M.D. of Bonnyville

Part of the Churchill and North Saskatchewan River Basins
Parts of Tp 055 to 066, R 01 to 10, W4M
Regional Groundwater Assessment

Prepared for the M.D. of Bonnyville

In conjunction with

Agriculture and Agri-Food Canada
Prairie Farm Rehabilitation Administration

Agriculture et Agroalimentaire Canada
Administration du rétablisseme agricole des Prairies

Prepared by
hydrogeological consultants ltd.
1-800-661-7972
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HYDROGEOLOGICAL CONSULTANTS LTD.

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E. Water Wells Recommended for Field Verification
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1. Project Overview

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

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

1.1 Purpose

This project is a regional groundwater assessment of the M.D. of Bonnyville prepared by Hydrogeological Consultants Ltd. (HCL) with financial and technical assistance from the Prairie Farm Rehabilitation Administration arm of Agriculture and Agri-Food Canada (AAFC-PFRA). The regional groundwater assessment provides the information to assist in the management of the groundwater resource within the M.D. Groundwater resource management involves determining the suitability of various areas in the M.D. for particular activities. These activities can vary from the development of groundwater for agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the M.D.**

The regional groundwater assessment will:

- identify the aquifers[1] within the surficial deposits[2]
- spatially identify the main aquifers
- describe the quantity and quality of the groundwater associated with each surficial aquifer
- identify the hydraulic relationship between aquifers
- identify possible groundwater depletion areas associated with each surficial aquifer.

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

[1] See glossary
[2] See glossary

1.2 The Project

This regional study should only be used as a guide. Detailed local studies are required to verify hydrogeological conditions at given locations.

The present project is made up of eight parts as follows:

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

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

1.3 About This Report

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

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

Appendix A features page-size copies of the figures within the report plus additional maps and cross-sections. An index of the page-size maps and figures is given at the beginning of Appendix A. A plastic M.D. map outline is provided to overlay the maps, and contains information such as towns, main rivers, etc.

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

Appendix C includes the following:

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

The Water (Ministerial) Regulation deals with the wellhead completion requirement (no more water-well pits), the proper procedure for abandoning unused water wells and the correct procedure for installing a pump in a water well. The new Water Act was proclaimed 10 Jan 1999.

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

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

Appendix F includes page-size copies of figures combining the M.D. of Bonnyville and Lakeland County.

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[3] See glossary

2. Introduction

2.1 Setting

The M.D. of Bonnyville is situated in east-central Alberta. This area is part of the Alberta High Plains portion of the Interior Plains region (Ozoray, Wallick and Lytviak, 1980). The study area, defined here as 'the M.D.', includes parts of the area bounded by townships 055 to 066, ranges 01 to 10, west of the 4th Meridian. The province of Saskatchewan forms the eastern boundary of the M.D. The other M.D. boundaries follow township or section lines. The M.D. occupies part of the Churchill and North Saskatchewan River Basins.

Regionally, the topographic surface ranges from less than 525 to more than 725 metres above mean sea level (AMSL). The lowest elevations occur along the Beaver River (see overlay) where it leaves the M.D. in township 061, and the highest elevations are in the northwestern parts of the M.D., as shown on Figure 1 and Page A-3. The area is well drained by numerous streams, the main ones being the Beaver and Sand rivers.

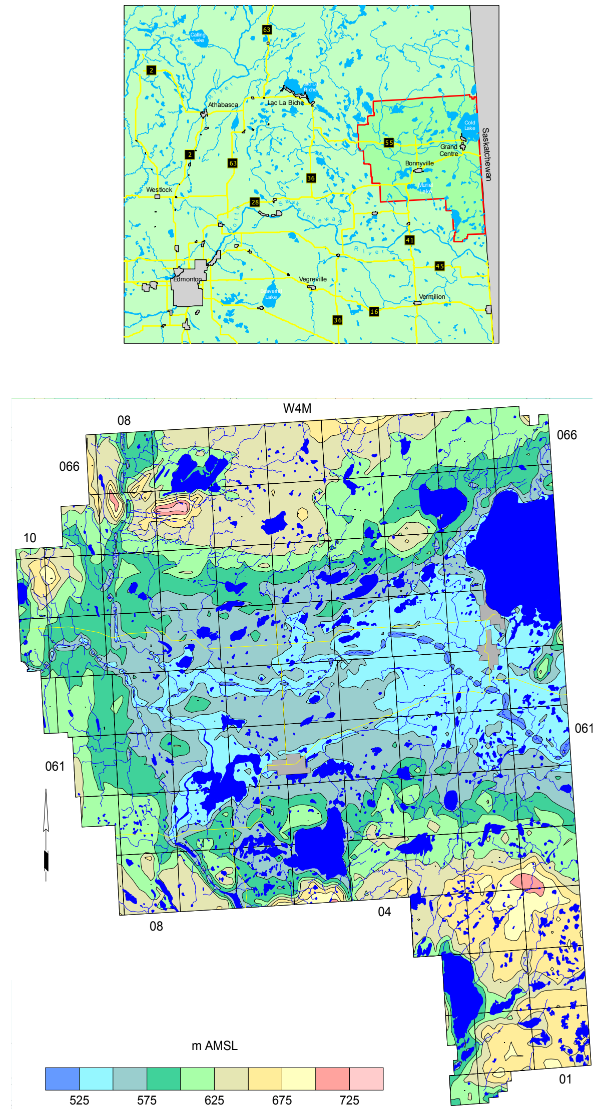

Figure 1. Index Map

2.2 Climate

The M.D. of Bonnyville lies within the Dfb climate boundary. This classification is based on potential evapotranspiration values determined using the Thornthwaite method (Thornthwaite and Mather, 1957), combined with the distribution of natural ecoregions in the area. The ecoregions map (Strong and Leggatt, 1981) shows that the M.D. is located in both the Low Boreal Mixedwood region and the Mid Boreal Mixedwood region. This vegetation change is influenced by increased precipitation and cooler temperatures, resulting in additional moisture availability.

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 the Cold Lake meteorological station within the M.D. measured 433 millimetres (mm), based on data from 1952 to 1993. The annual temperature averaged 1.4° C, with the mean monthly temperature reaching a high of 17.0 °C in July, and dropping to a low of -17 °C in January. The calculated annual potential evapotranspiration is 508 millimetres.

2.3 Background Information

2.3.1 Number, Type and Depth of Water Wells

There are currently records for 5,858 water wells in the groundwater database for the M.D., of which a proposed use is available for 5,167 water wells. Of the 5,167 water wells, 4,844 (94%) are for domestic/stock purposes. The remaining 323 water wells were completed for a variety of uses, including municipal, industrial, observation, irrigation, investigation, dewatering and monitoring. Based on a rural population of 8,069 (Phinney, 2002), there are 1.9 domestic/stock water wells per family of four. Of the 4,650 domestic or stock water wells with a completed depth, 3,954 (85%) are completed at depths of less than 50 metres below ground level. Details for lithology[4] are available for 3,635 water wells.

2.3.2 Number of Water Wells in Surficial and Bedrock Aquifers

There are 2,432 water well records with completion interval and lithologic information, such that the aquifer in which the water wells are completed can be identified. The water wells that were not drilled deep enough to encounter the bedrock plus water wells that have the bottom of their completion interval above the top of the bedrock are water wells completed in surficial aquifers. Of the 2,432 water wells for which aquifers could be defined, 2,425 (99.7%) are completed in surficial aquifers, with 75% having a completion depth of less than 50 metres below ground level. From Figure 2, it can be seen that most water wells in the M.D. are completed in aquifers in the upper surficial deposits. The water wells completed in the lower surficial deposits mainly occur along the linear bedrock lows. The lowest elevation of the linear bedrock low is the thalweg.

The data for seven 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.

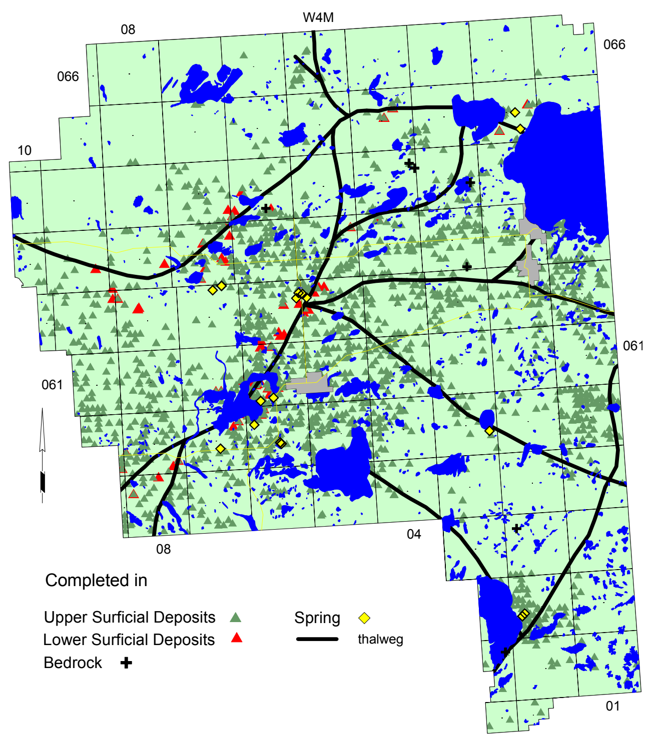

Figure 2. Location of Water Wells and Springs

There are currently records for 18 springs in the groundwater database; these springs generally occur in the vicinity of linear bedrock lows and are mainly at a surface elevation of less than 525 metres AMSL. Of the 14 springs having total dissolved solids (TDS) values, eleven have TDS concentrations of less than 1,000 milligrams per litre (mg/L). The springs have total hardness values that average 321 mg/L. There are no available flow rates in the groundwater database for the springs within the M.D.

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[4] See glossary

2.3.3 Casing Diameter and Type

Data for casing diameters are available for 3,678 water wells, with 2,282 (62%) indicated as having a diameter of less than 275 mm and 1,396 water wells having a surface-casing diameter of more than 275 mm. The casing diameters of greater than 275 mm are mainly bored or dug water wells and those with a surface-casing diameter of less than 275 mm are drilled water wells. In addition to the 3,678 water wells that have been designated as either bored or drilled water wells based on casing diameter, another 830 water wells have been designated as bored or drilled water wells based on the drilling method only, with no casing size indicated on the water well record. Of the 830 water wells having no casing size, 384 are drilled water wells and 446 are bored water wells. Of the 4,508 drilled and bored water wells, 3,650 have a completion date and a completion depth. From 1965 to 2000, most of the water wells completed in the M.D. were drilled. The completion depths of drilled water wells are mainly greater than 50 metres and for bored water wells are mainly less than 30 metres (see CD-ROM).

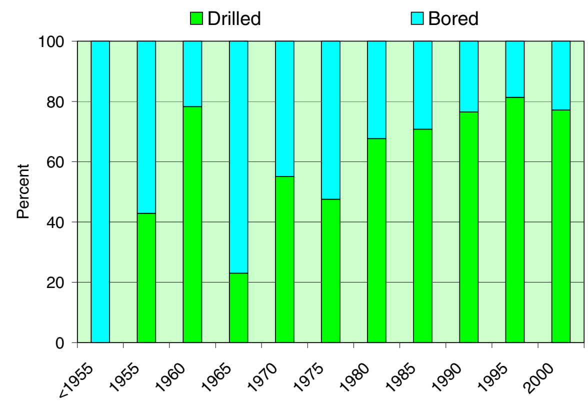

Figure 3. Casing Diameter Used in Water Wells

In the M.D., steel, galvanized steel and plastic surface casing materials have been used in 99% of the drilled water wells over the last 40 years. Until the mid-1960s, the type of surface casing used in drilled water wells was mainly undocumented. Steel casing was predominantly used in drilled water wells in the 1960s and 1970s but is currently being used in only 4% of the water wells drilled in the M.D. Galvanized steel surface casing was used in a maximum of 30% of the drilled water wells from the 1970s to the 1980s. Galvanized steel was last used in October 1984. Plastic casing was first used in May 1975 and is currently being used in 96% of the drilled water wells in the M.D.

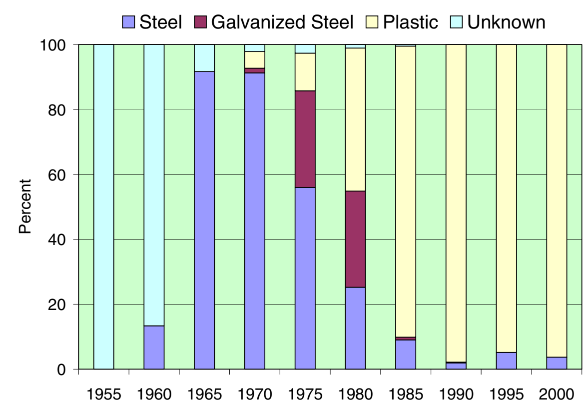

Figure 4. Surface Casing Types Used in Drilled Water Wells

2.3.4 Dry Water Test Holes

In the M.D., there are 7,109 records in the groundwater database. Of these 7,109 records, 171 are indicated as being dry or abandoned with “insufficient water”.

2.3.5 Requirements for Licensing

Water wells used for household needs in excess of 1,250 cubic metres per year (748 imperial gallons per day[5]) and all other groundwater use must be licensed. The only groundwater uses that do not need licensing are (1) household use of up to 1,250 m³/year and (2) groundwater with total dissolved solids in excess of 4,000 mg/L. In the last update from the Alberta Environment (AENV) groundwater database in September 2001, 139 groundwater allocations were shown to be within the M.D. Of the 139 licensed groundwater users, 94 (**which is 67% of all licensed water wells**) could be linked to the AENV groundwater database. Of the 139 licensed groundwater users, 66 are for agricultural purposes, 20 are for industrial, 17 are for exploration purposes, 11 are for municipal, seven are for commercial, six are for dewatering, and the remaining 12 are for registration, irrigation and recreation purposes. The total maximum authorized diversion from the water wells associated with

[5] see conversion table on page 57

these licences is 34,560 cubic metres per day (m³/day), although actual use could be less. Of the 34,560 m³/day, 23,398 m³/day (68%) is authorized for industrial purposes and 6,840 m³/day (20%) is for exploration purposes. The remaining 3,822 m³/day (11%) is allotted for dewatering, municipal and agricultural use as shown below in Table 1. A figure showing the locations of the licensed users is in Appendix A (Page A-7) and on the CD-ROM. Table 1 also shows a breakdown of the 139 licensed groundwater allocations by the aquifer in which the water well is completed. The largest total licensed allocations are in the Empress – Unit 3 and Bonnyville aquifers. Of the 9,265.9 m³/day licensed groundwater use in the Empress Aquifer – Unit 3, 89% of the groundwater allocation is from six injection water wells in 12-10-066-05 W4M.

	No. of	Licensed Groundwater Users* (m³/day)										
Aquifer **	Diversions	Agricultural	Commercial	Dewatering	Exploration	Industrial	Irrigation	Municipal	Recreation	Registry	Total	Percentage
Upper Surficial	26	111.5	0.0	0.0	0.0	1,702.2	0.0	0.0	0.0	12.4	1,826.1	5
Grand Centre	8	59.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	59.8	0
Sand River	2	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0
Marie Creek	17	72.7	3.4	1,841.8	0.0	0.0	3.4	0.0	0.0	0.0	1,921.3	6
Ethel Lake	7	32.1	3.4	0.0	0.0	0.0	0.0	13.5	23.6	0.0	72.6	0
Bonnyville	19	84.5	0.0	0.0	0.0	6,228.1	0.0	101.4	0.0	2.2	6,416.2	19
Muriel Lake	8	98.1	0.0	0.0	0.0	0.0	0.0	398.8	0.0	0.0	496.9	1
Bronson Lake	9	59.8	0.0	0.0	0.0	1,702.2	0.0	310.9	0.0	0.0	2,072.9	6
Empress - Unit 3	21	96.0	50.7	0.0	0.0	8,214.4	0.0	898.0	6.8	0.0	9,265.9	27
Empress - Unit 1	4	10.1	0.0	0.0	0.0	4,250.2	0.0	13.5	0.0	0.0	4,273.8	12
Bedrock	1	0.0	0.0	0.0	0.0	1,301.1	0.0	0.0	0.0	0.0	1,301.1	4
Unknown	17	0.0	0.0	0.0	6,840.0	0.0	0.0	0.0	0.0	0.0	6,840.0	20
Total	139	637.8	57.5	1,841.8	6,840.0	23,398.2	3.4	1,736.1	30.4	14.9	34,560.1	100
Percentage		2	0	5	20	68	0	5	0	0	100	

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

Table 1. Licensed Groundwater Diversions

Based on the 2001 Agriculture Census, the calculated water requirement for 166,774 livestock for the M.D. is in the order of 8,776 m³/day. This value does not include domestic animals, but does include intensive livestock use. Of the 8,776 m³/day average calculated livestock use, AENV has licensed a groundwater diversion of 638 m³/day (7%) and licensed a surface-water diversion of 107 m³/day (<1%). The remaining 93% of the calculated livestock use would have to be from unlicensed sources.

2.3.6 Base of Groundwater Protection

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[6] method to prepare a depth to the Base of Groundwater Protection surface. This depth, for the most part, would be the maximum drilling depth for a water well for agricultural purposes or for a potable water supply. If a water well has total dissolved solids exceeding 4,000 mg/L, the groundwater use does not require licensing by AENV. In the M.D., the depth to Base of Groundwater Protection ranges from less than 40 metres to more than 220 metres below ground level in the western part of the M.D., as shown on Figure 5 and on some cross-sections presented in Appendix A, and on the CD-ROM. The main area where the depth to Base of Groundwater Protection is less than 40 metres is south of the Town of Bonnyville.

6 See glossary

Of the 5,561 with completed depth data, 36 water wells are completed below the Base of Groundwater Protection. In the M.D., the Base of Groundwater Protection is mainly below the Empress Formation – Unit 3 (see Pages A-12, A-13, A-16 and A-17). These 36 water wells have been posted on the adjacent figure and show that they are mainly located where the depth to Base of Groundwater Protection is below 80 metres. Chemistry data are available for 12 of these water wells; TDS concentrations are greater than 4,000 mg/L for six water wells.

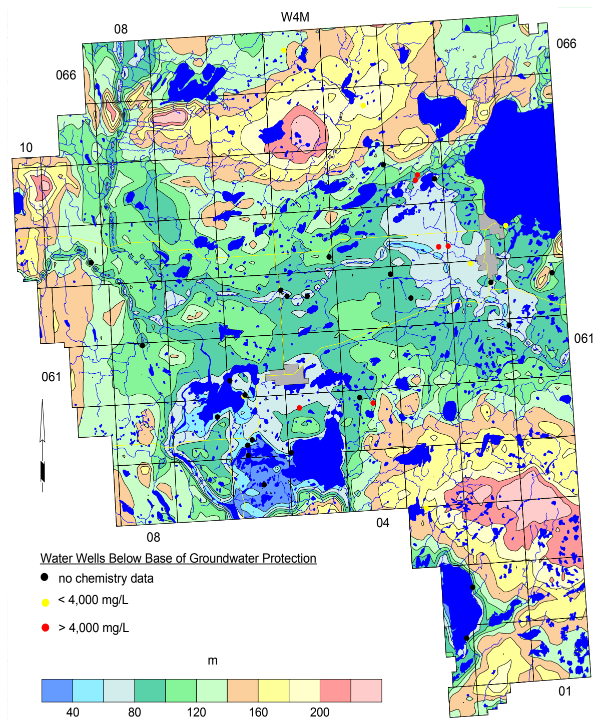

Figure 5. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are 26 AENV-operated observation water well within the M.D. Additional data can be obtained from some of the licensed groundwater diversions. In the past, the data for licensed diversions have been difficult to obtain from AENV, in part because of the failure of the licensee to provide the data.

Even with the available sources of data, the number of water-level data points relative to the size of the M.D. 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 (see section 7.0 of this report).

3. Terms

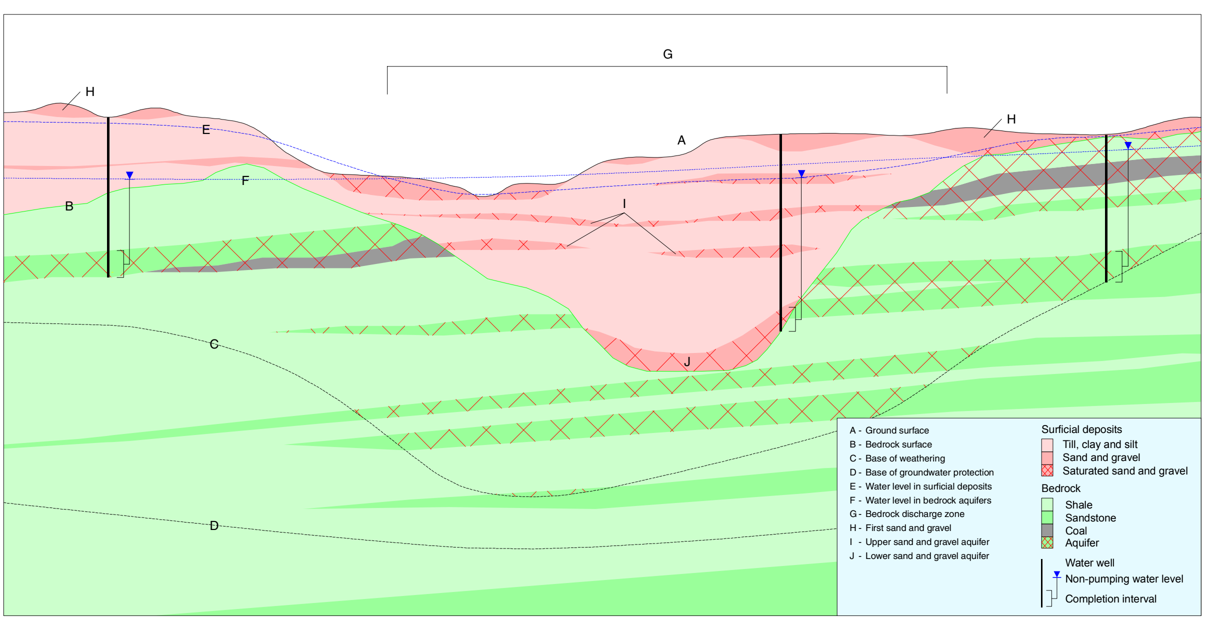

Figure 6. Generalized Cross-Section (for terminology only)

Depth in Metres: 0, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200, 220

	Formation		Unit or Member		
Lithology Description	Average Thickness (m)	Designation	Average Thickness (m)	Designation	Lithology Description
diamicton	< 25	Grand Centre	< 20	Vilna Member	clayey diamicton
			< 30	Kehiwin Member	sandy diamicton
			< 10	Reita Lake Member	clayey sand diamicton
			< 10	Hilda Lake Member	clayey diamicton
sand and gravelly sand	< 25	Sand River			
diamicton	< 25	Marie Creek	10	Unit 2	sandy diamicton
			10	Unit 1	clayey diamicton
silt and clay with sand	2	Ethel Lake			
diamicton	50	Bonnyville	25	Unit 2	sandy clay diamicton
			25	Unit 1	clayey diamicton
sand and gravel	35	Muriel Lake			
clayey diamicton	5	Bronson Lake			
sand and gravel, silt and clay	70	Empress	25	Unit 3	sand and gravel
			25	Unit 2	silt and sand, minor sand and gravel
			25	Unit 1	preglacial sand and gravel (lower surficial deposits)
shale, siltstone	100-200	Lea Park Formation			
sandstone, siltstone, shale, coal	90-120	Milk River Formation			
shale, siltstone	200-1000	*undivided Colorado Group*			

Figure 7. Generalized Geologic Column
(modified after Andriashek and Fenton, 1989)

4. Methodology

4.1 Data Collection and Synthesis

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

1) water well drilling reports
2) aquifer test results from some water wells
3) location of some springs
4) locations for some water wells determined during water well surveys
6) chemical analyses for some groundwaters
7) location of some flowing shot holes
8) location of some structure test holes
9) a variety of data related to the groundwater resource.

The main disadvantage to the database is the absence of quality control. Very little can be done to overcome this lack of quality control in the data collection, other than to assess the usefulness of control points relative to other data during the interpretation. Another disadvantage to the database is the lack of adequate spatial information. Any duplicate water wells that have been identified within the M.D. have been removed from the database used in this regional groundwater assessment.

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

The present project uses the 10TM coordinate system based on the NAD27 datum. This means that a record for the NW ¼ of section 33, township 062, range 02, W4M, would have a horizontal coordinate with an Easting of 308,175 metres and a Northing of 6,036,861 metres, the centre of the quarter section. If the water well has been repositioned by AAFC-PFRA using orthorectified aerial photos, the location will be more accurate, possibly within several tens of metres of the actual location. Once the horizontal coordinates are determined for a record, a ground elevation for that record is obtained from the 1:20,000 Digital Elevation Model (DEM); AltaLIS Ltd. provides the DEM.

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

After assigning spatial control for the ground location for the records in the groundwater database, the data are processed to determine values for hydrogeological parameters**.** As part of the processing, obvious keying errors in the database are corrected.

Where sufficient information is available, individual records are assigned to specific geological units in both the bedrock and the surficial deposits; the minimum information required is a value for the depth to bedrock and a value for depth to top and bottom of the completion intervals[7].

Also, where sufficient information is available, values for apparent transmissivity[8] and apparent yield[9] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. Since the last regional hydrogeological map covering most of the M.D. was published in 1980 (Ozoray, Wallick and Lytviak, 1980), 1,627 values for apparent transmissivity and 1,348 values for apparent yield have been added to the groundwater database. With the addition of the apparent yield values, including a 0.1 m³/day value assigned to dry water wells and water test holes, a hydrogeological map has been prepared to help illustrate the general groundwater availability across the M.D (Figure 8). The map is based on groundwater being obtained from all aquifers and has been prepared to allow direct comparison with the results provided on the Alberta Research Council hydrogeological maps.

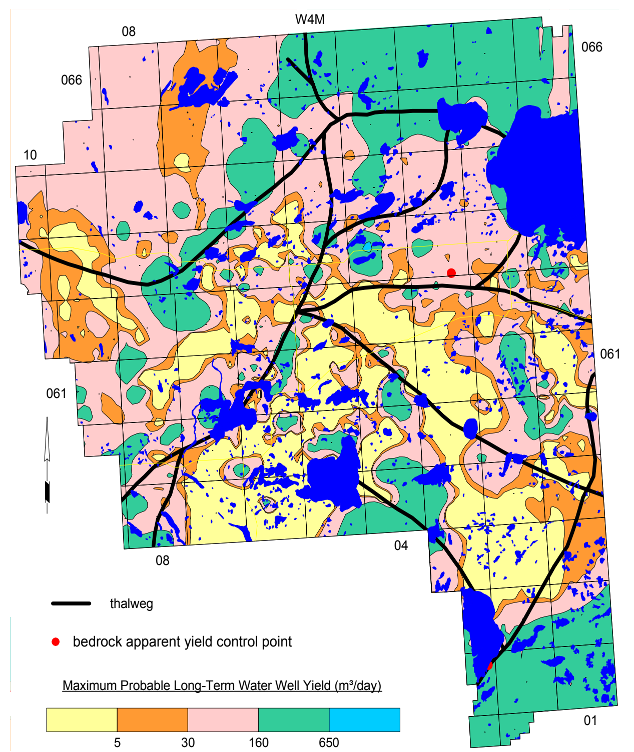

Figure 8. Hydrogeological Map

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

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

Values for apparent transmissivity, apparent yield and hydraulic conductivity are calculated from the DST summaries.

Published and unpublished reports and maps provide the final source of information to be included in the groundwater database. The reference section of this report lists the available reports. 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. Digital data of the Cold Lake stratigraphy were received from L. D. Andriashek (Andriashek and Fenton, 1989).

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

4.2 Spatial Distribution of Aquifers

Determination of the spatial distribution of the geological unit is based on:

1) quaternary geologic formation picks provided by L. D. Andriashek
2) published structure contour maps
3) lithologs provided by the water well drillers
4) geophysical logs from structure test holes
5) geophysical logs for wells drilled by the oil and gas industry
6) data from existing cross-sections.

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

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

4.3 Hydrogeological Parameters

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

After the water wells are assigned to a specific aquifer, the parameters from the water well records are assigned to the individual aquifers. The parameters include non-pumping (static) water level (NPWL), apparent transmissivity, and apparent water well yield. The total dissolved solids, sulfate, nitrate + nitrite (as N), chloride and total hardness concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers. **Since 1986, Alberta Health and Wellness has restricted access to chemical analysis data, and hence the database includes only limited amounts of chemical data since 1986.**

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of these parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid. The representative data set included using the available data from townships 055 to 066, ranges 01 to 10, W4M, plus a buffer area of at least one township. 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.

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

Cross-sections are prepared by first choosing control points from the database along preferred lines of section. Data from these control points are then obtained from the database and placed in an AutoCAD drawing with an appropriate vertical exaggeration. The data placed in the AutoCAD drawing include the geo-referenced lithology, completion intervals and 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; two (E-E’ and B-B’) are included in the text of this Report. The cross-sections are also included on the CD-ROM; page-size maps of the poster-size cross-sections are included in Appendix D of this report.

4.5 Software

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

- Acrobat 4.0
- ArcView 3.2
- AutoCAD 2000
- CorelDraw! 10.0
- Microsoft Office XP
- Surfer 7.0

5. Aquifers

5.1 Background

An aquifer is a permeable rock that is saturated. In this context, rock refers to subsurface materials, such as sand, gravel, sandstone and coal. If the non-pumping water level is above the top of the rock unit, this type of aquifer is an artesian aquifer. If the rock unit is not entirely saturated and the water level is below the top of the 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 M.D. The first geological setting includes the sediments that overlie the bedrock surface. In this report, these sediments are referred to as the surficial deposits. The second geological setting includes aquifers in the upper bedrock. The geological settings, the nature of the deposits making up the aquifers within each setting, the expected yield of water wells completed in aquifer(s) within different geologic units, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

5.1.1 Surficial Aquifers

Surficial deposits in the M.D. are mainly less than 100 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 150 metres. The Buried Helena and Beverly valleys are the main linear bedrock lows in the M.D (see Figure 11). Other linear bedrock lows include the Buried Sinclair, St. Paul and Vermilion valleys, and the Moore Lake, Big Meadow, Bronson Lake and Holyoke channels. The west-east cross-section E-E', Figure 9 shown below, passes across both the Buried Helena and Beverly valleys and shows the surficial deposits being in the order of 200 metres thick across the Buried Helena Valley.

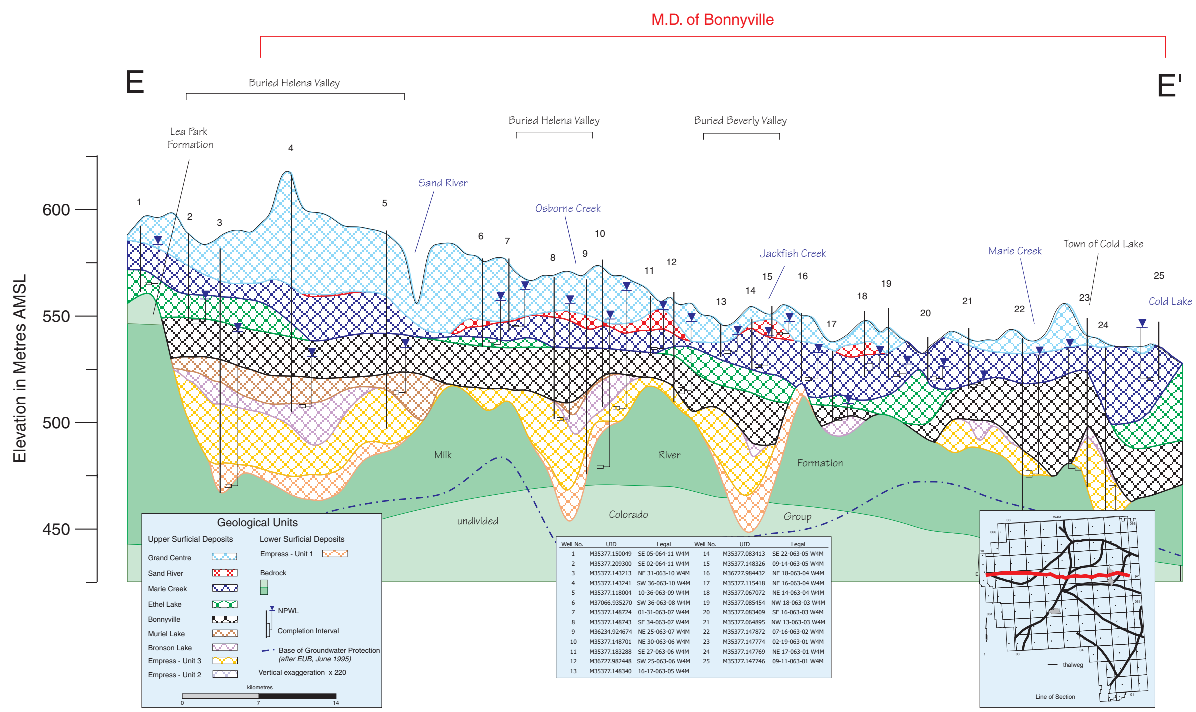
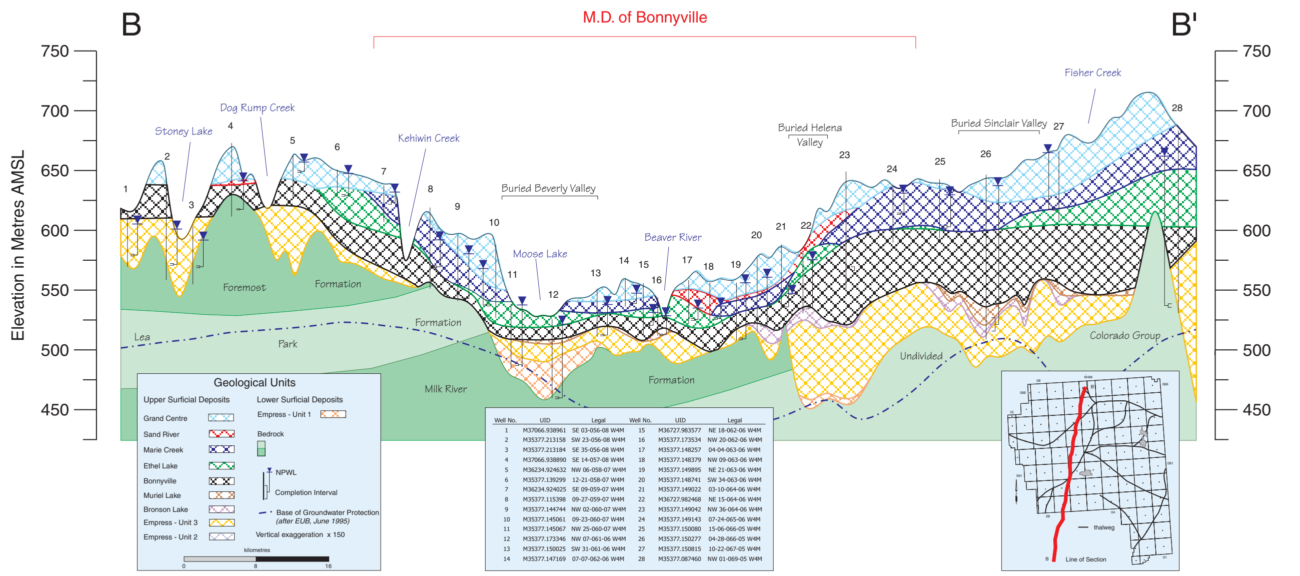


Figure 9. Cross-Section E - E'

In the M.D., the Base of Groundwater Protection extends below the bedrock surface but can extend into the Empress Formation, as shown on Figure 10 on the following page. A map showing the depth to the Base of Groundwater Protection is given on Page 7 of this report, in Appendix A, and on the CD-ROM.

The south-north cross-section B-B', Figure 10 shown below, passes across the Buried Beverly, Helena and Sinclair valleys and shows the surficial deposits being mainly less than 100 metres thick but in the order of 200 metres thick across the Buried Helena Valley.



Well No.	UID	Legal	Well No.	UID	Legal
1	M37066.938961	SE 03-056-08 W4M	15	M36727.983577	NE 18-062-06 W4M
2	M35377.213158	SW 23-056-08 W4M	16	M35377.173534	NW 20-062-06 W4M
3	M35377.213184	SE 35-056-08 W4M	17	M35377.148257	04-04-063-06 W4M
4	M37066.938890	SE 14-057-08 W4M	18	M35377.148379	NW 09-063-06 W4M
5	M36234.924632	NW 06-058-07 W4M	19	M35377.149895	NE 21-063-06 W4M
6	M35377.139299	12-21-058-07 W4M	20	M35377.148741	SW 34-063-06 W4M
7	M36234.924025	SE 09-059-07 W4M	21	M35377.149022	03-10-064-06 W4M
8	M35377.115398	09-27-059-07 W4M	22	M36727.982468	NE 15-064-06 W4M
9	M35377.144744	NW 02-060-07 W4M	23	M35377.149042	NW 36-064-06 W4M
10	M35377.145061	09-23-060-07 W4M	24	M35377.149143	07-24-065-06 W4M
11	M35377.145067	NW 25-060-07 W4M	25	M35377.150080	15-06-066-05 W4M
12	M35377.173346	NW 07-061-06 W4M	26	M35377.150277	04-28-066-05 W4M
13	M35377.150025	SW 31-061-06 W4M	27	M35377.150815	10-22-067-05 W4M
14	M35377.147169	07-07-062-06 W4M	28	M35377.087460	NW 01-069-05 W4M

Figure 10. Cross-Section B - B'

The main aquifers in the surficial materials are sand and gravel deposits. In order for a sand and gravel deposit to be an aquifer, it must be saturated; if not saturated, a sand and gravel deposit is not an aquifer. The top of the surficial aquifers has been determined from the non-pumping water level in water wells that are less than 20 metres deep. The base of the surficial deposits is the bedrock surface.

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the M.D., casing-diameter information is available for 2,361 of the 2,425 water wells completed in the surficial deposits; 269 (11%) of the 2,361 water wells have a casing diameter of more than 275 millimetres, and are assumed to be bored or dug water wells.

5.1.2 Bedrock Aquifers

In the M.D., the upper bedrock includes the Foremost, Lea Park and Milk River formations, and the *undivided* Colorado Group, as shown above in Figure 10. Some of this bedrock contains saturated rocks that are permeable enough to transmit groundwater for a specific need. In the M.D., the upper bedrock aquifer(s) are of minor importance and there are only a few water wells completed in the upper bedrock.

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[10] and lacustrine[11] deposits. The lacustrine deposits include clay, silt and fine-grained sand. The *upper surficial deposits* include the more traditional glacial deposits of till[12], meltwater deposits, and ice contact deposits. Pre-glacial materials are expected to be mainly present in association with the buried bedrock valleys.

5.2.1 Geological Characteristics of Surficial Deposits

While the surficial deposits are treated as one hydrogeologic unit, they consist of three hydraulic parts. The first unit is the sand and gravel deposits of the lower surficial deposits, when present. These deposits are mainly saturated. The second and third hydraulic units are associated with the sand and gravel deposits in the upper surficial deposits. The sand and gravel deposits in the upper surficial deposits occur mainly as pockets. The second hydraulic unit is the saturated part of these sand and gravel deposits; the third hydraulic unit is the unsaturated part of these deposits. For a graphical depiction of the above description, please refer to Figure 6, Page 7. While the unsaturated deposits are not technically an aquifer, they are significant as they provide a pathway for liquid contaminants to move downward into the groundwater.

The base of the surficial deposits is the bedrock surface, represented by the bedrock topography as shown on the adjacent map. There are numerous linear bedrock lows shown on the bedrock topography map. The lowest elevation of the linear bedrock low is the thalweg; the thalwegs for the linear bedrock lows in the present report are named as per Gold, Andriashek and Fenton, 1983.

Over the majority of the M.D., the surficial deposits are less than 100 metres thick (Page A-19). The exceptions are mainly in association with areas where buried bedrock valleys are present, where the deposits can have a maximum thickness of more than 200 metres. The main linear bedrock lows in the M.D. are southwest-northeast-trending, are designated as the Buried Helena Valley and the Buried Beverly Valley. The bedrock surface is at its lowest elevation of less than 440 metres AMSL within the Buried Helena Valley near Cold Lake. The lowest elevation of the bedrock surface within the Buried Beverly Valley is less than 460 metres AMSL.

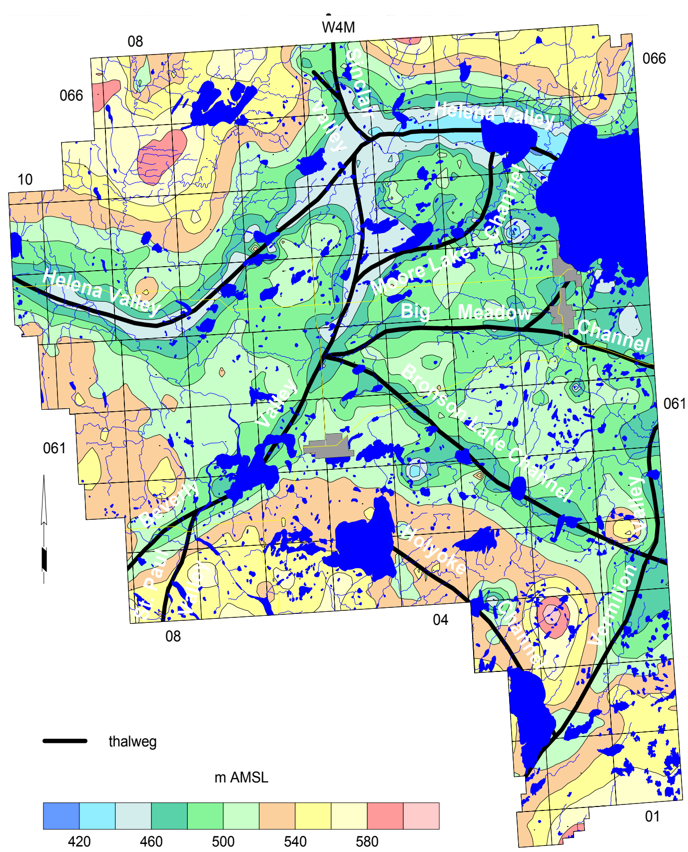


Figure 11. Bedrock Topography

10 See glossary
11 See glossary
12 See glossary

The Buried Helena Valley is the deepest and widest buried bedrock valley in the M.D. and is present in the north-central part of the M.D. The Valley is eight to twelve kilometres wide within the M.D., with local bedrock relief being up to 70 metres. Sand and gravel deposits can be expected in association with this bedrock low, with the sand and gravel deposits expected to be mainly less than 30 metres thick.

There are three buried bedrock valleys that are tributaries to the Buried Helena Valley: the Sinclair, Vermilion, and Imperial Mills valleys. The Buried Sinclair Valley, present in the northern part of the M.D. in townships 065 and 066, range 05, W4M, is eight to ten kilometres wide, with local bedrock relief being up to 80 metres. Sand and gravel deposits can be expected in association with this bedrock low, and can be more than 50 metres thick where the Buried Sinclair Valley joins the Buried Helena Valley.

The Buried Vermilion Valley, present in the southeastern part of the M.D., joins the Buried Helena Valley east of Cold Lake in Saskatchewan. The Buried Vermilion Valley is three to five kilometres wide, with local bedrock relief being up to 40 metres. In the County of Vermilion, where the Buried Vermilion Valley is more clearly defined, the Valley is eight to 15 kilometres wide, with bedrock relief being up to 100 metres. Sand and gravel deposits associated with this bedrock low are expected to be mainly less than ten metres thick.

The Buried Imperial Mills Valley is present in Lakeland County (see Appendix F). The Buried Kikino Valley present in Lakeland County connects two major buried valleys, the Beverly and Helena valleys (Andriashek and Fenton, 1989). The Buried Imperial Mills Valley joins the Buried Helena Valley in township 065, range 11, W4M. The Buried Kikino Valley, not well defined in Lakeland County, joins the Buried Helena Valley near Lac La Biche (Yoon, 1974).

The Buried Beverly Valley enters the M.D. in township 059, range 09, W4M and joins the Buried Helena Valley in township 065, range 05, W4M. The Buried Beverly Valley is five to eight kilometres wide within the M.D., with local bedrock relief being up to 60 metres. Sand and gravel deposits can be expected in association with this bedrock low, with the sand and gravel deposits expected to be mainly less than 20 metres thick.

There are three buried bedrock valleys that are tributaries to the Buried Beverly Valley: the Buried St. Paul, Kikino (Lakeland County) and Vegreville (County of St. Paul) valleys. The Buried Kikino Valley joins the Buried Beverly Valley in the County of Smoky Lake (Andriashek and Fenton, 1989). The Buried Vegreville Valley joins the Buried Beverly Valley in the County of St. Paul.

The Buried St. Paul Valley is the only tributary to the Buried Beverly Valley present within the M.D. The Buried St. Paul Valley, located in the southwestern part of the M.D., joins the Buried Beverly Valley in township 060, range 08, W4M. The Buried St. Paul Valley is not well defined in the M.D., but is expected to be one to two kilometres wide, with local bedrock relief being up to 30 metres. Sand and gravel deposits associated with this bedrock low are mainly less than ten metres thick.

The lower surficial deposits are composed mostly of fluvial and lacustrine deposits. In the Sand River area (73L), the preglacial sediments have been defined by Andriashek and Fenton (1989) to include primarily preglacial sand and gravel deposits, and in this report have not been differentiated between fluvial and lacustrine deposits. The lower sand and gravels are referred to by Andriashek and Fenton as the Empress Formation - Unit 1. The Empress Formation – Unit 1 occurs in the Buried Helena, Beverly and Sinclair valleys, and in parts of the Buried Vermilion Valley. The extent of the Empress Formation – Unit 1 has been defined and documented in the Sand River area (73L) by Yoon (1974), and by Andriashek and Fenton (1989). The total thickness of the Empress Formation – Unit 1 in the Buried Imperial Mills Valley is mainly less than 15 metres.

The upper surficial deposits are either directly or indirectly a result of glacial activity. The deposits include till, with generally minor sand and gravel deposits of meltwater origin, which are expected to occur mainly as isolated pockets. Because the meltwater channels are mainly an erosional feature, the sand and gravel deposits associated with these features are considered not to be significant aquifers. The Formations that comprise the upper surficial deposits have been defined by Andriashek and Fenton (1989) and are described in Section 5.3 of this report. The thickness of the upper surficial deposits is mainly less than 100 metres, but can be more than 150 metres in the northwestern and southwestern parts of the M.D.

The major meltwater channels in the M.D. have been outlined by Andriashek and Fenton (1989). In the M.D., there are four major meltwater channels: the Moore Lake, Big Meadow, Bronson Lake and Holyoke channels as shown previously on Figure 11. These meltwater channels mainly overlie linear bedrock lows. Because sediments associated with the lower sand and gravel deposits are indicated as being present in many of these linear bedrock lows, it is possible that the bedrock lows were originally tributaries to the buried bedrock valleys (Andriashek and Fenton, 1989).

Sand and gravel deposits occur throughout the M.D. (Figure 12). The sand and gravel deposits of more than ten metres thick occur mainly in association with linear bedrock lows. Thicknesses of more than 50 metres are expected at the junction of the Buried Helena and Sinclair valleys and in association with parts of the Holyoke Channel.

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 70% of the M.D. where sand and gravel deposits are present, the sand and gravel deposits are between 10 and 30% of the total thickness of the surficial deposits (Page A-21). The areas where sand and gravel deposits constitute more than 30% of the total thickness of the surficial deposits are mainly in the areas associated with linear bedrock lows.

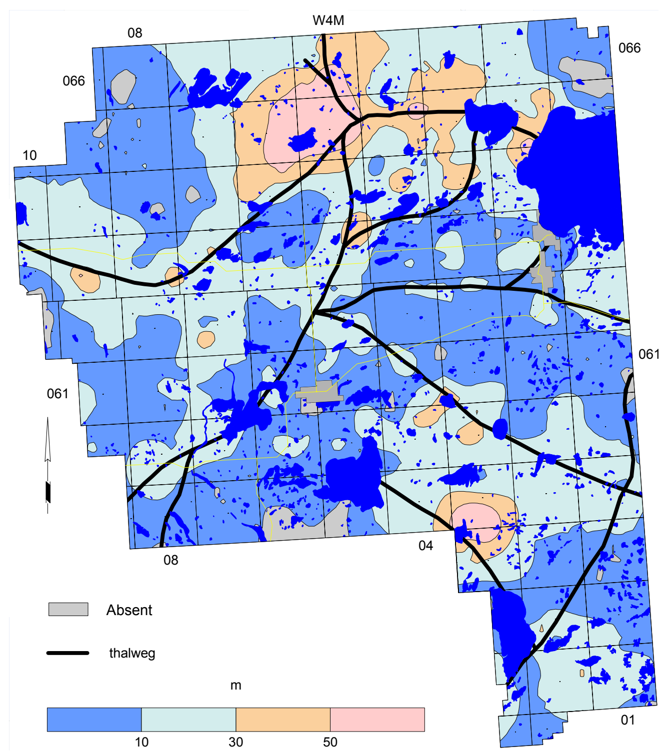


Figure 12. Thickness of Sand and Gravel Deposits

5.3 Surficial Deposits

5.3.1 Quaternary Stratigraphy

There are eight glacial formations and one preglacial formation present in the surficial deposits in the M.D. The eight glacial formations, from youngest to oldest, are: the Grand Centre, Sand River, Marie Creek, Ethel Lake, Bonnyville, Muriel Lake, Bronson Lake formations, and the upper two units (Units 2 and 3) of the Empress Formation. The preglacial formation is the lower unit (Unit 1) of the Empress Formation. A generalized geologic column, showing the eight formations, is illustrated on Figure 7, in Appendix A and on the CD-ROM. The following descriptions of the nine formations are modified from Andriashek and Fenton (1989):

"The Empress Formation is the oldest, and is divided into three units on the basis of lithology; Unit 1, preglacial sand and gravel; Unit 2, silt and clay; and Unit 3, glacial sand and gravel." The thickness of the Empress Formation is in the order of 70 metres. The Empress Formation – Unit 1, where present, rests on the top of the Lea Park and Milk River formations and the *undivided* Colorado Group.

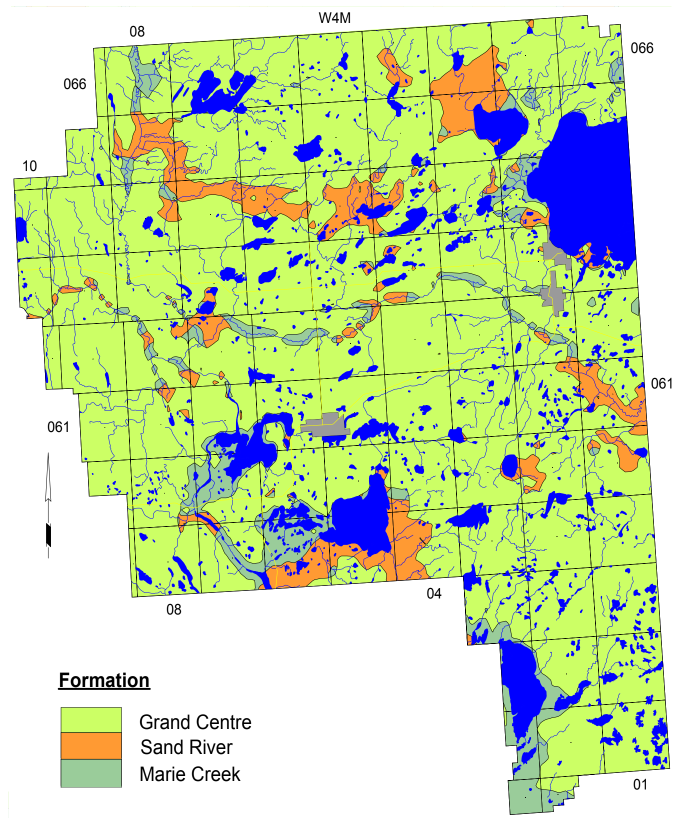


Figure 13. Surficial Geology Map

In the M.D., the sand and gravel deposits of the Empress Formation – Unit 1 are found on the floors of the Buried Helena and Beverly valleys and the southern portion of the Buried Sinclair Valley. "Unit 1 generally consists of thin (< 5 metres) basal gravel overlain by sand or gravelly sand ranging in thickness from 5 to 10 metres".

In the M.D., the silt and silty clay deposits of the Empress Formation – Unit 2 "is confined almost entirely to the bottoms of the valleys and channels", specifically segments of the Buried Helena, Beverly and Sinclair valleys, and a segment of the Moore Lake Channel. "The Unit is generally thick near the confluence of the Buried Helena and Beverly valleys", where the Unit can be up to 40 metres thick. There will be no direct review of the Empress Formation - Unit 2 because there are no water wells in the M.D. that are completed in the Unit; the only maps associated with the Empress Formation – Unit 2 to be included on the CD-ROM will be structure-contour maps.

In the M.D., the Empress Formation – Unit 3 is the lowest stratigraphic unit, all of whose sediments are of glacial origin. The sediments consist primarily of sand and gravel deposits. The determination of the areal extent and thickness of the Empress Formation – Unit 3 is the only Formation designation that differs from Andriashek and Fenton. The Empress Formation - Unit 3 directly overlies the bedrock surface in areas of bedrock highs. For this regional study, the determination of the areal extent and thickness of the Empress Formation – Unit 3 is calculated by subtracting the total thickness of the Bonnvyille, Muriel Lake and Bronson Lake formations from the top of the Bonnyville Formation.

The Bronson Lake Formation overlies the Empress Formation and consists of glacial clayey till and clay and has an average thickness of less than ten metres. “The Bronson Lake Formation lies primarily within or along segments of the major buried valleys and channels”.

The Muriel Lake Formation overlies the Bronson Lake Formation and consists of glacial sand and gravel and is approximately 35 metres thick. “The Muriel Formation lies both within segments of the buried valleys and (meltwater) channels.”

There are two units that comprise the overlying Bonnyville Formation. Unit 1 overlies the Muriel Lake Formation and is composed of approximately 25 metres of clayey till. Unit 2 is composed of approximately 25 metres of sandy till. In the M.D., the Bonnyville Formation is the only widespread formation that is continuous.

The glaciolacustrine silt and clay, and minor sand and gravel deposits of the overlying Ethel Lake Formation, have an average thickness of two metres. In the M.D., the Ethel Lake Formation is widespread, but not continuous.

The overlying Marie Creek Formation is broken down into two units, each approximately 25 metres thick. Unit 2 is composed of clayey till and Unit 1 is characterized by a coarse sand deposit. The upper part of the Marie Creek Formation outcrops, as shown on Figure 13.

The overlying Sand River Formation consists of up to 25 metres of sand and gravel. The Formation is primarily recognized in outcrops and test holes.

The Grand Centre Formation is the uppermost Quaternary stratigraphic formation, exposed at surface, and is mainly less than 25 metres thick. There are four members that comprise the Grand Centre Formation and have been defined based on grain size. The four members are: the Vilna, Kehiwin, Reita Lake and Hilda Lake members. The Vilna and Hilda Lake members are glacial clayey till deposits, and the Kehiwin and Reita Lake members are clayey till deposits overlain by stratified sand and gravel in places (Andreashek and Fenton, 1989).

5.3.2 Aquifers

Of the 2,432 water well records with completion interval and lithologic information, such that the aquifer in which the water wells are completed could be defined, 2,425 are completed in surficial aquifers.

Assigning the water well to specific geologic units is possible only if the completion interval is identified. With this information, it has been possible to designate the specific surficial aquifer of completion for 2,405 water wells. Of the 2,405 water wells, 2,295 are water wells completed in the upper surficial deposits and 110 are completed in the lower surficial deposits. The remaining 20 of the total 2,425 surficial water wells are identified as being completed in more than one surficial aquifer. The surficial water wells are mainly completed in the Marie Creek, Bonnyville, and the Empress – Unit 3 aquifers, as shown in the adjacent table.

Geologic Unit	No. of Surficial Water Wells
Upper Surficial Deposits	
Grand Centre	157
Sand River	56
Marie Creek	581
Ethel Lake	237
Bonnyville	572
Muriel Lake	198
Bronson Lake	69
Empress - Unit 3	425
Empress - Unit 2	0
Total	2,295
Lower Surficial Deposits	
Empress - Unit 1	110
Multiple Completions	20
Total	2,425

Table 2. Completion Aquifer

5.3.3 Sand and Gravel Aquifer(s)

The primary sources of groundwater in the M.D. are the aquifers in the surficial deposits. Since the sand and gravel aquifer(s) are not everywhere, the actual aquifer that is developed at a given location is usually dictated by the aquifer that is present. In the M.D., the thickness of the sand and gravel aquifer(s) is generally less than 30 metres, but can be more than 30 metres at the confluence of the Buried Helena and Sinclair valleys (Page A-20 and on CD-ROM). The non-pumping water-level surface in the sand and gravel aquifer(s) is a subdued replica of the topographic surface (see CD-ROM) and is sloped toward the Beaver River.

The adjacent map shows expected yields for water wells completed in sand and gravel aquifer(s). Over approximately 5% of the M.D., the sand and gravel deposits are not present, or if present, are not saturated; these areas are designated as grey on the adjacent map.

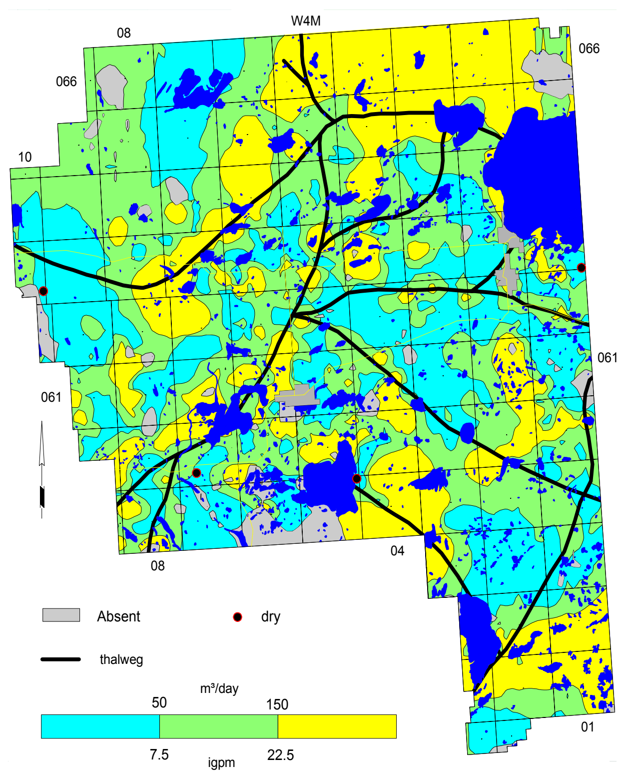


Figure 14. Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

In the M.D., there are 1,582 surficial water wells that have apparent yield values. The locations of four dry test holes are shown on the adjacent figure. Based on the aquifers that have been developed by existing water wells, these data show that water wells with yields of more than 50 m³/day from sand and gravel aquifer(s) can be expected in most of the M.D. The most notable areas where yields of more than 100 m³/day are expected are mainly in association with the buried bedrock valleys. The apparent yields tend to be more variable in areas of meltwater channels.

Of the 1,582 water well records with apparent yield values, 1,575 have been assigned to aquifers associated with specific geologic units. Forty-seven percent (742) of the 1,582 water wells completed in the sand and gravel aquifer(s) have apparent yields that are less than 50 m³/day, 26% (419) have apparent yield values that range from 50 to 150 m³/day, and 27% (421) have apparent yields that are greater than 150 m³/day, as shown in Table 3.

Aquifer	No. of Water Wells with Values for Apparent Yield	Number of Water Wells with Apparent Yields <50 m³/day	50 to 150 m³/day	>150 m³/day
Grand Centre	77	61	13	3
Sand River	39	25	8	6
Marie Creek	374	237	91	46
Ethel Lake	170	84	46	40
Bonnyvile	376	183	106	87
Muriel Lake	150	48	46	56
Bronson Lake	50	13	12	25
Empress - Unit 3	259	80	71	108
Empress - Unit 2	0	0	0	0
Empress - Unit 1	80	10	26	44
Multiple Completions	7	1	0	6
Totals	1,582	742	419	421

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

5.3.3.1 Chemical Quality of Groundwater from Surficial Deposits

The chemical analysis results of groundwaters from the surficial deposits indicate the groundwaters are generally chemically hard and high in dissolved iron. In the M.D. of Bonnyville, groundwaters from the surficial aquifers mainly have a chemical hardness of greater than 100 mg/L (see CD-ROM).

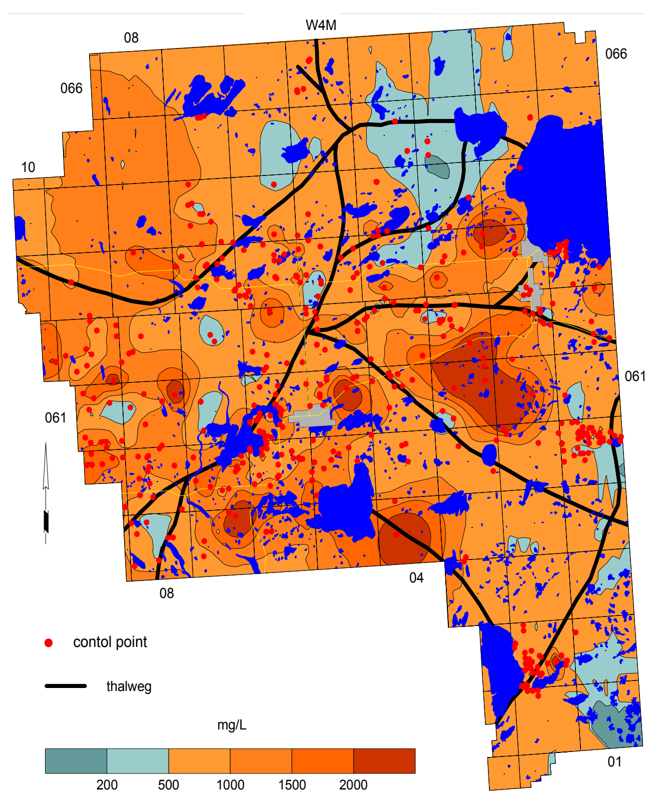


Figure 15. Total Dissolved Solids in Groundwater from Surficial Deposits

The Piper tri-linear diagram[13] for surficial deposits (Page A-25) shows the groundwaters are mainly calcium-magnesium-bicarbonate-type waters. More than 80% of the groundwaters from the surficial deposits have a TDS concentration of more than 500 mg/L. Groundwaters having TDS concentrations of less than 500 mg/L occur mainly in the vicinity of the confluence of the Moore Lake Channel and the Buried Helena Valley. Groundwaters having TDS concentrations of more than 2,000 mg/L occur mainly east of the Buried Beverly Valley. The highest median TDS concentrations occur below the Ethel Lake Aquifer (see Tables 5 to 13).

