5.3.5 Milan Aquifer

The Milan Aquifer is used to designate the sandstone beds that occur near the western limit of the *marine* Foremost Formation. The sandstone beds are included as one aquifer because the individual sandstone members, which can be identified to the east and south of the Region, are not generally discernible within the Region. The Milan Aquifer includes up to 40 metres of the *marine* Foremost Formation and up to 10 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 Smoky Lake Region.

5.3.5.1 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. From the Figure 8 cross-section, it can be seen that the dip of the continental/marine interface of the Foremost Formation is much steeper than the general dip of the individual formations. The depth to the top of the Milan Aquifer ranges from less than 20 metres in the vicinity of the Town of Smoky Lake to more than 100 metres toward its western extent.

5.3.5.2 Apparent Yield

The projected long-term yields for individual water wells completed in the Milan Aquifer are mainly less than 100 m³/day. The higher yields tend to be in water wells located along the southern part of the Region in townships 057, 058 and 059. A follow-up study (Hydrogeological Consultants Ltd, 1993) to a study conducted by PFRA for the Village of Warspite (PFRA, 1991) indicated a long-term yield of in the order of 400 m³/day for a water supply well completed in the Milan Aquifer.

A study for the Town of Smoky Lake (Hydrogeological Consultants Ltd, 1975) indicated a long-term yield of 75 m³/day for a water well completed in the Milan Aquifer.

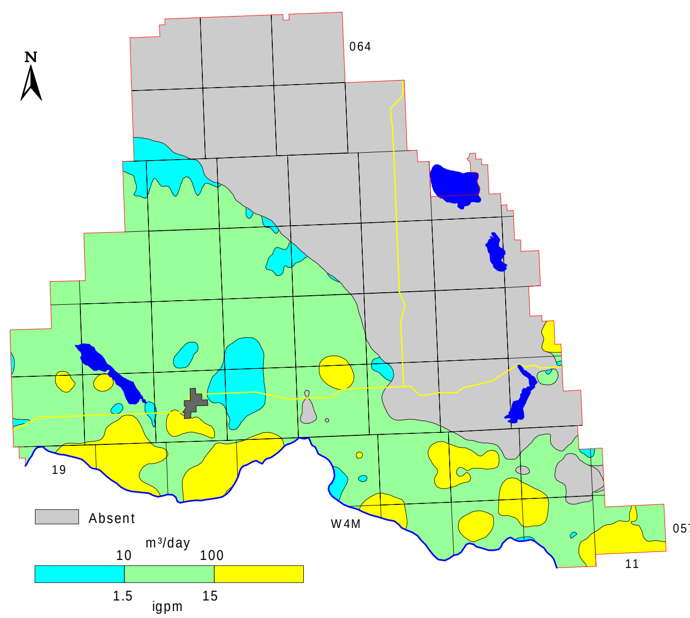

Figure 20. Apparent Yield for Water Wells Completed through Milan Aquifer

5.3.5.3 Quality

Groundwaters from the Milan Aquifer are mainly sodium-bicarbonate- or sodium-sulfate-type waters. The TDS concentrations in the groundwater are expected to be less than 1,000 mg/L east of range 18, and including the Town of Smoky Lake, and more than 1,000 mg/L west of range 17. At the Village of Warspite (Tp 059, R 18, W4M), three separate sandstone layers are included in the Milan Aquifer. Groundwaters from the upper two sandstone layers have TDS values of in the order of 850 mg/L, sulfate concentrations of between 250 and 300 mg/L and chloride concentrations of 10 mg/L (PFRA, 1991). The groundwater from the lower aquifer has a TDS value of 1,400 mg/L, a sulfate concentration of less than 30 mg/L and a chloride concentration of 365 mg/L (Hydrogeological Consultants Ltd., 1993).

Regionally, chloride concentrations of more than 250 mg/L can be expected in the groundwater from the Milan Aquifer over more than 15% of the Region. Chloride values of less than 10 mg/L can be expected in the vicinity of the Town of Smoky Lake and in the southeastern part of the Region.

