West Souris River Conservation District

Part of the Assiniboine River Basin
Twp 001 to 015, R 22 to 29, W1M
Regional Groundwater Assessment – Report

Prepared by
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West Souris River Conservation District

In conjunction with:

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Prairie Farm Rehabilitation Administration
Administration du rétablisseme agricole des Prairies

Canada

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

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

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

1 PROJECT OVERVIEW

“Water is the lifeblood of the earth.” – Anonymous

How a Province 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 can be used as a decision-support tool by the Province of Manitoba 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 Study Area prepared by Hydrogeological Consultants Ltd. (HCL) with financial and technical assistance from the Prairie Farm Rehabilitation Administration branch of Agriculture and Agri-Food Canada (AAFC-PFRA) and the West Souris River Conservation District. The study area is bounded by townships 001 to 015, ranges 22 to 29, W1M. The regional groundwater assessment provides information to assist in the management of groundwater resources within the Study Area. Groundwater resource management involves determining the suitability of various areas in the Study Area for particular activities. These activities can vary from the development of groundwater for country residential, agricultural or industrial purposes, to the siting of waste storage. **Proper management ensures protection and utilization of the groundwater resource for the maximum benefit of the people of the Study Area.**

The regional groundwater assessment will:

- identify the aquifers[1] within the surficial deposits[2] and bedrock
- spatially identify the main geologic units
- describe the quantity and quality of the groundwater associated with each geologic unit
- identify the hydraulic relationship between geologic units

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

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 Disks with Final Report and Data Files.

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

Additional technical details are available from files on the CD-ROM provided with the final version of this report. The files include the geo-referenced electronic groundwater database, maps showing distribution of various hydrogeological parameters, the groundwater query, ArcView files and ArcExplorer files. Likewise, all of the illustrations and maps shown in this report, plus additional maps, figures and cross-sections, are available on the CD-ROM. In order to avoid map-edge effects, all maps are based on an analysis of hydrogeological data from those parts of townships 001 to 015, ranges 22 to 29, W1M that make up the Study Area, plus a buffer area of 5,000 metres. For convenience, some 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 Study Area 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 copy of the *Water Rights Act*.
3) a copy of the Well Drilling Regulation under *The Ground Water and Water Well Act.*
4) interpretation of chemical analysis of drinking water
5) additional information.

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

Appendix E provides a list of water wells that have been field-verified and water wells that are recommended for field-verification.

This report, and the accompanying support documents, has been prepared in SI Units (metric); for conversions, please refer to Conversion Table on page 41.

[3] See glossary

2 INTRODUCTION

2.1 Setting

The Study Area is situated in southwestern Manitoba and is defined by the boundaries of the following rural municipalities (RMs): Edward, Arthur, Albert, Cameron, Pipestone, Sifton, Wallace and Archie.

Regionally, the topographic surface varies between 360 and 550 metres above mean sea level (AMSL). The lowest elevations occur mainly in association with the Assiniboine River in the northeastern part of the Study Area; the highest elevations are in the western parts of the Study Area, as shown on page A-5.

The Study Area is within the Assiniboine River Drainage Basin. The area is well drained by the Assiniboine and Souris rivers, and numerous creeks including Stony, Pipestone, Jackson and Graham. The Oak and Maple lakes receive water from the creeks in the area.

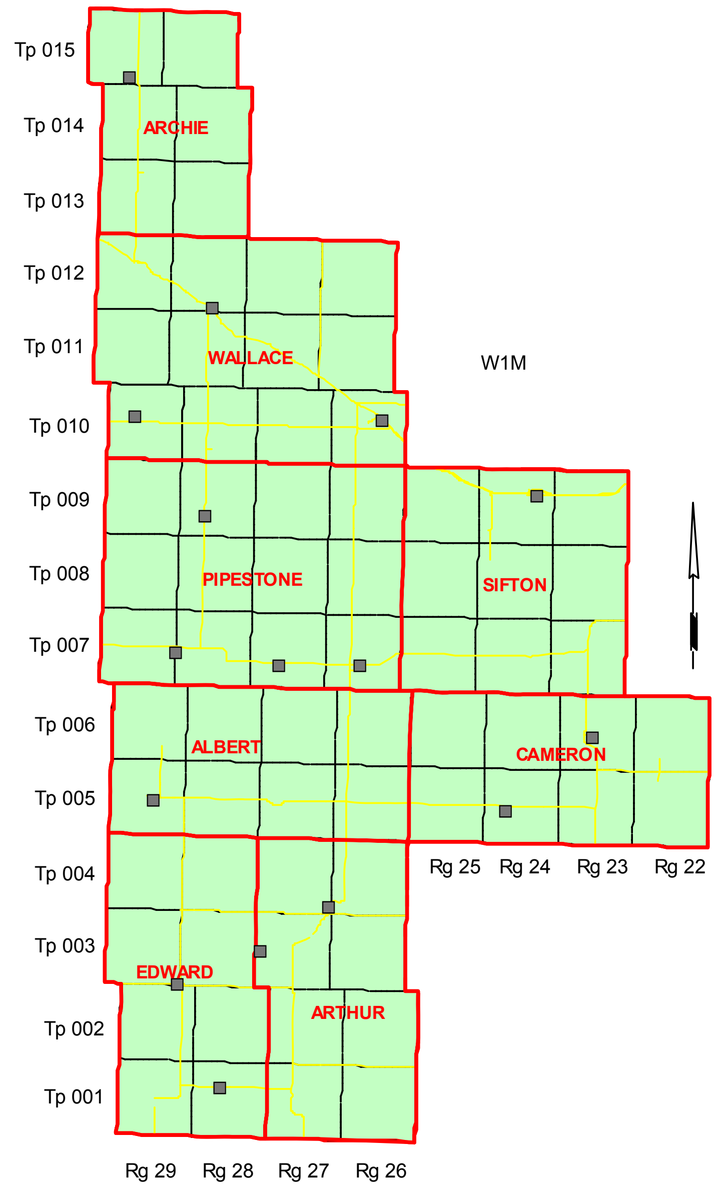

Figure 1. Rural Municipalities in Study Area

2.2 Climate

The Study Area lies within the humid, continental Dfb climate. 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.

This classification is based on potential evapotranspiration[4] values determined using the Thornthwaite method (Thornthwaite and Mather, 1957), combined with the distribution of natural ecoregions in the area. The ecoregions map (Manitoba Conservation Data Centre, 2001) shows that the Study Area is located in the Aspen Parkland region, a transition between boreal forest and grassland environments.

The mean annual precipitation averaged from two meteorological stations (Virden and Pierson) within the Study Area measured 453 millimetres (mm), based on data from 1971 to 2000. The annual temperature averaged 3.1° C, with the mean monthly temperature reaching a high of 19.2° C in July, and dropping to a low of -16.3° C in January (Environment Canada. http://www.climate.weatheroffice.ec.gc.ca/climate_normals/). The average annual potential evapotranspiration is 465 millimetres.

[4] See glossary

3 METHODOLOGY

3.1 Data Collection and Synthesis

The Province of Manitoba GW Drill database is the main source of groundwater data. The database includes the following information:

1) water well drilling reports
2) aquifer test results from some water wells.

Other groundwater data obtained include:

1) locations for some water wells determined during water well surveys
2) chemical analyses for some groundwaters (AAFC-PFRA[5]; and Betcher, 1983)
3) a variety of data related to the groundwater resource (as summarized in the original proposal).

The GW Drill database uses an area-land-based system without any 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 UTM coordinates for the centre of the land description.

The present project uses the UTM coordinate system based on the NAD83 datum. This means that a record for the NE ¼ of section 18, township 005, range 27, W1M would have a horizontal coordinate with an Easting of 347,657 metres and a Northing of 5,473,341 metres, depicting the centre of the quarter section. Once the horizontal coordinates are determined for a record, a ground elevation for that record gridded at 100-metre resolution is obtained from the Manitoba Geological Survey – Manitoba Industry, Economic Development and Mines.

At many locations within the Study Area, 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, it was assumed that 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 spelling errors in the database are corrected.

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

1) depth to bedrock
2) total thickness of sand and gravel below 15 metres
3) total thickness of saturated sand and gravel
4) depth to the top and bottom of completion intervals[6].

Also, where sufficient information is available, values for apparent transmissivity[7] and apparent yield[8] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. Where valid

[5] Chemical analysis data were provided by AAFC-PFRA to HCL and are mainly from field surveys conducted by the WSRCD in 2001, 2003 and 2004, and linked to a water well in the GW Drill database where possible. Chemical analysis data were not provided for townships 013 to 015 and ranges 26 to 29, W1M.
[6] See glossary
[7] For definitions of Transmissivity, see glossary
[8] For definitions of Yield, see glossary

detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity.

The hydrocarbon well database includes records for wells drilled for the oil and gas industry (GeoVista, Divestco Inc.). The information from this source includes:

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

Values for apparent transmissivity and apparent yield are calculated from the DST summaries. These data are used in the mapping of the parameter(s) associated with individual geologic units.

Published and unpublished reports and maps provide the final source of information that was included in the groundwater database. The reference section of this report lists the available reports. The only digital data from publications are from the Geological Atlas of the Western Canada Sedimentary Basin (Mossop and Shetsen, 1994). These data are used to support the geological interpretation of geophysical logs but cannot be distributed because of a licensing agreement.

3.2 Spatial Distribution of Geologic Units

Determination of the spatial distribution of the geologic units is based on:

1) 123 bedrock geologic formation tops provided by International Petrodata Limited
2) lithologs provided by the water well drillers
3) geophysical logs from structure test holes
4) geophysical logs for wells drilled by the oil and gas industry.

The geologic units 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[9] 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.

3.3 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 geologic unit in which individual water wells are completed. When the completion depth of a water well cannot be established, the data from that water well are not used in determining the distribution of hydraulic parameters.

After the water wells are assigned to a specific geologic unit, the parameters from the water well records are assigned to the individual geologic units. The parameters include non-pumping (static) water level (NPWL), apparent transmissivity, and apparent water well yield. The parameters are provided and calculated from data included on the water well drilling reports. The NPWL given on the water well record is usually the water level recorded when the water well was drilled, measured prior to the initial aquifer test. In areas where groundwater levels have since declined, the NPWL may now be lower and, accordingly, the potential apparent yield would be reduced. The total dissolved solids (TDS), sulfate, chloride, Nitrate + Nitrite (as N), fluoride and total hardness concentrations from the chemical analyses of the groundwaters are also assigned to applicable geologic units. Nitrate + Nitrite (as N) concentrations can often be attributed to physical conditions at or near the water well, and may not indicate general aquifer conditions.

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

Concentration in milligrams per litre unless otherwise stated
Note: indicated concentrations are for Aesthetic Objectives (AOs) except for Fluoride and Nitrate + Nitrite (as N), which are for Maximum Acceptable Concentrations (MACs)
SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality
Federal-Provincial-Territorial Committee on Drinking Water, March 2006

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

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[9] See glossary

After the values for the various parameters of the individual geologic units 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 for the present report included using the available data from the Study Area, plus a buffer area of at least 5,000 metres. Even when only limited data are available, grids are prepared. However, the grids prepared from the limited data must be used with extreme caution because the gridding process can be unreliable; for the maps, the areas with little or no data are identified.

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

3.4 Maps and Cross-Sections

After the 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.

After the appropriate grids are available, the maps are prepared by contouring the grids. Appendix A includes page-size maps from the text, plus additional page-size maps and figures that support the discussion in the text. A list of maps and figures that are included on the CD-ROM is given in Appendix B.

Water well records to be used on cross-sections are chosen from the GW Drill database, and where possible, have the following criteria: geo-referenced lithology; completion interval; and NPWL. Data from these water well control points are then placed in an AutoCAD drawing with an appropriate vertical exaggeration. Tops from individual geologic units are then transferred to the cross-section from the digitally prepared surfaces.

After the technical details of a cross-section have been finalized, the drawing file is moved to the software package CorelDraw! for simplification and presentation in a hard-copy form. Ten cross-sections are presented in Appendix A of this report and as poster-size drawings forwarded with this report; three (E-E’, I-I’ and J-J’) 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.

3.5 Software

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

- Acrobat 7.0
- AquaChem 3.7
- ArcView 3.2
- AutoCAD 2004
- CorelDraw! 12.0
- Grapher 3
- Microsoft Office 2003
- Surfer 8

4 BACKGROUND INFORMATION

4.1 Number, Type and Depth of Water Wells

In the Study Area, there are 4,089 records in the groundwater database. Of the 4,089 records, 3,869 are in the GW Drill database. The remaining 220 records of groundwater data were obtained from WSRCD field surveys, the Groundwater Availability Map Series for the Virden area (Betcher, 1983), and from groundwater investigations conducted by WaterMark Consulting Ltd. (January 2004).

Of these 4,089 records, 4,071 are classified as being records that are for water wells. The adjacent table provides a summary of the "type of work" making up the database records. Of the 4,071 water wells, there is a water use for 1,480 water wells; a water use is not given for the remaining 2,591 water wells. Of the 1,480 water wells, there are records for domestic (1,069), domestic/livestock (59) or livestock (203) purposes. The remaining 149 water wells were completed for municipal (102), industrial (4), investigation (2), irrigation (33) and other categories (8).

Type of Work	No. of Records
Water Well	4069
Water Test Hole	2
Piezometer	8
Water Test Hole - Abandoned	4
Bore Hole - Abandoned	6
Water Well Record	4071
Hydrogeological Data	18
Total Records	**4089**

Table 1. Groundwater Database Records

There are 953 reported domestic, domestic/livestock or livestock water wells with a completed depth, of which 787 (82%) are completed at depths of less than 20 metres below ground surface. Details for lithology[10] are available for 4,026 records.

4.2 Number of Surficial and Bedrock Water Wells

There are 1,463 water wells with sufficient completion interval and lithologic information to identify the geologic unit in which the water wells are completed. The water wells that were not drilled deep enough to encounter the bedrock and water wells that have the bottom of their completion interval above the top of the bedrock are completed in surficial deposits. Of the 1,463 water wells for which geologic units could be defined, 1,375 are completed in surficial deposits, with 1,172 (85%) having a completion depth of less than 20 metres below ground surface. The adjacent map shows that the water wells completed in the surficial deposits occur throughout the Study Area.

The data for 88 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 unit, with 68 (77%) having a completion depth of greater than 20 metres. From Figure 2 (also see page A-7), it can be seen that water wells completed in bedrock mainly occur in the northern and southeastern parts of the Study Area.

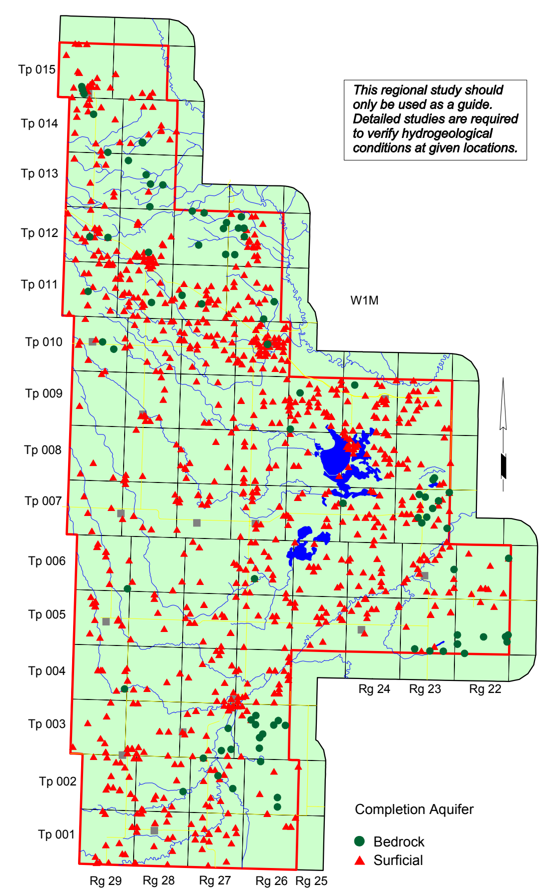


Figure 2. Locations of Surficial and Bedrock Water Wells

[10] See glossary

4.3 Casing Diameter and Type

Data for casing diameters are available for 1,363 water wells, with 856 (63%) indicated as having a diameter of less than 275 mm and 507 (37%) having a diameter of more than 275 mm. Water wells with casing diameters that exceed 275 mm are mainly bored, hand dug, or dug by backhoe and those with a surface-casing diameter of less than 275 mm are mainly drilled (see page A-6).

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. Within the Study Area, casing-diameter information is available for 1,153 of the 1,375 water wells completed in surficial deposits, of which 748 surficial water wells have a casing diameter of less than 275 millimetres and are assumed to be drilled water wells. Within the Study Area, casing-diameter information is available for 64 of the 88 water wells completed below the top of bedrock, of which 51 have a surface-casing diameter of less than 275 mm.

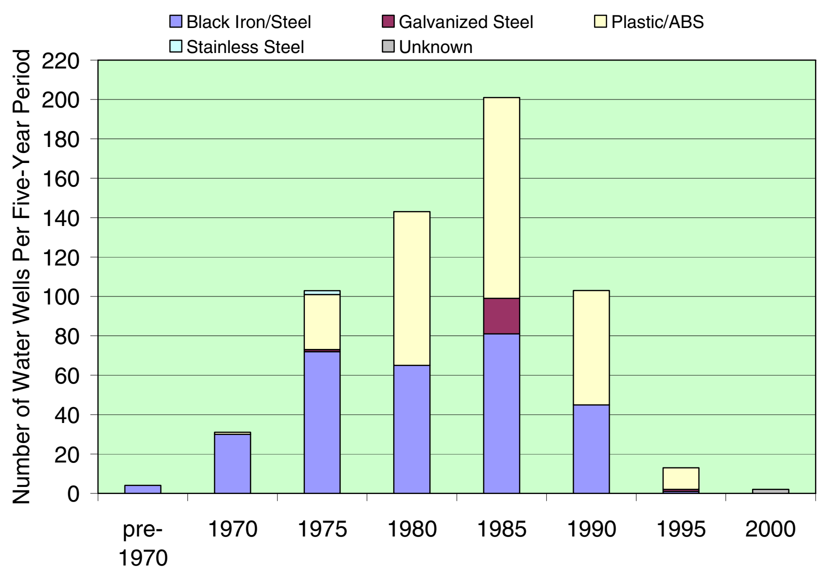


Figure 3. Surface Casing Types Used in Drilled Water Wells

Where the casing material is known, black iron/steel surface casing materials have been used in 58% of the drilled water wells over the last 35 years. For the remaining drilled water wells with known surface casing material, 40% were completed with plastic/ABS casing, and two percent were completed with galvanized steel casing. The type of surface casing in drilled water wells since 2000 has not been recorded in the GW Drill database. The use of steel surface casing averaged nearly 90% until the mid-1970s, at which time plastic casing started to replace the use of black iron/steel casing. Plastic/ABS casing was first used in March 1977, and was used in 85% of the water wells drilled between 1995 and 1999 in the Study Area. Galvanized steel surface casing in drilled water wells was first used in the Study Area in October 1977 and was used in eight percent of the drilled water wells from 1995 to 1999.

4.4 Requirements for Licensing

After 1972, with some exemptions, a diversion of groundwater required a licence. The diversion of up to 25,000 litres per day (approximately 5,500 imperial gallons per day[11]) for household use is exempt from the need for a licence under *The Water Rights Act*.

In the 2004 update from the *Water Rights* licensed well database, 30 groundwater licences are shown to have been approved within the Study Area, with the most recent groundwater user being registered in September 2004. An additional 25 applications are either "waiting for assessment" or the "assessment is underway" according to the Manitoba Water Stewardship (MWS). Of the 30 groundwater licences, 12 are for agricultural purposes (mainly stock watering), ten are for irrigation purposes, seven are for municipal purposes (mainly urban), and the remaining one is for domestic purposes. Of these 30 licensed groundwater diversions in the Study Area, 22 (73%) could be linked to a water well in the Manitoba Conservation (GW Drill) database, based only on legal description and water well owner. Although the name of the licensee and the water well locations are recorded by MWS, the water well completion data are not available. Without water well completion data, a more confident link to a water well in the GW Drill database is not possible.

The maximum amount of groundwater that can be diverted each year from the water wells associated with these licences is 6,568 m³/day, although actual use could be less. Of the 6,568 m³/day, 645 m³/day (10%) is licensed for agricultural purposes, 135 (2%) is licensed for domestic purposes, 4,513 (69%) is licensed for irrigation purposes, and 1,276 (19%) is licensed for municipal purposes, as shown below in Table 2. A figure showing the locations of the groundwater users with a licence is in Appendix A (see page A-8) and on the CD-ROM. Table 2 also shows a breakdown of the 30 groundwater licences by the geologic unit in which the water well is completed. Sixty-six percent of the total quantity of licensed groundwater use is from the Oak Lake deposits. The water wells associated with the eight licensed groundwater users where a specific geologic unit cannot be determined is because a corresponding link to a water well in the GW Drill database could not be determined without considerable effort.

Geologic Unit **	No. of Approved Licences	Licensed Groundwater Use* (m³/day) Domestic	Agricultural	Irrigation	Municipal	Total Licensed Groundwater Diversion (m³/day)	Percentage of Total Diversion
Multiple Surficial Completions	2	0	176	0	0	176	3
Alluvium	1	0	33	0	0	33	1
Oak Lake	12	0	169	3,504	693	4,367	66
Meltwater	0	0	0	0	0	0	0
Glacial Drift	7	0	153	0	144	297	5
Lower Surficial	0	0	0	0	0	0	0
Unclassified	8	135	114	1,008	438	1,696	26
Total	30	135	645	4,513	1,276	6,568	100
Percentage of Total Diversion[(1)]		2.1	9.8	68.7	19.4	100	

* - data from MWS ** - Geologic unit identified by HCL

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

Table 2. Licensed Groundwater Diversions

[11] see conversion table on page 41

Based on the 2001 Agriculture Census (Statistics Canada), the calculated water requirement for 251,240 livestock for the Study Area is in the order of 8,975 m³/day. This number includes intensive livestock use but not domestic animals and is based on an estimate of water use per livestock type. Of the 8,975 m³/day calculated for livestock use, MWS has authorized a groundwater diversion of 780 m³/day (9%) (645 m³/day for agricultural and 135 m³/day for domestic) but has not licensed any surface-water diversion for stock use in the Study Area. In this report, groundwater used for agricultural purposes includes groundwater diverted for stockwatering (free-ranging livestock) and feedlot (confined livestock) use.

Livestock Type [1]	Number	Estimated Water Requirement [2] (l/day)	Total Estimated Water Requirement (m³/day)
Total hens and chickens	27,896	0.2	6
Turkeys	459	0.7	0
Other poultry	1,970	0.2	0
Total cattle and calves	133,133	55	7,263
Total pigs	75,913	18	1,380
Total sheep and lambs	5,625	9	51
Horses and ponies	5,995	45	273
Goats	219	9	2
Rabbits	0	1	0
Mink	0	1	0
Fox	0	1	0
Bison	0	45	0
Deer and elk	0	16	0
Llamas and alpacas	30	9	0
Totals	251,240		8,975

(1) 2001 Agriculture Census
(2) based on Alberta Agriculta Food and Rural Development
Average Daily and Annual Water Requirements

Table 3. Estimated Water Requirement for Livestock in the Study Area

The remaining 8,195 m³/day (91%) of the calculated water requirement for livestock use could come from surface water or unlicensed groundwater sources. The discrepancy may be partially accounted for in several ways. Estimations for water requirements for livestock tend to be high. For example, some livestock water requirements would be made up from free-standing water, dugout storage and creeks following precipitation events, thus reducing the expected quantity needed. Also, it should be noted that 'domestic use', as defined in *The Water Rights Act*, can provide sufficient water for approximately 450 head of cattle, with no need for a licence.

Proper management of the groundwater resource requires water-level data. These data are often collected from monitoring water wells. At the present time, there are 78 Manitoba Water Resources Branch (WRB) monitoring wells that are active within the West Souris River Conservation District boundary (see page A-47 for the monitoring water well locations). 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; however, this has numerous implications with respect to data entry, collection and ownership.

5 TERMS

<table>
<tr><th></th><th colspan="4">Group and Formation</th><th colspan="3">Geologic Unit</th></tr>
<tr><th>Lithologic Description</th><th>Average Thickness (m)</th><th colspan="3">Designation</th><th>Average Thickness (m)</th><th>Depositional Environment</th><th>Material</th></tr>
<tr><td rowspan="5">sand, gravel, till, clay, silt</td><td rowspan="5">< 150</td><td colspan="3" rowspan="5">Surficial Deposits</td><td><30</td><td>Alluvium</td><td>Sand or Gravel</td></tr>
<tr><td><30</td><td>Oak Lake</td><td>Sand</td></tr>
<tr><td><25</td><td>Meltwater</td><td>Sand or Gravel</td></tr>
<tr><td><150</td><td>Glacial Drift</td><td>Gravel, Sand, Silt, Clay or Till</td></tr>
<tr><td><70</td><td>Lower Surficial Deposits</td><td>Sand or Gravel</td></tr>
<tr><td rowspan="4">shale, bentonite</td><td rowspan="4">120 to 335</td><td rowspan="4">Pierre Shale</td><td rowspan="4">Alberta/Saskatchewan Equivalents</td><td>Belly River Group</td><td>150</td><td colspan="2">Odanah Member</td></tr>
<tr><td rowspan="2">Lea Park Formation</td><td>15 to 150</td><td colspan="2">Millwood Member</td></tr>
<tr><td>2 to 12</td><td colspan="2">Pembina Member</td></tr>
<tr><td>Milk River Fomation</td><td>5 to 50</td><td colspan="2">Gammon Member</td></tr>
</table>

Figure 4. Geologic Column

(for larger version, see page A-9)

6 AQUIFERS

6.1 Background

An aquifer is a permeable geologic unit[12] that is saturated. In this context, "geologic" refers to subsurface materials, such as sand, gravel, sandstone and coal. Aquifers occur in one of two general geological settings in the Study Area. 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 bedrock. If the NPWL is above the top of the geologic unit, this type of aquifer is a confined or artesian aquifer. If the geologic unit is not entirely saturated and the water level is below the top of the geologic unit, this type of aquifer is a water-table aquifer. 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.

6.2 Surficial Deposits – Geological Characteristics

The surficial deposits are the sediments above the bedrock surface. While the surficial deposits are treated as one hydrogeologic unit[13], they consist of several hydraulic units[14].

For the present study, the surficial deposits have been assigned to five different groupings in the Study Area. The designations of the five groupings, from oldest to youngest, are: (a) Lower Surficial, (b) Glacial Drift, (c) Meltwater, (d) Oak Lake, and (e) Alluvium; sand or gravel deposits can be associated with any of the five groupings. The Lower Surficial deposits are associated with significant linear bedrock lows; sand or gravel deposits within the Lower Surficial deposits are generally saturated and continuous, though exceptions are not uncommon. Sand or gravel deposits associated with the Glacial Drift are expected to occur as pockets and may not always be saturated. Sand or gravel deposits associated with Meltwater and Alluvium may not be continuous and may not always be saturated. The Oak Lake deposits are present over a large area, but the sand or gravel deposits are not saturated everywhere.

Where sand or gravel deposits are not saturated, they technically are not an aquifer. However, the non-saturated sand or gravel deposits can provide a pathway for soluble contaminants to move downward into groundwater.

The base of the surficial deposits is the bedrock surface, represented by the bedrock surface topography as shown on Figure 5 and on page A-23. Regionally, the bedrock surface varies between 320 and 500 metres AMSL. The lowest elevations occur in the buried bedrock valleys.

Over the majority of the Study Area, the surficial deposits are less than 60 metres thick (see CD-ROM). The exceptions are mainly in association with areas where buried bedrock valleys are present, and in the west-central part of the Study Area, where the deposits can have a thickness of more than 100 metres.

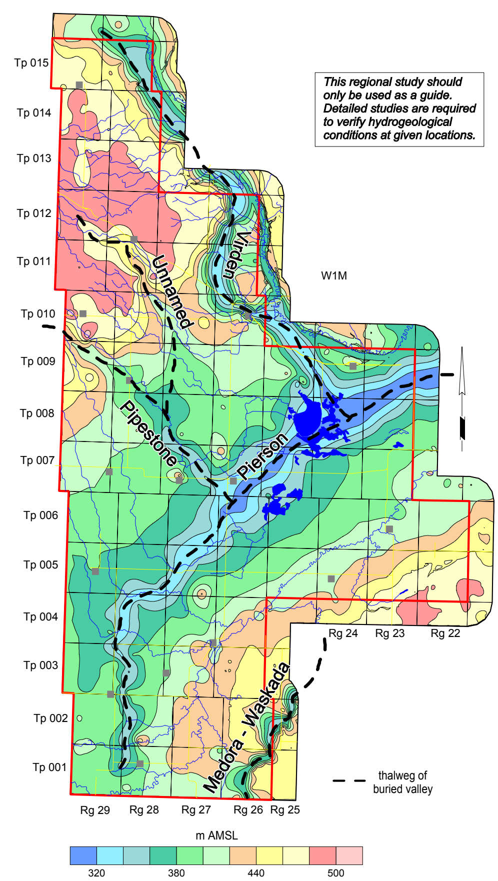
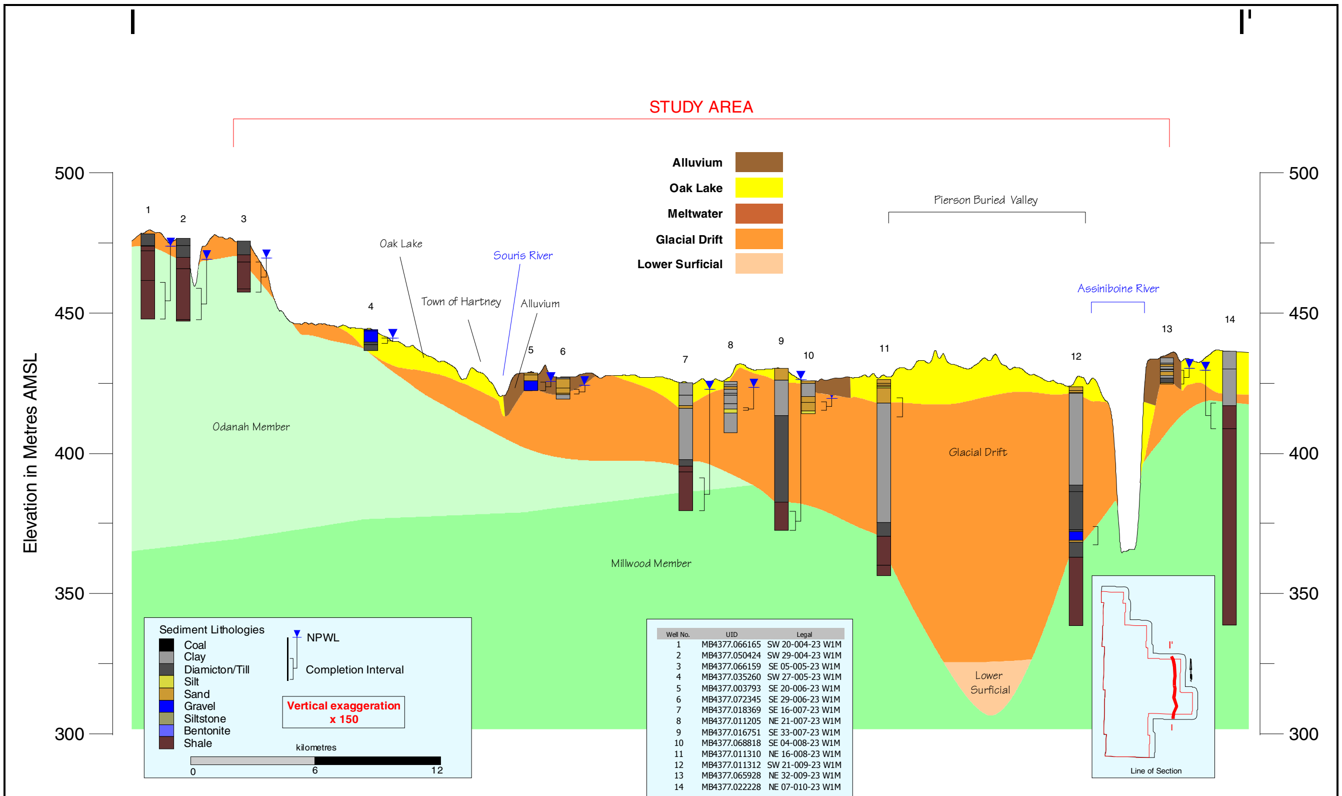


Figure 5. Bedrock Surface Topography

12 See glossary
13 See glossary
14 See glossary

6.2.1 Buried Valleys

The Pierson Buried Valley is the widest buried valley in the Study Area. The Pierson Buried Valley trends in a southwest-northeasterly direction from the provincial border in township 001, range 29, W1M to township 009, range 22, W1M. The Valley ranges from approximately four to nine kilometres wide, with local bedrock relief being mainly less than 75 metres. The lower surficial deposits, where present, overlie the bedrock surface in the Pierson Buried Valley, and are expected to be mainly less than 20 metres thick, as shown below on cross-section I-I'.



Well No.	UID	Legal
1	MB4377.066165	SW 20-004-23 W1M
2	MB4377.050424	SW 29-004-23 W1M
3	MB4377.066159	SE 05-005-23 W1M
4	MB4377.035260	SW 27-005-23 W1M
5	MB4377.003793	SE 20-006-23 W1M
6	MB4377.072345	SE 29-006-23 W1M
7	MB4377.018369	SE 16-007-23 W1M
8	MB4377.011205	NE 21-007-23 W1M
9	MB4377.016751	SE 33-007-23 W1M
10	MB4377.068818	SE 04-008-23 W1M
11	MB4377.011310	NE 16-008-23 W1M
12	MB4377.011312	SW 21-009-23 W1M
13	MB4377.065928	NE 32-009-23 W1M
14	MB4377.022228	NE 07-010-23 W1M

Figure 6. Cross-Section I - I'
(for larger version, see page A-20)

The Virden Buried Valley enters the Study Area from township 015, range 28, W1M and trends southeasterly to join the Pierson Buried Valley in township 008, range 24, W1M. The Virden Buried Valley is approximately three kilometres wide, with local bedrock relief being mainly less than 100 metres. The lower surficial deposits, where present, overlie the bedrock surface in the Virden Buried Valley, and are expected to be mainly less than 50 metres thick, as shown below on cross-section E - E'.

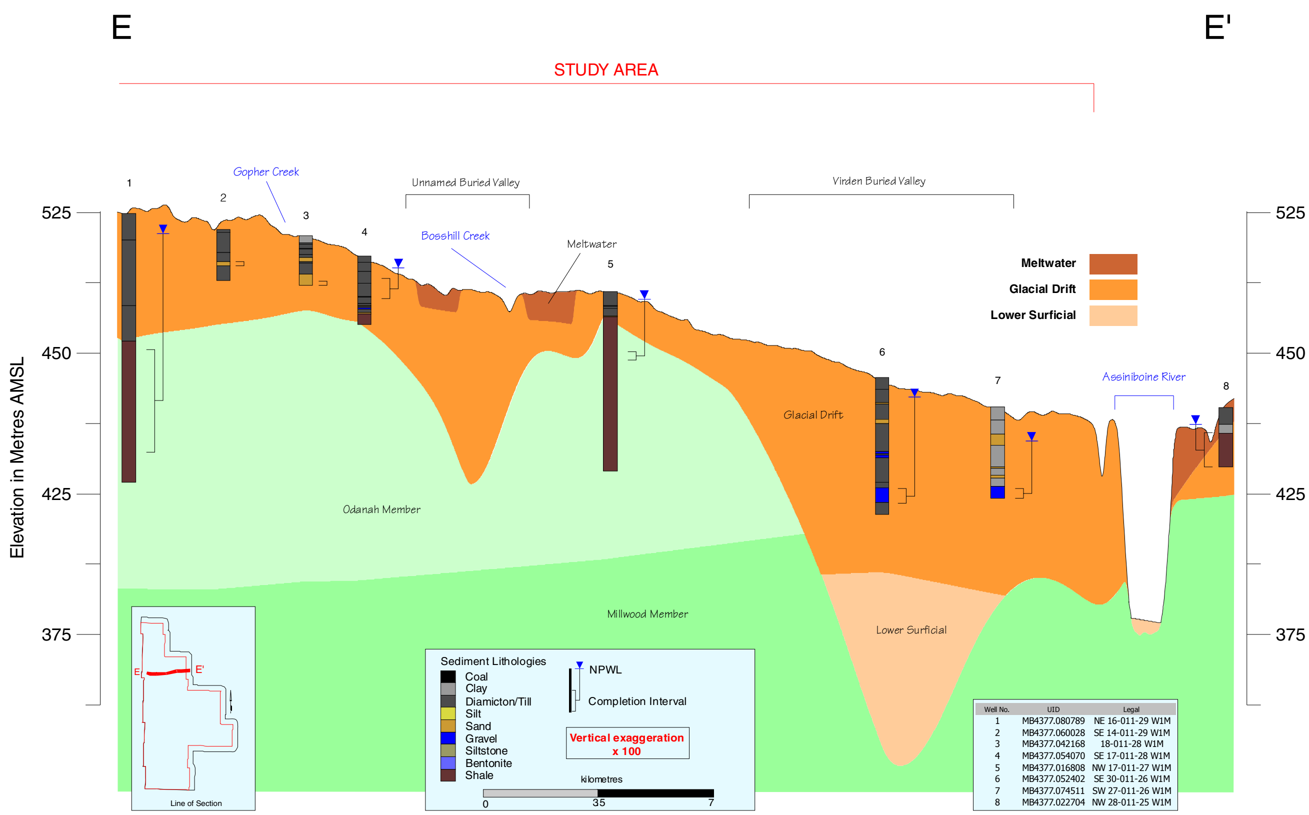


Figure 7. Cross-Section E – E'
(for larger version, see page A-15)

The Pipestone Buried Valley enters the Study Area from township 010, range 29, W1M and trends southeasterly to join the Pierson Buried Valley in township 006, range 26, W1M. The Pipestone Buried Valley is approximately two kilometres wide, with local bedrock relief being mainly less than 40 metres. The lower surficial deposits, where present, overlie the bedrock surface in the Pipestone Buried Valley, and are expected to be less than ten metres thick.

An unnamed buried valley is mainly less than two kilometres wide, with local bedrock relief being less than 30 metres, and is a tributary to the Pipestone Buried Valley. Lower surficial deposits are not expected to overlie the bedrock surface in the unnamed buried valley, as shown above in cross-section E – E'.

The Medora-Waskada Buried Valley trends in a southwest-northeasterly direction from the United States border in township 001, range 26, W1M and leaves the Study Area in township 003, range 25, W1M. There are insufficient data to determine the extent of the Medora-Waskada Buried Valley. The Medora-Waskada Buried Valley is less than two kilometres wide, with local bedrock relief being mainly less than 100 metres. The lower surficial deposits, where present, overlie the bedrock surface in the Medora-Waskada Buried Valley, and are expected to be less than 20 metres thick.

6.2.2 Surficial Stratigraphy

The surficial deposits are those sediments that are between the bedrock surface and ground level (see Section 6.2). For the present study, the surficial deposits have been assigned to five different groupings in the Study Area. The designations of the five groupings, from oldest to youngest, are: (a) Lower Surficial, (b) Glacial Drift, (c) Meltwater, (d) Oak Lake, and (e) Alluvium. A generalized geologic column (Figure 4) shows the surficial deposits and bedrock units, and is also in Appendix A (page A-9) and on the CD-ROM. The adjacent map shows the distribution of the various surficial deposits at ground level.

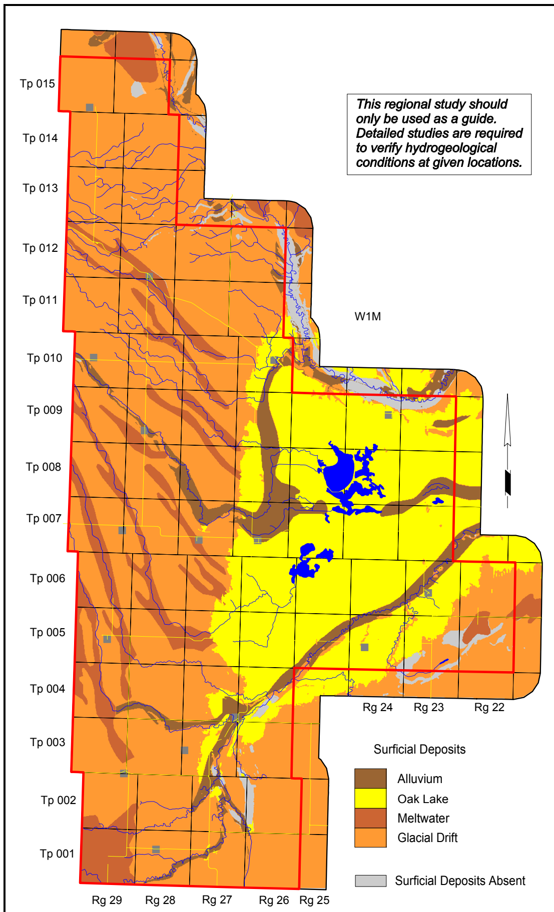


Figure 8. Surficial Deposits at Ground Level

The Lower Surficial deposits, the oldest of the surficial deposits, include water-sorted gravel, sand, silt and/or clay deposited on or near the bedrock surface. These deposits are associated with the thalwegs of major linear bedrock lows including the Buried Medora-Waskada, the Pierson Buried Valley and the Virden Buried Valley. The Lower Surficial deposits are generally less than 50 metres thick, with the top of the deposits being the base of the first Glacial Drift overlying the water-sorted deposits and usually occurring below an elevation of 520 metres AMSL; the Lower Surficial deposits are not present at ground level in the Study Area.

The top of the Glacial Drift can be the ground surface, the base of the Meltwater deposits, the base of the Oak Lake deposits, or the base of the Alluvium deposits. The base of the Glacial Drift can be the Lower Surficial deposits or the bedrock surface.

The Meltwater deposits are considered to be stratigraphically younger than the Glacial Drift and to be water-sorted deposits consisting of gravel, sand, silt or clay. The horizontal extent of the Meltwater deposits was determined from a soils map obtained from Manitoba Land Initiative (http://web2.gov.mb.ca/mli/.) The top of the Meltwater deposits for the most part is ground level. However, the Meltwater deposits can occur beneath the Oak Lake and the Alluvium deposits. The thickness of the Meltwater deposits was obtained by identifying groundwater records within the horizontal extents of the Meltwater deposits and selecting the base of the deepest water-sorted deposit above a depth of 10.7 metres. Once the control points had been selected and converted to an elevation in metres AMSL, the values were gridded to provide a spatial base for the Meltwater deposits.

The Oak Lake deposits are water-sorted sediments of deltaic/lacustrine origin and occur below an elevation of 450 metres AMSL. Their extent has been determined from groundwater records that show water-sorted sediments on the ground surface that are not associated with Meltwater or Alluvium deposits and occur below an elevation of 450 metres AMSL. The base of the Oak Lake deposits is the top of the first occurrence of Glacial Drift or the bedrock surface. Once the control points were selected and converted to an elevation in metres AMSL, the values were gridded to provide a spatial base for the Oak Lake deposits.

The Alluvium deposits are a water-sorted sediment that is considered to be the most recent of the surficial deposits. The thickness of the Alluvium deposits was obtained by identifying groundwater records within the horizontal extents of the Alluvium deposits as identified on the soils map and selecting the base of the deepest water-sorted deposit above a depth of 10.7 metres. Once the control points had been selected and converted to an elevation in metres AMSL, the values were gridded to provide a spatial base for the Alluvium deposits.

6.2.3 Water Wells Completed in Surficial Deposits

Of the 4,071 water wells in the database, 1,375 were defined as being completed in surficial deposits, based on lithologic information and water well completion details.

From the present hydrogeological analysis, 3,560 water wells are completed into surficial deposits. This number of water wells (3,560) is 2.6 times the number (1,375) determined to be completed in surficial deposits, based on lithologies given on the water well drilling reports. The larger number is obtained by comparing the elevation of the reported depth of a water well to the elevation of the bedrock surface at the same location. For example, if only the depth of a water well is known, the elevation of the completed depth can be calculated. If the elevation of the completed depth is above the elevation of the bedrock surface determined from the gridded bedrock topographic surface at the same location, then the water well is considered to be completed in surficial deposits.

Of the 3,560 water wells, 2,895 are completed in a specific geologic unit, and 665 water wells are completed in multiple surficial units. A breakdown of the number of water wells completed in a specific surficial geologic unit is shown on the adjacent table.

Geologic Unit	No. of Surficial Water Wells
Alluvium	54
Oak Lake	278
Meltwater	63
Glacial Drift	2,476
Lower Surficial Deposits	24
Total	2,895
Multiple Surficial Completions	665
Total	3,560

Table 4. Water Well Completion

6.2.4 Sand or Gravel Deposits

The primary sources of groundwater in the Study Area are the sand or gravel deposits in the surficial materials. The permeability of aquifers in the upper surficial deposits can be high. The high permeability combined with significant thickness leads to an extrapolation of high yields for water wells; however, because the sand or gravel deposits occur mainly as hydraulically discontinuous pockets, the long-term yields[15] of the water wells are expected to be less than the apparent yields.

Where the aquifers in the upper surficial deposits are absent or where the yields are low, the shallow surficial deposits can be more susceptible to drought, and the development of water wells for the domestic needs of single families may not be possible from these aquifers. Construction of a water supply well into the underlying bedrock may be the only alternative, provided that yields and quality of groundwater from the bedrock aquifers are suitable.

In the Study Area, there are 638 records for surficial water wells with apparent yield data, which is 18% of the 3,560 surficial water wells. Of the 638 records for surficial water wells, 63% have been assigned to water wells completed into Glacial Drift, 25% to water wells completed into multiple surficial units, 8% to water wells completed into the Oak Lake deposits, and the remaining 4% to water wells completed into the Meltwater, Alluvium and Lower Surficial deposits.

Geologic Unit	No. of Water Wells with Values for Apparent Yield	Number of Water Wells with Apparent Yields <10 m³/day	10 to 100 m³/day	100 to 300 m³/day	>300 m³/day
Multiple Completions	161	45	59	28	29
Alluvium	9	4	3	1	1
Oak Lake	51	5	21	13	12
Meltwater	11	2	6	2	1
Glacial Drift	404	98	159	74	73
Lower Surficial	2	0	0	0	2
Totals	638	154	248	118	118

Table 5. Apparent Yields of Water Wells Completed in Surficial Deposits

15 See glossary

One hundred and fifty-four (24%) of the 638 water wells completed in surficial deposits have apparent yield values that are less than ten m³/day, 248 (39%) have apparent yield values that range from 10 to 100 m³/day, 118 (18.5%) have apparent yield values that range from 100 to 300 m³/day, and 118 (18.5%) have apparent yields that are greater than 300 m³/day.

Apparent yields for water wells completed in the surficial deposits vary with location and with depth in the Study Area. As Figure 9 shows, most apparent yields are less than 100 m³/day and the majority of the water wells completed in the surficial deposits are less than 20 metres deep.

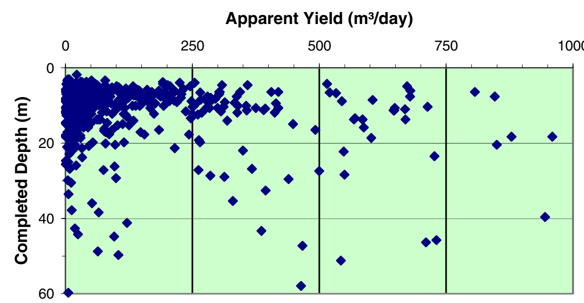


Figure 9. Yields vs Completed Depth

6.2.4.1 Chemical Quality of Groundwater from Surficial Deposits

Groundwaters from an aquifer in the surficial deposits can be expected to be chemically hard, with a total hardness of at least a few hundred mg/L, and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Forty percent of the groundwaters from the surficial deposits are reported to have dissolved iron concentrations that exceed the aesthetic objective (AO) of 0.3 mg/L. However, many iron analyses results are questionable due to varying sampling and analytical methodologies.

The Piper tri-linear diagram[16] for the surficial deposits (see page A-40) shows that the groundwaters from the surficial deposits are mainly a calcium-magnesium-bicarbonate or calcium-magnesium-sulfate type. More than 65% of the groundwaters from the surficial deposits have a TDS concentration that exceeds 500 mg/L.

In some areas where water wells are completed in surficial deposits, sulfate is the major anion[17]. The groundwaters with elevated levels of sulfate generally occur in areas where there are elevated levels of total dissolved solids. There are very few groundwaters from the surficial deposits with appreciable concentrations of the chloride ion; in more than 80% of the samples analyzed for the Study Area, the chloride ion concentration is less than 100 mg/L (see CD-ROM). In the Study Area, the Nitrate + Nitrite (as N) concentrations in the groundwaters from the surficial deposits exceed the maximum acceptable concentrations (MACs) of ten mg/L in 28 of the 132 groundwater samples analyzed (see CD-ROM).

The minimum, maximum and median[18] concentrations of TDS, sodium, sulfate, chloride and Nitrate + Nitrite (as N) in the groundwaters from water wells completed in the surficial deposits in the Study Area have been compared to the Summary of Guidelines for Canadian Drinking Water Quality (SGCDWQ) in the adjacent table. The range of concentrations shown in Table 6 is from values in the groundwater database; however, the extreme minimum and maximum concentrations generally represent less than 0.2% of the total number of analyses and should have little effect on the median values. These extreme values are not used in the preparation of the figures. Of the five constituents that have been compared to the SGCDWQ, median concentrations of TDS exceed the guidelines.

Constituent	No. of Analyses	Range for Study Area in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	163	3	4,760	642	500
Sodium	208	0	1,100	30	200
Sulfate	174	7	2,450	133	500
Chloride	208	1	1,660	24	250
Nitrate + Nitrite (as N)	132	<0.01	176	2	10

Note: indicated concentrations are for Aesthetic Objectives except for Nitrate + Nitrite (as N), which is for Maximum Acceptable Concentration (MAC)

SGCDWQ - Summary of Guidelines for Canadian Drinking Water Quality Federal-Provincial-Territorial Committee on Drinking Water, March 2006

Table 6. Concentrations of Constituents in Groundwaters from Surficial Deposits

16 See glossary
17 See glossary
18 See glossary

6.2.5 Alluvium Deposits

The Alluvium deposits are water-sorted sediments that are considered to be the most recent of the surficial deposits, with a thickness that is mainly less than 15 metres. The structure contours show that the top of the Alluvium deposits ranges in elevation from 380 to 500 metres AMSL (see CD-ROM). The regional groundwater flow direction in the Alluvium deposits is mainly downgradient to the southeast and northeast toward the Souris River basin (see CD-ROM).

6.2.5.1 Depth to Top

The Alluvium deposits, where present, lie at the surface.

6.2.5.2 Apparent Yield

The apparent yields for nine water wells completed into the Alluvium deposits range from 1.6 m³/day to 124 m³/day, with nearly 80% of the values being less than 50 m³/day (Table 5). Most of the water wells with values are in the southern four townships of the Study Area, as shown in the adjacent figure.

In the Study Area, there is one licensed water wellscompleted into the Alluvium deposits, with a total authorized diversion of 32.9 m³/day; this water well is in NW 25-001-26 W1M and is used for agricultural purposes.

6.2.5.3 Quality

There is sufficient data from one water well completed into the Alluvium deposits to determine the groundwater type (calcium, magnesium, sodium, potassium, bicarbonate, sulfate and chloride). The groundwater from the water well, in NE 09-007-26 W1M, is a calcium-magnesium-bicarbonate type. The water well in NE 09-007-26 W1M has a TDS concentration of 320 mg/L, a sulfate concentration of 44 mg/L, and a chloride concentration of 5 mg/L.

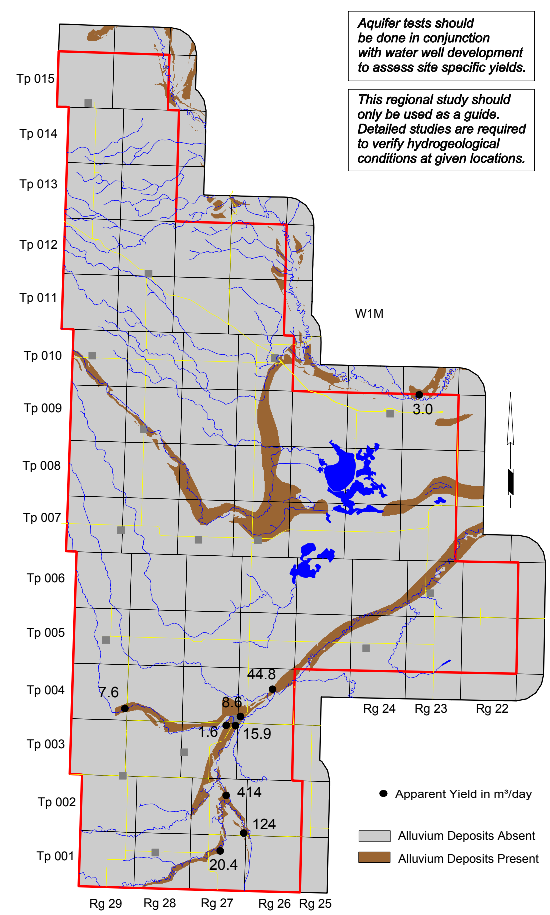


Figure 10. Apparent Yield for Water Wells Completed into Alluvium Deposits

6.2.6 Oak Lake Deposits

The Oak Lake deposits are water-sorted sediments of deltaic/lacustrine origin that occur below an elevation of 450 metres AMSL, and have a thickness that is mainly less than 30 metres. The structure contours show that the base of the Oak Lake deposits ranges in elevation from 400 to 450 metres AMSL (see CD-ROM). The regional groundwater flow direction in the Oak Lake deposits is mainly downgradient to the northwest and east toward the Souris River basin (see CD-ROM).

6.2.6.1 Depth to Top

The depth to the top of the Oak Lake deposits ranges from ground surface to 20 metres (see page A-27). The depth to the top of the Oak Lake deposits is based on the grid for the top of the Oak Lake deposits.

6.2.6.2 Apparent Yield

The apparent yields for 51 water wells completed into the Oak Lake deposits range from less than ten m³/day to more than 300 m³/day, with nearly than 50% of the values being more than 100 m³/day (Table 5).