There are groundwaters with sulfate as the main anion. The groundwaters with elevated levels of sulfate generally occur in areas where there are elevated levels of total dissolved solids. There are very few groundwaters from the surficial deposits with appreciable concentrations of the chloride ion and in 87% of the samples analyzed for surficial deposits in the M.D., the chloride ion concentration is less than 100 mg/L (see CD-ROM). The highest median chloride concentrations occur below the Bonnyville Aquifer (see Tables 5 to 13).

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	663	85	6846	748	500
Sodium	610	4	1650	112	200
Sulfate	667	0	3900	92	500
Chloride	673	0	1500	10	250
Nitrate + Nitrite (as N)	470	0	52	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 4. Concentrations of Constituents in Groundwaters from Surficial Aquifers

In the M.D, 99% of the samples from surficial deposits analyzed for nitrate + nitrate (as N) concentrations are below the maximum acceptable concentrations (MAC) of 10 mg/L (see CD-ROM).

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 M.D. have been compared to the SGCDWQ in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of the TDS concentration exceeds the guidelines.

[13] See glossary

5.3.4 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 isolated deposits are expected over approximately 95% of the M.D.

5.3.4.1 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 M.D., the thickness of the Upper Sand and Gravel Aquifer is generally less than ten metres, but can be more than 20 metres in the linear bedrock lows (see CD-ROM).

5.3.4.2 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 anticipated groundwater apparent yield in the Upper Sand and Gravel Aquifer is based on the expected yields of single water wells obtaining water from the total accessible seven glacial aquifers that comprise the Upper Sand and Gravel Aquifer.

The apparent yields for water wells completed through this Aquifer are expected to be mainly less than 150 m³/day, as shown on the adjacent figure. The large area of higher yields shown in the northeastern part of the M.D. is based on a few control points.

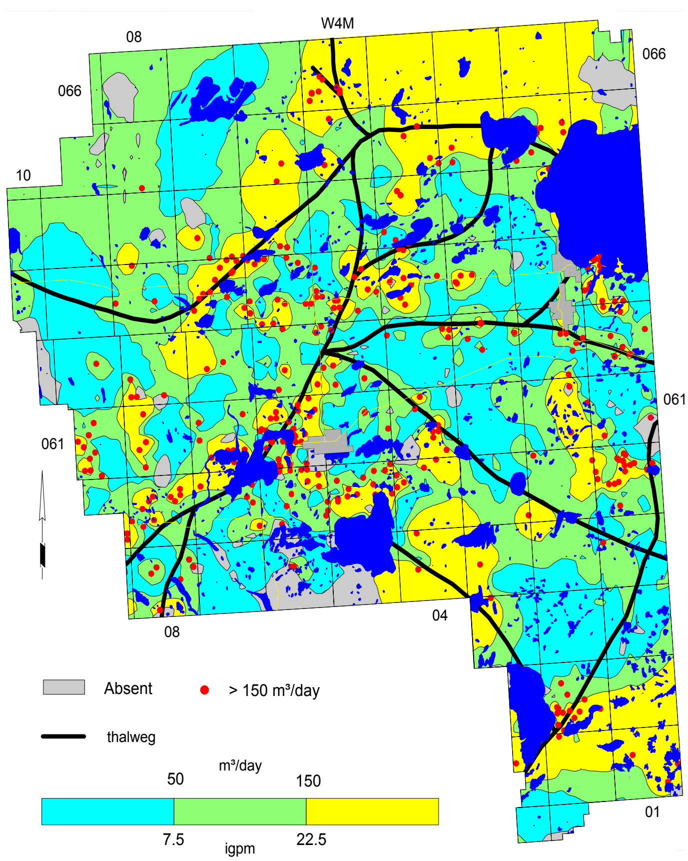

Figure 16. Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer

5.3.5 Grand Centre Aquifer

The Grand Centre Aquifer comprises the permeable parts of the Grand Centre Formation, as defined for the present program. The Grand Centre Formation is the uppermost formation, is present over most of the M.D., and has a thickness that is mainly less than 25 metres.

5.3.5.1 Depth to Top

The depth to the top of the Grand Centre Formation is a function of the thickness of the postglacial stratified deposits. The Grand Centre Formation lies at the surface in most places, except where it is buried by postglacial stratified sediment (Andriashek and Fenton, 1989).

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Grand Centre Aquifer are mainly in the range of 20 to 50 m³/day, with nearly 80% of the values being less than 50 m³/day (Table 3). Shown on the adjacent map is the location of one dry test hole in 02-01-063-01 W4M.

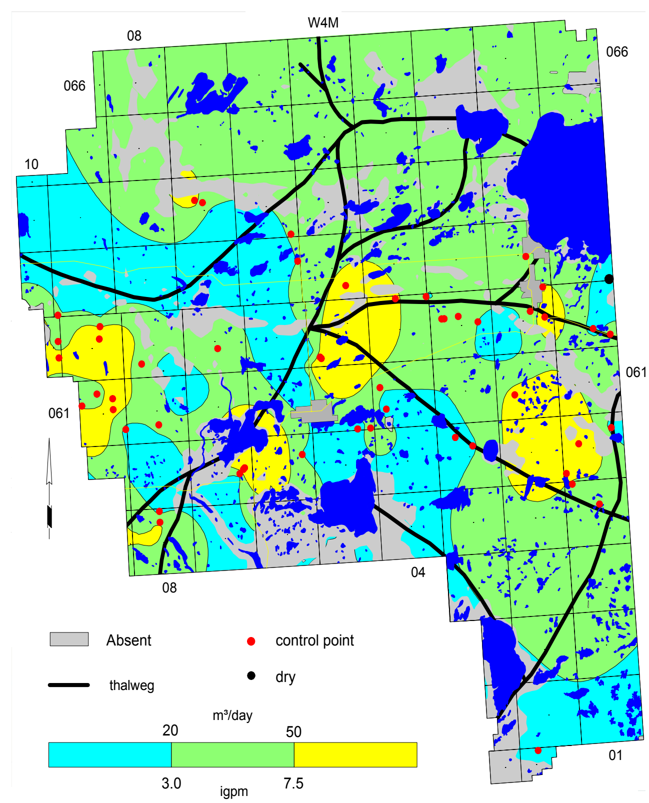

Figure 17. Apparent Yield for Water Wells Completed through Grand Centre Aquifer

In the M.D., there are eight licensed groundwater water wells completed through the Grand Centre Aquifer, with a total authorized diversion of 60 m³/day; seven of the eight licensed users are for agricultural purposes. Five of the eight licensed water wells could be linked to a water well in the AENV groundwater database.

5.3.5.3 Quality

The groundwaters from the Grand Centre Aquifer are a calcium-magnesium-bicarbonate type (see Piper diagram on CD-ROM). 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 Grand Centre Aquifer in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of the TDS concentration exceeds the guidelines but is below the median value of TDS for all surficial deposits.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	34	108	3586	554	748	500
Sodium	29	6.3	423	32	112	200
Sulfate	34	0	2071	46	92	500
Chloride	34	0	92	3	10	250
Nitrate + Nitrite (as N)	23	0	31	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 5. Concentrations of Constituents in Groundwaters from Grand Centre Aquifer

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Grand Centre Aquifer are below the median concentrations from water wells completed in all surficial deposits.

5.3.6 Sand River Aquifer

The Sand River Aquifer comprises the permeable parts of the Sand River Formation, which underlies the Grand Centre Formation. Structure contours have been prepared for the top of the Sand River Formation. The structure contours show the Sand River Formation ranges in elevation from less than 550 to more than 675 metres AMSL and has a thickness of in the order of 25 metres (see CD-ROM).

5.3.6.1 Depth to Top

The depth to the top of the Sand River Formation ranges from less than five metres below ground level to more than 15 metres at the Formation edges (Page A-30).

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Sand River Aquifer range mainly from 10 to 100 m³/day. The largest number of control points are in townships 061 and 062, ranges 03 to 05, and ranges 07 and 08, W4M. In the M.D., there are no control points from the groundwater database for the Sand River Aquifer north of township 064, W4M.

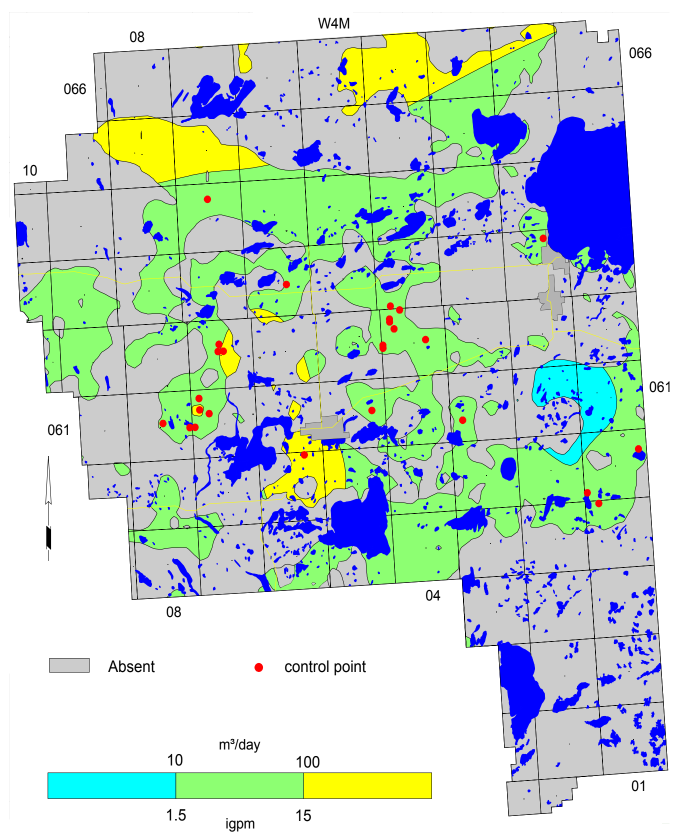

Figure 18. Apparent Yield for Water Wells Completed through Sand River Aquifer

In the M.D., there are two licensed water wells that are completed in the Sand River Aquifer, with a total authorized diversion of 13.5 m³/day; both are for agricultural purposes. Both licensed water wells could be linked to a water well in the AENV groundwater database.

5.3.6.3 Quality

There are sufficient data from three water wells to determine the groundwater type from the Sand River Aquifer; these data show that the groundwaters are calcium-magnesium bicarbonate and calcium-magnesium-sulfate types (see Piper diagram on CD-ROM). 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 Sand River Aquifer in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. None of the median values of the five constituents that have been compared to the SGCDWQ exceed the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	11	252	1196	465	748	500
Sodium	11	4	146	21	112	200
Sulfate	11	0	333	21	92	500
Chloride	11	0	27	2	10	250
Nitrate + Nitrite (as N)	7	0	1	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 6. Concentrations of Constituents in Groundwaters from Sand River Aquifer

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Sand River Aquifer are below the median concentrations from water wells completed in all surficial deposits.

5.3.7 Marie Creek Aquifer

The Marie Creek Aquifer comprises the permeable parts of the Marie Creek Formation, which underlies the Sand River Formation. Structure contours have been prepared for the top of the Marie Creek Formation. The structure contours show the Marie Creek Formation ranges in elevation from less than 540 to more than 650 metres AMSL and has a thickness of mainly less than 30 metres (see CD-ROM).

5.3.7.1 Depth to Top

The depth to the top of the Marie Creek Formation ranges from less than ten metres below ground level to more than 50 metres in the northwestern and southeastern parts of the M.D. (Page A-33).

5.3.7.2 Apparent Yield

The apparent yields for individual water wells completed through the Marie Creek Aquifer range mainly from 10 to 100 m³/day. Sixty-three percent of water wells completed in the Marie Creek Aquifer have apparent yields that are less than 50 m³/day. Shown on the adjacent map is the location of the one dry test hole in SE 08-060-07, W4M. The largest number of control points are in townships 060 to 063, W4M.

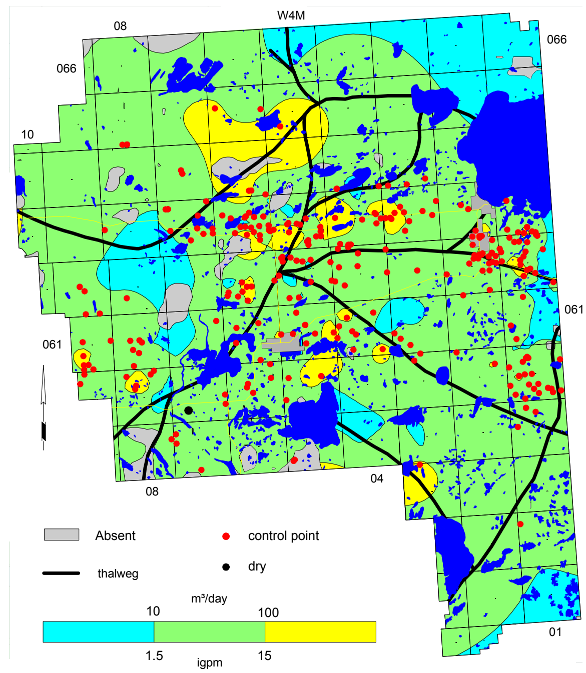

Figure 19. Apparent Yield for Water Wells Completed through Marie Creek Aquifer

In the M.D., there are 17 licensed water wells that are completed in the Marie Creek Aquifer, with a total authorized diversion of 1,921 m³/day; the highest allocations are for five dewatering water wells for the Town of Grand Centre, totalling 1,842 m^3/day. Sixteen of the 17 licensed water wells could be linked to a water well in the AENV groundwater database.

Extended aquifer tests conducted with two water source wells completed in the Marie Creek Aquifer in NW 20-062-03 W4M indicated a total long-term yield of 820 m³/day from both water source wells, based on an effective transmissivity of 180 metres squared per day (m²/day) (HCL, 1988b).

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	113	130	3730	627	748	500
Sodium	102	6	545	50	112	200
Sulfate	113	0	2308	65	92	500
Chloride	113	0	512	4	10	250
Nitrate + Nitrite (as N)	67	0	21	0.0	0.0	10

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

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Table 7. Concentrations of Constituents in Groundwaters from Marie Creek Aquifer

5.3.7.3 Quality

The groundwaters from the Marie Creek Aquifer are mainly a calcium-magnesium-bicarbonate type (see Piper diagram on CD-ROM). 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 Marie Creek Aquifer in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. 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 and chloride from water wells completed in the Marie Creek Aquifer are below the median concentrations from water wells completed in all surficial deposits. A groundwater sample from one of the water source wells in NW 20-062-03 W4M has a TDS concentration of 352 mg/L, a sodium concentration of 28 mg/L, a sulfate concentration of 3 mg/L, a chloride concentration of 7 mg/L, and a nitrate + nitrite (as N) of less than 0.2 mg/L.

5.3.8 Ethel Lake Aquifer

The Ethel Lake Aquifer comprises the permeable parts of the Ethel Lake Formation, which underlies the Marie Creek Formation. Structure contours have been prepared for the top of the Ethel Lake Formation. The structure contours show the Ethel Lake Formation ranges in elevation from less than 520 to more than 620 metres AMSL and has an average thickness of two metres but can be more than 30 metres (see CD-ROM).

5.3.8.1 Depth to Top

The depth to the top of the Ethel Lake Formation ranges from less than 30 metres below ground level to more than 50 metres in the southeastern part of the M.D. (Page A-36).

5.3.8.2 Apparent Yield

The apparent yields for individual water wells completed through the Ethel Lake Aquifer range mainly from 10 to 100 m³/day. Seventy-five percent of the water wells completed in the Ethel Lake Aquifer have apparent yields that are less than 100 m³/day. The fewest number of control points are north of the Buried Helena Valley and east of the Buried Vermilion Valley.

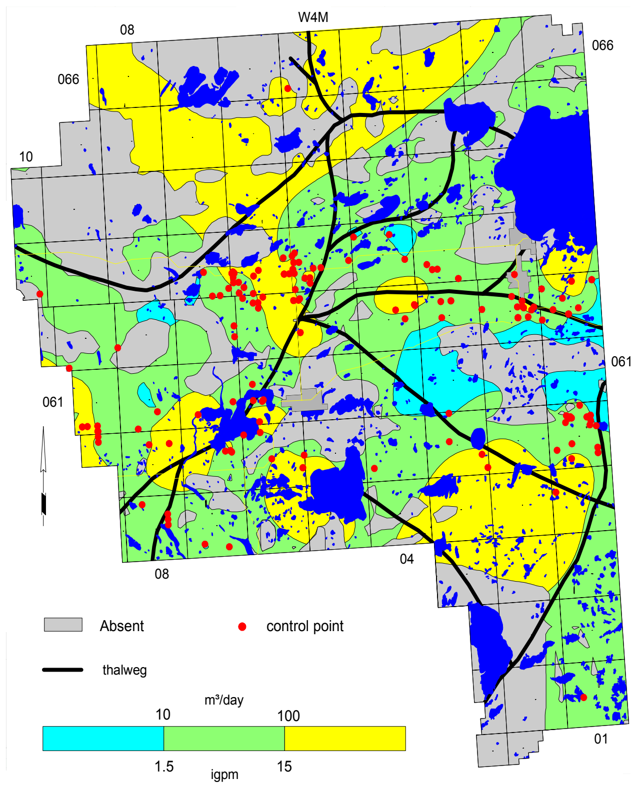

Figure 20. Apparent Yield for Water Wells Completed through Ethel Lake Aquifer

In the M.D., there are seven licensed water wells that are completed in the Ethel Lake Aquifer, with a total authorized diversion of 72 m³/day; the highest allocation of 24 m³/day is for an Alberta Recreation and Parks water well in 01-08-061-07 W4M. Four of the seven licensed water wells could be linked to a water well in the AENV groundwater database.

5.3.8.3 Quality

The groundwaters from the Ethel Lake Aquifer are mainly a calcium-magnesium type (see Piper diagram on CD-ROM). 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 Ethel Lake Aquifer in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	104	132	2488.7	621	748	500
Sodium	104	8	621.3	52	112	200
Sulfate	105	0	1437	60	92	500
Chloride	110	0	163	9	10	250
Nitrate + Nitrite (as N)	79	0	4	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 8. Concentrations of Constituents in Groundwaters from Ethel Lake Aquifer

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Ethel Lake Aquifer are below the median concentrations from water wells completed in all surficial deposits.

5.3.9 Bonnyville Aquifer

The Bonnyville Aquifer comprises the permeable parts of the Bonnyville Formation, which underlies the Ethel Lake Formation. In the M.D., the Bonnyville Formation is the only widespread formation that is continuous. Structure contours have been prepared for the top of the Bonnyville Formation. The structure contours show the Bonnyville Formation ranges in elevation from less than 500 to more than 600 metres AMSL and has a thickness of mainly less than 50 metres (see CD-ROM).

5.3.9.1 Depth to Top

The depth to the top of the Bonnyville Formation ranges from less than 30 metres below ground level to more than 80 metres in the southeastern part of the M.D. (Page A-39).

5.3.9.2 Apparent Yield

The apparent yields for individual water wells completed through the Bonnyville Aquifer are mainly in the range of 10 to 100 m³/day, with nearly 25% of the values being more than 150 m³/day. Shown on the adjacent map is the location of one dry test hole in NE 36-059-05 W4M.

In the M.D., there are 19 licensed groundwater water wells completed through the Bonnyville Aquifer, with a total authorized diversion of 6,416 m³/day, of which 6,228 m³/day is for industrial purposes. The highest diversions are for six water source wells in section 10, township 066, range 05, W4M. Fifteen of the 19 licensed water wells could be linked to a water well in the AENV groundwater database.

Extended aquifer testing was conducted with three water test holes completed for Husky Oil Operations Ltd. in the Bonnyville Aquifer in section 28, township 064, range 04, W4M. Initial results of the testing indicated that the long-term yield from the proposed water source wells would be approximately 1,000 m³/day, based on an effective transmissivity of 450 m²/day and a corresponding storativity of 0.0001 (HCL, June 1983). The 1987 licensed groundwater diversion from one water source well and one standby water well was 600,000 m³/yr (1,644 m³/day) (HCL, 1988).

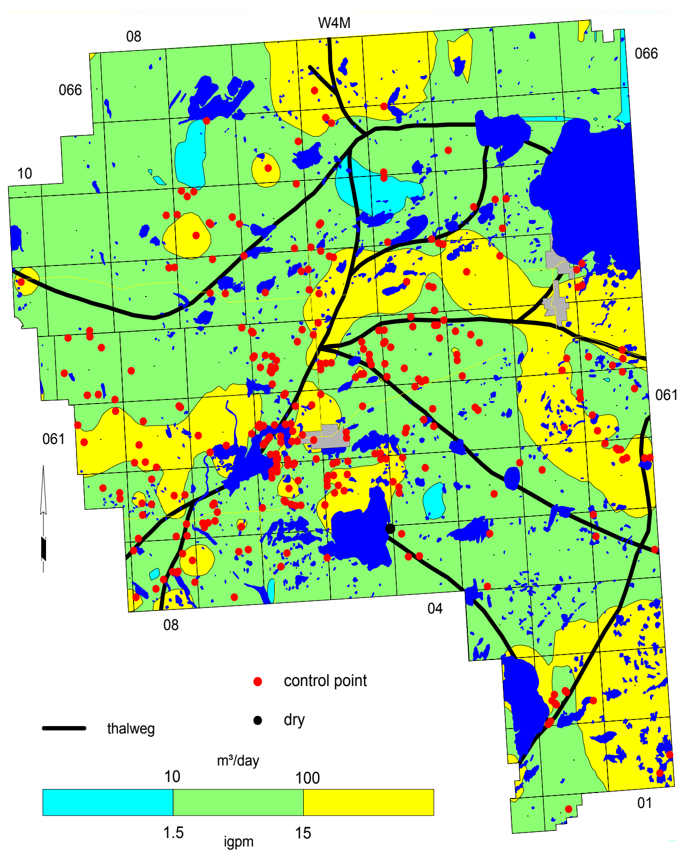

Figure 21. Apparent Yield for Water Wells Completed through Bonnyville Aquifer

5.3.9.3 Quality

The groundwaters from the Bonnyville Aquifer are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). 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 Bonnyville Aquifer in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	142	299	3490	759	748	500
Sodium	128	9	800	101	112	200
Sulfate	142	0	1422	118	92	500
Chloride	142	0	1213	8	10	250
Nitrate + Nitrite (as N)	98	0	3	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
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Table 9. Concentrations of Constituents in Groundwaters from Bonnyville Aquifer

The median concentration of TDS from water wells completed in the Bonnyville Aquifer is above the median TDS concentration from water wells completed in all surficial deposits.

A groundwater sample from the Husky water source well in 12C 28-064-04 W4M has a TDS concentration of 568 mg/L, a sodium concentration of 37 mg/L, a sulfate concentration of 24 mg/L, a chloride concentration of 1 mg/L, and a nitrate + nitrite (as N) of less than 0.2 mg/L (HCL, 1988).

5.3.10 Muriel Lake Aquifer

The Muriel Lake Aquifer comprises the permeable parts of the Muriel Lake Formation, which underlies the Bonnyville Formation. Structure contours have been prepared for the top of the Muriel Lake Formation. The structure contours show the Muriel Lake Formation ranges in elevation from less than 470 to more than 560 metres AMSL and has a thickness of mainly less than 30 metres (see CD-ROM).

5.3.10.1 Depth to Top

The depth to the top of the Muriel Lake Formation ranges from less than 30 metres below ground level to more than 80 metres at the Formation edges (Page A-42).

5.3.10.2 Apparent Yield

The apparent yields for individual water wells completed through the Muriel Lake Aquifer are mainly between 10 and 100 m³/day, with 32% of the values being less than 50 m³/day, 31% between 50 and 150 m³/day, and 37% of the values being more than 150 m³/day. Shown on the adjacent map are the locations of two dry test holes: one in SE 12-063-10 W4M and one in 16-03-063-10, W4M.

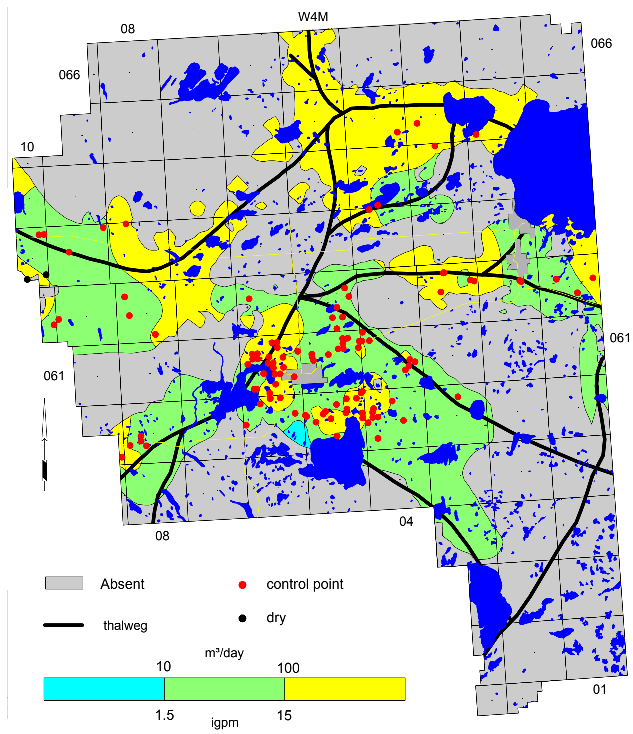

Figure 22. Apparent Yield for Water Wells Completed through Muriel Lake Aquifer

In the M.D., there are eight licensed water wells that are completed in the Muriel Lake Aquifer, with a total authorized diversion of 497 m³/day. The two highest allocations totalling 400 m³/day are for two Village of Glendon water supply wells in 01-26-060-08 W4M used for municipal purposes. Seven of the eight licensed water wells could be linked to a water well in the AENV groundwater database.

An extended aquifer test conducted with a water source well completed in the Muriel Lake Aquifer in 02-33-062-03 W4M indicated a total long-term yield of greater than 300 m³/day, based on an effective transmissivity of 130 m²/day (HCL, 1985b).

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	47	122	2405	994	748	500
Sodium	42	16	505	197	112	200
Sulfate	48	0	1130	187	92	500
Chloride	48	0	510	31	10	250
Nitrate + Nitrite (as N)	39	0	0	0.0	0.0	10

Table 10. Concentrations of Constituents in Groundwaters from Muriel Lake Aquifer

5.3.10.3 Quality

The groundwaters from the Muriel Lake Aquifer are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). 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 Muriel Lake Aquifer in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. 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 and chloride from water wells completed in the Muriel Lake Aquifer are greater than the median concentrations from water wells completed in all surficial deposits.

5.3.11 Bronson Lake Aquifer

The Bronson Lake Aquifer comprises the permeable parts of the Bronson Lake Formation, which underlies the Muriel Lake Formation. Structure contours have been prepared for the top of the Bronson Lake Formation. The structure contours show the Bronson Lake Formation ranges in elevation from less than 460 to more than 560 metres AMSL and has a thickness of mainly less than 15 metres (see CD-ROM).

5.3.11.1 Depth to Top

The depth to the top of the Bronson Lake Formation ranges from less than 50 metres below ground level to more than 80 metres at the Formation edges (Page A-45).

5.3.11.2 Apparent Yield

The apparent yields for individual water wells completed through the Bronson Lake Aquifer are mainly greater than 100 m³/day, with 50% of the values being more than 150 m³/day.

In the M.D., there are nine licensed water wells that are completed in the Bronson Lake Aquifer, with a total authorized diversion of 2,073 m³/day. The highest allocation of 1,702 m³/day is for a water source well in 12-10-065-05 W4M used for industrial purposes. All nine licensed water wells could be linked to a water well in the AENV groundwater database.

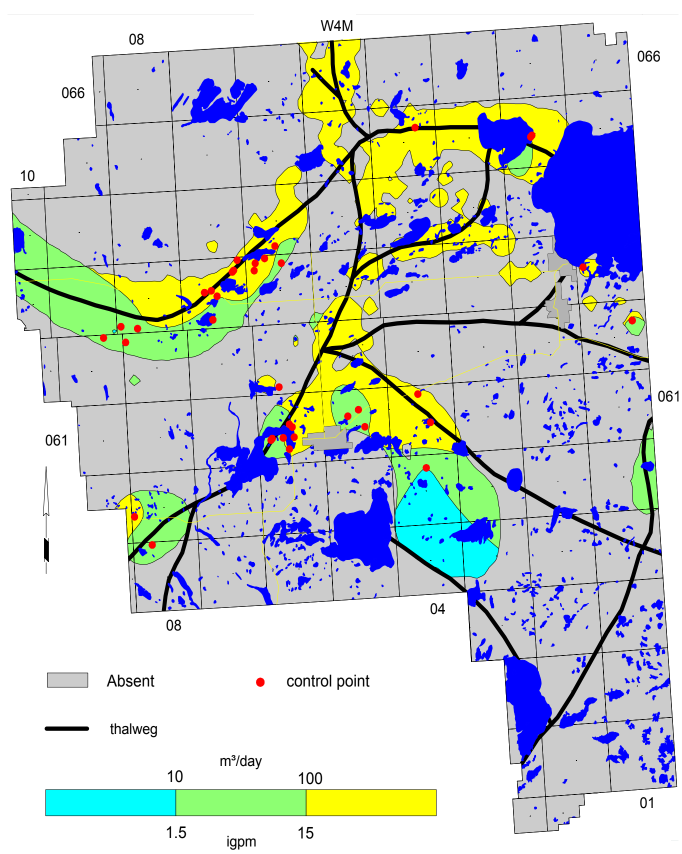

Figure 23. Apparent Yield for Water Wells Completed through Bronson Lake Aquifer

5.3.11.3 Quality

The groundwaters from the Bronson Lake Aquifer are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). 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 Bronson Lake Aquifer in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	23	223	1850	824	748	500
Sodium	23	35	520	189	112	200
Sulfate	23	0	617	100	92	500
Chloride	23	0	638	16	10	250
Nitrate + Nitrite (as N)	19	0	7	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 11. Concentrations of Constituents in Groundwaters from Bronson Lake Aquifer

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Bronson Lake Aquifer are greater than the median concentrations from water wells completed in all surficial deposits.

5.3.12 Empress Aquifer – Unit 3

The Empress Aquifer – Unit 3 comprises the permeable parts of the Empress Formation – Unit 3. Structure contours have been prepared for the top of the Empress Formation – Unit 3. The structure contours show the Empress Formation – Unit 3 ranges in elevation from less than 470 to more than 550 metres AMSL and has a thickness of mainly less than 50 metres (see CD-ROM).

5.3.12.1 Depth to Top

The depth to the top of Unit 3 ranges from less than 50 metres below ground level to more than 100 metres in parts of the north-central, northwestern and southeastern areas of the M.D. (Page A-48).

5.3.12.2 Apparent Yield

The apparent yields for individual water wells completed through the Empress Aquifer - Unit 3 are mainly greater than 100 m^3/day, with 31% of the values being less than 50 m^3/day, 27% between 50 and 150 m^3/day, and 42% of the values being more than 150 m^3/day.

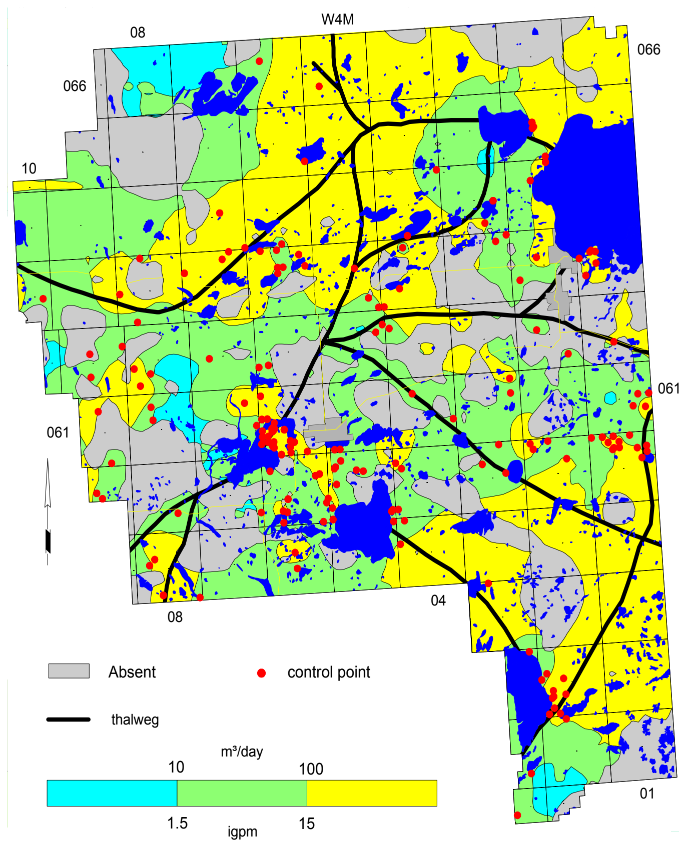

Figure 24. Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 3

In the M.D., there are 21 licensed water wells that are completed in the Empress Aquifer - Unit 3, with a total authorized diversion of 9,266 m^3/day. The highest allocation of 4,000 m^3/day is for a water source well in 05-22-065-04 W4M used for industrial purposes. Seventeen of the 21 licensed water wells could be linked to a water well in the AENV groundwater database.

An extended aquifer test conducted with a water source well completed in the Empress Aquifer – Unit 3 in 04-33-061-04 W4M indicated a total long-term yield of 380 m^3/day, based on an effective transmissivity of 130 m^2/day (HCL, May 1985). This water source well is currently licensed to divert 500 m^3/day for industrial purposes.

In 1982, BP Exploration was licensed to divert 470,000 m^3/year (1,300 m^3/day) for industrial purposes from a water source well completed in the Empress Aquifer - Unit 3 in 09-07-066-05 W4M. From 1978 to 1982, nearly 1,000,000 cubic metres were diverted from this water source well (HCL, 1983).

5.3.12.3 Quality

The groundwaters from the Empress Aquifer – Unit 3 are mainly a bicarbonate type, with calcium-magnesium or sodium as the main cation (see Piper diagram on CD-ROM). 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 Empress Aquifer - Unit 3 in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	149	85	6846	894	748	500
Sodium	136	8	1650	214	112	200
Sulfate	150	0	3900	123	92	500
Chloride	151	0	1500	38	10	250
Nitrate + Nitrite (as N)	105	0	52	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 12. Concentrations of Constituents in Groundwaters from Empress Aquifer – Unit 3

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Empress Aquifer – Unit 3 are greater than the median concentrations from water wells completed in all surficial deposits.

A groundwater sample from the water source well in 04-33-061-04 W4M has a TDS concentration of 868 mg/L, a sodium concentration of 323 mg/L, a sulfate concentration of 5 mg/L, a chloride concentration of 90 mg/L, and a nitrate + nitrite (as N) of less than 0.2 mg/L (HCL, May 1985).

A groundwater sample from the water source well in 09-07-066-05 W4M has a TDS concentration of 786 mg/L, a sodium concentration of 168 mg/L, a sulfate concentration of 121 mg/L, a chloride concentration of 8 mg/L, and a nitrate + nitrite (as N) of less than 0.2 mg/L (HCL, May 1983).

5.3.13 Lower Sand and Gravel Aquifer (Empress – Unit 1)

The Empress Aquifer – Unit 1 is a saturated sand and gravel deposit that occurs at or near the base of the surficial deposits in the deeper parts of the linear bedrock lows. Structure contours have been prepared for the top of the Empress Formation – Unit 1. The structure contours show the Empress Formation – Unit 1 ranges in elevation from less than 440 to more than 520 metres AMSL. The thickness of the Empress Formation – Unit 1 is mainly less than 15 metres but can be more than 15 metres in parts of the Buried Helena and Beverly valleys (see CD-ROM).

5.3.13.1 Depth to Top

The depth to the top of the Empress Formation – Unit 1 ranges from less than 50 metres below ground level to more than 150 metres in the north-central parts of the M.D. (Page A-51).

5.3.13.2 Apparent Yield

The apparent yields for individual water wells completed through the Empress Aquifer – Unit 1 are mainly greater than 100 m³/day, with 31% of the values being less than 50 m³/day, 27% between 50 and 150 m³/day, and 55% of the values being more than 150 m³/day.

In the M.D., there are four licensed water wells that are completed through the Empress Aquifer – Unit 1, with a total authorized diversion of 4,274 m³/day, of which 4,000 m³/day is for a water source well in 05-22-065-04 W4M used for industrial purposes. Three of the four licensed water wells could be linked to a water well in the AENV groundwater database.

In 1987, Canadian Occidental Petroleum Ltd. were licensed to divert 534,000 m³/year (1,465 m³/day) for industrial purposes from three water source wells completed in the Empress Aquifer - Unit 1 in section 13, township 063, range 08, W4M. In 1987, 257,479 m³ were diverted from these water source wells (HCL, 1983).

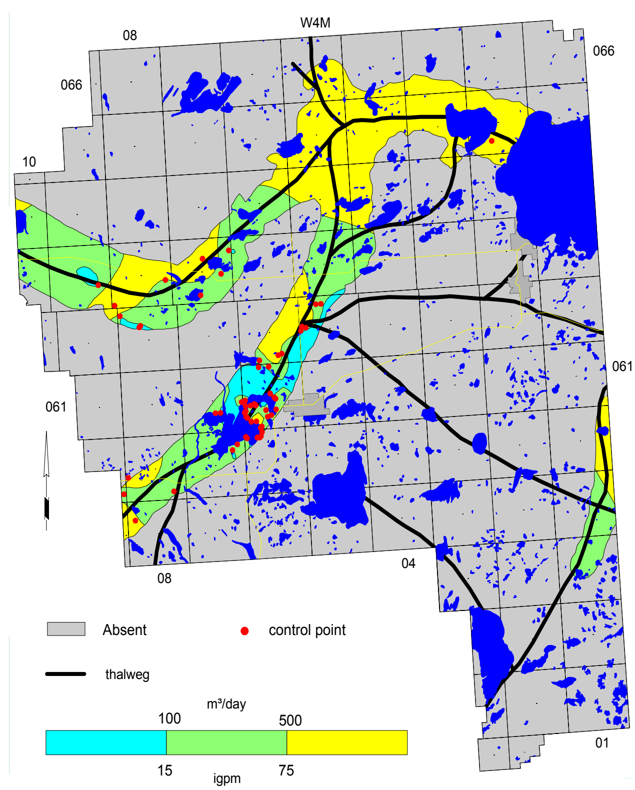

Figure 25. Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 1

5.3.13.3 Quality

The groundwaters from the Empress Aquifer – Unit 1 are primarily a sodium-bicarbonate type (see Piper diagram on CD-ROM). 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 Empress Aquifer – Unit 1 in the M.D. have been compared to the SGCDWQ and median concentrations from all surficial deposits in the adjacent table. Of the five constituents that have been compared to the SGCDWQ, the median values of TDS and sodium exceed the guidelines.

Constituent	No. of Analyses	Range for M.D. in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration GCDWQ
Total Dissolved Solids	29	270	2477	971	748	500
Sodium	29	11.4	609	280	112	200
Sulfate	30	3.36	1183	153	92	500
Chloride	30	0	495	56	10	250
Nitrate + Nitrite (as N)	26	0	2	0.0	0.0	10

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial Subcommittee on Drinking Water, March 2001

Table 13. Concentrations of Constituents in Groundwaters from Empress Aquifer – Unit 1

The median concentrations of TDS, sodium, sulfate and chloride from water wells completed in the Empress Aquifer – Unit 1 are greater than the median concentrations from water wells completed in all surficial deposits.

A groundwater sample from the water source well in 06-13-063-08 W4M has a TDS concentration of 946 mg/L, a sodium concentration of 248 mg/L, a sulfate concentration of 40 mg/L, a chloride concentration of 42 mg/L, and a nitrate + nitrite (as N) of 1.02 mg/L (HCL, 1983).

5.4 Bedrock

5.4.1 Geological Characteristics

In the M.D., the uppermost bedrock is the Lea Park Formation, consisting mainly of dark grey shales of marine origin. At locations where deep bedrock valleys occur, the Lea Park Formation has been eroded, exposing the Milk River Formation and the *undivided* Colorado Group (Pages A-12 to A-17). The Milk River Formation and the *undivided* Colorado Group are marine shales of Upper Cretaceous Age, the base of the marine shales are at an elevation of approximately 300 metres AMSL. Neither the Lea Park Formation, the Milk River Formation or the *undivided* Colorado Group contain any aquifers that would be suitable for the development of groundwater supplies, since they are considered essentially impermeable.

There will be no direct review of the Lea Park Formation, the Milk River Formation or the *undivided* Colorado Group in the text of this report; the only maps associated with the Lea Park Formation and the *undivided* Colorado Group to be included on the CD-ROM will be structure-contour maps.

6. Groundwater Budget

6.1 Hydrographs

In the M.D., there are 26 observation water wells that are part of the AENV regional groundwater-monitoring network where water levels are being measured and recorded with time. These observation water wells are completed in surficial deposits near linear bedrock lows (Page A-55). Of the 26 observation water wells, eight have not been monitored since 1999. For the AENV observation water wells that have not been reclaimed, suspended or capped, the observation water wells are located in areas of industrial groundwater users. The AENV observation water wells are completed in the Marie Creek, Bonnyville, Muriel Lake, Bronson Lake, Empress – Unit 3 and Empress – Unit 1 aquifers, as shown below in Table 14.

AENV Obs WW No.	Well Name	Aquifer Name	Legal	Period of Monitoring Data	UID	Status - Recommendation*
188	AE Obs Well: Iron River 2078E (East)	Marie Creek	04-27-063-07 W4M	1985 - 2000	M35377.151707	Industrial area
243	AE Obs Well: Cushing Lake 2411E	Marie Creek	16-32-058-03 W4M	1987 - 2000	M35377.138927	Energy development in area
251	AE Obs Well: Esso Seismic Stn.5 2362	Marie Creek	04-17-065-03 W4M	1985 - 2001	M35377.149203	Industrial area
184	AE Obs Well: Bonnyville 1708EA (East)	Bonnyville	16-10-062-05 W4M	1977 - 1991	M35377.092553	Reclaimed
187	AE Obs Well: Iron River 2079E (West)	Bonnyville	13-31-063-07 W4M	1982 - 2000	M35377.148711	Industrial area
200	AE Obs Well: Wolfe Lake Grazing 2349E	Bonnyville	04-35-064-06 W4M	1985 - 2000	M35377.149040	Levels once per year
272	AE Obs Well: Soar Lake 89-1	Bonnyville	07-13-059-01 W4M	1989 - 1992	M35377.140834	Cap, retain for possible future use
183	AE Obs Well: Glendon 80-W1 (Suspended)	Muriel Lake	SE 26-060-08 W4M	1985 - 1986	M35377.145233	Suspended
189	AE Obs Well: Esso TH-1	Muriel Lake	13-30-064-03 W4M	1985 - 2000	M35377.148989	Cap, retain for possible future use
193	AE Obs Well: Marie Lake 82-2 (West)	Muriel Lake	SW 09-065-02 W4M	1985 - 2000	M35377.149092	Industrial area
195	AE Obs Well: Bourque Lake 1947E	Muriel Lake	04-26-065-04 W4M	1989 - 2000	M35377.149081	Regional, industrial area
197	AE Obs Well: BP-Triad 82-1	Muriel Lake	SW 28-066-05 W4M	1982 - 2000	M35377.128720	Regional, industrial area
245	AE Obs Well: Truman 84-1 (No. 2265E)	Muriel Lake	05-21-063-09 W4M	1984 - 1989	M35377.143153	Cap, retain for possible future use
250	AE Obs Well: Esso Seismic Stn.5 2361E	Muriel Lake	04-17-065-03 W4M	1985 - 2001	M35377.149202	Industrial area
248	AE Obs Well: Truman 84-4	Bronson Lake	05-21-063-09 W4M	1984 - 1989	M35377.143162	Cap, retain for possible future use
185	AE Obs Well: Bonnyville 1708EB (West)	Empress - Unit 3	16-10-062-05 W4M	1977 - 1989	M35377.092551	Reclaimed
198	AE Obs Well: BP-Triad 2346E (West)	Empress - Unit 3	04-28-066-05 W4M	1985 - 2000	M35377.150271	Regional, industrial groundwater use
199	AE Obs Well: Wolfe Lake Grazing 2348E	Empress - Unit 3	04-35-064-06 W4M	1988 - 2000	M35377.149037	Levels once per year
242	AE Obs Well: Cushing Lake 2406E (West)	Empress - Unit 3	16-32-058-03 W4M	1987 - 2000	M35377.138924	Energy development in area
244	AE Obs Well: Cushing Lake 2412E (East)	Empress - Unit 3	16-32-058-03 W4M	1987 - 1996	M35377.138929	Cap, retain for possible future use
246	AE Obs Well: Truman 84-2 (No. 2266E)	Empress - Unit 3	05-21-063-09 W4M	1984 - 2000	M35377.143155	Cold Lake Area
247	AE Obs Well: Truman 84-3 (No. 2267E)	Empress - Unit 3	05-21-063-09 W4M	1984 - 1989	M35377.143158	Cap, retain for possible future use
249	AE Obs Well: Esso Seismic Stn.5 2360E	Empress - Unit 3	04-17-065-03 W4M	1985 - 2000	M35377.149200	Industrial area
186	AE Obs Well: Lessard 2091E	Empress - Unit 1	14-25-063-05 W4M	1985 - 2001	M35377.087724	Esso Cold Lake Expansion
192	AE Obs Well: Marie Lake 82-1	Empress - Unit 1	SW 09-065-02 W4M	1982 - 2000	M35377.149090	Industrial area
194	AE Obs Well: Bourque Lake 1772E South	Empress - Unit 1	04-26-065-04 W4M	1978 - 2001	M35377.149075	Regional, industrial area

*AENV Fax Communication, 1998

Table 14. AENV Obs WW Summaries

Seventeen hydrographs were compared to determine if there were any water-level trends in the observation water wells. Four water-level trends were observed. There were water-level rises and declines in all four water-level trends but the fluctuations have occurred over different intervals of time. Examples of the four water-level trends are shown on the hydrographs for AENV Obs WW Nos. 188, 193, 194, 197 and 242 on Page A-55. These observation water wells are located in different areas of the M.D. and have been monitored for at least 14 years. The location of the observation water wells and the water-level trends are shown on Page A-56.

Licensed groundwater use for industrial purposes represents 68% of the total groundwater licensed. Almost all of the 68% is from water source wells in township 063 to 066, ranges 01 to 06, W4M. Groundwater production from 17 water source wells is available from the EUB database. Figure 26 on the following page shows the reported average daily groundwater production from 1985 to 2001.

In the last 30 years, there have been more than ten enhanced-oil-recovery projects in the M.D. that have used groundwater for at least part of the time. The larger projects include Esso Cold Lake and Amoco Wolf Lake. Some of the smaller projects include Norcen Primrose Lake, Koch Ardmore, Worldwide Energy Ardmore, Union Texas Ardmore, BP Marguerite Lake, and COPL Iron River.

In the time frame from 1985 to 2001, the Amoco Wolf Lake project started in 1985 and Esso used groundwater for 34 months starting at the end of 1991. The groundwater use at the Wolf Lake facility started to decrease in 1990, just before Esso started their main groundwater diversion. At the Wolf Lake facility, the groundwater use was limited throughout the 1990s.

The reported daily groundwater diversion from industrial users from 1977 to 1985 was less than 2,000 m³/day. Since 1985, the total reported groundwater use has been more than 40 million cubic metres, an average of more than 7,000 cubic metres per day.

Three of the four water-level trends can be directly related to the groundwater diverted from two main enhanced-oil-recovery projects. The water-level fluctuations in AENV Obs WW No. 197 show the characteristics of Trend 1. The main characteristic of Trend 1 can be correlated to the start-up of the Amoco Wolf Lake project. From 1985 to 1990, the water level declined in response to the groundwater diversion from the Amoco Wolf Lake project. The reduced groundwater use at the Wolf Lake site beginning in the 1990s is reflected by the water-level rise in AENV Obs WW No. 197.

The water-level fluctuations in AENV Obs WW No 194 exhibit the characteristics of Trend 2. The main characteristic of Trend 2 can be correlated to the start-up of the Esso Cold Lake project. From 1978 to late 1991, the water level declined less than five metres. In late 1991, the water level declined more than 50 metres in response to the groundwater diversion from the Esso Cold Lake project.

The water-level fluctuations in AENV Obs WW No. 188 are an example of Trend 3. The main characteristic of Trend 3 is that the water-level fluctuations correlate to the combined groundwater diversion from the Amoco Wolf Lake and Esso Cold Lake projects. The hydrograph of AENV Obs WW No. 188 shows the water levels to decline from 1985 to 1990 in response to the groundwater diversion from Amoco Wolf Lake and again in 1992 in response to the groundwater diversion from Esso Cold Lake.

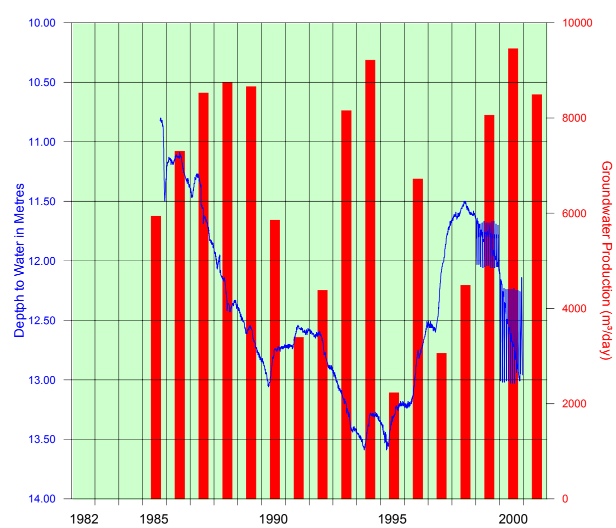

Figure 26. Annual Production vs Water Levels in AENV Obs WW No. 200

Another example illustrating the water-level characteristics of Trend 3 is AENV Obs WW No. 200. AENV Obs WW 200, in 04-35-064-06 W4M, is completed at a depth of 77.0 metres below ground level in the Bonnyville Aquifer. From 1985 to 1990, there was a net decline in the water level of approximately two metres in response to the groundwater production from the Amoco Wolf Lake project. From 1990 to 1991, the water level rose 0.5 metres. From 1991 to 1994, the water level declined about one metre in response to the groundwater production from the Esso Cold Lake project.

Even though there have been more than 40 million cubic metres of groundwater diverted from 1977 to 2001, the water levels in the observation water wells in various aquifers show that there has not been any negative impact on the aquifers.

In order to determine if the fluctuations were responding to precipitation, the 17 AENV Obs WWs were compared to the precipitation data measured at the Cold Lake weather station, the only weather station in the M.D. of Bonnyville with a complete data set for all years.

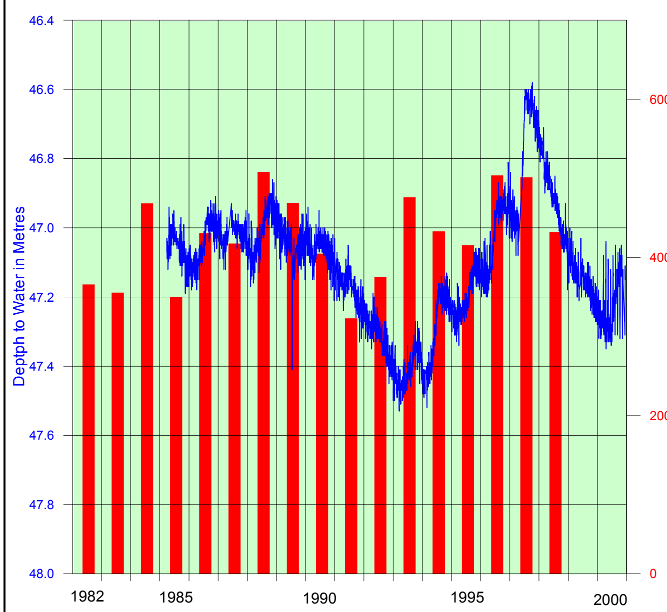

Figure 27. Annual Precipitation vs Water Levels in AENV Obs WW No. 193

The water-level fluctuations in AENV Obs WW No 193 exhibit the water-level characteristics of Trend 4. The main characteristic of Trend 4 is that the water-level fluctuations correlate to precipitation with no apparent relationship to groundwater diversion.

AENV Obs WW No. 193 in SW 09-065-02 W4M is completed at a depth of 72.5 metres below ground level in the Muriel Lake Aquifer. This observation water well is located west of Cold Lake and is primarily used to monitor the effect of industrial groundwater diversion. This hydrograph shows annual cycles of recharge in late spring/early summer and a decline throughout the remainder of the year. Overall annual fluctations are approximately 0.1 to 0.2 metres. From 1988 to 1993, there has been a net decline in the water level of approximately 0.6 metres. From 1993 to 1997, the water level rose 0.9 metres. From 1997 to 2000, the water level declined 0.7 metres. The comparison in Figure 27 shows that the water-level rise from 1985 to 1988 and the water-level decline from 1988 to 1991 reflects the changes in total annual precipitation measured at the Cold Lake weather station. In 1992 and 1993, the annual precipitation increases, but the water level continues to decline at the site of AENV Obs WW No. 193. This water-level decline may be in response to groundwater diversion from a nearby user.

The AENV Obs Water Wells and water-level trends are summarized in the table below.

Obs WW No.	Trend	Aquifer Name	Legal	Period of Monitoring Data
197	1	Muriel Lake	SW 28-066-05 W4M	1982 - 2000
198	1	Empress - Unit 3	04-28-066-05 W4M	1985 - 2000
186	2	Empress - Unit 1	13-31-063-07 W4M	1982 - 2000
194	2	Empress - Unit 1	04-26-065-04 W4M	1978 - 2001
195	2	Muriel Lake	04-26-065-04 W4M	1989 - 2000
249	2	Empress - Unit 3	04-17-065-03 W4M	1985 - 2000
250	2	Muriel Lake	04-17-065-03 W4M	1985 - 2001
187	3	Bonnyville	14-25-063-05 W4M	1985 - 2001
188	3	Marie Creek	04-27-063-07 W4M	1985 - 2000
200	3	Bonnyville	04-35-064-06 W4M	1985 - 2000
189	4	Muriel Lake	13-30-064-03 W4M	1985 - 2001
192	4	Empress - Unit 1	SW 09-065-02 W4M	1982 - 2000
193	4	Muriel Lake	SW 09-065-02 W4M	1985 - 2000
242	4	Empress - Unit 3	16-32-058-03 W4M	1987 - 2000
243	4	Marie Creek	16-32-058-03 W4M	1987 - 2000
244	4	Empress - Unit 3	16-32-058-03 W4M	1987 - 1996
251	4	Marie Creek	04-17-065-03 W4M	1985 - 2001

Table 15. Summary of Water-Level Trends in Observation Water Wells

A groundwater monitoring program by Mow-Tech Ltd. south of Ardmore has recorded the impact of groundwater diversion by two industrial groundwater users on water levels in the Empress Aquifer – Unit 3.

Records of the groundwater diversion from the Koch Exploration Canada Ltd. (Koch) Water Source Well (WSW) No. 04-33 are available from 1985 to 1997. The majority of the groundwater diverted from WSW No. 04-33 was from 1991 to 1995, as shown on Figure 28. Water Source Well No. 04-33 is completed from 78.0 to 80.5 metres below ground surface in the Empress Aquifer – Unit 3 in 04-33-061-04 W4M.

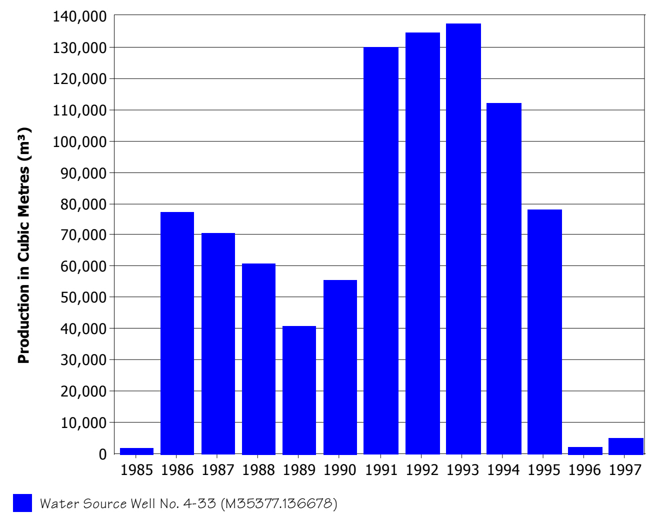

Figure 28. Annual Groundwater Diversion – WSW No. 04-33

Continuous water-level measurements in the Koch East and West observation water wells show that diversion from WSW No. 04-33 had an impact on the water level in the Empress Aquifer – Unit 3 at the site of both Koch observation water wells. The hydrograph for the East Obs WW is in Appendix A.

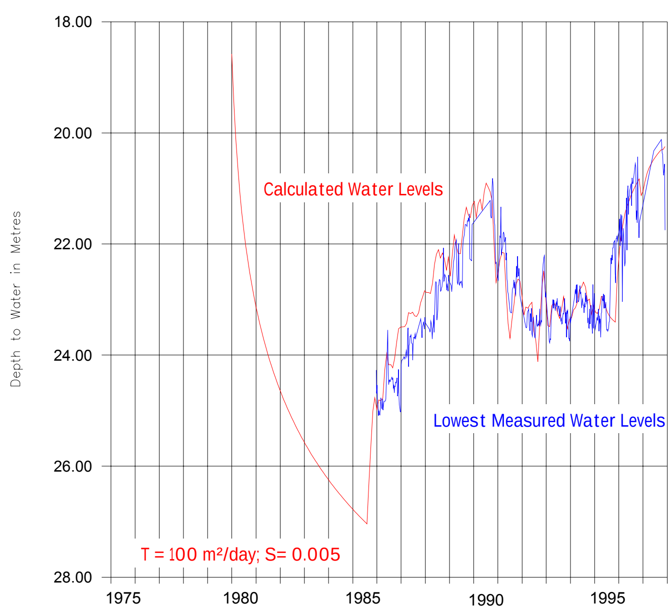

Figure 29. Water-Level Comparison – East Obs WW

In order to determine if the pumping from WSW No. 04-33 was the cause of the water-level fluctuations, a mathematical simulation using a model aquifer was completed. The model aquifer was used to calculate the water levels at the East Obs WW, based on the production from WSW No. 04-33 and from the Worldwide Energy plant site water source wells in township 061, range 03 W4M. The model is based on the annual groundwater production from WSW No. 04-33, and estimated groundwater production from the Worldwide Energy water source wells; the aquifer has an effective transmissivity of 100 (m^2/day) and a corresponding storativity of 0.005. The model assumes a homogeneous, isotropic aquifer of infinite areal extent and does not account for aquifer recharge.

6.2 Estimated Water Use from Unlicensed Groundwater Users

An estimate of the quantity of groundwater removed from each geologic unit in the M.D. must include both the licensed diversions and the unlicensed use. As stated previously on Page 6 of this report, the daily water requirement for livestock for the M.D. based on the 2001 census is estimated to be 8,776 cubic metres. Of the 8,776 m³/day required for livestock, 745 m³/day has been licensed by Alberta Environment, which includes both surface water and groundwater. To obtain an estimate of the quantity of groundwater being diverted from the individual geologic units, it has been assumed that the remaining 8,031 m³/day of water required for livestock watering is obtained from unlicensed groundwater use. In the groundwater database for the M.D., there are records for 4,844 water wells that are used for domestic/stock purposes. These 4,844 water wells include both licensed and unlicensed water wells. Of the 4,844 water wells, 658 water wells are used for stock, 989 are used for domestic/stock purposes, and 3,197 are for domestic purposes only.

There are 1,647 water wells that are used for stock or domestic/stock purposes (Table 16). There are 66 licensed groundwater users for agricultural (stock) purposes, giving 1,581 unlicensed stock water wells. (Please refer to Table 1 on Page 6 for the breakdown by aquifer of the 66 licensed stock groundwater users). By dividing the number of unlicensed stock and domestic/stock water wells (1,581) into the quantity of groundwater required for stock purposes that is not licensed (8,031 m³/day), the average unlicensed water well diverts 5.1 m³/day for stock purposes. Because of the limitations of the data, no attempt has been made to compensate for dugouts, springs or inactive water wells, and the average stock use is considered to be 5.1 m³/day per stock water well.

Groundwater for household use does not require licensing. Under the Water Act, a residence is protected for up to 3.4 m³/day. However, the standard groundwater use for household purposes is 1.1 m³/day. Since there are 4,186 water wells serving a population of 8,069, the domestic use per water well is 0.5 m³/day.

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

Domestic 0.5 m³/day
Stock 5.1 m³/day
Domestic/stock 5.6 m³/day

Based on using all available domestic, domestic/stock, and stock water wells and corresponding calculations, the following table was prepared. The table shows a breakdown of the 4,844 unlicensed and licensed water wells used for domestic, stock, or domestic/stock purposes by the geologic unit in which each water well is completed. The final column in the table equals the total amount of unlicensed groundwater that is being used for both domestic and stock purposes. The data provided in the table below indicate that there is an estimated 9,829 m³/day to be diverted from unlicensed domestic, stock, or domestic/stock water wells.

	Unlicensed and Licensed Groundwater Diversions							*Licensed Groundwater Diversions*	*Unlicensed Groundwater Diversions*
Aquifer Designation	Number of Domestic	Daily Use 0.5	Number of Stock	Daily Use (5.1 m³/day)	Number of Domestic and Stock	Daily Use (5.6 m³/day)	Totals m³/day	Totals (m³/day)	Totals m³/day
Grand Centre	69	33	28	142	41	228	403	59	344
Sand River	31	15	13	66	10	56	137	14	123
Marie Creek	292	141	95	483	136	756	1,380	73	1,307
Ethel Lake	107	52	38	193	71	395	640	32	608
Bonnyville	258	124	105	533	143	795	1,452	85	1,367
Muriel Lake	74	36	29	147	58	323	506	98	408
Bronson Lake	24	12	14	71	20	111	194	60	134
Empress - Unit 3	211	102	54	274	86	478	854	96	758
Empress - Unit 2	0	0	0	0	0	0	0	0	0
Empress - Unit 1	60	29	9	46	21	117	192	10	182
Multiple Completions	5	2	3	15	2	11	28	111	-83 (0)
Bedrock	3	1	0	0	1	6	7	0	7
Unknown	2,063	994	270	1,372	400	2,225	4,591	0	4,591
Totals	3,197	1,541	658	3,342	989	5,501	10,384	638	9,746 (9,829)

Table 16. Unlicensed and Licensed Groundwater Diversions

By assigning 0.5 m³/day for domestic use, 5.1 m³/day for stock use and 5.6 m³/day for domestic/stock use, and using the total maximum authorized diversion associated with any licensed water well that can be linked to a record in the database, a map has been prepared that shows the estimated groundwater use in terms of volume (licensed plus unlicensed) per section per day for the M.D. (not including springs).

