Yellowhead County

Part of the Athabasca River Basin
Tp 050 to 057, R 07 to 26, W5M
Regional Groundwater Assessment

Prepared for:

Yellowhead County

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.: **02-227**

March 2004

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The Association of Professional Engineers,
Geologists and Geophysicists of Alberta

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Acknowledgements

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Mr. Tony Cowen – AAFC-PFRA
Mr. Curtis Snell – AAFC-PFRA
Mr. Iain Bell – Yellowhead County

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 Yellowhead County in managing their groundwater. It is also a guide for future groundwater-related projects.**

1.1 Purpose

This project is a regional groundwater assessment of Yellowhead County prepared by Hydrogeological Consultants Ltd. (HCL) with financial and technical assistance from the Prairie Farm Rehabilitation Administration branch of Agriculture and Agri-Food Canada (AAFC-PFRA) and Yellowhead County. The project study area includes the parts of Yellowhead County bounded by townships 050 to 057, ranges 07 to 26, W5M (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 Yellowhead County.

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

Additional technical details are available from files on the CD-ROM 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 050 to 057, ranges 07 to 26, W5M, 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 recommended for field verification.

[3] See glossary

2 INTRODUCTION

2.1 Setting

Yellowhead County is situated in west-central Alberta. The extreme northern boundary is the McLeod River; the eastern boundary is the Pembina River. The other County boundaries follow township or section lines, which include parts of the area bounded by townships 050 to 057, ranges 07 to 26, W5M.

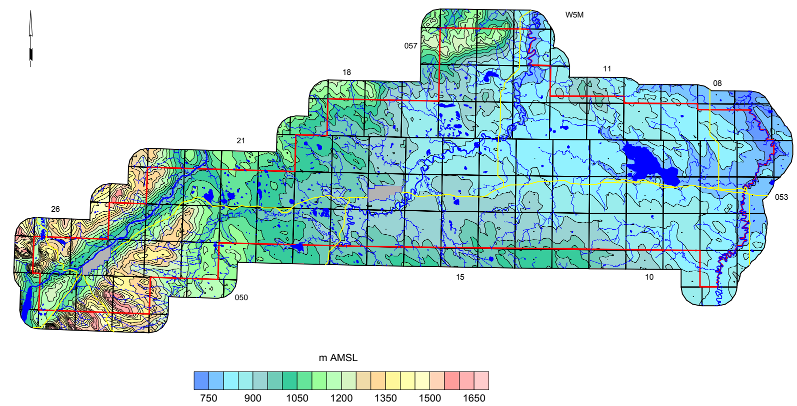

Figure 1. Surface Topography

Regionally, the topographic surface varies between 700 and 1,700 metres above mean sea level (AMSL). The lowest elevations occur mainly in the central and eastern parts of the County in association with the Pembina and McLeod rivers, and in Chip Lake; 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 Athabasca River basin. The area is well drained by the Athasbasca River, the McLeod River and the Pembina River.

2.2 Climate

Yellowhead County lies within the Dfb climate boundary. This classification is based on potential evapotranspiration[4] values determined using the Thornthwaite method (Thornthwaite and Mather, 1957), combined with the distribution of natural ecoregions in the area. The ecoregions map (Strong and Leggat, 1981) shows that the County is located mainly in the Upper and Lower Boreal Cordilleran regions; a small portion in the eastern part of the County is in the High Boreal Mixedwood Region. Increased precipitation and cooler temperatures, resulting in additional moisture availability, influence these vegetation changes.

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

The mean annual precipitation averaged from six meteorological stations within the County measured 533 millimetres (mm), based on data from 1917 to 1993. The mean annual temperature averaged 2.2° C, with the mean monthly temperature reaching a high of 14.8° C in July, and dropping to a low of -12.9° C in January. The calculated annual potential evapotranspiration is 453 millimetres.

[4] See glossary

2.3 Background Information

2.3.1 Number, Type and Depth of Water Wells

There are currently 9,630 records in the groundwater database for the County, of which 5,855 are water wells. Of the 5,855 water wells, there are records for domestic (3,539), domestic/stock (475) or stock (513) purposes. The remaining 1,328 water wells were completed for a variety of uses, the main ones being industrial (978) municipal (121) and observation (48); 113 of the remaining 181 water wells have an "unknown" purpose. Based on a study area rural population of 8,900[5], there are two domestic/stock water wells per family of four. There are 4,018 domestic or stock water wells with a completed depth, of which 3,125 (78%) are completed at depths of less than 50 metres below ground surface. Details for lithology[6] are available for 4,390 water wells.

2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 3,705 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 3,705 water wells for which aquifers could be defined, 222 are completed in surficial aquifers, with 171 (77%) having a completion depth of less than 50 metres below ground surface. The adjacent map shows that the water wells completed in the surficial deposits occur throughout the County, and frequently in the vicinity of linear bedrock lows.

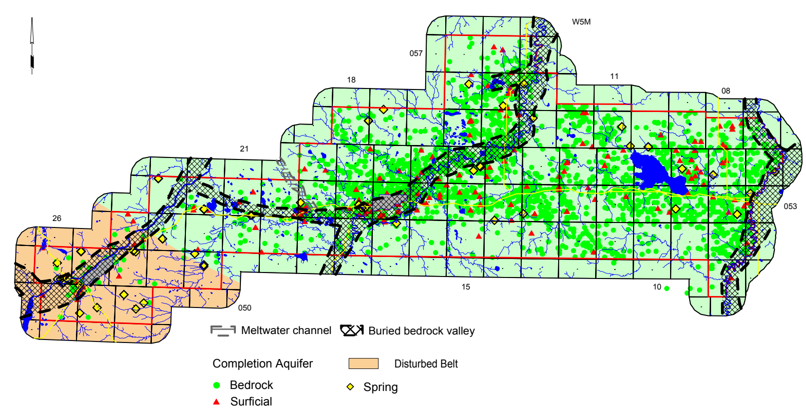

Figure 2. Location of Water Wells and Springs

The data for 3,483 water wells show that the top of the water well completion interval is below the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. From Figure 2 (also see page A-5), it can be seen that water wells completed in bedrock aquifers occur throughout the County.

Within Yellowhead County, there are currently records for 66 springs in the groundwater database, including five springs that were documented by Borneuf (1983). There are 46 springs having at least one total dissolved solids (TDS) value, with 85% having a TDS of less than 500 milligrams per litre (mg/L). There are nine springs in the groundwater database with flow rates that range from 45 litres per minute (lpm) to 1,100 lpm. No dates were given for the time of the flow-rate measurements.

5 Mr. Iain Bell of Yellowhead County; population for the entire Yellowhead County is 9,881 (Phinney, 2003)
6 See glossary

2.3.3 Casing Diameter and Type

Data for casing diameters are available for 4,394 water wells, with 4,375 (greater than 99%) indicated as having a diameter of less than 275 mm and 19 (less than 1%) having a diameter of more than 275 mm. The casing diameters of greater than 275 mm are mainly bored or dug water wells and those with a surface-casing diameter of less than 275 mm are mainly drilled water wells. The groundwater database suggests that 45 of the above-mentioned water wells in the County were bored, hand dug, or dug by backhoe. The complete water well database for the County suggests that 89 of the water wells in the County were bored or hand dug.

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 220 of the 222 water wells completed in the surficial deposits, of which 218 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 3,457 of the 3,483 water wells completed below the top of bedrock, of which 3,453 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 17 bedrock water wells completed with a water well screen.

Where the casing material is known, steel surface casing materials have been used in 84% of the drilled water wells over the last 50 years. For the remaining drilled water wells with known surface casing material, 8% were completed with galvanized steel casing, 7% with plastic casing and 0.3% with concrete, cribbing, fiberglass or other surface casing materials (used mostly in the 1970s). The main years where the type of surface casing was undocumented were between 1955 and 1965; only one water well was completed before 1955. Steel casing was in use in the 1950s and is still used in 80% of the water wells being drilled in the County. Galvanized steel surface casings were mainly used from the mid-1960s to the early 1980s, at which time plastic casing started to replace the use of galvanized steel casing.

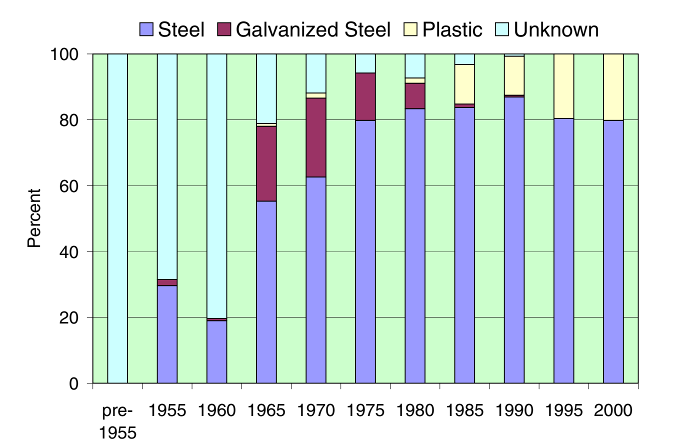

Figure 3. Surface Casing Types Used in Drilled Water Wells

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

2.3.4 Dry Water Test Holes

In the County, there are 9,630 records in the groundwater database. Of these 9,630 records, 73 (less than 1%) are indicated as being dry or abandoned with "insufficient water"[7]. Of the 73 "dry" water test holes, 57 are completed in bedrock aquifers; the remaining 16 "dry" water test holes are completed in surficial deposits. Only about 7% of all water wells with apparent yield estimates were judged to yield less than 6.5 m³/day (1 igpm).

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

2.3.5 Requirements for Licensing

Water wells used for household needs in excess of 3.4 cubic metres per day (1,250 cubic metres per year [m³/year] or 750 imperial gallons per day[8]) and all other groundwater use, with some exceptions, must be licensed. Groundwater diversions that do not need licensing include (1) household use of up to 1,250 m³/year and (2) groundwater with total dissolved solids in excess of 4,000 mg/L; (3) water wells eligible for registration, but not registered or licensed, can continue to be used without authorization but without the protection of the *Water Act,* and (4) some exempted diversions such as water supply wells with hand pumps, drainage of water for the purpose of dewatering a construction site, and some uses of groundwater for oil rig and camp water supply.

In the last update from the Alberta Environment (AENV) groundwater database in August 2003, 559 groundwater allocations were shown to be within the County, with the most recent groundwater user being authorized in April 2003 at report preparation time. Of the 559 authorized non-exempt groundwater users (licences and registrations), 385 (69%) are registrations for traditional agriculture use under the *Water Act*. These 385 users will continue to have an industry activity code of ‘registration’ but the groundwater will be used for stock and/or crop spraying. Typically, the groundwater diversion for crop spraying is less than one m³/day. Of the 385 registrations, 125 (32%) could be linked to the AENV groundwater database. Of the remaining 174 from the 559 authorized non-exempt groundwater users, 84 are for agricultural purposes (mainly stock watering), 36 are for municipal purposes (mainly urban), 31 are for industrial purposes (mainly oil injection), 11 are for commercial purposes (mainly bottling and aggregate companies), six are for dewatering purposes, one is for recreation purposes, one is for fishery purposes, and the remaining four are for other purposes (mainly for pulp mill companies). Of these 174 authorized non-exempt groundwater users in the County, 120 (69%) could be linked to the AENV groundwater database. The total maximum authorized diversion from the water wells associated with these licences and registrations is 17,908 m³/day, although actual use could be less. Of the 17,908 m³/day, 6,928 m³/day (38.7%) is authorized for municipal purposes, 4,172 m³/day (23.2%) is for industrial purposes, 4,156 m³/day (23.2%) is authorized for dewatering purposes, 1,188 m³/day (6.6%) is for agricultural purposes, 1,010 m³/day (5.6%) is for registrations, 222 m³/day (1.2%) is authorized for commercial purposes, 135 m³/day (0.75%) is authorized for fishery purposes, 96 (0.5%) is for other purposes, and the remaining 0.3 m³/day is allotted for recreation purposes, as shown below in Table 1. A figure showing the locations of the authorized non-exempt groundwater users is in Appendix A (page A-6) and on the CD-ROM. Approximately 60% of the total authorized groundwater allocations are in the Dalehurst Aquifer. The 27 users where an aquifer cannot be determined is because insufficient completion information is available.

Aquifer **	No. of Diversions	Registrations (m³/day)	Licensed Groundwater Users* (m³/day) Agricultural	Commercial	Dewatering	Fishery	Industrial	Municipal	Recreation	Other	Authorized Non-Exempt Total	Percentage
Multiple Surficial Completions	1	0.4	0	0	0	0	0	0	0	0	0.4	0.0
Upper Sand and Gravel	20	23	65	0	9	0	260	179	0	0	536	3.0
Lower Sand and Gravel	25	22	161	0	642	0	3	1,092	0	2	1,922	10.7
Lower Sand and Gravel/Dalehurst	1	0	0	0	0	0	0	483	0	0	483	2.7
Mulitple Bedrock Completion	63	109	173	222	237	0	1,514	115	0	0	2,370	13.2
Disturbed Belt	2	1	0	0	0	0	0	3	0	0	4	0.0
Dalehurst	266	453	669	0	3,268	135	1,607	4,421	0.3	94	10,647	59.5
Upper Lacombe	77	184	34	0	0	0	595	635	0	0	1,448	8.1
Lower Lacombe	35	82	44	0	0	0	0	0	0	0	126	0.7
Haynes	23	49	20	0	0	0	0	0	0	0	69	0.4
Upper Scollard	11	36	0	0	0	0	193	0	0	0	229	1.3
Lower Scollard	0	0	0	0	0	0	0	0	0	0	0	0.0
Upper Horseshoe Canyon	8	10	22	0	0	0	0	0	0	0	32	0.2
Unknown	27	41	0	0	0	0	0	0	0	0	41	0.2
Total	559	1,010	1,188	222	4,156	135	4,172	6,928	0	96	17,908	100
Percentage		5.6	6.6	1.2	23.2	0.8	23.3	38.7	0.0	0.5	100	

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

Table 1. Authorized Non-Exempt Groundwater Diversions

[8] see conversion table on page 60

Based on the 2001 Agriculture Census (Statistics Canada), the calculated water requirement for 184,886 livestock for the County is in the order of 7,962 m³/day. The number of livestock is for all of Yellowhead County but the estimated total number of livestock for the study area is unavailable. This number includes intensive livestock use but not domestic animals and is based on an estimate of water use per livestock type. Of the 7,962 m³/day calculated livestock use, AENV has authorized a groundwater diversion of 2,198 m³/day (agricultural and registration) (28%) and licensed a surface-water diversion (stock and registration) based on consumptive use of 565 m³/day (7%) for a total diversion of 2,763 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 and use as traditional agriculture use is used for watering livestock. Using this assumption, 35% of the estimated total water requirements of 7,962 m³/day is accounted for.

Livestock Type	Number	Estimated Water Requirement (m³/day)
Total hens and chickens	6,965	1
Turkeys	237	0
Other poultry	798	0
Total cattle and calves	87,542	4,776
Bulls, 1 year and over	1,470	100
Total cows	30,598	1,669
Heifers, 1 year and over	15,556	707
Calves, under 1 year	26,211	357
Total pigs	2,369	43
Total sheep and lambs	4,607	42
Horses and ponies	3,807	173
Goats	663	6
Rabbits	109	0
Mink	0	0
Fox	0	0
Bison	852	39
Deer and elk	2,849	45
Llamas and alpacas	253	2
Totals	184,886	7,962

Table 2. Estimated Water Requirement for Livestock in Yellowhead County

The remaining 5,199 m³/day (65%) 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 Groundwater Chemistry and Base of Groundwater Protection

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. There were four groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) for the surficial aquifers and three groundwater samples that had Nitrate + Nitrite (as N) concentrations that were greater than the SGCDWQ for the upper bedrock aquifer(s); a plot of Nitrate + Nitrite (as N) in surficial aquifers is on the accompanying CD-ROM. The TDS concentrations in the groundwaters from the upper bedrock in the County range from less than 500 to more than 3,300 mg/L (page A-32). Groundwaters from the bedrock aquifers frequently are chemically soft, with generally low concentrations of dissolved iron. The chemically soft groundwater is high in concentrations of sodium. Nine percent of the chemical analyses for upper bedrock water wells indicate a fluoride concentration above 1.5 mg/L, with most of the exceedances occurring in areas of linear bedrock lows (see CD-ROM).

The minimum, maximum and median[9] 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 3. Of the five constituents compared to the SGCDWQ, median concentrations of TDS exceed the guidelines.

Constituent	No. of Analyses	Minimum (in mg/L)	Maximum (in mg/L)	Median (in mg/L)	Concentration SGCDWQ
Total Dissolved Solids	1,346	210	3,321	523	500
Sodium	1,230	0	1,012	131	200
Sulfate	1,380	0	1,701	32	500
Chloride	1,334	0	463	2	250
Fluoride	1,234	0	22	0.2	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-Territorial Committee on Drinking Water, April 2003

Table 3. Concentrations of Constituents in Groundwaters from Upper Bedrock Aquifer(s)

In general, Alberta Environment defines the Base of Groundwater Protection as the elevation below which the groundwater will have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, formation elevations, and Alberta Energy and Utilities Board (EUB) information indicating the formations containing the deepest useable water for agricultural needs, a value for the depth to the Base of Groundwater Protection can be determined. These values are gridded using the Kriging[10] method to prepare a depth to the Base of Groundwater Protection surface. This depth, for the most part, would be the maximum drilling depth for a water well for agricultural purposes or for a potable water supply. If a water well has total dissolved solids exceeding 4,000 mg/L, the groundwater use does not require licensing by AENV. In the County, the depth to the Base of Groundwater Protection ranges from less than 50 metres in the northern and eastern parts of the County to more than 1,000 metres in the southwestern parts of the County, as shown on Figure 4, on some cross-sections presented in Appendix A, and on the CD-ROM.

There are 5,559 water wells with completed depth data, of which 32 are completed below the Base of Groundwater Protection. Most of these water wells are located along the Pembina River Valley. Of the 32 water wells completed below the Base of Groundwater Protection, 31 are/were used for domestic/stock purposes, and one water well is used for industrial purposes. Chemistry data are available for 12 water wells, which provided groundwaters with TDS ranging from 794 to 1,092 mg/L. In the County, the Base of Groundwater Protection passes below the Lower Lacombe Member (see pages A-11, A-14 and A-15).

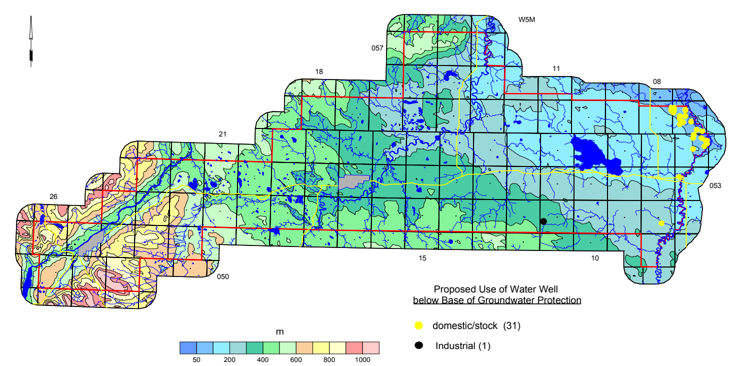

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there is one AENV-operated observation water well within the County (see page A-55 for the observation water well location). Additional data can be obtained from 27 water source wells and observation water wells, including 11 authorized non-exempt groundwater diversions. 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 Flagstaff County.

9 see glossary
10 See glossary

3 TERMS

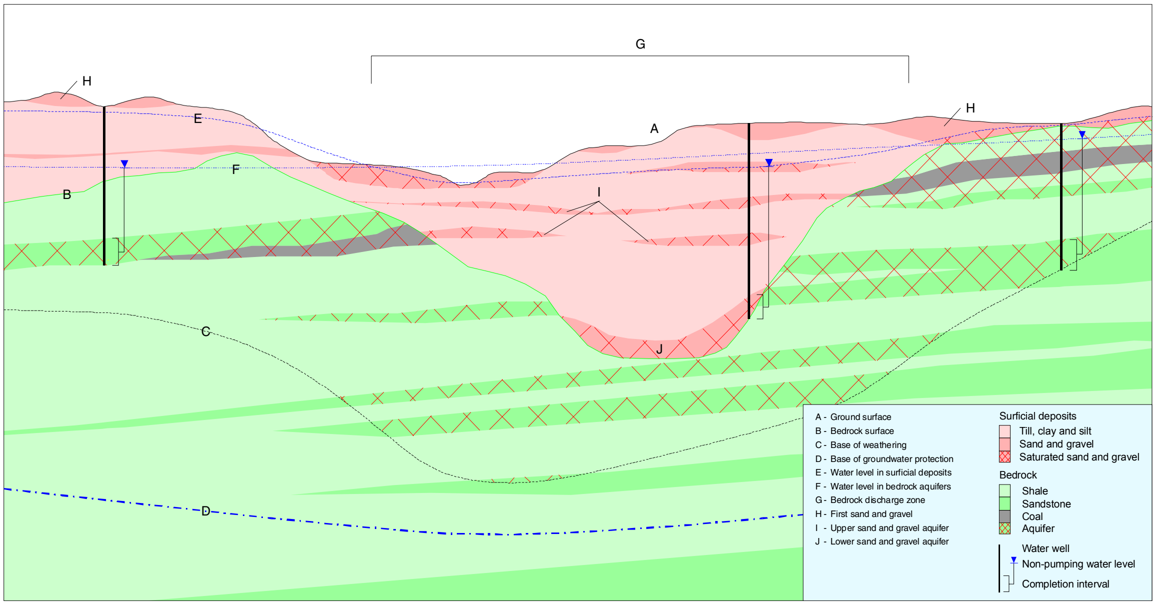

Figure 5. Generalized Cross-Section (for terminology only)

(for larger version, see page A-8)

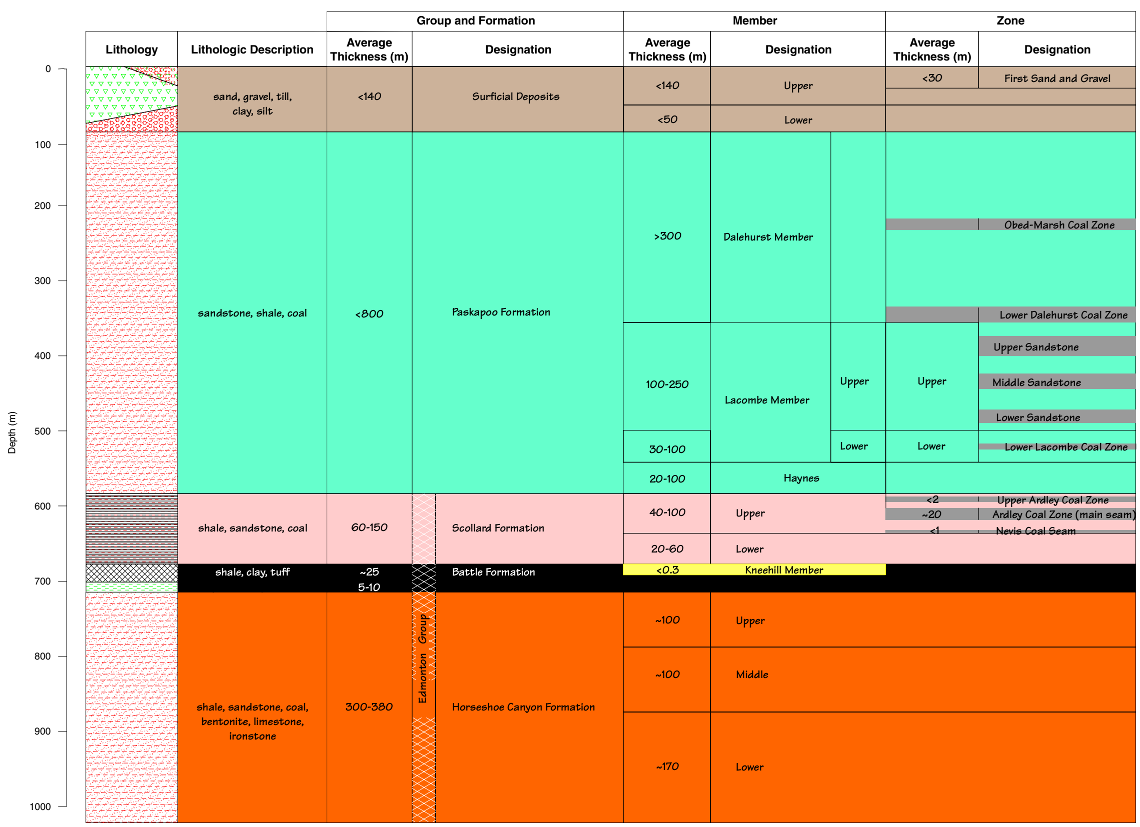

Figure 6. Geologic Column

(for larger version, see page A-9)

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[11]
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 SW ¼ of section 22, township 056, range 09, W5M would have a horizontal coordinate with an Easting of -17,075 metres and a Northing of 5,693,983 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.

[11] 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.

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[12].

Also, where sufficient information is available, values for apparent transmissivity [13] and apparent yield [14] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. Since the last regional hydrogeological map covering the eastern half of the County was published in 1972 (Ozoray, 1972), more than 1,000 values for apparent transmissivity and apparent yield have been added to the groundwater database. Since the last regional hydrogeological map covering the area of the County covering the western half of the County was published in 1977 (Vogwill, 1983), more than 700 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 75 m³/day. Approximately ten percent of the apparent yield values for these water wells are less than ten 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 7 and page A-10). The map is based on groundwater being obtained from all aquifers and has been prepared to allow direct comparison with the results provided on the Alberta Research Council (ARC) hydrogeological maps. In general, the ARC map shows lower estimated long-term yields. The differences between the two maps may be a result of fewer apparent yield values and the gridding method employed by ARC.

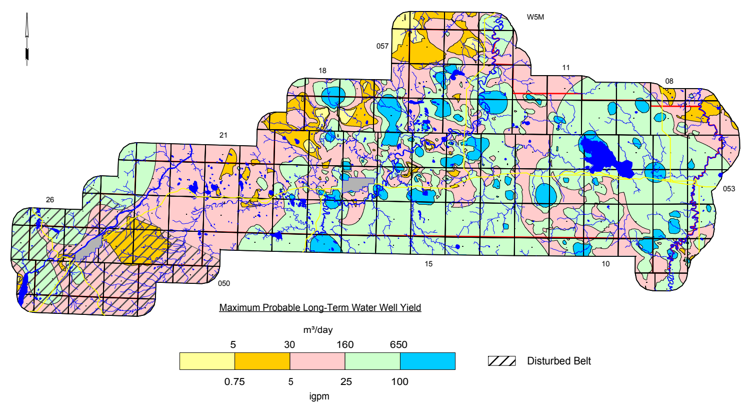

Figure 7. Hydrogeological Map

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.

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12 See glossary
13 For definitions of Transmissivity, see glossary
14 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 and chloride 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 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 050 to 057, ranges 07 to 26, W5M, 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.

4.3.1 Risk Criteria

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

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

Table 4. Risk of Groundwater Contamination Criteria

4.4 Maps and Cross-Sections

Once grids for geological surfaces have been prepared, various grids need to be combined to establish the extent and thickness of individual 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. Appendix A includes page-size maps from the text, plus additional page-size maps and figures that support the discussion in the text. A list of maps and figures that are included on the CD-ROM is given in Appendix B.

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

Once the technical details of a cross-section are correct, the drawing file is moved to the software package CorelDraw! for simplification and presentation in a hard-copy form. Six cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; only one (A-A') is included in the text of this report. The cross-sections are also included on the CD-ROM; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

4.5 Software

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

- Acrobat 5.0
- ArcView 3.2
- AutoCAD 2002
- CorelDraw! 11.0
- Microsoft Office XP
- 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[15] deposits. The *upper surficial deposits* include the traditional glacial sediments of till[16] and ice-contact deposits. Pre-glacial materials are expected to be present in association with linear bedrock lows. Meltwater channels are associated with glaciation.

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 5, page 9 and to page A-8. While the unsaturated deposits are not technically an aquifer, they are significant as they provide a pathway for soluble contaminants to move downward into the groundwater. Because of the significance of the shallow sand and gravel deposits, they have been mapped where they are present within one metres 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 in Figure 8 on the following page. Regionally, the bedrock surface varies between 650 and 1,500 metres AMSL. The lowest elevations occur along the present-day Pembina River valley at the eastern County boundary, as shown on Figure 8 and page A-17. Over the majority of the County, the surficial deposits are less than 30 metres thick (see CD-ROM).

The main southwest-northeast-trending linear bedrock lows in the County have been designated as the Buried Hinton, Edson and Onoway valleys. The Buried Hinton Valley is occupied by the present-day Athasbasca River in the western part of the County and is a tributary to the Buried High Prairie Valley. The Buried Hinton Valley is approximately six to nine kilometres wide, with local bedrock relief being less than 40 metres. Sand and gravel deposits can be expected in association with a bedrock low in the area south of the Town of Hinton, where the thickness of the sand and gravel deposits is expected to be mainly greater than 15 metres. Because the Buried Hinton Valley coincides with the Athasbasca River, sand and gravel deposits have largely been eroded and are mainly absent northeast of Hinton.

15 See glossary
16 See glossary

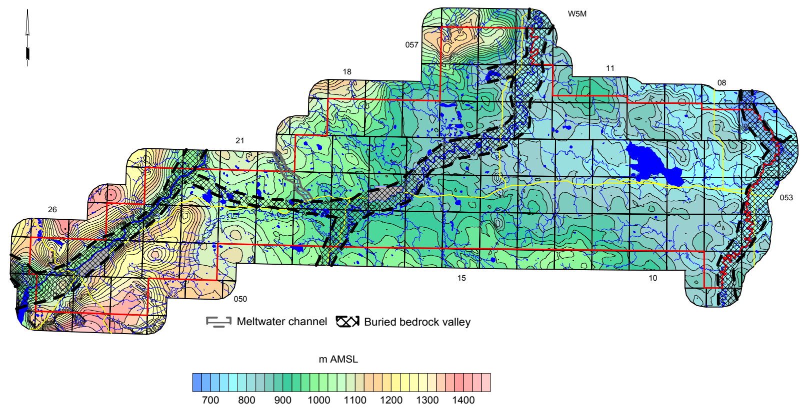

Figure 8. Bedrock Topography

The Buried Edson Valley coincides with the McLeod River in the central part of the County and is generally in reference to the portion of the buried valley near the Town of Edson. For the purposes of this report, the term "Buried Edson Valley" includes the buried valley that trends southwest-northeast across the County. The Buried Edson Valley is a tributary to the Buried High Prairie Valley located in Woodlands County. The Buried Edson Valley is approximately six to nine kilometres wide, with local bedrock relief being less than 40 metres. Sand and gravel deposits associated with the Buried Edson Valley can be expected to be mainly less than five metres.

The Buried Onoway Valley trends from southwest to northeast and coinides with the Pembina River in the eastern part of the County. The Buried Onoway Valley is approximately six to nine kilometres wide, with local bedrock relief being less than 40 metres. Sand and gravel deposits associated with the linear bedrock low can be expected to be mainly less than five metres.

The lower sand and gravel deposits are composed of fluvial deposits. Lower sand and gravel deposits are identified in association with the buried bedrock valleys. The total thickness of the lower sand and gravel deposits is mainly less than two metres, but can be more than five metres in the linear bedrock lows (see CD-ROM).

In the County, there is a linear bedrock low that trends northwest to southeast near the Town of Edson and has been indicated as being of meltwater origin and is referred to as the Sundance Glacial Meltwater Channel (Gabert and Roed, 1968). This meltwater channel is noted on the bedrock topography map.

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 the County (see CD-ROM). Because the meltwater channels are mainly an erosional feature, the sand and gravel deposits associated with these features are considered not to be significant aquifers. The upper sand and gravel deposits are usually less than two metres thick (see CD-ROM).

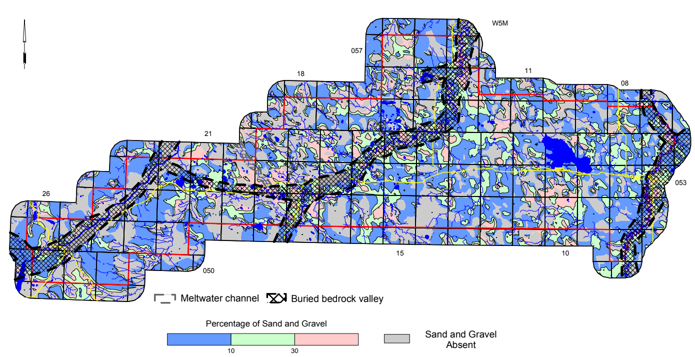

Figure 9. Amount of Sand and Gravel in Surficial Deposits

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

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 20% of the County where sand and gravel deposits are present, the sand and gravel deposits are more than 30% of the total thickness of the surficial deposits, as shown on the adjacent figure. The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly associated with linear bedrock lows and river valleys.

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.

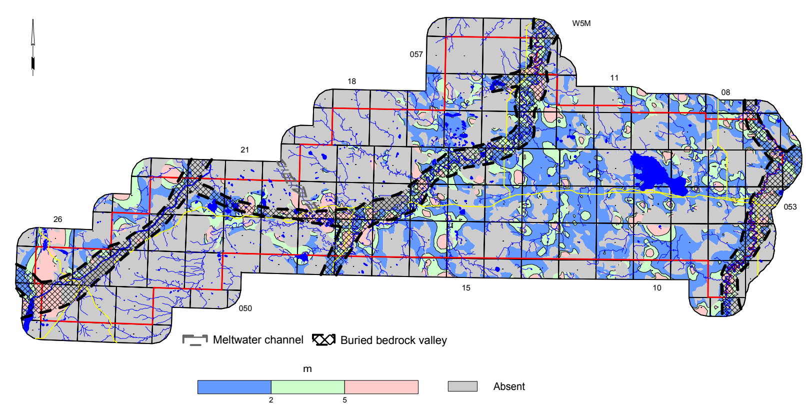

Figure 10. Thickness of Sand and Gravel Aquifer(s)

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 more than 60% 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 above map. In the County, the thickness of the Sand and Gravel Aquifer(s) is generally less than two metres, but can be more than five metres mainly in linear bedrock lows and river valleys, as shown in Figure 10, in Appendix A and on the CD-ROM.

Of the 5,855 water wells in the database, 222 were defined as being completed in surficial aquifers, based on lithologic information and water well completion details. From the present hydrogeological analysis, 542 water wells are completed in aquifers in the surficial deposits. Of the 542 water wells, 219 are completed in aquifers in the upper surficial deposits, 316 are completed in aquifers in the lower surficial deposits, and seven water wells are completed in multiple surficial aquifers. This number of water wells (542) is nearly two and a half times the number (222) determined to be completed in aquifers in the surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the elevation of the bedrock surface determined from the gridded bedrock topographic surface at the same location, then the water well is considered to be completed in an aquifer in the surficial deposits.

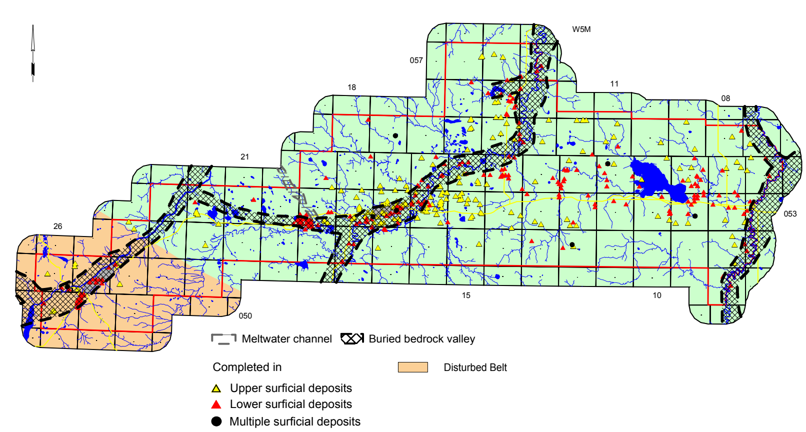

Figure 11. Water Wells Completed in Surficial Deposits

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 and in the Sundance meltwater channel, as shown above in Figure 11.

In the County, there are 101 records for surficial water wells with apparent yield data, which is 19% of the 542 surficial water wells. Seventeen percent of the 101 water wells completed in the Sand and Gravel Aquifer(s) have apparent yields that are less than ten m³/day, 38% have apparent yield values that range from 10 to 100 m³/day, and 45% have apparent yields that are greater than 100 m³/day. In addition to the 101 records for surficial water wells, there are eight records that indicate that the water well 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 eight dry test holes prior to gridding.

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 100 m³/day from the Sand and Gravel Aquifer(s) can be expected in 50% of the County where the Sand and Gravel Aquifer(s) are present. The most notable areas where yields of more than 300 m³/day are expected are mainly in association with linear bedrock lows.

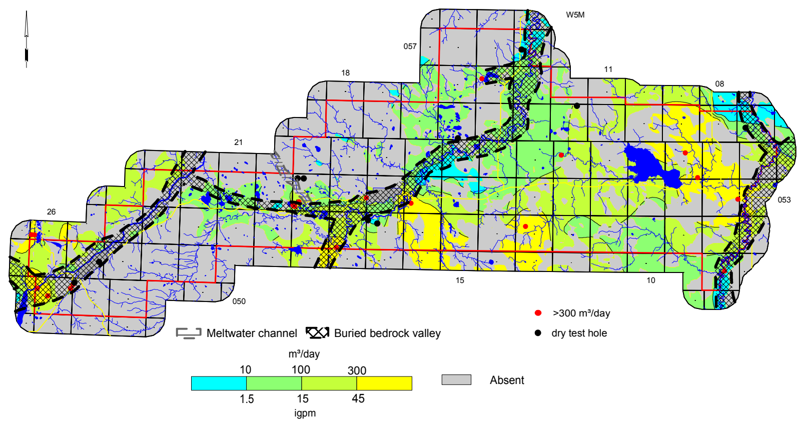

Figure 12. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

5.2.2.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analyses results of groundwaters from the surficial deposits indicate the groundwaters are generally chemically hard and high in dissolved iron. In Yellowhead County, groundwaters from the surficial aquifers mainly have a chemical hardness of greater than 200 and less than 400 mg/L (see CD-ROM).

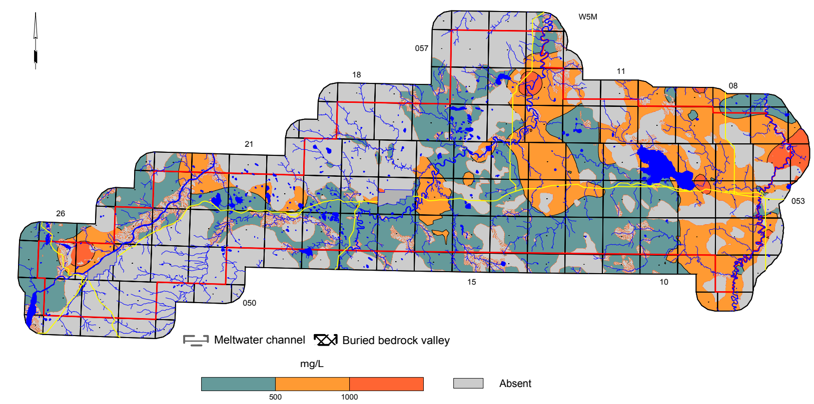

Figure 13. Total Dissolved Solids in Groundwater from Surficial Deposits

The Piper tri-linear diagram[17] for the surficial deposits (page A-26) shows that the groundwaters from the surficial deposits are mainly calcium-magnesium-bicarbonate waters. Sixty percent of the groundwaters from the surficial deposits have a TDS concentration of less than 500 mg/L. Fifty-three percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations of less than or equal to the aesthetic objective (AO) of 0.3 mg/L. However, many iron 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[18]. 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 nearly 80% of the samples analyzed for surficial deposits in the County, the chloride ion concentration is less than ten mg/L (see CD-ROM).

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 three of the 136 groundwater samples analyzed (up to about 1986).

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and Nitrate + Nitrite (as N) in the groundwaters from water wells completed in the surficial deposits in the County have been compared to the SGCDWQ in the adjacent table. The range of concentrations shown in Table 5 are 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, none of the median values exceeds the guidelines.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	231	122	2,480	450	500
Sodium	172	0	570	24	200
Sulfate	230	0	1,180	25	500
Chloride	221	0	197	3	250
Nitrate + Nitrite (as N)	136	0	40	0.1	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 5. Concentrations of Constituents in Groundwaters from Surficial Deposits

17 See glossary
18 See glossary

5.2.3 Upper Sand and Gravel Aquifer

The Upper Sand and Gravel Aquifer includes saturated sand and gravel deposits in the upper surficial deposits. Typically, these aquifers are present within the surficial deposits at no particular depth. Saturated sand and gravel deposits in the upper surficial deposits are not usually continuous over large areas but are expected over approximately 40% of the County.

5.2.3.1 Aquifer Thickness

The thickness of the Upper Sand and Gravel Aquifer is a function of two parameters: (1) the elevation of the non-pumping water-level surface associated with the surficial deposits; and (2) the depth to the bedrock surface or the depth to the top of the lower surficial deposits when present. In the County, the thickness of the Upper Sand and Gravel Aquifer is generally less than five metres.

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.

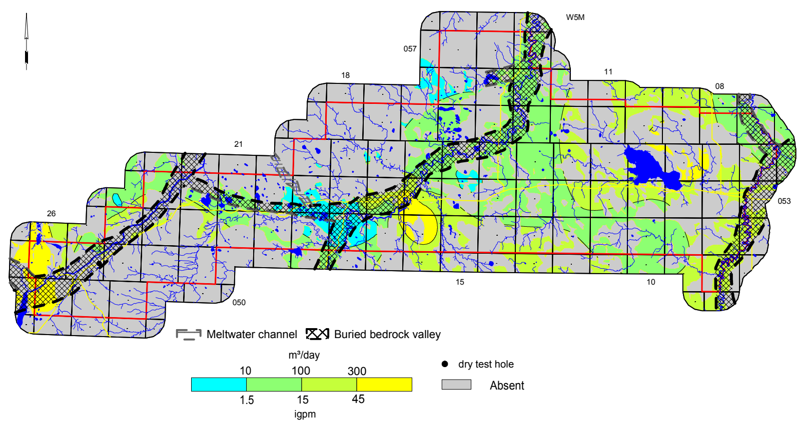

Figure 14. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

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.

Apparent yields for water wells completed through the Upper Sand and Gravel Aquifer range from less than ten m³/day to more than 300 m³/day. The most notable areas where yields of more than 300 m³/day may be possible are in the Buried Hinton Valley near the Town of Hinton and in the Buried Edson Valley east of the Town of Edson, where the saturated thickness of the upper sand and gravel deposits is more than five metres.

In the County, there is one dry water test hole completed in the Upper Sand and Gravel Aquifer.

In the County, there are 20 authorized non-exempt water wells that are completed through the Upper Sand and Gravel Aquifer, for a total authorized diversion of 536 m³/day (Table 1, page 6). The highest authorized amount is 179.1 m³/day for a water supply well in 16-12-053-08 W5M. Seven of the 20 authorized non-exempt water wells completed through the Upper Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

5.2.4 Lower Sand and Gravel Aquifer

The Lower Sand and Gravel Aquifer is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper part of the linear bedrock lows. The top of the lower surficial deposits is based on more than 1,000 control points across Alberta.

5.2.4.1 Aquifer Thickness

The thickness of the Lower Sand and Gravel Aquifer is mainly less than two metres, but can be up to ten metres in the linear bedrock lows (see CD-ROM).

5.2.4.2 Apparent Yield

Apparent yields for water wells completed through the Lower Sand and Gravel Aquifer range from less than ten m³/day to more than 300 m³/day. The most notable areas where yields of more than 300 m³/day are expected are mainly in areas where the thickness of the Lower Sand and Gravel Aquifer is greater than five metres.

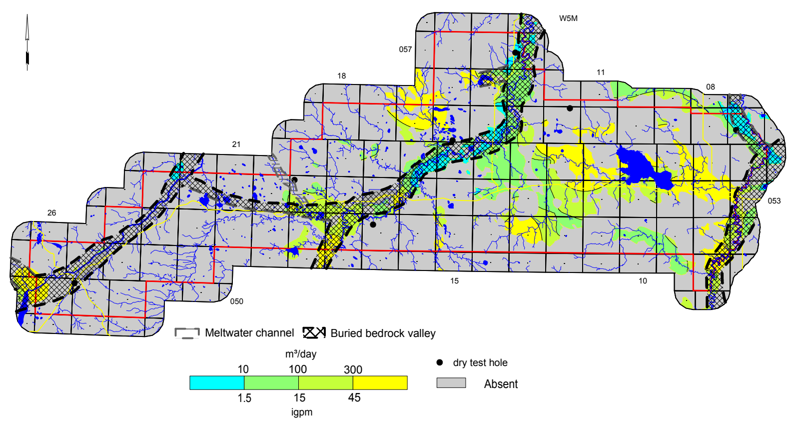

Figure 15. Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer

For most of the County, the Lower Sand and Gavel Aquifer is of limited groundwater importance mainly due to the Aquifer having a thickness of less than two metres. However, the lower sand and gravel deposits associated with the Buried Edson Valley have been an important source of groundwater for the Town of Edson for more than 40 years.

Since 1959, numerous aquifer tests have been conducted with water wells completed in the Lower Sand and Gravel Aquifer associated with the Buried Edson Valley. Extended aquifer tests conducted with water wells located in the Town of Edson area have indicated long-term yields ranging from 700 to 3,300 m³/day. In addition, because the McLeod River has locally downcut into the Aquifer, surface water can be induced to recharge the Lower Sand and Gravel Aquifer (Vogwill, 1983).

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

In the County, there are 25 non-exempt authorizations for water wells that are completed through the Lower Sand and Gravel Aquifer, for a total authorized diversion of 1,922 m³/day. Twelve of the 25 authorized non-exempt water wells completed through the Lower Sand and Gravel Aquifer could be linked to a water well in the AENV groundwater database.

Of the 1,922 m³/day, there are six non-exempt groundwater users that have been licensed to divert up to 1,091 m³/day for municipal purposes, of which 1,037 m³/day is for the Town of Edson.

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 Disturbed Belt, Paskapoo Formation (Dalehurst, Upper and Lower Lacombe, and Haynes members), as well as the Scollard, Battle and Whitemud and Upper Horseshoe Canyon formations, as shown below on cross-section A-A' (see page A-11). 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[19] and water well screens are a necessity.

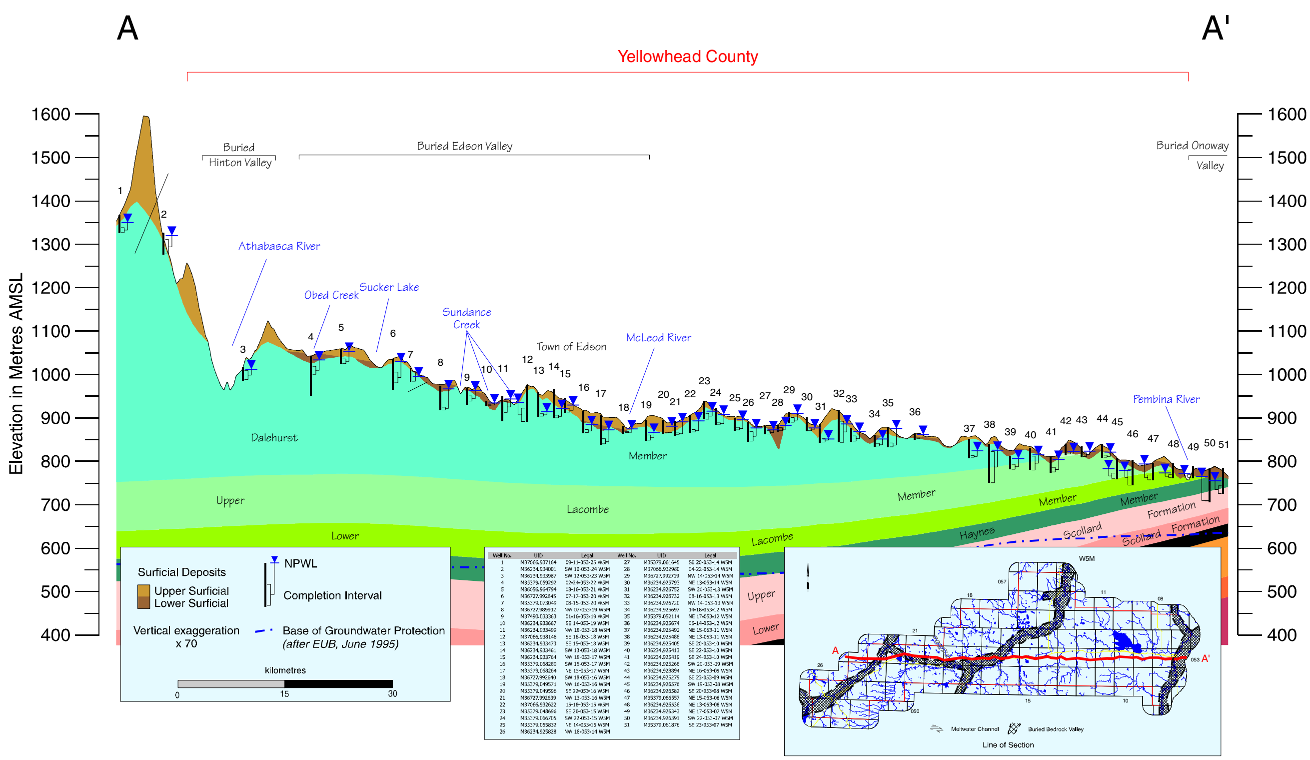

Figure 16. Cross-Section A - A'

In the study area, the Base of Groundwater Protection is variable, extending from a depth as little as 25 metres to a depth of over 1,000 metres below ground surface. In the County, the Base of Groundwater Protection is below the Lower Lacombe Member. A map showing the depth to the Base of Groundwater Protection is given in Figure 4 on page 8 of this report, in Appendix A (Page A-7), and on the CD-ROM.

[19] See glossary

5.3.2 Geological Characteristics

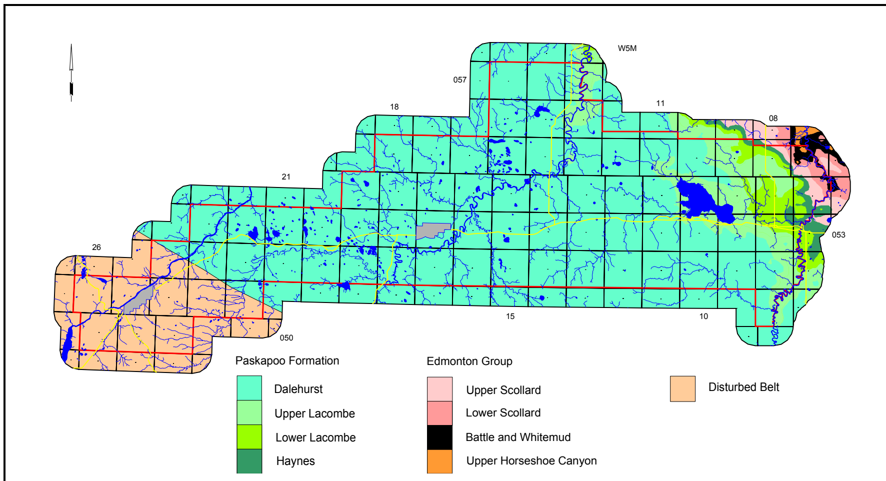

Figure 17. Bedrock Geology

The Disturbed Belt is the upper bedrock in the southwestern part of the County. The outline of the Disturbed Belt has been defined based on the Geological Map of Alberta (Hamilton et al, 1998, and Green, 1972). The Rocky Mountains and Foothills together form the Disturbed Belt, which is an area that has been deformed by folding and thrust faulting (Tokarsky, 1971). Water wells that were located within the Disturbed Belt boundary were defined as being completed in surficial deposits or in the Disturbed Belt Aquifer. The Paskapoo Formation in central Alberta consists of the Dalehurst, Lacombe and Haynes members (Demchuk and Hills, 1991). The Edmonton Group underlies the Paskapoo Formation. The Edmonton Group includes the Scollard, the Battle and Whitemud, and the Horseshoe Canyon formations and consists of fresh and brackish-water deposits of fine-grained sandstone and silty shale, thick coal seams, and numerous bentonite beds (Carrigy, 1971). A generalized geologic column is illustrated in Figure 6, in Appendix A, and on the CD-ROM.