In the Study Area, there are 12 licensed water wells completed through the Oak Lake deposits, with a total authorized diversion of 4,367 m³/day; the highest allocation is 1,493 m³/day for a water well in NW 30-005-25 W1M used for irrigation purposes.

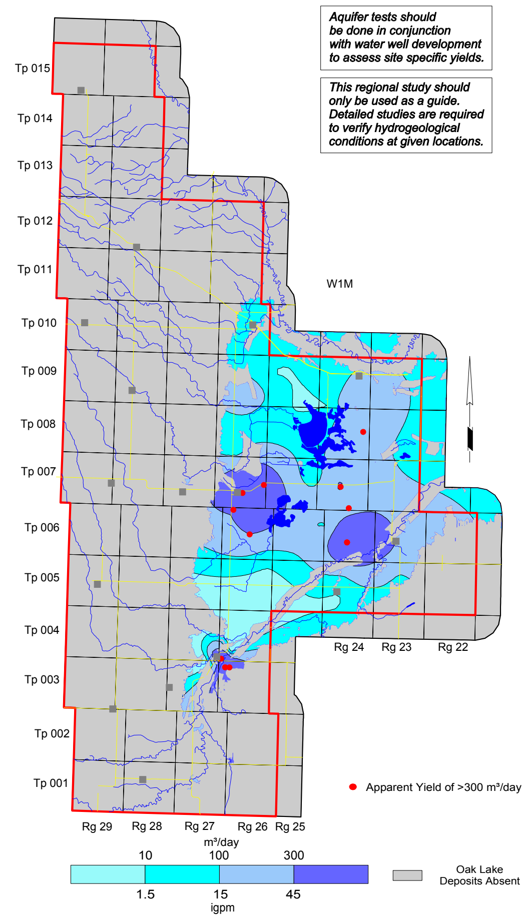


Figure 11. Apparent Yield for Water Wells Completed into Oak Lake Deposits

6.2.6.3 Quality

The groundwaters from the Oak Lake deposits are a calcium-magnesium-bicarbonate type (see Piper diagram on page A-40, and on the 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 into the Oak Lake deposits in the Study Area have been compared to the SGCDWQ and median concentrations from all surficial deposits in Table 7. Of the five constituents that have been compared to the SGCDWQ, none exceed the guidelines.

The median concentrations from water wells completed in the Oak Lake deposits are below the median concentrations for water wells completed in all surficial deposits.

Constituent	No. of Analyses	Range for Study Area in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	13	320	3,714	419	642	500
Sodium	17	2	106	10	30	200
Sulfate	16	<10	425	71	133	500
Chloride	17	2	111	9	24	250
Nitrate + Nitrite (as N)	7	0	14	<0.05	2	10

Table 7. Concentrations of Constituents in Groundwaters from Oak Lake Deposits

6.2.7 Meltwater Deposits

The Meltwater deposits are considered to be stratigraphically younger than the Glacial Drift and to be water-sorted deposits consisting of gravel, sand, silt or clay. Structure contours have been prepared for the top of the Meltwater deposits. The structure contours show that the Meltwater deposits range in elevation from below 460 to above 540 metres AMSL and have a thickness of mainly less than 15 metres (see CD-ROM). The regional groundwater flow direction in the Meltwater deposits is mainly downgradient southeast toward the Souris River basin (see CD-ROM).

6.2.7.1 Depth to Top

The depth to the top of the Meltwater deposits, where present, is mainly at ground surface in the western parts of the Study Area (see page A-31).

6.2.7.2 Apparent Yield

The apparent yields for 11 water wells completed into the Meltwater deposits range from less than ten m³/day to more than 300 m³/day, with nearly 75% of the values being less than 100 m³/day (Table 5).

In the Study Area, there are no licensed water wells that are completed into the Meltwater deposits.

6.2.7.3 Quality

There is sufficient data from one water well to determine the groundwater type. The groundwater from the water well in SW 13-005-29 W1M is a calcium-magnesium-type, with no dominant anion. The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and Nitrate + Nitrite (as N) in the groundwaters from water wells completed into the Meltwater deposits in the Study Area have been compared to the SGCDWQ and median concentrations from all surficial deposits in Table 8. Of the five constituents that have been compared to the SGCDWQ, the median value of TDS exceeds the guidelines. The median concentrations of TDS and sulfate from water wells completed into the Meltwater deposits are greater than the median concentrations for water wells completed in all surficial deposits.

Constituent	No. of Analyses	Range for Study Area in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	4	742	2,328	928	642	500
Sodium	6	0	43	8	30	200
Sulfate	5	<10	341	221	133	500
Chloride	5	<10	25	10	24	250
Nitrate + Nitrite (as N)	4	<0.01	3	1	2	10

Table 8. Concentrations of Constituents in Groundwaters from Meltwater Deposits

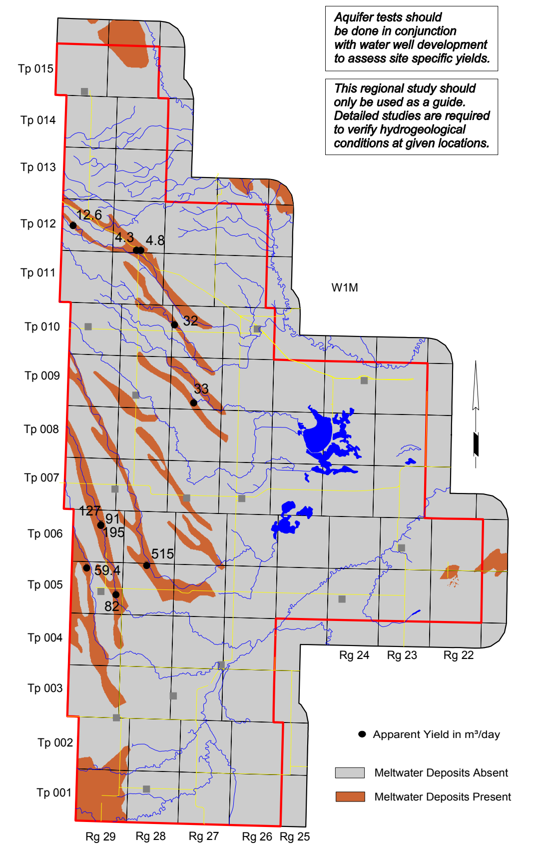


Figure 12. Apparent Yield for Water Wells Completed into Meltwater Deposits

6.2.8 Glacial Drift Deposits

The top of the Glacial Drift can be the ground surface, the base of the Meltwater deposits, the base of the Oak Lake deposits, or the base of the Alluvium deposits. The base of the Glacial Drift can be the Lower Surficial Deposits or the bedrock surface. Structure contours have been prepared for the top of the Glacial Drift deposits. The structure contours show that the Glacial Drift deposits range in elevation from below 400 to above 540 metres AMSL and have a thickness of mainly less than 150 metres (see CD-ROM). The regional groundwater flow direction in the Glacial Drift deposits is mainly downgradient to the northeast toward the Assiniboine River, and to the southeast and northwest toward the Souris River basin (see CD-ROM).

6.2.8.1 Depth to Top

In the Study Area, the depth to the top of the Glacial Drift deposits ranges from less than two metres below ground level to more than 15 metres where the Glacial Drift deposits underlie the Oak Lake deposits (see page A-34). The depth to the top of the Glacial Drift deposits is based on the grid for the top of the Glacial Drift deposits.

6.2.8.2 Apparent Yield

The apparent yields for 404 water wells completed into the Glacial Drift deposits range from less than 10 to more than 300 m³/day, with nearly 65% of the values being less than 100 m³/day. Some of the areas with data indicating apparent yields of more than 100 m³/day are in association with the buried valleys.

In the Study Area, there are seven licensed water wells that are completed into the Glacial Drift deposits, with a total authorized diversion of 297 m³/day; the highest allocation is 82.2 m³/day for a water well in Section 28-005-29 W1M used for municipal purposes.

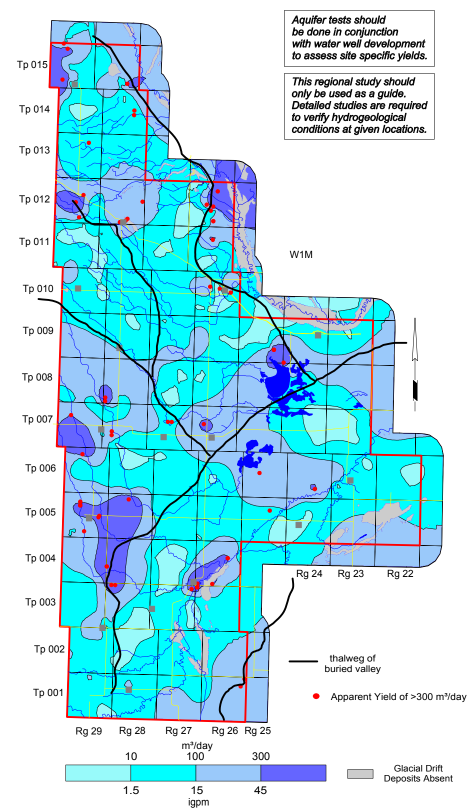


Figure 13. Apparent Yield for Water Wells Completed into Glacial Drift

6.2.8.3 Quality

The groundwaters from the Glacial Drift deposits are mainly a calcium-magnesium-type with no dominant anion (see Piper diagram on page A-40, and on the 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 Glacial Drift deposits in the Study Area have been compared to the SGCDWQ and median concentrations from all surficial deposits in Table 9. 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 Study Area in mg/L Minimum	Maximum	Median	All Surficial Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	99	3	4,760	758	642	500
Sodium	128	0	840	30	30	200
Sulfate	103	<10	2,450	153	133	500
Chloride	128	<0.5	917	26	24	250
Nitrate + Nitrite (as N)	91	<0.05	44	3	2	10

Table 9. Concentrations of Constituents in Groundwaters from Glacial Drift Deposits

The median concentrations of TDS, sodium, sulfate, chloride and nitrate + nitrite (as N) from water wells completed into the Glacial Drift deposits are the same or greater than the median concentrations for water wells completed in all surficial deposits.

6.2.9 Lower Surficial Deposits

The Lower Surficial deposits, the oldest of the surficial deposits, include water-sorted gravel, sand, silt and/or clay deposited on or near the bedrock surface. Structure contours have been prepared for the top of the Lower Surficial deposits based on 13 control points. The structure contours, based on the very limited amount of data, show that the Lower Surficial deposits range in elevation from below 330 to above 390 metres AMSL and have a thickness of mainly less than 50 metres, and a thickness of up to 70 metres in association with the Virden Buried Valley (see CD-ROM). The regional groundwater flow direction in the Lower Surficial deposits is mainly downgradient to the northeast and southeast toward the Souris River basin (see CD-ROM).

6.2.9.1 Depth to Top

In the Study Area, the depth to the top of the Lower Surficial deposits ranges from less than 15 metres below ground level to more than 100 metres (see page A-37). The depth to the top of the Lower Surficial deposits is based on the grid for the top of the Lower Surficial deposits and the grid for the land surface.

6.2.9.2 Apparent Yield

In the Study Area, there are two apparent yield values for water wells completed into the Lower Surficial deposits: a value of 971 m³/day from a water well in the Pierson Buried Valley, and a value from a water well in the Medora-Waskada Buried Valley of 5,359 m³/day.

In the Study Area, there is one licensed water well that is completed into the Lower Surficial deposits.

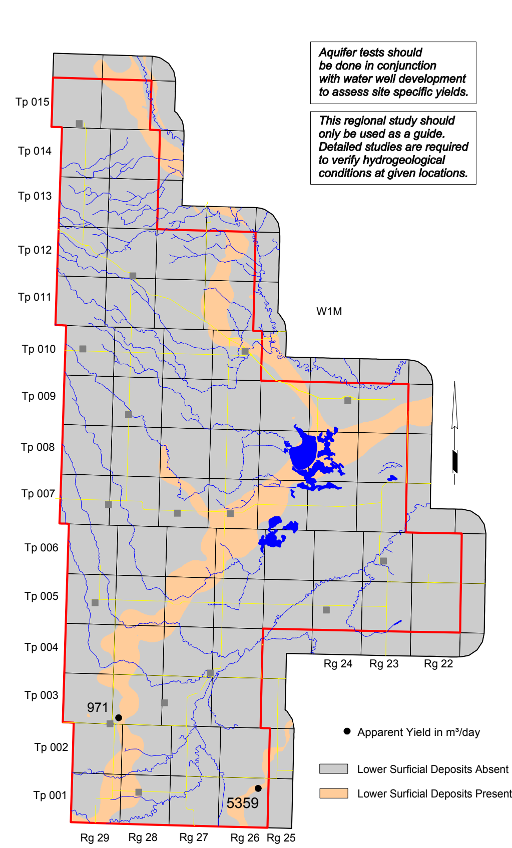


Figure 14. Apparent Yield for Water Wells Completed into Lower Surficial Deposits

6.2.9.3 Quality

There is sufficient data from seven water wells completed into the Lower Surficial deposits with values for the constituents that are needed to determine the groundwater type; the data show that the groundwaters are mainly a sodium-bicarbonate-type to sodium-chloride-type (see Piper diagram on page A-40, and on the 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 Lower Surficial deposits in the Study Area have been compared to the SGCDWQ and median concentrations from all surficial deposits in Table 10. Of the five constituents that have been compared to the SGCDWQ, the median value of sodium exceeds the guidelines.

Constituent	No. of Analyses	Range for Study Area in mg/L			All Surficial Median	Recommended Maximum Concentration SGCDWQ
		Minimum	Maximum	Median		
Total Dissolved Solids	7	159	1,684	470	642	500
Sodium	8	7	570	350	30	200
Sulfate	8	<10	542	23	133	500
Chloride	8	<10	591	216	24	250
Nitrate + Nitrite (as N)	3	0	1	0	2	10

Table 10. Concentrations of Constituents in Groundwaters from Lower Surficial Deposits

The median concentrations of sodium and chloride from water wells completed into the Lower Surficial deposits are greater than the median concentrations for water wells completed in all surficial deposits.

6.3 Bedrock

6.3.1 Bedrock Units

The upper bedrock includes formations that are generally less than 200 metres below the bedrock surface. In the Study Area, the upper bedrock includes the Odanah and Millwood members, as shown below on cross-section J-J' (see page A-21 and the CD-ROM). Some of this bedrock contains saturated geologic units that are permeable enough to transmit groundwater for a specific need.

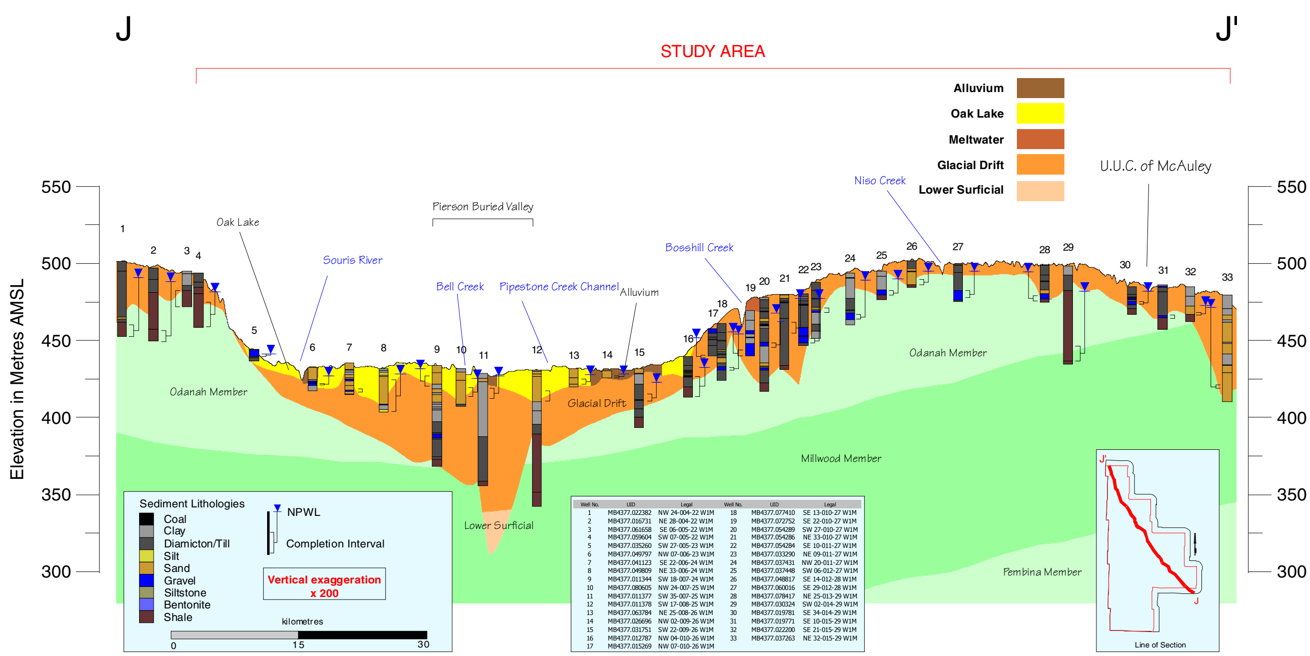


Figure 15. Cross-Section J - J'
(for larger version, see page A-21)

6.3.2 Geological Characteristics

The upper bedrock in the Study Area includes the Odanah Member and the Millwood Member of the Pierre Shale (Betcher, 1983). The adjacent bedrock geology map, showing the subcrop of the Odanah and Millwood members, has been prepared in part from the interpretation of geophysical logs related to oil and gas activity received from International Petrodata Limited.

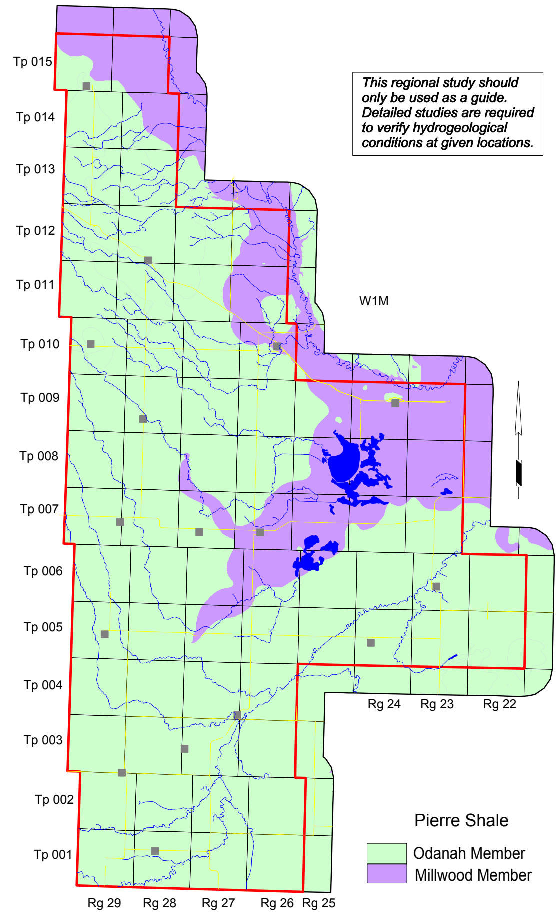


Figure 16. Bedrock Geology

The Odanah Member of the Pierre Shale is the upper bedrock in most of the Study Area. Hard, siliceous grey shale makes up a large part of the Odanah Member. The Odanah shales are often well-fractured and locally comprise low-yield aquifers. The Millwood Member is made up of soft, relatively impermeable marine shales that do not form useable aquifers (Tokarsky, 1986). In the Study Area, the Odanah and the Millwood members have a maximum thickness of 150 metres each.

Because the Millwood Member does not form a useable aquifer, there will be no direct review in the report. Structure-contour maps associated with the Millwood Member are included in Appendix A and on the CD-ROM.

6.3.3 Upper Bedrock Completions

Of the 4,071 water wells in the database, 88 were defined as being completed below the top of bedrock, based on lithologic information and water well completion details. However, at least a reported completion depth is available for 515 water wells completed below the bedrock surface. Assigning a water well to a specific geologic unit is possible only if the completion interval is identified. In order to make use of additional information within the groundwater database, it was assumed that the completion interval was the bottom 20% of the total completed depth of a water well. With this assumption, it has been possible to designate the specific bedrock aquifer of completion for an additional 347 bedrock water wells, giving a total of 435 water wells. The remaining 80 of the total 515 upper bedrock water wells are identified as being completed in more than one bedrock unit, as shown in Table 11. The bedrock water wells are mainly completed into the Odanah Member.

Geologic Unit	No. of Bedrock Water Wells
Multiple Completions	80
Odanah	374
Millwood	61
Total	515

Table 11. Bedrock Water Well Completions

There are 83 records for bedrock water wells that have apparent yield values, which is 16% of the 515 bedrock water wells in the Study Area.

Of the 83 water well records with apparent yield values, 75 have been assigned to specific geologic units. Twenty-nine (35%) of the 83 water wells completed in bedrock have apparent yields that are less than ten m³/day, 45 (54%) have apparent yield values that range from 10 to 50 m³/day, and nine (11%) have apparent yield values that are greater than 50 m³/day, as shown in Table 12.

Geologic Unit	No. of Water Wells with Values for Apparent Yield (*)	Number of Water Wells with Apparent Yields <10 m³/day	10 to 50 m³/day	>50 m³/day
Multiple Completions	8	2	5	1
Odanah	63	23	33	7
Millwood	12	4	7	1
Totals	83	29	45	9

Table 12. Apparent Yields of Bedrock Water Wells

Although it is generally accepted that the Millwood Member does not contain any aquifers that would be suitable for the development of groundwater supplies, the data indicate that there are 12 water wells completed into the Millwood Member with apparent yield data. It may be possible that the aquifer tests were conducted in a zone that differed from the final completion interval.

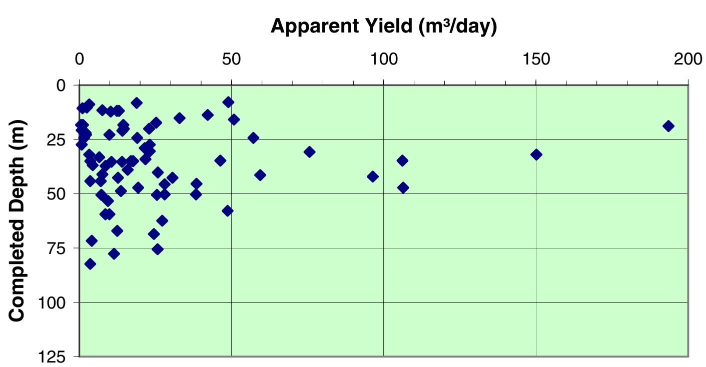


Figure 17. Bedrock Water Well Yields vs Completed Depth

Apparent yields for water wells completed in bedrock vary significantly over the Study Area both with location and with depth. As the graph shows, most apparent yields are less than 30 m³/day and the majority of the water wells are less than 75 metres deep, and all water wells with apparent yields of greater than 50 m³/day are less than 50 metres deep.

6.3.4 Odanah Member

The Odanah Member is the upper bedrock in most of the Study Area. Structure contours have been prepared for the top of the Member. The structure contours show that the Odanah Member ranges in elevation from below 350 to above 500 metres AMSL and has a maximum thickness of 150 metres. The regional groundwater flow direction in the Odanah Member is mainly downgradient to the southeast and northwest toward the Souris River basin. Local conditions may vary.

6.3.4.1 Depth to Top

The depth to the top of the Odanah Member is variable, ranging from less than ten metres at the northeastern and southeastern extent to more than 125 metres in the western part of the Study Area (see page A-42). The depth to the top of the Odanah Member is based on the grid for the top of the Odanah Member.

6.3.4.2 Apparent Yield

The apparent yields for individual water wells completed into the Odanah Member range mainly from 10 to 50 m³/day, and have a median apparent yield value of 14 m³/day.

In the Study Area, there are no licensed groundwater water wells that are completed into the Odanah Member.

6.3.4.3 Quality

The Piper tri-linear diagram for water wells completed into the Odanah Member (see page A-45) shows that groundwaters from bedrock aquifers are mainly sodium-sulfate or sodium-chloride-type waters; the majority of these groundwaters have a sodium ion concentration that exceeds 200 mg/L. Because the sodium concentration may be elevated in bedrock formations, the groundwater can pose a health risk to people on low-sodium diets.

In the Study Area, approximately 90% of the groundwater samples from the Odanah Member have fluoride concentrations that are too low to meet the recommended daily needs of people (less than 0.5 mg/L).

The TDS concentrations in the groundwaters from the Odanah Member range from less than 500 mg/L to more than 5,000 mg/L, with 70% of the samples having TDS concentrations of more than 1,000 mg/L (see page A-44).

The relationship between TDS and sulfate concentrations shows that when TDS values in the groundwaters from the Odanah Member exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

In the Study Area, nearly 70% of the chloride concentrations in the groundwaters from the Odanah Member are more than 250 mg/L.

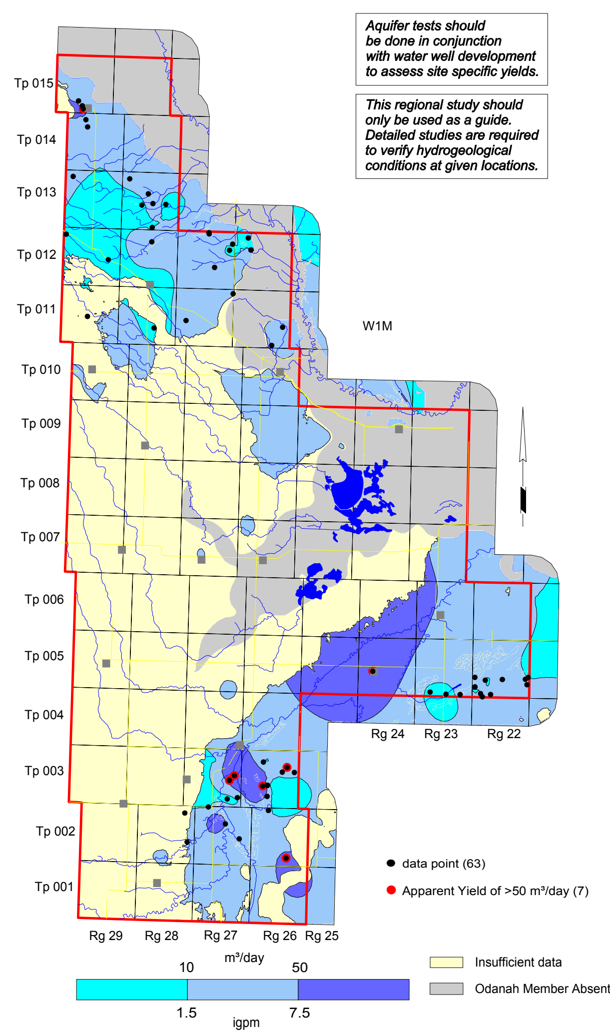


Figure 18. Apparent Yield for Water Wells Completed into Odanah Member

Constituent	No. of Analyses	Range for Study Area in mg/L Minimum	Maximum	Median	Recommended Maximum Concentration SGCDWQ
Total Dissolved Solids	13	492	5,120	2,960	500
Sodium	16	5	1,620	1195	200
Sulfate	14	<10	2,175	422	500
Chloride	17	<10	2,010	551	250
Fluoride	12	0	1	0	1.5

Note: indicated concentrations are for Aesthetic Objectives except for Fluoride, which is for Maximum Acceptable Concentration (MAC)

Table 13. Concentrations of Constituents in Groundwaters from Odanah Member

The minimum, maximum and median concentrations of TDS, sodium, sulfate, chloride and fluoride in the groundwaters from water wells completed into the Odanah Member in the Study Area have been compared to the SGCDWQ in Table 13. Of the five constituents compared to the SGCDWQ, median concentrations of TDS, sodium and chloride exceed the guidelines.

7 GROUNDWATER BUDGET

7.1 Hydrographs

In the Study Area, there are 78 active monitoring water wells that are part of the Water Resources Branch regional groundwater monitoring network where water levels are being measured and recorded as a function of time. Of the 78 active monitoring water wells, water level monitoring data were provided for 61, of which 59 could be matched to a water well in the GW Drill database. These 59 monitoring water wells are mainly completed in surficial deposits where the Oak Lake deposits are present, near the Pierson Buried Valley, and in close proximity to licensed water wells and water wells waiting for application assessment (see page A-47). Of the 59 monitoring water wells, six are completed in multiple surficial geologic units, two are completed in Alluvium deposits, 22 are completed in Oak Lake deposits, 26 are completed in Glacial Drift deposits, two are completed in Lower Surficial deposits, and one monitoring water well is completed in the Odanah Member.

Monitoring Water Well Name	Aquifer Name	Legal	Monitoring Interval	UID	Monitoring Water Well Name	Aquifer Name	Legal	Monitoring Interval	UID
HARTNEY #3 5NG-MN23	Alluvium	NW 20-006-23 W1M	1966 - 2003	MB4377.008266	OAK L. #22 5NG-MN27	Glacial Drift	NE 15-007-24 W1M	1970 - 2003	MB4377.011183
OAK L. 35C 5NG-MN32C	Alluvium	SW 35-007-24 W1M	1968 - 2002	MB4377.011189	OAK L. 41 5NG-MN36	Glacial Drift	NE 21-007-23 W1M	1968 - 2003	MB4377.011205
MELITA MR#6 5NG-MN19	Oak Lake	NE 13-005-26 W1M	1965 - 2003	MB4377.006925	MAPLE L. #6 5NG-MN42	Glacial Drift	NW 27-005-25 W1M	1970 - 2003	MB4377.012562
MAPLE L. #9 5NG-MN46	Oak Lake	NE 21-005-25 W1M	1971 - 2002	MB4377.015137	MAPLE L. #7 5NG-MN43	Glacial Drift	NW 27-005-25 W1M	1970 - 2003	MB4377.012563
MAPLE L. 10 5NG-MN47	Oak Lake	NE 21-005-25 W1M	1971 - 2002	MB4377.015138	MAPLE L. #8 5NG-MN45	Glacial Drift	NE 21-005-25 W1M	1971 - 2002	MB4377.015136
MAPLE L. 13 5NG-MN50	Oak Lake	NW 22-005-25 W1M	1971 - 2002	MB4377.015141	MAPLE L. 11 5NG-MN48	Glacial Drift	NE 21-005-25 W1M	1971 - 2002	MB4377.015139
OLA 8B 5NG-MN55	Oak Lake	NE 15-006-24 W1M	1980 - 2003	MB4377.041122	MAPLE L. 12 5NG-MN49	Glacial Drift	NW 22-005-25 W1M	1971 - 2002	MB4377.015140
OLA 5B 5NG-MN60	Oak Lake	NW 18-008-23 W1M	1981 - 2003	MB4377.041120	OLA 11 5NG-MN56	Glacial Drift	NW 36-005-26 W1M	1981 - 2003	MB4377.041132
OLA 7B 5NG-MN62	Oak Lake	NE 17-007-24 W1M	1981 - 2003	MB4377.041124	OLA 16 5NG-MN65	Glacial Drift	NW 28-007-26 W1M	1981 - 2003	MB4377.041134
OLA 14 5NG-MN63	Oak Lake	SE 32-007-25 W1M	1981 - 2003	MB4377.041128	OLA 6 5NG-MN66	Glacial Drift	SE 20-007-23 W1M	1981 - 2003	MB4377.041119
OLA 15 5NG-MN64	Oak Lake	NE 28-006-26 W1M	1981 - 2003	MB4377.041133	OLA 9 5NG-MN67	Glacial Drift	SW 12-006-25 W1M	1981 - 2003	MB4377.041126
OLA 3M 5NG-MN70	Oak Lake	SW 23-009-26 W1M	1981 - 2003	MB4377.041136	OLA 12 5NG-MN68	Glacial Drift	SE 24-006-27 W1M	1981 - 2003	MB4377.041138
OLA 23 5NG-MN73	Oak Lake	SW 07-009-23 W1M	1982 - 2003	MB4377.042575	5NG-MN77 OLA 40	Glacial Drift	NW 07-006-23 W1M	1984 - 2003	MB4377.049797
OLA-8 P.W. 5NG-MN79	Oak Lake	NE 15-006-24 W1M	1981 - 2003	MB4377.051293	OAK L. 33A 5NG-MN30A	Glacial Drift	NW 11-007-25 W1M	1968 - 2003	MB4377.011193
OLA-5 P.W. 5NG-MN80	Oak Lake	NE 18-008-23 W1M	1984 - 2003	MB4377.052711	OAK L. 35A 5NG-MN32A	Glacial Drift	SW 35-007-24 W1M	1968 - 2002	MB4377.011187
OLA-62 5NG-MN81	Oak Lake	NW 18-007-25 W1M	1985 - 2002	MB4377.055282	OAK L. 33B 5NG-MN30B	Glacial Drift	NW 11-007-25 W1M	1968 - 2003	MB4377.011194
OLA-62 'A' 5NG-MN82	Oak Lake	NW 18-007-25 W1M	1985 - 2002	MB4377.055283	OAK L. 35B 5NG-MN32B	Glacial Drift	SW 35-007-24 W1M	1968 - 2002	MB4377.011188
OLA-64 5NG-MN83	Oak Lake	NE 06-006-25 W1M	1985 - 2002	MB4377.055285	OAK L. 36B 5NG-MN33B	Glacial Drift	NE 23-008-24 W1M	1968 - 2003	MB4377.011200
OLA-65 'A' 5NG-MN84	Oak Lake	SE 03-007-24 W1M	1985 - 2002	MB4377.055284	OAK L. 40B 5NG-MN35B	Glacial Drift	NW 29-007-25 W1M	1970 - 2003	MB4377.011197
OLA-59 P.W. 5NG-MN85	Oak Lake	SE 18-008-25 W1M	1985 - 2003	MB4377.055279	OAK L. 34C 5NG-MN31C	Glacial Drift	SW 30-007-24 W1M	1968 - 2003	MB4377.011186
OLA 64B 5NG-MN86	Oak Lake	NE 06-006-25 W1M	1985 - 2002	MB4377.041916	MELITA MP 15 5NF-MN7	Lower Surficial	NW 31-002-28 W1M	1986 - 2003	MB4377.007423
OAK L. 33C 5NG-MN30C	Oak Lake	NW 11-007-25 W1M	1968 - 2003	MB4377.011195	G05NF019 PCA 98-3	Lower Surficial	NW 31-001-28 W1M	1998 - 2003	MB7764.106088
OAK L. 36C 5NG-MN33C	Oak Lake	NE 23-008-24 W1M	1968 - 2003	MB4377.011201	ANTLER #1 5NF-MN14	Surficial	SW 04-001-29 W1M	1977 - 2003	MB4377.031429
OLA 20 5NG-MN57	Oak_Lake	SE 36-005-26 W1M	1980 - 2002	MB4377.041131	OLA-1A 5NG-MN54	Surficial	NW 07-007-25 W1M	1981 - 2003	MB4377.041127
MELITA MP12 5NF-MN12	Glacial Drift	NW 27-004-27 W1M	1965 - 2003	MB4377.007174	OLA 4 5NG-MN58	Surficial	NE 02-009-25 W1M	1981 - 2003	MB4377.041129
ANTLER NO2,5NF-MN15	Glacial Drift	SE 11-001-29 W1M	1977 - 2003	MB4377.031430	OLA 7A 5NG-MN61	Surficial	NE 17-007-24 W1M	1981 - 2003	MB4377.041125
ANTLER #3 5NF-MN16	Glacial Drift	SW 03-001-29 W1M	1977 - 2003	MB4377.031431	OLA 2 5NG-MN69	Surficial	SE 14-008-26 W1M	1981 - 2003	MB4377.041135
RESTON #1 5NG-MN03	Glacial Drift	NW 22-007-27 W1M	1962 - 2002	MB4377.003898	5NG-MN72 OLA 21	Surficial	SW 08-006-24 W1M	1982 - 2003	MB4377.042595
MELITA MR5 5NG-MN18	Glacial Drift	NW 17-005-27 W1M	1965 - 2003	MB4377.007182	OAK L. 20A 5NG-MN26A	Odanah	SW 06-009-25 W1M	1968 - 2003	MB4377.011170
MELITA MP14 5NG-MN20	Glacial Drift	NW 28-005-27 W1M	1965 - 2003	MB4377.007183					

Table 14. Water Resources Branch Monitoring Water Well Summaries

The 59 monitoring water wells are located south of township 010. Six monitoring water wells from different parts of the Study Area are shown on page A-48. The 59 hydrographs were compared to determine if there were any water-level trends in the monitoring water wells. The most predominant trend was that there was a high water level in the mid-1970s, a low water level in the early 1990s and a second high water level in the late 1990s-early 2000s.

The Hartney #3 monitoring water well in NW 20-006-23 W1M is completed from 4.4 to 5.9 metres below ground surface into Alluvium deposits. The water level in the monitoring water well has been measured since 1966, as shown by the blue line in the adjacent graph. The water-level fluctuations tend to correlate to precipitation events. The water-level fluctuations in the monitoring water well show at least two peaks in most years, as shown in Figure 19. The first peak in a given year would be associated with recharge when the frost leaves the ground; the second peak coincides with the end of the growing season. Overall annual water-level fluctuations ranged in the order of 0.5 to 1.5 metres. The complete hydrograph suggests that there was a water-level rise from 1973 to 1976, a water-level decline from 1976 to 1981, a water-level rise from 1985 to 1986, a water-level decline from 1986 to 1988, a water-level rise from 1990 to 1991, a final water-level rise in early 1999, and a water-level decline since late 1999.

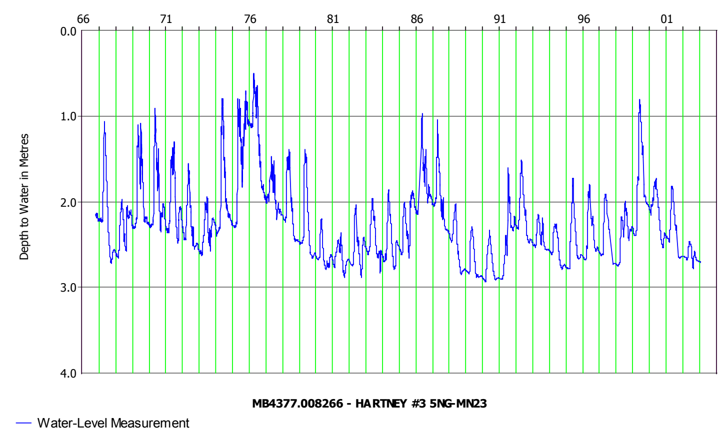


Figure 19. Hydrograph - Hartney #3 Monitoring Water Well

Another example illustrating the correlation between water levels and precipitation is the Melita MR #6 monitoring water well. This monitoring water well in NE 13-005-26 W1M is completed from 6.1 to 7.0 metres below ground surface into Oak Lake deposits. The water-level fluctuations in the Melita MR #6 monitoring water well has been compared to the monthly precipitation measured at the Pierson Weather Station. A ten-year interval was chosen in order to make an easier visual comparison. The complete hydrograph is shown on page A-48.

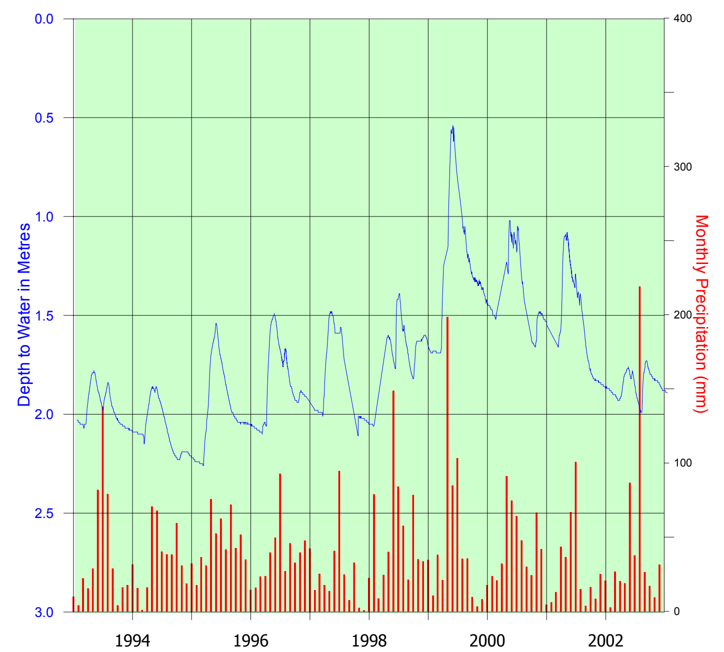


Figure 20. Monthly Precipitation and Water Levels in Melita MR #6 Monitoring Water Well

Overall, there appeared to be a fairly consistent relationship occurring between the monthly precipitation and the water levels in the Melita MR #6 monitoring water well. However, the relationship is not always apparent. For example, in April of 1999, there was just under 200 mm of precipitation and there was a corresponding 1^+ metres rise in water level. In August of 2002, there was 200^+ mm of precipitation and there was very little change in water level.

An attempt to determine a long-term relationship between water level and precipitation involved the comparison of trends in the water-level and precipitation data. The water-level data from the Oak Lake #35C monitoring water well were used and the average water level was determined for each day. For precipitation, the data from the Virden Weather Station were used; the monthly total for each month from April to October was included in the analysis.

The trends of both the water-level data and the precipitation data were obtained using fourth order polynomials. The adjacent graph shows their traces. The magenta trace is the trend line for the precipitation data and the blue trace is for the water level. From the two traces, there is an obvious similarity, that of higher position at either end and a lower position in the middle. When the trend line for the precipitation is calculated from the fourth order polynomial equation with a 3.5-year delay, the resulting trend line, in yellow, corresponds to the water level trend line from 1971 to midway through 1999. The failure of the calculated trend line to match at either end of the data set is a result of data limits.

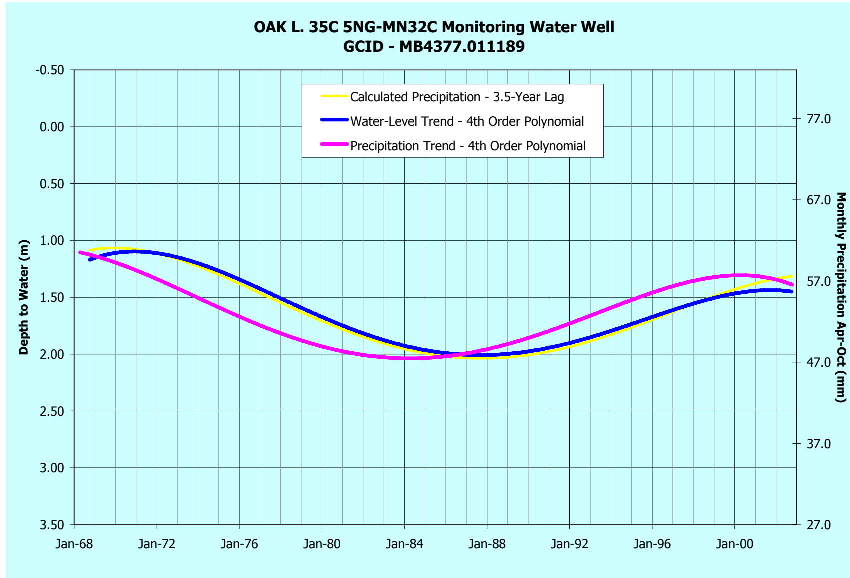


Figure 21. Trend Comparisons

The trend lines indicate that a minimum monthly precipitation of 47 mm, in the April to October time frame, is required to keep the water level above a depth of two metres. On this basis, every millimetre of precipitation above 47 mm will result in a water-level rise of 0.0485 metres. This would amount to a specific capacity of 21 percent for the aquifer.

The water-level fluctuations in the Waskada #1 monitoring water well exhibit a water-level trend that is different from the water-level trend of all of the other monitoring water wells. This monitoring water well in NW 31-002-28 W1M is completed from 103.6 to 110.3 metres below ground surface in the Lower Surficial deposits. The average completion depth of the 59 monitoring water wells is 17 metres.

Over the 16 years of water-level monitoring, the water level in the Waskada #1 monitoring water well, located in the Medora-Waskada Buried Valley, has declined more than eight metres. Because of the configuration of the water-level decline, it is possible that the decline is a result of a nearby groundwater diversion. The closest licensed groundwater user is more than 15 kilometres northeast in SE 27-002-27 W1M. This water well is licensed to divert 33 m³/day for agricultural purposes and would not be expected to result in the observed drawdown. The community of Pierson has water wells that are completed at a similar depth, but the diversion of groundwater for Pierson would not be expected to cause the observed drawdown.

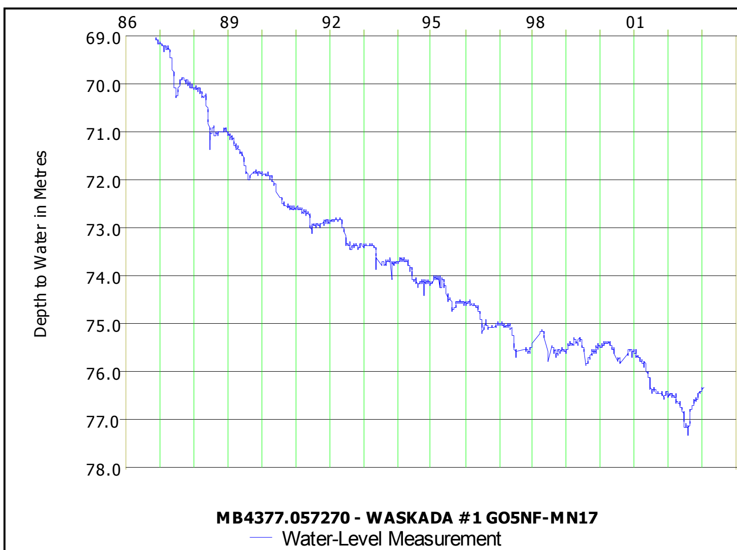


Figure 22. Hydrograph – Waskada #1 Monitoring Water Well

7.2 Estimated Groundwater Use in the Study Area

An estimate of the quantity of groundwater removed from each geologic unit in the Study Area must include both the groundwater diversions with licences and the groundwater diversions without licences. As stated previously on page 11 of this report, the daily water requirement for livestock for the Study Area based on the 2001 census is 8,975 cubic metres. As of late 2004, MWS has licensed the use of 780 m³/day of groundwater for livestock from 12 water wells. To obtain an estimate of the quantity of groundwater being diverted from the individual geologic units, it has been assumed that the remaining 8,195 m³/day of water required for livestock watering is obtained from sources that may not require licensing.

There are 203 water wells that are used for livestock purposes, of which 12 are licensed. There are 59 water wells that are listed as being for domestic/livestock and there are 1,069 water wells that are indicated as being for domestic use only, of one is which licensed.

To attribute the use of groundwater that is not accounted for by licensed groundwater sources, it is necessary to make some assumptions about the numbers of livestock associated with water wells that are identified for livestock, domestic/livestock and domestic use.

By assuming each livestock, domestic/livestock and domestic water well could be used as a water source for 25% of the maximum number of livestock that could be watered from a source not requiring licensing (up to 25 m³/day), it was possible to account for the unlicensed groundwater use. This results in a groundwater use of 6.0 m³/day for water wells designated for domestic and domestic/livestock use, and 6.3 m³/day for livestock use.

For the water wells listed as domestic and domestic/livestock, it was assumed the average groundwater use based on a family of four for per-person domestic purposes is 0.275 m³/day. Since there are 1,069 domestic and 59 domestic/livestock water wells in the Study Area serving a population of 6,427[19], and based on a family of the four, the domestic use per water well is in the order of 1.3 m³/day. It is assumed that these 1,128 water wells are active; however, many are very old and may no longer be in use or may have been abandoned.

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

Domestic Use* 7.3 m³/day, made up of 1.3 m³/day for domestic use plus 25% of (25 m³/day minus 1.3 m³/day) for livestock use.
Domestic/livestock* 7.3 m³/day, made up of 1.3 m³/day for domestic use plus 25% of (25 m³/day minus 1.3 m³/day) for livestock use
Livestock** 6.3 m³/day, made up of 25% of 25 m³/day

*It has been assumed that water supply wells designated as domestic or domestic/livestock use have both a livestock and a domestic component
**It has been assumed that there is no domestic-use component for a water well specifically designated for “Livestock” use.

The total calculated groundwater use for livestock purposes (7,871 m³/day), calculated using these numbers, approximates the estimated groundwater required for livestock watering from sources that may not require licensing (8,195 m³/day). The total quantity of groundwater used for domestic purposes would be 1,465 m³/day.

	No. of Unlicensed Water Wells	Livestock Use	Domestic Use	Total (m³/day)
Domestic	1,069	6,414	1,390	7,804
Domestic and Livestock	59	354	77	431
Livestock	191	1,203	0	1,203
	1,319	7,971	1,466	9,438

Table 15. Total Domestic and Stock Unlicensed Groundwater Diversions

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

19 From the eight RMs in the Study Area (Regional Health Authority and Municipality, 2003)

By assigning 7.3 m³/day for domestic use, 6.3 m³/day for livestock use and 7.3 m³/day for domestic/livestock use, and using the total maximum authorized diversion associated with any licensed water well, the map on page A-50 shows the estimated groundwater use in terms of volume per section per day for the Study Area (not including springs).

There are 2,616 sections in the Study Area. In 71% (1,868) of the sections in the Study Area, there is no domestic, livestock or licensed groundwater user. The groundwater use for the remaining 29% (746) of the sections varies from 6.3 m³/day to 1,493 m³/day, with an average use per section of 21.4 m³/day (3.3 igpm). The estimated water well use per section can be more than 30 m³/day in 40 of the 746 sections. Twenty-two of the 30 licensed groundwater users are in areas where the groundwater use is greater than 30 m³/day.

Groundwater Use within the Study Area (m³/day)		%
Domestic/Livestock (licensed and unlicensed)	10,218	*64*
Municipal (licensed)	1,265	*8*
Irrigation (licensed)	4,513	*28*
Total	15,996	*100*

Table 16. Total Groundwater Diversions

In summary, the estimated total groundwater use within the Study Area is 15,996 m³/day, with the breakdown as shown above in Table 16. Approximately 36% of the total estimated groundwater use is from licensed water wells.

8 SUMMARY OF FINDINGS

The results of the present study indicate that the primary sources of groundwater in the Study Area are the sand or gravel deposits in the surficial materials. Approximately 85% of the water wells with completion data are completed in surficial deposits. The surficial deposits have been assigned to five different groupings in the Study Area. The designations of the five groupings, from oldest to youngest, are: (a) Lower Surficial, (b) Glacial Drift, (c) Meltwater, (d) Oak Lake, and (e) Alluvium; sand or gravel deposits can be associated with any of the five groupings.

The Lower Surficial deposits are associated with significant linear bedrock lows; sand or gravel deposits within the Lower Surficial deposits are generally saturated and continuous, though exceptions are not uncommon. The most noteworthy bedrock lows include the Pierson Buried Valley and its tributaries, and the Medora-Waskada Buried Valley. At this time, the limits of the buried valleys are poorly defined in most areas. Therefore, test drilling would be warranted in areas where development of the aquifers associated with the buried valleys is anticipated.

Sand or gravel deposits associated with the Glacial Drift are expected to occur as pockets and may not always be saturated. Sand or gravel deposits associated with Meltwater and Alluvium may not be continuous and may not always be saturated. The Oak Lake deposits are present over a large area, but the sand or gravel deposits within the Oak Lake are not saturated everywhere.

Of the five different surficial-deposit groupings, the Oak Lake deposits are considered a significant source of groundwater for municipal and irrigation uses. Ninety percent of the total quantity of licensed groundwater use, where the specific geologic unit could be determined, is from the Oak Lake deposits. Eighty percent of the groundwater use that is licensed to water wells completed into the Oak Lake deposits is for irrigation purposes.

The groundwaters from the Oak Lake deposits are a calcium-magnesium-bicarbonate type, with TDS generally below 500 mg/L. The median concentrations of sodium, sulfate, chloride and Nitrate + Nitrite (as N) are below the SGCDWQ for water wells completed in surficial deposits. Elevated Nitrate + Nitrite (as N) and chloride concentrations, when present, can often be attributed to physical conditions at or near the water well, and may not indicate general aquifer conditions.

Where the aquifers in the sand or gravel deposits are absent or where the yields are low, the shallow surficial deposits can be more susceptible to drought, and the development of water wells for the domestic needs of single families may not be possible from these aquifers. Construction of a water supply well into the underlying bedrock may be the only alternative, provided that yields and quality of groundwater from the bedrock aquifers are suitable.

The main bedrock unit in the Study Area is the Odanah Member. Apparent yields from the Odanah Member are typically less than 50 m^3/day. Groundwaters from the Odanah Member are mainly sodium-sulfate or sodium-chloride-type waters; the majority of these groundwaters have a TDS concentration that exceeds 1,000 mg/L.

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. In 2001, 2003 and 2004, more than 350 groundwater samples were collected and analyzed for the Study Area by WSRCD personnel. Of the 350 groundwater samples collected, 133 were linked by legal location to a water well in the GW Drill database (see Appendix E). The groundwater database indicates that water levels were measured in four of the 133 matched water wells.

In order to better quantify the groundwater resources, it is recommended that:

- Some additional water wells be field-verified. Appendix E includes a list of 35 water wells where field-verification is recommended.

- The information available for the provincial observation water wells be updated. This includes obtaining values for aquifer parameters and chemical analysis results for groundwater from each observation water well.

Even though there are 78 observation water wells within the Study Area, there is little known about the impact local groundwater diversions are having on the groundwater. For example, there is little understanding of why the water level in the G05NF017 Waskada monitoring water well has declined more than eight metres since 1986.

An approach to obtain water-level data would be to conduct a field survey to identify water wells that are not in use that could be used as part of an observation water well network. West Souris River Conservation District, Rural Municipality personnel and/or local residents could measure the water levels in the water wells regularly.

An attempt to link the GW Drill database and MWS licensing databases was 65% successful in this study (see CD-ROM); 35% of the 30 licensed water wells do not appear to have corresponding records in the GW Drill database. The link was based on the legal location, and partially on the licence holder and the water well owner given in the GW Drill database. It is recommended that attempts be made in a future study to find and add missing drilling records to the GW Drill groundwater database and to determine the geologic unit in which the unlicensed water wells are completed.

