GROUNDWATER RESOURCES OF THE CARROT – SASKATCHEWAN RIVER WATERSHED

GROUNDWATER MANAGEMENT SECTION

WATER SCIENCES & MANAGEMENT BRANCH

MANITOBA CONSERVATION & WATER STEWARDSHIP

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THE CARROT-SASKATCHEWAN RIVER WATERSHED

The Carrot-Saskatchewan River Watershed is located in western Manitoba, along the Saskatchewan border, around the communities of The Pas and Carrot River. The watershed area is made up of the Carrot River, Pasquia River and the lower Saskatchewan River delta before it enters Cedar Lake, an area covering 6,800 km^2 (Figure 1).

The area includes the R.M. of Kelsey and surrounding hinterlands. The largest settlement is the Town of The Pas, with a population of just over 5500 residents, and a service area of about 15,000 in Manitoba and Saskatchewan. The Opaskwayak Cree Nation is home to about 4500 people. Cranberry Portage has a population of 575. The community of Wanless has a population of 200 people. Land use includes agriculture and forestry. Tourism, fishing and service industries are important to the local economy. Agricultural lands are located along the Carrot River. They are low lying and poorly drained. They are maintained through a system of dykes, drains and 5 pumping systems which move water into the Carrot, Saskatchewan and Pasquia river systems.

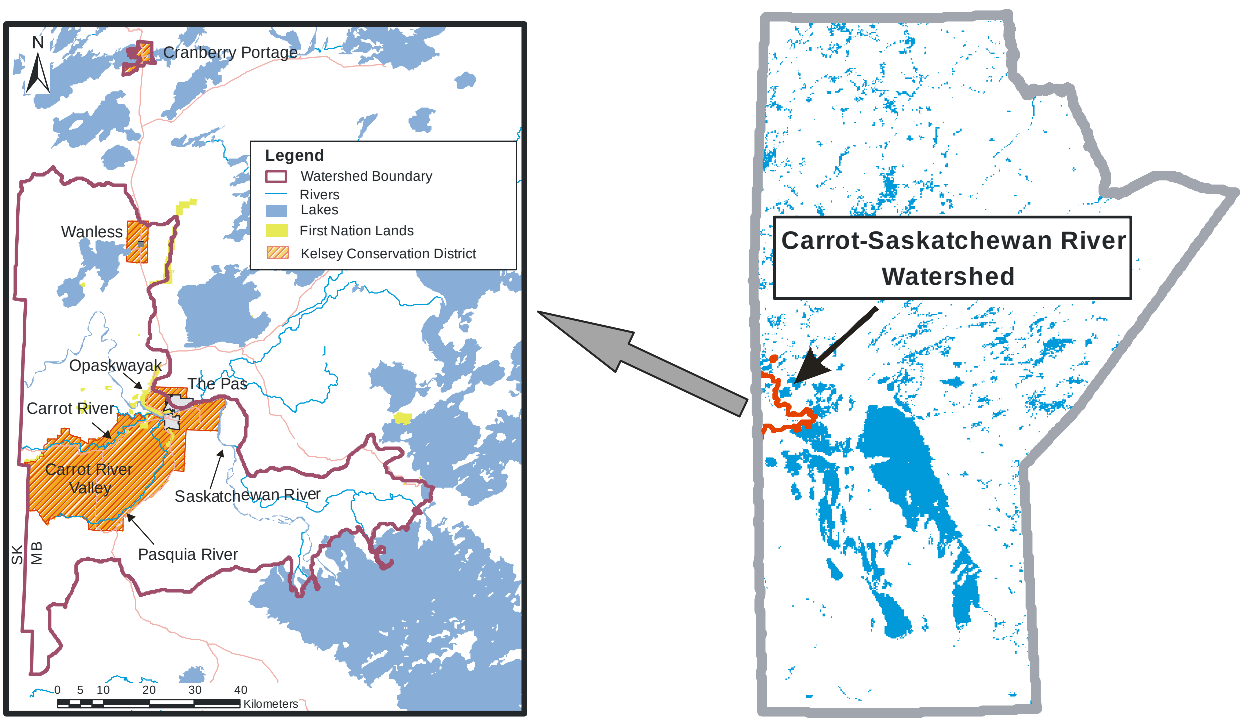


Figure 1. Location of Carrot-Saskatchewan River Watershed

The Saskatchewan River Basin area is vast, incorporating parts of Alberta, Saskatchewan and Montana, covering an area of 405,864 km^2. The river is formed by the confluence of major rivers that rise in the Rocky Mountains of Alberta and travel nearly 2000 km across the prairies to Lake Winnipeg. The portion in Manitoba is one of the largest freshwater deltas in North America. The Saskatchewan River Delta is noted for its rich biodiversity notably plants, mammals, fish, amphibians and birds.

River levels are influenced by hydropower dams located upstream in Saskatchewan and downstream at Grand Rapids.

The Carrot River watershed covers, 15,750 km^2, mostly in Saskatchewan. Only 1750 km^2 is located in Manitoba. The river is 300 km long. It empties into the Saskatchewan River upstream of The Pas, making it a sub-basin of the Saskatchewan River.

The highest point in the watershed is located in the northeast near Wanless, with an elevation of 341 metres above sea level. The lowest point in the watershed is located at the mouth of the delta, with an elevation of 251 metres above sea level (Figure # 2).

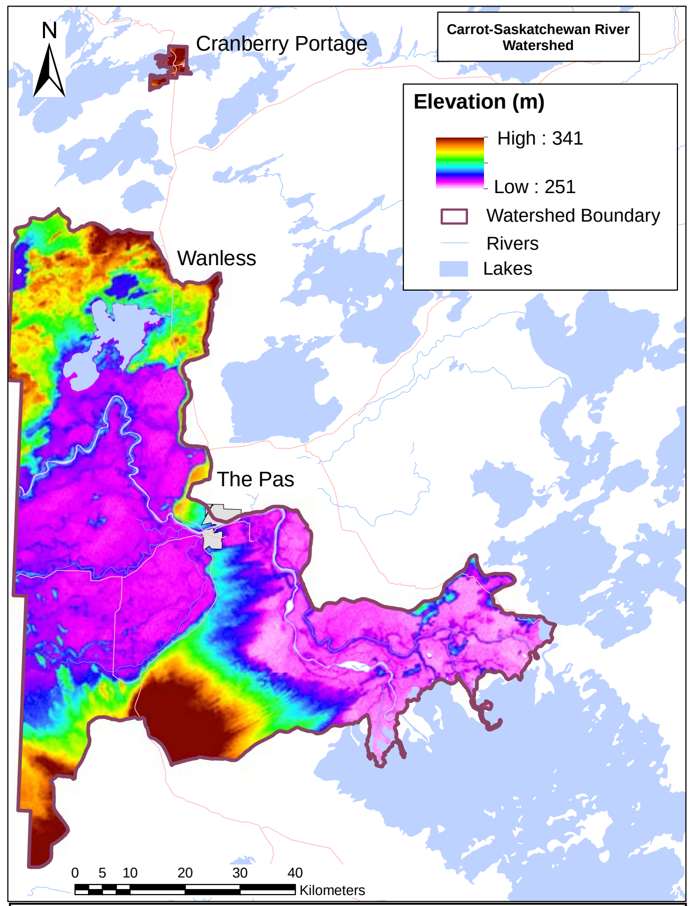


Figure 2. Surface Topography in the Carrot-Saskatchewan River Watershed

GEOLOGY AND AQUIFERS

GEOLOGY

In the Carrot-Saskatchewan River Watershed, geology consists of bedrock with overlying unconsolidated deposits of clays, silts, sands and gravel (drift). Large portions of the area are covered by geologically recent river deposits or gravel, sand and silt, and related organic wetland materials, which make up the Saskatchewan River delta. Drift materials deposited by the glaciers are more widespread and are found over top of bedrock and beneath the river deposits, where present. 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. The Cedar Lake Moraine is found east of the Pasquia River and is made of mostly silty material. Clay sediments related to Glacial Lake Agassiz are found south of The Pas (*Matile and Keller, 2006*).

The thickness of the drift can range from 0 to 70 metres, but is mostly within the range of 20 to 40 metres (Map # 1). Drift, or overburden, is the unconsolidated material found between the land surface and the bedrock surface. Drift thickness is controlled by surface topography and by irregularities in the underlying bedrock surface. There is a local variation in drift thickness caused by relief in the bedrock surface.

Within the watershed, drift deposits are not a significant source of groundwater. In most situations the thickness of drift is the minimum depth required to reach a bedrock aquifer. Pockets of thicker than normal drift are found in sinkholes, which pit the bedrock surface. They are too small in area to appear on the drift thickness maps, but are locally significant features.

Bedrock in most of the central watershed area consists of Paleozoic Interlake Group carbonate rock, which is predominantly limestone and dolomite. The carbonate limestone and dolomite Stonewall and Stony Mountain formations are found north of Wanless. Cranberry Portage rests on the Canadian Shield. The bedrock surface of the carbonate rock has considerable topographic relief caused by past erosion of the rock surface, leaving behind fissures and sinkholes. In some places the features have been filled by shale and sandstone bedrock related to the Swan River Formation (Pedersen, 1973; Bell, 2010).

Four aquifers types are found in the watershed: sand and gravel in drift, the carbonate aquifer, sandstone beds and the Precambrian shield.

SAND AND GRAVEL AQUIFERS

Map # 2 shows the distribution of wells completed in sand and gravel aquifers. Sand and gravel deposits may be found as alluvium, surface beach ridges, or as glaciofluvial units within or at the base of drift. Most of the wells are scattered and do not indicate any regionally continuous aquifers. Well depth ranges from three metres to forty metres (Map # 3). Probability of encountering a sand and gravel aquifer increases with increasing drift thickness (Map 1).

