The remaining 2,464 water wells have the top of their completion interval deeper than the top to the bedrock surface. From Figure 3, it can be seen that water wells completed in bedrock aquifers occur over most of the County.

Water wells not used for domestic needs must be licensed. At the end of 1996, 180 groundwater diversions were licensed in the County. Of the 180 licensed groundwater users, 155 are for agricultural purposes, and the remaining 25 are for industrial, municipal, diversion, domestic and other purposes. The total maximum authorized diversion from the water wells associated with these licences is 2,978 cubic metres per day (m³/day); 44% percent of the authorized groundwater diversion is allotted for agricultural use. The largest potable groundwater diversion licensed within the County is for the Village of New Sarepta, having a diversion of 179.2 m³/day. The largest licensed industrial groundwater diversions within the County are for three saline water source wells; the largest of these saline diversions is in 14-03-049-01 W5M; this saline water source well is completed at a depth of 1,300 metres below ground surface.

The adjacent table shows a breakdown of the 180 licensed groundwater diversions by the aquifer in which the water well is completed. Even though three saline water source wells are licensed, these supplies no longer need to be licensed. The highest licensed diversions are for water wells completed in the Lower Lacombe Aquifer; the majority of the Lower Lacombe groundwater is used for industrial purposes.

	Licensed Groundwater Users (m³/day)						
Aquifer	Agricultural	Industrial	Municipal	Diversion	Domestic	Other	Total
Upper Sand and Gravel	0	0	0	0	0	34	34
Lower Sand and Gravel	3	0	0	0	0	0	3
Upper Lacombe	29	0	0	0	0	0	29
Lower Lacombe	156	358	0	0	0	0	514
Haynes	239	0	243	0	20	0	502
Upper Scollard	132	0	0	54	0	0	186
Lower Scollard	157	0	0	0	5	0	162
Upper Horseshoe Canyon	369	0	0	0	44	0	413
Middle Horseshoe Canyon	212	24	243	0	0	0	479
Lower Horseshoe Canyon	0	0	0	0	0	0	0
Saline Source Wells	0	436	0	0	0	0	436
Unknown	10	95	115	0	0	0	220
Total	1,307	913	601	54	69	34	2,978

Table 1. Licensed Groundwater Diversions

Based on the 1996 Agriculture Census, the water requirement for livestock for the County is in the order of 12,250 m³/day, which is nine times the amount of the groundwater diversion licensed for agricultural purposes.

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

Groundwaters from the surficial deposits can be expected to be chemically hard with a high dissolved iron content. The total dissolved solids (TDS) concentrations in the groundwaters from the upper bedrock in the County are generally less than 1,500 milligrams per litre (mg/L). Groundwaters from the bedrock aquifers frequently are chemically soft with generally low concentrations of dissolved iron. The chemically soft groundwater is high in sodium concentration. Less than 20% of the chemical analyses indicate a fluoride concentration above 1.5 mg/L.

Alberta Environmental Protection (AEP) defines the Base of Groundwater Protection as the elevation below which the groundwater is expected to have more than 4,000 mg/L of total dissolved solids. By using the ground elevation, the bedrock surface and the Base of Groundwater Protection provided by the Alberta Energy and Utilities Board (EUB), a depth to the Base of Groundwater Protection can be determined. This depth, for the most part, would be the maximum drilling depth for a water supply well.

Over approximately 80% of the County, the depth to the Base of Groundwater Protection is more than 300 metres. There are only a few areas where the depth to the Base of Groundwater Protection is less than 200 metres; these areas are mainly west of range 02, W5M as shown on the adjacent map.

