GROUNDWATER RESOURCES OF THE COOKS-DEVILS CREEK WATERSHED

GROUNDWATER MANAGEMENT SECTION

WATER SCIENCES & MANAGEMENT BRANCH

MANITOBA CONSERVATION & WATER STEWARDSHIP

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THE COOKS-DEVILS CREEK WATERSHED

The Cooks –Devils Creek Watershed is located north-east of Winnipeg and covers 1826 km^2. The water shed area is made up of Cooks Creek, Devils Creek, part of Red River Floodway and several smaller streams, which flow into the Red River and ultimately into Lake Winnipeg.

The watershed covers significant portions of the municipalities of Springfield, East St. Paul, St. Clements and smaller portions of the municipalities of Taché, Ste. Anne, Reynolds and Brokenhead. The watershed area also includes the north-east part of the City of Winnipeg (Figure 1).

The highest point in the watershed is located in the southeast at an elevation of 309 metres above sea level. The lowest point in the watershed is located in the north with an elevation of 214 metres above sea level. The difference in elevation between the headwaters area and the mouth of Cooks Creek is about 80 metres. Most of this change in elevation is in the upper reach of the creek before it enters the central plain area. Land use includes residential, agriculture, commercial, aggregate mining and recreation. Large areas of watershed are covered by forest and farmland.

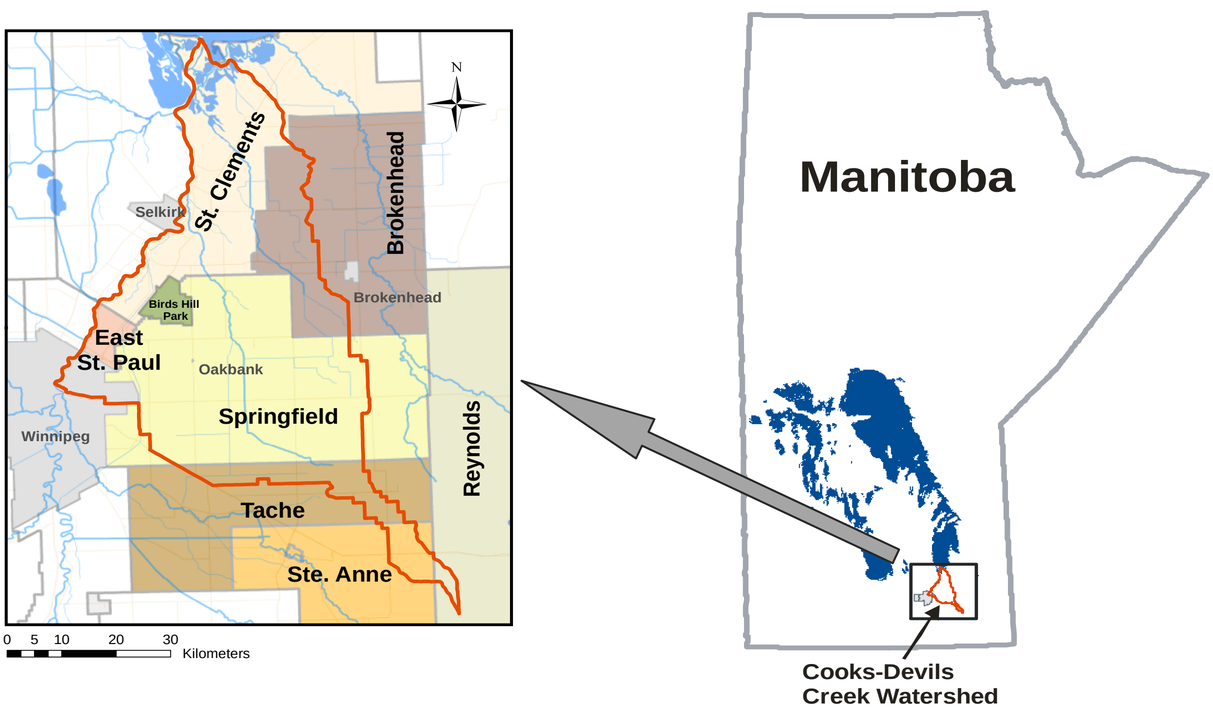

Figure 1. Location of Cooks-Devils Creek Watershed

GEOLOGY AND AQUIFERS

A considerable number of groundwater mapping studies have been undertaken in the region, including a 1:250,000 map sheet (*Betcher, 1991a; Betcher, 2007)*), studies based on the rural municipalities of St. Clements (Rutulis, 1973), Brokenhead (*Rutulis, 1979*), Tache (*Rutulis, 1984*) and Springfield (*Rutulis, 1990*) and the Cooks Creek Conservation District (*Rutulis, 1981*). More recently, groundwater was evaluated as part of a regional program in southeast Manitoba (*Wang et al, 2008*).

The geology of the watershed consists of surficial deposits overlying carbonate (limestone and dolomite) bedrock of the Red River Formation, sandstone of the Winnipeg Formation and granitic rock of the Canadian Shield (Figure 2).

Surficial deposits or "drift" are the unconsolidated geological materials over top of bedrock. Most of the drift was laid down by glaciers and is made up of units of clay till, clay and silt lake bottom sediment, sand beach ridges and glaciofluvial deposits. In most areas the drift is glacial lake bottom clay overlying silt and clay tills (Map# 1). In more elevated areas of the watershed, including the southeast portion, Birds Hill and local topographic highs we find coarser material, including sand and gravel, and glacial till.

Drift thickness is controlled by a combination of surface topography and by irregularities in the underlying bedrock surface. Drift may be anywhere from 0 to 50 metres thick (Map # 2). On average the drift thickness is in the range of 10 to 20 metres in most of the watershed. In an area of Birds Hill and South East part of the watershed it is commonly between 30 to 40 metres thick, but may approach 50 metres locally. The carbonate rock is exposed or is near ground surface in Garson and Tyndall located in the Rural Municipality of Broken Head. Surface geology is shown in Map # 1.

At the base of the drift, the bedrock is the Paleozoic Red River formation. The Red River formation is wedge shaped. It dips toward the west, while its upper surface has been eroded relatively horizontal. It is about 120 metres thick along the Red River, 30 to 60 metres thick in much of the central watershed and thins to just a few metres on the east side of the watershed (*Rutulis, 1981*). The Winnipeg Formation is about 50 metres thick. The Winnipeg Formation rests on Precambrian age crystalline igneous and metamorphic rock of the Canadian Shield and dips to the west. The depth to the top of the Precambrian slopes from 170 metres in the southwest, to 90 metres in the northeast part of the watershed (Figure 2).

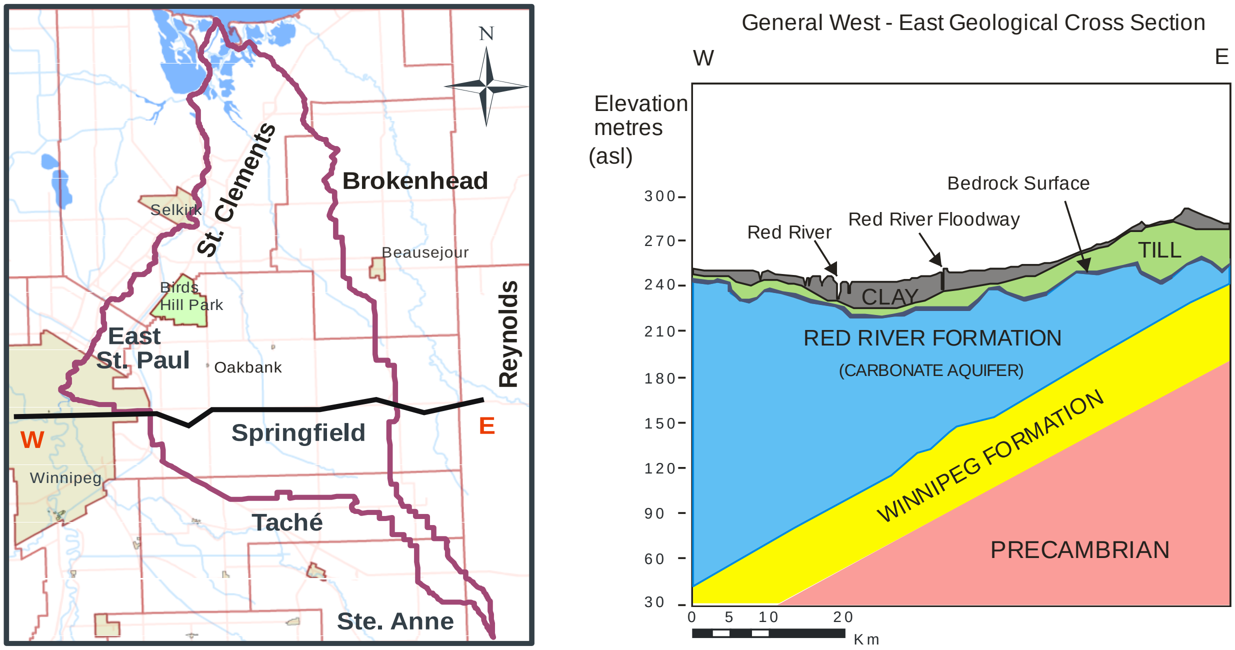

Figure 2. Aquifer Geology Map and Cross Section (*Source: Groundwater Availability Study, Winnipeg Area 1974)*

Aquifers are geological units which are porous and permeable enough to supply appreciable amounts of water to well. In most cases aquifers correspond to geological formations. Not all geological formations are aquifers. Some are aquitards, which permit groundwater to flow through them, but there is not enough flow to support a well.

Three types of aquifers are found in the Cooks-Devils Creek Watershed, which correspond to the geological units described in the previous section. In order of relative importance for water supply these are the Carbonate aquifer (Red River formation), sand and gravel aquifers and the Winnipeg sandstone aquifer. The Precambrian crystalline rock is not an aquifer in this area.

CARBONATE AQUIFER

The Carbonate aquifer is the primary source of water supply in the Cooks-Devils Creek Watershed. Nearly 90% of wells are completed in this aquifer. In most places water quality is good, and well yields are ample for domestic and agricultural uses.

The aquifer is partially confined above by the glacial drift and below by the upper shale unit of the Winnipeg Formation. In this area the Carbonate aquifer consists entirely of the Red River Formation, which is composed of limestone, dolomitic limestone, dolomite and chert. The pores, fractures and cavities found in the limestone and dolomite provide a reliable water source which is accessible throughout the entire watershed.

While variations in carbonate rock composition are influential, weathering near the bedrock surface is the overriding factor in development of porosity and permeability. Prior to glaciation, the rock was exposed to surface conditions. During this time, weathering created fractures, solution cavities, caverns and sinkholes within the rock. This weathering has given the upper surface of the bedrock an irregular surface and the rock itself good aquifer properties. The top few metres to tens of metres of rock constitute the main water-bearing zone of the Carbonate aquifer. Deeper, non-weathered water-bearing zones exist, but they are less likely to produce satisfactory amounts of water and there is a risk of deteriorating water quality with depth.

The depth to the top of the Carbonate aquifer varies from place to place and is equivalent to drift thickness. The depth ranges from 0 metres to more than 50 metres, although 10 to 40 metres is common. The variation in depth to the aquifer top (drift thickness) is the combined effect of surface topography and a weathered karst topography which forms the top of the carbonate (*Betcher, 2007*).

The static water level in the Carbonate aquifer commonly ranges from a few metres below ground in the north east part of watershed to more than 10 metres below ground level in the higher areas adjacent to Birds Hill Provincial Park. In low lying areas the water level may rise above the land surface, causing flowing wells (Map # 16).

Well yield in the Carbonate aquifer is variable but generally is in the range of 5 to 100 imperial gallons per minute (IGPM) (0.5 to 8 litres per second (L/s). In some areas the high capacity wells could yield 500 IGPM (38 L/s) to more than 1500 IGPM (115 L/s). Map #3 shows the reported test rates of individual wells completed in the Carbonate aquifer.

SAND AND GRAVEL AQUIFERS

Slightly more than 3% of wells in the watershed are completed in sand and gravel. Water quality and yields can be good, but are not consistent from one location to the next, resulting in a preference for the reliability of the Carbonate aquifer. Sand and gravel aquifers are favoured for water supply when water quality or yields in deeper aquifers are unsatisfactory, or the Carbonate aquifer is deep. Many wells in the Birds Hill area are drilled through the sand and gravel deposits and into the Carbonate aquifer (*Rutulis, 1981*). Map # 3 shows the distribution of wells completed in sand and gravel aquifers.

Sand and gravel deposits may be found as surface beach ridges, or as glaciofluvial units found near the surface, within or at the base of drift. Birds Hill is made up of sands and gravels deposited and reworked by glacial melt waters. *(Manitoba Energy and Mines, 1984).*

Sand and gravel aquifers are more common in the Birds Hill area, Mars Hill and related sandy uplands along the eastern side of the watershed. There are some deeper wells but in general, the well depth in sand and gravel aquifer is between 10 and 30 metres.

Well yield in the sand and gravel aquifers usually is in the 5 to 25 IGPM (0.5 to 2 L/s) range. The high capacity wells could yield up to 500 IGPM (40 L/s) (map # 4).

WINNIPEG SANDSTONE AQUIFER

The Winnipeg sandstone aquifer underlies the carbonate rock. About 2% of wells are completed in this aquifer. The Winnipeg aquifer offers plentiful, reliable supply, but poorer water quality and the cost of drilling deeper wells makes it a less attractive target in most places. Wells in the Winnipeg sandstone aquifer are most common in the southeast part of the watershed, where the aquifer is at its shallowest and water quality is better. One advantage in this area is that the water, although somewhat salty, is softer than in the Carbonate aquifer.

The Winnipeg sandstone aquifer is about 40 to 50 metres thick. The depth to the aquifer ranges from 40 metres in the eastern part of the Rural Municipality of Brokenhead to more than 110 metres east of Red River Floodway (*Rutulis, 1973*). The aquifer consists of poorly cemented white sandstone interspersed with a shale beds.

Shale beds at the top of the Winnipeg Formation form a pronounced aquitard which separates the Carbonate aquifer from the Winnipeg sandstone aquifer. As a consequence, groundwater quality and water levels can be quite different between the two bedrock aquifers. Well completions that span this shale barrier can cause unwanted migration of water from the Winnipeg Sandstone into the lower Carbonate aquifer, causing deterioration of the water quality in the Carbonate aquifer. This has sometimes been an issue in the Oakbank area *(Betcher, 1991b*).

Well yield from the sandstone aquifer typically ranges from about 5 to 100 IGMP (0.5 to 8 L/s) and can be as high as 200 IGPM (15 L/s) (Map # 5).

