SWAN LAKE INTEGRATED WATERSHED MANAGEMENT PLAN

GROUNDWATER RESOURCES AND ISSUES

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Introduction

Groundwater forms the primary source of rural, municipal and industrial water supply in the Swan Lake watershed. It also provides base flow to rivers and creeks and is an important component in sustaining many of the area's wetlands. Several extensive bedrock aquifers exist but in parts of the watershed the groundwater quality in these aquifers is saline or deteriorates rapidly with depth. Surficial sand and gravel aquifers are also present in some areas but, while some of these aquifers are very productive, most appear to have limited extent.

This summary of the geology and hydrogeology of the watershed is taken primarily from previous studies. Regional groundwater mapping of the Swan Lake 1:250,000 map sheet area was conducted by Betcher (1991) and mapping of the Duck Mountain 1:250,000 map sheet was done by Little and Sie (1976). Rutulis (1984) discussed the hydrogeology of the Swan River Formation in Manitoba. There have been a number of studies of the salt springs found in the northern part of the watershed including Cole (1949) and van Everdingen (1971). The surficial geology of the area was mapped by Nielsen (1988). The bedrock geology is summarized on a 1:1,000,000 map prepared by the Manitoba Mineral Resources Division (1979).

Geology

The topography of the western part of the watershed is dominated by the Duck Mountain and Porcupine Hills upland areas which are separated by the Swan River valley. The steep easterly slopes of the uplands grade to the west into a relatively flat lying plain known as the Westlake Plain. The Swan River valley is thought to have been formed by an eastward flowing river during the Tertiary (about 65 million to 2 million years ago).

The youngest bedrock units in the watershed are found beneath the upland areas of the Porcupine Hills and Duck Mountain on the west and extend to the base of the eastern escarpments of these uplands (see Figures 1 and 3). These rocks consist primarily of relatively soft bentonitic shale. As the land surface elevation decreases to the east, bedrock is composed of progressively older sediments (the youngest sediments lie at the top of the rock sequence with older sediments below) although shale remains the predominant lithology. Near the base of the escarpments the bedrock lithology changes to an interlayered sequence of sandstone and shale which extends further to the east. This geologic unit is known as the Swan River Formation and forms an important aquifer in the watershed. The Swan River Formation is underlain by much older bedrock composed of limestone, dolostone and shale. These rocks form the bedrock surface in the vicinity of Swan Lake. The bedrock geology is shown in plan view in Figure 1 and in an east-west cross-section in Figure 3. Note that a few test holes in the upland areas have intersected sandy to silty sediments lying at the till/bedrock contact. These are believed to be remnants of the Wynyard Formation which was deposited during the Tertiary. The extent of these sediments is unknown.

Bedrock is overlain by a variable thickness of overburden throughout the watershed, although there are a few very local areas where bedrock is found at ground surface. Overburden thickness varies from being absent where bedrock outcrops occur to as much as 300 meters or more below parts of Duck Mountain and the Porcupine Hills. The overburden is primarily composed of till (see Figure 2) which was deposited during a series of glacial advances and retreats over the past 2 million years. Till consist of unsorted mixtures of clay, silt, sand, gravel and boulders. Within or lying on the till we find scattered lenses or layers of sand and gravel which formed as outwash deposits in areas where large volumes of water flowed from the nearby glaciers.

Somewhat younger sediments, related to glacial Lake Agassiz which formed behind the most recent ice sheet as it retreated to the north and a second glacial lake which formed in the Swan River valley, are found overlying the till in the topographically lower parts of the watershed, particularly in the Swan River valley. These are mostly lacustrine (formed within lakes) sediments consisting of flat lying layers of clay, silt and sand. Sand deposits are also found along the lower flanks of Porcupine Mountain and south of Swan Lake. The sand deposits are ancient beaches that formed at the edges of Lake Agassiz as the lake level rose and fell. The youngest unconsolidated deposits, consisting of alluvial and organic materials, overlie the glacial and lacustrine sediments west of Swan Lake. See Figure 2 for a map of the surficial geology of the watershed and adjacent areas.

Hydrogeology

The geologic units discussed above can be divided into two hydrogeological classes: aquifers or aquitards. An aquifer is a geologic unit that can provide useful quantities of water to wells completed in the unit while an aquitard is less permeable and will not provide useful quantities of water to wells. In the Swan River watershed we find aquifers formed both by bedrock and overburden units. Bedrock aquifers consist of limestone and dolomite forming what is known as the Carbonate aquifer and by sandstones of the Swan River Formation which are termed the Swan River aquifer. Shale is generally not sufficiently permeable to form an aquifer although in some parts of the watershed the shale is fractured and low-capacity wells may be installed. Typically though, we would consider shale to be an aquitard. Sands or sand and gravel layers or lenses in the overburden form aquifers, although a sand or sand/gravel unit must be saturated throughout the year and sufficiently thick to form a usable aquifer. None of the overburden sand/gravel units has been formally identified with an aquifer name. Clays, tills and organic deposits are considered aquitards.