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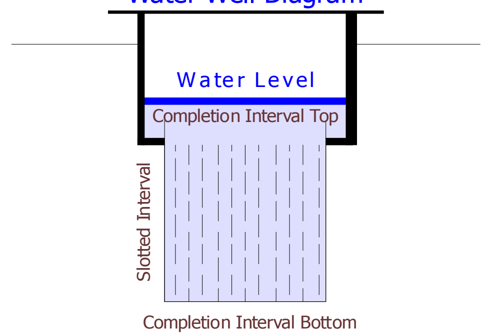
10 GLOSSARY

AAFC-PFRA	Prairie Farm Rehabilitation Administration Branch of Agriculture and Agri-Food Canada
AMSL	above mean sea level
Anion	negatively charged ion
Aquifer	a formation, group of formations, or part of a formation that contains saturated permeable rocks capable of transmitting groundwater to water wells or springs in economical quantities
Cation	positively charged ion
Completion Interval	see diagram
DEM	Digital Elevation Model
Dfb	one of the Köppen climate classifications; a Dfb climate consists of warm to cool summers, severe winters, and no dry season. The mean monthly temperature drops below -3° C in the coolest month, and exceeds 10° C in the warmest month.

Water Well Diagram



Completion Interval

DST	drill stem test
Evapotranspiration	a combination of evaporation from open bodies of water, evaporation from soil surfaces, and transpiration from the soil by plants (Freeze and Cherry, 1979)
Fluvial	produced by the action of a stream or river
Friable	poorly cemented
Geologic Unit	a distinguishable rock unit based on rock type and/or rock age
Hydraulic Conductivity	the rate of flow of water through a unit cross-section under a unit hydraulic gradient; units are length/time
Hydraulic Unit	a rock type where changes in hydraulic head at one location directly impact hydraulic-head condition at all locations measurable in less than a year
Hydrogeologic Unit	a hydrogeologic setting comprised of one or more saturated rock types where groundwater characteristics are closely related
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
l/day	litres per day
m²/day	metres squared per day

m^3 — cubic metres

m^3/day — cubic metres per day

mg/L — milligrams per litre

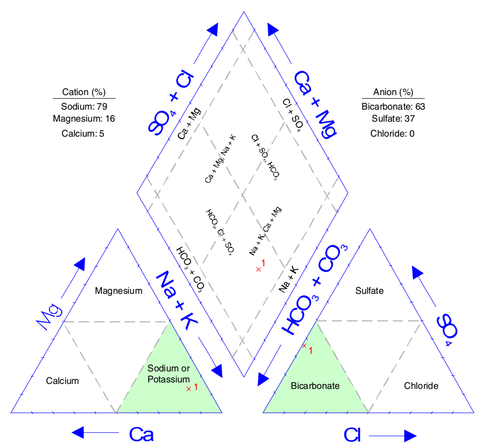
MWS — Manitoba Water Stewardship

MCWB — Manitoba Conservation Water Branch

Median — the value at the centre of an ordered range of numbers

NPWL — non-pumping water level

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

SGCDWQ — Summary of Guidelines for Canadian Drinking Water Quality

Surficial Deposits — includes all sediments above the bedrock

TDS — Total Dissolved Solids

Thalweg — the lowest elevation of a linear bedrock low

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, discharge rate and time of discharge

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; 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 and 70% of available drawdown

Long-Term Yield: the method used for determining the theoretical long-term yield in the Alberta Environment Groundwater Evaluation Guidelines, and based on effective transmissivity

11 CONVERSIONS

Multiply	by	To Obtain
Length/Area		
feet (ft)	0.3 048	metres
metres (m)	3.2 810	feet
hectares (ha)	2.4 711	acres
centimetre (cm)	0.0 328	feet
centimetre	0.3 937	inches
acres (ac)	0.4 047	hectares
inches (in)	25.4 000	millimetres
miles (mi)	1.6 093	kilometres
kilometre (km)	0.6 214	miles (statute)
square feet (ft^2)	0.0 929	square metres (m^2)
square metres (m^2)	10.7 639	square feet (ft^2)
square metres (m^2)	0.0 000	square kilometres (km^2)
Concentration		
grains/gallon (UK)	14.2 700	parts per million (ppm)
ppm	0.9 989	mg/L
mg/L	1.0 011	ppm
Volume (capacity)		
acre feet	1233.4 818	cubic metres
cubic feet	0.0 283	cubic metres
cubic metres	35.3 147	cubic feet
cubic metres	219.9 692	gallons (UK)
cubic metres	264.1 721	gallons (US liquid)
cubic metres	1000.0 000	litres
gallons (UK)	0.0 045	cubic metres
imperial gallons	4.5 460	litres
Rate		
litres per minute (lpm)	0.2 200	UK gallons per minute (igpm)
litres per minute	1.4 400	cubic metres/day (m^3/day)
igpm	6.5 463	cubic metres/day (m^3/day)
cubic metres/day	0.1 528	igpm

WEST SOURIS RIVER CONSERVATION DISTRICT

Appendix A

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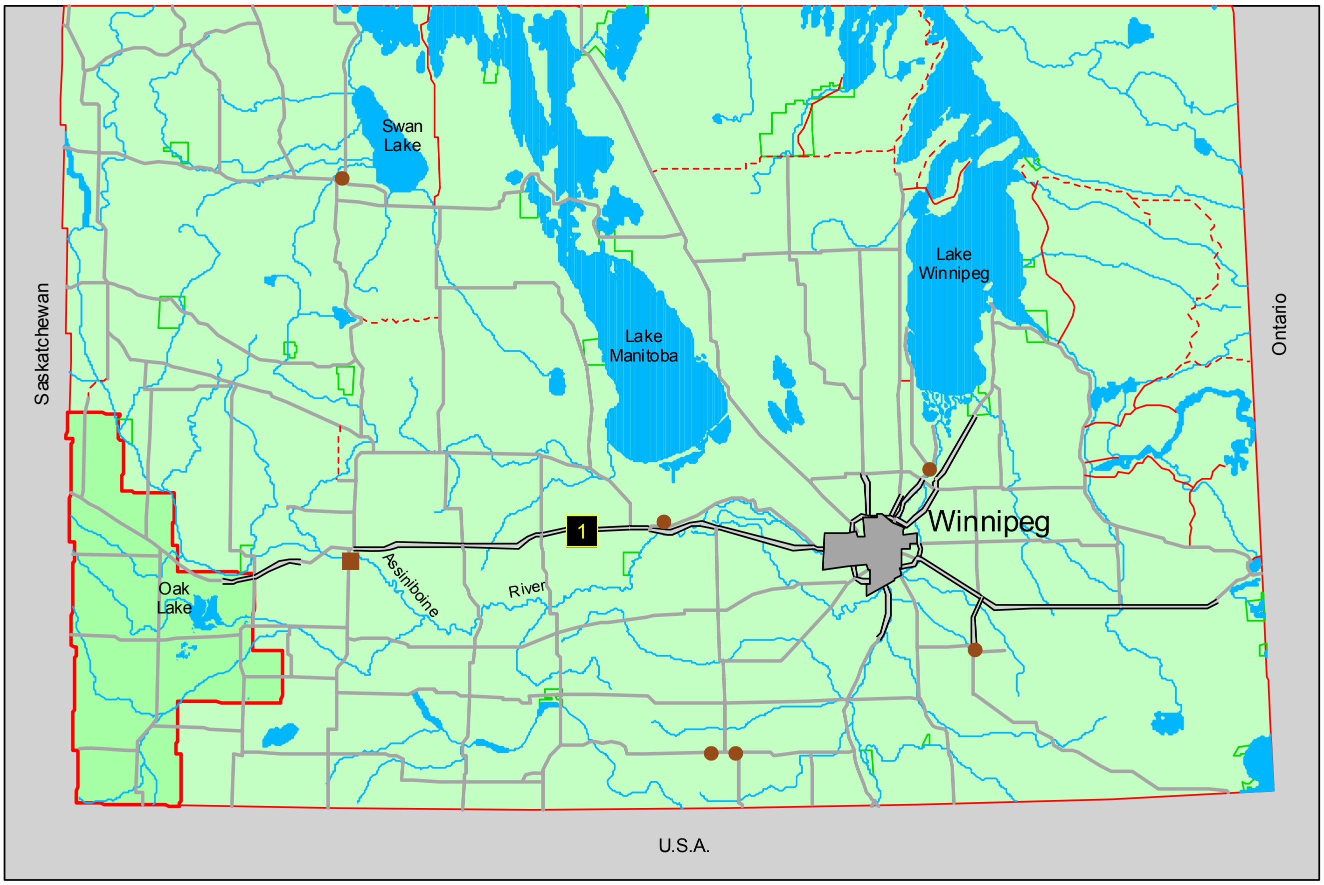
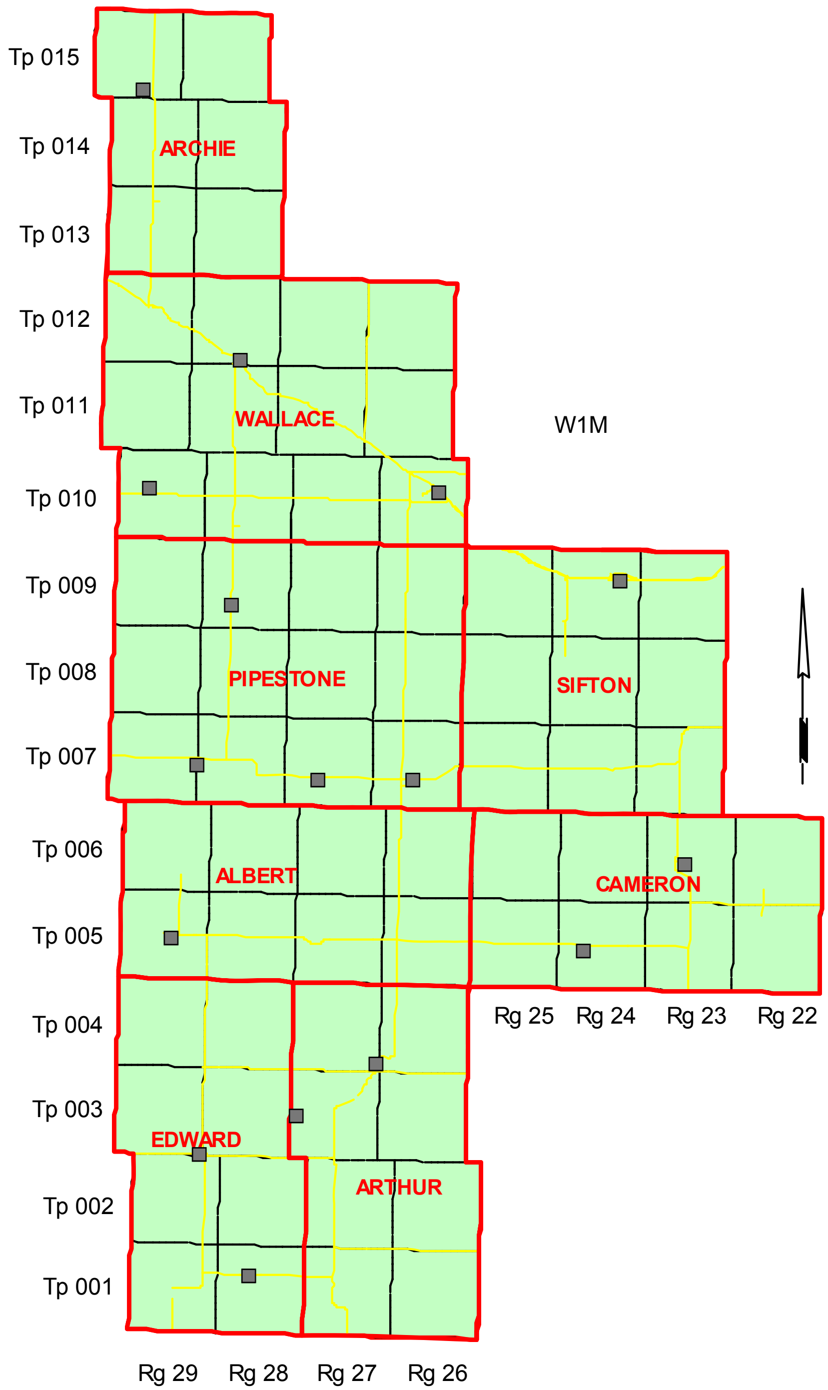
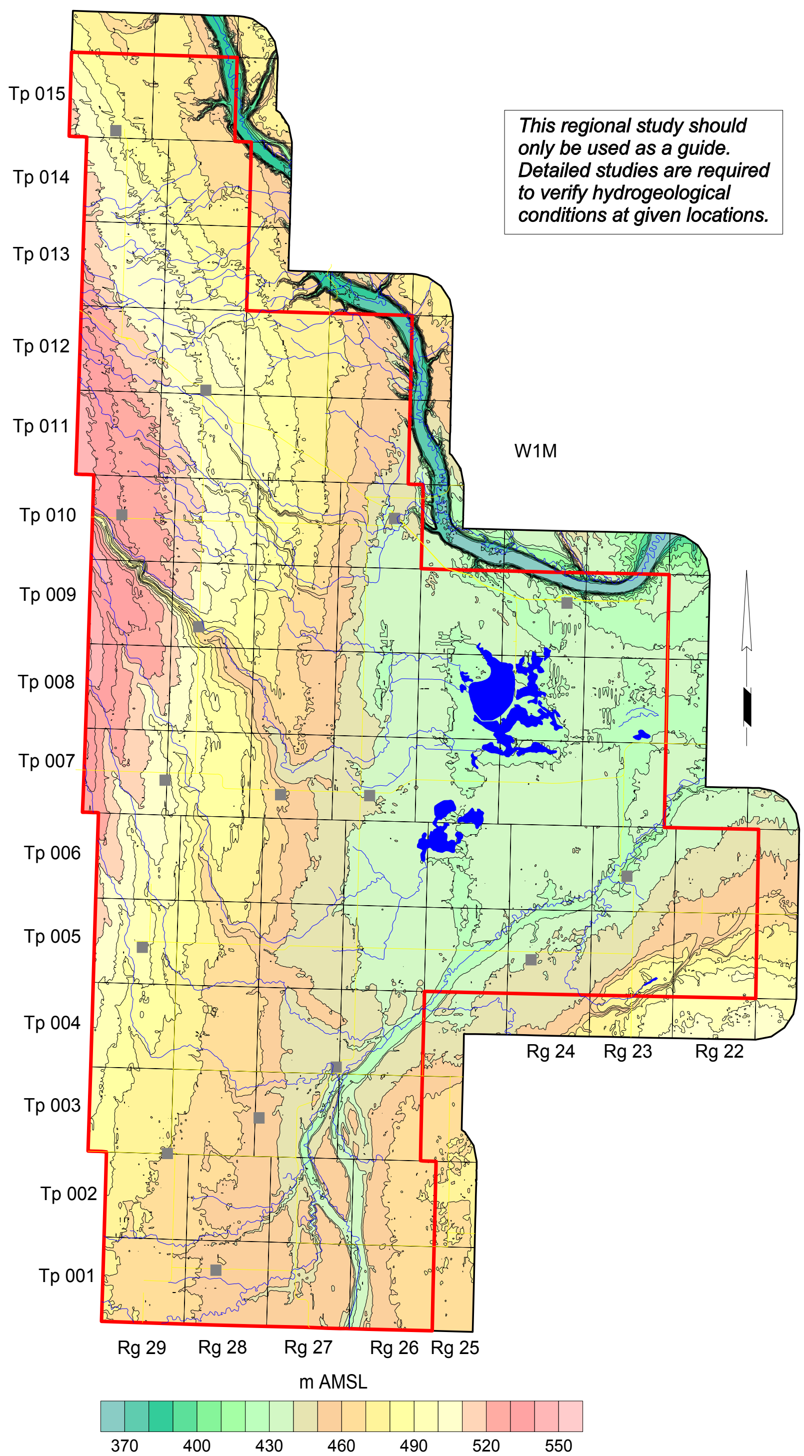


Rural Municipalities in Study Area

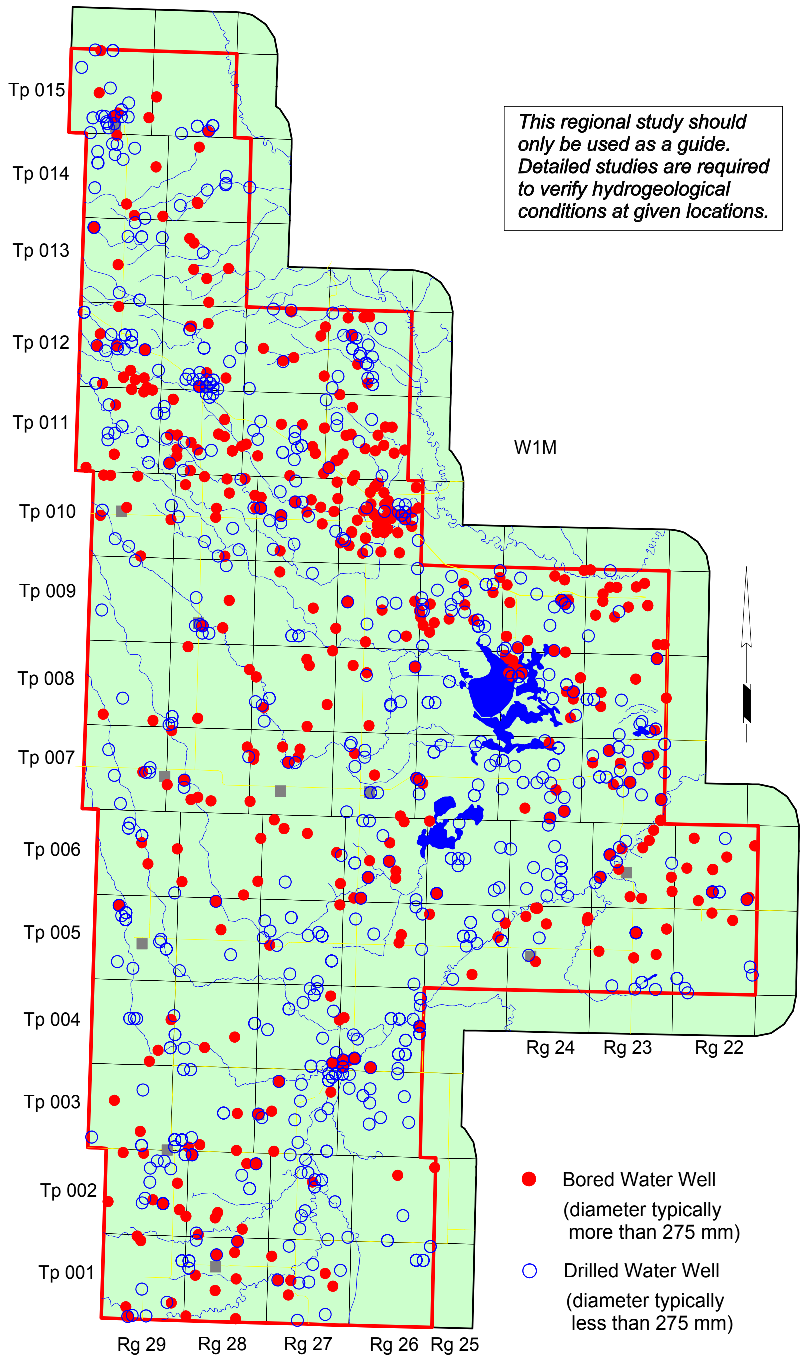


Surface Topography

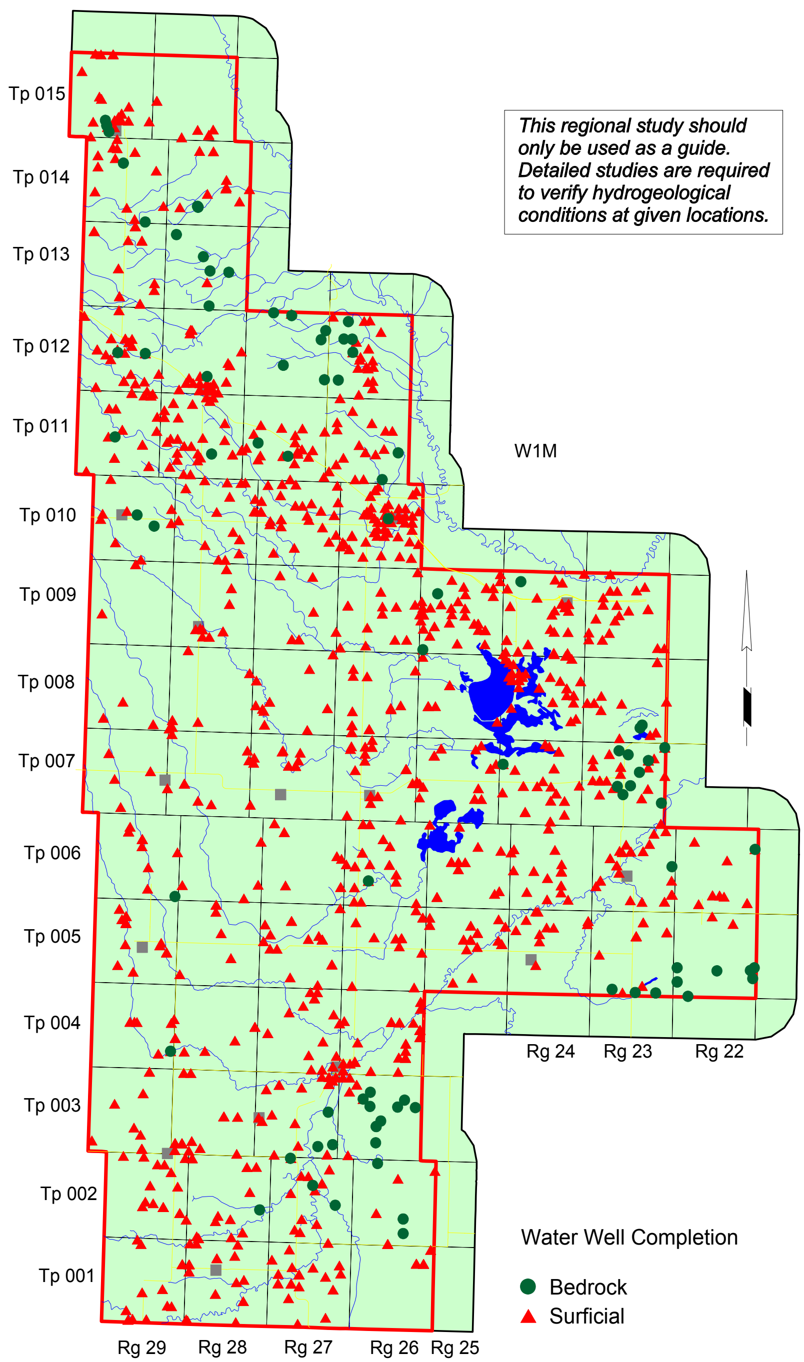
This regional study should only be used as a guide. Detailed studies are required to verify hydrogeological conditions at given locations.



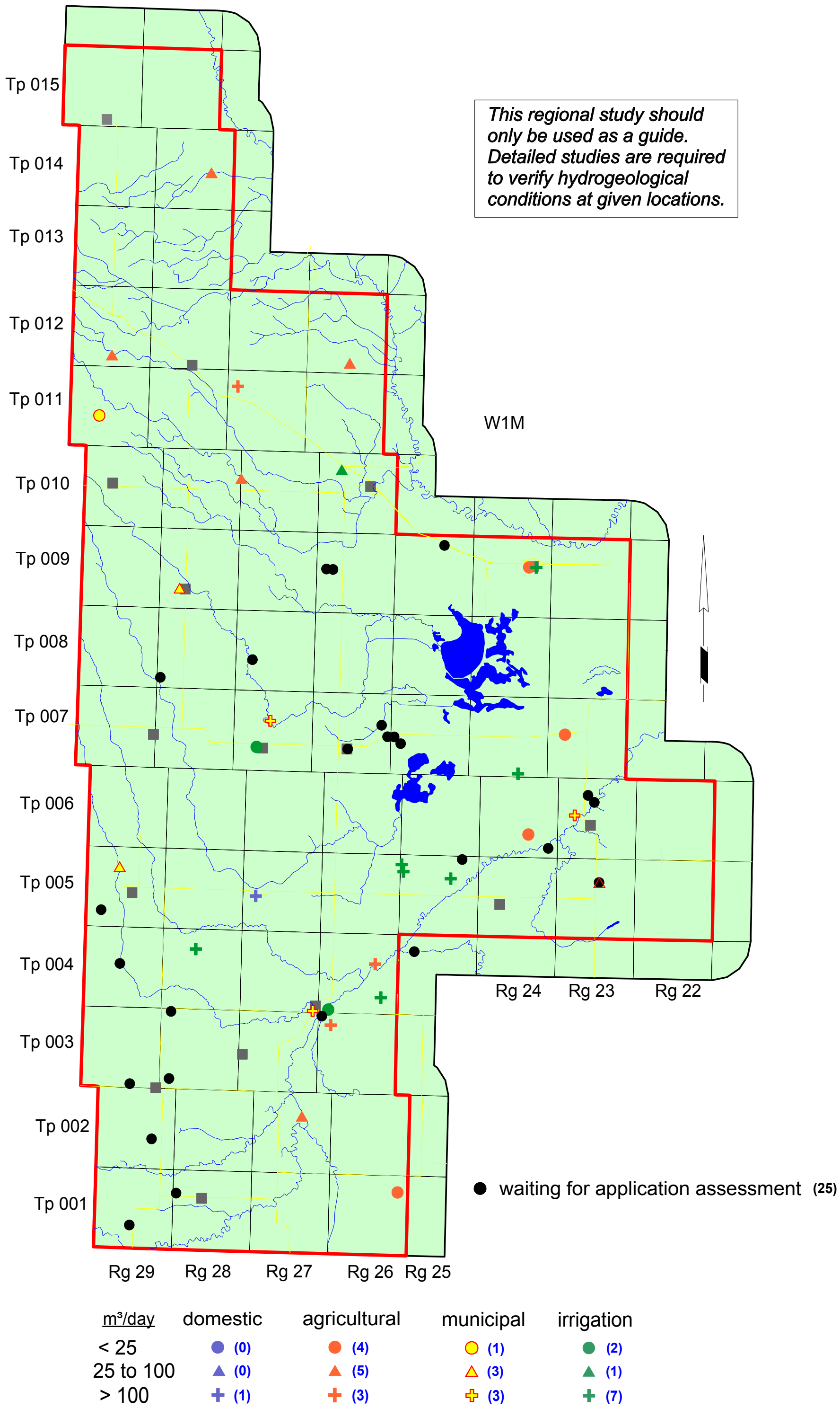
Location of Drilled and Bored Water Wells



Location of Surficial and Bedrock Water Wells



Licensed Water Wells

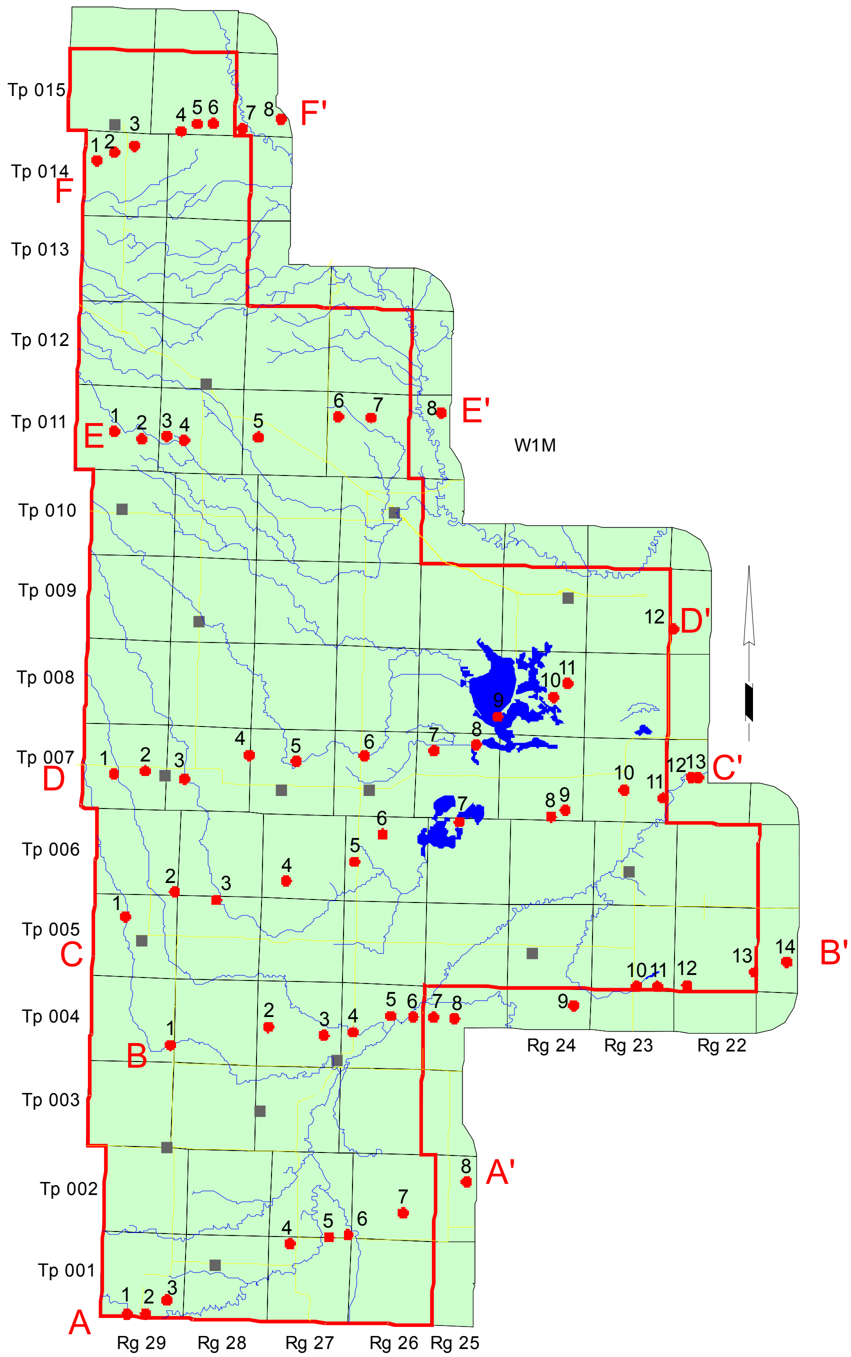


Generalized Geologic Column

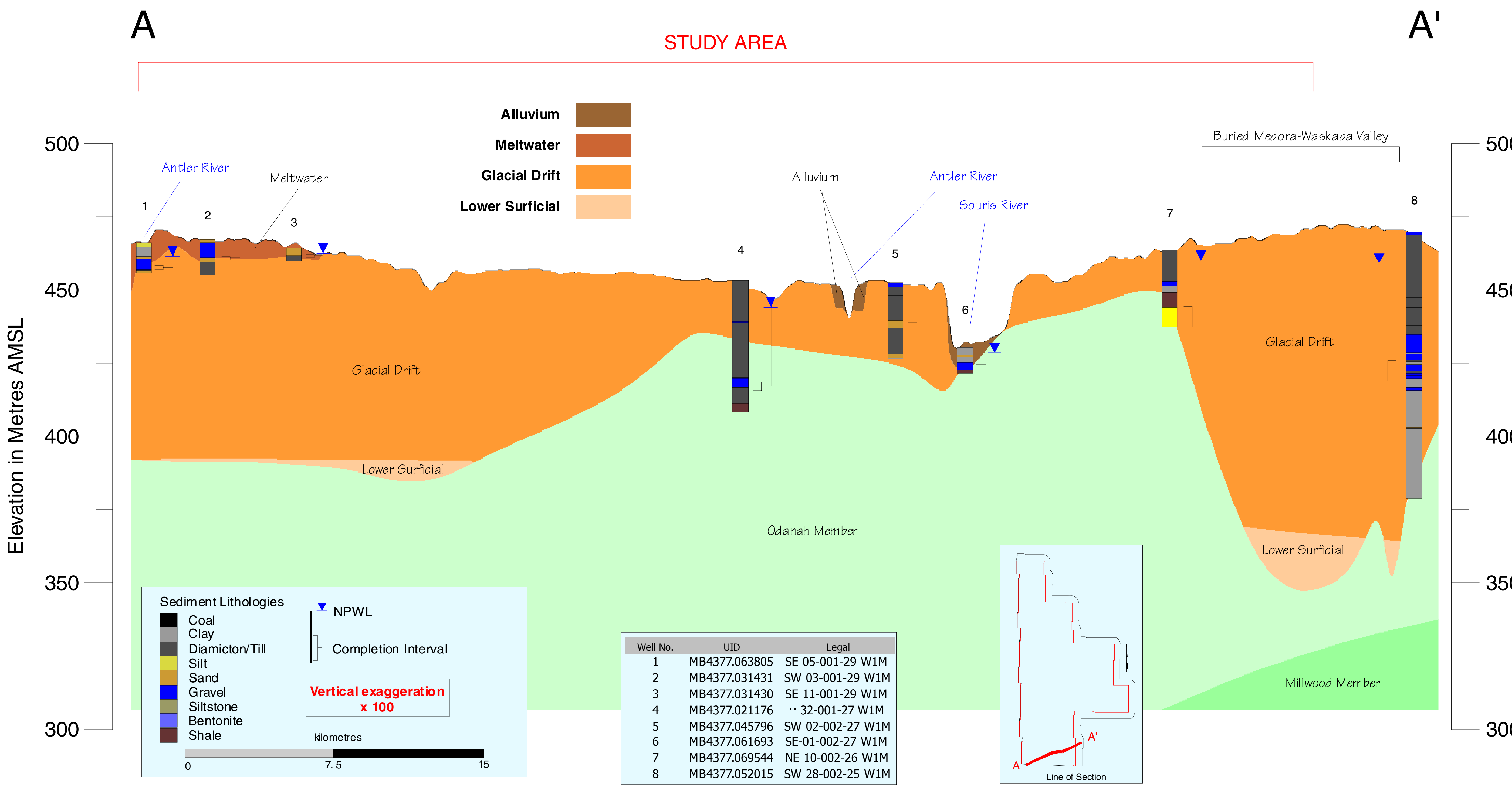
Group and Formation					Geologic Unit		
Lithologic Description	Average Thickness (m)	Designation			Average Thickness (m)	Depositional Environment	Material
sand, gravel, till, clay, silt	< 150	Surficial Deposits			<30	Alluvium	Sand or Gravel
					<30	Oak Lake	Sand
					<25	Meltwater	Sand or Gravel
					<150	Glacial Drift	Gravel, Sand, Silt, Clay or Till
					<70	Lower Surficial Deposits	Sand or Gravel
shale, bentonite	120 to 335	Pierre Shale	Alberta/Saskatchewan Equivalents	Belly River Group	150	Odanah Member	
				Lea Park Formation	15 to 150	Millwood Member	
					2 to 12	Pembina Member	
				Milk River Formation	5 to 50	Gammon Member	

Geologic Column

West – East Cross-Sections

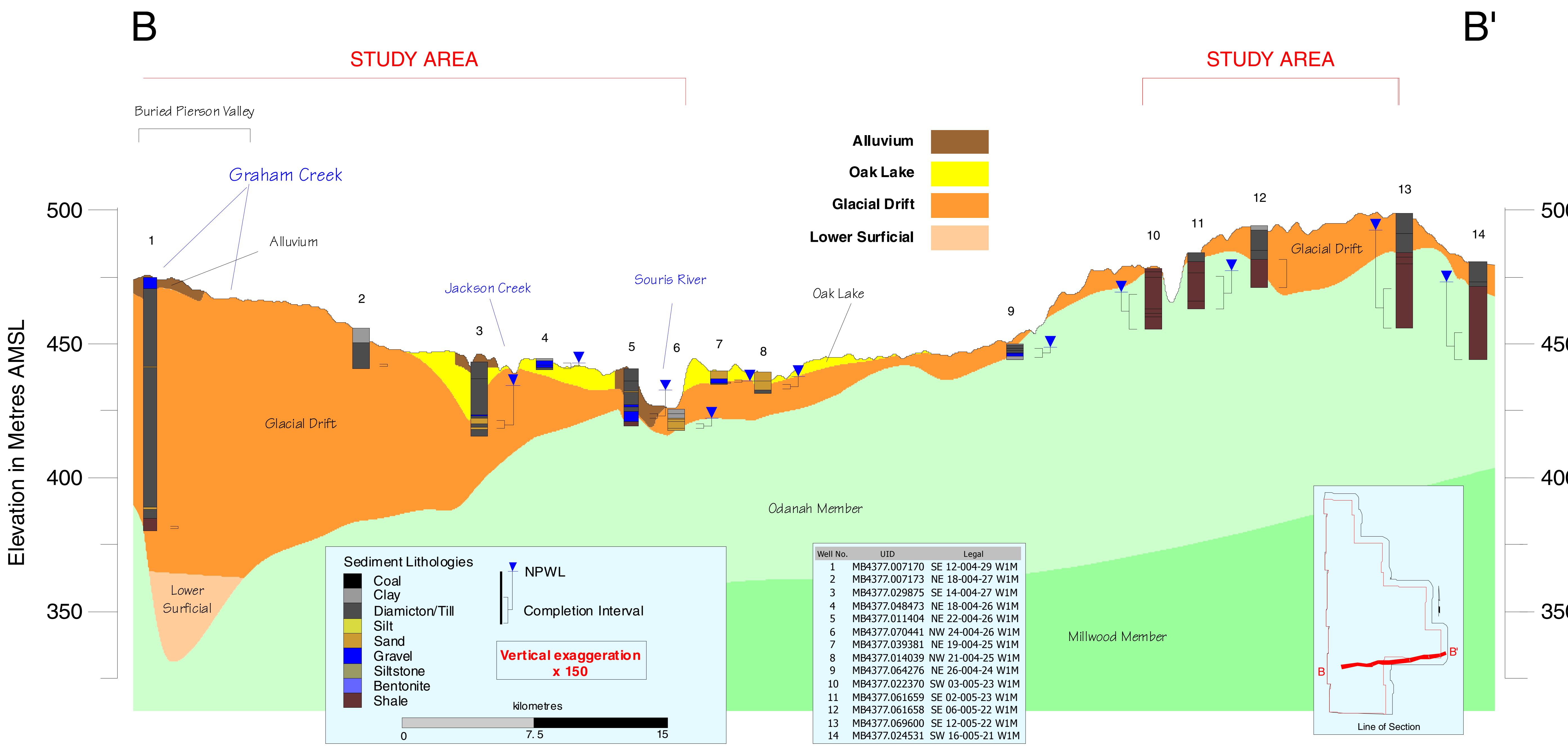


Cross-Section A - A'



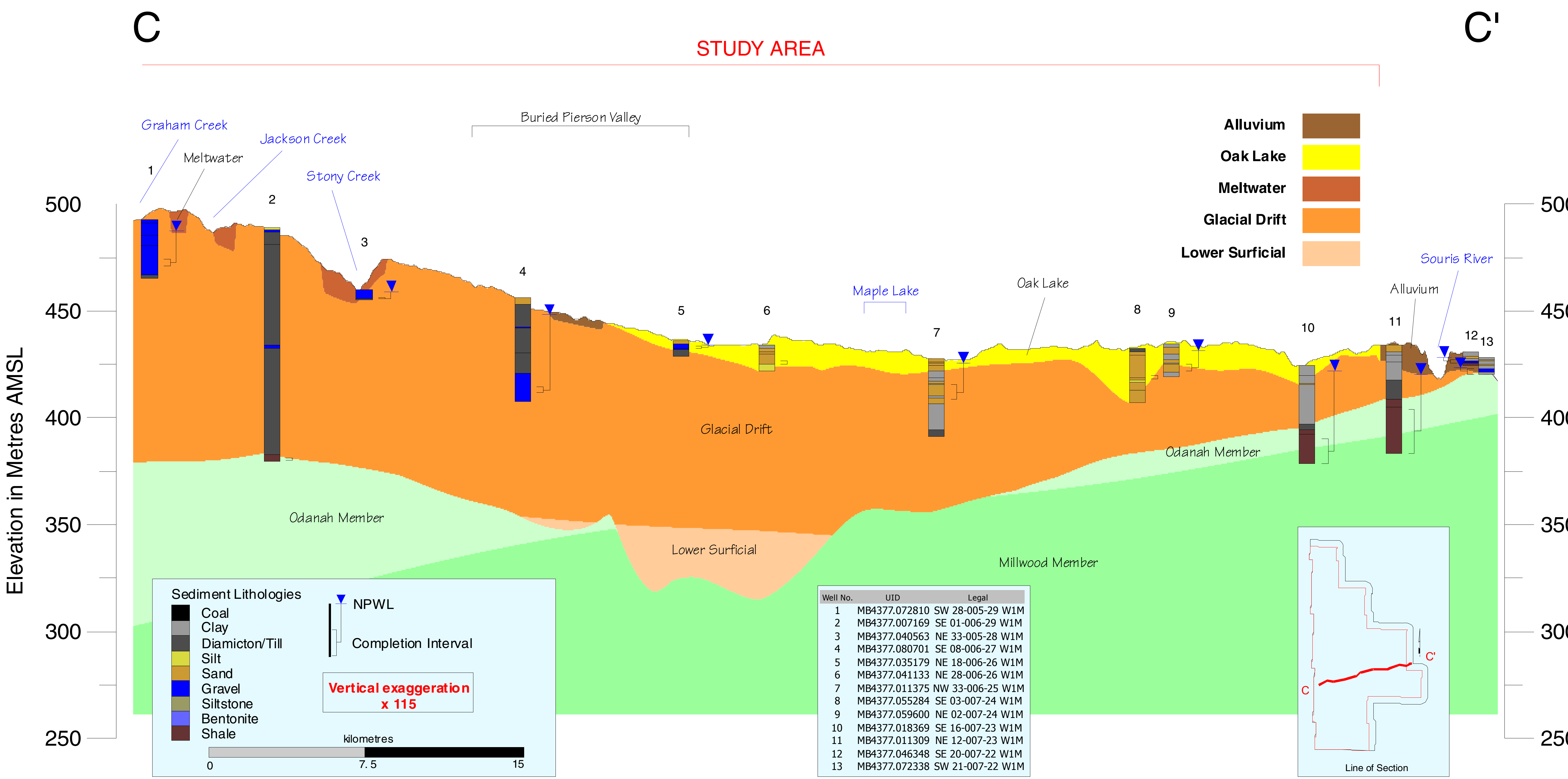
Well No.	UID	Legal
1	MB4377.063805	SE 05-001-29 W1M
2	MB4377.031431	SW 03-001-29 W1M
3	MB4377.031430	SE 11-001-29 W1M
4	MB4377.021176	·· 32-001-27 W1M
5	MB4377.045796	SW 02-002-27 W1M
6	MB4377.061693	SE-01-002-27 W1M
7	MB4377.069544	NE 10-002-26 W1M
8	MB4377.052015	SW 28-002-25 W1M

Cross-Section B - B'



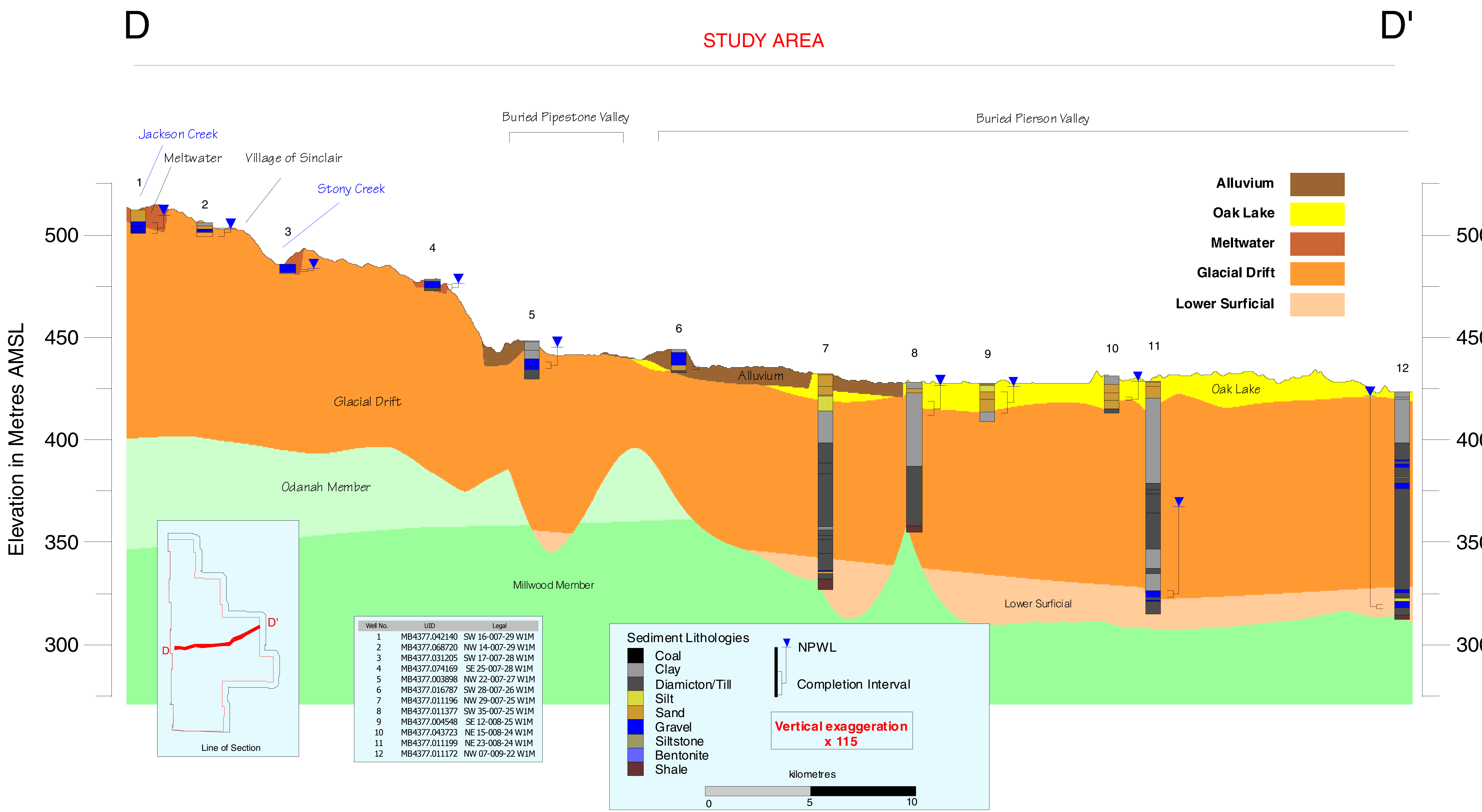
Well No.	UID	Legal
1	MB4377.007170	SE 12-004-29 W1M
2	MB4377.007173	NE 18-004-27 W1M
3	MB4377.029875	SE 14-004-27 W1M
4	MB4377.048473	NE 18-004-26 W1M
5	MB4377.011404	NE 22-004-26 W1M
6	MB4377.070441	NW 24-004-26 W1M
7	MB4377.039381	NE 19-004-25 W1M
8	MB4377.014039	NW 21-004-25 W1M
9	MB4377.064276	NE 26-004-24 W1M
10	MB4377.022370	SW 03-005-23 W1M
11	MB4377.061659	SE 02-005-23 W1M
12	MB4377.061658	SE 06-005-22 W1M
13	MB4377.069600	SE 12-005-22 W1M
14	MB4377.024531	SW 16-005-21 W1M

Cross-Section C - C'



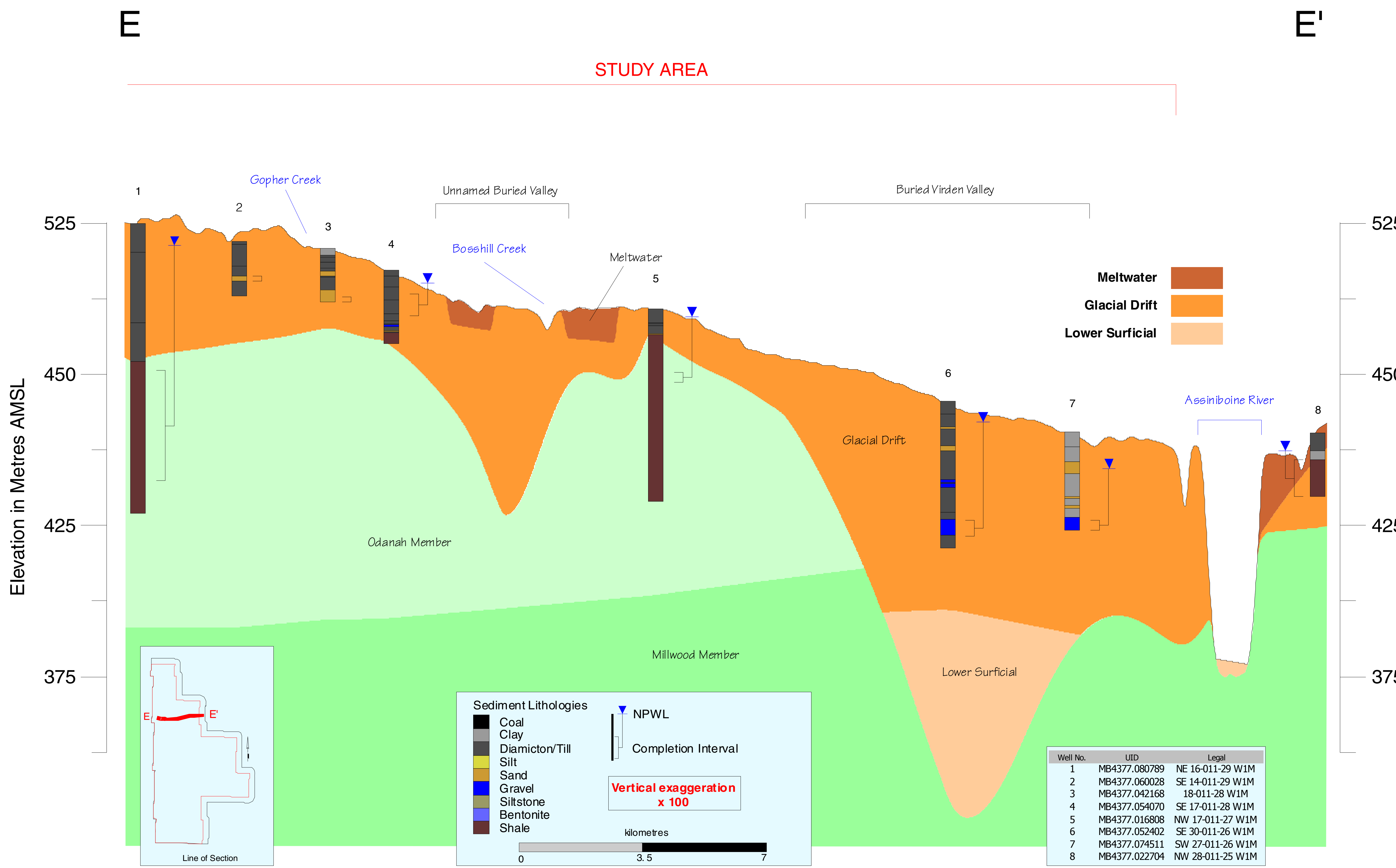
Well No.	UID	Legal
1	MB4377.072810	SW 28-005-29 W1M
2	MB4377.007169	SE 01-006-29 W1M
3	MB4377.040563	NE 33-005-28 W1M
4	MB4377.080701	SE 08-006-27 W1M
5	MB4377.035179	NE 18-006-26 W1M
6	MB4377.041133	NE 28-006-26 W1M
7	MB4377.011375	NW 33-006-25 W1M
8	MB4377.055284	SE 03-007-24 W1M
9	MB4377.059600	NE 02-007-24 W1M
10	MB4377.018369	SE 16-007-23 W1M
11	MB4377.011309	NE 12-007-23 W1M
12	MB4377.046348	SE 20-007-22 W1M
13	MB4377.072338	SW 21-007-22 W1M

Cross-Section D - D'



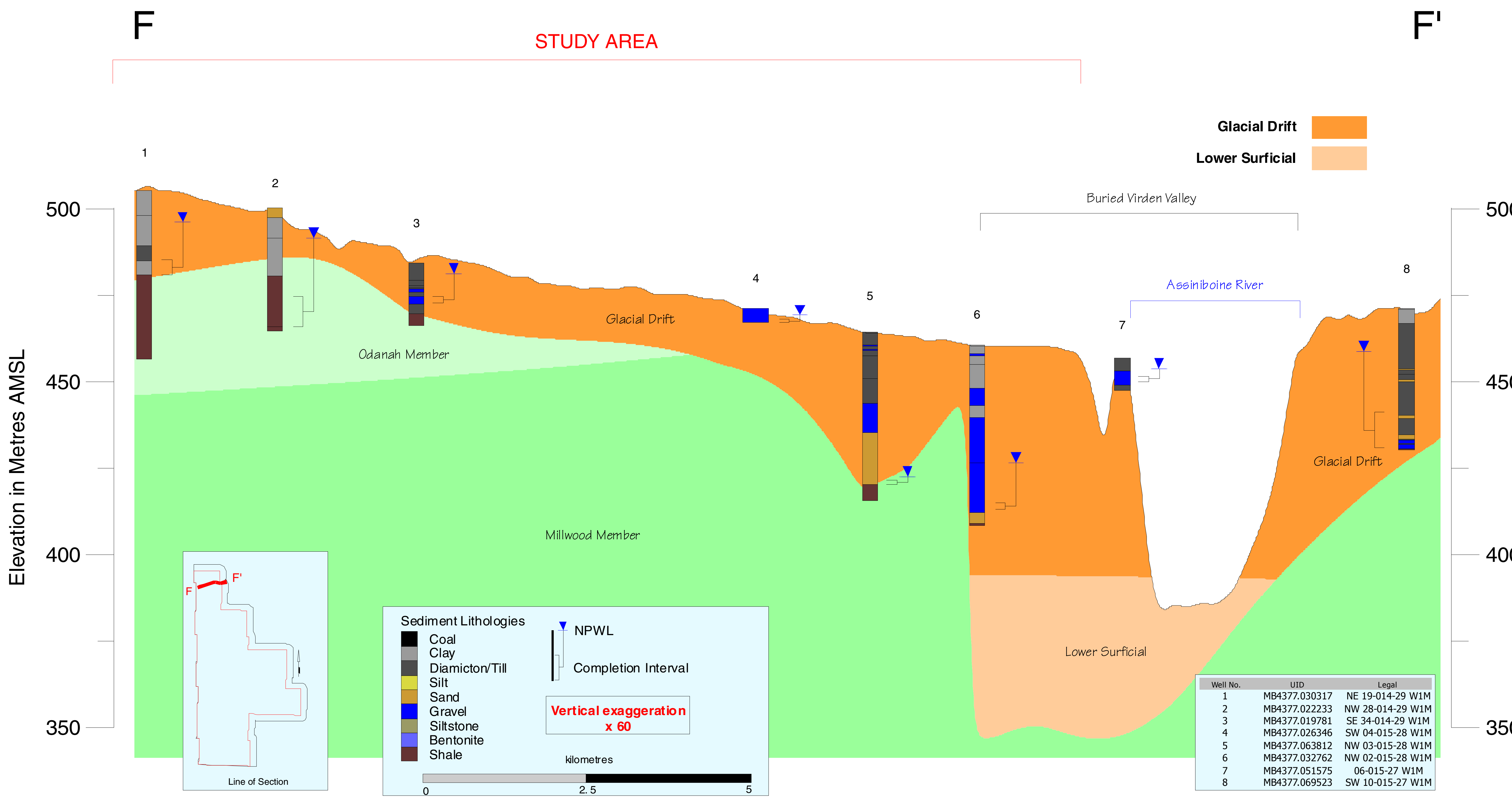
Well No.	UID	Legal
1	MB4377.042140	SW 16-007-29 W1M
2	MB4377.068720	NW 14-007-29 W1M
3	MB4377.031205	SW 17-007-28 W1M
4	MB4377.074169	SE 25-007-28 W1M
5	MB4377.003898	NW 22-007-27 W1M
6	MB4377.016787	SW 28-007-26 W1M
7	MB4377.011196	NW 29-007-25 W1M
8	MB4377.011377	SW 35-007-25 W1M
9	MB4377.004548	SE 12-008-25 W1M
10	MB4377.043723	NE 15-008-24 W1M
11	MB4377.011199	NE 23-008-24 W1M
12	MB4377.011172	NW 07-009-22 W1M