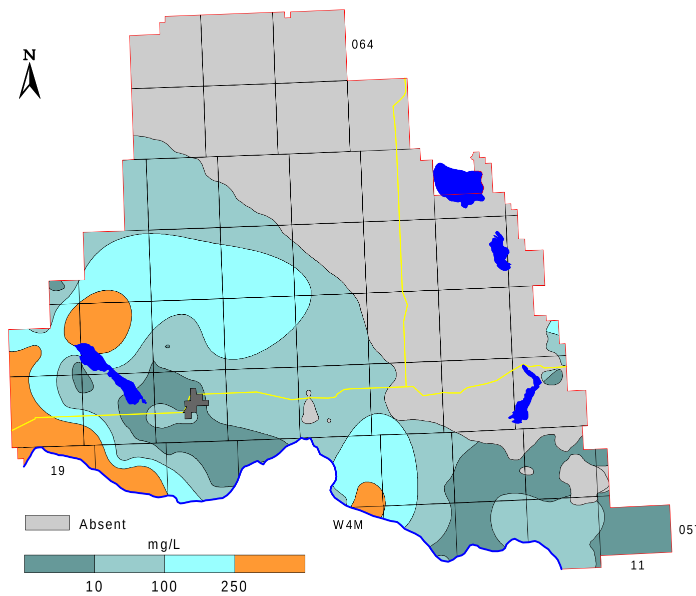

Figure 21. Chloride in Groundwater from Milan Aquifer

6 GROUNDWATER BUDGET

6.1 Groundwater Flow

A direct measurement of groundwater recharge or discharge is not possible from the data that are presently available. 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 the discharge is equal to the recharge. However, even the data that can be used to calculate the quantity of flow 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 of the width for the aquifer. For the present program, the flow has been estimated for those parts of the various aquifers within the Region. The aquifers include the surficial deposits as one hydraulic unit, the Buried Beverly Valley, the *continental* Foremost Aquifer, and the Milan Aquifer.

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	10	0.004	60	South	2400	185
Buried Beverly Valley	28	0.003	10	East	850	706
Continental Foremost	7	0.003	40	South	850	0
Milan Aquifer	9	0.003	40	South	1100	299

The flow through the Lower Sand and Gravel Aquifer associated with the Buried Beverly Valley is inconclusive. The value in the above table assumes that flow is along the length of the Aquifer. The water-level map indicates that flow in the Aquifer is westward from R 15 and eastward from R 14 in Tp 059, W4M. The Authorized Diversion refers to the amount of groundwater that can be diverted under licences issued by AEP.

A second method to establish recharge is to monitor water levels in an aquifer close to a groundwater diversion point. Some data are available from the Town of Smoky Lake water supply wells completed in the Upper Sand and Gravel Aquifer. Between 1984 and 1996, there has been groundwater production of up to 299,000 cubic metres per year (820 m^3/day) from the Upper Sand and Gravel Aquifer with no adverse effect on the water level in the Aquifer. Therefore, it can be concluded that recharge to the aquifer is offsetting the present diversion. A detailed analysis would be required to understand the nature of the recharge.

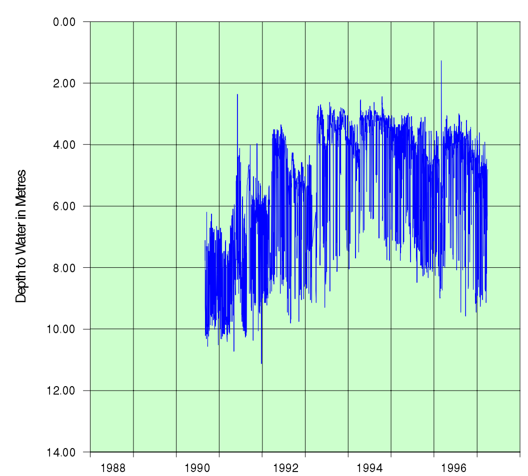

Figure 22. Water-Level Summary – Upper Sand and Gravel Aquifer

6.1.1 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is 1 to 6 cubic kilometres. This volume is based on an areal extent of 4,000 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).

