5.3.5 *Continental* Foremost Aquifer

The *continental* Foremost Aquifer comprises the porous and permeable parts of the *continental* Foremost Formation and subcrops in the majority of the County. The thickness of the *continental* Foremost Formation varies from less than 20 metres at the edge of the subcrop to more than 120 metres in the southern part of the County. The thickness of the *continental* Foremost Formation decreases in the vicinity of the North Saskatchewan and the Vermilion river valleys as a result of erosional processes. The *continental* Foremost Aquifer does not include the lower ten metres of the Formation, which is the Milan Aquifer.

5.3.5.1 Depth to Top

The depth to the top of the *continental* Foremost Formation is variable, ranging from less than 20 metres in the areas closely corresponding to the areas where the thickness of the surficial deposits is less than 20 metres, to more than 60 metres.

5.3.5.2 Apparent Yield

The projected long-term yields for individual water wells completed in the *continental* Foremost Aquifer are mainly between 10 and 100 m³/day. The adjacent map indicates that apparent yields of more than 100 m³/day are expected mainly east of range 11, W4M. The higher yields in these areas are a reflection of the greater thickness and not the higher permeability of the aquifer materials.

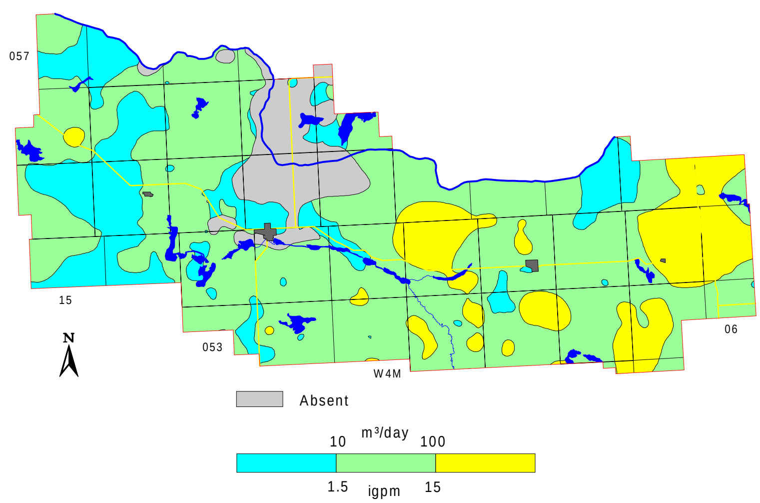

Figure 20. Apparent Yield for Water Wells Completed through continental Foremost Aquifer

5.3.5.3 Quality

The Piper tri-linear diagram shows the majority of the groundwaters to be sodium-bicarbonate or sodium-sulfate types (see CD-ROM). The TDS concentrations are expected to be in the order of 500 to 1,500 mg/L. The higher values are expected to be in the western part of the County. When TDS values exceed 1,300 mg/L, the sulfate concentrations exceed 400 mg/L. The sulfate concentrations are mainly below 500 mg/L. Chloride concentrations in the groundwater from the *continental* Foremost Aquifer are mainly less than 250 mg/L.

5.3.6 Milan Aquifer

The Milan Aquifer is used to designate a zone that occurs near the top and the western limit of the *marine* Foremost Formation and includes the lower part of the *continental* Foremost Formation. The sandstone beds are included as one aquifer because the individual sandstone members are not generally discernible throughout. The Milan Aquifer includes up to 40 metres of the *marine* Foremost Formation and up to ten metres of the overlying *continental* Foremost Formation. On the CD-ROM, the *marine* Foremost Aquifer and the Milan Aquifer are presented separately. However, for the most part the two aquifers are the same within the County.

5.3.6.1 Depth to Top

The depth to the top of the Milan Aquifer is a function of the depth to the stratigraphic border between the *continental* and *marine* facies of the Foremost Formation and the topographic surface. The depth to the top of the Milan Aquifer ranges from less than 50 metres to more than 150 metres.