Well yields in the sand and gravel aquifers vary from <1to 4 litres per second (L/s) (1 to 50 imperial gallons per minute (IGPM). High capacity wells could yield up to 550 IGPM (40 L/s) (Map # 4).

Sand and gravel aquifers are often of limited extent and may have uncertain long term yields because of their small size. In contrast the underlying carbonate aquifer is regionally available and has fairly reliable yields, making it the preferred target of well drillers.

CARBONATE AQUIFER

The Carbonate aquifer consists of limestone and dolomite bedrock. The aquifer is made up of the Interlake Group and the Stonewall and Stony Mountain Formations, which subcrop at the base of the drift.

The aquifer has a wedge shape thinning from 65 metres in the southwest to 20 metres in the northeast. The depth to the top of the carbonate aquifer ranges from 17 metres to more than 100 metres. Well completion depths in the carbonate aquifer are shown in Map # 5.

While variations in carbonate rock composition are important, weathering near the bedrock surface is the dominant factor in development of aquifer porosity and permeability. The top few metres to tens of metres of rock constitute the main water bearing zone of the Carbonate aquifer. Deeper, non-weathered zones are less likely to produce satisfactory amounts of water.

The Carbonate aquifer is the primary ground water source for the region. The pores, fractures and cavities found in the limestone and dolomite provide a reliable water source that is accessible throughout the watershed. Wells in the carbonate aquifer will almost always yield sufficient supply for household use.

Well yields in the Carbonate aquifer vary from <1 to 8 L/s (2 to 100 igpm). The high capacity wells could yield up to 75 L/s (1000 igpm (Map #6).

The main constraint on groundwater use in the carbonate aquifer is water quality. Despite sufficient supply, the quality may be too poor for municipal purposes and often requires treatment even for private well owners. Concerns include high salinity and hardness. Shallow wells and wells located within the Saskatchewan River delta and in the vicinity of Wanless have a lower frequency of water quality issues.

SANDSTONE AQUIFERS

The sandstone reported in drilling reports in the area appears to be occasional sandy beds within the carbonate aquifer. Sandstone may also be found filling sinkholes and crevasses at the top of the carbonate aquifer (Swan River formation) (Pedersen, 1973)

While sandstone may be encountered at some locations, it is rarely accessed for water supply. The water encountered in some wells has been described as “salty” or “soda water”. Yields in the range of 0.75 to 1L/s (10 to 15 igpm) have been reported. The sandstone beds are found at depths of 40 m to 100 m (130 to 330 ft).

The Winnipeg Sandstone aquifer is found beneath the thicker portions of the Carbonate Aquifer. It pinches out beneath the Carbonate aquifer as the Carbonate strata thin toward the north. The depth to the Winnipeg Sandstone, and the poor water quality within the Carbonate aquifer over top of it, makes it a poor candidate for water supply.

PRECAMBRIAN CRYSTALLINE ROCK

In most of the watershed Precambrian igneous and metamorphic crystalline rock of the Canadian Shield is found deep beneath Paleozoic rock. The Paleozoic rocks thin toward the north and are completely eroded away at Cranberry Portage. Depth to granite in the vicinity of Cranberry Portage is about 2 to 20 m. Wells completed in granite aquifer are shown on Map # 2. The Canadian Shield is water bearing only when fractured. Fractures most commonly occur in weathered horizons near the land surface. As a consequence, this zone is not considered to be an aquifer except near Cranberry Portage, where it is near the surface and apart from occasional pockets of sand and gravel, no other aquifer is available. Well yields in the Precambrian crystalline rock may be expected to be in the range of <0.08 to 0.75 L/s (<1 to 10 igpm).

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 springs, the bottoms of streams, lakes or wetlands, or is taken up by vegetation. Groundwater helps ensure streams 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. Often it takes a prolonged rain or heavy storm to cause recharge. Recharge may increase in late fall, when vegetation goes dormant, but stops once the ground is frozen. This pattern is commonly seen in groundwater monitoring well hydrographs.

Shallow groundwater flow is generated locally within the watershed. Local flow systems receive their water from precipitation and snow melt. Annual flooding of the Saskatchewan River delta provides an additional source of fresh water. Local flow systems are important because they are a source of fresh water to aquifers.

The central part of the watershed is influenced by deep groundwater flow, which originates from the west (Betcher et al, 1995). The deep groundwater is a source of saline water. As a consequence, deeper wells in central areas tend to have poor quality water. Water quality is best at shallow depths around the Saskatchewan River delta and in the northern parts of the watershed, where fresh water recharge is strongest. Recharge was a factor in the selection of the Carrot Valley groundwater source well, which is located within the area of influence of the Saskatchewan River delta.

GROUNDWATER USE

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

Municipal water supplies are operated by the Opaskwayak Cree Nation near The Pas and by the RM of Kelsey, which operates a rural water pipeline to 360 households in the Carrot Valley. Both source their water from the Carbonate aquifer. Two private users in The Pas obtain groundwater from the Carbonate aquifer for heating and cooling purposes (geothermal). The Town of The Pas obtains its water supply from the Saskatchewan River.

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 445 wells for this watershed in the groundwater database provided by the well drillers. These wells are not evenly distributed across the watershed, but are concentrated in settled areas around The Pas and along the highways #10, #282 and #283 (Map # 2).

The database shows about 80% of all wells on record were completed in the Carbonate aquifer. Ten percent of the wells were completed in sand and gravel. Less than two percent of wells were complete in granite and these were found exclusively in the Cranberry Portage area, where the carbonate aquifer is not present and there is little overburden cover. Five wells (1%) were completed in sandstone. A breakdown of wells by aquifer type is shown in Table 1.

Table 1 Total Number of Wells by Aquifer (all types):

Aquifer Type	**Number of Wells**	**% of Wells**
All aquifers (total)	445	100
Sand and gravel aquifers	44	10
Carbonate aquifer	358	80.5
Granite aquifer*	7	1.5
Sandstone aquifer	5	1
Unknown or other	9	2
Dry Well (insufficient or no supply)	23	5

*Cranberry Portage area only

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.

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 Carrot-Saskatchewan River Watershed, there is one active provincial monitoring well, which has recorded continuous water levels since 1998 (Figure 3).

Figure 3. Location of the Carrot River Dyke provincial groundwater observation well, near The Pas.

G05KJ010 (PID 103324) is located behind the dike on the south bank of the Carrot River on Hwy 283, nine kilometres southwest of The Pas. The well is located adjacent to the Saskatchewan River Delta and is 65.2m (214 ft) deep, making it comparable in depth to many wells in region and to the Carrot Valley water supply wells, which are located about 2 km to the northwest. The well takes continuous water level readings in the fractured Carbonate aquifer and monitors mainly natural conditions.

The hydrograph (Figure 4) shows that the static water level is high, within 2 m of ground surface. The water level may rise to or just above the surface, and consequently is prone to freezing in winter. Water levels vary within a 1 m range most years and over a 1.9 m range over several years.

The water level chart shows annual seasonal cycles and longer term climatic cycles. During the annual cycle there is a protracted annual peak. The peak may begin anytime from early to late summer and typically extends through the fall. This is later than for most monitoring wells in Manitoba, which typically peak in late spring.

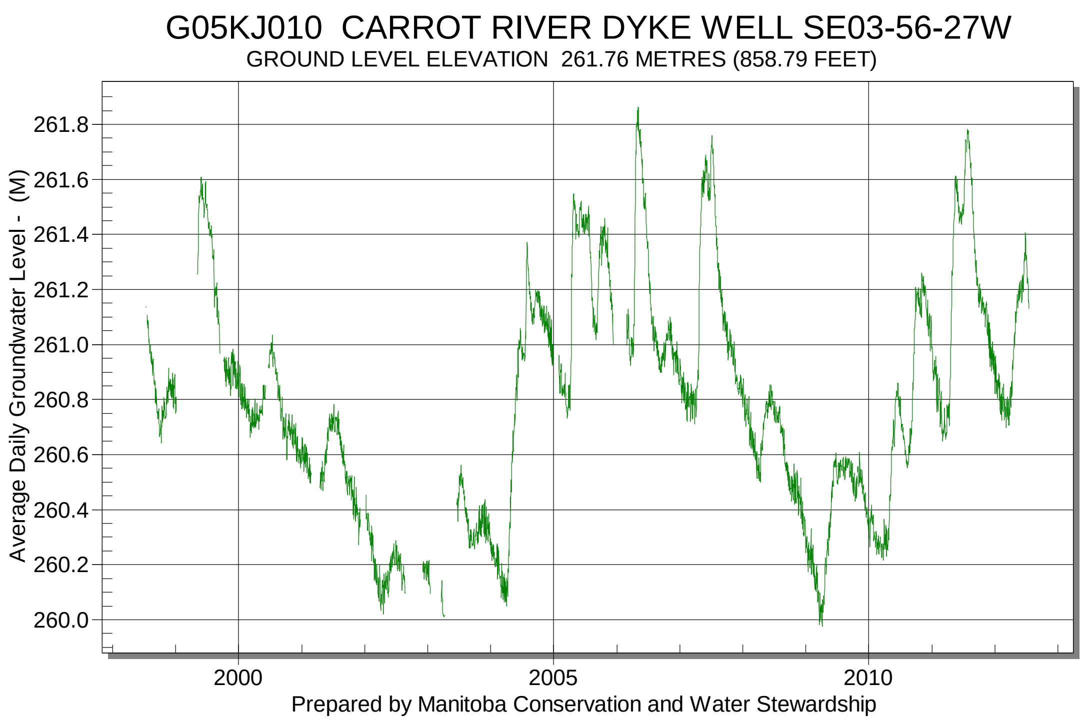


Figure 4. Hydrograph for the Carrot River provincial groundwater observation well. It monitors mainly ambient conditions and illustrates response to surface water levels in the Saskatchewan River Delta.

