August 2024

Watershed

Pomme de Terre River Watershed Total Maximum Daily Load Report 2024

A quantification of the total amount of phosphorus and bacteria that can be received by select streams and lakes in the Pomme de Terre River Watershed and maintain their ability to support swimming, fishing, and healthy biological communities.

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Acronyms

1W1P	One Watershed, One Plan
ac-ft/yr	acre feet per year
AFO	Animal Feeding Operation
AU	animal unit
AUID	Assessment Unit ID
BMP	best management practice
BOD_5	5-day Biochemical Oxygen Demand
BWSR	Board of Water and Soil Resources
CAFO	Concentrated Animal Feeding Operation
cfu	colony-forming unit
cfu/100 mL	colony-forming unit per 100 mL
chl-*a*	chlorophyll-a
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CV	Coefficient of Variation
CWMP	Comprehensive Watershed Management Plan
DNR	Minnesota Department of Natural Resources
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
HSPF	Hydrologic Simulation Program – FORTRAN
HSPF-SAM	Hydrologic Simulation Program – FORTRAN – Scenario Application Manager
HUC	Hydrologic Unit Code
IPHT	Imminent Public Health Threat
IWM	Intensive Watershed Monitoring
JPB	Joint Powers Board
LA	Load Allocation
lb	pound
lb/day	pounds per day

lb/yr	pounds per year
LC	Loading Capacity
LDC	Load Duration Curve
LGU	Local Government Unit
LiDAR	Light Detection and Ranging
m	meter
mg/L	milligrams per liter
mL	milliliter
MLCCS	Minnesota Land Cover Classification and Impervious Surface Area by Landsat and LiDAR
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
NVSS	Nonvolatile Suspended Solids
RES	River Eutrophication Standard
RIM	Reinvest in Minnesota
PDTRA	Pomme de Terre River Association
PTMApp	Prioritize, Target, and Measure Application
RUSLE	Revised Universal Soil Loss Equation
SDS	State Disposal System
SONAR	Statement of Need and Reasonableness
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation District
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
WASCOB	Water and Sediment Control Basin
WLA	Wasteload Allocation
WQBEL	Water Quality-Based Effluent Limit
WRAPS	Watershed Restoration and Protection Strategies

WRP	Wetland Reserve Program
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
VSS	Volatile Suspended Solids

Executive summary

The Clean Water Act (1972) requires that each state develop a study to identify and determine how to restore any water body that is deemed impaired by state regulations. A total maximum daily load (TMDL) study is required by the United States Environmental Protection Agency (EPA) as a result of the federal Clean Water Act. A TMDL identifies the pollutant that is causing the impairment and how much of that pollutant can enter the water body and still meet water quality standards.

This TMDL study addresses total phosphorus (TP), total suspended solids (TSS), and bacteria in the form of *Escherichia coli* (*E. coli*) impairments in three lakes (Barrett Lake, North Drywood Lake, and South Drywood Lake) and four streams (Pelican Creek, Muddy Creek, Unnamed Creek, and Unnamed Creek) located in the Pomme de Terre River Watershed, Hydrologic Unit Code (HUC) 07020002, that are on Minnesota's 2024 303(d) list of impaired waters.

Information from multiple sources was used to evaluate the ecological health of each water body, including:

- All available water quality data from the TMDL 10-year time period (2009 through 2018)
- Pomme de Terre River Watershed Hydrologic Simulation Program – FORTRAN (HSPF) model (1996 through 2017)
- Pomme de Terre River TMDL (MPCA 2015)
- Pomme de Terre River Comprehensive Watershed Management Plan (EOR Inc. 2019)
- BATHTUB lake water quality response modeling
- Published studies
- Stakeholder input

The following pollutant sources were evaluated for each impaired lake and stream: loading from upstream water bodies, point sources, feedlots, septic systems, wildlife, and lake sediments. This TMDL report used an inventory of pollutant sources to develop a load duration curve (LDC) model for each impaired stream, and a lake water quality response model (BATHTUB) for each impaired lake. A Hydrologic Simulation Program-FORTRAN – Scenario Application Manager (HSPF-SAM) model was used to estimate runoff volumes and TP loads from the direct drainage area of impaired lakes and from upstream tributaries. These models were then used to determine the pollutant reductions needed for the impaired water bodies to meet water quality standards. A summary of existing conditions, pollutant sources, and reductions needed to meet water quality standards for each impaired water body addressed in the TMDL is provided below.

Barrett Lake

Barrett Lake is a 529-acre impoundment of the Pomme de Terre River in Grant County. The city of Barrett is located along the west and south shorelines. The maximum depth of the lake is 28.0 feet, and the average depth is estimated at 8.5 feet. Water quality measurements describe Barrett Lake as eutrophic. The Pomme de Terre River carries sediments and nutrients from an expansive, well drained, and largely cultivated watershed area extending far north into Otter Tail County. Algae blooms impair water clarity during summer months.

The largest TP source to Barrett Lake is upstream Lake Pomme de Terre (52%) followed by direct drainage runoff (41%) and excess internal/unknown load (4%). Existing TP loads need to be reduced by 6,031 lbs/yr (45%) for Barrett Lake to achieve the North Central Hardwood Forests TP lake water quality standard of 40 µg/L. Most of the TP reductions needed are from direct drainage runoff (4,205 lbs/yr) and Pomme de Terre Lake (1,260 lbs/yr) as well as internal load reductions (570 lbs/yr).

North Drywood Lake

North Drywood Lake is a highly eutrophic lake located approximately 14 miles northwest of Appleton, Minnesota in Swift County. North Drywood Lake is in-line with Artichoke Creek and is connected to South Drywood Lake by a wetland channel. No public access nor outlet structures are present on this lake. Although the lake is shallow, turbid, and prone to winterkill, it provides valuable fish habitat. North Drywood Lake is 404 acres with a maximum depth of less than 4 feet and is classified as a shallow lake. Algae blooms and suspended sediment impair water clarity during summer months.

The largest TP source to North Drywood Lake is Artichoke Creek (39%) followed by excess internal/unknown load (29%), direct drainage runoff (16%), Unnamed Creek (11%) and South Drywood Lake (4%). Existing TP loads need to be reduced by 41,526 lbs/yr (89%) for North Drywood Lake to achieve the Western Corn Belt Plains and Northern Glaciated Plains ecoregion TP shallow lakes water quality standard of 90 µg/L. TP reductions are needed from Artichoke Creek (15,326 lbs/yr), internal load (13,788 lbs/yr), direct drainage runoff (6,403 lbs/yr), Unnamed Creek (4,315 lbs/yr) and improvements in upstream South Drywood Lake (1,693 lbs/yr).

South Drywood Lake

South Drywood Lake is a highly eutrophic lake located approximately 14 miles northwest of Appleton, Minnesota in Swift County. South Drywood Lake is connected to North Drywood Lake by a wetland channel. No public access nor outlet structures are present on this lake. Although the lake is shallow, turbid, and prone to winterkill, it provides valuable fish habitat. South Drywood Lake is 231-acres with a maximum depth of less than 4 feet and is classified as a shallow lake. Algae blooms and suspended sediment impair water clarity during summer months.

The largest TP source to South Drywood Lake is excess internal/unknown load (87%) followed by direct drainage runoff (12%). Existing TP loads need to be reduced by 14,807 lbs/yr (97%) for South Drywood Lake to achieve the Western Corn Belt Plains and Northern Glaciated Plains ecoregion shallow lakes TP water quality standard of 90 µg/L. TP reductions are needed from internal load (13,346 lbs/yr) and direct drainage runoff (1,461 lbs/yr).

In all three lakes, proposed implementation activities include: conducting shoreline condition inventories on a parcel-by-parcel basis using a uniform process, implementing shoreline restoration projects for erosion control based on shoreline inventories, implementing structural and nonstructural agricultural best management practices (BMPs) based on the Prioritize, Target, and Measure Application (PTMApp) modeling and best professional judgment within the direct drainage area, and conducting a series of lake outreach meetings to identify possible in-lake management strategies and engage affected landowners in lake water quality management. In-lake management strategies may include carp harvesting or barriers and whole-lake alum treatment

Unnamed Creek (-566)

Unnamed Creek (-566) is located in the southern half of the Pomme de Terre River Watershed upstream of the Drywood Lakes. The total drainage area to Unnamed Creek is 36 square miles and is comprised mostly of row crops (55%) with some open water (14%), emergent wetlands (13%), and grassland (9%). Unnamed Creek was evaluated against the stream eutrophication standard because of high concentrations of phosphorus and chlorophyll-a (chl-*a*) during the summer season. The largest source of phosphorus to the creek is from nonpoint agricultural runoff. TP reductions of 78% are needed to meet the Southern River Nutrient Region stream eutrophication standard of 0.15 mg/L.

Unnamed Creek (-547)

Unnamed Creek (-547) is located in the southern half of the Pomme de Terre River Watershed and is a tributary to the Pomme de Terre River from the east. The total drainage area to Unnamed Creek is 28 square miles and is comprised mostly of row crops (78%) with some grassland (7%) and impervious area (6%). The largest sources of sediment in the stream were determined to be from near stream disturbances and agricultural runoff from pastures and high tillage cropland. Imminent public health threat septic systems (IPHTs) and feedlots have a moderate potential to contribute to the *E. coli* impairment in Unnamed Creek. A reduction of approximately 30% in TSS concentration is required to meet the TSS Southern River Nutrient Region standard of 65 mg/L and a reduction of up to 92% is needed to meet the *E. coli* water quality standard of 126 org./100 mL. Microbial source tracking is recommended in this stream to determine the relative contribution of human and agricultural sources of *E. coli* compared to wildlife contributions.

Pelican Creek

Pelican Creek, located in the northern portion of the watershed, was evaluated because of high TSS concentrations and high *E. coli* concentrations above the water quality standard. The total drainage area to Pelican Creek is 133 square miles and is comprised mostly of row crops (32%) with some grassland (21%), open water (18%), and deciduous forest (14%). The largest sources of sediment in the stream were determined to be from near stream disturbances and agricultural runoff from pastures and high tillage cropland. IPHTs and wildlife have a moderate potential to contribute to the *E. coli* impairment in Pelican Creek. A reduction of approximately 64% in TSS concentration is required to meet the TSS Central River Nutrient Region standard of 30 mg/L and a reduction of up to 66% is needed to meet the *E. coli* water quality standard of 126 org./100 mL. Microbial source tracking is recommended in this stream to determine the relative contribution of human and agricultural sources of *E. coli* compared to wildlife contributions.

Muddy Creek

Muddy Creek is a limited resource value water in the Pomme de Terre River Watershed with elevated *E. coli* concentrations. The total drainage area to Muddy Creek is 144 square miles and is comprised mostly of row crops (64%) and grassland (13%). Feedlots and IPHTs have a moderate potential to contribute to the *E. coli* impairment in Muddy Creek. A reduction of up to 49% is needed to meet the *E. coli* water quality standard of 126 org./100 mL. Microbial source tracking is recommended in this stream to determine the relative contribution of human and agricultural sources of *E. coli* compared to wildlife contributions.

Targeted implementation activities were identified in Section 4 the Pomme de Terre River Watershed Comprehensive Management Plan (EOR Inc. 2019) that will make progress towards the nonpermitted source load reduction goals identified in this TMDL report. The TMDL report's results will support the selection of implementation activities in future watershed projects. More information about the Pomme de Terre River Watershed is located on the Minnesota Pollution Control Agency (MPCA) Watershed website.

1. Project overview

1.1 Purpose

Water quality monitoring in 2017 and 2018 resulted in three lakes and four streams in the Pomme de Terre River Watershed being added to Minnesota's 303(d) impaired waters list because they exceed established state water quality standards and do not support their designated uses. In accordance with the Clean Water Act, TMDL studies must be conducted on the impaired waters. The goals of this TMDL are to provide wasteload allocations (WLA) and load allocations (LA) for pollutant sources within the Pomme de Terre River Watershed and to quantify the pollutant reductions needed to meet Minnesota water quality standards. This TMDL report addresses the following impairments within the Pomme de Terre River Watershed (HUC 07020002) that are included in Minnesota's 2024 303(d) list (Figure 1):

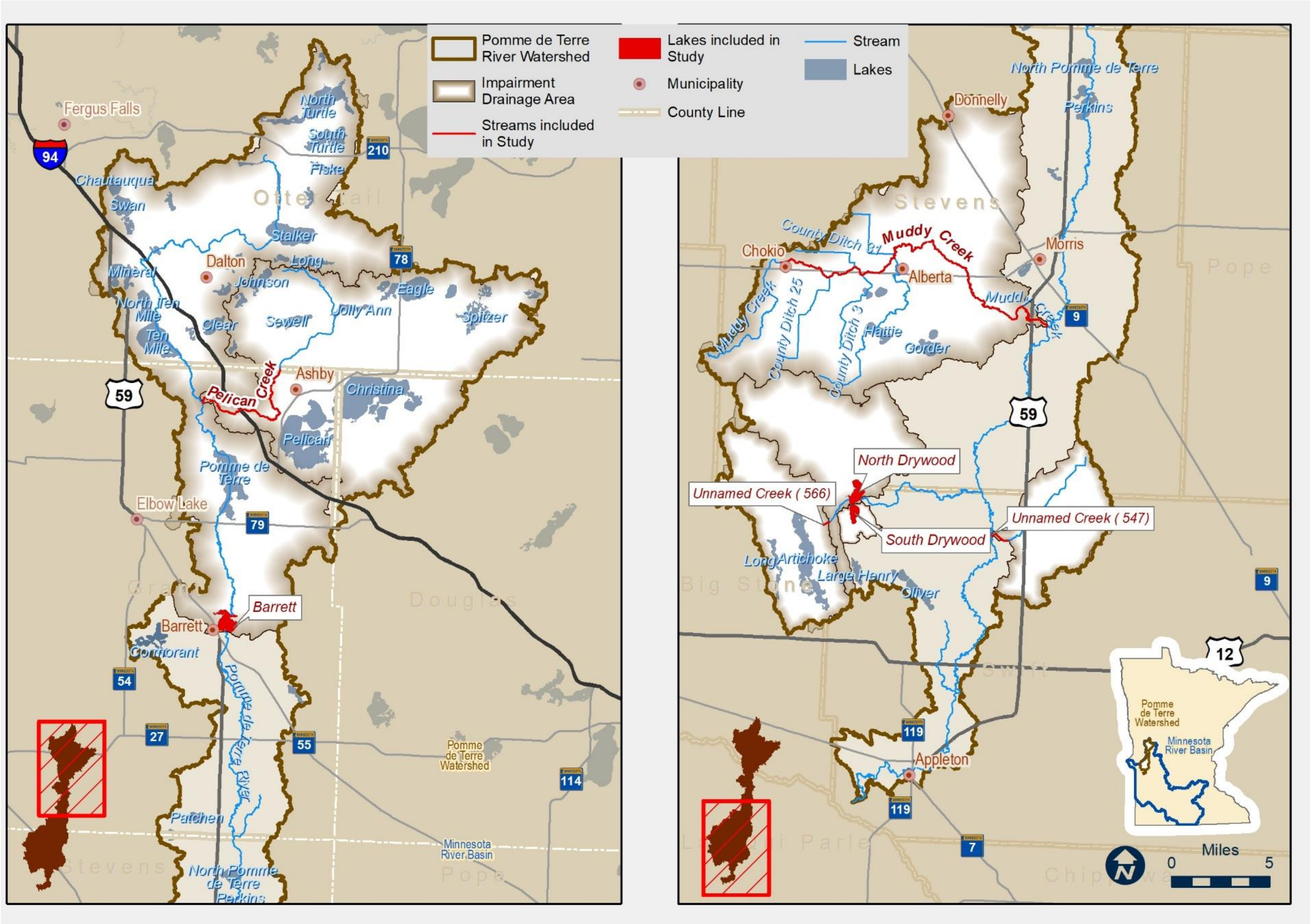
- aquatic recreation use impairments due to eutrophication (total phosphorus [TP]) in three lakes
- aquatic recreation use impairments due to *E. coli* in three stream reaches
- aquatic life use impairment due to eutrophication in one stream reach
- aquatic life use impairment due to TSS in two stream reaches

In the past, the MPCA completed TMDLs on an individual water body based on existing monitoring data and assessments. The 2007 Pomme de Terre River, Muddy Creek to Marsh Lake, Fecal Coliform TMDL (MPCA 2007a) and the 2011 Turbidity TMDL Assessment for the Pomme de Terre River (Pomme de Terre River Association [PDTRA] 2011) were completed through this process. The MPCA adopted a Watershed Approach in 2008, as recommended by the 2008 Biennial Report to the Legislature and directed by the Minnesota Legislature, to more efficiently and effectively use public resources to address water quality challenges across the state. The MPCA initiated the Intensive Watershed Monitoring (IWM) program to conduct two years of intensive monitoring and assessment once every 10 years on a rotating basis for each of Minnesota's 80 major watersheds. The 2015 Pomme de Terre River Watershed TMDL Report (MPCA 2015) addressed impairments identified during the first round of IWM completed in the Pomme de Terre River Watershed in 2007 and 2008. This TMDL report addresses additional impairments identified during the second round of IWM completed in the Pomme de Terre River Watershed in 2017 and 2018.

Other Pomme de Terre River Watershed studies completed that are referenced in this TMDL include:

- Pomme de Terre River HSPF Modeling Memo (RESPEC 2017)
- Pomme de Terre River CWMP (EOR Inc. 2019)

Figure 1. Impaired streams and lakes in the Pomme de Terre River Watershed addressed by this TMDL.



1.2 Identification of water bodies

Table 1 identifies and describes the lake and stream impairments in the Pomme de Terre River Watershed that will be addressed by TMDLs in this study.

Table 1. Aquatic Life and Aquatic Recreation Use Impairments in the Pomme de Terre River Watershed (07020002) addressed in this TMDL report.

Affected Use: Pollutant/ Stressor	DNR Lake ID/ AUID	Impaired Water Body	Location/Reach Description	Designated Use Class	Listing Year	Impairment Addressed by:
Aquatic Recreation: Eutrophication	26-0095-00	Barrett Lake	At Barrett	2B, 3C	2020	TP TMDL
	76-0149-00	South Drywood Lake	Near Correll	2B, 3C	2020	TP TMDL
	76-0169-00	North Drywood Lake	Near Correll	2B, 3C	2020	TP TMDL
	07020002-566	Unnamed Creek	Unnamed cr to Artichoke Creek	2Bg, 3C	2020	TP TMDL
Aquatic Recreation: *E. coli*	07020002-506	Pelican Creek	(T130 R41W S4, north line to Pomme de Terre River)	2Bg, 3C	2020	*E. coli* TMDL
	07020002-511	Muddy Creek	(T124 R44W S3, west line to Pomme de Terre River)	7	2020	*E. coli* TMDL
	07020002-547	Unnamed Creek	Unnamed creek to Pomme de Terre River	2Bg, 3C	2022	*E. coli* TMDL
Aquatic Life: TSS	07020002-506	Pelican Creek	(T130 R41W S4, north line to Pomme de Terre River)	2Bg, 3C	2020	TSS TMDL
	07020002-547	Unnamed Creek	Unnamed creek to Pomme de Terre River	2Bg, 3C	2024*	TSS TMDL

* Impairments included on the 2024 303(d) impaired waters list.

1.3 Priority ranking

The MPCA's TMDL commitments, as indicated on Minnesota's Section 303(d) impaired waters list, reflect Minnesota's priority ranking of the impairments addressed in this report. To meet the needs of EPA's *2022–2032 Vision for the Clean Water Act Section 303(d) Program* (EPA 2022), the MPCA aligned TMDL commitments with the watershed approach and other statewide strategies and initiatives in *Minnesota's Total Maximum Daily Load Studies Prioritization Framework* (MPCA 2024c). As part of these efforts, the MPCA identified water quality impaired segments to be addressed by TMDLs through the watershed approach and other statewide strategies and initiatives (MPCA 2024d).

2. Applicable water quality standards and numeric water quality targets

All water bodies have a Designated Use Classification, defined by the MPCA, which defines the optimal purpose for that water body (see Table 1). The lakes and streams addressed by this TMDL report fall into one of the following three designated use classifications:

2B - a healthy warm water aquatic community

2Bg - a warm water aquatic community that can be used for general use

3C - industrial consumption with a high level of treatment

7 – limited resource value waters

Class 2 waters are protected for aquatic life and aquatic recreation, and Class 3 waters are protected for industrial consumption as defined by Minn. R. ch. 7050.0140. The most protective of these classes is 2B, for which water quality standards are provided below.

> The Minnesota narrative water quality standard for all Class 2 waters (Minn. R. 7050.0150, subp. 3) states, "For all Class 2 waters, the aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments, and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters."

Class 7 waters have been shown through attainability analysis to have limited value as a water resource. The definition of Class 7 waters as defined by Minn. R. ch. 7050.0140 is below.

> Limited resource value waters include surface waters of the state that have been subject to a use attainability analysis and have been found to have limited value as a water resource. Water quantities in these waters are intermittent or less than one cubic foot per second at the 7Q10 flow as defined in part 7050.0130, subpart 3. These waters shall be protected so as to allow secondary body contact use, to preserve the groundwater for use as a potable water supply, and to protect aesthetic qualities of the water. It is the intent of the agency that very few waters be classified as limited resource value waters. The use attainability analysis must take into consideration those factors listed in Minnesota Statutes, section 115.44, subdivisions 2 and 3. The agency, in cooperation and agreement with the Department of Natural Resources with respect to determination of fisheries values and potential, shall use this information to determine the extent to which the waters of the state demonstrate that:
>
> A. the existing and potential faunal and floral communities are severely limited by natural conditions as exhibited by poor water quality characteristics, lack of habitat, or lack of water;

B. the quality of the resource has been significantly altered by human activity and the effect is essentially irreversible; or

C. there are limited recreational opportunities, such as fishing, swimming, wading, or boating, in and on the water resource.

The conditions in items A and C or B and C must be established by the use attainability analysis before the waters can be classified as limited resource value waters.

In addition to the Designated Use Classifications, water bodies in Minnesota must protect the downstream water bodies as defined in Minn. R. ch. 7050.0150.0155. "All waters must maintain a level of water quality that provides for the attainment and maintenance of the water quality standards of downstream waters, including the waters of another state."

2.1 Lakes

2.1.1 Lake eutrophication

Total phosphorus is often the limiting factor controlling primary production in freshwater lakes: as in-lake phosphorus concentrations increase, algal growth increases resulting in higher chl-*a* concentrations and lower water transparency. In addition to meeting phosphorus limits, chl-*a* and Secchi transparency standards must also be met. In developing the lake nutrient standards for Minnesota lakes (Minn. R. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions MPCA 2005). Clear relationships were established between the causal factor TP and the response variables chl-*a* and Secchi transparency. Based on these relationships, it is expected that by meeting the phosphorus target in each lake, the chl-*a* and Secchi standards will likewise be met.

In the Pomme de Terre River Watershed, one impaired lake (Barrett Lake) was assessed against the North Central Hardwood Forests Ecoregion water quality standards and two impaired lakes were assessed against the Shallow Lakes Northern Glaciated Plains Ecoregion water quality standards (Table 2). A separate water quality standard was developed for shallow lakes, which tend to have poorer water quality than deeper lakes in this ecoregion. According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 feet, or if the littoral zone (area where depth is less than 15 feet) covers at least 80% of the lake's surface area. North Drywood Lake and South Drywood Lakes are shallow lakes by this definition.

To be listed as impaired (Minn. R. 7050.0150, subp. 5), the summer season (June through September) monitoring data must show that the standards for both TP (the causal factor) and either chl-*a* or Secchi transparency (the response variables) were exceeded. If a lake is impaired with respect to only one of these criteria, it may be placed on a review list; a weight of evidence approach is then used to determine if it will be listed as impaired. For more details regarding the listing process, see the Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 303(b) Report and 303(d) List (MPCA 2018).

Table 2. Applicable lake eutrophication standards by impaired lake.

Impaired Lake (DNR Lake ID)	Ecoregion	Eutrophication Standard		
		TP (mg/L)	Chl-a (µg/L)	Secchi (m)
Barrett Lake (26-0095-00)	Lakes and Reservoirs in North Central Hardwood Forests	< 0.040	< 14	> 1.4
North Drywood Lake (76-0169-00) South Drywood Lake (76-0149-00)	Shallow Lakes in Northern Glaciated Plains Ecoregions	< 0.090	< 30	> 0.7

2.2 Streams

2.2.1 Eutrophication

A stream is considered impaired by eutrophication if the summer-average (June through September) data exceeds the water quality standard set in Minn. R. 7050.0222 for TP and at least one of the following response parameters: chl-*a*, pH, Diel DO flux or 5-day biochemical oxygen demand (BOD_5). A water does not meet eutrophication standards if the long-term mean of a single response parameter and the causal parameter exceed their respective criteria (Heiskary and Bouchard 2015). Additionally, if the TP concentration of a water exceeds and all response parameter measurements meet their respective river eutrophication standard (RES) criteria, then it is considered a “no response” water (Heiskary and Bouchard 2015). Datasets must consist of at least 12 samples to assess the impairment status of a river. The eutrophication standards for 2B streams in the Southern River Nutrient Region are in Table 3.

Table 3. Southern River Nutrient Region 2B stream eutrophication standards (Minn. R. 7050.0220, subp. 4).

Parameter	Standard
Total Phosphorus	Less than or equal to 150 µg/L
Chlorophyll-a (seston)	Less than or equal to 40 µg/L
Diel Dissolved Oxygen Flux	Less than or equal to 5.0 mg/L
Biochemical Oxygen Demand (BOD_5)	Less than or equal to 3.5 mg/L
pH	Greater than or equal to 6.5; Less than or equal to 9.0

2.2.2 Total suspended solids

The TSS criteria for Minnesota streams are stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The assessment window for these samples is April through September, so any TSS data collected outside of this period will not be considered for assessment purposes. The TSS standard for streams in the Central River Nutrient Region is 30 milligrams per liter (mg/L), and the TSS standard for streams in the Southern River Nutrient Region is 65 mg/L (Table 4). For assessment, the TSS concentration is not to be exceeded in more than 10% of samples within a 10-year data window. Existing TSS data from the TMDL report area covers a much larger spatial and temporal scale than was useable for the scope of this TMDL. TSS LDCs and TMDLs were developed for two stream impairments.

Table 4. Applicable TSS standard by impaired reach.

Impaired Stream (AUID)	River Nutrient Region	TSS Standard
Pelican Creek (07020002-506)	Central	<30 mg/L
Unnamed Creek (07020002-547)	Southern	<65 mg/L

For more information, refer to the Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment, 305(b) Report and 303(d) List, and the Regionalization of Minnesota's Rivers for Application of River Nutrient Criteria.

2.2.3 *E. coli*

The State of Minnesota has developed numeric water quality standards for bacteria (Minn. R. 7050.0222 and Minn R. 7050.0227), in this case *E. coli*, which are protective concentrations for short- and long-term exposure to pathogens in water. The *E. coli* numeric water quality standards vary based on the class of the water body. Class 2 and Class 7 water quality standards are described below and in Table 5. Although most are harmless, fecal indicator bacteria, such as *E. coli*, are used as an easy-to-measure parameter to evaluate the suitability of recreational waters for the presence of pathogens and probability of illness. Pathogenic bacteria, viruses, and protozoa pose a health risk to humans, potentially causing illnesses with gastrointestinal symptoms (nausea, vomiting, fever, headache, and diarrhea), skin irritations, or other symptoms. Pathogen types and quantities vary among fecal sources; therefore, human health risk varies based on the source of fecal contamination.

For Class 2 waters, *E. coli* concentrations are not to exceed 126 organisms per 100 milliliters (mL) as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 mL. The standard applies only between April 1 and October 31.

For Class 7 waters, *E. coli* concentrations are not to exceed 630 organisms per 100 mL as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 mL. The standard applies only between May 1 and October 31.

Table 5. Applicable *E. coli* standard by impaired reach.

Impaired Stream (AUID)	Water Body Class	Applicable *E. coli* Standard (Monthly Geometric Mean)
Pelican Creek (07020002-506)	Class 2	<126 org/100 mL
Unnamed Creek (07020002-547)	Class 2	<126 org/100 mL
Muddy Creek (07020002-511)	Class 7	<630 org/100 mL

Geometric average is used in place of an arithmetic average to measure the central tendency of the data, dampening the effect that very high or very low values have on arithmetic averages. *E. coli* can reproduce rapidly (hours to days) when waters become nutrient rich or very warm, and some individual readings can be orders of magnitude greater than the majority of all readings. The MPCA's Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)

Report and 303(d) List provides details regarding how waters are assessed for conformance to the *E. coli* standard (MPCA 2018). See also the MPCA website on bacteria.

The *E. coli* concentration standard of 126 organisms per 100 mL was considered reasonably equivalent to the previous fecal coliform standard of 200 organisms per 100 mL from a public health protection standpoint. The SONAR (Statement of Need and Reasonableness) section that supports this rationale uses a log plot that shows a good relationship between these two parameters (MPCA 2007b). The following regression equation was deemed reasonable to convert any data reported in fecal coliform to *E. coli* equivalents:

E coli concentration (equivalents) = 1.80 x (fecal coliform concentration)

It should also be noted that most analytical laboratories report *E. coli* in terms of colony-forming unit (cfu)/100 mL, not organisms per 100 mL. This TMDL report will present *E. coli* data in cfu/100 mL since all the monitored data collected for this TMDL were reported in these units. Bacteria TMDLs were written to achieve the bacteria water quality standard of 126 org/100 mL.

