County of Camrose No. 22

Part of the North Saskatchewan River Basin
Tp 041 to 050, R 16 to 22, W4M
Regional Groundwater Assessment

Prepared for County of Camrose No. 22

In conjunction with

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada
Prairie Farm Rehabilitation Administration | Administration du rétablisseme agricole des Prairies

Canada

Prepared by
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Our File No.: **04-101**

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Table of Contents

List of Figures

List of Tables

Appendices

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Mr. Terry Dash – AAFC-PFRA
Mr. Glen Brandt – AAFC-PFRA
Mr. Paul King – County of Camrose

For additional copies of the report/CD-ROM, please contact the following:

- 1-800-GEO-WELL
- The Groundwater Centre/Regional Groundwater Assessment

http://www.groundwatercentre.com/m_info_rgwa.asp

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 the County of Camrose No. 22 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 the County of Camrose No. 22 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) and the County of Camrose. The project study area includes the parts of the County of Camrose bounded by townships 041 to 050, ranges 16 to 22, W4M (herein referred to as the County). 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 country residential, 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 the County of Camrose.

[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 the County of Camrose, (b) the processes used for the present project, and (c) the groundwater characteristics in the County.

Additional technical details are available from files on the CD-ROM provided with 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. In order to avoid map-edge effects, all maps are based on an analysis of hydrogeological data from townships 041 to 050, ranges 16 to 22, W4M, plus a buffer area of 5,000 metres. 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 *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 *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 that have been field-verified and water wells that are recommended for field-verification.

[3] See glossary

2 INTRODUCTION

2.1 Setting

The County of Camrose is situated in central Alberta. The County boundaries mainly follow township or section lines, which include parts of the area bounded by townships 041 to 050, ranges 16 to 22, W4M.

Regionally, the topographic surface varies between 680 and 920 metres above mean sea level (AMSL). The lowest elevations occur mainly in association with the Battle River; the highest elevations are in the southwestern parts of the County, as shown on Figure 1 and page A-3.

The County is within the North Saskatchewan and South Saskatchewan River basins (see page A-4, and Cross-Sections F-F' and G-G' on pages A-19 and A-20). The area is well drained by the Battle River, Driedmeat Creek, Meeting Creek, and numerous lakes.

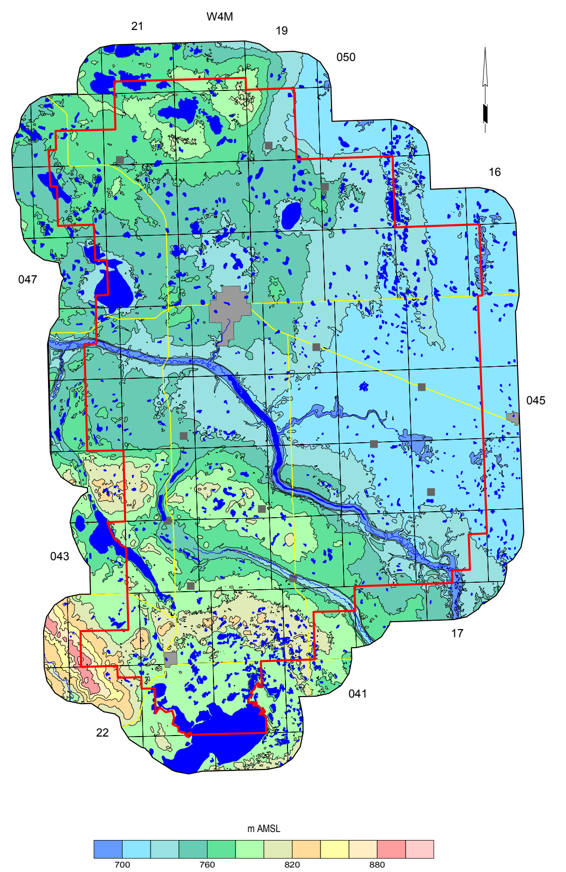

Figure 1. Surface Topography

2.2 Climate

The County of Camrose 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 Aspen Parkland region, a transition between boreal forest and grassland environments.

A Dfb climate consists of long, cool summers and severe winters. The mean monthly temperature drops below -3° C in the coolest month, and exceeds 10° C in the warmest month. 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 two meteorological stations within the County and one in Beaver County measured 493 millimetres (mm), based on data from 1971 to 2000. The annual temperature averaged 2.8° C, with the mean monthly temperature reaching a high of 16.3° C in July, and dropping to a low of -12.7° C in January. The calculated annual potential evapotranspiration is 494 millimetres.

[4] See glossary

2.3 Background Information

2.3.1 Number, Type and Depth of Water Wells

There are currently 7,517 records in the groundwater database for the County, of which 6,323 are water wells. Of the 6,323 water wells, there is a proposed use for 5,774 water wells, as shown in the adjacent table. Of the 5,774 water wells, there are records for domestic (3,214), domestic/stock (1,525) or stock (817) purposes. The remaining 218 water wells were completed for municipal (87), observation (56), industrial (25), and other numerous categories (50).

Date Completed	Domestic	Domestic/Stock	Stock	Municipal	Observation	Industrial	Other	Unknown	Total
No Date	1684	298	89	36	0	3	22	329	2107
pre-1955	86	455	7	4	0	1	1	85	552
1955	35	4	5	1	3	2	0	8	45
1960	49	8	11	2	0	1	0	21	70
1965	94	36	50	5	5	1	1	29	185
1970	115	51	98	1	0	0	2	22	265
1975	248	164	125	8	3	5	1	21	545
1980	282	203	119	13	35	6	7	20	617
1985	169	183	169	7	6	3	2	12	528
1990	170	77	70	2	0	2	2	2	319
1995	165	30	35	7	4	0	8	0	237
2000	117	16	39	1	0	1	4	0	173
Total	3214	1525	817	87	56	25	50	549	6323

Table 1. Proposed Use for Water Wells

Based on a rural population of 7,294 (Phinney, 2003), there are three domestic, domestic/stock and stock water wells per family of four. There are 5,288 domestic, domestic/stock or stock water wells with a completed depth, of which 4,054 (77%) are completed at depths of less than 60 metres below ground surface, and 41% are completed between 30 and 60 metres below ground surface.

Depth Completed (m)	Domestic	Domestic/Stock	Stock	Total	Percentage
<10	94	91	15	200	4
10 to 30	895	481	298	1,674	32
30 to 60	1,397	538	245	2,180	41
60 to 100	524	375	230	1,129	21
>100	59	25	21	105	2
Total	2,969	1,510	809	5,288	

Table 2. Completed Depths for Domestic, Domestic/Stock and Stock Water Wells

The highest percentages of domestic (47%) and domestic/stock (36%) water wells are completed between 30 and 60 metres below ground surface, and the highest percentage of stock water wells (37%) are completed between ten and 30 metres below ground surface, as shown below in Figure 2.

Details for lithology[5] are available for 2,969 water wells.

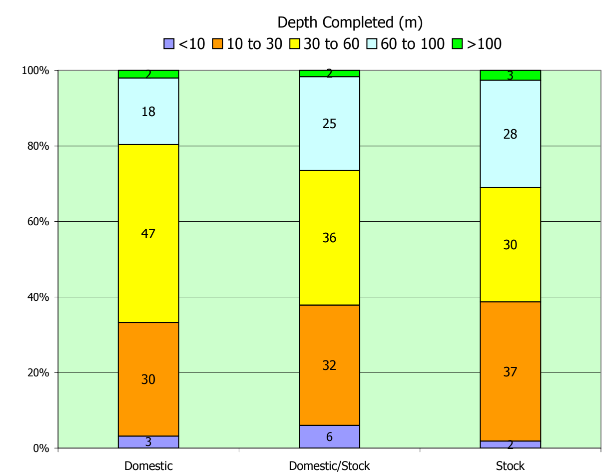

Figure 2. Percentage of Domestic, Domestic/Stock and Stock Water Wells vs Completed Depth

5 See glossary

2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 2,479 water wells 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 2,479 water wells for which aquifers could be defined, 305 are completed in surficial aquifers, with 204 (67%) having a completion depth of less than 30 metres below ground surface. The adjacent map shows that the water wells completed in the surficial deposits are mainly concentrated in the buried bedrock valley and adjacent to meltwater channels (see Figure 9 on page 15), and in the northwestern part of the County.

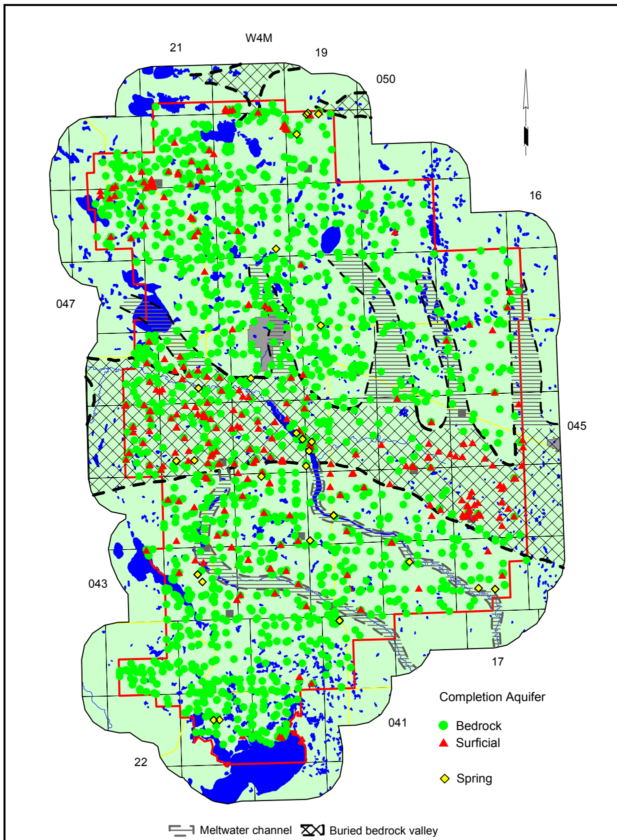

Figure 3. Locations of Water Wells and Springs

The data for 2,174 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 3 (also see page A-8), it can be seen that water wells completed in bedrock aquifers occur throughout the County.

Within the County of Camrose, there are currently records for 28 springs in the groundwater database, including three springs that were documented by Borneuf (1983). There are 14 springs having at least one total dissolved solids (TDS) value, with nine springs having a TDS of more than 500 milligrams per litre (mg/L). No flow rates for the 28 springs are available in the groundwater database.

2.3.3 Casing Diameter and Type

Data for casing diameters are available for 3,691 water wells, with 3,360 (91%) indicated as having a diameter of less than 275 mm and 331 (9%) having a diameter of more than 275 mm. The casing diameters of greater than 275 mm are mainly bored, hand dug, or dug by backhoe water wells and those with a surface-casing diameter of less than 275 mm are mainly drilled water wells. The entire water well database for the County suggests that 628 of the water wells in the County were bored, hand dug or dug by backhoe and 4,475 are drilled water wells.

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. Within the County, casing-diameter information is available for 278 of the 305 water wells completed in the surficial deposits, of which 251 surficial water wells have a casing diameter of less than 275 millimetres and are assumed to be drilled water wells. Within the County, casing-diameter information is available for 2,150 of the 2,174 water wells completed below the top of bedrock, of which 2,117 have a surface-casing diameter of less than 275 mm and have been mainly completed with either a perforated liner or as open hole; there are 45 bedrock water wells completed with a water well screen.

Where the casing material is known, steel surface casing materials have been used in 73% of the drilled water wells over the last 45 years. For the remaining drilled water wells with known surface casing material, 20% were completed with plastic casing, and seven percent were completed with galvanized steel casing. The main years where the type of surface casing was undocumented were prior to 1955 to the mid-1960s. The use of steel surface casing averaged at least 80% until the 1990s, at which time plastic casing started to replace the use of steel casing. Plastic casing was first used in May 1977, and is currently being used in 70% of the water wells drilled in the County. Galvanized steel surface casings in drilled water well were first used in the County in September 1956 and were last used in November 1994.

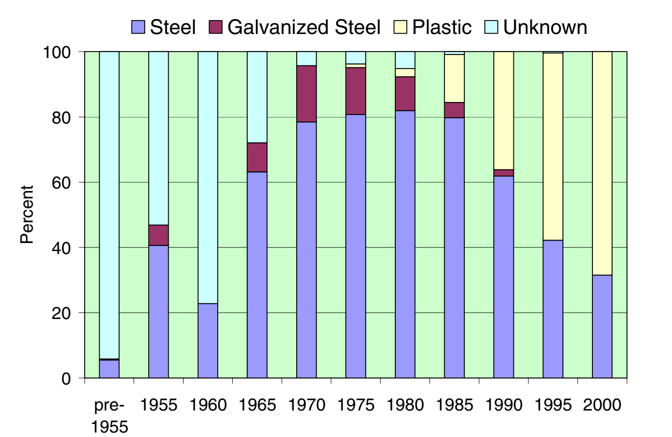

Figure 4. Surface Casing Types Used in Drilled Water Wells

2.3.4 Dry Water Test Holes

In the County, there are 7,517 records in the groundwater database. Of these 7,517 records, 128 (2%) are indicated as being "dry" or "abandoned" with "insufficient water"[6]. Of the 128 "dry" water test holes, ten are completed in surficial deposits and 117 are completed in Upper Bedrock Aquifer(s); the aquifer for the remaining one "dry" water test hole is unknown. Thirty percent of all water wells with apparent yield estimates were judged to yield less than 6.5 m³/day (1 igpm).

The locations of 127 (ten surficial and 117 bedrock) "dry" water test holes are shown on Figure 14 on page 19 and on Figure 21 on page 25, respectively.

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

2.3.5 Requirements for Licensing

With some exemptions, a diversion of groundwater starting after 01 Jan 1999 must have a licence. Exemptions include (1) the diversion for household use of up to 3.4 cubic metres per day (1,250 m³/year (750 imperial gallons per day[7]), (2) the diversion of groundwaters with total dissolved solids in excess of 4,000 mg/L, (3) the diversion from a manually pumped water well, or (4) a diversion of groundwater that was eligible for registration as “Traditional Agriculture Use” but was not registered can continue to be used for Traditional Agriculture Use but without the protection of the *Water Act*.

In the last update from the Alberta Environment (AENV) groundwater database, 1,066 groundwater licences and/or registrations were shown to be within the County, with the most recent groundwater user being registered in April 2003. Of the 1,066 licensed and registered groundwater users, 882 (83%) are registrations of Traditional Agriculture Use under the *Water Act*. These 882 registered users will continue to divert groundwater for stock watering and/or crop spraying. Typically, the groundwater diversion for crop spraying averages less than one m³/day so most registered groundwater diversion is for stock watering. Of the 882 registrations, 404 (46%) could be linked to the AENV groundwater database. Of the remaining 184 groundwater users, 140 are for agricultural purposes (mainly stock watering), 32 are for municipal purposes (mainly urban), six are for commercial purposes, three are for dewatering purposes, and the remaining three are for recreation purposes. Of these 184 licensed groundwater diversions in the County, 107 (58%) could be linked to the AENV groundwater database. The maximum amount of groundwater that can be diverted each year from the water wells associated with these licences and/or registrations is 5,338 m³/day, although actual use could be less. Of the 5,338 m³/day, 2,154 m³/day (40%) is registered for Traditional Agriculture Use, 1,066 m³/day (20%) licensed for agricultural purposes, 304 (6%) is licensed for commercial purposes, 521 (10%) is licensed for dewatering purposes, 1,263 (24%) is licensed for municipal purposes, and 30 m³/day (< 1%) is licensed for recreation purposes, as shown below in Table 3. A figure showing the locations of the groundwater users with either a licence or a registration is in Appendix A (page A-9) and on the CD-ROM. Table 3 also shows a breakdown of the 1,066 groundwater licences and/or registrations by the aquifer in which the water well is completed. Forty-five percent of the total quantity of licensed and registered groundwater use is from the Upper and Lower Horseshoe Canyon aquifers. The water wells associated with the 68 licensed and registered use where a specific aquifer cannot be determined is because insufficient completion information is available.

Aquifer **	No. of Licences and/or Registrations	Registrations (m³/day)	Licensed Groundwater Users* (m³/day)					Total Quantity of Licensed and/or Registered Groundwater Diversion (m³/day)	Percentage
			Agricultural	Commercial	Dewatering	Municipal	Recreation		
Multiple Surficial Completions	84	157	76	14	308	0	0	555	10.4
Upper Sand and Gravel	64	141	76	235	206	17	0	675	12.6
Lower Sand and Gravel	57	113	15	51	7	395	0	581	10.9
Mulitple Bedrock Completion	110	221	147	0	0	0	0	368	6.9
Upper Horseshoe Canyon	107	236	284	0	0	649	0	1,169	21.9
Middle Horseshoe Canyon	101	166	66	0	0	88	0	320	6.0
Lower Horseshoe Canyon	396	795	297	4	0	114	30	1,240	23.2
Bearpaw	79	179	71	0	0	0	0	250	4.7
Unknown	68	146	34	0	0	0	0	180	3.4
Total(1)	1,066	2,154	1,066	304	521	1,263	30	5,338	100
Percentage		40.4	20.0	5.7	9.8	23.7	0.6	100	

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

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

Table 3. Licensed and/or Registered Groundwater Diversions

7 see conversion table on page 65

Based on the 2001 Agriculture Census (Statistics Canada), the calculated water requirement for 1,266,016 livestock for the County is in the order of 9,536 m³/day. This number includes intensive livestock use but not domestic animals and is based on an estimate of water use per livestock type. Of the 9,536 m³/day calculated livestock use, AENV has authorized a groundwater diversion of 3,220 m³/day (agricultural and registration) (34%) and licensed a surface-water diversion (stock and registration) based on consumptive use of 912 m³/day (10%) for a total diversion of 4,132 m³/day. Agriculture purpose includes water diverted and used for stockwatering and feedlot use. This assumes the majority of the groundwater and surface water authorized for diversion for Traditional Agriculture Use is used for watering livestock. Using this assumption, 44% of the estimated total water requirements of 9,536 m³/day is accounted for.

Livestock Type	Number	Estimated Water Requirement (m³/day)
Total hens and chickens	972,700	199
Turkeys	60,817	41
Other poultry	4,068	1
Total cattle and calves	95,767	5,224
Bulls, 1 year and over	2,024	138
Total cows	39,927	2,178
Heifers, 1 year and over	9,498	432
Calves, under 1 year	36,325	495
Total pigs	30,603	556
Total sheep and lambs	8,671	79
Horses and ponies	3,751	171
Goats	1,031	9
Rabbits	272	0
Mink	0	0
Fox	0	0
Bison	137	6
Deer and elk	265	4
Llamas and alpacas	160	1
Totals	1,266,016	9,536

Table 4. Estimated Water Requirement for Livestock in the County of Camrose

The remaining 5,404 m³/day (57%) of the calculated water requirement for livestock use would have to be from other, including unlicensed, sources. The discrepancy may be partially accounted for in several ways. Based on some monitoring and reporting situations, the estimated water requirements for livestock, used by AENV, tend to be somewhat high. Some livestock water requirements would be made up from free-standing water following precipitation events, thus reducing the expected quantity needed. Also, it should be noted that 'household use', as defined in the *Water Act*, can provide sufficient water for about 75 head of cattle, with no need for a licence. It is possible that some such use may have been registered as Traditional Agriculture Use and would therefore be included in the registration quantity. Also, diversions of groundwater and surface water that were eligible for registration as Traditional Agriculture Use can continue to be used for traditional agricultural purposes without the need for authorization.

2.3.6 Base of Groundwater Protection

In general, AENV defines the Base of Groundwater Protection (BGP) 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 BGP can be determined. These values are gridded using the Kriging[8] method to prepare a depth to the BGP 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 TDS concentrations that exceed 4,000 mg/L, the groundwater use does not require licensing by AENV. The depth to the BGP is mainly less than 125 metres below ground surface in the central parts of the County but can be more than 300 metres below ground surface in the southwestern, southeastern and northeastern parts of the County, as shown on Figure 5 on the following page, on the cross-sections presented this report and in Appendix A, and on the CD-ROM.

[8] See glossary

There are 5,948 water wells with completed depth data, of which 23 appear to be completed below the BGP. Of the 23 water wells completed below the BGP, 13 water wells are completed less than ten metres below the BGP and ten are completed greater than or equal to ten metres below the BGP, as shown in the adjacent table. Chemistry details are available for ten of the 23 water wells, of which two water wells had TDS concentrations that were greater than 4,000 mg/L, both of which are from water wells that are completed at least ten metres below the BGP. In the County, the BGP mainly coincides with the top of the Bearpaw Formation (see pages A-14 to A-20).

Water Wells Completed below the
Base of Groundwater Protection (BGP)

	< 10 metres BGP	>= 10 metres BGP
TDS < 4,000 mg/L	4	4
TDS >= 4,000 mg/L	0	2
No TDS	9	4
Total Number	13	10

Table 5. Water Wells Completed below the Base of Groundwater Protection

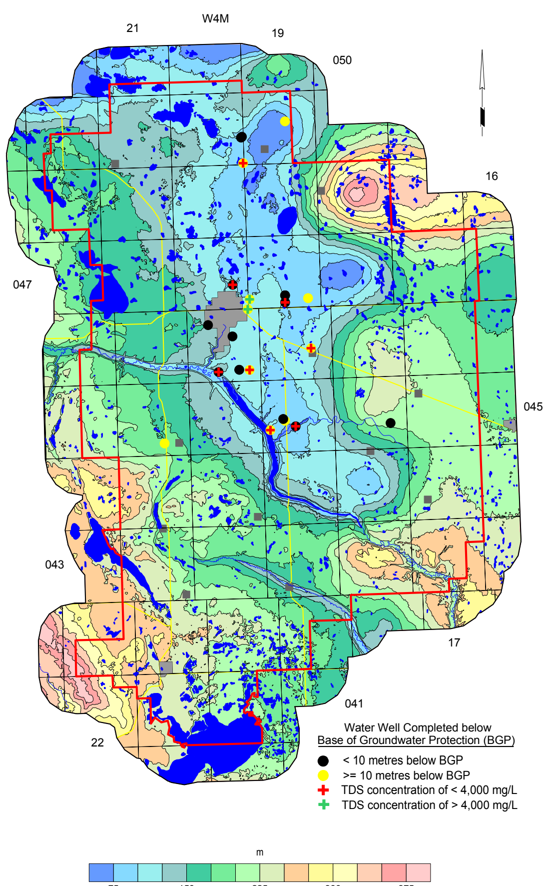

Figure 5. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are two AENV-operated observation water wells within the County (see page A-59 for the observation water well locations). In the past, the data for authorized diversions have been difficult to obtain from AENV, in part because of the failure of the applicant 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 the M.D. of Flagstaff.

3 TERMS

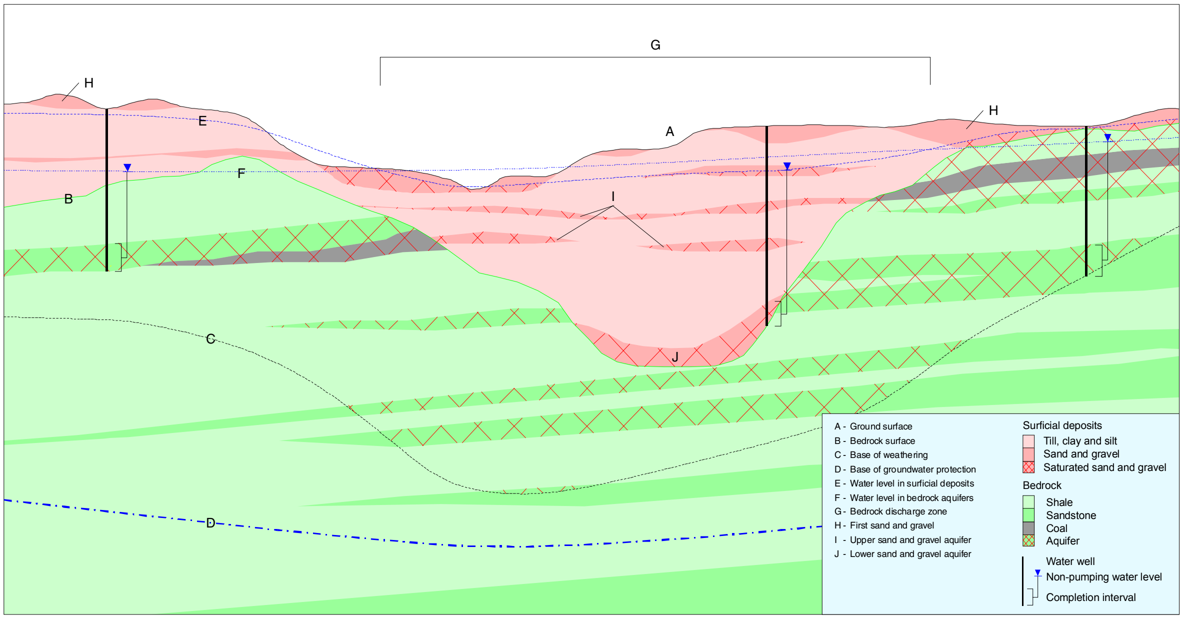

Figure 6. Generalized Cross-Section (for terminology only)

(for larger version, see page A-11)

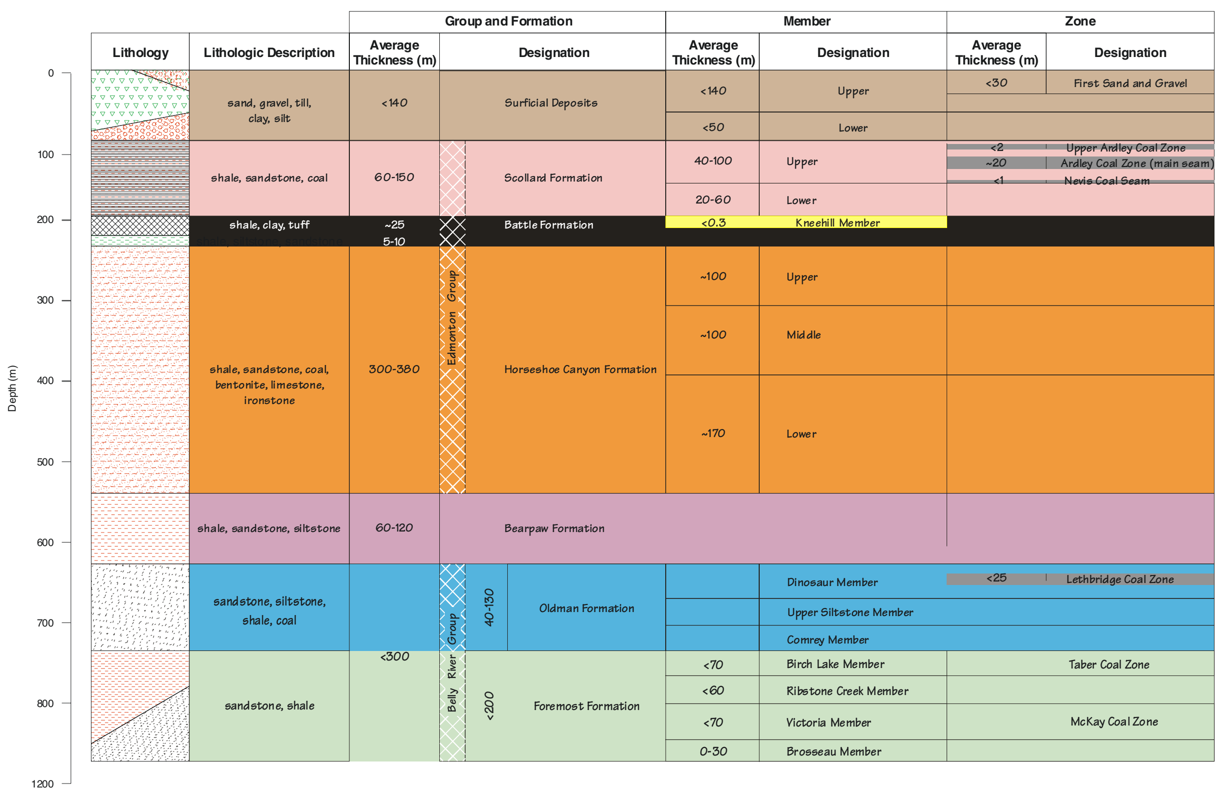

Figure 7. Geologic Column

(for larger version, see page A-12)

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) locations of some springs
4) locations for some water wells determined during water well surveys
5) chemical analyses for some groundwaters[9]
6) locations of some flowing shot holes
7) locations 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 NW ¼ of section 3, township 044, range 21, W4M would have a horizontal coordinate with an Easting of 136,754 metres and a Northing of 5,845,715 metres, the centre of the quarter section. If the water well has been repositioned by AAFC-PFRA using orthorectified aerial photographs, 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.

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].

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[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 after 1986.

[10] See glossary

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 maps covering the County were published in 1971 (Le Breton) and in 1979 (Stein), more than 2,500 values for apparent transmissivity and apparent yield have been added to the groundwater database. The median apparent yield of the water wells with apparent yield values in the County is 15 m³/day. Approximately 65% of the apparent yield values for these water wells are less than 30 m³/day. 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 8 and page A-13). 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 Geological Survey (AGS) hydrogeological maps. In general, the AGS maps show higher estimated long-term yields. The differences between the two map renderings may be a result of fewer apparent yield values, not applying a 0.1-m³/day for “dry” water wells, and the gridding method employed by the AGS.

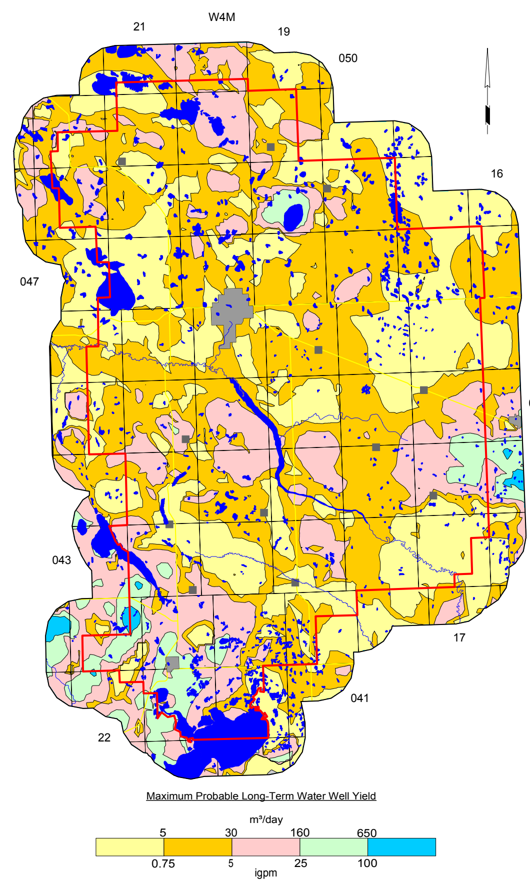

Figure 8. Hydrogeological Map

The EUB well database includes records for wells drilled for 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.

[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 depth of a water well cannot be established, 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, the potential apparent yield would be reduced. The total dissolved solids, sulfate, chloride and total hardness concentrations from the chemical analyses of the groundwaters 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). Nitrate + Nitrite (as N) concentrations are often related to water-well-specific data and may not indicate general aquifer conditions.

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 041 to 050, ranges 16 to 22, 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.

On some maps, values are posted as a way of showing anomalies to the underlying grid or as a means of emphasizing either the lack of sufficient data or areas where there is concentrated hydrogeological data control.

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 sufficient data are not available from the groundwater database, prepared maps have been masked with a solid faded pink colour to indicate these areas. These masks have been added to the Middle Horseshoe Canyon, the Lower Horseshoe Canyon, the Oldman and the Bearpaw 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.

Blue hues have been chosen to represent map areas where the chemical parameters are below the Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) and orange hues have been chosen to represent map areas where the chemical parameters are above the SGCDWQ.

Constituent	Recommended Maximum Concentration SGCDWQ (mg/L)	Colour Blends Used on Maps to Indicate Areas that are Below SGCDWQ	Colour Blends Used on Maps to Indicate Areas that Exceed SGCDWQ
Total Dissolved Solids	500		
Nitrate + Nitrite (as N)	10		
Sulfate	500		
Chloride	250		
Fluoride	1.5		

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Fluoride and Nitrate + Nitrite (as N), which are for Maximum Acceptable Concentrations (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
Federal-Provincial-Territorial Committee on Drinking Water, April 2003

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. Eight cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; only two (G-G' and A-A') 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
- AquaChem 3.6
- ArcView 3.2
- AutoCAD 2004
- CorelDraw! 12.0
- Grapher 3
- Microsoft Office 2003
- Surfer 8

5 AQUIFERS

5.1 Background

An aquifer is a permeable rock unit that is saturated. In this context, rock refers to subsurface materials, such as sand, gravel, sandstone and coal. If the NPWL is above the top of the rock unit, this type of aquifer is a confined or artesian aquifer. If the rock unit is not entirely saturated and the water level is below the top of the rock unit, this type of aquifer is a water-table aquifer. These types of aquifers occur in one of two general geological settings in the County. The first geological setting includes the sediments that overlie the bedrock surface. In this report, these 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.

5.2 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 [13] deposits. The *upper surficial deposits* include the traditional glacial sediments of till[14] and ice-contact deposits. Pre-glacial materials are expected to be present in association with linear bedrock lows. Meltwater channels are associated with glaciation.

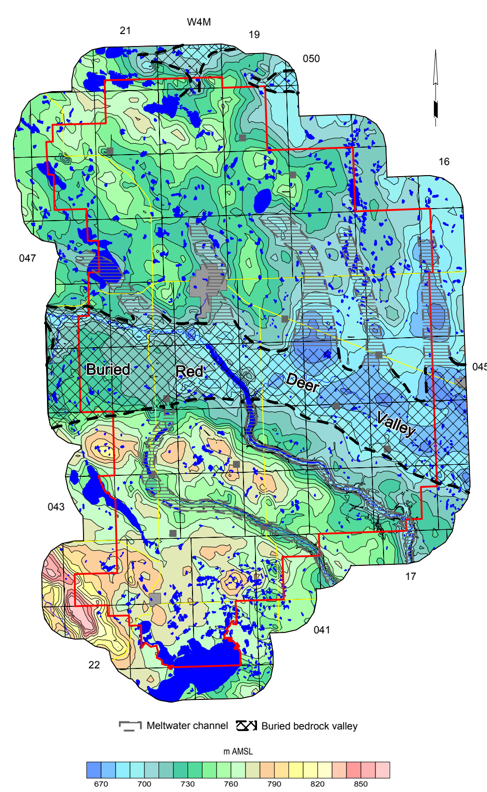

Figure 9. Bedrock Topography

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 preglacial sand and gravel deposits of the lower surficial deposits. 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 that occur close to ground surface. For a graphical depiction of the above description, please refer to Figure 6, page 10 and to page A-11. 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. Because of the significance of the shallow sand and gravel deposits, they have been mapped where they are present within one metre of the ground surface and are referred to as the “first sand and gravel”.

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown above in Figure 9 and on page A-22. Regionally, the bedrock surface varies between 650 and 890 metres AMSL. The lowest elevations occur in the buried bedrock valleys and meltwater channels.

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[13] See glossary
[14] See glossary

Over the majority of the County, the surficial deposits are less than 45 metres thick (see CD-ROM). The exceptions are mainly in association with areas where buried bedrock valleys and meltwater channels are present, where the deposits can have a thickness of more than 45 metres.

The Buried Red Deer Valley is the main linear bedrock low in the County; two unnamed bedrock valleys are present in the northern parts of the study area and are tributaries to the Buried Vegreville Valley present in Beaver County. The Buried Red Deer Valley is present in the central part of the County in parts of townships 043 to 046, and extends east-southeasterly to the County border. The Valley ranges from approximately nine to 15 kilometres wide, with local bedrock relief being less than 60 metres. Sand and gravel deposits can be expected in association with the bedrock low, but the thickness of the sand and gravel deposits is expected to be mainly less than 15 metres (see page A-23).

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. Lower surficial deposits occur over the County, but mainly in linear bedrock lows. The total thickness of the lower surficial deposits is mainly less than 30 metres, but can be more than 35 metres in the linear bedrock lows (see CD-ROM). The lowest part of the lower surficial deposits includes pre-glacial sand and gravel deposits. These deposits would generally overlie the bedrock surface in the Buried Red Deer Valley, as shown below on Cross-Section G-G’ and page A-20. The lowest sand and gravel deposits are of fluvial origin, are usually less than ten metres thick and may be discontinuous (see CD-ROM).

In the County, there are numerous linear bedrock lows that trend mainly northwest to southeast and are indicated as being of meltwater origin. Because sediments associated with the lower surficial deposits are indicated as being present in parts of the meltwater channels, it is possible that the meltwater channels were originally tributaries to the Buried Red Deer Valley. The two major meltwater channels south of the Buried Red Deer Valley have been outlined by Shetsen (1990).

The lower sand and gravel deposits are composed of fluvial deposits. Lower sand and gravel deposits are identified mainly in association with linear bedrock lows, as shown below on Cross-Section G-G’. In these areas, the total thickness of the lower sand and gravel deposits can be more than ten metres (see CD-ROM).

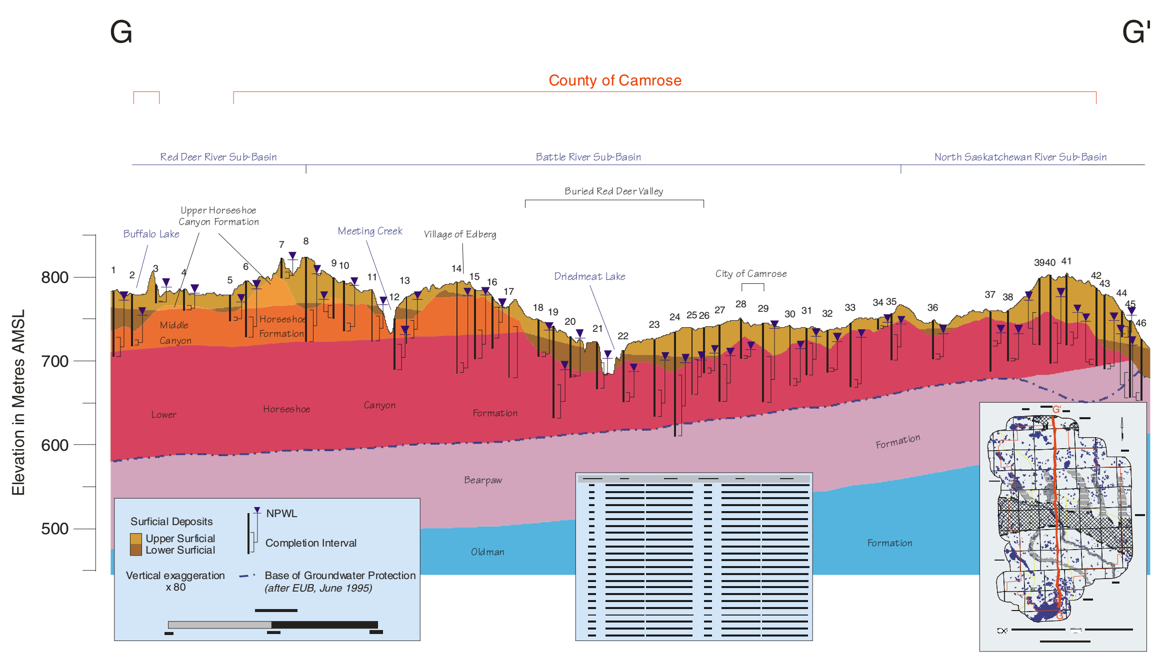

Figure 10. Cross-Section G - G'

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. The thickness of the upper surficial deposits is mainly less than 30 metres. Upper surficial deposits are present throughout most of the County (see CD-ROM). The upper sand and gravel deposits are mainly less than 15 metres thick (see CD-ROM).

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

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 75% of the County where sand and gravel deposits are present, the sand and gravel deposits are less than 25% of the total thickness of the surficial deposits, as shown on the adjacent figure. The areas where sand and gravel deposits constitute more than 25% of the total thickness of the surficial deposits are mainly in the Buried Red Deer Valley.

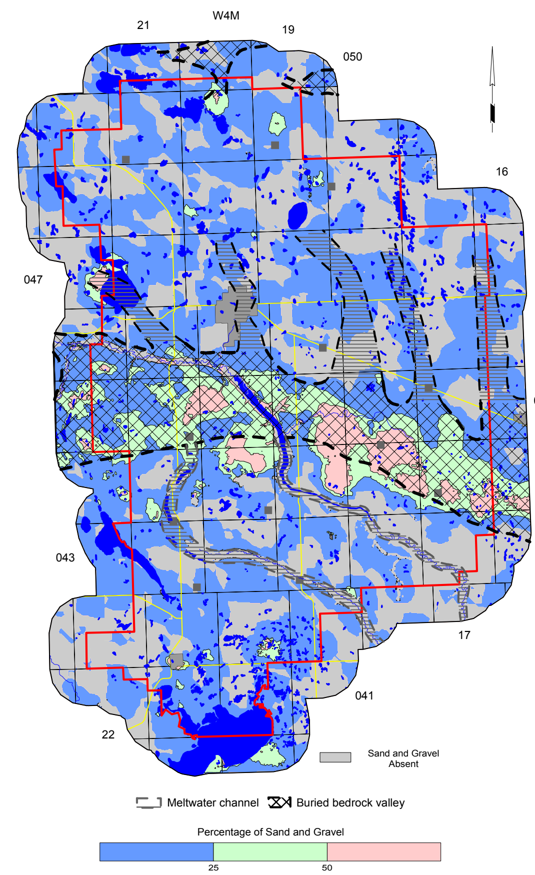

Figure 11. Amount of Sand and Gravel in Surficial Deposits

5.2.2 Sand and Gravel Aquifer(s)

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.

Since the Sand and Gravel Aquifer(s) are not present everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. Over 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 adjacent 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 in linear bedrock lows, as shown in Figure 12, in Appendix A and on the CD-ROM.

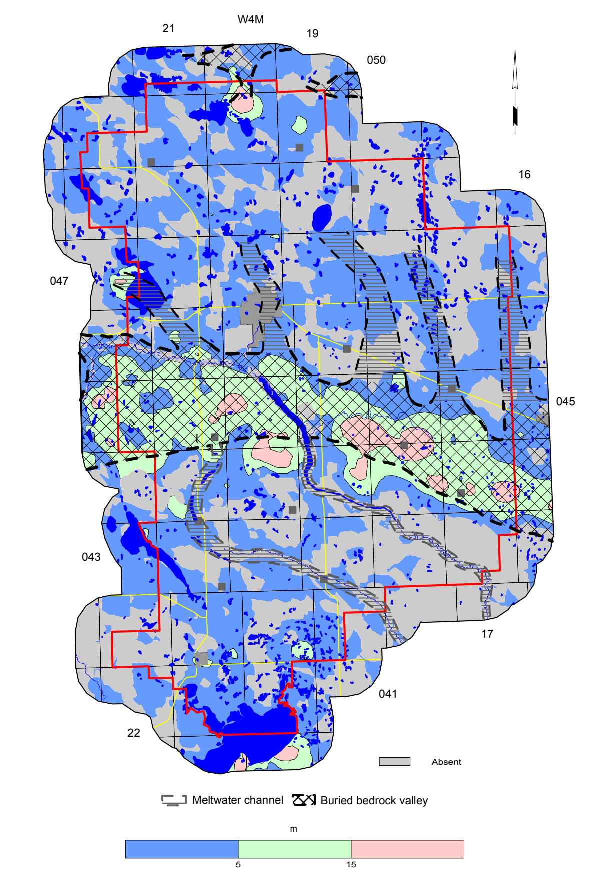

Figure 12. Thickness of Sand and Gravel Aquifer(s)

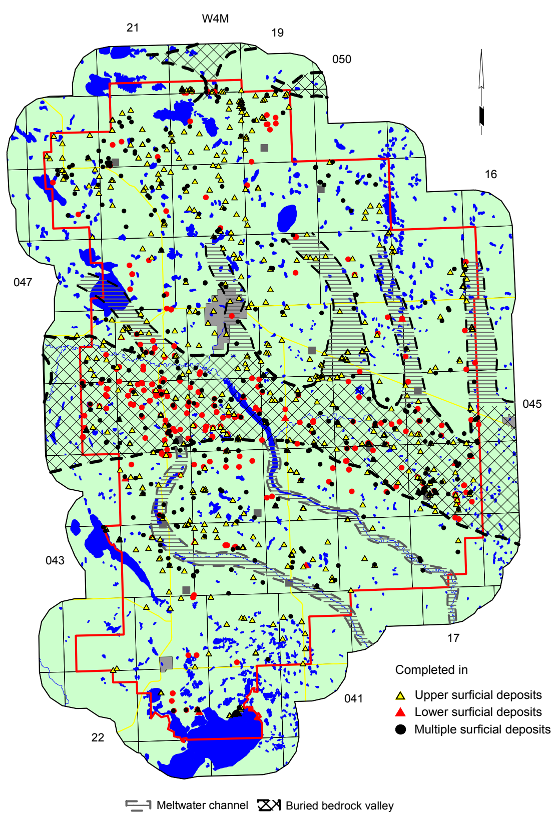

Figure 13. Water Wells Completed in Surficial Deposits

Of the 6,323 water wells in the database, 305 were defined as being completed in surficial aquifers, based on lithologic information and water well completion details. From the present hydrogeological analysis, 1,223 water wells are completed in aquifers in the surficial deposits. Of the 1,223 water wells, 556 are completed in aquifers in the upper surficial deposits, 289 are completed in aquifers in the lower surficial deposits, and 378 water wells are completed in multiple surficial aquifers. This number of water wells (1,223) is four times the number (305) 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. Water wells completed in the lower surficial deposits are mainly in the linear bedrock lows, and water wells completed in the upper surficial deposits are often in the linear bedrock lows but are also located throughout the County, as shown on the previous page in Figure 13.

In the County, there are 216 records for surficial water wells with apparent yield data, which is 18% of the 1,223 surficial water wells. Fifty-six (26%) of the 216 water wells completed in the Sand and Gravel Aquifer(s) have apparent yields that are less than ten m³/day, 120 (56%) have apparent yield values that range from 10 to 100 m³/day, and 40 (18%) have apparent yields that are greater than 100 m³/day. In addition to the 216 records for surficial water wells with apparent yield data, there are ten records that indicate that the water test hole is "dry". In order to depict a more accurate yield map, an apparent yield of 0.1 m³/day was assigned to each of the ten "dry" water test holes prior to gridding.

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	40	11	21	8
Lower Surficial	64	14	40	10
Multiple Completions	112	31	59	22
Totals	216	56	120	40

Table 6. Apparent Yields of Sand and Gravel Aquifer(s)

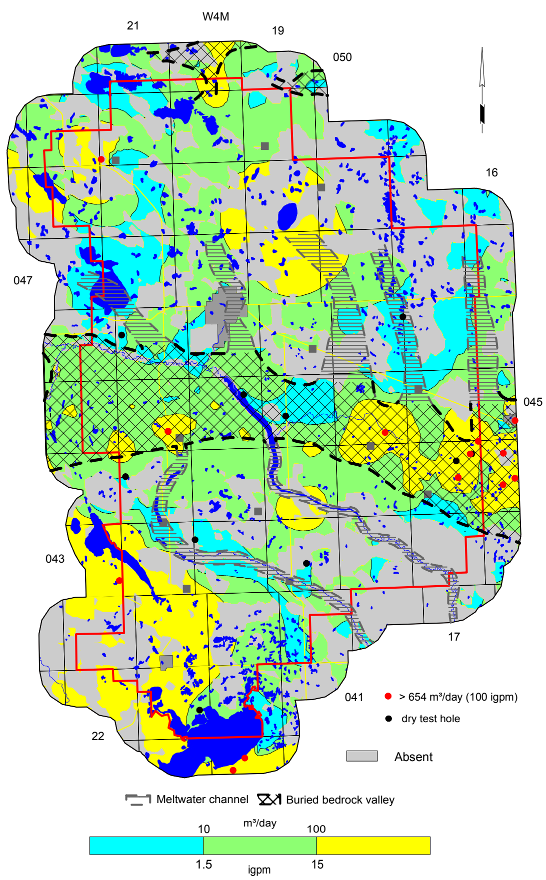

Figure 14. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

The adjacent map shows expected yields for water wells completed in the Sand and Gravel Aquifer(s).

Based on the aquifers that have been developed by existing water wells, these data show that water wells with yields of more than 654 m³/day (100 igpm) from the Sand and Gravel Aquifer(s) can be expected in the Buried Red Deer Valley in the eastern part of the County where the Sand and Gravel Aquifer(s) are present.

Apparent yields for water wells completed in the Sand and Gravel Aquifer(s) vary significantly over the County both with location and with depth. As Figure 15 shows, most apparent yields are less than 100 m³/day and the majority of the water wells completed in the Sand and Gravel Aquifer(s) are less than 60 metres deep. All but one water well that have apparent yields of greater than 150 m³/day are less than 40 metres deep. The exception is a water well in 04-10-050-20 W4M, which is completed in the Lower Sand and Gravel Aquifer.

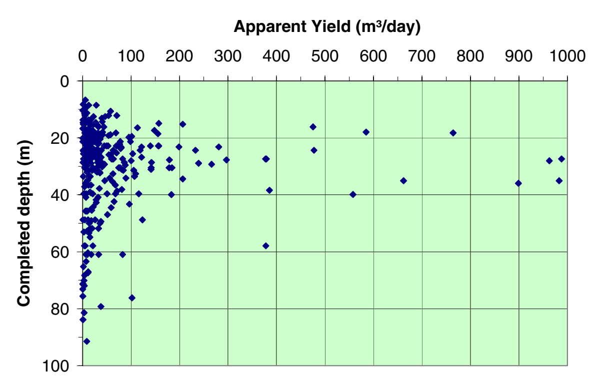

Figure 15. Sand and Gravel Water Well Yields vs Completed Depth

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

Groundwaters from an aquifer in the surficial deposits can be expected to be chemically hard, having a total 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.

In the County of Camrose, groundwaters from the surficial aquifers mainly have a chemical hardness of greater than 100 mg/L (see CD-ROM).

The Piper tri-linear diagram[15] for the surficial deposits (page A-32) shows that the groundwaters from the surficial deposits are a bicarbonate or sulfate-type with no dominant cation. More than 90% of the groundwaters from the surficial deposits have a TDS concentration of more than 500 mg/L. Fifty-five percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations of more than the aesthetic objective (AO) of 0.3 mg/L. However, many iron analyses results are questionable due to varying sampling and analytical methodologies.

In some areas, the groundwater chemistry of the surficial aquifers is such that sulfate is the major anion[16]. 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; in more than 90% of the samples analyzed for surficial deposits in the County, the chloride ion concentration is less than 100 mg/L (see CD-ROM).

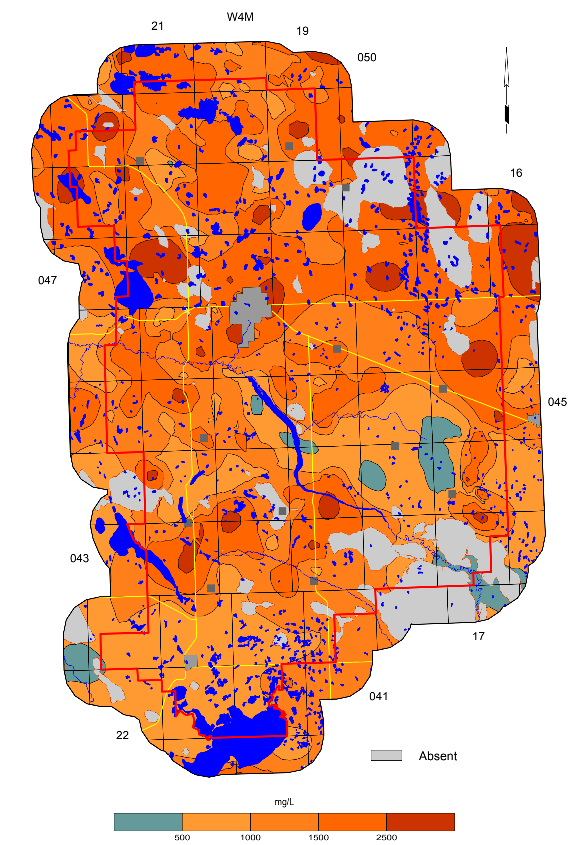

Figure 16. Total Dissolved Solids in Groundwater from Surficial Deposits

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 27 of the 356 groundwater samples analyzed (up to about 1986). A plot of Nitrate + Nitrite (as N) in surficial aquifers is on the accompanying CD-ROM.

The minimum, maximum and median[17] 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 Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) in the adjacent table. The range of concentrations shown in Table 7 is from values in the groundwater database; however, the extreme minimum and maximum concentrations generally represent less than 0.2% of the total number of analyses and should have little effect on the median values. These extreme values are not used in the preparation of the figures.

Of the five constituents that have been compared to the SGCDWQ, median concentrations of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	615	163	7,807	1,156	500
Sodium	397	0	570	329	200
Sulfate	618	0	5,297	259	500
Chloride	617	0	1,060	9	250
Nitrate + Nitrite (as N)	356	0	280	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-Territorial Committee on Drinking Water, April 2003

Table 7. Concentrations of Constituents in Groundwaters from Surficial Deposits

15 See glossary
16 See glossary
17 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 50% 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 mainly less than five metres but can be more than 15 metres in the buried bedrock valleys.

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.

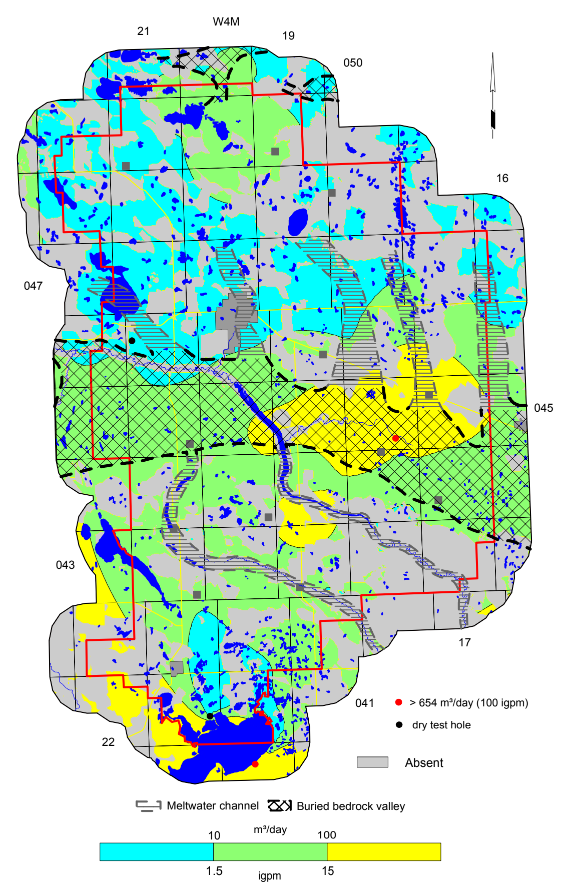

Figure 17. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

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.

Figure 17 indicates that in more than 80% of the County, water wells completed through the Upper Sand and Gravel Aquifer are expected to have apparent yields that are less than 100 m³/day. In the County, there are two "dry" water test holes completed in the Upper Sand and Gravel Aquifer.

In the County, there are 64 licensed and registered water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion of 675 m^3/day (Table 3, page 7), with a median authorized amount of 2.1 m³/day. Twenty-two of the 64 licences and registrations for water wells completed through the Upper Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

The highest authorized groundwater use is for a water source well completed in the Upper Sand and Gravel Aquifer in 12-35-043-21 W4M that is licensed to divert 206 m³/day for dewatering purposes and a water source well in SE 32-046-20 W4M that is licensed to divert 169 m³/day for commercial purposes.

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at the base of the surficial deposits in the deeper part of the linear bedrock lows.

5.2.4.1 Aquifer Thickness

The thickness of the Lower Sand and Gravel Aquifer is mainly less than ten metres (see CD-ROM).

5.2.4.2 Apparent Yield

The apparent yield values for individual water wells completed through the Lower Sand and Gravel Aquifer range from less than ten to greater than 100 m³/day, and have a median apparent yield of 30 m³/day. Water wells with yields of greater than 100 m³/day are expected to be in areas of linear bedrock lows, as shown on Figure 18.

In the County, there are two "dry" water test holes completed in the Lower Sand and Gravel Aquifer.

In the County, there are 57 licensed and registered water wells that are completed through the Lower Sand and Gravel Aquifer, for a total authorized diversion of 581 m³/day (Table 3, page 7), with a median authorized amount of three m³/day. Thirty-two of the 57 licences and registrations for water wells completed through the Lower Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

Groundwater diversion for municipal purposes represents 68% (395 m³/day) of the total 581 m³/day authorized for water wells completed in the Lower Sand and Gravel Aquifer; all 395 m³/day is diverted by the villages of Bawlf (152 m³/day), New Norway (132 m³/day) and Rosalind (111 m³/day).

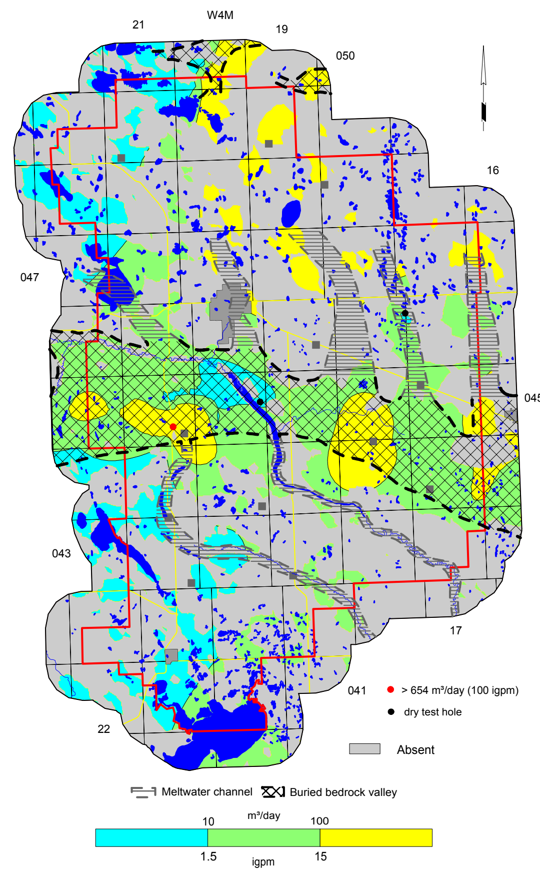

Figure 18. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

From 1960 to 1993, seven test holes have been drilled in Section 12 or NW 11-045-21 W4M for the Village of New Norway; of which six of the seven have been completed in the Lower Sand and Gravel Aquifer with a completed depth of less than 30 metres below ground surface. Aquifer tests conducted with the water test holes indicated apparent yields ranging from a low of 85 m³/day to a high of 1,000 m³/day. An extended aquifer test (three days of pumping and 13 hours of recovery) conducted by HCL with Water Test Hole (WTH) No. 4-78 in 12-11-045-21 W4M indicated a long-term yield of 136 m³/day based on an effective transmissivity of 43.5 metres squared per day (m²/day) (HCL, February 1981b). The Village of New Norway currently receives it groundwater supply from two water wells completed in the Lower Sand and Gravel Aquifer.

A chemical analysis of a groundwater sample collected in April 1978 from WTH No. 4-78 indicates the groundwater is a sodium-bicarbonate type, with a TDS concentration of 1,057 mg/L, a sulfate concentration of 290 mg/L, a chloride concentration of 82 mg/L, and a Nitrate + Nitrite (as N) concentration of less than 0.2 mg /L (HCL, February 1981b).

5.3 Bedrock

5.3.1 Bedrock Aquifers

The upper bedrock includes formations that are generally less than 200 metres below the bedrock surface. In the County, the upper bedrock includes the Edmonton Group (Scollard, Battle and Whitemud, and Horseshoe Canyon formations) and the Bearpaw Formation, as shown below on cross-section A-A' (see page A-14). 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[18] and water well screens are a necessity.

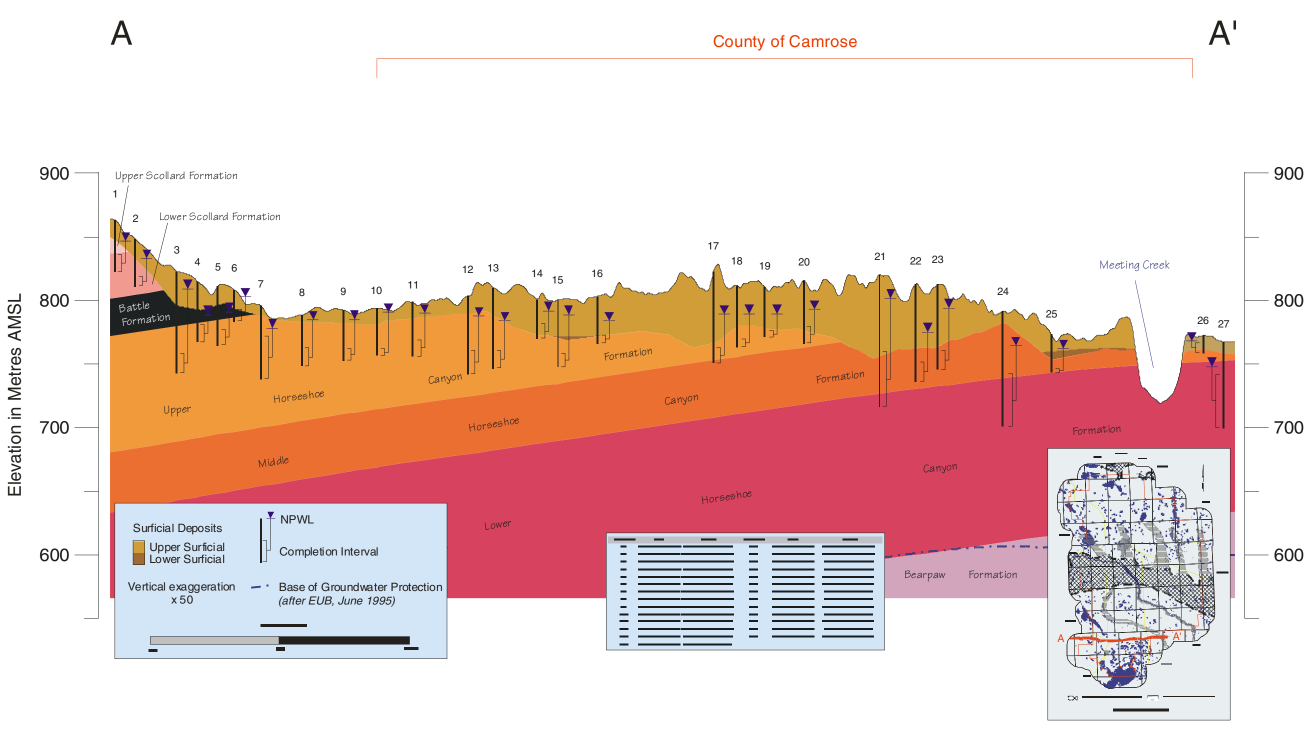

Figure 19. Cross-Section D - D'

Cross-section D-D' indicates that the Base of Groundwater Protection mainly coincides with the top of the Bearpaw Formation. The depth to the BGP is given on page 9 of this report, in Appendix A, and on the CD-ROM.

18 See glossary

5.3.2 Geological Characteristics

The upper bedrock in the County study area includes the Edmonton Group and the Bearpaw Formation. The Edmonton Group includes the Upper and Lower Scollard formations, the Battle and Whitemud formations, and the Upper, Middle and Lower Horseshoe Canyon formations. The adjacent bedrock geology map, showing the subcrop of different geological units, has been prepared in part from the interpretation of geophysical logs related to oil and gas activity.

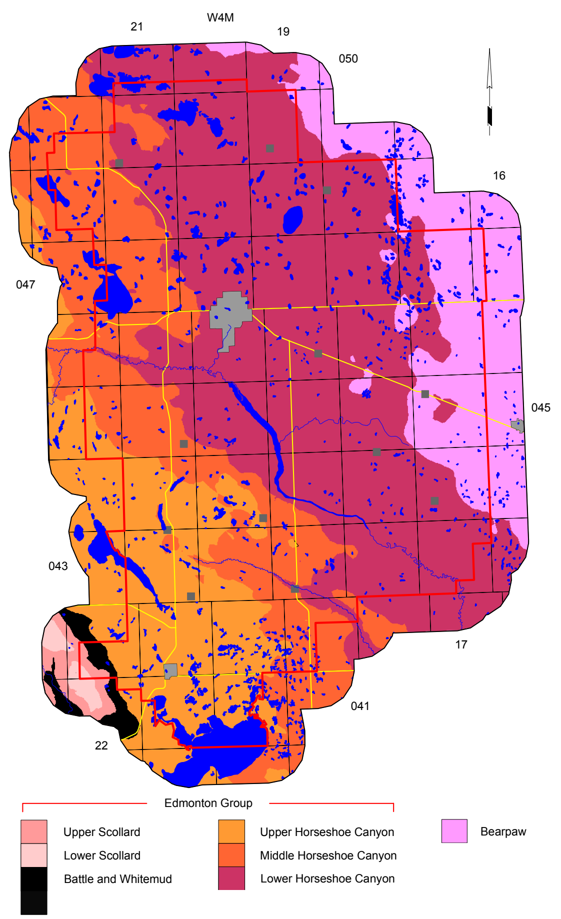

Figure 20. Bedrock Geology

The Scollard Formation has a maximum thickness of 80 metres and has two separate designations: Upper and Lower. The Upper Scollard consists mainly of sandstone, siltstone, shale and coal seams or zones. The Lower Scollard is composed mainly of shale and sandstone.

There will be no direct review of the Upper and Lower Scollard formations in the text of this report; there are insufficient or no hydrogeological data within the County to prepare meaningful maps. The only maps associated with the Upper and Lower Scollard formations to be included on the CD-ROM will be structure-contour maps.

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 and there will be no direct review of the Battle and Whitemud formations.

The Horseshoe Canyon Formation is the lower part of the Edmonton Group. In the County, the Horseshoe Canyon Formation has a maximum thickness of 295 metres and has three separate designations: Upper, Middle and Lower. In the County of Camrose, the Upper Horseshoe Canyon has a maximum thickness of 95 metres; the Middle Horseshoe Canyon has a maximum thickness of 50 metres, and the Lower Horseshoe Canyon has a maximum thickness of 150 metres.

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.

