In 2002, the Hamlet of Carseland currently is licensed to divert groundwater from five water supply wells. Two water supply wells are in SE 12-022-26 W4M (WSW Nos. 2 and 85-5) and in 2002 licensed for a total of 64 m³/day; one water supply well in NE 12-022-26 W4M (WSW No. 97-1) is licensed for 162.2 m³/day, and two water supply wells in SW 07-022-25 W4M (WSW No. 85-3 and Obs WW No. 85-3) are licensed for a total of 74.4 m³/day. One of the two water wells in SW 07 is used as an observation water well for standby purposes.

WSW No.	Licensed Diversion (m³/day) in 1992[1]	Licensed Diversion (m³/day) in 2002
1	33	0
2	164	30
85-3	196	74.4[2]
85-5	79	34
93-1	not applicable	not applicable
97-1	not applicable	162.2[3]
Total	472	301

(1) CH2M Hill, April 1992
(2) assumed combined total for WSW 85-3 and Obs WW No. 85-3
(3) assumed licensed to WSW 97-1

Table 15. Summary of Carseland Licensed WSWs (modified after CH2M Hill)

From 1975 to 1992, WSW No. 1 in SE 12-022-26 W4M was licensed to divert 33 m³/day, and by 1994 was no longer being used as a water supply well by the Hamlet of Carseland. The use of the water supply well was probably discontinued in 1992 or 1993 with the completion of WSW No. 93-1 in NE 12-022-26 W4M. On September 21, 1992, a water well was drilled in NE 12-022-26 W4M to be used for municipal purposes and was completed from 69.2 to 75.3 metres below ground surface. A second water well was drilled on September 25, 1992 and was completed from 71.9 to 76.5 metres below ground surface to used as an observation water well. The water well drilled on September 21, 1992 was reconstructed in November 1993, and was recompleted from 65.8 to 70.4 metres below ground surface, according to the driller's comments on the drilling record. Presumably, this water well became WSW No. 93-1. However, according to the AENV licensing database, a water well having a completion interval from 69.2 to 75.3 metres below ground surface is the water supply well that is currently licensed to divert 162 m³/day. In April 1997, WSW No. 97-1 was drilled and completed from 69.2 to 73.8 metres below ground surface, according to the information provided by Wheatland County. The driller's log for WSW No. 97-1 is not in the AENV database and the completion information for WSW No. 97-1 provided by Wheatland is in text form only. The available monitoring data provided by the County are from 1996 to 2000 and show that recorded production data are from WSW No. 2, WSW No. 85-3, WSW No. 85-5 and from WSW Nos. 93-1/97-1. Water levels are being measured in Obs WW Nos. 85-1, 85-3, 85-4 and 93-1. The graphical information provided by CH2M Hill also indicates that, since 1994, the groundwater monitoring program by the Hamlet of Carseland has not changed.

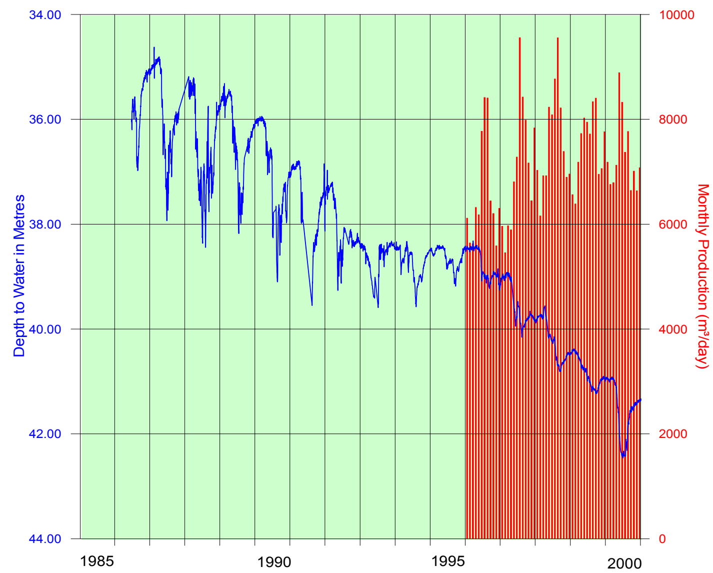

Figure 32. Groundwater Production in Carseland WSWs vs Water Levels in AENV Obs WW No. 220