GROUNDWATER FLOW

Groundwater flows from high elevation to low elevation and from high pressure to low pressure. Groundwater is recharged in upland areas and discharges to the surface in lowland areas, feeding into springs, the bottoms of streams, lakes or wetlands, or is taken up by vegetation. Groundwater helps to maintain minimum surface water levels and stream flow year round.

Groundwater is recharged most readily in elevated areas where permeable deposits are found at the ground surface. Once it reaches the water table, groundwater can flow a few centimetres to a few metres a day in sand or gravel aquifers, and even tens of metres a day or more in some highly fractured bedrock aquifers. In some aquitards, the water may move less than a few millimetres in a year.

Most groundwater recharge occurs in springtime, when melting snow, seasonally high rainfall and dormant vegetation allow significant amounts of water to reach the water table. In summer, vegetation intercepts much of the rainfall before it can reach the water table, except during heavy storms. Recharge may increase in late fall, when vegetation goes dormant, but stops once the ground is frozen.

The Cooks Creek area receives groundwater from inside and outside the watershed. The watershed is influenced a regional flow system originating from far to the west, an intermediate flow system originating east of the watershed around Milner Ridge, and local flow systems generated within the watershed, mainly off Birds Hill and Mars Hill (*Rutulis,1981*).

Groundwater flow in the Winnipeg sandstone is from southeast to northwest (Map #6). We only have a general understanding of groundwater flow in this aquifer because there are few monitoring wells available. Groundwater flow in the Carbonate aquifer is also dominantly from southeast to northwest, with the addition of outward flow from of recharge originating from Birds Hill (Map # 7).

A regional flow system from the west existed prior to glaciation and is still present in areas west of the Red River. This flow system was a source of saline water to the aquifers. Since glaciation, flow coming from the east has been a source of fresh water, which over geologic time has flushed saltier water toward the Red River. Local groundwater flow systems generated by Birds Hill have blocked the western displacement of salt water, resulting in a brackish to saline remnant within the basal Carbonate aquifer and the Winnipeg sandstone aquifer in the Oakbank region. (Map # 8) (*Betcher, 1991b*).

GROUNDWATER USE

Groundwater is used for domestic supply, municipal supply and for industrial use.

For most rural residents, domestic water sources are obtained through individual wells. Municipal supplies service areas of the watershed located within the City of Winnipeg, the RM of East St. Paul and parts of the RM of Springfield.

The City of Winnipeg obtains its water by aqueduct from Shoal Lake. The R.M. of East St. Paul obtains its municipal water source from six wells, four completed in sand and gravel and two in the Carbonate aquifer (PID 110021; 119996;119998; 80405; 80407;80880). The water is chlorinated prior to distribution to over 900 households.

The R.M. Springfield operates two wells located 4 km northwest of Oakbank. The wells (PID 77783; 134019) are completed in the sand and gravel Moosenose aquifer. The wells supply chlorinated water by pipeline to 500 households around Oakbank and 180 households in the Dugald area. Anola obtains its water from a well completed in the Winnipeg sandstone aquifer (PID 133866), which supplies 33 households. The water supply at Anola is treated to remove iron and manganese prior to chlorination.

There is a requirement under the *Ground Water and Water Well Act* for the reporting of all water wells drilled in Manitoba by a licensed well driller. There are records for 12314 wells and test holes for this watershed in the provincial groundwater database. These wells are distributed across the watershed.

The database shows about 88.5% of all wells were completed in the Carbonate aquifer and are found in all areas of the watershed. Sand and gravel wells were about 3.3% mostly around Birds Hill and Mars Hill areas. Sandstone aquifer wells were just 0.4% and more common in the southeast part of the watershed (Map # 9). A breakdown of wells and test holes by aquifer type is shown in Table1.

According to the *Manitoba Water Protection Handbook*, the average Manitoba uses 227 litres of water per day, or about 1000 litres for a household. Usually about 5 IGPM or more is needed from a well to comfortably supply a household, without extra storage tanks. Yields from the Carbonate aquifer commonly range from 10 to 100 imperial gallons per minute (IGPM) (1 to 8 L/s) (Map #3), in the Winnipeg sandstone yields are from 10 to 100 IGPM (1 to 8 L/s) (Map #5) and from sand and gravel is 10 to 25 IGPM (1 to 2 L/s) (Map #4). These yields are ample for most water uses.

Table 1 **Number of wells by Aquifer**

Aquifer Type	Number of Wells	% of Wells
All aquifers	12,314	100
Sand and gravel aquifers	405	3.3
Carbonate aquifer	10,900	88.5
Winnipeg sandstone aquifer	54	0.4
Limestone and sandstone aquifers (Interconnected)	223	1.8
Unknown or other	636	5.2
Dry Well / Insufficient supply	96	0.8

GROUNDWATER MONITORING

The Province of Manitoba through the Department of Conservation and Water Stewardship, Groundwater Management Section maintains a network of more than 800 groundwater observation wells in the province. Monitoring primarily involves continuously recording of water levels, plus occasional water quality sampling.

In undeveloped areas observation wells record show the aquifer responds under natural conditions. In developed areas, they will pick up the effects of development. Comparison of the hydrographs will show the difference. Monitoring allows groundwater supplies to be carefully managed so that these resources are available in the long term.

Groundwater storage is a balance between recharge and discharge. In the long term this is relatively stable. In the shorter term, storage may increase when surface water is plentiful or it may decrease during drought. Groundwater levels typically rise in spring and early summer and decline in fall and winter. In the longer term, they will generally increase over several wet years and decrease over a period of dry years. The changes in water levels may be recorded using monitoring wells.

In the Cooks-Devils Creek Watershed, there are 57 active provincial monitoring wells (Map # 10). There are about 46 observation wells completed in the Carbonate aquifer, six in sand and gravel aquifer, four in sandstone aquifer and one in silt and till aquifer. Water levels are recorded continuously in most wells, showing both short term and long term changes in each aquifer.

Monitoring well hydrographs tell us what is happening to the water supply. Figure 4 shows the hydrograph of monitoring well G05OJ063 (Selkirk SO-20) to natural conditions. The well is completed in the Carbonate aquifer. The hydrograph compared to precipitation shows a water level decline in response to a dry period from 1980 to 1995. The water levels recovered in wetter years that followed.

Development may cause changes in water levels. The Red River Floodway channel is in the southwestern part of watershed just east of the City of Winnipeg and has a significant impact on local groundwater (*Wang et al 2008*). The Floodway created a low point in the topography, which was below the local groundwater level at the time. As a result groundwater levels had to reach a new equilibrium with the Floodway channel. Provincial monitoring station G05OH002 (Red River Floodway 033) (Figure 5) located in NW26-10-4E, on the east side of east floodway embankment, reflects about six metre drop in the groundwater level near the floodway channel. As a result of the impact, people around floodway channel had to lower their pumps inside their wells and some wells were deepened. The effect diminishes with increased distance from the channel. The impact was one metre or less east and south of Winnipeg. Groundwater levels stabilized by the late 1960s. Groundwater continues to discharge into the Floodway, a notable example being some springs near the ski hill.

The widening of the Red River Floodway from 2005 to 2009 did not have a long term impact on groundwater levels because the Floodway was widened rather than deepened. A decline in groundwater levels is seen in 2008 during the construction period in G05OH002 (Figure 5), but not in G05OJ006 (Figure 6). The temporary decline in water levels was likely caused by dewatering during the construction phase and was limited to the vicinity of the floodway.

In 2004, the Province of Manitoba passed the "*The Floodway Authority Act*" to outline the responsibilities of the Manitoba Floodway Authority (MFA). MFA oversaw the planning and management of the project and consulted Manitobans regarding the expansion project, including groundwater protection. KGS Group Winnipeg, Manitoba has prepared groundwater monitoring activity reports annually for the Manitoba Floodway Authority in response to the requirements of Environmental License No. 2691 since 2005 (*KGS, 2008; KGS 2012*)

Groundwater Management Section has been monitoring the aquifers in this area since 1960s. Long term hydrographs of the area show natural variations in water levels. General signs of overdevelopment have not been observed. In most of the watershed development is sustainable and there are not indications of depletion of bedrock aquifers (*Wang et al, 2008*).

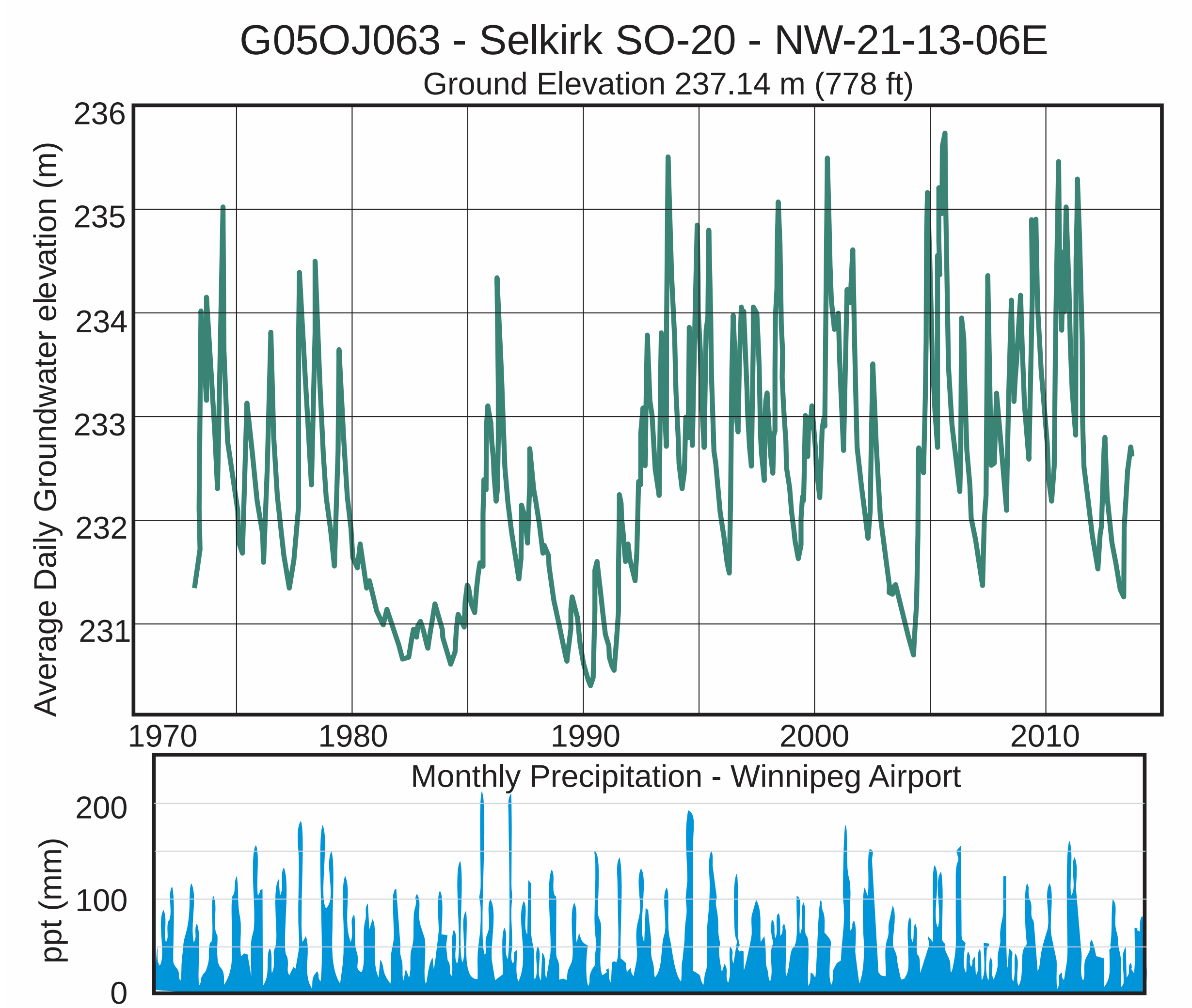

Figure 4 – Selkirk SO-20 monitoring station is located in the north central part of the watershed in the R.M. of St. Clements. The well is 21.6 metres deep and has been active since 1973. The water level fluctuates within a 5 m range, mostly as shorter-term seasonal variations responding to precipitation. The average water level was around 233 metres from 1973 to 1980; 232 metres from 1980 to 1995 prior to 1995 and 233 metres from 1995 to present. The well is located in an area of thin overburden and highly responsive to recharge. It shows normal water levels in most years and depressed water levels during a drought period from 1980 to 1995.

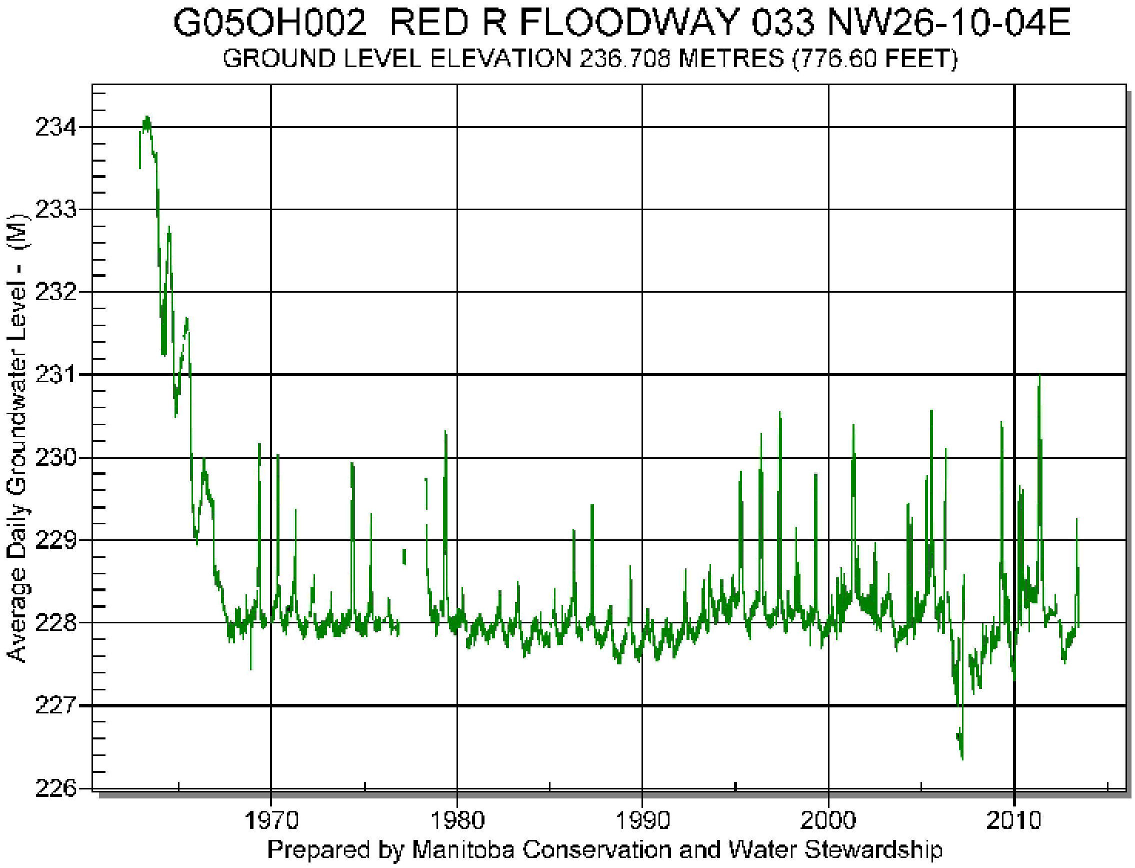

Figure 5 - Provincial Red River Floodway monitoring station near the floodway embankment. The construction of the floodway lowered the water table in its vicinity toward a groundwater base level determined by the base of the channel. The water table dropped six metres during initial construction and then stabilized. Expansion of the Floodway from 2005 to 2009 matches a drop of about 1.5 m in the hydrograph, likely caused by dewatering during the construction phase.

