Wheatland County

Part of the South Saskatchewan River Basin
Tp 021 to 028, R 17 to 26, W4M
Regional Groundwater Assessment

Prepared for Wheatland County

In conjunction with

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration
Administration du rétablissement agricole des Prairies

Canada

Western Irrigation District

Prepared by
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HYDROGEOLOGICAL CONSULTANTS LTD.

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Acknowledgements

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Mr. Terry Dash – AAFC-PFRA

Mr. Glen Brandt and Mr. Bill Franz – AAFC-PFRA

Mr. James Laslo – Wheatland County

1. Project Overview

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

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

1.1 Purpose

This project is a regional groundwater assessment of Wheatland County prepared by Hydrogeological Consultants Ltd. (HCL) with financial and technical assistance from the Prairie Farm Rehabilitation Administration branch of Agriculture and Agri-Food Canada (AAFC-PFRA), Wheatland County and the Western Irrigation District. 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 used in the regional groundwater assessment for Wheatland County.

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1 See glossary
2 See glossary

1.2 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 Familiarization 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.

1.3 About This Report

This report provides an overview of (a) the groundwater resources of Wheatland 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 files and ArcExplorer files. Likewise, all of the illustrations and maps shown in this 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. A plastic County map outline is provided to overlay the maps, and contains information such as towns, main rivers, etc.

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) interpretation of chemical analysis of drinking water
4) additional information.

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

2. Introduction

2.1 Setting

Wheatland County is situated in south-central Alberta. Most of this area is part of the western Alberta Plains region. The County is within the South Saskatchewan River basin; the Bow River forms the southern boundary along with a portion of the Siksika First Nation lands, and the Red Deer River forms the northeastern boundary. The other County boundaries are as shown on the adjacent index map.

Regionally, the topographic surface varies between 650 and 1,075 metres above mean sea level (AMSL). The lowest elevations occur mainly in the northeastern part of the County and the highest are in the southwestern parts of the County as shown on Figure 1 and page A-3. The area is well drained by numerous streams, including Crowfoot Creek, Parflesh Creek, Serviceberry Creek, and the Rosebud River, with the main ones being the Bow and Red Deer rivers.

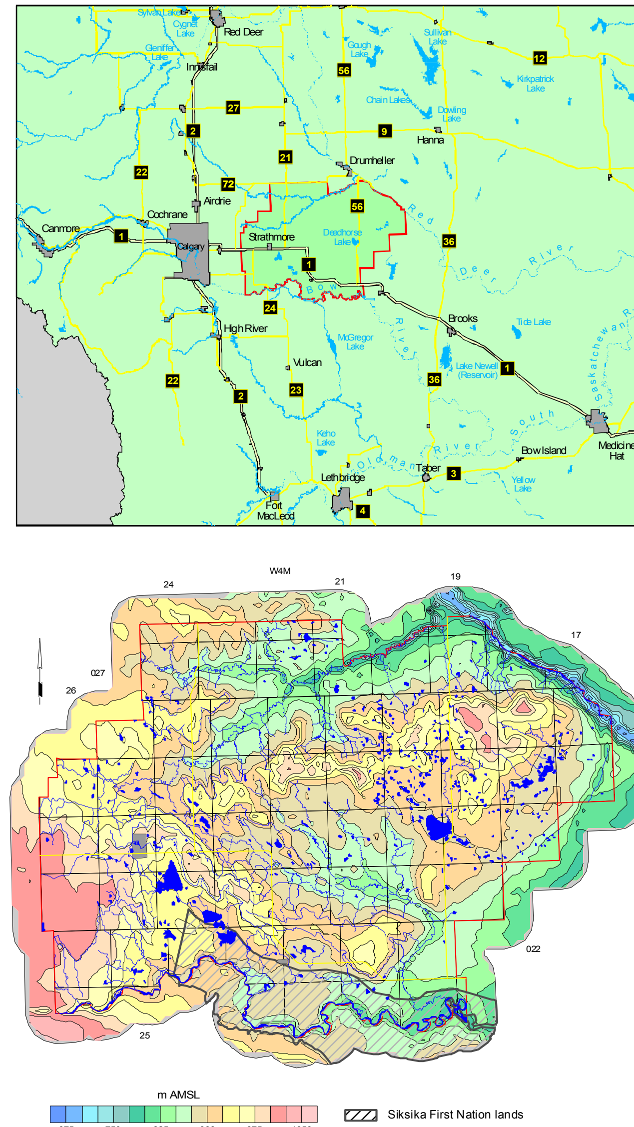

Figure 1. Index Map

2.2 Climate

Wheatland County lies within the transition zone between a humid, continental Dfb climate and a semiarid Bsk climate. 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 Leggat, 1981) shows that the County is located in the Mixed Grass region, a transition between Aspen Parkland and Dry Mixed Grass regions.

A Dfb climate consists of long, cool summers, severe winters and no dry season. The mean monthly temperature drops below -3° C in the coolest month, and exceeds 10° C in the warmest month. A Bsk climate is characterized by its moisture deficiency, where mean annual potential evapotranspiration exceeds the mean annual precipitation.

The mean annual precipitation averaged from three meteorological stations within the area measured 366 millimetres (mm), based on data from 1961 to 1993. The mean annual temperature averaged 3.9° C, with the mean monthly temperature reaching a high of 17.4° C in July, and dropping to a low of -11.1° C in January. The calculated annual potential evapotranspiration is 524 millimetres.

4 See glossary

2.3 Background Information

2.3.1 Number, Type and Depth of Water Wells

There are currently records for 4,188 water wells in the groundwater database for the County, of which 463 are within the Siksika First Nation lands. Of the 4,188 water wells, 3,566 are for domestic/stock purposes. The remaining 622 water wells were completed for a variety of uses, including municipal, observation, industrial, irrigation, investigation and dewatering. Based on a rural population of 7,240 (Phinney, 2001-2002), there are two domestic/stock water wells per family of four. There are 3,366 domestic or stock water wells with a completed depth, of which 2,645 (79%) are completed at depths of less than 60 metres below ground surface. Water wells in the eastern half of the County mainly have completion depths of less than 60 metres. Details for lithology[5] are available for 2,567 water wells.

2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 2,007 water well records with completion interval and lithologic information, such that the aquifer in which the water wells are completed can be identified. 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 2,007 water wells for which aquifers could be defined, 241 are completed in surficial aquifers, with 185 (77%) having a completion depth of less than 50 metres below ground surface. The adjacent map shows that the water wells completed in the surficial deposits occur mainly along the Bow River, and in linear bedrock lows.

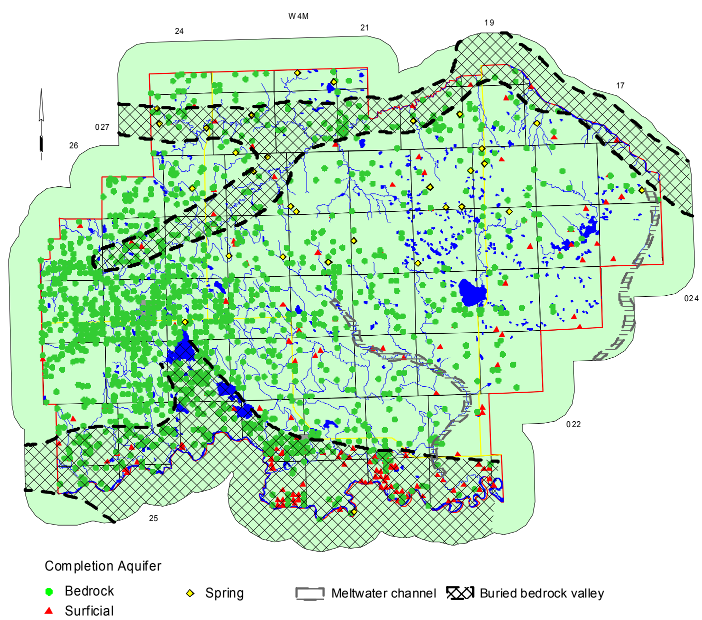

Figure 2. Location of Water Wells and Springs

The data for 1,766 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. From Figure 2 (also page A-4), it can be seen that most of the water wells completed in bedrock aquifers occur in the western part of the County. Within the County, casing-diameter information is available for 1,747 of the 1,766 water wells completed below the top of bedrock. These 1,747 bedrock water wells 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 38 bedrock water wells completed with a water well screen.

There are currently records for 33 springs in the groundwater database, including 11 springs that were documented by Borneuf (1983). There are 26 springs having at least one total dissolved solids (TDS) value, with a range from 313 to 2,618 milligrams per litre (mg/L); two of the 26 springs have TDS concentrations of less than 500 mg/L. Of the 30 available total hardness values, 21 have total hardness concentrations of more than 100 mg/L. The only available flow rate for a spring within the County is 68 litres per minute (lpm) measured in June 1969 for a spring in NE 08-024-24 W4M.

[5] See glossary

2.3.3 Casing Diameter and Type

Data for casing diameters are available for 2,578 water wells, with only two indicated as 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.

In the County, steel, galvanized steel and plastic surface casing materials have been used in 99.9% of the drilled water wells over the last 40 years. The remaining 0.1% was for two water wells completed with concrete-type surface casing in the 1960s. Until the mid-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 76% of the water wells being drilled in the County. Galvanized steel and plastic surface casing (PVC) have been used in less than 6% of the new water wells; galvanized steel was last used in April 1994 for the completion of a drilled water well.

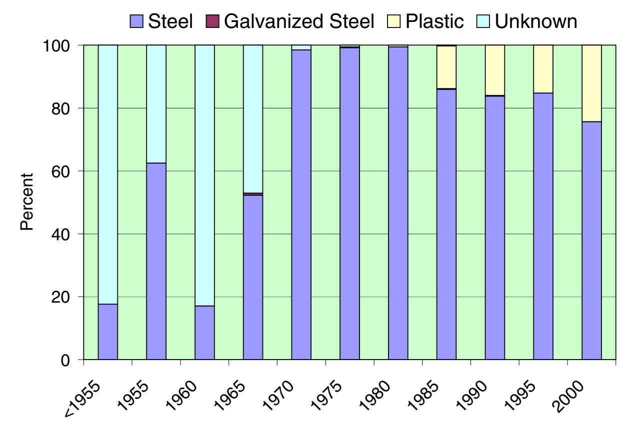

Figure 3. Surface Casing Types Used in Drilled Water Wells

Steel casing has been dominant in the County probably because it has resisted corrosion and also because water well drillers may be reluctant to use PVC if there have been no documented problems with steel casing in the area.

2.3.4 Dry Water Test Holes

In the County, there are 4,910 records in the groundwater database. Of these 4,910 records, 71 are indicated as being dry or abandoned with “insufficient water”. Also included in these dry test holes is any record that includes comments that state the water well goes dry in dry years. The 71 “dry” test hole records are located throughout the County.

2.3.5 Requirements for Licensing

Water wells used for household needs and all other groundwater use must be licensed if the use is in excess of 3.4 cubic metres per day (1,250 cubic metres per year) (750 imperial gallons per day[6]). The only groundwater users that do not need licensing are (1) household use of up to 1,250 m³/year and (2) groundwater with total dissolved solids in excess of 4,000 mg/L. In the last update from the Alberta Environment (AENV) groundwater database in September 2001, 202 groundwater allocations were shown to be within the County, with the most recent groundwater user being licensed in June 2000. Of the 202 licensed groundwater users, 136 (**which is 67% of all licensed water wells in the County**) could be linked to the AENV groundwater database. Of the 202 licensed groundwater users, 149 are for agricultural purposes, 25 are for municipal purposes, 18 are for exploration purposes (specifically cooperative and stock), seven are for commercial purposes, and the remaining three are for recreation or irrigation purposes. The total maximum authorized diversion from the water wells associated with these licences is 5,880 cubic metres per day (m³/day), although actual use could be less. Of the 5,880 m³/day, 4,518 m³/day (76.8%) is authorized for agricultural purposes, 584 (10%) is authorized for municipal purposes, 555 m³/day (9.4%) is authorized for exploration, and the remaining 223 m³/day (3.8%) is allotted for commercial, recreation or irrigation use, as shown in Table 1 on the following page. A figure showing the locations of the licensed users is in Appendix A (page A-6) and on the CD-ROM. Table 1 also shows a breakdown of the 202 licensed groundwater allocations by the aquifer in which the water well is completed. Approximately thirty-four percent of the total licensed groundwater allocations are in multiple bedrock completions (10.4%) and in unknown aquifers (24%). The aquifer name is unknown because there is no

[6] see conversion table on page 67

completion information available. Where an aquifer can be determined, the largest total licensed allocations are in the Upper Scollard Aquifer.

	No. of	Licensed Groundwater Users* (m³/day)							
Aquifer **	Diversions	Agricultural	Commerical	Municipal	Exploration	Irrigation	Recreation	Total	Percentage
Upper Sand and Gravel	9	129	0	10	0	0	0	139	2.4
Lower Sand and Gravel	14	150	0	277	0	0	3	430	7.3
Bedrock	22	538	0	51	0	0	24	613	10.4
Lower Lacombe	5	122	3	0	0	0	0	125	2.1
Haynes	24	759	120	4	0	0	0	883	15.0
Upper Scollard	29	900	63	3	0	0	0	966	16.4
Lower Scollard	15	728	0	0	0	0	0	728	12.4
Upper Horseshoe Canyon	17	184	0	84	0	0	0	268	4.6
Middle Horseshoe Canyon	15	73	0	74	0	0	0	147	2.5
Lower Horseshoe Canyon	8	139	0	37	0	0	0	176	3.0
Unknown	44	796	0	44	555	10	0	1,405	23.9
Total	202	4,518	186	584	555	10	27	5,880	100
Percentage		76.8	3.2	9.9	9.4	0.2	0.5	100	

* - data from AENV ** - Aquifer identified by HCL

Table 1. Licensed Groundwater Diversions

Based on the 2001 Agriculture Census (Statistics Canada), the calculated water requirement for 777,856 livestock for the County is in the order of 19,150 m³/day. This value includes intensive livestock use but not domestic animals. Of the 19,150 m³/day average calculated livestock use, AENV has licensed a groundwater diversion of 4,518 m³/day (24%) and licensed a surface-water diversion of 2,195 m³/day (11%). The remaining 65% of the calculated livestock use would have to be from unlicensed sources.

2.3.6 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 + nitrite (as N) concentrations were evident in 5% of the available chemical data for the surficial aquifers and 2% of the available chemical data for the upper bedrock aquifer(s); a plot of nitrate + 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 range from less than 500 to more than 2,000 mg/L (page A-30). Groundwaters from the bedrock aquifers frequently are chemically soft, with generally low concentrations of dissolved iron. The chemically soft groundwater is high in concentrations of sodium. More than 25% of the chemical analyses for bedrock water wells indicate a fluoride concentration above 1.5 mg/L, with most of the exceedances occurring in the western third of the County (see page A-31 and the CD-ROM).

The minimum, maximum and median[7] 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 Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) in Table 2. Of the five constituents compared to the SGCDWQ, median concentrations of TDS and sodium exceed the guidelines; maximum values of all five constituents exceed the guidelines.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	1,528	14	7,419	1,069	500
Sodium	975	0	2,333	350	200
Sulfate	1,503	0	5,180	285	500
Chloride	1,385	0	1,403	13	250
Fluoride	1,322	0	9.5	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)

SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
Federal-Provincial Subcommittee on Drinking Water, March 2001

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

7 see glossary

In general, Alberta Environment defines the Base of Groundwater Protection as the elevation below which the groundwater will have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, formation elevations, and Alberta Energy and Utilities Board (EUB) information indicating the formations containing the deepest useable water for agricultural needs, a value for the depth to the Base of Groundwater Protection can be determined. These values are gridded using the Kriging[8] 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 the Base of Groundwater Protection ranges from less than 125 metres at Eagle Lake southeast of Strathmore in the western part of the County, and in the Red Deer River Valley in the northeastern part of the County, to more than 500 metres below ground surface in the northeastern part of the County, as shown on Figure 4 and on some cross-sections presented in Appendix A and on the CD-ROM.

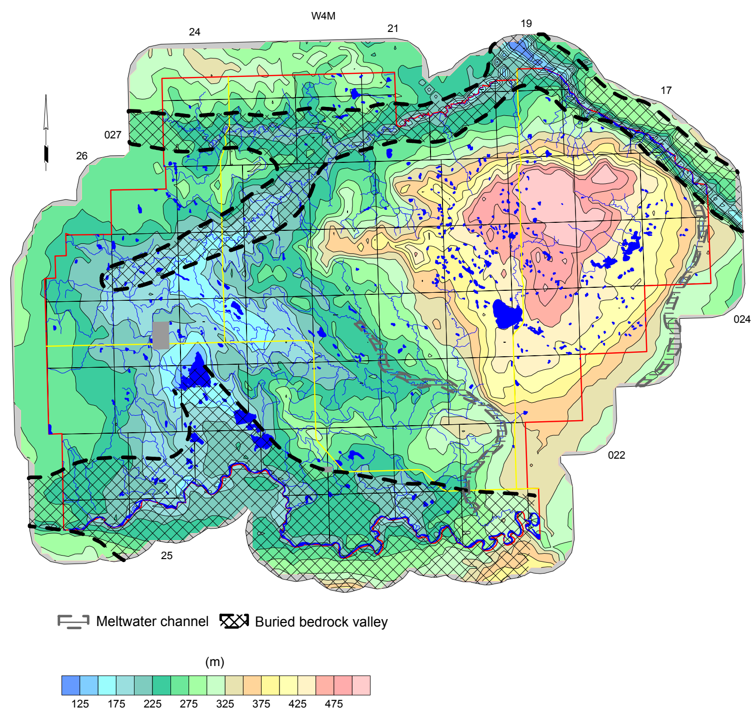

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

There are 3,918 water wells with completed depth data, of which none are completed below the Base of Groundwater Protection. In the County, the Base of Groundwater Protection is below the Upper Scollard Formation (see Figures A-11 to A-15).

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 three 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.

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, as has been the case in the Wildrose Country Ground Water Monitoring Association and Flagstaff County.

8 See glossary

3. Terms

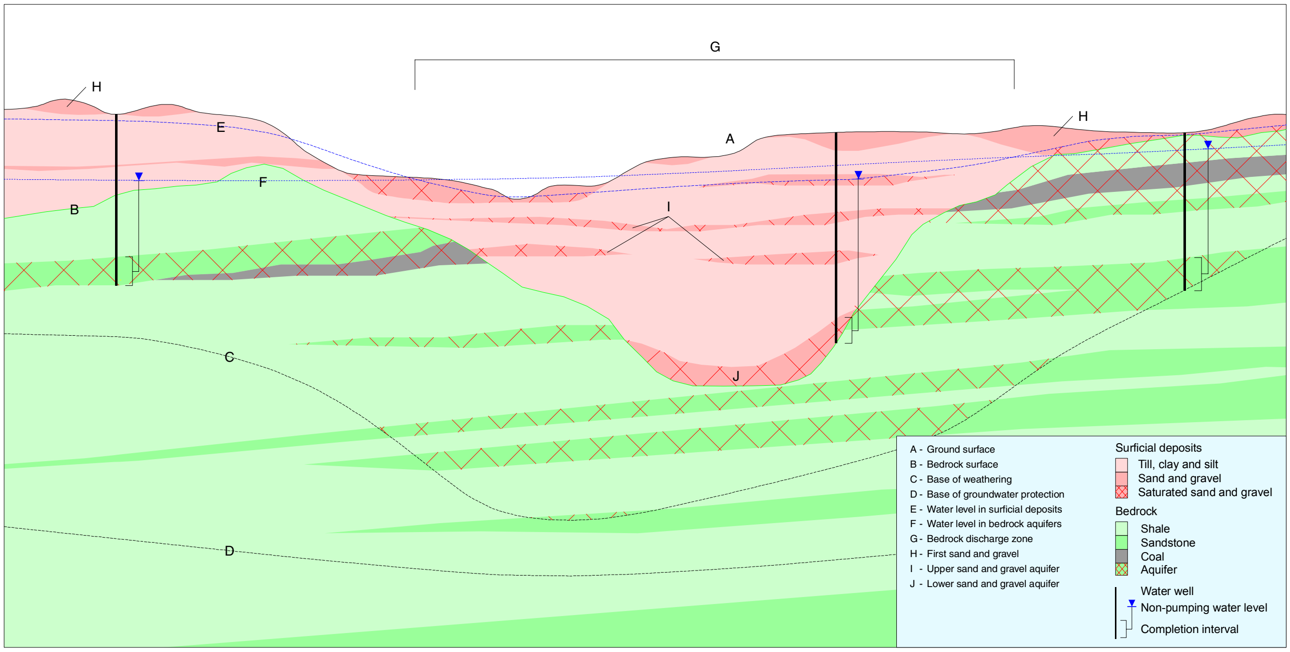

Figure 5. Generalized Cross-Section (for terminology only)

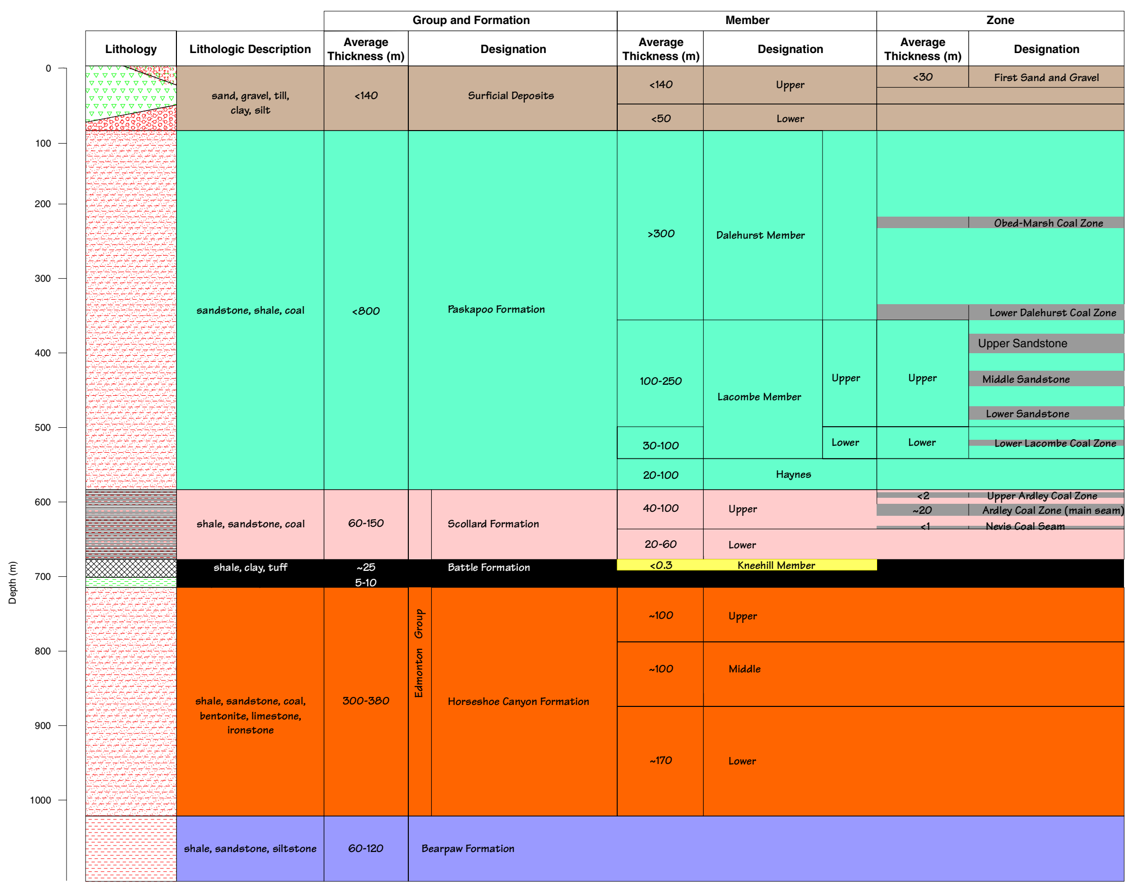

Figure 6. Geologic Column

4. Methodology

4.1 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) locations for some water wells determined during water well surveys
5) chemical analyses for some groundwaters[9]
6) location of some flowing shot holes
7) location of some structure test holes
8) a variety of data related to the groundwater resource.

The main disadvantage to the database is the reliability of the information entered into the database. 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 within the County have been removed from the database used in this regional groundwater assessment.

The AENV groundwater database uses an area-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 based on the NAD27 datum. This means that a record for the SE ¼ of section 10, township 025, range 24, W4M, would have a horizontal coordinate with an Easting of 121,342 metres and a Northing of 5,661,466 metres, the centre of the quarter section. If the water well has been repositioned by AAFC-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); AltaLIS Ltd. 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.

[9] 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.

Where possible, determinations are made from individual records in order to assign water wells to aquifers and to obtain values for the following:

1) depth to bedrock
2) total thickness of sand and gravel below 15 metres
3) total thickness of saturated sand and gravel
4) depth to the top and bottom of completion intervals[10].

Also, where sufficient information is available, values for apparent transmissivity[11] and apparent yield[12] 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 hydrogeological map covering at least a part of the County was published in 1974 (Ozoray and Lytviak, 1974), 1,535 values for apparent transmissivity and apparent yield have been added to the groundwater database. With the addition of the apparent yield values, including a 0.1-m³/day value assigned to "dry" water wells and water test holes, a hydrogeological map has been prepared to help illustrate the general groundwater availability across the County (Figure 7). The map is based on groundwater being obtained from all aquifers and has been prepared to allow direct comparison with the results provided on the Alberta Research Council hydrogeological maps.

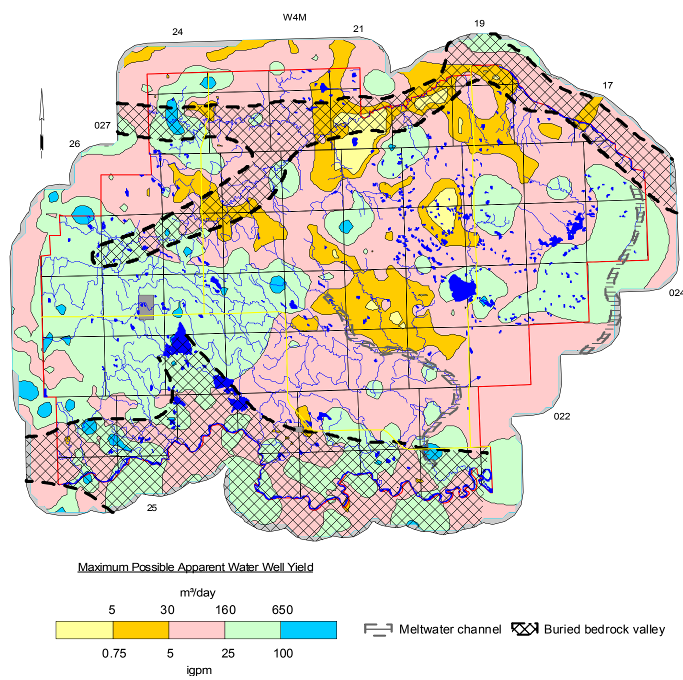

Figure 7. Hydrogeological Map

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 and apparent yield 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.

[10] See glossary
[11] For definitions of Transmissivity, see glossary
[12] For definitions of Yield, see glossary

4.2 Spatial Distribution of Aquifers

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

1) lithologs provided by the water well drillers
2) geophysical logs from structure test holes
3) geophysical logs for 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.

4.3 Hydrogeological Parameters

Water well records that indicate the depths to the top and bottom of their completion interval are compared digitally to the spatial distribution of the various geological surfaces. This procedure allows for the determination of the aquifer in which individual water 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, and apparent water well yield. The NPWL given on the water well record is usually the water level recorded when the water well was drilled, measured prior to the initial aquifer test. In areas where groundwater levels have since fallen, the NPWL may now be lower and accordingly, potential apparent yield would be reduced. 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).

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. The representative data set included using the available data from townships 021 to 028, ranges 17 to 26, W4M, plus a buffer area of at least 5,000 metres. 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; for the maps, the areas with little or no data are identified.

4.4 Maps and Cross-Sections

Once grids for geological surfaces have been prepared, various grids need to be combined to establish the extent and thickness of individual 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. For the upper bedrock aquifer(s) where areas of insufficient data are available from the groundwater database, prepared maps have been masked with a solid faded pink color to indicate these areas. These masks have been added to the Scollard and Horseshoe Canyon aquifers. Appendix A includes page-size maps from the text, plus additional page-size maps and figures that support the discussion in the text. A list of maps and figures that are included on the CD-ROM is given in Appendix B.

Cross-sections are prepared by first choosing control points from the database along preferred lines of section. Data from these control points are then obtained from the database and placed in an AutoCAD drawing with an appropriate vertical exaggeration. The data placed in the AutoCAD drawing include the geo-referenced lithology, completion intervals and non-pumping water levels. Data from individual 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. Seven cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; only two (C-C' and D-D') are included in the text of this report. The cross-sections are also included on the CD-ROM; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

4.5 Software

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

- Acrobat 5.0
- ArcView 3.2
- AutoCAD 2002
- CorelDraw! 10.0
- Microsoft Office XP
- Surfer 8

5. Aquifers

5.1 Background

An aquifer is a permeable rock that is saturated. In this context, rock refers to subsurface materials, such as sand, gravel, sandstone and coal. If the non-pumping water level is above the top of the rock, this type of aquifer is an artesian aquifer. If the rock is not entirely saturated and the water level is below the top of the rock, this type of aquifer is a water-table or unconfined 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 sediments 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.

5.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than 25 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 50 metres. The Buried Calgary Valley is the main linear bedrock low in the southern parts of the County; unnamed buried bedrock valleys are present in the northern parts of the County. Other linear bedrock lows are present in the form of meltwater channels (Shetsen, 1987). The south-north cross-section D-D', Figure 8 shown below (and also on page A-14), passes across the Buried Calgary Valley and the unnamed buried bedrock valleys, and shows the surficial deposits being in the order of 50 metres thick in the buried bedrock valleys.

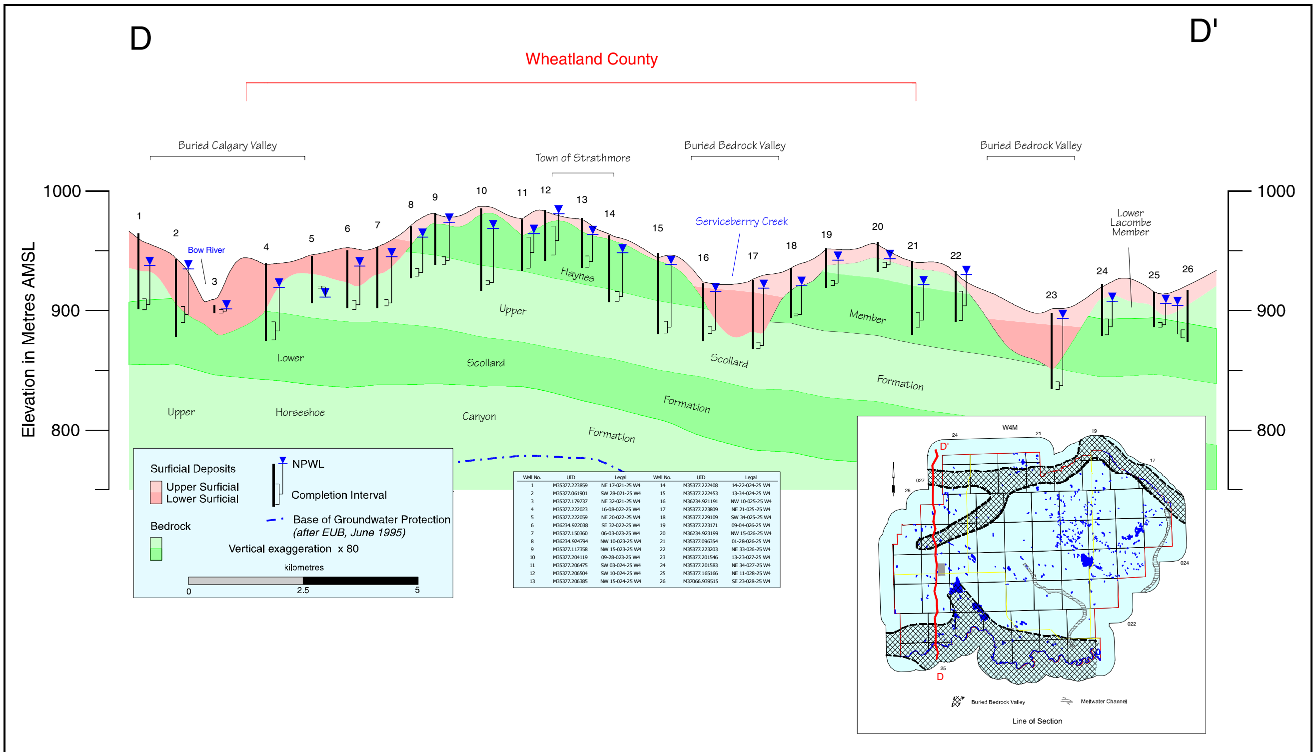

Figure 8. Cross-Section D - D'

The main aquifers in the surficial materials are sand and gravel deposits. In order for a sand and gravel deposit to be an aquifer, it must be saturated; if not saturated, a sand and gravel deposit is not an aquifer. The top of the surficial aquifers has been determined from the non-pumping water level in water wells 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 237 of the 241 water wells completed in the surficial deposits; all 237 surficial water wells have a casing diameter of less than 275 millimetres and are assumed to be drilled water wells.

5.1.2 Bedrock Aquifers

The upper bedrock includes formations that are less than 200 metres below the bedrock surface. In the County, the upper bedrock includes the Lower Lacombe and Haynes members of the Paskapoo Formation, the Upper Scollard and Lower Scollard formations, the Horseshoe Canyon Formation and the Bearpaw Formation. Cross-section C-C' (Figure 9 below and page A-13) shows that the aquifers in which water wells are completed are mainly within 100 metres of the ground surface. 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[13] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft.

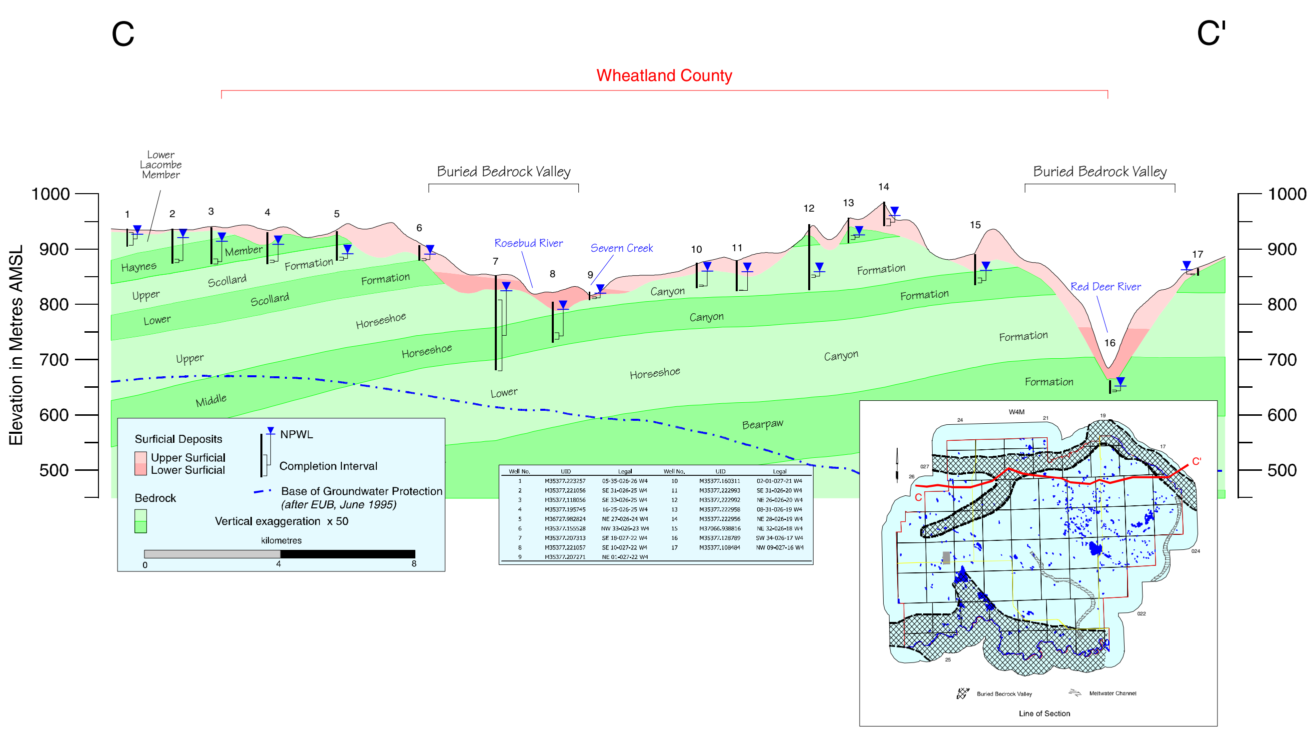

Figure 9. Cross-Section C - C'

In the County, the Base of Groundwater Protection extends mainly below the Lower Scollard Formation. 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.

13 See glossary

5.2 Aquifers in Surficial Deposits

The surficial deposits are the sediments above the bedrock surface. These include 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[14] and lacustrine[15] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the traditional glacial sediments of till[16] and ice-contact deposits. Pre-glacial materials are expected to be mainly present in the eastern two-thirds of the County, and in association with the buried bedrock valleys. Meltwater channels are associated with glaciation. In the County, there are two glacial meltwater channels (Shetsen, 1987): one in the south-central part of the County in association with the Buried Calgary Valley, and one in the northeastern part of the County in association with the unnamed bedrock valley (see Figure 10).

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeologic unit, they consist of three hydraulic units. The first unit is the sand and gravel deposits of the lower surficial deposits, when present. These deposits are mainly saturated. 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 is 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 soluble contaminants to move downward into the groundwater.

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 25 metres thick (see CD-ROM). The exceptions are mainly in association with areas where buried bedrock valleys are present, where the deposits can have a thickness of more than 50 metres. The main linear bedrock low in the County is west-east-trending and has been designated as the Buried Calgary Valley; the unnamed buried bedrock valley, and its tributaries in the northern parts of the County, joins the Buried Calgary Valley in Special Areas 2.

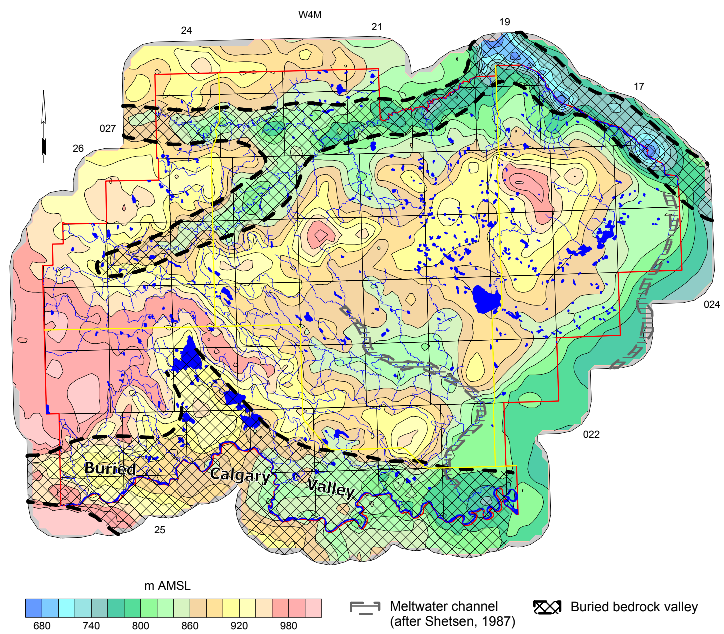

Figure 10. Bedrock Topography

The Buried Calgary Valley is present in the southern part of the County, and is coincidental with the present-day Bow River. The Valley is nine to fifteen kilometres wide within the map boundary, with local bedrock relief being up to 80 metres. Sand and gravel deposits can be expected in association with this bedrock low, with the sand and gravel deposits expected to be mainly less than 15 metres thick.

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14 See glossary
15 See glossary
16 See glossary

The unnamed buried bedrock valley present in the northeastern part of the County mainly parallels the stretch of present-day Red Deer River; the tributaries parallel the present-day Rosebud River and Serviceberry Creek. The valley that parallels the Red Deer River is less than nine kilometres wide within the County, with local bedrock relief being up to 100 metres. The tributaries are also less than nine kilometers wide, with local bedrock relief being in the order of 60 metres. Sand and gravel deposits can be expected in association with the unnamed bedrock valley, with the thickness of the sand and gravel deposits being mainly less than 15 metres; sand and gravel deposits in its tributaries are mainly less than five metres thick.

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur mainly in the linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than 40 metres, but can be more than 60 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 bedrock 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, two meltwater channels overlie the linear bedrock lows. Because sediments associated with the lower surficial deposits are indicated as being present in parts of the meltwater channel in the south-central part of the County, and in the second meltwater channel outside the map area, it is possible that the meltwater channels were originally tributaries to the buried bedrock valleys, as shown in the bedrock topography map on Figure 10.

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. Because the meltwater channels are mainly an erosional feature, the sand and gravel deposits associated with these features are considered not to be significant aquifers. The major meltwater channels in the County have been outlined by Shetsen (1987). The thickness of the upper surficial deposits is mainly less than 20 metres, but can be more than 30 metres in the eastern parts of the County. Upper surficial deposits are mainly absent from the buried bedrock valleys (see CD-ROM).

Sand and gravel deposits (Figure 11) 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 ten metres in the southeastern part of the County; the deposit of sand and gravel in this part of the County occurs in a part of the Bassano-Gem area. Extensive sand and gravel deposits in the Bassano-Gem area occur in thicknesses of more than twelve metres (Carlson, Turner and Geiger, 1969).

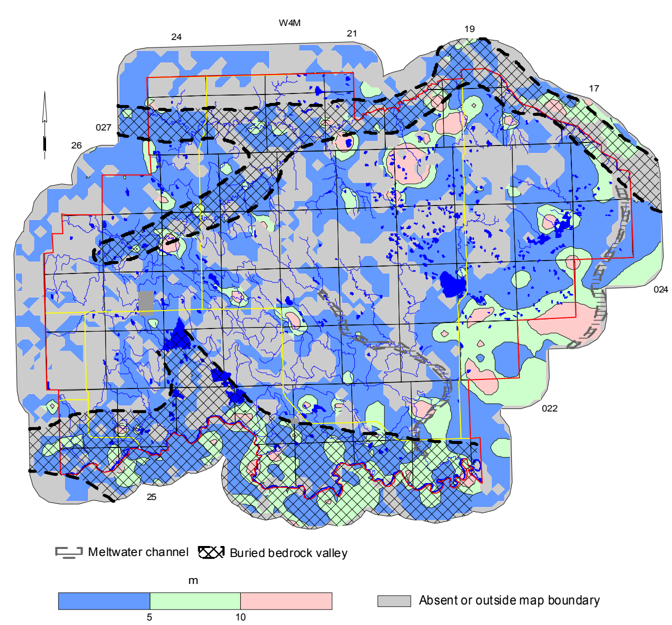

Figure 11. Thickness of Sand and Gravel Deposits

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 10% of the County where sand and gravel deposits are present, the sand and gravel deposits are more than 30% of the total thickness of the surficial deposits (page A-21). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly in the areas associated with linear bedrock lows.

5.2.2 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. Over approximately 50% of the County, the sand and gravel deposits are not present, or if present, are not saturated; these areas are designated as grey on the map. In the County, the thickness of the sand and gravel aquifer(s) is generally less than five metres, but can be more than five metres mainly in areas of, or near, linear bedrock lows, as shown in Figure 12, in Appendix A and on the CD-ROM.

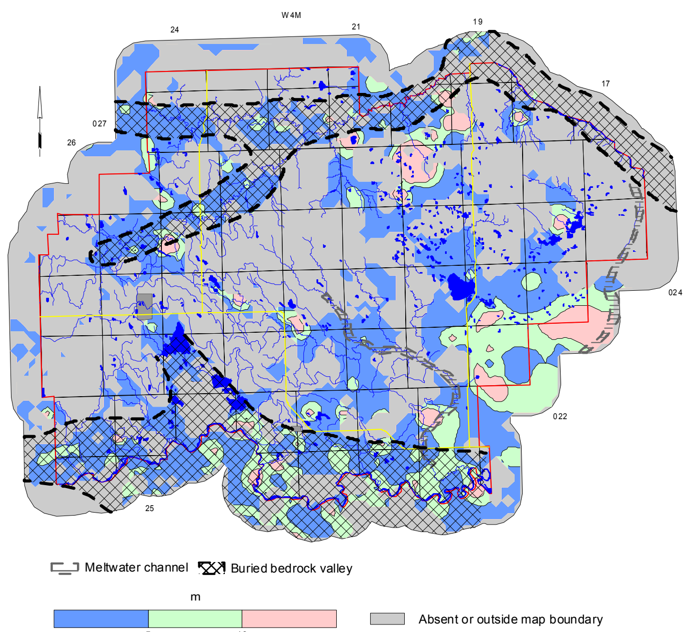

Figure 12. Thickness of Sand and Gravel Aquifer(s)

From the present hydrogeological analysis, 645 water wells are completed in aquifers in the surficial deposits. Of the 645 water wells, 120 are completed in aquifers in the upper surficial deposits, 180 are completed in aquifers in the lower surficial deposits, and 345 water wells are completed in multiple surficial aquifers. This number of water wells (645) is more than twice the number (241) 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 bedrock topographic surface at the same location, then the water well is considered to be completed in an aquifer in the surficial deposits.

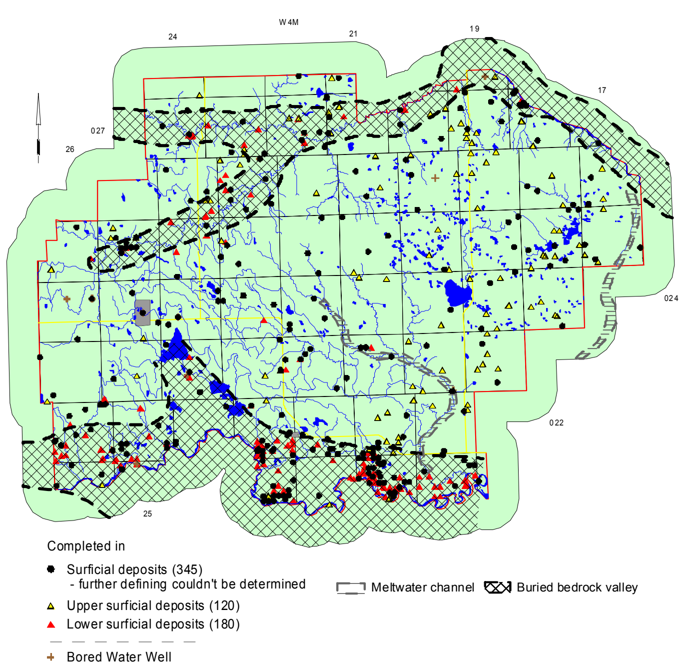

Figure 13. Water Wells Completed in Surficial Deposits

Water wells completed in the upper surficial deposits occur mainly near in the eastern third of the County. Water wells completed in the lower surficial deposits occur mainly in buried bedrock valleys (Figure 13).

In the County, there are 136 records for surficial water wells with apparent yield data, which is 21% of the 645 surficial water wells. Of the 136 water well records with apparent yield values, 56 have been assigned to aquifers associated with specific geologic units. Fifteen percent (20) of the 136 water wells completed in the sand and gravel aquifer(s) have apparent yields that are less than ten m³/day, 52% (71) have apparent yield values that range from 10 to 100 m³/day, and 33% (45) have apparent yields that are greater than 100 m³/day, as shown in Table 3. In addition to the 136 records for surficial water wells, there are 14 records that indicate that the water well is dry[17], or abandoned with "insufficient water". In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to the 14 dry holes prior to gridding. The majority of the dry holes are in multiple surficial completions.

Aquifer	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Upper Surficial	8	1	4	3
Lower Surficial	48	4	22	22
Multiple Completions	80	15	45	20
Totals	136	20	71	45

* - does not include dry test holes

Table 3. Apparent Yields of Sand and Gravel Aquifer(s)

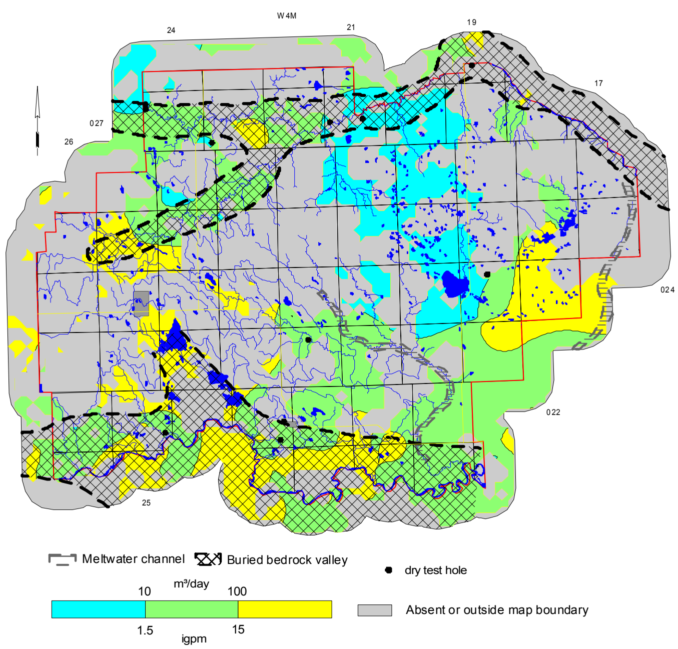

Figure 14. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

The adjacent map shows expected yields for water wells completed in sand and gravel aquifers(s).

Based on the aquifers that have been developed by existing water wells, these data show that water wells with yields of less than 100 m³/day from sand and gravel aquifer(s) can be expected in most of the County. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with the buried bedrock valleys.

17 "dry" can be due to a variety of reasons: skill of driller, type of drilling rig/method used, the geology

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits indicate the groundwaters are generally chemically hard and high in dissolved iron. In Wheatland County, groundwaters from the surficial aquifers mainly have a chemical hardness of greater than 200 mg/L (see CD-ROM).

The Piper tri-linear diagram[18] (page A-28) for surficial deposits shows the groundwaters have no dominant cation but are mainly bicarbonate-type waters. Nearly 90% of the groundwaters from the surficial deposits have a TDS concentration of more than 500 mg/L. Groundwaters having TDS concentrations of less than 500 mg/L occur mainly along the Bow River. Forty-five percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations of less than or equal to the aesthetic objective (AO) of 0.3 mg/L. However, many iron analysis results are questionable due to varying sampling and analytical methodologies.

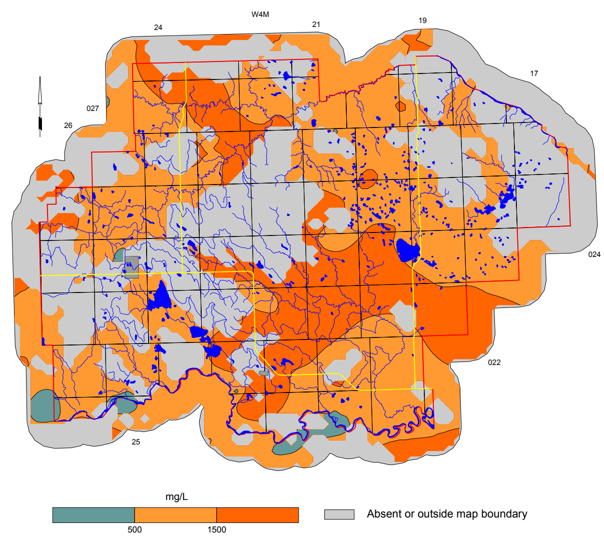

Figure 15. Total Dissolved Solids in Groundwater from Surficial Deposits

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 nearly 90% of the samples analyzed for surficial deposits in the County, the chloride ion concentration is less than 50 mg/L (see CD-ROM).

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	391	199	7,048	921	500
Sodium	289	0	1,722	175	200
Sulfate	390	0	4,514	254	500
Chloride	390	0	2,099	12	250
Nitrate + Nitrite (as N)	268	0	56	0.0	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)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 4. Concentrations of Constituents in Groundwaters from Surficial Deposits

In the County, the nitrate + nitrite (as N) concentrations in the groundwaters from the surficial deposits exceed the maximum acceptable concentrations (MAC) of ten mg/L in 14 of the 288 groundwater samples analyzed (up to about 1986).

The minimum, maximum and median 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 SGCDWQ in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS concentrations exceeds the guidelines.

[18] See glossary

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. Typically, these aquifers are present within the surficial deposits at no particular depth. Saturated sand and gravel deposits in the upper surficial deposits are not usually continuous over large areas but are expected over approximately 20% of the County.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the surficial deposits; and (2) the depth to the bedrock surface or the depth to the top of the lower surficial deposits when present. In the County, the thickness of the Upper Sand and Gravel Aquifer is generally less than 25 metres, but can be more than 50 metres in association with the linear bedrock lows present in the southeastern part of the County (see CD-ROM).

5.2.3.2 Apparent Yield

The permeability of the Upper Sand and Gravel Aquifer can be high. The high permeability combined with significant thickness leads to an extrapolation of high yields for water wells; however, because the sand and gravel deposits occur mainly as hydraulically discontinuous pockets, the long-term yields of the water wells are expected to be less than the apparent yields. The long-term yields for water wells completed through this Aquifer are expected to be mainly less than those shown on the adjacent figure. The apparent yields of greater than 100 m³/day shown in the western part of the County are the result of gridding one control point in township 026, range 23, W4M.

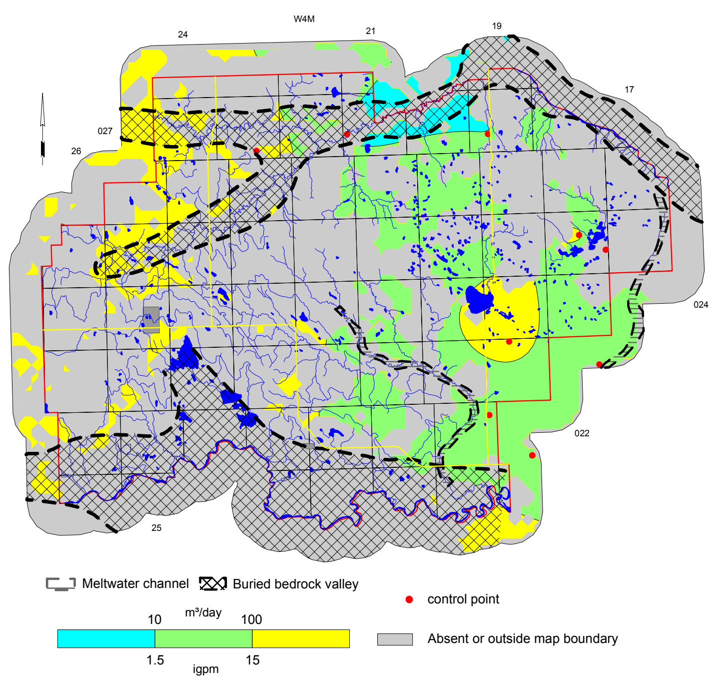

Figure 16. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

Where the Upper Sand and Gravel Aquifer is absent and where the yields are low, the development of water wells for the domestic needs of single families may not be possible from this Aquifer, and construction of a water supply well into the underlying bedrock may be the only alternative, provided that yields and quality of groundwater from the bedrock aquifer(s) are suitable.

In the County, there are nine licensed water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion of 139 m^3/day, of which 93% is used for agricultural purposes. Three of the nine licensed water wells completed through the Upper Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper part of the linear bedrock lows. The top of the lower surficial deposits is based on more than 1,000 control points across Alberta, including 13 in the County that are provided by Moran (1986) and Shetsen (1991).

5.2.4.1 Aquifer Thickness

The thickness of the Lower Sand and Gravel Aquifer is mainly less than five metres, but can be more than 15 metres in the buried bedrock valleys (see CD-ROM).

5.2.4.2 Apparent Yield

Apparent yields for water wells completed in the Lower Sand and Gravel Aquifer range from less than 10 m³/day to more than 100 m³/day. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with the Buried Calgary Valley.

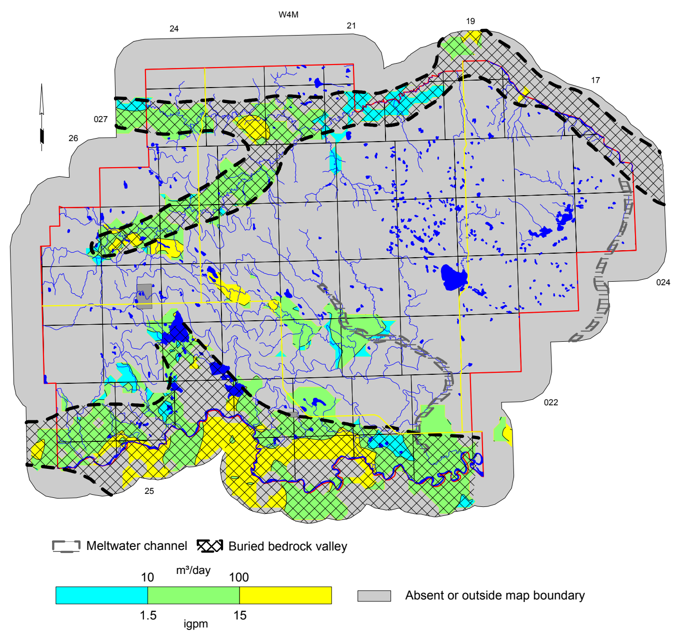

Figure 17. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

In the County, there are 14 licensed water wells that are completed through the Lower Sand and Gravel Aquifer, for a total authorized diversion of 430 m³/day, of which 64% is used for municipal purposes.

Thirteen of the 14 licensed water wells completed through the Lower Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

A preliminary groundwater study conducted for the Hamlet of Carseland in 1980 indicated that the existing 1975 Water Supply Well (WSW) in 06-12-022-26 W4M, and completed from 61.9 to 66.4 metres below ground surface in the Lower Sand and Gravel Aquifer, had an apparent yield of 137 m³/day (HCL, July 1980). In 1980, the Hamlet was pumping the 1975 WSW at a rate of 124 m³/day and required an additional water well to supply groundwater to a new subdivision. As a result of this preliminary study, HCL recommended that three water test holes be drilled. It was expected that although sand and gravel deposits associated with the Buried Calgary Valley might be thicker south of the Hamlet, the hydraulic data suggested that a higher yield might be encountered north of the existing water supply well. Carseland is currently licensed to divert groundwater from four water supply wells. Two water supply wells south of the 1975 water supply well in 01 and 02-12-022-26 W4M are licensed to divert a total of 64.2 m³/day, a third water supply well east of the 1975 WSW in 05-06-022-25 W4M is licensed to divert 37.2 m³/day, and a fourth water supply well north of the 1975 WSW is licensed to divert 162.2 m³/day. All four water supply wells are completed in the Lower Sand and Gravel Aquifer.

The groundwater from the 1975 WSW in 06-12-022-26 W4M has a TDS concentration of 775 mg/L, a sulfate concentration of 190 mg/L and a chloride concentration of 18.5 mg/L (HCL, July 1980).

5.3 Bedrock

5.3.1 Geological Characteristics

The upper bedrock in the County includes parts of the Paskapoo Formation, and the Scollard, Whitemud, Battle, Horseshoe Canyon and Bearpaw 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.

The Paskapoo Formation consists of cycles of thick, tabular sandstone, siltstone and mudstone layers (Glass, 1990). The maximum thickness of the Paskapoo Formation is generally less than 800 metres. In the County, only the Lower Lacombe and the Haynes members of the Paskapoo Formation are present.

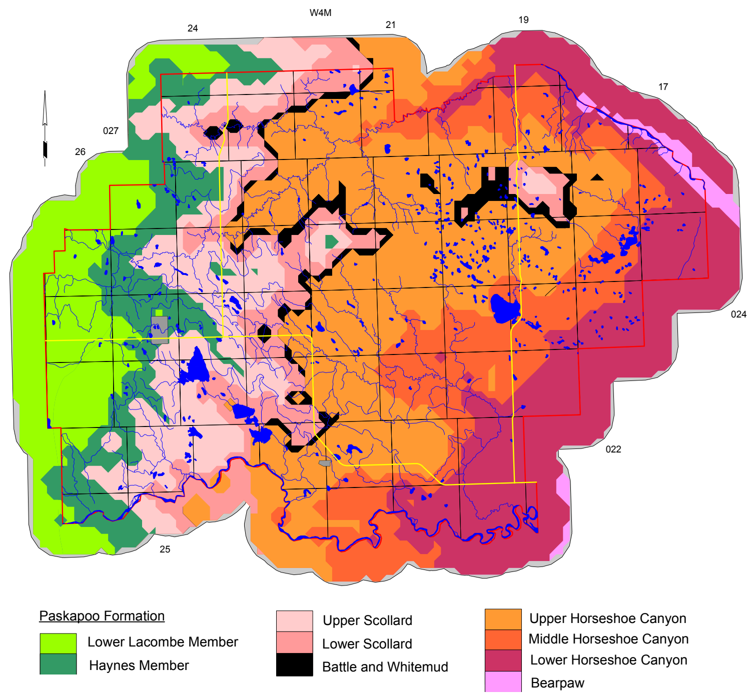

Figure 18. Bedrock Geology

The Lower Lacombe Member subcrops in the extreme western part of the County. 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 maximum thickness of the Lower Lacombe Member in other parts of Alberta is generally less than 100 metres; however, within the County, the Lower Lacombe Member has a maximum thickness of 135 metres.

The Haynes Member underlies the Lacombe Member and is composed mainly of sandstone with some siltstone, shale and coal. In other parts of Alberta, the Haynes Member has a maximum thickness of 100 metres; in the County, the Haynes Member has a maximum thickness of 50 metres.

The Scollard Formation underlies the Haynes Member, has a maximum thickness of 160 metres and has two separate designations: Upper and Lower. The Upper Scollard 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. In the County, the Upper Scollard has a maximum thickness of 80 metres; the Lower Scollard Formation has an average thickness of 30 metres, 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 is the upper bedrock in the eastern two-thirds of the County. 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 east-central part of the County immediately east of the area where the Battle and Whitemud formations and the Lower Scollard Formation subcrop. The Middle Horseshoe Canyon, which is up to 70 metres thick, subcrops in the eastern part of the County. The Lower Horseshoe Canyon, which is up to 170 metres thick, subcrops in the extreme eastern part of the County with the exception of a small area where the Bearpaw Formation subcrops.

The Horseshoe Canyon Formation consists of deltaic[19] 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.

The Bearpaw Formation underlies the Horseshoe Canyon Formation and is in the order of 130 metres thick within the County. The Bearpaw Formation consists of marine shale, siltstone and minor sandstone layers except in some areas where the thickness of the sandstone layers can be significant. The Bearpaw Formation "represents the final widespread marine unit in the Western Canada Foreland Basin" (Catuneanu et al, 1997).

There will be no direct review of the Bearpaw Formation in the text of this report because there are not sufficient data to create a meaningful contour map; the only maps associated with the Bearpaw Formation to be included on the CD-ROM will be structure-contour maps.

In the County, the Base of Groundwater Protection extends below the Upper Scollard Formation. 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.

5.3.2 Aquifers

Of the 4,188 water wells in the database, 1,766 were defined as being completed below the top of bedrock and 241 completed in surficial aquifers, based on lithologic information and water well completion details. However, at least a reported completion depth is available for 3,919 water wells completed below the bedrock surface. Assigning a water well to a specific geologic unit 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 the top of the completion interval was 80% of the total completed depth of a water well. With this assumption, it has been possible to designate the specific bedrock aquifer of completion for 2,357 water wells. The remaining 694 of the total 3,051 bedrock water wells are identified as being completed in more than one bedrock aquifer as shown in Table 4. The bedrock water wells are mainly completed in the Haynes, Upper Scollard and Upper Horseshoe Canyon aquifers.

Geologic Unit	No. of Bedrock Water Wells
Lower Lacombe	228
Haynes	380
Upper Scollard	419
Lower Scollard	242
Battle Formation	46
Upper Horseshoe Canyon	593
Middle Horseshoe Canyon	278
Lower Horseshoe Canyon	163
Bearpaw	8
Multiple Completions	694
Total	3,051

Table 5. Completion Aquifer

[19] See glossary

There are 1,381 records for bedrock water wells that have apparent yield values, which is 45% of the 3,051 bedrock water wells. In the County, yields for water wells completed in the upper bedrock aquifer(s) are mainly between 10 and 100 m³/day. Some of the areas with yields of more than 100 m³/day are in the western part of the County, and in association with the Buried Calgary Valley, as shown on the adjacent figure. These areas where higher yields are expected may identify locations of increased permeability resulting from the weathering process. In addition to the 1,381 records for bedrock water wells, there are 60 records that indicate that the water well is dry, or abandoned with "insufficient water". In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to the 60 dry holes prior to gridding. The majority of the dry holes are in the Upper Horseshoe Canyon Aquifer.

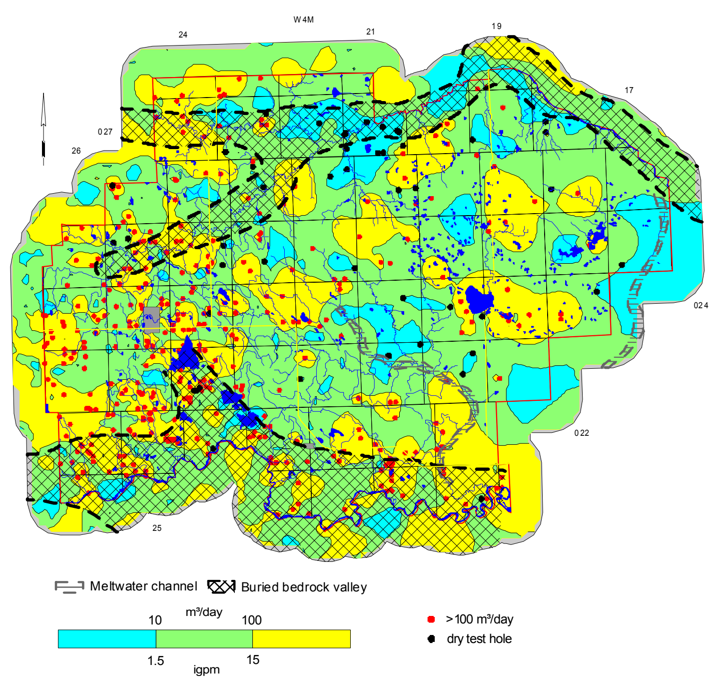

Figure 19. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

Of the 1,381 water well records with apparent yield values, 1,053 have been assigned to aquifers associated with specific geologic units. Twenty-one percent (286) of the 1,381 water wells completed in the bedrock aquifers have apparent yields that are less than ten m³/day, 50% (690) have apparent yield values that range from 10 to 100 m³/day, and 29% (405) have apparent yields that are greater than 100 m³/day, as shown in Table 5. The water well records having higher apparent yield values are expected to be in areas of increased permeability resulting from the weathering process.

Aquifer	Water Wells with Values for Apparent Yield (*)	with Apparent Yields <10 m³/day	10 to 100 m³/day	>100 m³/day
Lower Lacombe	97	22	43	32
Haynes	184	33	107	44
Upper Scollard	218	23	106	89
Lower Scollard	126	16	69	41
Battle	28	2	12	14
Upper Horseshoe Canyon	232	56	117	59
Middle Horseshoe Canyon	97	27	48	22
Lower Horseshoe Canyon	70	21	22	27
Bearpaw	1	0	0	1
Multiple Completions	328	86	166	76
Totals	1,381	286	690	405

* - does not include dry test holes

Table 6. Apparent Yields of Bedrock Aquifers

There are 28 water wells completed in the Battle Formation with apparent yield data. However, because very little significant permeability within the Battle Formation is expected, the apparent yields of greater than ten m³/day may be misleading. As a result, there will be no direct review of the Battle Formation in the text of this report. Any hydrogeological parameters that have been assigned to the Battle Formation will be included with the parameters associated with multiple completions.

5.3.3 Chemical Quality of Groundwater

The Piper tri-linear diagram for bedrock aquifers (page A-28) shows that all chemical types of groundwater occur in bedrock aquifers. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 500 mg/L to more than 2,000 mg/L, with the poorest quality being in the central part of the County (page A-30).