There are 2,874 sections in the M.D. In 59% (1,697) of the sections in the M.D., there is no domestic or stock or licensed groundwater user. The range in groundwater use for the remaining 1,177 sections with groundwater use is from 1 m³/day to more than 1,500 m³/day, with an average use per section of 38 m³/day (5.8 igpm). The estimated groundwater use per section is more than 30 m³/day in 65 of the 1,177 sections. There is at least one licensed groundwater user in 45 of the 65 sections. The most notable areas where water well use of more than 30 m³/day is expected occur mainly in the vicinity of licensed groundwater users, as shown on Figure 30.

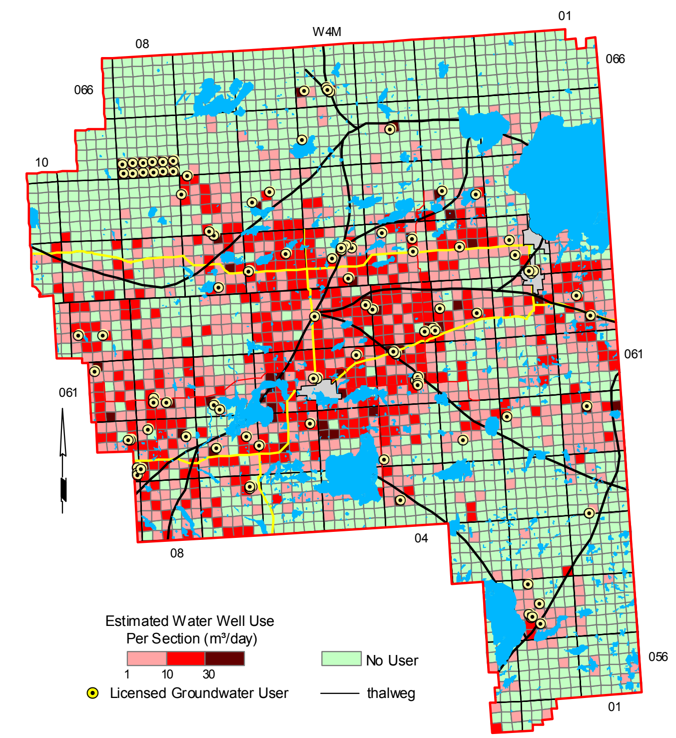

Figure 30. Estimated Water Well Use Per Section

Groundwater Use within the M.D. of Bonnyville (m³/day)		%
Domestic/Stock (licensed and unlicensed)	10,384	*23*
Municipal (licensed)	1,736	*4*
Commercial/Dewatering/Exploration et al (licensed)	32,186	*73*
Total	44,306	*100*

Table 17. Total Groundwater Diversions

In summary, the estimated total groundwater use within the M.D. of Bonnyville is 44,306 m³/day, with the breakdown as shown in the adjacent table. An estimated 11,431 m³/day is being withdrawn from unknown aquifer units. The remaining 32,875 m³/day has been assigned to specific aquifer units. Approximately 78% of the total estimated groundwater use is from licensed 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 M.D. One indirect method of measuring recharge is to determine the quantity of groundwater flowing laterally through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow through an aquifer must be averaged and estimated. To determine the flow requires a value for the average transmissivity of the aquifer, an average hydraulic gradient and an estimate for the width of the aquifer. For the present program, the flow has been estimated for those parts of the various aquifers within the M.D.

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 M.D. border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 18:

Aquifer/Area	Trans (m²/day)	Gradient (m/m)	Width (m)	Flow (m³/day)	Aquifer Flow (m³/day)	Licensed Diversion (m³/day)	Unlicensed Diversion (m³/day)	Total (m³/day)
Lower Sand and Gravel					3,600	4,274	182	4,456
Empress - Unit 1					3,600			
west	45	0.0025	8,000	900				
south	45	0.0050	8,000	1800				
east	45	0.0020	10,000	900				
Upper Surficial Deposits					89,100	20,318	5,049	25,367
Grand Centre					8,300	14	344	358
north	10	0.003	100,000	3333				
south	10	0.003	110,000	3667				
west	10	0.003	40,000	1333				
Sand River					2,300	60	123	183
southeast 1	10	0.007	12,000	800				
Southeast 2	10	0.007	16,000	1067				
northwest	10	0.003	10,000	286				
north	10	0.001	10,000	111				
Marie Creek					27,200	1,921	1,307	3,228
north	20	0.005	100,000	10000				
south	20	0.005	120,000	12000				
Ethel Lake					16,400	73	608	681
north	27	0.004	43,000	5160				
south	27	0.004	67,000	8040				
west	27	0.004	30,000	3240				
Bonnyville					12,600	6,416	1,367	7,783
north	21	0.003	80,000	4200				
south	21	0.004	100,000	8400				
Muriel Lake					3,200	496	408	904
north	15	0.004	12,000	720				
southwest	15	0.002	35,000	1167				
west	15	0.005	17,000	1275				
Bronson Lake					3,200	2,073	134	2,207
south central	17	0.003	14,000	793				
west	17	0.003	4,000	170				
north	17	0.008	25,000	3188				
Empress - Unit 3					15,900	9,266	758	10,024
north	20	0.005	100,000	10000				
south	20	0.002	60,000	2667				
west	20	0.004	40,000	3200				

Table 18. Groundwater Budget

The calculations of flow through individual aquifers as presented in the above table are very approximate and are intended only as a guide for future investigations. The calculated flow through the aquifers is estimated to be approximately 34 million cubic metres per year. The reported groundwater diversion over the last sixteen years is 41 million cubic metres per year. Since there has been no apparent “over-use” of the aquifers, the calculated flow through the aquifers may be less than the actual flow.

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the surficial deposits is 0.4 to 2.1 cubic kilometres. This volume is based on an areal extent of 710 square kilometres and a saturated sand and gravel thickness of ten 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).

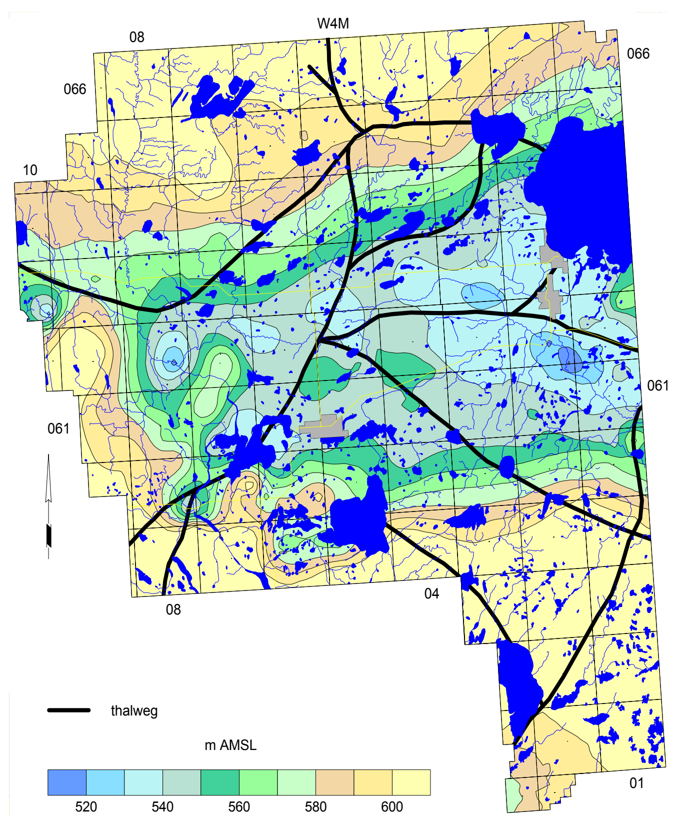

Figure 31. Non-Pumping Water-Level Surface Based on Water Wells Less than 20 metres Deep

The adjacent water-level map has been prepared from water levels associated with water wells completed in aquifers in the surficial deposits. The water levels from these water wells were used for the calculation of the saturated thickness of the surficial deposits. The water-level map for the surficial deposits shows a general flow in the direction of the topographic surface.

6.3.2 Recharge/Discharge

The hydraulic relationship between the groundwater in surficial deposits and groundwater in the bedrock was not investigated because of the lack of control due to the low permeability of the upper bedrock. Instead, the hydraulic relationship between the uppermost surficial deposits and the Lower Sand and Gravel Aquifer was established.

6.3.2.1 Uppermost Surficial Deposits/Lower Sand and Gravel Aquifer

The hydraulic gradient between the uppermost surficial deposits and the Lower Sand and Gravel Aquifer (Empress Aquifer – Unit 1) has been determined by subtracting the elevation of the non-pumping water-level surface associated with water wells completed in the Lower Sand and Gravel Aquifer from the elevation of the non-pumping water-level surface determined for all surficial water wells completed above a depth of 20 metres. Where the water level in the uppermost surficial deposits is at a higher elevation than the water level in the Lower Sand and Gravel Aquifer, there is the opportunity for groundwater to move from the uppermost surficial deposits into the Lower Sand and Gravel Aquifer. This condition would be considered as an area of recharge to the Lower Sand and Gravel Aquifer and an area of discharge from the uppermost surficial deposits. The amount of groundwater that would move from the uppermost surficial deposits to the Lower Sand and Gravel Aquifer is directly related to the vertical permeability of the sediments separating the two aquifers. On a regional basis, calculating the quantity of water involved is not possible because of the complexity of the geological setting and the limited amount of data.

When the hydraulic gradient is from the Lower Sand and Gravel Aquifer to the uppermost surficial deposits, the condition is a discharge area from the Lower Sand and Gravel Aquifer, and a recharge area to the uppermost surficial deposits.

The recharge classification shown on Figure 32 is used where the water-level surface in the uppermost surficial deposits is more than 15 metres above the water-level surface in the Lower Sand and Gravel Aquifer. The discharge areas are where the water level in the uppermost surficial deposits is more than ten metres lower than the water level in the Lower Sand and Gravel Aquifer. When the water level in the uppermost surficial deposits is between ten and 15 metres below the water level in the Lower Sand and Gravel Aquifer, the area is classified as a transition, that is, no recharge and no discharge.

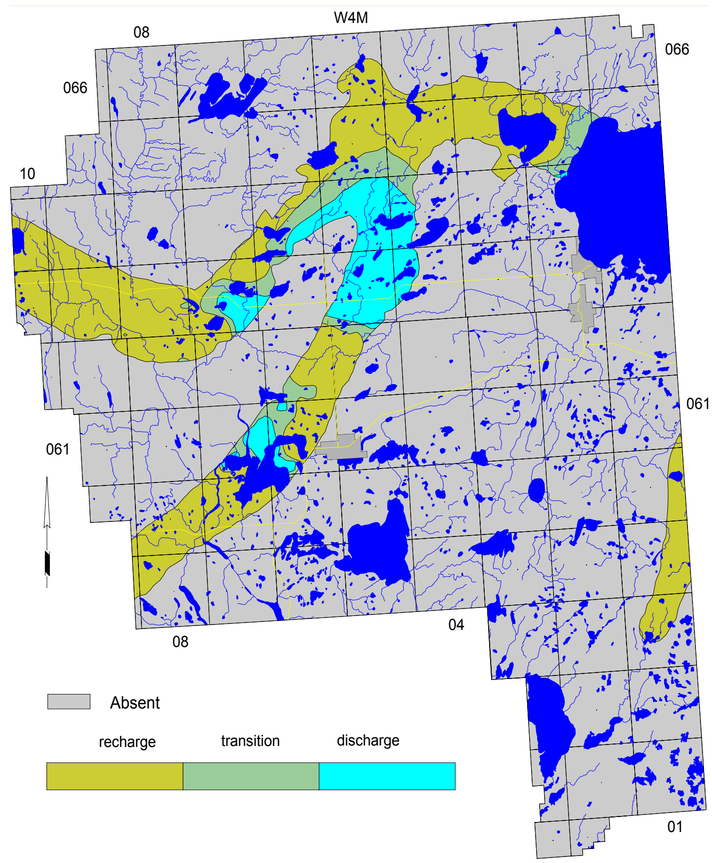

Figure 32. Recharge/Discharge Areas in Lower Sand and Gravel Aquifer

Figure 32 shows that, in more than 80% of the areas where the Lower Sand and Gravel is present in the M.D., there is a downward hydraulic gradient from the uppermost surficial deposits toward the Lower Sand and Gravel Aquifer (i. e. recharge). Ten percent of the areas with an upward hydraulic gradient from the Lower Sand and Gravel Aquifer to the uppermost surficial deposits (i. e. discharge) are mainly near the junction of the Buried Helena and Beverly valleys. The discharge in this area may be due to the groundwater flow being impeded in the Buried Beverly Valley by the deposits or the hydraulic gradient in the Buried Helena Valley. As a result, there is no opportunity for groundwater to move from the uppermost surficial deposits to the Lower Sand and Gravel Aquifer.

The remaining 10% of the M.D. are areas where there is a transition condition to the Lower Sand and Gravel Aquifer.

6.4 Areas of Groundwater Decline

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

The areas of groundwater decline in the sand and gravel aquifer(s) have been calculated by determining the frequency of non-pumping water level control points per five-year periods from 1960 to 2000. There were no control points before 1955. Of the 2,407 surficial water wells with a non-pumping water level and date in the M.D., 1,041 are from water wells completed before 1985 and 1,366 are from water wells completed after 1985. Where the earliest water level (before 1985) is at a higher elevation than the latest water level (after 1985), there is the possibility that some groundwater decline has occurred. Where the earliest water level is at a lower elevation than the latest water level, there is the possibility that the groundwater has risen at that location. The water level may have risen as a result of recharge in wetter years or may be a result of the water well being completed in a different surficial aquifer. In order to determine if the water-level decline is a result of groundwater use by licensed users, the licensed groundwater users were posted on the maps.

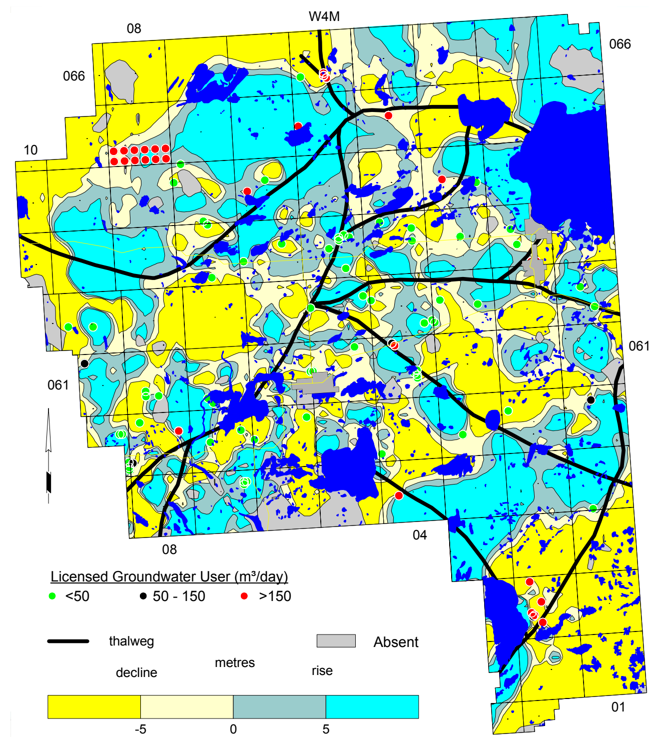

Figure 33. Changes in Water Levels in Sand and Gravel Aquifer(s)

Figure 33 indicates that in 50% of the M.D., it is possible that the non-pumping water level has declined. Of the 139 licensed groundwater users, most occur in areas where a water-level decline may exist. Table 19 shows that sixty-five percent of the areas where there has been a water-level decline of more than five metres corresponds to where there is no estimated water well use; 34% is less than 10 m³/day; 12% is between 10 and 30 m³/day per section; the remaining 1% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown previously on Figure 30. The areas of groundwater decline in the sand and gravel aquifer(s) where there is no estimated water well use suggests that groundwater production is not having an impact and that the decline may be due to variations in recharge to the aquifer.

Estimated Water Well Use	% of Area of Affected
<10	34
10 to 30	12
>30	1
no use	65

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

7. Recommendations

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

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

The quality of the data in the groundwater database is affected by two factors: a) the technical training of the persons collecting the data, and b) the quality control of the data. The possible options to upgrade the database include the creation of a "super" database, which includes only verified data. The first step would be to field-verify the 386 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. There are two water wells for which the M.D. has responsibility, neither one of which satisfies the above criteria; the five M.D.-operated water wells are included in Appendix E. It is recommended that these five M.D.-operated water wells plus the 386 water wells be field-verified, water levels be measured, a water sample be collected for analysis, and a short aquifer test be conducted. An attempt to update the quality of the entire database is not recommended.

Before an attempt is made to provide a major upgrade to the level of interpretation provided in this report, the accompanying maps and the groundwater query, it is recommended that the 391 water wells listed in Appendix E for which water well drilling reports are available, plus the five M.D.-operated water wells, be subjected to the following actions (see Pages C-2 to C-3):

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

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

A list of the 391 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 about 70% successful in this study (see CD-ROM). About 30% of licensed water wells do not appear to have corresponding records in the AENV groundwater database. There is a need to improve the quality of the AENV licensing database. It is recommended that attempts be made in a future study to find and add missing drilling records to the AENV groundwater database and to determine the aquifer in which the licensed water wells are completed.

While there are a few areas where water-level data are available, 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 (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. M.D. personnel and/or local residents could measure the water levels in the water wells regularly.

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. Imperial Oil Limited was contacted for this project but due to time constraints was unable to participate. 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 M.D. taking an active role in the activities associated with the construction of lease sites for the drilling of hydrocarbon wells, licensing of groundwater diversions, conducting of seismic programs, and conscientious groundwater monitoring of the licensed groundwater diversions.

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

Groundwater is a renewable resource and it must be managed.

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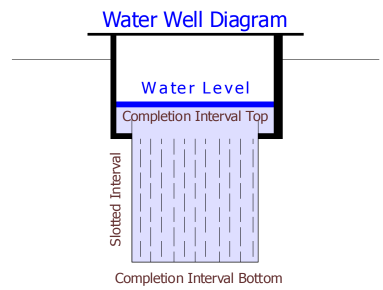
9. Conversions

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
inches	25.400 000	millimetres
miles	1.609 344	kilometres
kilometre	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^3/day)	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
US$	0.000 000	Canadian$

10. Glossary

AAFC-PFRA	Prairie Farm Rehabilitation Administration arm of Agriculture and Agri-Food Canada
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
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 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.



Completion Interval

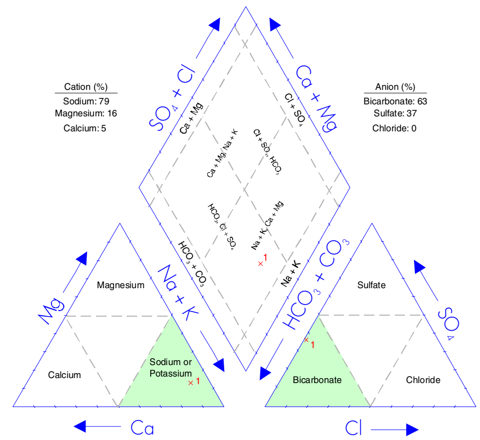
Evapotranspiration	a combination of evaporation from open bodies of water, evaporation from soil surfaces, and transpiration from the soil by plants (Freeze and Cherry, 1979)
Facies	the aspect or character of the sediment within beds of one and the same age (Pettijohn, 1957)
Fluvial	produced by the action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

mg/L — milligrams per litre

Median — the value at the center 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

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
NPWL	non-pumping water level
TDS	Total Dissolved Solids
WSW	Water Source Well or Water Supply Well

M.D. OF BONNYVILLE
Appendix A

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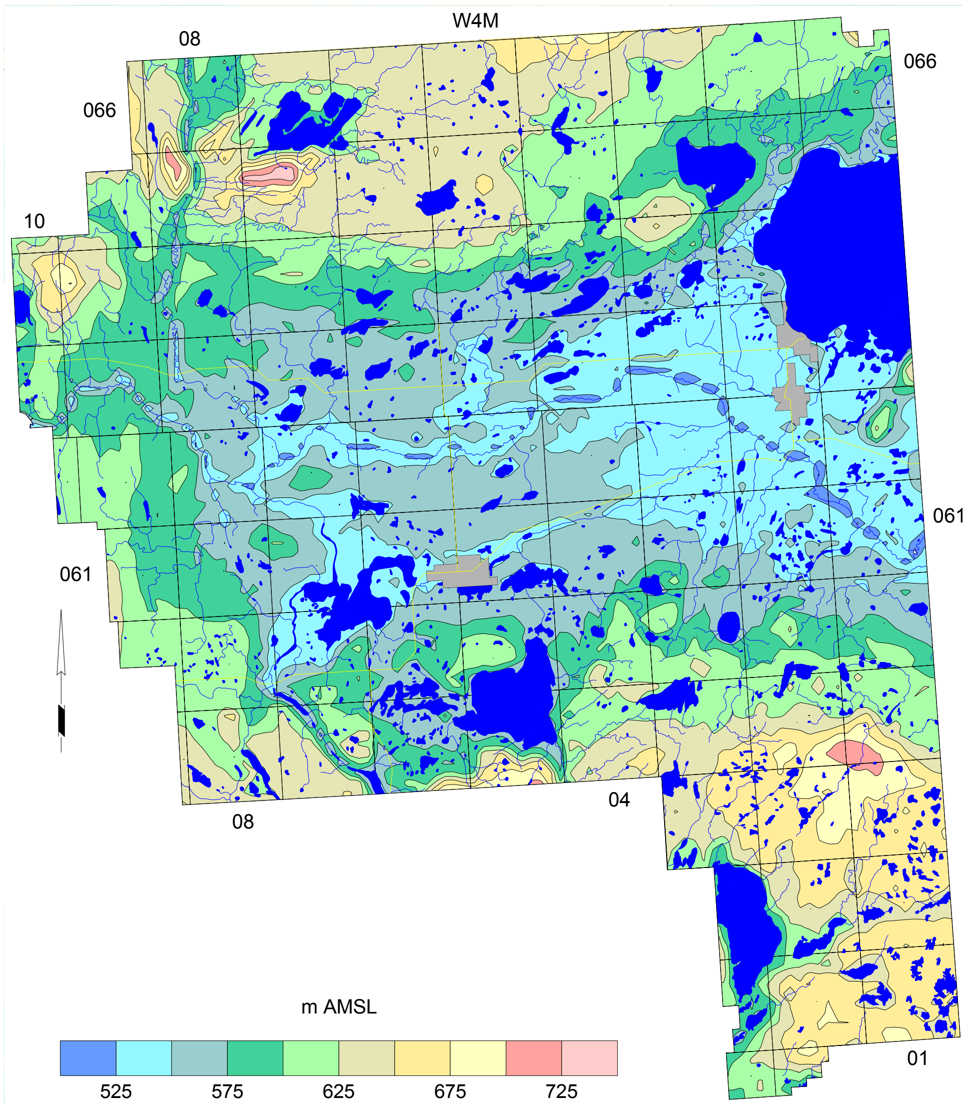
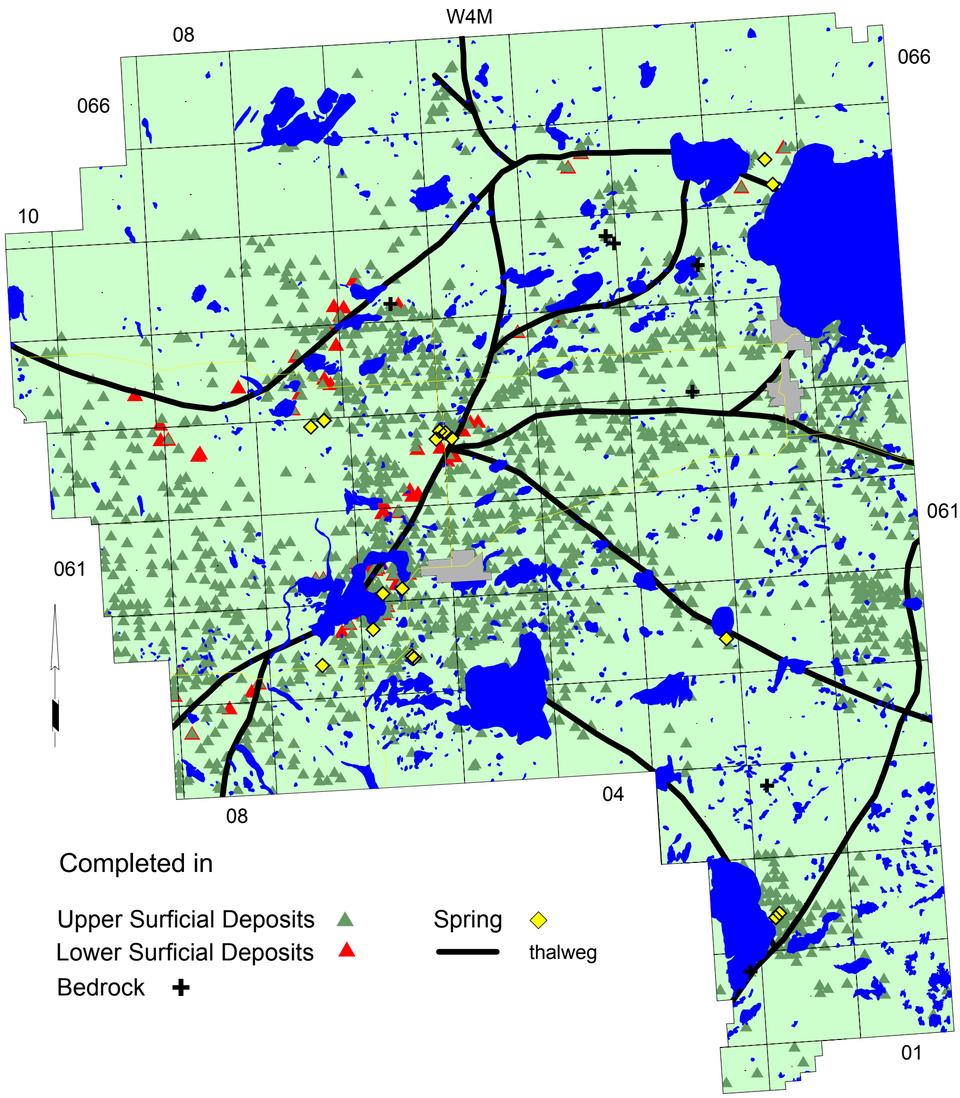
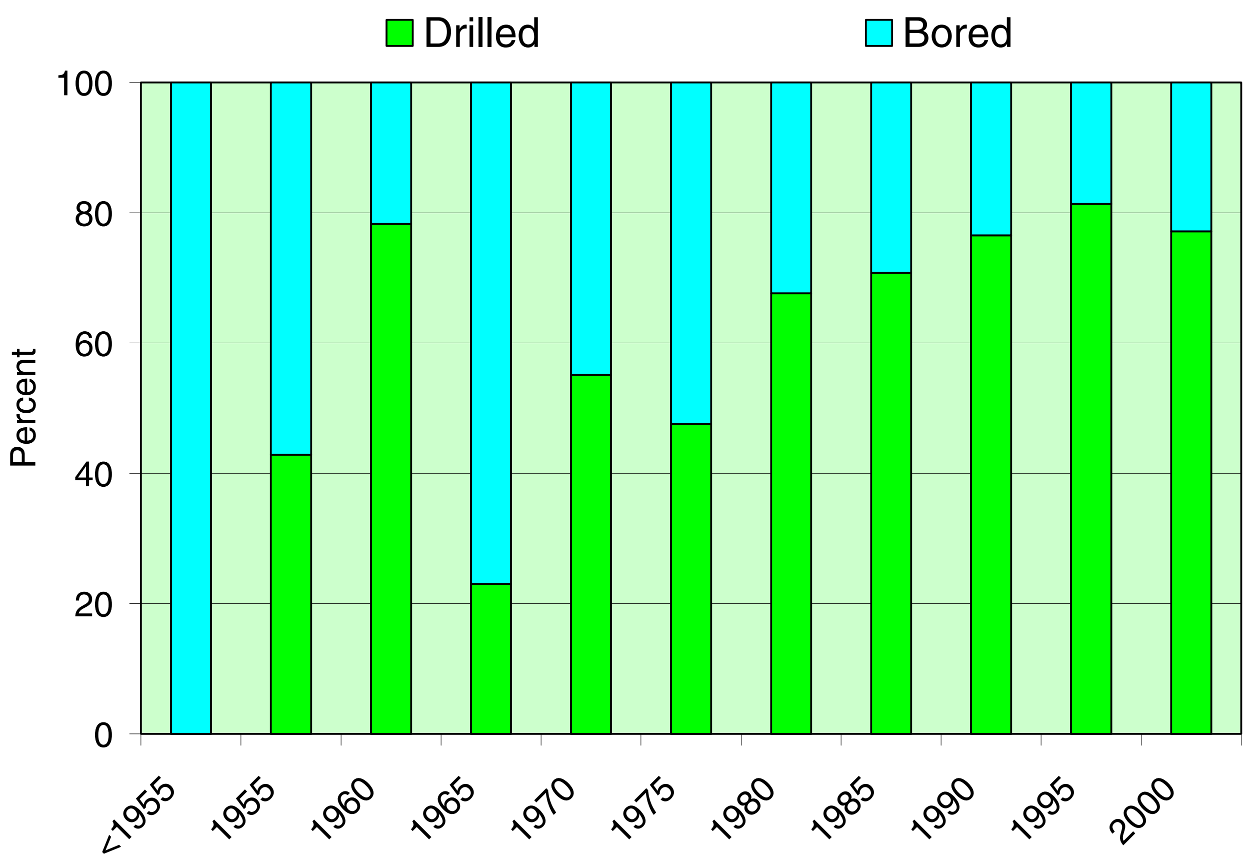
Surface Topography



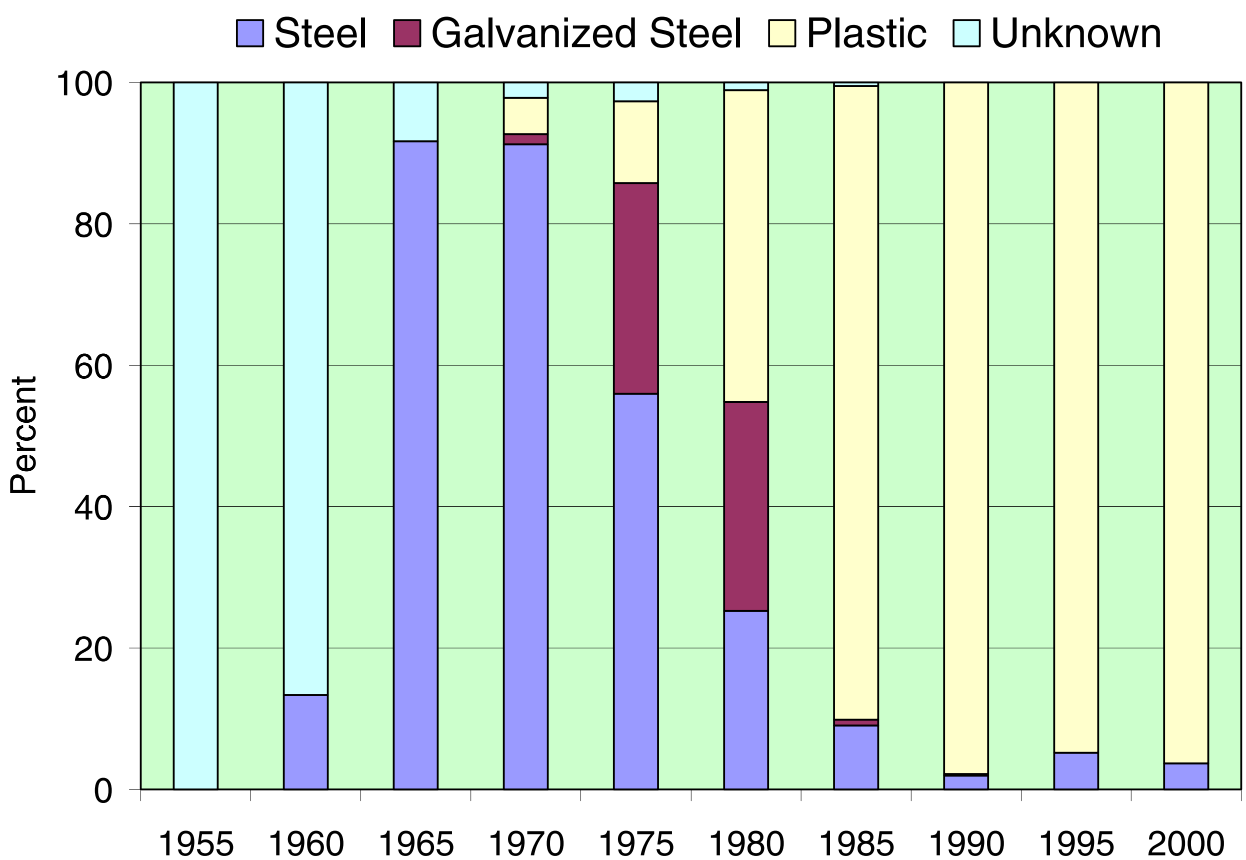
Location of Water Wells and Springs



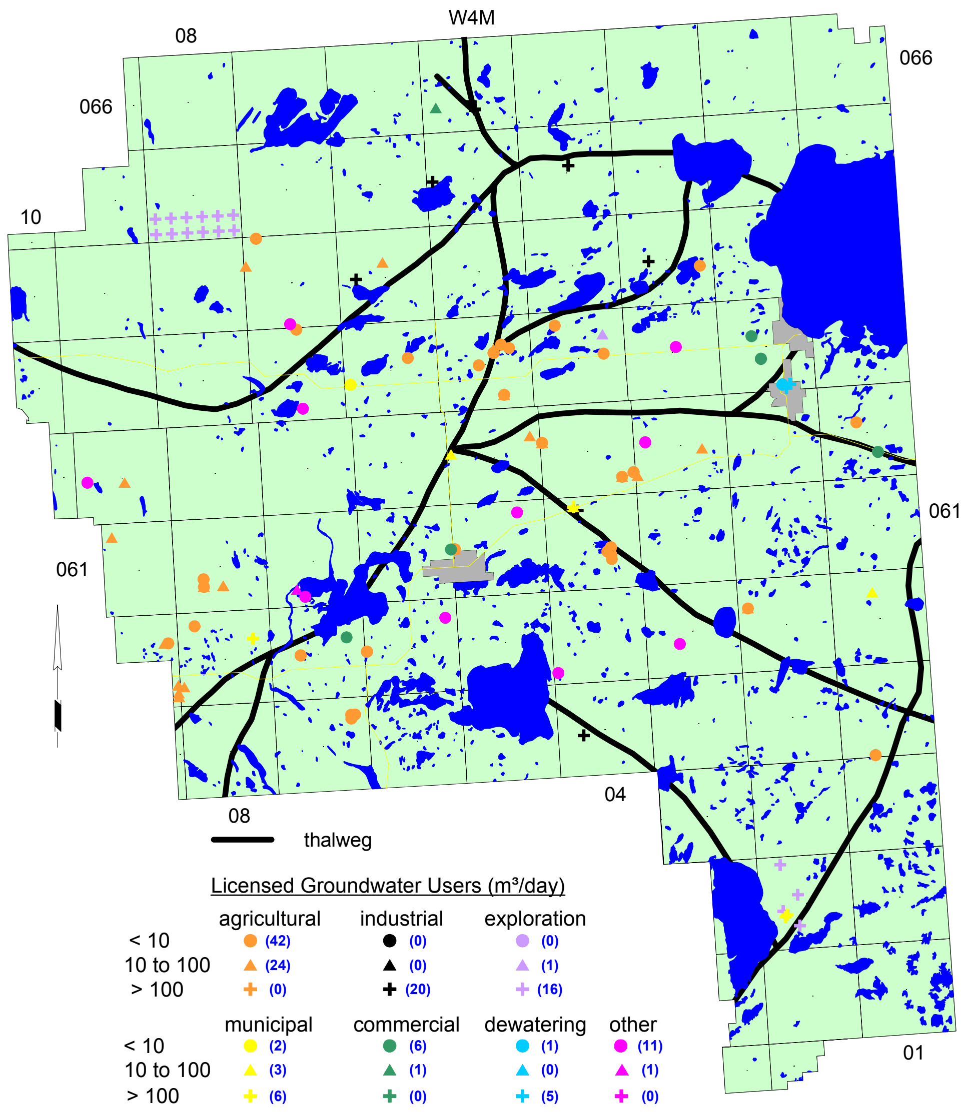
Casing Diameter Used in Water Wells



Surface Casing Types used in Drilled Water Wells

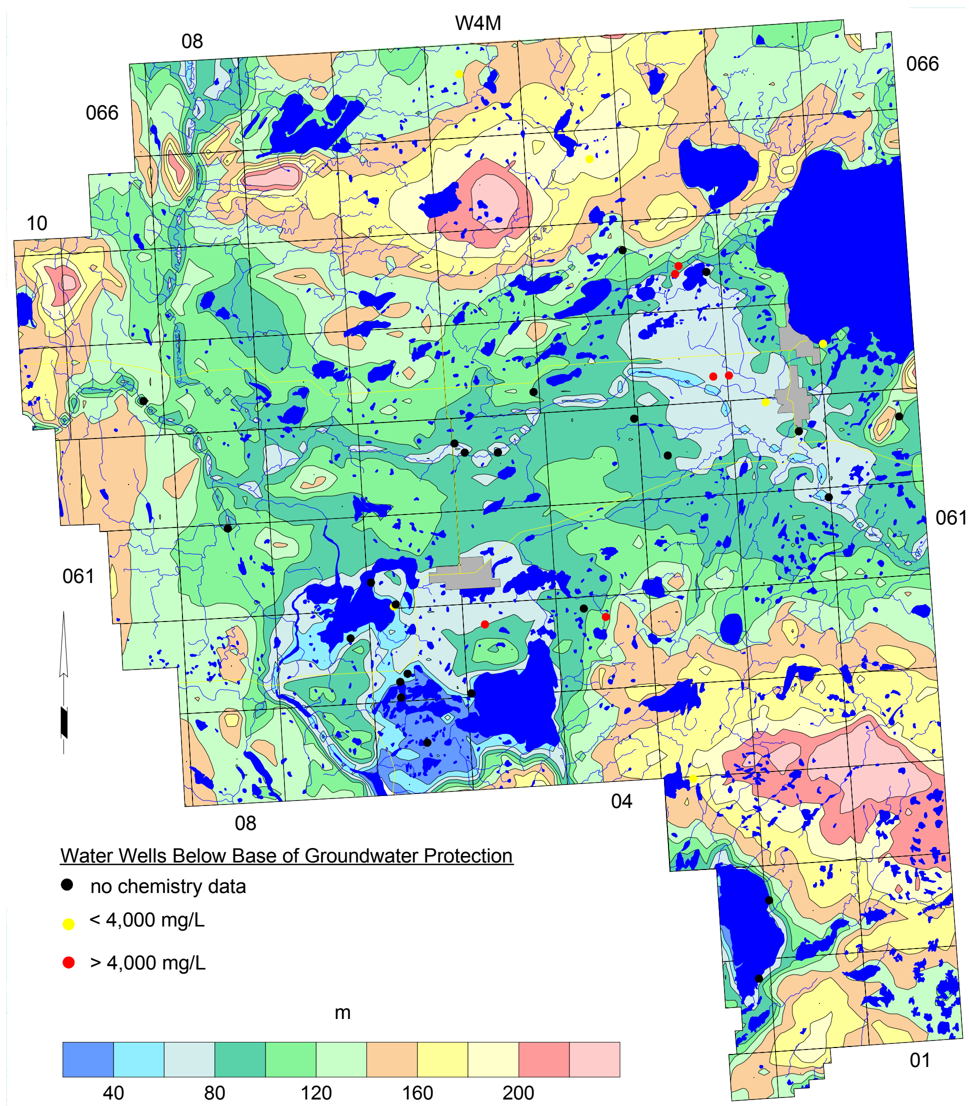


Licensed Water Wells



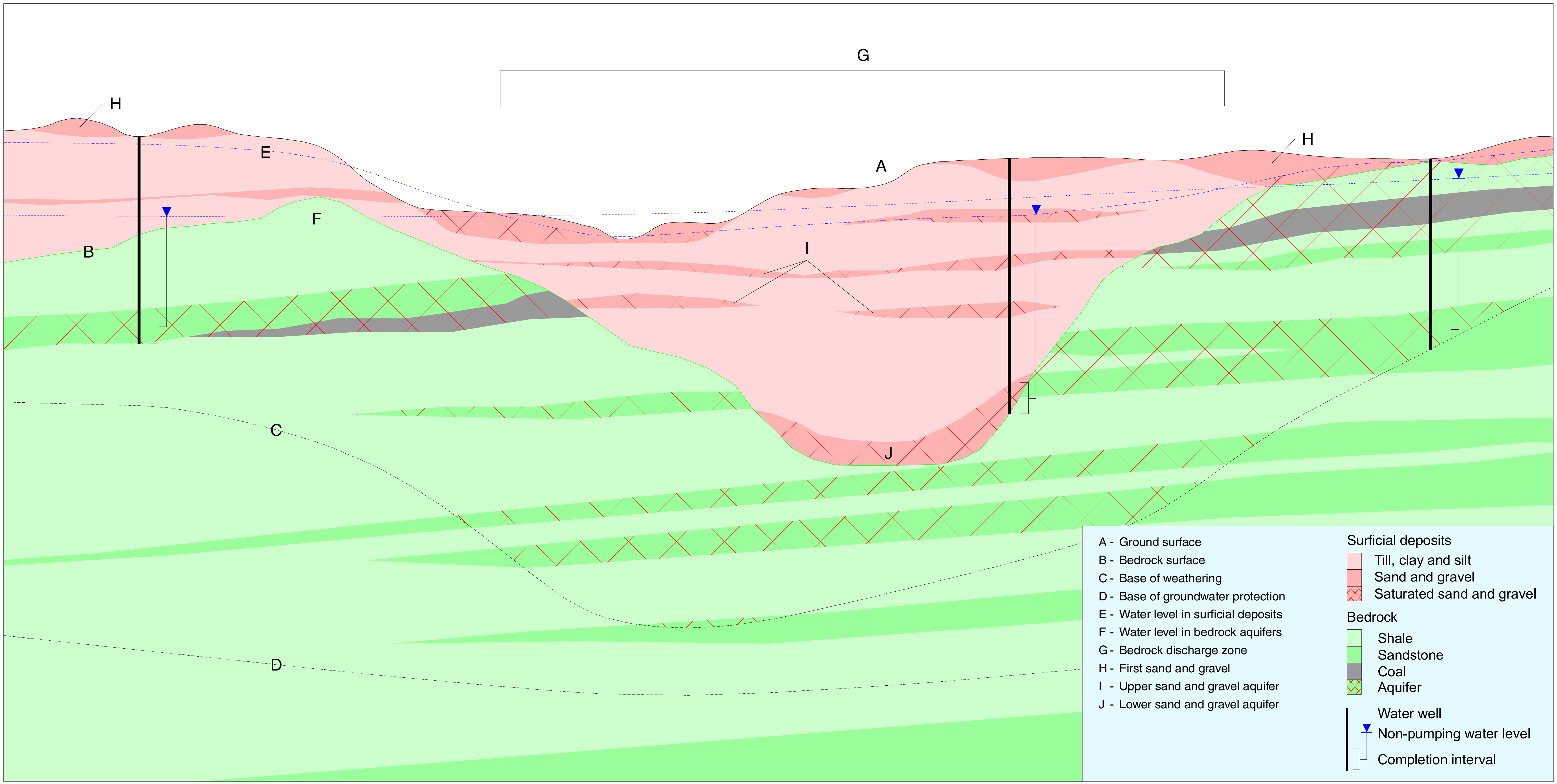
Depth to Base of Groundwater Protection

(modified after EUB, 1995)



Generalized Cross-Section

(for terminology only)



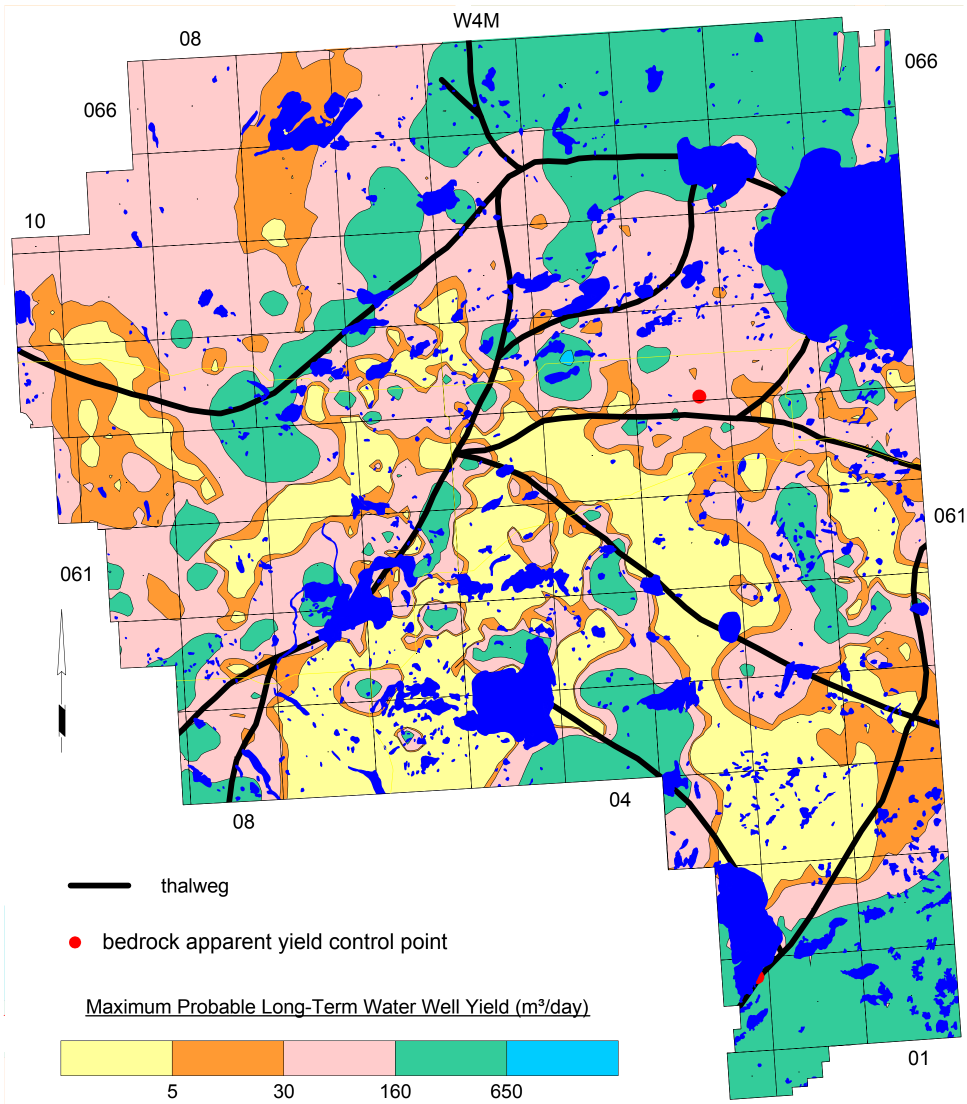
Generalized Geologic Column

(modified after Andriashek and Fenton, 1989)

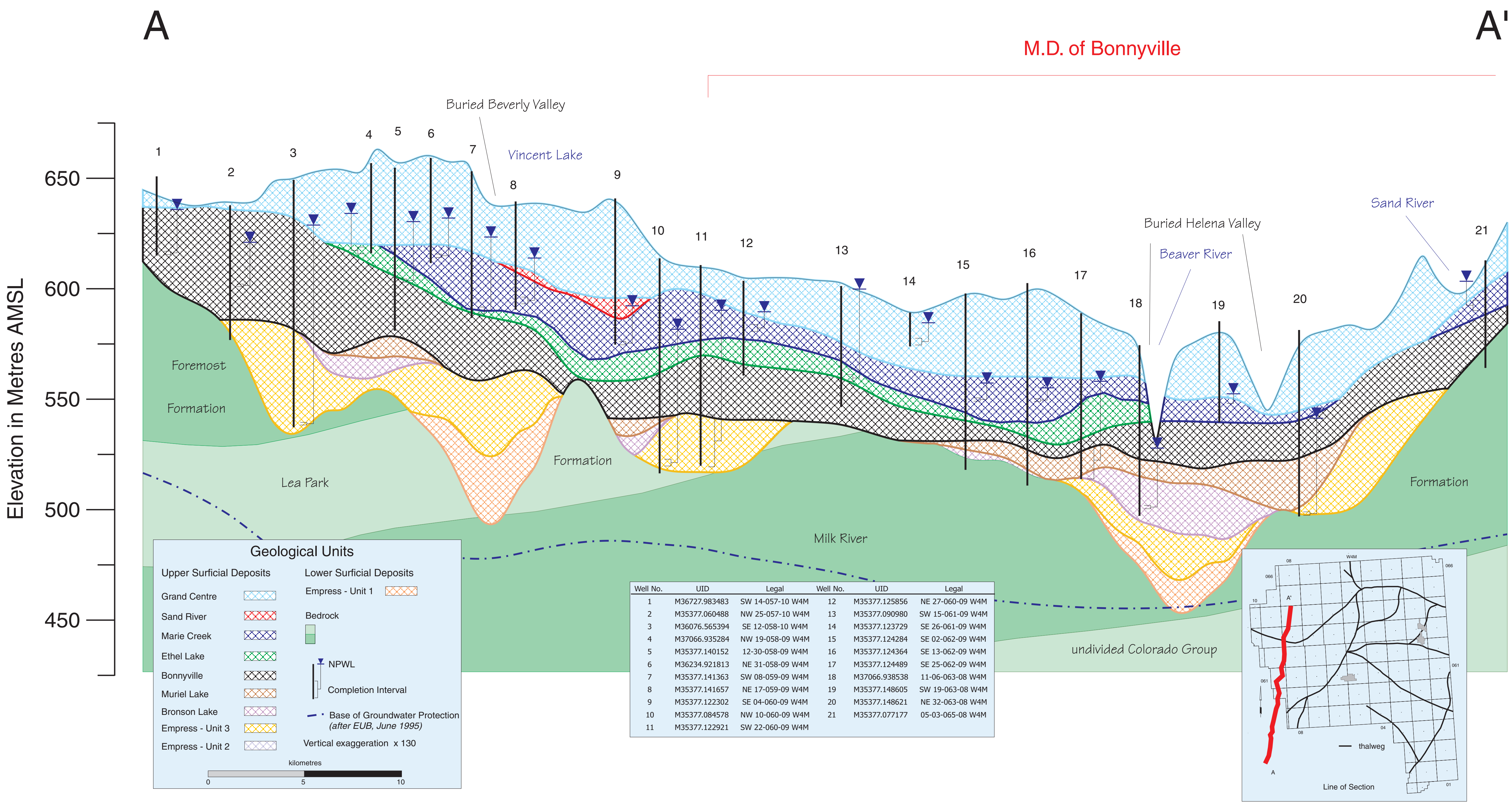
Depth in Metres: 0, 20, 40, 60, 80, 100, 120, 140, 160, 180, 200, 220

	Formation		Unit or Member		
Lithology Description	Average Thickness (m)	Designation	Average Thickness (m)	Designation	Lithology Description
diamicton	< 25	Grand Centre	< 20	Vilna Member	clayey diamicton
			< 30	Kehiwin Member	sandy diamicton
			< 10	Reita Lake Member	clayey sand diamicton
			< 10	Hilda Lake Member	clayey diamicton
sand and gravelly sand	< 25	Sand River			
diamicton	< 25	Marie Creek	10	Unit 2	sandy diamicton
			10	Unit 1	clayey diamicton
silt and clay with sand	2	Ethel Lake			
diamicton	50	Bonnyville	25	Unit 2	sandy clay diamicton
			25	Unit 1	clayey diamicton
sand and gravel	35	Muriel Lake			
clayey diamicton	5	Bronson Lake			
sand and gravel, silt and clay	70	Empress	25	Unit 3	sand and gravel
			25	Unit 2	silt and sand, minor sand and gravel
			25	Unit 1	preglacial sand and gravel (lower surficial deposits)
shale, siltstone	100-200	Lea Park Formation			
sandstone, siltstone, shale, coal	90-120	Milk River Formation			
shale, siltstone	200-1000	*undivided Colorado Group*			

Hydrogeological Map

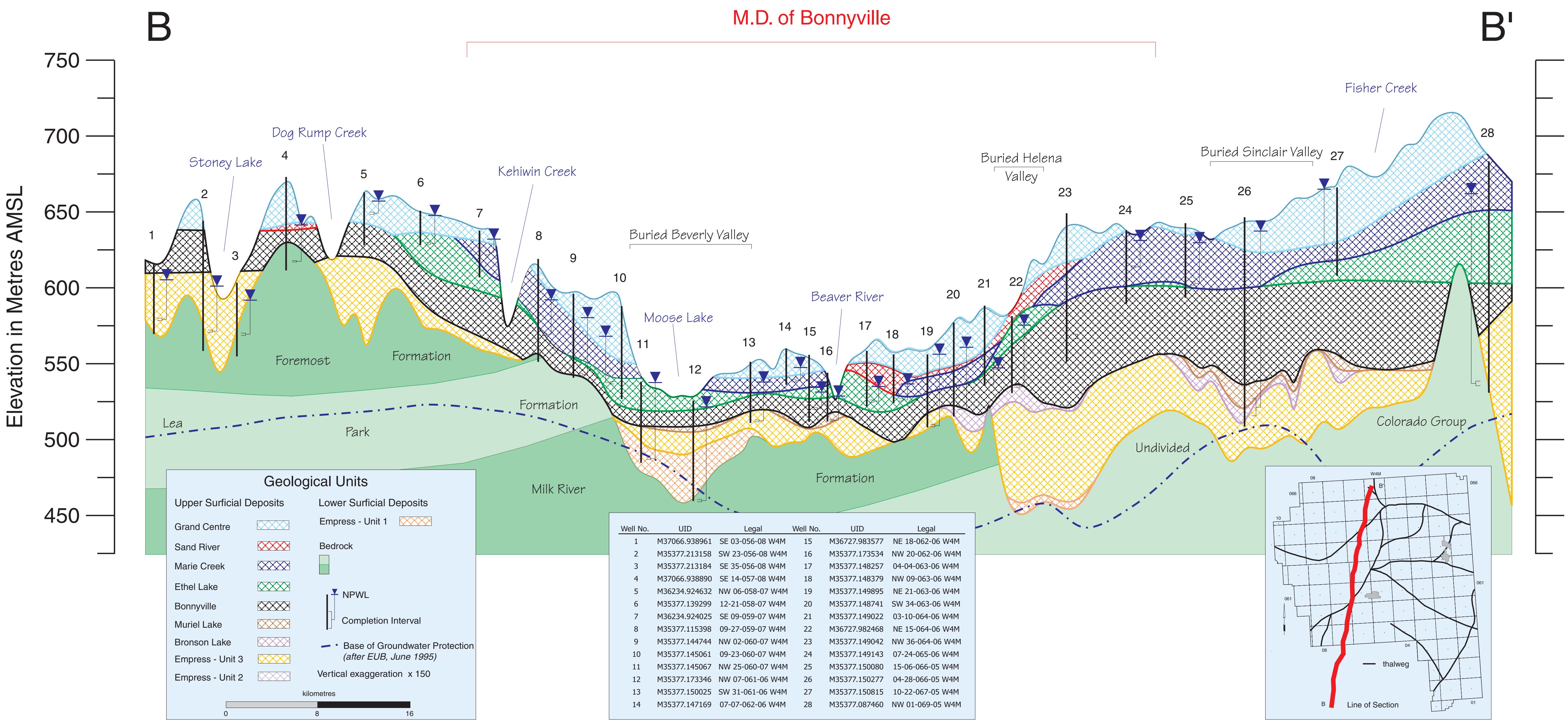


Cross-Section A - A'



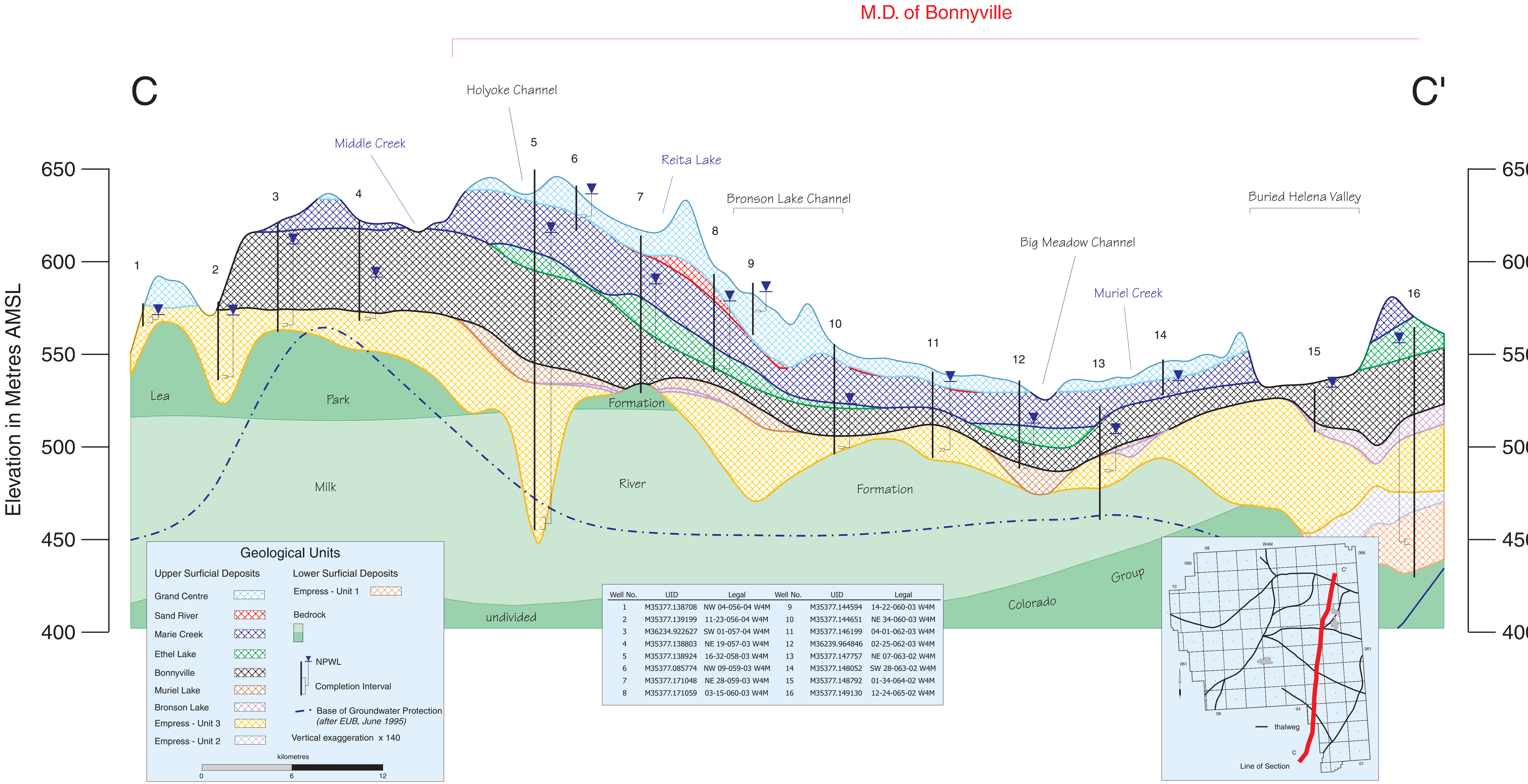
Well No.	UID	Legal	Well No.	UID	Legal
1	M36727.983483	SW 14-057-10 W4M	12	M35377.125856	NE 27-060-09 W4M
2	M35377.060488	NW 25-057-10 W4M	13	M35377.090980	SW 15-061-09 W4M
3	M36076.565394	SE 12-058-10 W4M	14	M35377.123729	SE 26-061-09 W4M
4	M37066.935284	NW 19-058-09 W4M	15	M35377.124284	SE 02-062-09 W4M
5	M35377.140152	12-30-058-09 W4M	16	M35377.124364	SE 13-062-09 W4M
6	M36234.921813	NE 31-058-09 W4M	17	M35377.124489	SE 25-062-09 W4M
7	M35377.141363	SW 08-059-09 W4M	18	M37066.938538	11-06-063-08 W4M
8	M35377.141657	NE 17-059-09 W4M	19	M35377.148605	SW 19-063-08 W4M
9	M35377.122302	SE 04-060-09 W4M	20	M35377.148621	NE 32-063-08 W4M
10	M35377.084578	NW 10-060-09 W4M	21	M35377.077177	05-03-065-08 W4M
11	M35377.122921	SW 22-060-09 W4M			

Cross-Section B - B'