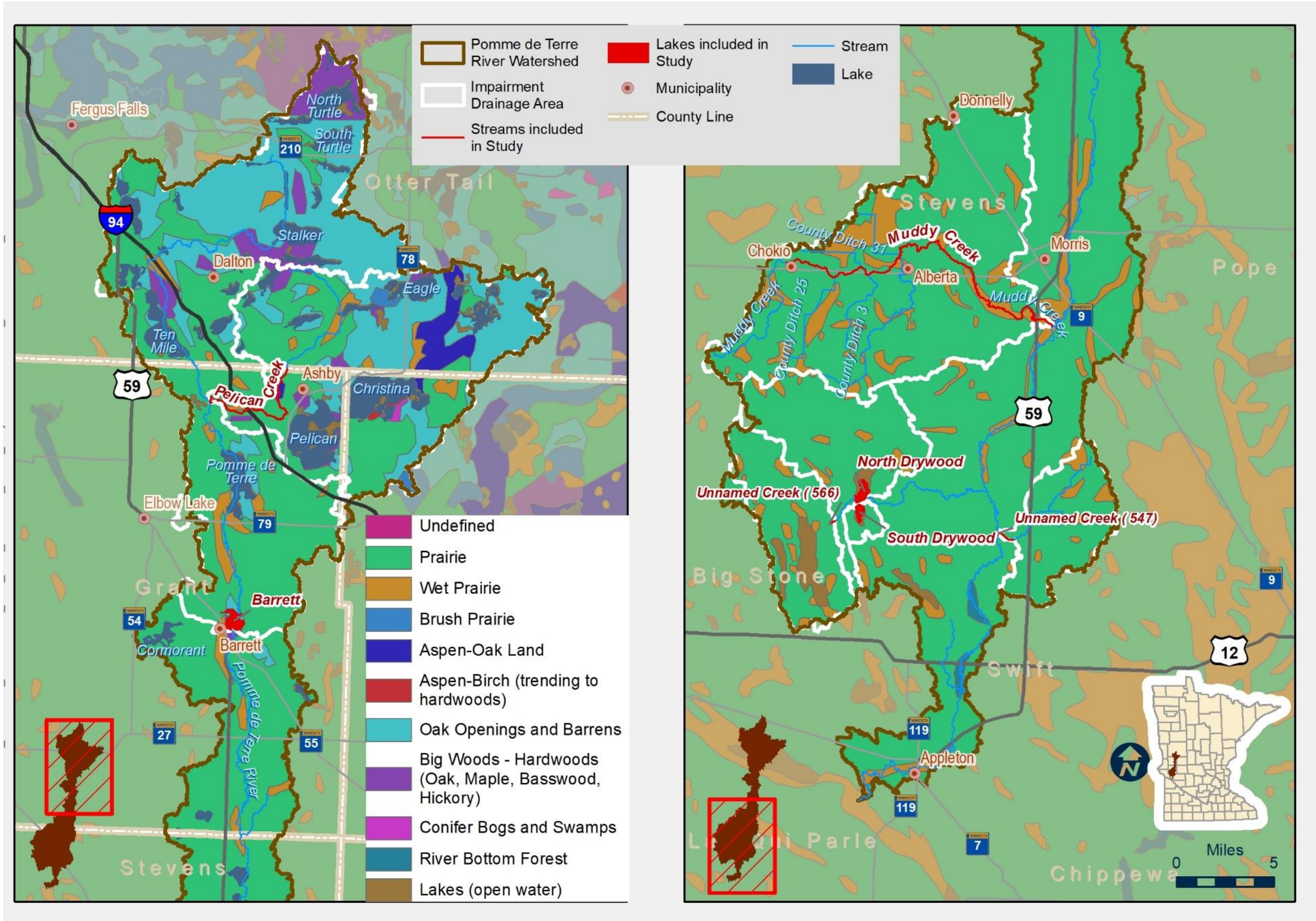
3. Watershed and water body characterization

The impaired streams and lakes included in this study are located within the Pomme de Terre River Watershed (HUC 07020002) of west-central Minnesota (Figure 1). The Pomme de Terre River Watershed drains approximately 875 square miles and drains portions of six counties (Otter Tail, Grant, Douglas, Big Stone, Swift, and Stevens) in the northwest Minnesota River Basin. The Pomme de Terre River Watershed has a population of about 15,000 with the two largest cities being Morris and Appleton.

The Pomme de Terre River Watershed is located on the traditional homelands of the Dakota Oyate. However, no part of the Pomme de Terre River Watershed is located within the boundary of federally recognized tribal land, and the TMDL does not allocate pollutant load to any federally recognized Tribal Nation in this watershed.

The Pomme de Terre River Watershed is located in two distinct ecoregions; the Northern Central Forest ecoregion in the northern third of the watershed and the Northern Glaciated Plains ecoregion in the southern two-thirds of the watershed. As a result, the watershed exhibits a stark contrast in its topography and land cover moving north to south. The previous Pomme de Terre River Watershed scale TMDL described the change in landscape across the watershed as follows: “The upper reach of the watershed is characterized by its relatively low gradient and prevalence of lakes and wetlands. Gradient increases moving downstream in the watershed as does the occurrence of development and row crop agriculture. Glacial sediments cover the entire Pomme de Terre River Watershed MPCA 2015).” According to the Minnesota Department of Natural Resources (DNR) Ecological Classification System, the watershed is located within the Minnesota River Prairie Subsection. Pre-European settlement vegetation in this subsection were primarily tall grass prairie with many islands of wet prairie and forested areas within the floodplain (Figure 2). The dominant land use change in the watershed is the conversion of the tall grass prairie to agricultural land. Today, the primary land use is row crops (52%).

Figure 2. Pre-settlement vegetation in the Pomme de Terre River Watershed.



3.1 Lakes

Barrett Lake is a 529-acre impoundment of the Pomme de Terre River in Grant County (Figure 3). The earliest available records of dam construction date back to 1936. The city of Barrett developed along the west and south shorelines. The maximum depth of the lake is 28.0 feet, and the average depth is estimated at 8.5 feet (Table 6). Water quality measurements describe Barrett Lake as eutrophic. The Pomme de Terre River carries sediments and nutrients into this impoundment lake from an expansive, well drained, and largely cultivated watershed area extending well north into Otter Tail County. Algae blooms and suspended solids impair water clarity during summer months.

North and South Drywood Lakes are highly eutrophic lakes located approximately 14 miles northwest of Appleton, Minnesota in Swift County (Figure 4). North Drywood Lake is in-line with Artichoke Creek and the lakes are connected by a wetland channel. No public access nor outlet structures are present on these lakes. Although the lakes are shallow, turbid, and prone to winterkill, they provide valuable fish habitat. North Drywood is 404 acres and South Drywood is 231-acres (Table 6). Both lakes have maximum depths less than four feet and are classified as shallow lakes.

The physical characteristics of the impaired lakes addressed in this TMDL report are listed in Table 6. Lake surface areas, lake volumes, mean depths, littoral areas (with depths less than 15 feet), and maximum depths were reported from DNR Lake Finder. Lake volumes were calculated by multiplying the mean depth with the lake surface area. Watershed areas were based on the DNR minor watershed boundaries with manual watershed delineations for lake watersheds smaller than the minor watershed boundaries using two-foot contours from Light Detection and Ranging (LiDAR).

Table 6. Impaired lake physical characteristics.

Impaired Lake (DNR ID)	Surface area (ac)	Littoral area (% total area)	Volume (acre-feet)	Mean depth (feet)	Maximum depth (feet)	Watershed area (incl. lake area) (ac)	Watershed area: Surface area ratio
Barrett Lake (26-0095-00)	529	79.7%	4,502	8.5	28	212,480	402
South Drywood Lake (76-0149-00)	231	100%	582	2.5	3.75	2,048	8.9
North Drywood Lake (76-0169-00)	404	100%	832	2.1	3.5	53,568	133

Figure 3. Barrett Lake aerial image (FSA 2019).

Figure 4. North and South Drywood Lakes aerial image (FSA 2019).

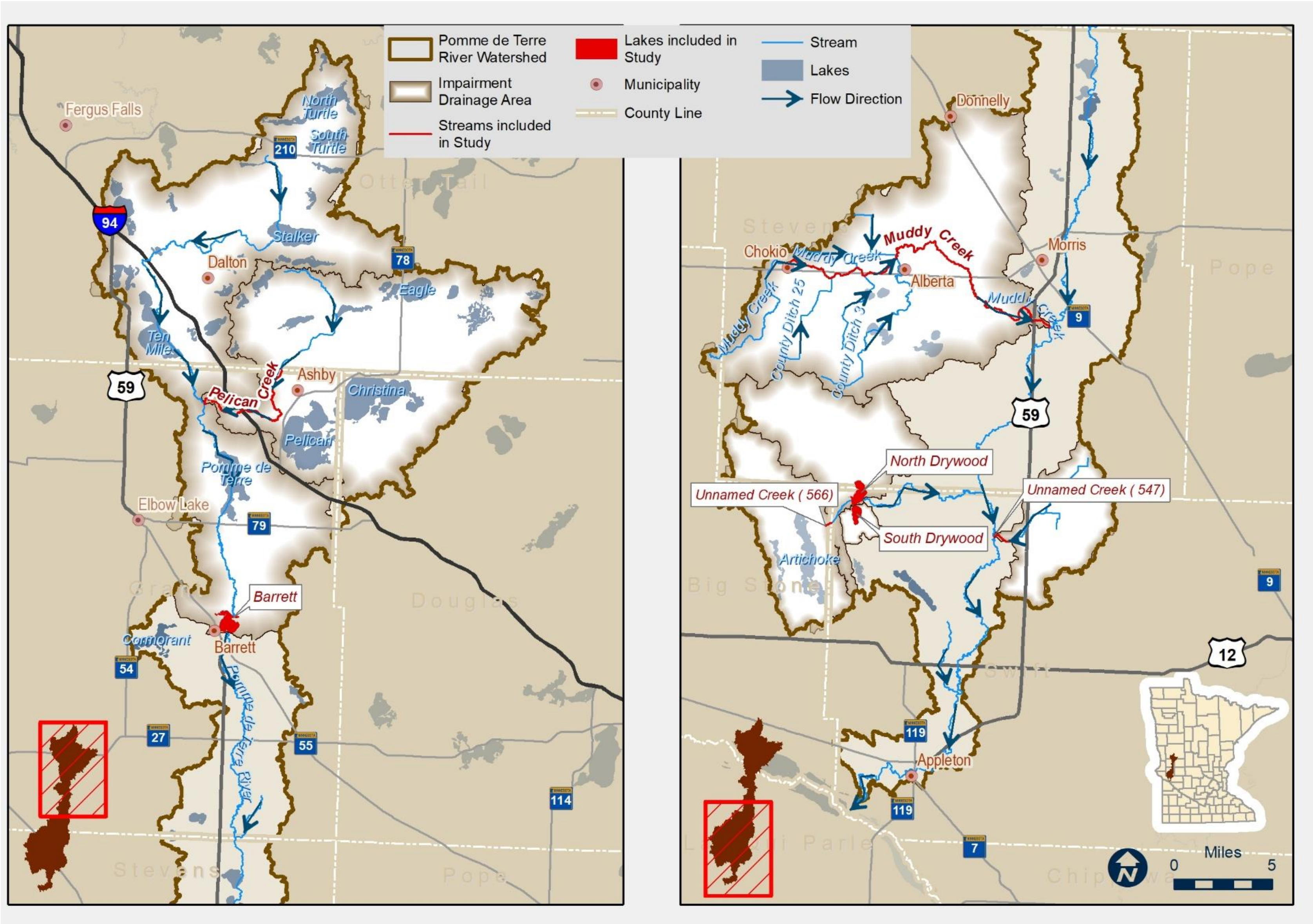
3.2 Streams

Direct and total drainage areas for the four impaired stream reaches are listed in Table 7. Direct drainage areas were delineated using the DNR minor (level 8) watershed boundaries, with manual watershed delineations to streams within or smaller than a minor watershed boundary using two-foot contours from LiDAR. The direct drainage areas include only the area downstream of any monitored upstream lake or stream. The flow through the watershed is characterized in Figure 5.

Table 7. Impaired stream reach direct drainage and total watershed areas.

AUID 07020002-XXX	Name/Description	Upstream AUID/Lake ID	Total drainage area (mi^2)
-506	Pelican Creek (T130 R41W S4, north line to Pomme de Terre R.)	-516	132.7
-511	Muddy Creek (T124 R44W S3, west line to Pomme de Terre R.)	-510	144.3
-547	Unnamed Creek (Unnamed Creek to Pomme de Terre River)	-548, -550	28.4
-566	Unnamed Creek (Unnamed Creek to Artichoke Creek)	06-0002-00	36.2

Figure 5. Flow direction through the Pomme de Terre River Watershed.



3.3 Land cover

Land cover in the Pomme de Terre River Watershed was assessed using the Minnesota Land Cover Classification and Impervious Surface Area by Landsat and LiDAR (MLCCS) (Rampi et al. 2016). This information is necessary to draw conclusions about pollutant sources and BMPs that may be applicable within each subwatershed.

The land cover distribution within impaired stream watersheds is summarized in Figure 6 and Table 8. The land cover in the Pomme de Terre River Watershed transitions from a mixture of cropland, grassland, and forest surrounding large lakes in the north to mostly cropland in the south. The land cover for Barrett Lake is typical for the northern half of the Pomme de Terre River Watershed, while the land cover for North and South Drywood Lakes is more typical of the southern half of the Pomme de Terre River Watershed. Overall, the land cover is row crops (52%) and managed or natural grassland (17%).

Figure 6. Land cover in the Pomme de Terre River Watershed (Rampi et al. 2016).

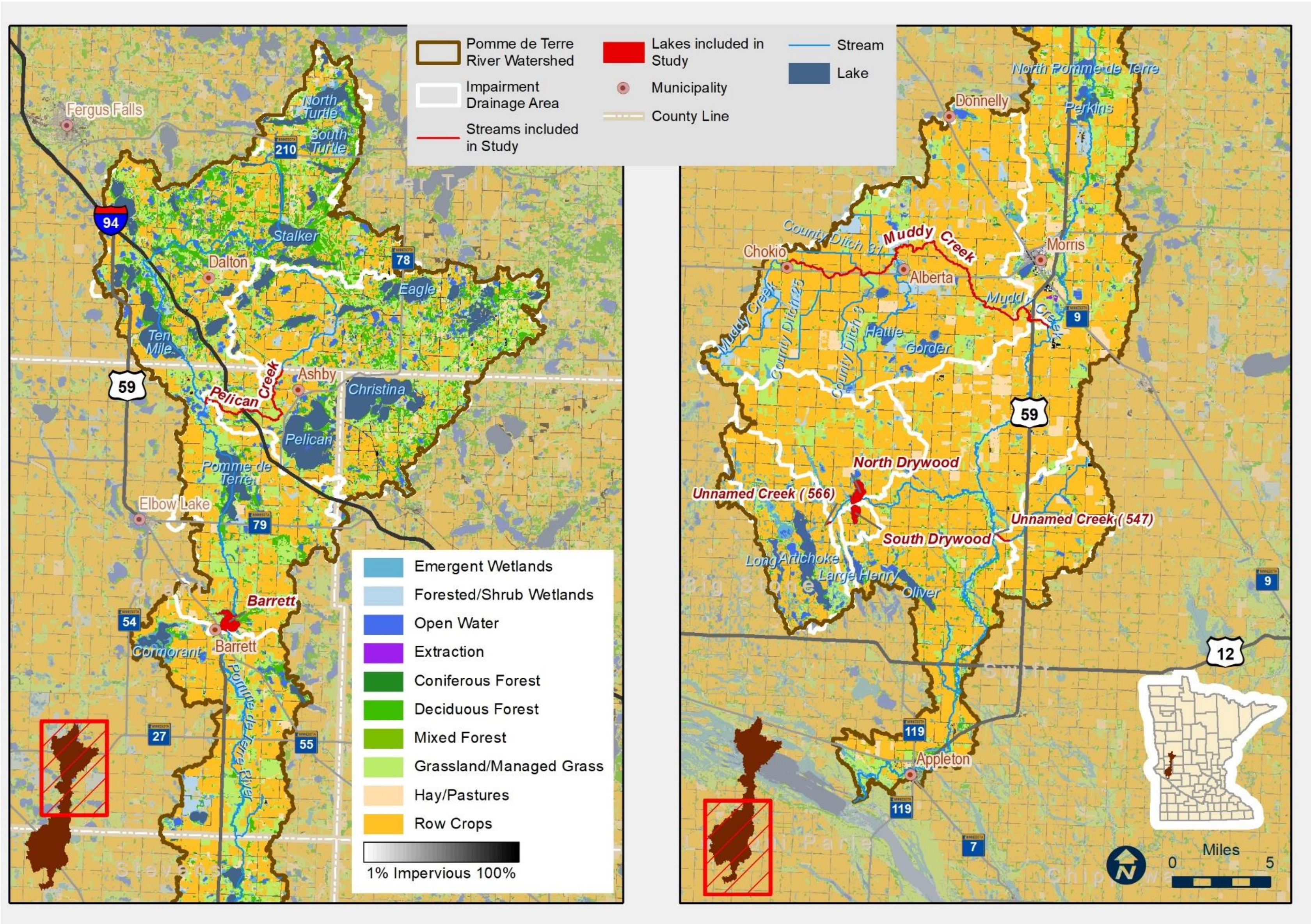


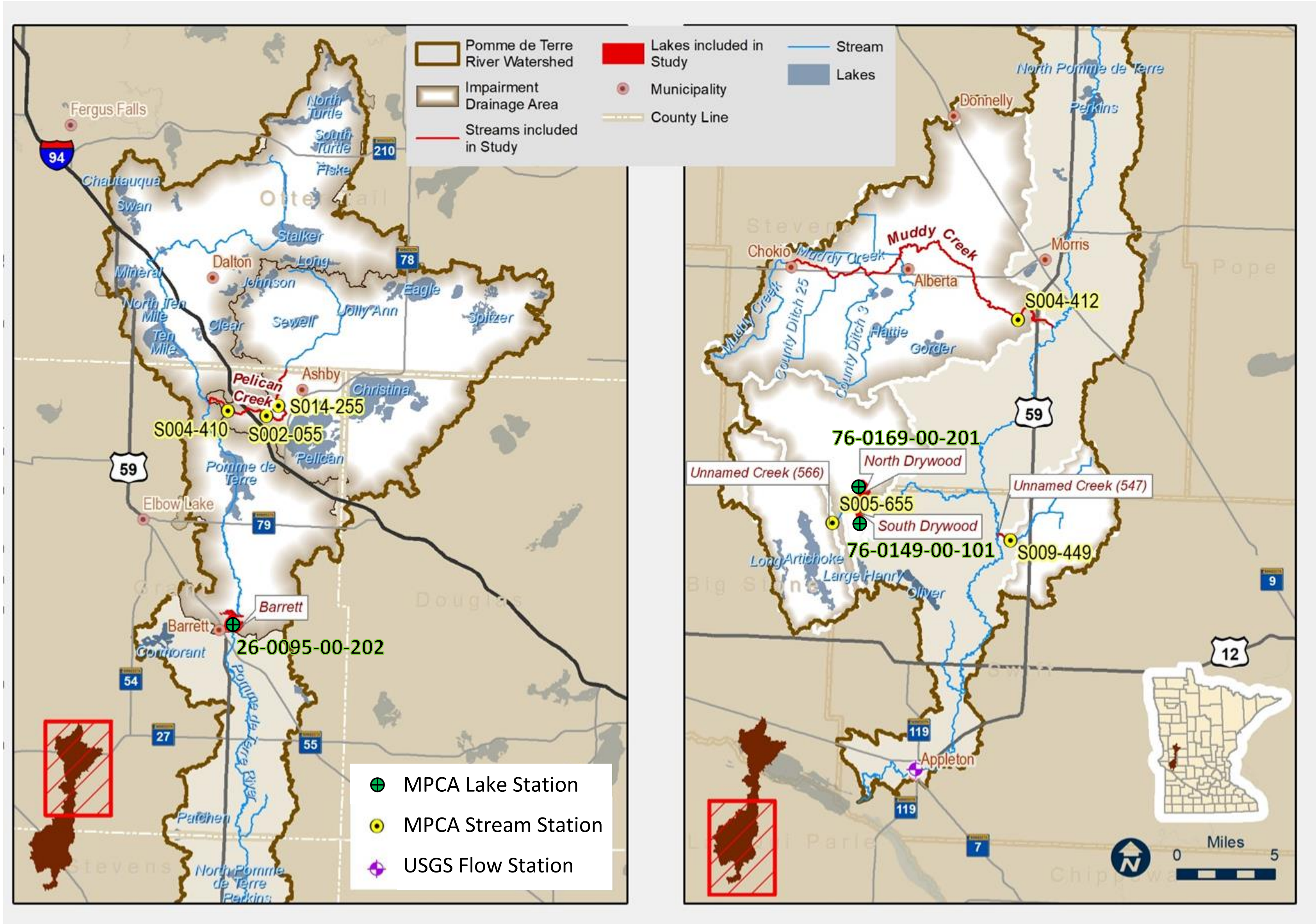
Table 8. Minnesota Land Cover Classification System (MLCCS) land cover for drainage areas of impaired water bodies in the Pomme de Terre River Watershed.

Water Body Lake ID/AUID	Impervious Area	Emergent Wetland	Forest and Shrub Wetland	Open Water	Extraction	Conifer Forest	Deciduous Forest	Managed and Natural Grass	Hay/ Pasture	Row Crops
Barrett Lake (26-0095-00)	6%	2%	3%	15%	0%	0%	15%	21%	4%	35%
South Drywood Lake (76-0149-00)	5%	5%	0%	12%	0%	0%	4%	3%	0%	70%
North Drywood Lake (76-0169-00)	5%	8%	1%	8%	0%	0%	2%	12%	1%	63%
Pelican Creek (-506)	6%	2%	3%	18%	0%	0%	14%	21%	4%	32%
Muddy Creek (-511)	5%	3%	6%	2%	0%	0%	1%	13%	5%	64%
Unnamed Creek (-547)	6%	2%	0%	1%	0%	0%	2%	7%	4%	78%
Unnamed Creek (-566)	5%	13%	1%	14%	0%	0%	3%	9%	0%	55%
Pomme de Terre River Watershed	**6%**	**3%**	**3%**	**8%**	**<1%**	**<1%**	**7%**	**17%**	**4%**	**52%**

3.4 Current/historical water quality

The existing in-stream and in-lake water quality conditions were quantified using data downloaded from the MPCA EQuIS database and available for the 10-year time period (2009 through 2018) and overlapping with the MPCA's most recent intensive monitoring conducted in the Pomme de Terre River Watershed from 2017-2018. This included water quality data measured at six stream and three lake water quality monitoring locations used by the MPCA (Figure 7). More information on MPCA's water quality monitoring plan for the Pomme de Terre River Watershed is included in Section 7.

Figure 7. Monitoring locations in the Pomme de Terre River Watershed.



3.4.1 Lake water quality conditions

Ten-year (2009 through 2018) summer season (June through September) averages of surface TP, chl-*a*, and Secchi transparency depth were calculated for each impaired lake (see Table 9 below).

Barrett Lake was the only lake evaluated against criteria for lakes and reservoirs in the North Central Hardwood Forest ecoregion. Barrett Lake exceeded the water quality standards for all parameters used to evaluate for a lake eutrophication impairment. Between 2009 and 2018, water quality data were available for TP and chl-*a* from four years (2009, 2011-2012, 2017) and for Secchi depth for eight years (2009, 2011 through 2017). Year 2009 was the only year measured where Barrett Lake met the water quality standards for Secchi depth. TP and chl-*a* did not meet the water quality standards during any year measured (Figure 8).

North Drywood Lake was evaluated against water quality standards for shallow lakes in the Northern Glaciated Plains ecoregion. North Drywood Lake exceeded the water quality standards for all parameters used to evaluate for a lake eutrophication impairment. This included data from three years for TP and chl-*a* (2009, 2011-2012) and four years for Secchi depth (2009, 2011-2012, 2018). The only year not to exceed the Secchi depth and chl-*a* water quality standards was 2009 (Figure 9).

South Drywood Lake was also evaluated against water quality standards for shallow lakes in the Northern Glaciated Plains ecoregion. South Drywood Lake exceeded the water quality standards for all parameters used to evaluate for a lake eutrophication impairment. This included data from two years for TP, chl-*a*, and Secchi depth (2011-2012) (Figure 10).

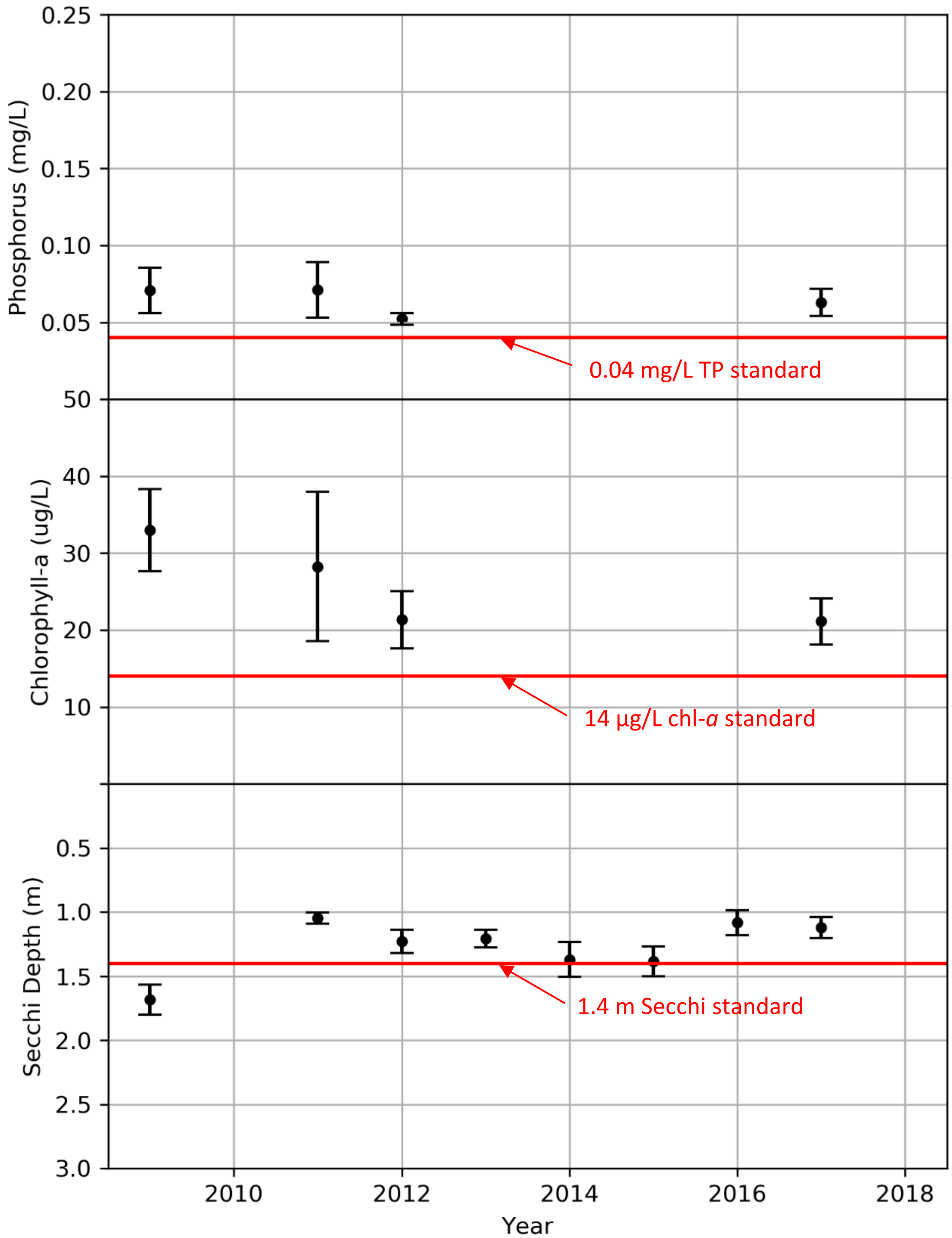
Table 9. Ten-year summer season mean TP, chl-*a*, and Secchi (2009-2018).

