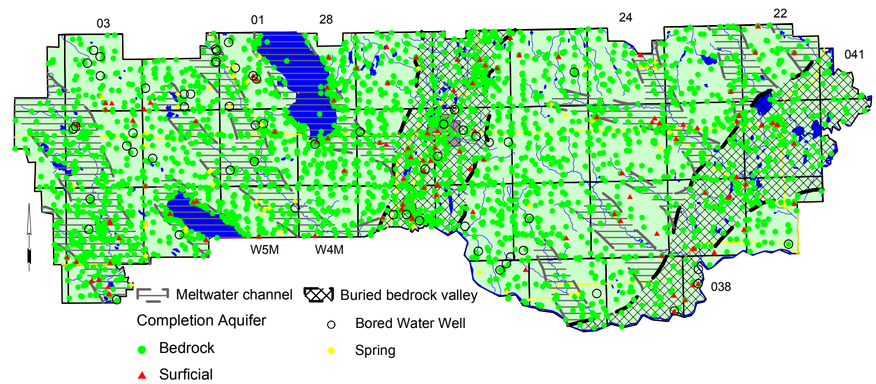


Figure 2. Location of Water Wells

The 4,234 water wells that have the top of their completion interval deeper than 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 throughout the County.

There are currently records for 45 springs in the groundwater database, located mainly in the vicinity of linear bedrock lows. More than 80% of the 18 available chemical values for springs indicate the groundwaters have total hardness concentrations of more than 200 milligram per litre (mg/L) and total dissolved solids (TDS) concentrations ranging from 350 to 850 mg/L.

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5 See glossary

3) Casing Diameter and Type

Data for casing diameters are available for 5,193 water wells, with 5,133 (99%) indicated as having a diameter of less than 275 mm and 60 having a diameter of more than 275 mm. The casing diameters of greater than 275 mm are mainly bored or dug water wells and those with a surface-casing diameter of less than 275 mm are drilled water wells. There are 60 large-diameter or bored water wells in the County and they are mainly in the areas where major meltwater channels are present in association with river valleys as shown on Figure 2.

In the County, 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 used in 70% of the water wells being drilled in the County in the 1990s. Steel is the main casing type used since surface casing type has been documented.

Galvanized steel was a maximum of 22% of the drilled water wells from the 1950s to the early 1990s. Galvanized steel was last used in July 1993.

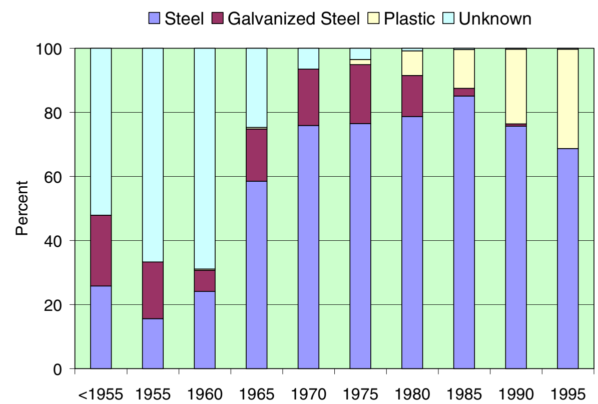

Figure 3. Surface Casing Types Used in Drilled Water Wells

4) Requirements for Licensing

Water wells used for household needs in excess of 1,250 cubic metres per year and providing groundwater with TDS of less than 4,000 mg/L must be licensed. At the end of 1999, 409 groundwater allocations were licensed in the County. Of the 409 licensed groundwater users, 271 could be linked to the Alberta Environment (AENV) groundwater database. Of the 409 licensed groundwater users, 319 are for agricultural purposes, and the remaining 90 are for commercial, industrial, municipal, recreation, fishery, exploration and dewatering purposes. The total maximum authorized diversion from the water wells associated with these licences is 16,963 cubic metres per day (m^3/day), although actual use could be less. Of the 16,963 m^3/day, 50% is allotted for municipal use, and 28% is allotted for agricultural use. The remaining 22% has been licensed for commercial, industrial, recreation, fishery, exploration and dewatering as shown in Table 2 on the following page; a figure showing the locations of the licensed users is in Appendix A (page A-5) and on the CD-ROM.

The largest single potable groundwater allocation within the County is for the Village of Alix, having a diversion of 1,146 m^3/day. The Alix water supply well, used for municipal purposes, is completed in the Upper Scollard Aquifer.

The following table shows a breakdown of the 409 licensed groundwater allocations by the aquifer in which the water well is completed. The largest total licensed allocations are in the Haynes and Upper Lacombe aquifers; the majority of the groundwater is used for municipal and agricultural purposes.

	No. of	Licensed Groundwater Users* (m³/day)									
Aquifer **	Diversions	Agricultural	Commerical	Industrial	Municipal	Recreation	Fishery	Exploration	Dewatering	Total	Percentage
Upper Sand and Gravel	3	62	0	0	0	0	44	0	0	106	1
Lower Sand and Gravel	14	27	248	0	372	0	0	0	615	1,262	7
Dalehurst	48	407	61	46	608	0	0	0	0	1,122	7
Upper Lacombe	158	2,274	141	895	352	53	0	8	0	3,723	22
Lower Lacombe	33	493	132	0	34	0	0	0	0	659	4
Haynes	63	577	162	0	5,307	3	0	0	0	6,049	36
Upper Scollard	28	412	0	0	1,244	3	0	278	0	1,937	11
Lower Scollard	9	74	0	0	18	0	98	0	0	190	1
Upper Horseshoe Canyon	22	197	34	0	446	0	0	0	0	677	4
Bedrock	17	138	186	0	187	0	5	152	0	668	4
Unknown	14	171	0	389	10	0	0	0	0	570	3
Total	409	4,832	964	1,330	8,578	59	147	438	615	16,963	100
Percentage		28	6	8	50	0	1	3	4	100	

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

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the calculated water requirement for livestock for the County is in the order of 15,258 m³/day. Of the 15,258 m³/day average calculated livestock use, AENV has licensed a groundwater diversion of 4,832 m³/day (32%) and a licensed surface-water diversion of 1,334 m³/day (9%). The remaining 59% of the calculated livestock use would have to be mainly from unlicensed sources.

5) Groundwater Chemistry and Base of Groundwater Protection

Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. High nitrate and nitrite (as N) were not evident in the available chemical data for the surficial or upper bedrock aquifer(s); a plot of nitrate and nitrite (as N) in surficial aquifers is on the accompanying CD-ROM. The TDS concentrations in the groundwaters from the upper bedrock in the County are generally less than 1,000 mg/L, and in the Eckville, Blackfalds and Lacombe areas groundwaters generally have less than 500 mg/L of TDS (page A-29). 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. Nearly 15% of the chemical analyses indicate a fluoride concentration above 1.5 mg/L, with most of the exceedances occurring in the south-central part of the County (see CD-ROM).

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 the County have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in Table 2. Of the five constituents compared to the GCDWQ, average values of TDS and sodium concentrations exceed the guidelines.

Constituent	Range for County in mg/L Minimum	Maximum	Average	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	64	2917	745	500
Sodium	0	925	230	200
Sulfate	0	1275	140	500
Chloride	<1	1050	9	250
Fluoride	0	8.6	0.7	1.5

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)

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[6] method to prepare a depth to the Base of Groundwater Protection surface. This depth, 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 has total dissolved solids exceeding 4,000 mg/L, the groundwater use does not require licensing by AENV. In the County, the depth to Base of Groundwater Protection ranges from less than 100 metres to more than 500 metres below ground level, as shown on Figure 4 and on each cross-section, where present.

Of the 6,998 water wells with completed depth data, 15 are completed below the Base of Groundwater Protection. Most of these water wells are located in buried bedrock valleys or meltwater channels and in other areas where the depth to Base of Groundwater Protection is less than 150 metres. The five water wells located west of Range 28, W4M that are completed below the Base of Groundwater Protection are used for industrial or investigation purposes. Chemistry data are available for two water wells, which provide groundwaters with TDS concentrations of less than 1,000 mg/L.

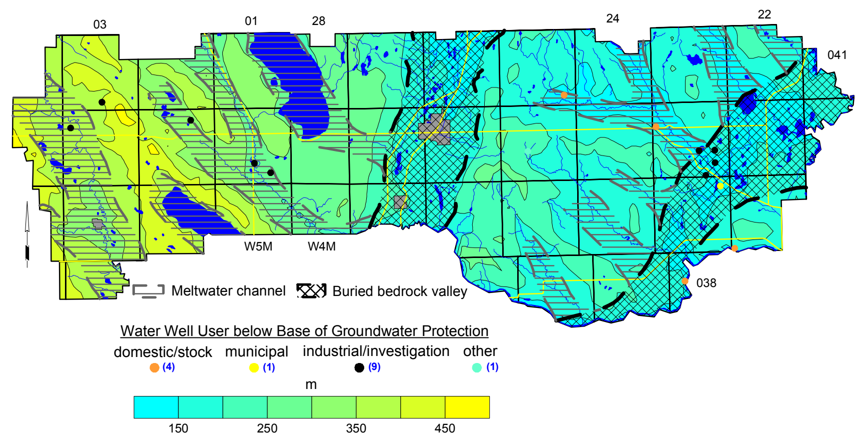

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are two AENV-operated observation water wells within the County. 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 AENV, in part because of the failure of the licensee to provide the data.

However, even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget (see section 6.0 of this report). 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.

[6] See glossary

III. Terms

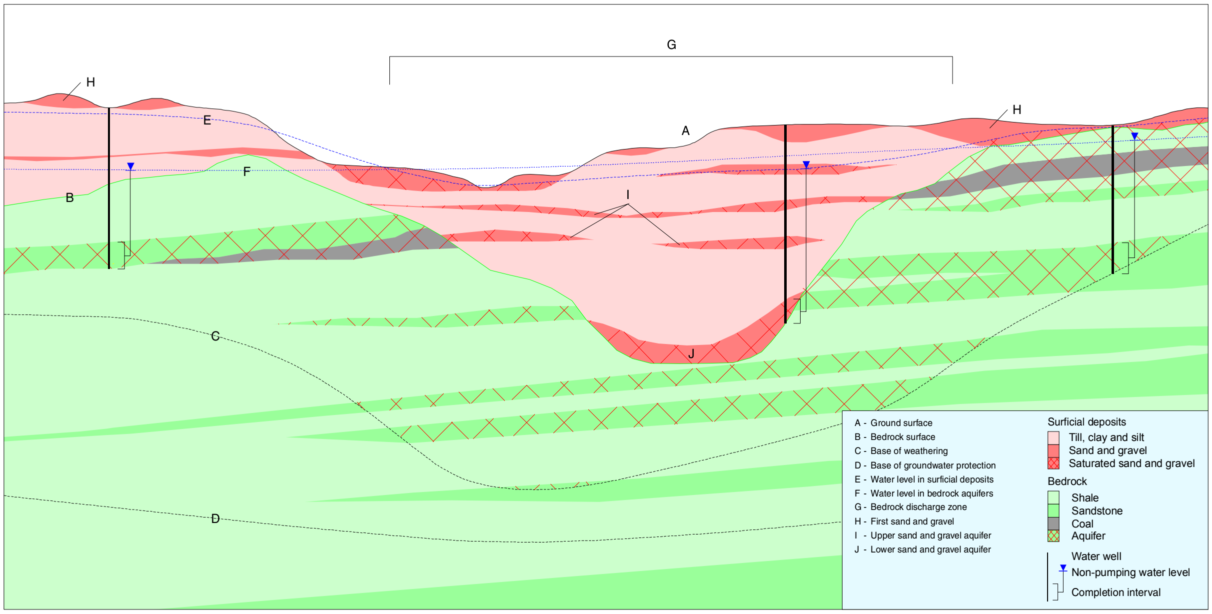

Figure 5. Generalized Cross-Section (for terminology only)

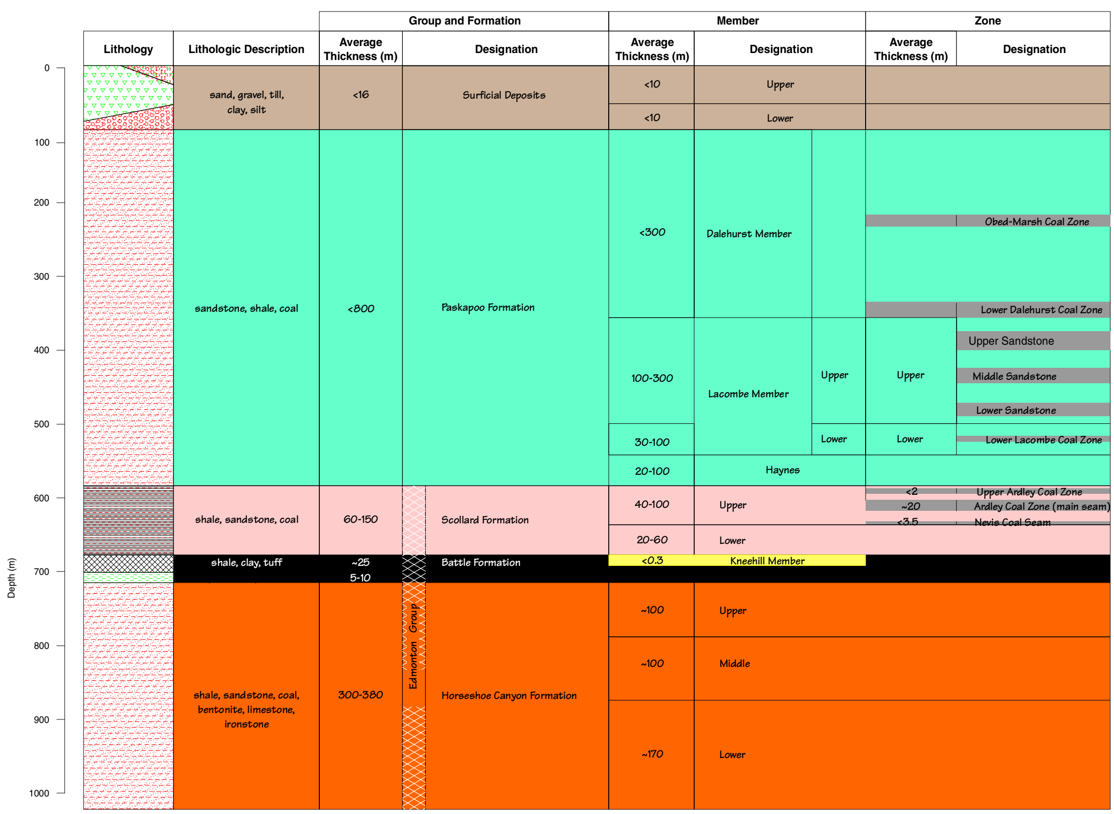

Figure 6. Geologic Column

IV. Methodology

A. Data Collection and Synthesis

The AENV 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
6) chemical analyses for some groundwaters
7) location of flowing shot holes
8) location of structure test holes
9) 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. Any duplicate water wells that have been identified for the County have been removed from the database used in this regional groundwater assessment.

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

The present project uses the 10TM coordinate system. This means that a record for the NW ¼ of section 26, township 039, range 22, W4M, would have a horizontal coordinate with an Easting of 131,135 metres and a Northing of 5,802,929 metres, the centre of the quarter section. If the water well has been repositioned by PFRA using orthorectified aerial photos, the location will be more accurate, possibly within several tens of 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); the Resource Data Division of AENV provides the DEM.

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

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[7] and apparent yield[8] 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 last regional hydrogeology map was published in 1971 (Tokarsky, 1971 and LeBreton, 1971), 2,800 values for apparent transmissivity and 2,485 values for apparent yield have been added to the groundwater database. With the addition of the apparent yield values, a hydrogeological map has been prepared to help illustrate the general groundwater availability across the County. The anticipated groundwater apparent yield is based on the expected yield of a single water well obtaining water from the total accessible stratigraphic section.

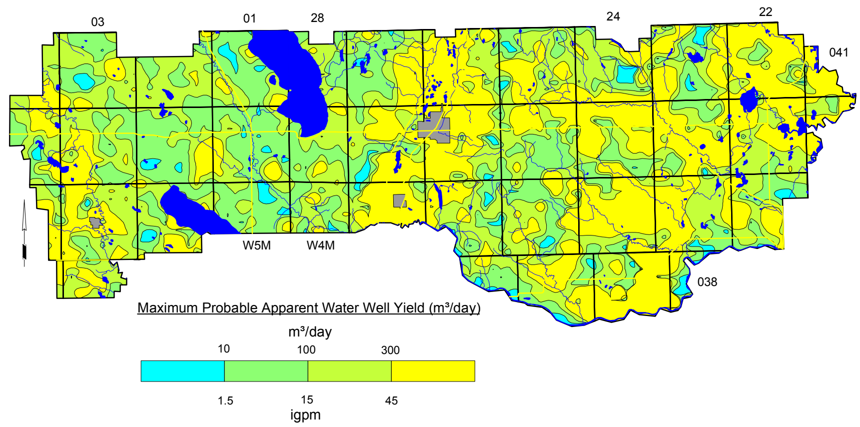

Figure 7. Hydrogeological Map

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 geologic 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. 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 support the geological interpretation of geophysical logs but cannot be distributed because of a licensing agreement.

7 For definitions of Transmissivity, see glossary
8 For definitions of Yield, see glossary

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 aquifers are defined by mapping the tops and bottoms of individual geologic units. The values for the elevation of the top and bottom of individual geologic units at specific locations help to determine the spatial distribution of the individual surfaces. Establishment of a surface distribution digitally requires preparation of a grid. The inconsistent quality of the data necessitates creating a representative sample set obtained from the entire data set. If the data set is large enough, it can be treated as a normal population and the removal of extreme values can be done statistically. When data sets are small, the process of data reduction involves a more direct assessment of the quality of individual points. Because of the uneven distribution of the data, all data sets are gridded using the Kriging method.

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

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 determining the distribution of hydraulic parameters.

After the water wells are assigned to a specific aquifer, the parameters from the water well records are assigned to the individual aquifers. The parameters include non-pumping (static) water level (NPWL), apparent transmissivity if neither aquifer nor effective volumes are available, and apparent water well yield. The total dissolved solids, sulfate and chloride concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers. In addition, chemical parameters of nitrate + nitrite (as N) are assigned to surficial aquifers and fluoride is assigned to upper bedrock aquifer(s). Since 1986, Alberta Health and Wellness has restricted access to chemical analysis data, and hence the database includes only limited amounts of chemical data since 1986.

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 grids prepared from the limited data must be used with extreme caution because the gridding process can be unreliable.

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 geologic units. For example, the relationship between an upper bedrock unit and the bedrock surface must be determined. This process provides both the outline and the thickness of the geologic unit.

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. For the upper bedrock aquifer(s) where areas of no data are available from the groundwater database, maps prepared have been masked with a solid brown color to indicate this area. These brown masks have been added to the Lower Lacombe, Haynes, Upper and Lower Scollard, and the Upper Horseshoe Canyon aquifers. For the Dalehurst and Upper Lacombe aquifers, control points have been added to the maps to show the extent of the available data. 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 geologic 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. Five cross-sections are presented in this report and as poster-size drawings forwarded with this report. The cross-sections also are in Appendix A, and are included on the CD-ROM; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

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 Professional Office 2000
- Surfer 6.04

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 the County. 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 geologic units, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

1) Surficial Aquifers

Surficial deposits in the County are mainly less than 20 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 40 metres. The Buried Red Deer River and Buffalo Lake valleys are the main southwest-northeast-trending linear bedrock lows in the County. Cross-section A-A’ shown below passes across the Buried Red Deer River and Buffalo Lake valleys and shows the surficial deposits being up to 50 metres thick within the Valley.

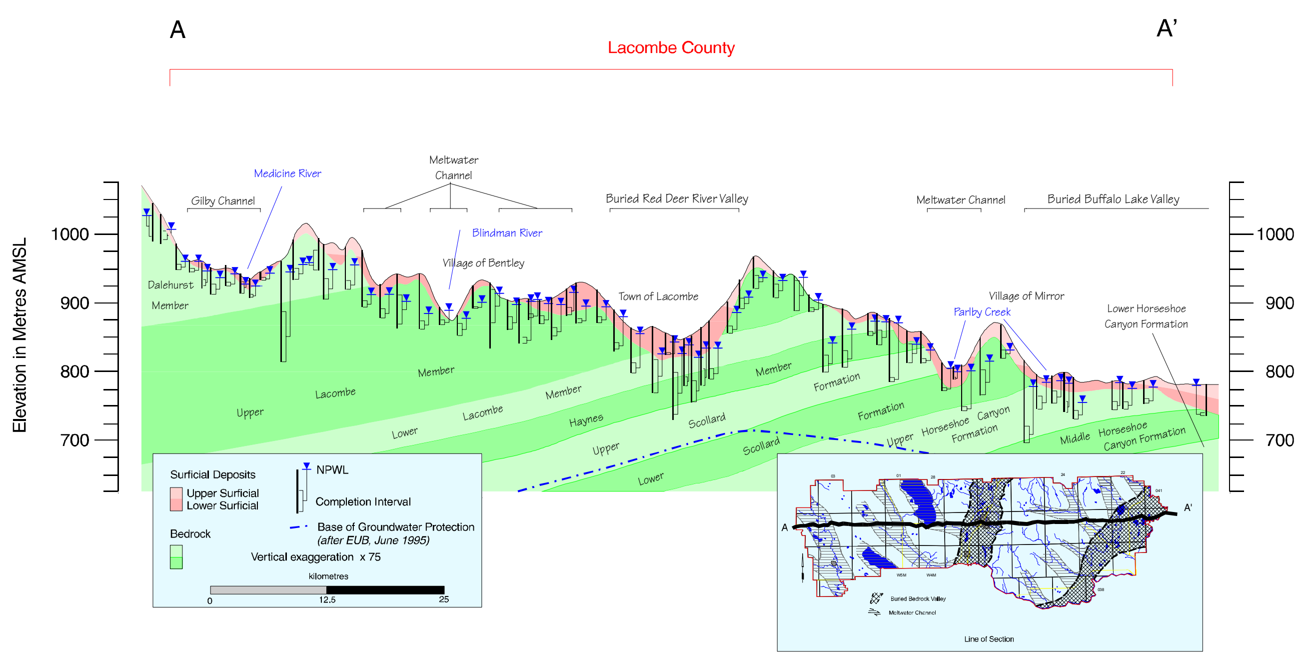

Figure 8. Cross-Section A - A'

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 20 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 County, casing-diameter information is available for 104 of the 123 water wells completed in the surficial deposits; four percent of these have a casing diameter of more than 275 millimetres, and are assumed to be bored or dug water wells.

2) Bedrock Aquifers

The upper bedrock includes the Paskapoo, Scollard, Whitemud, Battle and Upper Horseshoe Canyon formations. Cross-section B-B' (Figure 9) shows that the upper bedrock includes rocks that are less than 200 metres below the bedrock surface and above the Middle Horseshoe Canyon Formation. Some of this bedrock contains saturated rocks that are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, although some of the sandstones may be friable[9] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft.

The data for 4,234 water wells show that the top of the water well completion interval is below the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. Within the County, casing-diameter information is available for 4,140 of the 4,234 water wells completed below the top of bedrock. Of these 4,140 water wells, 99% have surface-casing diameters of less than 275 mm and these bedrock water wells have been mainly completed with either a perforated liner or as open hole; there are 26 bedrock water wells completed with a water well screen.

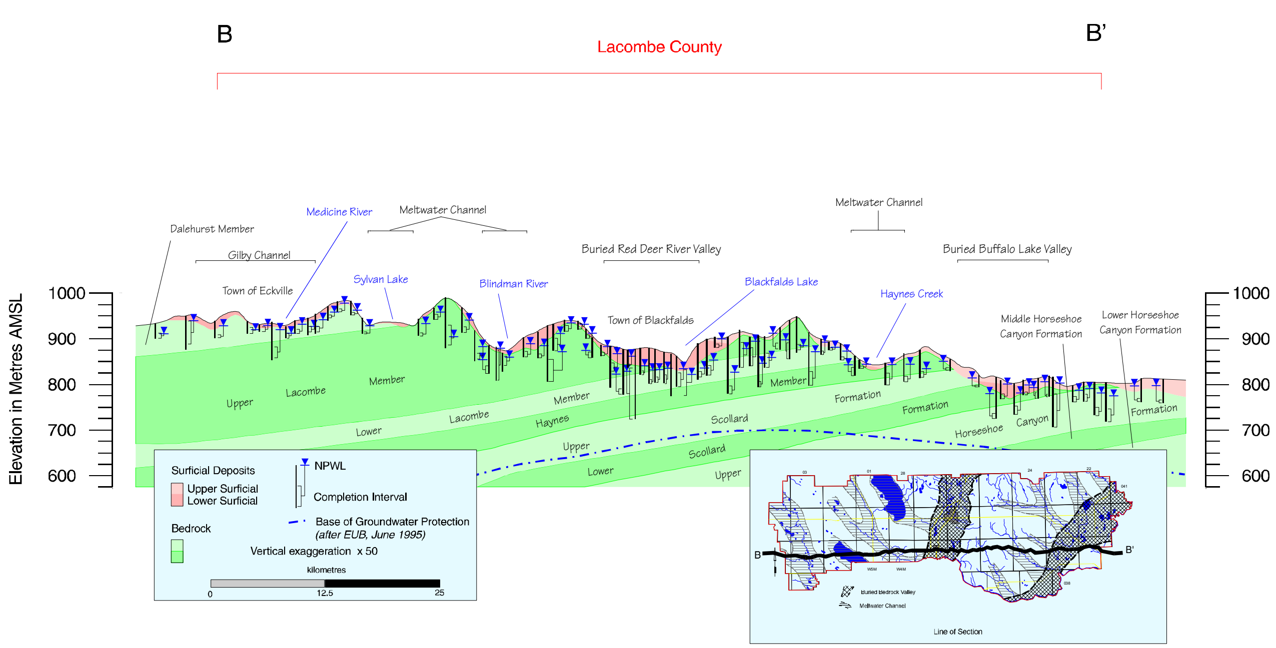

Figure 9. Cross-Section B - B'

9 See glossary

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 as a result of glaciation. The *lower surficial deposits* include pre-glacial fluvial[10] and lacustrine[11] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[12] and meltwater deposits. In the County, pre-glacial materials are expected to be mainly present in association with the linear bedrock lows.

1) Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeological unit, they consist of three hydraulic parts. The first unit is the sand and gravel deposits of the lower surficial deposits when present. These deposits are mainly saturated, where present. The second and third hydraulic 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 hydraulic unit is the saturated part of these sand and gravel deposits; the third hydraulic unit the unsaturated part of these deposits. For a graphical depiction of the above description, please refer to Figure 5, Page 8. 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.

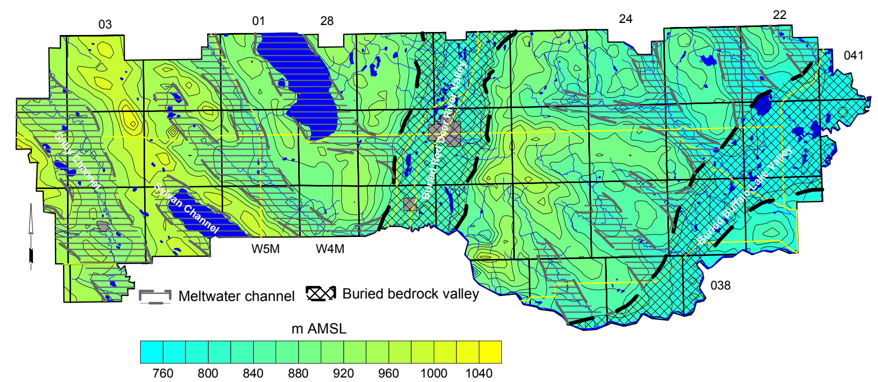

Figure 10. Bedrock Topography

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on the adjacent map.

Over the majority of the County, the surficial deposits are less than 30 metres thick (page A-17). The exceptions are mainly in association with areas where buried bedrock valleys are present, where the deposits can have a maximum thickness of close to 50 metres. The main southwest-northeast-trending linear bedrock lows in the County have been designated as the Buried Red Deer River Valley and the Buried Buffalo Lake Valley, as shown above on Figure 10.

The Buried Red Deer River Valley is present in the central part of the County, and extends northeast from the County border through the towns of Blackfalds and Lacombe to the northern County border. The Valley is approximately nine kilometres wide, with local bedrock relief being less than 80 metres. Sand and gravel deposits can be expected in association with this bedrock low, but the thickness of the sand and gravel deposits is expected to be mainly less than 15 metres.

The Buried Buffalo Lake Valley is present in the eastern part of the County, and extends northeast from the Red Deer River through the villages of Alix and Mirror to the northeastern County border. The Valley is approximately six to ten kilometres wide, with local bedrock relief being less than 60 metres. Sand and gravel deposits can be expected in association with this bedrock low, but the thickness of sand and gravel deposits is expected to be mainly less than ten metres.

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10 See glossary
11 See glossary
12 See glossary

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur over most of the County, but mainly in linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than 30 metres, but can be more than 30 metres in the buried bedrock valleys. The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally be expected to directly overlie the bedrock surface in the Buried Red Deer River and Buffalo Lake valleys. The lowest sand and gravel deposits are of fluvial origin, are usually less than five metres thick and may be discontinuous.

In the County, there are numerous linear bedrock lows that trend mainly northwest to southeast and are indicated as being of meltwater origin. Because sediments associated with the lower surficial deposits are indicated as being present in these linear bedrock lows, it is possible that the bedrock lows were originally tributaries to the Buried Red Deer River Valley and the Buried Buffalo Lake Valley as shown in the bedrock topography map on Figure 10. The two significant surface-water bodies in the County, Gull Lake and Sylvan Lake, appear to be associated with meltwater channels.

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

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

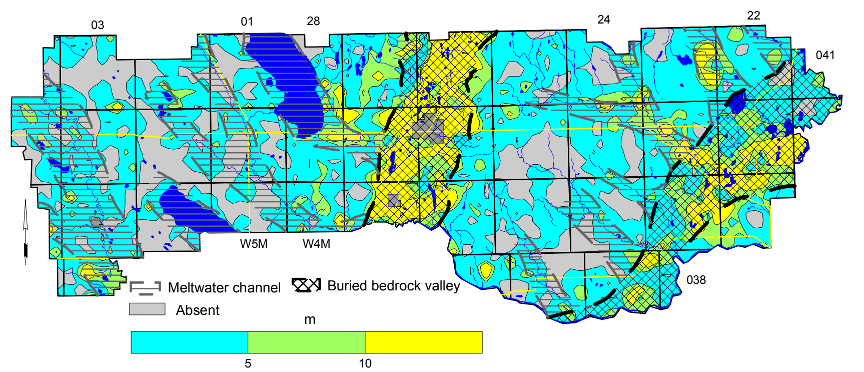

Figure 11. Thickness of Sand and Gravel Deposits

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 40% of the County, the sand and gravel deposits, where present, are more than 30% of the total thickness of the surficial deposits (page A-16). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly in the areas of the buried bedrock valleys and meltwater channels.

2) Sand and Gravel Aquifer(s)

One source of groundwater in the County includes aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. In the County, the thickness of the sand and gravel aquifer(s) is generally less than five metres, but can be more than ten metres in the vicinity of the Buried Red Deer River and Buffalo Lake valleys (page A-21).

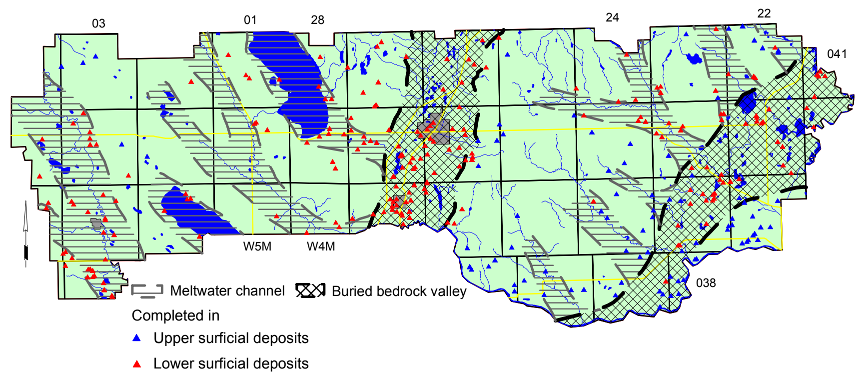

Figure 12. Water Wells Completed in Surficial Deposits

From the present hydrogeological analysis, 325 water wells are completed in aquifers in the surficial deposits. Of the 325 water wells, 92 are completed in aquifers in the upper surficial deposits and 233 are completed in aquifers in the lower surficial deposits. This number of water wells is more than twice the number (123) 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 elevation of the bedrock surface determined from the gridded topography surface at the same location, then the water well is considered to be completed in an aquifer in the surficial deposits.

The majority of the water wells completed in the upper surficial deposits are mainly not in association with linear bedrock lows as shown on Figure 12. A large number of water wells completed in the lower surficial deposits are located along the Buried Red Deer River and Buffalo Lake valleys and the Gilby Meltwater Channel.

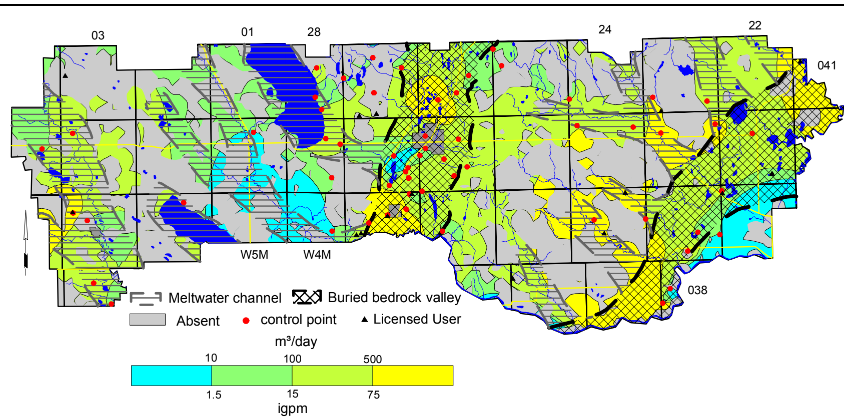

Figure 13. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

The adjacent map shows expected yields for water wells completed in sand and gravel aquifers(s). Over approximately 40% of the County, the sand and gravel deposits are not present, or if present, are not saturated.

Based on the aquifers that have been developed by existing water wells, these data show that water wells with yields of more than 100 m^3/day from sand and gravel aquifer(s) can be expected in most areas of the County. The most notable areas where yields of more than 100 m^3/day are expected are in association with the main linear bedrock lows. Higher yields could be a result of the gridding procedure used to process a limited number of data points. Licensed water wells completed in the Sand and Gravel Aquifer(s) are also shown on Figure 13.

a) Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the sand and gravel aquifers in the surficial deposits indicate the groundwaters are generally chemically hard and high in dissolved iron. In Lacombe County, groundwaters from the surficial aquifers mainly have a chemical hardness of greater than 200 and less than 400 mg/L.

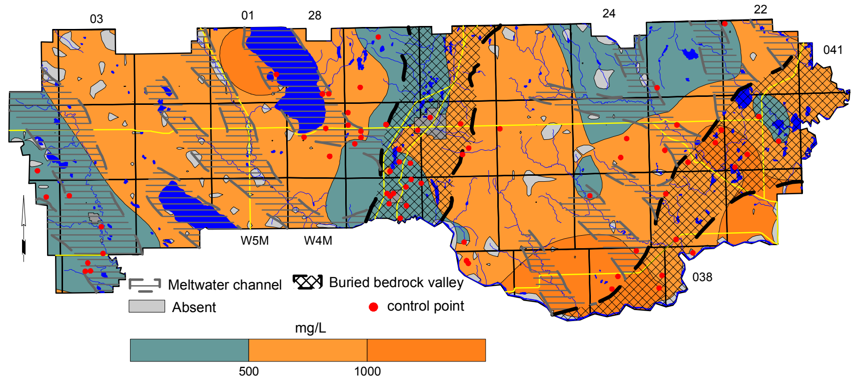

Figure 14. Total Dissolved Solids in Groundwater from Surficial Deposits

The Piper tri-linear diagrams[13] (see Appendix A) show the groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate or sodium-bicarbonate-type waters. The records with the sodium-bicarbonate waters were individually checked in the database to confirm the completion aquifer. Sixty percent of the groundwaters have a TDS concentration of more than 500 mg/L. The groundwaters with a TDS concentration of less than 500 mg/L occur in association with several of the linear bedrock lows. An exception is the Buried Buffalo Lake Valley, even though there are the greatest number of control points available, as shown on Figure 14. Seventy-two percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations of less than 1 mg/L. However, many iron analyses results are questionable due to varying sampling methodologies.

Although the majority of the groundwaters from the 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 70% of the samples analyzed in the County, the chloride ion concentration is less than 10 mg/L.

In the County, the nitrate + nitrite (as N) concentrations in the groundwaters from the surficial deposits exceed the maximum acceptable concentrations (MAC) of 10 mg/L in less than 10% of the samples (see CD-ROM).

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 County have been compared to the Guidelines for Canadian Drinking Water Quality (GCDWQ) in the adjacent table. Of the five constituents that have been compared to the GCDWQ, only the average values of TDS concentrations exceed the guidelines.

Constituent	Range for County in mg/L Minimum	Maximum	Average	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	45	7458	720	500
Sodium	2	536	105	200
Sulfate	3	4064	160	500
Chloride	<1	301	18	250
Nitrate + Nitrite (as N)	<0.05	55	3.8	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
GCDWQ - Guidelines for Canadian Drinking Water Quality, Sixth Edition Minister of Supply and Services Canada, 1996

Table 3. Concentrations of Constituents in Groundwaters from Surficial Aquifers

[13] See glossary

3) Upper Sand and Gravel Aquifer(s)

The Upper Sand and Gravel Aquifer(s) include saturated sand and gravel deposits in the upper surficial deposits. Typically, these aquifers are present within the surficial deposits at no particular depth. Saturated sand and gravel deposits are not continuous but are expected over approximately 15% of the County.

a) Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer(s) is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the surficial deposits; and (2) the depth to the bedrock surface or depth to top of lower surficial deposits when present. In the County, the thickness of the Upper Sand and Gravel is generally less than five metres, but can be more than ten metres in the vicinity of the Buried Buffalo Lake Valley (see CD-ROM).

b) Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer(s) can be high. The high permeability combined with significant thickness leads to an extrapolation of high yields for water wells; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the apparent yields of the water wells are limited. The apparent yields for water wells completed in this Aquifer are expected to be mainly less than 300 m³/day, except adjacent to parts of the Buried Red Deer River Valley in the southeastern part of the County as shown on Figure 15. Licensed water wells completed in the Upper Sand and Gravel Aquifer(s) are also shown on the figure. Higher yields present in the eastern part of the County could be a result of the gridding procedure used to process a very limited number of data points. Where the Upper Sand and Gravel Aquifer(s) 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 these Aquifer(s), and construction of a water supply well into the underlying bedrock may be the only alternative, provided yields and quality of groundwater from the bedrock aquifers are suitable.

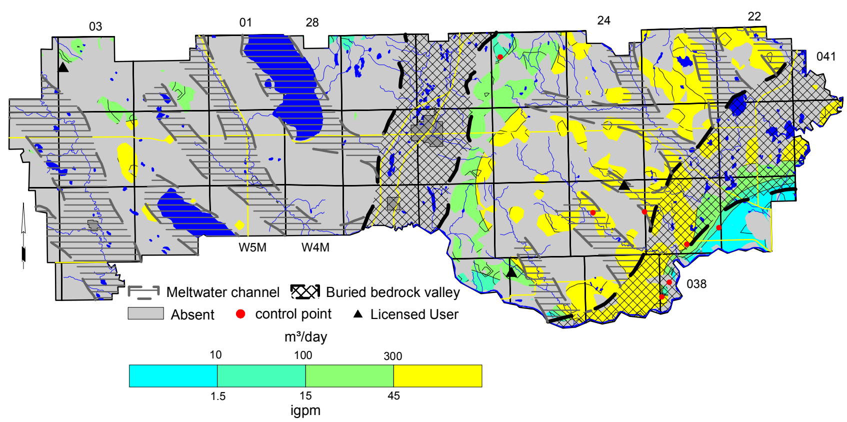

Figure 15. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer(s)

In the County, there are three licensed water wells that are completed in the Upper Sand and Gravel Aquifer(s), with a total authorized diversion of 106 m^3/day. The highest allocation of 57 m^3/day is for a water well in 11-19-041-03 W5M used for stock purposes.

4) Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deepest part of the pre-glacial linear bedrock lows. The top of the lower surficial deposits is based on more than 1,000 control points across Alberta. In the County, there are two control points provided by Allong, 1967 and Sham, 1984a.

a) Aquifer Thickness

The thickness of the Lower Sand and Gravel Aquifer is mainly less than five metres. In the County, the thickness of the Lower Sand and Gravel Aquifer is generally less than five metres, but can be more than 15 metres in the Buried Red Deer River Valley (see CD-ROM).

b) 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 (1) extreme western meltwater channel, (2) a tributary meltwater channel to the Buried Buffalo Lake Valley in the northeastern part of the County, and (3) in the vicinity of the towns of Lacombe and Blackfalds.