The Paskapoo Formation is the upper bedrock and is the main bedrock formation in the County. The Paskapoo Formation consists of cycles of thick, tabular sandstone, siltstone and mudstone layers (Glass, 1990). The maximum thickness of the Paskapoo Formation is generally less than 800 metres; in the County, the thickness is less than 500 metres.

The Dalehurst Member is the upper bedrock and subcrops in 80% of the County. This Member has a maximum thickness of 500 metres within the County and is mostly composed of shale and siltstone with sandstone, bentonite and coal seams or zones. Two prominent coal zones within the Dalehurst are the Obed-Marsh Coal (up to 30 metres thick) and the Lower Dalehurst Coal (up to 50 metres thick). The bottom of the Lower Dalehurst Coal is the border between the Dalehurst and Lacombe members (Demchuck and Hills, 1991). If the coal seams are not fractured, they are impermeable.

The Lacombe Member underlies the Dalehurst Member and has a maximum thickness of 230 metres in the County. The upper part of the Lacombe Member is mostly composed of shale interbedded with sandstone, and has a maximum thickness of 130 metres. The lower part of the Lacombe Member is composed of sandstone and coal layers. In the middle of the lower part of the Lacombe Member there is a coal zone, which can be up to five metres thick. In the County, the Lower Lacombe Member has a maximum thickness of 75 metres.

The Haynes Member underlies the Lacombe Member and is composed mainly of sandstone with some siltstone, shale and coal. In other parts of Alberta, the Haynes Member has a maximum thickness of 55 metres.

The Scollard Formation underlies the Haynes Member, is the upper bedrock in the northeastern part of the County, 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. In the County, the Upper Scollard Formation has a maximum thickness of 120 metres and the Lower Scollard has a maximum thickness of 70 metres.

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 and has three separate designations: Upper, Middle and Lower. In the County, the Upper Horseshoe Canyon has a maximum thickness of 250 metres; the Middle Horseshoe Canyon has a maximum thickness of 155 metres, and the Lower Horseshoe Canyon has a maximum thickness of 450 metres.

The Horseshoe Canyon Formation consists of deltaic[20] and fluvial sandstone, siltstone and shale with interbedded coal seams, bentonite and thin nodular beds of limestone and ironstone. Because of the low-energy environment in which deposition occurred, the sandstones, when present, tend to be finer grained. The lower 60 to 70 metres and the upper 30 to 50 metres of the Horseshoe Canyon Formation can include coarser grained sandstone deposits.

There will be no direct review of the Middle or Lower Horseshoe Canyon formations in the text of this report; there are insufficient or no hydrogeological data within the study area to prepare meaningful maps.

5.3.3 Upper Bedrock Completion Aquifer(s)

Of the 5,855 water wells in the database, 3,483 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 4,939 water wells completed below the bedrock surface. Of these 4,939 water wells, one is completed below the upper bedrock in the Lower Horseshoe Canyon Formation, giving a total of 4,938 water wells completed in upper bedrock aquifer(s). Assigning a water well to a specific geologic unit is possible only if the completion interval is identified. In order to make use of additional information within the groundwater database, it was assumed that the top of the completion interval was 80% of the total completed depth of a water well. With this assumption, it has been possible to designate the specific bedrock aquifer of completion for an additional 745 bedrock water wells, giving a total of 4,228 water wells. The remaining 711 of the total 4,939 upper bedrock water wells are identified as being completed in more than one bedrock aquifer, as shown in Table 6. The bedrock water wells are mainly completed in the Dalehurst Aquifer.

Geologic Unit	No. of Bedrock Water Wells
Disturbed Belt	348
Dalehurst	3,126
Upper Lacombe	461
Lower Lacombe	181
Haynes	59
Upper Scollard	27
Lower Scollard	8
Battle and Whitemud	3
Upper Horseshoe Canyon	14
Middle Horseshoe Canyon	0
Lower Horseshoe Canyon	1
Multiple Completions	711
Total	4,939

Table 6. Completion Aquifer for Upper Bedrock Water Wells

[20] See glossary

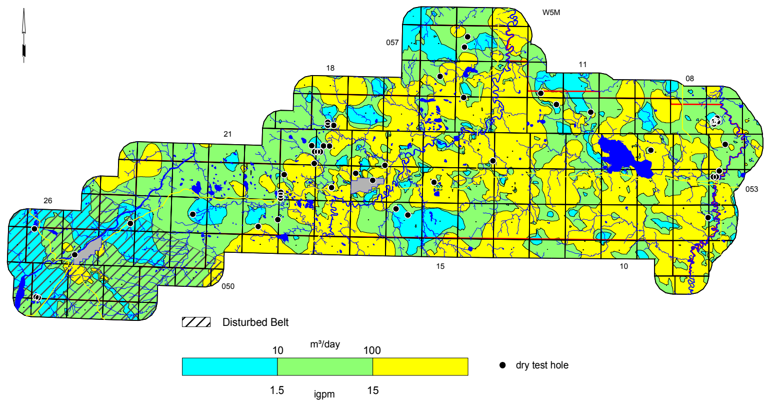

Figure 18. Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)

There are 1,912 records for bedrock water wells that have apparent yield values, which is 28% of the 6,930 bedrock water wells in the County. Yields for water wells completed in the upper bedrock aquifer(s) are mainly between 10 and 100 m³/day and have a median apparent yield of more than 70 m³/day. The areas in the southwestern part of the County where apparent yields of less than ten m³/day are shown are a result of the gridding process using limited data control. In addition to the 1,912 records for bedrock water wells with apparent yield values, there are 57 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 57 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
Disturbed Belt	73	34	26	13
Dalehurst	1,269	110	612	547
Upper Lacombe	196	6	79	111
Lower Lacombe	84	5	39	40
Haynes	22	2	12	8
Battle and Whitemud	2	1	1	0
Upper Scollard	16	1	10	5
Lower Scollard	5	0	5	0
Upper Horseshoe Canyon	8	1	6	1
Multiple Completions	310	30	151	129
Totals	1,912	156	915	841

Table 7. Apparent Yields of Bedrock Aquifers

Of the 1,912 water well records with apparent yield values, 1,602 have been assigned to aquifers associated with specific geologic units. Eight percent (156) of the 1,912 water wells completed in bedrock aquifers have apparent yields that are less than ten m³/day, 48% (915) have apparent yield values that range from 10 to 100 m³/day, and 44% (841) have apparent yield values that are greater than 100 m³/day, as shown in Table 7. In the Dalehurst Aquifer, nearly 45% of the apparent yield values are greater than 100 m³/day.

5.3.4 Chemical Quality of Groundwater

The Piper tri-linear diagram for bedrock aquifers (page A-26) shows that groundwaters from bedrock aquifers are mainly sodium-bicarbonate or calcium-magnesium-type waters.

The TDS concentrations in the groundwaters from the upper bedrock aquifer(s) range from less than 200 mg/L to more than 1,000 mg/L, with most of the groundwaters with higher TDS concentrations occurring in the eastern part of the County.

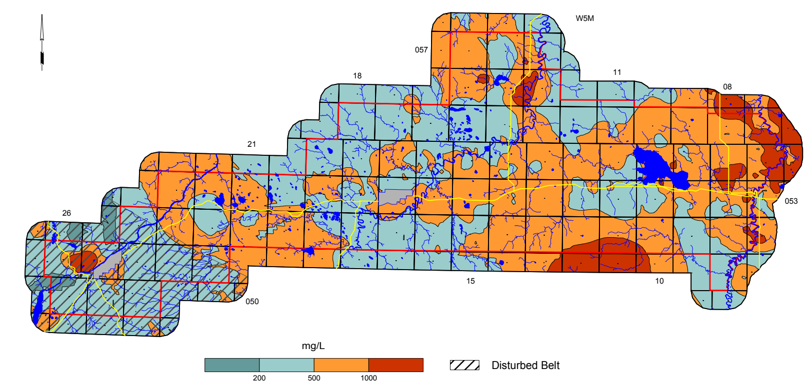

Figure 19. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The relationship between TDS and sulfate concentrations shows that when TDS values in the groundwaters from the upper bedrock aquifer(s) exceed 1,100 mg/L, the sulfate concentrations exceed 400 mg/L. The sulfate concentrations in groundwaters from the upper bedrock aquifer(s) were compared to the distance of completion depth from the top of the Upper Lacombe Member. The maximum sulfate concentrations generally increase with depth, as shown below in Figure 20, with the exception being the Lower Horsehoe Canyon Aquifer as a result of having limited data for sulfate concentrations.

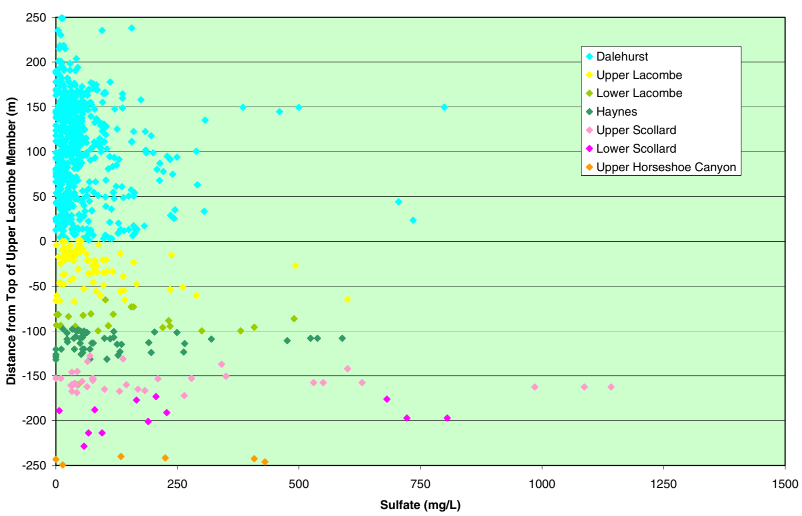

Figure 20. Distance from Top of Upper Lacombe Member vs Sulfate in Groundwaters from Upper Bedrock Aquifer(s)

In the County, more than 95% of the chloride concentrations in the groundwaters from the upper bedrock aquifer(s) are less than 50 mg/L. Chloride concentrations of greater than 50 mg/L are mainly associated with groundwaters from the Upper Horseshoe Canyon Aquifer.

The Nitrate + Nitrite (as N) concentrations are less than 0.1 mg/L in 81% of the chemical analyses for upper bedrock water wells. Approximately 55% of the total hardness values in the groundwaters from the upper bedrock aquifer(s) are less than 200 mg/L.

In the County, approximately 70% 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 21% of the groundwater samples from the entire County are between 0.5 and 1.5 mg/L and approximately 9% exceed the MAC for fluoride of 1.5 mg/L. Fluoride concentrations of greater than 1.5 mg/L are mainly associated with groundwaters from the Upper Horseshoe Canyon Aquifer.

5.3.5 Disturbed Belt Aquifer

The Disturbed Belt Aquifer comprises the permeable parts of the Disturbed Belt, as defined for the present program. The regional groundwater flow direction in the Disturbed Belt Aquifer is toward the Athasbasca River (see CD-ROM).

5.3.5.1 Depth to Top

The depth to the top of the Disturbed Belt is mainly greater than ten metres and is a reflection of the thickness of the surficial deposits (page A-30).

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Disturbed Belt Aquifer are mainly less than ten m³/day as shown on Figure 21. The areas showing water wells with yields of greater than 100 m³/day are expected to be in the Town of Hinton vicinity. There are no available apparent yield data for water wells completed through the Disturbed Belt Aquifer in township 050, ranges 21 to 24, W5M.

Shown on the adjacent map are the locations of six dry water test holes (page A-31).

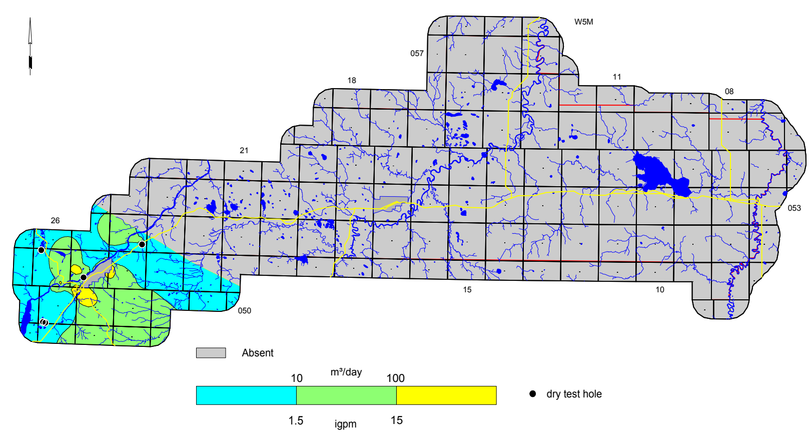

Figure 21. Apparent Yield for Water Wells Completed through Disturbed Belt Aquifer

There are two non-exempt groundwater users that have water wells completed through the Disturbed Belt Aquifer, for a total groundwater diversion of four m³/day.

Of the two non-exempt authorizations, one could be linked to a water well in the AENV groundwater database; the water well is the Jasper-Hinton Airport water supply well.

An extended aquifer test was conducted with the Jasper-Hinton Airport water supply well in August 1977 by Hydrogeological Consultants Ltd. (HCL, October 1977). The airport water supply well in NW 16-050-26 W5M is completed open hole from 14.9 to 45.7 metres below ground surface in the Disturbed Belt. The extended aquifer test conducted with the Jasper-Hinton Airport water supply well indicated a long-term yield of 50 m³/day, based on an effective transmissivity of 3.8 metres squared per day (m²/day). The water supply well is licensed to divert 3.4 m³/day.

5.3.5.3 Quality

The groundwaters from the Disturbed Belt Aquifer are mainly a bicarbonate type, with no dominant cation (see Piper diagram on CD-ROM), with more than 65% of the groundwater samples having TDS concentrations of less than 500 mg/L (page A-32). Nearly 90% of the sulfate concentrations in groundwaters from the Disturbed Belt Aquifer are less than 200 mg/L. Nearly 75% of the chloride concentrations from the Disturbed Belt Aquifer are less than ten mg/L.

A chemical analysis of a groundwater sample collected in August 1977 from the Jasper-Hinton Airport water supply well indicates the groundwater is a calcium-magnesium-bicarbonate type, with a TDS of 379 mg/L, a sulfate concentration of 5 mg/L, a chloride concentration of 2 mg/L, a fluoride concentration of 0.25 mg/L, and a total hardness of 324 mg/L (HCL, October 1977).

Of the five constituents that have been compared to the SGCDWQ, none of the constituents exceed the bedrock median values, except for fluoride, and none exceed the SGCDWQ.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	130	28	6,932	406	523	500
Sodium	111	0	1,012	128	131	200
Sulfate	130	0	440	18	32	500
Chloride	127	0	463	2	2	250
Fluoride	106	0	4	0.5	0.2	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 8. Apparent Concentrations of Constituents in Groundwaters from Disturbed Belt Aquifer

5.3.6 Dalehurst Aquifer

The Dalehurst Aquifer comprises the permeable parts of the Dalehurst Member, as defined for the present program. The Dalehurst Member subcrops under the surficial deposits in most of the County. The structure contours show that the Dalehurst Member ranges in elevation from less than 800 to more than 1,350 metres AMSL and has a maximum thickness of 500 metres. The regional groundwater flow direction in the Dalehurst Aquifer is mainly toward the McLeod River (see CD-ROM).

5.3.6.1 Depth to Top

The depth to the top of the Dalehurst Member ranges from less than ten metres to more than 30 metres in the northern part and also on the southern and western edges of the County (page A-33).

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Dalehurst Aquifer are mainly between 10 to 100 m³/day, as shown on Figure 22. The areas showing water wells with yields of greater than 100 m³/day are expected to be throughout the areal extent of the Aquifer.

Shown on the adjacent map are the locations of 28 dry water test holes.

There are 266 non-exempt groundwater users that have water wells completed through the Dalehurst Aquifer, for a total authorized groundwater diversion of 10,514 m³/day.

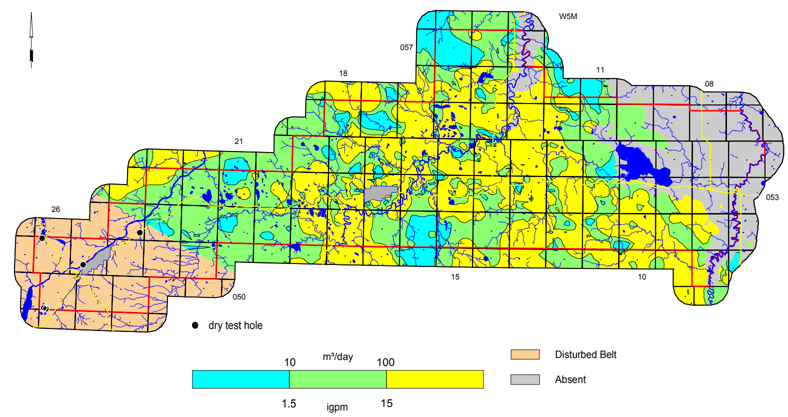

Figure 22. Apparent Yield for Water Wells Completed through Dalehurst Aquifer

Of the 266 non-exempt authorizations, 126 could be linked to water wells in the AENV groundwater database.

The highest non-exempt groundwater use is for eight authorizations that allow the Town of Edson to divert up to 4,233 m³/day from six water supply wells completed in the Dalehurst Aquifer for municipal purposes and one water supply well completed in both the Lower Sand and Gravel Aquifer and the Dalehurst Aquifer. The remaining water supply well is completed in the Lower Sand and Gravel Aquifer. The highest authorization of 1,504 m³/day is for WSW No. 15, which is completed from 44.8 to 65.5 metres below ground surface in the Dalehurst Aquifer.

Touchstone Petroleum Inc. is authorized to divert up to 240 m³/day from Water Source Well (WSW) No. 1-96 in the Carrot Creek Area in NW 12-053-13 W5M. The water source well is completed from 64.6 to 82.9 metres below ground surface in the Dalehurst Aquifer. Water-level monitoring since 1996 with WSW No. 1-96 and Observation Water Well (Obs WW) No. 2-96 indicated an effective transmissivity of 12 m²/day and corresponding storativity of 0.008 (HCL, March 2003).

5.3.6.3 Quality

The groundwaters from the Dalehurst Aquifer are mainly a bicarbonate type, with no dominant cation (see Piper diagram on CD-ROM), with 50% of the groundwater samples having TDS concentrations of less than 500 mg/L (page A-35). Seventy percent of the sulfate concentrations in groundwaters from the Dalehurst Aquifer are less than 50 mg/L. Nearly 90% of the chloride concentrations from the Dalehurst Aquifer are less than ten mg/L.

Chemical analyses collected from 1973 to 2000 from the six active Town of Edson water supply wells completed in the Dalehurst Aquifer indicate that the groundwaters are mainly a sodium-bicarbonate-type, with TDS concentrations being mainly less than 550 mg/L, sulfate concentrations mainly less than 50 mg/L, chloride concentrations mainly less than four mg/L, and fluoride concentrations mainly less than one mg/L. Chemical analyses collected from 1986 to 2000 from two of the six active water supply wells completed in the Dalehurst Aquifer in west Edson have TDS concentrations of greater than 550 mg/L, chloride concentrations ranging from 12 to 21 mg/L, and fluoride concentrations ranging from 2.4 to 3.3 mg/L (Komex International Ltd., March 2001).

A chemical analysis of a groundwater sample collected in February 1996 from WSW No. 1-96 and Obs WW No. 2-96 in NW 12-053-13 W5M indicates the groundwater is a sodium-bicarbonate type, with a TDS concentration of less than 600 mg/L, a sulfate concentration of less than 15 mg/L, a chloride concentration of less than 41 mg/L, and a fluoride concentration of in the order of three mg/L (HCL, April 1996).

Of the five constituents that have been compared to the SGCDWQ, all are below the guidelines. All median concentrations in the Dalehurst Aquifer are equal to or below 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	843	3.83	2,764	497	523	500
Sodium	791	2	781	114	131	200
Sulfate	864	0	1701	29	32	500
Chloride	827	0	93	2	2	250
Fluoride	798	0	22	0.2	0.2	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 9. Apparent Concentrations of Constituents in Groundwaters from Dalehurst Aquifer

5.3.7 Upper Lacombe Aquifer

The Upper Lacombe Aquifer comprises the permeable parts of the Upper Lacombe Member, as defined for the present program. Structure contours have been prepared for the top of the Upper Lacombe Member. The structure contours show that the Upper Lacombe Member ranges in elevation from less than 730 to more than 850 metres AMSL and has a maximum thickness of 130 metres. The non-pumping water level in the Upper Lacombe Aquifer is downgradient to the northwest toward the McLeod River and southeast toward the Pembina River (see CD-ROM).

5.3.7.1 Depth to Top

The depth to the top of the Upper Lacombe Member ranges from less than ten metres to more than 500 metres in the western part of the County (page A-36).

5.3.7.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Lacombe Aquifer are mainly greater than 100 m³/day. There are three dry water test holes that are completed in the Upper Lacombe Member. The areas where water wells with higher yields are expected are mainly where the Upper Lacombe Member subcrops under surficial deposits and would be most subjected to weathering processes.

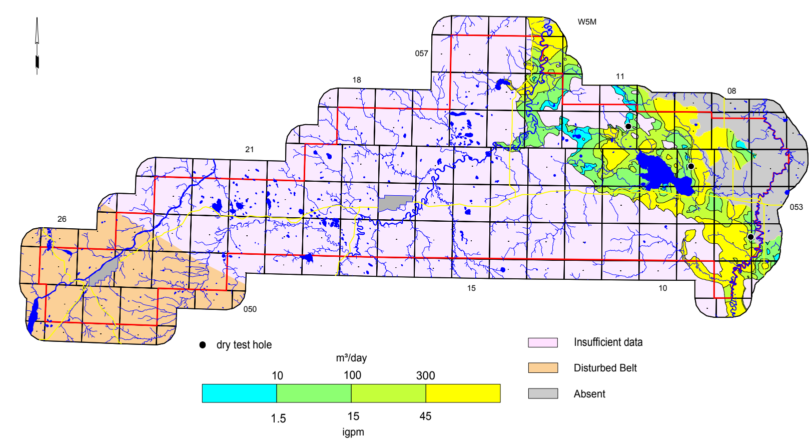

Figure 23. Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer

There are 77 non-exempt groundwater users that have water wells completed through the Upper Lacombe Aquifer, for a total authorized groundwater diversion of 1,448 m³/day, with 85% being diverted for municipal and industrial purposes.

Of the 77 non-exempt authorizations, 37 could be linked to water wells in the AENV groundwater database.

The highest non-exempt groundwater use in Yellowhead County is for an authorization that allows Beau Canada Exploration Ltd. (Beau Canada) 290 m³/day for industrial injection purposes at its Niton Rock Creek “N” Pool location in 08-10-055-10 W5M. Water Source Well No. 08-10 is completed from 40.2 to 60.4 metres below ground surface in the Upper Lacombe Aquifer. Long-term monitoring from WSW No. 08-10 indicated an aquifer transmissivity of 35 m²/day and a corresponding storativity of 0.00002 (HCL, February 2003).

The second highest non-exempt groundwater use is for an authorization that is in the name of Amoco Canada Petroleum Company (Amoco) for 220 m³/day from WSW No. 13-09 in 13-09-052-08 W5M, as part of its enhanced-oil-recovery program. WSW No. 13-09 is completed from 30.5 to 36.6 metres below ground surface in the Upper Lacombe Aquifer.

5.3.7.3 Quality

The groundwaters from the Upper Lacombe Aquifer are mainly a sodium-bicarbonate type (see Piper diagram on CD-ROM), with nearly 80% of the groundwater samples having TDS concentrations ranging mainly from 500 to 1,000 mg/L (page A-38). The sulfate concentrations in groundwaters from the Upper Lacombe Aquifer are mainly less than 100 mg/L. The chloride concentrations from the Upper Lacombe Aquifer are mainly less than ten mg/L. More than 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 November 1993 from WSW No. 08-10 in 08-10-055-10 W5M indicates that the groundwater is a sodium-bicarbonate type, with a TDS concentration of 529 mg/L, a sulfate concentration of 9 mg/L, a chloride concentration of 19 mg/L, and a fluoride concentration of 2.46 mg/L (HCL, Dec 1993).

A chemical analysis of a groundwater sample collected in October 2000 from WSW No. 13-09 in 13-09-052-08 W5M indicates that the groundwater is a sodium-sulfate-bicarbonate type, with a TDS concentration of 573 mg/L, a sulfate concentration of 152 mg/L, and a chloride concentration of 0.6 mg/L; fluoride concentrations were not analyzed (HCL, Feb 2001).

Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines. The median concentrations of TDS, sodium, sulfate, chloride and fluoride from water wells completed in the Upper Lacombe Aquifer are equal to or 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	107	221	1,576	598	523	500
Sodium	89	4	440	152	131	200
Sulfate	110	0	619	65	32	500
Chloride	109	0	98	2	2	250
Fluoride	92	0	5	0.2	0.2	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 10. Apparent Concentrations of Constituents in Groundwaters from Upper Lacombe Aquifer

5.3.8 Lower Lacombe Aquifer

The Lower Lacombe Aquifer comprises the permeable parts of the Lower Lacombe Member, as defined for the present program. Structure contours have been prepared for the top of the Lower Lacombe Member. The structure contours show that the Lower Lacombe Member ranges in elevation from less than 630 to more than 810 metres AMSL and has a maximum thickness of 120 metres. The non-pumping water level in the Lower Lacombe Aquifer is downgradient to the southwest toward the Pembina River (see CD-ROM).

5.3.8.1 Depth to Top

The depth to the top of the Lower Lacombe Member ranges from less than ten metres below ground level where the Member subcrops to more than 750 metres in the western part of the County (page A-39).

5.3.8.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Lacombe Aquifer are mainly in the range of 10 to 100 m³/day. There are no dry water test holes that are completed through the Lower Lacombe Aquifer. The areas showing water wells with yields of greater than 100 m³/day are expected to be mainly east of Chip Lake, as shown in Figure 24.

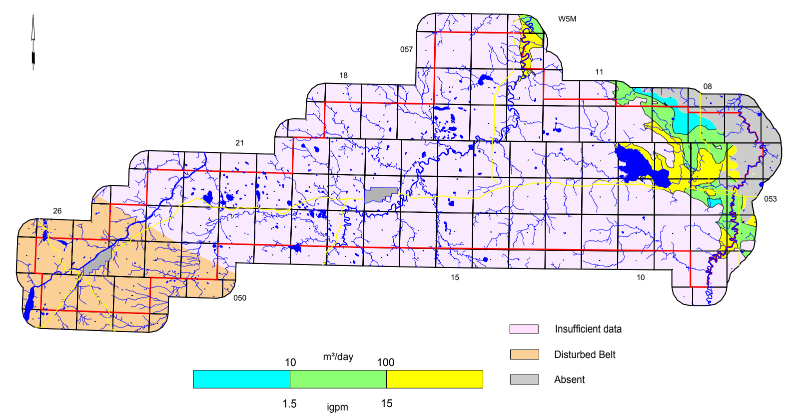

Figure 24. Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer

There are 35 non-exempt groundwater users that have water wells completed through the Lower Lacombe Aquifer, for a total authorized groundwater diversion of 126 m³/day. The highest single allocation is 27 m³/day for a water well in 05-36-053-09 W5M that is licensed to divert groundwater for agricultural purposes. Of the 35 non-exempt authorizations, 11 could be linked to water wells in the AENV groundwater database.

5.3.8.3 Quality

The groundwaters from the Lower Lacombe Aquifer are mainly a sodium-bicarbonate type (see Piper diagram on CD-ROM), with 80% of the groundwater samples having TDS concentrations ranging from 500 to 1,000 mg/L (page A-41). The sulfate concentrations in groundwaters from the Lower Lacombe Aquifer are mainly less than 300 mg/L. The chloride concentrations from the Lower Lacombe Aquifer are mainly less than ten mg/L. There are four analyses where the fluoride concentration exceeds 1.5 mg/L.

Constituent	No. of Analyses	Range for County in mg/L Minimum	Maximum	Median	All Bedrock Median	Maximum Concentration SGCDWQ
Total Dissolved Solids	62	395	1,315	710	523	500
Sodium	51	0	404	212	131	200
Sulfate	64	0	530	108	32	500
Chloride	61	0	95	2	2	250
Fluoride	53	0	12	0.2	0.2	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 Lower Lacombe 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, sulfate, chloride and fluoride from water wells completed in the Lower Lacombe Aquifer are equal to or greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

5.3.9 Haynes Aquifer

The Haynes Aquifer comprises the permeable parts of the Haynes Member, as defined for the present program. Structure contours have been prepared for the top of the Haynes Member. The structure contours show that the Haynes Member ranges in elevation from less than 560 to more than 780 metres AMSL and has a maximum thickness of 55 metres.

5.3.9.1 Depth to Top

The depth to the top of the Haynes Member ranges from less than ten metres below ground surface at the eastern extent to more than 900 metres in the western part of the County (page A-42). The non-pumping water level in the Haynes Aquifer is downgradient to the south toward the Pembina River (see CD-ROM).

5.3.9.2 Apparent Yield

The apparent yields for individual water wells completed through the Haynes Aquifer are mainly greater than 50 m³/day, with nearly 50% of the water wells completed in the Haynes Aquifer having apparent yield values that are greater than 100 m³/day. There is one dry water test hole that is completed through the Haynes Aquifer.

There are 23 non-exempt groundwater users that have water wells completed through the Haynes Aquifer, for a total authorized groundwater diversion of 69 m³/day.

All allocations are registrations and for agricultural purposes. Of the 23 non-exempt authorizations, eight could be linked to water wells in the AENV groundwater database.

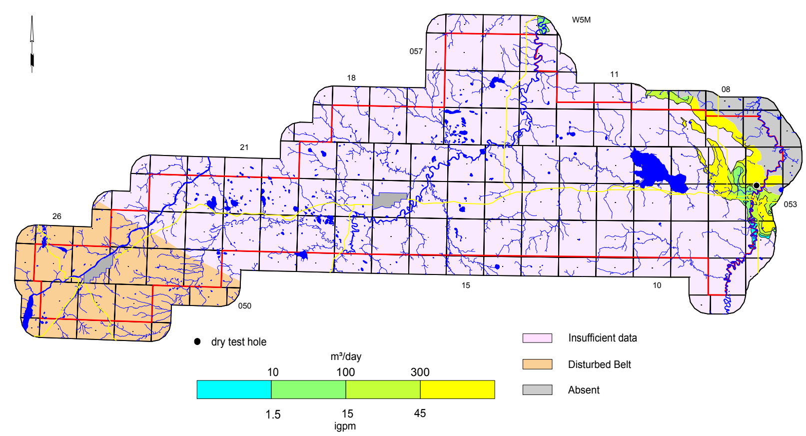

Figure 25. Apparent Yield for Water Wells Completed through Haynes Aquifer

5.3.9.3 Quality

The groundwaters from the Haynes Aquifer are mainly a bicarbonate type with no dominant cation (see Piper diagram on CD-ROM), with 70% of the values having TDS concentrations from 500 to 1,000 mg/L (page A-44). The sulfate concentrations in groundwaters from the Haynes Aquifer are mainly less than 150 mg/L. The chloride concentrations from the Haynes Aquifer are mainly less than ten mg/L. The fluoride concentrations from the Haynes Aquifer are mainly less than 0.5 mg/L.

Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines. The median concentrations of TDS and sulfate from water wells completed in the Haynes 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	23	149	1,592	780	523	500
Sodium	17	7	365	102	131	200
Sulfate	23	23	589	126	32	500
Chloride	24	0	62	1	2	250
Fluoride	18	0	1	0.1	0.2	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 12. Apparent Concentrations of Constituents in Groundwaters from Haynes Aquifer

5.3.10 Upper Scollard Aquifer

The Upper Scollard Aquifer comprises the permeable parts of the Upper Scollard Formation, as defined for the present program. Structure contours have been prepared for the top of the Formation. The structure contours show that the Upper Scollard Formation ranges in elevation from less than 500 to more than 760 metres AMSL and has a thickness of in the order of 120 metres. The non-pumping water level in the Upper Scollard Aquifer is downgradient to the south and downgradient to the north toward the Pembina River (see CD-ROM).

5.3.10.1 Depth to Top

The depth to the top of the Upper Scollard Formation ranges from less than ten metres below ground surface at the eastern extent to more than 900 metres in the western part of the County (page A-45).

5.3.10.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Scollard Aquifer are mainly in the range of 10 to 100 m³/day. There are two dry water test holes that are completed in the Upper Scollard Aquifer.

There are 11 non-exempt groundwater users that have water wells completed through the Upper Scollard Aquifer, for a total authorized groundwater diversion of 229 m³/day.

Of the 229 m³/day, Omer's Resources Ltd. has been licensed to divert 193 m³/day from a water source well in 10-15-052-08 W5M for industrial injection purposes.

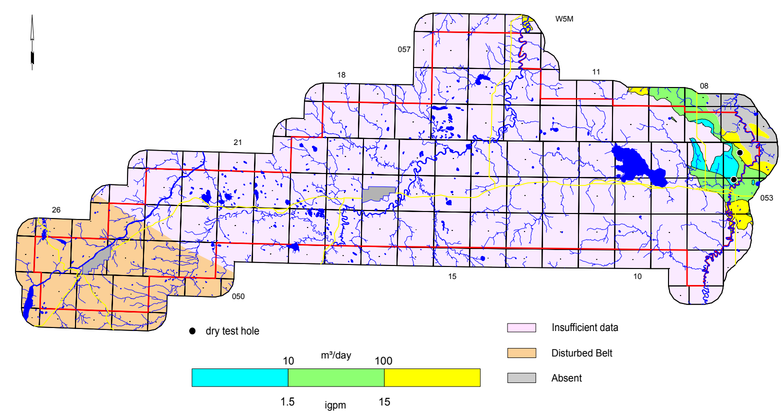

Figure 26. Apparent Yield for Water Wells Completed through Upper Scollard Aquifer

Of the 11 non-exempt authorizations, seven could be linked to water wells in the AENV groundwater database.

5.3.10.3 Quality

The groundwaters from the Upper Scollard Aquifer are a sodium-bicarbonate type with no dominant cation (see Piper diagram on CD-ROM), with groundwater samples having TDS concentrations ranging from greater than 500 to more than 1,000 mg/L (page A-47). The sulfate concentrations are mainly less than 100 mg/L. The chloride concentrations from the water wells completed in the Upper Scollard Aquifer are mainly less than ten mg/L. There is only one analysis where the fluoride concentration exceeds 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	13	601	1,708	950	523	500
Sodium	12	70	600	351	131	200
Sulfate	13	0	630	169	32	500
Chloride	13	0	12	0	2	250
Fluoride	12	0	3	0.7	0.2	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 13. Apparent Concentrations of Constituents in Groundwaters from Upper Scollard 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, sulfate and fluoride from water wells completed in the Upper Scollard Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

5.3.11 Lower Scollard Aquifer

The Lower Scollard Aquifer comprises the porous and permeable parts of the Lower Scollard Formation that underlie the Upper Scollard Formation. Structure contours have been prepared for the top of the Formation. The structure contours show that the Lower Scollard Formation ranges in elevation from less than 400 to more than 750 metres AMSL and has a maximum thickness of 40 metres. The non-pumping water level in the Lower Scollard Aquifer is downgradient to the south toward the Pembina River (see CD-ROM).

5.3.11.1 Depth to Top

The depth to the top of the Lower Scollard Formation ranges from less than ten metres below ground surface at the eastern extent to more than 1,100 metres in the western part of the County (page A-48).

5.3.11.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Scollard Aquifer range mainly from 10 to 100 m³/day. There is one dry water test hole that is completed in the Lower Scollard Aquifer. The areas showing water wells with yields of greater than 100 m³/day are expected mainly in the Buried Onoway Valley.

In the County, there are no non-exempt groundwater users that have water wells that are completed through the Lower Scollard Aquifer.

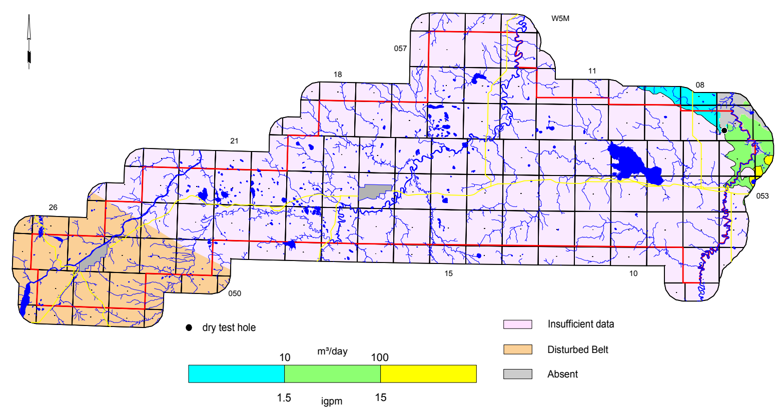

Figure 27. Apparent Yield for Water Wells Completed through Lower Scollard Aquifer

5.3.11.3 Quality

There is sufficient data from one analysis from a water well completed in the Lower Scollard Aquifer that indicates that the groundwater is a sodium-bicarbonate type. There are four water wells in the AENV groundwater database with chemistry data: the TDS concentrations are a maximum of greater than 1,000 mg/L, the sulfate concentrations are mainly greater than 200 mg/L, the chloride concentrations are less than ten mg/L, and the fluoride concentrations are less than 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	4	1044	2,228	1674	523	500
Sodium	3	395	726	444	131	200
Sulfate	4	166	805	464	32	500
Chloride	4	0	7	1	2	250
Fluoride	4	0	1	0.6	0.2	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 Lower Scollard Aquifer

Five constituents from the maximum of four water wells having chemistry data have been compared to the SGCDWQ. Of the five constituents, the median values of TDS and sodium exceed the guidelines. The median concentrations of TDS, sodium, sulfate and fluoride from water wells completed in the Lower Scollard Aquifer are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

5.3.12 Upper Horseshoe Canyon Aquifer

The Upper Horseshoe Canyon Aquifer comprises the permeable parts of the Upper Horseshoe Canyon Formation that underlie the Lower Scollard Formation. The Upper Horseshoe Canyon Formation subcrops under the surficial deposits in the extreme northeastern part 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 300 to more than 700 metres AMSL and has a thickness of up to 250 metres. The non-pumping water level in the Upper Horseshoe Canyon Aquifer is downgradient to the northeast and downgradient to the northwest toward the Pembina River.

5.3.12.1 Depth to Top

The depth to the top of the Upper Horseshoe Canyon Formation is variable, ranging from less than ten metres at the northeastern extent to more than 1,100 metres in the western part of the County (page A-51).

5.3.12.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Horseshoe Canyon Aquifer range mainly from 10 to 100 m³/day. There are four dry water test holes that are completed in the Upper Horseshoe Canyon Aquifer

There are eight non-exempt groundwater users that have water wells completed through the Upper Horseshoe Canyon Aquifer, for a total authorized groundwater diversion of 32.4 m³/day.

Of the eight non-exempt authorizations, five could be linked to water wells in the AENV groundwater database.

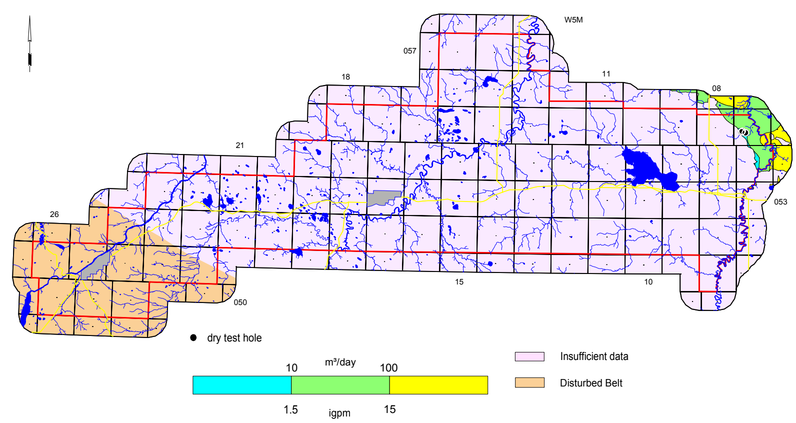

Figure 28. Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer

5.3.12.3 Quality

There is sufficient data from one analysis from a water well completed in the Upper Horseshoe Canyon Aquifer that indicates that the groundwater is a sodium-sulfate-bicarbonate type. Total dissolved solids concentrations range from less than 1,000 to more than 1,500 mg/L (page A-53). In the County, seven out of eight chemical analyses have sulfate concentrations that are less than ten mg/L. The areas showing sulfate concentrations that are greater than 100 mg/L are from water wells located east of the Pembina River in Parkland and Lac St. Anne counties. Chloride concentrations are mainly less than 100 mg/L. Three of seven analyses show fluoride concentrations that exceed 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	8	711	1,672	775	523	500
Sodium	7	295	571	367	131	200
Sulfate	8	0	721	0	32	500
Chloride	8	6	114	47	2	250
Fluoride	7	1	3	1.1	0.2	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 15. 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 TDS, sodium, chloride and fluoride are greater than the median concentrations from water wells completed in all upper bedrock aquifer(s).

6 GROUNDWATER BUDGET

6.1 Hydrographs

In the County, there is one observation water well that is part of the AENV regional groundwater monitoring network where water levels are being measured and recorded as a function of time. The hydrograph for AENV Obs WW: Edson in SE 22-053-17 W5M is shown below on Figure 29, on page A-55 and on the CD-ROM.

AENV Obs WW: Edson, located at the eastern end of the Town of Edson, was drilled in July 1960, and is completed from 36.3 to 37.8 metres below ground surface in the Lower Sand and Gravel Aquifer.

In an area where there are no pronounced seasonal uses of groundwater, the highest water level will usually occur in late spring/early summer and the lowest water level will be in late winter/early spring. In the adjacent figure, it was noted that the highest water levels occur in late winter/early spring and the lowest water levels are mainly during summer. This situation is a result of increased groundwater use by the Town of Edson during the summer months.

There have been five water supply wells completed in the Lower Sand and Gravel Aquifer used to provide water at various times to the Town of Edson since 1961: WSW Nos. 8, 9A, 11, and 12, and the Glenwood WSW. WSW Nos. 8, 9A and 12 are located at the eastern end of Edson and WSW No. 12 and the Glenwood WSW are located in the central and western parts of Edson, respectively. In 1985, WSW No. 12 was deepened and was recompleted in the Dalehurst Aquifer and in 1990 the Glenwood WSW was deepened to be completed in both the Lower Sand and Gravel Aquifer and the Dalehurst Aquifer (Komex International Ltd. 2001).

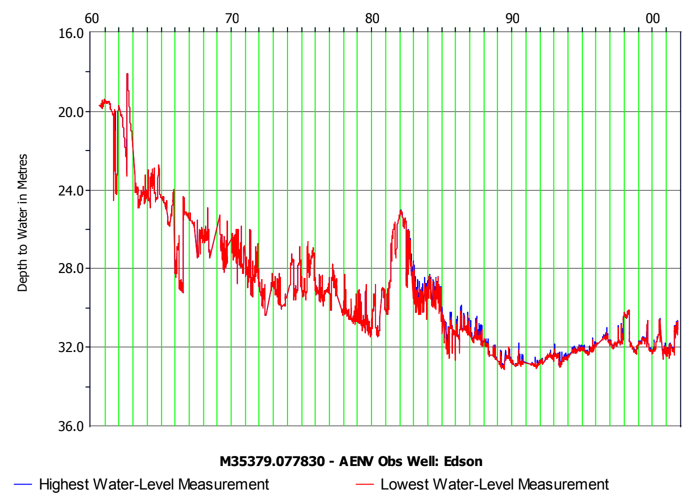

Figure 29. Hydrograph – AENV WW: Edson

From July 1961 to Dec 1979, the water level in AENV Obs WW: Edson declined from 19.68 to 31.44 metres below the reference point, for a total water-level decline of 11.78 metres. During this time interval the water-level decline in AENV Obs WW: Edson is in response to the groundwater diversion from WSW Nos. 8, 9A and 11.

As a result of the abandonment of WSW No. 11 and reduced groundwater diversion of WSW No. 9A in 1981, the water-level rose from a low of 30.33 metres on March 4, 1981 to a high of 25.05 metres below the reference point on January 26, 1982. However, in 1983, the annual groundwater diversion from WSW No. 8 increased in the order of 80,000 m³ from the previous year and in response, the water level declined 5.5 metres in AENV Obs WW: Edson. In 1986, WSW No. 8 was abandoned and the groundwater diversion from WSW No. 9A was increased. From 1989 to 1998, the water level in AENV Obs WW: Edson rose three metres in response to increased groundwater diversion from the Town of Edson bedrock completed water supply wells. Since 1998, there has been no significant change in the water level in AENV Obs WW: Edson

6.2 Estimated Groundwater Use in Yellowhead County

An estimate of the quantity of groundwater removed from each geologic unit in Yellowhead County must include both the authorized non-exempt and the exempt groundwater diversions. As stated previously on page 7 of this report, the daily water requirement for livestock for the County based on the 2001 census is estimated to be 7,962 cubic metres. As of January 2003, AENV has licensed the use of 2,763 m^3/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 5,199 m^3/day of water required for livestock watering is obtained from unauthorized groundwater use.

There are 988 water wells that are used for domestic/stock or stock purposes. There are 469 authorized non-exempt groundwater users for agricultural (stock) and registration (stock) purposes, giving 519 unauthorized non-exempt stock water wells. (Please refer to Table 1 on page 6 for the breakdown of aquifer of the 469 authorized non-exempt stock groundwater users). By dividing the number of unauthorized non-exempt stock and domestic/stock water wells (519) into the quantity required for stock purposes that is not authorized (5,199 m^3/day), the average unauthorized water well diverts 10.0 m^3/day per stock water well.

Groundwater for household use requires a non-exempt authorization if the use is more than 1,250 m^3/year. Under the *Water Act*, a residence is protected for up to 3.4 m^3/day. However, the standard groundwater use for household purposes (a family of four) is 1.1 m^3/day. Since there are 4,014 domestic or domestic/stock water wells in Yellowhead County serving a population of 8,900, the domestic use per water well is 0.55 m^3/day. It is assumed that these 4,014 water wells are active; however many are very old and may no longer be in use or 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	0.55 m^3/day
Stock	10.0 m^3/day
Domestic/stock	10.55 m^3/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, the following table was prepared. Table 16 shows a breakdown of the 4,258 unauthorized and authorized non-exempt water wells used for domestic, stock, or domestic/stock purposes by the geologic unit in which each water well is completed. The final column in the table equals the total amount of unauthorized groundwater that is being used for both domestic and stock purposes. The data provided in Table 16 indicate that most of the 9,844 m^3/day, estimated to be diverted from unauthorized domestic, domestic/stock or stock water wells is from the Dalehurst Aquifer.

Aquifer Designation	Unauthorized and Authorized Non-Exempt Groundwater Diversions: Number of Domestic	Daily Use (0.55 m³/day)	Number of Stock	Daily Use (18.7 m³/day)	Number of Domestic and Stock	Daily Use (19.2 m³/day)	Totals m³/day	Authorized Non-Exempt Groundwater Diversions: Totals (m³/day)	Unauthorized Groundwater Diversions: Totals m³/day
Multiple Surficial Completions	4	2	0	0	0	0	2	0	2
Upper Sand/Gravel	136	75	8	80	15	159	314	88	226
Lower Sand/Gravel	238	132	11	110	23	243	485	183	302
Multiple Bedrock Completions	319	177	97	972	105	1,110	2,259	282	1977
Disturbed	302	167	2	20	3	32	219	0	219
Dalehurst	1,868	1,035	236	2,364	235	2,484	5,884	1122	4762
Upper Lacombe	237	131	71	711	75	793	1,635	218	1417
Lower Lacombe	107	59	31	311	29	307	676	126	550
Haynes	33	18	9	90	10	106	214	69	145
Upper Scollard	11	6	4	40	12	127	173	36	137
Lower Scollard	6	3	2	20	0	0	23	0	23
Upper Horseshoe Canyon	7	4	8	80	3	32	116	32	84
Unknown	1	1	0	0	0	0	1	41	0
Totals [(1)]	3,269	1,812	479	4,798	510	5,392	12,002	2,197	9,844

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

Table 16. Total Groundwater Diversions by Aquifer

By assigning 0.55 m³/day for domestic use, 10.0 m³/day for stock use and 10.55 m³/day for domestic/stock use, and using the total maximum authorized diversion associated with any non-exempt 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).

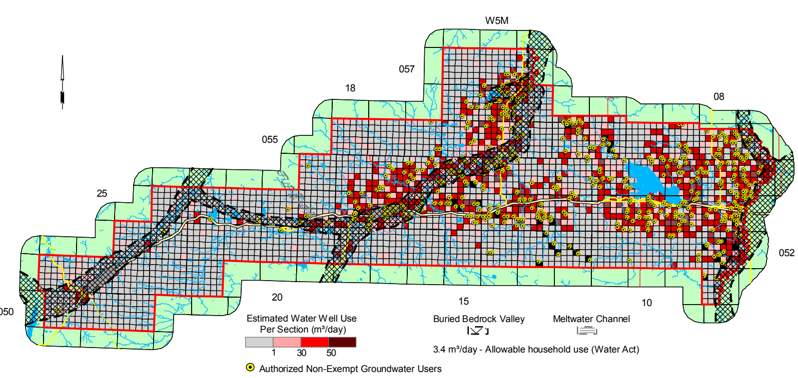

Figure 30. Estimated Water Well Use Per Section
(for larger version, see page A-54)

There are 2,798 sections in the County. In 62% (1,730) of the sections in the County, there is no domestic, stock or authorized non-exempt groundwater user. The range in groundwater use for the remaining 1,068 sections is from 0.2 m³/day to 2,940 m³/day (dewatering), with an average use per section of 20 m³/day (3.0 igpm). The estimated water well use per section can be more than 30 m³/day in 112 of the 1,068 sections. There are 159 of the total 559 authorized non-exempt groundwater users in areas of greater than 30 m³/day.

Groundwater Use within Yellowhead County (m³/day)		%
Domestic/Stock (including agriculture and registrations)	12,002	43
Municipal (licensed)	6,928	25
Commercial/Industrial/Dewatering et al (licensed)	8,781	32
Total	27,711	100

Table 17. Total Groundwater Diversions

In summary, the estimated total groundwater use within Yellowhead County is 27,711 m³/day, with the breakdown as shown in the adjacent table. An estimated 27,669 m³/day is being withdrawn from a specific aquifer. The remaining 42 m³/day (0.2%) is being withdrawn from unknown aquifer units. Of the 27,711 m³/day, 88% is being diverted from bedrock aquifers and 12% from surficial aquifers. Approximately 65% of the total estimated groundwater use is from authorized non-exempt 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 takes into consideration hydrogeological conditions outside the County border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 18.

Table 18 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Lower Sand and Gravel Aquifer. 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 18 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 (m)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Authorized Non-Exempt Diversion (m^3/day)	Exempted Diversion (m^3/day)	Total (m^3/day)
Lower Surficial					480	1,922	302	2,224
Edson Valley								
	75	0.001	8	480				
Disturbed Belt					5,300	4	219	223
Athabasca River Basin sub-basin								
Northwest	2	0.033	30	2,000				
Southeast	2	0.055	30	3,300				
Dalehurst					130,977	10,647	4,762	15,409
Athabasca River Basin sub-basin								
Athabasca River					30,507			
East	22	0.031	16	11,000				
West	22	0.067	10	14,667				
Northeast	22	0.013	8	2,200				
Southwest	22	0.015	8	2,640				
McLeod River					50,352			
Shining Bank Lake								
Southwest	22	0.020	16	7,200				
Northeast	22	0.013	16	4,400				
Pioneer					10,193			
Southwest	22	0.008	16	2,933				
Southeast	22	0.010	13	2,860				
Northeast	22	0.013	16	4,400				
Edson					14,025			
Southwest	22	0.013	16	4,400				
Southeast	22	0.013	15	4,125				
Northeast	22	0.010	25	5,500				
Bickerdike					7,933			
Southwest	22	0.008	15	2,750				
Southeast	22	0.008	16	2,933				
Northeast	22	0.007	15	2,250				
McLeod River South					6,600			
South	22	0.005	60	6,600				
Pembina River					11,367			
Northeast	22	0.008	30	5,500				
Southwest	22	0.017	16	5,867				
Upper Lacombe					33,199	1,448	1,417	2,865
Athabasca River sub-basin								
McLead River								
Northwest side of river					9,268			
North	0.25	0.004	70	70				
South	0.25	0.002	35	18				
East	27	0.007	15	2700				
West	27	0.008	30	6480				
Chip Lake basin					9,315			
Northeast	27	0.005	25	3375				
Southwest	27	0.010	22	5940				
North of Chip Lake Basin					8,316			
Northeast	27	0.010	22	5940				
Southwest	27	0.004	22	2376				
Pembina River					6,300			
East	27	0.007	35	6300				
Lower Lacombe					1,800	126	550	676
Regional Flow								
Southwest to northeast	12	0.002	75	1800				
Haynes					5,220	69	145	214
Regional Flow								
North to south	11.6	0.003	135	5220				
Upper Scollard					1,389	229	137	366
Regional Flow								
West to east	2	0.001	60	120				
Active Local Flow								

Table 18. Groundwater Budget

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers is 0.3 to 1.7 cubic kilometres. This volume is based on an areal extent of 2,800 square kilometres and a saturated thickness of two 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 a flow direction toward the Athabasca River, the McLeod River and the Pembina River.