In each year from 1986 to 1992, the water level in AENV Obs WW No. 220 declined approximately three metres during peak groundwater demand by Carseland in the summer and rose each fall and winter to a level that was between 0.5 to 1.0 metres less than the drawdown of the previous summer. The total licensed amount from the Carseland water supply wells from 1986 to 1992 was 472 m³/day. In 1992, the range of water-level fluctuations in AENV Obs WW No. 220 decreased from three metres to one metre, which may be a result of the completion of the water wells in September 1992. In mid-1993, the lowest water level declined from the lowest water level measured in 1992, which may be a result of increased diversion from WSW No. 93-1. The characteristics of the fluctuations in AENV Obs WW No. 220 from 1992 to 1996 changed in early 1997. From early 1997 to the end of the monitoring period in 2000, the water level in AENV Obs WW No. 220 declined more than three metres. This decline that began in early 1997 may be a result of the groundwater diversion from WSW No. 97-1.

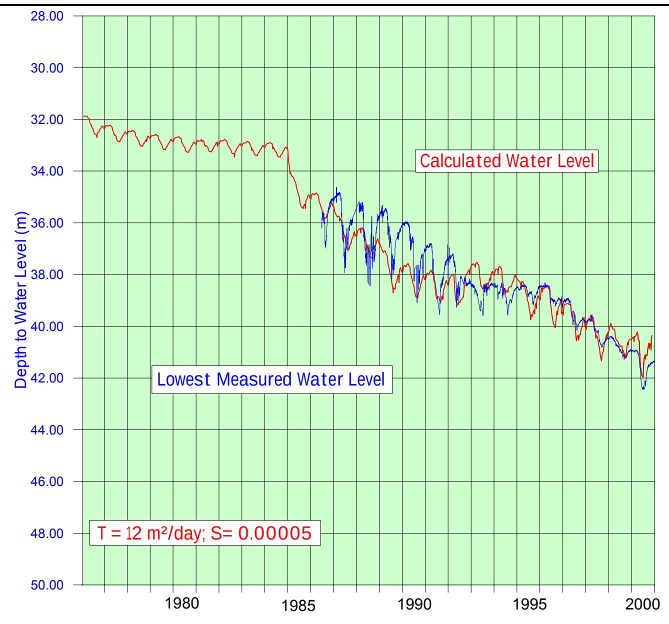

Figure 33. Water-Level Comparison - AENV Obs WW No. 220

A mathematical model called the *Infinite Aquifer Artesian Model* (IAAM)[20] was used to calculate water levels at a location corresponding to AENV Obs WW No. 220 based on estimated groundwater production from 1969 to 1995 and on the monthly recorded groundwater production from each of the four current producing water supply wells from 1996 to 2000. The locations of the Carseland water wells shown on the site map in Figure 31 were digitized in order to create a reasonable model aquifer. The model aquifer has an effective transmissivity of 12 m²/day, a corresponding storativity of 0.00005, is homogeneous and isotropic, and behaves as an aquifer of infinite areal extent; the model does not account for recharge to the aquifer. Therefore, if there were a decrease in recharge to the groundwater, a water-level decline could occur and the simulation would not account for the change.

Despite the limited data available, there is a reasonable degree of comparison between the calculated and measured water levels in AENV Obs WW No. 220.