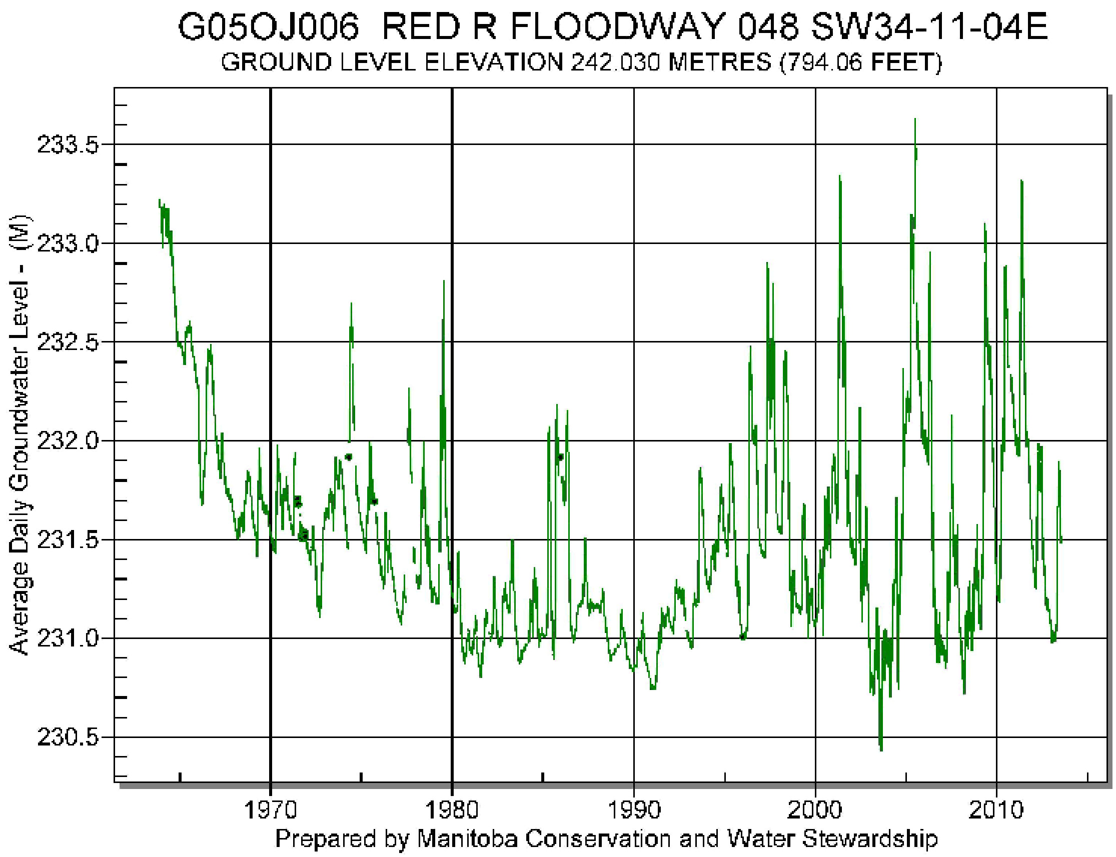

Figure 6 - Hydrograph shows long term groundwater monitoring in the sand and gravel aquifer west of Oakbank in the R.M. of Springfield. The well is 20.1 metres deep. The well has been active since 1963. The water level has fluctuated in a three metre range, responding to seasonal and longer term precipitation trends and to the influence of construction of the Red River Floodway. The Red River Floodway was started in 1962 and completed in 1968. An expansion, which did not deepen the floodway, was built between 2005 and 2010. A temporary drop of about 0.5 m could be attributed to dewatering during the construction phase in 2008. The Red River Floodway lowered the groundwater base level in its vicinity. This caused an overall drop in groundwater levels within the area of influence. This can be seen in the hydrograph, where groundwater levels decline steadily from 1963 to 1970. After 1970, water levels have averaged around 231.75 m, with the exception of a drought period from 1980 to 1995, then the average was closer to 231.1 m.

GROUNDWATER QUALITY

OVERVIEW

Even when sufficient quantities of water are available, they may not be usable if the quality is poor. Fresh, potable water is necessary for human consumption.

Groundwater begins as rainfall, snow or surface water that soaks into the ground and makes its way to the water table, where it begins to flow. The ground acts as a filter, which removes many surface contaminants. At the same time the water dissolves the rock matrix around it, picking up minerals and salts. The minerals that make up the rock vary with rock type and some are more soluble than others. Carbonate rock is somewhat water soluble and adds calcium, magnesium, sulphate and bicarbonate ions. The calcium and magnesium contribute to hardness. Sands and gravels often contain hard water and high iron. Sandstone containing water with sodium ions is sometimes naturally softened.

The longer that water flows underground, the more mineralized it becomes. Shallow groundwater which is recharged locally tends to have the lowest amount of dissolved minerals and is the most desirable for human use. Groundwater with distant recharge sources has spent a long time underground. As a result total dissolved solids content (TDS) increases and water quality diminishes. Water that is too mineralized to be used for a drinking water supply may still be useful for household purposes, stock watering or industrial and farmyard uses.

Good quality water is readily available in most parts of the watershed from the Carbonate aquifer or from sand and gravel aquifers. Poorer quality water in the Carbonate aquifer is a concern near Oakbank and near Dugald. Near Oakbank, sand and gravel aquifers where present, offer an alternative source. Near Dugald the Winnipeg sandstone aquifer is a suitable alternative to the Carbonate aquifer. The Winnipeg sandstone aquifer is a suitable aquifer in the southeast part of the watershed. Water quality quickly deteriorates in this aquifer toward the north and west.

The *Manitoba Water Quality Standards* (Manitoba Water Stewardship, 2011), *Objective and Guidelines* and the *Canadian Guidelines for Drinking Water Quality* (Health Canada, 2010) set limits on drinking water constituents. Some dissolved minerals such as calcium have no set health limit. Other constituents such as iron may affect taste and washing qualities and have a set aesthetic objective (AO). Constituents which may be detrimental to health, such as nitrates or bacteria, will have a Maximum Allowable Concentration (MAC).

DISSOLVED IONS

The *Guidelines for Canadian Drinking Water Quality* set the aesthetic objective for total dissolved solids (TDS) at 500 mg/L. This cut-off is rarely achieved for well water. Often for well water anything less than 1000 mg/L TDS is considered acceptable, although as much as 1500 mg/L may be tolerated for human consumption. Livestock tolerances are higher . Recommended limits for TDS concentration are shown in Table 2 (*Olkowski, 2009*).

When well water is sampled, it is most commonly analysed for major ions: calcium, magnesium, sodium, potassium, bicarbonate, sulphate and chloride, along with iron, fluoride, nitrate, pH, hardness and alkalinity. Bacteriological samples may also be taken.

Aesthetic objectives are set for most of these minerals in the *Guidelines for Canadian Drinking Water Quality* and high concentrations may affect palatability and personal tolerance for the water. The Canadian Maximum allowable concentrations are applied to constituents with specific health concerns. Council of Ministers of the Environment (CCME, 2005) sets water quality guidelines for agricultural uses.

Table 2 Recommended limits of Total Dissolved Solids

TDS Concentration Limit mg/L	For Consumption By:
500	Humans (good)
1000	Humans (fair)
1500	Humans (poor)
2000	Poultry
2500	Dairy Cattle
4000	Beef Cattle, Horses, Pigs
5000	Sheep
10,000	Industrial Processes (varies with use)

In the sand and gravel aquifers, total dissolved solids (tds) in most wells in the watershed are in the range of 200 to 500 mg/L, which is within objectives set in the *Guidelines for Canadian Drinking Water Quality* (Health Canada 2010). In the Carbonate aquifer, tds values are mostly between 200 mg/L and 800 mg/L (Map #11). Poorer quality water in the range of 1000 to 1800 mg/L in a small area in the eastern part of Oakbank and near Dugald.

Water quality in the Winnipeg sandstone aquifer is acceptable in the south-east part of the watershed near Dugald, where tds are in the range of 300 to 700 mg/L, but deteriorates toward the north and west where they can exceed 10,000 mg/L (Map #8). In some places the salty water from the Winnipeg Sandstone has intruded the lower part of the Carbonate aquifer. Therefore drilling to the deep sandstone aquifer is not recommended in these areas (*Betcher, 1991a; Scott, 2005*).

In 1991 Manitoba Water Resources and the Cooks Creek Conservation District prepared a report on Groundwater Quality within the Village of Oakbank in response to water quality complaints (*Betcher, 1991b*). The investigation found that groundwater quality varied within the community but was still potable. The report indicated that the poor water quality in some of the wells was due to the following factors:

- Leakage of poor quality groundwater from the overlying clays and till into the Carbonate aquifer because of well casing failures.
- Upward migration of saline groundwater from the Winnipeg sandstone into the Carbonate aquifer through deep wells interconnecting the two aquifers.

In 2004 Manitoba Water Stewardship, Office of Drinking Water and the Rural Municipality of Springfield, carried out a follow-up study to the 1991 Groundwater Quality Study in the Village of Oakbank. The follow-up study also found that no health based parameters analyzed exceeded the Guidelines for Canadian Drinking Water Quality (*Davies, 2005*). The 2004 findings remain consistent with 1991 investigation.

In Cooks-Devils Creek Watershed, nitrate concentrations above detection limits have been found in wells completed in the Carbonate aquifer and some in shallow sand and gravel wells in agricultural areas of the central part of the R.M. of Springfield and in southern part of R.M. of St. Clement. Elevated nitrate is not unusual in agricultural areas and usually attributed to natural organic matter, or leaching of septic systems, manure or fertilizers into the groundwater.

Locations of well waters samples tested for Nitrate-N is shown in Map #12. Of 734 water analyses for nitrate-N the 10 mg/L MAC was exceeded in only 11 domestic wells. This amounts to just over 1 % which is low compared to provincial wide sampling results. The higher concentration of nitrate was found in the Carbonate aquifer in agricultural areas in the northern part of the watershed where the drift is less than 10m thick (Map # 2). The thin overburden or in areas where sand and gravel deposits or carbonate rock are at or near the ground surface make it more susceptible to contamination.

Sulphate concentrations above the 500 mg/L objective set in the *Canadian Drinking Water Quality Guidelines* have been found in some wells completed in the Carbonate aquifer and in shallow silt or till aquifers (Map # 13). In Cooks-Devils Creek Watershed, the sources of sulphate may include oxidation of sulphide minerals or dissolution of gypsum incorporated into the tills, or oxidation of organic matters (*Betcher 1997*).

Minor elements or trace metals, which have occasionally exceeded *Guidelines for Canadian Drinking Water Quality* in Manitoba, include arsenic, fluoride, barium, boron and uranium. With the exception of fluoride, trace metals are usually not included in basic water well analysis, but may be requested as a separate analysis.

Fluoride is a naturally occurring trace element. Elevated concentration of fluoride have been found in bedrock sandstone and deep limestone aquifers in the central part of watershed in RM of Springfield and south east part of the watershed (Map # 14). The maximum allowable concentration (MAC) for fluoride is 1.5 mg/L. Of 263 well samples for fluoride, 25 had higher than recommended MAC. The samples with high fluoride were more common in deep limestone and sandstone aquifers. Only one sample from sand and gravel had high fluoride. Excessive consumption of fluoride may result in dental fluorosis characterized by mottling of the teeth, and may cause bones to be brittle.

Uranium is a naturally occurring radioactive element found in low concentrations in nature and in Manitoba may be found in drift derived from the Canadian Shield or sometimes in carbonate rock formations. Uranium above the MAC set in the *Canadian Drinking Water Standard*s was found in three well water samples in the watershed (Map # 15). Uranium levels in drinking water above the guideline can increase risk to kidney damage. The risk to human health is through ingestion only. Well water with uranium levels greater than 0.02 mg/L may be used for bathing, hand washing, and dishwashing.

The Guidelines for Canadian Drinking Water Quality sets the maximum allowable concentration for arsenic at 0.10 mg/L. Of 75 well samples for Arsenic, one exceeded the MAC. The well is located in the Town of Birds Hill (River Lot 94, St. Pauls). The source of the arsenic is likely a result of groundwater coming into contact with rocks or soils containing arsenic.

Of 121 well samples tested for barium and for boron none exceeded the MAC in the *Guidelines for Canadian Drinking Water Quality.*

Testing for trace metals is a good practice when drinking water samples are collected for routine analysis and sent to a lab that offers this service.

GROUNDWATER MANAGEMENT

WATER WELL CONSTRUCTION AND MAINTENANCE

A well that is properly constructed and maintained can last for many years. It is the responsibility of the well owner to ensure their well and water distribution system is properly constructed and that the well provides water that is safe for drinking. Well water contamination is often caused by improper or poorly constructed, maintained or improperly located wells. Wells and water distribution systems can deteriorate over time and at some point will need repair or replacement. The following measures are recommended to ensure effective and safe well operation:

- Retain an experienced and licensed well drilling contractor for the drilling, construction, hook up, maintenance and servicing of a well.
- Select a site where water will drain away from the well and is a safe distance from possible sources of contamination. Minimum separation distances between well and septic are regulated under the *Environment Act – Onsite Wastewater Management Systems Regulation, M.R. 83/2003* in Manitoba. Minimum setback distances from wells include at least eight metres for a septic tank and at least 15 metres for a disposal field for a well drilled and cased to a minimum of six metres below ground.
- Use a pitless adaptor and secure a proper well cap to the top of the well.
- Before the well is put into operation, ensure the well pump and the water distribution system is disinfected to kill any bacteria present.
- Wells within a designated flood area should have adequate well head protection to ensure flood waters do not enter directly into the well.
- Seal unused wells to the guideline recommended in Manitoba's Guide of Sealing Abandoned Water Wells (Manitoba Conservation, 2002): http://www.gov.mb.ca/waterstewardship/water_info/misc/abandoned_wells.pdf
- Guidance for well owners may be found at: http://www.wellaware.ca. The Well Aware book let was prepared by Green Communities Canada with the input from many government agencies. The guidebook encourages the well owners to understand the basics of well maintenance and operation, and to take the necessary actions to keep the water wells in safe running order.