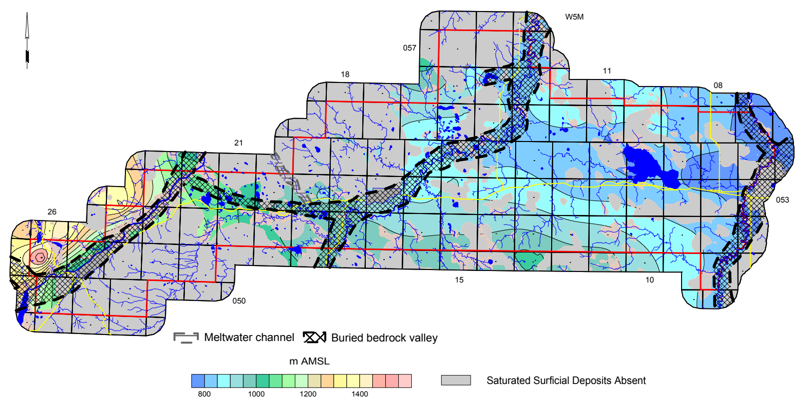

Figure 31. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

6.3.2 Recharge/Discharge

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

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

6.3.2.1 Bedrock Aquifers

Recharge to the bedrock aquifers within the County takes place from the overlying surficial deposits and from flow in the aquifer from outside the County. On a regional basis, calculating the quantity of water involved is not possible because of the complexity of the geological setting and the limited amount of data.

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

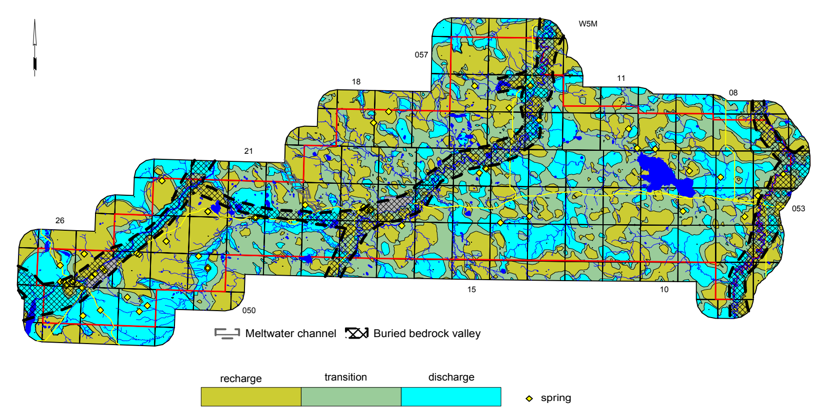

Figure 32. Bedrock Recharge/Discharge Areas

Figure 32 shows that, in more than 40% of the County, there is a downward hydraulic gradient from the bedrock surface toward the upper bedrock aquifer(s) (i. e. recharge). Areas where there is an upward hydraulic gradient from the bedrock to the bedrock surface (i. e. discharge) are mainly in the vicinity of river valleys and linear bedrock lows. 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 40% of the County land area being one of recharge to the bedrock, and the average precipitation being 533 mm per year, three percent 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 were required to differ by at least 365 days. 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.

With the absence of sufficient non-pumping water-level data at a given location for water wells completed in the surficial deposits, the areas of groundwater decline in the sand and gravel aquifer(s) have been calculated by determining the frequency of non-pumping water level control points per five-year period. Of the 367 surficial water wells with a non-pumping water level and date in the County and buffer area, 188 are from water wells completed before 1980 and 179 are from water wells completed after 1980.

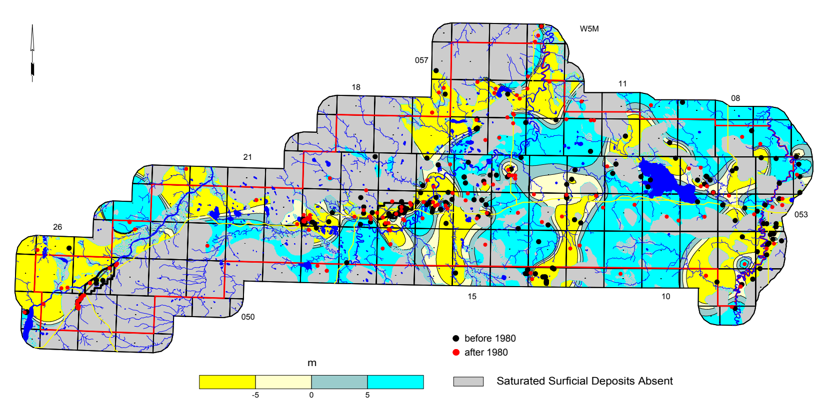

Figure 33. Changes in Water Levels in Surficial Deposits

Where the earliest water level (before 1980) is at a higher elevation than the latest water level (after 1980), there is the possibility that some groundwater decline has occurred. The interpretation of the adjacent map should be limited to areas where both earliest and latest water-level control points are present. Most of the areas in which the map suggests that there has been a decline in NPWL may reflect the nature of gridding a limited number of control points. Most of the areas where the map suggests that there has been a decline in NPWL may be a result of gridding a limited number of control points. The adjacent map, where sufficient control exists, indicates that there may have been a decline in the NPWL in parts of linear bedrock lows.

Where the earliest water level is at a lower elevation than the latest water level, there is the possibility that the groundwater has risen at that location. The water level may have risen as a result of recharge in wetter years or may be a result of the water well being completed in a different surficial aquifer. Of the 46 authorized non-exempt groundwater users completed in surficial aquifers that are authorized to divert groundwater, many occur in areas where insufficient control exists.

Estimated Water Well Use Per Section (m³/day)	*% of Area with More than a 5-Metre Projected Decline*
<10	*21*
10 to 30	*17*
30 to 50	*2*
>50	*4*
no use	*56*

Table 19. Water-Level Decline in Sand and Gravel Aquifer(s)

Figure 33 indicates that in 45% of the County where surficial deposits are present, it is possible that the non-pumping water level has declined. 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 or because the water wells are not on file with Alberta Environment.

In areas where a water-level decline exists, 56% of the areas has no estimated water well use; 21% is less than 10 m³/day, 17% of the use is between 10 and 30 m³/day, 2% of the use is between 30 and 50 m³/day per section;

and the remaining 4% of the declines occurred where the estimated groundwater use per section is greater than 50 m³/day, as shown in Table 19.

Of the 6,232 bedrock water wells with a non-pumping water level and date in the County and buffer area, there are 1,320 water wells with sufficient control to prepare the adjacent map. The adjacent map indicates that in 51% of the County it is possible that the non-pumping water level has declined. Of the authorized non-exempt groundwater users completed in upper bedrock aquifer(s) that are authorized to divert groundwater, most occur in areas where a water-level decline may have occurred.

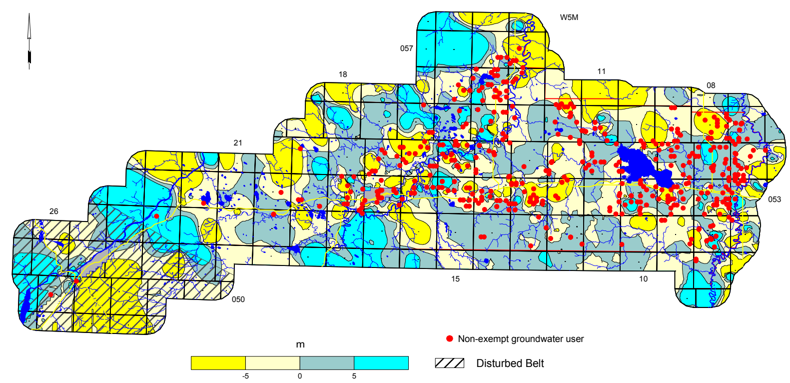

Figure 34. Areas of Potential Groundwater Depletion - Upper Bedrock Aquifer(s)

In areas where a water-level decline exists, 57% of the areas has no estimated water well use; 17% is less than 10 m³/day, 21% of the use is between 10 and 30 m³/day, 3% of the use is between 30 and 50 m³/day per section; and the remaining 2% of the declines occurred where the estimated groundwater use per section is greater than 50 m³/day, as shown below in Table 20. In the County where a water-level decline is indicated, most of the areas are where there is a non-exempt groundwater user.

Estimated Water Well Use Per Section (m³/day)	*% of Area with More than a 5-Metre Projected Decline*
<10	*17*
10 to 30	*21*
30 to 50	*3*
>50	*2*
no use	*57*

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

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

7 POTENTIAL FOR GROUNDWATER CONTAMINATION

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

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

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

To determine the nature of the materials on the land surface, the Agricultural Region of Alberta Soil Inventory Database (AGRASID) (CAESA, 1998), (Alberta Geological Survey, 1970) have been reclassified based on the relative permeability. The classification of materials is as follows:

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

To identify the areas where sand and gravel can be expected within one metre of the ground surface, all groundwater database records with lithologies were reviewed. From a total of 5,400 records with lithological descriptions in the area of the County, 832 have the top of a sand and gravel deposit present within one metre of ground level. In the remaining 4,568 records, the first sand and gravel deposit is deeper than one metre or not present. This information was gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.

7.1.1 Risk of Groundwater Contamination Map

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

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

Table 21. Risk of Groundwater Contamination Criteria

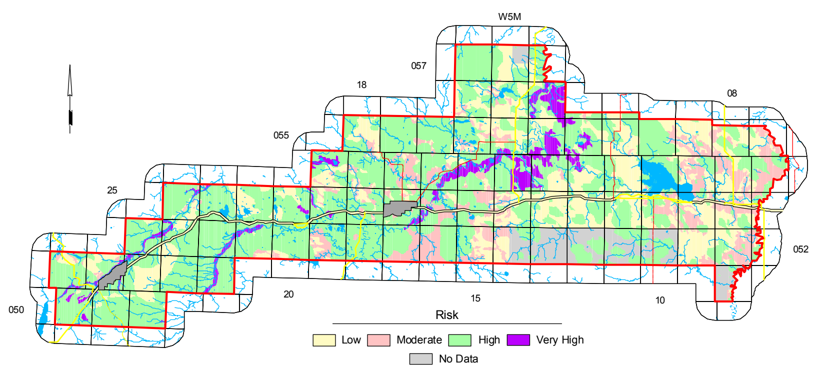

Figure 35. Risk of Groundwater Contamination

The Risk of Groundwater Contamination map shows that, in 60% of the County, there is a high or very high risk for the groundwater to be contaminated. These areas would be considered the least desirable ones for a development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only. Detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that contaminants will not affect groundwater quality.

8 RECOMMENDATIONS

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

1) the quality of the data
2) the coordinate system used for the horizontal control
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 220 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 well plus the 220 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.

The most notable areas where surficial water wells are completed in the Sand and Gravel Aquifer(s) are where the thickness of the Sand and Gravel Aquifer(s) is greater than five metres, particularly in the Buried Edson Valley. The median apparent yield value from surficial water wells in these areas is greater than 100 m^3/day (15 igpm).

The results of the present study indicate that the main source of groundwater in the County is aquifers in the upper bedrock aquifer(s). The median apparent yield value from all water wells completed in the upper bedrock aquifer(s) is in the order of 70 m^3/day (10.5 igpm). More than 30% of the water wells completed in the upper bedrock aquifer(s) have an apparent yield of greater than 100 m^3/day.

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 220 water wells listed in Appendix E for which water well drilling reports are available, plus the one 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 221 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 43% successful in this study (see CD-ROM); sixty-five percent of the 559 authorized non-exempt 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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161) Mow-Tech Ltd. Feb-1999e. Poco Petroleums Ltd. Poco Niton 15-21-055-12 W5M: Melvin Wagner Domestic Water Well Testing. Niton Junction Area. 15-21-055-12 W5M. [83G13 .N578J8 1999/02d]

162) Mow-Tech Ltd. Feb-1999f. Poco Petroleums Ltd. Poco Niton 15-21-055-12 W5M: Rose Marie Hughes Domestic Water Well Testing. Niton Junction Area. 15-21-055-12 W5M. [83G13 .N578J8 1999/02e]

163) Mow-Tech Ltd. Feb-1999g. Poco Petroleums Ltd. Poco Niton 15-21-055-12 W5M: Tom Bauman Domestic Water Well Testing. Niton Junction Area. 15-21-055-12 W5M. [83G13 .N578J8 1999/02a]

164) Mow-Tech Ltd. Feb-1999h. Poco Petroleums Ltd. Poco Niton 15-21-055-12 W5M: Walter Shukaliak Domestic Water Well Testing. Niton Junction Area. 15-21-055-12 W5M. [83G13 .N578J8 1999/02g]

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167) Mow-Tech Ltd. Mar-2000a. Burlington Resources Canada Energy Ltd. Burlington Rosevear: Glenda Rivard Domestic Water Well Testing. Pinedale Area. NW 05-054-14 W5M. [83F09 .P56 2000/03-002]

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169) Mow-Tech Ltd. Mar-2000c. Burlington Resources Canada Energy Ltd. Burlington Rosevear: Shayne Wolfe Domestic Water Well Testing. Pinedale Area. SE 07-054-14 W5M. [83F09 .P56 2000/03-001]

170) Mow-Tech Ltd. Sep-2000a. Burlington Resources Canada Energy Ltd. Burlington Rosevear 08-34-053-15 W5M: Myles Schnee Domestic Water Well Testing. Wolf Creek Area. SE 34-053-15 W5M. [83F09 .W6C7 2000/09-001]

171) Mow-Tech Ltd. Sep-2000b. Burlington Resources Canada Energy Ltd. Burlington Rosevear 16-27-053-15 W5M: Myles Schnee Domestic Water Well Testing. Wolf Creek Area. SE 34-053-15 W5M. [83F09 .W6C7 2000/09]

172) Mow-Tech Ltd. Oct-2000a. Burlington Resources Canada Energy Ltd. Burlingto Rosevear 04-29-053-15 W5M; Domestic Water Well Testing; Volume II. Pinedale Estates and Area. 04-29-053-15 W5M. [83F09 .P56 2000/10-001]

173) Mow-Tech Ltd. Oct-2000b. Burlington Resources Canada Energy Ltd. Burlington Rosevear 04-29-053-15 W5M; Domestic Water Well Testing; Volume I. Pinedale Estates & Area. 04-29-053-15 W5M. [83F09 .P56 2000/10]

174) Mow-Tech Ltd. May-2001a. Burlington Resources Canada Energy Ltd. Burlington Rosevear: Carl Tews Domestic Water Well Testing. Edson Area. SE 30-053-15 W5M. [83F09 .E375 2001/05]

175) Mow-Tech Ltd. May-2001b. Burlington Resources Canada Energy Ltd. Burlington Rosevear: Walter Tews Domestic Water Well Testing. Edson Area. SW 30-053-15 W5M. [83F09 .E375 2001/05-001]

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177) Mow-Tech Ltd. Oct-2001b. Burlington Resources Canada Energy Ltd. Burlington Rosevear: Collier Domestic Water Well Testing. Wolf Creek Area. NW 18-054-14 W5M. [83F09 .W6C7 2001/10-003]

178) Mow-Tech Ltd. Oct-2001c. Burlington Resources Canada Energy Ltd. Burlington Rosevear: Elzinga Water Well Testing. Wolf Creek Area. SE 24-054-15 W5M. [83F09 .W6C7 2001/10-004]

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183) Mow-Tech Ltd. Nov-2001b. Burlington Resources Canada Energy Ltd. Burlington McLeod: Jody Muldoon Domestic Water Well Testing. Peers Area. SW 30-054-14 W5M. [83G12 .P44 2001/11-003]

184) Mow-Tech Ltd. Nov-2001c. Burlington Resources Canada Energy Ltd. Burlington McLeod: Patricia Bodner Domestic Water Well Testing. Peers Area. SW 30-054-14 W5M. [83G12 .P44 2001/11-002]

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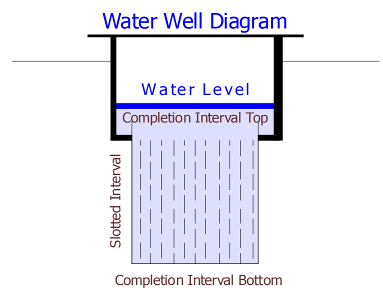
10 GLOSSARY

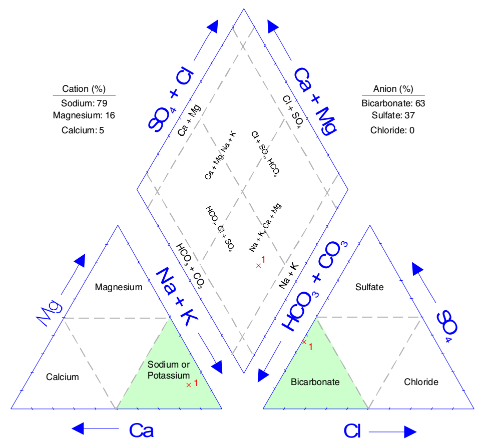
Anion	negatively charged ion
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities
Aquitard	a confining bed that retards but does not prevent the flow of water to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



Completion Interval

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

mm	millimetres
m²/day	metres squared per day
m³	cubic metres
m³/day	cubic metres per day
mg/L	milligrams per litre
Median	the value at the centre of an ordered range of numbers
Obs WW	Observation Water Well
Piper tri-linear diagram	a method that permits the major cation and anion compositions of single or multiple samples to be represented on a single graph. This presentation allows groupings or trends in the data to be identified. From the Piper tri-linear diagram, it can be seen that the groundwater from this sample water well is a sodium-bicarbonate-type. The chemical type has been determined by graphically calculating the dominant cation and anion. For a more detailed explanation, please refer to Freeze and Cherry, 1979



Piper Tri-Linear Diagram

Rock	earth material below the root zone
Surficial Deposits	includes all sediments above the bedrock
Thalweg	the line connecting the lowest points along a stream bed or valley; *longitudinal profile*
Till	a sediment deposited directly by a glacier that is unsorted and consisting of any grain size ranging from clay to boulders
Transmissivity	the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient: a measure of the ease with which groundwater can move through the aquifer
	Apparent Transmissivity: the value determined from a summary of aquifer test data, usually involving only two water-level readings
	Effective Transmissivity: the value determined from late pumping and/or late recovery water-level data from an aquifer test
	Aquifer Transmissivity: the value determined by multiplying the hydraulic conductivity of an aquifer by the thickness of the aquifer

Water Well	a hole in the ground for the purpose of obtaining groundwater; "work type" as defined by AENV includes test hole, chemistry, deepened, well inventory, federal well survey, reconditioned, reconstructed, new, old well-test
Yield	a regional analysis term referring to the rate a properly completed water well could be pumped, if fully penetrating the aquifer
	Apparent Yield: based mainly on apparent transmissivity
	Long-Term Yield: based on effective transmissivity
AAFC-PFRA	Prairie Farm Rehabilitation Administration Branch of Agriculture and Agri-Food Canada
AENV	Alberta Environment
AMSL	above mean sea level
BGP	Base of Groundwater Protection
DEM	Digital Elevation Model
DST	drill stem test
EUB	Alberta Energy and Utilities Board
GCDWQ	Guidelines for Canadian Drinking Water Quality
IAAM	*Infinite Aquifer Artesian Model.* The mathematical model is used to calculate water levels at a given location. The model has been used for more than 17 years by HCL for several hundred groundwater monitoring projects. The model aquifer is based on a solution of the well function equation. The simulation calculates drawdown by solving the well function equation using standard approximation methods. The drawdown at any given point at any given time uses the method of superposition.
NPWL	non-pumping water level
TDS	Total Dissolved Solids
WSW	Water Source Well or Water Supply Well

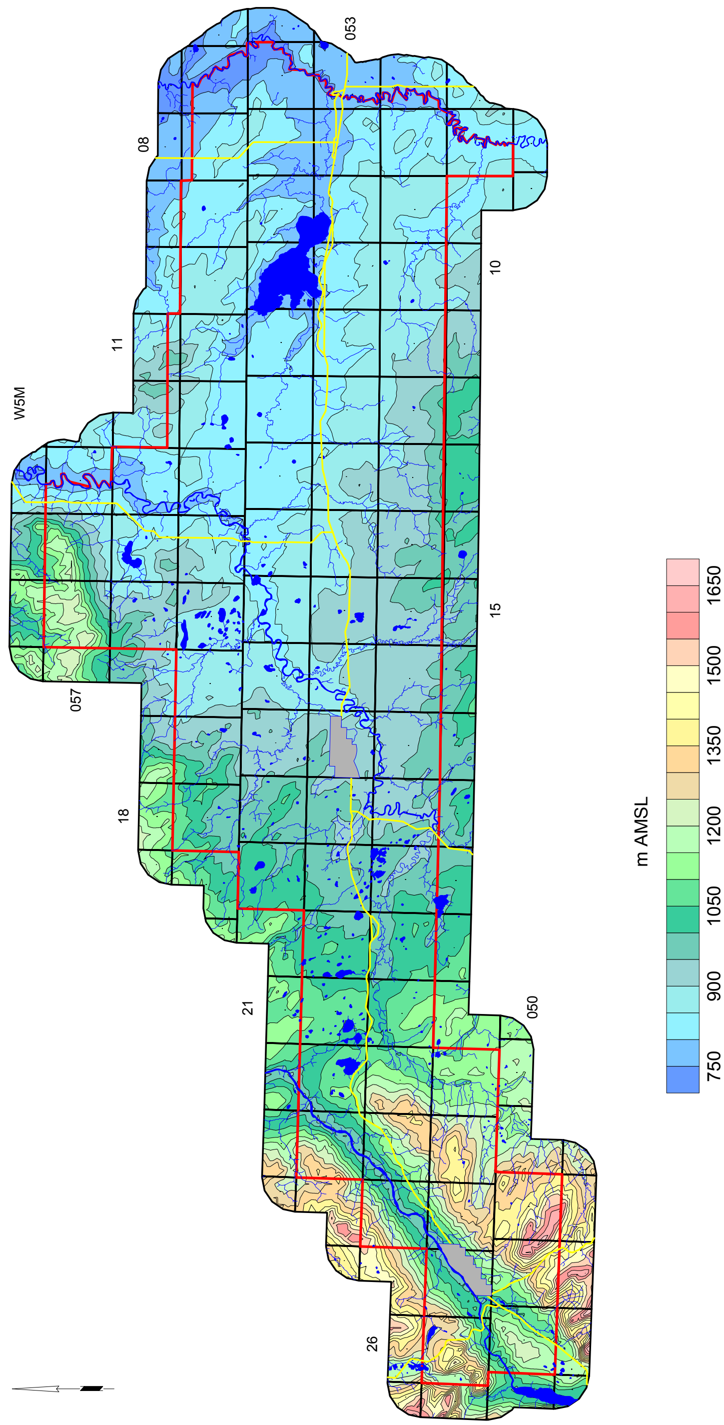
11 CONVERSIONS

Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	metres (m^2)
metres (m^2)	10.763 910	square feet (ft^2)
metres (m^2)	0.000 001	kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	ppm
ppm	0.998 859	mg/L
mg/L	1.001 142	ppm
Volume (capacity)		
acre feet	1233.481 838	cubic metres
cubic feet	0.028 317	cubic metres
cubic metres	35.314 667	cubic feet
cubic metres	219.969 248	gallons (UK)
cubic metres	264.172 050	gallons (US liquid)
cubic metres	1000.000 000	litres
gallons (UK)	0.004 546	cubic metres
imperial gallons	4.546 000	litres
Rate		
litres per minute	0.219 974	ipgm
litres per minute	1.440 000	cubic metres/day (m^3/day)
igpm	6.546 300	cubic metres/day (m^3/day)
cubic metres/day (m	0.152 759	igpm
Pressure		
psi	6.894 757	kpa
kpa	0.145 038	psi
Miscellaneous		
Celsius	F° = 9/5 (C° + 32)	Fahrenheit
Fahrenheit	C° = (F°- 32) * 5/9	Celsius
degrees	0.017 453	radians

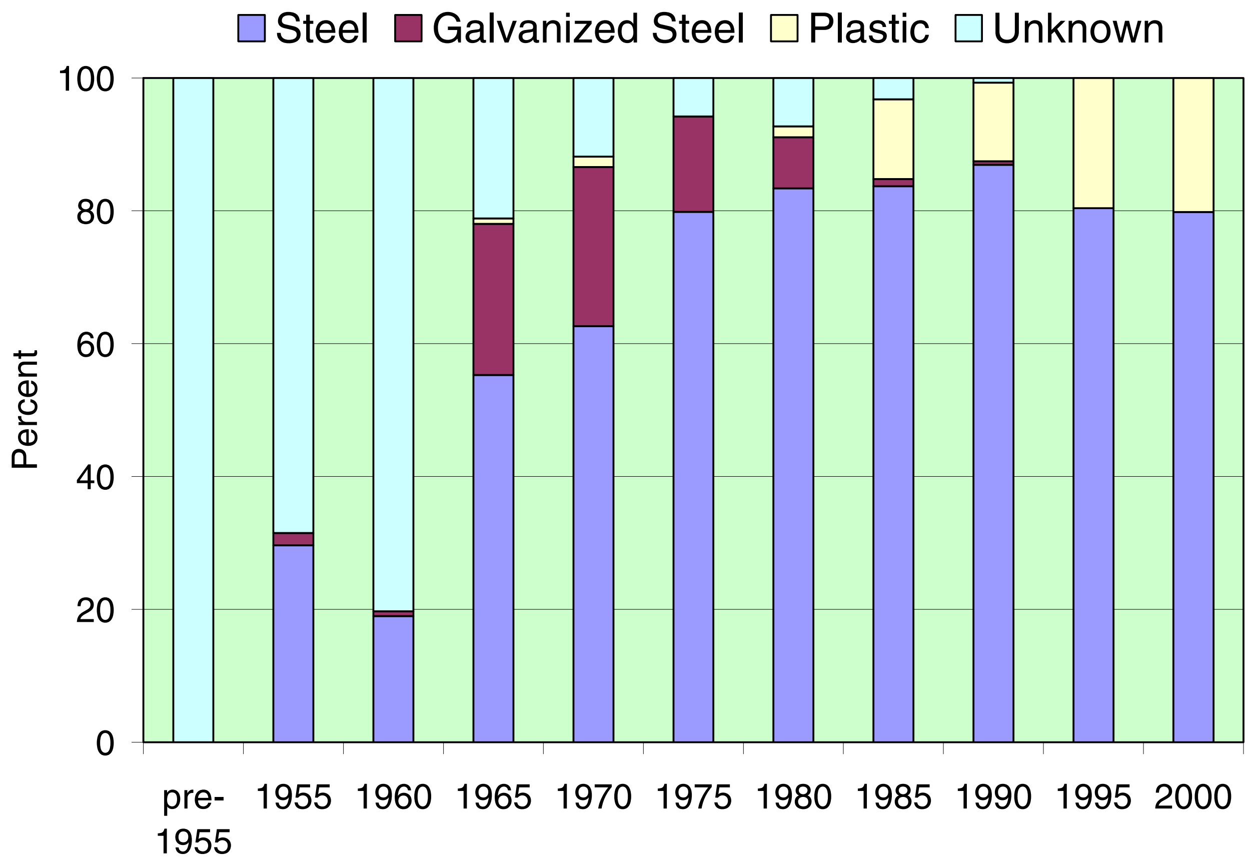
YELLOWHEAD COUNTY
Appendix A

Hydrogeological Maps and Figures

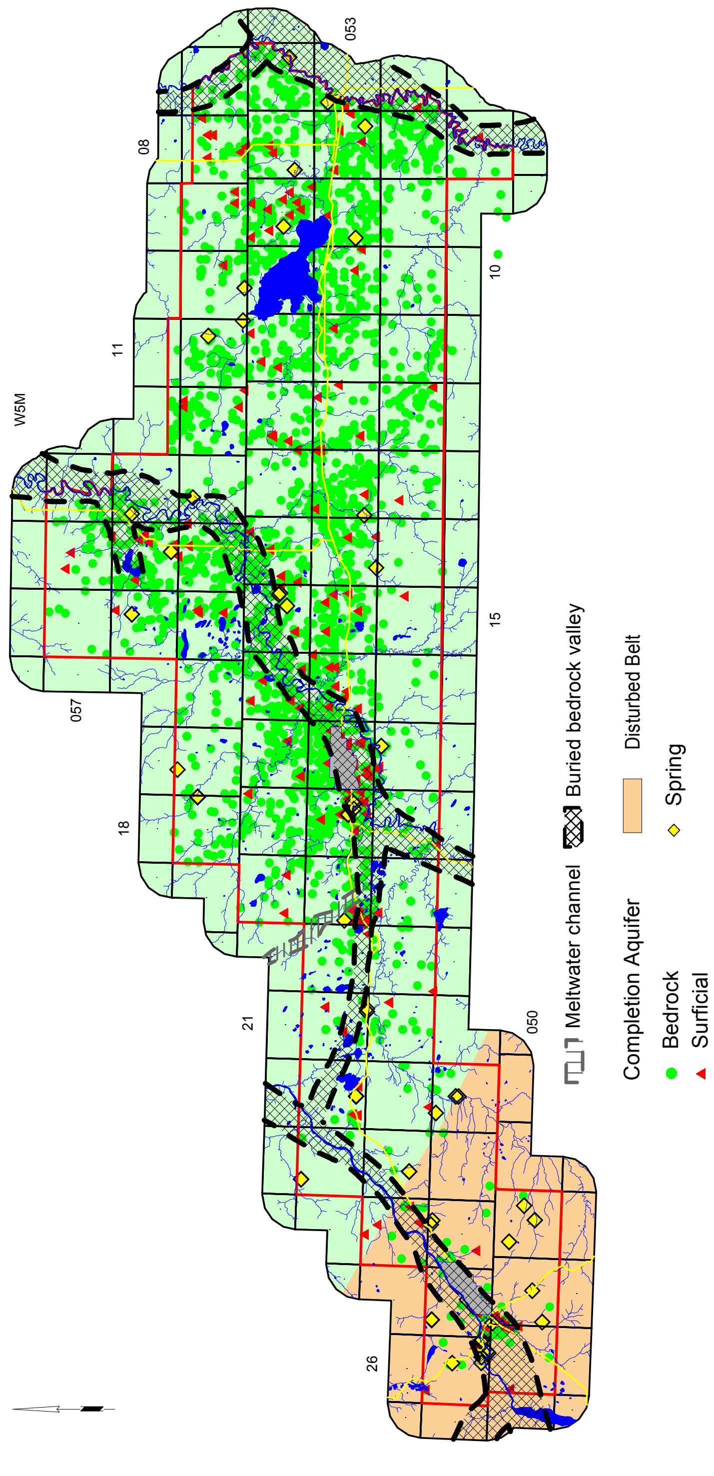
Surface Topography



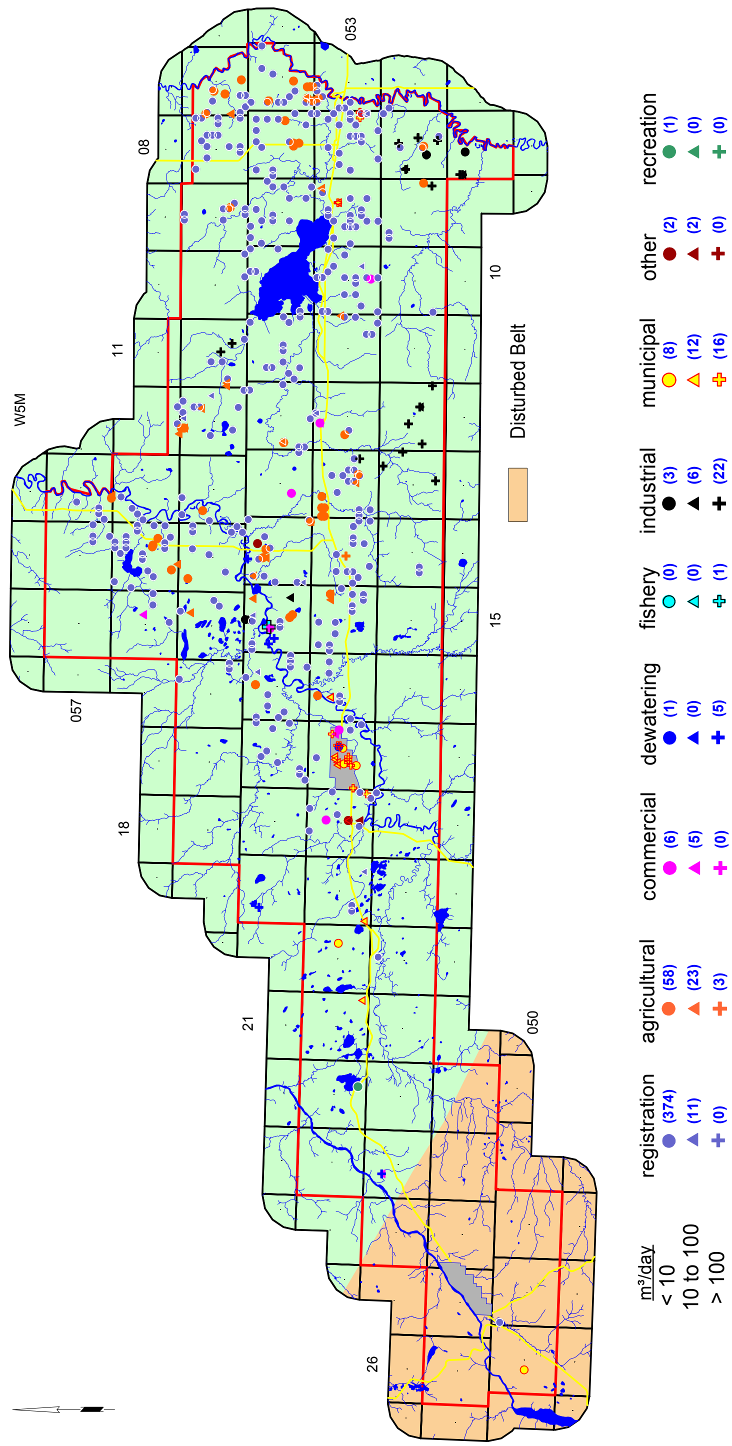
Surface Casing Types used in Drilled Water Wells



Location of Water Wells and Springs

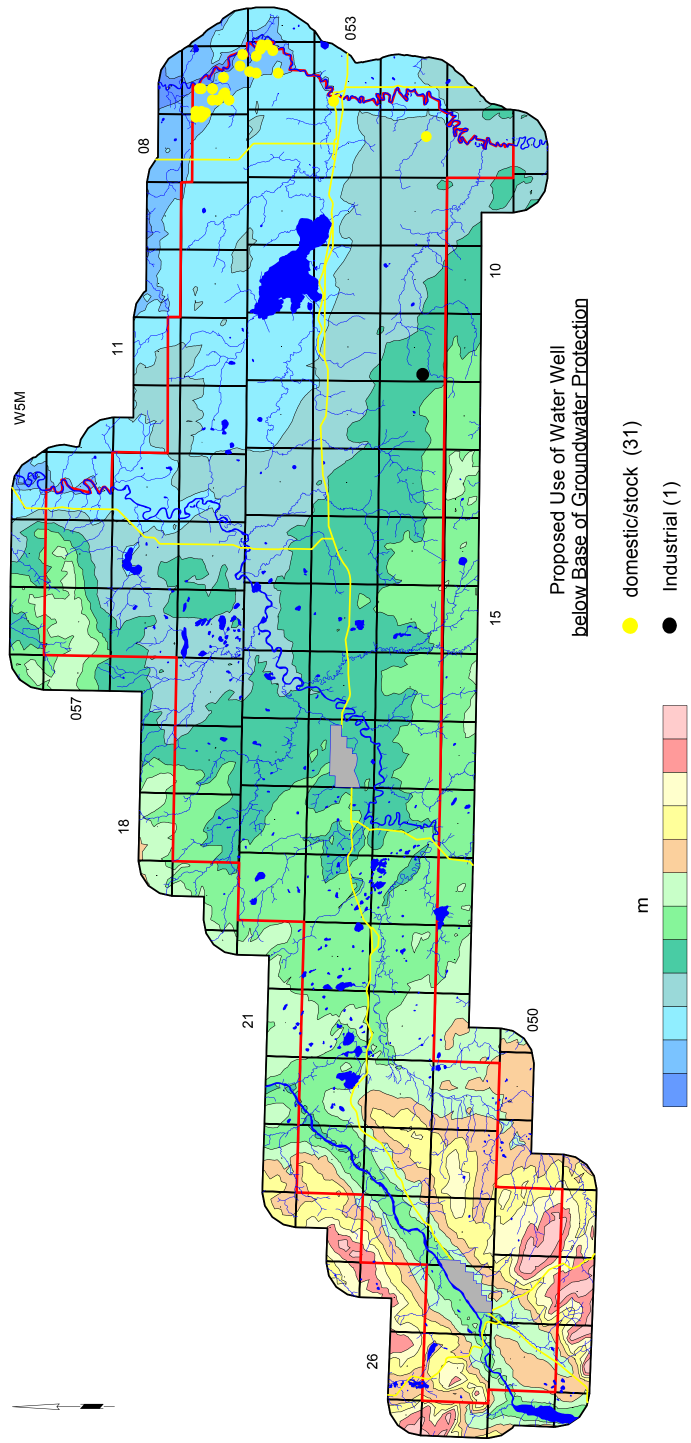


Authorized Non-Exempt Groundwater Water Wells

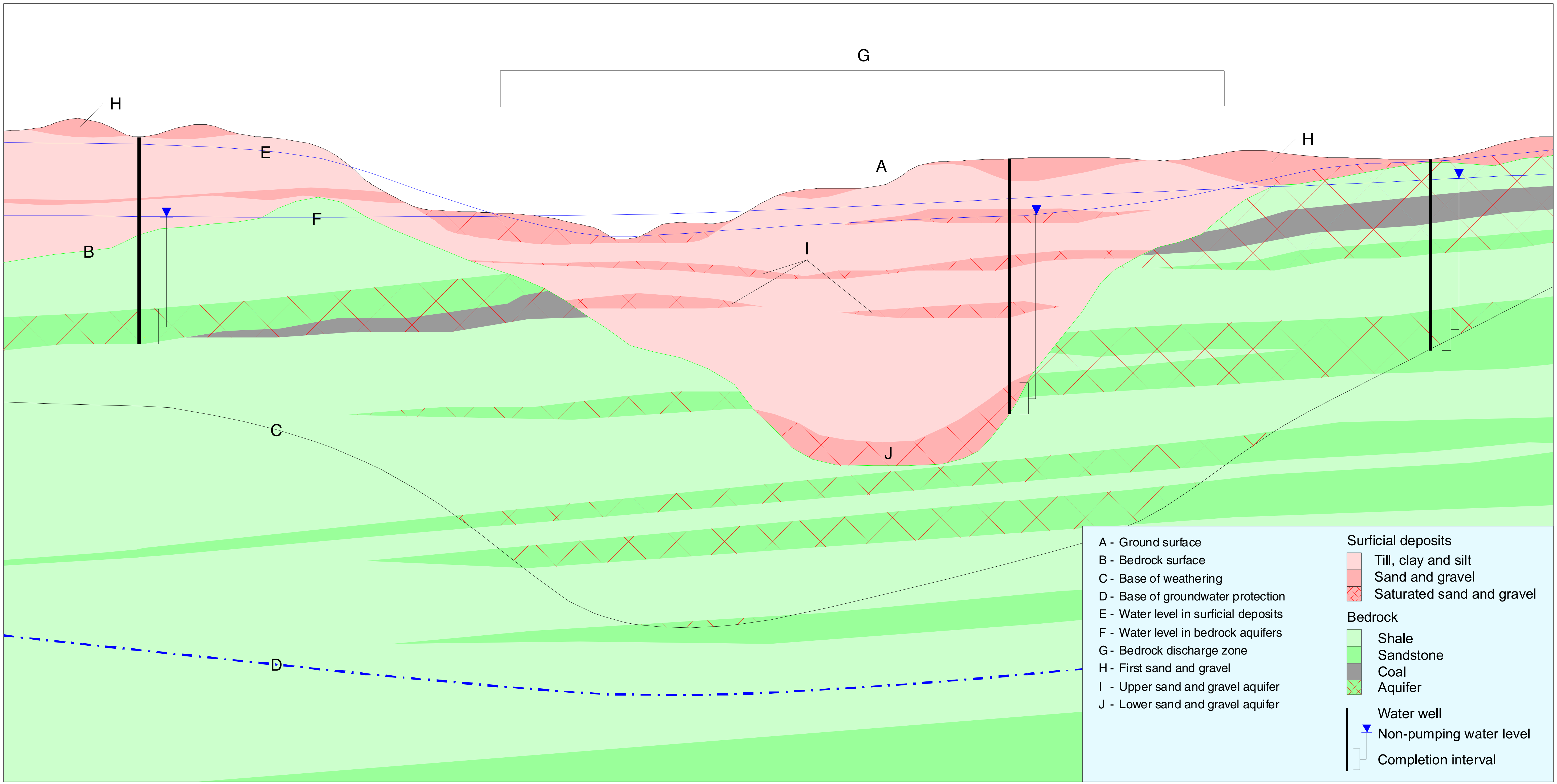


Depth to Base of Groundwater Protection

(modified after EUB, 1995)



Generalized Cross-Section
(for terminology only)

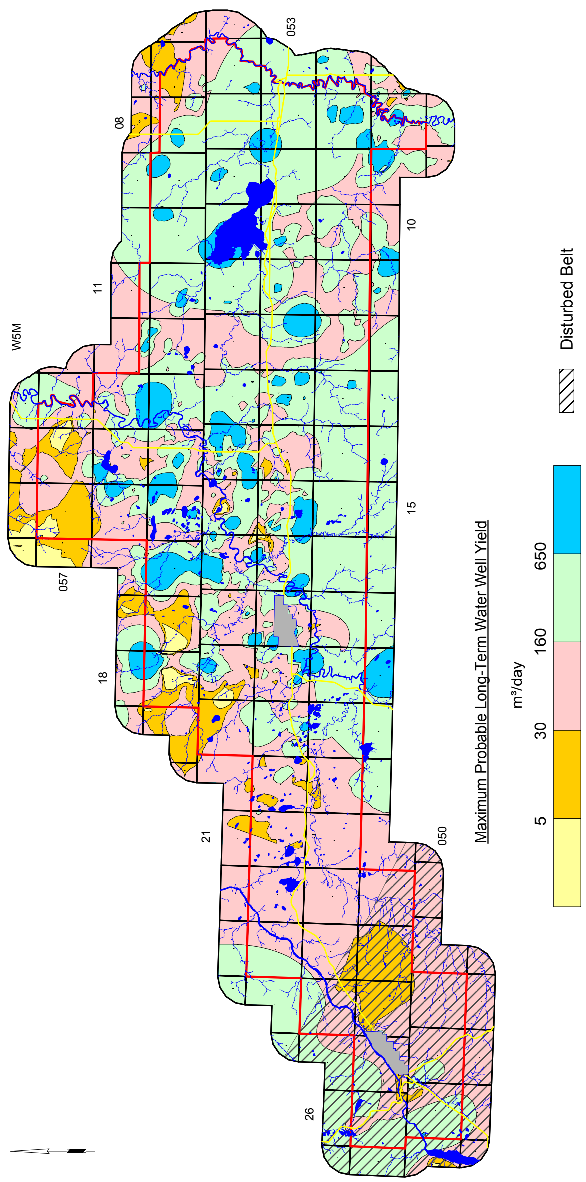


Geologic Column

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

Depth (m): 0, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000

Hydrogeological Maps



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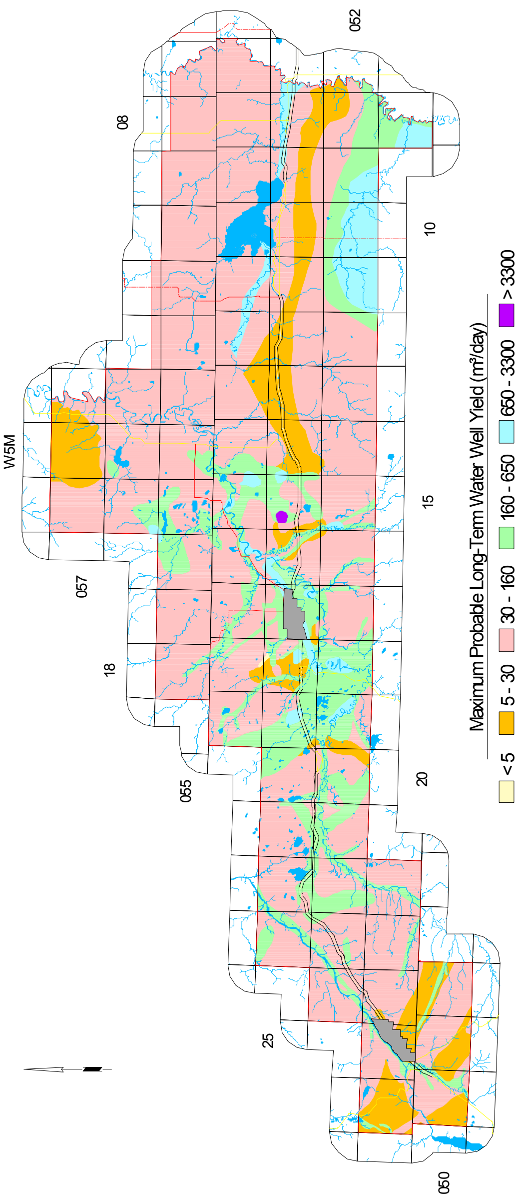

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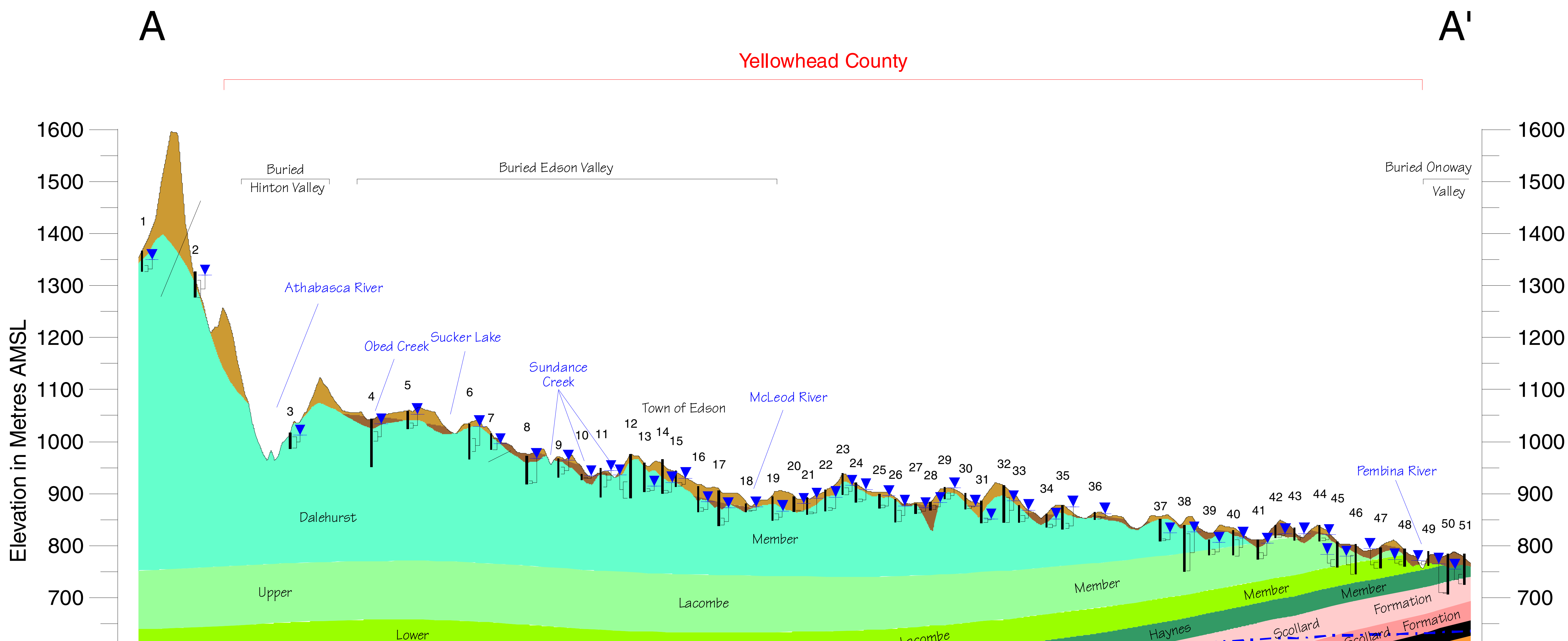
Cross-Section A - A'