Lake Type/Lake Name	Ten-year (2009-2018) Summer Season Mean (June – September)								
	TP			Chl-*a*			Secchi		
	(mg/L)	CV	n	(µg/L)	CV	n	(m)	CV	n
Lakes and Reservoirs in North Central Hardwood Forests	< 0.04	-	-	<14	-	-	>1.4	-	-
Barrett Lake	0.065	10%	15	26	12%	15	1.3	3%	96
Shallow Lakes in Northern Glaciated Plains Ecoregion	< 0.09	--	--	<30	--	--	>0.7	--	--
North Drywood Lake	0.54	12%	11	82	41%	11	0.58	18%	15
South Drywood Lake	0.78	34%	6	380	73%	6	0.15	19%	4

CV = Coefficient of variation, defined in BATHTUB as the standard error divided by the mean.
n = Sample size

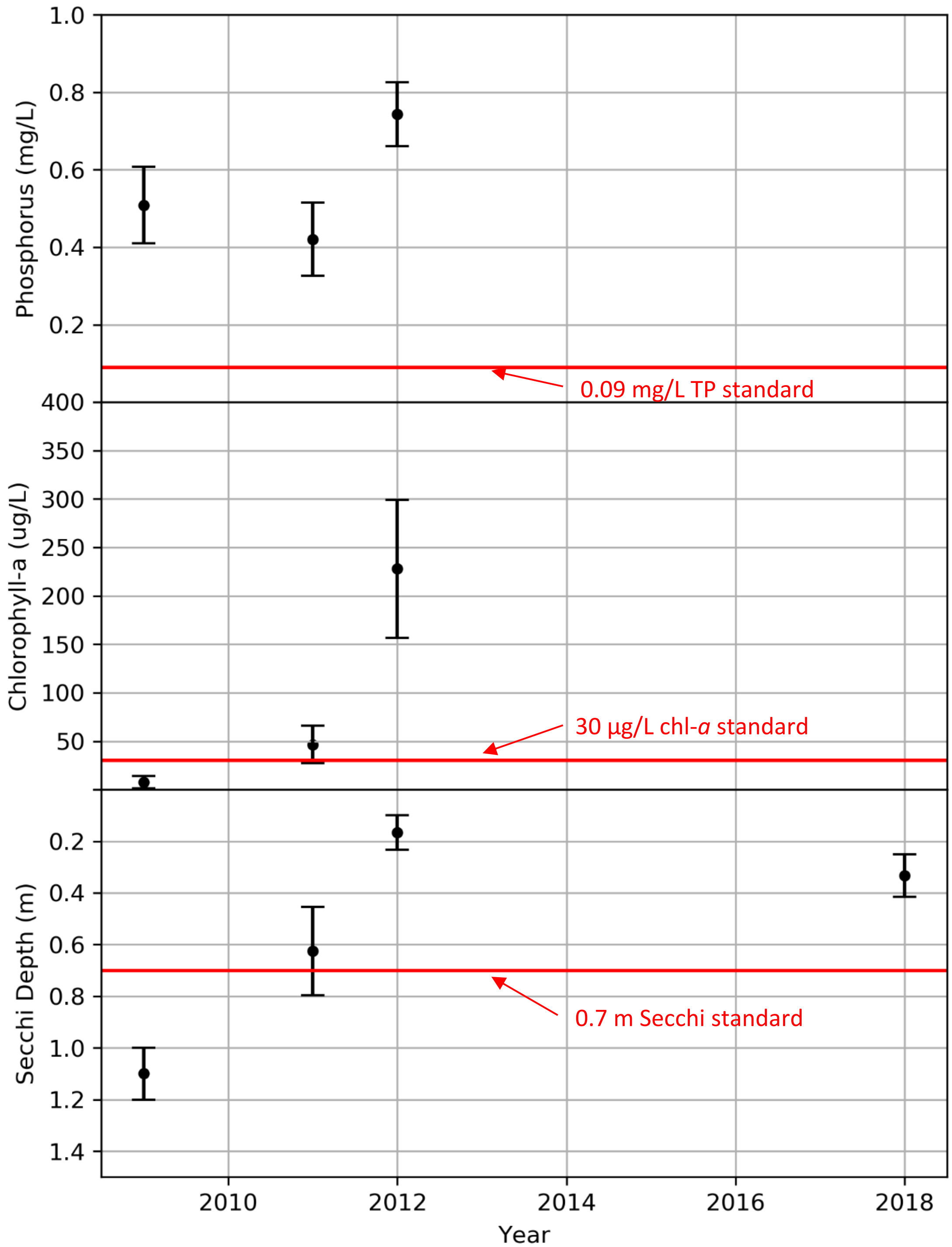
Figure 8 illustrates the summer season mean lake water quality concentrations with error bars representing the standard error for Barrett Lake. Phosphorus concentrations were above the water quality standard for all years with samples. The response parameters, chl-*a* and Secchi depth were also above the water quality standard for all years except 2009 and indicate the lake is impaired due to eutrophication.

Figure 8. Barrett Lake average annual TP, chl-*a*, and Secchi depth (2009-2018).



*Error bars are equal to the standard error.

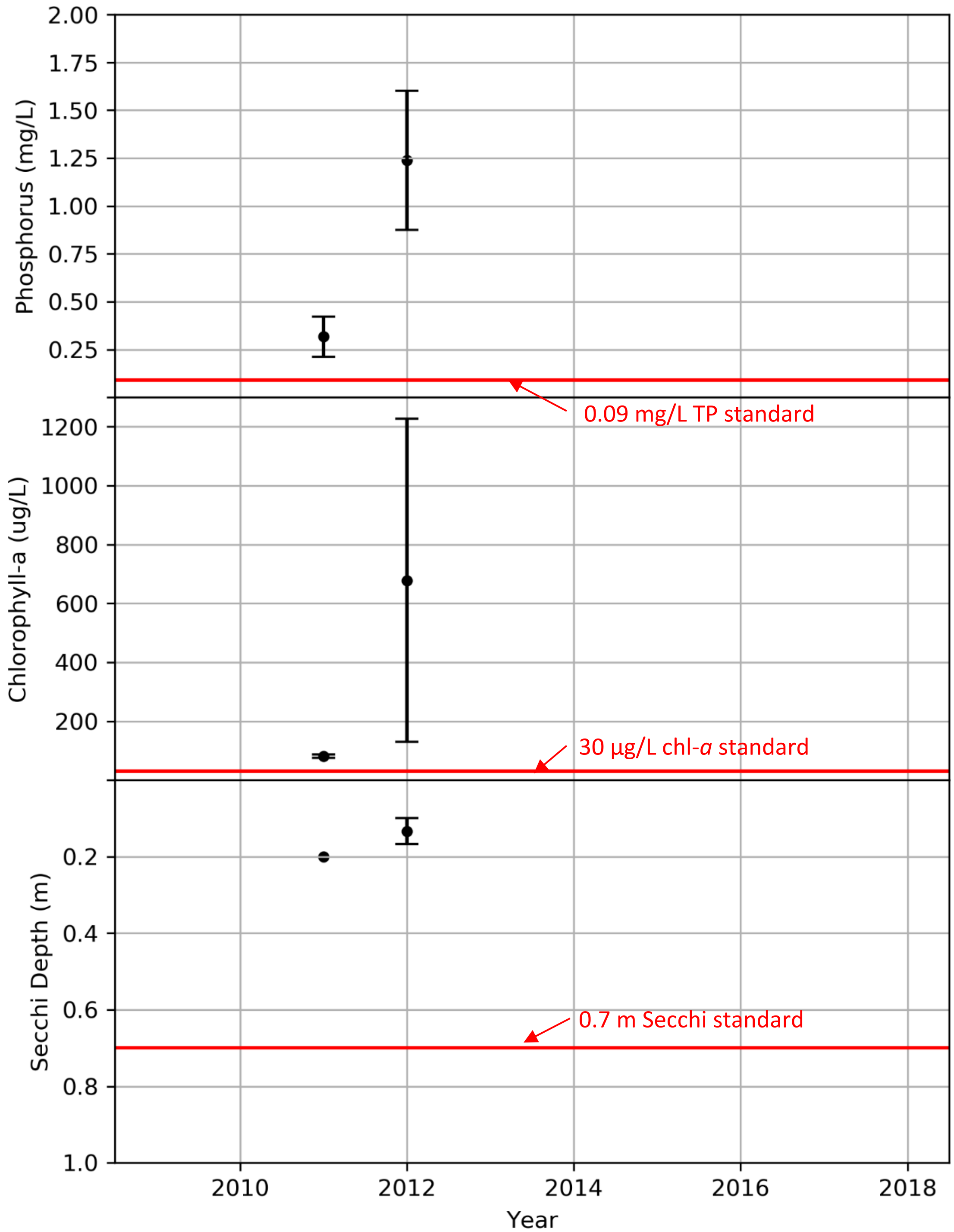
Figure 9. North Drywood average annual TP, chl-*a*, and Secchi depth (2009-2018).



*Error bars are equal to the standard error.

Figure 9 illustrates the summer season mean lake water quality concentrations with error bars representing the standard error for North Drywood Lake. Phosphorus concentrations were above the water quality standard for all years with samples. The response parameters, chl-*a*, and Secchi depth were also above the water quality standard for all years except 2009 and indicate the lake is impaired due to eutrophication.

Figure 10. South Drywood average annual TP, chl-*a*, and Secchi depth (2011-2012).



Error bars are equal to the standard error.

Figure 10 illustrates the summer season mean lake water quality concentrations with error bars representing the standard error for South Drywood Lake. Phosphorus concentrations were above the water quality standard for the two years with samples. The response parameters, chl-*a*, and Secchi depth were also above the water quality standard for all years and indicate the lake is impaired due to eutrophication.

3.4.1.1 Shallow Lake Phosphorus and Algae Relationships

The relationship between phosphorus concentration and the response variables (algae/chl-*a* and water clarity/Secchi depth) is often different in shallow lakes like North Drywood Lake and South Drywood Lake as compared to deeper lakes. In deeper lakes, algae abundance is often controlled by physical and chemical factors such as light availability, temperature, and nutrient concentrations. The biological components of lakes (such as microbes, algae, aquatic plants, zooplankton and other invertebrates, and fish) are distributed throughout the lake, along the shoreline, and on the bottom sediments (Funke and Pallardy 2018). In shallow lakes, the biological components are more concentrated into less volume and consequently exert a stronger influence on the ecological interactions within the lake. There is a denser biological community at the bottom of shallow lakes than in deeper lakes, because oxygen is replenished in the bottom waters and light can often penetrate to the bottom. These biological components can control the relationship between phosphorus and the response variables algae and water clarity.

The result of biological components' impact on water clarity is that shallow lakes normally exhibit one of two ecologically alternative stable states (Figure 11): the turbid water, algae-dominated state, and the clear water, aquatic plant-dominated state (Scheffer et al. 1993). The clear state is the most ecologically preferred, since algae communities are held in check by diverse and healthy zooplankton and fish communities (Figure 13). Fewer nutrients are released from the sediments in this state. This is because roots of aquatic plants stabilize the sediments, lessening the amount of sediment stirred up by wind-driven mixing.

Nutrient reduction or addition in a shallow lake does not lead to linear improvement or degradation in water quality (Figure 12). As external nutrient loads are decreased in a lake in the turbid water, algae-dominated state, no improvements in water quality may occur at first. Drastic reductions in nutrient loads or a change in the biological community, will cause the lake to abruptly shift from the turbid water, algae-dominated state to the clear water, aquatic plant-dominated state. Conversely, as external nutrient loads are increased in a shallow lake in the clear water, aquatic plant-dominated state, only slight degradations in water quality may occur at first. At some point, further increase in nutrient loads will cause the shallow lake to abruptly shift from the clear water, aquatic plant-dominated state to the turbid water, algae-dominated state. The general pattern in Figure 12 is often referred to as "hysteresis," meaning that when forces are applied to a system, it does not return completely to its original state nor does it follow the same trajectory on the way back.

The biological response of the lake to phosphorus inputs will depend on the stable state that the lake is in. For example, if the lake is in the clear state, the aquatic plants may be able to take up phosphorus instead of the algae. However, if enough stressors are present in the lake, increased phosphorus inputs may lead to a shift to the turbid state with an increase in algal density and decreased transparency. The two main categories of stressors that can shift the lake to the turbid state are:

- Disturbance to the aquatic plant community, for example from wind-driven mixing, bottom feeding fish (such as carp), boat motors, or light availability (influenced by algal density or water depth); and

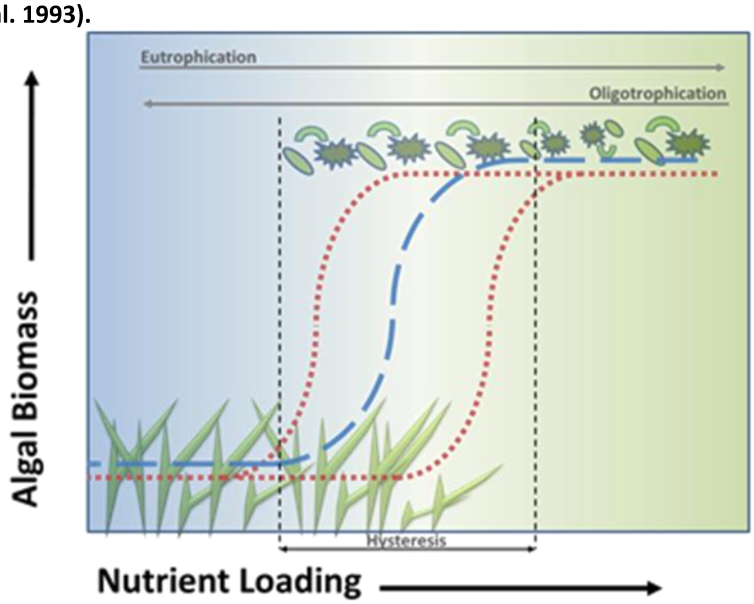
- A decrease in the number of zooplankton can result in an increase in algae. A decrease in the number of zooplankton is usually caused by an increase in the number of fish that feed directly on zooplankton due to a decrease in or absence of piscivorous fish (Figure 13).

One implication of the alternative stable states in shallow lakes is that different management approaches are used for shallow lake restoration than those used for restoration of deeper lakes. Shallow lake restoration often focuses on restoring the macrophyte, zooplankton, and fish communities to the lake. This is commonly achieved through a whole lake drawdown or fish kill in Minnesota.

Figure 11. Clear and turbid water states in shallow lakes.
CLEAR-AQUATIC PLANT DOMINATED STATE
Balanced fish community and abundant aquatic plants keep water clear.

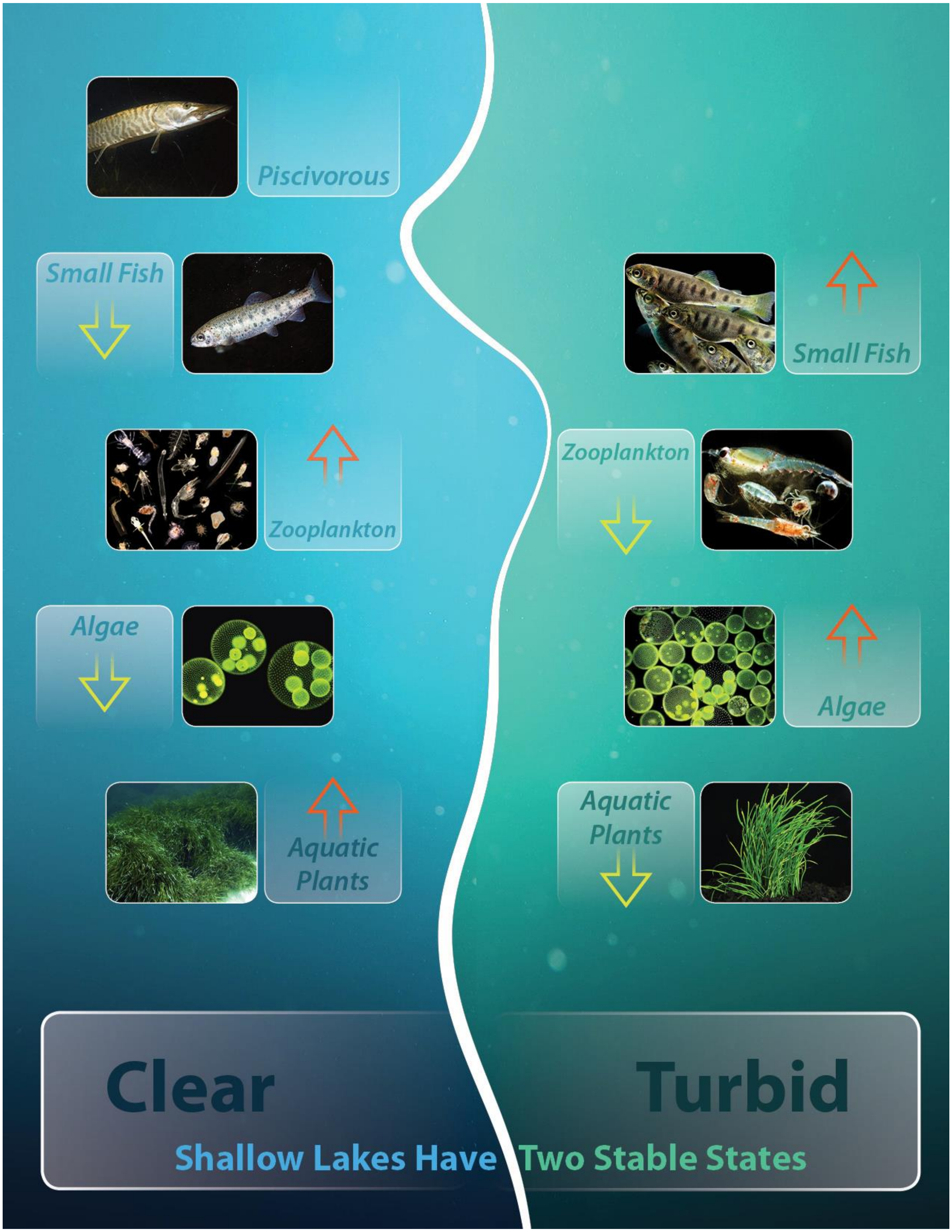
TURBID-ALGAE DOMINATED STATE
Too many rough fish and/or too few aquatic plants keep water turbid.

Figure 12. Nutrient loading and algae biomass hysteresis of alternative stable stats in shallow lakes (Scheffer et al. 1993).



The red dotted lines represent the two relationships between nutrient loading and the amount of algae in shallow lakes (hysteresis) as they become more eutrophic (delayed growth of algae as nutrient loading increases, and delayed loss of algae as nutrient loading decreases). In other words, there is a delay in shallow lake water quality changes in response to increases or decreases in nutrient loading.

Figure 13. Cascading biological communities in shallow lakes under clear and turbid water states.



3.4.1.2 Biological Conditions

North and South Drywood Lakes

A standard fish survey was completed by DNR in North Drywood Lake on July 22, 2013 (Lake Finder). No public access exists to the lake and recent fisheries management activities have been limited to population assessments. Although the lake is shallow, turbid, and prone to winterkill, 14 species of fish were caught during this assessment and the lake provides valuable fish habitat. Bigmouth buffalo, black bullhead, black crappie, brook stickleback, channel catfish, common carp, fathead minnow, freshwater drum, hybrid sunfish, largemouth bass, orangespotted sunfish, spottail shiner, walleye, and white sucker were found in the survey. The common carp total counts were above 1,000 but the average weights were below normal. Large numbers of small carp can disrupt vegetation and stir up sediments. Carp are likely having a negative impact on water quality in this lake.

No fish survey has been completed in South Drywood Lake but due to their interconnectedness – the fish population of South Drywood is likely very similar to North Drywood.

Barrett Lake

A standard fish survey was completed by DNR in Barrett Lake in 2017 to gain updated estimates of abundance and size structure of gamefish populations (Lake Finder). Survey protocol included an electrofishing survey completed on May 24 to sample largemouth bass. A netting survey utilizing trap nets and gill nets was conducted July 31 through August 3 to assess other gamefish populations. Water transparency at the time of the late-July fish survey measured 4.0 feet. Poor water clarity limits diversity and distribution of submergent plants. The lake supports a variety of game and nongame fish by natural reproduction and stocking efforts. Variable water quality and water levels likely limit natural recruitment. For more information see the DNR fisheries survey.

3.4.2 Stream eutrophication

Using data from the most recent 10-year period (2009 through 2018), summer (June through September) average concentrations of TP, chl-*a*, and pH were compared to the Southern River Nutrient Region Eutrophication standards for 2B streams for Unnamed Creek (-566).

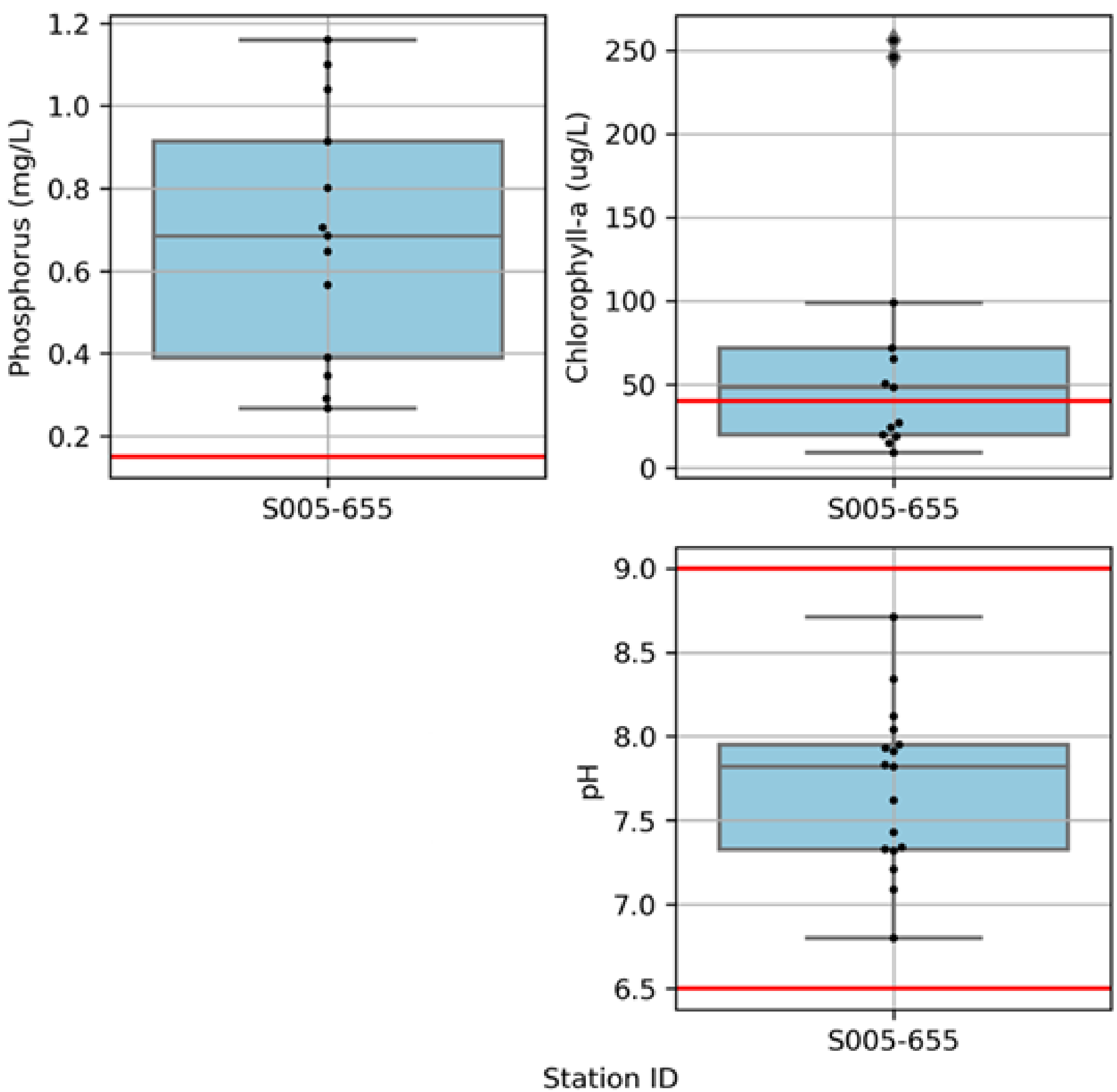
3.4.2.1 Unnamed Creek, Unnamed Creek to Artichoke Creek (07020002-566)

Water quality measurements for eutrophication, TP, chl-*a*, and pH, were collected on Unnamed Creek (-566) at station S005-655 over the summers of 2017-2018. The measurements taken on Unnamed Creek exhibited summer average TP concentrations and one response parameter, chl-*a*, above the water quality standards for streams. Thus, Unnamed Creek (-566) is impaired due to eutrophication. The pH of the stream however was within the water quality standards and no BOD or diel DO measurements were collected (S005-655; Table 10, Figure 14).

Table 10. Eutrophication exceedances at Unnamed Creek (07020002-566).

Eutrophication Parameters	Monitoring Station (Upstream to Downstream)	Number of Samples	Standard	Summer Average Concentration
Causal: Total Phosphorus (mg/L)	S005-655	13	0.15	0.68
Response: chl-*a* corrected for pheophytin (µg/L)	S005-655	13	40	73
Response: pH	S005-655	17	6.0 ≤ pH ≤9.0	7.7

Figure 14. TP and eutrophication parameters for Unnamed Creek (07020002-566) at monitoring station S005-655, 2017-2018. Gray line within the boxes indicates median value.



*The red lines represent the water quality standard for each parameter.

3.4.3 Total suspended solids

Using samples from the 10-year period (2009 through 2018), the percent of TSS samples exceeding the Central River Nutrient Region standard of 30 mg/L, from April through September, was calculated for Pelican Creek (-506).

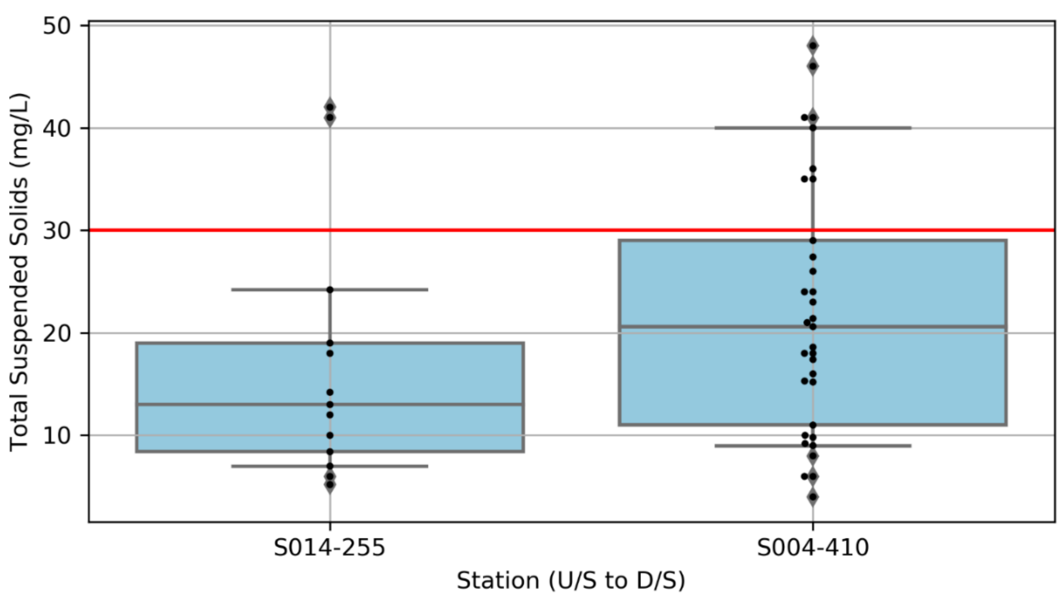
3.4.3.1 Pelican Creek, T130 R41W S4, north line to Pomme de Terre R (07020002-506)

TSS samples were collected for Pelican Creek (-506) at two monitoring stations, S014-255 and S004-410 from 2016 through 2018. TSS concentrations at both monitoring locations exhibited 90th percentile concentrations above the water quality standard for the Central River Nutrient Region. Furthermore, the number of samples exceeding the water quality standard was greater than 10% (Table 11). Therefore, Pelican Creek (-506) is impaired by TSS. The high TSS concentrations increased moving downstream with station S004-410 having a higher number of exceedances and higher median TSS concentration (Figure 15). Two TSS measurements were paired with volatile suspended solids (VSS) at station S014-255. In both samples, roughly 30% of the TSS were volatile and thus originating from organic matter (Table 12).

Table 11. TSS water quality exceedances by station in Pelican Creek (07020002-506), 2016-2018 (April-September).

Monitoring Station (Upstream to Downstream)	Number of Samples	Number of Exceedances	Percentage of Exceedances	90th Percentile Concentration (mg/L)
S014-255	13	2	15%	37.6
S004-410	33	8	24%	40.8

Figure 15. TSS concentration distribution by station (upstream to downstream) for the impaired reach of Pelican Creek (2016-2018).



*The red line represents the water quality standard.

Table 12. Volatile Suspended Solids concentrations in Pelican Creek (S014-255).