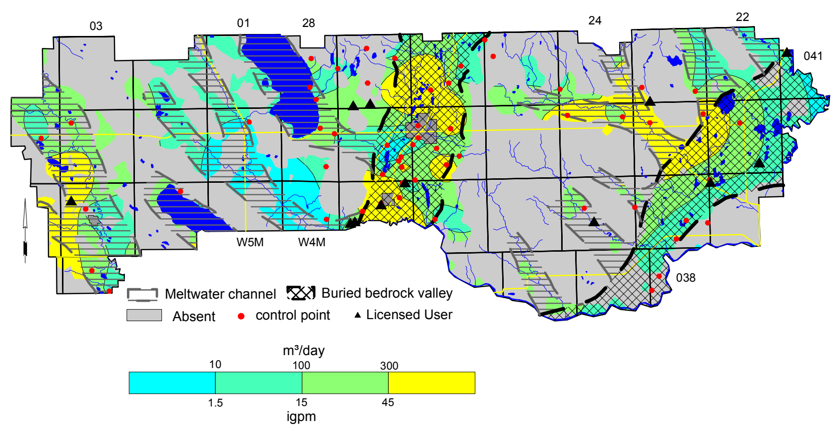

Figure 16. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

In the County, there are 14 licensed water wells that are completed in the Lower Sand and Gravel Aquifer, for a total authorized diversion of 1,262 m^3/day. The highest allocation of 507 m^3/day is for a sand and gravel company licensed to divert groundwater for dewatering purposes in NW 17-039-27 W4M. The second highest allocation is for the Town of Blackfalds, which is licensed to divert up to 372 m^3/day for municipal purposes from a water supply well in 03-27-039-27 W4M.

There are no chemistry data available in the groundwater database for the Town of Blackfalds water supply well completed in the Lower Sand and Gravel Aquifer or the sand and gravel company dewatering water well.

C. Bedrock

1) Geological Characteristics

The upper bedrock in the County is the Paskapoo, Scollard, Whitemud, Battle, and Upper Horseshoe Canyon formations. The Paskapoo Formation in central Alberta consists of the Dalehurst, Lacombe and Haynes members (Demchuk and Hills, 1991). The Edmonton Group underlies the Paskapoo Formation. The Edmonton Group includes the Scollard, Battle, Whitemud and Horseshoe Canyon formations. A generalized geologic column is illustrated in Figure 6, Appendix A and on the CD-ROM.

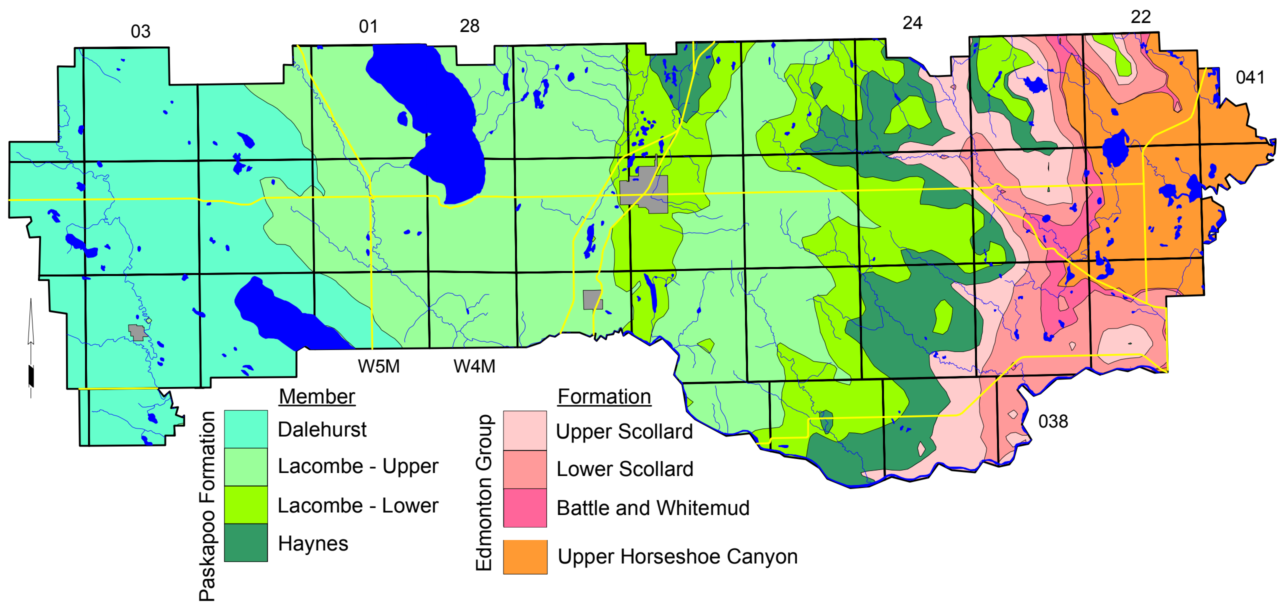

Figure 17. Bedrock Geology

The Paskapoo Formation is the upper bedrock and subcrops mainly west of range 23, W4M in the County. The Paskapoo Formation consists of cycles of thick, tablular sandstones, siltstone and mudstone layers (Glass, 1990). The maximum thickness of the Paskapoo Formation can be 800 metres, but in the County, the thickness is from 0 to 500 metres.

The Dalehurst Member is the upper bedrock and subcrops mainly west of Range 02, W5M. This Member has a maximum thickness of 300 metres within the County and is mostly composed of shale and siltstone with sandstone, bentonite and coal seams or zones. Two prominent coal zones within the Dalehurst are the Obed-Marsh Coal (up to 30 metres thick) and the Lower Dalehurst Coal (up to 50 metres thick). The bottom of the Lower Dalehurst Coal is the border between the Dalehurst and Lacombe members (Demchuk and Hills, 1991). In the County, the coal seams are not well developed. If the coal seams are not fractured, they are impermeable.

The Lacombe Member underlies the Dalehurst Member and subcrops mainly between range 01, W5M and range 24, W4M, within the County border. The Lacombe Member has a maximum thickness of 350 metres. The upper part of the Lacombe Member is mostly composed of shale interbedded with sandstone and has a maximum thickness of 250 metres. The lower part of the Lacombe Member is composed of sandstone and coal layers. In the middle of the lower part of the Lacombe Member there is a coal zone, which can be up to five metres thick. The lower part of the Lacombe Member has a maximum thickness of 100 metres. If the coal seams are not fractured, they are impermeable.

The Haynes Member underlies the Lacombe Member and subcrops mainly in range 24, W4M, within the County border. The Haynes Member has a maximum thickness of 100 metres and is composed mainly of sandstone with some siltstone, shale and coal. In the County, the Haynes Member has an average thickness of 40 metres.

The Scollard Formation underlies the Haynes Member and subcrops mainly in range 23, W4M. The Scollard Formation has a maximum thickness of 160 metres and has two separate designations: Upper and Lower. The Upper Scollard has an average thickness of 75 metres in the County and consists mainly of sandstone, siltstone, shale and coal seams or zones. Two prominent coal zones within the Upper Scollard are the Ardley Coal (up to 20 metres thick) and the Nevis Coal (up to 3.5 metres thick). The bottom of the Nevis Coal Seam is the border between the Upper and Lower Scollard formations. The Lower Scollard Formation has an average thickness of 50 metres in the County, and is composed mainly of shale and sandstone.

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

The Horseshoe Canyon Formation is the lower part of the Edmonton Group and subcrops in Ranges 21 and 22, W4M. The Horseshoe Canyon Formation has a maximum thickness of 350 metres and has three separate designations: Upper, Middle and Lower. The Upper Horseshoe Canyon, which can be up to 100 metres thick, is the uppermost bedrock in the eastern part of the County. The Middle Horseshoe Canyon, which is up to 70 metres thick, does not subcrop in the County.

The Horseshoe Canyon Formation consists of deltaic[14] and fluvial sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of limestone and ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be finer grained. The lower 60 to 70 metres and the upper 30 to 50 metres of the Horseshoe Canyon Formation can include coarser grained sandstone deposits.

There will be no direct review of the Middle or Lower Horseshoe Canyon formations in the text of this report; the only maps associated with the Middle Horseshoe Canyon Formation to be included on the CD-ROM will be structure-contour maps.

In the County, the Base of Groundwater Protection is below the Haynes Member where present. A map showing the depth to the Base of Groundwater Protection is given on page 7 of this report, in Appendix A, and on the CD-ROM.

[14] See glossary

2) Aquifers

Of the 7,388 water wells in the database, 4,234 were defined as being completed below the top of bedrock and 325 completed in surficial aquifers. However, at least a reported completion depth is available for the majority of the remaining 2,829 water wells. Assigning the water well 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 geologic 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 837 additional water wells for a total of 5,071 water wells. There are 702 water wells that have been identified as being completed in more than one bedrock aquifer.

Geologic Unit	No. of Bedrock Water Wells
Dalehurst	931
Upper Lacombe	2,255
Lower Lacombe	514
Haynes	485
Upper Scollard	282
Lower Scollard	215
Upper Horseshoe Canyon	370
Other	19
Multiple Completions	702
Total	5,773

Table 4. Completion Aquifer

The bedrock water wells are mainly completed in the Dalehurst and Lacombe aquifers, as shown in the above table.

There are 2,795 records for bedrock water wells that have apparent yield values, which is 48% of all bedrock water wells. In the County, yields for water wells completed in the upper bedrock aquifer(s) are mainly between ten and 100 m³/day. Some of the areas with yields of more than 100 m³/day indicated on the adjacent figure are in the vicinity of linear bedrock lows. These higher yield areas may identify areas of increased permeability resulting from the weathering process. In addition to the 2,795 water wells, there are records for 100 dry or abandoned water wells with “insufficient water”. In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to the 100 dry holes prior to gridding. Also included in these postings is any record that includes comments that state the water well goes dry in dry years.

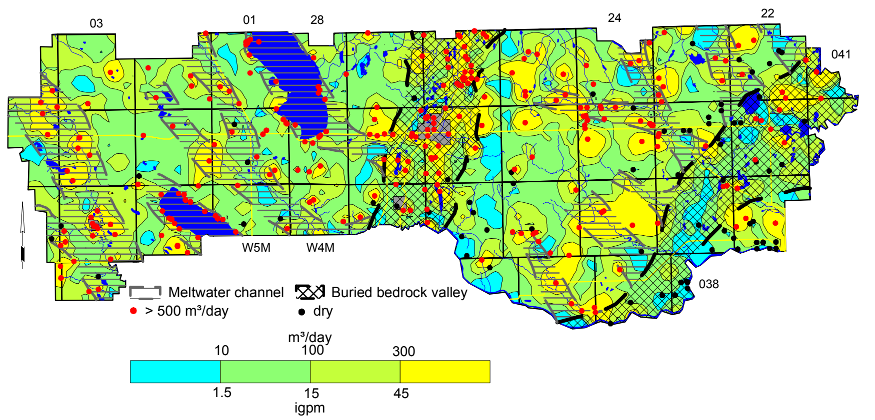

Figure 18. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Of the 2,795 water well records with apparent yield values, 2,504 have been assigned to aquifers associated with specific geologic units. Fifty percent (1,390) of the water wells completed in the bedrock aquifers have apparent yields that range from ten to 100 m³/day, 20% (549) have apparent yield values that range from 100 to 300 m³/day, and 18% (505) have apparent yields that are greater than 300 m³/day, as shown in the adjacent table. In the Haynes and Upper Scollard aquifers, there are more yield values that are greater than 100 m³/day than are less than 100 m³/day.

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 to 300 m³/day	>300 m³/day
Dalehurst	364	31	178	89	66
Upper Lacombe	1182	165	618	235	164
Lower Lacombe	279	43	140	55	41
Haynes	241	7	107	52	75
Upper Scollard	141	4	58	24	55
Lower Scollard	103	16	57	15	15
Upper Horseshoe Canyon	194	27	96	37	34
Other	1	0	1	0	0
Multiple Completions	290	58	135	42	55
Totals	2,795	351	1390	549	505

Table 5. Apparent Yields of Bedrock Aquifers

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 1,000 mg/L, with most of the groundwaters with lower TDS concentrations occurring in the western half of the County. The lower TDS concentrations may be a result of more active flow systems and shorter flow paths.

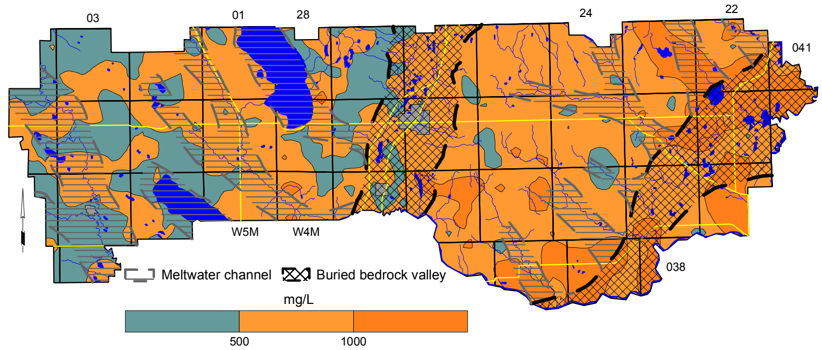

Figure 19. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The relationship between TDS and sulfate concentrations shows that when TDS values in the groundwaters from the upper bedrock aquifer(s) exceed 1,100 mg/L, the sulfate concentrations exceed 400 mg/L. The sulfate concentrations in groundwaters from the upper bedrock aquifer(s) were compared to the distance of completion depth from the top of the Upper Lacombe Member. The maximum sulfate concentrations generally increase with depth, as shown below in Figure 20. Groundwaters from Dalehurst water wells have sulfate concentrations of less than 200 mg/L.

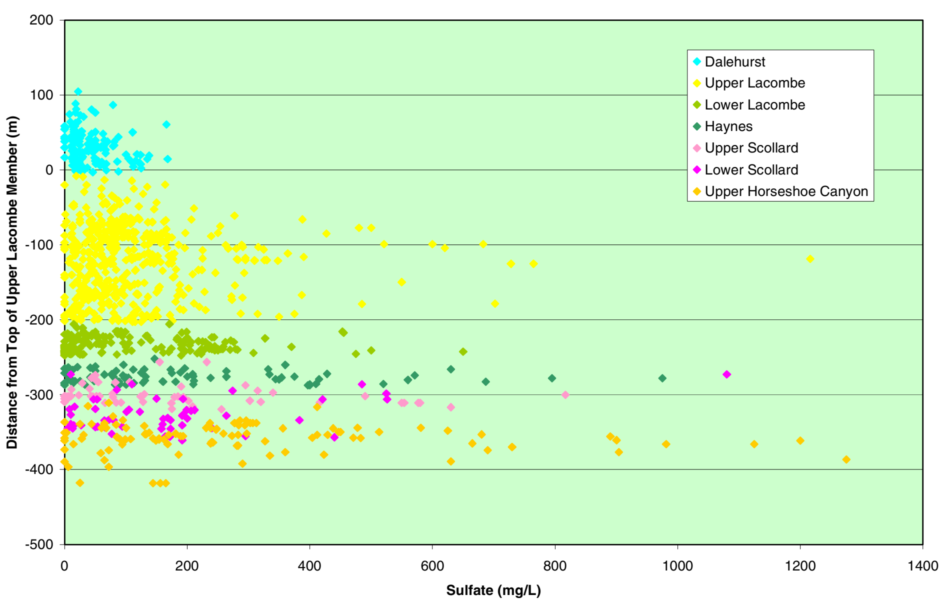

Figure 20. Distance from Top of Lacombe Member vs Sulfate in Groundwaters from Upper Bedrock Aquifer(s)

The chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 10 mg/L in approximately 85% of the County. The nitrate + nitrite (as N) concentrations are less than 0.1 mg/L in 80% of the chemical analyses for bedrock water wells.

In the County, approximately 60% of the groundwater samples from upper bedrock aquifer(s) have fluoride concentrations that are too low (less than 0.5 mg/L) to meet the recommended daily needs of people. Approximately 25% of the groundwater samples from the entire County are between 0.5 and 1.5 mg/L and approximately 15% exceed the maximum acceptable concentration for fluoride of 1.5 mg/L. The fluoride values of greater than 1.5 mg/L occur mainly in the south-central part of the County (page A-31).

The Piper tri-linear diagrams (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 calcium-magnesium-bicarbonate-sulfate types.

4) Dalehurst Aquifer

The Dalehurst Aquifer comprises the porous and permeable parts of the Dalehurst Member. The Dalehurst Member subcrops under the surficial deposits in the Western quarter of the County. The thickness of the Dalehurst Member varies from less than two metres at the eastern edge of the subcrop to more than 125 metres in the western part of the County; in the remaining part of the County, the Dalehurst Member has been eroded. The thickness of the Dalehurst Member decreases in the vicinity of Medicine River and Sylvan Lake as a result of erosional processes.

a) Depth to Top

The depth to top of the Dalehurst Member is a function of the thickness of the surficial deposits, which ranges from less than two metres to more than 50 metres (page A-32).

b) Apparent Yield

The apparent yields for individual water wells completed through the Dalehurst Aquifer are mainly in the range of ten to 100 m³/day. Water wells with higher yields are expected mainly in areas where meltwater channels are present.

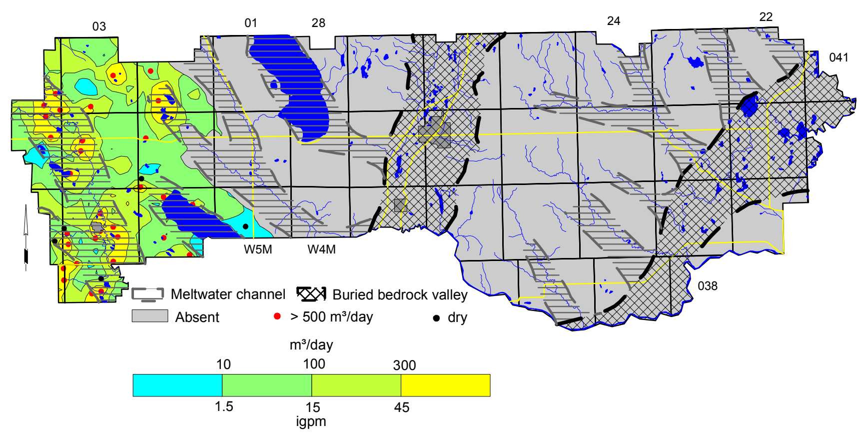

Figure 21. Apparent Yield for Water Wells Completed through Dalehurst Aquifer

Two Enerplus Resources Corporation (Enerplus) water source wells in township 038, range 04, W5M, just outside the County border, are authorized to divert a total of 565 m³/day (Hydrogeological Consultants Ltd. (HCL), 2000. The water source wells are completed in the Dalehurst Aquifer. Long-term monitoring of the two water source wells and five observation water wells indicated an effective transmissivity of 90 metres squared per day (m^2/day) and a corresponding storativity of 0.00001.

In the County, there are 48 licensed water wells that are completed in the Dalehurst Aquifer. The highest allocation of 169 m^3/day is for a Town of Eckville water supply well in 15-16-039-03 W5M.

c) Quality

The groundwaters from the Dalehurst Aquifer are mainly a sodium-bicarbonate-type (see Piper diagram on CD-ROM), with TDS concentrations ranging from less than 400 to more than 600 mg/L. The sulfate concentrations are all below 200 mg/L, and are mainly between ten and 50 mg/L. Chloride concentrations from the Dalehurst Aquifer are mainly less than ten mg/L. There are three out of 130 analyses where fluoride concentrations exceed 1.5 mg/L.

Groundwaters from the Enerplus water source wells that are completed in the Dalehurst Aquifer have TDS concentrations of less than 1,000 mg/L, sulfate concentrations of less than 25 mg/L, and chloride concentrations of less than 2.5 mg/L The groundwater from one water source well is a sodium-bicarbonate-type; the other groundwater is a calcium-magnesium-bicarbonate-type (HCL, 1991).

5) Upper Lacombe Aquifer

The Upper Lacombe Aquifer comprises the porous and permeable parts of the Upper Lacombe Member that underlies the Dalehurst Member, and subcrops under the surficial deposits in most of the middle part of the County. The Upper Lacombe Member has been eroded in the Buried Red Deer River Valley. The structure contours show the Upper Lacombe Member having a maximum thickness of in the order of 300 metres.

a) Depth to Top

The depth to the top of the Upper Lacombe Member ranges from less than ten metres below ground level where the Member subcrops in the eastern part of the County to more than 100 metres in the western part of the County.

b) Apparent Yield

The apparent yields for individual water wells completed through the Upper Lacombe Aquifer are mainly in the range of ten to 100 m³/day. Water wells with higher yields are expected mainly in areas where linear bedrock lows are present.

An extended aquifer test conducted with a water supply well completed in the Upper Lacombe Aquifer for the Village of Bentley indicated a long-term yield of 400 m³/day based on an effective transmissivity of 215 m²/day (HCL, 1976).

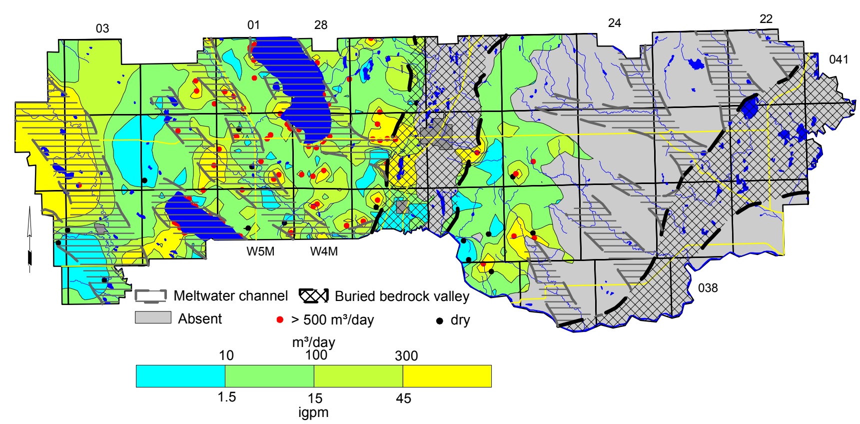

Figure 22. Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer

The Village of Bentley has two water supply wells in 03-26-040-01 W5M completed in the Upper Lacombe Aquifer that are licensed to divert a total of 320 m³/day. The largest single allocation for a water well completed in the Upper Lacombe is for a Suncor Resouces Inc. (Suncor) water source well in 12-05-039-03 W5M for 389 m³/day used for injection purposes. This high yield is not reflected in the above map because there were three dry holes in the vicinity and the Suncor water source well could not be matched up with a record in the groundwater database and, therefore, has not been included.

c) Quality

The groundwaters from the Upper Lacombe Aquifer are mainly a sodium-bicarbonate- or sodium-sulfate-type (see Piper diagram on CD-ROM), with TDS concentrations ranging from less than 500 to more than 1,000 mg/L. The sulfate concentrations are mainly below 250 mg/L. Chloride concentrations from the Upper Lacombe Aquifer are mainly less than ten mg/L. There are 48 out of 362 analyses where fluoride concentrations exceed 1.5 mg/L.

Groundwaters from the Village of Bentley water supply well that is completed in the Upper Lacombe Aquifer, have a TDS concentration of 288 mg/L, a sulfate concentration of less than 18 mg/L, and a chloride concentration of 4 mg/L. The groundwater from this water source well is a sodium-bicarbonate-type (HCL, 1975).

6) Lower Lacombe Aquifer

The Lower Lacombe Aquifer comprises the porous and permeable parts of the Lower Lacombe Member that underlies the Upper Lacombe Member, and subcrops under the surficial deposits in most of the Buried Red Deer River Valley, and mainly in ranges 24 and 25, W4M in the County. Structure contours have been prepared for the top of the Member, which underlies two-thirds of the County. The structure contours show the Lacombe Member having an average thickness of in the order of 50 metres.

i) Depth to Top

The depth to the top of the Lower Lacombe Member ranges from less than ten metres below ground level where the Member subcrops in the eastern part of the County to more than 250 metres in the western part of the County.

ii) Apparent Yield

The apparent yields for individual water wells completed through the Lower Lacombe Aquifer are mainly in the range of ten to 100 m^3/day. Water wells with higher yields are expected mainly in the areas where linear bedrock lows are present.

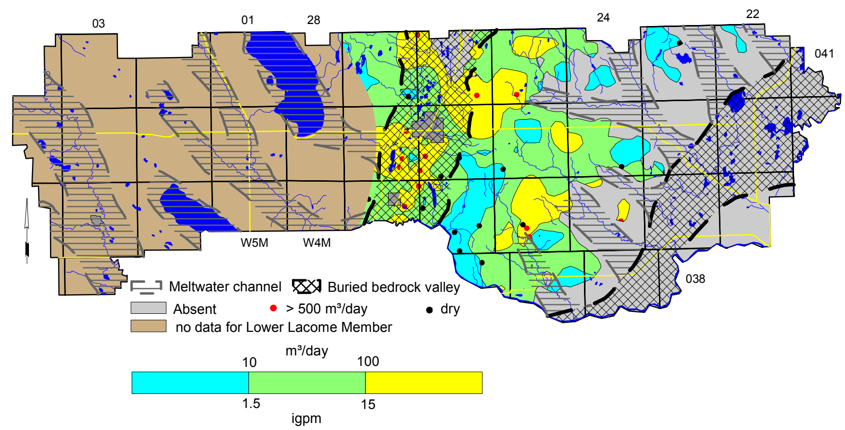

Figure 23. Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer

An extended aquifer test conducted with a water supply well for Eclipse Pork Ltd. completed in the Lower Lacombe Aquifer in SW 26-039-25 W4M indicated a long-term yield of 54 m^3/day based on an effective transmissivity of 32.5 m^2/day and corresponding storativity coefficient of 0.0001 (HCL, 1999). This water well is located close to the boundary of where water wells with apparent yields of greater than 100 m^3/day and less than 100 m^3/day are expected.

In the County, there are 33 licensed water wells that are completed in the Lower Lacombe Aquifer, for a total authorized groundwater diversion of 659 m^3/day. The highest single allocation is 118 m^3/day for a water well in 07-03-039-25 W4M.

iii) Quality

The groundwaters from the Lower Lacombe Aquifer are mainly a sodium-bicarbonate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are expected to range mainly from 500 to 1,000 mg/L, with higher concentrations expected at the southeastern edge of the Aquifer. The sulfate concentrations are mainly below 500 mg/L. The indications are that chloride concentrations in the Lower Lacombe Aquifer are expected to be mainly less than ten mg/L. There are 29 out of 121 analyses where fluoride concentrations exceed 1.5 mg/L.

Groundwaters from the Eclipse Pork Ltd. water supply well that is completed in the Lower Lacombe Aquifer, have a TDS concentration of 1,260 mg/L, a sulfate concentration of 455 mg/L, and a chloride concentration of 0.7 mg/L. The groundwater from this water supply well is a sodium-bicarbonate-type (HCL, 1999).

7) Haynes Aquifer

The Haynes Aquifer comprises the porous and permeable parts of the Haynes Member that underlies the Lower Lacombe Member. The Haynes Member subcrops under the surficial deposits in a small part of the Buried Red Deer River Valley, and further west in range 24, W4M in the County. Structure contours have been prepared for the top of the Member, which underlies most of the County. The structure contours show the Haynes Member having an average thickness of in the order of 40 metres.

i) Depth to Top

The depth to the top of the Haynes Member ranges from less than ten metres below ground level where the Member subcrops in the eastern part of the County to more than 300 metres in the western part of the County.

ii) Apparent Yield

The apparent yields for individual water wells completed through the Haynes Aquifer mainly exceed 100 m³/day. Water wells with higher yields are expected mainly in areas where linear bedrock lows are present.

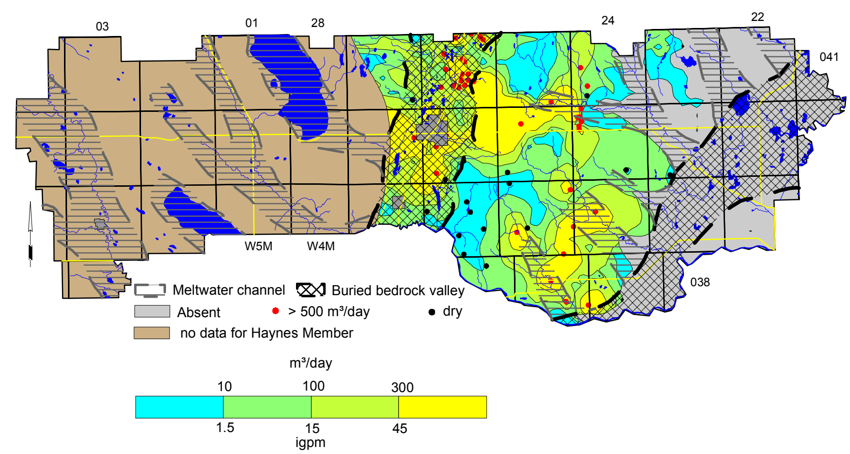

Figure 24. Apparent Yield for Water Wells Completed through Haynes Aquifer

An extended aquifer test conducted with the Town of Lacombe Water Supply Well (WSW) No. 5A completed in the Haynes Aquifer in 12-19-040-26 W4M indicated a long-term yield of more than 1,100 m³/day, based on an effective transmissivity of 50 m^2/day and corresponding storativity coefficient of 9.4×10^{-4} (HCL, 1994). However, since this water well was a replacement well for WSW No. 5, and the Town's groundwater supply needs did not require an increase, the existing licence authorizing 460 m³/day was transferred to WSW No. 5A.

In the County, there are 63 licensed water wells that are completed in the Haynes Aquifer, with a total authorized groundwater diversion of 6,050 m^3/day. Of the 6,050 m^3/day authorized to be diverted from the Haynes Aquifer, the Town of Lacombe has seven water supply wells that are authorized to divert 4,532 m^3/day. The Town of Blackfalds has a water supply well completed in the Haynes Aquifer authorized to divert 187 m^3/day.

iii) Quality

The groundwaters from the Haynes Aquifer are mainly a sodium-bicarbonate-type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are expected to range mainly from 500 to 1,000 mg/L, with lower concentrations expected near the Town of Blackfalds and at the northeastern edge of the Aquifer. The sulfate concentrations are mainly below 500 mg/L, with lower concentrations expected near the towns of Lacombe and Blackfalds. The chloride concentrations in the Haynes Aquifer are expected to be mainly less than ten mg/L. There are 11 out of 59 analyses where fluoride concentrations exceed 1.5 mg/L.

Groundwaters from the Town of Lacombe WSW No. 5A have a TDS concentration of 580 mg/L, a sulfate concentration of 3 mg/L, and a chloride concentration of 10 mg/L. The groundwater from this water supply well is a sodium-bicarbonate-type (HCL, 1994).

8) Upper Scollard Aquifer

The Upper Scollard Aquifer comprises the porous and permeable parts of the Upper Scollard Formation that underlies the Haynes Member, and subcrops under the surficial deposits mainly in parts of ranges 23 and 24, W4M. Structure contours have been prepared for the top of the Upper Scollard Formation, which underlies most of the County. The structure contours show the Upper Scollard having an average thickness in the County of 75 metres.

i) Depth to Top

The depth to the top of the Upper Scollard Formation ranges from less than ten metres below ground level where the Formation subcrops in the eastern part of the County to more than 350 metres in the western part of the County.

ii) Apparent Yield

The apparent yields for individual water wells completed through the Upper Scollard Aquifer are mainly more than 100 m³/day. The adjacent map indicates that water wells with apparent yields of more than 500 m³/day are expected mainly in association with areas where meltwater channels are present. In these areas, weathering processes may be increasing the local permeability.

There are a number of dry holes that were encountered in the area south of the Town of Lacombe, creating a low-yield area.

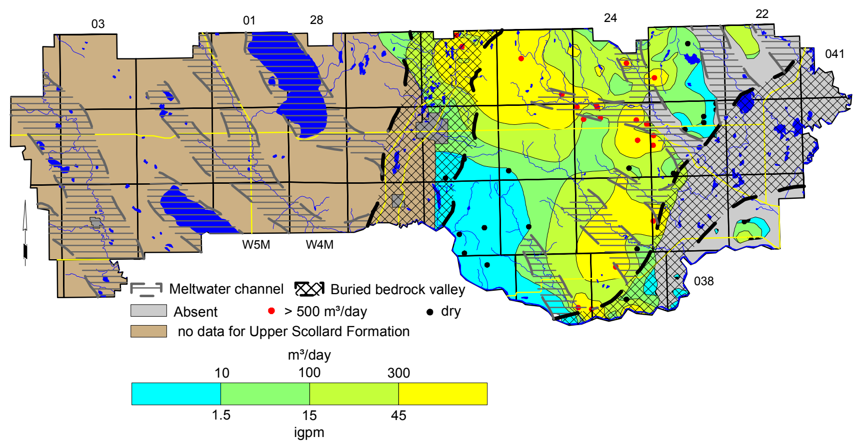

Figure 25. Apparent Yield for Water Wells Completed through Upper Scollard Aquifer

In the County, there are 28 licensed water wells that are completed in the Upper Scollard Aquifer, for a total authorized groundwater diversion of 1,938 m^3/day. The largest single allocation is for the Village of Alix, having a diversion of 1,146 m^3/day.

iii) Quality

The groundwaters from the Upper Scollard Aquifer are mainly a sodium-bicarbonate-type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are expected to range mainly from 500 to 1,500 mg/L. Sulfate concentrations are mainly less than 500 mg/L. There are 12 out of 52 analyses where fluoride concentrations exceed 1.5 mg/L.

The indications are that chloride concentrations in the Upper Scollard Aquifer are expected to be mainly less than ten mg/L.

9) Lower Scollard Aquifer

The Lower Scollard Aquifer comprises the porous and permeable parts of the Lower Scollard Formation that underlies the Upper Scollard Formation, and subcrops under the surficial deposits mainly in range 23, W4M. Structure contours have been prepared for the top of the Lower Scollard Formation, which underlies most of the County. The structure contours show the Lower Scollard Formation having an average thickness of 50 metres.

i) Depth to Top

The depth to the top of the Lower Scollard Formation ranges from less than ten metres below ground level where the Formation subcrops in the eastern part of the County to more than 500 metres in the western part of the County.

ii) Apparent Yield

The apparent yields for individual water wells completed through the Lower Scollard Aquifer range mainly from ten to 100 m³/day. The adjacent map indicates that water wells with apparent yields of more than 500 m³/day are expected mainly in townships 040 and 041, ranges 23 and 24, W4M. In these areas, weathering processes may be increasing the local permeability.

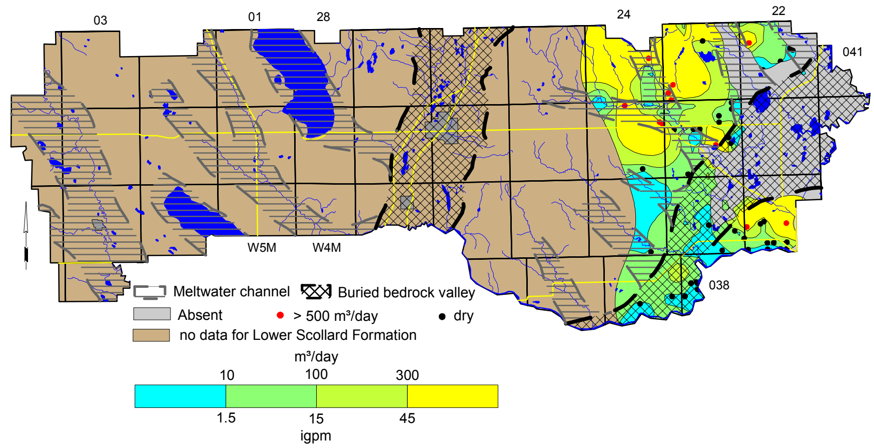

Figure 26. Apparent Yield for Water Wells Completed through Lower Scollard Aquifer

In the County, there are nine licensed water wells that are completed in the Lower Scollard Aquifer with a total authorized diversion of 190 m^3/day. The largest single allocation is used for stock and domestic purposes in 04-28-040-23 W4M, having a diversion of 98 m^3/day.

iii) Quality

The groundwaters from the Lower Scollard Aquifer are a mainly sodium-bicarbonate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are expected to range from less than 500 to more than 1,000 mg/L. Sulfate concentrations are mainly less than 250 mg/L.

Chloride concentrations in the groundwaters from the Lower Scollard Aquifer are expected to be mainly less than ten mg/L. There are three out of 45 analyses where fluoride concentrations exceed 1.5 mg/L.

Groundwaters from the domestic/stock water supply well in 04-28-040-23 W4M have a TDS concentration of 770 mg/L, a sulfate concentration of 168 mg/L, and a chloride concentration of 2 mg/L..

10) Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer comprises the porous and permeable parts of the Upper Horseshoe Canyon Formation that underlies the Lower Scollard Formation, and subcrops under the surficial deposits in the eastern part of the County, mainly in ranges 21 and 22, W4M. Structure contours have been prepared for the top of the Formation, which underlies all of the County. The structure contours show the Upper Horseshoe Canyon Formation having an average thickness of 100 metres.

i) Depth to Top

The depth to the top of the Upper Horseshoe Canyon Formation ranges from less than ten metres below ground level where the Formation subcrops in the eastern part of the County to more than 600 metres in the western part of the County.

ii) Apparent Yield

The apparent yields for individual water wells completed through the Upper Horseshoe Canyon Aquifer range mainly from ten to 100 m³/day. The adjacent map indicates that water wells with apparent yields of more than 300 m³/day are expected mainly in association with areas where linear bedrock lows are present. In these areas, weathering processes may be increasing the local permeability. There are no data from the groundwater database for the Aquifer west of range 23, W4M.

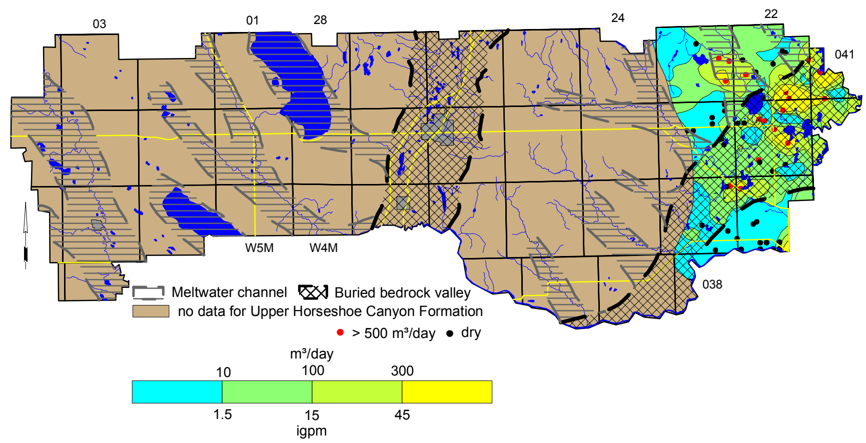

Figure 27. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer

Dry test holes appear to be more common where the upper bedrock is the Upper Horseshoe Canyon Formation.

In the County, there are 22 licensed water wells that are completed in the Upper Horseshoe Canyon Aquifer, with a total authorized groundwater diversion of 687 m^3/day. The Village of Alix operates five water supply wells that are completed in the Upper Horseshoe Canyon Aquifer, having a total authorized diversion of 445 m^3/day.

iii) Quality

The groundwaters from the Upper Horseshoe Canyon Aquifer are mainly sodium-bicarbonate- or sodium-sulfate-types (see Piper diagram on CD-ROM). Total dissolved solids concentrations are expected to range from less than 500 to more than 1,500 mg/L. The sulfate concentrations are mainly less than 500 mg/L.

The indications are that chloride concentrations in the groundwaters from the Upper Horseshoe Canyon Aquifer are expected to be mainly less than 50 mg/L. There are 11 out of 85 analyses where fluoride concentrations exceed 1.5 mg/L.

There are no chemical data available in the groundwater database for the five licensed Village of Alix water supply wells completed in the Upper Horseshoe Canyon Aquifer.

VI. Groundwater Budget

A. Hydrographs

There is one location in the County where water levels are being measured and recorded with time. This site is an observation water well (Obs WW) in 01-32-039-02 W5M that is part of the AENV regional groundwater-monitoring network. An additional observation water well, Obs WW No. 02-28, located west of the County's border in 02-28-038-04 W5M, has been monitored since 1978 by Mow-Tech Ltd.[15] and is also discussed in the text below. The water-level record for AENV Obs WW No. 391 is from 1992 to 1998 and the water-level record for Obs WW No. 02-28 is from 1978 to 2000.

AENV Obs WW No. 391, located at the northwestern end of Sylvan Lake, was drilled in 1990, and is screened from 31.4 to 32.9 metres below ground level in the Upper Lacombe Aquifer. The adjacent hydrograph shows annual cycles of recharge in late spring/early summer and a decline throughout the remainder of the year. Overall annual fluctuations are approximately 0.4 metres. From 1992 to 1998, there has been a net decline in the water level of approximately 0.6 metres. The water-level fluctuations in AENV Obs WW No. 391 in 01-32-039-02 W5M has been compared to the precipitation measured at the Eckville South weather station for the months March, April and May. The rise in water level in 1993 and 1994 would be associated with recharge when the frost leaves the ground. In 1997, the rise in water level late in the year would be associated with excess precipitation after most vegetation has been killed by frost and before the ground froze. The low water level at the start of most years is a result of no recharge to the groundwater flow system during the time of ground frost.

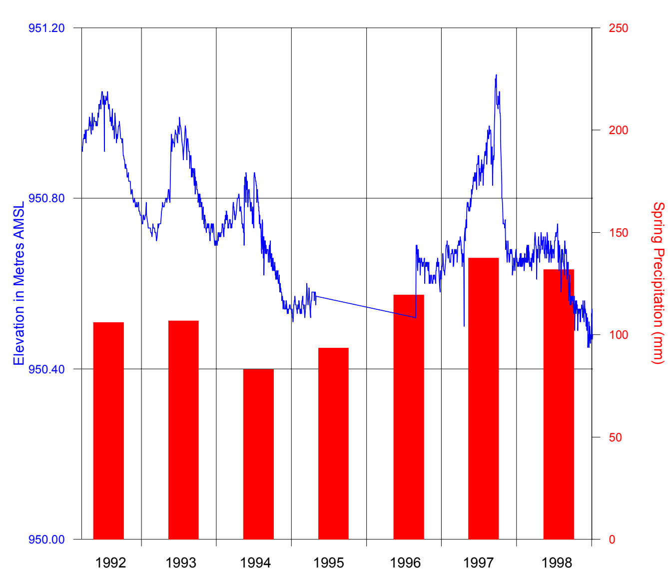

Figure 28. Summer Precipitation vs Water Level in AENV Obs WW No. 391

[15] Mow-Tech Ltd. 1-800-GEO-WELL

A second example illustrating the impact precipitation has on water levels is with an Enerplus observation water well. Enerplus (formerly Suncor) has maintained up to two water source wells and five observation water wells since 1978, all completed in the Dalehurst Aquifer. Enerplus has diverted an average of 200 m^3/day since 1979.