The relationship between TDS and sulfate concentrations shows that when TDS values in the groundwaters from the upper bedrock aquifer(s) exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

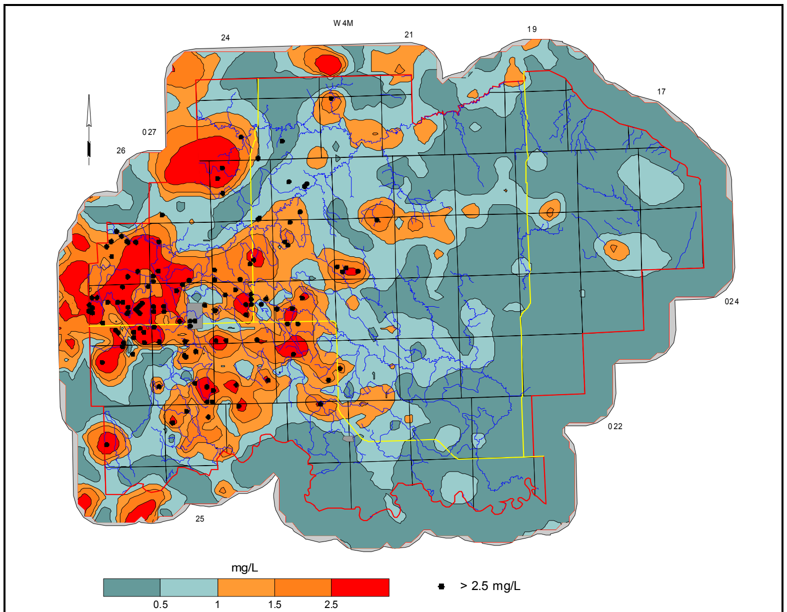

Figure 20. Fluoride in Groundwater from Upper Bedrock Aquifer(s)

In the County, 90% of the chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 100 mg/L. Chloride values of greater than 100 mg/L are mainly in the Horseshoe Canyon aquifers.

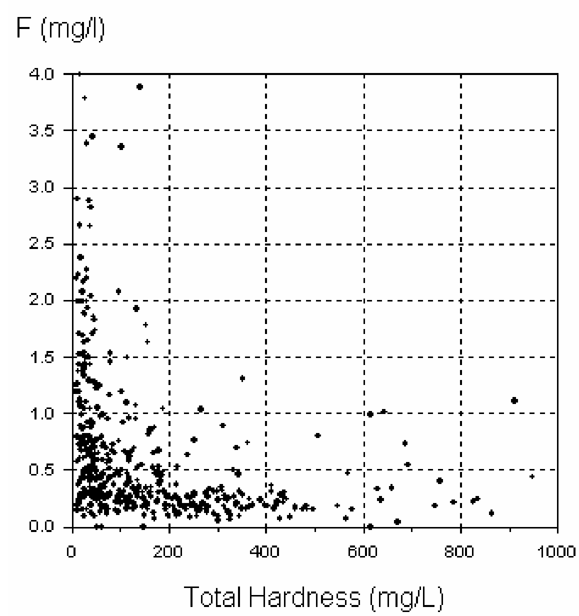

Figure 21. Fluoride vs Total Hardness in Groundwater from Upper Bedrock Aquifer(s)

The nitrate + nitrite (as N) concentrations are less than 0.1 mg/L in 75% of the chemical analyses for upper bedrock water wells. Eighty percent of the total hardness values in the groundwaters from the upper bedrock aquifer(s) are less than 200 mg/L.

In the County, approximately 35% 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 35% of the groundwater samples from the entire County are between 0.5 and 1.5 mg/L and approximately 30% exceed the maximum acceptable concentration for fluoride of 1.5 mg/L.

There appears to be an inverse relationship between fluoride and total hardness concentrations, as shown in Figure 20. In general, when total hardness is less than 150 mg/L, fluoride can be variable, but as total hardness increases, fluoride decreases. The higher values of total hardness occur mainly in the eastern part of the County and the higher values of fluoride occur mainly in the western part of the County (see page A – 31 and the CD-ROM).

A comparison was made of fluoride concentrations in the groundwaters from water wells in the County completed in aquifers in the upper bedrock. The comparison was made to determine if there was a relationship between fluoride concentrations and the aquifer of completion. In addition, the comparisons were extended to compare the trends established within the County to trends throughout Alberta. The comparisons are summarized below in Table 7.

In both Wheatland County and throughout Alberta, there are no significant trends or variations in the median fluoride concentrations in the groundwaters from water wells completed above the Upper Horseshoe Canyon Aquifer. However, median fluoride concentrations decrease consistently in aquifers of greater depth. The percentages of analyses with fluoride concentrations of greater than 1.5 mg/L but less than 2.5 mg/L exhibit a similar trend. For fluoride concentrations of greater than 2.5 mg/L, the percentages also decrease below the Lower Scollard Aquifer, but the highest percentages of fluoride concentrations of greater than 2.5 mg/L are in the groundwaters from water wells in the County completed in the Haynes Aquifer.

	Fluoride				Percentage of Analyses Greater than the SGCDWQ (1.5 mg/L)		Percentage of Analyses Greater than 2.5 mg/L	
	No. of Analyses		Median					
Aquifer Name	County	All Alberta	County	All Alberta	County	All Alberta	County	All Alberta
Lower Lacombe	87	934	0.8	0.42	33.3	23.4	18.4	13.0
Haynes	146	681	1.0	0.56	37.0	23.5	26.0	14.7
Upper Scollard	160	638	1.1	0.49	38.8	20.8	15.0	6.6
Lower Scollard	81	764	1.0	0.56	28.4	16.2	16.0	3.1
Upper Horseshoe Canyon	319	4,163	0.7	0.61	22.3	22.3	7.5	4.7
Middle Horseshoe Canyon	149	2,130	0.4	0.50	5.4	16.1	0.0	2.2
Lower Horseshoe Canyon	79	6,340	0.3	0.43	0	7.0	0	0.8
Bearpaw	5	2,649	0.1	0.45	0	4.7	0	0.4

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Table 7. Fluoride Concentrations in Groundwaters from Upper Bedrock Aquifer(s)

5.3.4 Lower Lacombe Aquifer

The Lower Lacombe Aquifer comprises the permeable parts of the Lower Lacombe Member, as defined for the present program. The top of the Lower Lacombe Member is the bedrock surface where the Lower Lacombe Member is present. Structure contours have been prepared for the top of the Lower Lacombe Member. The structure contours show the Lower Lacombe Member ranges in elevation from less than 900 to more than 1,000 metres AMSL and has a maximum thickness of 135 metres. The non-pumping water-level surface in the Lower Lacombe Aquifer is a subdued replica of the bedrock surface (see CD-ROM).

5.3.4.1 Depth to Top

The depth to the top of the Lower Lacombe Member is mainly less than 15 metres and is a reflection of the thickness of the surficial deposits (page A-33).

5.3.4.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Lacombe Aquifer are mainly in the range of 10 to 100 m³/day, with nearly 70% of the values being less than 100 m³/day (Table 5). The areas showing water wells with yields of greater than 100 m³/day are mainly associated with the eastern edge of the Aquifer.

There are five licensed water wells completed through the Lower Lacombe, for a total of 125 m³/day. Two water supply wells licensed for agricultural purposes in 05-02-023-26 W4M account for 85% of the total licensed diversions. All five licensed water wells could be linked to a water well in the AENV groundwater database. Four of the five licensed users are for agricultural purposes.

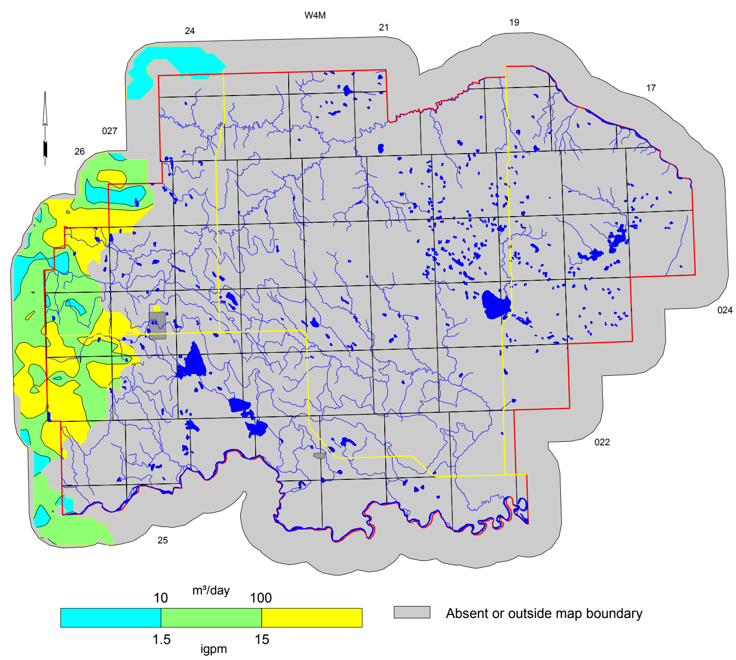

Figure 22. Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer

An extended aquifer test conducted with a water supply well completed in the Lower Lacombe Aquifer in NW 20-026-25 W4M indicated a long-term yield of 160 m³/day, based on an apparent transmissivity of 100 metres squared per day (m²/day) and an effective transmissivity of 25 m²/day after 1,000 minutes of pumping (HCL, October 1994).

5.3.4.3 Quality

The groundwaters from the Lower Lacombe Aquifer are mainly a bicarbonate-to-sulfate type, with sodium as the main cation (see Piper diagram on CD-ROM), with more than 50% of the groundwater samples having TDS concentrations of greater than 1,000 mg/L. The sulfate concentrations are mainly less than 1,000 mg/L. Chloride concentrations from the Lower Lacombe Aquifer are mainly less than 50 mg/L. The indications are that fluoride concentrations in the Lower Lacombe Aquifer are expected to be more than 2.5 mg/L where the depth to top of the Lower Lacombe Aquifer is mainly less than five metres below ground surface.

The groundwater from the water well in NW 20-026-25 W4M has a TDS concentration of 809 mg/L, a sulfate concentration of 222 mgL, a chloride concentration of 1 mg/L, and a fluoride concentration of 1.1 mg/L (HCL, October 1994).

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Lower Lacombe Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines in all upper bedrock aquifer(s) and the Lower Lacombe Aquifer. The median concentrations of sulfate and fluoride from water wells completed in the Lower Lacombe Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

Constituent	No. of Analyses	Range for County in mg/L			All Bedrock Median	Recommended Maximum Concentration SGCDWQ
		Minimum	Maximum	Median		
Total Dissolved Solids	101	373	4220	1020	1069	500
Sodium	66	0	1250	288	350	200
Sulfate	101	0	2750	365	285	500
Chloride	100	0	98	15	13	250
Fluoride	87	0	7	0.8	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)
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Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 8. Apparent Concentrations of Constituents in Groundwaters from Lower Lacombe Aquifer

The elevated fluoride concentrations in the western part of the County from water wells completed in all upper bedrock aquifer(s) shown in Figure 20 (page 25) are mainly a reflection of the underlying Haynes Aquifer rather than of the Lower Lacombe Aquifer.

Although the median value of fluoride concentrations is 0.8 mg/L from water wells completed in the Lower Lacombe Aquifer is slightly higher than fluoride concentrations from water wells in the County completed in upper bedrock aquifer(s).

5.3.5 Haynes Aquifer

The Haynes Aquifer comprises the permeable parts of the Haynes Member that underlie the Lower Lacombe Member, and subcrops under the surficial deposits in the western quarter of the County. Structure contours have been prepared for the top of the Member. The structure contours show the Haynes Member ranges in elevation from less than 870 to more than 990 metres AMSL and has a thickness of in the order of 50 metres. The non-pumping water level in the Haynes Aquifer is downgradient to the north toward the Rosebud River and downgradient south toward the Bow River.

5.3.5.1 Depth to Top

The depth to the top of the Haynes Member ranges from less than ten metres below ground surface at the eastern extent to more than 50 metres in the western part of the County (page A-36). The greatest depth is in areas where the Lower Lacombe Member is also present.

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Haynes Aquifer range mainly from 10 to 100 m³/day. The adjacent map indicates that water wells with apparent yields of more than 100 m³/day are expected in a number of areas.

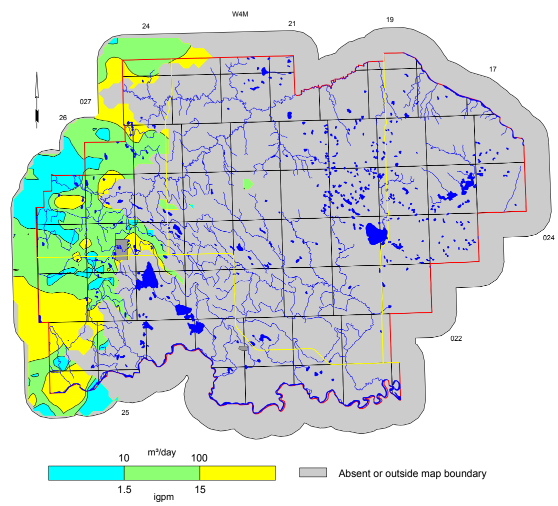

Figure 23. Apparent Yield for Water Wells Completed through Haynes Aquifer

In the County, there are 24 licensed water wells that are completed in the Haynes Aquifer, with a total authorized diversion of 883 m³/day; the two highest allocations are 113.3 m³/day for a water supply well licensed for commercial purposes in NE 23-021-26 W4M and 114.9 m³/day for a water supply well licensed for agricultural purposes in 05-02-024-25 W4M. Twenty of the 24 licensed water wells could be linked to a specific water well in the AENV groundwater database.

5.3.5.3 Quality

The groundwaters from the Haynes Aquifer are mainly a bicarbonate-to-sulfate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). Seventy-five percent of the TDS concentrations are between 500 and 1,500 mg/L. The sulfate concentrations are mainly below 500 mg/L and the chloride concentrations are mainly less than 50 mg/L. The indications are that fluoride concentrations in the Haynes Aquifer are expected to be more than 2.5 mg/L where the depth to top of the Haynes Aquifer is mainly greater than 30 metres, with lower values occurring mainly along the edge of the Aquifer.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	172	160	4492	777	1069	500
Sodium	109	0	700	269	350	200
Sulfate	169	0	2152	223	285	500
Chloride	167	0	479	6	13	250
Fluoride	146	0	8	1.0	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)
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Table 9. Apparent Concentrations of Constituents in Groundwaters from Haynes Aquifer

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Haynes Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentration of fluoride from water wells completed in the Haynes Aquifer is greater than the median concentration from water wells completed in all upper bedrock aquifer(s).

5.3.6 Upper Scollard Aquifer

The Upper Scollard Aquifer comprises the permeable parts of the Upper Scollard Formation that underlie the Haynes Member, and subcrops under the surficial deposits in the western quarter of the County. Structure contours have been prepared for the top of the Formation. The structure contours show the Upper Scollard Formation ranges in elevation from less than 840 to more than 1,000 metres AMSL and has a thickness of in the order of 80 metres. The non-pumping water level in the Upper Scollard Aquifer slopes mainly toward Serviceberry Creek and toward the Rosebud River in the northern part of the County.

5.3.6.1 Depth to Top

The depth to the top of the Upper Scollard Formation ranges from less than 20 metres below ground surface at the eastern extent to more than 100 metres in the western part of the County (page A-40).

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Scollard Aquifer range mainly from 10 to 100 m³/day; however, forty percent of the water wells completed in the Upper Scollard Aquifer have apparent yields that are greater than 100 m³/day. The adjacent map indicates that water wells with apparent yields of more than 100 m³/day are expected in a number of areas. In these areas, weathering processes may be increasing the local permeability.

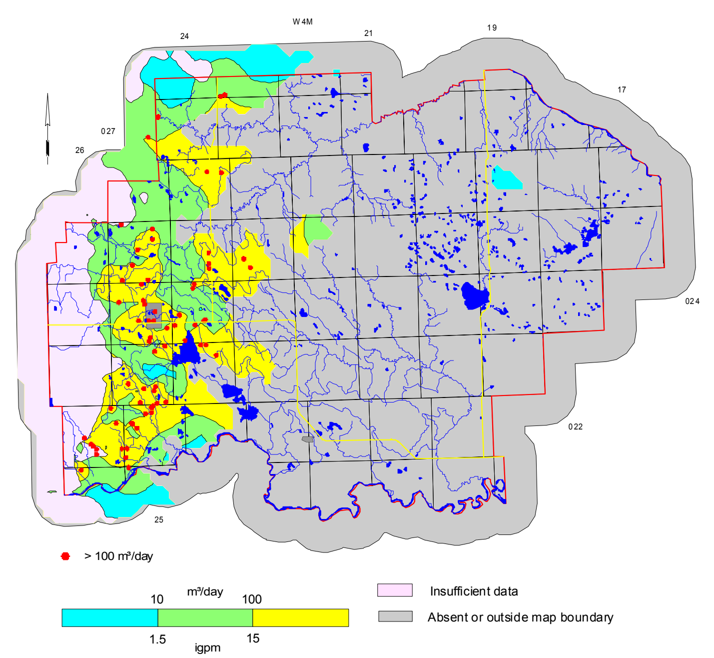

Figure 24. Apparent Yield for Water Wells Completed through Upper Scollard Aquifer

In the County, there are 29 licensed water wells that are completed in the Upper Scollard Aquifer, that are authorized to divert a total of 966 m³/day; the highest single allocation is 487 m³/day for a water supply well used to supply groundwater to a subdivision in 11-23-023-27 W4M. The next highest allocations of more than 80 m³/day are for two water supply wells used for municipal purposes, one in 04-07-024-27 W4M and one in NE 19-024-28 W4M. Five of the 29 licensed water wells could be linked to a water well in the AENV groundwater database.

An extended aquifer test was conducted in September 1998 with a water supply well for the Hutterian Brethren of Wheatland in 06-20-025-23 W4M; the water supply well is completed from 15.5 to 21.6 metres below ground surface in the Upper Scollard Aquifer. The aquifer test consisted of 3,003 minutes of pumping at 194 lpm and 6,661 minutes of recovery. Analysis of the aquifer test results indicated the water supply well has a long-term yield of 74 m³/day, based on an aquifer transmissivity of 215 m²/day and an effective transmissivity of 31.8 m²/day (HCL, October 1999). This water supply well is currently licensed to divert 50 m³/day of groundwater.

An extended aquifer test was conducted in August 1986 with a water supply well at the Green Drop Carseland batching plant in SE 16-022-26 W4M, located approximately 6,400 metres north of the Bow River, and completed from 81.1 to 97.5 metres below ground surface in the Upper Scollard Aquifer. The aquifer test consisted of 1,440 minutes of pumping at 91 lpm and 1,320 minutes of recovery and indicated a long-term yield of 60 m³/day based on an apparent transmissivity of 11.8 m²/day and an effective transmissivity of 5.5 m²/day. The water supply well is currently licensed to divert 44 m³/day of groundwater (HCL, August 1986).

5.3.6.3 Quality

The groundwaters from the Upper Scollard Aquifer are mainly a bicarbonate-to-sulfate type, with sodium as the main cation (see Piper diagram on CD-ROM). Total dissolved solids concentrations range mainly between 500 and 1,000 mg/L, with more than 90% of the groundwater samples having TDS concentrations of greater than 500 mg/L. The TDS concentrations of less than 500 mg/L may be a result of more active flow systems and shorter flow paths. The sulfate concentrations are mainly less than 500 mg/L. Nearly 75% of the chloride concentrations from the Upper Scollard Aquifer are less than ten mg/L.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	176	370	2716	837	1069	500
Sodium	118	41	896	305	350	200
Sulfate	171	11	1440	300	285	500
Chloride	170	0	95	8	13	250
Fluoride	160	0	10	1.1	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)
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Table 10. Apparent Concentrations of Constituents in Groundwaters from Upper Scollard Aquifer

A chemical analysis of a groundwater sample collected from the water supply well in 06-20-025-23 W4M in March 1999 indicates the groundwater is a sodium-sulfate type, with a TDS concentration of 2,090 mg/L, a sulfate concentration of 1,050 mg/L, a chloride concentration of 15.9 mg/L, and a fluoride concentration of 0.531 mg/L (HCL, October 1999).

The chemical analysis results for a groundwater sample collected from the water supply well in SE 16-022-26 W4M in September 1985 indicate the groundwater is a sodium-bicarbonate type, has a TDS concentration of 559 mg/L, a sulfate concentration of 165 mg/L, a chloride concentration of 19 mg/L, and a fluoride concentration of 0.80 mg/L (HCL, August 1986).

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Upper Scollard Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of sulfate and fluoride from water wells completed in the Upper Scollard Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

5.3.7 Lower Scollard Aquifer

The Lower Scollard Aquifer comprises the porous and permeable parts of the Lower Scollard Formation that underlie the Upper Scollard Formation, and subcrops under the surficial deposits mainly in the western third of the County. Structure contours have been prepared for the top of the Formation. The structure contours show the Lower Scollard Formation ranges in elevation from less than 760 to more than 960 metres AMSL and has an average thickness of 30 metres. The non-pumping water level in the Lower Scollard Aquifer is downgradient to the north toward the Rosebud River and toward the Bow River in the southern part of the County.

5.3.7.1 Depth to Top

The depth to the top of the Lower Scollard Formation ranges from less than 20 metres below ground surface at the eastern extent to more than 200 metres in the western part of the County (page A-43).

5.3.7.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Scollard Aquifer range mainly from 10 to 100 m³/day, with more than 85% of the values being greater than ten m³/day.

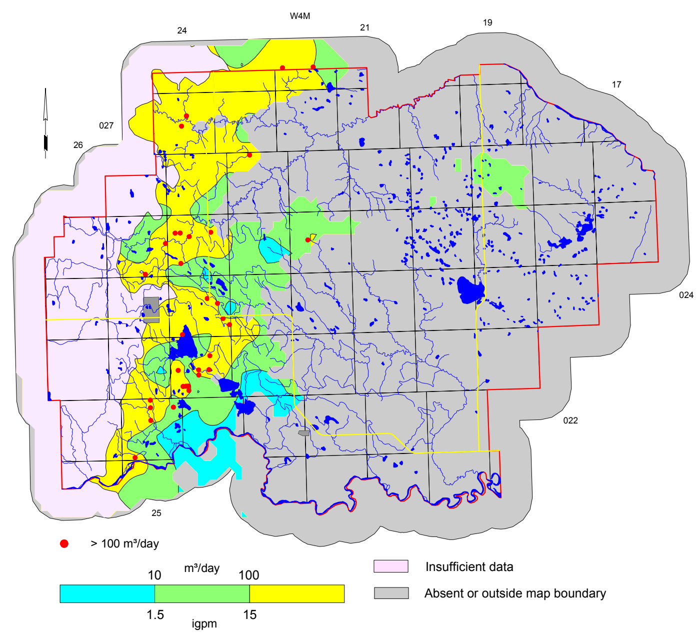

Figure 25. Apparent Yield for Water Wells Completed through Lower Scollard Aquifer

In the County, there are 15 licensed water wells that are completed in the Lower Scollard Aquifer, for a total authorized diversion of 728 m³/day. There are four water supply wells that are each licensed to divert 124 m³/day for a stock yard operation. Three of the four water supply wells are in section 8, township 023, range 24, W4M and the fourth water supply that is licensed for 124 m³/day is in NW 5-023-24 W4M. Fourteen of the 15 licensed water wells could be linked to a water well in the AENV groundwater database.

From 1978 to 1984, Thiessen Farms Ltd. diverted groundwater from three water supply wells completed mainly in the Lower Scollard Aquifer in SW 23-022-25 W4M. An extended aquifer test conducted with one of these water supply wells indicated a long-term yield of 185 m³/day (HCL, April 1980). The three water supply wells were subsequently licensed to divert up to 178 m³/day. In 1985, four water supply wells were completed in SE 23-022-25 W4M, mainly within the Lower Scollard Aquifer. The four water supply wells in SE 23-022-25 W4M are currently licensed to divert a total of 145 m³/day for agricultural purposes.

In 1994, three water supply wells completed in the Lower Scollard Aquifer were drilled at a second Thiessen Farms Ltd. operation in the south half of section 8, township 023, range 24, W4M. An extended aquifer test with one of these water supply wells indicated a long-term yield of 315 m³/day based on an apparent transmissivity of 80 m²/day, an effective transmissivity of 30 m²/day and a storage coefficient of 0.0004 (HCL, November 1994). These three water supply wells are completed in the Lower Scollard Aquifer and are currently licensed to divert 124.5 m³/day each.

An extended aquifer test conducted in March 1999 with a water supply well for the Hutterian Brethren of Wheatland in 13-20-025-23 W4M completed from 25.0 to 30.5 metres below ground surface in the Lower Scollard Aquifer. The aquifer test consisted of 3,226 minutes of pumping at 152 litres per minute and 5,645 minutes of recovery and indicated a long-term yield of 56.3 m^3/day based on an aquifer transmissivity of 57.6 m^2/day and an effective transmissivity of 8.9 m^2/day (HCL, October 1999). This water supply well is currently licensed for 50 m^3/day.

5.3.7.3 Quality

The groundwaters from the Lower Scollard Aquifer are a sodium-sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations range mainly between 500 and 1,500 mg/L, with more than 65% of the groundwater samples having TDS concentrations of greater than 1,000 mg/L. The sulfate concentrations are mainly greater than 150 mg/L, with more than 40% of the groundwater samples having sulfate concentrations of greater than 500 mg/L. Nearly 35% of the chloride concentrations from the Lower Scollard Aquifer are less than ten mg/L.

A groundwater sample collected from a water supply well in SE 23-022-25 W4M in July 1978 is a sodium-sulfate type, with a TDS concentration of 906 mg/L, a sulfate concentration of 405 mg/L, a chloride concentration of 29 mg/,L and a fluoride concentration of 2.32 mg/L (HCL, April 1980).

A groundwater sample collected from a water supply well in SW 08-023-24 W4M in June 1994 is a sodium-sulfate type, with a TDS concentration of 1,047 mg/L, a sulfate concentration of 554 mg/L, a chloride concentration of 10 mg/L, and a fluoride concentration of 2.08 mg/L (HCL, November 1994).

A groundwater sample collected from a water supply well in 13-20-025-23 W4M in May 1999 is a sodium-sulfate type, with a TDS concentration of 1,119 mg/L, a sulfate concentration of 440 mg/L, a chloride concentration of 11 mg/L, and a fluoride concentration of 2.3 mg/L (HCL, October 1999).

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Lower Scollard Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sodium, sulfate and fluoride from water wells completed in the Lower Scollard Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	103	320	6238	1190	1069	500
Sodium	62	161	930	390	350	200
Sulfate	99	25	4332	450	285	500
Chloride	99	3	798	12	13	250
Fluoride	81	0	7	1.0	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)
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Table 11. Apparent Concentrations of Constituents in Groundwaters from Lower Scollard Aquifer

5.3.8 Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer comprises the permeable parts of the Upper Horseshoe Canyon Formation that underlie the Lower Scollard Formation. The Upper Horseshoe Canyon Formation subcrops under the surficial deposits in approximately 75% of the County. Structure contours have been prepared for the top of the Formation. The structure contours show the Upper Horseshoe Canyon Formation ranges in elevation from less than 720 to more than 960 metres AMSL and has a thickness of up to 100 metres. The non-pumping water level in the Upper Horseshoe Canyon Aquifer is downgradient to the north toward the Rosebud River and toward the Bow River in the southern part of the County.

5.3.8.1 Depth to Top

The depth to the top of the Upper Horseshoe Canyon Formation is variable, ranging from less than ten metres at the eastern extent to more than 250 metres in the western part of the County (page A-46).

5.3.8.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Horseshoe Canyon Aquifer range mainly from 10 to 100 m^3/day, with more than 75% of the values being greater than ten m^3/day.

In the County, there are 16 licensed water wells completed in the Upper Horseshoe Canyon Aquifer, for a total authorized diversion of 265 m^3/day; the highest single diversion of 50.7 m^3/day is for the Village of Hussar water supply well in 16-22-024-20 W4M used for municipal purposes. Fifteen of the sixteen licensed water wells could be linked to a water well in the AENV groundwater database.

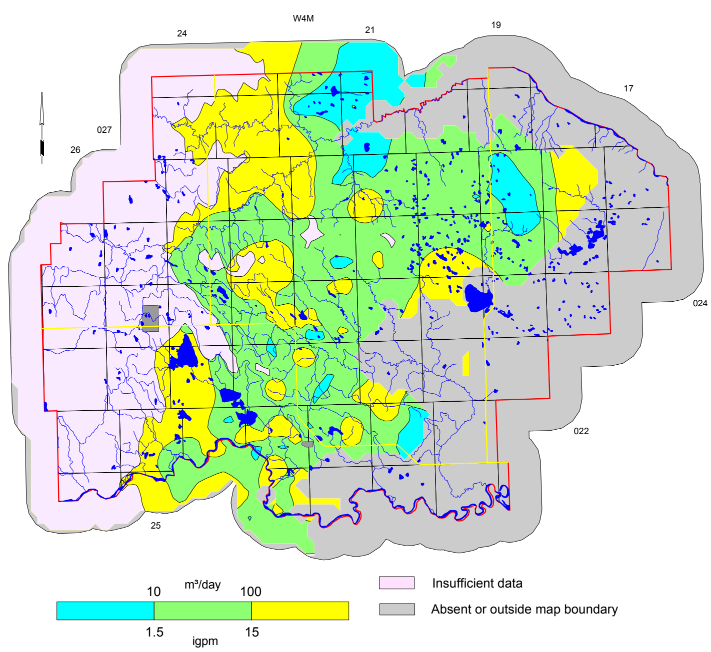

Figure 26. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer

Extended aquifer tests with two water supply wells (WSW No. 1-97 and WSW No. 2-97) were conducted for the Hutterian Brethren of Hillview in August 1998. These two water supply wells in NW 05-028-21 W4M are completed in the Upper Horseshoe Canyon Aquifer. Water Supply Well No. 1-97 is completed from 15.9 to 20.7 metres below ground surface in the upper part of the Upper Horseshoe Canyon Aquifer and WSW No. 2-97 is completed from 46.3 to 51.5 metres below ground surface in the lower part of the Upper Horseshoe Canyon Aquifer.

The results of the extended aquifer test with WSW No. 1-97 indicated a long-term yield of 28 m^3/day, based on 5,777 minutes of pumping at 25.9 lpm, 10,043 minutes of recovery, and apparent and effective transmissivities of 11.6 m^2/day. The results of the extended aquifer test with WSW No. 2-97 indicated a long-term yield of 19 m^3/day, based on 2,084 minutes of pumping at 53.1 lpm and 15,341 minutes of recovery, an apparent transmissivity of 2.9 m^2/day and an effective transmissivity of 1.9 m^2/day (HCL, September 1999). Water Supply Well No. 1-97 is currently licensed to divert 29 m^3/day of groundwater and WSW No. 2-97 is currently licensed to divert 19 m^3/day of groundwater, both for agricultural purposes.

5.3.8.3 Quality

The groundwaters from the Upper Horseshoe Canyon Aquifer are mainly a bicarbonate-to-sulfate type, with sodium as the main cation (see Piper diagram on CD-ROM). Total dissolved solids concentrations range mainly between 500 and 1,000 mg/L, with more than 65% of the groundwater samples having TDS concentrations of greater than 1,000 mg/L. The sulfate concentrations range from less than 100 to more than 500 mg/L. Eighty percent of the chloride concentrations from the Upper Horseshoe Canyon Aquifer are less than 100 mg/L.

The groundwaters from WSW Nos. 1-97 and 2-97 are a sodium-bicarbonate type. A groundwater sample collected from WSW No. 1-97 in September 1998 has a TDS concentration of 1,390 mg/L, a sulfate concentration of 464 mg/L, a chloride concentration of 4.2 mg/L, and a fluoride concentration of 0.21 mg/L. A groundwater sample collected from WSW No. 2-97 in September 1998 has a TDS concentration of 837 mg/L, a sulfate concentration of 0.5 mg/L, a chloride concentration of 165 mg/L, and a fluoride concentration of 2.23 mg/L. (HCL, September 1999).

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Upper Horseshoe Canyon Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Upper Horseshoe Canyon Aquifer are greater than the median concentrations, and fluoride is equal to the median concentrations from water wells completed in all upper bedrock aquifer(s).

Constituent	No. of Analyses	Range for County in mg/L			All Bedrock Median	Recommended Maximum Concentration SGCDWQ
		Minimum	Maximum	Median		
Total Dissolved Solids	372	394	7176	1213	1069	500
Sodium	224	27	1250	420	350	200
Sulfate	365	0	3293	326	285	500
Chloride	367	0	1403	24	13	250
Fluoride	319	0	5	0.7	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)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 12. Apparent Concentrations of Constituents in Groundwaters from Upper Horseshoe Canyon Aquifer

5.3.9 Middle Horseshoe Canyon Aquifer

The Middle Horseshoe Canyon Aquifer comprises the permeable parts of the Middle Horseshoe Formation that underlie the Upper Horseshoe Canyon Formation, and subcrops under the surficial deposits. Structure contours have been prepared for the top of the Formation, which underlies most of the County. The structure contours show the Middle Horseshoe Canyon Formation ranges in elevation from less than 600 to more than 880 metres AMSL and has an average thickness of 70 metres. The non-pumping water level in the Middle Horseshoe Canyon Aquifer is downgradient to the north toward the Rosebud River and toward the Bow River in the southern part of the County.

5.3.9.1 Depth to Top

The depth to the top of the Middle Horseshoe Canyon Formation is variable, ranging from less than ten metres at the eastern extent to more than 350 metres in the western part of the County (page A-49).

5.3.9.2 Apparent Yield

The apparent yields for individual water wells completed through the Middle Horseshoe Canyon Aquifer range mainly from 10 to 100 m³/day, with more than 70% of the values being greater than ten m³/day.

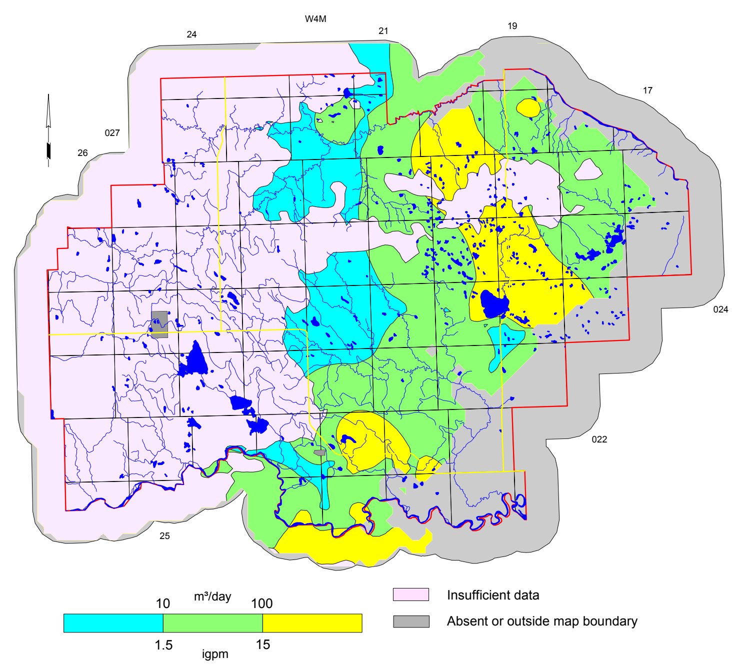

Figure 27. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer

In the County, there are 15 licensed water wells completed in the Middle Horseshoe Canyon Aquifer, for a total authorized diversion of 147 m³/day; the highest single diversion of 43.9 m³/day is for a County of Wheatland water supply well in 16-14-027-22 W4M used for municipal purposes. This water supply well is presumably licensed to divert groundwater for the Hamlet of Redland, but this water supply well could not be linked to a water well in the AENV groundwater database. Thirteen of the fifteen licensed water wells could be linked to a water well in the AENV groundwater database.

Six water test holes were drilled in 1982 for Dynamar Energy Ltd. in sections 10, 15, and 22, township 027, range 20, W4M. The main source of groundwater supply was expected to come from shallow sand and gravel deposits associated with the buried bedrock valley; however, because a significant quantity of clay-size particles were encountered during the drilling, five of the six water test holes were drilled deeper and were completed in the Middle Horseshoe Canyon Aquifer. Of the five water test holes completed in the Middle Horseshoe Canyon, two did not have sufficient groundwater entering each of the water test holes to conduct an aquifer test. Extended aquifer tests conducted with the remaining three water test holes indicated long-term yields ranging from less than 60 to more than 165 m³/day. The water test hole having the highest long-term yield is in 06-15-027-20 W4M (WTH Ni, 6-82) and was completed from 13.5 to 21.5 metres below ground surface in the Middle Horseshoe Canyon Aquifer (HCL, November 1982).

5.3.9.3 Quality

The groundwaters from the Middle Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate or sulfate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations range mainly between 500 and 1,000 mg/L, with only two values of TDS being less than 500 mg/L. The sulfate concentrations range mainly between 100 and 500 mg/L. Eighty percent of the chloride concentrations from the Middle Horseshoe Canyon Aquifer are less than 100 mg/L. The areas showing water wells with elevated fluoride concentrations are mainly associated with the edge of the Aquifer.

The groundwater from a water test hole in 14-10-027-20 W4M is a sodium-bicarbonate type, having a TDS concentration of 1,038 mg/L, a sulfate concentration of 160 mg/L, a chloride concentration of 21 mg/L, and a fluoride concentration of 0.45 mg/L (HCL, November 1982).

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Middle Horseshoe Canyon Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sodium and chloride from water wells completed in the Middle Horseshoe Canyon Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	165	99	4160	1304	1069	500
Sodium	106	18	1275	460	350	200
Sulfate	162	0	2049	183	285	500
Chloride	164	0	1100	22	13	250
Fluoride	149	0	2	0.4	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)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 13. Apparent Concentrations of Constituents in Groundwaters from Middle Horseshoe Canyon Aquifer

5.3.10 Lower Horseshoe Canyon Aquifer

The Lower Horseshoe Canyon Aquifer comprises the permeable parts of the Lower Horseshoe Canyon Formation that underlie the Middle Horseshoe Canyon Formation, and subcrops under the surficial deposits. Structure contours have been prepared for the top of the Formation. The structure contours show the Lower Horseshoe Canyon Formation ranges in elevation from less than 475 to more than 850 metres AMSL and has an average thickness of 170 metres. The non-pumping water level in the Lower Horseshoe Canyon Aquifer is downgradient to the north toward the Red Deer River and toward the Bow River in the southern part of the County.

5.3.10.1 Depth to Top

The depth to the top of the Lower Horseshoe Canyon Formation is variable, ranging from less than ten metres at the eastern extent, to more than 500 metres in the western part of the County (page A-52).

5.3.10.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Horseshoe Canyon Aquifer range mainly from 10 to 100 m^3/day, with more than 85% of the values being greater than ten m^3/day.

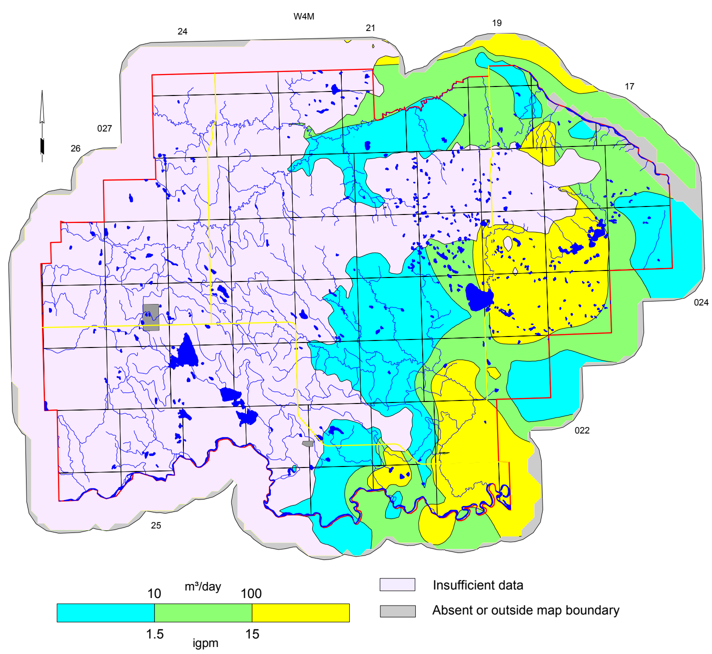

Figure 28. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

In the County, there are eight licensed water wells completed in the Lower Horseshoe Canyon Aquifer, for a total of 176 m^3/day. For one of the eight licensed groundwater users, no amount has been assigned to this water well and is possibly being used as a standby water well. The remaining seven licensed water wells are for Hutterian Brethren Colonies; five water wells are licensed to Sunshine Colony and two are licensed to the Ridgeland Colony. Of the five Sunshine Colony water supply wells, four are in section 17-024-18 W4M and are licensed to a total of 80.3 m^3/day, for both agricultural and municipal purposes. The two Ridgeland Colony water supply wells are in 14-05-025-17 W4M and are licensed to divert a total of 101.3 m^3/day for agricultural and municipal purposes. Six of the eight licensed water wells could be linked to a water well in the AENV groundwater database.

5.3.10.3 Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate type (see Piper diagram on CD-ROM). Total dissolved solids concentrations are mainly greater 500 mg/L, with only three TDS concentrations being less than 500 mg/L. The sulfate concentrations range mainly between 100 and 500 mg/L. Ninety percent of the chloride concentrations from the Lower Horseshoe Canyon Aquifer are less than 100 mg/L. The fluoride concentrations in the Lower Horseshoe Canyon Aquifer are expected to be more than 1.0 mg/L where the depth to top of the Lower Horseshoe Canyon Aquifer is mainly less than 50 metres below ground surface.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	89	14	3742	1088	1069	500
Sodium	55	0	1240	328	350	200
Sulfate	88	0	1961	152	285	500
Chloride	89	0	924	14	13	250
Fluoride	79	0	1	0.3	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)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 14. Apparent Concentrations of Constituents in Groundwaters from Lower Horseshoe Canyon Aquifer

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed in the Lower Horseshoe Canyon Aquifer in the County have been compared to the SGCDWQ and median concentrations from all upper bedrock aquifer(s) in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS and chloride from water wells completed in the Lower Horseshoe Canyon Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

6. Groundwater Budget

6.1 Hydrographs

In the County, there are three observation water wells that are part of the AENV regional groundwater-monitoring network. These are locations where water levels are being measured and recorded as a function of time: AENV Obs Water Well Nos. 218 and 219 are in 05-10-022-21 W4M near Cluny, and AENV Obs WW No. 220 is in 13-06-022-25 W4M near Carseland (see Figure A-57).

AENV Obs WW No. 218 is completed open hole from 64.0 to 72.5 metres below ground surface in multiple bedrock aquifers within the Horseshoe Canyon Formation. AENV Obs WW No. 219 is completed from 12.5 to 14.3 metres below ground surface in both the Upper Sand and Gravel Aquifer and the Upper Horseshoe Canyon Aquifer. Groundwater monitoring data for AENV Obs WW No 218 are available from mid-1986 to mid-1997, and from mid-1986 to the end of 2000 for AENV Obs WW No. 219.

The adjacent hydrograph shows annual cycles of recharge and decline throughout the year. In an area where there are no expected seasonal uses of groundwater, the highest water level will usually occur in late spring/early summer and the lowest water level will be in late winter/early spring. The highest water levels in AENV Obs WW Nos. 218 and 219 generally occur in the late fall/early winter and the lowest water levels generally occur in the spring (see Figure A-58). Overall annual fluctuations in AENV Obs WW No. 218 mainly range from 0.1 to 0.3 metres. In 1997, the water level rose from a low of 12.58 metres in March to a high of 11.78 metres below ground surface in May. From 1987 to 1991, there has been a net decline in the water level of approximately 0.4 metres.

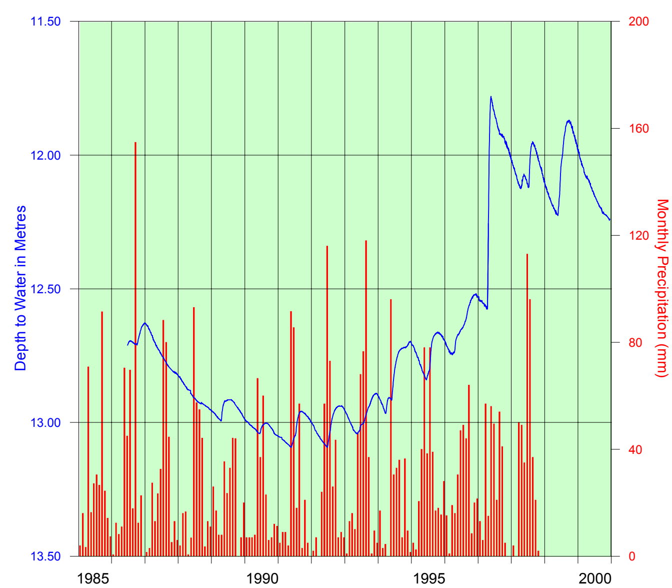

Figure 29. Precipitation vs Water Levels in AENV Obs WW No. 218

The water-level fluctuations in AENV Obs WW No. 218 in 05-10-022-21 W4M have been compared to the precipitation measured at the Gleichen weather station. In 1987 and 1988, there were no annual cycles of recharge in response to a decrease in precipitation. In 1989 and 1990, the rise in water level in late spring/early summer could be associated with recharge when the frost leaves the ground. From 1991 to 1996, the rise in water level late in the year could be associated with excess precipitation after most vegetation has been killed by frost and before the ground froze. The water-level rise in March 1997 may be a calibration adjustment of the water-level recorder.

The closest licensed groundwater users to AENV Obs WW Nos. 218 and 219 are in sections 07 and 08, township 022, range 20, W4M, six kilometres to the west. In this area, there are 11 licensed groundwater users. All 11 groundwater licences are held by the Cluny Hutterite Colony, and since 1997 have been authorized to divert up to 190 m³/day for exploration purposes. There is no completion information available in the AENV licensed database for the Cluny Hutterite Colony water wells; however, completion data are available in the AENV groundwater database for the Cluny Hutterite Colony water wells in sections 07 and 08, township 022, range 20, W4M, all of which are completed in the Lower Horseshoe Canyon Aquifer.

It does not appear that groundwater diversion from the Cluny Hutterite Colony water wells is having an effect on the water-level fluctuations in AENV Obs WW No. 218 because of the distance from the observation water well.

AENV Obs WW No. 220 is located in 13-06-022-25 W4M near Carseland, and is completed from 61.6 to 64.6 metres below ground surface in the Lower Surficial Aquifer. Groundwater monitoring data for AENV Obs WW No. 220 are available from mid-1986 to the end of 2000.

The water-level fluctuations in AENV Obs WW No. 220 appear to be related to seasonal groundwater uses. The adjacent hydrograph shows that the highest water levels in AENV Obs WW No. 220 occur in late winter/early spring and the lowest water levels are in late summer/early fall. This situation is a result of an increase in groundwater use by the Hamlet of Carseland during the summer months. The present data indicate that water levels in AENV Obs WW No. 220 have declined an average of 0.5 metres per year. The decline has been recorded since 1986 in AENV Obs WW No. 220, which is approximately one kilometre southeast of the Hamlet of Carseland water supply wells.

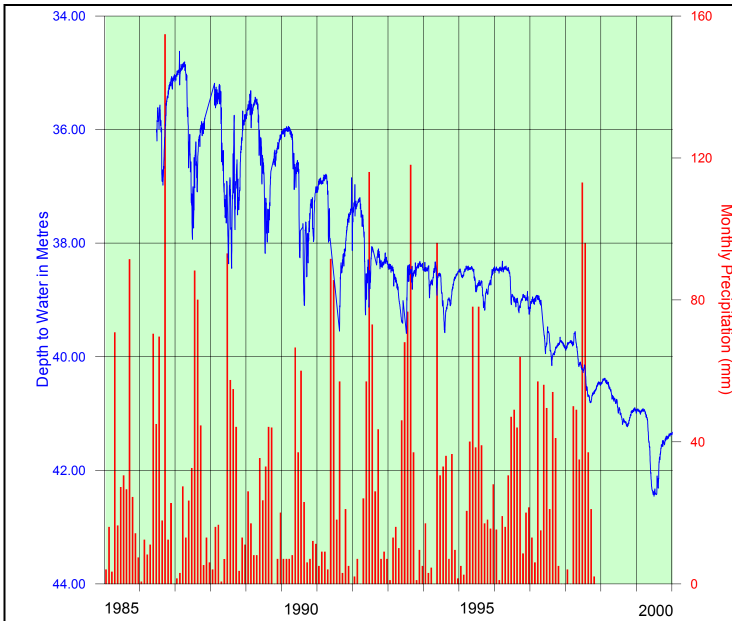

Figure 30. Monthly Groundwater Precipitation vs Water Levels in AENV Obs WW No. 220

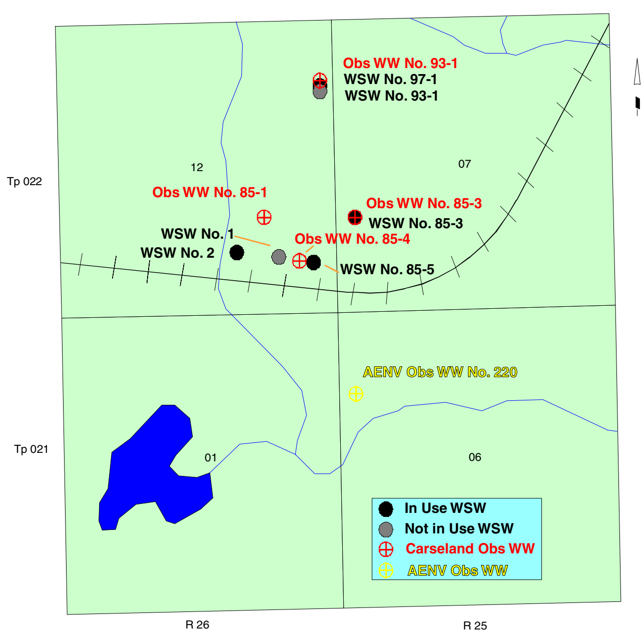

Figure 31. Site Map – Carseland Water Wells (modified after CH2M Hill)

Of the six water supply wells shown in the adjacent figure, groundwater is currently being diverted from WSW Nos. 2, 85-3, 85-5 and 97-1.

Records of the groundwater diversion from the four producing water supply wells in the Hamlet of Carseland have been made available to HCL by Wheatland County. Water levels are currently being monitored in Obs WW No. 85-1, Obs WW No. 85-3, Obs WW No. 85-4 and Obs WW No. 93-1. The Hamlet's water supply wells and observation water wells are all completed in the Lower Sand and Gravel Aquifer.

The data include daily groundwater diversions, and weekly water levels from four observation water wells from January 1996 to December 2000. CH2M Hill provided HCL with a site diagram of the Carseland water wells (both water supply and observation), graphs showing groundwater production and water levels from 1994 to 1999, and licensing information for the four water supply wells in 1992.

WSW No.	Licensed Diversion (m^3/day) in 1992[1]	in 2002
1	33	0
2	164	30
85-3	196	74.4[2]
85-5	79	34
93-1	not applicable	not applicable
97-1	not applicable	162.2[3]
Total	472	301

(1) CH2M Hill, April 1992
(2) assumed combined total for WSW 85-3 and Obs WW No. 85-3
(3) assumed licensed to WSW 97-1

Table 15. Summary of Carseland Licensed WSWs (modified after CH2M Hill)

In 2002, the Hamlet of Carseland currently is licensed to divert groundwater from five water supply wells. Two water supply wells are in SE 12-022-26 W4M (WSW Nos. 2 and 85-5) and in 2002 licensed for a total of 64 m³/day; one water supply well in NE 12-022-26 W4M (WSW No. 97-1) is licensed for 162.2 m³/day, and two water supply wells in SW 07-022-25 W4M (WSW No. 85-3 and Obs WW No. 85-3) are licensed for a total of 74.4 m³/day. One of the two water wells in SW 07 is used as an observation water well for standby purposes.

From 1975 to 1992, WSW No. 1 in SE 12-022-26 W4M was licensed to divert 33 m³/day, and by 1994 was no longer being used as a water supply well by the Hamlet of Carseland. The use of the water supply well was probably discontinued in 1992 or 1993 with the completion of WSW No. 93-1 in NE 12-022-26 W4M. On September 21, 1992, a water well was drilled in NE 12-022-26 W4M to be used for municipal purposes and was completed from 69.2 to 75.3 metres below ground surface. A second water well was drilled on September 25, 1992 and was completed from 71.9 to 76.5 metres below ground surface to used as an observation water well. The water well drilled on September 21, 1992 was reconstructed in November 1993, and was recompleted from 65.8 to 70.4 metres below ground surface, according to the driller's comments on the drilling record. Presumably, this water well became WSW No. 93-1. However, according to the AENV licensing database, a water well having a completion interval from 69.2 to 75.3 metres below ground surface is the water supply well that is currently licensed to divert 162 m³/day. In April 1997, WSW No. 97-1 was drilled and completed from 69.2 to 73.8 metres below ground surface, according to the information provided by Wheatland County. The driller's log for WSW No. 97-1 is not in the AENV database and the completion information for WSW No. 97-1 provided by Wheatland is in text form only. The available monitoring data provided by the County are from 1996 to 2000 and show that recorded production data are from WSW No. 2, WSW No. 85-3, WSW No. 85-5 and from WSW Nos. 93-1/97-1. Water levels are being measured in Obs WW Nos. 85-1, 85-3, 85-4 and 93-1. The graphical information provided by CH2M Hill also indicates that, since 1994, the groundwater monitoring program by the Hamlet of Carseland has not changed.

In each year from 1986 to 1992, the water level in AENV Obs WW No. 220 declined approximately three metres during peak groundwater demand by Carseland in the summer and rose each fall and winter to a level that was between 0.5 to 1.0 metres less than the drawdown of the previous summer. The total licensed amount from the Carseland water supply wells from 1986 to 1992 was 472 m³/day. In 1992, the range of water-level fluctuations in AENV Obs WW No. 220 decreased from three metres to one metre, which may be a result of the completion of the water wells in September 1992. In mid-1993, the lowest water level declined from the lowest water level measured in 1992, which may be a result of increased diversion from WSW No. 93-1. The characteristics of the fluctuations in AENV Obs WW No. 220 from 1992 to 1996 changed in early 1997. From early 1997 to the end of the monitoring period in 2000, the water level in AENV Obs WW No. 220 declined more than three metres. This decline that began in early 1997 may be a result of the groundwater diversion from WSW No. 97-1.

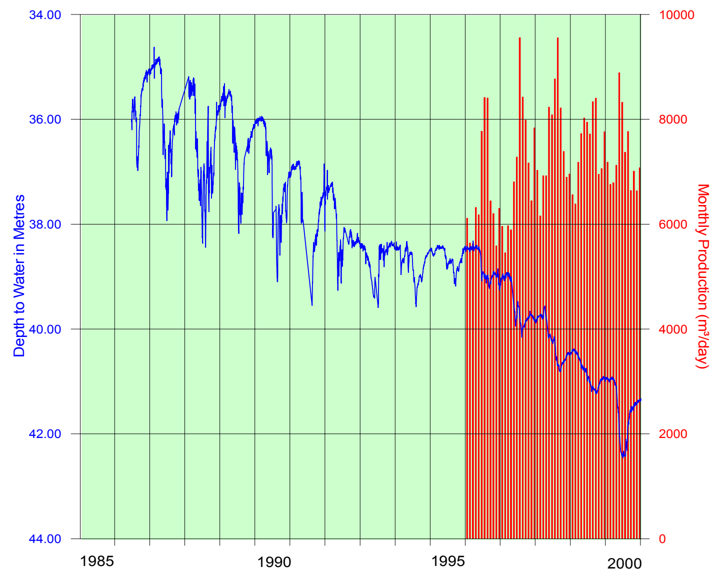

Figure 32. Groundwater Production in Carseland WSWs vs Water Levels in AENV Obs WW No. 220

A mathematical model called the *Infinite Aquifer Artesian Model* (IAAM)[20] was used to calculate water levels at a location corresponding to AENV Obs WW No. 220 based on estimated groundwater production from 1969 to 1995 and on the monthly recorded groundwater production from each of the four current producing water supply wells from 1996 to 2000. The locations of the Carseland water wells shown on the site map in Figure 31 were digitized in order to create a reasonable model aquifer. The model aquifer has an effective transmissivity of 12 m²/day, a corresponding storativity of 0.00005, is homogeneous and isotropic, and behaves as an aquifer of infinite areal extent; the model does not account for recharge to the aquifer. Therefore, if there were a decrease in recharge to the groundwater, a water-level decline could occur and the simulation would not account for the change.

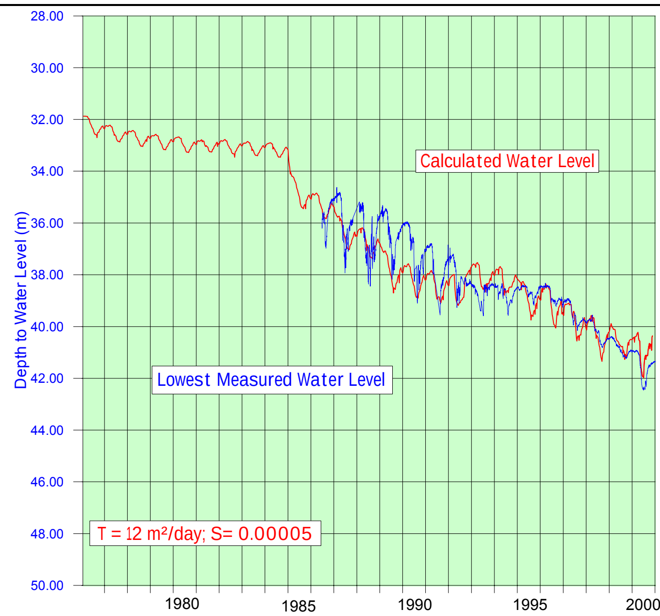

Figure 33. Water-Level Comparison - AENV Obs WW No. 220

Despite the limited data available, there is a reasonable degree of comparison between the calculated and measured water levels in AENV Obs WW No. 220.

[20] See glossary

6.2 Estimated Water Use from Unlicensed Groundwater Users

An estimate of the quantity of groundwater removed from each geologic unit in Wheatland County must include both the licensed diversions and the unlicensed use. As stated previously on page 6 of this report, the daily water requirement for livestock for the County based on the 2001 census is estimated to be 19,150 cubic metres. Of the 19,150 m³/day required for livestock, 6,713 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 12,437 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 3,566 water wells that are used for domestic/stock purposes. These 3,566 water wells include both licensed and unlicensed water wells. Of the 3,566 water wells, 408 water wells are used for stock, 566 are used for domestic/stock purposes, and 2,592 are for domestic purposes only.

There are 944 water wells that are used for stock or domestic/stock purposes (Table 16). There are 149 licensed groundwater users for agricultural (stock) purposes, giving 825 unlicensed stock water wells. (Please refer to Table 1 on page 6 for the breakdown by aquifer of the 202 licensed stock groundwater users). By dividing the number of unlicensed stock and domestic/stock water wells (825) into the quantity of groundwater required for stock purposes that is not licensed (12,437 m³/day), the average unlicensed water well diverts 15.1 m³/day for stock purposes. 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 15.1 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 (a family of four) is 1.1 m³/day. Since there are 3,158 domestic water wells in Wheatland County serving a population of 7,240, the domestic use per water well is 0.6 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	0.6 m³/day
Stock	15.1 m³/day
Domestic/stock	15.7 m³/day

Based on using all available domestic, domestic/stock, and stock water wells and corresponding calculations, the following table was prepared. Table 16 on the following page shows a breakdown of the 3,566 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 Table 16 indicate that most of the 11,975 m³/day, estimated to be diverted from unlicensed domestic, stock, or domestic/stock water wells, is from multiple bedrock completions or the Upper Horseshoe Canyon Aquifer.

Aquifer Designation	Unlicensed and Licensed Groundwater Diversions							Licensed Groundwater Diversions	Unlicensed Groundwater Diversions
	Number of Domestic	Daily Use (0.6 m³/day)	Number of Stock	Daily Use (15.1 m³/day)	Number of Domestic and Stock	Daily Use (15.7 m³/day)	Totals m³/day	Totals (m³/day)	Totals m³/day
Multiple Surficial Completions	188	108	28	422	29	453	983	0	983
Upper Sand/Gravel	80	46	10	151	8	125	321	129	193
Lower Sand/Gravel	131	75	9	136	4	63	273	150	123
Multiple Bedrock Completions	441	253	101	1,521	120	1,876	3,649	538	3,115
Lower Lacombe	167	96	17	256	30	469	821	122	699
Haynes	245	140	50	753	50	782	1,675	759	918
Upper Scollard	239	137	49	738	77	1204	2,078	900	1,181
Lower Scollard	141	81	22	331	44	688	1,100	728	373
Upper Horseshoe Canyon	366	210	49	738	103	1610	2,557	184	2,376
Middle Horseshoe Canyon	179	103	23	346	36	563	1,012	73	940
Lower Horseshoe Canyon	106	61	13	196	22	344	600	139	462
Bearpaw	6	3	0	0	1	16	19	0	19
Unknown	303	174	37	557	42	656	1,387	796	593
Totals (1)	2,592	1,486	408	6,143	566	8,847	16,475	4,518	11,975

(1) The values given in the table have been rounded and, therefore, the columns and rows may not add up equally

Table 16. Unlicensed and Licensed Groundwater Diversions

By assigning 0.6 m³/day for domestic use, 15.1 m³/day for stock use and 15.7 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 map has been prepared that shows the estimated groundwater use in terms of volume (licensed plus unlicensed) per section per day for the County (not including springs).

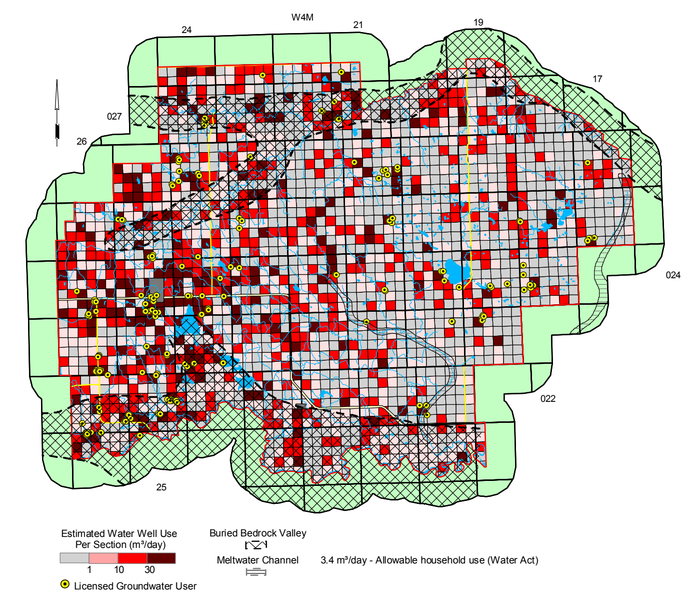

Figure 34. Estimated Water Well Use Per Section

There are 2,040 sections in the County. In 23% (926) of the sections in the County, there is no domestic or stock or licensed groundwater user. The range in groundwater use for the remaining 1,114 sections with groundwater use is from 0.6 m³/day to more than 440 m³/day, with an average use per section of 17 m³/day (2.6 igpm). The estimated water well use per section can be more than 30 m³/day in 208 of the 1,114 sections. There is at least one licensed groundwater user in 40 of the 208 sections. The most notable areas where water well use of more than 30 m³/day is expected to occur is mainly in the vicinity of the Town of Strathmore, as shown on Figure 34.

Groundwater Use within Wheatland County (m³/day)		%
Domestic/Stock (licensed and unlicensed)	16,475	92
Municipal (licensed)	584	3
Commercial/Dewatering/Exploration et al (licensed)	778	4
Total	17,837	100

Table 17. Total Groundwater Diversions

In summary, the estimated total groundwater use within Wheatland County is 17,837 m³/day, with the breakdown as shown in the adjacent table. An estimated 15,841 m³/day is being withdrawn from a specific aquifer. The remaining 1,996 m³/day or 11% is being withdrawn from unknown aquifer units. Approximately 33% of the total estimated groundwater use is from licensed water wells. Of the 17,837 m³/day, 78% is being diverted from bedrock aquifers, 10% from surficial aquifers, and 11% from unknown aquifers.

6.3 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; flow through the aquifers takes into consideration hydrogeological conditions outside the County border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 18.

Table 18 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Haynes Aquifer. However, even where use is less than the calculated aquifer flow, there can still be local impacts on water levels as shown by the groundwater monitoring in the Carseland area. The calculations of flow through individual aquifers as presented in the adjacent table are very approximate and are intended only as a guide for future investigations.

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)
Upper Surficial					14,300	139	182	321
southeast	58	0.0062	40,000	14277				
Lower Surficial					4,000	430	0	430
Rosebud River low								
west to east	91	0.0029	5,000	1300				
Serviceberry Creek low								
west to east	91	0.0032	5,000	1456				
Buried Calgary Valley								
west to east	91	0.0017	8,000	1213				
Lower Lacombe					2,800	125	696	821
Northern								
north	28	0.007	15,000	2800				
Haynes					800	883	792	1,675
Northern								
north	10	0.004	20,000	750				
Upper Scollard					9,700	966	1,112	2,078
Serviceberry Basin								
northeast	21	0.010	8,000	1680				
northwest	21	0.010	20,000	4200				
southeast	21	0.010	2,000	420				
Eagle Lake Basin								
northeast	21	0.004	15,000	1350				
southeast	21	0.004	8,000	672				
southwest	21	0.004	16,000	1344				
Lower Scollard					8,020	728	372	1,100
Western								
northwest	33	0.004	32,000	3840				
Eagle Lake Basin								
northeast	33	0.003	16,000	1760				
southeast	33	0.003	9,000	990				
southwest	33	0.003	13,000	1430				
Upper Horseshoe Canyon					13,460	265	2,293	2,558
North eastern								
north	23	0.003	20,000	1150				
South								
south	23	0.003	40,000	2300				
Western								
north	23	0.005	25,000	2875				
Crowfoot Basin								
northeast	23	0.003	20,000	1380				
souteast	23	0.001	20,000	575				
east	23	0.008	30,000	5175				
Middle Horseshoe Canyon					12,710	147	865	1,012
Northeast								
northeast	22	0.004	15,000	1238				
northwest	22	0.003	15,000	880				
southeast	22	0.003	15,000	825				
South								
south	22	0.006	30,000	3960				
east	22	0.003	13,000	715				
West								
northeast	22	0.002	40,000	1760				
Crowfoot Basin								
northeast	22	0.004	22,000	1815				
southeast	22	0.002	10,000	440				
southwest	22	0.004	13,000	1073				
Lower Horseshoe Canyon					6,000	176	424	600
Northeast								
northeast	30	0.001	60,000	2400				
Southeast								
south	30	0.002	60,000	3600				

Table 18. Groundwater Budget

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the surficial deposits is 0.5 to 3.1 cubic kilometres. This volume is based on an areal extent of 2,060 square kilometres and a saturated thickness of five metres. The variation in the total volume is based on the value of porosity that is used for the surficial deposits. 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 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 (indicated by grey areas on the map). The water-level map for the surficial deposits shows a general flow direction toward the Bow River and Serviceberry Creek.

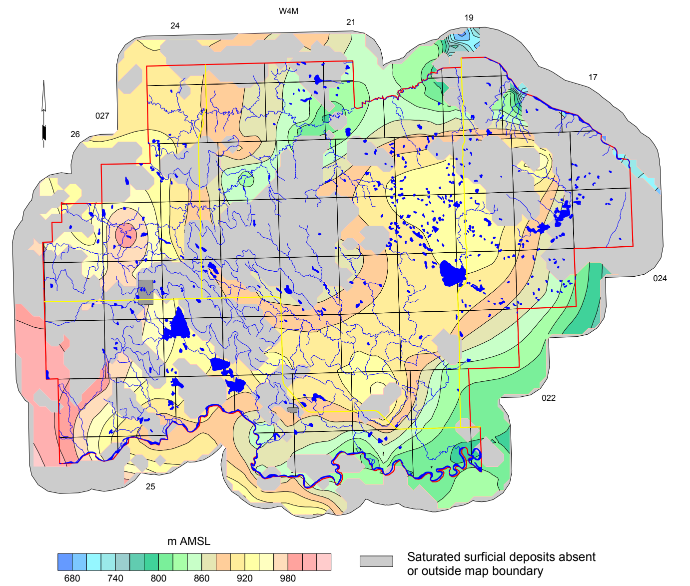

Figure 35. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

6.3.2 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 hydraulic unit. 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.

6.3.2.1 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. 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.

In the absence of sufficient water-level data in the surficial deposits, a reasonable hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) could not be determined. Therefore, the first objective was to determine the location of springs, flowing shot holes and any water wells that had a water level measurement depth of less than 0.1 metres. These locations would reflect where there is an upward hydraulic gradient from the bedrock to the surficial deposits (i. e. discharge). The depth to water level for water wells completed in 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 bedrock surface. This resulting depth to water level grid was contoured to reflect the positioning of springs, flowing shot holes and flowing water wells (i. e. discharge). The recharge classification is used where the water level in the upper bedrock aquifer(s) is more than two metres below bedrock surface. The discharge areas are where the water level in the upper bedrock aquifer(s) is more than ten metres above the bedrock surface. When the depth to water level in the upper bedrock aquifer(s) is between two metres below and ten metres above the bedrock surface, the area is classified as a transition, that is, no recharge and no discharge.