[19] See glossary

The Bearpaw Formation is in the order of 100 metres thick. The Bearpaw Formation includes transgressive, shallow marine (shoreface) and open marine facies[20] deposits. 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).

The Oldman Formation underlies the Bearpaw Formation and has a maximum thickness of 130 metres. The Oldman Formation is composed of continental deposits, sandstone, siltstone, shale and coal. The Oldman Formation is the upper part of the Belly River Group.

5.3.3 Upper Bedrock Completion Aquifer(s)

Geologic Unit	No. of Bedrock Water Wells
Lower Scollard	1
Battle and Whitemud	0
Upper Horseshoe Canyon	446
Middle Horseshoe Canyon	558
Lower Horseshoe Canyon	2,662
Bearpaw	407
Oldman	4
Multiple Completions	699
Total	4,776

Table 8. Completion Aquifer for Upper Bedrock Water Wells

Of the 6,323 water wells in the database, 2,174 were defined as being completed below the top of bedrock, based on lithologic information and water well completion details. However, at least a reported completion depth is available for 4,776 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 completion interval was the bottom 20% 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 an additional 1,903 bedrock water wells, giving a total of 4,077 water wells. The remaining 699 of the total 4,776 upper bedrock water wells are identified as being completed in more than one bedrock aquifer, as shown in Table 8. The bedrock water wells are mainly completed in the Lower Horseshoe Canyon Aquifer.

There are 1,443 records for bedrock water wells that have apparent yield values, which is 30% of the 4,776 bedrock water wells in the County.

Nearly 90% of the water wells completed in the Upper Bedrock Aquifer(s) have apparent yield values of less than 100 m³/day, with a median apparent yield of 13 m³/day. Many of the areas with yields of more than 100 m³/day are in the southwestern part of the County where the Upper Horseshoe Canyon is the upper bedrock, and in association with the buried bedrock valleys. These higher yield areas may identify areas of increased permeability resulting from the weathering process.

In addition to the 1,443 records for bedrock water wells with apparent yield values, there are 117 records that indicate that the water well/water test hole 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 117 "dry" water test holes prior to gridding.

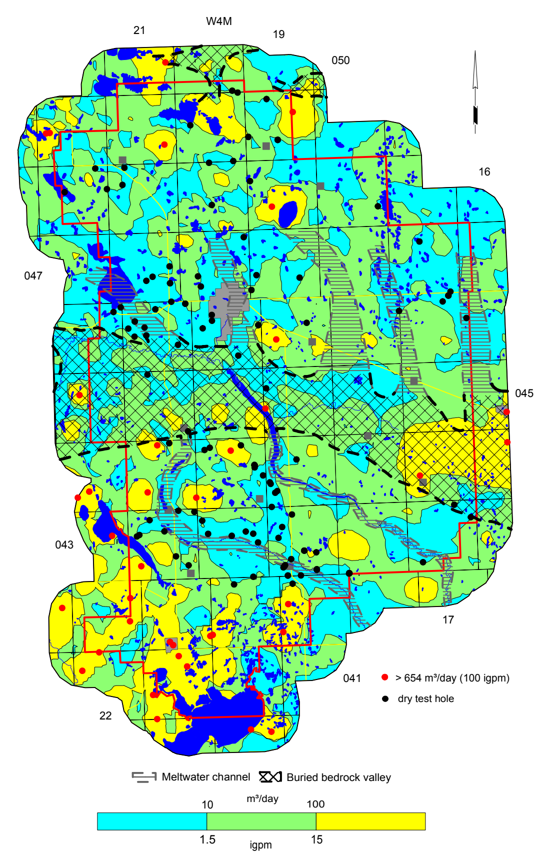

Figure 21. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

20 See glossary

Of the 1,443 water well records with apparent yield values, 1,147 have been assigned to aquifers associated with specific geologic units. Six hundred and thirty (43.7%) of the 1,443 water wells completed in bedrock aquifers have apparent yields that are less than ten m³/day, 644 (44.6%) have apparent yield values that range from 10 to 100 m³/day, and 169 (11.7%) have apparent yield values that are greater than 100 m³/day, as shown in Table 9.

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
Lower Scollard	1	0	0	1
Battle and Whitemud	0	0	0	0
Upper Horseshoe Canyon	183	13	94	76
Middle Horseshoe Canyon	154	70	70	14
Lower Horseshoe Canyon	720	358	310	52
Bearpaw	89	42	45	2
Oldman	1	1	0	0
Multiple Completions	296	146	125	25
Totals	1,443	630	644	169

* - does not include dry test holes

Table 9. Apparent Yields of Bedrock Aquifers

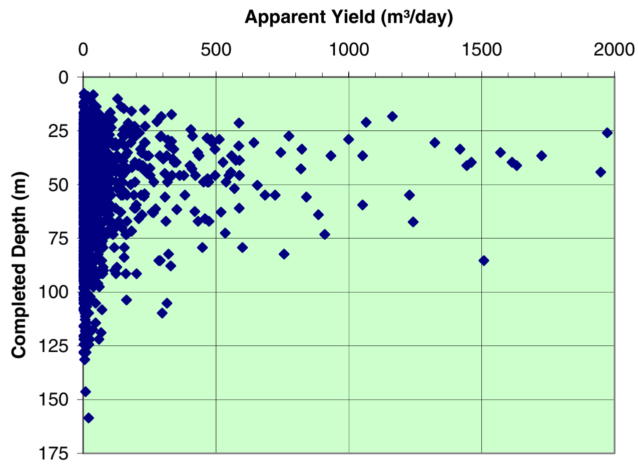

Figure 22. Bedrock Water Well Yields vs Completed Depth

Apparent yields for water wells completed in the Upper Bedrock Aquifer(s) vary significantly over the County both with location and with depth. As the graph shows, most apparent yields are less than 100 m³/day and the majority of the water wells are less than 75 metres deep. All but one water well with apparent yields of greater than 1,000 m³/day are less than 75 metres deep. The exception is a water well in NW 27-044-20 W4M, and is completed in the Lower Horseshoe Canyon Aquifer.

5.3.4 Chemical Quality of Groundwater

The Piper tri-linear diagram for Upper Bedrock Aquifer(s) (page A-32) shows that groundwaters from bedrock aquifers are mainly sodium-bicarbonate or sodium-sulfate-type waters; the majority of these groundwaters have a sodium ion concentration that exceeds 200 mg/L. Because the sodium concentration can be elevated, the groundwater can pose a risk to people on low sodium diets.

In the County, approximately 16% 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 23% of the groundwater samples from the entire County are between 0.5 and 1.5 mg/L and approximately 61% exceed the MAC for fluoride of 1.5 mg/L, with fluoride concentrations of greater than five mg/L occurring in the western part of the County (see CD-ROM).

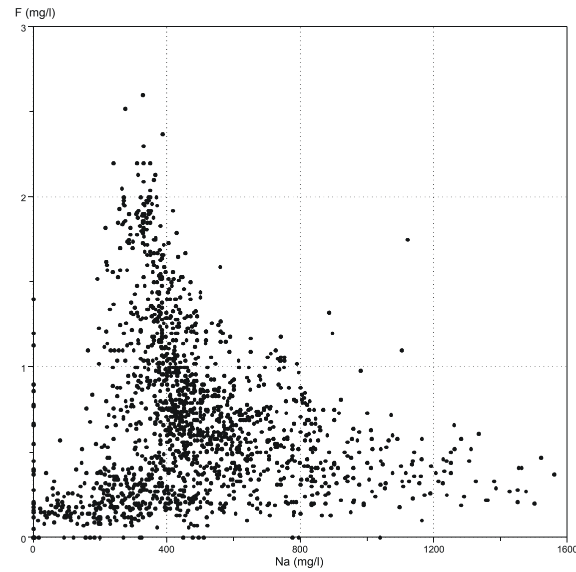

Figure 23. Fluoride vs Sodium Concentrations in Groundwater in Upper Bedrock Aquifer(s)

The fluoride concentrations in the groundwaters appear to be a function of the sodium concentration. Below a sodium concentration of 220 mg/L, there is generally very little fluoride in the groundwater. When the sodium concentration reaches 230 mg/L, the maximum fluoride concentration can increase dramatically. As the sodium concentration increases, the maximum solubility of fluoride decreases and once the sodium concentration reaches 500 mg/L the maximum solubility of fluoride is below the MAC of 1.5 mg/L, as shown above in Figure 23 and on page A-37.

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 most of the groundwaters with higher TDS concentrations occurring in the northern part of the County (see page A-35).

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.

In the County, more than 80% of the chloride concentrations in the groundwaters from the Upper Bedrock Aquifer(s) are less than 250 mg/L.

In the County, there were 31 groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the SGCDWQ for the Upper Bedrock Aquifer(s). Approximately 85% of the total hardness values in the groundwaters from the Upper Bedrock Aquifer(s) are less than 200 mg/L.

The minimum, maximum and median 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 SGCDWQ in Table 10. Of the five constituents compared to the SGCDWQ, median concentrations of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	2,486	143	8,874	1,205	500
Sodium	1,708	22	2,115	440	200
Sulfate	2,493	0	5,341	85	500
Chloride	2,507	0	4,135	22	250
Fluoride	2,058	0	6.25	0.6	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. Concentrations of Constituents in Groundwaters from Upper Bedrock Aquifer(s)

5.3.5 Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer comprises the permeable parts of the Upper Horseshoe Canyon Formation that underlie the Battle Formation. The Upper Horseshoe Canyon Formation subcrops under the surficial deposits in the southwestern quarter of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Upper Horseshoe Canyon Formation ranges in elevation from less than 730 to more than 810 metres AMSL and has a maximum thickness of 95 metres. The non-pumping water level in the Upper Horseshoe Canyon Aquifer is mainly downgradient to the southeast and southwest toward Beaver Lake and to the southeast toward Buffalo Lake.

5.3.5.1 Depth to Top

The depth to the top of the Upper Horseshoe Canyon Formation is variable, ranging from less than 25 metres at the eastern extent to more than 100 metres in the extreme western part of the County (page A-43).

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Horseshoe Canyon Aquifer range mainly from 10 to 100 m³/day, and have a median apparent yield value of 52 m³/day. There is one “dry” water test hole that is completed in the Upper Horseshoe Canyon Aquifer.

In the County, there are 107 licensed and registered groundwater users with water wells that are completed in the Upper Horseshoe Canyon Aquifer, for a total authorized diversion of 1,169 m³/day, an average authorized diversion of 11 m³/day. Of the 1,169 m³/day, the Town of Bashaw is licensed to divert 645 m³/day from three water supply wells. Fifty-nine of the 107 licensed and registered water wells could be linked to a water well in the AENV groundwater database.

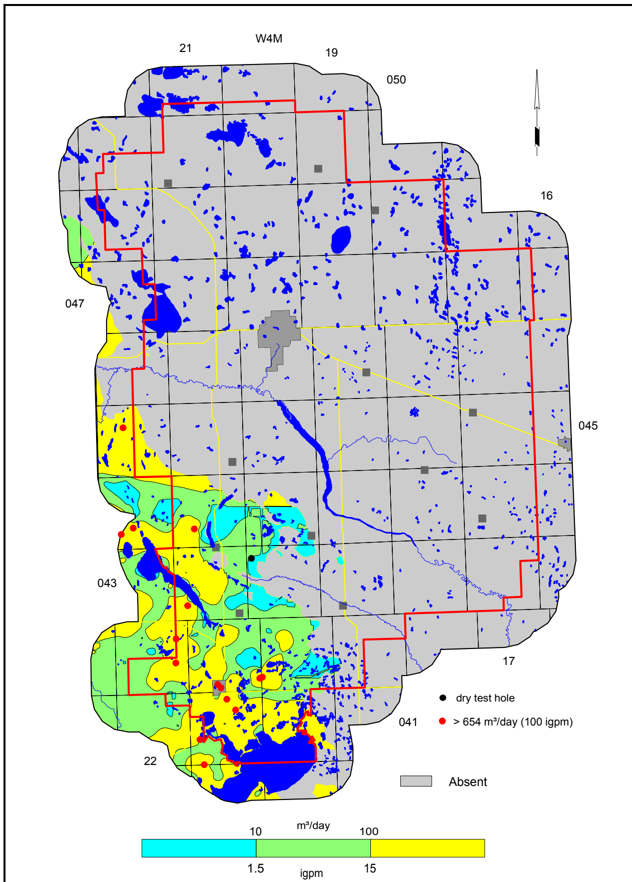

Figure 24. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer

Extended aquifer tests were conducted with WTH No. 1-79, WTH No. 2-79 and WTH No. 4-79 by HCL from April to August 1979 for the Town of Bashaw (HCL, Dec 1979). All three water test holes are completed in the Upper Horseshoe Canyon Aquifer. WTH Nos. 1-79 and 2-79 are completed at a depth of 40 metres below ground surface and WTH No. 4-79 has a completed depth of 67 metres below ground surface. The results of the aquifer tests indicated that WTH No. 1-79 has a long-term yield of 560 m³/day and WTH No. 4-79 has a long-term yield of 177 m³/day. Both WTH Nos. 1-79 (WSW No. 4) and 2-79 (WSW No. 5) are authorized to divert 275 m³/day and WTH No. 4-79 (WSW No. 3A) is authorized to divert 95 m³/day. The effect on the water levels in nearby water wells by pumping WTH No. 1-79 continuously for 20 years at a rate of 560 m³/day was calculated to be a drawdown of less than five metres.

Figure 36 on page 44 indicates areas where changes in water levels in bedrock water wells may have occurred. The Town of Bashaw is in an area where the water level has oscillated between a water-level decline of less than five metres and a water-level rise of less than five metres.

5.3.5.3 Quality

The groundwaters from the Upper Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate type, (see Piper diagram on CD-ROM). Total dissolved solids concentrations range from less than 500 to more than 1,000 mg/L (page A-45), with more than 95% of the groundwater values having TDS concentrations of greater than 500 mg/L. The sulfate concentrations range from less than 100 to more than 500 mg/L, with 70% of the groundwater samples having sulfate concentrations that range from 100 to 500 mg/L. The chloride concentrations range from less than ten to more than 100 mg/L, with 75% of the groundwater samples having chloride concentrations of less than ten mg/L. Nearly 75% of the groundwater samples have fluoride concentrations that are less than 0.5 mg/L.

A chemical analysis of a groundwater sample collected from the Town of Bashaw WSW No. 4 in 07-04-042-21 W4M in June 1979 indicated the groundwater is a sodium-bicarbonate type, with a TDS concentration of 946 mg/L, a sulfate concentration of 172 mg/L, a chloride concentration of 4 mg/L, and a fluoride concentration of 0.46 mg/L (HCL, Dec-1979).

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	141	160	3,118	933	1,205	500
Sodium	97	36.0	1,133	317	440	200
Sulfate	142	0	1325	169	85	500
Chloride	142	0	1484	4	22	250
Fluoride	117	0	2	0.3	0.6	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, April 2002

Table 11. Apparent Concentrations of Constituents in Groundwaters from Upper Horseshoe Canyon Aquifer

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 from water wells completed in the Upper Horseshoe Canyon Aquifer are greater than the median concentrations from water wells completed in all Upper Bedrock Aquifer(s).

A comparison was made of fluoride concentrations in the groundwaters from water wells in the County completed in Upper Bedrock Aquifer(s) with fluoride concentrations in the groundwaters from water wells in the adjacent counties of Leduc, Wetaskiwin and Ponoka. Groundwaters that report more than 1.5 mg/L of fluoride in water wells completed in the Horseshoe Canyon aquifers are shown by the coloured postings on the figure below. The comparison was made to determine if the trend of elevated fluoride concentrations in the Upper Horseshoe Canyon Aquifer shown below would extend into the County of Camrose. The data show that in the County of Camrose, fluoride concentrations of more than 1.5 mg/L are in water wells completed mainly in the Lower Horseshoe Canyon Aquifer, as shown below in Figure 25 and on page A-36.

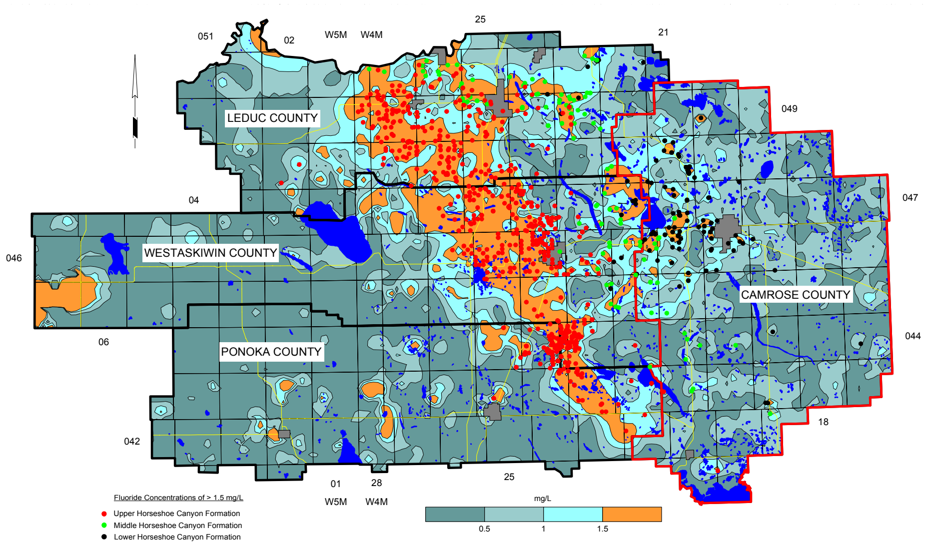

Figure 25. Fluoride in Groundwater in Upper Bedrock Aquifer(s)

5.3.6 Middle Horseshoe Canyon Aquifer

The Middle Horseshoe Canyon Aquifer comprises the permeable parts of the Middle Horseshoe Canyon Formation, as defined for the present program. The Middle Horseshoe Canyon Formation is present under the surficial deposits in the southwestern third of the County. The structure contours show that the Middle Horseshoe Canyon Formation ranges in elevation from less than 680 to more than 780 metres AMSL and has a maximum thickness of 50 metres. The regional groundwater flow direction in the Middle Horseshoe Canyon Aquifer is mainly downgradient to the northward to the Battle River, and to the southwest and northeast toward Meeting Creek (see CD-ROM).

5.3.6.1 Depth to Top

The depth to the top of the Middle Horseshoe Canyon Formation is variable, ranging from less than 25 metres at the northeastern extent to more than 150 metres in the extreme southwestern part of the County (page A-46).

5.3.6.2 Apparent Yield

Ninety-one percent (140) of the 154 apparent yield values for individual water wells completed through the Middle Horseshoe Canyon Aquifer are less than 100 m³/day, of which 45% (70) apparent yield values are less than ten, and 45% (70) range from ten to 100 m³/day. The remaining 14 (9%) of the 154 apparent yield values are greater than 100 m³/day. In the County, there are ten "dry" water test holes completed in the Middle Horseshoe Canyon Aquifer.

Without the inclusion of the ten "dry" water test holes, the median apparent yield value for water wells completed in the Middle Horseshoe Canyon Aquifer is 13.4 m³/day. With the inclusion of the ten "dry" water test holes, the median apparent yield value is 11.4 m³/day.

There are 101 licensed and registered groundwater users that have water wells completed through the Middle Horseshoe Canyon Aquifer, for a total authorized diversion of 320 m³/day, an average authorized diversion of 3.2 m³/day. Of the 320 m³/day, the Village of Edberg is licensed to divert 44 m³/day from three water supply wells, and the Village of Ferintosh is licensed to divert a total of 41.1 m³/day from five water supply wells (see Section 6.5.4). Sixty of the 101 licensed and registered water wells could be linked to a water well in the AENV groundwater database.

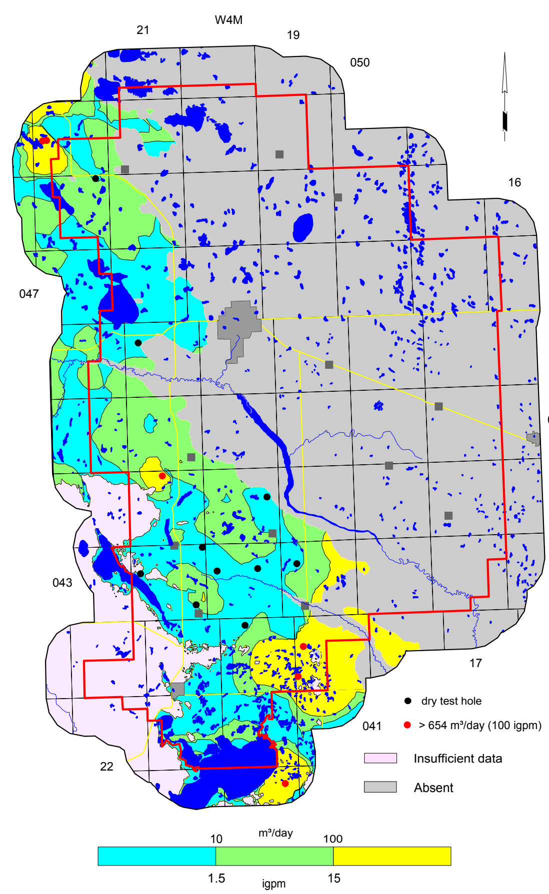

Figure 26. Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer

5.3.6.3 Quality

The groundwaters from the Middle Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate or sodium-sulfate-type (see Piper diagram on CD-ROM), with 75% of the groundwater samples having TDS concentrations ranging from 500 to 1,500 mg/L (page A-48). Sixty percent of the sulfate concentrations in groundwaters from the Middle Horseshoe Canyon Aquifer are less than 500 mg/L. Nearly 90% of the chloride concentrations from the Middle Horseshoe Canyon Aquifer are less than 50 mg/L. Nearly 90% of the groundwater samples have fluoride concentrations that are less than 1.5 mg/L.

A chemical analysis of a groundwater sample collected in December 1986 from one of the Village of Edberg's water supply wells in SE 14-044-20 W4M indicates the groundwater is a sodium-bicarbonate type, with a TDS concentration of 639 mg/L, a sulfate concentration of 60 mg/L, a chloride concentration of nine mg/L, and a fluoride concentration of 0.53 mg/L.

A chemical analysis of a groundwater sample collected in May 1997 from one of the Village of Ferintosh's water supply wells in 11-03-044-21 W4M indicates the groundwater is a sodium-bicarbonate type, with a TDS concentration of 851 mg/L, a sulfate concentration of 0.4 mg/L, a chloride concentration of 103 mg/L, and a fluoride concentration of 1.43 mg/L (AAFC-PFRA, 1998).

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 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			All Bedrock Median	Recommended Maximum Concentration SGCDWQ
		Minimum	Maximum	Median		
Total Dissolved Solids	243	409	5,160	953	1,205	500
Sodium	168	0.0	1,462	323	440	200
Sulfate	245	0	3150	150	85	500
Chloride	244	0	588	9	22	250
Fluoride	211	0	4	0.6	0.6	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 12. Apparent Concentrations of Constituents in Groundwaters from Middle Horseshoe Canyon Aquifer

5.3.7 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. The Lower Horseshoe Canyon Formation is present under the surficial deposits in most of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Lower Horseshoe Canyon Formation ranges in elevation from less than 650 to more than 770 metres AMSL and has a maximum thickness of 130 metres. The non-pumping water level in the Lower Horseshoe Canyon Aquifer is mainly downgradient toward the north and northeast the Battle River, and to the south and north toward Meeting Creek.

5.3.7.1 Depth to Top

The depth to the top of the Lower Horseshoe Canyon Formation is variable, ranging from less than 25 metres at the northeastern extent to more than 200 metres in the extreme southwestern part of the County (page A-49).

5.3.7.2 Apparent Yield

Fifty percent (358) of the 720 apparent yield values for individual water wells completed through the Lower Horseshoe Canyon Aquifer are less than ten m³/day; 43% (310) range from ten to 100 m³/day, and 7% (52) are greater than 100 m³/day. There are 75%) "dry" water test holes that are completed in the Lower Horseshoe Canyon Aquifer in the County.

Without the inclusion of the 75 "dry" water test holes, the median apparent yield value for water wells completed in the Lower Horseshoe Canyon Aquifer is 10.3 m³/day. With the inclusion of the 75 "dry" water test holes, the median apparent yield value is 8.4 m³/day.

There are 396 licensed and registered groundwater users that have water wells completed through the Lower Horseshoe Canyon Aquifer, for a total authorized diversion of 1,240 m³/day, an average authorized diversion of 3.1 m³/day. The highest authorized groundwater use of 50 m³/day is for a water supply well in SE 03-048-20 W4M with a completed depth of 21.3 metres below ground surface.

Of the 396 licensed and registered groundwater users, 189 could be linked to water wells in the AENV groundwater database.

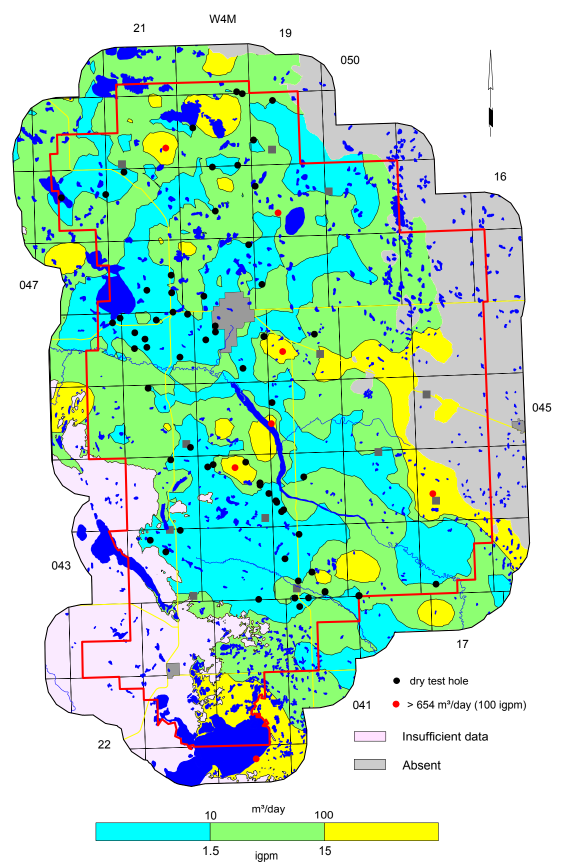

Figure 27. Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer

5.3.7.3 Quality

The groundwaters from the Lower Horseshoe Canyon Aquifer are mainly a sodium-bicarbonate or sodium-sulfate-type (see Piper diagram on CD-ROM), with 75% of the groundwater samples having TDS concentrations ranging from 500 to 2,000 mg/L (page A-51). Nearly 80% of the sulfate concentrations in groundwaters from the Lower Horseshoe Canyon Aquifer are less than 500 mg/L. Sixty percent of the chloride concentrations from the Lower Horseshoe Canyon Aquifer are less than 50 mg/L. Nearly 60% of the groundwater samples have fluoride concentrations that range from 0.5 to 1.5 mg/L.

A groundwater sample was collected for chemical analysis during the aquifer test with one of the two licensed water wells that supplies groundwater at Miquelon Lake Provincial Park in 08-33-049-20 W4M in February 1980. The analysis indicated the groundwater is a sodium-bicarbonate type, with a TDS concentration of 757 mg/L, a sulfate concentration of < 5 mg/L, a chloride concentration of 25 mg/L, and a fluoride concentration of 0.11 mg/L (HCL, Feb-1981a).

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, chloride and fluoride 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).

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	1553	143	8,874	1288	1,205	500
Sodium	1154	0.0	2,111	454	440	200
Sulfate	1563	0	5341	55	85	500
Chloride	1571	0	3319	31	22	250
Fluoride	1291	0	6	0.7	0.6	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 13. Apparent Concentrations of Constituents in Groundwaters from Lower Horseshoe Canyon Aquifer

5.3.8 Bearpaw Aquifer

The Bearpaw Aquifer comprises the permeable parts of the Bearpaw Formation that underlie the Lower Horseshoe Canyon Formation. The Bearpaw Formation is present under all of the County. The structure contours show that the Bearpaw Formation ranges in elevation from less than 510 to more than 710 metres AMSL and has a thickness of up to 100 metres. The non-pumping water level in the Bearpaw Aquifer is mainly downgradient to the south toward the Battle River and east and northwest toward Amisk Creek.

5.3.8.1 Depth to Top

The depth to the top of the Bearpaw Formation is variable, ranging from less than 25 metres at the eastern extent to more than 300 metres in the extreme southwestern part of the County (page A-52).

5.3.8.2 Apparent Yield

Forty-seven percent (42) of the 89 apparent yield values for individual water wells completed through the Bearpaw Aquifer are less than ten m³/day; 51% (45) range from ten to 100 m³/day, and 2% (2) are greater than 100 m³/day. There are 12 “dry” water test holes that are completed in the Bearpaw Aquifer.

Without the inclusion of the 12 dry water test holes, the median apparent yield value for water wells completed in the Bearpaw Aquifer is 10.5 m³/day. With the inclusion of the 12, the median apparent yield value is 9.2 m³/day.

In the County, there are 79 licensed and registered groundwater users that have water wells that are completed in the Bearpaw Aquifer, for a total authorized diversion of 250 m³/day, an average authorized diversion of 3.1 m³/day. The highest single diversion is authorized to divert 29 m³/day in 16-02-044-18 W4M for agricultural purposes.

Of the 79 licensed and registered groundwater users, 44 could be linked to water wells in the AENV groundwater database.

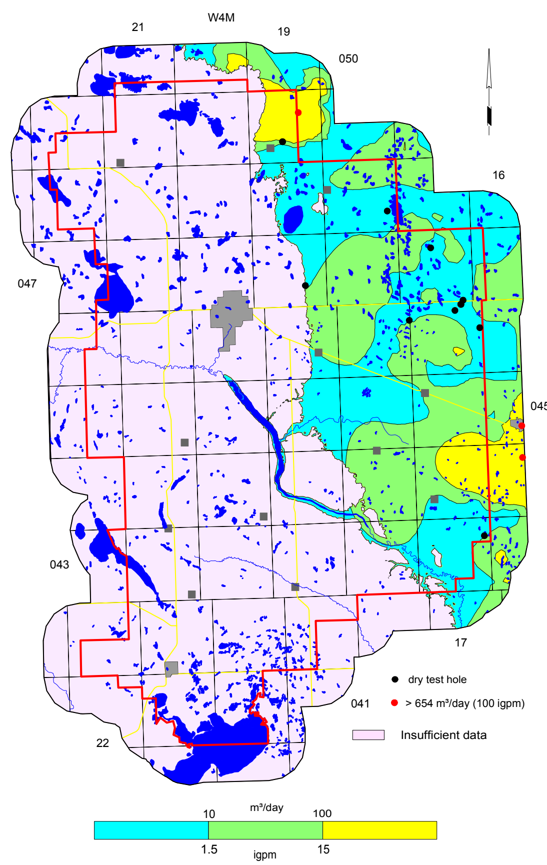

Figure 28. Apparent Yield for Water Wells Completed through Bearpaw Aquifer

5.3.8.3 Quality

The groundwaters from the Bearpaw Aquifer are mainly a sodium-bicarbonate or sodium-sulfate-type (see Piper diagram on CD-ROM), with 75% of the groundwater samples having TDS concentrations of greater than 1,000 mg/L (page A-54). Nearly 80% of the sulfate concentrations in groundwaters from the Bearpaw Aquifer are less than 500 mg/L. Sixty-five percent of the chloride concentrations from the Bearpaw are less than 100 mg/L. Fifty percent of the groundwater samples have fluoride concentrations that are less than 0.5 mg/L and 50% of the groundwater samples have fluoride concentrations that range from 0.5 mg/L to 1.5 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	263	385	7,515	1296	1,205	500
Sodium	165	0.0	1,690	455	440	200
Sulfate	261	0	4800	52	85	500
Chloride	263	0	1258	42	22	250
Fluoride	201	0	1	0.5	0.6	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, April 2002

Table 14. Apparent Concentrations of Constituents in Groundwaters from Bearpaw Aquifer

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 Bearpaw Aquifer are greater than the median concentrations from water wells completed in all Upper Bedrock Aquifer(s).

5.3.9 Oldman Aquifer

The Oldman Aquifer comprises the permeable parts of the Oldman Formation that underlie the Bearpaw Formation and is present under all of the County. Structure contours have been prepared for the top of the Formation. The structure contours show that the Oldman Formation ranges in elevation from less than 410 to more than 630 metres AMSL and has a maximum thickness of 130 metres. There are insufficient non-pumping water-level data to determine the gradient in the Oldman Aquifer.

5.3.9.1 Depth to Top

The depth to the top of the Oldman Formation is variable, ranging from less than 100 metres at the northeastern extent to more than 400 metres in the southwestern part of the County (page A-55).

5.3.9.2 Apparent Yield

In the County, there are no water wells completed in the Oldman Aquifer with apparent yield values. Within the larger study area, there are four water wells with apparent yield values; three are less than five m³/day and the fourth water well has an apparent yield of 25 m³/day, as shown in Figure 29.

In the County, there are no licensed or registered groundwater water wells that are completed in the Oldman Aquifer.

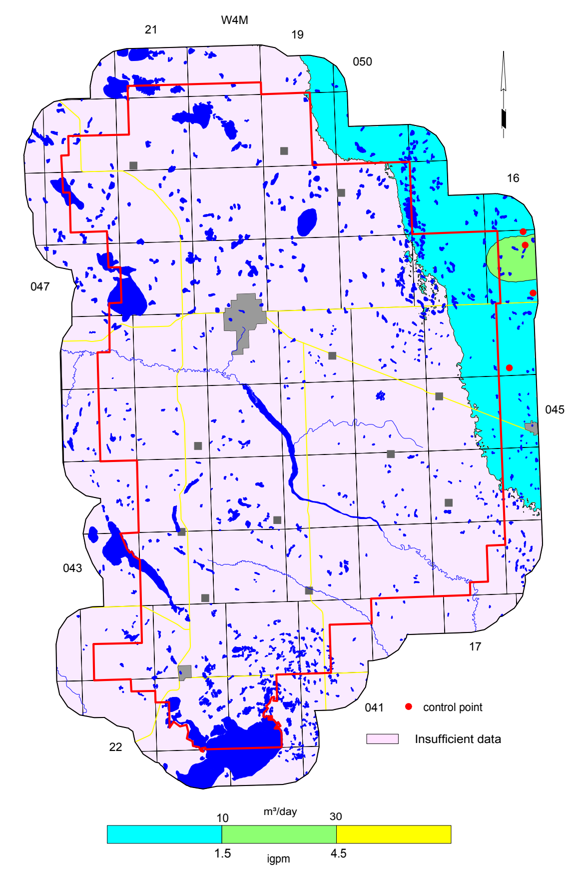

Figure 29. Apparent Yield for Water Wells Completed through Oldman Aquifer

5.3.9.3 Quality

In the County, there are two water wells completed in the Oldman Aquifer with sufficient data to determine the groundwater type. One water well in 01-12-047-17 W4M, completed open-hole at a depth of 104 metres below ground surface, is a sodium-chloride-type; the other water well, in NE 12-045-17 W4M, is completed from 103 to 107 metres below groundwater surface and is a sodium-bicarbonate-type. The water well in 01-12-047-17 W4M has a TDS concentration of 3,437 mg/L, a sulfate concentration of 657 mg/L, a chloride concentration of 1,250 mg/L and a fluoride concentration of 0.98 mg/L. The water well in NE 12-045-17 W4M has a TDS concentration of 740 mg/L, a sulfate concentration of 30 mg/L, a chloride concentration of 36 mg/L, and a fluoride concentration of 0.56 mg/L.

6 GROUNDWATER BUDGET

6.1 Hydrographs

In the County, there are two observation water wells that are part of the AENV regional groundwater monitoring network where water levels are being measured and recorded as a function of time: (1) AENV Obs WW Ferintosh Regional Landfill 85-1 (Ferintosh Landfill Obs WW) in 04-14-044-21 W4M; and (2) AENV Obs Water Well (WW): Camrose Regional Landfill 85-1 (AENV Camrose Landfill Obs WW) in 12 16-046-20 W4M (see page A-59).

AENV Ferintosh Landfill Obs WW is completed from 25.3 to 35.1 metres below ground surface in the Upper Horseshoe Canyon Aquifer. The water level in the Obs WW has been measured since November 1985, as shown by the blue line in the adjacent graph. From early 1987 to early 1990, there was a net decline of one metre. From 1991 to 1996, overall annual water-level fluctuations mainly ranged from 0.25 to 0.5 metres. From 1997 to 2000, the overall annual water-level fluctuation rose up to one metre. From late 2000 to early 2003, there was a net decline of nearly 1.5 metres.

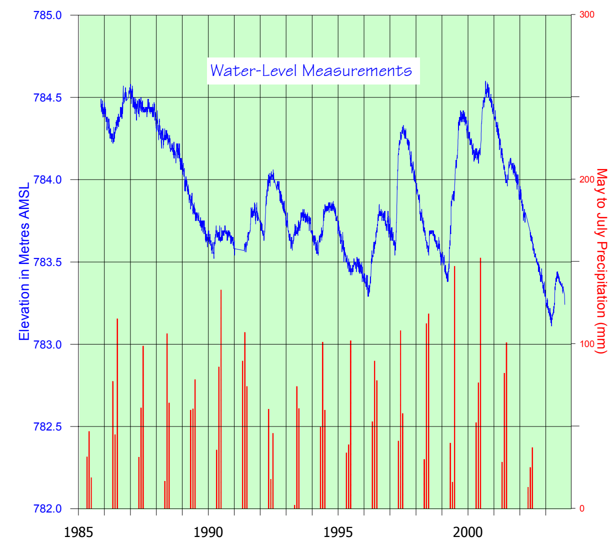

Figure 30. Hydrograph – AENV Ferintosh Landfill Obs WW

The water-level fluctuations in AENV Ferintosh Landfill Obs WW have been compared to the May, June and July precipitation measured at the Camrose weather station. In an area where there are no pronounced seasonal uses of groundwater, the highest yearly water level will mostly occur in late spring/early summer and the lowest yearly water level will be in late winter/early spring. In the adjacent figure, it is apparent there is not a consistent yearly fluctuation in the water levels, but the main annual rise where present, does correspond to the highest month of spring/summer precipitation measured at the Camrose weather station.

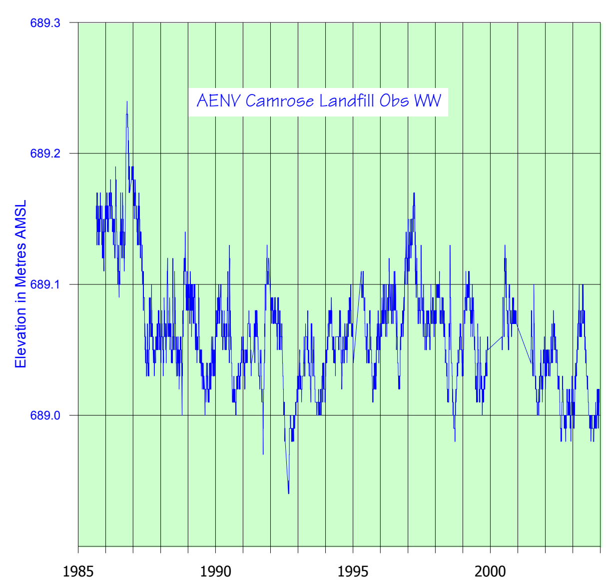

Figure 31. Hydrograph – AENV Camrose Landfill Obs WW

AENV Camrose Landfill Obs WW is completed from 64.3 to 78.0 metres below ground surface in the Lower Horseshoe Canyon Aquifer. The water level in the AENV Camrose Landfill Obs WW has been measured since August 1985, as shown by the blue line in the adjacent graph. This hydrograph shows annual cycles of water-level rise and decline; however, the water-level rise begins in fall and the decline begins in spring. Overall annual fluctuations are approximately 0.1 metres.

The limited amount of data indicates that, in the area of the observation water wells, there is no depletion of the groundwater resource.

6.2 Estimated Groundwater Use in the County of Camrose

An estimate of the quantity of groundwater removed from each geologic unit in the County of Camrose must include both the groundwater diversions with licences and/or registrations and the groundwater diversions without licences and/or registrations. As stated previously on page 8 of this report, the daily water requirement for livestock for the County based on the 2001 census is 9,536 cubic metres. As of late 2003, AENV has licensed the use of 4,132 m³/day for livestock, 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 5,045 m³/day of water required for livestock watering is obtained from unauthorized groundwater use.

There are 2,342 water wells that are used for domestic/stock or stock purposes. There are 1,022 licensed and registered groundwater users for agricultural (stock) and registration (stock) purposes, giving 1,320 unlicensed and not registered stock water wells. (Please refer to Table 3 on page 7 for the breakdown of aquifer of the 1,022 licensed and registered stock groundwater users). By dividing the number of unlicensed and not registered stock and domestic/stock water wells (1,320) into the quantity required for stock purposes that is not licensed and registered (5,405 m³/day), the average unauthorized water well diverts 4.1 m³/day per stock water well.

Groundwater for household use does not require a licence if the use is less than 1,250 m³/year. 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 4,739 domestic or domestic/stock water wells in the County of Camrose serving a population of 7,294, and based on a family of four, the domestic use per water well is in the order of 0.4 m³/day. It is assumed that these 4,739 water wells are active; however, many are very old and may no longer be in use or may have been abandoned.

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 0.4 m³/day
Stock 4.1 m³/day
Domestic/stock 4.5 m³/day

Because of the limitations of the data, no attempt has been made to compensate for dugouts, springs or inactive water wells.

Based on using all available domestic, domestic/stock, and stock water wells and corresponding calculations, Table 15 was prepared. Table 15 show a breakdown of the domestic water wells and stock water wells with or without licences and registrations by the geologic unit in which each water well is completed. The total domestic groundwater use is 1,824 m³/day and the total stock groundwater use is 8,813 m³/day, giving a total domestic and stock groundwater use of 10,636 m³/day. The data provided in Table 15 indicate that 40% of the 10,636 m³/day is from the Lower Horseshoe Canyon Aquifer.

Aquifer Designation	Number of Domestic	Total Domestic Use (0.4 m³/day)	Number of Stock	Number of Domestic and Stock	Number of Licensed Stock and/or Registrations	Total Number of Stock Water Wells Without Licences and/or Registrations	Total Stock Use Without Licenses and/or Registrations (4.1 m³/day)	Total Licensed Stock and/or Registered Groundwater Use (m³/day)	Total Stock Use (m³/day)
Multiple Surficial Completions	153	92	78	85	82	81	332	233	565
Upper Surficial	250	165	43	179	60	162	663	217	880
Lower Surficial	131	76	42	66	45	63	258	128	386
Multiple Bedrock Completions	318	185	149	164	110	203	831	368	1,199
Lower Scollard	0	0	0	1	0	1	4	0	4
Upper Horseshoe Canyon	186	129	71	148	103	116	475	520	995
Middle Horseshoe Canyon	298	160	80	117	92	105	430	232	662
Lower Horseshoe Canyon	1,427	793	319	634	383	570	2,334	1,092	3,426
Bearpaw	220	129	27	114	79	62	254	250	504
Oldman	1	1	1	2	0	3	12	0	12
Foremost	1	0	0	0	0	0	0	0	0
Unknown	229	94	7	15	68	-46 (0)	0	180	180
Totals [(1)]	3,214	1,824	817	1,525	1,022	1,320 (1,366)	5,593	3,220	8,813

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

Table 15. Total Domestic and Stock Groundwater Diversions by Aquifer

By assigning 0.4 m³/day for domestic use, 4.1 m³/day for stock use and 4.5 m³/day for domestic/stock use, and using the total maximum authorized diversion associated with any licensed and/or registered water well, a map has been prepared that shows the estimated groundwater use in terms of volume per section per day for the County (not including springs).

There are 1,479 sections in the County. In 20% (298) of the sections in the County, there is no domestic, stock or licensed and registered groundwater user. The groundwater use for the remaining 1,181 sections varies from 0.4 m³/day to 770 m³/day (mainly the Town of Bashaw), with an average use per section of 11 m³/day (<2 igpm). The estimated water well use per section can be more than 30 m³/day in 51 of the 1,479 sections. There are 125 of the total 1,066 licensed and/or registered groundwater users in areas where the groundwater use is greater than 30 m³/day.

Groundwater Use within the County of Camrose (m³/day)		%
Domestic/Stock (including agriculture and/or registrations)	10,636	83
Municipal (licensed)	1,263	10
Commercial/Dewatering/Recreation (licensed)	855	7
Total	12,754	100

Table 16. Total Groundwater Diversions

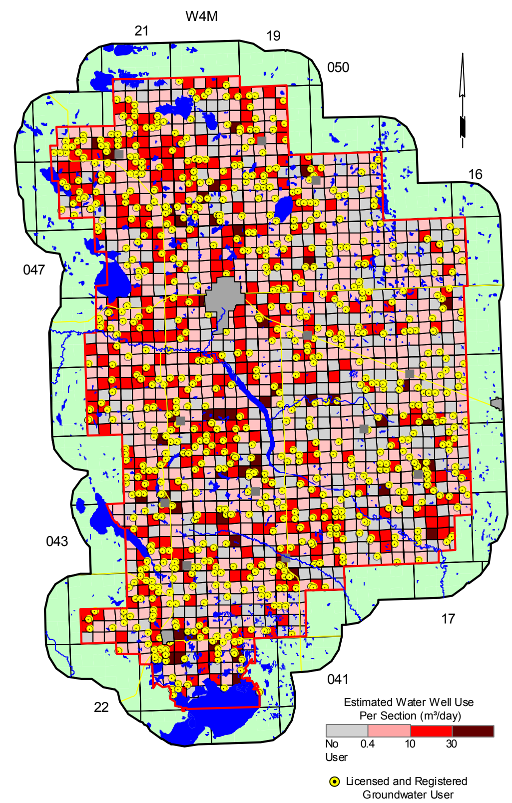

Figure 32. Estimated Water Well Use Per Section
(for larger version, see page A-61)

In summary, the estimated total groundwater use within the County of Camrose is 12,754 m³/day, with the breakdown as shown above in Table 16. An estimated 12,480 m³/day is being withdrawn from a specific aquifer. The remaining 274 m³/day (2%) is being withdrawn from unknown aquifer units. Of the 12,480 m³/day, 73% is being diverted from bedrock aquifers and 27% from surficial aquifers. Approximately 40% of the total estimated groundwater use is from licensed and/or registered water wells.

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 various parts of individual 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 also 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 17.

Table 17 indicates that there is more groundwater flowing through the aquifers than the estimated use. However, even where use is less than the calculated aquifer flow, there can still be local impacts on water levels. The calculations of flow through individual aquifers as presented in Table 17 are very approximate and are intended only as a guide; more detailed investigations are needed to better understand the groundwater flow.

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (km)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed and/or Registered Diversion (m^3/day)	Not Licensed and/or Registered Diversion (m^3/day)	Total (m^3/day)
Upper Surficial					9,347	675	663	1,338
Miquelon Lake Region								
South/Southeast	19.8	0.006	28.8	3,564				
Buried Red Deer Valley								
East/Southeast	19.8	0.003	12.8	792				
North	19.8	0.004	19.2	1,358				
Northeast	19.8	0.004	11.2	832				
Meeting Creek Region								
North	19.8	0.003	17.6	871				
South	19.8	0.003	22.4	1,386				
Buffalo Lake Region								
South	19.8	0.002	17.6	545				
Lower Surficial					1,283	581	258	839
Buried Red Deer Valley								
East of Battle River	26	0.001	13	173				
West of Battle River	26	0.003	13	1,109				
Upper Horseshoe Canyon					2,502	1,169	475	1,644
Beaver Lake Region								
North	12.4	0.003	24	797				
Southeast	12.4	0.005	11	651				
Southwest	12.4	0.006	11	868				
Buffalo Lake Region								
Southeast	12.4	0.002	10	186				
Middle Horseshoe Canyon					3,026	320	430	750
Bittern Lake Region								
Southwest	8.6	0.003	19	516				
Battle River Region								
North	8.6	0.002	6	115				
Meeting Creek Region								
Southwest	8.6	0.005	24	1,032				
Northeast	8.6	0.005	24	1,106				
Buffalo Lake Region								
Southwest	8.6	0.003	10	258				
Lower Horseshoe Canyon					13,771	1,240	2,334	3,574
Hamlet of Kingman Region								
Southeast	17.2	0.008	13	1,720				
Hamlet of Round Hill Region								
Northeast	17.2	0.003	11	602				
Bittern Lake Region								
West of Battle River	17.2	0.003	30	1,634				
Demay Lake Region								
Southwest	17.2	0.004	11	803				
East/Northeast	17.2	0.003	24	1,290				
Battle River Region								
Northeast	17.2	0.008	26	3,302				
North	17.2	0.003	13	550				
Meeting Creek Region								
South	17.2	0.003	38	2,064				
North	17.2	0.003	22	1,204				
Buffalo Lake Area								
Southwest	17.2	0.002	22	602				
Bearpaw					1,095	250	254	504
Amisk Creek Region								
East	3.3	0.004	24	330				
Northwest	3.3	0.004	18	207				
Village of Bawlf Region								
Southeast	3.3	0.002	26	141				
Battle River Region								
South	3.3	0.003	22	231				
Northeast	3.3	0.002	29	186				

Table 17. Groundwater Budget

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers is 0.96 to 5.7 cubic kilometres. This volume is based on an areal extent of 3,830 square kilometres and a saturated thickness of 5 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 non-pumping water-level map has been prepared from water levels associated with water wells completed to depths of less than 20 metres 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 and for calculations of recharge/discharge areas. 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 the main flow direction toward the Buried Red Deer Valley.

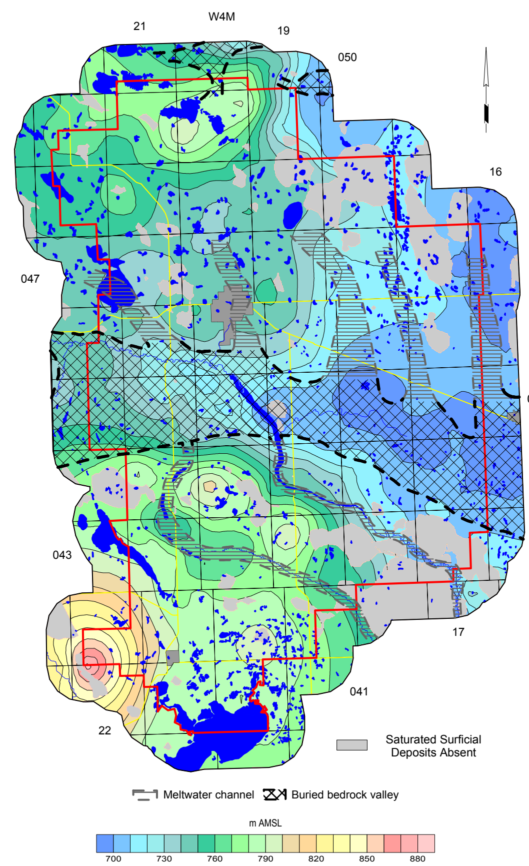

Figure 33. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

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 Surficial Deposits/Bedrock Aquifer

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.

The hydraulic gradient between the surficial deposits and the Upper Bedrock Aquifer(s) has been determined by subtracting the non-pumping water-level surface associated with all water wells completed in the Upper Bedrock Aquifer(s) from the non-pumping water-level surface determined for all water wells in the surficial deposits. The recharge classification is used where the water level in the surficial deposits is more than five metres above the water level in the Upper Bedrock Aquifer(s). The discharge areas are where the water level in the surficial deposits is more than two metres lower than the water level in the bedrock. When the water level in the surficial deposits is between five metres above and two metres below the water level in the bedrock, the area is classified as a transition, that is, no recharge and no discharge.

The locations of flowing water wells and springs are shown on Figure 34. These locations would reflect where there is an upward hydraulic gradient from the bedrock to the surficial deposits (i. e. discharge).

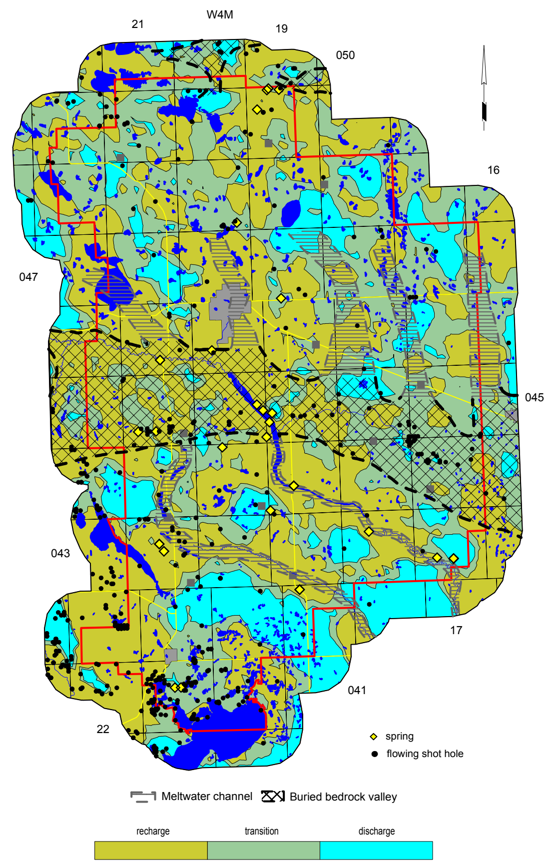

Figure 34. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

Figure 34 shows that, in 50% of the County, there is a downward hydraulic gradient (i. e. recharge) from the surficial deposits toward the Upper Bedrock Aquifer(s). The areas south of the Buried Red Deer Valley showing where there is an upward hydraulic gradient (i .e. discharge) from the bedrock to the surficial deposits are mainly a result of gridding a limited amount of data. 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 50% of the County land area being one of recharge to the bedrock, and the average precipitation being 493 mm per year, 0.3% 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 water-level decline in the Sand and Gravel Aquifer(s) and in the Upper Bedrock Aquifer(s), the following approach was attempted. The available non-pumping water-level elevation for each water well was first sorted by location, and then by date of water-level measurement. The dates of measurements in the Sand and Gravel Aquifer(s) were required to differ by at least one year. For water wells completed in the Upper Bedrock Aquifer(s), there were sufficient non-pumping water-level data that the dates of measurements were required to differ by at least ten years. Only the earliest and latest control points at a given location were used. The method of calculating changes in water levels is at best an estimate. Additional data would be needed to verify water-level change.

6.4.1 Sand and Gravel Aquifer(s)

Of the 1,000 surficial water wells with a NPWL and date in the County and buffer area, there are 114 water wells with sufficient control to prepare the adjacent map.

The interpretation of the adjacent map should be limited to areas where both earliest and latest water level control points are present; these areas indicated on Figure 35 are mainly in the Buried Red Deer Valley.

Where the earliest water level is at a higher elevation than the latest water level, there is the possibility that some groundwater decline has occurred. The adjacent map indicates that there may have been a decline in the NPWL in 60% of the County.

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.

Estimated Water Well Use Per Section (m³/day)	*% of Area with a Decline*
<10	*25*
10 to 30	*25*
>30	*26*
no use	*24*

Table 18. Water-Level Decline in Sand and Gravel Aquifer(s)

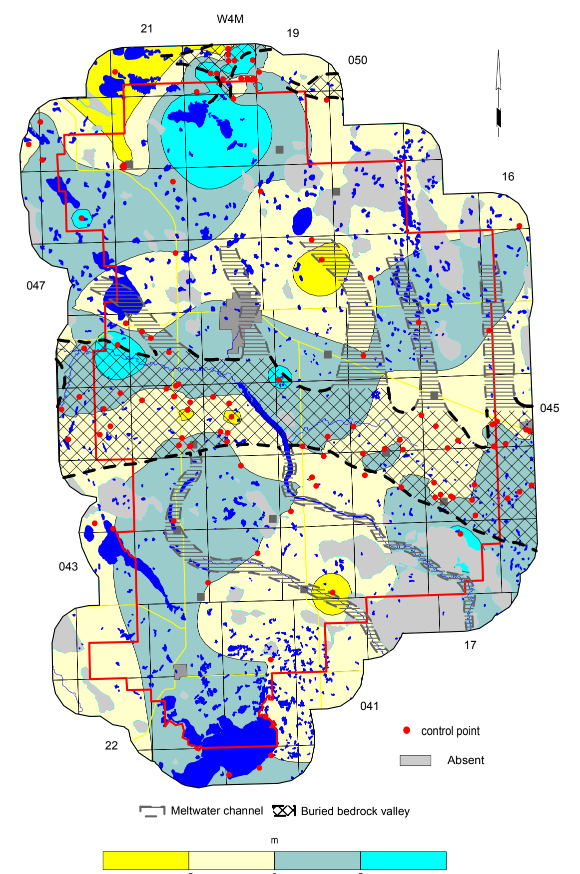

Figure 35. Changes in Water Levels in Sand and Gravel Aquifer(s)

In areas where a water-level decline is projected, 24% of the areas has no estimated water well use; 25% is less than ten m³/day, 25% of the use is between ten and 30 m³/day, and the remaining 26% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown in Table 18.

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(s) or because the water wells are not on file with AENV.

6.4.2 Upper Bedrock Aquifer(s)

Of the 5,040 water wells completed in the Upper Bedrock Aquifer(s) with a non-pumping water level and a corresponding date in the County and buffer area, there are 332 water wells with sufficient control to prepare the adjacent map. The adjacent map indicates that in 50% of the County, it is possible that the NPWL has declined.

In areas where a water-level decline of more than five metres is projected, 41% of the areas has no estimated water well use; 2% is less than ten m³/day, 40% of the use is between ten and 30 m³/day, and the remaining 17% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown below in Table 19.

Estimated Water Well Use Per Section (m³/day)	*% of Area with More than a 5-Metre Projected Decline*
<10	*2*
10 to 30	*40*
>30	*17*
no use	*41*

Table 19. Water-Level Decline of More than Five Metres in Upper Bedrock Aquifer(s)

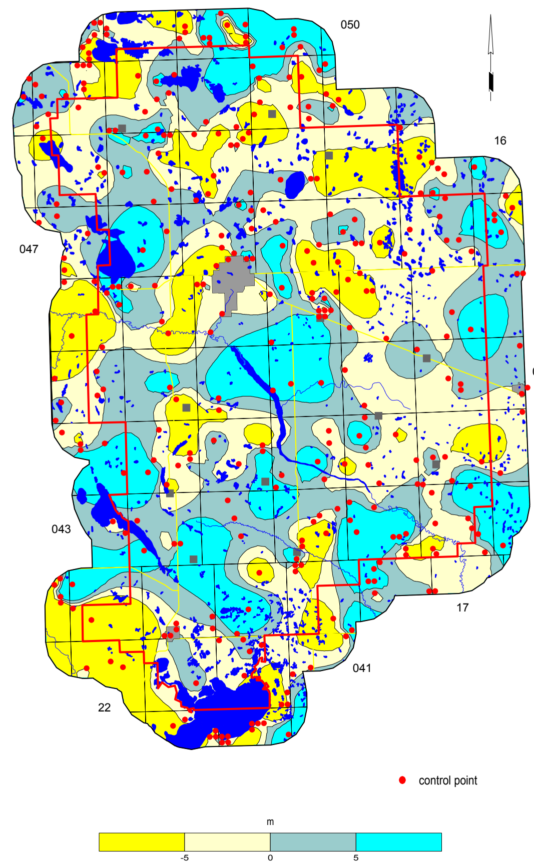

Figure 36. Areas of Potential Groundwater Decline – Upper Bedrock Aquifer(s)

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(s) or because the water wells are not on file with AENV.

6.5 Discussion of Specific Issues

As per the Request for Proposal, the County requested that comments be made, where possible, on the following three study areas and issues. The issue is stated at the beginning of each of the following sections. In addition to the three study areas, the County made a special request to assist the Village of Ferintosh to develop an alternate groundwater supply.

6.5.1 Area 1 – North Slope of Battle River/Driedmeat Lake Townships 044 and 045, Ranges 17 to 19, W4M

Is there any hydrogeological reason for the apparent water-level decline in the water wells along the north slope of the Battle River in townships 044 and 045, ranges 17 to 19, W4M?

In the absence of available current water-level data in Area 1, HCL conducted a field-verified water well survey in May 2004 to help determine if there is a water-level decline in Area 1 (north slope of the Battle River/Driedmeat Lake). A visit was made to 57 landowners, including 12 locations south of Driedmeat Lake and the Battle River. Of the 57 land locations, water levels were measured in 22 water wells, of which 16 are completed in Upper Bedrock Aquifer(s), and five are completed in the surficial deposits, as shown on Figure 37; the completion aquifer for the remaining water well could not be determined due to insufficient completion details. Water levels were measured when possible during the water well survey. Spatial coordinates for water wells located during the survey were obtained using a Global Positioning System (GPS) unit.

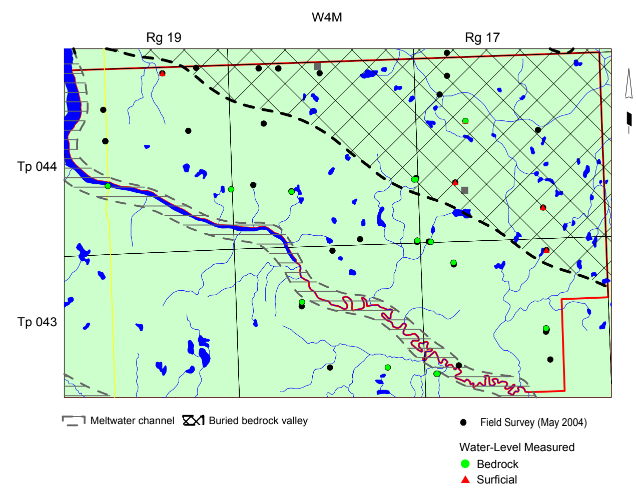

Figure 37. Field-Verified Water Well Survey – Area 1

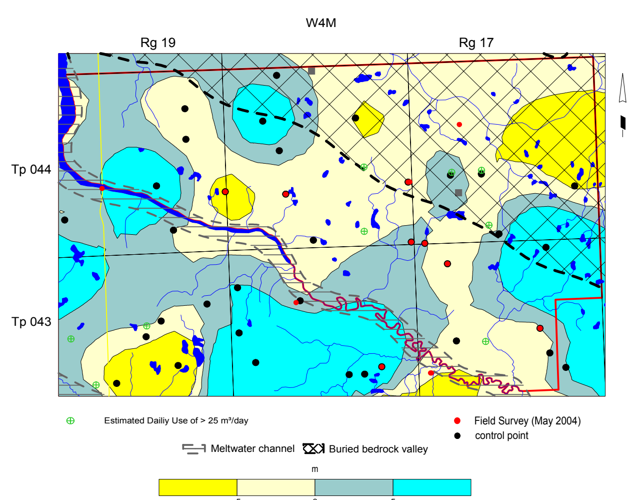

Figure 38. Non-Pumping Water-Level Decline in Upper Bedrock Aquifer(s) – Area 1

The interpretation of Figures 38 and 39 should be limited to areas where both earliest and latest water-level control points are present; these areas indicated on Figure 37 show the water levels measured in surficial water wells are mainly in the Buried Red Deer Valley, but the water levels measured in bedrock water wells are throughout Area 1.

The adjacent map indicates that in 60% of Area 1, it is possible that the NPWL has declined in the Upper Bedrock Aquifer(s). In most areas where a water-level decline is projected, there is an estimated daily groundwater use per section of greater than 25 m³/day. 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(s) or because the water wells are not on file with AENV.

The adjacent map indicates that there may have been a decline in the NPWL in the surficial deposits north of the Battle River/Driedmeat Lake in 50% of the Buried Red Deer Valley; in the area immediately north of the Battle River/Driedmeat Lake, there has mainly been a rise in the NPWL in the surficial deposits.

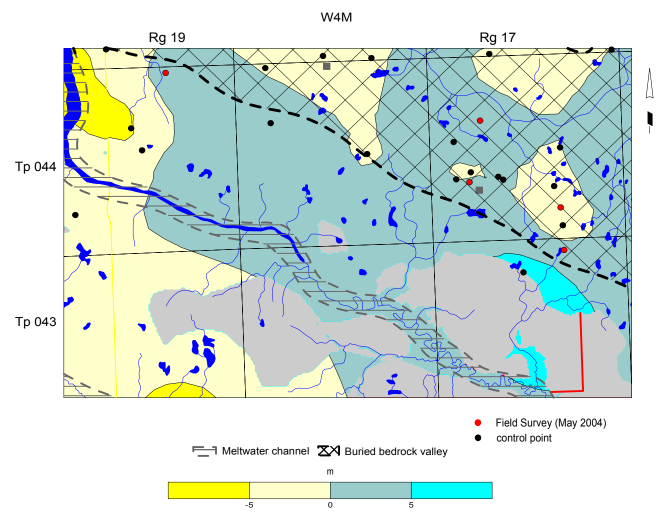

Figure 39. Non-Pumping Water-Level Decline in Surficial Deposits – Area 1

Cross-section SW-NE was prepared to help illustrate the change in water levels in both the surficial deposits and the Upper Bedrock Aquifer(s). Where possible, a water well with an “early” and a “late” NPWL was used in the cross-section.

Cross-section SW-NE shows water wells numbered 11 to 15 are completed in the Sand and Gravel Aquifer(s): Nos. 11, 12 and 15 in the Upper Sand and Gravel Aquifer, and Nos. 13 and 14 in the Lower Sand and Gravel Aquifer. There appears to be a decline in the NPWL in the water wells completed in the Upper Sand and Gravel Aquifer, but a NPWL rise in the water wells completed in the Lower Sand and Gravel Aquifer.