Date	Volatile Suspended Solids (VSS) Concentration (mg/L)	Total Suspended Solids (TSS) Concentrations (mg/L)	VSS (as % of TSS)
8/3/2017	4.4	13	33.8%
7/10/2018	6	19	31.6%

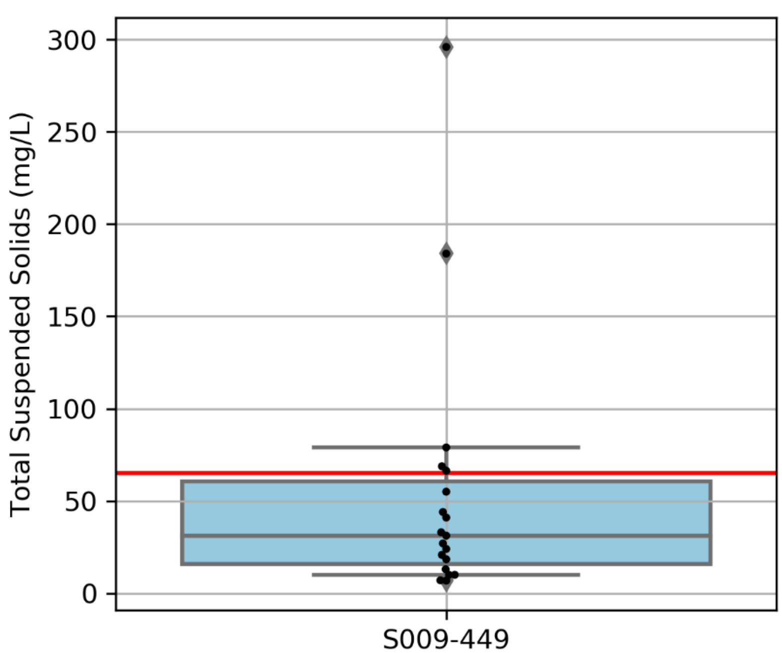
3.4.3.2 Unnamed Creek, Unnamed Creek to Pomme de Terre R. (07020002-547)

TSS samples were collected for Unnamed Creek (-547) at one monitoring station, S009-449, from 2017 through 2018. TSS concentrations at S009-449 exhibited 90th percentile TSS concentrations above the water quality standard for the Southern River Nutrient Region. Furthermore, the number of samples exceeding the water quality standard was greater than 10% (Table 13). In addition, the Pomme de Terre Stressor Identification Update (MPCA 2024a) identified TSS as a stressor to aquatic biology in this reach. Therefore, Unnamed Creek (-547) is impaired by TSS. The distribution of TSS samples at S009-449 is shown in Figure 16.

Table 13. TSS water quality exceedances by station in Unnamed Creek (07020002-547), 2017-2018 (April-September).

Monitoring Station	Number of Samples	Number of Exceedances	Percentage of Exceedances	90th Percentile Concentration (mg/L)
S009-449	19	5	26%	100

Figure 16. TSS concentration distribution for the impaired reach of Unnamed Creek (2017-2018).



*The red line represents the water quality standard.

3.4.4 *E. coli*

Using samples from the ten-year period (2009 through 2018), geometric mean *E. coli* concentrations were calculated by month from April through October for Pelican Creek (07020002-506) and Muddy Creek (07020002-511).

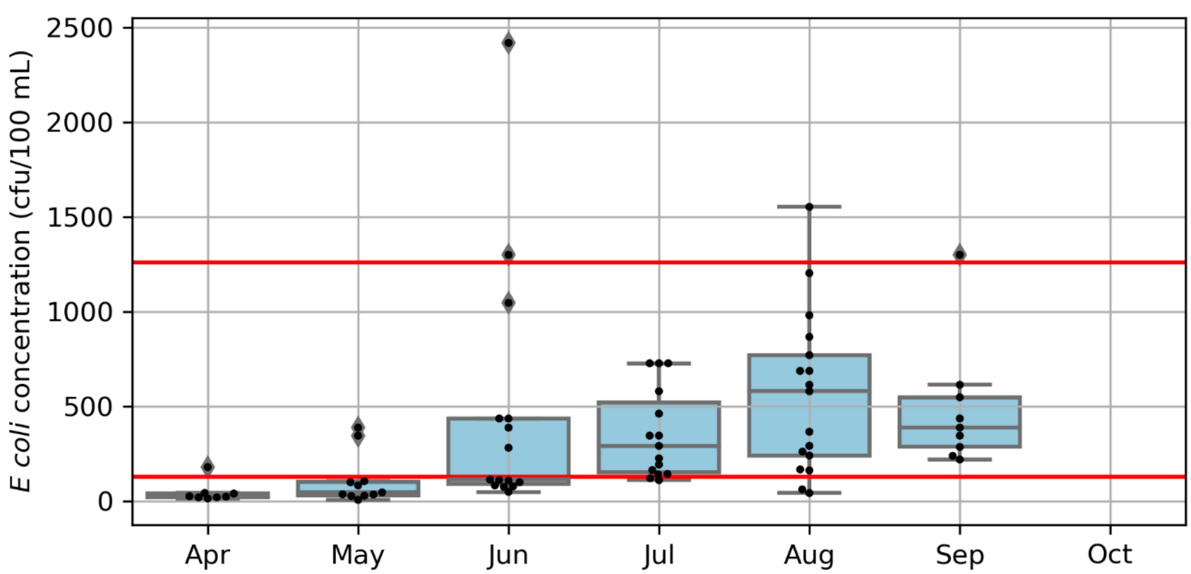
3.4.4.1 Pelican Creek, T130 R41W S4, north line to Pomme de Terre R (07020002-506)

E. coli samples for Pelican Creek (-506) were collected at station S004-410 during 2010, 2012, and 2016 through 2018. Samples taken during this time exhibited monthly geometric mean concentrations above the water quality standard of 126 org/100 mL during the months of June through September. In addition, the acute standard of 1,260 org/100 mL was exceeded twice in June and once each in August and September (Table 14). During the months of April through September, the *E. coli* concentrations increased from April through August with *E. coli* concentrations highest in September (Figure 17).

Table 14. Geometric mean *E. coli* (cfu/100 mL) concentrations by month in Pelican Creek (07020002-506), 2010, 2012, 2016 through 2018.

Monitoring Station	Month	Number of Samples	Geometric Mean (cfu/100 mL)	Minimum (cfu/100 mL)	Maximum (cfu/100 mL)	Total Samples >1,260 cfu/100 mL
S004-410	April	8	31	13	179	0
	May	11	57	5	387	0
	June	15	226	48	2,420	2
	July	15	285	110	727	0
	August	17	386	41	1,553	1
	September	9	416	219	1,300	1

Figure 17. *E. coli* (cfu/100 mL) by month in Pelican Creek (07020002-506) at monitoring station S004-410 (2010, 2012, 2016-2018).



*The red lines represent the water quality standards for Class 2 waters (126 cfu/100 mL and 1,260 cfu/100 mL).

3.4.4.2 Muddy Creek, T124 R44W S3, west line to Pomme de Terre R (07020002-511)

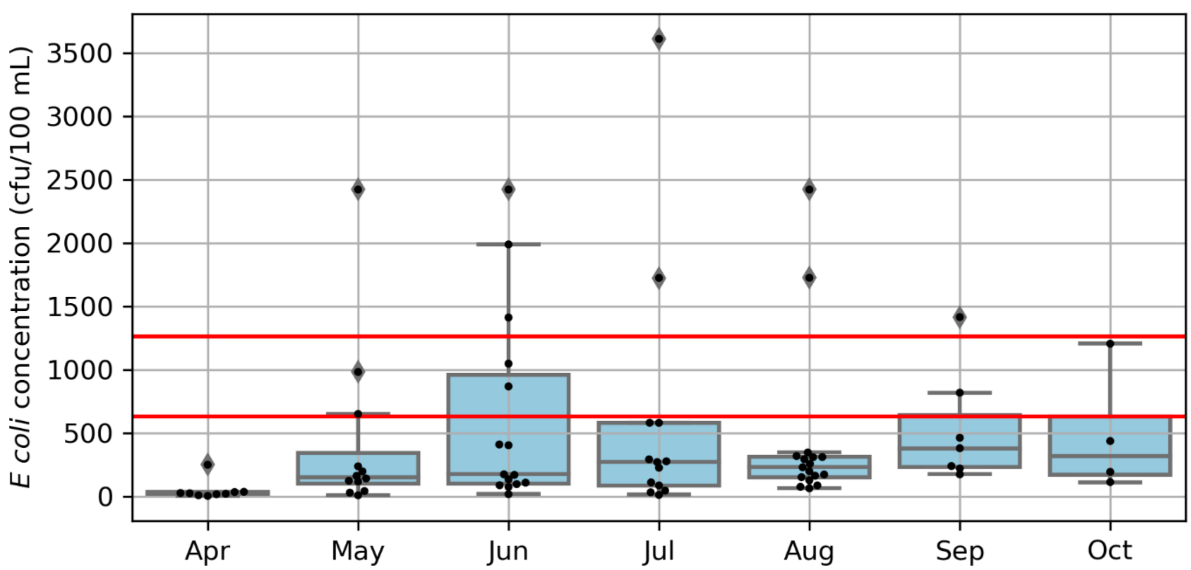
E. coli samples for Muddy Creek (-511) were collected at station S004-412 during 2010, 2012, and 2016 through 2018. More than 10% of the samples were above the acute standard of 1,260 cfu/100 mL during the months of June through September. Combined, 13% of the samples taken in Muddy Creek were above the acute standard (Table 15). From May through October, *E. coli* concentrations stay above the 126 cfu/100 mL associated with the downstream Pomme de Terre River (07020002-501) TMDL (Stevens County SWCD 2008). The maximum *E. coli* concentrations peak during the middle of summer in July (Figure 18).

Table 15. Geometric mean *E. coli* (cfu/100 mL) concentrations by month in Muddy Creek (07020002-511), 2010, 2012, 2016 through 2018.

Monitoring Station	Month	Number of Samples	Geometric Mean (cfu/100 mL)	Minimum (cfu/100 mL)	Maximum (cfu/100 mL)	Total Samples >1,260 cfu/100 mL
S004-412	May	12	155	8	2,420	1
	June	**15**	**275**	**16**	**2,420**	**3**
	July	**13**	**208**	**11**	**3,609**	**2**
	August	**17**	**240**	**62**	**2,420**	**2**
	September	**7**	**406**	**172**	**1,414**	**1**
	October	4	325	111	1,203	0

Months that exceed the water quality standard are highlighted in **bold**

Figure 18. *E. coli* (cfu/100 mL) by month in Muddy Creek (07020002-511) at monitoring station S004-412 (2010, 2012, 2016 through 2018).



The red lines represent the water quality standard for class 7 waters (630 cfu/100 mL and 1260 cfu/100 mL).

3.4.4.3 Unnamed Creek, Unnamed Creek to Pomme de Terre R. (07020002-547)

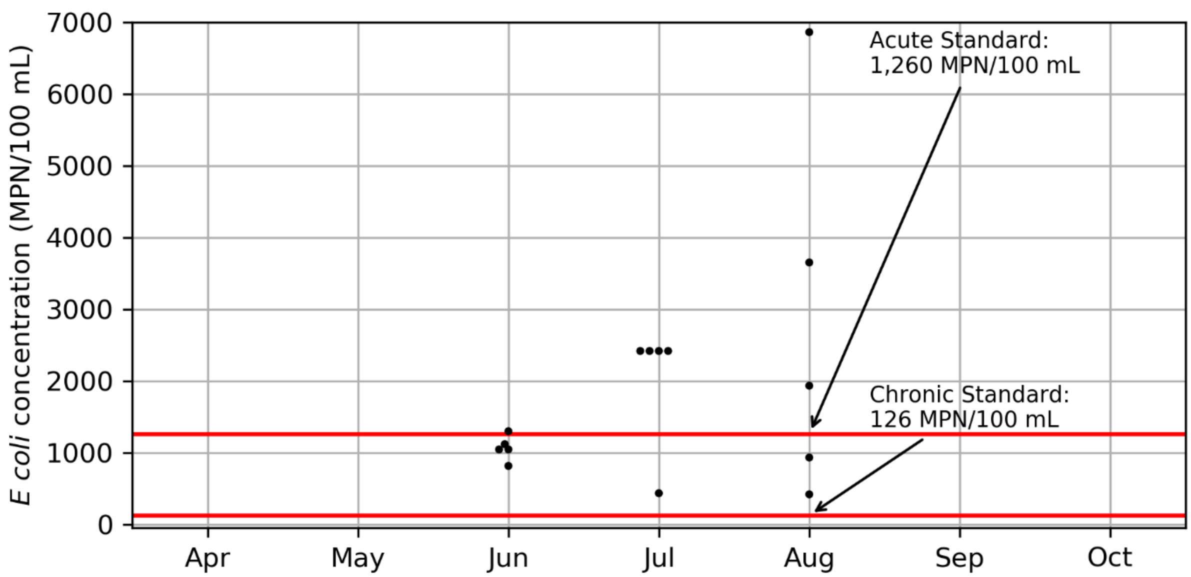
E. coli samples for Unnamed Creek (-547) were collected at station S009-449 during 2017-2018. Samples taken during this time exhibited monthly geometric mean concentrations above the water quality standard of 126 org/100 mL in all months. In addition, the acute standard of 1,260 org/100 mL was exceeded once in June, four times in July and three times in August (Table 16). Combined, 53% of the samples taken in Unnamed Creek were above the acute standard. The *E. coli* concentrations are shown by month in Figure 19.

Table 16. Geometric mean *E. coli* (cfu/100 mL) concentrations by month in Unnamed Creek (07020002-547), (2017-2018).

Monitoring Station	Month	Number of Samples	Geometric Mean (cfu/100 mL)	Minimum (cfu/100 mL)	Maximum (cfu/100 mL)	Total Samples >1,260 cfu/100 mL
S009-449	**June**	**5**	**1,054**	**816**	**1,300**	**1**
	July	**5**	**1,717**	**435**	**2,420**	**4**
	August	**5**	**1,802**	**420**	**6,867**	**3**

Months that exceed the water quality standard are highlighted in bold

Figure 19. *E. coli* (cfu/100 mL) by month in Unnamed Creek (07020002-547) at monitoring station S009-449 (2017-2018).



The red lines represent the water quality standard for class 2 waters (126 cfu/100 mL and 1,260 cfu/100 mL).

3.5 Pollutant source summary

3.5.1 Permitted source types

Regulated sources of pollutants include wastewater treatment plant (WWTP) effluent, National Pollutant Discharge Elimination System (NPDES) permitted feedlots, construction stormwater, and industrial stormwater. Pollutant loads from NPDES permitted wastewater and stormwater sources were accounted for using the methods described in the corresponding allocation methodology sections in Section 4 for phosphorus (4.1.3), TSS (4.2.3), and *E. coli* (4.3.3).

3.5.1.1 Regulated stormwater

Regulated stormwater delivers and transports pollutants to surface waters and is generated in the watershed during precipitation events. The sources of pollutants in stormwater are many, including decaying vegetation (leaves, grass clippings, etc.), domestic and wild animal waste, soil, deposited particulates from air, road salt, and oil and grease from vehicles. There are two types of regulated stormwater in the watershed:

Regulated Construction Stormwater

Construction stormwater is regulated by NPDES permits (MNR100001) for any construction activity disturbing: (a) one acre or more of soil, (b) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The WLA for stormwater discharges, from sites where there are construction activities, reflects the number of construction sites greater than one acre in size that are expected to be active in the impaired lake or stream subwatershed at any one time.

Regulated Industrial Stormwater

As of September 2024, there were no active industrial stormwater permits discharging to an impaired subwatershed in the Pomme de Terre River Watershed. Industrial stormwater is regulated by NPDES permits (MNR050000) if the industrial activity has the potential for significant materials and activities to be exposed to stormwater discharges. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired lake or stream subwatershed for which NPDES industrial stormwater permit coverage is required.

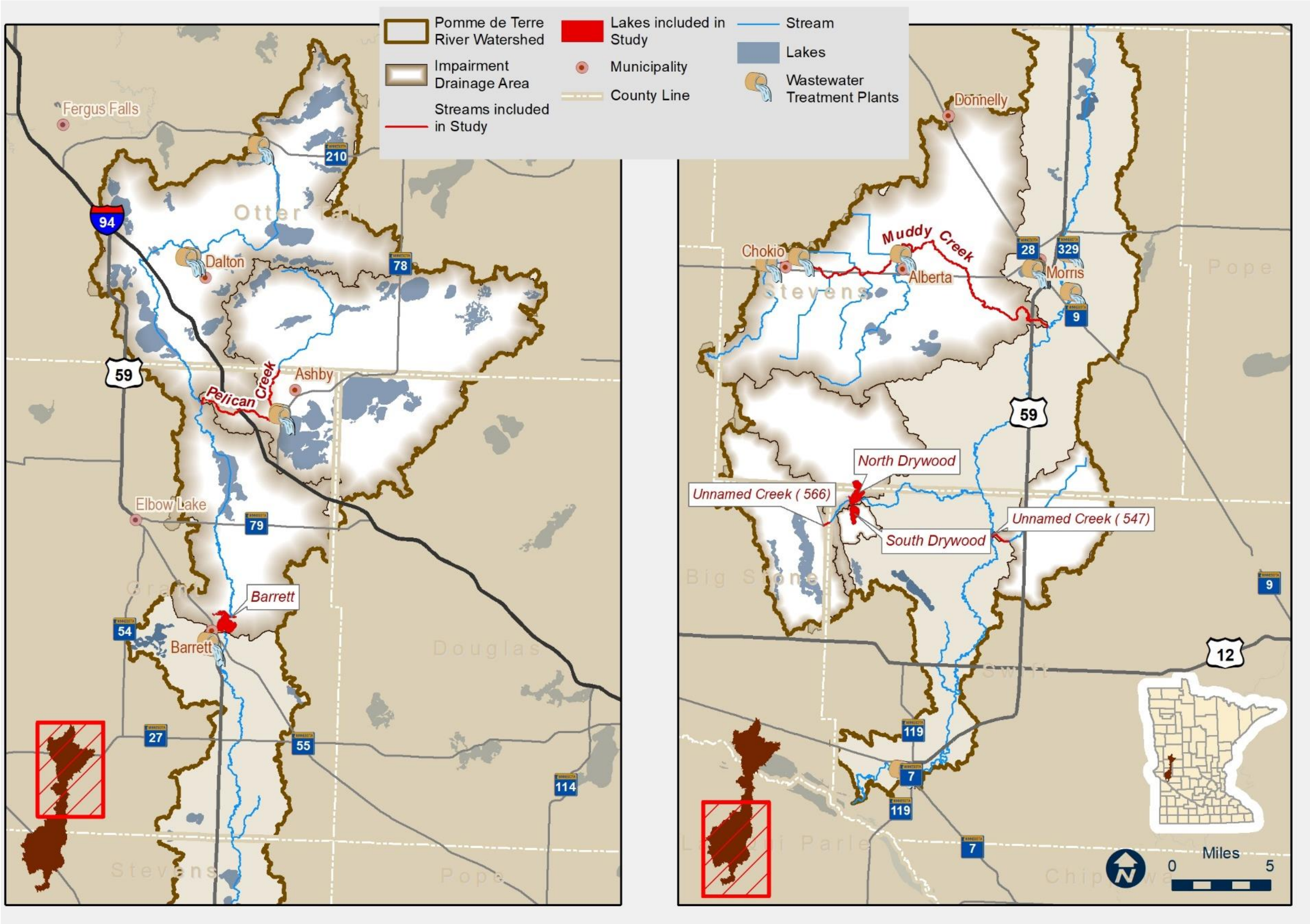
Regulated Nonmetallic Mining Stormwater

There are 17 sites in the Pomme de Terre River Watershed covered under the nonmetallic mining general permit (MNG490000), with only one site located within the direct drainage area of an impaired lake or stream addressed in this TMDL. Nonmetallic mining is regulated by NPDES/SDS permits if the facility discharges stormwater, mine site dewatering, or nonstormwater discharges to waters of the state. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired lake or stream subwatershed for which NPDES/SDS nonmetallic mining permit coverage is required.

3.5.1.2 Municipal Wastewater

Municipal wastewater is the domestic sewage and wastewater collected and treated by municipalities before being discharged to water bodies as municipal wastewater effluent. Three WWTPs discharge to impaired water bodies in the Pomme de Terre River Watershed including, Ashby WWTP, Alberta WWTP, and Chokio WWTP. WWTPs in the Pomme de Terre River Watershed are shown in Figure 20. The Chokio WWTP discharges to Muddy Creek but is not considered a source of *E. coli* and therefore was not assigned a WLA.

Figure 20. Permitted wastewater treatment plants in the Pomme de Terre River Watershed.



3.5.1.3 Land Application of Biosolids

The application of biosolids from WWTPs are highly regulated, monitored, and tracked (see Minn. R. ch. 7041 Sewage Sludge Management and Minn. R. ch. 7080 Individual Subsurface Sewage Treatment Systems). Pathogen reduction in biosolids is required prior to spreading on agricultural fields. Disposal methods that inject or incorporate biosolids within 24 hours of land application result in minimal possibility for mobilization of bacteria to downstream surface waters. While surface application could conceivably present a risk to surface waters, little to no runoff or bacteria transport are expected if permit restrictions are followed. Therefore, land application of biosolids was not included as a source of bacteria.

3.5.1.4 Confined Animal Feeding Operations

Concentrated Animal Feeding Operation (CAFOs) is defined by the EPA based on the number and type of animals. The MPCA currently uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the definition of an animal unit (AU). In Minnesota, the following types of livestock facilities are required to operate under a NPDES permit or a state issued State Disposal System (SDS) Permit: a) all federally defined CAFOs that have a discharge to waters of the U.S., some of which are under 1000 AUs in size; and b) all CAFOs and non-CAFOs that have 1,000 or more AUs.

CAFOs and Animal Feeding Operations (AFOs) with 1,000 or more AUs must be designed to contain all manure contaminated runoff from precipitation events of a 25-year, 24-hour storm event. Having and complying with an NPDES permit allows some enforcement protection if a facility discharges due to a 25-year, 24-hour precipitation event and the discharge does not contribute to a water quality impairment. Large CAFOs permitted with an SDS permit or NPDES permit must contain or treat all runoff, regardless of the precipitation event. Therefore, many large CAFOs in Minnesota have chosen to have a NPDES permit, even if discharges have not occurred in the past at the facility. A current manure management plan that complies with Minn. R. 7020.2225 and the respective permit is required for all CAFOs and AFOs with 1,000 or more AUs.

For feedlots with NPDES permits, surface applied solid manure is prohibited during the month of March. Winter application of manure (December through February) requires fields to be approved in their manure management plan, and the feedlot owner/operator must follow a standard list of setbacks and BMPs. Winter application of surface applied liquid manure is prohibited except for emergency manure application as defined by the NPDES permit. “Winter application” refers to application of manure to frozen or snow-covered soils, except when manure can be applied below the soil surface.

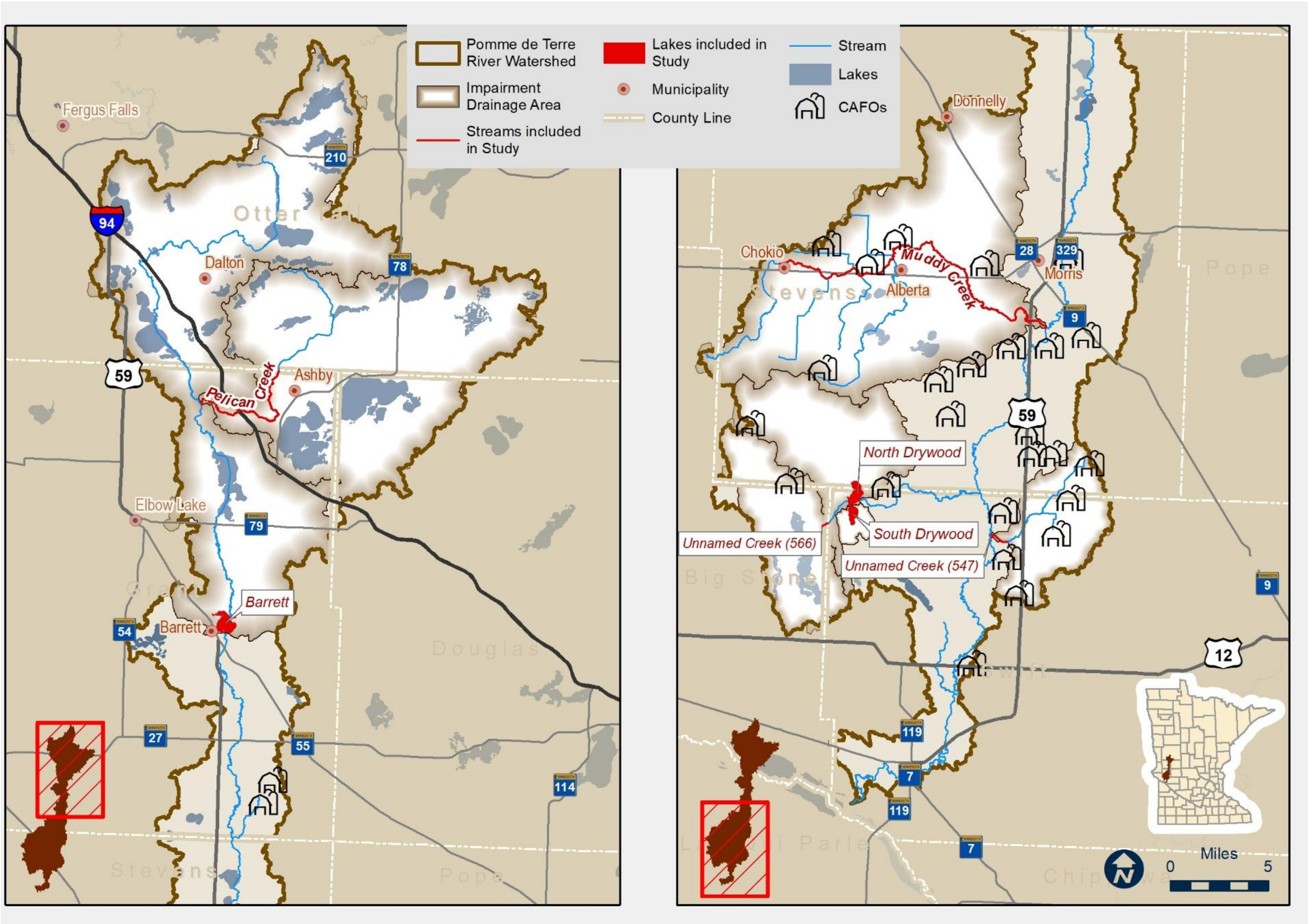
CAFOs are inspected by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved by the EPA. All CAFOs are inspected by the MPCA on a routine basis including field inspections, offsite monitoring, and compliance assistance.

As of 2024 there are 10 active NPDES permitted CAFOs located within an impaired water body’s subwatershed in the Pomme de Terre River Watershed (Table 17). CAFOs in the Pomme de Terre River Watershed are shown in Figure 21.

Table 17. CAFOs located within an impaired water body subwatershed in the Pomme de Terre River Watershed.

AUID (07020002)	Permit ID	Name	Animal Type	Animal Units (AU)
(-566)	MNG440469	Taffe Pork, LLC	Swine	1,500
(-511)	MNG440002	Loren Schmidgall Farm – Site 1	Swine	1,200
(-511)	MNG440270	Farmco Supply LLP – Sec 5	Swine	2,315
(-511)	MNG440830	Martys Swine Systems Inc – East Side	Swine	990
(-511)	MNG440831	Martys Swine Systems Inc – West Side	Swine	990
(-511)	MNG441061	West Line Pork	Swine	990
(-547)	MNG440126	Outback Five Inc	Swine	1,250
(-547)	MNG440548	Farmco Supply LLP – Sec 34	Swine	990
(-547)	MNG440749	District 45 Dairy	Dairy	11,495
(-547)	MNG441057	Farfield Hog Farm	Swine	990

Figure 21. CAFOs in the Pomme de Terre River Watershed.



3.5.2 Nonpermitted source types

3.5.2.1 Lake phosphorus source summary

This section provides a brief description of the nonpoint sources in the Pomme de Terre River Watershed that contribute to excess nutrients in the impaired lakes. Phosphorus in lakes often originates from surrounding landscapes. Phosphorus from sources such as phosphorus-containing fertilizer, manure, and the decay of organic matter can adsorb to soil particles. Wind and water action erode the soil, detach particles, and convey them via stormwater runoff to nearby water bodies where the phosphorus becomes available for algal and aquatic plant growth. Organic material, such as leaves and grass clippings, can leach dissolved phosphorus into standing water and runoff, or be conveyed directly to water bodies where biological action breaks down the organic matter and releases phosphorus. In addition, phosphorus in lake sediments can be released and transported to surface waters through chemical release under no oxygen (anoxic) bottom water conditions, fish excretion, and physical disturbance of the sediments from wind or wave action or bottom fish feeding behaviors.

The following sources of phosphorus that do not require an NPDES permit were evaluated:

- Direct drainage runoff and loading from upstream waters
- Nonpermitted feedlots
- Subsurface sewage treatment systems (SSTS)
- Atmospheric deposition
- Internal loading

Direct drainage runoff and upstream tributaries

A Hydrologic Simulation Program-FORTRAN – Scenario Application Manager (HSPF-SAM) model was used to estimate runoff volumes and TP loads from the direct drainage area of impaired lakes and from upstream tributaries (Table 18). The HSPF-SAM model generates overland runoff flows on a daily time step for 53 individual subwatersheds (average area 10,565 acres) in the Pomme de Terre River Watershed based on land cover and soil type over a 21-year (1996 through 2016) period (RESPEC 2017). TP loads from near-stream, in-stream, feedlot, and manure application sources are implicitly incorporated in the HSPF-SAM TP load estimates since the HSPF model is calibrated to stream monitoring data.

