5.3.6 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 in one aquifer because the individual sandstone members, which can be identified to the east and south of the County, are not generally discernible within the County. 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 County of Thorhild.

5.3.6.1 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 northeastern part of the County, in the Long Lake area, to more than 240 metres toward its western extent.

5.3.6.2 Apparent Yield

The projected long-term yields for individual water wells completed in the Milan Aquifer are mainly less than 100 m³/day. The adjacent map includes 12 values within the County. Eight of the 12 values are between 18 and 51 m³/day. The remaining four values vary between 134 and 4,420 m³/day. The very high value, which is not included in the analysis, is for a water well in Tp 059, R 20, W4M. The water well is 120 metres deep and the water level is approximately 25 metres lower than another water well completed in the Milan Aquifer less than five kilometres north.

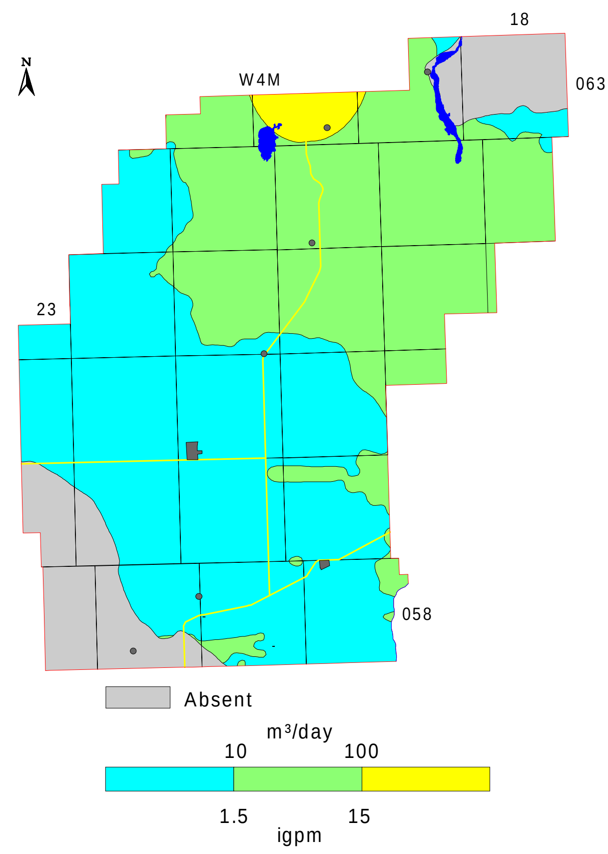

Figure 17. Apparent Yield for Water Wells Completed through Milan Aquifer

5.3.6.3 Quality

Groundwaters from the Milan Aquifer are mainly bicarbonate- or chloride-type waters. Within the County there are results available from nine chemical analyses. The results indicate that, within the majority of the County, the TDS are expected to be in the order of 1,000 to 1,500 mg/L. However, the results from the *marine* Foremost Formation indicate that TDS values can exceed 1,500 mg/L in the extreme southeastern corner of the County.

Chloride concentrations of more than 250 mg/L can be expected in the groundwater from the Milan Aquifer throughout the western and southern parts of the County, where the Aquifer is present. Where the Milan Aquifer subcrops, chloride concentrations are generally less than 100 mg/L. The large extent of the area where chloride concentrations are greater than 250 mg/L is based on very few data points on a regional scale. When the chloride ion concentrations in the groundwaters from the Milan Aquifer are combined with the chloride ion concentrations in the groundwaters from the *marine* Foremost Formation, groundwaters with chloride concentrations of greater than 250 mg/L are only expected in the area south of Tp 060. This situation is best illustrated by the chloride ion concentration shown for the *marine* Foremost Formation.

