LWF LAKE WINNIPEG FOUNDATION

Truro Creek; Photo: Paul Mutch

SEINE RAT ROSEAU WATERSHED DISTRICT

2020 regional report

LAKE WINNIPEG
community-based monitoring network

SEINE RAT ROSEAU WATERSHED DISTRICT

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Lake Winnipeg Community-Based Monitoring Network: Overview

The Lake Winnipeg Community-Based Monitoring Network (LWCBMN), coordinated by the Lake Winnipeg Foundation (LWF), mobilizes citizens and watershed partners to collect water samples across Manitoba in order to measure phosphorus concentration. Phosphorus is the nutrient responsible for blue-green algae blooms on Lake Winnipeg. Phosphorus comes from diverse sources across the watershed, including municipal wastewater and agricultural runoff.

Different sub-watersheds contribute different proportions of Lake Winnipeg's total phosphorus load. With the help of a strong network of watershed partners and citizen scientists, this long-term monitoring program is identifying phosphorus hotspots – localized areas that contribute higher amounts of phosphorus to waterways than other areas. Targeting actions to reduce phosphorus loading in hotspots will reduce the amount of phosphorus entering Manitoba's lakes and rivers, and improve the health of Lake Winnipeg.

Snow melts, floods and heavy rainfall events are responsible for most of the phosphorus that is flushed from the land and carried into our waterways. LWCBMN samples frequently throughout the season, and particularly during the spring melt, to ensure we capture phosphorus runoff during these high-water events.

Most LWCBMN sampling is conducted at stations where water flow is continuously monitored by the Water Survey of Canada (WSC). By tracking flow online using the WSC's real-time data, the network can notify partners and citizen scientists across the watershed to ensure frequent sampling during peak flows.

Sites with flow data can be coupled with LWCBMN data to calculate **phosphorus loads**. We need several samples throughout the season, corresponding to changes in flow, to accurately calculate these loads. Phosphorus loads can subsequently be used to calculate **phosphorus export**, based on the area of the watershed.

Phosphorus load is the total amount of phosphorus flowing past a sample site over a given period of time, expressed as tonnes per year.

Phosphorus export is the amount of phosphorus exported by each hectare of land in a year, expressed as kg/ha/y.

Sample Collection & Site Map

Water samples are collected using a weighted sampling device that collects source water directly into a 500 mL Nalgene polyethylene bottle. The sampling device is lowered slowly into the water just before it hits the bottom, the bottle is filled, then slowly brought back to the surface. It is rinsed three times prior to sample collection. Next, a 60 mL Nalgene polyethylene bottle containing 1 mL 4N H_2SO_4 is filled with whole water from the collection bottle.

In 2020, 575 unfiltered water samples were collected and analyzed from 54 sites. Of these 54 LWCBMN sampling sites, 44 are located near flow-metered WSC stations, two are located near non-flow-metered WSC stations, one is located near a USGS station, and seven are not located near any stations.

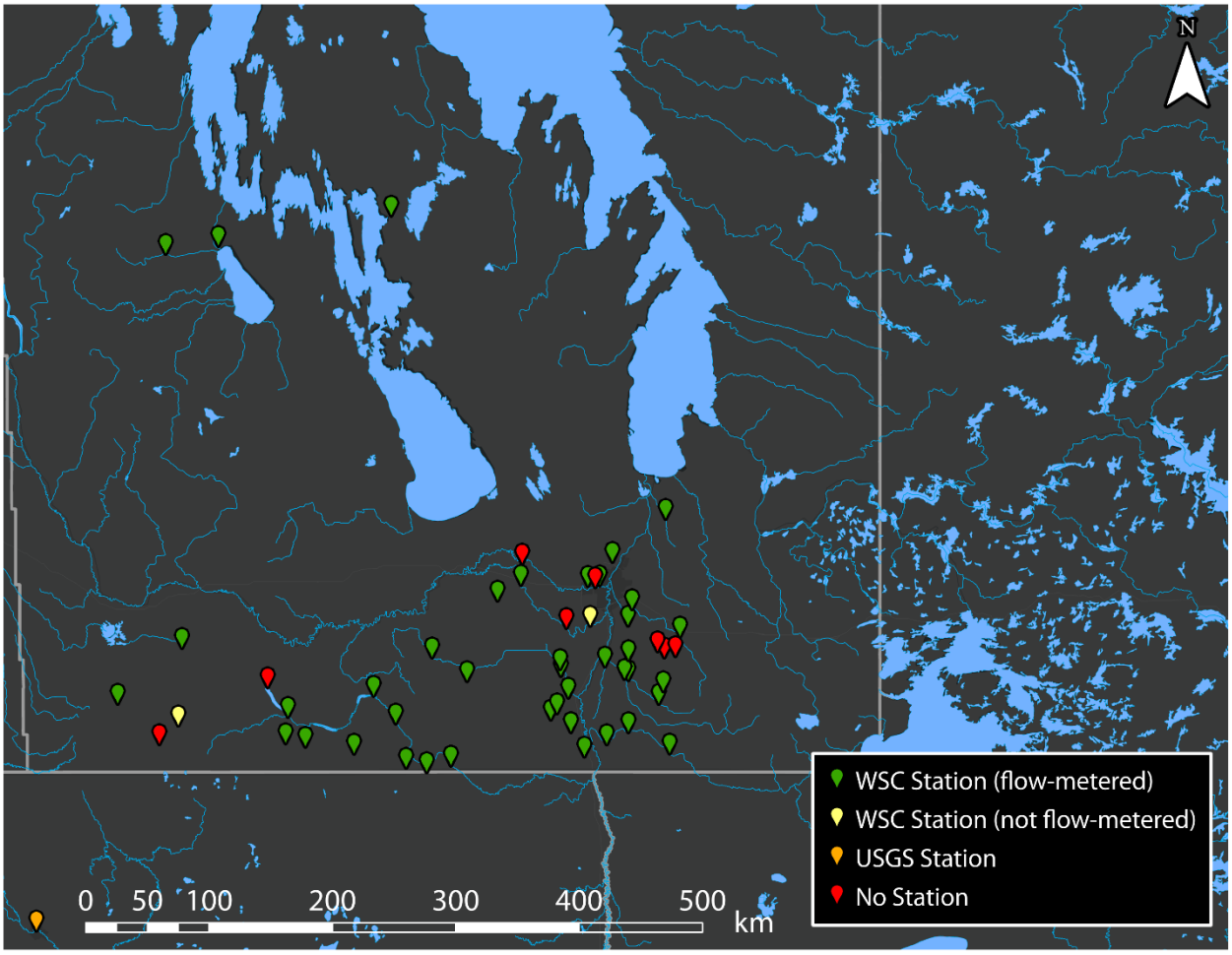


Figure 1: Map of LWCBMN sampling sites in 2020. Locations shown provided at least one sample. Colours indicate nearby station type.

Laboratory & Data Analysis

LWCBMN water samples are analysed for total phosphorus concentration. The analysis of a sample for total phosphorus (TP) is a two-step procedure involving first the chemical digestion/conversion of all P forms to orthophosphate (PO_4^{3-}) followed by the analysis of the concentration of PO_4^{3-}. The digestion procedure is patterned after USGS Water-Resources Investigations Report 03-4174. The concentration of PO_4^{3-} in the sample was determined following Murphy & Riley (1962). The result of this analytical method is determination of unfiltered total phosphorus in mg/L.

Laboratory analysis on LWCBMN water samples was conducted in partnership with Dr. Nora Casson at her laboratory at the University of Winnipeg. Quality assurance of laboratory methods for the determination of total phosphorus was completed on samples sent from Proficiency Testing Canada. Proficiency testing allows us to assess the quality of our results as compared to the results of other laboratories across the country. We received excellent passing grades of 92/100 in November 2023 and 94/100 in May 2024, further highlighting the consistency and accuracy of our laboratory methods.

Our laboratory results provide a record of the phosphorus concentrations for every day that water samples were collected, but we are equally interested in reporting the actual load of phosphorus each year in each watershed that we sample. To create this record, we multiply concentrations by the volume of water that flowed past the station every day, using flow data from Water Survey of Canada (WSC) stations.

WSC's real-time flow data subsequently undergoes additional quality assurance and quality control processes and is later published as historical flow data. Historical data is released by WSC as the official version of the data, with additional notes about unique site characteristics or considerations affecting data quality (e.g., the COVID-19 pandemic reduced field visits in 2020). Our 2020 data analysis used historical flow data.

For each station, gaps between concentration observations are filled by linear interpolation to create a continuous daily record. For the WSC flow record before or after the first or last water sample collected, we estimate the missing daily mean concentrations to be equal to the first or last measured concentration, respectively. These measured and estimated daily concentrations are then multiplied by daily flow to create a record of daily phosphorus loads.

Larger watersheds generate greater river flow and typically larger phosphorus loads. Comparing the intensity of phosphorus sources, especially among watersheds of varying sizes, is possible through the calculation of average load exported from each unit area of the watershed. Hence, we also report phosphorus export, which is simply the annual load divided by the watershed area that contributed to this load.

The export per unit area is indicative of the relative intensity of the sources generating phosphorus export, even among watersheds of different sizes. This is why we display maps of phosphorus export (and not load) in this report. Hotspots identified in these reports export several times more phosphorus per hectare than non-hotspot watersheds. Identifying hotspots can help government agencies to focus phosphorus reduction programs efficiently throughout the province.

LWCBMN By the Numbers - 2020

Table 1: Summary of 2020 LWCBMN sampling activity by region.

Region	Number of sites	Number of samples	Site with highest regional total phosphorus (TP) export (kg/ha/y)	Mean % of spring* water load	Mean % of spring* TP load
City of Winnipeg	3	23	Sturgeon Creek at St. James Bridge - 0.33	91.43	90.99
East Interlake	1	19	Grassmere Creek Drain near Middlechurch - 0.18	97.65	96.92
Inter-Mountain	2	20	Mossy River below outlet of Dauphin Lake - 0.0036	45.68	7.77
Pembina Valley	13	217	Mowbray Creek near Mowbray - 0.50	76.00	73.60
Redboine	9	128	La Salle River at Elie - 0.53	94.36	94.38
Seine Rat Roseau	13	133	Pansy Drain near Sarto - 1.52	70.17	79.78

*LWCBMN defines "Spring" as March 1 to May 31, inclusive.

Raw data (phosphorus concentration and water flow) from LWCBMN's 2020 field season is available online at LakeWinnipegDataStream.ca, an open access hub for sharing water data.

Seine Rat Roseau Watershed District

The Seine Rat Roseau Watershed District (SRRWD) is located east of the Red River, extending almost to Ontario and to the United States. SRRWD consists of three major sub-watersheds: the Seine, Rat and Roseau River watersheds. The primary land use in SRRWD is agriculture, specifically cereal crops and livestock. The Seine River watershed has the most intensively developed hog industry of all watersheds in Manitoba (Seine River Integrated Watershed Management Plan, 2010). In addition to agricultural activities, wastewater treatment plants and lagoons in municipalities throughout SRRWD contribute phosphorus to local waterways. Major municipalities include Steinbach, St-Pierre-Jolys and Lorette.

In partnership with LWCBMN, SRRWD staff and volunteers sampled 13 sites in the SRRWD region, all of which were near actively monitored flow-metered WSC stations. For the sites where flow is not measured, useful information can be drawn from the phosphorus concentrations; however, we cannot calculate the phosphorus load because we cannot multiply the phosphorus concentration by the volume of water flowing by sampling the site.

SRRWD Website (srrwd.ca) / SRRWD Watershed Plans (srrwd.ca/watershed-plans)

Characteristics of the 2020 Field Season

2020 was a moderately dry year in southern Manitoba.[1]. As well, from March to May 2020, a historically important season for phosphorus export, most of southern Manitoba experienced severely to extremely dry conditions[2].

The mean peak discharge data across all LWCBMN sties with analyzed water samples was April 21, 2020 (with a standard deviation of 30.76 days). In 2020, an average of 77.06% of stream discharge occurred in spring (March 1 - May 31) across LWCBMN sites (with a standard deviation of 19.10%).

In 2020, the operational capacity of LWCBMN was reduced due to the COVID-19 pandemic. Sampling activities were maintained by LWF staff and watershed district partners at priority, long-term sites within the network. To prevent COVID-19 transmission, sampling protocols and equipment were adjusted for volunteers who wished to continue sampling. All historical streamflow data from WSC in 2020 includes a remark that "Due to measures in place to limit the spread of the coronavirus, regular visits to this station were reduced or no longer conducted throughout 2020. This may have impacted data quality in 2020".

[1] https://www.gov.mb.ca/sd/pubs/water/drought/2020/drought_conditions_report_oct_2020.pdf
[2] https://www.gov.mb.ca/sd/pubs/water/drought/2020/drought_conditions_report_may_2020.pdf

Manitoba Watershed District Map

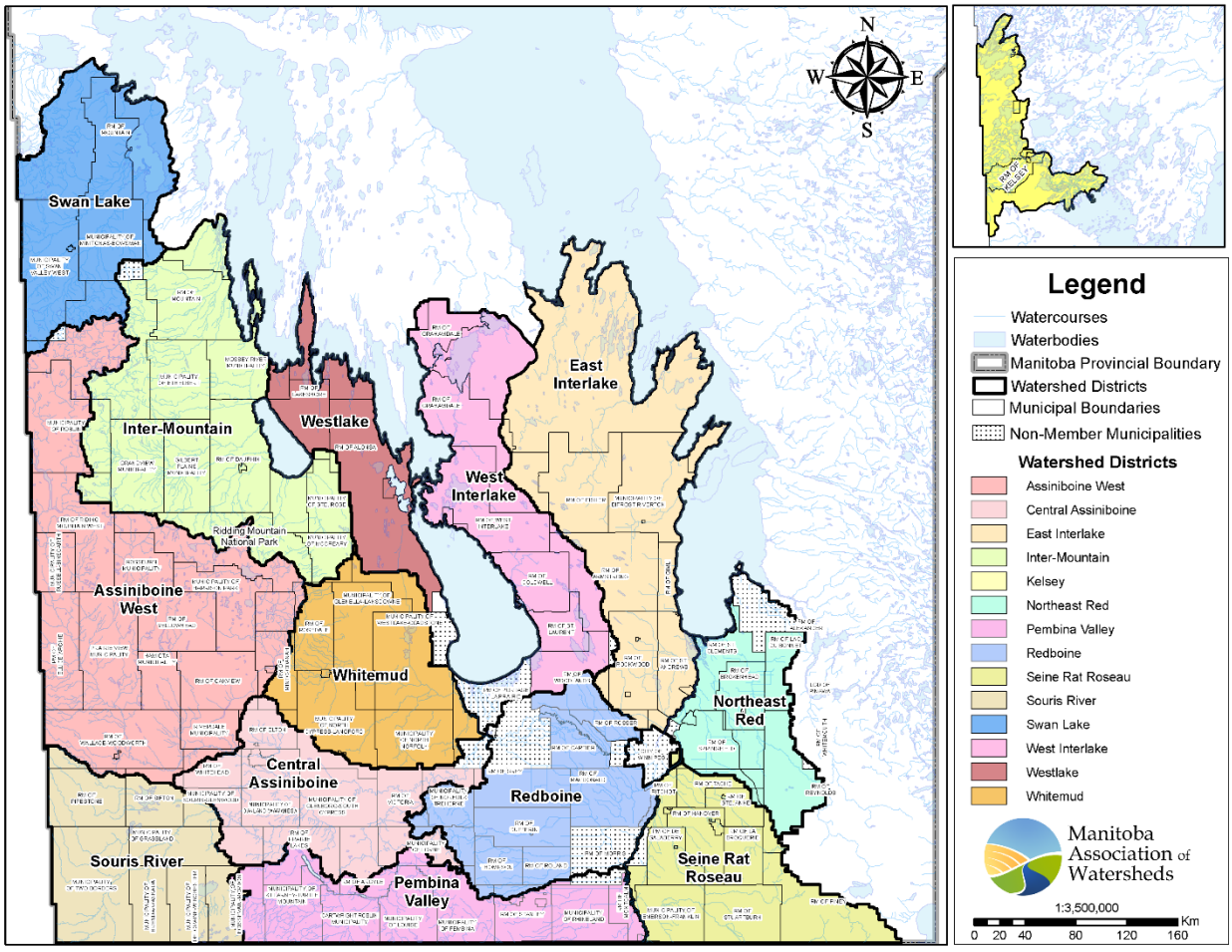


Figure 2: Manitoba Watershed District Boundaries. There are 14 total watershed districts, with 12 of 14 participating in LWCBMN (all but Kelsey & Westlake). Map provided by Manitoba Association of Watersheds (updated July 2022[KF1]).

2020 Results – SRRWD Summary

Table 2: Summary of 2020 LWCBMN results in SRRWD. Letters correspond to drainage areas in Figure 3. Data shown represents sites with sampling efforts adequate enough to calculate loads/exports. [1]See footnote for explanation of acronyms/abbreviations.