5.3.6.2 Apparent Yield

The Milan Aquifer is present in the western half of the County. The apparent yields for individual water wells completed in the Milan Aquifer are mainly less than ten m³/day. The lower yields occur in the northern two-thirds of the area occupied by the Milan Aquifer within the County. Water well yields are expected to be mainly between 10 and 100 m³/day in the southern third of the Aquifer. The higher yields of more than 100 m³/day tend to be in water wells located in township 054, range 14, W4M. An extended aquifer test conducted with a water test hole completed in the Milan Aquifer (Hydrogeological Consultants Ltd., 1998 [in progress]) indicated a long-term yield of 630 m³/day.

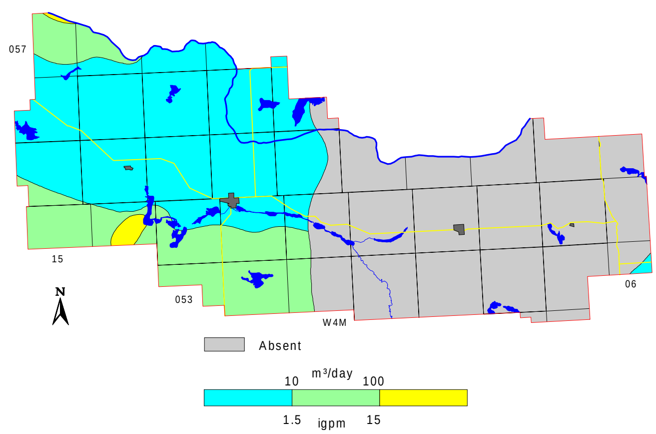

Figure 21. Apparent Yield for Water Wells Completed through Milan Aquifer

5.3.6.3 Quality

The Piper tri-linear diagram shows the majority of the groundwaters are sodium-bicarbonate or sodium-chloride types (see CD-ROM). The TDS concentrations are expected to be mainly less than 2,000 mg/L. The higher values are expected to be in the western part of the County. The sulfate concentrations range mainly from 100 to 500 mg/L.

Chloride concentrations in the groundwater from the Milan Aquifer are mainly less than ten mg/L in the northeastern two-thirds of the Aquifer but exceed 250 mg/L in the southwestern third of the Aquifer. Chloride concentrations in excess of 1,000 mg/L were typical in the groundwaters from the water test holes completed in the Milan Aquifer in sections 16 and 24, township 054, range 14, W4M (Hydrogeological Consultants Ltd., 1998 [in progress]).

5.3.7 *Marine* Foremost Aquifer

There is no detailed discussion for the *marine* Foremost Aquifer in this report; however, maps for this Aquifer are provided on the CD-ROM.

5.3.8 Ribstone Creek Aquifer

The Ribstone Creek Aquifer comprises the porous and permeable parts of the Ribstone Creek Member. Structure contours have been prepared for the top and bottom of the Member, which underlies 70% of the western half of the County. The structure contours show the Member being mostly less than ten metres thick. However, because of the local hydrogeological setting, the Ribstone Creek Aquifer is mainly incorporated into the Milan Aquifer and the amount of information for the Ribstone Creek Aquifer interval is very limited. The Groundwater Query does not include information for the Ribstone Creek Aquifer, only the Milan Aquifer.

5.3.8.1 Depth to Top

The depth to the top of the Ribstone Creek Member is mainly less than 100 metres below ground level, but can be more than 120 metres in the northwestern part of the County.

5.3.8.2 Apparent Yield

The apparent yields for individual water wells completed through the Ribstone Creek Aquifer are mainly less than 100 m³/day. Water wells with higher yields are expected at the northeastern edge of the Aquifer.

A study for the Town of Two Hills indicated a long-term yield of 130 m³/day for a water supply well completed in the Ribstone Creek Aquifer (Geoscience Consulting Ltd., 1976).

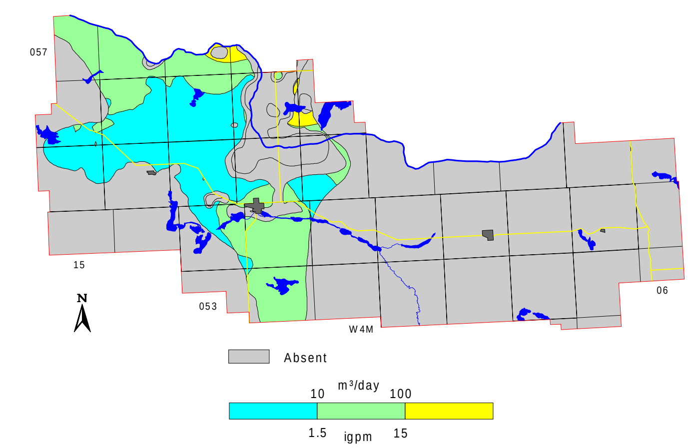

Figure 22. Apparent Yield for Water Wells Completed through Ribstone Creek Aquifer

