5.3.5 Upper Lacombe Aquifer

The Upper Lacombe Aquifer comprises the porous and permeable parts of the Upper Lacombe Member that underlies the Dalehurst Member, and subcrops under the surficial deposits in one half of the northeastern one-third of the M.D. The thickness of the Upper Lacombe Member is mainly between 40 and 100 metres but varies from less than 20 metres at the northeastern edge to more than 160 metres in the southwestern part of the M.D.

5.3.5.1 Depth to Top

The depth to the top of the Upper Lacombe Member ranges from less than 20 metres below ground level where the Formation subcrops in the northeastern part of the M.D. to more than 320 metres in the western part of the M.D. The greatest depth is in areas where the Dalehurst Member is present.

5.3.5.2 Apparent Yield

The apparent yields for individual water wells completed through the Upper Lacombe Aquifer are mainly less than 150 m³/day, based on data from the groundwater database. The adjacent map indicates that apparent yields of more than 150 m³/day are expected where the Aquifer subcrops and this could be a result of increased permeability due to weathering processes. There are little or no data from the groundwater database for the Aquifer west of range 07, W5M, and the map indicates that expected water well yields are between 50 and 150 m³/day in this area.

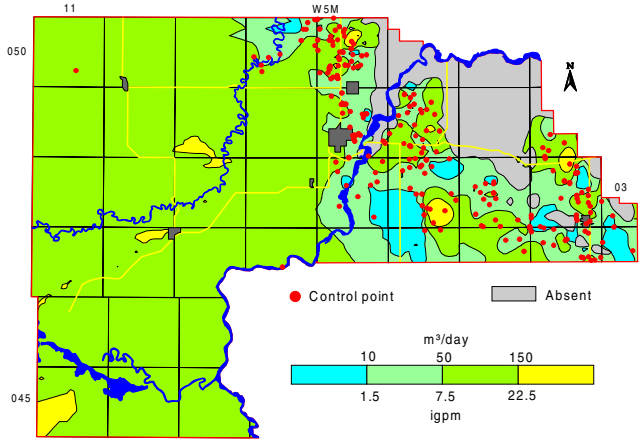

Figure 20. Apparent Yield for Water Wells Completed through Upper Lacombe Aquifer

Six water source wells from the EUB database have been designated as being completed in the Upper Lacombe Aquifer. From 1962 to 1998, a total of 4.2 million cubic metres of groundwater was pumped from these water source wells. In 1972, the groundwater production from the Upper Lacombe Aquifer was 280,000 cubic metres, using four water source wells. This average water source well diversion rate from the Upper Lacombe Aquifer in 1972 is almost four times the average daily diversion per water source well from the Dalehurst Aquifer. By 1975, the production from the Upper Lacombe Aquifer had decreased to an average of 88 m³/day per water source well, 46% of the 1975 production. Because there are no water levels to go with the production, it is not known if the decrease in production was based on water need or on the ability of the Aquifer to provide the larger quantity of groundwater on a long-term basis.

A water supply well completed for the Village of Breton in 1959 in SE 02-048-04 W5M is completed in the Upper Lacombe Aquifer. When the water supply well was drilled, the non-pumping water level was 4.3 metres below the top of casing. In 1976, the highest measured water level in the Upper Lacombe Aquifer was 4.9 metres below the top of casing at the site of a water test hole designated as WTH No. 1-76 (HCL, 1976). In 1976, the population of the Village exceeded 500, an increase of 150 from 1974. Based on a water need of 200 litres per person per day, the average water needs of the Village between 1959 and 1976 were in the order of 60 m³/day. During this same time frame, there was a water-level decline of approximately 0.6 metres in the Aquifer in which the 1959 water supply well is completed. The absence of a significant water-level decline indicates that there has been sufficient recharge to the Aquifer to sustain the Village of Breton's water needs.

An analysis of an aquifer test by Geoscience Consulting Ltd. (Geoscience, 1976) indicates the 1959 water supply well has a projected 20-year safe yield of more than 200 m³/day. The Village of Breton is in an area designated on the map as having an apparent yield of between 10 and 50 m³/day. The presence of a higher yield than indicated by the map helps to illustrate that the maps are regional in nature and that the hydrogeological conditions at a given location must be determined by an appropriate groundwater investigation.