Overall annual fluctuations range from approximately one to three metres. From 1981 to 1985, there was a net decline in the water level of approximately four metres as a result of an increased average groundwater production of 365 m^3/day from the two water source wells complete with limited recharge due to below-average precipitation. There has been a general rise in water levels in Obs WW No. 02-28 since the early 1990s in response to a reduced average groundwater diversion of 106 m^3/day and seasonal recharge.

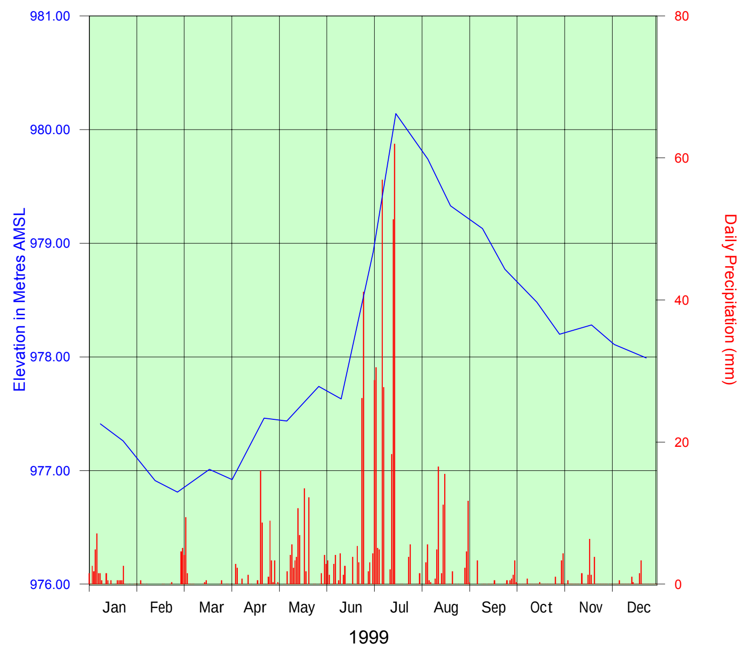

Figure 29. 1999 Daily Precipitation vs Water Level in Obs WW No. 02-28

The water-level fluctuations in Obs WW No. 02-28 have been compared to the 1999 daily precipitation measured at the Red Deer airport weather station. The comparison shows that the water-level fluctuation reflects the changes in daily precipitation. The impact of recharge to the groundwater regime is most easily observed in July as shown in the adjacent figure.

In June and July 1999, the water level in Obs WW No. 02-28 rose more than two metres. The rate and magnitude of the rise was unprecedented in the previous 22 years of groundwater monitoring. The change in water level in 1999 has been plotted on the above graph along with daily precipitation measured at the Red Deer airport 46 kilometres from the Obs WW. From June 25 to July 16, 1999, the total precipitation was 363 mm and corresponds to the rise in water level of more than two metres. There has been no quantification of the results.

B. Estimated Water Use from Unlicensed Groundwater Users

An estimate of the quantity of groundwater removed from each geologic unit in Lacombe County must include both the licensed diversions and the unlicensed use. As stated previously on page 8 of this report, the daily water requirement for livestock for the County based on the 1996 census is estimated to be 15,258 cubic metres. Of the 15,258 m³/day required for livestock, 6,166 m³/day has been licensed by Alberta Environment which includes both surface water and groundwater. To obtain an estimate of the quantity of groundwater being diverted from the individual geologic units, it has been assumed that the remaining 9,092 m³/day of water required for livestock watering is obtained from unlicensed groundwater use. In the groundwater database for the County, there are records for 6,505 water wells that are used for domestic/stock purposes. These 6,505 water wells include both licensed and unlicensed water wells. Of the 6,505 water wells, 950 water wells are used for stock, 1,758 are used for domestic/stock purposes, and 3,797 are for domestic purposes only.

There are 2,708 water wells that are used for stock or domestic/stock purposes. There are 319 licensed groundwater users for agricultural (stock) purposes, giving 2,389 unlicensed stock water wells. (Please refer to Table 2 on page 8 for the breakdown by aquifer of the 319 licensed stock groundwater users). By dividing the number of unlicensed stock and domestic/stock water wells (2,389) into the quantity of groundwater required for stock purposes that is not licensed (9,052 m³/day), the average unlicensed water well diverts 3.8 m³/day. Because of the limitations of the data, no attempt has been made to compensate for dugouts, springs or inactive water wells, and the average stock use is considered to be 3.8 m³/day per stock water well.

Groundwater for household use does not require licensing. Under the Water Act, a residence is protected for up to 3.4 m³/day. However, the standard groundwater use for household purposes is 1.1 m³/day.

To obtain an estimate of the groundwater from each geologic unit, there are three possibilities for a water well. A summary of the possibilities and the quantity of water for each use is as follows:

Domestic 1.1 m³/day
Stock 3.8 m³/day
Domestic/stock 4.9 m³/day

Based on using all available domestic, domestic/stock, and stock water wells and corresponding calculations, the following table was prepared. The table shows a breakdown of the 6,505 unlicensed and licensed water wells used for domestic, stock, or domestic/stock purposes by the geologic unit in which each water well is completed. The final column in the table equals the total amount of unlicensed groundwater that is being used for both domestic and stock purposes. The data provided in the table below indicate that most of the 11,332 m³/day, estimated to be diverted from unlicensed domestic, stock, or domestic/stock water wells, is from the Dalehurst and Upper Lacombe aquifers.

	Unlicensed and Licensed Groundwater Diversions							***Licensed Groundwater Diversions***	***Unlicensed Groundwater Diversions***
Aquifer Designation	Number of Domestic	Daily Use (1.1 m³/day)	Number of Stock	Daily Use (3.8 m³/day)	Number of Domestic and Stock	Daily Use (4.9 m³/day)	Totals m³/day	Totals (m³/day)	Totals m³/day
Upper Sand/Gravel	36	40	14	53	37	182	274	62	212
Lower Sand/Gravel	101	111	39	148	54	265	524	27	497
Bedrock	353	388	90	343	149	731	1,462	138	1,324
Dalehurst	359	395	141	537	277	1,359	2,290	407	1,883
Upper Lacombe	1,355	1,491	328	1,248	401	1,967	4,706	2,274	2,432
Lower Lacombe	272	299	83	63	114	559	921	493	428
Haynes	270	297	42	160	118	579	1,036	577	459
Upper Scollard	118	130	49	186	90	442	758	412	346
Lower Scollard	93	102	50	190	55	270	562	74	488
Upper Horseshoe Canyon	157	173	61	232	102	500	905	197	708
Unknown	683	751	53	202	361	1,771	2,724	171	2,553
Totals	3,797	4,177	950	3,363	1,758	8,624	16,164	4,832	11,332

Table 6. Unlicensed Groundwater Diversions

By assigning 1.1 m³/day for domestic use, 3.8 m³/day for stock use and 4.9 m³/day for domestic/stock use, and using the total maximum authorized diversion associated with any licensed water well that can be linked to a record in the database, a figure has been prepared that shows the estimated groundwater use in terms of volume (licensed plus unlicensed) per section per day for the County.

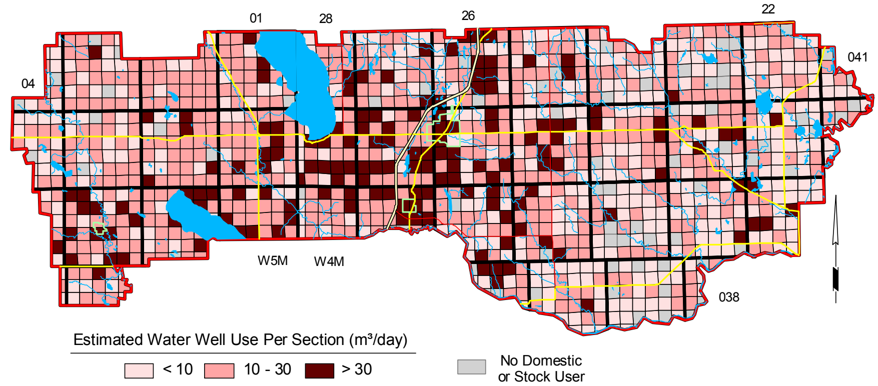

Figure 30. Estimated Water Well Use Per Section

There are 1,269 sections in the County. The estimated water well use per section can be more than 30 m³/day in 158 of the 1,269 sections. The most notable areas where water well use of more than 30 m³/day is expected occur mainly in the central part of the County, as shown on Figure 30. The only AENV-operated observation water well in the County is on the northwestern side of Sylvan Lake (page A-55). The north side of Sylvan Lake has an estimated water well use predominantly of more than 30 m^3/day. There has been a gradual decline in water level in the AENV Obs WW since it was put into use in 1992.

In summary, the estimated total groundwater use within Lacombe County is 28,295 m³/day, with the breakdown as shown in the adjacent table. Approximately 89% of this estimated total (25,172 m³/day) could be assigned to specific aquifer units. The remaining 11% of this total (3,123 m³/day) is being withdrawn from unknown aquifer units.

Groundwater Use within Lacombe County (m³/day)		%
Domestic/Stock (licensed and unlicensed)	16,164	*57*
Municipal (licensed)	8,578	*30*
Industrial/Commercial/Fishery etc. (licensed)	3,553	*13*
Total	28,295	*100*

Table 7. Total Groundwater Diversions

The range in groundwater use per section is from 1.1 to more than 1,300 m³/day. The average groundwater use per section across the County is in the order of 22.3 m³/day (3.4 igpm).

Approximately 60% of the total estimated groundwater use is from licensed water wells.

C. Groundwater Flow

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

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

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (m)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed Diversion (m^3/day)	Unlicensed Diversion (m^3/day)	Total (m^3/day)
Lower Sand and Gravel					1,807	1,262	497	1,759
Red Deer River								
north	75	0.001	8,000	487				
Buffalo Lake								
north	75	0.001	12000	1032				
Gilby Channel								
southeast	100	0.000	6000	288				
Dalehurst					64,200	1,122	1,833	2,955
Medicine River								
east	65	0.006	25,000	10,156				
wesy	65	0.006	30,000	12,188				
East Edge								
east	65	0.004	30,000	7,800				
Upper Lacombe					34,614	3,723	2,432	6,155
Blindman River								
west	40	0.012	25,000	12000				
east	40	0.008	25,000	8,000				
Gull Lake								
west & east	30	0.004	20,000	2,400				
East Area								
west	45	0.009	20,000	7,714				
east	45	0.005	20,000	4,500				

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (km)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed Diversion (m^3/day)	Unlicensed Diversion (m^3/day)	Total (m^3/day)
Lower Lacombe					10,880	659	428	1,087
west	35	0.008	32,000	8,960				
east	15	0.004	32,000	1,920				
Haynes					22,898	6,049	459	6,508
North stream								
southwest	13000	60.000	0	3,120				
northeast	18000	60.000	0	6,480				
South stream								
southwest	18000	60.000	0	4,050				
northeast	13000	60.000	0	2,925				
South area								
southwest	13000	60.000	0	3,900				
West								
west	30000	35.000	0	2,423				
Upper Scollard					18,308	1,937	346	2,283
west	85	0.004	35,000	11,442				
east	85	0.002	35,000	6,865				
Lower Scollard					3,969	190	488	678
west	25	0.005	13,000	1,625				
east	25	0.004	25,000	2,344				
Upper Horseshoe					900	677	708	1385
	30	0.004	8,000	900				

Table 8. Groundwater Budget

The above table indicates that there is significantly more groundwater flowing through the aquifers than the total of the licensed and unlicensed diversions from the individual aquifers, except for the Upper Horseshoe Canyon Aquifer. The estimated flow through the Lower Sand and Gravel Aquifer and the total estimated groundwater use from the Lower Sand and Gravel Aquifer are similar in magnitude. The calculations of flow through individual aquifers as presented in the above table are very approximate and are intended as a guide for future investigations.

1) Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.3 to 2.1 cubic kilometres. This volume is based on an areal extent of 1,400 square kilometres and a saturated sand and gravel thickness of five metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared from water levels associated with water wells completed in aquifers in the surficial deposits. The water wells that post in the absent area are a reflection of the spatial control. The water levels from these water wells were used for the calculation of the saturated thickness of the surficial deposits. In areas where the elevation of the water-level surface is below the bedrock surface, the surficial deposits are not saturated. The water-level map for the surficial deposits shows a general flow direction toward the Buried Red Deer River Valley in the central part of the County, and towards the Buried Buffalo Lake Valley in the eastern part of the County.

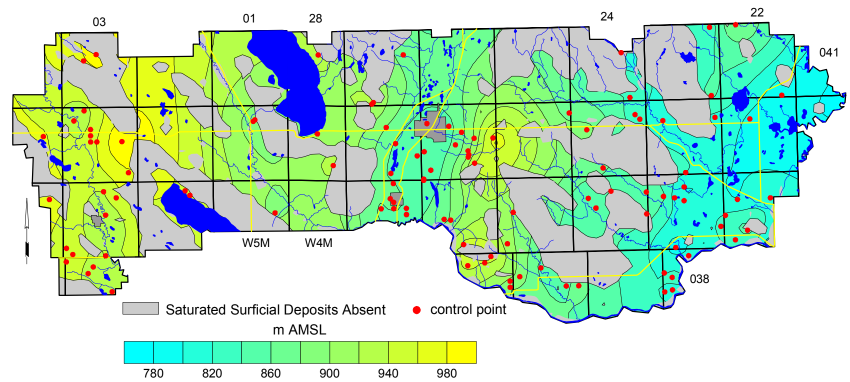

Figure 31. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

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.

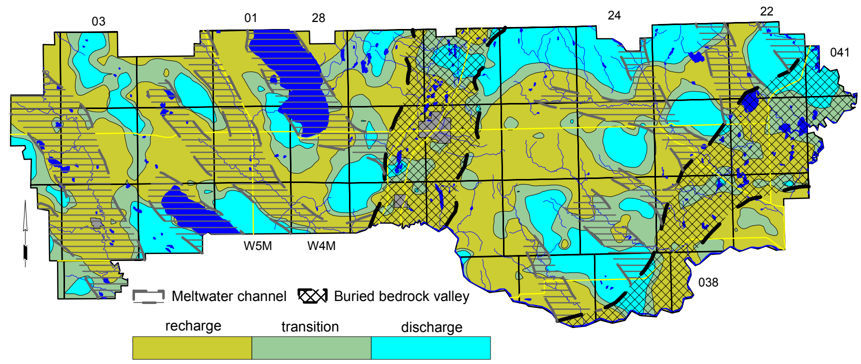

Figure 32. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

The adjacent map shows that, in more than 60% of the County, there is a downward hydraulic gradient from the surficial deposits toward the upper bedrock aquifer(s). These areas tend to be mainly at higher elevations. Areas where there is an upward hydraulic gradient (i.e. discharge) from the bedrock to the surficial deposits are mainly in the vicinity of linear bedrock lows except in the northeastern part of the County, which may be a result of gridding processes. The remaining parts of the County 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 County takes place from the overlying surficial deposits and from flow in the aquifer from outside the County. The recharge/discharge maps show that generally for most of the County, there is a downward hydraulic gradient from the surficial deposits to the bedrock, i.e. recharge to the bedrock aquifers. On a regional basis, calculating the quantity of water involved is not possible because of the complexity of the geological setting and the limited amount of data. However, because of the generally low permeability of the upper bedrock materials, the volume of water is expected to be small.

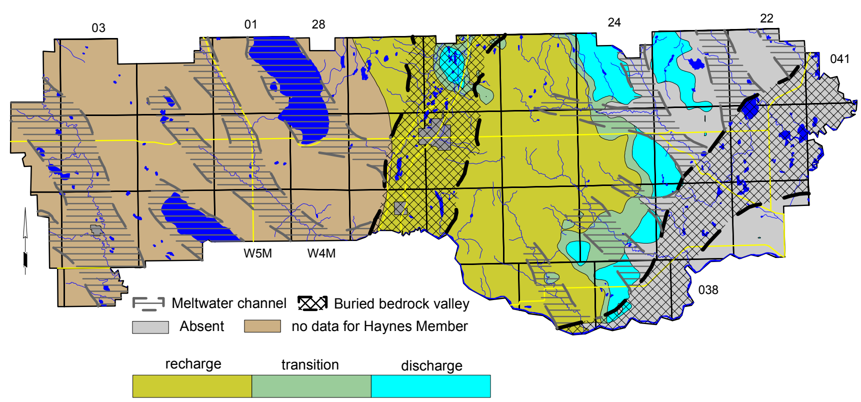

Figure 33. Recharge/Discharge Areas between Surficial Deposits and Haynes Aquifer

The hydraulic relationship between the surficial deposits and the Haynes Aquifer indicates that in more than 80% of the County where the Haynes Aquifer is present and there is data control, there is a downward hydraulic gradient (i.e. recharge). Discharge areas for the Haynes Aquifer are mainly associated with the edge of the Aquifer or in areas of linear bedrock lows.

The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers indicates there is mainly a downward hydraulic gradient (see CD ROM).

D. Areas of Groundwater Decline

The areas of groundwater decline in both the sand and gravel aquifer(s) and in the bedrock aquifers have been determined by using a similar procedure in both situations. Because major development began occurring in the 1970s, the changes in water-level maps are based on the differences between water-level elevations available before 1965 and after 1985. Where the earliest water level is at a higher elevation than the latest water level, there is the possibility that some groundwater decline has occurred. Where the earliest water level is at a lower elevation than the latest water level, there is the possibility that the groundwater has risen at that location. The water level may have risen as a result of recharge in wetter years or may be a result of the water well being completed in a different bedrock aquifer. In order to determine if the water-level decline is a result of groundwater use by licensed users, the licensed groundwater users were posted on the maps.

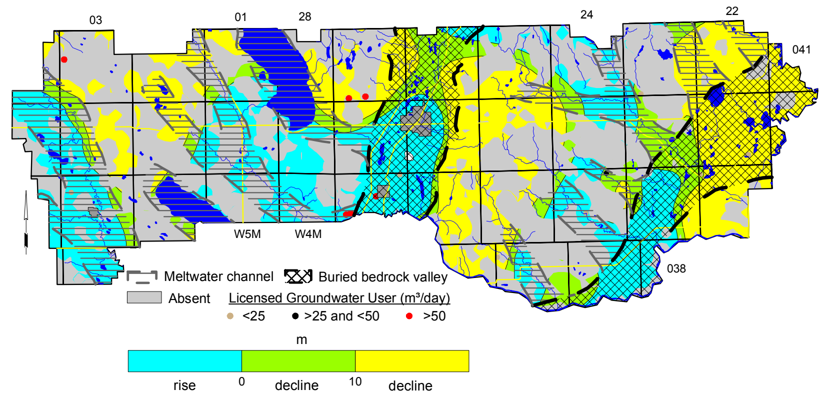

Figure 34. Changes in Water Levels in Sand and Gravel Aquifer(s)

Of the 156 water wells completed in the sand and gravel aquifer(s) with a NPWL and test date, 129 are from water wells completed before 1965 and 27 are from water wells completed after 1985. The above map shows that it may have been possible there has been a rise in the NPWL in areas of linear bedrock lows. However, the areas that indicate a decline of more than ten metres are based on only one or two control points.

Nearly 46% of the areas where there has been a water-level decline of more than ten metres in sand and gravel aquifer(s) corresponds to where the estimated water well use is between ten and 30 m³/day, and 41% of the decline occurred where the estimated water well use is more than 30 m³/day shown on Figure 30.

Of the 4,173 bedrock water wells with a NPWL and test date, 905 are from water wells completed before 1965 and 3,268 are from water wells completed after 1985. The adjacent map indicates that in 60% of the County, it is possible that the NPWL has declined. Of the 261 groundwater users authorized to divert less than 25 m³/day, many occur in areas where a water-level rise exists.

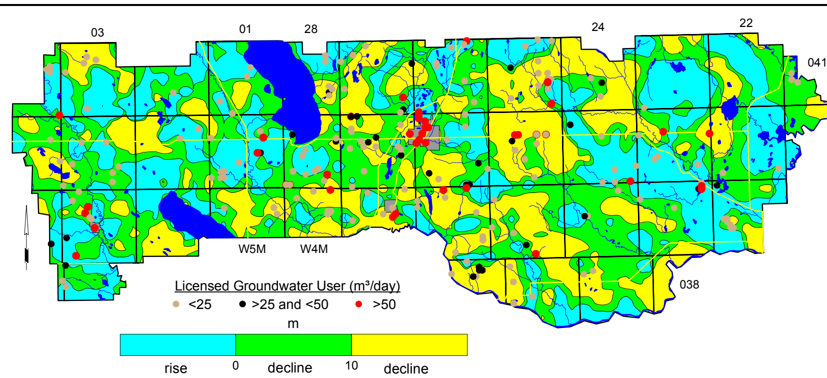

Figure 35. Changes in Water Levels in Upper Bedrock Aquifer(s)

Forty-one percent of the areas where there has been a water-level decline of more than ten metres in upper bedrock aquifer(s) corresponds to where the estimated water well use is between ten and 30 m³/day, and 45% of the decline occurred where the estimated water well use is more than 30 m³/day shown on Figure 30.

VII. 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
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 more than 130 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 the County has responsibility do not satisfy the above criteria, it is recommended that they be field-verified, water levels be measured, a water sample be collected for analysis, and a short aquifer test be conducted. There are two County-operated water wells that are also included in Appendix E. An attempt to update the quality of the entire database is not recommended.

An attempt in this study to link the AENV groundwater and licensing databases was about 66% successful. About one-third of licensed water wells do not appear to have corresponding records in the AENV groundwater database. There is a need to improve the quality of the AENV licensing database. It is recommended that attempts be made in a future study to find and add missing drilling records to the AENV groundwater database and determine the aquifer in which the licensed water well is completed.

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. Monitoring of water levels in domestic and stock water wells is a practice that is recommended by PFRA in the "Water Wells That Last for Generations" manual and accompanying videos (Alberta Agriculture, Food And Rural Development, 1996)(Appendix E). Of the more than 130 water wells recommended for field verification, 31 of the bedrock water wells are in areas of water-level decline. No surficial water wells are recommended for field verification in areas of water-level decline; however, because the flow through the Lower Sand and Gravel Aquifer and the present use are similar in magnitude, additional water wells should be added to the list of water wells recommended for field verification.

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 water well network. County personnel and/or local residents could measure the water levels in the water wells regularly.

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 provide a major upgrade to the level of interpretation provided in this report and the accompanying maps and groundwater query, it is recommended that the 130 water wells for which water well drilling reports are available be subjected to the following actions (see pages C-2 to C-3):

1) The horizontal location of the water well should be determined within ten 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 five and 115 minutes of pumping, and analyzed for major and minor ions.

A list of the 130 water wells that could be considered for the above program is given in Appendix E.

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

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

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

Groundwater is a renewable resource and it must be managed.

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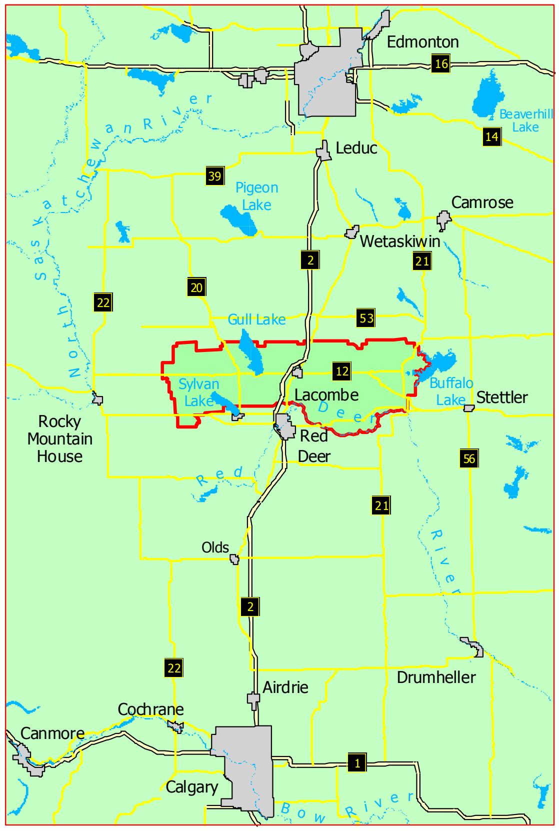
IX. Conversions

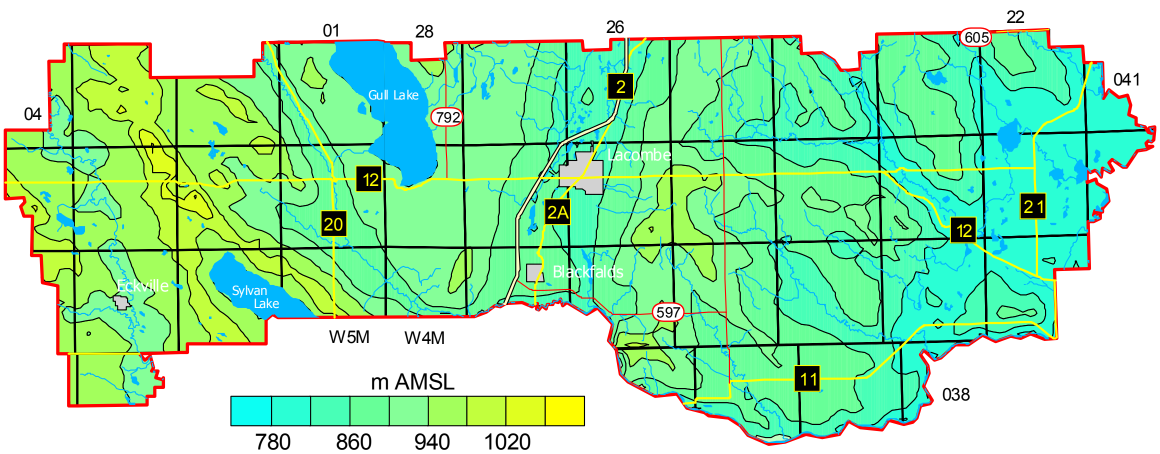
Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	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

LACOMBE COUNTY
Appendix A

Hydrogeological Maps and Figures

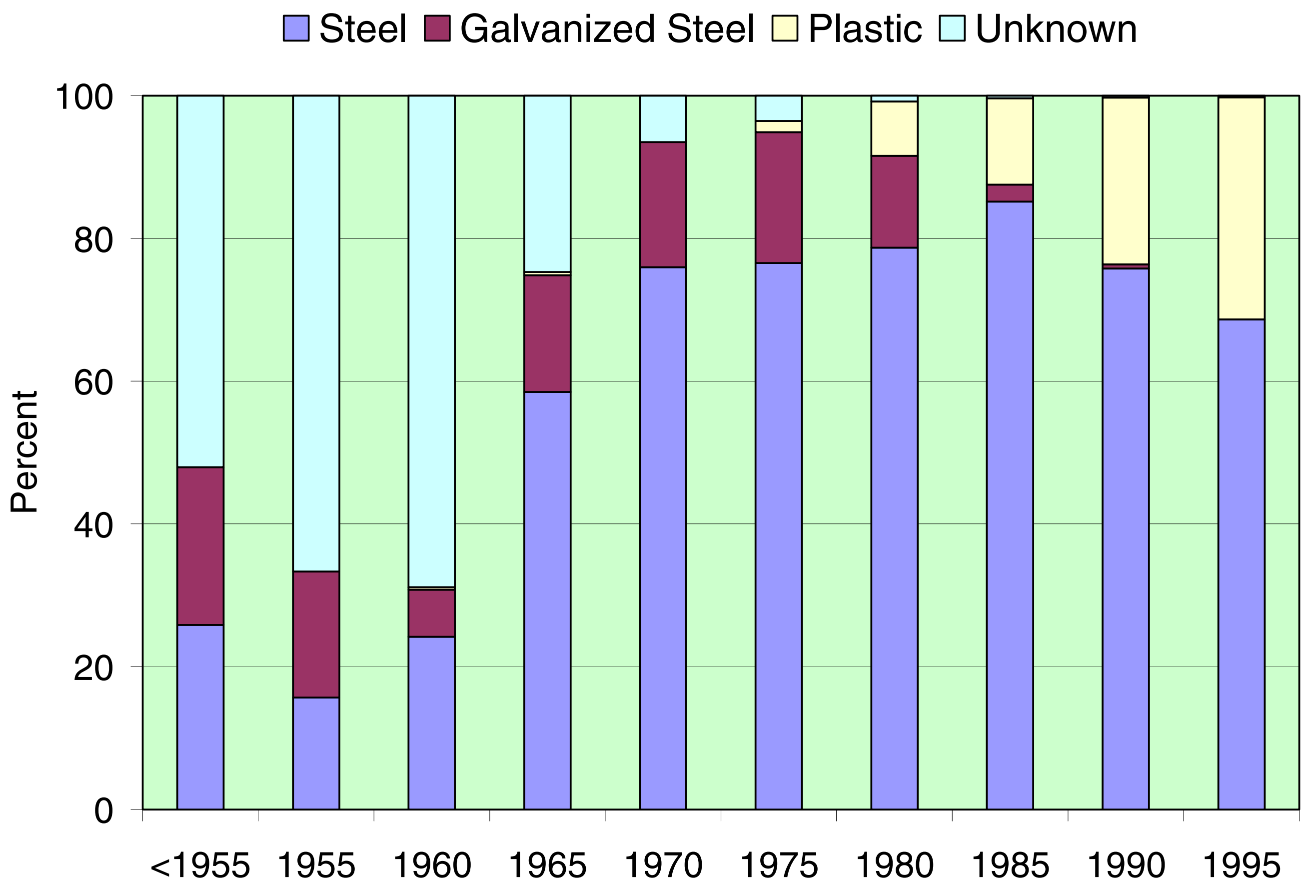
Index Map / Surface Topography



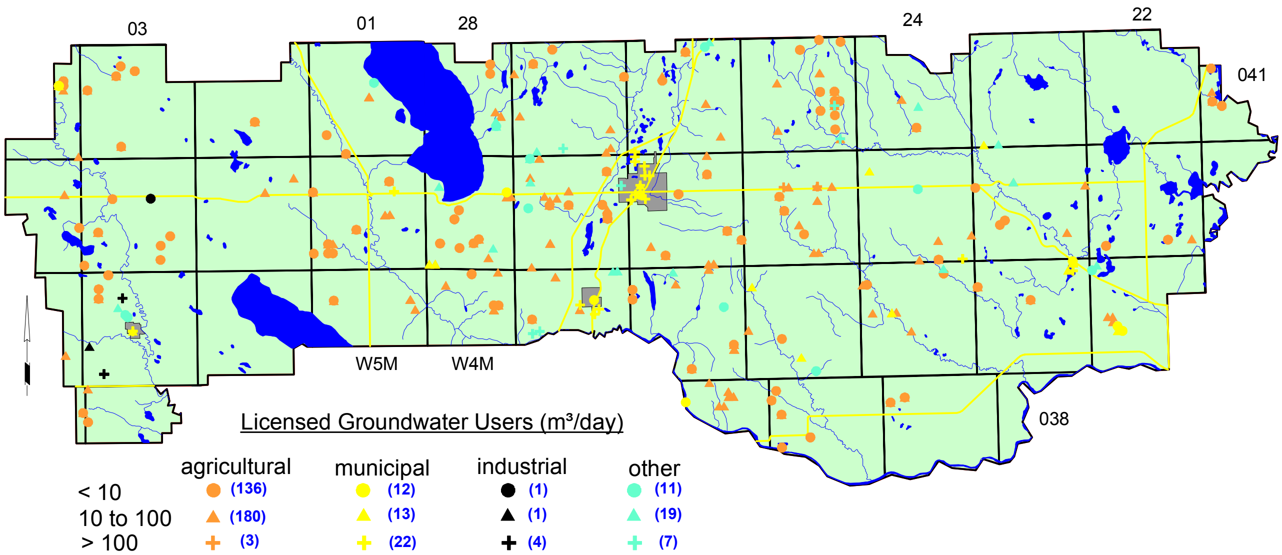


Lacombe County

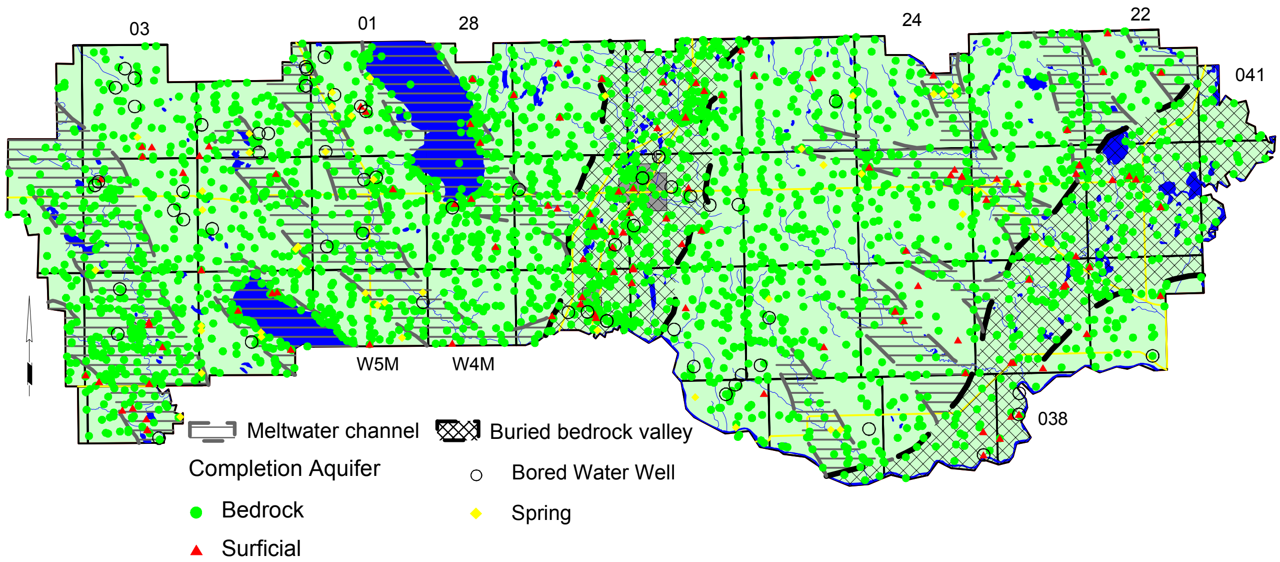
Surface Casing Types used in Drilled Water Wells



Licensed Water Wells

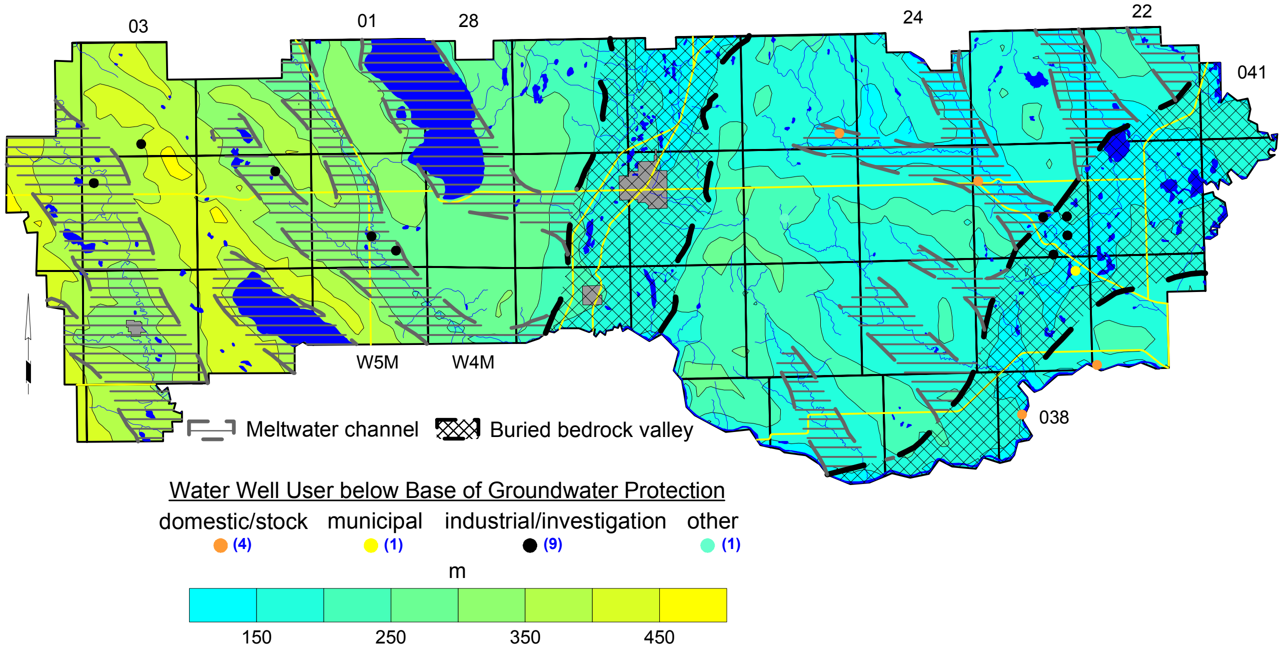


Location of Water Wells



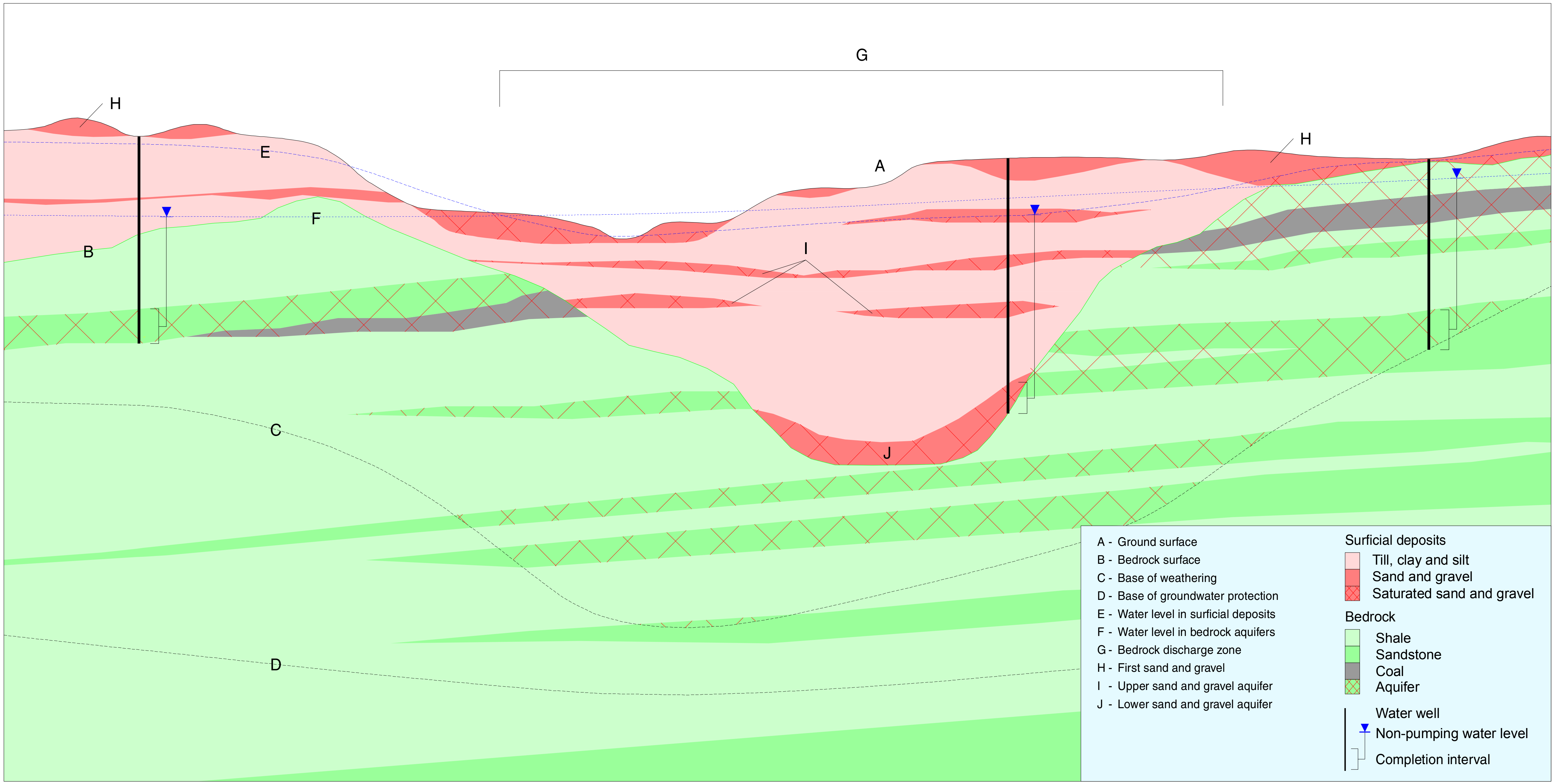
Depth to Base of Groundwater Protection

(modified after EUB, 1995)



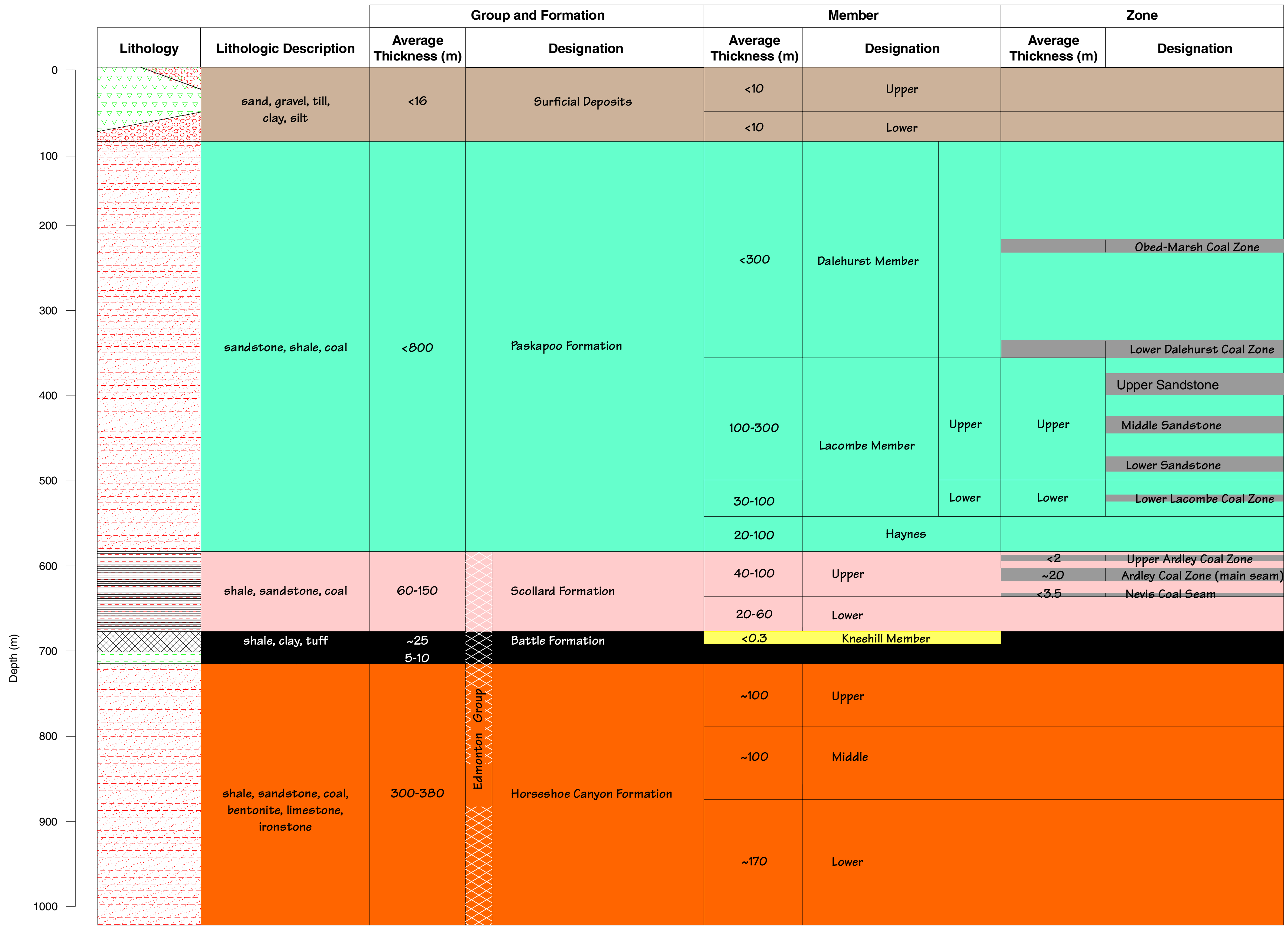
Generalized Cross-Section

(for terminology only)

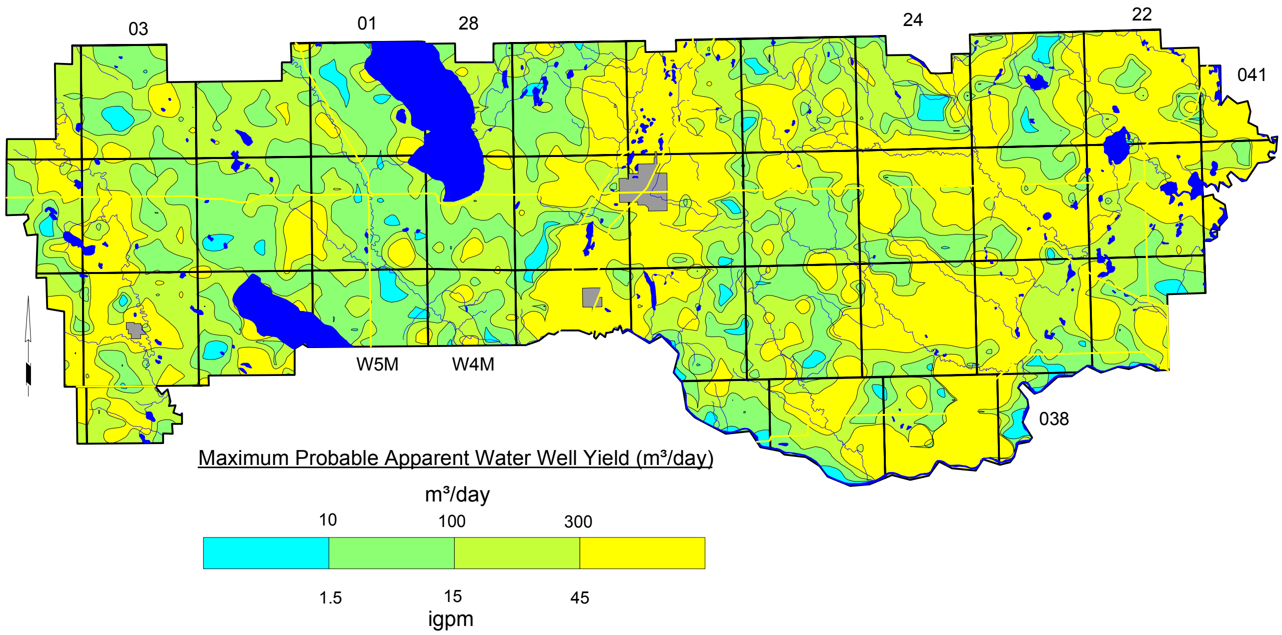


hydrogeological consultants ltd.

