6 GROUNDWATER BUDGET

6.1 Hydrographs

In the M.D., there is one observation water well that is part of the AENV regional groundwater monitoring network where water levels are being measured and recorded as a function of time: AENV Obs Water Well: Smith 2420E (No. 86-1) in 08-10-072-01 W5M. The water level in AENV Obs WW No. 86-1 has been measured since 1988. The hydrograph for AENV Obs Water Well No. 86-1 is below on Figure 25, on page A-40 and on the CD-ROM.

AENV Obs WW No. 86-1 is located near the Hamlet of Smith, was reconditioned in May 1987, and is completed from 50.3 to 51.8 metres below ground surface in the Lower Sand and Gravel Aquifer in association with the Buried High Prairie Valley. The obs water well diagram shown on Figure 24 shows a NPWL of 39.65 metres below ground level. This water level was measured prior to an aquifer test conducted on July 16, 1989.

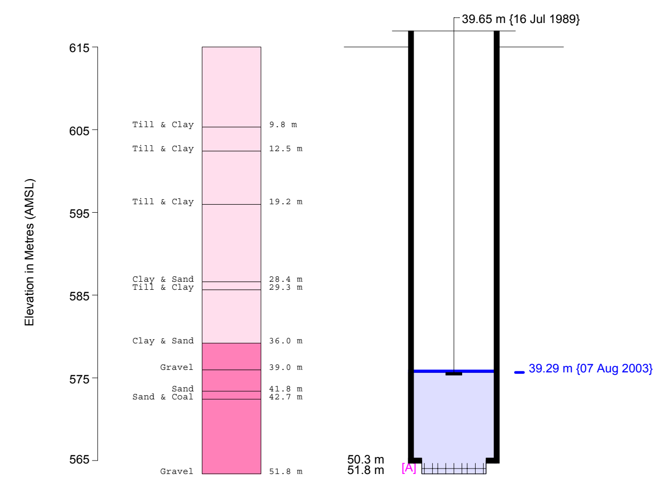

Figure 24. AENV Obs Water Well No. 86-1 Well Diagram

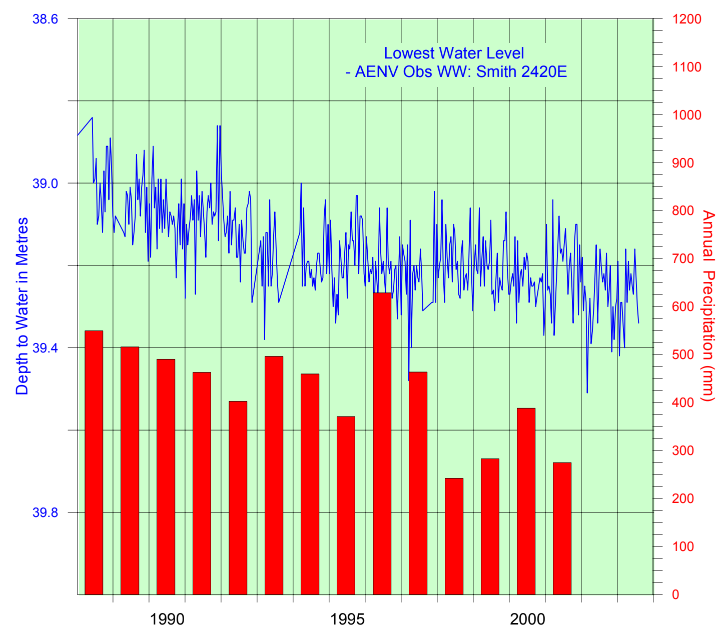

Figure 25. Annual Precipitation vs Water Levels in AENV Obs WW No. 86-1

The water level in AENV Obs WW No. 86-1 has declined from 38.8 metres below ground surface in July 1988 to 39.3 metres below ground surface in August 2003, a net decline in the water level of 0.5 metres. In an area where there are no pronounced seasonal uses of groundwater, the highest water level will usually occur in late spring/early summer and the lowest water level will be in late winter/early spring.

The water-level fluctuations in AENV Obs WW No. 86-1 in 08-10-072-01 W5M have been compared to the annual precipitation measured at the Slave Lake weather station from 1988 to 2002; the comparison is shown in the adjacent figure. The comparison shows that, in general, the water-level fluctuation does not reflect the changes in annual precipitation or a seasonal use of groundwater.