A Canadian Occidental Petroleum Ltd. (COPL) water source well in 06-08-050-08 W5M is completed in the Upper Lacombe Aquifer. This water source well is authorized to divert 300 m³/day (HCL, 1997a).

5.3.5.3 Quality

The groundwaters from the Upper Lacombe Aquifer are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are expected to be mainly greater than 500 mg/L, with lower values mainly in townships 047 to 049, ranges 03, 04 and 05, W5M where the depth to the bottom of the Upper Lacombe Member is less than 50 metres. The sulfate concentrations in the groundwaters are generally less than 100 mg/L. The chloride concentrations of the groundwaters from the Upper Lacombe Aquifer range from less than 4 to a high of 13 mg/L.

Between 1965 and 1975, eighteen groundwater samples were collected from the Village of Breton 1959 water supply well completed in the Upper Lacombe Aquifer (Geoscience, 1976). The TDS concentrations ranged from 312 to 568 mg/L, sulfate concentrations ranged from 6 to 70 mg/L and chloride concentrations ranged from below the detection limit to 16 mg/L.

Groundwater from the COPL 06-08 water source well completed in the Upper Lacombe Aquifer has a TDS concentration of 514 mg/L, a sulfate concentration of 81 mg/L and a chloride concentration of 9.3 mg/L (HCL, 1995a).

5.3.6 Lower Lacombe Aquifer

The Lower Lacombe Aquifer comprises the porous and permeable parts of the Lower Lacombe Member and subcrops under the surficial deposits in nearly one half of the northeastern one-third of the M.D. The thickness of the Lower Lacombe Member is mainly between 60 and 80 metres but varies from less than 20 metres at the northeastern edge to more than 90 metres in the south-central part of the M.D.

5.3.6.1 Depth to Top

The depth to the top of the Lower Lacombe Member varies from less than 50 metres below ground level in the northeastern part of the M.D. to more than 450 metres in the southwestern part of the M.D.

5.3.6.2 Apparent Yield

The apparent yields for individual water wells completed through the Lower Lacombe Aquifer are mainly less than 10 m³/day. The lower yields presented in the central and extreme northwestern parts of the M.D. could be a result of the gridding procedure used to process a very limited number of data points. The areas where water wells with higher yields are expected are mainly where the Lower Lacombe Member subcrops under the surficial deposits and would be most subjected to weathering processes.

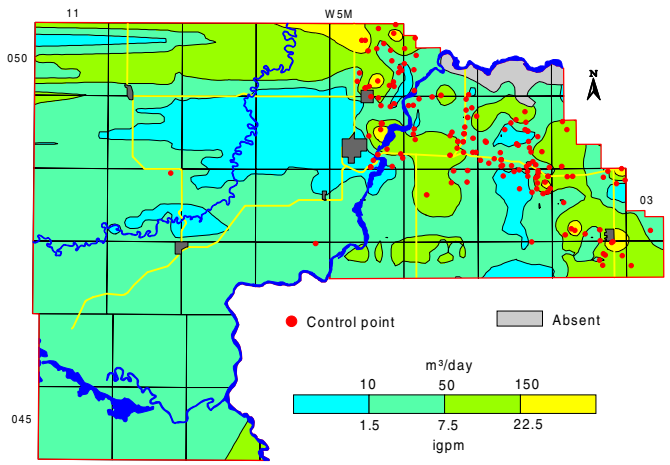

Figure 21. Apparent Yield for Water Wells Completed through Lower Lacombe Aquifer

There are four water source wells from the EUB database that have been designated as being completed in the Lower Lacombe Aquifer. From 1962 to 1998, slightly less than one million cubic metres of groundwater was diverted from these water source wells. The maximum combined production was in 1978, when the average daily production was 140 m³/day, an average of 35 m³/day from each water source well.

5.3.6.3 Quality

The groundwaters from the Lower Lacombe Aquifer are mainly a sodium-bicarbonate type (see CD-ROM). The TDS concentrations are mostly between 500 and 1,000 mg/L. The sulfate concentrations are generally less than 100 mg/L. Chloride concentrations in the groundwaters from the Lower Lacombe Aquifer range from less than 10 to more than 250 mg/L. The chloride values increase toward the western extent of the M.D.

All of the chemical parameter maps exhibit higher values in the southwestern corner of the M.D. as a result of the gridding process using limited data control.