The HSPF-SAM annual flow and loads were averaged over the 2009 to 2016 time period to overlap with the 10-year (2009 through 2018) in-lake phosphorus conditions (Table 9 in Section 2.1.1) to which the lake water quality response models were calibrated for this TMDL (see Section 4.1.1.1).

The predicted distribution of TP loads by source (i.e., phosphorus source fate contribution) to Barrett, North Drywood, and South Drywood Lakes were estimated from the HSPF-SAM model (Figure 22 and Figure 23). Note that because North and South Drywood Lakes were modeled in the same subbasin in HSPF-SAM, the distribution of TP loads by source are summarized for both lakes together. For both Barrett Lake and the Drywood Lakes, high till cropland and low till cropland were the dominant sources of phosphorus. Other TP sources to Barrett Lake, in order from largest to smallest contribution, include developed, pasture, atmospheric deposition, wetlands, point sources, forest, grassland and feedlots.

Other minor TP sources to the Drywood Lakes include developed, wetlands, and atmospheric deposition. The sources of phosphorus to Barrett Lake are more diverse than North and South Drywood Lakes which reflects the more diverse land cover in the northern half of the Pomme de Terre River Watershed.

Upstream lakes can also contribute significant TP loads to downstream impaired lakes. The 2009 through 2018 average June through September in-lake TP concentration and HSPF-SAM predicted flows were used to estimate TP loads from upstream impaired lakes (Table 18). The total direct drainage runoff and upstream tributary TP loads summarized in Table 18 were used to determine existing conditions in the TMDL summary tables for each lake in Section 4.1.

Table 18. Average annual flow volumes and TP loads (1996-2016) for lake direct and upstream tributary drainage areas.

Impaired Lake	TP Source	HSPF-SAM Subbasin	Drainage Area (ac)	Flow (ac-ft/yr)	TP Load (lb/yr)	TP lb/acre/yr	Concentration ug/L
Barrett	Direct Drainage*	A460, A470	14,559	4,265	5,575	0.38	481
	Pomme de Terre Lake (-565)	A480	197,526	53,916	7,123	0.04	49
North Drywood	Direct Drainage*	A220**	7,242	3,216	7,479	1.03	855
	Artichoke Creek (-536)	A240	38,344	12,728	18,417	0.48	532
	Unnamed Creek	A230	5,514	2,403	5,126	0.93	784
	South Drywood Lake	A220**	2,051	809	1,913	0.93	870
South Drywood	Direct Drainage*	A220**	1,820	809	1,879	1.03	854

* Excludes lake surface area.

** North Drywood and South Drywood Lakes were modeled in the same HSPF-SAM subbasin. The direct drainage TP loads and flow to each lake are based on an area-weighted fraction of the total TP load and flow for the 9,681-acre A220 subbasin.

Figure 22. HSPF-SAM subbasin A460 average annual predicted phosphorus source fate contribution (lb/yr) to Barrett Lake (1996-2016). Sources ordered based on magnitude.

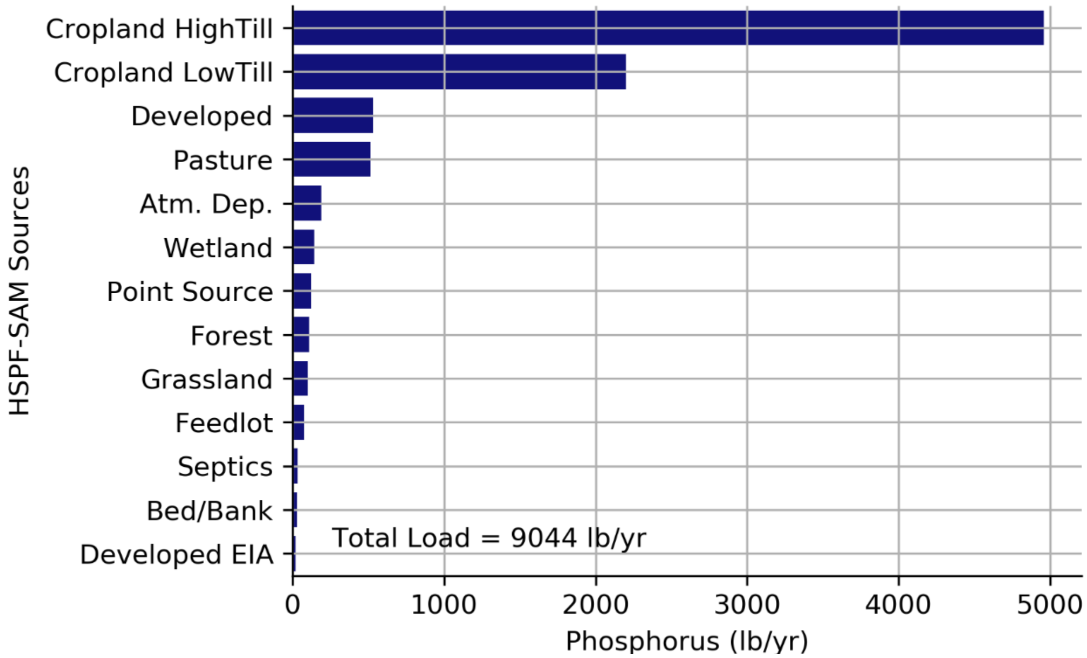
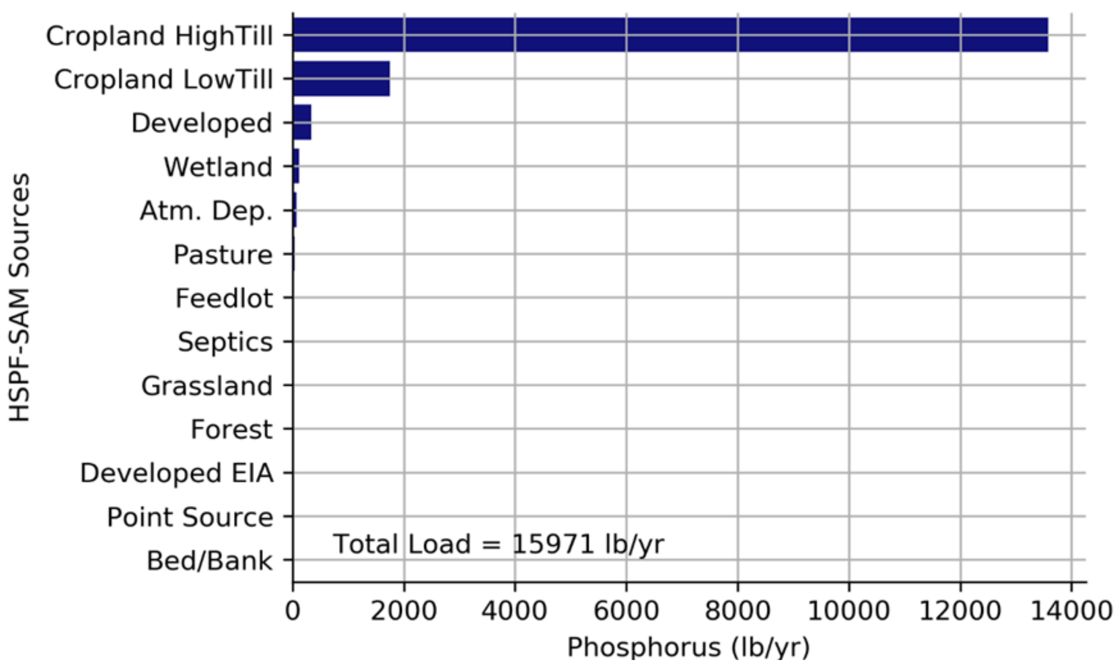


Figure 23. HSPF-SAM subbasin A220 average annual predicted phosphorus source fate contribution (lb/yr) to North and South Drywood Lakes. Sources ordered based on magnitude (1996-2016).



__Nonpermitted feedlots__

AFOs under 1,000 AUs and those that are not federally defined as CAFOs are not required to operate under NPDES or SDS permits. In Minnesota, feedlots with greater than 50 AUs, or greater than 10 AUs in shoreland areas, are required to register with the state. Facilities with AUs below these thresholds are not required to register with the state but are regulated by state rules in regard to discharge to ground and surface waters.

The animals raised in AFOs produce manure that is stored in piles, pits, lagoons, tanks, and other storage devices. The manure is then applied or injected to area fields as fertilizer. When stored and applied properly, this beneficial use of manure provides a natural source for crop nutrition and builds soil organic matter and health. It also lessens the need for fuel and other natural resources that are used in the production of fertilizer. AFOs, however, can pose environmental concerns. Inadequately managed manure runoff from open lot feedlot facilities and improper application of manure can contaminate surface or groundwater.

Livestock are potential sources of nutrients to lakes and streams in the Pomme de Terre River Watershed, particularly when direct access to surface waters is not restricted and/or where feeding structures are located adjacent to riparian areas.

Animal waste from nonpermitted AFOs can be delivered to surface waters from failure of manure containment, runoff from the AFO itself, or runoff from agricultural fields where the manure is applied. While a full accounting of the fate and transport of manure was not conducted for this project, a large portion of it is ultimately applied to the land, and therefore, this source is of possible concern. Minn. R. 7020.2225 contains several requirements for land application of manure, including the requirement that manure and process wastewater must not be applied in a manner that will result in a discharge to waters of the state. Manure practices that inject or incorporate manure pose lower risk to surface waters than surface application with little or no incorporation. In addition, manure application on frozen/snow covered ground in late winter months presents a high risk for runoff. Note that most of the feedlots in the direct drainage area of each impaired lake incorporate manure either through knife injection or incorporation within four days and have no emergency winter application. Therefore, feedlots are not likely a significant source of phosphorus to the impaired lakes.

Runoff during precipitation and snow melt can carry phosphorus from uncovered feedlots to nearby surface waters. For the purpose of this TMDL report, nonpermitted feedlots are defined as being all registered feedlots without an NPDES or SDS Permit that house under 1,000 AUs. While these feedlots do not fall under NPDES or SDS requirements, other regulations still apply.

TP loads to impaired lakes from nonpermitted, registered feedlots are included in the HSPF-SAM predicted watershed loads summarized in Table 18. The total annual feedlot AUs in the direct drainage area of each impaired lake are summarized in Table 19.

Table 19. MPCA registered feedlots in the Pomme de Terre River Watershed (Accessed May 2, 2024 MPCA Feedlot Database).

Impaired Reach (AUID)	Total Number of Animal Units (AU)	Primary Livestock							
		Beef		Swine		Dairy		Other	
		Non CAFO Feedlots	CAFOs	Non CAFO Feedlots	CAFOs	Non CAFO Feedlots	CAFOs	Non CAFO Feedlots	CAFOs
North Drywood Lake	7,172	1	0	4	2	0	0	0	0
South Drywood Lake	0	0	0	0	0	0	0	0	0
Barrett Lake	93	2	0	0	0	0	0	0	0
Pomme de Terre River Watershed	99,553	59	3	38	24	9	5	2	1

Shoreline subsurface sewage treatment systems

Phosphorus loads from SSTS were estimated based on assumptions described in the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (Barr Engineering 2004) and county specific estimates of failing septic system rates based on the MPCA 2012 SSTS Annual Report, Appendix C (McCarthy 2013). The 2020 SSTS Annual Report does not have county specific data. The total shoreline SSTS loads due to failing systems for each lake in Table 20 were used to determine existing conditions in the TMDL summary tables for each lake in Section 4.1.7.

Table 20. Shoreline SSTS assumptions and phosphorus loads to impaired lakes.

	Shoreline SSTS[a]	Seasonal Residence (4 mo/yr)	Permanent Residence	Conforming Systems	Failing Systems[b]	Capita per Residence[c]	P Production per Capita	Conforming SSTS %P “ passing”	Failing ISTS %P “ passing”	Conforming Systems	Failing Systems	P Load Conforming SSTS	P Load Failing SSTS	Total Shoreline SSTS P Load	Total Shoreline SSTS P Load due to Failing System
Impaired Lake	#	%	%	%	%	#	lb/yr	%	%	#	#	lb/yr	lb/yr	lb/yr	lb/yr
Barrett	57	0%	100%	100%	0%	2.5	1.95	20%	43%	57	0	31.1	0	31.1	**0**
North Drywood	3	0%	100%	79%	21%	2.5	1.95	20%	43%	2	1	2.0	2.1	4.1	**2.1**
South Drywood	2	100%	0%	79%	21%	2.5	1.95	20%	43%	2	0	0.7	0	0.7	**0**

[a] Based on counts of shoreline residences from current aerial imagery.

[b] Based on the estimate of percent of failing septic systems by County in the MPCA 2012 SSTS Annual Report Appendix C. https://www.pca.state.mn.us/sites/default/files/wq-wwists1-51.pdf. The new report (SSTS Annual Report 2020) does not have county specific compliance data, the most recent report with this kind of data was the 2012 report.

[c] Based on the estimated number of people per household by County from the 2020 Census.

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the air and is deposited directly onto surface waters. Average phosphorus atmospheric deposition loading rates were approximately 0.37 pounds per acre per year (lbs/ac/yr) for an average rainfall year for the Minnesota River Basin (Twaroski et al. 2007). This rate was applied to the lake surface areas in the Pomme de Terre River Watershed to determine the total atmospheric deposition load per year to the impaired lakes.

The total annual atmospheric deposition loads for each lake in Table 21 were used to determine existing conditions in the TMDL summary tables for each lake in Section 4.1.

Table 21. Atmospheric deposition phosphorus loads to impaired lakes.

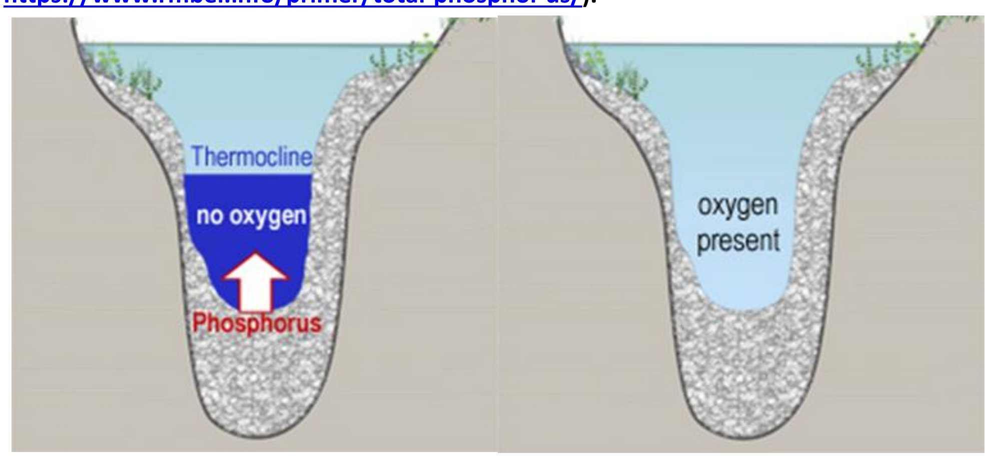
Impaired Lake	Atmospheric Deposition Phosphorus Load (lb/yr)
Barrett Lake	197
South Drywood Lake	86
North Drywood Lake	144

Internal Loading

Internal loading in lakes refers to the phosphorus within a lake's bottom sediments or aquatic plants that is released back into the water column. Internal loading can occur via:

1. Chemical release from bottom sediments: Caused by anoxic (lack of oxygen) conditions in the overlying water column layers or high pH (greater than 9). If a lake's hypolimnion (bottom area) remains anoxic for a portion of the summer season, the phosphorus released due to anoxia will be distributed throughout the water column during fall mixing. In shallow lakes, the periods of anoxia can last for short periods of time and occur frequently (Figure 24).

Figure 24. Sediment phosphorus release under anoxic (no oxygen) conditions in lakes (From: RMBEL https://www.rmbel.info/primer/total-phosphor us/).



2. Physical disturbance of bottom sediments: Caused by motorized boat activity, and wind-driven mixing/wave action. This is more common in shallow lakes than in deeper lakes.

3. Fish feeding and excretion: Benthivorous (bottom feeding fish) move phosphorus from the sediment to the water by feeding on lake bottom food items, providing new phosphorus for algae growth. Some studies have shown that release of phosphorus from fish feeding can release more

phosphorus than all other lake organisms combined, and can be on the same order of magnitude of external, watershed loading (Brabrand et al. 1990; Persson 1997).

Internal load was estimated for each impaired lake as the amount of unknown/excess load added to each lake to calibrate the BATHTUB water quality response models to existing (2009 through 2018) summer season average in-lake TP concentrations (see Section 4.1.1.1).

Table 22. Internal phosphorus loads to impaired lakes.

Impaired Lake	Internal Phosphorus Load (lb/yr)	TP lb/acre/yr	Concentration µg/L
Barrett Lake	570	1.08	0.33
North Drywood Lake	13,346	33.0	10.14
South Drywood Lake	13,788	59.7	18.3

Lake Phosphorus Source Summary

Existing TP loads to each impaired lake are summarized by source in Table 23 through Table 25 below. The largest TP source to Barrett Lake is upstream Lake Pomme de Terre (53%) followed by direct drainage runoff (42%) and excess internal/unknown load (4%) (Table 23). The largest TP source to South Drywood Lake is excess internal/unknown load (87%) followed by direct drainage runoff (12%) (Table 24). The largest TP source to North Drywood Lake is Artichoke Creek (39%) followed by excess internal/unknown load (29%), direct drainage runoff (16%), Unnamed Creek (11%) and South Drywood Lake (4%) (Table 25).

Table 23. Barrett Lake existing TP loads by source (2009-2018).

TP Source	TP Load (lb/yr)	TP Load (% total)
Direct Drainage	5,609	42%
Shoreline SSTS	31	<1%
Lake Pomme de Terre	7,123	53%
Atmospheric Deposition	197	1%
Excess Internal/Unknown Load	569	4%
Total	**13,496**	

Table 24. South Drywood Lake existing TP loads by source (2009-2018).

TP Source	TP Load (lb/yr)	TP Load (% total)
Direct Drainage	1,879	12%
Shoreline SSTS	1	<0.1%
Atmospheric Deposition	86	0.6%
Excess Internal/Unknown Load	13,346	87%
Total	**15,312**	

Table 25. North Drywood Lake existing TP loads by source (2009-2018).

TP Source	TP Load (lb/yr)	TP Load (% total)
Direct Drainage	7,479	16%
Shoreline SSTS	4	<0.1%
Unnamed Creek	5,126	11%
Artichoke Creek	18,417	39%
South Drywood Lake	1,913	4%
Atmospheric Deposition	144	0.3%
Excess Internal/Unknown Load	13,788	29%
Total	**46,871**	

3.5.2.2 Stream Phosphorus Source Summary

The HSPF-SAM model was used to estimate the stream TP sources throughout the Pomme de Terre River Watershed (Figure 26). The subwatersheds with the highest TP yield are located in the southwestern portion of the watershed and contribute to Unnamed Creek (-566). The model predicts that the largest source of TP is from agriculture (Figure 25). TP yields in the Pomme de Terre River Watershed were also estimated at the field scale using PTMApp. PTMApp is a GIS model that estimates TP based on a high-resolution elevation raster and land use. The PTMApp model predicts a similar distribution of TP yields as the HSPF-SAM model (Figure 27).

Phosphorus is generally applied to farm fields as either animal manure or fertilizer. The type, timing, placement, and rate of application are all factors in determining how much phosphorus leaves the landscape. After the application of phosphorus, the management practices used on a farm field impact the transport of phosphorus. Generally, practices that reduce erosion and runoff from fields limit the particulate phosphorus movement in the landscape. For Unnamed Creek (-566), high till agricultural fields are predicted to contribute 88% of the TP. In addition, fields with tile drains are more likely to be sources of phosphorus to the stream. Tile drains are designed to remove excess water off the landscape efficiently. In the process, nutrients that would have otherwise been trapped in the soil and vegetation are transported to nearby water bodies. TP loads from tile drainage are not explicitly quantified in the HSPF-SAM model but are implicitly included in the overall load estimates.

Figure 25. HSPF-SAM subbasin A240 predicted phosphorus source fate contribution (lb/yr) to Unnamed Creek (-566) (1996-2016).

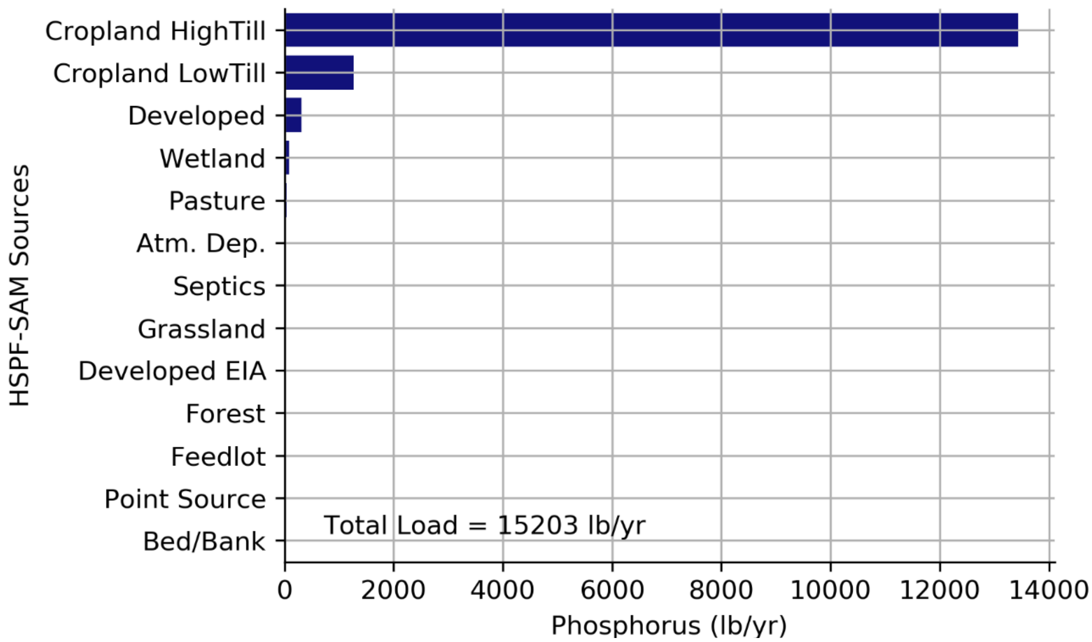


Table 26. MPCA registered feedlots in the TP impaired reach drainage area and the Pomme de Terre River Watershed (Accessed May 2, 2024 MPCA Feedlot Database).

Impaired Reach (AUID)	Number of Animal Units (AU)	Primary Livestock							
		Beef		Swine		Dairy		Other	
		Non CAFO Feedlots	CAFOs	Non CAFO Feedlots	CAFOs	Non CAFO Feedlots	CAFOs	Non CAFO Feedlots	CAFOs
Unnamed Creek (-566)	1,820	0	0	1	1	0	0	0	0
Watershed	99,553	59	3	38	24	9	5	2	1

Figure 26. HSPF-SAM 1996-2016 average annual TP yield (lb/acre-yr) by subwatershed.

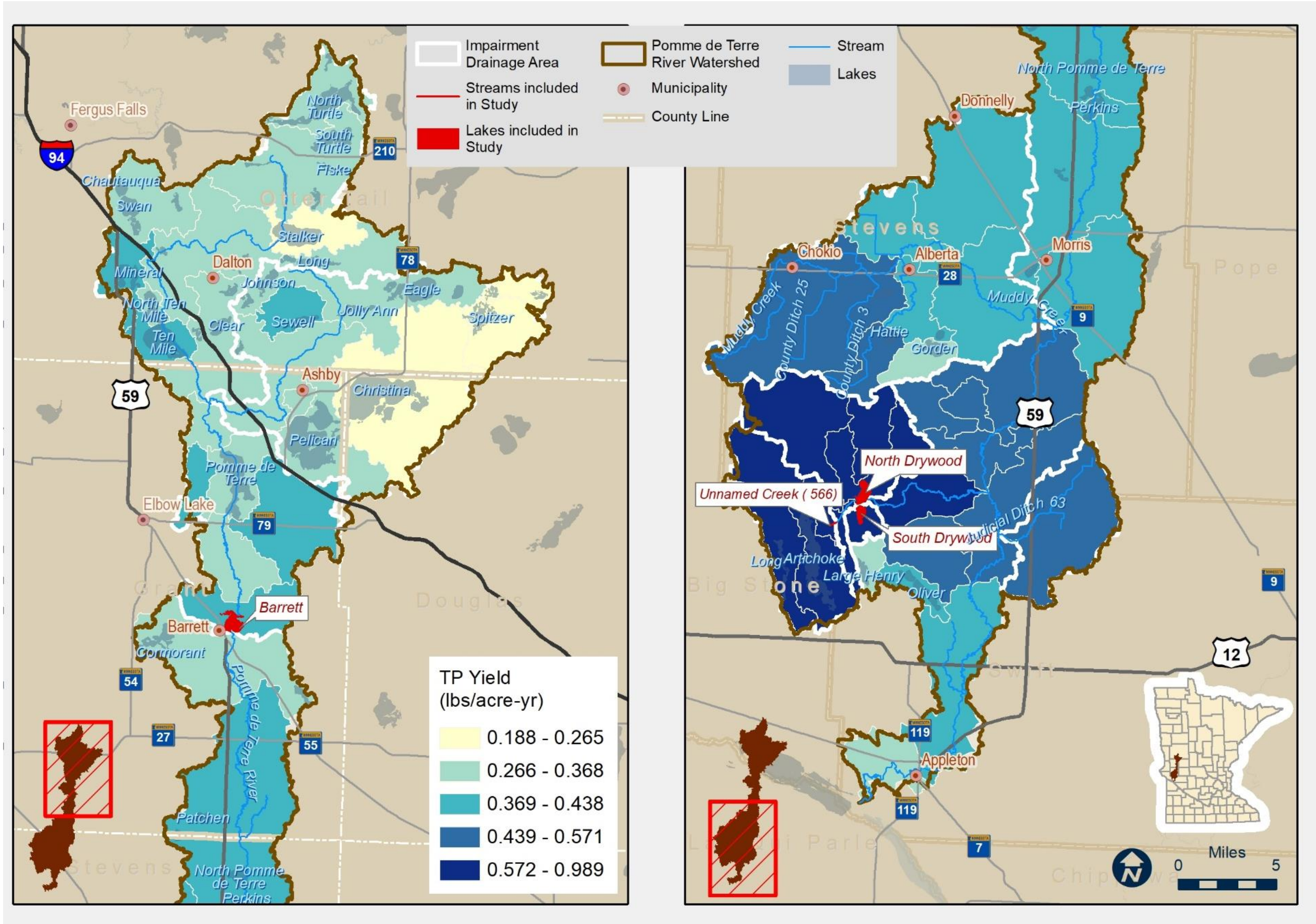
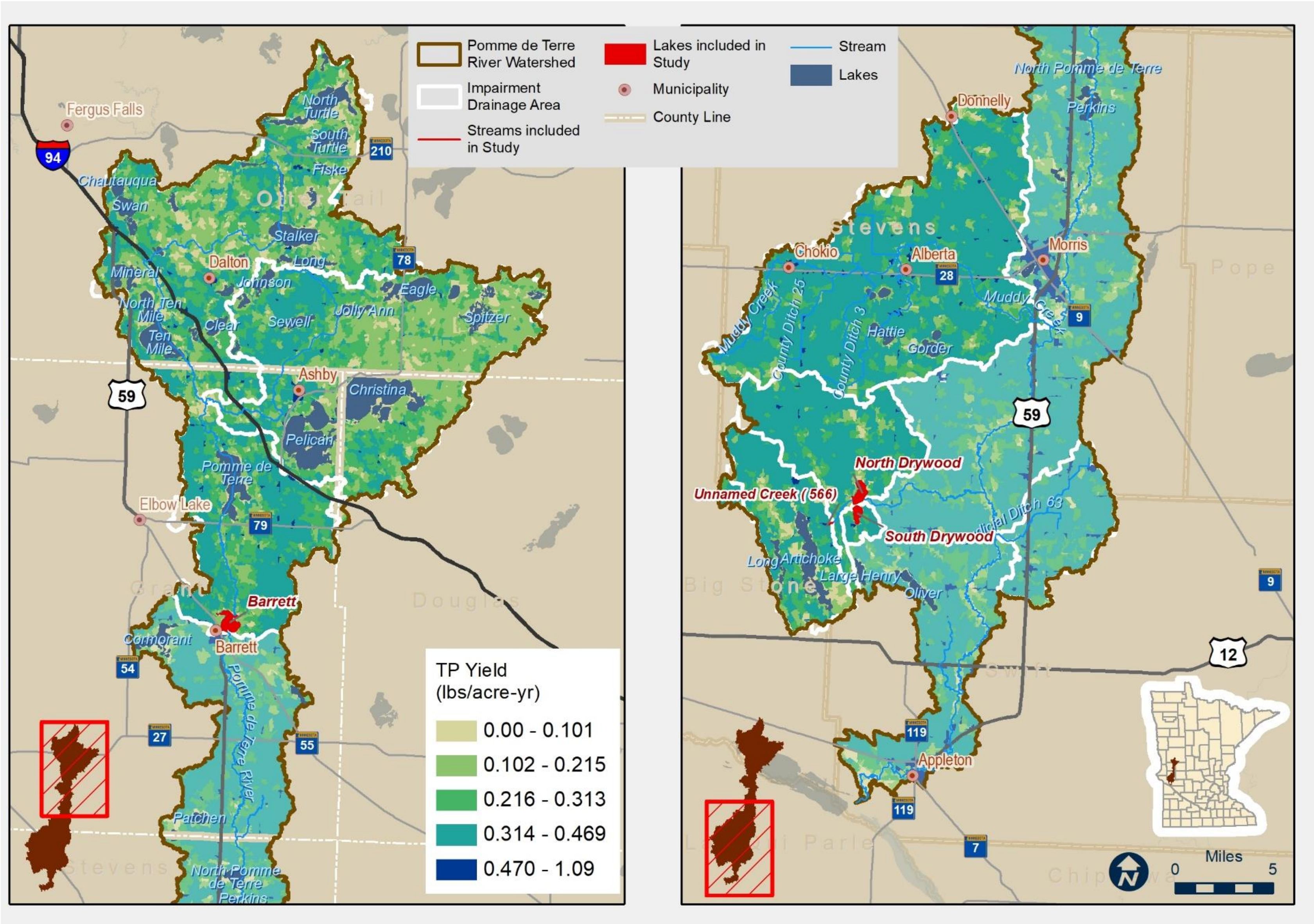


Figure 27. PTMApp annual TP yield at the field scale.