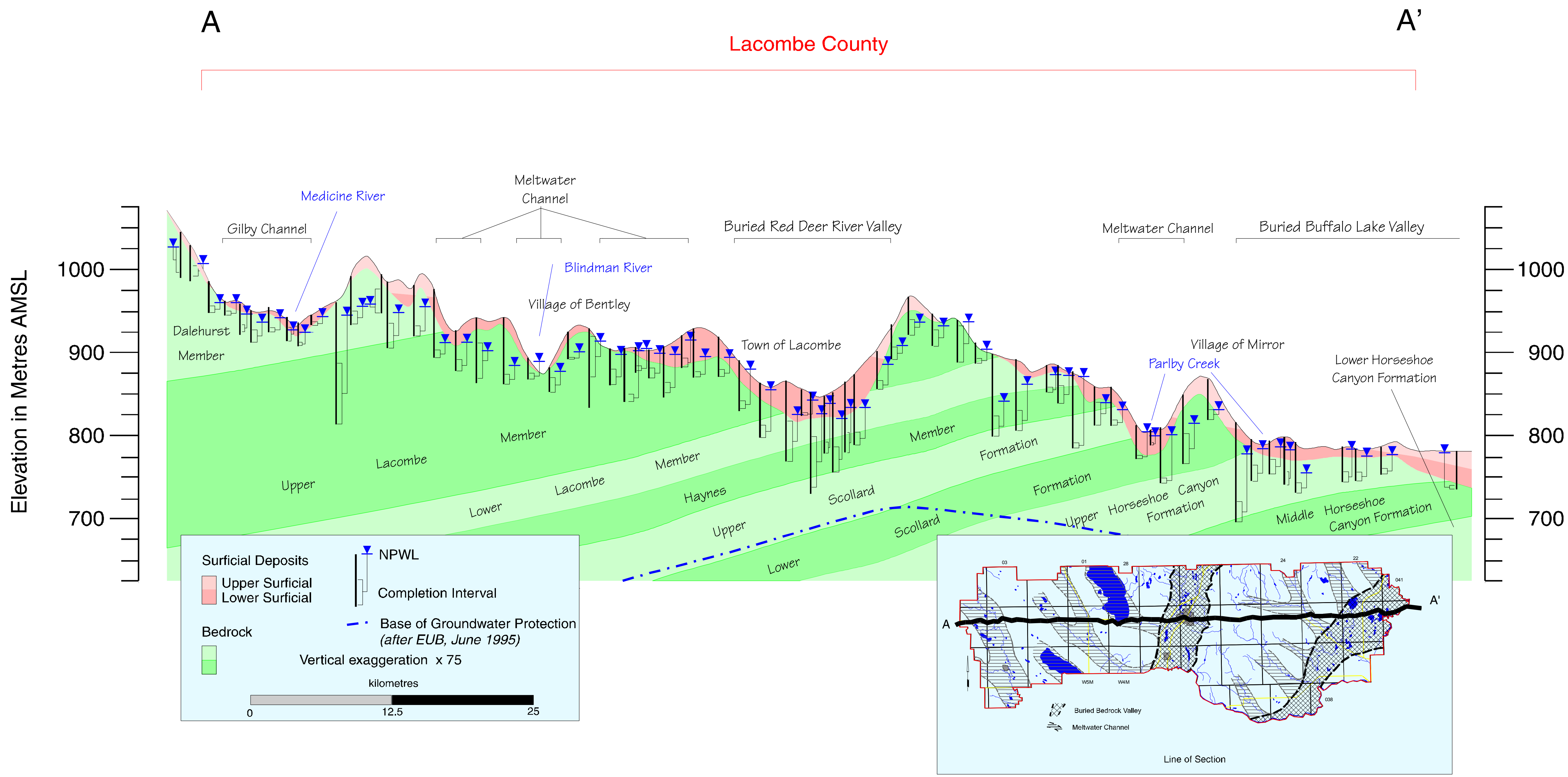
Geologic Column



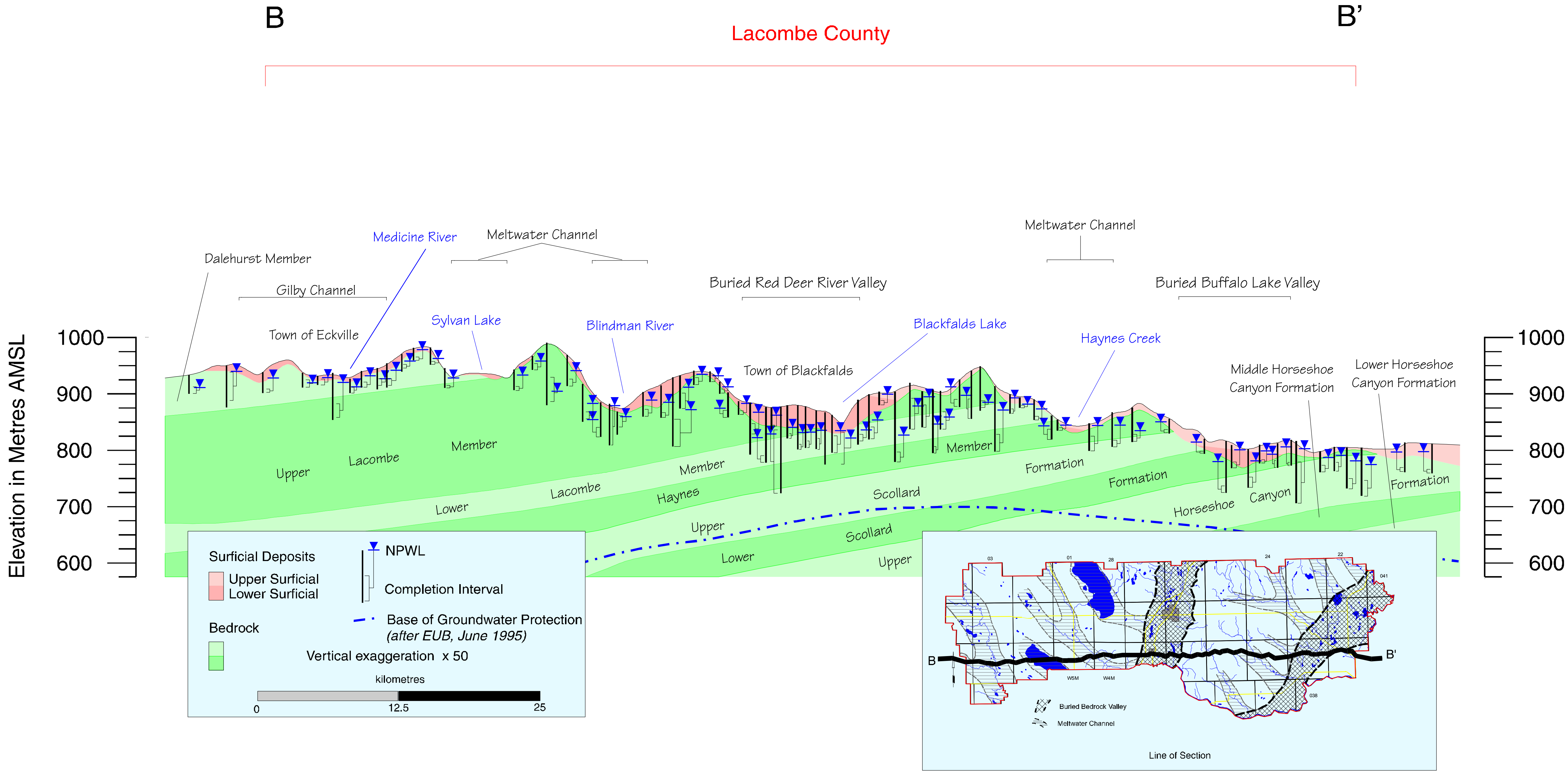
Hydrogeological Map



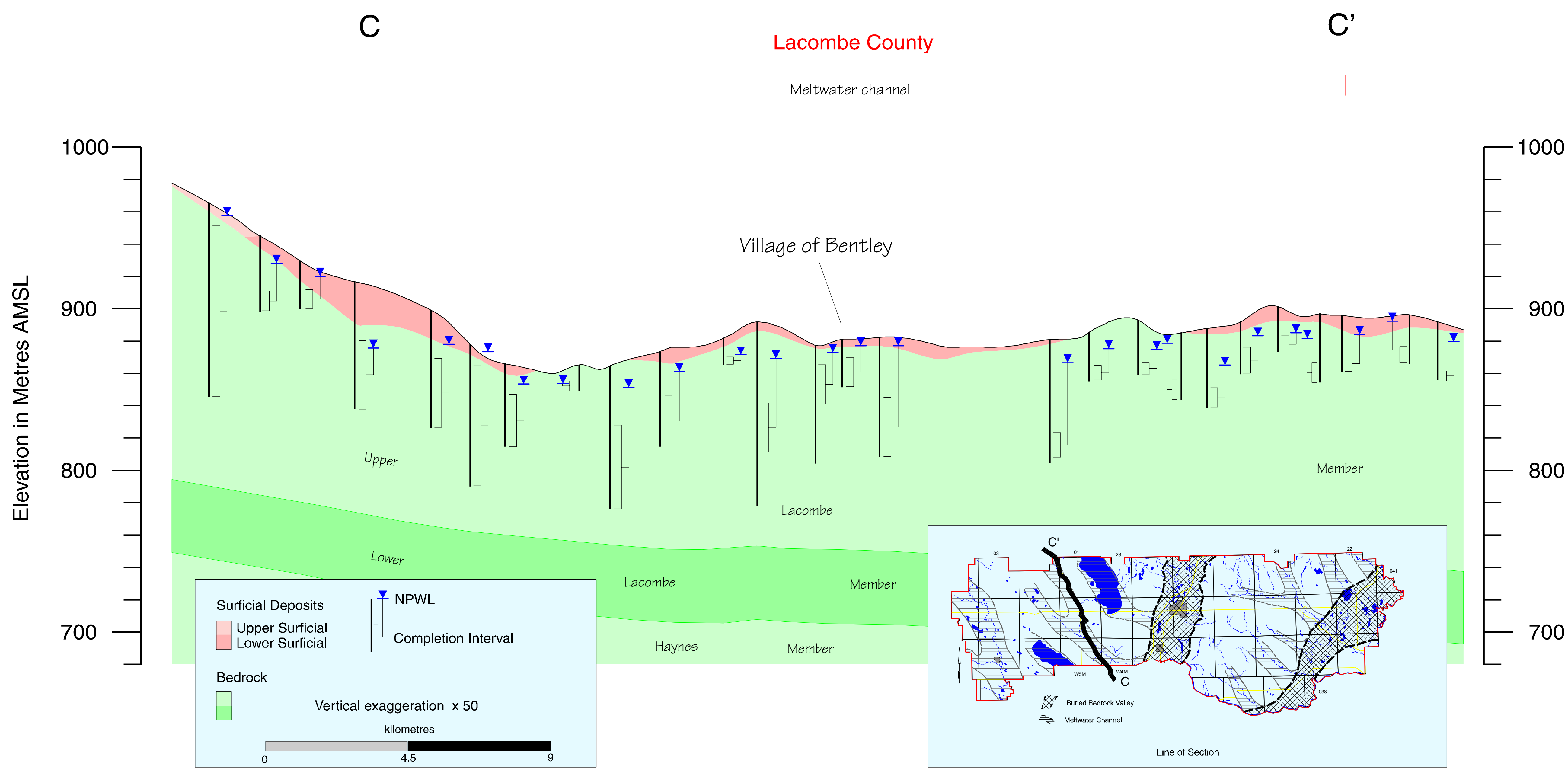
Cross-Section A - A'



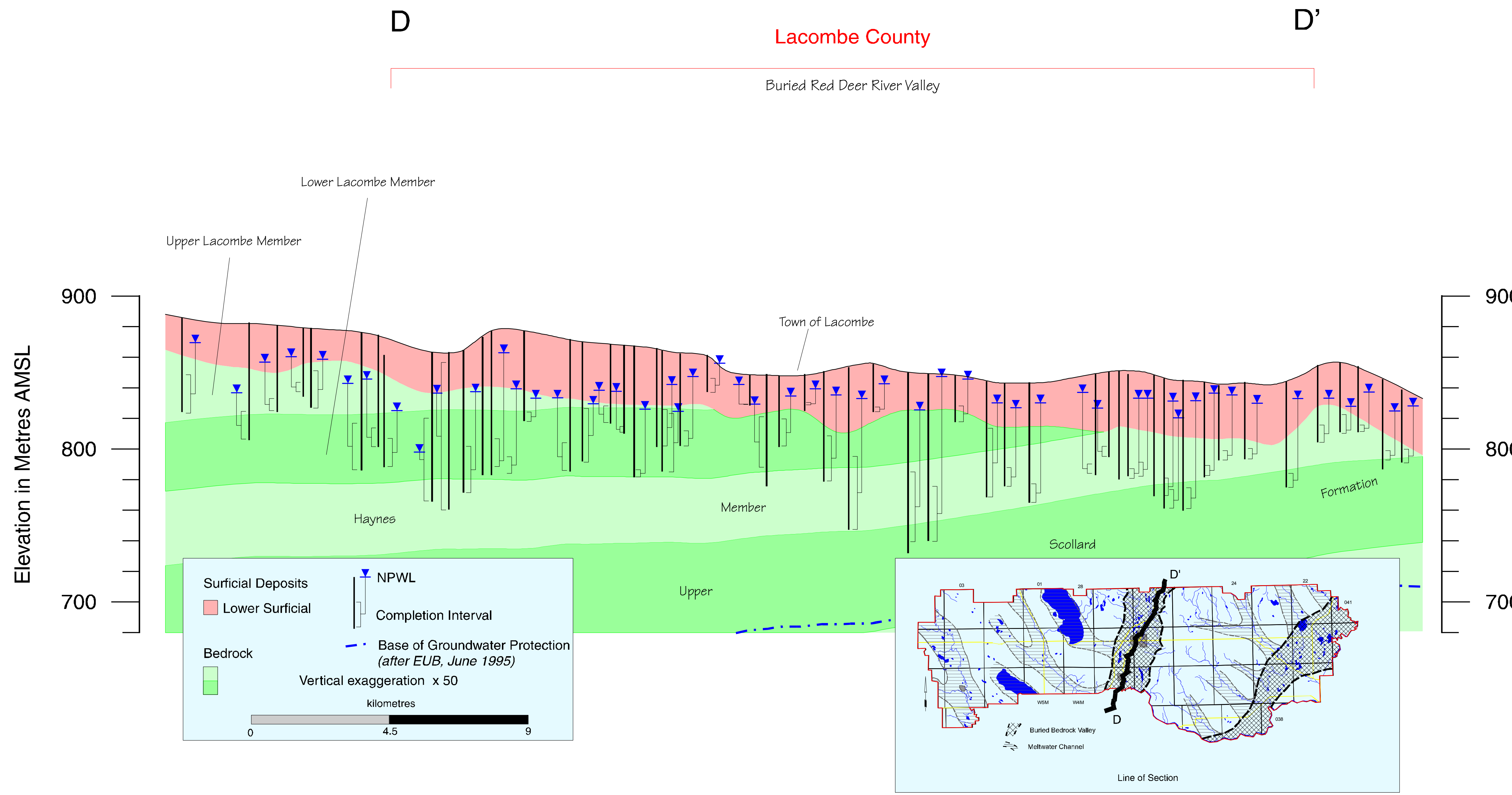
Cross-Section B - B'



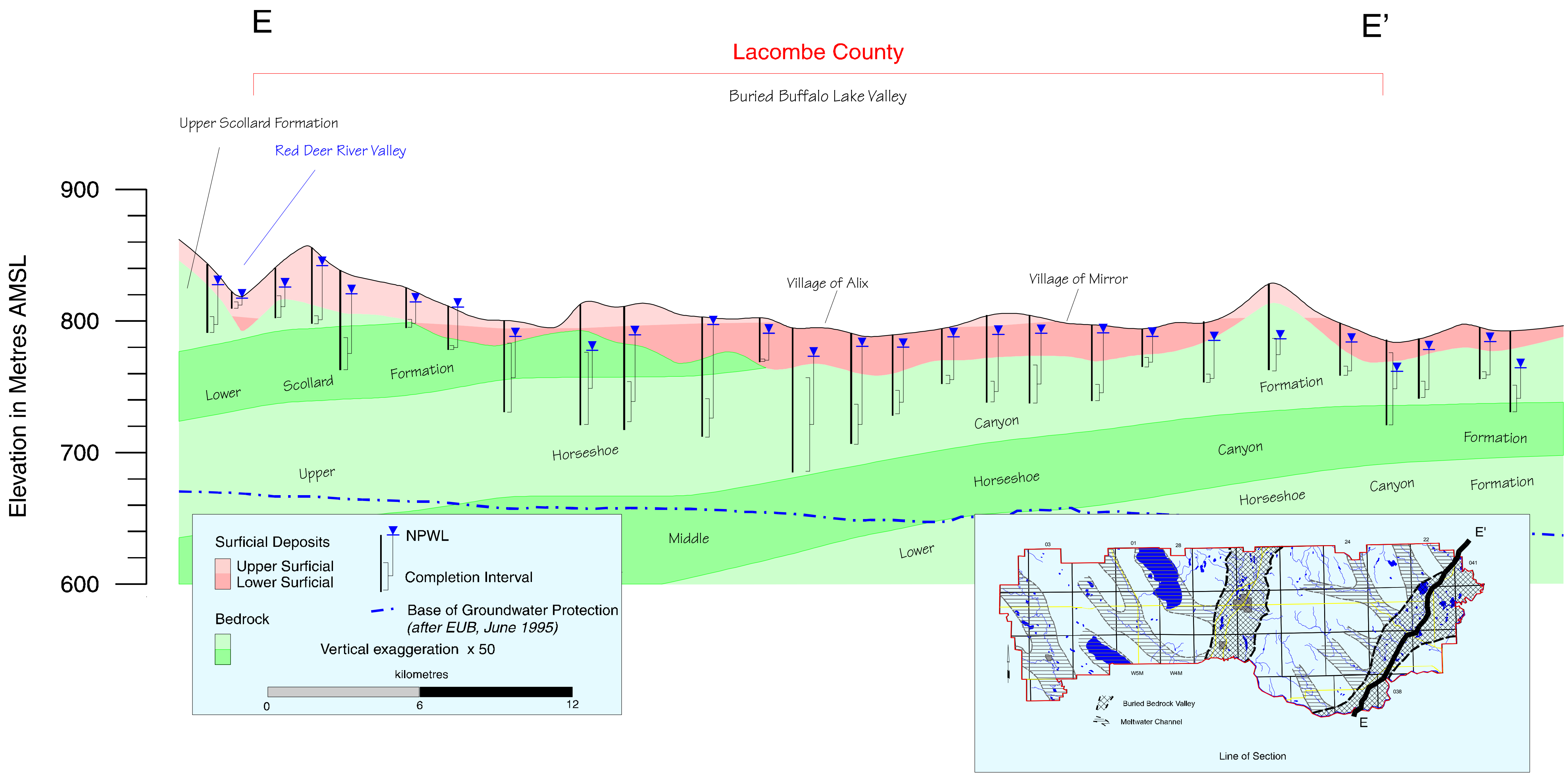
Cross-Section C - C'



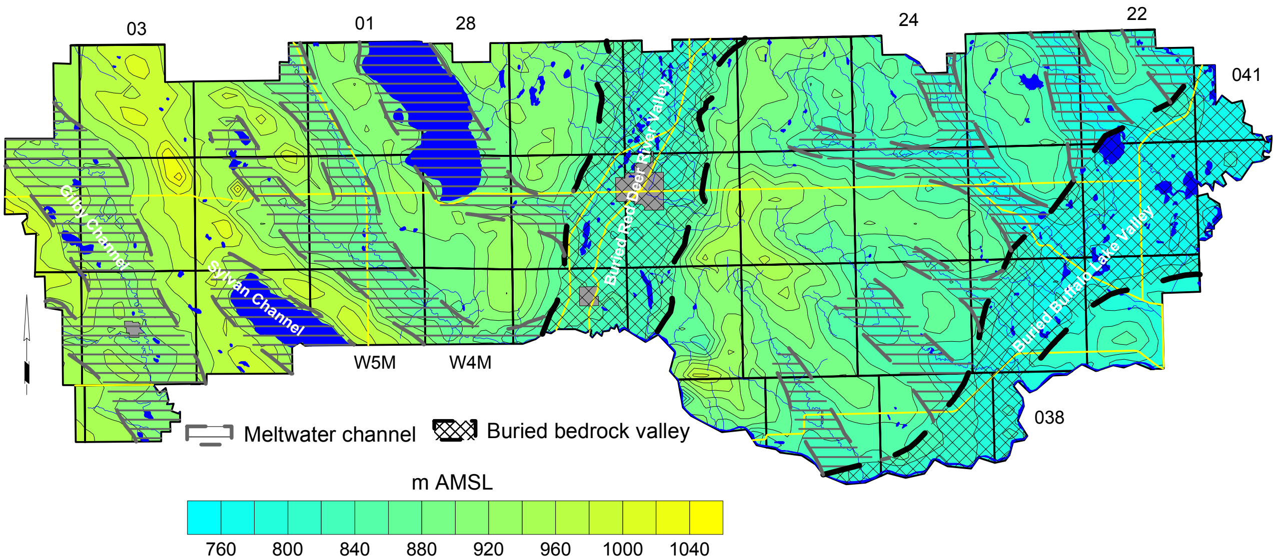
Cross-Section D - D'



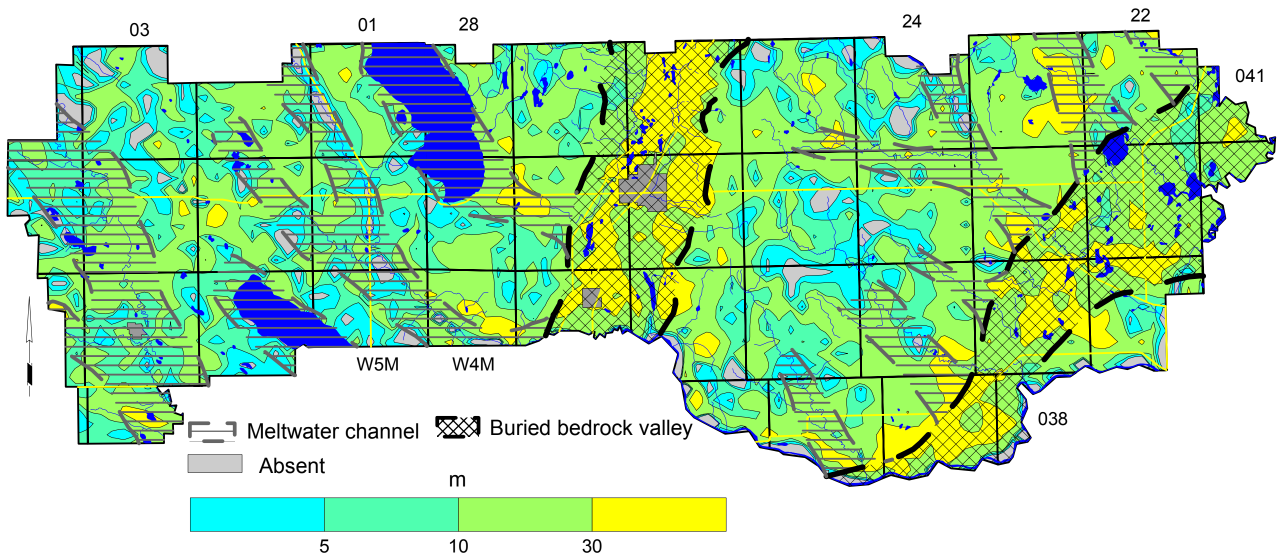
Cross-Section E - E'



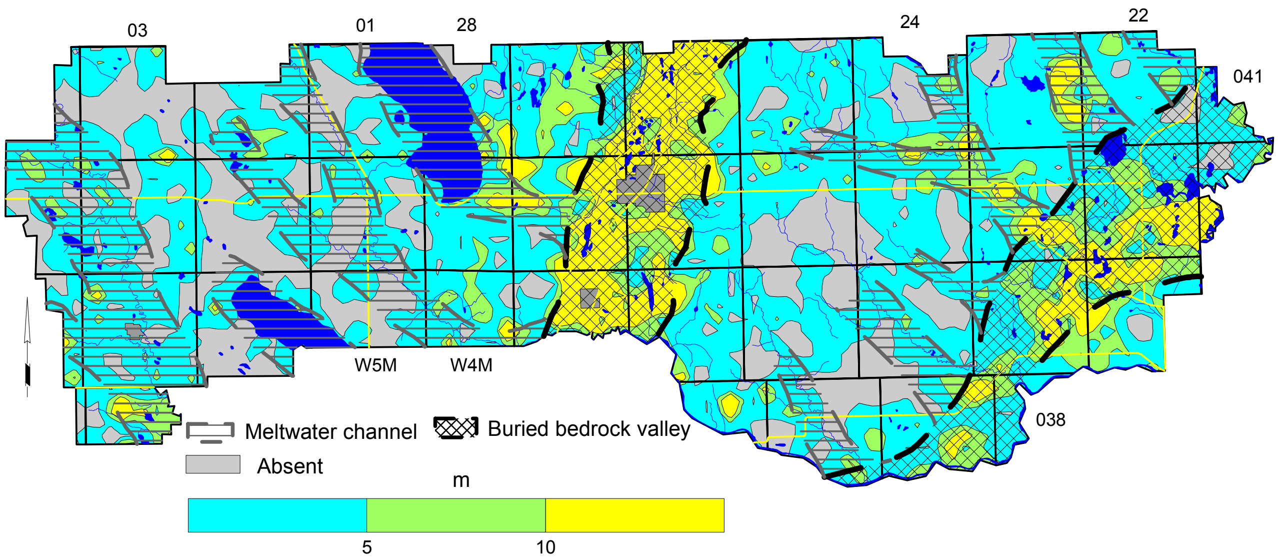
Bedrock Topography



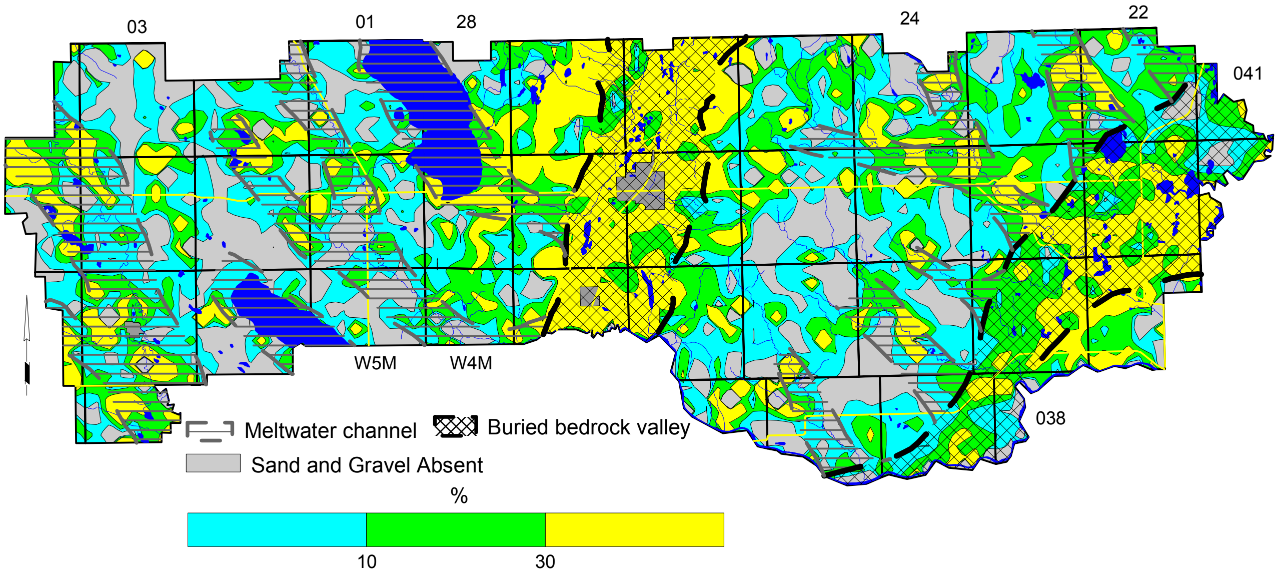
Thickness of Surficial Deposits



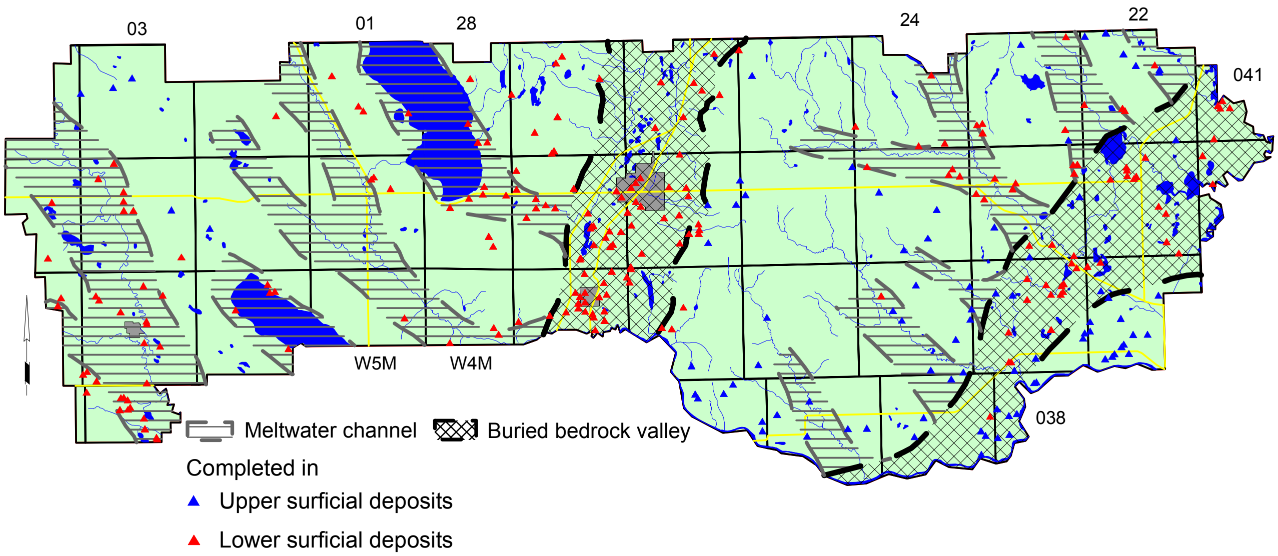
Thickness of Sand and Gravel Deposits



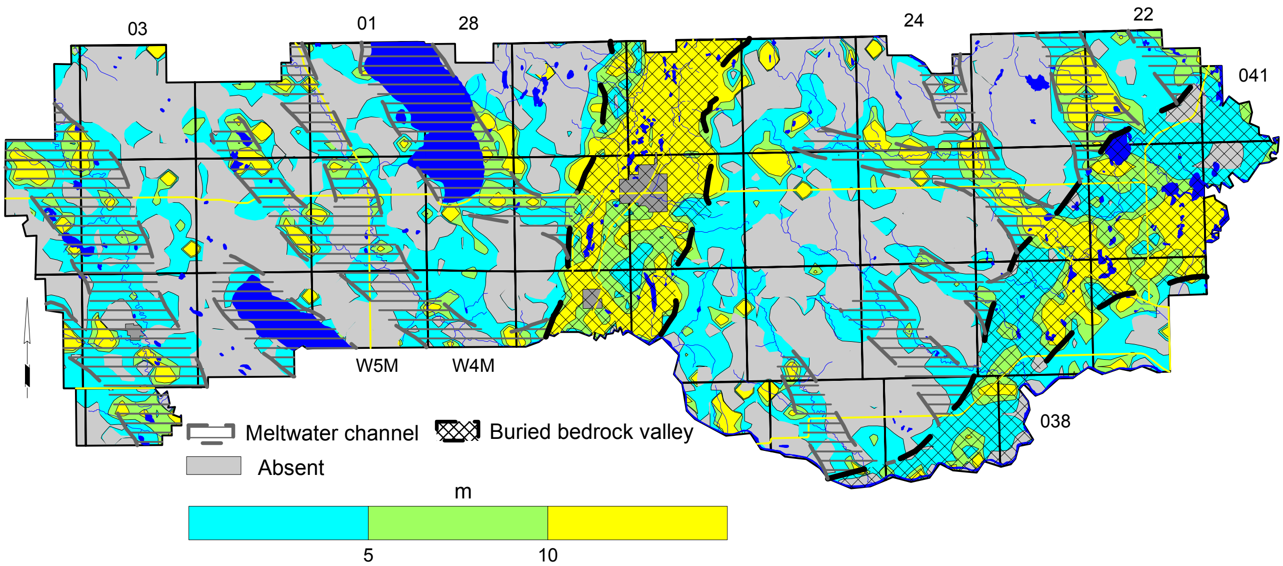
Amount of Sand and Gravel in Surficial Deposits



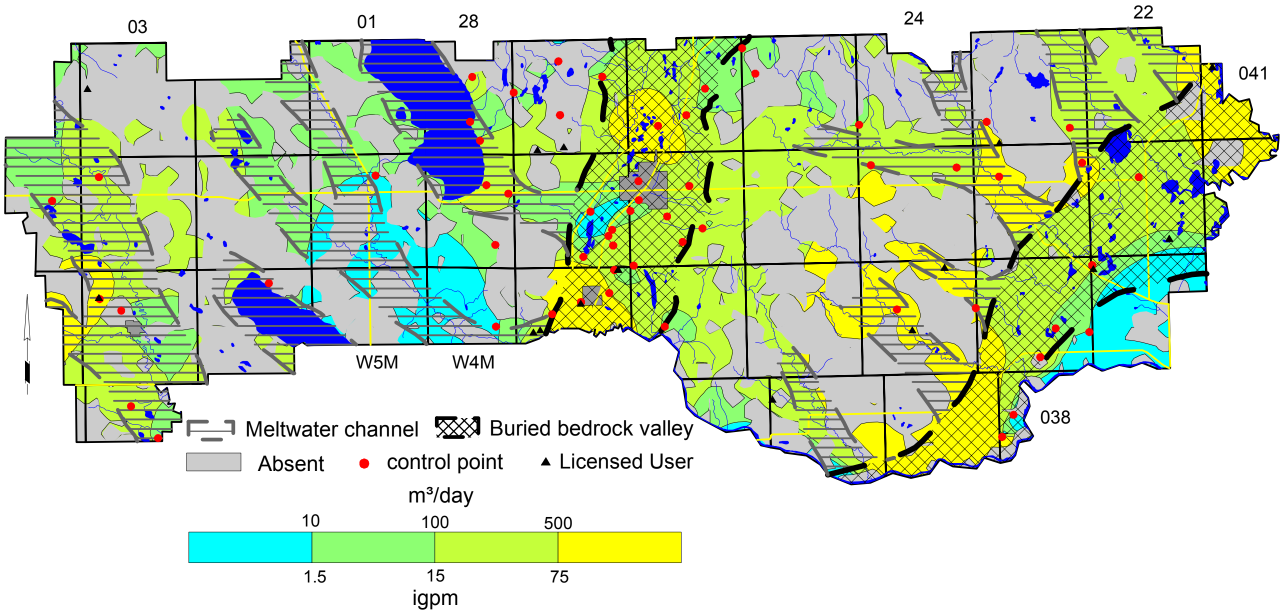
Water Wells Completed In Surficial Deposits