6.2 Estimated Groundwater Use in M.D. of Lesser Slave River

An estimate of the quantity of groundwater removed from each geologic unit in the M.D. of Lesser Slave River must include both the groundwater diversions with licences and/or registrations and the groundwater diversions without licences and/or registrations. As stated previously on page 7 of this report, the daily water requirement for livestock for the M.D. based on the 2001 census is estimated to be 1,486 cubic metres. As of January 2003, AENV has licensed the use of 391 m³/day for livestock, which includes both surface water and groundwater. To obtain an estimate of the quantity of groundwater being diverted from the individual geologic units, it has been assumed that the remaining 1,095 m³/day of water required for livestock watering is obtained from unauthorized groundwater use.

There are 230 water wells that are used for domestic/stock or stock purposes. There are 82 licensed and registered groundwater users for agricultural (stock) and registration (stock) purposes, giving 148 unlicensed and not registered groundwater stock water wells. (Please refer to Table 1 on page 6 for the breakdown of aquifer of the 82 licensed and registered stock groundwater users). By dividing the number of stock and domestic/stock water wells (148) into the quantity required for stock purposes that is not licensed and registered (1,095 m³/day), the average water well with a licence and registration diverts 7.4 m³/day per stock water well.

Groundwater for household use does not require a licence if the use is less than 1,250 m³/year. Under the *Water Act*, a residence is protected for up to 3.4 m³/day. However, the standard groundwater use for household purposes (a family of four) is 1.1 m³/day. Since there are 104 domestic or domestic/stock water wells in the M.D. of Lesser Slave River serving a population of 2,825, the domestic use per water well is 0.8 m^3/day. It is assumed that these 104 water wells are active; however, many are very old and may no longer be in use or 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 for each use is as follows:

Domestic 0.8 m³/day
Stock 7.4 m³/day
Domestic/stock 8.2 m³/day

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

Based on using all available domestic, domestic/stock, and stock water wells and corresponding calculations, the following table was prepared. Table 11 shows a breakdown of the 980 (750+126+104) water wells for which there is no licence and registration used for domestic, stock, or domestic/stock purposes by the geologic unit in which each water well is completed. The final column in the table equals the total amount of groundwater that is being used for both domestic and stock purposes from water wells for which there is no licence and registration. The data provided in Table 11 indicate that most of the 2,201 m³/day, estimated to be diverted from domestic, stock, or domestic/stock water wells for which there is no licence and registration, is from the Upper Sand and Gravel Aquifer.

	Groundwater Diversions from Water Wells With or Without Licences and/or Registrations							*Groundwater Diversions With Licences and/or Registrations*	*Groundwater Diversions Without Licences and/or Registrations*
Aquifer Designation	Number of Domestic	Daily Use (0.8 m³/day)	Number of Stock	Daily Use (7.4 m³/day)	Number of Domestic and Stock	Daily Use (8.2 m³/day)	Totals m³/day	Totals (m³/day)	Totals m³/day
Multiple Surficial Completions	81	67	21	155	24	197	420	14	406
Upper Sand and Gravel	349	288	42	311	39	321	919	15	904
Lower Sand and Gravel	22	18	5	37	2	16	72	27	45
Mulitple Bedrock Completion	14	12	3	22	1	8	42	6	36
Oldman	4	3	2	15	0	0	18	5	13
Foremost	220	182	51	377	36	296	855	129	726
Lea Park	20	17	2	15	1	8	40	0	40
Milk River	1	1	0	0	0	0	1	0	1
Unknown	39	32	0	0	1	8	40	10	30
Totals (1)	750	620	126	932	104	854	2,407	206	2,201

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

Table 11. Total Groundwater Diversions by Aquifer

By assigning 0.8 m³/day for domestic use, 7.4 m³/day for stock use and 8.2 m³/day for domestic/stock use, and using the total maximum authorized diversion associated with any licensed and/or registered water well, a map has been prepared that shows the estimated groundwater use in terms of volume per section per day for the M.D. (not including springs).