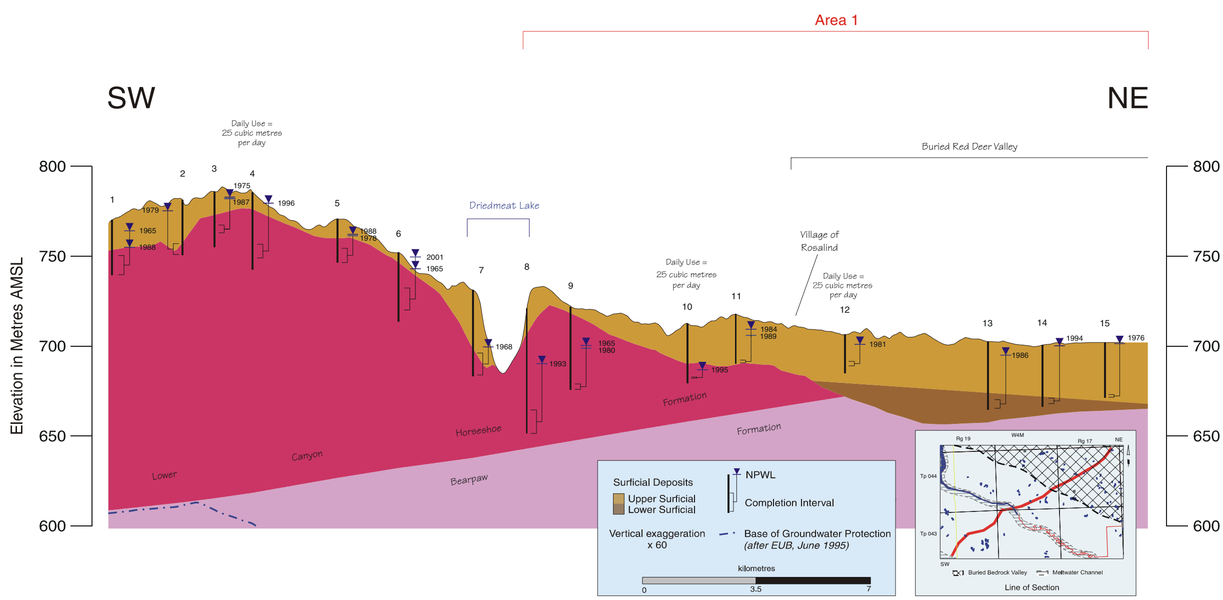

Figure 40. Southwest-Northeast Cross-section – Area 1

Cross-section SW-NE shows water wells numbered 1 to 10 are completed in the Lower Horseshoe Canyon Aquifer. Water Well Nos. 1 to 7 are located south of the Battle River/Driedmeat Lake, and Water Well Nos. 8 to 10 are located north of the Battle River/Driedmeat Lake in Area 1. The indications are that there may be a NPWL decline in Water Well Nos. 1 to 3, but a NPWL rise in Water Well Nos. 4 to 7. On the north side of Driedmeat Lake, there appears to be a NPWL decline in Water Well Nos. 8 to 10.

A water-level decline may be occurring in some areas but are not significant and would not be expected to interface with the normal operation of a water well. The perceived water-level decline may be a result of water well performance and water well maintenance.

6.5.2 Area 2 – Three Water Test Sites for Community Water Wells

Identify three locations for community water wells considered most suitable for the development of groundwater supplies based on the following criteria:

1) the apparent long-term yield of area water wells is greater than 131 m³/day (20 igpm)
2) the concentration of TDS in groundwater is less than 2,000 mg/L
3) the water well locations should be easily accessible, if possible

In addition, a fourth criteria was considered: the locations should not be in areas of potential NPWL decline in the surficial deposits and Upper Bedrock Aquifer(s). The areas shaded in red on the adjacent figure fulfill the four requirements and are based on the regional data available. Also shown on the figure are the locations where the licensed groundwater use is greater than 10 m³/day. Three preferred locations in each of the north, east and south portions of the county are summarized in the abbreviated gwQuery results below:

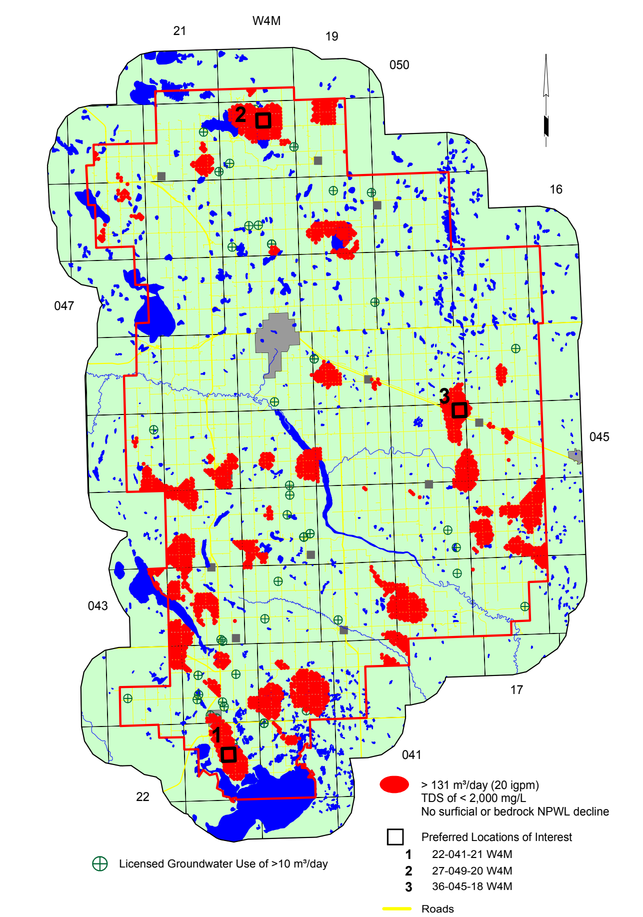

Figure 41. Areas of Groundwater Potential – Area 2

MOW-TECH LTD. gwQuery Results (metric)
NE 22-041-21 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	39	1	612	15	19
Lower Surficial Deposits	0	8	1	612	15	19
Bedrock Surface	9					
Upper Horseshoe Canyon Formation	9	713	-1	696	80	--

MOW-TECH LTD. gwQuery Results (metric)
NE 27-049-20 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	59	7	1594	402	24
Lower Surficial Deposits	61	242	59	1594	402	24
Bedrock Surface	62					
Lower Horseshoe Canyon Formation	62	245	22	1252	126	27
Bearpaw Formation	120	--	--	--	--	--

NW 36-045-18 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	250	4	1177	203	35
Bedrock Surface	10					
Lower Horseshoe Canyon Formation	10	194	3	1074	16	93
Bearpaw Formation	23	12	9	1245	51	185
Oldman Formation	117	--	--	--	--	--

Table 20. gwQuery Results – Three Locations

6.5.3 Area 3 – Three Areas for Groundwater-Based Industrial Development

Identify two or three areas with the best potential for groundwater supplies to support water-based industrial development

Two locations considered most suitable for the development to support water-based industrial development were identified using the following criteria:

1) the apparent long-term yield of area water wells is greater than 500 m³/day (76 igpm)
2) the concentration of TDS in groundwater is less than 1,000 mg/L
3) locations should not be in areas of potential NPWL decline in the surficial deposits and Upper Bedrock Aquifer(s)

The areas shaded in red on the adjacent figure fulfill the three requirements and are based on the regional data provided as part of the regional groundwater assessment. Also shown on the figure are the locations where the licensed groundwater use is greater than 10 m³/day. The two preferred locations based on highest apparent yields are summarized in the abbreviated gwQuery results below:

MOW-TECH LTD. gwQuery Results (metric)
NE 08-044-17 W4M

Detailed Results Formation Name	Top metre	Yield m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L
Upper Surficial Deposits	--	30	7	952	251	45
Lower Surficial Deposits	16	16	8	952	251	45
Bedrock Surface	22					
Lower Horseshoe Canyon Formation	22	1329	8	377	12	3
Bearpaw Formation	43	4	15	664	61	26
Oldman Formation	140	--	--	--	--	--

MOW-TECH LTD. gwQuery Results (metric)
NE 11-045-22 W4M

Detailed Results Formation Name	Top metre	Yield m³/day	NPWL metre	TDS mg/L	Sulfate mg/L	Chloride mg/L
Upper Surficial Deposits	--	24	4	1276	567	7
Lower Surficial Deposits	20	79	4	1276	567	7
Bedrock Surface	26					
Upper Horseshoe Canyon Formation	26	582	-2	796	277	7
Middle Horseshoe Canyon Formation	28	19	9	852	142	21
Lower Horseshoe Canyon Formation	75	12	9	1546	--	580
Bearpaw Formation	214	--	--	--	--	--

Table 21. gwQuery Results – Two Locations

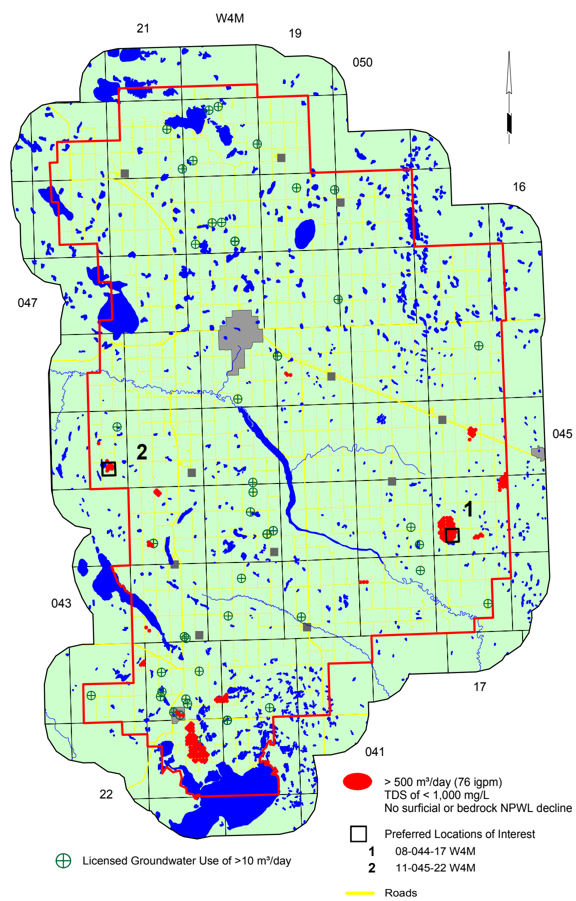

Figure 42. Areas of Groundwater Potential – Area 3

6.5.4 Area 4 – Village of Ferintosh

Groundwater is the main source of water developed for household use in the Village of Ferintosh. The Village has a population of 168 (Phinney, 2004) and is licensed to divert an annual groundwater diversion of 15,000 m³ (1,250 m³/month) from five water supply wells. Water Supply Well Nos. 1, 2, 3 and 4 have been in use since December 1998, and WSW No. 5 has been in use since Nov 2002. All five water supply wells are completed in fractured shale and coal in the Middle Horseshoe Canyon Aquifer.

Groundwater production data from April 2002 to June 2004 was provided by the Village of Ferintosh. The data indicated monthly diversion ranged from a low of 770 m³ in November 2003 to a high 1,205 m³ in July 2003, as shown on Figure 43. In 2003, 37% of the total groundwater production was diverted from WSW No. 1 The total groundwater production in 2003 from the Village of Ferintosh WSW Nos. 1, 2, 3, 4, and 5 was 11,582 m³/day, 77% of the 15,000 m³ authorized by AENV.

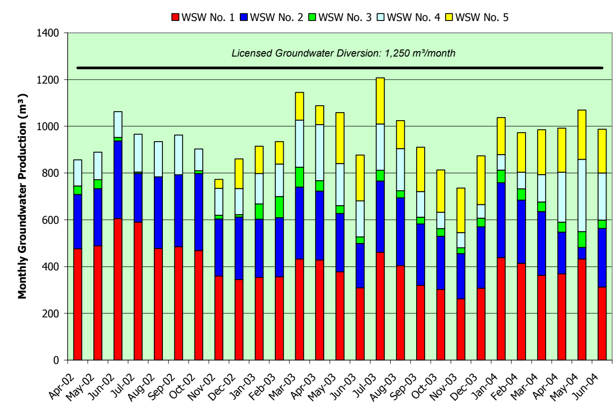

Figure 43. Village of Ferintosh 2002 – 2004 Monthly Groundwater Production

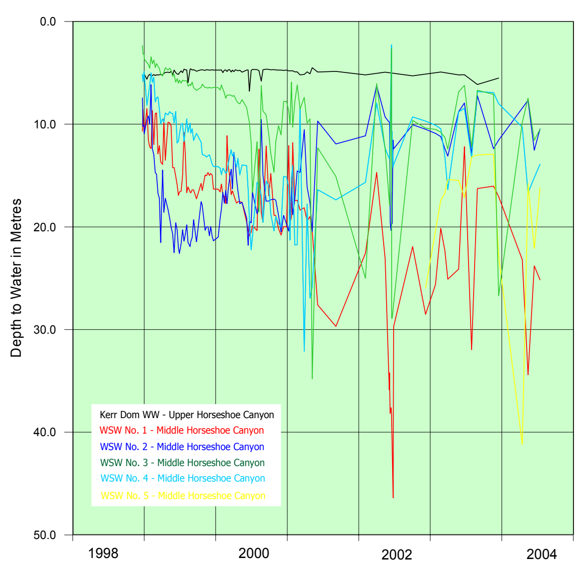

Figure 44. Village of Ferintosh Water-Level Measurements

Water levels are measured in the five water supply wells, two observation water wells, and one domestic water well (see page A-71 for locations). Water-level measurements for WSW No. 1, 2, 3, 4 and 5, and the Kerr Domestic Water Well (Dom WW) are shown in the hydrographs on Figures 44 and 45, on pages A-73 and A-74.

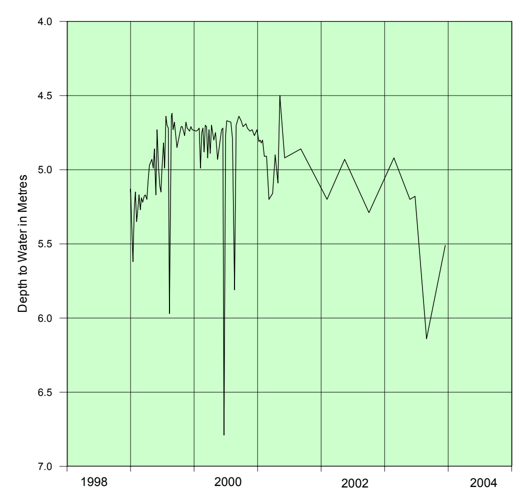

Figure 45. Village of Ferintosh Water-Level Measurements in Kerr Dom WW

The Village maintained a conscientious groundwater monitoring program from 1999 to early 2001. Since 2001, the inconsistency in frequency of water-level measurements in the water supply wells and observation well wells has compromised the interpretation of the data.

The Village of Ferintosh would like to increase the availability of groundwater for the community. Because individual water well yields are low, a lineament analysis was completed in an attempt to identify more favourable drilling sites for future test drilling. The belief is that the lineaments are a reflection of fracturing occurring in one or more geological units. If a drilling site is selected at the intersection of two lineament traces, there is a higher probability of encountering geological units that are fractured.

Lineament traces identified in the general vicinity of Ferintosh are shown below on Figure 46. There are two sets of lineament traces, one orientated northwest-southeast and a second set at approximately 90 degrees to the first set. A total of five intersections have been identified as preferred drilling sites; three proposed drilling sites are along one northwest-southeast lineament trace and two are along a second northwest-southeast lineament trace. The features that were used to identify individual traces help establish the preferred locations.

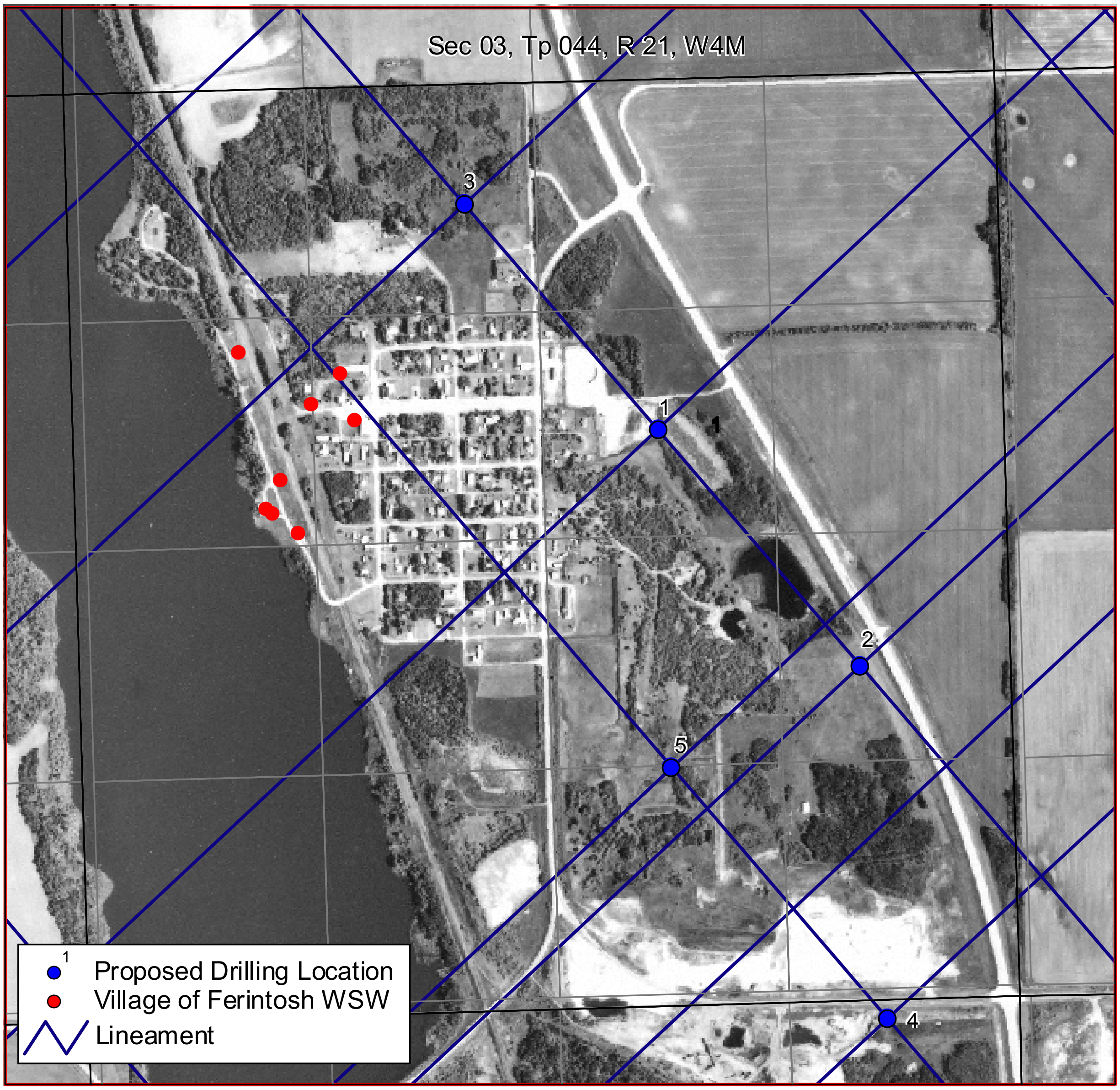

Figure 46. Village of Ferintosh Proposed Water Test Hole Drilling Sites

When drilling at a given location, the maximum drilling depth is approximately 100 metres. For the present program the maximum drilling depth has been increased to include a sandstone layer near the base of the Horseshoe Canyon Formation.

Site	Location	10° Transverse Mercator (10TM) - NAD27		Depth in Metres
		Easting	Northing	
1	10-03-044-21 W4M	137376	5845517	160 - 190
2	08-03-044-21 W4M	137732	5845102	160 - 190
3	14-03-044-21 W4M	137038	5845912	160 - 190
4	16-34-043-21 W4M	137780	5844480	160 - 190
5	02-03-044-21 W4M	137401	5844922	160 - 190

Table 22. Maximum Depth to Drill for Proposed Water Test Hole Drilling Sites for the Village of Ferintosh

The expected apparent yield and chemistry quality for the five sites are summarized in the abbreviated gwQuery results below:

10-03-044-21 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	18	8	942	200	49
Lower Surficial Deposits	10	--	11	942	200	49
Bedrock Surface	11					
Upper Horseshoe Canyon Formation	11	2	9	615	147	44
Middle Horseshoe Canyon Formation	28	13	9	766	74	30
Lower Horseshoe Canyon Formation	74	8	33	1231	41	275

08-03-044-21 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	--	12	1237	336	44
Bedrock Surface	13					
Upper Horseshoe Canyon Formation	13	13	11	659	148	40
Middle Horseshoe Canyon Formation	30	11	14	848	161	25
Lower Horseshoe Canyon Formation	77	6	32	1249	46	283

14-03-044-21 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	20	4	734	98	53
Lower Surficial Deposits	11	--	8	734	98	53
Bedrock Surface	13					
Upper Horseshoe Canyon Formation	13	--	7	575	151	43
Middle Horseshoe Canyon Formation	25	12	6	702	19	26
Lower Horseshoe Canyon Formation	72	10	34	1209	34	267

16-34-043-21 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	--	7	1768	544	43
Bedrock Surface	16					
Upper Horseshoe Canyon Formation	16	34	3	762	184	33
Middle Horseshoe Canyon Formation	20	8	10	1006	281	22
Lower Horseshoe Canyon Formation	66	4	15	1264	47	286

02-03-044-21 W4M

Detailed Results	Top	Yield	NPWL	TDS	Sulfate	Chloride
Formation Name	metre	m³/day	metre	mg/L	mg/L	mg/L
Upper Surficial Deposits	--	--	7	1343	356	50
Bedrock Surface	14					
Upper Horseshoe Canyon Formation	14	20	6	713	174	40
Middle Horseshoe Canyon Formation	22	11	9	908	149	36
Lower Horseshoe Canyon Formation	68	6	21	1250	44	278

Table 23. gwQuery Results – Village of Ferintosh Proposed Water Test Hole Drilling Sites

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 240 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 is one water well for which the County has responsibility; the County-operated water well is included in Appendix E. It is recommended that the County-operated water wells plus the 240 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 240 water wells listed in Appendix E for which water well drilling reports are available, plus the County–operated water well, 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 241 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 49% successful in this study (see CD-ROM); 51% of the licensed and/or registered 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 authorized non-exempt 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.

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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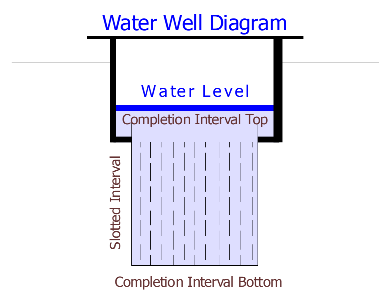
9 GLOSSARY

Anion	negatively charged ion
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
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)

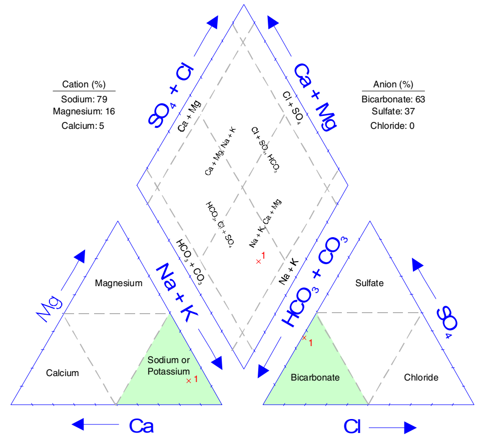


Completion Interval

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
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^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

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 20 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

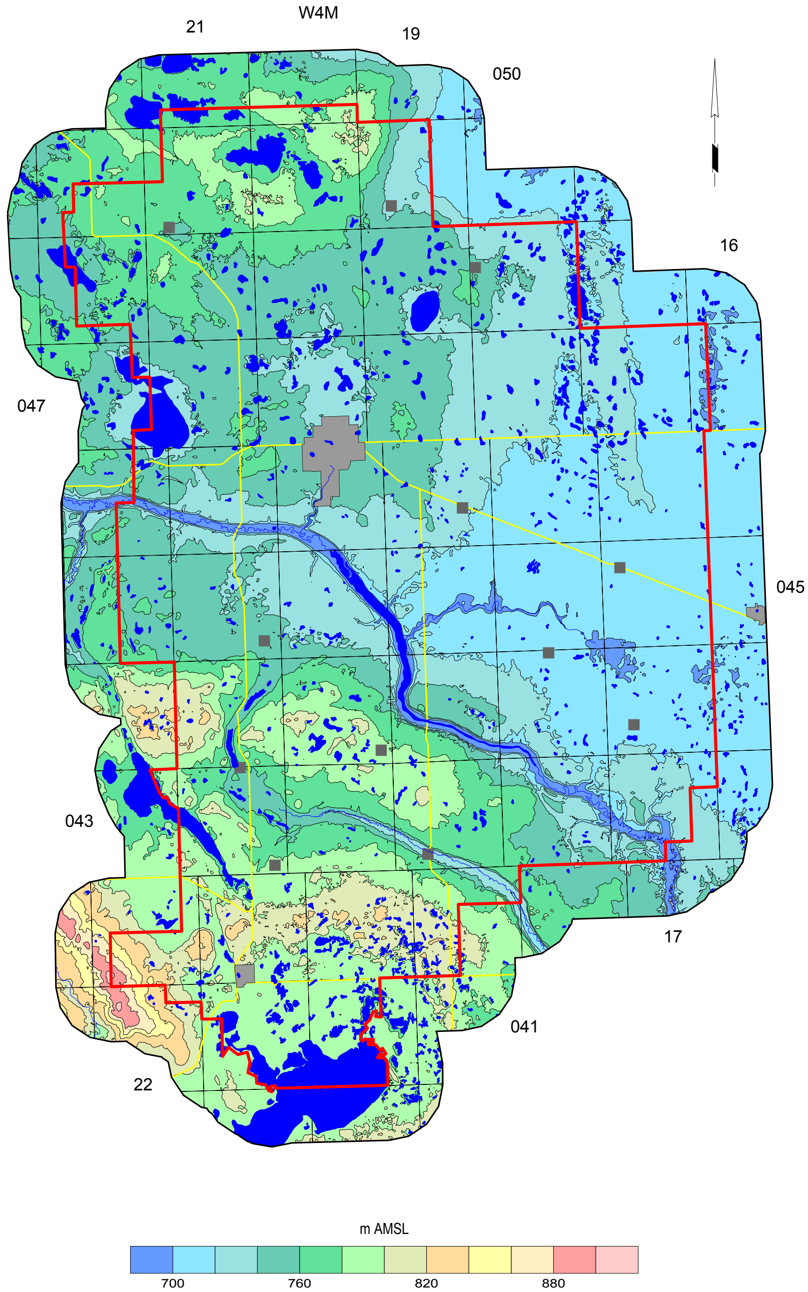
Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometre	0.621 370	miles (statute)
square feet (ft^2)	0.092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

COUNTY OF CAMROSE NO. 22

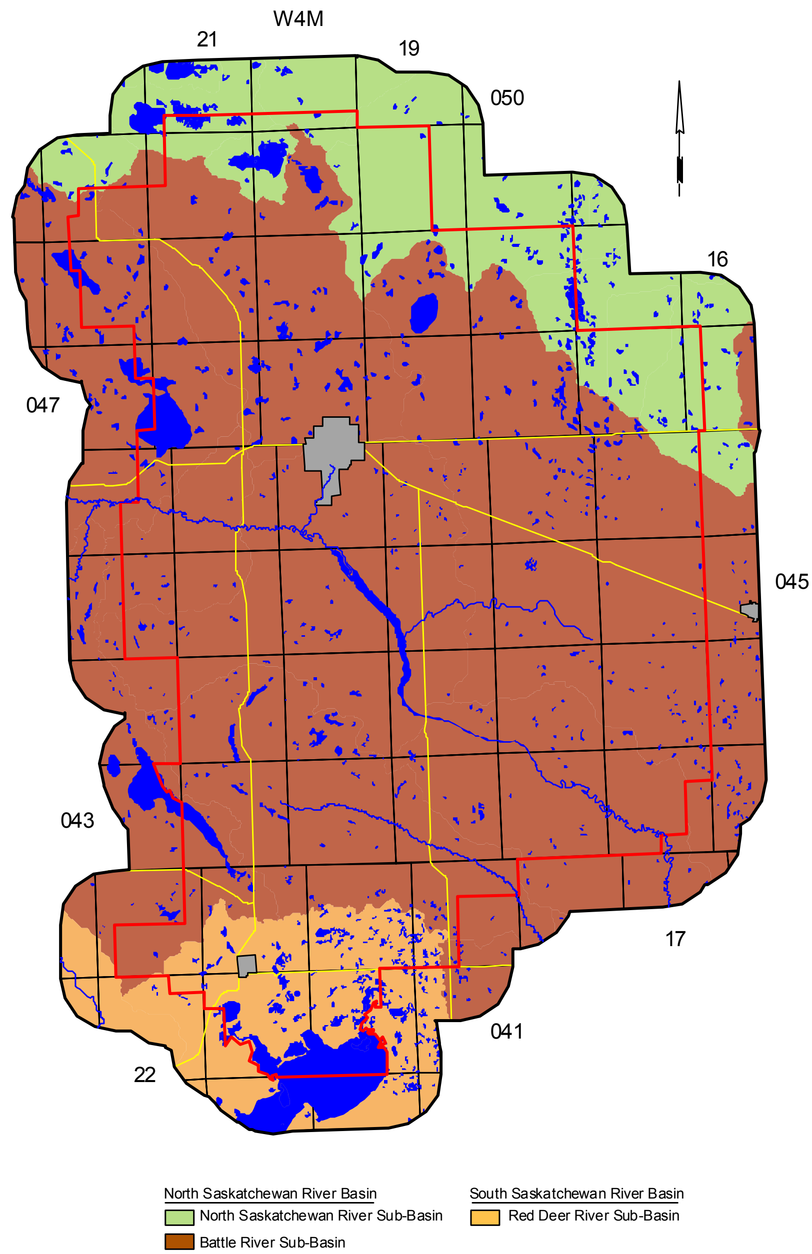
Appendix A

Hydrogeological Maps and Figures

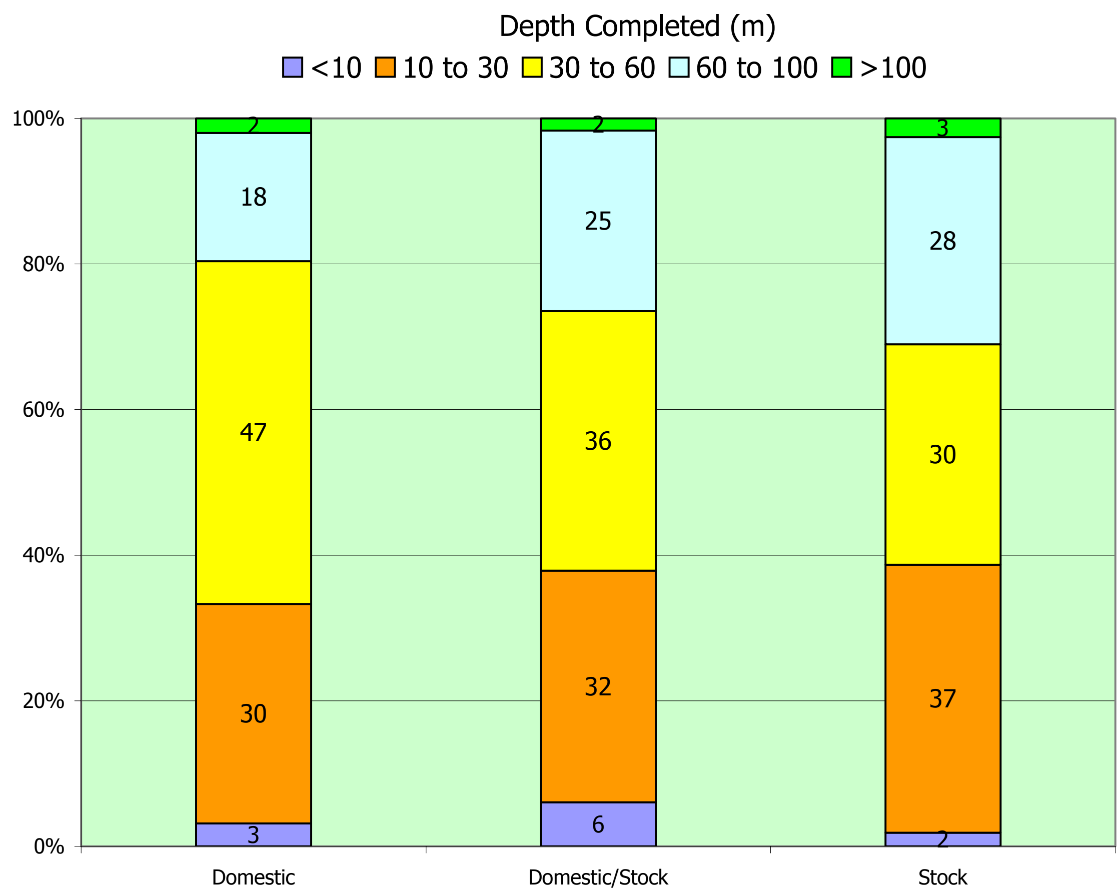
Surface Topography



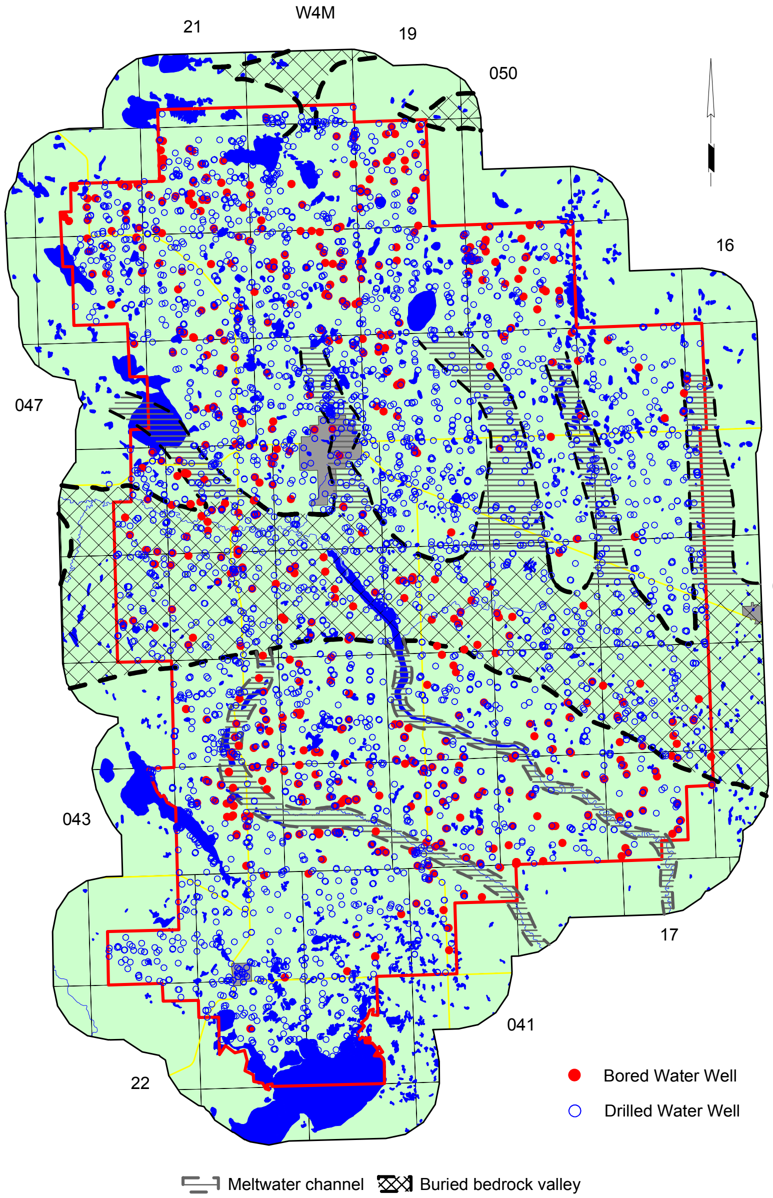
River Sub-Basins



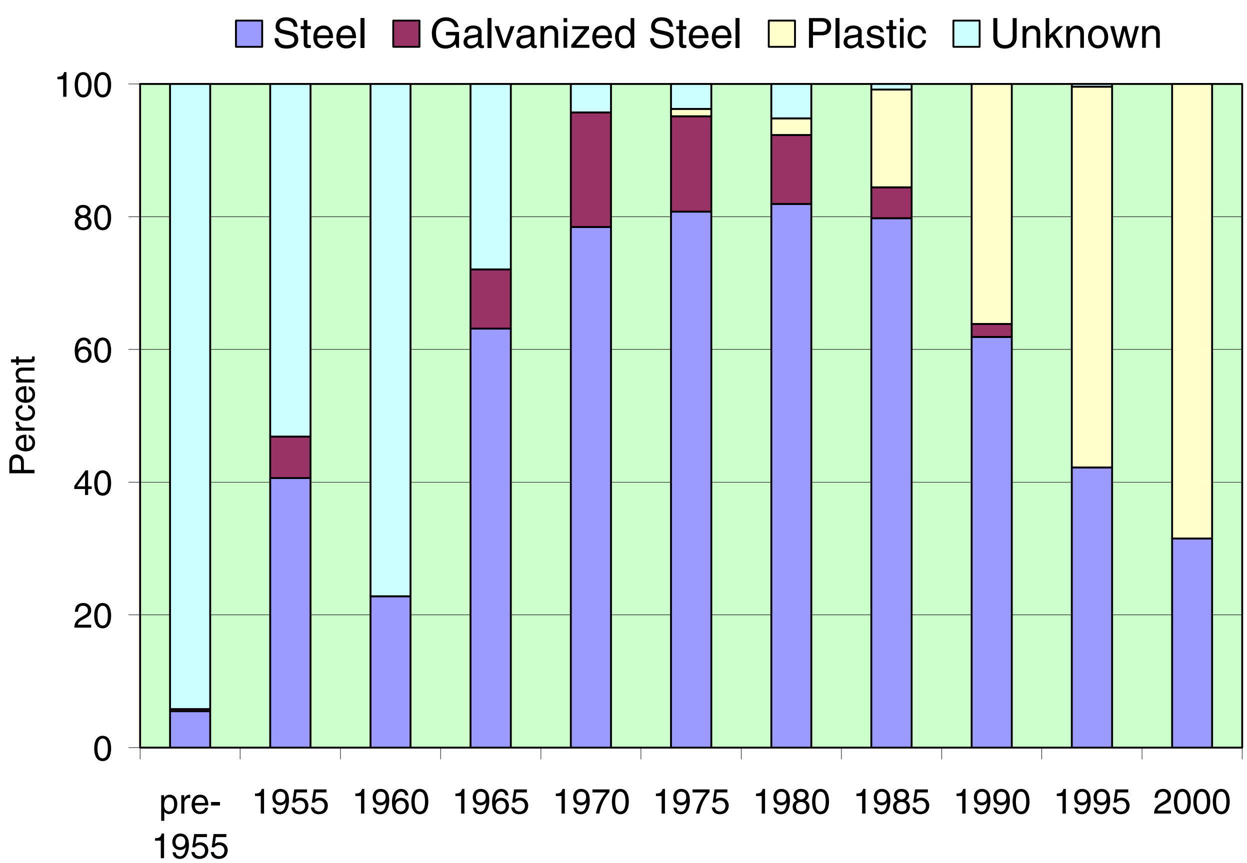
Percentage of Domestic, Domestic/Stock and Stock Water Wells vs Completed Depth



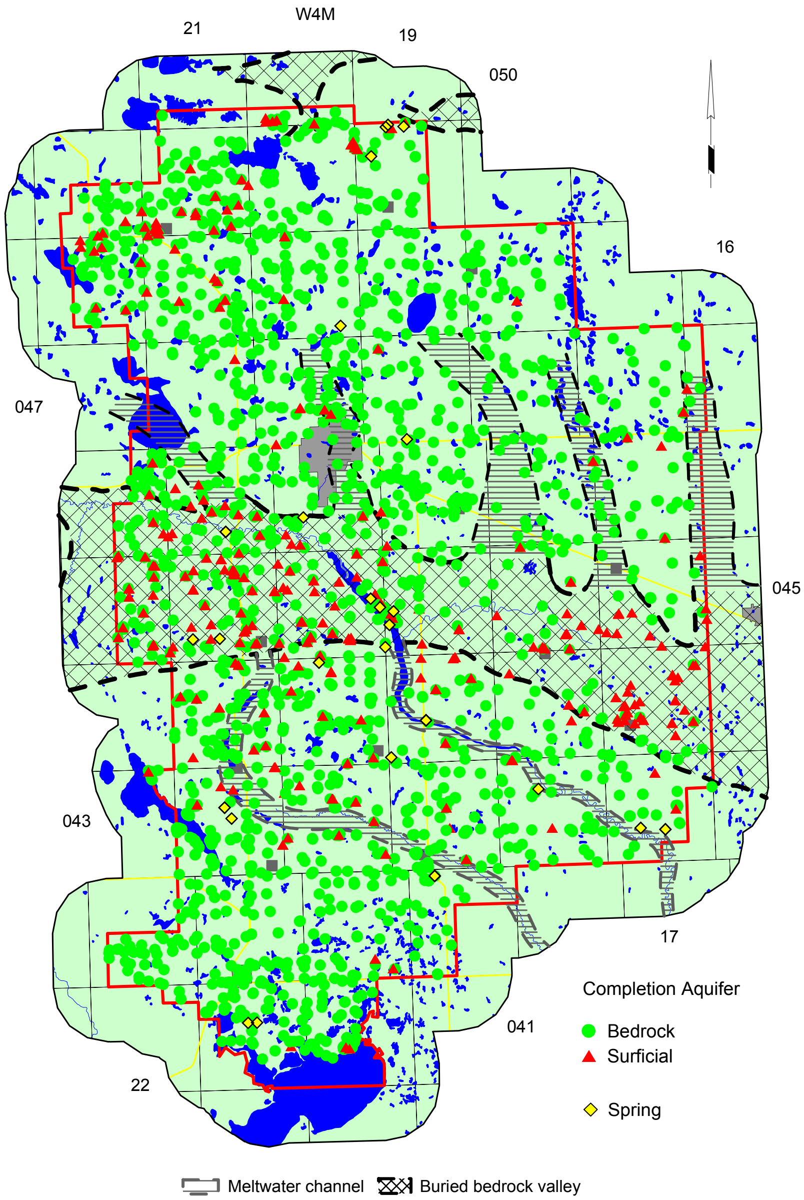
Locations of Drilled and Bored Water Wells



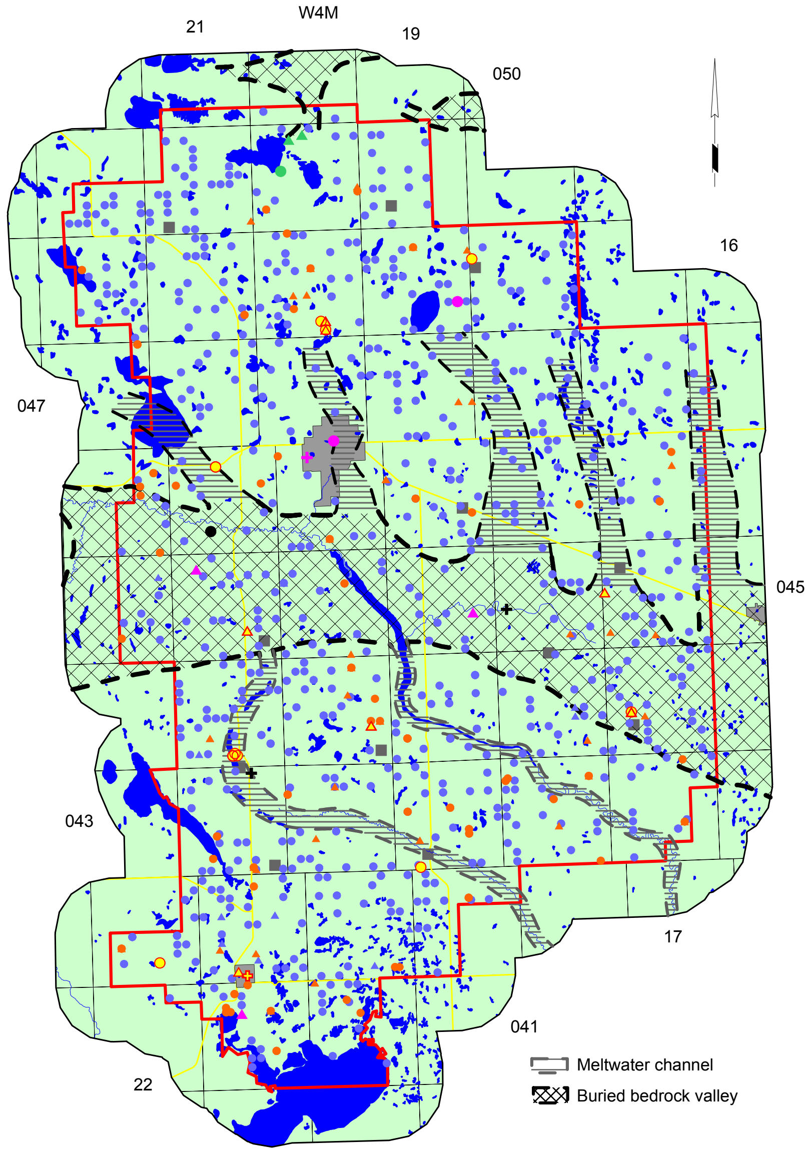
Surface Casing Types used in Drilled Water Wells



Locations of Water Wells and Springs



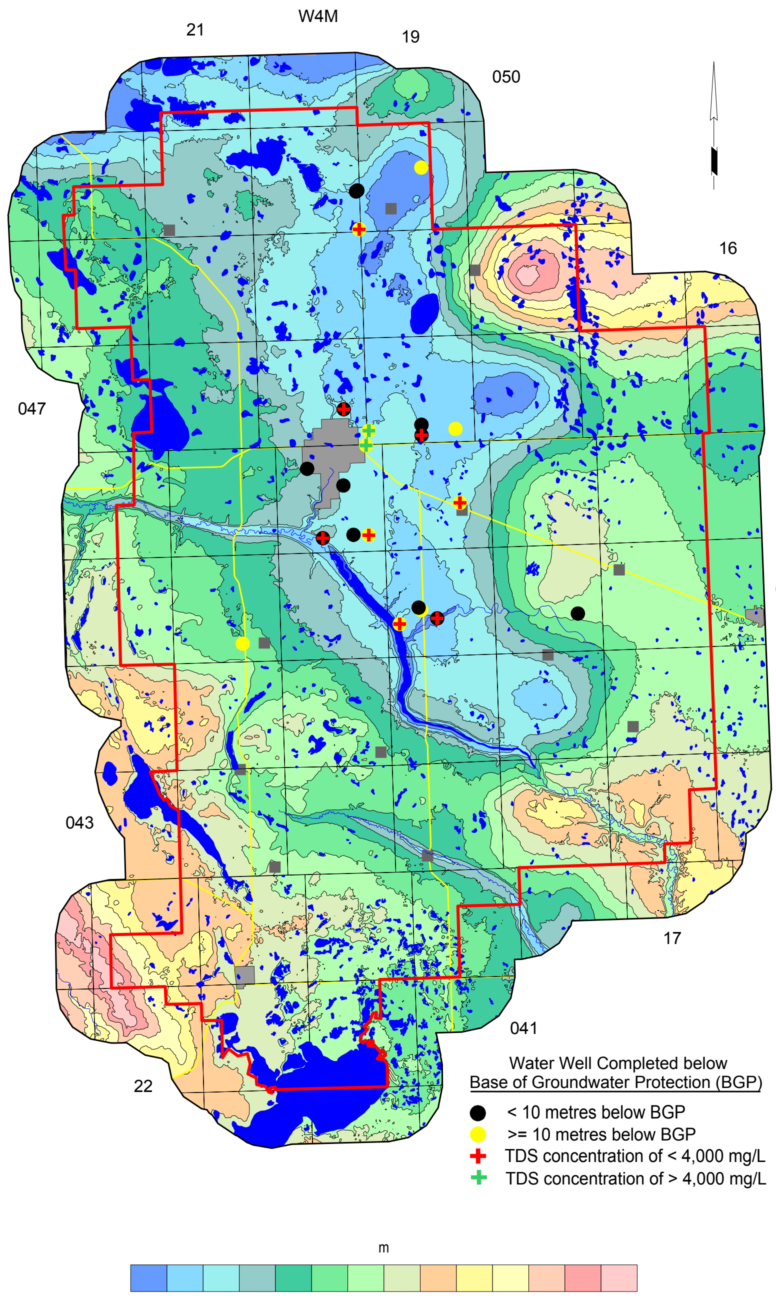
Licensed and Registered Groundwater Water Wells



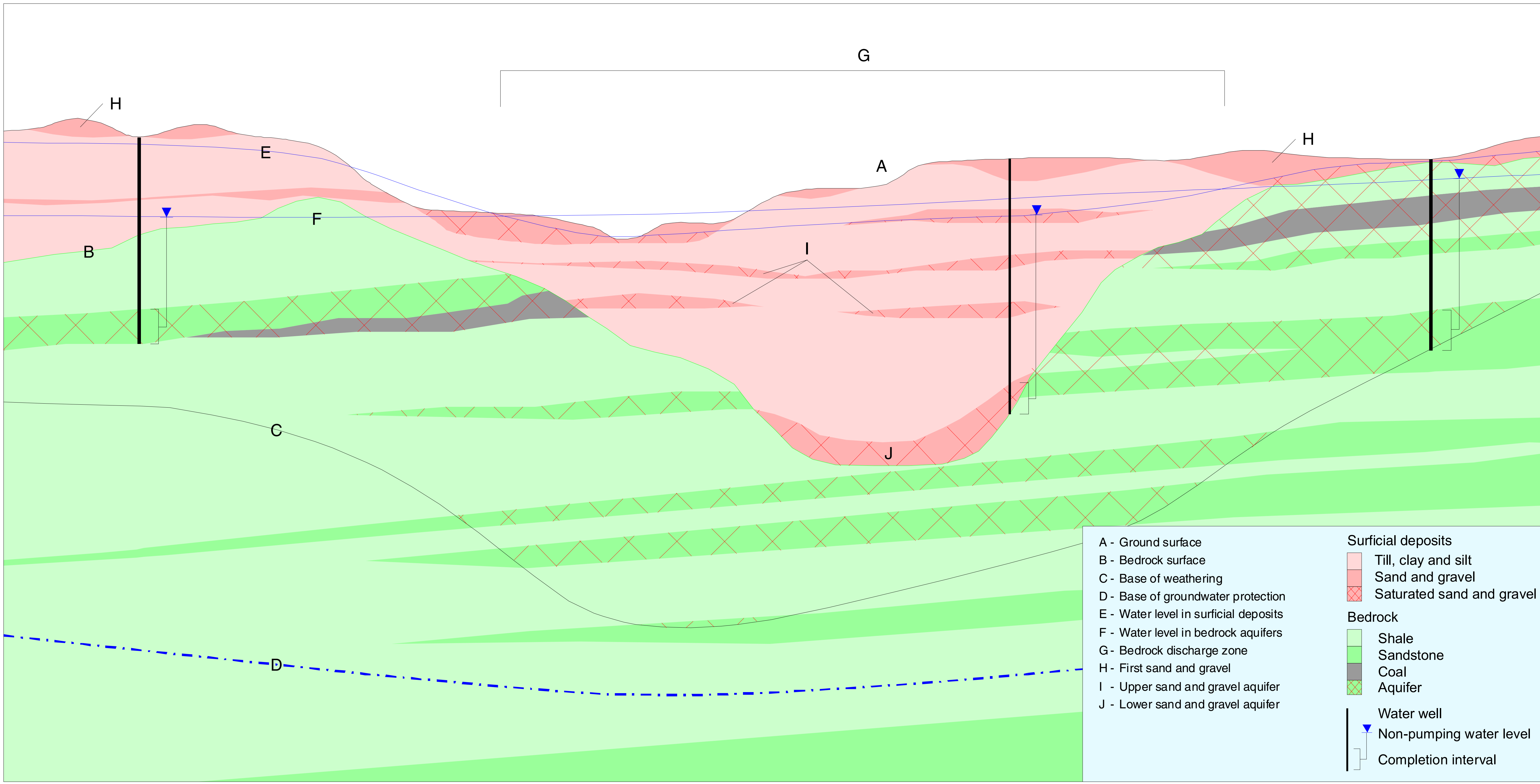
m³/day	registration	agricultural	commercial	dewatering	municipal	recreation
< 10	(866)	(99)	(2)	(1)	(13)	(1)
10 to 100	(16)	(41)	(3)	(0)	(17)	(2)
> 100	(0)	(0)	(1)	(2)	(2)	(0)

Depth to Base of Groundwater Protection

(modified after EUB, 1995)



Generalized Cross-Section
(for terminology only)

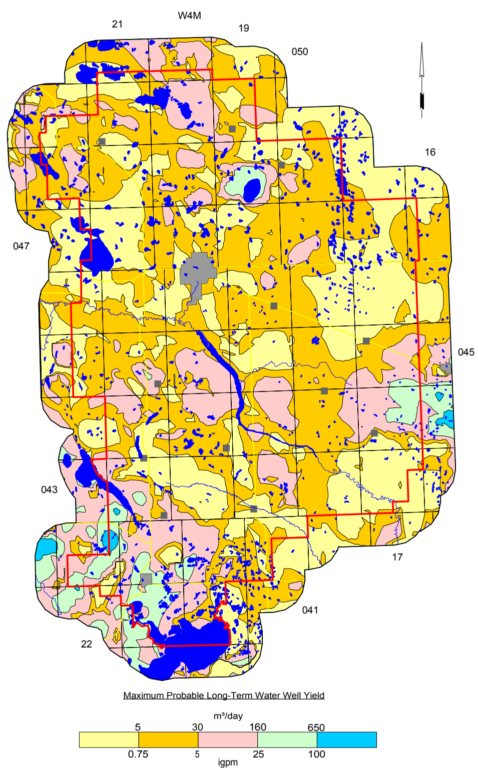


Geologic Column

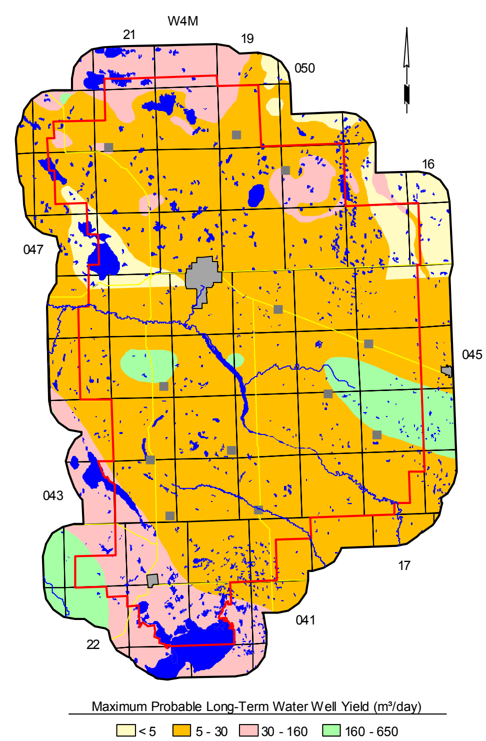
Depth (m): 0, 100, 200, 300, 400, 500, 600, 700, 800, 1200

Lithologic Description	Group and Formation: Average Thickness (m)	Group	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		
shale, sandstone, coal	60-150	Edmonton Group		Scollard Formation	40-100	Upper	<2	Upper Ardley Coal Zone
							~20	Ardley Coal Zone (main seam)
							<1	Nevis Coal Seam
					20-60	Lower		
shale, clay, tuff	~25			Battle Formation	<0.3	Kneehill Member		
shale, siltstone, sandstone	5-10							
shale, sandstone, coal, bentonite, limestone, ironstone	300-380			Horseshoe Canyon Formation	~100	Upper		
					~100	Middle		
					~170	Lower		
shale, sandstone, siltstone	60-120			Bearpaw Formation				
sandstone, siltstone, shale, coal	<300	Belly River Group	40-130	Oldman Formation		Dinosaur Member	<25	Lethbridge Coal Zone
						Upper Siltstone Member		
						Comrey Member		
sandstone, shale			<200	Foremost Formation	<70	Birch Lake Member		Taber Coal Zone
					<60	Ribstone Creek Member		
					<70	Victoria Member		McKay Coal Zone
					0-30	Brosseau Member		

Hydrogeological Maps

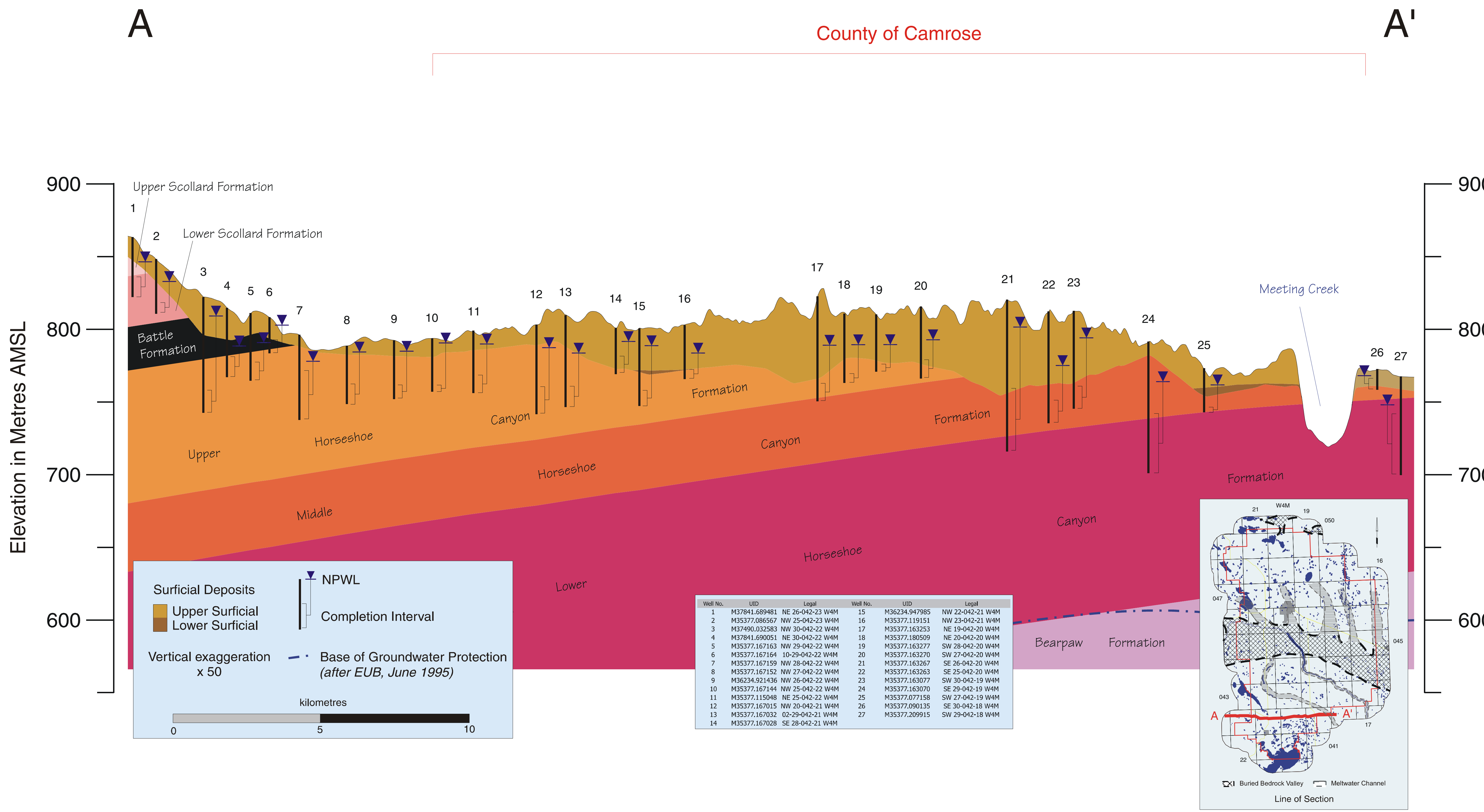


2004 Hydrogeological Consultants (HCL)



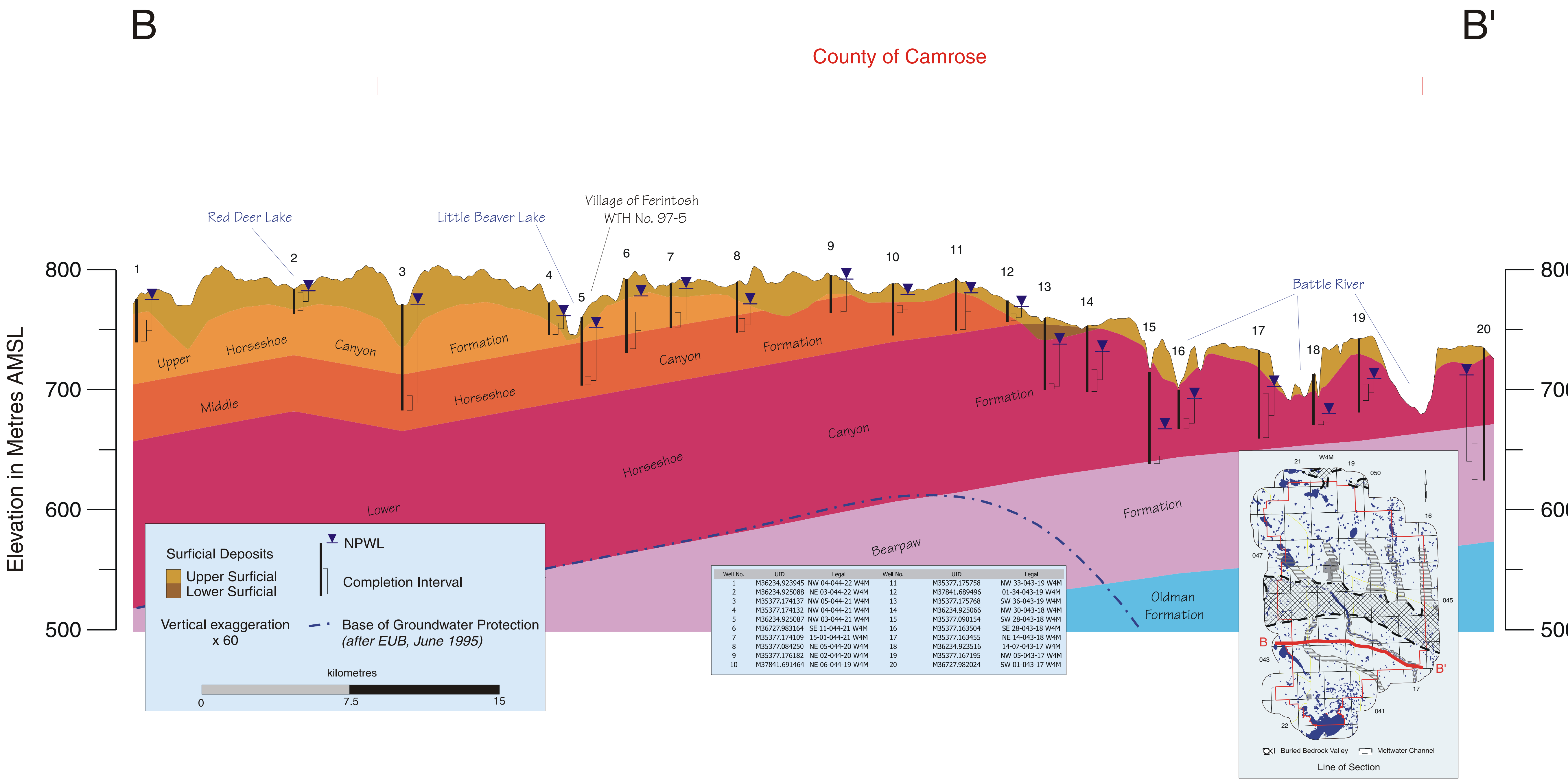
1971, 1979 Alberta Geological Survey

Cross-Section A - A'



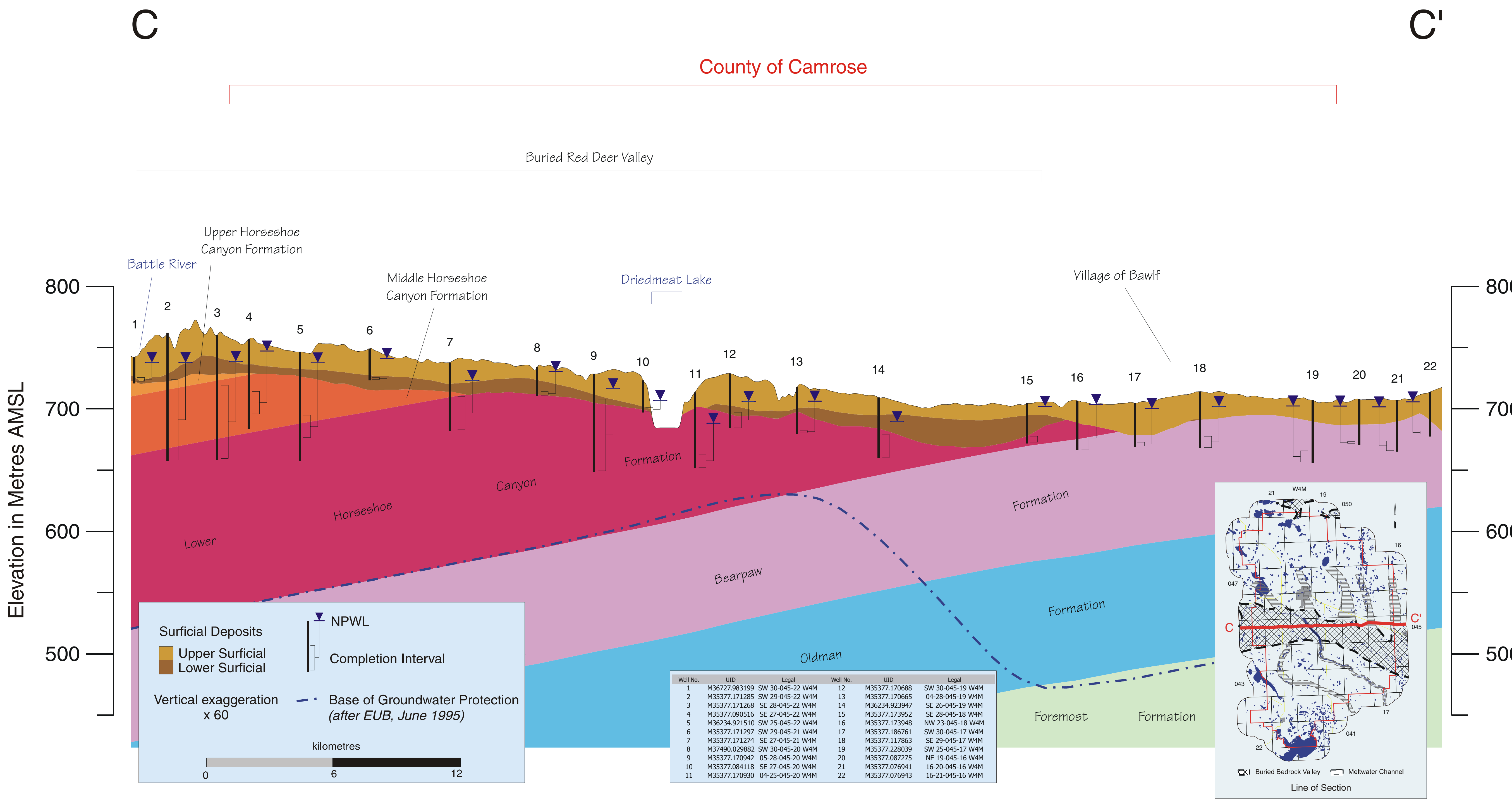
Well No.	UID	Legal	Well No.	UID	Legal
1	M37841.689481	NE 26-042-23 W4M	15	M36234.947985	NW 22-042-21 W4M
2	M35377.086567	NW 25-042-23 W4M	16	M35377.119151	NW 23-042-21 W4M
3	M37490.032583	NW 30-042-22 W4M	17	M35377.163253	NE 19-042-20 W4M
4	M37841.690051	NE 30-042-22 W4M	18	M35377.180509	NE 20-042-20 W4M
5	M35377.167163	NW 29-042-22 W4M	19	M35377.163277	SW 28-042-20 W4M
6	M35377.167164	10-29-042-22 W4M	20	M35377.163270	SW 27-042-20 W4M
7	M35377.167159	NW 28-042-22 W4M	21	M35377.163267	SE 26-042-20 W4M
8	M35377.167152	NW 27-042-22 W4M	22	M35377.163263	SE 25-042-20 W4M
9	M36234.921436	NW 26-042-22 W4M	23	M35377.163077	SW 30-042-19 W4M
10	M35377.167144	NW 25-042-22 W4M	24	M35377.163070	SE 29-042-19 W4M
11	M35377.115048	NE 25-042-22 W4M	25	M35377.077158	SW 27-042-19 W4M
12	M35377.167015	NW 20-042-21 W4M	26	M35377.090135	SE 30-042-18 W4M
13	M35377.167032	02-29-042-21 W4M	27	M35377.209915	SW 29-042-18 W4M
14	M35377.167028	SE 28-042-21 W4M			