Figure 5 shows a comparison of the hydrograph to annual and winter precipitation and Figure 6 shows a comparison of the hydrograph to the surface water level of the Saskatchewan River at The Pas. The water levels in the well do not appear to respond to precipitation. In contrast the hydrograph shows a subdued and delayed response to water level changes in the Saskatchewan River.

Flow in the Saskatchewan River is determined by precipitation and melting snowpack across its basin, which extends from Manitoba through Saskatchewan and Alberta. Because its headwaters are located in the Rocky Mountains, where melting of snowpack occurs in May and June, and the long distance the water travels to reach the delta, the Saskatchewan River at The Pas peaks later in the season than rivers where flow is locally derived. Flow is regulated by dams located in Alberta and Saskatchewan, with the dam at Tobin Lake, immediately upstream having the greatest influence. The dams mitigate flood peaks, while overall flow is reduced by water diversions upstream, mostly for irrigation and municipal use.

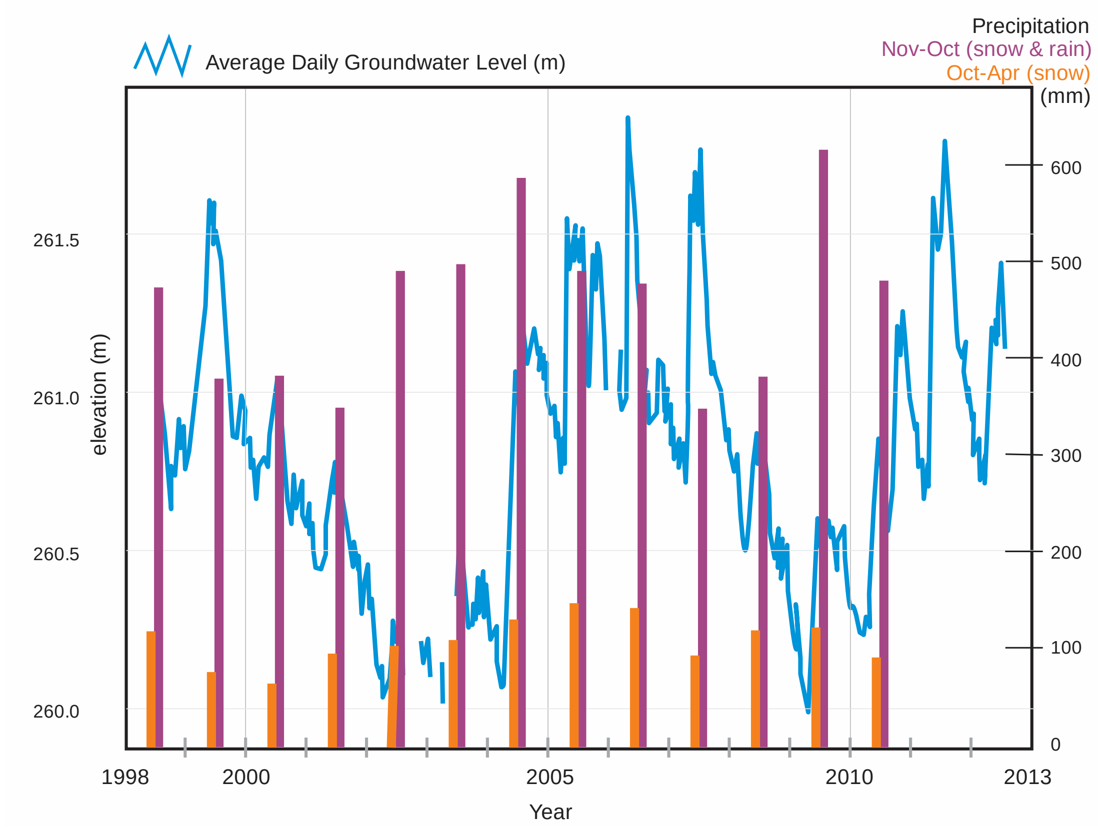


Figure 5. Comparison of average daily groundwater level compared to local annual precipitation and winter snowfall

The strong seasonal response of the hydrograph to changes in surface water levels indicate a good degree of hydraulic connectedness, where pressure influences are felt at depth. The response is not always immediate and may be delayed by up to four months for peaks, and longer for recession. The delayed and sustained response to surface flows, suggest that some groundwater recharge is taking place. Improved water quality in the vicinity of the delta, compared to the nearby Carrot Valley, affirms this.

The well was tested for laboratory results in general chemistry in 1996 (Table 4). The water quality for the well is reasonable. Total dissolved solids are just under 700 mg/. This is above the aesthetic objective set in the Canadian Drinking Water Guidelines, but within a range considered acceptable for well water. Most other constituents have relatively low concentrations. The water is very hard, which is not unusual in carbonate aquifers.

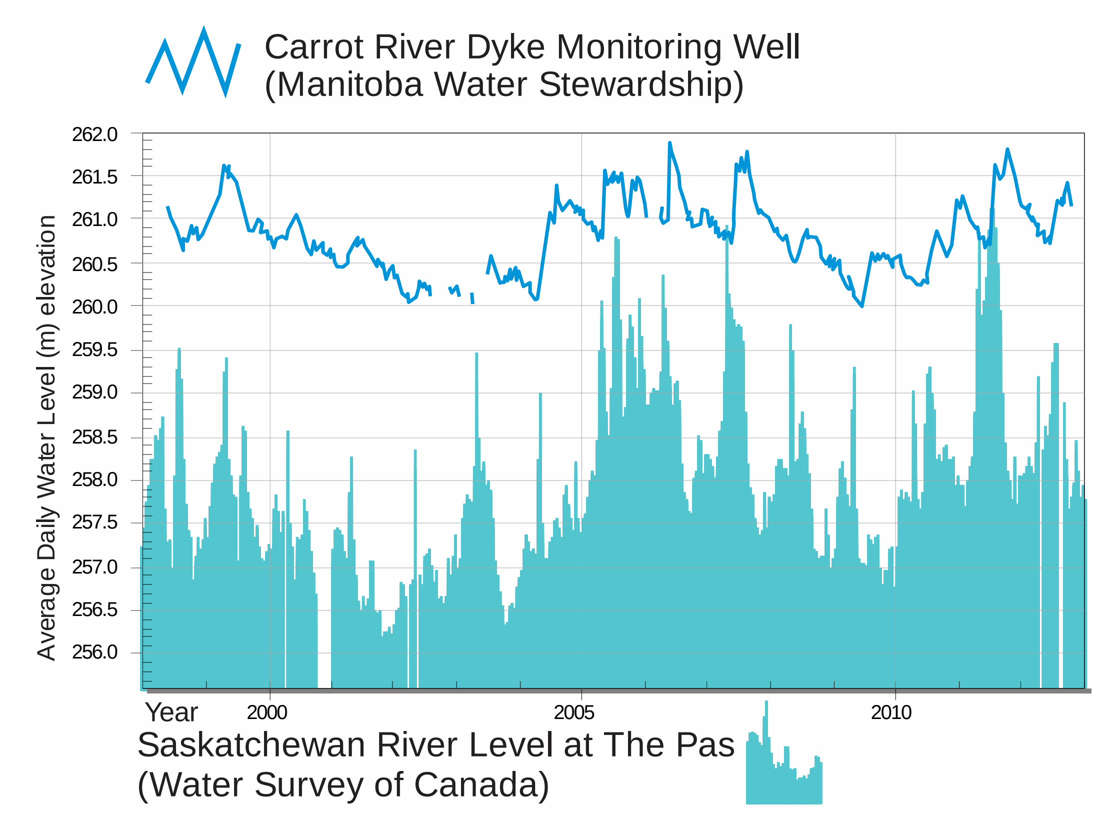


Figure 6. Comparison of average daily groundwater level compared to maximum annual daily discharge of the Saskatchewan River

Table 2 Provincial Observation Well in the Carrot-Saskatchewan River Watershed

Well Name	Land Location	Aquifer	Depth m/feet	Monitoring Record	Status	Type
G05KJ010 CARROT RIVER DYKE – PID 103324	SE-03-56-27W	Carbonate	65.2 m 214 ft	1998-present	Active	Water Levels

Water Quality Results in mg/L

Year	TDS	Hard	pH	Ca	Mg	Na	HCO_3	SO_4	Cl	Fe	NO_3-N	F
1996	691*	280	8.1	48.4	38.6	113	212	<10	220	0.02	<0.01	0.3

*calculated based on an EC of 1080 uS/cm

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.

In the Carrot-Saskatchewan River watershed, much of the carbonate aquifer has poor quality water due to the influence of deep regional groundwater flow from outside the watershed boundaries. The deep water source tends to be highly mineralized to saline. Better quality water is found where local recharge is taking place. This occurs in more elevated areas around Wanless and in areas within the Saskatchewan River delta.

Hard water and high iron are additional concerns. Nitrate currently does not appear to be a problem in this area.

The *Manitoba Water Quality Standards* (Manitoba Water Stewardship, 2011)*, Objective and Guidelines* and the *Canadian Guidelines for Drinking Water Quality* (Health Canada, 2010) sets 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 3 (*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.

Some routine parametres and their significance are shown in Table 4. 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 3 Recommended limits of Total Dissolved Solids (*Olkowski, 2009*)

TDS Concentration Limit mg/L	For Consumption By:
Up to 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 carbonate and sand and gravel aquifers total dissolved solids in most of the wells in this watershed are in the range of 300 mg/L to 1000 mg/L which considered fair for human consumption (Map # 7). In the Carrot Valley and the portion of The Pas south of the Saskatchewan River total dissolved solids often exceed 1000 mg/L. Near Wanless, the water in the carbonate aquifer is in the range of 300 mg/L to 500 mg/L which within the aesthetic objective set for in the *Guidelines for Canadian Drinking Water Quality*. Total dissolved solids tend to increase with increasing well depth.