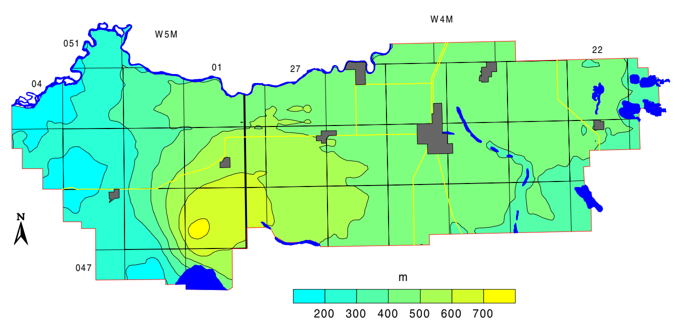

Figure 4. Depth to Base of Groundwater Protection (after EUB, 1995)

Proper management of the groundwater resource requires water-level data. These data are often collected from observation water wells. At the present time, there are sixteen AEP-operated observation water wells within the County. Additional data can be obtained from some of the licensed groundwater diversions. In the past, these data for licensed diversions have been difficult to obtain from AEP, in part because of the failure of the licensee to provide the data. Within the County, however, there is one groundwater monitoring project operated by Mow-Tech Ltd. from which meaningful water-level data can be obtained.

However, even with the available sources of data, the number of water-level data points relative to the size of the County is too few to provide a reliable groundwater budget. 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.

3 TERMS

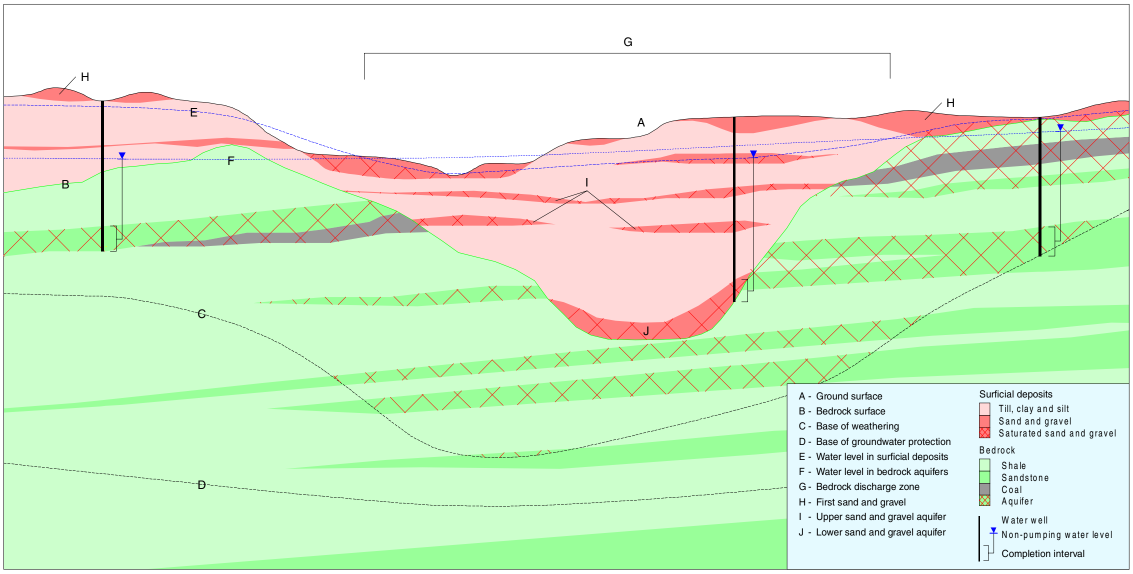

Figure 5. Generalized Cross-Section (for terminology only)

Lithology	Lithologic Description	Group and Formation: Thickness (m)	Group and Formation: Designation	Member: Thickness (m)	Member: Designation	Zone: Thickness (m)	Zone: Designation
	sand, gravel, till, clay, silt	<40	Surficial Deposits	<40	Upper	<20	First Sand and Gravel
				<30	Lower		
	sandstone, shale, coal	<200	Paskapoo Formation – Lacombe Member	0-70	Upper		Upper Sandstone
							Middle Sandstone
							Lower Sandstone
				30-70	Lower		Lower Lacombe Coal Zone
	sandstone, shale, coal		Paskapoo Formation – Haynes Member	20-60			
	shale, sandstone, siltstone, coal	60-220	Edmonton Group – Scollard Formation	60-150	Upper	<2	Upper Ardley Coal Zone
						~20	Ardley Coal Zone (main seam)
						<1	Nevis Coal Seam
				20-80	Lower		
	shale, claystone, tuff, bentonite	~25	Edmonton Group – Battle Formation	<0.3	Kneehills Member		
	shale, siltstone, sandstone	5-10	Edmonton Group – Whitemud Formation				
	shale, sandstone, coal, bentonite, limestone, ironstone	300-380	Edmonton Group – Horseshoe Canyon Formation	~100	Upper		
				~100	Middle		
				<10	Drumheller Member		
				~170	Lower		
	shale, sandstone, siltstone	60-120	Bearpaw Formation				