Well No.	UID	Legal	Well No.	UID	Legal
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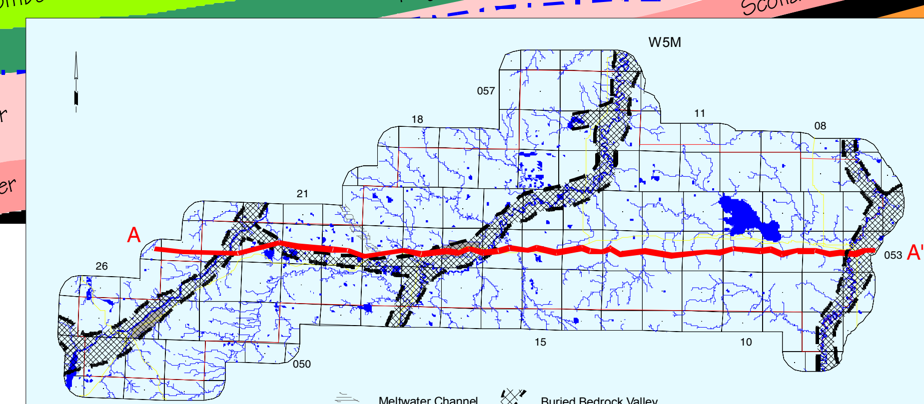
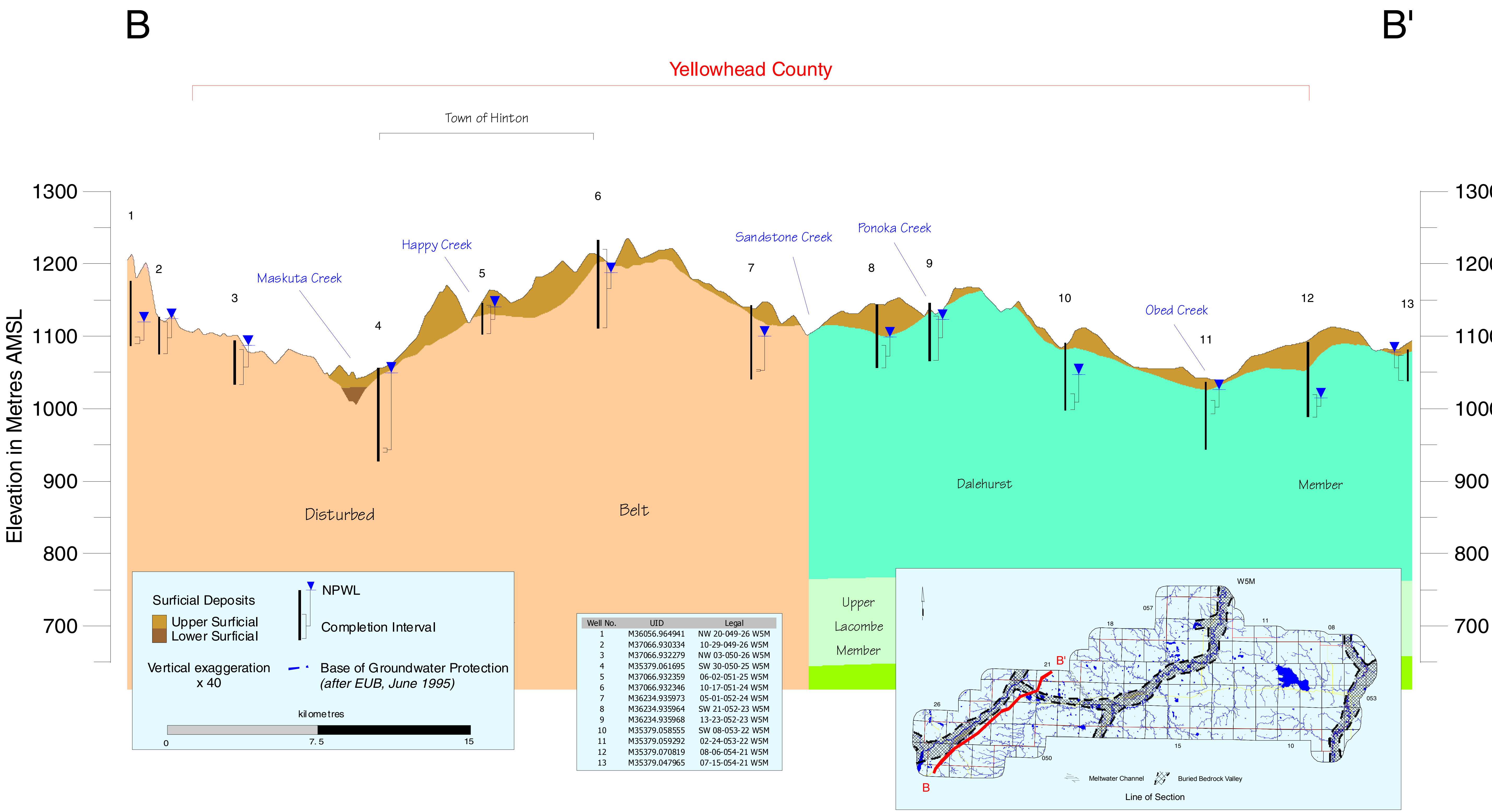
2	M36234.934001	SW 10-053-24 W5M	28	M37066.932980	04-22-053-14 W5M
3	M36234.933987	SW 12-053-23 W5M	29	M36727.992719	NW 14-053-14 W5M
4	M35379.059292	02-24-053-22 W5M	30	M36234.925793	NE 13-053-14 W5M
5	M36056.964794	03-16-053-21 W5M	31	M36234.926752	SW 20-053-13 W5M
6	M36727.992645	07-17-053-20 W5M	32	M36234.926732	08-16-053-13 W5M
7	M35379.073049	08-15-053-20 W5M	33	M36234.926720	NW 14-053-13 W5M
8	M36727.989902	NW 07-053-19 W5M	34	M36234.925697	14-18-053-12 W5M
9	M37490.033363	01-16-053-19 W5M	35	M35379.052114	NE 17-053-12 W5M
10	M36234.933667	SE 14-053-19 W5M	36	M36234.925674	06-14-053-12 W5M
11	M36234.933499	NW 18-053-18 W5M	37	M36234.925492	NE 15-053-11 W5M
12	M37066.938146	SE 16-053-18 W5M	38	M36234.925486	NE 13-053-11 W5M
13	M36234.933473	SE 15-053-18 W5M	39	M36234.925405	SE 20-053-10 W5M
14	M36234.933461	SW 13-053-18 W5M	40	M36234.925413	SE 22-053-10 W5M
15	M36234.933764	NW 18-053-17 W5M	41	M36234.925419	SE 24-053-10 W5M
16	M35379.068280	SW 16-053-17 W5M	42	M36234.925266	SW 20-053-09 W5M
17	M35379.068264	NE 15-053-17 W5M	43	M36234.928894	NE 16-053-09 W5M
18	M36727.992640	SW 18-053-16 W5M	44	M36234.925279	SE 23-053-09 W5M
19	M35379.049571	NW 16-053-16 W5M	45	M36234.926576	SW 19-053-08 W5M
20	M35379.049596	SE 22-053-16 W5M	46	M36234.926582	SE 20-053-08 W5M
21	M36727.992639	NW 13-053-16 W5M	47	M35379.066557	NE 15-053-08 W5M
22	M37066.932622	15-18-053-15 W5M	48	M36234.926536	NE 13-053-08 W5M
23	M35379.048696	SE 20-053-15 W5M	49	M36234.926343	NE 17-053-07 W5M
24	M35379.066705	SW 22-053-15 W5M	50	M36234.926391	SW 22-053-07 W5M
25	M35379.055832	NE 14-053-15 W5M	51	M35379.061876	SE 23-053-07 W5M
26	M36234.925828	NW 18-053-14 W5M			



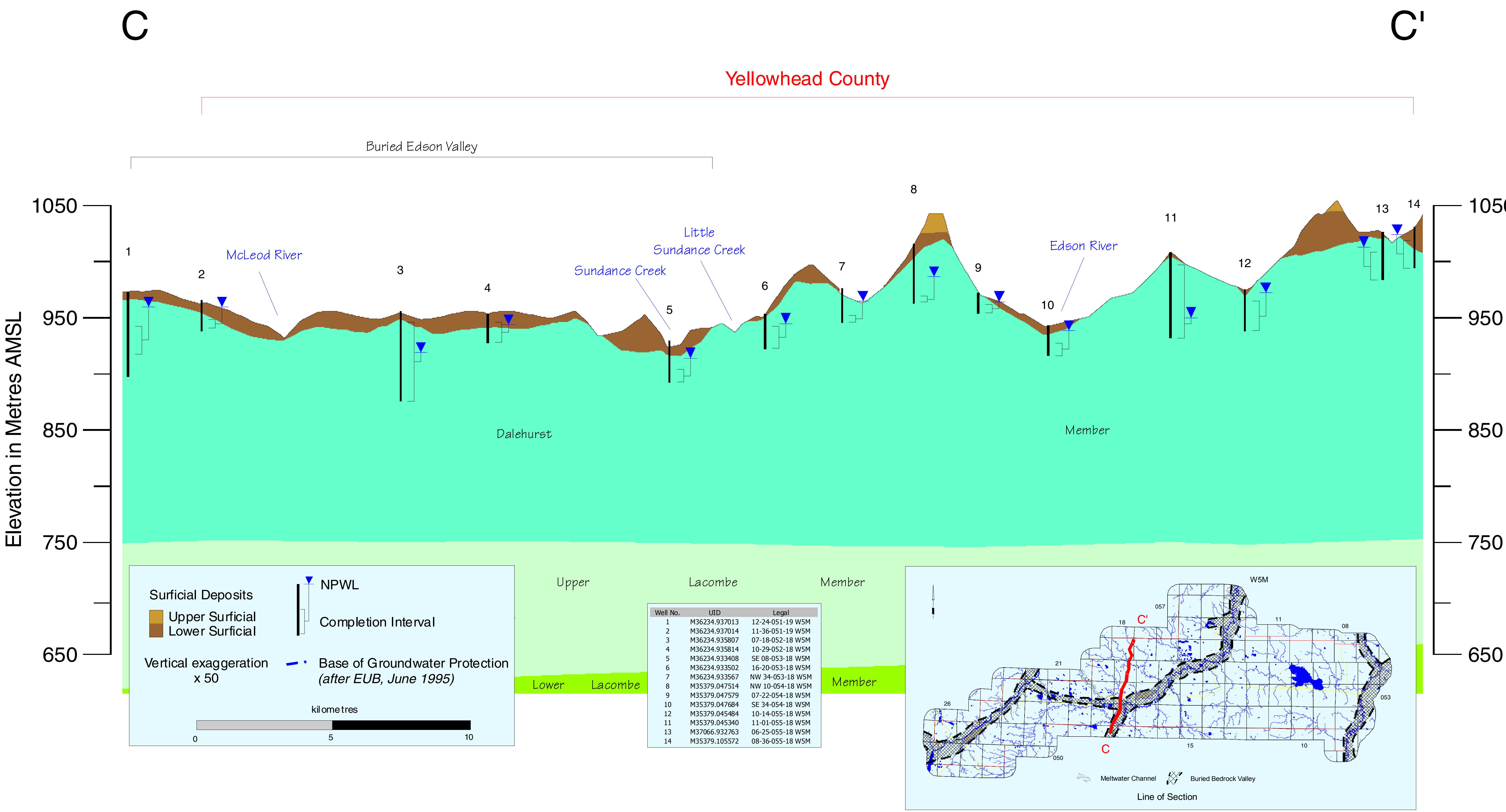
Line of Section

Cross-Section B - B'



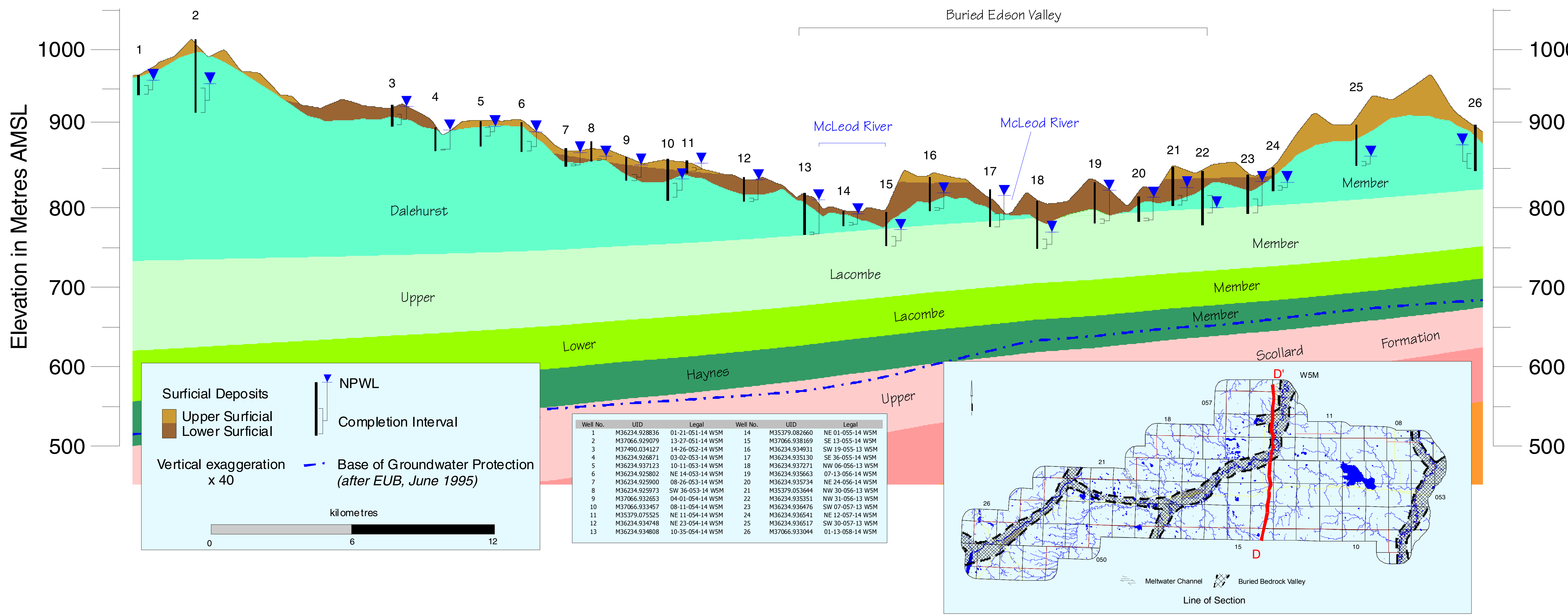
Well No.	UID	Legal
1	M36056.964941	NW 20-049-26 W5M
2	M37066.930334	10-29-049-26 W5M
3	M37066.932279	NW 03-050-26 W5M
4	M35379.061695	SW 30-050-25 W5M
5	M37066.932359	06-02-051-25 W5M
6	M37066.932346	10-17-051-24 W5M
7	M36234.935973	05-01-052-24 W5M
8	M36234.935964	SW 21-052-23 W5M
9	M36234.935968	13-23-052-23 W5M
10	M35379.058555	SW 08-053-22 W5M
11	M35379.059292	02-24-053-22 W5M
12	M35379.070819	08-06-054-21 W5M
13	M35379.047965	07-15-054-21 W5M

Cross-Section C - C'



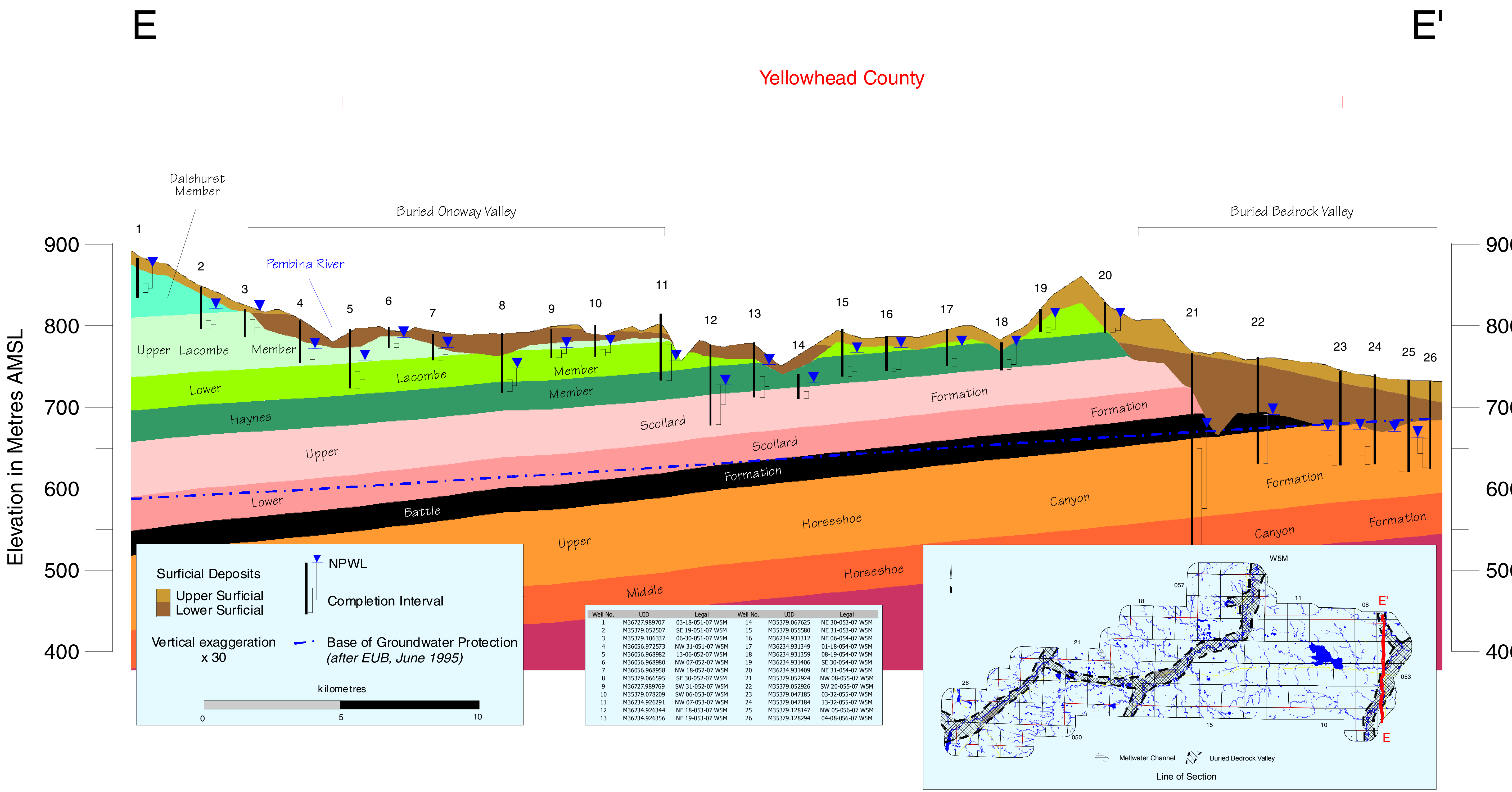
Well No.	UID	Legal
1	M36234.937013	12-24-051-19 W5M
2	M36234.937014	11-36-051-19 W5M
3	M36234.935807	07-18-052-18 W5M
4	M36234.935814	10-29-052-18 W5M
5	M36234.933408	SE 08-053-18 W5M
6	M36234.933502	16-20-053-18 W5M
7	M36234.933567	NW 34-053-18 W5M
8	M35379.047514	NW 10-054-18 W5M
9	M35379.047579	07-22-054-18 W5M
10	M35379.047684	SE 34-054-18 W5M
12	M35379.045484	10-14-055-18 W5M
11	M35379.045340	11-01-055-18 W5M
13	M37066.932763	06-25-055-18 W5M
14	M35379.105572	08-36-055-18 W5M

Cross-Section D - D'



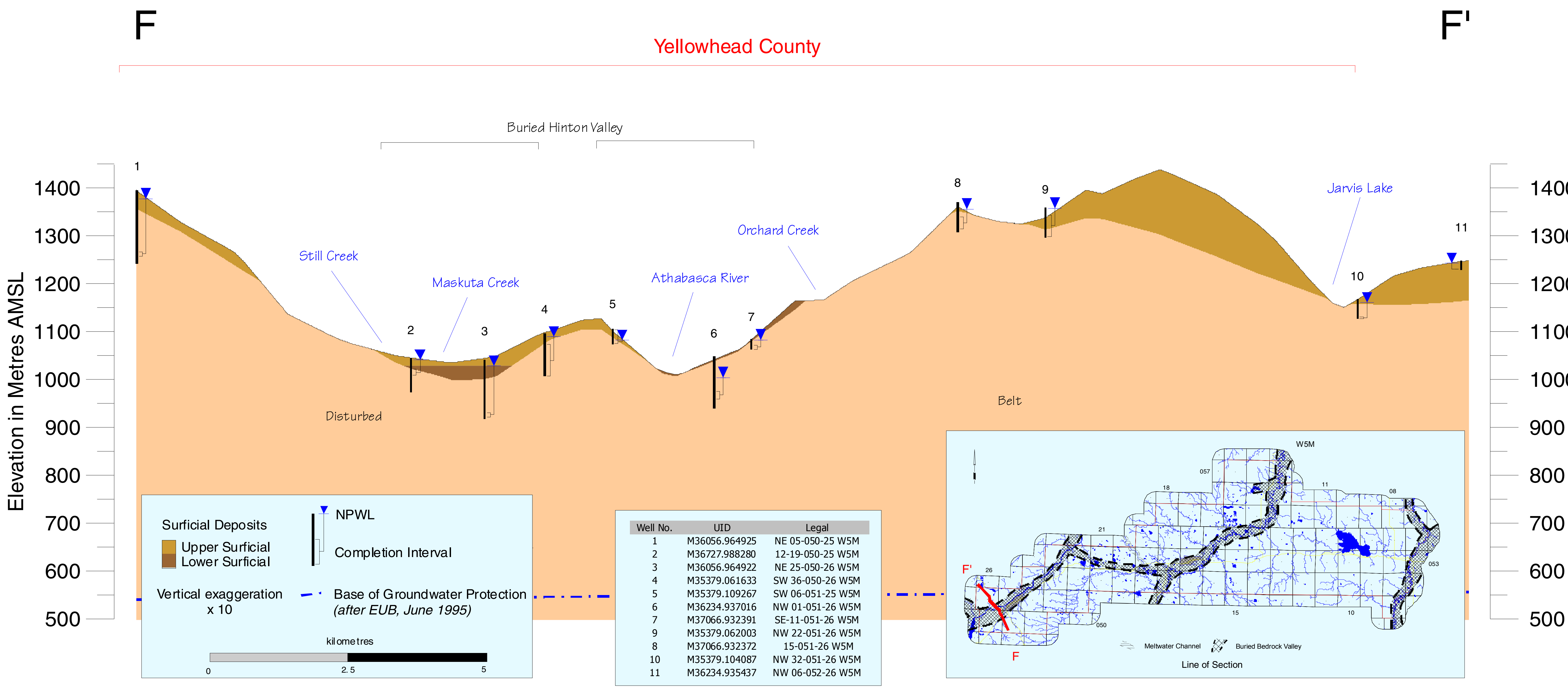
Well No.	UID	Legal	Well No.	UID	Legal
1	M36234.928836	01-21-051-14 W5M	14	M35379.082660	NE 01-055-14 W5M
2	M37066.929079	13-27-051-14 W5M	15	M37066.938169	SE 13-055-14 W5M
3	M37490.034127	14-26-052-14 W5M	16	M36234.934931	SW 19-055-13 W5M
4	M36234.926871	03-02-053-14 W5M	17	M36234.935130	SE 36-055-14 W5M
5	M36234.937123	10-11-053-14 W5M	18	M36234.937271	NW 06-056-13 W5M
6	M36234.925802	NE 14-053-14 W5M	19	M36234.935663	07-13-056-14 W5M
7	M36234.925900	08-26-053-14 W5M	20	M36234.935734	NE 24-056-14 W5M
8	M36234.925973	SW 36-053-14 W5M	21	M35379.053644	NW 30-056-13 W5M
9	M37066.932653	04-01-054-14 W5M	22	M36234.935351	NW 31-056-13 W5M
10	M37066.933457	08-11-054-14 W5M	23	M36234.936476	SW 07-057-13 W5M
11	M35379.075525	NE 11-054-14 W5M	24	M36234.936541	NE 12-057-14 W5M
12	M36234.934748	NE 23-054-14 W5M	25	M36234.936517	SW 30-057-13 W5M
13	M36234.934808	10-35-054-14 W5M	26	M37066.933044	01-13-058-14 W5M

Cross-Section E - E'



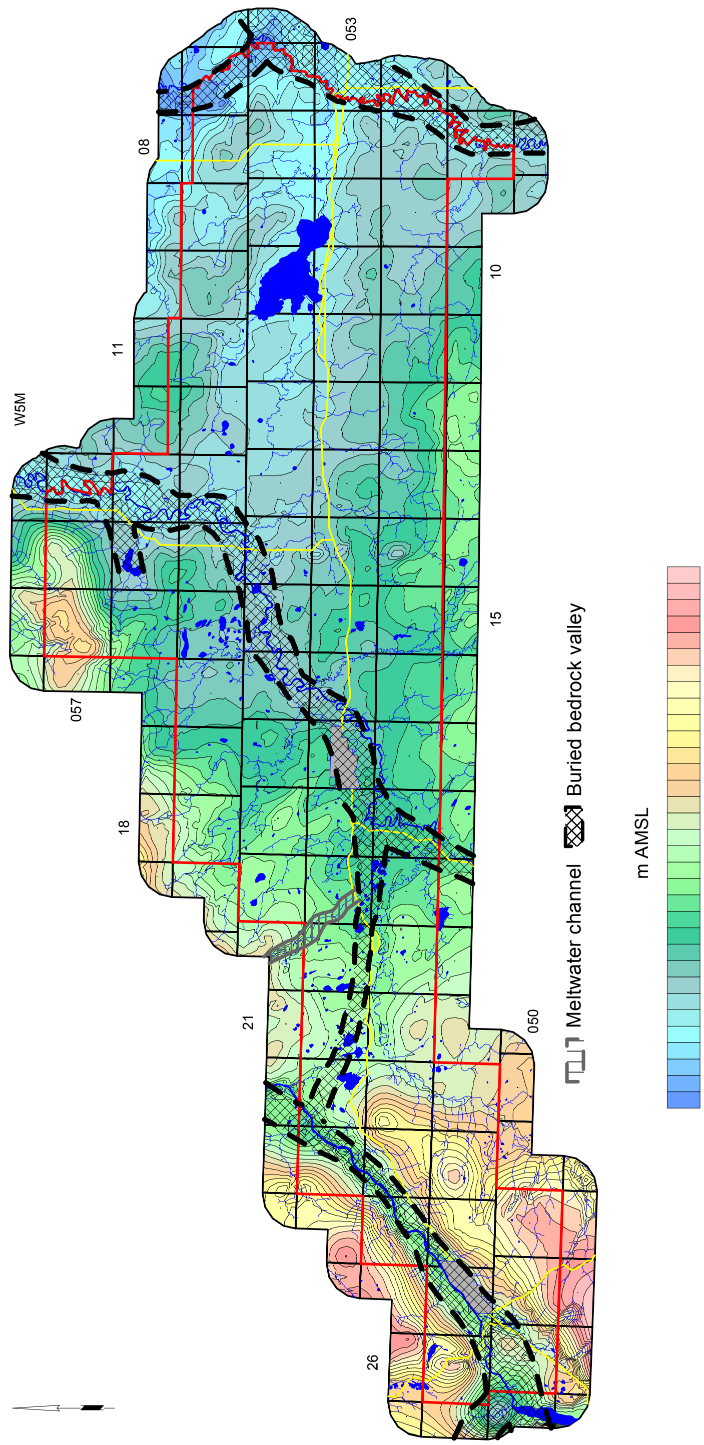
Well No.	UID	Legal	Well No.	UID	Legal
1	M36727.989707	03-18-051-07 W5M	14	M35379.067625	NE 30-053-07 W5M
2	M35379.052507	SE 19-051-07 W5M	15	M35379.055580	NE 31-053-07 W5M
3	M35379.106337	06-30-051-07 W5M	16	M36234.931312	NE 06-054-07 W5M
4	M36056.972573	NW 31-051-07 W5M	17	M36234.931349	01-18-054-07 W5M
5	M36056.968982	13-06-052-07 W5M	18	M36234.931359	08-19-054-07 W5M
6	M36056.968980	NW 07-052-07 W5M	19	M36234.931406	SE 30-054-07 W5M
7	M36056.968958	NW 18-052-07 W5M	20	M36234.931409	NE 31-054-07 W5M
8	M35379.066595	SE 30-052-07 W5M	21	M35379.052924	NW 08-055-07 W5M
9	M36727.989769	SW 31-052-07 W5M	22	M35379.052926	SW 20-055-07 W5M
10	M35379.078209	SW 06-053-07 W5M	23	M35379.047185	03-32-055-07 W5M
11	M36234.926291	NW 07-053-07 W5M	24	M35379.047184	13-32-055-07 W5M
12	M36234.926344	NE 18-053-07 W5M	25	M35379.128147	NW 05-056-07 W5M
13	M36234.926356	NE 19-053-07 W5M	26	M35379.128294	04-08-056-07 W5M

Cross-Section F - F'

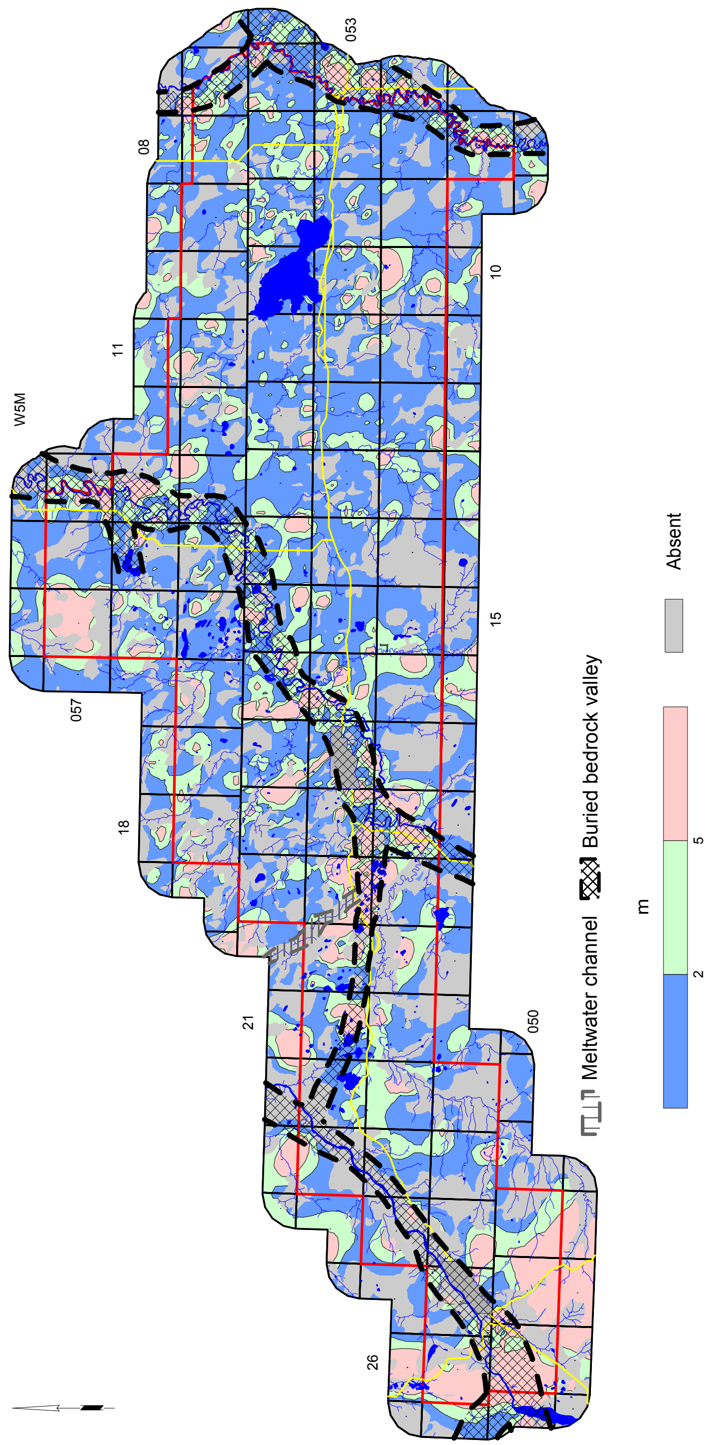


Well No.	UID	Legal
1	M36056.964925	NE 05-050-25 W5M
2	M36727.988280	12-19-050-25 W5M
3	M36056.964922	NE 25-050-26 W5M
4	M35379.061633	SW 36-050-26 W5M
5	M35379.109267	SW 06-051-25 W5M
6	M36234.937016	NW 01-051-26 W5M
7	M37066.932391	SE-11-051-26 W5M
9	M35379.062003	NW 22-051-26 W5M
8	M37066.932372	15-051-26 W5M
10	M35379.104087	NW 32-051-26 W5M
11	M36234.935437	NW 06-052-26 W5M

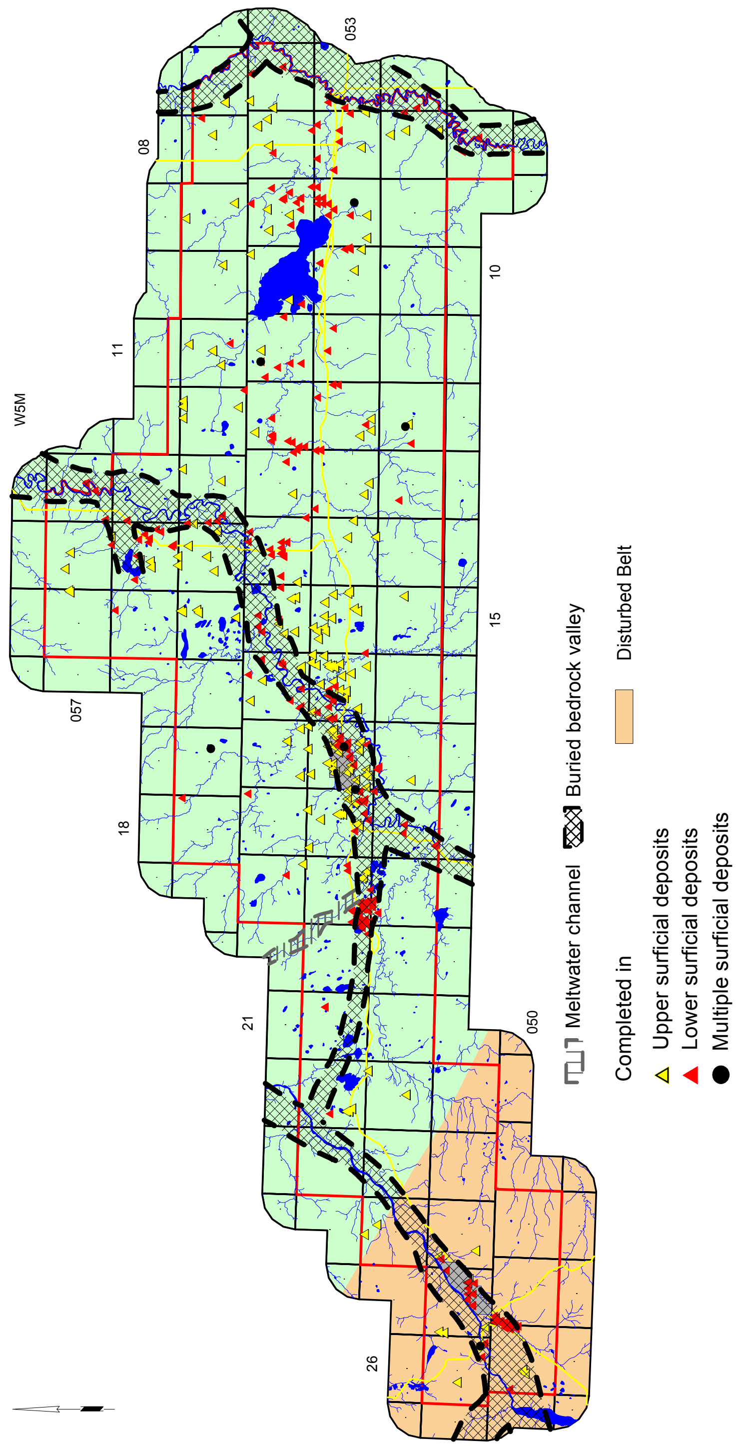
Bedrock Topography



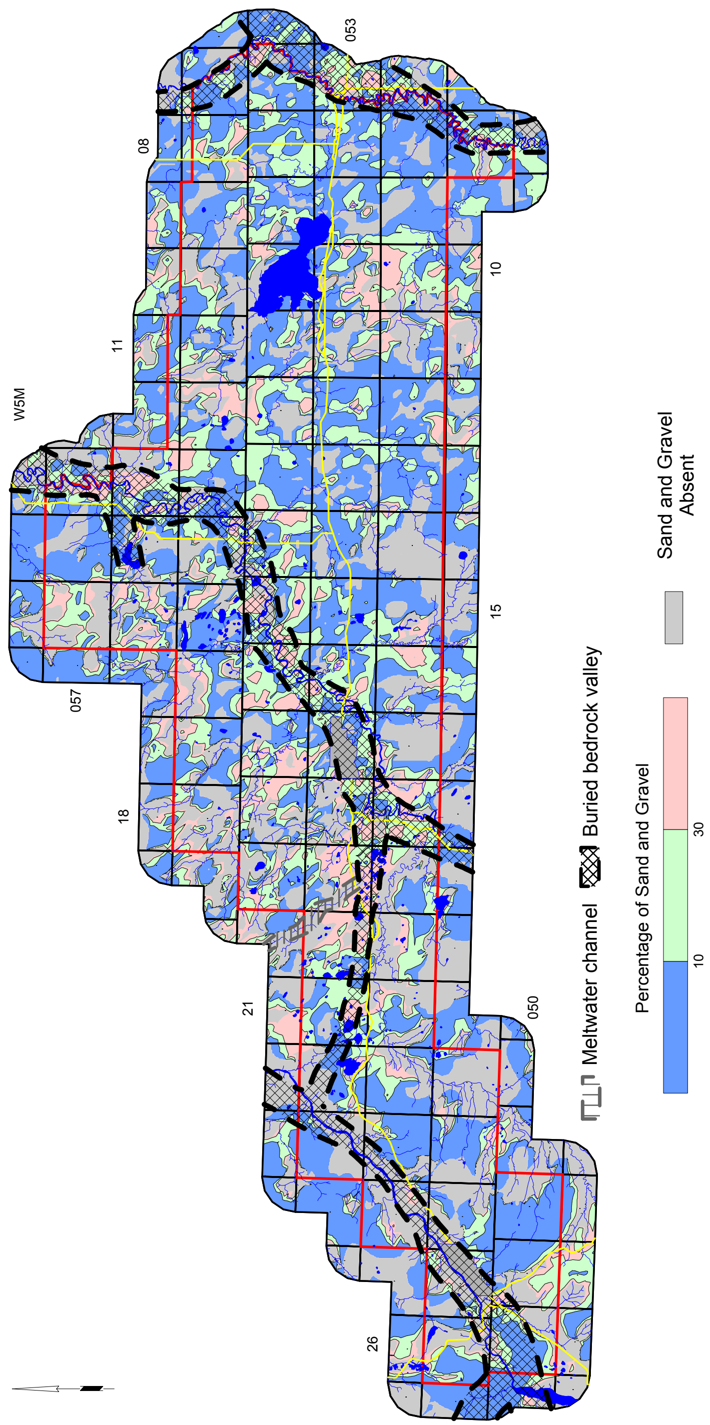
Thickness of Sand and Gravel Deposits



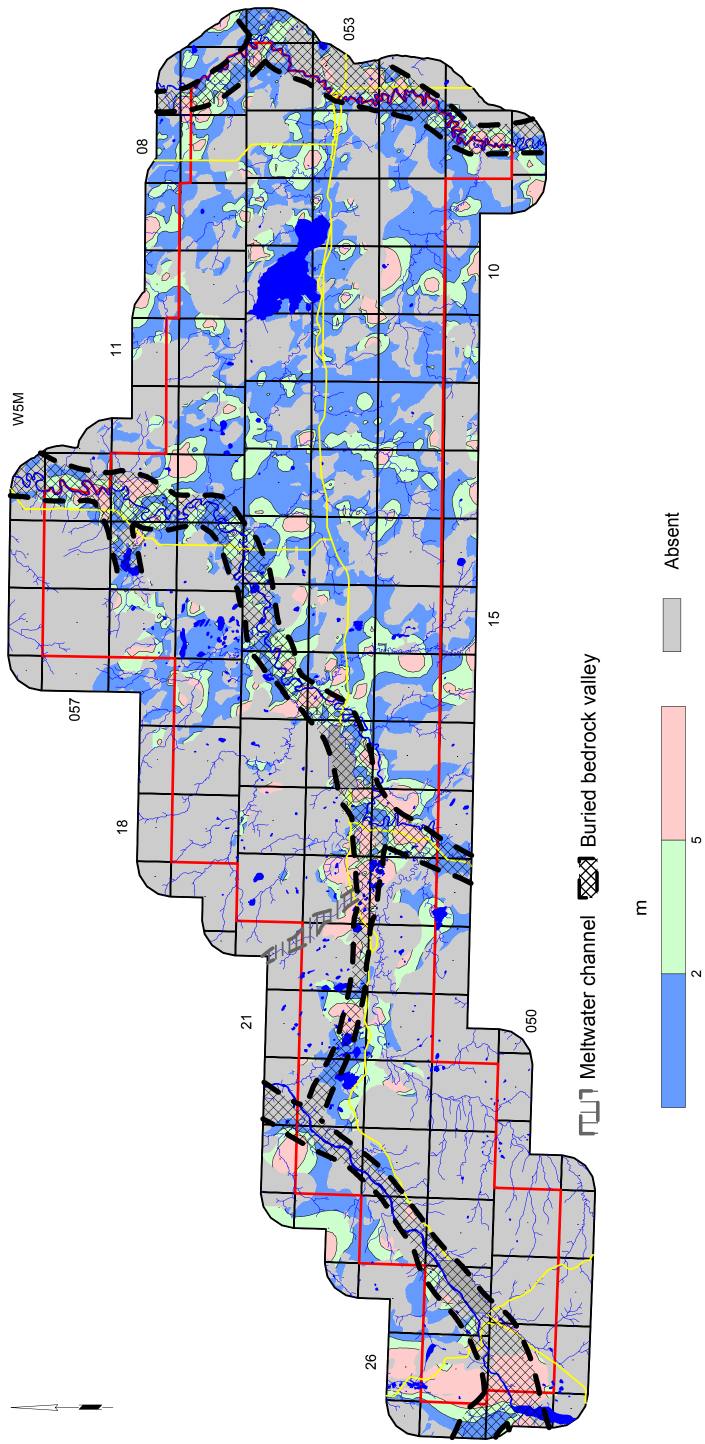
Water Wells Completed In Surficial Deposits



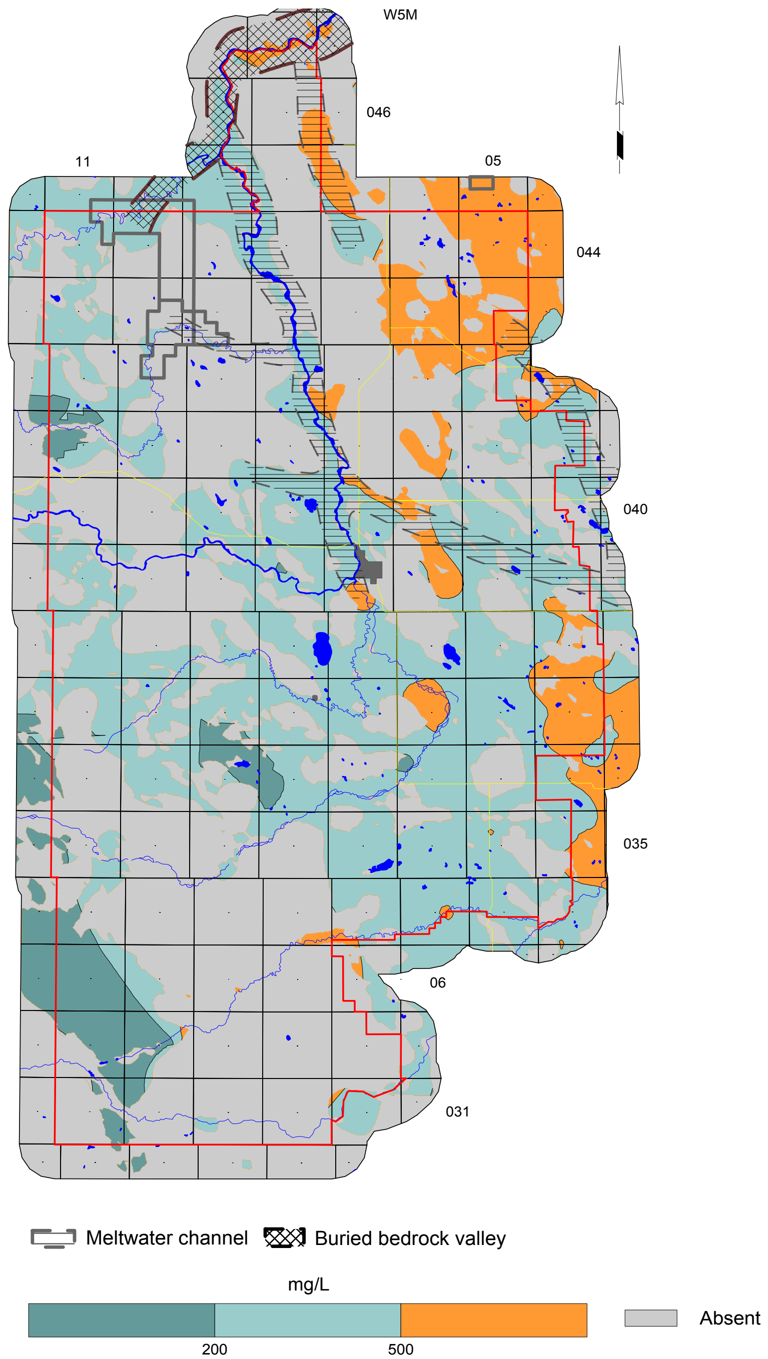
Amount of Sand and Gravel in Surficial Deposits



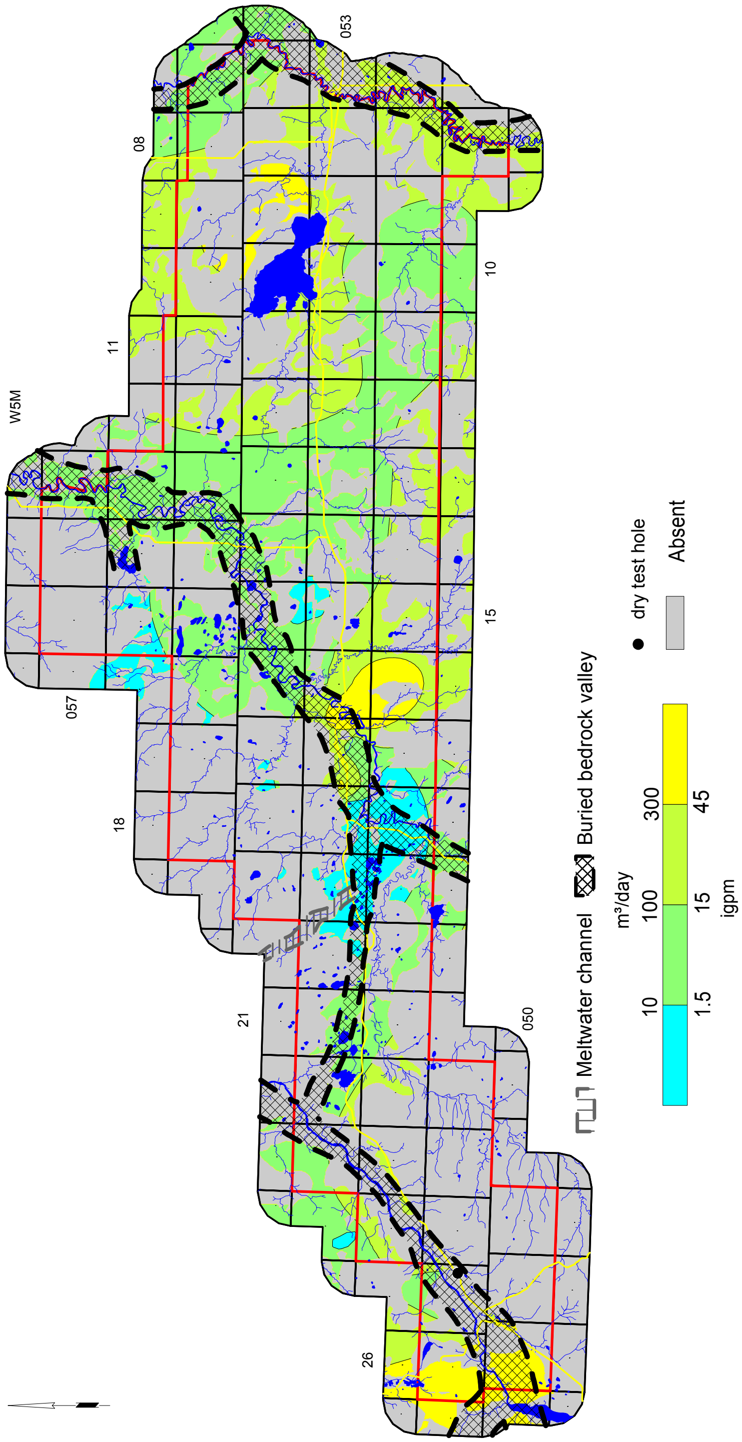
Thickness of Sand and Gravel Aquifer(s)



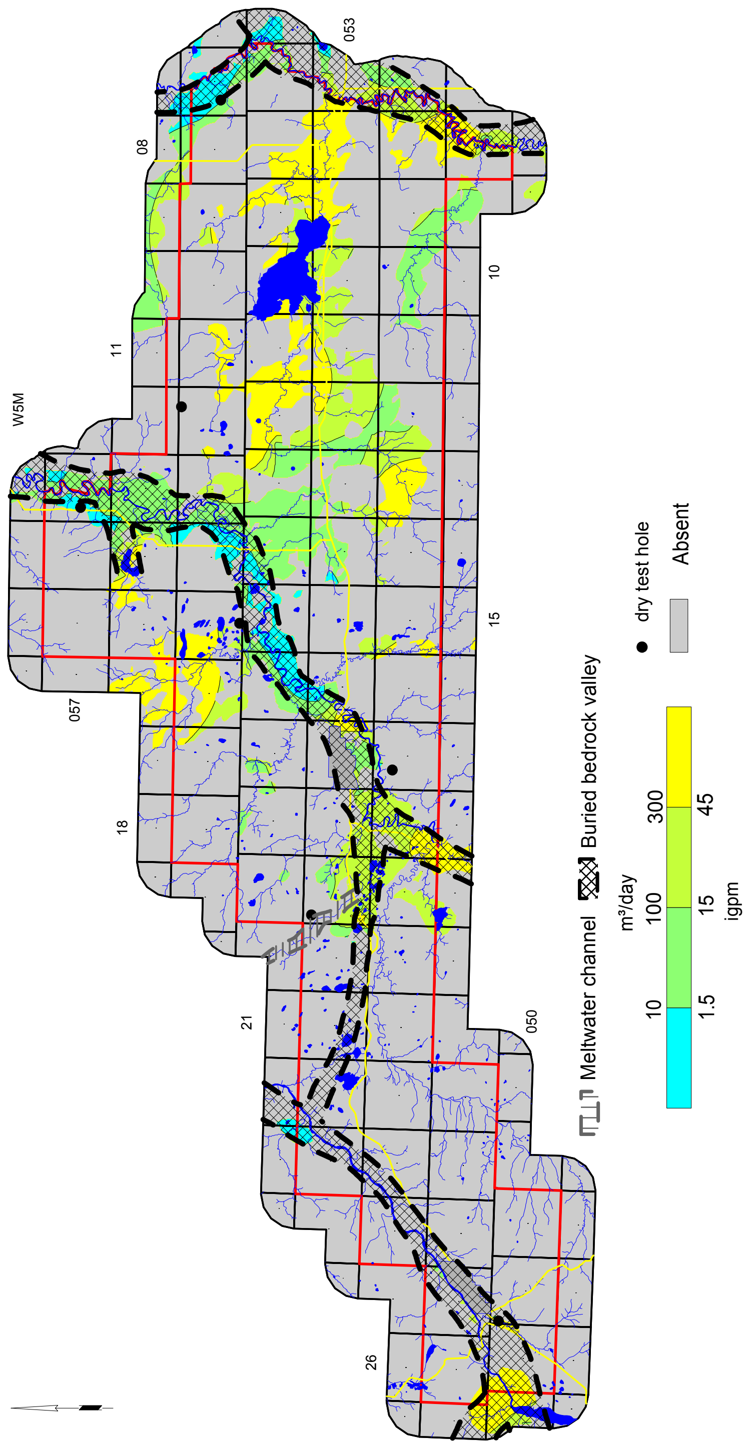
Total Dissolved Solids in Groundwater from Surficial Deposits



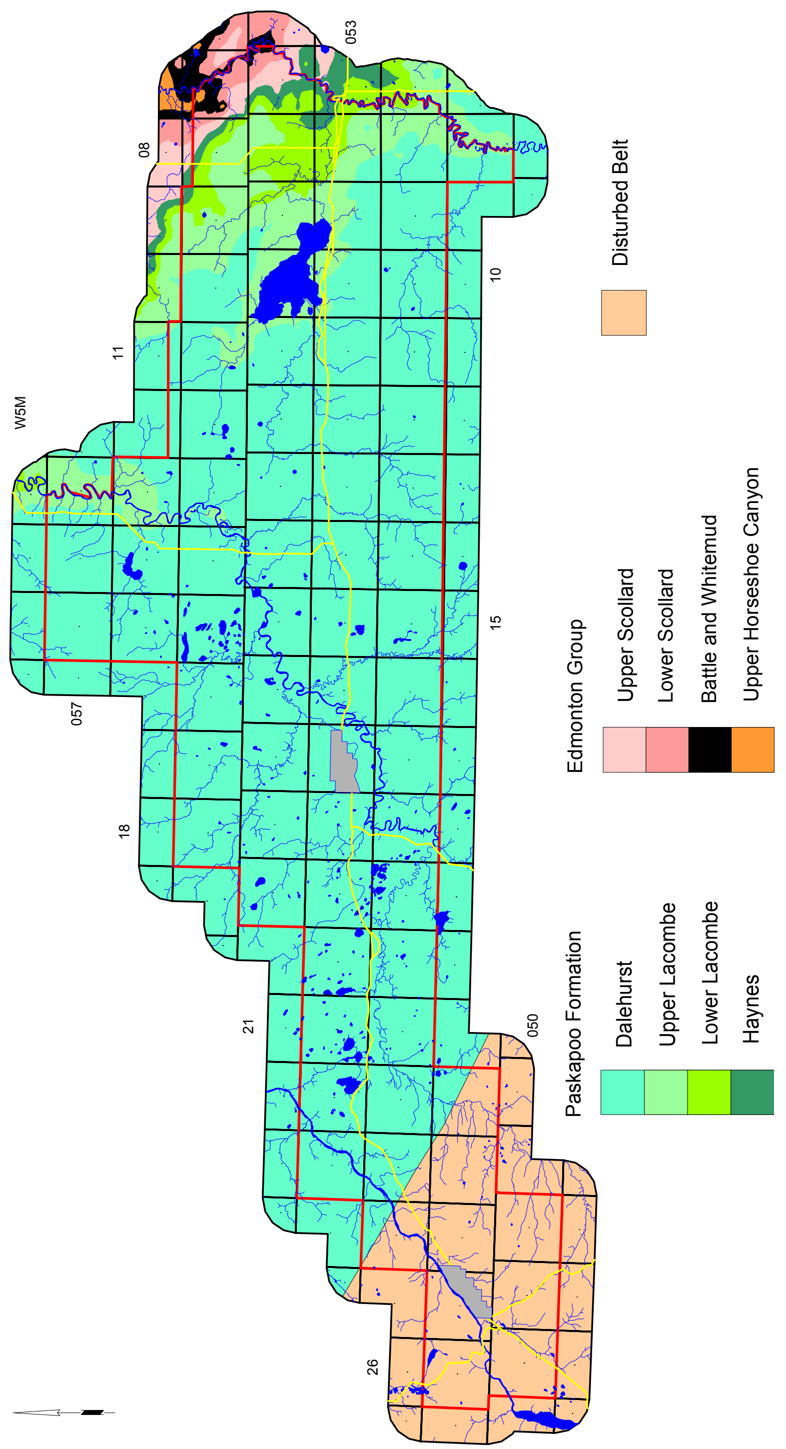
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