There are 1,568 sections in the M.D. In 81% (1271) of the sections in the M.D., there is no domestic, stock or licensed and registered groundwater user. The range in groundwater use for the remaining 297 sections is from one m³/day to 1,274 m³/day (injection), with an average use per section of 18 m³/day (2.7 igpm). The estimated water well use per section can be more than 30 m³/day in 18 of the 297 sections. There are 18 of the total 97 licensed and/or registered groundwater users in areas of greater than 30 m³/day.

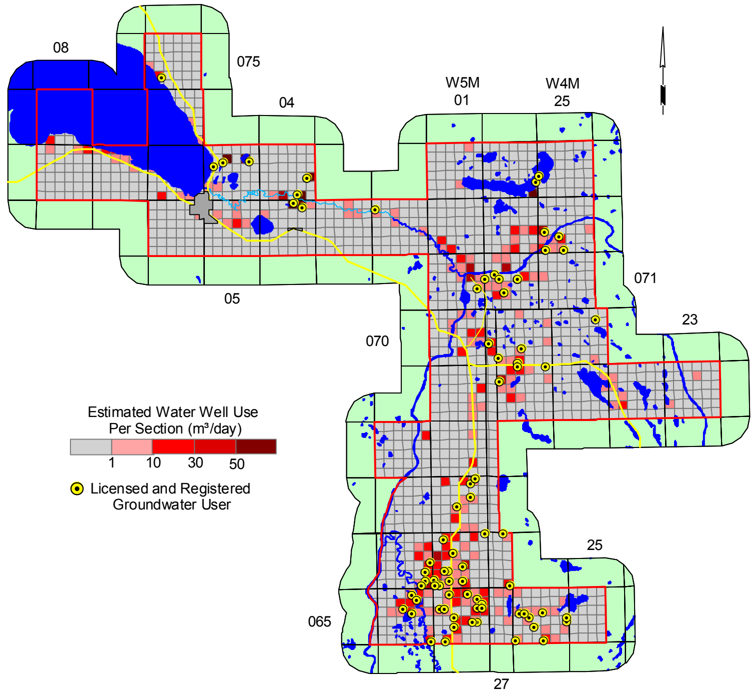

Figure 26. Estimated Water Well Use Per Section
(for larger version, see page A-39)

Groundwater Use within the M.D. of Lesser Slave River (m³/day)		%
Domestic/Stock (including agriculture and registrations)	2,407	*45*
Municipal (licensed)	1	*0*
Commercial/Industrial/Recreation (licensed)	2,892	*55*
Total	5,300	*100*

Table 12. Total Groundwater Diversions

In summary, the estimated total groundwater use within the M.D. of Lesser Slave River is 5,300 m³/day, with the breakdown as shown in the adjacent table. An estimated 5,260 m³/day is being withdrawn from a specific aquifer. The remaining 40 m³/day (1%) is being withdrawn from unknown aquifer units. Of the 5,260 m³/day, 20% is being diverted from bedrock aquifers and 80% from surficial aquifers. Approximately 65% of the total estimated groundwater use is from licensed and registered water wells.

6.3 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 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 various parts of individual 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; flow through the aquifers takes into consideration hydrogeological conditions outside the M.D. border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 13.

Aquifer/Area	Trans (m^2/day)	Gradient (m/m)	Width (m)	Flow (m^3/day)	Aquifer Flow (m^3/day)	Licensed and Registered Diversion (m^3/day)	Not Licensed and Registered Diversion (m^3/day)	Total (m^3/day)
Surficial					13,259	14	406	420
Athabasca Basin								
Southeast part of area								
West	29	0.00625	25.6	4,640				
East-central part of area								
Northwest	29	0.00625	12.8	2,320				
Northeast	29	0.00139	16	644				
Fawcett Lake								
Northwest	29	0.00417	14.4	1,740				
Southeast	29	0.00938	14.4	3,915				
Lower Surficial					2,100	2,903	45	2,948
Lesser Slave River Basin								
Southeast	35	0.006	10	2,100				
Foremost Formation					4,268	173	726	899
Lesser Slave River Basin								
Northwest part of area					1,900			
North	7.5	0.004	19	600				
Northeast	7.5	0.008	21	1,300				
Athabasca Basin								
Southeast part of area					2,368			
Southeast								
Northwest	7.5	0.004	19	514				
West 1	7.5	0.005	27	1,020				
West 2	7.5	0.006	13	533				
East	7.5	0.003	13	300				

Table 13. Groundwater Budget

Table 13 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Lower Sand and Gravel Aquifer. However, even where use is less than the calculated aquifer flow, there can still be local impacts on water levels. The calculations of flow through individual aquifers as presented in Table 13 are very approximate and are intended only as a guide; more detailed investigations are needed to better understand the groundwater flow.