Figure 6. Geologic Column

4 METHODOLOGY

4.1 Data Collection and Synthesis

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

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

The main disadvantage to the database is the absence of quality control. Very little can be done to overcome this lack of quality control in the data collection, other than to assess the usefulness of control points relative to other data during the interpretation. Another disadvantage to the database is the lack of adequate spatial information. However, unlike other areas in the Province, duplicate water well IDs are not a problem in the County.

The AEP groundwater database uses a land-based system with only a limited number of records having a value for ground elevation. The locations for records usually include a quarter section description; a few records also have a land description that includes a Legal Subdivision (Lsd). For digital processing, a record location requires a horizontal coordinate system. In the absence of an actual location for a record, the record is given the coordinates for the centre of the land description. This situation has been improved for Leduc County. Prairie Farm Rehabilitation Administration (PFRA) has re-positioned 5,787 water wells within the County using aerial photographs and subdivision plans. These coordinates are provided with the records on the CD-OM.

The present project uses the 10TM coordinate system. This means that a record for the SE ¼ of section 24, township 049, range 27, W4M, would have a horizontal coordinate with an Easting of 79,352 metres and a Northing of 5,896,100 metres, the centre of the quarter section. If the water well has been positioned by PFRA, the location will be more accurate, possibly within several 10s of metres of the actual location. Once the horizontal coordinates are determined, a ground elevation is obtained from the 1:20,000 Digital Elevation Model (DEM) from the Resource Data Division of AEP.

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

Where possible, determinations are made from individual records for the following:

1) depth to bedrock;
2) total thickness of sand and gravel;
3) thickness of first sand and gravel when present within one metre of ground surface;
4) total thickness of saturated sand and gravel; and

5) depth to the top and bottom of completion interval.

Also, where sufficient information is available, values for apparent transmissivity[3] and apparent yield[4] are calculated, based on the aquifer test summary data supplied on the water well drilling reports. The apparent transmissivity results are then used to estimate a value for hydraulic conductivity[5]. The conductivity values are obtained by dividing the apparent transmissivity by the completion interval. To obtain a value for regional transmissivity of the aquifer, the hydraulic conductivity is multiplied by the effective thickness of the aquifer based on nearby e-log information. Where valid detailed aquifer test results exist, the interpreted data provide values for aquifer transmissivity and effective transmissivity. When calculating the apparent long-term yield, values for effective or aquifer transmissivity are used, if available.

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

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

Values for apparent transmissivity, apparent yield and hydraulic conductivity are calculated from the DST summaries. Also, the DST summaries are used to obtain water level elevations.

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

4.2 Spatial Distribution of Aquifers

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

1) lithologs provided by the water well drillers;
2) geophysical logs from structure test holes;
3) wells drilled by the oil and gas industry; and
4) data from existing cross-sections.

The identification of aquifers becomes a two-step process: first, mapping the tops and bottoms of individual geological units; and second, identifying the porous and permeable parts of each geological unit.

After obtaining values for the elevation of the top and bottom of individual geological units at specific locations, the spatial distribution of the individual surfaces can be determined. Digitally, establishment of the distribution of a surface requires the preparation of a grid. The inconsistent quality of the data

3 For definitions of Transmissivity, see glossary
4 For definitions of Yield, see glossary
5 See glossary

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[6] 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.

The porous and permeable parts of the individual geological units have been mainly determined from geophysical logs.

4.3 Hydrogeological Parameters

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

After the water wells are assigned to a specific aquifer, the parameters from the water well records are assigned to the individual aquifers. The parameters include non-pumping (static) water level (NPWL), transmissivity and projected water well yield. The total dissolved solids, chloride and sulfate concentrations from the chemical analysis of the groundwater are also assigned to applicable aquifers.

Once the values for the various parameters of the individual aquifers are established, the spatial distribution of these parameters must be determined. The distribution of individual parameters involves the same process as the distribution of geological surfaces. This means establishing a representative data set and then preparing a grid. Even when only limited data are available, grids are prepared. However, the data from these grids must be used with extreme caution because the gridding process can be unreliable.