5.3.7 Haynes Aquifer

The Haynes Aquifer comprises the porous and permeable parts of the Haynes Member. The Haynes Member underlies the Lower Lacombe Member and subcrops in the northeastern part of the M.D, in parts of township 50, ranges 04 to 06, W5M. The thickness of the Haynes Member is mainly between 40 and 80 metres but varies from less than 20 metres at the northeastern edge to more than 100 metres in townships 046 and 047, ranges 10 and 11, W5M.

5.3.7.1 Depth to Top

The depth to the top of the Haynes Member is variable, ranging from less than 50 metres in the northeastern part of the M.D. to more than 500 metres in the southwestern part of the M.D.

5.3.7.2 Apparent Yield

The adjacent map shows yields for individual water wells completed through the Haynes Aquifer are mainly between 10 and 50 m³/day. Lower yields in the extreme northwestern and southwestern parts of the M.D. could be a result of the gridding procedure used to process a very limited number of data points.

Four water source wells from the EUB database have been designated as being completed in the Haynes Aquifer. From 1962 to 1986, slightly more than one half million cubic metres of groundwater was diverted from these water source wells. The maximum combined production was in 1973, when the average daily production was 215 m³/day, an average of 54 m³/day from each water source well.

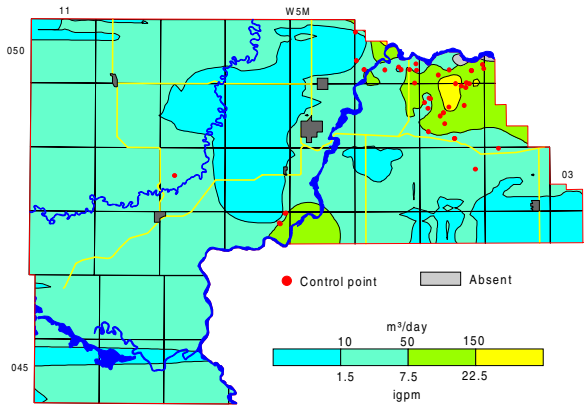

Figure 22. Apparent Yield for Water Wells Completed through Haynes Aquifer

An aquifer test conducted with a water test hole completed in the Haynes Aquifer and drilled in 14-32-048-04 W5M in 1981 (HCL, 1989) indicated a long-term yield of 75 m³/day based on a transmissivity of 0.06 m²/day. Additional data for the Haynes Aquifer are available for a water source well in the Alder Flats area, south of the M.D., in 01-17-045-07 W5M (HCL, 1995b). An extended aquifer test indicated a long-term yield of 45 m³/day based on an effective transmissivity of 0.25 m²/day.

5.3.7.3 Quality

The groundwaters from the Haynes Aquifer are mainly a bicarbonate type (see CD-ROM). The TDS concentrations are mostly between 500 and 750 mg/L. The sulfate concentrations are generally less than 250 mg/L east of the North Saskatchewan River and more than 250 west of the River. Chloride concentrations in the groundwaters from the Haynes Aquifer range from less than four to more than ten mg/L. Groundwater from the Alder Flats area water source well (HCL, 1995b), which is completed in the Haynes Aquifer, has a TDS concentration of 1,245 mg/L, a sulfate concentration of 1 mg/L and a chloride concentration of 360 mg/L. Two chemical parameter maps on the CD-ROM exhibit anomalous values as a result of the gridding process using limited data control.

5.3.8 Upper Scollard Aquifer

The Upper Scollard Aquifer comprises the porous and permeable parts of the Upper Scollard Formation which subcrops under the surficial deposits in a small area in the extreme northeastern part of the M.D. The thickness of the Upper Scollard Member increases to the southwest and can reach more than 140 metres in the southwestern part of the M.D. In general terms, the permeability of the Upper Scollard Aquifer is very low. Higher local permeability can be expected when the depth of burial is less than 100 metres and weathering processes have occurred. In the eastern two-thirds of the M.D., the Upper Scollard is above the Base of Groundwater Protection.

5.3.8.1 Depth to Top

The depth to the top of the Upper Scollard Formation is variable, ranging from less than 50 metres in the northeastern part of the M.D. to more than 550 metres in the southwestern part of the M.D.