Cross-Section B - B'



Well No.	UID	Legal	Well No.	UID	Legal
1	M36234.923945	NW 04-044-22 W4M	11	M35377.175758	NW 33-043-19 W4M
2	M36234.925088	NE 03-044-22 W4M	12	M37841.689496	01-34-043-19 W4M
3	M35377.174137	NW 05-044-21 W4M	13	M35377.175768	SW 36-043-19 W4M
4	M35377.174132	NW 04-044-21 W4M	14	M36234.925066	NW 30-043-18 W4M
5	M36234.925087	NW 03-044-21 W4M	15	M35377.090154	SW 28-043-18 W4M
6	M36727.983164	SE 11-044-21 W4M	16	M35377.163504	SE 28-043-18 W4M
7	M35377.174109	15-01-044-21 W4M	17	M35377.163455	NE 14-043-18 W4M
8	M35377.084250	NE 05-044-20 W4M	18	M36234.923516	14-07-043-17 W4M
9	M35377.176182	NE 02-044-20 W4M	19	M35377.167195	NW 05-043-17 W4M
10	M37841.691464	NE 06-044-19 W4M	20	M36727.982024	SW 01-043-17 W4M

Cross-Section C - C'



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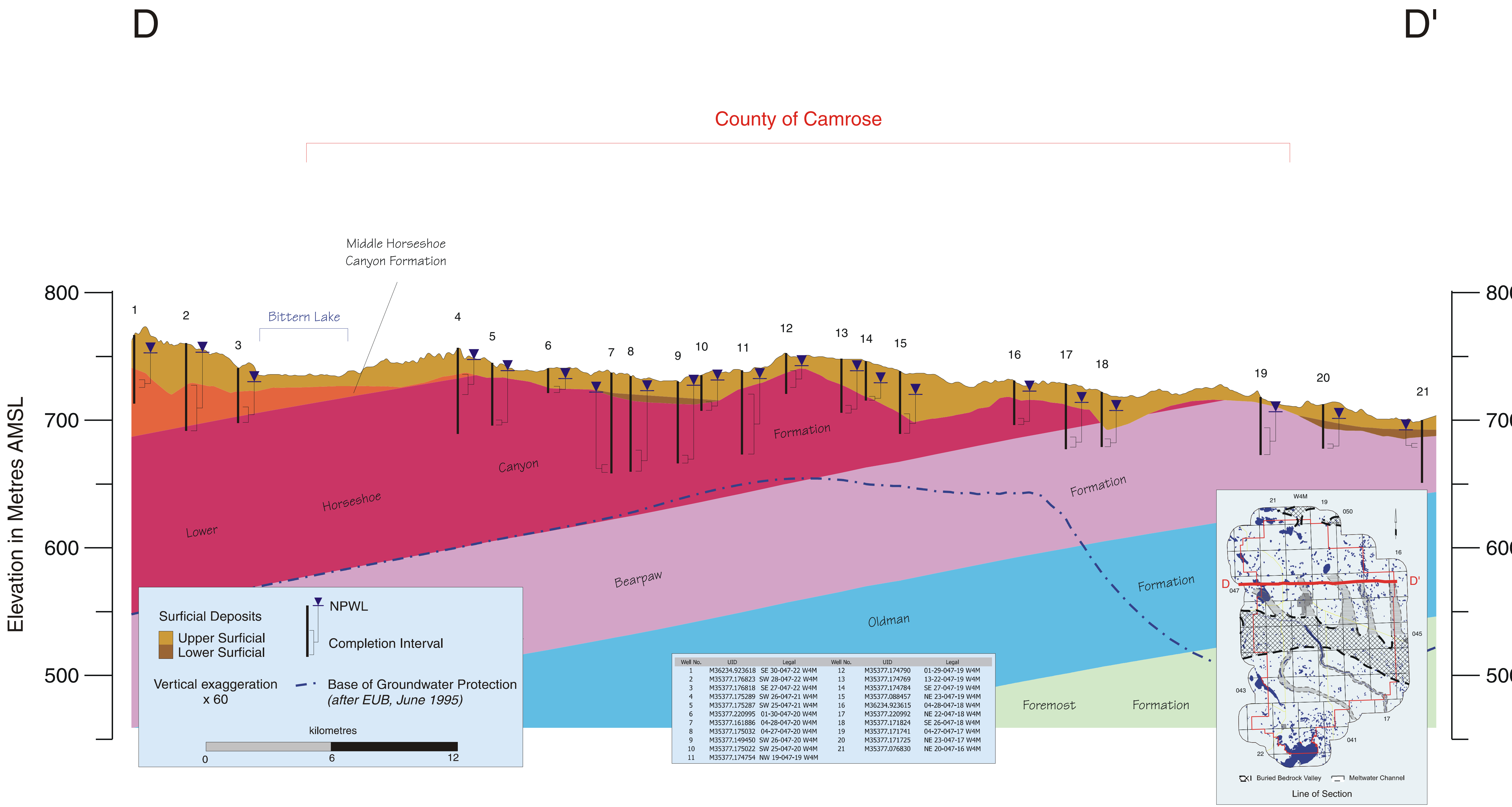
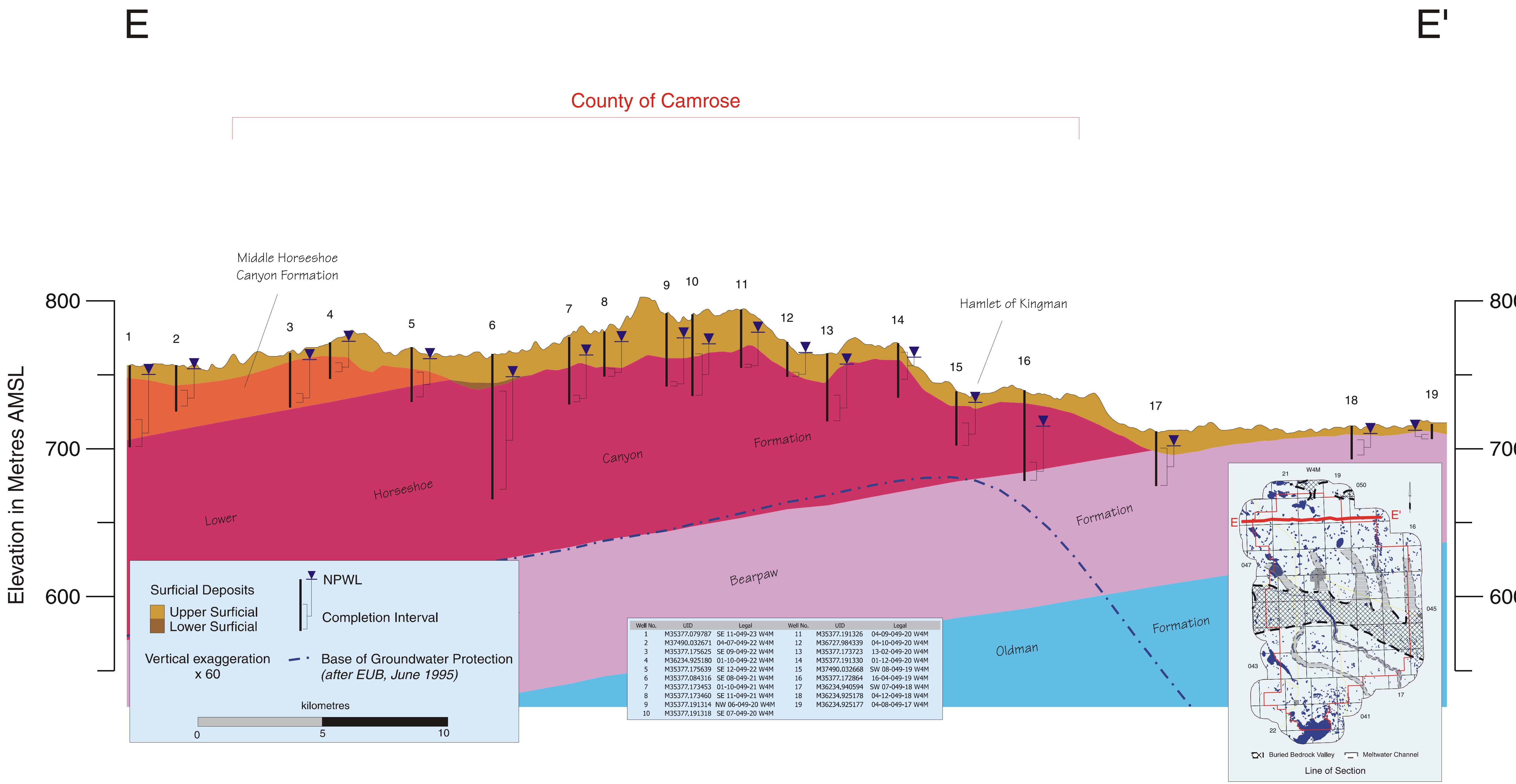
1	M36727.983199	SW 30-045-22 W4M	12	M35377.170688	SW 30-045-19 W4M
2	M35377.171285	SW 29-045-22 W4M	13	M35377.170665	04-28-045-19 W4M
3	M35377.171268	SE 28-045-22 W4M	14	M36234.923947	SE 26-045-19 W4M
4	M35377.090516	SE 27-045-22 W4M	15	M35377.173952	SE 28-045-18 W4M
5	M36234.921510	SW 25-045-22 W4M	16	M35377.173948	NW 23-045-18 W4M
6	M35377.171297	SW 29-045-21 W4M	17	M35377.186761	SW 30-045-17 W4M
7	M35377.171274	SE 27-045-21 W4M	18	M35377.117863	SE 29-045-17 W4M
8	M37490.029882	SW 30-045-20 W4M	19	M35377.228039	SW 25-045-17 W4M
9	M35377.170942	05-28-045-20 W4M	20	M35377.087275	NE 19-045-16 W4M
10	M35377.084118	SE 27-045-20 W4M	21	M35377.076941	16-20-045-16 W4M
11	M35377.170930	04-25-045-20 W4M	22	M35377.076943	16-21-045-16 W4M

Cross-Section D - D'



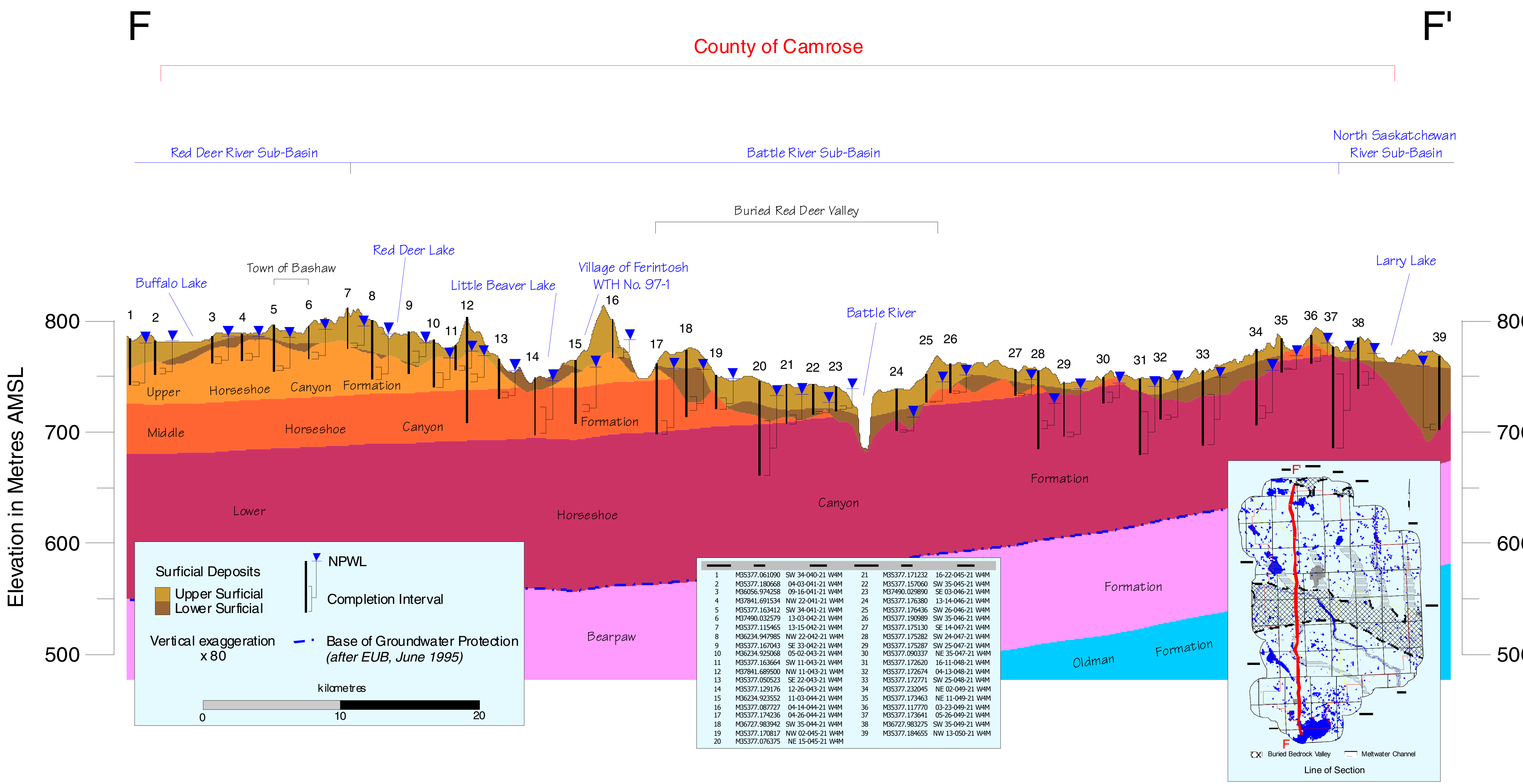
Well No.	UID	Legal	Well No.	UID	Legal
1	M36234.923618	SE 30-047-22 W4M	12	M35377.174790	01-29-047-19 W4M
2	M35377.176823	SW 28-047-22 W4M	13	M35377.174769	13-22-047-19 W4M
3	M35377.176818	SE 27-047-22 W4M	14	M35377.174784	SE 27-047-19 W4M
4	M35377.175289	SW 26-047-21 W4M	15	M35377.088457	NE 23-047-19 W4M
5	M35377.175287	SW 25-047-21 W4M	16	M36234.923615	04-28-047-18 W4M
6	M35377.220995	01-30-047-20 W4M	17	M35377.220992	NE 22-047-18 W4M
7	M35377.161886	04-28-047-20 W4M	18	M35377.171824	SE 26-047-18 W4M
8	M35377.175032	04-27-047-20 W4M	19	M35377.171741	04-27-047-17 W4M
9	M35377.149450	SW 26-047-20 W4M	20	M35377.171725	NE 23-047-17 W4M
10	M35377.175022	SW 25-047-20 W4M	21	M35377.076830	NE 20-047-16 W4M
11	M35377.174754	NW 19-047-19 W4M			

Cross-Section E - E'



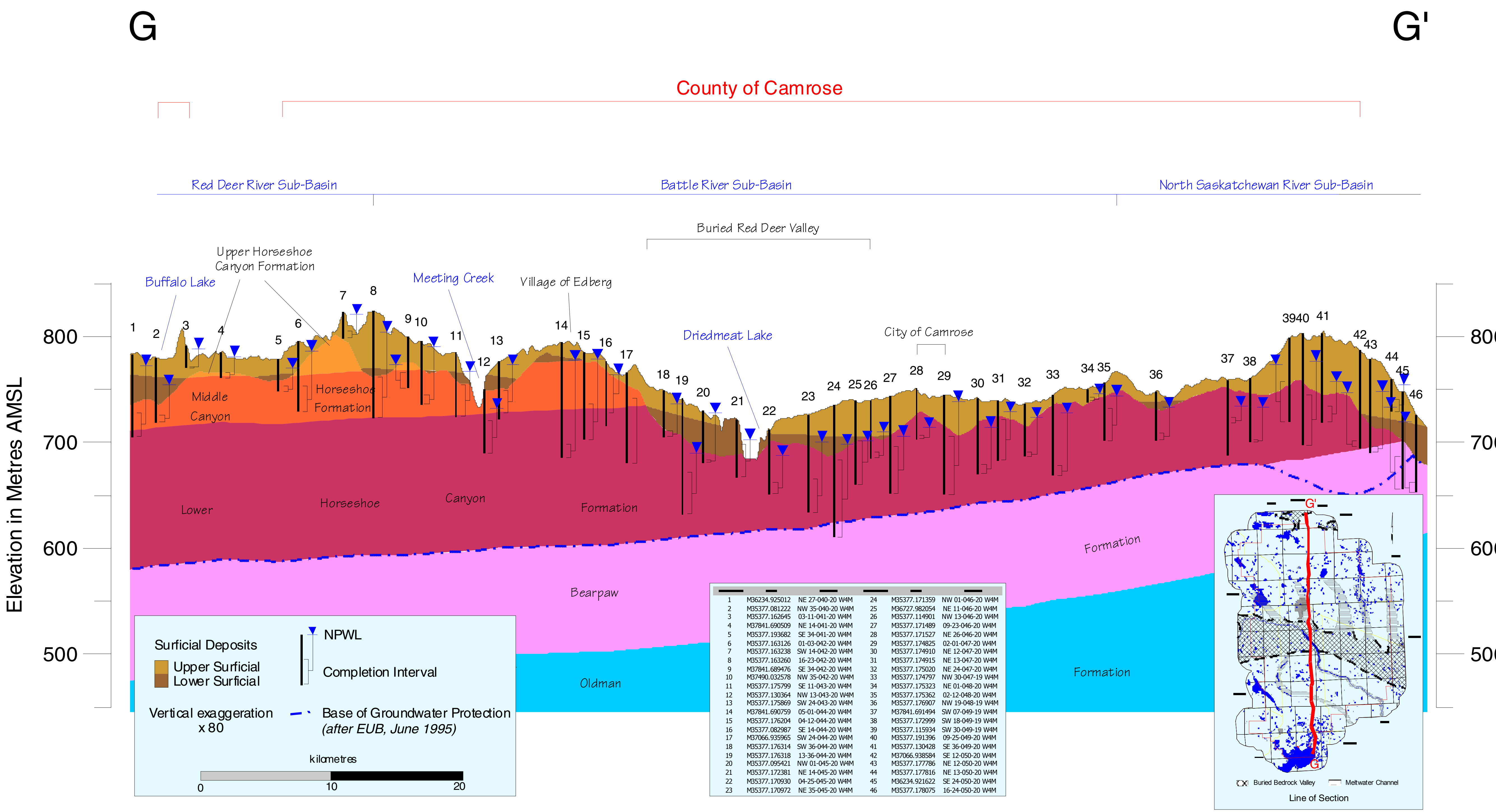
Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.079787	SE 11-049-23 W4M	11	M35377.191326	04-09-049-20 W4M
2	M37490.032671	04-07-049-22 W4M	12	M36727.984339	04-10-049-20 W4M
3	M35377.175625	SE 09-049-22 W4M	13	M35377.173723	13-02-049-20 W4M
4	M36234.925180	01-10-049-22 W4M	14	M35377.191330	01-12-049-20 W4M
5	M35377.175639	SE 12-049-22 W4M	15	M37490.032668	SW 08-049-19 W4M
6	M35377.084316	SE 08-049-21 W4M	16	M35377.172864	16-04-049-19 W4M
7	M35377.173453	01-10-049-21 W4M	17	M36234.940594	SW 07-049-18 W4M
8	M35377.173460	SE 11-049-21 W4M	18	M36234.925178	04-12-049-18 W4M
9	M35377.191314	NW 06-049-20 W4M	19	M36234.925177	04-08-049-17 W4M
10	M35377.191318	SE 07-049-20 W4M			

Cross-Section F - F'



[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
1	M35377.061090	SW 34-040-21 W4M	21	M35377.171232	16-22-045-21 W4M
2	M35377.180668	04-03-041-21 W4M	22	M35377.157060	SW 35-045-21 W4M
3	M36056.974258	09-16-041-21 W4M	23	M37490.029890	SE 03-046-21 W4M
4	M37841.691534	NW 22-041-21 W4M	24	M35377.176380	13-14-046-21 W4M
5	M35377.163412	SW 34-041-21 W4M	25	M35377.176436	SW 26-046-21 W4M
6	M37490.032579	13-03-042-21 W4M	26	M35377.190989	SW 35-046-21 W4M
7	M35377.115465	13-15-042-21 W4M	27	M35377.175130	SE 14-047-21 W4M
8	M36234.947985	NW 22-042-21 W4M	28	M35377.175282	SW 24-047-21 W4M
9	M35377.167043	SE 33-042-21 W4M	29	M35377.175287	SW 25-047-21 W4M
10	M36234.925068	05-02-043-21 W4M	30	M35377.090337	NE 35-047-21 W4M
11	M35377.163664	SW 11-043-21 W4M	31	M35377.172620	16-11-048-21 W4M
12	M37841.689500	NW 11-043-21 W4M	32	M35377.172674	04-13-048-21 W4M
13	M35377.050523	SE 22-043-21 W4M	33	M35377.172771	SW 25-048-21 W4M
14	M35377.129176	12-26-043-21 W4M	34	M35377.232045	NE 02-049-21 W4M
15	M36234.923552	11-03-044-21 W4M	35	M35377.173463	NE 11-049-21 W4M
16	M35377.087727	04-14-044-21 W4M	36	M35377.117770	03-23-049-21 W4M
17	M35377.174236	04-26-044-21 W4M	37	M35377.173641	05-26-049-21 W4M
18	M36727.983942	SW 35-044-21 W4M	38	M36727.983275	SW 35-049-21 W4M
19	M35377.170817	NW 02-045-21 W4M	39	M35377.184655	NW 13-050-21 W4M
20	M35377.076375	NE 15-045-21 W4M			

Cross-Section G - G'



1	M36234.925012	NE 27-040-20 W4M	24	M35377.171359	NW 01-046-20 W4M
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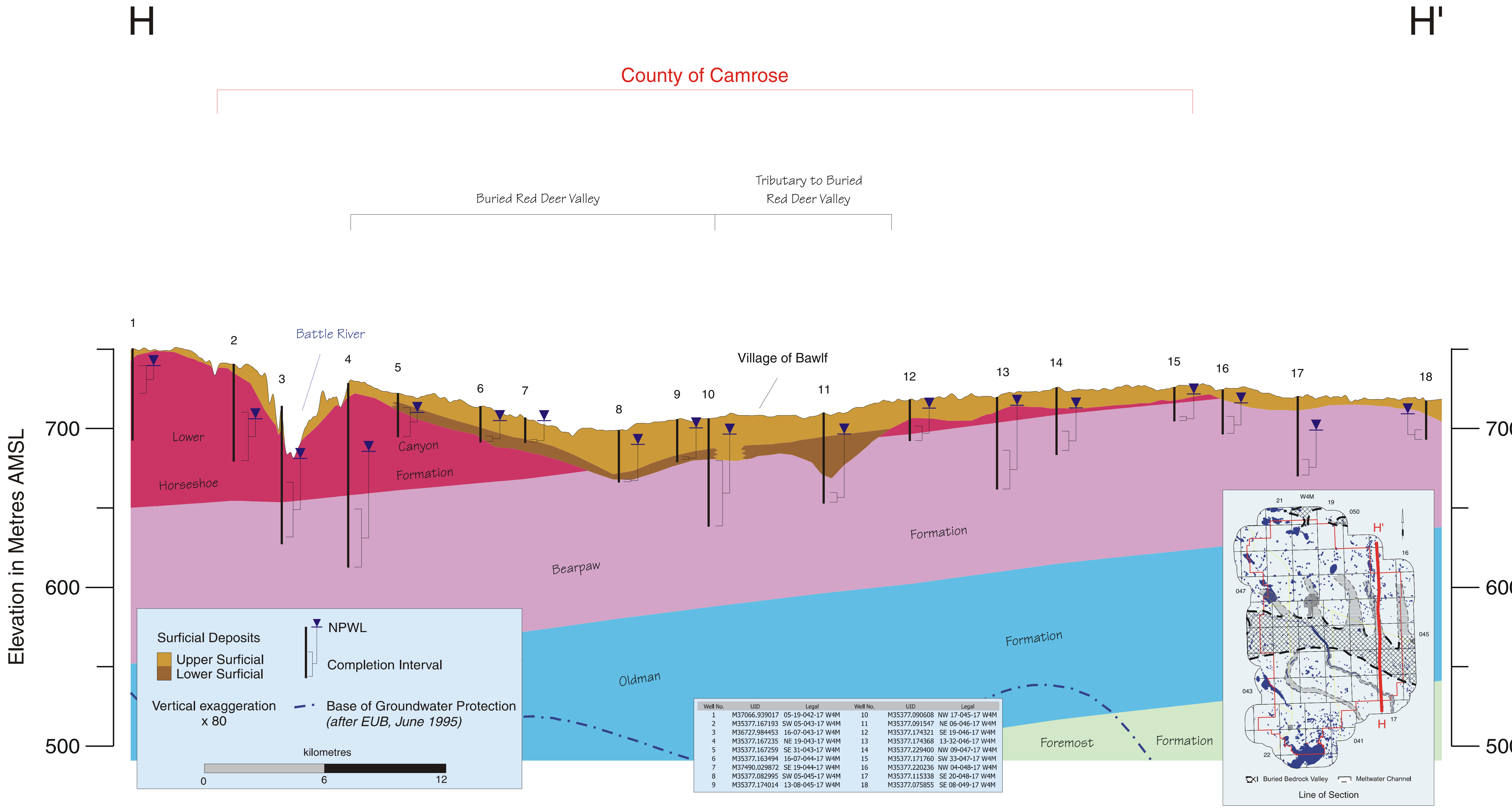
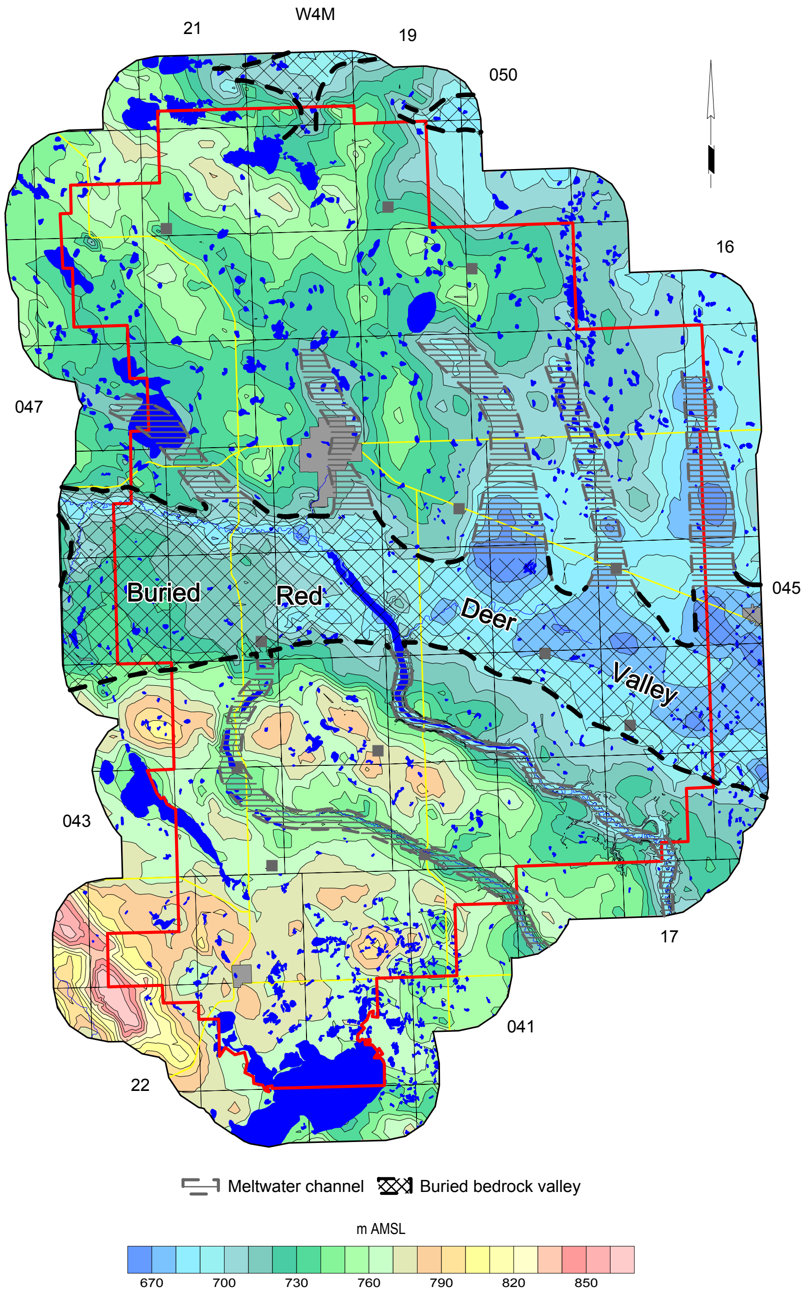
4	M37841.690509	NE 14-041-20 W4M	27	M35377.171489	09-23-046-20 W4M
5	M35377.193682	SE 34-041-20 W4M	28	M35377.171527	NE 26-046-20 W4M
6	M35377.163126	01-03-042-20 W4M	29	M35377.174825	02-01-047-20 W4M
7	M35377.163238	SW 14-042-20 W4M	30	M35377.174910	NE 12-047-20 W4M
8	M35377.163260	16-23-042-20 W4M	31	M35377.174915	NE 13-047-20 W4M
9	M37841.689476	SE 34-042-20 W4M	32	M35377.175020	NE 24-047-20 W4M
10	M37490.032578	NW 35-042-20 W4M	33	M35377.174797	NW 30-047-19 W4M
11	M35377.175799	SE 11-043-20 W4M	34	M35377.175323	NE 01-048-20 W4M
12	M35377.130364	NW 13-043-20 W4M	35	M35377.175362	02-12-048-20 W4M
13	M35377.175869	SW 24-043-20 W4M	36	M35377.176907	NW 19-048-19 W4M
14	M37841.690759	05-01-044-20 W4M	37	M37841.691494	SW 07-049-19 W4M
15	M35377.176204	04-12-044-20 W4M	38	M35377.172999	SW 18-049-19 W4M
16	M35377.082987	SE 14-044-20 W4M	39	M35377.115934	SW 30-049-19 W4M
17	M37066.935965	SW 24-044-20 W4M	40	M35377.191396	09-25-049-20 W4M
18	M35377.176314	SW 36-044-20 W4M	41	M35377.130428	SE 36-049-20 W4M
19	M35377.176318	13-36-044-20 W4M	42	M37066.938584	SE 12-050-20 W4M
20	M35377.095421	NW 01-045-20 W4M	43	M35377.177786	NE 12-050-20 W4M
21	M35377.172381	NE 14-045-20 W4M	44	M35377.177816	NE 13-050-20 W4M
22	M35377.170930	04-25-045-20 W4M	45	M36234.921622	SE 24-050-20 W4M
23	M35377.170972	NE 35-045-20 W4M	46	M35377.178075	16-24-050-20 W4M

Cross-Section H - H'

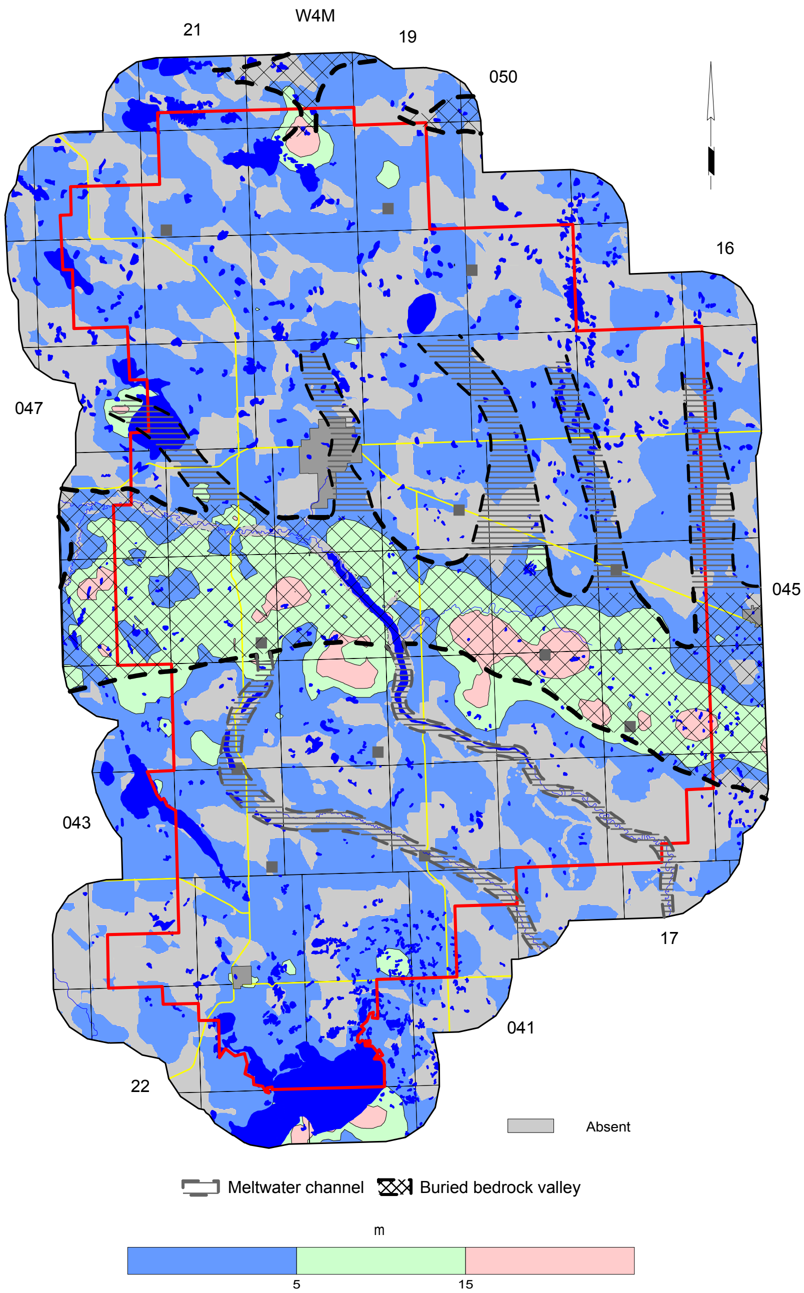


Well No.	UID	Legal	Well No.	UID	Legal
1	M37066.939017	05-19-042-17 W4M	10	M35377.090608	NW 17-045-17 W4M
2	M35377.167193	SW 05-043-17 W4M	11	M35377.091547	NE 06-046-17 W4M
3	M36727.984453	16-07-043-17 W4M	12	M35377.174321	SE 19-046-17 W4M
4	M35377.167235	NE 19-043-17 W4M	13	M35377.174368	13-32-046-17 W4M
5	M35377.167259	SE 31-043-17 W4M	14	M35377.229400	NW 09-047-17 W4M
6	M35377.163494	16-07-044-17 W4M	15	M35377.171760	SW 33-047-17 W4M
7	M37490.029872	SE 19-044-17 W4M	16	M35377.220236	NW 04-048-17 W4M
8	M35377.082995	SW 05-045-17 W4M	17	M35377.115338	SE 20-048-17 W4M
9	M35377.174014	13-08-045-17 W4M	18	M35377.075855	SE 08-049-17 W4M

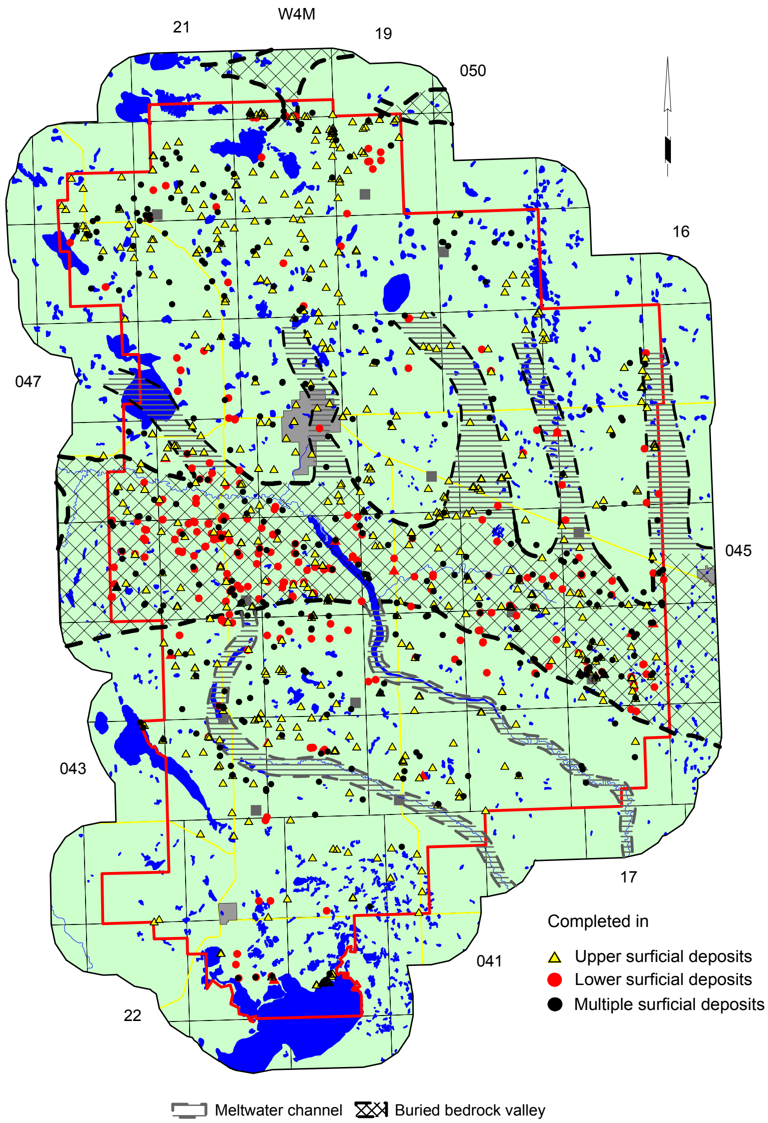
Bedrock Topography



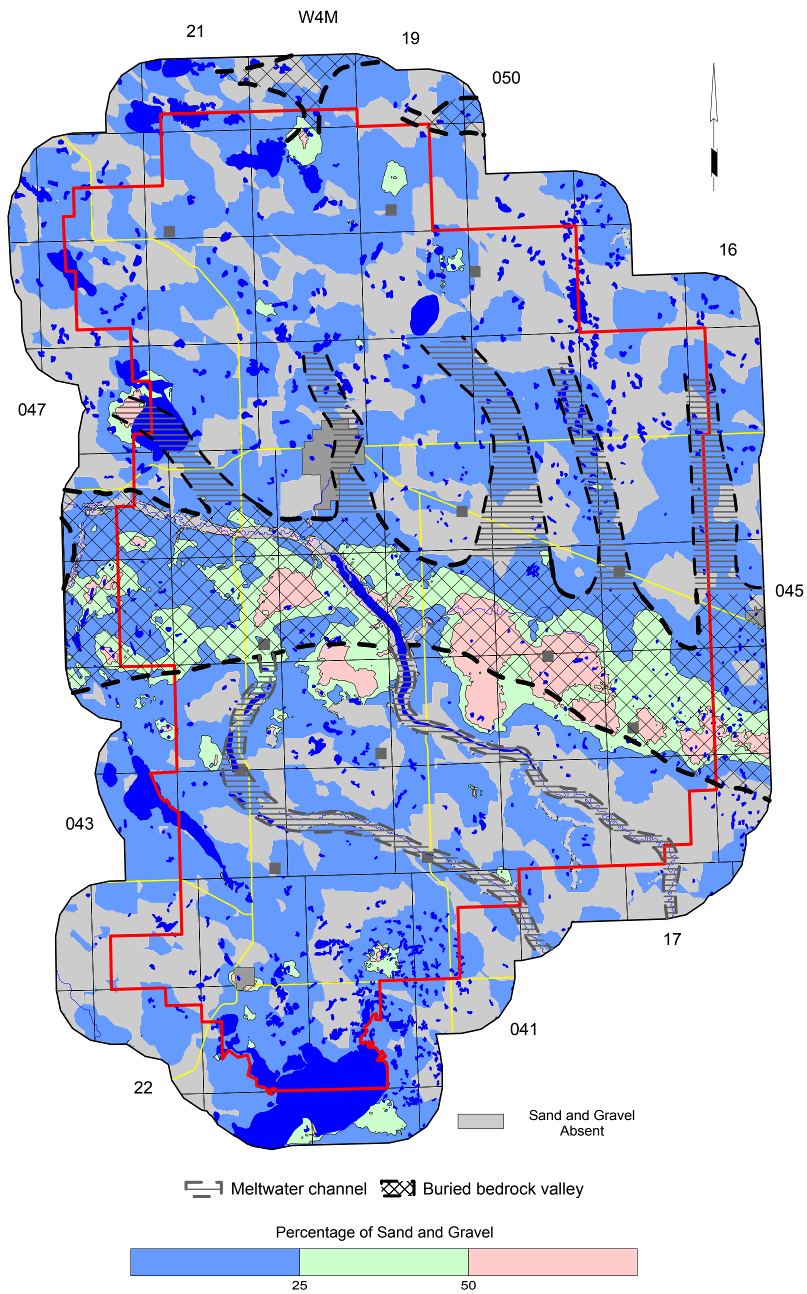
Thickness of Sand and Gravel Deposits



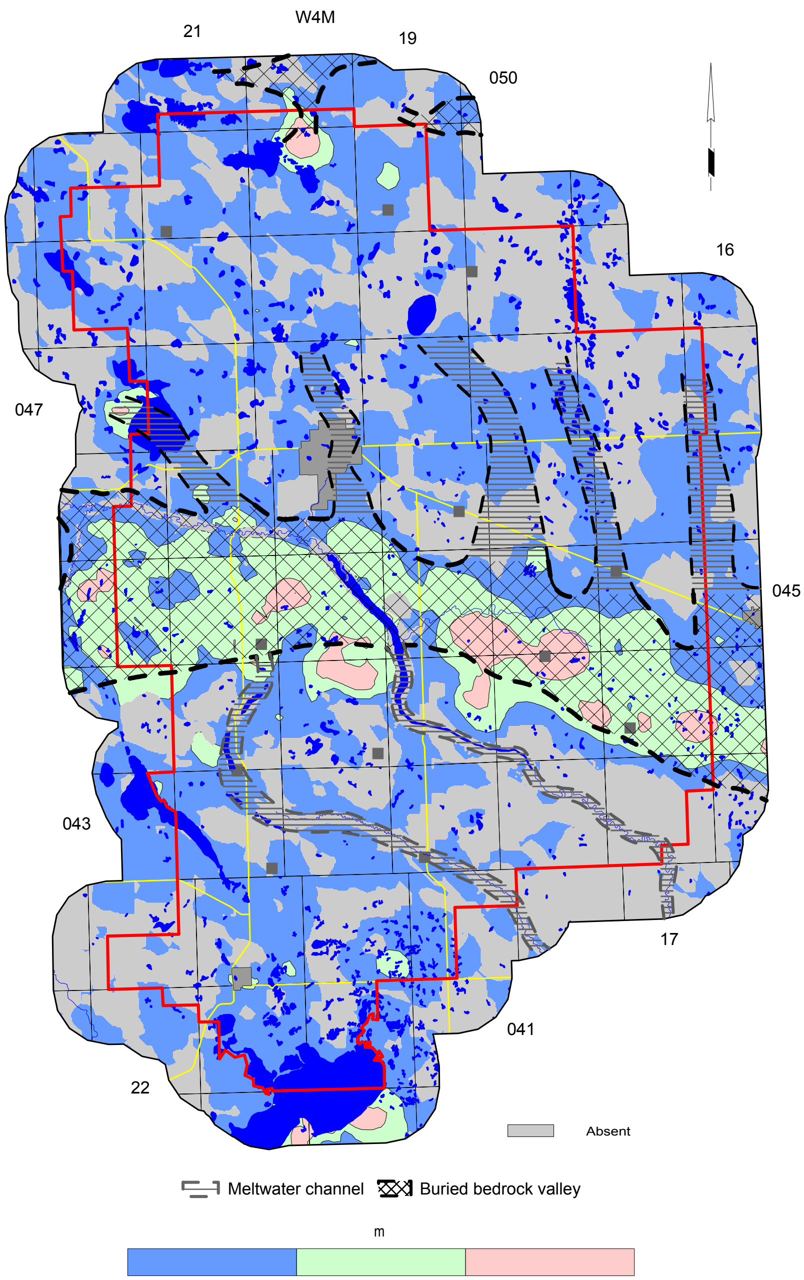
Water Wells Completed In Surficial Deposits



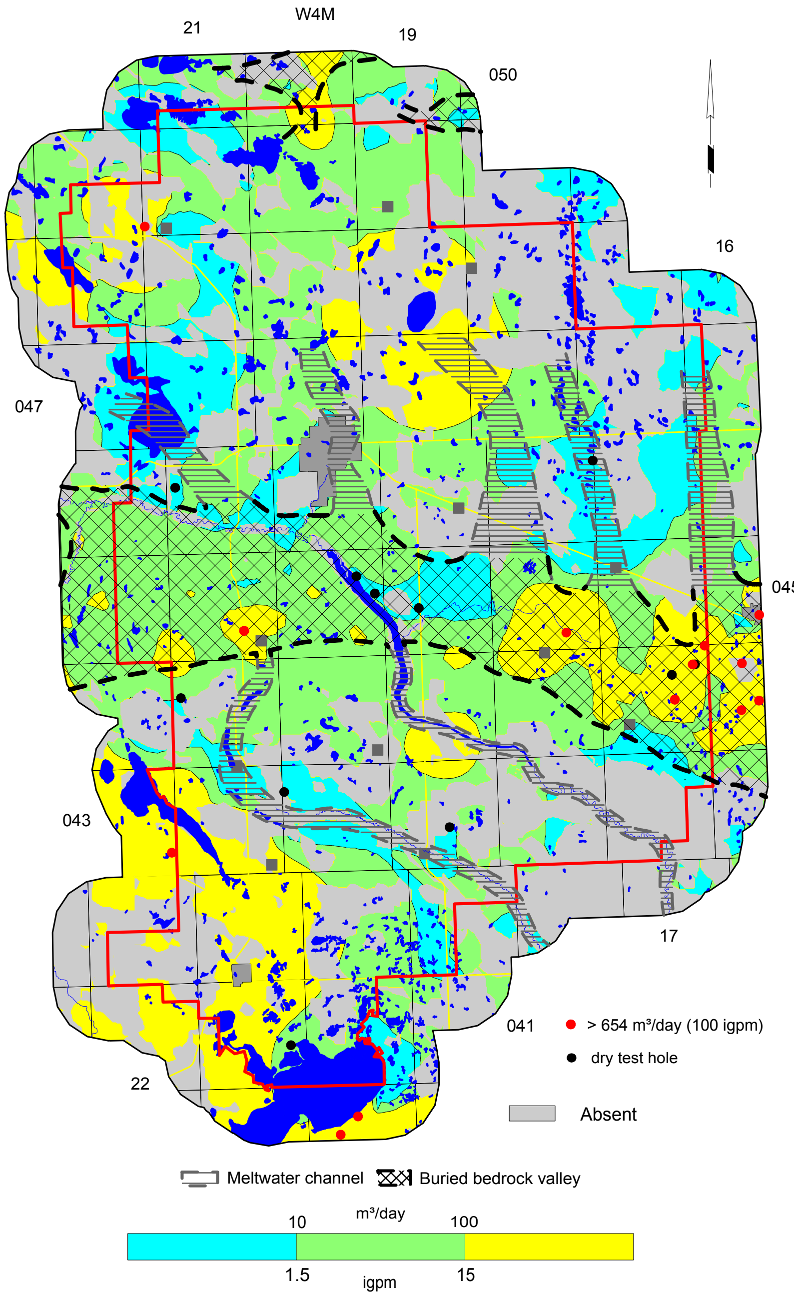
Amount of Sand and Gravel in Surficial Deposits



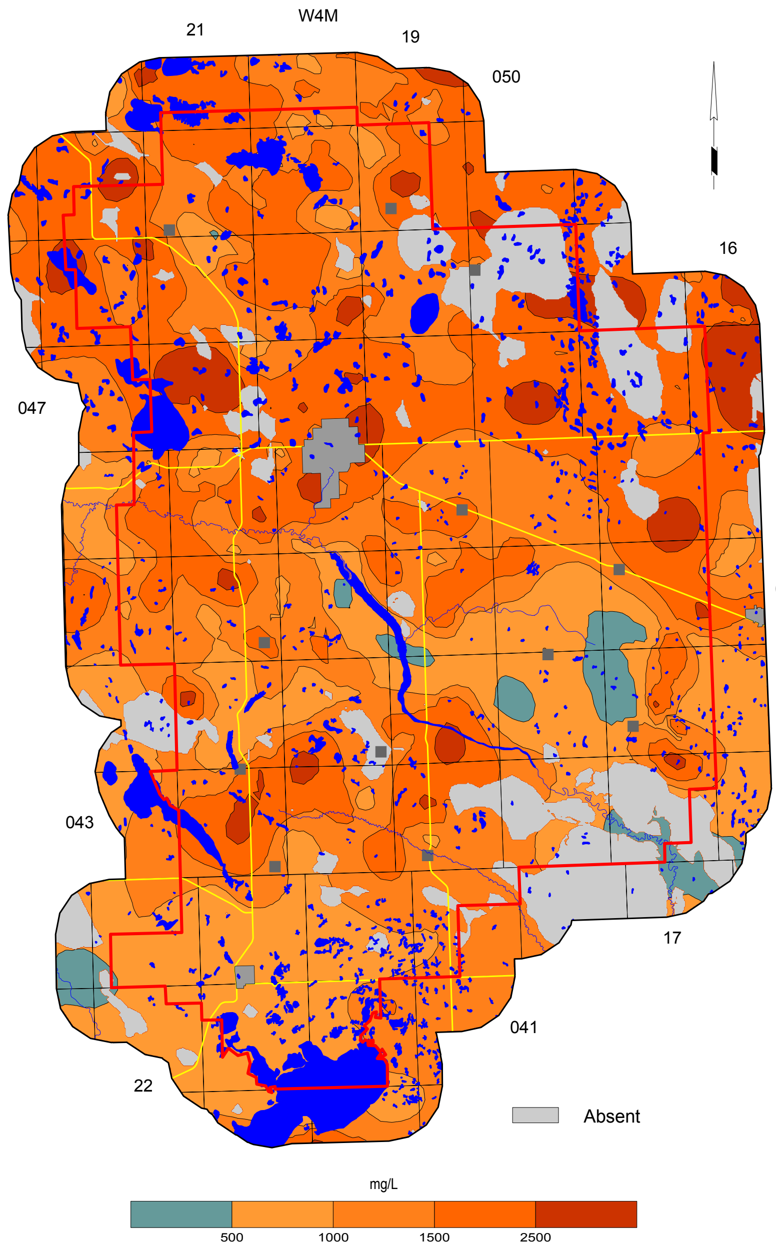
Thickness of Sand and Gravel Aquifer(s)



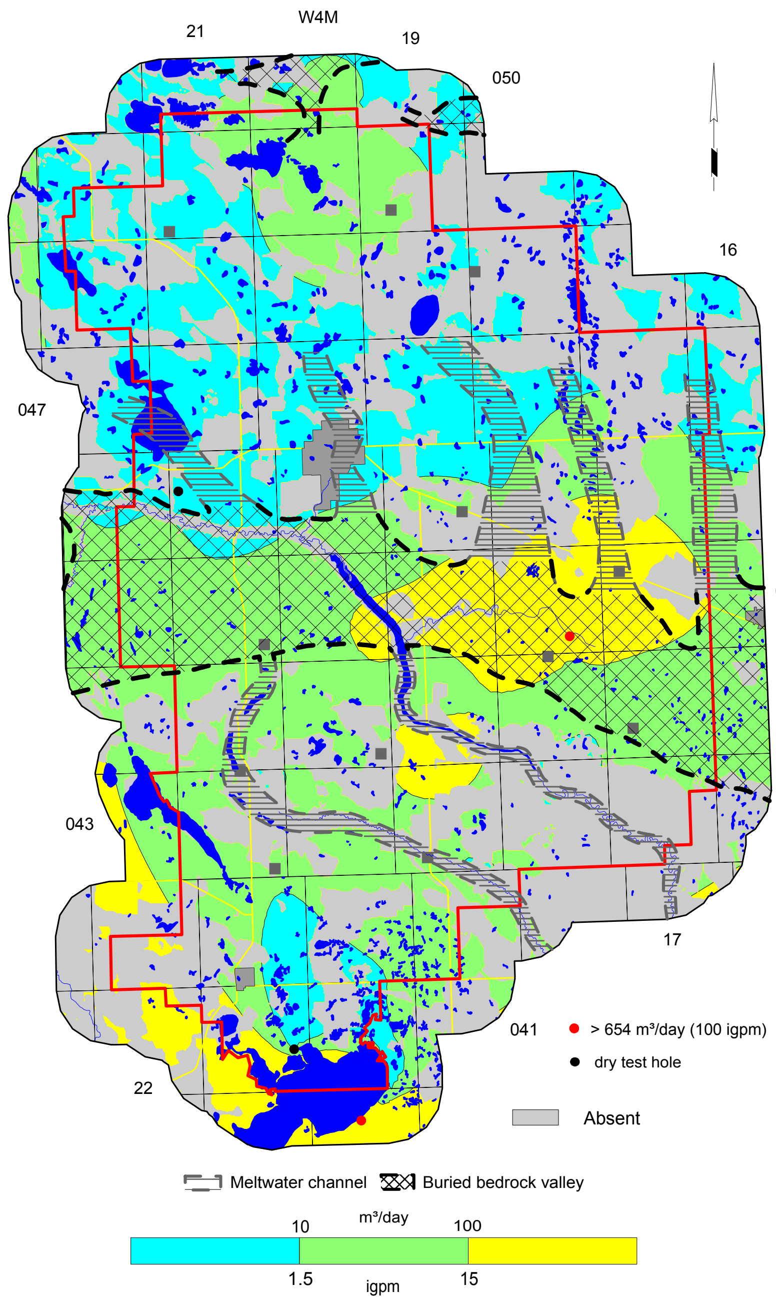
Apparent Yield of Water Wells Completed in Sand and Gravel Aquifer(s)



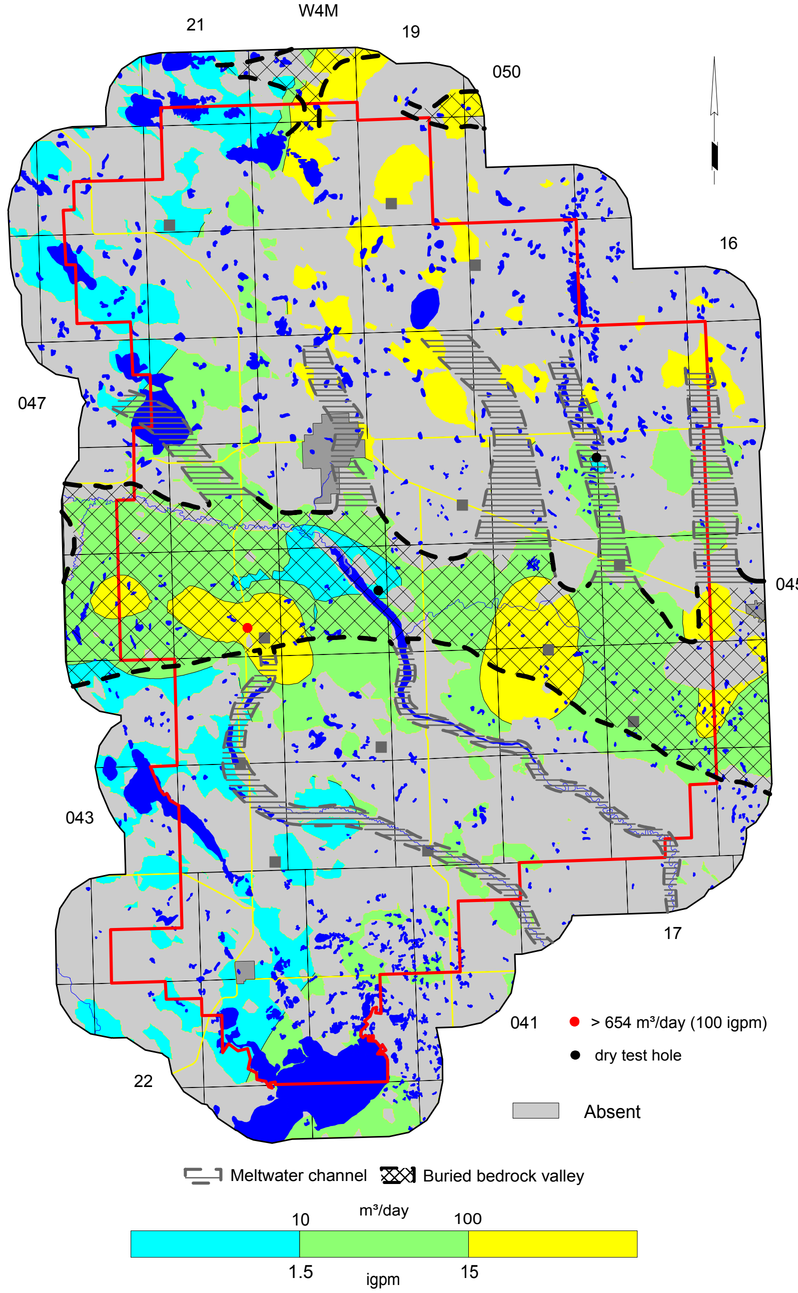
Total Dissolved Solids in Groundwater from Surficial Deposits



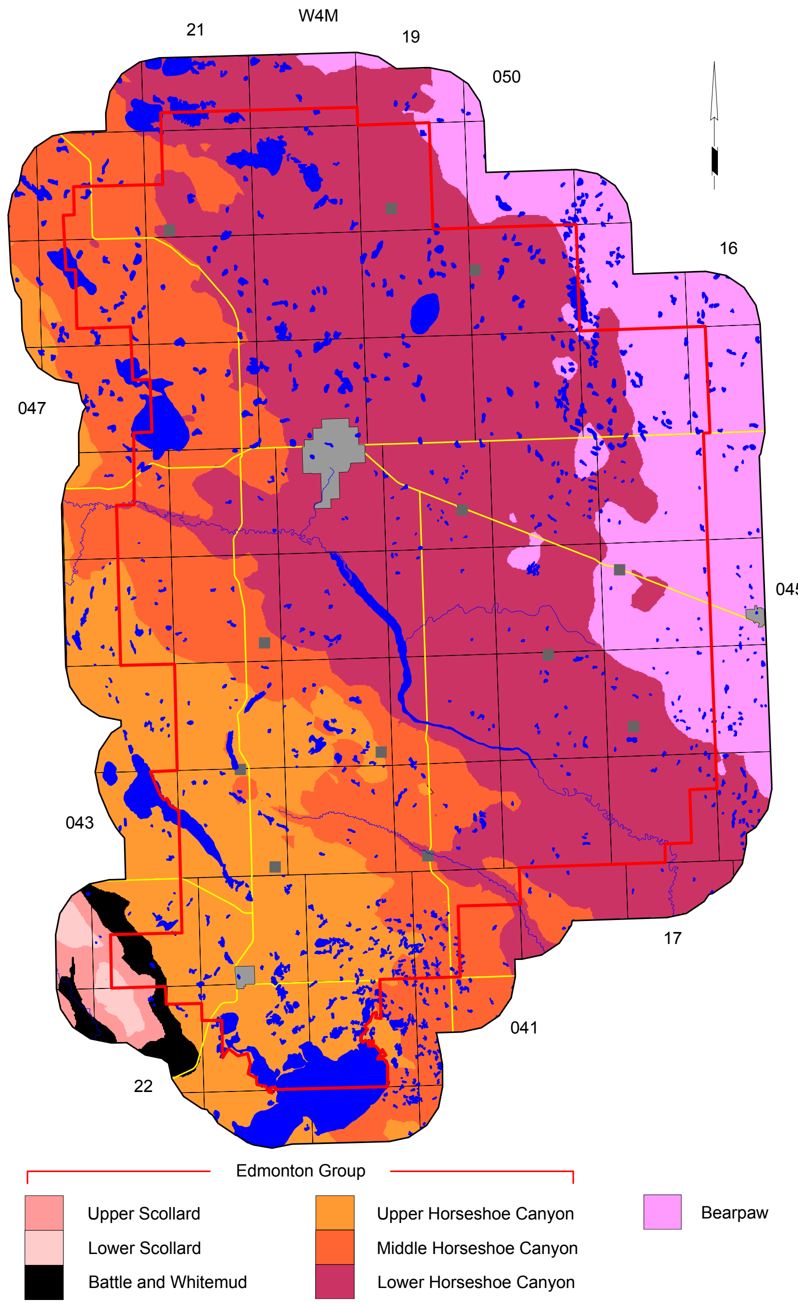
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



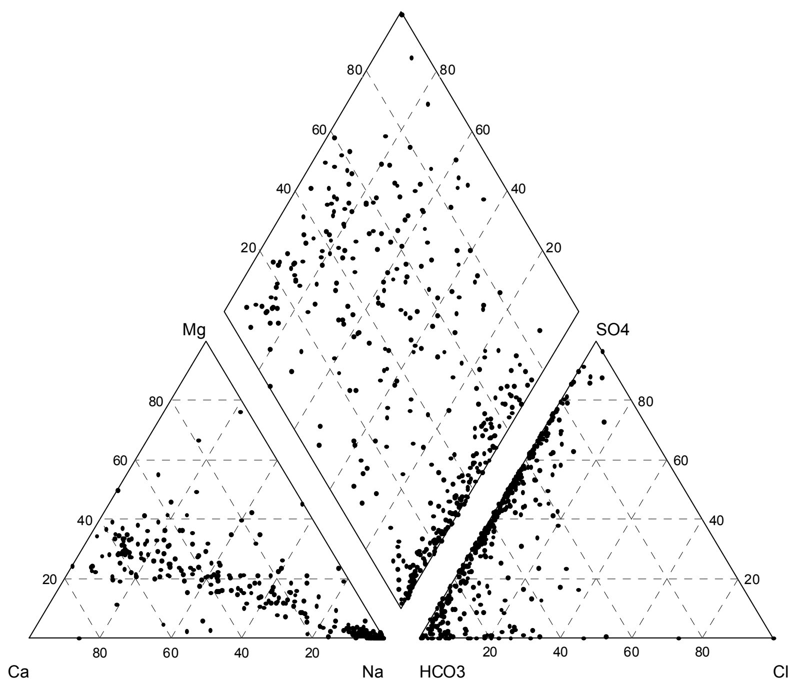
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