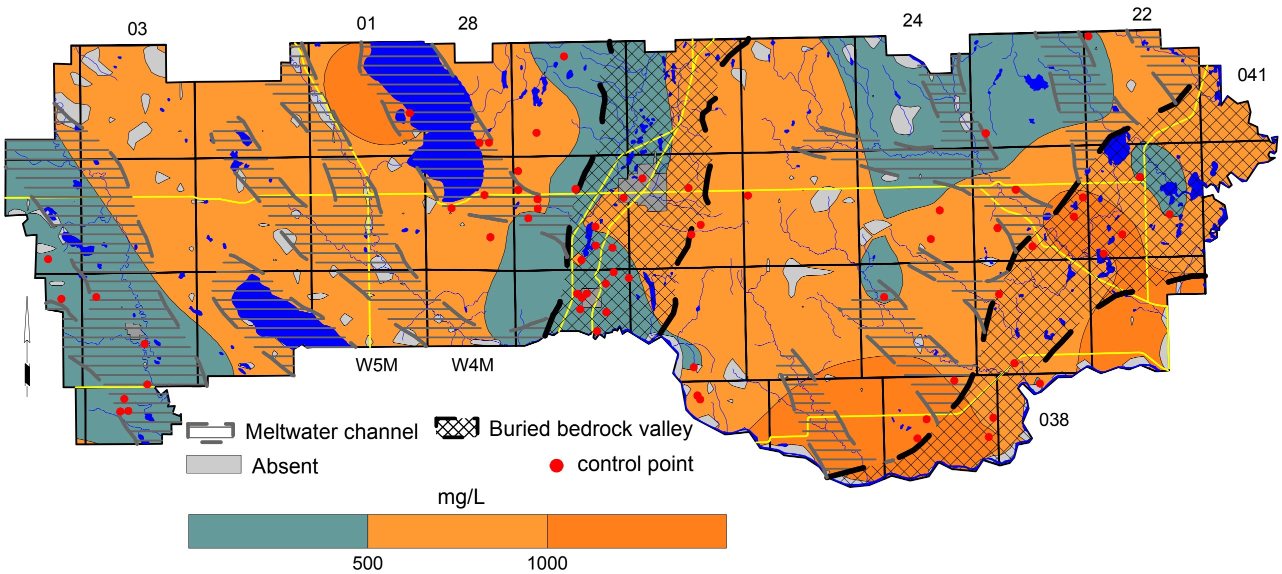
Thickness of Sand and Gravel Aquifer(s)



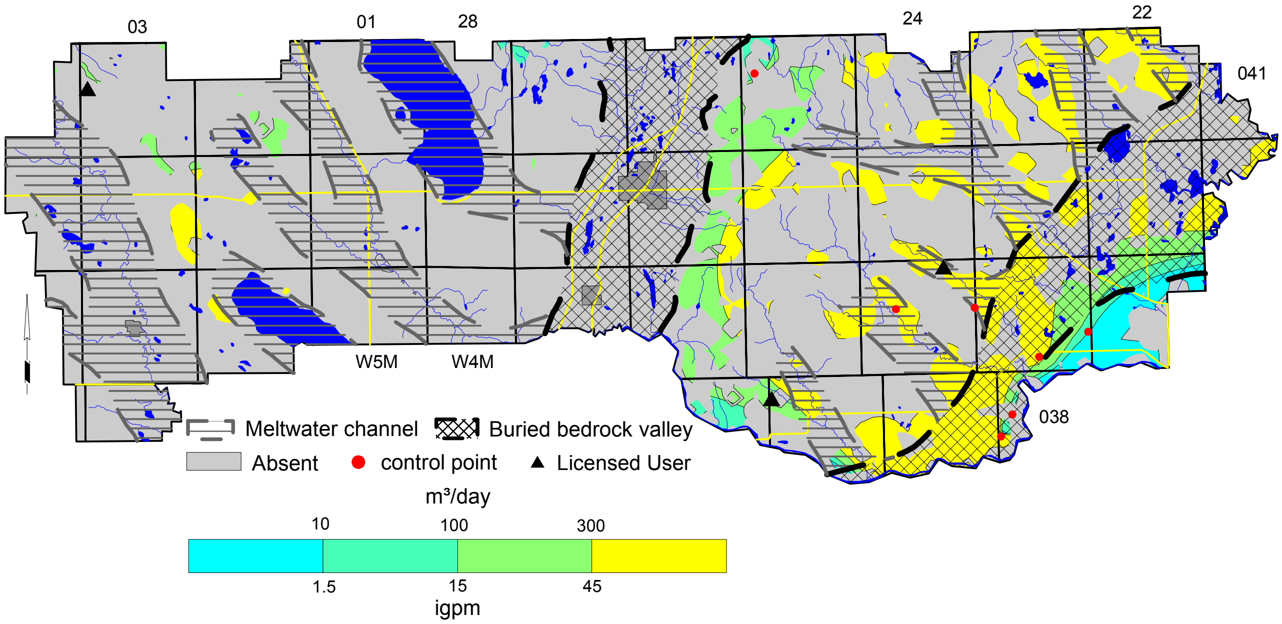
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



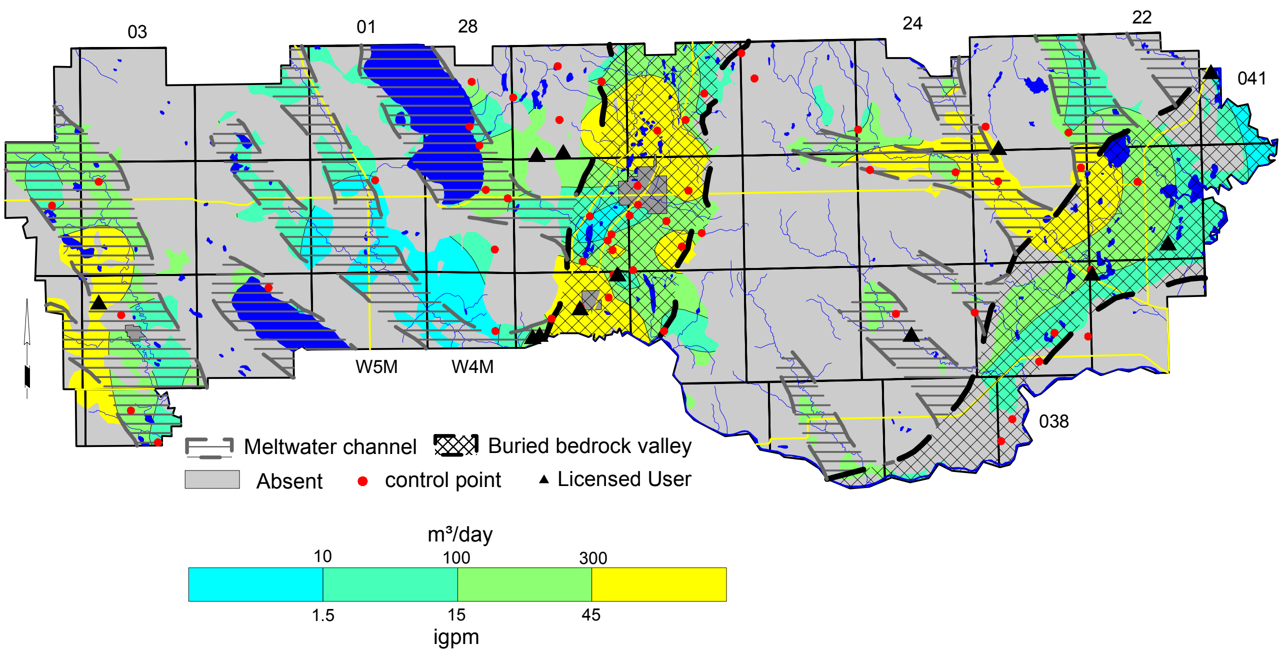
Total Dissolved Solids in Groundwater from Surficial Deposits



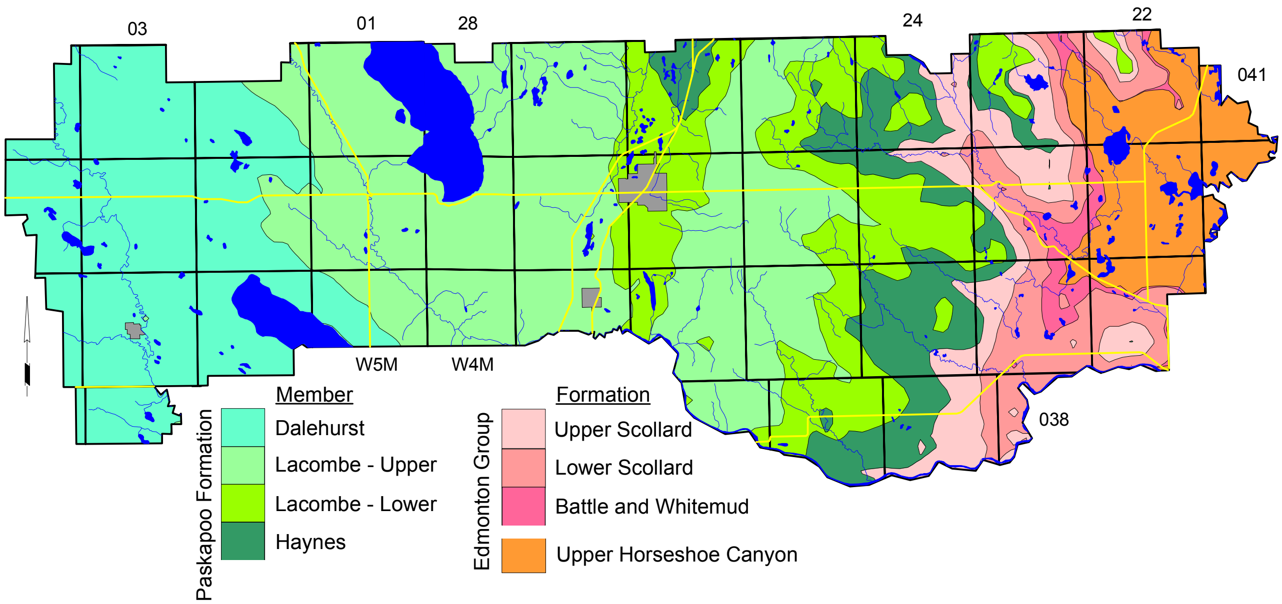
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer(s)



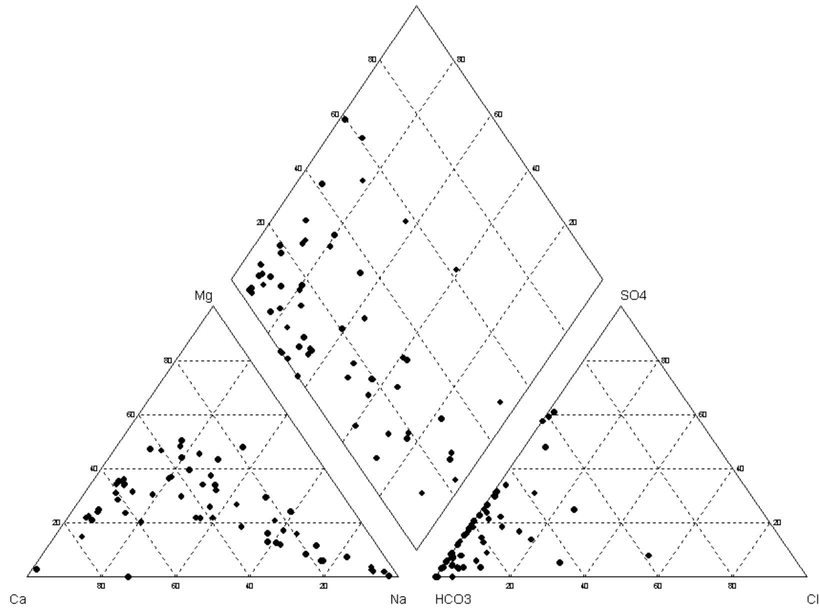
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer(s)



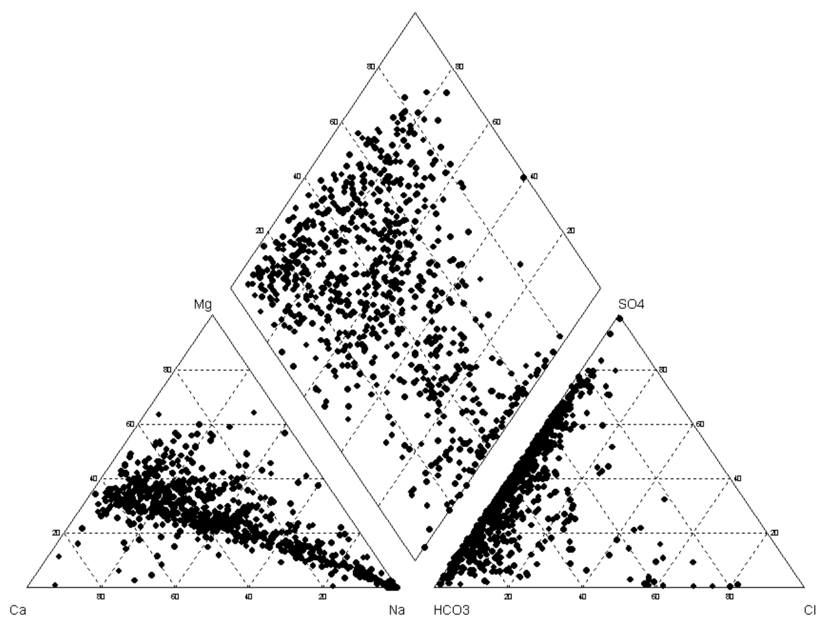
Bedrock Geology



Piper Diagrams

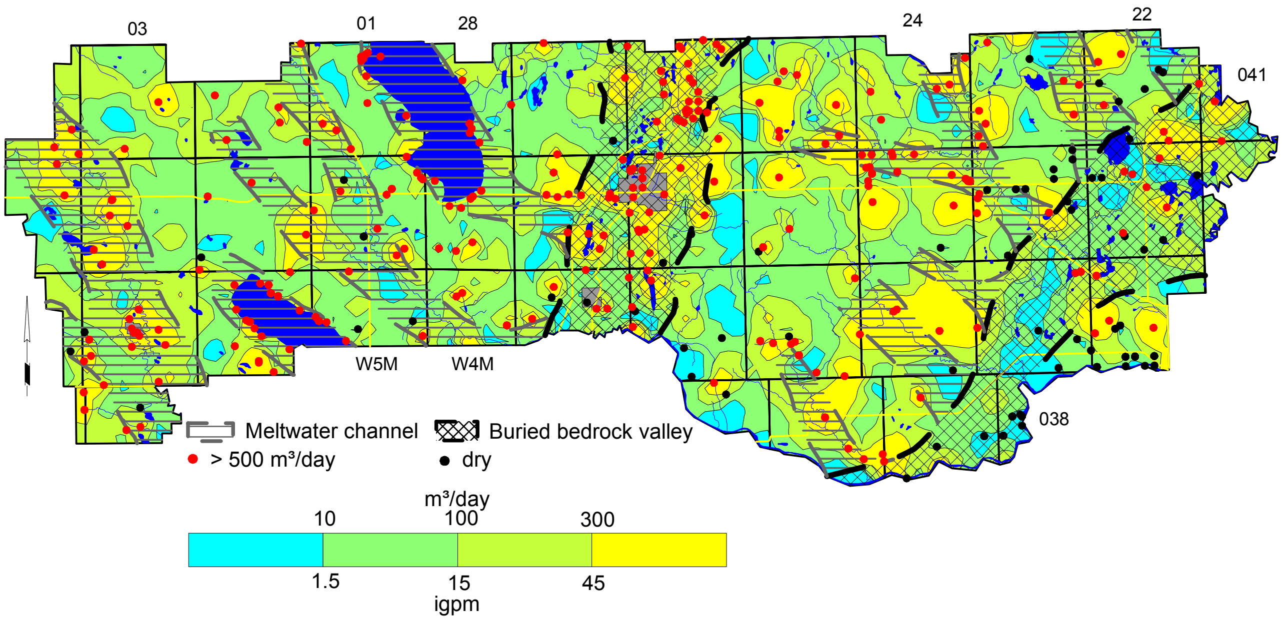


Surficial Deposits

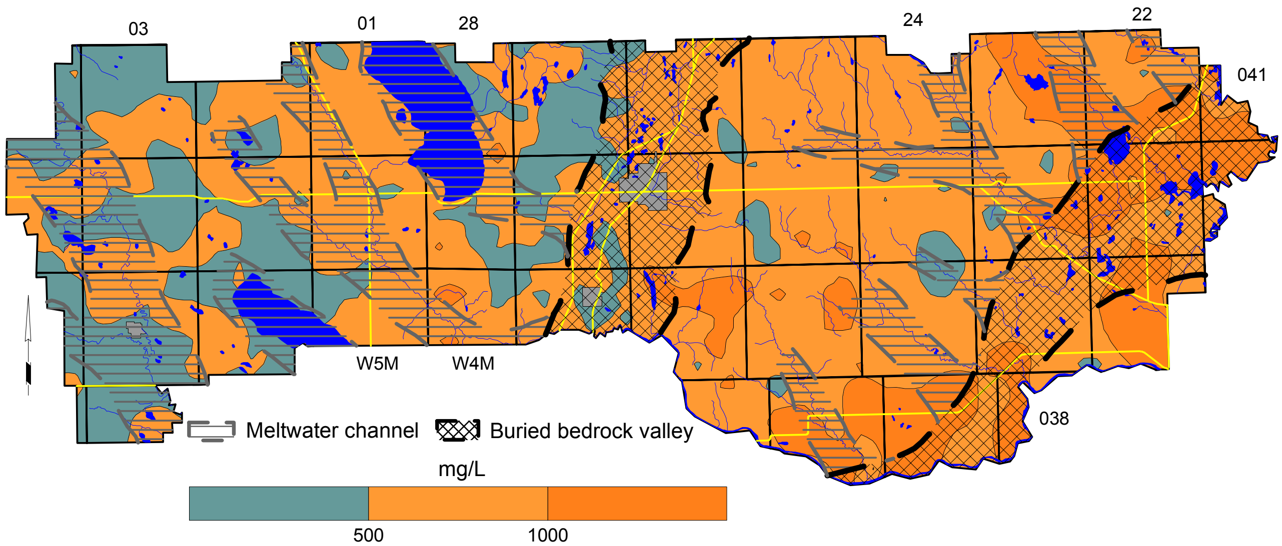


Bedrock Aquifers

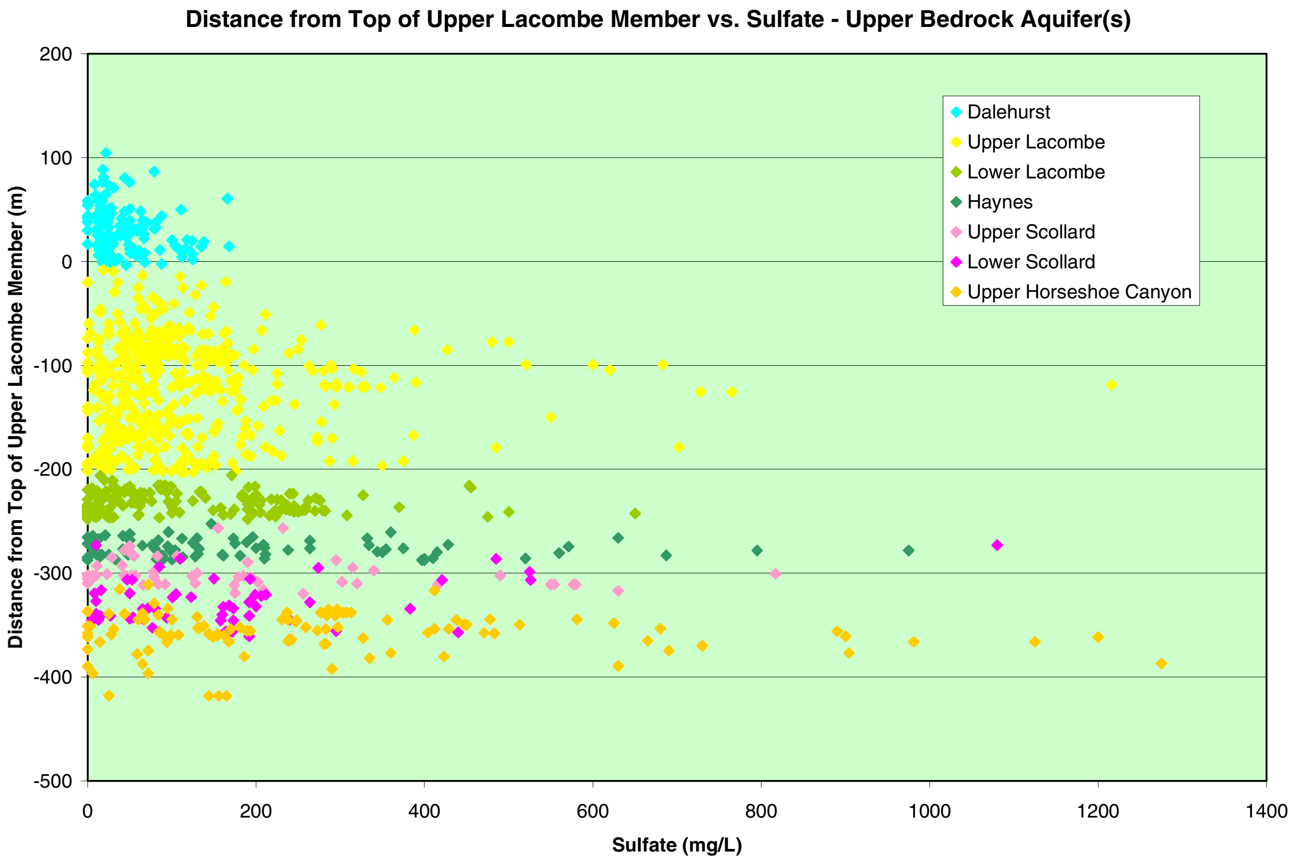
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



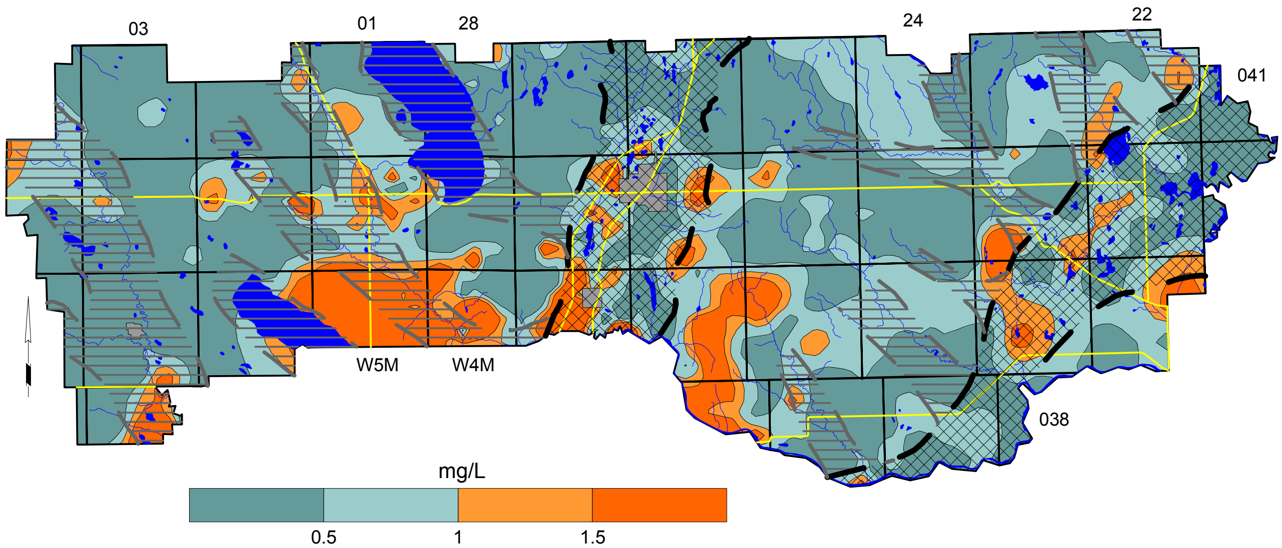
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



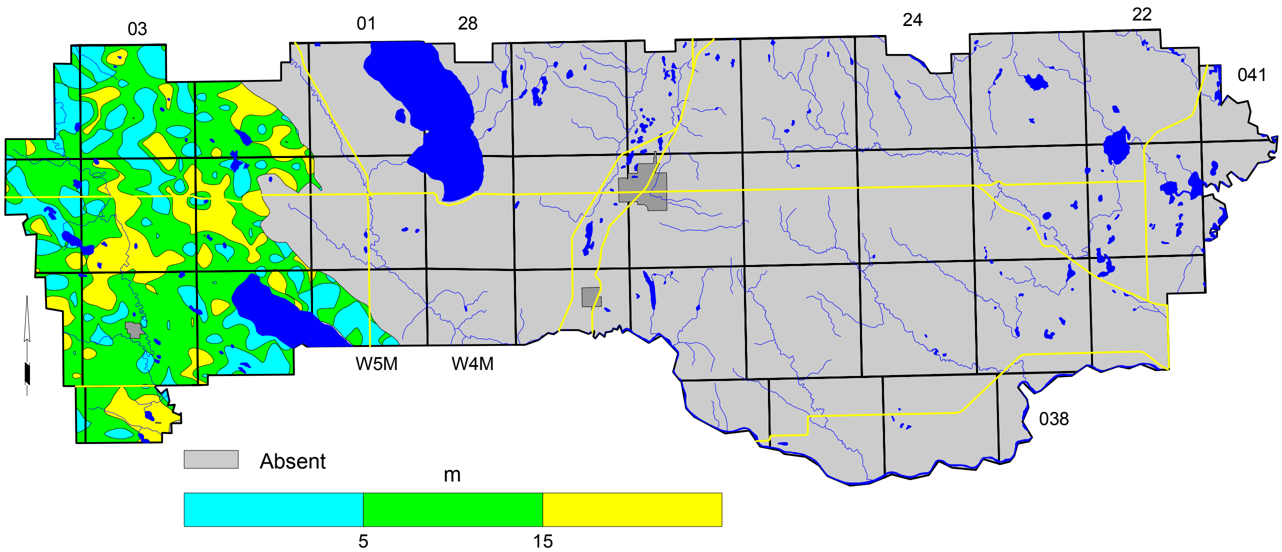
Distance from Top of Upper Lacombe Member vs Sulfate in Groundwater from Upper Bedrock Aquifer(s)



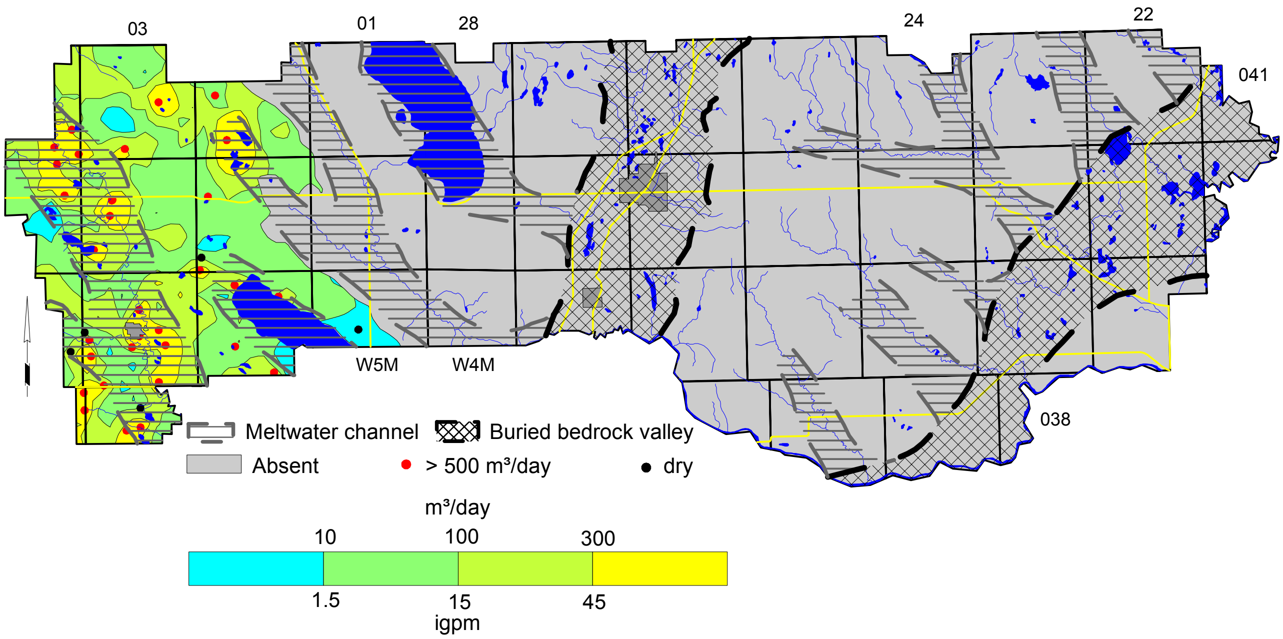
Fluoride in Groundwater from Upper Bedrock Aquifer(s)



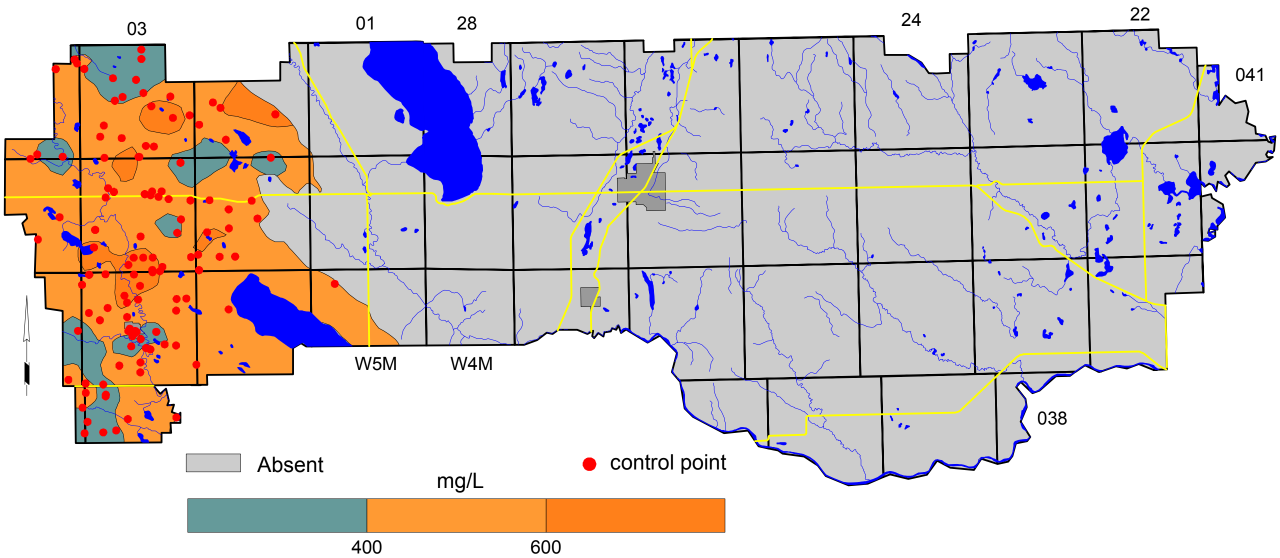
Depth to Top of Dalehurst Member



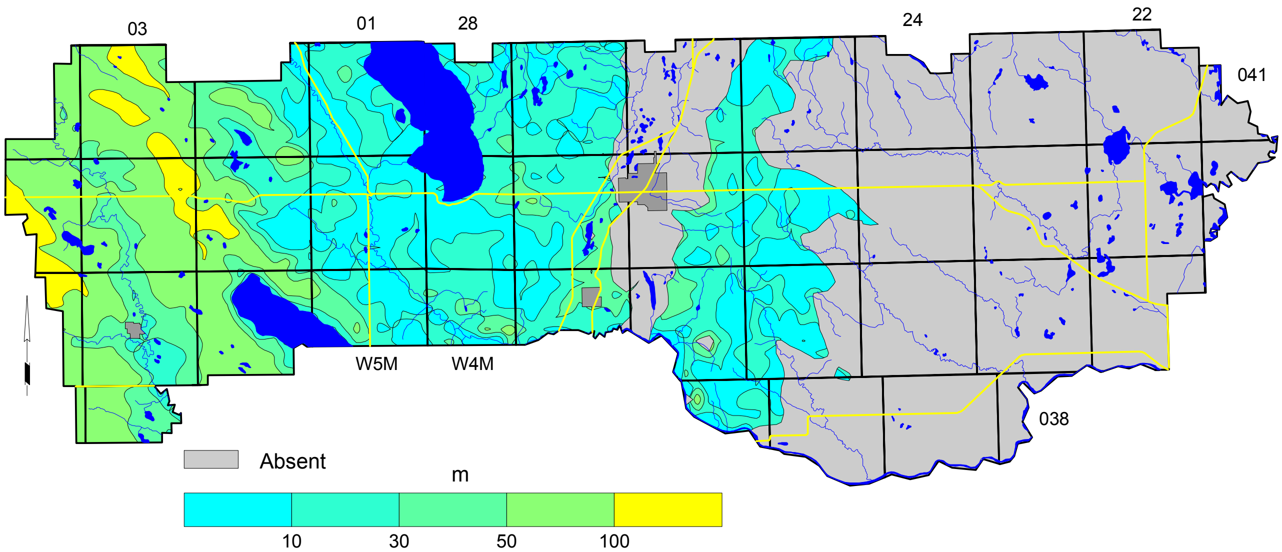
Apparent Yield for Water Wells Completed through Dalehurst Aquifer



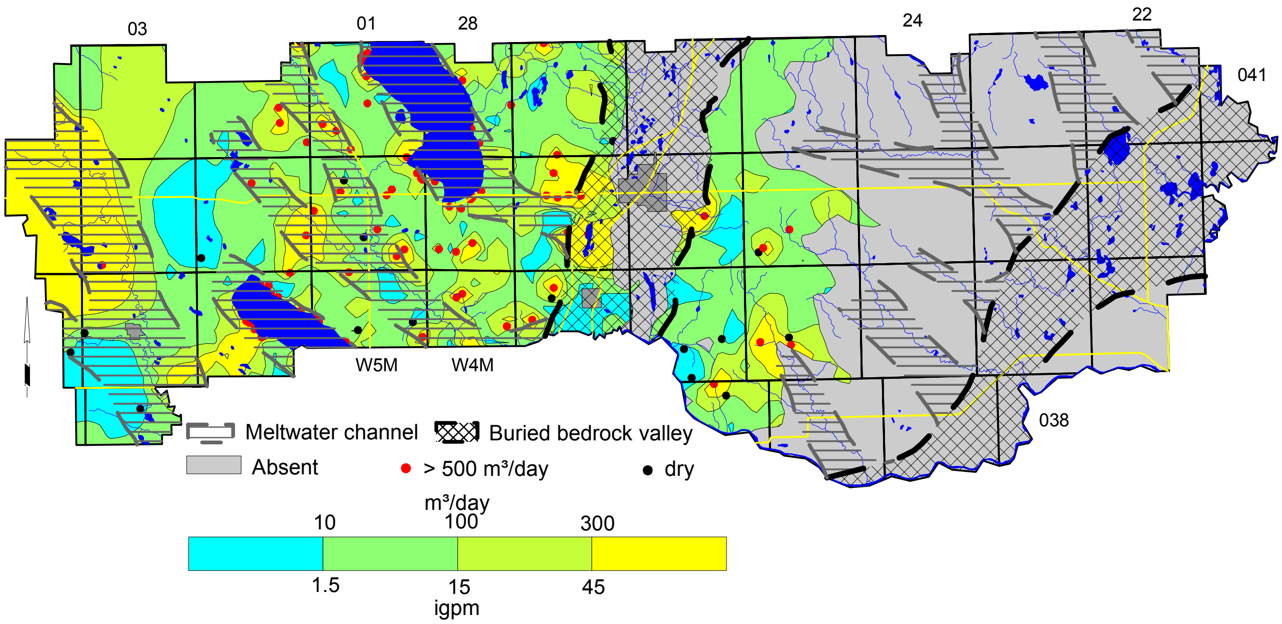
Total Dissolved Solids in Groundwater from Dalehurst Aquifer



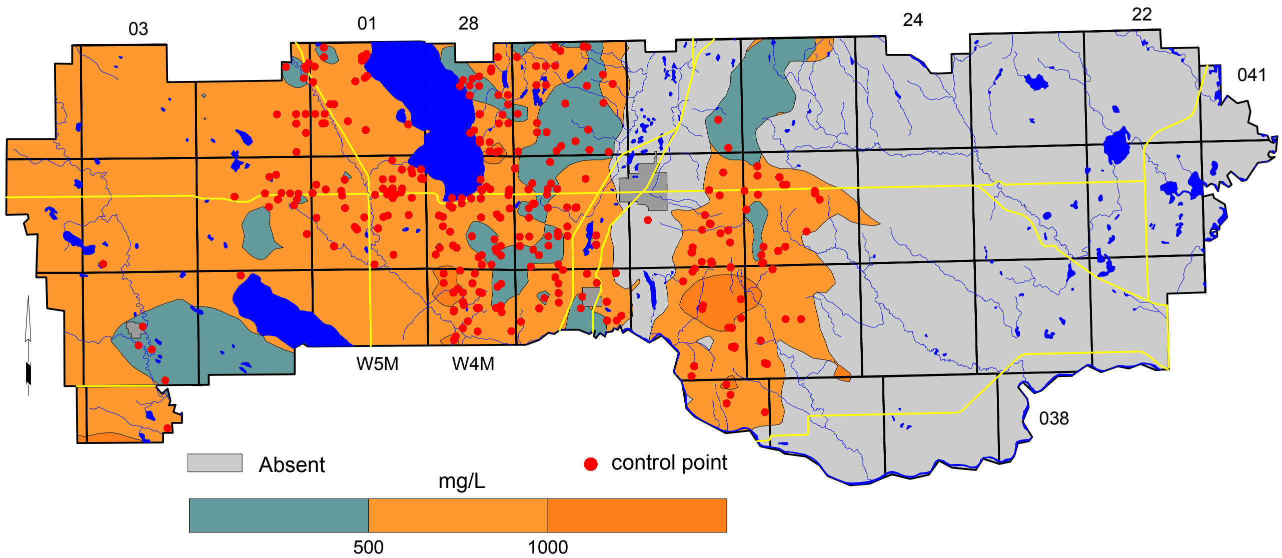
Depth to Top of Upper Lacombe Member



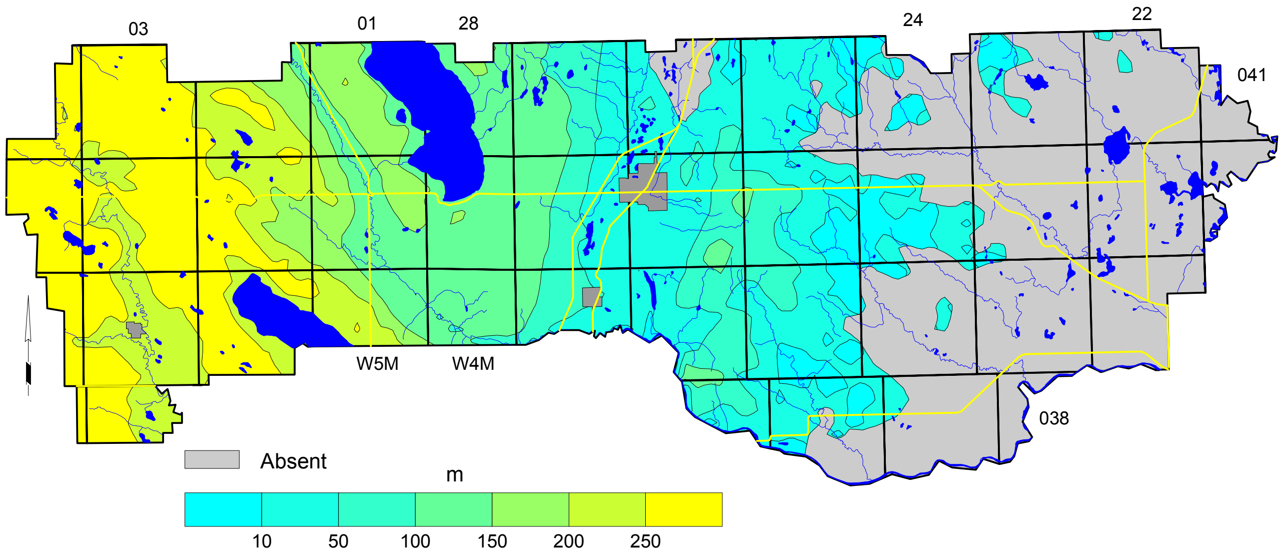
Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer



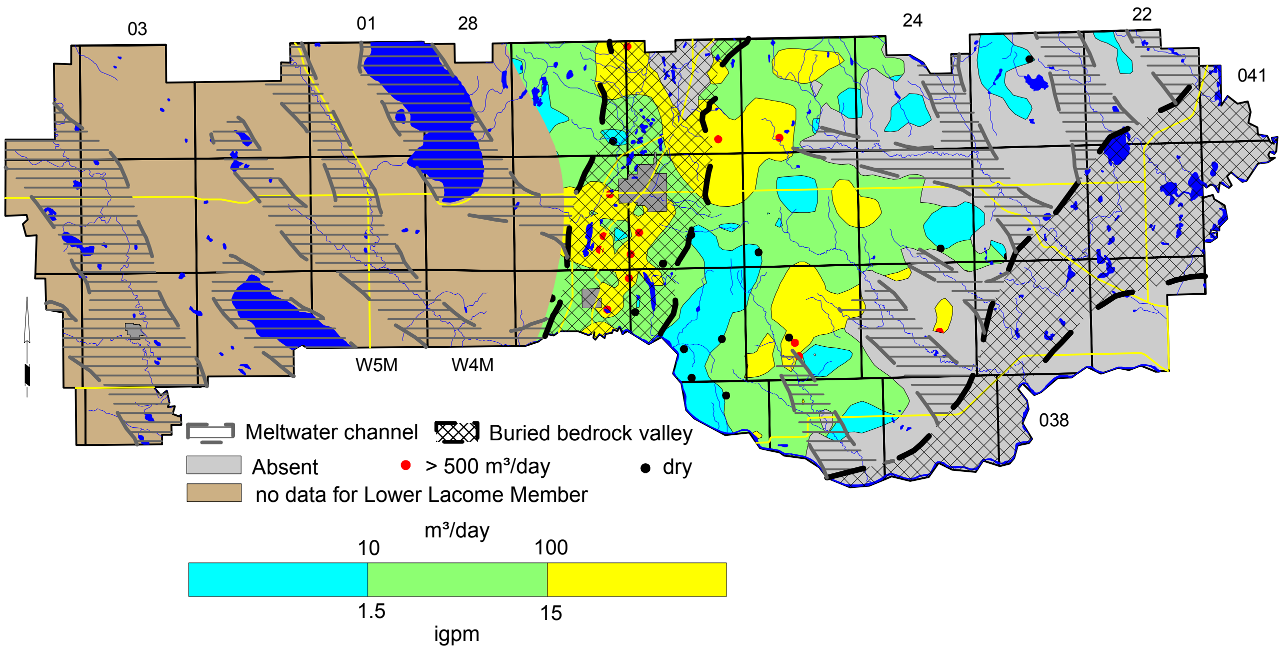
Total Dissolved Solids in Groundwater from Upper Lacombe Aquifer