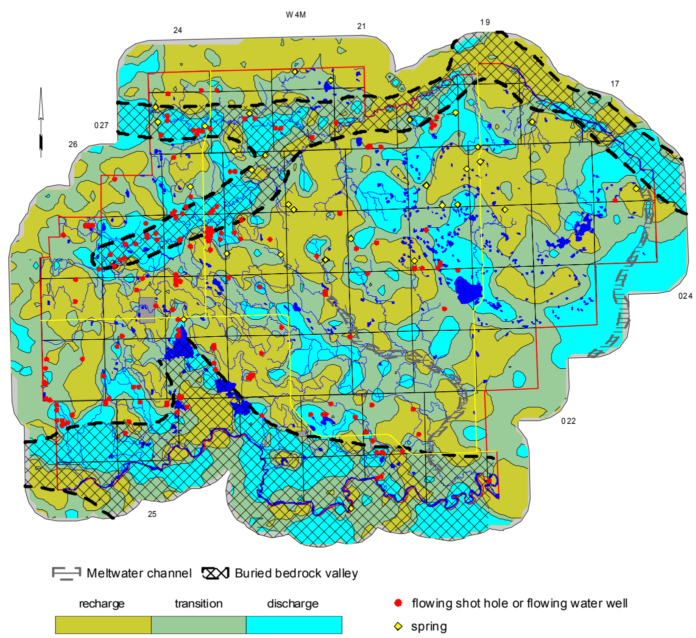

Figure 36. Recharge/Discharge Areas in Upper Bedrock Aquifer(s)

Figure 36 shows that, in more than 50% of the County, there is a downward hydraulic gradient from the bedrock surface toward the upper bedrock aquifer(s) (i. e. recharge). Areas where there is an upward hydraulic gradient from the bedrock to the bedrock surface (i. e. discharge) are mainly in the vicinity of creeks and river valleys and major meltwater channels. The remaining parts of the County are areas where there is a transition condition.

Because of the paucity of data, recharge/discharge maps for the individual bedrock aquifers have not been attempted.

With 70% of the County land area being one of recharge to the bedrock, and the average precipitation being 340 mm per year, 1.6% of the annual precipitation is sufficient to provide the total calculated quantity of groundwater flowing through the upper bedrock aquifer(s).

6.4 Areas of Groundwater Decline

In order to determine the areas of possible groundwater decline in the sand and gravel aquifer(s), the available non-pumping water-level elevation for each water well completed in the sand and gravel aquifer(s) was first sorted by location, and then by date of water-level measurement. The dates of measurements were required to differ by at least 365 days. Only the earliest and latest control points at a given location were used.

The areas of groundwater decline in the sand and gravel aquifer(s) have been calculated by determining the frequency of non-pumping water level control points per five-year period from 1960 to 2000. Of the 207 surficial water wells with a non-pumping water level and date in the County, 76 are from water wells completed before 1975 and 131 are from water wells completed after 1980.

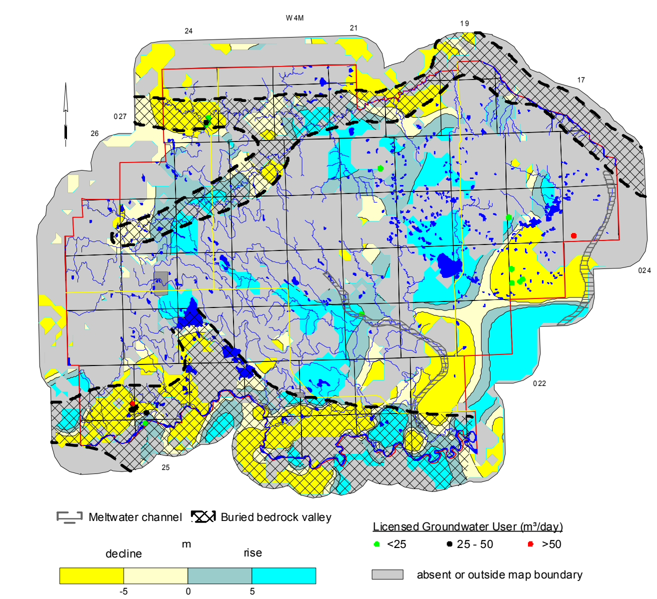

Figure 37. Changes in Water Levels in Sand and Gravel Aquifer(s)

Where the earliest water level (before 1975) is at a higher elevation than the latest water level (after 1980), there is the possibility that some groundwater decline has occurred. The adjacent map suggests that there has been a decline in the NPWL in areas of linear bedrock lows.

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 surficial 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 map.

Estimated Water Well Use (m³/day)	*% of Area with More than a 5-Metre Decline*
<10	*21*
10 to 30	*21*
>30	*9*
no use	*49*

Table 19. Water-Level Decline of More than 5 Metres in Sand and Gravel Aquifer(s)

Figure 37 indicates that in 50% of the County where sand and gravel is present, it is possible that the non-pumping water level has declined. The Hamlet of Carseland is in one of the areas of decline shown on Figure 36. AENV Obs WW No. 220 in 13-06-022-25 W4M is in this area of water-level decline. The hydrograph from AENV Obs WW No. 220 indicates that there has been a water-level decline since 1986. Of the 23 licensed groundwater users that are completed in sand and gravel aquifer(s), 19 occur in areas where a water-level decline may exist and two licensed groundwater users occur in an area of rise. There are two licensed groundwater users that are shown in township 025, range 17, W4M; although this is an area where saturated sand and gravel deposits are expected to be absent, the absence may reflect the nature of gridding a limited number of control points. The areas of groundwater decline in the sand and gravel aquifer(s) where there is no estimated water well use suggest that groundwater diversion is not having an impact and that the decline may be due to variations in recharge to the aquifer.

In areas where a water-level decline of more than five metres is indicated on Figure 37, 49% of the areas has no estimated water well use; 21% of the use is less than ten m³/day; 21% of the use is between 10 and 30 m³/day per section; the remaining 9% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown previously in Table 19.

Of the 4,101 bedrock water wells with a NPWL and test date, 1,591 are from water wells completed before 1975 and 1,697 are from water wells completed after 1980. The adjacent map indicates that in more than 50% of the County, it is possible that the NPWL has declined. It may have been possible there has been a decline in the NPWL in areas of linear bedrock lows and near areas of discharge. Of the 146 groundwater users completed in upper bedrock aquifer(s) that are authorized to divert less than 50 m³/day, most occur in areas where a water-level rise exists. The two bedrock-completed AENV Obs WWs (Nos. 218 and 219) in 05-10-022-21 W4M are in one area of water-level rise. The hydrographs from these two observation water wells indicate that there was a water-level rise from 1991 to 1997.

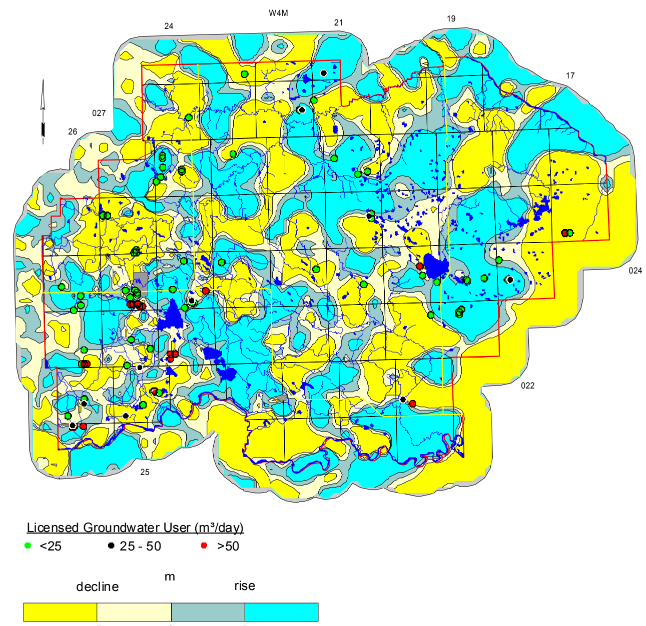

Figure 38. Changes in Water Levels in Upper Bedrock Aquifer(s)

In areas where a water-level decline of more than five metres is indicated on Figure 38, 46% of the areas has no estimated water well use; 26% is less than ten m³/day; 19% is between 10 and 30 m³/day per section; the remaining 9% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown below in Table 20.

Estimated Water Well Use (m³/day)	*% of Area with More than a 5-Metre Decline*
<10	*26*
10 to 30	*19*
>30	*9*
no use	*46*

Table 20. Water-Level Decline of More than 5 Metres in Upper Bedrock Aquifer(s)

The areas of groundwater decline in the upper bedrock aquifer(s) where there is no estimated water well use suggest that groundwater production is not having an impact and that the decline may be due to variations in recharge to the aquifer.

6.5 Discussion of Specific Study Areas

As per the Request for Proposal, Wheatland County requested that comments be made, where possible, on the following four study areas and issues. The issue is stated at the beginning of each of the following sections. Figure 39 shows the four specific study areas in the County; in Figure 40, the four specific study areas have been color outlined on the bedrock geology map; Figure 41 shows the apparent yield for water wells completed in the Sand and Gravel Aquifer(s); and Figure 42 shows the apparent yield for water wells completed in the Upper Bedrock Aquifer(s).

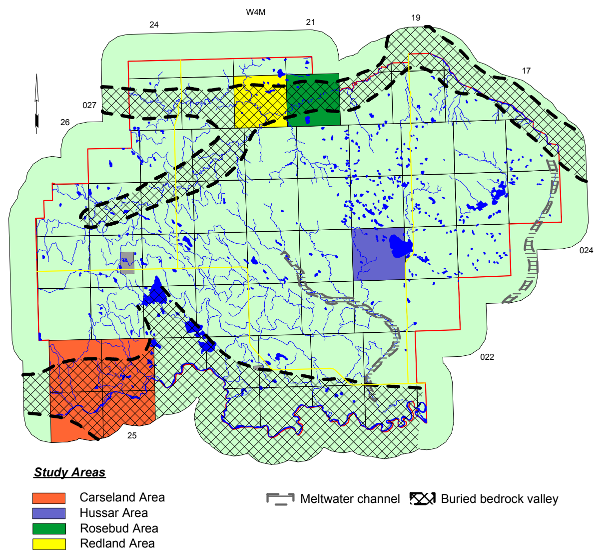

Figure 39. Specific Study Areas

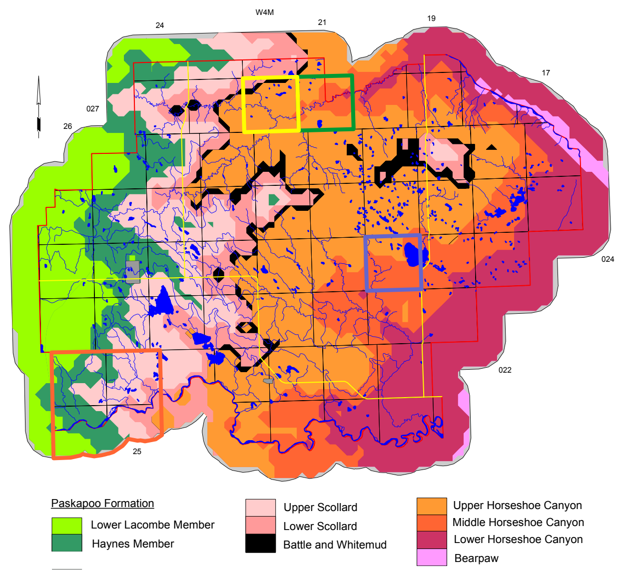

Figure 40. Bedrock Geology of Specific Study Areas

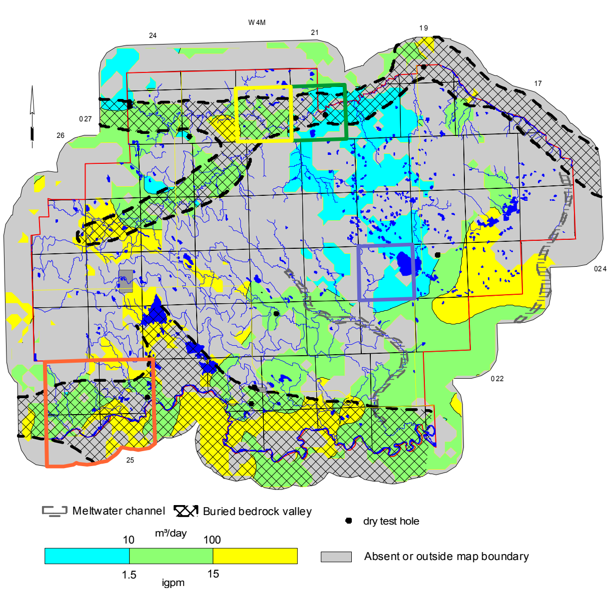

Figure 41. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) - Specific Study Areas

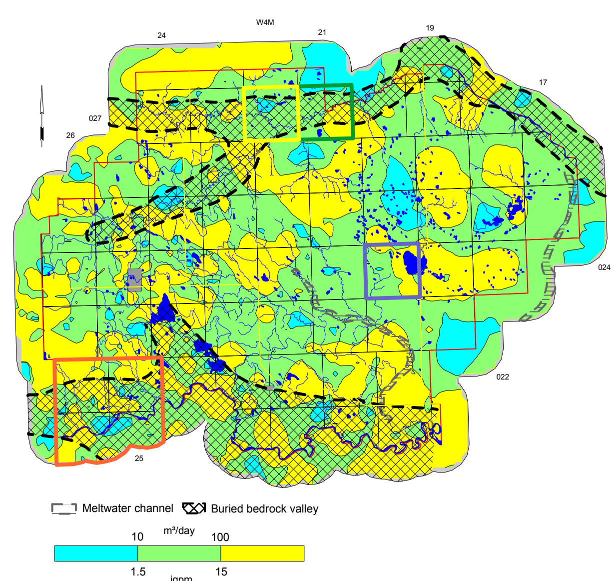

Figure 42. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) - Specific Study Areas

6.5.1 Carseland Area

What are the possible causes of the apparent reduction in yields of aquifers in this area?

The Hamlet of Carseland is licensed to divert a total of 300 m³/day from five licensed water supply wells that are completed in the Lower Sand and Gravel Aquifer (see Table 15, page 42).

The available monitoring data provided by the County are from 1996 to 2000 and show that production data are recorded daily from WSW No. 2, WSW No. 85-3, WSW No. 85-5 and WSW Nos. 93-1/97-1. Water levels are being measured weekly to the nearest 0.01 metres in Obs WWs 85-1, 85-3, 85-4 and 93-1.

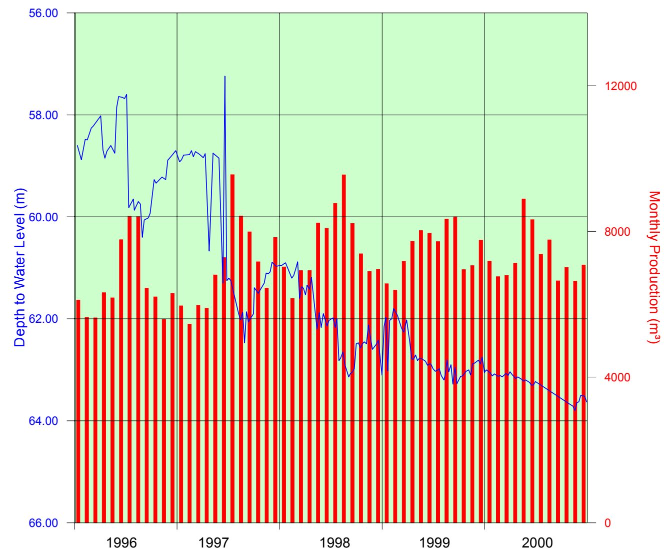

Figure 43. Groundwater Production vs Water Levels in Obs WW No. 93-1

From 1996 to 2000, the water level in all four of the Carseland Obs WWs declined approximately five to six metres. From 1996 to 1998, the maximum water-level decline during peak production ranged between two and three metres per year in Obs WW No. 93-1. In 1999 and 2000, the water level in Obs No. 93-1 declined in the order of one metre. The decrease in the rate of water-level decline in 1999 and 2000 may be a result of decreased groundwater production during the months of peak demand.

	Annual Groundwater Production (m³)					
WSW No.	1996	1997	1998	1999	2000	Total
2	9,992	10,304	7,588	7,907	3,770	39,561
85-3	15,773	19,652	13,881	14,544	17,868	81,718
85-5	6,996	8,349	6,324	7,972	14,976	44,617
93-1/97-1	45,422	46,485	63,344	59,107	50,955	265,313
Total	78,183	84,790	91,137	89,530	87,569	431,209

Table 21. Carseland WSW Groundwater Production

From 1996 to 2000, the majority of the groundwater diverted from the Carseland water supply wells was from WSW No. 97-1. The aquifer model, *IAAM,* was used to calculate water levels at a location corresponding to Obs WW No. 93-1. The model is based on the estimated groundwater production from 1969 and the monthly recorded groundwater production from each of the four producing water supply wells. The model aquifer has an effective transmissivity of 34 m²/day, a corresponding storativity of 3 x 10^{-5}, is homogeneous and isotropic, and behaves as an aquifer of infinite areal extent; the model does not account for recharge to the aquifer.

The adjacent figure shows there is a reasonable degree of comparison between the calculated and measured water levels in Obs WW No. 93-1 from mid-1996 to mid-1998.

However, in late 1998 to 2000, the difference between the calculated and measured water levels increased to as much as three metres. The difference between measured and calculated water levels indicates that, from the present understanding of the local hydrogeology, the continued water-level decline in all four Carseland Obs WWs is a result of overuse of the Lower Sand and Gravel Aquifer in the Carseland Area.

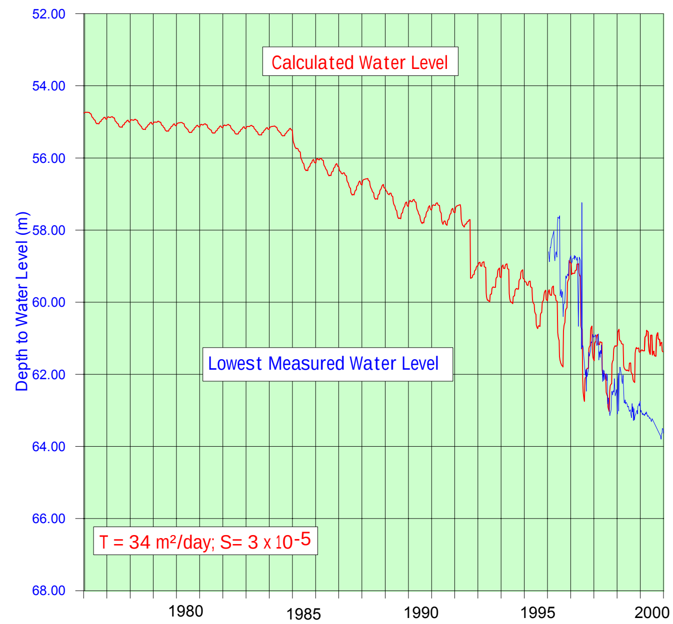

Figure 44. Water-Level Comparison - Obs WW No. 93-1

The closest licensed groundwater water wells to the Carseland WSWs are three water supply wells in NW 05-022-25 W4M, more than 2 kilometres east of the Hamlet of Carseland. These three water supply wells completed in 1993 and 1994 in the Lower Sand and Gravel Aquifer have been licensed to divert up to 72.2 m³/day since 1999 for agricultural (feedlot) purposes.

In view of the water levels continuing to decline, it is recommended that the Hamlet of Carseland investigate supplementing their present groundwater supply. There are indications that a significant aquifer may be present in the Upper Scollard Aquifer. The results of an extended aquifer test conducted with a water supply well completed in the Upper Scollard Aquifer in SE 16-022-26 W4M indicated a long-term yield of 60 m³/day. The depth to the top of the Upper Scollard in the Hamlet of Carseland is about 70 metres below ground surface.

However, a test-drilling program would be needed to evaluate the Upper Scollard Aquifer in the Carseland area.

6.5.2 Hussar Area

The Village of Hussar is in an area of low apparent groundwater yields. Is there an alternative groundwater supply?

The Village of Hussar is licensed to divert a total of 131.8 m³/day from four water supply wells, as shown below in Table 22.

WSW No.	Licensed Diversion (m³/day)	Legal	Completed Date	Completion Aquifer
#N/A	13.5	02-13-024-20 W4M	Aug-74	Middle Horseshoe Canyon
91-1	16.9	13-14-024-20 W4M	Apr-91	Middle Horseshoe Canyon
Old Brown No. 1	50.7	16-22-024-20 W4M	Dec-78	Upper Horseshoe Canyon
New Brown No. 2 (91-2)	50.7	16-22-024-20 W4M	Apr-91	Upper Horseshoe Canyon

Table 22. Village of Hussar Licensed WSW

Groundwater monitoring data from 1992 to 2000 were provided to HCL by the Village of Hussar. The data show that combined production data from Old Brown WSW No. 1 (WSW No. 1) and Old Brown WSW No. 2 (WSW No. 2) are recorded monthly; the annual groundwater production from 1992 to 2000 is given in the adjacent table. Water levels were recorded in WSW No. 1 seven times in 1994 and four times in 1995; in 2000, water levels were measured three times in WSW Nos. 1 and 2.

Year	Total Groundwater Production (m³/day) WSW No.1 and WSW No. 2
1992	19,893
1993	21,207
1994	21,892
1995	23,416
1996	21,715
1997	22,596
1998	25,786
1999	21,122
2000	23,155
Total	200,782

Table 23. Groundwater Production

The aquifer model, *IAAM,* was used to calculate water levels at a location corresponding to WSW No. 1. The model is based on the combined monthly recorded groundwater production from WSW Nos. 1 and 2. The model aquifer has an effective transmissivity of 30 m²/day, a corresponding storativity of 0.001, is homogeneous and isotropic, and behaves as an aquifer of infinite areal extent; the model does not account for recharge to the aquifer.

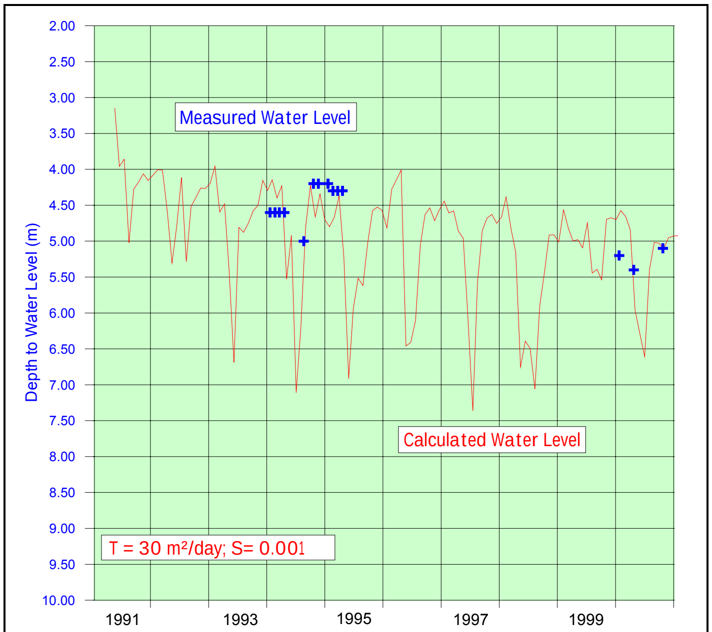

Figure 45. Water-Level Comparison – WSW No. 1

The adjacent figure shows there is a reasonable degree of comparison between the calculated and measured water levels in WSW No. 1.

In 2000, the average pumping from WSW Nos. 1 and 2 was 65 m³/day. The Hussar population of 157 has remained unchanged since at least 1997 (Phinney 1998, 2001-2002). Based on a continued average pumping rate of 65 m³/day for the next 20 years, an apparent transmissivity of 30 m²/day and a corresponding storativity of 0.001, the water level will decline to 5.6 metres below ground surface. If the combined pumping from WSW Nos. 1 and 2 is increased to the maximum licensed amount of 101.4 m³/day, the water level will decline to 7.78 metres below ground surface, or 76% of the available drawdown.

Water Supply Well Nos. 1 and 2 are the only two water wells in the Hussar Area that are completed in the Upper Horseshoe Canyon Aquifer. The Upper Horseshoe Canyon is of limited extent in the Hussar Area. WSW No. 1 is completed in shale and sandstone from 11.8 to 18.2 metres below ground surface and has an apparent yield of 105 m³/day. WSW No. 2 is completed in sandstone from 14.0 to 16.8 metres below ground surface and has an apparent yield of 340 m³/day. The closest water well outside the Hussar Area and completed in the Upper Horseshoe Canyon Aquifer is approximately four kilometres north in 04-04-025-20 W4M, and has an apparent yield of 320 m³/day.

The Middle Horseshoe Canyon Aquifer is present throughout the Hussar Area. The depth to the top of the Middle Horseshoe Canyon Formation is 18 metres below ground surface. In the Hussar Area, the expected apparent yield of water wells completed in the Middle Horseshoe Canyon Aquifer is in the order of 170 m³/day.

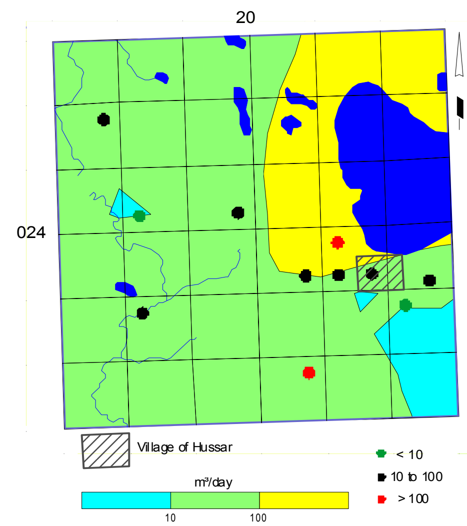

Figure 46. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer – Hussar Area

The depth to the top of the Lower Horseshoe Canyon Formation in 16-22-024-20 W4M is 75 metres below ground surface. In the Hussar Area, the expected apparent yield of water wells completed in the Lower Horseshoe Canyon Aquifer is in the order of 26 m³/day.

Based on the available data, apparent yields are expected to be the highest in the Upper Horseshoe Canyon Aquifer, which is the Aquifer in which the Hussar WSW Nos. 1 and 2 are completed. It is further recommended that monitoring of groundwater water levels be intensified to provide better data for assessing the long-term sustainability of the aquifers in the Hussar Area. Also, a more detailed assessment of groundwater availability in the general areas should be undertaken, using the present regional assessment as a starting point.

6.5.3 Rosebud and Redland Areas

The Rosebud and Redland areas are adjacent to each other (see Figure 39) and in this report the two areas have been grouped together for purposes of discussion. The Rosebud Area is township 027, range 21, W4M and the Redland Area is township 027, range 22, W4M.

What is the approximate extent and potential (yield and water quality) of the aquifers in the Redland area?

The upper bedrock in the Redland and Rosebud areas is the upper and middle parts of the Horseshoe Canyon Formation.

In the Rosebud area, the Upper Horseshoe Canyon Aquifer is mainly absent (Figure 47). The expected yield for water wells completed in the Upper Horseshoe Canyon Aquifer in the Rosebud area is less than ten m³/day. Higher apparent yields are expected for water wells completed in the Upper Horseshoe Canyon Aquifer in the Redland area. However, the majority of the control points are in township 027, range 22, W4M in the Redland area (Figures 47 and 48).

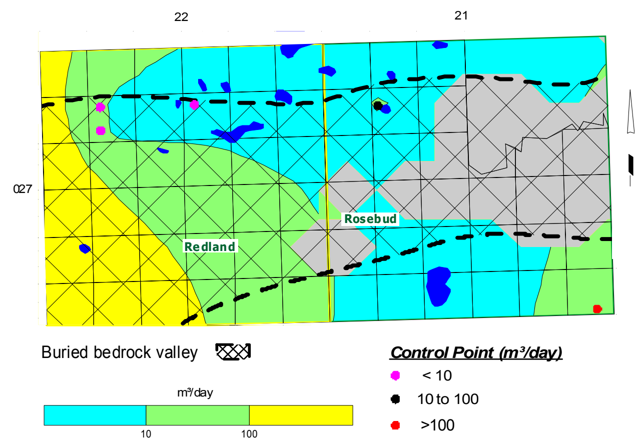

Figure 47. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer - Redland and Rosebud Areas

The depth to the top of the Upper Horseshoe Canyon Formation in 16-14-027-20 W4M is 81 metres below ground surface. The expected apparent yield of water wells completed in the Upper Horseshoe Canyon Aquifer at this location is less than 20 m³/day.

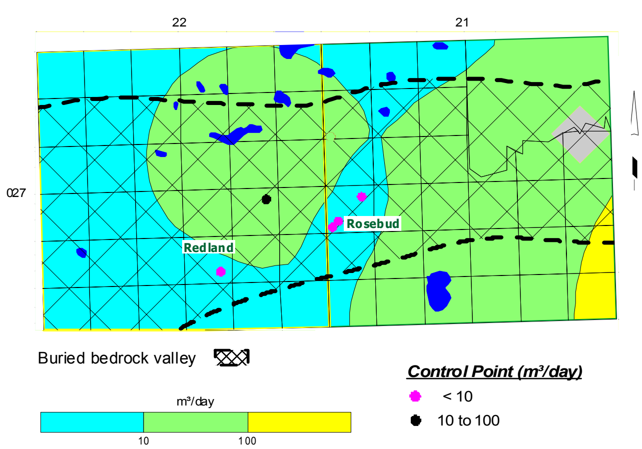

Figure 48. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer – Redland and Rosebud Areas

Groundwaters from water wells completed in the Redland and Rosebud areas in the Upper Horseshoe Canyon Aquifer are expected to have TDS concentrations of 1,130 mg/L.

In the Redland and Rosebud areas, the values for apparent yield for water wells completed in the Middle Horseshoe Canyon Aquifer are less than ten m³/day (Figure 48) except for two Rosebud water supply wells in NE 14-027-22 W4M, which have apparent values of 22.3 and 40.6 m³/day, respectively.

The depth to the top of the Middle Horseshoe Canyon Formation in 16-14-027-20 W4M is 96 metres below ground surface. The expected apparent yield of water wells completed in the Middle Horseshoe Canyon Aquifer at this location is less than 30 m³/day.

Groundwaters from water wells completed in the Redland and Rosebud areas in the Middle Horseshoe Canyon Aquifer are expected to have TDS concentrations of 1,240 mg/L.

The County of Wheatland is licensed to divert a total of 6.8 m³/day for municipal purposes from two water supply wells located within the Rosebud Area in 03-18-027-21 W4M. There is no water well completion information in the AENV licensing database to determine the aquifer in which these two water supply wells are completed.

The County of Wheatland is licensed to divert groundwater from two water wells located within the Redland Area, but are used to supply groundwater to the Hamlet of Rosebud. Water Supply Well No. 1 in 16-14-027-22 W4M is licensed to divert 43.9 m³/day. A second water well (WSW No. 2) in 15-14-027-22 W4M is licensed by the County to be used as a standby water supply well for the Hamlet of Rosebud. Both water supply wells in NE 14-027-22 W4M are completed in the Middle Horseshoe Canyon Aquifer. There are no other licensed water wells completed in the Middle Horseshoe Canyon Aquifer in the Rosebud and Redland areas.

The available monitoring data provided to HCL by Wheatland County for the two Hamlet of Rosebud water supply wells in NE 14-027-22 W4M included two drillers' logs, an aquifer test conducted with WSW No. 1 in August 1995, chemical analyses, and monthly groundwater production for the 2000 monitoring year. In 2000, an average of 27.7 m³/day was diverted. No water-level data were provided by the County.

Water Supply Well No. 1, drilled in October 1987, is completed from 89.9 to 97.5 metres below ground surface in the Middle Horseshoe Canyon Aquifer and had a non-pumping water level of 51.8 metres below ground surface. WSW No. 2, drilled in October 1987, is completed from 91.4 to 97.5 metres below ground surface in the Middle Horseshoe Canyon Aquifer and had a non-pumping water level of 54.0 metres below ground surface.

An aquifer test with WSW No. 1 was conducted on August 21, 1995. The test consisted of 60 minutes of pumping at an average of 56.8 litres per minute and 60 minutes of recovery. The pre-test water level was 59.8 metres below ground surface. The water level drew down 24.6 metres during the pumping interval, with 7.7 metres occurring during the first two minutes of pumping. An effective transmissivity of 3.8 m²/day was obtained from the Jacob analysis of the water-level decline after ten minutes of pumping. After ten minutes of recovery, the water level recovered to within 4.1 metres of its pre-test water level. The effective transmissivity value calculated from the recovery data is 10.7 m²/day. The aquifer parameters obtained from the aquifer test with WSW No. 1 indicate that WSW No. 1 has a projected long-term yield of 39 m³/day, close to the licensed amount of 43.9 m³/day.

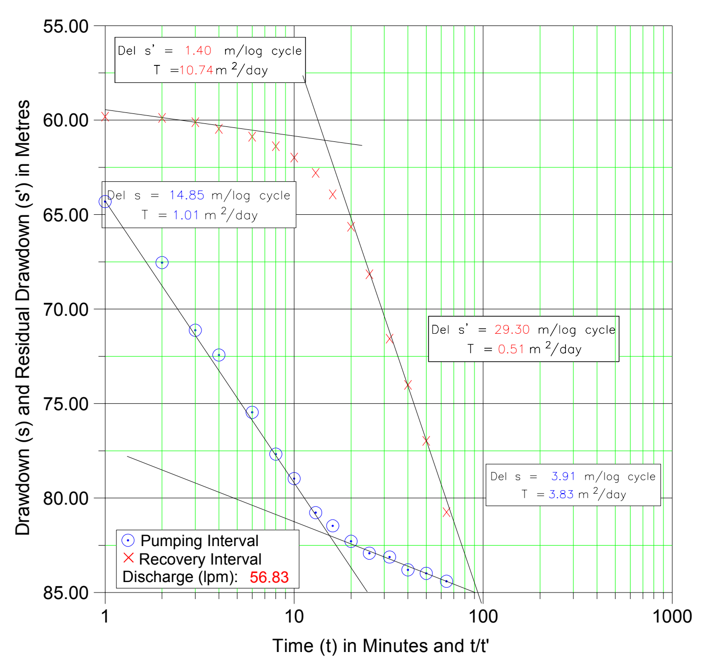

Figure 49. Aquifer Test with WSW No. 1

A groundwater sample collected in December 1998 from WSW Nos. 1 and 2 in NE 14-027-22 W4M has a TDS concentration of 1,018 mg/L, a sulfate concentration of 105 mg/L, a chloride concentration of 31.3 mg/L, and a fluoride concentration of 0.84 mg/L.

The water level recorded prior to the aquifer test with WSW No. 1 in 1995 is eight metres lower than the non-pumping water level measured in WSW No. 1 in 1987. Additional groundwater monitoring data would need to be made available in order to provide a reasonable interpretation regarding the apparent water-level decline at the sites of WSW Nos. 1 and 2.

What comments can be made regarding the apparent water-level decline in the aquifer supplying the Rosebud community.

Water-level monitoring data from the two Hamlet of Rosebud water supply wells would need to be provided in order to determine if there has been a water-level decline.

It might be beneficial to the Hamlet of Rosebud to field-verify the water wells within the Area. The level of verification should include obtaining meaningful horizontal coordinates for the water wells and verifying the water level and completed depth.

7. 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 122 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. There are 13 water wells for which the County has responsibility, of which eleven satisfy the above criteria; the 13 County-operated water wells are included in Appendix E. It is recommended that these 13 County-operated water wells plus the 122 water wells be field-verified, water levels be measured, a water sample be collected for analysis, and a short aquifer test be conducted. An attempt to update the quality of the entire database is not recommended.

Before an attempt is made to provide a major upgrade to the level of interpretation provided in this report, the accompanying maps and the groundwater query, it is recommended that the 122 water wells listed in Appendix E for which water well drilling reports are available, plus the 13 County–operated water wells, 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.

This additional information would provide a baseline to be used for comparison to either existing chemical analyses or aquifer tests, or to determine if future monitoring would be necessary if significant changes in the aquifer parameters had occurred.

A list of the 133 water wells that could be considered for the above program is given in Appendix E and on the CD-ROM.

An attempt to link the AENV groundwater and licensing databases was 67% successful in this study (see CD-ROM); thirty-three percent 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 to determine the aquifer in which the licensed water wells are completed.

While there are a few areas where water-level data are available at different times, 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 were being provided with a tax credit if they accurately measured 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 (Buchanan, Bob (editor). Alberta Agriculture, Food and Rural Development, 1996).

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.

Communities that are concerned about apparent water-level declines in the aquifers in which their water supply wells are completed should implement a conscientious groundwater monitoring program.

In the case of the four specific study areas, the results of the present study indicate the following conclusions and recommendations:

- Area 1

In view of the continued water-level decline in the Hamlet of Carseland observation water wells, it is recommended that the Hamlet of Carseland investigate supplementing their present groundwater supply. There are indications that an alternative groundwater supply to the Lower Sand and Gravel Aquifer may be present in the Upper Scollard Aquifer. However, a test-drilling program would be needed to evaluate the Upper Scollard Aquifer in the Carseland area.

- Area 2

Based on the available data, apparent yields are expected to be the highest in the Upper Horseshoe Canyon Aquifer, which is the Aquifer in which the Hussar WSW Nos. 1 and 2 are completed. It is recommended that an engineer be consulted, if the Village of Hussar is considering a water supply from a rural pipeline.

It is further recommended that monitoring of groundwater water levels be intensified to provide better data for assessing the long-term sustainability of the aquifers in the Hussar Area. Also, a more detailed assessment of groundwater availability in the general areas should be undertaken, using the present regional assessment as a starting point.

- Areas 3 and 4

Additional water-level monitoring data from the two Hamlet of Rosebud water supply wells is needed to determine if there has been a water-level decline.

The upper bedrock in the Redland and Rosebud areas is the upper and middle parts of the Horseshoe Canyon Formation. In the Rosebud area, the expected yield for water wells completed in the Upper Horseshoe Canyon Aquifer is less than ten m^3/day. Slightly higher apparent yields are expected for water wells completed in the Upper Horseshoe Canyon Aquifer in the Redland area.

The depth to the top of the Middle Horseshoe Canyon Formation in 16-14-027-20 W4M is 96 metres below ground surface. The expected apparent yield of water wells completed in the Middle Horseshoe Canyon Aquifer is less than 30 m^3/day.

A more detailed assessment of groundwater availability in the general areas should be undertaken, using the present regional assessment as a starting point. The assessment should include field-verification of water wells within the immediate area of Redland and Rosebud; verification should include obtaining meaningful horizontal coordinates for the water well(s), a present water level in the water well(s) and a confirmation of the completed depth(s).

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.

In summary, for the next level of study, the database needs updating. The updating of information for existing water wells requires more details for the water wells listed in Appendix E; the additional information for new water wells is mainly better spatial control.

Groundwater is a renewable resource and it must be managed.

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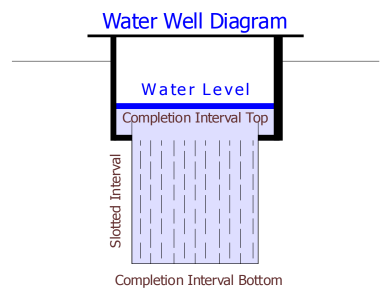
9. Glossary

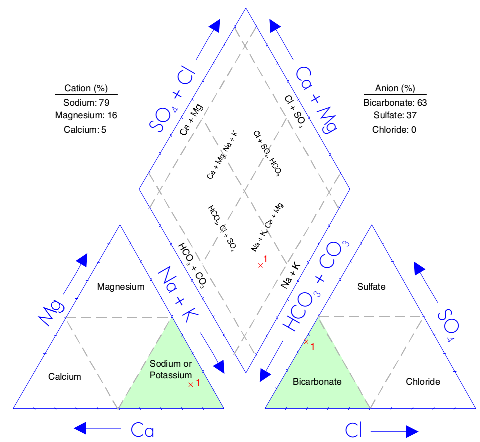
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities
Aquitard	a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer
Available 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
Completion Interval	see diagram
Deltaic	a depositional environment in standing water near the mouth of a river
Dewatering	the removal of groundwater from an aquifer for purposes other than use
Dfb	one of the Köppen climate classifications; a Dfb climate consists of warm to cool summers, severe winters, and no dry season. The mean monthly temperature drops below -3° C in the coolest month, and exceeds 10° C in the warmest month.



Completion Interval

Evapotranspiration	a combination of evaporation from open bodies of water, evaporation from soil surfaces, and transpiration from the soil by plants (Freeze and Cherry, 1979)
Facies	the aspect or character of the sediment within beds of one and the same age (Pettijohn, 1957)
Fluvial	produced by the action of a stream or river
Friable	poorly cemented
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
km	kilometre
Kriging	a geo-statistical method for gridding irregularly-spaced data (Cressie, 1990)
Lacustrine	fine-grained sedimentary deposits associated with a lake environment and not including shore-line deposits
Lithology	description of rock material
Lsd	Legal Subdivision
m	metres
mm	millimetres
m^2/day	metres squared per day
m^3	cubic metres

m^3/day	cubic metres per day
mg/L	milligrams per litre
Median	the value at the centre of an ordered range of numbers
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

AAFC-PFRA	Prairie Farm Rehabilitation Administration Branch of Agriculture and Agri-Food Canada
AENV	Alberta Environment
AMSL	above mean sea level
BGP	Base of Groundwater Protection
DEM	Digital Elevation Model
DST	drill stem test
EUB	Alberta Energy and Utilities Board
GCDWQ	Guidelines for Canadian Drinking Water Quality
IAAM	*Infinite Aquifer Artesian Model.* The mathematical model is used to calculate water levels at a given location. The model has been used for more than 17 years by HCL for several hundred groundwater monitoring projects. The model aquifer is based on a solution of the well function equation. The simulation calculates drawdown by solving the well function equation using standard approximation methods. The drawdown at any given point at any given time uses the method of superposition.
NPWL	non-pumping water level
TDS	Total Dissolved Solids
WSW	Water Source Well or Water Supply Well

10. Conversions

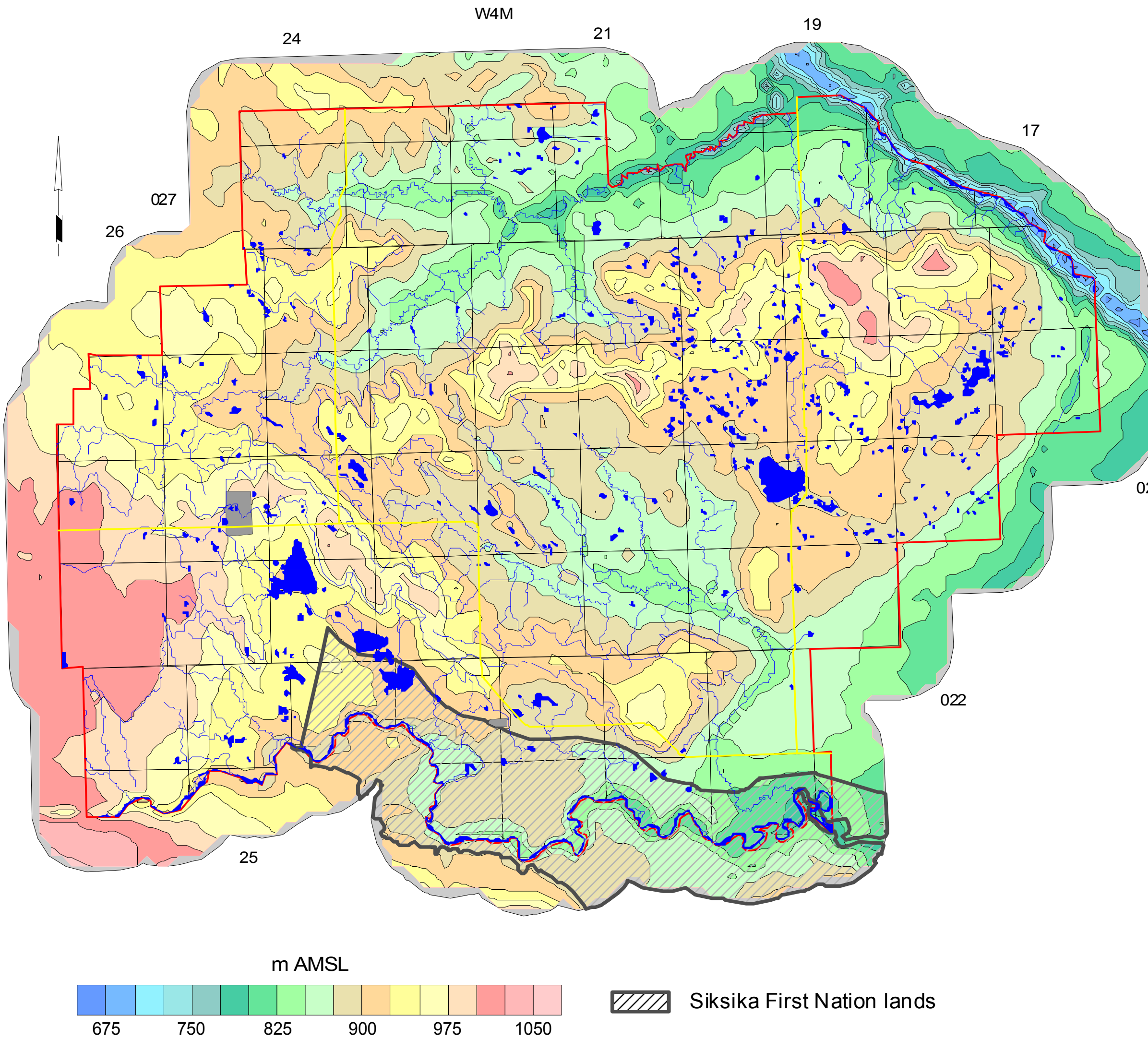
Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	metres (m^2)
metres (m^2)	10.763 910	square feet (ft^2)
metres (m^2)	0.000 001	kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	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	0.219 974	ipgm
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 (m	0.152 759	igpm
Pressure		
psi	6.894 757	kpa
kpa	0.145 038	psi
Miscellaneous		
Celsius	F° = 9/5 (C° + 32)	Fahrenheit
Fahrenheit	C° = (F°- 32) * 5/9	Celsius
degrees	0.017 453	radians

WHEATLAND COUNTY

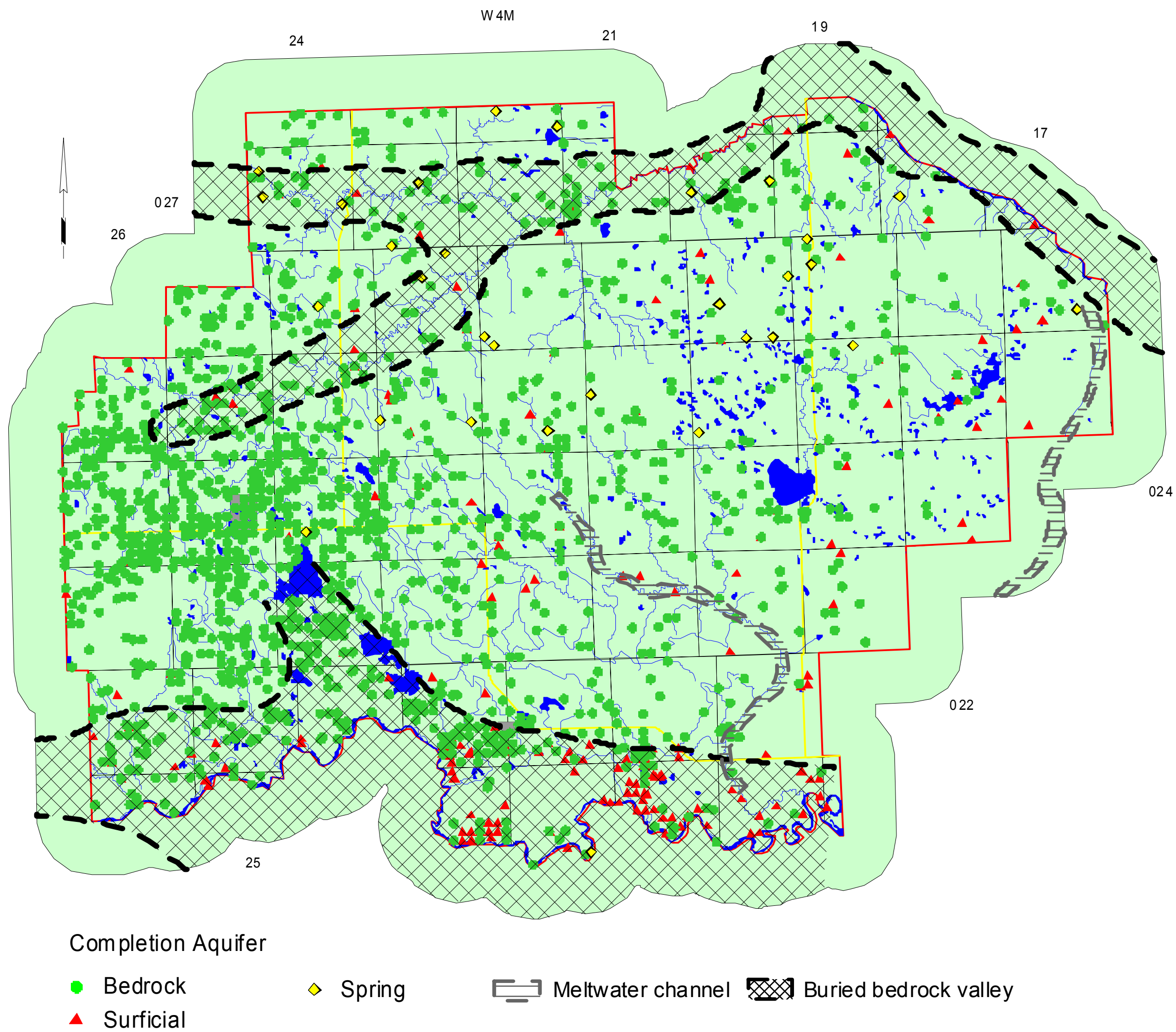
Appendix A

Hydrogeological Maps and Figures

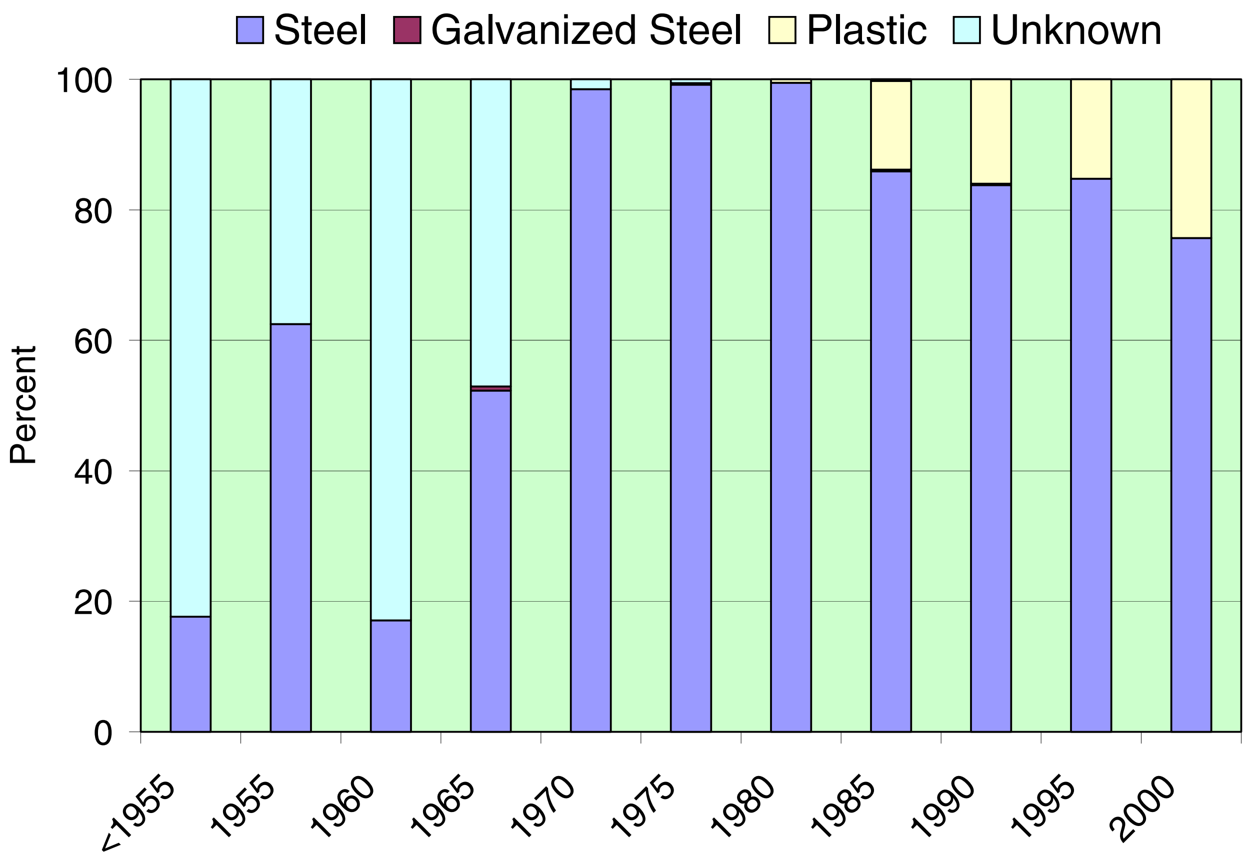
Surface Topography



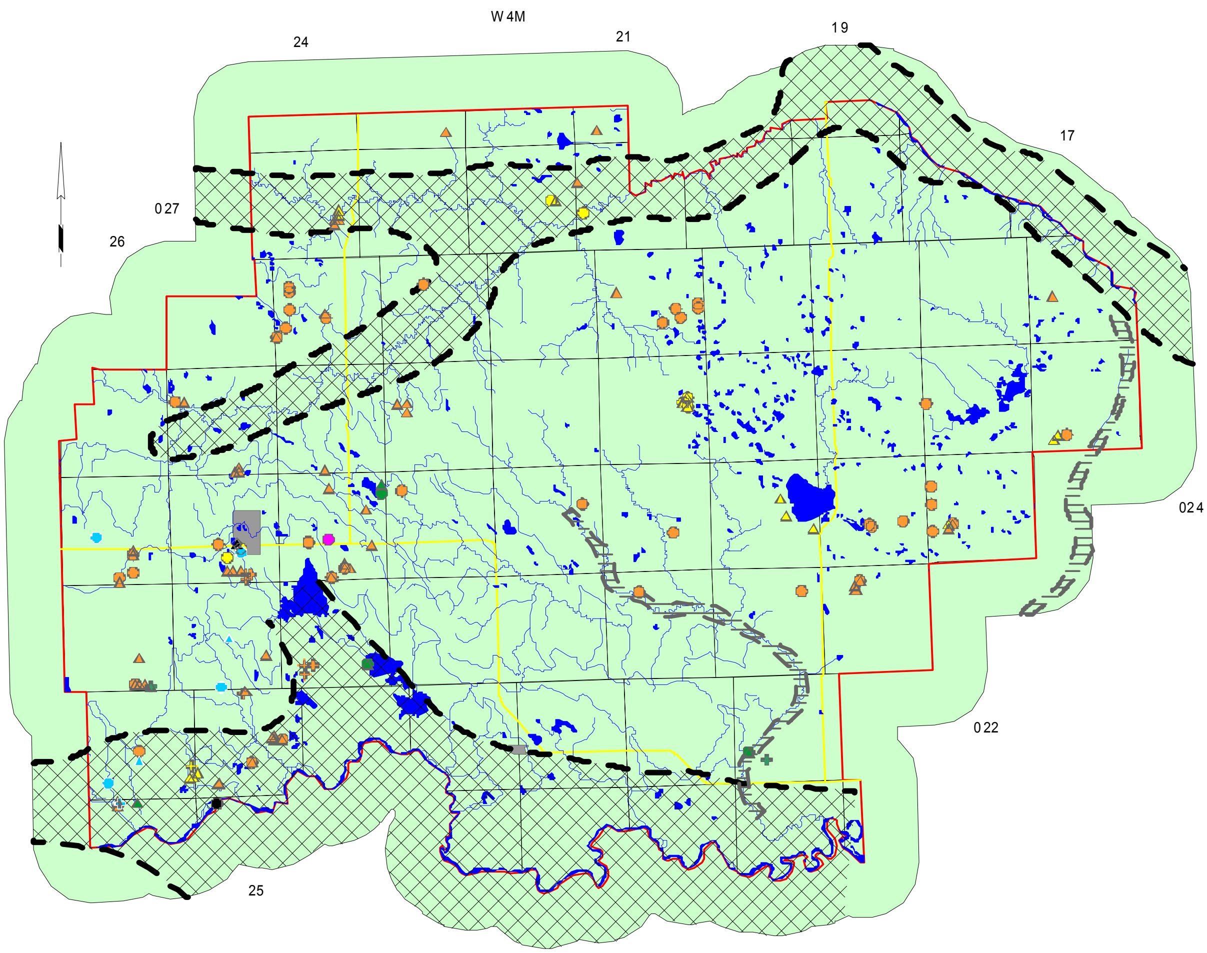
Location of Water Wells and Springs



Surface Casing Types used in Drilled Water Wells



Licensed Water Wells



Meltwater channel   Buried bedrock valley

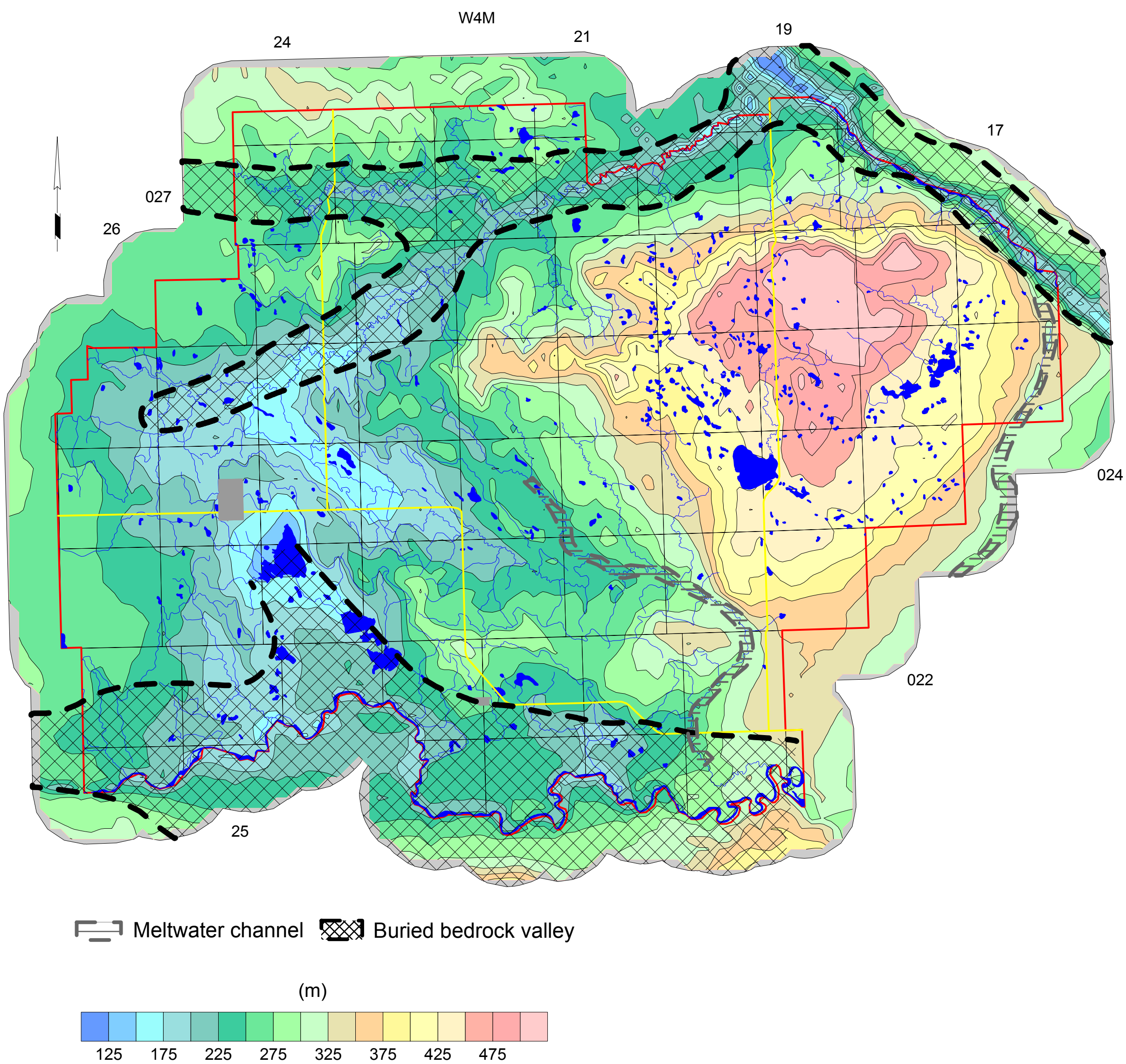
Licensed Groundwater Users (m³/day)

	agricultural	municipal	exploration
< 10	(51)	(9)	(9)
10 to 100	(86)	(15)	(7)
> 100	(12)	(1)	(2)

	commercial	recreation	irrigation
< 10	(4)	(1)	(1)
10 to 100	(2)	(1)	(0)
> 100	(1)	(0)	(0)

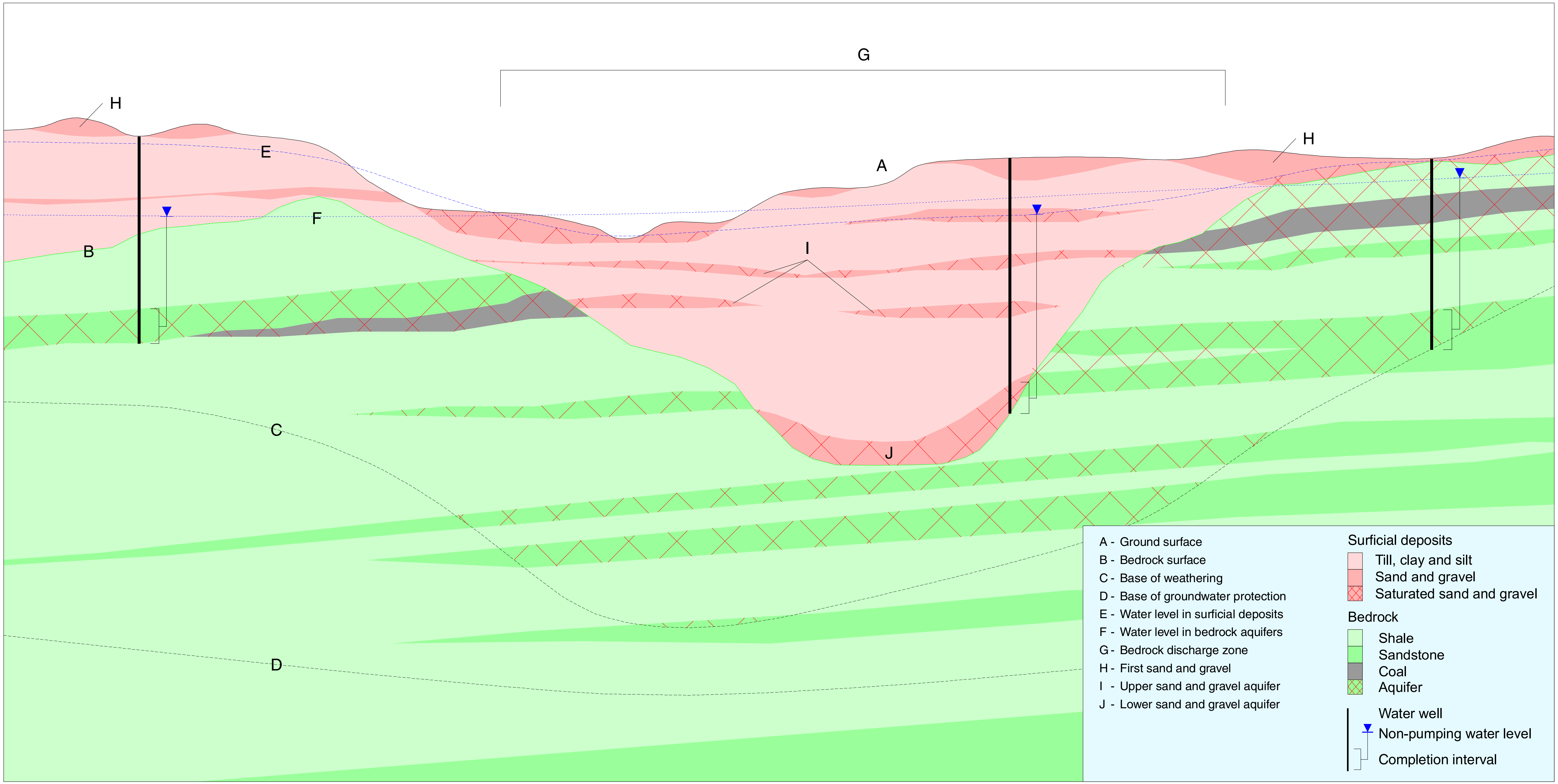
Depth to Base of Groundwater Protection

(modified after EUB, 1995)



Generalized Cross-Section

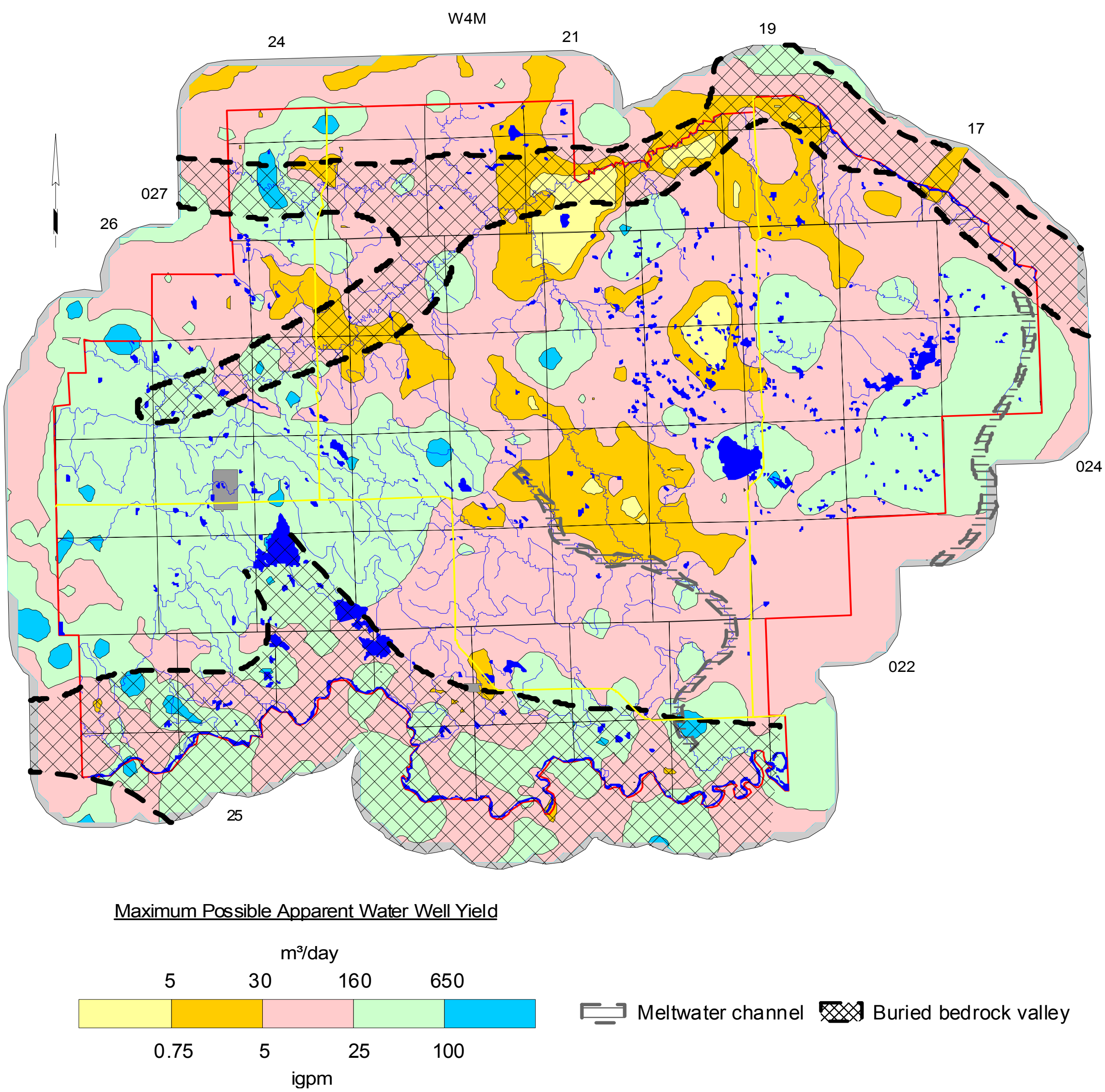
(for terminology only)