AQUIFER AND WELLHEAD PROTECTION

Aquifer protection is essential for a sustainable use of groundwater resources. This may be accomplished through good land use and well construction practices. Aquifer contamination may occur when there is a contaminant present and there is a pathway into the aquifer.

Potential for groundwater contamination is more likely to occur where aquifers are at or near ground surface. Low permeability materials such as clay or till at the land surface form a protective layer over top of aquifers. In Manitoba, if the top of an aquifer is within six metres of the surface, it is considered to have a higher risk of contamination. This risk may be reduced through judicious land use. The drilling log of your well will give a good indication of the depth to the aquifer and any cover. Shallow sand and gravel aquifers are found in the RM of Springfield near Birds Hill. The Carbonate aquifer is found at shallow depths near Garson and Tyndall. (Map #2).

Activities that might release contaminants at the surface should be undertaken in areas away from wells and where aquifers are deeply buried. In some cases, local governments may designate what sort of land use is appropriate in the vicinity of municipal source wells (Ontario Ministry of the Environment, 2001).

High density rural residential subdivisions may compromise water quality if septic systems are too closely spaced, too close to wells, or if they do not function properly. Manitoba Conservation and Water Stewardship regulates the installation, operation and decommissioning of septic systems under the *Environment Act* to protect groundwater resources.

Wells may form a conduit for contaminants to migrate underground. Wells should be thoroughly grouted on the outside and the tops capped. Wells that are abandoned should be sealed from bottom to top with grout.

Wells may also form a conduit for groundwater movement between aquifers. Parts of the Winnipeg sandstone aquifer and the basal Carbonate aquifer contain poor quality water (Map # 8). Lower permeability layers within the Carbonate aquifer and shale at the top of the Winnipeg sandstone inhibit the vertical migration of poor quality water into fresher overlying aquifers. Drilling wells into the brackish water zone not only can spoil the water in that well, it can allow the migration of brackish water into fresh water aquifers. If enough mixing occurs it may even degrade the quality of surrounding wells. A situation like this has occurred before around Oakbank.

To avoid intermixing of aquifer water, wells should not be drilled into the basal Carbonate aquifer or the Winnipeg sandstone in areas where water quality is known to be poor. Wells should not be completed into both the Carbonate aquifer and the Winnipeg sandstone aquifer at the same time.

FLOWING WELLS

Flowing wells occur when water pressure in the aquifer causes the water level to rise above the ground surface. Flowing wells are often found in low lying areas surrounded by uplands. The actual water level may fluctuate with the seasons, which means some wells may only flow for part of the year or during years with high water levels

Flowing conditions make it more difficult for a driller to complete a well and to construct it so as to control the flow. Wells with considerable volume of flow may be difficult to plug.

Flowing wells are a concern because of the uncontrolled discharge of water. Wells which are allowed to flow freely will deplete the groundwater resource. The increased surface runoff may flood drains, or saturate the ground, causing drainage problems. If the water quality if poor enough, it could degrade the land. These problems can be avoided by ensuring that well drilling and construction methods are used to control the flow of water.

The locations of flowing wells are shown in Map # 16. Most flowing wells are located along Cooks Creek and Devils Creek in the central and north east part of the watershed. The shaded area shows where there a greater likelihood of flowing wells being encountered. Wells drilled in these area could flow and may have a water level up to 4 m above ground.

REGULATION

Groundwater in Manitoba is regulated under a number of Acts and Regulations: The *Environment Act*; the *Water Safety Act*; the *Water Rights Act*; the *Ground Water and Water Well Act* and the *Health Act*. Groundwater management is under the jurisdiction of the Department of Conservation and Water Stewardship. The *Environment Act* provides legislation protecting groundwater quality, while The *Water Rights Act* provides for the sustainable development of groundwater use. The *Ground Water and Water Well Act* introduced in 1963, deals with water well regulation and with water wells completed by a drilling contractor. With the exception of controlling flowing wells and pollution prevention, the Act does not cover household wells dug by the well owner with their own equipment.

In 2012, Manitoba Conservation and Water Stewardship introduced a new *Groundwater and Water Well Act* into the legislature which was passed and received Royal Assent. The new *Act* will replace the existing *Ground Water and Water Well Act.* The new Act deals with a number of issues not currently included in legislation or where strengthening of legislation is needed to provide additional protection to groundwater and aquifers. The current *Ground Water and Well Water Act* will remain in force until regulations are developed and in effect for the various sections of the new *Groundwater and Water Well Act.*

Groundwater is managed sustainably when the rate of water removal does not cause long term, irreversible declines in water levels or other undesirable impacts. Groundwater may be managed based on aquifers or on individual wells. Water budgets are sometimes developed for well known aquifers with distinct boundaries. Budgets estimate the amount of groundwater stored in, entering and leaving an aquifer. More often aquifers are managed on a well by well basis. Pumping tests are performed on production wells to ensure that the water use from that well does not negatively impact surrounding well owners through interference. The latter method is used in the Cooks-Devils Creek Watershed area for licensing purposes.

Groundwater licenses are required when domestic groundwater use exceeds 25,000 litres per day and/or if the water is distributed to multiple users the general public. A licence is also needed for use that is not for water supply. Groundwater licensing helps to ensure that groundwater resources are managed wisely so that the long term supply is protected.

SUMMARY

Groundwater supply is readily available throughout the Cooks -Devils Creek Watershed. Three main aquifers are available: scattered sand and gravel aquifers, the Carbonate aquifer and the Winnipeg sandstone aquifer. The vast majority of well owners obtain their supply from the upper part of the Carbonate aquifer. The City of Winnipeg provides treated water from Shoal Lake within city limits. East Saint Paul operates wells in the Carbonate aquifer and in sand and gravel to supply households within that municipality. The RM of Springfield operates municipal wells in sand and gravel and a pipeline which services residences in the Oakbank area. A well in the Winnipeg sandstone aquifer is used as a communal supply in Dugald and Anola.

Good quality water is available in most areas from the upper Carbonate aquifer or from sand and gravel aquifers. The Winnipeg sandstone aquifer is a suitable source of water in the southeast part of the watershed, but becomes saline in the north and west. Because the Winnipeg sandstone aquifer and at some locations, the lower Carbonate aquifer tend to be saline, deep wells in these areas should be avoided. Likewise, wells should not be completed in more than one aquifer.

Excessive hardness , or excessive levels of total dissolved solids, sulphates, nitrate, fluoride, iron or uranium were reported in some wells in the Carbonate aquifer. At most locations, suitable water quality is available from at least one of the three possible aquifers.

Groundwater monitoring hydrographs, some dating back more than 40 years, indicate that water levels respond to short and long term precipitation and climate events. These hydrographs do not show signs of depletion and are good indicators that use has been sustainable to date. Construction of the Red River Floodway permanently lowered the water table in the vicinity of the Floodway. The magnitude of decline depended on proximity to the floodway. Water levels in the affected areas stabilized within a few years and have remained stable.

Well owners can protect their water source for years to come by following good well construction and maintenance practices. Routine water quality testing is also recommended.

PREPARED BY DAVID TOOP, P. GEO AND M. IQBAL, G.I.T.

GROUNDWATER MANAGEMENT SECTION, MANITOBA CONSERVATION AND WATER STEWARDSHIP, 2013

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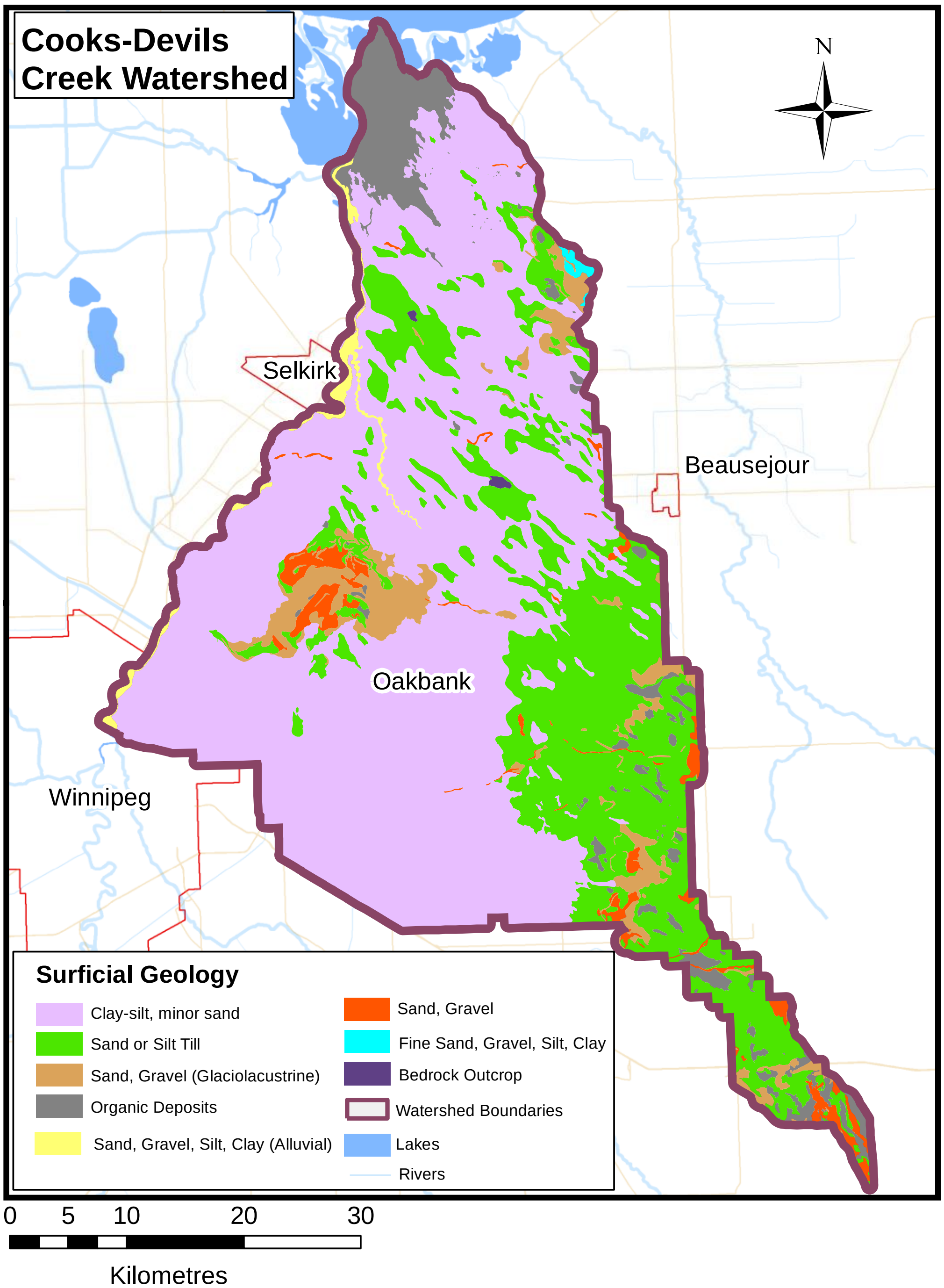
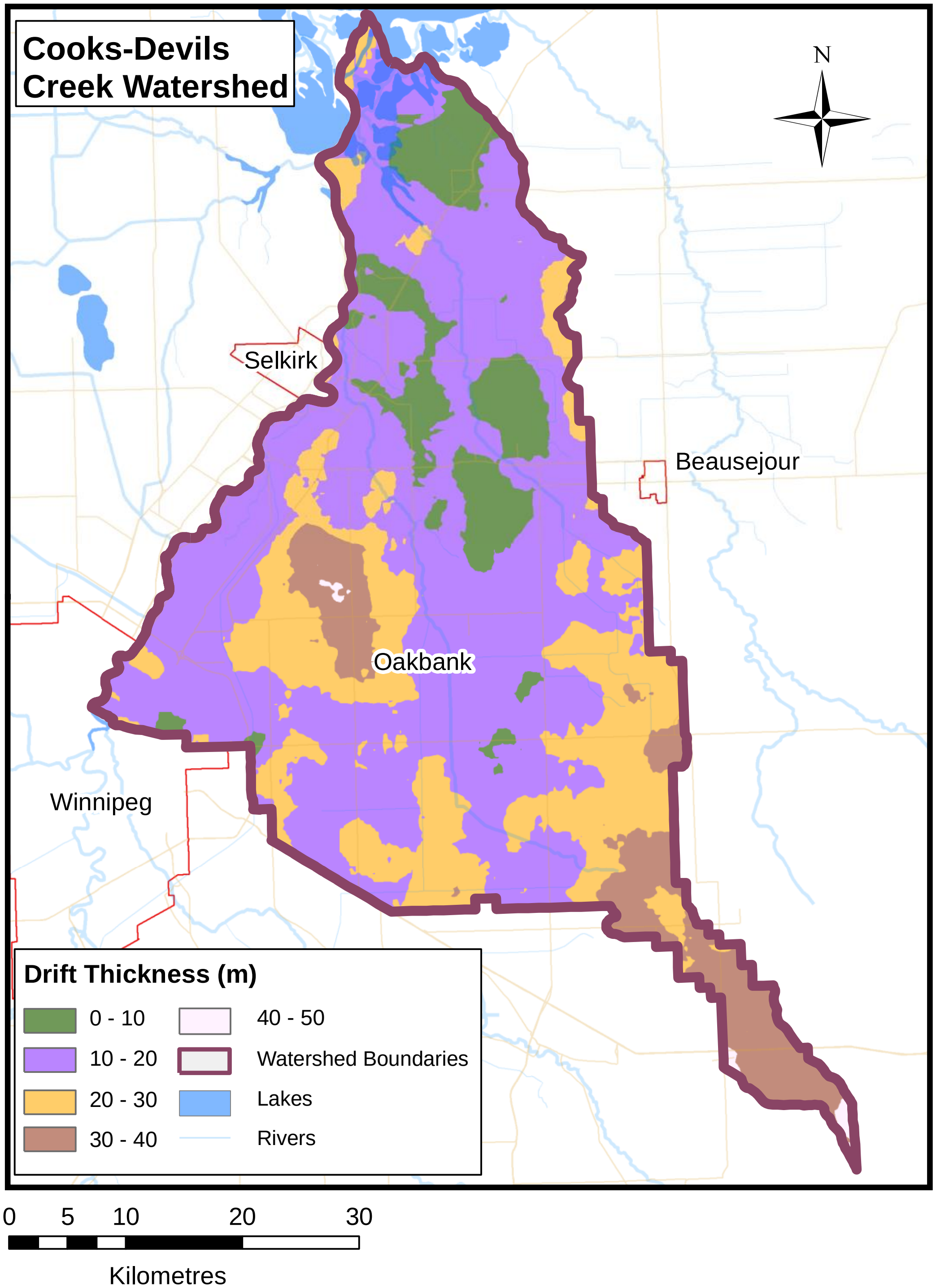
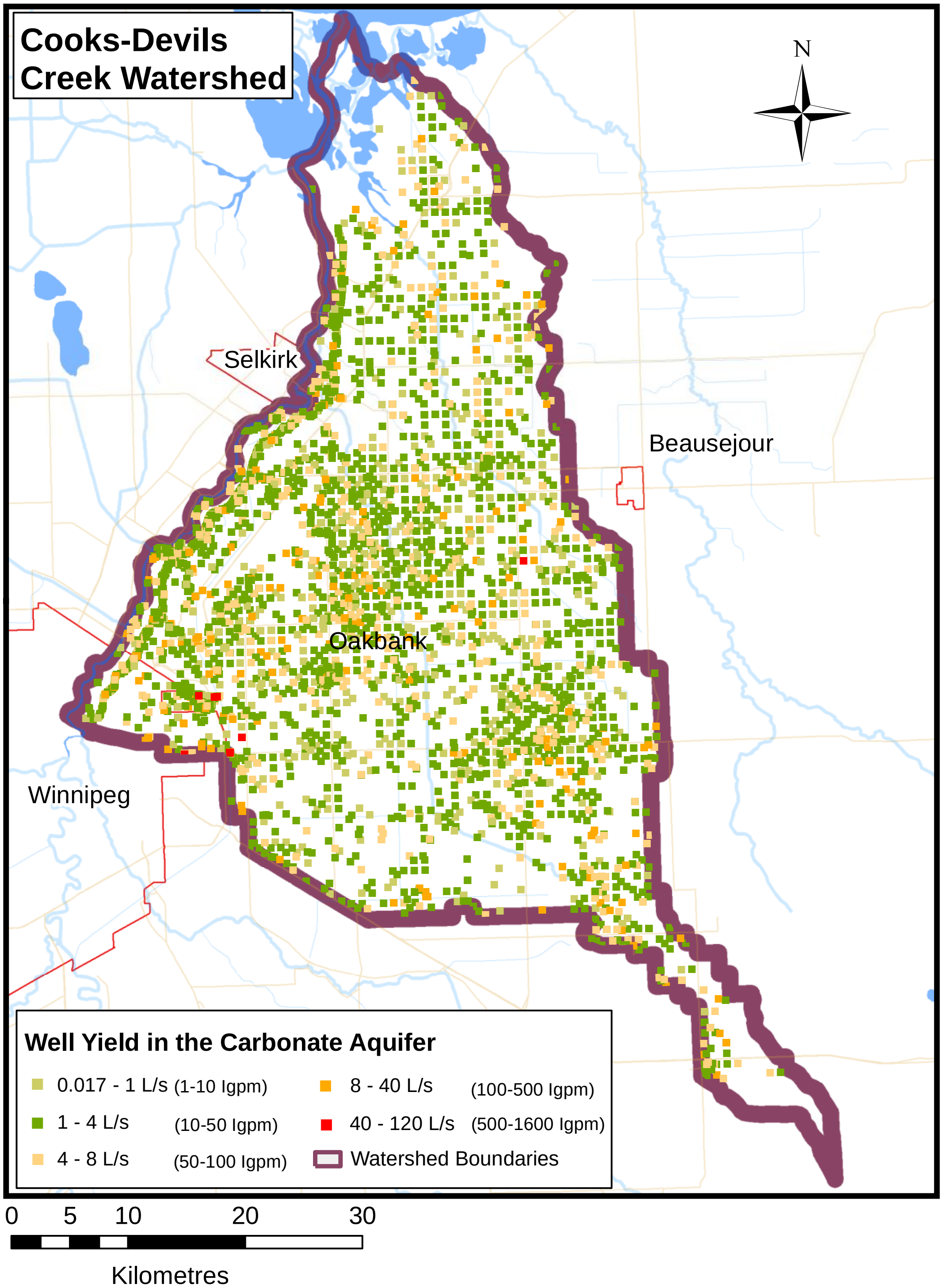
MAPS