Water hardness is a property caused by high calcium and magnesium. The optimum range of hardness according to the *Guidelines for Canadian Drinking Water Quality* is from 80 to 100 mg/L. Water with hardness greater than 200 mg/L is considered poor and water with hardness greater than 500 mg/L is normally considered unacceptable for domestic purposes.

In this watershed particularly in the Carrot Valley and regions around The Pas (Parsons et al, 2011), hardness in most of the wells has been exceeded from 200 mg/L which is considered very hard water (Map #8). Hard water is mainly as aesthetic concern. It reduces the ability of soap to produce lather, causes scale buildup in pipes, plumbing fixtures and appliances and may affect the taste of tea and coffee. Water softeners may be used to reduce hardness, but will raise sodium levels in the water. If sodium levels are already high, softening may not be an option.

High levels of sodium exceeding drinking water guidelines have been found in most wells in this watershed (Map # 9). The Canadian drinking water quality aesthetic objective for sodium is 200 mg/L. The sodium is naturally occurring, a result of water entering the region from deep regional groundwater flow systems. Sodium may be an issue for those suffering high blood pressure.

High levels of iron are found in many wells, particularly those completed in sand and gravel (Map# 10). The Aesthetic Objective (AO) for iron in drinking water is less than or equal to 0.3 mg/L. High concentrations of iron may give the water an unpleasant colour and taste and may cause the staining of laundry and bathroom fixtures. Softeners will remove a small amount of iron. Significant iron problems may require treatment such as sand filters or reverse osmosis.

Nitrates do not appear to be an issue in the Carrot-Saskatchewan Watershed.

Minor elements or trace metals, which have occasionally exceeded *Guidelines for Canadian Drinking Water Quality* in parts of Manitoba, include arsenic, fluoride, barium, boron and uranium. With the exception of fluoride, trace metals are usually not included in basic water well analysis and may require separate testing. In the Carrot-Saskatchewan River Watershed, where tested, trace metals concentrations including fluoride, barium, boron, arsenic and mercury were within acceptable amounts for *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.

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).

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.

To avoid upward migration of saline water, deep wells should not be drilled into the Carbonate aquifer where water quality is known to be poor. If poor quality water is encountered the poor quality zone should be sealed off from other zones, or if the well is abandoned, the well should be carefully grouted from bottom to top.

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 # 11. Most are located along the Carrot River and highway # 238, and are likely a consequence of flow from surrounding uplands.

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 Saskatchewan-Carrot River 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.

SUMMARY

Groundwater supply is readily available throughout populated areas of the Saskatchewan-Carrot River watershed. Three main aquifers are available: scattered sand and gravel aquifers, Precambrian crystalline rock, and the Carbonate aquifer. The vast majority of well owners obtain their supply from the upper part of the carbonate aquifer. The Carbonate aquifer is found throughout the region except Cranberry Portage, where Precambrian rock is used instead. Scattered sand and gravel units of limited size may be found anywhere. Occasionally sandstone beds are reported within the Carbonate Aquifer. The Winnipeg Sandstone is also found beneath most of the watershed, but is usually too deep and the water quality too poor to be accessed as an aquifer. Availability of water is rarely a concern.

Water quality is the main constraining factor in well groundwater use in The Pas and the Carrot Valley agricultural region. Hardness, high iron, high sodium and high total dissolved solids are issues. Hardness is not unusual for carbonate aquifers. Deep groundwater flow systems from the west are responsible for elevated salinity in deeper wells. Water quality is better in near Wanless, and better quality water may be sourced within the Saskatchewan River delta area. These areas receive recharge of fresh water.

The Pas obtains its water supply from the Saskatchewan River. Public systems obtaining groundwater from the Carbonate aquifer, supply the Opaskwayak Cree Nation and the Carrot Valley agricultural region. Others use private wells.

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.

GROUNDWATER MANAGEMENT SECTION, MANITOBA CONSERVATION AND WATER STEWARDSHIP, 2014

REFERENCES

Bell, Jeffrey J. 2010. Hydrogeology of The Pas Area of Manitoba. GeoCanada 2010, Calgary, Alberta. (Abstract). 4 pp.

Betcher, R, G. Grove and C. Pupp. 1995. *Groundwater in Manitoba: Hydrogeology, Quality Concerns, Management.* National Hydrology Research Institute Contribution No.CS-93017. Environmental Sciences Division, NHRI, Environment Canada.

Canadian Council of Ministers of the Environment (CCME). 2005. *Canadian water quality guidelines for the protection of agricultural water uses.*

Health Canada, 2010. *Guidelines for Canadian Drinking Water Quality* . Ottawa.

Manitoba Water Stewardship, 2011. *Manitoba Water Quality Standards, Objectives and Guidelines.* Report 2011-01, Winnipeg.

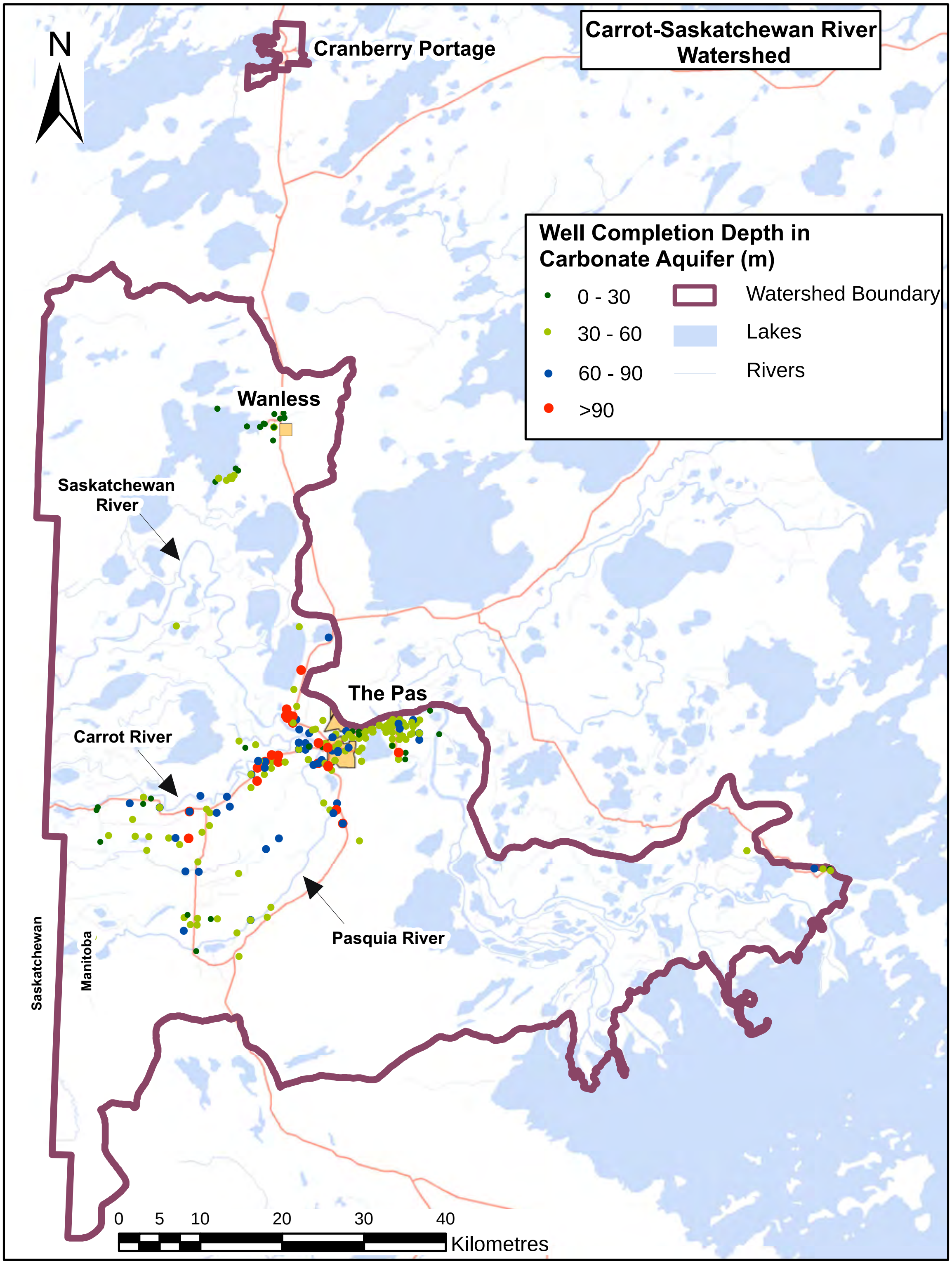
Matile, GL.D. and G.R. Keller 2006. *Surficial Geology of The Pas map sheet, (NTS 63F), Manitoba*. Surificial Geology Compilation Map Series SG-63F, Manitoba Science, Technology, Energy and Mines. (Map).

Ontario Ministry of the Environment, 2001. *Protocol: Delineation of wellhead protection areas for municipal groundwater supply wells under direct influence of surface water*. PIBS 4168e. 5 pp.