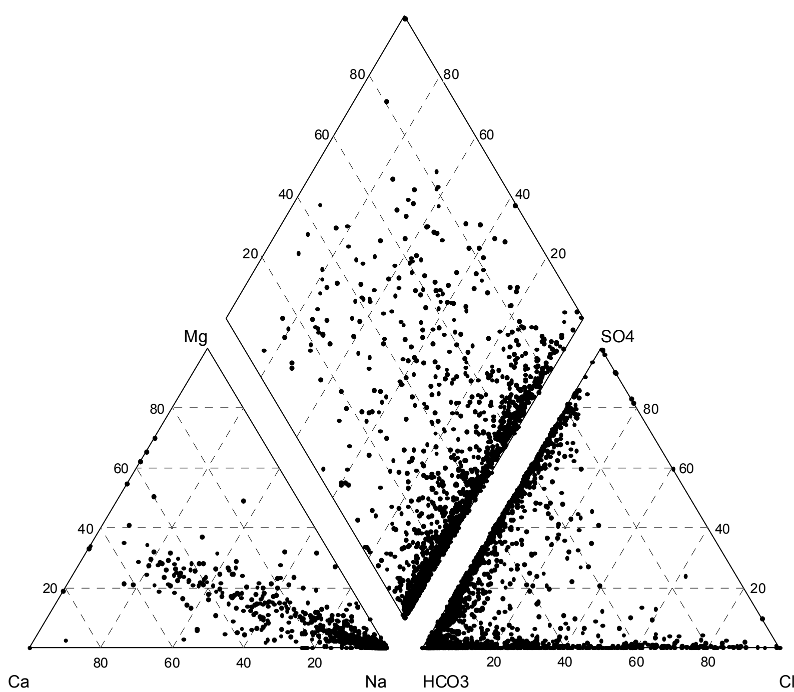
Bedrock Geology



Piper Diagrams

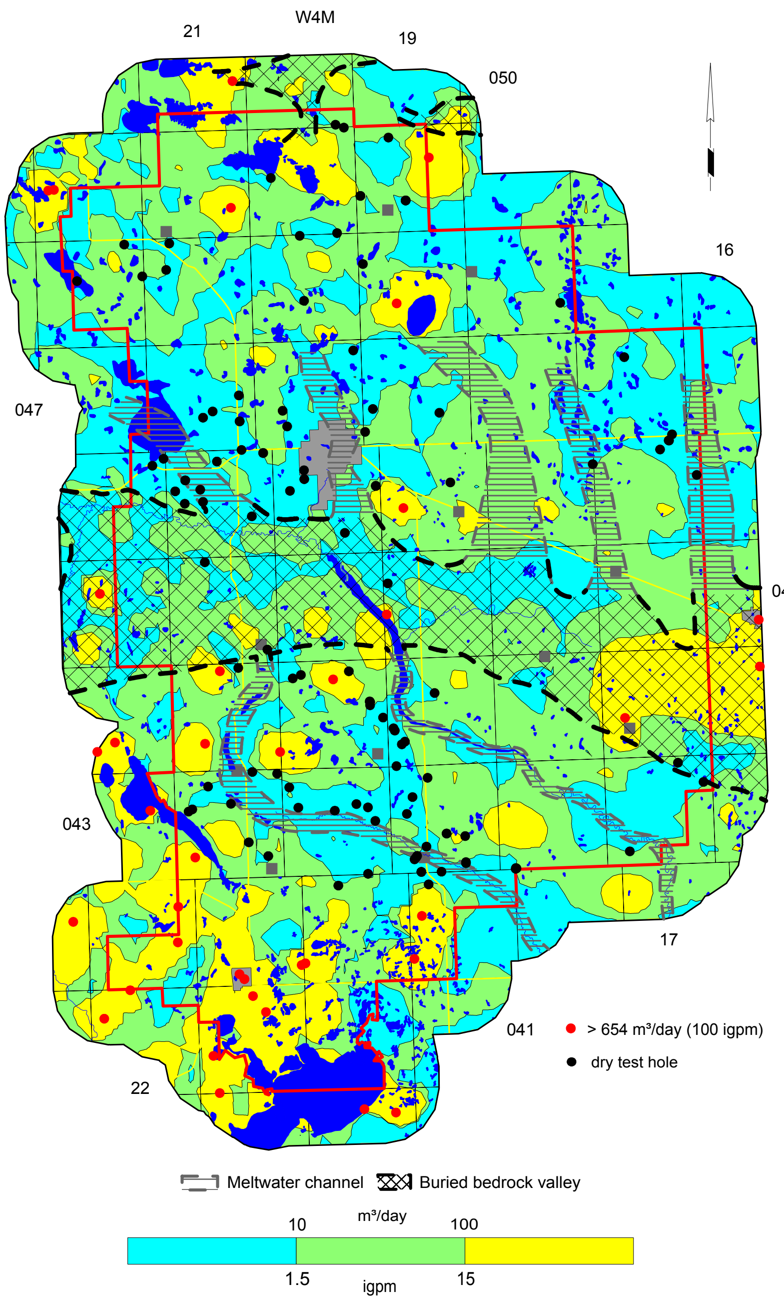


Surficial Deposits

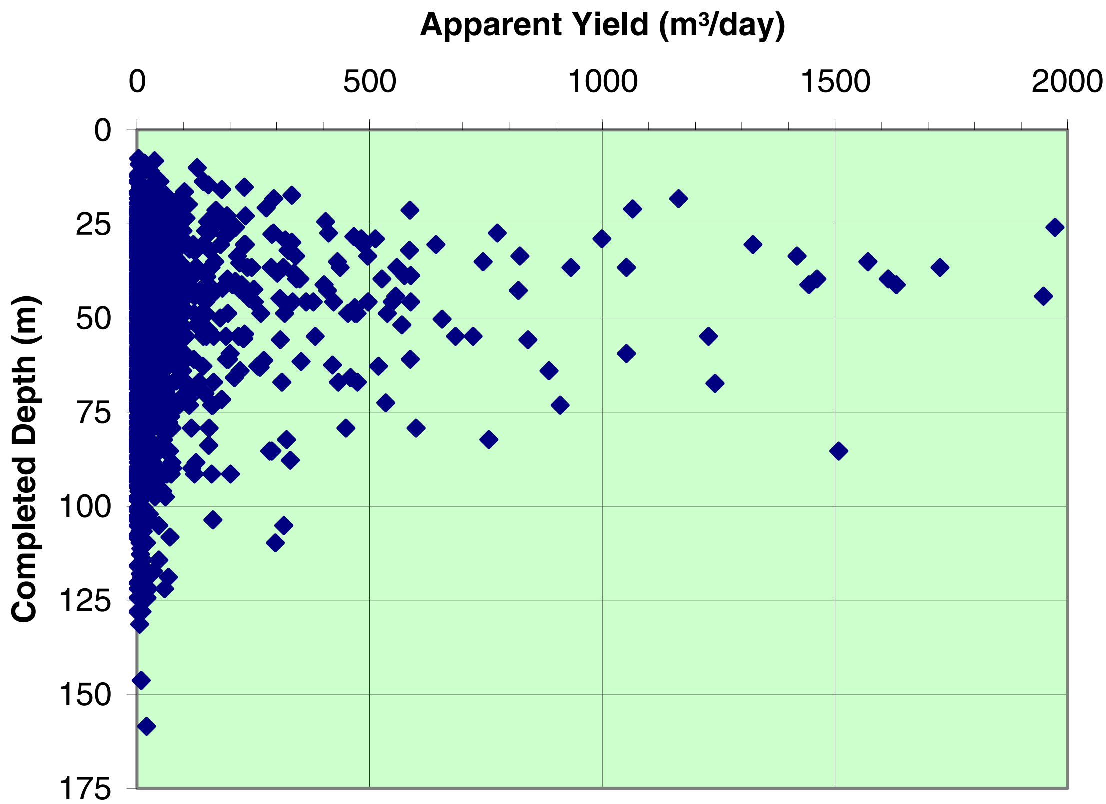


Bedrock Aquifers

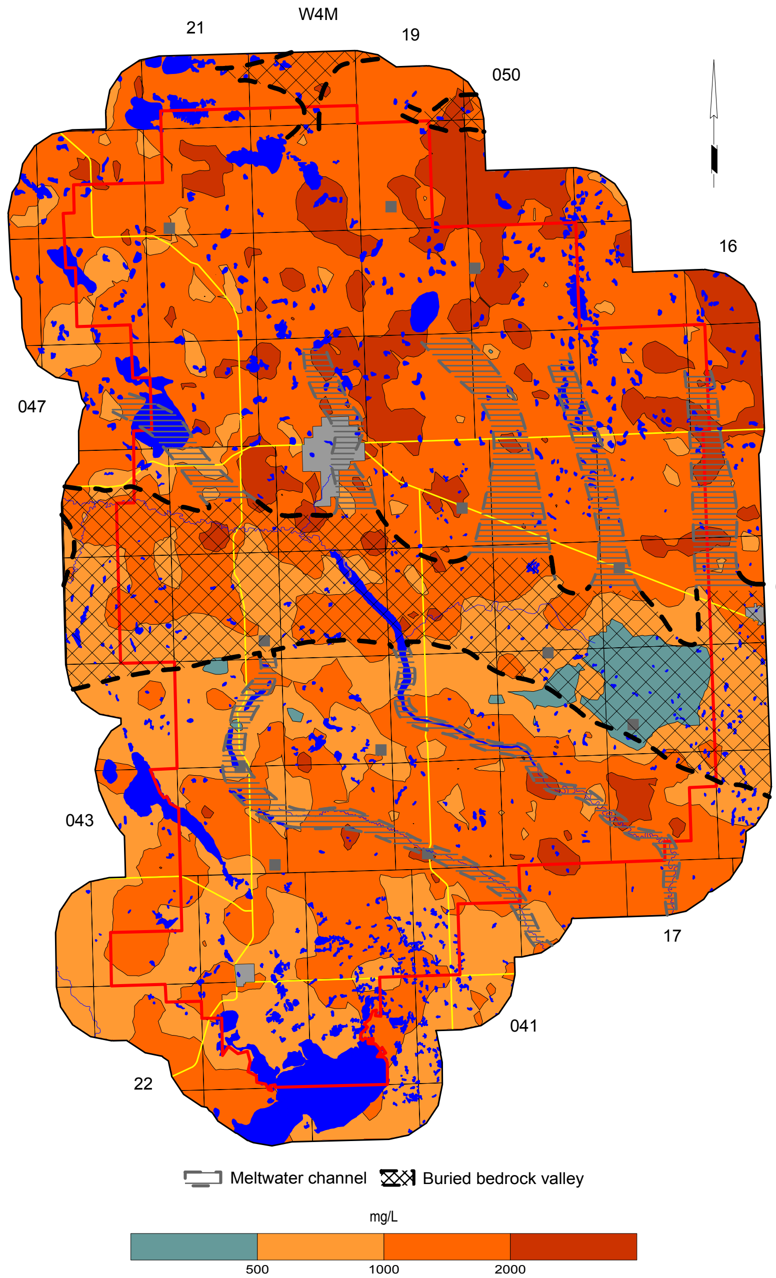
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



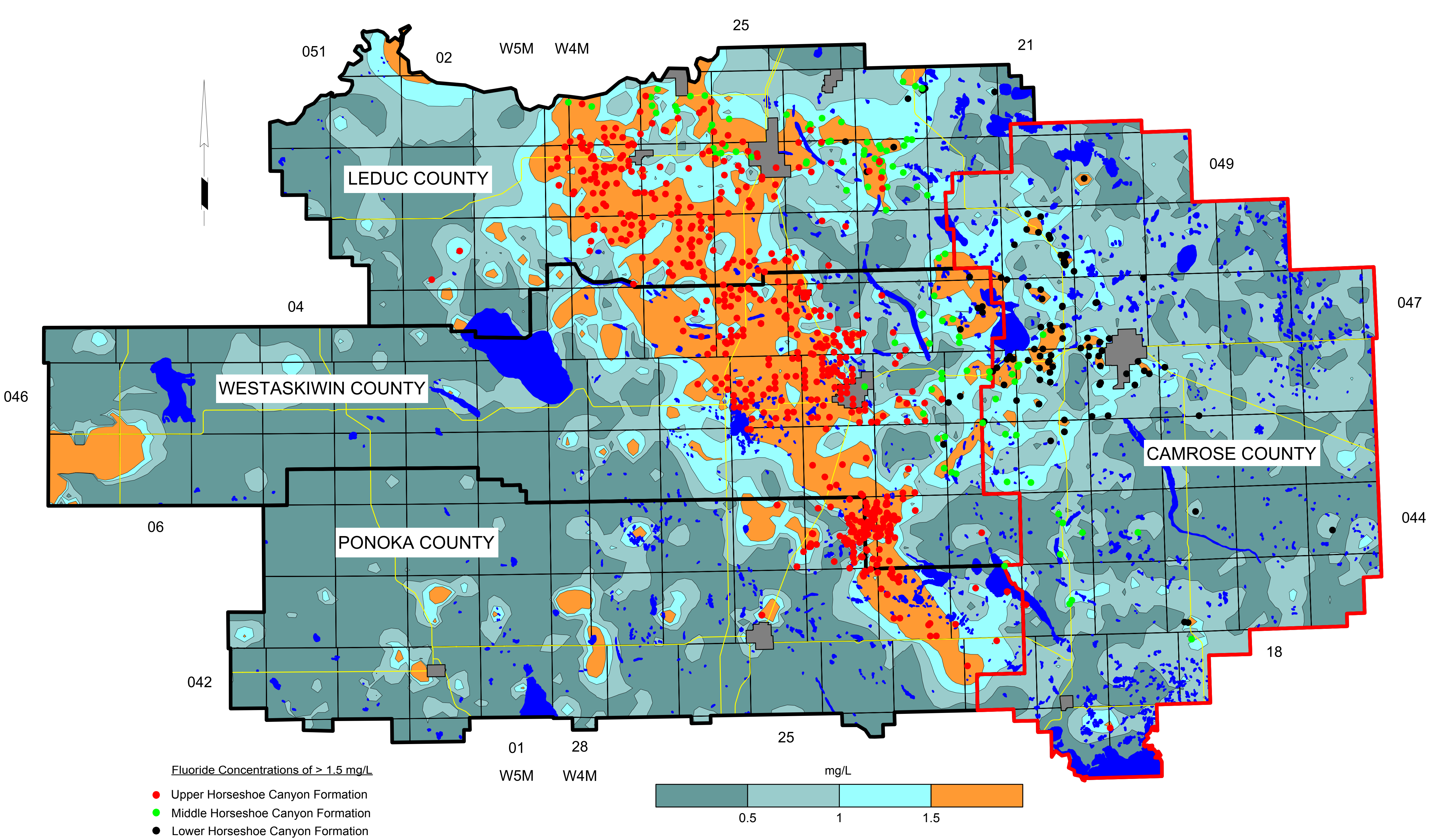
Bedrock Water Well Yields vs Completed Depth



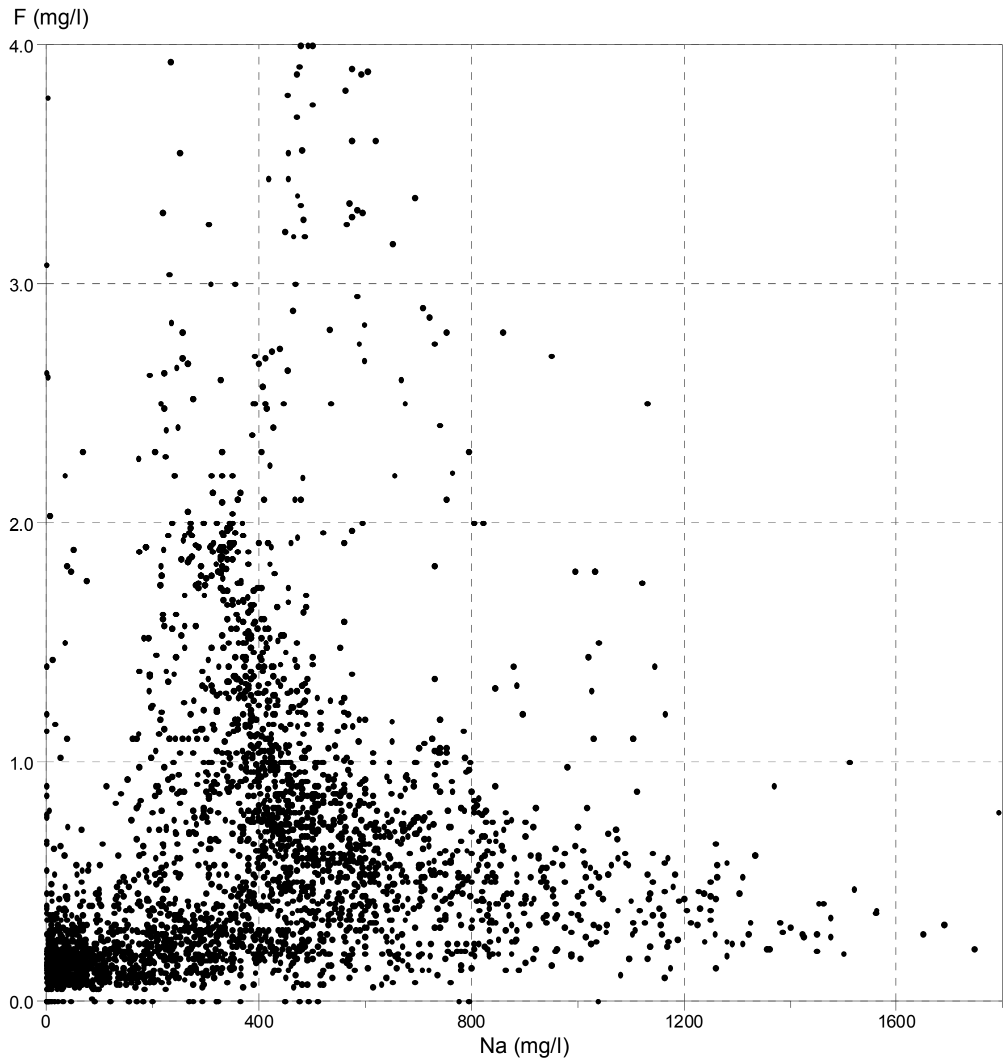
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



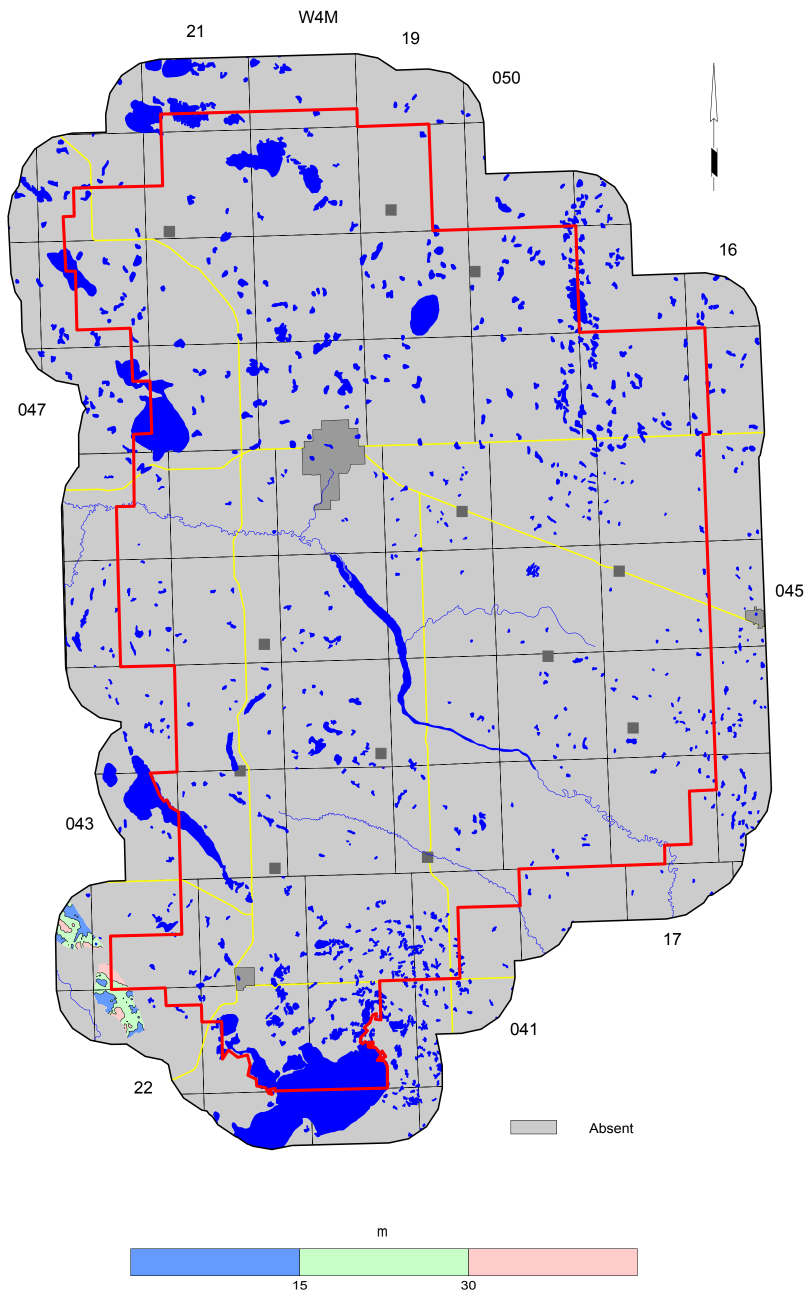
Fluoride in Groundwater from Upper Bedrock Aquifer(s) in Camrose County and Surrounding Counties



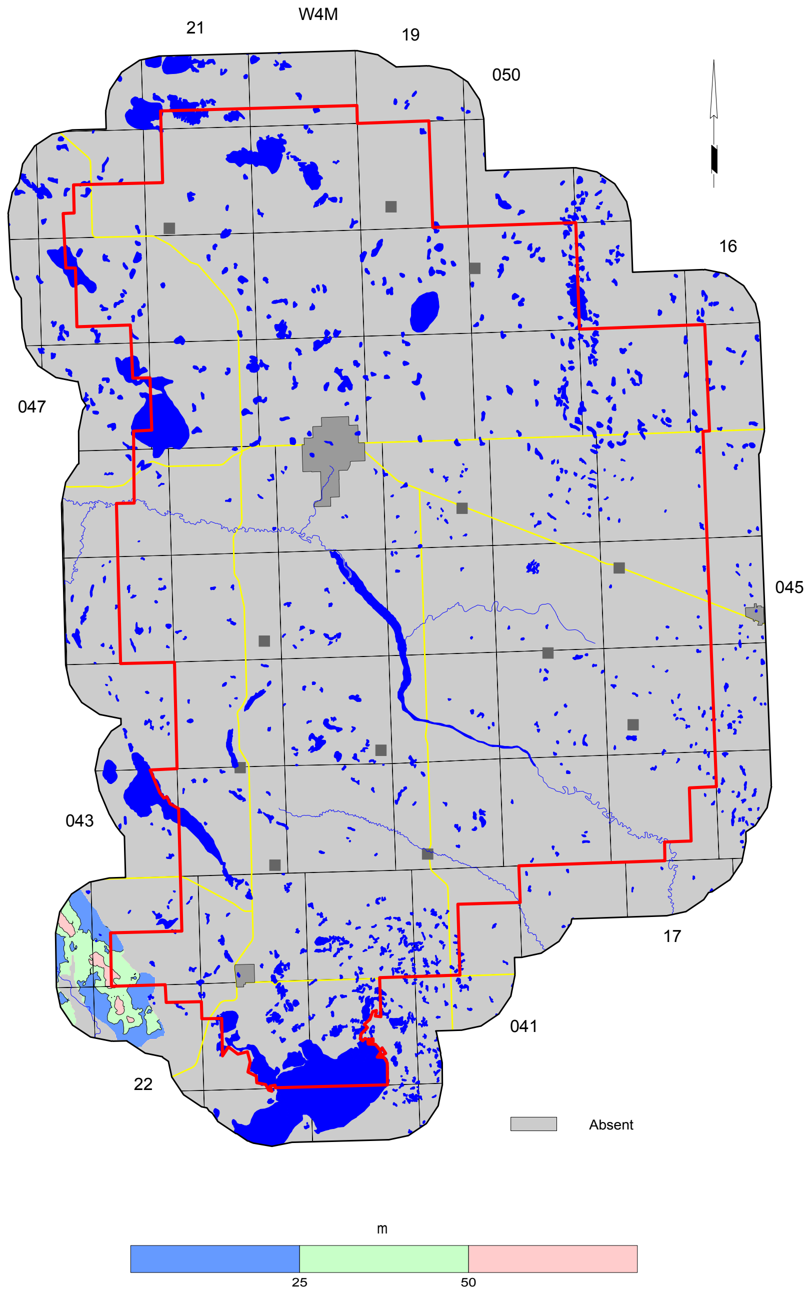
Fluoride vs Sodium Concentrations



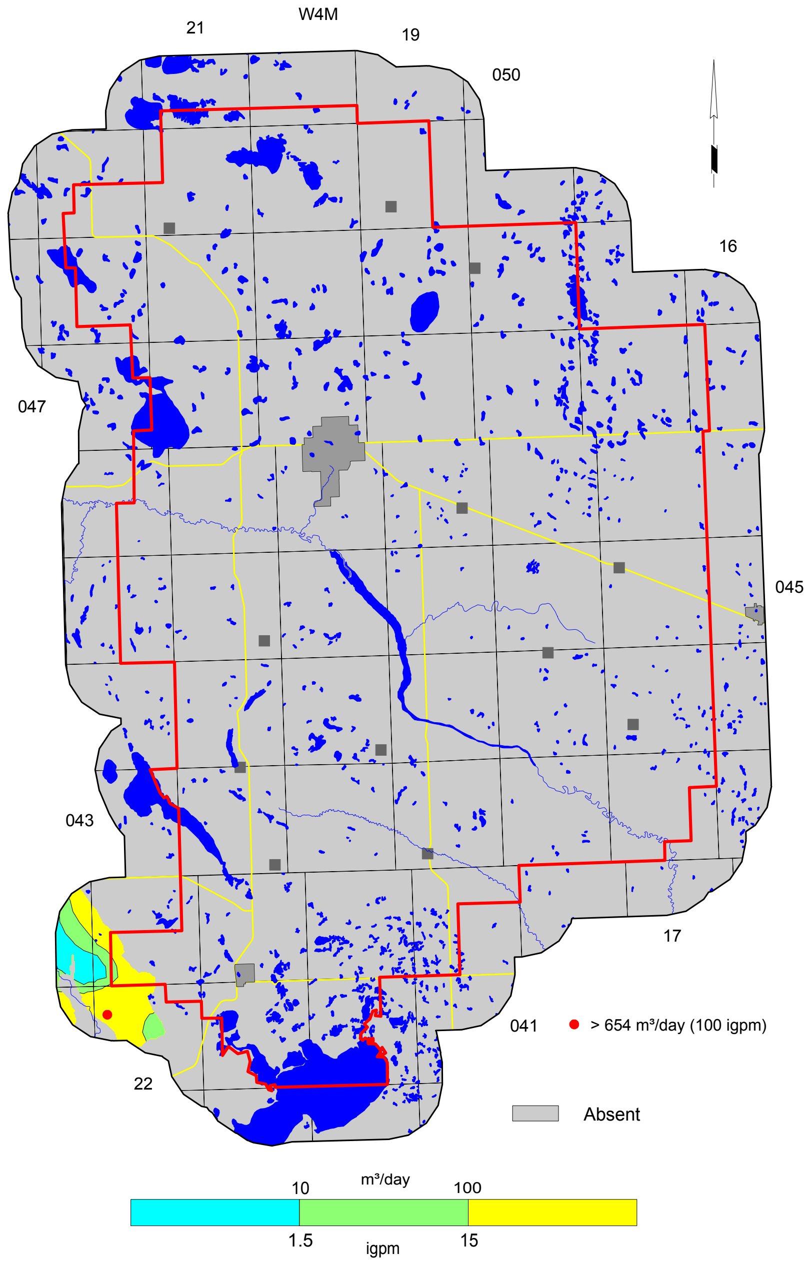
Depth to Top of Upper Scollard Formation



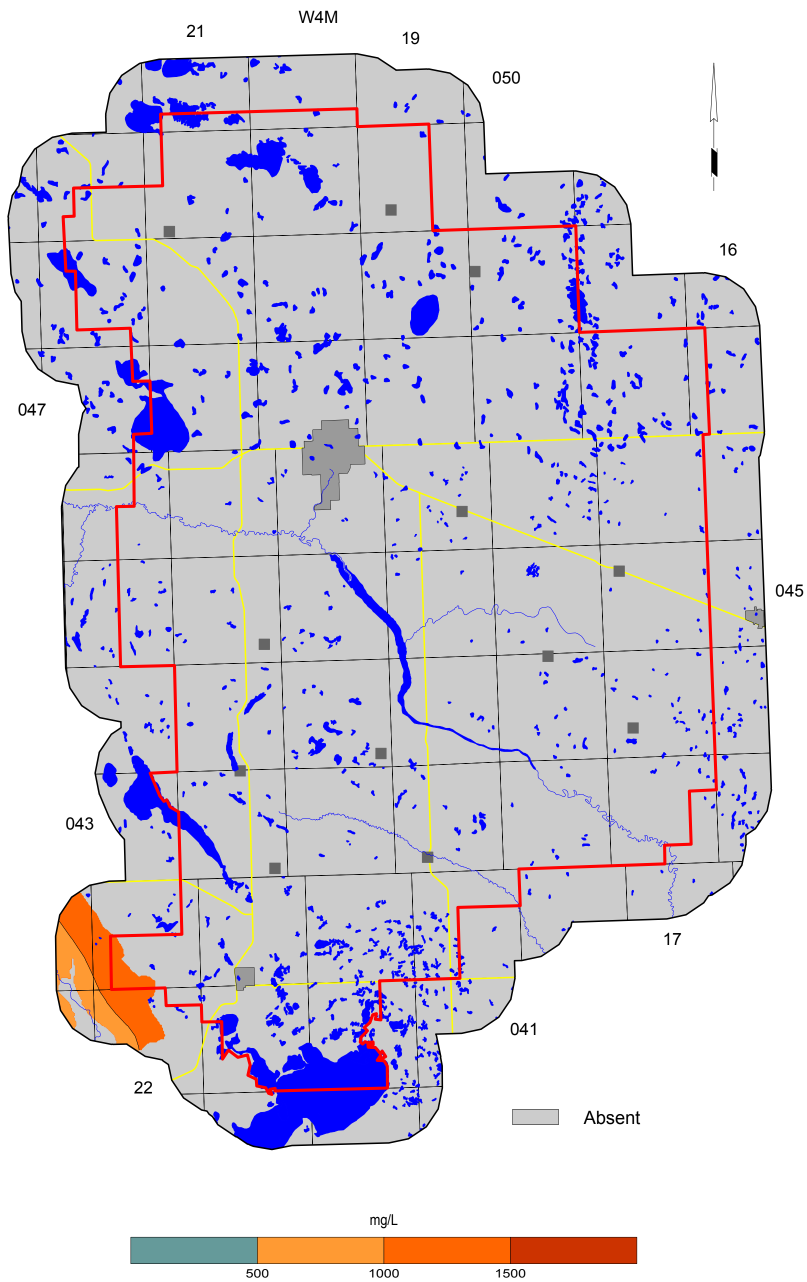
Depth to Top of Lower Scollard Formation



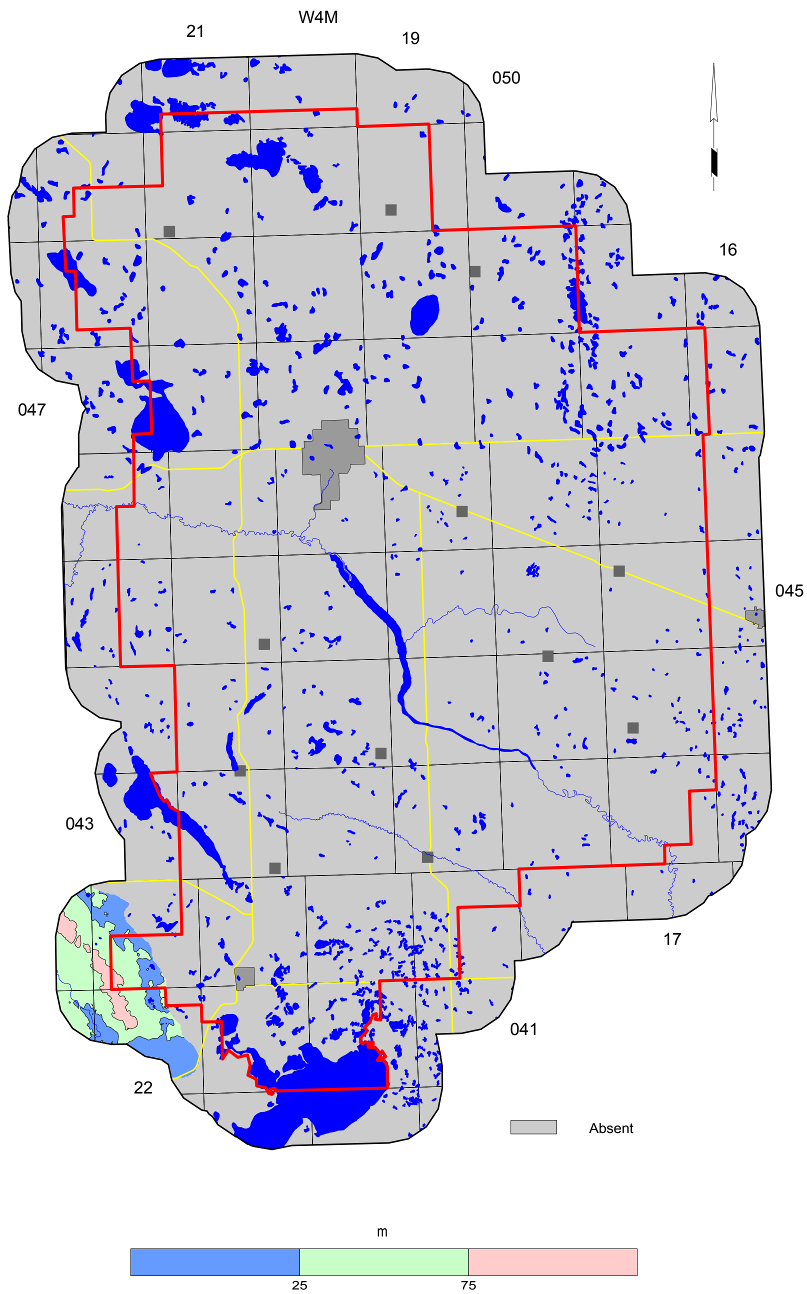
Apparent Yield for Water Wells Completed through Lower Scollard Aquifer



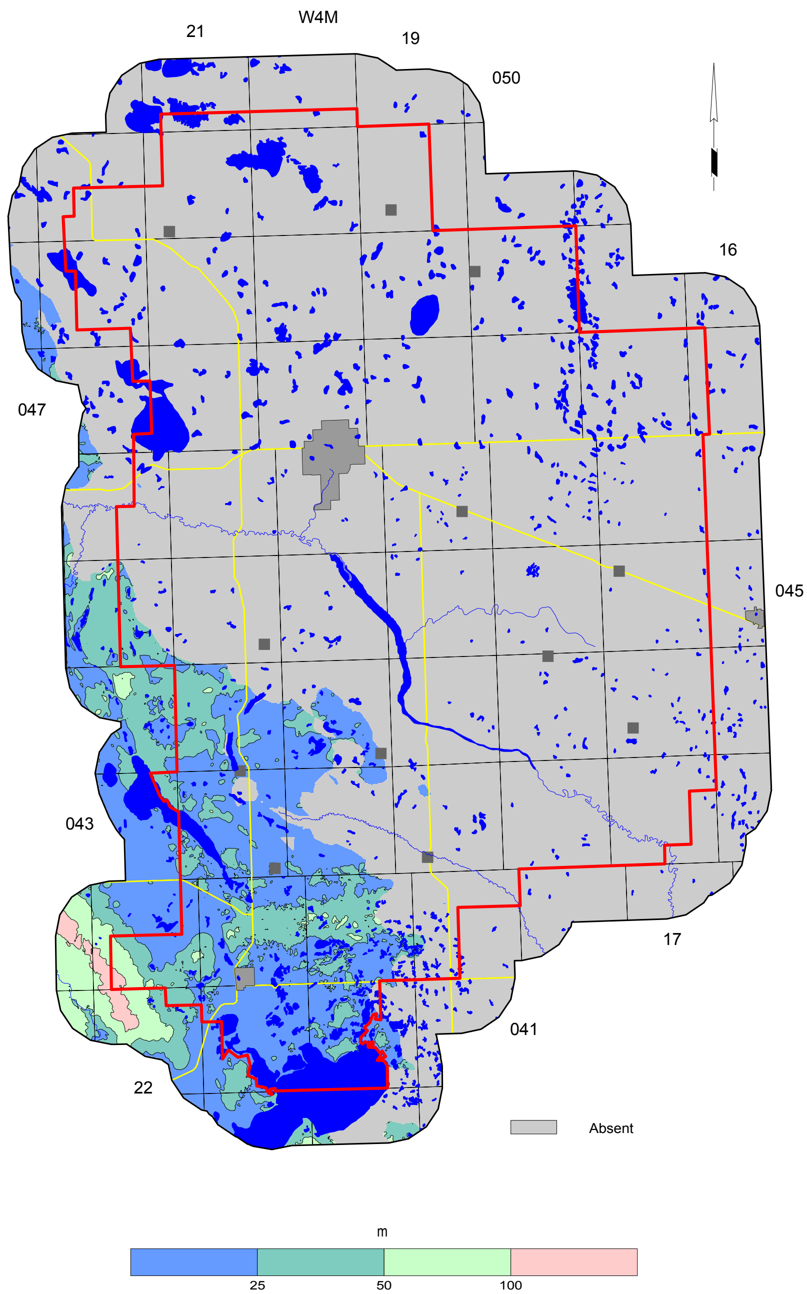
Total Dissolved Solids in Groundwater from Lower Scollard Aquifer



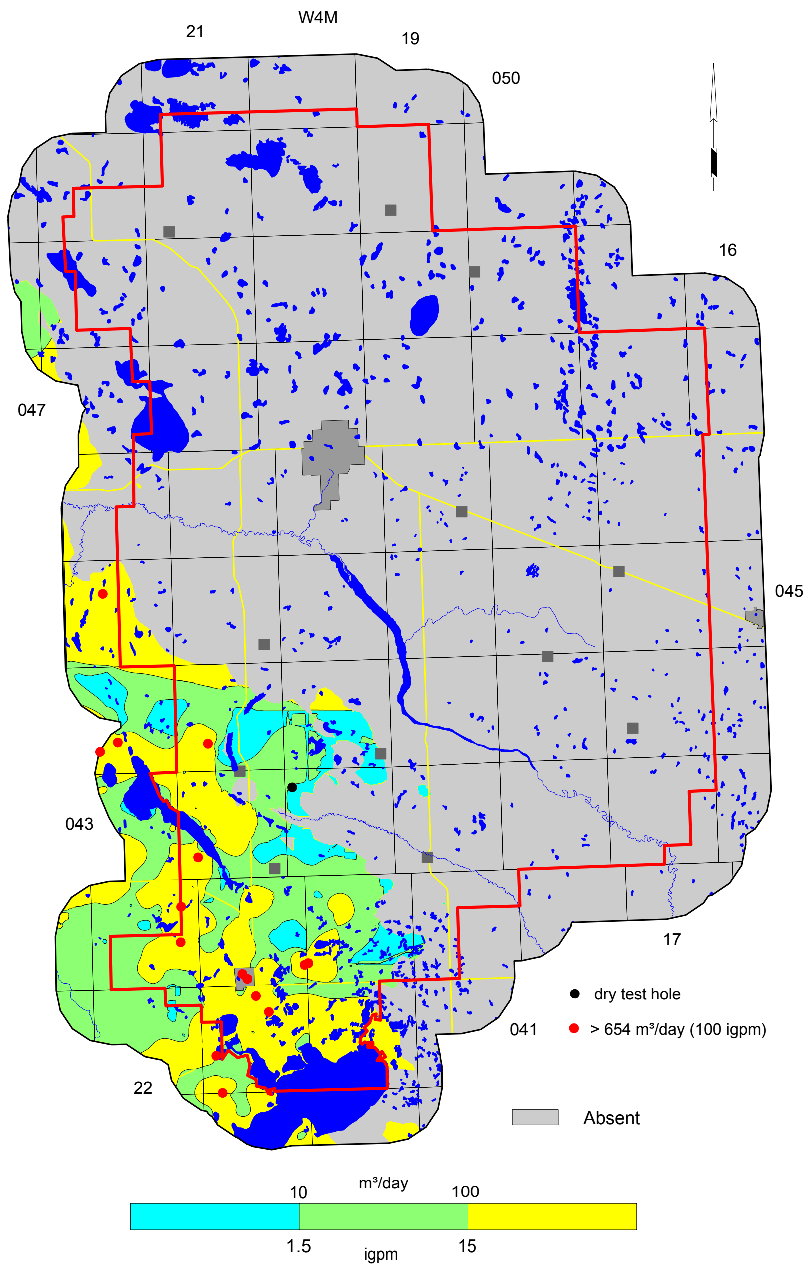
Depth to Top of Battle Formation



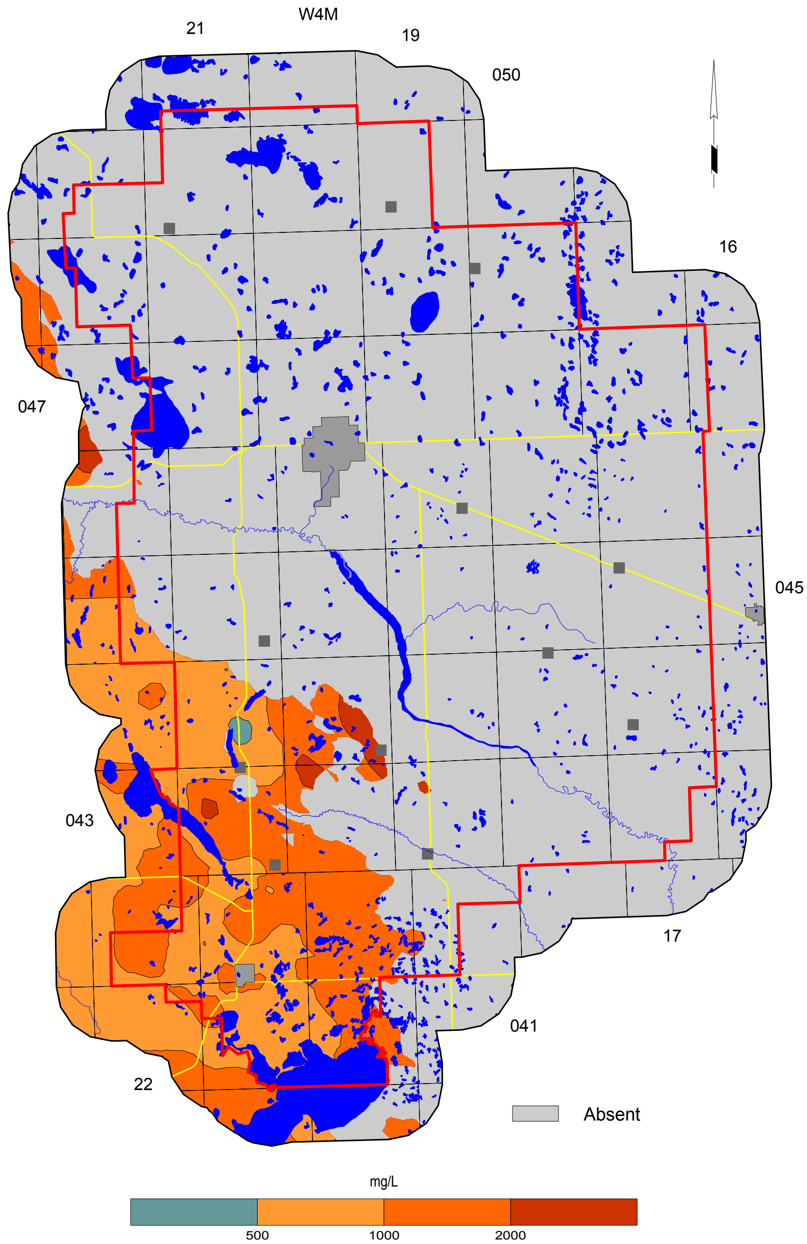
Depth to Top of Upper Horseshoe Canyon Formation



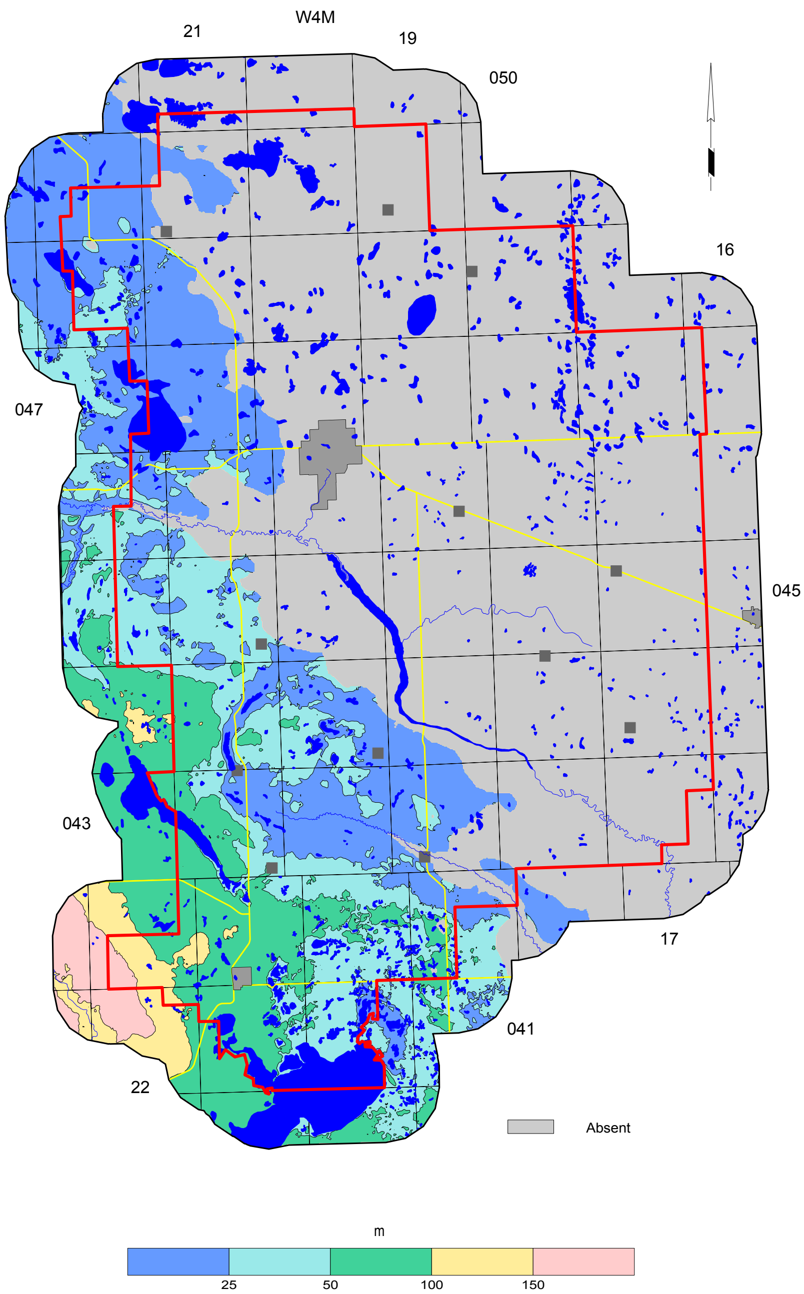
Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer



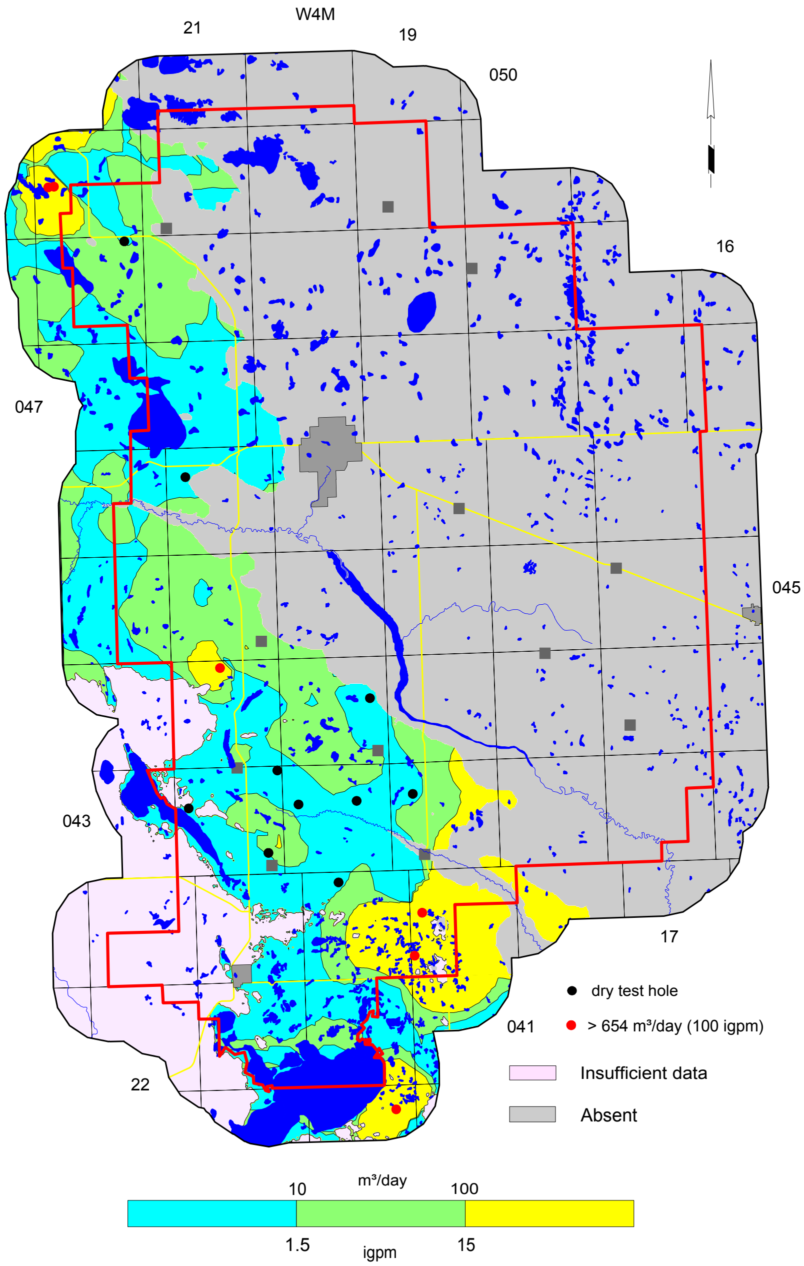
Total Dissolved Solids in Groundwater from Upper Horseshoe Canyon Aquifer



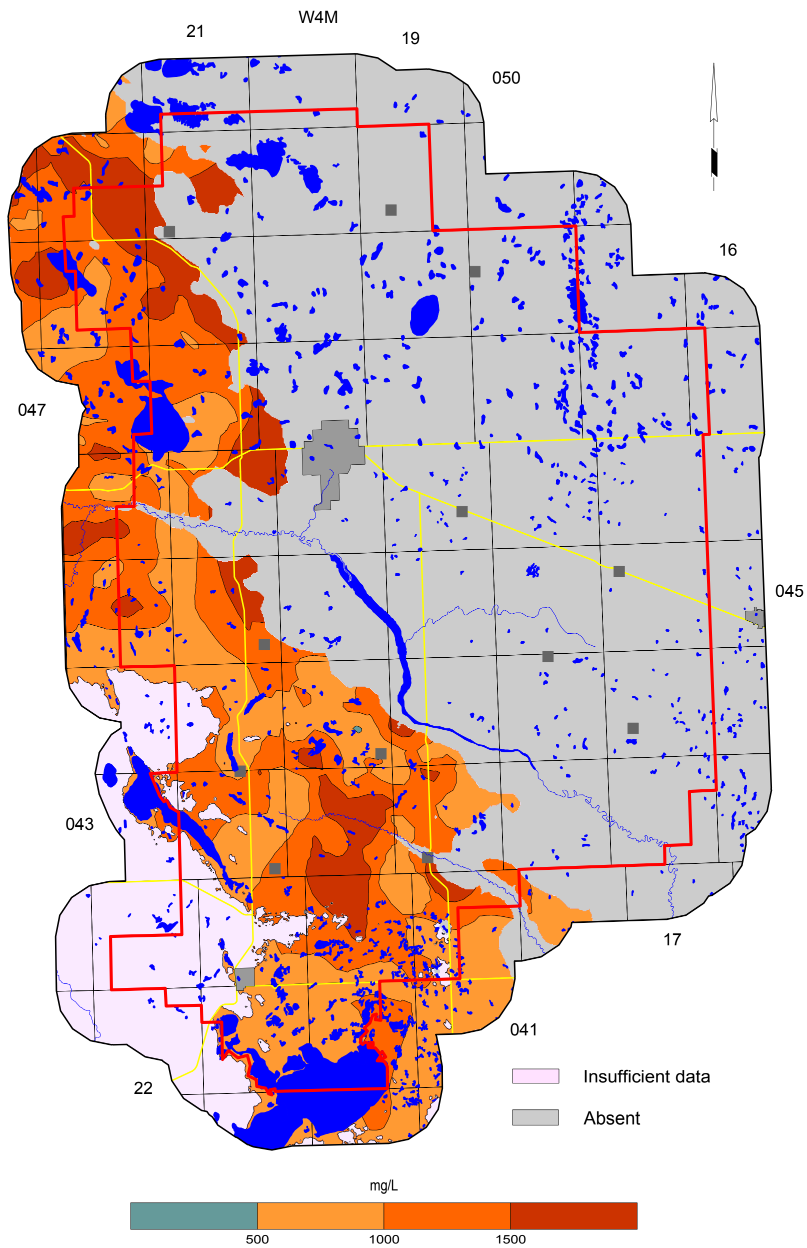
Depth to Top of Middle Horseshoe Canyon Formation



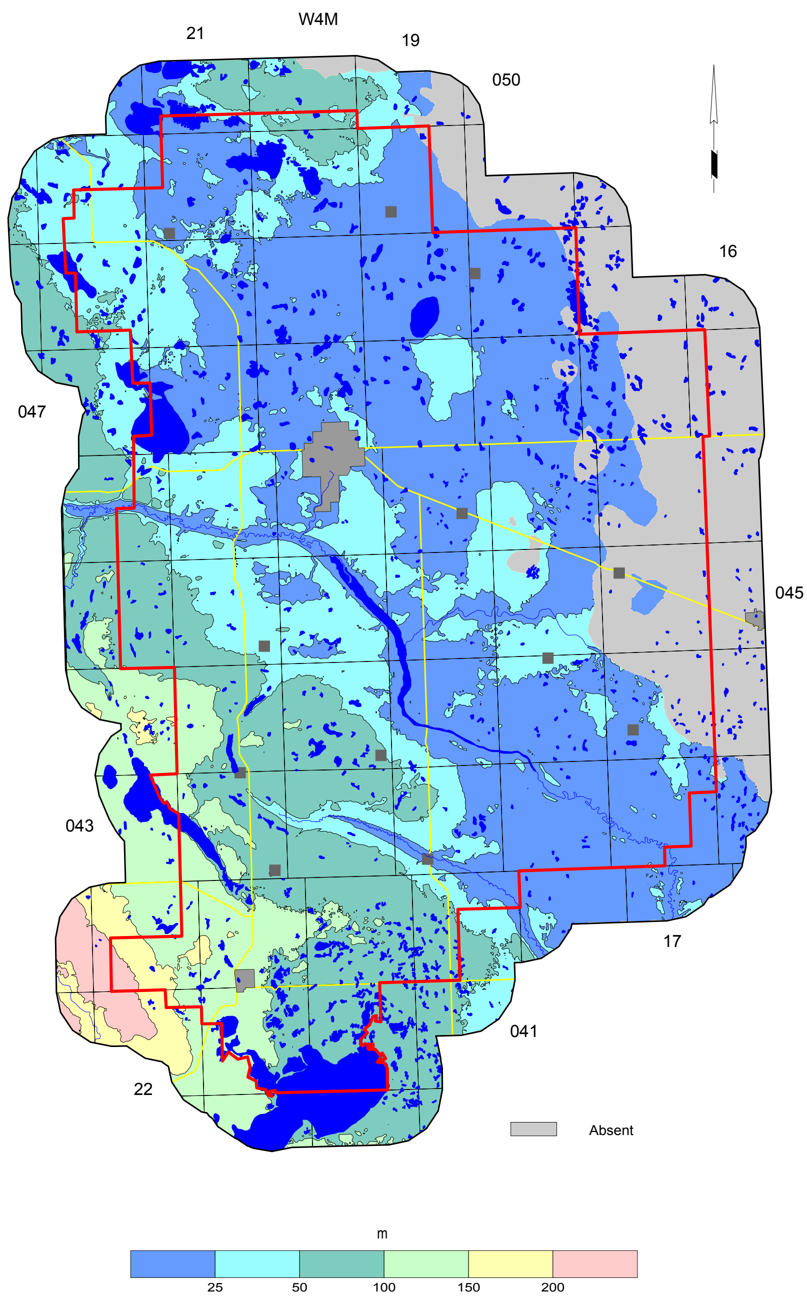
Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer



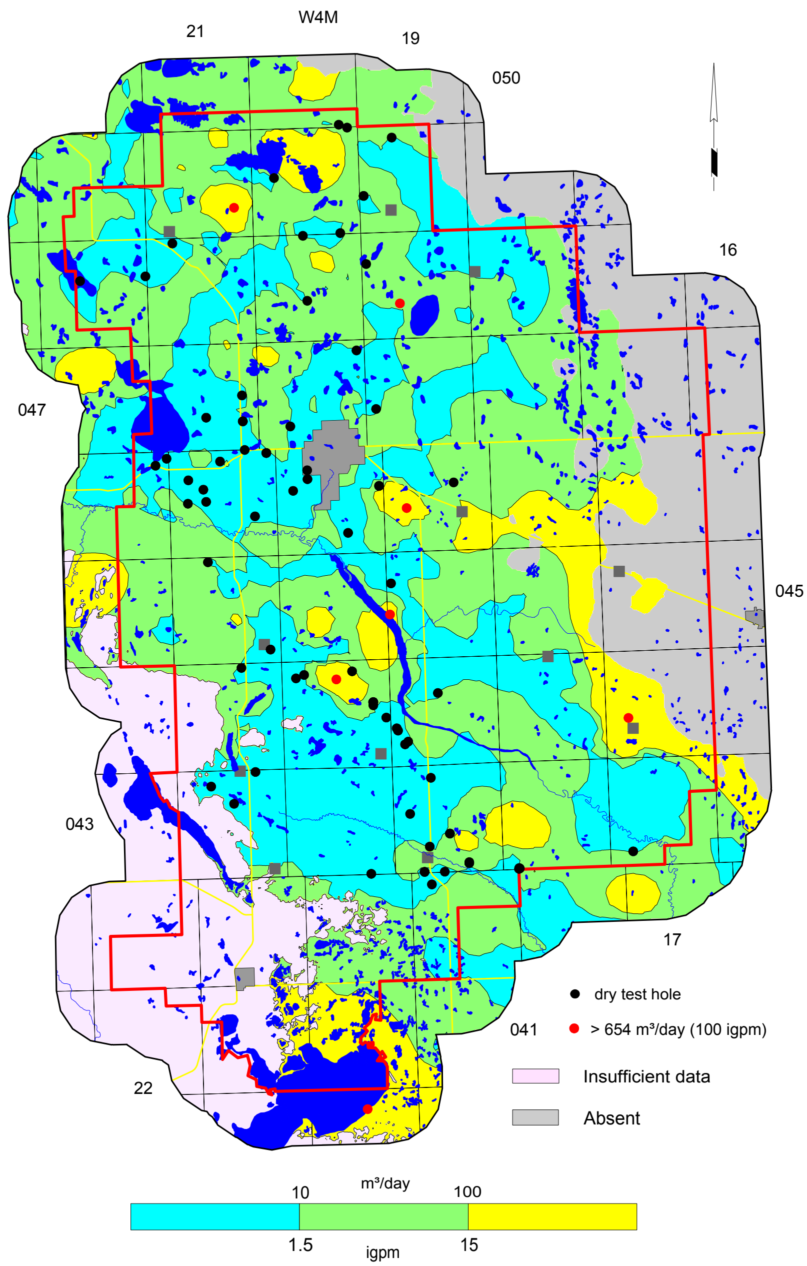
Total Dissolved Solids in Groundwater from Middle Horseshoe Canyon Aquifer



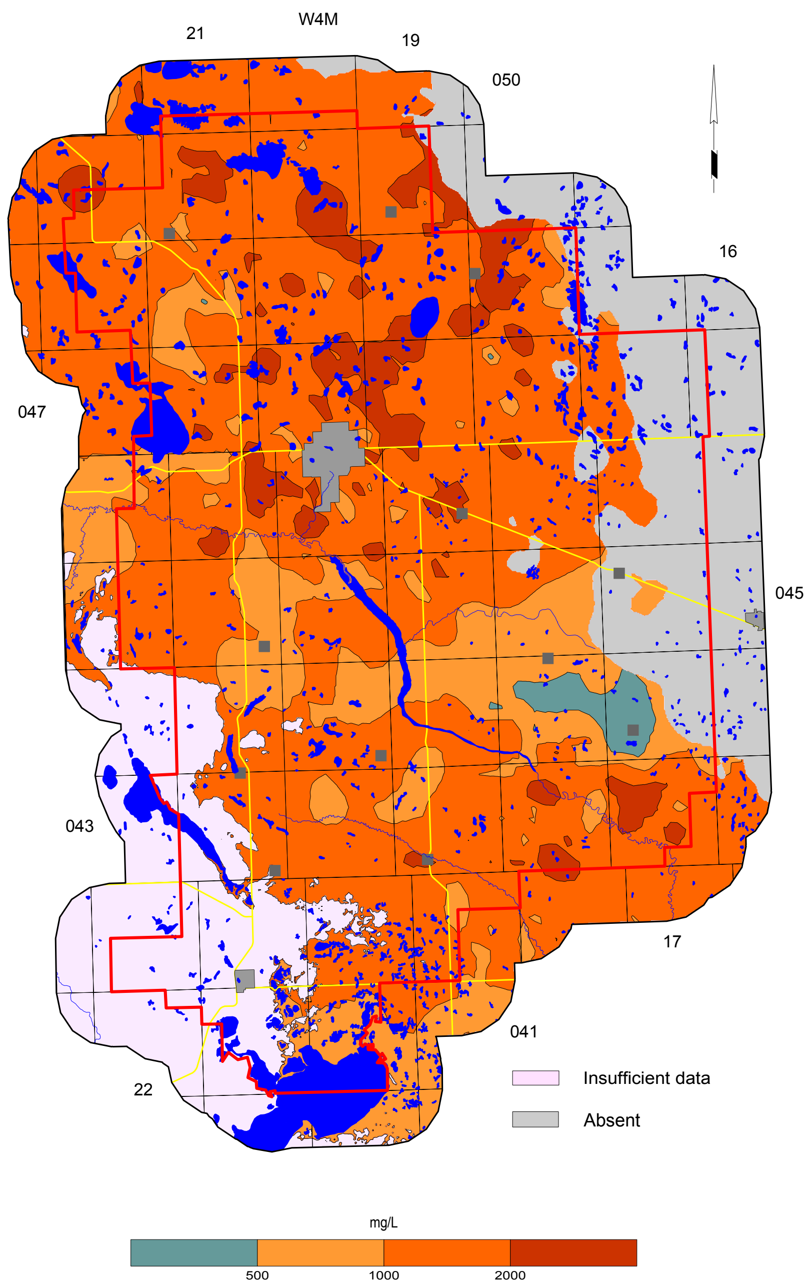
Depth to Top of Lower Horseshoe Canyon Formation



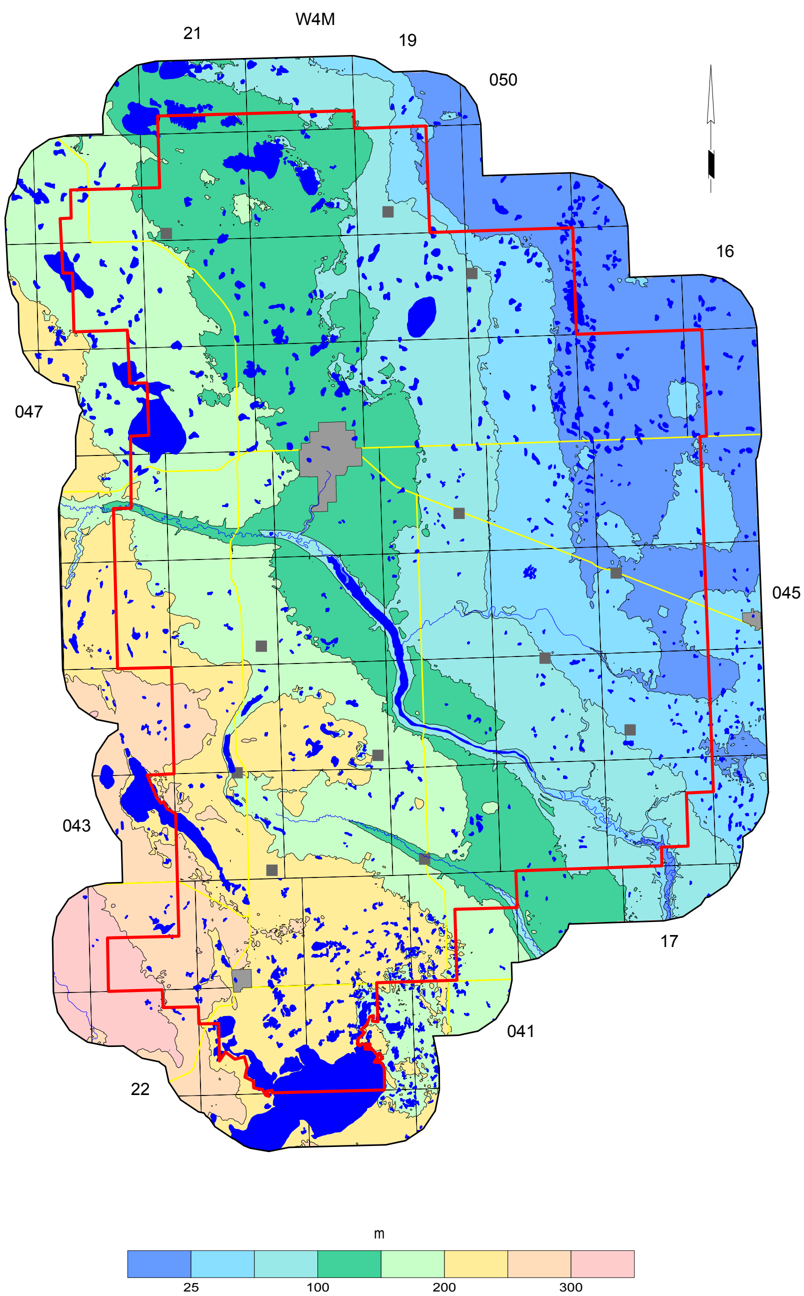
Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer



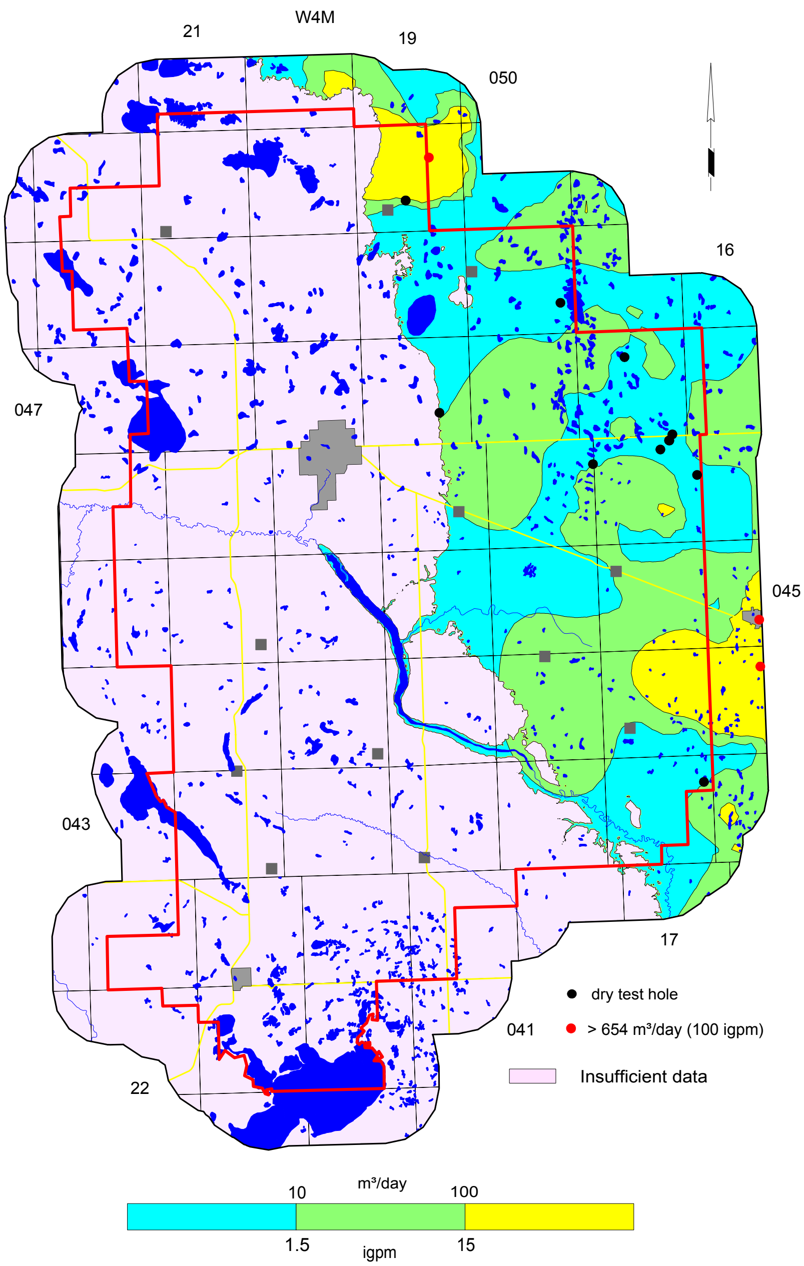
Total Dissolved Solids in Groundwater from Lower Horseshoe Canyon Aquifer



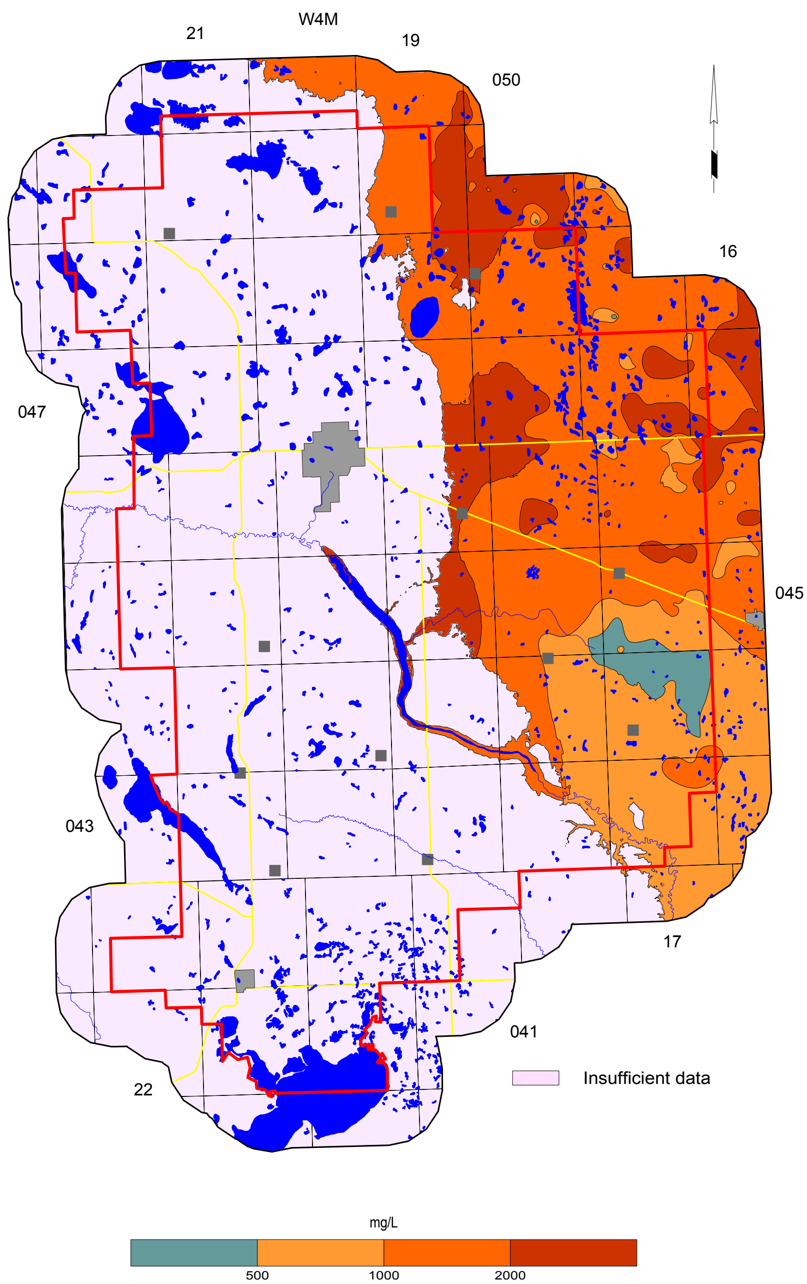
Depth to Top of Bearpaw Formation



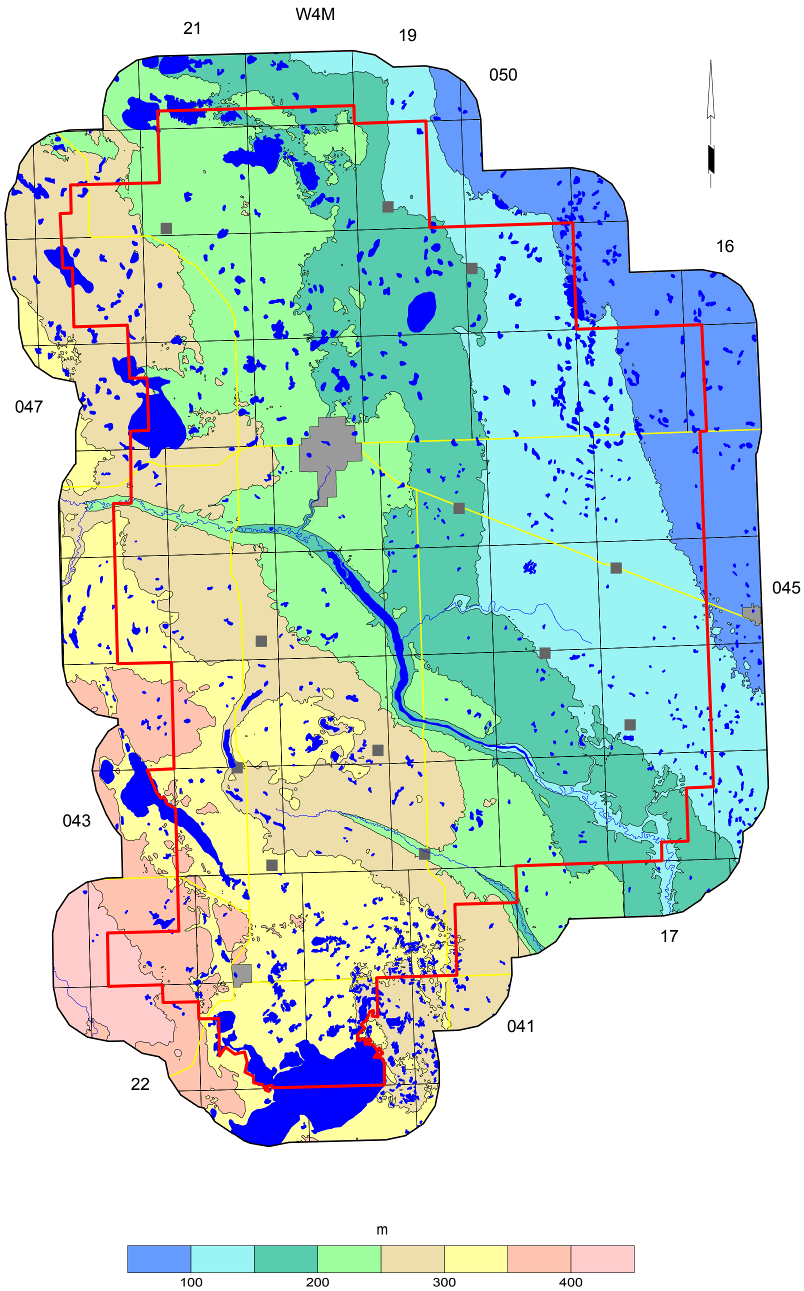
Apparent Yield for Water Wells Completed through Bearpaw Aquifer



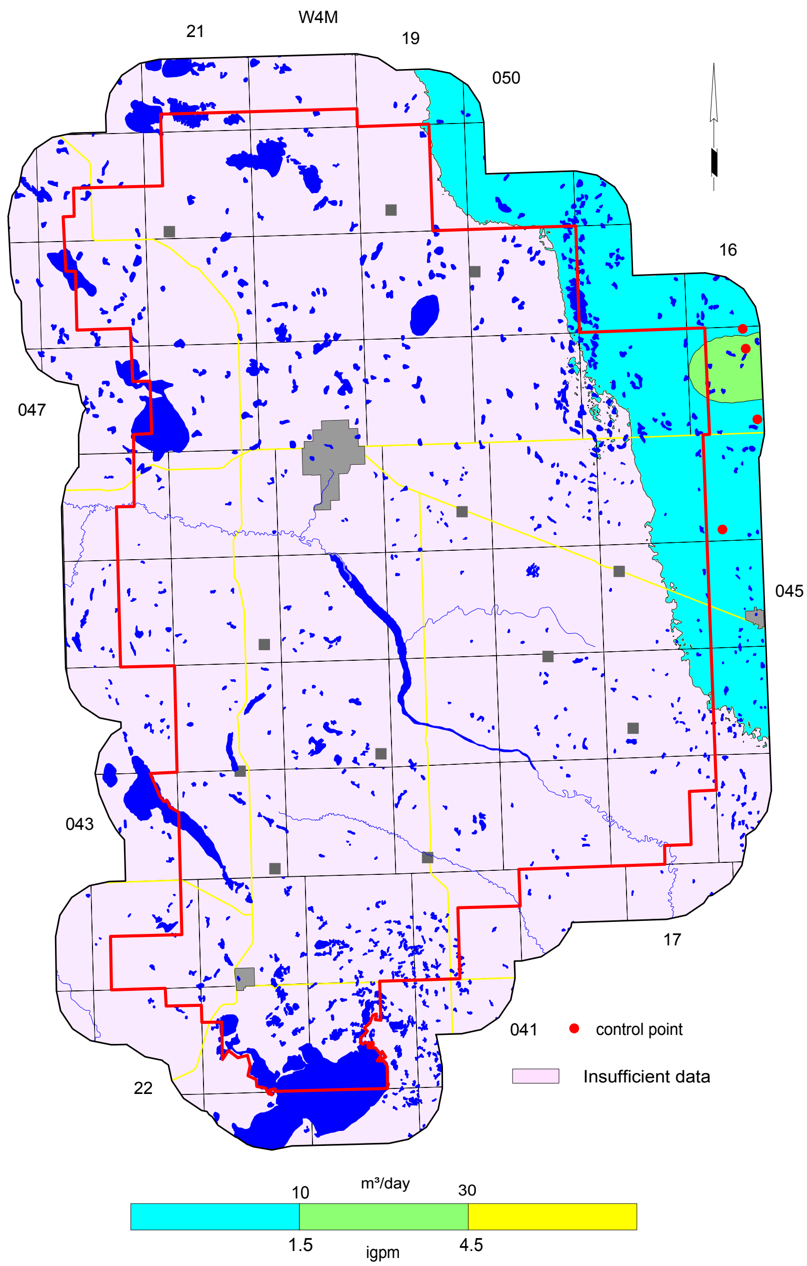
Total Dissolved Solids in Groundwater from Bearpaw Aquifer



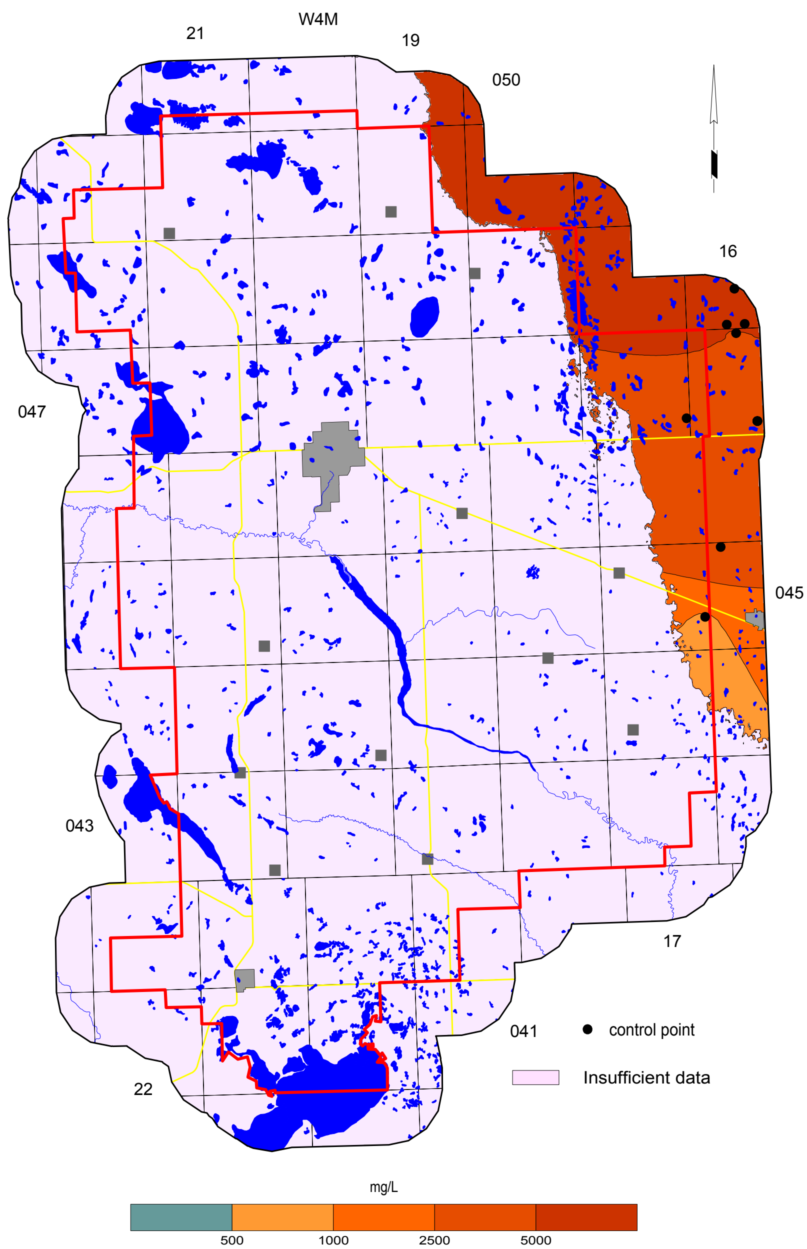
Depth to Top of Oldman Formation



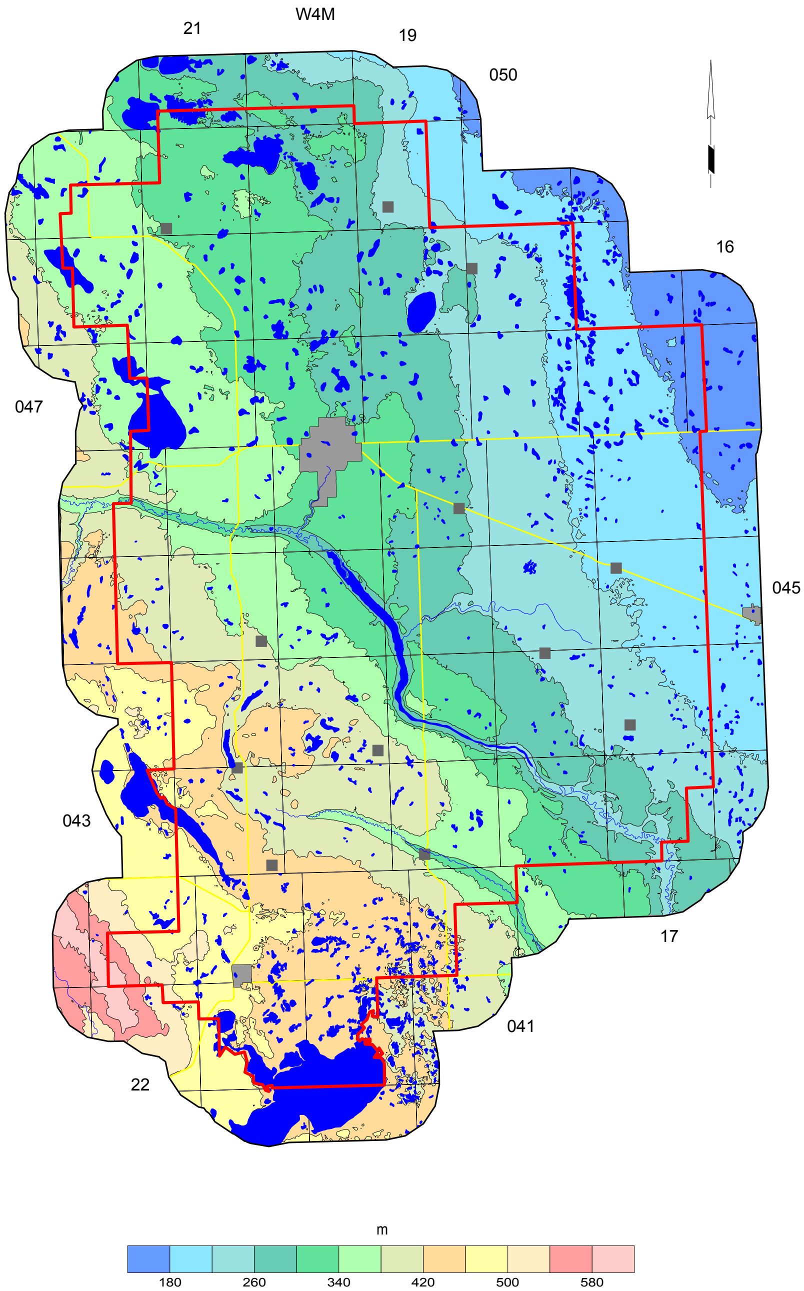
Apparent Yield for Water Wells Completed through Oldman Aquifer



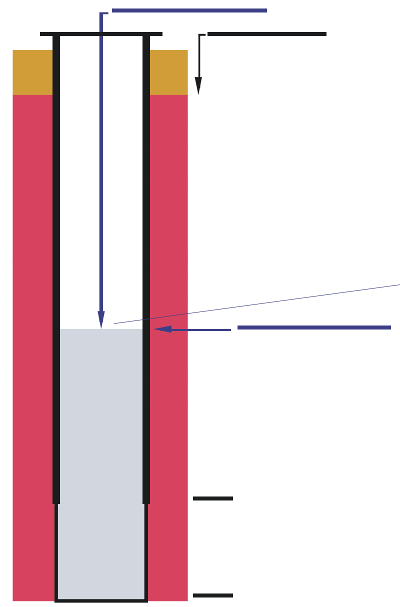
Total Dissolved Solids in Groundwater from Oldman Aquifer

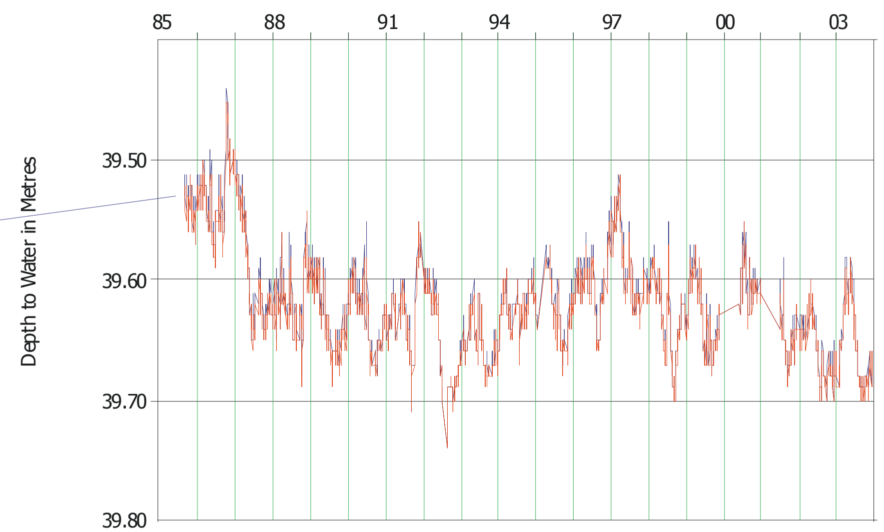


Depth to Top of Foremost Formation



AENV Observation Water Wells

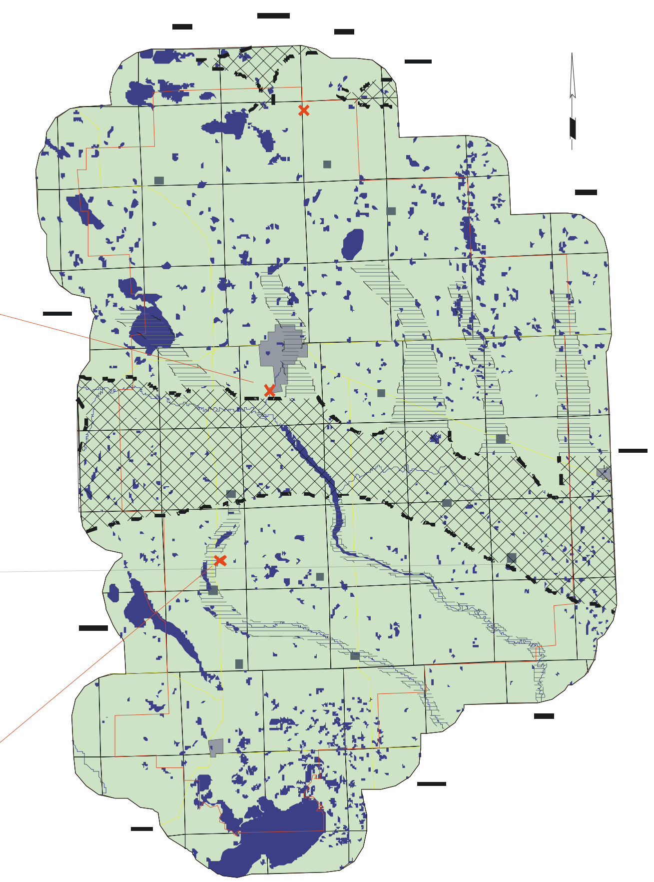


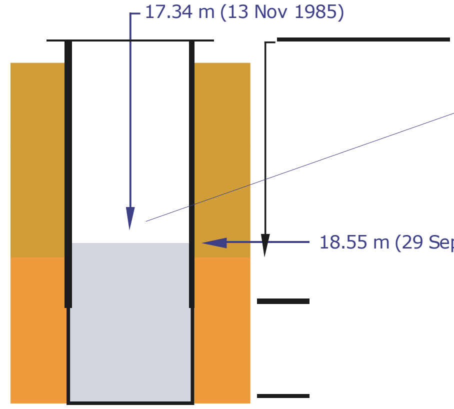


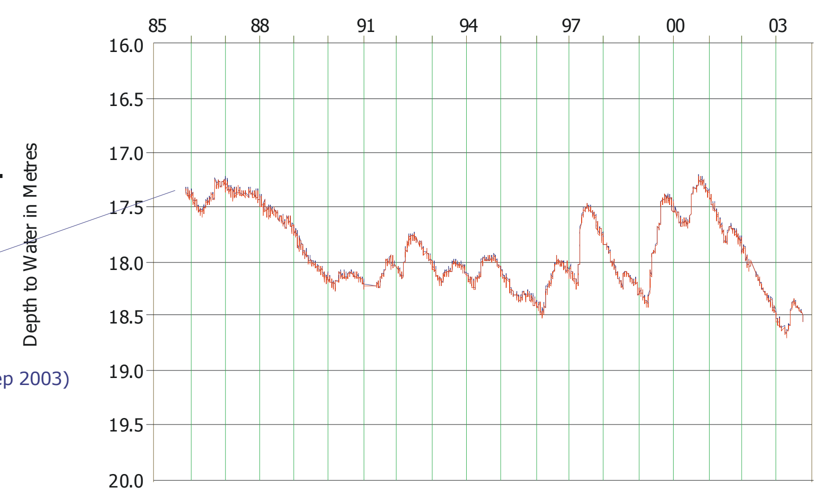
M35377.151351 - AENV Observation Water Well: Camrose R. L. 85 - 1

Highest Water-Level Measurement — Lowest Water-Level Measurement

- Non-Pumping Water Level
- Upper Surficial Deposits
- Upper Horseshoe Canyon Formation
- Lower Horseshoe Canyon Formation



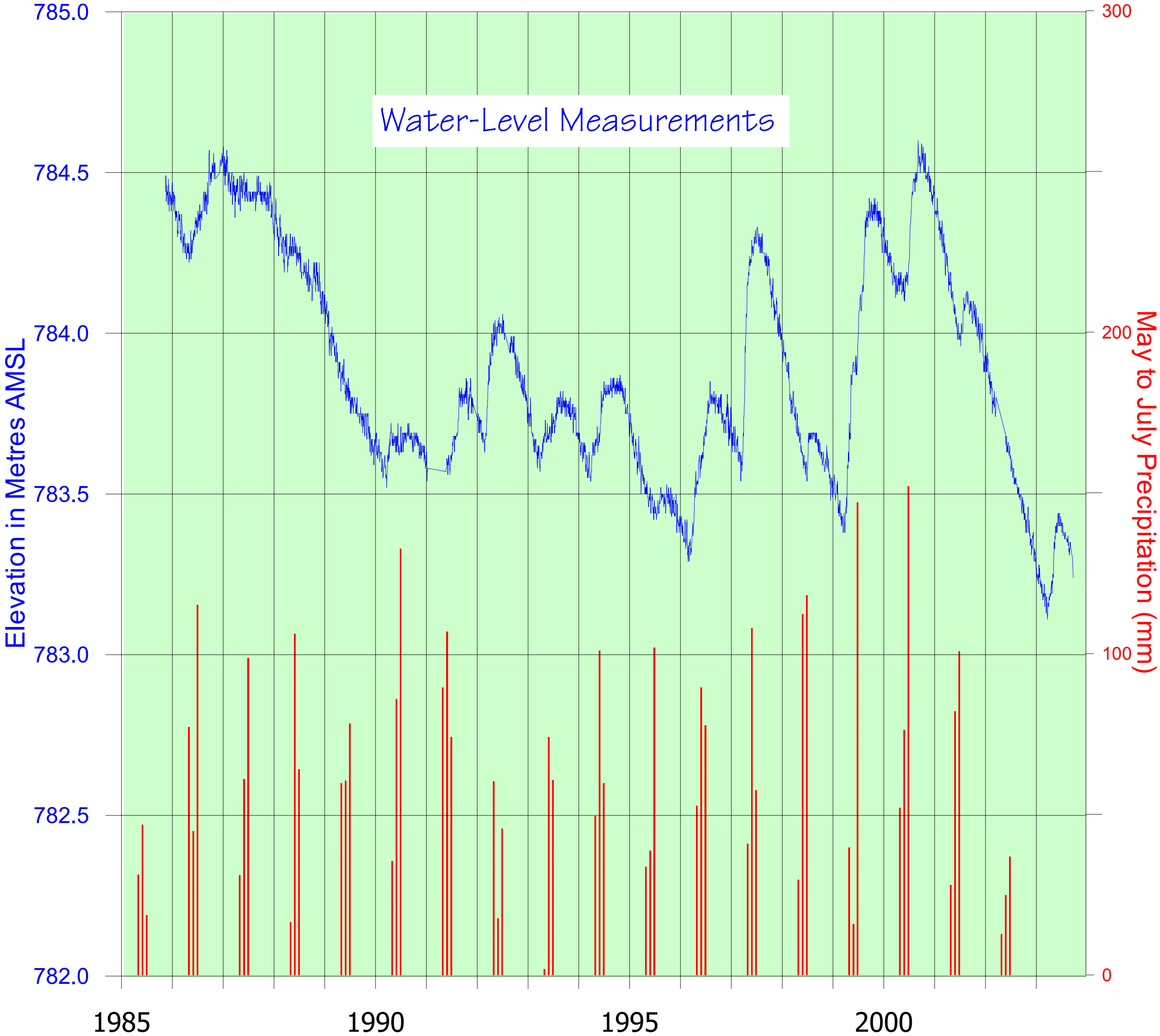




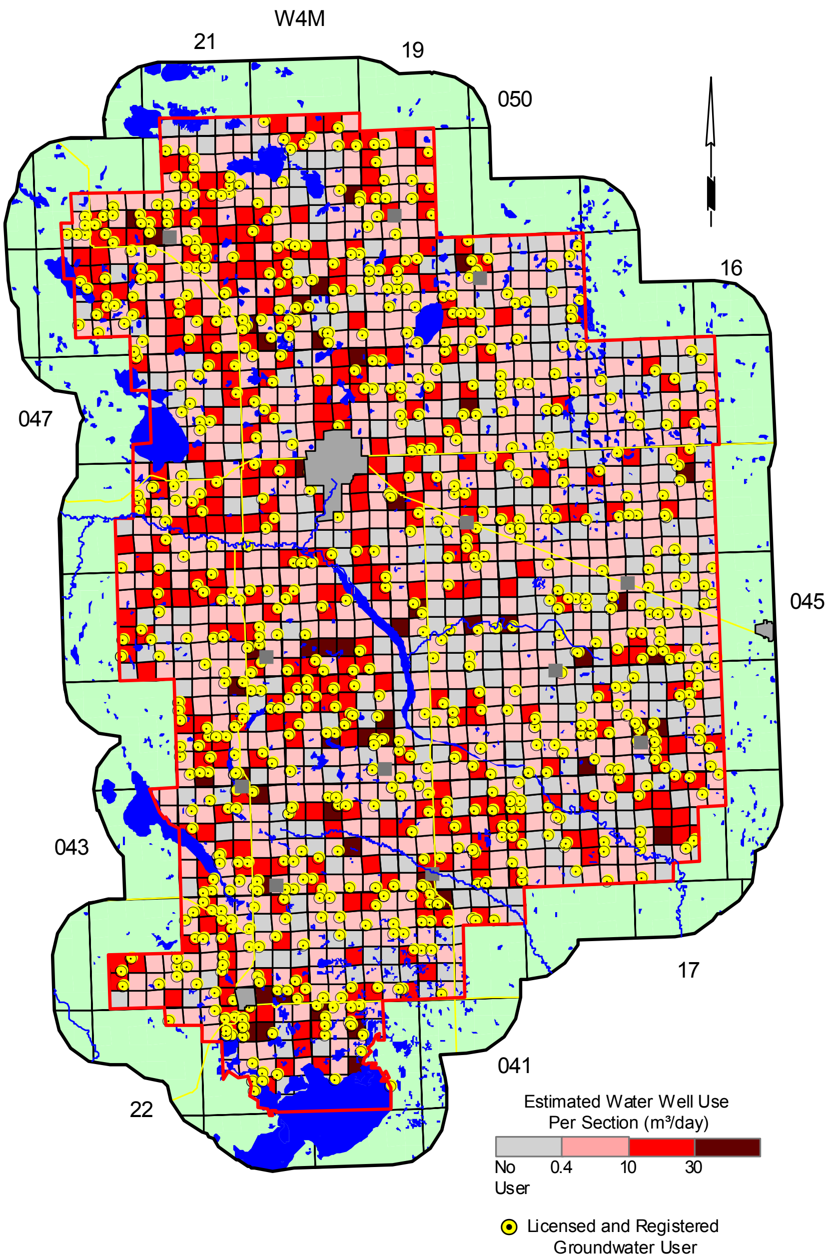
M35377.087727 - AENV Obs Well: Ferintosh Reg Landfill 85 - 1

Highest Water-Level Measurement — Lowest Water-Level Measurement

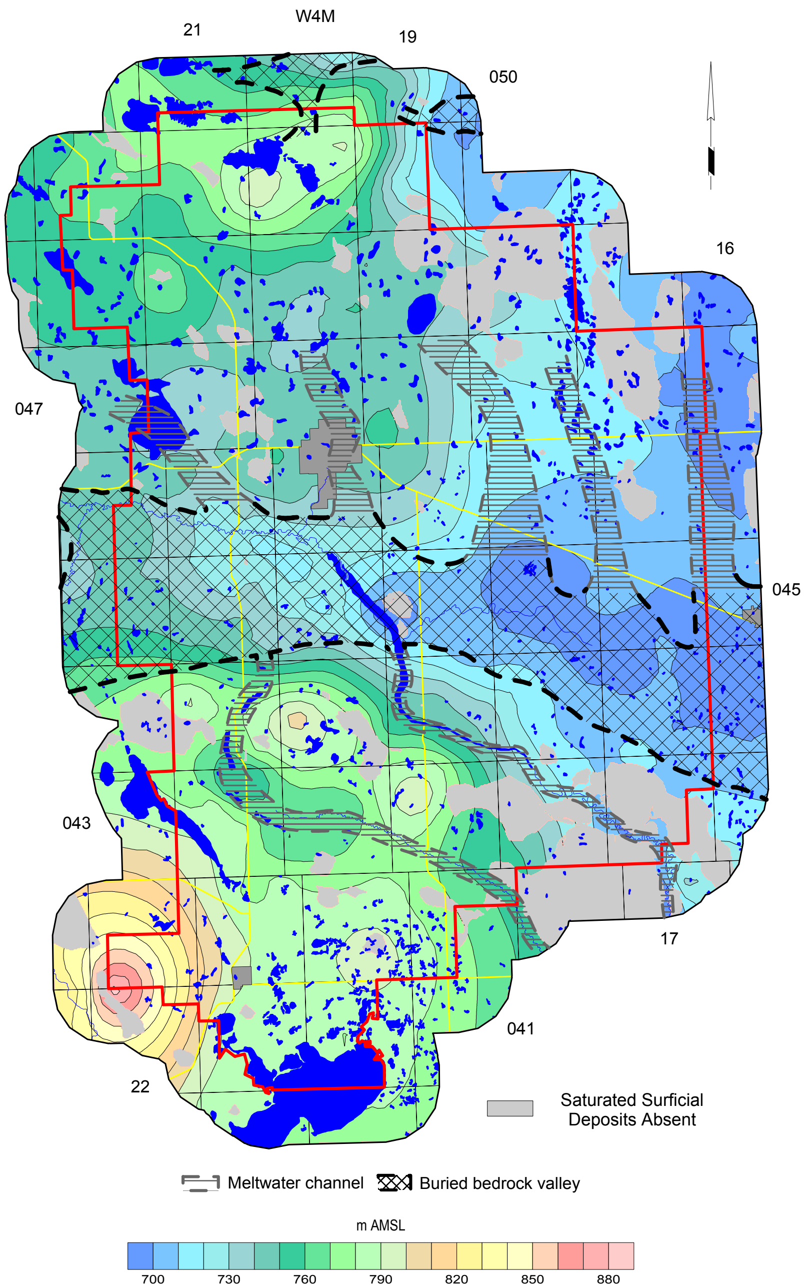
AENV Ferintosh Landfill Obs WW and Camrose Precipitation



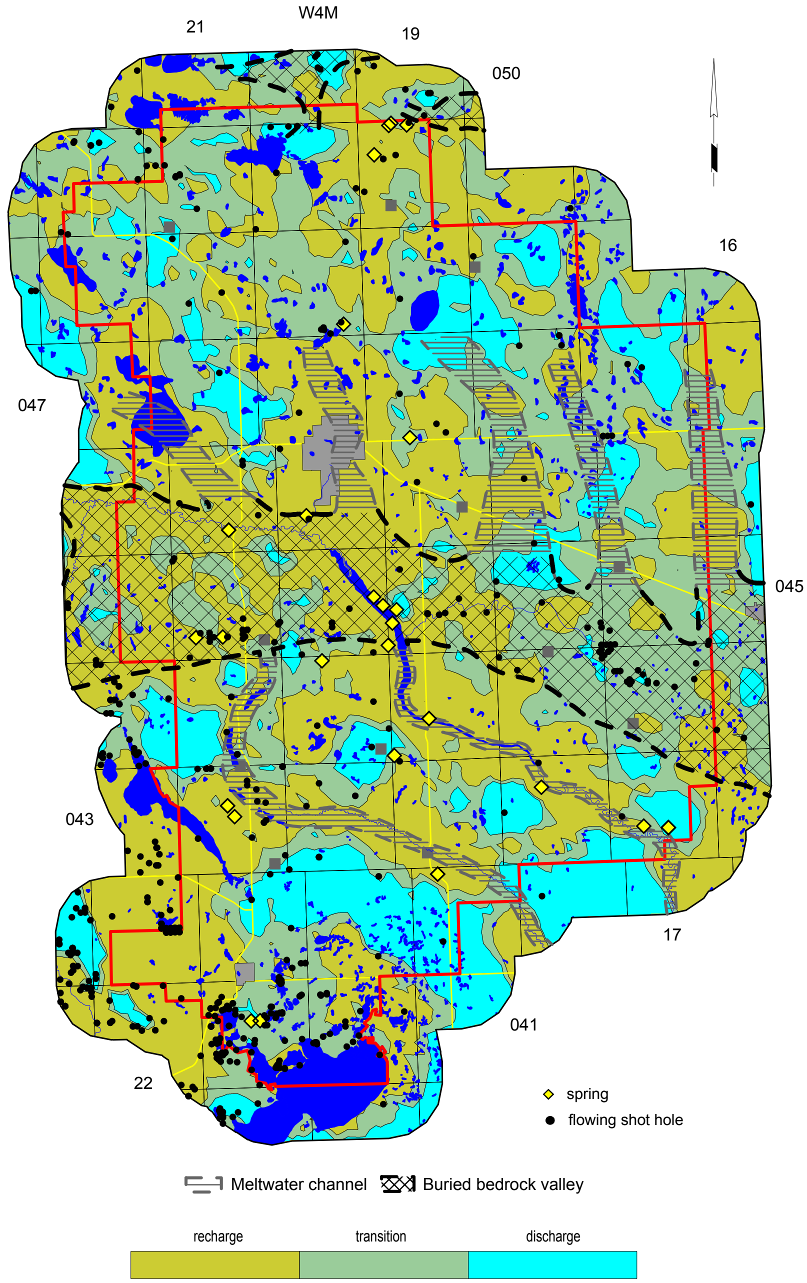
Estimated Water Well Use Per Section



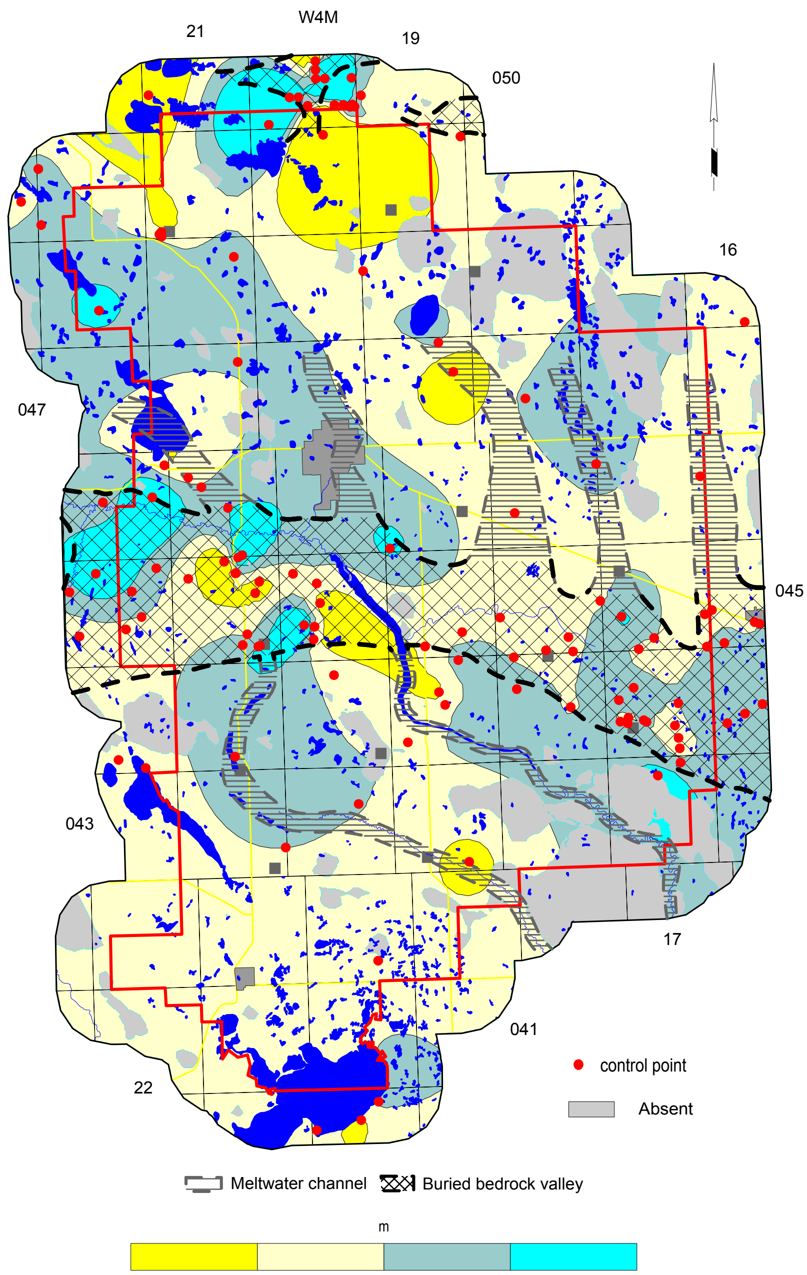
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



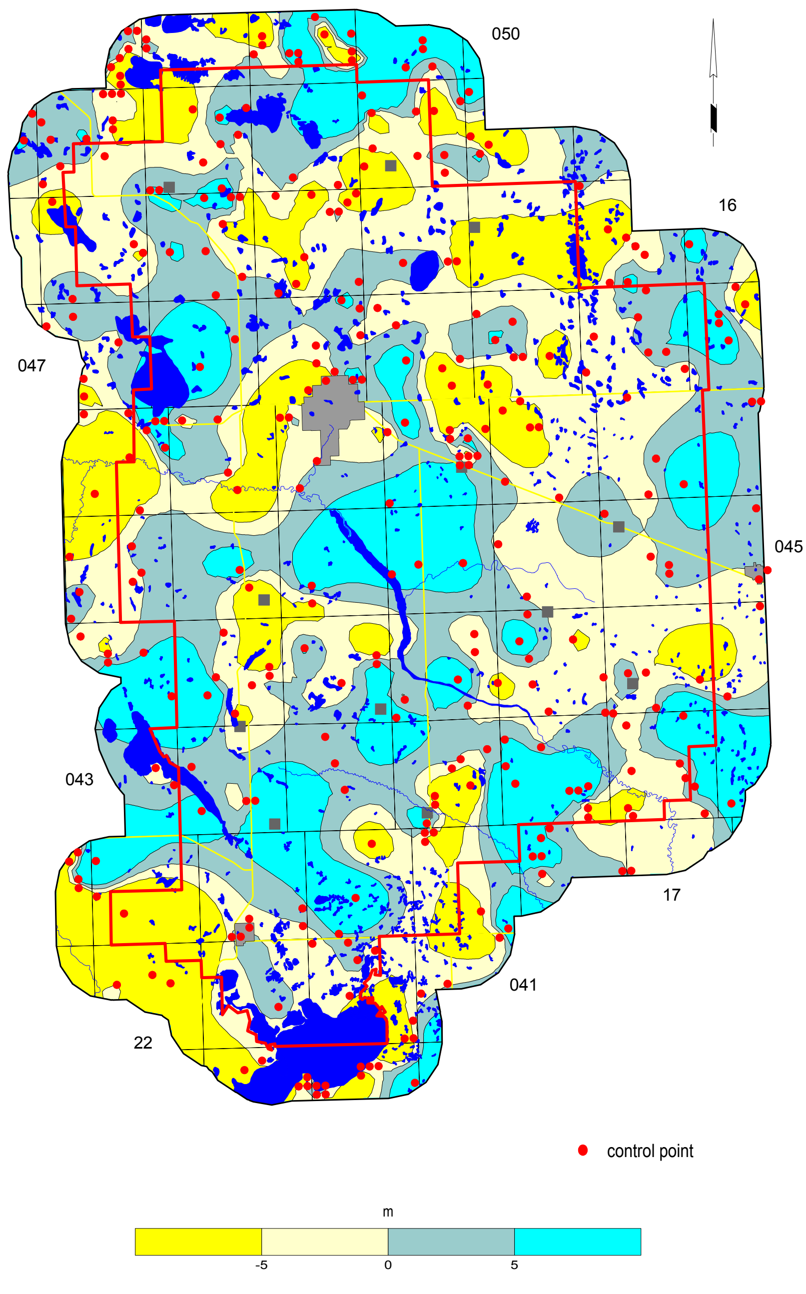
Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)



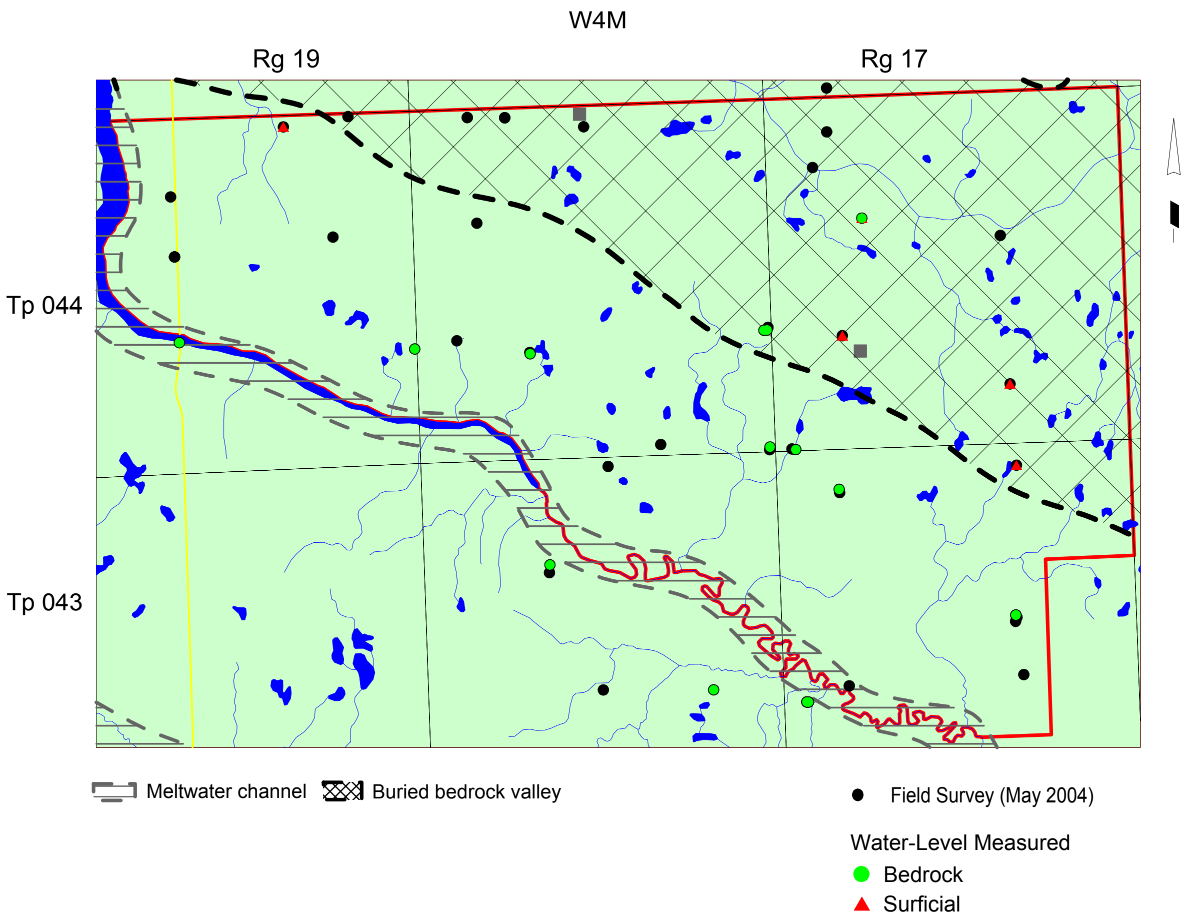
Changes in Water Levels in Surficial Deposits



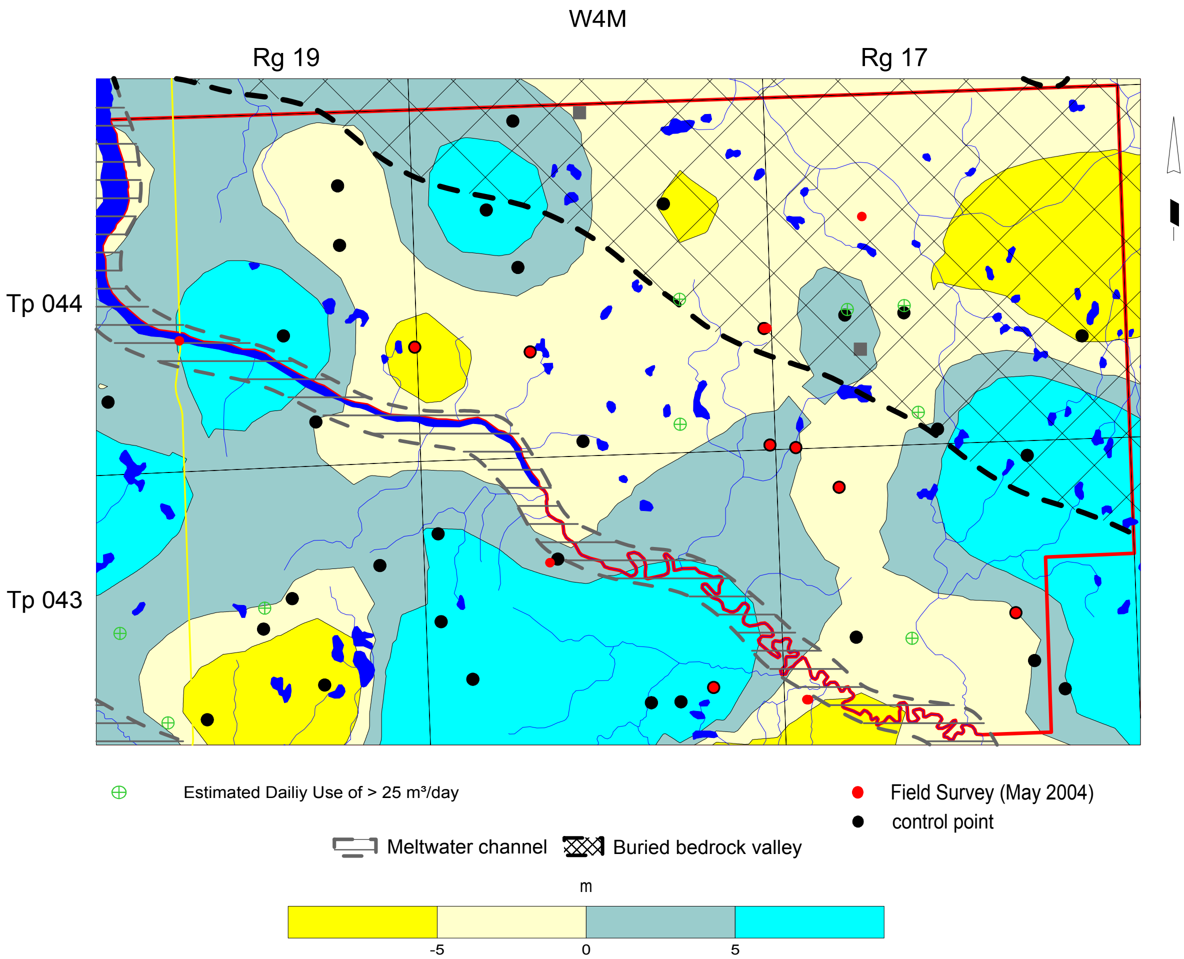
Areas of Potential Groundwater Decline in Upper Bedrock Aquifer(s)



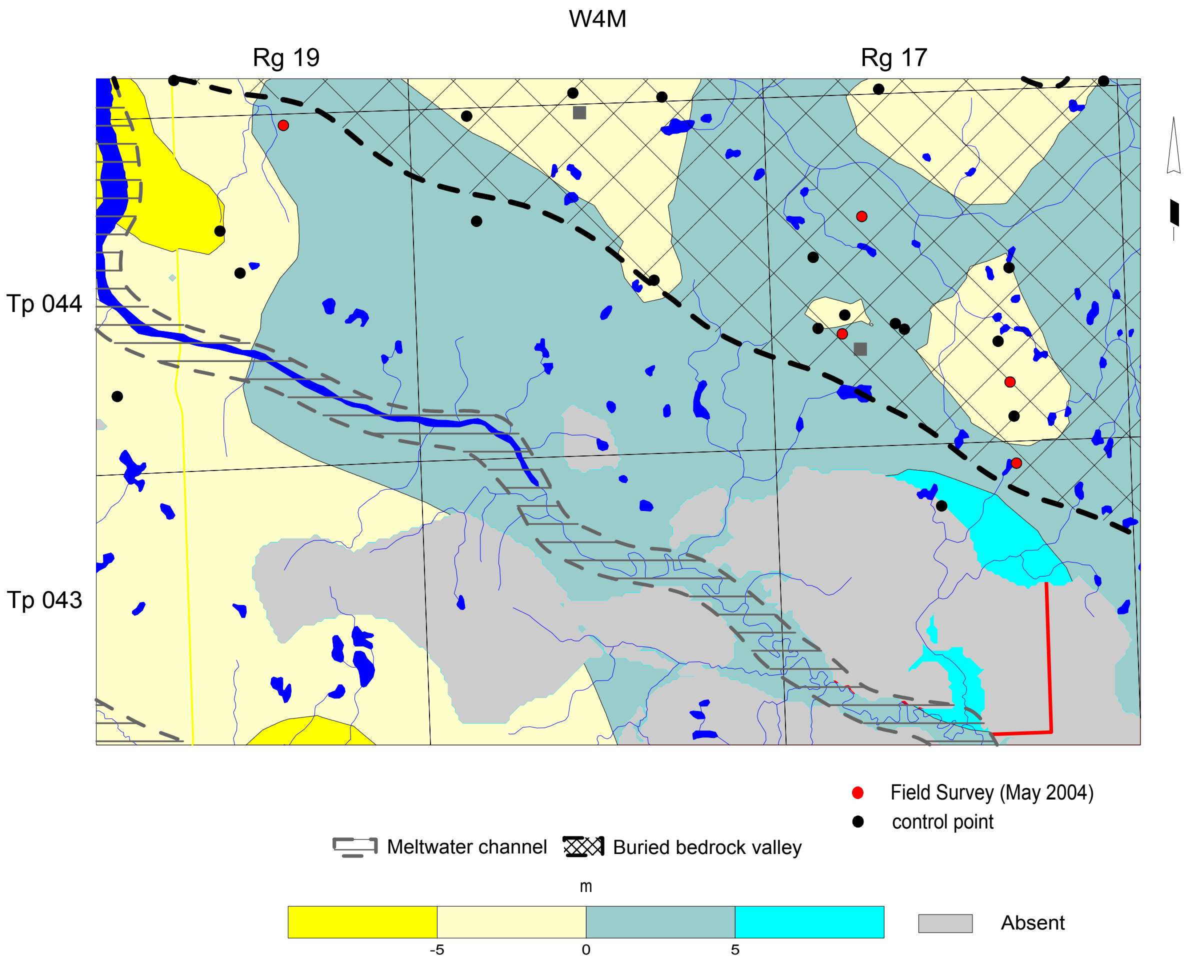
Field-Verified Water Well Survey - Area 1



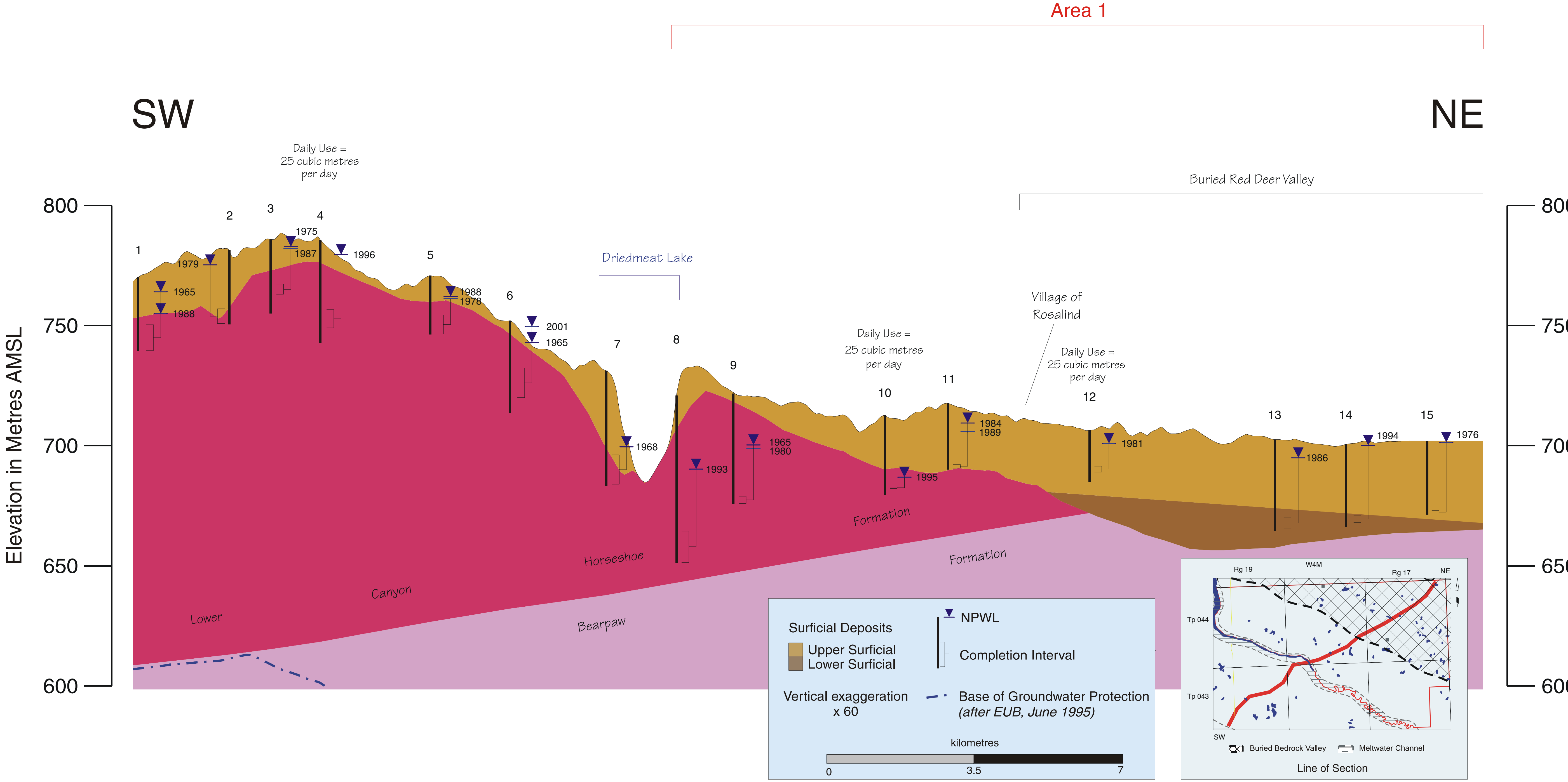
Non-Pumping Water-Level Decline in Upper Bedrock Aquifer(s) - Area 1



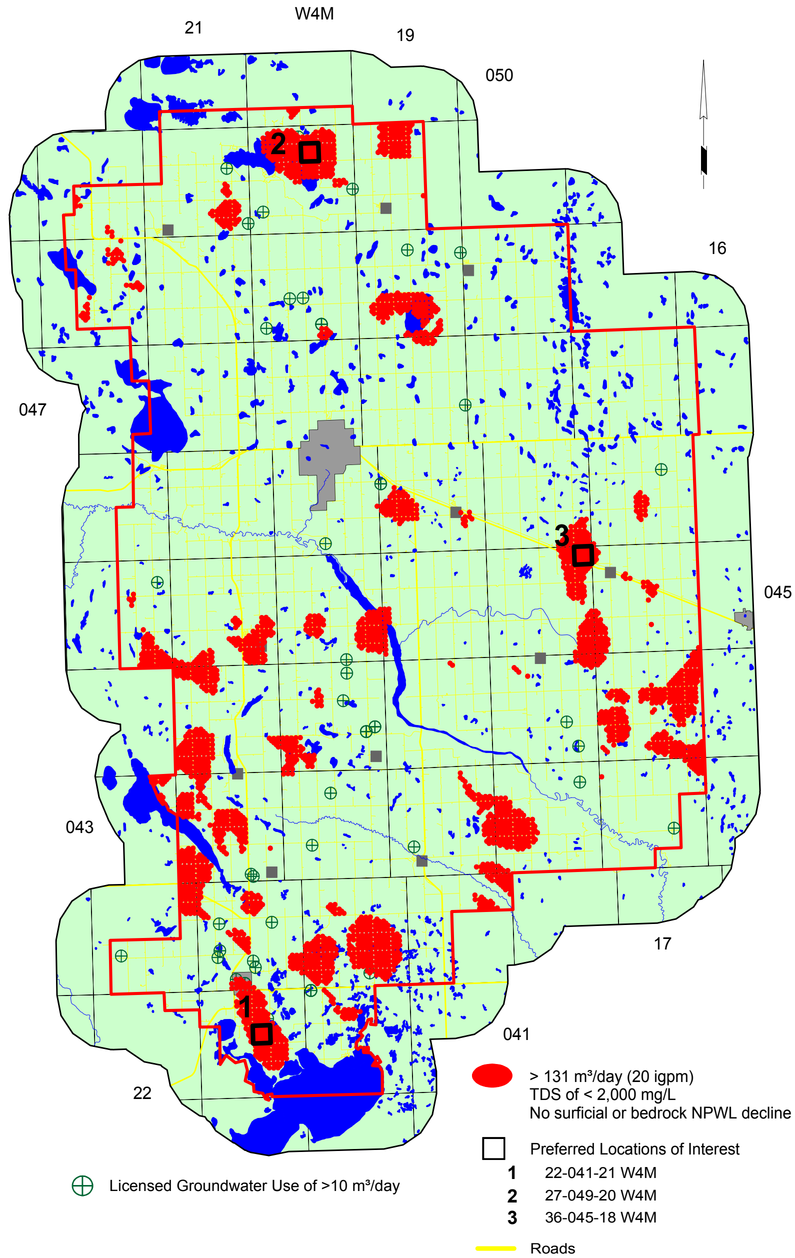
Non-Pumping Water-Level Decline in Surficial Deposits – Area 1