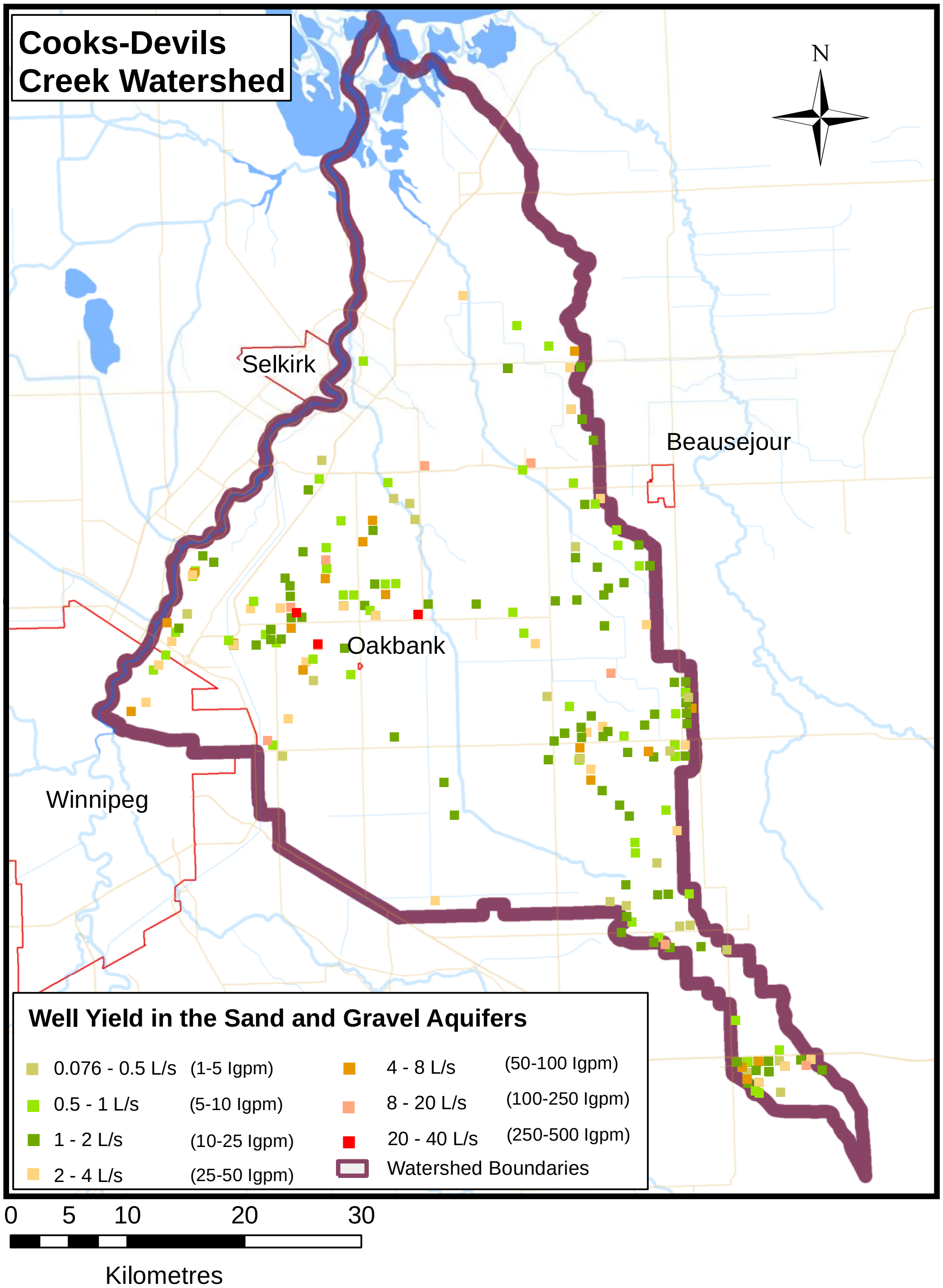
Map # 1 - Surficial Geology



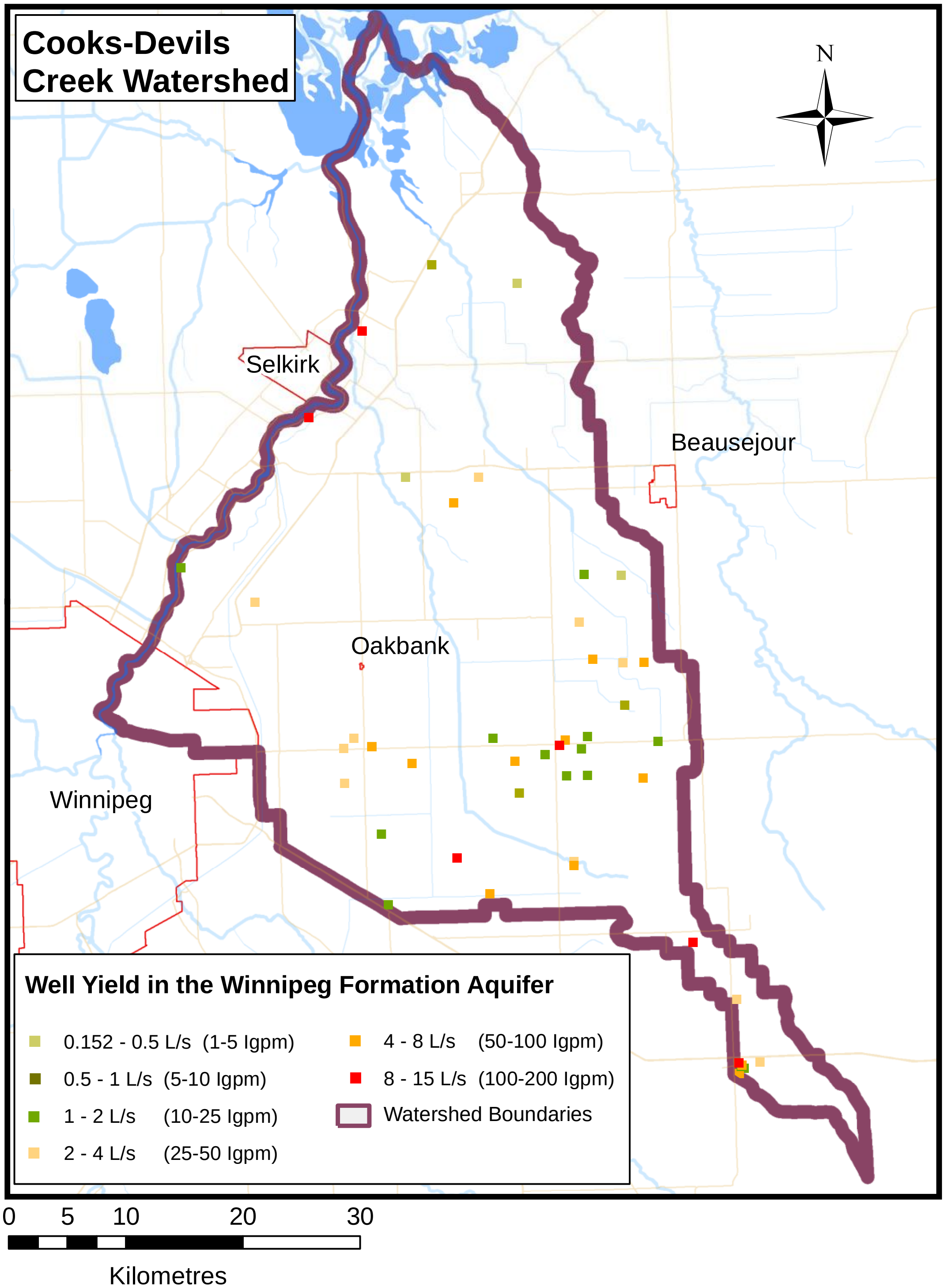
Map # 2 – Drift Thickness (metres)



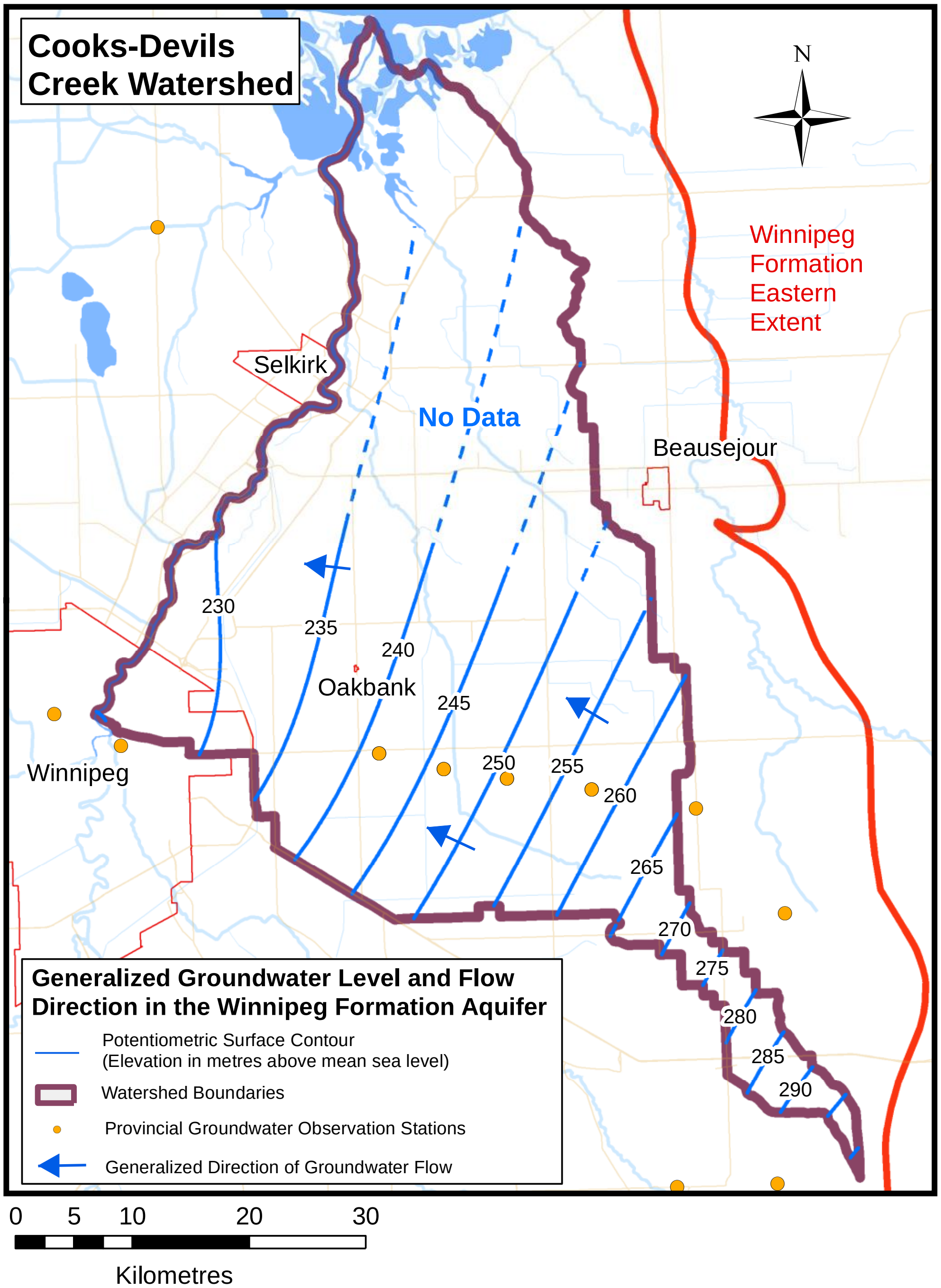
Map # 3 – Well Yield in the Carbonate Aquifer