Cross-Section E - E'



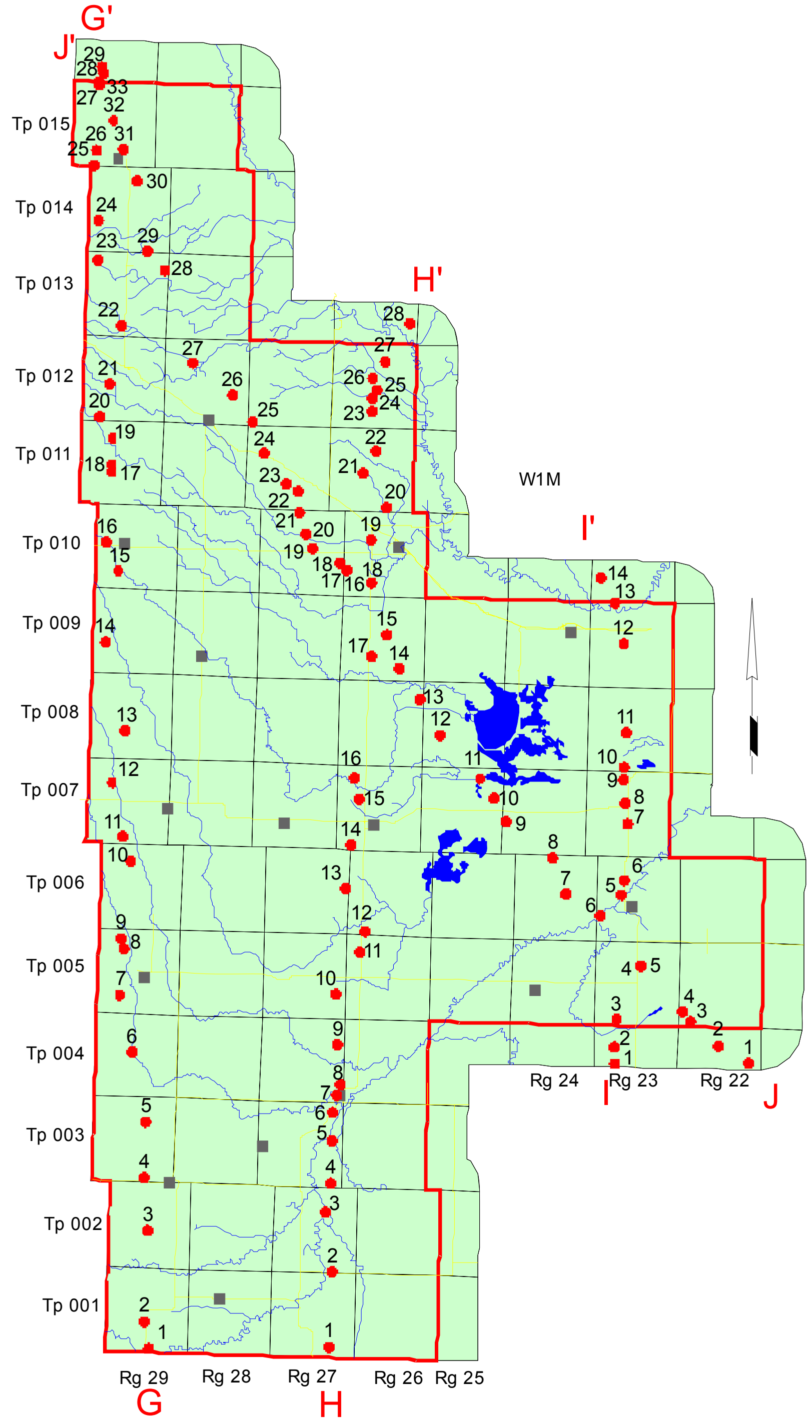
Well No.	UID	Legal
1	MB4377.080789	NE 16-011-29 W1M
2	MB4377.060028	SE 14-011-29 W1M
3	MB4377.042168	18-011-28 W1M
4	MB4377.054070	SE 17-011-28 W1M
5	MB4377.016808	NW 17-011-27 W1M
6	MB4377.052402	SE 30-011-26 W1M
7	MB4377.074511	SW 27-011-26 W1M
8	MB4377.022704	NW 28-011-25 W1M

Cross-Section F - F'

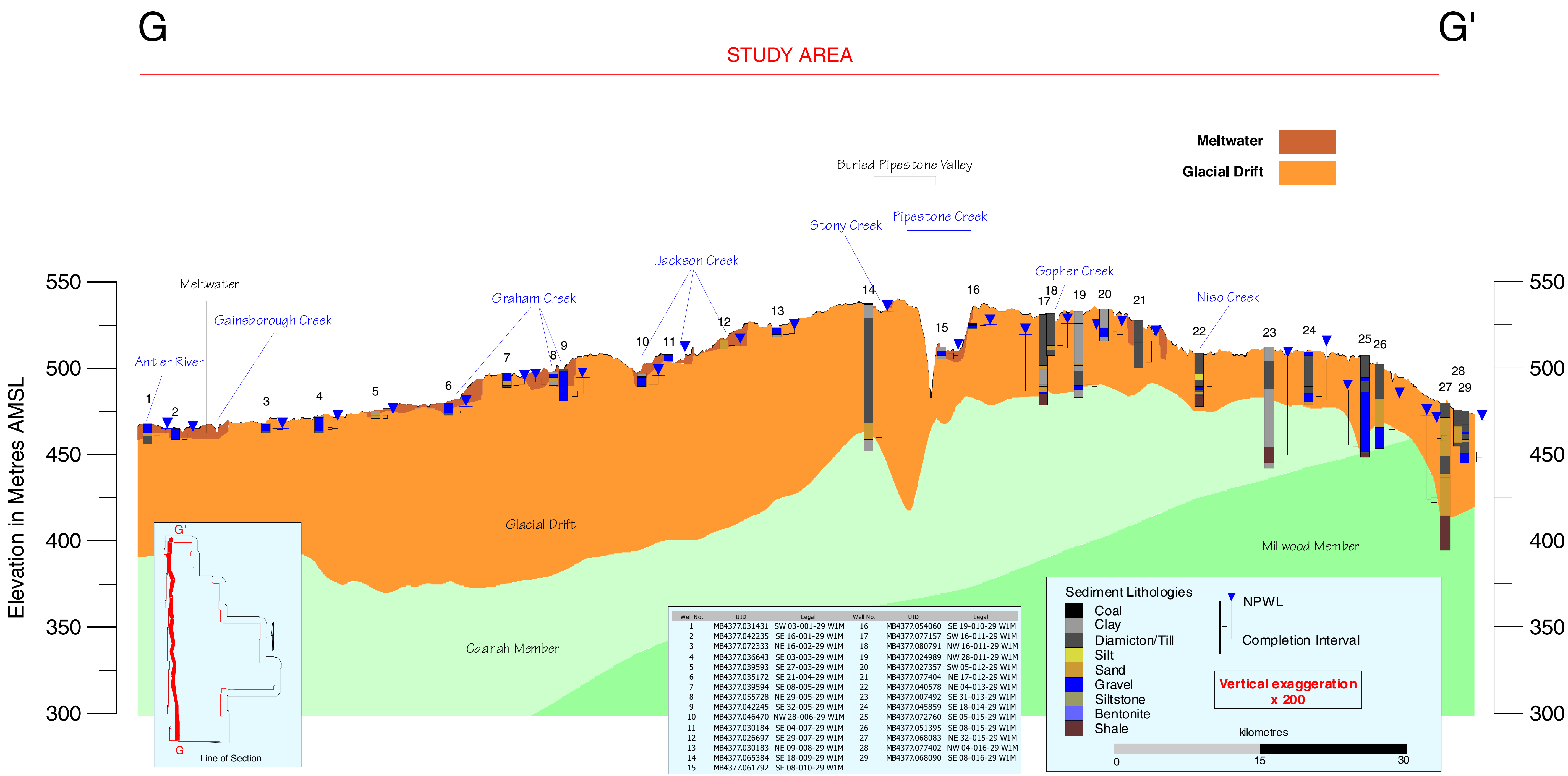


Well No.	UID	Legal
1	MB4377.030317	NE 19-014-29 W1M
2	MB4377.022233	NW 28-014-29 W1M
3	MB4377.019781	SE 34-014-29 W1M
4	MB4377.026346	SW 04-015-28 W1M
5	MB4377.063812	NW 03-015-28 W1M
6	MB4377.032762	NW 02-015-28 W1M
7	MB4377.051575	06-015-27 W1M
8	MB4377.069523	SW 10-015-27 W1M

South – North Cross-Sections



Cross-Section G - G'



Well No.	UID	Legal	Well No.	UID	Legal
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2	MB4377.042235	SE 16-001-29 W1M	17	MB4377.077157	SW 16-011-29 W1M
3	MB4377.072333	NE 16-002-29 W1M	18	MB4377.080791	NW 16-011-29 W1M
4	MB4377.036643	SE 03-003-29 W1M	19	MB4377.024989	NW 28-011-29 W1M
5	MB4377.039593	SE 27-003-29 W1M	20	MB4377.027357	SW 05-012-29 W1M
6	MB4377.035172	SE 21-004-29 W1M	21	MB4377.077404	NE 17-012-29 W1M
7	MB4377.039594	SE 08-005-29 W1M	22	MB4377.040578	NE 04-013-29 W1M
8	MB4377.055728	NE 29-005-29 W1M	23	MB4377.007492	SE 31-013-29 W1M
9	MB4377.042245	SE 32-005-29 W1M	24	MB4377.045859	SE 18-014-29 W1M
10	MB4377.046470	NW 28-006-29 W1M	25	MB4377.072760	SE 05-015-29 W1M
11	MB4377.030184	SE 04-007-29 W1M	26	MB4377.051395	SE 08-015-29 W1M
12	MB4377.026697	SE 29-007-29 W1M	27	MB4377.068083	NE 32-015-29 W1M
13	MB4377.030183	NE 09-008-29 W1M	28	MB4377.077402	NW 04-016-29 W1M
14	MB4377.065384	SE 18-009-29 W1M	29	MB4377.068090	SE 08-016-29 W1M
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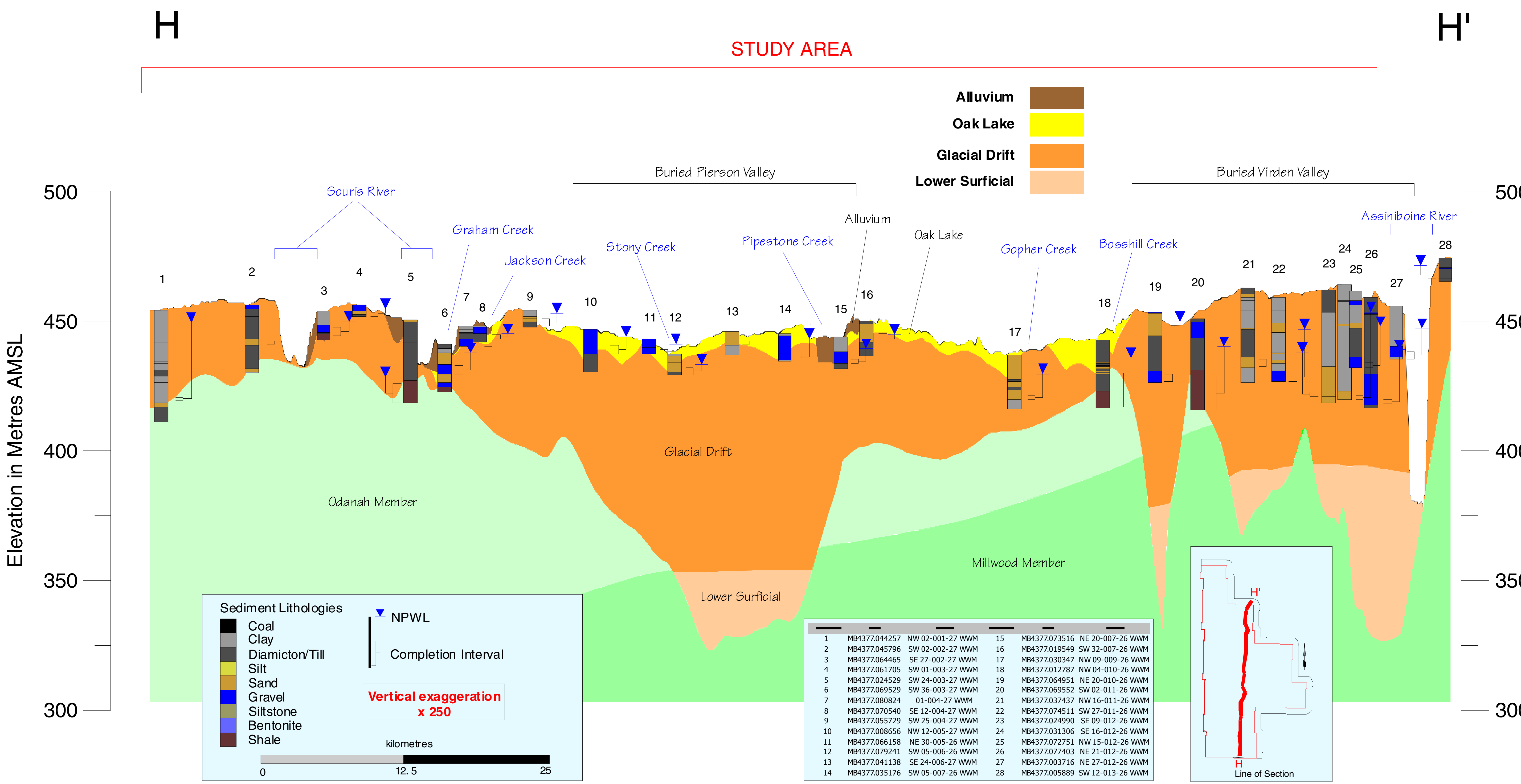
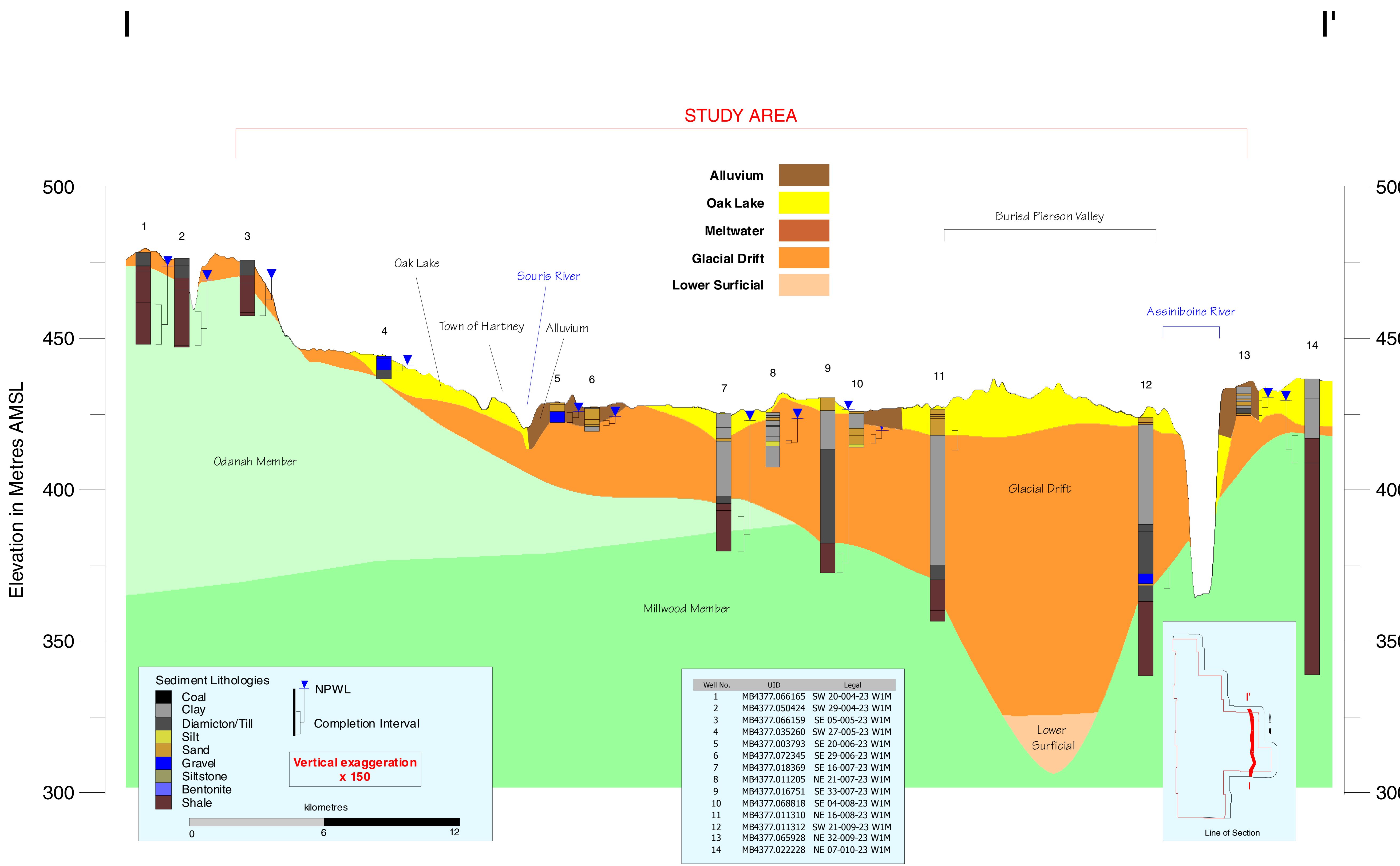
Cross-Section H - H'



1	MB4377.044257	NW 02-001-27 WWM	15	MB4377.073516	NE 20-007-26 WWM
2	MB4377.045796	SW 02-002-27 WWM	16	MB4377.019549	SW 32-007-26 WWM
3	MB4377.064465	SE 27-002-27 WWM	17	MB4377.030347	NW 09-009-26 WWM
4	MB4377.061705	SW 01-003-27 WWM	18	MB4377.012787	NW 04-010-26 WWM
5	MB4377.024529	SW 24-003-27 WWM	19	MB4377.064951	NE 20-010-26 WWM
6	MB4377.069529	SW 36-003-27 WWM	20	MB4377.069552	SW 02-011-26 WWM
7	MB4377.080824	01-004-27 WWM	21	MB4377.037437	NW 16-011-26 WWM
8	MB4377.070540	SE 12-004-27 WWM	22	MB4377.074511	SW 27-011-26 WWM
9	MB4377.055729	SW 25-004-27 WWM	23	MB4377.024990	SE 09-012-26 WWM
10	MB4377.008656	NW 12-005-27 WWM	24	MB4377.031306	SE 16-012-26 WWM
11	MB4377.066158	NE 30-005-26 WWM	25	MB4377.072751	NW 15-012-26 WWM
12	MB4377.079241	SW 05-006-26 WWM	26	MB4377.077403	NE 21-012-26 WWM
13	MB4377.041138	SE 24-006-27 WWM	27	MB4377.003716	NE 27-012-26 WWM
14	MB4377.035176	SW 05-007-26 WWM	28	MB4377.005889	SW 12-013-26 WWM

Cross-Section I - I'



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3	MB4377.066159	SE 05-005-23 W1M
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5	MB4377.003793	SE 20-006-23 W1M
6	MB4377.072345	SE 29-006-23 W1M
7	MB4377.018369	SE 16-007-23 W1M
8	MB4377.011205	NE 21-007-23 W1M
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10	MB4377.068818	SE 04-008-23 W1M
11	MB4377.011310	NE 16-008-23 W1M
12	MB4377.011312	SW 21-009-23 W1M
13	MB4377.065928	NE 32-009-23 W1M
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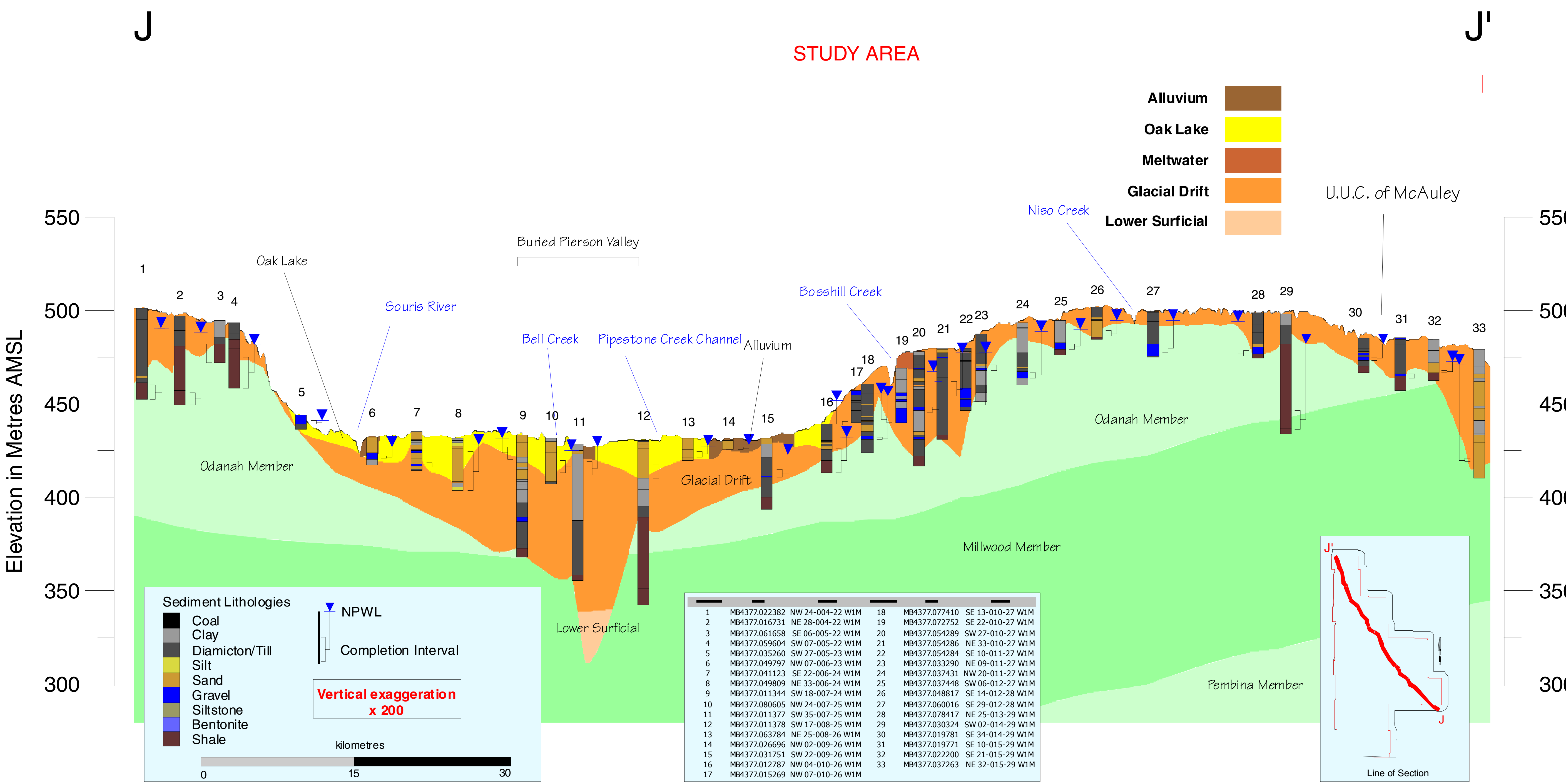
Cross-Section J - J'



1	MB4377.022382	NW 24-004-22 W1M	18	MB4377.077410	SE 13-010-27 W1M
2	MB4377.016731	NE 28-004-22 W1M	19	MB4377.072752	SE 22-010-27 W1M
3	MB4377.061658	SE 06-005-22 W1M	20	MB4377.054289	SW 27-010-27 W1M
4	MB4377.059604	SW 07-005-22 W1M	21	MB4377.054286	NE 33-010-27 W1M
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6	MB4377.049797	NW 07-006-23 W1M	23	MB4377.033290	NE 09-011-27 W1M
7	MB4377.041123	SE 22-006-24 W1M	24	MB4377.037431	NW 20-011-27 W1M
8	MB4377.049809	NE 33-006-24 W1M	25	MB4377.037448	SW 06-012-27 W1M
9	MB4377.011344	SW 18-007-24 W1M	26	MB4377.048817	SE 14-012-28 W1M
10	MB4377.080605	NW 24-007-25 W1M	27	MB4377.060016	SE 29-012-28 W1M
11	MB4377.011377	SW 35-007-25 W1M	28	MB4377.078417	NE 25-013-29 W1M
12	MB4377.011378	SW 17-008-25 W1M	29	MB4377.030324	SW 02-014-29 W1M
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14	MB4377.026696	NW 02-009-26 W1M	31	MB4377.019771	SE 10-015-29 W1M
15	MB4377.031751	SW 22-009-26 W1M	32	MB4377.022200	SE 21-015-29 W1M
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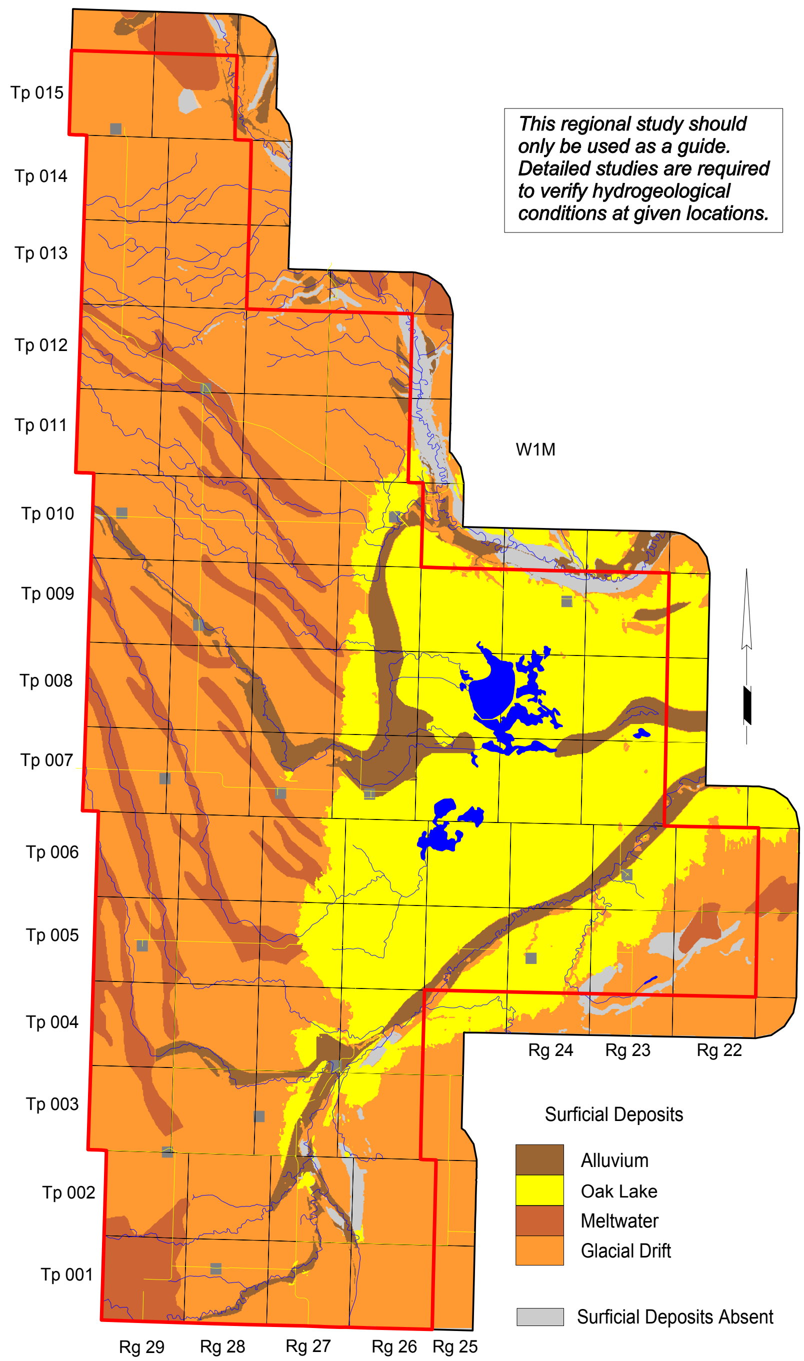
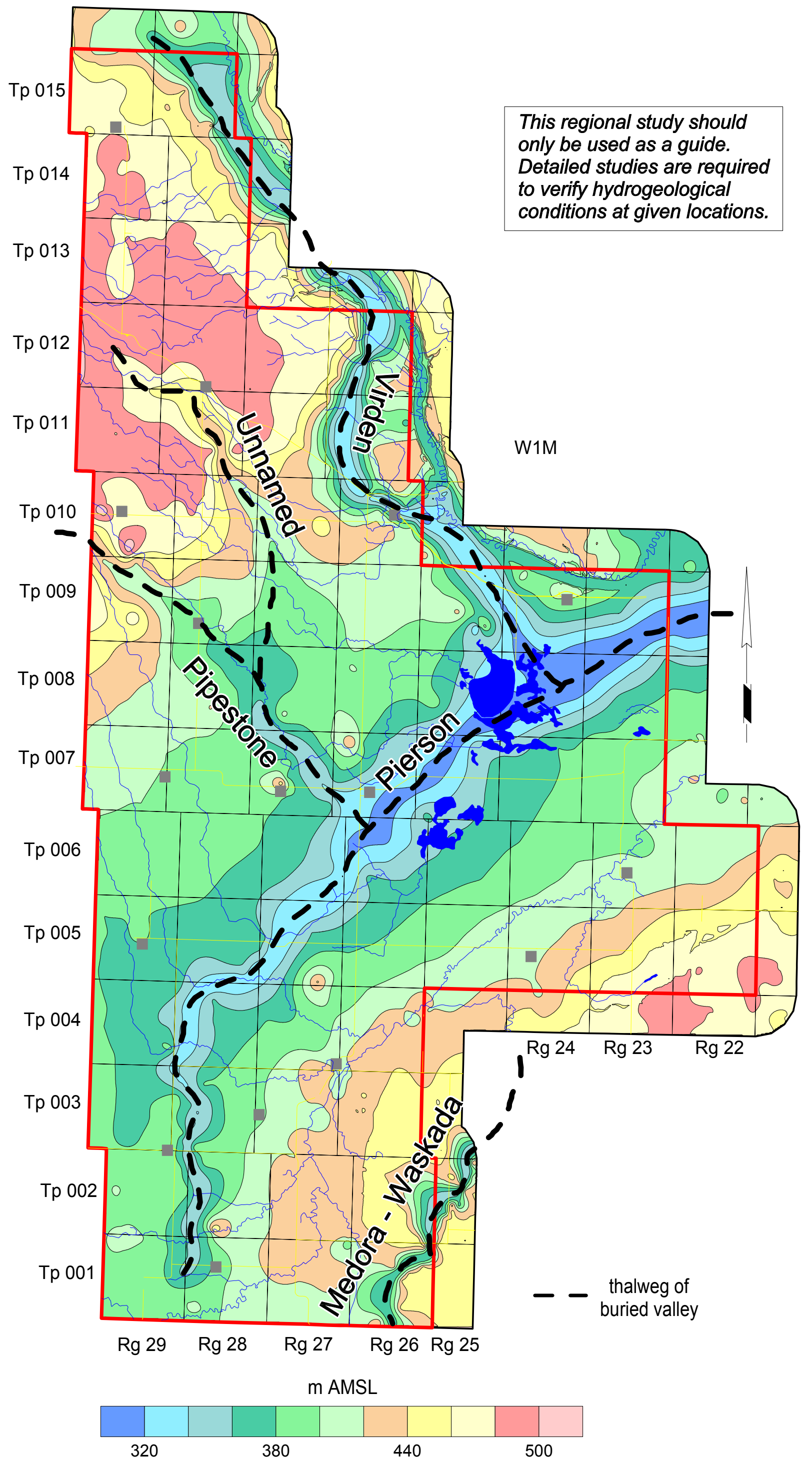
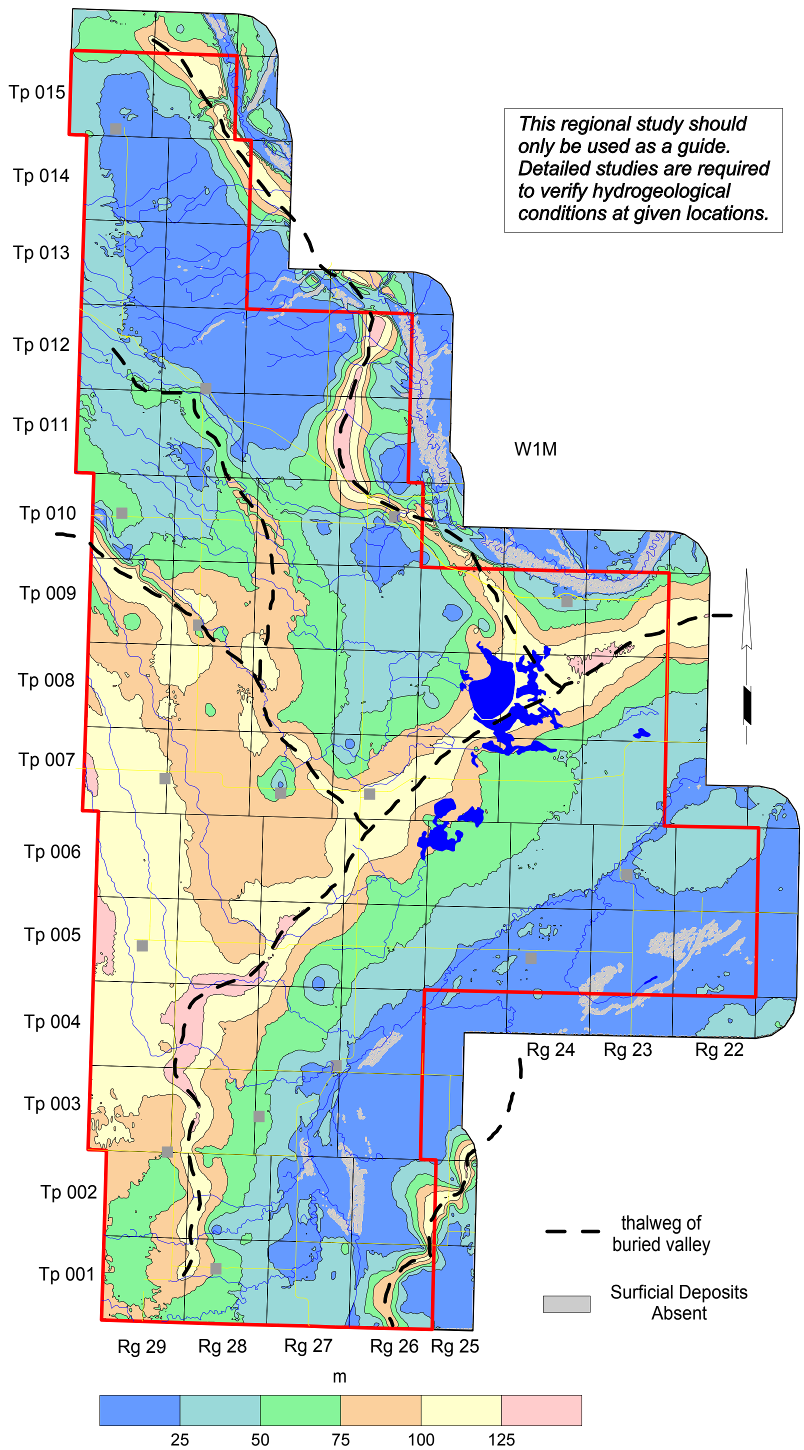
Surficial Deposits at Ground Level



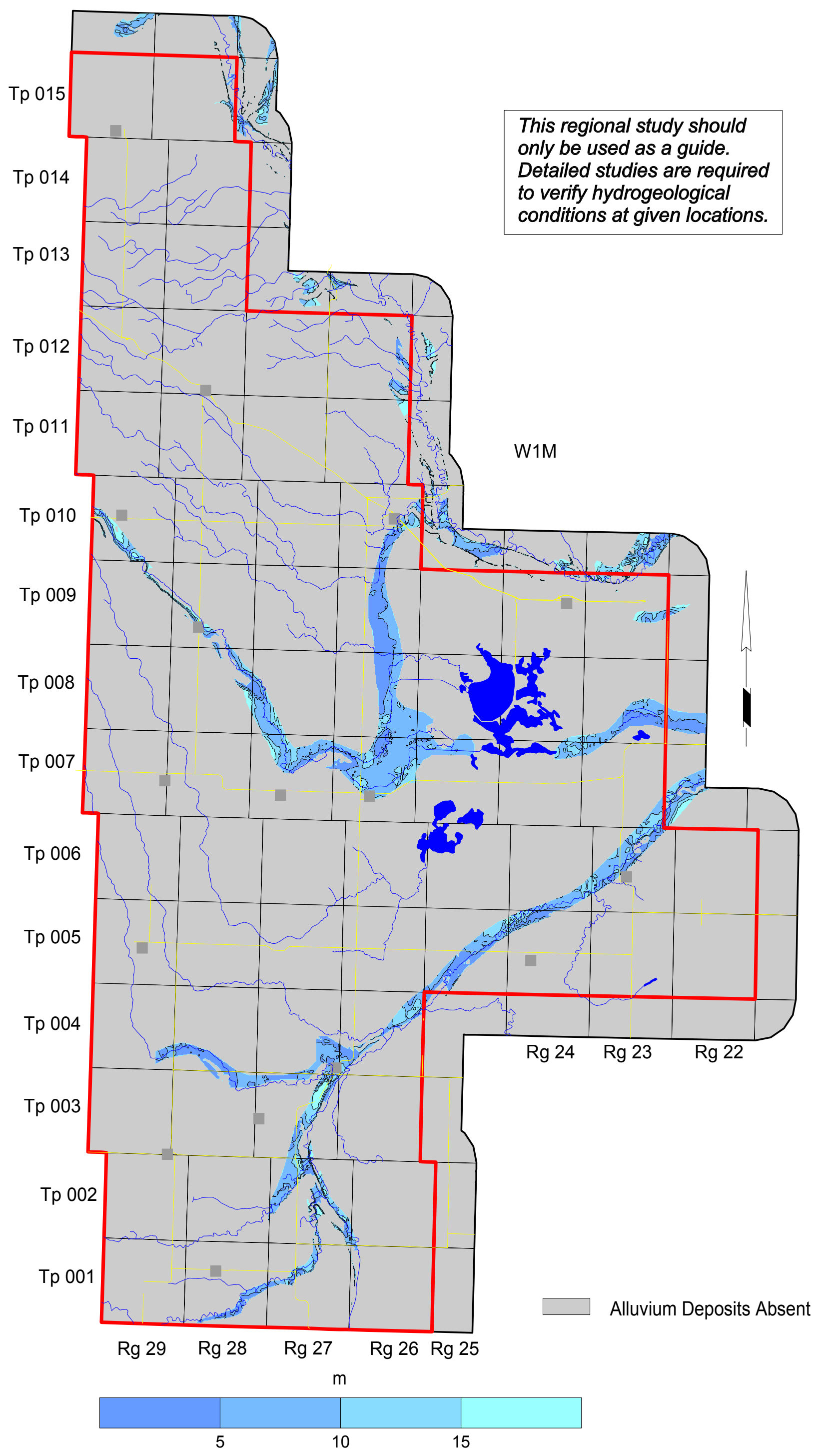
Bedrock Surface Topography



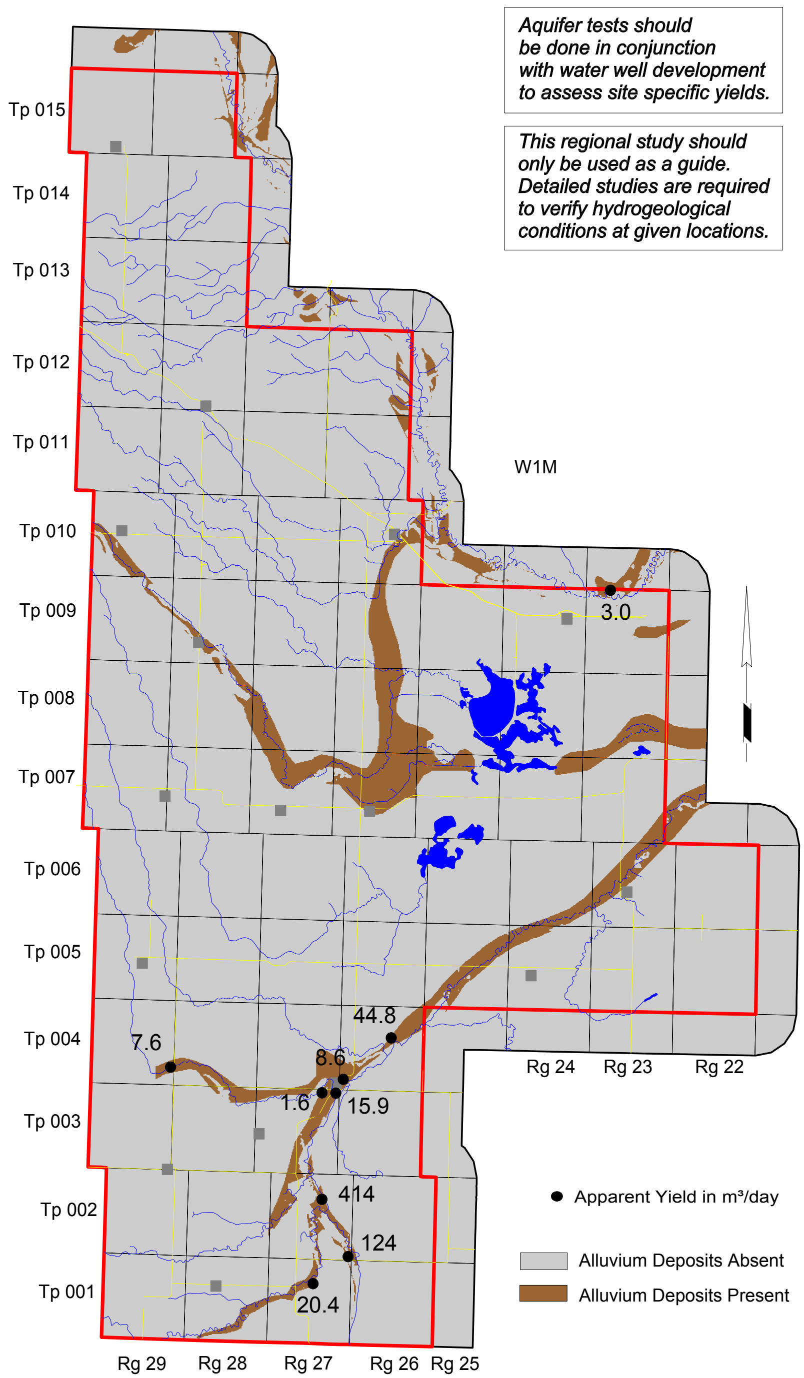
Thickness of Surficial Deposits



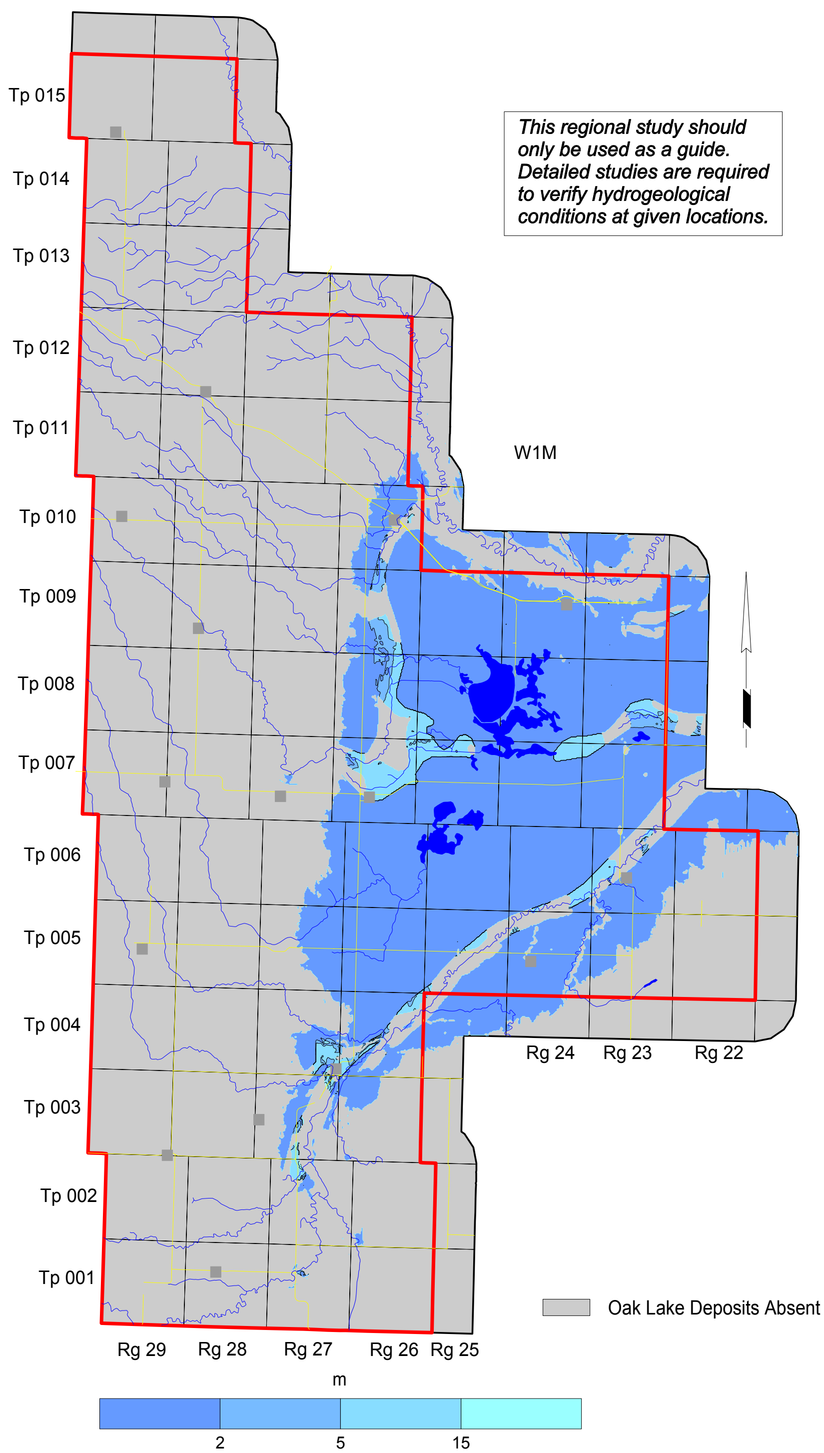
Thickness of Alluvium Deposits



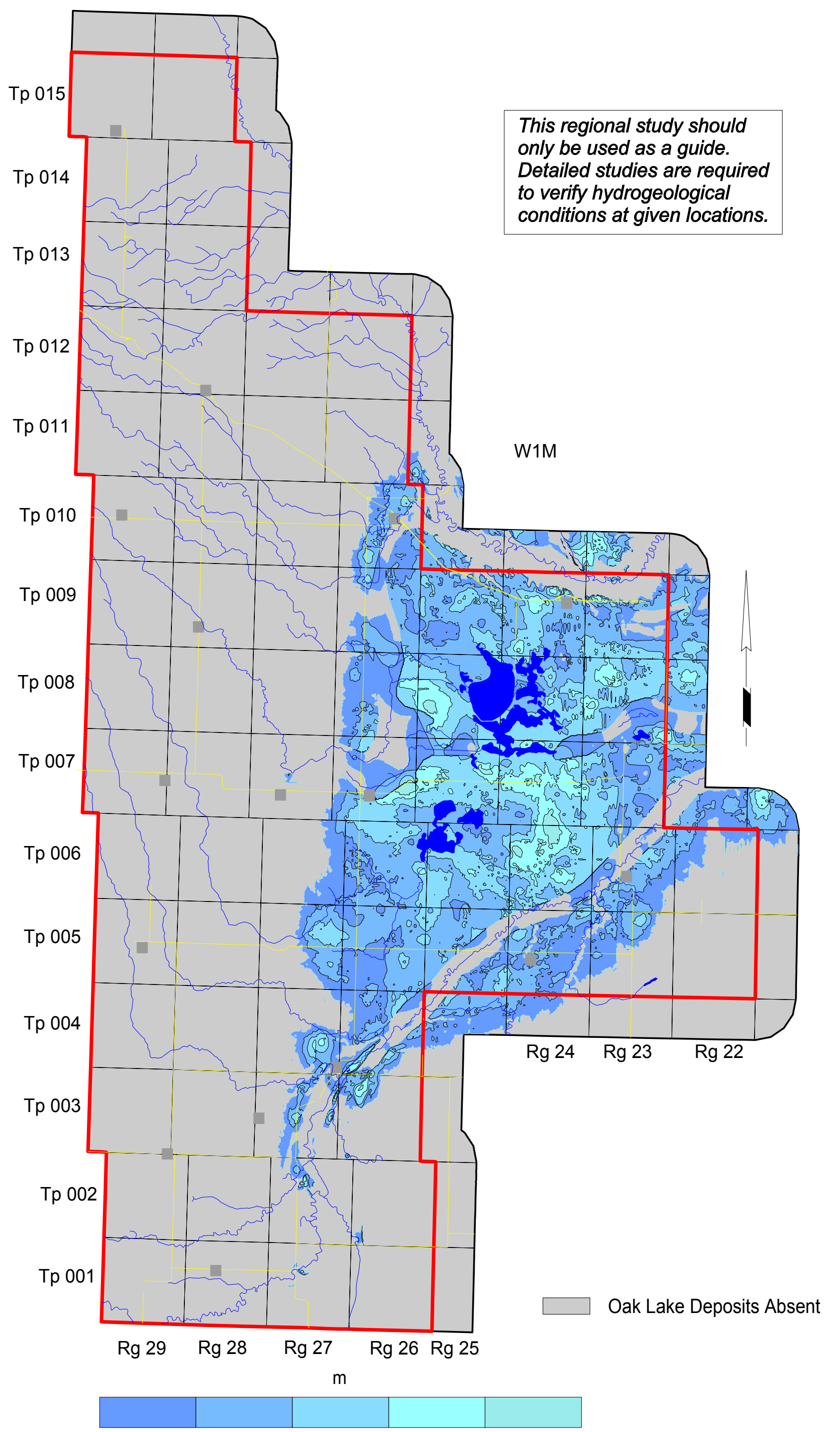
Apparent Yield for Water Wells Completed into Alluvium Deposits