Carbonate Aquifer

The Carbonate aquifer directly underlies surficial materials in the area surrounding Swan Lake (see Figure 1) but also lies within typical well construction depths beneath the Swan

River aquifer in the Westlake Plain, much of the Swan River valley and the lower parts of the Manitoba Escarpment. Water well records have been submitted for only a few dozen wells drilled into the aquifer in this watershed (see Figure 4). Reported well yields range from about 1 gpm to 40 gpm. There is little known about where recharge occurs to this aquifer or where it discharges.

Groundwater quality in the Carbonate aquifer is poor throughout most of its extent with total dissolved solids (TDS) contents typically exceeding 1000 mg/L and increasing to 3,000+ mg/L in the Swan River valley. Groundwaters with a TDS content exceeding about 1000 mg/L are generally undesirable as a drinking or household water source; groundwater with a TDS content above 2000 mg/L will likely have a salty taste in this area. It is expected that water quality in the aquifer will decline significantly with depth although there is little sampling information to support this.

Numerous salt springs occur near Dawson Bay and on the west side of Swan Lake. These springs discharge directly from exposures of the aquifer or in areas where the aquifer is covered by shallow overburden. It is believed that the springs are associated with ancient reef structures in the bedrock which allow upwelling of deeper saline waters. The salt springs have salinities near to that found in sea water or even higher and are remarkable natural features, little known outside the local area. Water from some of these springs or from shallow wells dug near the springs was evaporated and the residual salt shipped south by York Boats and Red River carts to the settlement areas near Portage and Winnipeg from about 1818-1874.

Swan River Aquifer

Sandstone beds in the Swan River Formation form the most utilized aquifer in the watershed and surrounding areas. The aquifer extends east and north from the Manitoba Escarpment and underlies the Swan River valley (Figure 1). The aquifer is also accessible at typical well construction depths from the lower parts of the Escarpment. The Swan River aquifer is the source of water for several hundred farm, business and rural properties in the watershed including the Louisiana Pacific OSB plant (Figure 4). It is also the water source for municipal water systems supplying the Town of Minitonas and the village of Bowsman.

Regional studies indicate groundwater flow is from the topographic highs formed by the Porcupine Hills and Duck Mountain toward the topographic lows formed by the major lakes. The Swan and Woody Rivers are thought to be significant discharge areas as outcrops of the aquifer have been mapped along these rivers. Yields from wells completed into the aquifer are quite variable, depending on the thickness, grain size and cementing of the sandstone layers intersected by the well. Reported yields range from about 1 gpm to 100 gpm with a mean of about 20 gpm.

Groundwater quality is also quite variable. Total dissolved solids concentrations in analyses available in the Water Stewardship data base range from 316 mg/L to 15,000 mg/L (Figure 5). Most wells produce groundwater with a TDS in excess of 1000 mg/L.

As discussed previously, groundwaters with a TDS in excess of 1000 mg/L are generally undesirable from an aesthetic standpoint. Groundwaters frequently contain elevated sodium and sulphate concentrations although these groundwaters may be quite "soft" and desirable for household uses since a water softener is not needed. Spatial trends in water quality are not clear – there is an expectation that water quality should deteriorate with depth in the aquifer but this has not been well established. There also seem to be "pockets" of groundwater with distinct properties, likely reflecting local recharge conditions where the pockets are of fresh water and undisturbed older groundwaters where the water is saline.

Sand and Gravel Aquifers

Sand and gravel aquifers are widely distributed in the watershed although they have been formed in a variety of geological settings. Shallow sands are found inter-layered with silts and clays throughout much of the Swan River valley and along the base of the Porcupine Hills. Well yields are generally low and many wells in these areas are completed as large diameter construction to take advantage of well bore storage. Deeper sand and gravel aquifers are found in many areas, usually as inter-beds or outwash within the glacial tills. Well yields may be substantial from some of these aquifers, such as the thick gravels which form the source of water supply for the Town of Swan River.

Groundwater quality is again quite variable but in many areas the shallow sands have TDS concentrations less than 600 mg/L. Water quality in deeper sands ranges from about 500-3000 mg/L which appears to reflect whether the aquifer receives recharge from the surface (low TDS) or not (high TDS).

Drinking Water Quality Issues

Health-based drinking water quality guidelines (Guidelines for Canadian Drinking Water Quality 2008 published by Health Canada) are exceeded in some samples from private wells. Boron and fluoride have been found at elevated concentrations, mostly in samples of "soft" water from wells completed into the Swan River aquifer. Nitrate has also been found to exceed the 10 mg/L guideline in a number of samples, primarily from shallow wells into the Carbonate aquifer or shallow wells into sand/gravel aquifers. Nitrate may be introduced into an aquifer by downward seepage from farm fields, manure storage areas, livestock pens, septic fields or other sources. A sampling program conducted by the province in 1999 and 2000 found many of the shallow sand and gravel wells in the watershed produce water containing coliform bacteria. Coliform contamination is generally related to well maintenance and construction – large diameter shallow wells are rather notorious for contamination by bacteria.