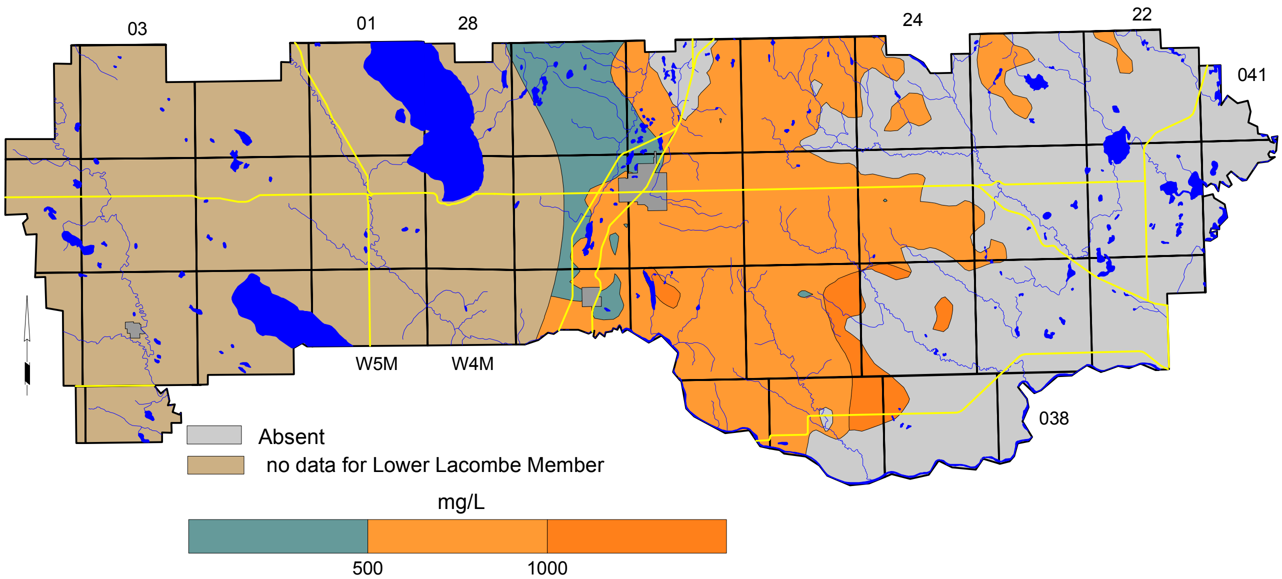
Depth to Top of Lower Lacombe Member



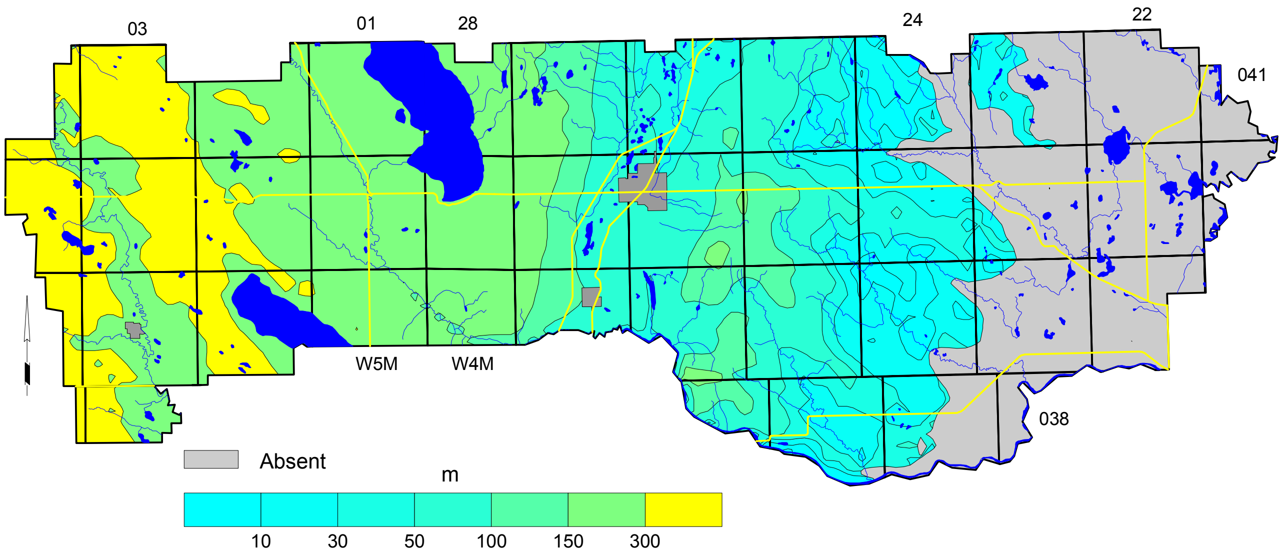
Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer



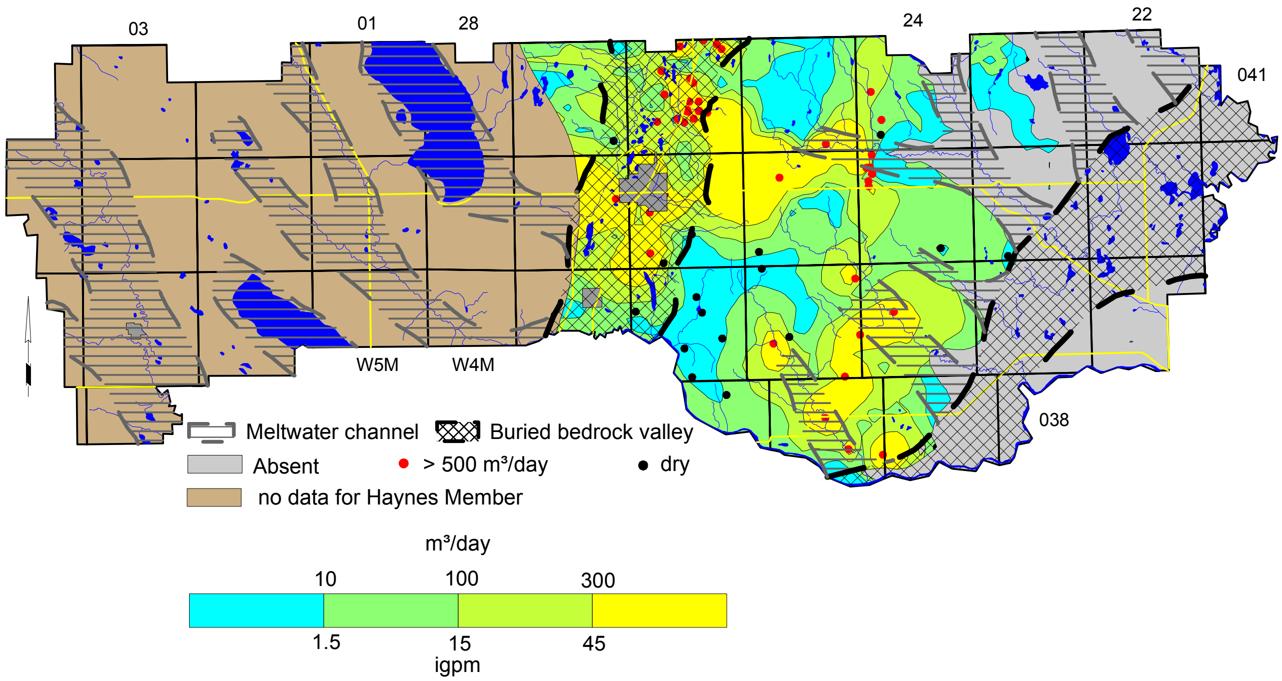
Total Dissolved Solids in Groundwater from Lower Lacombe Aquifer



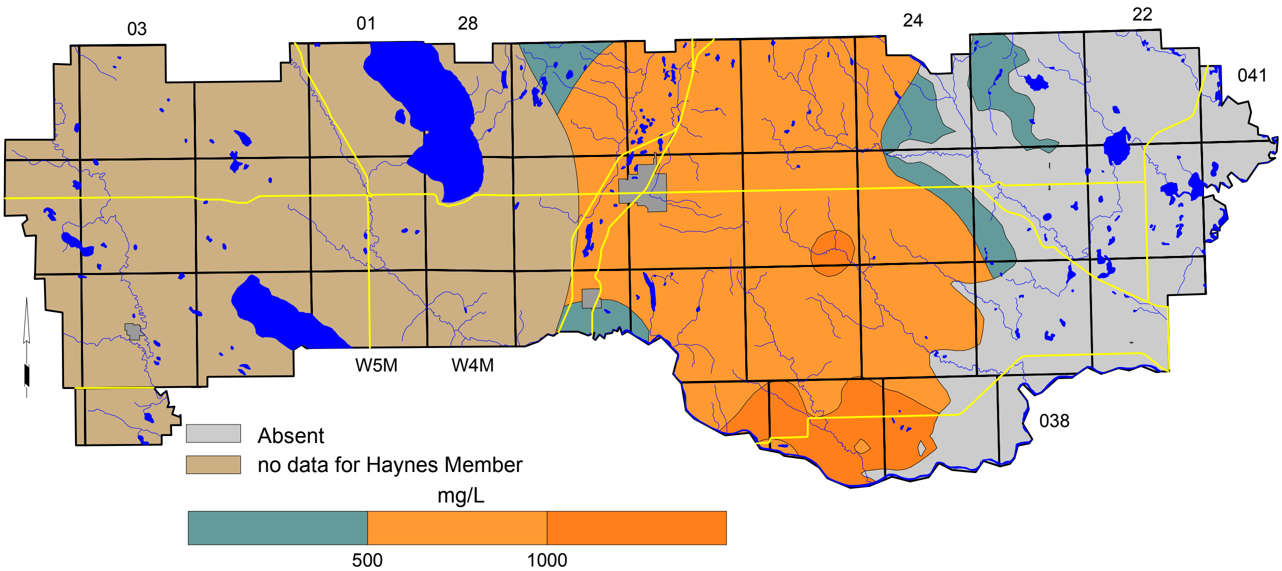
Depth to Top of Haynes Member



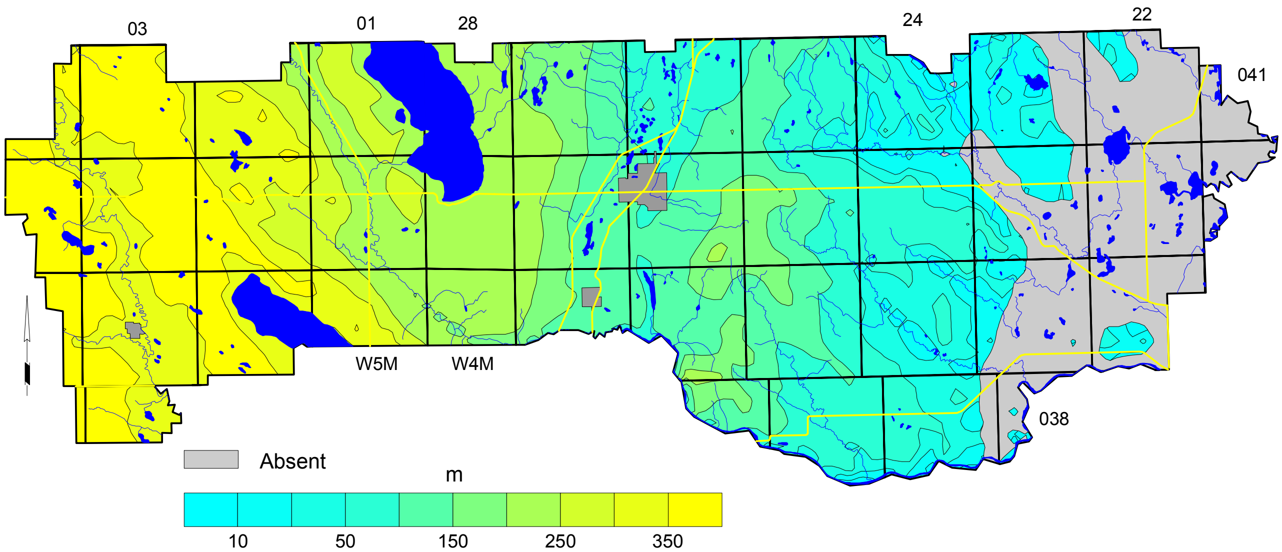
Apparent Yield for Water Wells Completed through Haynes Aquifer



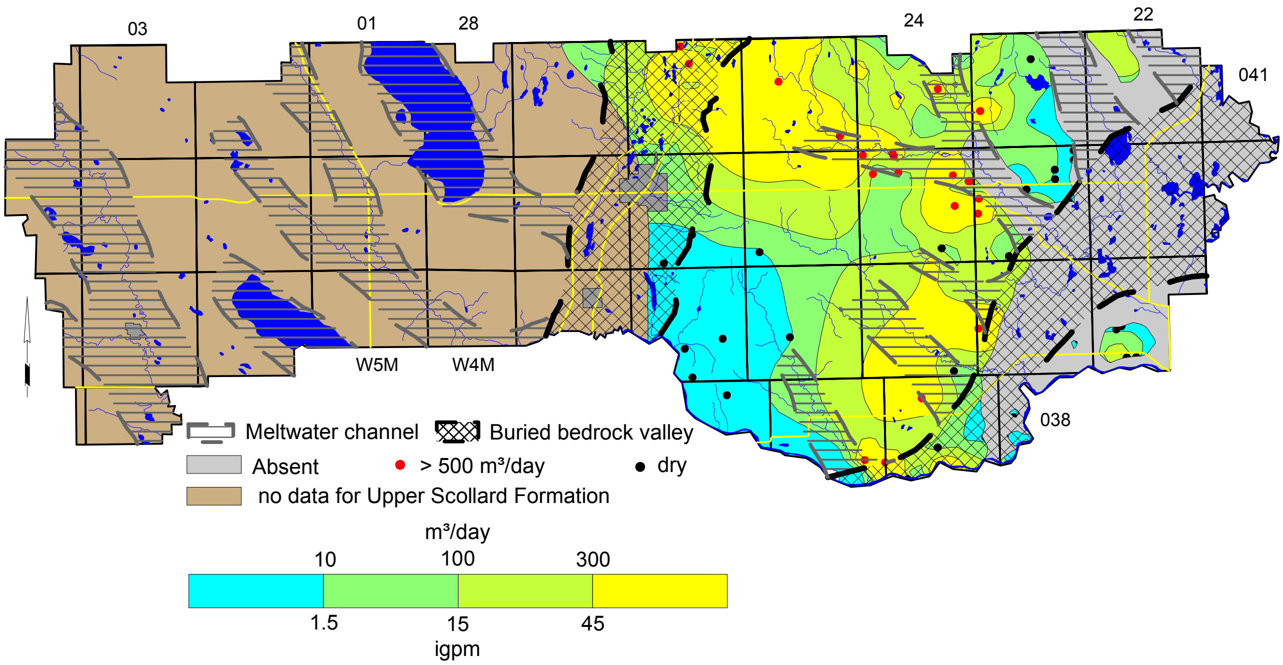
Total Dissolved Solids in Groundwater from Haynes Aquifer



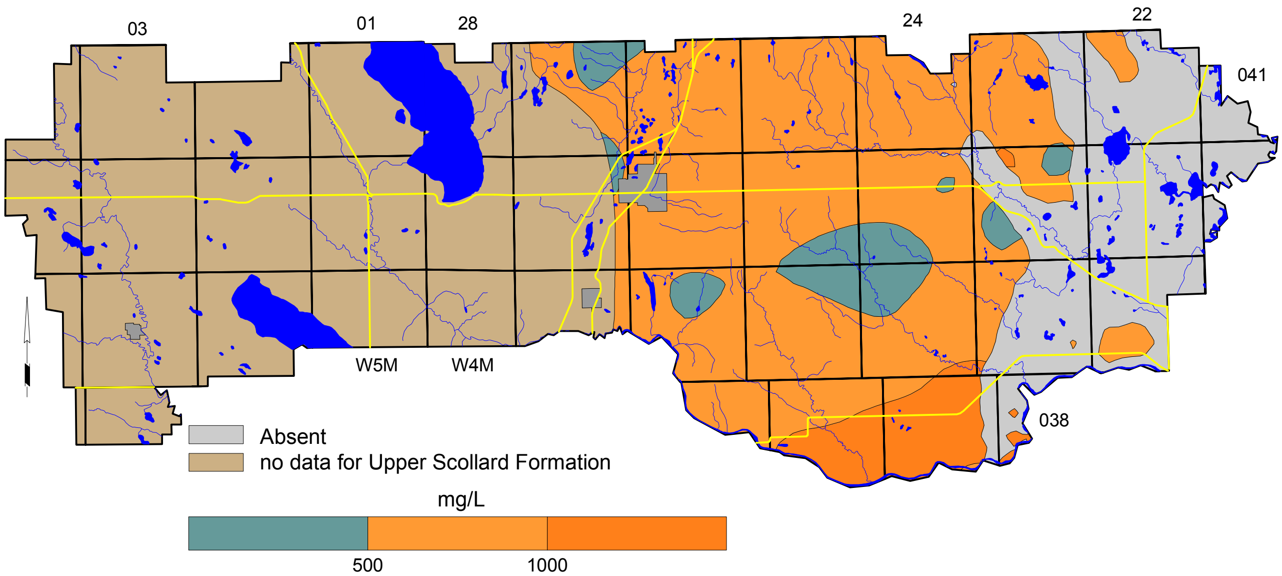
Depth to Top of Upper Scollard Formation



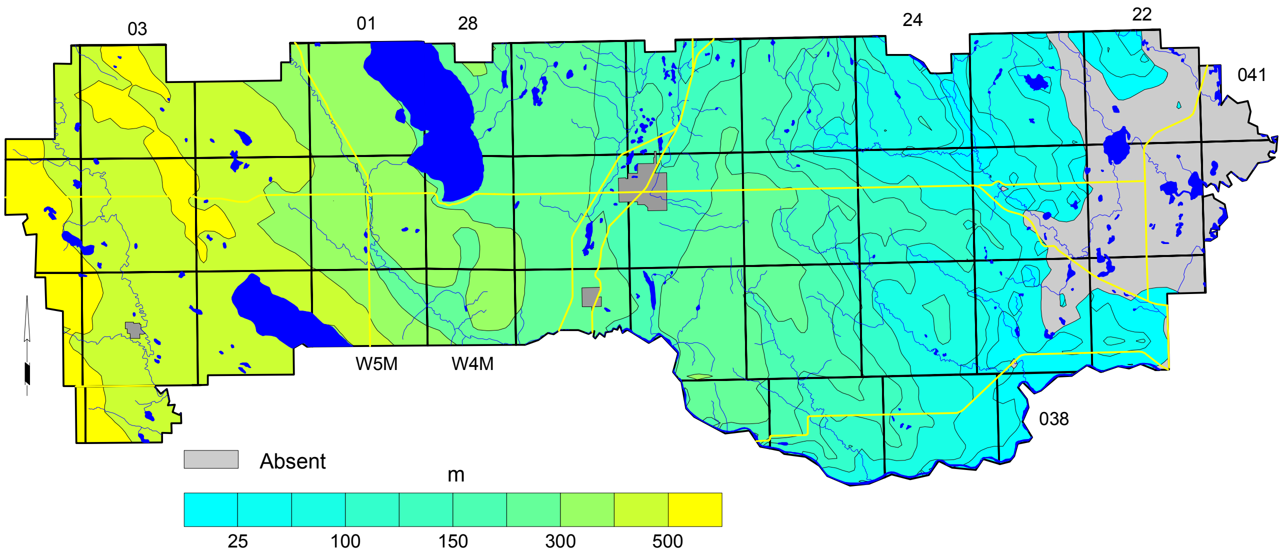
Apparent Yield for Water Wells Completed through Upper Scollard Aquifer



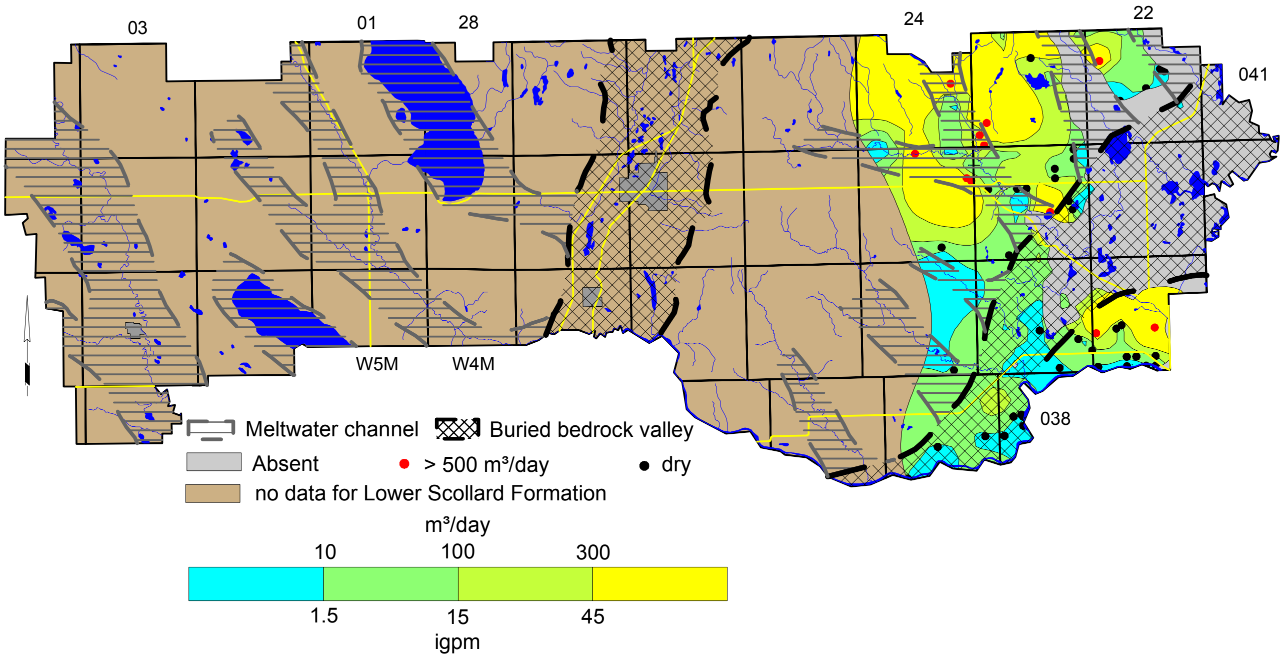
Total Dissolved Solids in Groundwater from Upper Scollard Aquifer



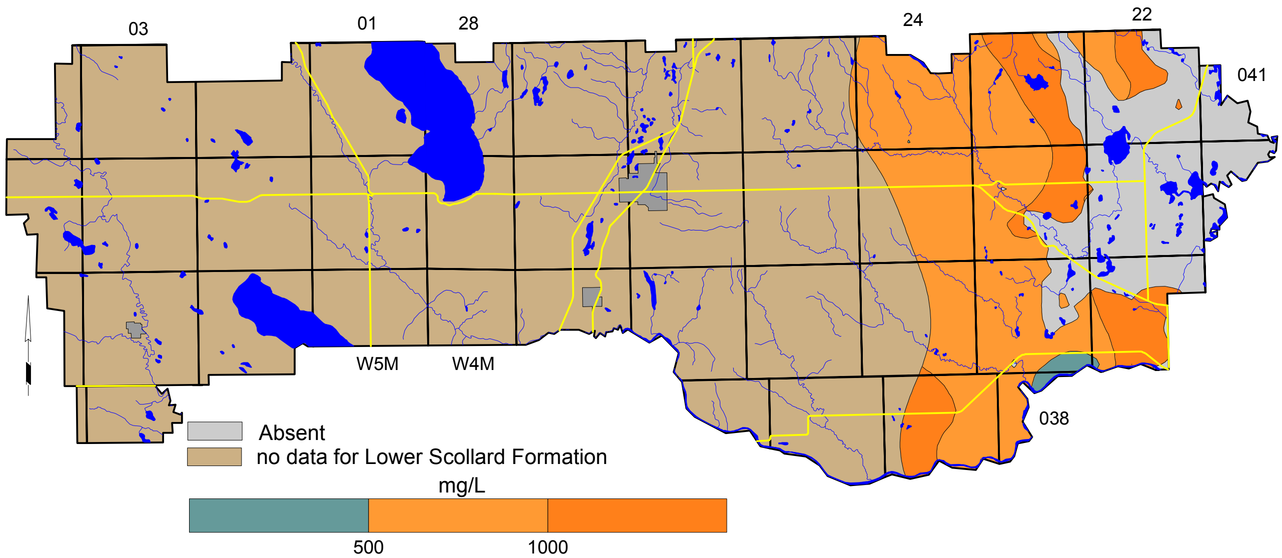
Depth to Top of Lower Scollard Formation



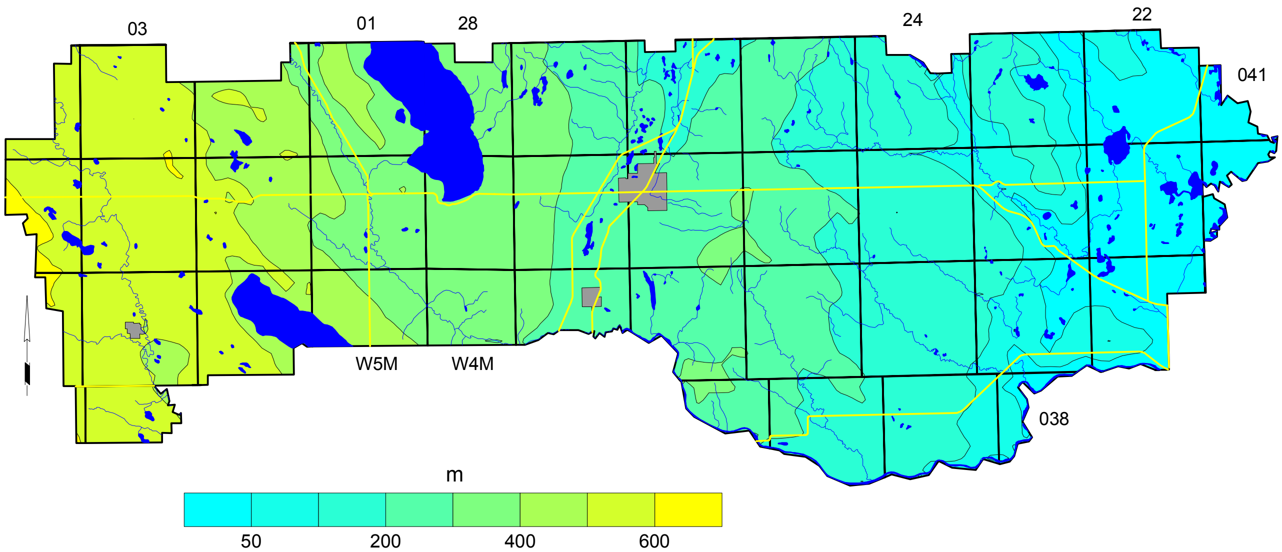
Apparent Yield for Water Wells Completed through Lower Scollard Aquifer



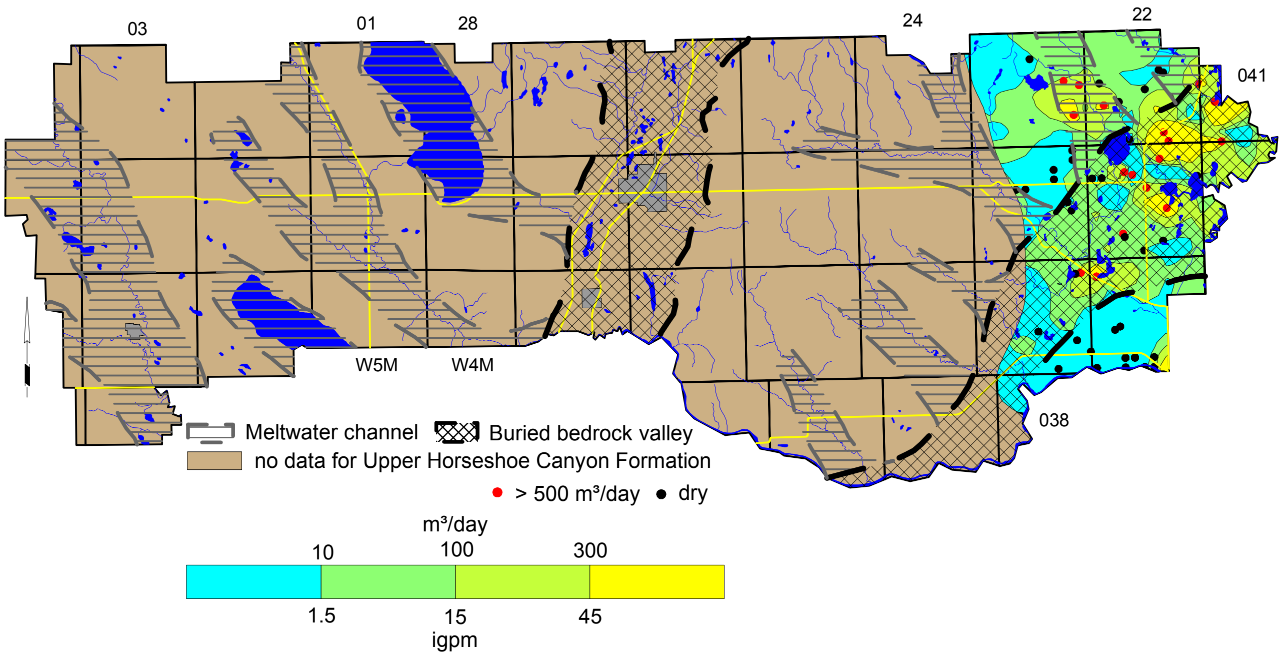
Total Dissolved Solids in Groundwater from Lower Scollard Aquifer



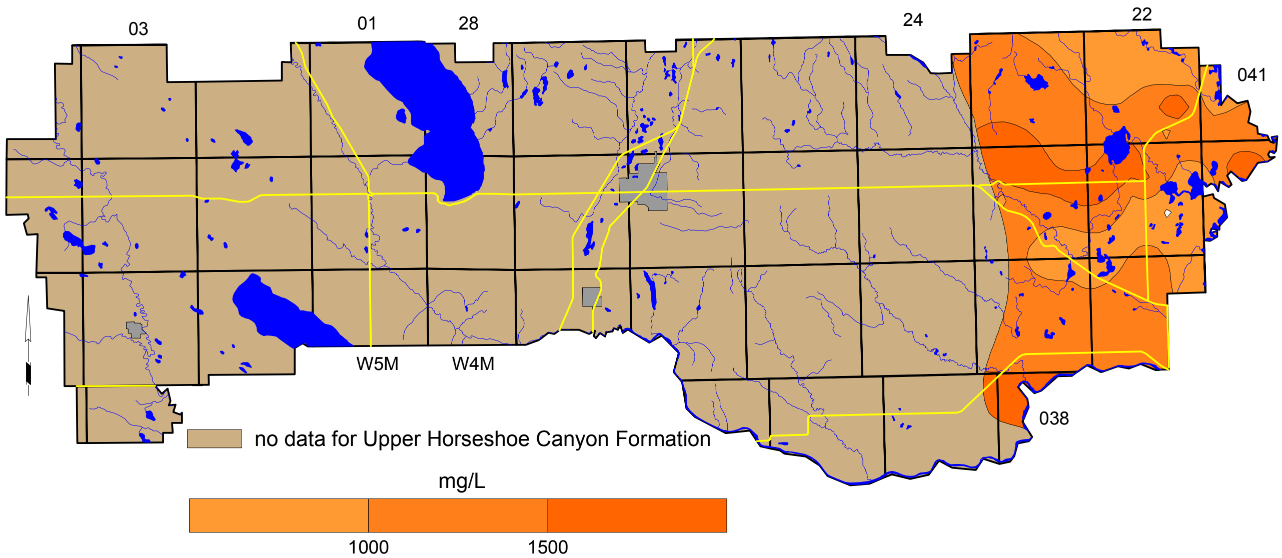
Depth to Top of Upper Horseshoe Canyon Formation



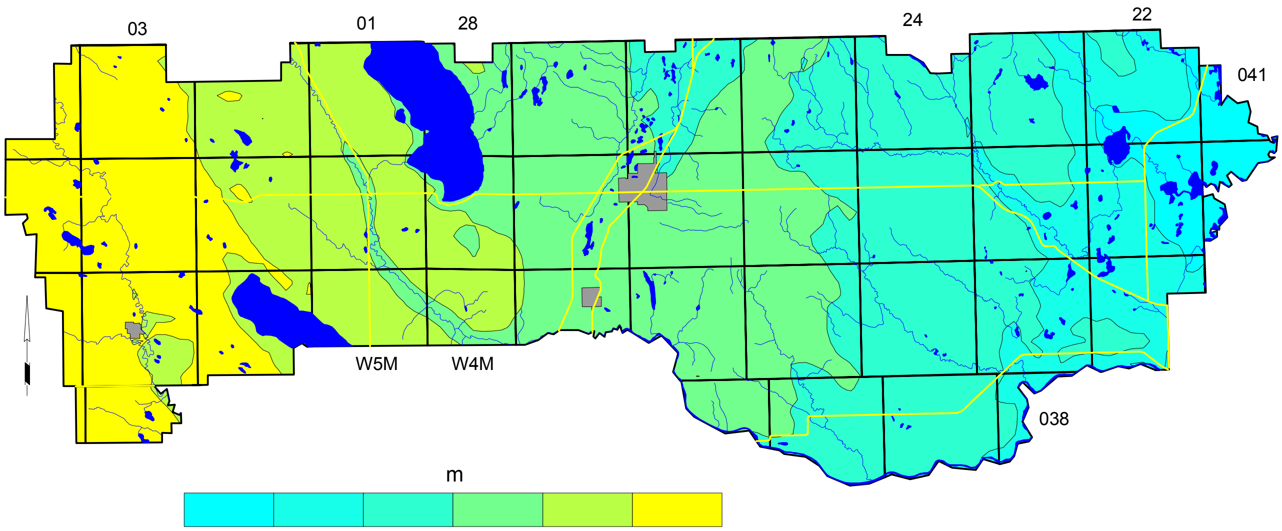
Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer



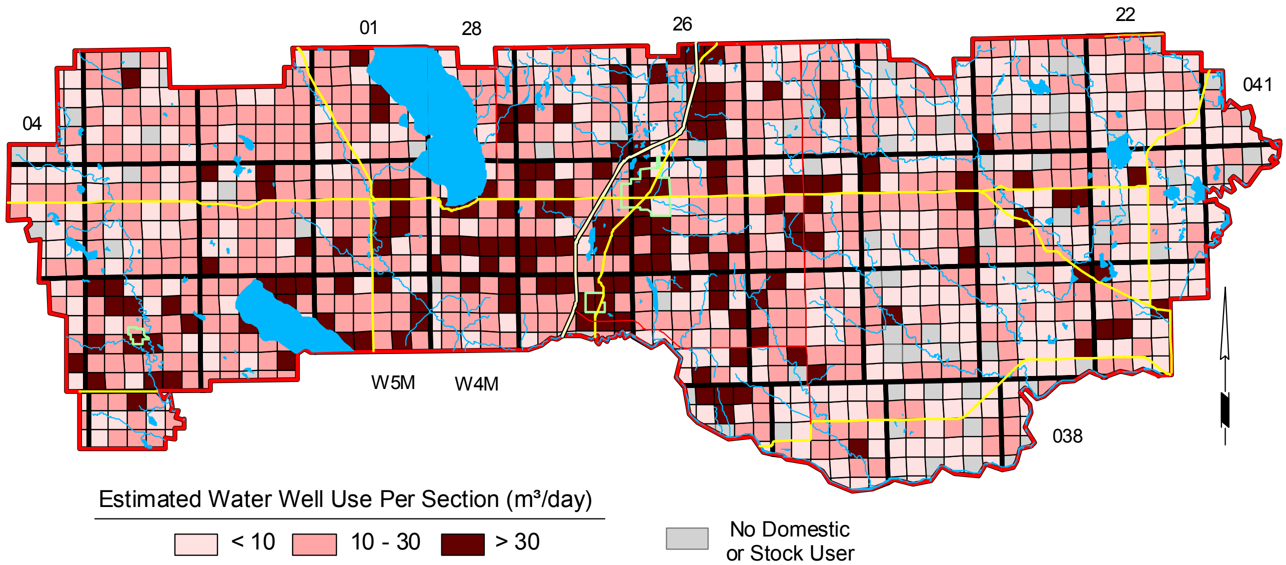
Total Dissolved Solids in Groundwater from Upper Horseshoe Canyon Aquifer



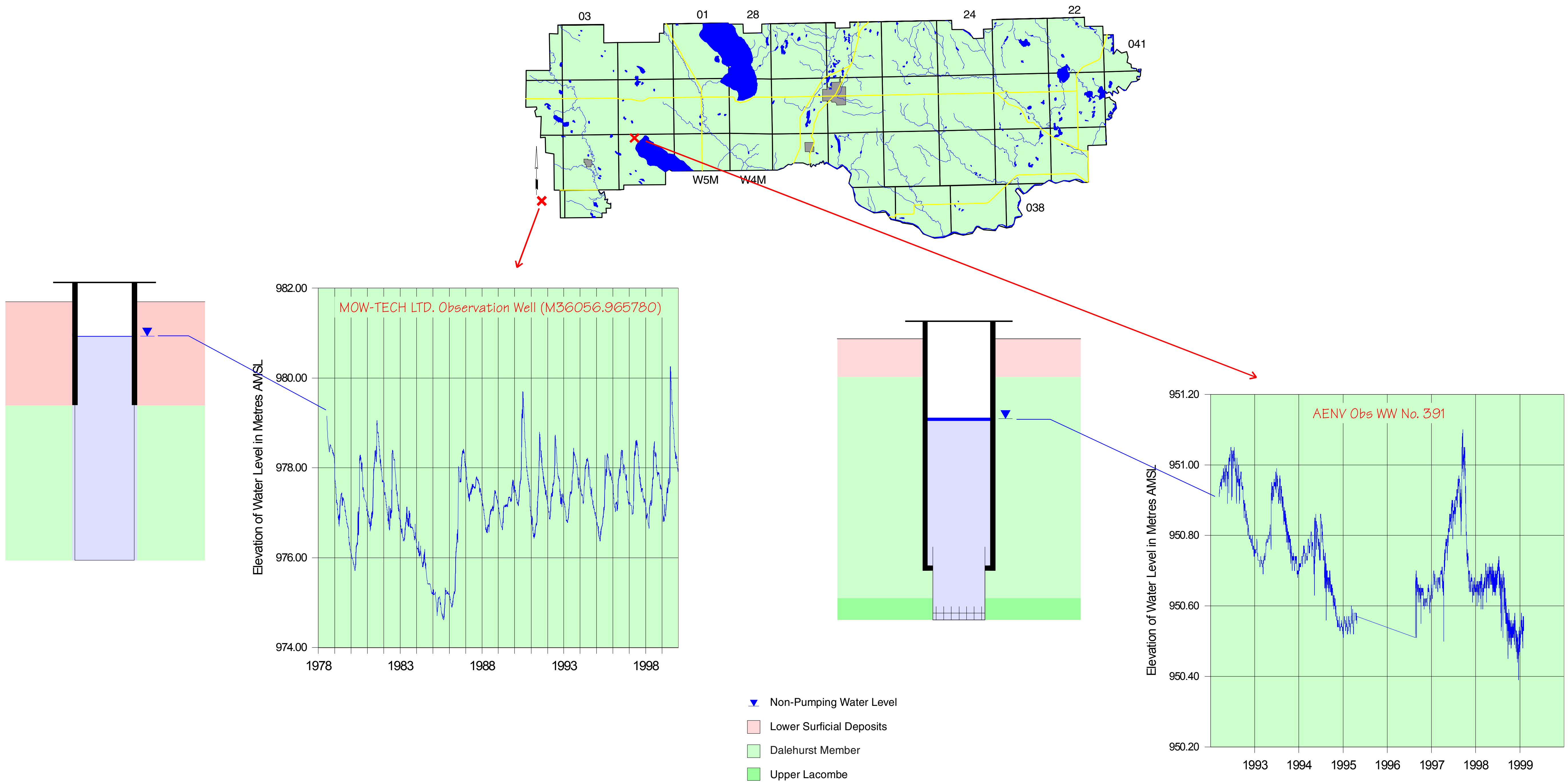
Depth to Top of Middle Horseshoe Canyon Formation