5.3.8.2 Apparent Yield

The adjacent map was prepared using five control points from the AEP groundwater database and the summary results of DSTs from the EUB database. The apparent yields for water wells completed through the Upper Scollard Aquifer range from less than 10 to more than 150 m³/day where the Formation is the upper bedrock. However, there are little or no data for most of the M.D. due to the depth to the top of the Formation. There are no water source wells in the EUB database that are indicated as being completed in this Formation in the M.D.

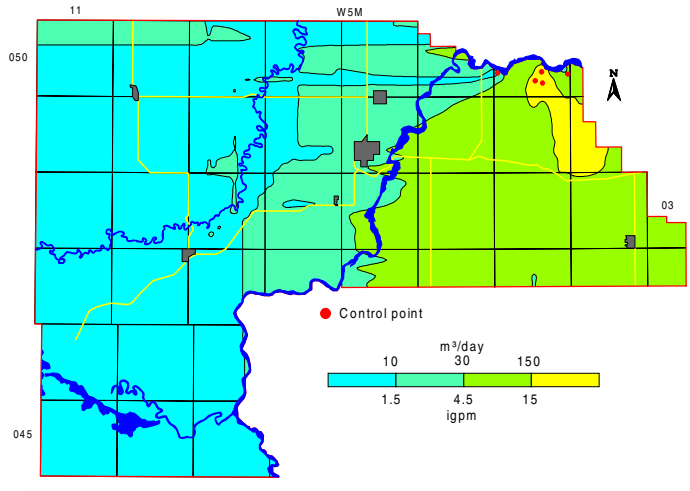

Figure 23. Apparent Yield for Water Wells Completed through Upper Scollard Aquifer

5.3.8.3 Quality

The groundwaters from the Upper Scollard Aquifer are mainly a sodium-bicarbonate type. The TDS concentrations in groundwaters from the Upper Scollard Aquifer are mainly less than 500 mg/L. The higher TDS values are in the eastern third of the M.D. The sulfate concentrations are mainly between 100 and 200 mg/L. Chloride concentrations in the groundwaters from the Upper Scollard Aquifer in the extreme eastern part of the M.D. are expected to be less than 50 mg/L.

6 GROUNDWATER BUDGET

6.1 Hydrographs

There are three locations in the M.D. where water levels are being measured and recorded with time. These sites are observation water wells (Obs WWs) that are part of the AEP regional groundwater-monitoring network. Two Obs WWs are in 07-20-049-07 W5M in the vicinity of the Town of Drayton Valley Landfill and one observation water well, AEP Obs WW No. 321, is in 16-18-048-08 W5M. The hydrograph for AEP Obs WW No. 321 is shown on the adjacent figure and in Appendix A; water-level measurements for the other two Obs WWs are also shown in Appendix A, but are of limited use.

AEP Obs WW No. 321 is completed at a depth of 61.0 metres in the Dalehurst Aquifer and is located between the Pembina and North Saskatchewan rivers. Between the Pembina and NSR in townships 047 to 049, ranges 08 and 09, W5M, there are 249 water source wells that have been completed in the Dalehurst Aquifer.