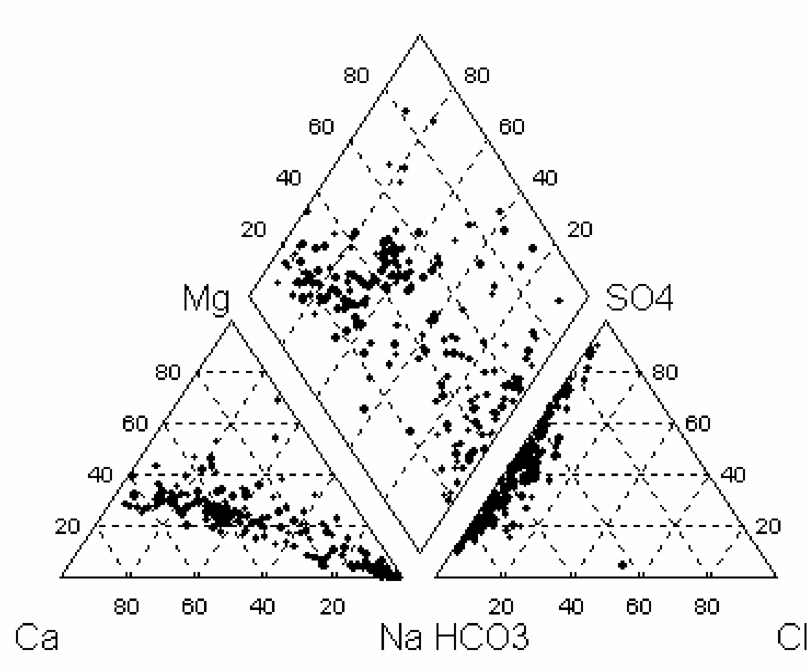
Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer



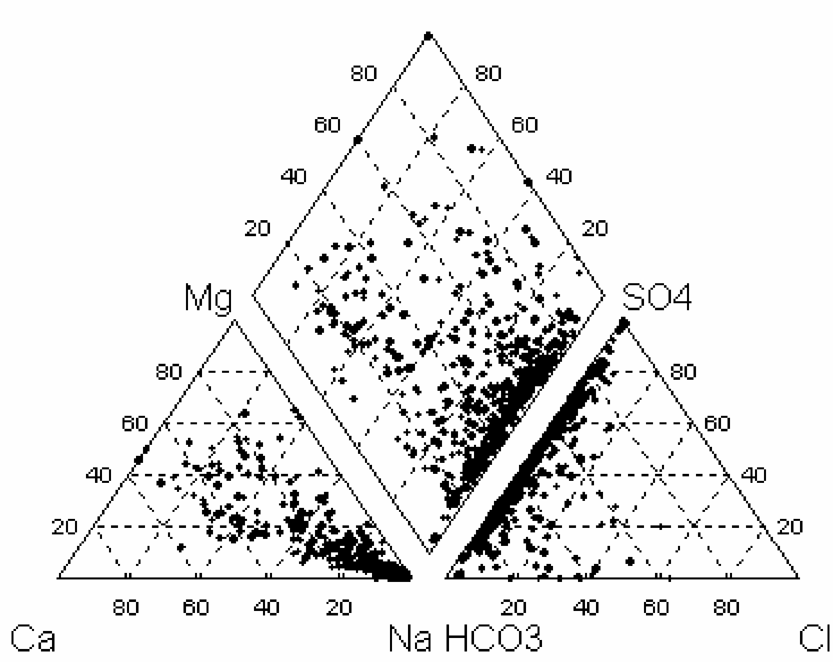
Bedrock Geology



Piper Diagrams

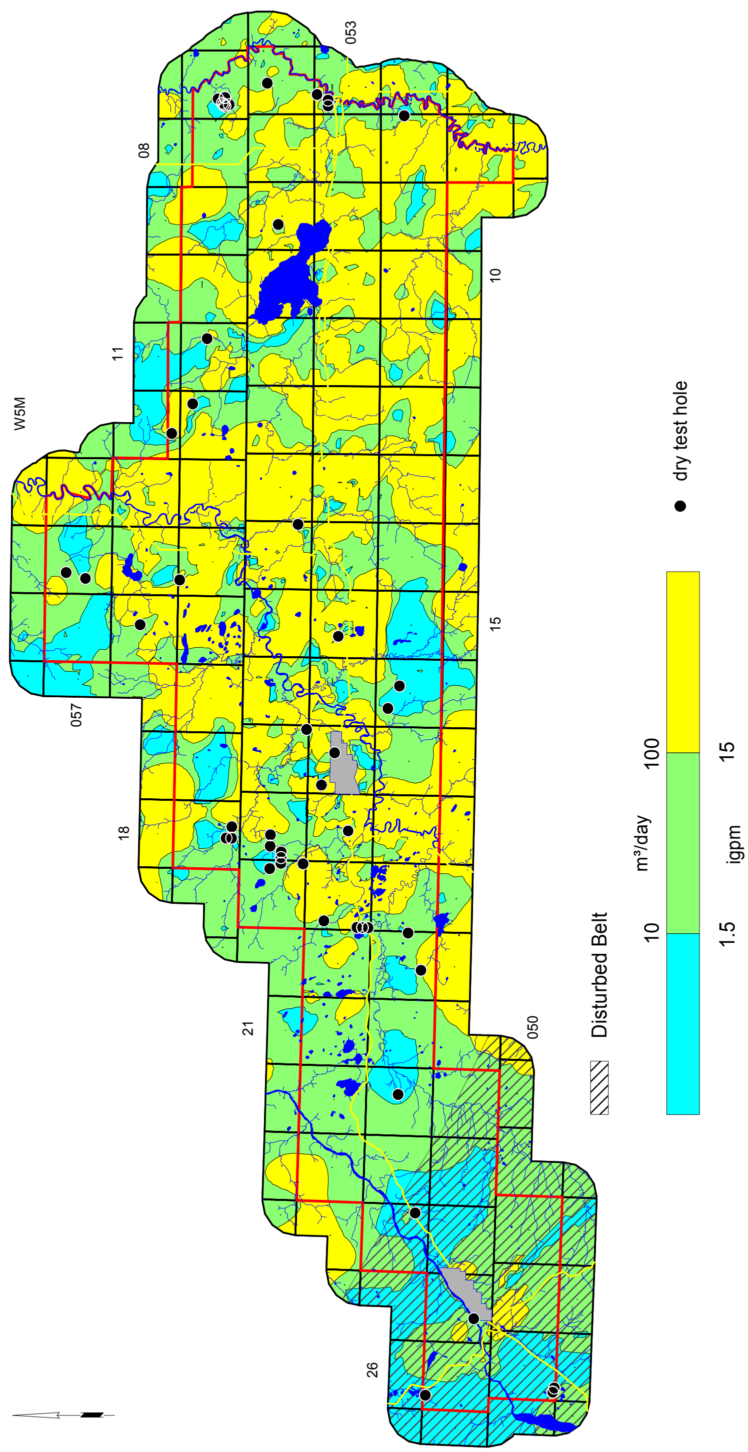


Surficial Deposits

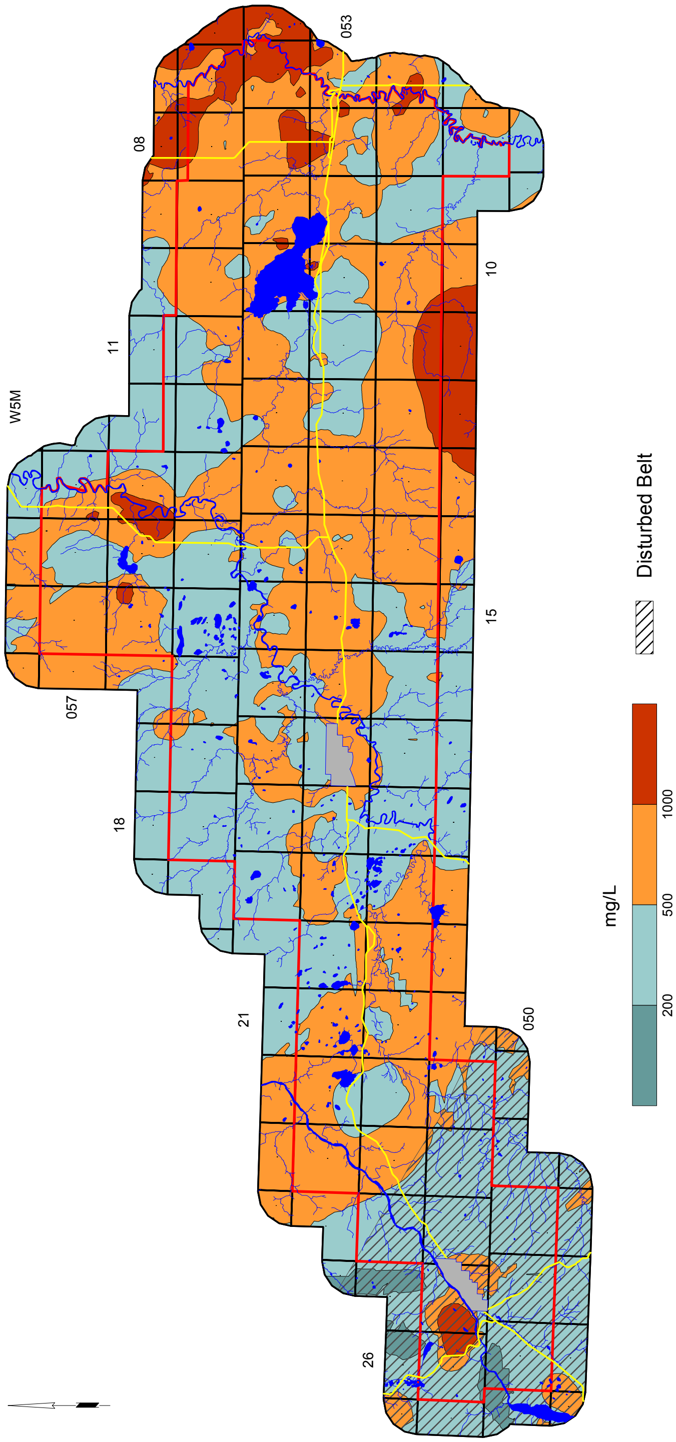


Bedrock Aquifers

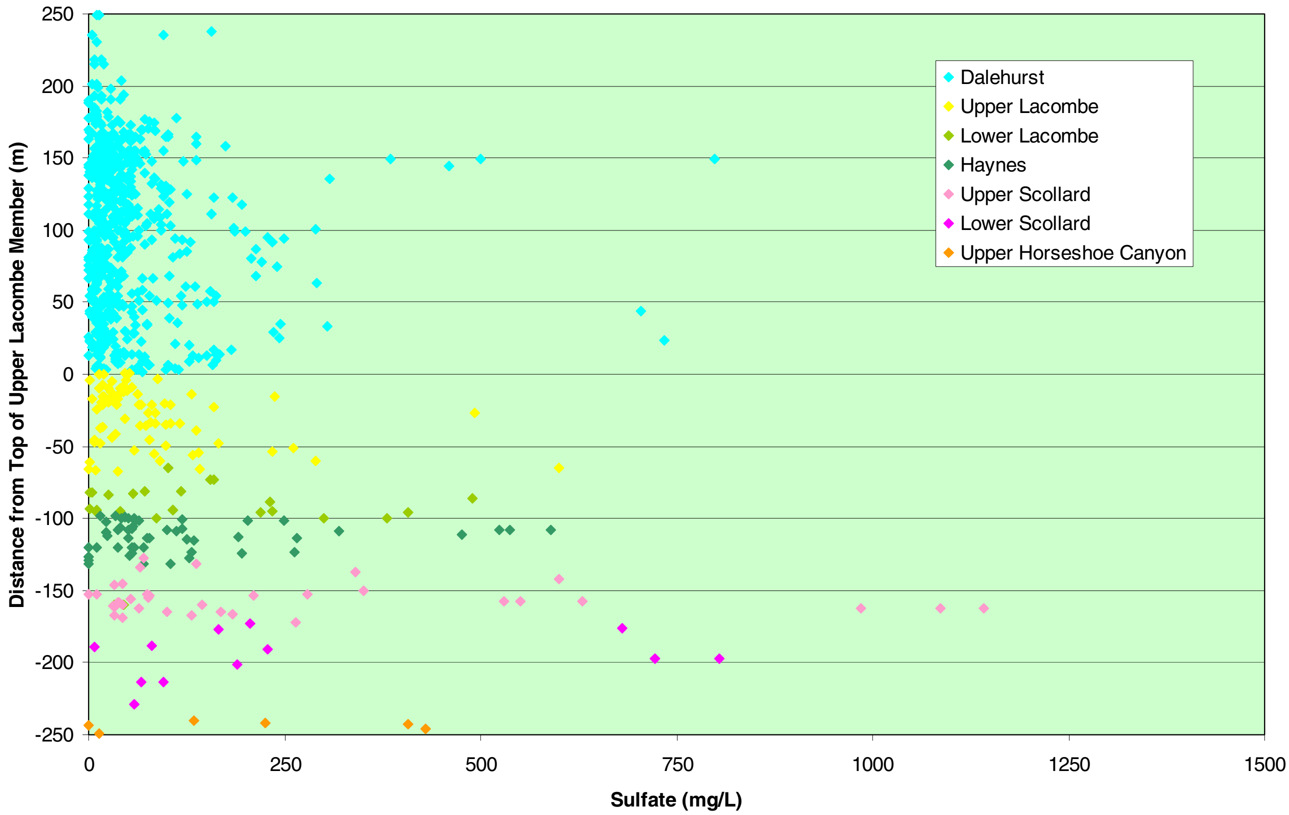
Apparent Yield for Water Wells Completed in Upper Bedrock Aquifer(s)



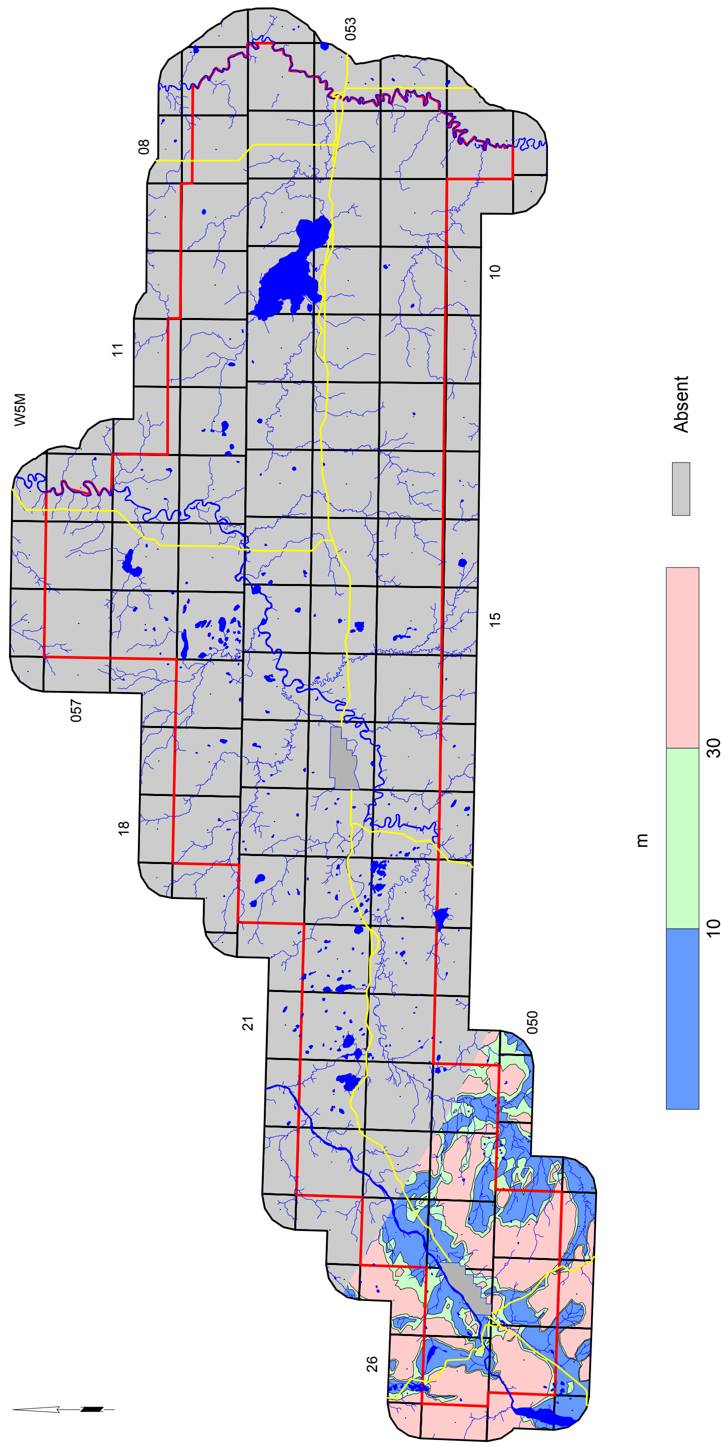
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)



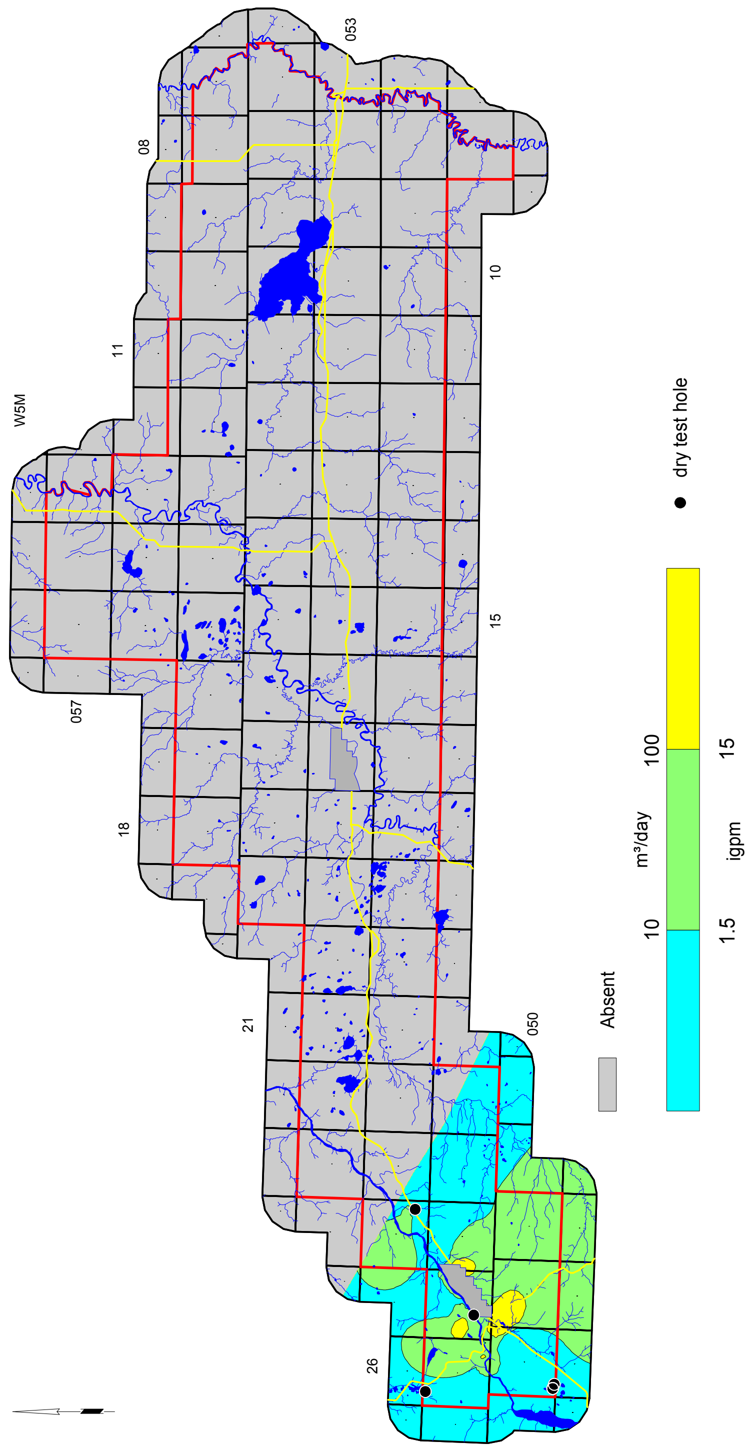
Distance from Top of Upper Lacombe Member vs Sulfate in Groundwater from Upper Bedrock Aquifer(s)



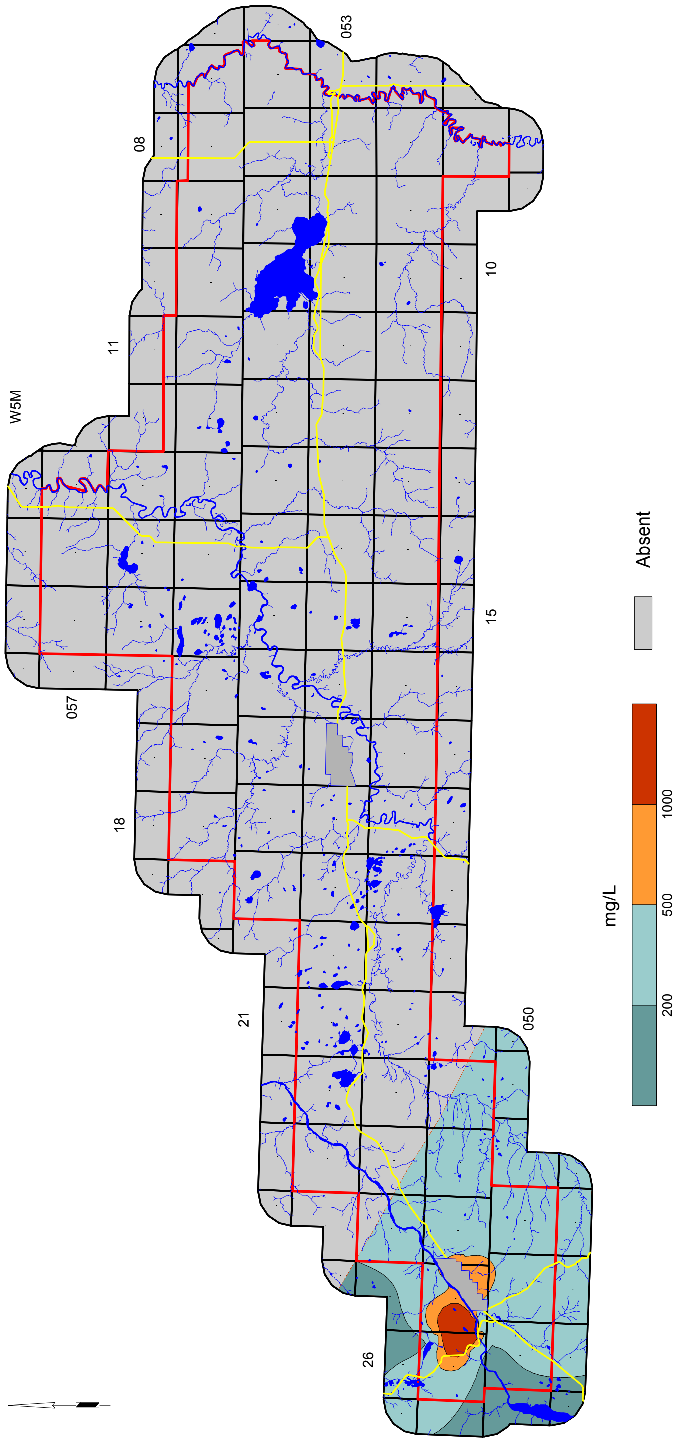
Depth to Top of Disturbed Belt



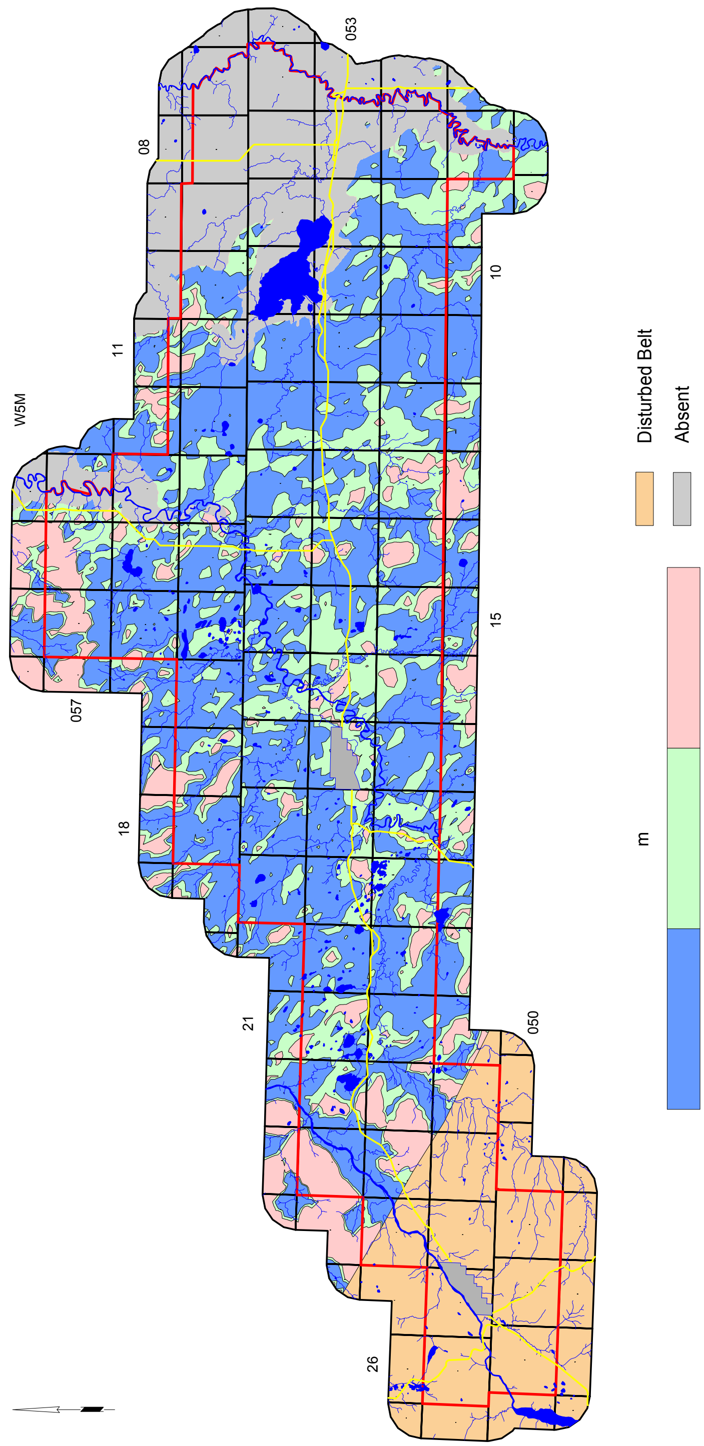
Apparent Yield for Water Wells Completed through Disturbed Belt Aquifer



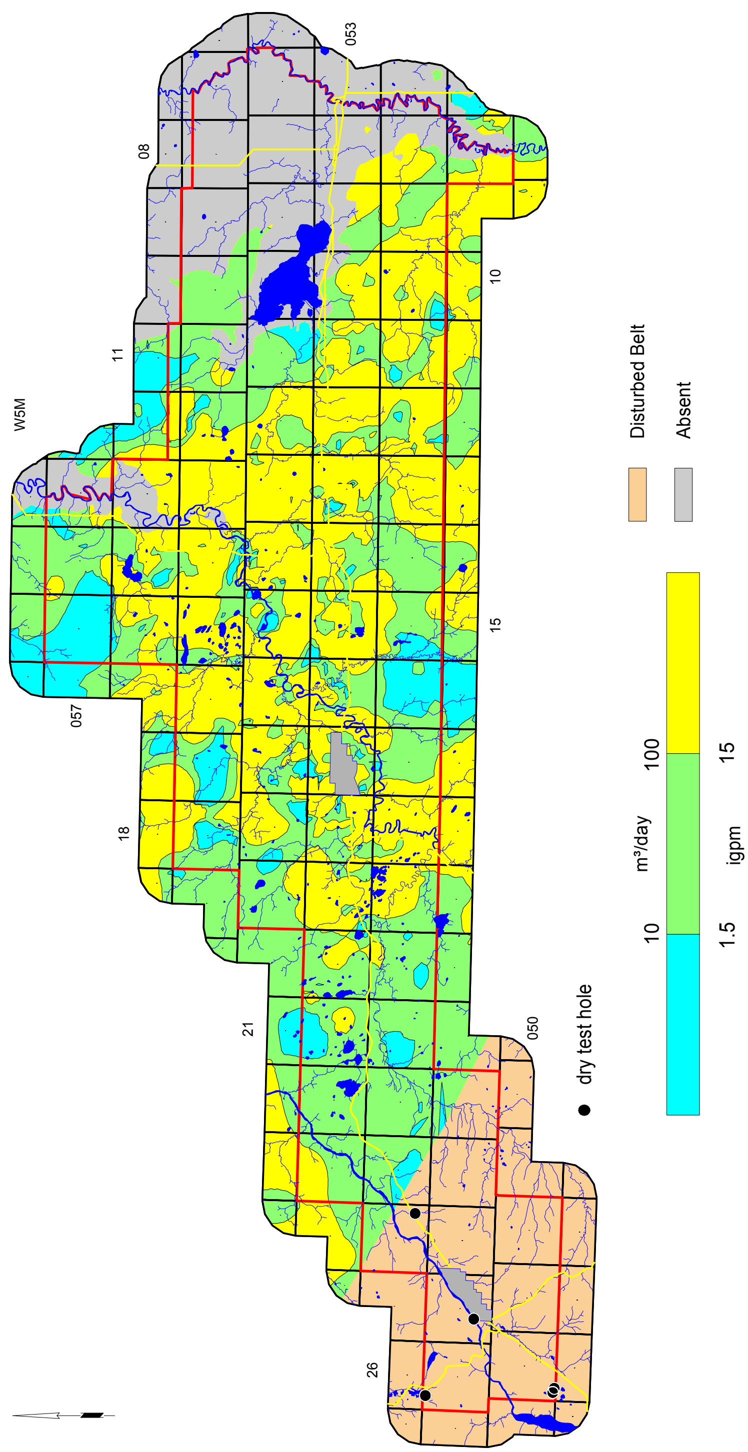
Total Dissolved Solids in Groundwater from Disturbed Belt Aquifer



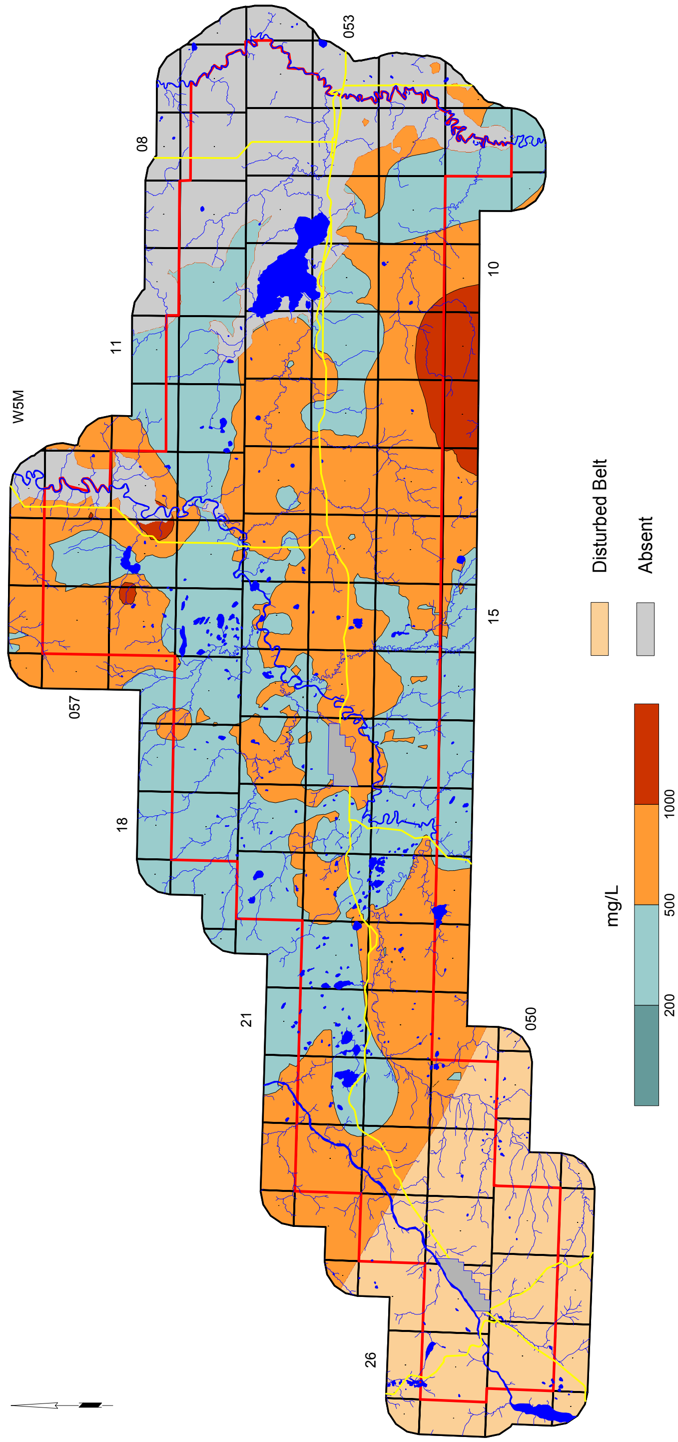
Depth to Top of Dalehurst Member



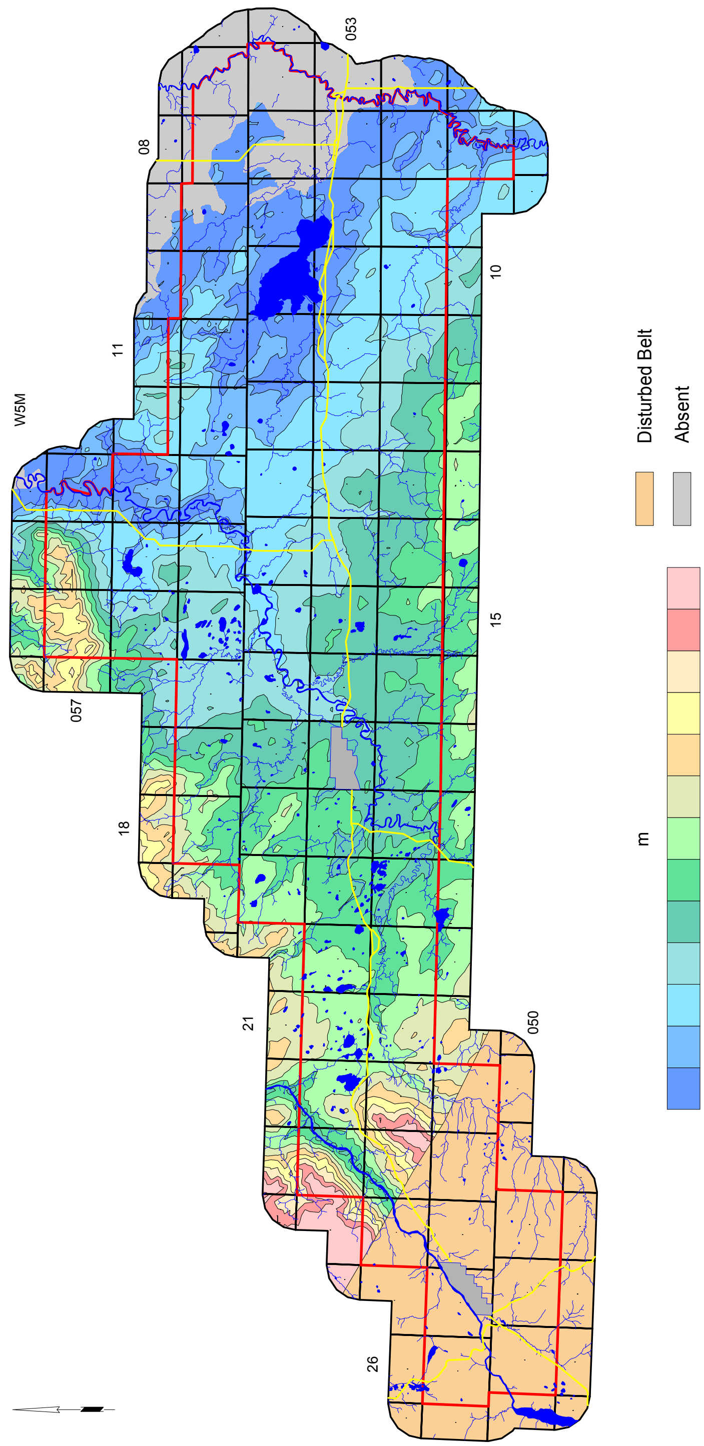
Apparent Yield for Water Wells Completed through Dalehurst Aquifer



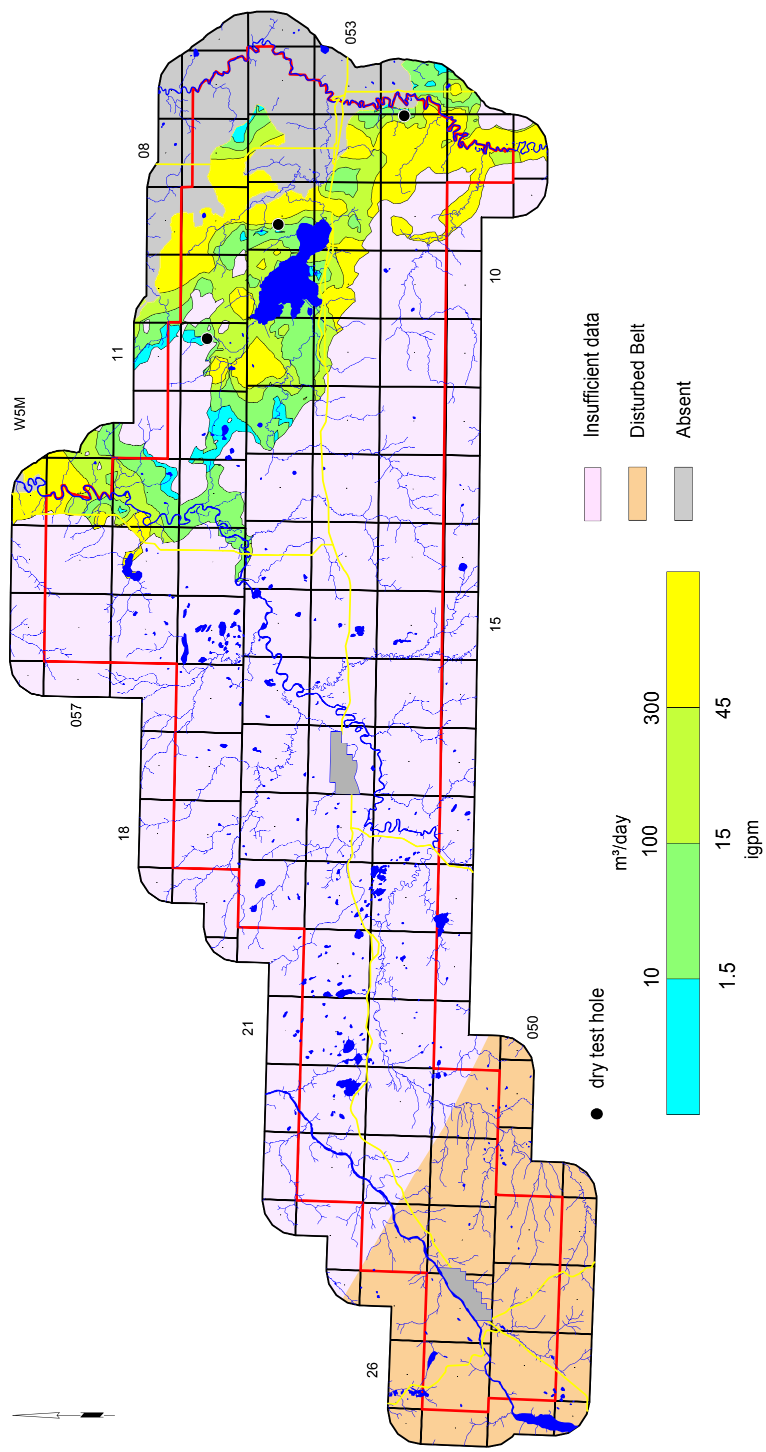
Total Dissolved Solids in Groundwater from Dalehurst Aquifer



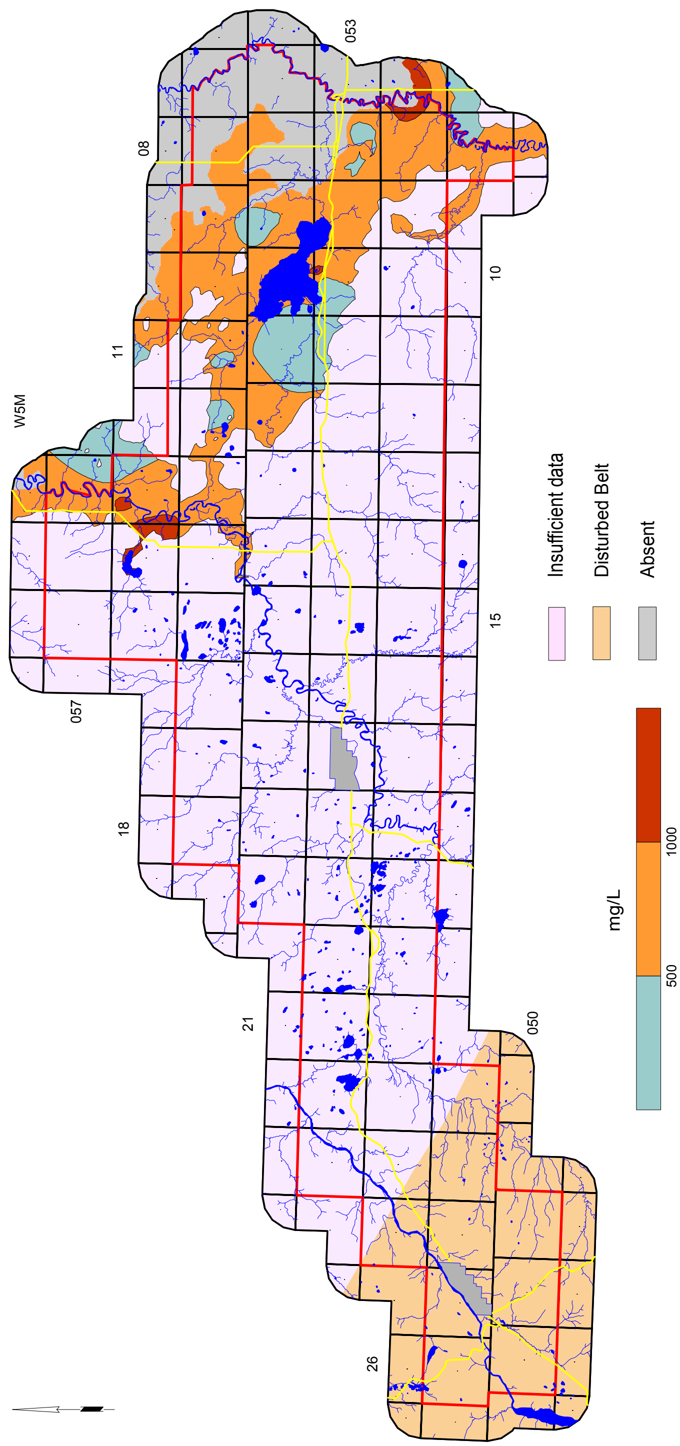
Depth to Top of Upper Lacombe Member



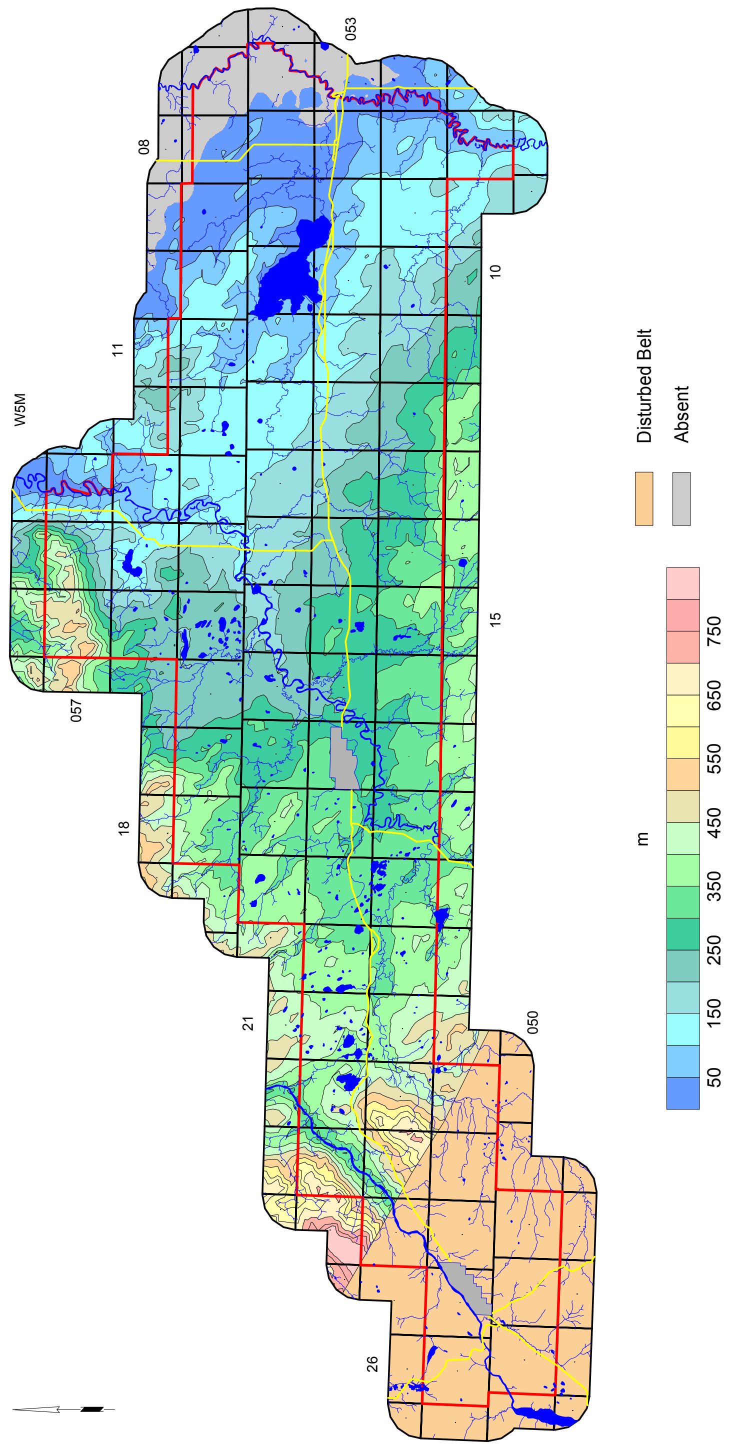
Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer



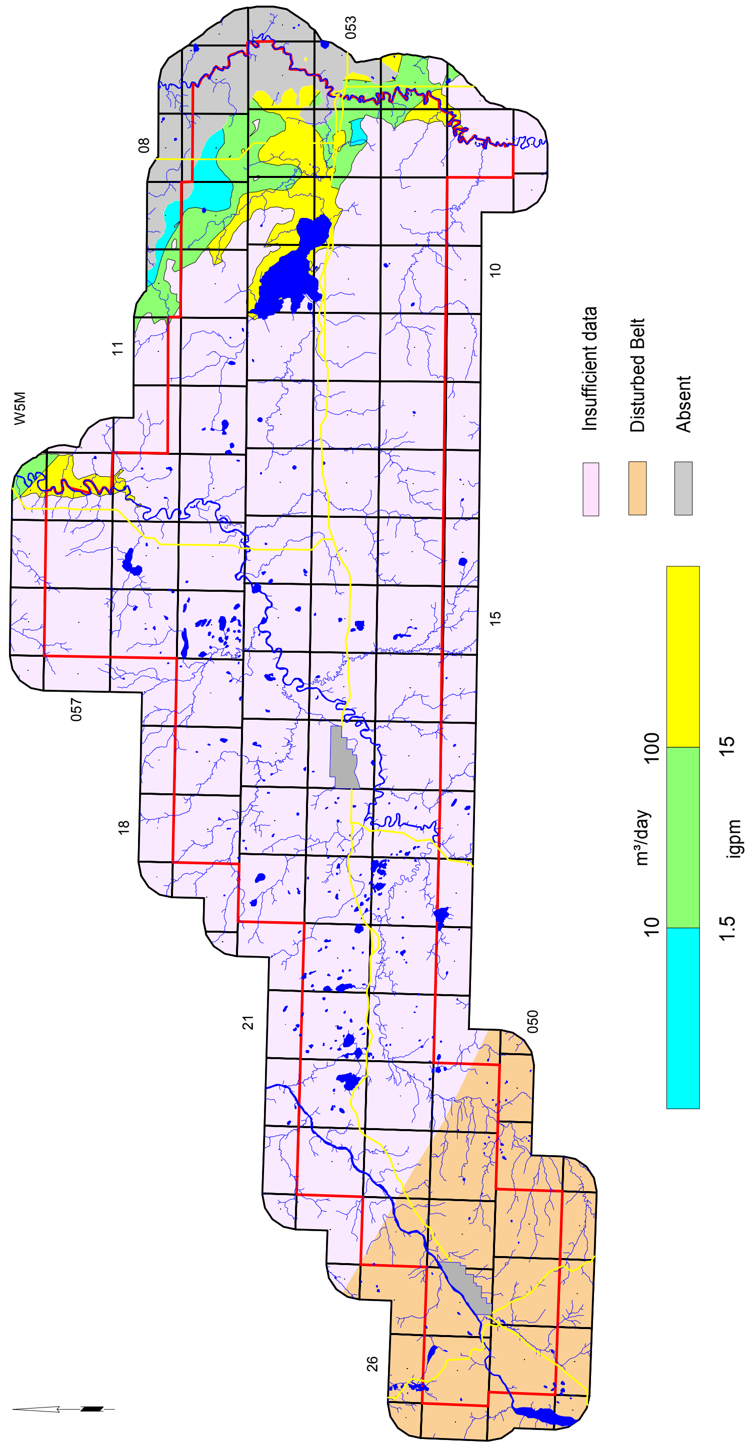
Total Dissolved Solids in Groundwater from Upper Lacombe Aquifer