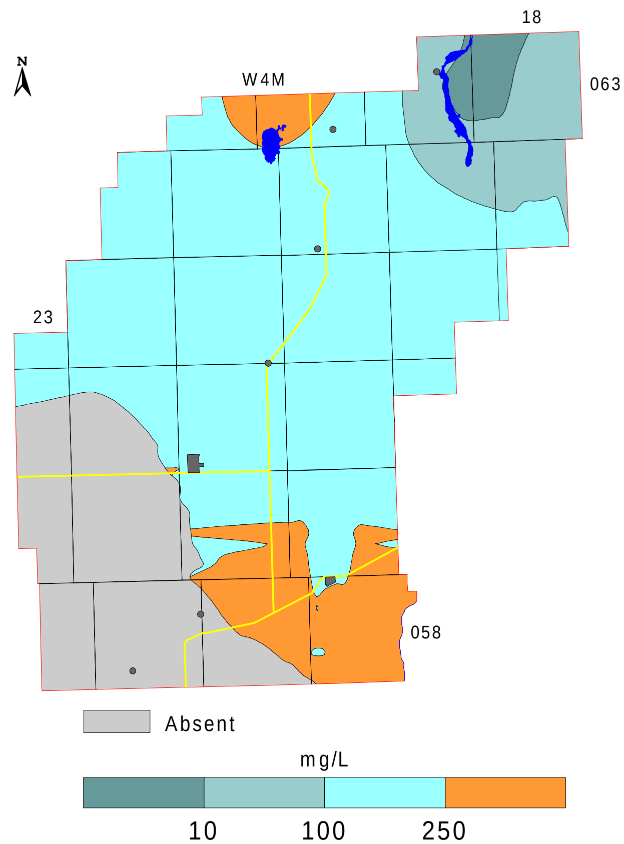

Figure 18. Chloride in Groundwater from marine Foremost Aquifer

In general terms, the deeper the Milan Aquifer is below ground level, the lower the yields and the higher the TDS and chloride ion concentrations. The Aquifer could be developed for domestic supplies in the northern two-thirds of the County, except in the extreme northeastern part of the County where the Aquifer is not present. In the southeastern part of the County, groundwater from the Aquifer would have limited uses without treatment because of the high TDS and high concentrations of the chloride ion; in the southwestern part of the County, the Aquifer is absent.

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 County. The aquifers include the surficial deposits as one hydraulic unit, the Buried Egremont Valley, the Oldman Aquifer, 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)
Surficial Deposits	1	0.002	50	Southeast	100
Buried Egremont Valley	20	0.002	5	Southeast	200
Oldman	5	0.002	25	South	250
continental Foremost	2	0.004	50	South/Southeast	400
Milan	5	0.002	30	Northwest/Southeast	300

The recharge to these aquifers would not be restricted to the County of Thorhild.

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 0.2 to 1.5 cubic kilometres. This volume is based on an areal extent of 2,100 square kilometres and a saturated sand and gravel thickness of two 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 all water wells completed in aquifers in the surficial deposits, except in the vicinity of the Buried Egremont Valley. In the vicinity of the Buried Egremont Valley, only the water levels from water wells completed in the deeper sand and gravel deposits have been included.

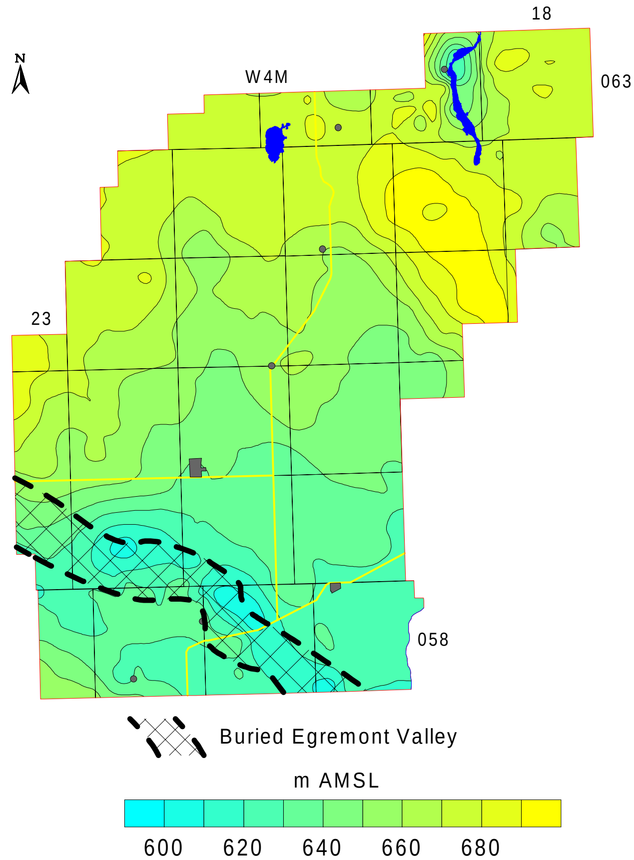

Figure 19. Non-Pumping Water-Level Surface in Surficial Deposits

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.