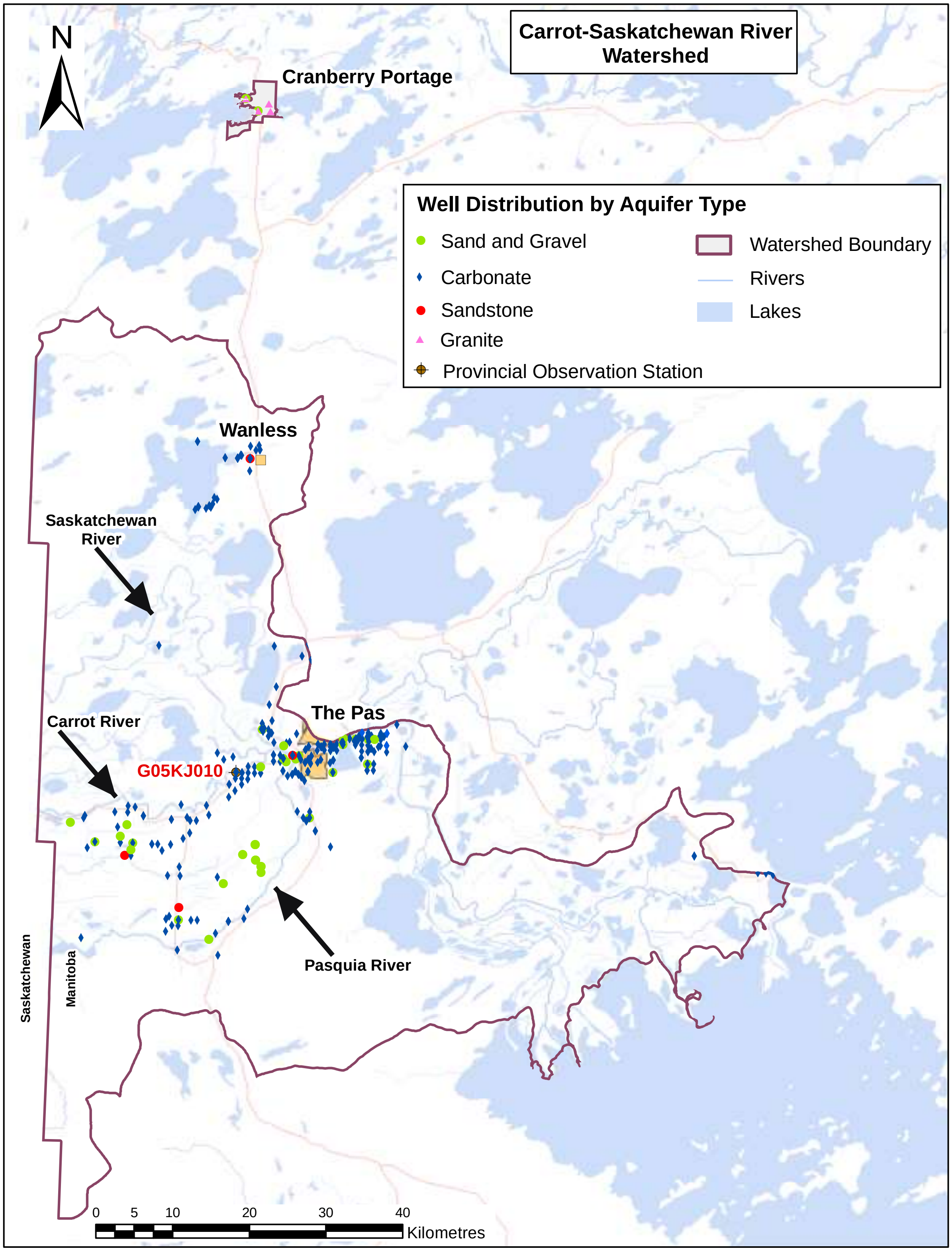
Olkowski, Andrew. 2009. *Livestock Water Quality: A Field Guide for Cattle, Horses, Poultry and Swine.* University of Saskatchewan, Saskatoon. 180 pp.

Pedersen, A. 1973. *Groundwater Availability in The Pas area, Manitoba.* Groundwater Availability Studies, Report #9, Manitoba Agriculture, Winnipeg. 45 pp.

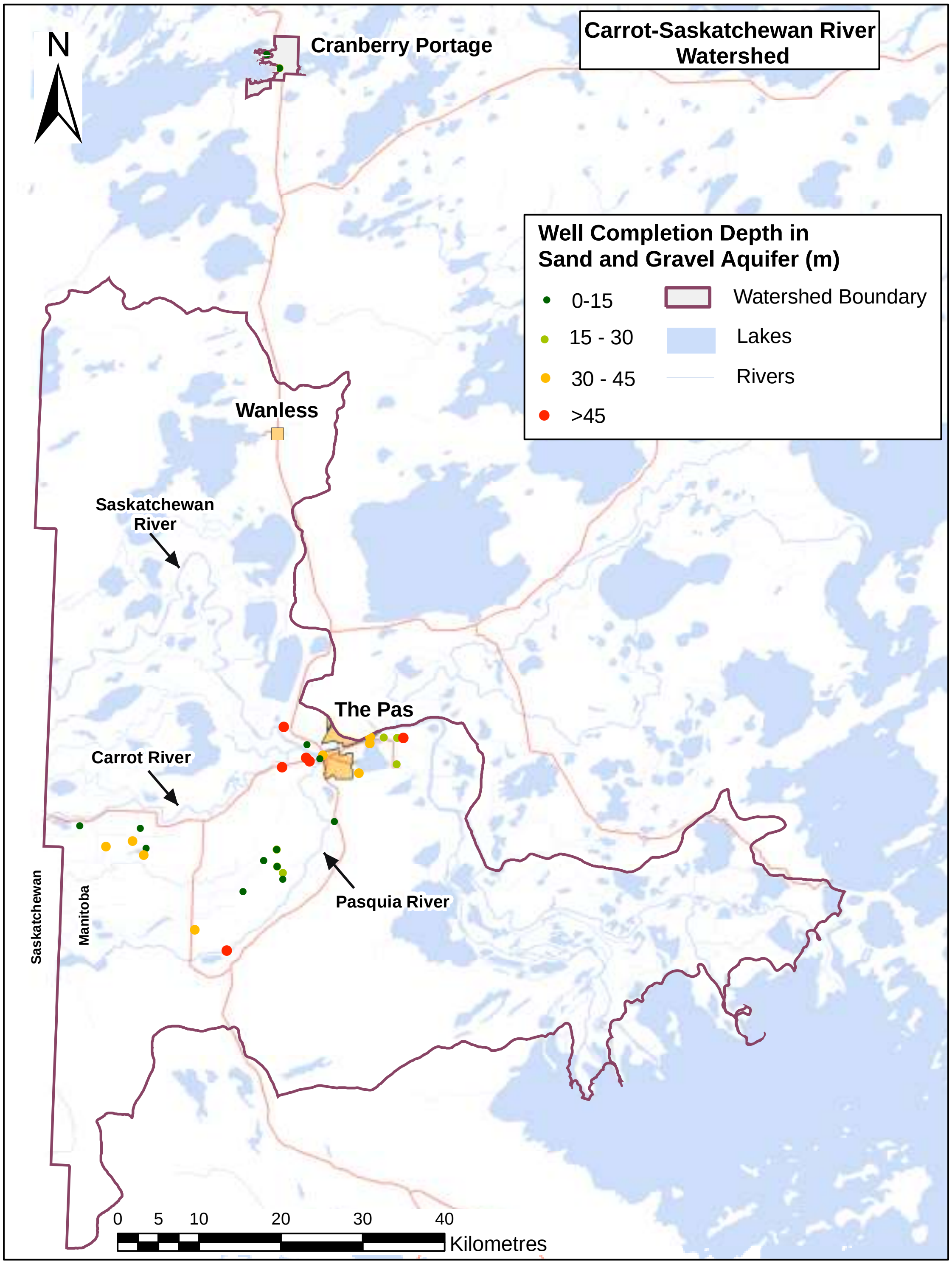
Parsons, Travis and Jamiee Schmidt 2011. *Rural Municipality of Kelsey Ralls Island municipal rural water system feasibility study*. Manitoba Water Services Board, Brandon. 38 pp.



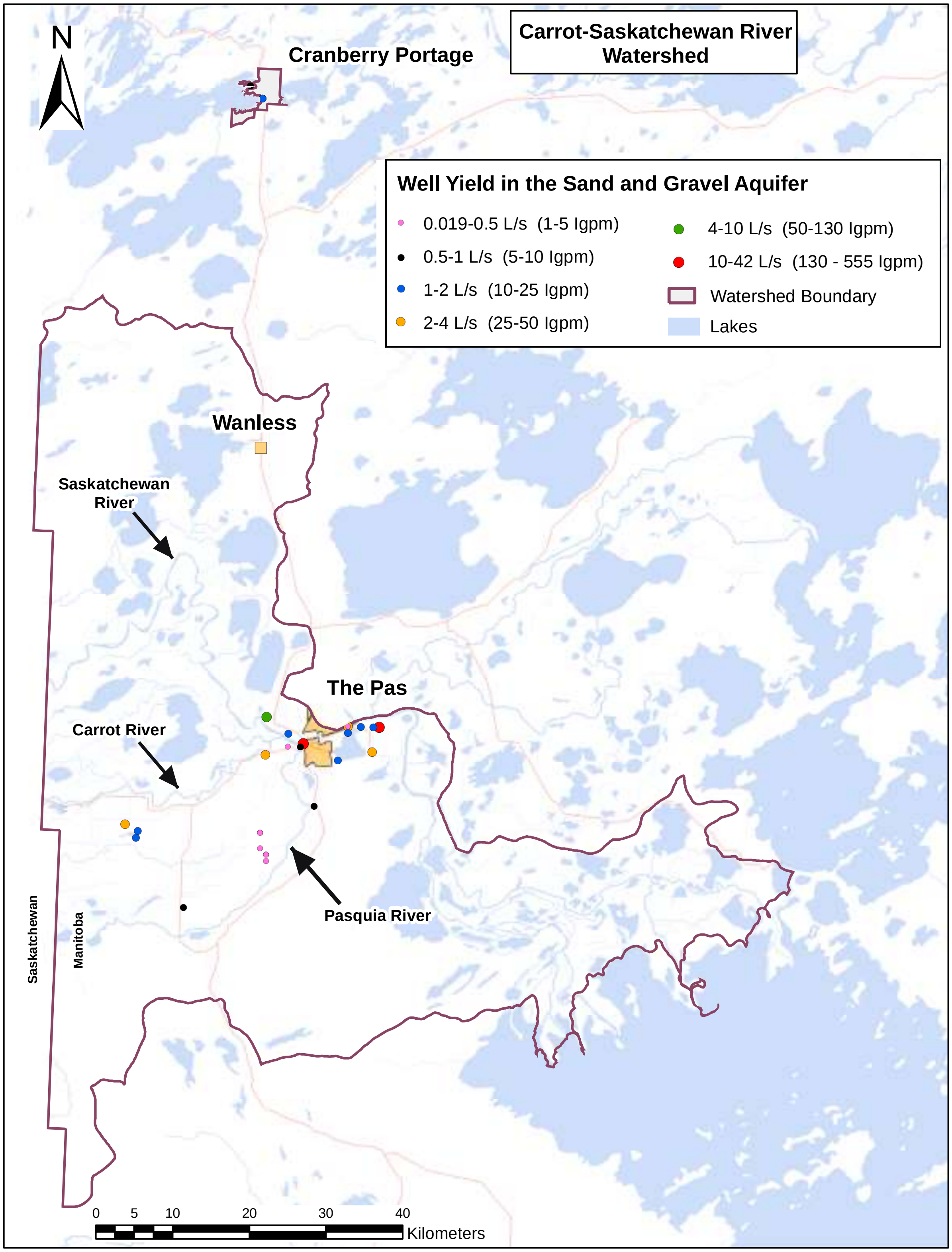
Map #1 - Drift Thickness (metres)