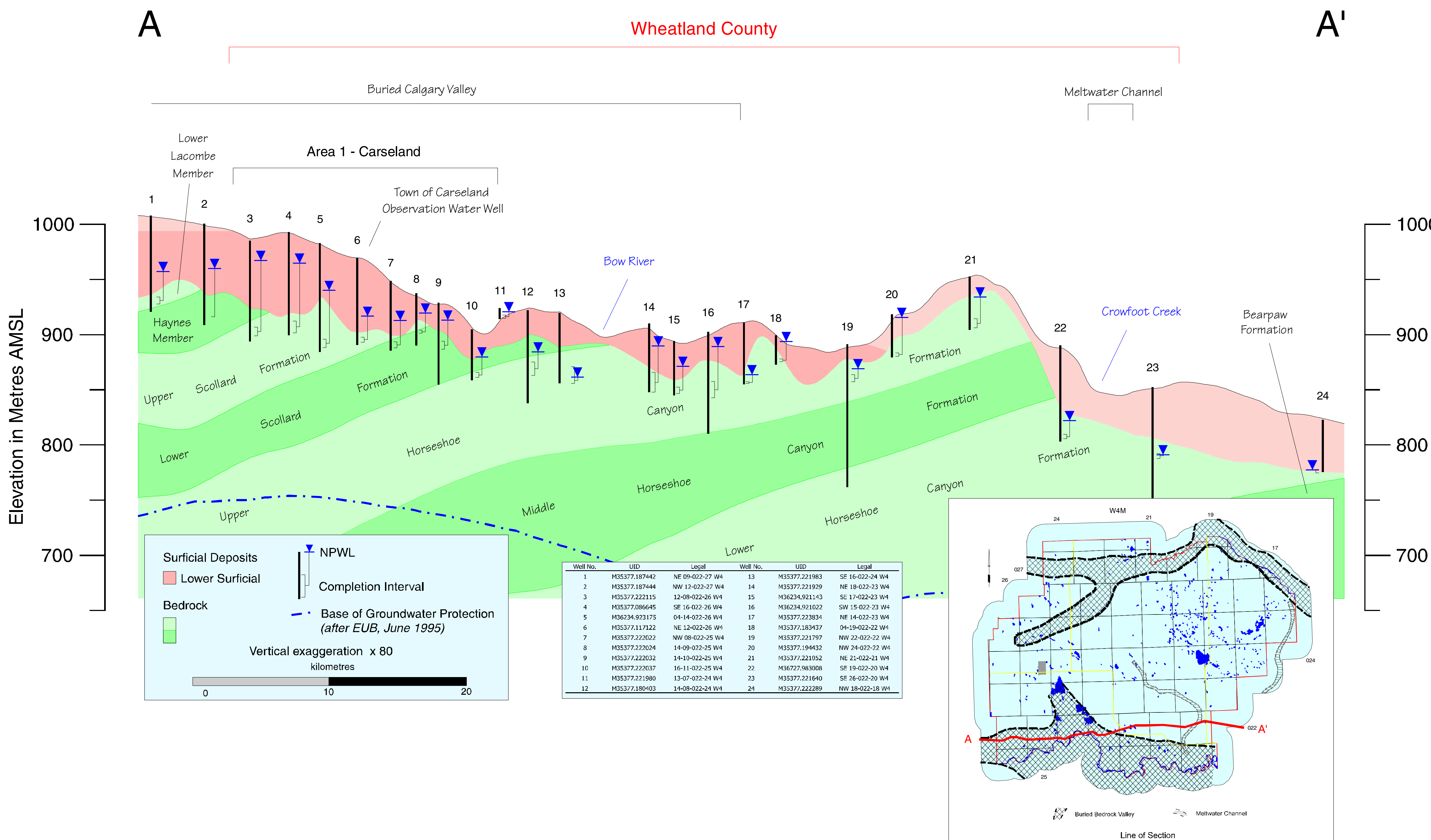
Geologic Column

Lithologic Description	Group and Formation: Average Thickness (m)	Group and Formation: Designation	Member: Average Thickness (m)	Member: Designation	Zone: Average Thickness (m)	Zone: Designation
sand, gravel, till, clay, silt	<140	Surficial Deposits	<140	Upper	<30	First Sand and Gravel
			<50	Lower		
sandstone, shale, coal	<800	Paskapoo Formation	>300	Dalehurst Member		Obed-Marsh Coal Zone
						Lower Dalehurst Coal Zone
			100-250	Lacombe Member – Upper	Upper	Upper Sandstone
						Middle Sandstone
						Lower Sandstone
			30-100	Lacombe Member – Lower	Lower	Lower Lacombe Coal Zone
			20-100	Haynes		
shale, sandstone, coal	60-150	Scollard Formation	40-100	Upper	<2	Upper Ardley Coal Zone
					~20	Ardley Coal Zone (main seam)
					<1	Nevis Coal Seam
			20-60	Lower		
shale, clay, tuff	~25	Battle Formation	<0.3	Kneehill Member		
	5-10					
shale, sandstone, coal, bentonite, limestone, ironstone	300-380	Edmonton Group – Horseshoe Canyon Formation	~100	Upper		
			~100	Middle		
			~170	Lower		
shale, sandstone, siltstone	60-120	Bearpaw Formation				

Hydrogeological Map



Cross-Section A - A'



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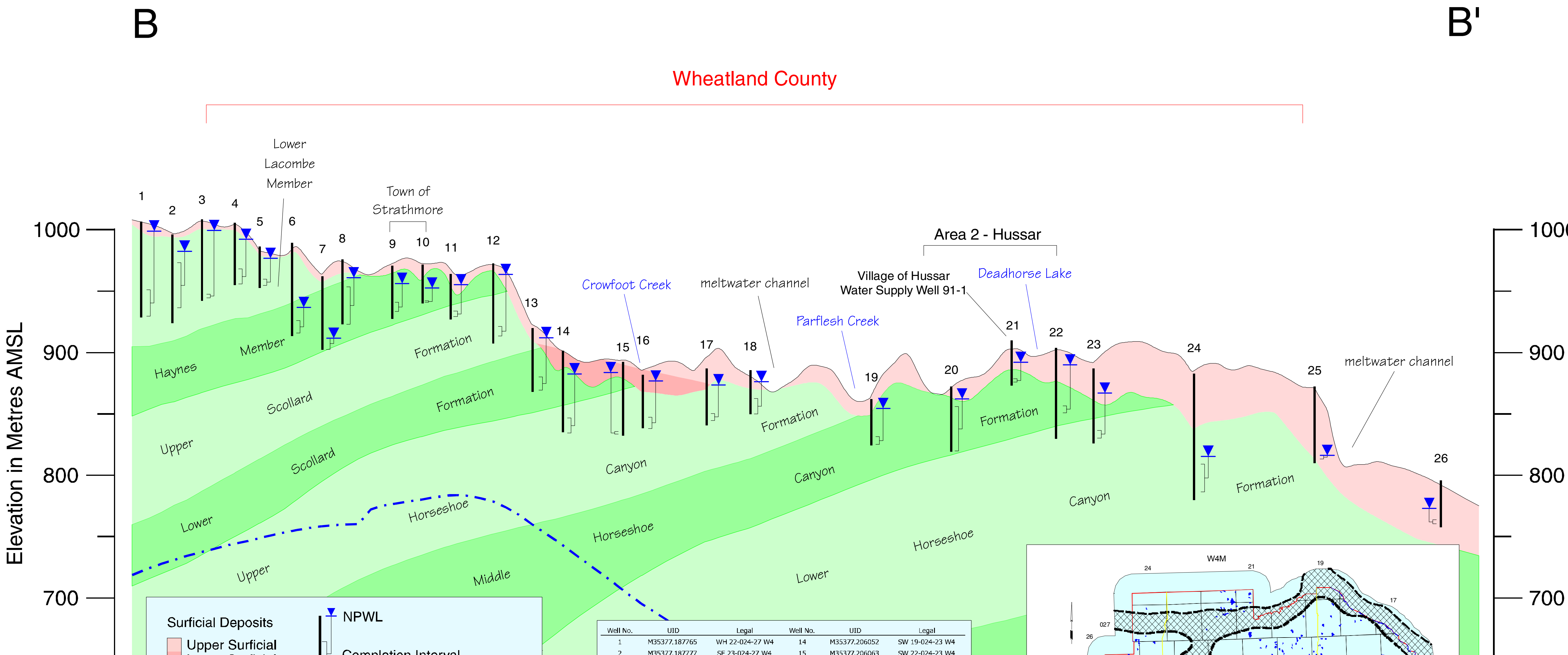
3	M35377.222115	12-08-022-26 W4	15	M36234.921143	SE 17-022-23 W4
4	M35377.086645	SE 16-022-26 W4	16	M36234.921022	SW 15-022-23 W4
5	M36234.923175	04-14-022-26 W4	17	M35377.223834	NE 14-022-23 W4
6	M35377.117122	NE 12-022-26 W4	18	M35377.183437	04-19-022-22 W4
7	M35377.222022	NW 08-022-25 W4	19	M35377.221797	NW 22-022-22 W4
8	M35377.222024	14-09-022-25 W4	20	M35377.194432	NW 24-022-22 W4
9	M35377.222032	14-10-022-25 W4	21	M35377.221052	NE 21-022-21 W4
10	M35377.222037	16-11-022-25 W4	22	M36727.983008	SE 19-022-20 W4
11	M35377.221980	13-07-022-24 W4	23	M35377.221640	SE 26-022-20 W4
12	M35377.180403	14-08-022-24 W4	24	M35377.222289	NW 18-022-18 W4

Cross-Section B - B'



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3	M35377.222561	SW 19-024-26 W4	16	M37066.936078	SW 23-024-23 W4
4	M35377.091361	08-20-024-26 W4	17	M35377.206112	SW 17-024-22 W4
5	M35377.088007	05-22-024-26 W4	18	M35377.206117	SW 22-024-22 W4
6	M35377.138683	SE 23-024-26 W4	19	M36234.923037	SW 22-024-21 W4
7	M35377.223516	SW 19-024-25 W4	20	M35377.206018	SW 20-024-20 W4
8	M35377.116243	SW 20-024-25 W4	21	M35377.088004	NW 14-024-20 W4
9	M35377.222404	SE 22-024-25 W4	22	M35377.219520	03-18-024-19 W4
10	M35377.114521	SW 24-024-25 W4	23	M35377.206206	SW 16-024-19 W4
11	M35377.226316	02-19-024-24 W4	24	M35377.205958	SW 17-024-18 W4
12	M36727.982794	SE 21-024-24 W4	25	M35377.205946	NE 30-024-17 W4
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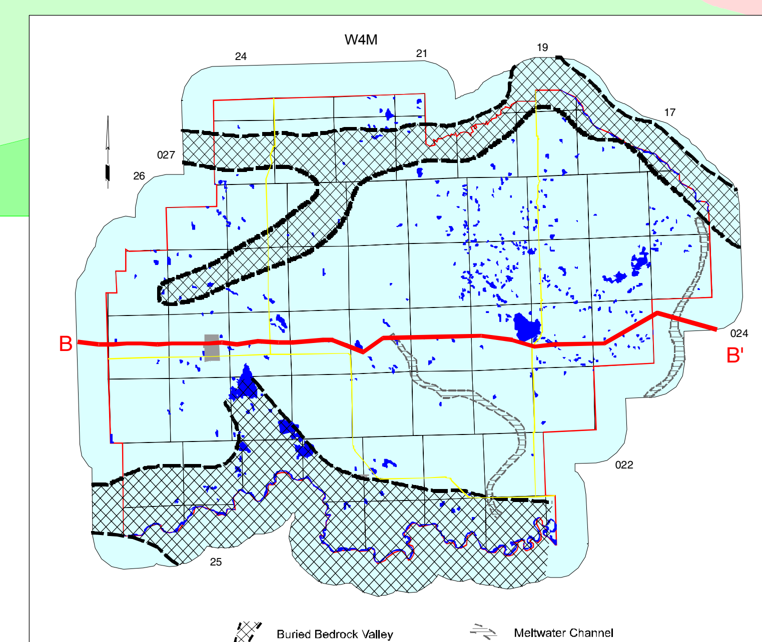
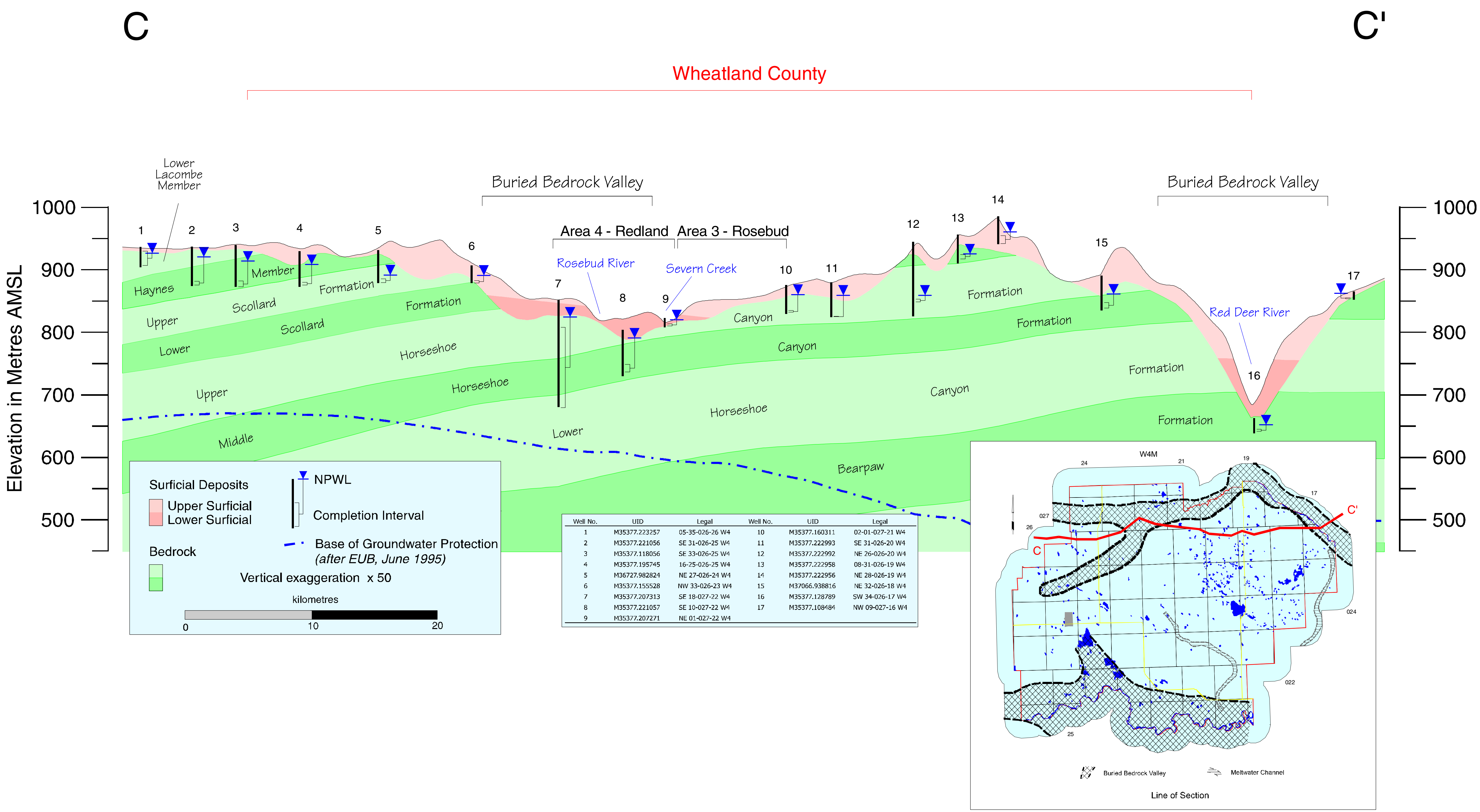


Line of Section

Cross-Section C - C'



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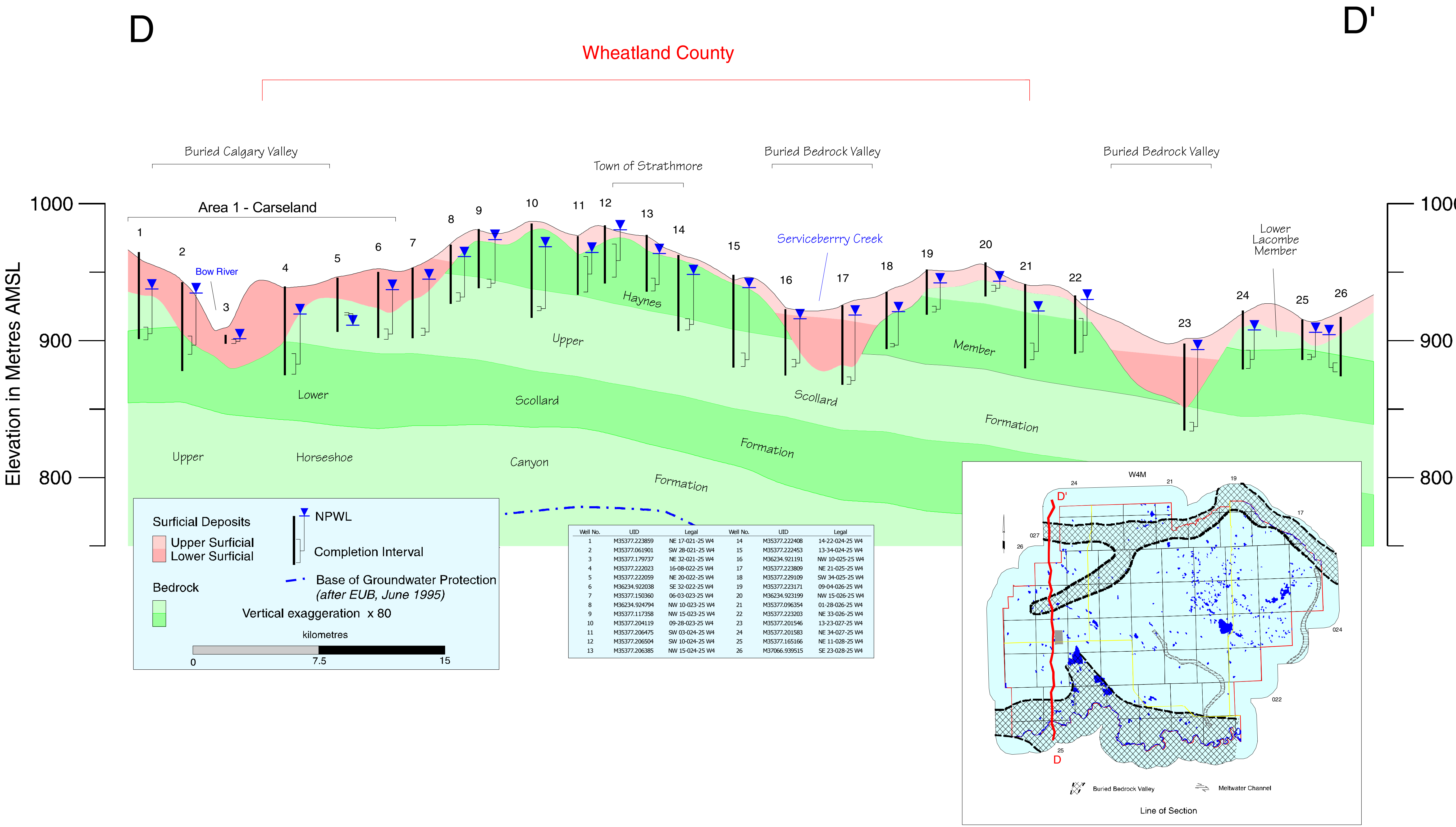
3	M35377.118056	SE 33-026-25 W4	12	M35377.222992	NE 26-026-20 W4
4	M35377.195745	16-25-026-25 W4	13	M35377.222958	08-31-026-19 W4
5	M36727.982824	NE 27-026-24 W4	14	M35377.222956	NE 28-026-19 W4
6	M35377.155528	NW 33-026-23 W4	15	M37066.938816	NE 32-026-18 W4
7	M35377.207313	SE 18-027-22 W4	16	M35377.128789	SW 34-026-17 W4
8	M35377.221057	SE 10-027-22 W4	17	M35377.108484	NW 09-027-16 W4
9	M35377.207271	NE 01-027-22 W4			

Cross-Section D - D'



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3	M35377.179737	NE 32-021-25 W4	16	M36234.921191	NW 10-025-25 W4
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7	M35377.150360	06-03-023-25 W4	20	M36234.923199	NW 15-026-25 W4
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11	M35377.206475	SW 03-024-25 W4	24	M35377.201583	NE 34-027-25 W4
12	M35377.206504	SW 10-024-25 W4	25	M35377.165166	NE 11-028-25 W4
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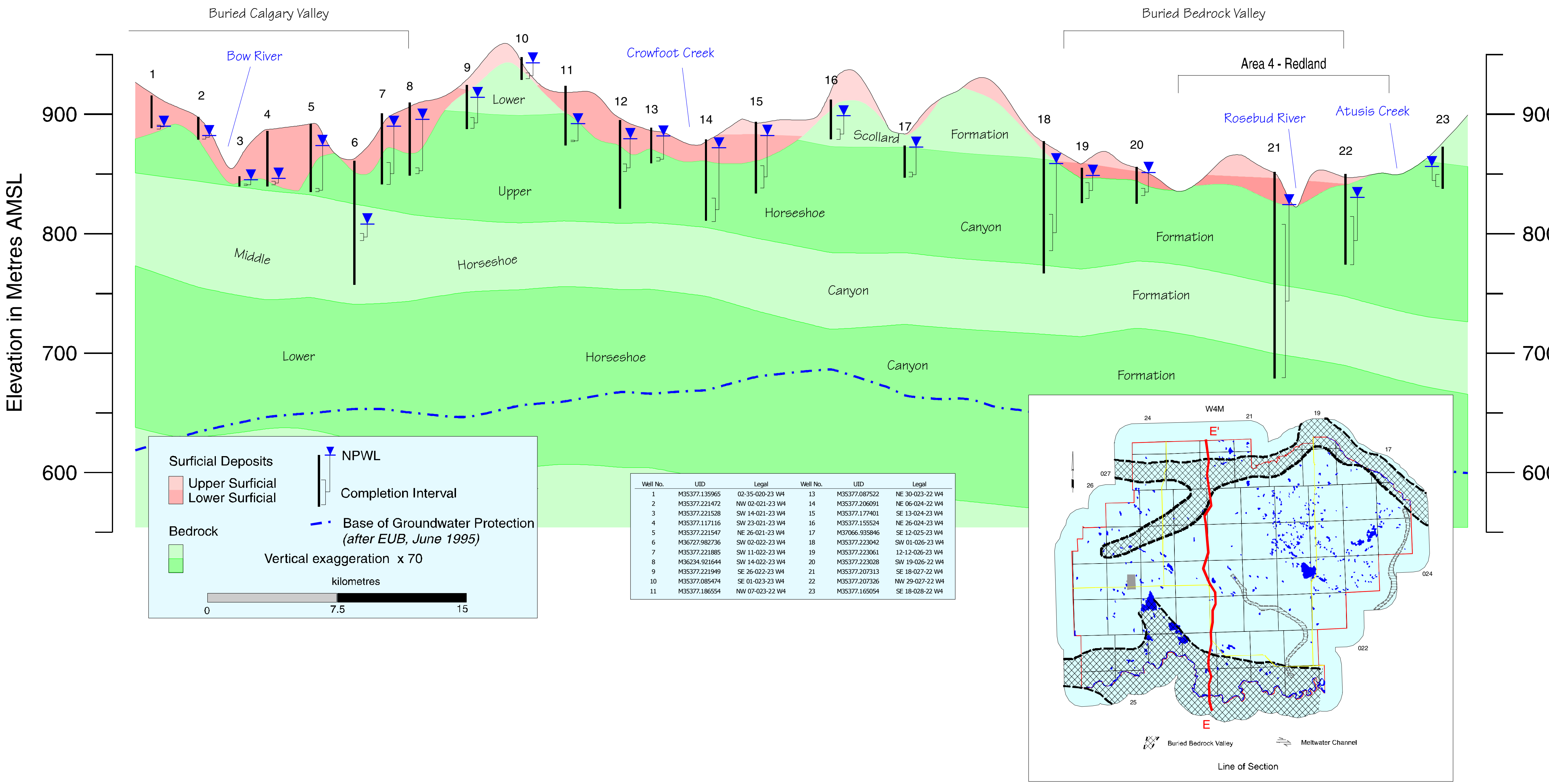
Cross-Section E - E'



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3	M35377.221528	SW 14-021-23 W4	15	M35377.177401	SE 13-024-23 W4
4	M35377.117116	SW 23-021-23 W4	16	M35377.155524	NE 26-024-23 W4
5	M35377.221547	NE 26-021-23 W4	17	M37066.935846	SE 12-025-23 W4
6	M36727.982736	SW 02-022-23 W4	18	M35377.223042	SW 01-026-23 W4
7	M35377.221885	SW 11-022-23 W4	19	M35377.223061	12-12-026-23 W4
8	M36234.921644	SW 14-022-23 W4	20	M35377.223028	SW 19-026-22 W4
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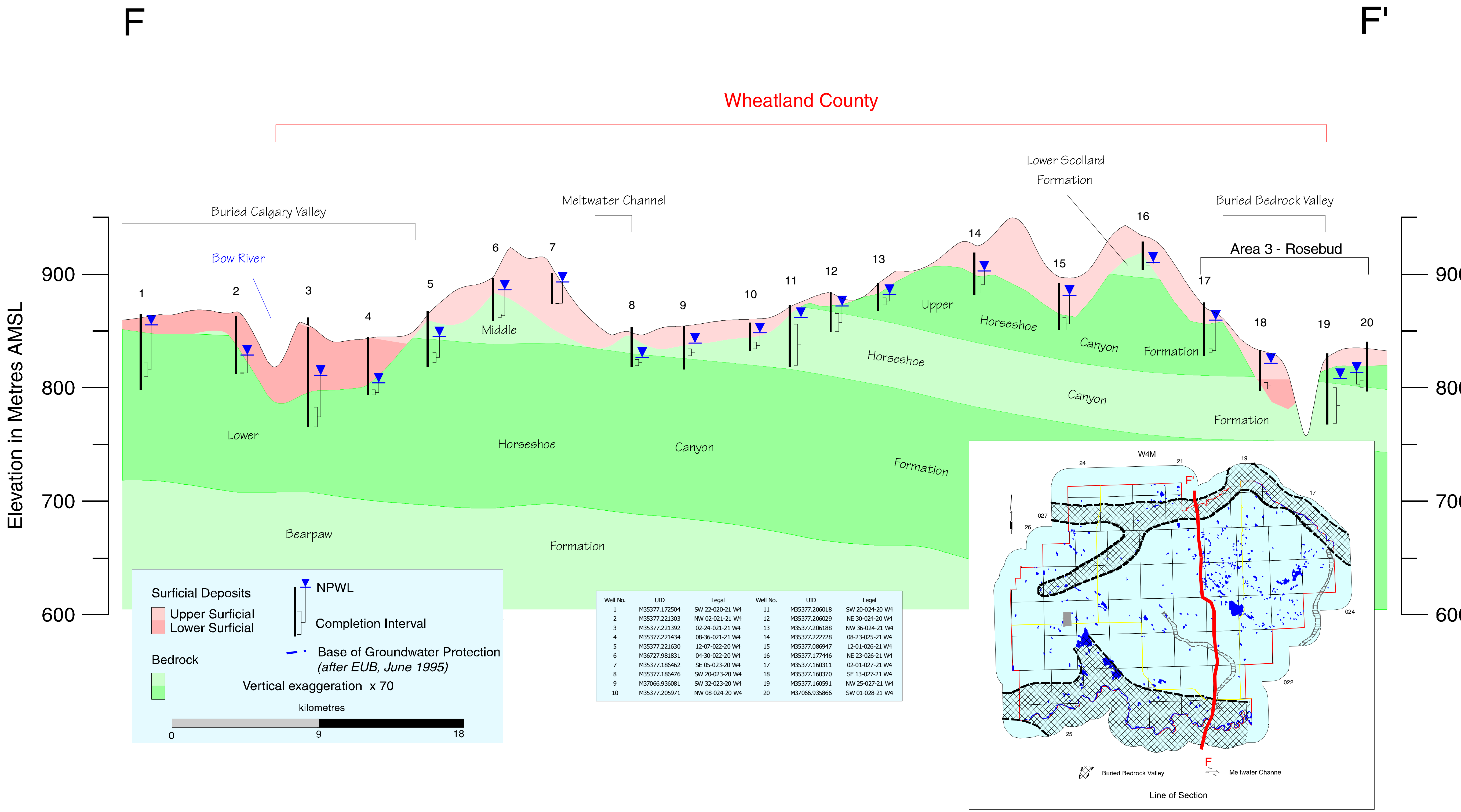
Cross-Section F - F'



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3	M35377.221392	02-24-021-21 W4	13	M35377.206188	NW 36-024-21 W4
4	M35377.221434	08-36-021-21 W4	14	M35377.222728	08-23-025-21 W4
5	M35377.221630	12-07-022-20 W4	15	M35377.086947	12-01-026-21 W4
6	M36727.981831	04-30-022-20 W4	16	M35377.177446	NE 23-026-21 W4
7	M35377.186462	SE 05-023-20 W4	17	M35377.160311	02-01-027-21 W4
8	M35377.186476	SW 20-023-20 W4	18	M35377.160370	SE 13-027-21 W4
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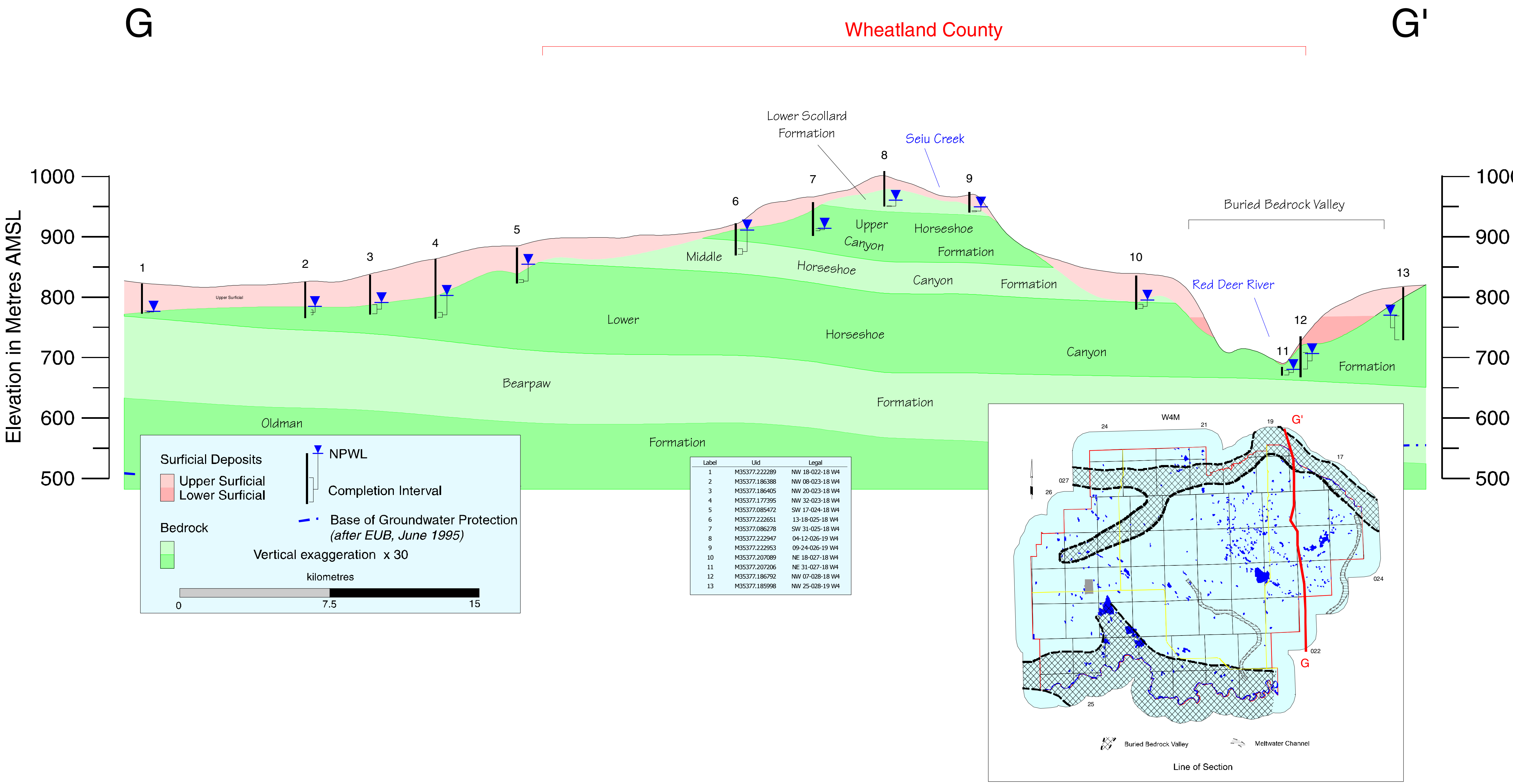
Cross-Section G - G'



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4	M35377.177395	NW 32-023-18 W4
5	M35377.085472	SW 17-024-18 W4
6	M35377.222651	13-18-025-18 W4
7	M35377.086278	SW 31-025-18 W4
8	M35377.222947	04-12-026-19 W4
9	M35377.222953	09-24-026-19 W4
10	M35377.207089	NE 18-027-18 W4
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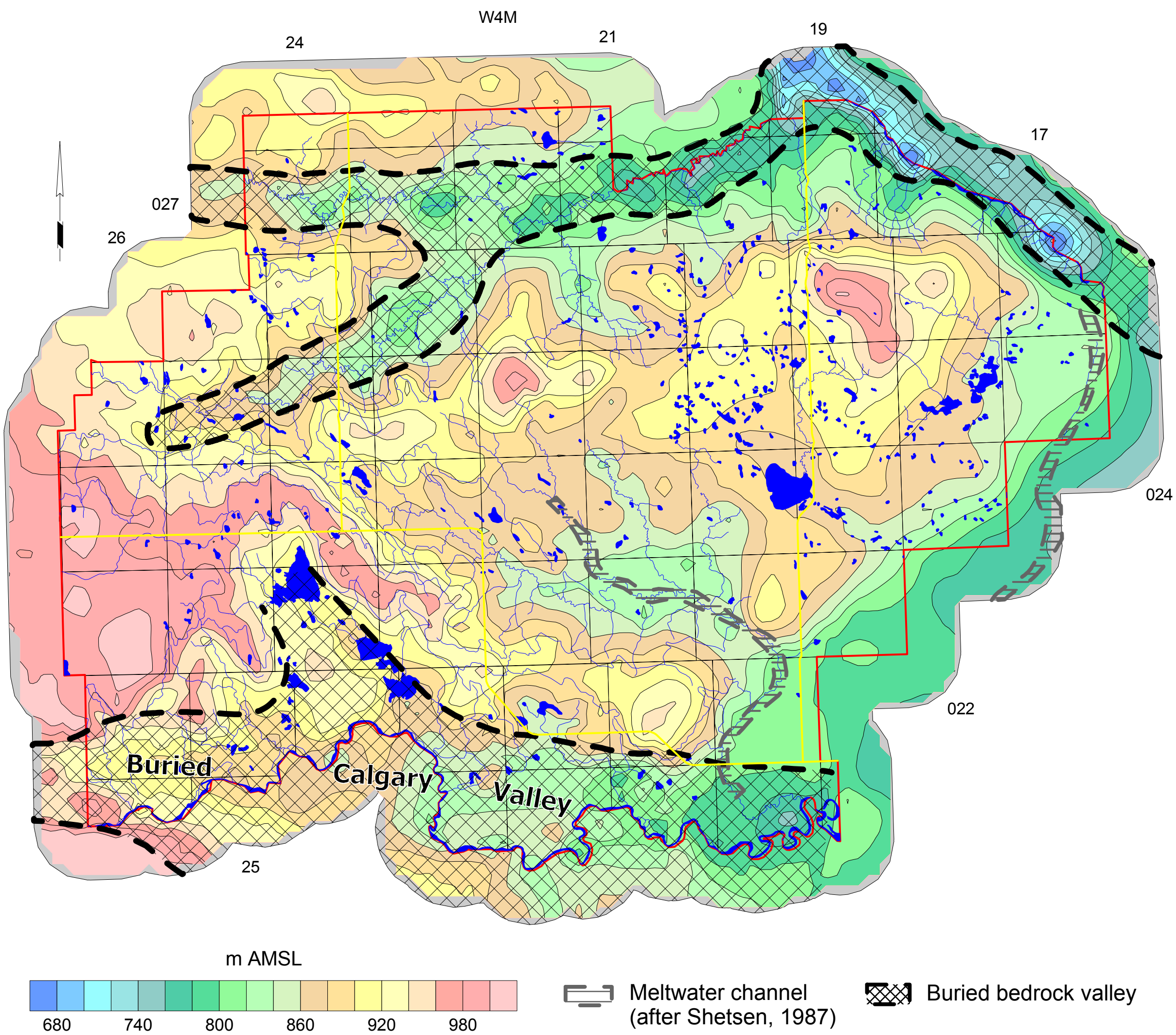
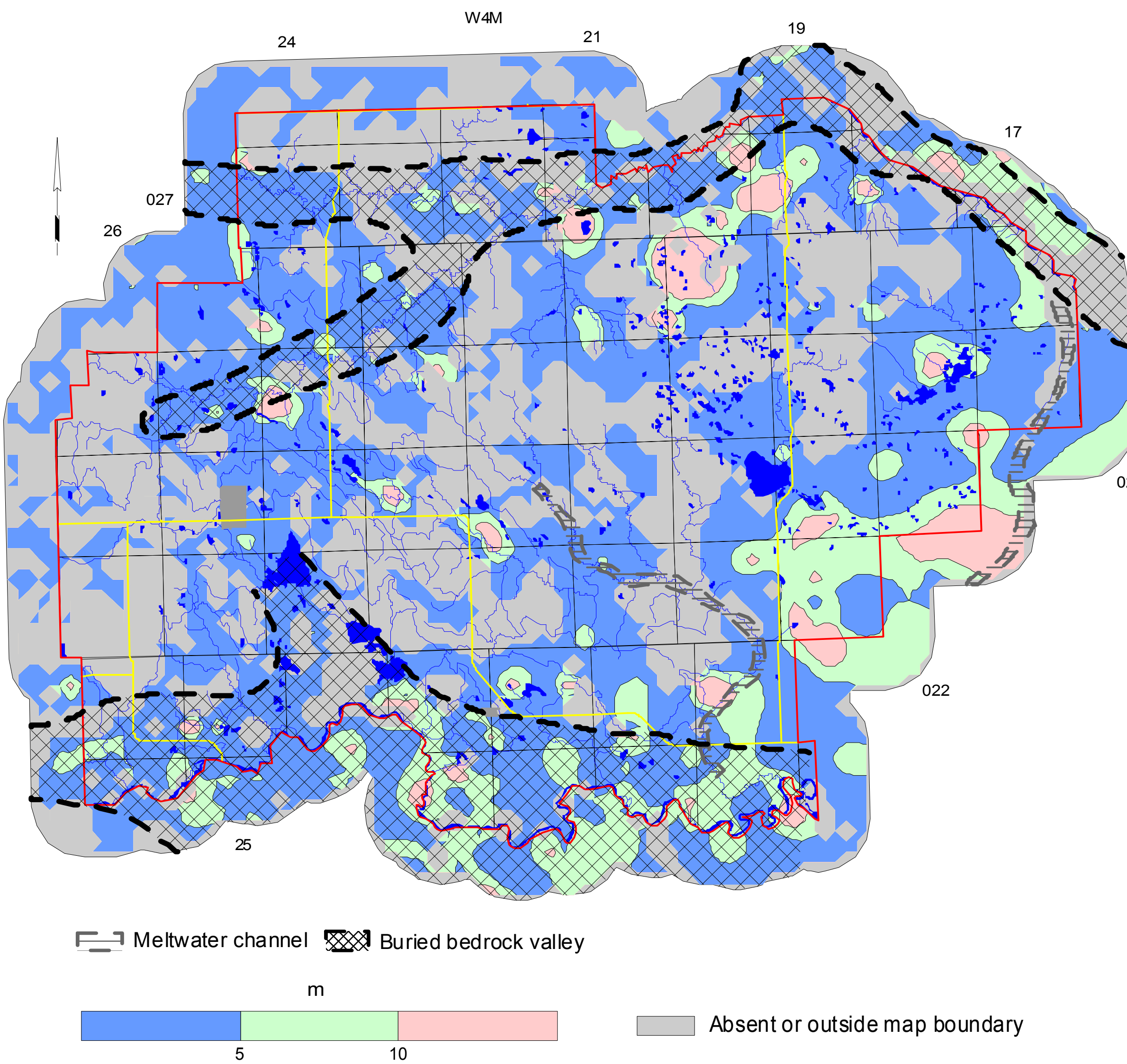
13	M35377.185998	NW 25-028-19 W4

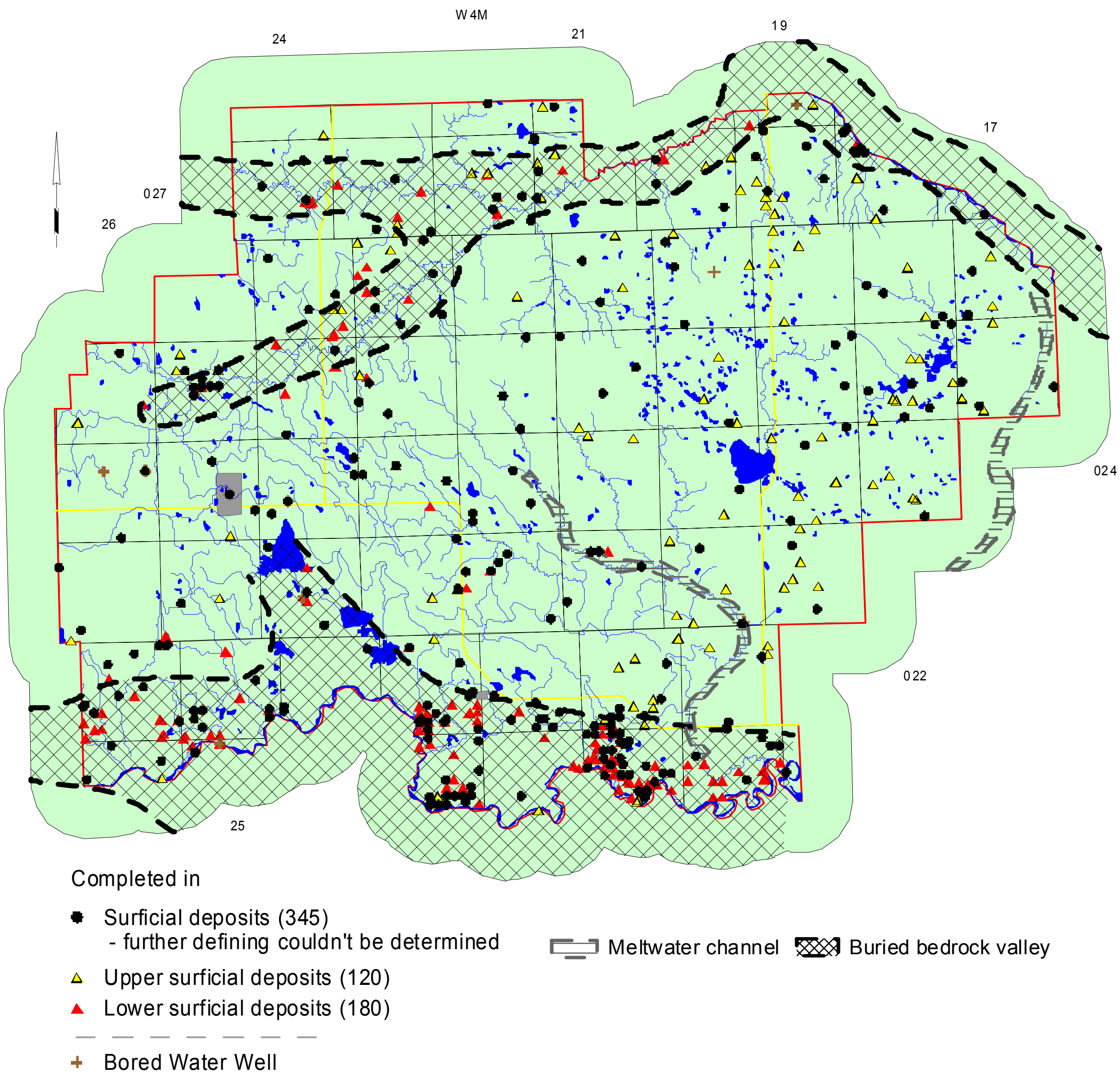
Bedrock Topography



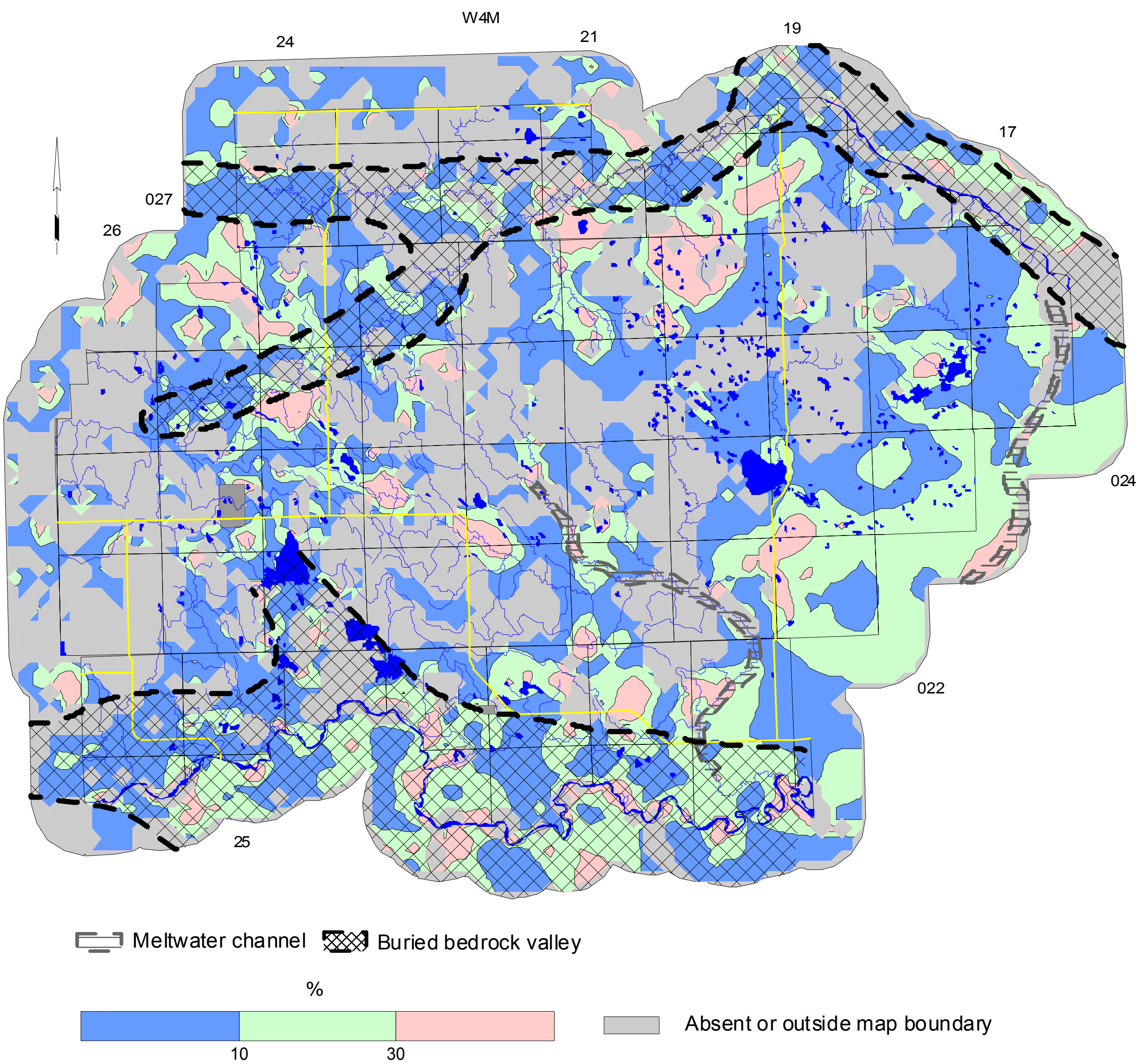
Thickness of Sand and Gravel Deposits



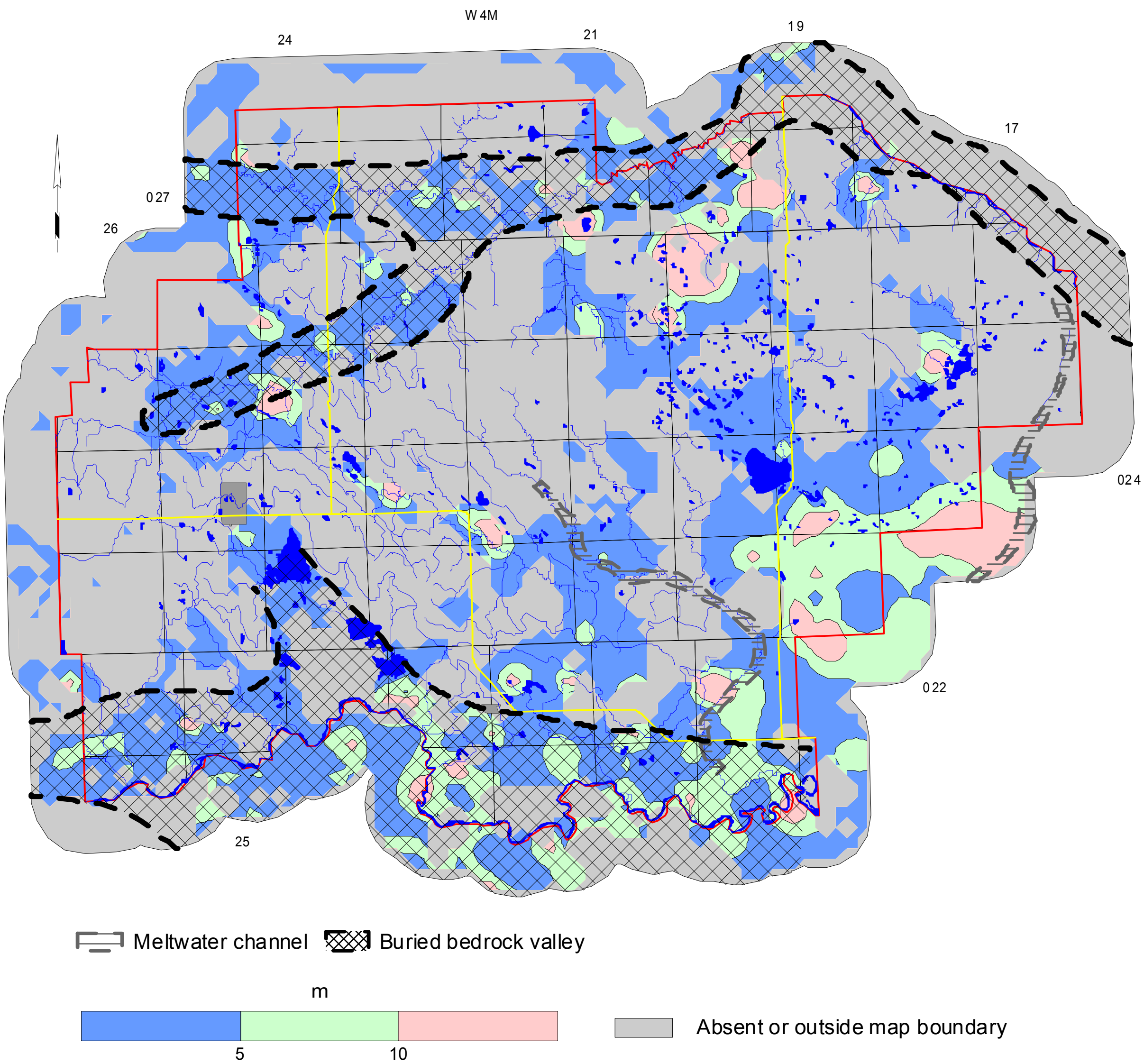
Water Wells Completed In Surficial Deposits



Amount of Sand and Gravel in Surficial Deposits

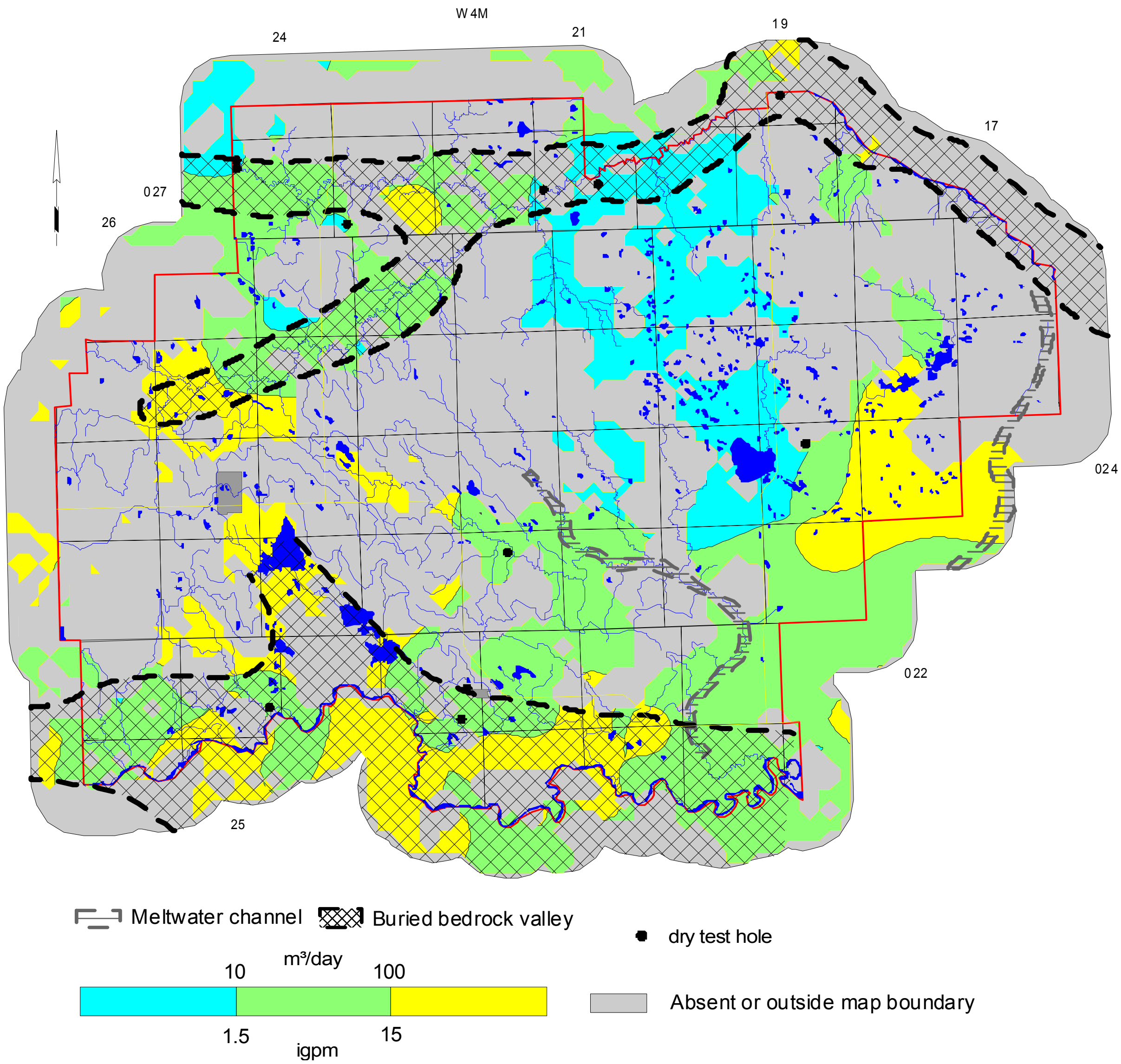


Thickness of Sand and Gravel Aquifer(s)

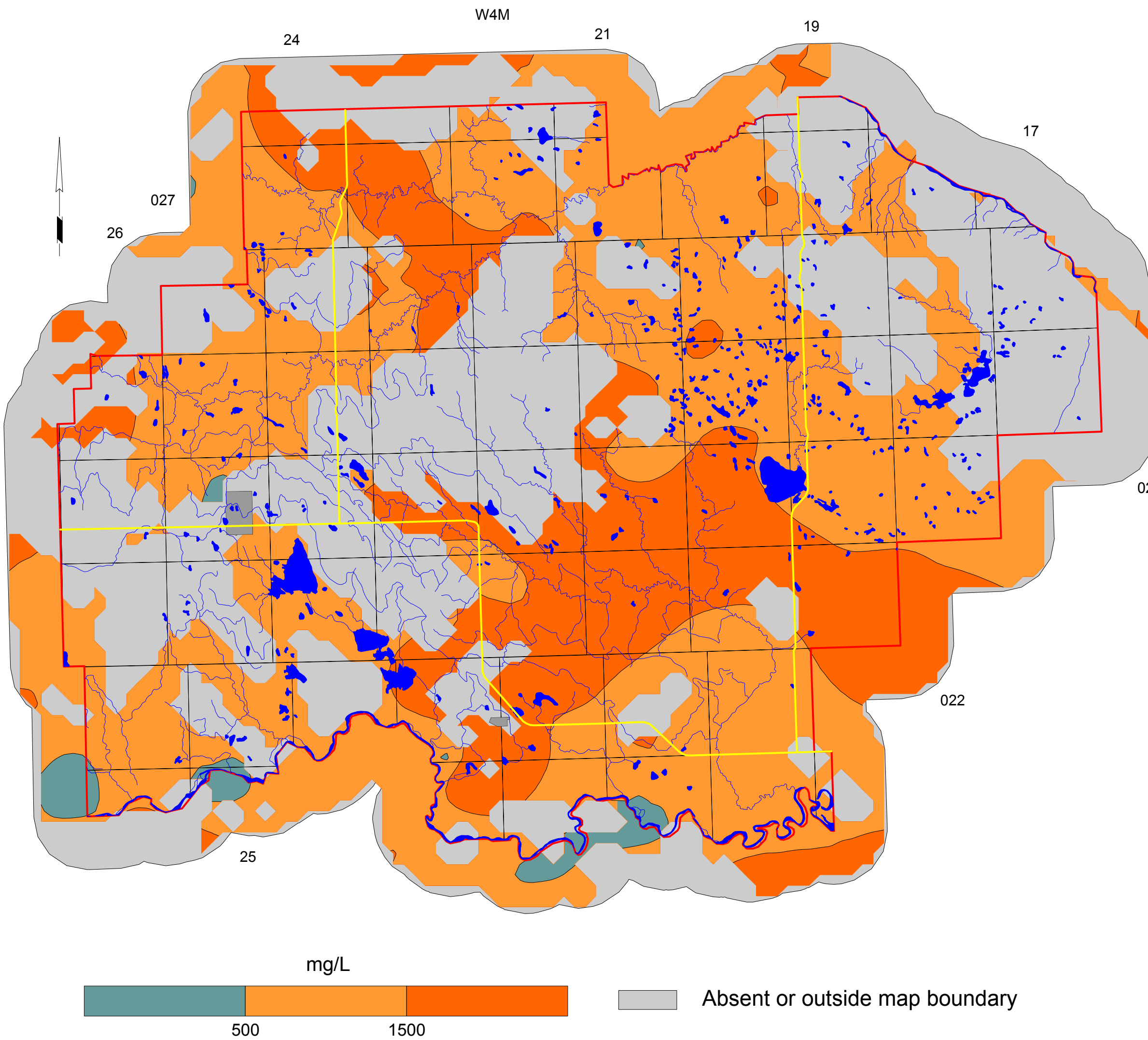


Thickness of Sand and Gravel Aquifer(s)

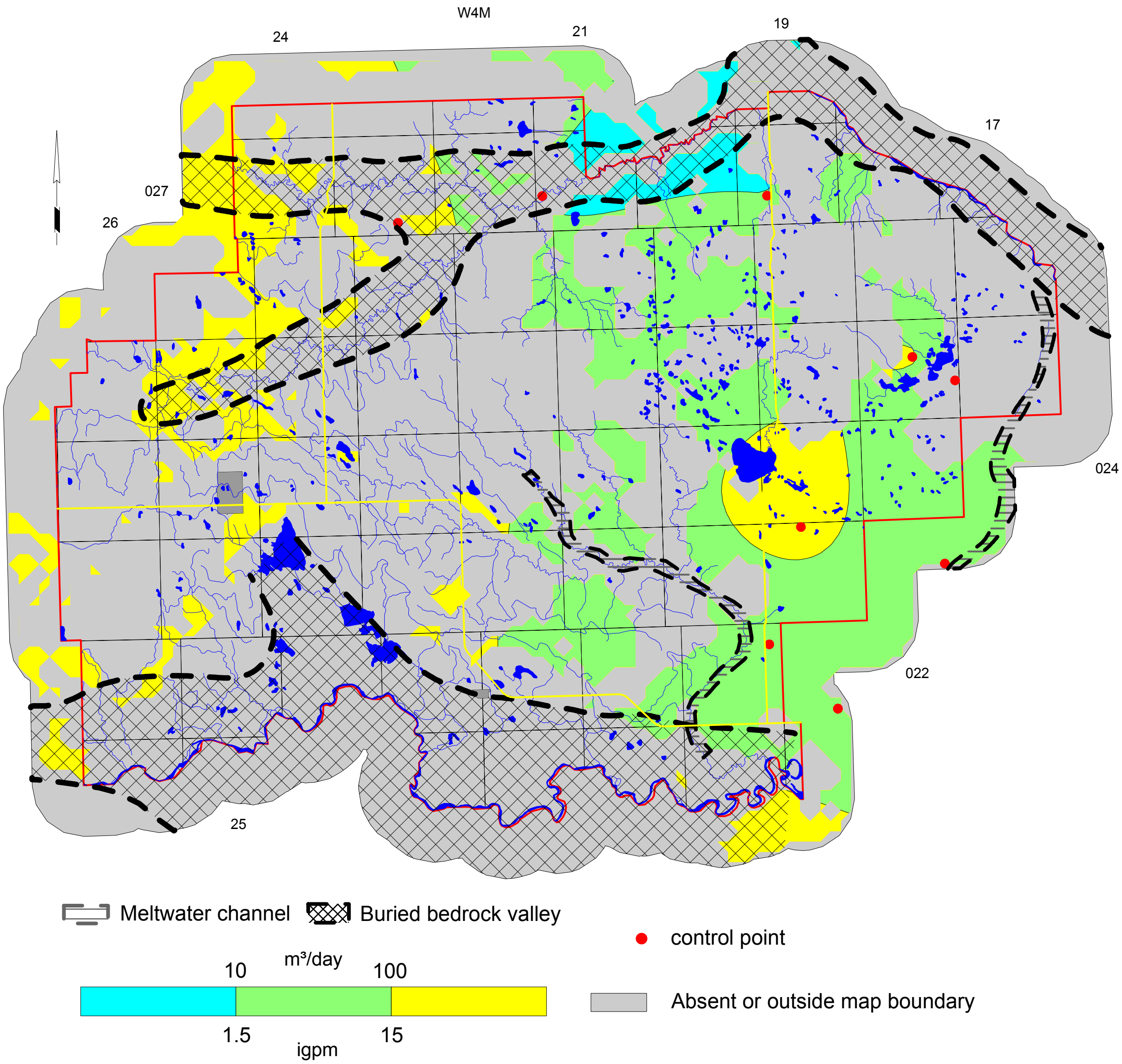
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



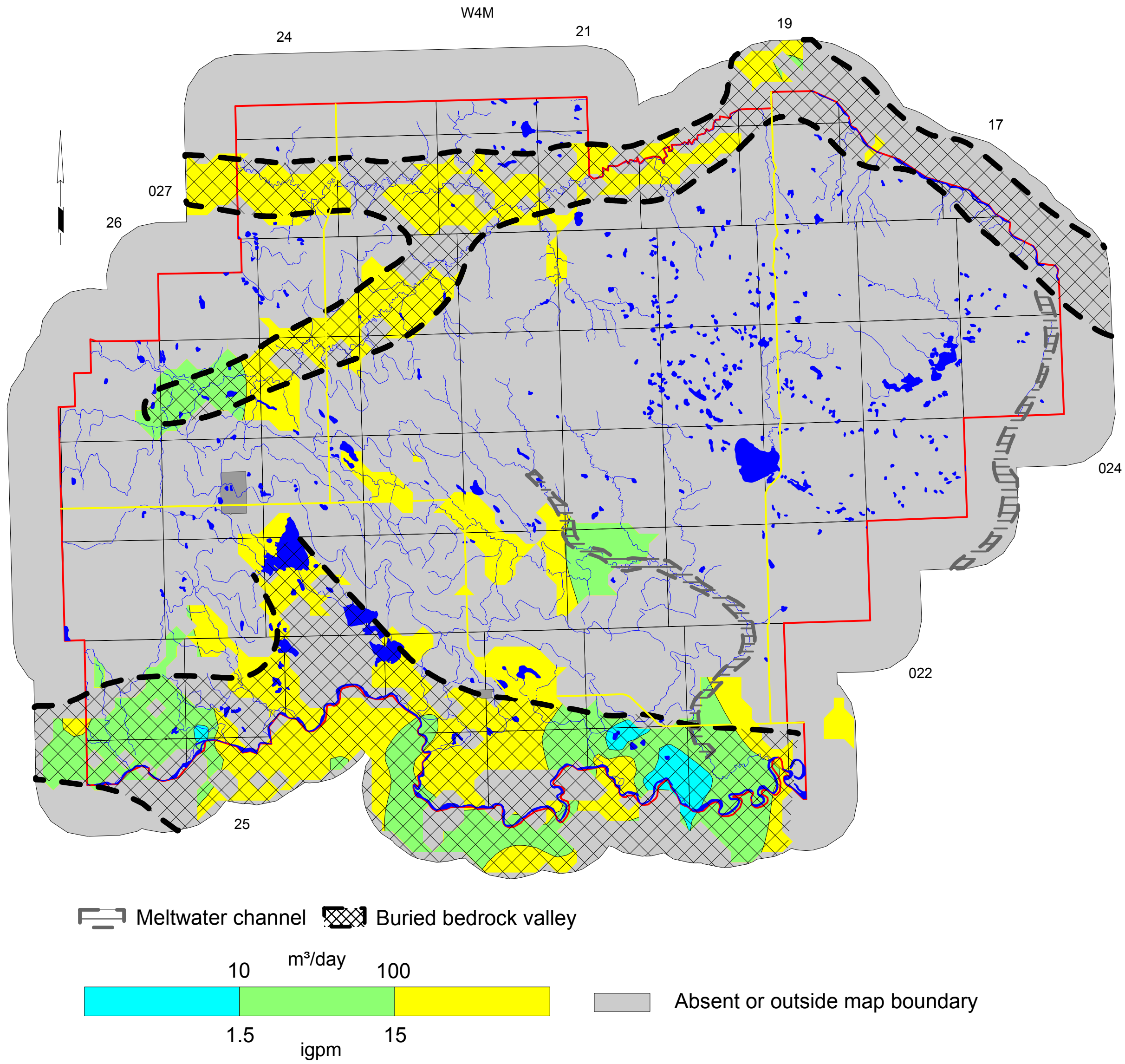
Total Dissolved Solids in Groundwater from Surficial Deposits



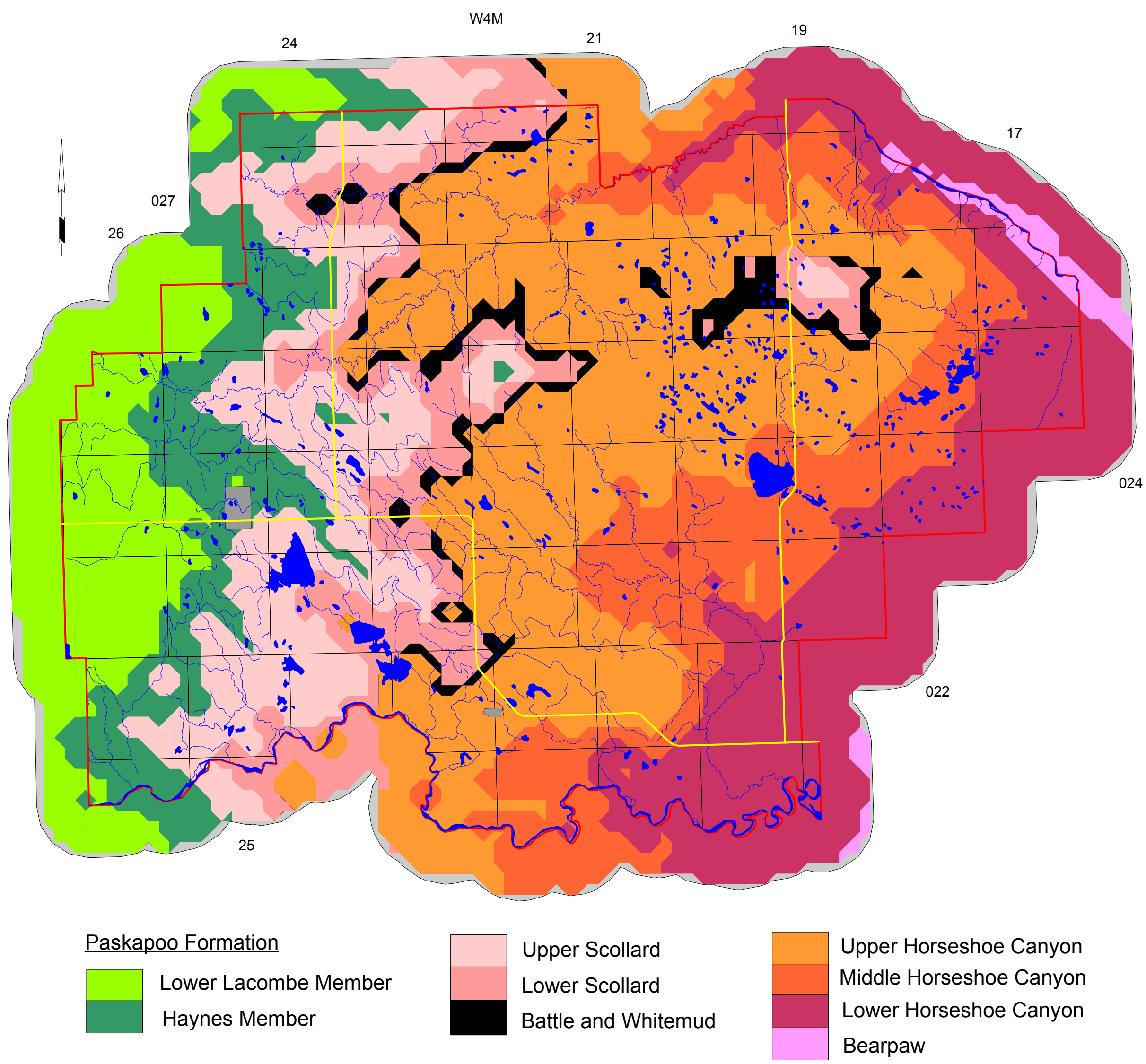
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