4.3.1 Risk Criteria

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

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6 See glossary

4.4 Maps and Cross-Sections

Once grids for geological surfaces have been prepared, various grids need to be combined to establish the extent and thickness of individual geological 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 geological unit. The thickness of the porous and permeable part(s) of the geological unit is used to determine the aquifer transmissivity by multiplying the hydraulic conductivity by the thickness.

Grids must also be combined to allow the calculation of projected long-term yields for individual water wells. The grids related to the elevation of the NPWL and the elevation of the top of the aquifer are combined to determine the available drawdown[7]. The available drawdown data and the transmissivity values are used to calculate values for projected long-term yields for individual water wells, completed in a specific aquifer.

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

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

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

4.5 Software

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

- Microsoft Professional Office 97
- Surfer 6.04
- ArcView 3.1
- AutoCAD 14.01
- CorelDRAW! 8.0
- Acrobat 3.0

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7 See glossary

5 AQUIFERS

5.1 Background

An aquifer is a porous and permeable rock that is saturated. If the NPWL is above the top of the rock unit, this type of aquifer is an artesian aquifer. If the rock unit is not entirely saturated and the water level is below the top of the unit, this type of aquifer is a water-table aquifer. These types of aquifers occur in one of two general geological settings in the County. The first geological setting is the sediments that overlie the bedrock surface. In this report, these are referred to as the surficial deposits. The second geological setting includes aquifers in the upper bedrock. The geological settings, the nature of the deposits making up the aquifers within each setting, the expected yield of water wells completed in different aquifers, and the general chemical quality of the groundwater associated with each setting are reviewed separately.

5.1.1 Surficial Aquifers

Surficial deposits in the County are mainly less than 20 metres thick, except in areas of linear bedrock lows where the thickness of the surficial deposits can exceed 40 metres. The Buried Beverly and Warberg (sic*) valleys are the main southwest-northeast-trending linear bedrock lows in the County. The Buried Beverly Valley and the North Saskatchewan River occupy the same linear bedrock low at the northwestern border of the County. Strawberry Creek and the Buried Warburg Valley, an extension of the Buried Stony Valley (Carlson, 1967), occupy the same linear bedrock low in the northwest-central part of the County. Cross-section A-A' passes across the Buried Warburg Valley and shows the surficial deposits being up to 40 metres thick within the Valley.

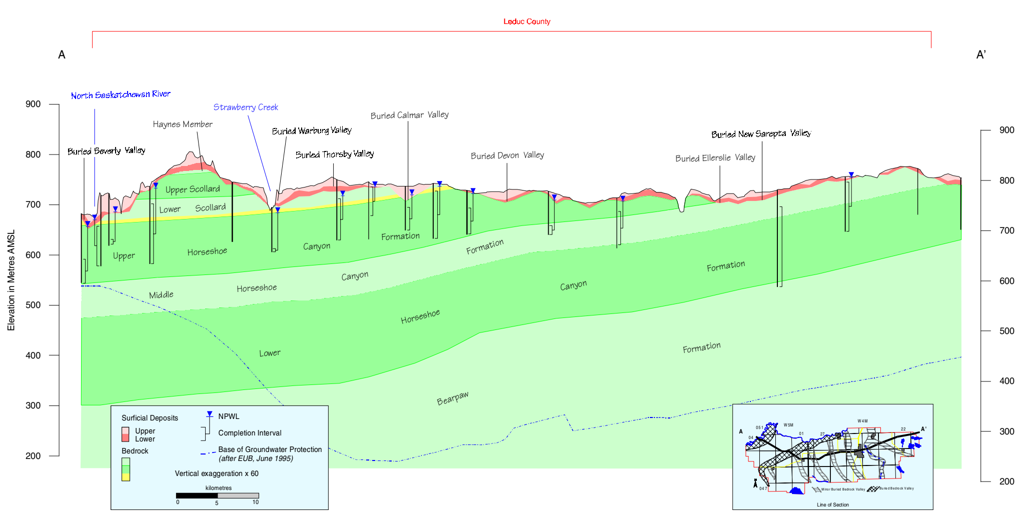

Figure 7. Cross-Section A - A'

The main aquifers in the surficial materials are sand and gravel deposits. In order for a sand and gravel deposit to be an aquifer, it must be saturated; if not saturated, a sand and gravel deposit is not an aquifer. The top of the surficial aquifers has been determined from the NPWL in water wells that are less than 15 metres deep. The base of the surficial deposits is the bedrock surface.