Many of the wells in the watershed also produce water which exceeds aesthetic drinking water guidelines. Sulphate, sodium and chloride are found naturally at elevated concentrations in many wells, particularly bedrock wells. Sulphate can have a laxative effect on some users while sodium and chloride can cause a salty taste to the water. Iron and, to a lesser extent, manganese is also found to exceed aesthetic guidelines in some wells from all aquifers. These elements can cause staining of laundry and plumbing fixtures and may build up the well and reduce pumping efficiency or lock submersible pumps to the casing. Water hardness is an issue as well – the hardness of many groundwaters is high enough that in-home water treatment is necessary to combat excessive soap usage and other issues associated with hard waters.

Groundwater Monitoring

The Groundwater Management Section of Manitoba Water Stewardship currently operates 6 groundwater monitoring wells within the watershed. Water levels are recorded on a continuous basis in each of the wells. The longest water level record is for a monitoring well completed into the Swan River aquifer near Bowsman which was installed in 1964. A second observation well is located near the Minitonas town well, again completed into the Swan River aquifer, with water level records dating to 1995. In 1995 the province also installed 4 monitoring wells, 3 into the Swan River aquifer and one into coarse gravel overlying the Swan River aquifer, to monitor water level changes associated with groundwater withdrawal by the Louisiana Pacific OSB plant. The locations of the 6 monitoring wells are shown in Figure 6.

Water levels in all observation wells, except perhaps for the well installed into coarse gravel near the Louisiana Pacific facility, are affected to some degree by pumping which masks natural water level fluctuations. Water levels in all the monitoring wells have been relatively stable over the period of record, indicating that none of the systems being monitored is removing more water than the local aquifer can sustain. Monitoring results from the observation well near the Minitonas municipal well are shown on Figure 7.

No regular monitoring of groundwater quality has been carried out in any of the observation wells. Water quality changes in most groundwater systems occur very slowly, particularly where the aquifer is well protected from surface contaminants by a thick layer of overlying clayey material such as we find for the Swan River aquifer.

** Note – there is no data included regarding the report on groundwater monitoring which may be carried out near potential sources of contamination either voluntarily by the owner or as required by an Environment Act licence. For instance, the EA licence for Louisiana Pacific requires water quality monitoring to be carried out in a number of on-site monitoring wells. Manitoba Conservation may include this in their part of the report. You may wish to amalgamate the two discussions of groundwater monitoring or put in a note that monitoring is covered in two separate reports.

Groundwater Sustainability and Vulnerability

While no formal studies of groundwater recharge rates have been carried out on any of the aquifers in the watershed, on a regional scale the current rates of fresh groundwater withdrawal are undoubtedly only a very small fraction of the amount of groundwater in storage and the amount being recharged on an annual basis. Limits to sustainability for individual projects may nonetheless be encountered if very large volumes of water are withdrawn, in some situations where the aquifer is bounded by low-permeability materials (for instance, a sand/gravel aquifer entirely contained within glacial till) or where withdrawal may lead to deterioration in groundwater quality. In aquifers or portions of aquifers where these situations may exist, careful study may be required to assess the long-term sustainability of a proposed development.

Water levels in monitoring wells near the Minitonas, Bowsman and Louisiana Pacific pumping centers appear to show stabilized drawdown cones although interpretation of the water level information is hindered by the absence of monitoring information away from pumping centers ("background" water level changes due to weather and climatic changes) and actual consumptive groundwater use over time. Installation of several additional monitoring wells to provide information on background water level changes in the major aquifers would be useful.

Groundwater vulnerability refers to the relative ease by which a contaminant can migrate from near the ground surface into an underlying aquifer. In Manitoba we have generally considered an aquifer to be vulnerable to contamination if it is overlain by less than 6 m of clay-rich overburden. Groundwater vulnerability mapping was carried out in the Duck Mountain area in the late 1970's by the province but no similar mapping has been undertaking in the northern 2/3 of the watershed.

The most vulnerable aquifers are shallow sands found in much of the Swan River valley and along the Manitoba Escarpment. As well, areas where the Carbonate aquifer is found near or at ground surface will also be susceptible to contamination. This classification system is supported by the rather sparse existing water quality information which shows nitrate contamination in a number of shallow private wells completed in sands and gravels.

Sources of Additional Information

Betcher, R. N., 1991. Groundwater Availability Map Series Swan Lake Area (63-C). Manitoba Water Resources.

Cole, G. E., 1938. The Mineral Resources of Manitoba. Economic Survey Board, Province of Manitoba.

Little, J. and D. Sie, 1976. Groundwater Availability Map Series Duck Mountain Area (62-N). Manitoba Water Resources.

Manitoba Mineral Resources Division, 1979. Map 79-2 Geological Map of Manitoba, Scale 1:1,000,000.

Nielsen, E., 1988. Surficial Geology of the Swan River Area. Manitoba Energy and Mines, Geological Services. Geological Report GR80-7.

Rutulis, M., 1984. Dakota Aquifer System in the Province of Manitoba. In: Geohydrology of the Dakota Aquifer, Edited by D. G. Jorgensen and D. Signor, National Water Well Association, Worthington, D. H.

Van Everdingen, R. O., 1971. Surface-Water Composition in Southern Manitoba Reflecting Discharge of Saline Subsurface Waters and Subsurface Dissolution of Evaporites. IN: Geoscience Studies in Manitoba, Edited by A. C. Turnock, The Geological Association of Canada, Special Paper Number 9.