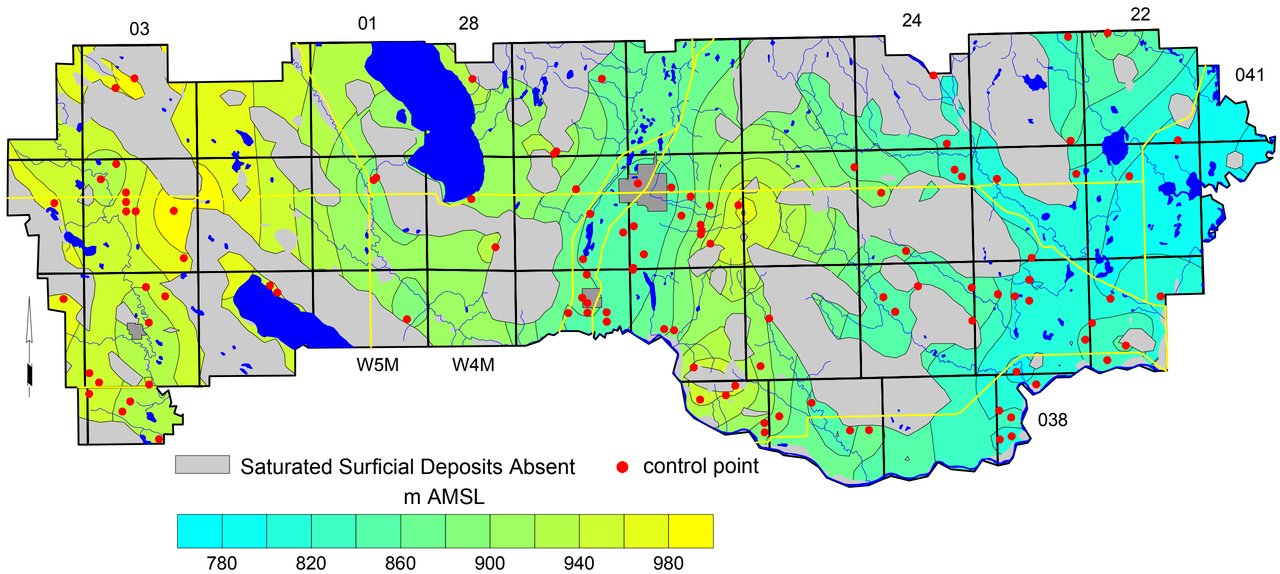
Estimated Water Well Use Per Section



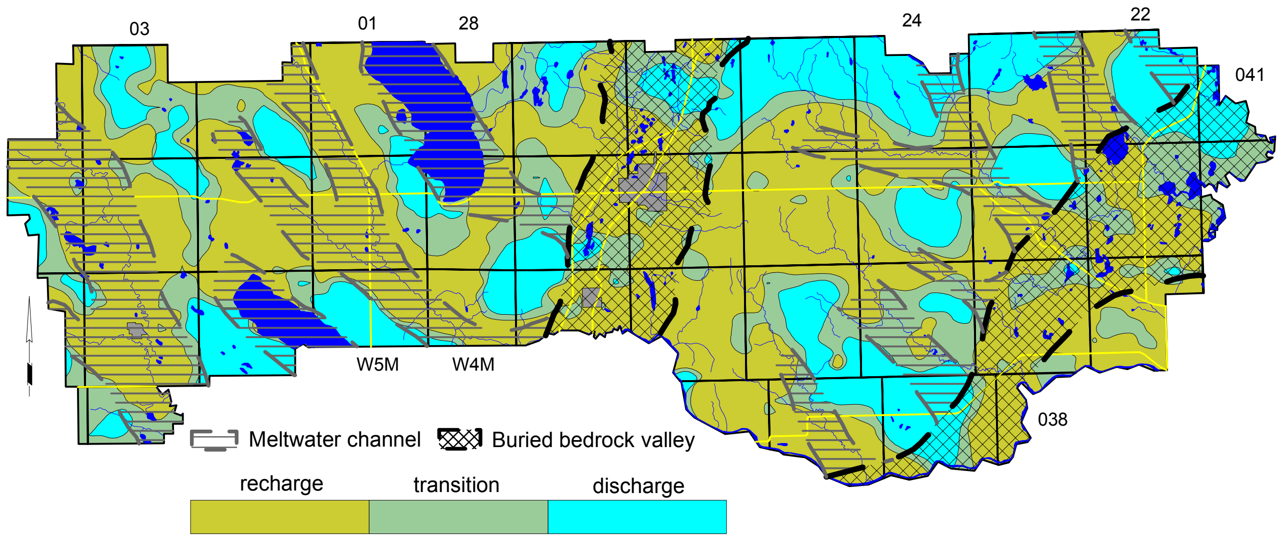
Hydrographs - AENV & MOW-TECH LTD.Observation Water Wells



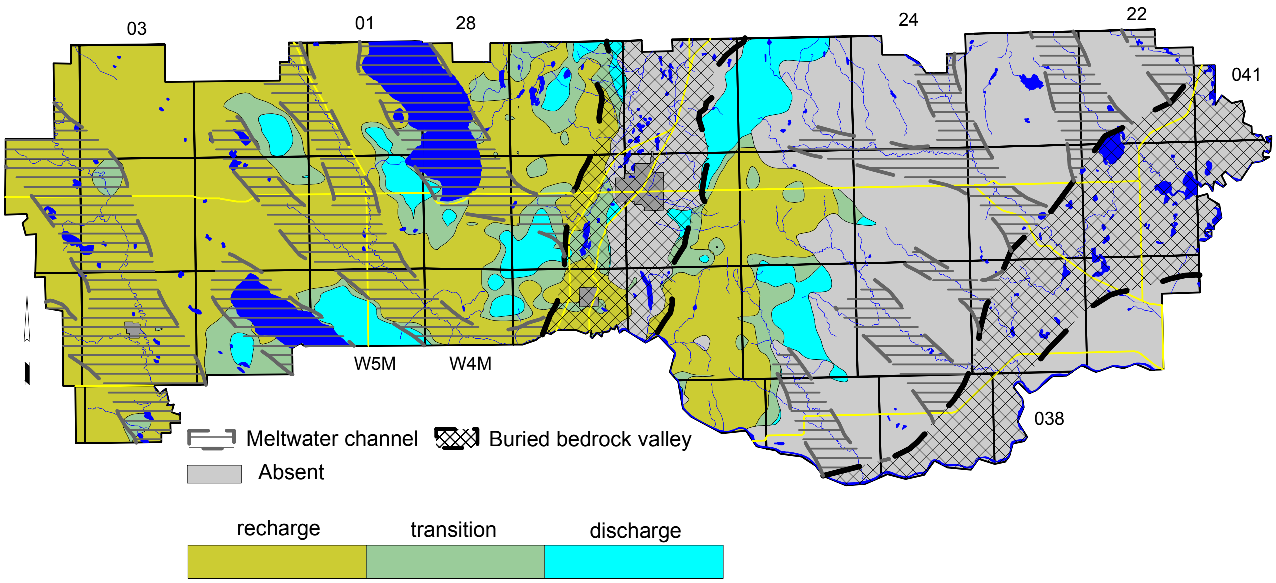
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



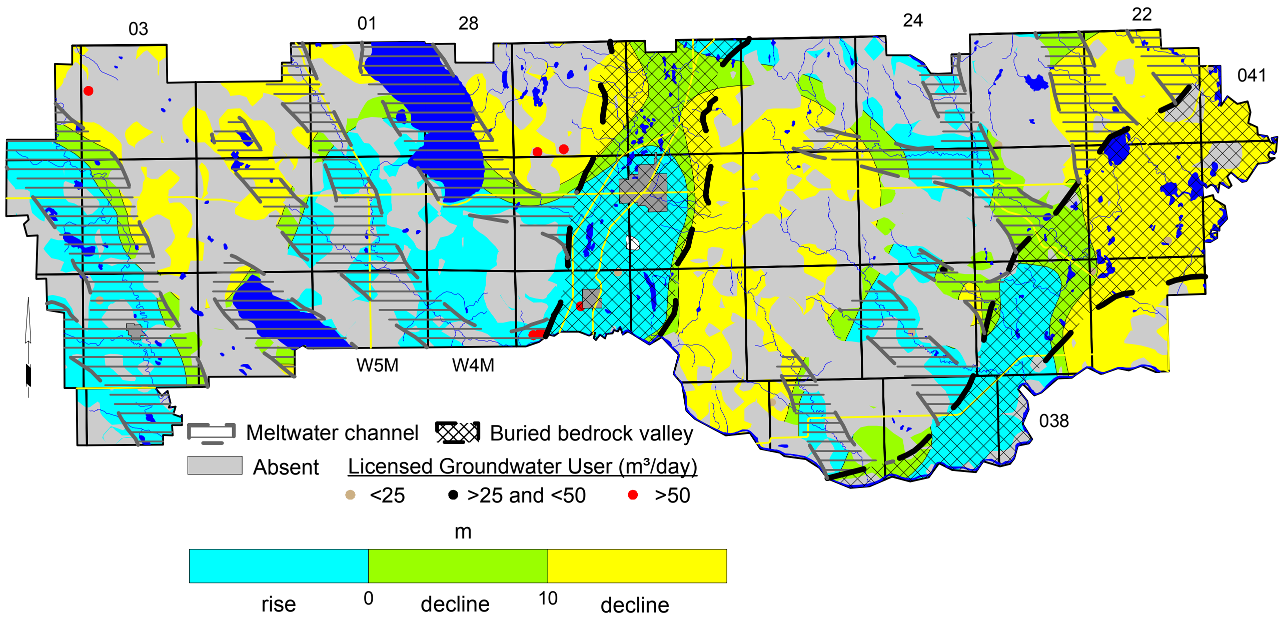
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



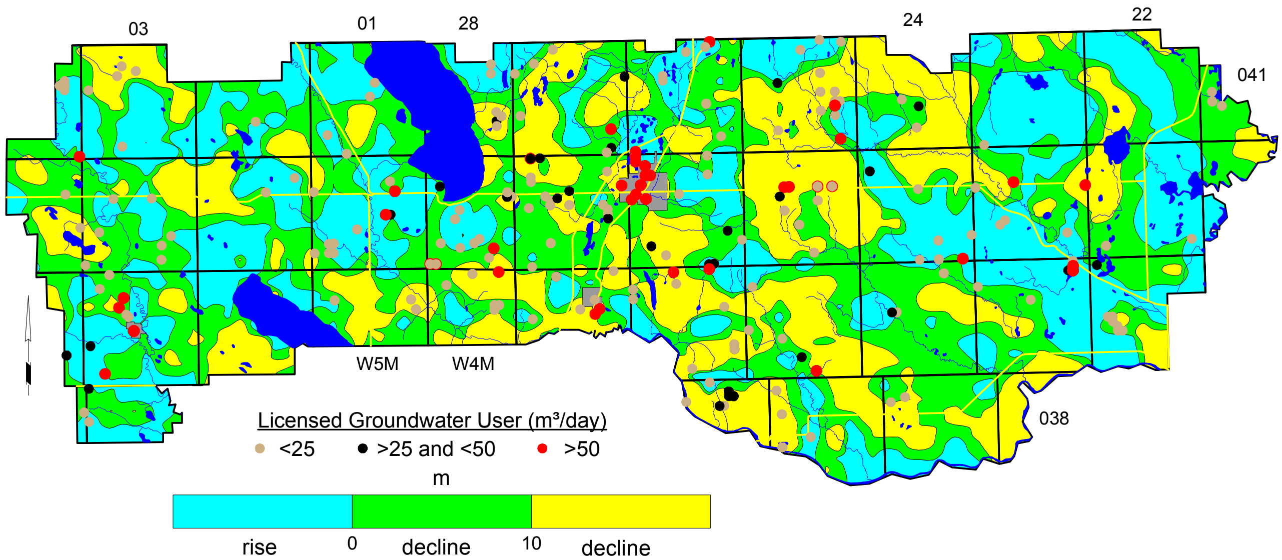
Recharge/Discharge Areas between Surficial Deposits and Upper Lacombe Aquifer



Changes in Water Levels in Sand and Gravel Aquifer(s)



Changes in Water Levels in Upper Bedrock Aquifer(s)



LACOMBE COUNTY

Appendix B

Maps and Figures on CD-ROM

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Thickness of Upper Sand and Gravel (not all drill holes fully penetrate surficial deposits)
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Chloride in Groundwater from Dalehurst Aquifer
Fluoride in Groundwater from Dalehurst Aquifer
Piper Diagram - Dalehurst Aquifer
Recharge/Discharge Areas between Surficial Deposits and Dalehurst Aquifer
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c) Upper Lacombe Member

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Changes in Water Levels - Lower Lacombe Aquifer

LACOMBE COUNTY
Appendix C

General Water Well Information

Domestic Water Well Testing

Purpose and Requirements

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

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

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

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

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

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

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

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

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

Procedure

Site Diagrams

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

Surface Details

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

Groundwater Discharge Point

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

Water-Level Measurements

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

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

Discharge Measurements

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

Water Samples

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

Water Act - Water (Ministerial) Regulation

PROVINCE OF ALBERTA

WATER ACT

WATER (MINISTERIAL) REGULATION

Alberta Regulation 205/98

EXTRACT FROM THE
ALBERTA GAZETTE

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ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

Table of Contents

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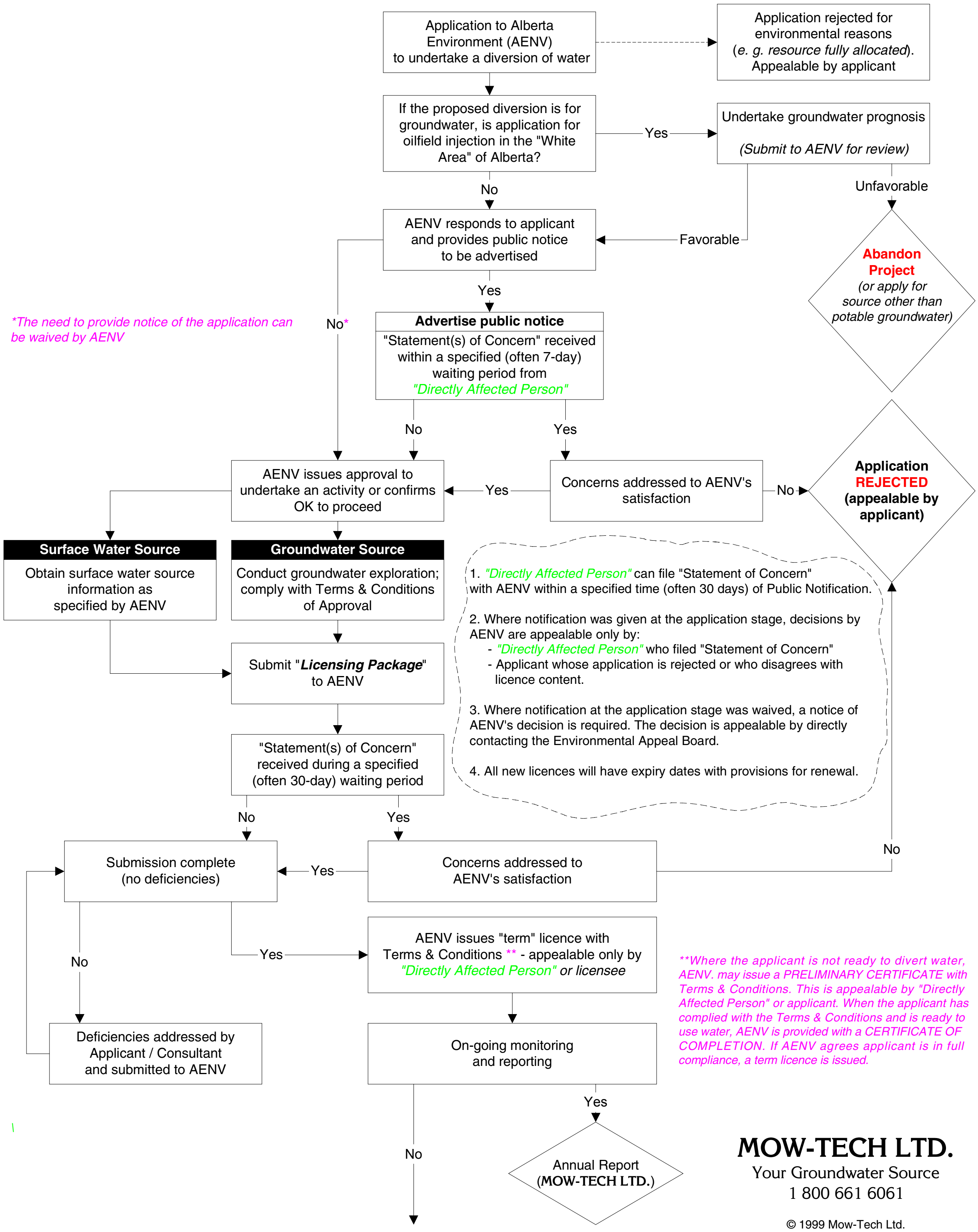
Water Act – Flowchart



*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.*

Interpretation of Chemical Analysis of Drinking Water

Stony Plain - Lac Ste. Anne Health Unit

HEAD OFFICE
P.O. Box 210
Stony Plain, Alberta
Canada T0E 2G0
Telephone: 963-2206
Fax: 963-7612

SUB-OFFICES
Box 4323
Spruce Grove, Alberta
T7X 3B5
Telephone: 962-4072

163 Provincial Bldg.
Whitecourt, Alberta
T0E 2L0
Telephone: 778-5555
Fax: 778-3852

Box 430
Fox Creek, Alberta
T0H 1P0
Telephone: 622-3730

HOME CARE:
Box 210
Stony Plain, Alberta
T0E 2G0
Telephone: 963-3366

INTERPRETATION OF CHEMICAL ANALYSIS OF DRINKING WATER

1. TOTAL DISSOLVED SOLIDS (TDS) - The recommended limit is 1000 mg/L for untreated and 500 mg/L for treated waters. TDS indicates the approximate organic and inorganic substances in the water. It will be high if other components of the analysis are high.

2. IRON - Amounts over 0.3 mg/L, usually stain laundry and plumbing fixtures and cause undesirable tastes. Iron filtration can be utilized. Iron bacteria may also be the cause of increased iron content.

3. CALCIUM - This is a constituent of hardness. Excessive calcium in drinking water may be a factor in disorders of the kidneys, bladder and urinary system.

4. MAGNESIUM - This is a constituent of hardness.

5. HARDNESS - A maximum acceptable concentration has not been established. Hardness is caused mainly by calcium and magnesium. Levels between 80 and 100 mg/L are satisfactory: 100 to 200 mg/L are less acceptable: more than 200 mg/L are considered to be poor and in excess of 500 mg/L are unacceptable for most domestic purposes. Softening can be helpful in given circumstances.

6. SODIUM - Ideally, there should be no more than 200mg/L. The average intake of sodium from water is only a small fraction of that consumed in a normal diet. Persons suffering from hypertension or congestive heart failure may require a sodium-restricted diet, in which case the intake of sodium from drinking water could become significant. Your physician should be informed of the sodium content.

7. NITRITE-NITROGEN & NITRATE-NITROGEN (NO2 + NO3) - The maximum acceptable concentration is 10 mg/L. Any amount over that may be harmful to children up to 12 months of age, causing a condition known as methaemoglobinaemia. Presence may indicate a contaminating source although other instances, e.g. fertilizer and decomposing vegetation can cause an elevated figure.

8. NITRITE-NITROGEN - The maximum acceptable concentration is 1.0 Mg/L. Nitrite is unstable in water and converts to nitrate. An elevated figure may indicate a pollution problem.

9. FLUORIDE - Approximately 1 mg/L of fluoride is recommended in drinking water in order to give developing teeth some protection against decay. If the fluoride is higher than 1.5 mg/L you should talk to the dental staff of the Health Unit about the possibility of mottled enamel; if the fluoride is lower than 0.7 mg/L please ask about fluoride supplements for your children.

10. SULPHATE - The maximum acceptable concentration is 500 mg/L. Taste becomes noticeable between 250 and 600 mg/L and a laxative effect may be noticed by new users when sulphate combines with sodium or magnesium.

-2-

11. CHLORIDE - The recommended limit is 250 mg/L. Chloride content is usually low and an increase may indicate a nearby source of pollution (particularly if NO2 and NO3 and nitrite are high). Some wells contain naturally occurring chlorides. A salty taste may be evident.

12. ALKALINITY T (Total) - Alkalinity below 500 mg/L is generally accepted. Excessive alkalinity may result in incrustations on utensils, service pipes and water heaters.

13. BICARBONATE _ Upper limit not established. Relates to alkalinity as bicarbonate of sodium, calcium and magnesium.

NOTE: mg/L = milligrams per litre.

The preceding notes and standards are for your guidance only based on an intake of 2 litres of water per day. The figures may be interpreted in a variety of ways and the public health inspector for your area can be contacted for further advice.
Telephone: Stony Plain - 963-2206; Spruce Grove - 962-4072; Whitecourt - 778-5555.

For stock water and other agricultural uses the requirements are not necessarily the same as for domestic use. Please consult your District Agriculturalist for that kind of advice.

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 Mendoza (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

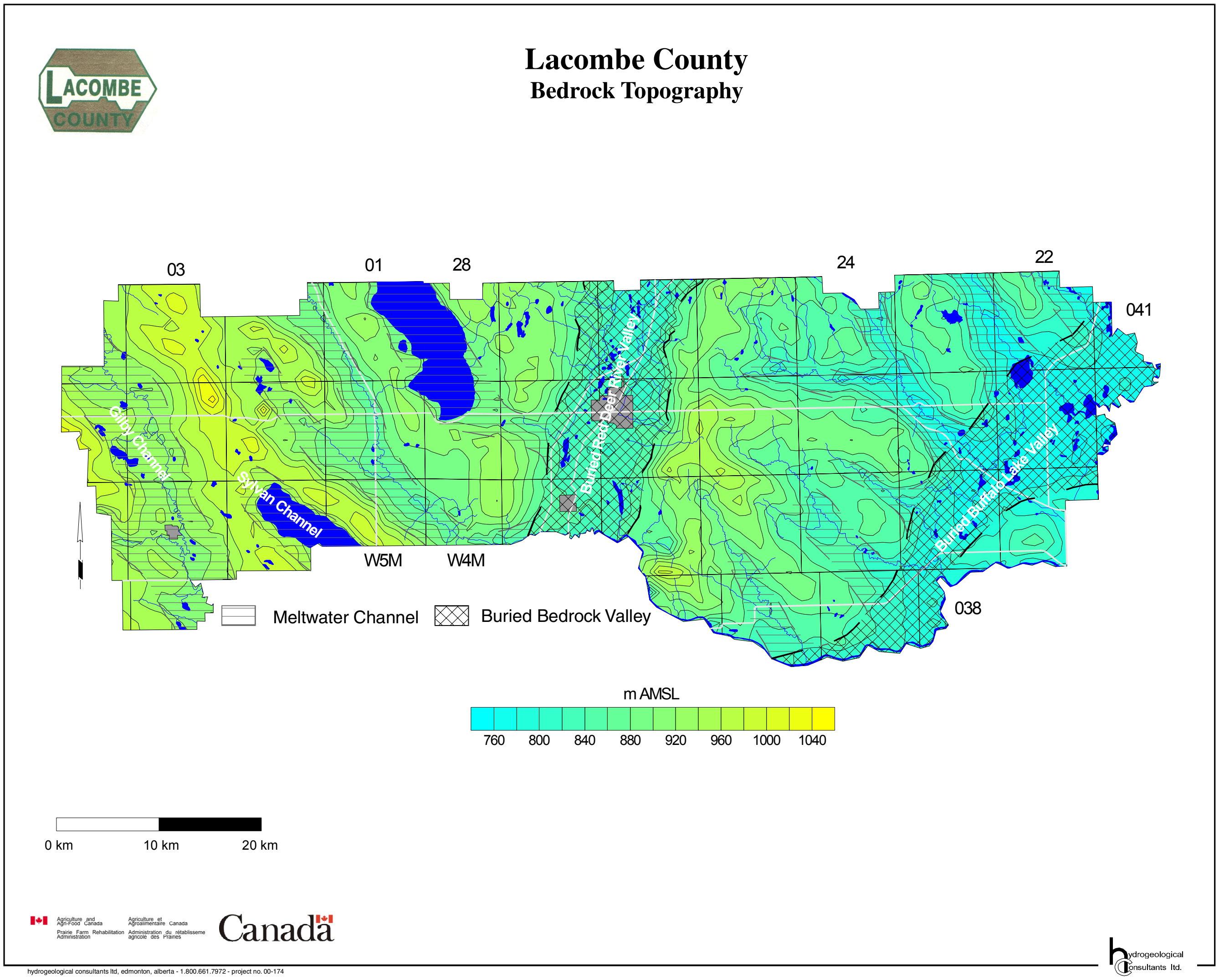
Bill Franz (Red Deer: 403-340-4290)
Terry Dash (Calgary: 403-292-5719)

LOCAL HEALTH DEPARTMENTS

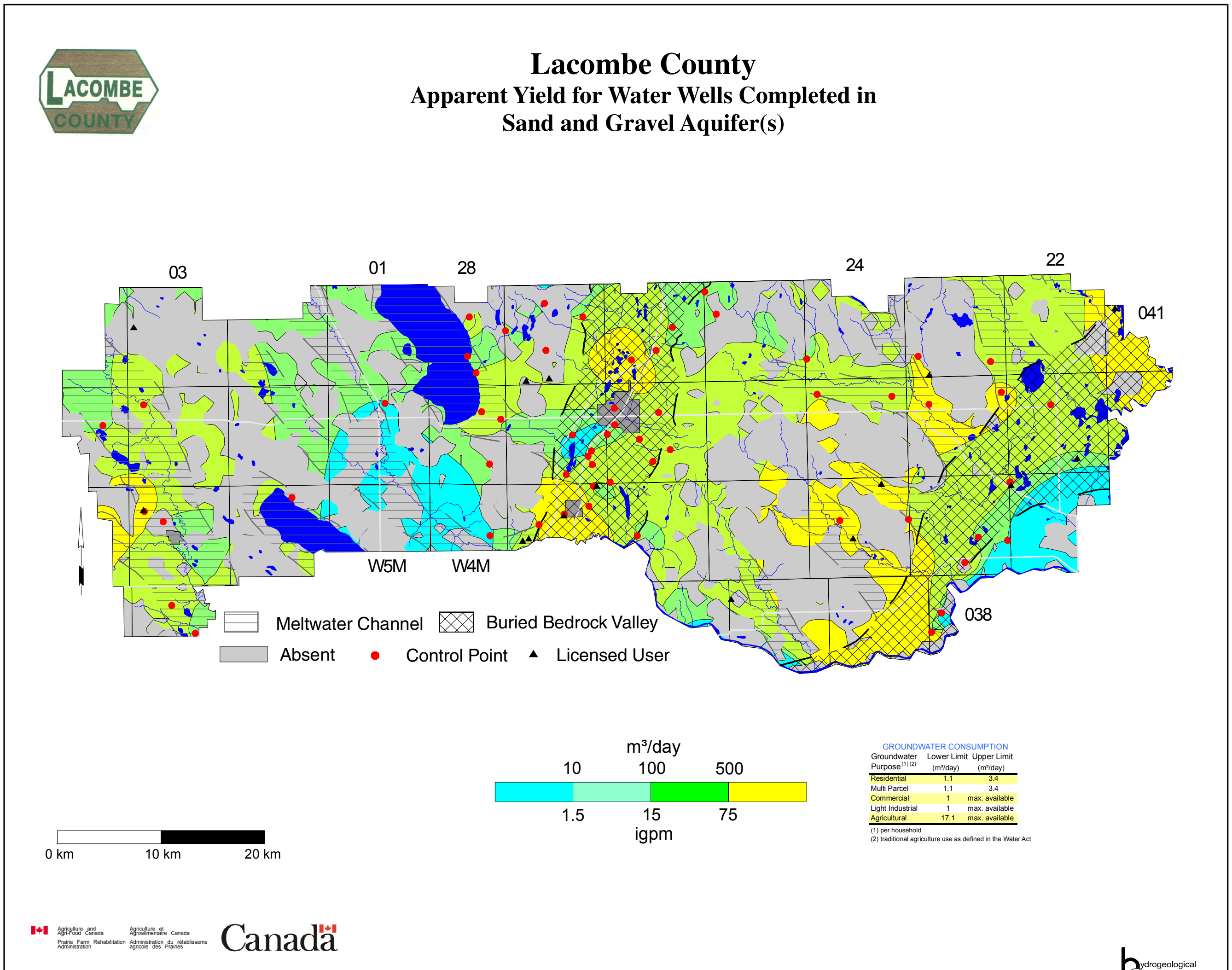
LACOMBE COUNTY
Appendix D

Maps and Figures Included as Large Plots

Bedrock Topography



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



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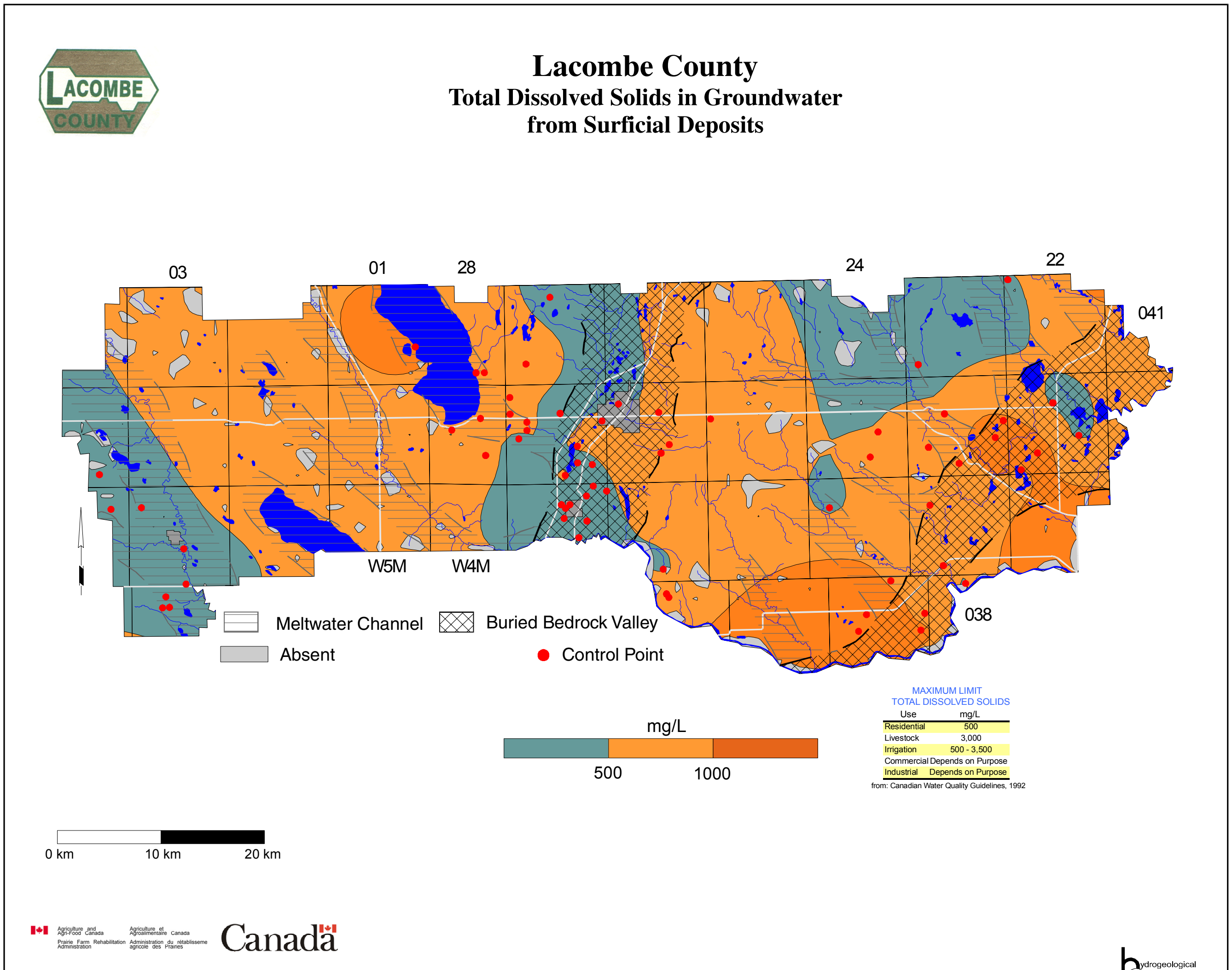
Total Dissolved Solids in Groundwater from Surficial Deposits



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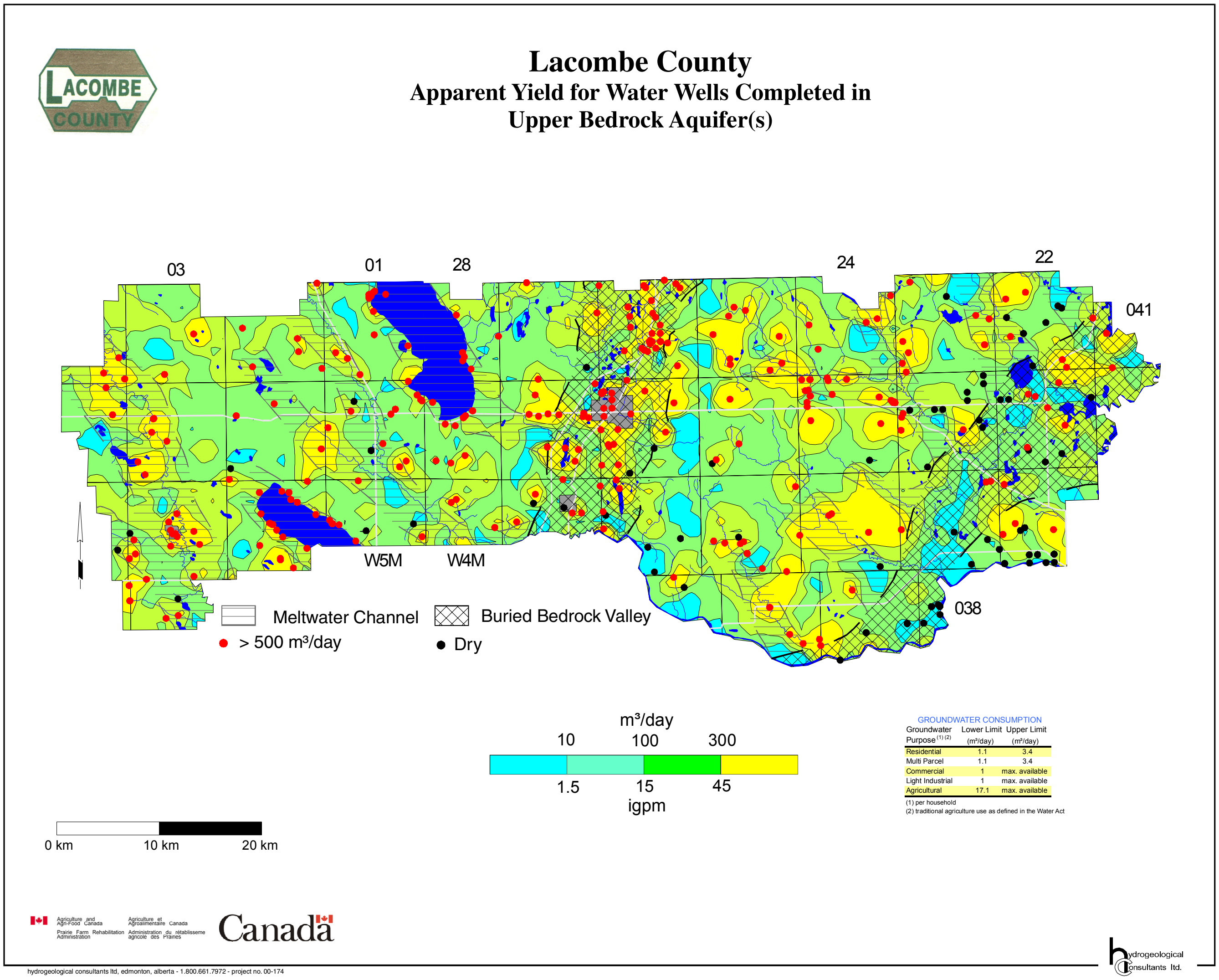
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

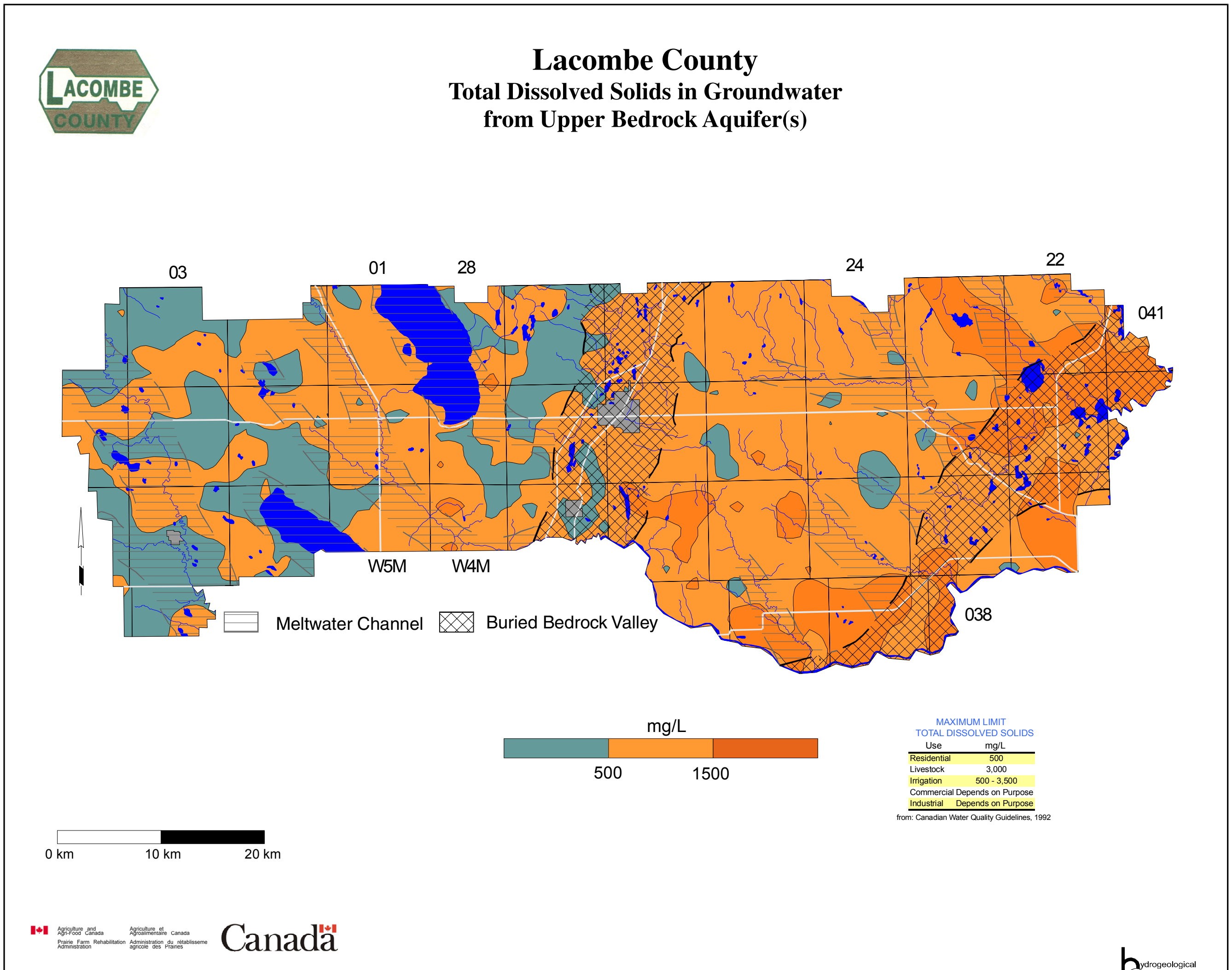


GROUNDWATER CONSUMPTION

Groundwater Purpose (1) (2)	Lower Limit (m^3/day)	Upper Limit (m^3/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