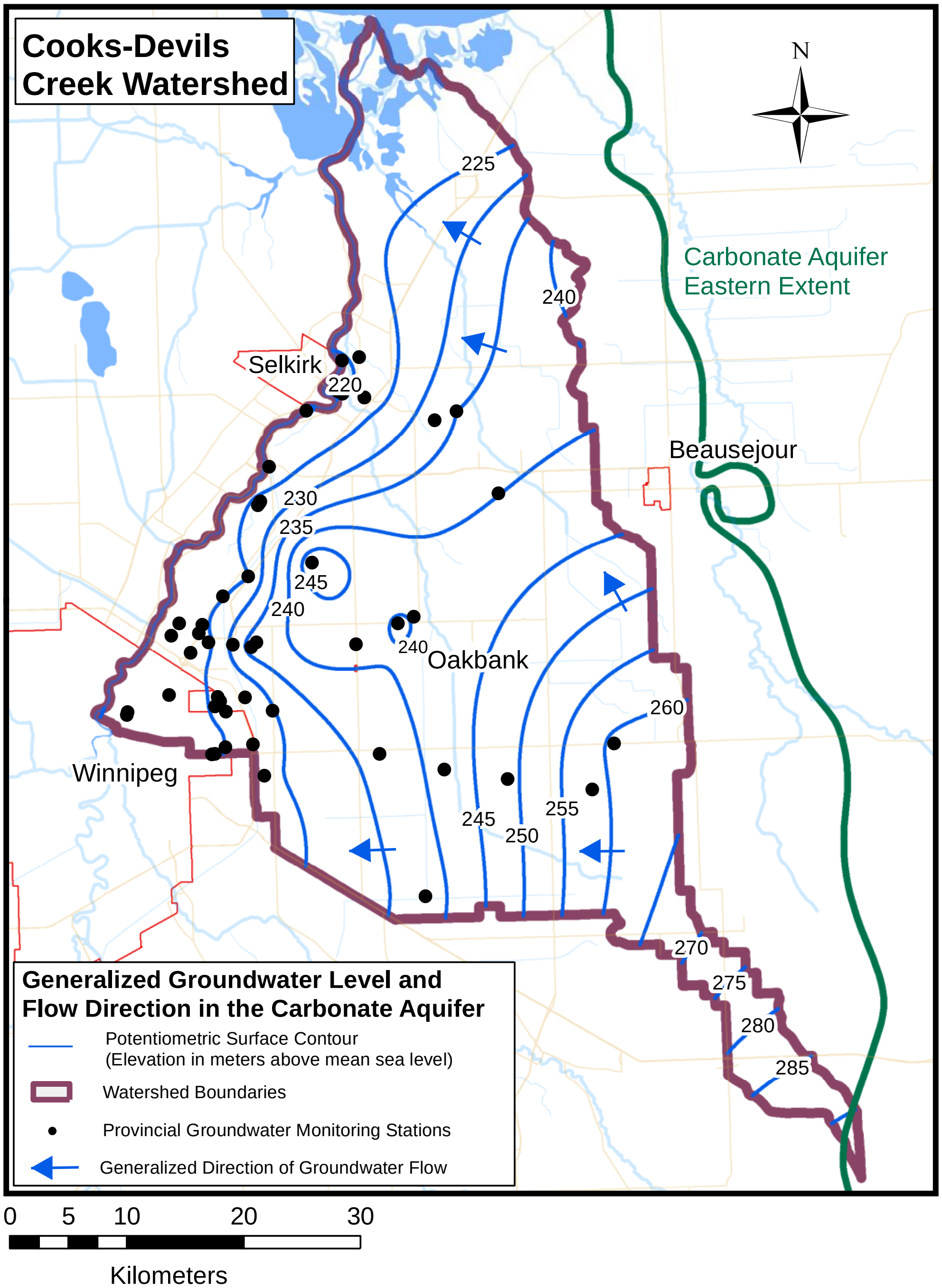
Map # 4 – Well Yield in Sand and Gravel Aquifers



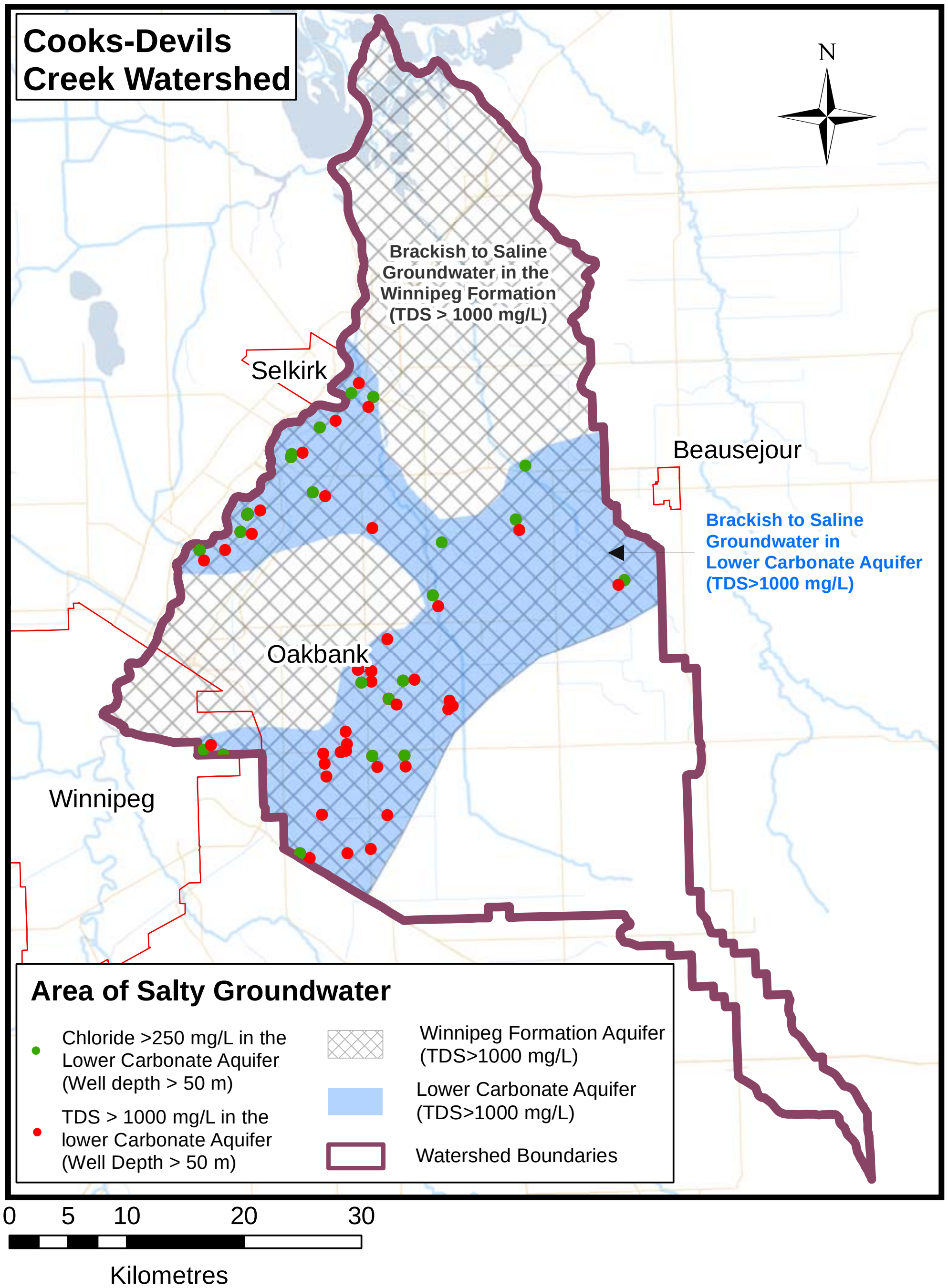
Map # 5 – Well Yield in the Winnipeg Formation Aquifer



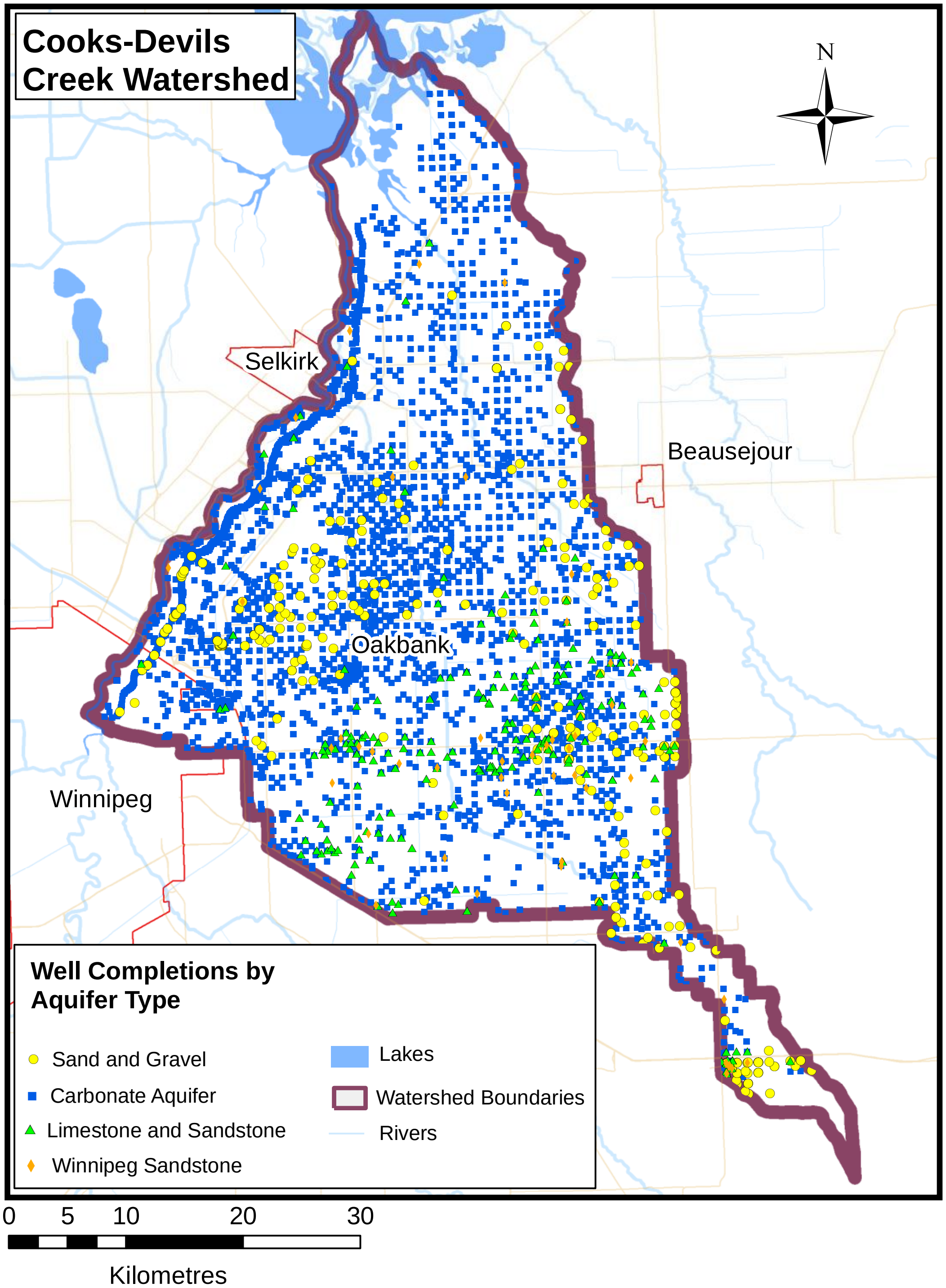
Map # 6 – Location of Provincial Groundwater Monitoring Wells Completed in the Winnipeg Sandstone Aquifer and Generalized Groundwater Flow Direction