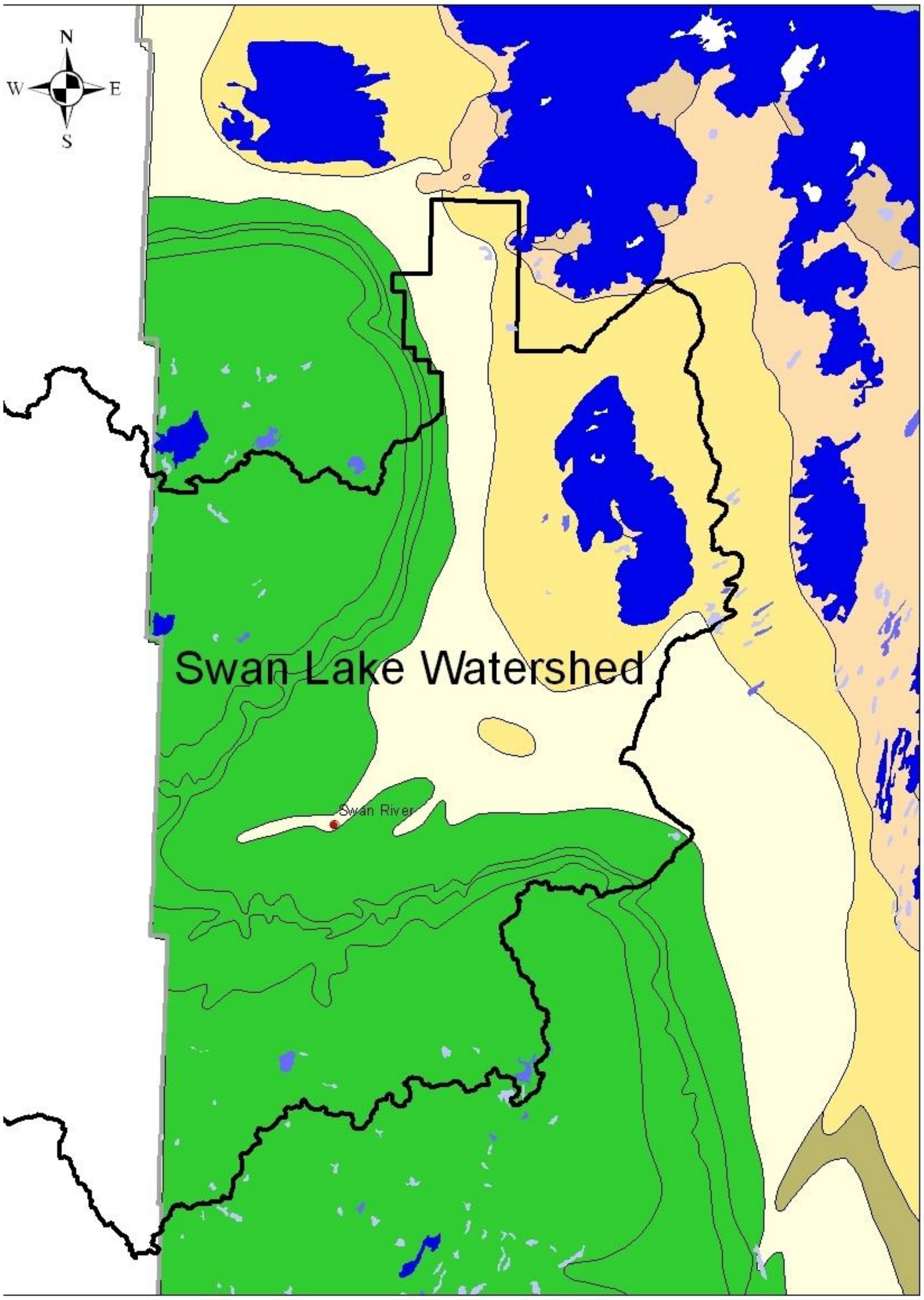

Figure 1. Bedrock geology of the watershed and area.