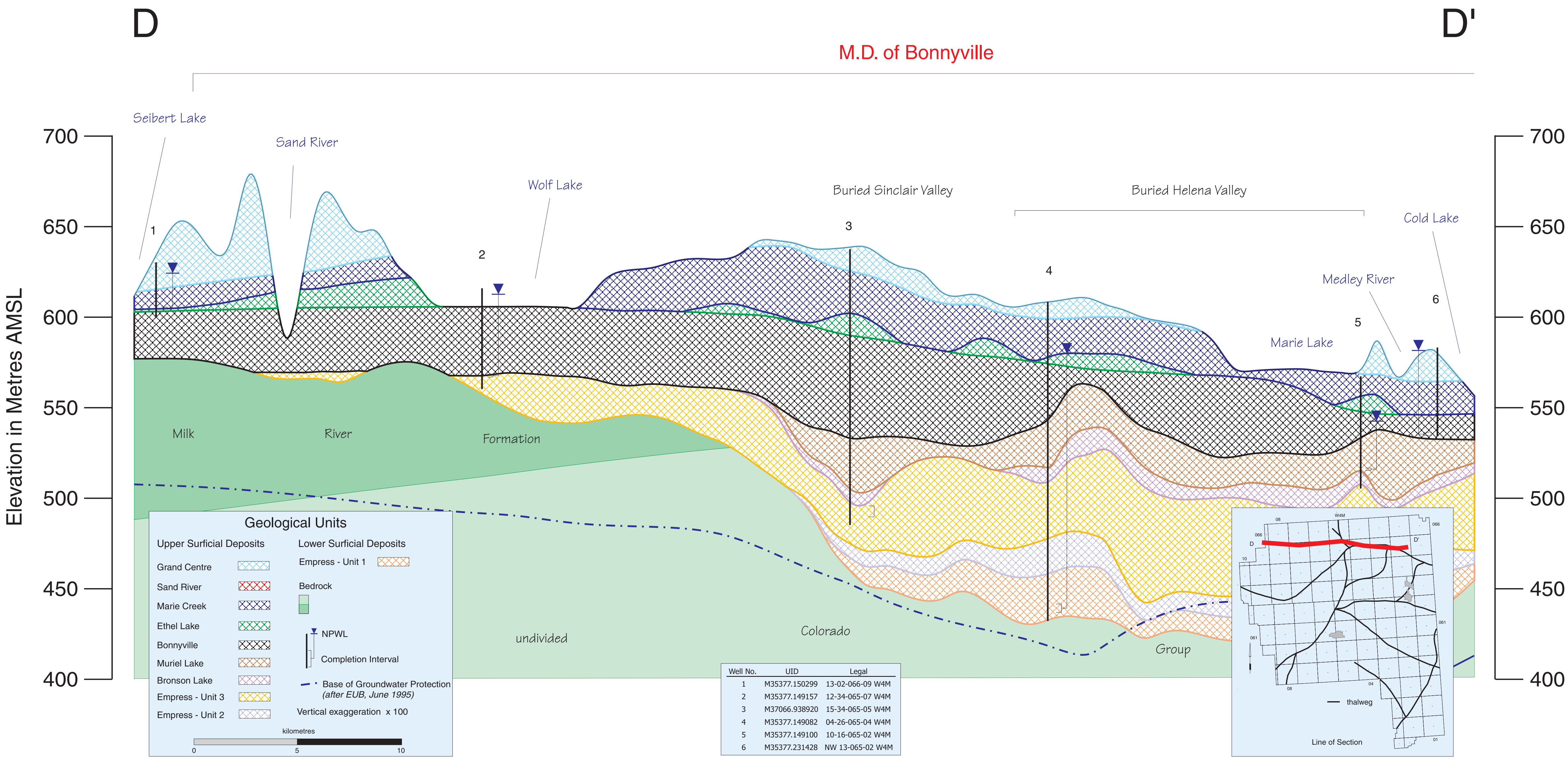
Well No.	UID	Legal	Well No.	UID	Legal
1	M37066.938961	SE 03-056-08 W4M	15	M36727.983577	NE 18-062-06 W4M
2	M35377.213158	SW 23-056-08 W4M	16	M35377.173534	NW 20-062-06 W4M
3	M35377.213184	SE 35-056-08 W4M	17	M35377.148257	04-04-063-06 W4M
4	M37066.938890	SE 14-057-08 W4M	18	M35377.148379	NW 09-063-06 W4M
5	M36234.924632	NW 06-058-07 W4M	19	M35377.149895	NE 21-063-06 W4M
6	M35377.139299	12-21-058-07 W4M	20	M35377.148741	SW 34-063-06 W4M
7	M36234.924025	SE 09-059-07 W4M	21	M35377.149022	03-10-064-06 W4M
8	M35377.115398	09-27-059-07 W4M	22	M36727.982468	NE 15-064-06 W4M
9	M35377.144744	NW 02-060-07 W4M	23	M35377.149042	NW 36-064-06 W4M
10	M35377.145061	09-23-060-07 W4M	24	M35377.149143	07-24-065-06 W4M
11	M35377.145067	NW 25-060-07 W4M	25	M35377.150080	15-06-066-05 W4M
12	M35377.173346	NW 07-061-06 W4M	26	M35377.150277	04-28-066-05 W4M
13	M35377.150025	SW 31-061-06 W4M	27	M35377.150815	10-22-067-05 W4M
14	M35377.147169	07-07-062-06 W4M	28	M35377.087460	NW 01-069-05 W4M

Cross-Section C - C'



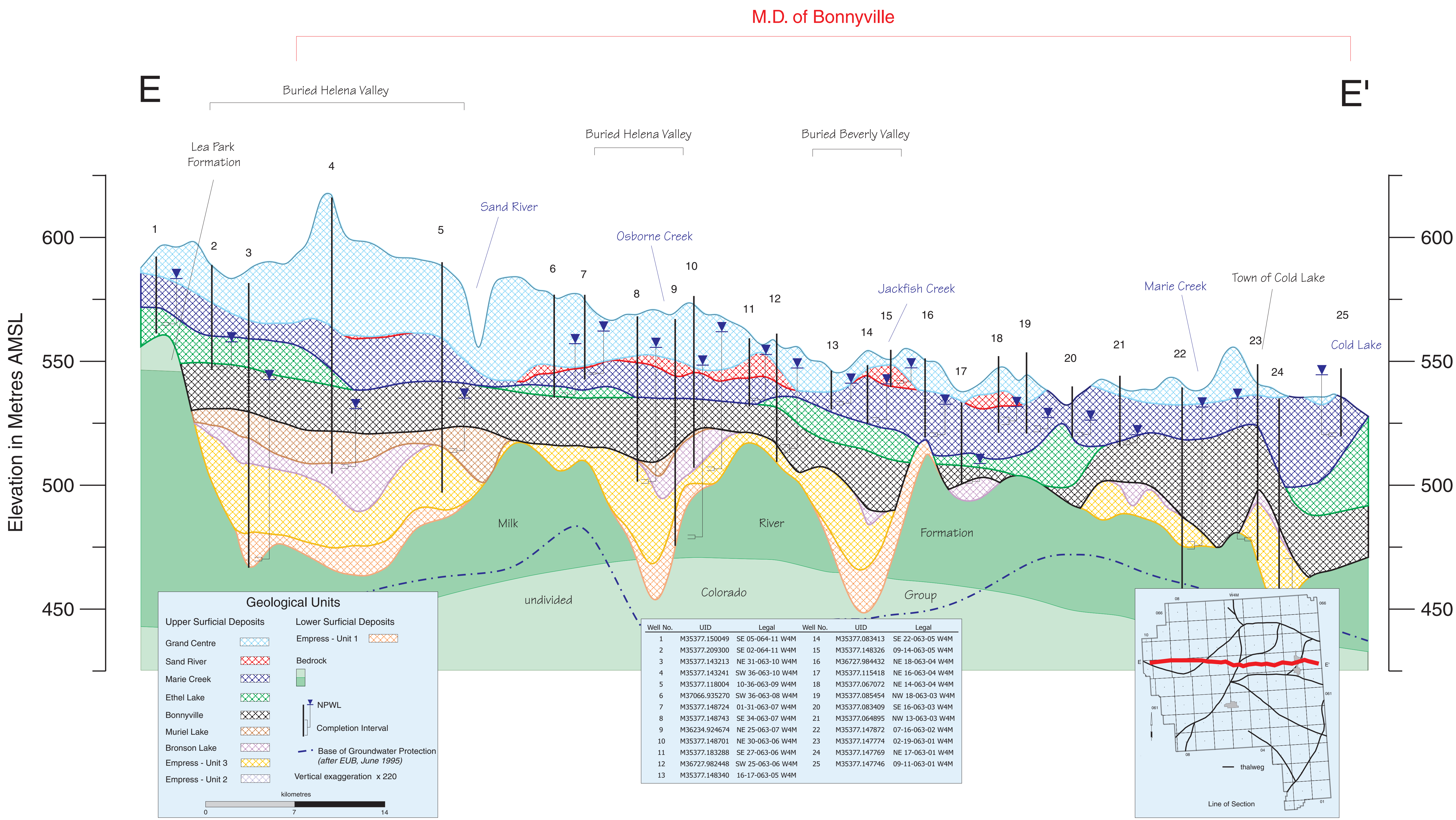
Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.138708	NW 04-056-04 W4M	9	M35377.144594	14-22-060-03 W4M
2	M35377.139199	11-23-056-04 W4M	10	M35377.144651	NE 34-060-03 W4M
3	M36234.922627	SW 01-057-04 W4M	11	M35377.146199	04-01-062-03 W4M
4	M35377.138803	NE 19-057-03 W4M	12	M36239.964846	02-25-062-03 W4M
5	M35377.138924	16-32-058-03 W4M	13	M35377.147757	NE 07-063-02 W4M
6	M35377.085774	NW 09-059-03 W4M	14	M35377.148052	SW 28-063-02 W4M
7	M35377.171048	NE 28-059-03 W4M	15	M35377.148792	01-34-064-02 W4M
8	M35377.171059	03-15-060-03 W4M	16	M35377.149130	12-24-065-02 W4M

Cross-Section D - D'



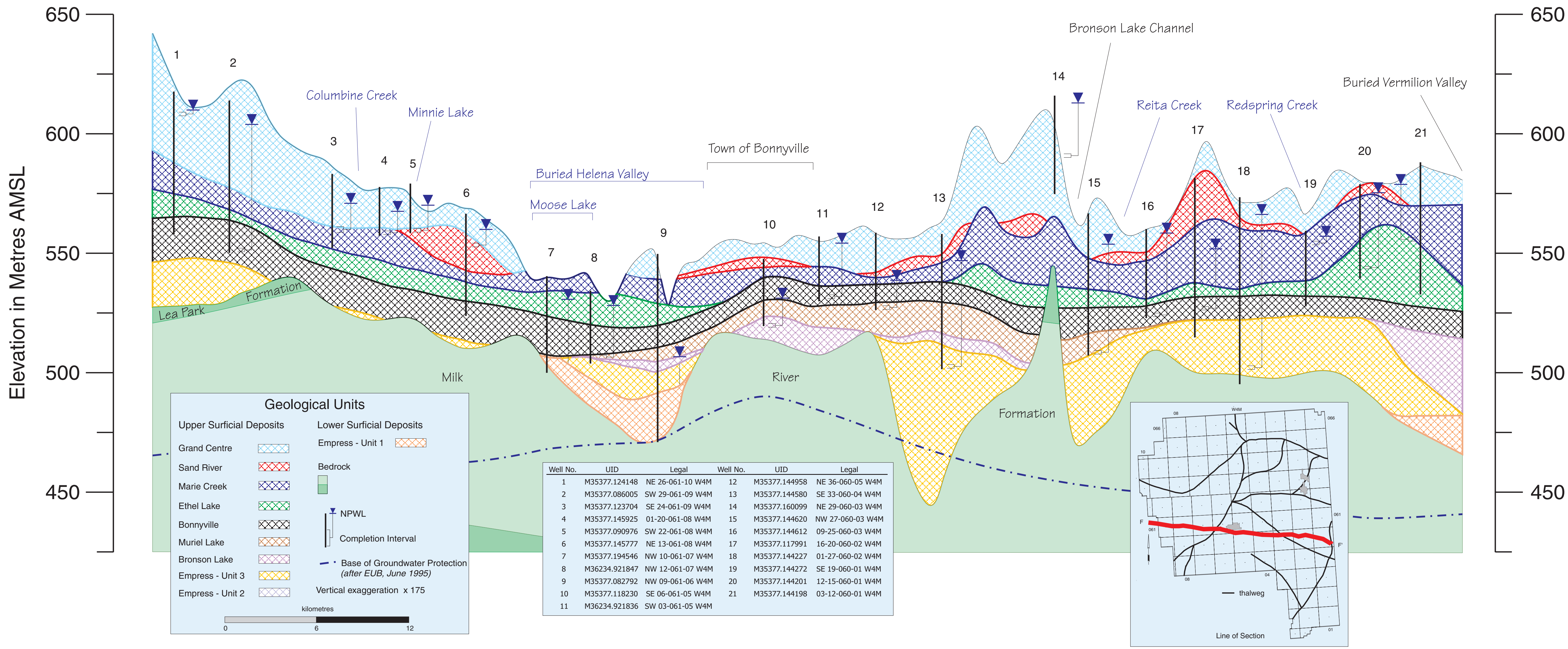
Well No.	UID	Legal
1	M35377.150299	13-02-066-09 W4M
2	M35377.149157	12-34-065-07 W4M
3	M37066.938920	15-34-065-05 W4M
4	M35377.149082	04-26-065-04 W4M
5	M35377.149100	10-16-065-02 W4M
6	M35377.231428	NW 13-065-02 W4M

Cross-Section E - E'



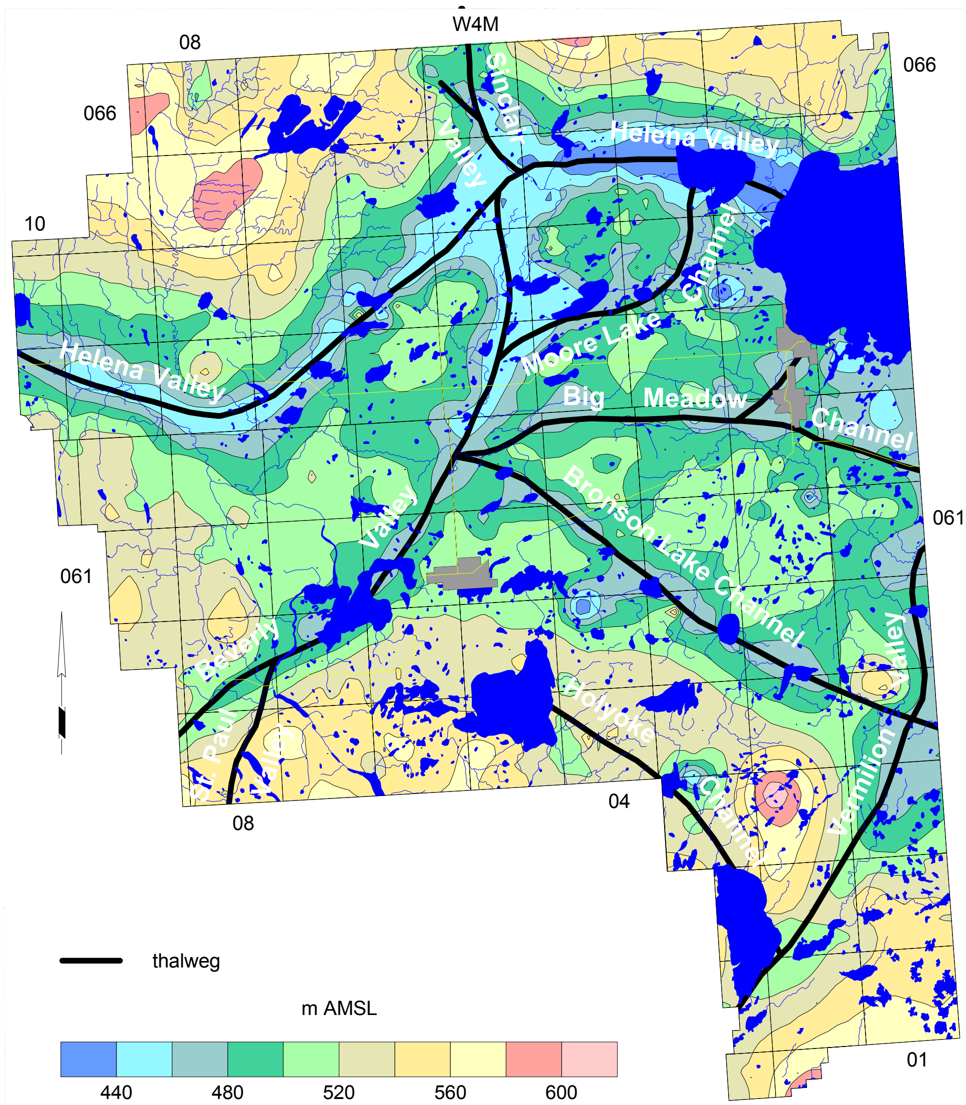
Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.150049	SE 05-064-11 W4M	14	M35377.083413	SE 22-063-05 W4M
2	M35377.209300	SE 02-064-11 W4M	15	M35377.148326	09-14-063-05 W4M
3	M35377.143213	NE 31-063-10 W4M	16	M36727.984432	NE 18-063-04 W4M
4	M35377.143241	SW 36-063-10 W4M	17	M35377.115418	NE 16-063-04 W4M
5	M35377.118004	10-36-063-09 W4M	18	M35377.067072	NE 14-063-04 W4M
6	M37066.935270	SW 36-063-08 W4M	19	M35377.085454	NW 18-063-03 W4M
7	M35377.148724	01-31-063-07 W4M	20	M35377.083409	SE 16-063-03 W4M
8	M35377.148743	SE 34-063-07 W4M	21	M35377.064895	NW 13-063-03 W4M
9	M36234.924674	NE 25-063-07 W4M	22	M35377.147872	07-16-063-02 W4M
10	M35377.148701	NE 30-063-06 W4M	23	M35377.147774	02-19-063-01 W4M
11	M35377.183288	SE 27-063-06 W4M	24	M35377.147769	NE 17-063-01 W4M
12	M36727.982448	SW 25-063-06 W4M	25	M35377.147746	09-11-063-01 W4M
13	M35377.148340	16-17-063-05 W4M			

Cross-Section F - F'

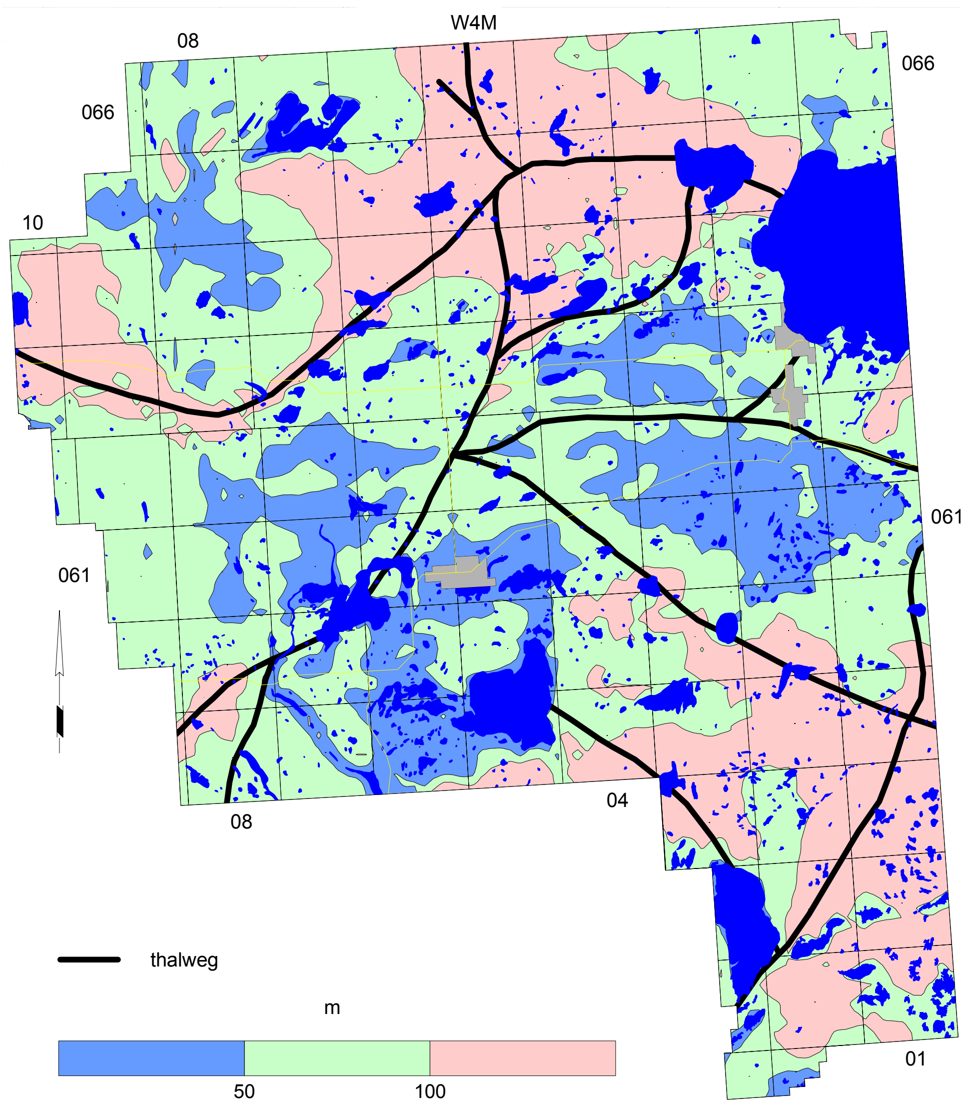


Well No.	UID	Legal	Well No.	UID	Legal
1	M35377.124148	NE 26-061-10 W4M	12	M35377.144958	NE 36-060-05 W4M
2	M35377.086005	SW 29-061-09 W4M	13	M35377.144580	SE 33-060-04 W4M
3	M35377.123704	SE 24-061-09 W4M	14	M35377.160099	NE 29-060-03 W4M
4	M35377.145925	01-20-061-08 W4M	15	M35377.144620	NW 27-060-03 W4M
5	M35377.090976	SW 22-061-08 W4M	16	M35377.144612	09-25-060-03 W4M
6	M35377.145777	NE 13-061-08 W4M	17	M35377.117991	16-20-060-02 W4M
7	M35377.194546	NW 10-061-07 W4M	18	M35377.144227	01-27-060-02 W4M
8	M36234.921847	NW 12-061-07 W4M	19	M35377.144272	SE 19-060-01 W4M
9	M35377.082792	NW 09-061-06 W4M	20	M35377.144201	12-15-060-01 W4M
10	M35377.118230	SE 06-061-05 W4M	21	M35377.144198	03-12-060-01 W4M
11	M36234.921836	SW 03-061-05 W4M			

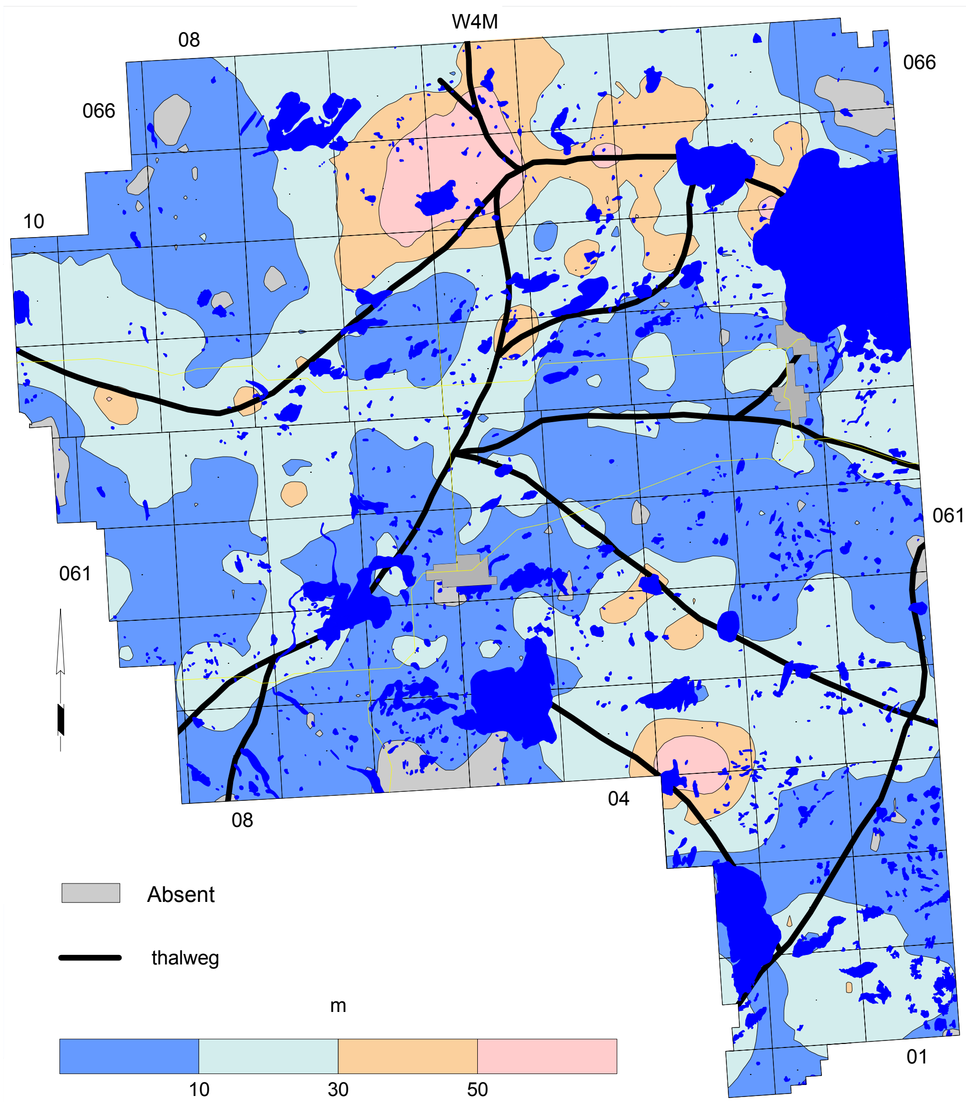
Bedrock Topography



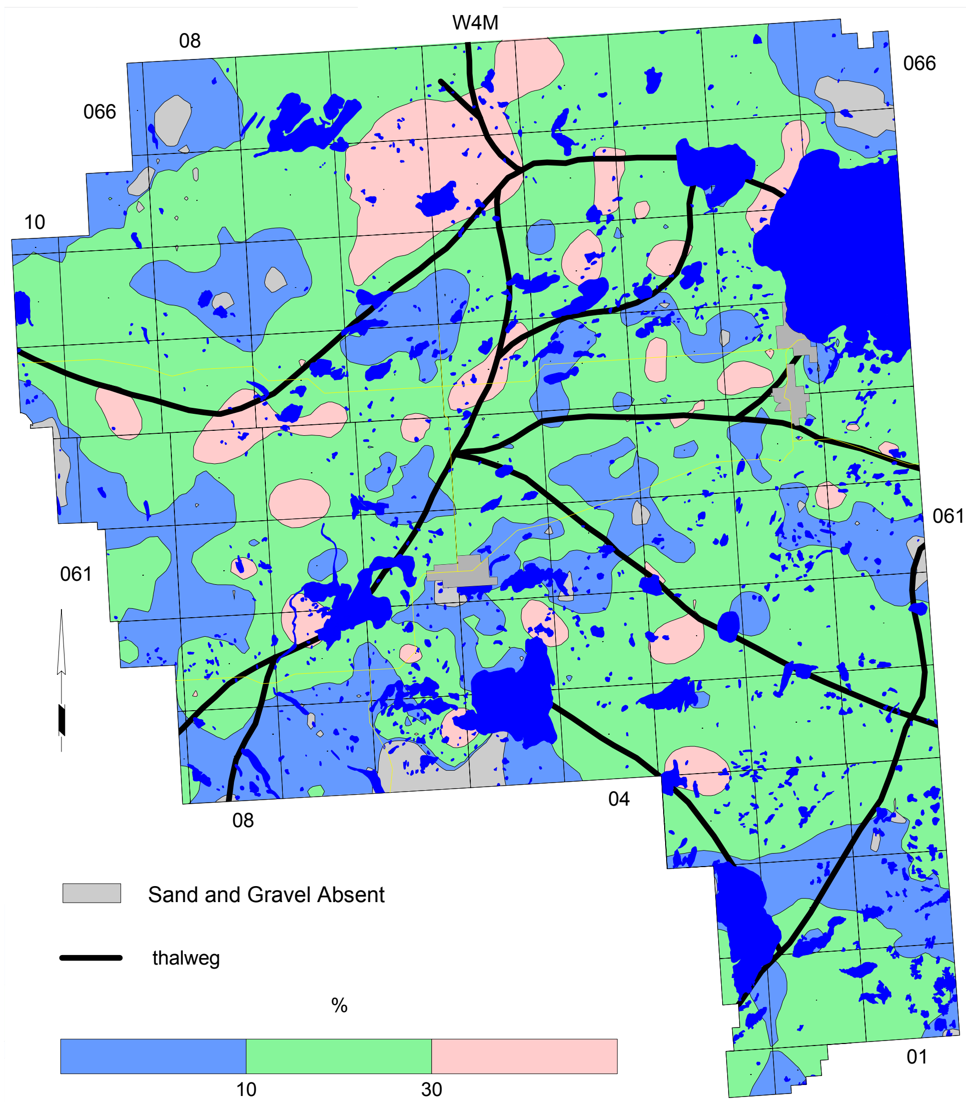
Thickness of Surficial Deposits



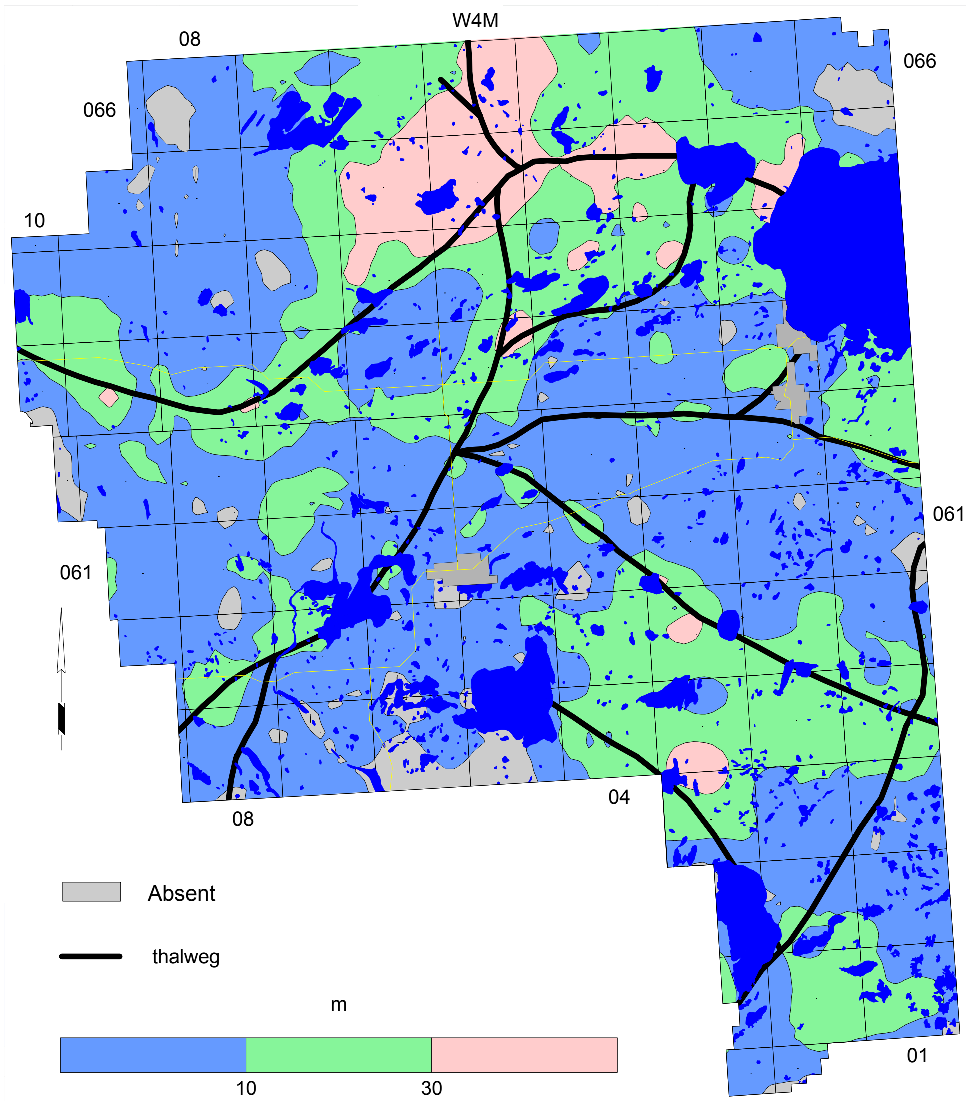
Thickness of Sand and Gravel Deposits



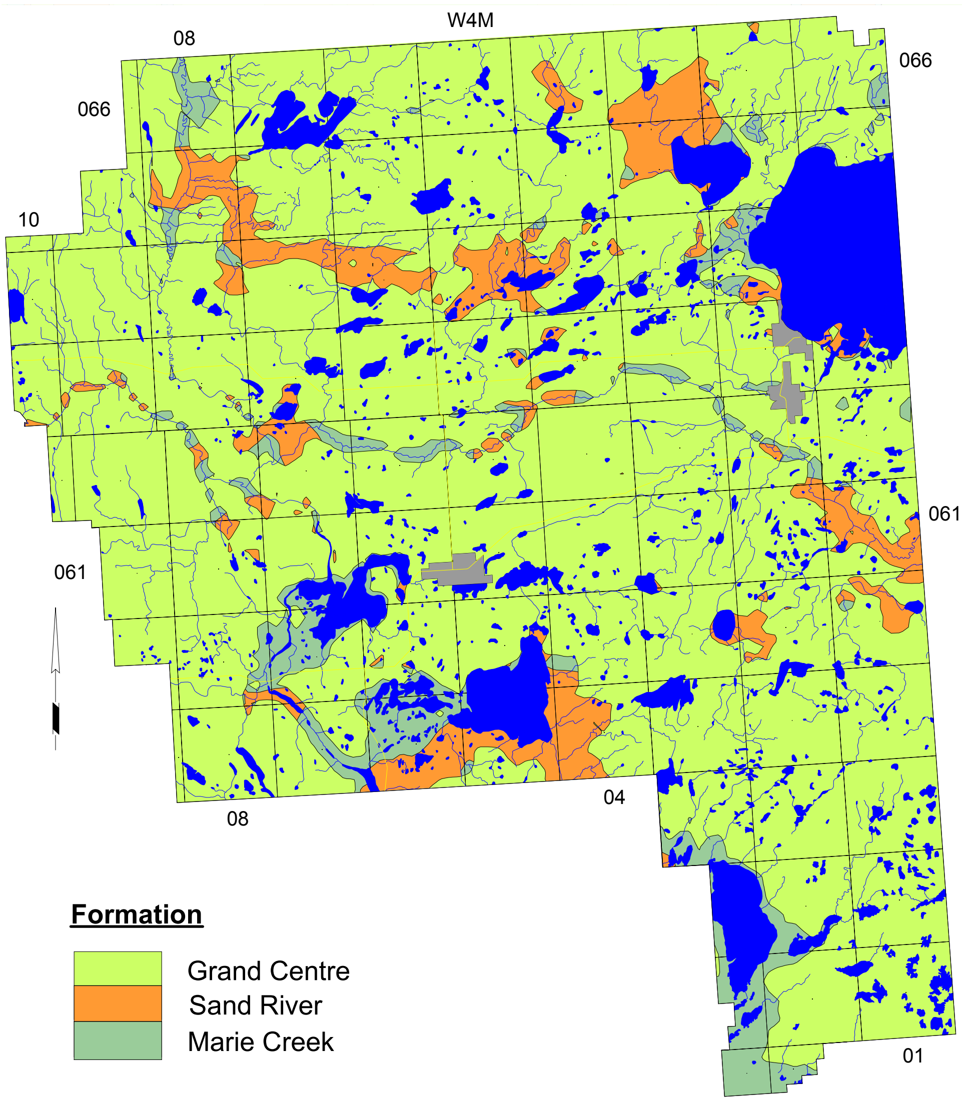
Amount of Sand and Gravel in Surficial Deposits



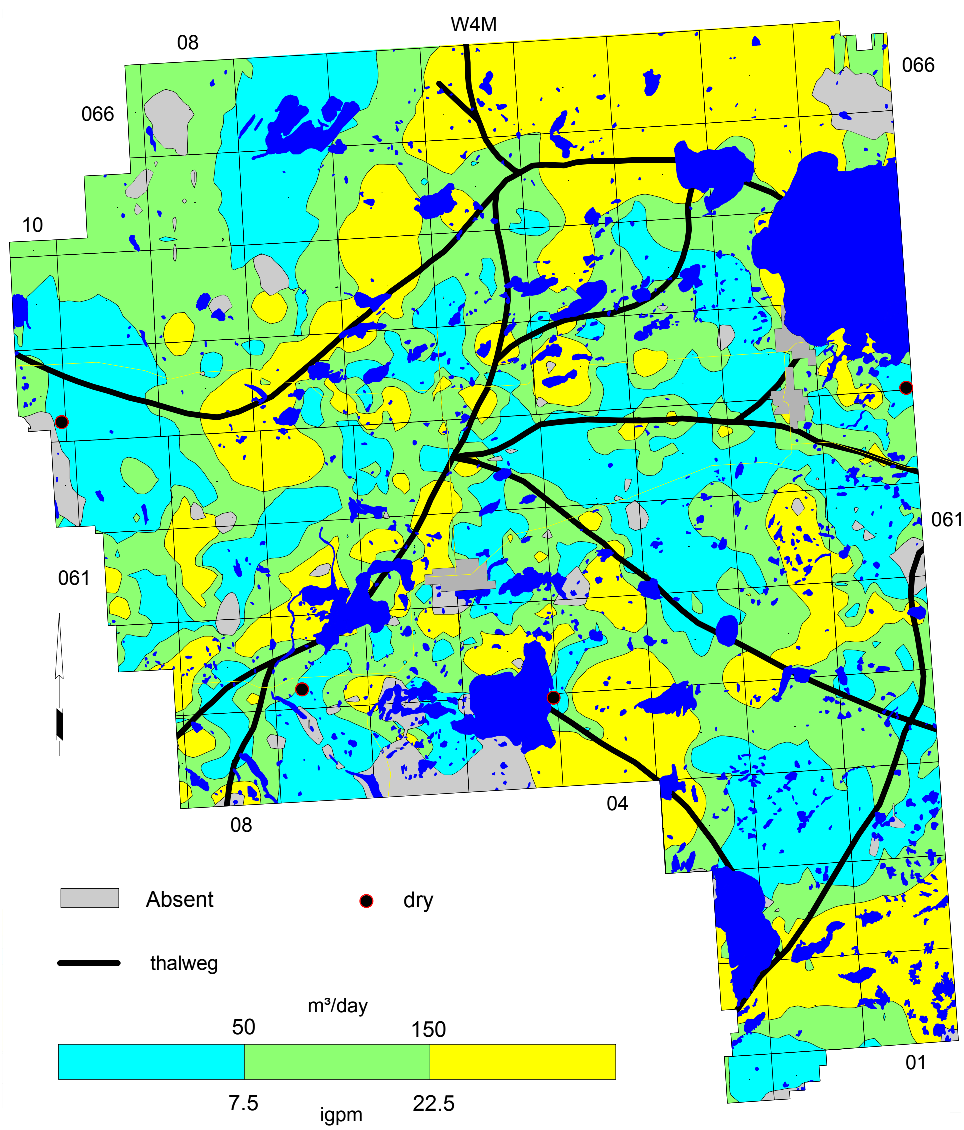
Thickness of Sand and Gravel Aquifer(s)



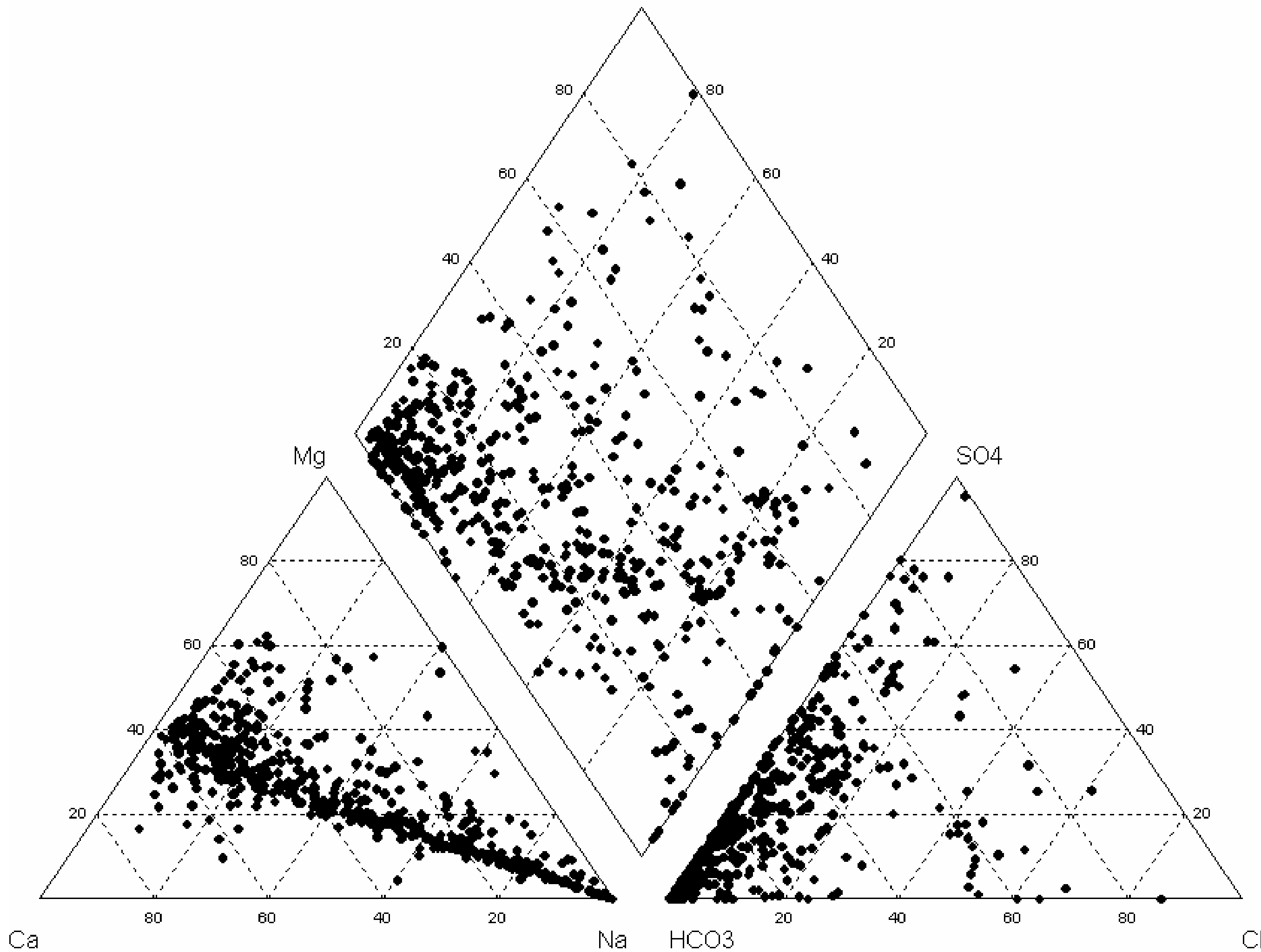
Surficial Geology



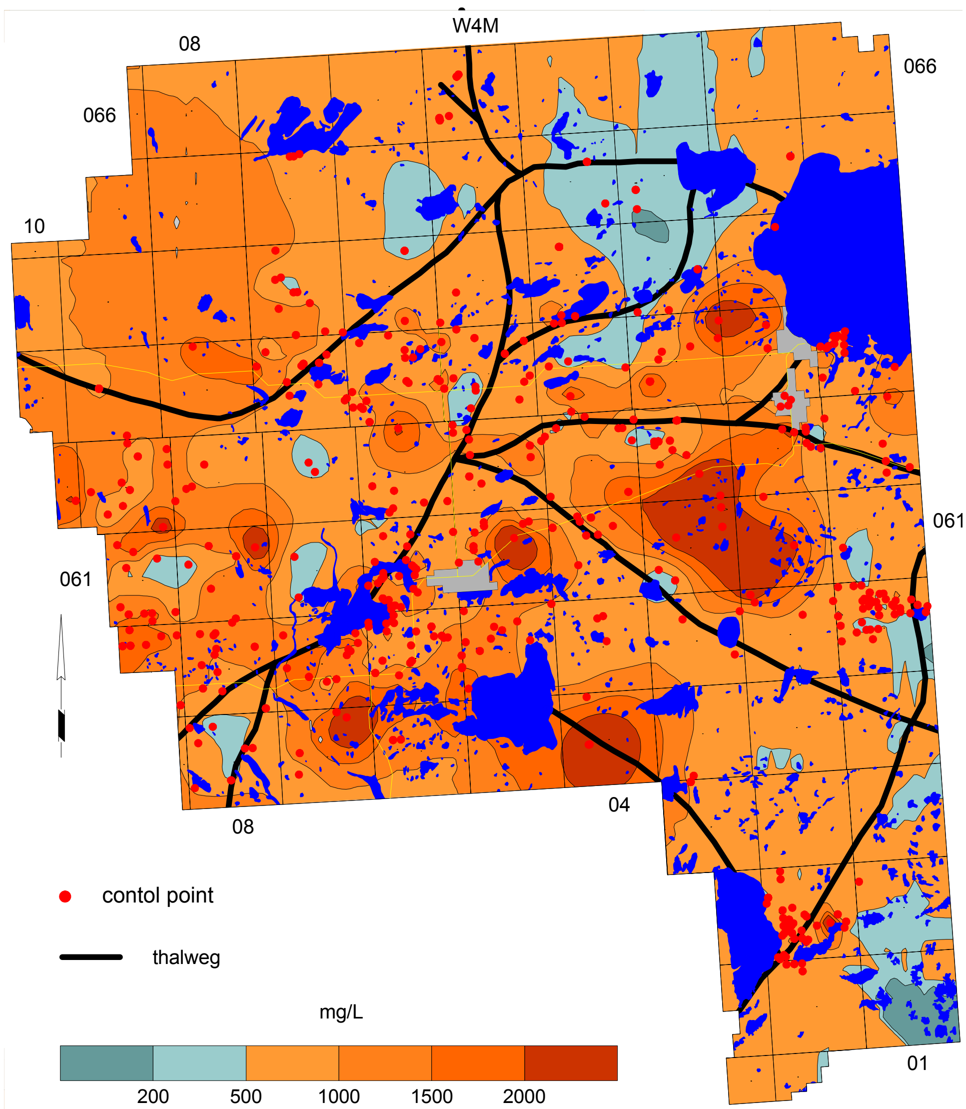
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)



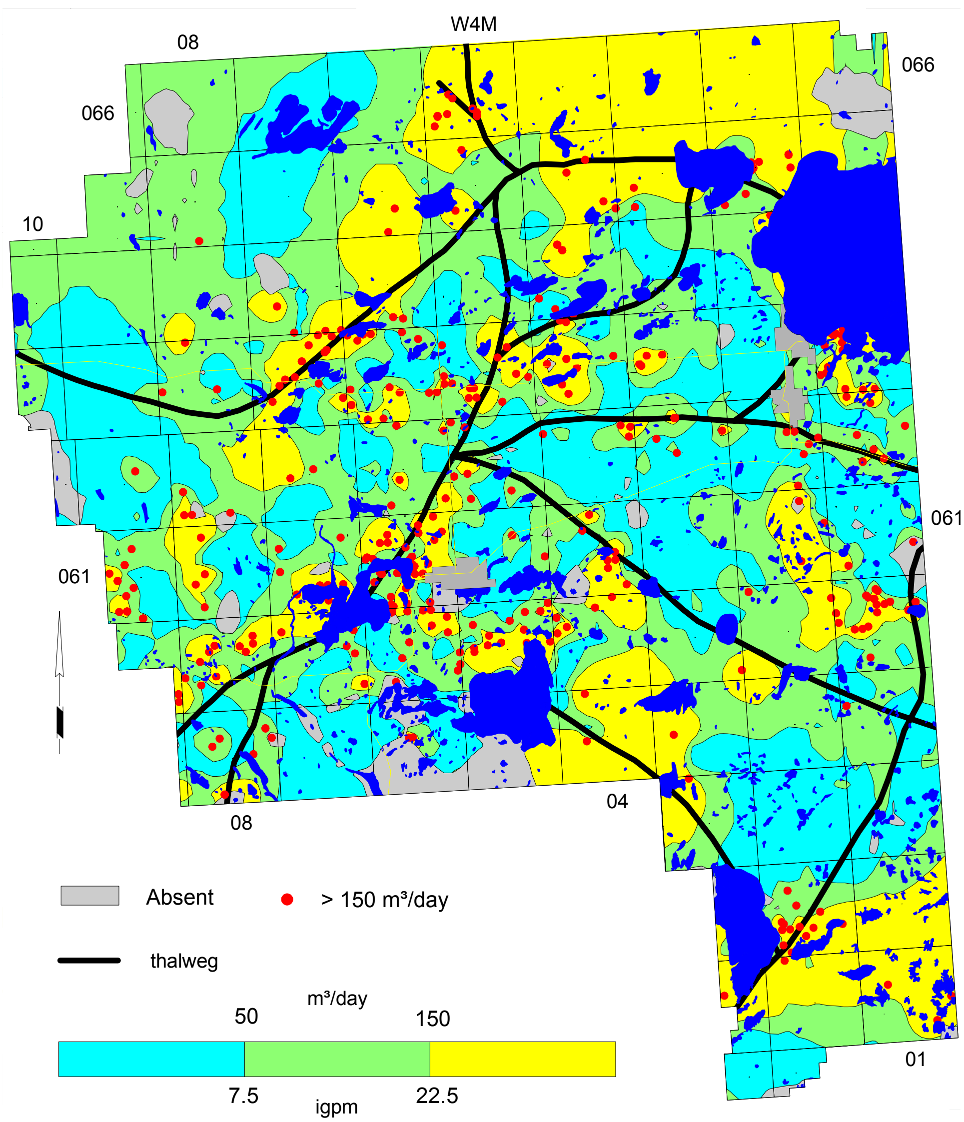
Piper Diagram – Surficial Deposits



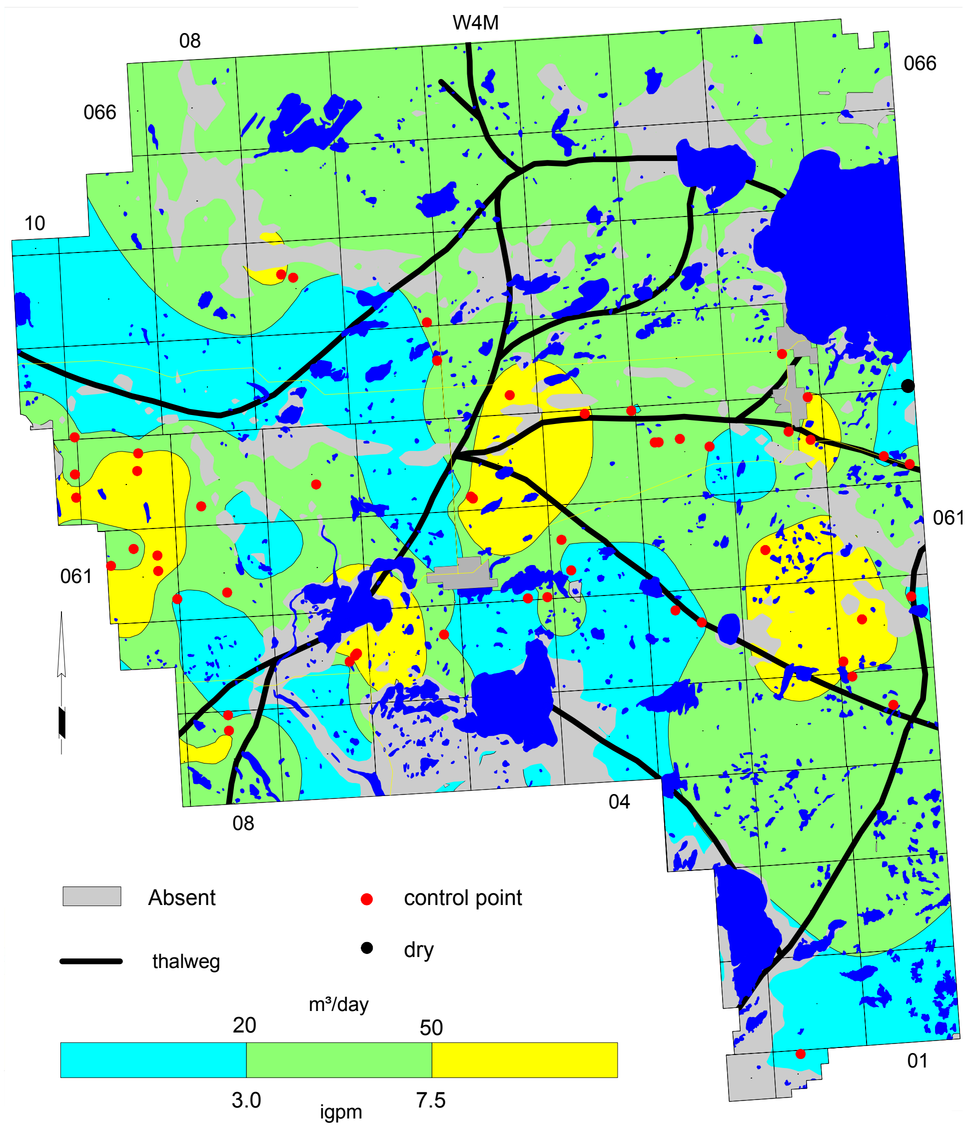
Total Dissolved Solids in Groundwater from Surficial Deposits



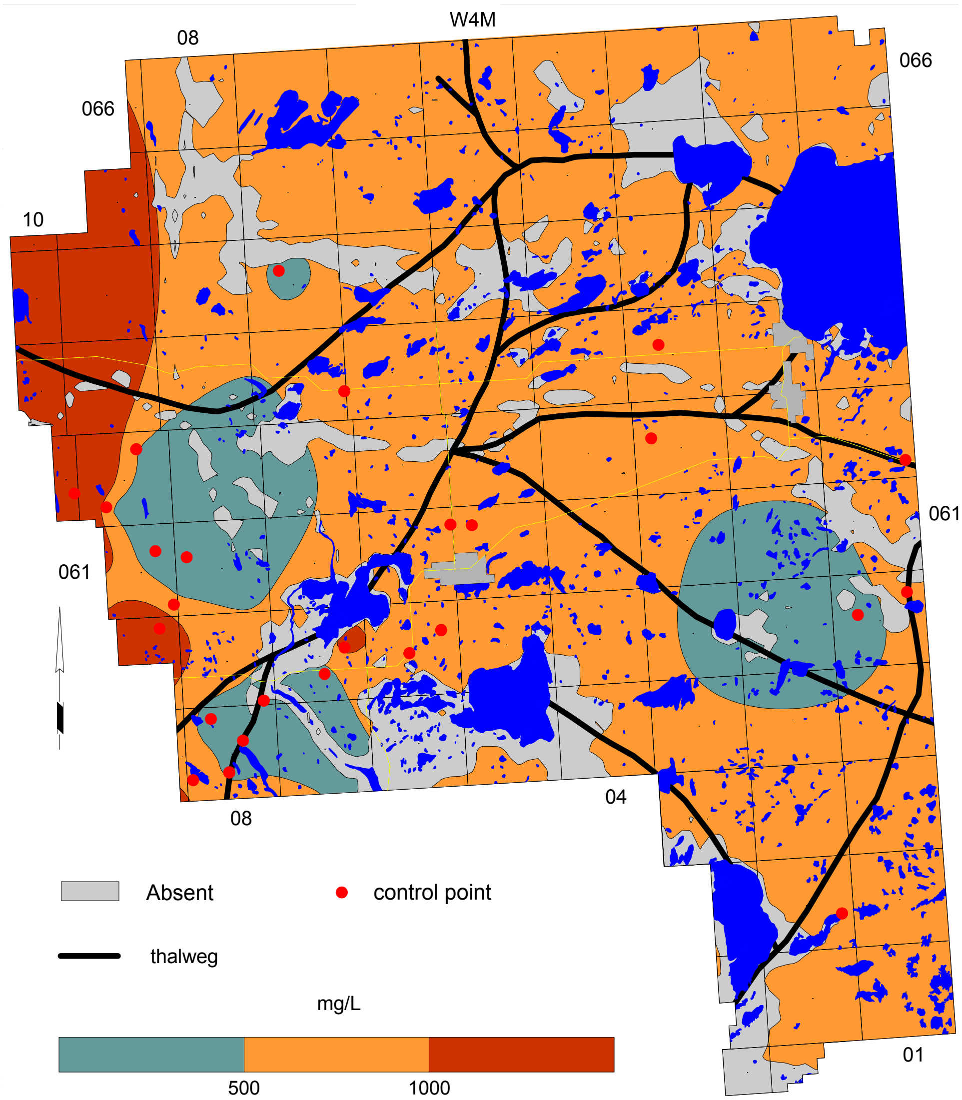
Apparent Yield for Water Wells Completed through Upper Sand and Gravel Aquifer



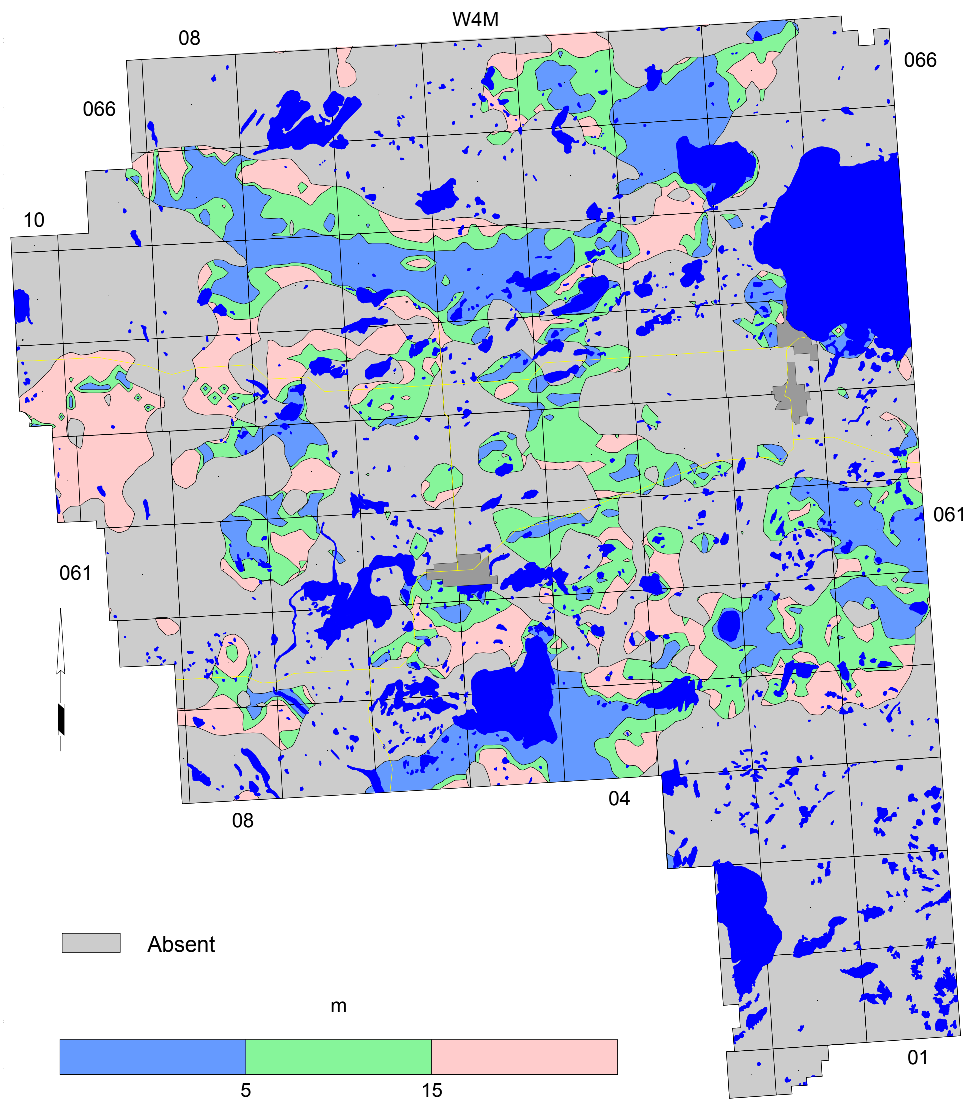
Apparent Yield for Water Wells Completed through Grand Centre Aquifer



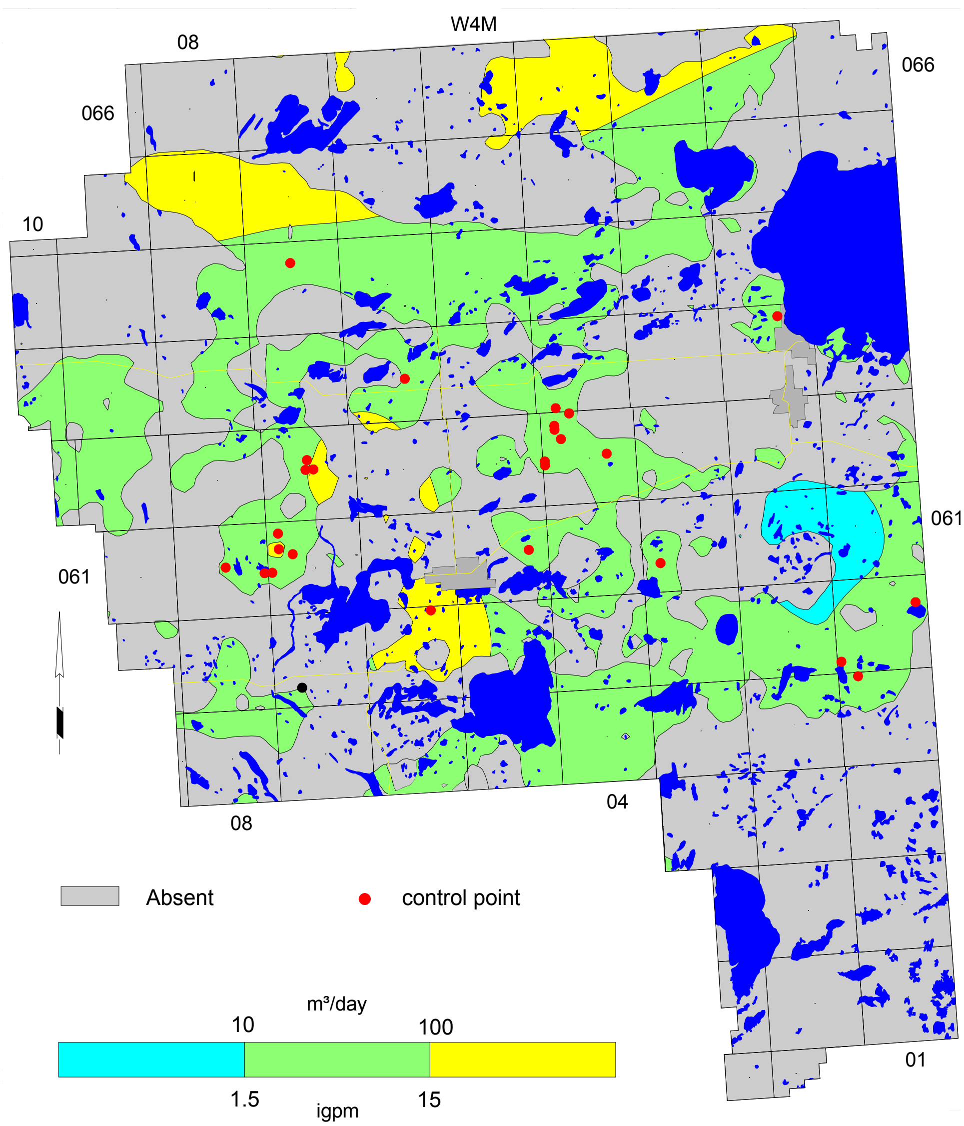
Total Dissolved Solids in Groundwater from Grand Centre Aquifer