3.5.2.3 Stream Total Suspended Solids Source Summary

The HSPF-SAM model was used to determine the distribution of sediment yields throughout the Pomme de Terre River Watershed. The highest sediment yields are located in the southern half of the watershed (Figure 28), an area that includes Unnamed Creek. Most of the sediment in Unnamed Creek is predicted to come from agricultural sources (Figure 29). The other impaired stream reach, Pelican Creek, is in the northern half of the watershed which has the more stringent standards of the Central River Nutrient Region. The model predicts that most of the sediment reaching Pelican Creek is coming from the direct drainage subwatershed followed by the subwatershed directly to the north. Pelican and Christiana Lake contribute little sediment to Pelican Creek (Figure 30) due to settling out of sediment in the two lakes. The HSPF-SAM model predicts that the largest source of sediment to Pelican Creek is from bed/bank erosion and high till agricultural land.

Near Stream Disturbance

In the Pomme de Terre River Watershed, riparian areas have been converted to both agricultural and urban land. Native vegetation along streams limit bank erosion due to a sufficient root structure and efficient use of soil moisture throughout the year. Conversion from native vegetation to agricultural or urban land uses can worsen streambank erosion due to shallower and less dense root structure, exposed soil, greater runoff, and physical disturbance by livestock. Urban soils tend to have higher rates of erosion than undisturbed soils due to less root stabilization of the soil, more areas of exposed soil, and more concentrated runoff flowpaths. In rural areas, conversion from native vegetation to pastureland and cropland increases streambank erosion because of the replacement of deep-rooted vegetation with shallow rooted plants. In addition, livestock increases erosion by trampling streambanks and disturbing the channel, which loosens the soil and increases the area of bare soils near the stream. Minnesota's Buffer Law requires perennial vegetative buffers of up to 50 feet along lakes, rivers, and streams and buffers of 16.5 feet along ditches. Since March 2021, for the counties of the Pomme de Terre River Watershed, parcels adjacent to Minnesota waters are between 94% to 100% compliant with the Minnesota Buffer Law.

Agricultural Runoff

The amount of sediment from croplands depends on the management practices implemented. An important factor is the type of tillage equipment used. High tillage practices, such as plowing and disking, loosen the soil making it easier for wind and rain to wash it away. Low-till and no-till options, however, can limit the amount of erosion occurring. The HSPF-SAM model included different soil erosion rates between high tillage cropland and low tillage cropland. Sediment transport in croplands can be further reduced by implementing other conservation practices, such as grassed waterways, contour buffer strips, and filter strips. The PTMApp model was used in the Pomme de Terre River Watershed to estimate sediment yields at the field scale (Figure 32). PTMApp uses the Revised Universal Soil Loss Equation (RUSLE) to estimate the sediment load.

Differences between HSPF-SAM and PTMApp in predicting runoff stem from the different scale at which they operate. HSPF-SAM is a subwatershed scale model matching closest to the HUC12 scale and represents more accurately what is observed in the stream. The HSPF model was developed to aid in the development of TMDLs. PTMApp is a field-based model, it is more accurate at predicting field specific erosion and was developed to help identify and prioritize conservation projects.

Figure 28. HSPF-SAM 1996-2016 average annual sediment yield (tons/acre-yr) by subwatershed.

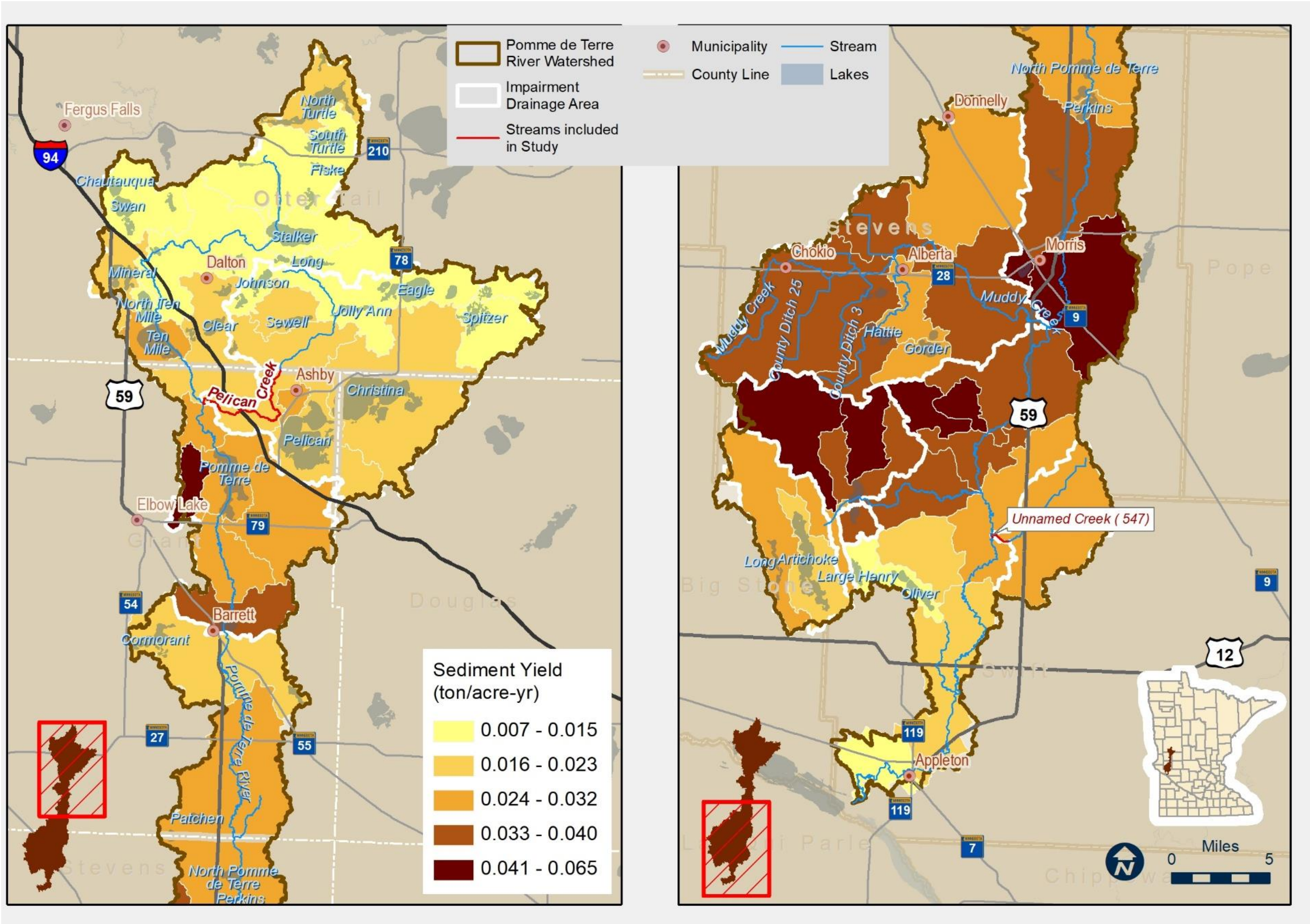
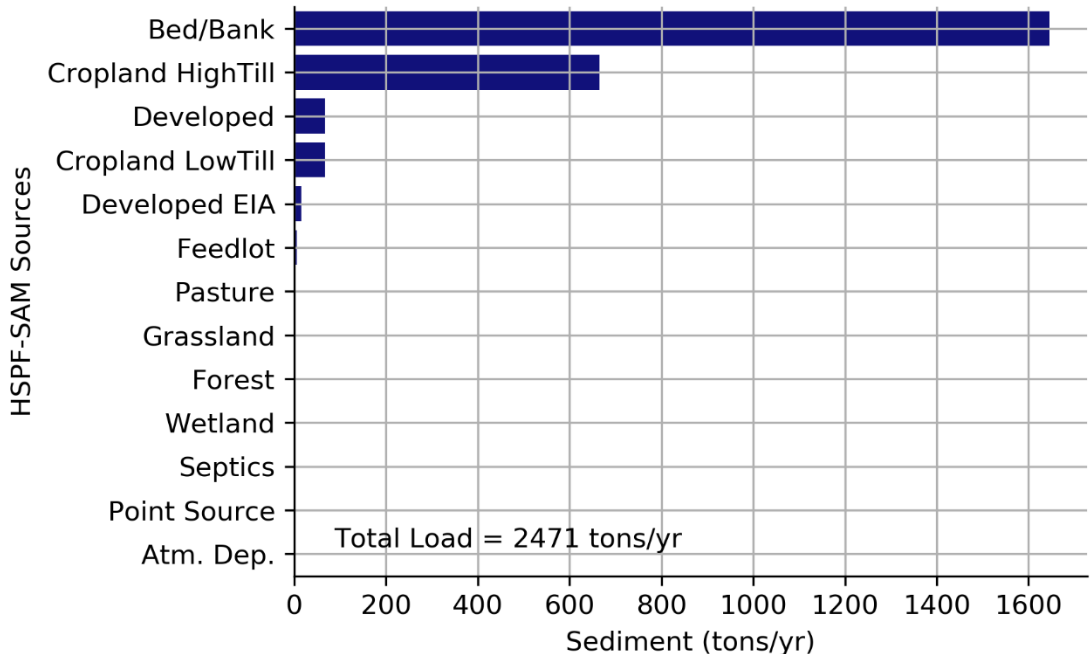


Figure 29. HSPF-SAM subbasin A30 1996-2016 predicted sediment basin load (tons/yr).



Note: The HSPF-SAM subbasin A30 contains the Pomme de Terre River and therefore the sediment from stream bed and bank erosion represents the river and not Unnamed Creek (-547).

Figure 30. HSPF-SAM 1996-2016 sediment basin fate for Pelican Creek.

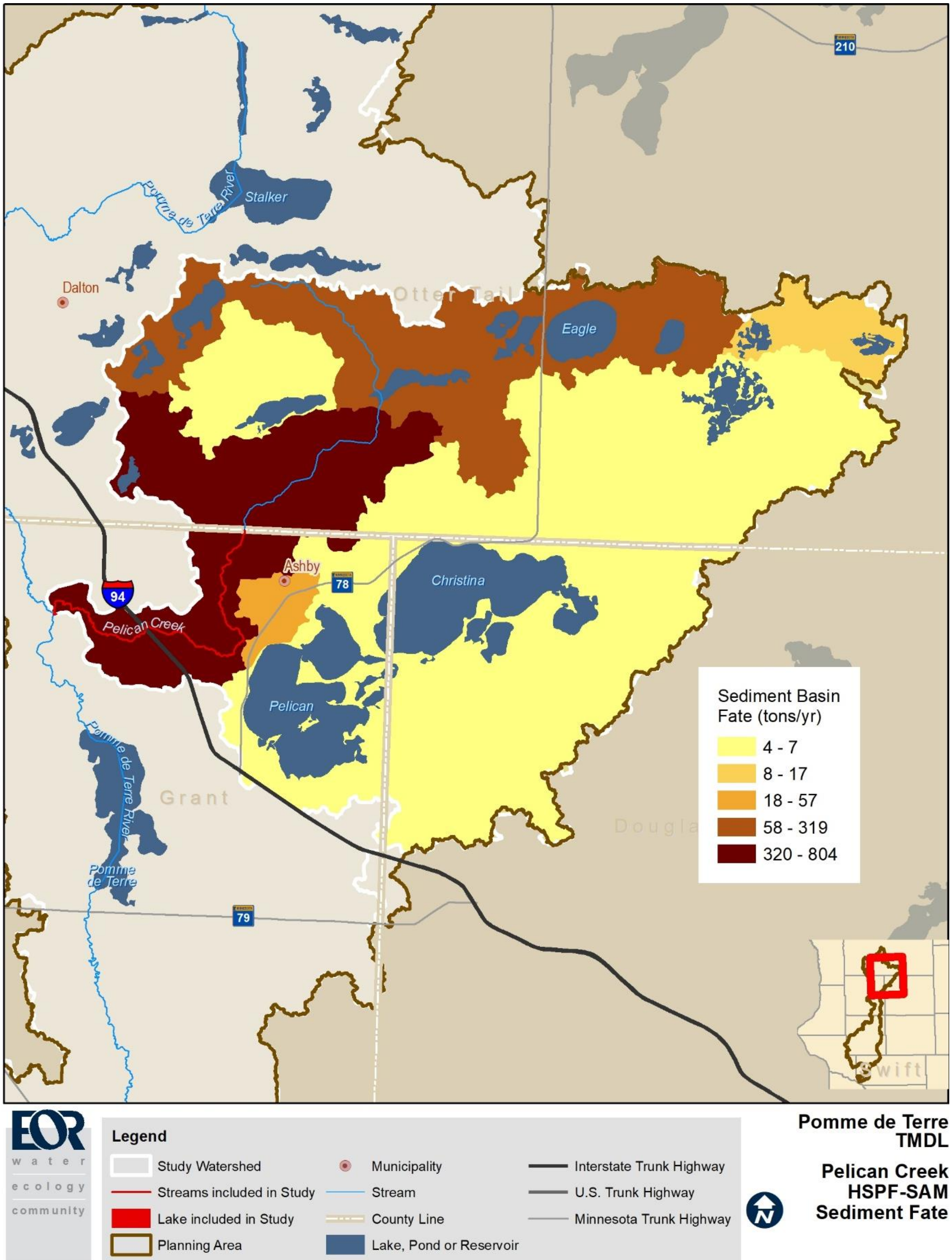


Figure 31. HSPF-SAM 1996-2016 predicted sediment source fate contribution (tons/yr) for Pelican Creek (A840).

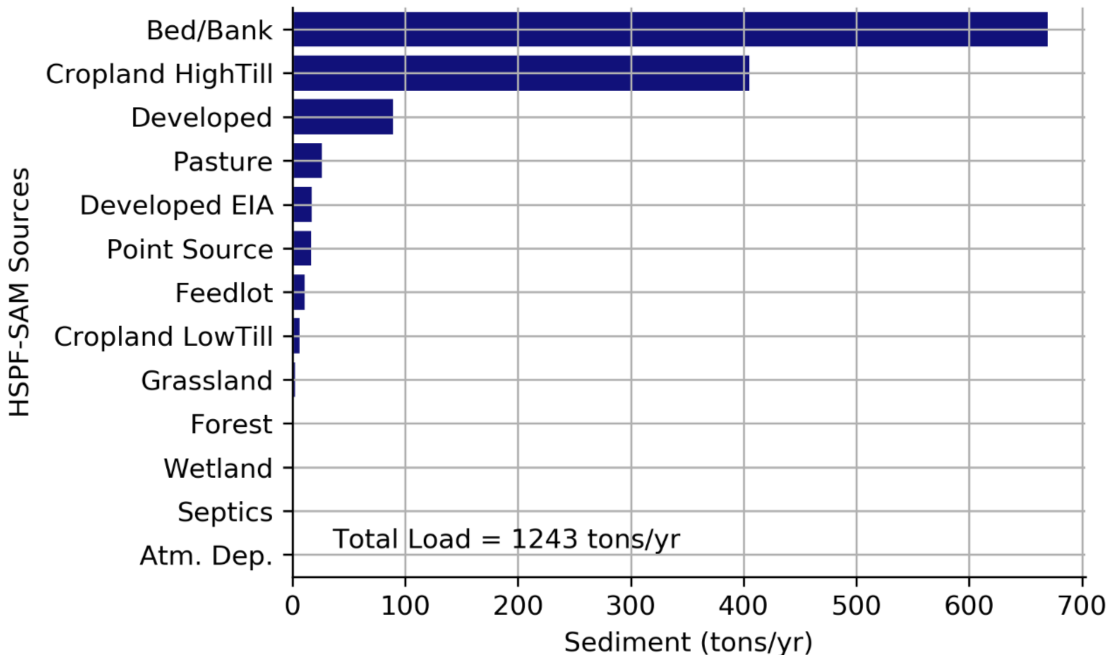
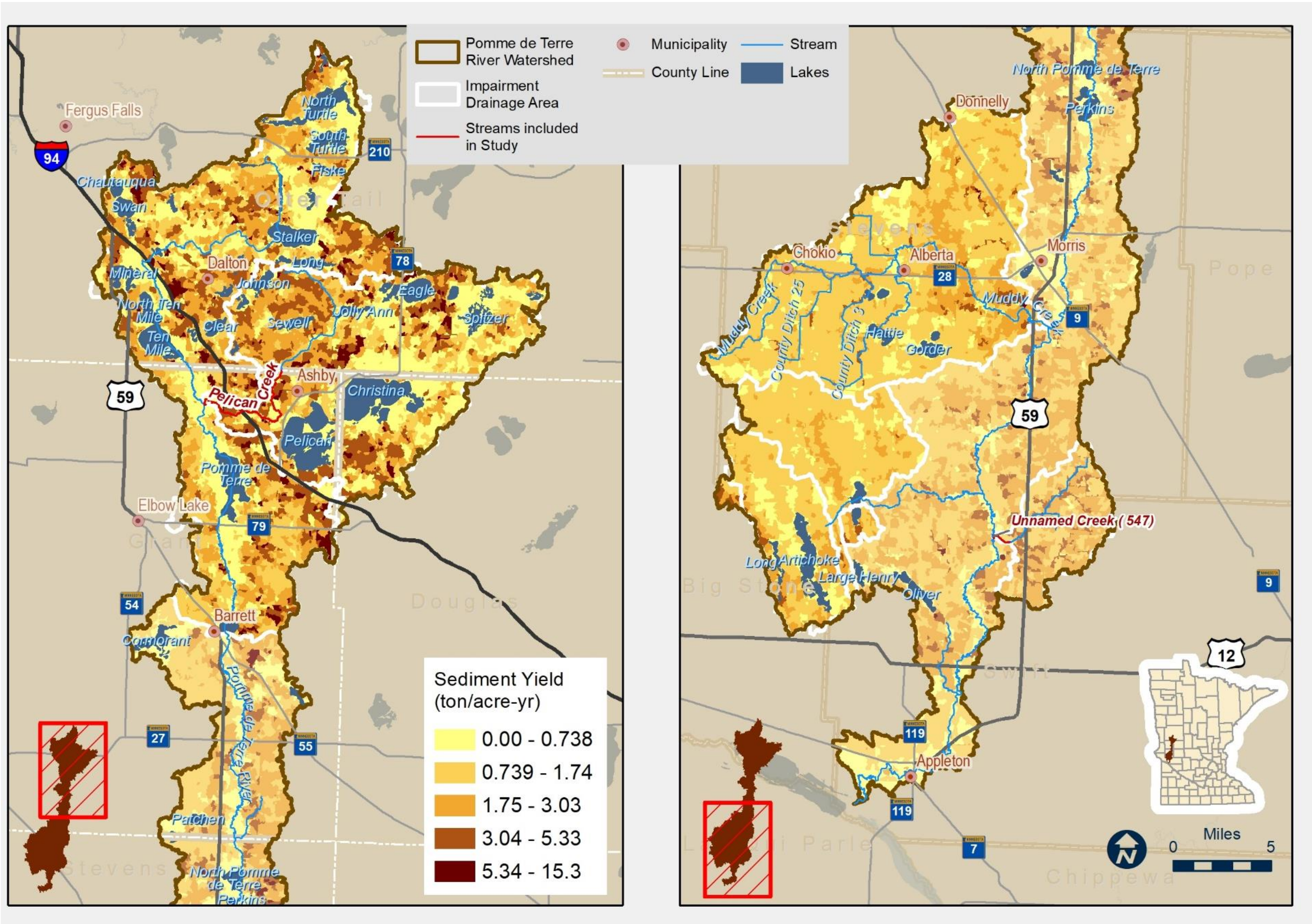


Figure 32. PTMApp annual sediment yield at the field scale.



3.5.2.4 Stream *E. coli* Source Summary

Individual Sewage Treatment Systems

"Failing" SSTS are specifically defined as systems that are failing to protect groundwater from contamination. Based on County SSTS compliance reports, failing SSTS were not considered a significant source of fecal pollution to surface water because these systems do not discharge partially treated sewage to the ground surface. However, systems which discharge partially treated sewage to the ground surface, road ditches, tile lines, and directly into streams, rivers, and lakes are considered an IPHT. IPHT systems also include illicit discharges from unsewered communities (sometimes called "straight-pipes"). Straight pipes are illegal and pose an imminent threat to public health as they convey raw sewage from homes and businesses directly to surface water. Community straight pipes are more commonly found in small rural communities.

IPHT data are derived from surveys of County staff and County level SSTS status inventories. Table 27 provides the estimated percentage of IPHT septic systems as reported by each County to MPCA as of 2016. The number of IPHT within the impaired stream subwatershed was estimated based on the county IPHT percentages and the county population estimates from 2020 US Census data area weighted to the portion of the County within the impaired stream drainage area (Table 28).

Table 27. County Estimated IPHT as Percentage of all SSTS.

County	IPHT (as % of all septics)
Big Stone	12%
Douglas	2%
Grant	9%
Otter Tail	5%
Stevens	21%
Swift	21%

Table 28. Estimated Number of IPHT in each Impaired Stream Subwatershed.

Impaired Reach (AUID)	2020 US Census Counts		Estimated Number of IPHT
	Population	Households	
Muddy Creek (-506)	**1,477**	**716**	**151**
Big Stone	5	2	1
Stevens	1,472	714	150
Pelican Creek (-511)	**1,838**	**1,331**	**84**
Douglas	280	171	4
Grant	769	517	47
Otter Tail	789	643	33
Unnamed Creek (-547)	**104**	**45**	**11**
Stevens	38	15	4
Swift	66	30	7
Watershed	**15,248**	**7,966**	**1,156**
Big Stone	57	39	5
Douglas	281	171	4
Grant	2,128	1,304	118
Otter Tail	3,062	2,051	103
Stevens	7,906	3,343	703
Swift	1,814	1,058	223

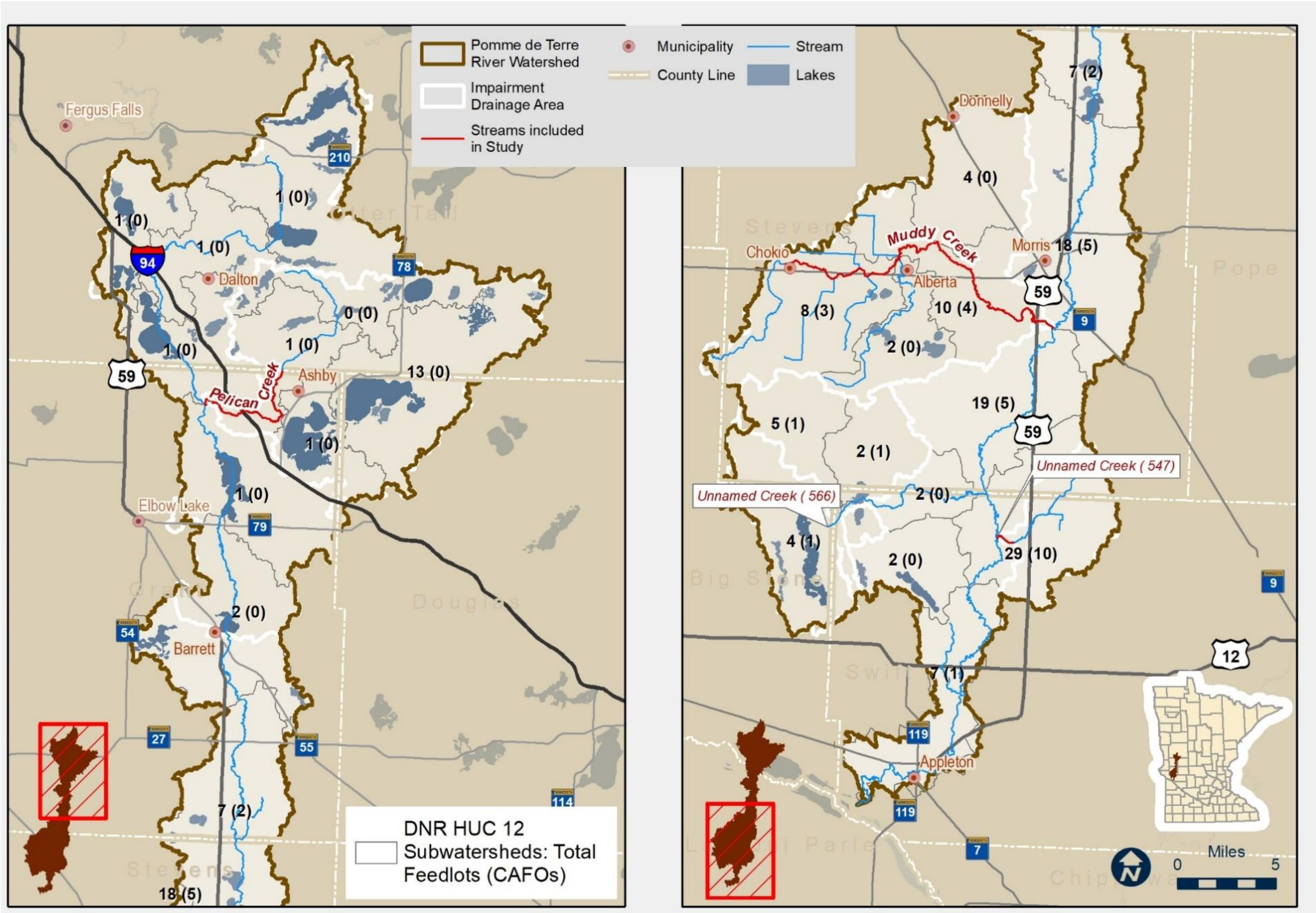
Livestock Manure

Runoff from livestock feedlots, pastures, and manure land application areas has the potential to be a significant source of fecal coliform bacteria. There is considerable spatial variation in the type and density of livestock across the Pomme de Terre River Watershed (Figure 33). North of Barrett Lake there are 22 registered feedlots, none of which are registered as CAFOs. South of Barrett Lake there are 119 registered feedlots, 33 of which are registered as CAFOs. In total, there are an estimated 99,553 AUs in the Pomme de Terre River Watershed based on the MPCA Feedlot Database (Accessed May 2, 2024, Table 29).

Most feedlots either primarily raise beef cattle or swine. The type of livestock raised in a feedlot changes the management of the facility and the potential for sources of *E. coli* to streams. Swine facilities are typically enclosed and therefore the primary concern is manure application. Typically, manure is stored throughout the year in pits. The pits are typically completely emptied twice a year once right before planting crops in early spring and again after harvest in late fall. Manure application can become a source of *E. coli* if the manure is over-applied beyond what the soil can absorb, not incorporated into the soil, applied right before or during wet conditions, and under frozen conditions. For feedlots with NPDES permits, surface applied solid manure is prohibited during the month of March. Winter application of manure (December through February) requires fields to be approved in their manure management plan, and the feedlot owner/operator must follow a standard list of setbacks and BMPs. Winter application of surface applied liquid manure is prohibited except for emergency manure application as defined by the NPDES permit. “Winter application” refers to application of manure to frozen or snow-covered soils, except when manure can be applied below the soil surface. Similar issues with manure management can arise in beef and dairy facilities (bovine facilities). Bovine facilities;

however, are more likely to have open feedlots where precipitation can potentially move bacteria from the open lot areas. In addition, some facilities graze their animals. When over-grazing occurs, including over-grazing of woodlands, severe erosion and manure runoff can result. However, properly managed pasture can increase infiltration of precipitation into the soil profile, reducing runoff and water quality impact.

Figure 33. Number of feedlots by HUC-12 subwatershed in the Pomme de Terre River Watershed (2022).



The first number represents the total number of feedlots in the subwatershed and the second number represents the number of CAFOs.

Table 29. MPCA registered feedlots in the *E. coli* impaired reach drainage areas and the Pomme de Terre River Watershed (Accessed May2, 2024 MPCA Feedlot Database).