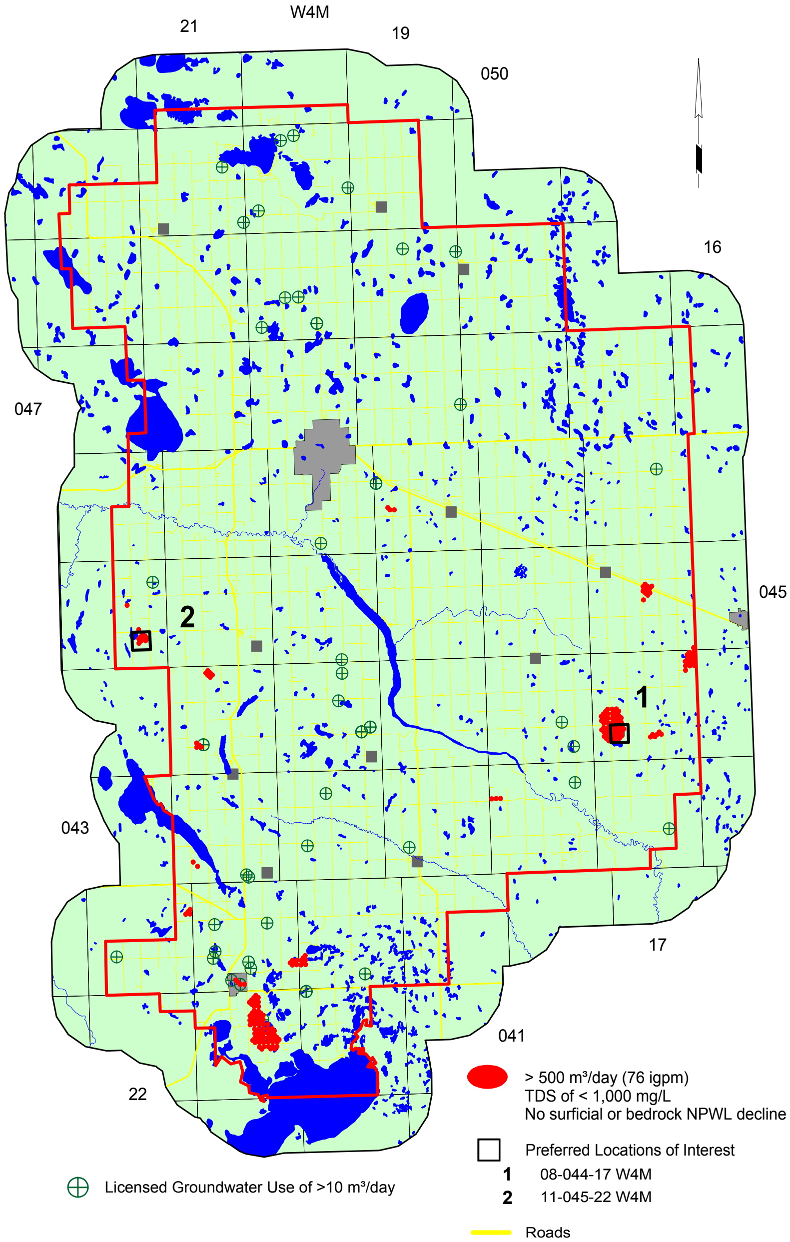
SW-NE Cross-Section – Area 1



Areas of Groundwater Potential – Area 2

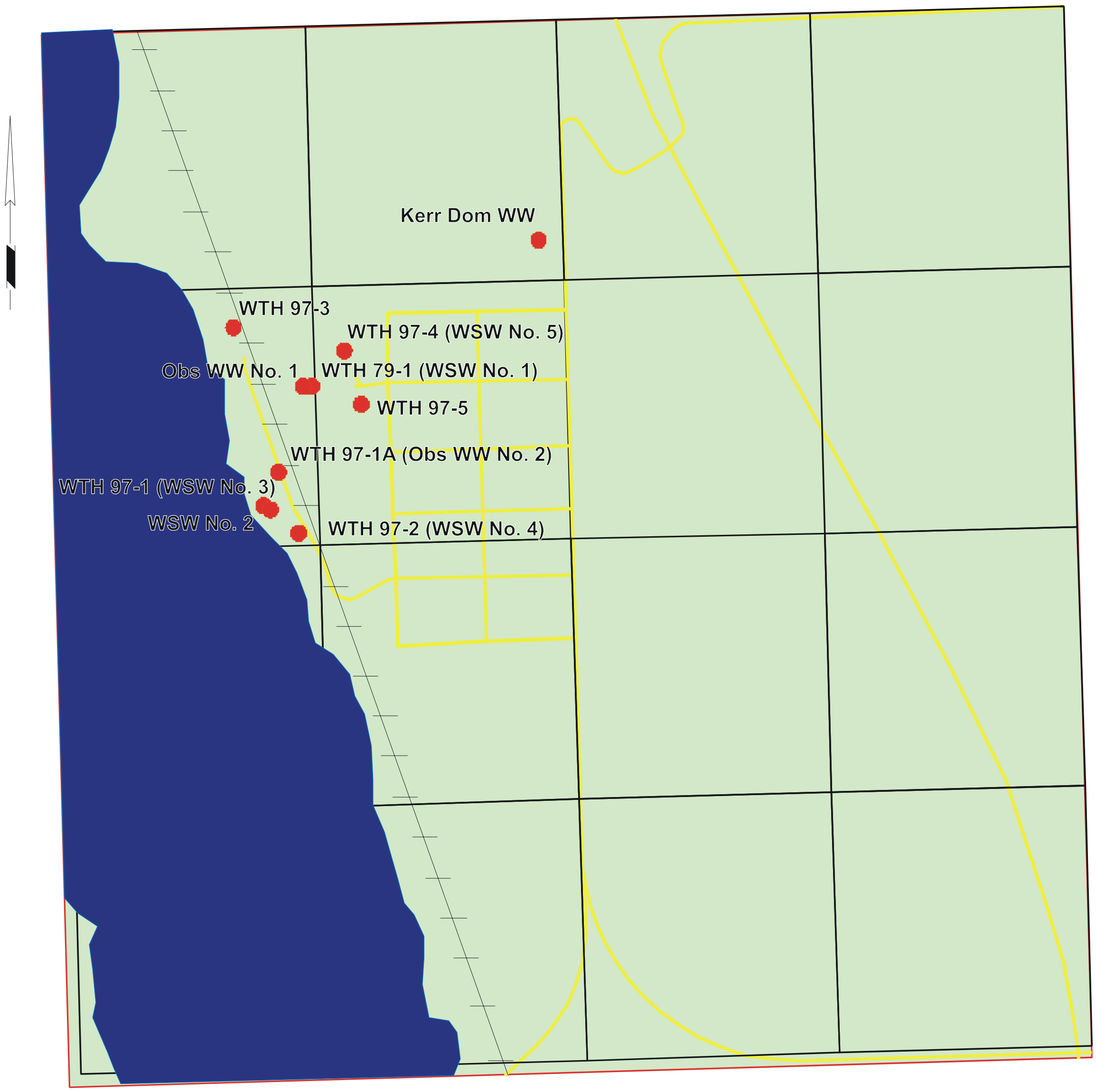


Areas of Groundwater Potential – Area 3

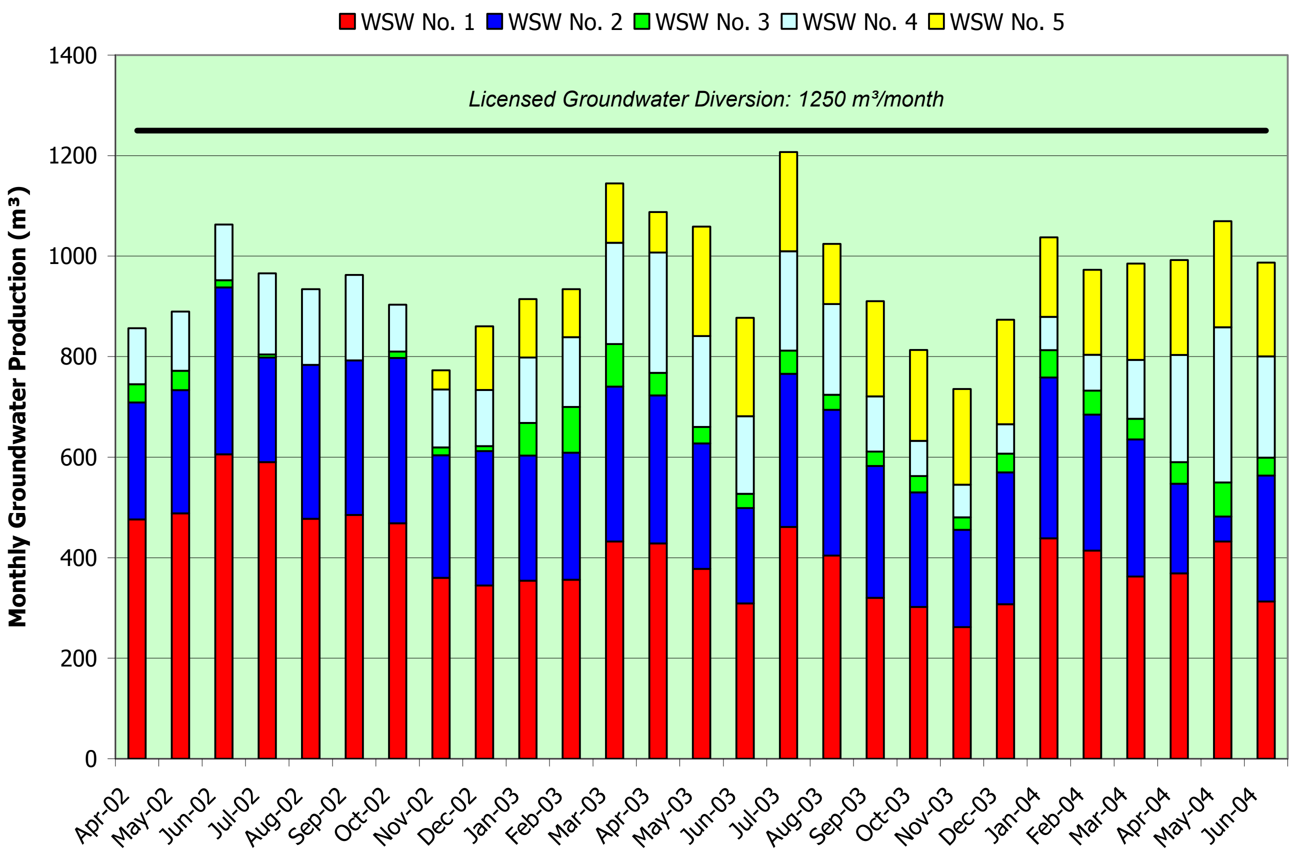


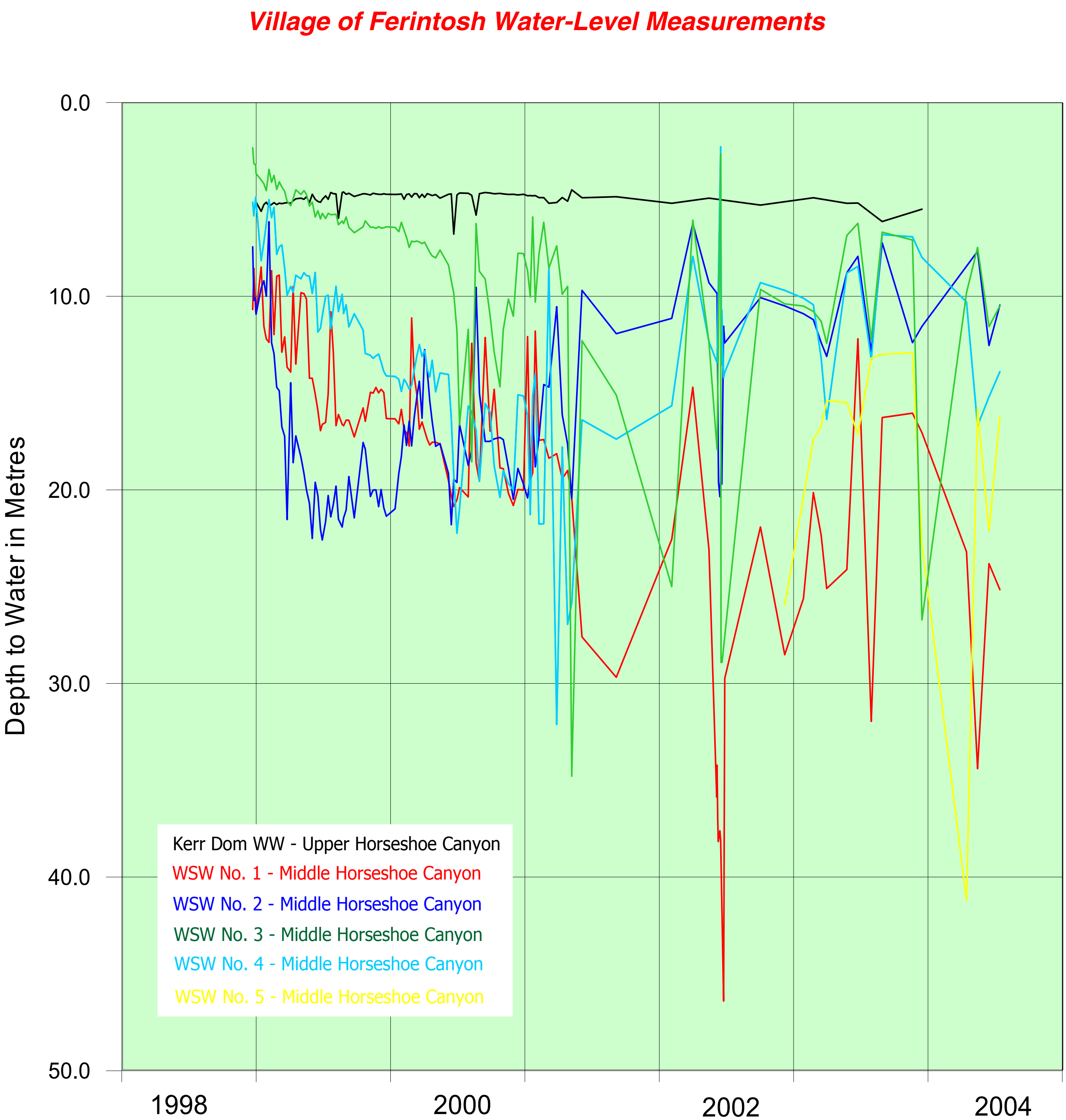
Village of Ferintosh Water Wells

Section 03, Township 044, Range 21, W4M

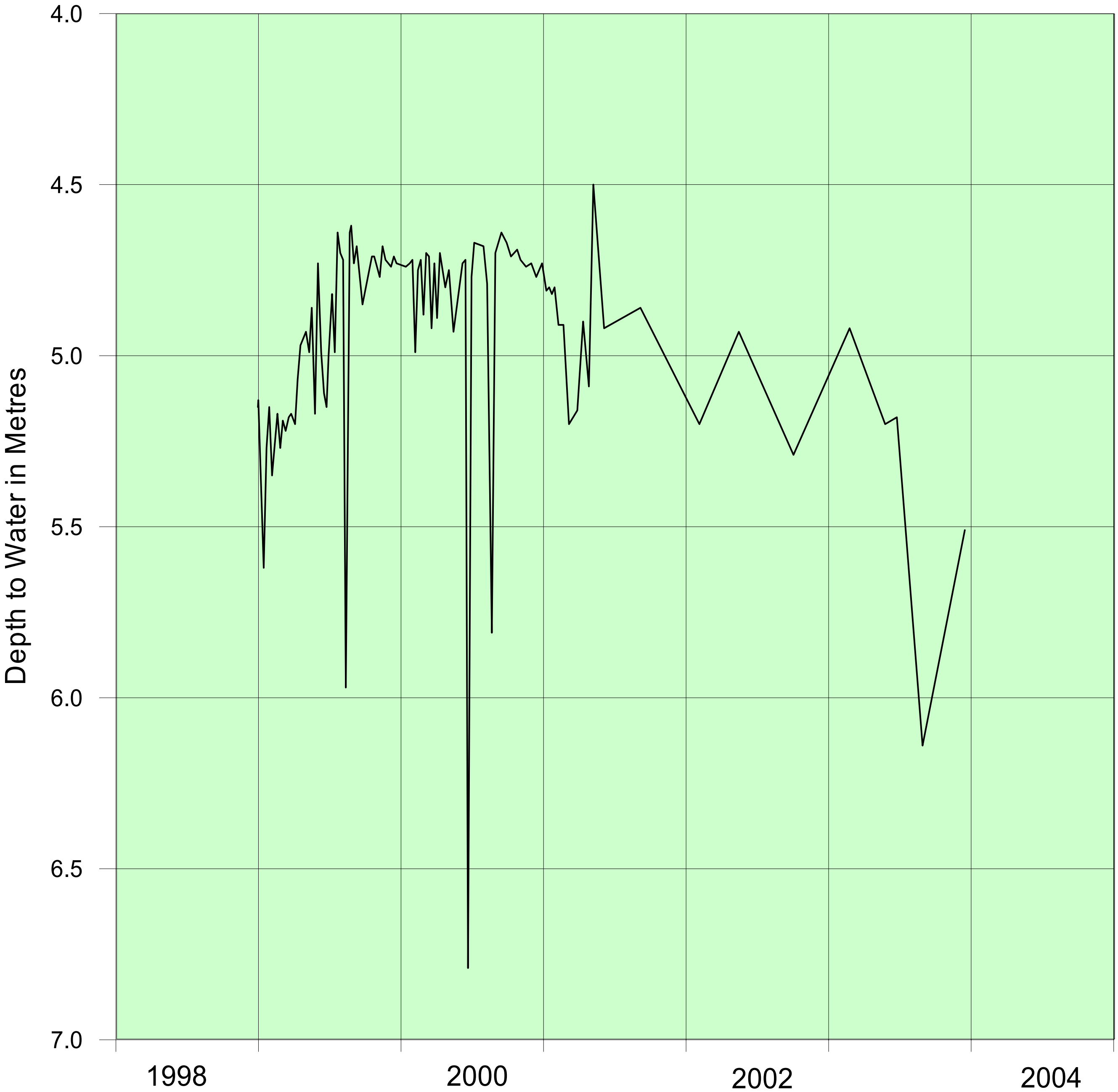


Village of Ferintosh 2002 – 2004 Monthly Groundwater Production

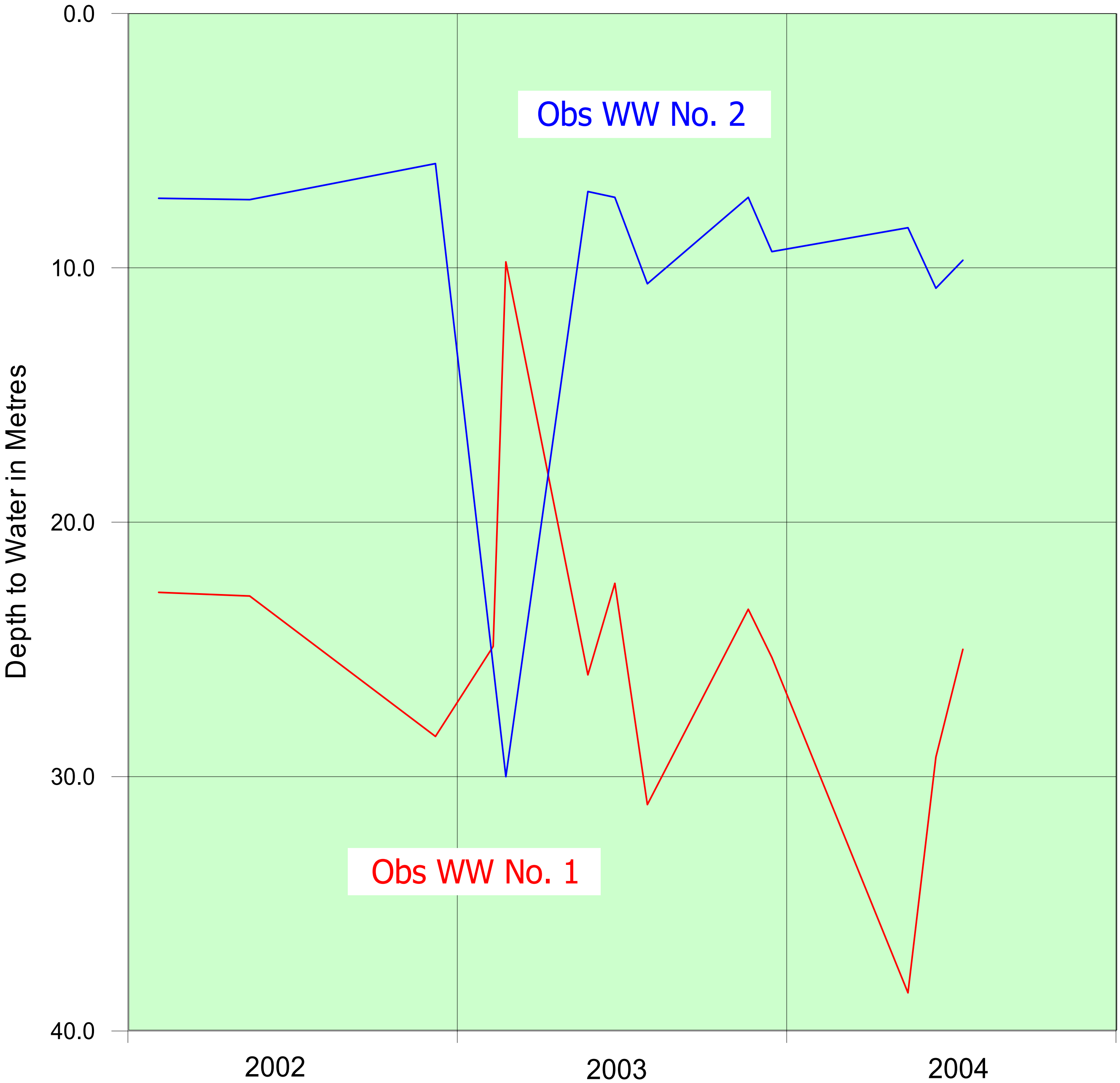



Village of Ferintosh Water-Level Measurements
Depth to Water in Metres
0.0
10.0
20.0
30.0
40.0
50.0
1998
2000
2002
2004
Kerr Dom WW - Upper Horseshoe Canyon
WSW No. 1 - Middle Horseshoe Canyon
WSW No. 2 - Middle Horseshoe Canyon
WSW No. 3 - Middle Horseshoe Canyon
WSW No. 4 - Middle Horseshoe Canyon
WSW No. 5 - Middle Horseshoe Canyon

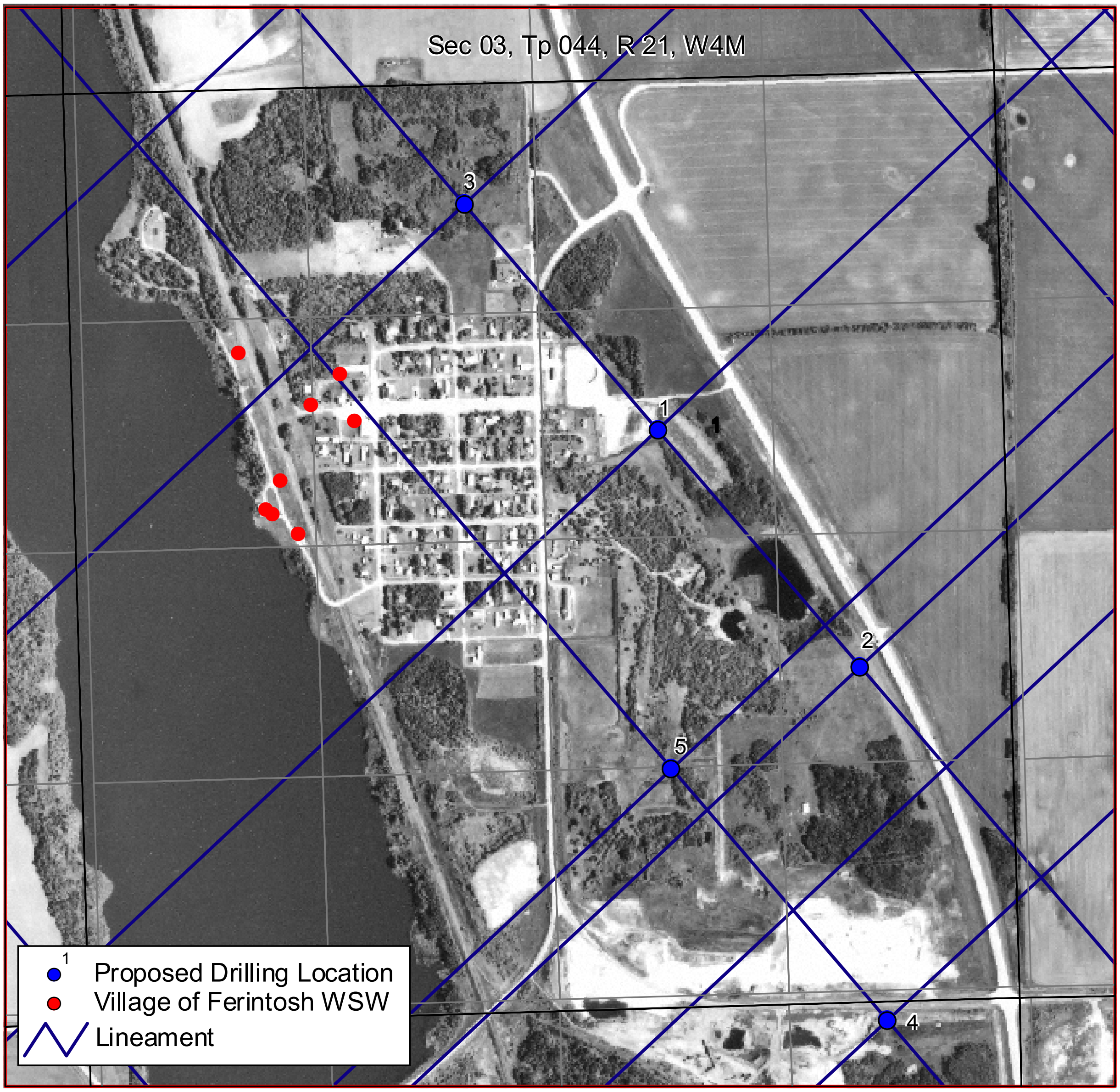
Village of Ferintosh Water-Level Measurements – Kerr Dom WW



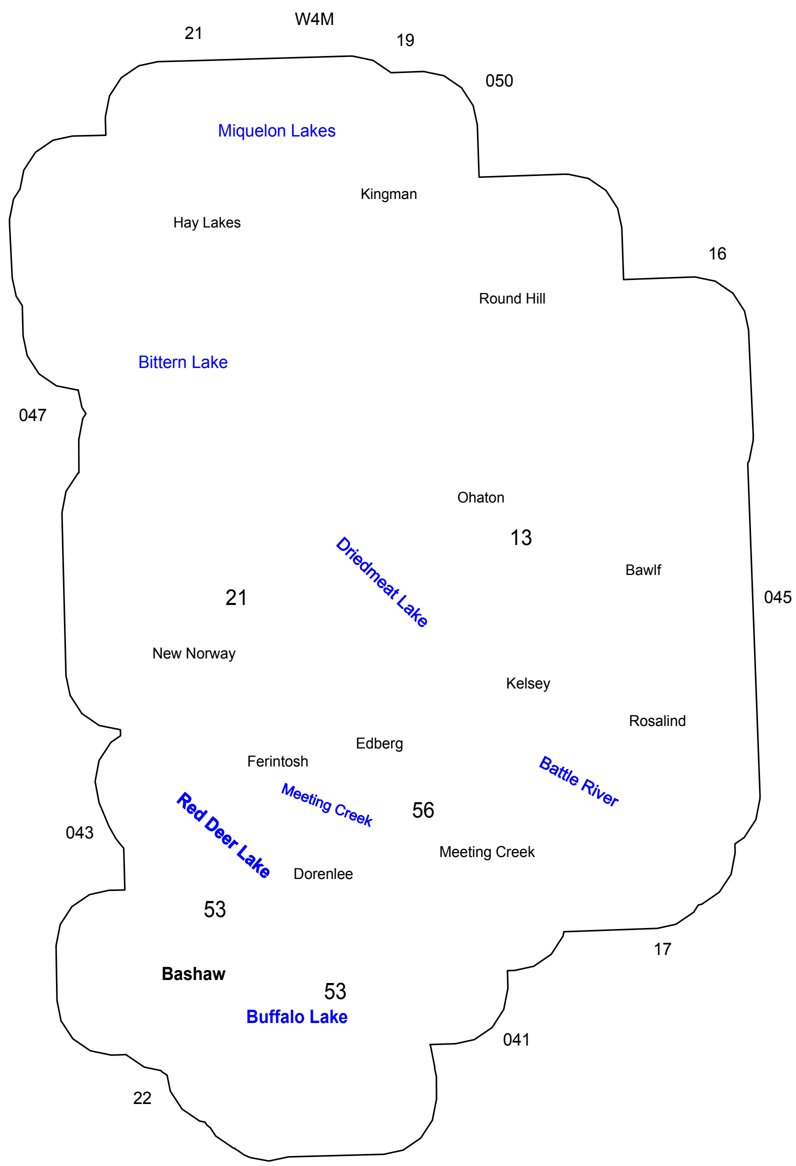
Village of Ferintosh Water-Level Measurements – Obs WW Nos. 1 and 2



Village of Ferintosh Proposed Water Test Hole Drilling Sites



Overlay


21
W4M
19
050
Miquelon Lakes
Kingman
Hay Lakes
16
Round Hill
Bittern Lake
047
Ohaton
13
Driedmeat Lake
Bawlf
21
045
New Norway
Kelsey
Rosalind
Edberg
Ferintosh
Battle River
Meeting Creek
Red Deer Lake
56
043
Meeting Creek
Dorenlee
53
17
Bashaw
53
Buffalo Lake
041
22

COUNTY OF CAMROSE NO. 22

Appendix B

Maps and Figures on CD-ROM

MAPS AND FIGURES ON CD-ROM

3) Bedrock Aquifers

C **a) General**

C01 Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)
C02 Bedrock Water Well Yields vs Completed Depth
C03 Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)
C04 Sulfate in Groundwater from Upper Bedrock Aquifer(s)
C05 Chloride in Groundwater from Upper Bedrock Aquifer(s)
C06 Fluoride in Groundwater from Upper Bedrock Aquifer(s)
C07 Fluoride in Groundwater from Upper Bedrock Aquifer(s) in Camrose County and Surrounding Counties
C08 Fluoride vs Sodium Concentrations
C09 Total Hardness of Groundwater from Upper Bedrock Aquifer(s)
C10 Piper Diagram - Bedrock Aquifer(s)
C11 Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)
C12 Non-Pumping Water-Level Surface in Upper Bedrock Aquifer(s)
C13 Areas of Potential Groundwater Decline - Upper Bedrock Aquifer(s)

b) Upper Scollard Formation

C14 Depth to Top of Upper Scollard Formation
C15 Structure-Contour Map - Upper Scollard Formation

c) Lower Scollard Formation

C16 Depth to Top of Lower Scollard Formation
C17 Structure-Contour Map - Lower Scollard Formation

d) Battle Formation

C18 Depth to Top of Battle Formation
C19 Structure-Contour Map - Battle Formation

e) Upper Horseshoe Canyon Formation

C20 Depth to Top of Upper Horseshoe Canyon Formation
C21 Structure-Contour Map - Upper Horseshoe Canyon Formation
C22 Non-Pumping Water-Level Surface - Upper Horseshoe Canyon Aquifer
C23 Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer
C24 Total Dissolved Solids in Groundwater from Upper Horseshoe Canyon Aquifer
C25 Sulfate in Groundwater from Upper Horseshoe Canyon Aquifer
C26 Chloride in Groundwater from Upper Horseshoe Canyon Aquifer
C27 Fluoride in Groundwater from Upper Horseshoe Canyon Aquifer
C28 Piper Diagram - Upper Horseshoe Canyon Aquifer

f) Middle Horseshoe Canyon Formation

C29 Depth to Top of Middle Horseshoe Canyon Formation
C30 Structure-Contour Map - Middle Horseshoe Canyon Formation
C31 Non-Pumping Water-Level Surface - Middle Horseshoe Canyon Aquifer
C32 Apparent Yield for Water Wells Completed through Middle Horseshoe Canyon Aquifer
C33 Total Dissolved Solids in Groundwater from Middle Horseshoe Canyon Aquifer
C34 Sulfate in Groundwater from Middle Horseshoe Canyon Aquifer
C35 Chloride in Groundwater from Middle Horseshoe Canyon Aquifer
C36 Fluoride in Groundwater from Middle Horseshoe Canyon Aquifer
C37 Piper Diagram - Middle Horseshoe Canyon Aquifer

g) Lower Horseshoe Canyon Formation

C38 Depth to Top of Lower Horseshoe Canyon Formation
C39 Structure-Contour Map - Lower Horseshoe Canyon Formation
C40 Non-Pumping Water-Level Surface - Lower Horseshoe Canyon Aquifer
C41 Apparent Yield for Water Wells Completed through Lower Horseshoe Canyon Aquifer
C42 Total Dissolved Solids in Groundwater from Lower Horseshoe Canyon Aquifer
C43 Sulfate in Groundwater from Lower Horseshoe Canyon Aquifer
C44 Chloride in Groundwater from Lower Horseshoe Canyon Aquifer
C45 Fluoride in Groundwater from Lower Horseshoe Canyon Aquifer
C46 Piper Diagram - Lower Horseshoe Canyon Aquifer

COUNTY OF CAMROSE NO. 22
Appendix C

General Water Well Information

Domestic Water Well Testing

Purpose and Requirements

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

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

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

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

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

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

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

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

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

Procedure

Site Diagrams

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

Surface Details

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

Groundwater Discharge Point

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

Water-Level Measurements

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

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

Discharge Measurements

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

Water Samples

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

Water Act - Water (Ministerial) Regulation

PROVINCE OF ALBERTA

WATER ACT

WATER (MINISTERIAL) REGULATION

Alberta Regulation 205/98

EXTRACT FROM THE
ALBERTA GAZETTE

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Note: After Jan. 25/99 use area code (780)

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ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

Table of Contents

1

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/

WATER WELL INSPECTORS
Jennifer McPherson (Edmonton: 780-427-6429)

WATER WELL LICENSING
Alan Hingston (Edmonton: 780-427-6429)

GEOPHYSICAL INSPECTION SERVICE
Edmonton: 780-427-3932

COMPLAINT INVESTIGATIONS
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)

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Dean Lien (Edmonton: 780-427-2433)

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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

COUNTY OF CAMROSE NO. 22

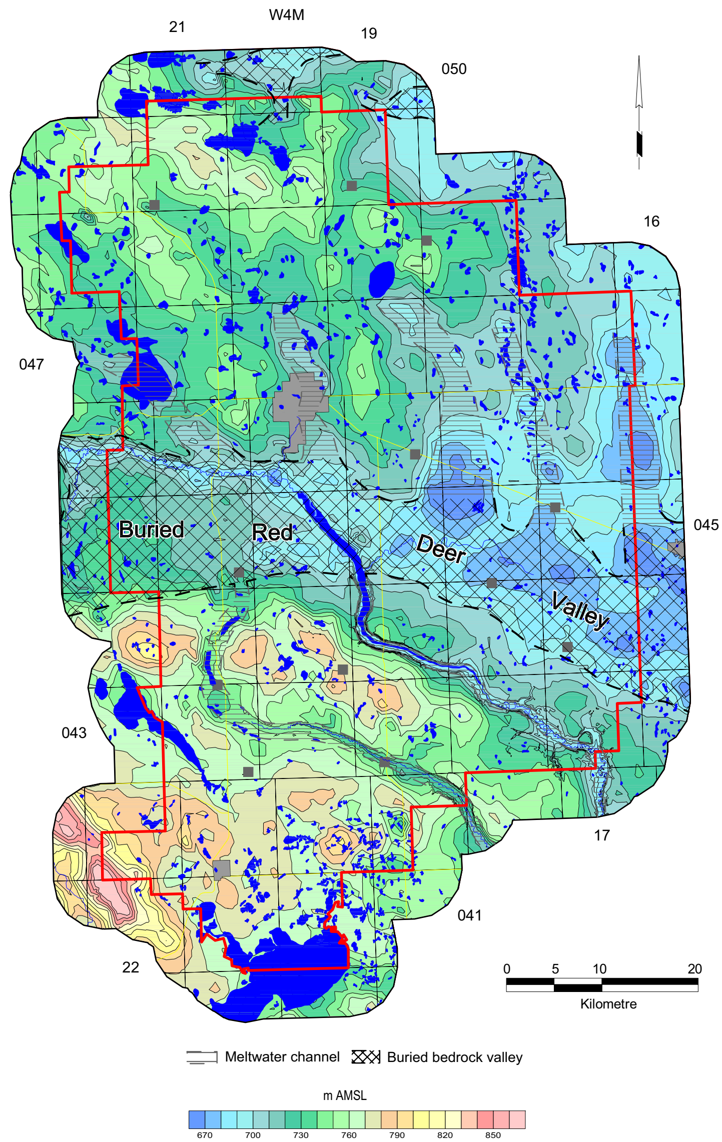
Appendix D

Maps and Figures Included as Large Plots

Bedrock Topography

County of Camrose No. 22

Bedrock Topography



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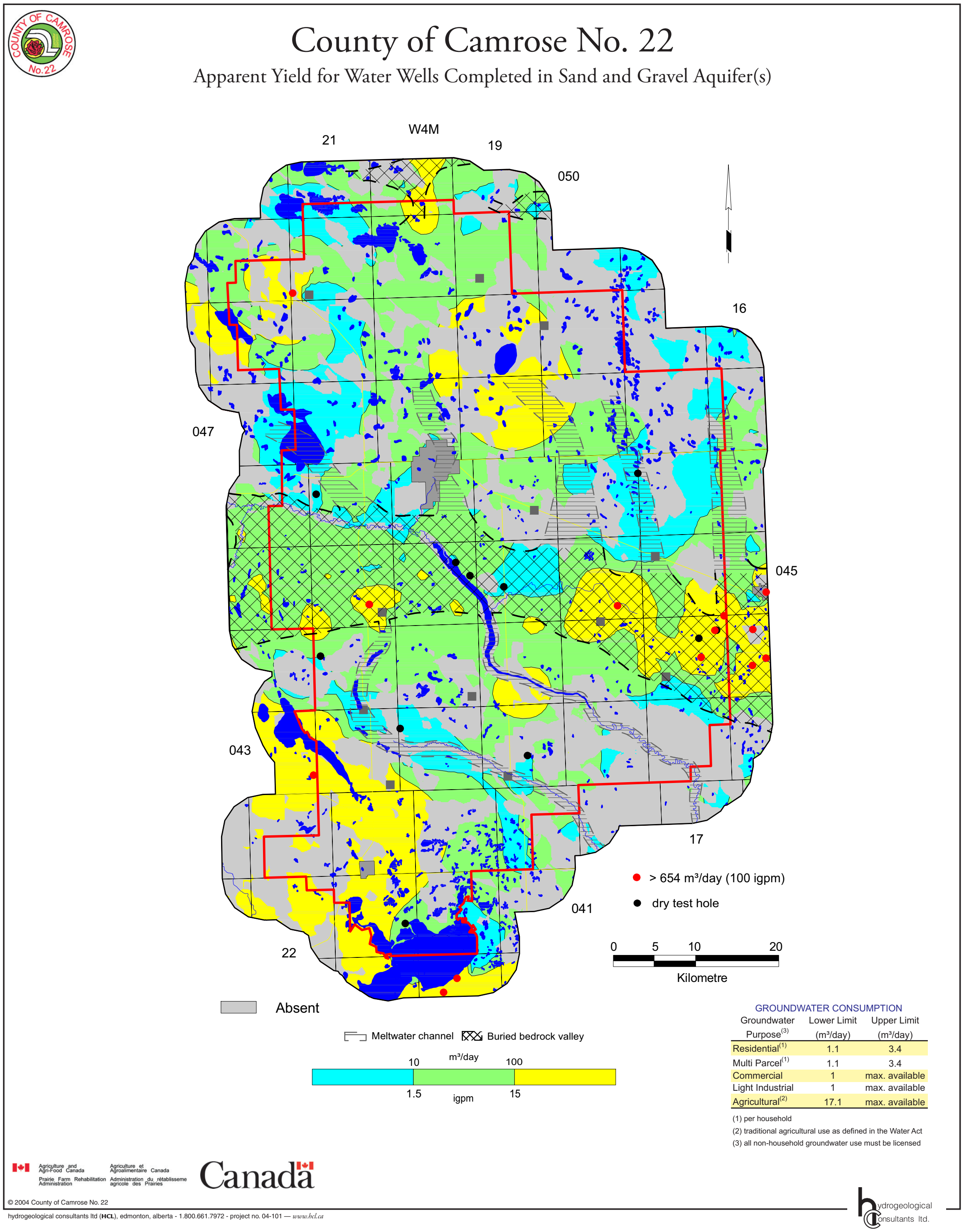
hydrogeological consultants ltd.

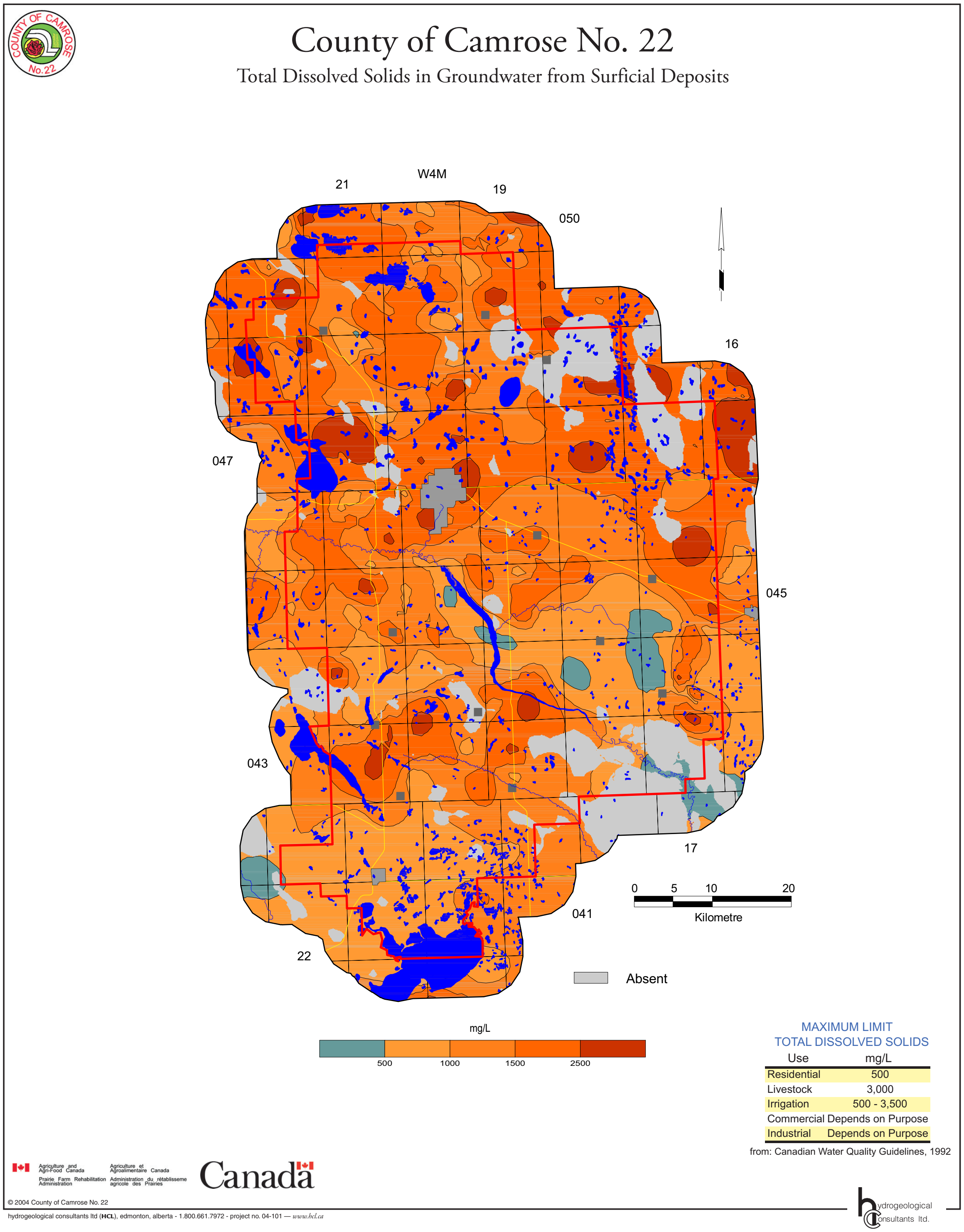
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



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

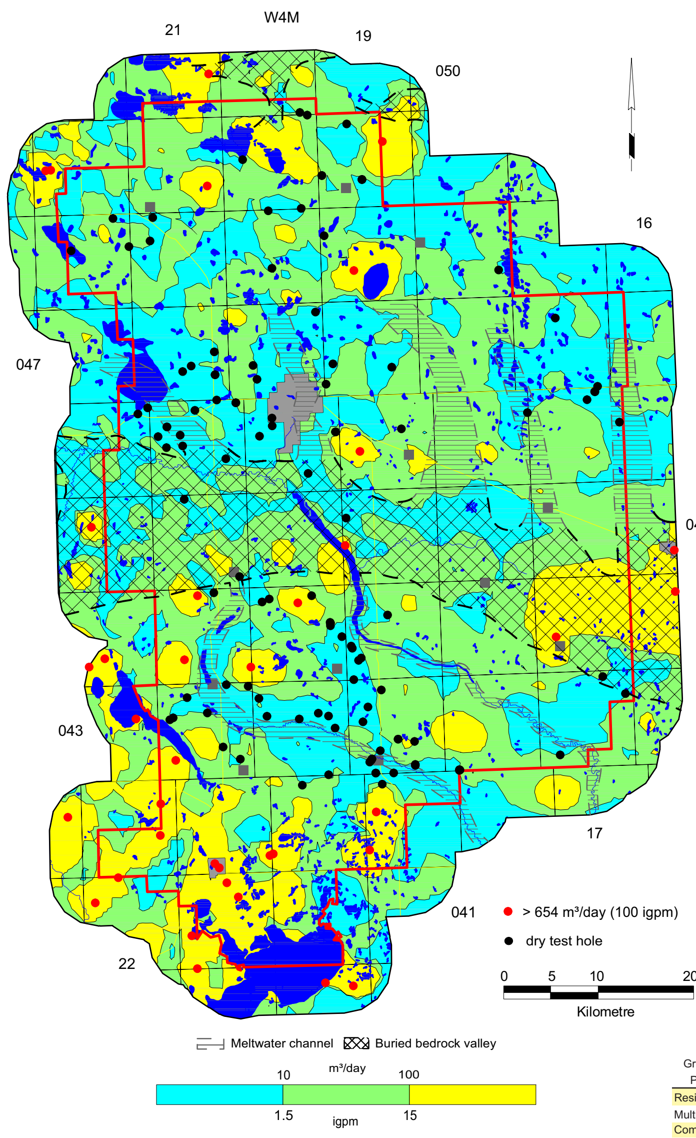
Total Dissolved Solids in Groundwater from Surficial Deposits



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

County of Camrose No. 22

Apparent Yield for Water Wells Completed in Upper Bedrock 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

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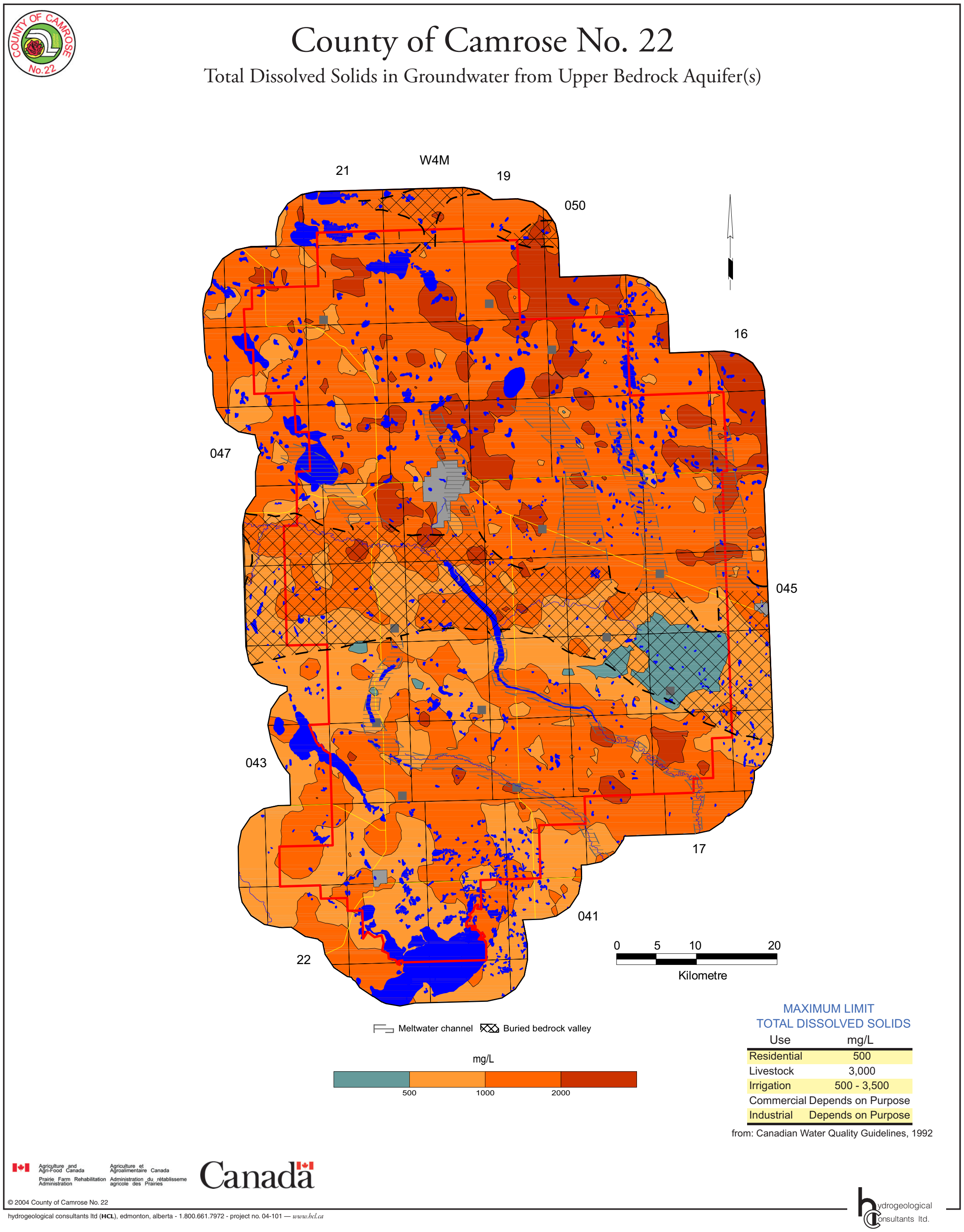
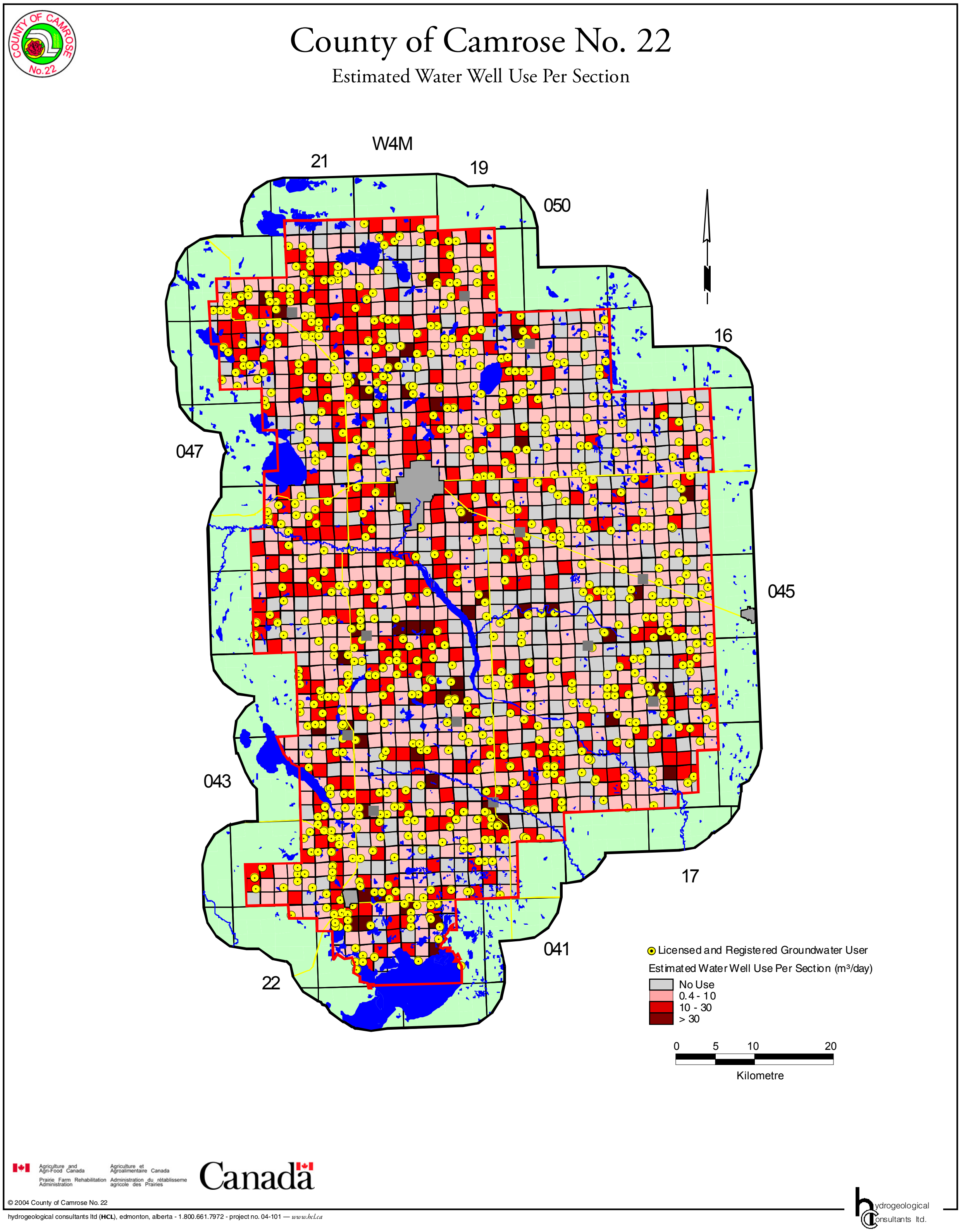
hydrogeological consultants ltd.

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



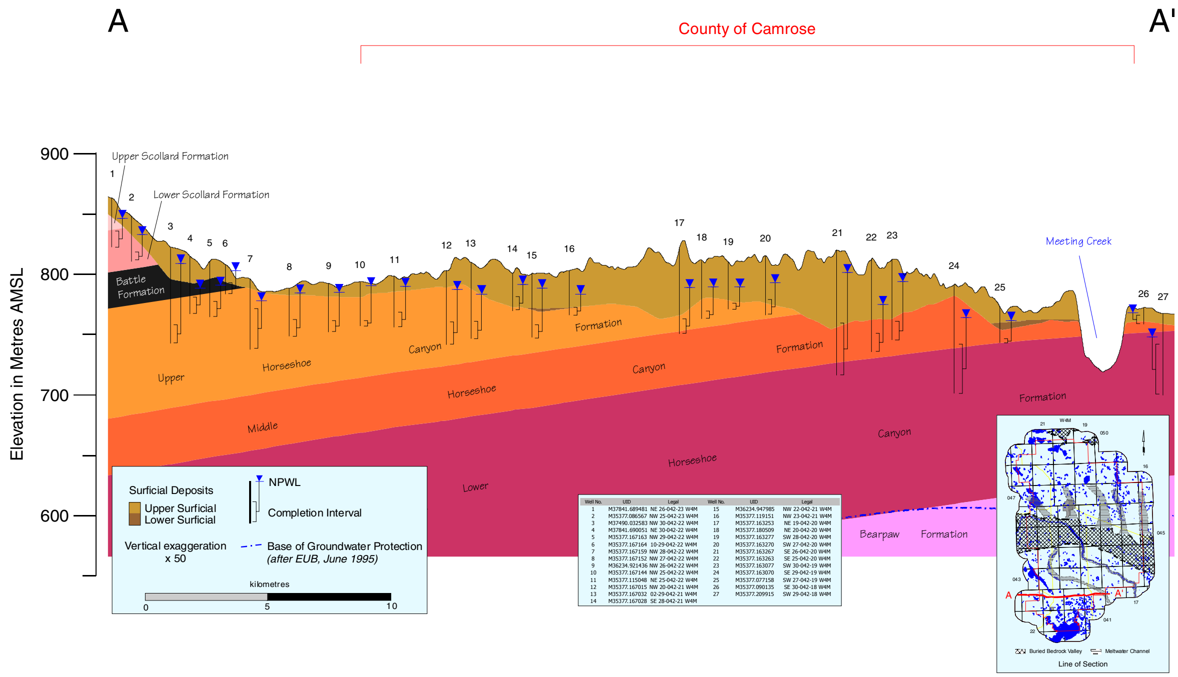
Estimated Water Well Use Per Section



Cross-Section A - A'

County of Camrose No. 22

Cross-Section A - A'



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8	M35377.167152	NW 27-042-22 W4M	22	M35377.163263	SE 25-042-20 W4M
9	M36234.921436	NW 26-042-22 W4M	23	M35377.163077	SW 30-042-19 W4M
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12	M35377.167015	NW 20-042-21 W4M	26	M35377.090135	SE 30-042-18 W4M
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14	M35377.167028	SE 28-042-21 W4M			

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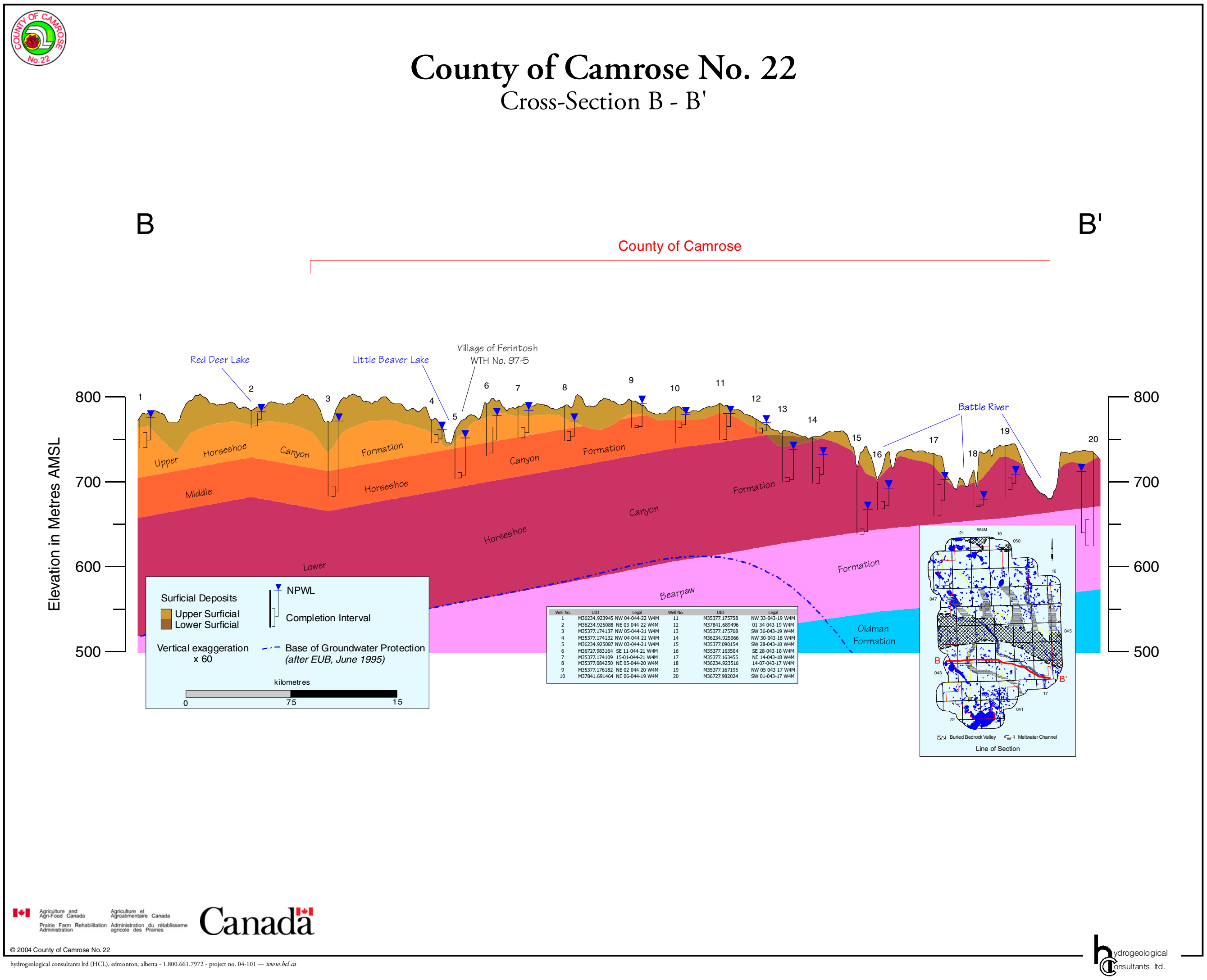
Cross-Section B - B'



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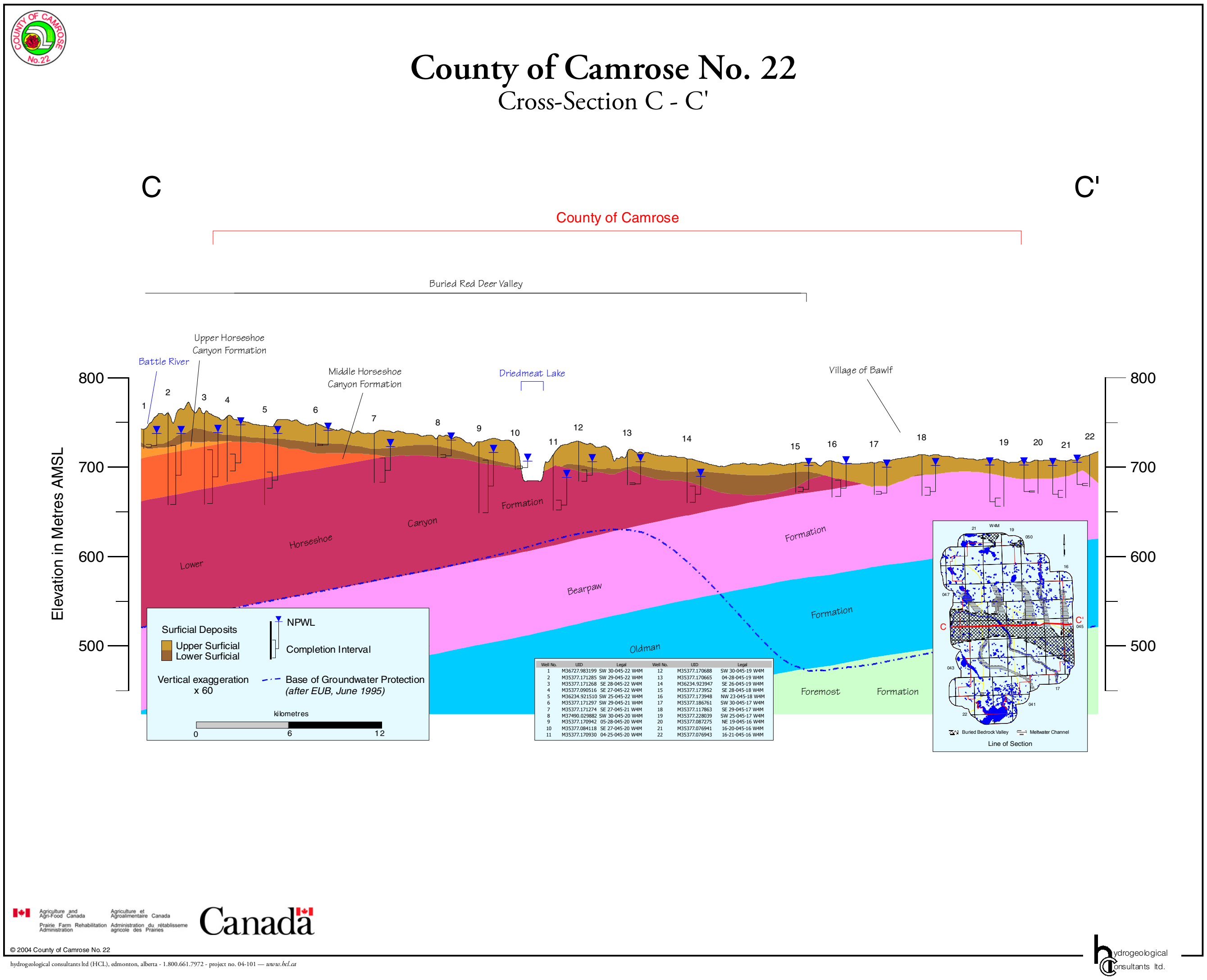

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5	M36234.921510	SW 25-045-22 W4M	16	M35377.173948	NW 23-045-18 W4M
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7	M35377.171274	SE 27-045-21 W4M	18	M35377.117863	SE 29-045-17 W4M
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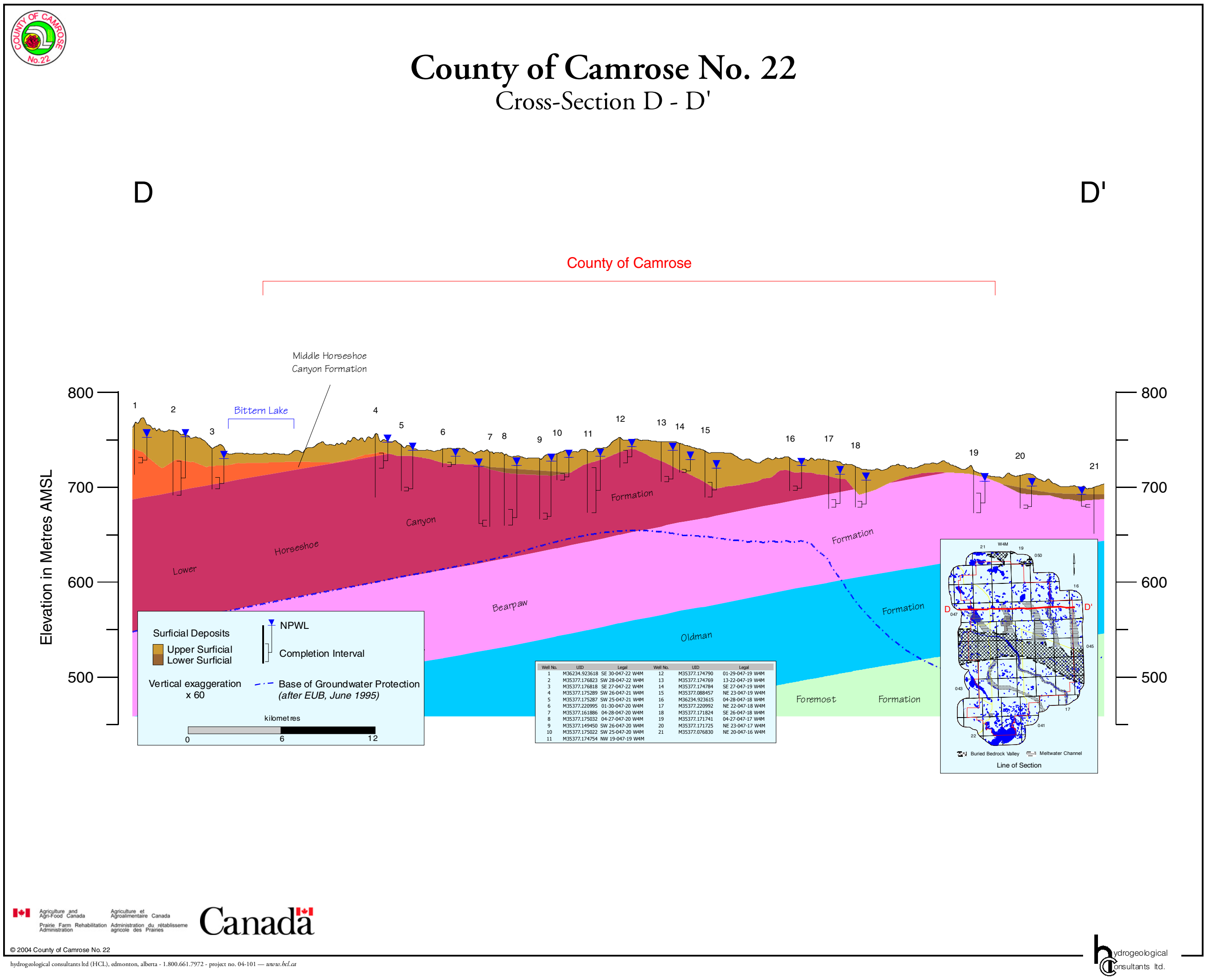