	Site Name	WSC Station	GDA (km^2)	IDA (km^2)	Gross/ Incr.	TP load (tonnes/y)	TP export (kg/ha/y)
A	Joubert Creek at St-Pierre-Jolys	05OE007	348.29	140.09	Incr.	8.95	0.64
B	Joubert Creek near Pansy	05OE015	208.20	*NA*	gross	25.53	1.23
C	Manning Canal near Île-des-Chênes	05OE006	480.77	*NA*	gross	20.00	0.42
D	Marsh River near Otterburne	05OE010	399.60	*NA*	gross	25.82	0.65
E	Pansy Drain near Sarto	05OE014	44.31	*NA*	gross	6.73	1.52
F	Rat River near St-Pierre-Jolys	05OE001-05OE007	1074.86	*NA*	gross	26.67	0.25
G	Roseau River at Gardenton	05OD004	4186.29	*NA*	gross	101.26	0.25
H	Roseau River near Dominion City	05OD001	4707.44	521.15	Incr.	17.07	0.33
I	Seine River near Prairie Grove + Seine River Diversion near Île-des-Chênes	05OE011+ 05OH009	1747.94	701.43	Incr.	2.12	0.030
J	Seine River near Ste. Anne	05OH007	554.82	*NA*	gross	22.95	0.41
K	Tourond Creek near Tourond	05OE009	210.07	165.76	Incr.	8.80	0.53

To compare 2020 results to other years of data, please see LWCBMN regional reports online at https://lakewinnipegfoundation.org/lwcbmn-regional-reports

[1] WSC = Water Survey of Canada.
GDA = gross drainage area (i.e., the total watershed area).
IDA = incremental drainage area (i.e., the total watershed area minus the total watershed area of any contained upstream sites with data adequate for load/export calculation).
Gross/Incr. = whether or not the adjacent TP load/export listed is from the gross or incremental ("Incr.") drainage area of a site.

2020 Results – Hotspot Map

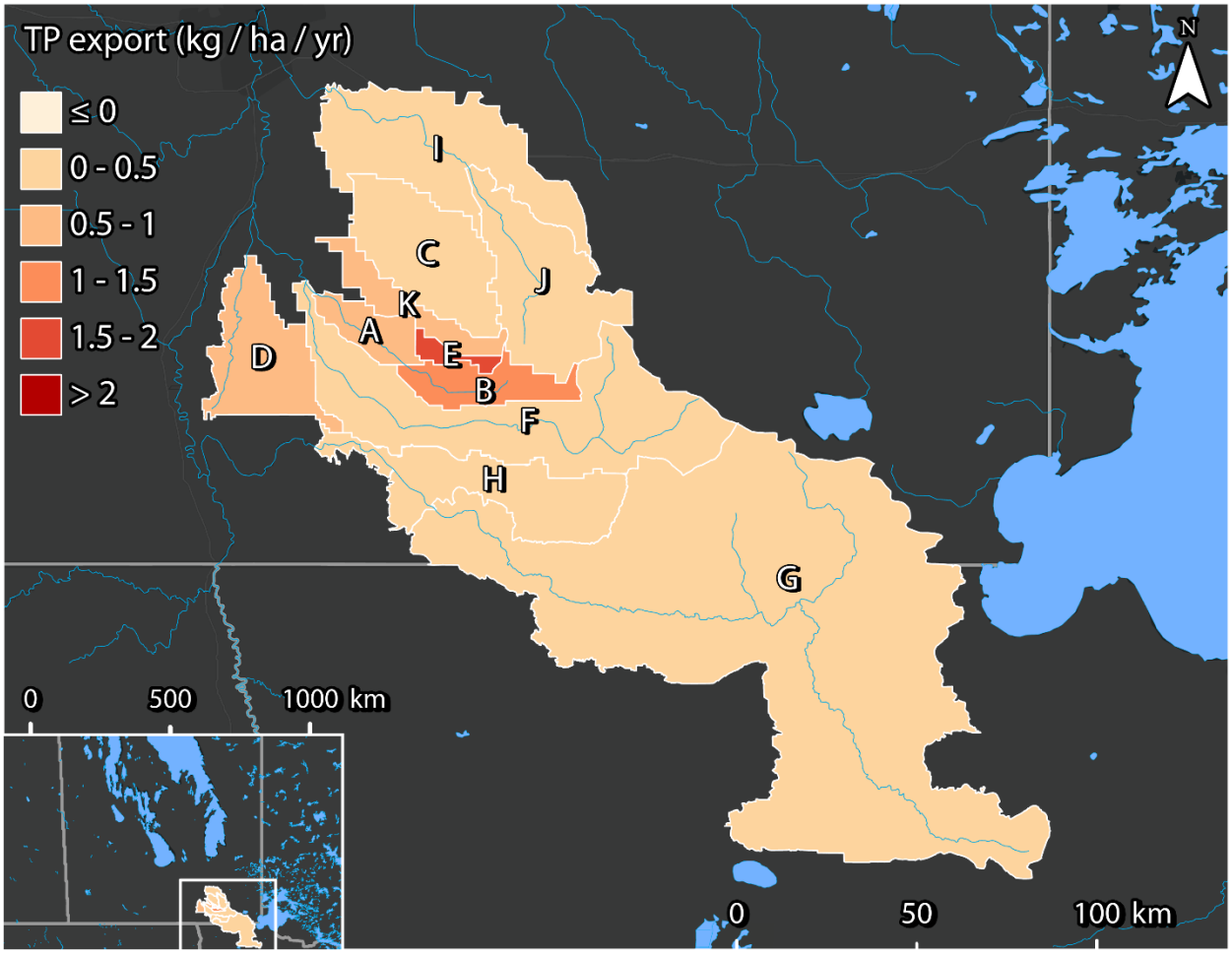


Figure 3: 2020 LWCBMN TP Export Hotspots in SRRWD. Letters correspond to sites listed in Table 2.

2020 Results – Individual Sites

Seine River near Ste. Anne

The upper Seine River sampling site drains a largely forested area of approximately. The drainage area includes a portion of Sandilands Provincial Forest. This sampling site is located at Water Survey of Canada flow meter 05OH007, near Ste. Anne, MB. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 3: Indices of discharge and phosphorus from the gross drainage area of Seine River near Ste. Anne (05OH007) in 2020.

Gross drainage area:	554.82 km^2
Peak discharge:	28.30 $m^3 s^{-1}$ (2020-04-08)
Peak TP concentration:	1.70 mg/L (2020-03-30)
% of water load in spring:	71.03%
% of TP load in spring:	91.32%
Water load:	0.054 $km^3 y^{-1}$
TP load:	22.95 tonnes P y^{-1}
Water export:	96.71 mm y^{-1}
TP export:	0.41 kg P $ha^{-1} y^{-1}$

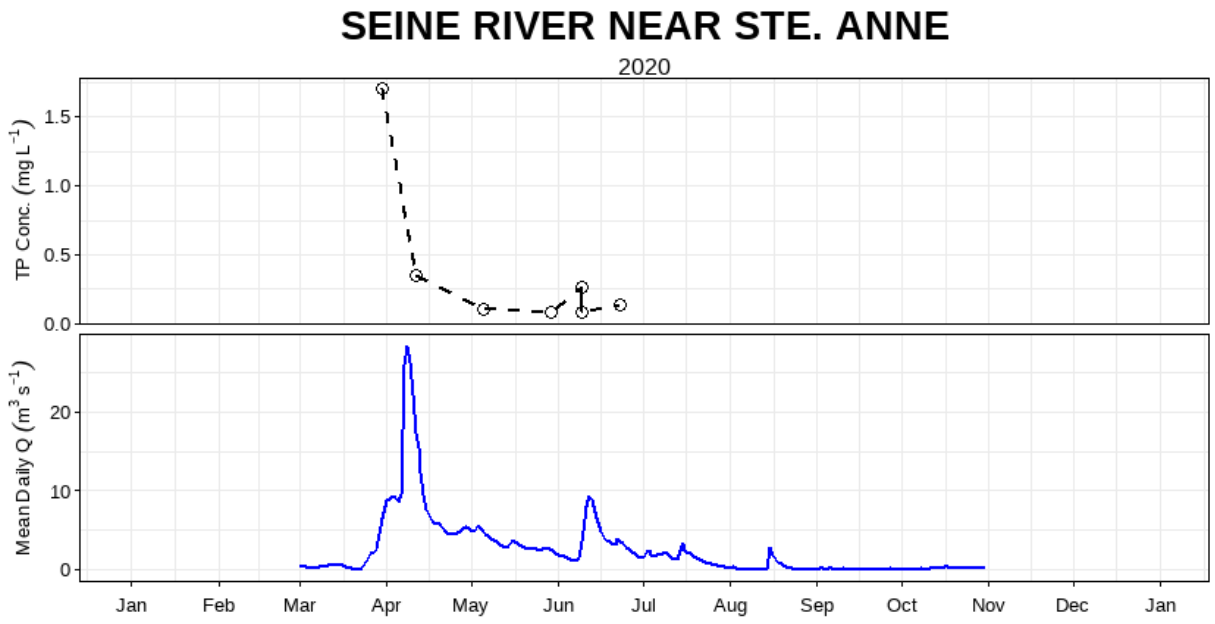


Figure 4: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Seine River near Ste. Anne (05OH007).

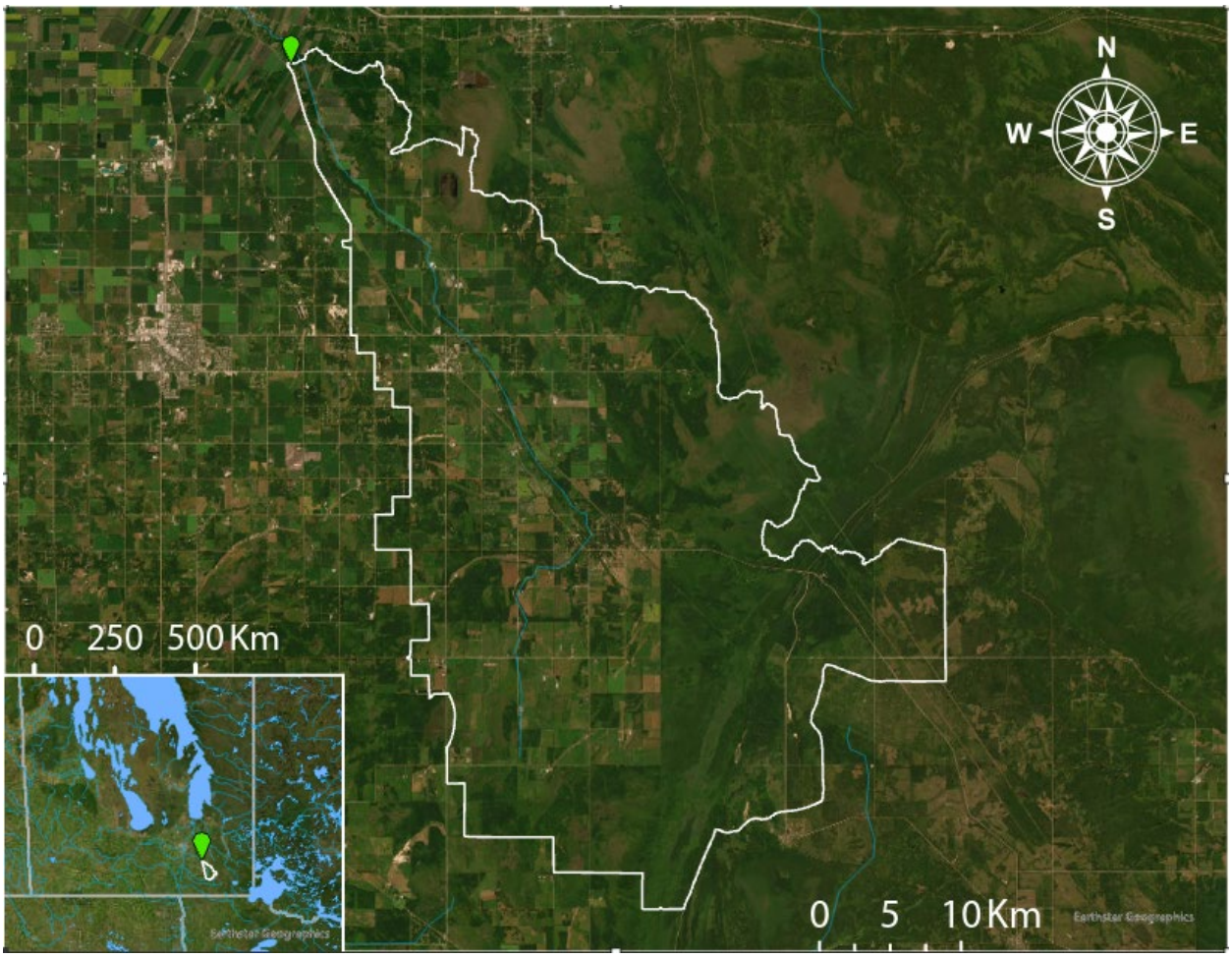


Figure 5: WSC station 05OH007 (green) and drainage area polygon (white - source: WSC). LWCBMN samples directly at the WSC station.

Manning Canal near Île-des-Chênes

The Manning Canal is a sub-watershed of the larger Seine River watershed. The Manning Canal drains a largely agricultural area which includes dense livestock and crop land as well as the growing city of Steinbach. This sampling site is located at Water Survey of Canada flow meter 05OE006, near Île-des-Chênes, MB. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 4: Indices of discharge and phosphorus from the gross drainage area of Manning Canal near Île-des-Chênes (05OE006) in 2020.

Gross drainage area:	480.77 km^2
Peak discharge:	28.50 $m^3 s^{-1}$ (2020-04-07)
Peak TP concentration:	2.00 mg/L (2020-04-30)
% of water load in spring:	85.32%
% of TP load in spring:	83.74%
Water load:	0.025 $km^3 y^{-1}$
TP load:	20.00 tonnes P y^{-1}
Water export:	53.00 mm y^{-1}
TP export:	0.42 kg P $ha^{-1} y^{-1}$

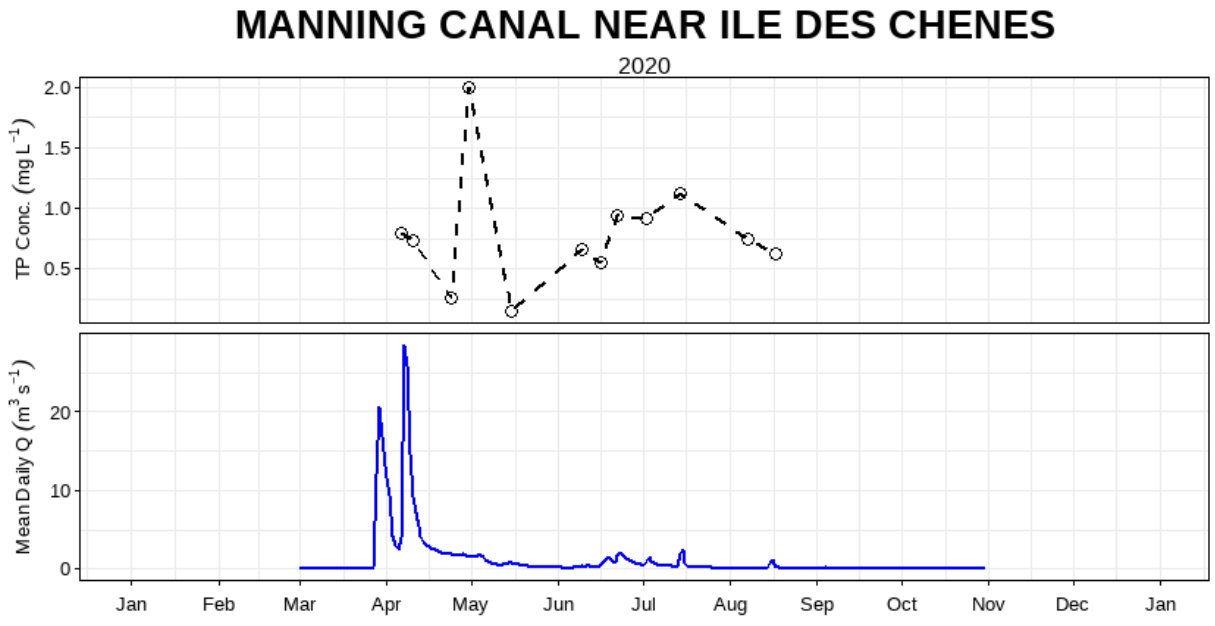


Figure 6: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Manning Canal near Île-des-Chênes (05OE006).