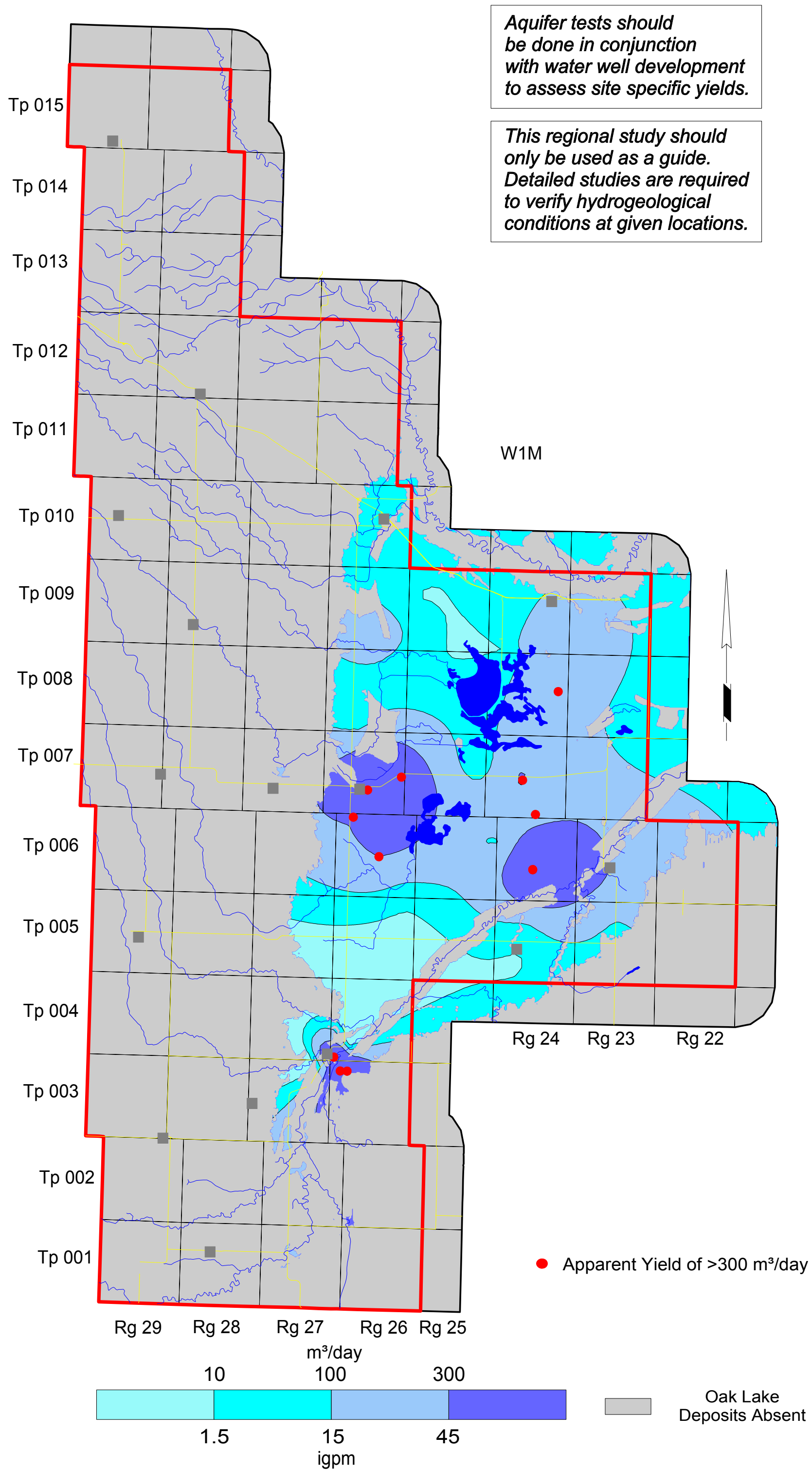
Depth to Top of Oak Lake Deposits



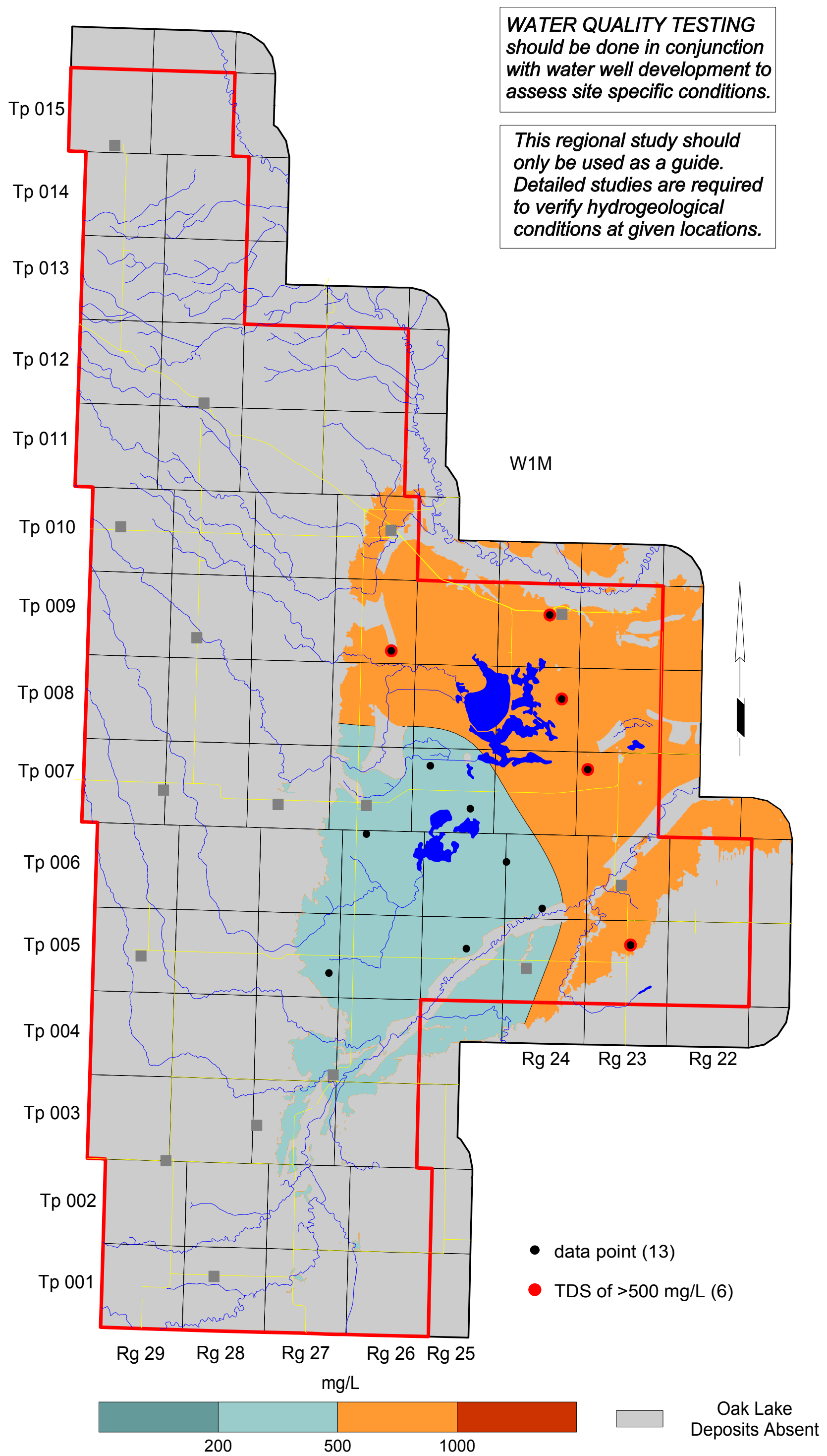
Thickness of Oak Lake Deposits



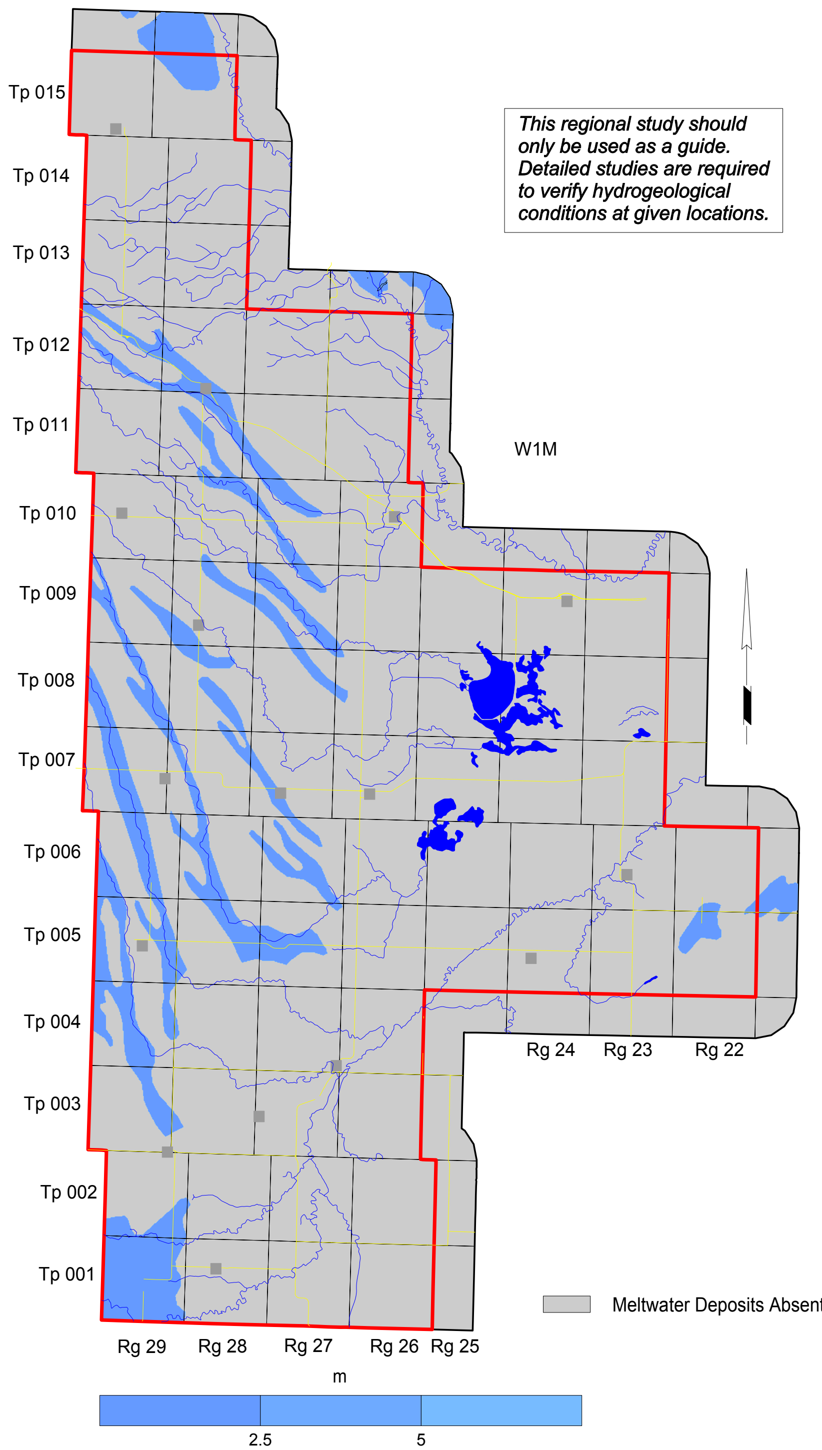
Apparent Yield for Water Wells Completed into Oak Lake Deposits



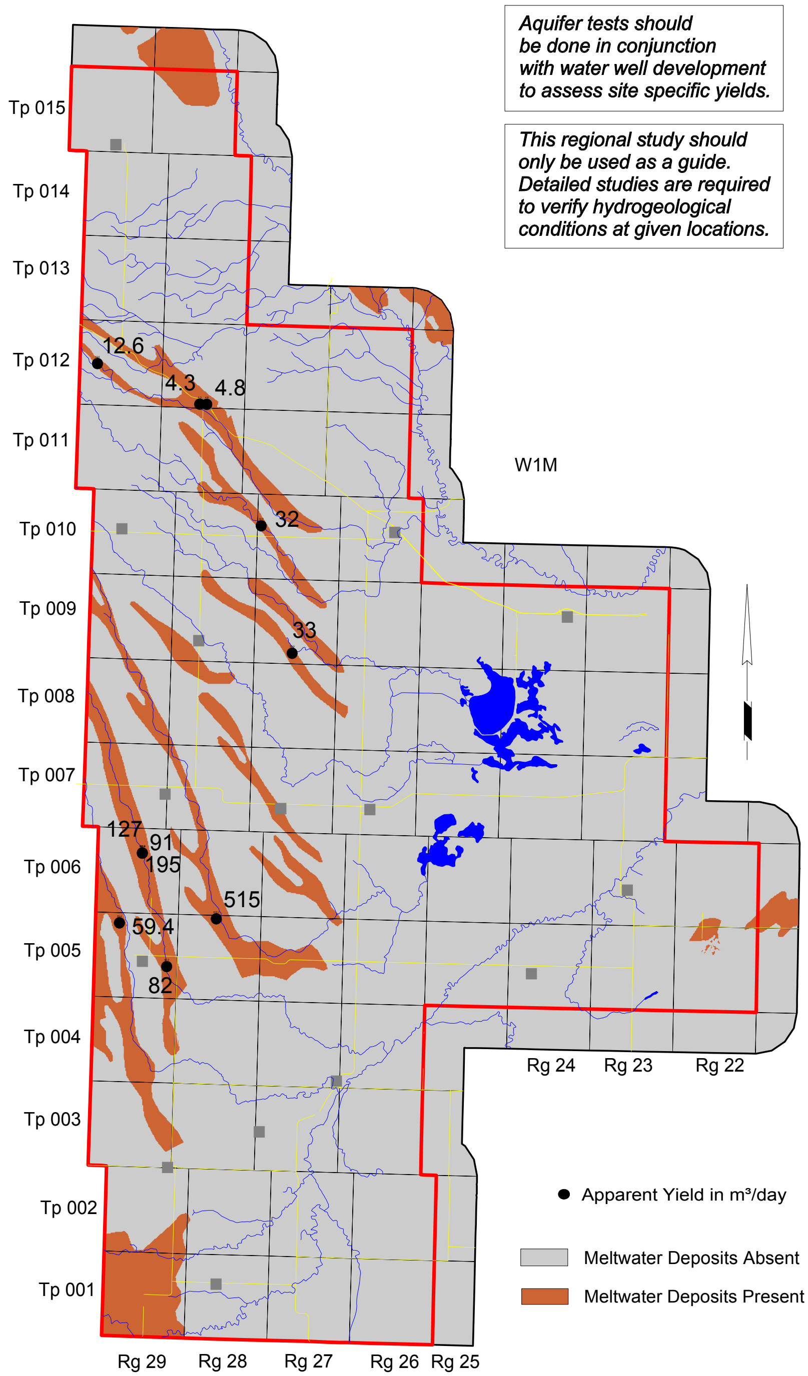
Total Dissolved Solids in Groundwater from Oak Lake Deposits



Depth to Top of Meltwater Deposits



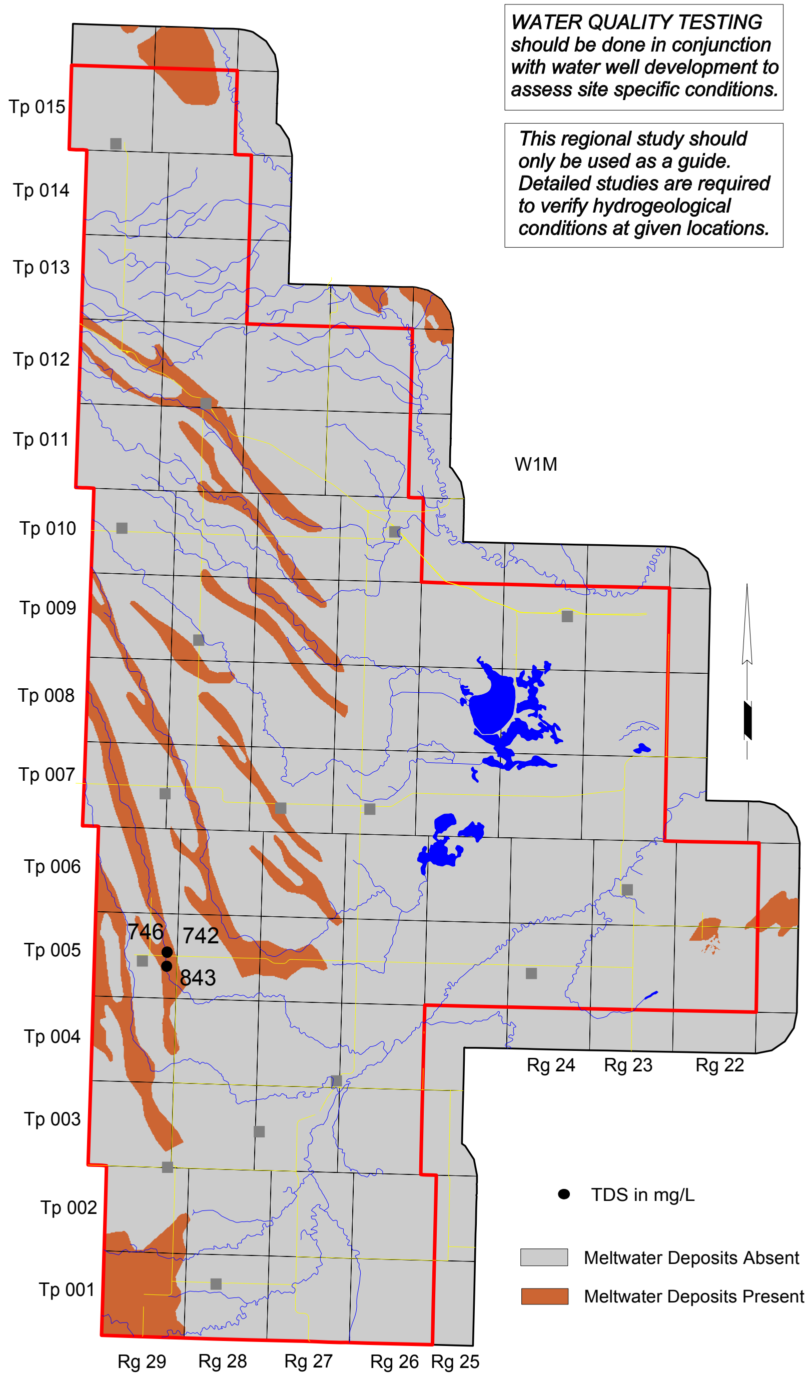
Apparent Yield for Water Wells Completed into Meltwater Deposits



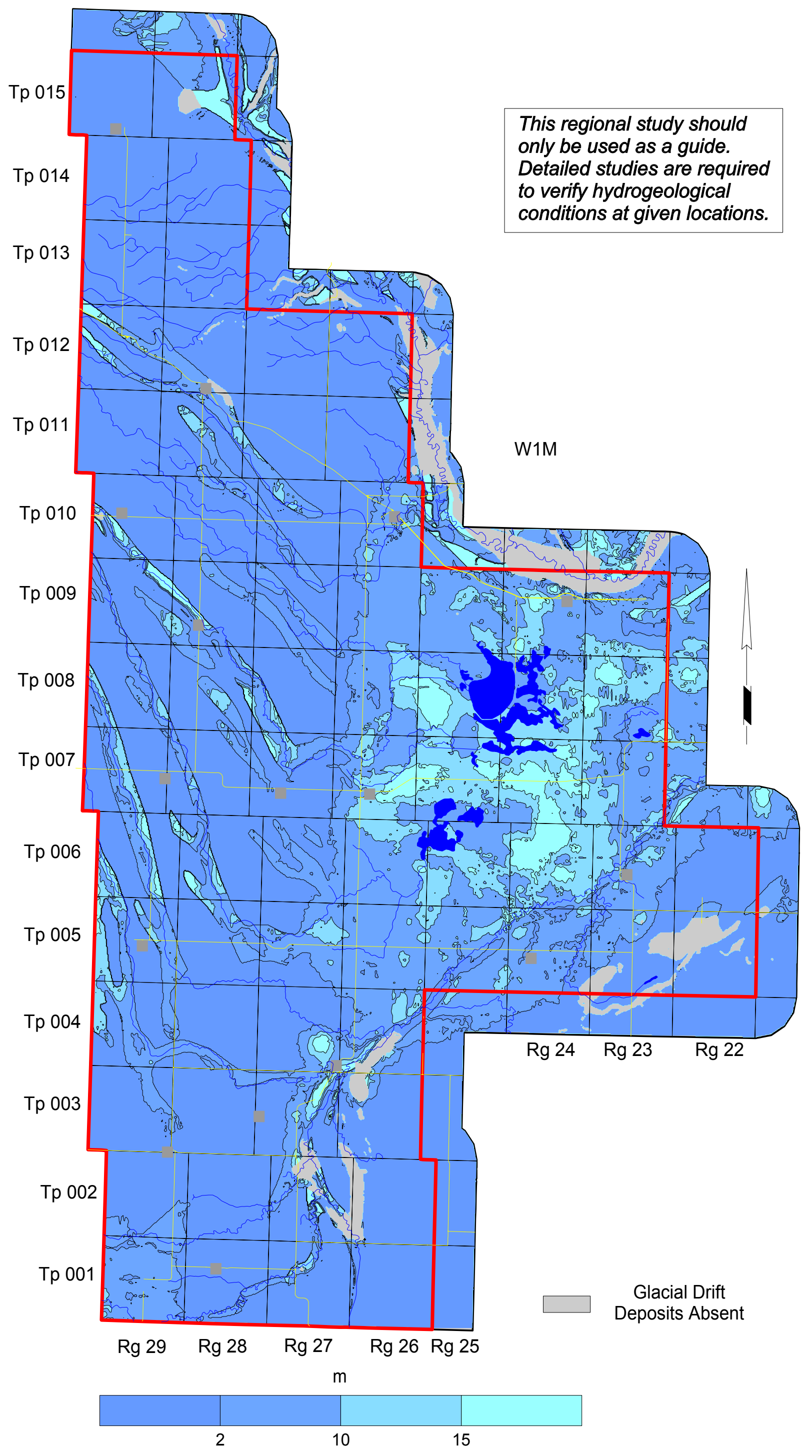
Total Dissolved Solids in Groundwater from Meltwater Deposits

WATER QUALITY TESTING should be done in conjunction with water well development to assess site specific conditions.

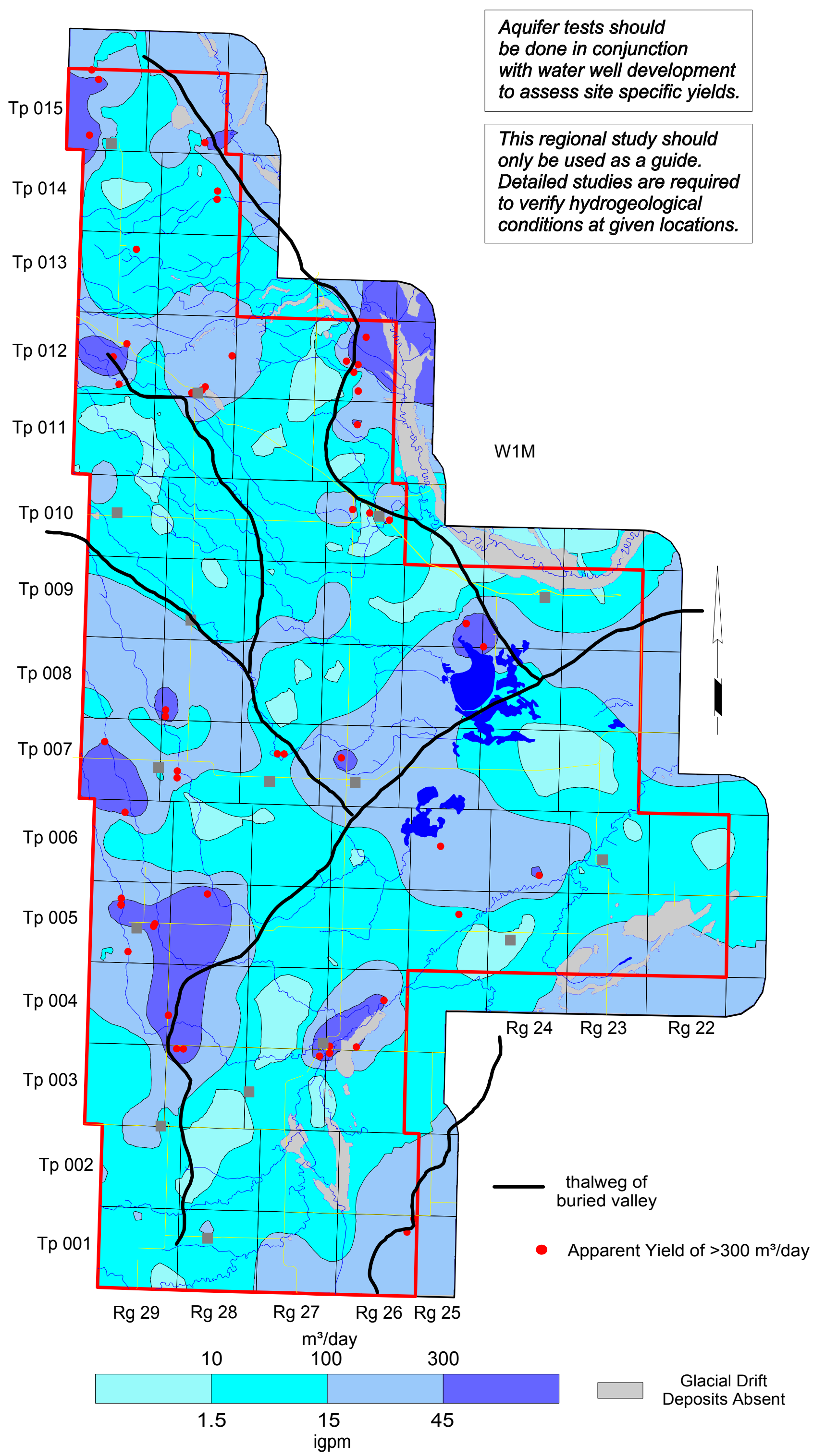
This regional study should only be used as a guide. Detailed studies are required to verify hydrogeological conditions at given locations.



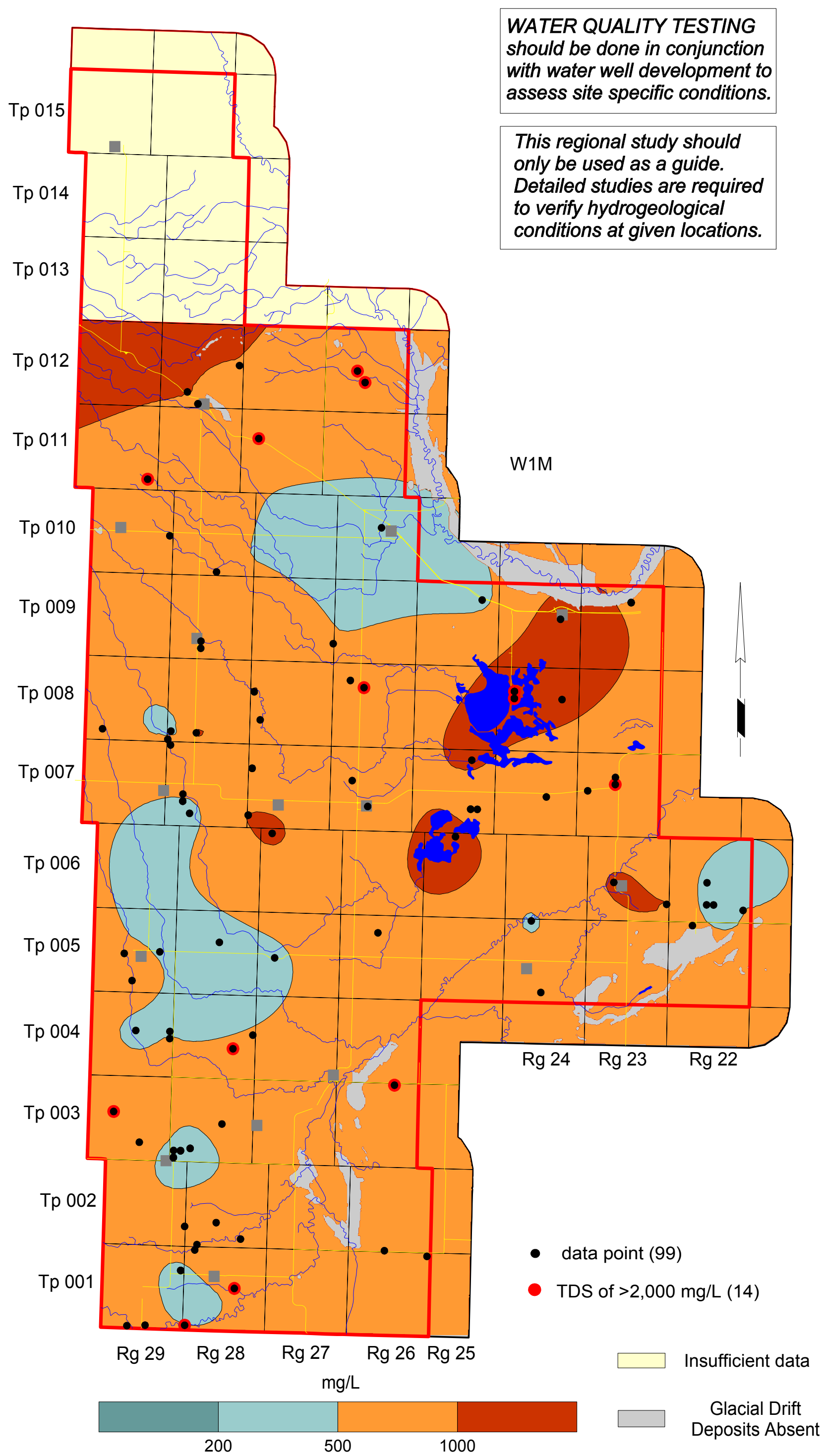
Depth to Top of Glacial Drift Deposits



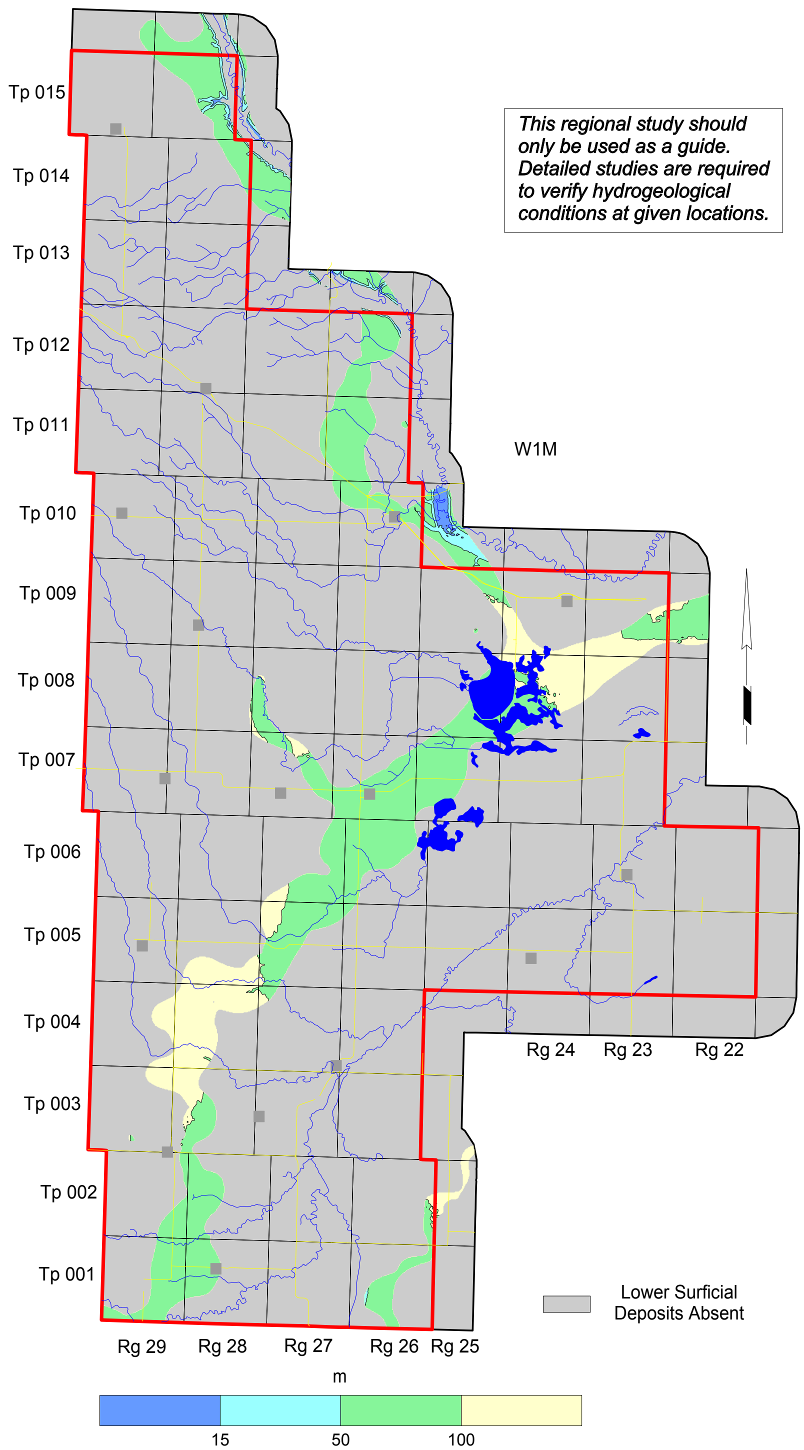
Apparent Yield for Water Wells Completed into Glacial Drift Deposits



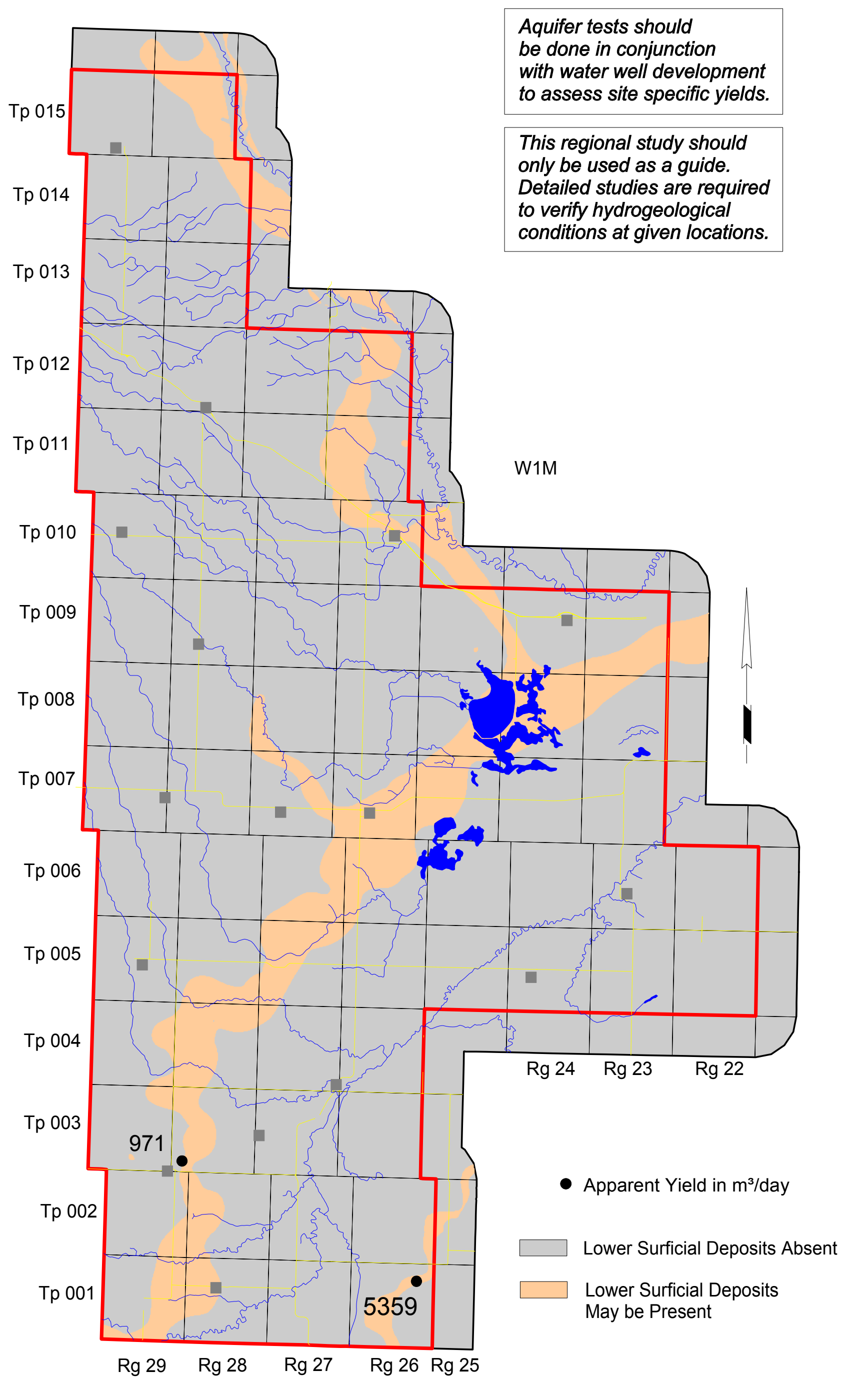
Totals Dissolved Solids in Groundwater from Glacial Drift Deposits



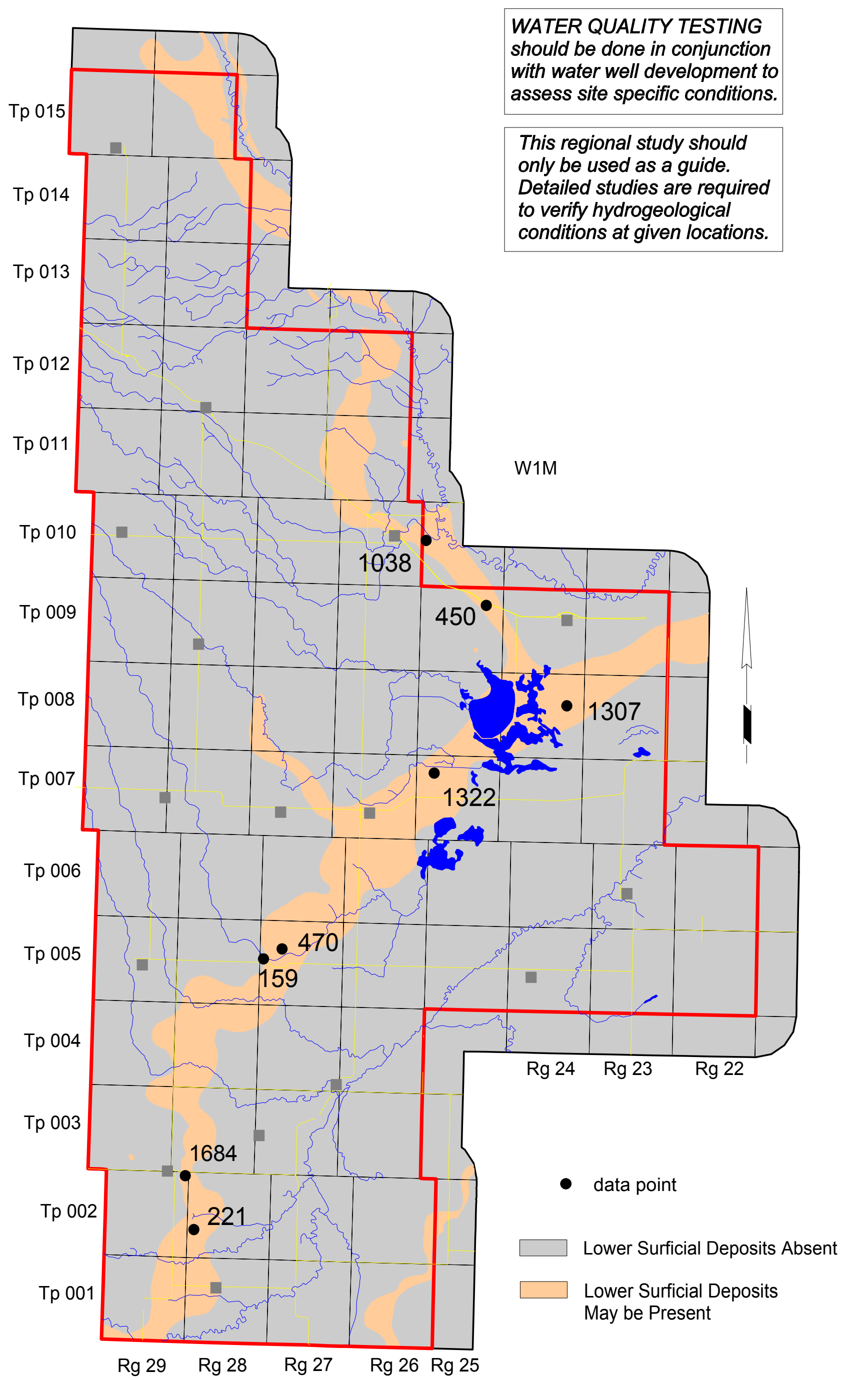
Depth to Top of Lower Surficial Deposits



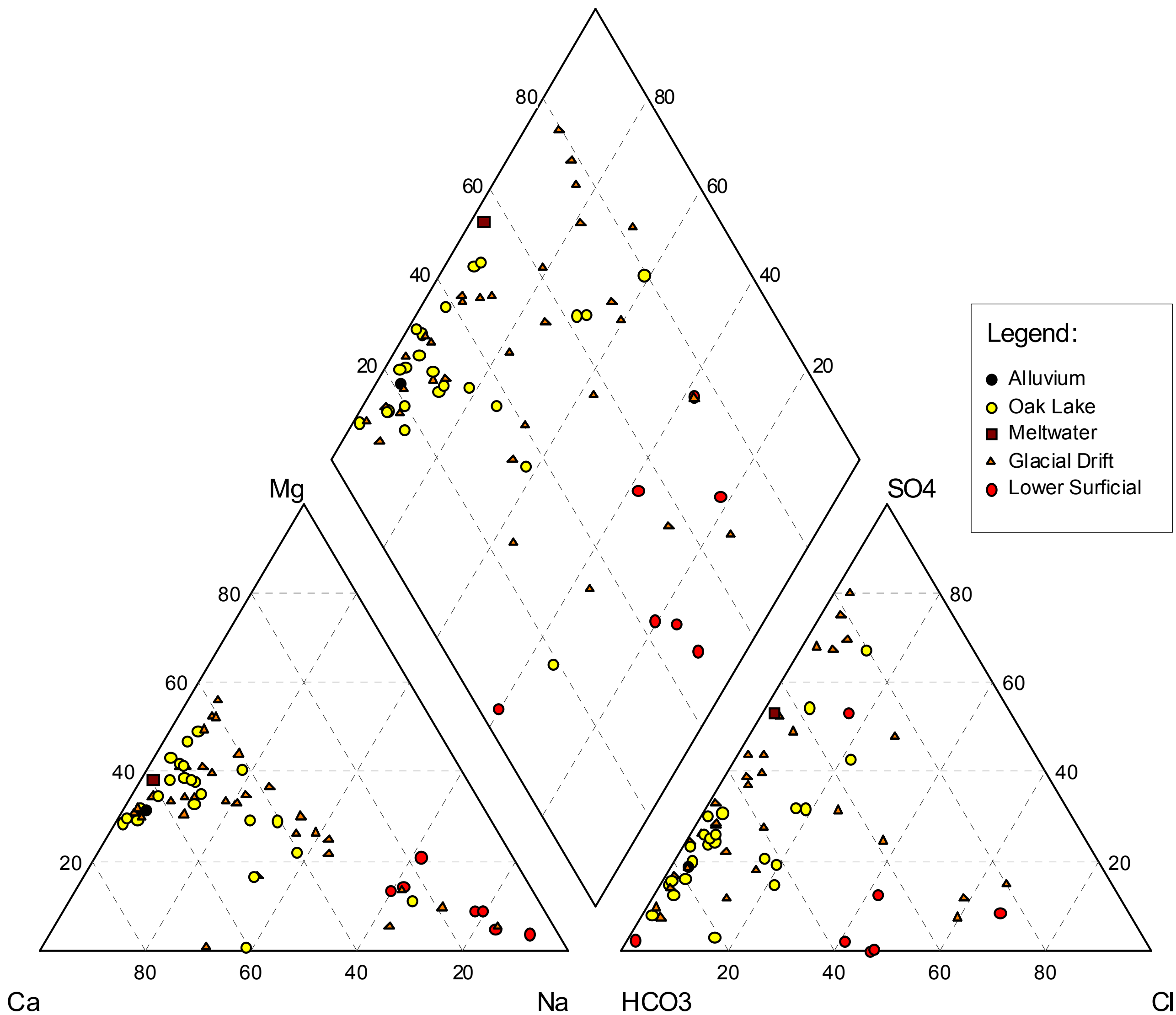
Apparent Yield for Water Wells Completed into Lower Surficial Deposits



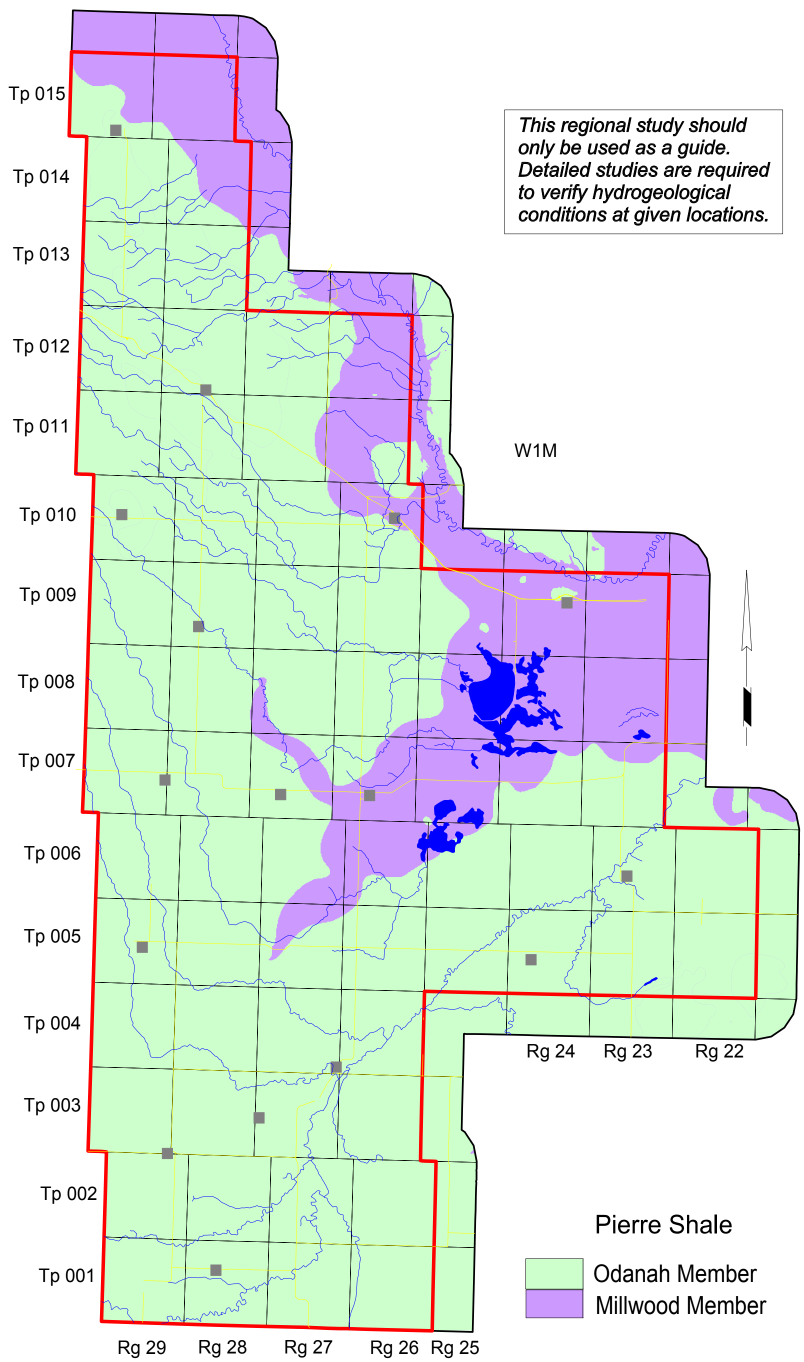
Total Dissolved Solids in Groundwater from Lower Surficial Deposits



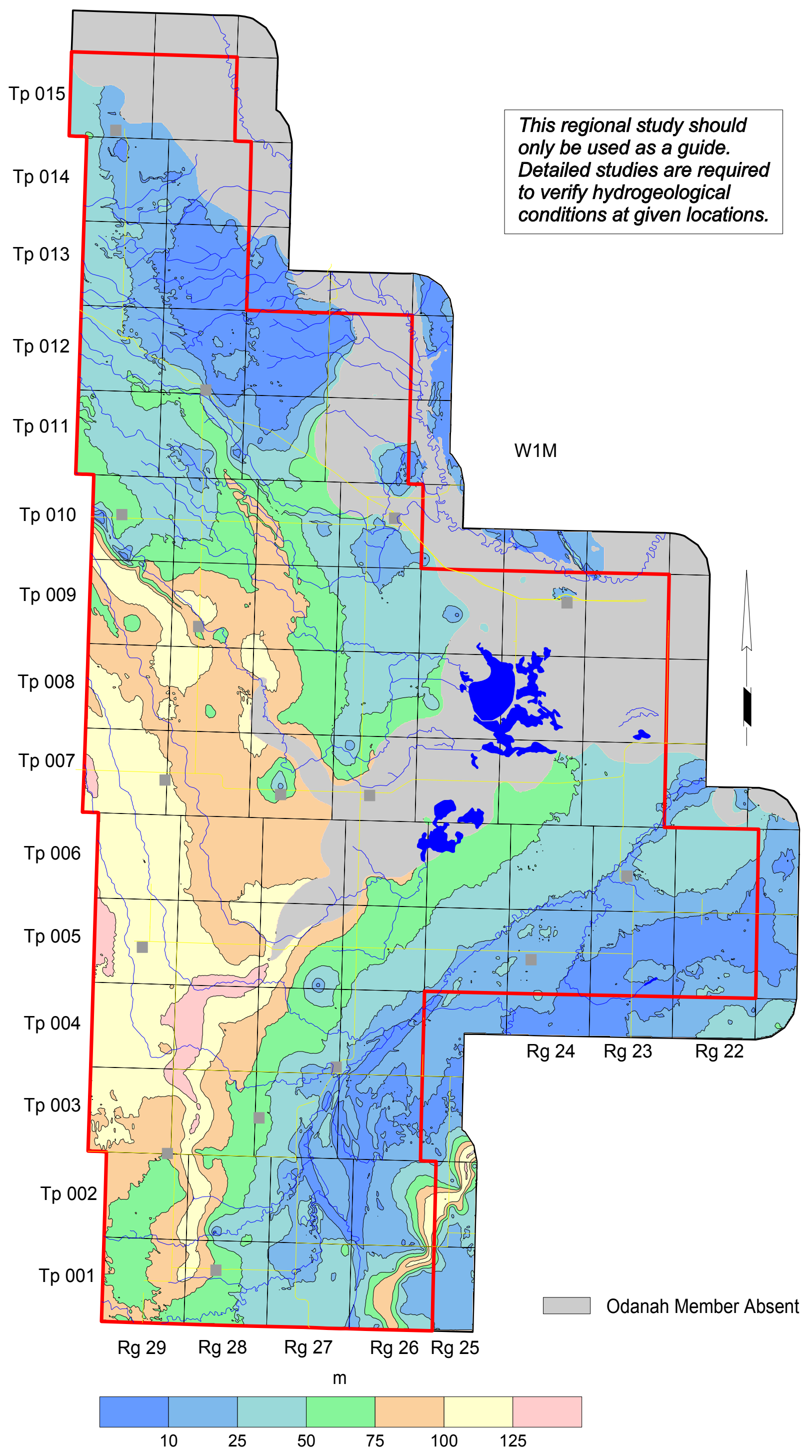
Piper Diagram – Surficial Deposits



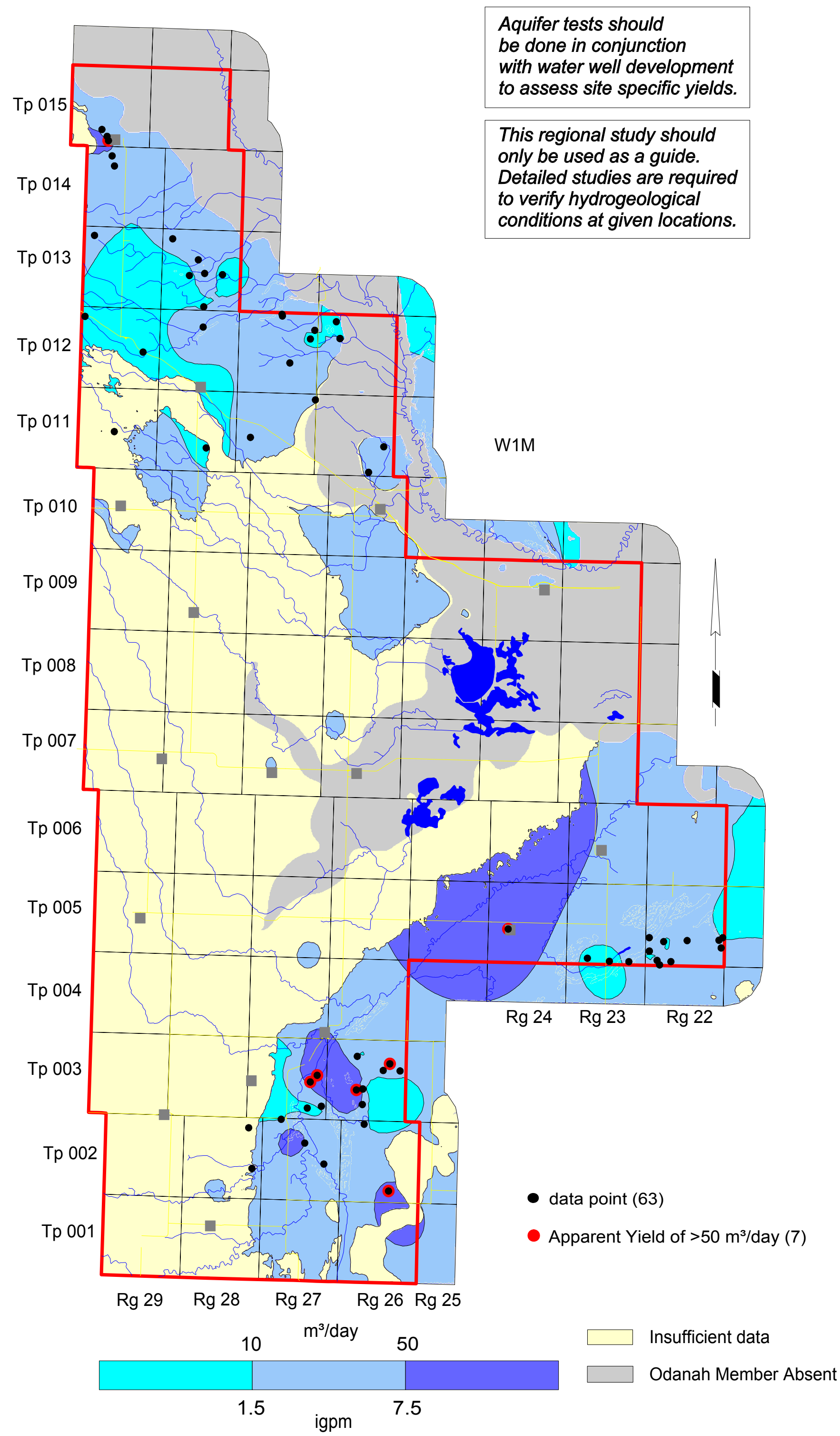
Bedrock Geology



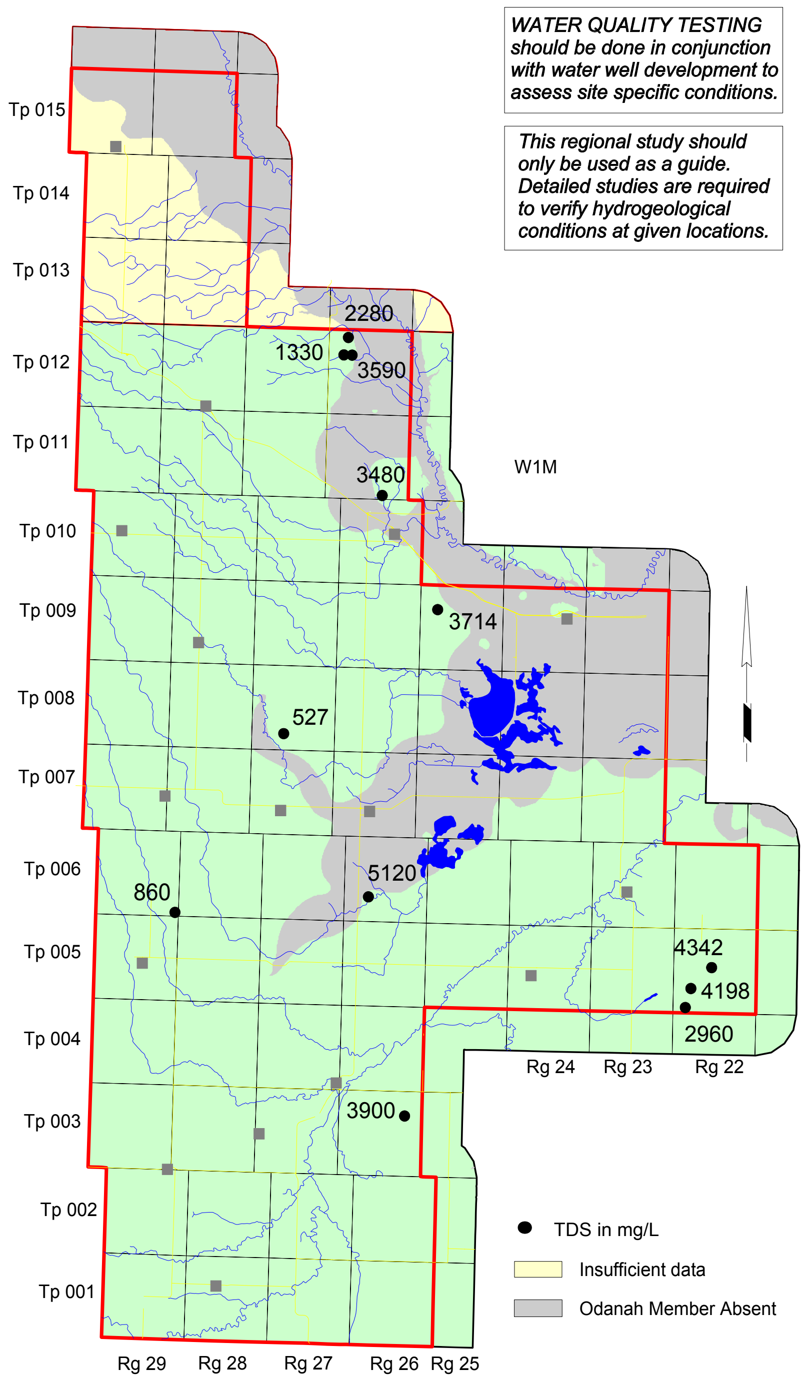
Depth to Top of Odanah Member



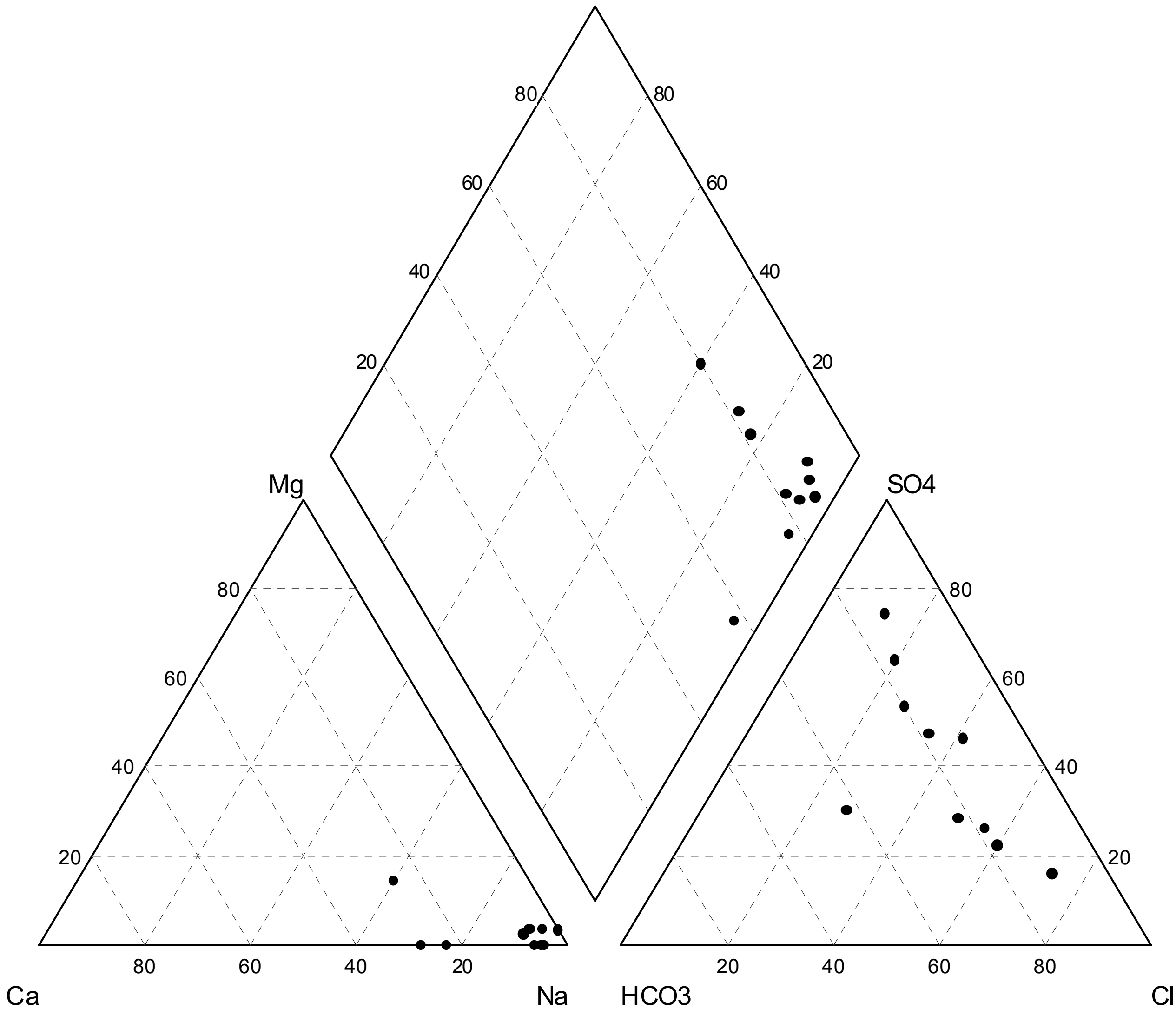
Apparent Yield for Water Wells Completed into Odanah Member