[20] See glossary

6.2 Estimated Water Use from Unlicensed Groundwater Users

An estimate of the quantity of groundwater removed from each geologic unit in Wheatland County must include both the licensed diversions and the unlicensed use. As stated previously on page 6 of this report, the daily water requirement for livestock for the County based on the 2001 census is estimated to be 19,150 cubic metres. Of the 19,150 m^3/day required for livestock, 6,713 m^3/day has been licensed by Alberta Environment, 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 12,437 m^3/day of water required for livestock watering is obtained from unlicensed groundwater use. In the groundwater database for the County, there are records for 3,566 water wells that are used for domestic/stock purposes. These 3,566 water wells include both licensed and unlicensed water wells. Of the 3,566 water wells, 408 water wells are used for stock, 566 are used for domestic/stock purposes, and 2,592 are for domestic purposes only.

There are 944 water wells that are used for stock or domestic/stock purposes (Table 16). There are 149 licensed groundwater users for agricultural (stock) purposes, giving 825 unlicensed stock water wells. (Please refer to Table 1 on page 6 for the breakdown by aquifer of the 202 licensed stock groundwater users). By dividing the number of unlicensed stock and domestic/stock water wells (825) into the quantity of groundwater required for stock purposes that is not licensed (12,437 m^3/day), the average unlicensed water well diverts 15.1 m^3/day for stock purposes. Because of the limitations of the data, no attempt has been made to compensate for dugouts, springs or inactive water wells, and the average stock use is considered to be 15.1 m^3/day per stock water well.

Groundwater for household use does not require licensing. Under the Water Act, a residence is protected for up to 3.4 m^3/day. However, the standard groundwater use for household purposes (a family of four) is 1.1 m^3/day. Since there are 3,158 domestic water wells in Wheatland County serving a population of 7,240, the domestic use per water well is 0.6 m^3/day.

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	0.6 m^3/day
Stock	15.1 m^3/day
Domestic/stock	15.7 m^3/day

Based on using all available domestic, domestic/stock, and stock water wells and corresponding calculations, the following table was prepared. Table 16 on the following page shows a breakdown of the 3,566 unlicensed and licensed water wells 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 unlicensed groundwater that is being used for both domestic and stock purposes. The data provided in Table 16 indicate that most of the 11,975 m^3/day, estimated to be diverted from unlicensed domestic, stock, or domestic/stock water wells, is from multiple bedrock completions or the Upper Horseshoe Canyon Aquifer.

Aquifer Designation	*Unlicensed and Licensed Groundwater Diversions* Number of Domestic	Daily Use (0.6 m³/day)	Number of Stock	Daily Use (15.1 m³/day)	Number of Domestic and Stock	Daily Use (15.7 m³/day)	Totals m³/day	*Licensed Groundwater Diversions* Totals (m³/day)	*Unlicensed Groundwater Diversions* Totals m³/day
Multiple Surficial Completions	188	108	28	422	29	453	983	0	983
Upper Sand/Gravel	80	46	10	151	8	125	321	129	193
Lower Sand/Gravel	131	75	9	136	4	63	273	150	123
Multiple Bedrock Completions	441	253	101	1,521	120	1,876	3,649	538	3,115
Lower Lacombe	167	96	17	256	30	469	821	122	699
Haynes	245	140	50	753	50	782	1,675	759	918
Upper Scollard	239	137	49	738	77	1204	2,078	900	1,181
Lower Scollard	141	81	22	331	44	688	1,100	728	373
Upper Horseshoe Canyon	366	210	49	738	103	1610	2,557	184	2,376
Middle Horseshoe Canyon	179	103	23	346	36	563	1,012	73	940
Lower Horseshoe Canyon	106	61	13	196	22	344	600	139	462
Bearpaw	6	3	0	0	1	16	19	0	19
Unknown	303	174	37	557	42	656	1,387	796	593
Totals [1]	2,592	1,486	408	6,143	566	8,847	16,475	4,518	11,975

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

Table 16. Unlicensed and Licensed Groundwater Diversions

By assigning 0.6 m³/day for domestic use, 15.1 m³/day for stock use and 15.7 m³/day for domestic/stock use, and using the total maximum authorized diversion associated with any licensed water well that can be linked to a record in the database, a map has been prepared that shows the estimated groundwater use in terms of volume (licensed plus unlicensed) per section per day for the County (not including springs).