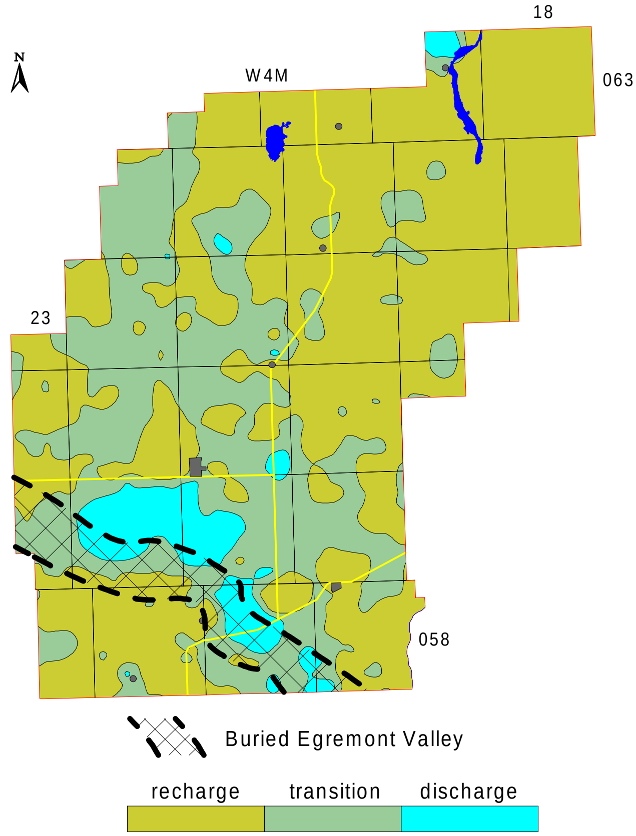

Figure 20. Recharge/Discharge Areas between Surficial Deposits and Upper Bedrock Aquifer

The adjacent map shows that in more than 60% of the County there is a downward hydraulic gradient between the surficial deposits and the upper bedrock aquifers. Areas where there is an upward hydraulic gradient are mainly associated with lows in the bedrock surface. This appears to be the situation in the southwestern part of the County, where the Buried Egremont Valley is present. The other parts of the County where there is either transition or discharge may indicate the presence of meltwater channels.

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 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. 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.

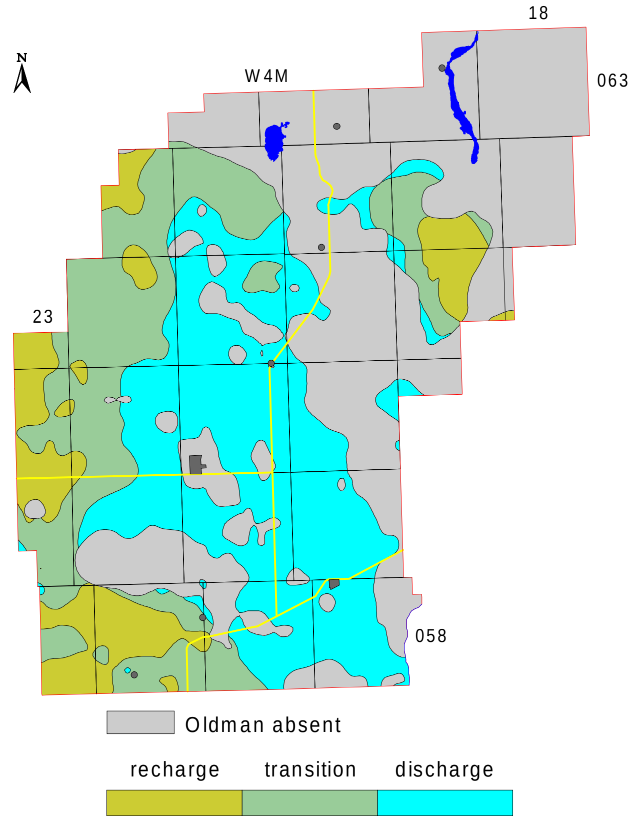

Figure 21. Recharge/Discharge Areas between Surficial Deposits and Oldman Aquifer