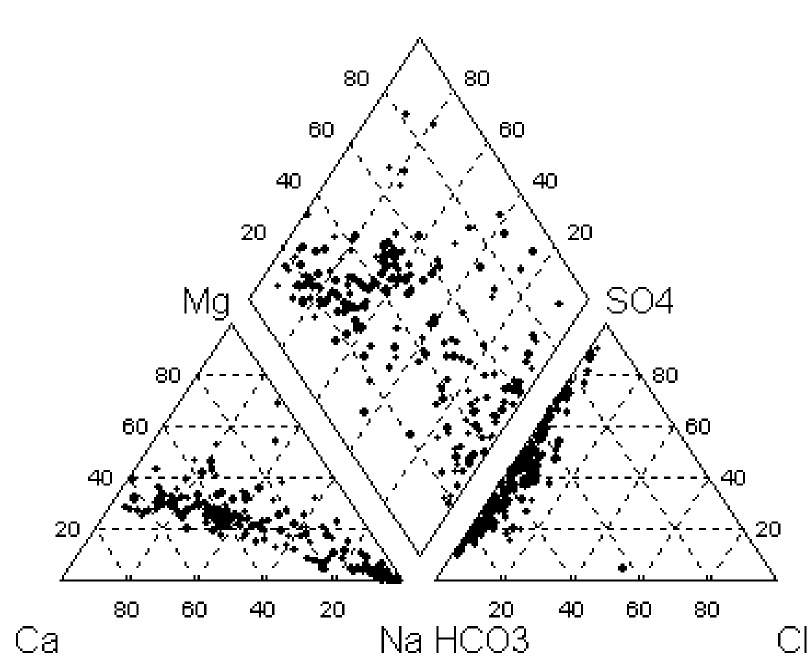
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



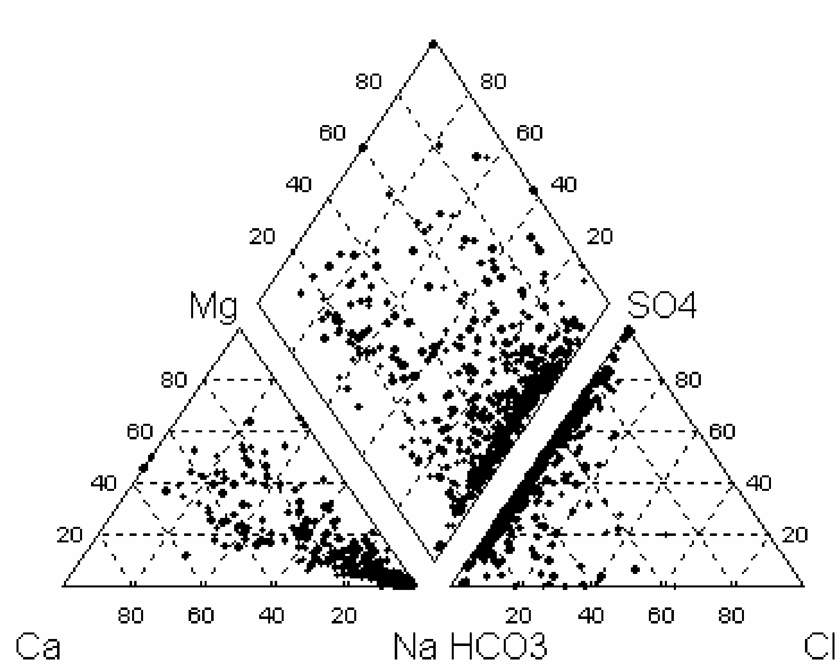
Bedrock Geology



Piper Diagrams

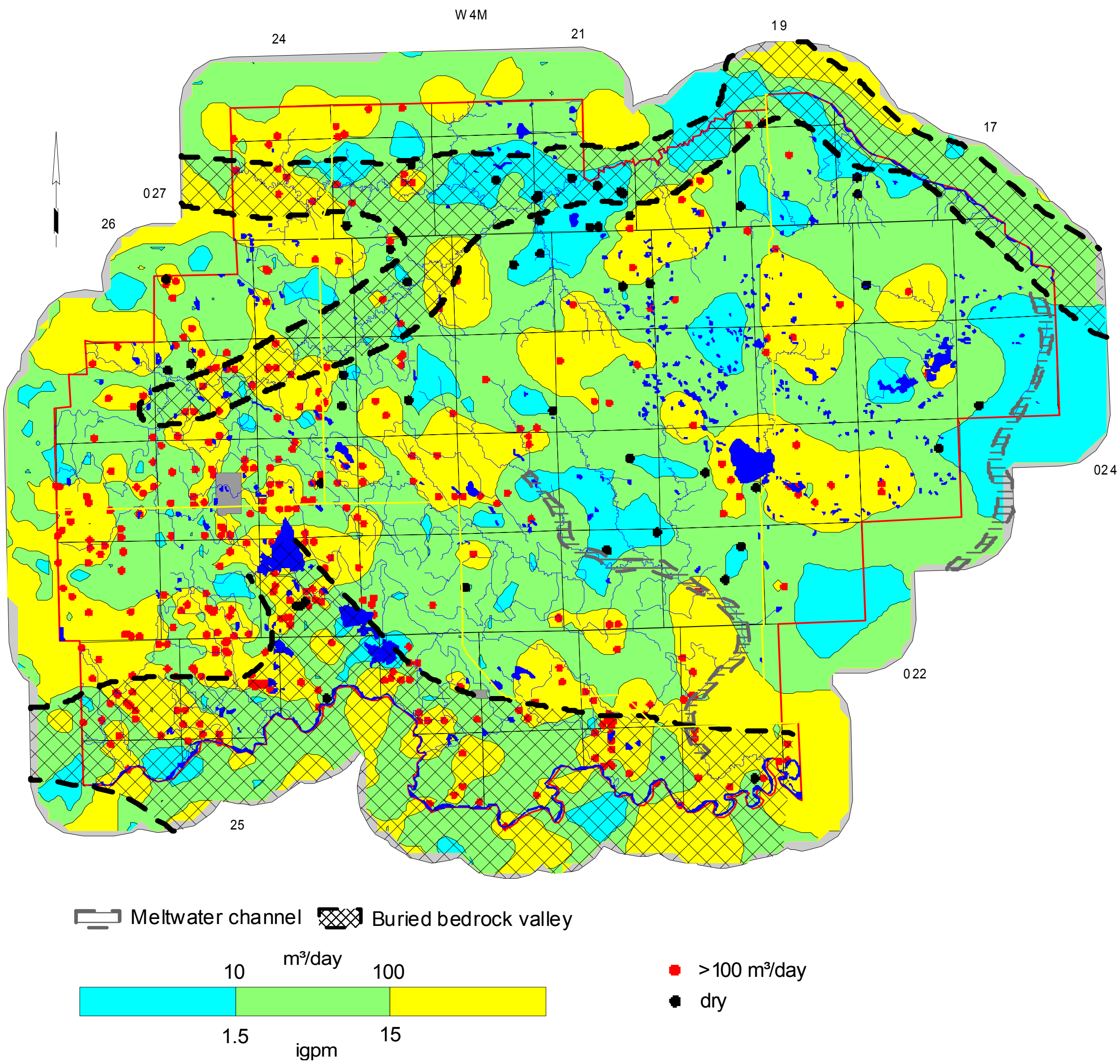


Surficial Deposits

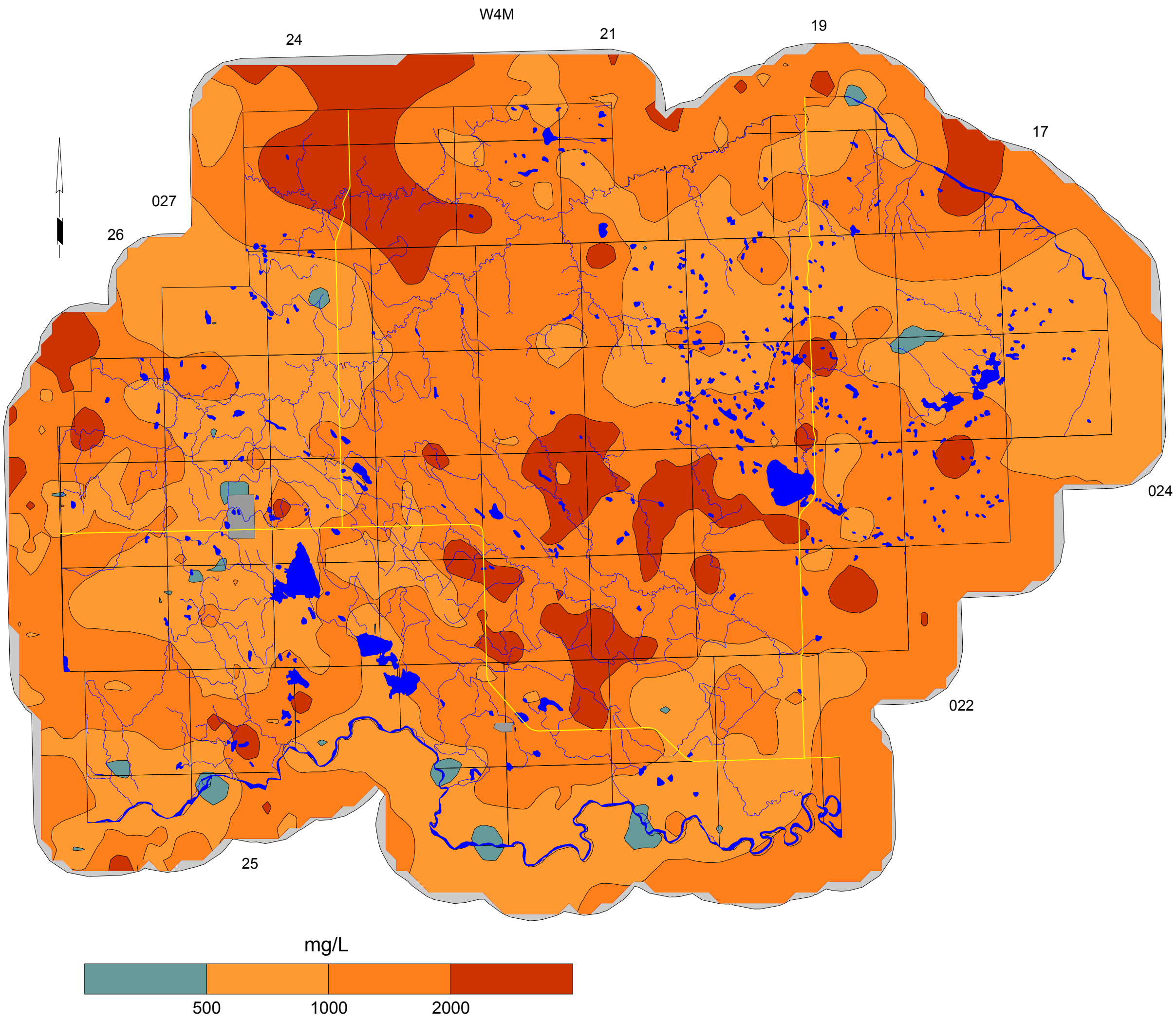


Bedrock Aquifers

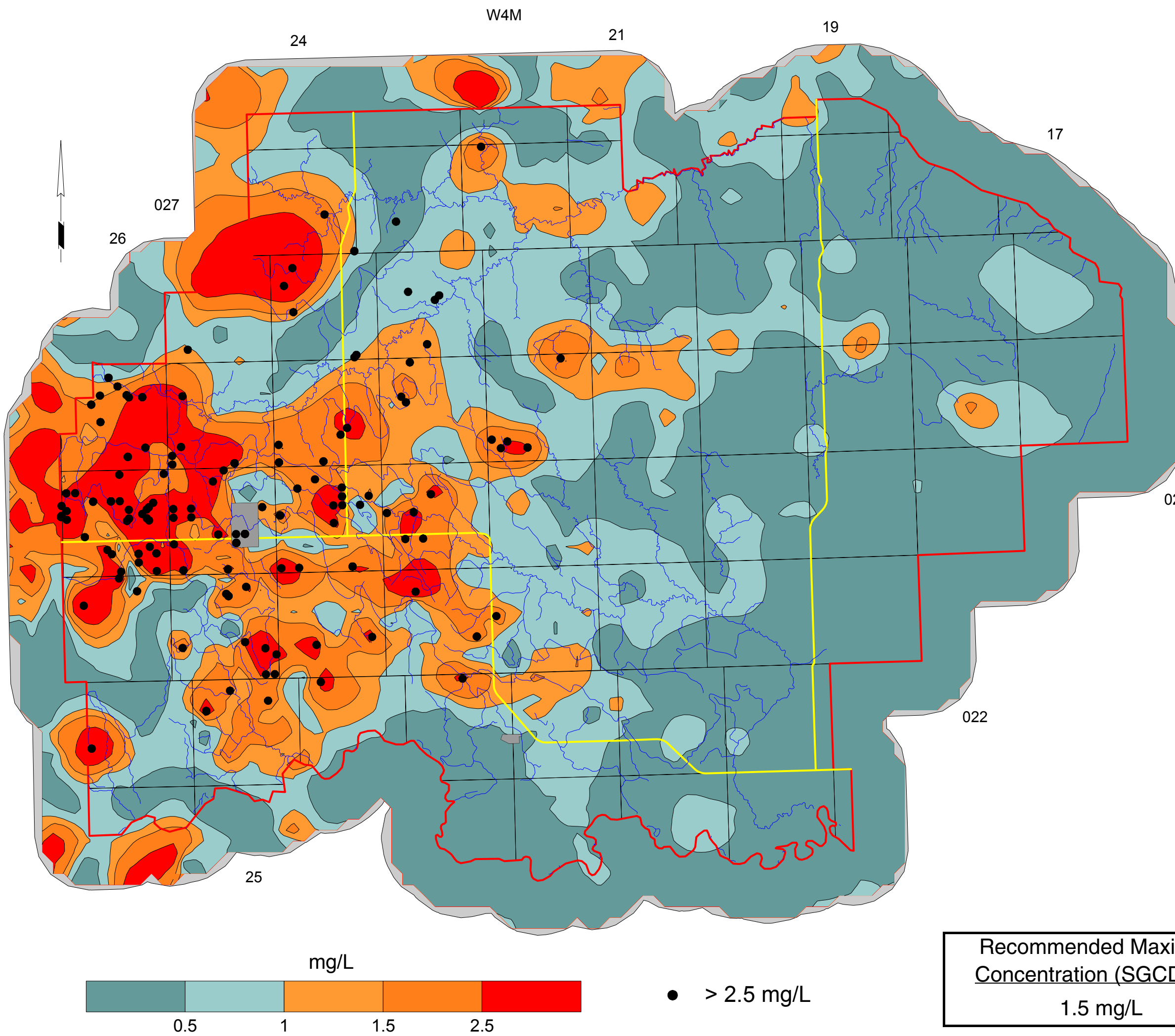
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



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

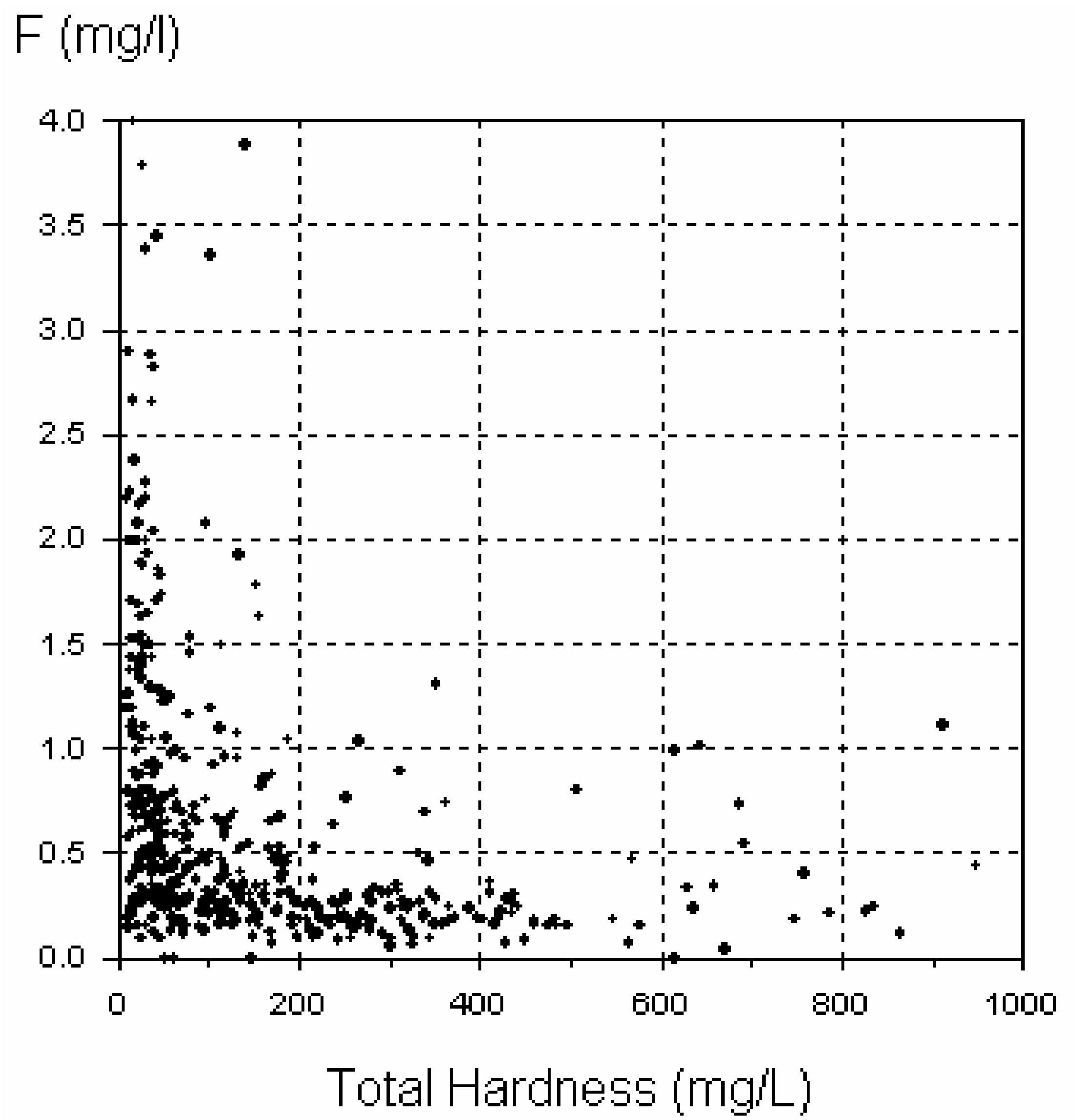


Fluoride in Groundwater from Upper Bedrock Aquifer(s)

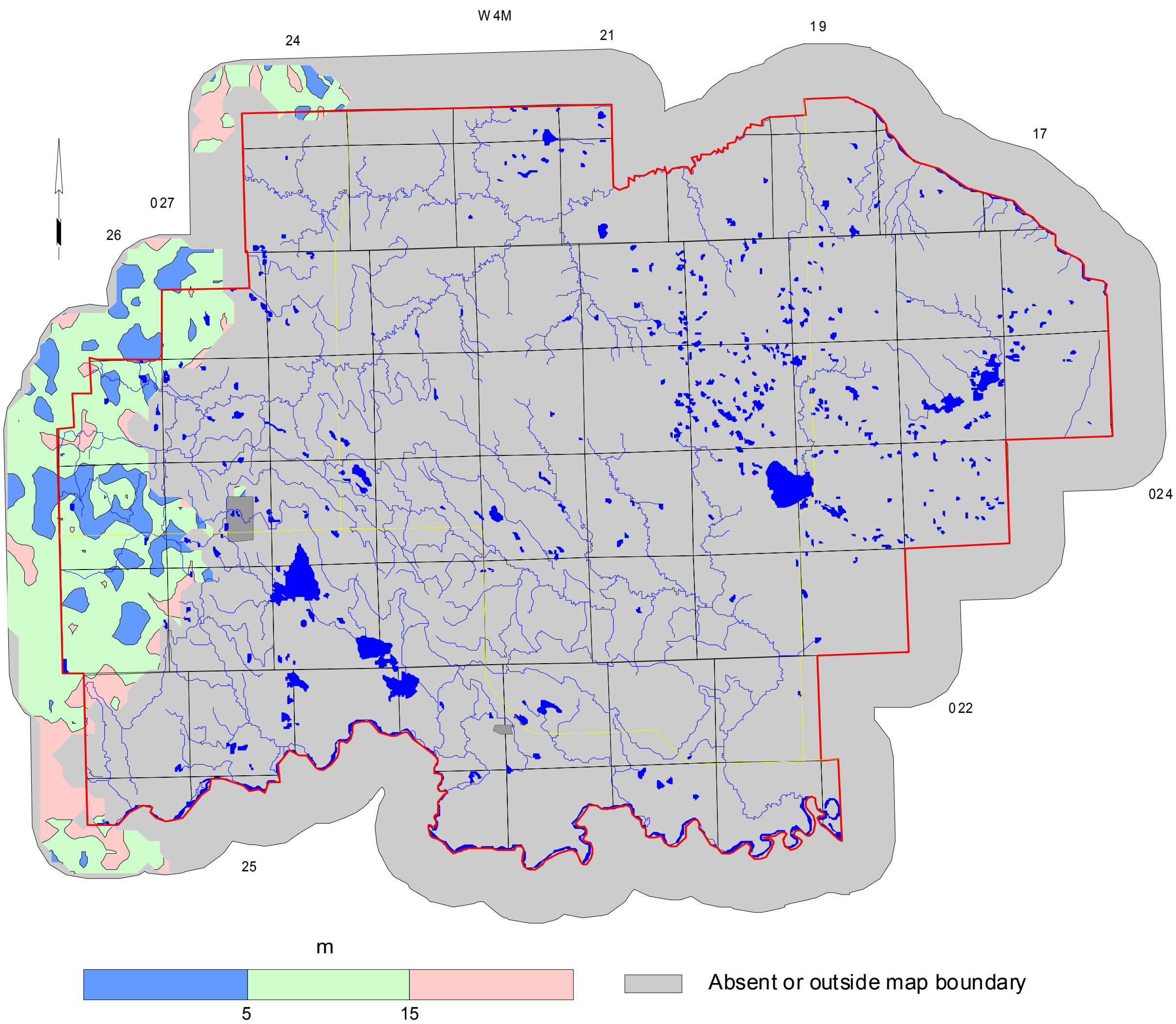


Recommended Maximum
Concentration (SGCDWQ)
1.5 mg/L

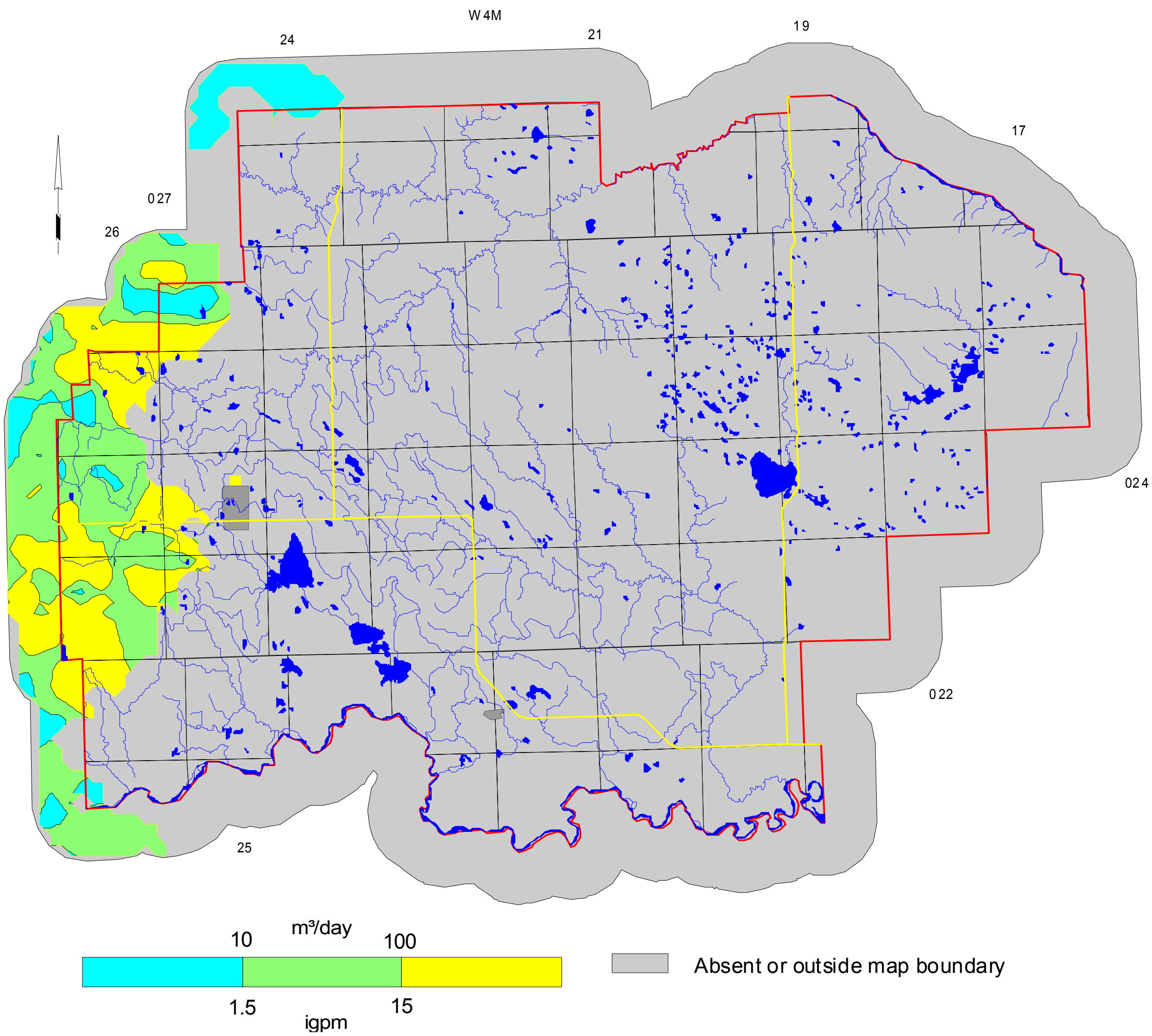
Fluoride vs Total Hardness in Groundwater from Upper Bedrock Aquifer(s)



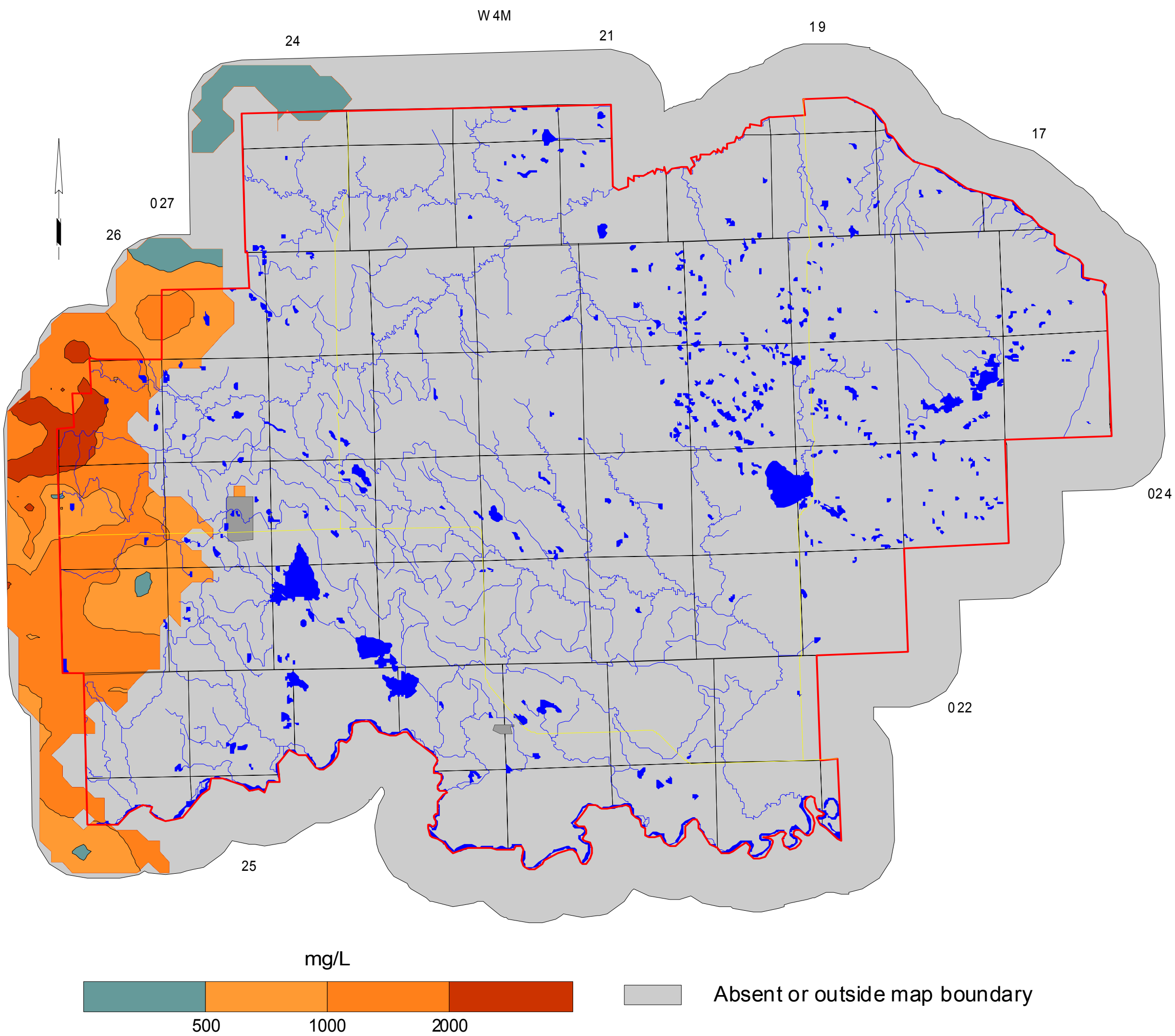
Depth to Top of Lower Lacombe Member



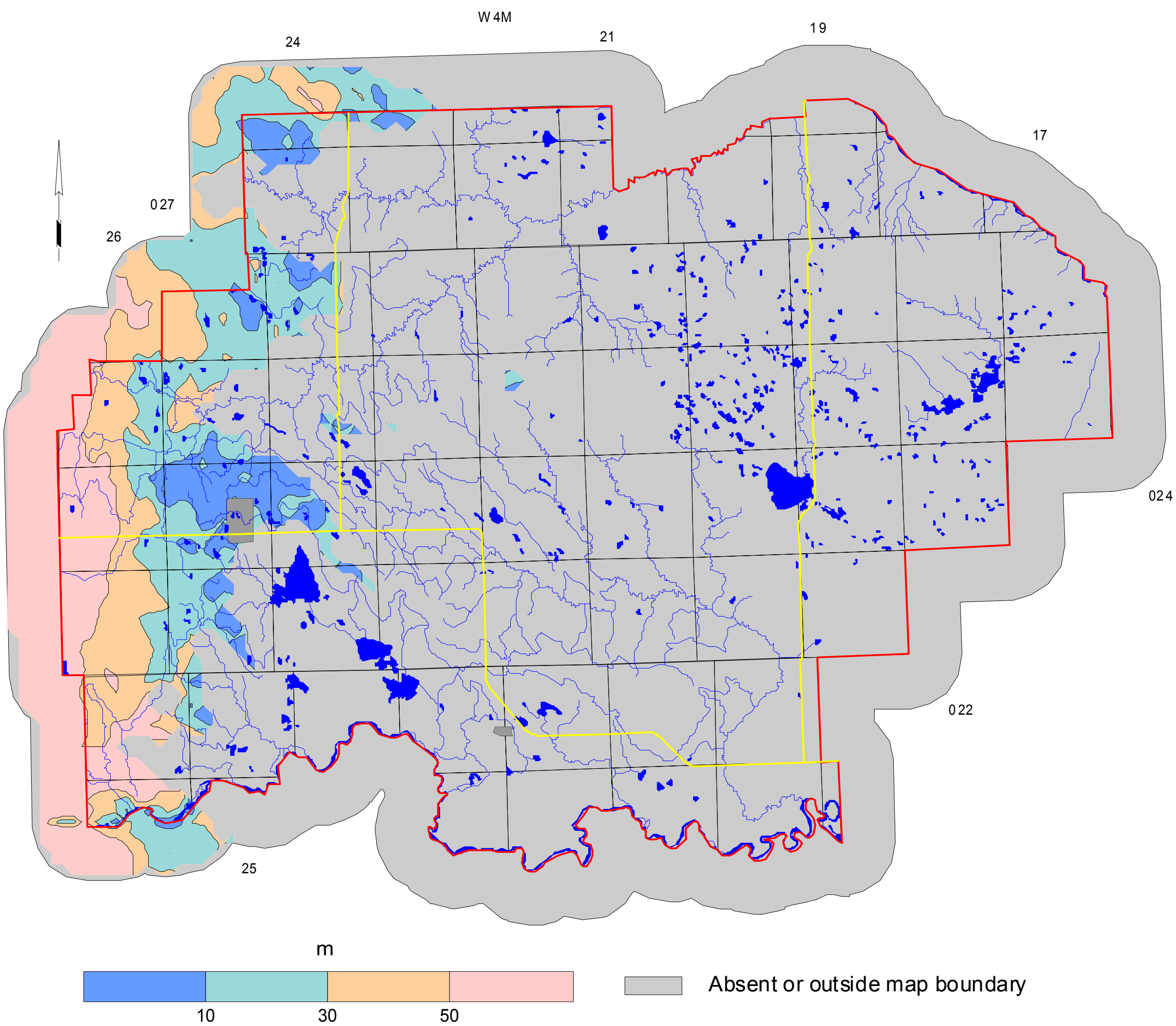
Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer



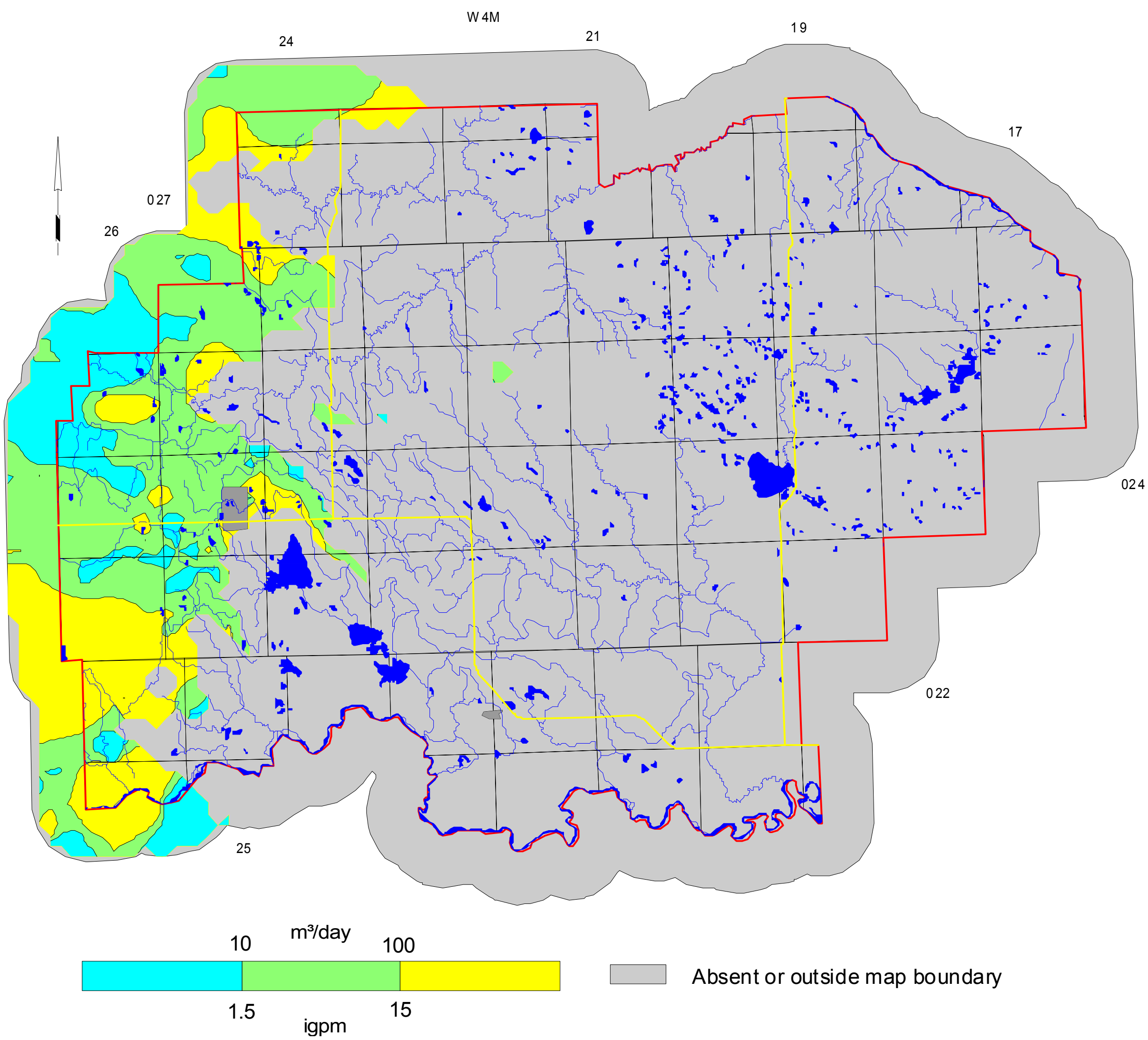
Total Dissolved Solids in Groundwater from Lower Lacombe Aquifer



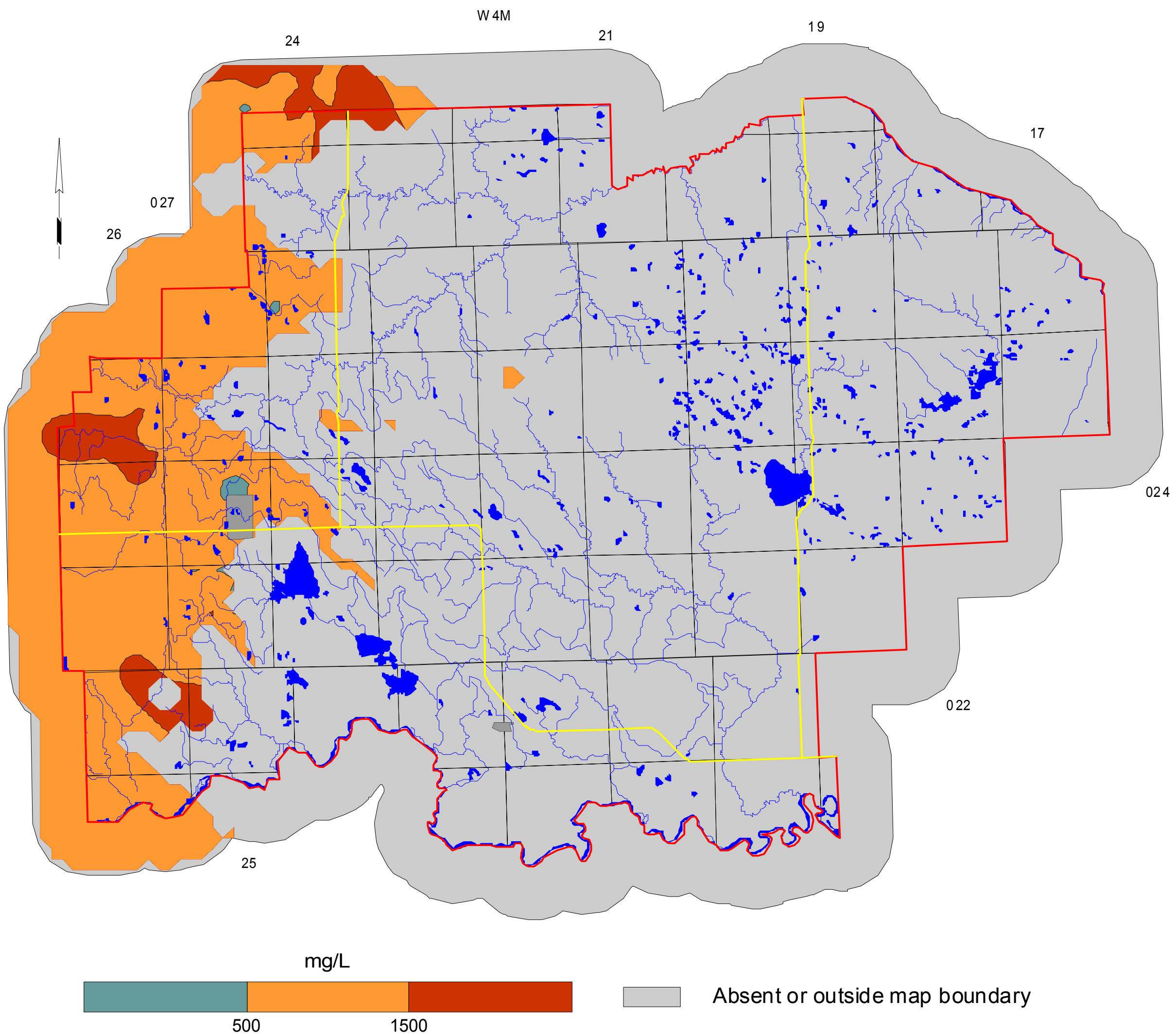
Depth to Top of Haynes Member



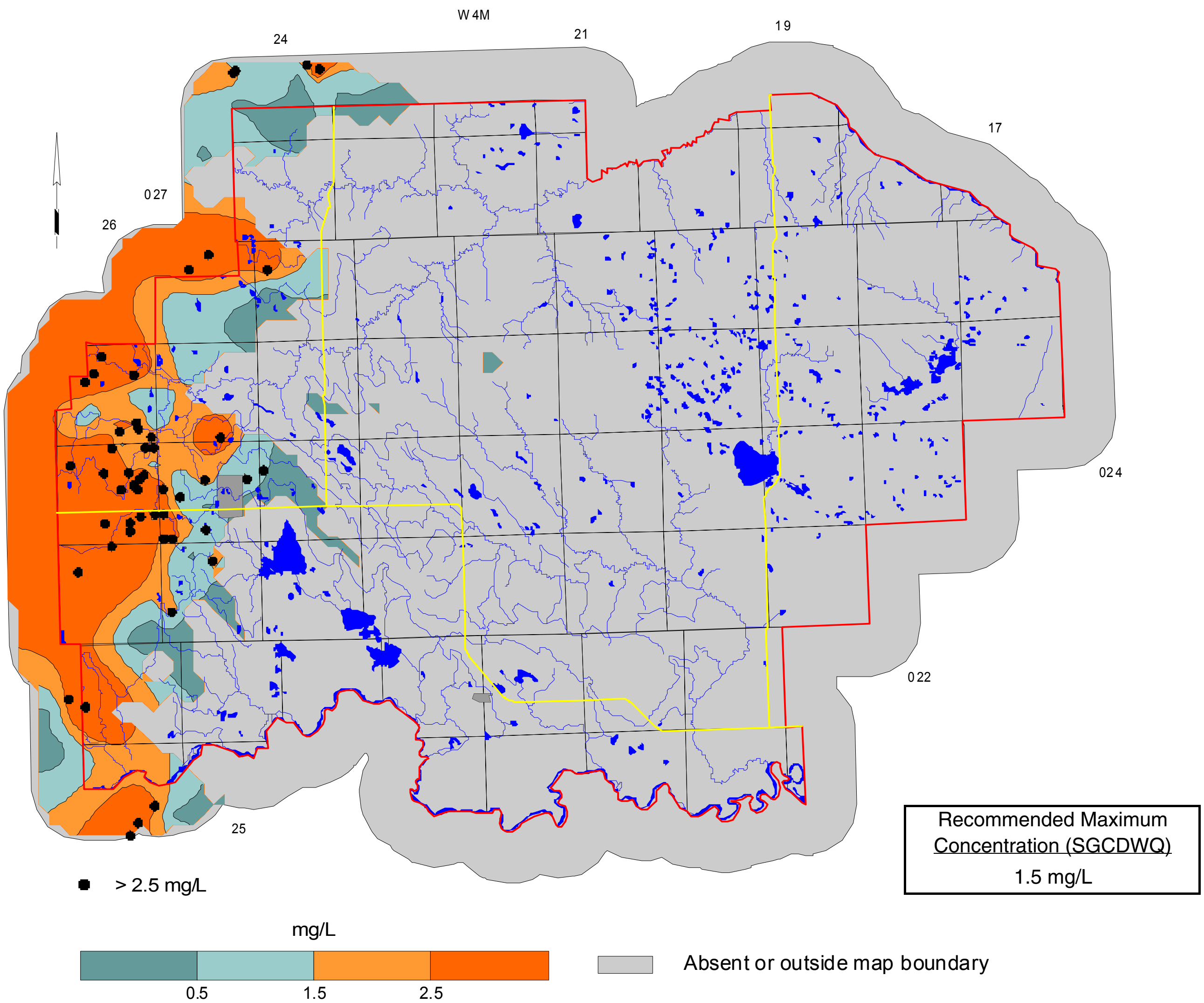
Apparent Yield for Water Wells Completed through Haynes Aquifer



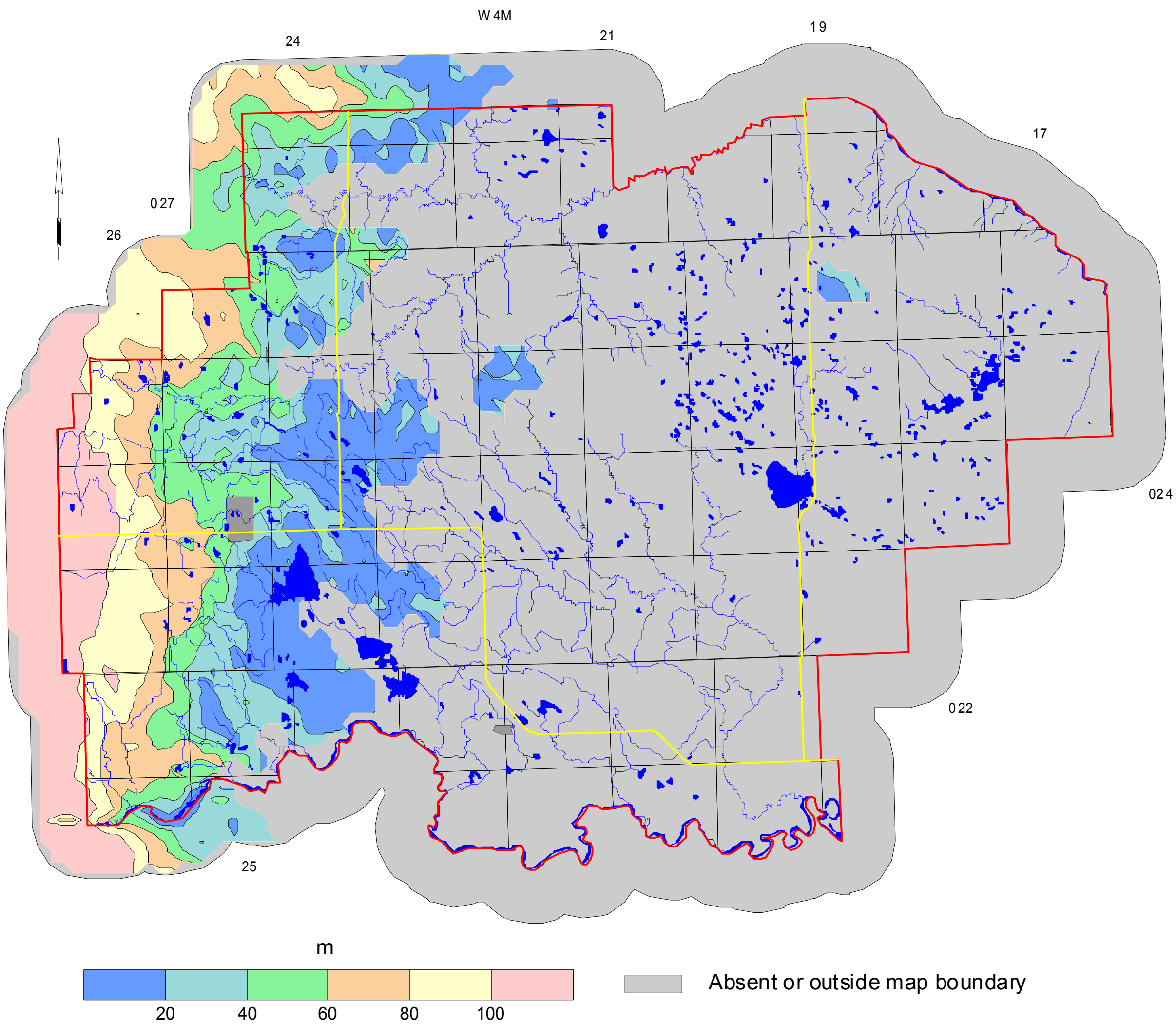
Total Dissolved Solids in Groundwater from Haynes Aquifer



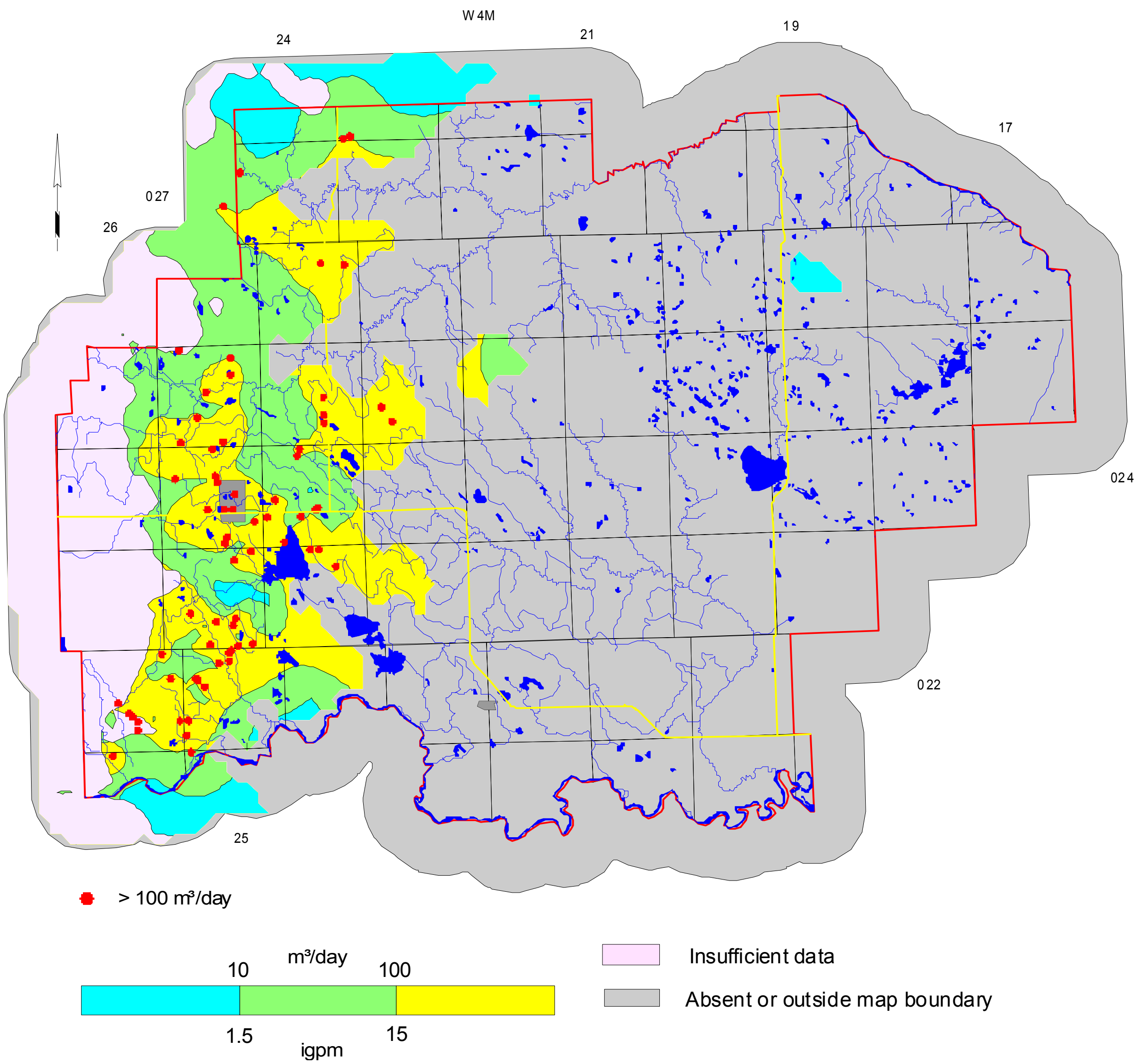
Fluoride in Groundwater from Haynes Aquifer



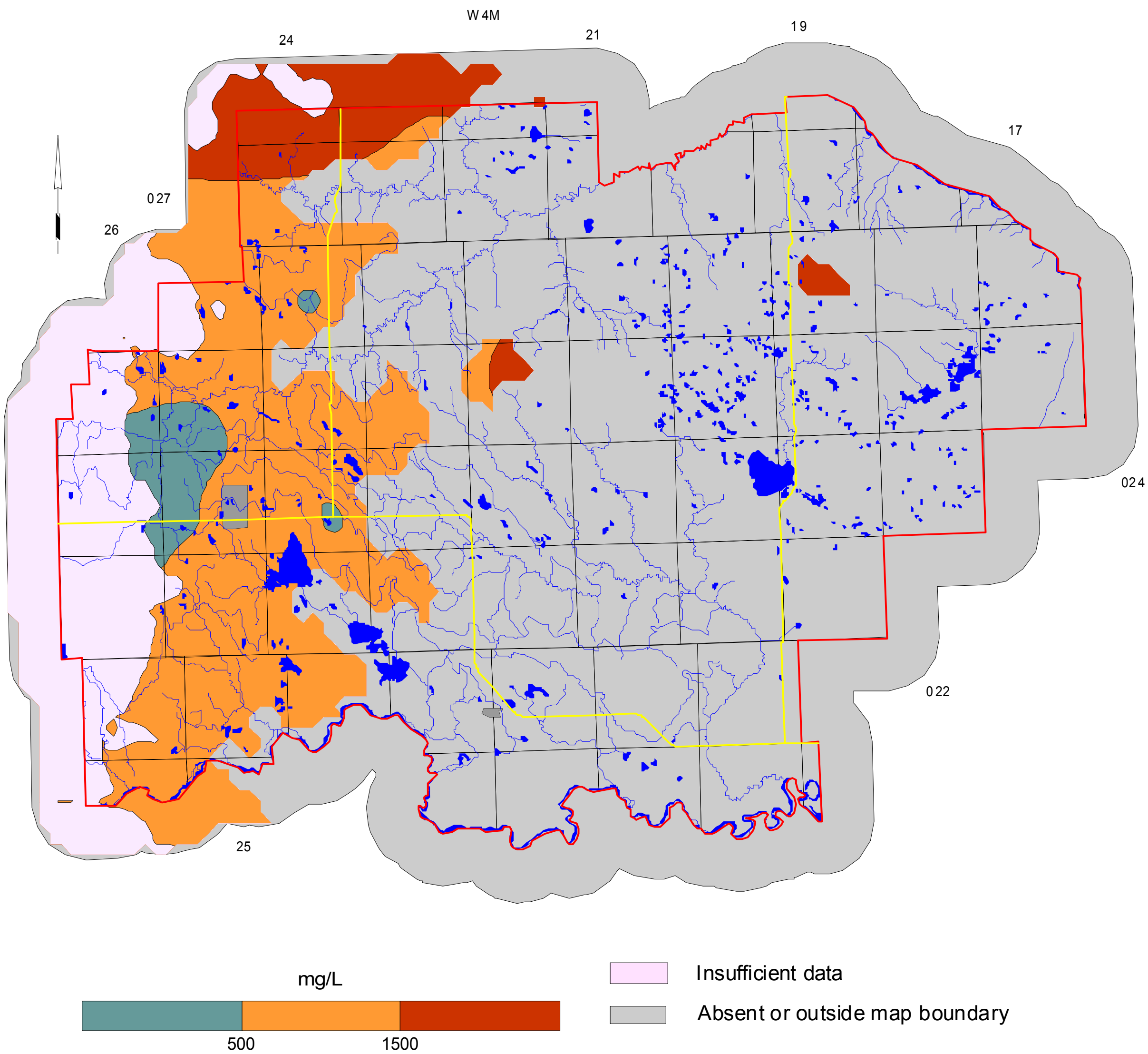
Depth to Top of Upper Scollard Formation



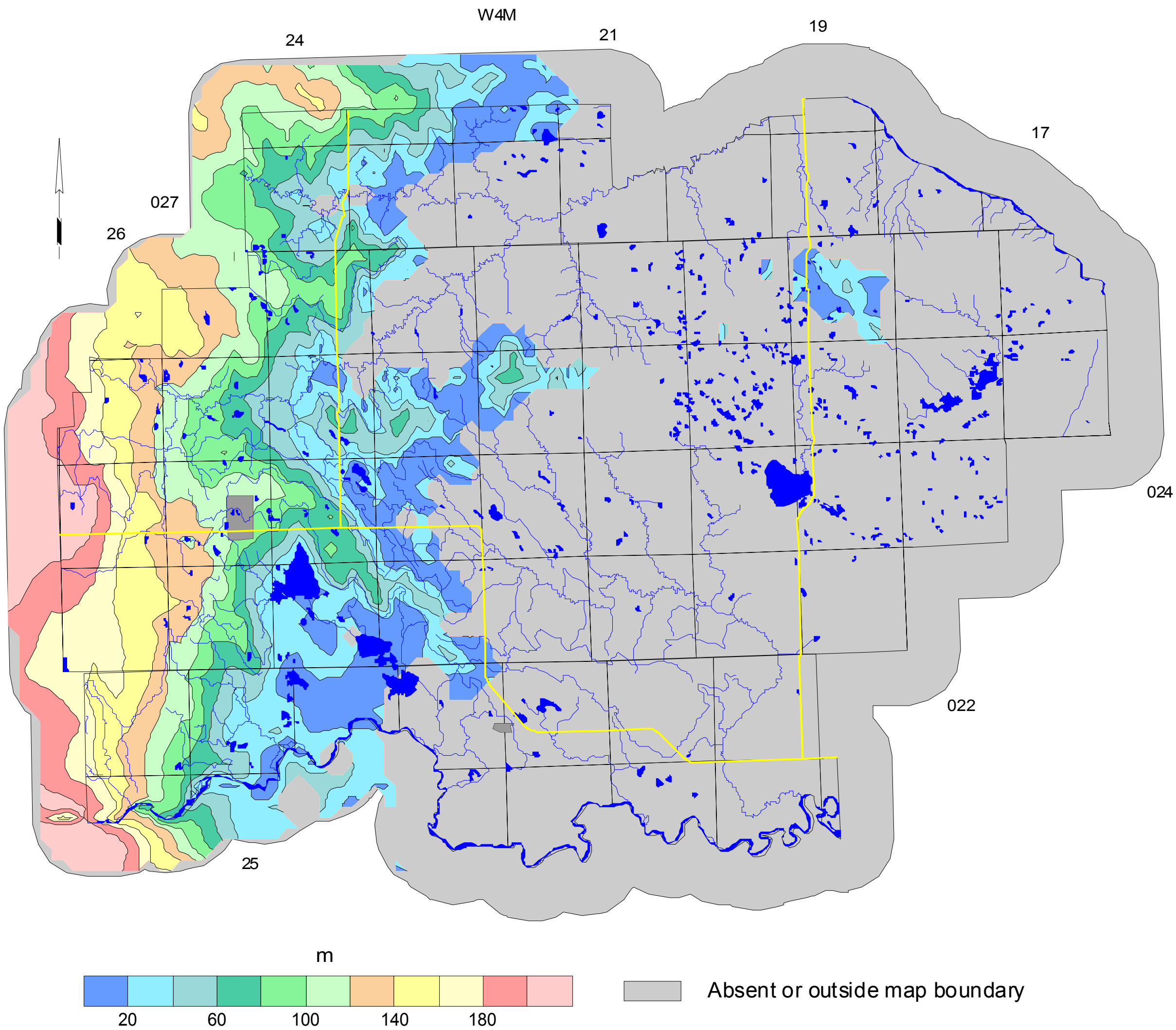
Apparent Yield for Water Wells Completed through Upper Scollard Aquifer



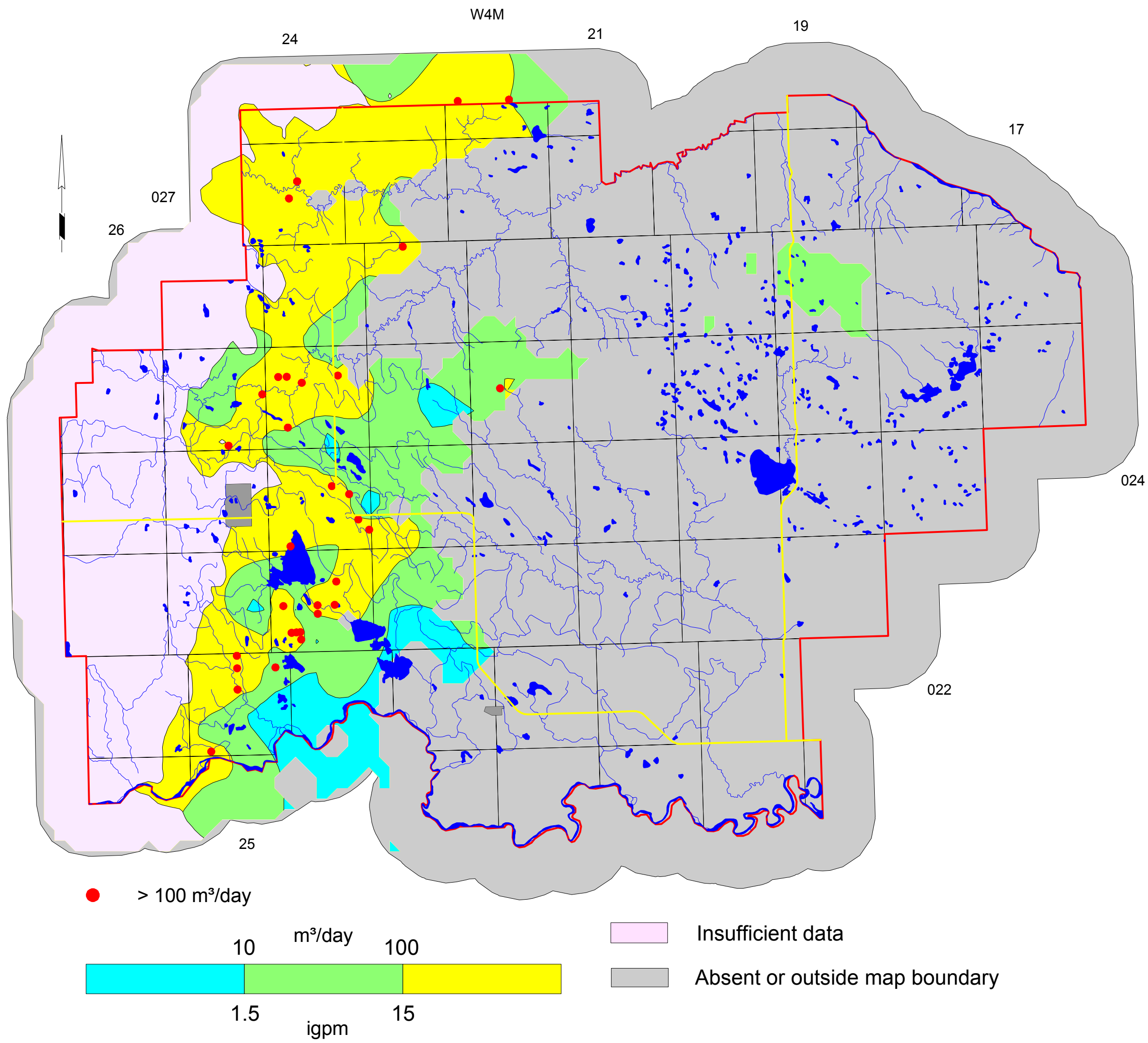
Total Dissolved Solids in Groundwater from Upper Scollard Aquifer



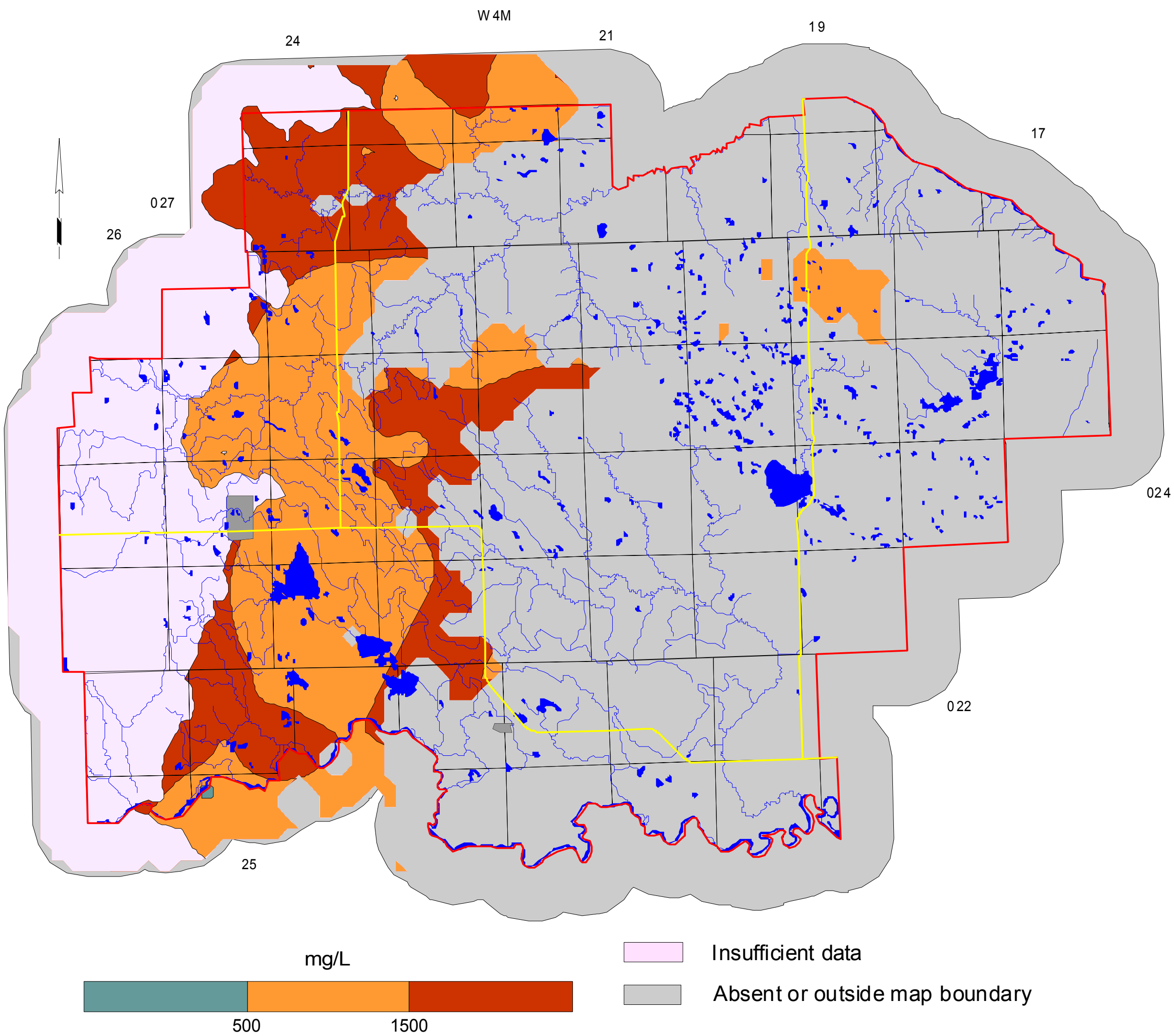
Depth to Top of Lower Scollard Formation



