5.3.2.1 Chemical Quality of Groundwater

The total dissolved solids (TDS) concentrations in the groundwater from the upper bedrock aquifers range from 300 to 3,000 mg/L. In more than 50% of the area, TDS values range from 1,000 to 2,000 mg/L. The values remain less than 1,000 mg/L in the eastern part of the County.

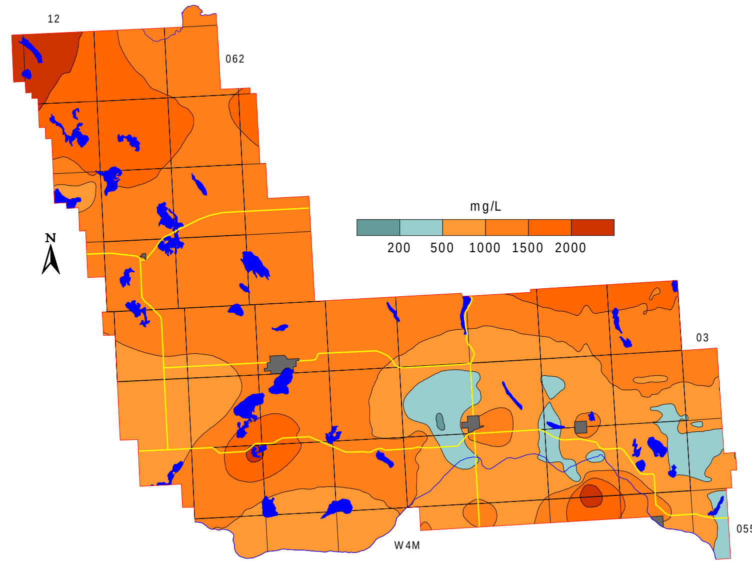

Figure 13. Total Dissolved Solids in Groundwater from Upper Bedrock Aquifer(s)

The low TDS areas west and east of Elk Point correspond to locations where lows in the bedrock surface, resulting from meltwater channels, are present. In the northwestern part of the County, where the upper bedrock is the Lea Park Formation, the TDS concentrations are expected to exceed 2,000 mg/L. The higher TDS values southwest of the Town of St. Paul occur in an area where the upper bedrock is the *continental* Foremost Formation. A relationship between TDS and sulfate concentrations shows that when TDS values exceed 1,200 mg/L, the sulfate concentration exceeds 400 mg/L.

The Piper tri-linear plots show that all chemical types of groundwater occur in the bedrock aquifers. However, the majority of the groundwaters are a sodium-bicarbonate type.

5.3.3 *Continental* Foremost Aquifer

The *continental* Foremost Aquifer is part of the *continental* Foremost Formation, which underlies approximately two thirds of the County. However, there are only eight water wells completed in the *continental* Foremost Aquifer north of township 058. The majority of the water wells completed in the *continental* Foremost Aquifer are south of the Town of St. Paul.

5.3.3.1 Depth to Top

The depth to the top of the *continental* Foremost Aquifer is mostly less than 100 metres. The largest area where the top of the *continental* Foremost Aquifer is more than 100 metres below ground level is in township 059, range 10, W4M, north of the Buried Beverly Valley.

5.3.3.2 Apparent Yield

The projected long-term yields for individual water wells completed through the *continental* Foremost Aquifer vary from less than 50 to more than 100 m^3/day. The higher yields are mainly in the central part of the County, south and east of the Town of St. Paul. This area is on the south side of the Buried Beverly Valley and also is an area where the depth to the top of the Lea Park Formation is at its greatest. The higher yield areas appear to be related to weathering or fracturing.

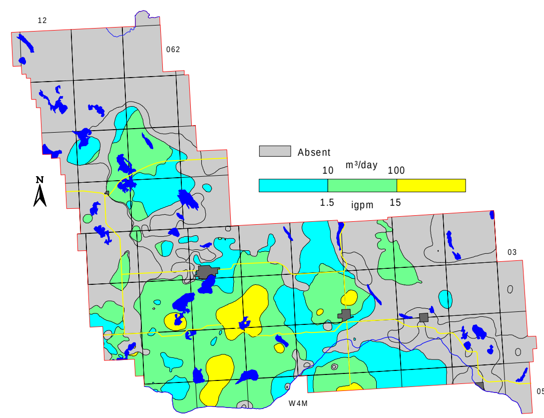

Figure 14. Apparent Yield for Water Wells Completed through* continental *Foremost Aquifer

The low-yield area between the towns of Elk Point and St. Paul corresponds to an area where the *continental* Foremost Aquifer is more than 50 metres thick but where there appears to be little or no fracturing or weathering of the *continental* Foremost Formation.

5.3.3.3 Quality

The Piper tri-linear plots show that all chemical types of groundwater occur in the *continental* Foremost Aquifer. However, the majority of the groundwaters are sodium-bicarbonate or sodium-sulfate types.