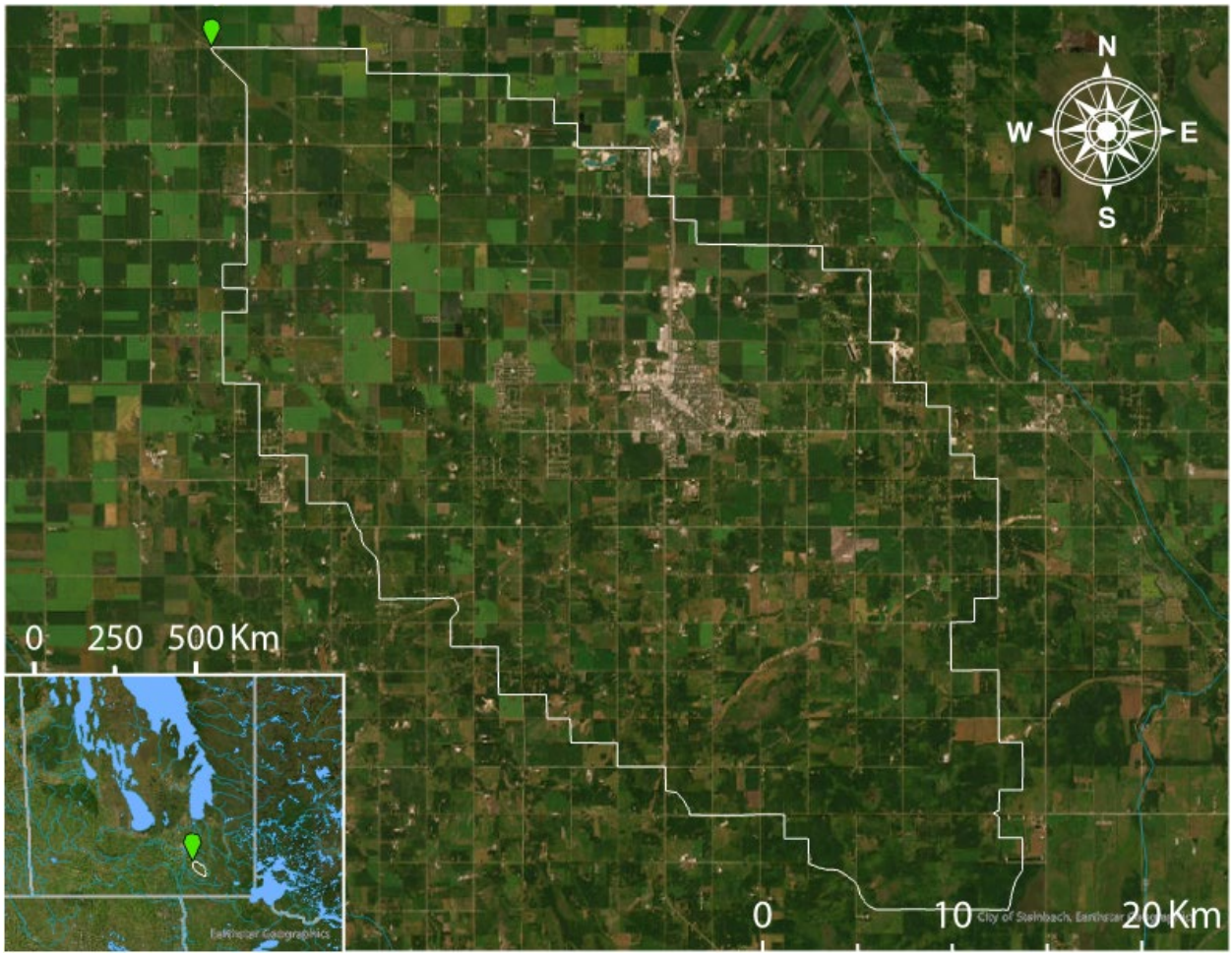


Figure 7: WSC station 05OE006 (green) and drainage area polygon (white - source: AAFC). LWCBMN samples directly at the WSC station.

Seine River near Prairie Grove and the Seine River Diversion near Île-des-Chênes

Together, the Seine River near Prairie Grove, MB, and the Seine River Diversion sampling sites drain a largely agricultural area. Water flowing down the Seine River towards Prairie Grove is diverted into the Seine River Diversion when water levels and flows are high. Both sampling sites share a drainage area, therefore, phosphorus and water loads are added together to accurately calculate the phosphorus export for the drainage area. The Prairie Grove and Diversion sites are located at Water Survey of Canada flow meters 05OH009 and 05OE011, respectively. The sampling efforts at these sites provided adequate coverage to calculate TP loads and exports.

Table 5: Peak discharge & TP concentration from Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011).

Site:	Seine River near Prairie Grove	Seine River near Île-des-Chênes
Station:	05OH009	05OE011
Peak discharge:	14.50 $m^3 s^{-1}$ (2020-04-09)	65.00 $m^3 s^{-1}$ (2020-04-08)
Peak TP concentration:	0.70 mg/L (2020-03-31)	2.15 mg/L (2020-04-30)

Table 6: Indices of discharge and phosphorus from the combined incremental drainage area of Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011). See Supplemental Table 1 for gross calculations.

Incremental drainage area:	701.43 km^2
% of water load in spring:	76.79%
% of TP load in spring:	85.20%
[1]Incremental water load:	0.010 $km^3 y^{-1}$
[1]Incremental TP load:	2.12 tonnes P y^{-1}
[2]Incremental water export:	14.96 mm y^{-1}
[2]Incremental TP export:	0.030 kg P $ha^{-1} y^{-1}$

[1] Incremental loads are calculated by subtracting gross "Manning Canal near Île-des-Chênes" and "Seine River near Ste. Anne" values from the combined values of gross "Seine River near Prairie Grove" and "Seine River near Île-des-Chênes".

[2] Incremental exports are calculated by dividing incremental loads by incremental drainage areas.

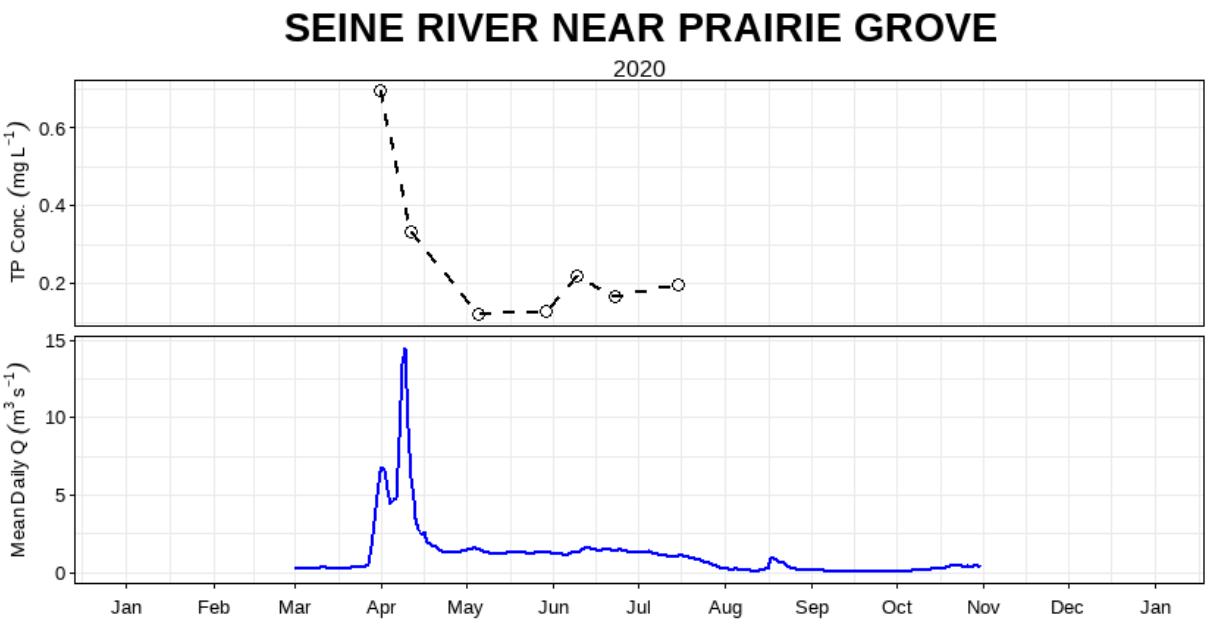


Figure 8: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Seine River near Prairie Grove (05OH009).

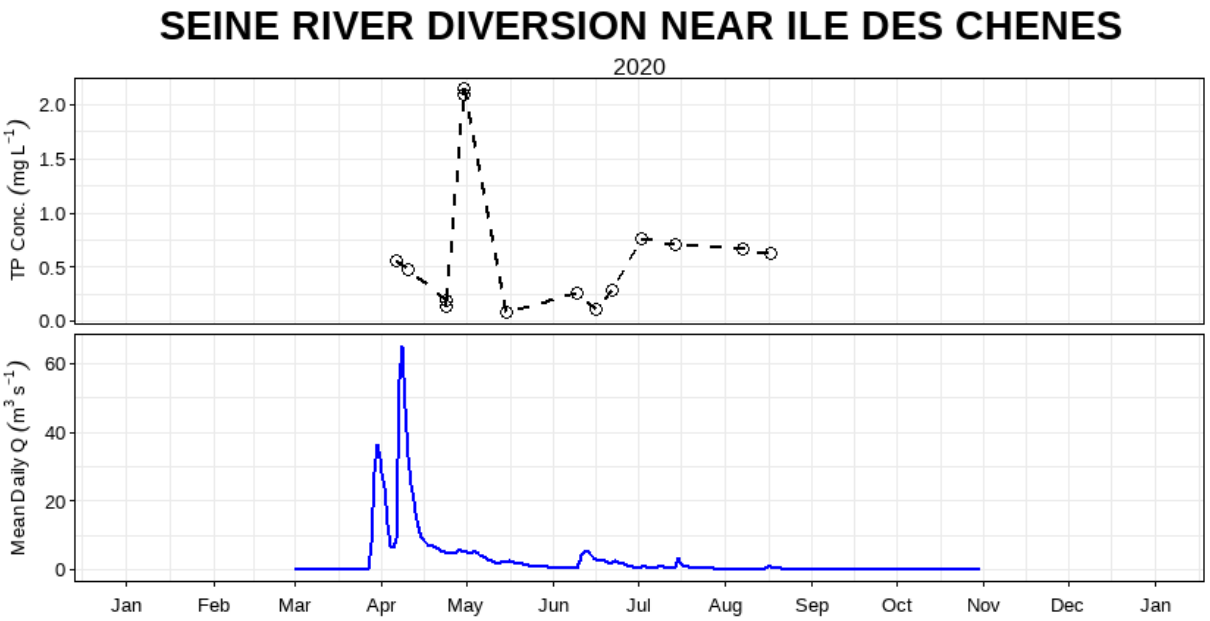


Figure 9: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Seine River Diversion near Île-des-Chênes (05OE011).

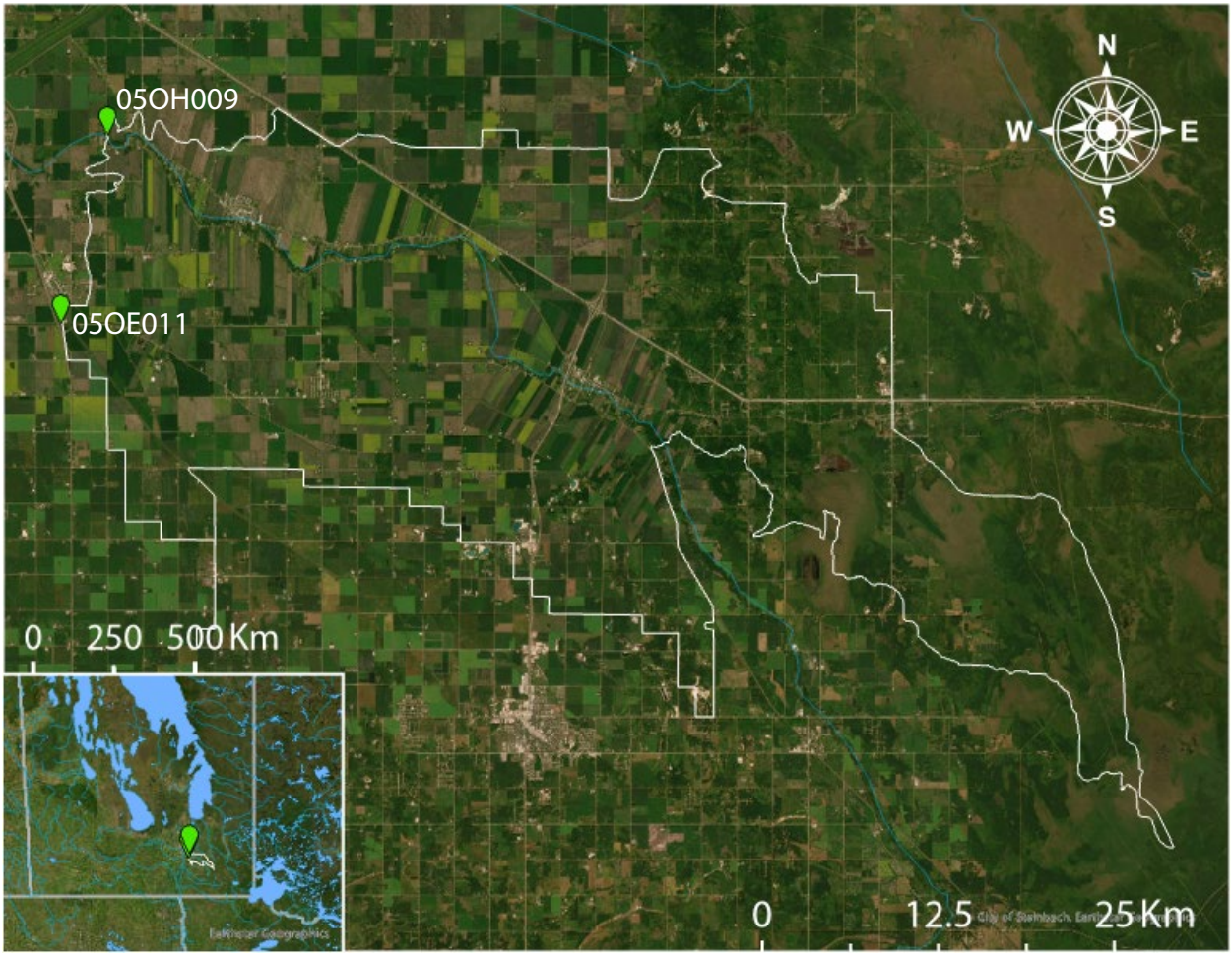


Figure 10: WSC stations 05OE011 & 05OH009 (green) and combined drainage area polygon for each respective station (white - source: 05OE011 [AAFC], 05OH009 [WSC]). LWCBMN samples directly at both WSC stations. See Supplemental Figure 1 for upstream drainage areas used to calculate incremental area.

Pansy Drain near Sarto

The sampling site is located at Water Survey of Canada flow meter 05OE014, near Sarto, MB. Pansy drain flows north into Tourond Creek, before flowing into the Red River south of Saint Adolphe, MB. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 7: Indices of discharge and phosphorus from the gross drainage area of Pansy Drain near Sarto (05OE014) in 2020.

Gross drainage area:	44.31 km^2
Peak discharge:	1.91 $m^3 s^{-1}$ (2020-04-08)
Peak TP concentration:	4.76 mg/L (2020-04-09)
% of water load in spring:	90.60%
% of TP load in spring:	99.16%
Water load:	0.0024 $km^3 y^{-1}$
TP load:	6.73 tonnes P y^{-1}
Water export:	55.27 mm y^{-1}
TP export:	1.52 kg P $ha^{-1} y^{-1}$

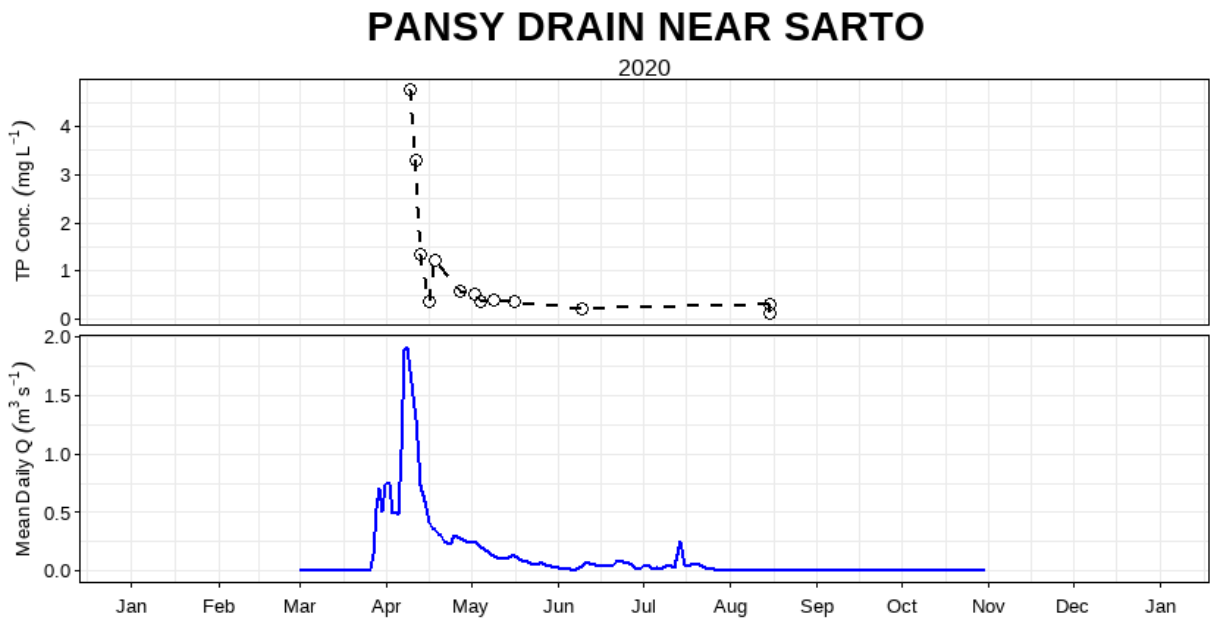


Figure 11: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Pansy Drain near Sarto (05OE014).