Total Dissolved Solids in Groundwater from Odanah Member

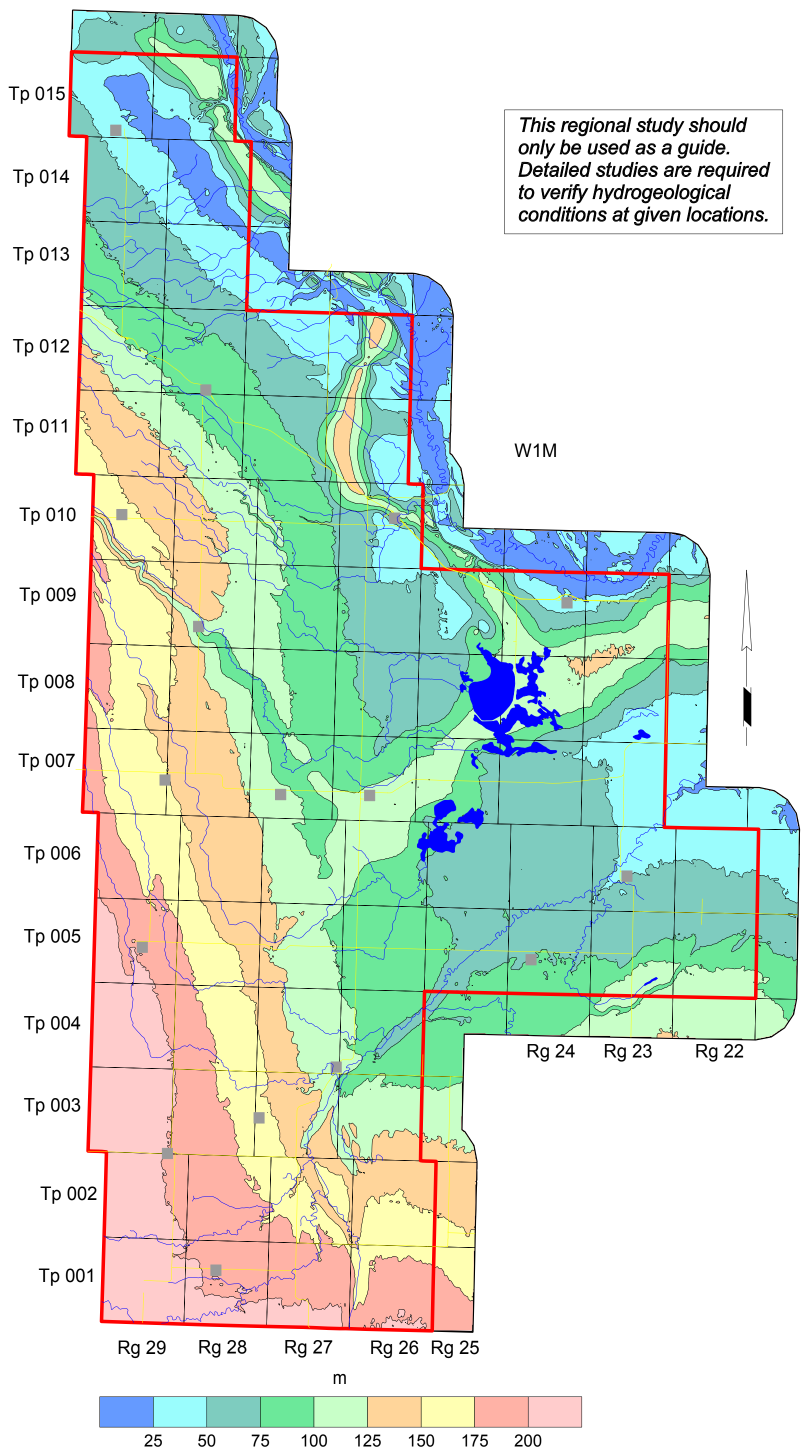


Piper Diagram – Odanah Member

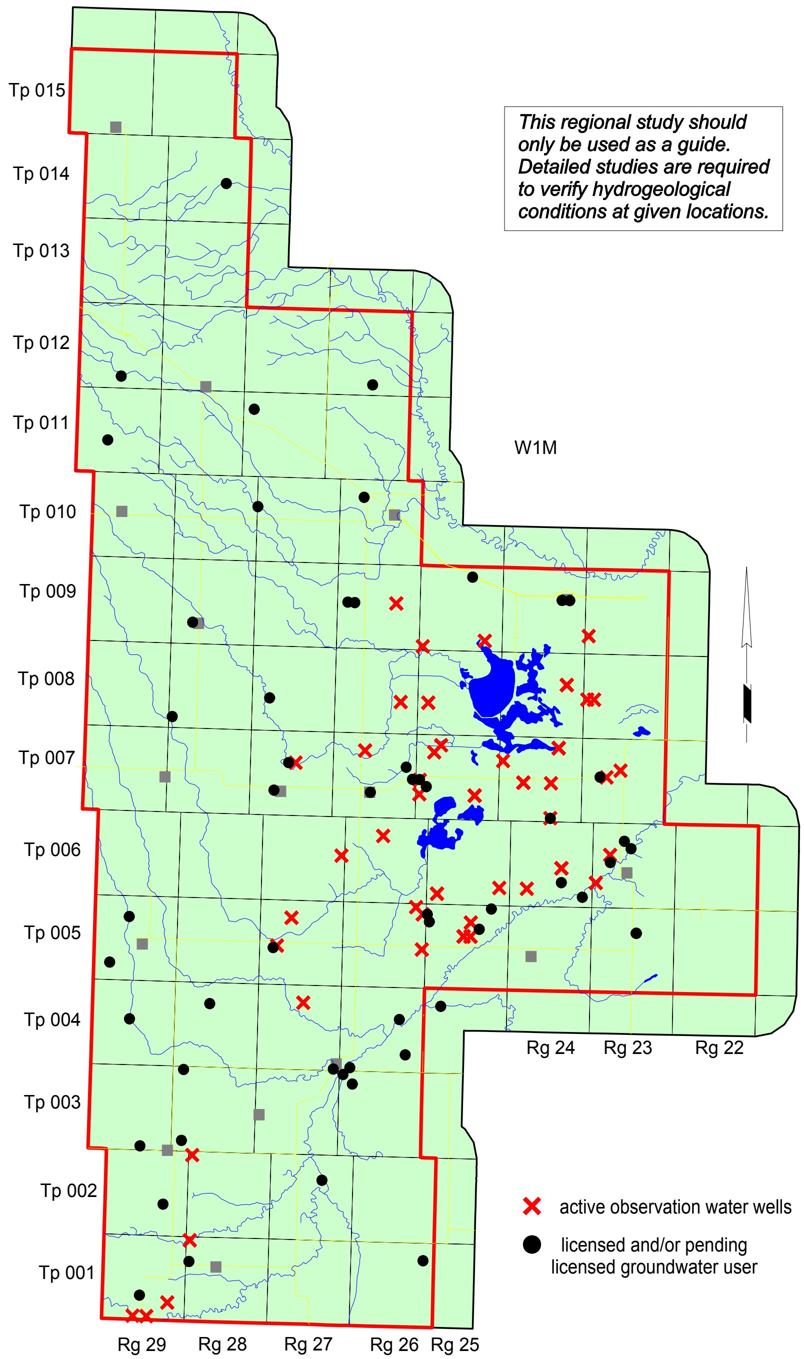


Depth to Top of Millwood Member

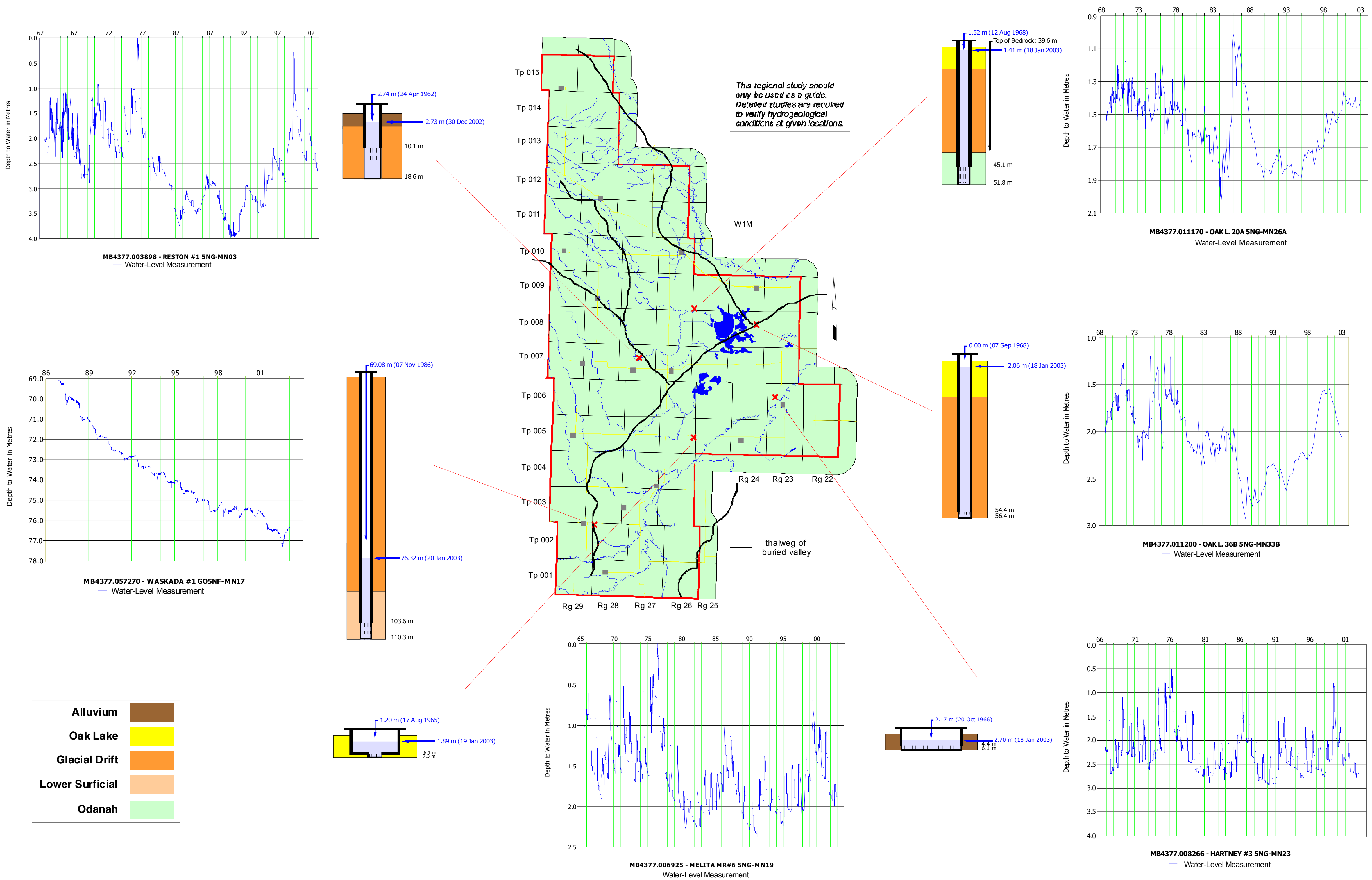
This regional study should only be used as a guide. Detailed studies are required to verify hydrogeological conditions at given locations.



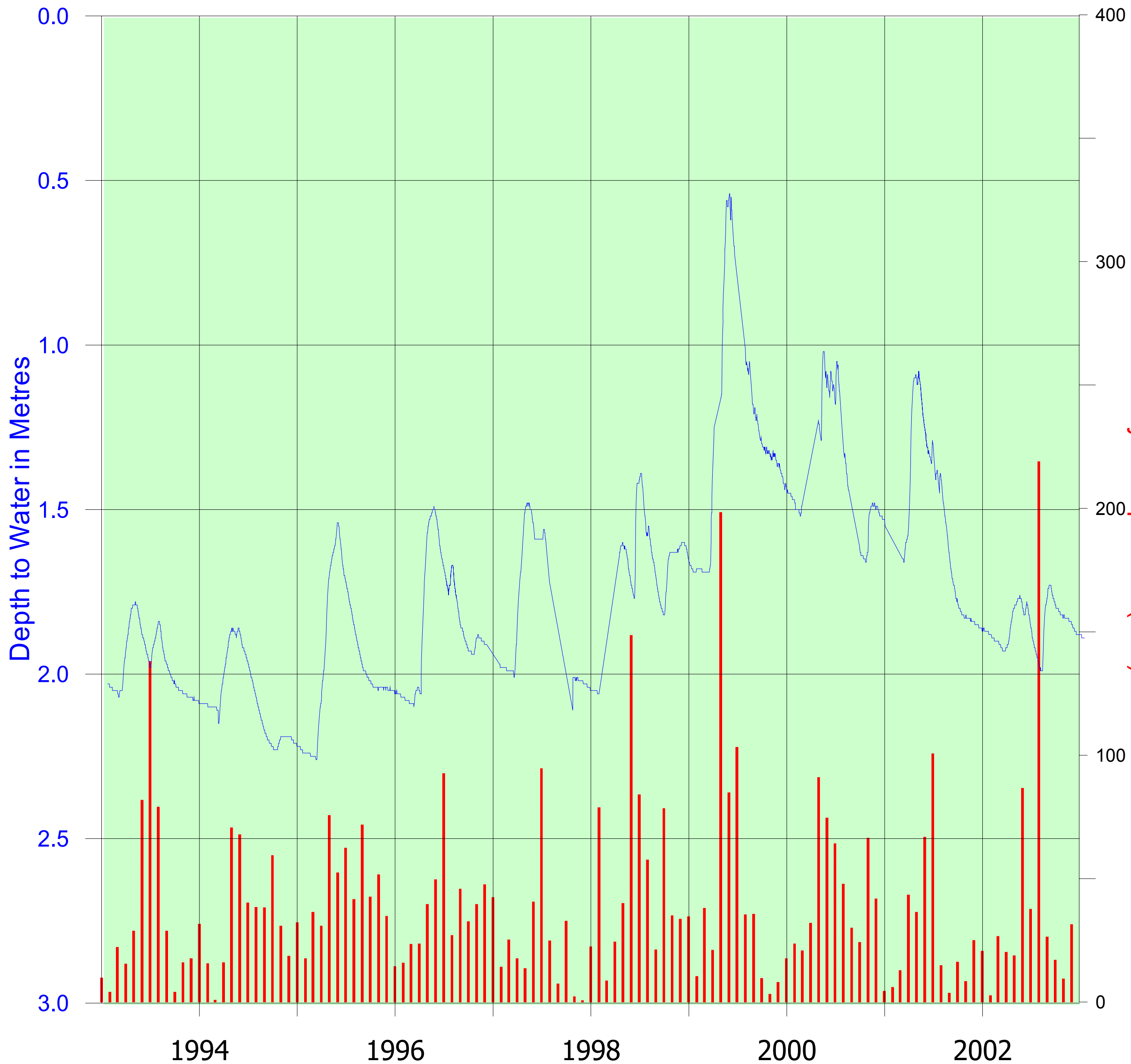
Locations of Active Water Resources Branch Monitoring Water Wells



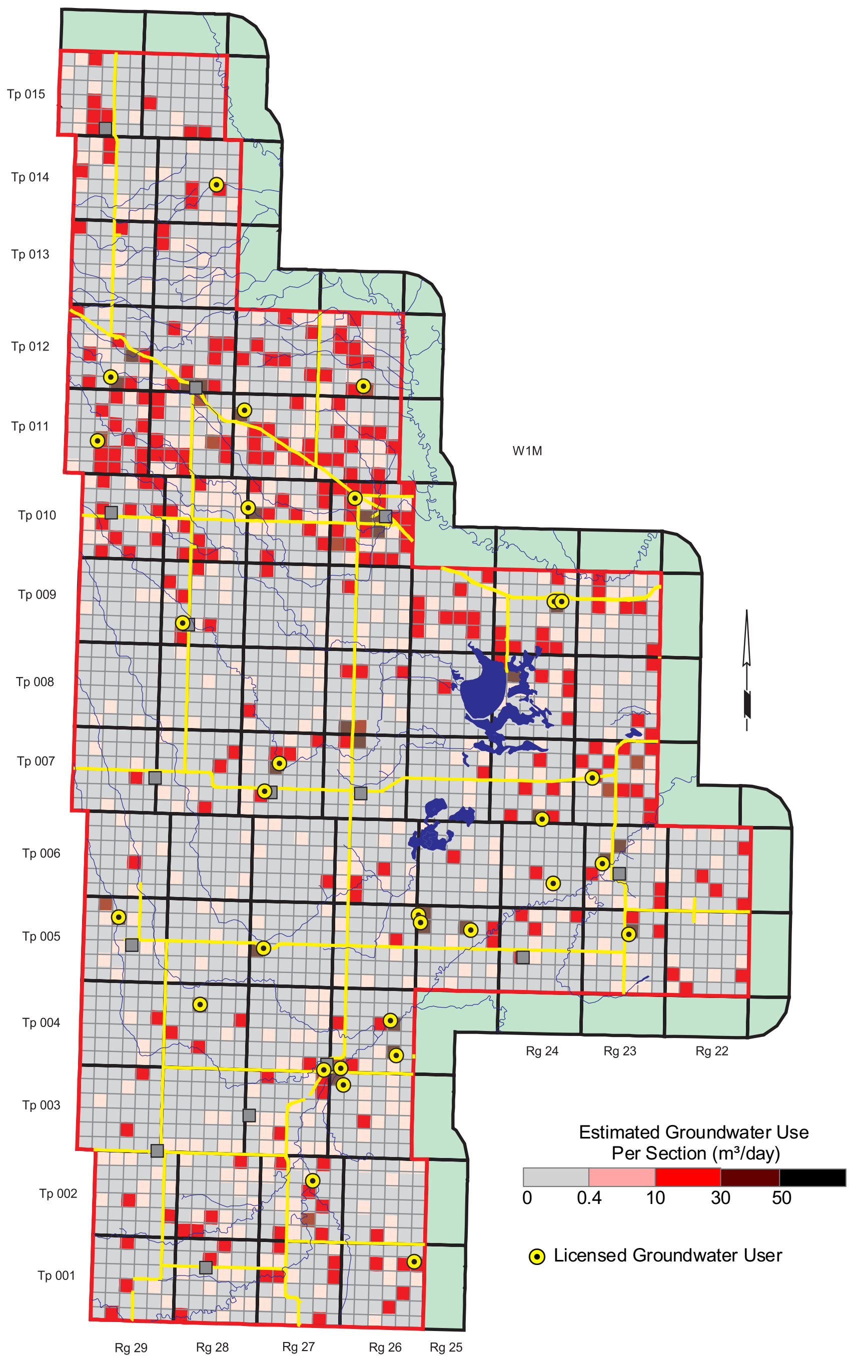
Hydrographs



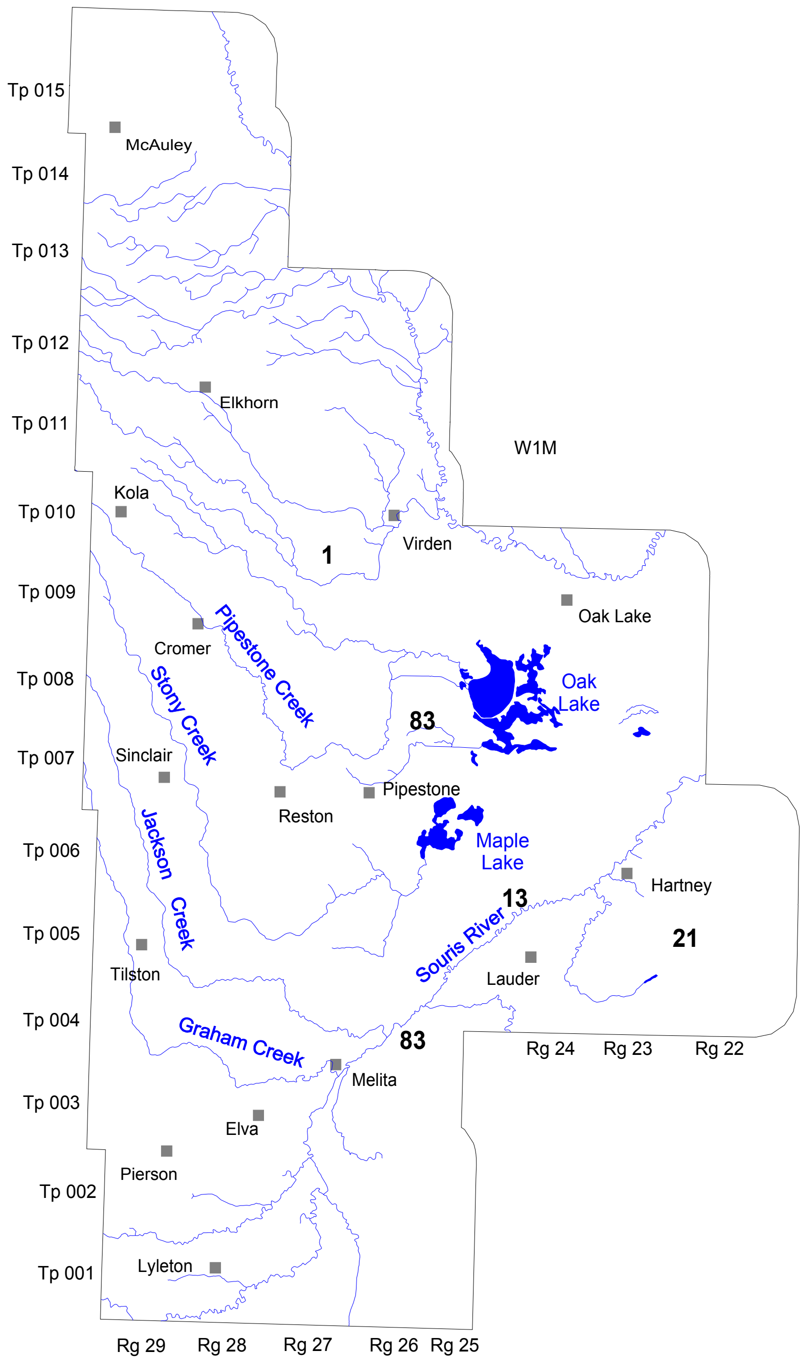
Monthly Precipitation and Water Levels in Melita MR #6 Monitoring Water Well



Estimated Water Well Use Per Section



Overlay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Tp 002
Tp 001
McAuley
Elkhorn
Kola
Virden
1
W1M
Oak Lake
Cromer
Pipestone Creek
Stony Creek
Oak Lake
83
Sinclair
Pipestone
Reston
Jackson Creek
Maple Lake
Hartney
13
Souris River
21
Tilston
Lauder
Graham Creek
83
Melita
Elva
Pierson
Lyleton
Rg 24
Rg 23
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WEST SOURIS RIVER CONSERVATION DISTRICT
Appendix B

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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 RIGHTS ACT

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The Water Rights Act

Table of Contents Regulations

HER MAJESTY, by and with the advice and consent of the Legislative Assembly of Manitoba, enacts as follows:

Definitions

1 In this Act,

"agricultural purposes" means the use of water at a rate of more than 25,000 litres per day for the production of primary agricultural products, but does not include the use of water for irrigation purposes; (« fins agricoles »)

"aquatic ecosystem" means the components of the earth related to, living in or located in or on water or the beds or shores of a water body, including but not limited to

(i) all organic and inorganic matter, and

(ii) all living organisms and their habitat,

and their interacting natural systems; (« écosystème aquatique »)

"construct", in relation to works and water control works, includes alter, reconstruct or improve; (« construire »)

"divert" includes block, dam, impound, obstruct, interfere with, remove, dispose of, alter or change the course or position of, or disturb, whether wholly or partially, any water whether flowing or at rest; (« dériver »)

"domestic purposes" means the use of water, obtained from a source other than a municipal or community water distribution system, at a rate of not more than 25,000 litres per day, for household and sanitary purposes, for the watering of lawns and gardens, and the watering of livestock and poultry; (« fins domestiques »)

"industrial purposes" means the use of water obtained from a source other than a municipal or community water distribution system, for the operation of an industrial plant producing goods or services other than primary agricultural products, but does not include the sale or barter of water for those purposes or the use of water for recreational purposes; (« fins industrielles »)

"irrigation purposes" means the use of water at a rate of more than 25,000 litres per day for the artificial application to soil to supply moisture essential to plant growth; (« fins d'irrigation »)

"licence" means a licence issued under this Act; (« licence »)

"licensee" means a person who holds a valid and subsisting licence; (« détenteur d'une licence »)

"maintain", in relation to works or water control works, includes keep in existence; (« entretenir »)

"minister" means the member of the Executive Council charged by the Lieutenant Governor in Council with the administration of this Act; (« ministre »)

"municipal purposes" means the use of water by a municipality or a community for the purpose of supplying a municipal or community water distribution system for household and sanitary purposes, for industrial use or uses related to industry, for the watering of streets, walks, paths, boulevards, lawns and gardens, for the protection of property, for the flushing of sewers, and for other purposes usually served by a municipal or community water distribution system; (« fins municipales »)

"permit" means a permit issued under this Act; (« permis »)

"permittee" means a person who holds a valid and subsisting permit; (« détenteur d'un permis »)

"water" means all water on or below the surface of the ground; (« eau »)

"water body" means any location where water flows or is present, whether the flow or the presence of water is continuous, intermittent or occurs only during a flood, and includes wetlands and aquifers; (« plan d'eau »)

"water control works" means any dyke, dam, surface or subsurface drain, drainage, improved natural waterway, canal, tunnel, bridge, culvert borehole or contrivance for carrying or conducting water, that

(a) temporarily or permanently alters or may alter the flow or level of water, including but not limited to water in a water body, by any means, including drainage, or

(b) changes or may change the location or direction of flow of water, including but not limited to water in a water body, by any means, including drainage; (« ouvrages de régularisation des eaux »)

"well" means an artificial orifice in the ground constructed for the purpose of obtaining water; (« puits »)

"works" includes any excavation, well, structure, plant, operation or contrivance that diverts, or may divert, or is likely to divert water. (« ouvrages »)

S.M. 2000, c. 18, s. 2; S.M. 2005, c. 26, s. 42.

Property in water

2 Except as otherwise provided in this Act, all property in, and all rights to the use, diversion or control of, all water in the province, insofar as the legislative jurisdiction of the Legislature extends thereto, are vested in the Crown in right of Manitoba.

S.M. 2000, c. 18, s. 3.

Prohibition against use of water

3(1) Except as otherwise provided in this Act or the regulations, no person shall

(a) in any manner whatsoever use or divert water, unless he or she holds a valid and subsisting licence to do so; or

(b) construct, establish, operate or maintain any works, unless he or she holds a valid and subsisting licence to do so; or

(c) control water or construct, establish, operate or maintain any water control works, unless he or she holds a valid and subsisting licence to do so.

Exception

3(2) Subsection (1) does not apply

(a) to a person exercising a right under any other Act of the Legislature or any Act of the Parliament of Canada; or

(b) to a person using water for domestic purposes, where the person has lawful access to the water; or

(c) to a person who constructs a well to obtain water for domestic purposes.

S.M. 2000, c. 18, s. 4.

Removal of unauthorized works or water control works

4(1) Where a person is using, diverting or controlling water or has constructed or established or is operating or maintaining any works or water control works in breach of section 3, the minister may make an order requiring the person, within a period of time stated in the order,

(a) to cease using or diverting the water; or

(b) to remove the works or water control works; or

(b.1) to cease controlling the water; or

(c) to repair or reconstruct or alter the works or water control works in a manner stated in the order;

as the case may be, and the order shall further state that if the person to whom it is directed fails to comply with the order the minister or a person authorized by the minister may, without further notice or legal process and at the expense of the person, take or cause to be taken the steps set out in subsection (3).

Service of order

4(2) An order made under subsection (1) shall be served on the person to whom it is directed

(a) by personal service; or

(b) by leaving a copy of the order with an adult person on the affected land; or

(c) by posting a copy of the order in a conspicuous place on the affected land, if no adult person is found thereon.

Minister may remove works or water control works

4(3) Where after service in accordance with subsection (2) of an order made under subsection (1) the person to whom it is directed fails to comply therewith, the minister may, without further notice or legal process and at the expense of the person, do or cause to be done such things as he or she deems necessary to stop the use, diversion or control of the water, or cause the works or water control works to be breached, blocked, filled, demolished or removed or to be otherwise dealt with as he or she deems necessary or advisable to enforce the order, as the case may be.

Power to enter lands
4(4) The minister or any person authorized by him may enter upon or cross any lands for the purpose of taking any of the steps authorized under subsection (3).

Recovery of expense
4(5) Any expense incurred by the minister in taking or causing to be taken the steps authorized under subsection (3) for the purpose of enforcing an order made under subsection (1) is a debt due to the Crown and is recoverable in any court of competent jurisdiction from the person to whom the order is directed.

4(6) Repealed, S.M. 2005, c. 26, s. 42.

Liability of minister
4(7) Except as provided in subsection 24(2), neither the minister nor any person authorized by him is liable for damages for anything done without negligence under this section, or for anything that is necessarily done as incidental to an act authorized under this section.

S.M. 1989-90, c. 90, s. 40; S.M. 2000, c. 18, s. 5; S.M. 2005, c. 26, s. 42.

Issue of licences
5(1) Subject to section 7, the minister may issue a licence to any person who applies therefor, authorizing

(a) the use or diversion of water for any purpose; or

(b) the construction, establishment, operation or maintenance of works for any purpose; or

(c) the control of water and the construction, establishment, operation or maintenance of water control works.

Terms and conditions of licences
5(2) Every licence is subject to such terms and conditions as may be prescribed in the regulations and such further terms and conditions as may be required by the minister.

5(3) Repealed, S.M. 1989-90, c. 90, s. 40.

Form of licences
5(4) Every licence shall be in a form prescribed in the regulations or, where that form is not so prescribed, in a form prescribed by the minister.

S.M. 1989-90, c. 90, s. 40; S.M. 2000, c. 18, s. 6.

Application for licence
6(1) An application for a licence shall be submitted to the minister and shall contain or have enclosed therewith such information, particulars and plans as may be prescribed in the regulations.

Form of application for licence
6(2) An application for a licence shall be in a form prescribed in the regulations or, where that form is not so prescribed, in a form prescribed by the minister.

Publication of application
6(3) Where, by reason of the scope and nature of the use, diversion or control of water or the construction, establishment, operation or maintenance of works or water control works proposed in an application for a licence and their possible impact on other persons, the minister so directs, the applicant shall, forthwith after submitting the application, publish or cause to be published in a newspaper having general circulation in the area affected, a notice of the application, and the notice shall state

(a) the nature of the licence applied for;

(b) that any person wishing to object to the application may do so in writing to the minister within 15 days of the publication of the notice; and

(c) any other information or particulars that the minister may require.

Public hearing
6(4) Upon expiry of the 15 days provided in subsection (3) in respect of any application, and before the minister determines whether or not to grant the application, a public hearing shall be held before the Municipal Board at which any person may make representations, either himself or through counsel, for or against the application.

S.M. 2000, c. 18, s. 7.

Preliminary work
7(1) Where it is necessary to carry out any preliminary work prior to the use, diversion or control of water or the construction or establishment of works or water control works, the minister shall not issue a licence authorizing the use, diversion or control of the water or the construction or establishment of the works or water control works until the preliminary work has been completed.

Permit for preliminary work
7(2) No person shall commence or carry out any preliminary work required under subsection (1) unless and until he obtains a permit authorizing the preliminary work.

Issue of permits
7(3) The minister may issue a permit to any person who applies therefor, authorizing any preliminary work required under subsection (1), and the permit may also authorize the permittee to enter upon public or private lands to make surveys and do such other things as the minister deems necessary to carry out the preliminary work.

Terms and conditions of permits
7(4) Every permit is subject to such terms and conditions as may be prescribed in the regulations and such further terms and conditions as may be required by the minister.

Application for permit
7(5) An application for a permit required under subsection (2) shall be submitted to the minister and shall contain or have enclosed therewith

(a) such information, particulars and plans relating to the proposed use, diversion or control of water or the proposed construction or establishment of works or water control works as the minister may require; and

(b) if required by the minister, an agreement in writing, made between and executed by both the applicant and the owner of the lands to be affected, whereby the applicant undertakes to pay to the owner compensation for any damage that may result to the lands or any buildings or other improvements thereon in the course of and arising out of the preliminary work to be authorized by the permit.

7(6) Repealed, S.M. 1989-90, c. 90, s. 40.

Form of permits and applications
7(7) Every permit and every application for a permit shall be in a form prescribed in the regulations or, where that form is not so prescribed, in a form prescribed by the minister.

S.M. 1989-90, c. 90, s. 40; S.M. 2000, c. 18, s. 8.

Application of sections 8 and 11

7.1 Sections 8 and 11 do not apply to licences for the control of water and the construction, establishment, operation or maintenance of water control works.

S.M. 2000, c. 18, s. 9.

Precedence of licences

8(1) Licences have precedence in relation to one another according to the date of submission of the application for each licence.

Where no preliminary work

8(2) For the purposes of subsection (1), the date of submission of an application for a licence, where no preliminary work is required prior to the issuance of the licence, is

(a) the date on which the application, together with such information, particulars and plans as may be required under section 6, is submitted to the minister; and

(b) where any information, particulars or plans, or a part of any information, particulars or plans, required under section 6 are not submitted to the minister together with the application but at a subsequent time, the date on which the information, particulars or plans or the part thereof are so submitted.

Where preliminary work completed

8(3) For the purposes of subsection (1), the date of submission of an application for a licence issued after the completion of preliminary work pursuant to a permit is

(a) the date on which the application for the permit, together with such things as may be required under section 7, is submitted to the minister; and

(b) where any thing, or a part of any thing, required under section 7 is not submitted to the minister together with the application for the permit but at a subsequent time, the date on which the thing or the part thereof is so submitted.

Where submission dates identical

8(4) Where the date of submission established under subsection (2) or (3) in respect of any licence is identical with the date of submission established under subsection (2) or (3) in respect of any other licence, the licences have precedence in relation to one another according to the priority of purpose established for each licence in the order of priority prescribed in section 9.

Where priority of purpose identical

8(5) Where the priority of purpose established in respect of any licence under subsection (4) is identical with the priority of purpose established in respect of any other licence under subsection (4), the licences have precedence in relation to one another as the regulations may provide.

Precedence of renewed licences

8(6) A licence that is renewed in accordance with the regulations retains the precedence originally established for it under this section.

Priorities

9 The order of priority of the purposes for which water may be used or diverted, or works constructed, established or maintained, in accordance with this Act is as follows:

1. domestic purposes;

2. municipal purposes;

3. agricultural purposes;

4. industrial purposes;

5. irrigation purposes;

6. other purposes.

Protecting and maintaining aquatic ecosystems
9.1(1) In considering an application for a licence

(a) to use or divert water; or

(b) to construct, establish, operate or maintain works, other than works relating to the drainage of water;

the minister shall consider scientific and other information relating to the groundwater and water body levels, and the in-stream flows, that are necessary to ensure that aquatic ecosystems are protected and maintained.

Licence may be denied
9.1(2) The minister may refuse to issue a licence if, in the opinion of the minister, the action authorized by the licence would negatively affect an aquatic ecosystem.

S.M. 2005, c. 26, s. 42.

Suspending licence for aquatic ecosystem purposes
9.2 The minister may suspend or restrict the rights under a licence for a specified period if

(a) in the minister's opinion,

(i) a groundwater level,

(ii) a water body level, or

(iii) an in-stream flow,

is insufficient to ensure that aquatic ecosystems are protected and maintained; and

(b) the minister's opinion is based on scientific information about protecting and maintaining an aquatic ecosystem of the type under consideration.

S.M. 2005, c. 26, s. 42.

Application for use in the future
10 Where the minister is satisfied that an applicant for a licence does not intend to use, divert or control the water or to construct or establish the works or water control works to which the application relates, for at least 1 year from the date of the filing of the application, he or she may defer the granting of the licence or refuse to grant the licence.

S.M. 2000, c. 18, s. 10.

Change of title to land
11 Where an estate or interest in land is transferred, any subsisting licence relating to the estate or interest expires automatically as of the date of the transfer, unless the minister, upon the application of the transferee, transfers the licence to the transferee.

Subsidiary use for domestic purposes
12 Subject to the approval of the minister, a person who has a licence to use or divert water for industrial, agricultural or irrigation purposes may use or divert, or permit others, with or without a fee or charge therefor, to use or divert part of the water for domestic purposes.

Reservation of water
13(1) Notwithstanding any other provision of this Act, the minister may reserve any unlicenced water

(a) in order that a survey may be made as to how the water may be used or diverted to the greatest advantage of the residents of the province; or

(b) for such uses and purposes specified by the minister as in his opinion will be of the greatest advantage to the residents of the province;

and may fix a period of time within which the reservation may be utilized.

Restriction on licences
13(2) Where water has been reserved under subsection (1), the minister shall not issue a licence in respect thereof except in accordance with the terms of the reservation.

Cancellation of licence
14(1) Where a person applies to the minister for a licence to use or divert water at any place or point and all the water available for use or diversion at that place or point has already been allocated to other licensees or in the opinion of the minister further allocation would negatively affect an aquatic ecosystem, if the purpose for which the applicant will use the water is higher in priority in the order of priority established therefor under section 9 than that of the purpose of one or more of those other licensees, the minister may issue the licence to the applicant and, subject to section 19, may cancel or restrict the rights under the licence of any one or more of those other licensees ranking lower than the applicant in priority of purpose.

Compensation
14(2) A person whose existing licence is cancelled or whose rights under his existing licence are restricted under subsection (1) in favor of a new applicant for a licence is entitled to receive from and shall be paid by the applicant compensation for any loss or damage suffered by him as a consequence of the cancellation or restriction.

Agreement respecting compensation
14(3) The minister shall not issue a licence to an applicant under subsection (1) until he receives from the applicant an agreement, executed by both the applicant and the person whose licence is cancelled or restricted under that subsection, containing the applicant's undertaking to pay to the person the compensation for which provision is made in subsection (2), and the amount of the compensation and the terms of the payment thereof shall be set out in the agreement or determined in accordance with subsection (4), as the case may be.

Arbitration
14(4) Where an applicant for a licence and a person whose license is cancelled or whose rights under a licence are restricted fail to agree on the amount of the compensation payable by the applicant under subsection (2), the amount thereof shall be determined in accordance with the provisions of *The Arbitration Act*.

Compensation where no renewal or transfer
14(5) Where a licensee applies for a renewal or transfer of his licence and the minister declines to renew or transfer the licence by virtue of an application for a higher priority use, compensation is payble by the new user as provided in this section.

S.M. 2005, c. 26, s. 42.

Investigations re levels and in-stream flows

14.1 Using scientific methods, the minister may undertake investigations into groundwater or water body levels, or in-stream flows, anywhere in Manitoba, to determine whether aquatic ecosystems are being negatively affected by insufficient levels or flows.

S.M. 2005, c. 26, s. 42.

Non-use of licence

15 Where a licensee fails to use or divert water under the authority of and for the purposes authorized by the licence, or fails to use or divert water to the extent authorized by the licence, for a continuous period of 1 year or more, the minister may, subject to section 19, make an order

(a) amending the licence to reduce the amount of water that may be used or diverted thereunder; or

(b) cancelling the licence.

Unsafe works or water control works

16 Where in the opinion of the minister works or water control works constructed, established or maintained under a licence are unsafe, the minister may make an order requiring the licensee

(a) to make repairs or additions to the works or water control works or any part thereof; or

(b) to demolish, or to demolish and reconstruct, the works or water control works or any part thereof;

to put the works or water control works in a safe condition and, if the licensee fails to comply with the order, the minister may, subject to section 19, suspend or cancel the licence in whole or in part.

S.M. 2000, c. 18, s. 11.

Removal or acquisition of works or water control works

17(1) Where a licence authorizing the construction, establishment or maintenance of works or water control works

(a) expires, and the licensee fails to apply for its renewal in accordance with the regulations; or

(b) is cancelled by the minister under this Act;

the minister may

(c) make an order requiring the person who owns or is occupying the land in respect of which the licence was issued or on which the works or water control works are situated to breach, block, fill, demolish or remove the works or water control works; or

(d) for and on behalf of the government and in accordance with the regulations, assume ownership and control of the works or water control works.

Removal by minister

17(2) Where a person fails to comply with an order made under subsection (1) in respect of any works or water control works, the minister may, subject to section 4, which applies with such modifications as the circumstances require, dispose of or remove the works or water control works, or cause the works or water control works to be disposed of or removed, in such manner, and may impose such terms and conditions with respect to the works or water control works, as the minister deems necessary.

Compensation
17(3) Where the minister assumes ownership and control of works or water control works under subsection (1) upon the expiry of a licence, the government shall compensate the licensee therefor.

Failure to agree on compensation
17(4) Where the parties cannot agree as to the amount of the compensation payable under subsection (3), the amount of the compensation shall be determined in accordance with the provisions of *The Arbitration Act*.

S.M. 2000, c. 18, s. 12.

Entry on land
18 The minister or a person authorized by the minister may enter on any land for the purpose of

(a) inspecting any works or water control works constructed or established, or being constructed, established or maintained, by a licensee or permit holder; or

(b) investigating a suspected or alleged contravention of this Act or the regulations.

S.M. 1989-90, c. 90, s. 40; S.M. 2000, c. 18, s. 13.

Suspension and cancellation of licence
19(1) In addition to any suspension or cancellation of a licence that may be authorized under any other provision of this Act, the minister or a person authorized by him in writing may, for cause,

(a) suspend a licence or permit for any stated period of time or until a condition is met;

(b) where in the opinion of the minister it is in the public interest to do so, cancel a licence or permit whether or not it has first been suspended under clause (a).

Notice and hearing before cancellation
19(2) A licence or permit shall not be cancelled under subsection (1) or any other provision of this Act until after notice and a hearing in accordance with subsections (3), (4) and (5).

Notice of hearing
19(3) The notice required under subsection (2) shall require the person to whom it is directed to attend before the Municipal Board upon a day specified in the notice which shall not be less than 30 days after the date of service of the notice, to show cause why the licence or permit should not be cancelled.

Service of notice
19(4) The notice referred to in subsection (3) shall be served personally, or by registered mail addressed to the last known address of the person to whom it is directed.

Notice of cancellation
19(5) Where, after notice and a hearing, the minister cancels a licence or permit, he shall, by a notice in writing sent by registered mail, notify the person affected of the cancellation.

Removal of obstructions
20 The minister or any person authorized by him may open up, remove or destroy, or cause to be opened up, removed or destroyed,

(a) any dam constructed by beaver; or

(b) any natural obstruction howsoever caused that diverts a flow of water existing prior to the obstruction;

and for that purpose may enter upon or cross any lands; and neither the minister nor the person so authorized by him for the purpose is liable for damage to land or persons arising out of anything done without negligence under this section or anything necessarily done as incidental to an act authorized under this section.

Interprovincial boundary waters

21(1) The minister, for and on behalf of the government, may enter into an arrangement or agreement with the government of any other province of Canada or with the Government of Canada or with the Government of Nunavut for the establishment and constitution of a board that, when established and constituted, shall, to the extent permitted by the legislative powers of the governments that are parties to the arrangement or agreement, have jurisdiction and such power and authority as is vested in it by the arrangement or agreement, to regulate and control the use of interprovincial waters, or the use of the boundary waters between the province and the Northwest Territories or between the province and Nunavut, or the use of waters in any stream or streams flowing through more than one of the provinces or through one or more than one of the provinces and the Northwest Territories or Nunavut.

Representative on board

21(2) The Lieutenant Governor in Council may appoint a representative or representatives of the government to the board established under subsection (1).

S.M. 1999, c. 17, s. 5.

Agreements with other governments

22 The minister may enter into an arrangement or agreement with the government of any other province of Canada or the Government of Canada or any agency for the making of water measurements, the carrying out of investigations and the collection and publication of data respecting water resources and the best methods of utilizing them.

Offence and penalty

23(1) A person who contravenes or fails to comply with

(a) a provision of this Act or the regulations; or

(b) an order made under this Act; or

(c) a condition of a licence or permit issued under this Act;

is guilty of an offence and liable on summary conviction to a fine of not more than $10,000. or to imprisonment for not more than three months or both and, where the person is a corporation, to a fine of not more than $25,000.

Offence and penalty

23(2) Any person who obstructs, hinders or interferes with a servant or agent of the government engaged in the performance of his duties in the course of the administration of this Act is guilty of an offence and liable to a fine not exceeding $10,000. or to imprisonment for not more than three months or both and, where the person is a corporation, to a fine not exceeding $25,000.

Offence and penalty

23(3) Any person who defaces, alters or removes any survey monument, bench mark or water gauge or other instrument or device placed by a duly authorized person engaged in making surveys or levels in connection with any works or water control works authorized under this Act, is guilty of an offence and liable to a fine not exceeding $10,000. or to imprisonment for not more than three months or to both and, where the person is a corporation, to a fine not exceeding $25,000.

Continuing offence
23(4) Each day's continuance of any act or default that is an offence under this Act constitutes a separate offence for the purposes of this section.

S.M. 1989-90, c. 90, s. 40; S.M. 2000, c. 18, s. 14.

Appeal
24(1) Any person who is affected by an order or decision of the minister under this Act may, within 30 days of the making of the order or decision, appeal the order or decision to the Municipal Board, and the decision of the Municipal Board, notwithstanding anything to the contrary in *The Municipal Board Act*, is final and not subject to further appeal.

Appeal does not act as a stay
24(2) An appeal of an order or decision does not stay the order or decision, or affect the power of the minister to take authorized steps pending the appeal. But if the appeal is successful the minister may enter into an agreement with the appellant to compensate him or her for any loss or damage that the appellant incurred as a result of the order or decision.

S.M. 2005, c. 26, s. 42.

Crown bound
25 The Crown is bound by this Act.

Water Resources Conservation Act takes precedence
25.1 This Act is subject to the provisions of *The Water Resources Conservation Act*.

S.M. 2000, c. 11, s. 8.; S.M. 2005, c. 26, s. 42.

Regulations
26 For the purpose of carrying out the provisions of this Act according to their intent, the Lieutenant Governor in Council may make such regulations as are ancillary thereto and are not inconsistent therewith; and every regulation made under, and in accordance with the authority granted by, this section has the force of law; and, without restricting the generality of the foregoing, the Lieutenant Governor in Council may make regulations,

(a) prescribing the information, particulars and plans to be submitted with any application for a licence;

(b) respecting the duration and renewal of licences and permits and prescribing the terms and conditions to which they are subject;

(c) prescribing forms for use under this Act and the information and particulars to be contained therein;

(d) respecting returns, reports and statements to be submitted by licensees and permittees;

(e) prescribing fees and charges that shall be paid in respect of applications, licences and permits;

(f) authorizing the establishment or placing or construction of devices for computing or measuring the volume and discharge of water in any place;

(g) respecting the approval and inspection of works and water control works;

(h) respecting the use and disposition of water by licensees;

(i) respecting the measurement of water generally;

(j) regulating the passage of logs, timber and other products of the forest through waters and through or over works;

(k) regulating the water rates that may be charged by licensees, and the publication of tariffs of rates;

(l) respecting the construction of fishways to permit the free and unobstructed passage of fish up and down stream;

(m) respecting the storage, pondage, regulation, diversion or utilization of water for any purpose and for the protection of any source of water;

(m.1) respecting the control of water;

(n) respecting the construction, maintenance, operation and purchase, and the assumption of ownership and control, of any works or water control works, as may be necessary or desirable, and for the regulation and control, in the interests of all water users, of the flow of water that may from time to time pass through, by or over the works or water control works;

(o) exempting or excluding from the application of all or any part of this Act any class of works, water control works or activity.

S.M. 2000, c. 18, s. 15.

Priority over Municipal Act

27 Where there is a conflict between this Act and *The Municipal Act*, this Act prevails.

S.M. 2000, c. 18, s. 16.