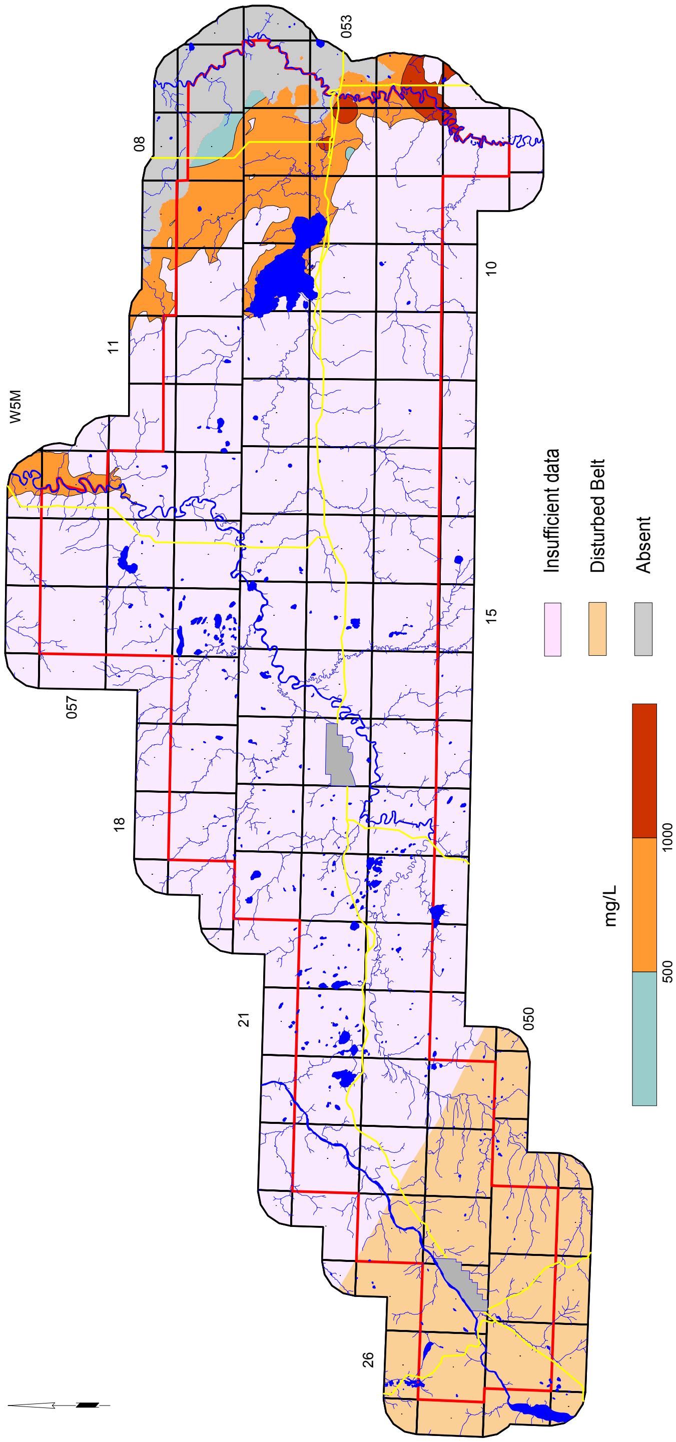
Depth to Top of Lower Lacombe Member



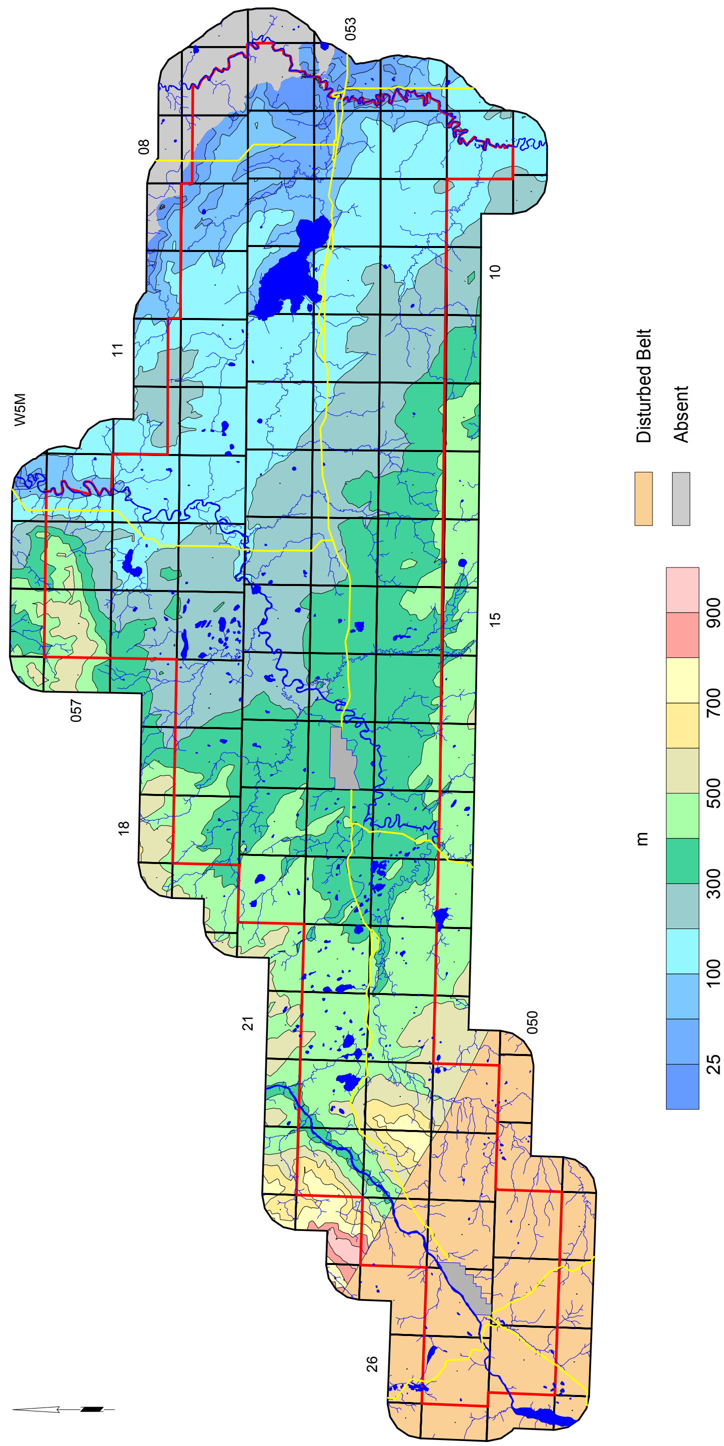
Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer



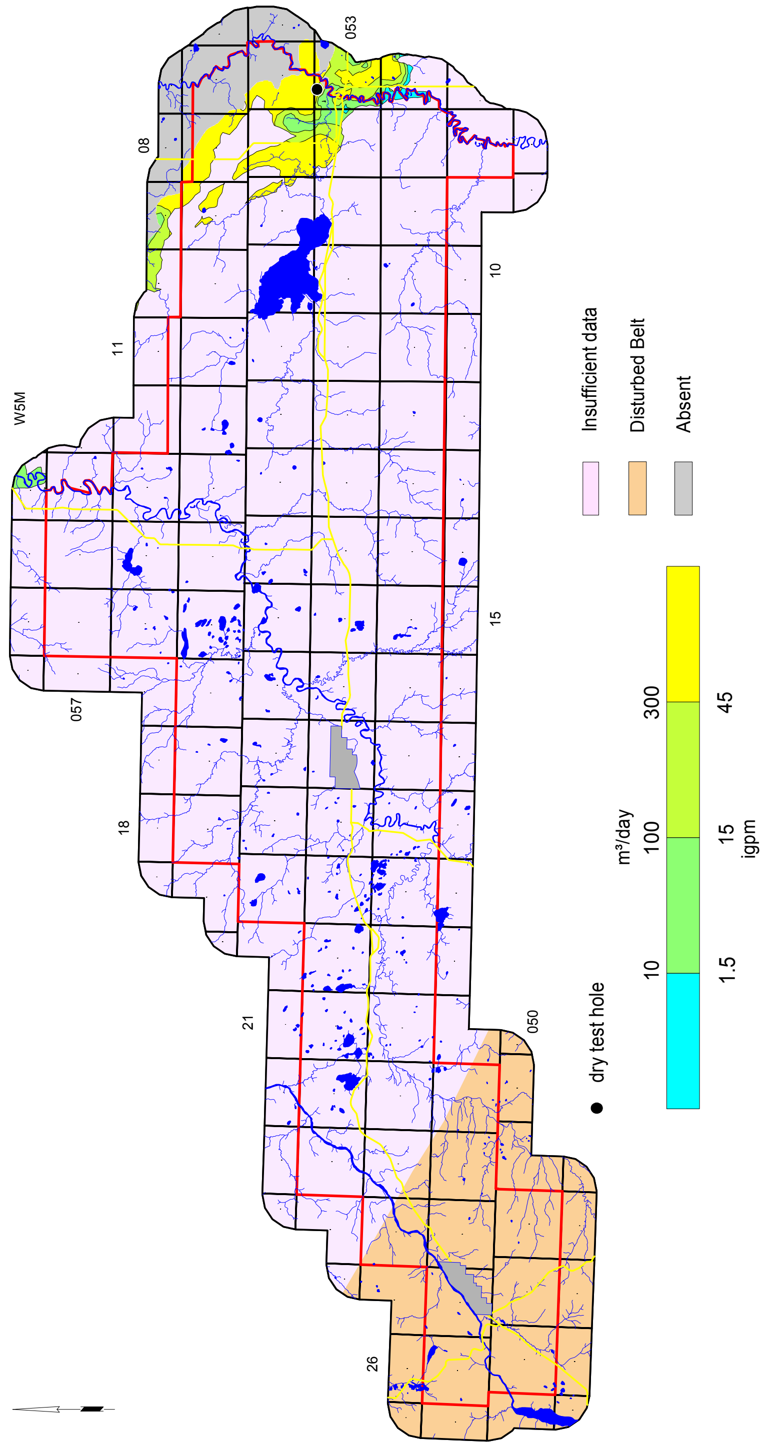
Total Dissolved Solids in Groundwater from Lower Lacombe Aquifer



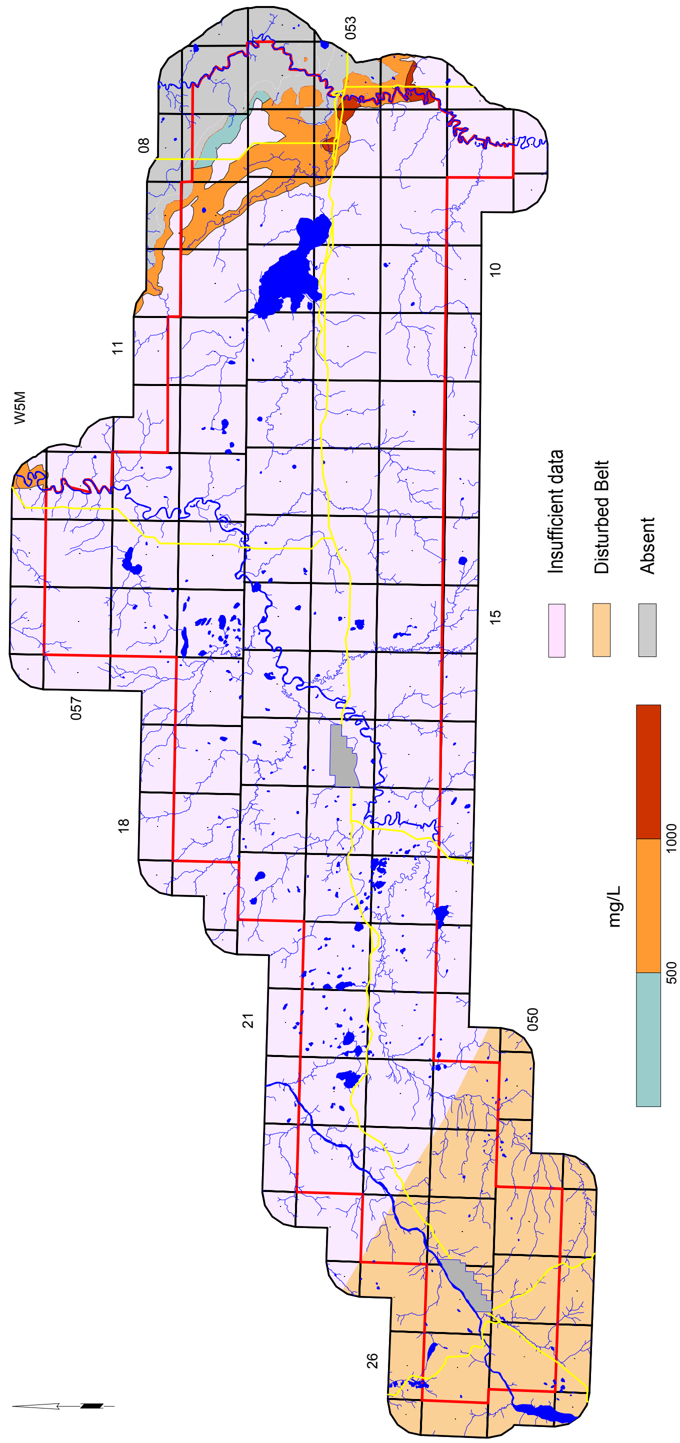
Depth to Top of Haynes Member



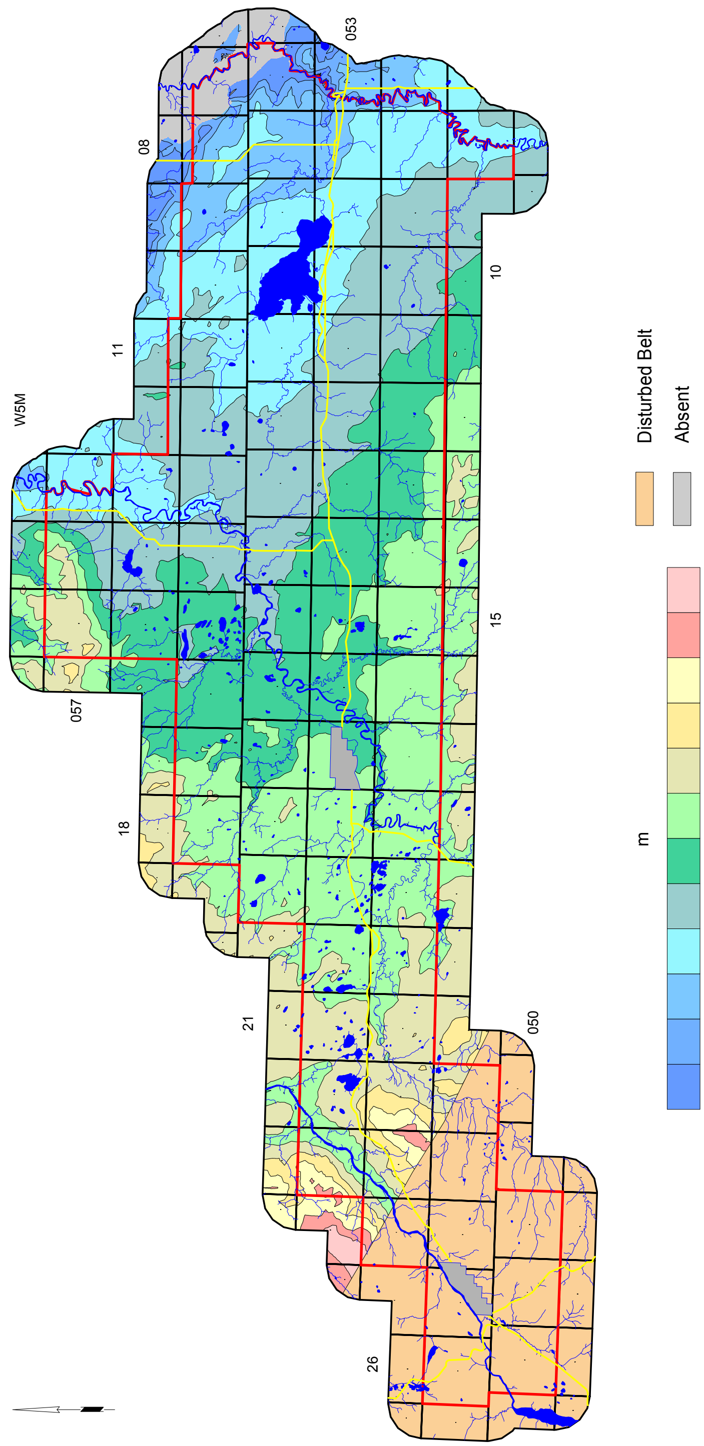
Apparent Yield for Water Wells Completed through Haynes Aquifer



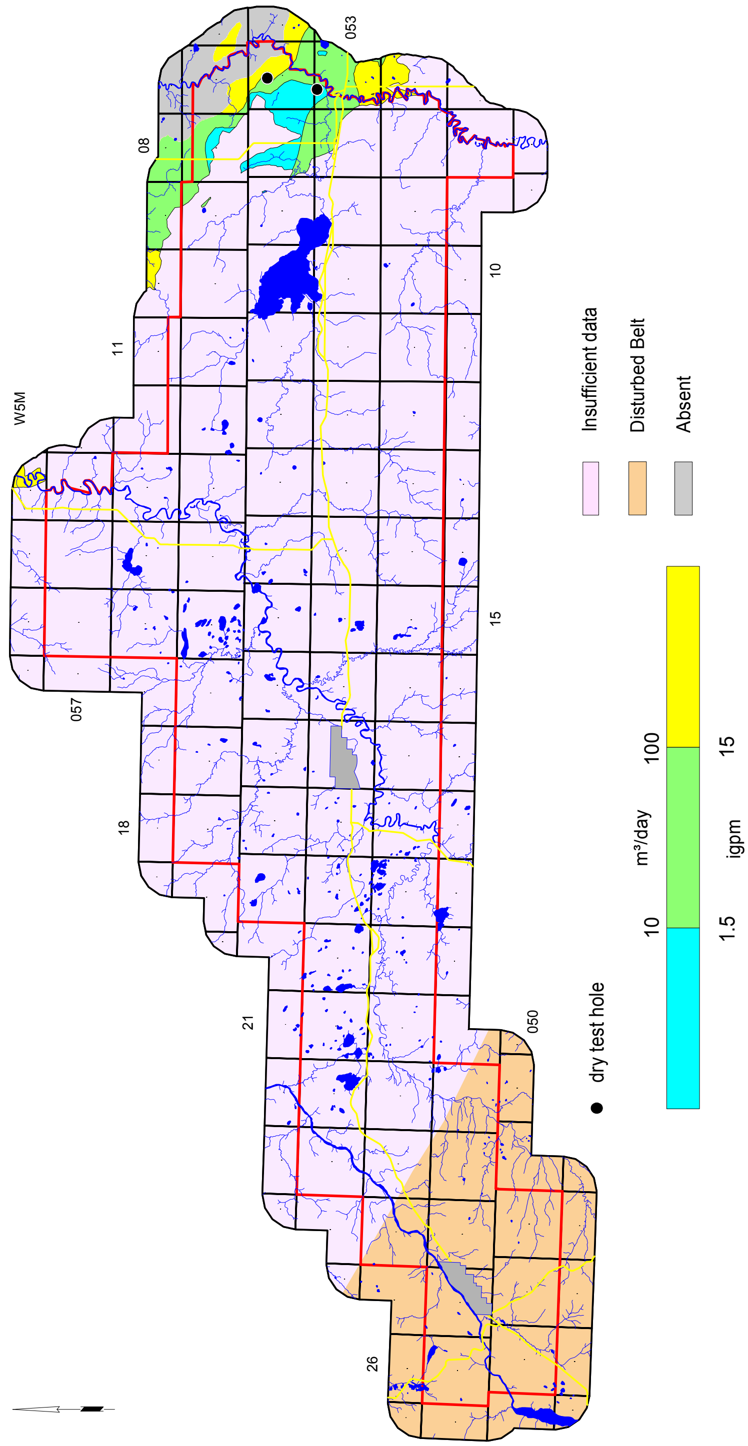
Total Dissolved Solids in Groundwater from Haynes Aquifer



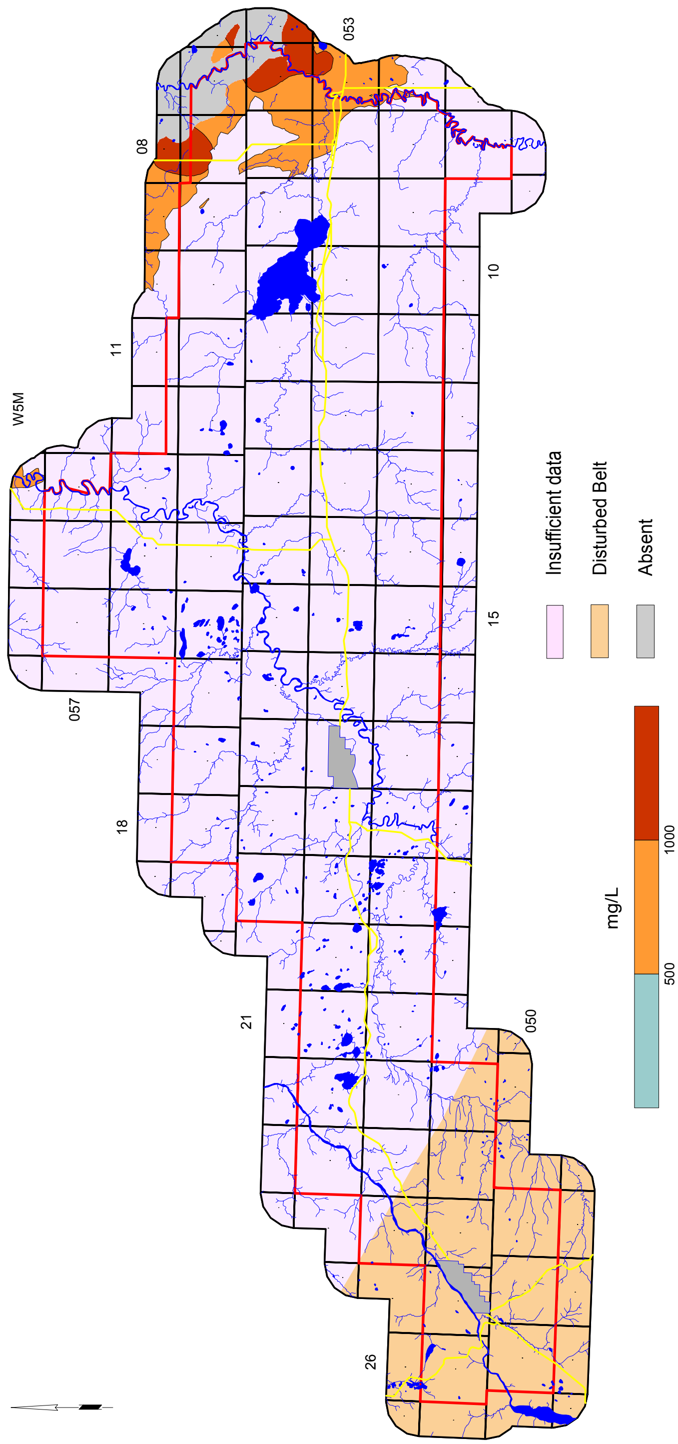
Depth to Top of Upper Scollard Formation



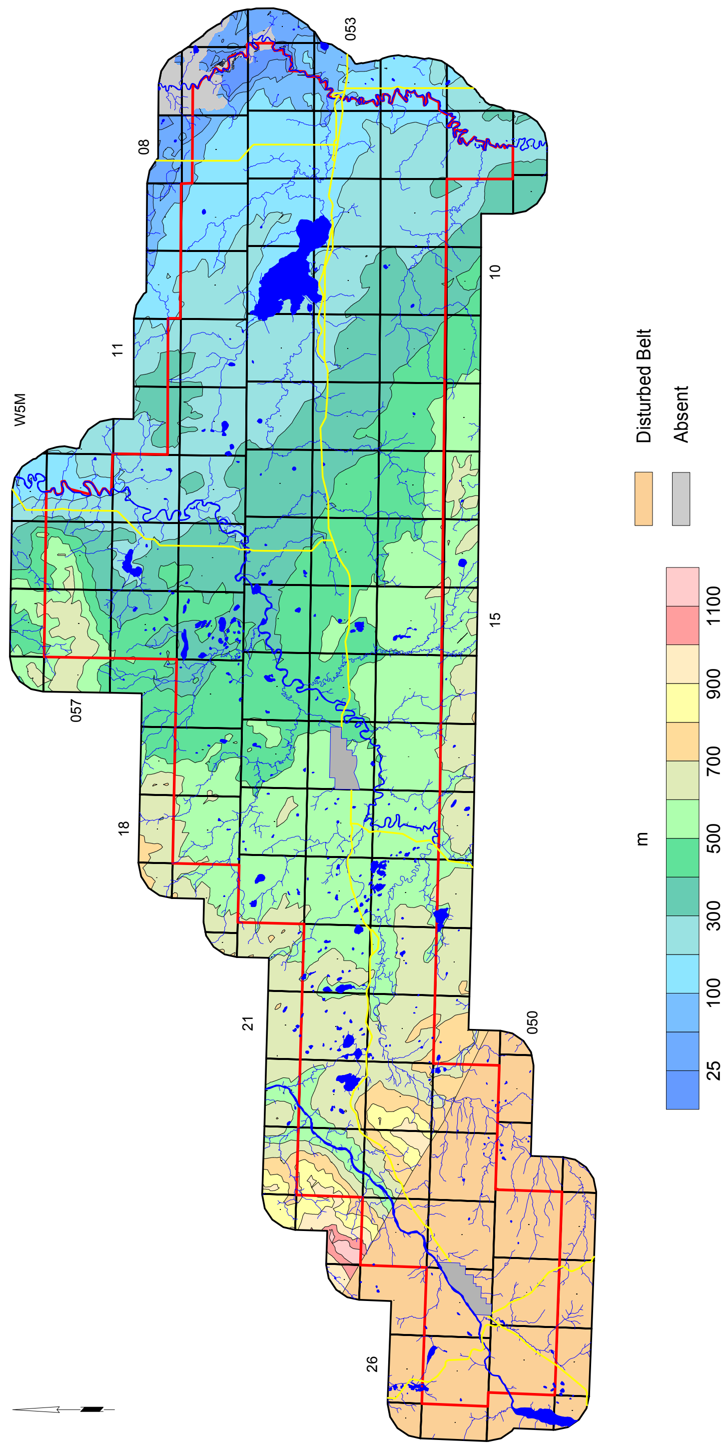
Apparent Yield for Water Wells Completed through Upper Scollard Aquifer



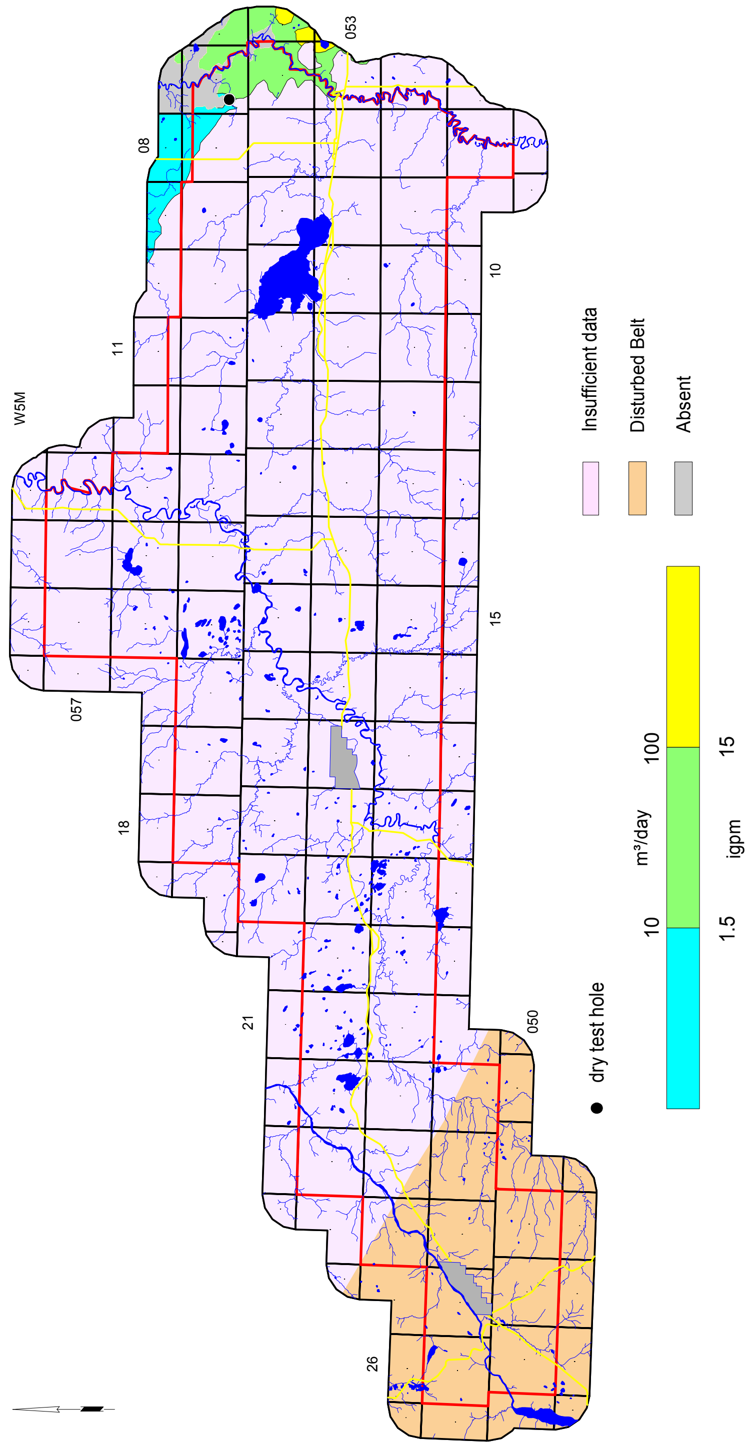
Total Dissolved Solids in Groundwater from Upper Scollard Aquifer



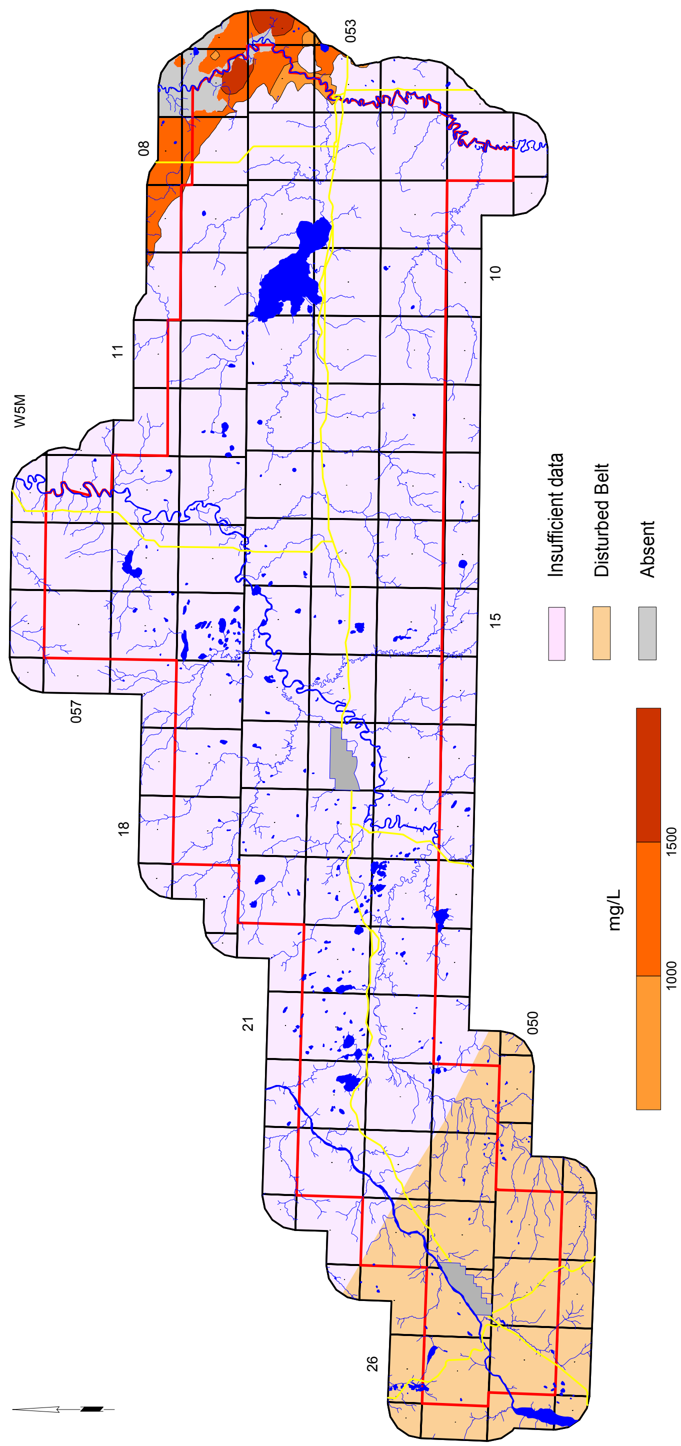
Depth to Top of Lower Scollard Formation



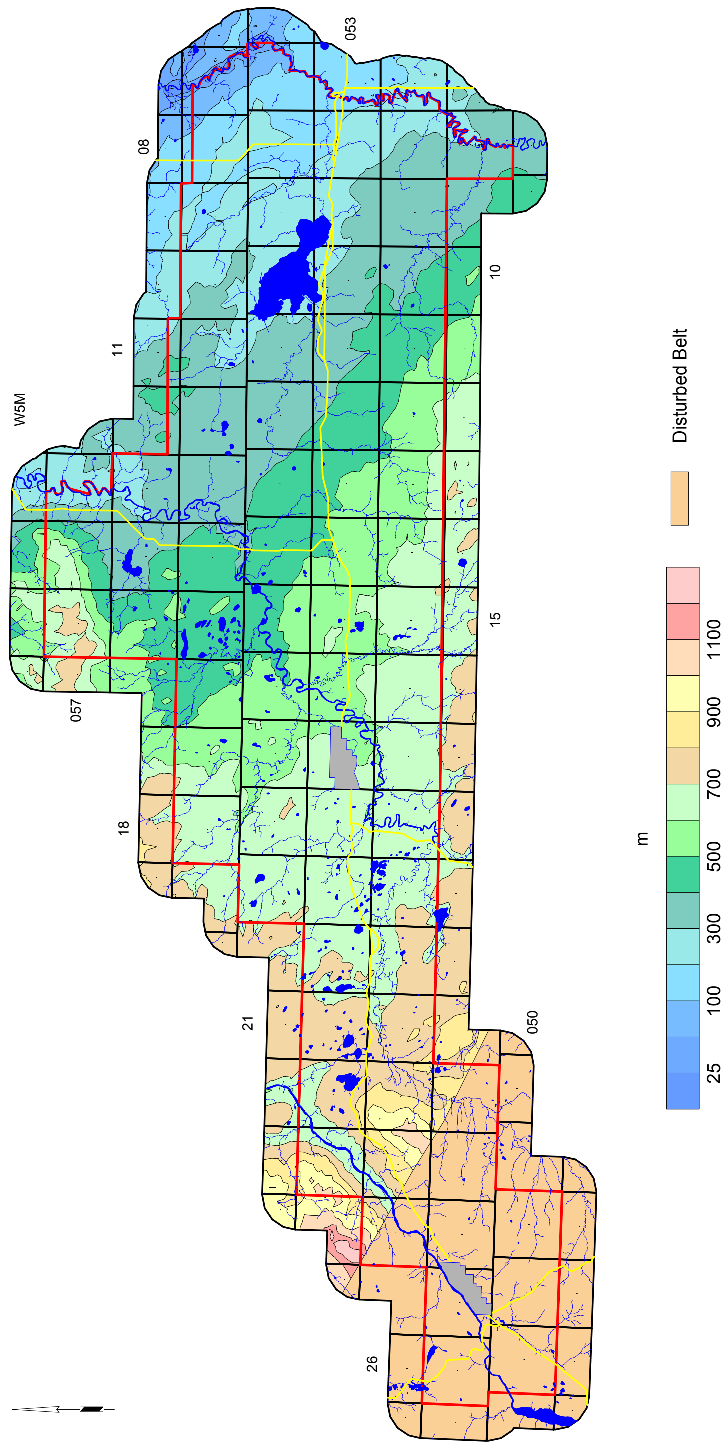
Apparent Yield for Water Wells Completed through Lower Scollard Aquifer



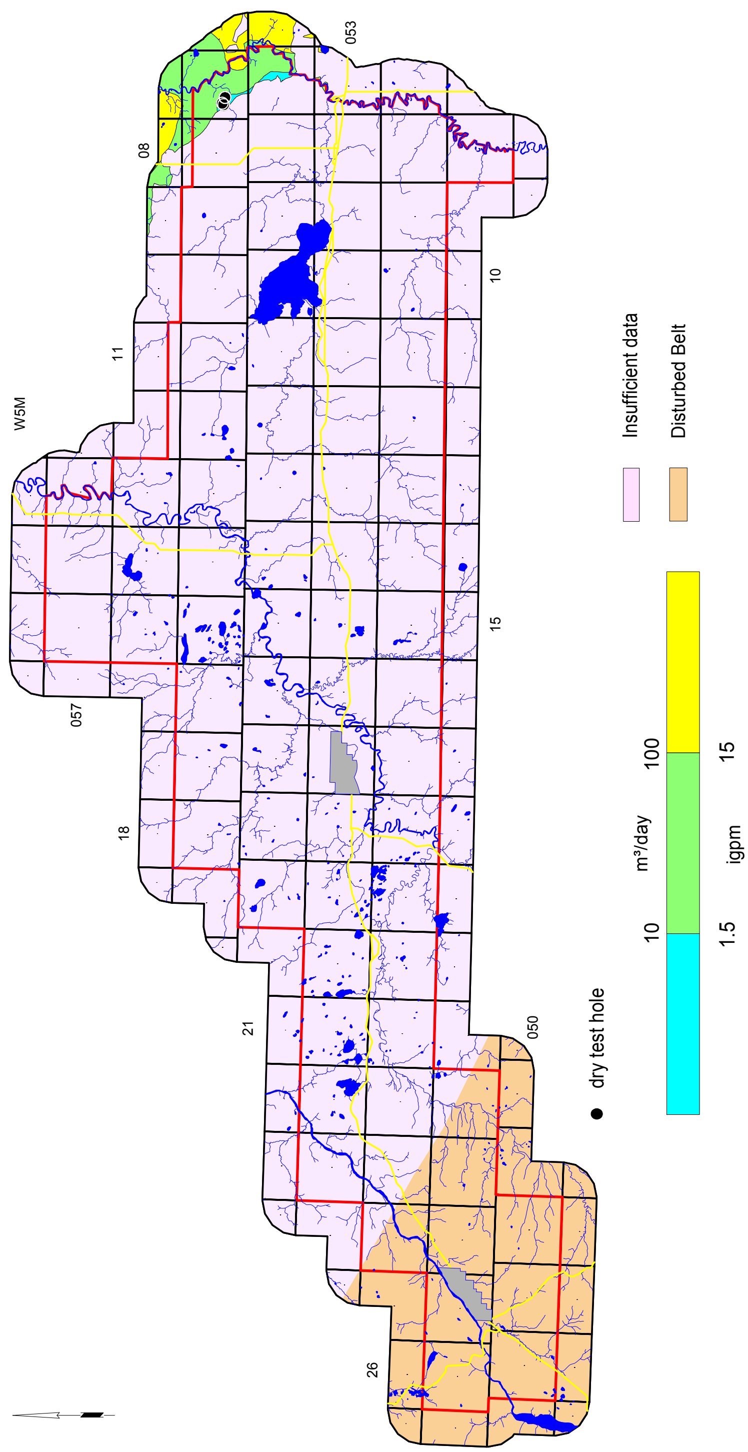
Total Dissolved Solids in Groundwater from Lower Scollard Aquifer



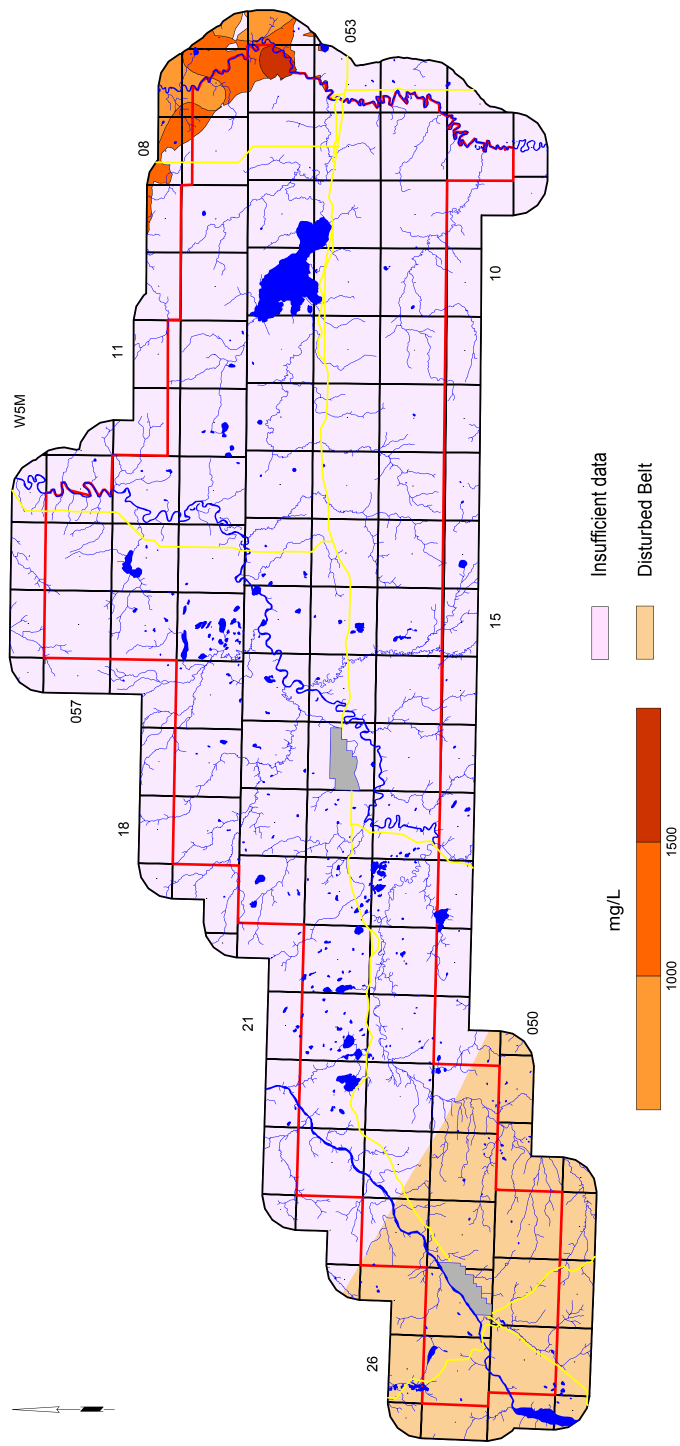
Depth to Top of Upper Horseshoe Canyon Formation



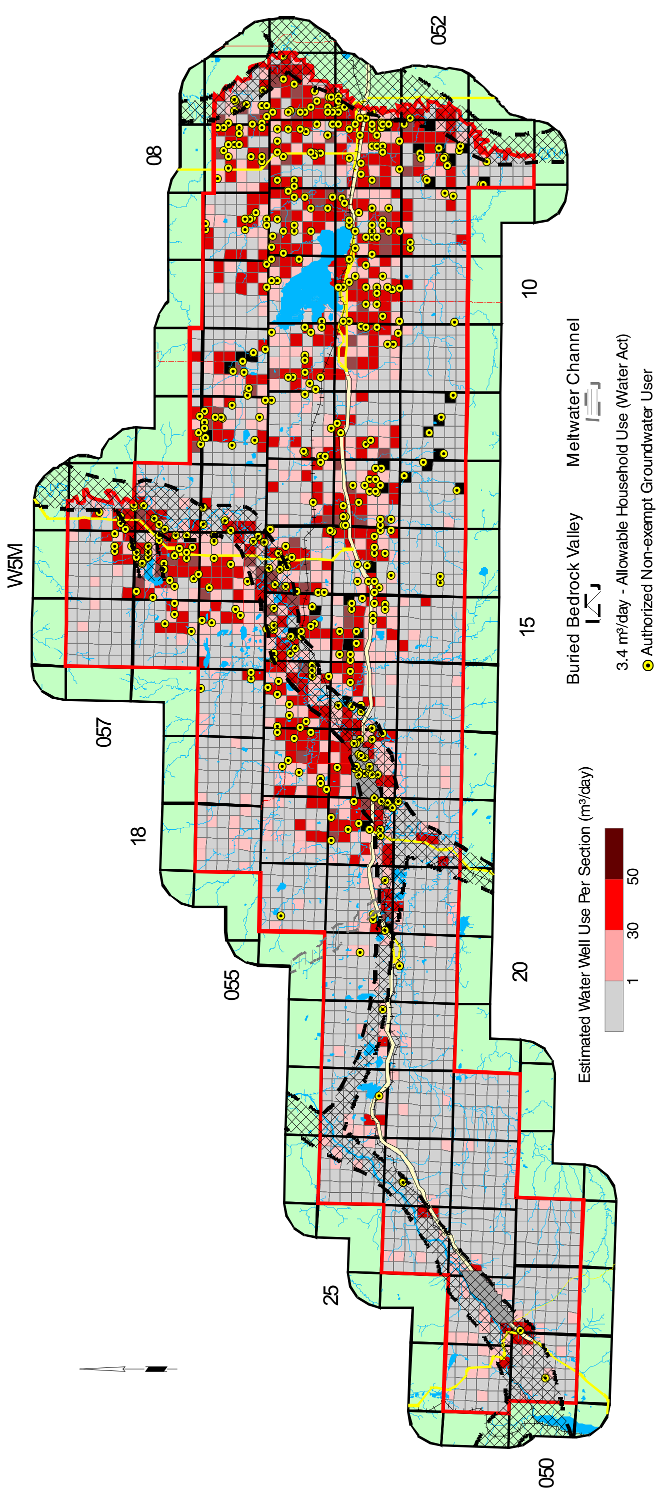
Apparent Yield for Water Wells Completed through Upper Horseshoe Canyon Aquifer



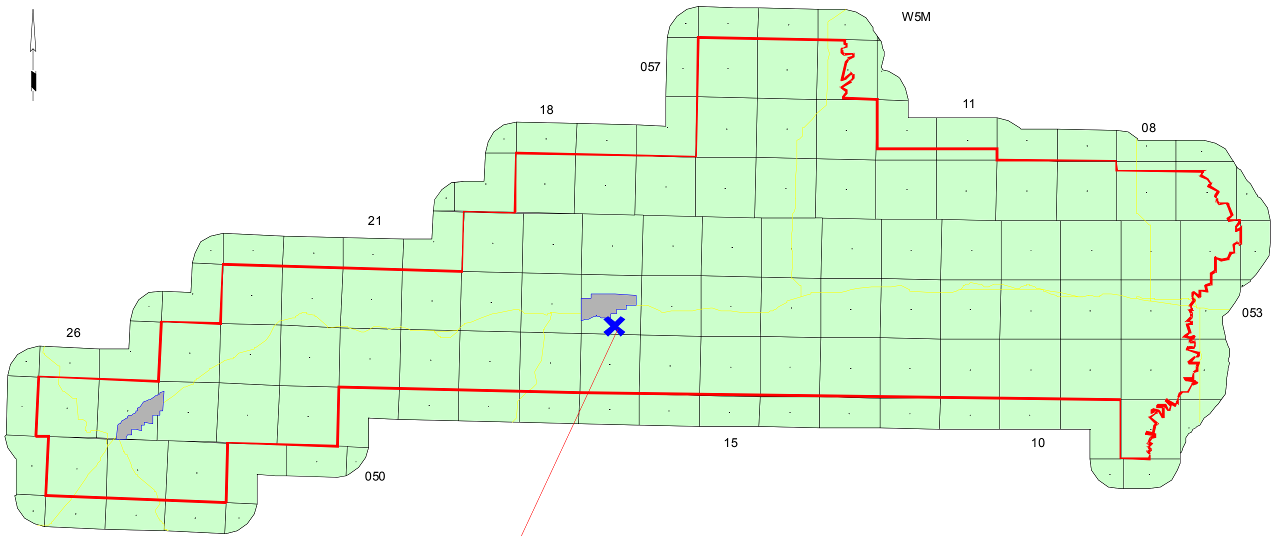
Total Dissolved Solids in Groundwater from Upper Horseshoe Canyon Aquifer