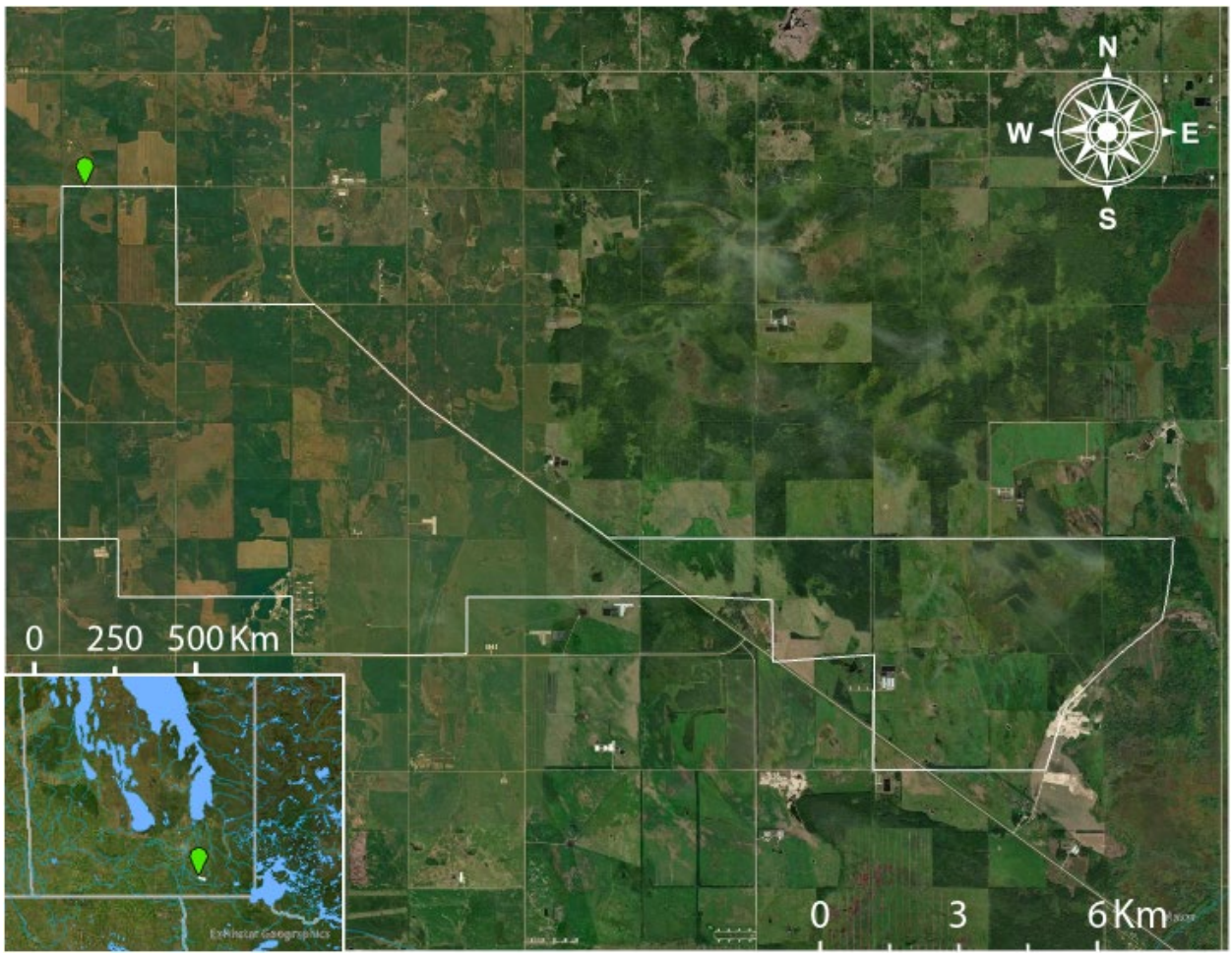


Figure 12: WSC station 05OE014 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Tourond Creek near Tourond

Tourond Creek drains a largely agricultural area before flowing into the Red River south of Saint Adolphe, MB. This sampling site is located at Water Survey of Canada flow meter 05OE009, near Tourond, MB. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 8: Indices of discharge and phosphorus from the incremental drainage area of Tourond Creek near Tourond (05OE009) in 2020.

Incremental drainage area:	165.76 km^2
Peak discharge	10.70 $m^3 s^{-1}$ (2020-03-29)
Peak TP concentration	3.04 mg/L (2020-08-07)
% of water load in spring:	91.92%
% of TP load in spring:	92.30%
[1]Incremental water load:	0.0086 $km^3 y^{-1}$
[1]Incremental TP load:	8.80 tonnes P y^{-1}
[2]Incremental water export:	51.96 mm y^{-1}
[2]Incremental TP export:	0.53 kg P $ha^{-1} y^{-1}$

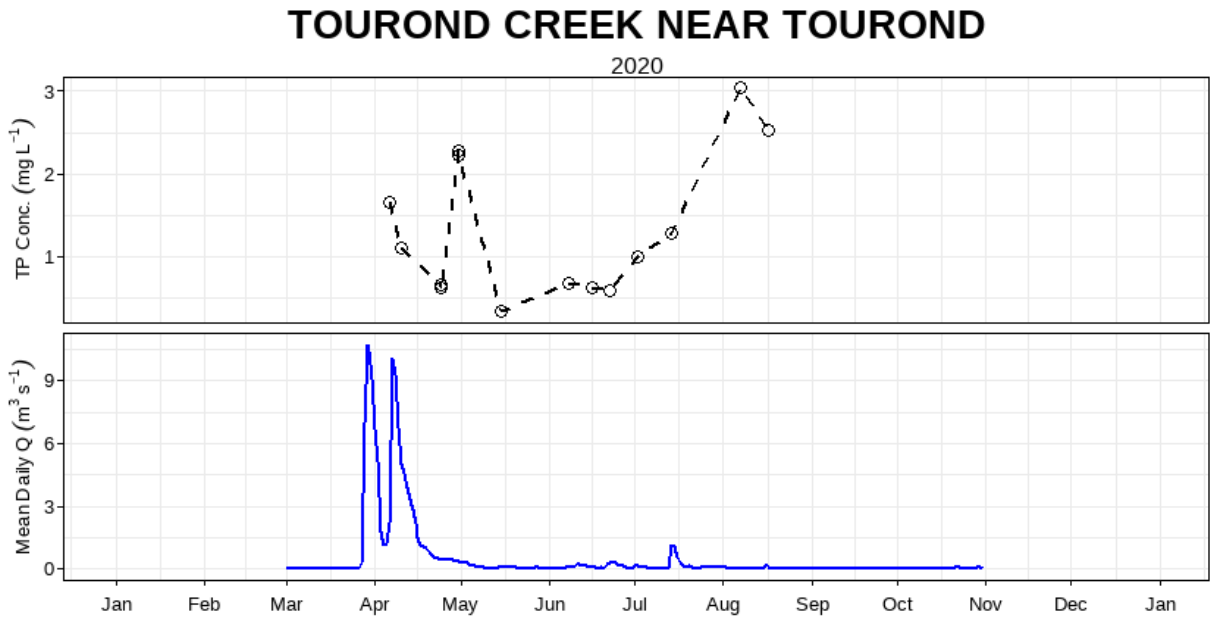


Figure 13: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Tourond Creek near Tourond (05OE009).

[1] Incremental loads are calculated by subtracting gross "Pansy Drain near Sarto" values from gross "Tourond Creek near Tourond" values.

[2] Incremental exports are calculated by dividing incremental loads by incremental drainage areas.

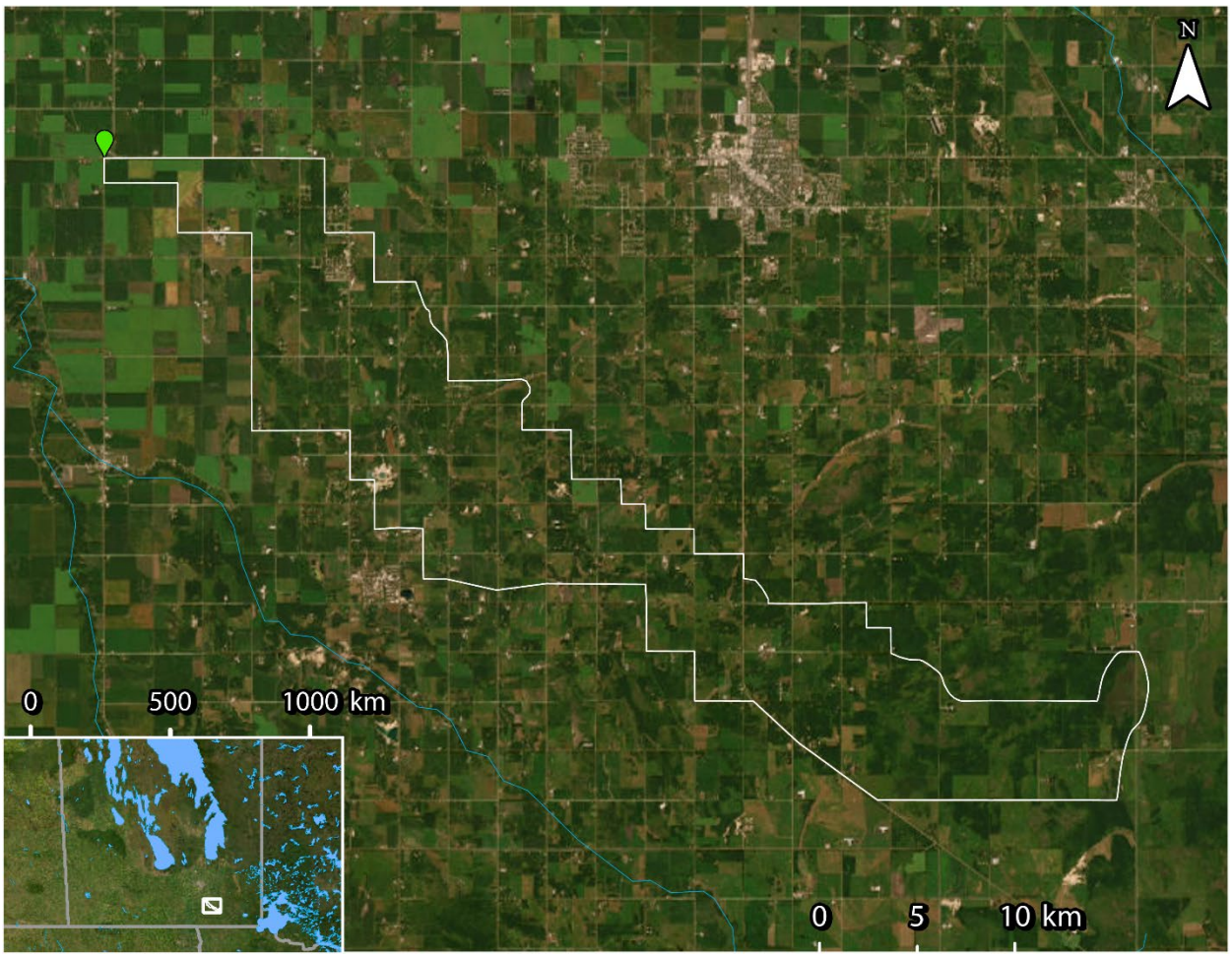


Figure 14: WSC station 05OE009 (green) and incremental drainage area polygon (white - source: AAFC) LWCBMN samples directly at the WSC station. See Supplemental Figure 2 for upstream drainage areas used to calculate incremental area.

Joubert Creek near Pansy

This sampling site is the most upstream sampling site on the Joubert Creek, a tributary of the Rat River. The area that drains into this site consists of pasture and forage crop land. This sampling site is located at Water Survey of Canada flow meter 05OE015, near Pansy, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 9: Indices of discharge and phosphorus from the gross drainage area of Joubert Creek near Pansy (05OE015) in 2020.

Gross drainage area:	208.2 km^2
Peak discharge:	17.20 $m^3 s^{-1}$ (2020-06-14)
Peak TP concentration:	3.34 mg/L (2020-04-30)
% of water load in spring:	49.41%
% of TP load in spring:	82.60%
Water load:	0.038 $km^3 y^{-1}$
TP load:	25.53 tonnes P y^{-1}
Water export:	183.80 mm y^{-1}
TP export:	1.23 kg P $ha^{-1} y^{-1}$

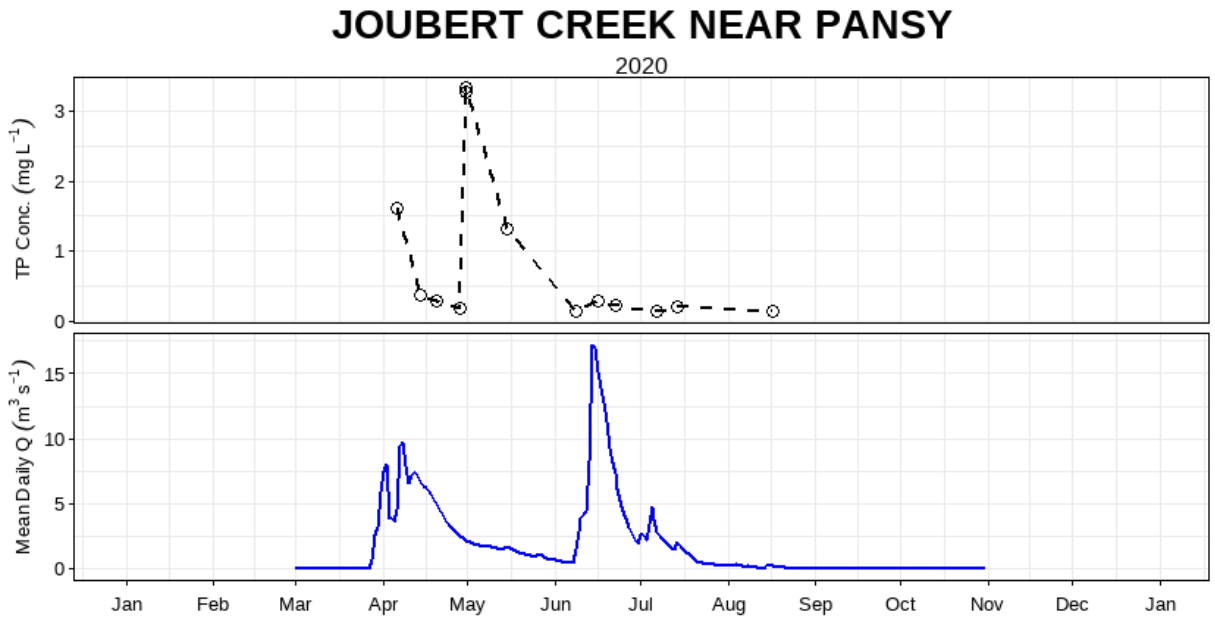


Figure 15: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Joubert Creek near Pansy (05OE015).