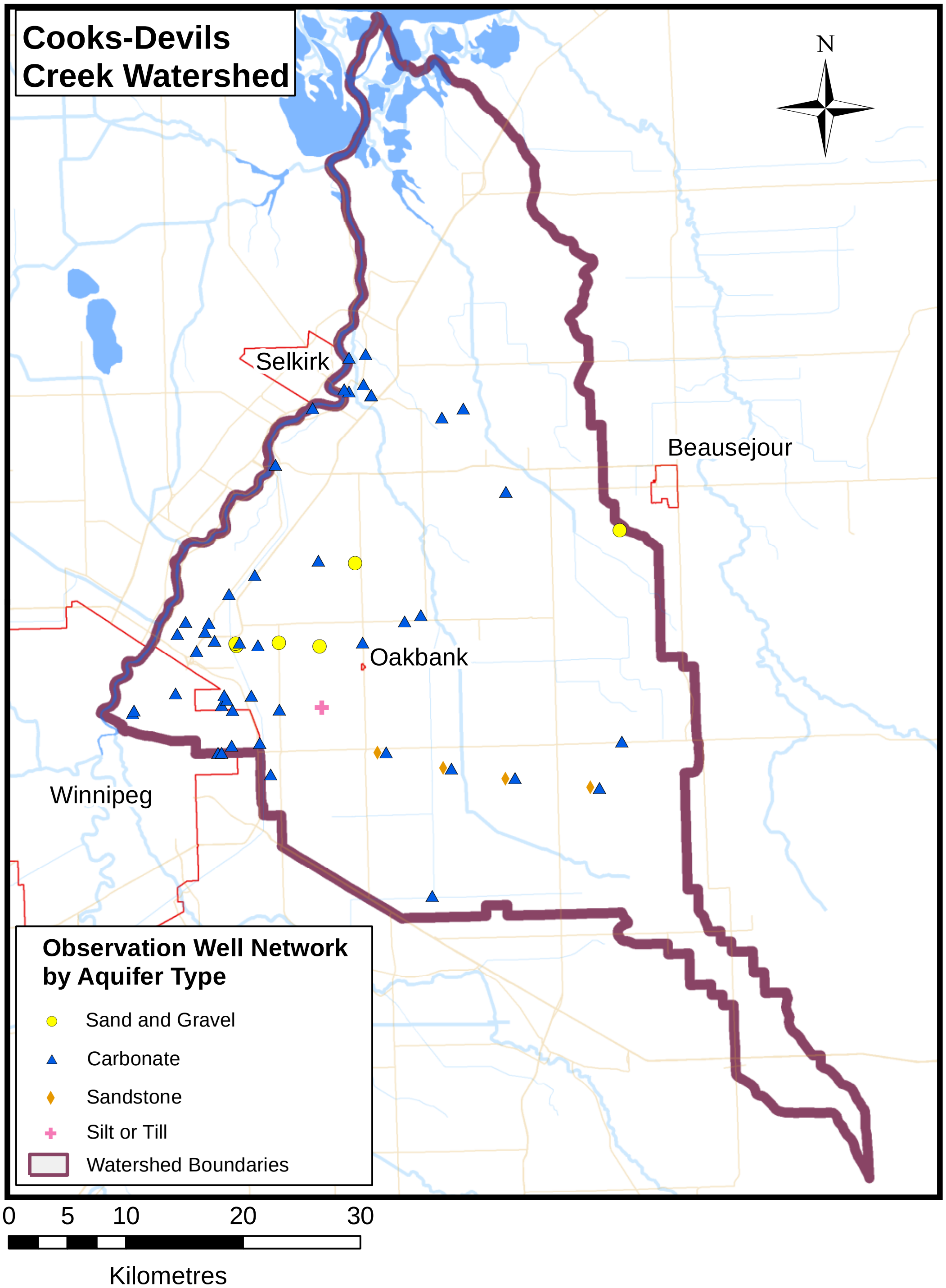
Map # 7 – Location of Provincial Groundwater Monitoring Wells Completed in the Carbonate Aquifer and Generalized Groundwater Flow Direction



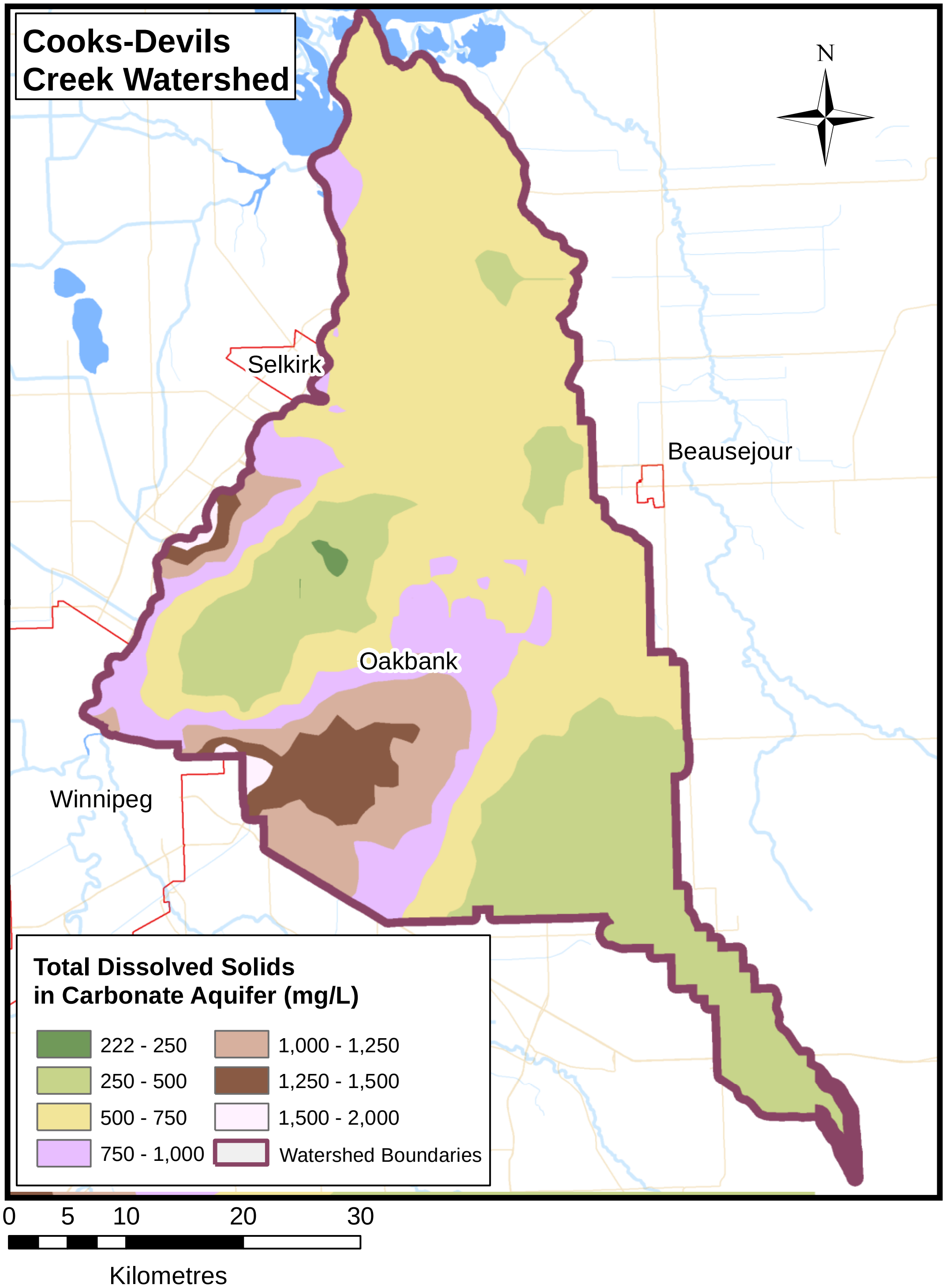
Map # 8 – Area of high total dissolved solids in the Winnipeg Sandstone Aquifer and in the Lower Carbonate Aquifer



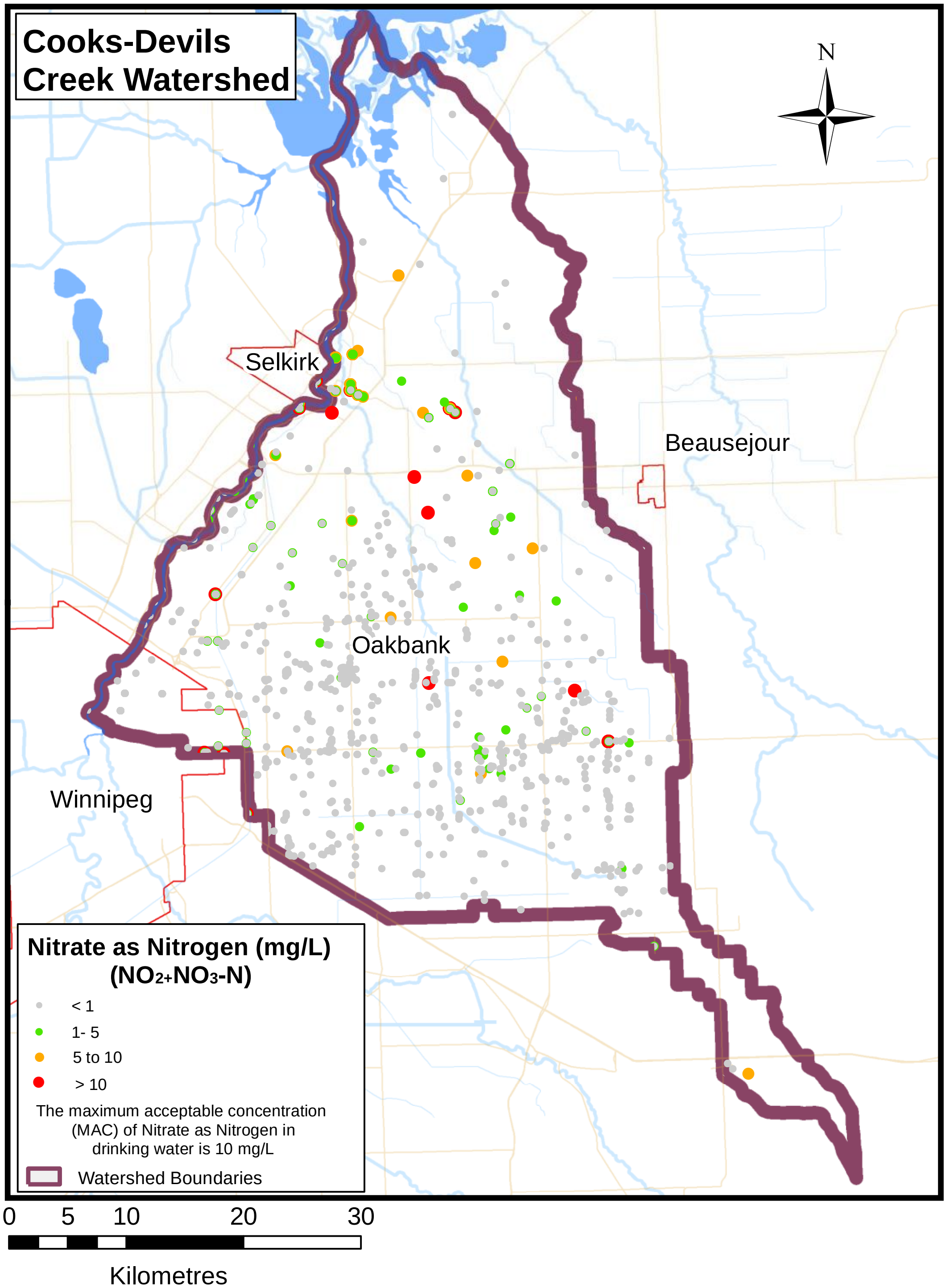
Map # 9 – Distribution of Wells by Aquifer Type



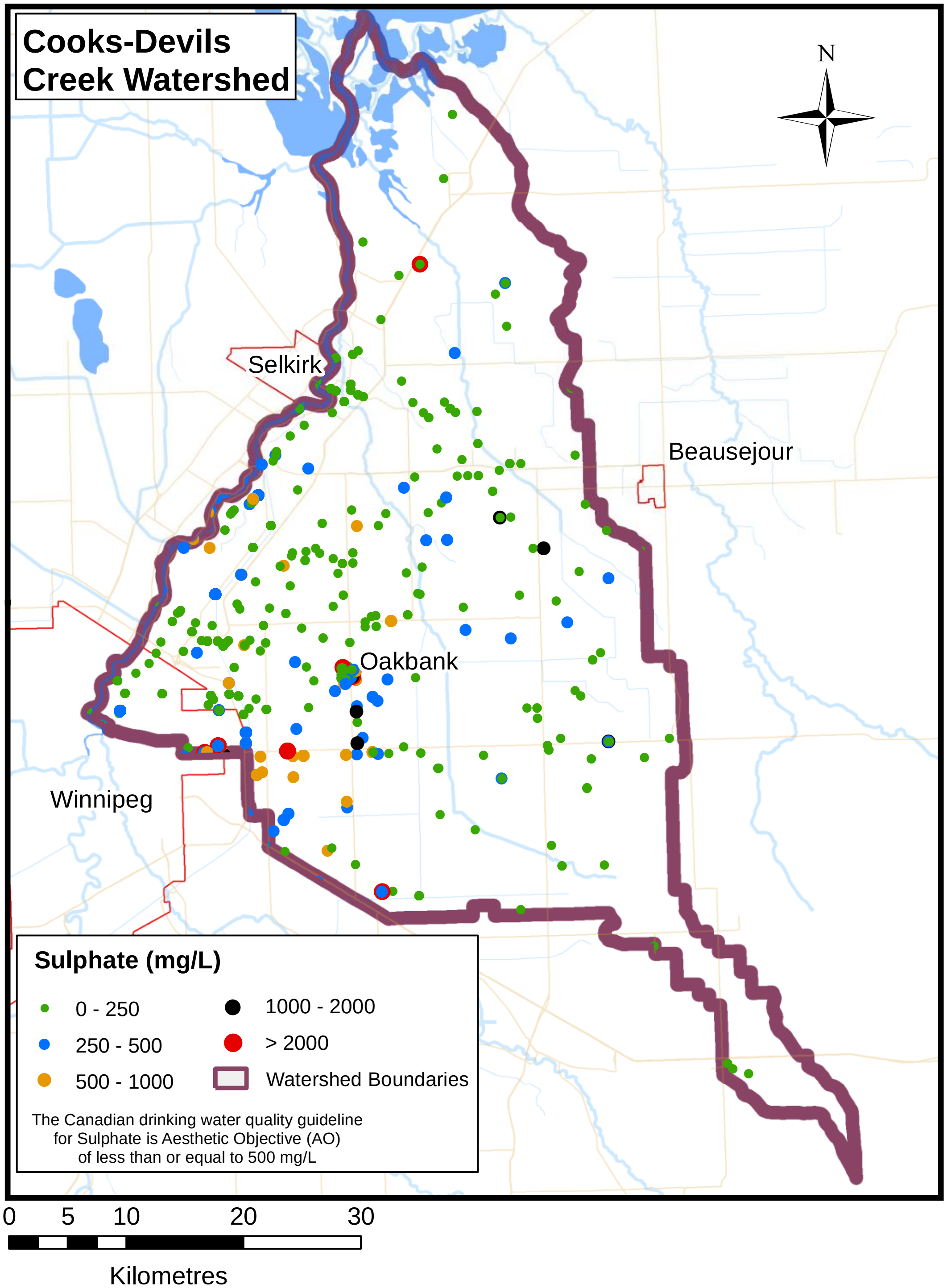
Map # 10 – Provincial Observation Station by Aquifer Type