* Carlson, 1970; to be spelled like the Village of Warburg in the report and on figures, hereinafter.

For a water well with a small-diameter casing to be effective in surficial deposits and to provide sand-free groundwater, the water well must be completed with a water well screen. Some water wells completed in the surficial deposits are completed in low-permeability aquifers and have a large-diameter casing. The large-diameter water wells may have been hand dug or bored and because they are completed in very low permeability aquifers, most of these water wells would not benefit from water well screens. The groundwater from an aquifer in the surficial deposits usually has a chemical hardness of at least a few hundred mg/L and a dissolved iron concentration such that the groundwater must be treated before being used for domestic needs. Within the County, casing diameter information is available for 62 of the 126 water wells completed in the surficial deposits; 20 of these have a casing diameter of more than 450 millimetres, and are assumed to be bored or dug water wells.

5.1.2 Bedrock Aquifers

The upper bedrock includes rocks that are less than 200 metres below the bedrock surface. Some of this bedrock contains porous, permeable and saturated rocks that are permeable enough to transmit groundwater for a specific need. Water wells completed in bedrock aquifers usually do not require water well screens, although some of the sandstones are friable[8] and water well screens are a necessity. The groundwater from the bedrock aquifers is usually chemically soft.

The data for 2,464 water wells show that the top of the water well completion interval is below the bedrock surface, indicating that the water wells are completed in at least one bedrock aquifer. Within the County, casing diameter information is available for 1,874 of the 2,464 water wells completed in the bedrock aquifers. Of these 1,874 water wells, 99% have surface casing diameters of less than 275 mm and these bedrock water wells have been mainly completed with either a slotted liner or as open hole. There were 21 bedrock water wells that were completed with a water well screen. Records from 17 of these 21 bedrock water wells indicated the presence of coal in the screened interval.

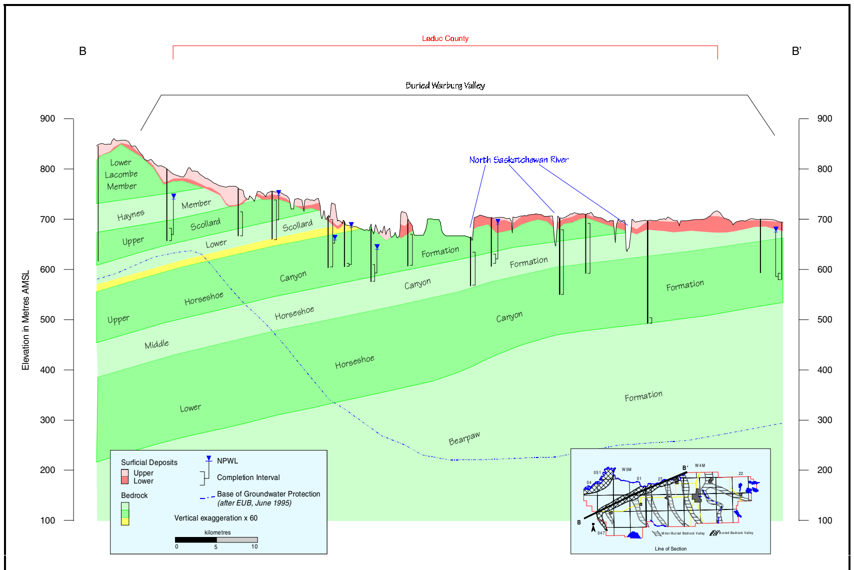

Figure 8. Cross-Section B - B'

The upper bedrock includes the Paskapoo, Scollard and Horseshoe Canyon formations (Figure 8). In the County, the Paskapoo Formation consists of the Lacombe and Haynes members. The Bearpaw Formation underlies the Lower Horseshoe Canyon Formation and is a regional aquitard[9].

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8 See glossary
9 See glossary