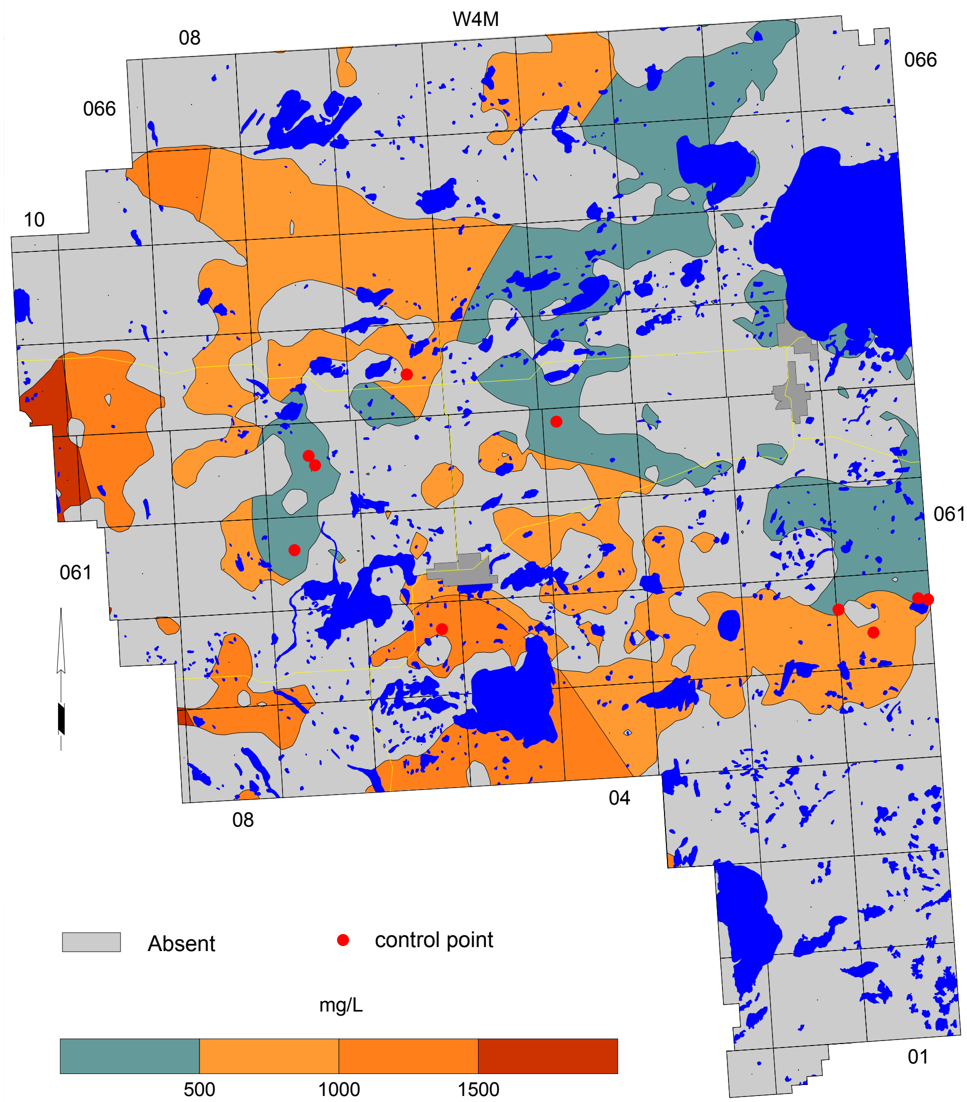
Depth to Top of Sand River Formation



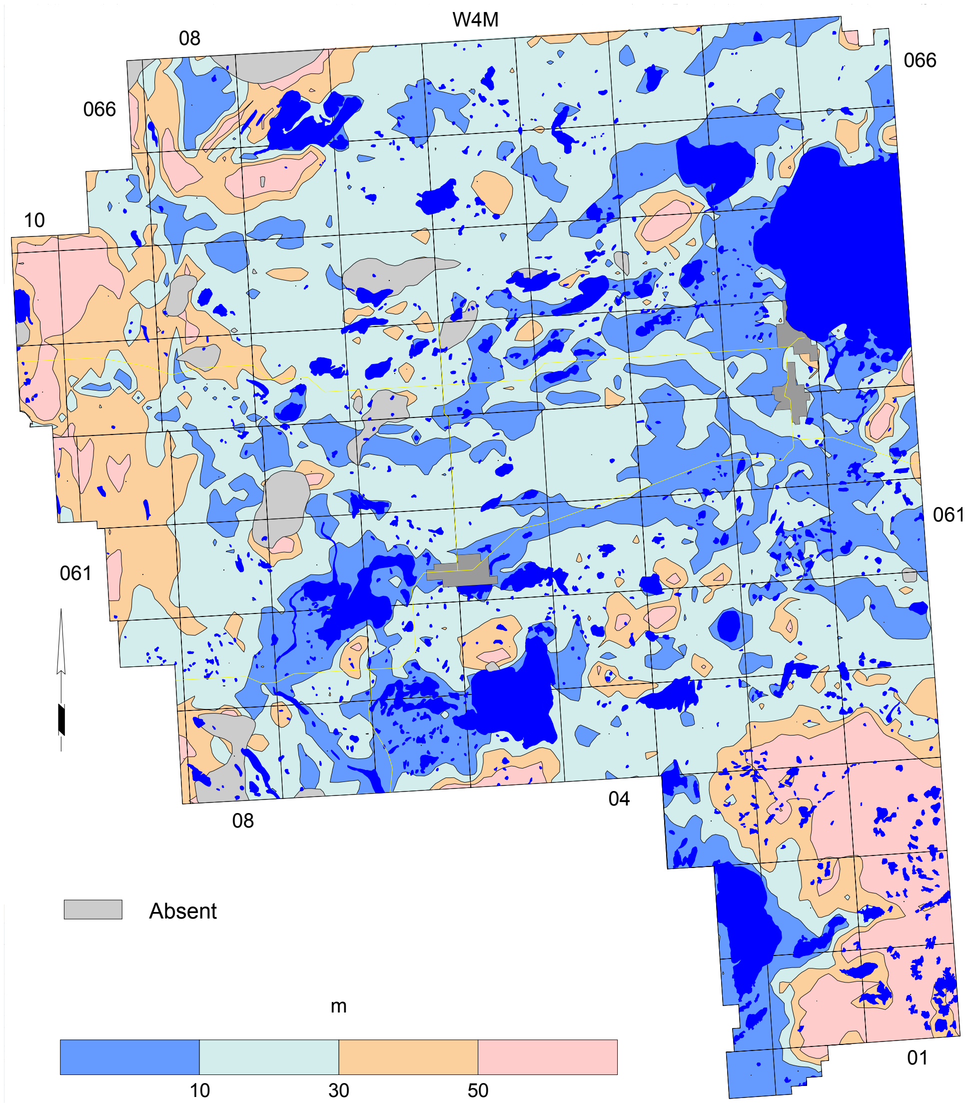
Apparent Yield for Water Wells Completed through Sand River Aquifer



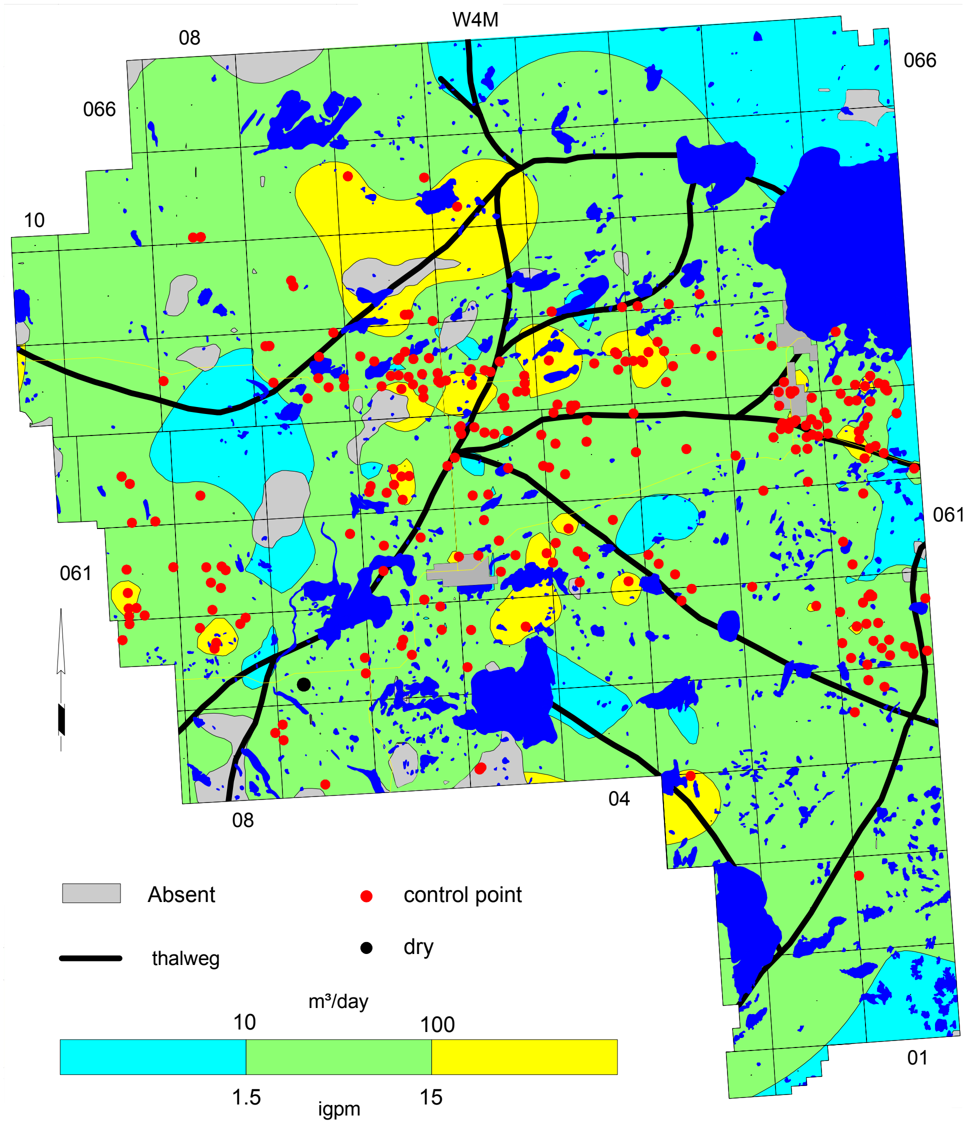
Total Dissolved Solids in Groundwater from Sand River Aquifer



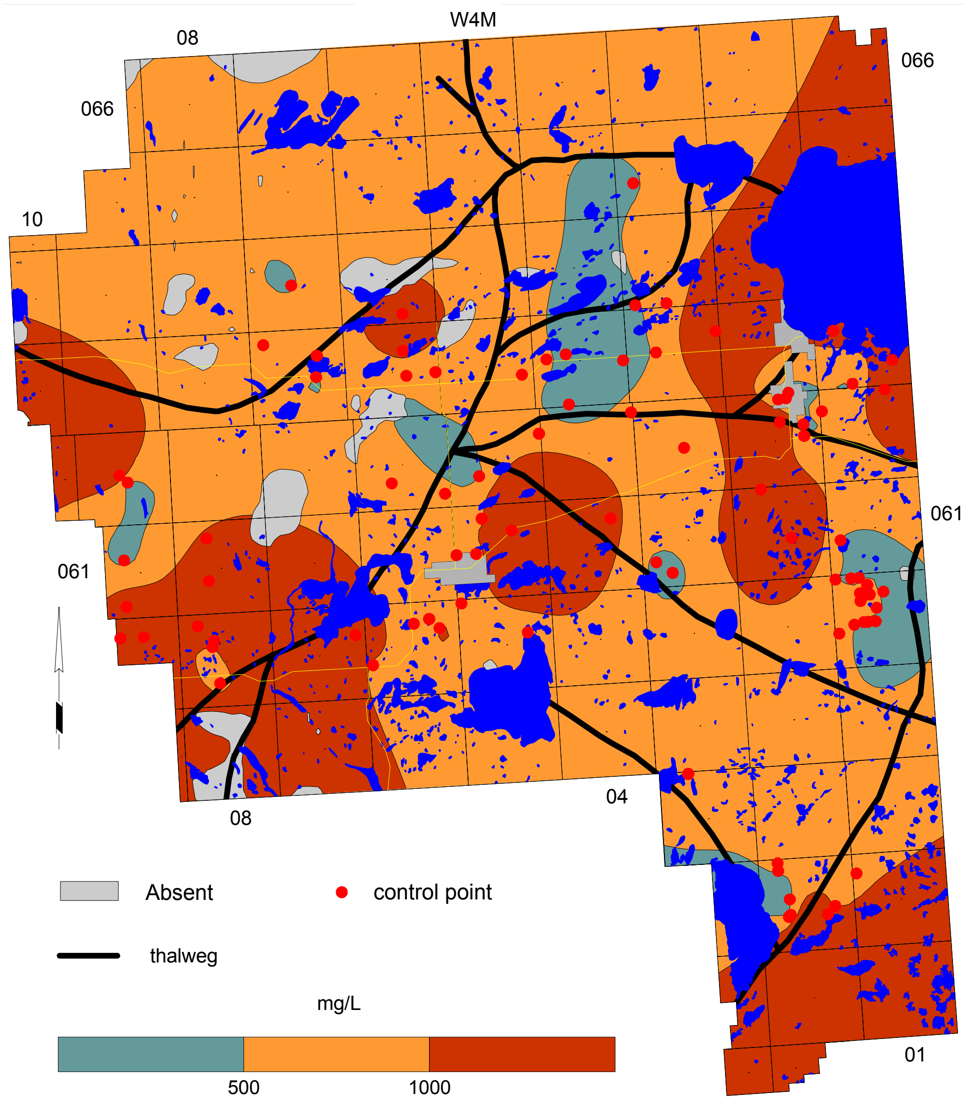
Depth to Top of Marie Creek Formation



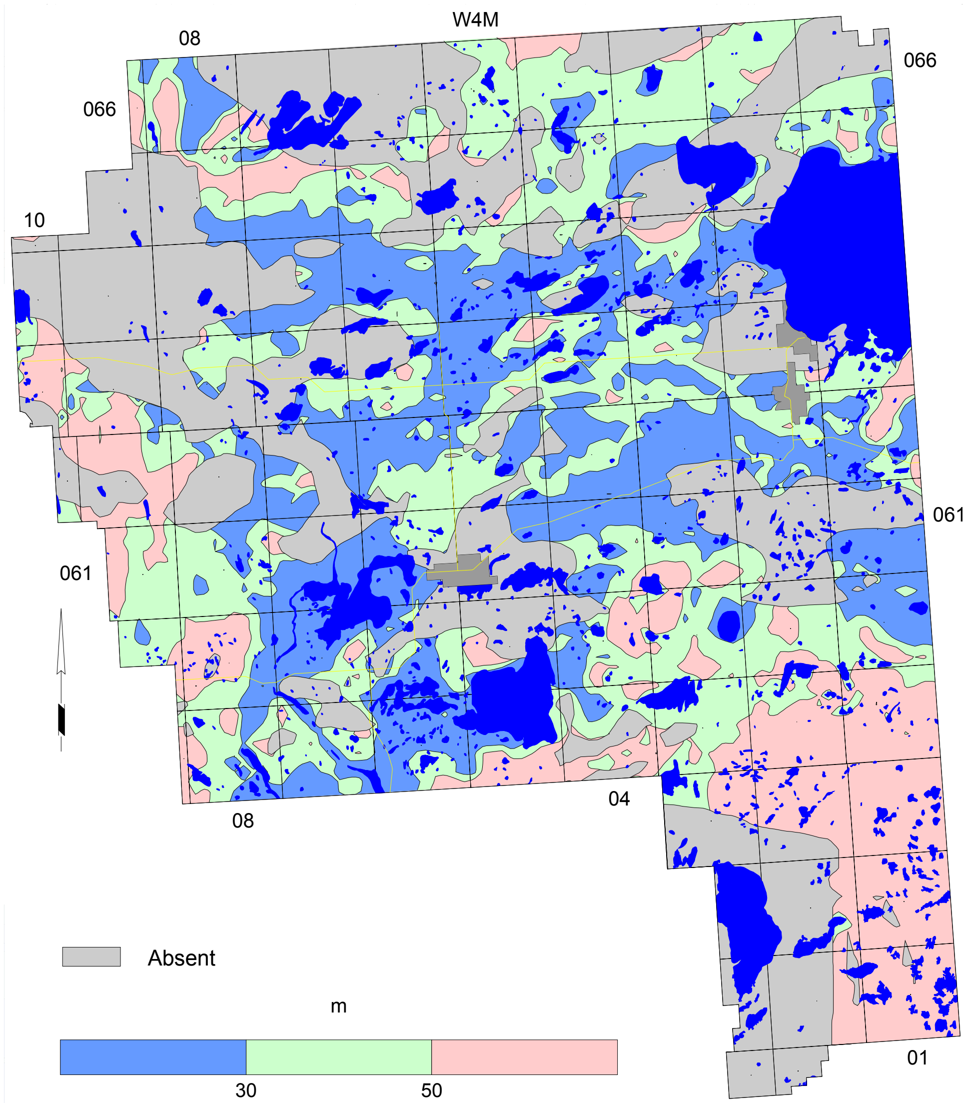
Apparent Yield for Water Wells Completed through Marie Creek Aquifer



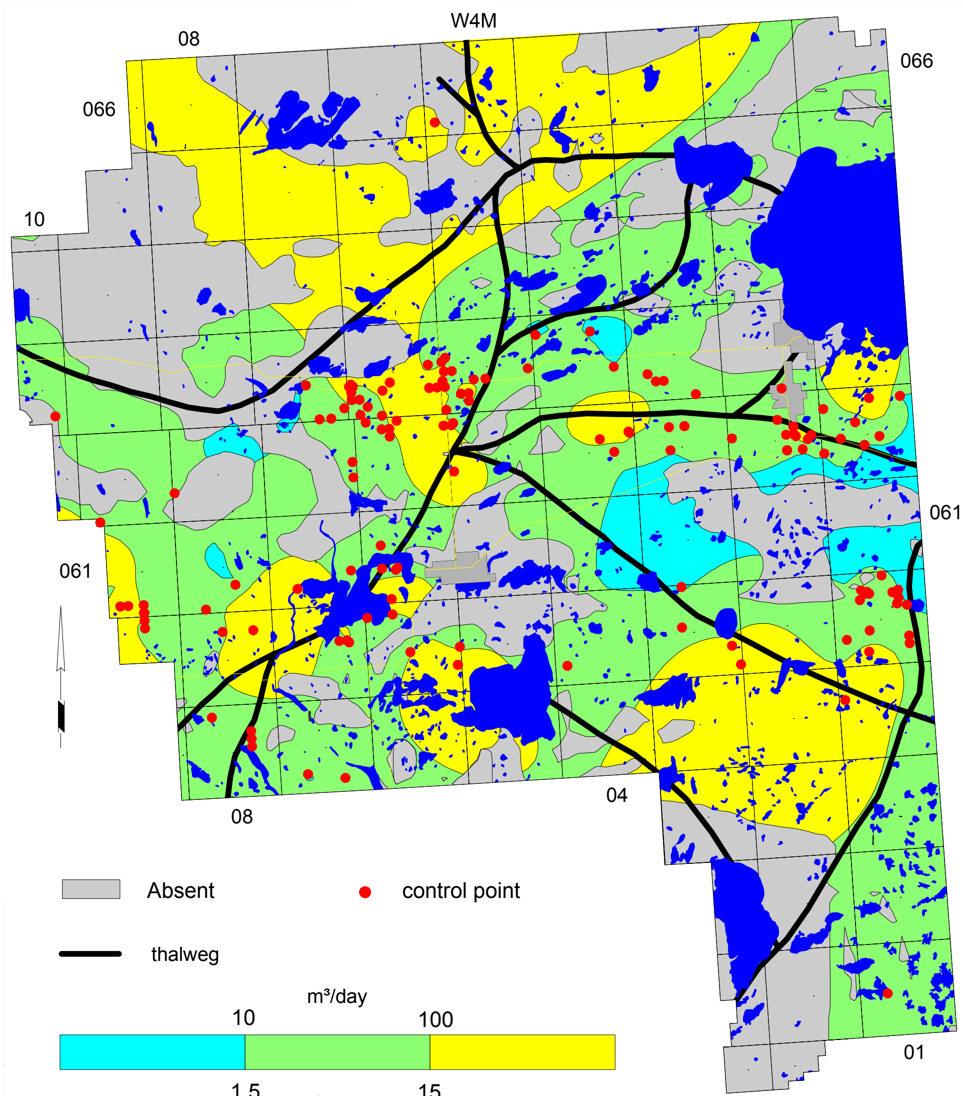
Total Dissolved Solids in Groundwater from Marie Creek Aquifer



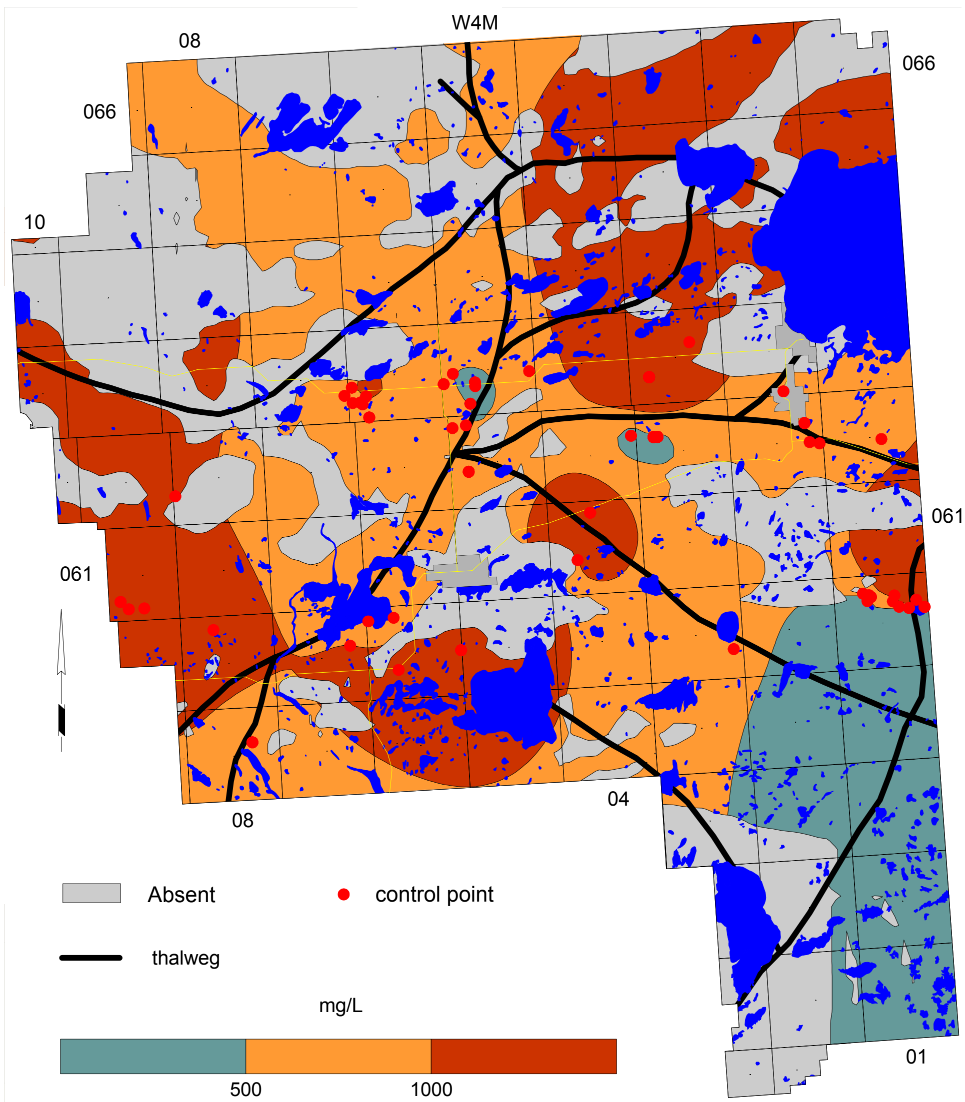
Depth to Top of Ethel Lake Formation



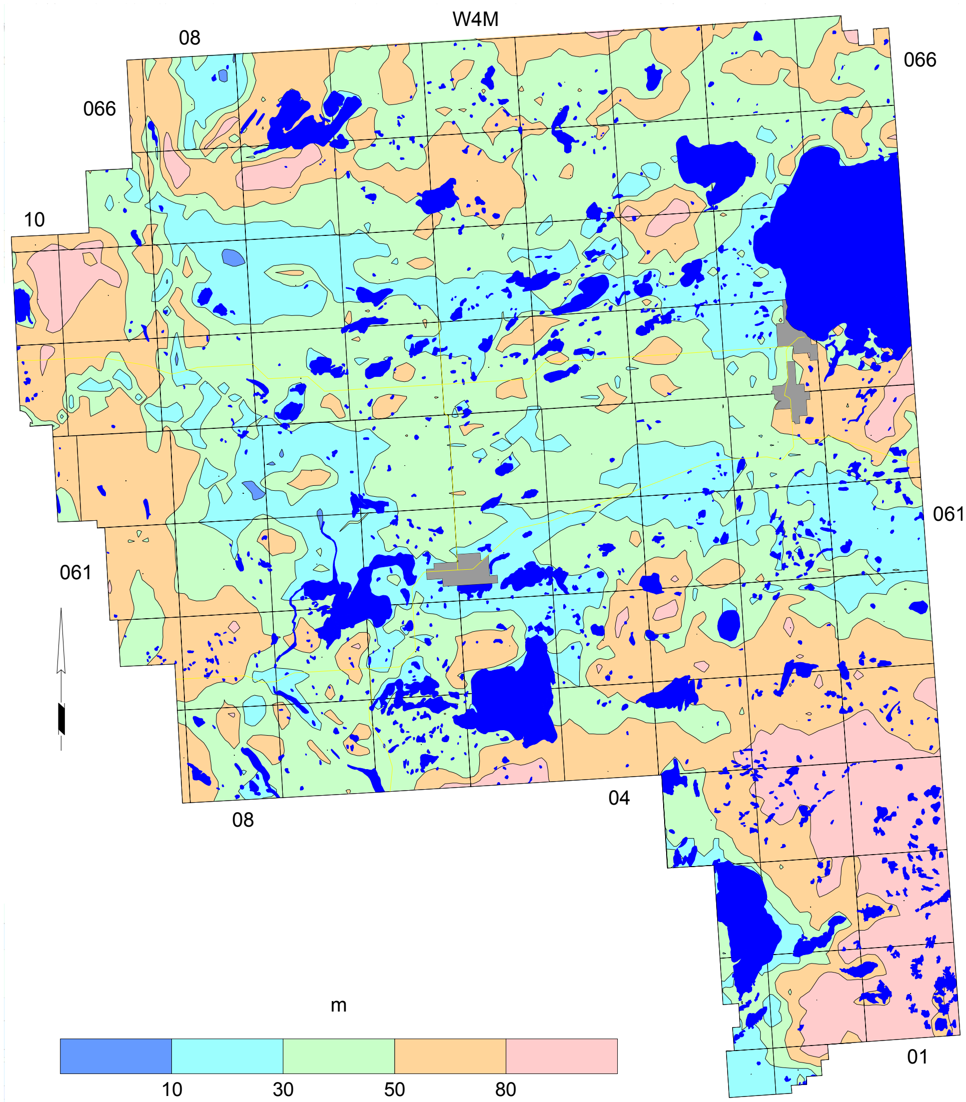
Apparent Yield for Water Wells Completed through Ethel Lake Aquifer



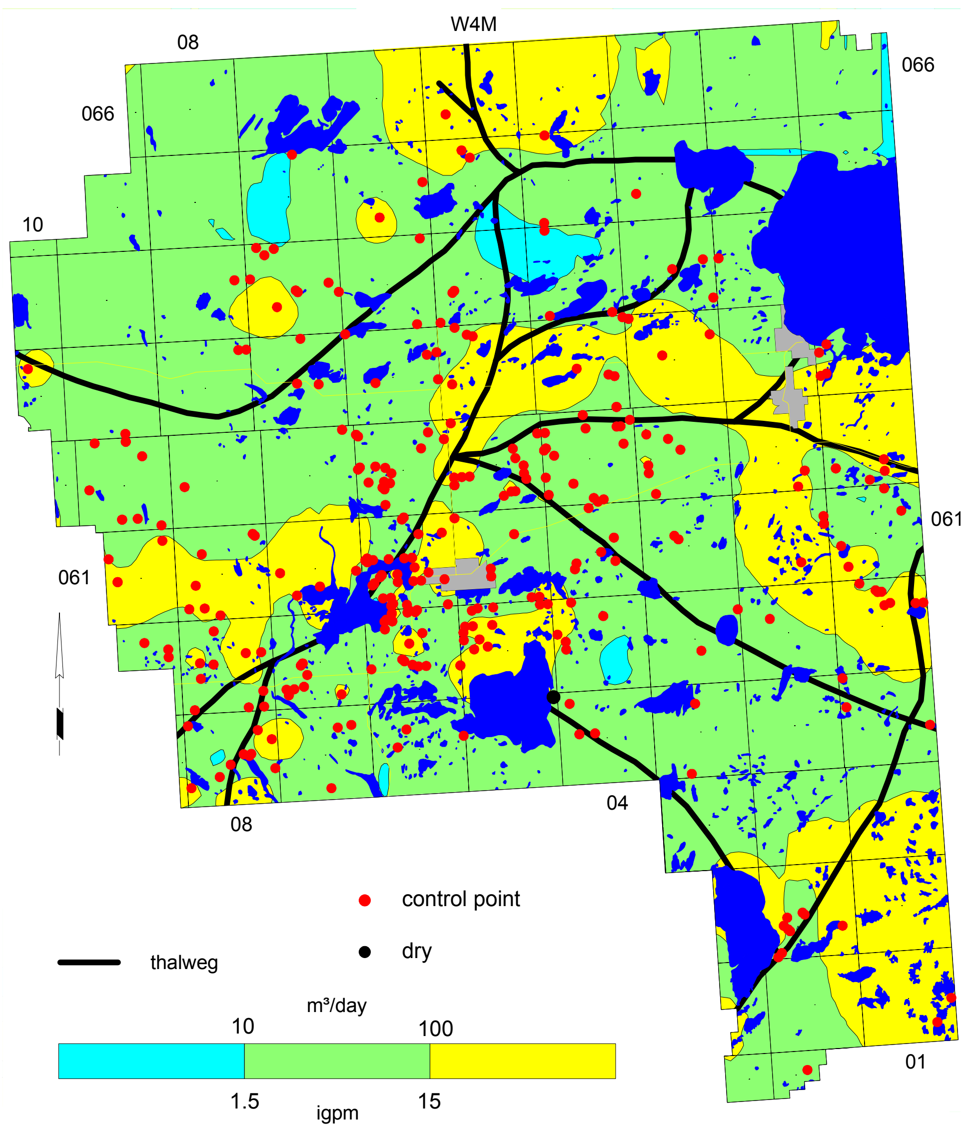
Total Dissolved Solids in Groundwater from Ethel Lake Aquifer



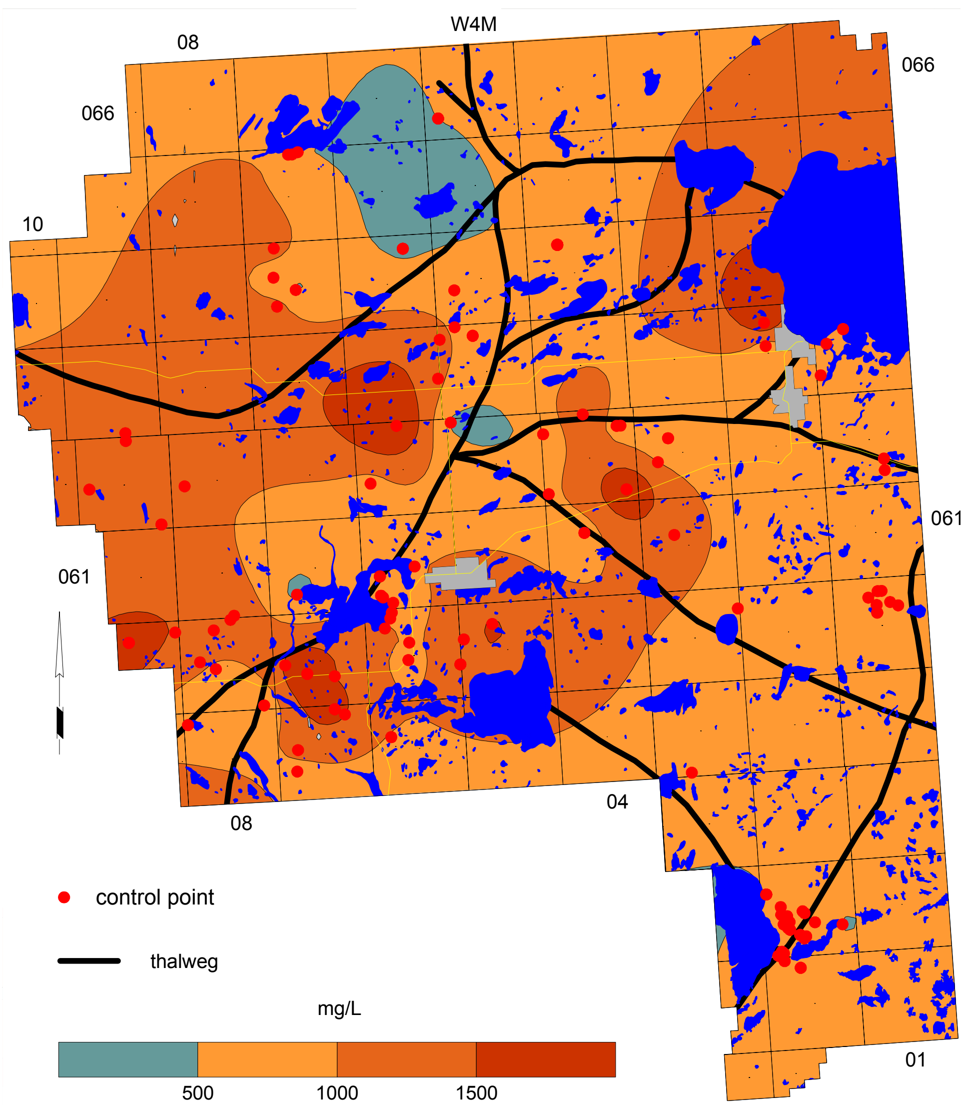
Depth to Top of Bonnyville Formation



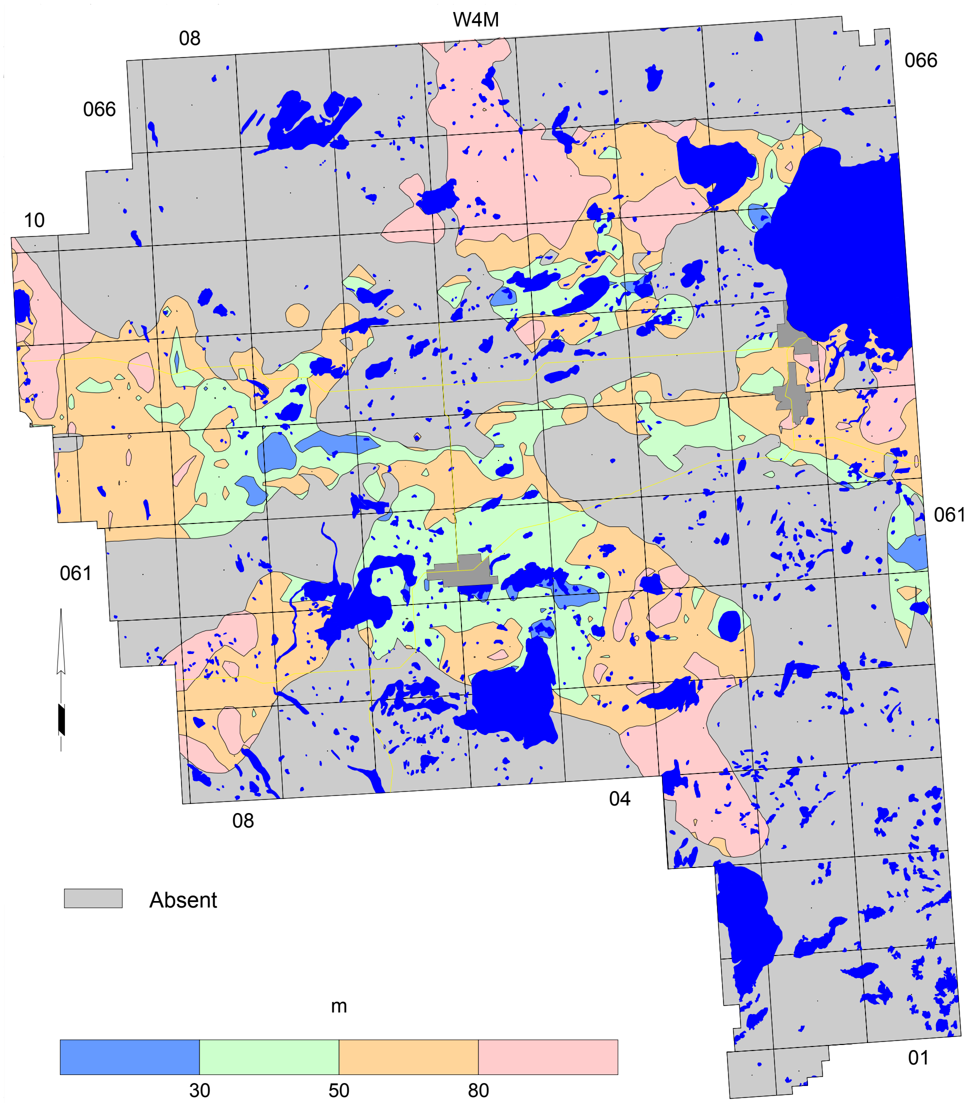
Apparent Yield for Water Wells Completed through Bonnyville Aquifer



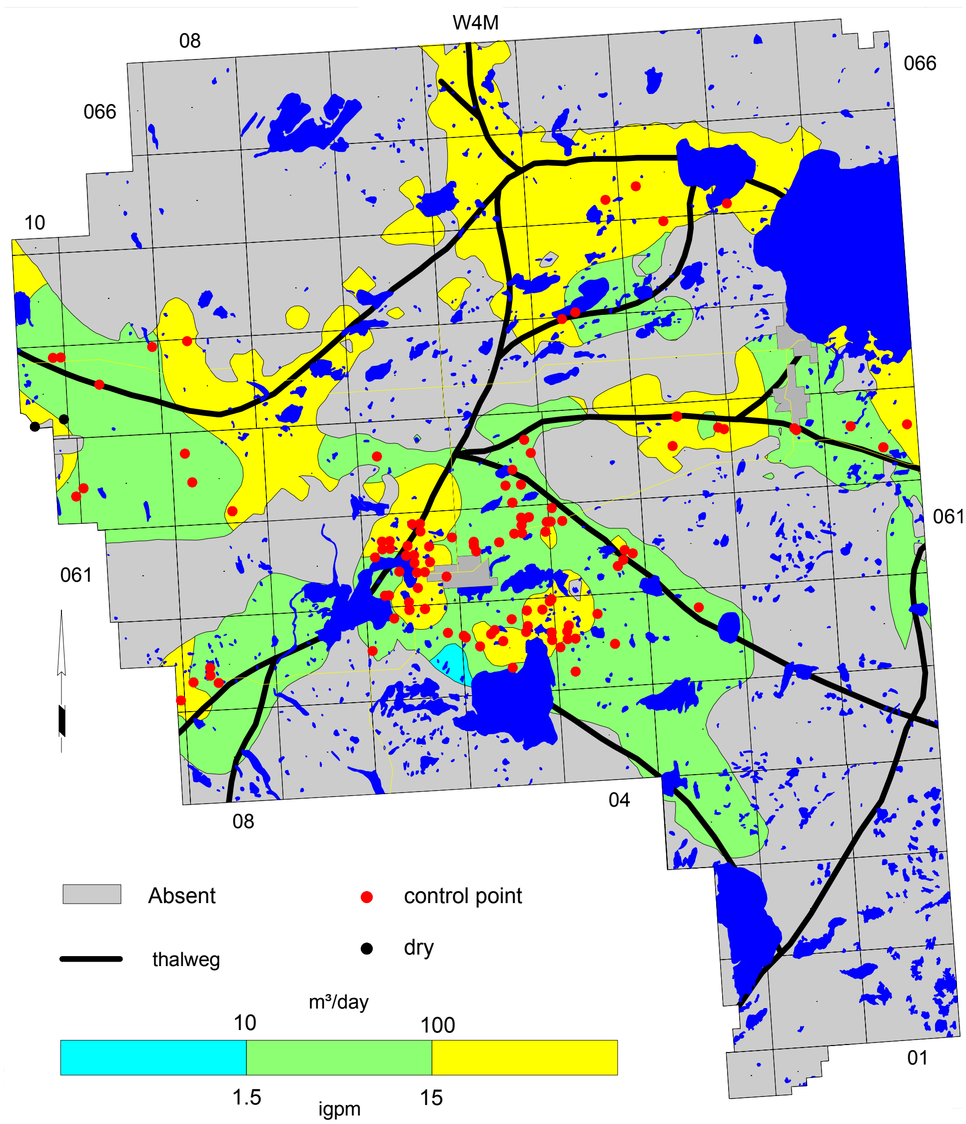
Total Dissolved Solids in Groundwater from Bonnyville Aquifer



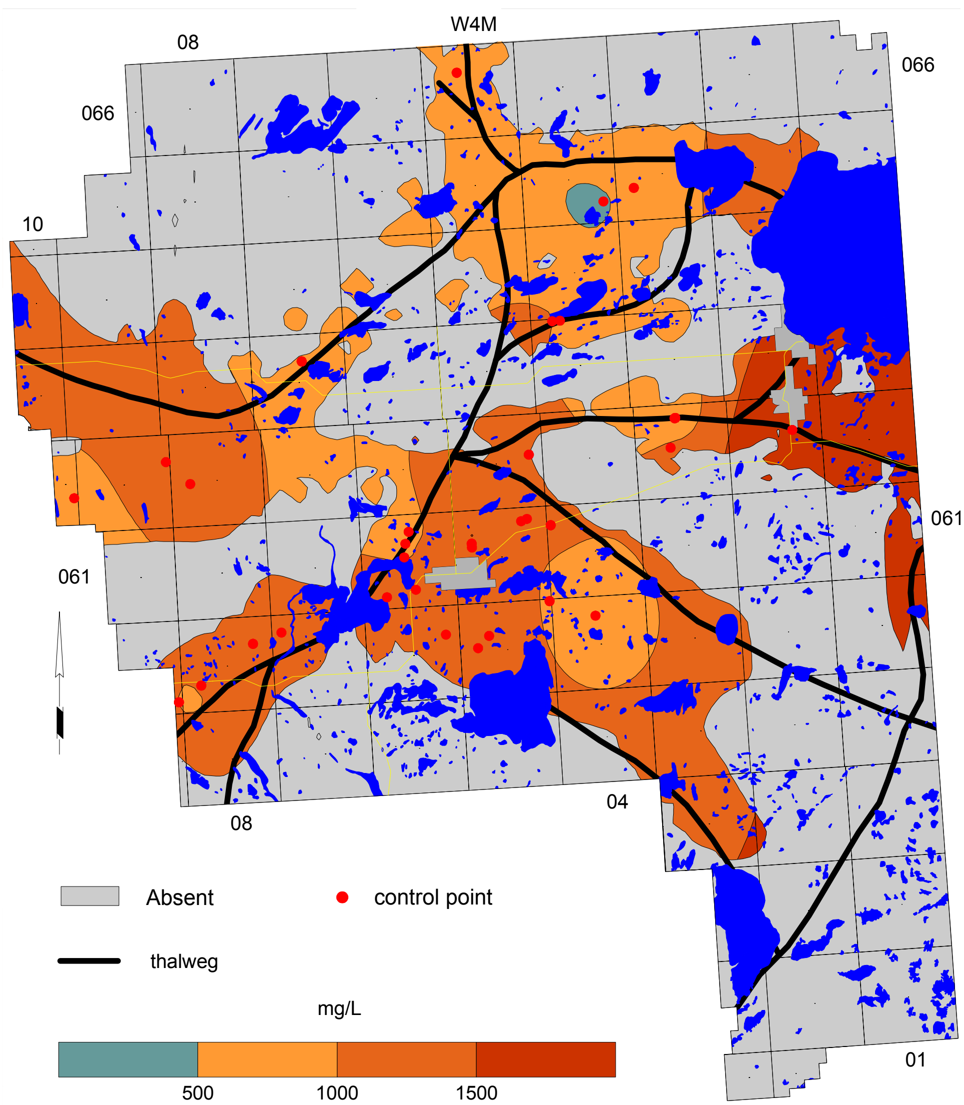
Depth to Top of Muriel Lake Aquifer



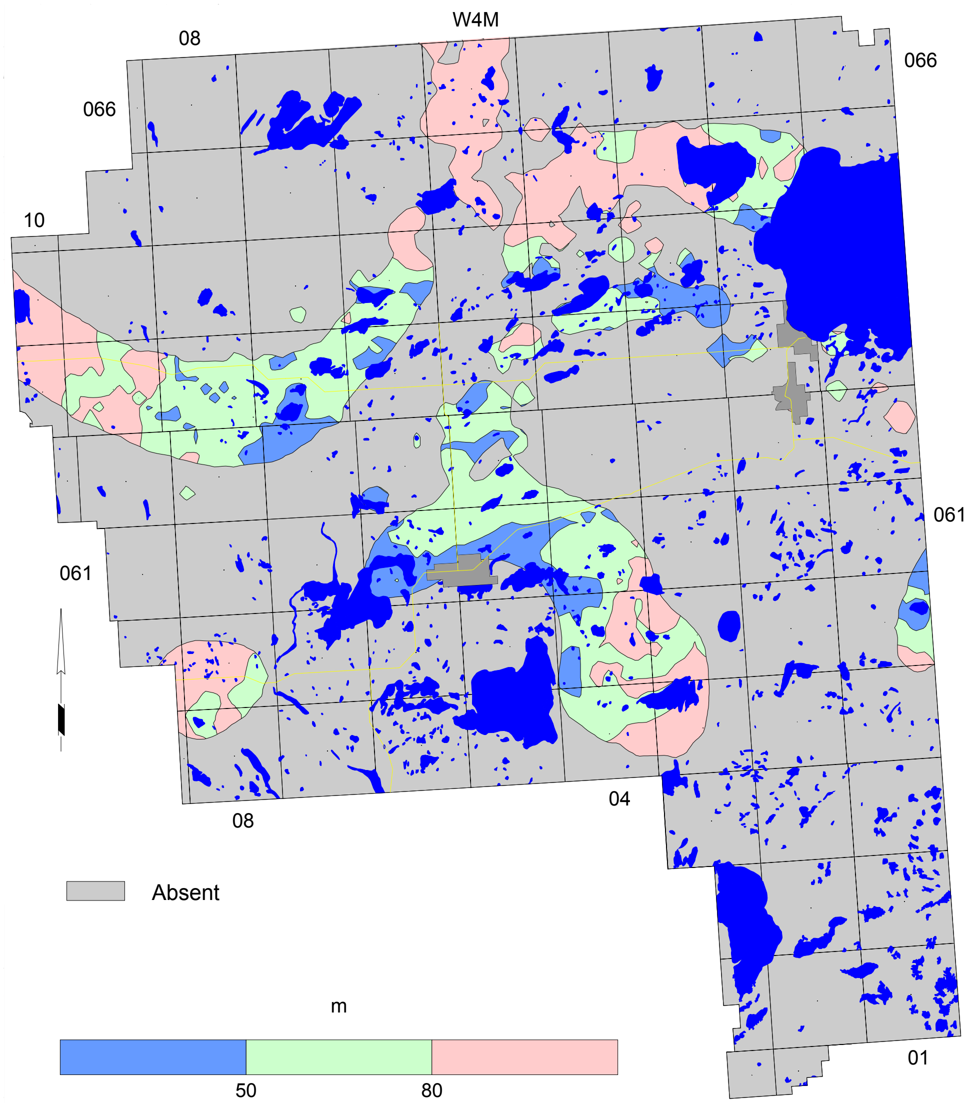
Apparent Yield for Water Wells Completed through Muriel Lake Aquifer



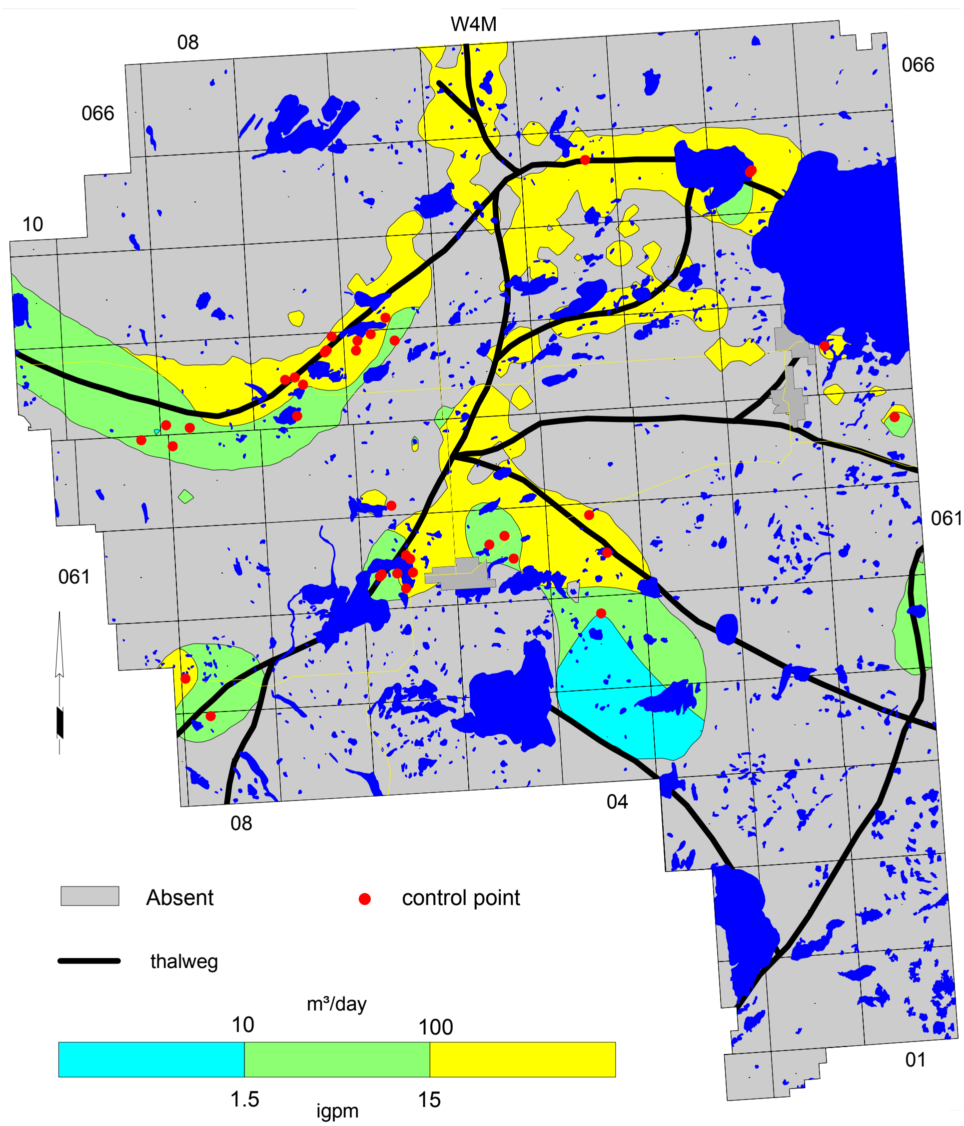
Total Dissolved Solids in Groundwater from Muriel Lake Aquifer



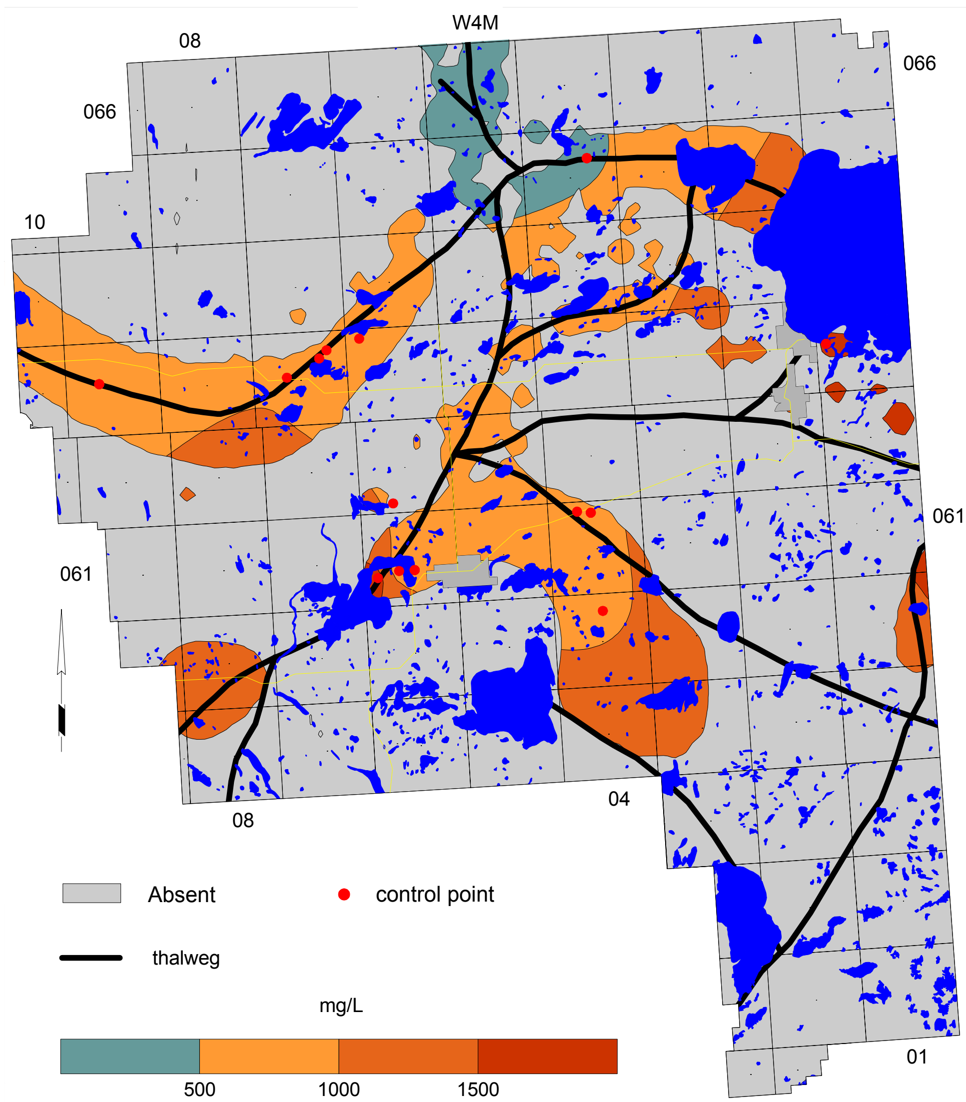
Depth to Top of Bronson Lake Formation



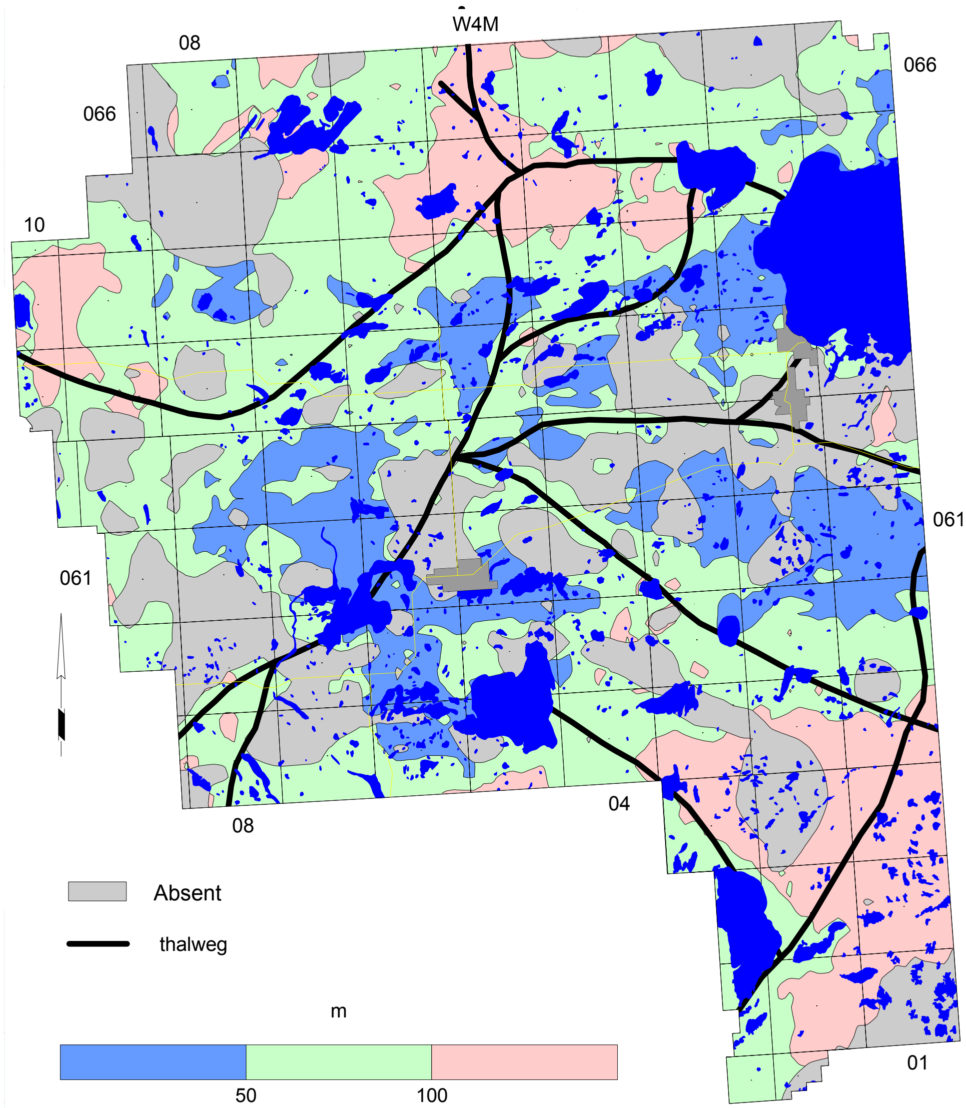
Apparent Yield for Water Wells Completed through Bronson Lake Aquifer



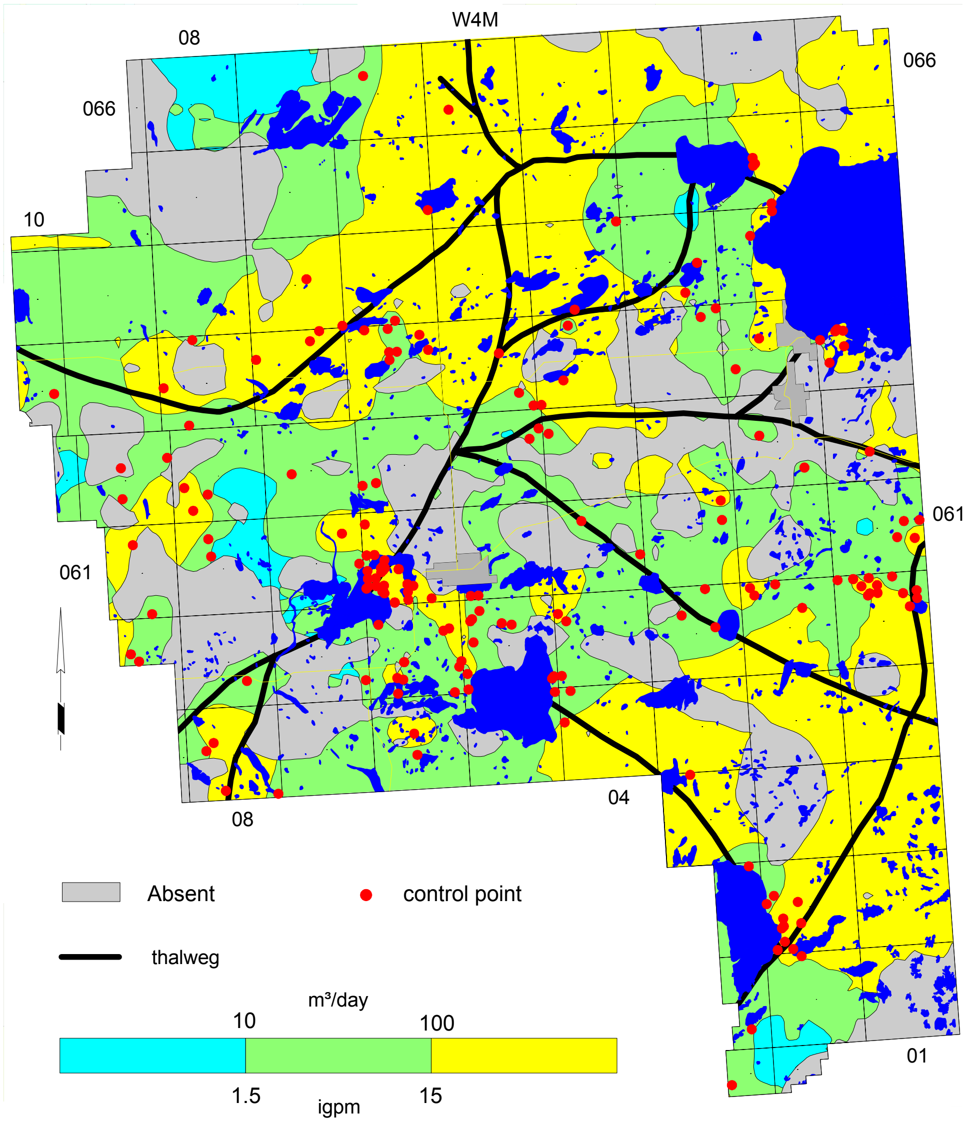
Total Dissolved Solids in Groundwater from Bronson Lake Aquifer