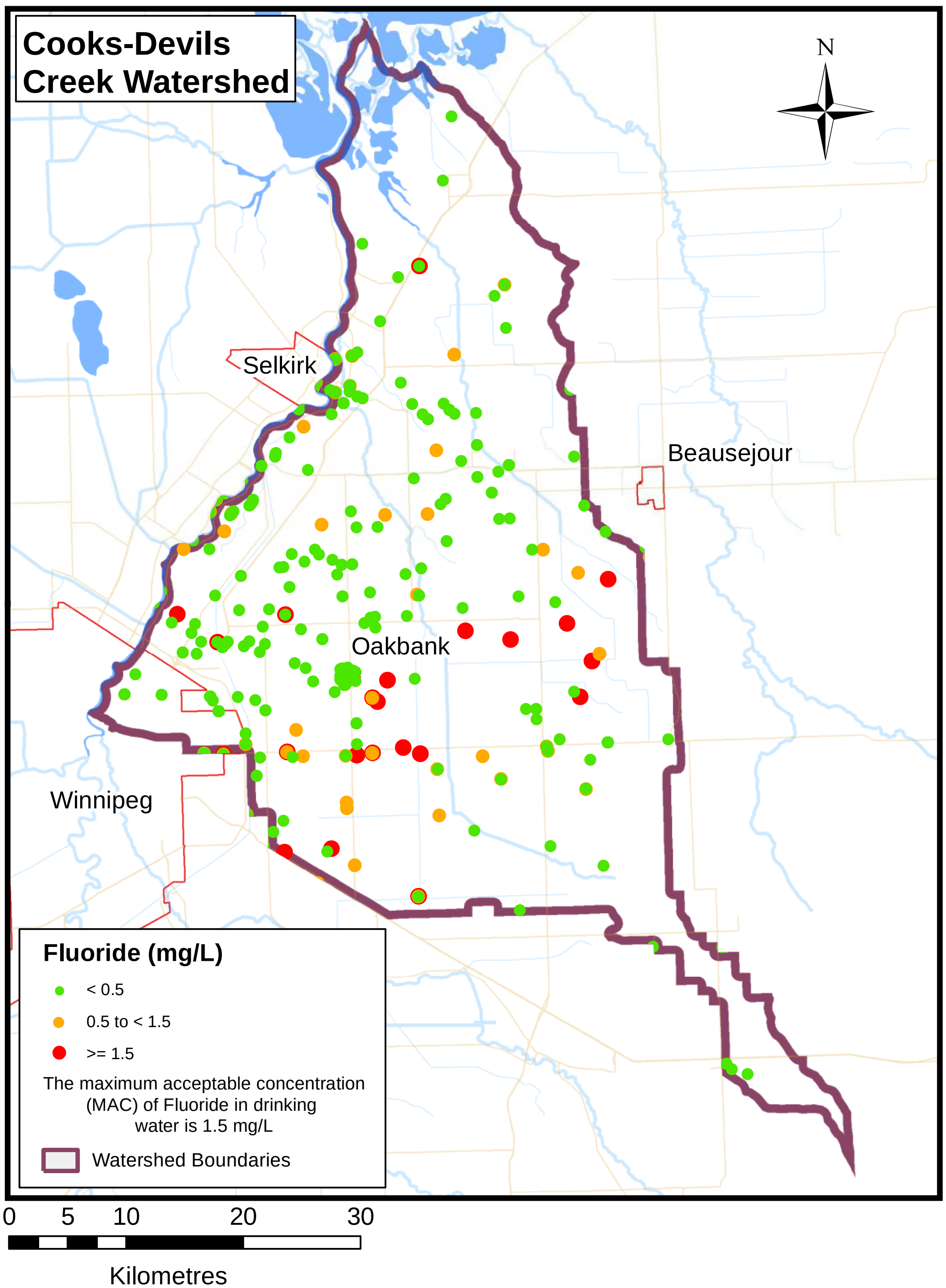
Map # 11 – Total Dissolved Solids (TDS) in the Carbonate Aquifer



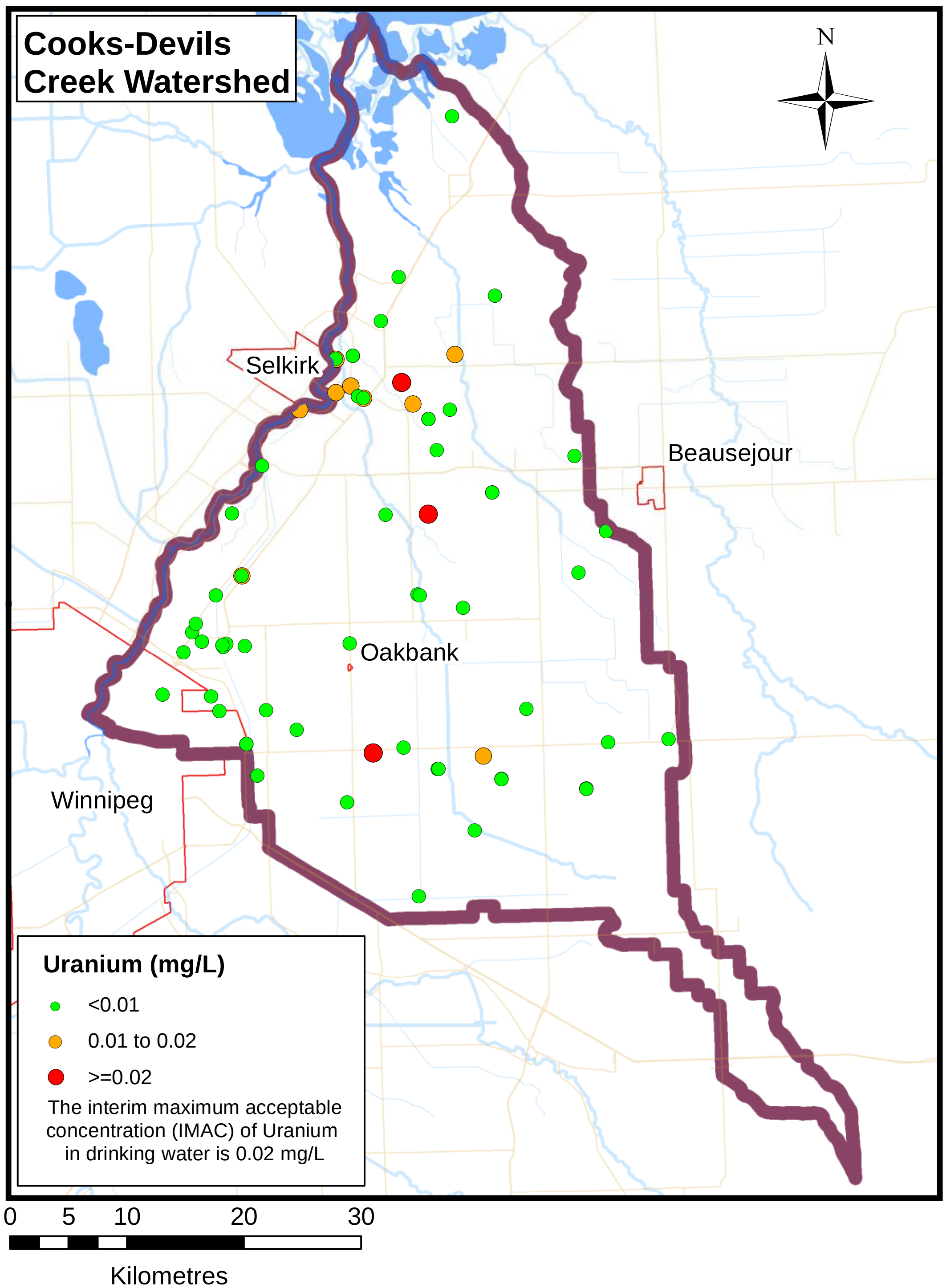
Map # 12 – Nitrate-N in Groundwater (All Aquifers)



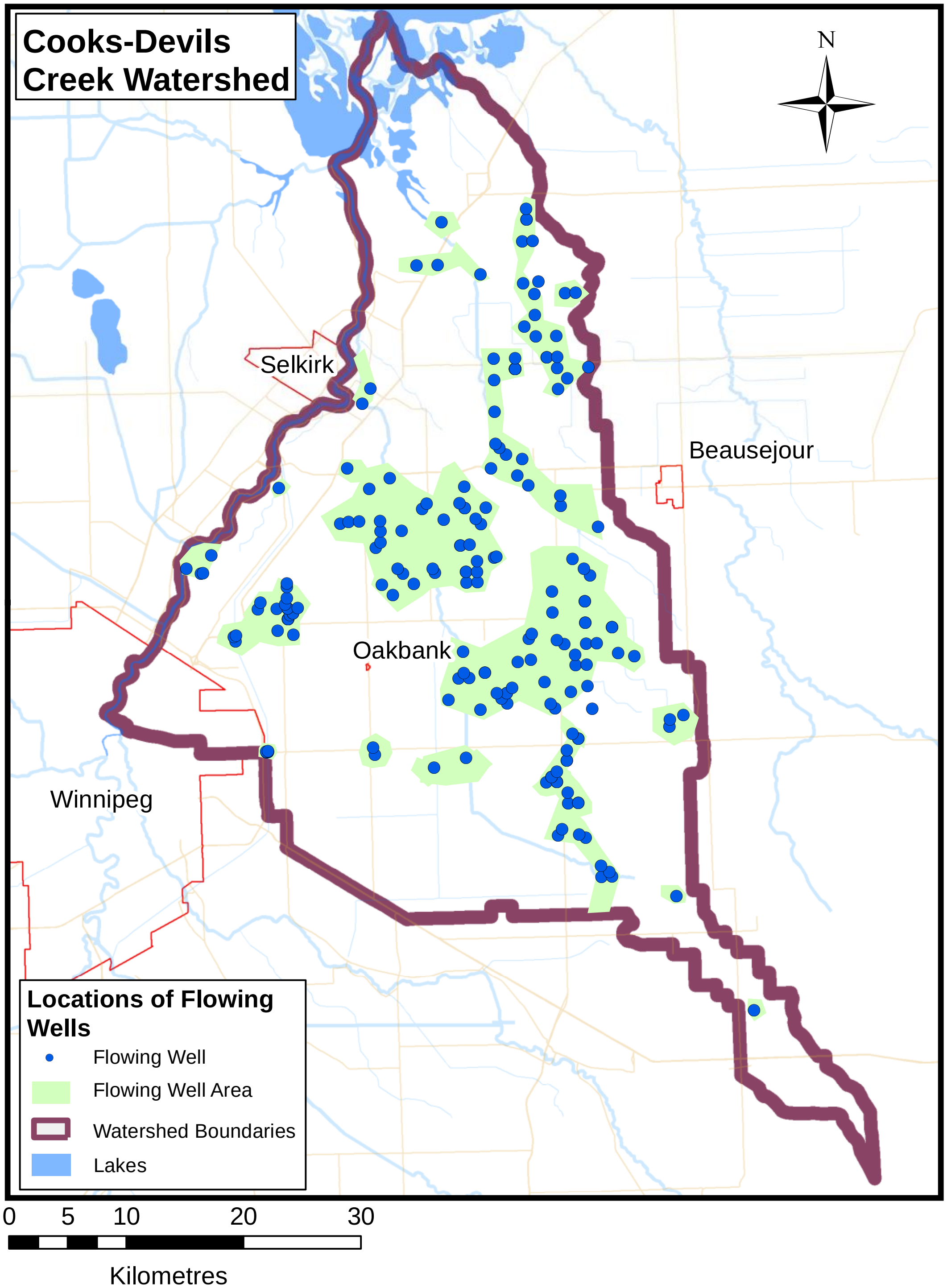
Map # 13 – Sulphate Concentrations in All Aquifers



Map # 14 – Fluoride Concentrations in All Aquifers



Map # 15 – Uranium Concentrations in All Aquifers



Map # 16 – Location of Flowing Wells and Regions

GLOSSARY OF GROUNDWATER RELATED TERMS

Aquifer – Water bearing geological formation capable of supplying enough water to a well to serve as a water source.

Aquitard – A geological formation that contains and transmits water, but in insufficient quantities to be used as a water source.

Arsenic – Most of the arsenic found in Manitoba well water occurs naturally. It is a result of groundwater coming into contact with rocks or soils containing arsenic. The MAC for arsenic in drinking water is 0.01 mg/L.

Barium – Barium found in Manitoba well water usually occurs naturally. It is the result of groundwater coming into contact with bedrock or minerals containing barium. The MAC for arsenic in drinking water is 1.0 mg/L.

Carbonate Rock – A sedimentary rock formed from the accumulation of Carbonate minerals precipitated organically or inorganically. Rocks are chiefly limestone and dolostone.

Confined Aquifer – An aquifer bounded above and below by impermeable beds, or by beds of distinctly lower permeability than that of the aquifer itself; an aquifer containing confined groundwater.

Discharge – As related to aquifer discharge, groundwater flows towards the surface and may escape as a spring, seep, or baseflow or by evaporation or transpiration.

Glacial Till – A glacial deposit composed of mostly unsorted sand, silt, clay and boulders and laid down directly by the melting ice.

Glaciofluvial Deposits – Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice.

Groundwater – All water under the surface of the ground, whether in solid or liquid form.

Guidelines for Canadian Drinking Water Quality – Published by Health Canada. The guidelines set Maximum Acceptable Concentration (MAC) for constituents which cause negative health effects, Aesthetic Objectives (AO) for constituents which cause taste, odour or washing problems. Operational Guideline Values (OG) are used for constituents which interfere with water treatment processes.

Hardness – The ability of water to react with soap. Hard water requires a considerable amount of soap to produce lather. It causes scaling of hot water pipes, boilers and appliances. Hardness comes from excessive amounts of calcium and magnesium dissolved in the water. Hard water is usually softened using salt. Sodium is more soluble in water and takes the place of calcium and magnesium ions.

Iron – The most common sources of iron in groundwater are naturally occurring, for example from weathering of iron bearing minerals and rocks. The AO for iron in drinking water is ≤0.3 mg/L.

Lacustrine Deposits – the deposits which have been accumulated in fresh-water areas (Lake Deposits).

Nitrate – The main form in which nitrogen occurs in groundwater. Decaying plant or animal matter, agricultural fertilizers, manure and domestic sewage are all sources of nitrate. The MAC for nitrate (as nitrogen) in drinking water is 10 mg/L.

Observation Well – A well used for the purpose of collecting groundwater information such as groundwater or quality. It may also be called a "monitoring well".

Permeability – The ability of a water bearing material to transmit water.

Pitless Well Construction – Refers to use of a specially designed underground discharge assembly which is attached to a water well casing to provide a frost-free connection and water tight seal.

Total Dissolved Solids (TDS) – mainly to the inorganic substances that are dissolved in water.

Unconfined Aquifer – An aquifer in which there are no confining beds between the capillary fringe and land surface, and where the top of the saturated zone (the water table) is at atmospheric pressure.

Water Table – The depth at which all the void space in the ground has been filled with water and is at one atmosphere pressure.

Well Yield – The maximum sustained volume of water a well can produce. This usually expressed as gallons per minute, or in standard metric, litres per second. Well yield is usually estimated at time of drilling using production tests or more accurately using pumping tests.