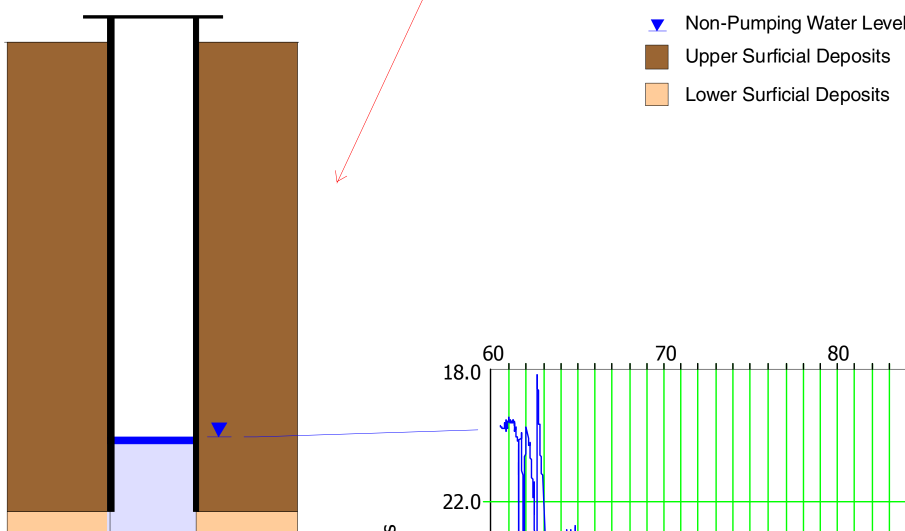


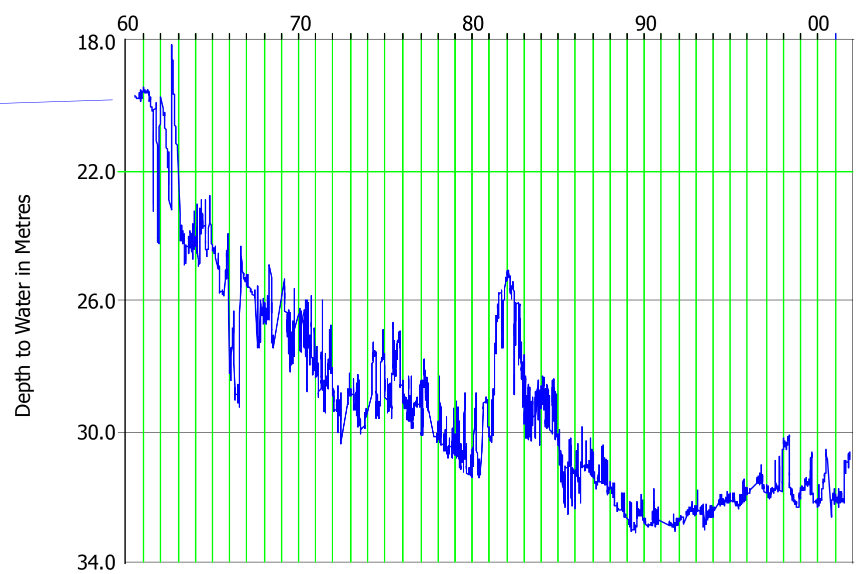
Estimated Water Well Use Per Section



AENV Observation Water Well



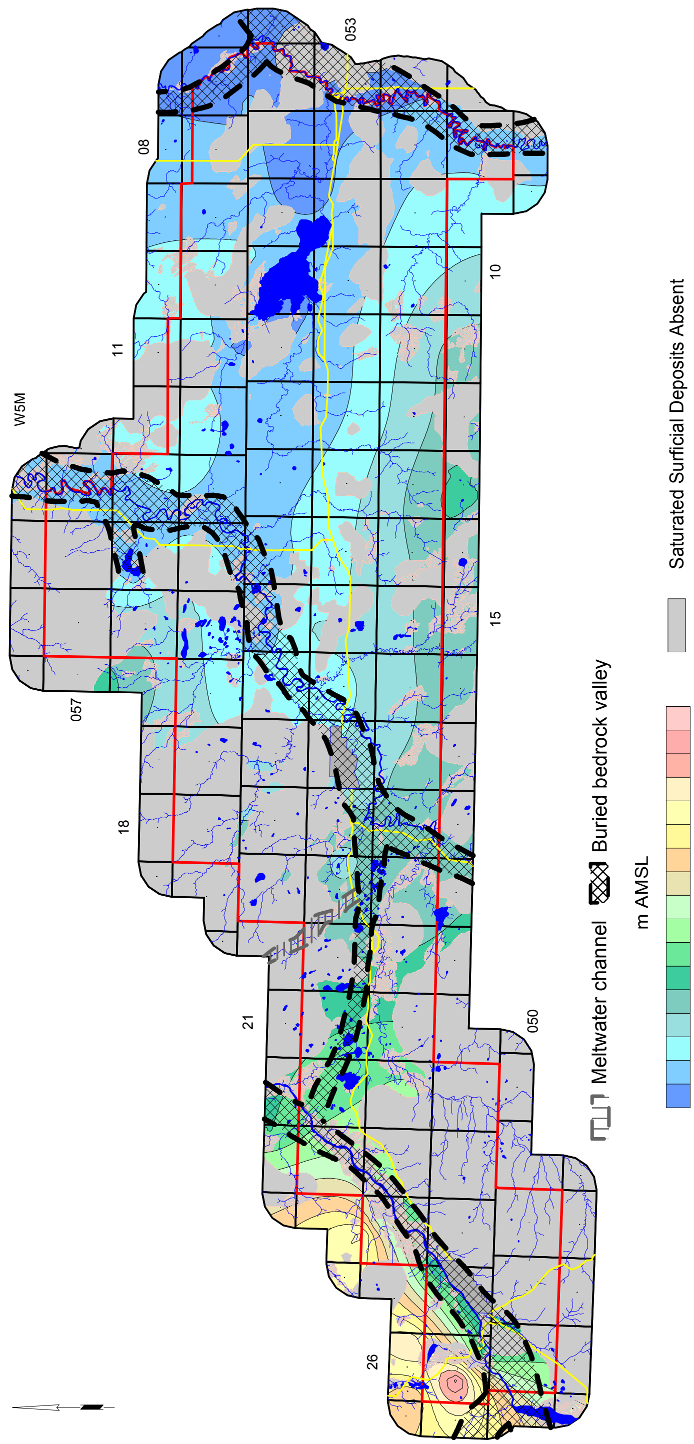




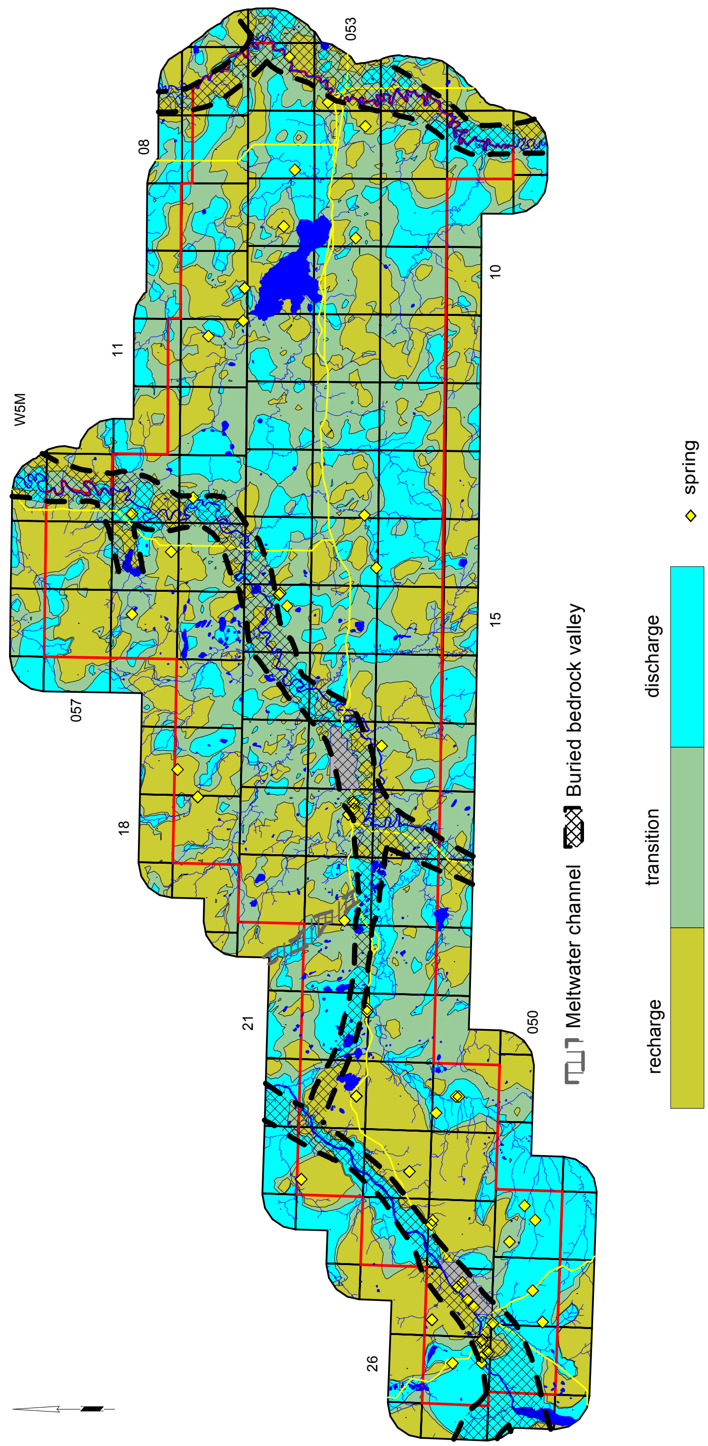
M35379.077830 - AENV Obs Well: Edson

Water-Level Measurement

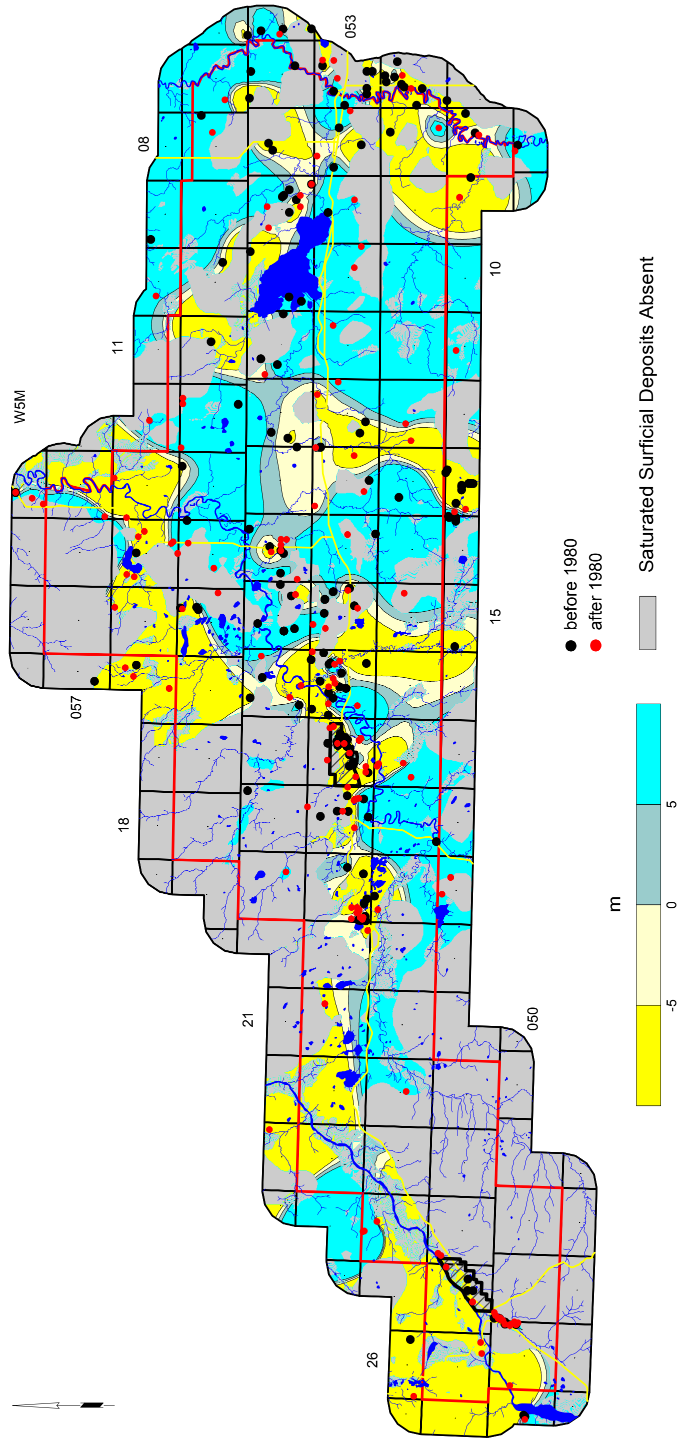
Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep



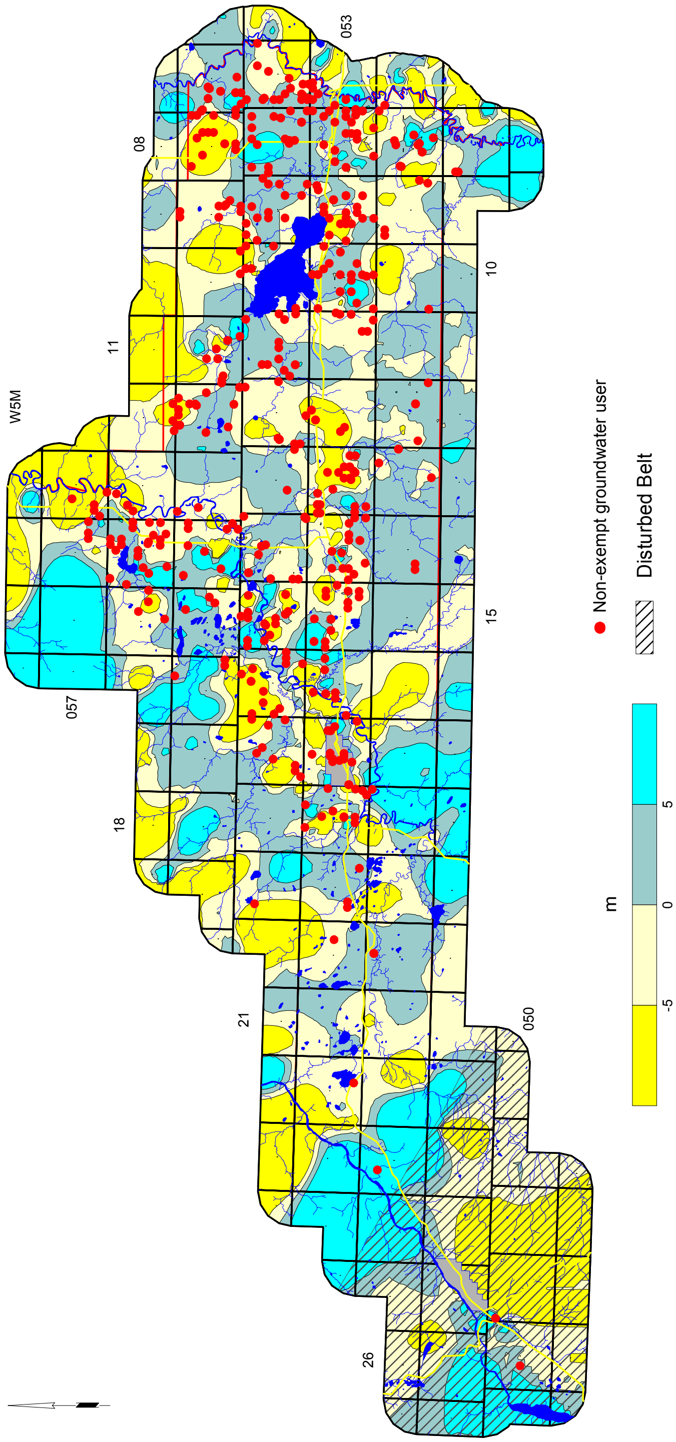
Bedrock Recharge/Discharge Areas



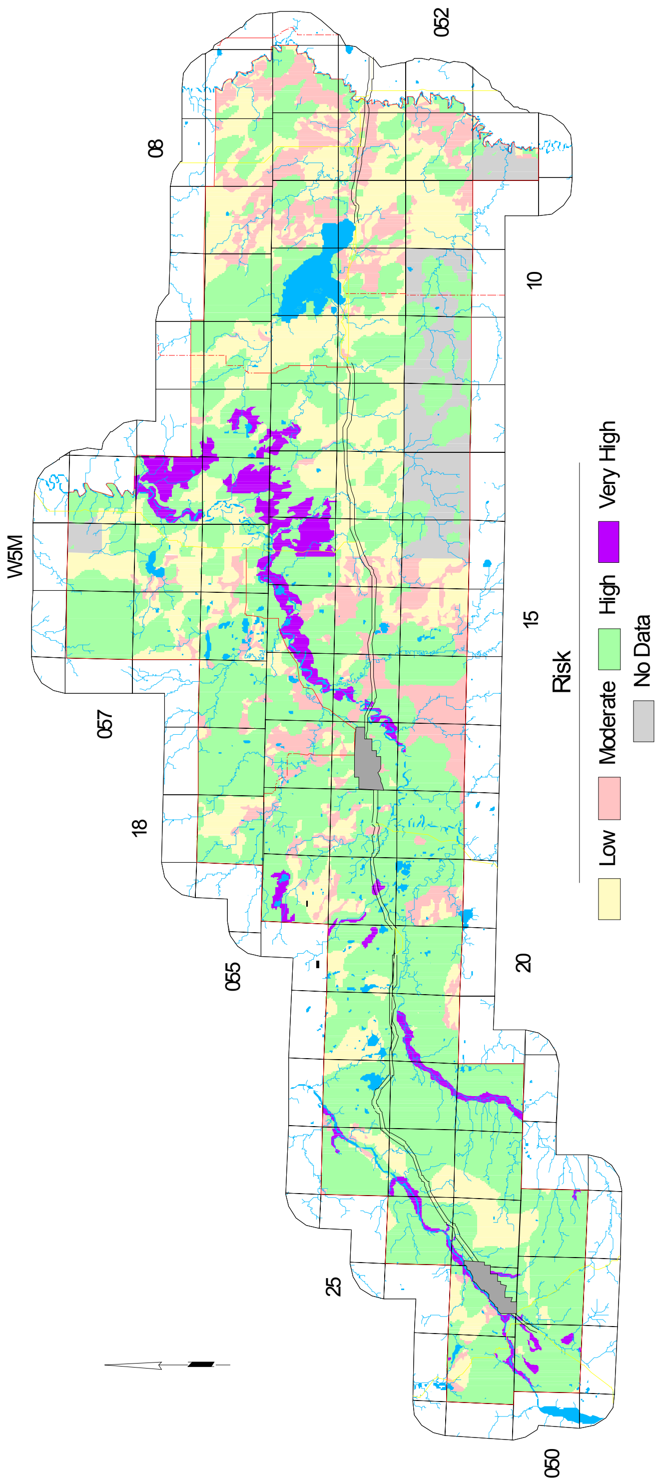
Changes in Water Levels in Surficial Deposits



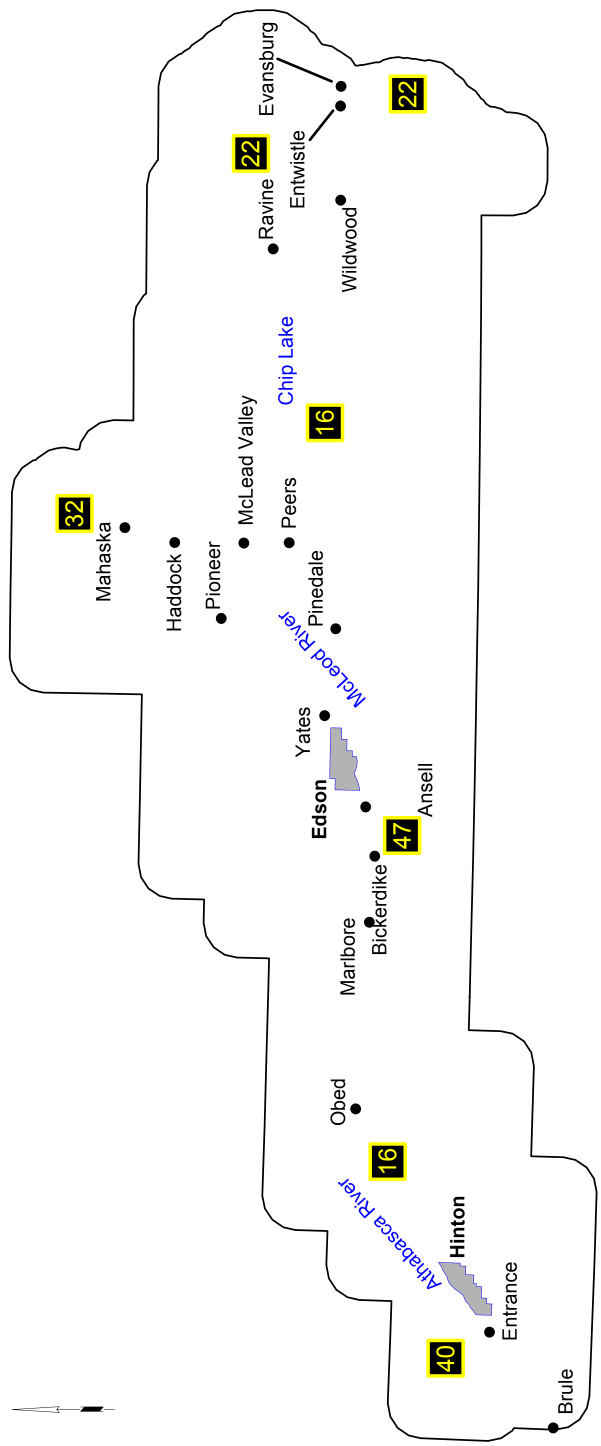
Areas of Potential Groundwater Depletion - Upper Bedrock Aquifer(s)



Risk of Groundwater Contamination



Overlay


Evansburg
22
Entwistle
22
Ravine
Wildwood
Chip Lake
16
McLead Valley
Peers
32
Mahaska
Haddock
Pioneer
Pinedale
McLeod River
Yates
Edson
Ansell
47
Bickerdike
Marlbore
Obed
16
Athabasca River
Hinton
Entrance
40
Brule

YELLOWHEAD COUNTY
Appendix B

Maps and Figures on CD-ROM

PROPOSED MAPS AND FIGURES ON CD-ROM

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A02 Surface Topography
A03 Surface Casing Types used in Drilled Water Wells
A04 Location of Water Wells and Springs
A05 Minimum Depth of Existing Water Wells
A06 Maximum Depth of Existing Water Wells
A07 Difference Between the Maximum and Minimum Depth of Existing Water Wells
A08 Depth to Base of Groundwater Protection
A09 Hydrogeological Maps
A10 Generalized Cross-Section (for terminology only)
A11 Geologic Column
A12 Cross-Section A - A'
A13 Cross-Section B - B'
A14 Cross-Section C - C'
A15 Cross-Section D - D'
A16 Cross-Section E - E'
A17 Cross-Section F - F'
A18 Bedrock Topography
A19 Bedrock Geology
A20 Relative Permeability
A21 Risk of Groundwater Contamination
A22 Authorized Non-Exempt Groundwater Water Wells
A23 Estimated Water Well Use per Section
A24 Water Wells Recommended for Field Verification

2) Surficial Aquifers

a) Surficial Deposits

B01 Thickness of Surficial Deposits
B02 Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep
B03 Total Dissolved Solids in Groundwater from Surficial Deposits
B04 Sulfate in Groundwater from Surficial Deposits
B05 Nitrate + Nitrite (as N) in Groundwater from Surficial Deposits
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b) First Sand and Gravel

B15 Thickness of First Sand and Gravel

c) Upper Sand and Gravel

B16 Thickness of Upper Surficial Deposits
B17 Thickness of Upper Sand and Gravel (not all drill holes fully penetrate surficial deposits)
B18 Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

d) Lower Sand and Gravel

B19 Structure-Contour Map - Top of Lower Sand and Gravel Deposits
B20 Depth to Top of Lower Sand and Gravel Deposits
B21 Thickness of Lower Sand and Gravel Deposits
B22 Apparent Yield for Water Wells Completed through Lower Sand and Gravel Aquifer
B23 Non-Pumping Water-Level Surface in Lower Sand and Gravel Aquifer

3) Bedrock Aquifers

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b) Disturbed Belt

c) Dalehurst Member

d) Upper Lacombe Member

YELLOWHEAD COUNTY
Appendix C

General Water Well Information

Domestic Water Well Testing

Purpose and Requirements

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

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

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

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

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

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

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

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

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

Procedure

Site Diagrams

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

Surface Details

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

Groundwater Discharge Point

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

Water-Level Measurements

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

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

Discharge Measurements

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

Water Samples

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

Water Act - Water (Ministerial) Regulation

PROVINCE OF ALBERTA

WATER ACT

WATER (MINISTERIAL) REGULATION

Alberta Regulation 205/98

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ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

Table of Contents

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
Rob George (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)

FARMERS ADVOCATE
Dean Lien (Edmonton: 780-427-2433)

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

Curtis Snell (Westlock: 780-349-3963) - snellc@em.agr.ca
Tony Cowen (Edmonton: 780-495-4911) - cownent@agr.gc.ca

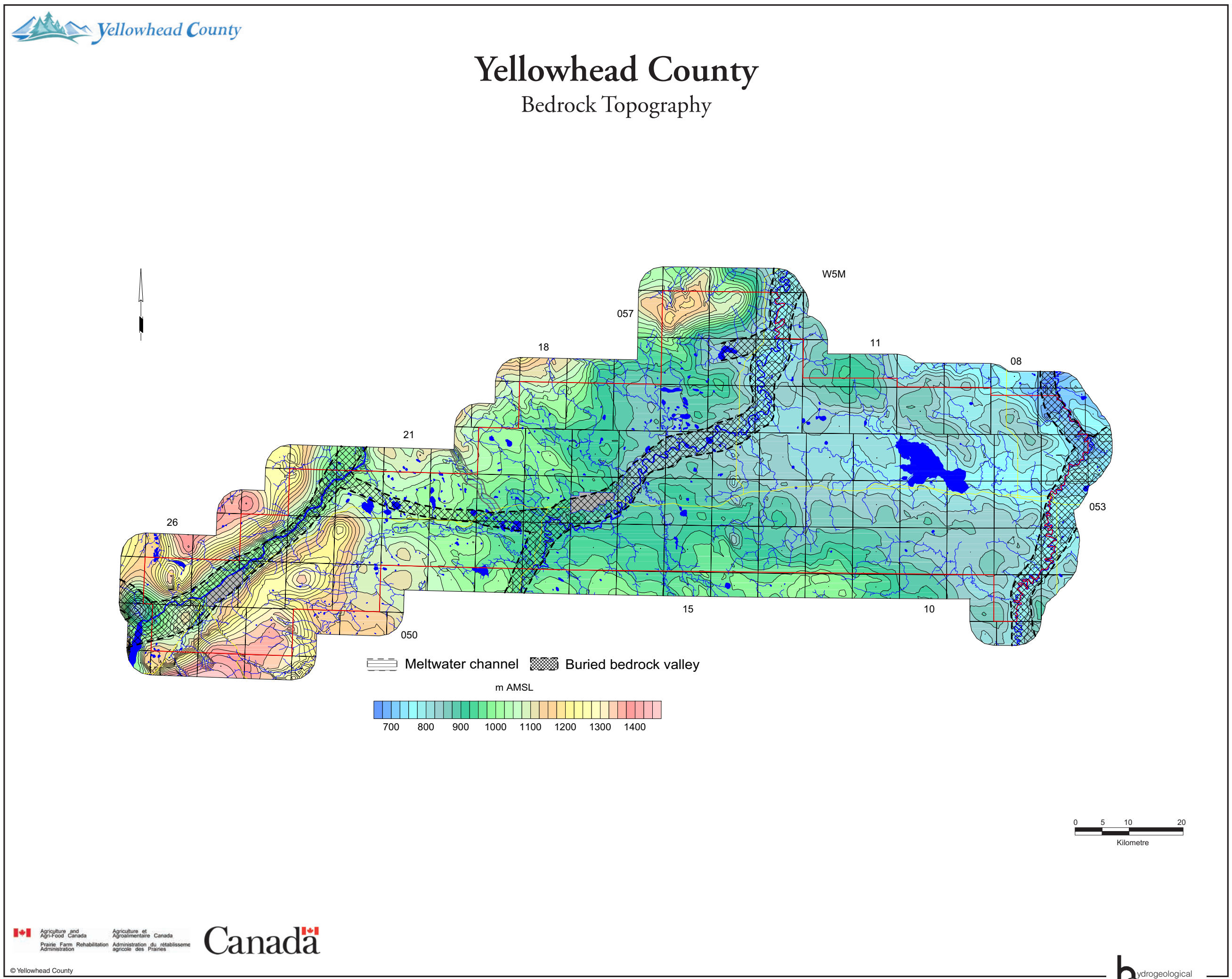
WILDROSE COUNTRY GROUND WATER MONITORING ASSOCIATION
Dave Andrews (Irricana: 403-935-4478)

LOCAL HEALTH DEPARTMENTS

YELLOWHEAD COUNTY
Appendix D

Maps and Figures Included as Large Plots

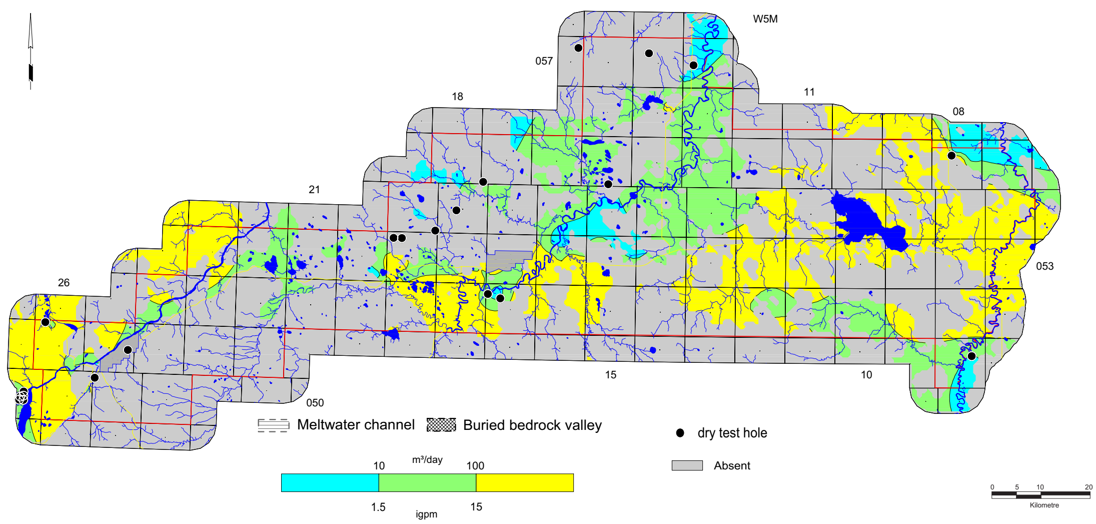
Bedrock Topography



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

Yellowhead County

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



GROUNDWATER CONSUMPTION

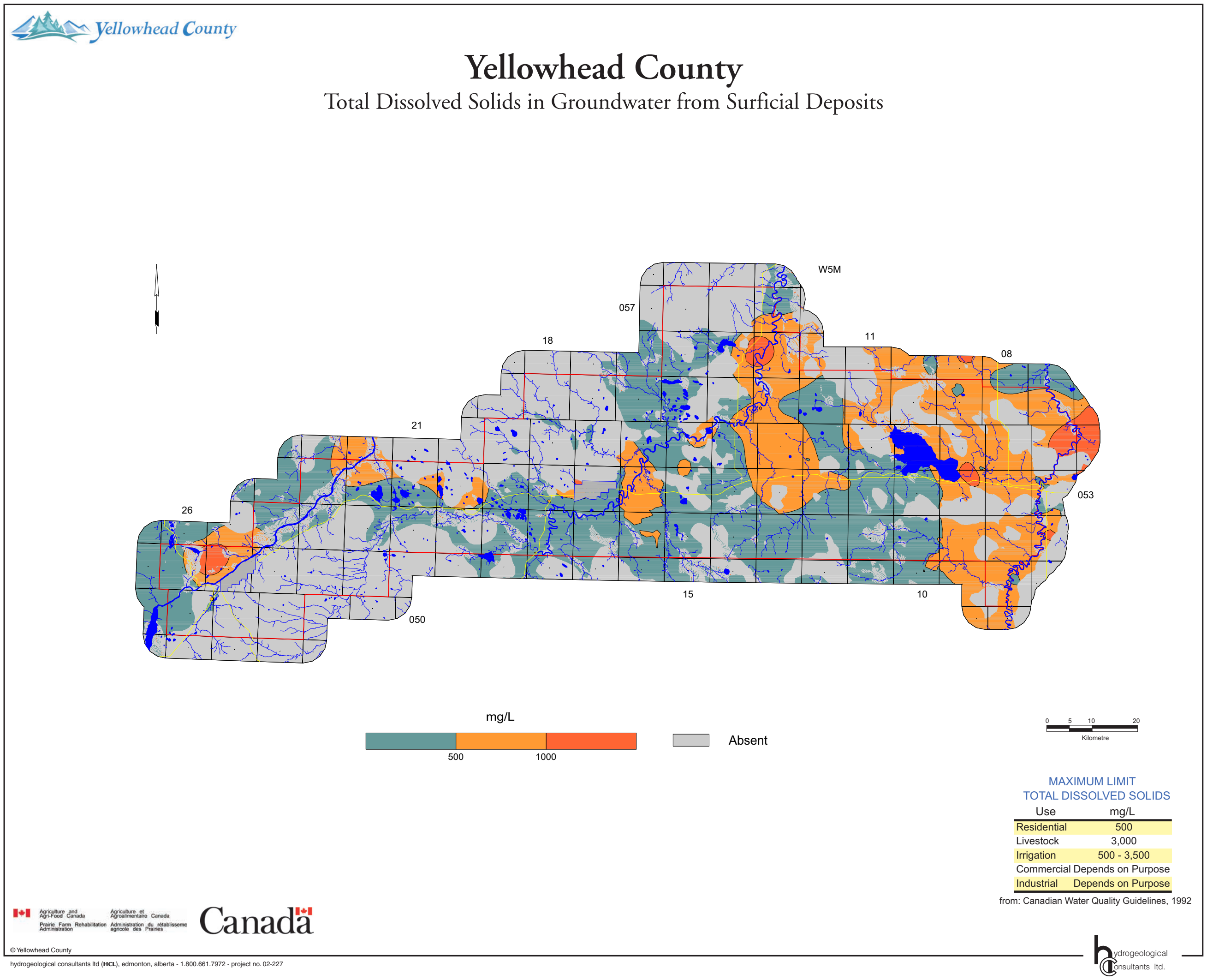
Groundwater Purpose[3]	Lower Limit (m³/day)	Upper Limit (m³/day)
Residential[1]	1.1	3.4
Multi Parcel[1]	1.1	3.4
Commercial	1	max. available
Light Industrial	1	max. available
Agricultural[2]	17.1	max. available

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

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

hydrogeological consultants ltd (HCL), edmonton, alberta - 1.800.661.7972 - project no. 02-227

Total Dissolved Solids in Groundwater from Surficial Deposits



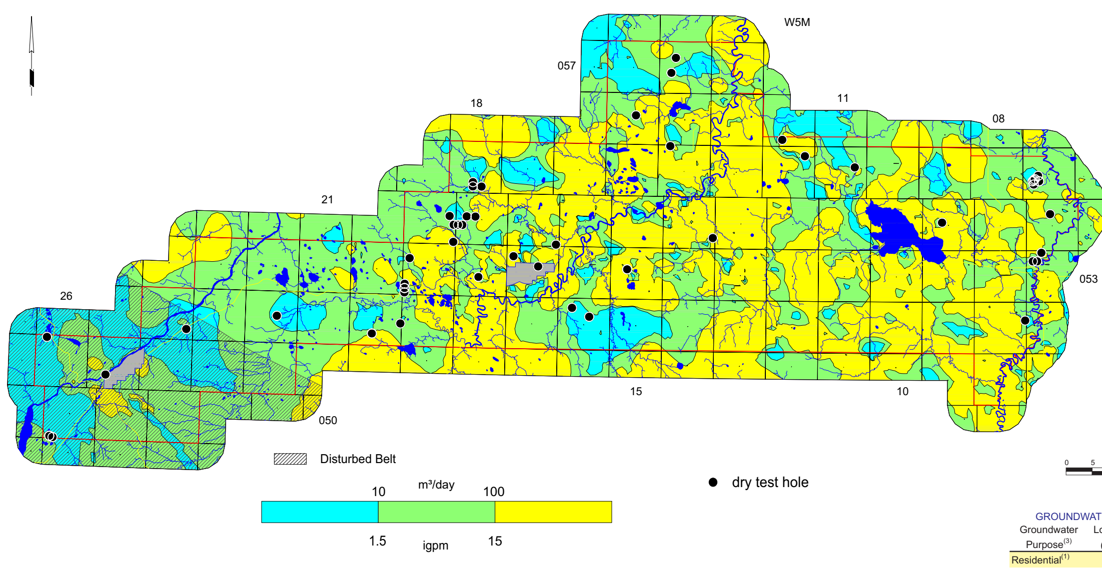
Use	mg/L
Residential	500
Livestock	3,000
Irrigation	500 - 3,500
Commercial	Depends on Purpose
Industrial	Depends on Purpose

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

Yellowhead County

Yellowhead County

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



GROUNDWATER CONSUMPTION

Groundwater Purpose[3]	Lower Limit (m^3/day)	Upper Limit (m^3/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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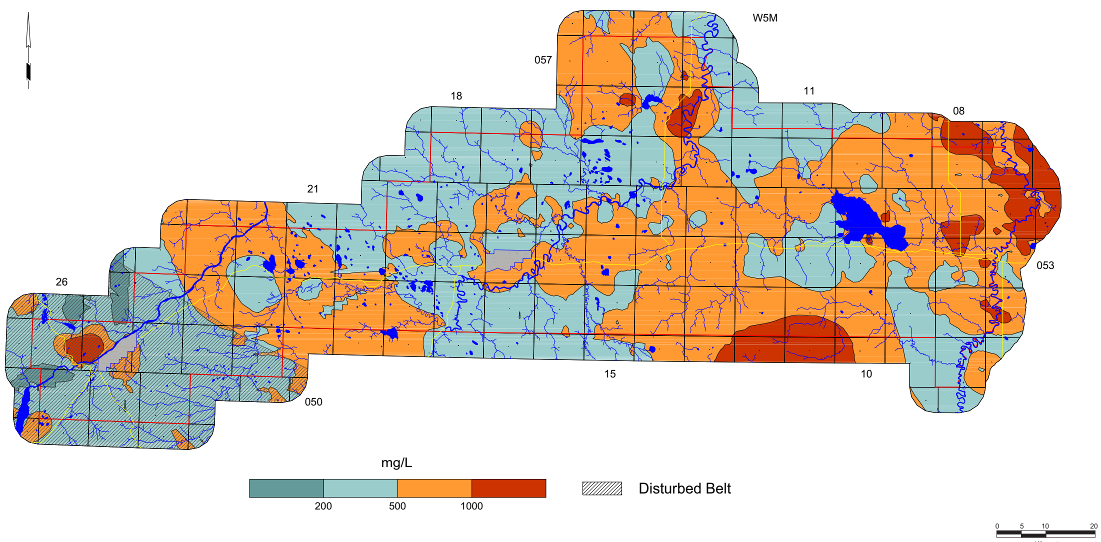
Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

Yellowhead County

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



MAXIMUM LIMIT
TOTAL DISSOLVED SOLIDS

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

from: Canadian Water Quality Guidelines, 1992

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

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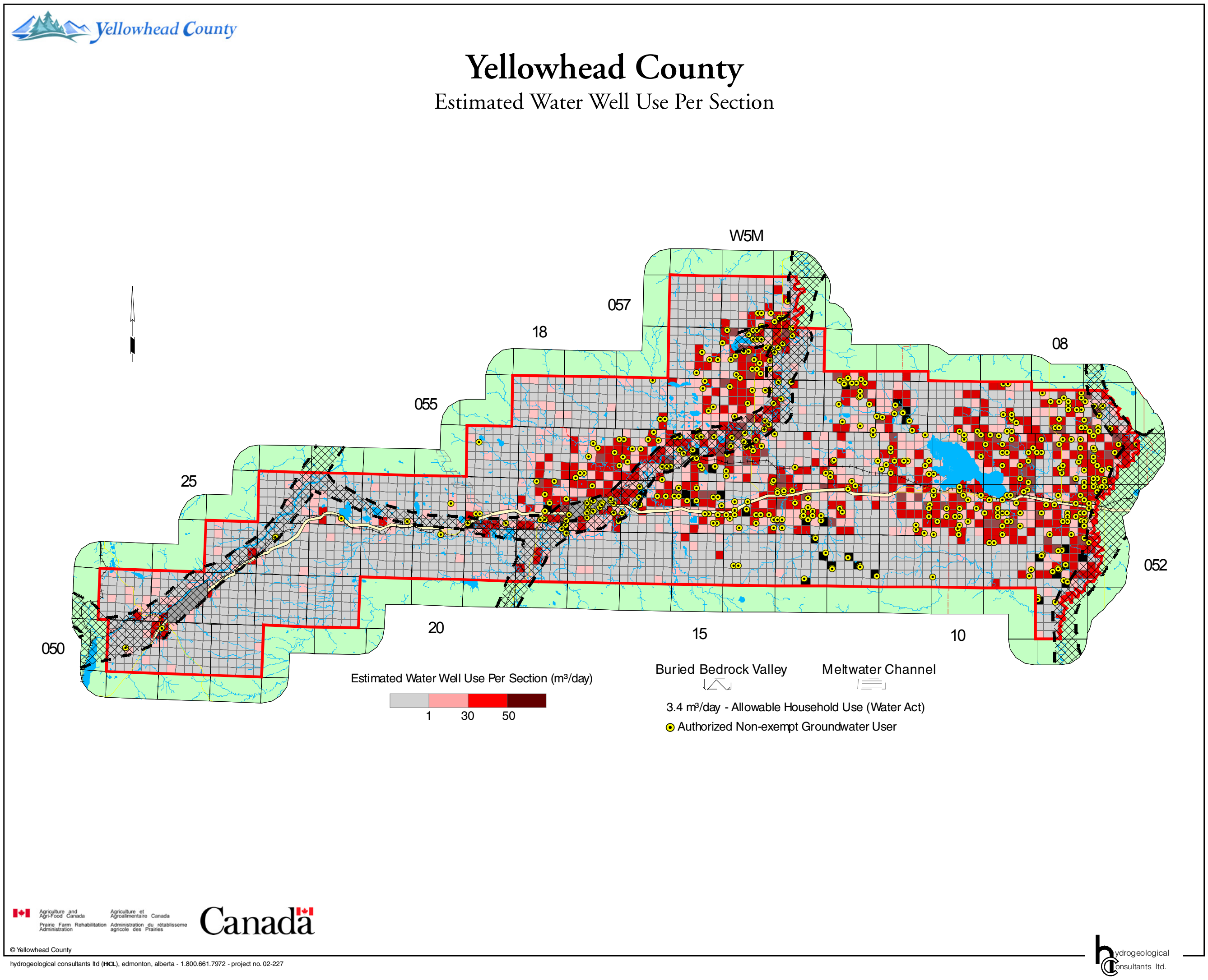
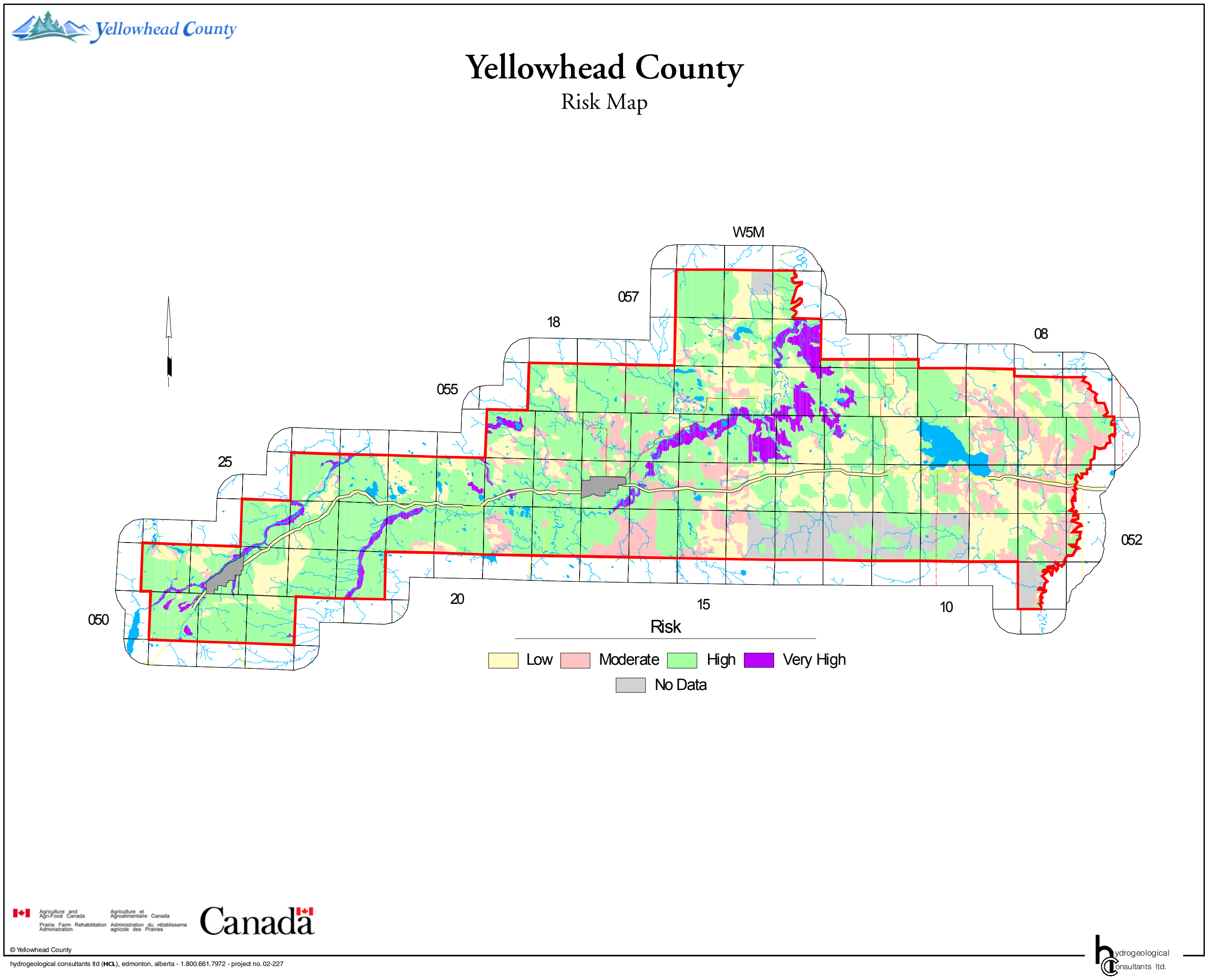
Estimated Water Well Use Per Section



Risk Map


Yellowhead County
Yellowhead County
Risk Map
W5M
057
18
08
055
25
052
050
20
15
10
Risk
Low
Moderate
High
Very High
No Data
Canada
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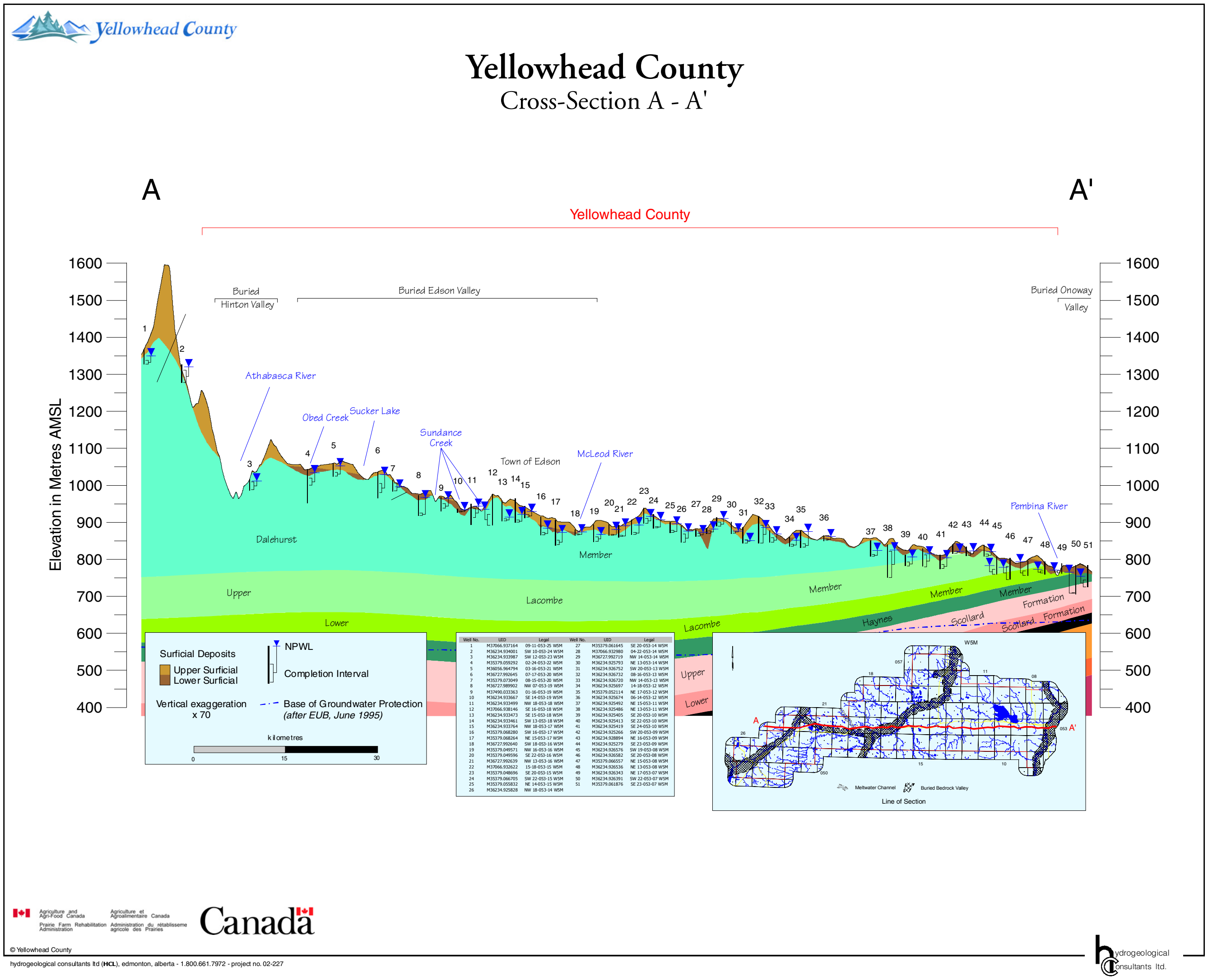
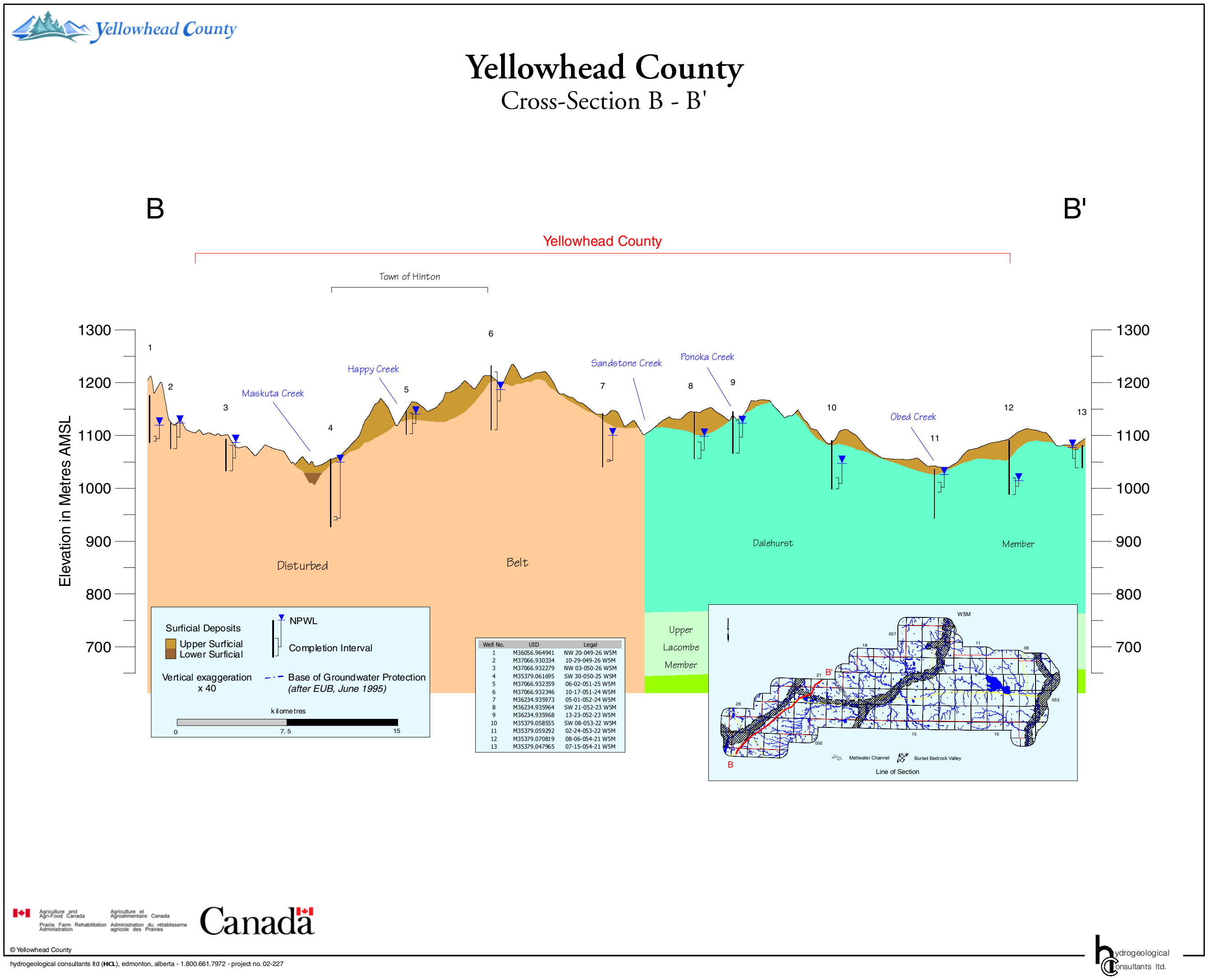
Cross-Section A - A'