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GROUND WATER AND WATER WELL ACT

THE GROUND WATER AND WATER WELL ACT
(C.C.S.M. c. G110)

Well Drilling Regulation

Regulation 228/88 R
Registered June 16, 1988

Definitions and interpretation
1(1) In this regulation **"licence"** means a licence to engage in the business of drilling wells.

1(2) A reference by number to a form means the form of that number set out in the Schedule.

Application and fee
2 An applicant for a licence shall file with the director an application in Form 1 together with the licence fee.

Term of licence
3 Unless sooner suspended, a licence expires on December 31 at the end of the period for which it is issued.

Form of licence and identification plates
4(1) A licence shall be in Form 2.

4(2) An identification plate for each drilling machine that the licensee is authorized to operate shall be in Form 3.

4(3) The identification plate shall be mounted on the drilling machine so that it is readily visible at all times.

All persons making use of this consolidation are reminded that it has no legislative sanction. Amendments have been inserted into the base regulation for convenience of reference only. The original regulation should be consulted for purposes of interpreting and applying the law. Only amending regulations which have come into force are consolidated. This regulation consolidates the following amendments: 123/89.

LOI SUR LES EAUX SOUTERRAINES ET LES PUITS
(c. G110 de la C.P.L.M.)

Règlement sur le forage des puits

Règlement 228/88 R
Date d'enregistrement : le 16 juin 1988

Définition
1(1) Dans le présent règlement, le terme « **permis** » désigne le permis autorisant l'exploitation d'une entreprise de forage de puits.

1(2) Toute mention de formule numérotée renvoie à la formule de l'annexe portant le numéro correspondant.

Demande de permis et droits
2 La personne qui demande un permis dépose auprès du directeur une demande au moyen de la formule 1, accompagnée des droits exigibles à l'égard du permis.

Durée du permis
3 À moins qu'il ne soit suspendu plus tôt, le permis expire le 31 décembre, au terme de la période pour laquelle il a été délivré.

Forme du permis et plaque d'identité
4(1) La forme du permis est prévue à la formule 2.

4(2) La plaque d'identité de chaque foreuse que le titulaire de permis est autorisé à utiliser revêt la forme prévue à la formule 3.

4(3) La plaque d'identité est installée sur la foreuse de façon à être bien en vue à tout moment.

Veuillez noter que la présente codification n'a pas été sanctionnée par le législateur. Les modifications ont été apportées au règlement de base dans le seul but d'en faciliter la consultation. Le lecteur est prié de se reporter au règlement original pour toute question d'interprétation ou d'application de la loi. La codification ne contient que les règlements modificatifs qui sont entrés en vigueur. Le présent règlement regroupe les modifications suivantes : 123/89.

Fees
5(1) The fee for a licence is governed by the number of drilling machines the applicant intends to operate in the province.

5(2) The fee for each drilling machine is $10.

Log and samples required
6 During the drilling of a well, the well driller shall

(a) keep a log with such information as is necessary to complete the report required to be made under section 7, and all information relative to each sample required to be taken under clause (b); and

(b) take samples of materials at intervals of not more than 10 feet, and at each change of geological strata, and upon request from the director in writing, place each sample in a separate bag correctly labelled in ink indicating the location of the well, the depth at which the sample was taken, the date on which it was taken and the owner of the well.

Report
7 Within five days of completion of the drilling of a well, the well driller shall make a report in Form 4 and send it by mail or deliver it to the director.*

Provision of samples
8 Where a well driller has been requested by the director to bag and label the samples taken as required under clause 6(b), he shall, within 30 days of the completion of the drilling of a well, ship those samples collect, in a suitable container, to the director, or deliver them to a representative of the Water Control and Conservation Branch.*

Droits
5(1) Le montant des droits exigés à l'égard du permis dépend du nombre de foreuses que le requérant entend utiliser dans la province.

5(2) Les droits sont de 10 $ par foreuse.

Livre de bord et échantillons
6 Lors du forage d'un puits, le foreur de puits :

a) conserve un livre de bord qui contient les renseignements nécessaires à la rédaction du rapport exigé en vertu de l'article 7, ainsi que les renseignements relatifs à chaque échantillon dont l'alinéa b) exige le prélèvement;

b) prélève des échantillons de matières à des intervalles ne dépassant pas 10 pieds et à chaque changement de couche géologique, et, à la demande écrite du directeur, place chaque échantillon dans un sac distinct, qu'il étiquette convenablement à l'encre, en indiquant l'emplacement du puits, la profondeur à laquelle l'échantillon a été prélevé, la date à laquelle il a été prélevé ainsi que le nom du propriétaire du puits.

Rapport
7 Dans les cinq jours suivant la fin du forage d'un puits, le foreur de puits rédige un rapport en la forme prévue à la formule 4, qu'il fait parvenir au directeur par la poste ou qu'il lui livre directement.*

Fourniture des échantillons
8 Si le directeur demande à un foreur de puits de mettre en sac et d'étiqueter les échantillons prélevés selon les exigences de l'alinéa 6b), le foreur de puits, dans les 30 jours suivant la fin du forage du puits, expédie au directeur ces échantillons aux frais du destinataire, dans un récipient adéquat, ou les livre à un représentant de la Direction des ressources hydrauliques.*

* Address: Director of Water Resources Branch, Province of Manitoba, 1577 Dublin Avenue, Winnipeg R3E 3J5.

* Adresse : Directeur de la Direction des ressources hydrauliques, province du Manitoba, 1577, avenue Dublin, Winnipeg R3E 3J5

Confidentiality
9 At the request of a well driller in writing, supported by reasons satisfactory to the minister, the samples and reports of the well may be held confidential by the director for a period not exceeding six months.

Rapports et échantillons confidentiels
9 À la demande écrite du foreur de puits, s'appuyant sur des motifs jugés satisfaisants par le ministre, la teneur des échantillons et des rapports relatifs au puits peut être gardée confidentielle par le directeur pendant une période ne dépassant pas six mois.

Test of yield
10 A test of yield of the well shall be made by the well driller upon completion of the drilling operations by means of a bailer, pump, or other device or method approved by the director.

Essai de rendement
10 Au terme des travaux de forage, le foreur de puits effectue un essai de rendement du puits à l'aide d'une cuiller, d'une pompe ou d'autres appareils ou méthodes approuvés par le directeur.

Casing
11 In drilling a well, the well driller shall install a previously unused casing.

Coffrage
11 Lors du forage d'un puits, le foreur de puits installe un coffrage neuf.

Exclusion of surface water, etc.
12 In completing a well installation which includes constructing a well pit, installing a pumping system, and making underground connections to the well, the well driller shall take adequate precaution to prevent surface water from entering the well.

Prévention de la pénétration des eaux de surface
12 Lorsqu'il exécute les travaux relatifs aux installations de puits, qui comprennent la construction d'une fosse, l'installation d'un système de pompage et l'établissement de raccordements souterrains au puits, le foreur de puits prend les mesures nécessaires pour empêcher les eaux de surface de pénétrer dans le puits.

13 Where

(a) any water that might impair the usefulness of a well; or

(b) any other liquid or soluble substance that might affect the quality of the ground water produced from the well;

is encountered in drilling a well, the well driller shall construct the well in such a manner that the water or liquid or soluble substance cannot enter the well.

13 Si l'une des substances suivantes est décelée lors du forage d'un puits, le foreur de puits construit le puits de façon à ce que la substance décelée ne puisse pénétrer dans le puits :

a) des eaux susceptibles de diminuer l'utilité d'un puits;

b) d'autres liquides ou substances solubles susceptibles d'altérer la qualité des eaux souterraines extraites du puits.

Artesian conditions
14 Where a well driller has been notified that artesian conditions may exist at the site of a proposed well, he shall take adequate precautions to ensure that the well casing is firmly sealed in the impermeable formation above the artesian aquifer.

Conditions artésiennes
14 Dans le cas où un foreur de puits est avisé que des conditions artésiennes peuvent exister à l'emplacement d'un puits projeté, il fait en sorte, en prenant les précautions nécessaires, que le coffrage du puits soit fixé de manière étanche dans la formation imperméable située au-dessus de la nappe artésienne.

Abandoned wells
15 Where a well is dry or abandoned, the owner shall fill and seal it in a manner sufficient to prevent the vertical movement of water in it.

Puits abandonnés
15 Le propriétaire remplit et obture les puits secs ou abandonnés de façon à empêcher le mouvement vertical de l'eau à l'intérieur des puits.

Entrance of non-potable water into aquifer

16 A well driller shall construct each well so as to effectively prevent the entrance of non-potable water or other deleterious matter into any aquifer and to prevent intermixing of water.

Entrance of non-potable water into well

17 If non-potable water enters a well after the date of completion of the well, the owner shall immediately seal off the non-potable water in a manner so as to prevent impairment of the quality of other water.

17.1 A well driller shall construct each well so as to effectively prevent the entrance of non-potable water or other deleterious matter into any aquifer and to prevent intermixing of water.

M.R. 123/89

17.2 If non-potable water enters a well after the date of completion of the well, the owner shall immediately seal off the non-potable water in a manner so as to prevent impairment of the quality of other water.

M.R. 123/89

Repeal

18 Manitoba Regulation G110-R1 is repealed.

Mesures préventives

16 Le foreur de puits doit prendre des mesures efficaces visant à empêcher l'eau non potable et d'autres matières délétères de pénétrer dans la formation aquifère ou de se mêler à l'eau.

Réparations

17 Si de l'eau non potable pénètre dans un puits après la date d'achèvement du puits, le propriétaire doit obturer immédiatement la source d'eau non potable de façon à ce que la qualité de l'eau potable ne se détériore pas.

17.1 Le foreur de puits doit prendre des mesures efficaces visant à empêcher l'eau non potable et d'autres matières délétères de pénétrer dans la formation aquifère ou de se mêler à l'eau.

R.M. 123/89

17.2 Si de l'eau non potable pénètre dans un puits après la date d'achèvement du puits, le propriétaire doit obturer immédiatement la source d'eau non potable de façon à ce que la qualité de l'eau potable ne se détériore pas.

R.M. 123/89

Abrogation

18 Le *règlement du Manitoba* G110-R1 est abrogé.

SCHEDULE

Form 1

PROVINCE OF MANITOBA

WATER RESOURCES BRANCH

APPLICATION FOR LICENCE TO CARRY ON THE BUSINESS OF DRILLING WATER WELLS

1. Name of Applicant (business) ______________________________

2. Address of Applicant (business) ______________________________

3. Telephone (business) ______________________________

4. I/We have been drilling water wells for ____________ years.

5. I/We drilled ____________ water wells in the preceding 12 months.

6. Give names and addresses of the last three persons for whom you have drilled wells:

   (1) ______________________________

   (2) ______________________________

   (3) ______________________________

7. I/We intend to operate the following drilling machines under this licence:

Make	Model	Type
(1)		
(2)		
(3)		
(4)		
(5)		
(6)		

8. I hereby apply for a licence that will authorize me to operate ____________________ drilling machine(s) in the Province of Manitoba.

Date ______________________________
(day) (month) (year)

____
Signature of Applicant

Note: Return complted form together with remittance made payable to the Minister of Finance of Manitoba, and addressed to the Director of Water Resources Branch, Province of Manitoba, Winnipeg. (Licence fee is $10. for each drilling machine).

OFFICE USE ONLY

Amount received ____________________ by: Cash, Cheque, M.O. # ____________________

Receipt No. ____________________ Issued by: ____________________

Form 2

Manitoba
Natural Resources
Water Resources

L I C E N C E

TO CARRY ON THE BUSINESS
OF DRILLING WATER WELLS

LICENCE NO. 194

ISSUED TO ____________________

OF ____________________

IN ACCORDANCE WITH PROVISIONS OF THE GROUND WATER AND WATER WELL ACT.

THIS LICENCE AUTHORIZES THE HOLDER TO OPERATE____________________ DRILLING MACHINES IN THE PROVINCE OF MANITOBA DURING THE PERIOD FOR WHICH THIS LICENCE IS VALID.

DATED AT WINNIPEG, MANITOBA, THIS __________ DAY OF __________ 19____

THIS LICENCE EXPIRES ON THE ____________________

____
DIRECTOR, WATER RESOURCES BRANCH

Form 3

PROVINCE OF MANITOBA
WATER RESOURCES BRANCH

THE OPERATION OF THIS MACHINE TO DRILL

WATER WELLS

IN MANITOBA IS AUTHORIZED UNDER

LICENCE NO.

Plate Form and Yearly
Validation Strip

ANNEXE

Formule 1

PROVINCE DU MANITOBA

DIRECTION DES RESSOURCES HYDRAULIQUES

DEMANDE DE PERMIS D'EXPLOITATION D'UNE ENTREPRISE DE FORAGE DE PUITS

1. Nom ou raison sociale du requérant et de son entreprise : ______

2. Adresse de l'entreprise du requérant : ______

3. N° de téléphone de l'entreprise : ______

4. J'oeuvre dans le domaine du forage des puits depuis ______ ans.

5. J'ai procédé au forage de ______ puits au cours des 12 derniers mois.

6. Veuillez donner le nom et l'adresse des trois dernières personnes pour lesquelles vous avez foré des puits :

   (1) ______

   (2) ______

   (3) ______

7. J'entends utiliser les foreuses suivantes aux termes du présent permis :

Marque	Modèle	Type
(1)		
(2)		
(3)		
(4)		
(5)		
(6)		

8. Je demande par les présentes un permis qui m'autorisera à utiliser ______________ foreuse(s) dans la province du Manitoba.

Date ________________________________
(jour) (mois) (année)

____
Signature du requérant

Remarque : Retourner la formule remplie accompagnée du paiement à l'ordre du ministre des Finances du Manitoba et adressée au directeur de la Direction des ressources hydrauliques, province du Manitoba, Winnipeg. (Les droits de permis sont de 10 $ par foreuse.)

ESPACE RÉSERVÉ À L'ADMINISTRATION

Montant reçu ______________________ Paiement : espèces, chèque, mandat n° __________

Reçu n° ______________________ Délivré par : ______________________

Formule 2

Ressources naturelles
Manitoba
Ressources hydrauliques

P E R M I S

D'EXPLOITATION D'UNE
ENTREPRISE DE FORAGE DE PUITS

PERMIS N° 194

DÉLIVRÉ À ____

DE ____

AUX TERMES DES DISPOSITIONS DE LA *LOI SUR LES EAUX SOUTERRAINES ET LES PUITS*.

LE PRÉSENT PERMIS AUTORISE LE TITULAIRE À UTILISER ____________________ FOREUSES DANS LA PROVINCE DU MANITOBA AU COURS DE LA PÉRIODE DE VALIDITÉ DU PRÉSENT PERMIS.

FAIT À WINNIPEG (MANITOBA), LE ____________________ 19______
(DATE)

LE PRÉSENT PERMIS EXPIRE LE ____

____
DIRECTEUR, DIRECTION DES
RESSOURCES HYDRAULIQUES

Formule 3

PROVINCE DU MANITOBA
DIRECTION DES RESSOURCES HYDRAULIQUES

L'UTILISATION DE CETTE FOREUSE DANS LE BUT DE FORER DES

PUITS

AU MANITOBA EST AUTORISÉE EN VERTU DU

PERMIS N°

Formule des plaques et bordereau
de validation annuelle

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

For more information about this report, contact:

MANITOBA WATER STEWARDSHIP

WATER - http://www.gov.mb.ca/natres/watres/wrb_main.html

R.N. Betcher (Winnipeg: 204-945-7420) – bbetcher@gov.mb.ca

AGRICULTURE AND AGRI-FOOD CANADA (PRAIRIE FARM REHABILITATION ADMINISTRATION)

Stella Fedeniuk (Brandon: 204-578-3637) -

WEST SOURIS RIVER CONSERVATION DISTRICT
Glen Campbell (Reston: 204-877-3020)

For more information about water wells and water quality, contact:

VIDEOS
Will the Well Go Dry Tomorrow? (Mow-Tech Ltd.: 1-800 GEO WELL)
Water Wells that Last (PFRA – Edmonton Office: 780-495-3307)
Ground Water and the Rural Community (Ontario Ground Water Association)

BOOKLET
Water Wells that Last (PFRA – Edmonton Office: 780-495-3307);
http://www.agric.gov.ab.ca/water/wells/index.html
Quality Farm Dugouts - http://www.agric.gov.ab.ca/esb/dugout.html

LOCAL HEALTH DEPARTMENTS

WEST SOURIS RIVER CONSERVATION DISTRICT
Appendix D

Maps and Figures Included as Large Plots

Bedrock Surface Topography 2
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Total Dissolved Solids in Groundwater from Oak Lake Deposits 5
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Cross-Section F - F' 14
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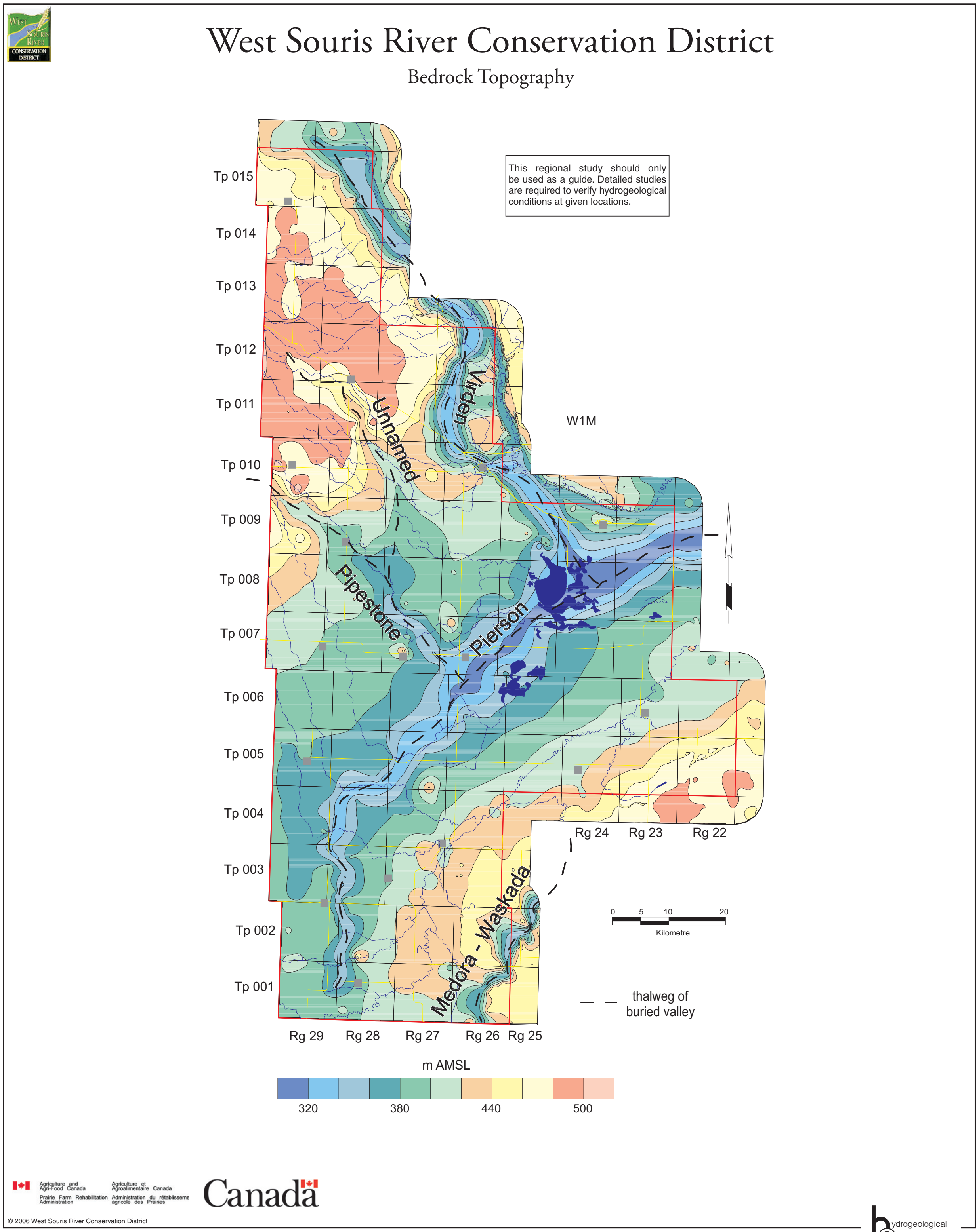
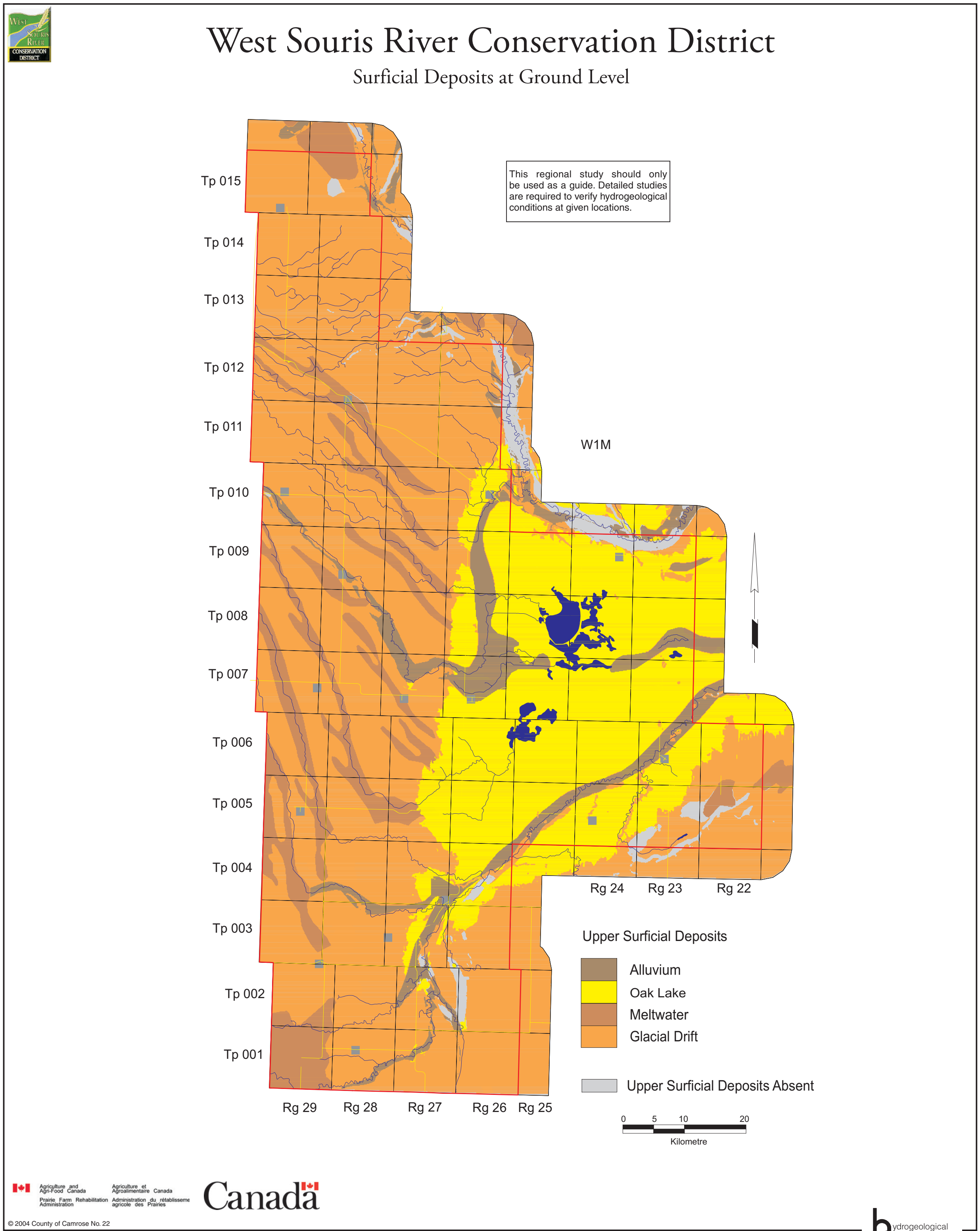
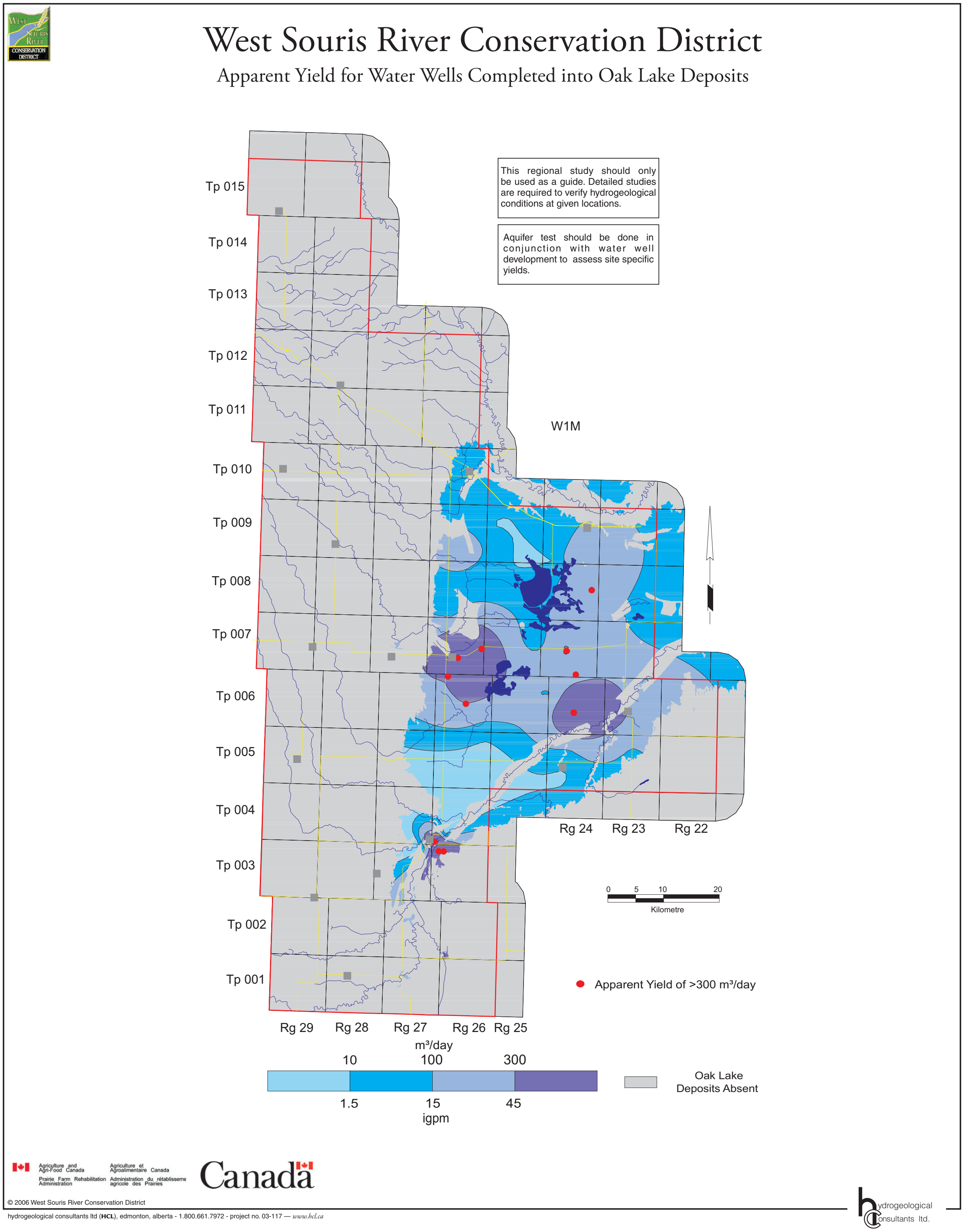
Bedrock Surface Topography



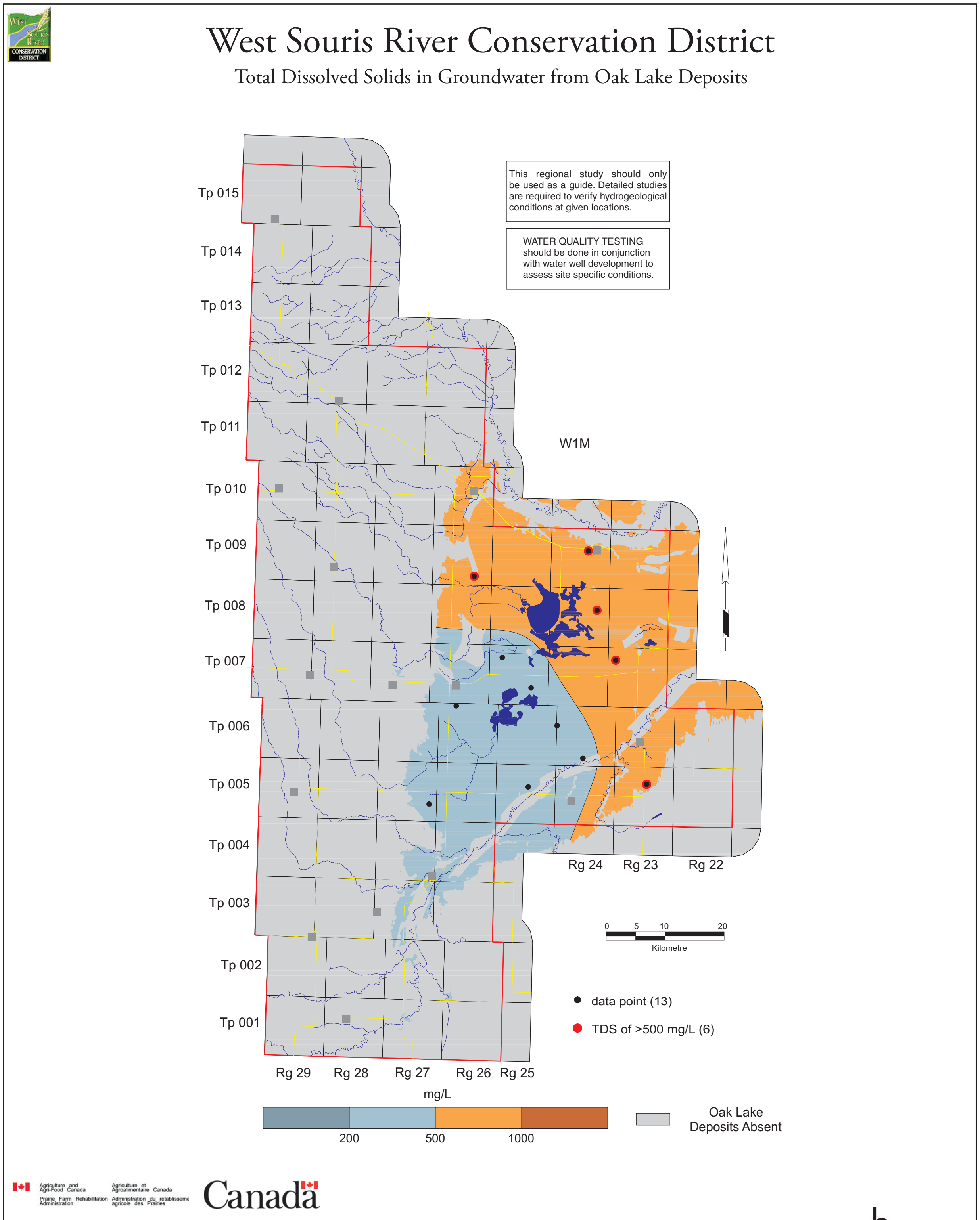
Surficial Deposits at Ground Level



Apparent Yield for Water Wells Completed into Oak Lake Deposits

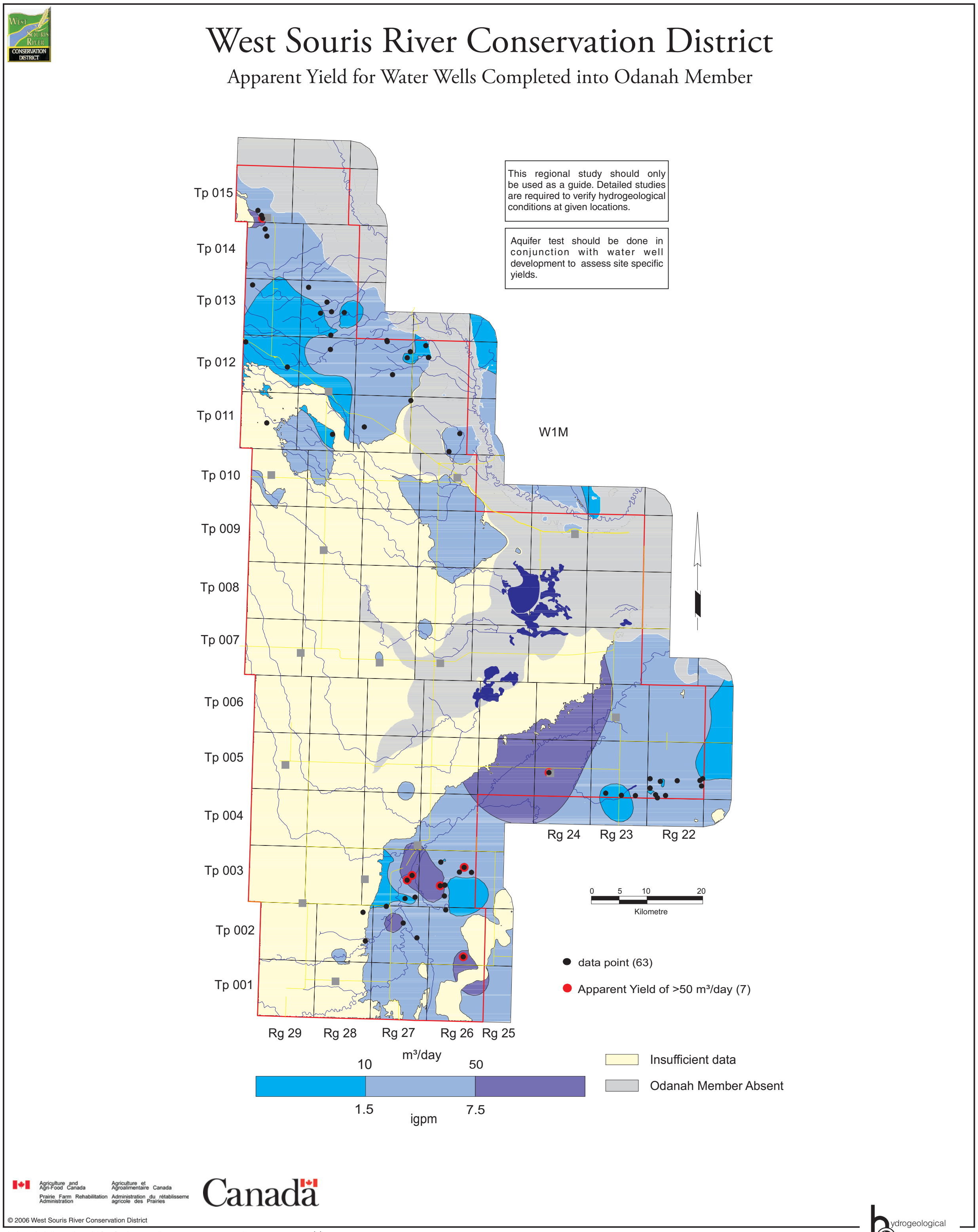


Total Dissolved Solids in Groundwater from Oak Lake Deposits

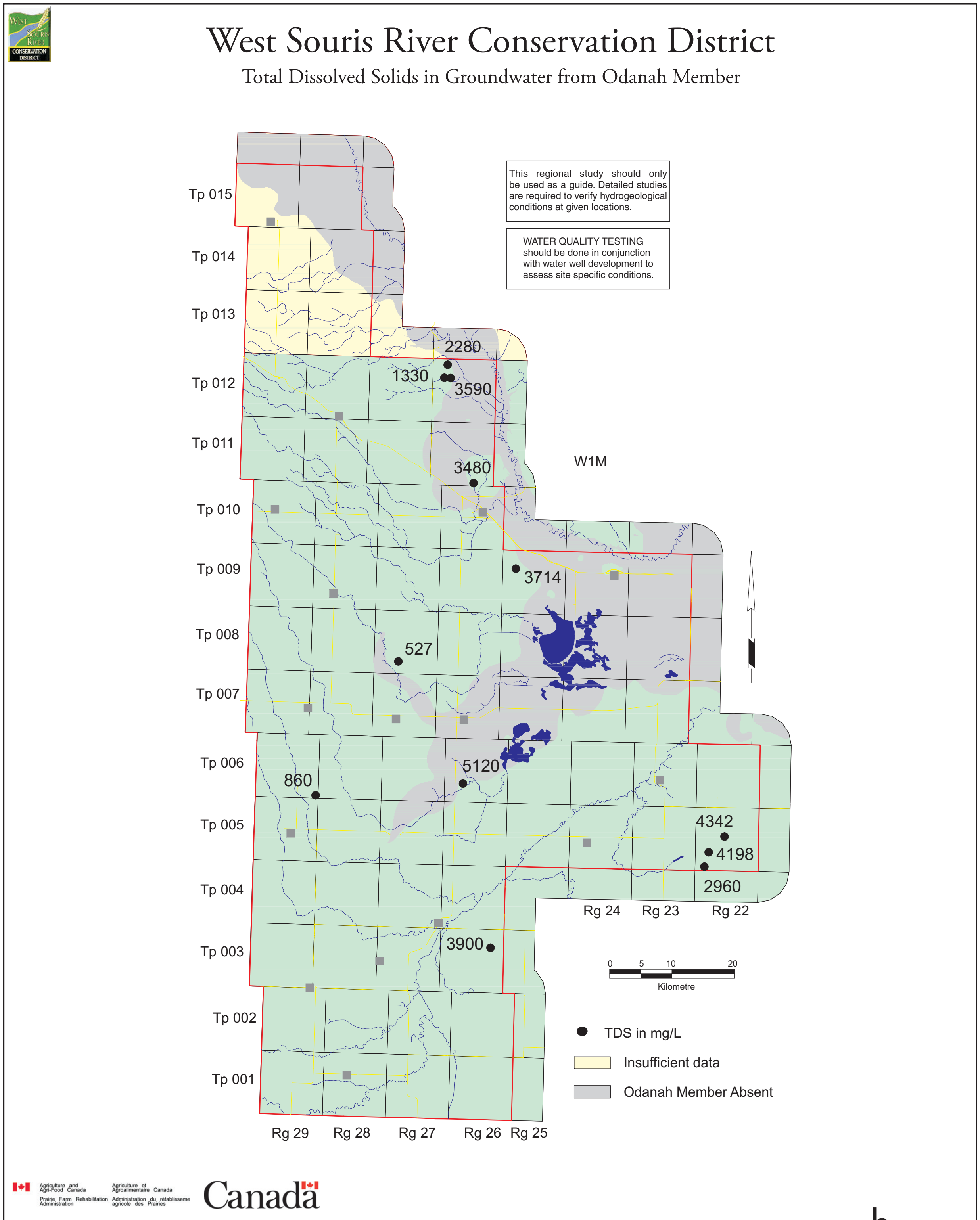


hydrogeological consultants ltd (HCL), edmonton, alberta - 1.800.661.7972 - project no. 03-117 — www.hcl.ca

Apparent Yield for Water Wells Completed into Odanah Member

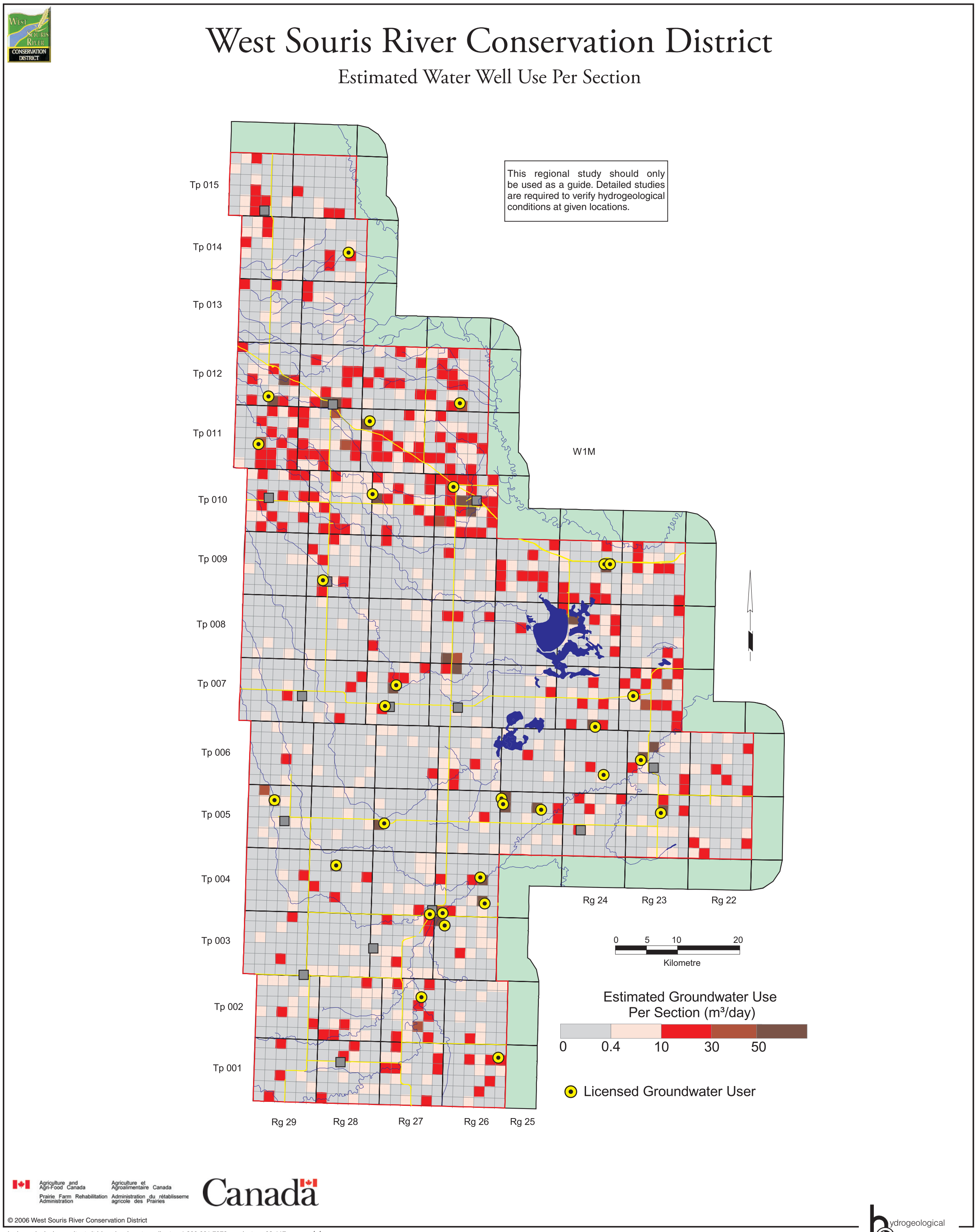


Total Dissolved Solids in Groundwater from Odanah Member

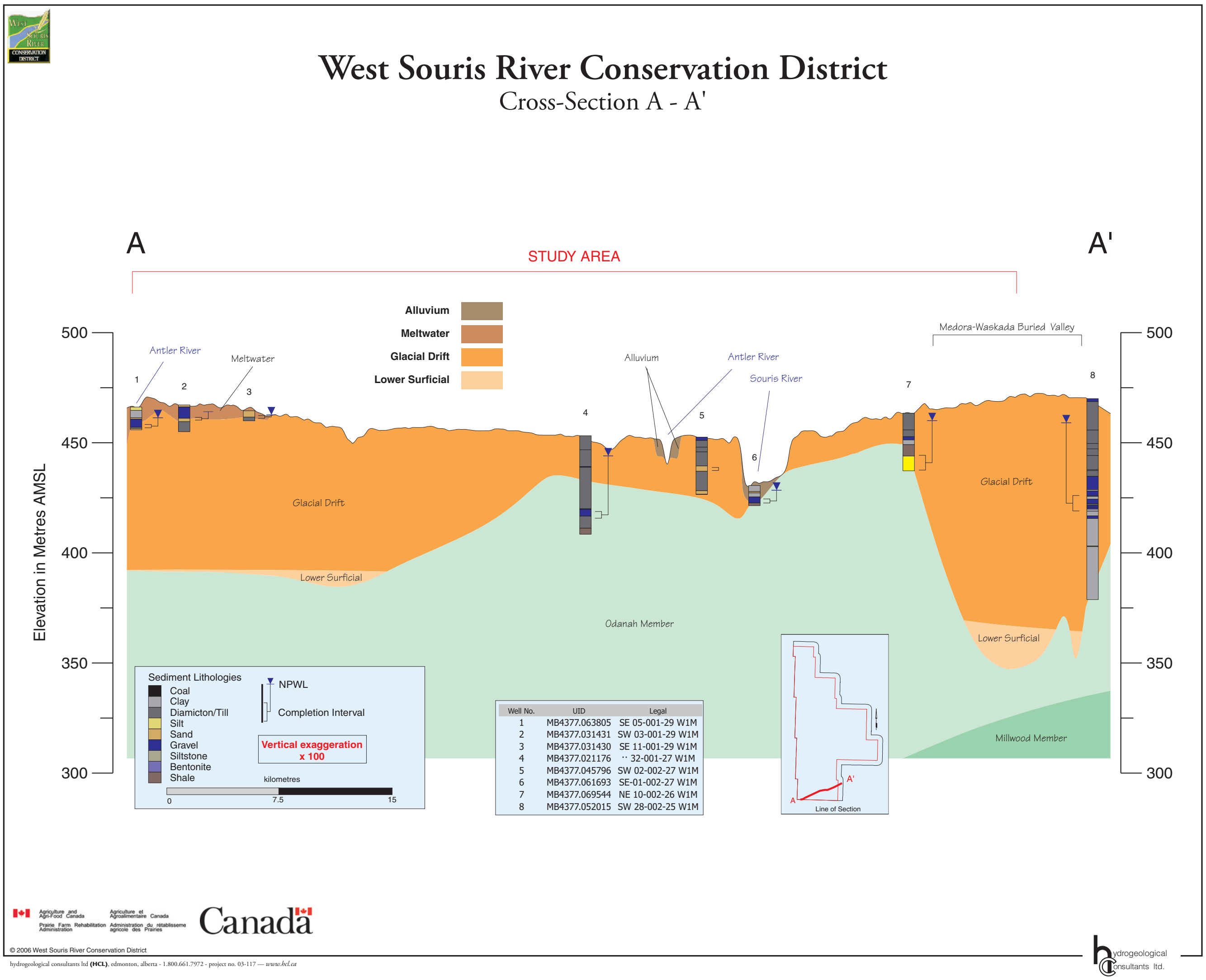


hydrogeological consultants ltd (HCL), edmonton, alberta - 1.800.661.7972 - project no. 03-117 — www.hcl.ca

Estimated Water Well Use Per Section



Cross-Section A - A'



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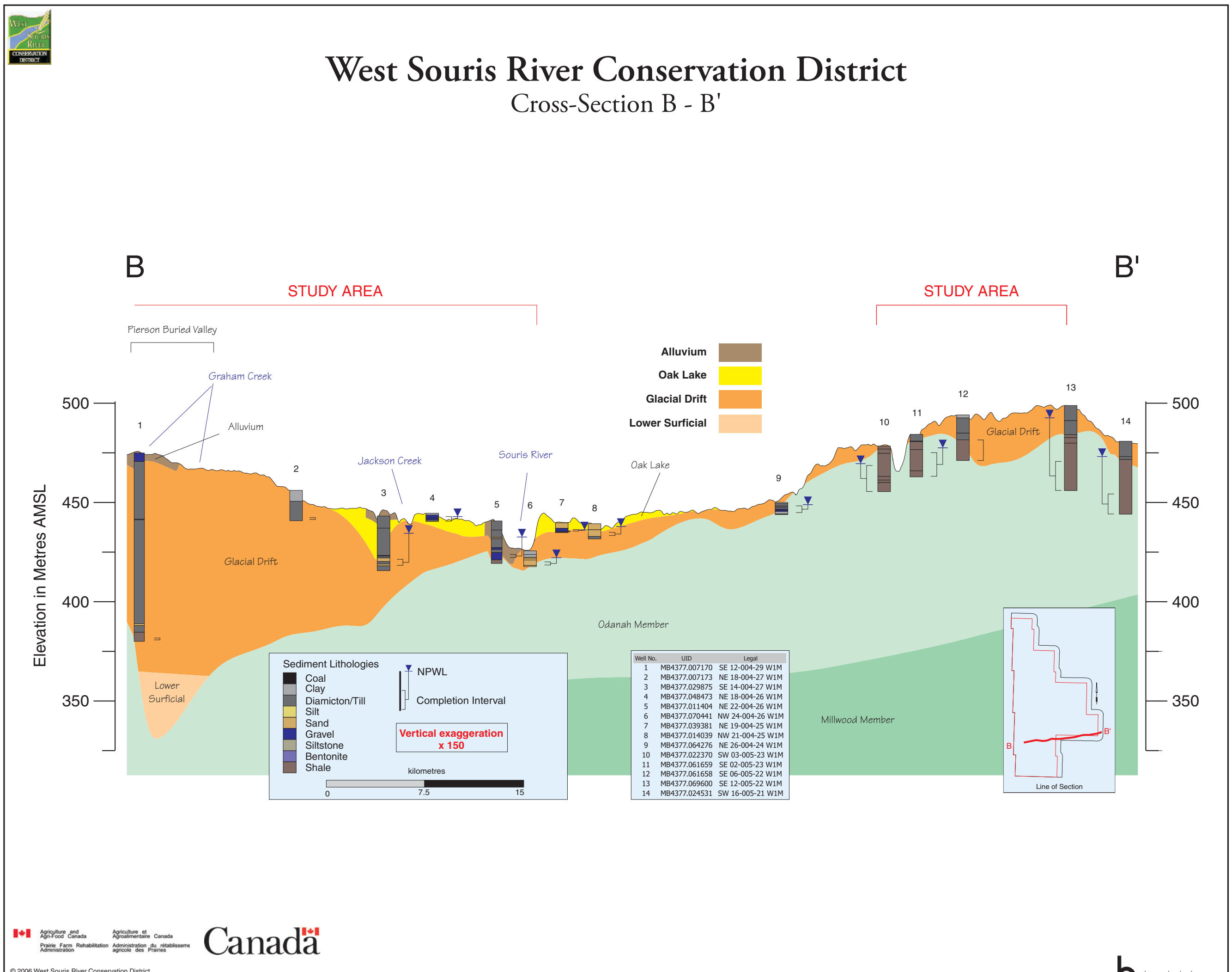
4	MB4377.021176	·· 32-001-27 W1M
5	MB4377.045796	SW 02-002-27 W1M
6	MB4377.061693	SE-01-002-27 W1M
7	MB4377.069544	NE 10-002-26 W1M
8	MB4377.052015	SW 28-002-25 W1M

Cross-Section B - B'



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4	MB4377.048473	NE 18-004-26 W1M
5	MB4377.011404	NE 22-004-26 W1M
6	MB4377.070441	NW 24-004-26 W1M
7	MB4377.039381	NE 19-004-25 W1M
8	MB4377.014039	NW 21-004-25 W1M
9	MB4377.064276	NE 26-004-24 W1M
10	MB4377.022370	SW 03-005-23 W1M
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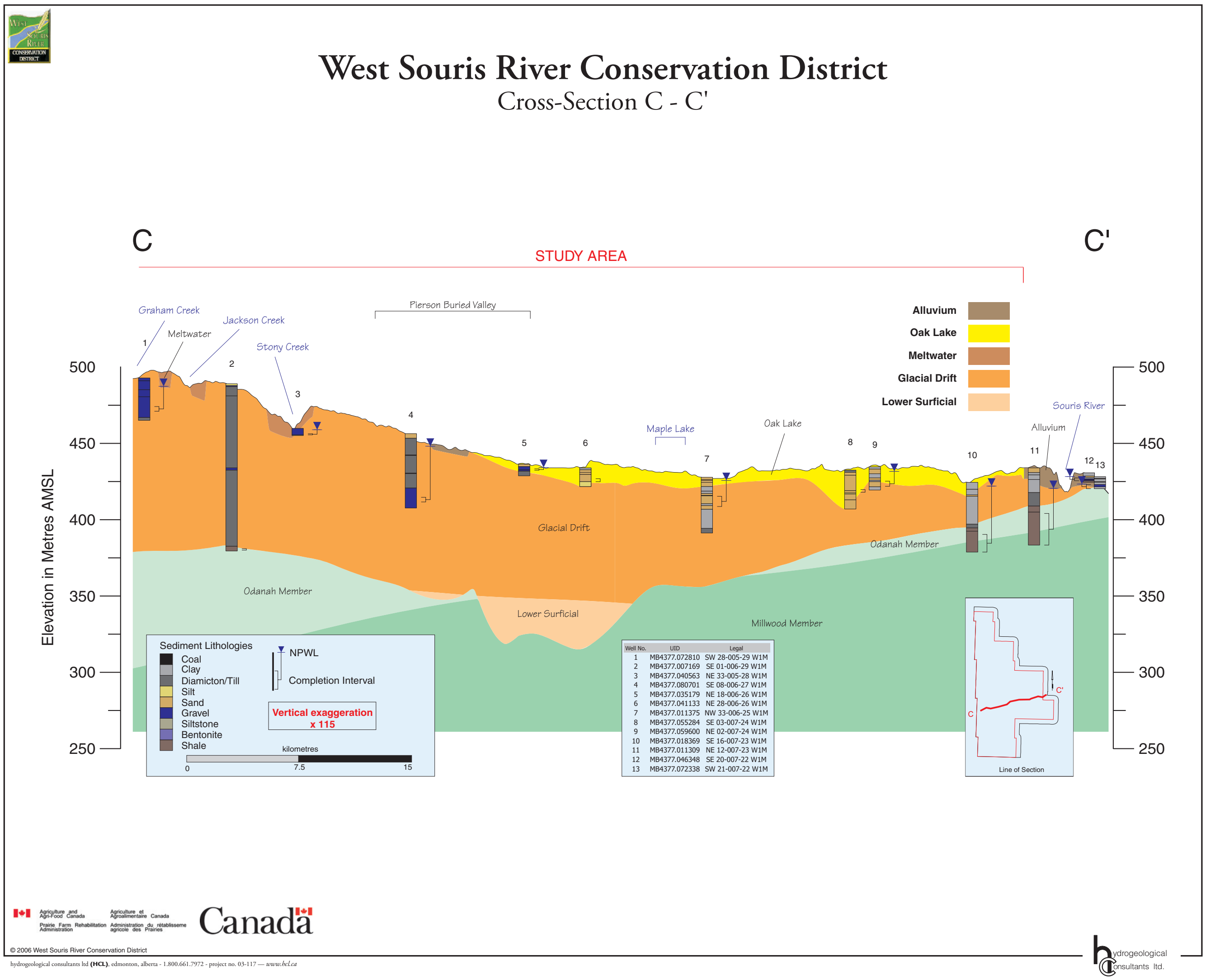
Cross-Section C - C'