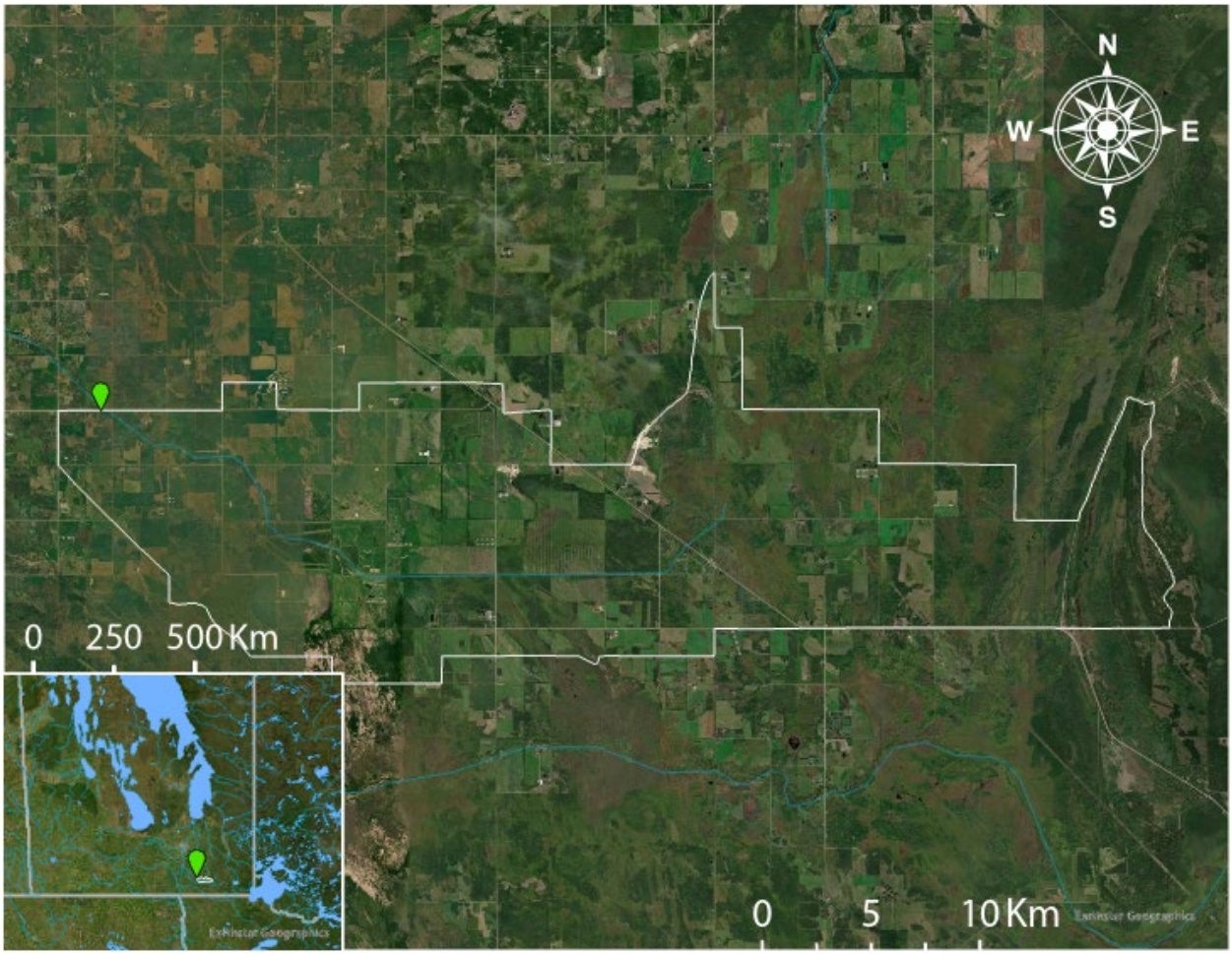


Figure 16: WSC station 05OE015 (green), and drainage area polygon (source: AAFC). LWCBMN samples directly at the WSC station.

Joubert Creek at St-Pierre-Jolys

This sampling site is located just before Joubert Creek flows into the Rat River. The incremental area that drains into this sample site is primarily pasture and forage cropland, as well as a portion of the community of St-Pierre-Jolys, MB. This sampling site is located at Water Survey of Canada flow meter 05OE007, near St-Pierre-Jolys. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 10: Indices of discharge and phosphorus from the incremental drainage area of Joubert Creek near St-Pierre-Jolys (05OE007). See Supplemental Table 3 for gross calculations.

Incremental drainage area:	140.08 km^2
Peak discharge	19.30 $m^3 s^{-1}$ (2020-06-16)
Peak TP concentration	1.91 mg/L (2020-04-30)
% of water load in spring:	53.37%
% of TP load in spring:	70.37%
[1]Incremental water load:	0.0094 $km^3 y^{-1}$
[1]Incremental TP load:	8.95 tonnes P y^{-1}
[2]Incremental water export:	67.18 mm y^{-1}
[2]Incremental TP export:	0.64 kg P $ha^{-1} y^{-1}$

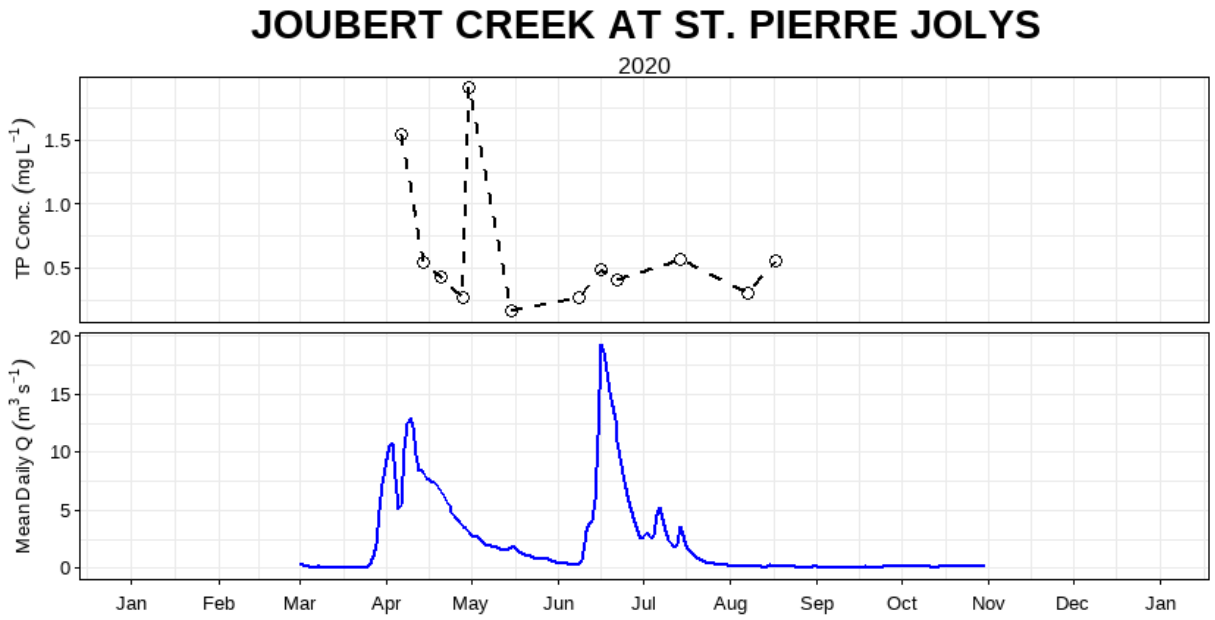


Figure 17: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Joubert Creek near St-Pierre-Jolys (05OE007).

[1] Incremental loads are calculated by subtracting gross "Joubert Creek near Pansy" values from gross "Joubert Creek near St-Pierre-Jolys" values.

[2] Incremental exports are calculated by dividing incremental loads by incremental drainage areas.

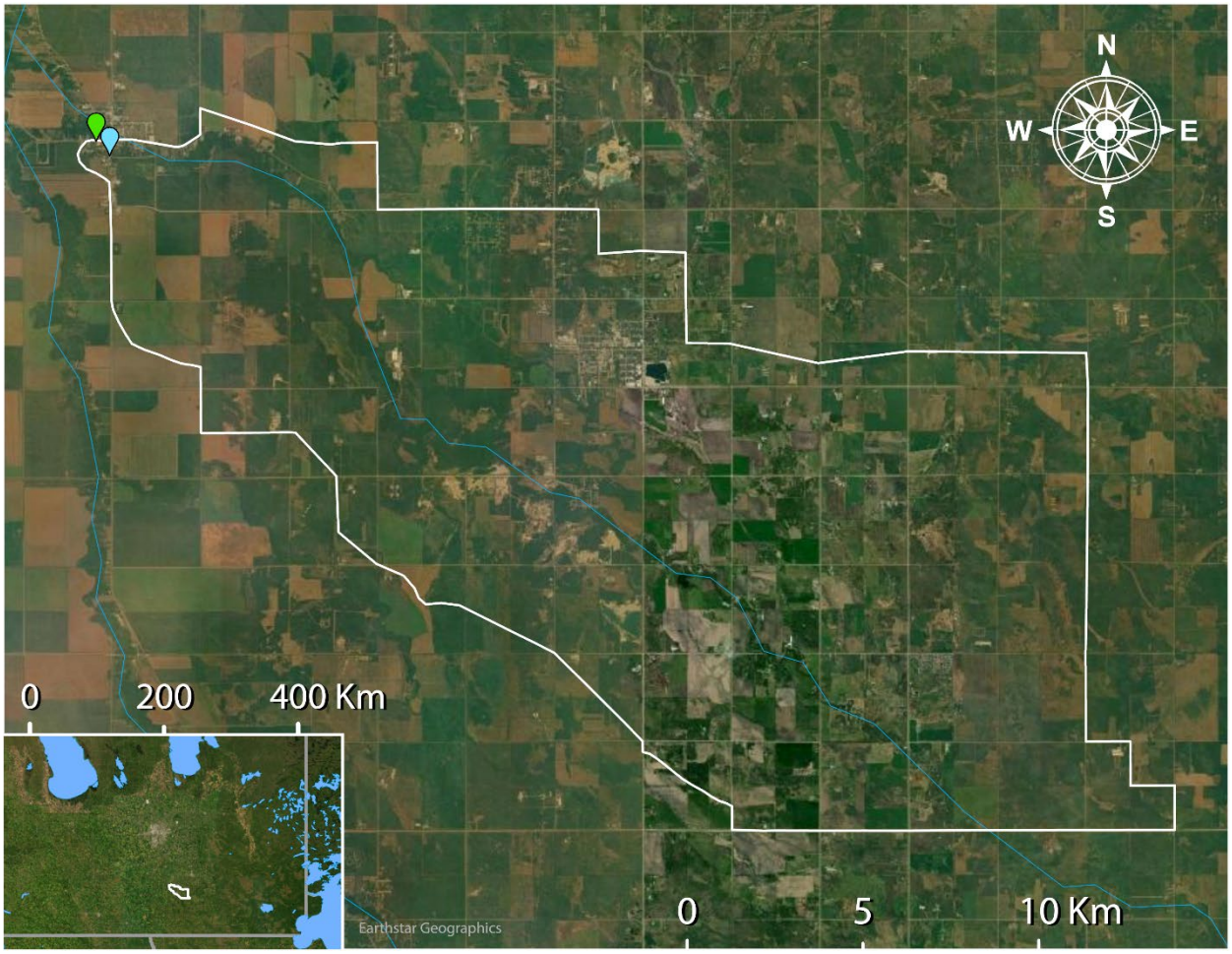


Figure 18: WSC station 05OE007 (green), sampling site (blue) and incremental drainage area polygon (white - source: WSC). See Supplemental Figure 3 for upstream drainage areas used to calculate incremental area. LWCBMN samples ~350m upstream of the WSC station. Between the WSC station and sampling site, there are no new tributaries or major hydrological changes to the waterway.

Rat River near St-Pierre-Jolys

This sampling site is located near Water Survey of Canada station 05OE001, just upstream from where Joubert Creek flows into the Rat River. This drainage area contains the community of St-Pierre-Jolys, MB. Discharge was estimated by subtracting Joubert Creek near St-Pierre-Jolys discharge (05OE007) from Rat River near Otterburne (05OE001). The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 11: Indices of discharge and phosphorus from the gross drainage area of Rat River near St-Pierre-Jolys (05OE001-05OE007) in 2020.

Gross drainage area:	1074.86 km^2
Peak discharge:	48.20 $m^3 s^{-1}$ (2020-06-18)
Peak TP concentration:	0.85 mg/L (2020-04-30)
% of water load in spring:	49.89%
% of TP load in spring:	70.25%
Water load:	0.14 $km^3 y^{-1}$
TP load:	26.67 tonnes P y^{-1}
Water export:	128.71 mm y^{-1}
TP export:	0.25 kg P $ha^{-1} y^{-1}$

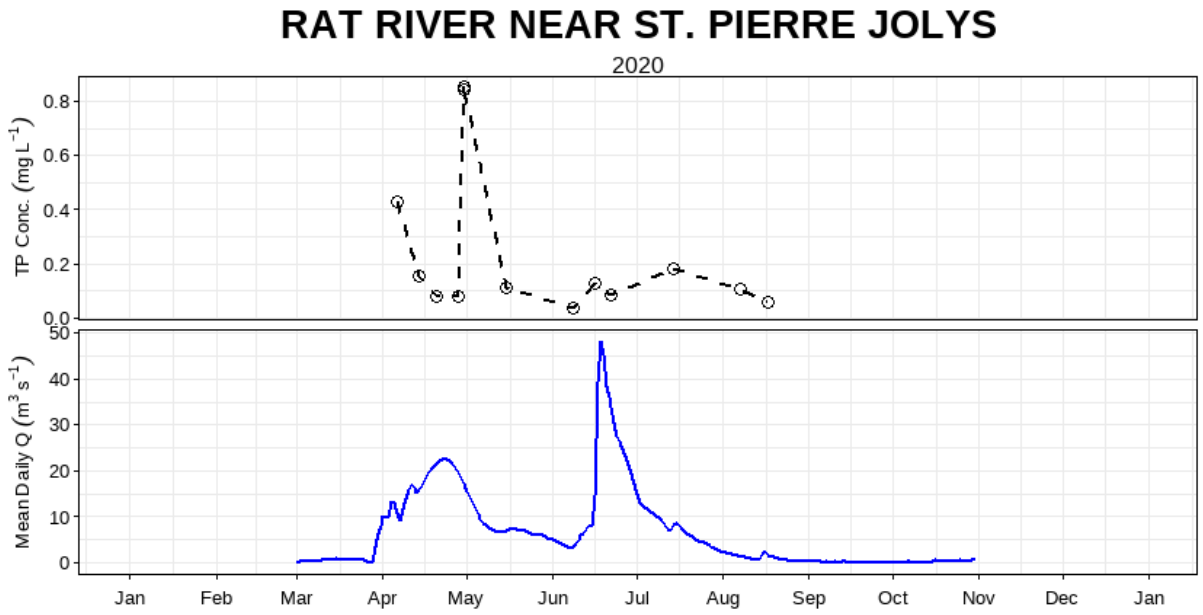


Figure 19: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Rat River near St-Pierre-Jolys (estimated by calculating the flow at WSC station 05OE001 – 05OE007).

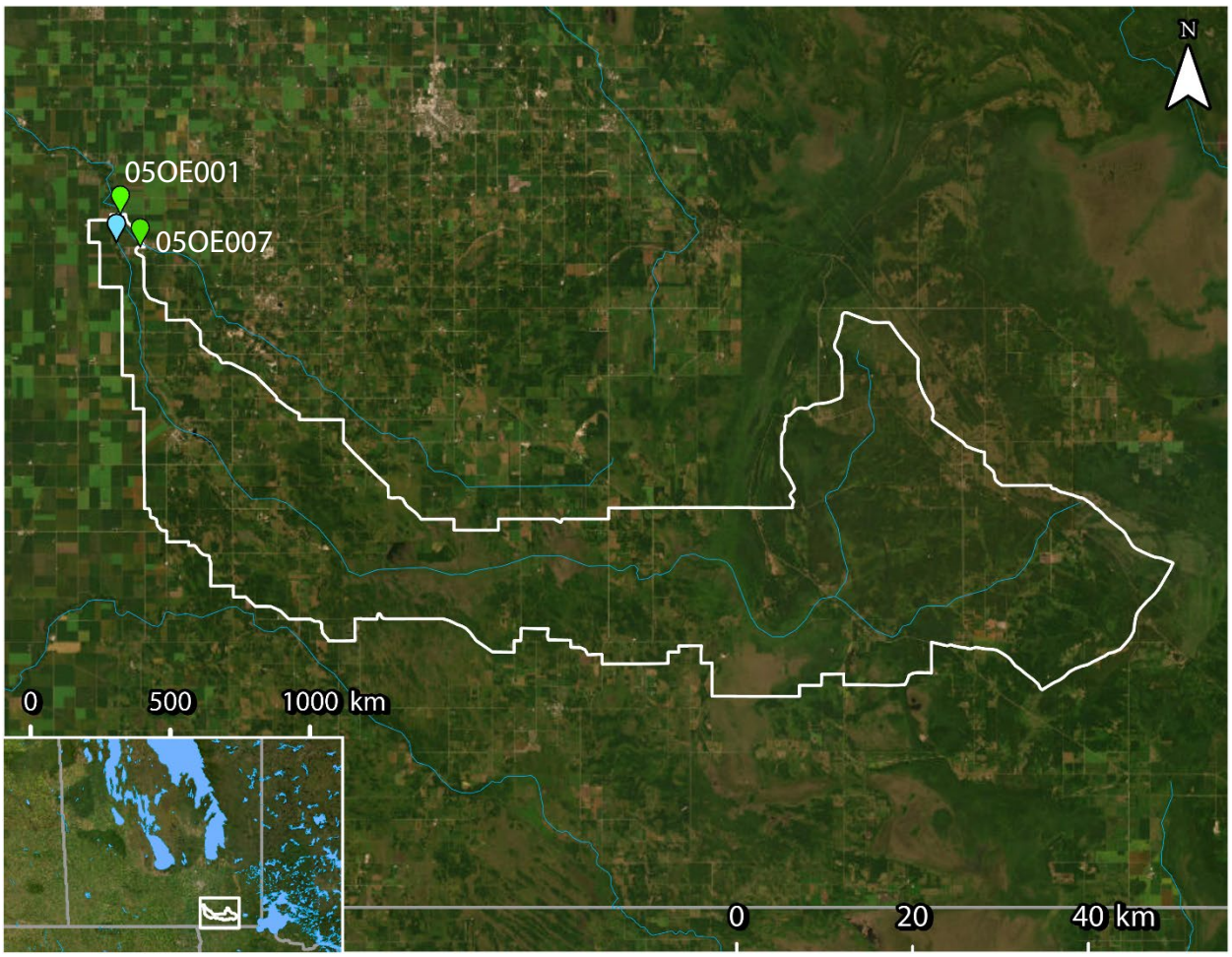


Figure 20: WSC stations 05OE001 & 05OE007 (green), sampling site (blue), and gross drainage area polygon (source: AAFC). Since LWCBMN samples ~2 km upstream of 05OE001 (before Joubert Creek connects to Rat River), the area upstream of 05OE007 is subtracted from 05OE001 to estimate flow at the sampling site.