5.3.8.3 Quality

There were six water well records in the database with sufficient information to determine the chemical type of groundwaters from the Ribstone Creek Aquifer; the groundwaters are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are expected to be mainly less than 1,500 mg/L. The higher values are expected to be in the northwestern part of the County, and in the vicinity of the Town of Two Hills. The sulfate concentrations range mainly from 100 to 250 mg/L. Chloride concentrations in the groundwater from the Ribstone Creek Aquifer are mainly less than 100 mg/L, but are expected to exceed 250 mg/L in the northwestern part of the County.

Groundwater from the Ribstone Creek Aquifer from a Town of Two Hills water supply well has a TDS value of in the order of 1,000 mg/L, a sulfate concentration of more than 250 mg/L and a chloride concentration of 20 mg/L (Geoscience Consulting Ltd., 1976).

5.3.9 Victoria Aquifer

The Victoria Aquifer comprises the porous and permeable parts of the Victoria Member. Structure contours have been prepared for the top and bottom of the Member, which underlies the western half of the County. The structure contours show the Member as being mostly less than 15 metres thick. However, because of the local hydrogeological setting, the Victoria Aquifer is mainly incorporated into the Milan Aquifer. The amount of information for the Victoria Aquifer interval is very limited. The Groundwater Query includes information for the Victoria Aquifer over a very small area where it is not included in the Milan Aquifer; otherwise, the Victoria Aquifer interval is included in the Milan Aquifer.

5.3.9.1 Depth to Top

The depth to the top of the Victoria Member is mainly less than 140 metres below ground level. The greatest depth is in the areas along the southern edge of the County.

5.3.9.2 Apparent Yield

The apparent yields for individual water wells completed through the Victoria Aquifer are mainly in the range of 10 to 100 m³/day. The areas where water wells with higher yields are expected are mainly near the Town of Two Hills and the areas to the north.

A study for the Town of Two Hills indicated a long-term yield of 300 m³/day for a water supply well completed in the Victoria Aquifer (Geoscience Consulting Ltd., 1976).

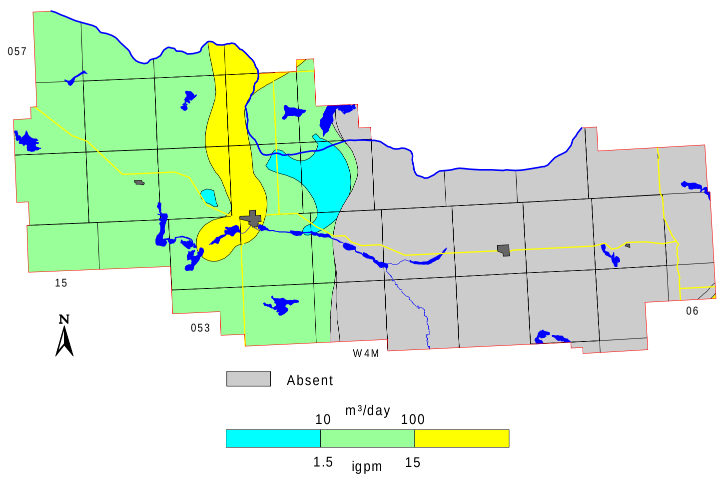

Figure 23. Apparent Yield for Water Wells Completed through Victoria Aquifer

5.3.9.3 Quality

There are four water well records in the database with sufficient information to determine the chemical type of groundwaters from the Victoria Aquifer; they are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are expected to be mainly less than 1,500 mg/L. The higher values are expected to be in the northwestern and northeastern parts of the Aquifer. The sulfate concentrations range mainly from 100 to 500 mg/L. Chloride concentrations in the groundwater from the Victoria Aquifer are mainly less than 100 mg/L, but exceed 250 mg/L in the western part of the County.