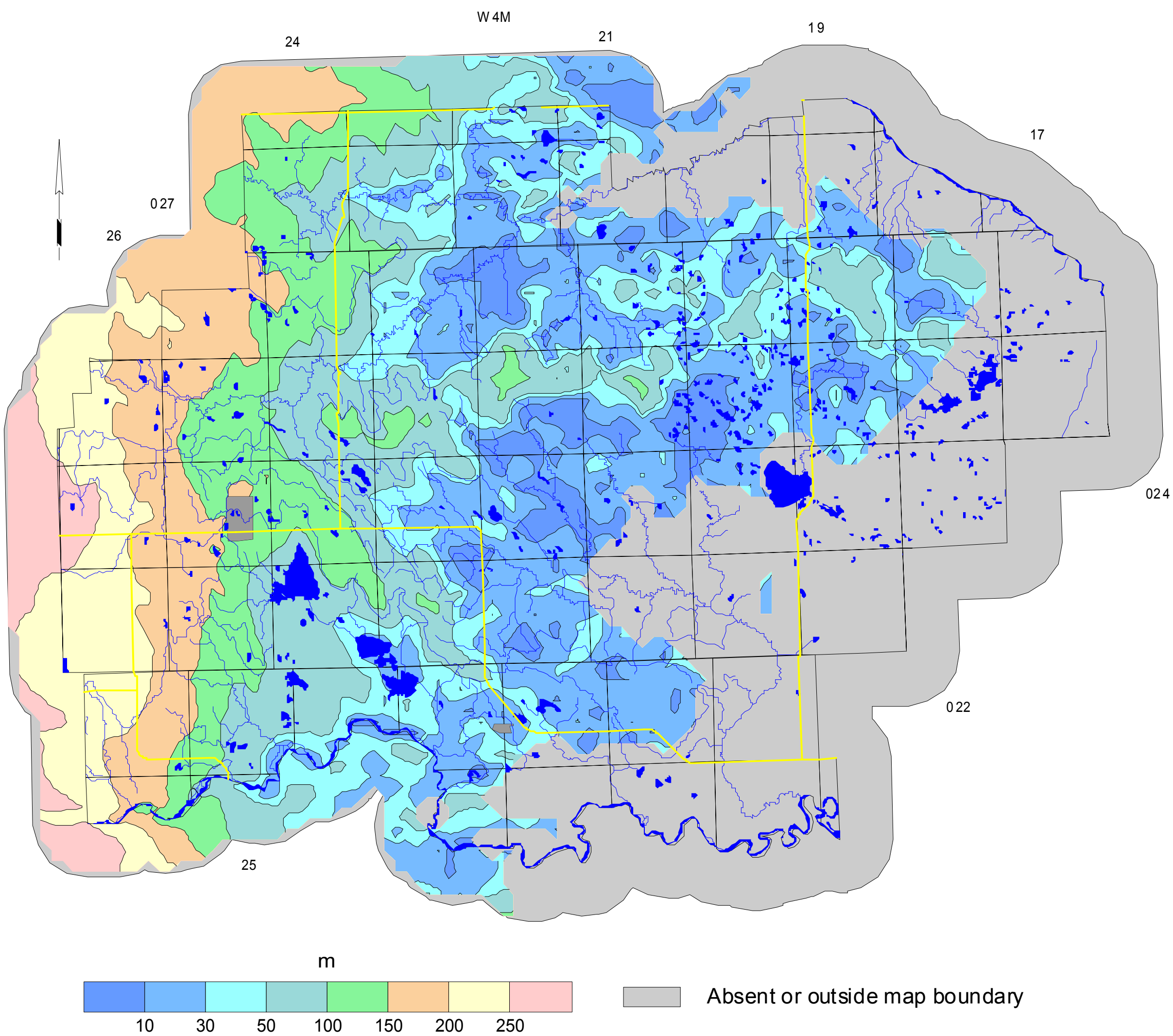
Apparent Yield for Water Wells Completed through Lower Scollard Aquifer



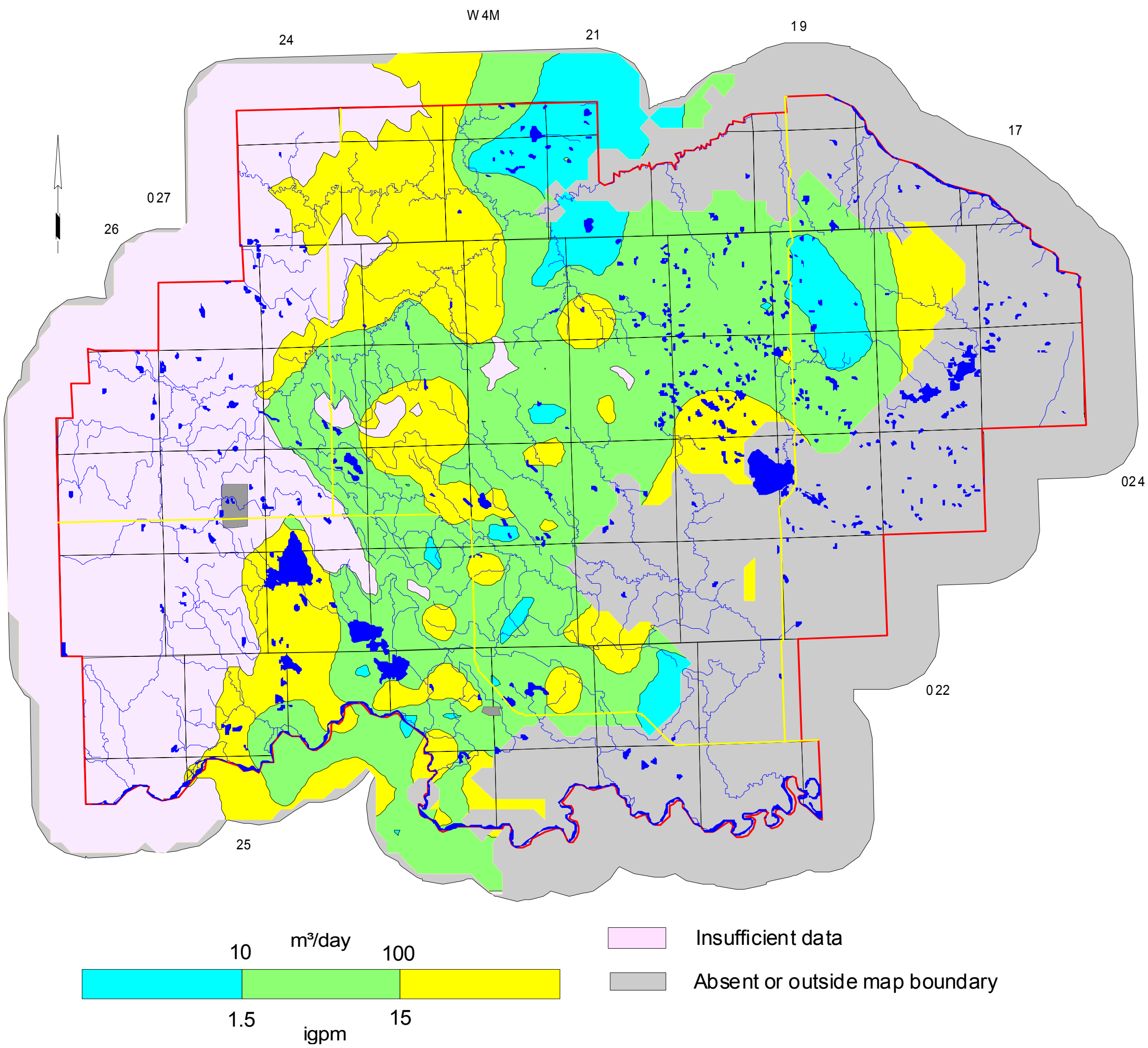
Total Dissolved Solids in Groundwater from Lower Scollard Aquifer



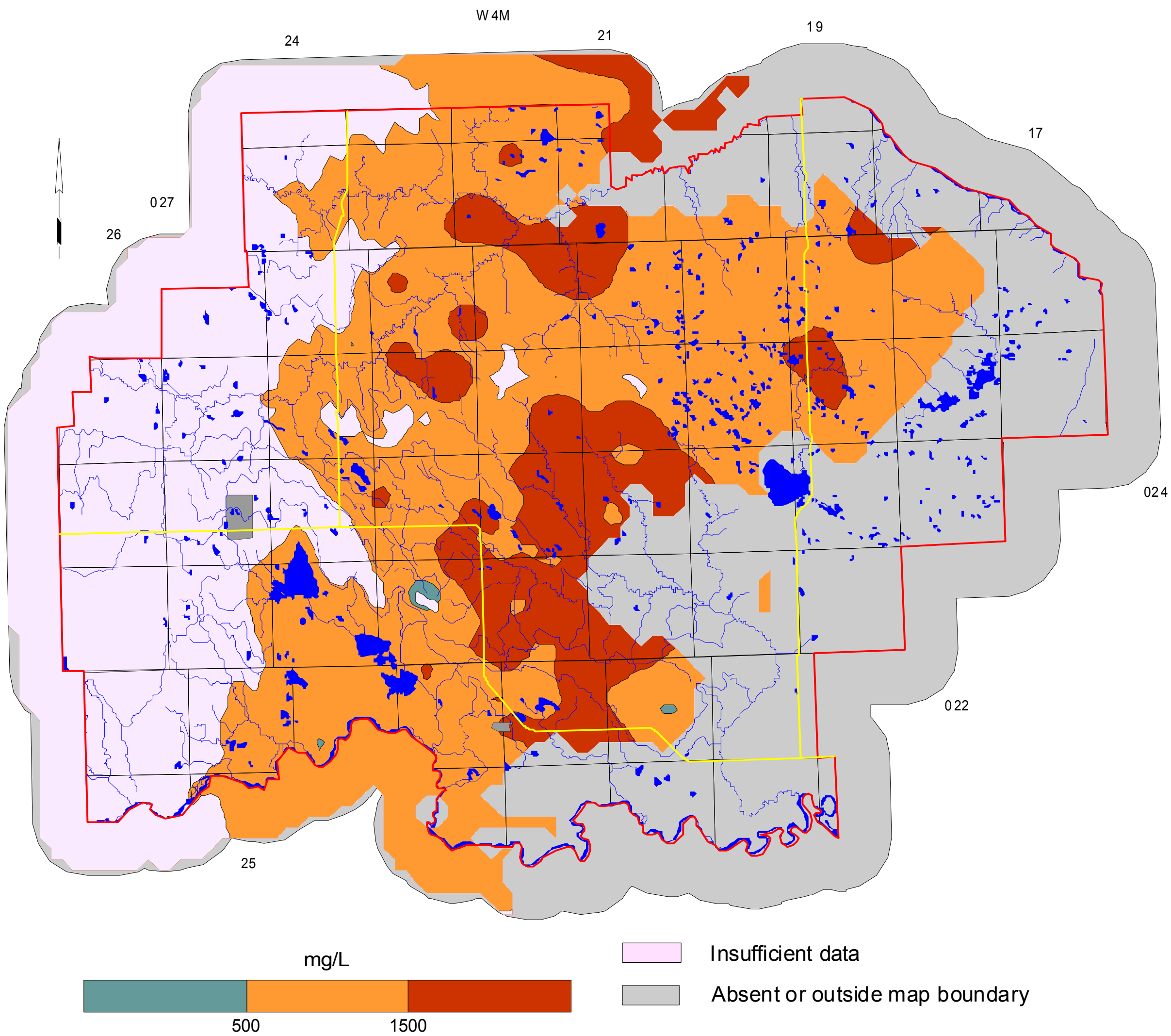
Depth to Top of Upper Horseshoe Canyon Formation



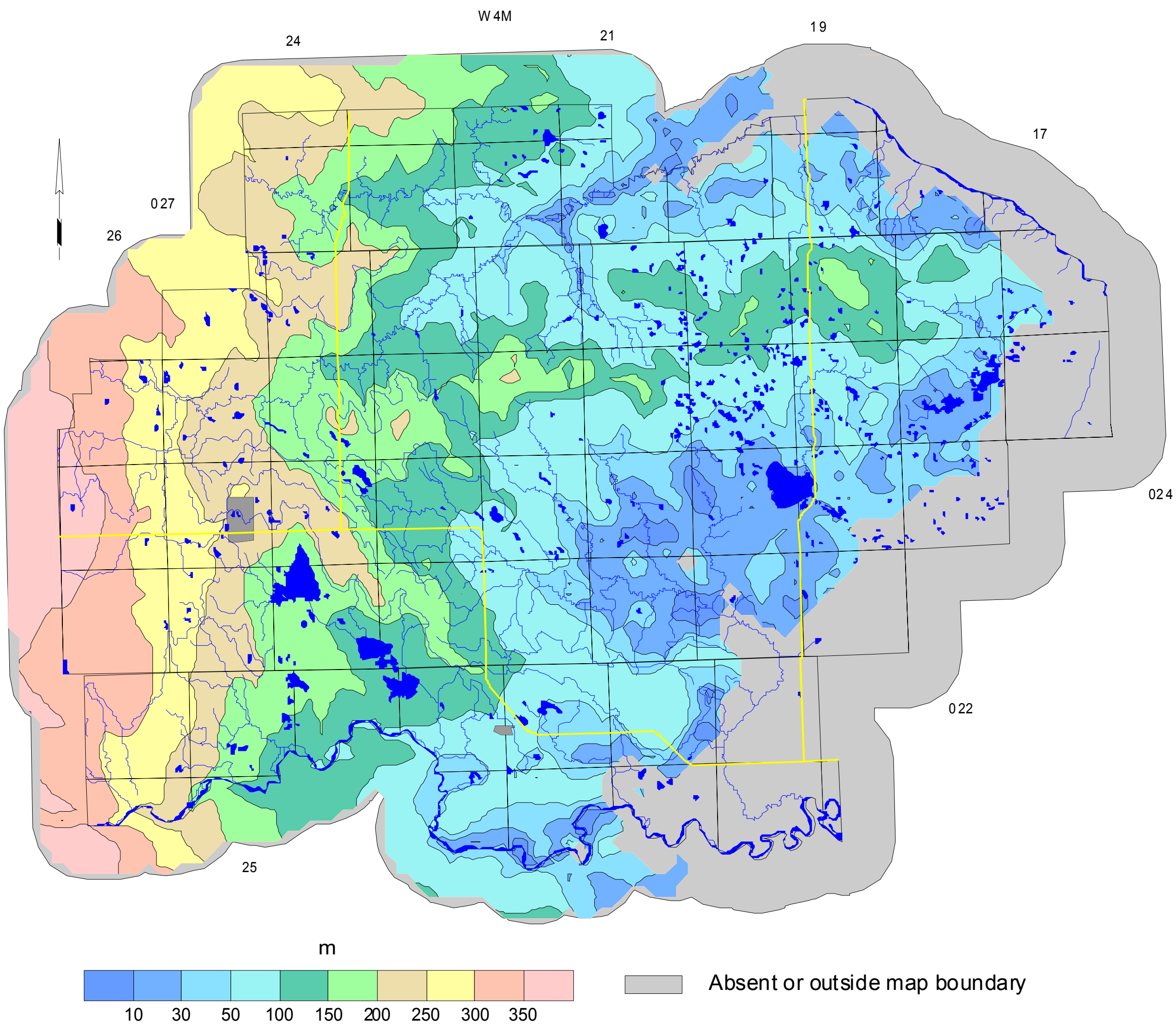
Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer



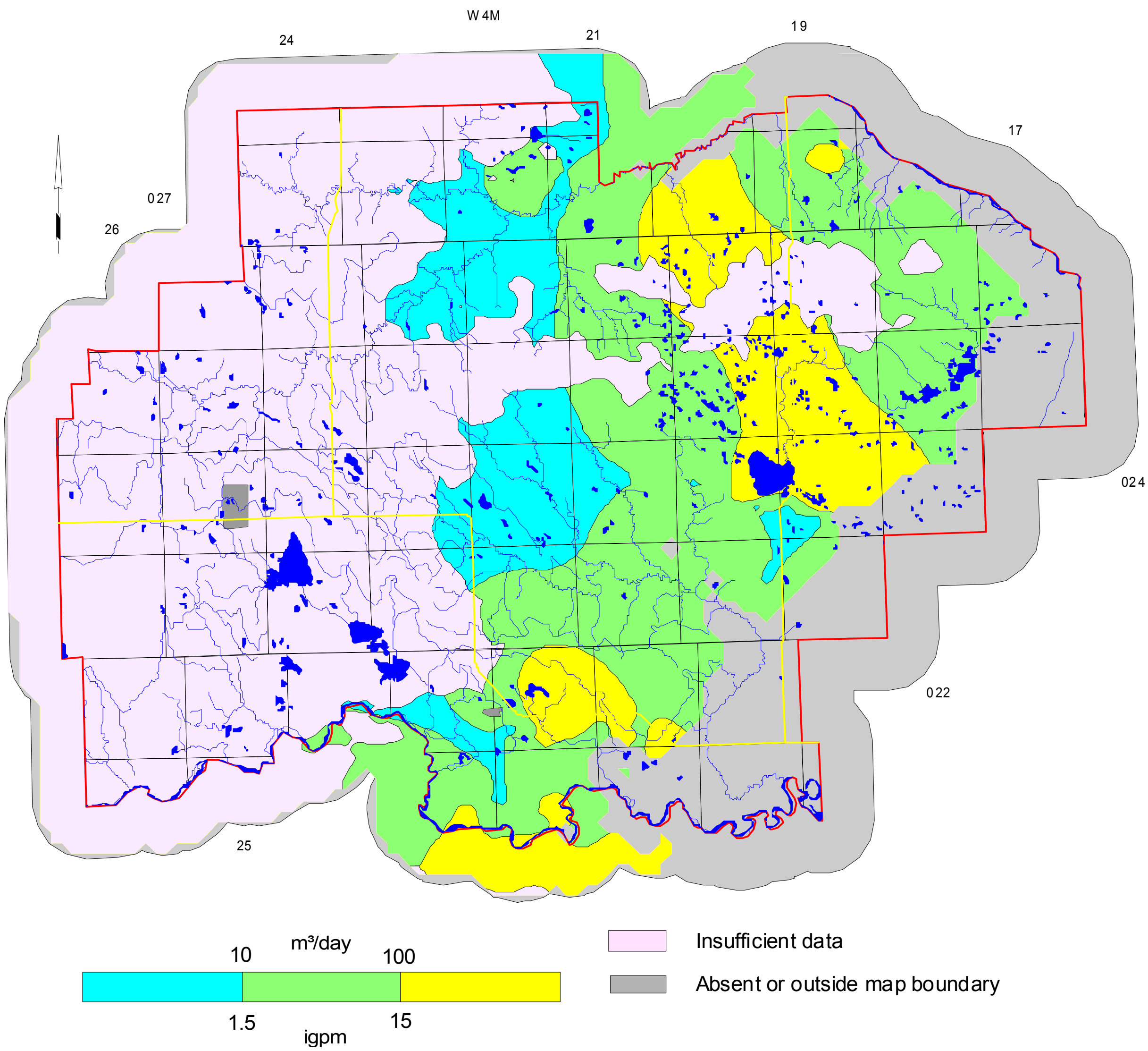
Total Dissolved Solids in Groundwater from Upper Horseshoe Canyon Aquifer



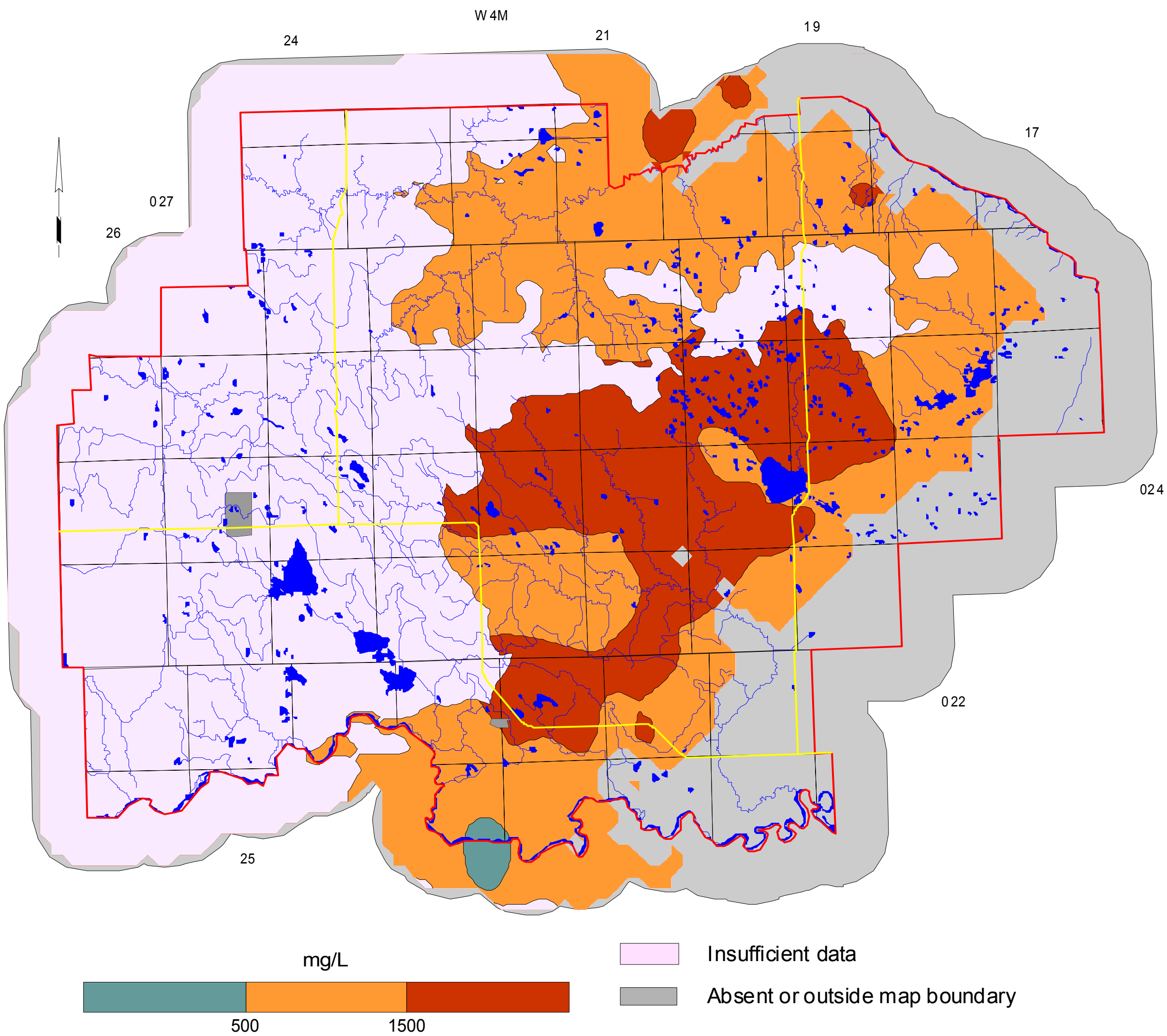
Depth to Top of Middle Horseshoe Canyon Formation



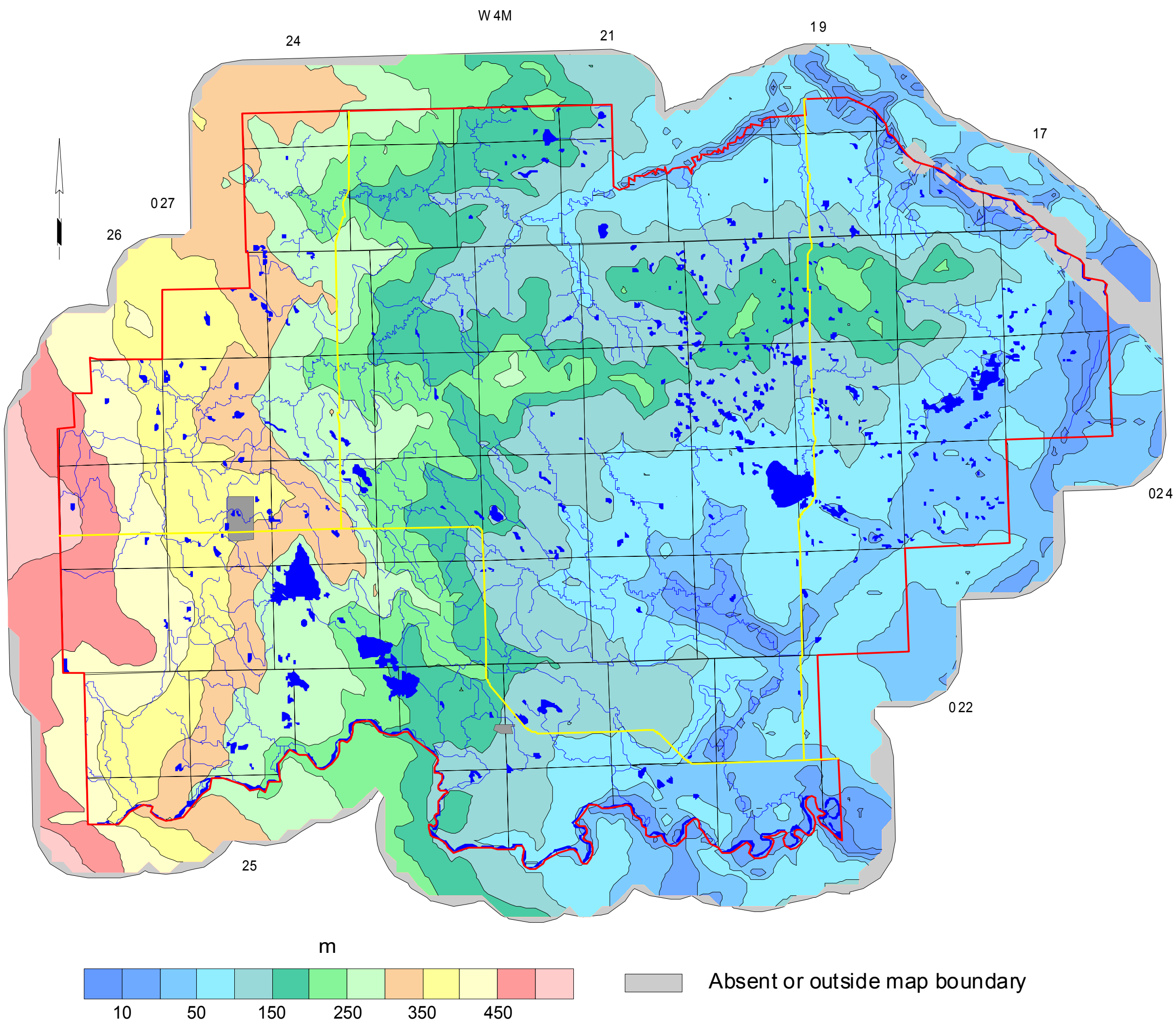
Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer



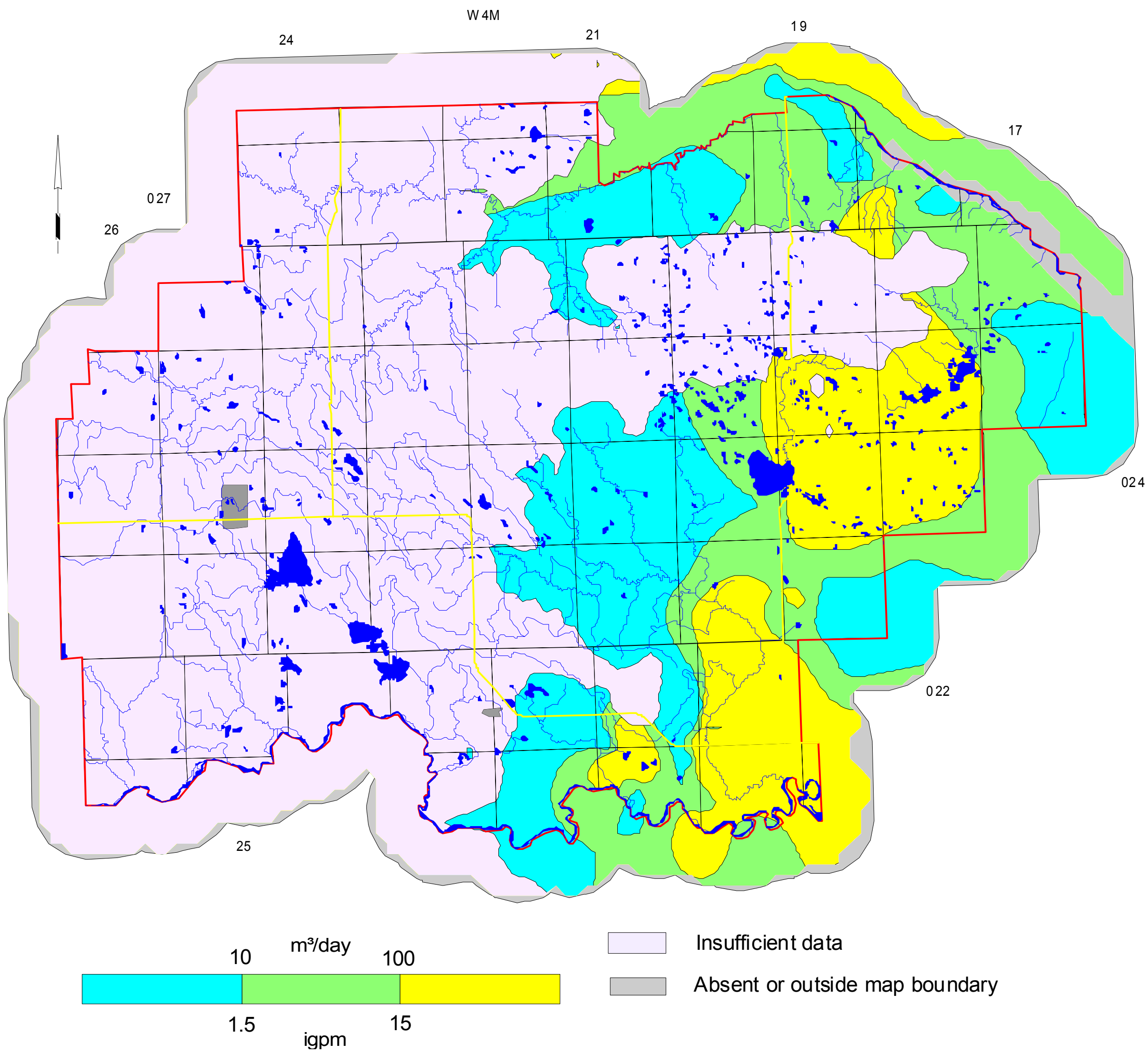
Total Dissolved Solids in Groundwater from Middle Horseshoe Canyon Aquifer



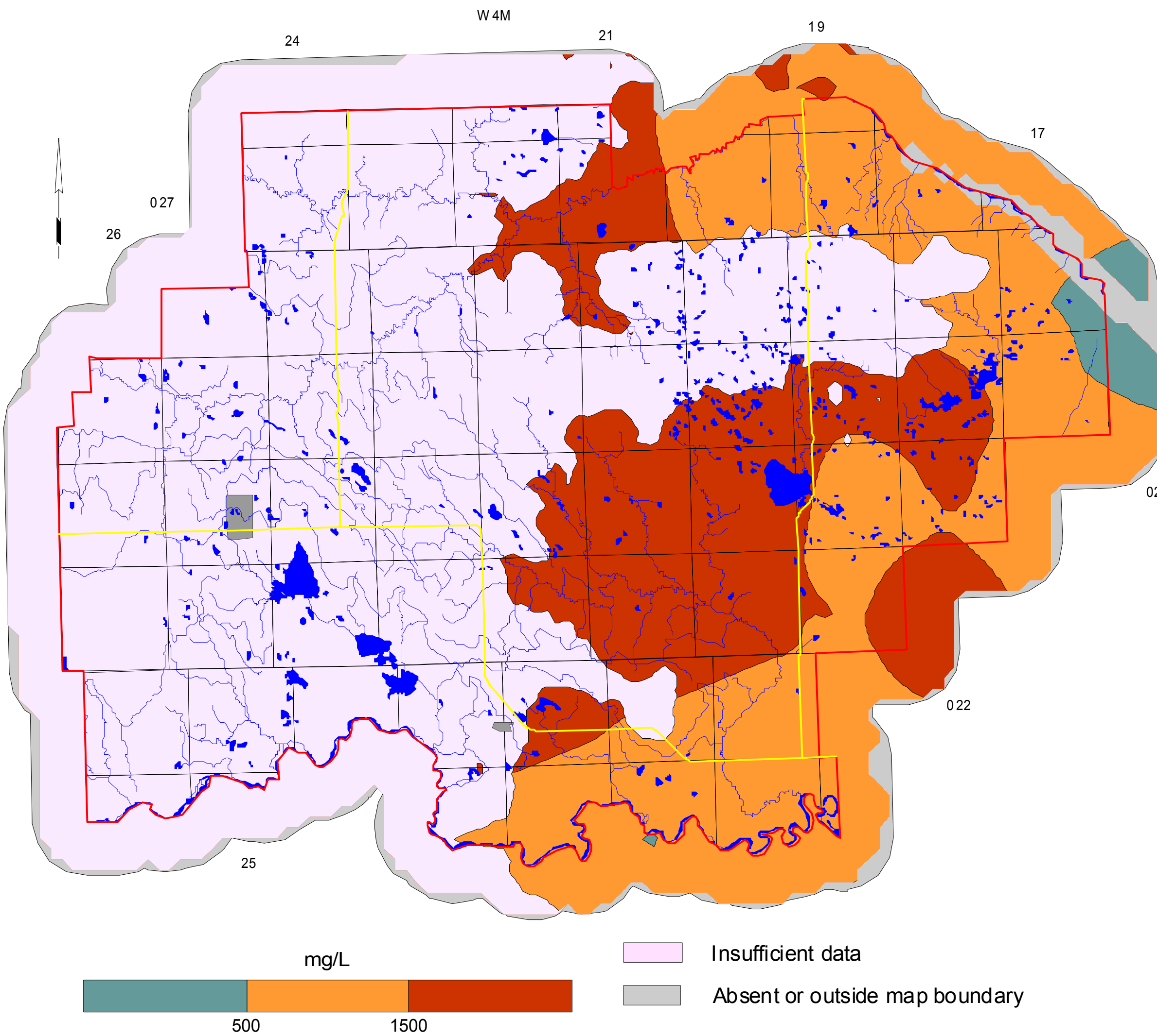
Depth to Top of Lower Horseshoe Canyon Formation



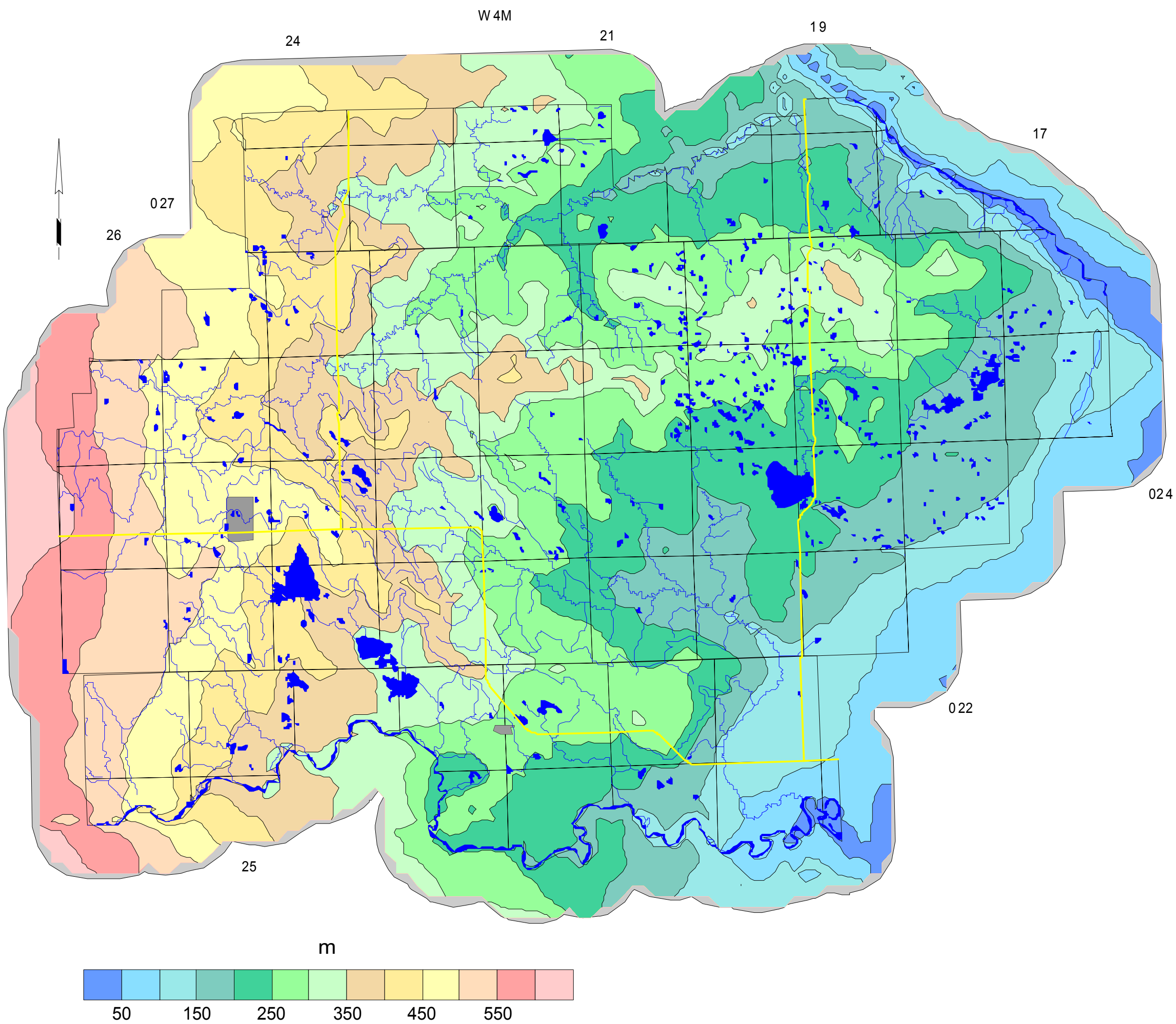
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer



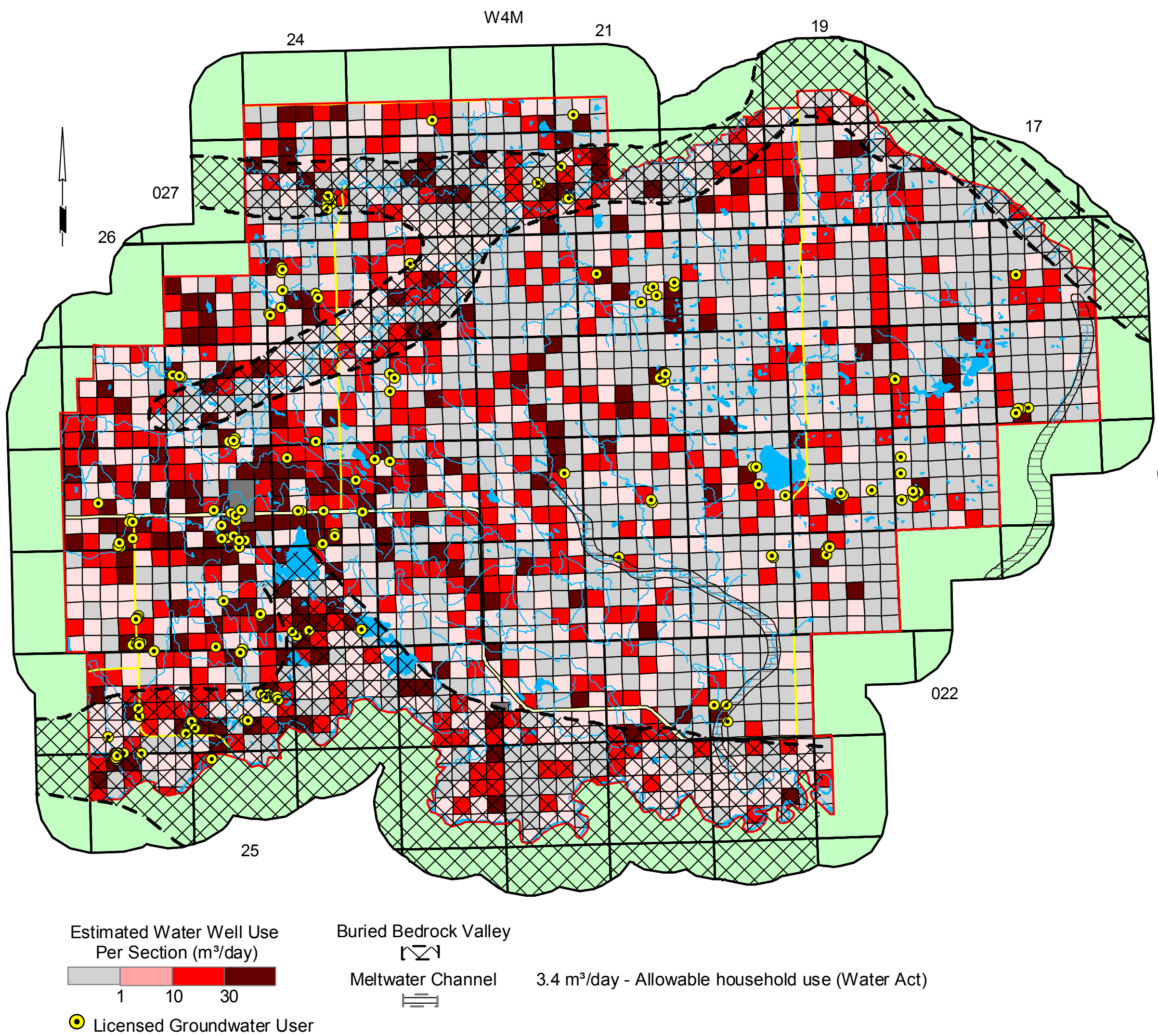
Total Dissolved Solids in Groundwater from Middle Horseshoe Canyon Aquifer



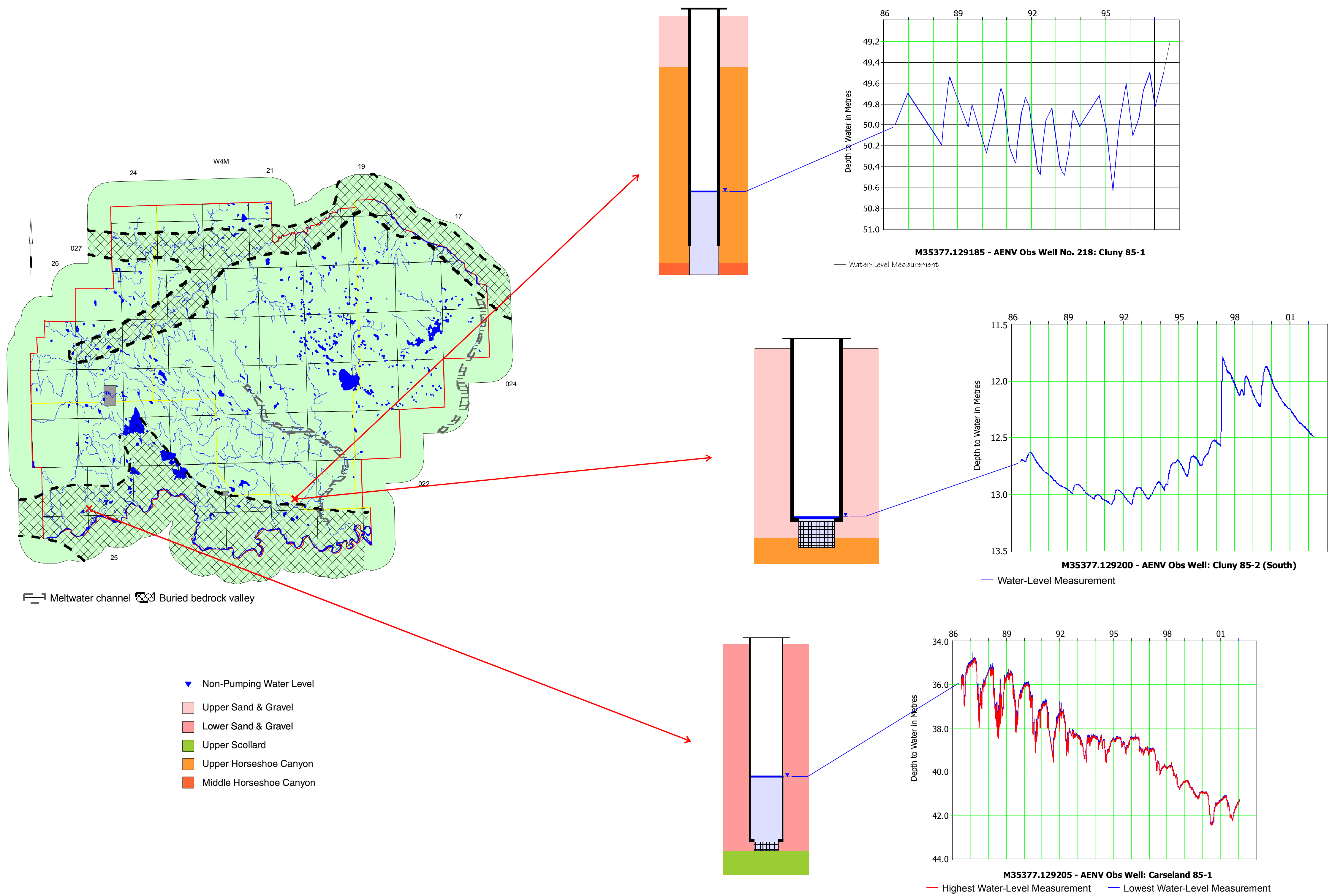
Depth to Top of Bearpaw Formation



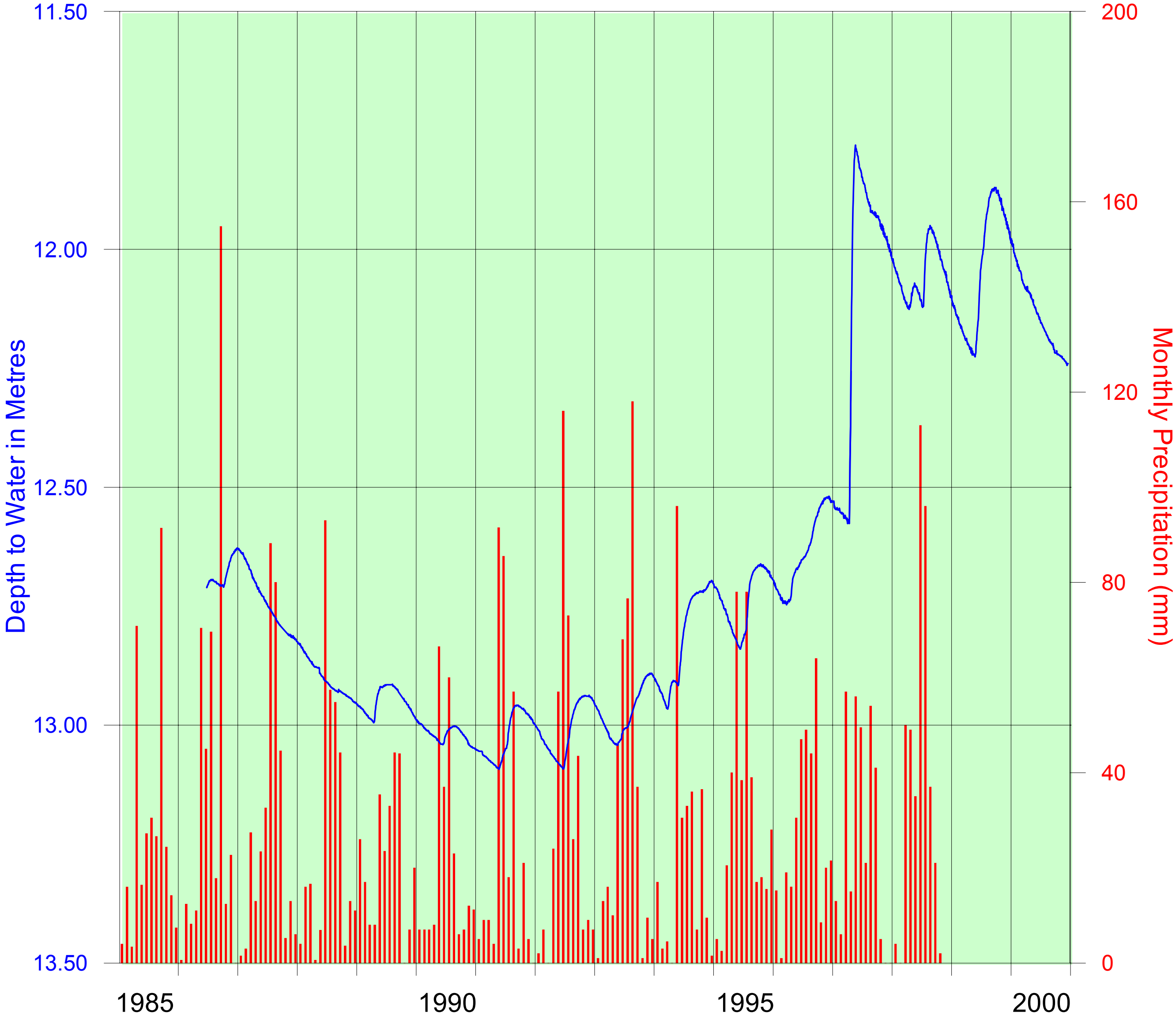
Estimated Water Well Use Per Section

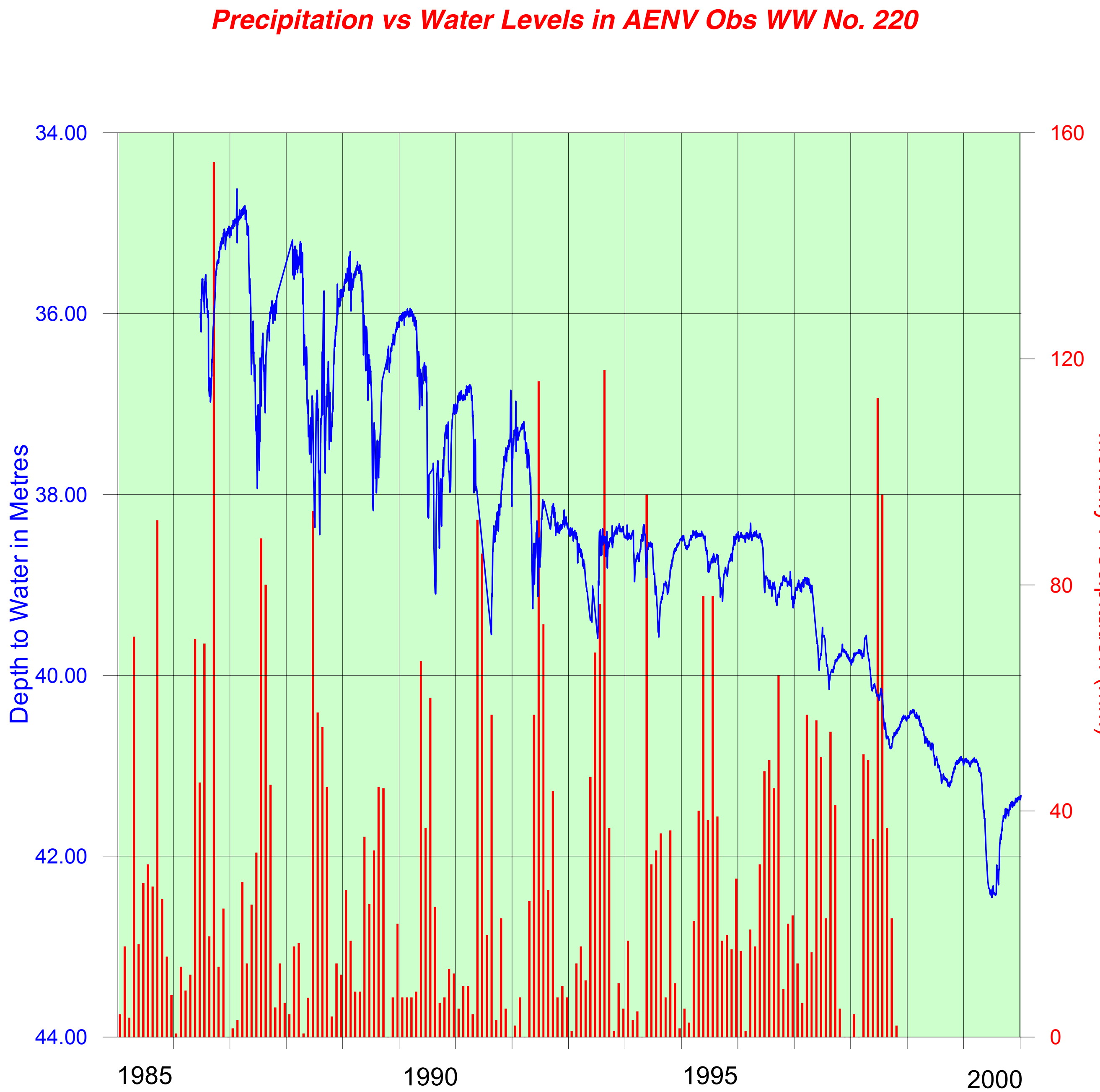


Hydrographs

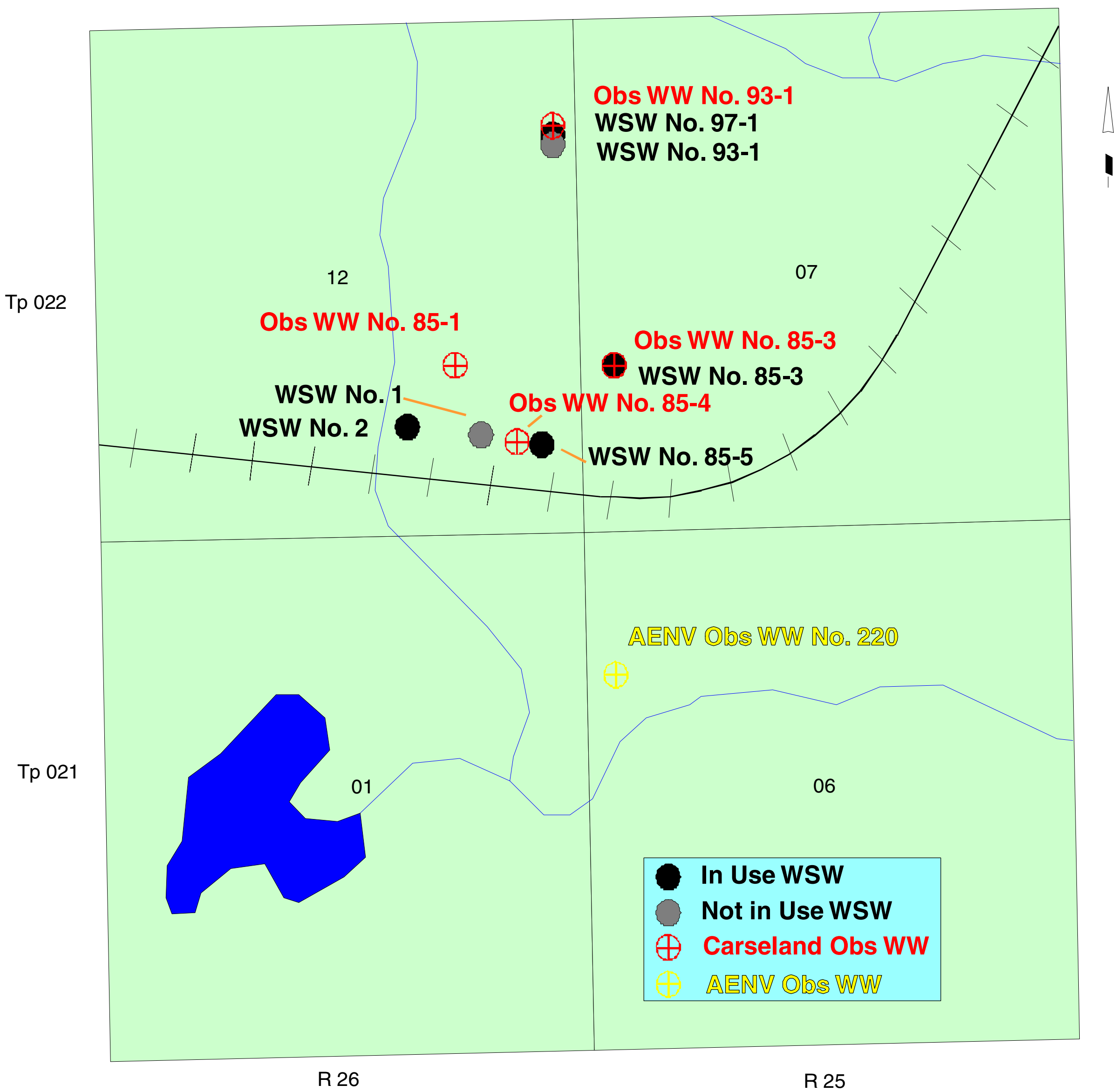


Precipitation vs Water Levels in AENV Obs WW No. 218

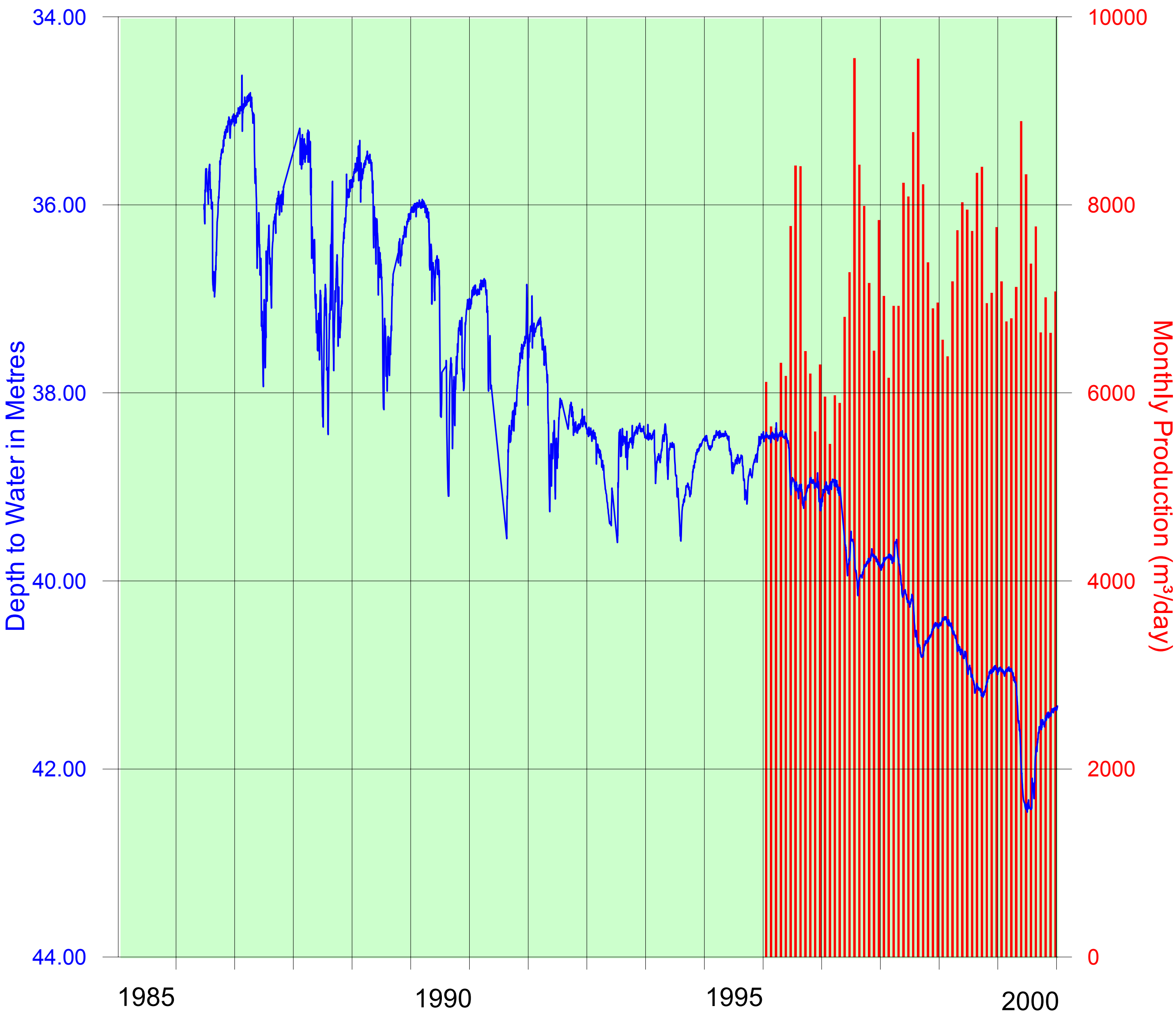



Precipitation vs Water Levels in AENV Obs WW No. 220
Depth to Water in Metres
34.00
36.00
38.00
40.00
42.00
44.00
Monthly Precipitation (mm)
160
120
80
40
0
1985
1990
1995
2000

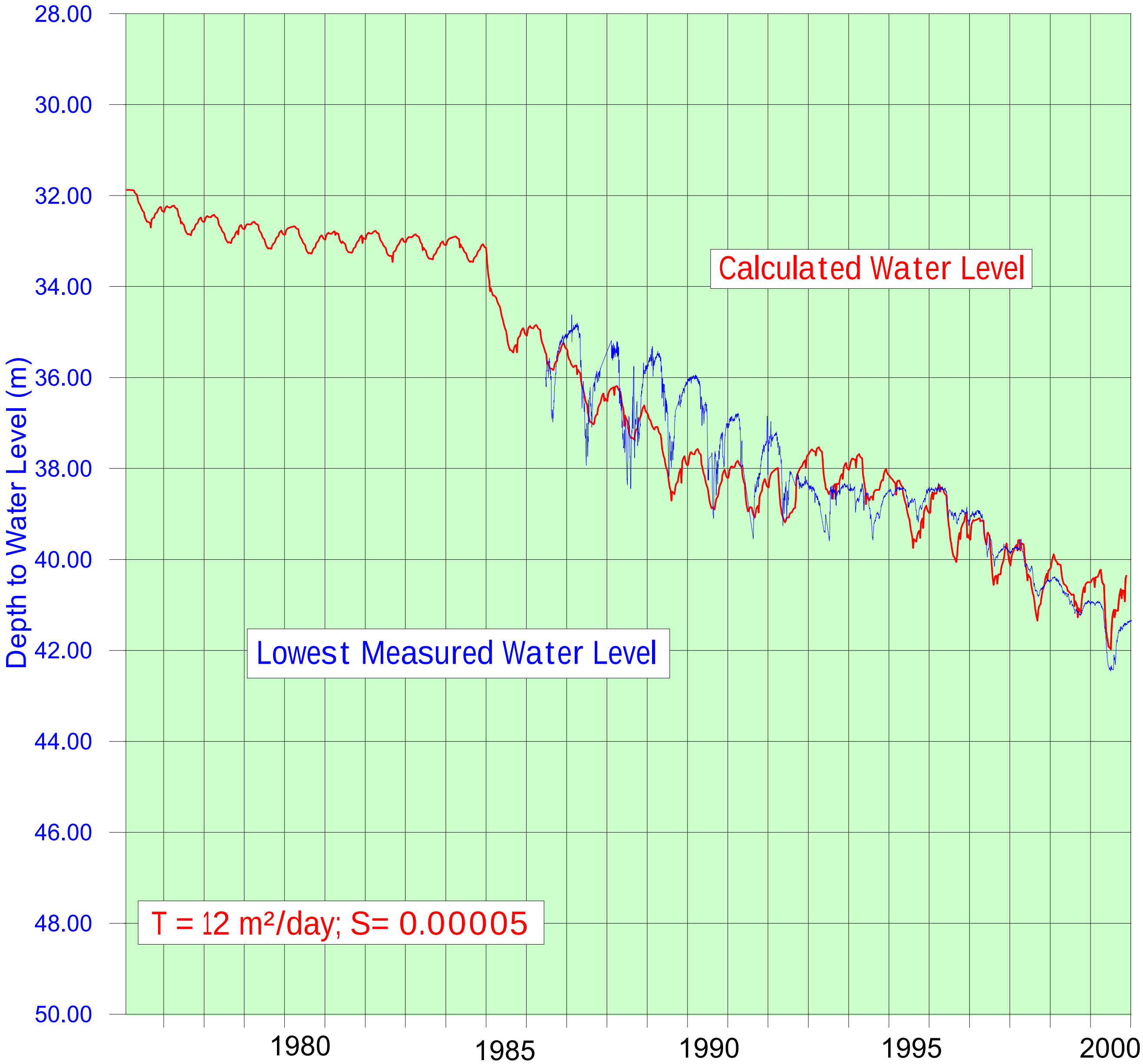
Site Map – Carseland Water Wells



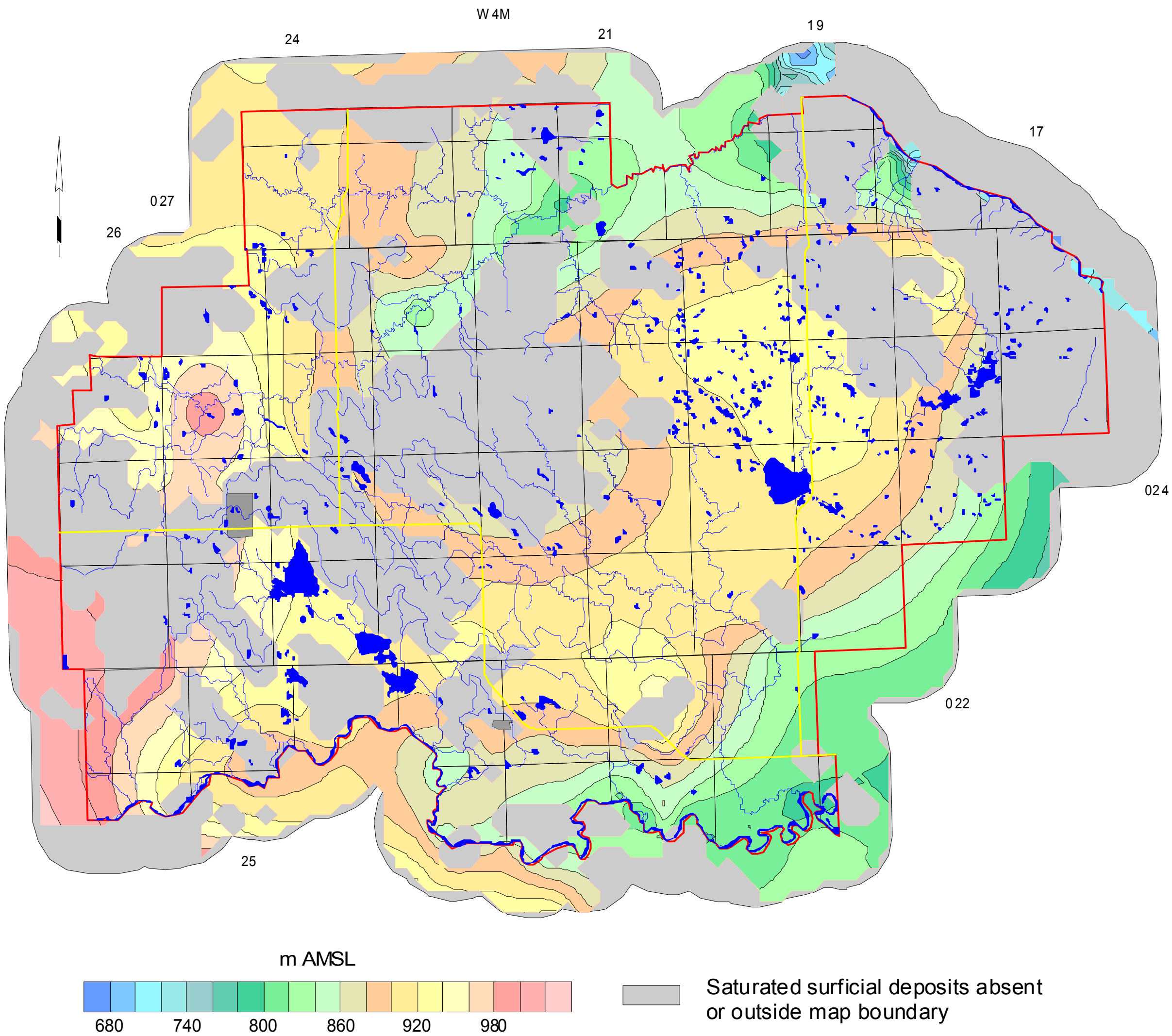
Groundwater Production from Carseland Water Supply Wells vs Water Levels in AENV Obs WW No. 220