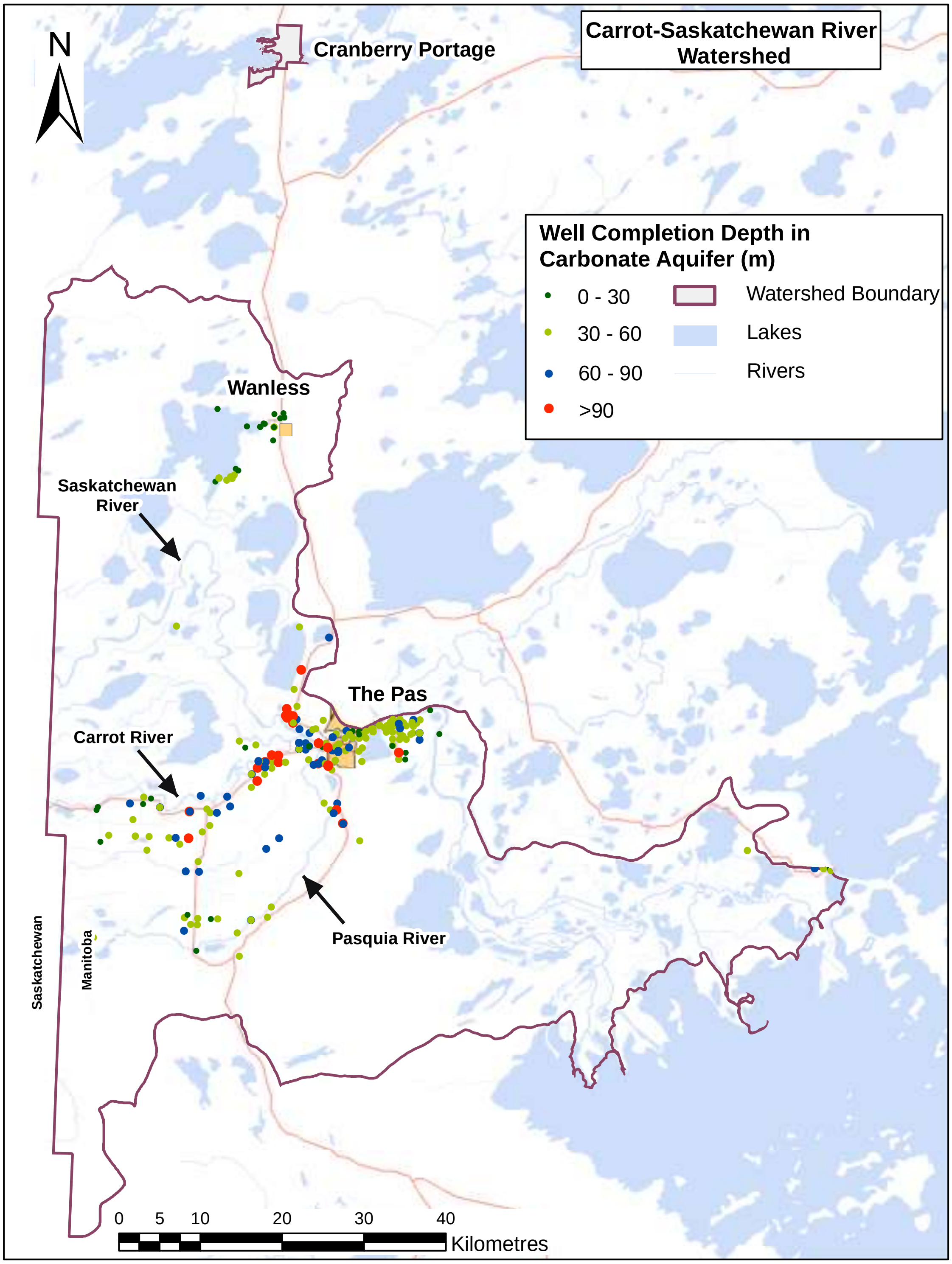
Map # 2 – Well Distribution by Aquifer Type



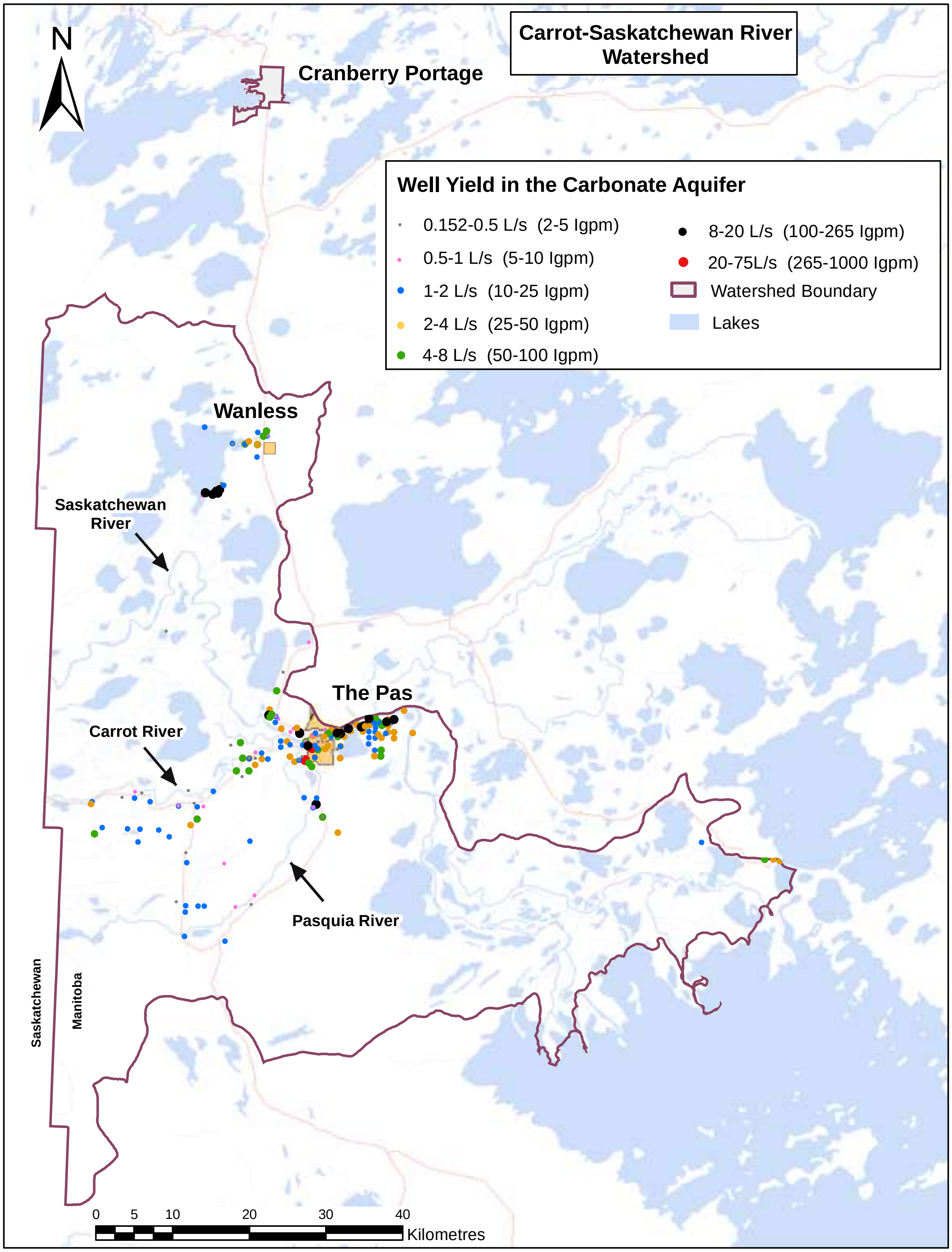
Map # 3- Well Completion Depths in Sand and Gravel Aquifer (metres)