5.3.10 Lea Park Aquitard

The Lea Park Formation is composed mainly of shale and has a very low permeability. In most of the area, the top of the Lea Park Formation coincides with the Base of Groundwater Protection. A map showing the depth to the Base of Groundwater Protection is given on page 6 of this report, in Appendix A, page A – 6, and on the CD-ROM.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are five observation water wells in the County where water levels are being measured and recorded with time. Four sites are observation water wells (Obs WWs) that are part of the AEP regional groundwater-monitoring network. Two of the four AEP Obs WWs are located in the vicinity of the Town of Two Hills: Obs WW No. 173 is in 12-32-054-12 W4M and Obs WW No. 174 is in 05-11-054-13 W4M; Obs WW No. 270 is in 15-22-055-12 W4M south of the Hamlet of Duvernay and Obs WW No. 240 is in NW 07-055-06 W4M northeast of the Village of Derwent. Their hydrographs are shown in the adjacent figure. The other groundwater monitoring site is a part of the Highland Feeders Limited facility.

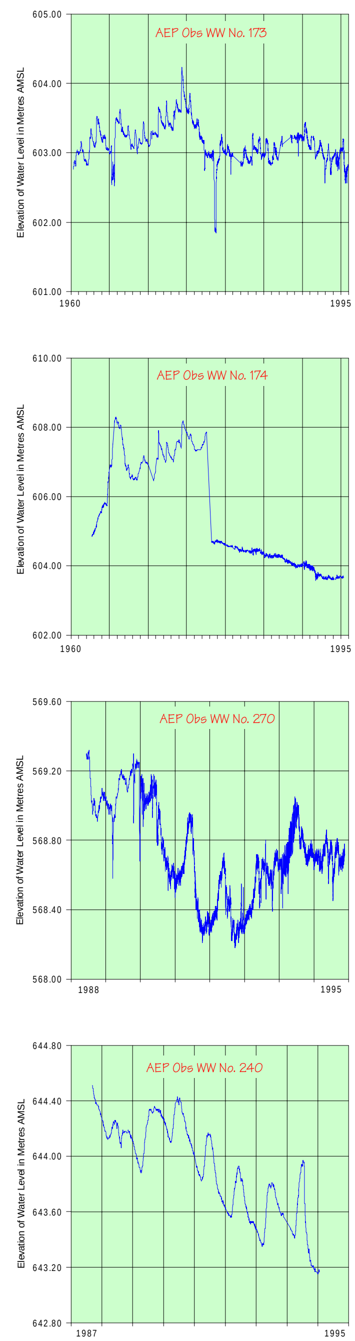

Figure 24. Hydrographs - AEP Observation Water Wells

AEP Obs WW No. 173 is completed open hole at a depth from 30.5 to 76.2 metres below ground level in the Milan Aquifer. This observation water well is located approximately 30 metres from the Town of Two Hills WSW No. 4 (Geoscience Consulting Ltd. 1976), which is completed in the Ribstone Creek Aquifer interval of the Milan Aquifer. The hydrograph shows that water levels generally rose a total of one metre between 1960 and 1974. From 1974 to 1978 the water declined approximately one metre. Between 1978 and 1995 the general water level has not changed more than one half a metre. There are annual fluctuations in the water level, with rises in the spring and fall and declines in the winter and summer and an overall annual fluctuation of approximately 30 cm. The water-level decline in 1965 was not in response to pumping from WSW No. 4 since the water supply well did not exist until 1968. However, the water-level decline in 1978 may have been interference from the pumping of WSW No. 4. The observation water well is no longer part of the AEP Observation Water Well Network.

AEP Obs WW No. 174 is completed at a depth of 54.9 metres below ground level in the Milan Aquifer. This hydrograph has two distinct parts. Between 1962 and 1977, the water level fluctuates as much as two metres over several months and the water level generally rises more than two metres. In late 1977 and early 1978, the water level declines more than two metres. After this decline, the water level fluctuates a matter of a few centimetres and generally declines for 18 years. The 18-year decline is in the order of one metre. The hydrograph does not show any annual fluctuation. The change in character of the hydrograph in 1978 indicates a significant change in local use of groundwater or a change in the observation water well itself.