Marsh River near Otterburne

The Marsh River sampling site drains an area consisting mainly of agricultural land. This sampling site is located directly upstream of where the Marsh River flows into the Rat River. The sampling site is located at Water Survey of Canada flow meter 05OE010, near Otterburne, MB. The sampling effort provided excellent coverage to calculate TP loads and exports.

Table 12: Indices of discharge and phosphorus from the gross drainage area of Marsh River near Otterburne (05OE010) in 2020.

Gross drainage area:	399.6 km^2
Peak discharge:	42.70 $m^3 s^{-1}$ (2020-04-23)
Peak TP concentration:	1.04 mg/L (2020-08-17)
% of water load in spring:	96.11%
% of TP load in spring:	92.87%
Water load:	0.086 $km^3 y^{-1}$
TP load:	25.82 tonnes P y^{-1}
Water export:	213.97 mm y^{-1}
TP export:	0.65 kg P $ha^{-1} y^{-1}$

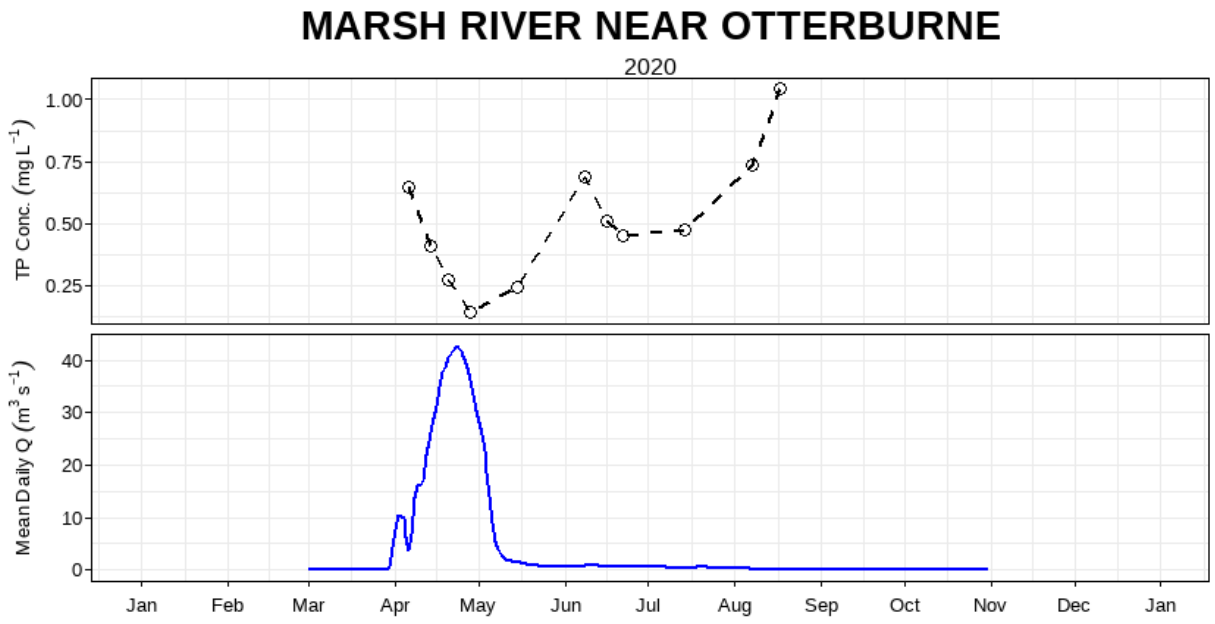


Figure 21: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Marsh River near Otterburne (05OE010).

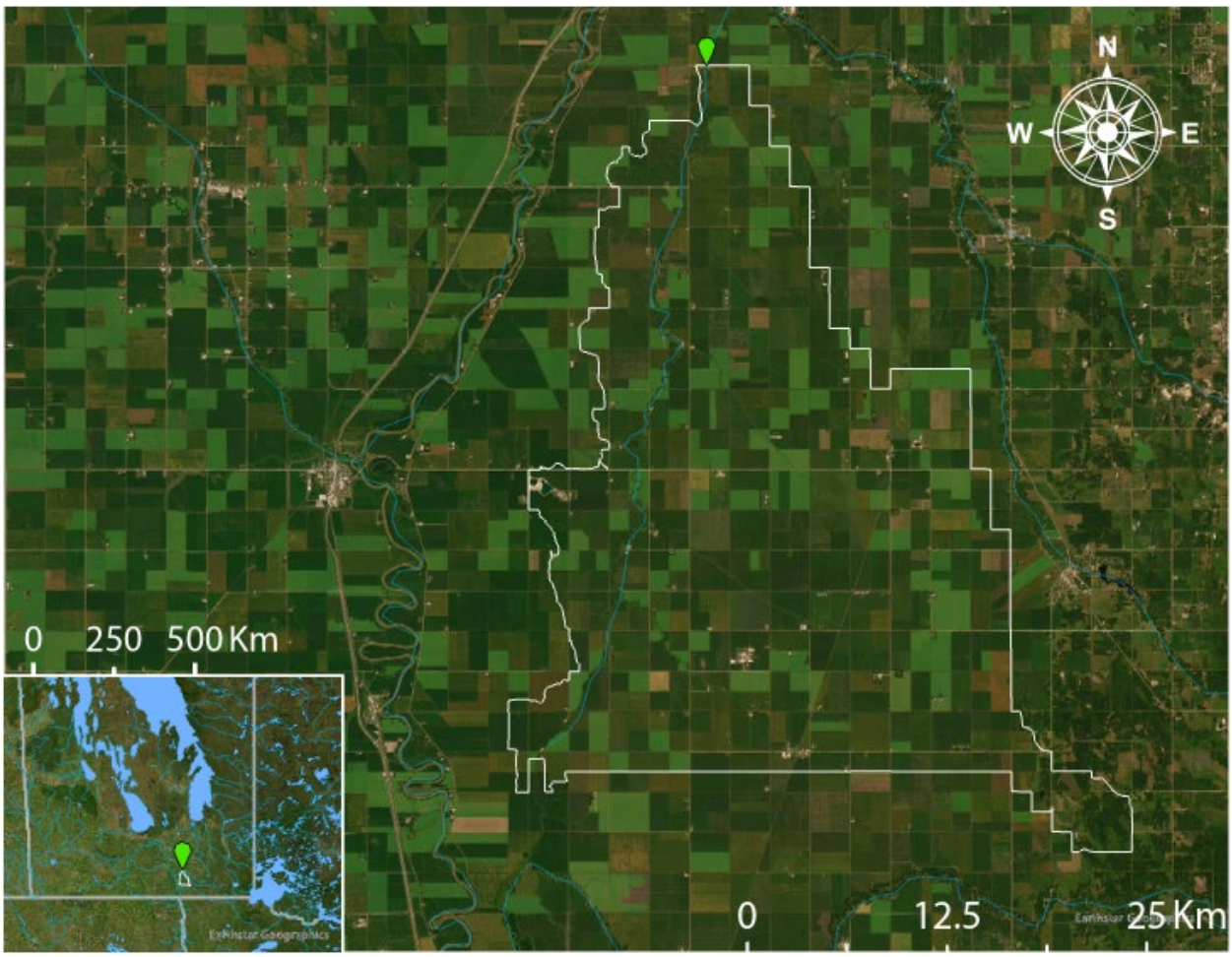


Figure 22: WSC station 05OE010 (green) and drainage area polygon (white – source: AAFC). LWCBMN samples directly at the WSC station.

Roseau River at Gardenton

This sampling site is the most upstream sampling site on the Roseau River. The majority of this drainage area is located in Minnesota and Ontario. This drainage area is not densely populated and is largely forested. This sampling site is located at Water Survey of Canada flow meter 05OD004, near Gardenton, MB. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 13: Indices of discharge and phosphorus from the gross drainage area of Roseau River at Gardenton (05OD004) in 2020.

Gross drainage area:	4186.29 km^2
Peak discharge:	93.00 $m^3 s^{-1}$ (2020-04-12)
Peak TP concentration:	0.29 mg/L (2020-04-11)
% of water load in spring:	55.93%
% of TP load in spring:	45.24%
Water load:	0.61 $km^3 y^{-1}$
TP load:	101.24 tonnes P y^{-1}
Water export:	145.33 mm y^{-1}
TP export:	0.24 kg P $ha^{-1} y^{-1}$

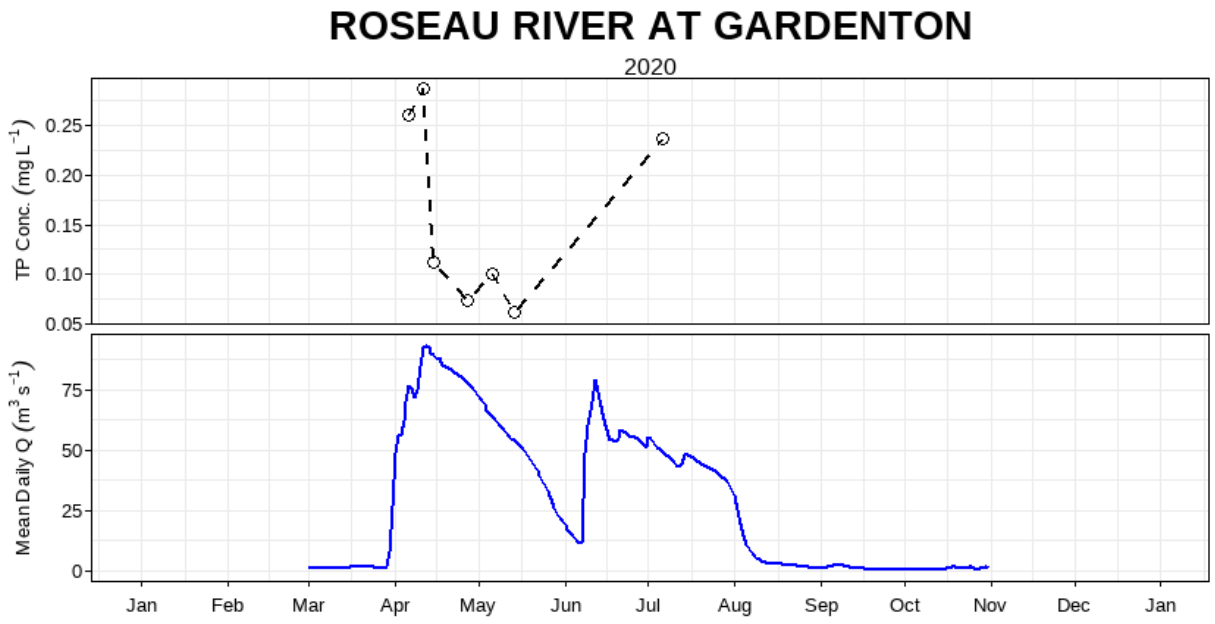


Figure 23: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Roseau River near Gardenton (05OD004).

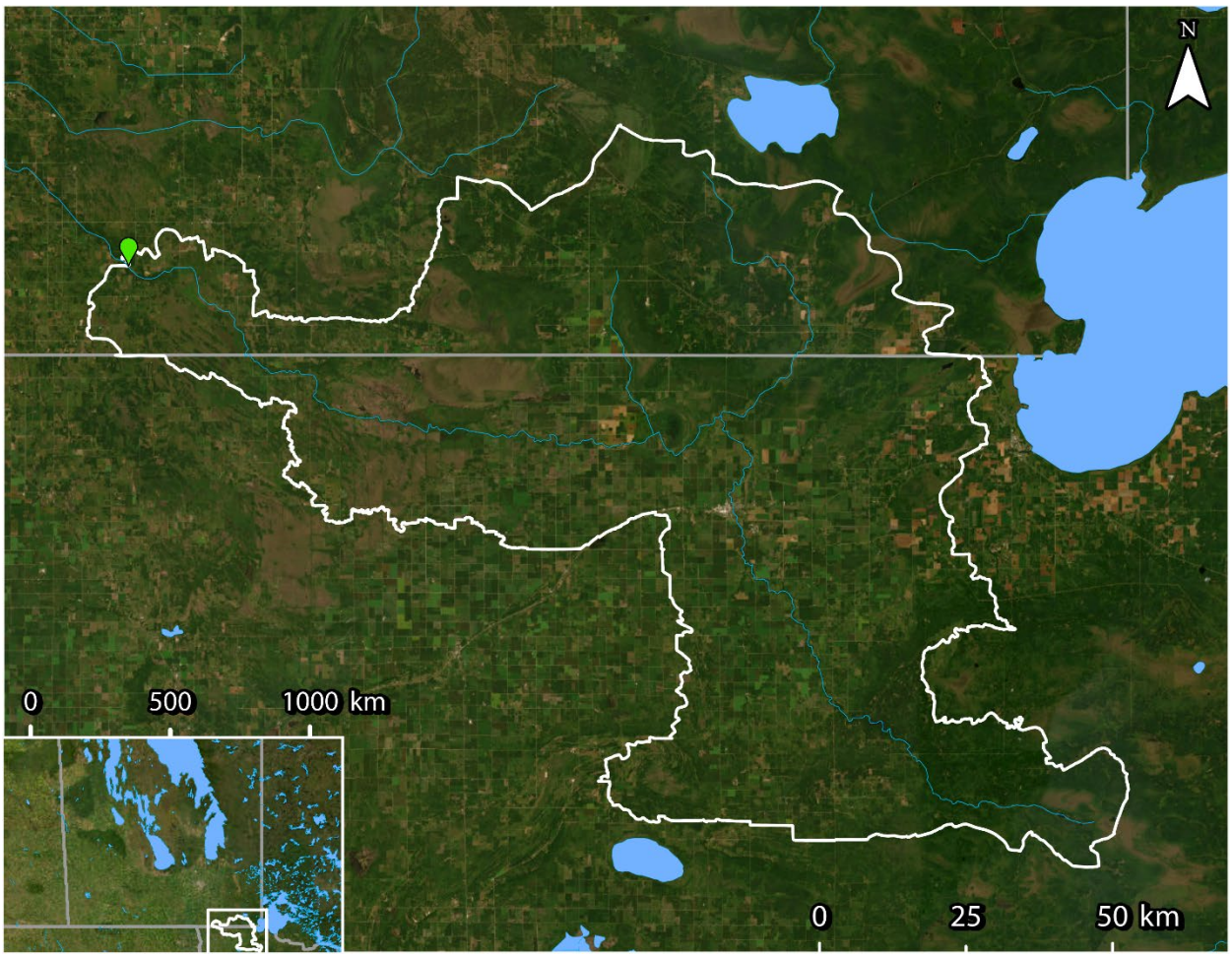


Figure 24: WSC station 05OD004 (green) and drainage area polygon (white – source: WSC). LWCBMN samples directly at the WSC station.

Roseau River near Dominion City

This downstream stretch of the Roseau River drains a largely forested incremental drainage area and the community of Stuartburn, MB. This sampling site is located at Water Survey of Canada flow meter 05OD001, near Dominion City, MB. The sampling effort provided adequate coverage to calculate TP loads and exports.

Table 14: Indices of discharge and phosphorus from the incremental drainage area of Roseau River near Dominion City (05OD001). See Supplemental Table 4 for gross calculations.