**** need legend to go along with the map

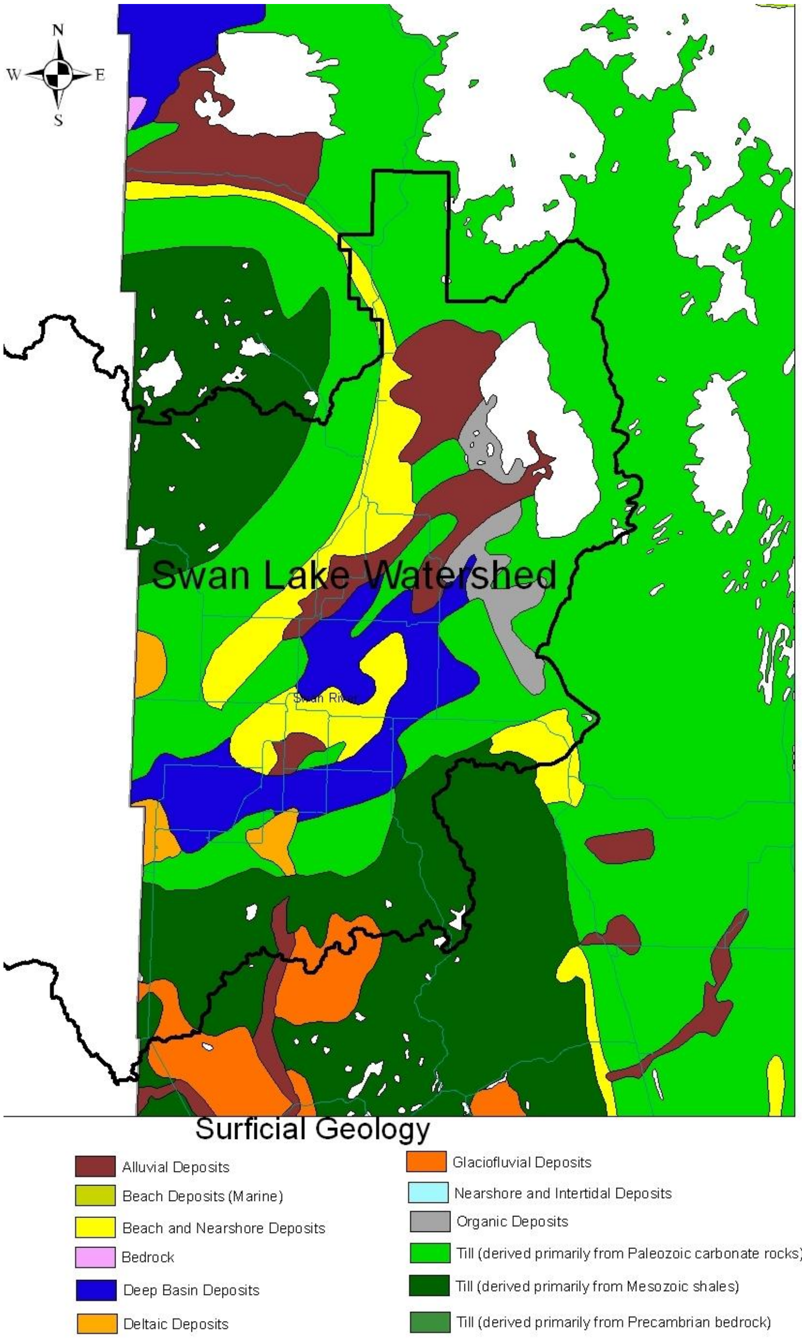

Figure 2. Surficial geology

**** need to divide this up into aquifers vs aquitard and more understandable geology

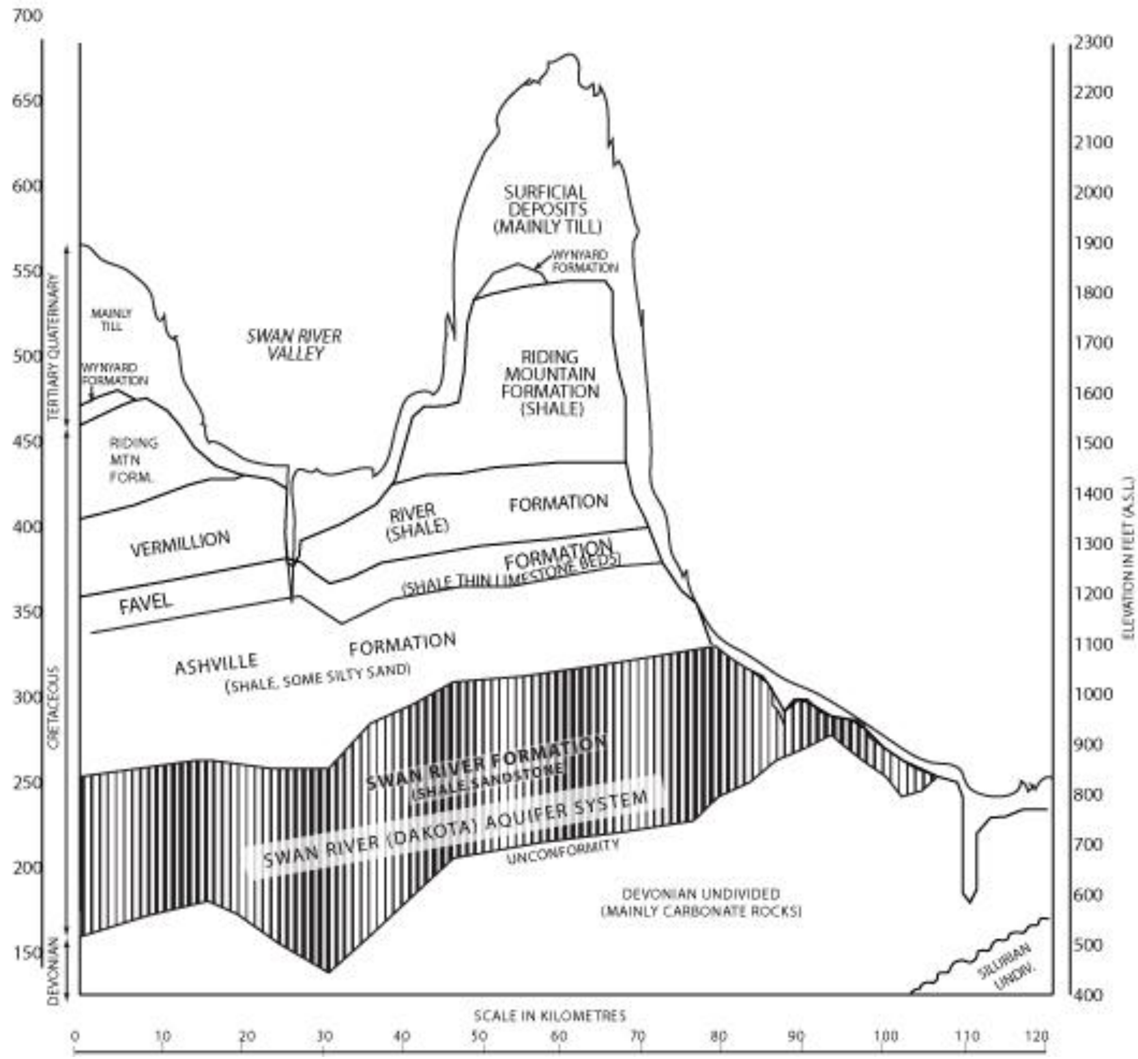

Figure 3. West to east cross-section through the watershed.