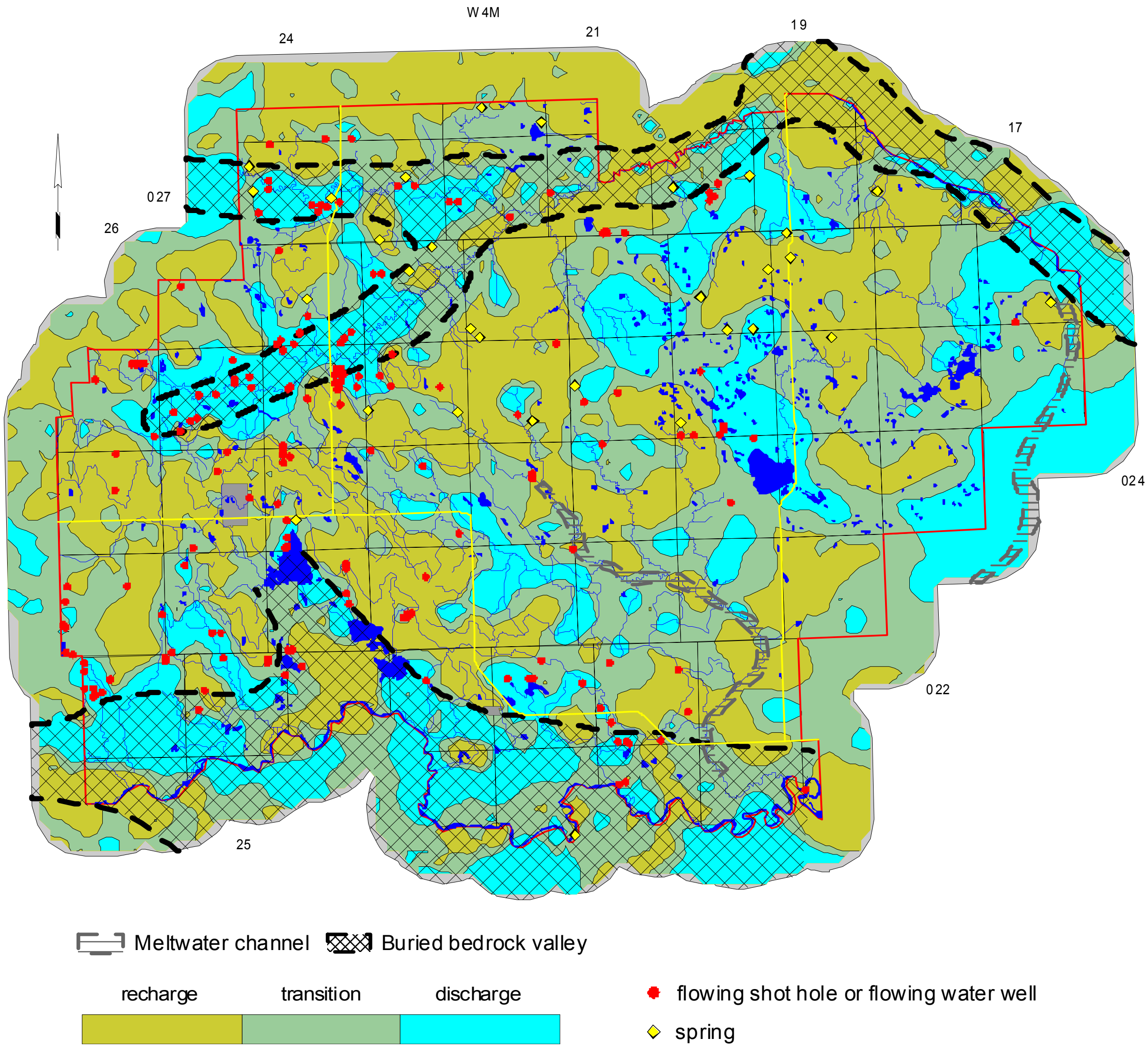
Water-Level Comparison in AENV Obs WW No. 220



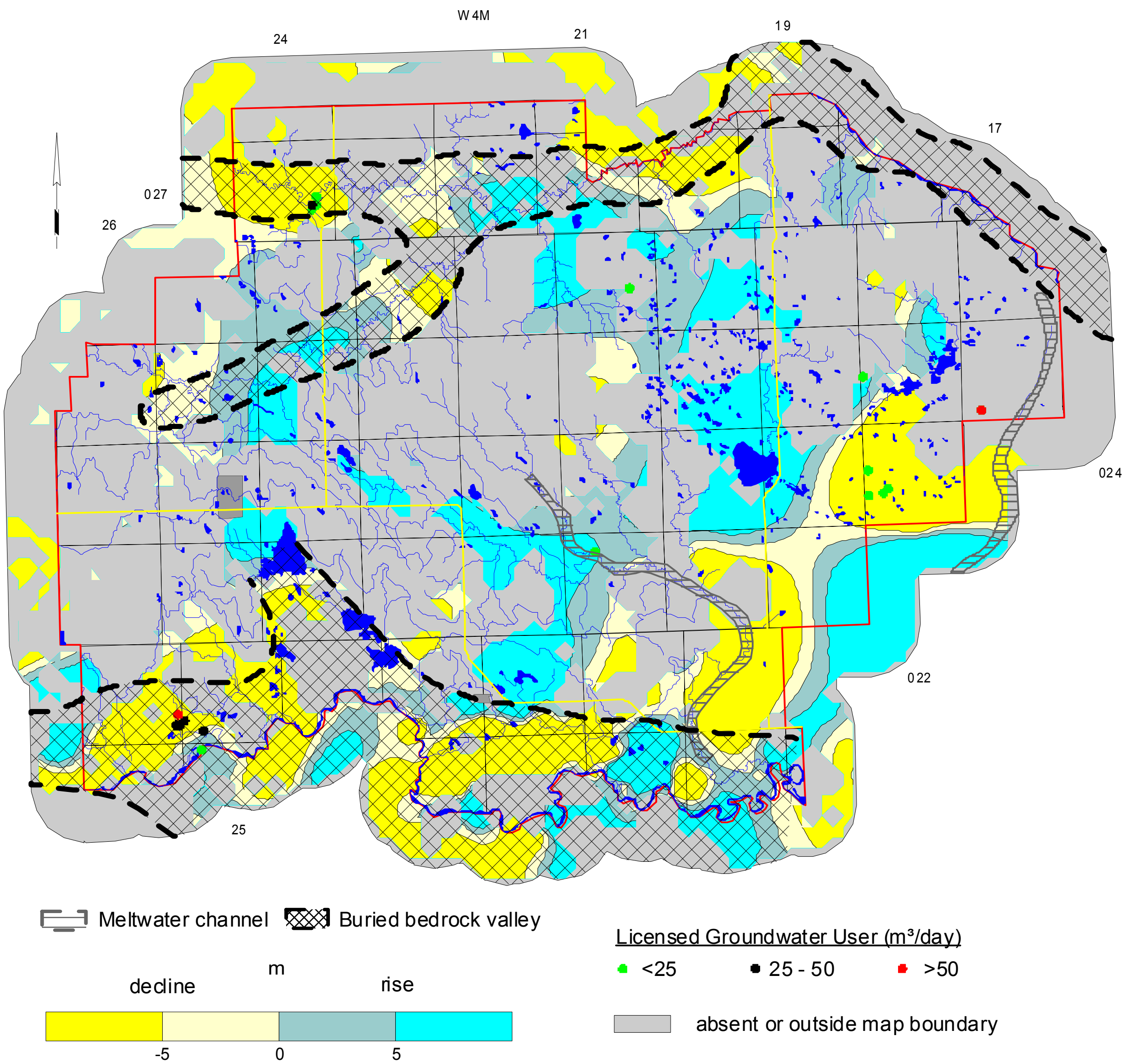
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



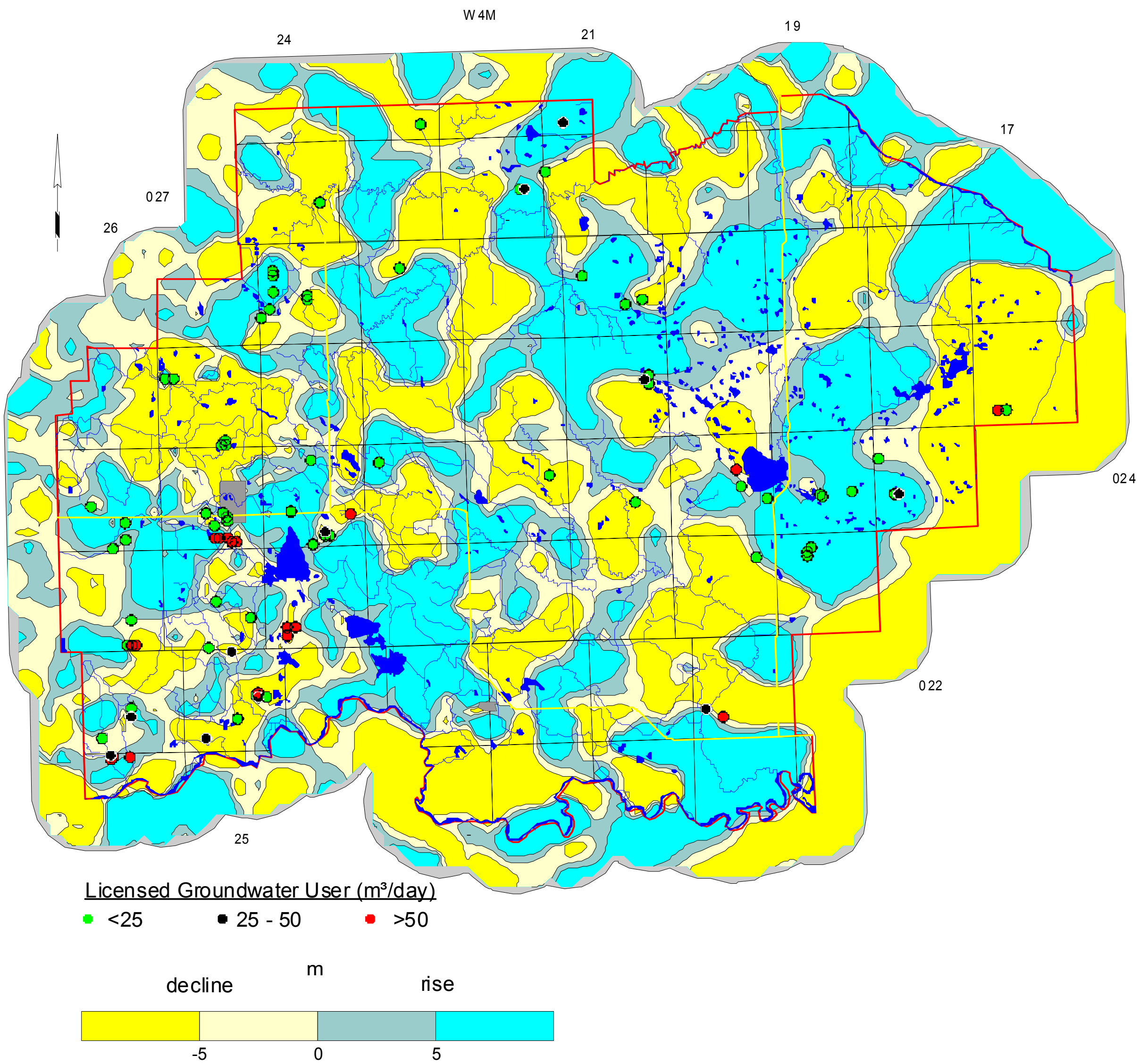
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



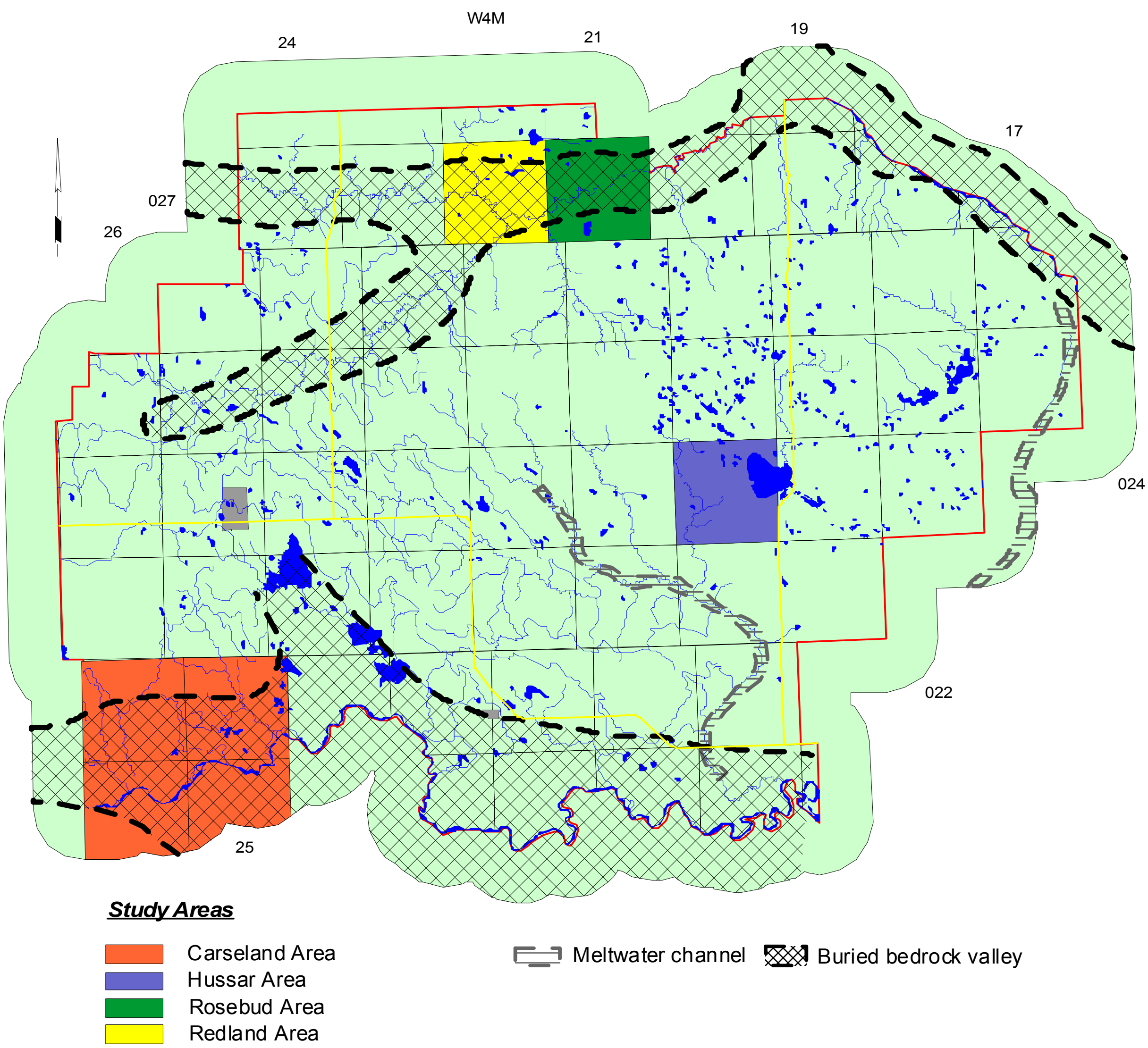
Changes in Water Levels in Sand and Gravel Aquifer(s)



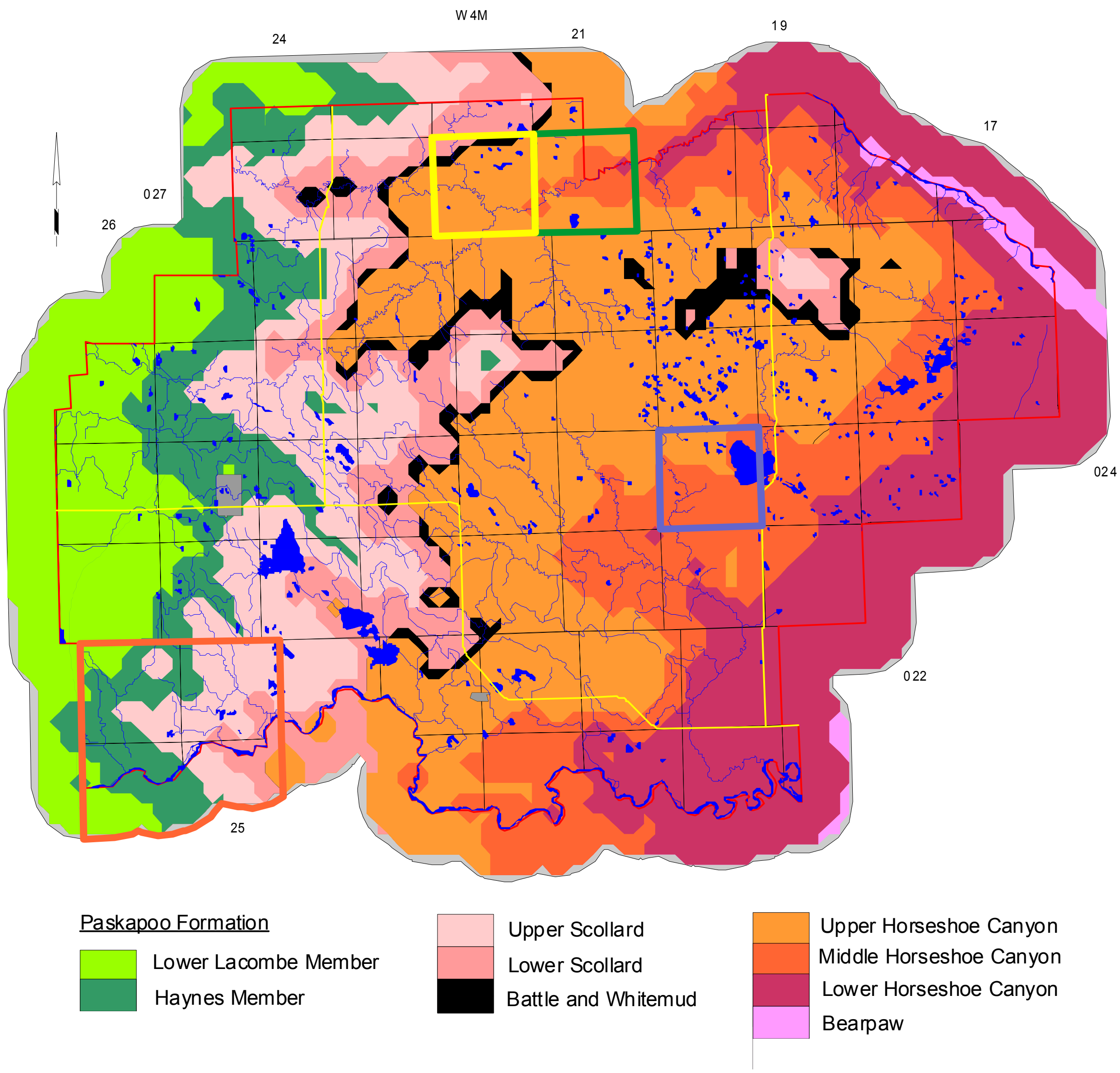
Changes in Water Levels in Upper Bedrock Aquifer(s)



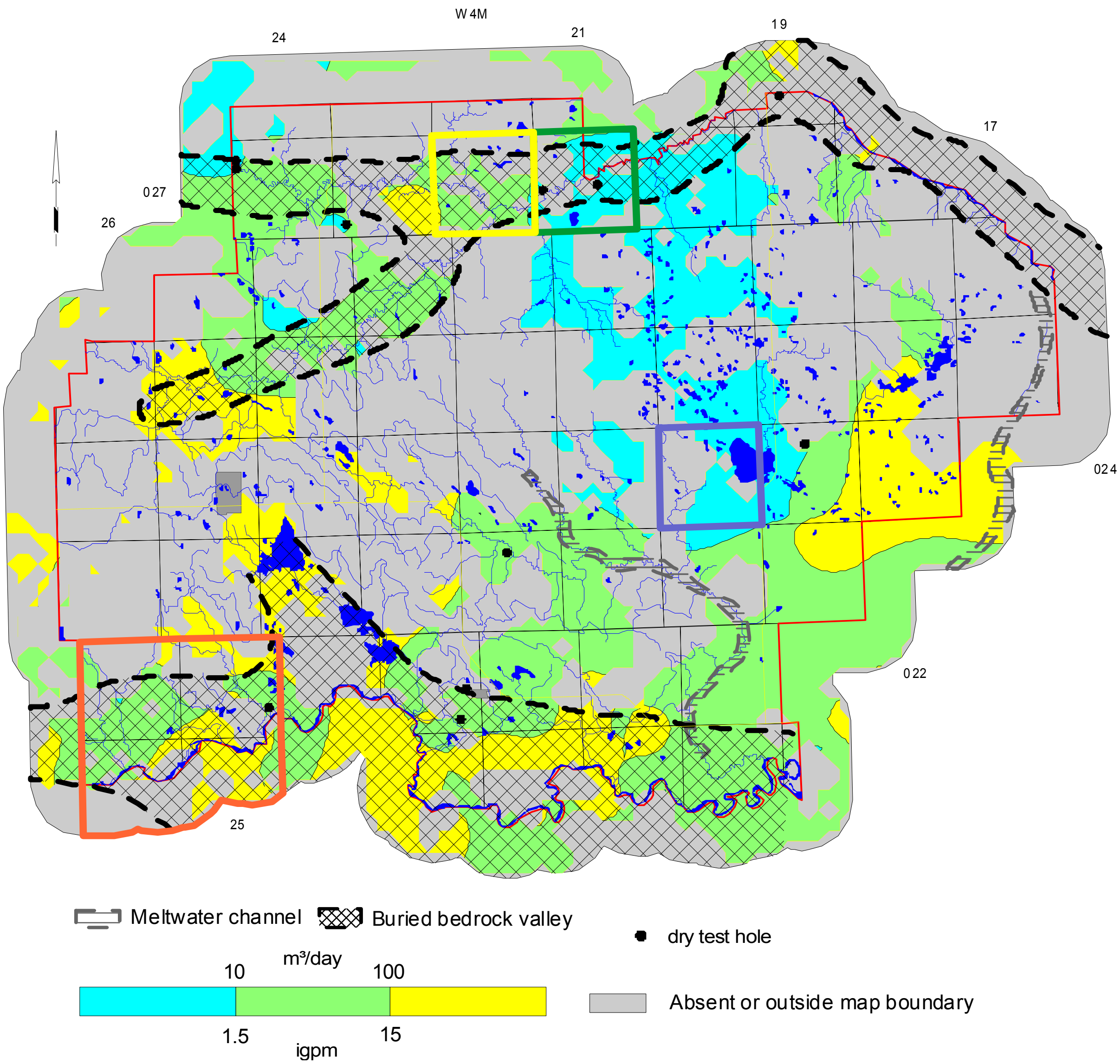
Specific Study Areas



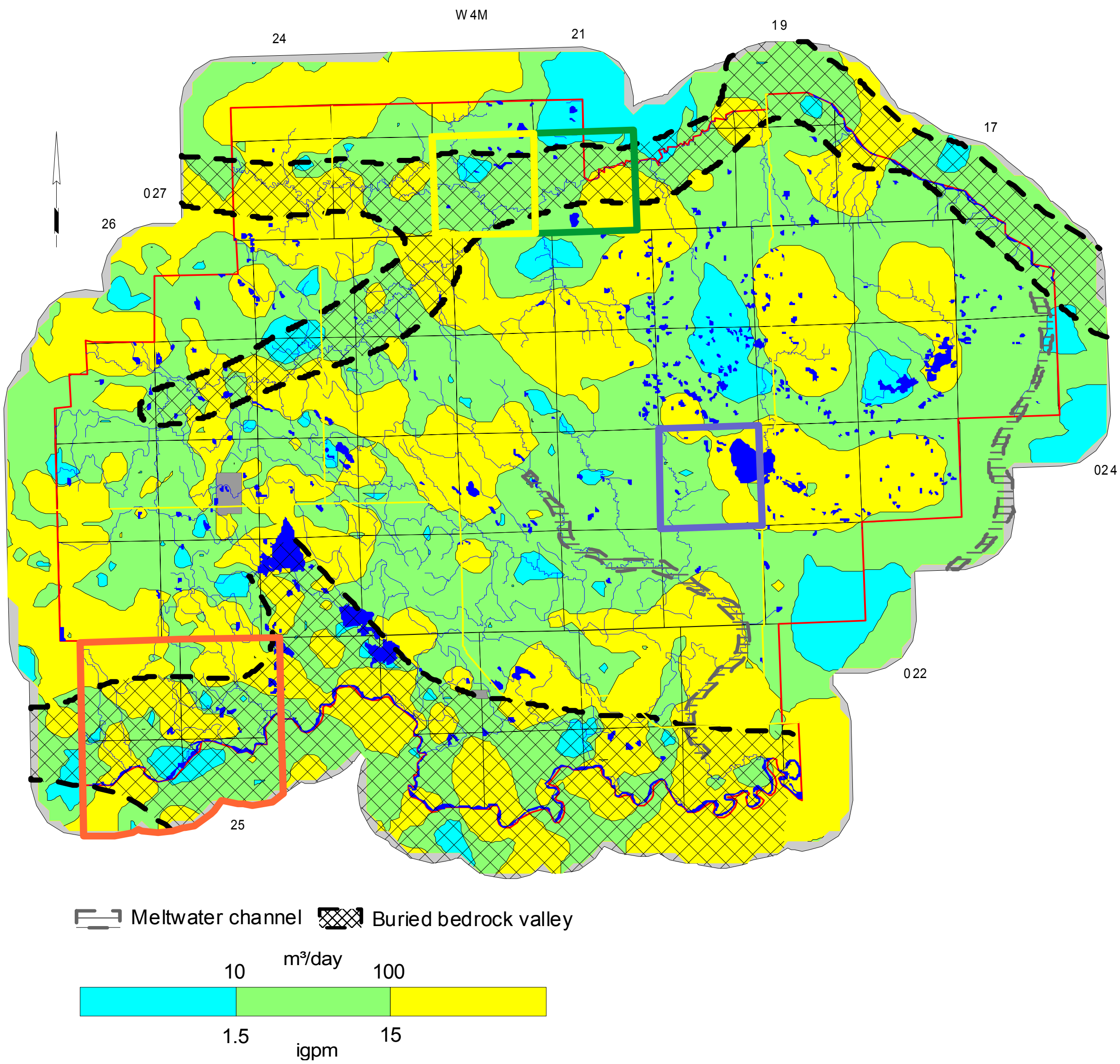
Bedrock Geology of Specific Study Areas



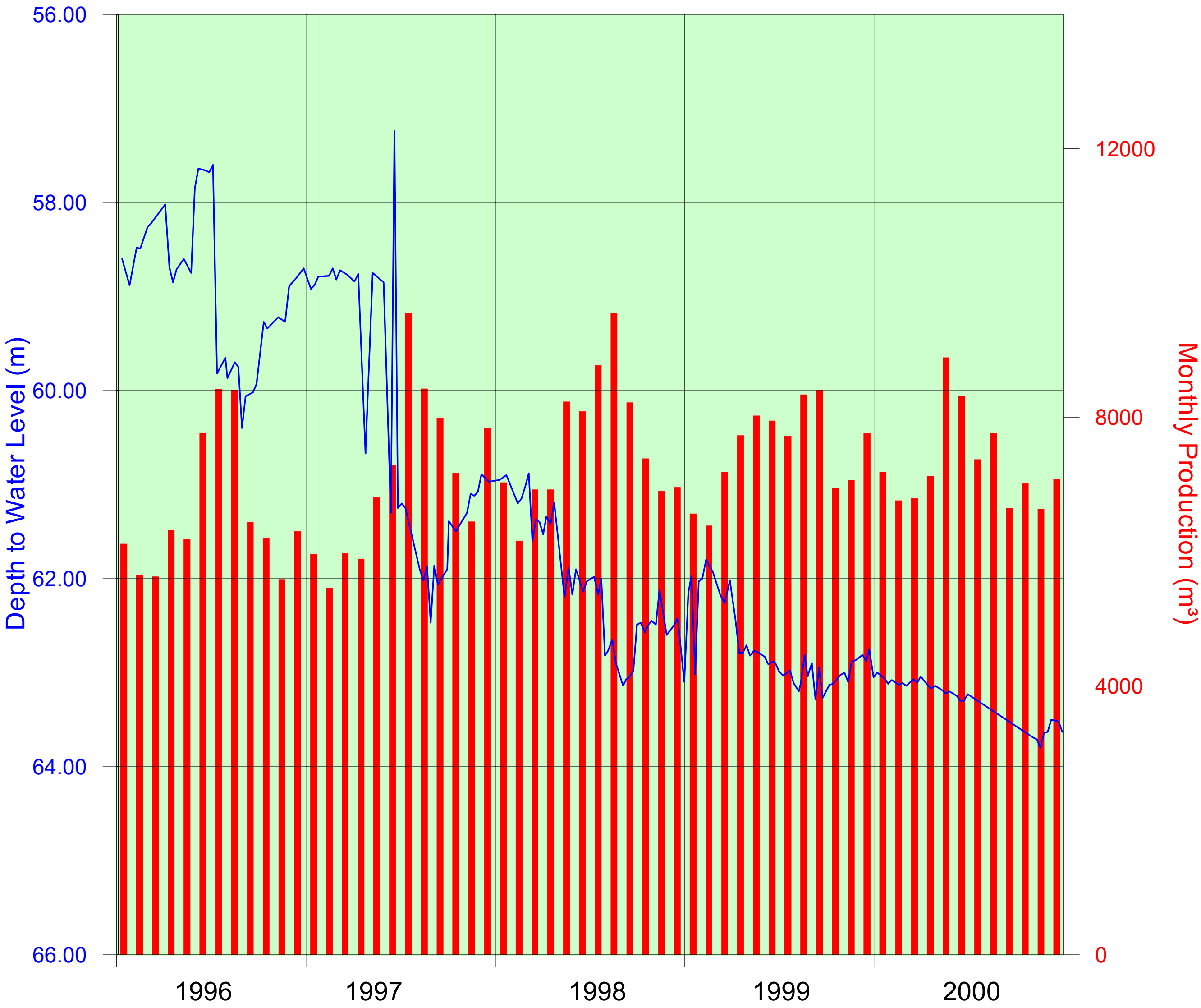
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) – Specific Study Areas



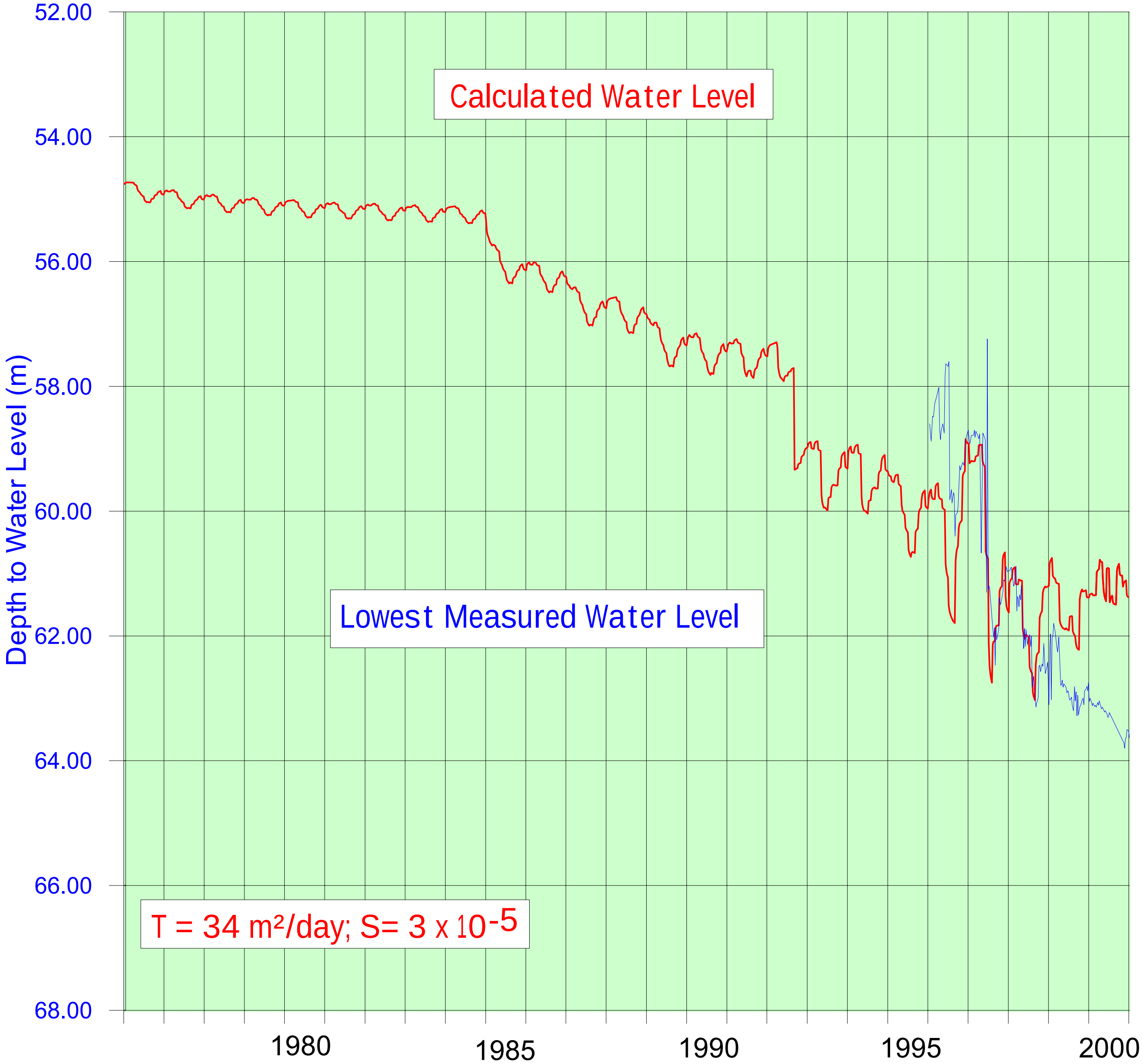
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s) – Specific Study Areas



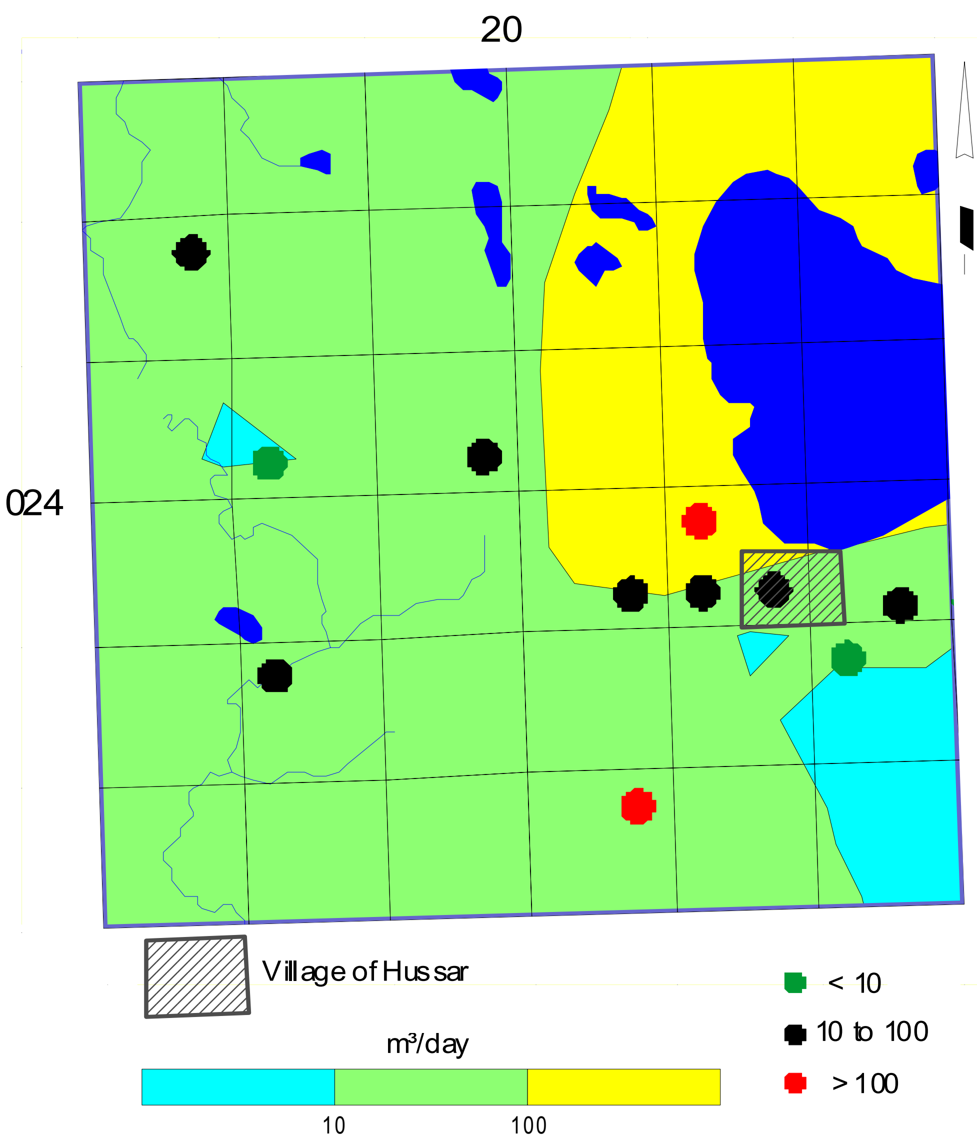
Groundwater Production vs Water Levels in Obs WW No. 93-1 – Carseland Area



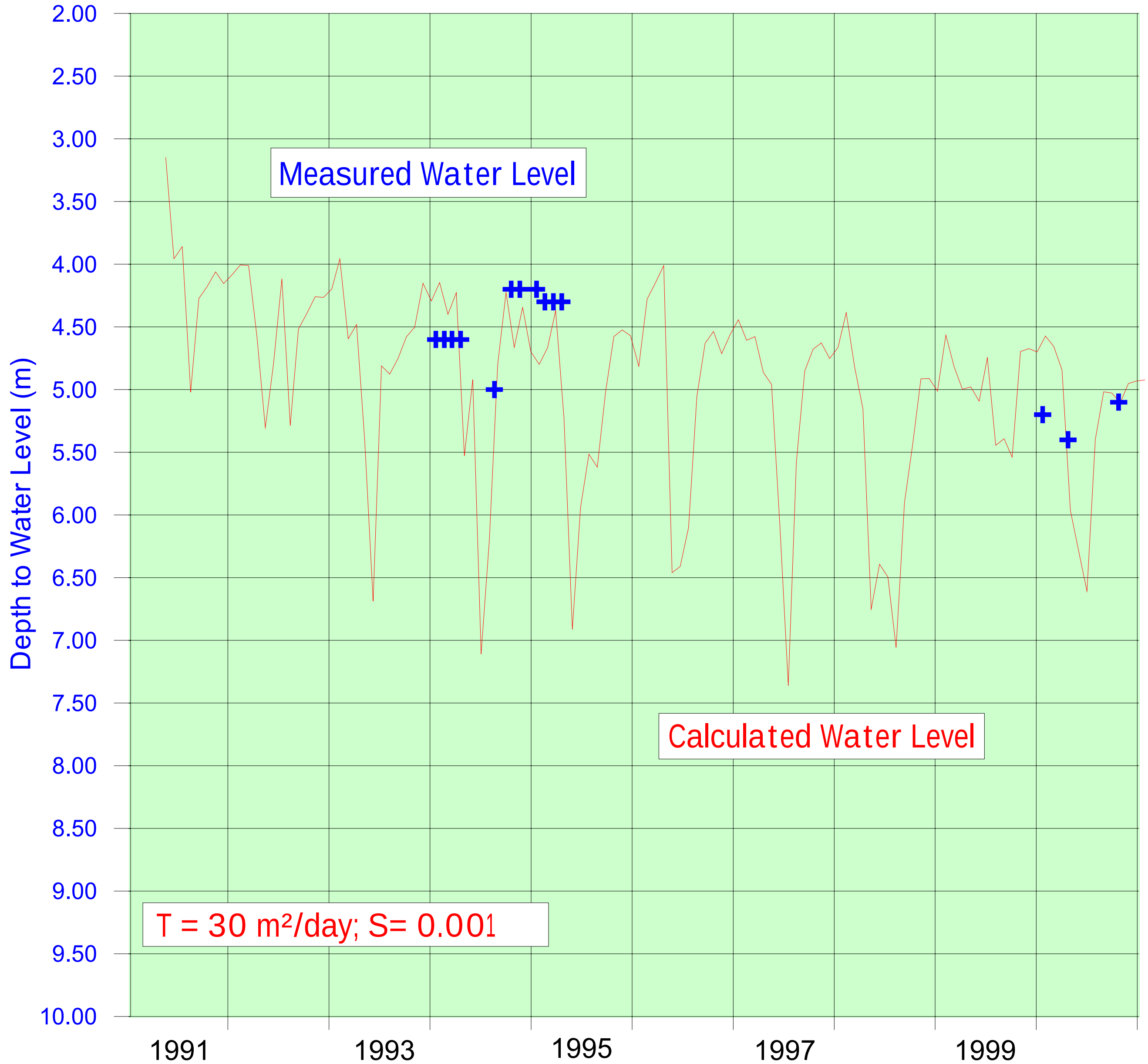
Water-Level Comparison in Obs WW No. 93-1 – Carseland Area



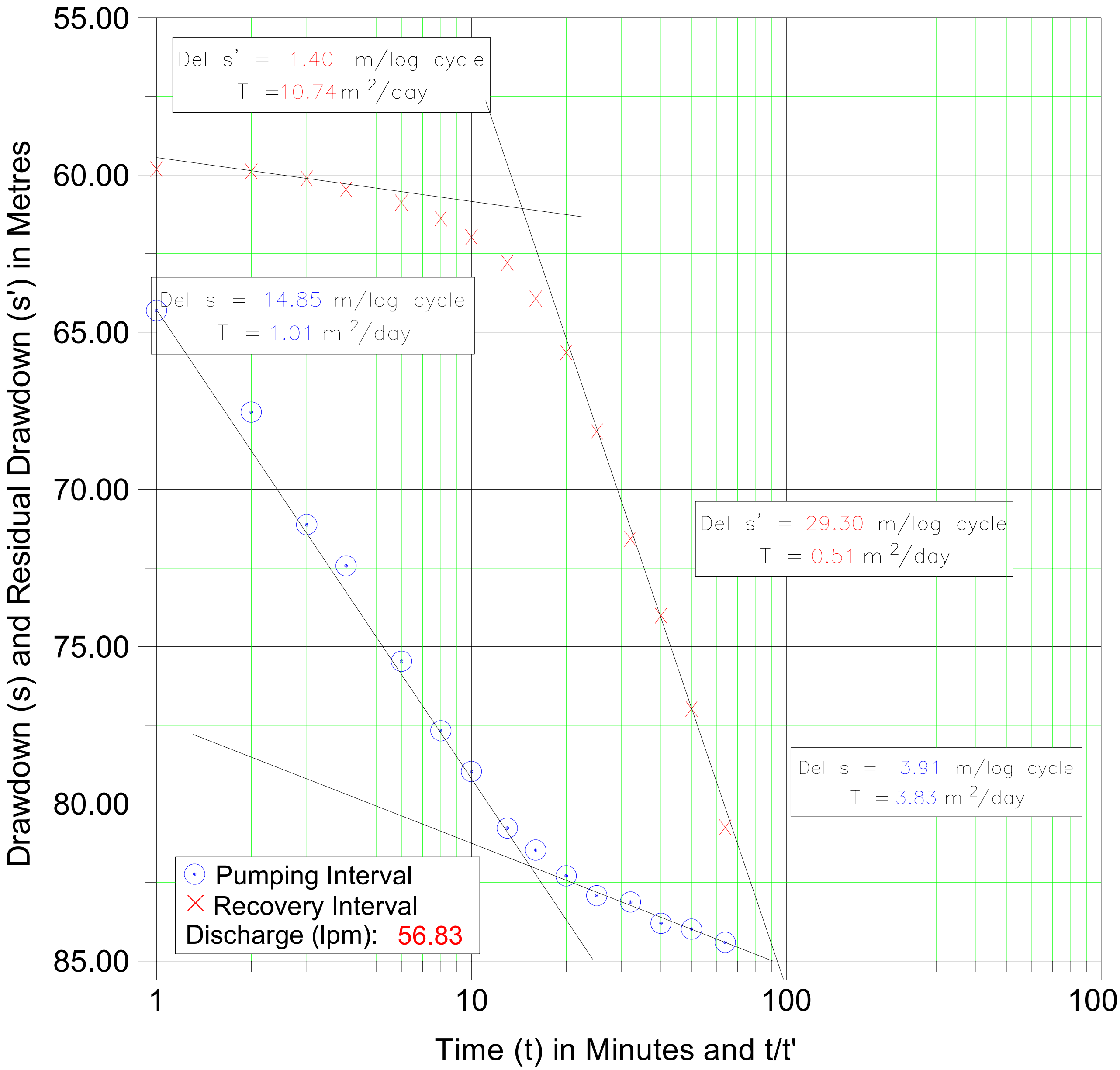
Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer – Hussar Area



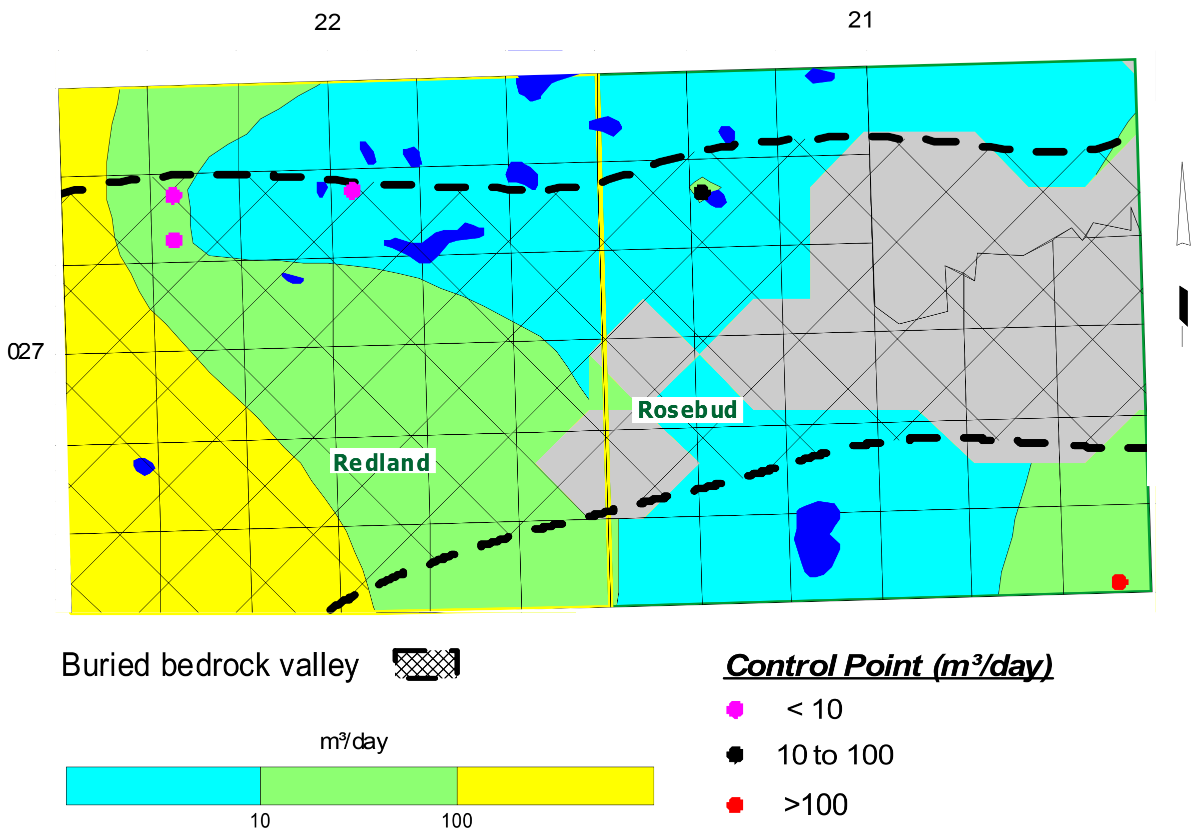
Water-Level Comparison in Water Supply Well No. 1 – Hussar Area



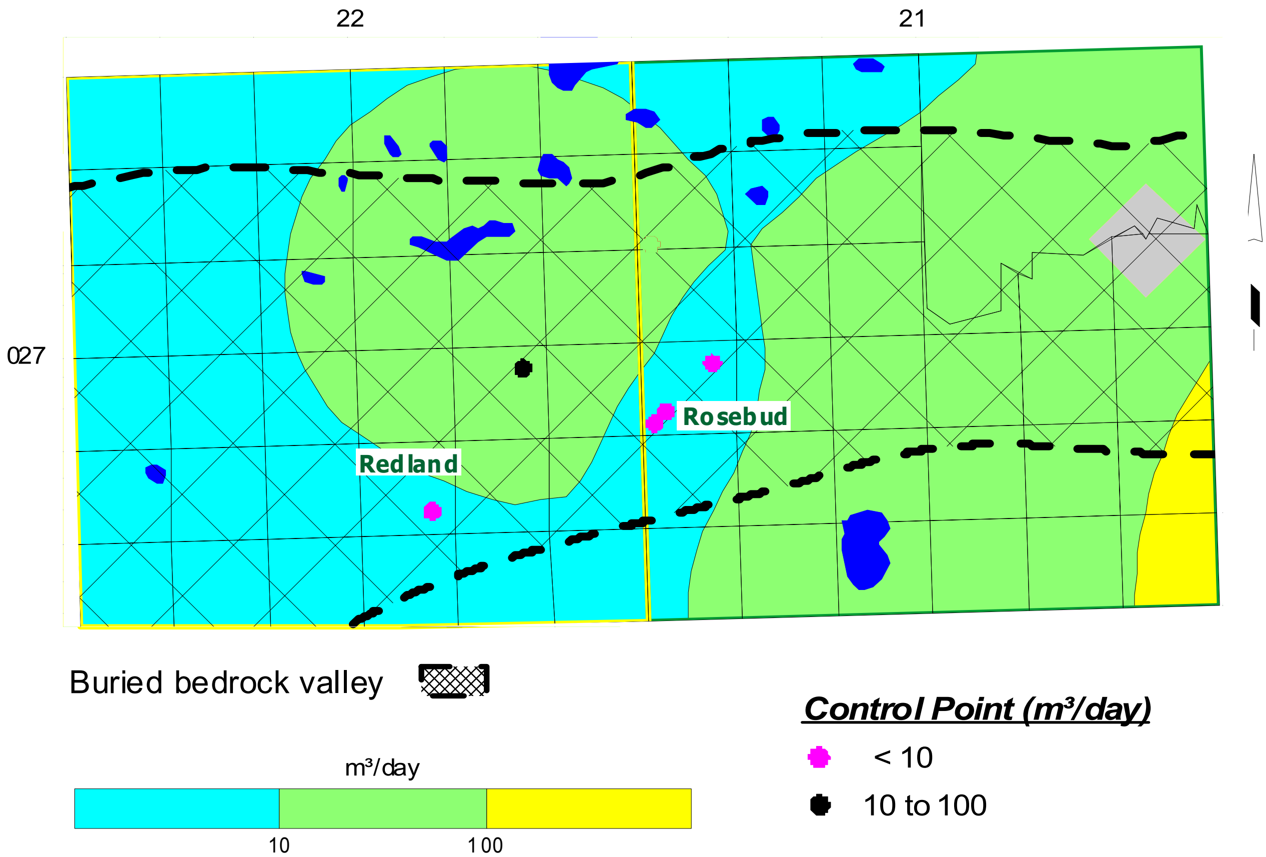
Aquifer Test With Water Supply Well No. 1 – Rosebud Area



Apparent Yield with Water Wells Completed through Upper Horseshoe Canyon Aquifer – Redland and Rosebud Areas



Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer – Redland and Rosebud Areas



WHEATLAND COUNTY
Appendix B

Maps and Figures on CD-ROM

1) General

Index Map/Surface Topography
Location of Water Wells and Springs
Surface Casing Types used in Drilled Water Wells
Licensed Water Wells
Depth to Base of Groundwater Protection
Generalized Cross-Section (for terminology only)
Generalized Geologic Column
Depth of Existing Water Wells
Hydrogeological Map
Cross-Section A - A'
Cross-Section B - B'
Cross-Section C - C'
Cross-Section D - D'
Cross-Section E - E'
Cross-Section F -F'
Cross-Section G - G'
Bedrock Topography
Bedrock Geology
Estimated Water Well Use Per Section
Water Wells Recommended for Field Verification

2) Surficial Aquifers

a) Surficial Deposits

Thickness of Surficial Deposits
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep
Total Dissolved Solids in Groundwater from Surficial Deposits
Sulfate in Groundwater from Surficial Deposits
Nitrate + Nitrite (as N) in Groundwater from Surficial Deposits
Chloride in Groundwater from Surficial Deposits
Total Hardness in Groundwater from Surficial Deposits
Piper Diagram - Surficial Deposits
Thickness of Sand and Gravel Deposits
Amount of Sand and Gravel in Surficial Deposits
Thickness of Sand and Gravel Aquifer(s)
Water Wells Completed in Surficial Deposits
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)
Changes in Water Levels in Sand and Gravel Aquifer(s)

b) Upper Sand and Gravel

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

c) Lower Sand and Gravel

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

3) Bedrock Aquifers

a) General

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

d) Lower Lacombe Member

Depth to Top of Lower Lacombe Member
Structure-Contour Map - Lower Lacombe Member
Non-Pumping Water-Level Surface - Lower Lacombe Aquifer
Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer
Total Dissolved Solids in Groundwater from Lower Lacombe Aquifer
Sulfate in Groundwater from Lower Lacombe Aquifer
Chloride in Groundwater from Lower Lacombe Aquifer
Fluoride in Groundwater from Lower Lacombe Aquifer
Piper Diagram - Lower Lacombe Aquifer

e) Haynes Member

Depth to Top of Haynes Member
Structure-Contour Map - Haynes Member
Non-Pumping Water-Level Surface - Haynes Aquifer
Apparent Yield for Water Wells Completed through Haynes Aquifer
Total Dissolved Solids in Groundwater from Haynes Aquifer
Sulfate in Groundwater from Haynes Aquifer
Chloride in Groundwater from Haynes Aquifer
Fluoride in Groundwater from Haynes Aquifer
Piper Diagram - Haynes Aquifer

f) Upper Scollard Formation

Depth to Top of Upper Scollard Formation
Structure-Contour Map - Upper Scollard Formation
Non-Pumping Water-Level Surface - Upper Scollard Aquifer
Apparent Yield for Water Wells Completed through Upper Scollard Aquifer
Total Dissolved Solids in Groundwater from Upper Scollard Aquifer
Sulfate in Groundwater from Upper Scollard Aquifer
Chloride in Groundwater from Upper Scollard Aquifer
Fluoride in Groundwater from Upper Scollard Aquifer
Piper Diagram - Upper Scollard Aquifer

g) Lower Scollard Formation

Depth to Top of Lower Scollard Formation
Structure-Contour Map - Lower Scollard Formation
Non-Pumping Water-Level Surface - Lower Scollard Aquifer
Apparent Yield for Water Wells Completed through Lower Scollard Aquifer
Total Dissolved Solids in Groundwater from Lower Scollard Aquifer
Sulfate in Groundwater from Lower Scollard Aquifer
Chloride in Groundwater from Lower Scollard Aquifer
Fluoride in Groundwater from Lower Scollard Aquifer
Piper Diagram - Lower Scollard Aquifer

WHEATLAND 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

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ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

Table of Contents

Chemical Analysis of Farm Water Supplies

Adapted from Agdex 716 (D04) Published April 1991

A routine chemical analysis tests the water for 15 chemical parameters. It will reveal the hardness and iron concentration as well as the presence of other chemicals such as chlorides, sulphates, nitrates and nitrites. Chemicals, other than those listed below, can be tested but arrangements should be made with the lab before the sample is submitted. These special requests' must be clearly specified on the request form. Your farm water supply should be analyzed whenever a new water source is constructed, or when a change in water quality is noticed.

Your local health unit can provide you with the necessary water sample containers. Water samples specifically for human consumption must be submitted to the health unit.

The water sample you take should be representative. Choose an outlet as close to the source as possible. For most domestic samples, allow the water to run through the faucet for about five minutes and then fill the sample container.

Once you have obtained a good water sample, take it to your local health unit for forwarding to the appropriate laboratory. After the laboratory analysis is completed, the health inspector or technologist will receive a copy of the analysis and will be able to help you interpret the results.

Water Quality Criteria

It is not essential for private supplies to meet these guidelines. People have different reactions and tolerances to different minerals. If any chemical in your water exceeds drinking water limits consult you family doctor or local health unit.

All levels listed below (except pH) are listed in parts per million (ppm). Many labs report results in milligrams/Litre (mg/L), which is equivalent to ppm.

Sodium

Sodium is not considered a toxic metal, and 5,000 to 10,000 milligrams per day are consumed by normal adults without adverse effects. The average intake of sodium from water is only a small fraction of that consumed in a normal diet.

Persons suffering from certain medical conditions such as hypertension may require a sodium restricted diet, in which case the intake of sodium from drinking water could become significant. Sodium levels as low as 20 ppm are sometimes a concern to them. A maximum level of 300 (200*) ppm sodium has traditionally been used as a guideline but the "Guidelines for Canadian Drinking Water Quality" list no maximum acceptable concentration.

Sodium is a significant factor in assessing water for irrigation and plant watering. High sodium levels affect soil structure and a plant's ability to take up water.

Potassium

Potassium is usually only found in quantities of a few ppm in water. There is no recommended limit for potassium but levels over 2,000 ppm may be harmful to human nervous systems. Alberta water supplies rarely contain more than 20 ppm.

Calcium
Calcium is one cause of "hardness" in water. Calcium is not a hazard to health but is undesirable because it may be detrimental for domestic uses such as washing, bathing and laundering. It also tends to cause encrustations in kettles, coffee makers and water heaters. 200 ppm is often considered an acceptable limit.

Magnesium
Magnesium is another constituent causing "hardness" in water. A suggested limit of 150 ppm is used because of taste considerations.

Iron
Iron levels as low as 0.2 to 0.3 ppm will usually cause the staining of laundry and plumbing fixtures. The presence of iron bacteria in water supplies will often cause these symptoms at even lower levels. Iron gives water a metallic taste that may be objectionable to some persons at one to two ppm. Most water contains less that five ppm iron but occasionally levels over 30 ppm are found. Iron and iron bacteria are not considered a health concern.

Sulphate (SO4)
Sulphate concentrations over 500 ppm can be laxative to some humans and livestock. Sulphate levels over 500 ppm may be a concern for livestock on marginal intakes of certain trace minerals. Very high levels of sulphates have been associated with some brain disorders in cattle and pigs.

Chloride
Due to taste considerations the suggested maximum level for chloride is 250 ppm. Most water in Alberta contains less than 20 ppm chloride, although chloride in the 2,000 ppm range can be found.

NO2 Nitrogen (Nitrite)
Due to its toxicity, the maximum acceptable concentration of nitrite in drinking water is one ppm. Nitrite is usually an indicator of very direct contamination by sewage or manure because nitrites are unstable and quickly become nitrates.

The concentration in livestock water should not exceed 10 ppm.

NO3 Nitrogen (Nitrate)
Nitrates are also an indicator of contamination by human or livestock wastes, excessive fertilization or seepage from dump sites. The maximum acceptable concentration in drinking water is 10 ppm. The figure is based on the potential for the nitrate poisoning of infants. Adults can tolerate higher levels but high nitrate levels may cause irritation of the stomach and bladder. The suggested maximum for livestock use is 1,000 ppm.

Fluoride
Fluorides occur naturally in most well waters and are desirable since they help prevent dental cavities. Between one and 1.5 ppm is desirable. As fluoride levels increase above this amount there is an increase in the tendency to cause tooth mottling.

Fluoride levels less than four ppm are not considered a problem for livestock.

TDS Inorganic (Total Dissolved Solids)
This is a measure of the inorganic minerals dissolved in the water. As a general rule less than 1,000 (500*) ppm TDS is considered satisfactory. Levels higher than this are not necessarily a problem; it depends on the specific minerals present.

The suitability for livestock deteriorates as TDS exceeds the 2,000 to 3,000 ppm range.

Conductivity
Conductivity is measured in micro Siemens per centimetre. It can be used to estimate the total dissolved solids in the water. Multiplying the conductivity by 0.65 will give a good approximation of the total dissolved solids. Conductivity tests are often used to assess water suitability for irrigation.

pH
pH is a measure of how acidic or basic the water is. The pH scale goes from zero (acidic) to 14 (basic) with seven being neutral. The generally accepted range for pH is 6.5 to 8.5 with an upper limit of 9.5.

Hardness
The harder the water is the greater its ability to neutralize soap suds. Hardness is caused primarily by calcium and magnesium, but is expressed as ppm equivalent of calcium carbonate. Hard water causes soap curd which makes bathroom fixtures difficult to keep clean and causes greying of laundry.

Hard water will also tend to form scale in hot water tanks, kettles, piping systems, etc.

Type of Water	**Amount of Hardness**	
	ppm	**grains per gallon**
Soft	0- 50	0-3
Moderately Soft	50 - 100	3-6
Moderately Hard	100 - 200	6-12
Hard	200 - 400	12- 23
Very Hard	400 - 600	23 - 35
Extremely Hard	Over 600	Over 35

Alkalinity
Alkalinity is not a specific substance but rather a combined effect of several substances. It is a measure of the resistance of a water to a change in pH. The alkalinity of most Alberta waters is in the range of 100 - 500 ppm, which is considered acceptable. Water with higher levels is often used. Alkalinity is a factor in corrosion or scale deposition and may affect some livestock when over 1,000 ppm.

Water Treatment
Water treatment equipment can often improve water quality significantly. Each type of water treatment equipment has its limitations and thus should be selected carefully. For more information on water treatment please refer to the Agdex 71 6 D series of fact sheets.

Helpful Conversions
1 ppm (part per million) = 1 mg/L (milligram per litre)
1 gpg (grain per gallon) = 17.1 ppm (parts per million)

References
Guidelines for Canadian Drinking Water Quality (1987) Health and Welfare Canada

*Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial-Territorial Committee on Environment and Occupational Health. March 2001. Summary of Guidelines for Canadian Drinking Water Quality.