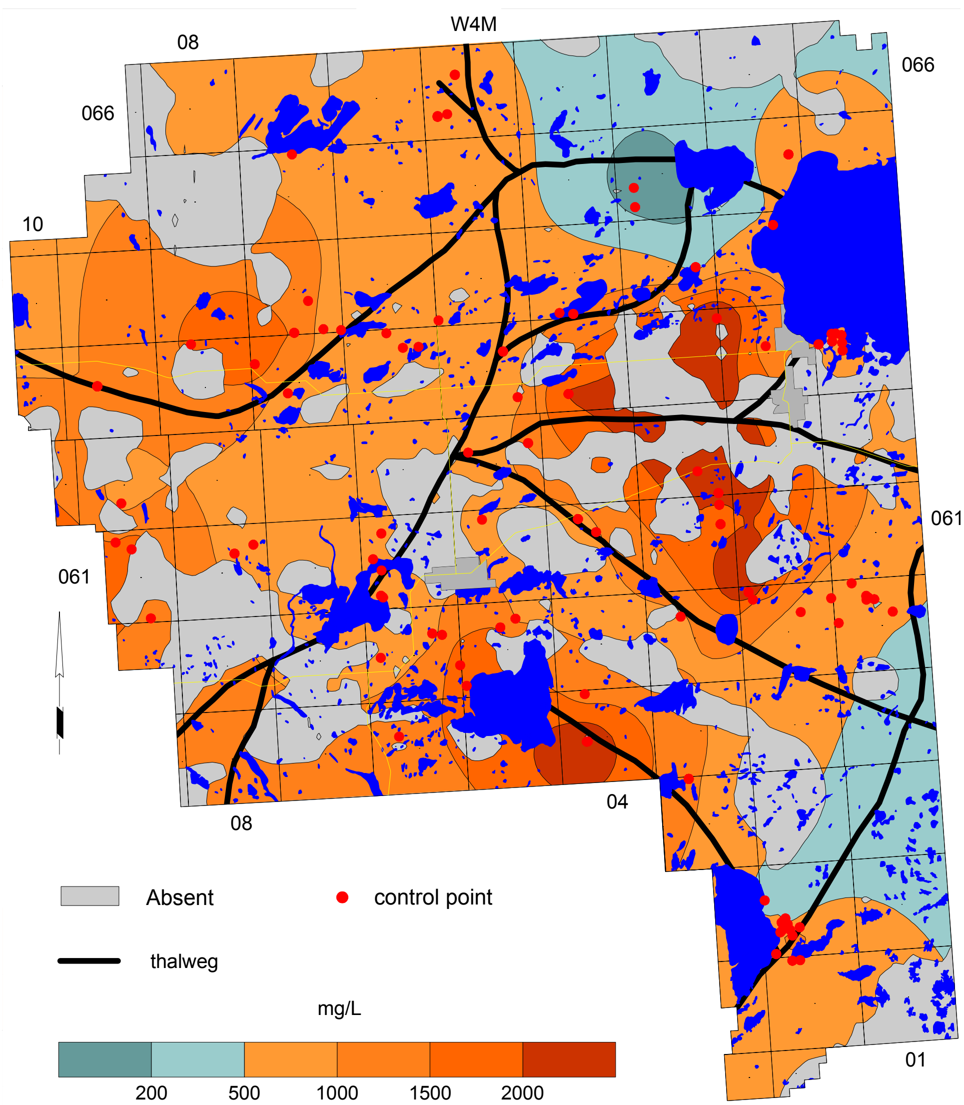
Depth to Top of Empress Formation – Unit 3



Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 3



Total Dissolved Solids in Groundwater from Empress Aquifer – Unit 3



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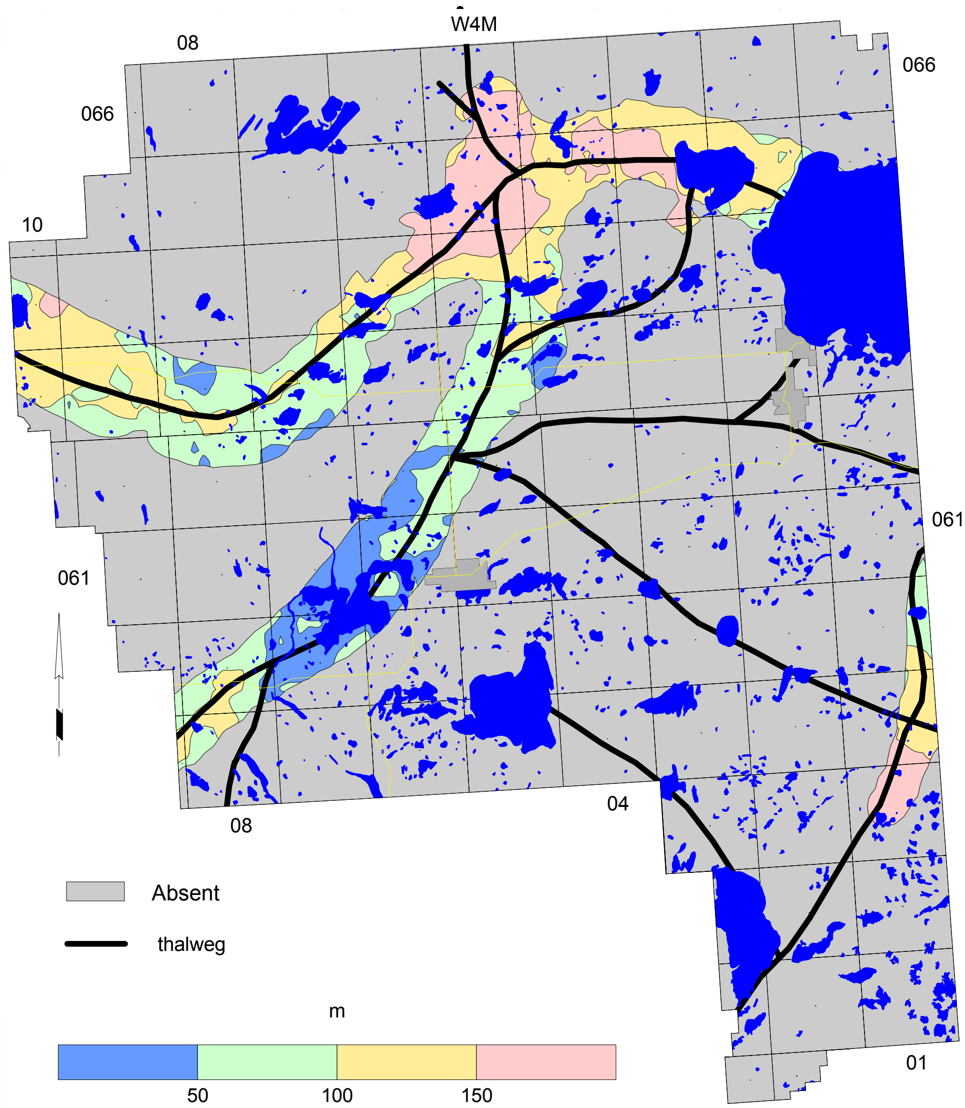
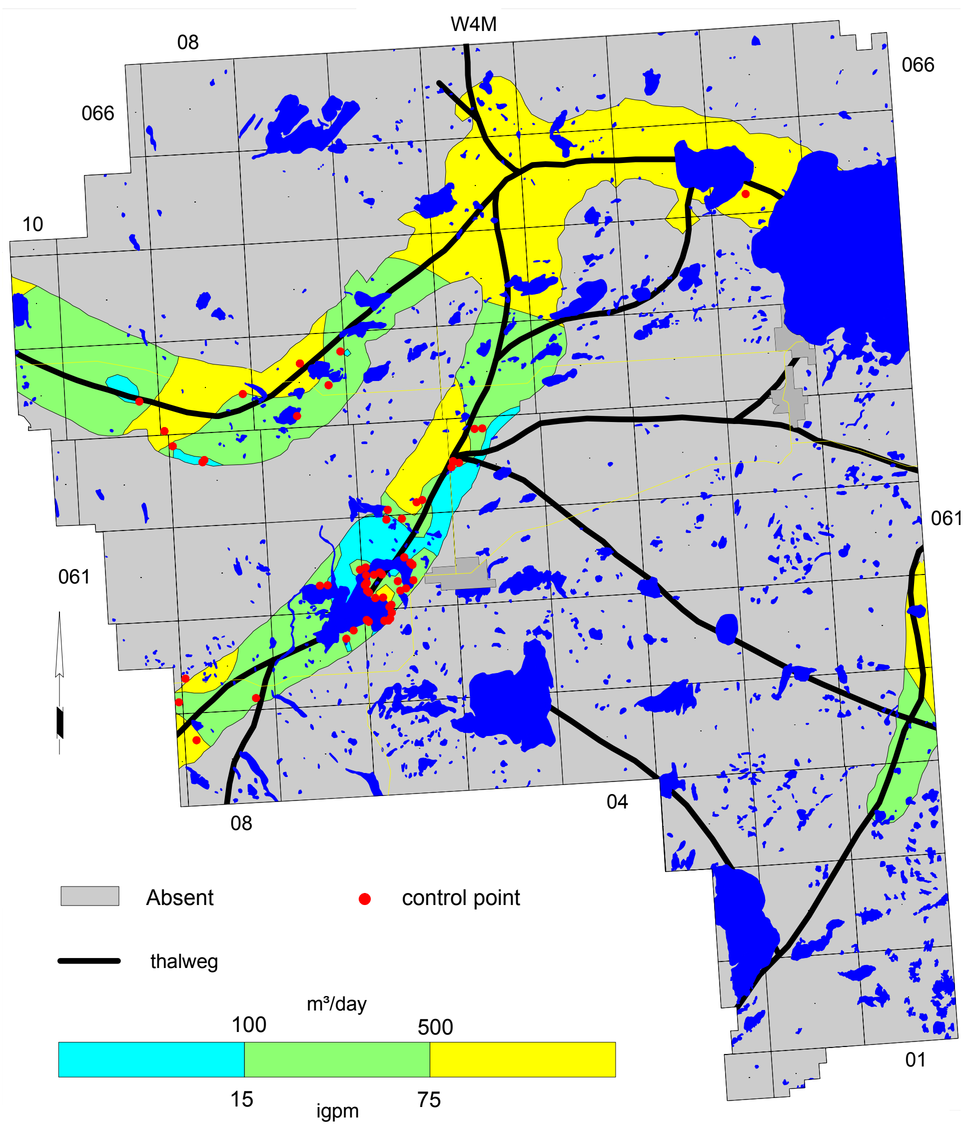
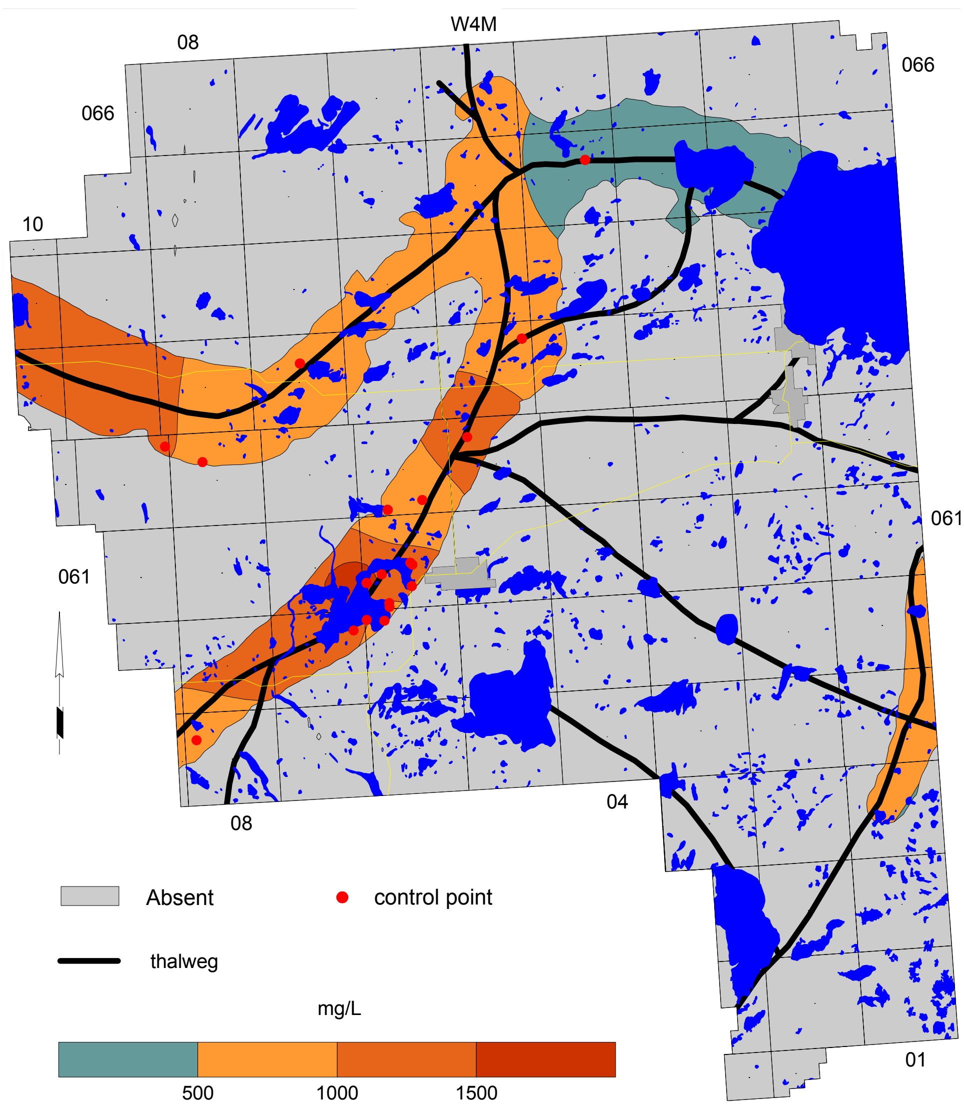


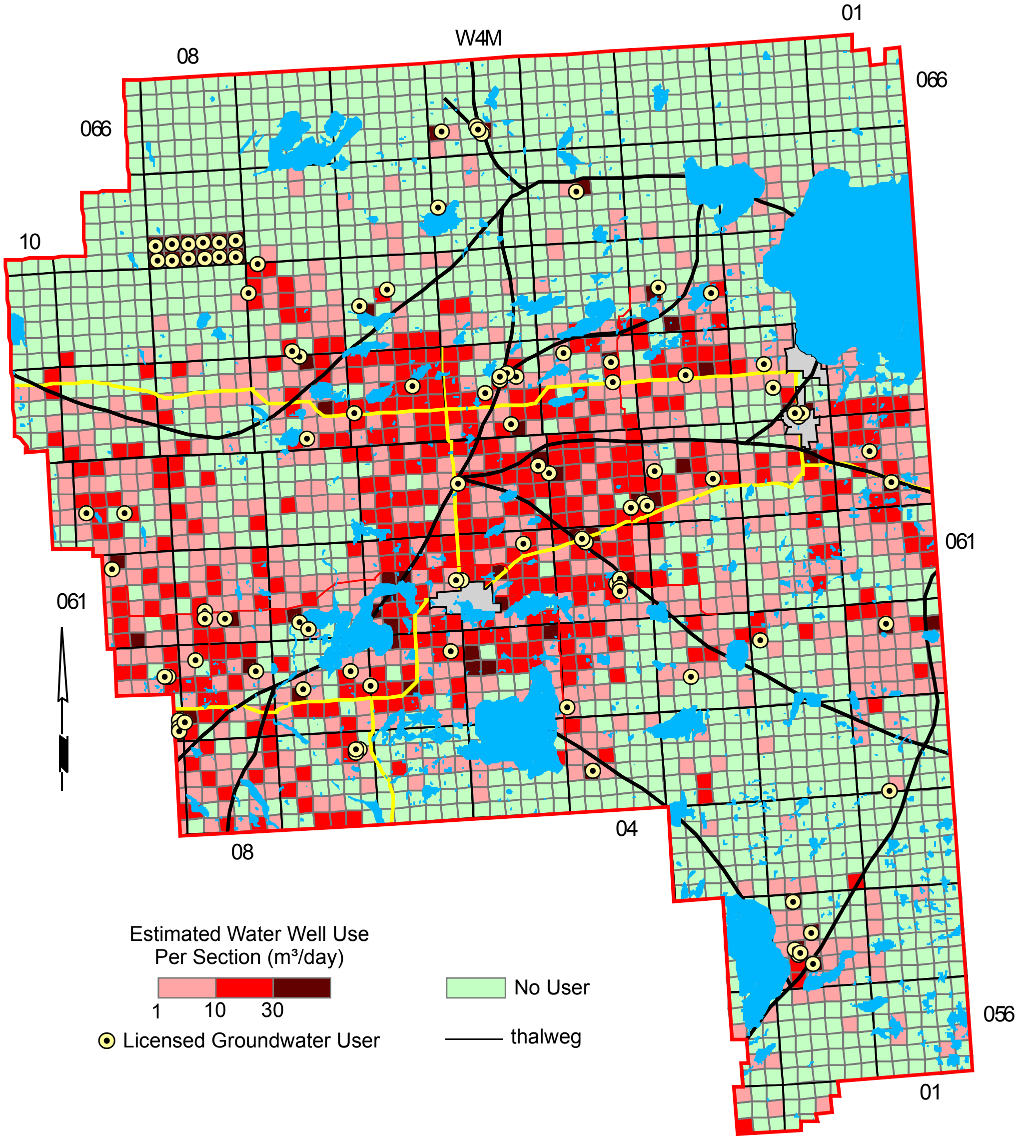
Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 1



Total Dissolved Solids in Groundwater from Empress Aquifer – Unit 1



Estimated Water Well Use Per Section



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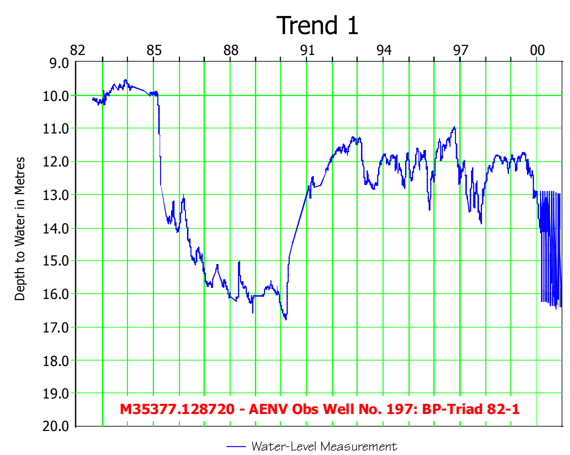
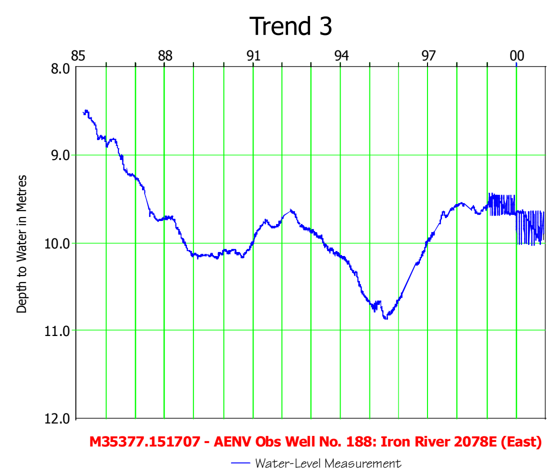
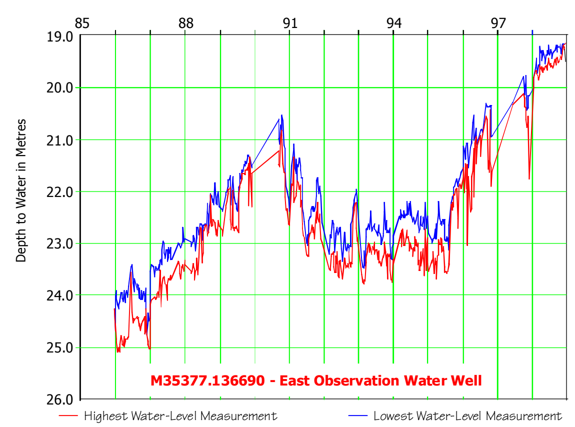
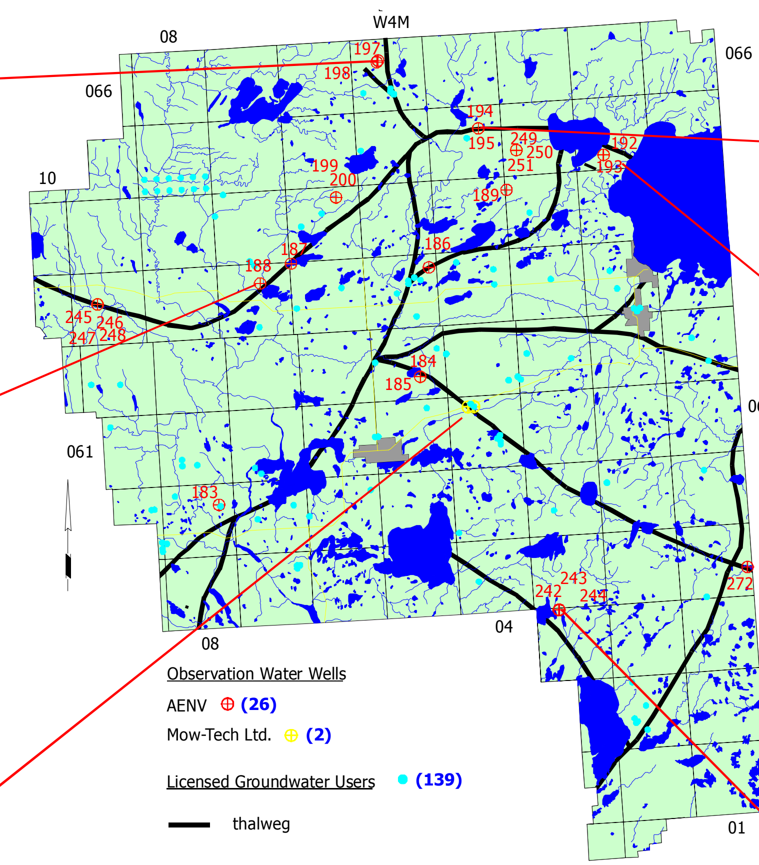
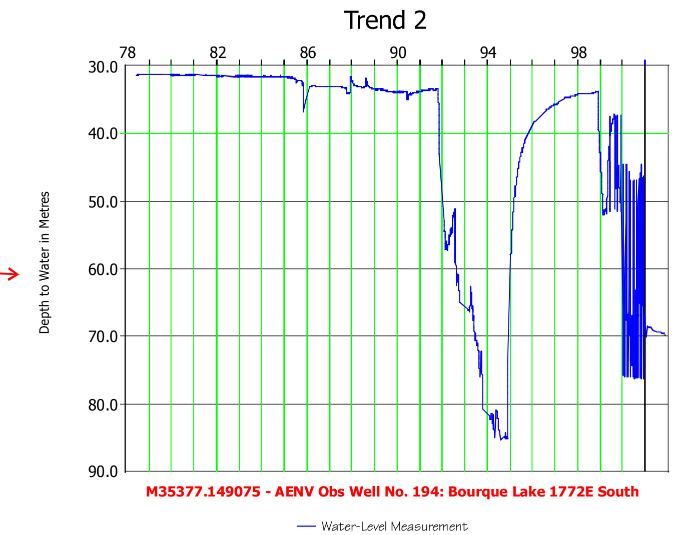


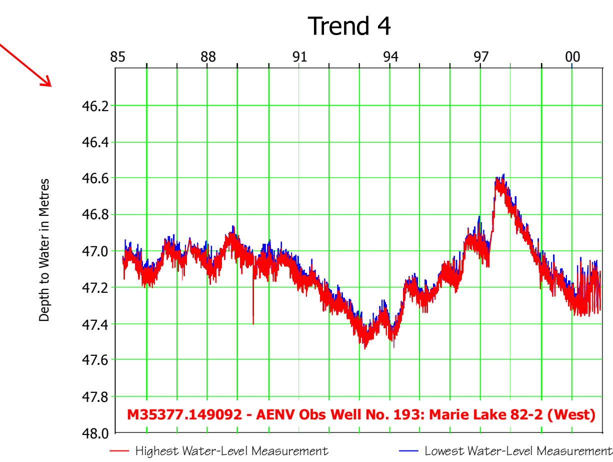


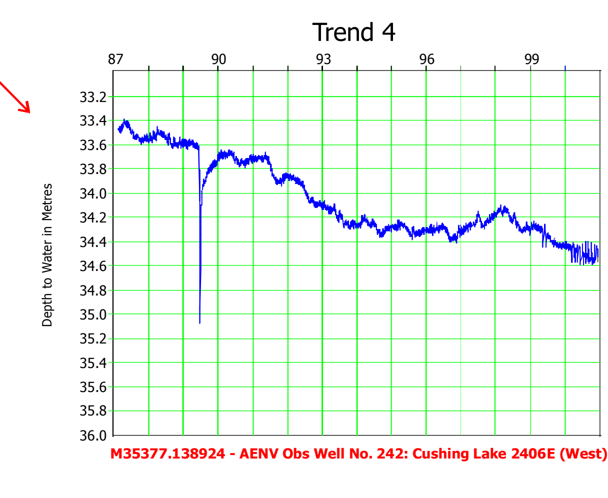




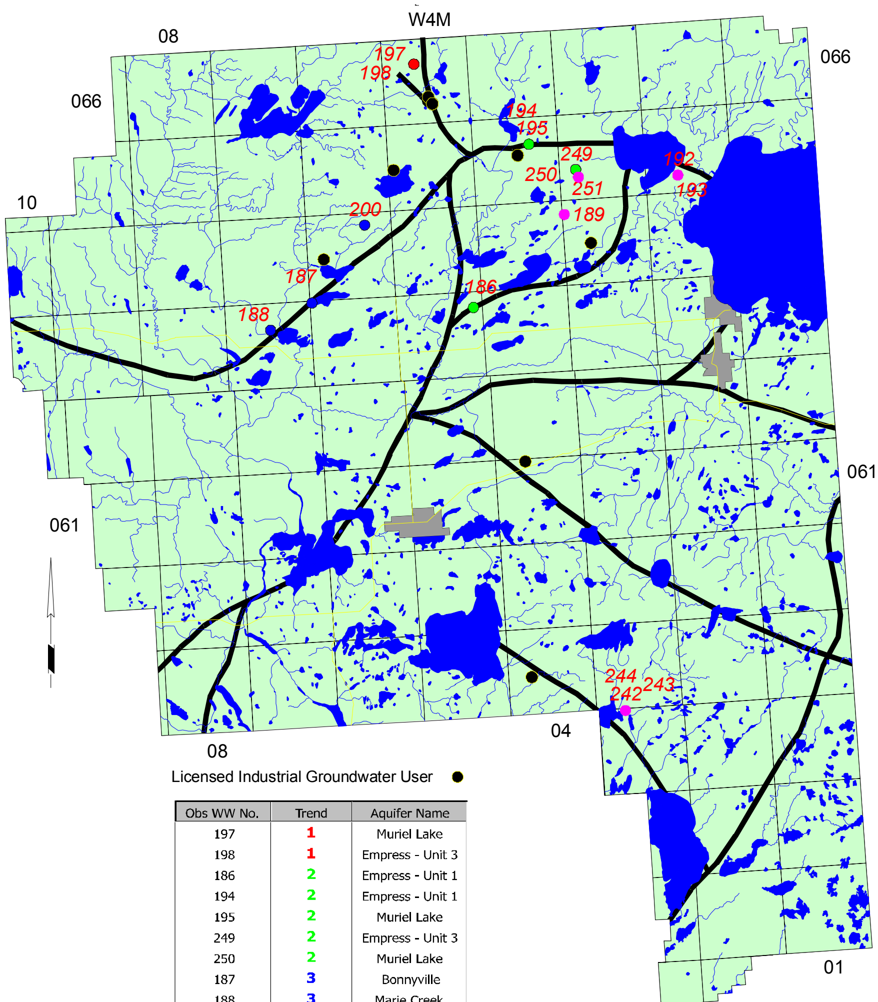
Aquifer Name	AENV Obs WW No.	Mow-Tech Obs WW No.
Marie Creek	188, 243, 251	
Bonnyville	184, 187, 200, 272	
Muriel Lake	183, 189, 193, 195, 197, 245, 250	
Bronson Lake	248	
Empress - Unit 3	185, 198, 199, 242, 244, 246, 247, 249	East, West
Empress - Unit 1	186, 192, 194	







AENV Observation Water Wells Having Similar Water-Level Trends



Obs WW No.	Trend	Aquifer Name
197	1	Muriel Lake
198	1	Empress - Unit 3
186	2	Empress - Unit 1
194	2	Empress - Unit 1
195	2	Muriel Lake
249	2	Empress - Unit 3
250	2	Muriel Lake
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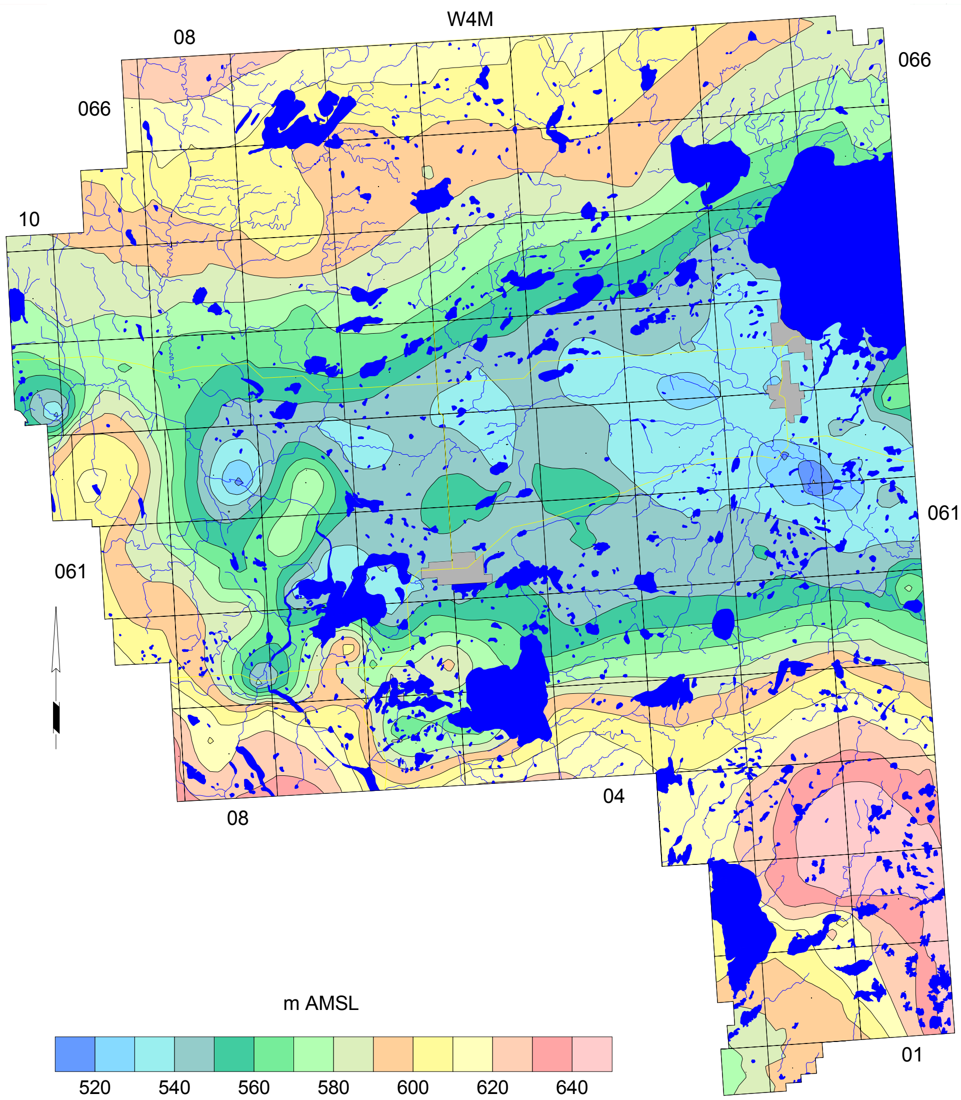
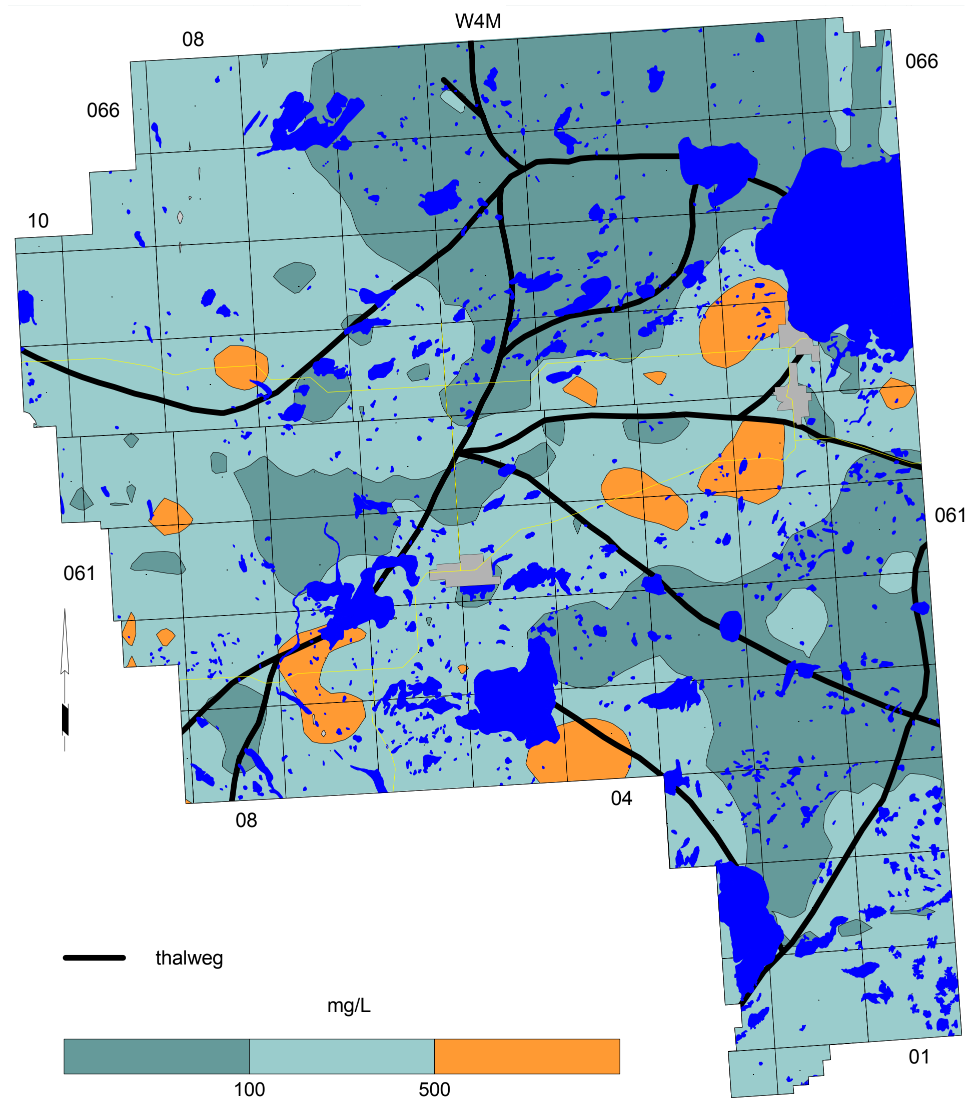
188	3	Marie Creek
200	3	Bonnyville
189	4	Muriel Lake
192	4	Empress - Unit 1
193	4	Muriel Lake
242	4	Empress - Unit 3
243	4	Marie Creek
244	4	Empress - Unit 3
251	4	Marie Creek

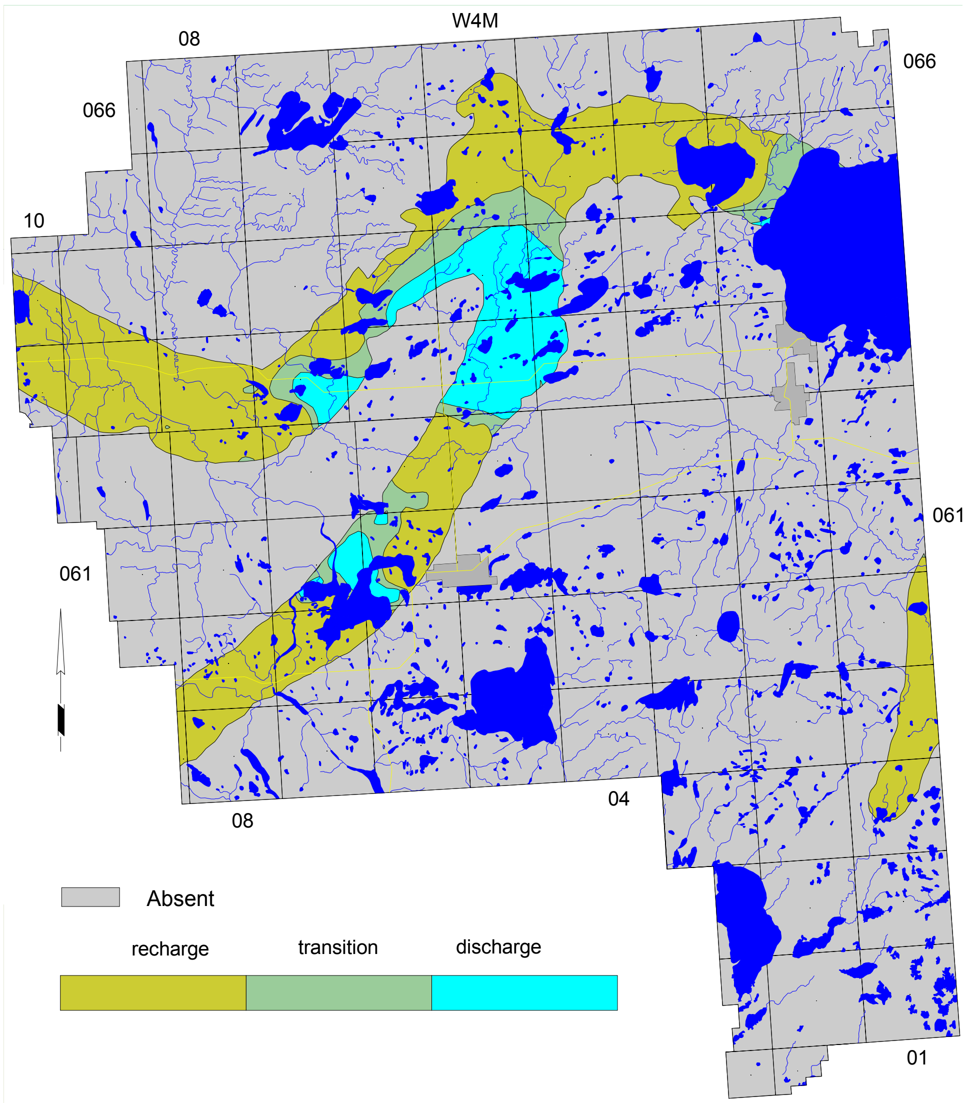
Non-Pumping Water-Level Surface in Surficial Deposits
Based on Water Wells Less than 20 metres Deep



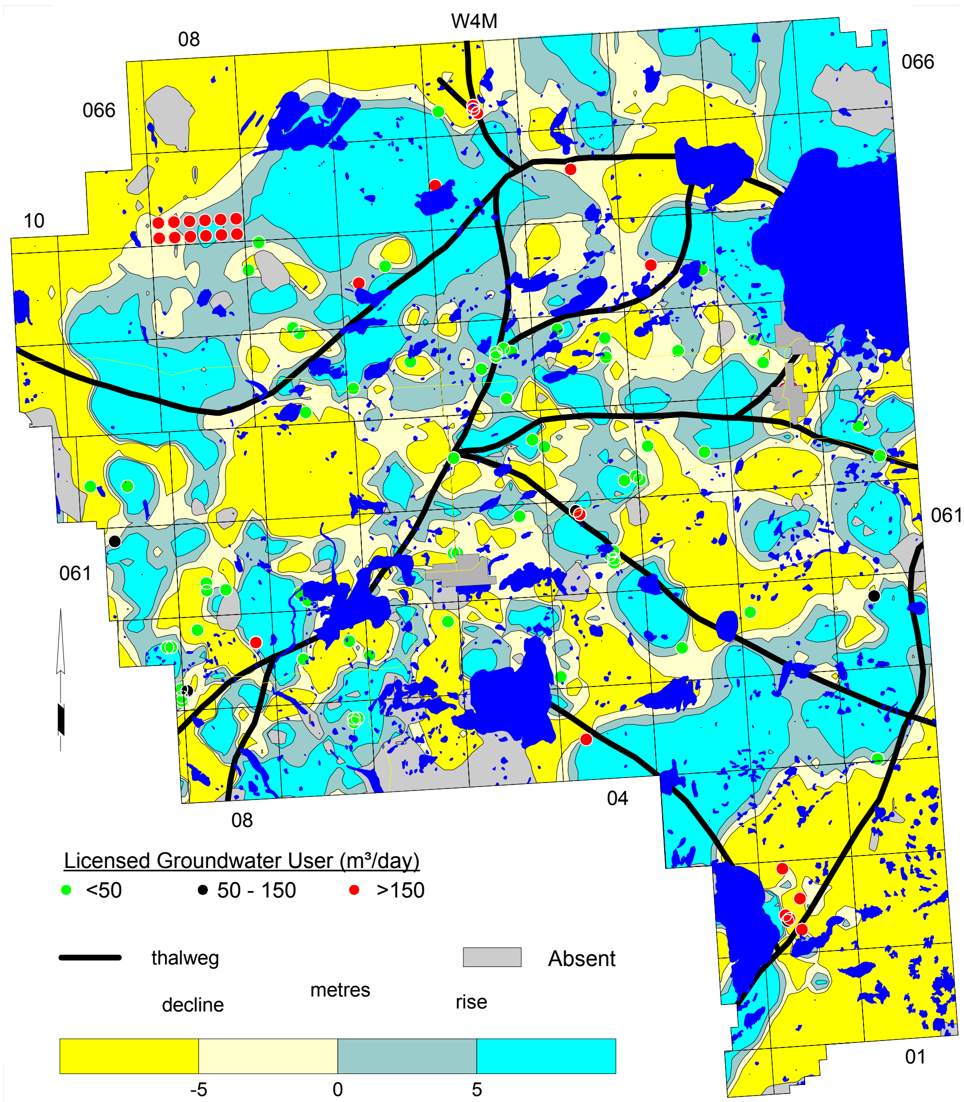
Sulfate in Groundwater from Surficial Deposits



Recharge/Discharge Areas in Empress Aquifer – Unit 1



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



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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 GAZETTE

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ALBERTA REGULATION 205/98

Water Act

WATER (MINISTERIAL) REGULATION

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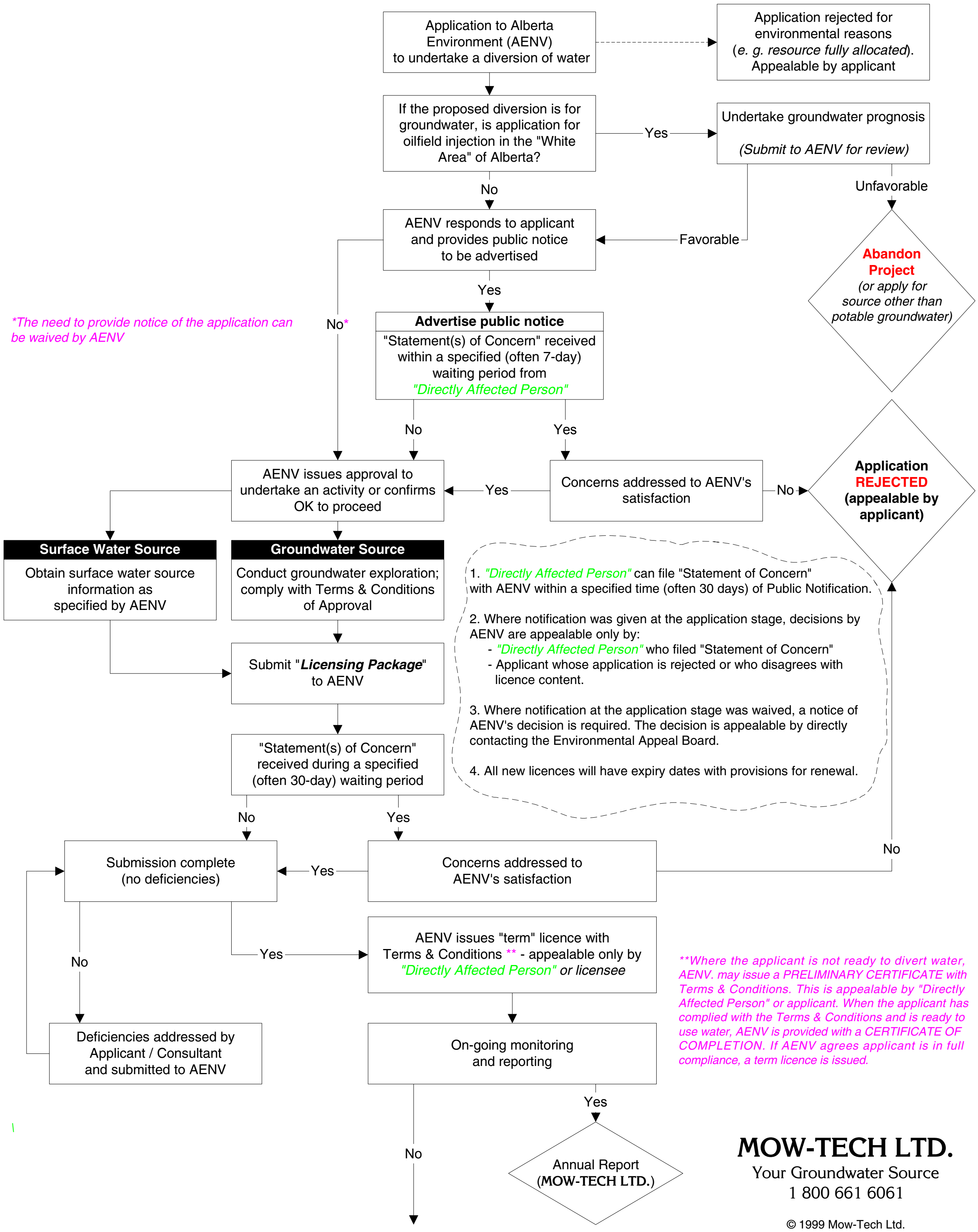
Water Act – Flowchart



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

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)

ALBERTA ENVIRONMENT

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) ARM OF AGRICULTURE AND AGRI-FOOD CANADA (AAFC)

Keith Schick (Vegreville: 780-632-2919)
Tony Cowen (Edmonton: 780-495-4911)

WILDROSE COUNTRY GROUND WATER MONITORING ASSOCIATION

Dave Andrews (Irricana: 403-935-4478)

LOCAL HEALTH DEPARTMENTS

M.D. OF BONNYVILLE

Appendix D

Maps and Figures Included as Large Plots

Bedrock Topography 2
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s) 3
Total Dissolved Solids in Groundwater from Surficial Deposits 4
Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 1 5
Estimated Water Well Use Per Section 6
Cross-Section A - A’ 7
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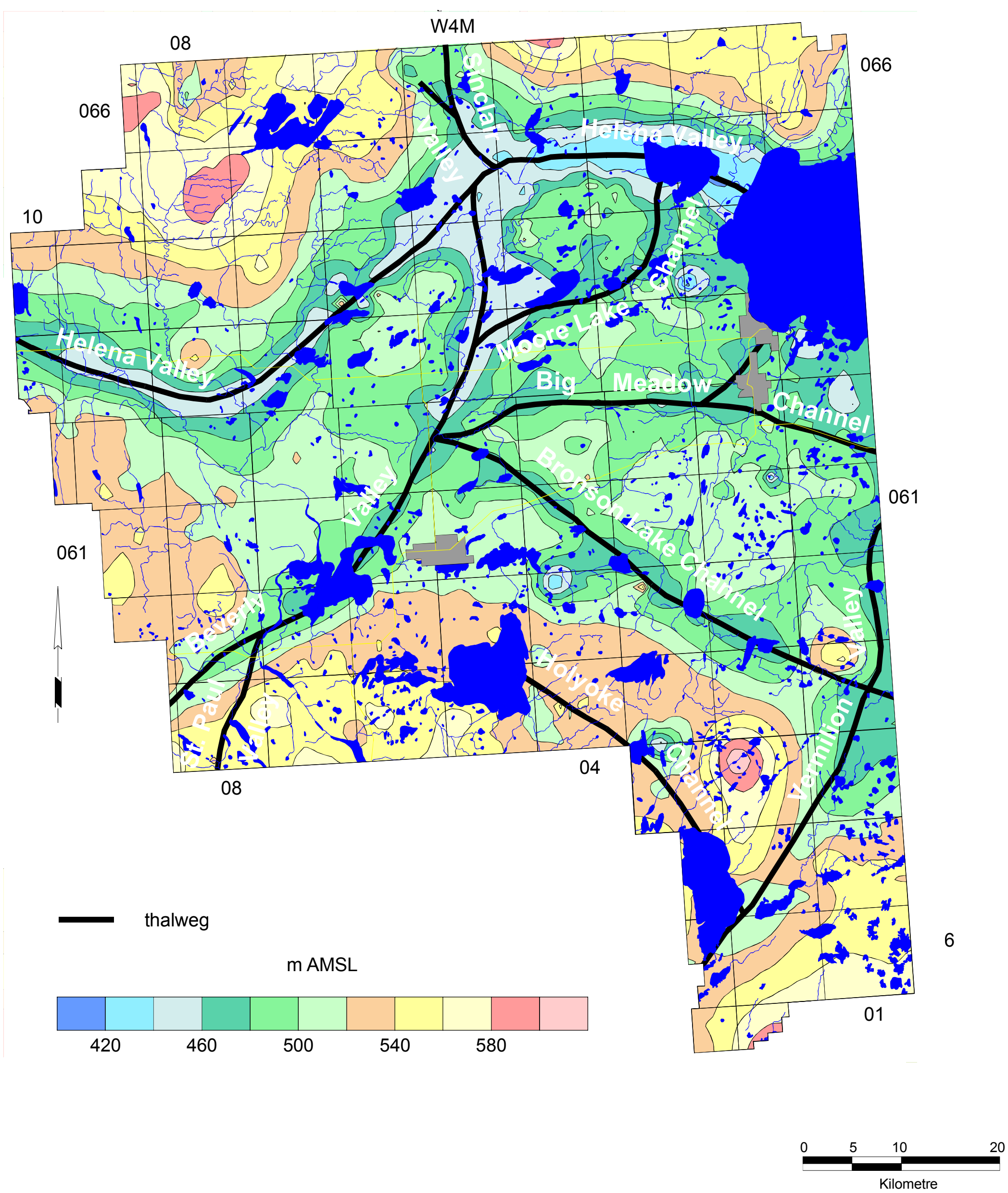
Bedrock Topography

M.D. of Bonnyville
Bedrock Topography



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

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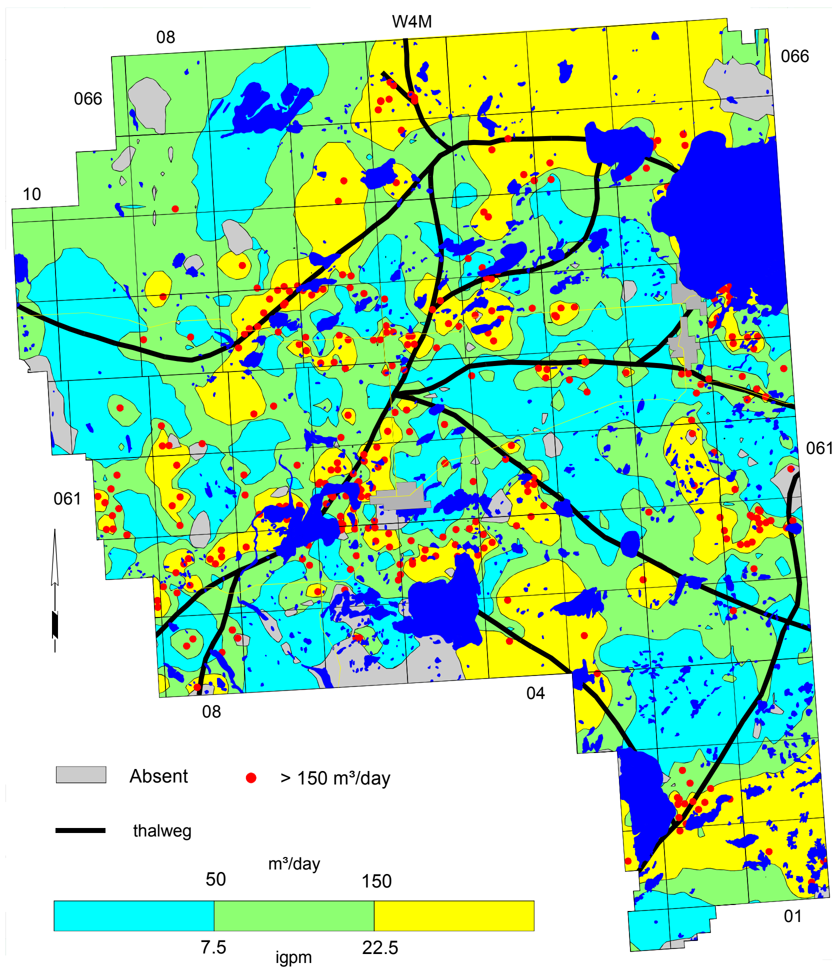
Apparent Yield for Water Wells Completed in Sand and Gravel Aquifer(s)

M.D. of Bonnyville
Apparent Yield for Water Wells Completed in Sand and Gravel 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

0 5 10 20
Kilometre

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Prairie Farm Rehabilitation Administration / Administration du rétablissement agricole des Prairies
Canada

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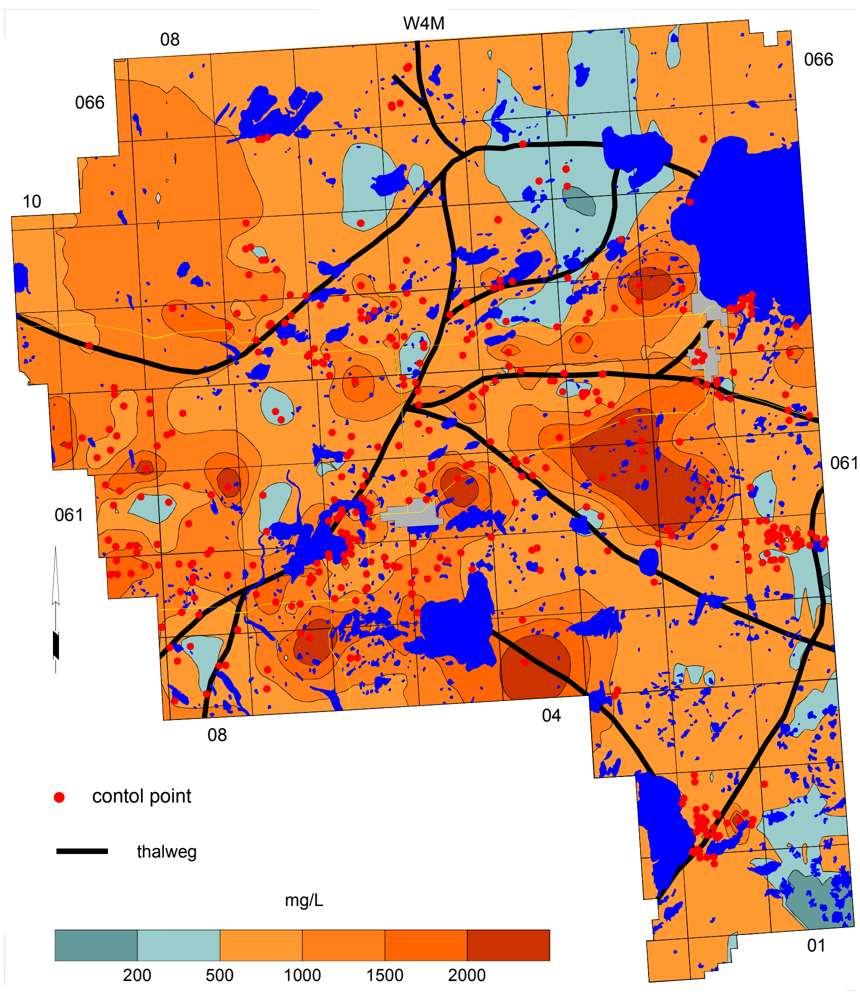
Total Dissolved Solids in Groundwater from Surficial Deposits

M.D. of Bonnyville
Total Dissolved Solids in Groundwater from Surficial Deposits



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

0 5 10 20
Kilometre

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

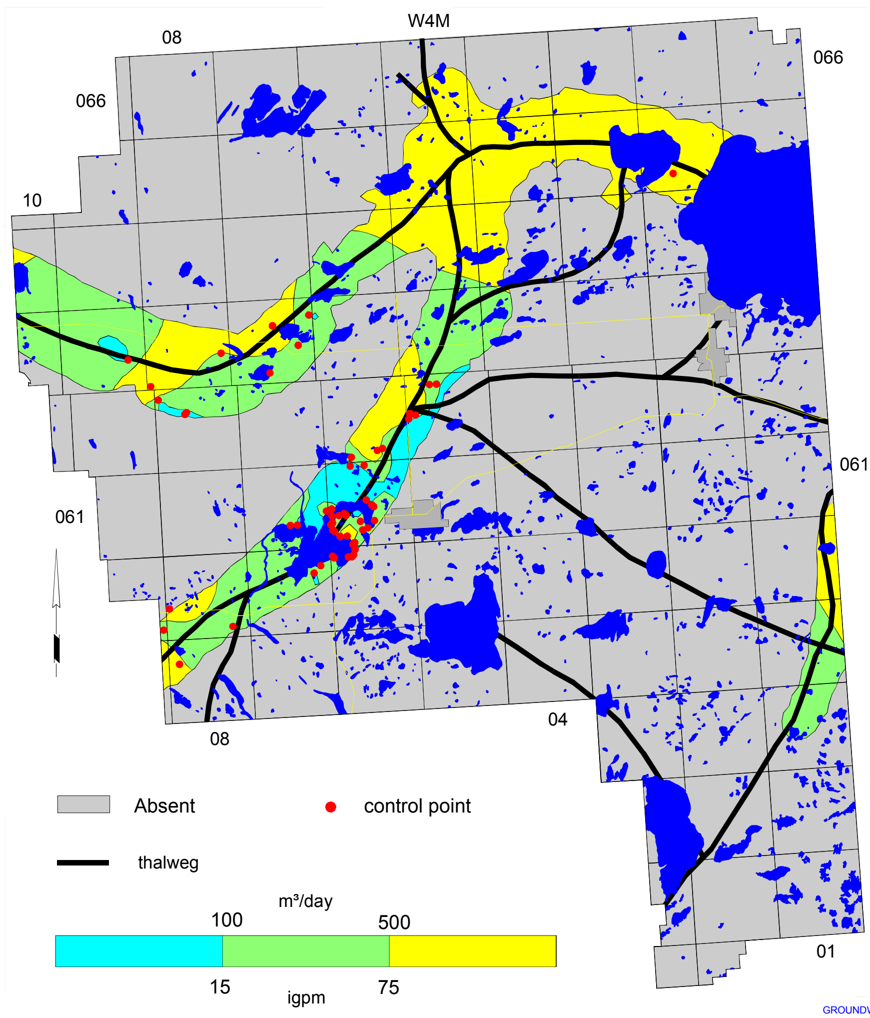
hydrogeological consultants ltd, edmonton, alberta - 1.800.661.7972 - project no. 01-186

hydrogeological consultants ltd.