**** Show the location of the cross-section on a map

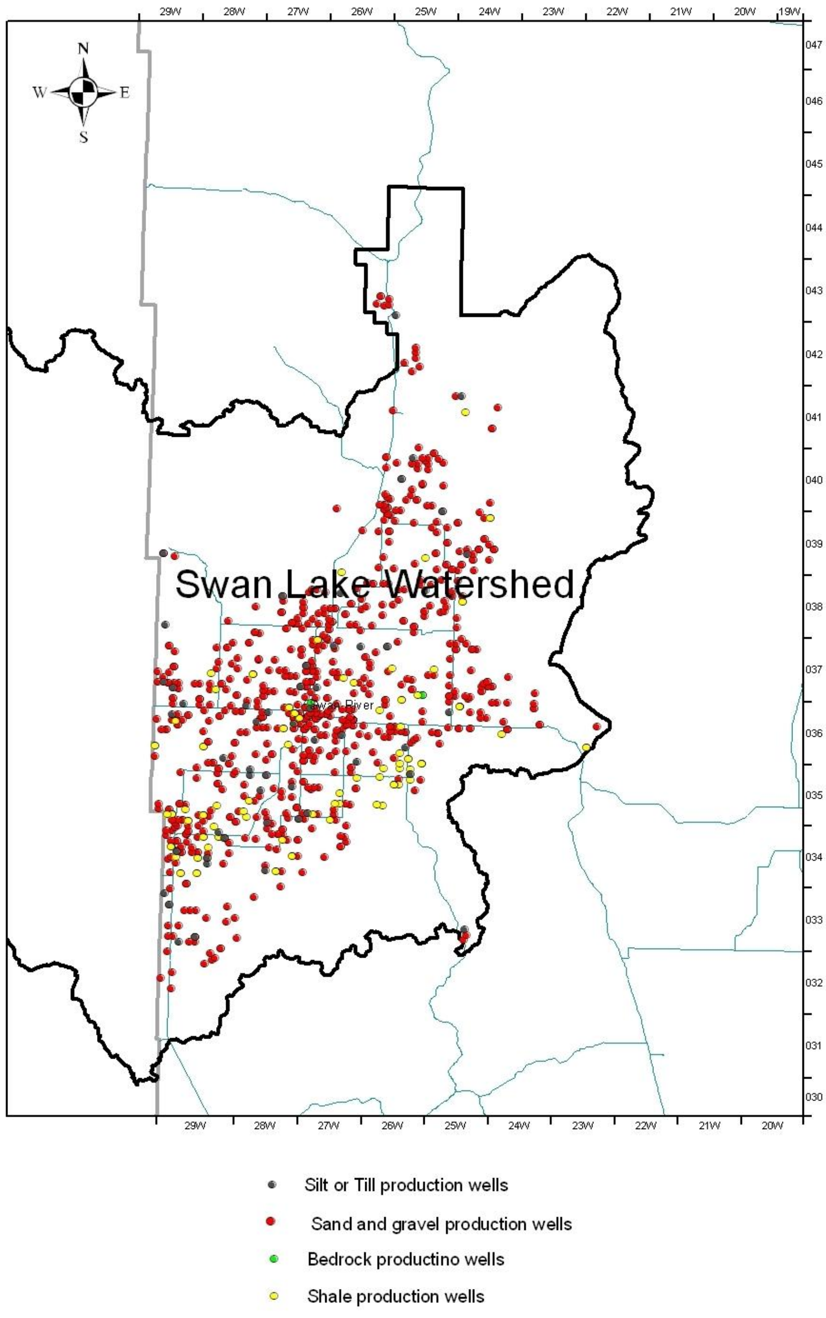

Figure 4. Distribution of water wells for which logs are on file with the province. Most water wells are completed into sandstone of the Swan River Formation or sand/gravel aquifers in the overburden.