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



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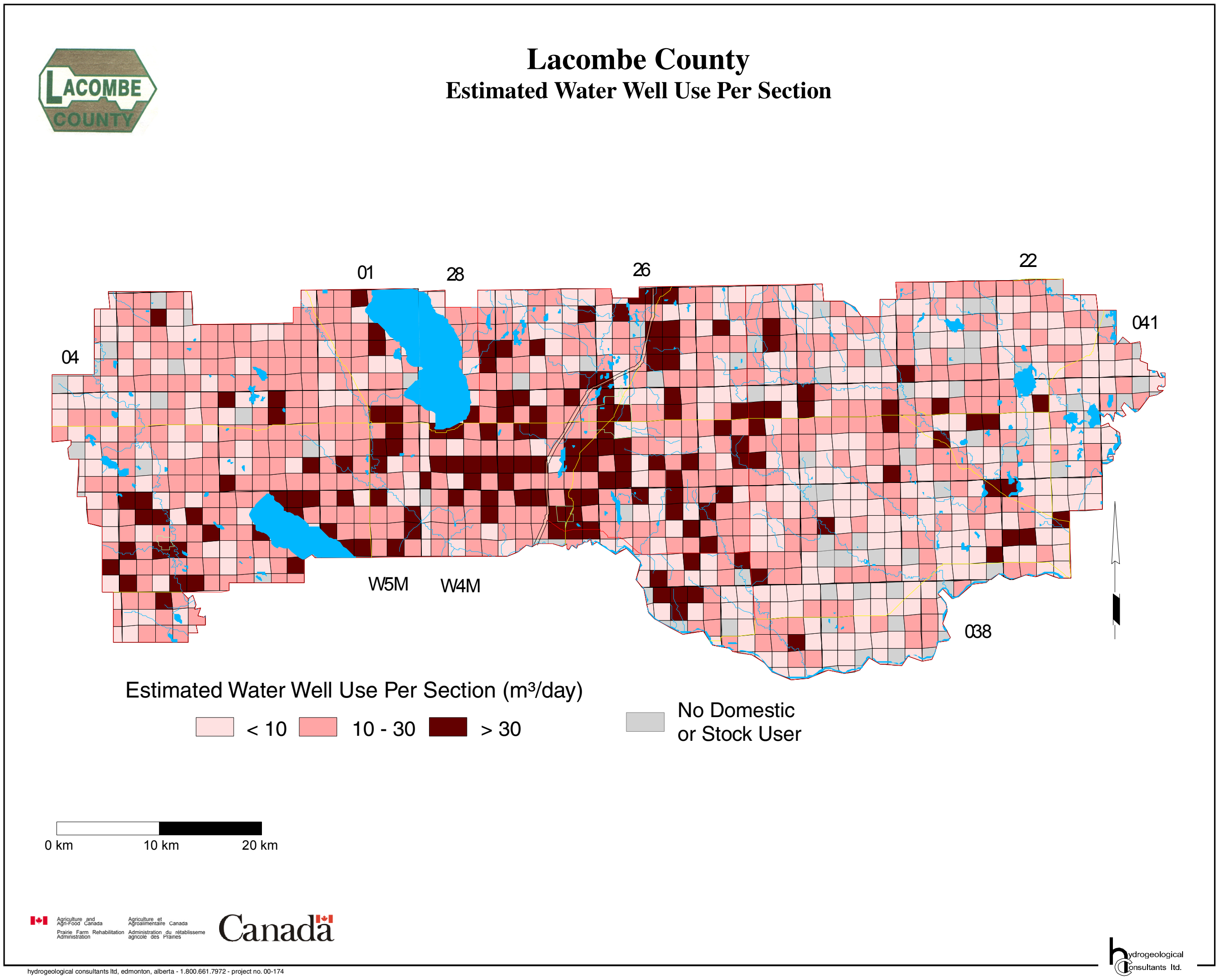
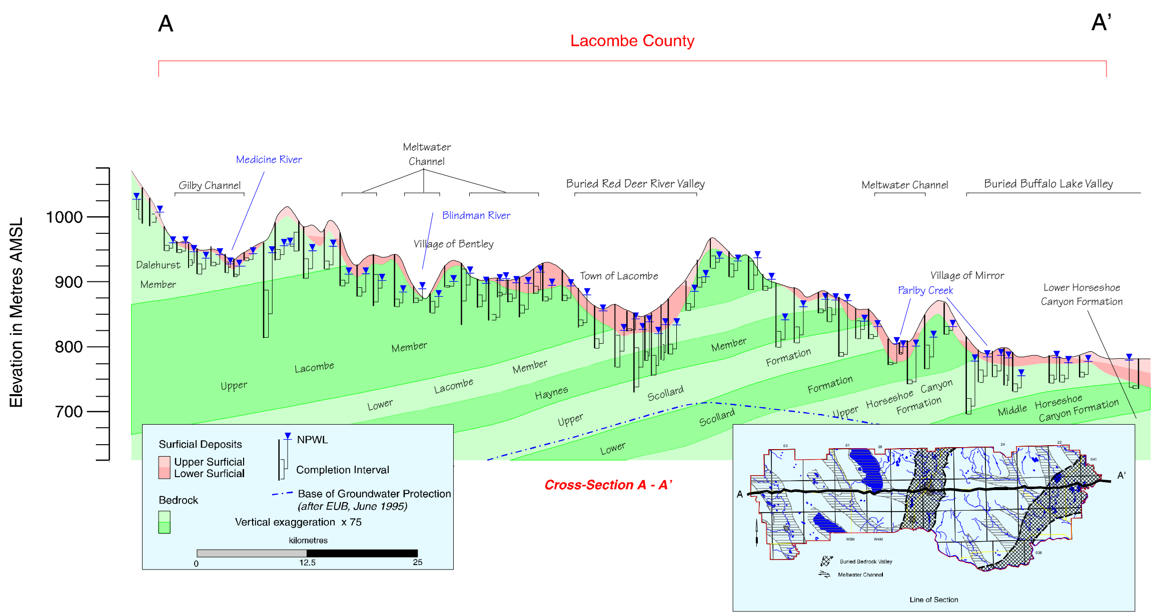
Estimated Water Well Use Per Section



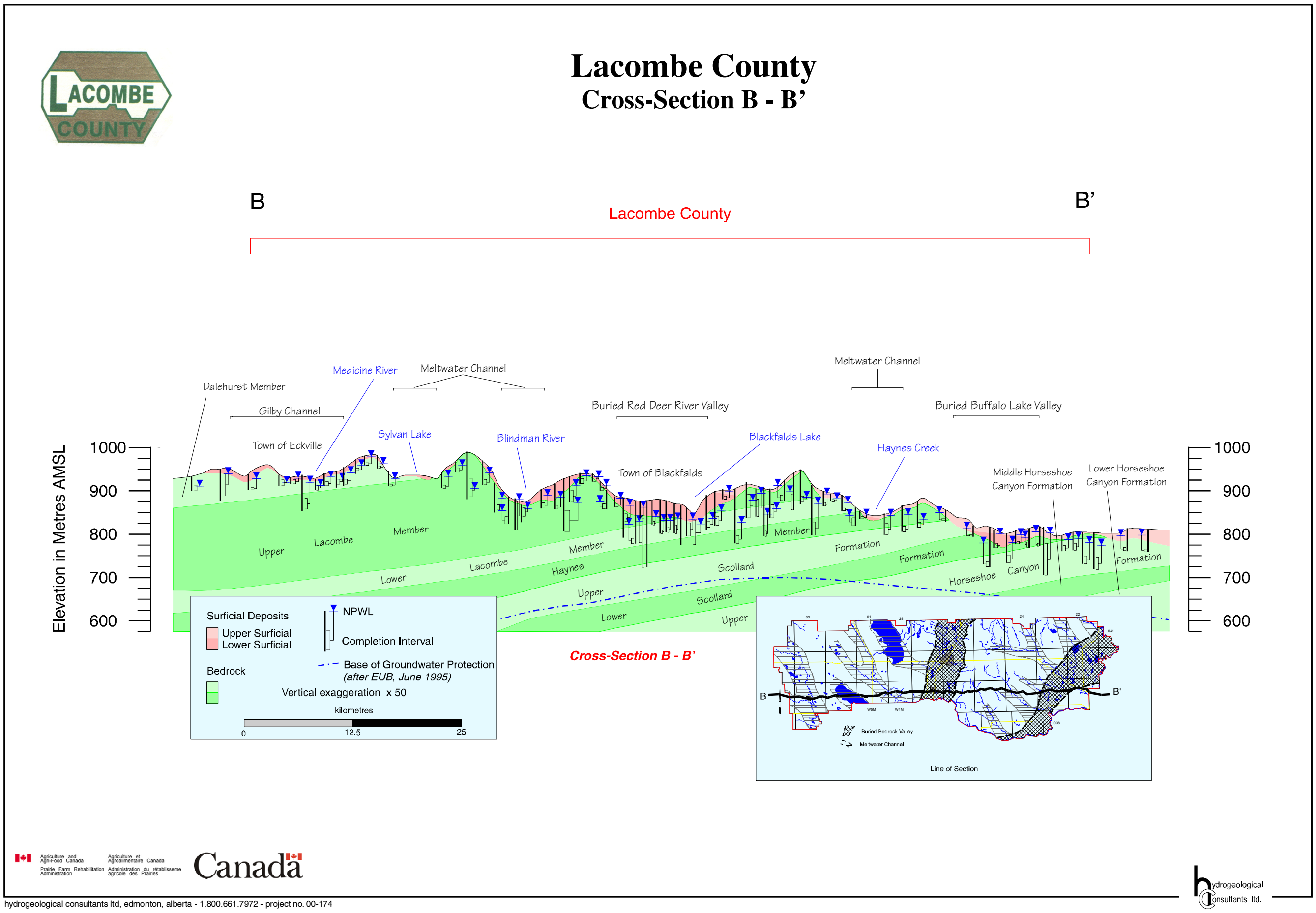
Cross-Section A - A'

Lacombe County
Cross-Section A - A'

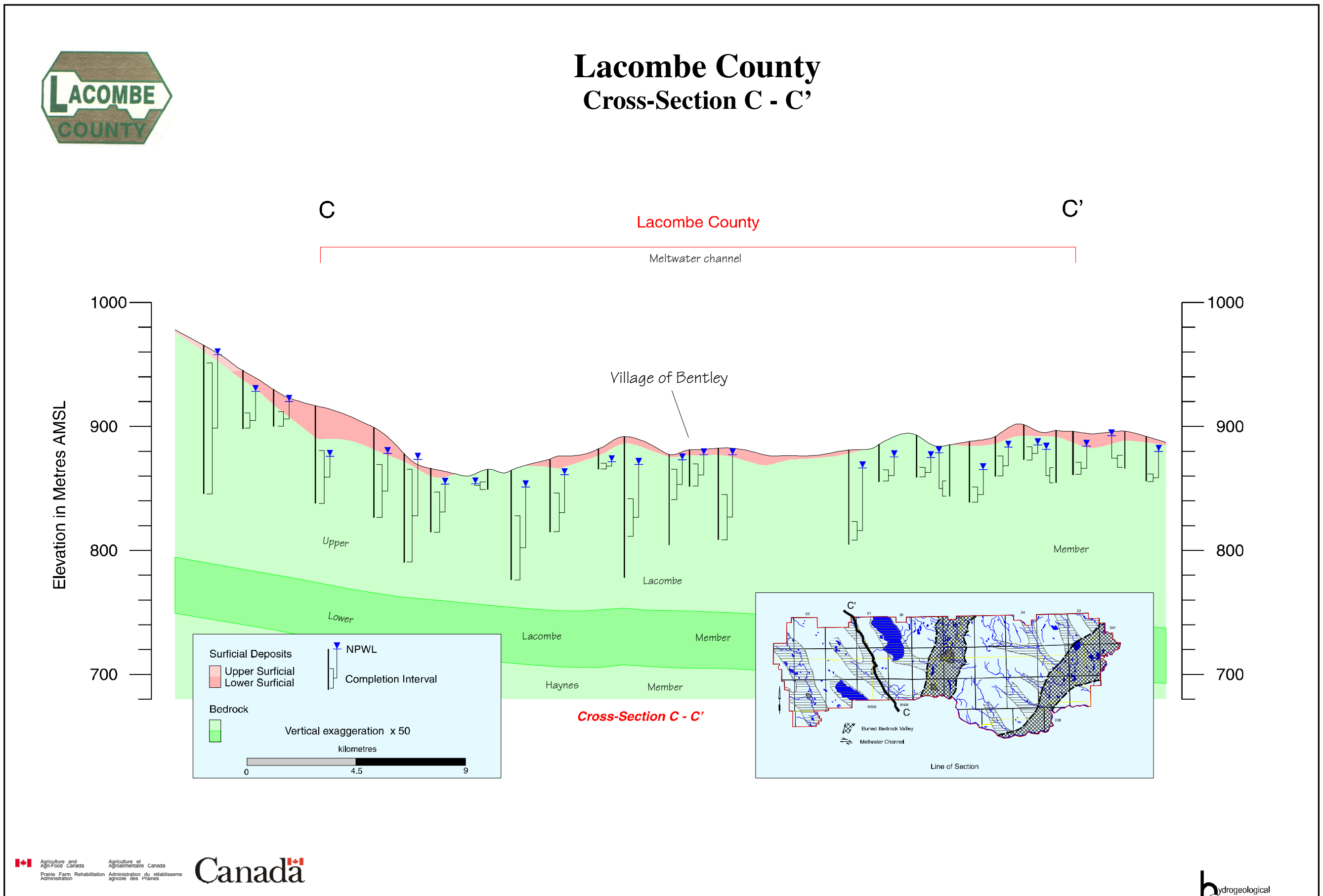


Canada

Cross-Section B - B’



Cross-Section C - C'



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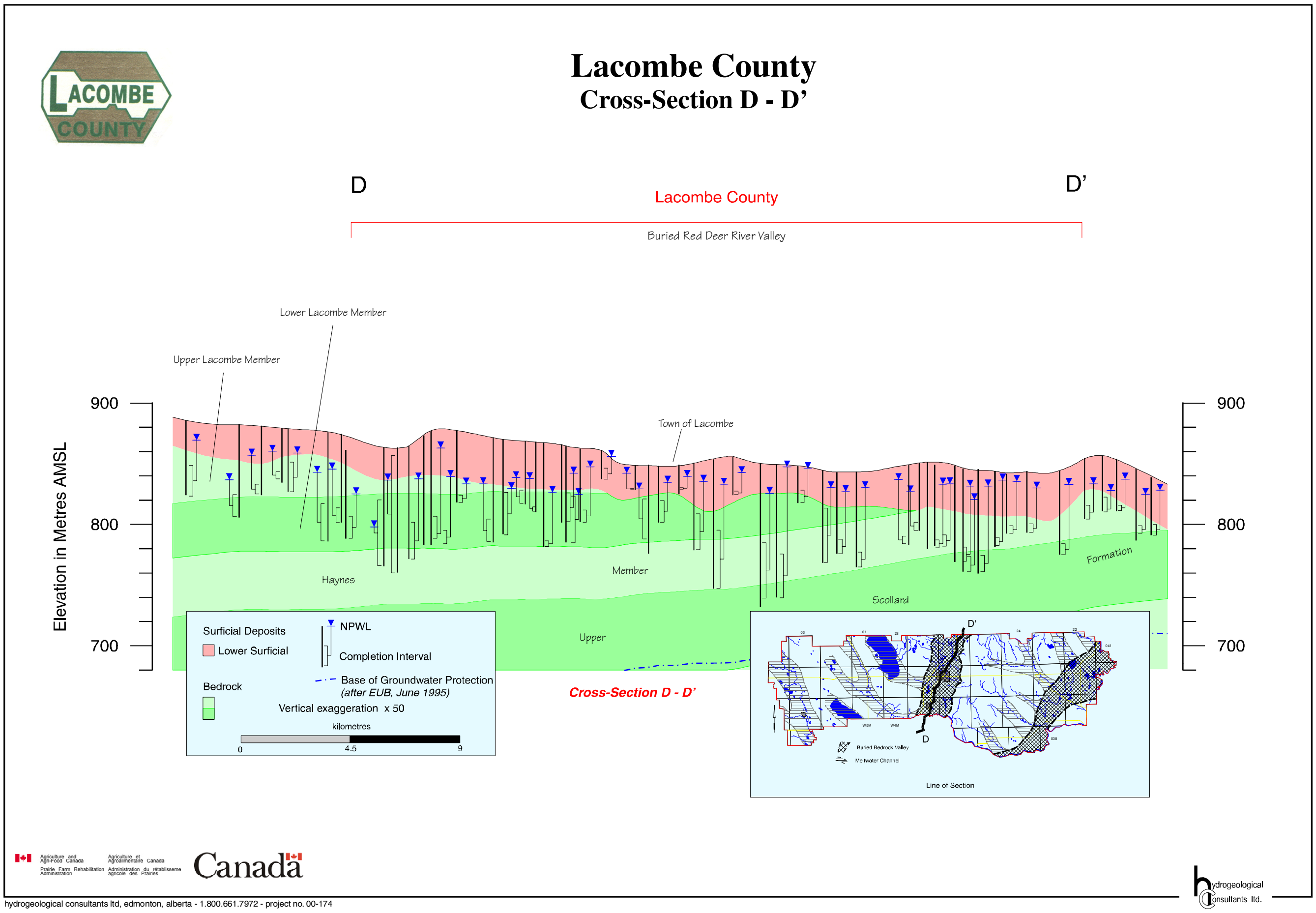
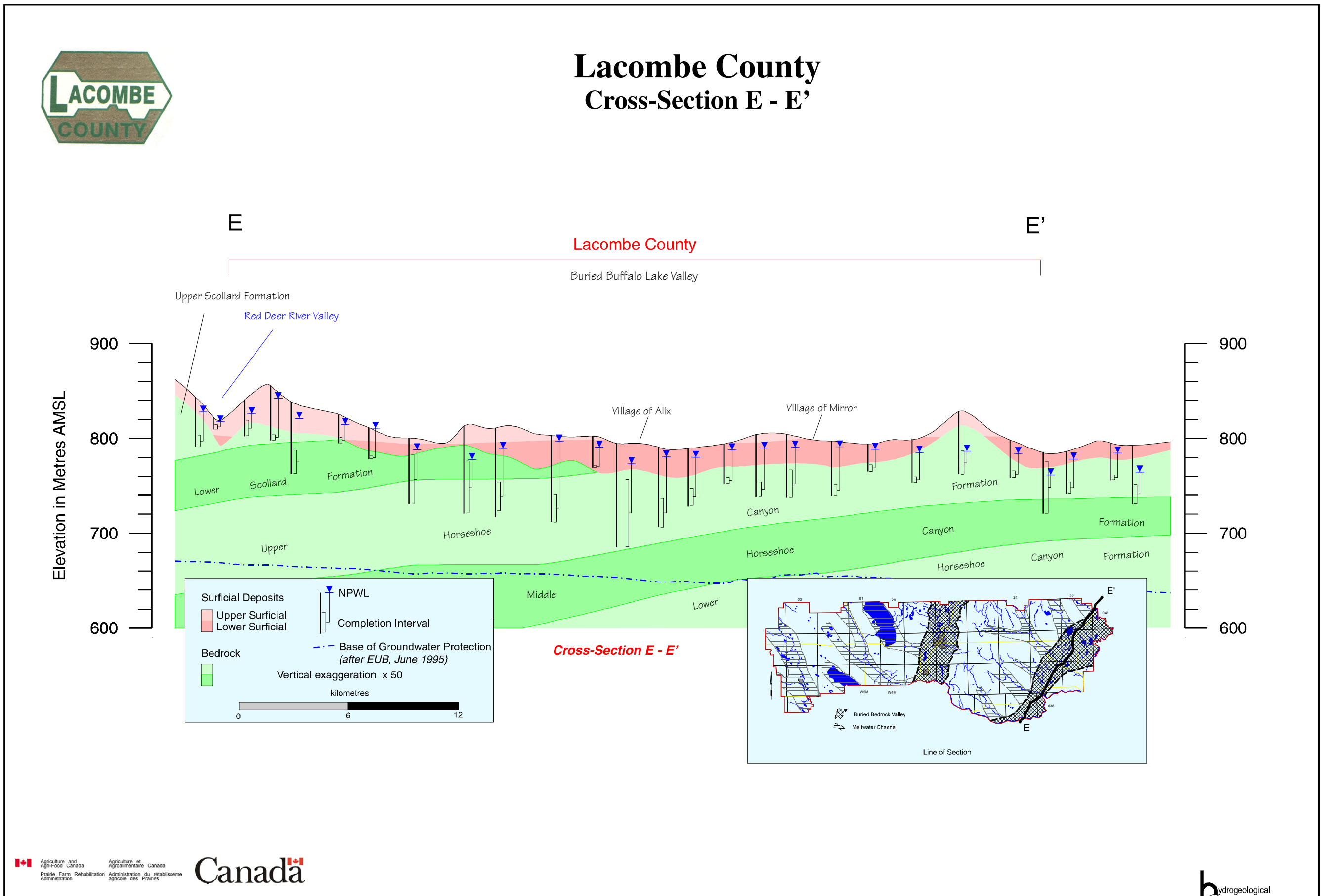
Cross-Section D - D’



Cross-Section E - E'



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LACOMBE COUNTY

Appendix E

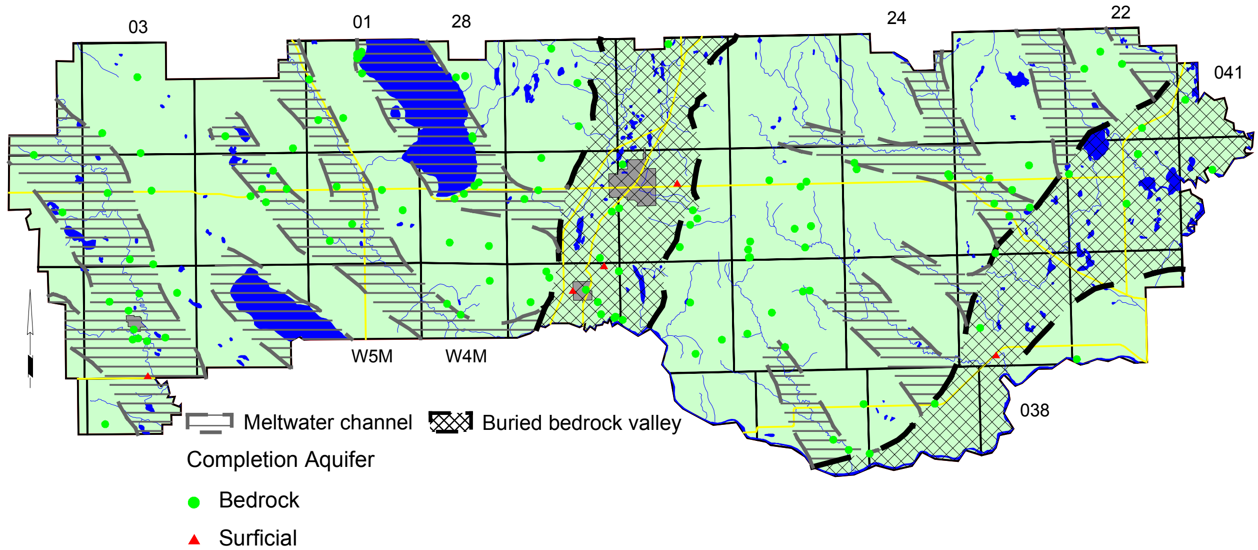
Water Wells Recommended for Field Verification

and

County-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 Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Alberta Government Services	13-18-040-26 W4M	Lower Lacombe	26-Sep-88	24.4	80.1	9.4	30.8	M36076.566626
Anderson, Sven R.	NW 10-039-03 W5M	Dalehurst	22-Jun-81	27.4	90.0	10.7	35.0	M35379.037104
Beamish, L.	12-15-040-22 W4M	Upper Horseshoe Canyon	21-Mar-80	56.1	184.0	9.5	31.0	M35377.074151
Bentley Farm Supplies Ltd.	NE 22-040-01 W5M	Upper Lacombe	18-Jul-80	25.9	85.0	7.6	25.0	M35379.031790
Berge, D.A.	NW 26-039-27 W4M	Lower Lacombe	01-Aug-73	57.9	190.0	42.7	140.0	M35377.066073
Botting, Gary	SW 17-039-23 W4M	Lower Scollard	21-Oct-77	36.6	120.0	14.3	47.0	M35377.080440
Brannen, Bill	08-23-039-27 W4M	Lower Lacombe	30-Jun-83	54.9	180.0	26.2	86.0	M35377.066314
Brown, William	SW 04-040-23 W4M	Upper Scollard	08-Jul-78	64.0	210.0	36.6	120.0	M35377.068906
Buelow, Walter	NW 20-041-22 W4M	Upper Horseshoe Canyon	07-Mar-78	68.6	225.0	49.4	162.0	M35377.066694
Butcher, Garry	SE 26-040-02 W5M	Upper Lacombe	10-Jun-77	36.6	120.0	30.5	100.0	M35379.037908
Cameron, R.C.	SE 09-039-25 W4M	Lower Lacombe	12-Jul-75	36.6	120.0	10.4	34.0	M35377.079020
Carlyle, Don	SE 34-040-22 W4M	Upper Horseshoe Canyon	26-Jul-69	27.4	90.0	7.3	24.0	M35377.074289
Carlyle, Don	SE 34-040-22 W4M	Upper Horseshoe Canyon	20-Aug-70	21.3	70.0	1.2	4.0	M35377.074290
Carlyle, Don	SE 34-040-22 W4M	Upper Horseshoe Canyon	30-Apr-74	24.4	80.0	2.7	9.0	M35377.081428
Carroll, Bill	08-28-041-01 W5M	Upper Lacombe	20-Jun-77	27.4	90.0	6.7	22.0	M35379.030586
Central Alberta Florists Ltd.	NW 36-039-27 W4M	Surficial	29-Aug-69	39.6	130.0	30.8	101.0	M35377.066462
Chessor, D.	SW 21-039-25 W4M	Upper Lacombe	07-Jul-76	22.9	75.0	7.0	23.0	M35377.080470
Chitwood, Doug	SW 27-041-22 W4M	Lower Scollard	19-Jun-85	27.4	90.0	10.7	35.0	M35377.066732
Copland, H.	NW 02-041-22 W4M	Upper Horseshoe Canyon	22-Mar-79	45.7	150.0	14.3	47.0	M35377.066632
Deer Valley Meadows Camp	SW 06-039-22 W4M	Lower Scollard	22-May-85	15.2	50.0	3.7	12.0	M35377.069200
Dell, Elmer	03-03-039-03 W5M	Surficial		2.7	9.0	0.6	2.0	M35379.037021
Duckworth, T.	SW 33-039-27 W4M	Upper Lacombe	02-May-67	18.3	60.0	3.1	10.0	M35377.080856
Eclipse Pork Ltd.	SW 26-039-25 W4M	Lower Lacombe	25-Feb-98	18.3	60.0	11.9	38.9	M36480.615337
Ellsworth, H.O.	13-13-040-01 W5M	Upper Lacombe	15-May-74	36.6	120.0	24.4	80.0	M35379.031362
Engel, Egon	SE 16-039-03 W5M	Dalehurst	21-Aug-80	18.6	61.0	2.4	8.0	M35379.037178
Evans, R.	NE 36-039-27 W4M	Lower Lacombe		54.9	180.0	24.7	81.0	M35377.066468
Evans, R.	NE 36-039-27 W4M	Lower Lacombe	10-Aug-79	54.9	180.0	31.4	103.0	M35377.066470
F.E.M. Farms Ltd.	NW 12-039-26 W4M	Upper Lacombe	27-Aug-74	30.5	100.0	16.8	55.0	M35377.080729
Fjallman, E.	NW 20-039-27 W4M	Upper Lacombe	26-May-81	59.4	195.0	12.8	42.0	M35377.087338
Fluit, H.	SE 27-039-25 W4M	Lower Lacombe	23-Oct-80	33.5	110.0	6.1	20.0	M35377.194027
Freeman, Don	13-19-041-01 W5M	Upper Lacombe	06-Aug-83	10.7	35.0	6.4	21.0	M35379.030565
Freeman, T. Dev	SW 31-040-26 W4M	Upper Scollard	06-Sep-78	112.8	370.0	30.5	100.0	M35377.068543
Fretwell, Ralph	NW 11-040-25 W4M	Lower Lacombe	17-Oct-73	36.6	120.0	20.7	68.0	M35377.067966
Fretwell, Ralph	NW 11-040-25 W4M	Lower Lacombe	11-Jun-85	15.9	52.0	15.9	52.0	M35377.067968
Friesen, I.	11-10-040-25 W4M	Lower Lacombe	31-Mar-73	36.6	120.0	21.9	72.0	M35377.067959
Gabert, Ray	SE 18-039-25 W4M	Upper Lacombe	05-Nov-77	30.5	100.0	4.3	14.0	M35377.080521
Geddert, Dave	NE 07-041-01 W5M	Upper Lacombe	23-Sep-80	17.7	58.0	9.8	32.0	M35379.030278
Geertsma, H.	NW 16-040-23 W4M	Lower Scollard	09-Jul-82	39.6	130.0	0.6	2.0	M35377.069186
Gilliard, Tim	NE 27-040-23 W4M	Upper Scollard	02-Aug-78	48.8	160.0	34.6	113.4	M35377.069515
Graupner, Jim	SE 33-041-01 W5M	Upper Lacombe	04-Aug-78	27.4	90.0	5.8	19.0	M35379.031079
Gull Lake Baptist Camp	NW 02-041-28 W4M	Upper Lacombe	20-Jul-84	36.6	120.0	7.6	25.0	M35377.068944
Gustavson, G.	03-29-039-03 W5M	Dalehurst	30-Jun-67	31.1	102.0	13.4	44.0	M35379.037332
Gyori, Tom	NE 05-041-02 W5M	Dalehurst	26-Jul-77	36.6	120.0	10.7	35.0	M35379.031674
Hahn, Art	01-09-040-28 W4M	Upper Lacombe	09-Apr-78	33.5	110.0	17.4	57.0	M35377.067713

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Halberg, Leonard	SW 27-041-28 W4M	Upper Lacombe	25-Sep-78	17.4	57.0	3.1	10.0	M35377.069305
Halberg, Victor	SE 27-041-28 W4M	Upper Lacombe	26-Sep-78	36.6	120.0	26.2	86.0	M35377.069300
Harink, Henry	SE 10-039-26 W4M	Haynes	28-May-86	134.1	440.0	94.3	309.4	M35377.053799
Hausen, Allan	04-18-041-21 W4M	Upper Horseshoe Canyon	15-Apr-79	36.6	120.0	7.7	25.4	M35377.163151
Henderson Cattle Co	SW 27-040-26 W4M	Surficial	2-Mar-79	61.0	200.0	52.4	172.0	M35377.068322
Henderson, Ron	NE 22-039-26 W4M	Upper Lacombe	20-Sep-77	39.6	130.0	19.2	63.0	M35377.080732
Hill, Glen	SE 33-041-01 W5M	Upper Lacombe	1-Aug-81	15.2	50.0	7.6	25.0	M35379.031160
Hodenfield, J.	NE 29-041-22 W4M	Upper Scollard	25-Apr-79	36.6	120.0	19.8	65.0	M35377.066740
Hoffman, R.	SE 25-040-24 W4M	Upper Scollard	1-Nov-73	30.5	100.0	0.0	0.1	M35377.067407
Hornet, Ed	SE 16-040-23 W4M	Lower Scollard	26-Aug-75	54.9	180.0	20.7	68.0	M35377.069159
Hughes, Don	NW 01-040-28 W4M	Upper Lacombe	17-Oct-79	32.0	105.0	7.6	25.0	M35377.067475
Huss, Ernest R.	SE 06-040-25 W4M	Upper Lacombe	17-Nov-74	30.5	100.0	18.3	60.0	M35377.067409
Huss, Keith	NE 10-040-26 W4M	Upper Lacombe	20-Sep-78	30.5	100.0	6.4	21.0	M35377.067940
Huss, W.F.	01-06-040-25 W4M	Upper Lacombe	25-Mar-70	36.6	120.0	24.7	81.0	M35377.067406
Ilchuk, Ken	SW 28-040-25 W4M	Upper Lacombe	2-Dec-79	30.5	100.0	15.5	51.0	M35377.081681
James, Bert	NE 15-040-26 W4M	Upper Lacombe	15-Jun-77	32.0	105.0	3.1	10.0	M35377.068125
Johnson, A.L.	NE 22-041-27 W4M	Upper Lacombe	11-Mar-77	30.5	100.0	14.0	46.0	M35377.069044
Kerr, Doug	NW 02-041-28 W4M	Upper Lacombe	28-Oct-80	39.0	128.0	11.3	37.0	M35377.068936
Kieboom, Albert	NW 27-039-27 W4M	Surficial	6-May-80	16.8	55.0	12.5	41.0	M35377.066081
Kilpatrick, Ronald B.	SW 26-040-28 W4M	Upper Lacombe	21-Oct-81	34.1	112.0	3.7	12.0	M35377.081710
Kinna, Robert	SW 04-040-03 W5M	Dalehurst	19-Jul-73	27.1	89.0	7.3	24.0	M35379.031421
Knutson, Cliff	SW 35-040-02 W5M	Upper Lacombe	25-Nov-82	55.5	182.0	22.9	75.0	M35379.038879
Kriese, A.E.	NE 13-040-27 W4M	Lower Lacombe	25-Aug-83	64.0	210.0	14.6	48.0	M35377.081699
Kuipers, Hank	NE 20-040-27 W4M	Upper Lacombe	23-Oct-79	46.9	154.0	24.1	79.0	M35377.081705
Land, Herbert	SE 28-041-03 W5M	Dalehurst	18-Mar-66	21.6	71.0	11.3	37.0	M35379.039633
Larkin Bros	NE 05-039-23 W4M	Surficial	17-Oct-67	27.1	89.0	9.1	30.0	M35377.078674
Lawton Bros.	SW 03-041-04 W5M	Dalehurst	4-Aug-78	18.3	60.0	6.1	20.0	M35379.039414
Lenz Farms	SW 16-040-01 W5M	Upper Lacombe	13-Sep-73	30.5	100.0	9.8	32.0	M35379.031398
Livam, August	NE 14-040-04 W5M	Dalehurst	15-Sep-83	34.1	112.0	21.3	70.0	M35379.032505
Low, Don	12-33-039-27 W4M	Upper Lacombe	13-May-81	38.1	125.0	9.1	30.0	M35377.066425
Maddox, Bill	SW 08-041-03 W5M	Dalehurst	9-Apr-66	16.8	55.0	7.9	26.0	M35379.039124
Martin, Jim	SW 14-038-25 W4M	Haynes	11-Oct-84	32.0	105.0	19.8	65.0	M35377.079593
Mcauley, Terrence	SW 07-038-24 W4M	Haynes	15-May-74	42.7	140.0	33.2	109.0	M35377.053152
Mccullough, Ray	NE 32-040-27 W4M	Upper Lacombe	5-Nov-81	24.4	80.0	7.6	25.0	M35377.069073
McDonald, Adaire	SW 14-039-03 W5M	Dalehurst	16-Oct-79	24.4	80.0	2.4	8.0	M35379.037154
McNary, D.	SE 19-040-27 W4M	Upper Lacombe	24-Sep-76	53.3	175.0	32.0	105.0	M35377.081703
McTavish, D.A.	SE 26-040-28 W4M	Upper Lacombe	16-Sep-75	41.5	136.0	11.3	37.0	M35377.081724
Medin, H. & D.	NE 19-038-03 W5M	Dalehurst	20-Jul-76	16.8	55.0	9.1	30.0	M35379.036847
Meston, Calvin	SW 22-040-23 W4M	Lower Scollard	21-Feb-86	18.3	60.0	4.6	15.0	M35377.069256
Meullerm, Armin	02-27-040-02 W5M	Upper Lacombe	9-Oct-81	33.5	110.0	8.2	27.0	M35379.038390
Meyers, L.	09-28-039-03 W5M	Dalehurst	30-May-63	25.0	82.0	12.2	40.0	M35379.037328
Nabess, K	NE 23-039-27 W4M	Lower Lacombe	28-Jul-79	67.1	220.0	22.9	75.0	M35377.069333
NEWALTA Corporation	11-21-039-03 W5M	Dalehurst	26-Oct-85	36.0	118.1	19.2	63.0	M36076.564466
Oppermann, Al.	02-33-041-01 W5M	Upper Lacombe	11-Aug-81	32.0	105.0	10.1	33.0	M35379.031151
Orange, J.	NE 30-040-24 W4M	Haynes	2-Nov-74	29.0	95.0	10.7	35.0	M35377.067552
Pacific Petroleum Ltd.	02-27-040-03 W5M	Dalehurst	15-Jun-79	38.7	127.0	25.6	84.0	M35379.037727

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Parlby, H.	SE 15-040-23 W4M	Lower Scollard	24-Jul-68	22.9	75.0	4.0	13.0	M35377.069156
Pearson, Glen	NE 21-040-02 W5M	Dalehurst	5-Jun-63	79.2	260.0	61.0	200.0	M35379.037757
Perlick, J.	SE 24-039-27 W4M	Lower Lacombe	2-Jan-78	54.9	180.0	30.5	100.0	M35377.066331
Pluister, Hank	SW 36-039-28 W4M	Upper Lacombe	28-Mar-80	45.7	150.0	29.6	97.0	M35377.066624
Polson, Esker	SW 26-040-25 W4M	Lower Lacombe	24-Sep-80	27.4	90.0	6.7	22.0	M35377.068536
Porkka, Roy	NE 22-040-28 W4M	Upper Lacombe	19-Jul-78	29.9	98.0	5.8	19.0	M35377.067946
Proudfoot, J.	NE 33-041-26 W4M	Haynes	15-Oct-76	64.0	210.0	12.2	40.0	M35377.082334
Pulst, S. F.	SW 14-040-26 W4M	Upper Lacombe	1-Jan-58	25.0	82.0	4.3	14.0	M35377.081600
R. Rainforth & Sons Ltd	NE 03-040-25 W4M	Lower Lacombe	12-Nov-76	27.4	90.0	15.2	50.0	M35377.081675
Raymond, Dave	SW 01-041-02 W5M	Upper Lacombe	4-Aug-80	73.2	240.0	61.6	202.0	M35379.031322
Ree, Paul	02-29-040-01 W5M	Upper Lacombe	17-Aug-77	36.6	120.0	11.1	36.5	M35379.039258
Riebel, G	SE 29-040-21 W4M	Upper Horseshoe Canyon	27-Jul-77	32.0	105.0	8.2	27.0	M35377.061010
Robinson, Marvin	SE 25-038-25 W4M	Haynes	22-Oct-75	68.6	225.0	51.8	170.0	M35377.053328
Salomons, John	NW 03-040-26 W4M	Upper Lacombe	30-Nov-78	18.3	60.0	6.1	20.0	M35377.067865
Sanche, J.	SE 33-041-01 W5M	Upper Lacombe	9-May-77	27.4	90.0	4.9	16.0	M35379.030848
Sandquist, Don	08-02-040-27 W4M	Lower Lacombe	1-Oct-84	83.8	275.0	39.6	130.0	M35377.067449
Sather, Alan	NE 06-040-25 W4M	Upper Lacombe	4-Nov-80	13.7	45.0	6.4	21.0	M35377.067427
Schmidt, Alex	SE 33-041-01 W5M	Upper Lacombe	16-May-79	32.0	105.0	5.9	19.5	M35379.031081
Schmidt, Don	SE 25-040-24 W4M	Lower Scollard	5-Nov-77	61.0	200.0	21.9	72.0	M35377.067416
Schmidt, Don	SE 25-040-24 W4M	Upper Scollard	13-Apr-74	30.5	100.0	2.1	7.0	M35377.081503
Scott, Garth	NE 08-041-01 W5M	Upper Lacombe	12-Dec-84	24.4	80.0	5.2	17.0	M35379.030284
Shultz, A.	09-26-039-03 W5M	Dalehurst	1-Jan-63	24.4	80.0	13.1	43.0	M35379.037309
Skjonsberg, Len	14-20-040-03 W5M	Dalehurst	6-Oct-66	24.4	80.0	4.1	13.5	M35379.037594
Smith, Dale	SE 03-040-03 W5M	Dalehurst	18-Jul-86	38.1	125.0	24.4	80.0	M35379.031411
Smith, Ed	SE 33-041-01 W5M	Upper Lacombe	1-May-81	18.3	60.0	3.7	12.0	M35379.031108
Smith, G.	SE 31-040-24 W4M	Haynes	4-Dec-76	27.4	90.0	11.6	38.0	M35377.067591
Smith, John	SE 22-040-02 W5M	Upper Lacombe	12-Sep-78	42.7	140.0	27.3	89.6	M35379.037759
Sorpold, Pete	NE 21-039-28 W4M	Upper Lacombe	30-Sep-74	48.8	160.0	22.9	75.0	M35377.066566
Speer, V.	NW 18-039-26 W4M	Lower Lacombe	28-Sep-79	48.8	160.0	28.4	93.0	M35377.053837
Sturgeon, J.	SW 30-040-22 W4M	Upper Horseshoe Canyon	1-Oct-72	41.2	135.0	15.2	50.0	M35377.074264
Surkan, John	NE 11-038-25 W4M	Upper Scollard	13-Jul-81	53.3	175.0	33.5	110.0	M35377.053269
Talsma, Doug	10-33-041-27 W4M	Upper Lacombe	17-Oct-81	27.4	90.0	2.1	7.0	M35377.069284
Terris, Morley	01-16-039-03 W5M	Upper Lacombe	3-Jul-69	30.5	100.0	22.9	75.0	M35379.037177
Thevenaz, M. A.	04-08-040-01 W5M	Upper Lacombe	26-Nov-68	26.8	88.0	4.0	13.0	M35379.031285
Thomas, Tom	SW 03-041-03 W5M	Dalehurst	11-Jul-73	30.5	100.0	10.7	35.0	M35379.038692
Touchette, Leo	SE 27-038-24 W4M	Upper Scollard	11-Oct-79	73.2	240.0	54.9	180.0	M35377.053194
Turnbull, Ian	SE 10-041-27 W4M	Upper Lacombe	23-Jun-77	27.4	90.0	10.7	35.0	M35377.068664
Turney, G.	SE 29-040-23 W4M	Upper Horseshoe Canyon	31-Jul-78	67.1	220.0	7.6	25.0	M35377.069803
Vallet, Clayton	16-06-040-25 W4M	Upper Lacombe	11-Jul-78	42.7	140.0	30.5	100.0	M35377.067421
Wagner, Terry	NE 22-040-25 W4M	Upper Lacombe	5-Aug-79	24.4	80.0	7.3	24.0	M35377.068455
Wessner, Marcel & Gloria	SE 24-039-27 W4M	Lower Lacombe	3-Aug-84	54.9	180.0	30.4	99.8	M35377.066336
Wigmore, Art	06-22-039-28 W4M	Upper Lacombe	26-Oct-64	69.5	228.0	43.6	143.0	M35377.066570
Williams, Don	WH 22-040-28 W4M	Upper Lacombe	10-May-82	27.7	91.0	1.2	4.0	M35377.067805
Wilson, Ed	10-16-039-03 W5M	Dalehurst	12-Dec-75	32.0	105.0	19.8	65.0	M35379.037200
Yakunin, Marilee	NW 02-041-28 W4M	Upper Lacombe	4-Aug-87	31.7	104.0	6.7	22.0	M35377.081962

LACOMBE COUNTY-OPERATED WATER WELLS

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
County of Lacombe	NE 09-039-25 W4M	Lower Lacombe	20-Aug-76	27.4	90.0	7.9	26.0	M35377.079042
County of Lacombe	SE 36-040-01 W5M	Upper Lacombe	29-May-80	32.0	105.0	9.5	31.0	M35379.041582
County of Lacombe	NE 29-040-28 W4M	Upper Lacombe	01-Jul-71	32.0	105.0	11.3	37.0	M35377.062607