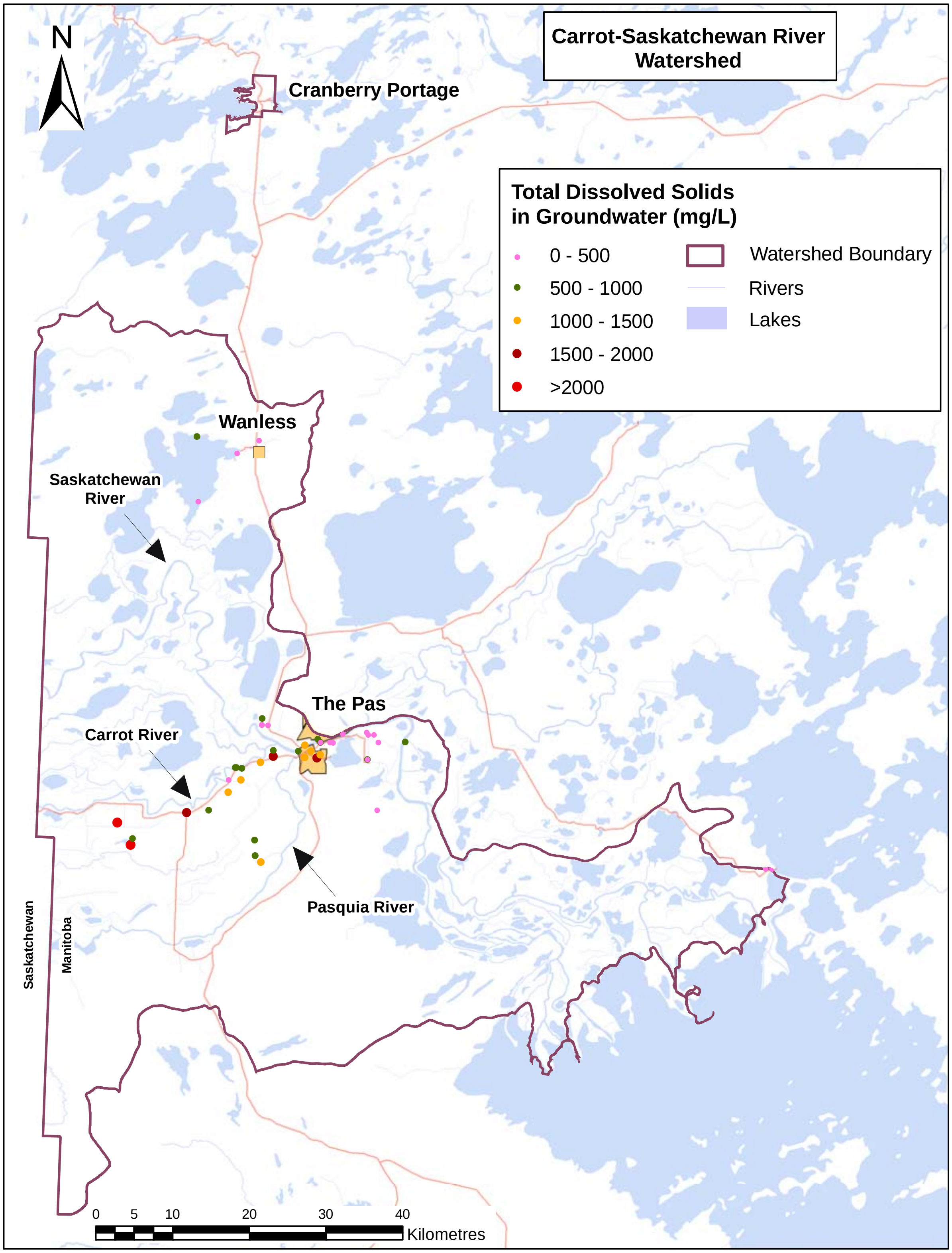
Map # 4 – Reported Pumping Test Rates in the Sand and Gravel Aquifer



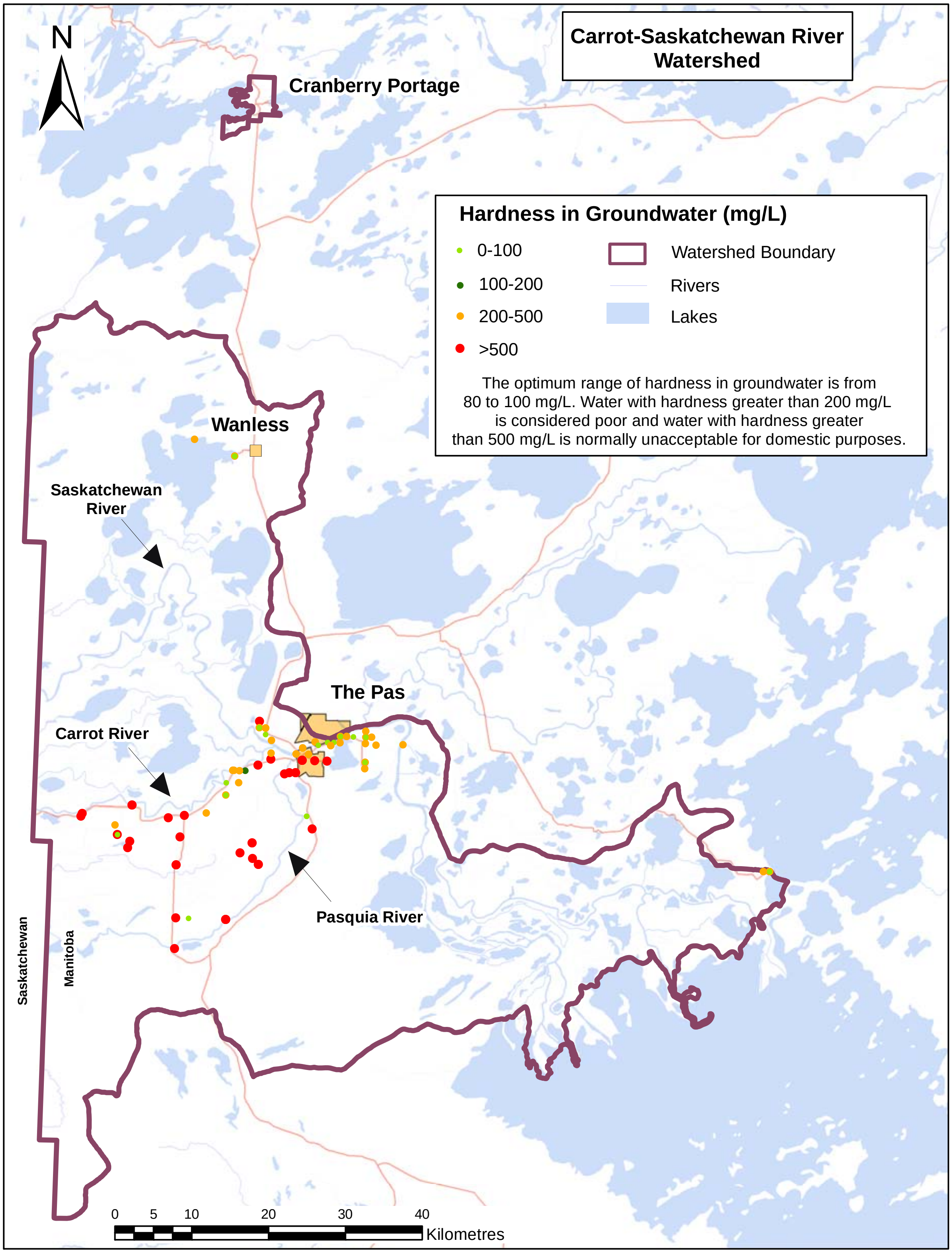
Map # 5 – Well Completion Depths in the Carbonate Aquifer



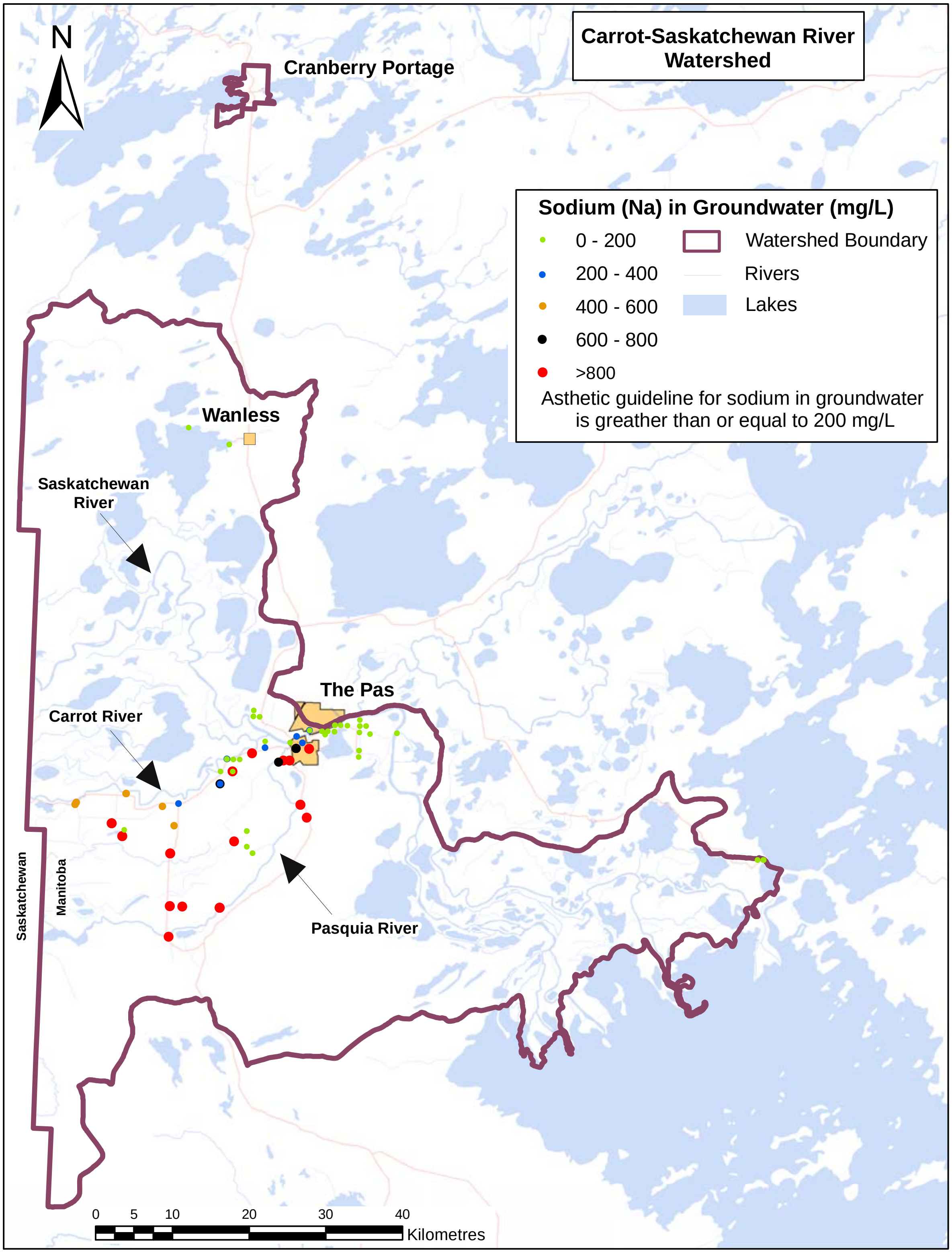
Map # 6 – Reported Pumping Test Rates in the Carbonate Aquifer