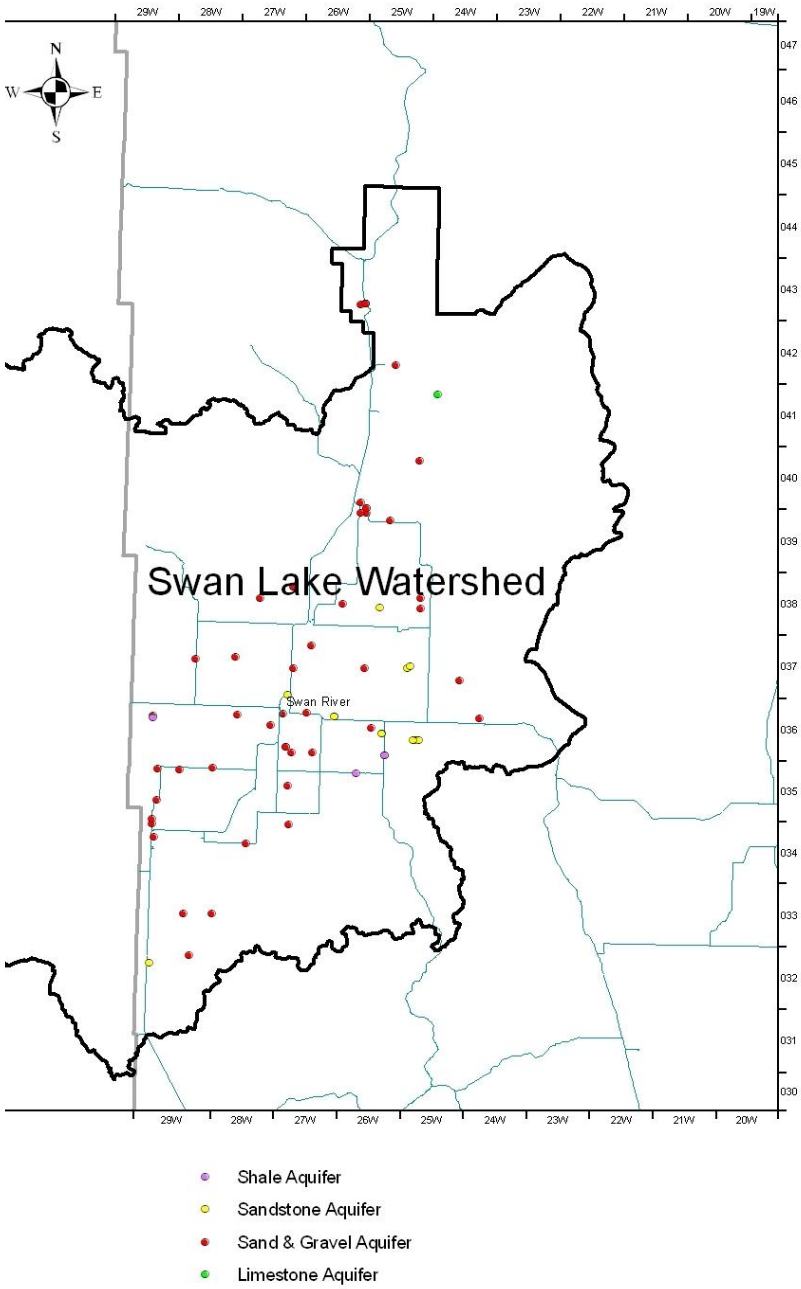

Figure 5. Total dissolved solids content of groundwater samples from all aquifers.

*** revisions needed. Show TDS by size of dot, different coloured dots for the different aquifers. Use consistent names for aquifers = Swan River aquifer, Carbonate aquifer

