C. 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 laterally through each individual aquifer. This method assumes that there is sufficient recharge to the aquifer to maintain the flow through the aquifer and the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow through an aquifer must be averaged and estimated. To determine the flow requires a value for the average transmissivity of the aquifer, an average hydraulic gradient and an estimate for the width of the aquifer. For the present program, the flow has been estimated for those parts of the various aquifers within the 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 lateral groundwater flow through the individual aquifers can be summarized as follows:

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (m)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed Diversion (m^3/day)	Unlicensed Diversion (m^3/day)	Total (m^3/day)
Lower Sand and Gravel					1,807	1,262	497	1,759
Red Deer River								
north	75	0.001	8,000	487				
Buffalo Lake								
north	75	0.001	12000	1032				
Gilby Channel								
southeast	100	0.000	6000	288				
Dalehurst					64,200	1,122	1,833	2,955
Medicine River								
east	65	0.006	25,000	10,156				
wesy	65	0.006	30,000	12,188				
East Edge								
east	65	0.004	30,000	7,800				
Upper Lacombe					34,614	3,723	2,432	6,155
Blindman River								
west	40	0.012	25,000	12000				
east	40	0.008	25,000	8,000				
Gull Lake								
west & east	30	0.004	20,000	2,400				
East Area								
west	45	0.009	20,000	7,714				
east	45	0.005	20,000	4,500				

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (km)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed Diversion (m^3/day)	Unlicensed Diversion (m^3/day)	Total (m^3/day)
Lower Lacombe					10,880	659	428	1,087
west	35	0.008	32,000	8,960				
east	15	0.004	32,000	1,920				
Haynes					22,898	6,049	459	6,508
North stream								
southwest	13000	60.000	0	3,120				
northeast	18000	60.000	0	6,480				
South stream								
southwest	18000	60.000	0	4,050				
northeast	13000	60.000	0	2,925				
South area								
southwest	13000	60.000	0	3,900				
West								
west	30000	35.000	0	2,423				
Upper Scollard					18,308	1,937	346	2,283
west	85	0.004	35,000	11,442				
east	85	0.002	35,000	6,865				
Lower Scollard					3,969	190	488	678
west	25	0.005	13,000	1,625				
east	25	0.004	25,000	2,344				
Upper Horseshoe					900	677	708	1385
	30	0.004	8,000	900				

Table 8. Groundwater Budget

The above table indicates that there is significantly more groundwater flowing through the aquifers than the total of the licensed and unlicensed diversions from the individual aquifers, except for the Upper Horseshoe Canyon Aquifer. The estimated flow through the Lower Sand and Gravel Aquifer and the total estimated groundwater use from the Lower Sand and Gravel Aquifer are similar in magnitude. The calculations of flow through individual aquifers as presented in the above table are very approximate and are intended as a guide for future investigations.

1) Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 0.3 to 2.1 cubic kilometres. This volume is based on an areal extent of 1,400 square kilometres and a saturated sand and gravel thickness of five 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 from water levels associated with water wells completed in aquifers in the surficial deposits. The water wells that post in the absent area are a reflection of the spatial control. The water levels from these water wells were used for the calculation of the saturated thickness of the surficial deposits. In areas where the elevation of the water-level surface is below the bedrock surface, the surficial deposits are not saturated. The water-level map for the surficial deposits shows a general flow direction toward the Buried Red Deer River Valley in the central part of the County, and towards the Buried Buffalo Lake Valley in the eastern part of the County.

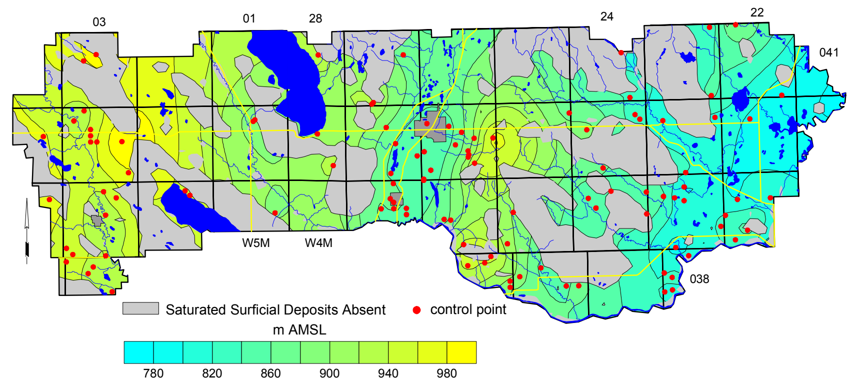

Figure 31. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

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. In areas where the surficial deposits are unsaturated, the extrapolated water level for the surficial deposits is used.