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers is 2.0 to 12.1 cubic kilometres. This volume is based on an areal extent of 1,347 square kilometres and a saturated thickness of 30 metres. The variation in the total volume is based on the value of porosity that is used for the surficial deposits. 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 non-pumping water-level map has been prepared from water levels associated with water wells completed to depths of less than 20 metres in aquifers in the surficial deposits. The water levels from these water wells were used for the calculation of the saturated thickness of the surficial deposits and for calculations of recharge/discharge areas. In areas where the elevation of the water-level surface is below the bedrock surface, the surficial deposits are not saturated (indicated by grey areas on the map). The water-level map for the surficial deposits shows a flow direction toward the Athabasca River and the Lesser Slave River.

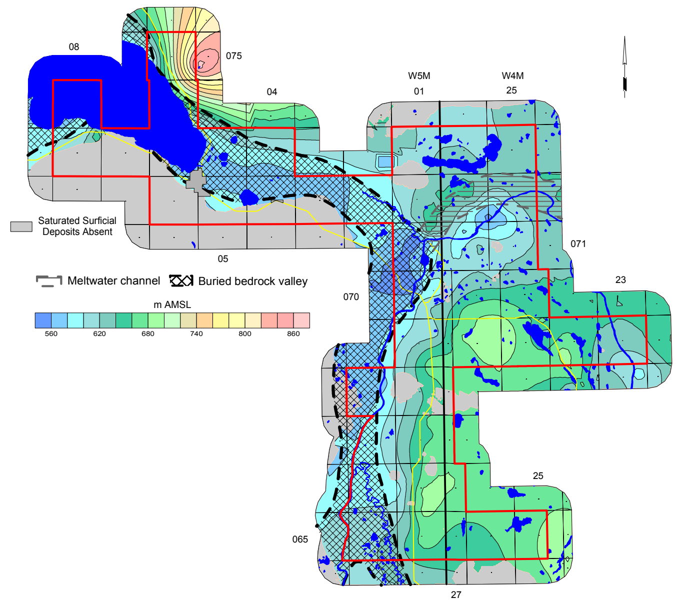

Figure 27. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

6.3.2 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 hydraulic unit. 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.

6.3.2.1 Surficial Deposits/Bedrock Aquifers

Recharge to the bedrock aquifers within the M.D. takes place from the overlying surficial deposits and from flow in the aquifer from outside the M.D. 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.

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 is used 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, that is, no recharge and no discharge.

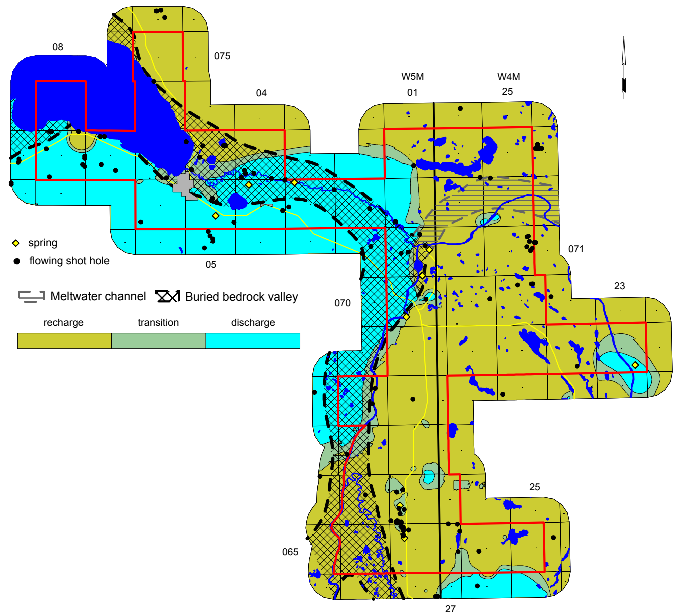

Figure 28. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

The location of springs, flowing shot holes and any water wells that had a water level measurement depth of less than 0.1 metres are shown on Figure 28. These locations would reflect where there is an upward hydraulic gradient from the bedrock to the surficial deposits (i. e. discharge).