The third AEP Obs WW completed in the Milan Aquifer is AEP Obs WW No. 270. This observation water well is located in 15-22-055-12 W4M and is completed with a water well screen, with the bottom of the screen 20.6 metres below ground level. The monitoring of the water level in this observation water well began in 1988. Over the eight years of record, the water level shows an annual fluctuation that indicates the influence of municipal use. The lowest water level occurs in late summer/early fall with the highest water level in late spring/early summer. The annual fluctuations are less than one metre. In 1990 and 1991, there is a general decline in the water level followed by a general rise during 1993 and 1994. The change in water level between 1988 and 1995 is similar to the water-level change observed in Obs WW No. 173 over the same time interval.

AEP Obs WW No. 240 is completed at a depth of 26.0 metres below ground level in NW 07-055-06 W4M. This observation water well is completed with a water well screen in the *continental* Foremost Aquifer. Water-level data are available from 1987 to early 1995. The hydrograph shows a typical annual fluctuation, with a rise in water level in late spring/early summer, followed by a gradual decline until the late spring/early summer of the following year. Over the eight years of record, the water level has declined approximately one metre.

The Highland Feeders Limited water supply wells in Tp 054, R 14, W4M are completed in the Milan Aquifer. The water supply wells have been used to divert 650,000 cubic metres of groundwater from 1992 to 1997. The W. Sawchuk Domestic Water Well (Dom WW), located less than 1.6 kilometres from the Highland Feeders Limited facility, is completed in the *continental* Foremost Aquifer. This Dom WW is used as an observation water well by Highland Feeders Limited. Even though there was a significant change in water level in early 1995, the change is not related to the diversion by Highland Feeders Limited (Hydrogeological Consultants Ltd., June 1998).

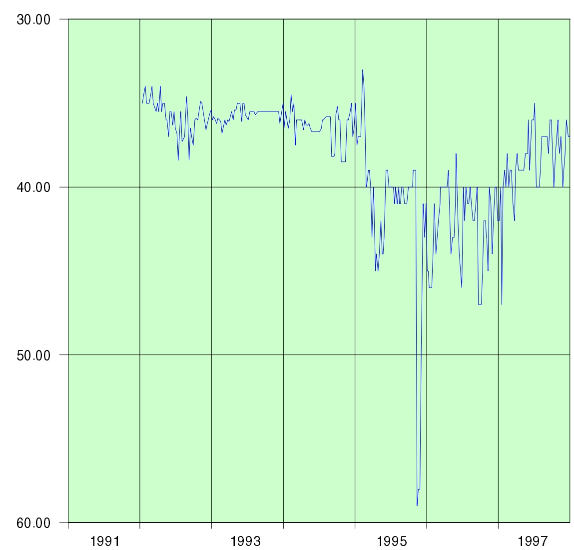

Figure 25. Water-Level Summary - W. Sawchuk Dom WW

6.2 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the County. One indirect method of measuring recharge is to determine the quantity of groundwater flowing through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer, and that the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow through an aquifer must be averaged and estimated. To determine the flow requires a value for the average transmissivity of the aquifer, an average hydraulic gradient and an estimate for the width of the aquifer. For the present program, the flow has been estimated for aquifers within the County.

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer. Based on these assumptions, the estimated groundwater flow through the individual aquifers can be summarized as follows:

Aquifer Designation	Transmissivity (m^2/day)	Gradient (m/m)	Width (km)	Main Direction of Flow	Quantity (m^3/day)	Authorized Diversion (m^3/day)
Surficial Deposits					800	
Vermilion Channel and Buried Elk Point Valley	10	0.003	8	South/North	200	
Vermilion Channel and Buried Elk Point Valley	15	0.005	8	North	600	
Buried Vegreville Valley					900	774
	20	0.003	15	Northeast	900	
continental Foremost					1,300	150
east of Two Hills	7	0.004	40	North	1,150	
west of Two Hills	4	0.001	40	East	150	
Milan Aquifer					750	792
	5	0.003	50	Northeast	750	
Ribstone Creek					300	151
	5	0.002	30	Northeast	300	
Victoria					800	566
	10	0.002	40	Northeast	800	

The above table indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers. However, because of the very approximate nature of the calculation of the quantity of groundwater flowing through the individual aquifers, more detailed work is required to more precisely determine the flow through the aquifers.