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.

a) 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 below 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.

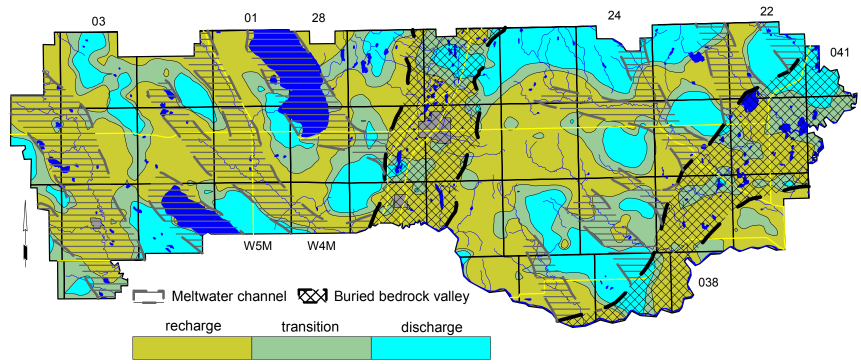

Figure 32. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

The adjacent map shows that, in more than 60% of the County, there is a downward hydraulic gradient from the surficial deposits toward the upper bedrock aquifer(s). These areas tend to be mainly at higher elevations. Areas where there is an upward hydraulic gradient (i.e. discharge) from the bedrock to the surficial deposits are mainly in the vicinity of linear bedrock lows except in the northeastern part of the County, which may be a result of gridding processes. The remaining parts of the County are areas where there is a transition condition.

Because of the paucity of data, a calculation of the volumes of groundwater entering and leaving the surficial deposits has not been attempted.

b) Bedrock Aquifers

Recharge to the bedrock aquifers within the County takes place from the overlying surficial deposits and from flow in the aquifer from outside the County. The recharge/discharge maps show that generally for most of the County, there is a downward hydraulic gradient from the surficial deposits to the bedrock, i.e. recharge to the bedrock aquifers. On a regional basis, calculating the quantity of water involved is not possible because of the complexity of the geological setting and the limited amount of data. However, because of the generally low permeability of the upper bedrock materials, the volume of water is expected to be small.

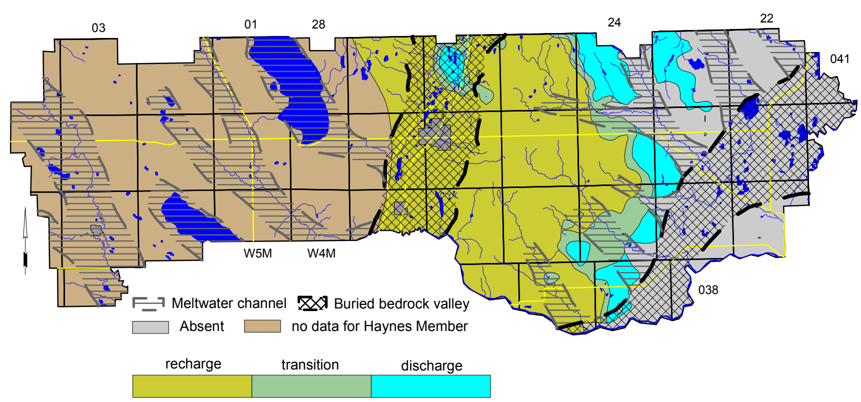

Figure 33. Recharge/Discharge Areas between Surficial Deposits and Haynes Aquifer

The hydraulic relationship between the surficial deposits and the Haynes Aquifer indicates that in more than 80% of the County where the Haynes Aquifer is present and there is data control, there is a downward hydraulic gradient (i.e. recharge). Discharge areas for the Haynes Aquifer are mainly associated with the edge of the Aquifer or in areas of linear bedrock lows.

The hydraulic relationship between the surficial deposits and the remainder of the bedrock aquifers indicates there is mainly a downward hydraulic gradient (see CD ROM).

D. Areas of Groundwater Decline

The areas of groundwater decline in both the sand and gravel aquifer(s) and in the bedrock aquifers have been determined by using a similar procedure in both situations. Because major development began occurring in the 1970s, the changes in water-level maps are based on the differences between water-level elevations available before 1965 and after 1985. Where the earliest water level is at a higher elevation than the latest water level, there is the possibility that some groundwater decline has occurred. Where the earliest water level is at a lower elevation than the latest water level, there is the possibility that the groundwater has risen at that location. The water level may have risen as a result of recharge in wetter years or may be a result of the water well being completed in a different bedrock aquifer. In order to determine if the water-level decline is a result of groundwater use by licensed users, the licensed groundwater users were posted on the maps.