Figure 24. Hydrograph - AEP Observation Water Well No. 321

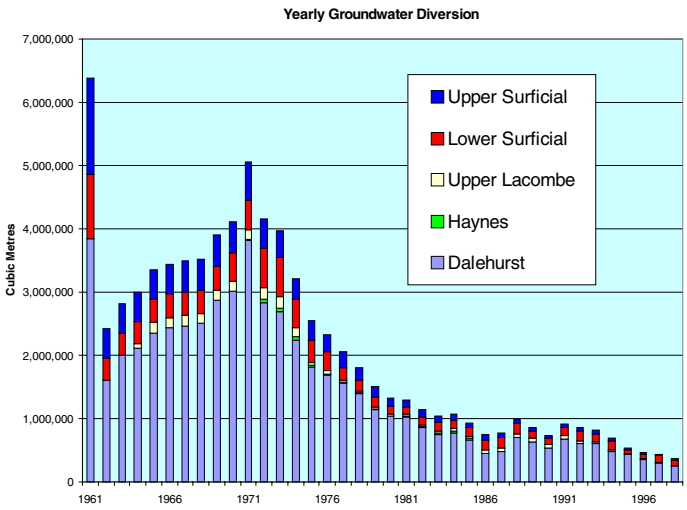

Figure 25. Annual Groundwater Production - WSWs

Within the M.D., there are 400 water source wells that have EUB Well Licences. Of the 400 water source wells, 336 have recorded groundwater production. The groundwater production record begins in 1961 and is on-going. The total groundwater production from the water source wells in 1961 was 6.3 million cubic metres. However, the 1961 value for total production is significantly higher than for 1962. The 1961 value may be a result of estimated amounts rather than measured, or it may be an estimate of the total production for all years up to the end of 1961. From 1962 to 1971, the annual production more than doubled, from 2.5 to 5.0 million cubic metres. From 1971, the annual production has decreased, to less than 0.5 million cubic metres in 1998. The adjacent graph shows the different aquifers from which the groundwater production has been obtained.

Mow-Tech Ltd. operates groundwater-monitoring projects at eight locations in the M.D. At five of the locations, data are available from at least 1990. Four of the five locations are water source wells completed in an aquifer in the Dalehurst Member and one is a water source well completed in an aquifer in the Upper Lacombe Member. The results of these groundwater-monitoring programs show that over a time span that includes up to 40 years, there has been no general lowering of water levels in the Dalehurst or the Upper Lacombe aquifers.

Aquifer Designation	Average Annual Diversion (m^3)	Number of Years	Water Level						
			Date	Depth (m)	Date	Depth (m)	Date	Depth (m)	Location
Dalehurst	17,238	33	12-Feb-66	19.8	02-Dec-88	28.7	29-Dec-98	23.6	08-15-049-09 5
Dalehurst	15,031	38	06-Oct-60	25.8	19-Jan-89	27.4	16-Jan-99	25.8	06-34-049-08 5
Dalehurst	26,440	6			09-Aug-90	15.9	24-Jul-97	16.6	16-05-047-09 5
Dalehurst	28,983	9			09-May-90	18.0	27-Jul-98	22.0	06-16-047-10 5
Upper Lacombe	57,435	35	13-Jul-64	12.2	10-Nov-88	11.3	29-Nov-98	9.6	06-08-050-08 5

Table 7. Groundwater-Monitoring Summary

The water source well completed in the Upper Lacombe Aquifer has been used to divert slightly more than two million cubic metres of groundwater between 1961 and 1998. The diversion peaked in the early 1970s with yearly production of more than 160,000 cubic metres. The maximum diversion in recent years was in 1990, when the diversion was 50,000 cubic metres. Since 1990, the annual groundwater diversion has decreased to less than 10,000 cubic metres and the water level has risen slightly more than three metres, to a level of 9.6 metres below the top of casing. The water well drilling report indicates that when the water source well was drilled in 1964, the water level was 12.2 metres below top of casing. While the water level of 12.2 metres may not be exact, the data indicate that there has been no significant lowering of the water level in the Aquifer after the diversion of more than two million cubic metres of groundwater from the Upper Lacombe Aquifer.

The total reported groundwater production from all of the WSWs in the M.D. of Brazeau from 1961 to 1998 has been 110 million cubic metres, with 74% having been obtained from aquifers in the upper bedrock and 3% from sand or gravel aquifers in the surficial deposits. The remaining 23% of the groundwater production is from aquifers that cannot be identified from the information provided by the EUB for the individual water source wells. The total production of 110 million cubic metres is 89,000 acre-feet.

6.2 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are available for the M.D. One indirect method of measuring recharge is to determine the quantity of groundwater flowing laterally through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and 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 those parts of the various aquifers within the M.D.