Incremental drainage area:	521.15 km^2
Peak discharge:	128.00 $m^3 s^{-1}$ (2020-04-12)
Peak TP concentration:	0.31 mg/L (2020-04-01)
% of water load in spring:	55.58%
% of TP load in spring:	53.72%
[1]Incremental water load:	0.14 $km^3 y^{-1}$
[1]Incremental TP load:	17.08 tonnes P y^{-1}
[2]Incremental water export:	23.64 mm y^{-1}
[2]Incremental TP export:	0.33 kg P $ha^{-1} y^{-1}$

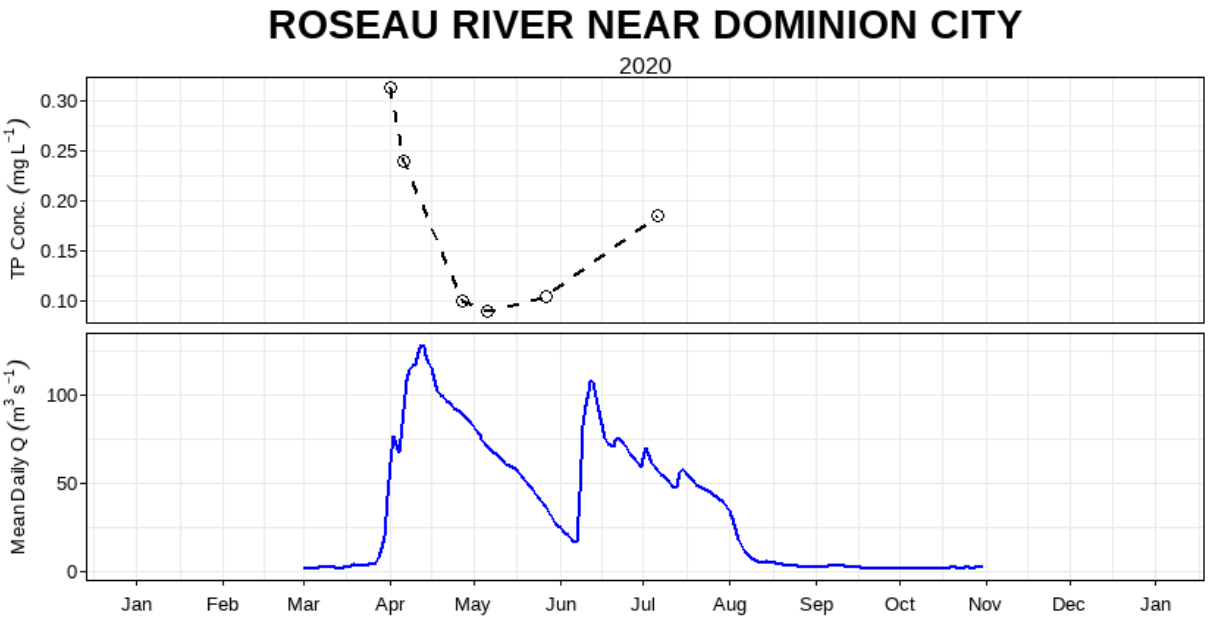


Figure 25: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration (mg L^{-1}) over the 2020 sampling season at Roseau River near Dominion City (05OD001).

[1] Incremental loads are calculated by subtracting gross "Roseau River at Gardenton" values from gross "Roseau River near Dominion City" values.

[2] Incremental exports are calculated by dividing incremental loads by incremental drainage areas.

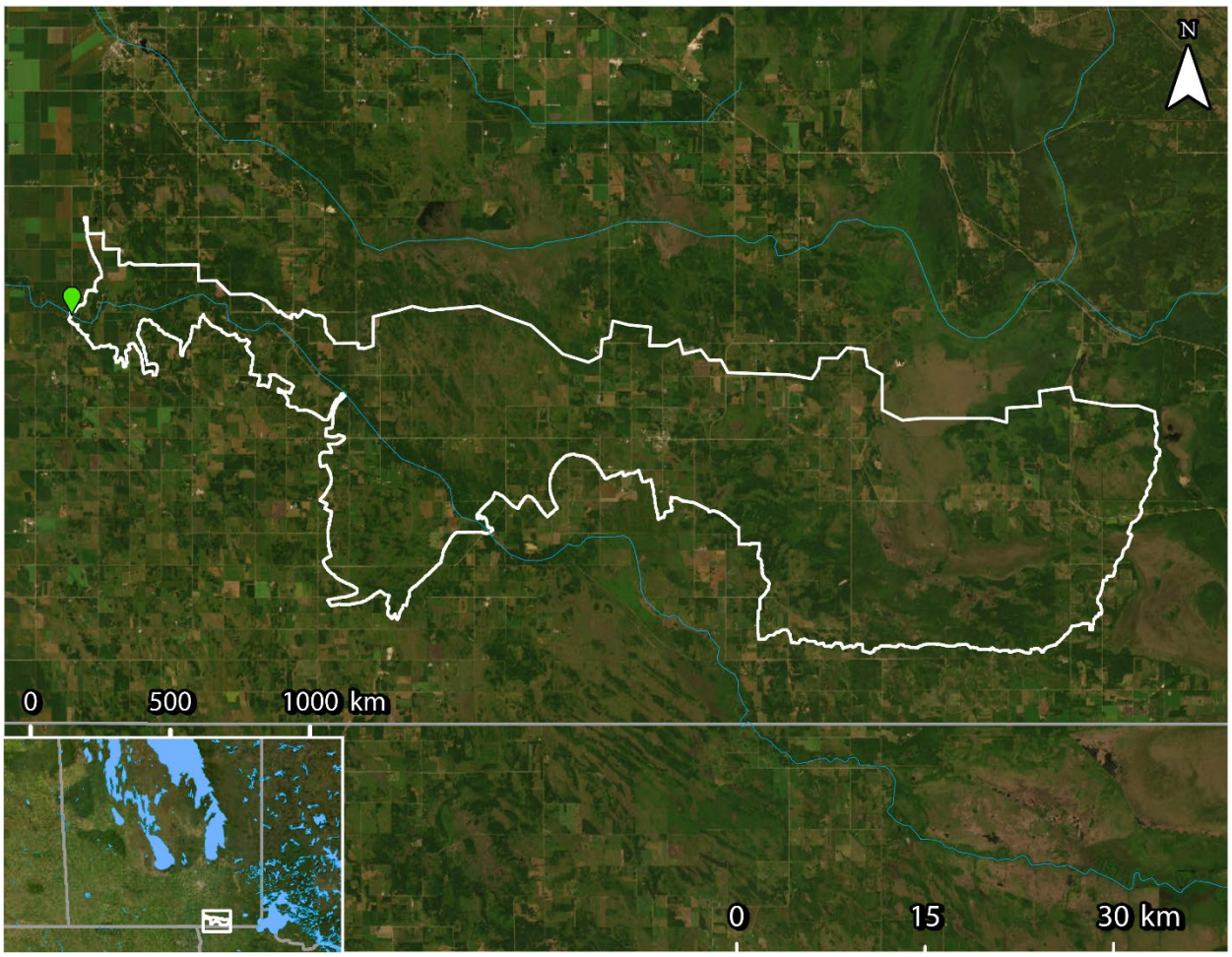


Figure 26: WSC station 05OD001 (green) and drainage area polygon (white - source: WSC). LWCBMN samples directly at the WSC station. See Supplemental Figure 4 for upstream drainage areas used to calculate incremental area.

Main Drain near Dominion City

The majority of this drainage area is located in Manitoba, with a small portion extending into the United States. This sampling site drains a more densely agricultural area than the other sampling sites in the Roseau River watershed. This sampling site is located at Water Survey of Canada flow meter 05OD028, near Dominion City, MB. There were not enough samples to do load and export calculations.

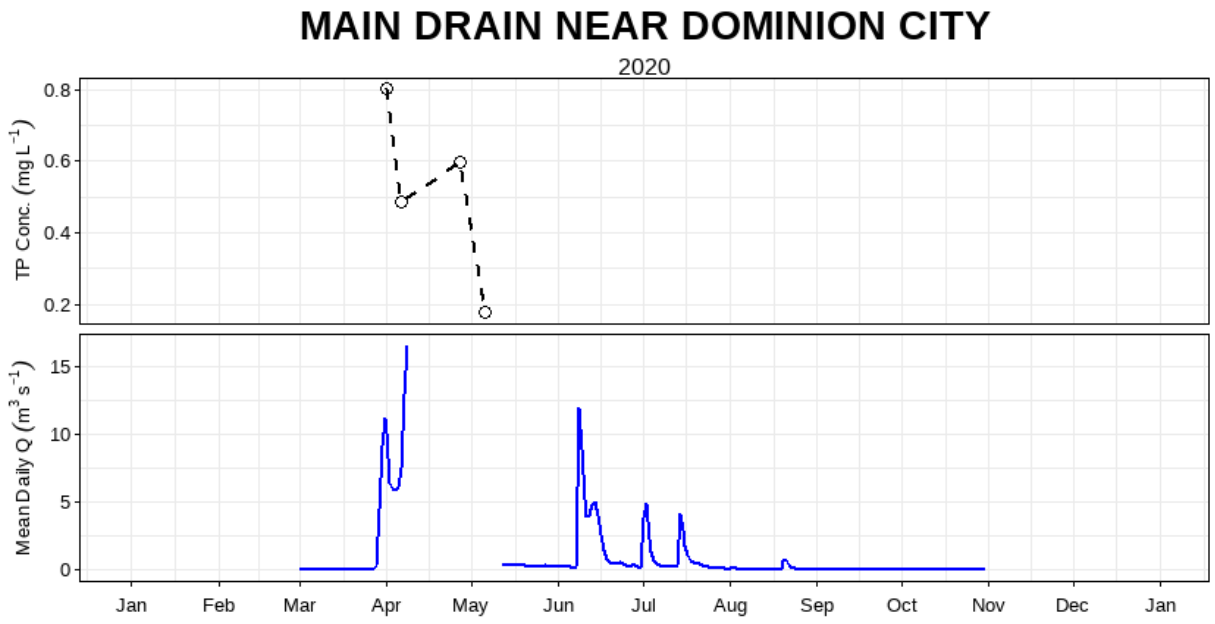


Figure 27: Mean daily discharge ($m^3 s^{-1}$) and total phosphorus concentration ($mg L^{-1}$) over the 2020 sampling season at Main Drain near Dominion City (05OD028).

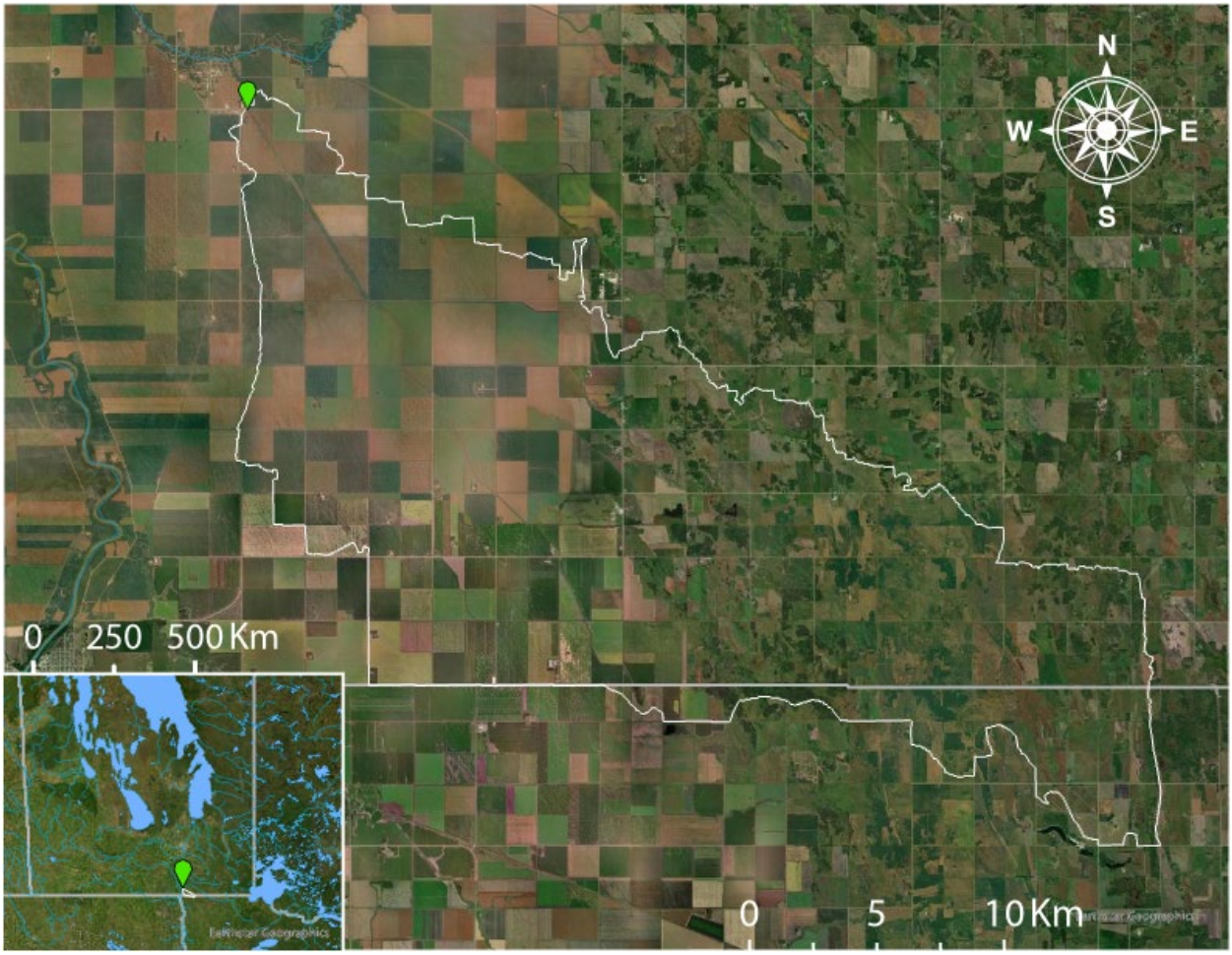


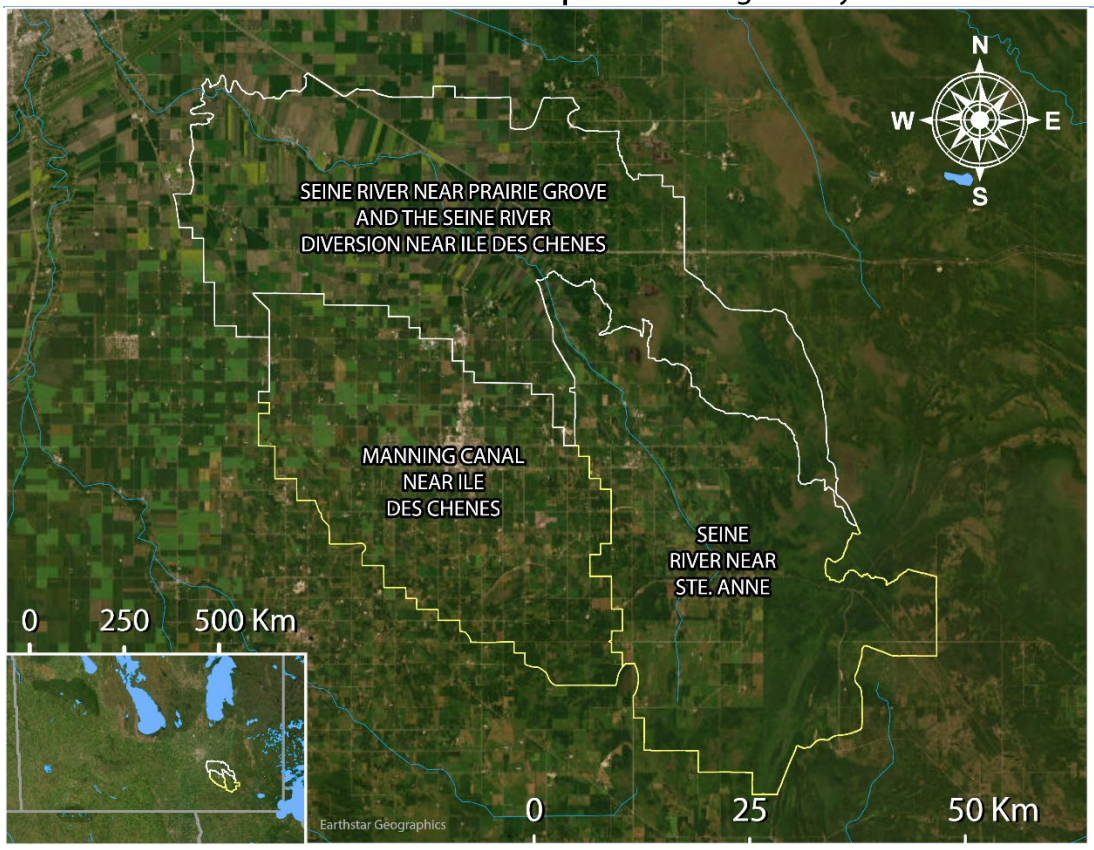
Figure 28: WSC station 05OD028 (green) and drainage area polygon (white – source: WSC). LWCBMN samples directly at the WSC station.

Incremental Calculations

Seine River near Prairie Grove and the Seine River Diversion near Île-des-Chênes

Supplemental Table 1: Indices of discharge and phosphorus from the combined gross drainage area and stream discharge of Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011).