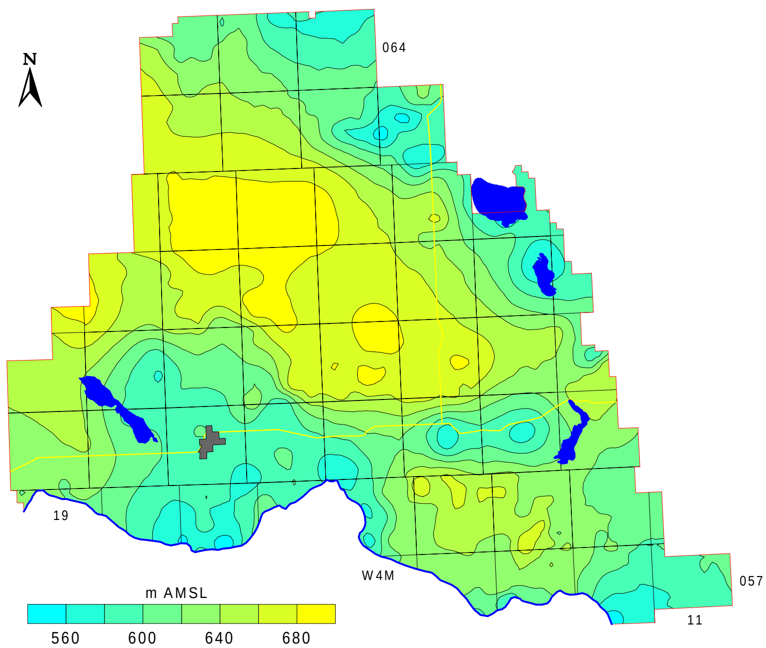

Figure 23. Non-Pumping Water-Level Surface in Surficial Deposits

The adjacent water-level map has been prepared by considering all water wells completed in aquifers in the surficial deposits, except in the vicinity of the buried valleys. In the vicinity of the Buried Beverly and Kikino valleys, only the water levels from water wells completed in the deeper sand and gravel deposits have been included.

6.1.2 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, relative to the bedrock aquifers.

6.1.2.1 Surficial Deposits/Bedrock Aquifers

The hydraulic gradient between the surficial deposits and the bedrock aquifers has been determined by subtracting the non-pumping water-level surface for all water wells in the surficial deposits from the non-pumping water-level surface associated with all water wells completed in bedrock aquifers. The recharge classification on the adjacent map 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. 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.

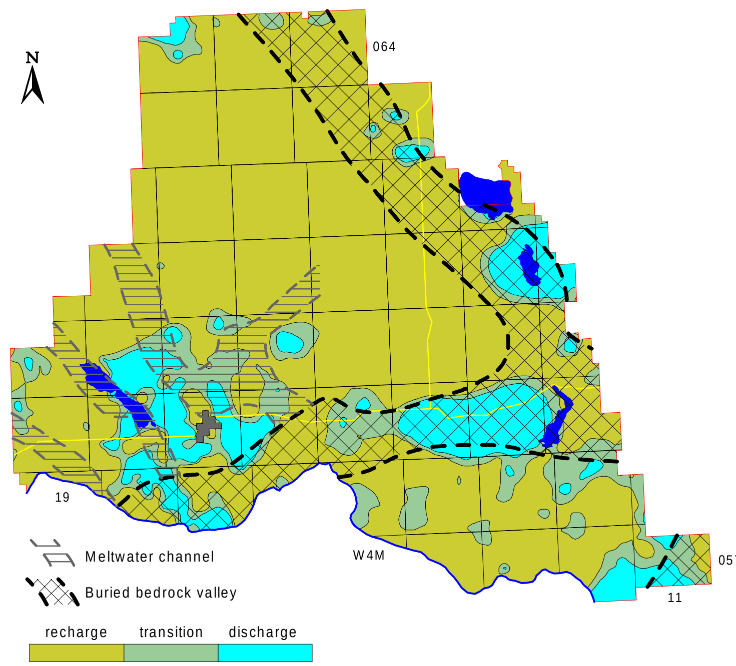

Figure 24. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer(s)

The map above shows that in more than 80% of the Region there is a downward hydraulic gradient between the surficial deposits and the upper bedrock aquifers. Areas where there is an upward hydraulic gradient, discharge from the bedrock, are mainly associated with lows in the bedrock surface. The remaining parts of the Region are areas where there is a transition condition.

Because of the paucity of data, a meaningful calculation of the volumes of groundwater entering and leaving the surficial deposits is not possible.

6.2 Bedrock Aquifers

Recharge to the bedrock aquifers within the Region takes place from the overlying surficial deposits and from flow in the aquifer from outside the Region. The recharge/discharge maps show that generally for most of the Region, there is a downward hydraulic gradient from the surficial deposits to the bedrock. If the flow of 2,000 m^3/day through the two main bedrock aquifers is maintained by recharge from the surficial deposits, and since the two main aquifers occupy an area of 2,000 square kilometres, the average recharge to the bedrock aquifers would need to be 1 m^3 per square kilometre per year. This quantity of water would be significantly less than 0.01% of the annual precipitation.