The hydraulic relationship between the surficial deposits and the Oldman Aquifer indicates that in 50% of the County where the Oldman is present, there is an upward hydraulic gradient. The presence of a discharge area at the eastern extent of a formation is not uncommon; what is uncommon in this situation is the size of the area where the upward hydraulic gradient exists. Since the main flow in the Aquifer is toward the south, the upward hydraulic gradient over the large area may be a result of the lower permeability in the surficial deposits.

The recharge/discharge configuration for the *continental* Foremost Formation and the surficial deposits shows discharge from the bedrock in the general area of the Buried Egremont Valley. The extensive areas of transitional flow suggest that meltwater valleys or sandstone channels in the bedrock may be present. All of the transmissivity values of greater than 9 m²/day occur in the transitional area of the *continental* Foremost Formation.

The hydraulic relationship between the surficial deposits and the Milan Aquifer shows that throughout almost all of the County there is a downward hydraulic gradient.

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, the 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 1,255 records in the area of the County with lithology descriptions, 130 have sand and gravel within one metre of ground level. In the remaining 1,125 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.

7.1.1 Risk of Contamination Map

The information from the reclassification of the surficial geology map is the basis for preparing the initial risk map. The depth to the first sand and gravel is then used to modify the initial map and to prepare the final map. The criteria used for preparing the final Risk of Groundwater Contamination map are outlined in the adjacent table.

Surface Permeability	Sand or Gravel Present Top Within One Metre Of Ground Surface	Groundwater Contamination Risk
Low	No	Low
Moderate	No	Moderate
High	No	High
Low	Yes	High
Moderate	Yes	High
High	Yes	Very High

Table 2. Risk of Groundwater Contamination Criteria

The Risk of Groundwater Contamination map shows that, in less than 25% of the County, there is a high or very high risk of the groundwater being contaminated. These areas would be considered the least desirable ones for development that has a product or by-product that could cause groundwater contamination. However, because the map has been prepared as part of a regional study, the designations are a guide only; detailed hydrogeological studies must be completed at any proposed development site to ensure the groundwater is protected from possible contamination. At all locations, good environmental practices should be exercised in order to ensure that groundwater contamination would not affect groundwater quality.

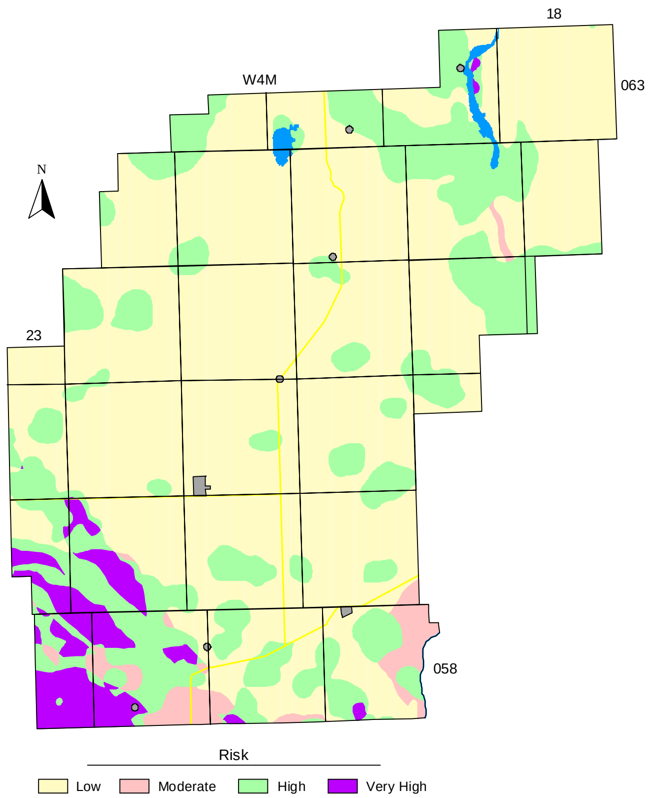

Figure 22. Risk of Groundwater Contamination