Impaired Reach (AUID)	Number of AU	Primary Livestock							
		Beef		Swine		Dairy		Other	
		Non-CAFO Feedlots	CAFOs	Non-CAFO Feedlots	CAFOs	Non-CAFO Feedlots	CAFOs	Non-CAFO Feedlots	CAFOs
Pelican Creek (-506)	2,218	12	0	2	0	4	0	1	0
Muddy Creek (-511)	11,046	5	0	7	6	1	1	0	0
Unnamed Creek (-547)	32,721	17	0	17	3	1	1	0	0
Watershed	99,553	59	3	38	24	9	5	2	1

Natural growth

When evaluating sources of *E. coli* in the Pomme de Terre River Watershed, it is important to recognize the potential for natural reproduction of *E. coli* in soil and sediment. Research in the last 20 years has found the persistence of *E. coli* in soil, beach sand, and sediments throughout the year in the north central United States without the continuous presence of sewage or mammalian sources. An Alaskan study (Adhikari Hrishikesh et al. 2007) found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions. A study of cold water streams in southeastern Minnesota completed by the MPCA staff found the resuspension of *E. coli* in the stream water column due to stream sediment disturbance. A study near Duluth, Minnesota (Ishii et al. 2010) found that *E. coli* were able to grow in agricultural field soil. A study by Chandrasekaran et al. (2015) of ditch sediment in the Seven Mile Creek Watershed in southern Minnesota found that strains of *E. coli* had become naturalized to the water−sediment ecosystem. Survival and growth of fecal coliform has been documented in stormsewer sediment in Michigan (Marino and Gannon 1991). The growth and persistence of *E. coli*, which has been studied and documented in our region and beyond, greatly complicates the clear identification of sources of pathogens to surface waters. As such, the information provided in this section includes the most likely sources based on the best available information.

Pets

Human pets (dogs and cats) can contribute bacteria to a watershed when their waste is not properly managed. When this occurs, bacteria can be introduced to waterways from:

- Dog parks
- Residential yard runoff (spring runoff after winter accumulation)
- Rural areas where there are no pet cleanup ordinances
- Animal elimination of excrement directly into water bodies

Dog waste can be a significant source of pathogen contamination of water resources (Geldreich 1996). Dog waste in the immediate vicinity of a waterway could be a significant local source with local water quality impacts. Domestic cats, even those that spend some time outdoors, are most likely to have their waste collected indoors and were not considered a source of bacteria for this TMDL report. Feral cats may contribute to bacteria levels in urban streams and rivers (Ram et al. 2007). However, it is generally thought that these sources may be only minor contributors of fecal contamination on a watershed scale because the estimated magnitude of this source is very small compared to other sources.

Wildlife

Bacteria can be contributed to surface water by wildlife (e.g., beaver, deer, geese, and ducks) dwelling in water bodies, within conveyances to water bodies, or when their waste is carried to stormwater inlets, creeks, and ditches during stormwater runoff events. Only 7% of the Pomme de Terre River Watershed is classified as forest where wildlife can congregate throughout the year. However, of the total forested area, 85% of the conifer forest and 57% of the deciduous forest is within a 150 m buffer of open water or wetland (41% of the watershed). This distribution lends itself to higher densities of animals near water and may lead to higher *E. coli* concentrations in the streams. Pelican Creek may have higher concentrations of *E. coli* from wildlife because of drainage from Lake Christina, which is a critical staging area for migrating waterfowl in both spring and fall. Shallow basins in this area also support colonial nesting water birds (e.g., shorebirds) and other wildlife. The portion of bacteria from wildlife in Unnamed Creek is most likely very limited because of the very small portion of the watershed in natural conditions.

Summary

The potential of *E. coli* sources to contribute to impairment in each *E. coli* impaired stream is summarized in Table 30. IPHTs and wildlife have a moderate potential to contribute to the *E. coli* impairment in Pelican Creek. IPHTs and feedlots have a moderate potential to contribute to the *E. coli* impairment in Muddy Creek and Unnamed Creek.

Table 30. *E. coli* source potential by impaired reach.

Impaired Reach	IPHT	Feedlots	Pets	Wildlife
Pelican Creek (-506)	**Moderate** Potentially up to 151 IPHTs in the 133 sq. mi. drainage area	**Low** 15 total feedlots in the 133 sq. mi. drainage area	**Very low** Very low population density in the drainage area	**Moderate** Near Lake Christina, an important migratory waterfowl staging area
Muddy Creek (-511)	**Moderate** Potentially up to 84 IPHTs in the 144 sq. mi. drainage area	**Moderate** 43 total feedlots in the 144 sq. mi. drainage area	**Very low** Very low population density in the drainage area	**Low** Potential for migratory waterfowl in nearby shallow basins
Unnamed Creek (-547)	**Moderate** Potentially up to 11 IPHTs in the 28 sq. mi. drainage area	**Moderate** 13 total feedlots in the 28 sq. mi. drainage area	**Very low** Very low population density in the drainage area	**Very low** Very small proportion of drainage area in natural conditions

4. TMDL development

A water body's TMDL represents the loading capacity (LC), or the amount of pollutant that a water body can assimilate while still meeting water quality standards. The LC is allocated to the water body's pollutant sources. The allocations include WLAs for NPDES-permitted sources, LAs for nonpermitted sources (including natural background), and a margin of safety (MOS), which is implicitly or explicitly defined. The sum of the allocations and MOS cannot exceed the LC, or TMDL.

Natural background consideration

"Natural background" is defined in both Minnesota rule and statute: Minn. R. 7050.0150, subp. 4, "Natural causes" means the multiplicity of factors that determine the physical, chemical or biological conditions that would exist in the absence of measurable impacts from human activity or influence." The Clean Water Legacy Act (Minn. Stat. § 114D.10, subd. 10) defines natural background as "characteristics of the water body resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics that affect the physical, chemical or biological conditions in a water body, but does not include measurable and distinguishable pollution that is attributable to human activity or influence."

Natural background was given consideration in the development of LA in this TMDL. Natural background is the landscape condition that occurs outside of human influence. Natural background conditions refer to inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment and therefore natural background is accounted for and addressed through the MPCA's water body assessment process. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study. The source assessment exercises indicate that natural background inputs are generally low compared to livestock, cropland, failing SSTS, and other anthropogenic sources.

Based on the MPCA's water body assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the water bodies' ability to meet state water quality standards. For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL allocation tables and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment. Federal law instructs an agency to distinguish between natural and nonpoint source loads "[w]herever possible." 40 C.F.R. § 130.2(g). However, Minnesota law does not compel the MPCA to develop a separate LA for natural background sources, distinct from other nonpoint sources.

4.1 Phosphorus

4.1.1 Loading capacity methodology

4.1.1.1 Lake Response Model

The modeling software BATHTUB (Version 6.1) was selected to link phosphorus loads with in-lake water quality. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army

Corps of Engineers (Walker 1999). It has been used successfully in many lake studies in Minnesota and throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June through September) mean surface water quality. BATHTUB's timescales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, upstream lakes, direct drainage runoff, the atmosphere, sources internal to the lake, and groundwater; and outputs through the lake outlet, water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments.

System Representation in Model

In typical applications of BATHTUB, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. For this study, the direct drainage runoff and outflow from an upstream tributary or impaired lake (e.g., Artichoke Creek or Lake Pomme de Terre) were defined as separate tributaries to each lake (i.e., segment).

Model Inputs

The input required to run the BATHTUB model includes lake morphometry, climate data, and water quality and flow data for runoff contributing to the lake. Observed lake water quality data are also entered into the BATHTUB program to facilitate model verification and calibration. Lake segment inputs are listed in Table 32; tributary inputs are listed in Table 34 in the *Model Calibration* discussion below.

Climate data used in the lake BATHTUB models are summarized in Table 31. Average annual precipitation rates are based on the Minnesota Climatology Working Group Gridded Precipitation Database of annual average precipitation for the 10-year time-period of 2009 through 2018 at Appleton. Average annual evaporation rates are estimated from the 2009 through 2018 annual average precipitation less the 2008 through 2017 average annual runoff depth for the Pomme de Terre River Watershed at the USGS flow gage in Appleton. Note that flow data were not available in 2018 at the time of the report development. However, the 2008 through 2017, 10-year time-period was used to calculate an average annual runoff depth for the Pomme de Terre River Watershed. Precipitation and evaporation rates apply only to the lake surface areas.

There is some inherent amount of uncertainty associated with this evaporation estimation method because annual runoff measurements are not always directly correlated to annual precipitation measurements. One notable example occurred in 2011 where the PRISM estimate of annual precipitation is the lowest of the 10-year period, but the USGS gage derived runoff estimate is the highest of the 10-year period. These discrepancies could be due to localized differences in the spatial distribution of rainfall patterns used to measure annual precipitation compared to the rainfall patterns of the entire Pomme de Terre River Watershed, which contribute to the generation of annual average runoff measured at the watershed outlet.

Average phosphorus atmospheric deposition loading rates were estimated to be 41.7 milligrams per meter squared per year (mg/m^2-yr) for the Minnesota River Basin (Twaroski et al. 2007), applied over each lake's surface area.

Table 31. 2009-2018 average annual precipitation and evaporation estimates at Appleton, MN.

Year	PRISM Precipitation (in)	Runoff Depth (in)	Evaporation Estimate (in)
2008	--	2.9	24.3
2009	25.1	4.8	20.3
2010	31.7	5.9	25.8
2011	23.3	9.6	13.7
2012	29.8	2.3	27.5
2013	27.7	3.4	24.3
2014	28.5	4.3	24.1
2015	29.5	3.1	26.4
2016	33.0	2.5	30.5
2017	28.0	5.4	22.6
2018	31.2	n/a	n/a
10-year Average	28.8	4.4	24.0

n/a – flow data were not available in 2018 at the time of the report development

Table 32. BATHTUB segment input data for impaired lakes.

Impaired Lake	Surface Area (sq km)	Lake Fetch (km)	Mean Depth (m)	Total Phosphorus	
				(µg/L)	CV (%)
Barrett Lake	2.1433	9.8508	2.59	65.0	10%
North Drywood	1.5695	6.2582	0.63	540.0	12%
South Drywood	0.9348	4.1611	0.77	780.0	34%

CV = Coefficient of variation, defined in BATHTUB as the standard error divided by the mean.

Model Equations

BATHTUB allows a choice among several different phosphorus sedimentation models. The Canfield-Bachmann Lake phosphorus sedimentation model (Canfield Jr. and Bachmann 1981) best represents the lake water quality response of Minnesota lakes, and is the model used by the majority of lake TMDLs in Minnesota. In order to perform a uniform analysis, Canfield-Bachmann Lakes was selected as the standard equation for the study.

Model Calibration

The lake models were calibrated to existing water quality data, found in Table 9 in Section 3.4.1, and then were used to determine the phosphorus LC (TMDL) of each lake.

Because some amount of internal loading is implicit in the BATHTUB lake water quality model, the calibrated internal loading rates from the BATHTUB model represents the excess sediment release rate beyond the average background release rate implicitly accounted for by the model development lake dataset. The BATHTUB model development lake dataset is less representative of the shallow lake type and therefore accounts for less implicit internal loading in shallow lakes.

The predicted in-lake TP concentration was lower than the average observed (monitored) concentration for all impaired lakes. Therefore, an explicit additional load was added to calibrate the lake models (Table 33). It is widely recognized that Minnesota lakes in agricultural regions have histories of high phosphorus loading and/or very poor water quality. For this reason, it is reasonable that internal loading may be higher than that of the lakes in the data set used to derive the Canfield-Bachmann lakes formulation.

Due to the extremely shallow nature and current turbid water, algae-dominated state conditions in North and South Drywood Lakes, the very large amount of excess internal loading needed to calibrate the lake BATHTUB models to existing conditions represents the imbalance between phosphorus loading and in-lake phosphorus concentrations under turbid water, algae-dominated conditions (refer to the hysteresis) relationship between phosphorus loading and algae biomass in shallow lakes, as discussed in Section 3.4.1.1.

Table 33. Impaired lake BATHTUB model calibration values.

Impaired Lake	Calibration Value	Uncalibrated Predicted TP (µg/L)	Calibrated Predicted TP (µg/L)
Barrett Lake	Add 0.33 mg/m2-d of internal/unknown load	62.5	65.0
North Drywood Lake	Add 10.91 mg/m2-d of internal/unknown load	404.5	540.0
South Drywood Lake	Add 17.73 mg/m2-d of internal/unknown load	214.6	780.0

<u>Determination of Lake Loading Capacity</u>

Using the existing conditions model as a starting point, excess internal loading was first reduced to zero to represent internal load reduction through use of an alum treatment or to represent the shift from a turbid water, algae dominated state to a clear water, plant dominated state through the use of biological manipulation to improve lake water clarity. Next, the phosphorus concentrations of upstream, impaired lakes were set at their applicable water quality standards to represent progress towards achieving the TMDLs of upstream impaired lakes. The phosphorus concentrations of upstream, unimpaired lakes were set to their existing phosphorus concentration. Finally, phosphorus concentrations associated with tributaries (include upstream reaches and direct drainage runoff) were reduced until the model indicated that the TP state standard was met, to the nearest whole number. Tributary concentrations needed to achieve the state water quality standard for each impaired lake is summarized in Table 34.

In Table 34, Calibrated TP Concentration refers to the current concentration of TP as modeled by HSPF for the tributary source indicated (upstream direct drainage, lake, etc.). Calibrated TP Load refers to the annual load in pounds delivered per year by the tributary source indicated. These two columns represent the “current modeled state” of the tributaries. “TMDL TP Concentration” refers to the concentration that the tributary source indicated needs to be at in order to achieve water quality standards. Similarly, the “TMDL TP Load" refers to the level of TP loading in pounds that the tributary source would need to be at in order to achieve water quality standards.

Table 34. Tributary and upstream lake calibrated and TMDL TP concentrations and loads for each impaired lake.

Impaired Lake	Tributary	Calibrated TP Concentration (µg/L)	Calibrated TP Load (lb/yr)	TMDL TP Concentration (µg/L)	TMDL TP Load (lb/yr)
Barrett	Direct Drainage	483.56	5,605.9	46.3	536.8
	Lake Pomme de Terre	48.6	7,122.8	48.6	7,122.8
North Drywood Lake	Direct Drainage	855.95	7,482.8	138.0	1,206.4
	Unnamed Creek	784.85	5,125.7	139.0	907.8
	Artichoke Creek	532.31	18,417.1	100.0	3,459.9
	South Drywood Lake	780.00	1,913.4	90.0	220.8
South Drywood Lake	Direct Drainage	854.71	1,880.0	215.5	475.1

Minnesota lake water quality standards are based on a large lake database that establishes a clear relationship between TP, chl-*a*, and Secchi transparency (MPCA 2005). When the TP standard is met, the chl-*a* and Secchi transparency standards will likewise be met (see Section 2.1.1 Lake Eutrophication Applicable Water Quality Standards). With this process, a series of models were developed that included a level of phosphorus loading consistent with lake water quality state standards, or the TMDL goal. Actual load values are calculated within the BATHTUB software, so loads from the TMDL goal models could be compared to the loads from the existing conditions models to determine the amount of load reduction required.

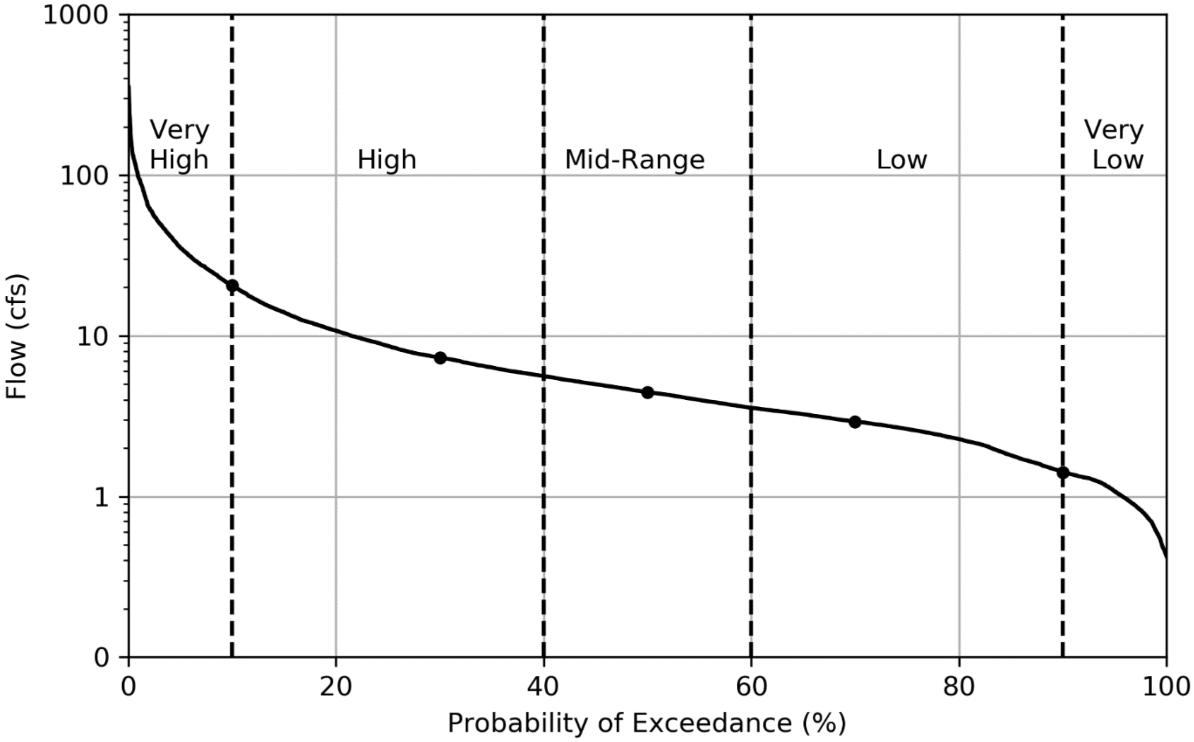
4.1.1.2 Stream Load Capacity and Load Reduction

In order to align with the RES, the LC is based on the seasonal (June through September) average of the midpoint flows of five equally spaced flow zones: 0% to 20%, 20% to 40%, 40% to 60%, 60% to 80%, and 80% to 100% exceeds flows. In other words, the average seasonal flow is the average of the 10%, 30%, 50%, 70%, and 90% exceeds flows (Figure 34). This type of averaging was used over a simple average of all flows in order to limit the bias of very high flows on phosphorus loading, recognizing that the effects of phosphorus (i.e., algal growth) are most problematic at lower flows.

Note that these five flow zones are divided up differently than those used for the *E. coli* and TSS TMDLs. The phosphorus approach is based on using an average of the five flow zones and having five “equally-sized” zones to avoid weighting some zones more than others when calculating the average. The LC was calculated as the average seasonal flow multiplied by the South River Nutrient Region TP standard of 150 µg/L.

The existing concentration of the impaired reach was calculated as the average of the seasonal (June through September) average phosphorus concentrations of the years of available data. The overall estimated concentration-based percent reduction needed to meet each TMDL was calculated as the existing concentration minus the TP standard (150 µg/L), divided by the existing concentration.

Figure 34. Sample flow duration curve from Unnamed Creek (07020002-566) to illustrate calculation of average seasonal flow.



4.1.2 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources. The LA includes all sources of phosphorus that do not require NPDES permit coverage, including boundary conditions, unregulated direct drainage runoff, internal loading, groundwater, and atmospheric deposition, a consideration for natural background conditions, and any other identified loads are described in Section 3.5.2.1 and 3.5.2.2. The LA is calculated as the remaining portion of the LC once the WLA and MOS are subtracted for each impaired lake or stream. The remainder of the LA, after subtraction of atmospheric deposition and internal loading, was used to determine the direct drainage runoff for each impaired lake on an areal basis.

4.1.2.1 Boundary Conditions

Boundary conditions are the LAs assigned to sources within upstream lake subwatersheds. Reductions assigned to these boundary conditions are either based on achieving the water quality standard if the upstream lake is impaired, or zero if the upstream lake currently meets water quality standards. LAs, WLAs and reductions needed to achieve the water quality standards of impaired, upstream lakes are based on the assumptions of the upstream lake TMDL. Therefore, NPDES-permitted sources located in an upstream lake subwatershed are not assigned WLAs as part of any downstream lake TMDLs as these sources would receive WLAs as part of the upstream lake TMDL. Boundary conditions included in this TMDL include Pomme de Terre Lake in the Barrett Lake TMDL and South Drywood Lake in the North Drywood Lake TMDL. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study (Section 3.5.2). For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL tables, and reductions should focus on the major human attributed sources identified in the source assessment.

4.1.3 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources. If a permittee that is assigned a WLA in this report has previously been assigned one or more WLAs for the same pollutant for another TMDL, the applicable permit(s) and/or associated planning documents will need to address the most restrictive WLA.

4.1.3.1 MS4 Regulated Stormwater

There is no Municipal Separate Storm Sewer Systems (MS4) regulated stormwater in the direct drainage area of an impaired lake or stream addressed by this TMDL.

4.1.3.2 Regulated construction stormwater

A categorical WLA was assigned to all regulated construction activity in each impaired subwatershed. The five-year average fraction of each county under construction, reported in the Minnesota Stormwater Manual (Table 35), was area weighted by the percent of each county within each impaired subwatershed to determine the annual average percentage of the subwatershed under construction. Then the annual average percentage of the subwatershed under construction was multiplied by the direct drainage runoff load component to determine the construction stormwater WLA. The direct drainage runoff load component is equal to the total TMDL (LC) minus the sum of other wastewater WLAs, and the MOS. Approximately 0.018% (four acres) of Unnamed Creek (07020002-566) on average was estimated to be under construction over the past five years.

Table 35. County five-year average construction activity for Unnamed Creek (07020002-566).

County	Annual Area Under construction (% of Total Area)
Big Stone	0.017%
Stevens	0.021%
Swift	0.012%

4.1.3.3 Regulated industrial stormwater

There are currently no industrial stormwater permits in the watershed. A categorical industrial stormwater WLA was estimated by the percentage of each county with an active industrial stormwater permit (Table 36) based on permits accessed on February 18, 2020 from the [MPCA Industrial Permit](#) webpage in the event of future industrial stormwater activity.

Table 36. County industrial stormwater permit area as a percent of the total county area for Unnamed Creek (07020002-566).

County	Area Covered by Industrial Stormwater Permit (% of Total Area)
Big Stone	0.009%
Stevens	0.048%
Swift	0.006%

4.1.3.4 Regulated Nonmetallic Mining

There is one active regulated nonmetallic mine in the direct drainage area of an impaired lake or stream addressed by this TMDL (Table 37). A categorical WLA was assigned based on the fraction of the watershed with mining activity, using Google Earth aerial imagery to measure the approximate footprint of each mine. The fraction was multiplied by the LC to determine the industrial stormwater WLA. The TMDL report will not result in new or modified permit limits for the one active regulated nonmetallic mine in the direct drainage area of an impaired lake or stream addressed by this TMDL.

Table 37. Nonmetallic mining sites in the Barrett Lake Watershed.

Site	NPDES Permit Number (Station ID)	Approximate Area Contributing Stormwater (acres)
Aggregate Industries Inc. – Elbow Lake Sand & Gravel (J1-1442)	MNG490073 (SD016)	25

4.1.3.5 Confined Animal Feeding Operations

There is one NPDES permitted CAFO in the direct drainage area of one phosphorus impaired stream (Unnamed Creek, -566). CAFOs and feedlots with 1,000 or more AUs must be designed to contain all manure contaminated runoff from precipitation events of a 25-year, 24-hour storm event. Having and complying with an NPDES permit allows some enforcement protection if a facility discharges due to a 25-year, 24-hour precipitation event and the discharge does not contribute to a water quality impairment. Facilities that are permit compliant are generally not a source of phosphorus to surface waters and these facilities were assigned a zero waste LA consistent with the conditions of the permit.

4.1.3.6 Regulated Municipal and Industrial Wastewater

There are no NPDES-permitted municipal or industrial wastewater facilities whose surface discharge stations fall within the direct drainage area of a TP impaired stream or lake addressed by this TMDL. NPDES-permitted municipal or industrial wastewater facilities located in the direct drainage area of an upstream lake or stream would be subject to WLAs of the upstream water body TMDL, or future TMDL if it were to become impaired. For example, Ashby WWTP discharges upstream of Pomme de Terre Lake (26-0097-00), which is currently meeting state water quality standards for shallow lakes in the North Central Hardwoods Forest ecoregion. As such, Ashby WWTP was not assigned a WLA as part of the Barrett Lake TMDL since no reductions were assigned to upstream Pomme de Terre Lake.

4.1.4 Margin of safety

The MOS accounts for uncertainty about pollutant loadings and water body response. It reflects the degree of characterization and accuracy of the estimates of the source loads and the level of confidence in the analysis of the relationship between the source loads and the impact upon the receiving water. In concept, it ensures attainment and maintenance of water quality standards for the allocated pollutant. As such, it reduces the remaining pollutant allocation to nonpoint and point sources.

An explicit MOS equal to 10% of the LC was used for the North Drywood Lake, South Drywood Lake and Unnamed Creek TMDLs and an explicit MOS equal to 5% of the LC was used for the Barrett Lake TMDL based on the following considerations:

- Larger MOS needed for shallower lakes (North and South Drywood) compared to deeper lakes (Barrett) because of greater uncertainty in the water quality response of shallow lakes to TP load reductions (see Section 3.4.1.1: Shallow Lake Phosphorus and Algae Relationships)
- BATHTUB model calibration using added internal load with values typical of very shallow, eutrophic lakes (see Section 3.5.2.1: Internal Loading)
- Generally good agreement between BATHTUB model predicted and observed values indicating that the models reasonably reflect the conditions in the lakes and their subwatersheds
- Three or more years of in-lake water quality data used to calibrate the BATHTUB model
- Best professional judgement of the overall TMDL development
- Reasonable and achievable WLAs

An explicit 10% MOS was accounted for in the TMDL for Unnamed Creek. This MOS is sufficient to account for uncertainties in predicting phosphorus loads to streams. This explicit MOS is considered to be appropriate based on:

- Some uncertainty extrapolating flows in upstream areas of the watershed based on HSPF-SAM model calibration at stream gages near the outlet of the Pomme de Terre River Watershed
- Two years of monitoring data (2017 to 2018) collected during the TMDL 10-year time-period (2009 through 2018) which did not overlap with HSPF-SAM flow estimates (1996 through 2016) used to estimate the existing seasonal TP loads to the stream
- Allocations that are a function of flow, which vary from high to low flows
- Best professional judgement of the overall TMDL development
- Reasonable and achievable WLAs

In addition to the explicit MOS, an implicit MOS is factored into the TMDL through the use of critical conditions and seasonal variability in the establishment of water quality standards by the State of Minnesota and the use of conservative assumptions in the determination of critical conditions using the monitoring data and the use of a watershed pollutant loading model to determine the contribution of phosphorus from point and nonpoint sources.

4.1.5 Seasonal variation and critical conditions

In-lake and in-stream water quality varies seasonally. In Minnesota lakes and streams, the majority of the watershed phosphorus load often enters the lake during spring runoff. During the summer season months (June through September), phosphorus concentrations may not change drastically if major runoff events do not occur. However, chl-*a* concentrations generally peak during the summer season due to warmer temperatures that foster higher algal growth rates. The summer season also corresponds to the peak recreational period for Minnesota lakes and streams. This seasonal variation in water quality and summer season critical condition is taken into account in the TMDL by using the eutrophication standards (which are based on summer season averages) as the TMDL goals. The load reductions are designed so that the lakes and streams will meet the water quality standards over the course of the summer season when algae levels are typically highest (June through September).

4.1.6 Percent reduction

Phosphorus load reductions were calculated based on the existing average annual load and annual LC for the impaired lakes and the existing average daily load and daily LC for the impaired stream. The estimated percent reductions provide a rough approximation of the overall reduction needed for the water body to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce TP loads in the watershed. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount. TP reduction assigned to a specific source are meant to inform implementation.

4.1.7 TMDL summary

4.1.7.1 Barrett Lake (26-0095-00)

- 303(d) listing year: 2020
- Baseline year(s): 2013, based on the mid-range year of the existing monitoring data used to determine the TP load reduction (2009 through 2017)
- Numeric standard used to calculate TMDL: 40 µg/L TP

Table 38. Barrett Lake (26-0095-00) TP TMDL and allocations.

Barrett Lake Load Component		Existing	Goal		Reduction	
		(lb/yr)	(lb/yr)	(lb/day)	(lb/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	1.4	1.4	0.0038	0.0	0%
	Industrial stormwater (MNR500000)	1.4	1.4	0.0038	0.0	0%
	Total WLA	**2.8**	**2.8**	**0.0076**	**0.0**	
Load Allocations	*Direct drainage runoff*	*5,609.0*	*1,404*	*3.847*	*4,205.0*	*75%*
	*Internal load**	*569.1*	*0.0*	*0.000*	*569.1*	*100%*
	Total Watershed/In-lake	6,178.1	1,404.0	3.847	4,774.1	77%
	Boundary Condition: Lake Pomme de Terre	7,122.9	5,862.3	16.061	1,260.6	18%
	Atmospheric	197.0	197.0	0.540	0.0	0%
	Total LA	**13,498.0**	**7,463.3**	**20.448**	**6,034.7**	
MOS			**393.0**	**1.077**		
TOTAL		**13,500.8**	**7,859.1**	**21.533**	**6,034.7**	**45%**

* The internal load is the excess internal load above background values.