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);
http://www.agric.gov.ab.ca/water/wells/index.html
Quality Farm Dugouts - http://www.agric.gov.ab.ca/esb/dugout.html

ALBERTA ENVIRONMENT

WATER - http://www3.gov.ab.ca/env/water.cfm

GROUNDWATER INFORMATION SYSTEM - http://www.telusgeomatics.com/tgpub/ag_water/

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WATER WELL LICENSING
Rob George (Edmonton: 780-427-6429)

GEOPHYSICAL INSPECTION SERVICE
Edmonton: 780-427-3932

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Jerry Riddell (Edmonton: 780-422-4851)

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
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PRAIRIE FARM REHABILITATION ADMINISTRATION (PFRA) BRANCH OF AGRICULTURE AND AGRI-FOOD CANADA (AAFC)

Glen Brandt (Red Deer: 403-340-4290) - brandtg@agr.gc.ca
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Terry Dash (Calgary: 403-292-5719) - dasht@agr.gc.ca

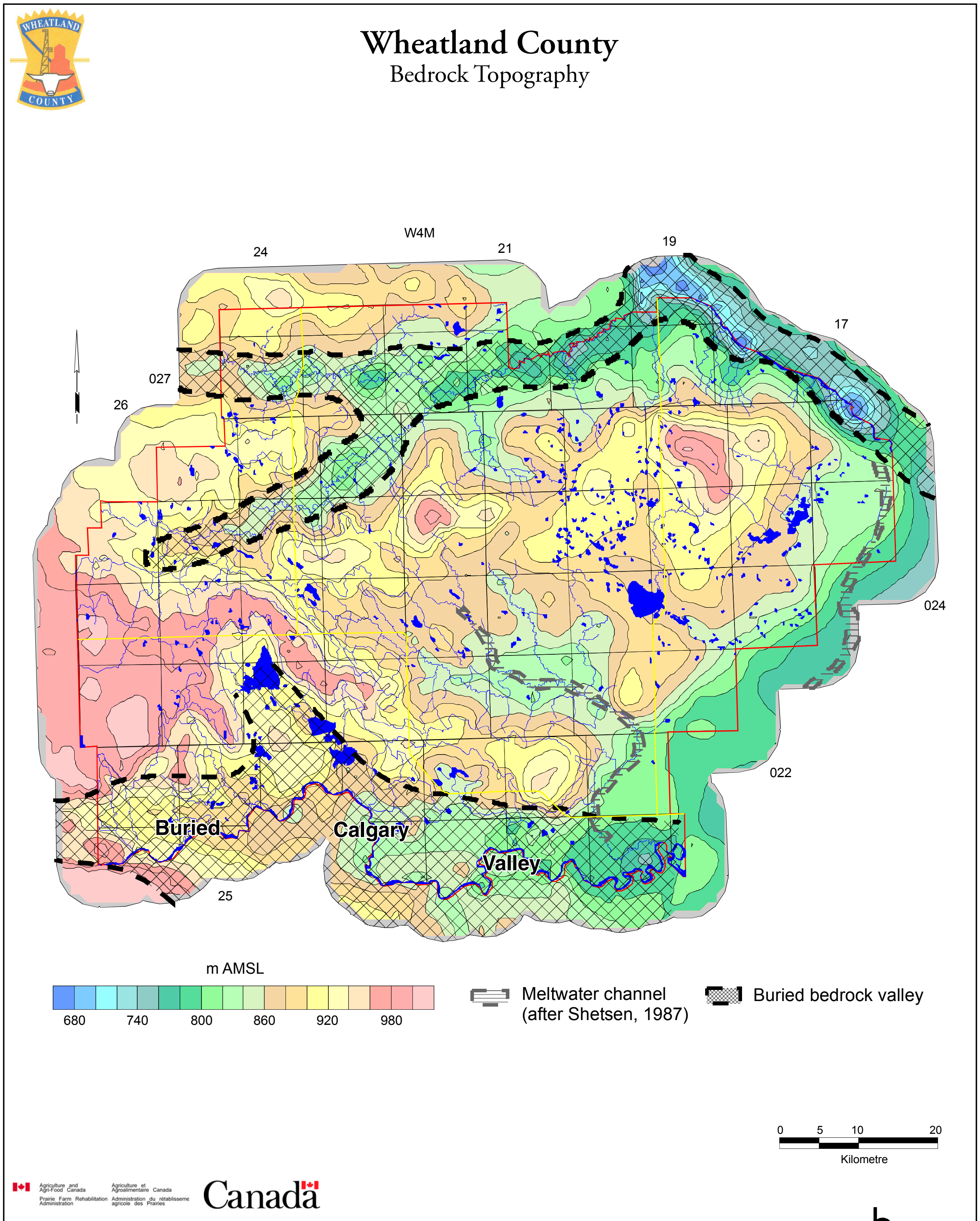
WILDROSE COUNTRY GROUND WATER MONITORING ASSOCIATION
Dave Andrews (Irricana: 403-935-4478)

LOCAL HEALTH DEPARTMENTS

WHEATLAND COUNTY
Appendix D

Maps and Figures Included as Large Plots

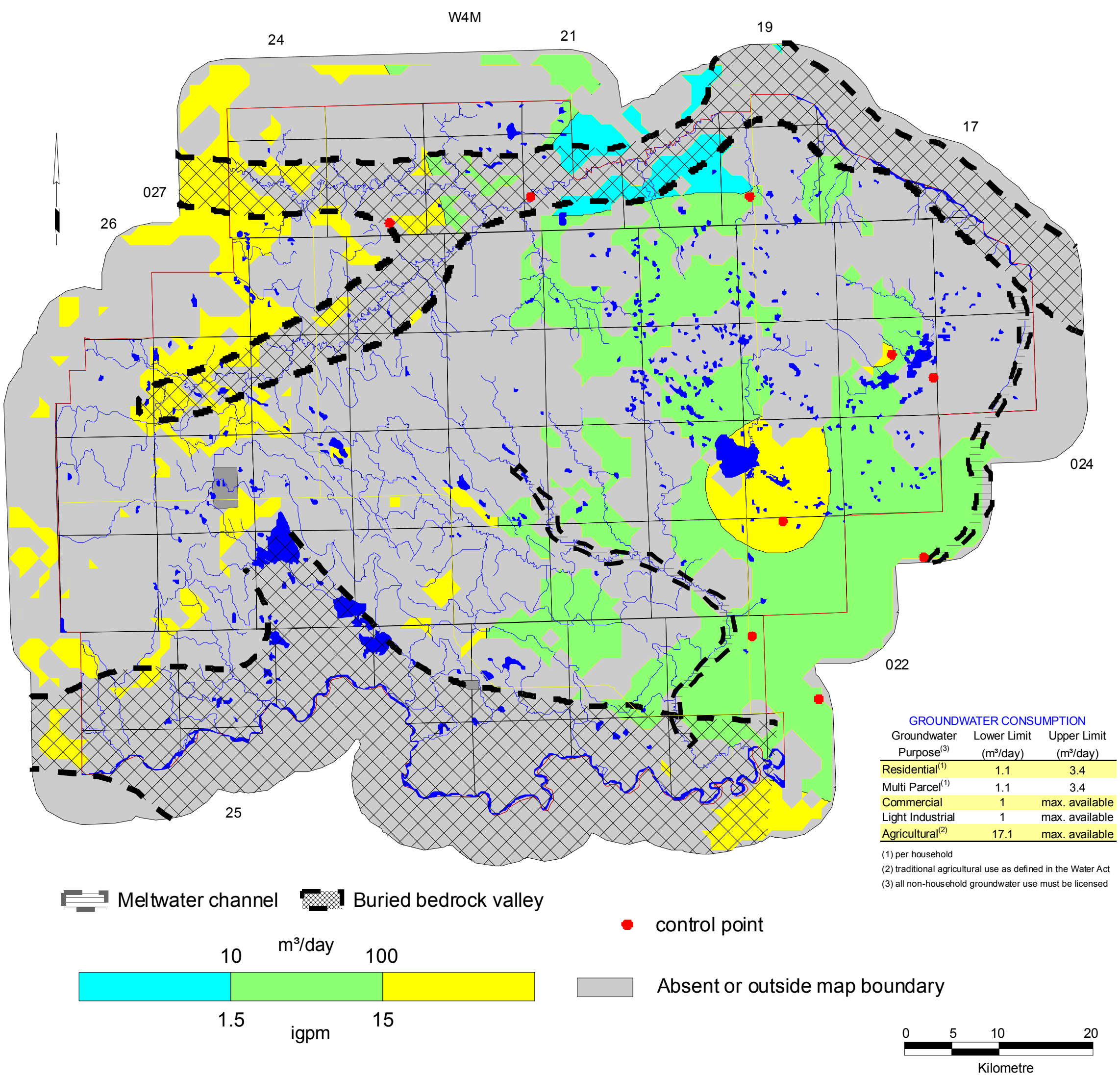
Bedrock Topography



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

Wheatland County

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

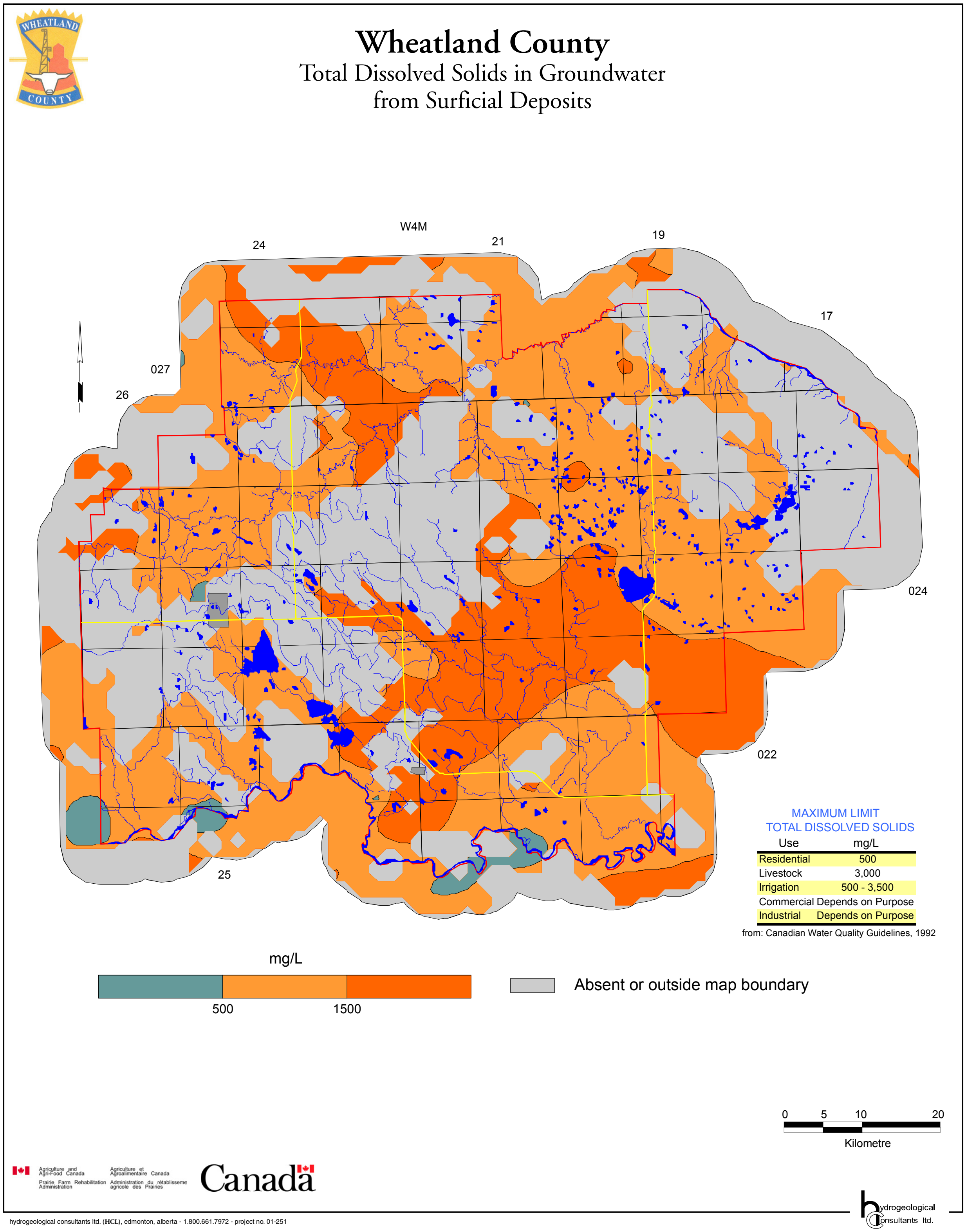


GROUNDWATER CONSUMPTION

Groundwater Purpose(3)	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential(1)	1.1	3.4
Multi Parcel(1)	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural(2)	17.1	max. available

(1) per household
(2) traditional agricultural use as defined in the Water Act
(3) all non-household groundwater use must be licensed

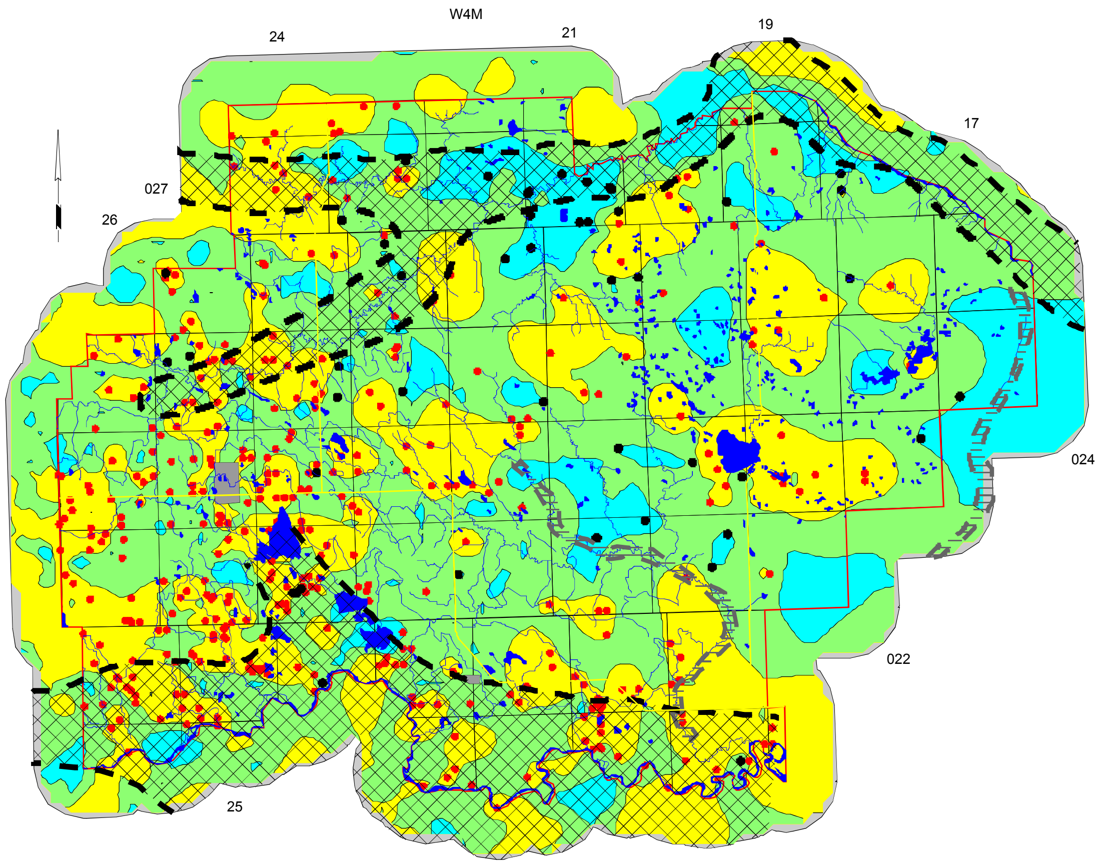
Total Dissolved Solids in Groundwater from Surficial Deposits



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

Wheatland County

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



Meltwater channel
Buried bedrock valley

m³/day: 10, 100
igpm: 1.5, 15

>100 m³/day
dry test hole

GROUNDWATER CONSUMPTION

Groundwater Purpose[3]	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential[1]	1.1	3.4
Multi Parcel[1]	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural[2]	17.1	max. available

(1) per household
(2) traditional agricultural use as defined in the Water Act
(3) all non-household groundwater use must be licensed

0 5 10 20
Kilometre

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Prairie Farm Rehabilitation Administration / Administration du rétablissement agricole des Prairies
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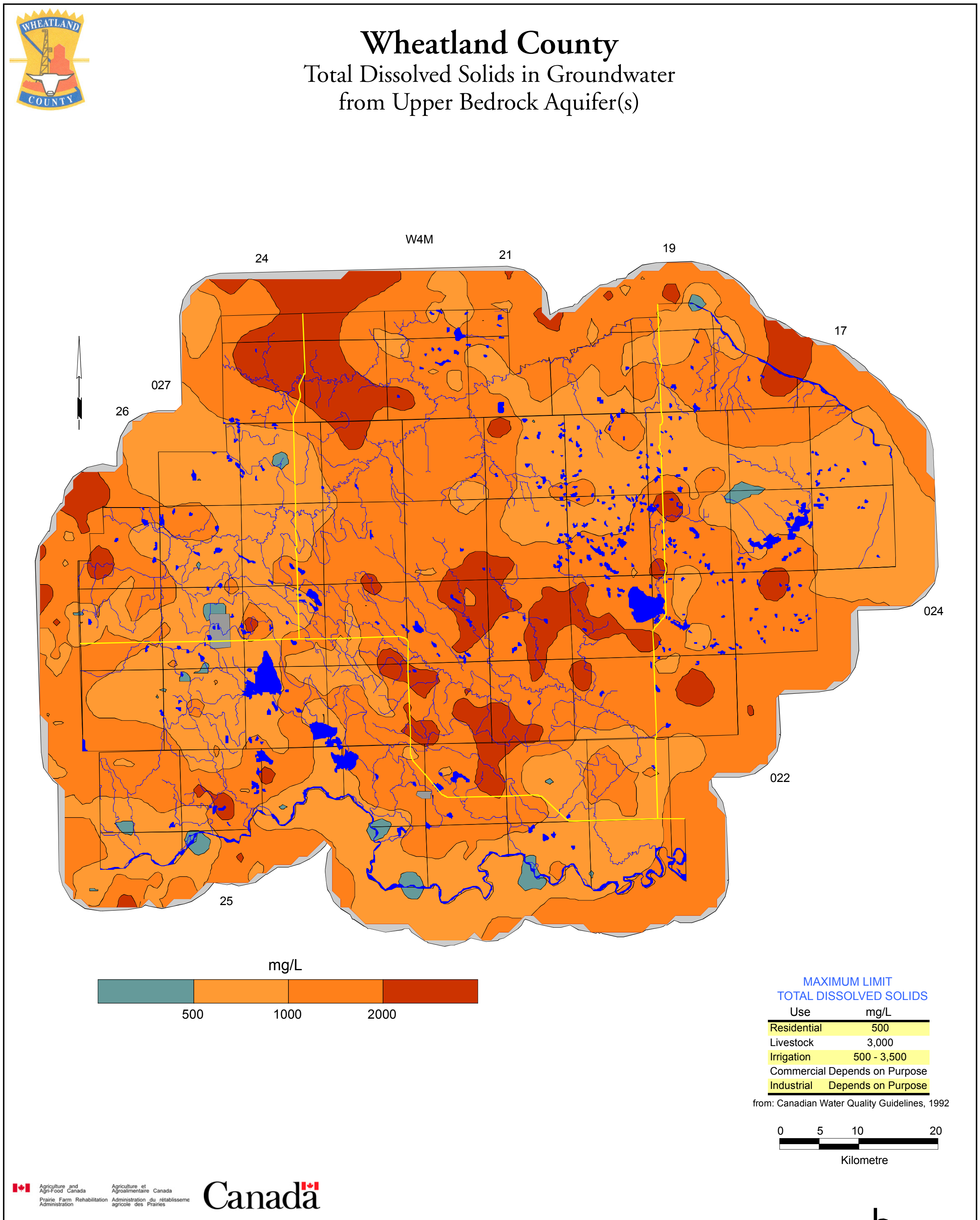
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



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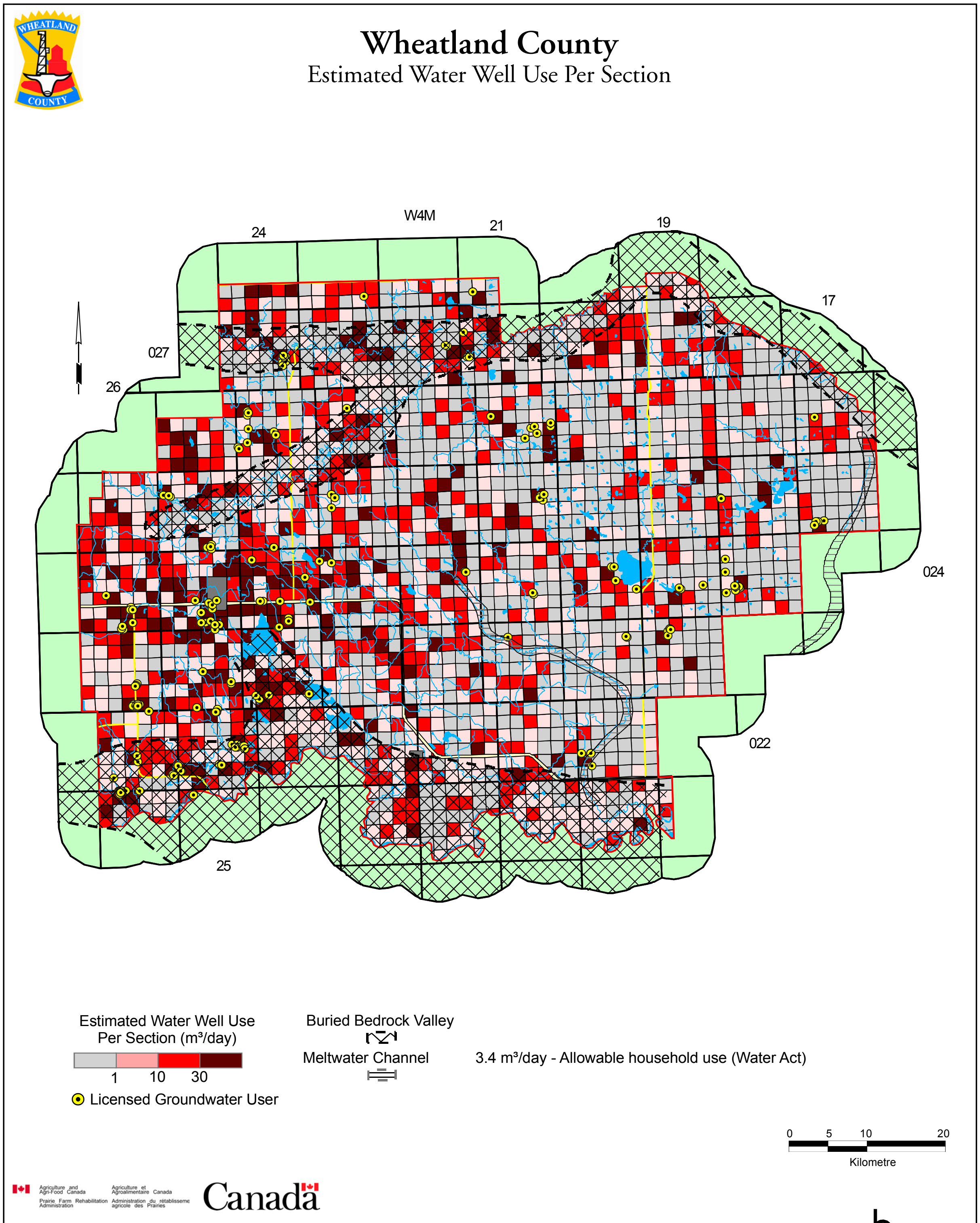
Estimated Water Well Use Per Section



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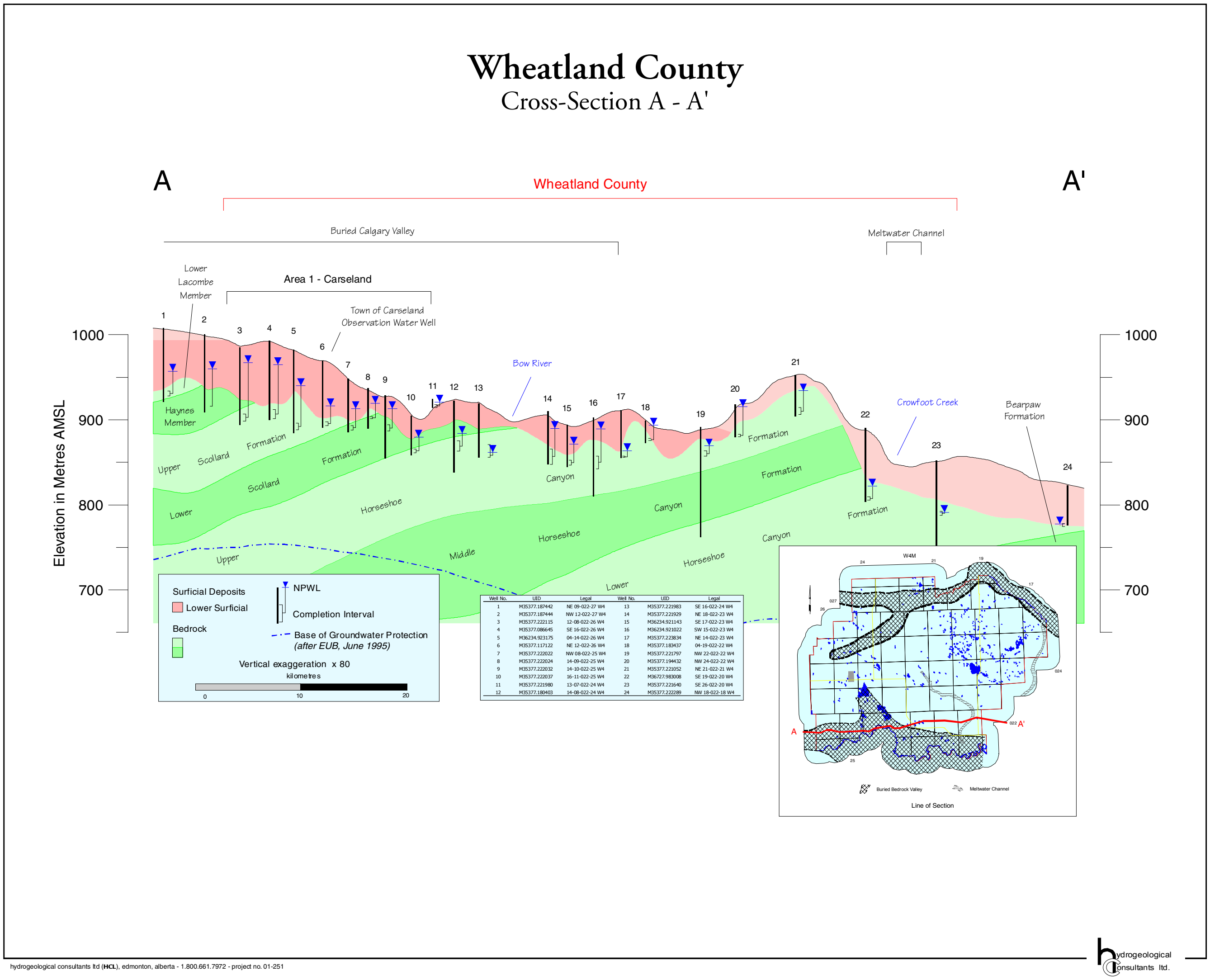
Cross-Section A - A'



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3	M35377.222115	12-08-022-26 W4	15	M36234.921143	SE 17-022-23 W4
4	M35377.086645	SE 16-022-26 W4	16	M36234.921022	SW 15-022-23 W4
5	M36234.923175	04-14-022-26 W4	17	M35377.223834	NE 14-022-23 W4
6	M35377.117122	NE 12-022-26 W4	18	M35377.183437	04-19-022-22 W4
7	M35377.222022	NW 08-022-25 W4	19	M35377.221797	NW 22-022-22 W4
8	M35377.222024	14-09-022-25 W4	20	M35377.194432	NW 24-022-22 W4
9	M35377.222032	14-10-022-25 W4	21	M35377.221052	NE 21-022-21 W4
10	M35377.222037	16-11-022-25 W4	22	M36727.983008	SE 19-022-20 W4
11	M35377.221980	13-07-022-24 W4	23	M35377.221640	SE 26-022-20 W4
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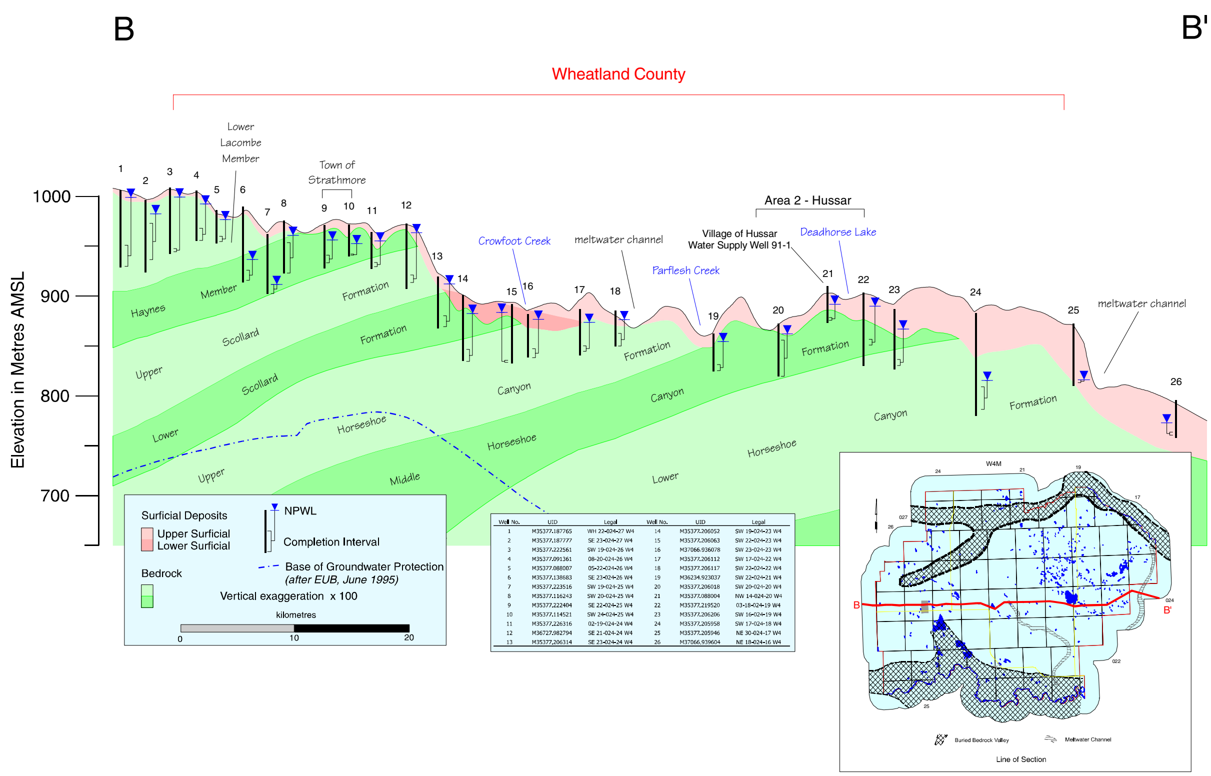
Cross-Section B - B'

Wheatland County
Cross-Section B - B'



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6	M35377.138683	SE 23-024-26 W4	19	M36234.923037	SW 22-024-21 W4
7	M35377.223516	SW 19-024-25 W4	20	M35377.206018	SW 20-024-20 W4
8	M35377.116243	SW 20-024-25 W4	21	M35377.088004	NW 14-024-20 W4
9	M35377.222404	SE 22-024-25 W4	22	M35377.219520	03-18-024-19 W4
10	M35377.114521	SW 24-024-25 W4	23	M35377.206206	SW 16-024-19 W4
11	M35377.226316	02-19-024-24 W4	24	M35377.205958	SW 17-024-18 W4
12	M36727.982794	SE 21-024-24 W4	25	M35377.205946	NE 30-024-17 W4
13	M35377.206314	SE 23-024-24 W4	26	M37066.939604	NE 18-024-16 W4

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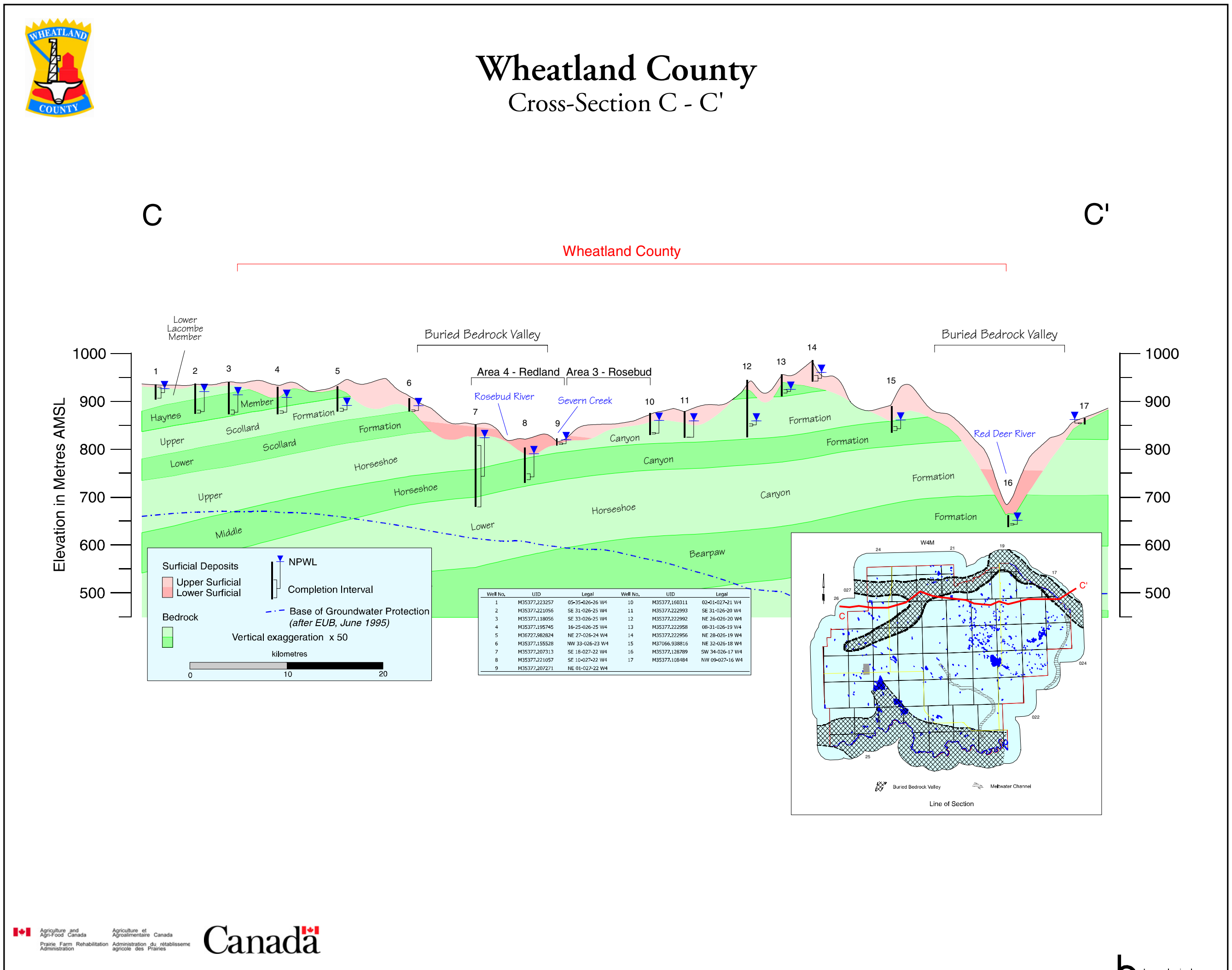
Cross-Section C - C'



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7	M35377.207313	SE 18-027-22 W4	16	M35377.128789	SW 34-026-17 W4
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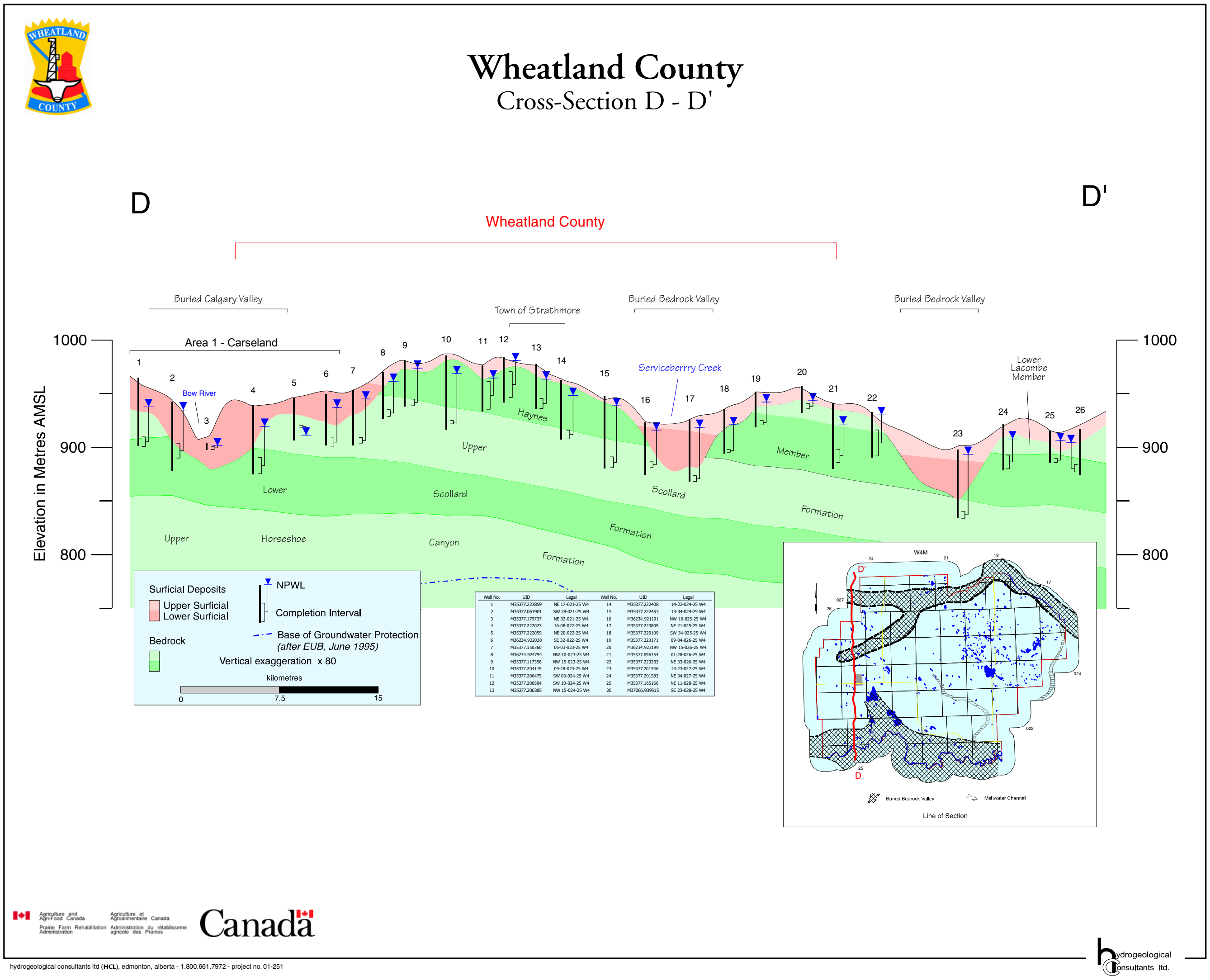
Cross-Section D - D'



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9	M35377.117358	NW 15-023-25 W4	22	M35377.223203	NE 33-026-25 W4
10	M35377.204119	09-28-023-25 W4	23	M35377.201546	13-23-027-25 W4
11	M35377.206475	SW 03-024-25 W4	24	M35377.201583	NE 34-027-25 W4
12	M35377.206504	SW 10-024-25 W4	25	M35377.165166	NE 11-028-25 W4
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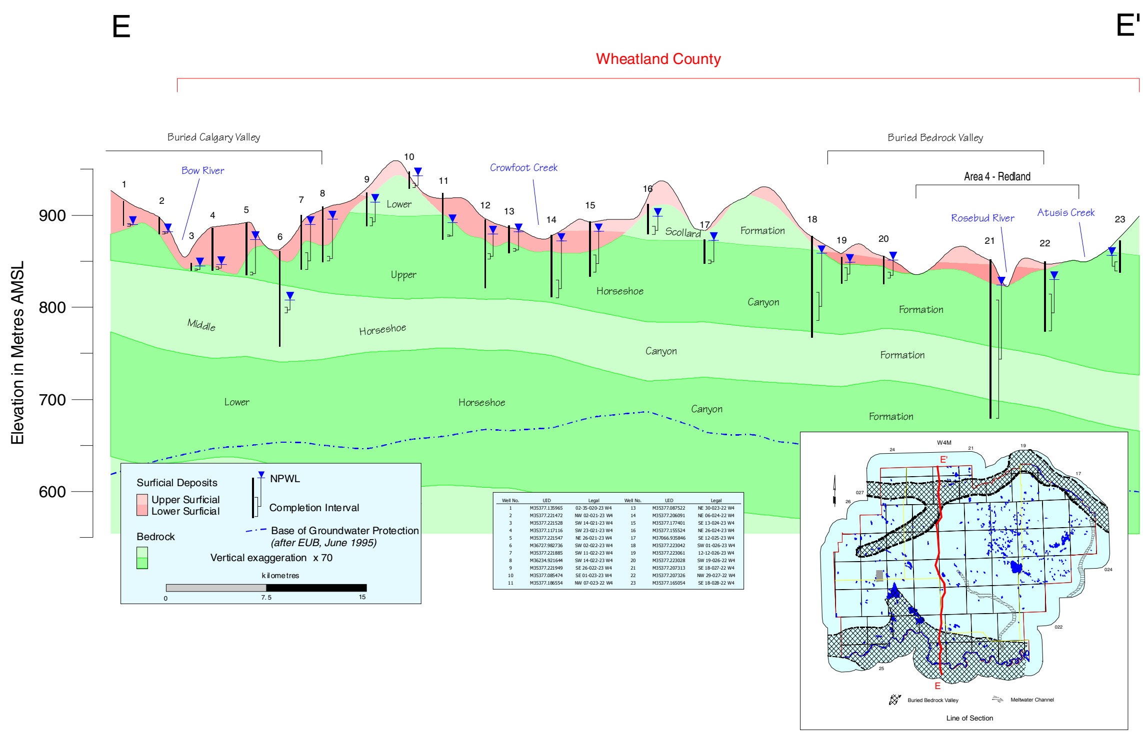
Cross-Section E - E'

Wheatland County
Cross-Section E - E'



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7	M35377.221885	SW 11-022-23 W4	19	M35377.223061	12-12-026-23 W4
8	M36234.921644	SW 14-022-23 W4	20	M35377.223028	SW 19-026-22 W4
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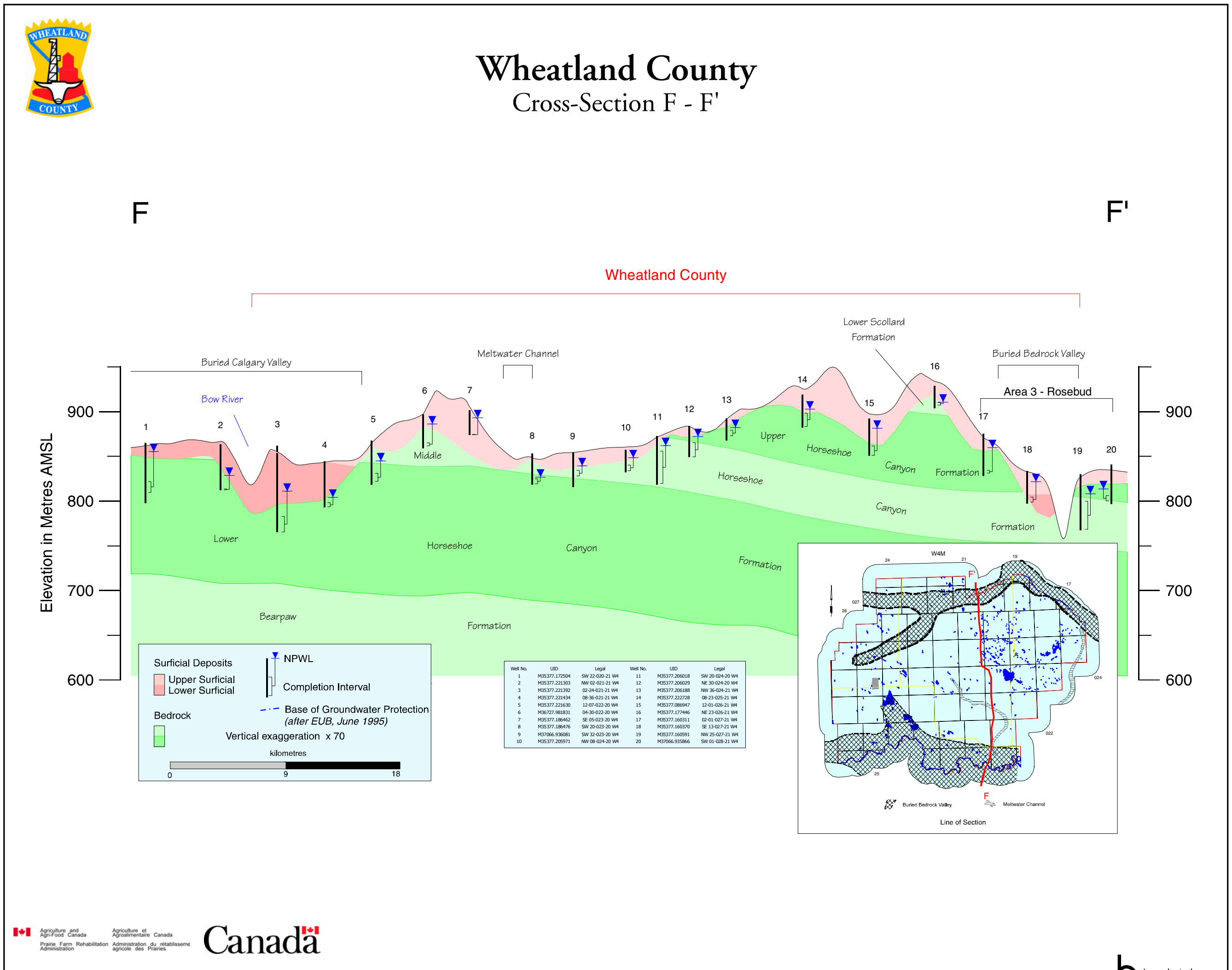
10	M35377.085474	SE 01-023-23 W4	22	M35377.207326	NW 29-027-22 W4
11	M35377.186554	NW 07-023-22 W4	23	M35377.165054	SE 18-028-22 W4

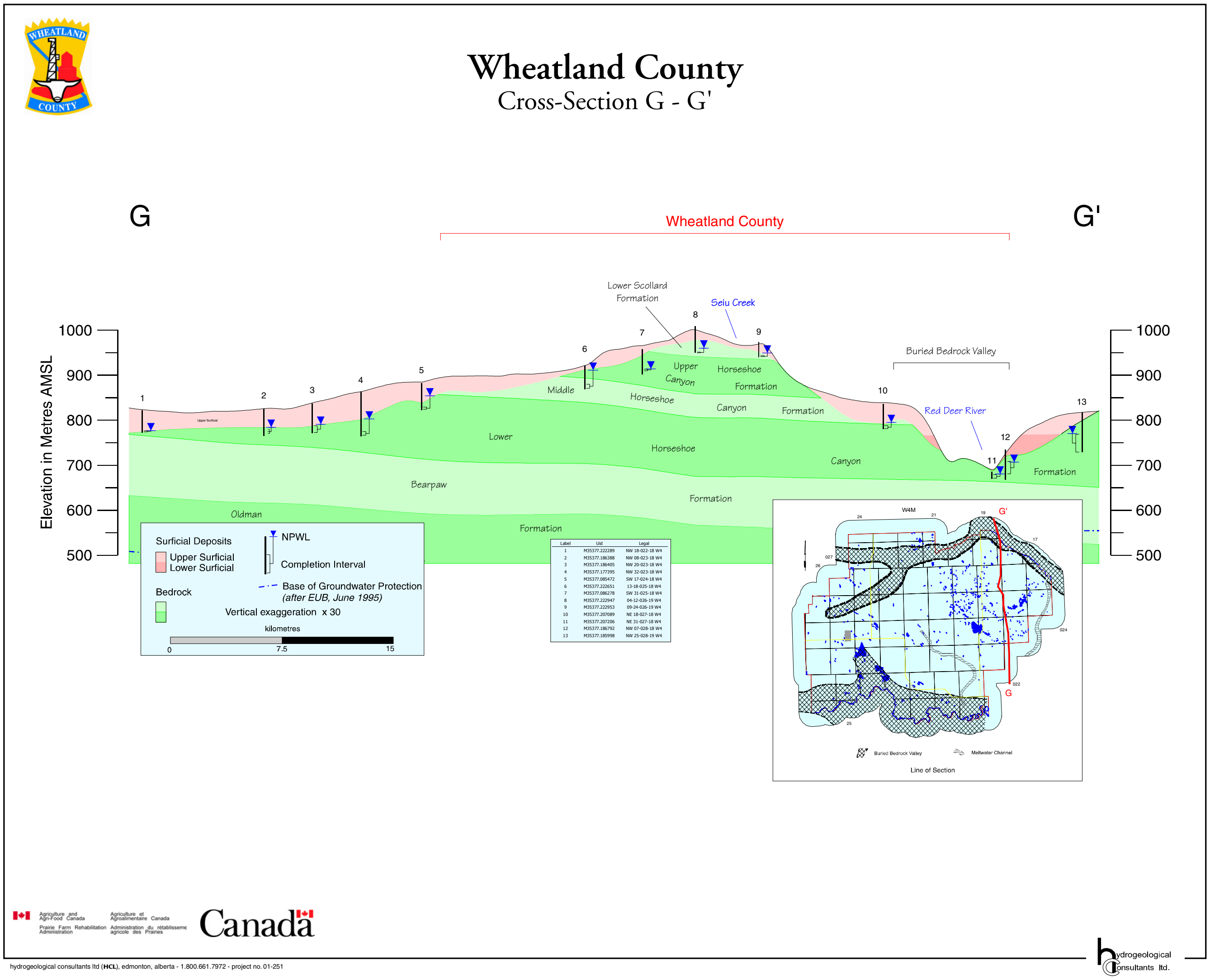
Cross-Section F - F'



Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.172504	SW 22-020-21 W4	11	M35377.206018	SW 20-024-20 W4
2	M35377.221303	NW 02-021-21 W4	12	M35377.206029	NE 30-024-20 W4
3	M35377.221392	02-24-021-21 W4	13	M35377.206188	NW 36-024-21 W4
4	M35377.221434	08-36-021-21 W4	14	M35377.222728	08-23-025-21 W4
5	M35377.221630	12-07-022-20 W4	15	M35377.086947	12-01-026-21 W4
6	M36727.981831	04-30-022-20 W4	16	M35377.177446	NE 23-026-21 W4
7	M35377.186462	SE 05-023-20 W4	17	M35377.160311	02-01-027-21 W4
8	M35377.186476	SW 20-023-20 W4	18	M35377.160370	SE 13-027-21 W4
9	M37066.936081	SW 32-023-20 W4	19	M35377.160591	NW 25-027-21 W4
10	M35377.205971	NW 08-024-20 W4	20	M37066.935866	SW 01-028-21 W4

hydrogeological consultants ltd (HCL), edmonton, alberta - 1.800.661.7972 - project no. 01-251

Cross-Section G - G'



Label	Uid	Legal
1	M35377.222289	NW 18-022-18 W4
2	M35377.186388	NW 08-023-18 W4
3	M35377.186405	NW 20-023-18 W4
4	M35377.177395	NW 32-023-18 W4
5	M35377.085472	SW 17-024-18 W4
6	M35377.222651	13-18-025-18 W4
7	M35377.086278	SW 31-025-18 W4
8	M35377.222947	04-12-026-19 W4
9	M35377.222953	09-24-026-19 W4
10	M35377.207089	NE 18-027-18 W4
11	M35377.207206	NE 31-027-18 W4
12	M35377.186792	NW 07-028-18 W4
13	M35377.185998	NW 25-028-19 W4

WHEATLAND COUNTY

Appendix E

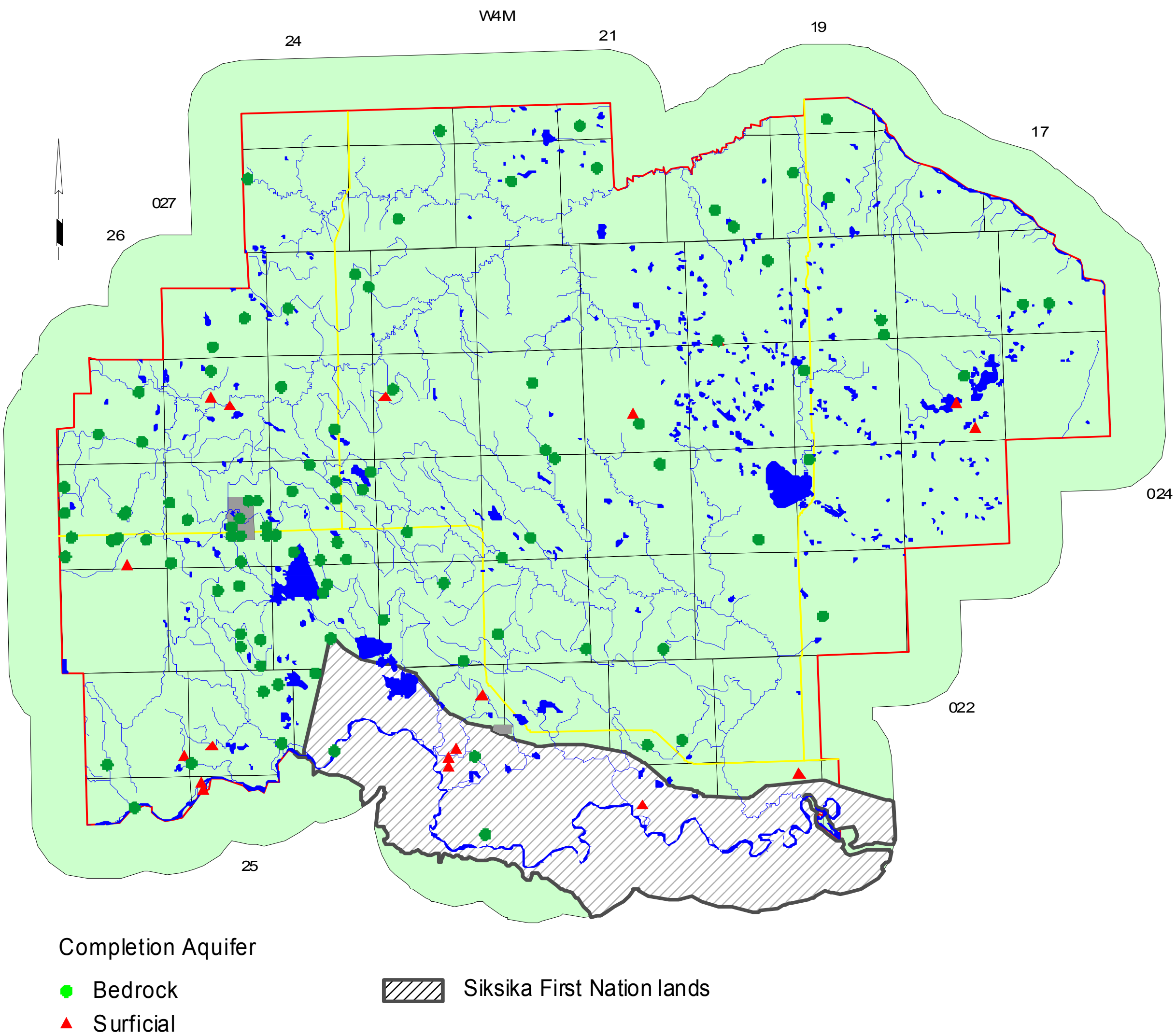
Water Wells Recommended for Field Verification

including

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 Environment	13-06-022-25 W4M	Upper Scollard	31-Oct-85	64.61	212.0	36.88	121.0	M35377.129205
Appleyard, Bruce	NW 12-023-25 W4M	Lower Scollard	01-Jun-75	51.81	170.0	6.1	20.0	M35377.204036
Armstrong, Jack	07-30-025-19 W4M	Upper Horseshoe Canyon	18-Nov-80	18.29	60.0	5.49	18.0	M35377.222680
Bazant, F. T.	SE 22-025-25 W4M	Surficial	01-Jul-84	39.62	130.0	1.52	5.0	M35377.223524
Bazant, Frank	SE 33-025-25 W4M	Haynes	21-Aug-75	54.86	180.0	9.14	30.0	M35377.223557
Beaudreau, Bob	NE 22-025-18 W4M	Middle Horseshoe Canyon	19-Jul-86	41.15	135.0	13.72	45.0	M35377.222657
Bernard, T.	NW 17-024-25 W4M	Haynes	23-Jul-76	27.43	90.0	6.1	20.0	M35377.206400
Bosen, Ole	SE 35-021-20 W4M	Surficial	23-Jul-74	46.33	152.0	33.53	110.0	M35377.221302
Breaker, Fred (Jr.)*	SW 09-022-24 W4M	Upper Horseshoe Canyon	21-Jun-84	39.32	129.0	21.03	69.0	M35377.221982
Brownscombe, M.	NW 22-027-22 W4M	Upper Horseshoe Canyon	01-Jul-69	72.23	237.0	33.53	110.0	M35377.207317
Burne, Elisa & Martin & Brian	NE 27-023-23 W4M	Upper Horseshoe Canyon	01-Oct-74	51.81	170.0	30.48	100.0	M35377.086293
Caralta Farms Ltd.	NW 08-022-25 W4M	Surficial	10-Oct-85	60.35	198.0	34.75	114.0	M35377.222022
Chalmers, Jack	SE 02-023-23 W4M	Lower Scollard	01-Apr-84	27.43	90.0	17.37	57.0	M35377.186596
Chenard, Marcel	12-25-026-24 W4M	Upper Scollard	11-Aug-76	41.15	135.0	26.82	88.0	M35377.223150
Chisholm, Rob	04-36-022-25 W4M	Lower Scollard	10-Jul-80	24.08	79.0	3.2	10.5	M35377.222099
Christensen, Art	SE 05-026-20 W4M	Surficial	06-Aug-74	19.81	65.0	10.67	35.0	M35377.222971
Christensen, Art	SE 05-026-20 W4M	Upper Horseshoe Canyon	25-May-83	48.77	160.0	14.93	49.0	M35377.222973
Clark, James	05-28-027-21 W4M	Middle Horseshoe Canyor	27-Jan-57	36.88	121.0	19.81	65.0	M35377.160607
Colpoys, Vic	NW 18-023-23 W4M	Lower Scollard	22-Jul-82	36.27	119.0	27.43	90.0	M35377.186618
County of Wheatland No. 16	08-28-023-24 W4M	Lower Scollard	24-May-77	43.89	144.0	3.44	11.3	M35377.222394
Cretin, Charlie	12-02-023-21 W4M	Upper Horseshoe Canyon	05-Aug-65	19.81	65.0	2.44	8.0	M35377.186488
Dahl, Svend	NW 03-028-19 W4M	Lower Horseshoe Canyon	13-Mar-86	71.93	236.0	54.25	178.0	M35377.185910
Deeg, Randy	02-26-025-26 W4M	Haynes	04-Sep-81	56.69	186.0	4.24	13.9	M35377.223627
Department of Parks & Wildlife	SE 31-021-25 W4M	Surficial	15-Feb-78	6.71	22.0	4.98	16.3	M35377.050590
Department of Parks & Wildlife	SE 31-021-25 W4M	Surficial	16-Feb-78	6.40	21.0	1.71	5.6	M35377.077424
Dettmer, E. C.	SW 01-026-19 W4M	Upper Horseshoe Canyon	01-May-73	62.48	205.0	51.81	170.0	M35377.222933
Dougan, Bryce	NE 21-025-25 W4M	Surficial	01-Oct-83	57.91	190.0	7.31	24.0	M35377.223809
Downey, Ha	04-14-023-25 W4M	Upper Scollard	12-Oct-77	41.15	135.0	10.67	35.0	M35377.204050
Elder, Ronald	SE 09-024-22 W4M	Upper Horseshoe Canyon	17-Apr-81	39.62	130.0	6.71	22.0	M35377.206095
Fair, Ray	SE 11-025-26 W4M	Haynes	20-Nov-81	30.48	100.0	3.41	11.2	M35377.223596
Faster Wheeler Ltd.	NW 05-022-26 W4M	Upper Scollard	28-May-75	82.29	270.0	48.46	159.0	M35377.222104
Gauthier, Margaret	04-12-026-19 W4M	Battle	05-Jul-79	60.96	200.0	48.77	160.0	M35377.222947
Grant, Gordon	04-27-025-22 W4M	Upper Scollard	04-Oct-77	22.86	75.0	15.24	50.0	M35377.222794
Grey, R. N.	NW 10-024-26 W4M	Lower Lacombe	25-Feb-75	15.85	52.0	6.1	20.0	M35377.222536
Gron, Paul	13-26-023-25 W4M	Upper Scollard	17-Aug-78	36.57	120.0	7.62	25.0	M35377.204103
Harriman, Norman	NW 17-026-24 W4M	Upper Scollard	14-Mar-75	35.96	118.0	15.24	50.0	M35377.095507
Harwood Farms Ltd.	SE 36-024-24 W4M	Lower Scollard	19-Jun-85	43.28	142.0	14.02	46.0	M35377.206354
Harwood, Jim	NW 05-024-24 W4M	Upper Scollard	02-Jun-64	27.43	90.0	-0.03	-0.1	M35377.206243
Heinricks, Wally	NW 32-022-24 W4M	Lower Scollard	28-Jun-78	43.58	143.0	15.24	50.0	M35377.221998
Heinzlmeir, Harold J.	NE 10-025-24 W4M	Upper Scollard	30-Nov-73	46.02	151.0	38.1	125.0	M35377.222865
Helfrich, Eugene	NW 24-024-25 W4M	Haynes	01-Apr-73	39.62	130.0	13.72	45.0	M35377.222427
Helfrick, Ralph	NE 23-024-25 W4M	Haynes	01-Aug-73	24.38	80.0	3.66	12.0	M35377.222420
Hendricks, Bill	SW 29-024-24 W4M	Haynes	14-Jul-76	18.29	60.0	12.19	40.0	M35377.206330
Hendry, K. A.	SE 03-024-26 W4M	Surficial	01-Apr-69	15.85	52.0	2.29	7.5	M35377.222476
High Hopr Farms Ltd.	04-05-024-22 W4M	Upper Horseshoe Canyon	02-Aug-78	53.95	177.0	10.88	35.7	M35377.219533
Hillview Colony Ltd.	NW 05-028-21 W4M	Upper Horseshoe Canyon	13-Aug-97	51.45	168.8	30	98.4	M36256.405151
Jackson, Bob	NW 06-024-26 W4M	Lower Lacombe	08-Sep-75	41.15	135.0	4.57	112244.0	M35377.222517
Jackson, George	SW 19-024-26 W4M	Lower Lacombe	06-Jun-75	64.00	210.0	9.14	112288.0	M35377.222561
Janzen, Herb M.	SE 28-021-26 W4M	Upper Scollard	06-Jul-78	71.62	235.0	17.65	238273.0	M35377.180297
Jensen, O.	NE 26-026-20 W4M	Upper Horseshoe Canyon	30-Oct-73	96.01	315.0	85.34	112719.0	M35377.222992
Jensen, Wayne	SE 03-025-22 W4M	Upper Horseshoe Canyon	13-Apr-76	27.43	90.0	5.18	112485.0	M35377.222758
Jorgensen, William J.	SW 15-027-19 W4M	Upper Horseshoe Canyon	01-Mar-78	36.57	120.0	15.85	123481.0	M35377.207234
Keimeny, Andy	NW 33-024-24 W4M	Upper Scollard	30-Jul-76	32.00	105.0	14.63	122598.0	M35377.206351

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Knight, Jack	NE 12-024-25 W4M	Upper Scollard	01-Oct-69	59.13	194.0	25.91	85.0	M35377.206429
Laprise, M.	04-09-022-21 W4M	Middle Horseshoe Canyon	21-Jun-79	35.36	116.0	18.29	60.0	M35377.221720
Larsen, K.	SW 17-023-19 W4M	Lower Horseshoe Canyon	14-May-74	59.43	195.0	42.67	140.0	M35377.186444
Legg, T.	NW 01-028-23 W4M	Upper Scollard	01-May-74	27.43	90.0	13.72	45.0	M35377.165077
Lehmann, Jens	09-28-023-25 W4M	Upper Scollard	20-Aug-82	63.40	208.0	16.76	55.0	M35377.204119
Lyalta Community Centre.	NW 09-025-26 W4M	Lower Lacombe	12-Jun-75	22.86	75.0	7.01	23.0	M35377.223587
Manyheads, Mathew*	NW 10-023-24 W4M	Lower Scollard	05-Nov-75	27.43	90.0	21.33	70.0	M35377.222338
Mccamus, Frank W.	13-27-023-24 W4M	Lower Scollard	03-Jun-81	41.15	135.0	16.76	55.0	M35377.222389
Mitzner, Cristine	NE 27-024-24 W4M	Lower Scollard	30-Aug-79	27.43	90.0	7.62	25.0	M35377.206326
Newell, Raymond	16-24-026-24 W4M	Lower Scollard	16-May-79	28.95	95.0	4.66	15.3	M35377.223149
Nightingale Community Hall Associatio	SE 30-025-24 W4M	Lower Scollard	17-Mar-75	55.17	181.0	4.57	15.0	M35377.222905
Old Woman, Joseph (Jr.)*A26	NE 04-022-23 W4M	Lower Surficial	21-Jun-84	9.14	30.0	4.57	15.0	M35377.221851
Ornburn, A.	SE 13-024-25 W4M	Upper Scollard	01-May-73	50.29	165.0	22.86	75.0	M35377.206436
Oster, Jim	SW 15-025-18 W4M	Surficial	02-May-75	22.25	73.0	12.19	40.0	M35377.222649
Papp, John	05-11-022-21 W4M	Middle Horseshoe Canyon	04-Jul-77	28.95	95.0	6.1	20.0	M35377.221724
Parks & Wildlife	10-31-021-25 W4M	Lower Surficial	04-Feb-77	6.40	21.0	2.68	8.8	M35377.221606
Payne, Dale	NW 19-024-25 W4M	Upper Scollard	03-Jul-78	68.27	224.0	18.29	60.0	M35377.223826
Penner, Dave	SW 01-023-25 W4M	Upper Scollard	12-Apr-78	37.49	123.0	19.81	65.0	M35377.203944
Peterson, Herman	SE 16-025-21 W4M	Surficial	01-Apr-81	24.99	82.0	15.24	50.0	M35377.222717
Pig Improvement Canada Ltd.	SE 10-024-24 W4M	Upper Scollard	06-Feb-84	21.33	70.0	10.06	33.0	M35377.206286
Ramsey, Andrew	NE 08-024-23 W4M	Upper Horseshoe Canyon	03-Jun-82	48.77	160.0	15.85	52.0	M35377.092252
Rasmussen, Gordon	NW 35-024-22 W4M	Upper Horseshoe Canyon	24-Apr-86	47.24	155.0	10.36	34.0	M35377.206135
Raweater, Ricky*	SE 04-022-23 W4M	Lower Surficial	10-Jul-84	15.24	50.0	3.96	13.0	M35377.221836
Red Gun, Harry*	SE 14-021-23 W4M	Middle Horseshoe Canyon	22-Jun-84	8.53	28.0	6.71	22.0	M35377.221527
Romaniuk, Dan	05-11-023-25 W4M	Upper Scollard	12-Jun-86	42.06	138.0	18.9	62.0	M35377.204018
Roppel, Harold	NE 09-027-23 W4M	Lower Scollard	01-Jul-77	18.90	62.0	9.14	30.0	M35377.207344
Running Rabbit, Gary*	NE 20-021-21 W4M	Lower Surficial	25-Jun-84	10.06	33.0	4.11	13.5	M35377.221372
Sandhill Colony Ltd.	SW 30-027-24 W4M	Upper Scollard	01-May-74	27.74	91.0	6.1	20.0	M35377.207417
Sandum, Gordon	NW 02-025-18 W4M	Surficial	01-Mar-71	33.53	110.0	19.81	65.0	M35377.222635
Schoff, H. Dale	SW 06-024-25 W4M	Haynes	03-Jun-74	32.00	105.0	15.24	50.0	M35377.206493
Seeley, Jim	NE 09-026-17 W4M	Lower Horseshoe Canyon	10-May-88	49.98	164.0	36.57	120.0	M35377.128768
Seeley, Ralph	NW 08-026-17 W4M	Middle Horseshoe Canyon	06-May-88	49.98	164.0	37.79	124.0	M35377.128754
Seitz, Chris	NW 07-024-24 W4M	Upper Scollard	13-Sep-74	54.86	180.0	25.91	85.0	M35377.177346
Seitz, Chris	NW 07-024-24 W4M	Upper Scollard	09-Apr-85	51.51	169.0	24.08	79.0	M35377.219523
Setlef, Ernie	NE 10-024-25 W4M	Upper Scollard	21-Jun-74	82.29	270.0	34.14	112.0	M35377.206418
Sibley, E. G.	NE 22-024-24 W4M	Upper Scollard	27-Oct-64	18.29	60.0	2.13	7.0	M35377.206311
Skibsted, Willard	02-22-024-26 W4M	Lower Lacombe	25-Sep-85	39.01	128.0	16.76	55.0	M35377.222570
Skibsted, Willard	SE 22-024-26 W4M	Lower Lacombe	20-Aug-85	24.69	81.0	7.86	25.8	M35377.222569
Stangness, Nils	NW 26-022-25 W4M	Lower Scollard	01-Aug-71	60.96	200.0	34.14	112.0	M35377.223853
Stanley, Bob	09-11-024-26 W4M	Haynes	22-Jul-86	28.95	95.0	6.4	21.0	M35377.222543
Stephens, Miles	NW 30-024-26 W4M	Lower Lacombe	19-Aug-77	21.33	70.0	8.47	27.8	M35377.130449
Stevenson, Duncan	09-04-026-25 W4M	Haynes	05-May-76	30.48	100.0	9.14	30.0	M35377.223171
Stimpson, Ralph	NE 01-023-22 W4M	Upper Horseshoe Canyon	12-Jul-84	64.00	210.0	30.02	98.5	M35377.186538
Stocker, Bruno	SW 35-024-21 W4M	Middle Horseshoe Canyon	21-Apr-81	39.62	130.0	24.38	80.0	M35377.206182
Swagar, Bill	SW 25-024-24 W4M	Upper Horseshoe Canyon	18-Jul-80	71.62	235.0	13.72	45.0	M35377.206322
Thiessen Farms Ltd.	NW 12-022-25 W4M	Upper Horseshoe Canyon	11-Dec-79	49.68	163.0	35.36	116.0	M35377.080315
Thurston, Ron	SE 14-026-25 W4M	Haynes	01-Apr-82	36.57	120.0	6.1	20.0	M35377.223183
Toft, Gary	NW 20-027-19 W4M	Middle Horseshoe Canyon	13-May-86	53.34	175.0	27.43	90.0	M35377.207246
Town of Carseland	02-12-022-26 W4M	Lower Surficial	10-Jun-81	64.92	213.0	42.91	140.8	M35377.222129
Town of Strathmore	SE 15-024-25 W4M	Upper Scollard	16-Sep-74	54.86	180.0	42.67	140.0	M35377.206380
Turning Robe, Frank*	SW 10-022-23 W4M	Surficial	22-Jun-84	12.50	41.0	8.84	29.0	M35377.221880
W. I. D.	NW 11-024-25 W4M	Haynes	28-May-82	22.86	75.0	9.45	31.0	M35377.206422
W. I. D.	NW 11-024-25 W4M	Haynes	02-Jun-82	22.25	73.0	9.45	31.0	M35377.206423
W. Will Farm Ltd.	NE 03-024-20 W4M	Middle Horseshoe Canyon	01-Sep-82	33.53	110.0	9.45	31.0	M35377.205967
Walker, Bruce	NE 07-023-22 W4M	Upper Horseshoe Canyon	25-Sep-78	21.94	72.0	12.8	42.0	M35377.186555
West Bend Ind	15-07-024-26 W4M	Lower Lacombe	20-Sep-76	45.72	150.0	14.72	48.3	M35377.148099

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Western Feedlots Ltd.	SW 02-024-25 W4M	Upper Scollard	09-Sep-74	44.19	145.0	12.19	40.0	M35377.206468
Western Feedlots Ltd.	SW 02-024-25 W4M	Upper Scollard	17-May-85	38.71	127.0	25.3	83.0	M35377.206472
Wheatland Colony Ltd.	10-19-025-23 W4M	Lower Surficial	12-Aug-98	32.61	107.0	9.13	30.0	M36315.386669
Wheatland Colony Ltd.	13-20-025-23 W4M	Lower Scollard	10-May-95	30.47	100.0	6.04	19.8	M36315.386670
Wheeler, Gene	12-10-025-21 W4M	Upper Horseshoe Canyon	03-Nov-78	28.65	94.0	21.94	72.0	M35377.222713
Wheeler, Keith	SW 02-024-24 W4M	Lower Scollard	01-Nov-72	76.81	252.0	19.81	65.0	M35377.206224
Williams, Larry	SE 31-024-19 W4M	Middle Horseshoe Canyor	01-Sep-77	45.72	150.0	15.24	50.0	M35377.206214
Yellow Old Woman, Jeannie*	NW 02-022-23 W4M	Upper Horseshoe Canyon	27-Jul-84	21.03	69.0	5.49	18.0	M35377.221823
Yule, Allen	SE 26-022-23 W4M	Surficial	12-Sep-79	36.57	120.0	10.67	35.0	M35377.221949
Zieffle, Harvey	NW 14-024-25 W4M	Haynes	16-Jan-73	38.40	126.0	27.43	90.0	M35377.206365
Ziehr, Norbert	SE 04-024-24 W4M	Upper Scollard	21-Mar-79	34.44	113.0	15.24	50.0	M35377.206232
	NE 03-027-20 W4M	Upper Horseshoe Canyon	28-Apr-57	38.40	126.0	4.57	15.0	M35377.160025
	NE 09-027-20 W4M	Middle Horseshoe Canyor	07-May-69	46.02	151.0	27.43	90.0	M35377.160027

* Water wells located on the Siksika First Nation lands

WHEATLAND 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 Wheatland No. 16	04-07-022-26 W4M	Lower Surficial	31174	67.97	223.0	45.11	148.0	M35377.222111
County of Wheatland No. 16	06-07-027-21 W4M	Middle Horseshoe Canyon	32051	36.57	120.0	5.18	17.0	M35377.160330
County of Wheatland No. 16	08-28-023-24 W4M	Lower Scollard	28269	43.89	144.0	3.44	11.3	M35377.222394
County of Wheatland No. 16	16-05-022-21 W4M	Middle Horseshoe Canyon	30277	51.81	170.0	15.85	52.0	M35377.221696
County of Wheatland No. 16	NE 12-022-26 W4M	Upper Scollard	33872	76.5	251.0	53.95	177.0	M35377.117122
County of Wheatland No. 16	NE 12-022-26 W4M	Upper Scollard	33868	75.28	247.0	54.56	179.0	M35377.117121
County of Wheatland No. 16	NE 12-022-26 W4M	Upper Scollard	34289	70.41	231.0	54.56	179.0	M35377.062170
County of Wheatland No. 16	NE 14-027-22 W4M	Middle Horseshoe Canyon	32077	97.53	320.0	53.95	177.0	M35377.207307
County of Wheatland No. 16	NE 14-027-22 W4M	Middle Horseshoe Canyon	32077	120.39	395.0	51.81	170.0	M35377.207306
County of Wheatland No. 16	NE 24-027-22 W4M	Upper Surficial	32058	32	105.0	6.71	22.0	M35377.086853
County of Wheatland No. 16	NW 11-024-24 W4M	Bedrock	28775	13.72	45.0	3.35	11.0	M35377.206294
County of Wheatland No. 16	SE 16-024-24 W4M	Haynes	35984	13.11	43.0	3.05	10.0	M36234.924807
County of Wheatland No. 16	SE 16-024-24 W4M	Haynes	35985	13.41	44.0	2.13	7.0	M36234.924806