The TDS concentration ranges from less than 500 to over 2,000 mg/L in the *continental* Foremost Aquifer. The groundwaters with a TDS of less than 500 mg/L occur west and north of the Town of Elk Point. Groundwaters with a TDS of over 1,000 mg/L can be expected in the central part of the area in townships 056 and 057, ranges 09 and 10, W4M. When TDS values exceed 1,200 mg/L, the sulfate concentrations exceed 400 mg/L.

Very few chemical analysis results indicate a fluoride concentration above 1.0 mg/L.

The chloride concentration of the groundwater from the *continental* Foremost Aquifer ranges from less than 10 to over 100 mg/L. In the central part of the County, the chloride concentration is less than 10 mg/L, while in the northern and southern parts of the County, higher chloride concentrations occur.

5.3.4 Lea Park "Aquitard"

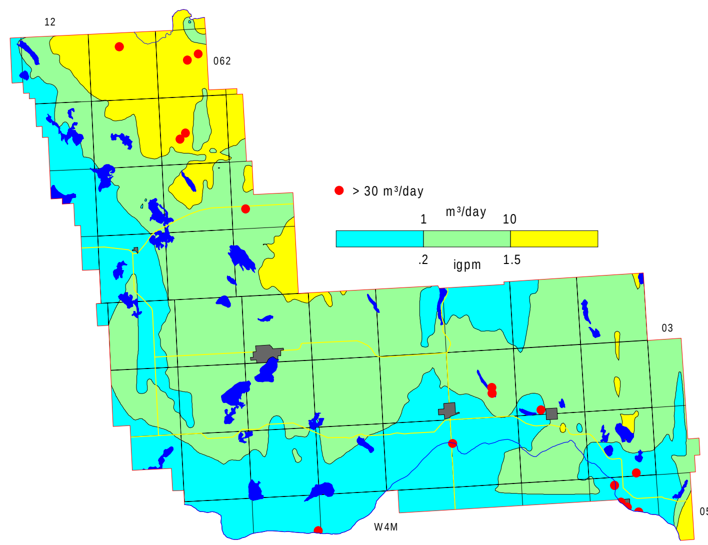

Figure 15. Apparent Yield for Water Wells Completed through Lea Park "Aquitard"

The Lea Park Formation is mostly composed of shale with only minor amounts of bentonitic sandstone present in some areas. Generally the Lea Park Formation is an aquitard. Since there are water wells completed in the Lea Park, the designation "aquitard" is being used to indicate that the Lea Park Formation can be permeable under special conditions. These conditions would include weathering and/or fracturing. The adjacent map shows that water wells completed in the Lea Park Formation are expected to have lower yields in the western and southern parts of the County. The control points in the northeastern and southeastern parts of the County are locations where the projected long-term yields for existing water wells exceed 30 m^3/day, with some water wells having projected yields of several hundred cubic metres per day.

The existence of water wells completed in the Lea Park Formation is an anomalous condition based on the geology of the Formation. The high projected yields could be the result of collapsed structures and fracturing associated with the collapse process. It is also possible for the collapsed blocks to contain some of the Foremost Formation, which together with a high degree of fracturing and weathering, could be responsible for high transmissivity values and hence the high projected water well yields.

The TDS of the groundwater from the Lea Park Formation can be more than 3,000 mg/L. In the southern part of the County, near the North Saskatchewan River, the TDS concentration is less than 1,000 mg/L. These lower values are a result of the "flushing" of the aquifer by short, active groundwater flow systems. In the northern part of the County, the TDS are greater than 1,000 mg/L because of slower, longer groundwater flow paths.

6 GROUNDWATER BUDGET

Estimation of the groundwater budget for the sand and gravel aquifers and the bedrock aquifers requires different methods. This is because recharge to and discharge from the bedrock aquifers is mainly through the surficial deposits while most of the recharge to and discharge from the surficial deposits is from the land surface.

6.1 Aquifers in Surficial Deposits

The groundwater in the surficial deposits is the net result of recharge to and discharge from these deposits. The recharge is mainly from precipitation, although some groundwater enters the surficial deposits from the underlying bedrock. The discharge includes losses to bedrock aquifers, discharge from springs, evapotranspiration, and discharge from water wells. The change in the quantity of groundwater in the surficial deposits is apparent from the change in the water level associated with individual aquifers within the surficial deposits. Often these water-level changes are measured and recorded in water wells intended specifically for that purpose; these water wells are referred to as observation water wells. When a graph of the changes with time is prepared, it is referred to as a hydrograph.