Gross drainage area:	1747.94 km^2
Water load:	0.090 $km^3\ y^{-1}$
TP load:	45.07 tonnes P y^{-1}
Water export:	69.83 mm y^{-1}
TP export:	0.34 kg P $ha^{-1}\ y^{-1}$

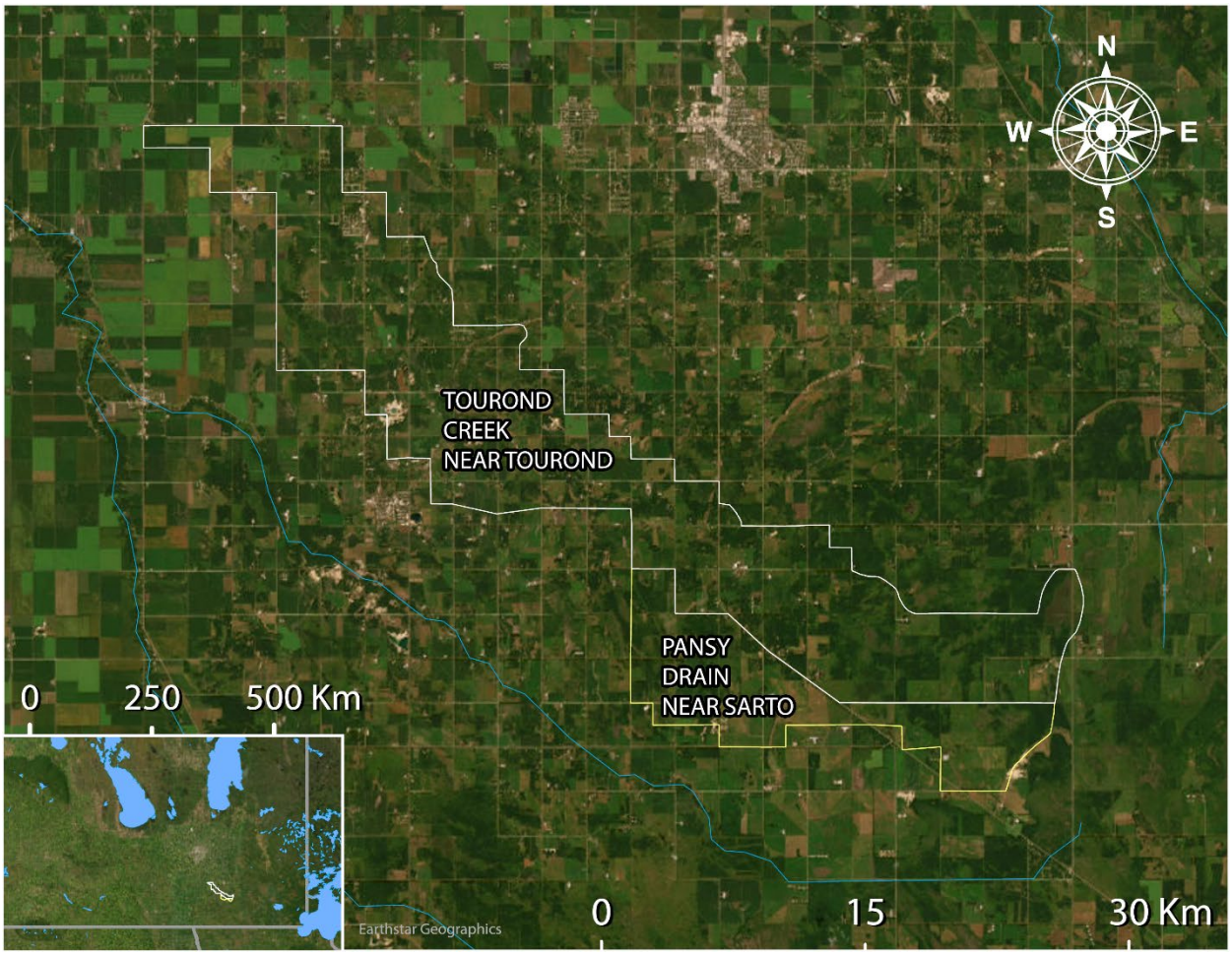


Supplemental Figure 1: Incremental drainage area in white (combined area of WSC stations Seine River near Prairie Grove and the Seine River Diversion near Île-des-Chênes) and upstream drainage areas in yellow (Manning Canal near Île-des-Chênes and Seine River near Ste. Anne). The combined incremental drainage area for Seine River near Prairie Grove (05OH009) and Seine River near Île-des-Chênes (05OE011) was calculated by adding the former two gross drainage areas together and subtracting the upstream gross drainage areas of Manning Canal near Île-des-Chênes (05OE006) and Seine River near Ste. Anne (05OH007).

Tourond Creek near Tourond

Supplemental Table 2: Indices of discharge and phosphorus from the gross drainage area of Tourond Creek near Tourond (05OE009) in 2020.

Gross drainage area:	210.07 km^2
Water load:	0.011 $km^3\ y^{-1}$
TP load:	15.53 tonnes P y^{-1}
Water export:	52.66 mm y^{-1}
TP export:	0.74 kg P $ha^{-1}\ y^{-1}$

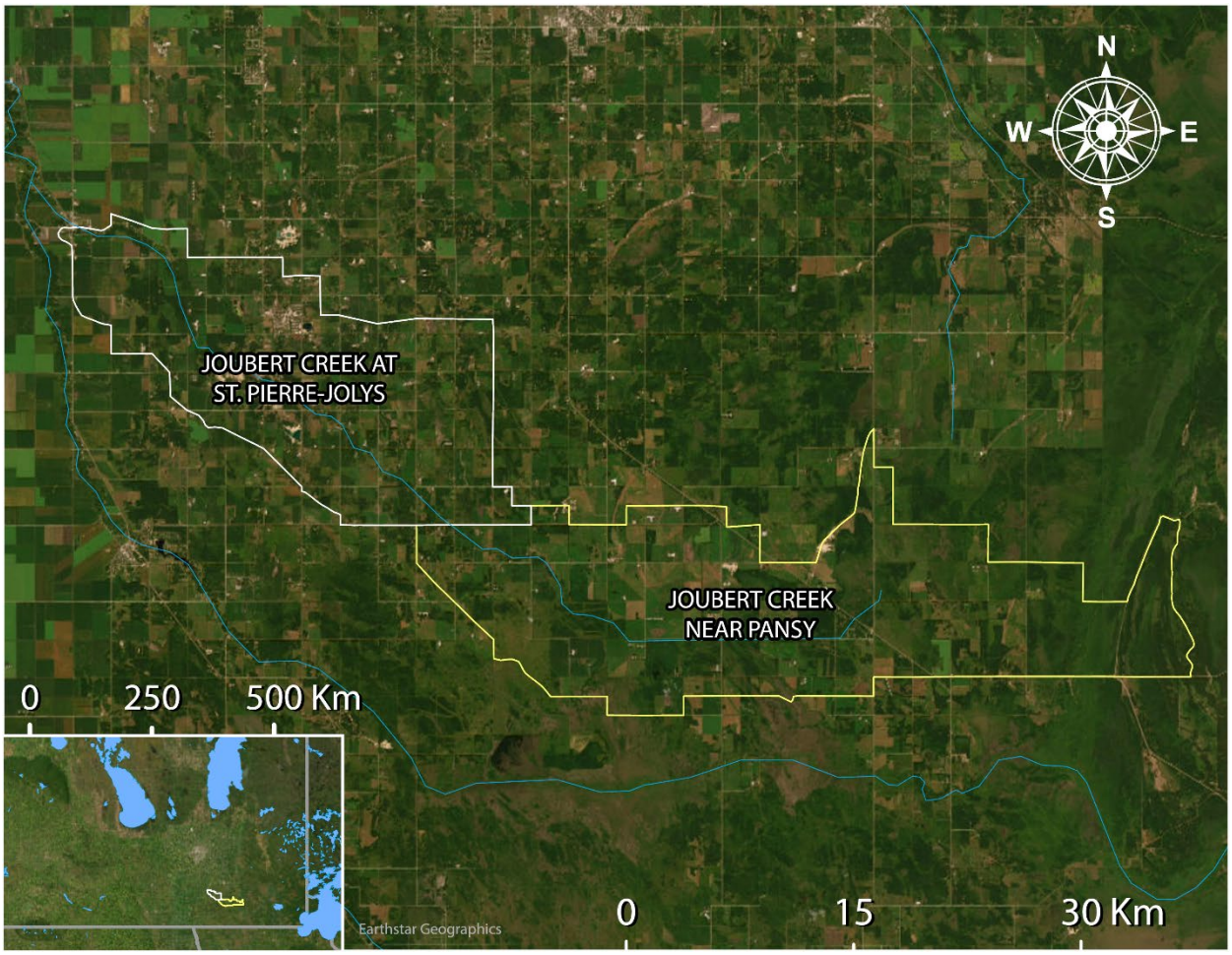


Supplemental Figure 2: Incremental drainage area in white and upstream drainage area in yellow. Incremental loads are calculated by subtracting gross "Pansy Drain near Sarto" values from gross "Tourond Creek near Tourond" values.

Joubert Creek at St-Pierre-Jolys

Supplemental Table 3: Indices of discharge and phosphorus from the gross drainage area of Joubert Creek near St-Pierre-Jolys (05OE007) in 2020.

Gross drainage area:	348.29 km^2
Water load:	0.048 km^3 y^{-1}
TP load:	34.48 tonnes P y^{-1}
Water export:	136.89 mm y^{-1}
TP export:	0.99 kg P ha^{-1} y^{-1}

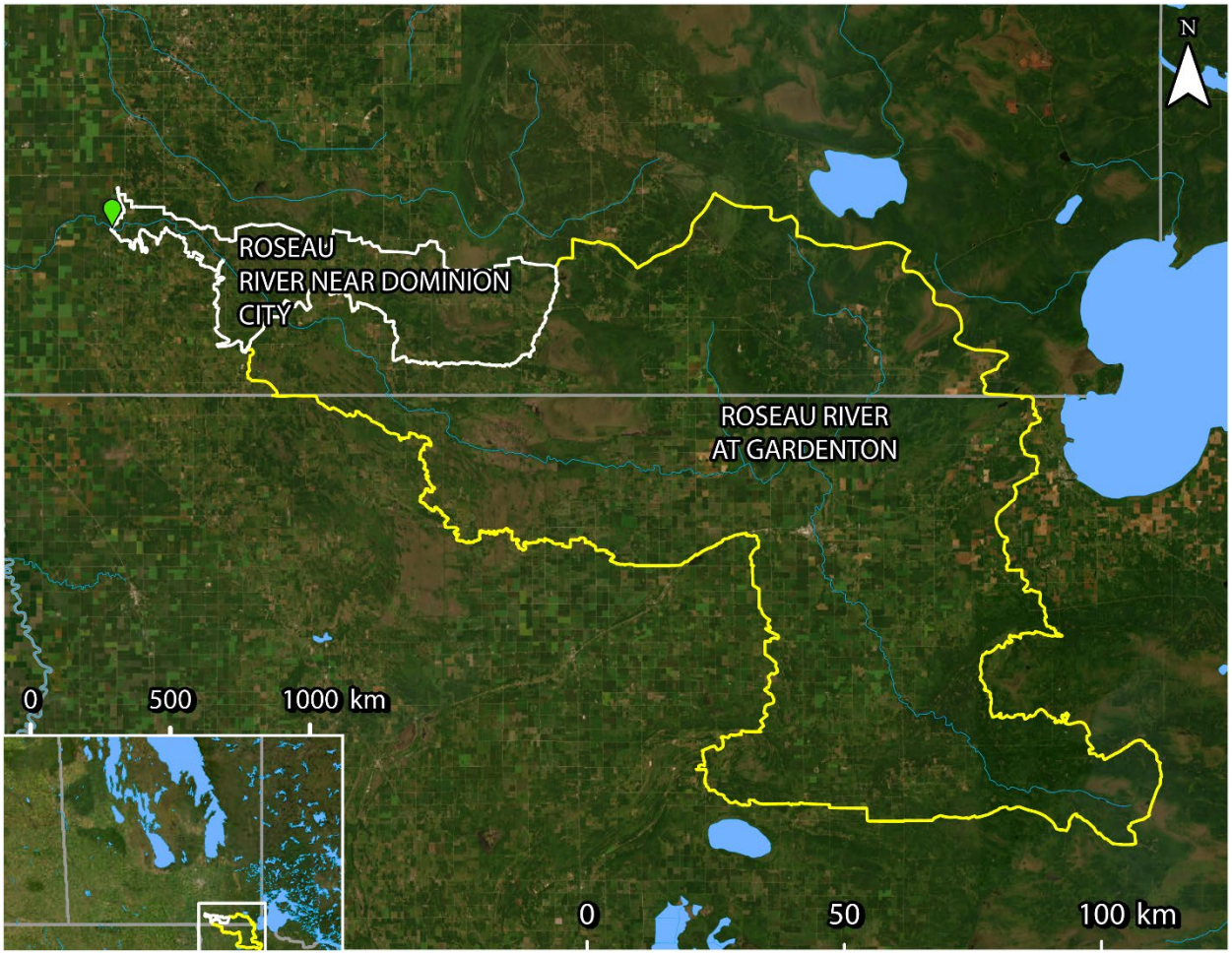


Supplemental Figure 3: Incremental drainage area in white and upstream drainage area in yellow. Incremental loads are calculated by subtracting gross "Joubert Creek near Pansy" values from gross "Joubert Creek near St-Pierre-Jolys" values.

Roseau River near Dominion City

Supplemental Table 4: Indices of discharge and phosphorus from the gross drainage area Roseau River near Dominion City (05OD001) in 2020.

Gross drainage area:	4707.44 km^2
Water load:	0.75 km^3 y^{-1}
TP load:	118.32 tonnes P y^{-1}
Water export:	158.43 mm y^{-1}
TP export:	0.25 kg P ha^{-1} y^{-1}



Supplemental Figure 4: Incremental drainage area in white and upstream incremental drainage areas in yellow. Incremental loads are calculated by subtracting gross "Roseau River at Gardenton" values from gross "Roseau River near Dominion City" values.

Map Sources

Drainage area polygons

Primarily, and whenever possible, drainage area polygons were taken from the Water Survey of Canada's (WSC) National Hydrometric Network Basin Polygons. Released on July 15, 2022, this prerelease version of the dataset contains drainage area polygons for over 7300 of the 7896 active and discontinued WSC stations. According to WSC, this dataset will continue to be updated as new polygons are added. For our analysis, we used drainage areas from this dataset.

Link: https://catalogue.ec.gc.ca/geonetwork/srv/eng/catalog.search#/metadata/0c121878-ac23-46f5-95df-eb9960753375

Secondarily, when no WSC drainage area polygons were available, or when it was necessary to enable accurate incremental calculations, we used drainage area polygons from the Total Gross Drainage Areas of the Agriculture and Agri-Food Canada (AAFC)'s Watersheds Project – 2013

Link: https://open.canada.ca/data/en/dataset/67c8352d-d362-43dc-9255-21e2b0cf466c

Due to the required use of drainage area polygons from two different datasets, some polygons may slightly overlap. Hotspot maps, as a result, have a few instances where a drainage area is visually cut off. However, most of these instances are very minor, and we display all watersheds in their full extent on each sampling site's individual section.

Map layers

Satellite imagery used in all maps is from the World Imagery map layer (Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community). World Imagery provides one meter or better satellite and aerial imagery in many parts of the world and lower resolution satellite imagery worldwide.

Lake and river map data used in all maps is from North America Environmental Atlas (Lakes, Rivers). The North American Environmental Atlas – Lakes & Rivers datasets display area hydrographic features (Lakes: major lakes and reservoirs; Rivers: major rivers, streams, and canals) of North America at a reference spatial scale of 1:1,000,000. Credits: Commission for Environmental Cooperation (CEC). 2023. "North American Atlas – Lakes and Rivers". Natural Resources Canada (NRCan), Instituto Nacional de Estadística y Geografía (INEGI), Comisión Nacional del Agua (CONAGUA), U.S. Geological Survey (USGS). Ed. 3.0, Vector digital data [1:1,000,000].

The **Lake Winnipeg Community-Based Monitoring Network** (LWCBMN) is a collaborative, long-term phosphorus monitoring program designed to identify localized phosphorus hotspots where action is required to improve Lake Winnipeg water quality. LWCBMN mobilizes citizen volunteers and watershed partners to collect water samples across Manitoba, generating robust water-quality data that is useful to community practitioners, academic researchers, government scientists and policy-makers alike. Focusing research, resources and action in phosphorus hotspots is necessary to reduce phosphorus loading to Lake Winnipeg.

LWCBMN is delivered in partnership with Manitoba's watershed districts, LWF's science advisors, volunteer citizen scientists and Dr. Nora Casson's laboratory at the University of Winnipeg. Thank you to all who make this network possible!

The **Lake Winnipeg Foundation** (LWF) advocates for change and coordinates action to improve the health of Lake Winnipeg. Combining the commitment of our grassroots membership and the expertise of our science advisors, LWF is nationally recognized for our unique capacity to link science and action. Our goal is to ensure policy and practices informed by evidence are implemented and enforced.

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