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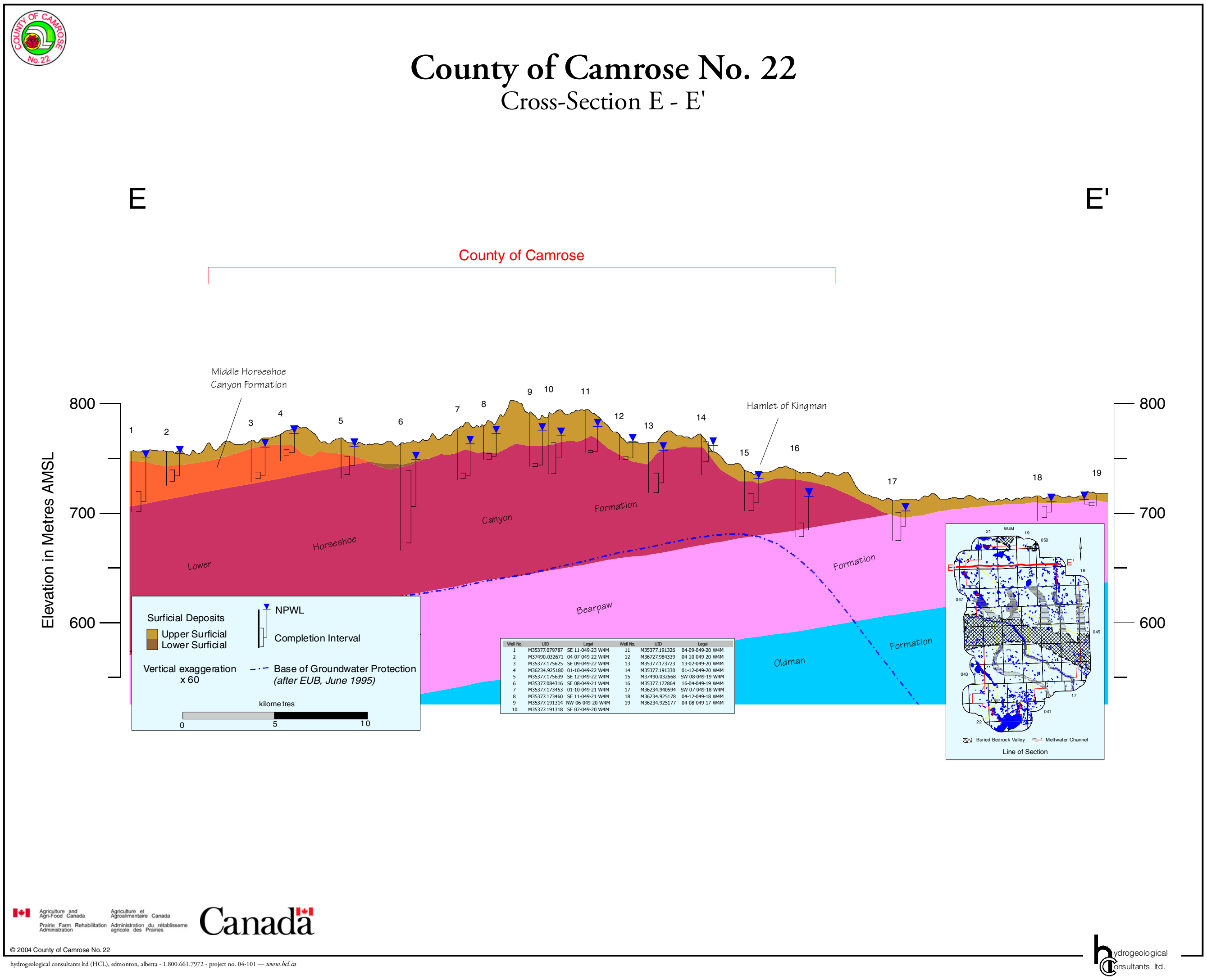

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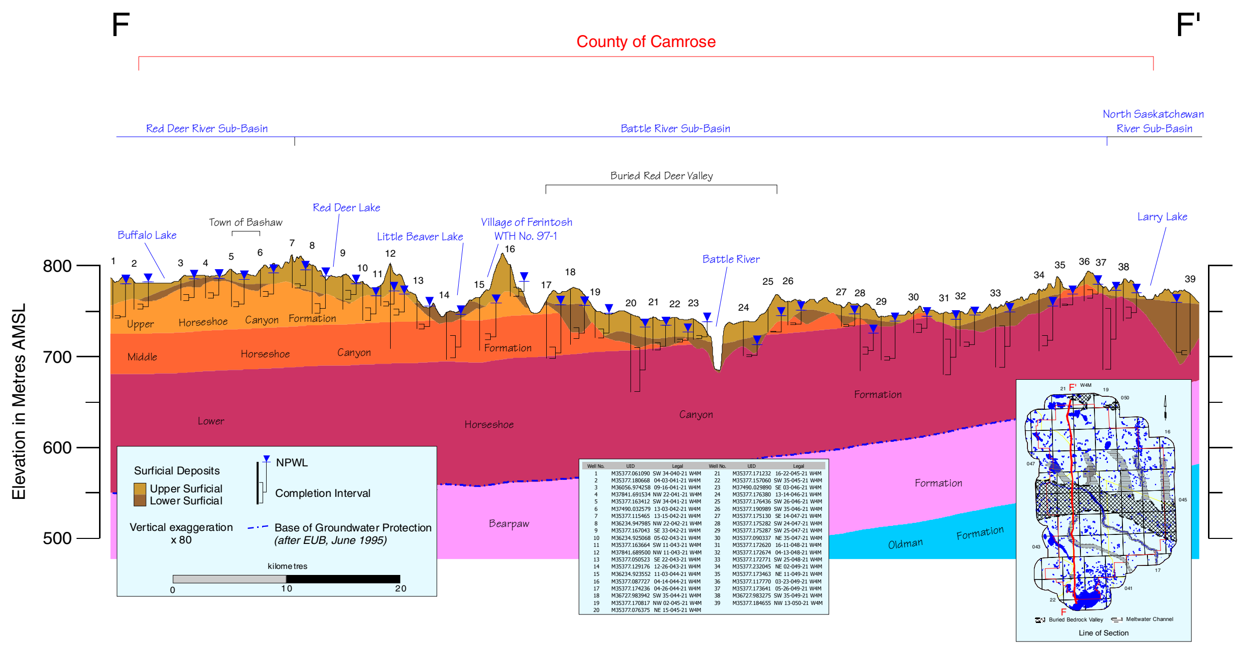
Cross-Section F - F'

County of Camrose No. 22

Cross-Section F - F'



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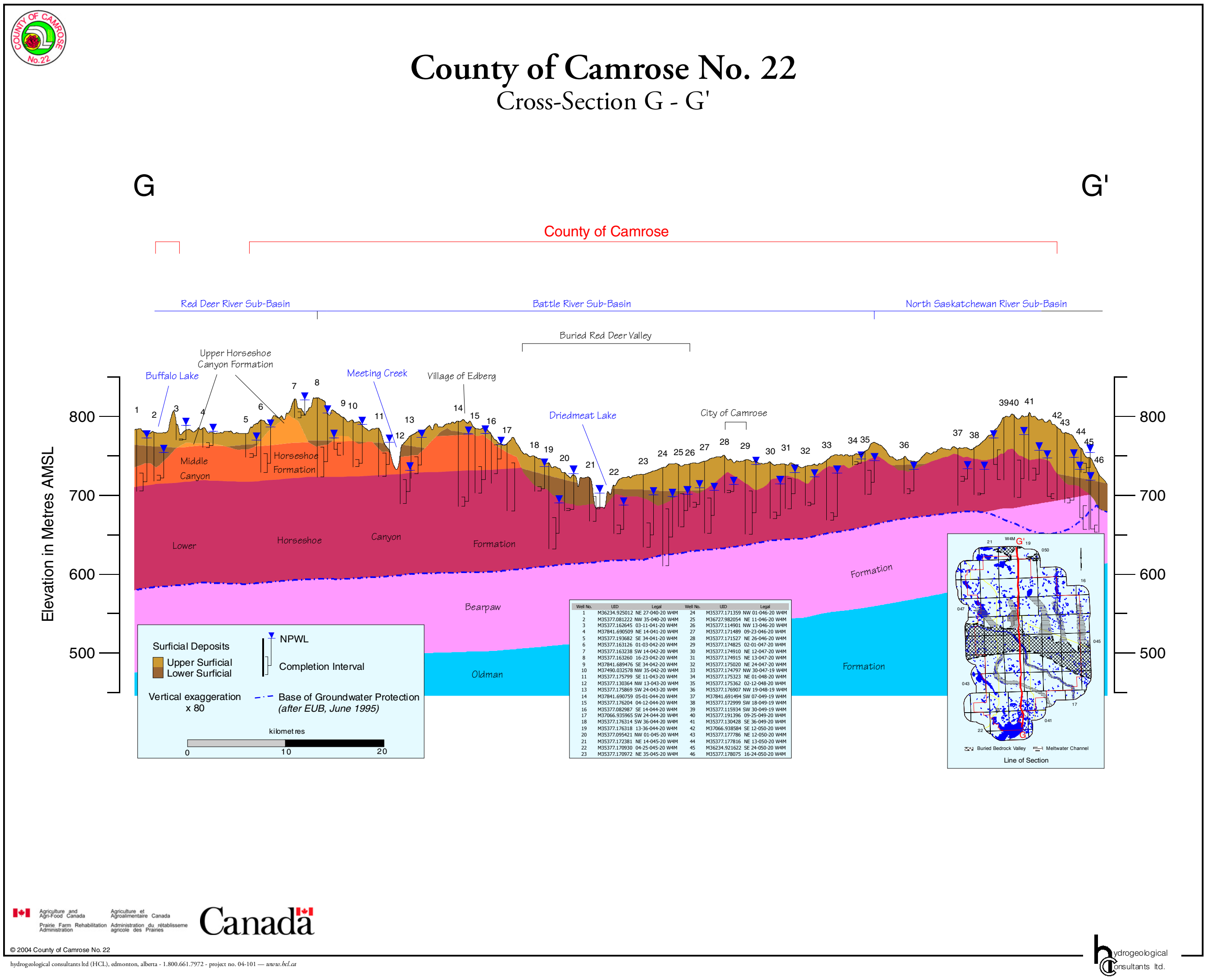
Cross-Section G - G'



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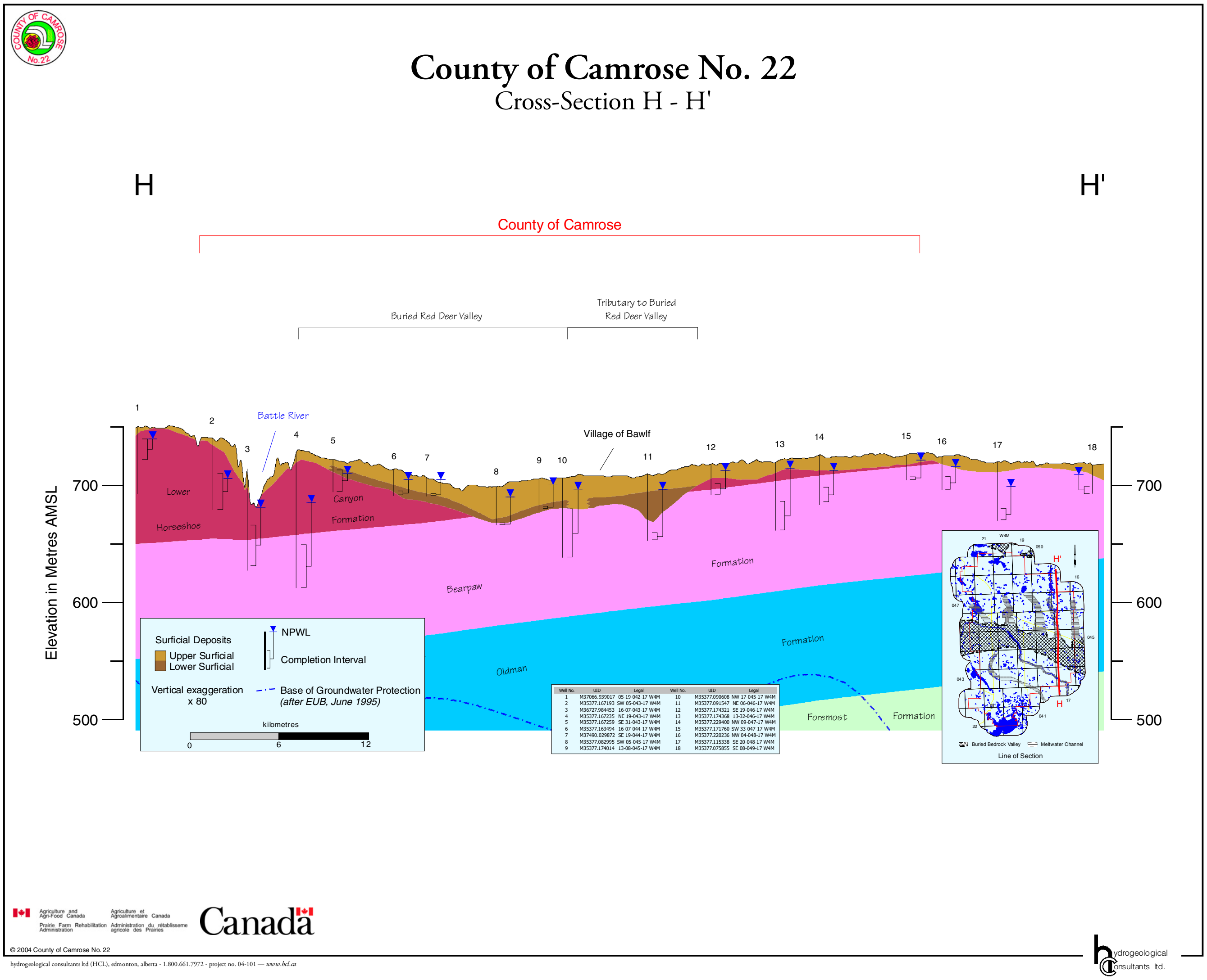

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5	M35377.167259	SE 31-043-17 W4M	14	M35377.229400	NW 09-047-17 W4M
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7	M37490.029872	SE 19-044-17 W4M	16	M35377.220236	NW 04-048-17 W4M
8	M35377.082995	SW 05-045-17 W4M	17	M35377.115338	SE 20-048-17 W4M
9	M35377.174014	13-08-045-17 W4M	18	M35377.075855	SE 08-049-17 W4M

COUNTY OF CAMROSE NO. 22

Appendix E

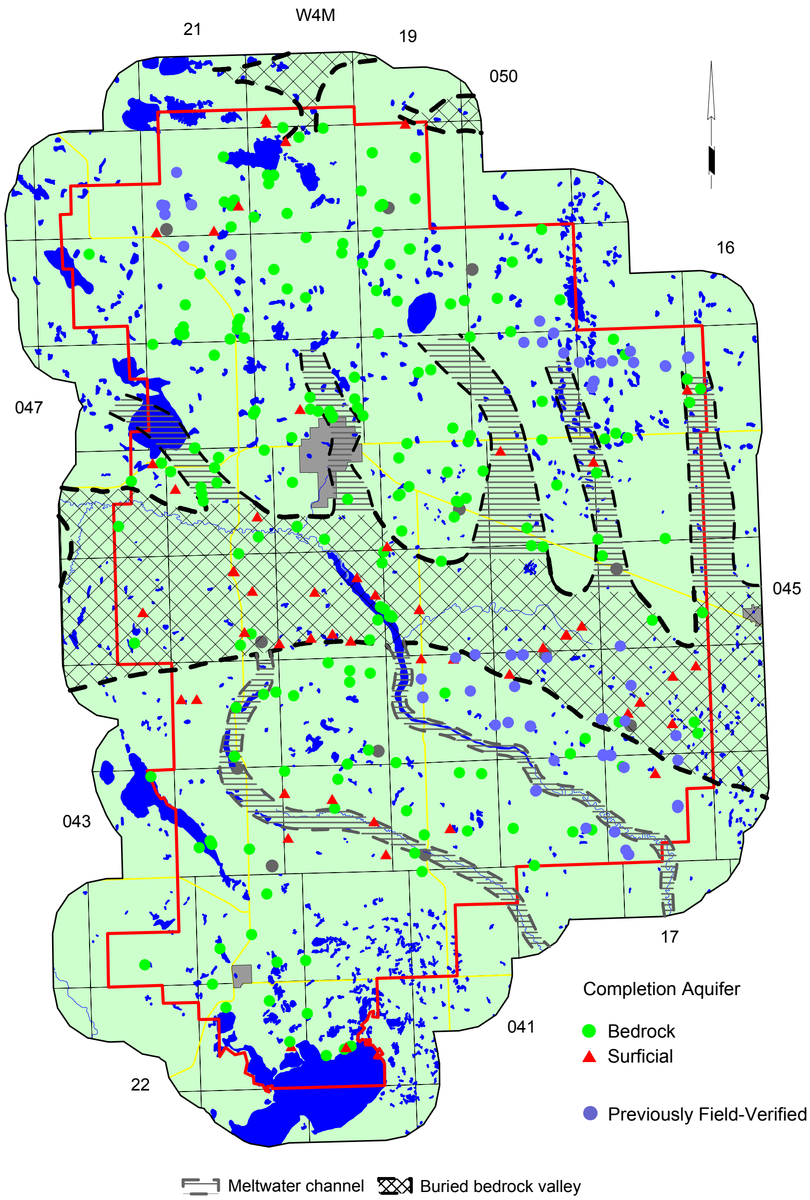
Water Wells That Have been Field-Verified
and Water Wells That Are Recommended for Field-Verification

including

County-Operated Water Wells

Water Wells That Have Been Field-Verified and Water Wells That Are Recommended For Field-Verification

(details on following pages)



WATER WELLS THAT HAVE BEEN FIELD-VERIFIED

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	Date Field Verified	UID
Acehoida, Kon	NE 03-006-14 W4M	Milk River	31-Mar-89	249.9	820.0	12.2	40.0	10-Jun-99	M35377.118436
Aden School Divison	---16-001-10 W4M	Milk River	09-May-40	115.8	380.0	18.3	60.0	13-Aug-01	M35377.094985
Alberta Environment	12-26-006-14 W4M	Milk River	18-Jan-85	213.4	700.0	2.3	7.5	24-Jun-99	M35377.118490
Alberta Environment	16-17-006-11 W4M	Milk River		216.4	710.0	57.9	190.0	03-Dec-00	M35377.127957
Als Farms Ltd.	SE 08-007-11 W4M	Milk River	25-Jan-90	234.7	770.0	24.4	80.0	03-Jun-99	M35377.083451
Anderson, Roy	SW 30-007-06 W4M	Milk River						07-May-01	M38022.504596
Ashley	NE 09-005-09 W4M	Milk River		213.4	700.0			30-Jul-99	M35377.119097
Ayers, Gordon L.	SE 26-003-07 W4M	Milk River	01-Jan-53	182.9	600.0	0.0	0.1	17-May-01	M35377.128418
Bailey, Carson, H.	02-06-005-13 W4M	Milk River	01-Jan-43	175.9	577.0	1.5	5.0	02-Jun-99	M35377.118418
Bailie, Carson	SW 06-005-13 W4M	Milk River	27-Mar-90	179.8	590.0	2.1	7.0	02-Jun-99	M35377.082849
Bailie, Dick	SE 34-006-14 W4M	Milk River		243.8	800.0			21-Jun-99	M35377.118509
Bailie, Laura	08-21-006-14 W4M	Milk River	01-Jan-43	216.7	711.0			21-Jun-99	M35377.118471
Baker, Claude	NH 06-007-11 W4M	Bedrock	09-Oct-54	237.7	780.0			16-Jul-99	M35377.129456
Ball, Adrianna	SW 03-007-15 W4M	Milk River						03-Jun-99	M35377.129668
Barrows, T.	SW 15-007-10 W4M	Milk River		202.7	665.0			09-Aug-99	M35377.129323
Beaver Oils Ltd.	08-24-002-11 W4M	Milk River		214.3	703.0			29-Dec-00	M35377.114348
Bechthold, A.	SE 22-007-11 W4M	Milk River	25-Nov-89	222.5	730.0	14.6	48.0	04-Aug-99	M35377.084193
Beisterfeldt, L.	SE 11-005-07 W4M	Milk River		218.5	717.0			13-Jun-01	M35377.118676
Bennett, E. C.	NW 03-005-07 W4M	Milk River		204.2	670.0	-6.1	-20.0	11-Jun-01	M35377.118633
Bennett, Ed. C.	NW 03-005-07 W4M	Milk River	14-May-49	237.7	780.0			11-Jun-01	M35377.118618
Bennett, Foster	SW 03-005-07 W4M	Milk River	20-May-49	225.5	740.0			13-Jun-01	M35377.118619
Bianchi, Nick	SW 19-001-10 W4M	Milk River	26-Sep-58	170.7	560.0	57.9	190.0	23-Apr-01	M35377.094997
Biesterfeldt, Terry	SE 11-005-07 W4M	Milk River	12-Aug-50	278.3	913.0			13-Jun-01	M35377.118669
Black, Barry	NE 10-003-10 W4M	Milk River		176.8	580.0			09-Sep-99	M35377.092617
Black, Sid	15-10-003-10 W4M	Milk River	01-Jan-61	152.4	500.0			09-Sep-99	M35377.128540
Bodnaruk, Betty	NE 18-006-08 W4M	Milk River	10-Jun-88	267.0	876.0	12.8	42.0	11-May-01	M35377.119454
Borden's	SE 16-008-10 W4M	[unknown]						10-Aug-99	M38022.504471
Britner Farms	15-33-004-12 W4M	Milk River	01-Jan-60	262.1	860.0	33.5	110.0	27-May-99	M35377.128360
Brustead, J.	NE 20-008-10 W4M	Milk River	01-Jan-20	274.3	900.0			10-Aug-99	M35377.129827
Brustead, M. O.	NE 20-008-10 W4M	Milk River		237.7	780.0			10-Aug-99	M35377.129828
Bullis, Herb	SE 36-005-12 W4M	Milk River						25-May-99	M38022.504410
Burbridge Farms Ltd.	SW 17-009-12 W4M	Upper Surficial						30-May-01	M35377.135061
C. M. C. Black Butte	08-18-001-08 W4M	Bedrock	30-Apr-60	236.2	775.0	87.5	287.0	25-Jun-01	M35377.094881
Campbell, D. M.	NW 01-007-08 W4M	Milk River	01-Jan-31	225.5	740.0	-2.4	-8.0	06-Jun-01	M35377.129064
Canada Customs/ Lamont Billingsly	02-03-001-10 W4M	Milk River	01-Nov-63	175.3	575.0	105.2	345.0	16-May-01	M35377.094900
Canada Montana Gas Company	NW 08-004-06 W4M	[unknown]						25-Jun-01	M38022.504633
Canada Montana Gas Company	NE 12-004-07 W4M	[unknown]						25-Jun-01	M38022.504634
Canadian Gulf Oil Company	13-19-008-08 W4M	Milk River	25-Nov-54	238.7	783.0			23-May-01	M35377.129541
Canadian Montana Gas Company Ltd.	NE 08-003-08 W4M	Milk River	04-Jul-51	245.1	804.0	35.7	117.2	30-Sep-00	M35377.087553
Canadian Natural Gas Company	NE 29-008-11 W4M	Milk River	01-Jan-26	192.0	630.0			04-Aug-99	M35377.129910
Carlson, T.	SE 09-008-09 W4M	Bedrock	01-Jan-35	281.9	925.0	-6.1	-20.0	25-May-01	M35377.129689
Chesney, Matt & Boyd	EH 27-007-09 W4M	Milk River	27-Dec-53	281.9	925.0			21-Sep-99	M35377.129291
Chin Valley Ranch Ltd.	NW 21-006-11 W4M	Milk River	20-Dec-81	155.4	510.0	14.0	46.0	21-May-99	M35377.129225
Chin Valley Ranch Ltd.	SE 19-006-11 W4M	Milk River	07-Jul-86	227.4	746.0	74.7	245.0	21-May-99	M35377.129201
Collin, Stewart	NE 33-004-12 W4M	Milk River	07-Jan-89	222.5	730.0	73.5	241.0	27-May-99	M35377.128367
Collin, Vincent	SW 14-006-14 W4M	Milk River	01-Jan-29	228.6	750.0	15.2	50.0	23-Jun-99	M35377.118453
Collins, John	SW 14-006-14 W4M	Milk River		249.9	820.0	7.8	25.5	23-Jun-99	M35377.118455
Collins, Loren	SW 14-006-14 W4M	Milk River	12-Jul-91	231.3	759.0	16.8	55.0	23-Jun-99	M35377.124485
Collins, Marvin	SE 21-006-08 W4M	Milk River	18-Mar-95	207.3	680.0	0.0	-0.1	14-Sep-99	M35377.220004
Conquergood, T. H.	SH 27-007-10 W4M	Milk River	01-Jan-44	223.7	734.0			11-Jun-01	M35377.129373
Conquerville School	NE 24-008-10 W4M	Milk River		243.8	800.0	7.6	25.0	03-Dec-00	M35377.129849
Conrade, Howard	SW 08-005-14 W4M	Milk River						30-Jun-99	M38022.504448
Cooke, J.	SE 17-007-11 W4M	Milk River	01-Jan-29	195.1	640.0	-0.6	-2.0	04-Aug-99	M35377.129497
County of Forty Mile	05-24-005-06 W4M	Milk River	01-Mar-73	335.3	1100.0	304.8	1000.0	28-May-01	M35377.128310
County of Forty Mile	NW 24-005-06 W4M	Milk River		304.8	1000.0			28-May-01	M35377.128330
County of Forty Mile	NE 14-006-09 W4M	Milk River	20-Sep-84	263.6	865.0	19.8	65.0	14-Sep-99	M35377.129007
County of Forty Mile	16-03-004-10 W4M	Milk River	01-Jul-67	225.5	740.0	38.1	125.0	16-Aug-01	M35377.118732
County of Forty Mile	SW 27-005-14 W4M	Milk River	07-Mar-00	243.8	800.0			25-Jun-99	M37066.938717
Courtney, Ralph	NW 23-006-09 W4M	Bedrock	11-May-50	256.3	841.0			18-Sep-99	M35377.129008
Courtney, Ralph	NE 18-006-08 W4M	Milk River						11-May-01	M38022.504629
Coverdale, Charles Claude	04-21-006-11 W4M	Milk River	01-Oct-72	213.4	700.0	61.0	200.0	21-May-99	M35377.129222
Coverdale, Todd	NW 08-004-13 W4M	Milk River	14-Jan-89	170.7	560.0			12-Jul-99	M35377.118377
Cowie, Bruce	SW 28-006-10 W4M	Milk River	17-Nov-89	224.3	736.0	18.3	60.0	07-Jun-99	M35377.129123
Cowie, Jack	10-08-006-10 W4M	Milk River	01-Jan-63	266.7	875.0	64.0	210.0	22-Jul-99	M35377.129098
Cowie, W.	NE 08-006-10 W4M	Milk River	01-Jan-23	274.3	900.0	30.5	100.0	22-Jul-99	M35377.129100
Craft, F. J.	NH 20-007-07 W4M	Bedrock	01-Jan-32	243.8	800.0	-3.1	-10.0	03-May-01	M35377.129048
Cunningham, Stan	SW 27-006-08 W4M	Milk River		240.8	790.0			14-Sep-99	M35377.119513
D'Agnone, Domenico	16-06-007-14 W4M	Milk River	11-Jul-50	229.8	754.0	6.1	20.0	02-May-00	M35377.118569
Dangerfield Farming & Ranching	NE 08-001-10 W4M	Milk River	24-Oct-75	182.9	600.0	37.5	123.0	16-May-01	M35377.094910
Dann, S. H.	---14-005-07 W4M	Milk River	10-Nov-49	295.6	970.0			13-Jun-01	M35377.118781

WATER WELLS RECOMMENDED FOR FIELD-VERIFICATION THAT MEET CRITERIA

		Aquifer	Date Water	Completed Depth		NPWL		
Owner	Location	Name	Well Drilled	Metres	Feet	Metres	Feet	UID
Adamson, Ernest	13-22-047-19 W4M	Lower Horseshoe Canyon	04-Oct-85	42.7	140.0	9.5	31.0	M35377.174769
Adamson, Harvey	SW 30-048-19 W4M	Lower Horseshoe Canyon	24-Dec-79	36.6	120.0	6.1	20.0	M35377.176948
Affleck, Lyle	07-33-046-21 W4M	Lower Horseshoe Canyon	26-Apr-82	63.4	208.0	21.9	72.0	M35377.176477
Affleck, Lyle	SE 33-046-21 W4M	Middle Horseshoe Canyon	28-May-75	32.3	106.0	8.8	29.0	M35377.176476
Alberta Department of Highways	SW 36-046-22 W4M	Surficial	01-May-58	30.5	100.0	9.1	30.0	M35377.176714
Alberta Wheat Pool Ltd.	SE 04-045-18 W4M	Surficial	09-Nov-66	37.2	122.0	10.7	35.0	M35377.173891
Anderson, H.	04-09-049-20 W4M	Lower Horseshoe Canyon	01-Sep-83	39.0	128.0	15.2	50.0	M35377.191326
Anderson, Hazel	··-08-049-19 W4M	Lower Horseshoe Canyon	27-Jan-81	24.4	80.0	7.0	23.0	M35377.172926
Anderson, Ted	SE 34-045-21 W4M	Lower Surficial	05-Sep-78	23.5	77.0	10.4	34.0	M35377.171464
Armena Rec Association Ltd.	SW 12-048-21 W4M	Lower Horseshoe Canyon	19-Aug-85	42.7	140.0	7.3	24.0	M35377.172658
Astley, Norm	SW 08-046-20 W4M	Lower Horseshoe Canyon	07-Jun-79	67.1	220.0	37.5	123.0	M35377.171383
Badry, Cliff	NE 12-045-17 W4M	Oldman	15-May-82	107.3	352.0	3.1	10.0	M35377.174026
Balla, Bill	EH 35-043-22 W4M	Upper Horseshoe canyon	24-Aug-79	37.2	122.0	2.4	8.0	M35377.068928
Banack, Chester	NW 34-046-18 W4M	Bearpaw	31-Jul-82	36.6	120.0	3.4	11.0	M35377.174464
Banack, Wm	16-12-048-19 W4M	Lower Horseshoe Canyon	27-Sep-75	59.1	194.0	35.1	115.0	M35377.176875
Baptist, Ross	NE 32-046-19 W4M	Lower Horseshoe Canyon	06-Jun-80	16.5	54.0	7.9	26.0	M35377.174547
Barker, Wayde	SW 21-046-21 W4M	Lower Horseshoe Canyon	23-May-85	52.4	172.0	32.0	105.0	M35377.176423
Benson, C.	NE 28-043-17 W4M	Surficial	30-Jul-49	24.4	80.0	18.3	60.0	M35377.167251
Bergquist, Lawrence	SE 22-046-18 W4M	Bearpaw	10-Aug-79	36.6	120.0	11.6	38.0	M35377.174430
Berkhart, Doug	SW 12-044-17 W4M	Bearpaw	06-Mar-78	48.8	160.0	7.0	23.0	M35377.163534
Bethany Lutheran Church	SE 05-043-18 W4M	Lower Horseshoe Canyon	20-Sep-76	15.9	52.0	4.0	13.0	M35377.163367
Bianowski, Fred	NE 28-048-19 W4M	Lower Horseshoe Canyon	11-Jan-73	14.6	48.0	4.3	14.0	M35377.176937
Bianowski, Fred	16-28-048-19 W4M	Lower Horseshoe Canyon	23-Oct-84	7.6	25.0	3.4	11.0	M35377.176939
Biever, Roger	12-31-045-19 W4M	Lower Horseshoe Canyon	01-Nov-82	45.7	150.0	23.5	77.0	M35377.170704
Bjorge, Marvin	SW 06-046-17 W4M	Bearpaw	22-Sep-72	28.0	92.0	9.5	31.0	M35377.174291
Blum, Doug	08-20-046-21 W4M	Lower Horseshoe Canyon	12-Jul-79	48.8	160.0	30.5	100.0	M35377.176410
Boese, John	NE 08-043-19 W4M	Lower Horseshoe Canyon	01-Aug-79	42.7	140.0	17.4	57.0	M35377.170589
Boese, Vernon	SE 19-043-19 W4M	Middle Horseshoe Canyon	01-Jun-72	35.4	116.0	12.8	42.0	M35377.175694
Borman, Eldon	NW 04-046-18 W4M	Bearpaw	13-Mar-75	50.0	164.0	1.1	3.5	M35377.174394
Boulten, Keith	16-10-044-17 W4M	Lower Surficial	01-Jan-70	27.4	90.0	4.9	16.0	M35377.163523
Bowden, Heinz	SW 36-043-19 W4M	Lower Horseshoe Canyon	30-Nov-74	24.4	80.0	7.3	24.0	M35377.175769
Bowlan, Harry	NW 11-047-20 W4M	Lower Horseshoe Canyon	05-Jun-68	33.8	111.0	18.3	60.0	M35377.174877
Bowman, Ken	NW 01-048-21 W4M	Lower Horseshoe Canyon	28-Jun-76	41.2	135.0	8.2	27.0	M35377.172530
Braseth, Angus	NW 13-041-21 W4M	Upper Horseshoe canyon	14-May-79	38.1	125.0	5.2	17.0	M35377.162985
Broughton, W.	SE 18-043-18 W4M	Lower Horseshoe Canyon	21-Mar-79	29.0	95.0	6.2	20.3	M35377.163461
Brown, Randy	SE 27-046-19 W4M	Lower Horseshoe Canyon	13-Aug-80	31.1	102.0	16.2	53.0	M35377.174518
Brown, Richard	NW 22-048-21 W4M	Lower Horseshoe Canyon	01-Jul-75	42.7	140.0	6.7	22.0	M35377.172745
Buban, W.	SW 16-048-21 W4M	Middle Horseshoe Canyon	23-Aug-68	15.2	50.0	6.4	21.0	M35377.172702
Cail, Jim	NW 10-047-20 W4M	Lower Horseshoe Canyon	01-Aug-78	30.5	100.0	12.2	40.0	M35377.174870
Cail, John	04-15-047-20 W4M	Lower Horseshoe Canyon	23-May-81	36.6	120.0	8.8	29.0	M35377.174932
Camrose, County Of	SW 18-045-19 W4M	Lower Horseshoe Canyon	02-Jul-70	25.9	85.0	4.6	15.0	M35377.163926
Canfield, J.	16-17-048-20 W4M	Lower Horseshoe Canyon	08-May-79	41.2	135.0	8.2	27.0	M35377.175395
Carlson, Gunner	NE 32-046-17 W4M	Bearpaw	16-Jun-70	36.6	120.0	4.9	16.0	M35377.174369
Carter, G.R.	SW 06-046-19 W4M	Surficial	04-Sep-75	36.6	120.0	28.0	92.0	M35377.174585
Chamney, Harold And Sonda	SW 16-041-20 W4M	Middle Horseshoe Canyon	21-Oct-83	54.9	180.0	7.0	23.0	M35377.162766
Chant, Austin	NW 20-046-20 W4M	Lower Horseshoe Canyon	10-Feb-76	42.7	140.0	18.3	60.0	M35377.171451
Christian, Jim	13-02-045-20 W4M	Lower Surficial	19-May-66	31.4	103.0	7.6	25.0	M35377.163990
Clennin, Doug	NE 33-045-18 W4M	Bearpaw	15-Mar-79	41.2	135.0	1.8	6.0	M35377.173971
Condes, Carl	NE 03-045-21 W4M	Lower Horseshoe Canyon	16-Oct-81	54.9	180.0	9.1	30.0	M35377.170832
Cowan, Dave	SW 25-044-21 W4M	Middle Horseshoe Canyon	01-Sep-77	27.4	90.0	6.1	20.0	M35377.174232
Cupido, N.	SH 26-049-21 W4M	Lower Horseshoe Canyon	01-Oct-82	103.6	340.0	8.5	28.0	M35377.173642
Currie, Kevin	NE 11-049-21 W4M	Lower Horseshoe Canyon	02-Mar-78	35.1	115.0	14.3	47.0	M35377.173461
Dawbin, Bill	14-07-043-20 W4M	Surficial	21-Oct-83	9.8	32.0	1.2	4.0	M35377.175795
Deljay Constr	NW 01-046-21 W4M	Lower Horseshoe Canyon	19-Oct-79	33.5	110.0	15.5	51.0	M35377.176321
Department of Public Works	SW 20-049-20 W4M	Lower Horseshoe Canyon	11-Mar-69	59.4	195.0	0.4	1.3	M35377.191375

WATER WELLS RECOMMENDED FOR FIELD-VERIFICATION THAT MEET CRITERIA

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Department of Public Works	SW 20-049-20 W4M	Lower Horseshoe Canyon	11-Mar-69	39.0	128.0	5.4	17.7	M35377.191376
Department of Public Works	SW 20-049-20 W4M	Lower Horseshoe Canyon	11-Mar-69	36.6	120.0	6.2	20.2	M35377.191380
Dereniuk, B.H.	NW 14-046-19 W4M	Lower Horseshoe Canyon	01-Jan-78	21.3	70.0	12.2	40.0	M35377.174616
Drowk	SW 05-050-20 W4M	Upper Surficial	05-May-76	26.8	88.0	4.0	13.0	M35377.177522
Dyer, Wilf	NE 13-045-20 W4M	Lower Horseshoe Canyon	18-Jan-85	43.6	143.0	13.7	45.0	M35377.170649
Egert, Eldon	SE 03-044-20 W4M	Middle Horseshoe Canyon	01-Apr-76	51.8	170.0	6.1	20.0	M35377.176186
Egert, Ron	NE 02-044-20 W4M	Middle Horseshoe Canyon	14-Apr-76	31.4	103.0	3.1	10.0	M35377.176182
Erickson, Floyd E.	NE 32-049-20 W4M	Lower Horseshoe Canyon	22-Jul-80	67.1	220.0	21.3	70.0	M35377.191406
Fast, Stan	15-01-043-20 W4M	Surficial	09-Dec-81	21.9	72.0	19.8	65.0	M35377.175774
Fearon, Roy	SW 32-046-19 W4M	Lower Horseshoe Canyon	16-Jun-78	25.9	85.0	19.8	65.0	M35377.174539
Forne, Leroy	NW 12-048-18 W4M	Bearpaw	01-Nov-71	48.8	160.0	8.5	28.0	M35377.171569
Forsberg, Ray	NW 13-043-20 W4M	Surficial	30-Apr-65	26.2	86.0	19.2	63.0	M35377.175807
Fransen, Donald Garry	SE 34-045-21 W4M	Lower Surficial	28-Sep-77	23.2	76.0	11.0	36.0	M35377.171462
Freier, Ken	WH 08-049-19 W4M	Lower Horseshoe Canyon	18-Sep-86	42.7	140.0	19.5	64.0	M35377.172909
Friesen, A.	NW 31-043-20 W4M	Upper Horseshoe canyon	10-Nov-81	22.9	75.0	4.3	14.0	M35377.175912
Galenza, Carl	14-31-047-21 W4M	Lower Horseshoe Canyon	11-Sep-85	30.5	100.0	3.7	12.0	M35377.175303
Gallaher, Jim	SE 33-048-22 W4M	Middle Horseshoe Canyon	01-Jan-69	27.4	90.0	3.1	10.0	M35377.175563
Geldart, Richard	NW 12-049-21 W4M	Lower Horseshoe Canyon	06-Oct-78	54.9	180.0	21.3	70.0	M35377.173470
Gibson, C.G.	12-10-049-19 W4M	Lower Horseshoe Canyon	16-Sep-77	32.0	105.0	14.0	46.0	M35377.172957
Gibson, Geo	NW 35-049-20 W4M	Lower Horseshoe Canyon	24-Aug-79	73.2	240.0	9.1	30.0	M35377.191420
Gibson, Ray	SE 36-046-22 W4M	Middle Horseshoe Canyon	14-May-76	38.1	125.0	15.2	50.0	M35377.176694
Gladiotis Holdings Ltd	NE 36-046-21 W4M	Middle Horseshoe Canyon	10-May-71	18.6	61.0	6.6	21.8	M35377.176513
Gould, Rick & Rita	13-16-044-17 W4M	Upper Surficial	18-Nov-77	15.2	50.0	5.5	18.0	M35377.163566
Gregorwich, Steve	NW 02-045-18 W4M	Upper Surficial	05-Aug-75	16.2	53.0	4.3	14.0	M35377.173883
Gregorwich, Steve	NW 02-045-18 W4M	Upper Surficial	14-Jun-78	18.0	59.0	4.0	13.0	M35377.173884
Groeller, John	SE 06-049-21 W4M	Lower Surficial	25-Sep-71	22.6	74.0	8.8	29.0	M35377.173342
Grundberg, Carmen	NW 11-047-20 W4M	Lower Horseshoe Canyon	03-Oct-84	59.4	195.0	18.3	60.0	M35377.174892
Gudmunson, L.	NW 35-048-18 W4M	Bearpaw	23-Oct-79	25.9	85.0	11.3	37.0	M35377.171894
Harmider, Ron	SE 31-046-18 W4M	Upper Surficial	01-Aug-79	21.3	70.0	6.7	22.0	M35377.174454
Haselwood, Louis	SW 26-046-22 W4M	Lower Horseshoe Canyon	10-May-85	70.1	230.0	27.4	90.0	M35377.176630
Haugen, A.K.	NE 33-044-20 W4M	Lower Horseshoe Canyon	01-Jul-74	74.7	245.0	21.6	71.0	M35377.176299
Haugen, Rick	13-09-048-19 W4M	Lower Horseshoe Canyon	23-Oct-85	22.9	75.0	0.6	2.0	M35377.176867
Heie, Don	NW 32-048-19 W4M	Lower Horseshoe Canyon	17-Sep-71	35.7	117.0	12.2	40.0	M35377.176951
Heise, Benno	NW 33-045-18 W4M	Bearpaw	16-Nov-79	48.8	160.0	-0.6	-2.0	M35377.173969
Hendrickson, George	NE 05-048-21 W4M	Middle Horseshoe Canyon	14-Apr-76	15.2	50.0	6.4	21.0	M35377.172580
Herget, B.	08-05-048-21 W4M	Middle Horseshoe Canyon	23-Feb-81	24.4	80.0	1.8	6.0	M35377.172573
Hilgartner, Cliff	01-13-047-21 W4M	Lower Horseshoe Canyon	05-Aug-81	25.9	85.0	7.0	23.0	M35377.175127
Hills Ranching Co Ltd	16-04-046-20 W4M	Lower Horseshoe Canyon	20-May-77	79.2	260.0	39.0	128.0	M35377.171369
Hiway Service	SW 31-045-17 W4M	Bearpaw	27-Jun-55	56.4	185.0	11.0	36.0	M35377.174084
Hodgetts, Steve	SW 36-048-20 W4M	Lower Horseshoe Canyon	29-Dec-79	48.8	160.0	12.2	40.0	M35377.175485
Horte, Vernon	SW 18-049-19 W4M	Lower Horseshoe Canyon	01-Sep-83	59.7	196.0	27.4	90.0	M35377.172999
Hoyme, Cliff	13-14-046-20 W4M	Lower Horseshoe Canyon	29-Sep-79	67.1	220.0	33.5	110.0	M35377.171415
Humpage, Milt	05-08-046-19 W4M	Lower Horseshoe Canyon	09-Apr-80	36.6	120.0	19.8	65.0	M35377.174594
Huseby, Terrance	SW 19-047-16 W4M	Bearpaw	04-Sep-54	27.4	90.0	10.7	35.0	M35377.076826
Isaac, Edgar	SW 34-043-20 W4M	Middle Horseshoe Canyon	18-Nov-79	42.7	140.0	12.8	42.0	M35377.175923
Isaac, Melvin	NW 01-045-20 W4M	Lower Horseshoe Canyon	02-May-78	48.8	160.0	10.1	33.0	M35377.095421
Jaycock, Arlen	SE 02-049-21 W4M	Lower Horseshoe Canyon	17-Jan-81	39.6	130.0	4.6	15.0	M35377.173225
Johnson, Rick	11-17-049-20 W4M	Lower Horseshoe Canyon	26-Nov-81	36.6	120.0	25.3	83.1	M35377.191345
Johnson, W.	SW 16-041-20 W4M	Middle Horseshoe Canyon	03-Aug-77	41.2	135.0	3.1	10.0	M35377.162714
Johnston, Gerald	13-06-045-20 W4M	Surficial	10-May-84	35.4	116.0	6.1	20.0	M35377.164021
Kaechele, Wes	05-10-042-22 W4M	Upper Horseshoe canyon	01-Nov-68	39.6	130.0	32.9	108.0	M35377.167077
Karlstrom, Vic	NW 05-043-19 W4M	Lower Horseshoe Canyon	04-Dec-59	45.7	150.0	12.2	40.0	M35377.170558
Kasa, Randall O.	03-14-043-19 W4M	Lower Horseshoe Canyon	10-Sep-82	40.5	133.0	19.8	65.0	M35377.170613
Keller, Robert	13-21-045-20 W4M	Surficial	04-Dec-78	22.9	75.0	9.1	30.0	M35377.170771
Kennedy, Brant	SW 02-044-18 W4M	Lower Horseshoe Canyon	05-Jun-79	43.0	141.0	21.9	72.0	M35377.175939
Kennedy, Doug	SE 31-043-17 W4M	Lower Horseshoe Canyon	07-Oct-77	19.5	64.0	8.5	28.0	M35377.167258
Klassin, Jody	SE 10-045-22 W4M	Middle Horseshoe Canyon	14-Jun-85	73.2	240.0	15.9	52.0	M35377.171133
Klevgaard, Bjorn	SE 34-043-19 W4M	Middle Horseshoe Canyon	01-Oct-70	13.7	45.0	3.7	12.0	M35377.175760
Klevgaard, Magnus	NE 21-043-20 W4M	Middle Horseshoe Canyon	05-Nov-70	24.4	80.0	10.7	35.0	M35377.175847
Kneeland, Marvin	13-12-043-18 W4M	Lower Horseshoe Canyon	25-Jul-84	11.0	36.0	3.1	10.0	M35377.163452

WATER WELLS RECOMMENDED FOR FIELD-VERIFICATION THAT MEET CRITERIA

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Krause, Kenneth	01-08-045-20 W4M	Lower Surficial	29-Nov-80	14.6	48.0	6.1	20.0	M35377.164044
Krueger, Peter	SE 01-047-19 W4M	Lower Horseshoe Canyon	30-May-82	37.2	122.0	6.4	21.0	M35377.182949
Kyle, Gordon	NE 33-049-19 W4M	Surficial	24-May-54	39.6	130.0	10.7	35.0	M35377.173191
Layden, Mike	08-05-047-17 W4M	Bearpaw	20-Aug-82	25.9	85.0	9.5	31.0	M35377.171654
Leibel, Frank	NW 14-046-19 W4M	Lower Horseshoe Canyon	01-Jan-78	21.3	70.0	12.2	40.0	M35377.174618
Leoch, Ken	NW 12-044-17 W4M	Bearpaw	20-Aug-73	58.5	192.0	5.5	18.0	M35377.163540
Liebl, Joe	06-13-046-21 W4M	Upper Surficial	04-Jun-85	10.4	34.0	4.9	16.0	M35377.176371
Litle, D.	SW 30-041-20 W4M	Upper Horseshoe canyon	11-Sep-79	30.5	100.0	7.0	23.0	M35377.162832
Lovrod, Ole M.	13-19-046-17 W4M	Bearpaw	10-Aug-71	30.5	100.0	5.5	18.0	M35377.174322
Lymall, Charles	05-05-050-20 W4M	Upper Surficial	17-May-76	20.4	67.0	4.3	14.0	M35377.177525
Magnien, Walter	NE 12-047-20 W4M	Lower Horseshoe Canyon	21-Jun-79	71.6	235.0	27.4	90.0	M35377.174910
Martin Bros.	10-13-047-20 W4M	Lower Horseshoe Canyon	09-Mar-67	18.6	61.0	10.4	34.0	M35377.174916
Martin, Bill	SE 13-047-20 W4M	Lower Horseshoe Canyon	09-Jun-76	65.5	215.0	15.9	52.0	M35377.174911
Mcgarvey, Wayne	NW 08-043-21 W4M	Upper Horseshoe canyon	18-Aug-78	36.3	119.0	6.7	22.0	M35377.163616
Mcgregor, Jim	NW 11-047-20 W4M	Lower Horseshoe Canyon	20-Sep-83	73.2	240.0	34.8	114.0	M35377.174891
Mcnary, Walter	NE 28-046-21 W4M	Lower Horseshoe Canyon	01-Jul-73	65.5	215.0	20.7	68.0	M35377.176452
Megli, Ervin	SW 36-044-20 W4M	Lower Horseshoe Canyon	11-Jun-70	44.2	145.0	12.8	42.0	M35377.176314
Meglie, Ray	SE 34-044-20 W4M	Lower Horseshoe Canyon	16-Apr-77	48.8	160.0	15.2	50.0	M35377.176303
Merland Exp Ltd	SE 25-046-19 W4M	Lower Horseshoe Canyon	02-Aug-85	24.4	80.0	7.6	25.0	M35377.174511
Miller, Dave	SW 16-041-20 W4M	Middle Horseshoe Canyon	31-Aug-78	41.2	135.0	3.7	12.0	M35377.162728
Mills, Charlie	NW 30-046-21 W4M	Middle Horseshoe Canyon	06-Aug-81	30.5	100.0	12.2	40.0	M35377.176462
Miquelon Lake Prov Park	SW 20-049-20 W4M	Lower Horseshoe Canyon	01-Jan-63	33.8	111.0	4.0	13.0	M35377.191382
Miquelon Prov Park #2-80	08-33-049-20 W4M	Lower Horseshoe Canyon	04-Feb-80	73.2	240.0	11.4	37.4	M35377.172010
Miquelon Prov Park #3-80	04-33-049-20 W4M	Lower Surficial	07-Feb-80	32.9	108.0	57.9	190.0	M35377.172004
Moore, J.W.	06-01-048-21 W4M	Lower Horseshoe Canyon	11-Nov-69	24.4	80.0	3.1	10.0	M35377.172525
Moore, Jim	03-01-048-21 W4M	Lower Horseshoe Canyon	17-Nov-76	45.7	150.0	12.5	41.0	M35377.172520
Moore, Noel	SW 04-048-21 W4M	Lower Horseshoe Canyon	26-Apr-79	48.8	160.0	6.7	22.0	M35377.172566
Morris, A.K.	SE 34-047-21 W4M	Lower Horseshoe Canyon	10-Jun-70	28.4	93.0	7.0	23.0	M35377.175308
Muirhead, John	NE 20-046-19 W4M	Lower Horseshoe Canyon	20-Jun-77	21.0	69.0	11.9	39.0	M35377.174495
Munro, Carcy	16-35-046-19 W4M	Lower Horseshoe Canyon	22-Nov-85	33.5	110.0	12.2	40.0	M35377.174562
Neave, Bert	NE 08-048-18 W4M	Lower Horseshoe Canyon	01-Nov-71	25.9	85.0	6.1	20.0	M35377.171519
Nederlof, Ron	SE 04-047-21 W4M	Lower Horseshoe Canyon	27-Aug-82	41.2	135.0	9.1	30.0	M35377.174957
Nelson, John	NE 34-044-19 W4M	Surficial	17-Aug-63	21.3	70.0	13.7	45.0	M35377.176169
Ness, Gladys	05-08-049-19 W4M	Lower Horseshoe Canyon	01-Sep-83	45.1	148.0	3.7	12.0	M35377.172884
New Norway, Village Of	12-11-045-21 W4M	Surficial	23-Aug-78	27.4	90.0	1.5	5.0	M35377.171081
New Norway, Village Of	---11-045-21 W4M	Middle Horseshoe Canyon	07-Jun-60	33.5	110.0	5.8	19.0	M35377.171097
Newstead, Norman	NW 14-045-22 W4M	Lower Surficial	31-Oct-78	25.0	82.0	8.7	28.5	M35377.171187
Noden, Douglas	SE 03-046-21 W4M	Lower Horseshoe Canyon	08-May-69	54.9	180.0	24.7	81.0	M35377.176325
Nordin, Terrence	NW 20-048-20 W4M	Lower Horseshoe Canyon	07-May-80	39.6	130.0	10.7	35.0	M35377.175409
Olsen, Lloyd	09-28-047-17 W4M	Bearpaw	26-Oct-82	17.7	58.0	2.7	9.0	M35377.171747
Olsen, Lyle	NW 20-044-21 W4M	Surficial	01-May-70	33.5	110.0	22.6	74.0	M35377.174207
Olson, Elmer	SW 16-047-20 W4M	Surficial	06-Nov-81	19.5	64.0	2.6	8.5	M35377.174970
Olson, Elmer	SE 15-047-18 W4M	Lower Horseshoe Canyon	01-Oct-82	27.4	90.0	6.1	20.0	M35377.171800
Olson, Frank	NE 08-043-21 W4M	Upper Horseshoe canyon	25-Jul-84	33.5	110.0	4.3	14.0	M35377.163657
Orr, C.	16-07-044-17 W4M	Lower Horseshoe Canyon	01-Jan-66	26.8	88.0	8.5	28.0	M35377.163493
Ozment, Ken	NW 15-047-20 W4M	Lower Horseshoe Canyon	29-May-86	32.9	108.0	9.1	30.0	M35377.174934
Pattison, W.S.	02-29-048-19 W4M	Lower Horseshoe Canyon	20-Aug-74	36.6	120.0	13.7	45.0	M35377.176940
Pederson, Harvey	05-18-047-16 W4M	Surficial	27-Mar-82	31.1	102.0	6.7	22.0	M35377.076821
Pederson, Henry	NW 07-047-16 W4M	Bearpaw	07-Sep-58	34.4	113.0	9.1	30.0	M35377.072002
Penner, Waldon	05-10-045-20 W4M	Upper Surficial	01-Jan-65	23.8	78.0	7.6	25.0	M35377.164078
Person Bros	NW 06-049-20 W4M	Lower Horseshoe Canyon	27-Jul-84	49.4	162.0	16.8	55.0	M35377.191314
Peterson, E.	11-12-049-21 W4M	Surficial	01-Jan-28	45.7	150.0	24.4	80.0	M35377.173475
Radke, Garry W.	16-27-042-21 W4M	Upper Horseshoe canyon	06-Nov-80	32.9	108.0	13.1	43.0	M35377.167027
Ramstad, Dennis	SE 19-046-19 W4M	Lower Horseshoe Canyon	30-Aug-79	77.7	255.0	43.3	142.0	M35377.174479
Rawson, Paul	NE 30-044-18 W4M	Lower Surficial	24-Oct-70	23.5	77.0	18.0	59.0	M35377.176024
Rayments	SE 13-045-20 W4M	Lower Horseshoe Canyon	16-Dec-74	28.0	92.0	12.2	40.0	M35377.170629
Raymond, Neil	SW 18-045-19 W4M	Lower Horseshoe Canyon	04-May-83	33.8	111.0	18.0	59.0	M35377.163993
Reich, Don	SE 03-046-17 W4M	Bearpaw	12-May-81	57.9	190.0	27.4	90.0	M35377.174282
Reimer, Fred	SE 28-043-20 W4M	Lower Surficial	16-Oct-78	11.3	37.0	4.6	15.0	M35377.175891
Reiten, Arthur	SE 05-047-20 W4M	Lower Horseshoe Canyon	01-Jan-78	36.6	120.0	9.1	30.0	M35377.174847

WATER WELLS RECOMMENDED FOR FIELD-VERIFICATION THAT MEET CRITERIA

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Reuter, Carl	SE 18-047-16 W4M	Bearpaw	30-Aug-58	27.4	90.0	9.1	30.0	M35377.076820
Ring, Darryl	SE 27-047-19 W4M	Lower Horseshoe Canyon	01-Jul-75	30.5	100.0	15.2	50.0	M35377.174784
Rittenhouse, Bill	SE 28-046-21 W4M	Lower Horseshoe Canyon	07-Oct-77	62.5	205.0	30.5	100.0	M35377.176445
Robertson, Al	NE 20-046-21 W4M	Lower Horseshoe Canyon	28-Jan-70	52.4	172.0	20.7	68.0	M35377.176417
Rosalind, Village Of	06-17-044-17 W4M	Surficial	16-Aug-76	24.7	81.0	5.4	17.7	M35377.163618
Rosland, Arne	SW 34-045-19 W4M	Lower Horseshoe Canyon	17-Nov-65	27.7	91.0	10.4	34.0	M35377.170714
Ruhl, M.	NW 11-047-20 W4M	Lower Horseshoe Canyon	07-Sep-68	45.7	150.0	22.9	75.0	M35377.174880
Rylchuk, Mike	NE 08-043-21 W4M	Upper Horseshoe canyon	30-Jul-84	33.5	110.0	4.3	14.0	M35377.163658
Sandburg, Bruce	06-11-042-21 W4M	Upper Horseshoe canyon	15-Jul-82	25.9	85.0	1.4	4.5	M35377.166989
Scabar, Don	16-11-049-21 W4M	Lower Horseshoe Canyon	28-Feb-78	35.1	115.0	11.6	38.0	M35377.173462
Schneider, Ron	NW 11-046-19 W4M	Lower Horseshoe Canyon	01-Jun-82	36.6	120.0	4.6	15.0	M35377.174597
Schou, A.	12-08-041-20 W4M	Upper Horseshoe canyon	01-Sep-69	27.4	90.0	3.7	12.0	M35377.162640
Schrauwen, Peter	NE 29-041-21 W4M	Upper Horseshoe canyon	05-Nov-75	24.4	80.0	1.5	5.0	M35377.163347
Schultz, Darryl	SE 04-047-21 W4M	Lower Horseshoe Canyon	06-May-80	36.6	120.0	7.6	25.0	M35377.174956
Schultz, Russell	NW 08-042-21 W4M	Upper Horseshoe canyon	13-Oct-71	27.4	90.0	3.1	10.0	M35377.166978
Schwab, I.	SW 20-046-19 W4M	Lower Horseshoe Canyon	20-Nov-71	32.0	105.0	18.3	60.0	M35377.174491
Selin, Carl	SE 03-049-21 W4M	Upper Surficial	17-Sep-82	14.6	48.0	10.7	35.0	M35377.173241
Servold	SW 16-041-20 W4M	Surficial		36.6	120.0	1.5	5.0	M35377.162733
Severson, Ron	15-13-045-20 W4M	Lower Horseshoe Canyon	23-Apr-83	39.6	130.0	13.7	45.0	M35377.170642
Shantz, Melvin	NE 12-047-21 W4M	Lower Horseshoe Canyon	01-Sep-68	24.4	80.0	6.1	20.0	M35377.175125
Shantz, Ron	NW 15-042-21 W4M	Upper Horseshoe canyon	05-May-84	41.2	135.0	19.5	64.0	M35377.167001
Sharkey, Bob	NW 10-046-22 W4M	Middle Horseshoe Canyon	23-Nov-73	47.2	155.0	30.5	100.0	M35377.176553
Shuman Real Estate	05-08-046-20 W4M	Lower Horseshoe Canyon	07-Jun-76	65.5	215.0	39.0	128.0	M35377.171382
Shute, E.	NE 08-043-21 W4M	Upper Horseshoe canyon	28-Aug-78	34.8	114.0	6.1	20.0	M35377.163640
Shute, Kenneth G.	SE 06-048-19 W4M	Lower Horseshoe Canyon	01-Jul-81	45.7	150.0	12.2	40.0	M35377.176860
Siemens, Ben D.	NE 19-044-20 W4M	Middle Horseshoe Canyon		56.7	186.0	9.1	30.0	M35377.176246
Simonson, Dave	SW 27-049-19 W4M	Lower Horseshoe Canyon	19-Sep-84	14.6	48.0	6.1	20.0	M35377.173100
Sims, Dale	SE 36-046-22 W4M	Lower Horseshoe Canyon	07-Jun-85	70.1	230.0	25.0	82.0	M35377.176707
Skaret, Rodney	NW 04-048-21 W4M	Middle Horseshoe Canyon	21-Jun-82	24.4	80.0	6.1	20.0	M35377.172570
Skudesness Lutheran Church	SW 33-047-17 W4M	Bearpaw	02-Jul-80	21.3	70.0	4.6	15.0	M35377.171760
Smith, Stan	SW 12-048-21 W4M	Lower Horseshoe Canyon	01-Jun-69	37.8	124.0	3.1	10.0	M35377.172628
Sproule, K. Glen	NE 31-041-21 W4M	Upper Horseshoe canyon	20-Jul-79	65.5	215.0	17.1	56.0	M35377.163390
Sroka, Roy	NE 31-046-17 W4M	Bearpaw	29-Mar-82	29.9	98.0	2.7	9.0	M35377.174363
Stang, Don	NE 14-046-19 W4M	Lower Horseshoe Canyon	14-Jan-84	22.3	73.0	9.5	31.0	M35377.174651
Stauffer, Ed	NW 34-048-20 W4M	Lower Horseshoe Canyon	16-Jul-73	19.8	65.0	4.3	14.0	M35377.175479
Steere, Don	NE 24-047-20 W4M	Lower Horseshoe Canyon	01-Jul-75	54.9	180.0	7.6	25.0	M35377.175019
Strilchuck, Joe	SW 04-048-18 W4M	Lower Horseshoe Canyon	19-Jul-82	26.8	88.0	6.4	21.0	M35377.171493
Swedberg, Allan	NE 31-042-19 W4M	Lower Horseshoe Canyon	12-Mar-82	54.9	180.0	30.8	101.0	M35377.163084
Szott, Peter	NE 09-045-17 W4M	Bearpaw	06-Jul-70	33.2	109.0	15.2	50.0	M35377.174018
Tabler, Joe	01-11-044-18 W4M	Lower Horseshoe Canyon	21-Jun-70	45.7	150.0	21.3	70.0	M35377.175966
Teeple, Homer	09-18-048-19 W4M	Lower Horseshoe Canyon	01-Jan-78	42.7	140.0	12.2	40.0	M35377.176898
Thompson, Harold	15-32-044-19 W4M	Surficial	02-Sep-80	18.9	62.0	7.6	25.0	M35377.176162
Thompson, Jim	NE 23-045-21 W4M	Lower Surficial	15-Aug-79	16.8	55.0	9.1	30.0	M35377.171238
Toews, Harvey	NE 27-044-20 W4M	Lower Horseshoe Canyon	17-Aug-79	48.8	160.0	19.8	65.0	M35377.176272
Toews, Noah	SE 25-044-21 W4M	Middle Horseshoe Canyon	18-Oct-78	38.4	126.0	5.6	18.3	M35377.174229
Tollefson, Carl	NW 25-048-20 W4M	Lower Horseshoe Canyon	19-May-83	67.1	220.0	9.5	31.0	M35377.175439
Tomaszewski, Allen	13-31-047-18 W4M	Lower Horseshoe Canyon	15-Jul-83	37.2	122.0	30.5	100.0	M35377.171844
Trout, P.A.	16-27-041-21 W4M	Upper Horseshoe canyon	30-Nov-76	45.7	150.0	4.6	15.0	M35377.163232
Trush, Robert	NE 11-049-21 W4M	Lower Horseshoe Canyon	18-Jul-83	28.4	93.0	15.9	52.0	M35377.173463
Tylosky, Lynn	SE 11-045-18 W4M	Surficial	28-May-82	19.2	63.0	1.5	5.0	M35377.173924
Vanderberg, Joe	SE 16-048-20 W4M	Lower Horseshoe Canyon	20-Dec-79	36.6	120.0	6.1	20.0	M35377.175380
Vanpetten, Norman	13-22-044-19 W4M	Lower Horseshoe Canyon	27-Sep-80	40.2	132.0	10.7	35.0	M35377.176127
Viske, Garfield	NW 11-043-18 W4M	Lower Horseshoe Canyon	27-Nov-81	57.9	190.0	18.3	60.0	M35377.163450
Warkentin, Peter	SE 30-049-19 W4M	Lower Horseshoe Canyon	15-Feb-83	48.8	160.0	18.3	60.0	M35377.173115
Weder, Ivo	NE 02-047-19 W4M	Lower Horseshoe Canyon	01-Oct-78	39.6	130.0	14.0	46.0	M35377.174682
Welda, Ralph	SE 02-048-21 W4M	Lower Horseshoe Canyon	12-Jul-77	22.9	75.0	5.5	18.0	M35377.172241
Wilcox, Leo	08-36-045-20 W4M	Lower Horseshoe Canyon	10-Dec-75	39.9	131.0	19.2	63.0	M35377.170976
Wilkie, Elmer	SW 11-043-21 W4M	Upper Horseshoe canyon	01-Sep-73	22.9	75.0	5.8	19.0	M35377.163664
Wilson, Ken	04-26-048-21 W4M	Lower Horseshoe Canyon	13-Jul-81	42.7	140.0	4.6	15.0	M35377.172780
Wolski, Eugene	SW 18-045-19 W4M	Lower Horseshoe Canyon	27-Aug-76	67.1	220.0	15.2	50.0	M35377.163945
Young, Leon	SW 07-042-20 W4M	Upper Horseshoe canyon	14-Dec-85	35.1	115.0	14.6	48.0	M35377.163145
Young, Melvin	04-06-044-19 W4M	Middle Horseshoe Canyon	27-Mar-84	29.0	95.0	8.5	28.0	M35377.176064
Yurkoski, E.	15-21-048-18 W4M	Lower Horseshoe Canyon	27-Jun-79	33.8	111.0	14.0	46.0	M35377.171635
Zeniuk, John	NW 12-048-19 W4M	Lower Horseshoe Canyon	01-Sep-72	36.0	118.0	20.9	68.5	M35377.176874
Zubkowski, Ed	01-22-044-21 W4M	Middle Horseshoe Canyon	21-May-81	27.4	90.0	6.1	20.0	M35377.174212

COUNTY OF CAMROSE-OPERATED WATER WELL

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
County of Camrose	SW 18-045-19 W4M	Lower Horseshoe Canyon	02-Jul-70	25.91	85.0	4.57	15.0	M35377.076327