Apparent Yield for Water Wells Completed through Empress Aquifer – Unit 1

M.D. of Bonnyville

Apparent Yield for Water Wells Completed through Empress Aquifer - Unit 1



GROUNDWATER CONSUMPTION

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

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

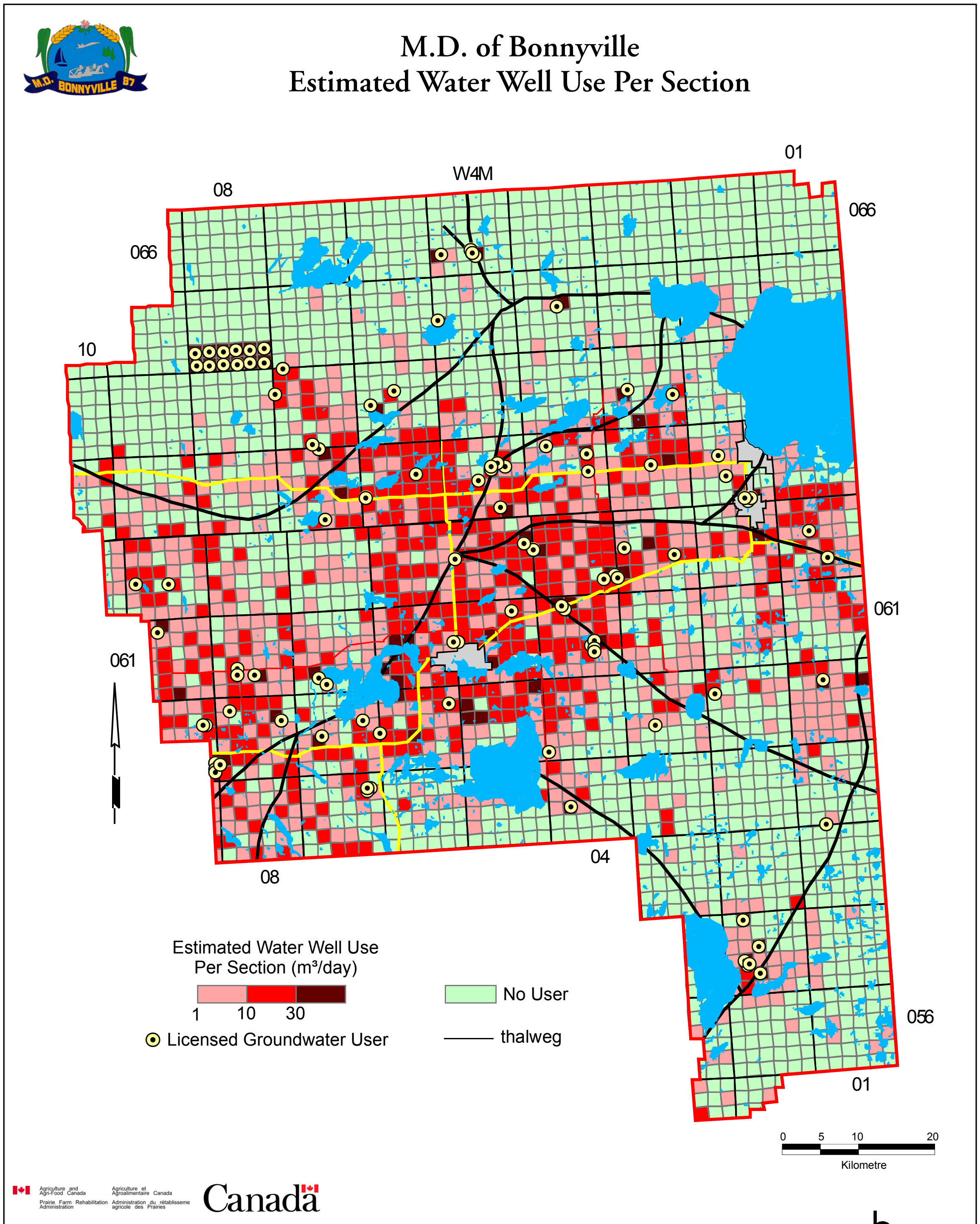
0 5 10 20
Kilometre

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

Canada

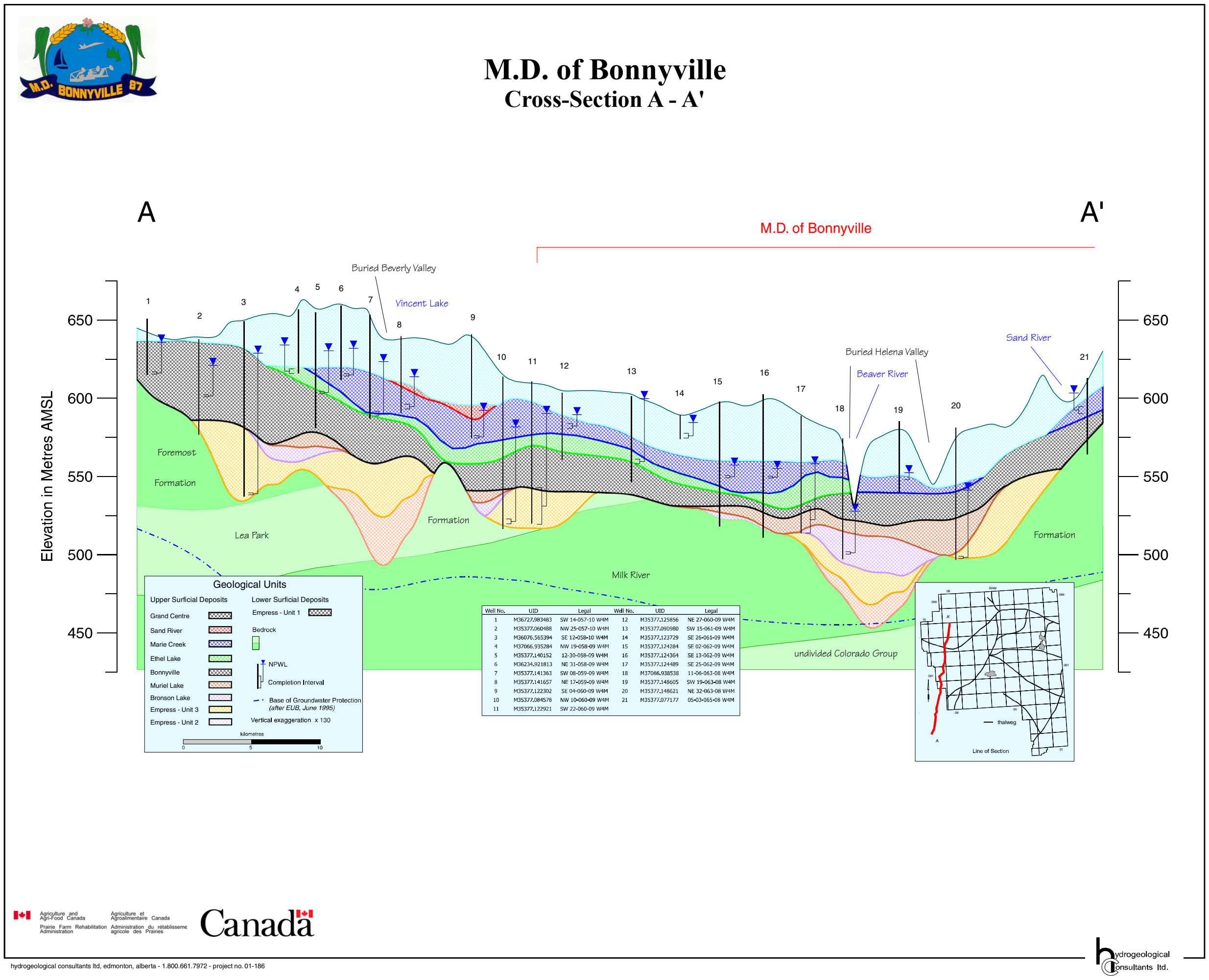
hydrogeological consultants ltd.

Estimated Water Well Use Per Section



hydrogeological consultants ltd. (HCL), edmonton, alberta - 1.800.661.7972 - project no. 01-186

Cross-Section A - A'



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2	M35377.060488	NW 25-057-10 W4M	13	M35377.090980	SW 15-061-09 W4M
3	M36076.565394	SE 12-058-10 W4M	14	M35377.123729	SE 26-061-09 W4M
4	M37066.935284	NW 19-058-09 W4M	15	M35377.124284	SE 02-062-09 W4M
5	M35377.140152	12-30-058-09 W4M	16	M35377.124364	SE 13-062-09 W4M
6	M36234.921813	NE 31-058-09 W4M	17	M35377.124489	SE 25-062-09 W4M
7	M35377.141363	SW 08-059-09 W4M	18	M37066.938538	11-06-063-08 W4M
8	M35377.141657	NE 17-059-09 W4M	19	M35377.148605	SW 19-063-08 W4M
9	M35377.122302	SE 04-060-09 W4M	20	M35377.148621	NE 32-063-08 W4M
10	M35377.084578	NW 10-060-09 W4M	21	M35377.077177	05-03-065-08 W4M
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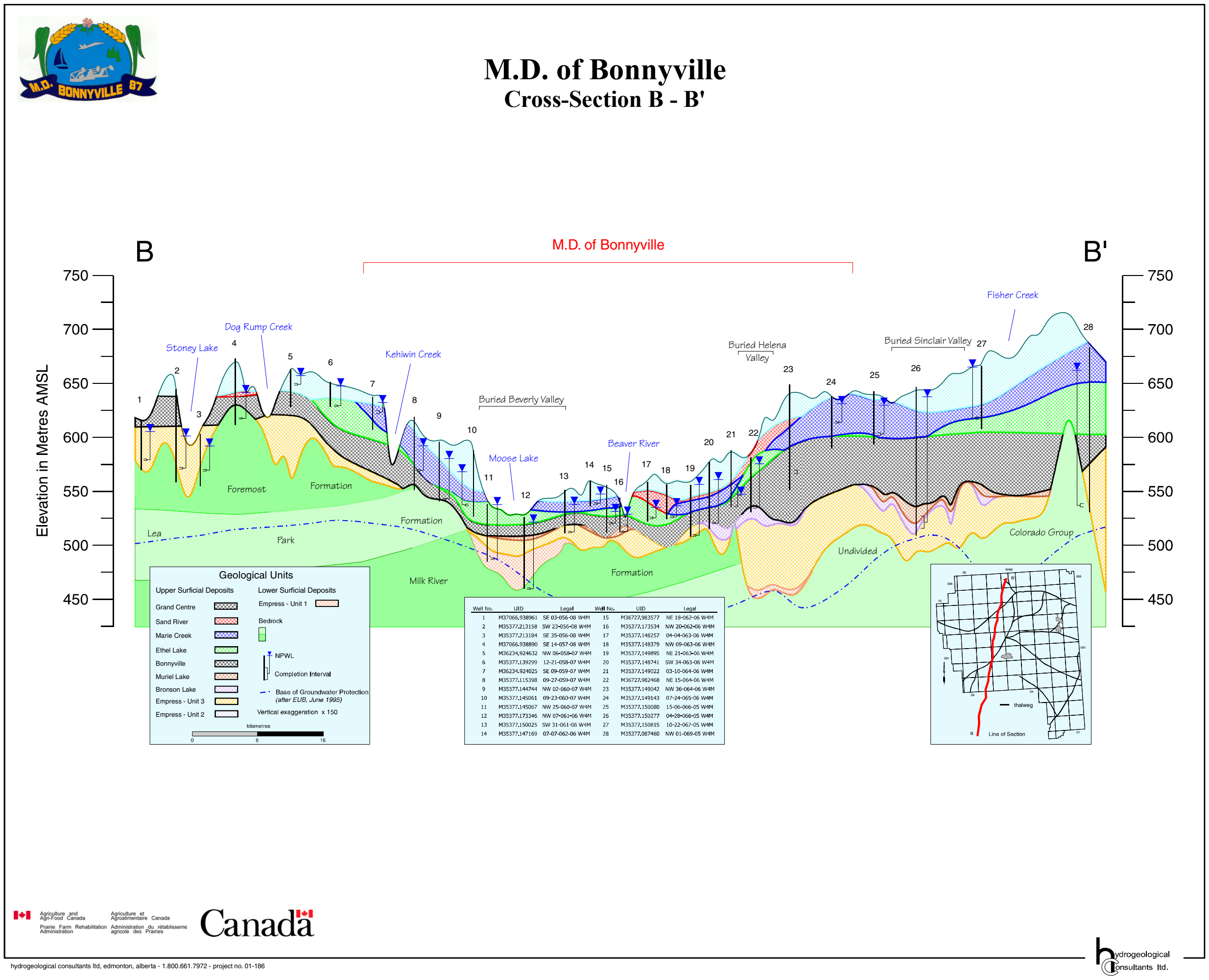
Cross-Section B - B'



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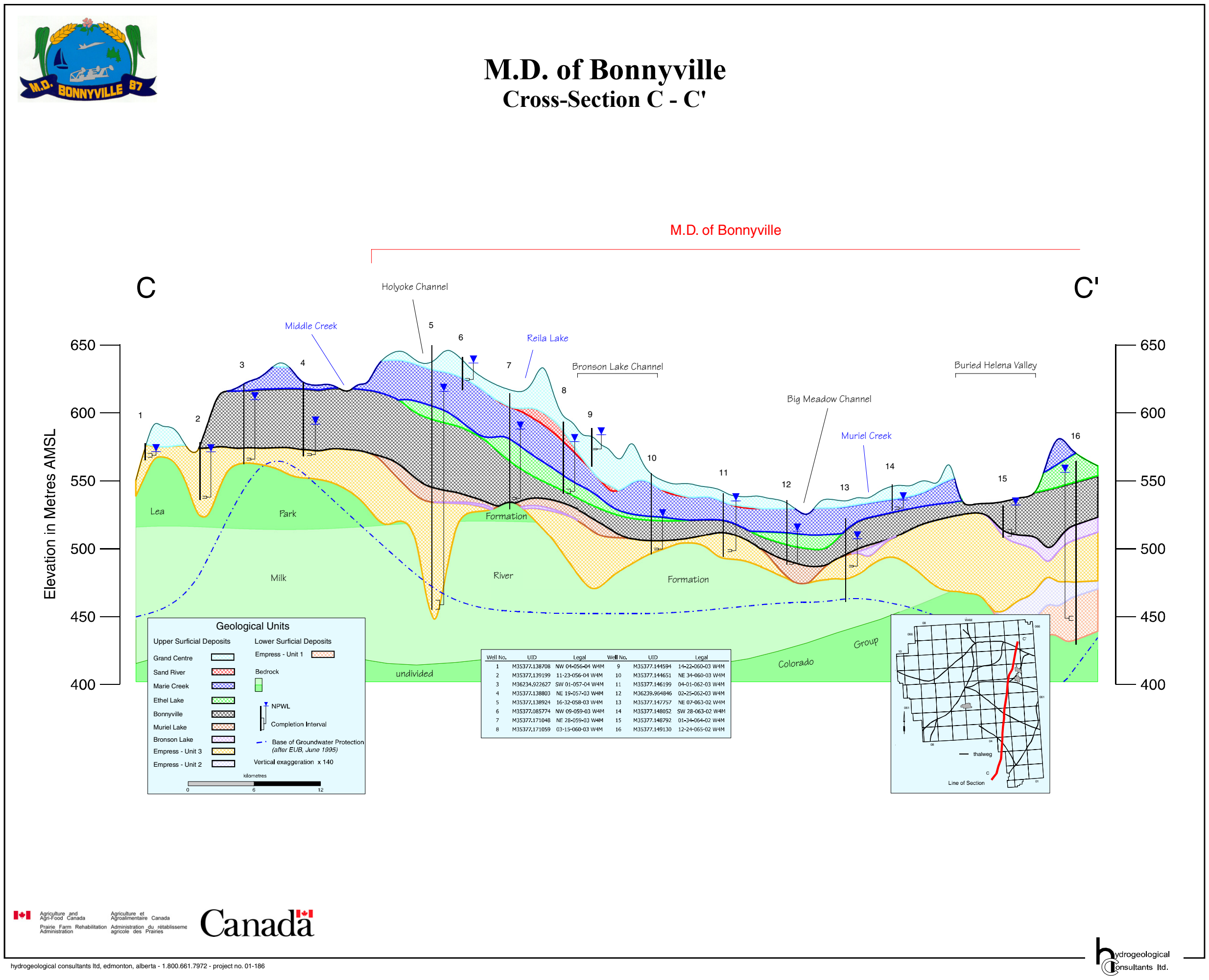
2	M35377.213158	SW 23-056-08 W4M	16	M35377.173534	NW 20-062-06 W4M
3	M35377.213184	SE 35-056-08 W4M	17	M35377.148257	04-04-063-06 W4M
4	M37066.938890	SE 14-057-08 W4M	18	M35377.148379	NW 09-063-06 W4M
5	M36234.924632	NW 06-058-07 W4M	19	M35377.149895	NE 21-063-06 W4M
6	M35377.139299	12-21-058-07 W4M	20	M35377.148741	SW 34-063-06 W4M
7	M36234.924025	SE 09-059-07 W4M	21	M35377.149022	03-10-064-06 W4M
8	M35377.115398	09-27-059-07 W4M	22	M36727.982468	NE 15-064-06 W4M
9	M35377.144744	NW 02-060-07 W4M	23	M35377.149042	NW 36-064-06 W4M
10	M35377.145061	09-23-060-07 W4M	24	M35377.149143	07-24-065-06 W4M
11	M35377.145067	NW 25-060-07 W4M	25	M35377.150080	15-06-066-05 W4M
12	M35377.173346	NW 07-061-06 W4M	26	M35377.150277	04-28-066-05 W4M
13	M35377.150025	SW 31-061-06 W4M	27	M35377.150815	10-22-067-05 W4M
14	M35377.147169	07-07-062-06 W4M	28	M35377.087460	NW 01-069-05 W4M

Cross-Section C - C'



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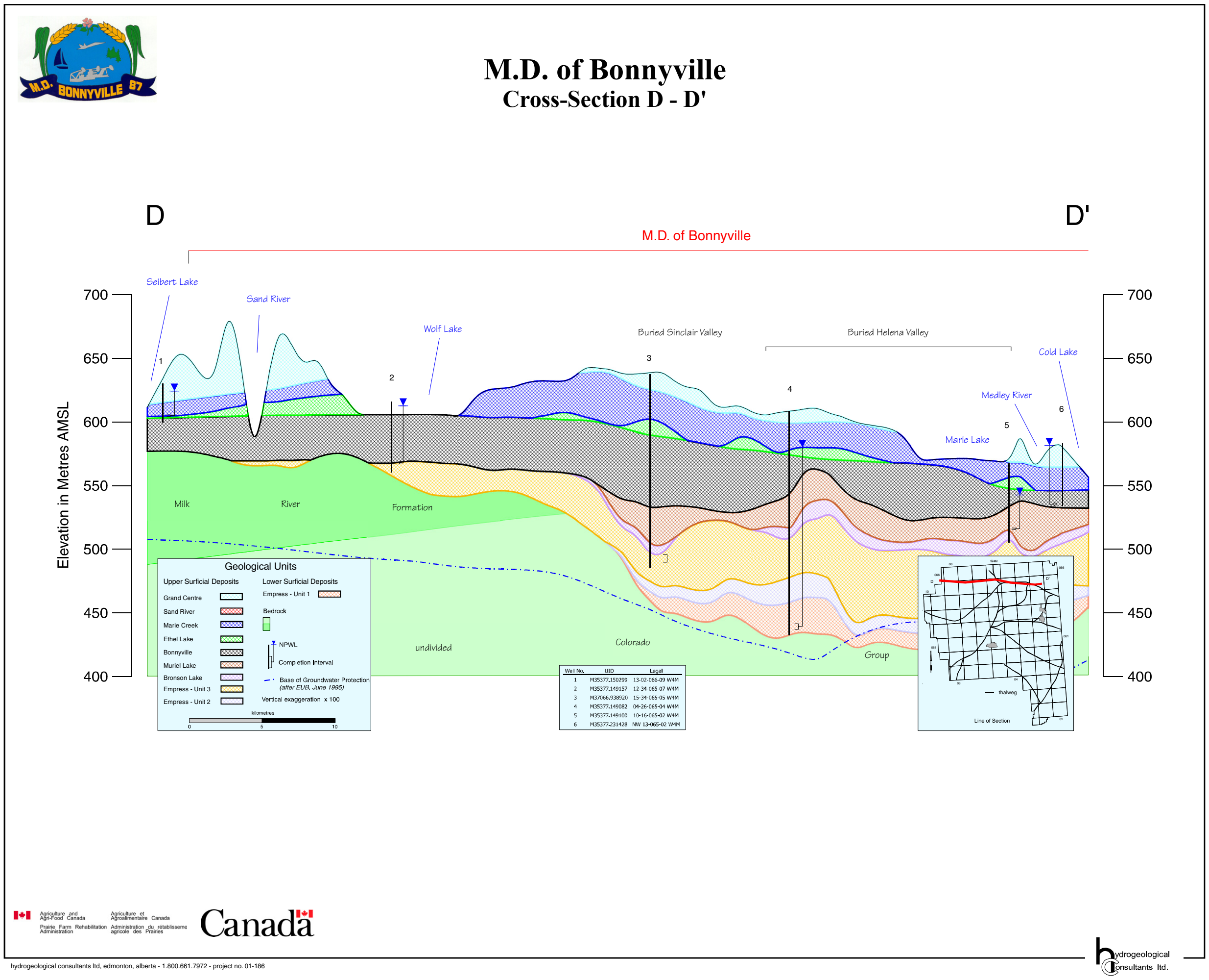
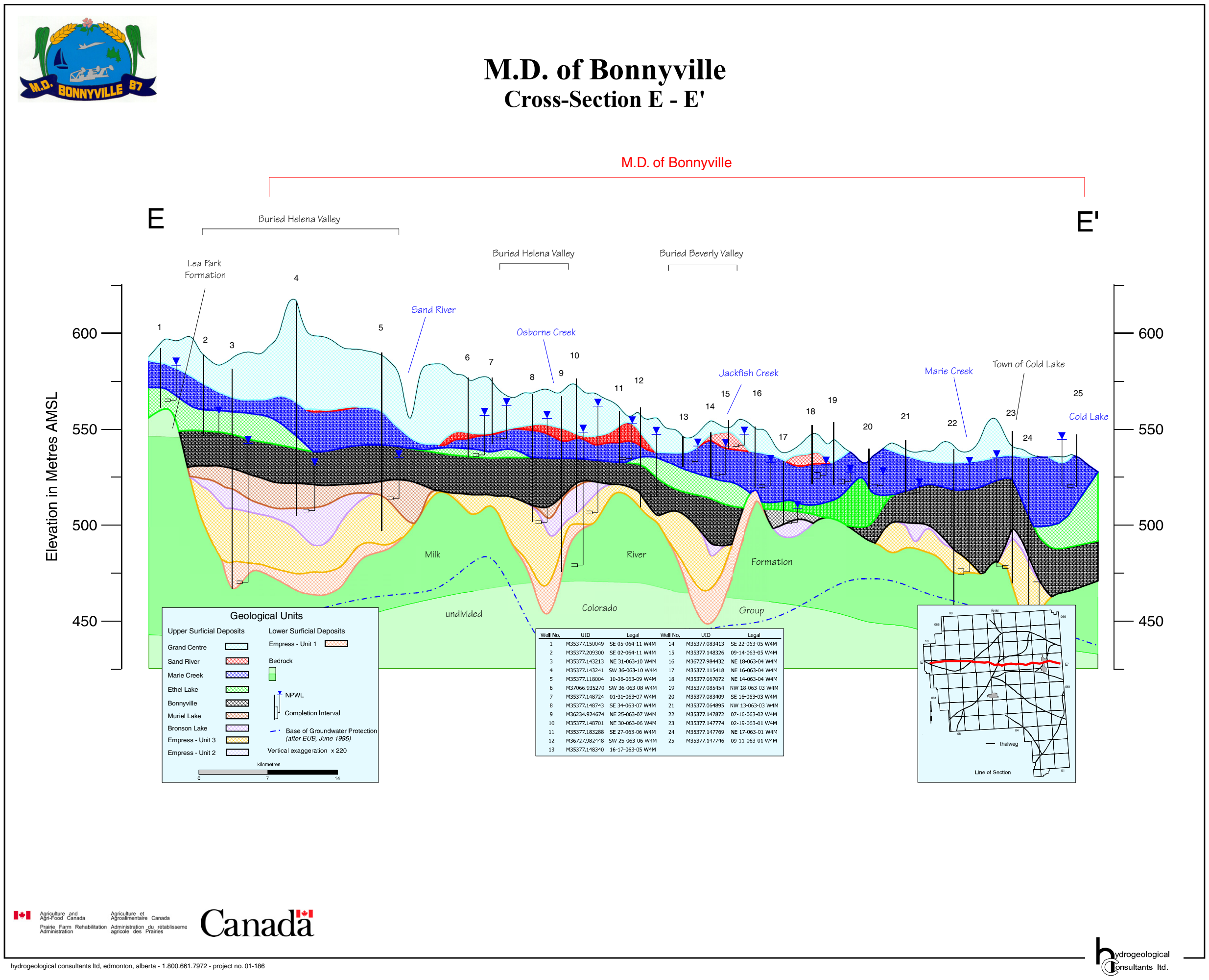
2	M35377.139199	11-23-056-04 W4M	10	M35377.144651	NE 34-060-03 W4M
3	M36234.922627	SW 01-057-04 W4M	11	M35377.146199	04-01-062-03 W4M
4	M35377.138803	NE 19-057-03 W4M	12	M36239.964846	02-25-062-03 W4M
5	M35377.138924	16-32-058-03 W4M	13	M35377.147757	NE 07-063-02 W4M
6	M35377.085774	NW 09-059-03 W4M	14	M35377.148052	SW 28-063-02 W4M
7	M35377.171048	NE 28-059-03 W4M	15	M35377.148792	01-34-064-02 W4M
8	M35377.171059	03-15-060-03 W4M	16	M35377.149130	12-24-065-02 W4M

Cross-Section D - D’



Cross-Section E - E’



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3	M35377.143213	NE 31-063-10 W4M	16	M36727.984432	NE 18-063-04 W4M
4	M35377.143241	SW 36-063-10 W4M	17	M35377.115418	NE 16-063-04 W4M
5	M35377.118004	10-36-063-09 W4M	18	M35377.067072	NE 14-063-04 W4M
6	M37066.935270	SW 36-063-08 W4M	19	M35377.085454	NW 18-063-03 W4M
7	M35377.148724	01-31-063-07 W4M	20	M35377.083409	SE 16-063-03 W4M
8	M35377.148743	SE 34-063-07 W4M	21	M35377.064895	NW 13-063-03 W4M
9	M36234.924674	NE 25-063-07 W4M	22	M35377.147872	07-16-063-02 W4M
10	M35377.148701	NE 30-063-06 W4M	23	M35377.147774	02-19-063-01 W4M
11	M35377.183288	SE 27-063-06 W4M	24	M35377.147769	NE 17-063-01 W4M
12	M36727.982448	SW 25-063-06 W4M	25	M35377.147746	09-11-063-01 W4M
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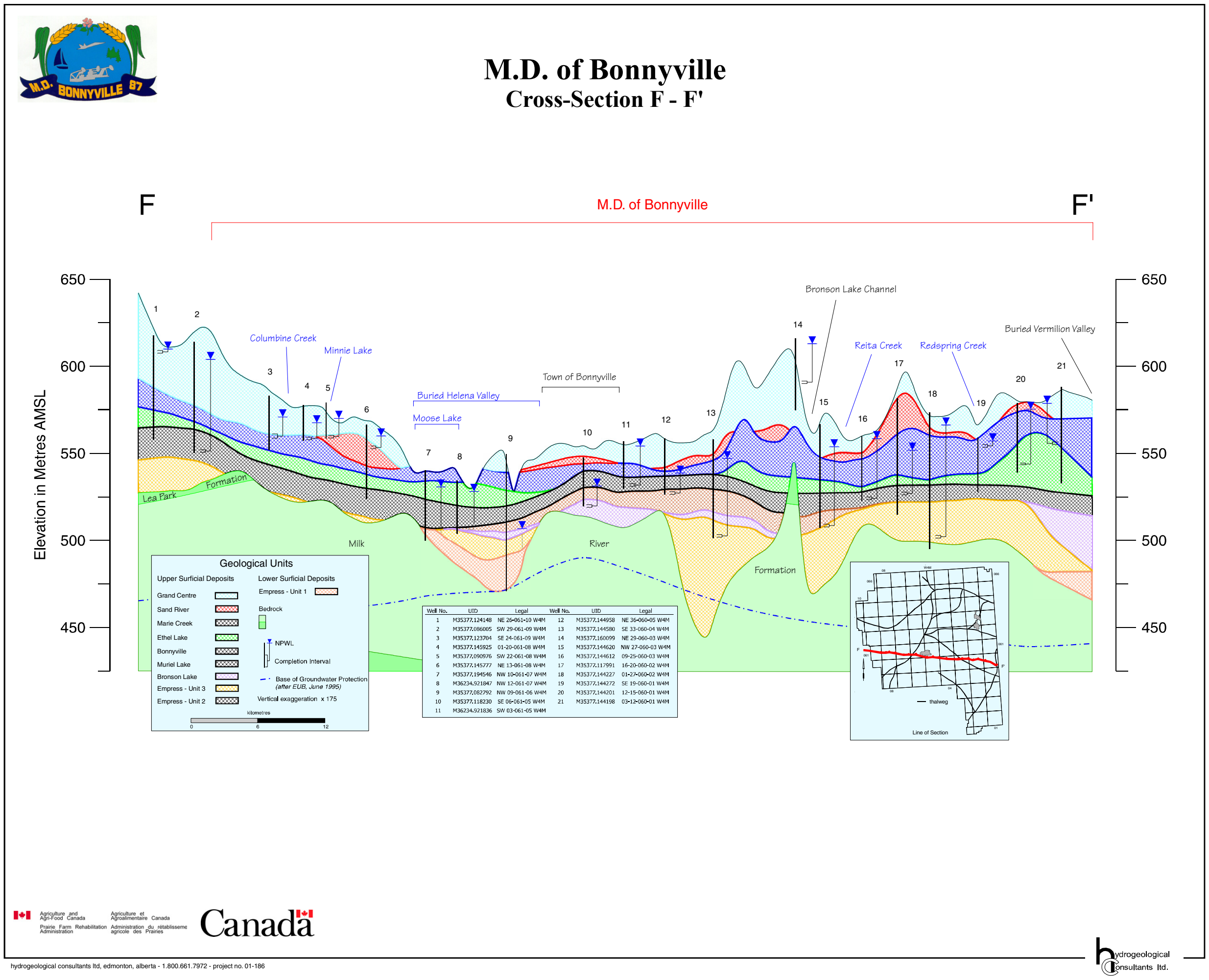
Cross-Section F - F'



M.D. OF BONNYVILLE

Appendix E

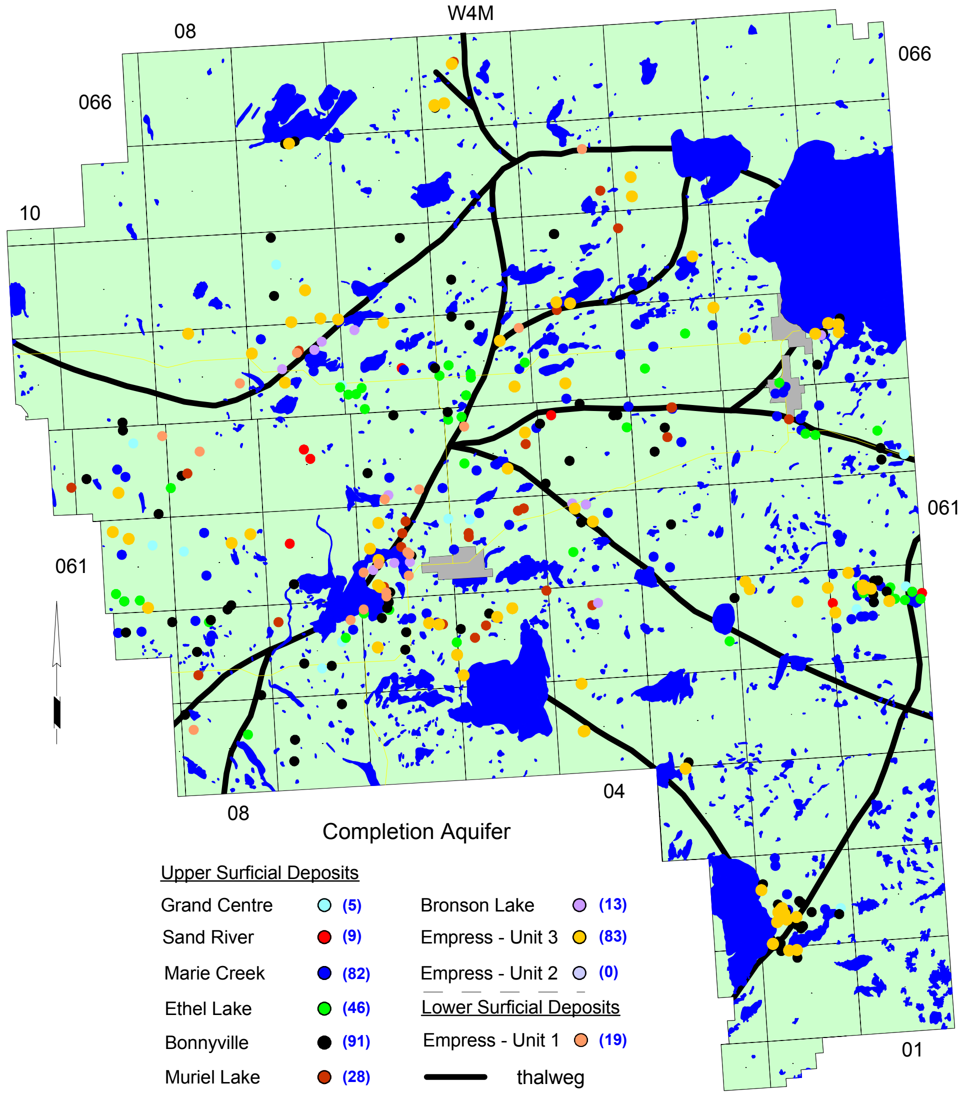
Water Wells Recommended for Field Verification

and

M. D.-Operated Water Wells

Water Wells Recommended for Field Verification

(details on following pages)



WATER WELLS RECOMMENDED FOR FIELD VERIFICATION

Owner	Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
Alberta Energy & Natural Resources	11-34-065-07 W4M	Empress - Unit 3	19-Sep-76	50.59	166.0	1.16	3.8	M35377.147615
Alberta Environment	04-17-065-03 W4M	Marie Creek	20-Sep-85	9.45	31.0	6	19.7	M35377.149203
Alberta Environment	04-35-064-06 W4M	Bonnyville	30-Jul-85	77.11	253.0	10.7	35.1	M35377.149040
Alberta Environment	16-10-062-05 W4M	Bonnyville	28-Aug-91	45.11	148.0	21.46	70.4	M35377.092553
Alberta Environment	SW 28-066-05 W4M	Muriel Lake	25-Mar-82	126.18	414.0	7.62	25.0	M35377.128720
Alberta Environment	SW 27-063-07 W4M	Muriel Lake	01-Apr-82	57.30	188.0	8.15	26.7	M35377.148708
Alberta Environment	04-17-065-03 W4M	Muriel Lake	19-Sep-85	95.40	313.0	14.11	46.3	M35377.149202
Alberta Environment	04-26-065-04 W4M	Bronson Lake	02-Feb-80	95.09	312.0	23.22	76.2	M35377.149081
Alberta Environment	04-17-065-03 W4M	Empress - Unit 3	08-Sep-85	118.26	388.0	32	105.0	M35377.149200
Alberta Environment	04-28-066-05 W4M	Empress - Unit 3	15-Jul-85	149.34	490.0	13.62	44.7	M35377.150271
Alberta Environment	16-10-062-05 W4M	Empress - Unit 3	28-Aug-91	76.20	250.0	25.33	83.1	M35377.092551
Alberta Environment	04-26-065-04 W4M	Empress - Unit 1	03-Mar-78	165.80	544.0	28.35	93.0	M35377.149080
Alberta Environment	04-27-063-07 W4M	Empress - Unit 1	08-Apr-82	97.84	321.0	9.82	32.2	M35377.151710
Alberta Environment	14-25-063-05 W4M	Empress - Unit 1	16-Jul-82	135.32	444.0	18.32	60.1	M35377.087724
Alberta Environment & Katshan, A.	16-32-058-03 W4M	Marie Creek	12-Aug-86	39.01	128.0	3.29	10.8	M35377.138927
Alberta Environment & Katshan, A.	16-32-058-03 W4M	Empress - Unit 3	28-Jul-86	194.15	637.0	10.24	33.6	M35377.138924
Alberta Environment & Katshan, A.	16-32-058-03 W4M	Empress - Unit 3	22-Aug-86	131.06	430.0	10.15	33.3	M35377.138929
Alberta Forest Service	NE 34-065-07 W4M	Bonnyville	08-Sep-77	6.10	20.0	2.65	8.7	M35377.149161
Alberta Forest Service	11-34-065-07 W4M	Bonnyville	30-Sep-68	24.99	82.0	3.43	11.3	M35377.149158
Alberta Forest Service	12-34-065-07 W4M	Bonnyville	09-Sep-77	48.77	160.0	3.05	10.0	M35377.149157
Alberta Housing & Public Works	13-20-061-05 W4M	Muriel Lake	05-Nov-81	38.40	126.0	10.97	36.0	M35377.136656
Alberta Recreation & Parks	01-29-063-01 W4M	Bonnyville	08-Aug-80	38.40	126.0	6.16	20.2	M35377.146700
Albrico Services Ltd.	01-17-062-04 W4M	Bonnyville	09-Apr-85	41.45	136.0	13.72	45.0	M35377.146587
Allen, Doug	SW 04-063-01 W4M	Marie Creek	29-Mar-86	17.37	57.0	4.88	16.0	M35377.147662
Amerada Petroleum Corporation	02-33-062-03 W4M	Muriel Lake	11-Jul-66	65.23	214.0	12.89	42.3	M35377.146400
Anderson, Lyle	NW 05-061-06 W4M	Empress - Unit 3	09-Apr-83	38.71	127.0	18.29	60.0	M35377.145289
Antoniuk, Bill	08-05-062-06 W4M	Empress - Unit 1	02-Sep-81	33.53	110.0	13.72	45.0	M35377.147162
Aulotte, Lawrence	NW 19-057-02 W4M	Empress - Unit 3	01-Jul-73	45.11	148.0	34.84	114.3	M35377.139176
Axell, Albert	16-22-063-03 W4M	Ethel Lake	06-Jun-84	17.68	58.0	3.05	10.0	M35377.148160
Bacque, Roland	NE 21-061-09 W4M	Marie Creek	02-Oct-79	46.94	154.0	8.32	27.3	M35377.123680
Bauer, Brian	14-29-061-06 W4M	Empress - Unit 3	10-Dec-84	45.72	150.0	13.11	43.0	M35377.146432
Beaucage, Norman	NW 09-062-06 W4M	Marie Creek	12-Jun-85	27.43	90.0	18.29	60.0	M35377.147184
Beaver River Holdings	05-32-062-05 W4M	Ethel Lake	07-Jun-80	26.21	86.0	15.54	51.0	M35377.147014
Beaver River Holdings	NW 29-062-05 W4M	Empress - Unit 1	05-Jun-80	89.00	292.0	31.39	103.0	M35377.147000
Belanger, Ron	NE 32-059-04 W4M	Empress - Unit 3	10-Oct-81	78.63	258.0	23.16	76.0	M35377.141063
Bell, William G.	SE 06-064-03 W4M	Marie Creek	08-Aug-81	24.99	82.0	7.31	24.0	M35377.149643
Bercier, Earnest R.	SE 35-061-05 W4M	Muriel Lake	03-Jun-82	50.29	165.0	20.73	68.0	M35377.136548
Boisvert, Raymond	NW 25-060-07 W4M	Empress - Unit 1	27-Mar-84	51.20	168.0	0.46	1.5	M35377.145067
Boyd, Rob	08-05-061-06 W4M	Bonnyville	07-Jun-86	39.01	128.0	12.19	40.0	M35377.145215
BP Exploration Canada Ltd.	08-07-066-05 W4M	Bonnyville	20-Oct-83	41.15	135.0	19.81	65.0	M35377.150082
BP Exploration Canada Ltd.	09-07-066-05 W4M	Empress - Unit 3	27-Oct-76	117.95	387.0	8.96	29.4	M35377.150086
BP Exploration Canada Ltd.	09-07-066-05 W4M	Empress - Unit 3	30-Sep-76	118.26	388.0	8.78	28.8	M35377.150091
BP Exploration Canada Ltd.	09-07-066-05 W4M	Empress - Unit 3	29-Sep-76	117.95	387.0	9.08	29.8	M35377.150141
BP Exploration Canada Ltd.	11-08-066-05 W4M	Empress - Unit 3	29-Mar-78	115.51	379.0	1.52	5.0	M35377.150153
Braunstein, Steve	08-36-063-03 W4M	Empress - Unit 3	12-Mar-77	39.62	130.0	7.31	24.0	M35377.146762
Breitenstein, Henry	16-23-062-02 W4M	Marie Creek	30-Jun-80	18.29	60.0	9.75	32.0	M35377.146181
Brosseau, Raymond	SE 02-064-07 W4M	Empress - Unit 3	18-Dec-74	70.71	232.0	17.68	58.0	M35377.148877
Brousseau, Yves	SW 09-061-09 W4M	Ethel Lake	04-Jul-81	60.96	200.0	26.46	86.8	M35377.123405
Bruneau, John	SE 17-057-02 W4M	Bonnyville	04-Sep-74	33.53	110.0	24.69	81.0	M35377.139092
Burak, John	NE 04-061-09 W4M	Marie Creek	10-Aug-74	34.44	113.0	7.41	24.3	M35377.123371
Burak, John	NE 04-061-09 W4M	Ethel Lake	21-Oct-82	37.79	124.0	7.31	24.0	M35377.123373
Burak, Peter	NW 28-060-09 W4M	Marie Creek	27-Nov-78	35.66	117.0	21.33	70.0	M35377.123027
Burshtinski, Donald	SW 31-059-08 W4M	Bonnyville	04-Jul-80	50.29	165.0	36.57	120.0	M35377.141461

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
Burton, Terry	13-05-061-06 W4M	Empress - Unit 3	23-Mar-84	37.49	123.0	7.92	26.0	M35377.145299
Cabay, Joe	SW 21-062-03 W4M	Muriel Lake	04-Apr-86	47.85	157.0	10.36	34.0	M35377.146361
Cabay, Walter	13-21-062-03 W4M	Bonnyville	19-Sep-84	32.61	107.0	6.1	20.0	M35377.146365
Cadrin, Marcel	NE 28-060-09 W4M	Bonnyville	06-Aug-83	76.20	250.0	15.24	50.0	M35377.123067
Callaghan, N.	12-25-061-08 W4M	Empress - Unit 3	15-Jul-80	65.22	214.0	37.18	122.0	M35377.145944
Calliou, Allan	SW 13-057-02 W4M	Grand Centre	20-Nov-73	14.93	49.0	7.68	25.2	M35377.139008
Calliou, Dave	SW 14-057-02 W4M	Marie Creek	13-Oct-78	10.97	36.0	6.1	20.0	M36727.983793
Calliou, Ted	03-30-057-02 W4M	Bonnyville	08-Sep-73	14.93	49.0	4.97	16.3	M35377.139347
Canadian Occidental Petroleum Ltd	06-13-063-08 W4M	Empress - Unit 1	15-Dec-84	107.28	352.0	31.39	103.0	M35377.093890
Cardinal, Alex	13-16-060-01 W4M	Marie Creek	09-Jul-74	19.51	64.0	7.74	25.4	M35377.144225
Cardinal, Edward	SW 33-060-01 W4M	Marie Creek	04-Nov-75	24.99	82.0	13.84	45.4	M35377.144523
Cardinal, James Sr.	NW 28-060-01 W4M	Empress - Unit 3	09-Nov-75	45.11	148.0	17.98	59.0	M35377.144413
Cardinal, Jim	13-23-060-01 W4M	Ethel Lake	23-Aug-73	33.53	110.0	6.4	21.0	M35377.144349
Cardinal, Lloyd	03-15-057-02 W4M	Bonnyville	31-Jul-74	48.77	160.0	37.98	124.6	M35377.139025
Cardinal, Morris	08-17-057-02 W4M	Marie Creek	07-Sep-78	10.06	33.0	7.62	25.0	M36727.983731
Cardinal, Roy	15-16-057-02 W4M	Bonnyville	04-Jul-73	68.27	224.0	56.7	186.0	M37066.935422
Cardinal, Roy	NE 16-057-02 W4M	Bonnyville	04-Jul-73	68.27	224.0	56.69	186.0	M35377.139039
Cardinal, Sam	02-17-057-02 W4M	Empress - Unit 3	13-Aug-74	82.29	270.0	44.74	146.8	M35377.139174
Cardinal, Wilfred	07-27-060-01 W4M	Bonnyville	29-Jun-74	41.45	136.0	1.98	6.5	M35377.144394
Cardinal, William	NW 27-060-01 W4M	Marie Creek	20-Jan-80	13.72	45.0	10.45	34.3	M36727.983790
Carriere, Michael	SW 16-061-06 W4M	Bronson Lake	10-Jun-86	36.88	121.0	4.27	14.0	M35377.145952
Carson, Price	SE 03-063-02 W4M	Ethel Lake	15-May-78	40.23	132.0	29.66	97.3	M35377.147708
C-D Farms	16-26-062-04 W4M	Bonnyville	28-Oct-85	47.24	155.0	22.86	75.0	M35377.146647
Chacula, Lawrence	SE 27-063-06 W4M	Marie Creek	14-Jun-78	24.69	81.0	6.1	20.0	M35377.183288
Charawich, Peter	SW 07-063-06 W4M	Ethel Lake	01-Jul-73	41.15	135.0	28.04	92.0	M35377.148284
Charawich, Steve	16-12-063-07 W4M	Grand Centre	01-Aug-79	8.23	27.0	4.57	15.0	M35377.148429
Charawich, Steve	NE 12-063-07 W4M	Ethel Lake	03-Aug-84	33.83	111.0	23.47	77.0	M35377.148433
Charron, Lawrence	NE 05-063-05 W4M	Ethel Lake	17-Mar-83	13.72	45.0	3.05	10.0	M35377.148106
Chernik, John	06-17-062-03 W4M	Bonnyville	14-Jul-86	26.21	86.0	10.67	35.0	M35377.146294
Christenson, Joel	16-21-062-07 W4M	Sand River	20-Sep-81	20.42	67.0	5.79	19.0	M35377.136001
Colanda Dairy	16-36-060-05 W4M	Muriel Lake	22-Jul-83	28.04	92.0	3.66	12.0	M35377.144952
Cold Lake Provincial Park	NW 20-063-01 W4M	Marie Creek	16-Sep-76	41.76	137.0	19.81	65.0	M35377.147783
Cold Lake Provincial Park	SE 19-063-01 W4M	Bonnyville	14-Sep-76	15.24	50.0	3.35	11.0	M35377.147772
Cold Lake Provincial Park	02-19-063-01 W4M	Bronson Lake	21-Aug-80	71.32	234.0	13.72	45.0	M35377.147774
Cold Lake Provincial Park	SW 19-063-01 W4M	Empress - Unit 3	10-Jun-80	93.87	308.0	45.72	150.0	M35377.147775
Cold Lake Provincial Park	08-05-064-04 W4M	Empress - Unit 3	15-Aug-84	74.67	245.0	2.44	8.0	M35377.148817
Cold Lake Provincial Park	SE 20-063-01 W4M	Empress - Unit 3	05-Feb-81	68.58	225.0	15.54	51.0	M35377.147777
Cold Lake Provincial Park	13-20-063-01 W4M	Empress - Unit 3	12-Aug-80	81.68	268.0	26.21	86.0	M35377.147785
Cold Lake Provincial Park	13-20-063-01 W4M	Empress - Unit 3	01-Aug-80	81.68	268.0	26.21	86.0	M35377.147786
Cold Lake Provincial Park	NE 20-063-01 W4M	Empress - Unit 3	08-Feb-81	67.05	220.0	18.17	59.6	M35377.147844
Cole, William	01-26-060-06 W4M	Grand Centre	08-Jun-84	28.65	94.0	20.12	66.0	M35377.144893
Collins, Albert	NW 28-060-01 W4M	Ethel Lake	07-Nov-75	21.33	70.0	7.83	25.7	M35377.144412
Collins, Albert	16-29-060-01 W4M	Ethel Lake	17-Jul-74	27.43	90.0	17.95	58.9	M35377.144487
Collins, Archie	13-28-060-01 W4M	Empress - Unit 3	07-Jul-74	73.45	241.0	14.2	46.6	M35377.144411
Collins, August	NW 32-060-01 W4M	Marie Creek	12-Sep-78	9.45	31.0	6.4	21.0	M36727.983717
Collins, Claude	01-31-062-04 W4M	Sand River	01-Apr-84	9.14	30.0	2.74	9.0	M35377.146673
Collins, Joe	11-28-060-01 W4M	Marie Creek	21-Aug-73	15.24	50.0	6.67	21.9	M35377.144428
Collins, Lloyd	NE 32-060-01 W4M	Marie Creek	11-Sep-78	9.14	30.0	6.1	20.0	M36727.983716
Collins, Philomen	NW 28-060-01 W4M	Marie Creek	16-Jun-74	16.15	53.0	5.12	16.8	M35377.144409
Collins, Wm	12-28-060-01 W4M	Ethel Lake	28-Aug-73	29.26	96.0	19.96	65.5	M35377.144417
Cote, Paul	13-21-064-07 W4M	Grand Centre	20-Jun-81	50.59	166.0	42.06	138.0	M35377.148996
Coulombe, Ruth	SE 13-060-06 W4M	Bonnyville	20-May-82	69.19	227.0	46.63	153.0	M35377.144656
Croteau, Albert	15-27-060-05 W4M	Empress - Unit 3	08-May-80	60.35	198.0	20.12	66.0	M35377.144743
Currie, Robert	NW 05-061-06 W4M	Bonnyville	29-May-79	16.15	53.0	7.01	23.0	M35377.145278
Daigneault, Jerry	NW 32-057-02 W4M	Marie Creek	17-Jan-80	7.31	24.0	13.72	45.0	M36727.983727
Dalbar Feeders	13-13-062-02 W4M	Ethel Lake	22-May-78	46.94	154.0	36.57	120.0	M35377.146056
Daniels, John	---17-057-02 W4M	Empress - Unit 3	16-Sep-74	65.22	214.0	44.35	145.5	M35377.139163

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
Daniels, Louis	NE 08-057-02 W4M	Bonnyville	01-Jun-73	17.37	57.0	8.9	29.2	M35377.138812
Daniels, Louis	NW 08-057-02 W4M	Empress - Unit 3	01-Jun-73	17.37	57.0	8.83	29.0	M37066.935491
Dargais, Robert	SE 36-060-09 W4M	Bonnyville	13-Sep-79	65.53	215.0	36.57	120.0	M35377.123296
Davediuk, Paul	10-31-060-02 W4M	Empress - Unit 3	13-Sep-85	52.12	171.0	10.67	35.0	M35377.144310
Denney, Ron	NW 06-060-05 W4M	Empress - Unit 3	01-Aug-84	49.38	162.0	19.48	63.9	M35377.144453
Department of Environment	08-32-061-04 W4M	Bronson Lake	21-Oct-75	56.39	185.0	10.06	33.0	M35377.136712
Department of Highways	NE 14-064-03 W4M	Empress - Unit 3	29-May-60	22.86	75.0	2.44	8.0	M35377.148901
Dery, Jack	SE 20-063-02 W4M	Empress - Unit 3	22-Feb-76	51.81	170.0	1.83	6.0	M35377.147911
Deschamps, David	NW 32-056-02 W4M	Bonnyville	11-Nov-75	26.82	88.0	22.83	74.9	M35377.138463
Deschamps, Ernest	SW 33-056-02 W4M	Bonnyville	22-Jun-74	39.01	128.0	20.42	67.0	M35377.138466
Deschamps, George	12-08-057-02 W4M	Empress - Unit 3	05-Aug-74	71.62	235.0	33.31	109.3	M35377.138830
Deschamps, George	NE 08-057-02 W4M	Empress - Unit 3	05-Aug-74	71.62	235.0	33.2	108.9	M37066.935440
Deschamps, Joe	NE 32-056-02 W4M	Empress - Unit 3	26-Jun-74	48.46	159.0	19.81	65.0	M35377.138465
Deschamps, Louise	SW 17-057-02 W4M	Empress - Unit 3	24-Aug-74	25.60	84.0	14.02	46.0	M35377.139093
Desjarlais, Allen	SE 29-060-01 W4M	Marie Creek	15-Jul-74	15.85	52.0	6.8	22.3	M35377.144484
Desjarlais, Christina	03-17-057-02 W4M	Bonnyville	17-Jul-73	46.02	151.0	20.74	68.0	M37066.935462
Desjarlais, Christina	03-17-057-02 W4M	Bonnyville	17-Jul-73	46.02	151.0	20.76	68.1	M35377.139083
Desjarlais, Clifford	05-05-057-02 W4M	Bonnyville	21-Nov-75	39.62	130.0	21.33	70.0	M35377.138782
Desjarlais, Edward	05-28-060-01 W4M	Ethel Lake	01-Jul-74	28.04	92.0	14.26	46.8	M35377.144402
Desjarlais, Eliza	SW 05-057-02 W4M	Bonnyville	01-Jul-73	28.04	92.0	25.27	82.9	M35377.138774
Desjarlais, Frank	16-17-060-01 W4M	Marie Creek	09-Aug-73	44.80	147.0	11.28	37.0	M35377.144258
Desjarlais, James Sr.	04-34-060-01 W4M	Bonnyville	18-Jun-74	23.47	77.0	9.3	30.5	M35377.144549
Desjarlais, Ken	SE 06-057-02 W4M	Empress - Unit 3	07-Sep-78	22.86	75.0	19.81	65.0	M36727.983735
Desjarlais, Lawrence Jr.	09-26-060-01 W4M	Grand Centre	22-Aug-73	18.29	60.0	2.29	7.5	M35377.144393
Desjarlais, Lawrence Sr.	01-33-060-01 W4M	Bonnyville	09-Aug-73	31.70	104.0	9.91	32.5	M35377.144521
Desjarlais, Mary	06-17-057-02 W4M	Empress - Unit 3	23-Aug-74	73.15	240.0	24.29	79.7	M35377.139068
Desjarlais, Richard	NW 17-060-01 W4M	Marie Creek	07-Jun-74	22.25	73.0	12.19	40.0	M35377.144243
Desjarlais, Richard	NW 32-060-01 W4M	Empress - Unit 3	21-Jul-83	65.83	216.0	27.13	89.0	M35377.144508
Desjarlais, Robert	NE 29-060-01 W4M	Marie Creek	14-Sep-78	18.29	60.0	14.02	46.0	M36727.983719
Desjarlais, Theresa	NW 28-060-01 W4M	Empress - Unit 3	25-Jun-74	39.32	129.0	-0.98	-3.2	M35377.144406
Desjarlais, William	SE 28-060-01 W4M	Bonnyville	11-Jun-74	39.32	129.0	-0.3	-1.0	M35377.144399
Desjarlais, William	01-06-057-02 W4M	Bonnyville	01-Jul-73	25.60	84.0	18.28	60.0	M37066.935496
Desjarlais, William	SE 06-057-02 W4M	Empress - Unit 3	01-Jul-73	25.60	84.0	18.2	59.7	M35377.138787
Desrosiers, Wayne	01-20-063-03 W4M	Marie Creek	21-Aug-82	22.25	73.0	10.36	34.0	M35377.148119
Dmyterko, Steve	05-17-062-05 W4M	Ethel Lake	13-May-83	35.96	118.0	11.58	38.0	M35377.146750
Drake, William	03-27-062-02 W4M	Marie Creek	18-May-78	34.75	114.0	28.95	95.0	M35377.146308
Drummond Oil And Gas Ltd.	02-33-062-03 W4M	Marie Creek	14-Feb-78	21.60	70.9	2.63	8.6	M36239.964848
Drummond Oil And Gas Ltd.	02-33-062-03 W4M	Muriel Lake	01-Jan-66	65.20	213.9	12.89	42.3	M36239.964849
Dubois, Dennis	09-32-064-07 W4M	Bonnyville	03-May-80	47.55	156.0	12.19	40.0	M35377.149027
Dumont, Arthur	NE 21-060-06 W4M	Bonnyville	28-Aug-85	46.94	154.0	16.15	53.0	M35377.144838
Dumont, Louis	13-12-057-02 W4M	Bonnyville	03-Dec-75	17.37	57.0	3.44	11.3	M35377.139007
Durocher, David	01-25-060-01 W4M	Sand River	27-Jun-74	25.60	84.0	7.44	24.4	M35377.144377
Durocher, Fred	SE 09-057-02 W4M	Bonnyville	06-Aug-74	16.76	55.0	4.91	16.1	M35377.138853
Durocher, Philip	02-09-057-02 W4M	Bonnyville	25-Jul-74	39.01	128.0	24.14	79.2	M35377.138851
Durocher, Phillip	06-09-057-02 W4M	Bonnyville	12-Jul-73	10.97	36.0	6.1	20.0	M35377.138860
Durocher, Phillip	SE 09-057-02 W4M	Bonnyville	25-Jul-74	39.01	128.0	24.15	79.2	M37066.935439
Dutertre, Robert	SW 22-062-07 W4M	Sand River	21-Sep-84	36.88	121.0	7.62	25.0	M35377.136006
Easthope, Don	SW 16-063-07 W4M	Empress - Unit 3	24-Jul-75	60.04	197.0	10.67	35.0	M35377.148518
Ehnes, Gabriel	SE 33-061-04 W4M	Ethel Lake	20-Dec-65	28.04	92.0	6.58	21.6	M35377.136667
Ehnes, Gabriel	SE 33-061-04 W4M	Bronson Lake	30-Jun-84	52.12	171.0	7.01	23.0	M35377.136669
Elizabeth Ir Community Hall	12-28-060-01 W4M	Marie Creek	21-Aug-73	15.85	52.0	6.61	21.7	M35377.144421
Elizabeth Ir School	10-28-060-01 W4M	Empress - Unit 3	05-Nov-75	39.01	128.0	1.31	4.3	M35377.144446
Elizabeth Metis Settlement	12-28-060-01 W4M	Empress - Unit 3	07-Aug-81	54.56	179.0	21.33	70.0	M35377.144405
Elock, Randal	SW 20-060-08 W4M	Bonnyville	17-Sep-84	65.22	214.0	44.74	146.8	M35377.145154
Emery, Clint	NW 35-062-01 W4M	Marie Creek	02-May-86	45.72	150.0	39.93	131.0	M35377.146016
Enzenauer, Brian	NW 06-062-04 W4M	Bonnyville	28-Dec-78	36.57	120.0	17.07	56.0	M35377.146519

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
Erickson, Fay	NE 26-063-07 W4M	Bronson Lake	21-Apr-79	68.88	226.0	4.88	16.0	M35377.148700
Esso Resources Canada Ltd.	05-12-065-04 W4M	Muriel Lake	12-Nov-83	82.90	272.0	9.14	30.0	M35377.149054
Esso Resources Canada Ltd.	13-05-065-03 W4M	Empress - Unit 3	20-Jul-82	110.33	362.0	24.44	80.2	M35377.149187
Faust, Howard	02-05-061-06 W4M	Empress - Unit 1	10-Aug-84	67.36	221.0	17.37	57.0	M35377.145185
Fayant, Brian	SW 32-057-02 W4M	Marie Creek	31-Aug-78	13.11	43.0	4.57	15.0	M36727.983728
Fayant, Ervin	14-09-057-02 W4M	Empress - Unit 3	03-Dec-75	78.02	256.0	41.42	135.9	M35377.138865
Fayant, Ervine	SW 17-057-02 W4M	Empress - Unit 3	01-Jul-73	46.33	152.0	22.87	75.0	M37066.935460
Fayant, Irvine	SW 17-057-02 W4M	Empress - Unit 3	01-Jul-73	46.33	152.0	22.77	74.7	M35377.139089
Fersovitch, Henry	16-08-062-05 W4M	Marie Creek	24-May-79	29.26	96.0	14.32	47.0	M35377.146716
Fielding, Gary	SE 04-064-03 W4M	Marie Creek	19-Sep-84	22.86	75.0	8.53	28.0	M35377.148824
Filipchuk, Micheal	SW 20-059-07 W4M	Bonnyville	05-May-82	42.06	138.0	21.33	70.0	M35377.141415
Flammond, Merv	NW 28-060-01 W4M	Bonnyville	20-Jan-80	26.82	88.0	17.68	58.0	M36727.983795
Flammond, Ronnie	SE 17-057-02 W4M	Marie Creek	06-Sep-74	10.67	35.0	5.18	17.0	M35377.139059
Foley, Harold S.	13-05-061-06 W4M	Bonnyville	15-Sep-80	29.87	98.0	6.4	21.0	M35377.145284
Fontaine, Roger	07-28-060-05 W4M	Empress - Unit 3	10-Sep-86	60.96	200.0	28.04	92.0	M35377.144745
Foulds, Allen	03-12-062-01 W4M	Grand Centre	20-Sep-82	24.08	79.0	9.14	30.0	M35377.145846
Fox, Ron	12-04-062-06 W4M	Bronson Lake	22-Jul-86	45.11	148.0	18.29	60.0	M35377.147159
Fox, W. S.	NW 10-060-07 W4M	Grand Centre	05-Oct-78	18.29	60.0	3.05	10.0	M35377.144810
Fraser, Allan	NW 07-061-06 W4M	Empress - Unit 1	06-Apr-81	45.72	150.0	12.15	39.9	M35377.145548
Gagne, Antoine	15-20-061-07 W4M	Sand River	19-Jan-81	43.28	142.0	11.89	39.0	M35377.145405
Galberg, Ester	NE 15-063-06 W4M	Sand River	29-Jul-82	41.76	137.0	36.57	120.0	M35377.148442
Gamache, Ivon	12-27-060-06 W4M	Marie Creek	30-May-79	31.70	104.0	23.01	75.5	M35377.144905
Gamache, Larry	NE 13-063-04 W4M	Marie Creek	13-Apr-86	30.78	101.0	21.94	72.0	M35377.147991
Georgenson, R. W.	05-31-060-06 W4M	Empress - Unit 1	10-Oct-85	42.67	140.0	19.81	65.0	M35377.144940
Gladue, Elvina	NW 17-057-02 W4M	Bonnyville	31-Aug-74	39.32	129.0	22.62	74.2	M35377.139143
Griffith, Bill	NE 18-062-09 W4M	Bonnyville	05-Aug-86	68.58	225.0	46.94	154.0	M35377.124411
Gullactson, P.	SW 07-063-01 W4M	Bonnyville	20-May-76	55.17	181.0	10.97	36.0	M35377.147727
Gustafson, Henry	NW 17-062-08 W4M	Muriel Lake	06-Oct-79	59.43	195.0	37.79	124.0	M35377.147413
Hall, Dave	08-31-063-06 W4M	Bronson Lake	31-Oct-85	68.27	224.0	15.24	50.0	M35377.148702
Hallwachs, Darwin	04-27-061-04 W4M	Empress - Unit 3	17-Dec-82	77.11	253.0	13.41	44.0	M35377.136621
Hansen, Jens	NE 33-063-06 W4M	Empress - Unit 3	01-May-86	96.92	318.0	13.11	43.0	M35377.148735
Harasem, Bill	SE 26-061-09 W4M	Grand Centre	16-Jun-84	14.63	48.0	4.57	15.0	M35377.123729
Hebert, Raymond	NW 29-061-05 W4M	Grand Centre	30-Nov-84	10.97	36.0	7.62	25.0	M35377.136492
Hochachka, Mike	13-07-062-08 W4M	Ethel Lake	28-Sep-81	62.18	204.0	39.62	130.0	M35377.147392
Hochachka, Paul	01-27-061-08 W4M	Empress - Unit 3	18-Jun-75	91.44	300.0	16.06	52.7	M35377.145946
Hollwacks, Brian	01-26-060-06 W4M	Empress - Unit 3	18-May-83	86.56	284.0	54.86	180.0	M35377.144891
Hope, Lyle	NE 33-062-04 W4M	Bonnyville	14-Sep-79	57.30	188.0	26.52	87.0	M35377.146686
Hunter, John	12-30-062-01 W4M	Marie Creek	26-Nov-80	30.48	100.0	21.33	70.0	M35377.145994
Hupalo, Leon	SW 32-060-08 W4M	Marie Creek	08-Jul-80	41.45	136.0	15.24	50.0	M35377.145323
Hurtubise, Ron	SE 26-060-06 W4M	Sand River	26-Aug-78	29.26	96.0	17.68	58.0	M35377.144889
Husereau, Paul	SW 31-062-05 W4M	Ethel Lake	05-Sep-85	28.04	92.0	21.64	71.0	M35377.147006
Husky Oil Operations Ltd.	12-28-064-04 W4M	Bonnyville	14-Mar-83	70.71	232.0	42.06	138.0	M35377.148866
Husky Oil Operations Ltd.	12-28-064-04 W4M	Bonnyville	15-Mar-83	69.49	228.0	40.54	133.0	M35377.148863
Imperial Oil Canada Ltd.	13-30-064-03 W4M	Muriel Lake	18-Jun-80	83.21	273.0	8.33	27.3	M35377.148989
Jackknife, Adolphus	NE 23-060-01 W4M	Ethel Lake	11-Jun-74	25.30	83.0	5.49	18.0	M35377.144355
Jackknife, William	NE 24-060-01 W4M	Ethel Lake	29-Aug-73	12.80	42.0	3.66	12.0	M35377.144372
Jacknife, John	SW 25-060-01 W4M	Ethel Lake	19-Jul-74	31.39	103.0	7.65	25.1	M35377.144379
Jacknife, Mike	SW 25-060-01 W4M	Sand River	11-Sep-78	12.50	41.0	7.31	24.0	M36727.983722
Jackson, Roy	04-04-063-04 W4M	Marie Creek	10-Sep-81	17.37	57.0	4.57	15.0	M35377.147874
Jubinville, Leon	WH 17-061-06 W4M	Empress - Unit 3	28-May-85	43.89	144.0	14.93	49.0	M35377.146080
Jubinville, Louis	SW 33-061-09 W4M	Empress - Unit 3	19-Aug-83	88.69	291.0	21.73	71.3	M35377.123801
Jubinville, Norman	13-32-063-05 W4M	Bonnyville	28-Oct-82	23.47	77.0	6.1	20.0	M35377.148502
Kalinski, Tim	SW 05-063-06 W4M	Ethel Lake	04-Sep-82	28.65	94.0	20.27	66.5	M35377.148261
Karas, A.	13-28-061-08 W4M	Marie Creek	11-Oct-81	16.76	55.0	11.28	37.0	M35377.145947
Karasiuk, Stanley	NW 33-063-08 W4M	Empress - Unit 3	30-Jul-86	73.15	240.0	43.89	144.0	M35377.148624
Karasiuk, Steve	NE 28-060-04 W4M	Muriel Lake	08-Feb-86	53.64	176.0	10.97	36.0	M35377.144527
Katham, Arthur	SW 04-059-03 W4M	Bonnyville	04-Nov-85	68.27	224.0	9.14	30.0	M35377.140920