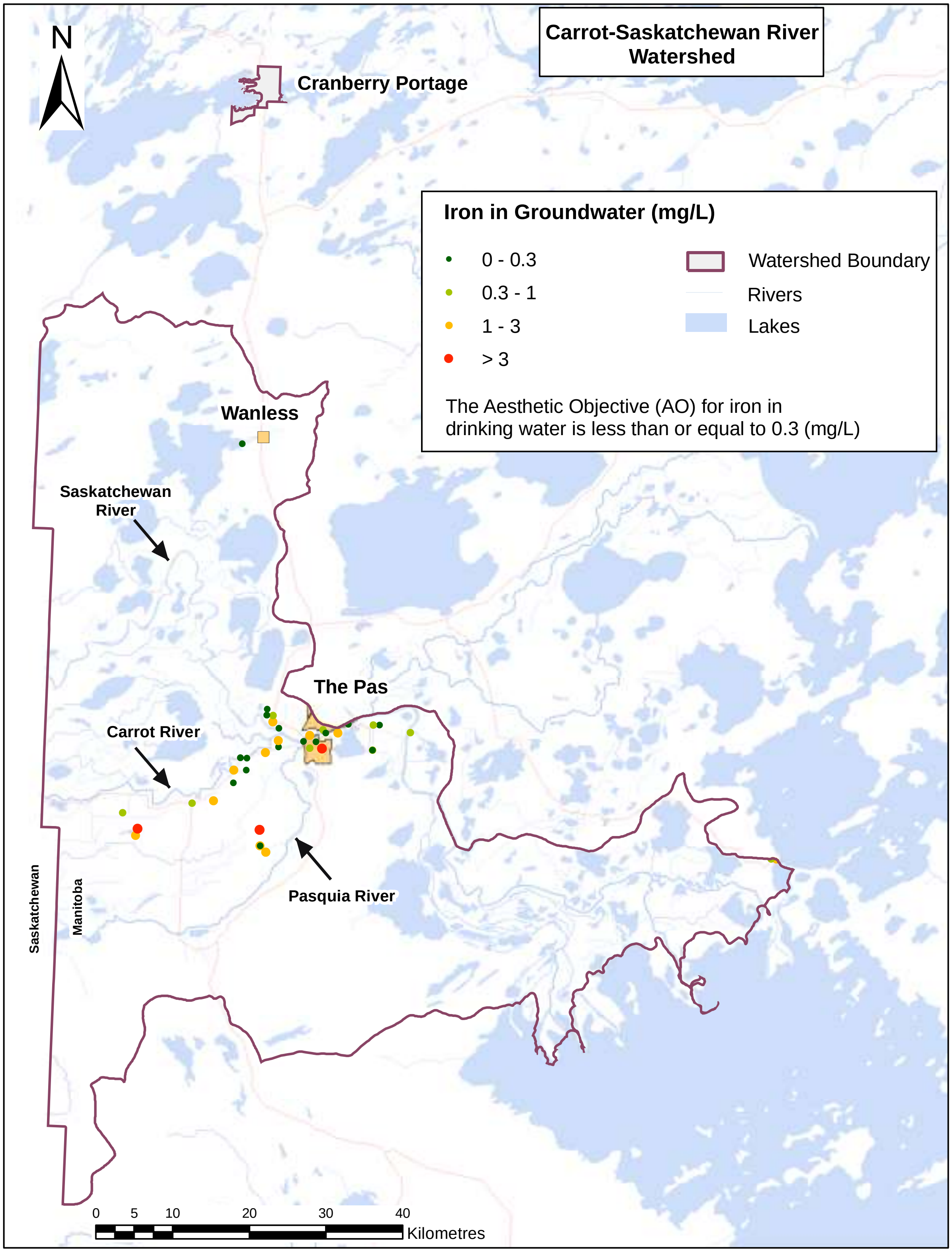
Map # 7 – TDS in the Carbonate and Sand & Gravel Aquifers



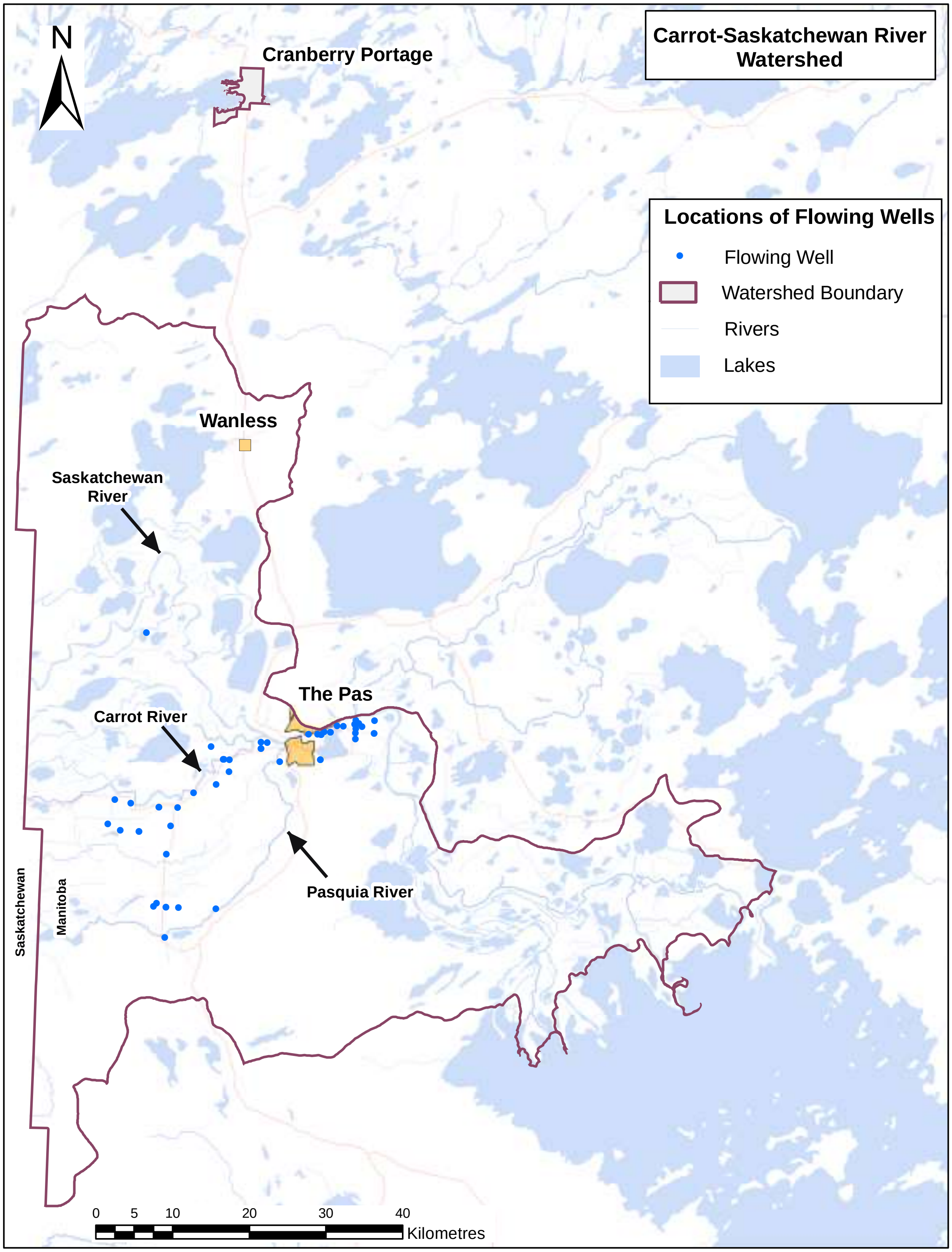
Map # 8 – Hardness in the Carbonate and Sand & Gravel Aquifers



Map # 9 – Sodium in the Carbonate and Sand & Gravel Aquifers



Map # 10 – Iron in the Carbonate and Sand & Gravel Aquifers



Map # 11 – Location of Flowing Wells

GLOSSARY OF GROUNDWATER RELATED TERMS

Alluvium – Sediment deposited by running water. Alluvial (*adj*)

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.

Carbonate Rock – A sedimentary rock formed from the accumulation of carbonate minerals made of up limestone and/or dolomite.

Glacial Till- Unsorted boulders, sand, silt and mostly clay left behind by melting glaciers.

Groundwater – All water below the surface of the ground.

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.

Moraine – A glacial deposit of coarse unsorted material left at the margins of an ice sheet.

Nitrate – The main form of nitrogen in groundwater. The MAC for nitrate (as nitrogen) in drinking water is 10 mg/L. Decaying organic matter, fertilizers, manure and sewage are sources of nitrate.

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 formation to transmit water.

Porosity – The volume of void space in a rock, expressed as a fraction. A rock needs both porosity and permeability to be a good aquifer.

Sinkhole – A small, steep depression found at the surface of carbonate rock. It forms when caverns in the rock collapse.

Total Coliforms – Group of bacteria that are found naturally in the environment and in the intestines of humans and animals.

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

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.