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6	MB4377.041133	NE 28-006-26 W1M
7	MB4377.011375	NW 33-006-25 W1M
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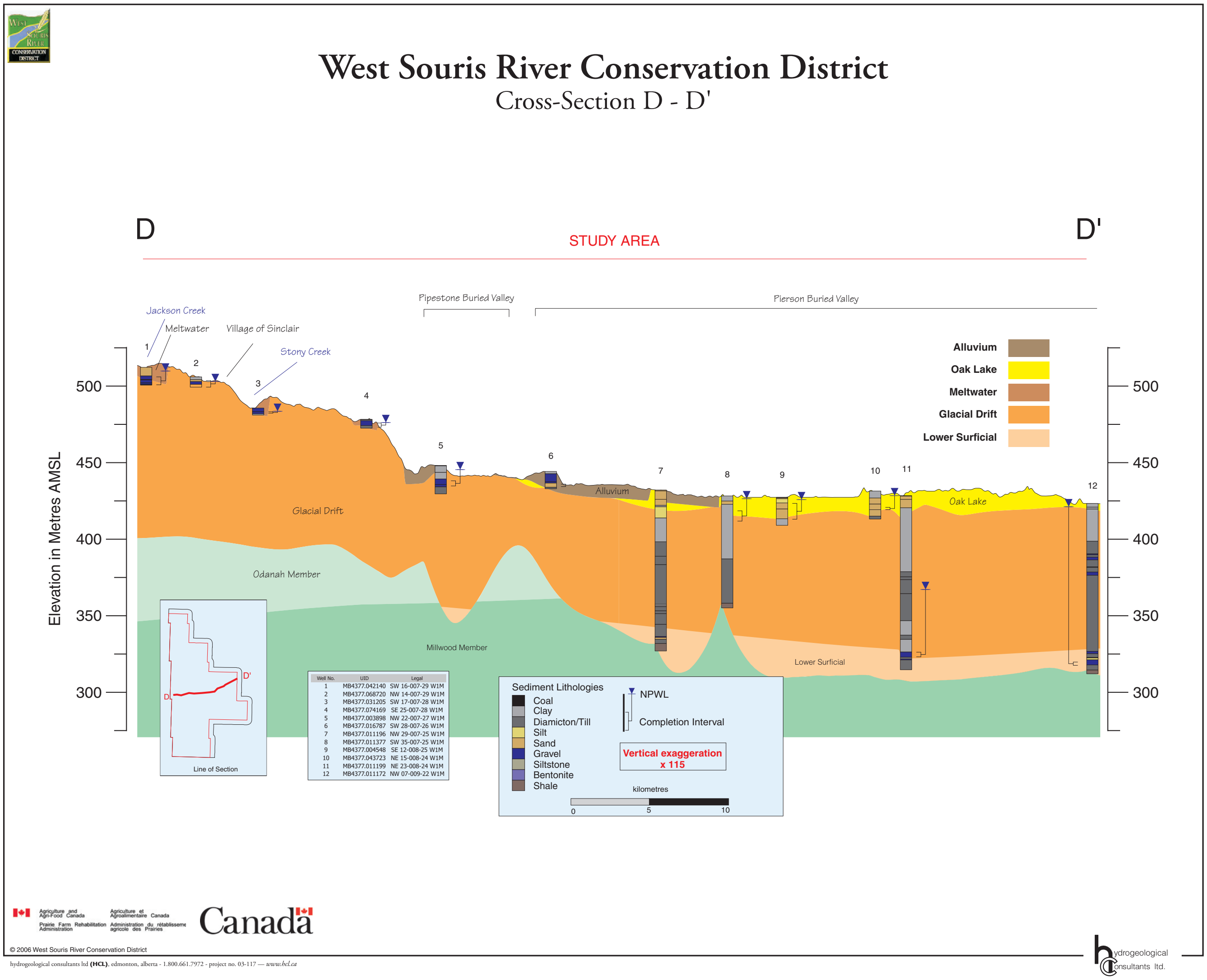
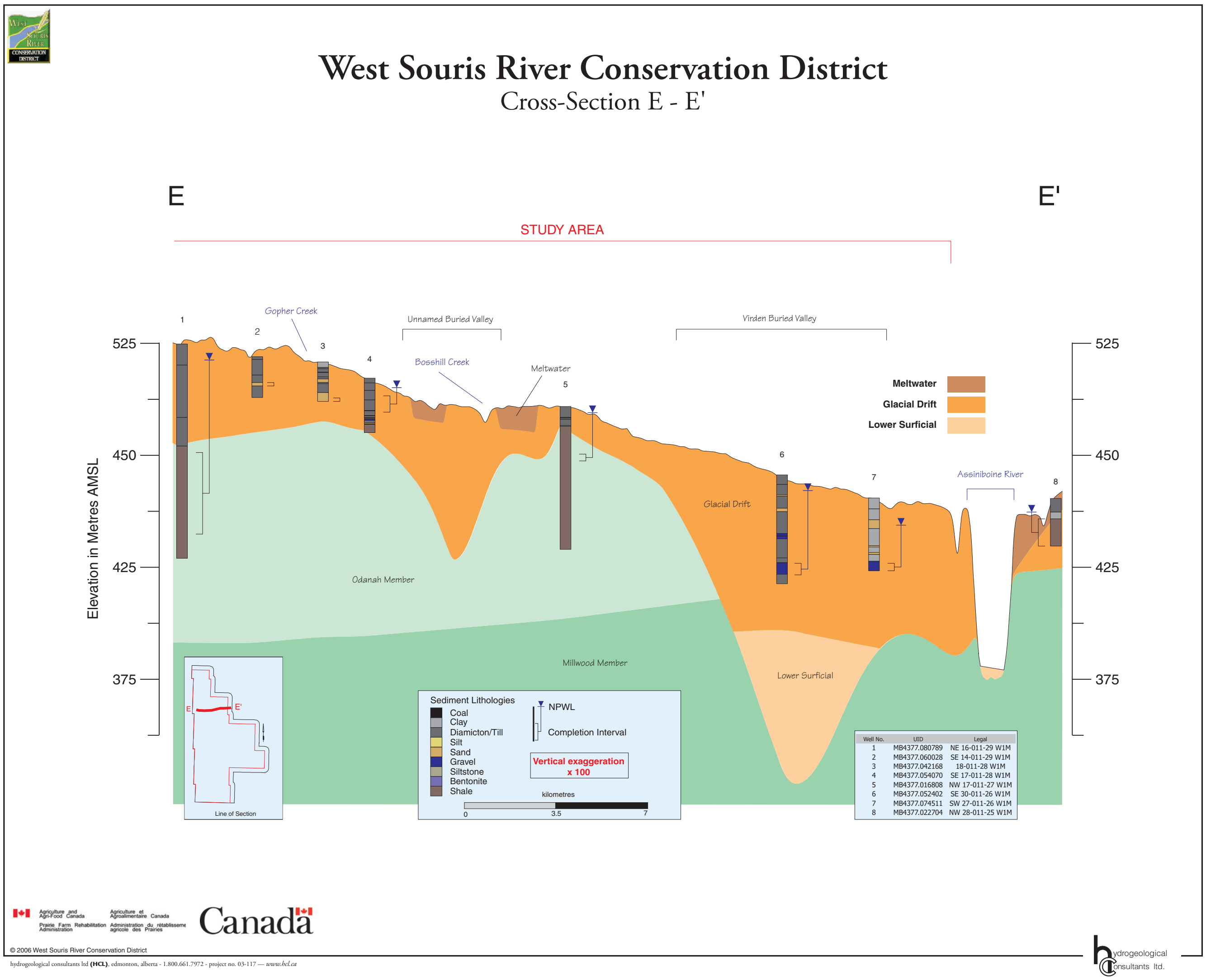
Cross-Section D - D’



Cross-Section E - E'



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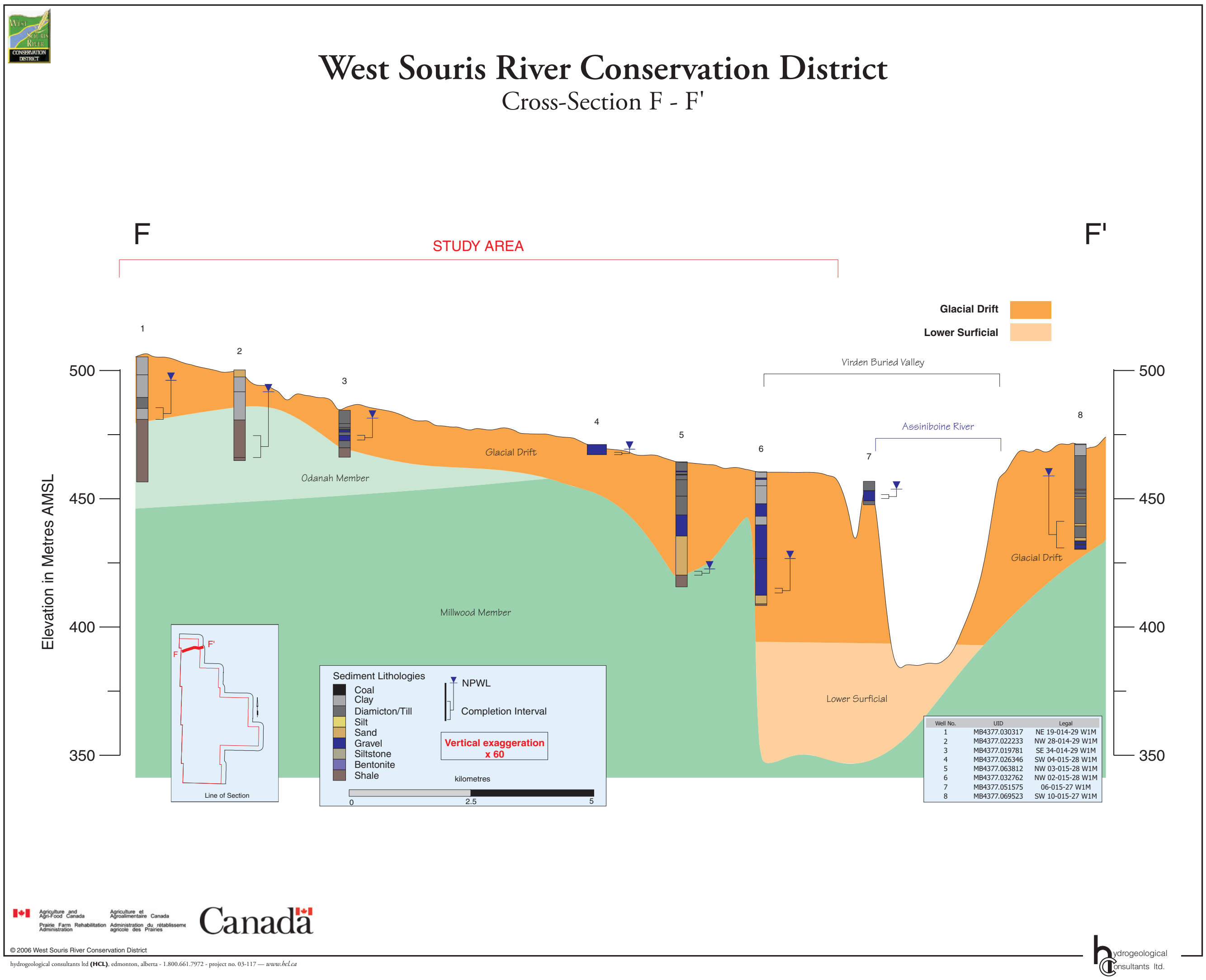
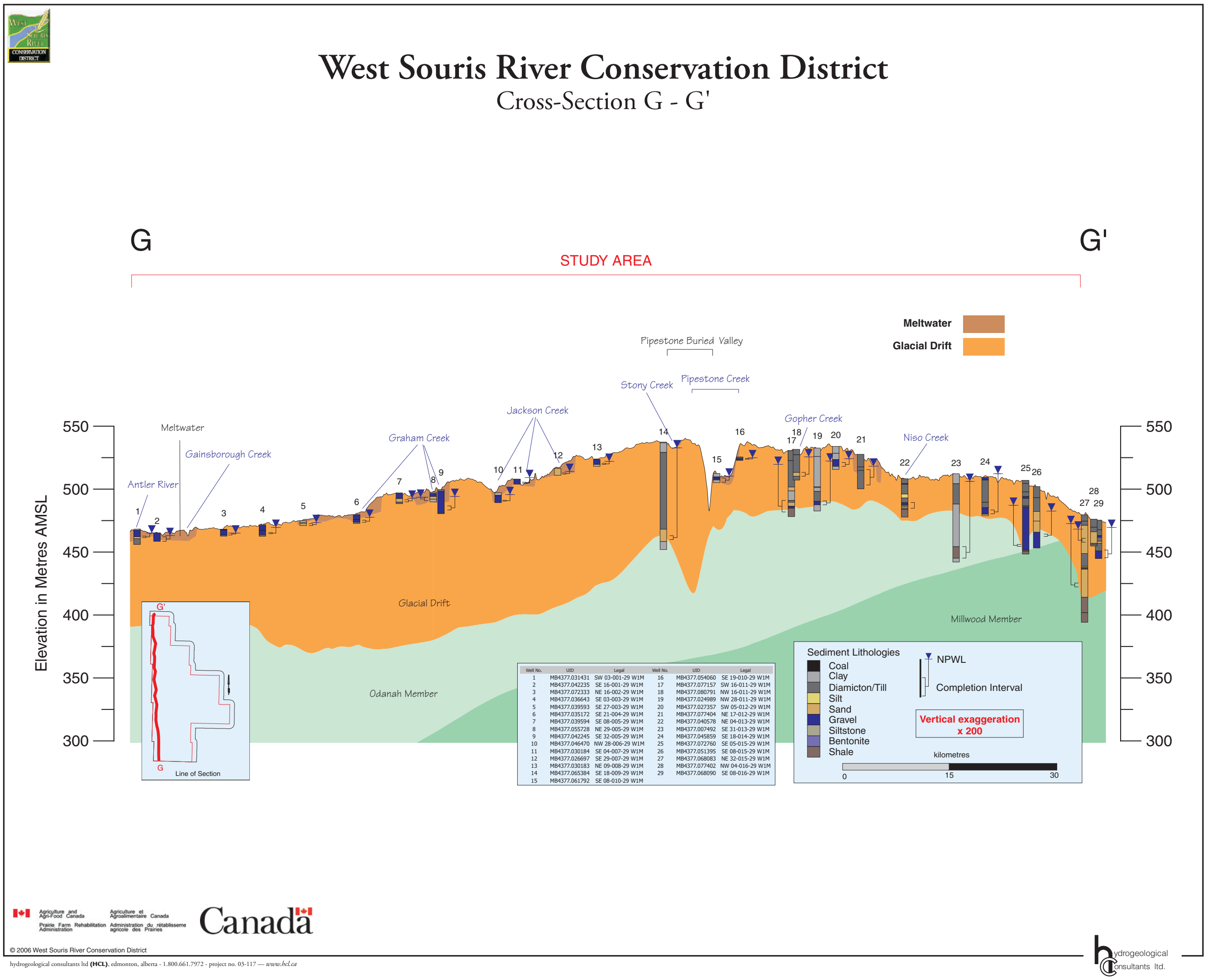
6	MB4377.052402	SE 30-011-26 W1M
7	MB4377.074511	SW 27-011-26 W1M
8	MB4377.022704	NW 28-011-25 W1M

Cross-Section F - F'



Cross-Section G - G'



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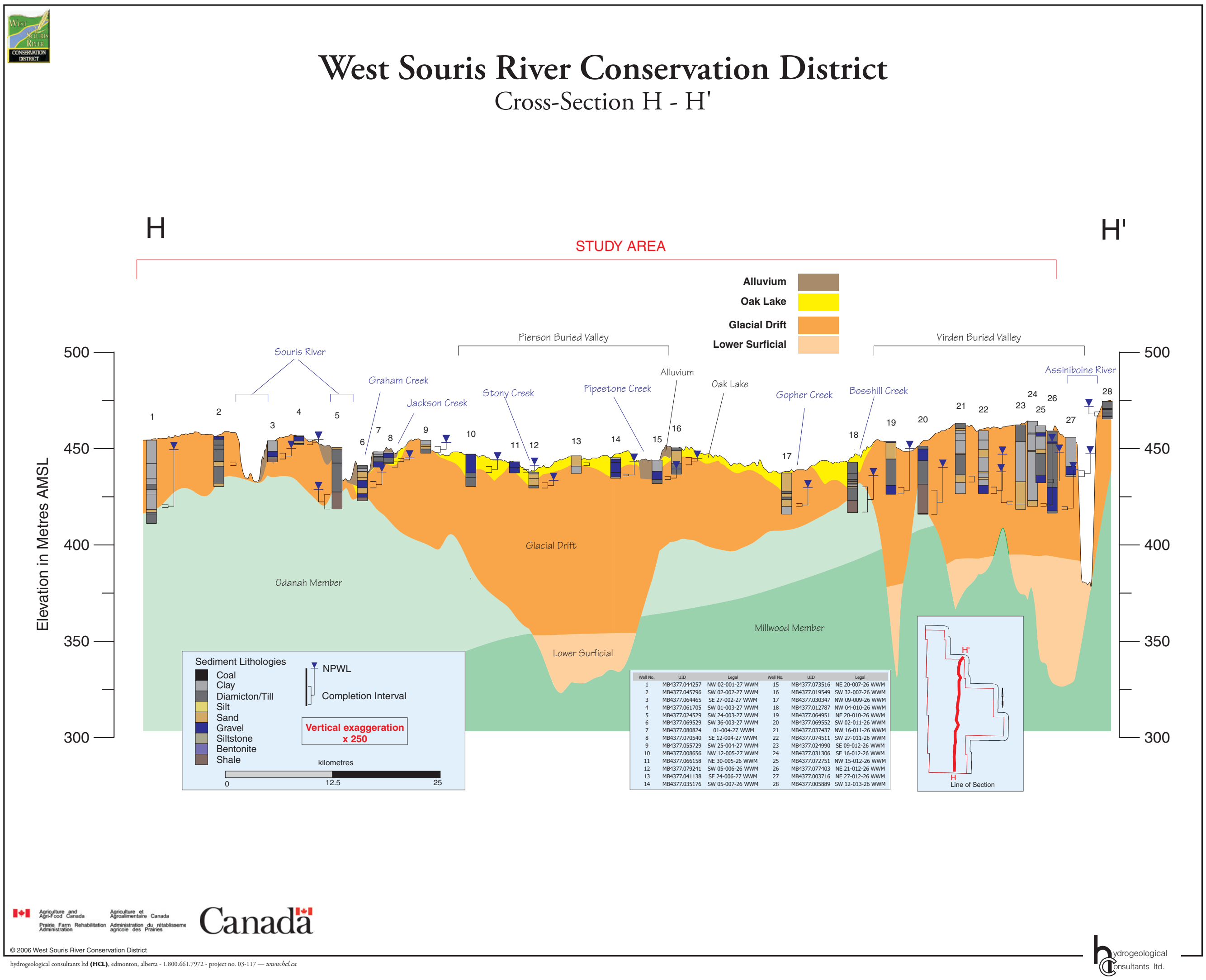
Cross-Section H - H'



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4	MB4377.061705	SW 01-003-27 WWM	18	MB4377.012787	NW 04-010-26 WWM
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6	MB4377.069529	SW 36-003-27 WWM	20	MB4377.069552	SW 02-011-26 WWM
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12	MB4377.079241	SW 05-006-26 WWM	26	MB4377.077403	NE 21-012-26 WWM
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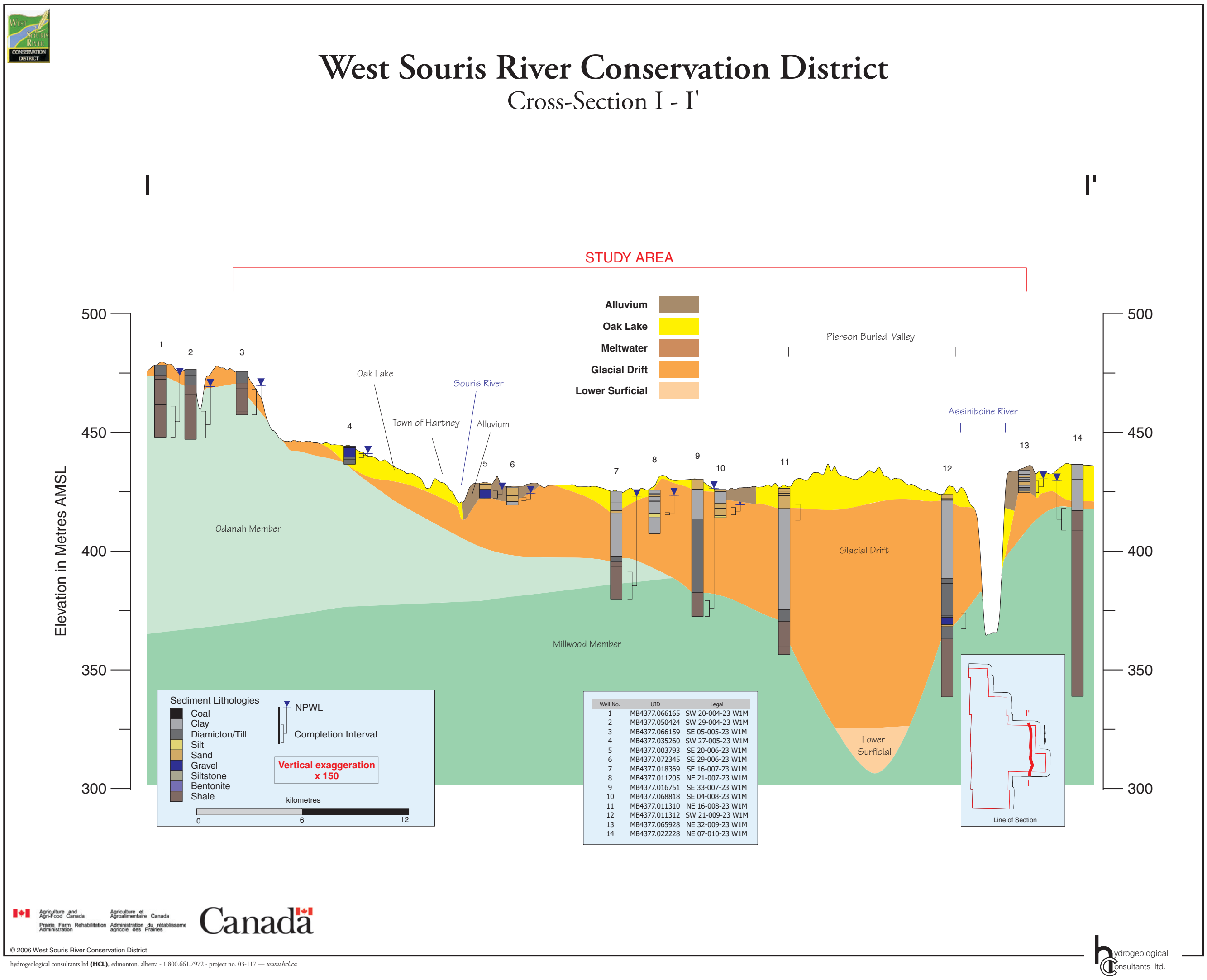
Cross-Section I - I'



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7	MB4377.018369	SE 16-007-23 W1M
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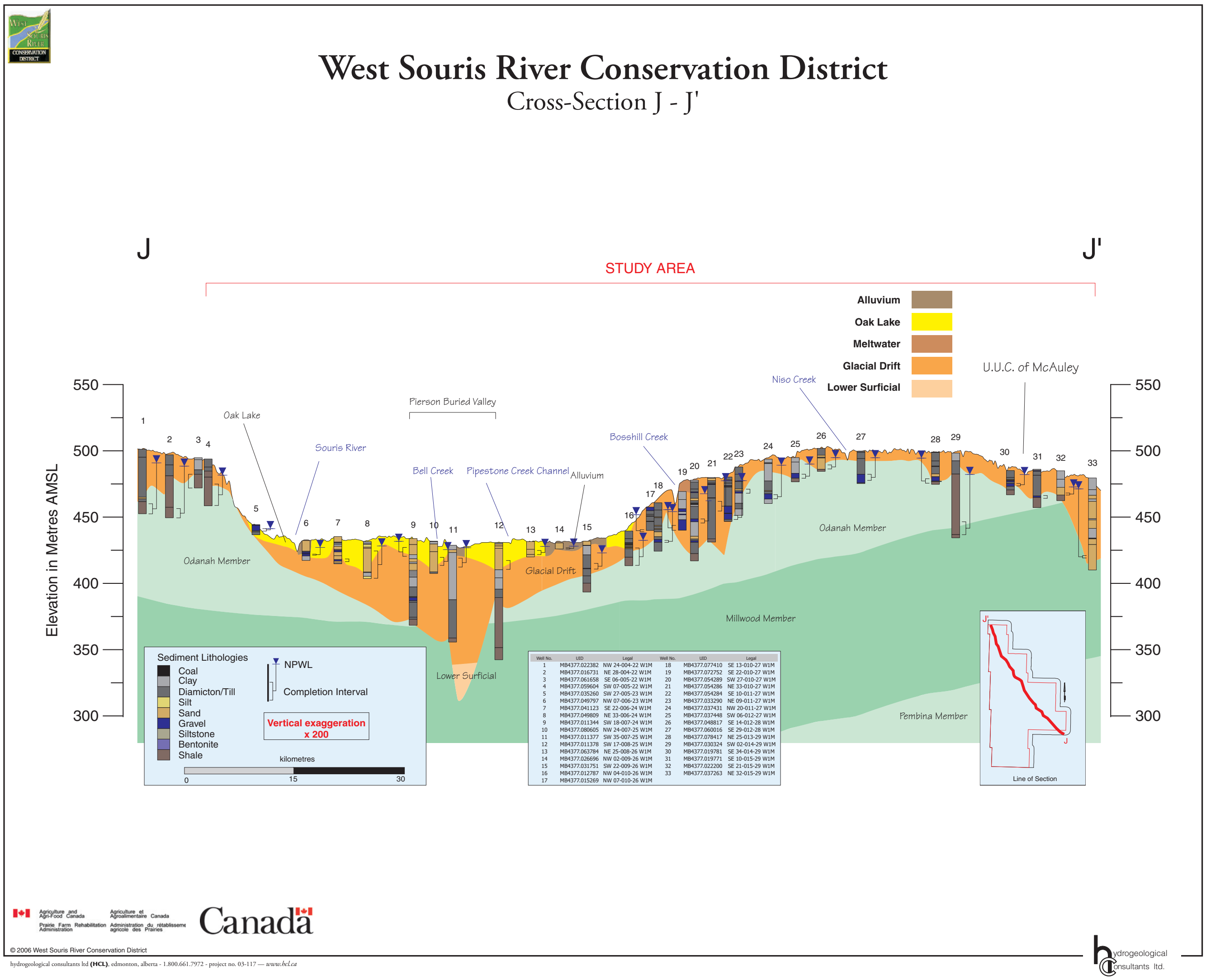
Cross-Section J - J'



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5	MB4377.035260	SW 27-005-23 W1M	22	MB4377.054284	SE 10-011-27 W1M
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12	MB4377.011378	SW 17-008-25 W1M	29	MB4377.030324	SW 02-014-29 W1M
13	MB4377.063784	NE 25-008-26 W1M	30	MB4377.019781	SE 34-014-29 W1M
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17	MB4377.015269	NW 07-010-26 W1M			

WEST SOURIS RIVER CONSERVATION DISTRICT

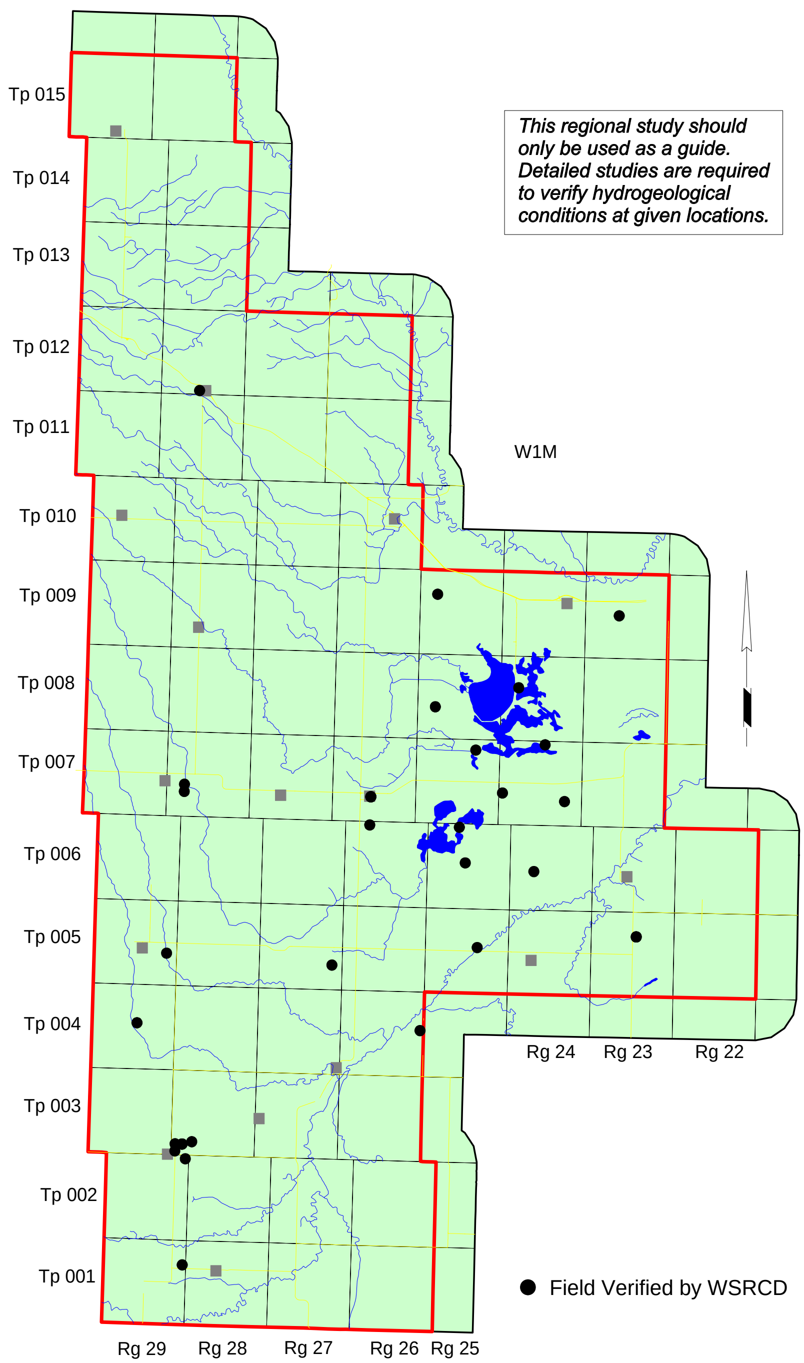
Appendix E

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

Water Wells That Have Been Field-Verified

Water Wells That Are Recommended For Field-Verification

(details on following pages)



WATER WELLS THAT HAVE BEEN FIELD-VERIFIED

Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	Date Field Verified*	UID
SE 01-010-29 WWM	Glacial Drift	08-Apr-13				0.0	04-Dec-01	MB4377.001230
NE 19-009-28 WWM	Glacial Drift	21-Sep-22			12.19	40.0	04-Dec-01	MB4377.003344
SW 21-005-26 WWM	Glacial Drift	19-Jun-63					14-Nov-01	MB4377.004420
SW 13-002-28 WWM	Odanah	01-Jul-63	54.0	177.0	0	0.0	14-Nov-01	MB4377.004592
SW 09-008-27 WWM	Odanah	20-Jul-67					03-Feb-03	MB4377.010037
NW 10-008-29 WWM	Glacial Drift	20-Jul-67					03-Dec-01	MB4377.010111
SW 36-001-29 WWM	Lower Surficial	15-Jul-68					14-Nov-01	MB4377.011471
NE 13-004-29 WWM	Glacial Drift	09-Aug-68					03-Feb-03	MB4377.011476
NW 23-007-23 WWM	Millwood	01-Nov-69	62.5	205.0	3.35	11.0	04-Dec-01	MB4377.012725
···-23-009-24 WWM	Glacial Drift	25-Sep-70	27.1	89.0	3.66	12.0	14-Jan-04	MB4377.014007
SE 26-003-26 WWM	Odanah	05-Apr-72	15.9	52.0	4.57	15.0	27-Jan-04	MB4377.016786
SE 27-002-28 WWM	Bedrock	16-Nov-73	75.6	248.0	23.17	76.0	27-Jan-04	MB4377.018408
NE 36-007-23 WWM	Millwood	19-Sep-74	50.3	165.0	3.35	11.0	14-Jan-04	MB4377.022384
NW 02-009-26 WWM	Oak_Lake	11-Nov-76	4.6	15.0	2.44	8.0	03-Feb-03	MB4377.026696
SE 24-012-28 WWM	Glacial Drift	12-Jan-77	39.6	130.0	6.10	20.0	12-Mar-04	MB4377.029314
NE 09-008-29 WWM	Glacial Drift	12-Oct-77	4.0	13.0	1.52	5.0	03-Feb-03	MB4377.030183
NW 01-011-29 WWM	Glacial Drift	20-Apr-77	65.2	214.0	8.23	27.0	12-Mar-04	MB4377.030349
SW 03-010-28 WWM	Glacial Drift	28-Oct-77	37.8	124.0	4.57	15.0	02-Feb-03	MB4377.030511
SE 16-012-26 WWM	Glacial Drift	01-Jan-77	44.2	145.0	10.67	35.0	12-Mar-04	MB4377.031306
SE 20-003-29 WWM	Glacial Drift	10-Sep-79	12.2	40.0	4.57	15.0	27-Jan-04	MB4377.036112
NE 36-005-27 WWM	Glacial Drift	21-Sep-79	5.8	19.0	1.22	4.0	14-Nov-01	MB4377.036124
SW 17-006-26 WWM	Glacial Drift	01-Oct-79					14-Nov-01	MB4377.036400
NW 20-011-27 WWM	Glacial Drift	03-Oct-79	29.9	98.0	4.57	15.0	12-Mar-04	MB4377.037431
SW 06-012-27 WWM	Surficial	05-Oct-79	15.6	51.0	4.88	16.0	12-Mar-04	MB4377.037448
SW 15-005-23 WWM	Bedrock	02-Oct-80	8.5	28.0	2.44	8.0	14-Jan-04	MB4377.039277
NE 28-005-26 WWM	Glacial Drift	05-May-80				0.0	03-Feb-03	MB4377.039441
SE 24-004-29 WWM	Glacial Drift	14-Oct-80	8.5	28.0	3.35	11.0	13-Jan-04	MB4377.040429
SE 08-012-28 WWM	Glacial Drift	29-Aug-80	18.9	62.0	4.88	16.0	12-Mar-04	MB4377.040461
SW 16-001-28 WWM	Glacial Drift	17-Jun-80	11.6	38.0	2.44	8.0	14-Nov-01	MB4377.040579
SE 20-007-23 WWM	Glacial Drift	16-Oct-80	8.2	27.0			04-Dec-01	MB4377.041119
SE 34-009-24 WWM	Surficial	26-Mar-81	8.2	27.0	3.05	10.0	14-Jan-04	MB4377.041784
NE 17-006-23 WWM	Glacial Drift	09-Jul-81	9.5	31.0	3.35	11.0	27-Jan-03	MB4377.041875
SW 18-002-29 WWM	Glacial Drift	30-Jun-81	10.7	35.0	3.35	11.0	14-Nov-01	MB4377.042240
NW 31-009-23 WWM	Bedrock	18-Jun-82	8.8	29.0	4.27	14.0	14-Jan-04	MB4377.044236
SW 27-007-27 WWM	Surficial	11-Aug-82	7.3	24.0	4.57	15.0	03-Feb-03	MB4377.044538
SW 30-007-27 WWM	Glacial Drift	24-Apr-82	6.4	21.0	1.83	6.0	03-Feb-03	MB4377.044539
NW 04-008-28 WWM	Glacial Drift	27-Apr-82	7.5	24.5	1.83	6.0	03-Feb-03	MB4377.044546
SE 24-006-29 WWM	Glacial Drift	12-Aug-82	5.8	19.0	1.83	6.0	04-Dec-01	MB4377.044551
SE 03-008-27 WWM	Glacial Drift	13-Oct-82					04-Dec-01	MB4377.045514
SE 05-008-27 WWM	Glacial Drift	13-Oct-82			4.27	14.0	14-Nov-01	MB4377.045516
SE 04-002-26 WWM	Glacial Drift	12-Jul-82					13-Jan-04	MB4377.045791
SE 12-006-23 WWM	Glacial Drift	28-Jul-83	8.5	28.0	3.66	12.0	13-Jan-04	MB4377.048099
SW 28-008-26 WWM	Glacial Drift	05-Jul-83	14.9	49.0	5.79	19.0	12-Jan-04	MB4377.048103
SE 12-009-27 WWM	Glacial Drift	18-Oct-83	9.1	30.0	2.44	8.0	14-Jan-04	MB4377.048106
SE 29-012-26 WWM	Odanah	29-Aug-83	11.9	39.0	1.52	5.0	12-Mar-04	MB4377.048203
SW 32-012-26 WWM	Odanah	30-Sep-83	8.8	29.0	2.44	8.0	12-Mar-04	MB4377.048204
NW 19-008-27 WWM	Glacial Drift	13-Jun-85	8.5	28.0	4.27	14.0	14-Jan-04	MB4377.054090
SE 03-010-29 WWM	Surficial	22-Apr-85	5.2	17.0	3.05	10.0	04-Dec-01	MB4377.054102
NW 16-009-25 WWM	Surficial	25-Sep-85	8.2	27.0	2.74	9.0	04-Dec-01	MB4377.054117
NE 27-009-23 WWM	Glacial Drift	22-Aug-85	14.9	49.0	9.14	30.0	03-Feb-03	MB4377.054932
NW 21-003-26 WWM	Millwood	05-Nov-86	30.8	101.0	6.71	22.0	27-Jan-04	MB4377.055720
NE 06-008-27 WWM	Surficial	19-Aug-86	7.5	24.5	5.49	18.0	04-Dec-01	MB4377.055722
NW 29-008-26 WWM	Glacial Drift	22-Sep-86	11.3	37.0	1.83	6.0	12-Jan-04	MB4377.057009
SE 19-001-27 WWM	Surficial	29-Sep-86	8.5	28.0	2.44	8.0	27-Jan-04	MB4377.057013
SW 06-001-28 WWM	Glacial Drift	13-Oct-87	9.1	30.0	2.13	7.0	13-Jan-04	MB4377.058279
SW 12-001-29 WWM	Surficial	14-Oct-87	9.1	30.0	1.83	6.0	13-Jan-04	MB4377.058280

WATER WELLS THAT HAVE BEEN FIELD-VERIFIED (continued)

Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	Date Field Verified*	UID
NE 13-010-29 W1M	Glacial Drift	01-Dec-87	8.8	29.0	2.44	8.0	03-Feb-03	MB4377.058378
NW 31-007-28 W1M	Glacial Drift	20-Nov-87	8.2	27.0	1.22	4.0	08-Jan-04	MB4377.058381
NE 14-005-29 W1M	Glacial Drift	17-Nov-87	9.1	30.0	2.74	9.0	13-Jan-04	MB4377.059598
SW 22-007-24 W1M	Glacial Drift	15-Sep-87	17.4	57.0	4.27	14.0	14-Nov-01	MB4377.060018
SE 06-005-22 W1M	Odanah	24-Oct-88	22.9	75.0	0.00	0.0	13-Jan-04	MB4377.061658
NW 28-009-23 W1M	Surficial	20-May-88	12.2	40.0	4.27	14.0	15-Jan-04	MB4377.061660
NW 03-003-27 W1M	Surficial	07-Sep-88	10.7	35.0	2.44	8.0	27-Jan-04	MB4377.061711
NE 24-004-29 W1M	Surficial	24-Aug-88	7.5	24.5	3.66	12.0	04-Dec-01	MB4377.061764
NW 05-008-29 W1M	Glacial Drift	19-Apr-88	8.8	29.0	1.83	6.0	12-Jan-04	MB4377.061790
SE 10-003-29 W1M	Glacial Drift	19-Aug-88	8.8	29.0	3.05	10.0	15-Jan-04	MB4377.062897
NW 22-005-28 W1M	Glacial Drift	19-Aug-88	8.8	29.0	2.74	9.0	13-Jan-04	MB4377.062898
NE 32-005-24 W1M	Glacial Drift	28-Jul-88	8.8	29.0	2.74	9.0	14-Jan-04	MB4377.062916
SE 02-007-26 W1M	Surficial	15-Jul-88	8.5	28.0	4.27	14.0	03-Feb-03	MB4377.062927
NW 06-007-27 W1M	Glacial Drift	14-Jul-88	11.6	38.0	6.40	21.0	08-Jan-04	MB4377.062931
NE 25-008-26 W1M	Surficial	05-May-88	9.8	32.0	3.66	12.0	12-Jan-04	MB4377.063784
SE 05-001-29 W1M	Glacial Drift	22-Sep-88	9.1	30.0	4.57	15.0	13-Jan-04	MB4377.063805
NW 01-006-22 W1M	Glacial Drift	24-Oct-89	12.2	40.0	3.05	10.0	13-Jan-04	MB4377.065341
NW 22-010-26 W1M	Glacial Drift	26-May-89	39.0	128.0	3.05	10.0	12-Mar-04	MB4377.065362
NE 33-002-27 W1M	Surficial	26-Sep-89	11.3	37.0	3.66	12.0	27-Jan-04	MB4377.066162
NW 33-005-24 W1M	Surficial	10-Oct-89	8.8	29.0	3.66	12.0	03-Feb-03	MB4377.066656
SE 30-007-23 W1M	Surficial	13-Sep-89	8.8	29.0	2.74	9.0	13-Jan-04	MB4377.066680
NW 16-012-26 W1M	Glacial Drift	25-Oct-89	52.4	172.0	22.56	74.0	12-Mar-04	MB4377.066922
SW 29-012-26 W1M	Odanah	28-Oct-90	18.6	61.0	4.57	15.0	12-Mar-04	MB4377.068834
NE 04-005-29 W1M	Glacial Drift	28-Jun-90	10.4	34.0	3.05	10.0	13-Jan-04	MB4377.069500
SE 22-001-28 W1M	Glacial Drift	10-Apr-90	5.8	19.0	2.74	9.0	03-Feb-03	MB4377.069503
SE 06-002-28 W1M	Glacial Drift	06-Apr-90	8.8	29.0	3.05	10.0	15-Jan-04	MB4377.069505
NW 09-002-28 W1M	Glacial Drift	09-Apr-90	8.8	29.0	3.05	10.0	15-Jan-04	MB4377.069506
NE 05-007-28 W1M	Glacial Drift	06-Jun-90	10.4	34.0	2.44	8.0	12-Jan-04	MB4377.069511
SW 09-007-28 W1M	Surficial	05-Jun-90	8.5	28.0	1.83	6.0	12-Jan-04	MB4377.069512
NE 31-006-27 W1M	Glacial Drift	04-Jun-90	11.6	38.0	1.52	5.0	12-Jan-04	MB4377.069539
NW 35-003-26 W1M	Glacial Drift	04-Oct-90	11.3	37.0	2.74	9.0	27-Jan-04	MB4377.069546
SW 02-011-26 W1M	Odanah	06-Jun-90	35.4	116.0	10.97	36.0	12-Mar-04	MB4377.069552
SW 28-006-23 W1M	Surficial	03-Oct-90	5.8	19.0	2.44	8.0	05-Dec-01	MB4377.069587
NE 13-007-23 W1M	Glacial Drift	28-Aug-90			0.00	0.0	04-Dec-01	MB4377.069588
SE 12-005-22 W1M	Odanah	12-Jul-90	42.7	140.0	6.10	20.0	04-Dec-01	MB4377.069600
SW 06-008-28 W1M	Glacial Drift	01-May-90	18.1	59.5	6.10	20.0	08-Jan-04	MB4377.070886
SW 14-004-28 W1M	Glacial Drift	11-Apr-91	8.8	29.0	3.05	10.0	04-Feb-04	MB4377.072060
SE 12-002-29 W1M	Glacial Drift	20-Mar-91	5.8	19.0	2.44	8.0	03-Feb-03	MB4377.072062
NE 16-002-29 W1M	Glacial Drift	15-Mar-91	4.6	15.0	3.05	10.0	14-Nov-01	MB4377.072333
SE 29-006-23 W1M	Surficial	20-Jun-91	5.8	19.0	2.74	9.0	03-Feb-03	MB4377.072345
SE 24-004-28 W1M	Glacial Drift	24-Apr-91	10.7	35.0	5.79	19.0	04-Feb-04	MB4377.072349
NE 20-007-26 W1M	Glacial Drift	30-May-91	10.1	33.0	4.57	15.0	12-Jan-04	MB4377.073516
SE 15-006-26 W1M	Surficial	25-Sep-92	11.9	39.0	2.74	9.0	03-Feb-03	MB4377.074655
SW 35-005-22 W1M	Surficial	29-Jun-93	7.6	25.0	0.91	3.0	03-Feb-03	MB4377.075920
SE 28-007-23 W1M	Glacial Drift	07-Oct-93	14.6	48.0	2.74	9.0	13-Jan-04	MB4377.076173
SE 25-007-25 W1M	Glacial Drift	10-Jun-93	13.7	45.0	5.49	18.0	14-Nov-01	MB4377.077289
NE 15-003-28 W1M	Glacial Drift	07-Jul-93	11.9	39.0	4.88	16.0	13-Jan-04	MB4377.077290
NE 30-007-23 W1M	Oak_Lake	13-Sep-93	9.1	30.0	3.66	12.0	13-Jan-04	MB4377.077405
NW 25-007-23 W1M	Surficial	04-May-94	8.5	28.0	3.96	13.0	04-Dec-01	MB4377.079205
SE 27-005-29 W1M	Surficial	20-Sep-94	9.5	31.0	3.96	13.0	04-Dec-01	MB4377.079308
NE 16-006-22 W1M	Glacial Drift	26-Apr-95	8.8	29.0	3.66	12.0	13-Jan-04	MB4377.080537
NW 02-002-28 W1M	Glacial Drift	20-Sep-95	8.8	29.0	3.66	12.0	27-Jan-04	MB4377.080771
SW 27-009-26 W1M	Surficial	12-Mar-96	7.9	26.0	1.83	6.0	03-Feb-03	MB4377.102647
NW 16-005-29 W1M	Glacial Drift		8.2	27.0	5.06	16.6	03-Feb-03	MB7764.104259
NW 11-001-28 W1M	Glacial Drift		8.9	29.0	1.37	4.5	14-Nov-01	MB7764.104526

WATER WELLS THAT HAVE BEEN FIELD-VERIFIED (continued)

Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	Date Field Verified*	UID
NE 04-009-25 W1M	Surficial		5.5	18.0	2.44	8.0	04-Dec-01	MB7764.106512
SE 19-007-23 W1M	Glacial Drift		8.9	29.0	4.58	15.0	03-Feb-03	MB7764.108247
SW 17-007-23 W1M	Surficial		8.9	29.0	3.51	11.5	04-Dec-01	MB7764.108248
NE 22-009-24 W1M	Oak_Lake						03-Feb-03	MB7764.109786
NE 04-005-24 W1M	Glacial Drift						03-Feb-03	MB7764.110333
NE 18-006-25 W1M	Oak_Lake						04-Dec-01	MB7764.110334
SW 32-008-23 W1M	Oak_Lake						14-Nov-01	MB7764.110389
NW 19-007-25 W1M	Oak_Lake						14-Nov-01	MB7764.110393
SW 24-005-29 W1M	Meltwater						03-Feb-03	MB7764.110651
NW 02-006-29 W1M	Meltwater						04-Dec-01	MB7764.110652
NE 22-009-29 W1M	Glacial Drift						04-Dec-01	MB7764.110656
NE 11-007-25 W1M	Glacial Drift		10.1	33.0	1.34	4.4	03-Feb-03	MB7764.111571
NE 31-002-29 W1M	Glacial Drift		8.5	28.0	1.83	6.0	14-Nov-01	MB7764.113137
SW 06-009-26 W1M	Glacial Drift		5.8	19.0	1.53	5.0	04-Dec-01	MB7764.115248
NW 27-005-24 W1M	Glacial Drift		11.9	39.0	3.97	13.0	04-Dec-01	MB7764.115257
NE 33-002-29 W1M	Glacial Drift		9.2	30.0	3.05	10.0	14-Nov-01	MB7764.118353
SW 02-004-29 W1M	Glacial Drift		11.6	38.0	2.75	9.0	04-Dec-01	MB7764.118357
NW 27-006-27 W1M	Glacial Drift				1.83	6.0	04-Dec-01	MB7764.118362
NE 07-008-27 W1M	Glacial Drift		9.2	30.0	3.45	11.3	13-Jan-04	MB7764.118923
NE 32-005-22 W1M	Glacial Drift						03-Feb-03	MB7764.120498
04-13-014-28 W1M	Glacial Drift	24-Sep-02	30.5	100.0			24-Sep-02	MB7946.583588
01-07-014-27 W1M	Surficial	27-Sep-02	17.7	58.0			27-Sep-03	MB7946.667303

* Date Sampled or analyzed

WATER WELLS RECOMMENDED FOR FIELD-VERIFICATION THAT MEET CRITERIA

Location	Aquifer Name	Date Water Well Drilled	Completed Depth Metres	Completed Depth Feet	NPWL Metres	NPWL Feet	UID
NE 36-002-29 W1M	Lower Surficial	23-Jul-65	109.1	358.0	3.35	11.0	MB4377.007175
NW 12-005-27 W1M	Surficial	13-Oct-66	11.0	36.0	3.66	12.0	MB4377.008659
SW 21-009-23 W1M	Surficial	22-Jul-68	56.7	186.0	0.00	0.0	MB4377.011312
NE 17-006-24 W1M	Surficial	24-May-68	16.5	54.0	0.00	0.0	MB4377.011341
NE 11-007-24 W1M	Surficial	27-May-68	16.5	54.0	3.35	11.0	MB4377.011342
NW 34-007-24 W1M	Surficial	07-Aug-68	15.9	52.0	3.05	10.0	MB4377.011343
SW 18-007-24 W1M	Surficial	28-May-68	13.4	44.0	2.13	7.0	MB4377.011344
NW 20-008-24 W1M	Glacial Drift	17-Jul-68	79.9	262.0	0.00	0.0	MB4377.011346
SE 22-005-25 W1M	Surficial	18-May-68	6.7	22.0	1.52	5.0	MB4377.011368
SE 21-006-25 W1M	Surficial	22-May-68	13.4	44.0	2.44	8.0	MB4377.011373
NW 33-006-25 W1M	Glacial Drift	16-Aug-68	19.2	63.0	2.13	7.0	MB4377.011375
SW 35-007-25 W1M	Glacial Drift	31-May-68	16.5	54.0	1.83	6.0	MB4377.011377
SW 17-008-25 W1M	Surficial	04-Jun-68	20.1	66.0	0.00	0.0	MB4377.011378
SW 29-009-25 W1M	Odanah	06-Jun-68	40.2	132.0	0.00	0.0	MB4377.011382
NE 09-007-26 W1M	Surficial	23-Apr-74	8.8	29.0	3.96	13.0	MB4377.021502
NE 09-007-26 W1M	Glacial Drift	22-Apr-74	11.9	39.0	3.35	11.0	MB4377.021503
NE 09-007-26 W1M	Alluvium	24-Apr-74	7.6	25.0	2.44	8.0	MB4377.021506
NE 09-007-26 W1M	Surficial	23-Apr-74	10.7	35.0	3.96	13.0	MB4377.021507
NE 06-003-28 W1M	Glacial Drift	23-Oct-75	4.9	16.0	1.52	5.0	MB4377.024237
NE 06-003-28 W1M	Glacial Drift	23-Oct-75	4.9	16.0	1.83	6.0	MB4377.024239
NE 06-003-28 W1M	Glacial Drift	21-Oct-75	4.0	13.0	1.22	4.0	MB4377.024249
NW 06-003-28 W1M	Glacial Drift	20-Oct-75	4.0	13.0	1.22	4.0	MB4377.024256
SW 17-007-28 W1M	Glacial Drift	22-Sep-77	3.4	11.0	2.13	7.0	MB4377.031205
SW 22-004-29 W1M	Glacial Drift	30-May-78	5.2	17.0	1.83	6.0	MB4377.035161
NE 32-006-26 W1M	Oak_Lake	30-Aug-78	6.4	21.0	1.52	5.0	MB4377.035175
SW 13-005-29 W1M	Meltwater	17-Oct-78	6.4	21.0	3.05	10.0	MB4377.035234
SW 27-005-23 W1M	Oak_Lake	16-Oct-78	4.6	15.0	2.74	9.0	MB4377.035276
SW 27-005-23 W1M	Surficial	12-Oct-78	5.2	17.0	2.74	9.0	MB4377.035277
SW 27-005-23 W1M	Surficial	12-Oct-78	4.9	16.0	2.74	9.0	MB4377.035278
NW 05-003-28 W1M	Glacial Drift	02-Oct-79	7.0	23.0	0.00	0.0	MB4377.036674
SW 06-003-28 W1M	Glacial Drift	02-Oct-79	3.7	12.0	0.00	0.0	MB4377.036687
SE 04-012-28 W1M	Glacial Drift	05-Jun-80	45.7	150.0	3.66	12.0	MB4377.040586
SE 24-004-26 W1M	Surficial	29-Jun-81	4.6	15.0	2.13	7.0	MB4377.041996
NW 08-007-28 W1M	Glacial Drift	19-Oct-81	6.4	21.0	0.91	3.0	MB4377.042139
SE 25-001-29 W1M	Glacial Drift	26-May-83	5.5	18.0	2.74	9.0	MB4377.049433