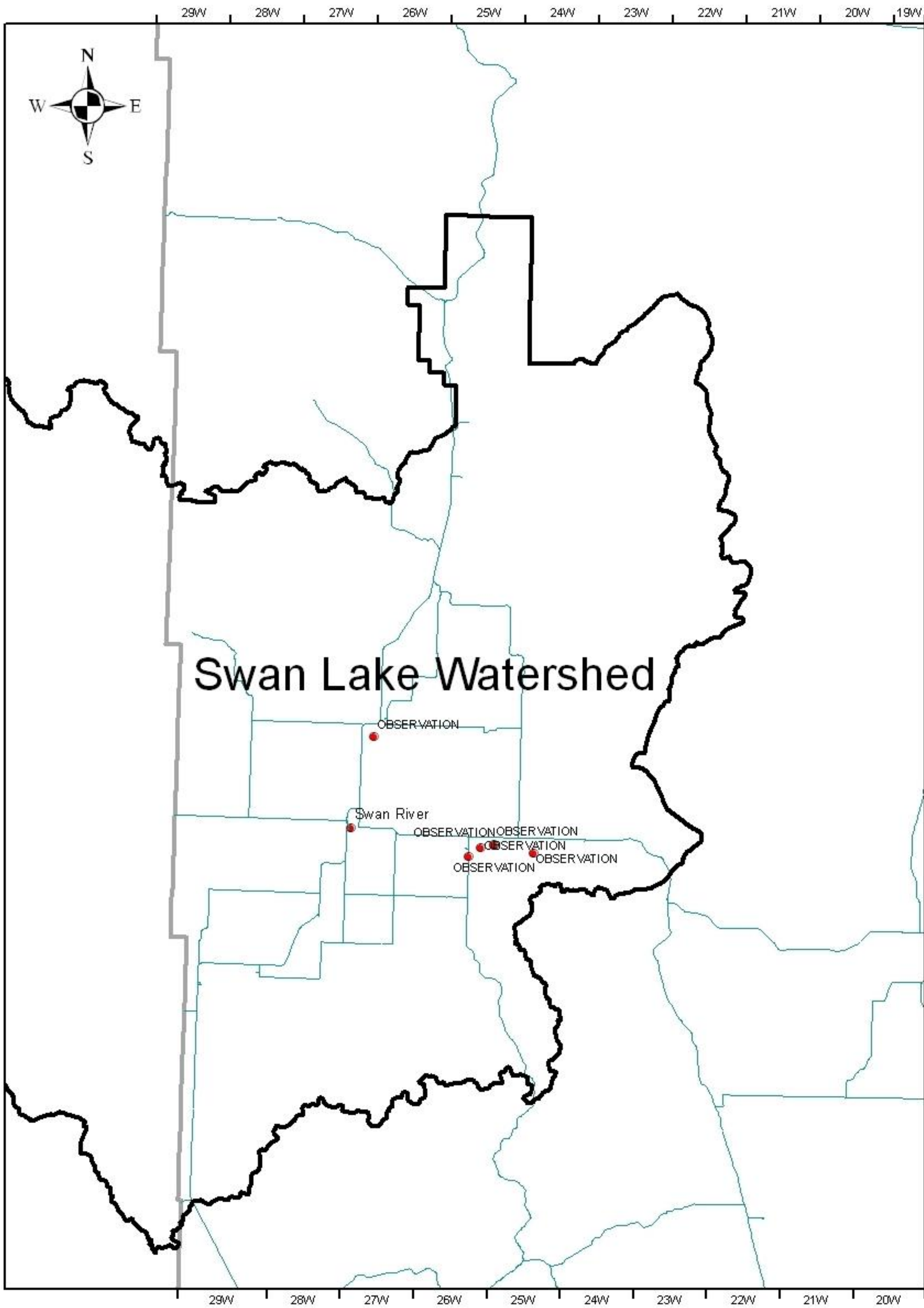

Figure 6. Locations of provincial observation wells in the watershed.

**** designated names for the monitoring wells, not just calling all of them observation

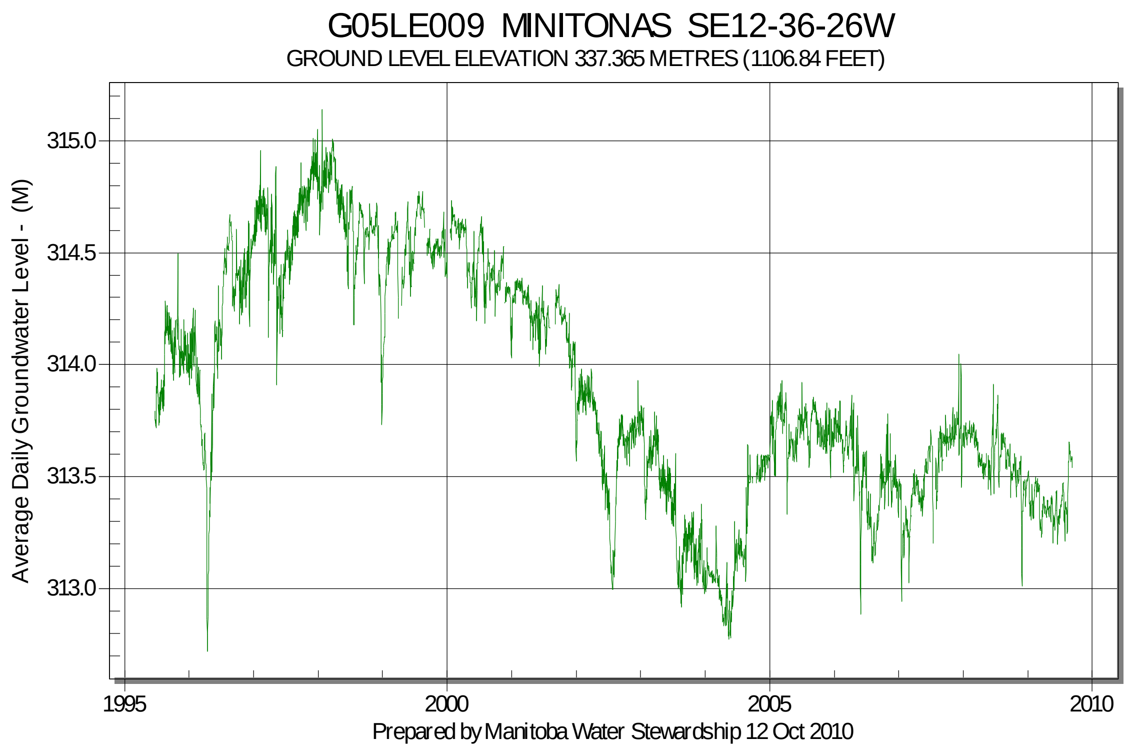

Figure 7. Groundwater levels in a provincial observation well near Minitonas. Groundwater levels are affected by pumping from the Minitonas municipal wells. Water levels have varied by about 2 m over the 15 years of record.