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
Kelahear, Gary	NE 32-060-06 W4M	Bonnyville	08-May-86	28.35	93.0	8.53	28.0	M35377.145099
Kissel, Allen	10-16-060-06 W4M	Bonnyville	30-Sep-78	43.58	143.0	35.17	115.4	M35377.144739
Kissel, Barry & Marilyne	NW 27-061-09 W4M	Empress - Unit 3	16-Jul-82	103.63	340.0	33.53	110.0	M35377.123751
Kissel, Randy	01-18-062-06 W4M	Bonnyville	30-Jul-80	40.84	134.0	18.29	60.0	M35377.147424
Knudsen, Tom	SW 13-063-05 W4M	Marie Creek	20-Jul-83	35.36	116.0	20.42	67.0	M35377.148321
Koch Exploration Canada Ltd.	04-33-061-04 W4M	Empress - Unit 3	04-Mar-85	80.46	264.0	7.74	25.4	M35377.136678
Kohlman, Vincent J.	16-08-064-07 W4M	Bonnyville	14-Aug-80	51.81	170.0	7.62	25.0	M35377.148959
Koluk, Harry	12-21-061-03 W4M	Bonnyville	05-May-86	47.55	156.0	15.24	50.0	M35377.136318
Kondro, Neil	04-21-063-07 W4M	Bronson Lake	21-Jun-84	78.02	256.0	27.74	91.0	M35377.148668
Kopala, Edward	09-13-060-06 W4M	Ethel Lake	11-Jun-73	55.17	181.0	45.87	150.5	M35377.144660
Kopala, Mike	01-13-060-06 W4M	Empress - Unit 3	03-Jun-73	80.16	263.0	49.07	161.0	M35377.144652
Kozlow, P.	01-23-062-02 W4M	Marie Creek	13-Jun-80	32.31	106.0	27.43	90.0	M35377.146168
Krill, Alex	NW 08-063-03 W4M	Ethel Lake	10-Feb-77	45.72	150.0	25.6	84.0	M35377.147875
Kryzanowski, Mike	04-33-060-08 W4M	Ethel Lake	15-Aug-79	64.61	212.0	36.57	120.0	M35377.145328
Kryzanowski, Mike	SW 33-060-08 W4M	Bonnyville	16-Oct-86	89.91	295.0	42.67	140.0	M35377.145329
Kubista, Danny	04-18-063-05 W4M	Ethel Lake	04-Oct-83	25.91	85.0	12.19	40.0	M35377.148350
Kunec, Mike	04-26-063-05 W4M	Empress - Unit 3	09-Nov-68	94.48	310.0	-0.15	-0.5	M35377.148479
Kwiatkowski, Andrew	09-18-062-08 W4M	Bonnyville	31-Mar-81	60.96	200.0	36.57	120.0	M35377.147432
Kwiatkowski, Ed	NW 34-062-09 W4M	Bonnyville	29-Mar-81	79.24	260.0	53.34	175.0	M35377.124779
Kwiotkowski, Charles	SE 03-063-09 W4M	Bonnyville	12-May-79	76.20	250.0	64	210.0	M35377.143082
Kyle, Peter	16-18-060-06 W4M	Empress - Unit 3	15-Nov-80	47.55	156.0	18.29	60.0	M35377.144794
La Corey Ranger Station	09-13-063-06 W4M	Bonnyville	22-May-80	44.80	147.0	24.38	80.0	M35377.148411
Lacorey Ranger Station	NE 13-063-06 W4M	Marie Creek	24-Jul-68	20.73	68.0	14.72	48.3	M35377.147620
Lafreniere, Roger	SE 21-061-06 W4M	Muriel Lake	17-Oct-80	32.31	106.0	3.66	12.0	M35377.146123
Langley, Ron	10-13-063-05 W4M	Ethel Lake	22-Jun-83	38.71	127.0	18.29	60.0	M35377.148322
Langridge, John	05-24-062-05 W4M	Muriel Lake	19-Oct-82	50.59	166.0	24.38	80.0	M35377.146809
Langridge, John	04-25-062-05 W4M	Empress - Unit 3	04-Aug-81	61.57	202.0	46.02	151.0	M35377.146820
Laporte, Albert	13-18-061-05 W4M	Marie Creek	30-Aug-79	19.51	64.0	3.05	10.0	M35377.136595
Laporte, Robert G.	01-32-061-05 W4M	Marie Creek	16-Apr-79	14.63	48.0	3.66	12.0	M35377.136514
Lay, Loraine	13-15-062-03 W4M	Marie Creek	04-May-77	18.29	60.0	4.27	14.0	M35377.146281
Lefebvre, Edmond	SE 25-063-03 W4M	Marie Creek	14-May-85	13.11	43.0	4.27	14.0	M35377.148206
Leguerrier, Paul	SE 17-061-04 W4M	Ethel Lake	03-Oct-80	30.17	99.0	5.03	16.5	M35377.136364
Lepine, Ben	09-27-060-01 W4M	Ethel Lake	22-Aug-73	26.82	88.0	6.67	21.9	M35377.144398
Lepine, Clara	SE 27-060-01 W4M	Ethel Lake	08-Sep-78	23.77	78.0	3.66	12.0	M36727.983721
Lessard Hall	01-11-063-05 W4M	Empress - Unit 3	26-Jun-80	75.28	247.0	22.55	74.0	M35377.148159
Levesque, Barry	13-15-061-06 W4M	Empress - Unit 1	07-Jul-85	54.86	180.0	14.32	47.0	M35377.145821
Levesque, John	13-09-063-05 W4M	Ethel Lake	30-Apr-82	23.77	78.0	10.67	35.0	M35377.148156
Lilley, Gary	04-31-060-06 W4M	Ethel Lake	29-Jun-82	13.11	43.0	5.33	17.5	M35377.144938
Lingrell, Alfred	16-25-060-02 W4M	Empress - Unit 3	25-Nov-84	59.43	195.0	15.24	50.0	M35377.144192
Loiselle, Ben	01-01-064-07 W4M	Empress - Unit 3	04-Apr-84	75.59	248.0	7.31	24.0	M35377.148874
Lokszyn, Lawrence	16-27-062-09 W4M	Grand Centre	02-Jul-82	18.29	60.0	9.595	31.5	M35377.124515
Long, Neil	NE 13-062-02 W4M	Ethel Lake	04-Jun-79	42.06	138.0	9.578	31.4	M35377.146061
Lukinuk, George	01-04-064-07 W4M	Empress - Unit 3	28-Apr-83	87.17	286.0	9.561	31.4	M35377.148953
Lund, Mitchel	16-05-061-03 W4M	Marie Creek	11-Apr-78	61.57	202.0	9.544	31.3	M35377.136267
Mahdiuk, William	SW 01-060-08 W4M	Bonnyville	15-Jun-81	58.52	192.0	9.527	31.3	M35377.144659
Maruniak, Jerry	04-18-063-05 W4M	Ethel Lake	27-Apr-85	23.77	78.0	9.51	31.2	M35377.148352
Matichuk, John	SW 15-061-06 W4M	Bronson Lake	19-Oct-85	46.94	154.0	9.493	31.1	M35377.145815
Mccaffrey, Jerry	13-23-062-02 W4M	Muriel Lake	20-May-85	80.46	264.0	9.476	31.1	M35377.146180
Mcfeeter, Larry	09-25-060-03 W4M	Bonnyville	05-Nov-81	36.57	120.0	9.459	31.0	M35377.144612
Mcgregor, Tom	01-31-063-07 W4M	Marie Creek	16-Apr-82	32.31	106.0	9.442	31.0	M35377.148724
Mclean, Arcen	SE 17-057-02 W4M	Marie Creek	15-Jan-80	12.50	41.0	9.425	30.9	M36727.983796
Mcmann, Greg	SE 18-061-01 W4M	Marie Creek	27-May-71	18.29	60.0	9.408	30.9	M35377.145231
Mcmann, Lorry	12-26-061-04 W4M	Marie Creek	15-Dec-76	23.16	76.0	9.391	30.8	M35377.136581
Michaud, Claude	SE 27-061-05 W4M	Marie Creek	12-Jul-80	15.24	50.0	9.374	30.8	M35377.136447
Misiwich, Ed	14-12-060-03 W4M	Ethel Lake	13-Sep-85	46.94	154.0	9.357	30.7	M35377.144216
Misiwich, Paul	01-31-060-02 W4M	Empress - Unit 3	07-Sep-85	55.47	182.0	9.34	30.6	M35377.144303
Mitchell, Terry	11-23-060-05 W4M	Marie Creek	24-Jun-79	11.89	39.0	9.323	30.6	M35377.144707

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
Montpetit, Bernard L.	16-07-061-06 W4M	Bronson Lake	20-Aug-75	47.85	157.0	14.32	47.0	M35377.145575
Morris, Bob	16-32-063-04 W4M	Muriel Lake	16-Jun-81	57.30	188.0	2.13	7.0	M35377.148187
Morton, Everett	SW 17-064-05 W4M	Bonnyville	15-Aug-81	35.05	115.0	9.75	32.0	M35377.148873
Mueller	SW 17-061-06 W4M	Empress - Unit 1	13-Jun-80	64.61	212.0	6.1	20.0	M35377.145986
Murphy Oil Company Ltd.	04-16-061-08 W4M	Marie Creek	20-Aug-82	20.73	68.0	9.75	32.0	M35377.145798
Nadeau, Albert	04-25-060-06 W4M	Muriel Lake	25-May-78	72.84	239.0	15.85	52.0	M35377.144876
Nelson, Eric	NW 15-061-06 W4M	Empress - Unit 1	16-Apr-85	51.51	169.0	9.14	30.0	M35377.145828
Nesimuk, Bernard & Joyce	02-03-061-08 W4M	Bonnyville	30-Sep-80	65.83	216.0	29.26	96.0	M35377.145469
Nicholson, Gary	03-25-060-07 W4M	Marie Creek	14-Jun-79	39.32	129.0	18.9	62.0	M35377.145065
Nicol, Evan & Darlene	08-36-062-04 W4M	Marie Creek	19-Sep-85	29.56	97.0	12.19	40.0	M35377.146694
Nordstrom, Bob	06-35-059-07 W4M	Bonnyville	24-Aug-75	58.52	192.0	21.33	70.0	M35377.141528
Normand, Aurele	08-25-062-05 W4M	Marie Creek	25-Aug-81	26.21	86.0	15.54	51.0	M35377.146812
Nowak, Robert	SE 13-062-10 W4M	Grand Centre	27-May-79	24.38	80.0	17.68	58.0	M35377.124908
Nowak, Robert	SE 13-062-10 W4M	Muriel Lake	29-Oct-80	75.59	248.0	52.42	172.0	M35377.124912
Olszowka, Alan	15-01-062-06 W4M	Marie Creek	12-Jul-84	33.53	110.0	13.41	44.0	M35377.147148
Olzewski, Linda	SE 17-057-02 W4M	Marie Creek	06-Sep-78	16.46	54.0	15.85	52.0	M36727.983730
Panteluk, Mike	07-05-061-06 W4M	Empress - Unit 1	20-Dec-84	44.50	146.0	17.07	56.0	M35377.145204
Papp, Richard	11-15-061-06 W4M	Bonnyville	29-Oct-83	31.39	103.0	1.68	5.5	M35377.145819
Papson, Bill	05-21-063-04 W4M	Marie Creek	10-Apr-84	29.87	98.0	11.58	38.0	M35377.148010
Parks & Rec	SE 08-061-07 W4M	Bonnyville	24-Sep-83	12.80	42.0	1.52	5.0	M35377.150028
Perry, Phil	03-35-061-05 W4M	Muriel Lake	12-Jun-81	49.98	164.0	25.6	84.0	M35377.136552
Persely, Ed S.	13-02-062-06 W4M	Empress - Unit 1	08-Sep-81	61.57	202.0	21.33	70.0	M35377.147152
Plamondon, Allan	NE 19-061-08 W4M	Grand Centre	15-Nov-85	9.45	31.0	1.83	6.0	M35377.145924
Powder, Robert	NW 33-056-02 W4M	Empress - Unit 3	19-Nov-75	65.53	215.0	23.59	77.4	M35377.138469
Pratt, Joe	07-20-060-01 W4M	Grand Centre	16-Aug-73	15.24	50.0	4.11	13.5	M35377.144304
Prybysh, William	13-26-060-06 W4M	Marie Creek	10-Jul-79	28.65	94.0	12.8	42.0	M35377.144899
Prymych, Jim	NE 09-062-09 W4M	Empress - Unit 3	23-Jun-84	78.63	258.0	39.62	130.0	M35377.124359
Quinn, Romeo	SW 18-060-01 W4M	Marie Creek	12-Sep-78	15.24	50.0	9.14	30.0	M36727.983723
Rancier, Larry	12-20-061-05 W4M	Muriel Lake	03-Jun-78	40.84	134.0	6.76	22.2	M35377.136634
Rash, Preston	01-15-064-07 W4M	Empress - Unit 3	26-Nov-80	64.00	210.0	14.32	47.0	M35377.148968
Rezel, Geo	SE 30-059-08 W4M	Empress - Unit 1	03-Feb-73	93.57	307.0	49.68	163.0	M35377.141447
Richter, Mike	NW 15-062-09 W4M	Marie Creek	23-Oct-84	62.18	204.0	49.38	162.0	M35377.124379
Robert, Alfred W.	SW 26-060-06 W4M	Empress - Unit 3	20-Apr-80	51.81	170.0	24.44	80.2	M35377.144897
Robert, Daniel J.	16-25-061-06 W4M	Grand Centre	31-May-83	17.07	56.0	7.92	26.0	M35377.146282
Romanuk, Ken	NH 05-061-06 W4M	Muriel Lake	06-Jul-83	41.15	135.0	9.75	32.0	M35377.145442
Rooks, Doug	01-27-060-02 W4M	Empress - Unit 3	23-Sep-83	71.62	235.0	6.71	22.0	M35377.144227
Roy, Clermont	07-32-060-06 W4M	Bonnyville	20-May-81	12.80	42.0	2.44	8.0	M35377.144962
Roy, Valere	05-10-061-06 W4M	Empress - Unit 1	19-Aug-78	38.71	127.0	17.07	56.0	M35377.145719
Scott, Gerald	SE 32-060-06 W4M	Ethel Lake	02-Jun-83	17.68	58.0	9.14	30.0	M35377.144966
Scott, Stephen	NE 18-063-05 W4M	Ethel Lake	13-May-86	19.51	64.0	10.36	34.0	M35377.148363
Scott, Tom	04-16-063-05 W4M	Ethel Lake	26-Aug-80	21.33	70.0	7.62	25.0	M35377.148329
Severn, George	13-21-060-08 W4M	Marie Creek	10-May-82	45.41	149.0	9.54	31.3	M35377.145175
Sharples, Albert	13-08-059-07 W4M	Bonnyville	23-Nov-84	62.18	204.0	27.43	90.0	M35377.141230
Shepert, Tim	13-27-060-04 W4M	Bronson Lake	21-May-80	61.26	201.0	15.24	50.0	M35377.144505
Shideler, Eleanor	04-17-061-06 W4M	Bonnyville	30-Oct-80	34.44	113.0	14.63	48.0	M35377.145990
Shymchuk, Peter	13-14-063-07 W4M	Marie Creek	26-Jun-84	26.52	87.0	18.29	60.0	M35377.148455
Sibley, Mel	NE 33-062-06 W4M	Bonnyville	30-Apr-79	48.16	158.0	20.73	68.0	M35377.150045
Slevinsky, Tim	12-30-062-04 W4M	Bonnyville	30-Jul-81	44.19	145.0	33.53	110.0	M35377.146667
Smith Bros.	04-16-060-07 W4M	Bonnyville	17-May-76	33.83	111.0	10.97	36.0	M35377.145037
Smith, Al	SW 02-061-09 W4M	Empress - Unit 3	23-Jul-79	65.22	214.0	6.55	21.5	M35377.123217
Smith, D.	NW 19-060-05 W4M	Bonnyville	07-Aug-85	65.22	214.0	43.58	143.0	M35377.144515
Soloway, Edward	NE 21-060-01 W4M	Marie Creek	28-Jan-80	13.11	43.0	11.4	37.4	M36727.983791
Soloway, Edward	NE 21-060-01 W4M	Bonnyville	22-Jun-74	42.67	140.0	13.41	44.0	M35377.144335
Soloway, Edward	SW 19-060-01 W4M	Empress - Unit 3	09-Sep-73	79.24	260.0	37.15	121.9	M35377.144280
Sourray, Richard	08-20-057-02 W4M	Marie Creek	30-Aug-78	10.67	35.0	7.01	23.0	M36727.983729
Spasiuk, Metro	SW 28-060-08 W4M	Marie Creek	09-Feb-73	26.82	88.0	8.23	27.0	M35377.147343
Sribney, John	09-10-062-01 W4M	Bonnyville	05-Aug-81	64.00	210.0	17.68	58.0	M35377.145814

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
St. Arnault, Florent	NE 27-060-09 W4M	Marie Creek	14-Apr-82	22.86	75.0	14.02	46.0	M35377.125856
Stordal, Oscar	09-23-060-07 W4M	Ethel Lake	27-Aug-80	51.20	168.0	19.81	65.0	M35377.145061
Storey, Walter	13-25-062-04 W4M	Bonnyville	18-Jan-86	46.33	152.0	19.81	65.0	M35377.146629
Strus, Mike	09-03-064-06 W4M	Marie Creek	15-Oct-82	30.48	100.0	10.67	35.0	M35377.148933
Swan, Moses & Elizabeth Settle.	15-16-060-01 W4M	Marie Creek	21-Jun-74	19.20	63.0	7.38	24.2	M35377.144237
Theroux, Marc	12-28-060-05 W4M	Bonnyville	27-Oct-77	46.94	154.0	22.37	73.4	M35377.144753
Theroux, Prosper L.	16-20-060-05 W4M	Muriel Lake	02-Feb-76	67.05	220.0	40.84	134.0	M35377.144548
Thomas, Alfred D.	NW 23-059-08 W4M	Ethel Lake	15-Dec-82	50.29	165.0	37.79	124.0	M35377.141420
Tiller, K.	04-28-062-08 W4M	Empress - Unit 1	20-Dec-78	30.17	99.0	7.31	24.0	M35377.147449
Tiller, William	SE 21-062-09 W4M	Marie Creek	19-May-79	57.60	189.0	50.29	165.0	M35377.124452
Tiller, William	SE 36-062-09 W4M	Empress - Unit 1	07-Dec-85	93.26	306.0	60.04	197.0	M35377.124786
Tkachuk, Mike	SW 01-062-09 W4M	Bonnyville	28-May-79	67.05	220.0	30.48	100.0	M35377.124278
Tollefson, Conrad	01-19-063-04 W4M	Marie Creek	10-Jul-73	35.96	118.0	20.73	68.0	M35377.148006
Tolley, Del	NE 15-062-01 W4M	Ethel Lake	15-Nov-85	42.37	139.0	30.17	99.0	M35377.145860
Tomm, Robert	07-23-060-07 W4M	Grand Centre	30-Jul-78	30.48	100.0	12.19	40.0	M35377.145059
Tourangeau, Albert	13-19-060-01 W4M	Sand River	12-Jul-74	13.11	43.0	4.02	13.2	M35377.144288
Tourangeau, John	NE 22-060-01 W4M	Empress - Unit 3	29-Jun-74	47.55	156.0	13.41	44.0	M35377.144338
Town of Grand Centre	09-34-062-02 W4M	Marie Creek		10.06	33.0	3.54	11.6	M35377.146329
Town of Grand Centre	09-34-062-02 W4M	Marie Creek		8.84	29.0	3.08	10.1	M35377.146330
Town of Grand Centre	11-34-062-02 W4M	Marie Creek		12.80	42.0	7.71	25.3	M35377.146323
Truhn, Ron	09-07-061-03 W4M	Marie Creek	31-Aug-78	44.80	147.0	27.43	90.0	M35377.136285
Uiel, Robert	SE 26-060-06 W4M	Marie Creek	15-Jun-84	40.23	132.0	18.29	60.0	M35377.144894
Union Texas of Canada Ltd.	02-25-062-04 W4M	Ethel Lake	17-Feb-78	46.94	154.0	23.04	75.6	M35377.146625
Van Raes Bros.	SW 26-063-07 W4M	Bronson Lake	20-Apr-81	59.74	196.0	2.04	6.7	M35377.148698
Van Raes, Jean August	SW 26-063-07 W4M	Marie Creek	26-Apr-78	22.25	73.0	5.18	17.0	M35377.148696
Vasseur, George	SE 19-061-06 W4M	Empress - Unit 3	22-Jun-81	33.53	110.0	0.3	1.0	M35377.146097
Vasseur, Raymond	01-28-061-06 W4M	Muriel Lake	29-Jul-80	47.24	155.0	12.19	40.0	M35377.146421
Vlanik, Roland	NW 31-062-05 W4M	Bonnyville	28-Oct-85	44.50	146.0	14.32	47.0	M35377.147010
Wakulchyk Bros.	SE 07-063-06 W4M	Ethel Lake	19-Apr-74	28.65	94.0	21.33	70.0	M35377.148281
Wakulchyk, Tom	12-08-063-06 W4M	Ethel Lake	18-Jun-81	41.15	135.0	28.65	94.0	M35377.148376
Walchuk, Dan	16-03-062-01 W4M	Bonnyville	05-Jul-85	57.30	188.0	14.93	49.0	M35377.145665
Ward, Robert	09-15-063-06 W4M	Marie Creek	25-Apr-83	48.77	160.0	41.76	137.0	M35377.148446
Watrich, Ed	14-34-060-08 W4M	Bonnyville	03-Oct-80	63.40	208.0	36.57	120.0	M35377.145342
Wells, Allan	NW 31-060-01 W4M	Marie Creek	13-Sep-78	10.67	35.0	6.71	22.0	M36727.983718
Werstiuk, Senni	NW 08-060-08 W4M	Muriel Lake	28-Dec-80	82.29	270.0	48.16	158.0	M35377.144719
Wildeman, Robert	04-20-060-05 W4M	Muriel Lake	19-Sep-84	69.19	227.0	44.5	146.0	M35377.144541
Williams, Rodger	SW 33-063-05 W4M	Bonnyville	23-Oct-82	26.21	86.0	6.1	20.0	M35377.148508
Willis, Richard	11-28-060-01 W4M	Ethel Lake	08-Aug-73	21.33	70.0	9.45	31.0	M35377.144431
Wilson, Ira	04-09-063-04 W4M	Empress - Unit 3	26-Sep-84	65.22	214.0	45.69	149.9	M35377.147970
Wilson, John	SE 04-064-04 W4M	Empress - Unit 3	10-Apr-86	76.20	250.0	0.3	1.0	M35377.148791
Winther, Robert	NE 03-061-09 W4M	Ethel Lake	07-Aug-79	32.00	105.0	14.93	49.0	M35377.123333
Wizniuk, Peter	15-30-060-07 W4M	Muriel Lake	11-Nov-82	42.97	141.0	4.88	16.0	M35377.147339
Wolgien, Bert	13-27-061-06 W4M	Muriel Lake	03-Dec-81	49.98	164.0	18.29	60.0	M35377.146416
World Wide Energy Company Ltd.	03-28-061-04 W4M	Bonnyville	26-Jan-78	36.88	121.0	10.39	34.1	M35377.136652
World Wide Energy Company Ltd.	10-17-059-04 W4M	Empress - Unit 3	01-Nov-82	118.87	390.0	43.07	141.3	M35377.140992
World Wide Energy Company Ltd.	10-17-059-04 W4M	Empress - Unit 3	20-Oct-82	96.92	318.0	41.83	137.2	M35377.141000
Woycenko, William	16-10-060-07 W4M	Bonnyville	05-May-78	41.76	137.0	6.1	20.0	M35377.144813
Yavis, Randy	NW 29-060-06 W4M	Bonnyville	22-May-81	32.31	106.0	20.12	66.0	M35377.144926
Zaboschuk, John	SW 30-063-07 W4M	Empress - Unit 3	31-Mar-86	61.57	202.0	30.17	99.0	M35377.148720

M.D. OF BONNYVILLE-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 Bonnyville	04-18-063-05 W4M	Ethel Lake	25-Jul-80	20.42	67.0	7.62	25.0	M35377.148349
M.D. of Bonnyville	SE 15-062-02 W4M	Ethel Lake	23-May-89	8.84	29.0	4.88	16.0	M35377.146120
M.D. of Bonnyville	16-15-060-05 W4M	Marie Creek	16-Jul-84	17.07	56.0			M35377.144480
M.D. of Bonnyville	12-10-060-05 W4M	Muriel Lake	09-Aug-84	29.56	97.0	5.79	19.0	M35377.144467
M.D. of Bonnyville	SE 22-059-08 W4M	Bonnyville	26-May-87	41.45	136.0	35.05	115.0	M35377.141376
M.D. of Bonnyville	NE 03-061-07 W4M	Bonnyville	28-May-92	24.38	80.0	3.66	12.0	M35377.118232

M.D. OF BONNYVILLE AND LAKELAND COUNTY STUDY AREAS
Appendix F

Hydrogeological Maps and Figures

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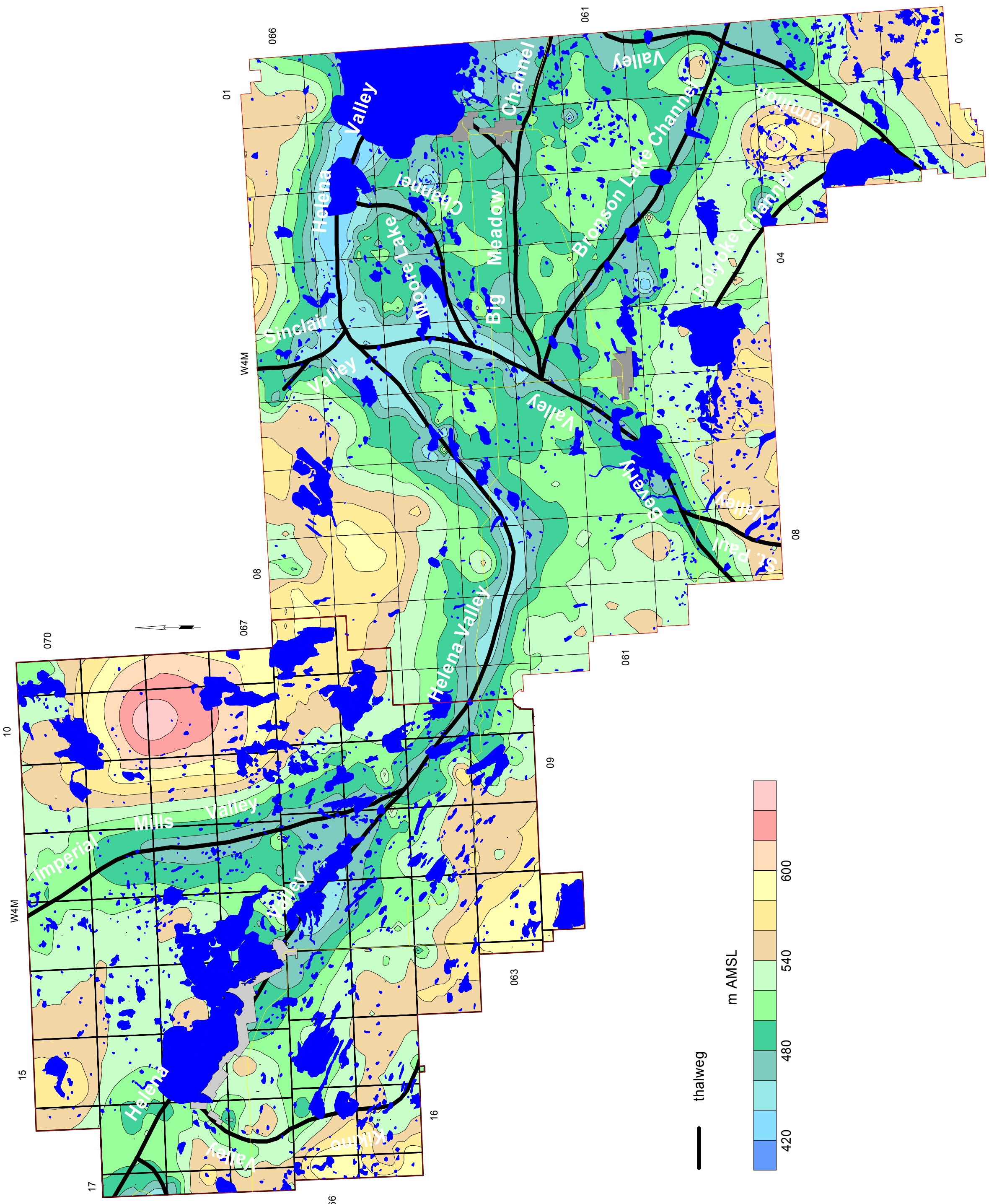
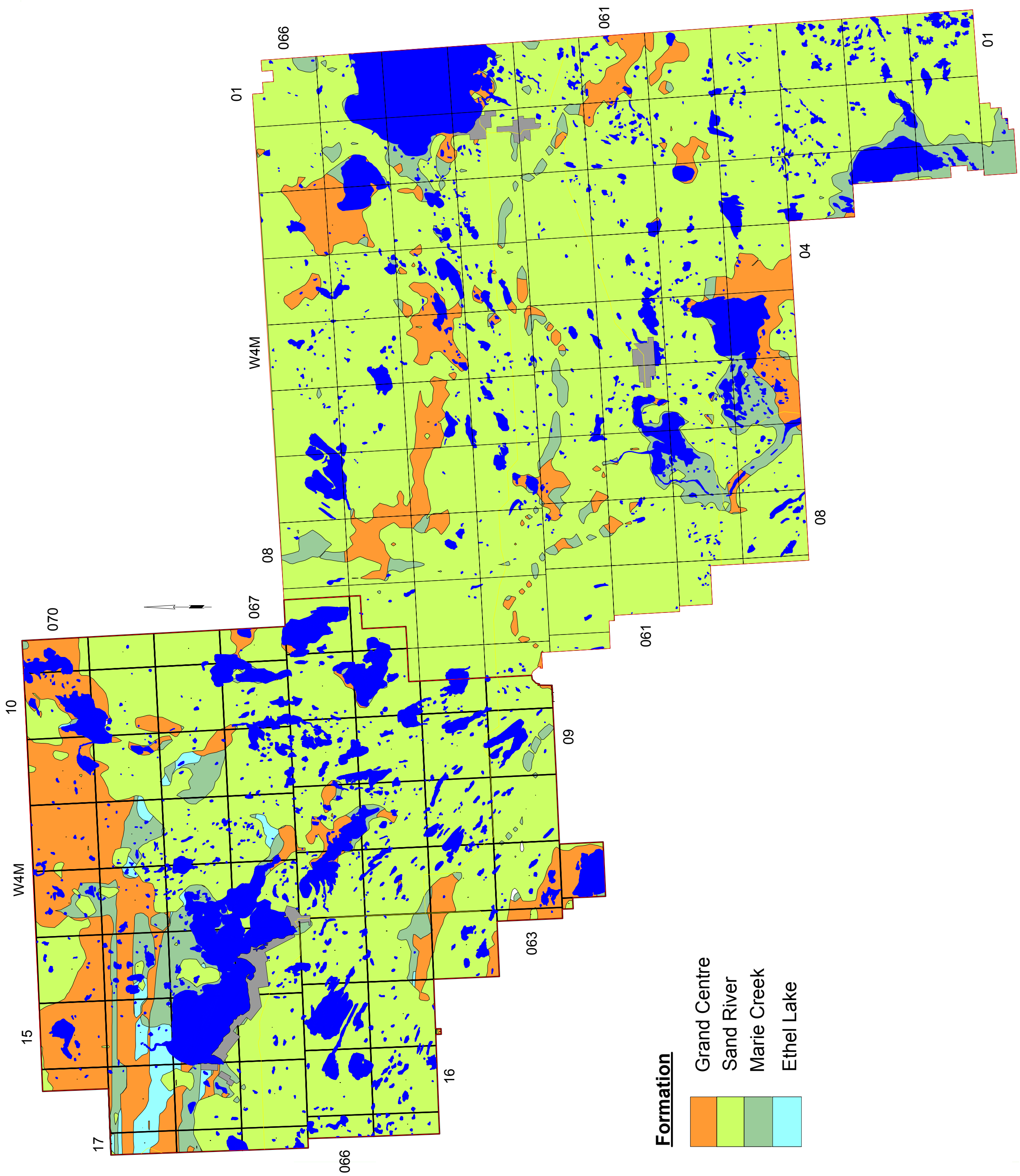
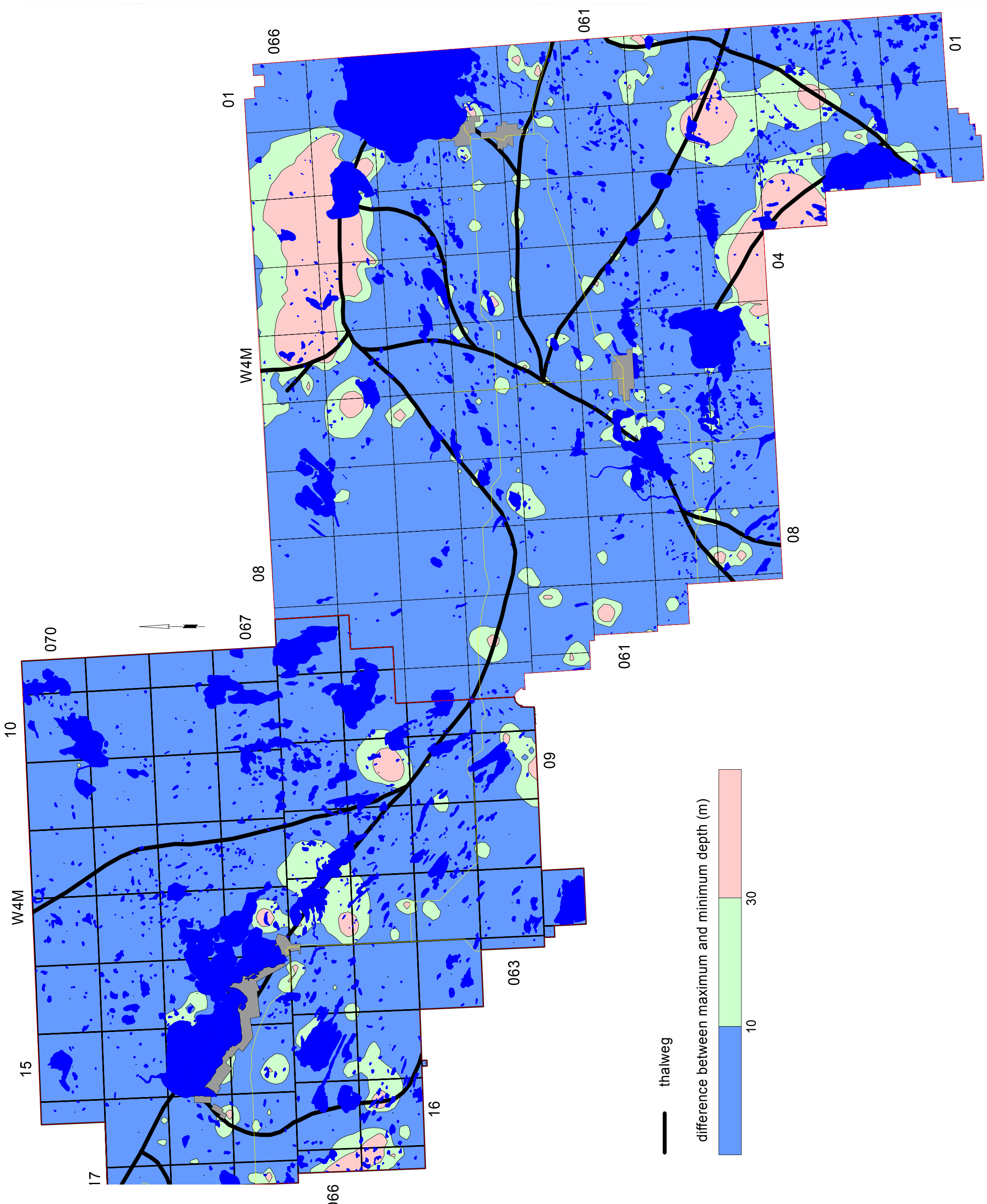
Bedrock Topography Map



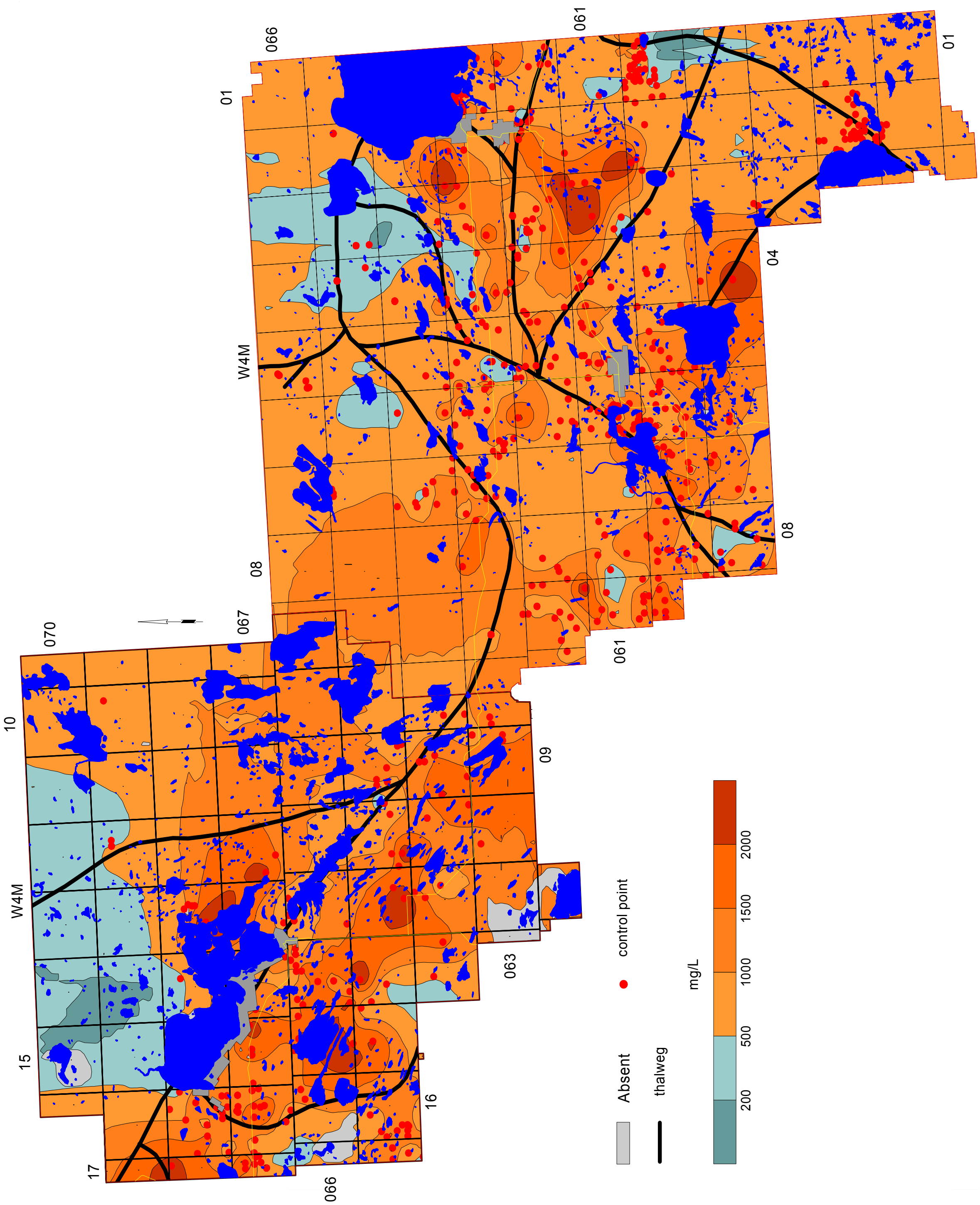
Surficial Geology Map



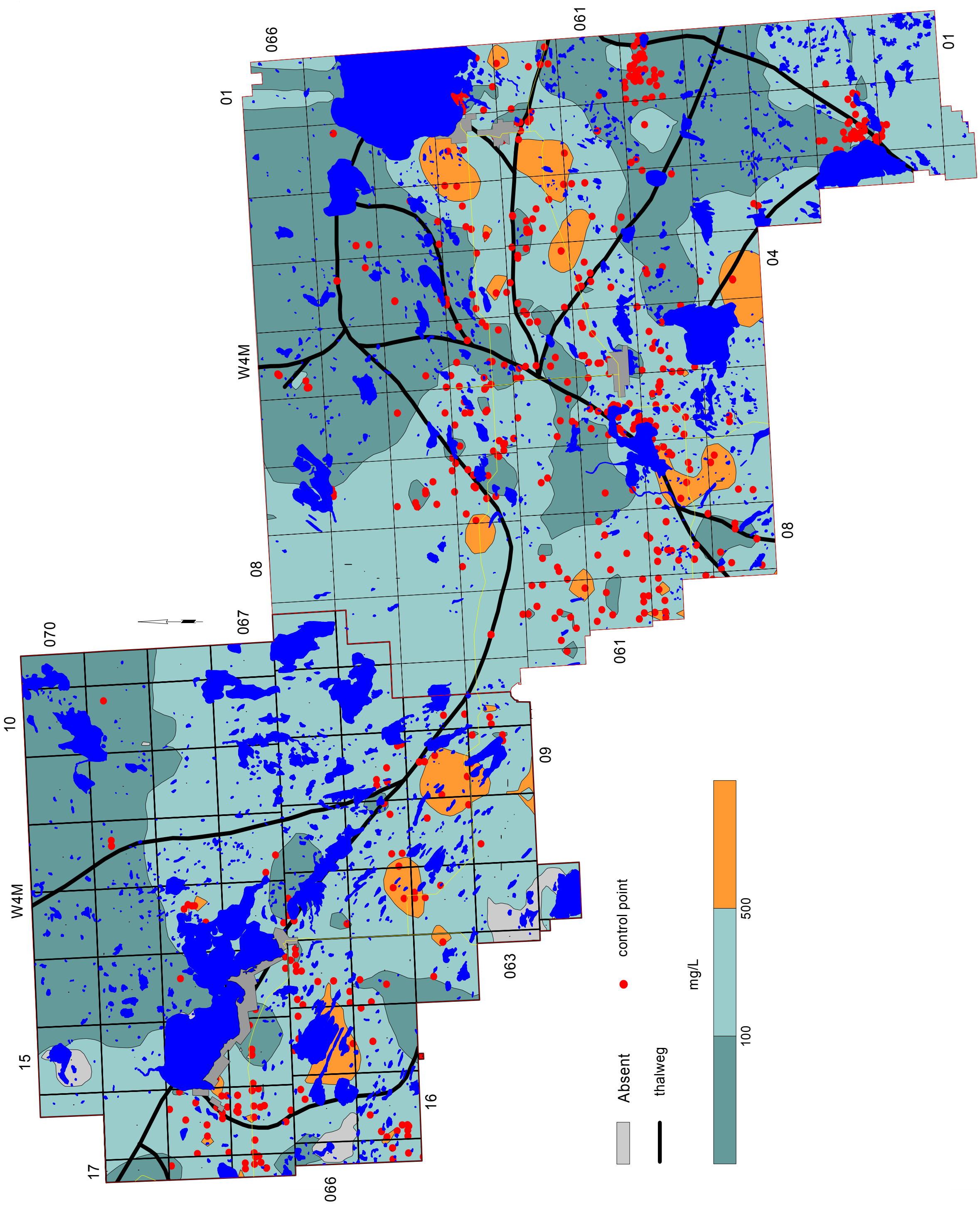
Depth of Existing Water Wells



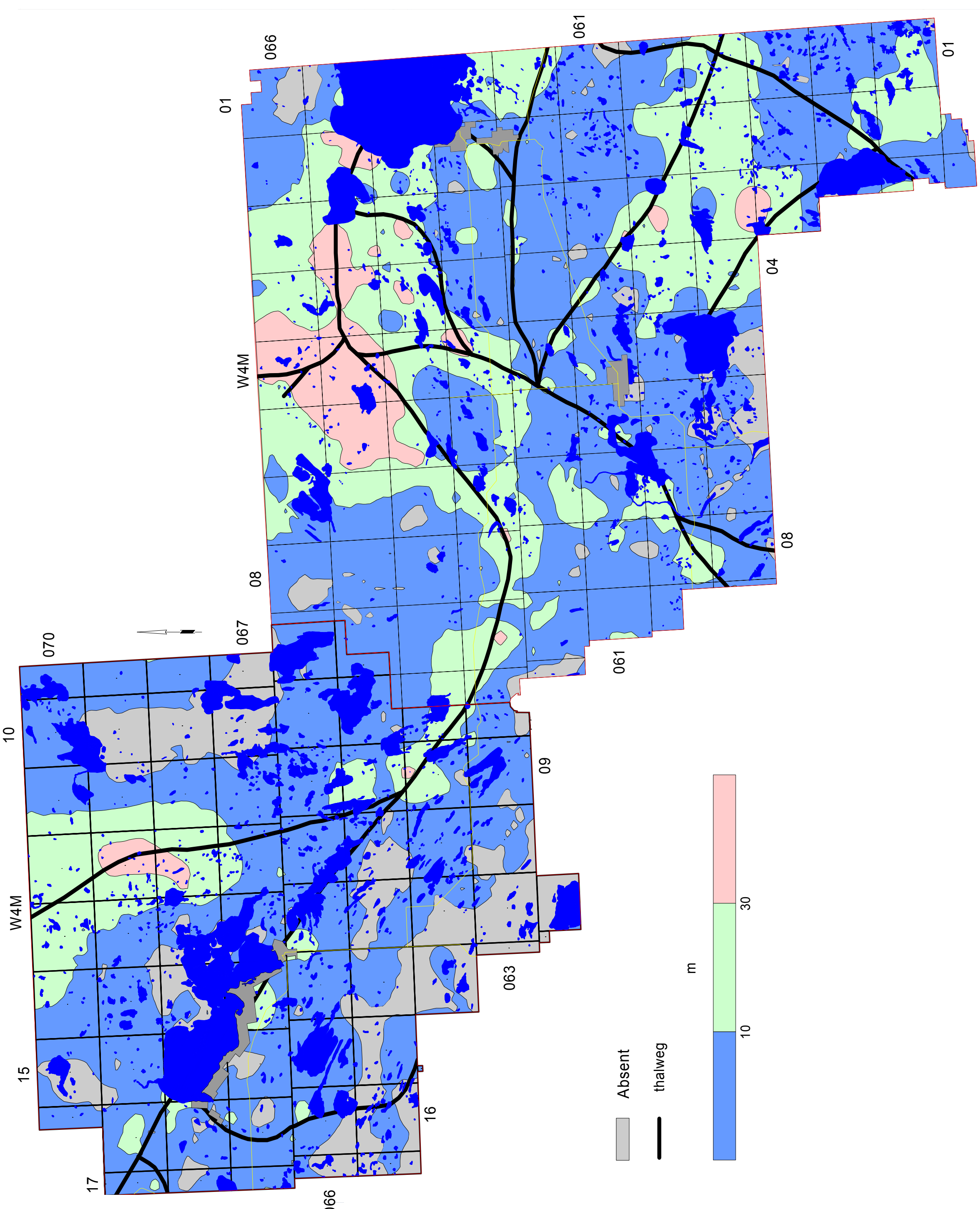
Total Dissolved Solids in Groundwater from Surficial Deposits



Sulfate in Groundwater from Surficial Deposits



Thickness of Sand and Gravel Aquifer(s)



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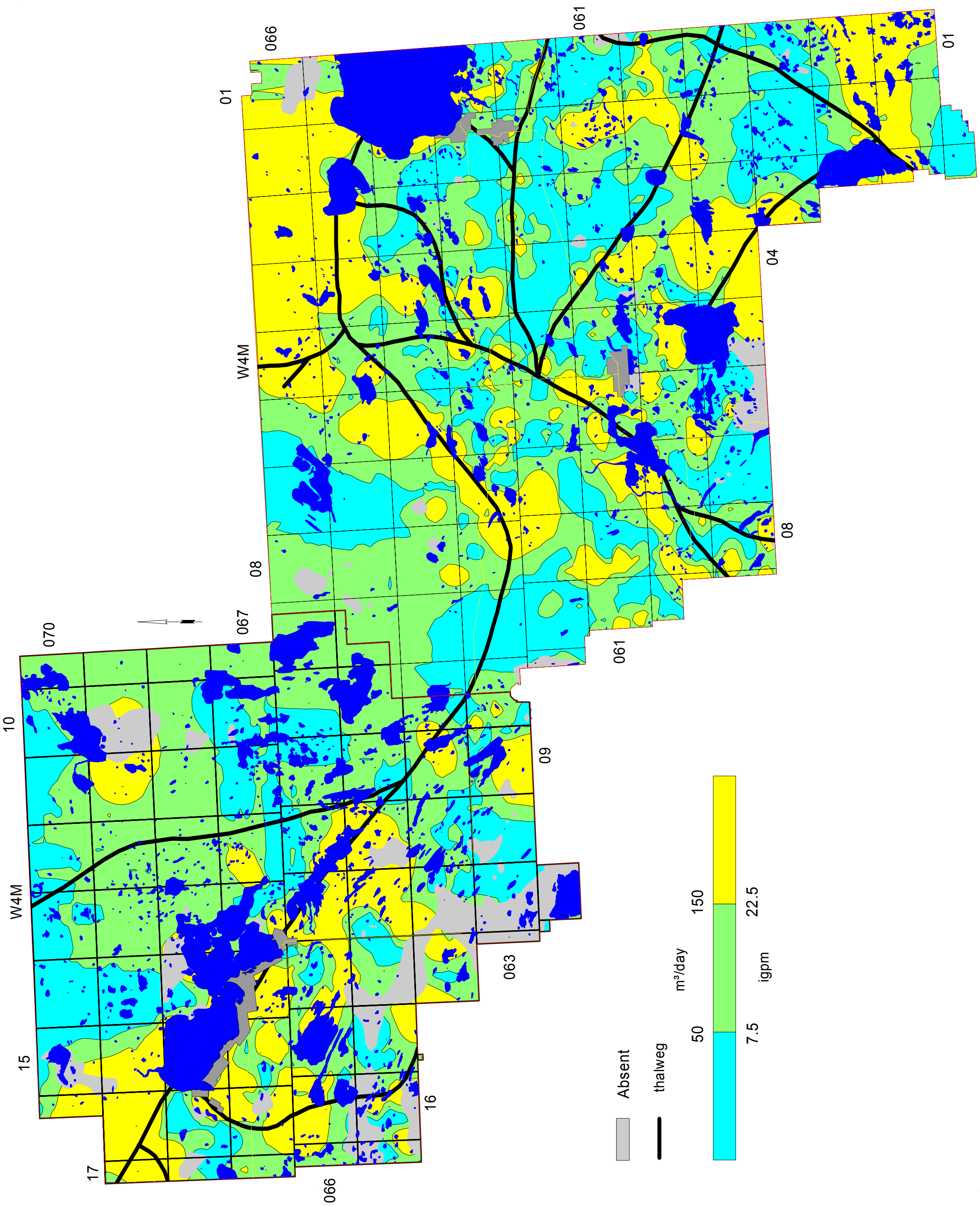
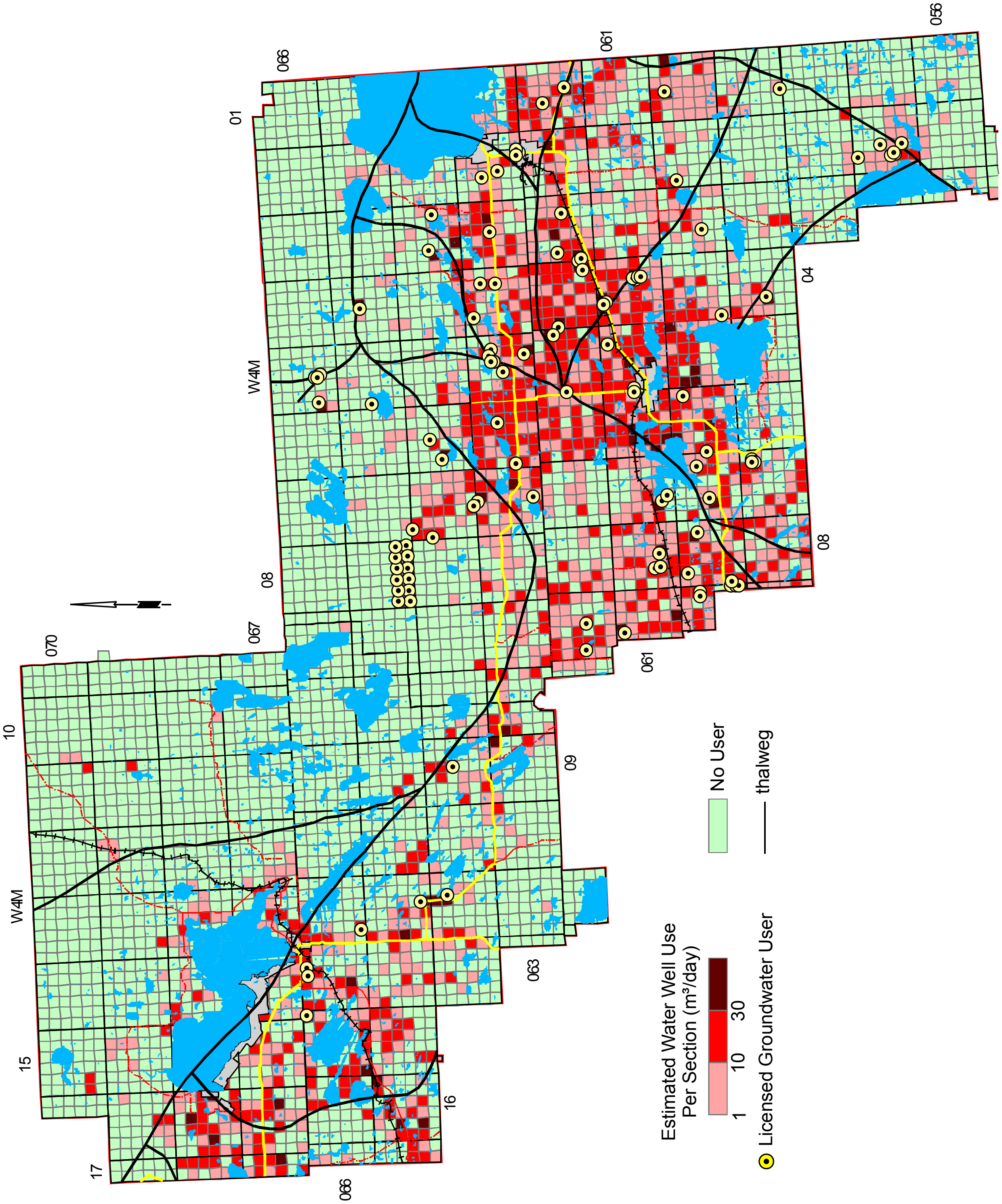
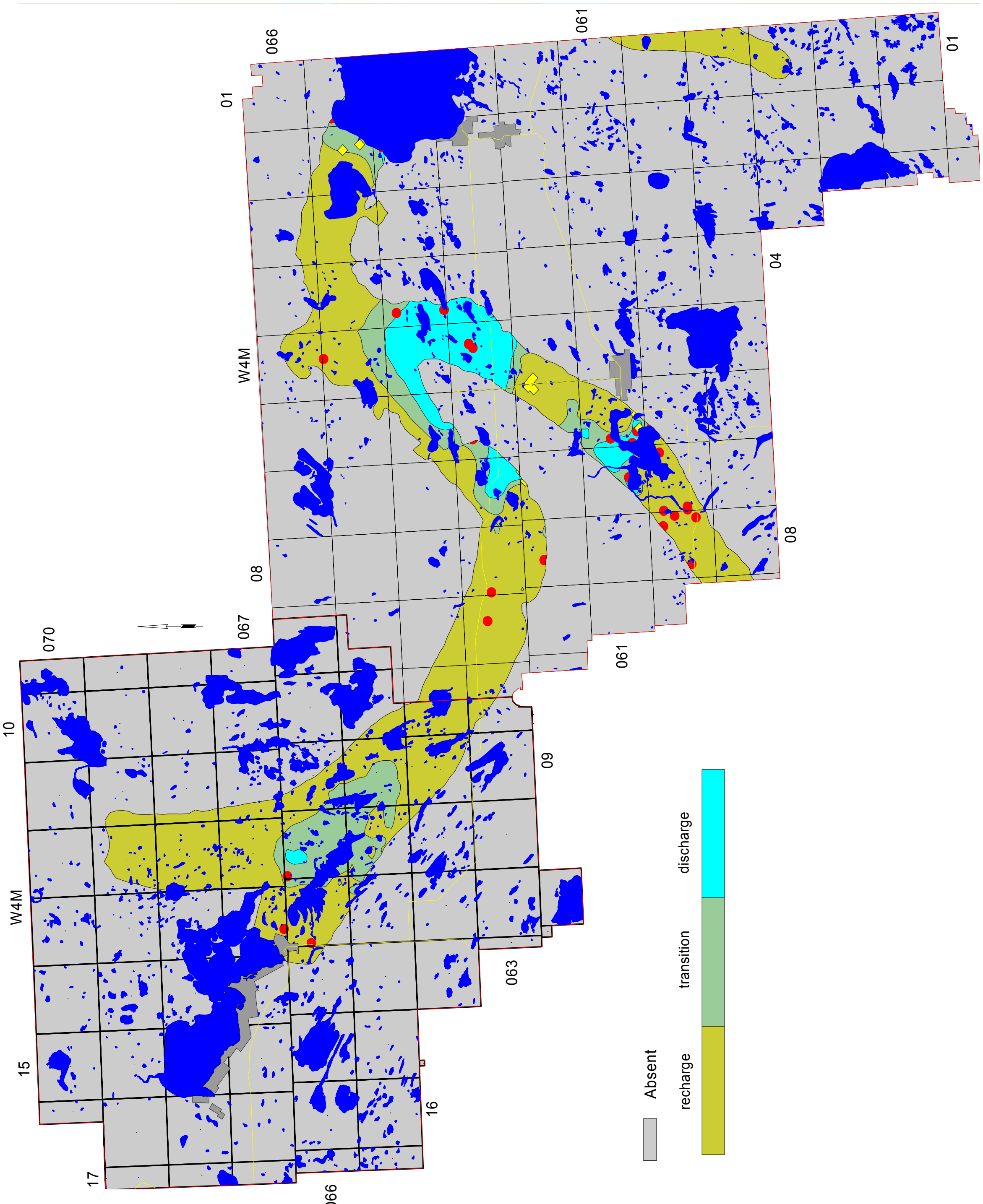
Apparent Yield in Sand and Gravel Aquifer(s)



Estimated Water Well Use Per Section



Recharge/Discharge Areas in Empress Aquifer – Unit 1



Changes in Water Levels in Sand and Gravel Aquifer