6.1.1 Hydrographs

There are two observation water wells in the County where water levels are being measured and recorded with time. These observation water wells are part of the AEP groundwater-monitoring network. One of the observation water wells is in the west-central part of the County in 12-12-059-11 W4M (AEP Obs WW No. 392). This observation water well is completed in the Lower Sand and Gravel Aquifer in the depth interval from 120 to 128 metres below ground level. Water-level measurements are available from this observation water well from 1993 to 1996. Over this time frame, there has been a general decline in the water level of 0.3 metres.

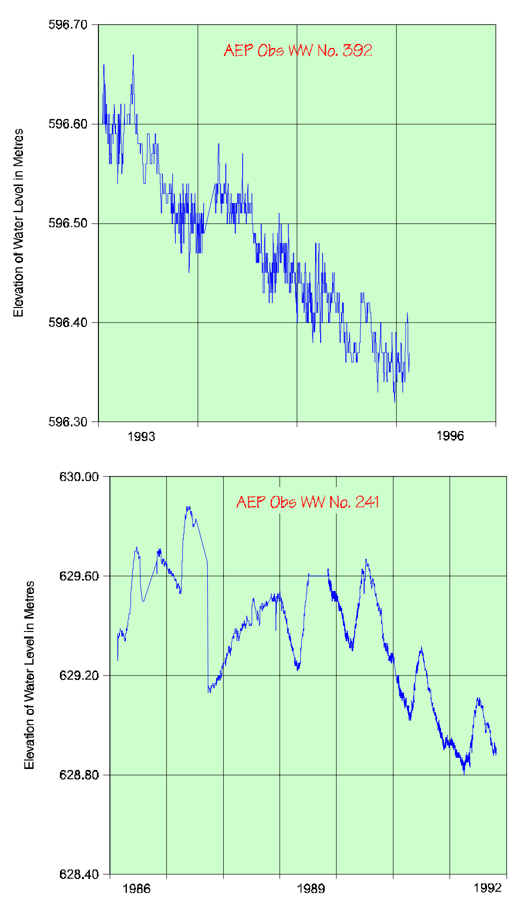

Figure 16. Hydrographs 392 and 241

The second observation water well is in the southern part of the County in 08-34-055-06 W4M (AEP Obs WW No. 241). The observation water well is 36.0 metres deep and is completed partially through the Upper Sand and Gravel Aquifer and partially through the upper bedrock, which is the *continental* Foremost Formation. Water levels were measured and recorded in this observation water well between 1986 and 1992. In 1987, there appears to be a discontinuity in the water-level record. Late in the year, the water level shows a decline of more than 0.5 metres in a day. Undoubtedly, this change was a result of re-calibration of the recording equipment. In late 1989, part of the water-level record is missing. Because of these breaks, it is difficult to determine what has been happening to the water level over the seven years of record. However, between 1990 and 1992, the water level did decline slightly more than 0.4 metres.

The 1989, 1990, 1991, and 1992 water-level changes in the AEP Obs WW No. 241 show a typical annual fluctuation in water level. This change includes a rise in the water level in late spring/early summer and then a decline in the water level from mid-summer to late-spring/early-summer of the following year. In 1989 and 1990, the rise in water level was more than 0.4 metres; in 1991 and 1992, the rise was approximately 0.3 metres. The rise in water level in late spring/early summer occurs after the frost has left the ground.

6.1.2 Quantity of Groundwater

An estimate of the volume of groundwater stored in the sand and gravel aquifers in the surficial deposits is one to four cubic kilometres. This volume is based on an areal extent of 3,200 square kilometres and a saturated sand and gravel thickness of four 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).

Because the sand and gravel deposits are mainly confined aquifers, the change in water level in the aquifer remains a function of the storativity of the aquifer rather than the porosity. The storativity values for the sand and gravel range from 8.9×10^{-4} to 2.2×10^{-4}. Based on a storativity value of 5×10^{-4}, and an available drawdown[13] of 20 metres, a total volume of available groundwater from the confined aquifer is 0.03 cubic kilometres.

If the decline in water level in the AEP Obs WW No. 392 were representative of the entire County, the 0.3-metre decline in three years would represent a 480,000 m^3 decrease in the volume of groundwater in the aquifers. This decrease would be 1.6% of the estimated available groundwater from the sand and gravel aquifers without using the groundwater stored in the aquifer proper. The decrease in the volume of groundwater represented by the water-level decline could be a result of either a decrease in recharge or an increase in discharge.

The groundwater in the Lower Sand and Gravel Aquifer in the Buried Beverly Valley flows from west to east. Based of an average transmissivity of 30 m^2/day, a gradient of 0.004, and an average valley width of ten kilometres, total estimated flow for the Buried Beverly Valley is 1,200 m^3/day.

6.1.3 Recharge/Discharge

The hydraulic relationship between the groundwater in the sand and gravel aquifer and the groundwater in the bedrock aquifer is given by the non-pumping water levels 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.

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[13] See glossary