The flow through each aquifer assumes that by taking a large enough area, an aquifer can be considered as homogeneous, the average gradient can be estimated from the non-pumping water-level surface, and flow takes place through the entire width of the aquifer. Based on these assumptions, the estimated lateral 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)
Upper Sand and Gravel					**2,820**	**98**
Upper Sand and Gravel (Pembina Valley)	6	0.003	50	Southeast and northwest	900	
Upper Sand and Gravel (North Saskatchewan Valley)	8	0.003	80	Southeast and northwest	1,920	
Lower Sand and Gravel					**320**	**913**
Lower Sand and Gravel (Pembina Valley)	10	0.002	8	Southeast and northwest	160	
Lower Sand and Gravel (North Saskatchewan Valley)	10	0.002	8	Southeast and northwest	160	
				Surficial Deposits Total	**3,140**	**1,011**
Dalehurst						
	10	0.0125	20	Northeast	3,000	
	10	0.0125	20	Southwest - North	3,000	
	10	0.0125	25	Northwest	3,000	
	10	0.0125	25	Southeast - South	3,000	
				Total	**12,000**	**13,369**
Upper Lacombe						
	20	0.006	30	East	4,000	
	20	0.008	10	Northwest	2,000	
	20	0.003	20	Northeast	1,000	
	20	0.004	20	Southwest	2,000	
				Total	**9,000**	**3,525**
Lower Lacombe						
	15	0.004	30	East	2,000	
	15	0.005	20	Northwest	2,000	
				Total	**4,000**	**1,958**
Haynes						
	10	0.003	60	North	2,000	
				Total	**2,000**	**710**
Upper Scollard						
	45	0.003	30	Northwest	4,000	
				Total	**4,000**	**3,110**

Table 8. Groundwater Budget

The above table indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Dalehurst Aquifer. Although values have been calculated for the flow through both the Upper Sand and Gravel Aquifer and the Lower Sand and Gravel Aquifer, there was difficulty in obtaining a reasonable value for hydraulic gradient. 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 establish the flow through the aquifers.

There is no direct link between the EUB Well Licence and the groundwater diversion authorized by AEP. Likewise, there is no direct link between the information in the AEP Groundwater Database and either the EUB Well Licence or the AEP approval. Mow-Tech Ltd. has attempted to establish the link with a reasonable degree of certainty through their groundwater database. From a total of 336 water source wells, it has been possible to link 119 and to compare the diversion reported to the EUB with the diversion authorized by AEP. The total average daily diversion in 1996 was 7,921 cubic metres. The reported diversion was 25% of the authorized diversion, with the diversion from five points exceeding the authorized diversion.

In the case of agriculture, the water requirement based on the 1996 census is 5,650 cubic metres per day, while the authorized diversion is 376 cubic metres per day.

6.2.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.5 to 3.0 cubic kilometres. This volume is based on an areal extent of 3,300 square kilometres and a saturated sand and gravel thickness of three metres. The variation in the total volume is based on the value of porosity that is used for the sand and gravel. One estimate of porosity is 5%, which gives the low value of the total volume. The high estimate is based on a porosity of 30% (Ozoray, Dubord and Cowen, 1990).

The adjacent water-level map has been prepared by considering water wells completed in aquifers in the surficial deposits. These water levels were used for the calculation of saturated surficial deposits and for calculations of recharge/discharge areas.

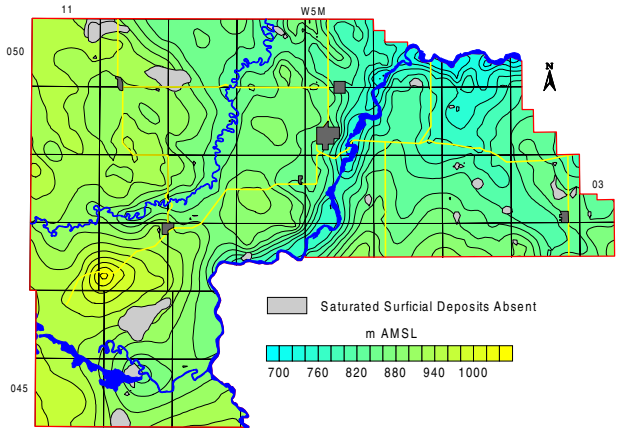

Figure 26. Non-Pumping Water-Level Surface in Water Wells Completed in Surficial Deposits

6.2.2 Recharge/Discharge

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

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

6.2.2.1 Surficial Deposits/Bedrock Aquifers

The hydraulic gradient between the surficial deposits and the upper bedrock aquifer(s) has been determined by subtracting the non-pumping water-level surface associated with all water wells completed in the upper bedrock aquifer(s) from the non-pumping water-level surface determined for all water wells in the surficial deposits. The recharge classification on the map on the following page includes those areas where the water level in the surficial deposits is more than five metres above the water level in the upper bedrock aquifer(s). The discharge areas are where the water level in the surficial deposits is more than five metres lower than the water level in the bedrock. When the water level in the surficial deposits is between five metres above and five metres below the water level in the bedrock, the area is classified as a transition.