Figure 28 shows that, in 65% of the M.D., there is a downward hydraulic gradient (i. e. recharge) from the surficial deposits toward the upper bedrock aquifer(s). 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. The remaining parts of the M.D. are areas where there is a transition condition.

Because of the paucity of data, recharge/discharge maps for the individual bedrock aquifers have not been attempted.

With 65% of the M.D. land area being one of recharge to the bedrock, and the average precipitation being 485 mm per year, 0.1 percent of the annual precipitation is sufficient to provide the total calculated quantity of groundwater flowing through the upper bedrock aquifer(s).

6.4 Areas of Groundwater Decline

In order to determine the areas of possible water-level decline in the Sand and Gravel Aquifer(s) and in the Upper Bedrock Aquifer(s), the following approach was attempted. The available non-pumping water-level elevation for each water well was first sorted by location, and then by date of water-level measurement. The dates of measurements were required to differ by at least 365 days. Only the earliest and latest control points at a given location were used. The method of calculating changes in water levels is at best an estimate. Additional data would be needed to verify water-level change.

Of the 284 surficial water wells with a non-pumping water level and date in the M.D. and buffer area, there are 40 water wells with sufficient control to prepare the adjacent map.

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. The interpretation of the adjacent map should be limited to areas where control points are present. Most of the areas in which the map suggests that there has been a decline in NPWL may reflect the nature of gridding a limited number of control points. The adjacent map, where sufficient control exists, indicates that there may have been a decline in the NPWL in most areas.

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 surficial aquifer.

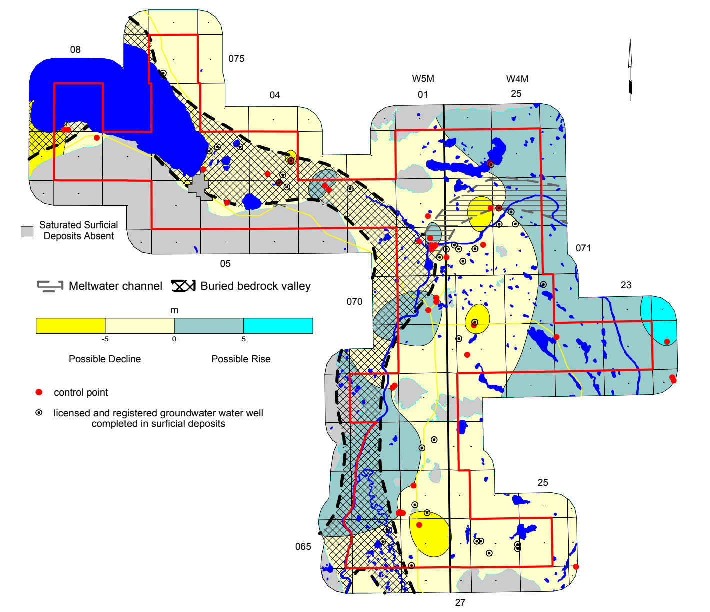

Figure 29. Changes in Water Levels in Surficial Deposits

Of the 43 licensed and registered groundwater users completed in surficial aquifers, most occur in areas where a decline in the NPWL may have occurred.

Figure 29 indicates that in 70% of the M.D. where surficial deposits are present, it is possible that the non-pumping water level has declined. The areas of groundwater decline in the Sand and Gravel Aquifer(s) where there is no estimated water well use suggest that groundwater diversion is not having an impact and that the decline may be due to variations in recharge to the Aquifer(s) or because the water wells are not on file with Alberta Environment.

In areas where a water-level decline of more than five metres may exist, 42% of the areas has no estimated water well use; 28% is less than 10 m³/day, 27% of the use is between 10 and 30 m³/day; and the remaining 3% of the declines occurred where the estimated groundwater use per section is greater than 30 m³/day, as shown in Table 14.

Estimated Water Well Use Per Section (m³/day)	*% of Area with More than a 5-Metre Projected Decline*
<10	*28*
10 to 30	*27*
>30	*3*
no use	*42*

Table 14. Water-Level Decline in Sand and Gravel Aquifer(s)