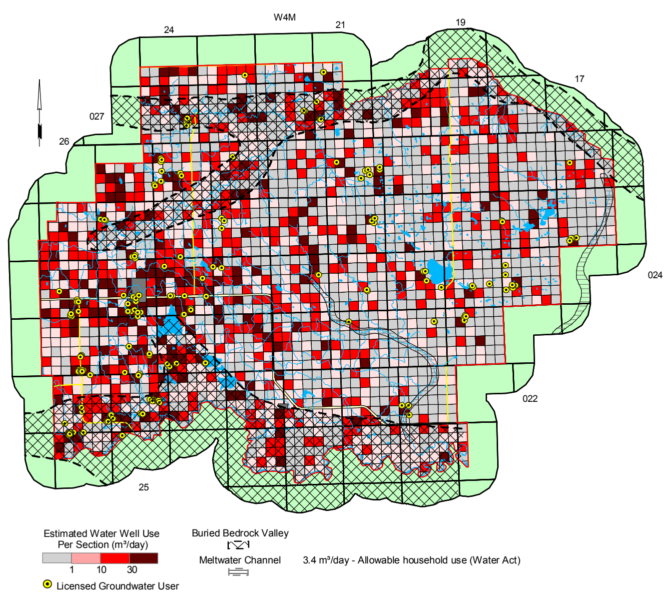

Figure 34. Estimated Water Well Use Per Section

There are 2,040 sections in the County. In 23% (926) of the sections in the County, there is no domestic or stock or licensed groundwater user. The range in groundwater use for the remaining 1,114 sections with groundwater use is from 0.6 m³/day to more than 440 m³/day, with an average use per section of 17 m³/day (2.6 igpm). The estimated water well use per section can be more than 30 m³/day in 208 of the 1,114 sections. There is at least one licensed groundwater user in 40 of the 208 sections. The most notable areas where water well use of more than 30 m³/day is expected to occur is mainly in the vicinity of the Town of Strathmore, as shown on Figure 34.

Groundwater Use within Wheatland County (m³/day)		%
Domestic/Stock (licensed and unlicensed)	16,475	92
Municipal (licensed)	584	3
Commercial/Dewatering/Exploration et al (licensed)	778	4
Total	17,837	100

Table 17. Total Groundwater Diversions

In summary, the estimated total groundwater use within Wheatland County is 17,837 m³/day, with the breakdown as shown in the adjacent table. An estimated 15,841 m³/day is being withdrawn from a specific aquifer. The remaining 1,996 m³/day or 11% is being withdrawn from unknown aquifer units. Approximately 33% of the total estimated groundwater use is from licensed water wells. Of the 17,837 m³/day, 78% is being diverted from bedrock aquifers, 10% from surficial aquifers, and 11% from unknown aquifers.

6.3 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; flow through the aquifers takes into consideration hydrogeological conditions outside the County border. Based on these assumptions, the estimated lateral groundwater flow through the individual aquifers has been summarized in Table 18.

Table 18 indicates that there is more groundwater flowing through the aquifers than has been authorized to be diverted from the individual aquifers, except for the Haynes Aquifer. However, even where use is less than the calculated aquifer flow, there can still be local impacts on water levels as shown by the groundwater monitoring in the Carseland area. The calculations of flow through individual aquifers as presented in the adjacent table are very approximate and are intended only as a guide for future investigations.