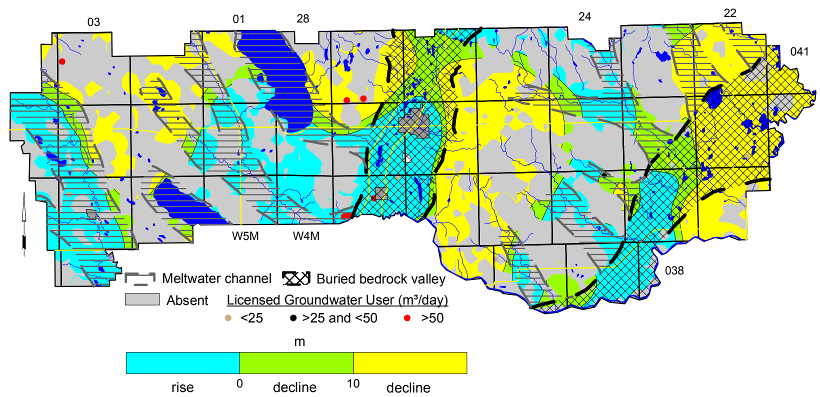

Figure 34. Changes in Water Levels in Sand and Gravel Aquifer(s)

Of the 156 water wells completed in the sand and gravel aquifer(s) with a NPWL and test date, 129 are from water wells completed before 1965 and 27 are from water wells completed after 1985. The above map shows that it may have been possible there has been a rise in the NPWL in areas of linear bedrock lows. However, the areas that indicate a decline of more than ten metres are based on only one or two control points.

Nearly 46% of the areas where there has been a water-level decline of more than ten metres in sand and gravel aquifer(s) corresponds to where the estimated water well use is between ten and 30 m³/day, and 41% of the decline occurred where the estimated water well use is more than 30 m³/day shown on Figure 30.

Of the 4,173 bedrock water wells with a NPWL and test date, 905 are from water wells completed before 1965 and 3,268 are from water wells completed after 1985. The adjacent map indicates that in 60% of the County, it is possible that the NPWL has declined. Of the 261 groundwater users authorized to divert less than 25 m³/day, many occur in areas where a water-level rise exists.

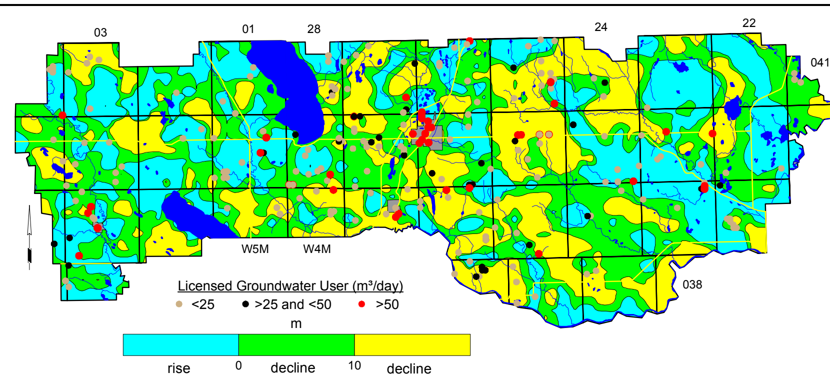

Figure 35. Changes in Water Levels in Upper Bedrock Aquifer(s)

Forty-one percent of the areas where there has been a water-level decline of more than ten metres in upper bedrock aquifer(s) corresponds to where the estimated water well use is between ten and 30 m³/day, and 45% of the decline occurred where the estimated water well use is more than 30 m³/day shown on Figure 30.

VII. Recommendations

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

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

The quality of the data in the groundwater database is affected by two factors: a) the technical training of the persons collecting the data, and b) the quality control of the data. The possible options to upgrade the database include the creation of a “super” database, which includes only verified data. The first step would be to field-verify the more than 130 existing water wells listed in Appendix E. These water well records indicate that a complete water well drilling report is available along with at least a partial chemical analysis. The level of verification would have to include identifying the water well in the field, obtaining meaningful horizontal coordinates for the water well and the verification of certain parameters such as water level and completed depth. Even though the water wells for which the County has responsibility do not satisfy the above criteria, it is recommended that they be field-verified, water levels be measured, a water sample be collected for analysis, and a short aquifer test be conducted. There are two County-operated water wells that are also included in Appendix E. An attempt to update the quality of the entire database is not recommended.