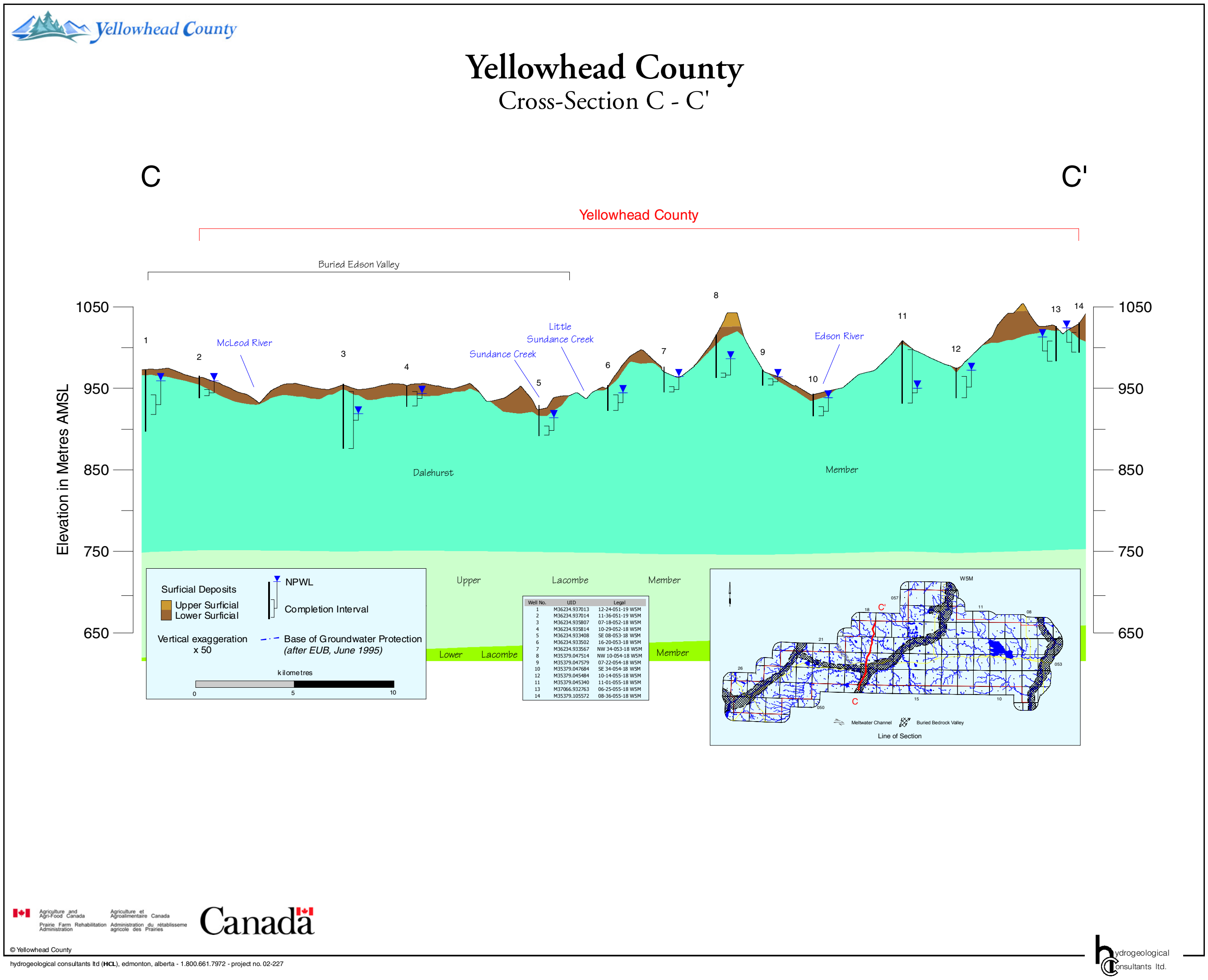


Cross-Section B - B'



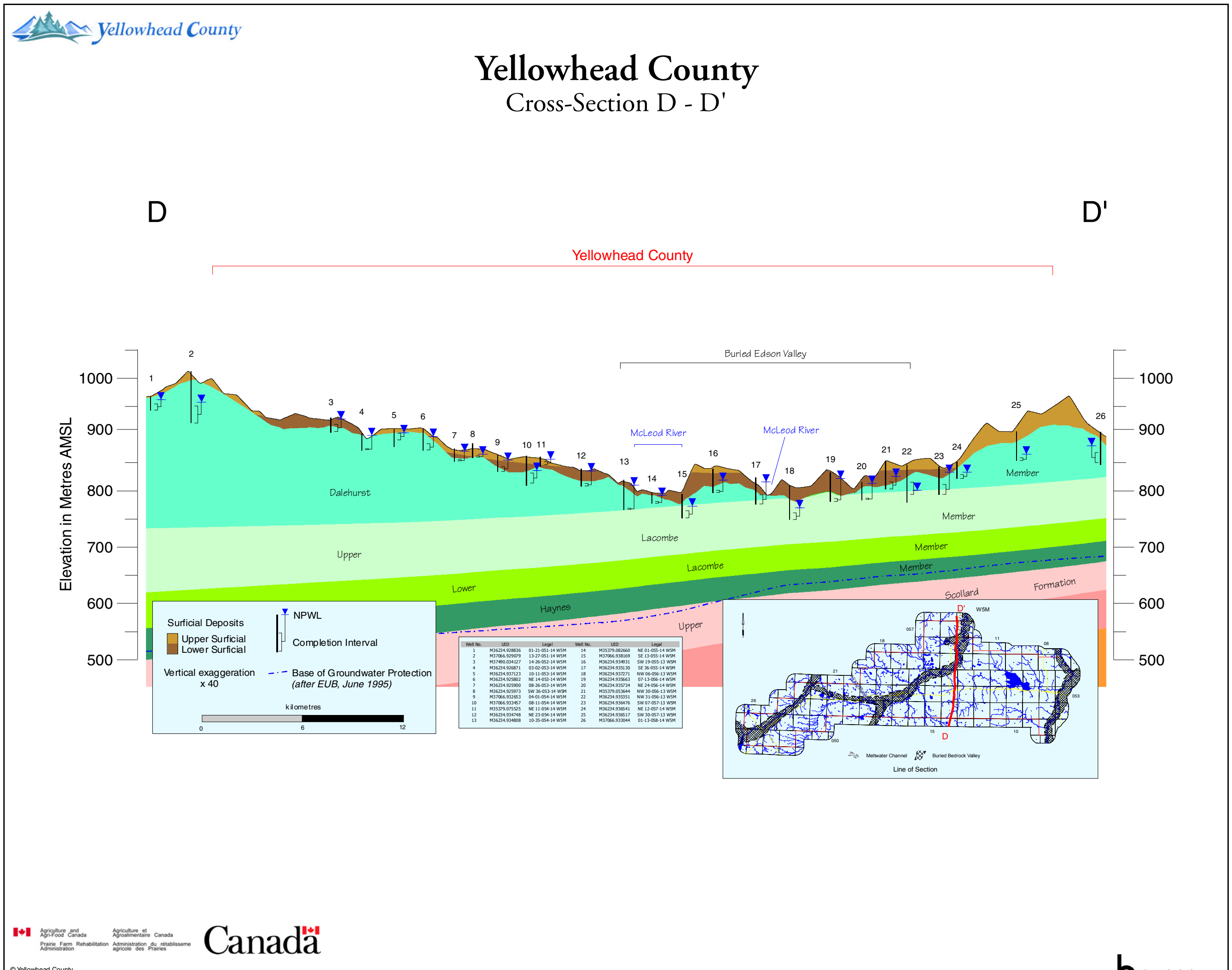
Well No.	UID	Legal
1	M36056.964941	NW 20-049-26 W5M
2	M37066.930334	10-29-049-26 W5M
3	M37066.932279	NW 03-050-26 W5M
4	M35379.061695	SW 30-050-25 W5M
5	M37066.932359	06-02-051-25 W5M
6	M37066.932346	10-17-051-24 W5M
7	M36234.935973	05-01-052-24 W5M
8	M36234.935964	SW 21-052-23 W5M
9	M36234.935968	13-23-052-23 W5M
10	M35379.058555	SW 08-053-22 W5M
11	M35379.059292	02-24-053-22 W5M
12	M35379.070819	08-06-054-21 W5M
13	M35379.047965	07-15-054-21 W5M

Cross-Section C - C'



Well No.	UID	Legal
1	M36234.937013	12-24-051-19 W5M
2	M36234.937014	11-36-051-19 W5M
3	M36234.935807	07-18-052-18 W5M
4	M36234.935814	10-29-052-18 W5M
5	M36234.933408	SE 08-053-18 W5M
6	M36234.933502	16-20-053-18 W5M
7	M36234.933567	NW 34-053-18 W5M
8	M35379.047514	NW 10-054-18 W5M
9	M35379.047579	07-22-054-18 W5M
10	M35379.047684	SE 34-054-18 W5M
12	M35379.045484	10-14-055-18 W5M
11	M35379.045340	11-01-055-18 W5M
13	M37066.932763	06-25-055-18 W5M
14	M35379.105572	08-36-055-18 W5M

Cross-Section D - D’



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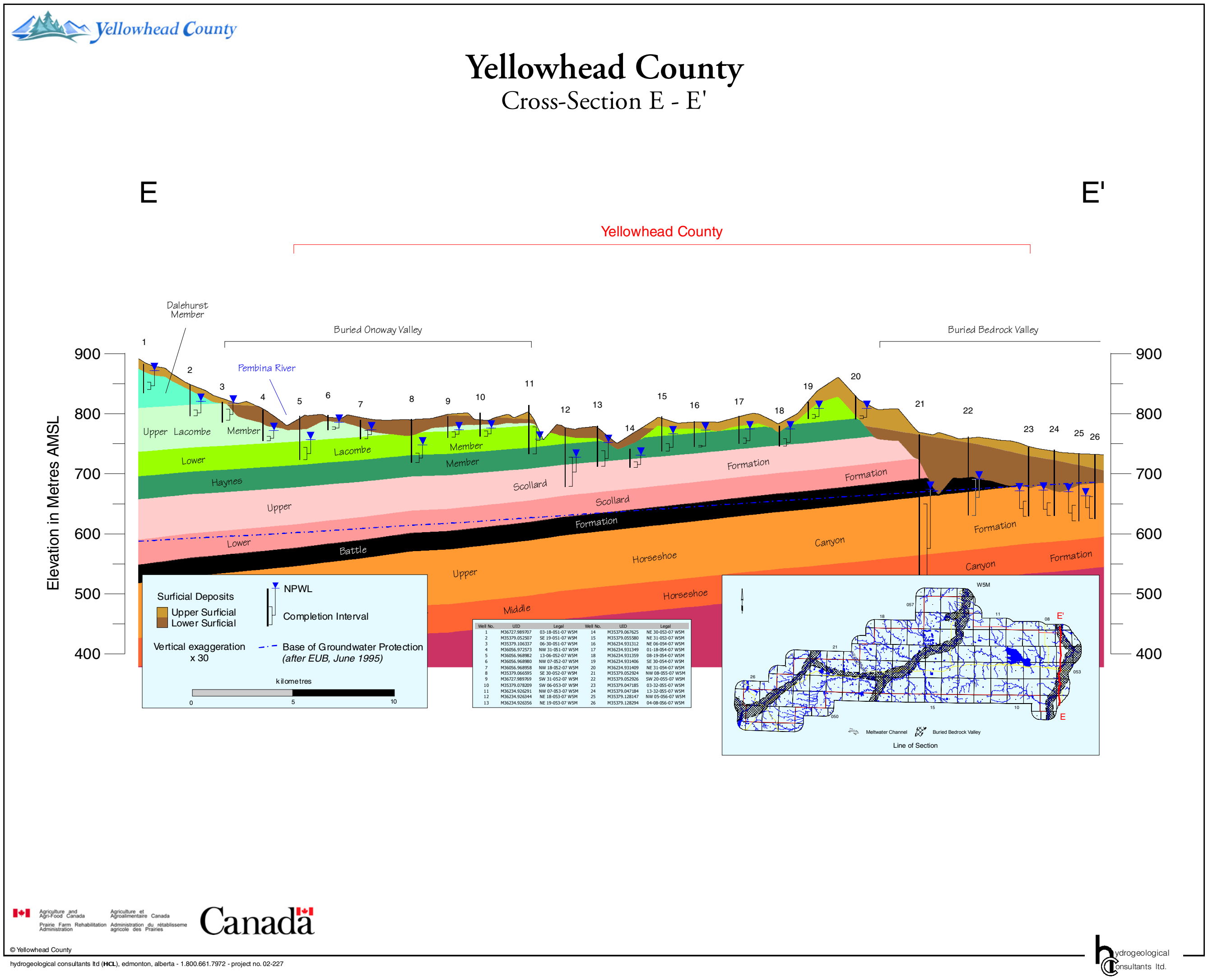
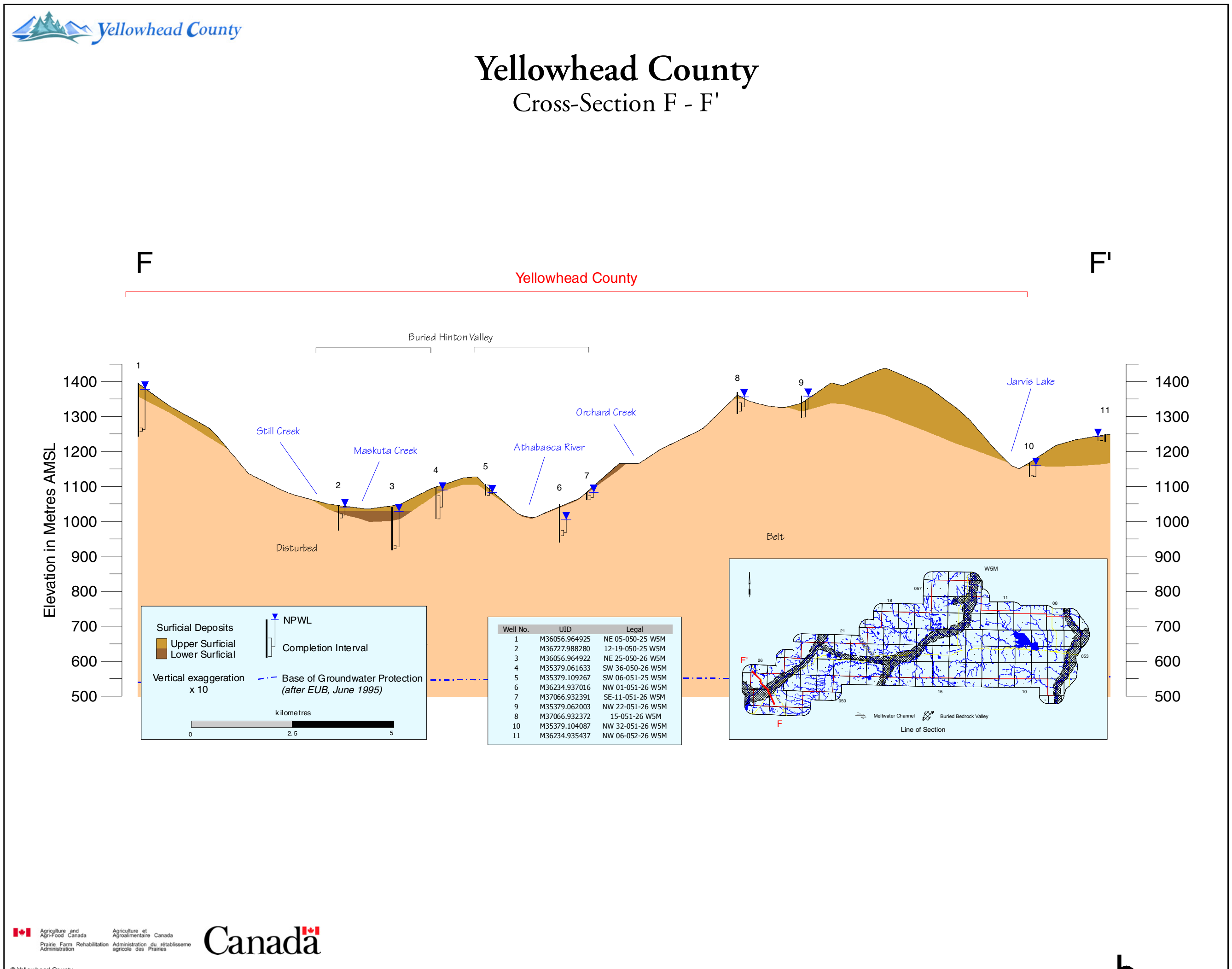
Cross-Section E - E'



Well No.	UID	Legal	Well No.	UID	Legal
1	M36727.989707	03-18-051-07 W5M	14	M35379.067625	NE 30-053-07 W5M
2	M35379.052507	SE 19-051-07 W5M	15	M35379.055580	NE 31-053-07 W5M
3	M35379.106337	06-30-051-07 W5M	16	M36234.931312	NE 06-054-07 W5M
4	M36056.972573	NW 31-051-07 W5M	17	M36234.931349	01-18-054-07 W5M
5	M36056.968982	13-06-052-07 W5M	18	M36234.931359	08-19-054-07 W5M
6	M36056.968980	NW 07-052-07 W5M	19	M36234.931406	SE 30-054-07 W5M
7	M36056.968958	NW 18-052-07 W5M	20	M36234.931409	NE 31-054-07 W5M
8	M35379.066595	SE 30-052-07 W5M	21	M35379.052924	NW 08-055-07 W5M
9	M36727.989769	SW 31-052-07 W5M	22	M35379.052926	SW 20-055-07 W5M
10	M35379.078209	SW 06-053-07 W5M	23	M35379.047185	03-32-055-07 W5M
11	M36234.926291	NW 07-053-07 W5M	24	M35379.047184	13-32-055-07 W5M
12	M36234.926344	NE 18-053-07 W5M	25	M35379.128147	NW 05-056-07 W5M
13	M36234.926356	NE 19-053-07 W5M	26	M35379.128294	04-08-056-07 W5M

Cross-Section F - F'



Well No.	UID	Legal
1	M36056.964925	NE 05-050-25 W5M
2	M36727.988280	12-19-050-25 W5M
3	M36056.964922	NE 25-050-26 W5M
4	M35379.061633	SW 36-050-26 W5M
5	M35379.109267	SW 06-051-25 W5M
6	M36234.937016	NW 01-051-26 W5M
7	M37066.932391	SE-11-051-26 W5M
9	M35379.062003	NW 22-051-26 W5M
8	M37066.932372	15-051-26 W5M
10	M35379.104087	NW 32-051-26 W5M
11	M36234.935437	NW 06-052-26 W5M

hydrogeological consultants ltd (HCL), edmonton, alberta - 1.800.661.7972 - project no. 02-227

YELLOWHEAD COUNTY

Appendix E

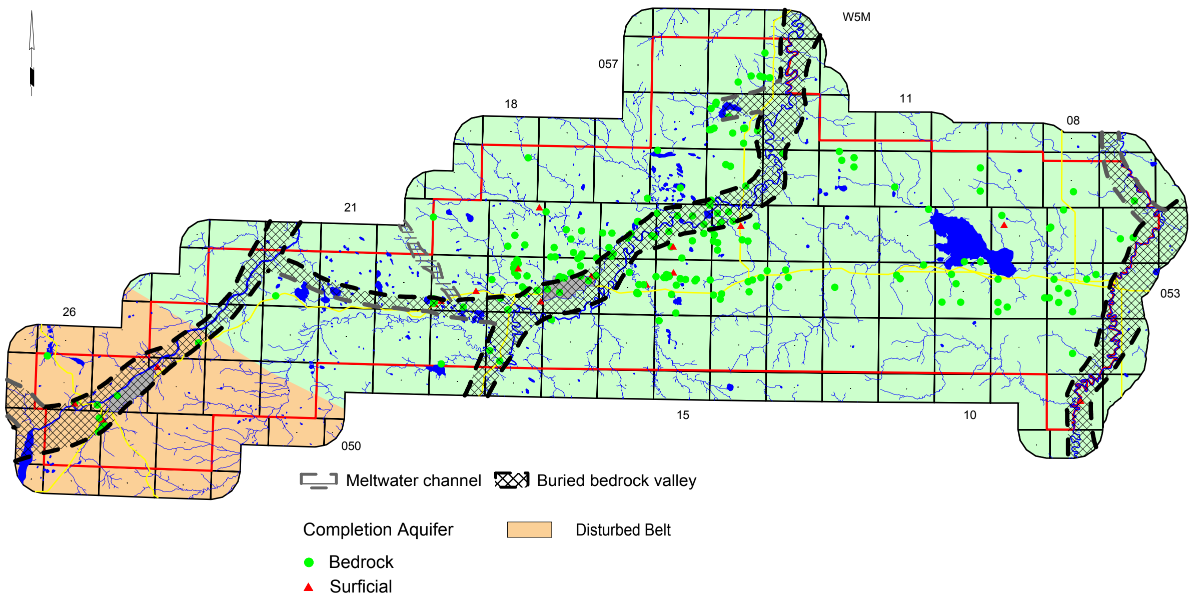
Water Wells Recommended for Field Verification

including

County-Operated Water Wells

Water Wells Recommended for Field Verification

(details on following pages)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Alberta Department of Highways	SE 14-053-19 W5M	Lower Surficial	20-Apr-60	8.53	28.0	3.05	10.0	M36234.933667
Alberta Forestry	04-30-054-19 W5M	Dalehurst Member	02-Aug-83	21.33	70.0	9.14	30.0	M35379.047850
Anderson, Ray	04-03-054-10 W5M	Upper Lacombe Member	14-Nov-73	18.59	61.0	11.58	38.0	M36234.931701
Armstrong, Jeannette	SW 08-053-18 W5M	Dalehurst Member	27-May-79	24.38	80.0	14.02	46.0	M36234.933409
Baker, T	NW 25-053-08 W5M	Upper Scollard	17-Oct-85	51.81	170.0	16.46	54.0	M36234.926617
Barress, Albert	SW 10-057-14 W5M	Dalehurst Member	05-Nov-85	44.19	145.0	18.9	62.0	M36234.936534
Basaraba, June	02-06-054-17 W5M	Dalehurst Member	13-Nov-75	27.43	90.0	21.34	70.0	M35379.047447
Baudin, David	NE 36-054-15 W5M	Dalehurst Member	01-Sep-82	28.95	95.0	23.78	78.0	M35379.047136
Bellmond, Ed	SW 34-053-18 W5M	Dalehurst Member	27-May-82	30.48	100.0	26.22	86.0	M36234.933565
Benesch, Walter	SE 13-053-09 W5M	Dalehurst Member	08-Jul-75	24.38	80.0	28.66	94.0	M36234.925246
Bennett, H.	SE 32-054-14 W5M	Dalehurst Member	18-Feb-69	17.37	57.0	31.1	102.0	M36234.934787
Bennett, John	NE 09-051-25 W5M	Disturbed Belt	28-Apr-77	60.04	197.0	33.54	110.0	M37066.932281
Bergeron, M.	NE 20-053-17 W5M	Dalehurst Member	19-Sep-73	30.48	100.0	35.98	118.1	M36234.933794
Berkholtz, R.	16-24-053-15 W5M	Dalehurst Member	16-Jun-64	21.33	70.0	38.42	126.1	M35379.048858
Bernicki, Ted	NW 18-053-17 W5M	Dalehurst Member	30-Jul-75	30.48	100.0	40.86	134.1	M36234.933764
Bibeau, Armand	03-29-054-09 W5M	Upper Surficial	25-May-81	45.11	148.0	43.3	142.1	M36234.931669
Blais	NE 30-051-24 W5M	Upper Surficial	24-Sep-94	42.67	140.0	45.74	150.1	M36982.852976
Block, Allan	NW 22-053-15 W5M	Dalehurst Member	16-Nov-89	41.15	135.0	48.18	158.1	M35379.052796
Bochek, Joe	SE 34-053-17 W5M	Dalehurst Member	29-Jul-74	30.48	100.0	50.62	166.1	M36234.934190
Bodner, Kim	NW 17-054-16 W5M	Dalehurst Member	04-Apr-77	30.48	100.0	53.06	174.1	M35379.047096
Boyes, Frank	SW 18-054-14 W5M	Dalehurst Member	05-May-80	54.86	180.0	55.5	182.1	M36234.934703
Boyes, Frank	SW 18-054-14 W5M	Dalehurst Member	17-Sep-74	30.48	100.0	57.94	190.1	M36234.934705
Bradersen, Wade	NE 07-053-10 W5M	Dalehurst Member	16-Aug-79	45.72	150.0	60.38	198.1	M36234.925378
Breth, Elizabeth	NE 09-056-14 W5M	Dalehurst Member	27-May-79	22.86	75.0	62.82	206.1	M36234.935647
Bright, D.	SE 28-053-18 W5M	Dalehurst Member	01-Dec-71	32	105.0	65.26	214.1	M36234.933534
Brooks, Lawrence	04-16-055-11 W5M	Upper Lacombe Member	26-Nov-80	18.29	60.0	67.7	222.1	M35379.048071
Brown, Floyd	SW 25-053-14 W5M	Dalehurst Member	12-Aug-71	36.57	120.0	70.14	230.1	M36234.925889
Brunning	SW 29-053-15 W5M	Dalehurst Member	12-Sep-93	51.81	170.0	72.58	238.1	M35379.078312
Buckle, Stan	SW 25-053-17 W5M	Upper Surficial	14-Sep-81	41.15	135.0	75.02	246.1	M35379.066856
Burzinski, Kris	SW 18-056-14 W5M	Dalehurst Member	05-Aug-94	13.72	45.0	77.46	254.1	M35379.089946
Bush, Clara	NE 13-054-16 W5M	Dalehurst Member	12-Jun-71	18.29	60.0	79.9	262.2	M35379.046972
Butts, Donald	SE 15-053-18 W5M	Dalehurst Member	16-May-75	18.29	60.0	82.34	270.2	M36234.934092
Cadrain, Greg	NW 18-054-16 W5M	Dalehurst Member	15-Jul-85	36.57	120.0	84.78	278.2	M35379.047123
Canadian Armed Forces	NW 32-051-26 W5M	Disturbed Belt	03-Jul-74	21.94	72.0	87.22	286.2	M37066.932374
Canadian Forest Oil Ltd.	02-22-051-08 W5M	Lower Surficial	16-Nov-01	39.32	129.0	89.66	294.2	M37231.572073
Cartwright, Richard	NE 15-053-18 W5M	Dalehurst Member	17-Jul-79	36.57	120.0	92.1	302.2	M37066.938148
Cassidy, A. E.	NE 06-051-25 W5M	Disturbed Belt	07-Jul-82	86.86	285.0	94.54	310.2	M37066.932353
Chapman, Harold	SE 17-053-15 W5M	Dalehurst Member	04-Jun-59	18.29	60.0	96.98	318.2	M35379.048681
Chapman, Lawrence	SW 31-052-15 W5M	Dalehurst Member	26-Sep-83	30.48	100.0	99.42	326.2	M37066.928076
Chison, Ron	12-27-053-16 W5M	Dalehurst Member	06-May-76	36.57	120.0	101.86	334.2	M35379.049735
Christe, R.B	08-16-054-16 W5M	Dalehurst Member	25-Jun-75	30.48	100.0	104.3	342.2	M35379.104469
Close, Willie	SW 29-053-15 W5M	Dalehurst Member	27-May-87	36.57	120.0	106.74	350.2	M35379.048937
Cold Creek Ranchers Station	09-29-053-11 W5M	Dalehurst Member	07-Sep-79	24.38	80.0	109.18	358.2	M36234.925561
Coulter, Roy	NW 14-053-14 W5M	Dalehurst Member	12-Jun-78	27.74	91.0	111.62	366.2	M36234.925798
Cressman, Warren	SW 05-054-17 W5M	Dalehurst Member	20-Aug-84	25.6	84.0	114.06	374.2	M35379.047366
Cunningham, Walter	NE 07-057-13 W5M	Upper Lacombe Member	09-Aug-83	42.67	140.0	116.5	382.2	M36234.936480
Darrimont, Margret	SW 28-053-11 W5M	Dalehurst Member	11-Oct-71	33.53	110.0	118.94	390.2	M36234.925548
Degner, Herb	04-30-050-25 W5M	Disturbed Belt	26-May-84	134.11	440.0	121.38	398.2	M36727.988293
Desjarlais, A.	SW 07-053-19 W5M	Dalehurst Member	26-Aug-76	51.2	168.0	123.82	406.3	M35379.095578
Dickson, Al	SW 20-053-12 W5M	Dalehurst Member	15-May-78	22.86	75.0	126.26	414.3	M36234.925708
Dixon, H.R.	NE 19-054-14 W5M	Dalehurst Member	13-Jun-80	25.91	85.0	128.7	422.3	M36234.934722

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Donkin, Mitch	NW 30-054-15 W5M	Dalehurst Member	07-Jun-80	30.48	100.0	12.19	40.0	M35379.047089
Donkin, Shelly	SE 33-053-18 W5M	Dalehurst Member	20-Aug-86	57.91	190.0	45.72	150.0	M36234.933558
Dummett, Chris	NE 12-057-14 W5M	Dalehurst Member	20-Nov-84	28.95	95.0	18.29	60.0	M36234.936541
Elzinga, Andrew	14-24-054-15 W5M	Dalehurst Member	07-Apr-69	30.48	100.0	6.1	20.0	M35379.046973
Elzinga, Doug	SE 24-054-15 W5M	Dalehurst Member	16-Jun-93	21.94	72.0	7.92	26.0	M35379.070931
Enge, Lawrence	04-32-054-09 W5M	Upper Lacombe Member	23-Nov-78	27.43	90.0	7.62	25.0	M36234.931677
Fahrion, E	03-20-054-15 W5M	Dalehurst Member	01-Apr-73	28.95	95.0	3.05	10.0	M35379.046890
Fenwick, Jeff	NE 20-053-17 W5M	Dalehurst Member	21-Jun-75	44.19	145.0	31.7	104.0	M36234.933793
Fickle Lake Recreation Area	SW 05-052-19 W5M	Dalehurst Member	05-Oct-68	44.19	145.0	5.18	17.0	M35379.042801
Fillmore, Ed	SE 31-056-14 W5M	Dalehurst Member	01-Aug-73	24.38	80.0	5.79	19.0	M36234.935762
Findlay, Mike	NE 31-055-15 W5M	Dalehurst Member	15-Nov-76	15.24	50.0	5.79	19.0	M35379.095534
Fisher, Tom	NW 23-053-15 W5M	Dalehurst Member	24-May-83	18.29	60.0	1.52	5.0	M35379.048835
Fluker, Milt	SE 01-054-17 W5M	Dalehurst Member	21-Jul-83	36.57	120.0	6.1	20.0	M35379.047224
Fossheim, Einar A.	NE 01-055-16 W5M	Dalehurst Member	21-Oct-81	24.38	80.0	11.89	39.0	M35379.045232
Fuchs, Richard	04-30-050-25 W5M	Disturbed Belt	13-May-84	138.68	455.0	9.14	30.0	M36727.988292
Gauchier, John	SW 07-053-19 W5M	Dalehurst Member	01-Aug-75	61	200.1	10.1	33.1	M36076.566864
Gervais, Frank	SH 29-053-15 W5M	Dalehurst Member	15-Oct-80	36.57	120.0	27.43	90.0	M35379.048932
Gheist, Adolph	SE 16-054-17 W5M	Dalehurst Member	20-Mar-85	16.76	55.0	7.92	26.0	M35379.047839
Giezen, A.	SW 25-055-10 W5M	Upper Lacombe Member	09-Nov-69	38.4	126.0	19.81	65.0	M35379.047889
Goertzen, Dave	SW 29-053-15 W5M	Dalehurst Member	18-Jun-94	54.86	180.0	27.99	91.8	M35379.091784
Gonkwicz, Stan	NE 32-054-08 W5M	Lower Lacombe Member	29-Jan-81	30.48	100.0	10.67	35.0	M36234.931545
Gouchier, John	NW 06-053-19 W5M	Dalehurst Member	29-Sep-75	60.96	200.0	10.12	33.2	M36234.933743
Grodzicki, John	SE 31-052-17 W5M	Dalehurst Member	19-Jul-79	24.38	80.0	3.66	12.0	M35379.068158
Hallett, D	SE 30-053-08 W5M	Lower Lacombe Member	12-Sep-77	51.81	170.0	12.19	40.0	M36234.926630
Hampshire, Mary	01-02-054-10 W5M	Upper Lacombe Member	25-Jul-75	24.38	80.0	16.15	53.0	M36234.931700
Hansen, Bert	SW 31-050-25 W5M	Lower Surficial	24-Apr-90	73.15	240.0	11.9	39.0	M35379.056759
Hawkins, L	NE 07-053-14 W5M	Dalehurst Member	30-Mar-83	24.38	80.0	7.31	24.0	M36234.926900
Hecht, Gerald	SW 14-053-16 W5M	Dalehurst Member	08-Feb-89	36.57	120.0	20.42	67.0	M35379.056671
Hecht, Gerald	SW 14-053-16 W5M	Dalehurst Member	24-Sep-94	41.15	135.0	22.95	75.3	M35379.091785
Hecht, Gerald	SW 14-053-16 W5M	Dalehurst Member	27-Sep-94	33.53	110.0	23	75.5	M35379.091786
Helstien, Bill	NW 22-053-18 W5M	Dalehurst Member	20-Apr-76	39.62	130.0	33.22	109.0	M36234.933511
Henault, D.	SW 20-053-13 W5M	Dalehurst Member	15-Jul-75	41.15	135.0	34.44	113.0	M36234.926752
Henault, R.	SW 28-053-13 W5M	Dalehurst Member	02-Aug-85	42.67	140.0	17.68	58.0	M36234.926794
Herbert, D.	SW 30-056-14 W5M	Dalehurst Member	30-May-69	22.86	75.0	7.62	25.0	M36234.935757
Hicks, Ashley	NW 10-055-08 W5M	Lower Lacombe Member	03-Aug-78	51.2	168.0	27.43	90.0	M35379.047365
Holloway, Kevin	SW 09-054-18 W5M	Dalehurst Member	05-Jun-85	36.57	120.0	17.37	57.0	M35379.047478
Holmen, Garry	SW 17-053-14 W5M	Dalehurst Member	18-Aug-77	18.29	60.0	4.57	15.0	M36234.925812
Hope, Rod #Site 6	NE 24-050-26 W5M	Disturbed Belt	18-Jun-81	83.82	275.0	0	0.0	M37066.932222
Ice, Fern	NW 23-053-14 W5M	Dalehurst Member	07-Nov-77	18.29	60.0	7.62	25.0	M36234.925879
Improvement District No. 14	NW 06-053-19 W5M	Lower Surficial	24-Jul-90	25.6	84.0	2.38	7.8	M36076.566164
Iwanciwski, Michael	NW 28-054-15 W5M	Dalehurst Member	28-Nov-71	27.43	90.0	-0.03	-0.1	M35379.047037
Jackson, W	SW 26-053-08 W5M	Lower Lacombe Member	24-Feb-81	30.48	100.0	18.29	60.0	M36234.926621
Jaydel Farms	SE 32-053-13 W5M	Dalehurst Member	06-Aug-70	36.57	120.0	7.92	26.0	M36234.926827
Jensen, Terry	NE 28-053-18 W5M	Dalehurst Member	03-May-77	33.53	110.0	16.46	54.0	M36234.933538
Jensen, Verner	SE 12-053-18 W5M	Lower Surficial		30.48	100.0	3.35	11.0	M36234.933442
Jerke, O.	NE 07-053-09 W5M	Dalehurst Member	19-May-76	30.48	100.0	24.99	82.0	M36234.925228
Jerke, Otto A.	NE 06-053-09 W5M	Dalehurst Member	01-Jun-83	35.36	116.0	25.91	85.0	M36234.925220
Johnson, A	NE 04-053-08 W5M	Upper Lacombe Member	01-Jan-64	16.76	55.0	5.49	18.0	M36234.926487
Johnson, Gary	09-03-056-14 W5M	Dalehurst Member	13-Oct-89	30.48	100.0	20.19	66.2	M36234.935639
Johnson, Jim	NE 24-050-26 W5M	Disturbed Belt	17-Jun-82	82.29	270.0	0	0.0	M37066.932278
King, Larry	SE 28-055-14 W5M	Dalehurst Member	20-Mar-90	30.48	100.0	18.26	59.9	M35379.052418
King, Larry	SW 28-055-14 W5M	Dalehurst Member	20-Mar-90	24.38	80.0	13.58	44.6	M35379.052419
Klut, E	SE 15-054-15 W5M	Dalehurst Member	01-Aug-72	27.43	90.0	3.05	10.0	M35379.046788
Koprivnak, Bill	SW 14-053-18 W5M	Dalehurst Member	25-Sep-81	36.57	120.0	28.95	95.0	M36234.933469
Lario Oil & Gas Ltd	NE 29-053-10 W5M	Upper Lacombe Member	23-Sep-76	13.11	43.0	8.23	27.0	M36234.925433

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Lawton Farms	NW 33-055-12 W5M	Dalehurst Member	24-May-85	36.57	120.0	16.76	55.0	M36234.934880
Lee, Davis	NW 28-055-12 W5M	Dalehurst Member	10-Nov-88	36.57	120.0	19.88	65.2	M36234.934865
Lemieux, Ted	SW 30-057-13 W5M	Dalehurst Member	18-Dec-79	42.67	140.0	30.48	100.0	M36234.936516
Lenndertse, John	SE 10-054-18 W5M	Dalehurst Member	12-Jul-83	30.48	100.0	21.33	70.0	M35379.047505
Liturak, Roy	NE 29-053-15 W5M	Upper Surficial	08-May-92	27.13	89.0	15.54	51.0	M35379.066603
Lorey, Erwin	NE 35-053-11 W5M	Upper Lacombe Member	23-Feb-84	48.77	160.0	5.49	18.0	M36234.925586
Ludwig, Elcke	SE 13-054-16 W5M	Dalehurst Member	03-Oct-77	18.29	60.0	3.05	10.0	M35379.046961
Mahon, Bill	SE 25-053-17 W5M	Dalehurst Member	17-May-77	36.57	120.0	10.67	35.0	M36234.934120
May, John	SW 05-054-16 W5M	Dalehurst Member	11-Dec-73	48.77	160.0	20.11	66.0	M37066.930060
McCaffrey, Sharon	SE 04-054-15 W5M	Dalehurst Member	12-Jun-78	36.57	120.0	27.43	90.0	M35379.046615
Mccallister, Norman	SE 34-055-12 W5M	Dalehurst Member	28-Feb-79	34.44	113.0	28.35	93.0	M36234.934885
Mcniven, David	NE 11-057-14 W5M	Dalehurst Member	01-Nov-81	64	210.0	56.08	184.0	M36234.936538
Mcphee, Pat	NW 34-053-18 W5M	Dalehurst Member	02-Jul-76	30.48	100.0	11.58	38.0	M36234.933567
Mcrobie, Nick	07-08-054-15 W5M	Dalehurst Member	18-Jun-76	22.86	75.0	13.72	45.0	M35379.046638
Merrill, Ellen	NE 21-053-15 W5M	Dalehurst Member	27-Sep-75	36.57	120.0	21.44	70.3	M35379.048714
Merrill, Ellen	NE 21-053-15 W5M	Dalehurst Member	02-Oct-81	36.57	120.0	22.53	73.9	M35379.048715
Mizera, Larry	SW 08-054-17 W5M	Dalehurst Member	17-Sep-82	10.36	34.0	2.13	7.0	M35379.047492
Moberly, E.	SE 36-050-26 W5M	Disturbed Belt	23-Feb-71	15.24	50.0	5.32	17.5	M37066.932196
Mona, H.	SW 24-053-16 W5M	Upper Surficial	02-Sep-82	24.38	80.0	11.58	38.0	M35379.049706
Monsma, Clarence	SW 21-053-15 W5M	Dalehurst Member	07-Nov-69	31.39	103.0	20.42	67.0	M35379.048709
Moore, Doug	NW 02-051-26 W5M	Disturbed Belt	03-Nov-81	79.24	260.0	47.24	155.0	M35379.105537
Munro, R.A.	SW 03-053-19 W5M	Dalehurst Member	13-Oct-78	54.86	180.0	25.91	85.0	M36234.933590
Myrholm, Tom	SE 30-053-09 W5M	Upper Lacombe Member	07-Jul-75	22.86	75.0	7.01	23.0	M36234.925335
Neale, R.S.	SE 15-056-14 W5M	Dalehurst Member	23-Feb-77	30.48	100.0	15.46	50.7	M36234.935676
Neale, Robert	SE 15-056-14 W5M	Dalehurst Member	05-Dec-91	53.95	177.0	15.91	52.2	M35379.062732
Nelson, Lynette	03-08-053-22 W5M	Dalehurst Member	19-Jun-72	16.15	53.0	9.37	30.7	M36234.933964
Neufeld, Garry & Pat	NW 33-055-13 W5M	Dalehurst Member	06-Mar-90	25.91	85.0	16.22	53.2	M35379.052121
Nikolyuk, W	SW 18-053-08 W5M	Upper Lacombe Member	09-Jun-82	30.48	100.0	14.63	48.0	M36234.926572
Nitz, Jim	SE 23-053-16 W5M	Dalehurst Member	11-Jun-85	42.67	140.0	18.75	61.5	M35379.049603
Ohnysty, John	NW 19-054-08 W5M	Lower Lacombe Member	20-Aug-70	32	105.0	18.29	60.0	M36234.931486
Ohnysty, John	14-19-054-08 W5M	Lower Lacombe Member	28-Oct-60	33.53	110.0	15.85	52.0	M36234.931488
ONESYK	09-17-054-07 W5M	Haynes Member	26-Oct-66	22.86	75.0	7.62	25.0	M36234.931348
Osadchuck, John	SE 28-053-17 W5M	Dalehurst Member	03-Oct-79	36.57	120.0	9.14	30.0	M36234.934150
Ottoson, Ernie	SW 02-054-17 W5M	Dalehurst Member	25-Jan-85	48.77	160.0	32.31	106.0	M35379.047298
PARK	NW 06-053-19 W5M	Dalehurst Member	04-Sep-75	40.23	132.0	7.62	25.0	M36234.933744
Parker, Ken	NW 18-054-14 W5M	Dalehurst Member	16-Jul-74	24.38	80.0	18.29	60.0	M36234.934710
Parks Dept/Maintanence Shop	NW 32-051-26 W5M	Disturbed Belt	01-Jun-70	41.15	135.0	7.92	26.0	M35379.104087
PELICAN SPRUCE MILLS	NE 23-053-17 W5M	Dalehurst Member	17-Sep-82	48.77	160.0	24.69	81.0	M36234.934111
Pelke, E.	SW 04-053-15 W5M	Dalehurst Member	18-Dec-73	30.48	100.0	7.31	24.0	M35379.048601
Peters, Dan	NW 05-054-16 W5M	Dalehurst Member	05-Nov-82	42.67	140.0	11.58	38.0	M35379.046913
Petley, L.E.	NE 22-053-14 W5M	Dalehurst Member	09-Nov-77	24.38	80.0	5.18	17.0	M36234.925874
Pillage, Brian	NW 21-053-17 W5M	Dalehurst Member	31-Aug-79	54.86	180.0	36.57	120.0	M36234.933829
Pitcher, Jim	SW 19-053-18 W5M	Dalehurst Member	18-May-78	18.29	60.0	12.8	42.0	M36234.933500
Preece, Joan	NE 34-053-17 W5M	Dalehurst Member	23-Aug-84	32	105.0	9.14	30.0	M36234.934194
Prince, Bessie	SW 07-053-19 W5M	Dalehurst Member	01-Aug-75	43.3	142.1	9.1	29.9	M36076.566946
Public Works, Dept Of	SE 17-053-17 W5M	Dalehurst Member	01-Oct-70	67.05	220.0	41.44	136.0	M37066.937154
Radcliffe, Allen	SW 15-054-14 W5M	Dalehurst Member	09-Sep-75	18.29	60.0	4.57	15.0	M36234.934663
Radcliffe, Curtis	NE 23-054-14 W5M	Dalehurst Member	01-Apr-85	30.48	100.0	3.66	12.0	M36234.934748
Radcliffe, R.	01-15-054-14 W5M	Dalehurst Member	27-Sep-67	16.76	55.0	4.27	14.0	M35379.109414
Radcliffe, Ray	NW 22-054-14 W5M	Lower Surficial	11-Apr-71	13.41	44.0	5.18	17.0	M36234.934741
Radcliffe, Rick	SW 28-054-14 W5M	Dalehurst Member	28-Jun-84	18.29	60.0	11.89	39.0	M36234.934763
Rechner, M.	SE 06-055-14 W5M	Dalehurst Member	04-Jan-68	22.86	75.0	9.45	31.0	M36234.934984
Rinke, Geo	SE 31-054-14 W5M	Dalehurst Member	31-Jul-72	18.29	60.0	2.44	8.0	M36234.934779
Riopka, Steve	NW 21-053-17 W5M	Dalehurst Member	08-Jun-79	60.96	200.0	44.5	146.0	M36234.933830
Ritcher, Fran	SE 16-052-08 W5M	Dalehurst Member	06-Oct-80	22.86	75.0	16.76	55.0	M35379.123379
Rivard, Richard	SE 30-054-14 W5M	Dalehurst Member	13-Jun-89	15.24	50.0	1.83	6.0	M36234.934774
Robert Neale	SW 14-056-14 W5M	Dalehurst Member	09-Aug-78	28.95	95.0	15.98	52.4	M36234.935669

WATER WELLS RECOMMENDED FOR FIELD VERIFICATION (continued)

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Robinson, B.	NW 15-054-07 W5M	Upper Scollard	08-Nov-81	24.38	80.0	6.1	20.0	M36234.931341
Robinson, Gordon	SW 29-053-15 W5M	Dalehurst Member	25-May-92	51.81	170.0	25.6	84.0	M35379.066706
Rupert, Lauri	SW 08-053-19 W5M	Lower Surficial	06-Jun-83	36.6	120.1	15.2	49.9	M36076.564746
Rurka, M.	NE 30-056-14 W5M	Dalehurst Member	01-Nov-72	22.86	75.0	0.3	1.0	M36234.935760
Russell, Cecil W.	NW 12-055-10 W5M	Upper Lacombe Member	27-Mar-75	30.48	100.0	15.24	50.0	M35379.047864
Saken, Walter	13-13-054-15 W5M	Dalehurst Member	18-Sep-74	27.43	90.0	5.79	19.0	M35379.046754
Sanders, Jack	13-30-054-17 W5M	Dalehurst Member	15-Nov-72	18.29	60.0	6.71	22.0	M35379.047765
Sanders, Jom	NW 23-053-18 W5M	Dalehurst Member	05-Oct-72	18.29	60.0	12.5	41.0	M36234.933519
Saunders, Bill/Rcmp	NW 15-054-16 W5M	Dalehurst Member	06-Jun-78	39.62	130.0	27.43	90.0	M35379.104471
Schafer, Harold	SW 26-054-16 W5M	Dalehurst Member	11-Aug-86	27.43	90.0	22.55	74.0	M35379.047165
Sharra, Margaret	NW 06-053-19 W5M	Dalehurst Member	01-Aug-75	61	200.1	9.1	29.9	M36076.566524
Shirley, Ben	SW 13-053-18 W5M	Dalehurst Member	08-Dec-74	65.53	215.0	44.19	145.0	M36234.933461
Simmonds, Niel	NW 02-051-26 W5M	Lower Surficial	23-May-84	12.5	41.0	10.01	32.8	M37066.932407
Simmons, George	01-03-054-17 W5M	Dalehurst Member	11-Jun-71	42.67	140.0	11.28	37.0	M35379.047316
Smith, Ken	SW 04-053-18 W5M	Dalehurst Member	28-Jul-62	30.48	100.0	14.63	48.0	M36234.933398
Snyder, Ken	SW 36-054-18 W5M	Lower Surficial	01-Sep-70	20.42	67.0	8.53	28.0	M35379.047717
Stanton, Mike	SW 23-053-16 W5M	Dalehurst Member	22-Sep-87	33.53	110.0	20.12	66.0	M35379.049605
Stepaniuk, S	NW 16-053-08 W5M	Lower Lacombe Member	19-Mar-73	48.77	160.0	31.7	104.0	M36234.926562
Stevens, Annie May	SE 27-054-16 W5M	Dalehurst Member	11-Jun-77	36.57	120.0	22.25	73.0	M35379.047227
Stobel, P	08-08-054-15 W5M	Upper Surficial	21-Jun-71	24.38	80.0	18.29	60.0	M35379.046643
Swedberg, Oscar	NW 05-052-18 W5M	Dalehurst Member	13-Jun-74	38.1	125.0	22.86	75.0	M36234.935797
Tait, Charles	NE 09-053-10 W5M	Dalehurst Member	14-Jul-76	39.62	130.0	26.82	88.0	M36234.925382
Tanghe, Bob	SW 21-054-17 W5M	Dalehurst Member	14-Aug-81	18.29	60.0	4.57	15.0	M35379.047669
Tate, D	SW 20-053-08 W5M	Upper Lacombe Member	16-Oct-79	28.95	95.0	13.72	45.0	M36234.926585
Tews, Carl	SE 30-053-15 W5M	Dalehurst Member	03-Jul-84	36.57	120.0	25.91	85.0	M35379.048952
Tews, W.	SW 30-053-15 W5M	Dalehurst Member	01-Sep-73	36.57	120.0	17.68	58.0	M35379.048954
The Church of Jesus Christ	SE 27-053-17 W5M	Dalehurst Member	20-Sep-82	24.38	80.0	7.62	25.0	M36234.934143
The Rojan Grp	NE 26-055-18 W5M	Dalehurst Member	11-Feb-84	24.38	80.0	5.79	19.0	M35379.045534
Thomas, Munroe	16-15-054-17 W5M	Dalehurst Member	28-Jul-76	30.48	100.0	15.24	50.0	M35379.047826
Tiby, Roger	NW 03-054-17 W5M	Dalehurst Member	06-May-82	24.38	80.0	9.14	30.0	M35379.047356
Tindill, Dave & Rosemary	NE 25-053-14 W5M	Dalehurst Member	11-Sep-79	36.57	120.0	22.86	75.0	M36234.925894
Tobin, Dan	NW 15-054-16 W5M	Dalehurst Member	19-Mar-86	21.33	70.0	12.19	40.0	M35379.047065
Townsend, Ed	SW 14-055-14 W5M	Dalehurst Member	20-Jul-77	24.38	80.0	6.1	20.0	M36234.935017
Townsend, J.	SW 21-056-14 W5M	Dalehurst Member	29-May-69	19.81	65.0	9.75	32.0	M36234.935713
Turner, Mark	SW 29-053-15 W5M	Dalehurst Member	15-May-89	36.57	120.0	24.38	80.0	M35379.057722
Twiss, R.F.	NW 10-055-15 W5M	Dalehurst Member	09-Aug-78	24.38	80.0	9.45	31.0	M35379.045117
Tymchuck, Jim	SE 07-054-16 W5M	Dalehurst Member	30-Oct-85	57.91	190.0	27.43	90.0	M35379.046934
Uden, Warren	NW 21-053-10 W5M	Upper Lacombe Member	16-Apr-75	36.57	120.0	13.11	43.0	M36234.925410
Vanance, Oliver	NW 12-052-24 W5M	Disturbed Belt	17-Jul-75	53.34	175.0	4.57	15.0	M36234.935396
Velechko, Peter	16-27-054-15 W5M	Dalehurst Member	05-Aug-72	50.29	165.0	27.43	90.0	M35379.047008
Waddell, A	NW 12-052-24 W5M	Disturbed Belt	31-Jul-74	44.19	145.0	6.1	20.0	M36234.935388
Walker, Jack	SE 16-054-18 W5M	Dalehurst Member	13-Jun-83	73.15	240.0	51.81	170.0	M35379.047539
Wall, Calvin	NW 23-053-15 W5M	Dalehurst Member	27-Mar-84	27.43	90.0	6.1	20.0	M35379.048837
Weaver, K.G.	NW 07-052-18 W5M	Dalehurst Member	03-Nov-73	30.48	100.0	1.83	6.0	M36234.935803
Wigley, Dale	SE 27-055-12 W5M	Dalehurst Member	03-Sep-73	44.19	145.0	33.53	110.0	M36234.934862
Willetts, Don	NE 12-057-14 W5M	Dalehurst Member	09-Sep-86	36.57	120.0	24.38	80.0	M36234.936542
Williams, Blaine	SE 18-056-14 W5M	Dalehurst Member	02-Jun-84	18.29	60.0	4.57	15.0	M36234.935693
Williams, Blaine	SW 18-056-14 W5M	Dalehurst Member	02-Jun-84	18.3	60.0	4.57	15.0	M36444.263671
Wodley, M.E.	NW 27-053-18 W5M	Upper Surficial	01-May-71	30.48	100.0	10.67	35.0	M36234.933529
Wolfe, John	NE 07-054-14 W5M	Dalehurst Member	26-Oct-76	22.86	75.0	10.67	35.0	M36234.934646
Wolfe, Shane	SE 07-054-14 W5M	Dalehurst Member	18-Jun-96	19.81	65.0	3.53	11.6	M36234.937185
Wunderlick, Rick	SW 18-053-14 W5M	Dalehurst Member	24-Aug-82	32	105.0	12.19	40.0	M36234.925824
Yoder, Christian	SW 13-056-14 W5M	Dalehurst Member	15-May-76	36.57	120.0	18.29	60.0	M36234.935665
York, Owen	SE 08-053-09 W5M	Dalehurst Member	29-Oct-82	29.26	96.0	14.32	47.0	M36234.925229
Young, Geo	NE 03-055-07 W5M	Battle	01-Aug-73	32.31	106.0	6.1	20.0	M35379.046998
Zatorski, Ed	NW 36-054-11 W5M	Upper Lacombe Member	24-Oct-86	21.94	72.0	9.14	30.0	M36234.934385
Ziegert, C.	NW 08-053-08 W5M	Upper Lacombe Member	18-Aug-80	27.43	90.0	9.14	30.0	M36234.926490

YELLOWHEAD COUNTY-OPERATED WATER WELLS

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
M.D. of Yellowhead	NW 10-055-15 W5M	Dalehurst Member	21-Nov-94	38.7	127.0	7.3	24.0	M35379.100636