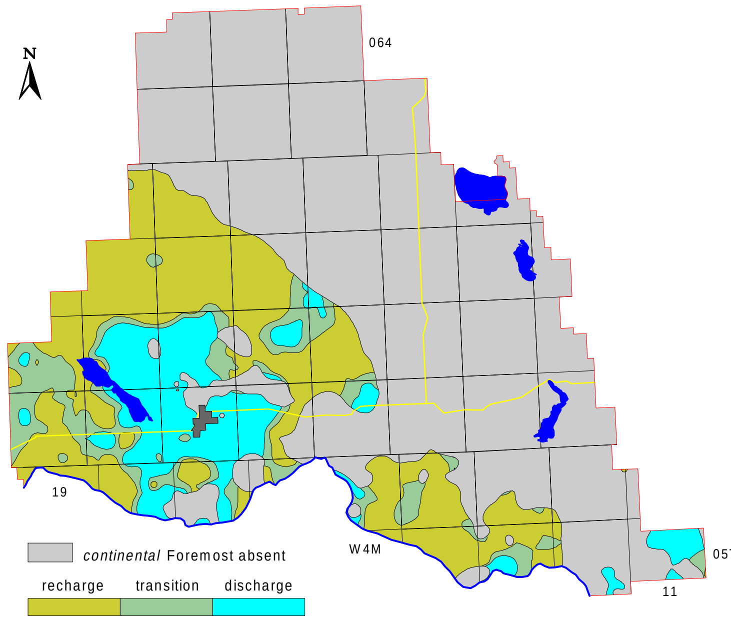

Figure 25. Recharge/Discharge Areas between Surficial Deposits and continental Foremost Aquifer

The hydraulic relationship between the surficial deposits and the *continental* Foremost Aquifer indicates that in 40% of the Region where the *continental* Foremost is present, there is an upward hydraulic gradient. This discharge area is mainly present in the area of bedrock lows. The presence of a discharge area at the eastern extent of a formation is not uncommon; this does not appear to be the situation for the *continental* Foremost Aquifer, probably as a result of the paucity of data.

The hydraulic relationship between the surficial deposits and the Milan Aquifer shows a similar situation to the *continental* Foremost Aquifer but of a lesser magnitude due to the paucity of data.

7 POTENTIAL FOR GROUNDWATER CONTAMINATION

The most common sources of contaminants that can impact groundwater originate on or near the ground surface. The contaminant sources can include leachate from landfills, effluent from leaking lagoons or from septic fields, and petroleum products from storage tanks or pipeline breaks. The agricultural activities that generate contaminants include spreading of fertilizers, pesticides, herbicides and manure. The spreading of highway salt can also degrade groundwater quality.

When activities occur that do or can produce a liquid which could contaminate groundwater, it is prudent (from a hydrogeological point of view) to locate the activities where the risk of groundwater contamination is minimal. Alternatively, if the activities must be located in an area where groundwater can be more easily contaminated, then necessary action must be taken to minimize the risk of groundwater contamination.

The potential for groundwater contamination is based on the concept that the easier it is for a liquid contaminant to move downward, the easier it is for the groundwater to become contaminated. In areas where there is groundwater discharge, liquid contaminants cannot enter the groundwater flow systems to be distributed throughout the area. When there are groundwater recharge areas, low-permeability materials impede the movement of liquid contaminants downward. Therefore, if the soils develop on a low-permeability parent material of till or clay, the downward migration of a contaminant is slower relative to a high-permeability parent material such as sand and gravel of fluvial origin. Once a liquid contaminant enters the subsurface, the possibility for groundwater contamination increases if it coincides with a higher permeability material within one metre of the land surface.

To determine the nature of the materials on the land surface, the surficial geology map prepared by the Alberta Research Council (Shetsen, 1990) has been reclassified based on the relative permeability. The classification of materials is as follows:

1. high permeability - sand and gravel;
2. moderate permeability - silt, sand with clay, gravel with clay, and bedrock; and
3. low permeability - clay and till.

To identify the areas where sand and gravel can be expected within one metre of the ground surface, all groundwater database records with lithologies were reviewed. From a total of 2,190 records in the area of the Region with lithology descriptions, 472 have sand and gravel within one metre of ground level. In the remaining 1,718 records, the first sand and gravel is deeper or not present. This information was then gridded to prepare a distribution of where the first sand and gravel deposit could be expected within one metre of ground level.