An attempt in this study to link the AENV groundwater and licensing databases was about 66% successful. About one-third of licensed water wells do not appear to have corresponding records in the AENV groundwater database. There is a need to improve the quality of the AENV licensing database. It is recommended that attempts be made in a future study to find and add missing drilling records to the AENV groundwater database and determine the aquifer in which the licensed water well is completed.

While there are a few areas where water-level data are available, on the overall, there are an insufficient number of water levels to set up a groundwater budget. One method to obtain additional water-level data is to solicit the assistance of the water well owners who are stakeholders in the groundwater resource. In the M.D. of Rocky View and in Flagstaff County, water well owners are being provided with a tax credit if they accurately measure the water level in their water well once per week for a year. A pilot project indicated that approximately five years of records are required to obtain a reasonable data set. The cost of a five-year project involving 50 water wells would be less than the cost of one drilling program that may provide two or three observation water wells. Monitoring of water levels in domestic and stock water wells is a practice that is recommended by PFRA in the “Water Wells That Last for Generations” manual and accompanying videos (Alberta Agriculture, Food And Rural Development, 1996)(Appendix E). Of the more than 130 water wells recommended for field verification, 31 of the bedrock water wells are in areas of water-level decline. No surficial water wells are recommended for field verification in areas of water-level decline; however, because the flow through the Lower Sand and Gravel Aquifer and the present use are similar in magnitude, additional water wells should be added to the list of water wells recommended for field verification.

A second approach to obtain water-level data would be to conduct a field survey to identify water wells not in use that could be used as part of an observation water well network. County personnel and/or local residents could measure the water levels in the water wells regularly.

In general, for the next level of study, the database needs updating. It requires more information from existing water wells, and additional information from new ones.

Before an attempt is made to provide a major upgrade to the level of interpretation provided in this report and the accompanying maps and groundwater query, it is recommended that the 130 water wells for which water well drilling reports are available be subjected to the following actions (see pages C-2 to C-3):

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

A list of the 130 water wells that could be considered for the above program is given in Appendix E.

In addition to the data collection associated with the existing water wells, all available geophysical logs should be interpreted to establish a more accurate spatial definition of individual aquifers.

There is also a need to provide the water well drillers with feedback on the reports they are submitting to the regulatory agencies. The feedback is necessary to allow for a greater degree of uniformity in the reporting process. This is particularly true when trying to identify the bedrock surface. One method of obtaining uniformity would be to have the water well drilling reports submitted to the AENV Resource Data Division in an electronic form. The money presently being spent by AENV to transpose the paper form to the electronic form should be used to allow for a technical review of the data and follow-up discussions with the drillers.

An effort should be made to form a partnership with the petroleum industry. The industry spends millions of dollars each year collecting information relative to water wells. Proper coordination of this effort could provide significantly better information from which future regional interpretations could be made. This could be accomplished by the County taking an active role in the activities associated with the construction of lease sites for the drilling of hydrocarbon wells and conducting of seismic programs.

Groundwater is a renewable resource and it must be managed.

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IX. Conversions

Multiply	by	To Obtain
Length/Area		
feet	0.304 785	metres
metres	3.281 000	feet
hectares	2.471 054	acres
centimetre	0.032 808	feet
centimetre	0.393 701	inches
acres	0.404 686	hectares
inchs	25.400 000	millimetres
miles	1.609 344	kilometres
kilometer	0.621 370	miles (statute)
square feet (ft^2)	0.092 903	square metres (m^2)
square metres (m^2)	10.763 910	square feet (ft^2)
square metres (m^2)	0.000 001	square kilometres (km^2)
Concentration		
grains/gallon (UK)	14.270 050	parts per million (ppm)
ppm	0.998 859	mg/L
mg/L	1.001 142	ppm
Volume (capacity)		
acre feet	1233.481 838	cubic metres
cubic feet	0.028 317	cubic metres
cubic metres	35.314 667	cubic feet
cubic metres	219.969 248	gallons (UK)
cubic metres	264.172 050	gallons (US liquid)
cubic metres	1000.000 000	litres
gallons (UK)	0.004 546	cubic metres
imperial gallons	4.546 000	litres
Rate		
litres per minute (lpm)	0.219 974	UK gallons per minute (igpm)
litres per minute	1.440 000	cubic metres/day (m^3/day)
igpm	6.546 300	cubic metres/day (m^3/day)
cubic metres/day	0.152 759	igpm