Aquifer/Area	Trans (m²/day)	Gradient (m/m)	Width (m)	Flow (m³/day)	Aquifer Flow (m³/day)	Licensed Diversion (m³/day)	Unlicensed Diversion (m³/day)	Total (m³/day)
Upper Surficial					14,300	139	182	321
southeast	58	0.0062	40,000	14277				
Lower Surficial					4,000	430	0	430
Rosebud River low								
west to east	91	0.0029	5,000	1300				
Serviceberry Creek low								
west to east	91	0.0032	5,000	1456				
Buried Calgary Valley								
west to east	91	0.0017	8,000	1213				
Lower Lacombe					2,800	125	696	821
Northern								
north	28	0.007	15,000	2800				
Haynes					800	883	792	1,675
Northern								
north	10	0.004	20,000	750				
Upper Scollard					9,700	966	1,112	2,078
Serviceberry Basin								
northeast	21	0.010	8,000	1680				
northwest	21	0.010	20,000	4200				
southeast	21	0.010	2,000	420				
Eagle Lake Basin								
northeast	21	0.004	15,000	1350				
southeast	21	0.004	8,000	672				
southwest	21	0.004	16,000	1344				
Lower Scollard					8,020	728	372	1,100
Western								
northwest	33	0.004	32,000	3840				
Eagle Lake Basin								
northeast	33	0.003	16,000	1760				
southeast	33	0.003	9,000	990				
southwest	33	0.003	13,000	1430				
Upper Horseshoe Canyon					13,460	265	2,293	2,558
North eastern								
north	23	0.003	20,000	1150				
South								
south	23	0.003	40,000	2300				
Western								
north	23	0.005	25,000	2875				
Crowfoot Basin								
northeast	23	0.003	20,000	1380				
souteast	23	0.001	20,000	575				
east	23	0.008	30,000	5175				
Middle Horseshoe Canyon					12,710	147	865	1,012
Northeast								
northeast	22	0.004	15,000	1238				
northwest	22	0.003	15,000	880				
southeast	22	0.003	15,000	825				
South								
south	22	0.006	30,000	3960				
east	22	0.003	13,000	715				
West								
northeast	22	0.002	40,000	1760				
Crowfoot Basin								
northeast	22	0.004	22,000	1815				
southeast	22	0.002	10,000	440				
southwest	22	0.004	13,000	1073				
Lower Horseshoe Canyon					6,000	176	424	600
Northeast								
northeast	30	0.001	60,000	2400				
Southeast								
south	30	0.002	60,000	3600				

Table 18. Groundwater Budget

6.3.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the surficial deposits is 0.5 to 3.1 cubic kilometres. This volume is based on an areal extent of 2,060 square kilometres and a saturated thickness of five 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 water-level map has been prepared from water levels associated with water wells completed 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. 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 general flow direction toward the Bow River and Serviceberry Creek.

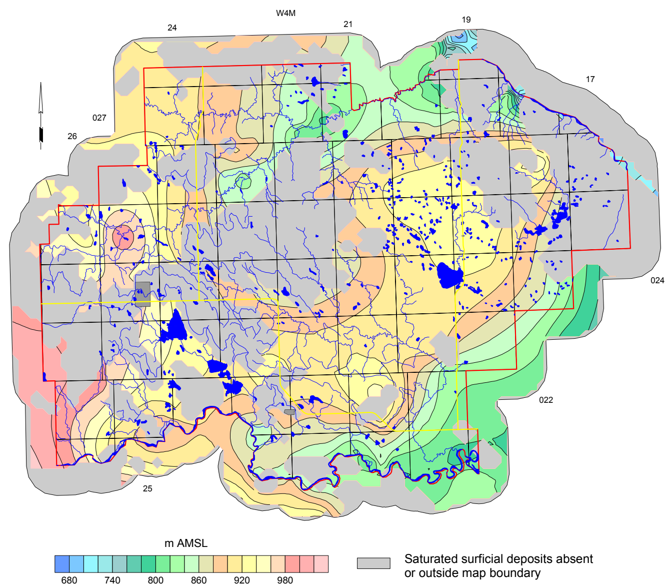

Figure 35. Non-Pumping Water-Level Surface in Surficial Deposits Based on Water Wells Less than 20 Metres Deep

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.