4.1.7.2 North Drywood Lake (76-0169-00)

- 303(d) listing year: 2020
- Baseline year(s): 2010, based on the mid-range year of the existing monitoring data used to determine the TP load reduction (2009 through 2012)
- Numeric standard used to calculate TMDL: 90 µg/L TP

Table 39. North Drywood Lake (76-0169-00) TP TMDL and allocations.

North Drywood Lake Load Component		Existing	Goal		Reduction	
		(lb/yr)	(lb/yr)	(lb/day)	(lb/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	1.2	1.2	0.0033	0.0	0%
	Industrial stormwater (MNR500000)	1.2	1.2	0.0033	0.0	0%
	Total WLA	**2.4**	**2.4**	**0.0066**	**0.0**	
Load Allocations	*Direct drainage runoff*	*7,478.3*	*1,075.4*	*2.944*	*6,402.9*	*86%*
	Failing septics	*2.1*	*0.0*	*0.000*	*2.1*	*100%*
	*Internal load**	*13,788.2*	*0.0*	*0.000*	*13,788.2*	*100%*
	Unnamed Creek	*5,125.7*	*811.1*	*2.221*	*4,314.6*	*84%*
	Artichoke Creek	*18,417.1*	*3,091.2*	*8.463*	*15,325.9*	*83%*
	Total Watershed/In-lake	44,811.4	4,977.7	13.628	39,833.7	89%
	Boundary Condition: South Drywood Lake**	1,913.4	220.8	0.605	1,692.6	88%
	Atmospheric	144.3	144.3	0.395	0.0	0%
	Total LA	**46,869.1**	**5,342.8**	**14.628**	**41,526.3**	
MOS			**593.9**	**1.626**		
TOTAL		**46,871.5**	**5,939.1**	**16.261**	**41,526.3**	**89%**

* The internal load is the excess internal load above background values.

** This value represents the reduction lake outlet concentration.

4.1.7.3 South Drywood Lake (76-0149-00)

- 303(d) listing year: 2020
- Baseline year(s): 2011, based on the mid-range year of the existing monitoring data used to determine the TP load reduction (2011 to 2012)
- Numeric standard used to calculate TMDL: 90 µg/L TP

Table 40. South Drywood Lake (76-0149-00) TP TMDL and allocations.

South Drywood Lake Load Component		Existing	Goal		Reduction	
		(lb/yr)	(lb/yr)	(lb/day)	(lb/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.2	0.2	0.0005	0.0	0%
	Industrial stormwater (MNR500000)	0.2	0.2	0.0005	0.0	0%
	Total WLA	**0.4**	**0.4**	**0.0010**	**0.0**	
Load Allocations	*Direct drainage runoff*	*1,879.6*	*418.6*	*1.146*	*1,461.0*	*78%*
	Failing septics	*0.0*	*0.0*	*0.000*	*0.0*	*0%*
	*Internal load**	*13,345.7*	*0.0*	*0.000*	*13,345.7*	*100%*
	Total Watershed/In-lake	15,225.3	418.6	1.146	14,806.7	97%
	Atmospheric	85.9	85.9	0.235	0.0	0%
	Total LA	**15,311.2**	**504.5**	**1.381**	**14,806.7**	
MOS			**56.1**	**0.154**		
TOTAL		**15,311.6**	**561.0**	**1.536**	**14,806.7**	**97%**

* The internal load is the excess internal load above background values.

4.1.7.4 Unnamed Creek, Unnamed Cr. to Artichoke Cr (07020002-566)

- 303(d) listing year: 2020
- Baseline year(s): 2017, based on the mid-range year of the existing monitoring data used to determine the TP load reduction (2017 to 2018)
- Numeric standard used to calculate TMDL: 150 µg/L TP
- Seasonal flow used to calculate loads is 7 cfs

Table 41. Unnamed Creek (07020002-566) seasonal (June – September) phosphorus TMDL and allocations.

Unnamed Creek 07020002-566		Existing TP Load	Allowable TP Load	Estimated Load Reduction	
TMDL Parameter		(lb/d)	(lb/d)	(lb/d)	(%)
Wasteload Allocations	*Taffe Pork, LLC (MNG440469)*	0	0	0	0%
	Construction stormwater (MNR1000001)	0.001	0.001	0	0%
	Industrial stormwater (MNR050000)	0.0007	0.0007	0	0%
	Total WLA	**0.0017**	**0.0017**	**0**	**0%**
Load Allocation	*Direct drainage runoff*	25.9	5.1	20.8	80%
	Total LA	**25.9**	**5.1**	**20.8**	**80%**
10% Margin of Safety			0.6		
Total Loading Capacity		**25.9**	**5.7**	**20.8**	**80%**

4.2 Total suspended solids

4.2.1 Loading capacity methodology

The loading capacities for impaired stream reaches receiving a TMDL, as a part of this study, were determined using LDCs. The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report, only five points on the entire LC curve are depicted (the midpoints of the designated flow zones). However, the entire curve represents the TMDL and is what the EPA ultimately approves.

Flow and LDCs are used to determine the flow conditions (flow regimes) under which exceedances occur. Flow duration curves provide a visual display of the variation in flow rate for the stream. The x-axis of the plot indicates the percentage of time that a flow exceeds the corresponding flow rate as expressed by the y-axis. LDCs take the flow distribution information, constructed for the stream, and factor in pollutant loading to the analysis. A standard curve is developed by applying a particular pollutant standard or criteria to the stream flow duration curve and is expressed as a load of pollutant per day. The standard curve represents the upper limit of the allowable in-stream pollutant load (LC) at a particular flow. Monitored loads of a pollutant are plotted against this curve to display how they compare to the standard. Monitored values that fall above the curve represent an exceedance of the standard.

For each LDC, continuous flow data were based on HSPF-SAM model simulations for 1996 through 2016. Continuous flow records were based on HSPF-SAM Reach A840 for Pelican Creek (07020002-506). The drainage area of Unnamed Creek (07020002-547) is located within a larger HSPF-SAM subbasin of the Pomme de Terre River mainstem. Continuous flow records were based on area-weighting flow contributions from the HSPF-SAM Subbasin A30 (that is to say, excluding flows from the upstream HSPF-SAM Reaches) to the drainage area of Unnamed Creek (07020002-547). The loading capacities were determined by applying the applicable TSS water quality standard to the flow duration curve to produce a TSS standard curve. The TSS loading capacities presented in the allocation tables represent the median TSS load (lb/day) along the TSS standard curve within each flow regime. A TSS LDC and a TMDL allocation table are provided for each stream in Section 4.2.6.

The existing TSS loads for Pelican Creek (07020002-506) were based on TSS concentration data collected at monitoring stations S014-255 and S004-410 from April through September during the TMDL 10-year time period of 2009-2018 paired with HSPF-SAM simulated flows by date. The existing TSS loads for Unnamed Creek (07020002-547) were based on TSS concentration data collected at monitoring station S009-449 from April through September during the TMDL 10-year time period of 2009 through 2018 paired with HSPF-SAM simulated flows by date.

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve.

4.2.2 Load allocation methodology

The LA is allocated to existing or future nonpermitted sources of TSS, as described in Section 3.5.2.3, that are located downstream of any other impaired waters with TMDLs located in the Pomme de Terre River Watershed. The remainder of the LC (TMDL) after subtraction of the MOS and WLAs was used to determine the LA for each impaired stream, on an areal basis.

Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study (Section 3.5.2.3). For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL tables, and reductions should focus on the major human attributed sources identified in the source assessment.

4.2.3 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources. If a permittee that is assigned a WLA in this report has previously been assigned one or more WLAs for the same pollutant for another TMDL, the applicable permit(s) and/or associated planning documents will need to address the most restrictive WLA.

4.2.3.1 MS4 Regulated Stormwater

There is no MS4 regulated stormwater in a TSS impaired stream drainage area addressed by this TMDL.

4.2.3.2 Regulated Construction Stormwater

A categorical WLA was assigned to all regulated construction activity in each impaired subwatershed. The five-year average fraction of each county under construction, reported in the Minnesota Stormwater Manual (Table 42), was area weighted by the percent of each county within each impaired subwatershed to determine the annual average percentage of the subwatershed under construction. Then the annual average percentage of the subwatershed under construction was multiplied by the direct drainage runoff load component to determine the construction stormwater WLA. The direct drainage runoff load component is equal to the total TMDL (LC) minus the sum of other wastewater WLAs, and the MOS. Approximately 0.035% (30 acres) of Pelican Creek (07020002-506) on average was estimated to be under construction over the past five years.

Table 42. Construction activity covered under the Construction Stormwater General Permit, by county for Pelican Creek (07020002-506).

County	Annual Area Under Construction (% of total area)
Douglas	0.049%
Grant	0.025%
Otter Tail	0.033%

4.2.3.3 Regulated Industrial Stormwater

There are currently no industrial stormwater permits in the watershed. In the event of future industrial stormwater activity, a categorical industrial stormwater WLA was estimated by the percentage of each county with an active industrial stormwater permit (Table 43) based on permits accessed on February 18, 2020, from the MPCA Industrial Permit webpage.

Table 43. County Industrial Stormwater Permit area as a percent of the total county area for Pelican Creek (07020002-506).

County	Industrial Stormwater Permit Area (% of total area)
Douglas	0.02%
Grant	0.0005%
Otter Tail	0.14%

4.2.3.4 Regulated Municipal and Industrial Wastewater

An individual WLA was provided for each NPDES-permitted municipal or industrial wastewater facility whose surface discharge stations fall within an impaired stream subwatershed. There is one NPDES-permitted municipal or industrial wastewater facility, the Ashby WWTP (MNG580087) located within the TSS impaired reach subwatershed. The WLA was set equal to the current NPDES permit effluent limit (45 mg/L) and the maximum daily flow of 0.782 mgd (6 inches per day of discharge volume from the secondary pond surface area), resulting in a monthly average TSS permit limit of 133 kg/day. The NPDES permit for WWTPs may contain water quality based effluent limits that account for the nonvolatile suspended solids (NVSS) characteristics of the discharge. Such limits would be consistent with the assumptions and requirements of the TMDLs' WLAs.

4.2.4 Margin of safety

The MOS accounts for uncertainty about pollutant loadings and water body response. It reflects the degree of characterization and accuracy of the estimates of the source loads and the level of confidence in the analysis of the relationship between the source loads and the impact upon the receiving water. In concept, it ensures attainment and maintenance of water quality standards for the allocated pollutant. As such, it reduces the remaining pollutant allocation to nonpoint and point sources.

An explicit MOS equal to 10% of the LC was used for the stream TMDLs based on the following considerations:

- Sufficient monitoring data available for the impaired reaches
- Adequate calibration and validation of the HSPF model
- Some inherent uncertainty in flow estimates by HSPF-SAM models
- One year of monitoring data (2016) collected during the TMDL 10-year time period (2009 through 2018) that overlapped with HSPF-SAM flow estimates (1996 through 2016) to estimate existing TSS loads for the LDCs
- Allocations that are a function of flow, which vary from high to low flows
- Best professional judgement of the overall TMDL development
- Reasonable and achievable WLAs

In addition to the explicit MOS, an implicit MOS is factored into the TMDL through the use of critical conditions and seasonal variability in the establishment of water quality standards by the State of Minnesota and the use of conservative assumptions in the determination of critical conditions using the monitoring data and the use of a watershed pollutant loading model to determine the contribution of sediment from point and nonpoint sources.

4.2.5 Seasonal variation and critical conditions

The TSS water quality standard applies for the period April through September which corresponds to the open water season when aquatic organisms are most active and when high stream TSS concentrations generally occur. TSS loading varies with the flow regime and season. Spring is associated with large flows from snowmelt, the summer is associated with the summer season as well as periodic storm events and receding streamflows, and the fall brings increasing precipitation and rapidly changing agricultural landscapes.

Critical conditions and seasonal variation are addressed in this TMDL through several mechanisms. The TSS standard applies during the open water months, and data were collected throughout this period. The water quality analysis conducted on these data evaluated variability in flow through the use of five flow regimes: from high flows, such as flood events, to low flows, such as baseflow. Through the use of LDCs and monthly summary figures, TSS loading was evaluated at actual flow conditions at the time of sampling (and by month).

4.2.6 Percent reduction

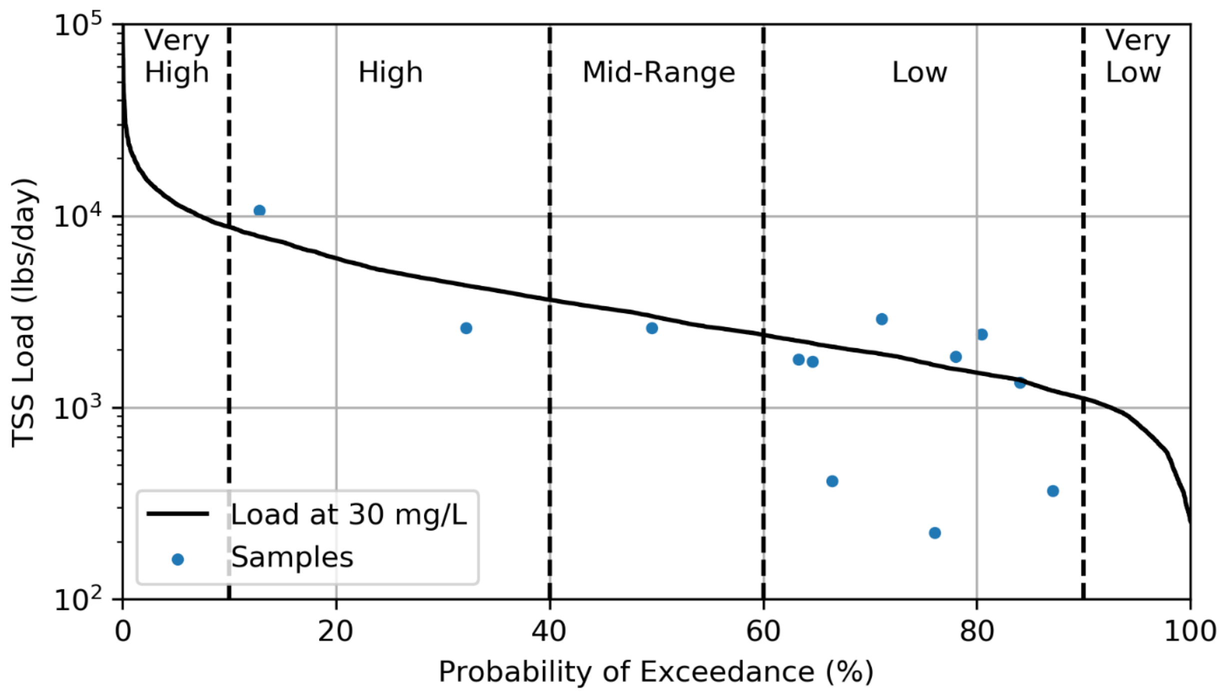
TSS load reductions were calculated based on the existing 10-year 90th percentile TSS concentration reduction needed to achieve the applicable state water quality standard for each impaired stream. The estimated percent reductions provide a rough approximation of the overall reduction needed for the water body to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce TSS concentrations in the watershed. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount.

4.2.7 TMDL summary

4.2.7.1 TSS TMDL: Pelican Creek, T130 R41W S4, north line to Pomme de Terre R. (07020002-506)

- 303(d) listing year: 2020
- Baseline year(s): 2017, based on the mid-range year of the existing monitoring data used to determine the TSS concentration reduction (2016 through 2018)
- Numeric standard used to calculate TMDL: 30 mg/L TSS
- Exceedances are occurring during high and low flows. However, we cannot rule out that exceedances are not occurring at the other flow ranges due to the small number of samples collected.

Figure 35. TSS load duration curve: Pelican Creek, T130 R41W S4, north line to Pomme de Terre R. (07020002-506).



Continuous flow based on HSPF-SAM Reach A840 simulated for 1996 through 2016. Existing TSS loads based on TSS concentration data from monitoring stations S014-255 and S004-410 collected during the 10-year TMDL time-period of 2009 through 2018.

Table 44. Pelican Creek (07020002-506) TSS TMDL and allocations.

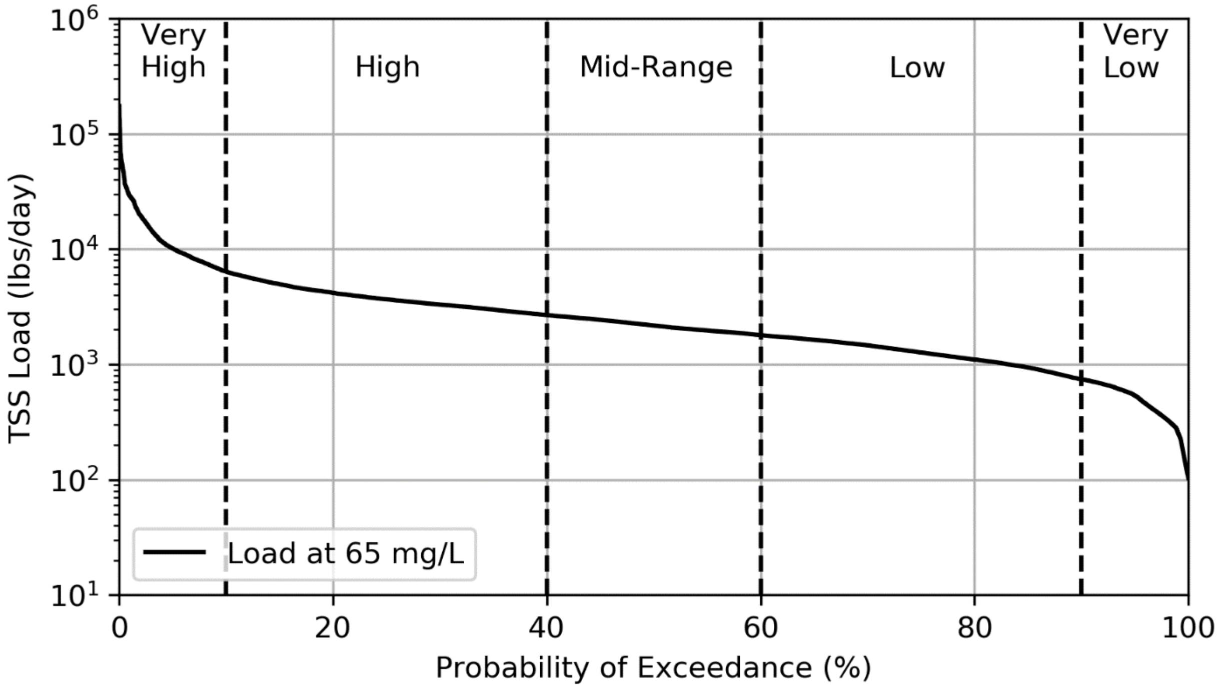
Pelican Creek (07020002-506)		Flow Regime				
		Very High (cfs)	High (cfs)	Mid-Range (cfs)	Low (cfs)	Very Low (cfs)
		71.4	**31.6**	**18.3**	**10.6**	**5.1**
TMDL Parameter		**Total Suspended Solids (lb/day)**				
Waste Load Allocations	*Ashby WWTP (MNG580087)*	293.0	293.0	293.0	293.0	293.0
	Construction stormwater (MNR1000001)	1.3	0.6	0.3	0.2	0.1
	Industrial stormwater (MNR050000)	3.0	1.3	0.8	0.4	0.2
	Total WLA	**297.3**	**294.9**	**294.1**	**293.6**	**293.3**
Load Allocations	*Direct drainage runoff*	4,899.9	2,005.0	1,035.6	478.4	79.9
	Total LA	**4,899.9**	**2,005.0**	**1,035.6**	**478.4**	**79.9**
10% Margin of Safety		577.5	255.6	147.8	85.8	41.5
Total Loading Capacity		**5,774.7**	**2,555.5**	**1,477.5**	**857.8**	**414.7**
Existing 90th percentile TSS concentration (mg/L)		41				
Percent Reduction to Achieve 30 mg/L TSS Standard*		27%				

*The reduction was estimated using a concentration reduction based approach to ensure that the 90th percentile TSS concentration will be achieved.

4.2.7.2 TSS TMDL: Unnamed Creek, Unnamed Creek to Pomme de Terre R. (07020002-547)

- 303(d) listing year: 2024
- Baseline year(s): 2017, based on the mid-range year of the existing monitoring data used to determine the TSS concentration reduction (2017-2018)
- Numeric standard used to calculate TMDL: 65 mg/L TSS

Figure 36. TSS load duration curve: Unnamed Creek, Unnamed Creek to Pomme de Terre R. (07020002-547).



Continuous flow records were based on area-weighting flow contributions from the HSPF-SAM Subbasin A30 (that is to say, excluding flows from the upstream HSPF-SAM reaches) to the drainage area of Unnamed Creek (07020002-547). Existing TSS loads were based on TSS concentration data from monitoring station S009-449 collected during the 10-year TMDL time-period of 2009 through 2018. No TSS concentration data were collected from Unnamed Creek (07020002-547) during the HSPF-SAM model time-period (1996 through 2016) to calculate existing TSS loads. Samples collected for the assessment were collected in 2017 and 2018 and therefore do not appear as a reference on the LDC.

Table 45. Unnamed Creek (07020002-547) TSS TMDL and allocations.

Unnamed Creek (07020002-547)		Flow Regime				
		Very High (cfs)	High (cfs)	Mid-Range (cfs)	Low (cfs)	Very Low (cfs)
		28.9	10.5	6.2	3.6	1.5
TMDL Parameter		Total Suspended Solids (lb/day)				
Existing Load*		NA	NA	NA	NA	NA
Wasteload Allocations	*Outback Five Inc. (MNG440126)*	*0*	*0*	*0*	*0*	*0*
	Farmco Supply LLP - Sec 34 (MNG440548)	*0*	*0*	*0*	*0*	*0*
	District 45 Dairy (MNG440749)	*0*	*0*	*0*	*0*	*0*
	Fairfield Hog Farm (MNG441057)	*0*	*0*	*0*	*0*	*0*
	Construction stormwater (MNR1000001)	*1.4*	*0.5*	*0.3*	*0.2*	*0.1*
	Industrial stormwater (MNGR050000)	*1.7*	*0.6*	*0.4*	*0.2*	*0.1*
	Total WLA	**3.1**	**1.1**	**0.7**	**0.4**	**0.2**
Load Allocations	*Direct drainage runoff*	*9,116.0*	*3,301.5*	*1,954.4*	*1,140.1*	*480.8*
	Total LA	**9,116.0**	**3,301.5**	**1,954.4**	**1,140.1**	**480.8**
10% Margin of Safety		1,013.2	367	217.2	126.7	53.5
Total Loading Capacity		10,132.3	3,669.6	2,172.3	1,267.2	534.5
Existing 90th percentile TSS concentration (mg/L)		100				
Percent Reduction to Achieve 65 mg/L TSS Standard**		35%				

* Water quality data collected after HSPF model simulation so there are no paired flow regimes to list as existing loads.

**Concentration based reduction calculated from 90th percentile concentration of 2017-2018 assessment data, see section 4.2.6.

4.3 *E. coli*

4.3.1 Loading capacity methodology

The loading capacities for impaired stream reaches receiving a TMDL, as a part of this study, were determined using LDCs. The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report, only five points on the entire LC curve are depicted (the midpoints of the designated flow zones). However, the entire curve represents the TMDL and is what the EPA ultimately approves.

Flow and LDC are used to determine the flow conditions (flow regimes) under which exceedances occur. Flow duration curves provide a visual display of the variation in flow rate for the stream. The x-axis of the plot indicates the percentage of time that a flow exceeds the corresponding flow rate as expressed by the y-axis. LDCs take the flow distribution information constructed for the stream and factor in pollutant loading to the analysis. A standard curve is developed by applying a particular pollutant standard or criteria to the stream flow duration curve and is expressed as a load of pollutant per day. The standard curve represents the upper limit of the allowable in-stream pollutant load (LC) at a particular flow. Monitored loads of a pollutant are plotted against this curve to display how they compare to the standard. Monitored values that fall above the curve represent an exceedance of the standard.

For each LDC, continuous flow data were based on HSPF-SAM model simulations for 1996 through 2016. Continuous flow records were based on HSPF-SAM Reach A840 for Pelican Creek (07020002-506) and HSPF-SAM Reach A310 for Muddy Creek (07020002-511). The drainage area of Unnamed Creek (07020002-547) is located within a larger HSPF-SAM subbasin of the Pomme de Terre River mainstem. Continuous flow records were based on area-weighting flow contributions from the HSPF-SAM subbasin A30 (that is to say, excluding flows from the upstream HSPF-SAM reaches) to the drainage area of Unnamed Creek (07020002-547).

The loading capacities were determined by applying the *E. coli* water quality standard to the flow duration curve to produce a bacteria standard curve. For Muddy Creek the more stringent *E. coli* standard for Class 2 waters of 126 cfu/100 mL was applied instead of the Class 7 water quality standard. Muddy Creek is directly upstream of the Pomme de Terre River Muddy (Mud) Creek to Minnesota River (Marsh Lake) reach, which has a fecal coliform TMDL (Stevens County SWCD 2008). Loading capacities presented in the allocation tables represent the median *E. coli* load (in billion org/day) along the bacteria standard curve within each flow regime. A bacteria LDC and a TMDL allocation table are provided for each stream in Section 4.3.6.

The existing *E. coli* loads for Pelican Creek (07020002-506) were based on *E. coli* concentration data collected at monitoring station S004-410 from April through October during the TMDL 10-year time period of 2009 through 2018 paired with HSPF-SAM simulated flows by date. The existing *E. coli* loads for Muddy Creek (07020002-511) were based on *E. coli* concentration data collected at monitoring station S004-412 from April through October during the TMDL 10-year time period of 2009 through 2018 paired with HSPF-SAM simulated flows by date. No *E. coli* concentration data were collected from Unnamed Creek (07020002-547) during the HSPF-SAM model time-period (1996 through 2016) to calculate existing *E. coli* loads.

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve.

4.3.2 Load allocation methodology

The LA is allocated to existing or future nonpermitted sources of *E. coli*, as described in Section 3.5.2.4, that are located downstream of any other impaired waters with TMDLs located in the Pomme de Terre River Watershed. The remainder of the LC (TMDL) after subtraction of the MOS and WLAs was used to determine the LA for each impaired stream, on an areal basis.

Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study (Section 3.5.2.3). For all impairments addressed in this TMDL report, natural background sources are implicitly included in the LA portion of the TMDL tables, and reductions should focus on the major human attributed sources identified in the source assessment.

4.3.3 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources. If a permittee that is assigned a WLA in this report has previously been assigned one or more WLAs for the same pollutant for another TMDL, the applicable permit(s) and/or associated planning documents will need to address the most restrictive WLA.

4.3.3.1 NPDES/SDS permitted animal feeding operations

NPDES permitted, SDS permitted, and CAFOs not requiring permits are required to be designed and operated in a manner such that they have zero discharge. WLAs are not assigned to these AFOs; this is equivalent to a WLA of zero. All other non-CAFO feedlots and the land application of all manure are accounted for in the LA for nonpermitted sources.

CAFOs located within an impaired reach subwatershed are shown in (Table 46). Due to the requirements of permitted CAFOs to completely contain runoff, facilities that are permit compliant are not a source of *E. coli* to surface waters and these facilities were assigned a zero waste LA consistent with the conditions of the permit. There are no CAFOs in the Pelican Creek Watershed.

Table 46. CAFOs in *E. coli* impaired reach subwatersheds.

Impaired Reach (AUID)	Name	Permit	Number of Animal Units (AU)
Muddy Creek (07020002-511)	Loren Schmidgall Farm – Site 1	MNG440002	1,200
	Farmco Supply LLP –Sec. 5	MNG440270	990
	Martys Swine Systems Inc – East Site	MNG440830	990
	Martys Swine Systems Inc – West Site	MNG440831	990
	West Line Pork	MNG441061	990
Unnamed Creek (07020002-547)	Outback Five Inc.	MNG440126	1,250
	Farmco Supply LLP – Sec 34	MNG440548	990
	District 45 Dairy	MNG440749	11,495
	Fairfield Hog Farm	MNG441057	990

Municipal and industrial wastewater

An individual WLA was provided for all NPDES-permitted WWTPs that have fecal coliform discharge limits (200 org/100 mL, March 1 through October 31) and whose surface discharge stations fall within an impaired stream subwatershed.

The WLAs are based on *E. coli* loads even though the facilities' discharge limits are based on fecal coliform. Like *E. coli*, fecal coliform is an indicator of fecal contamination. The primary function of a bacterial effluent limit is to assure that the effluent is being adequately disinfected to ensure a complete or near-complete kill of fecal bacteria prior to discharge (MPCA 2007). Stabilization pond WWTPs are required to test fecal coliform bacteria levels in effluent twice per week during discharge. Dischargers to Class 2 waters are required to meet fecal coliform bacteria from April through October while wastewater disinfection is required during all months for dischargers within 25 miles of a potable water supply system intake (Minn. R. 7053.0215, subp. 1). The geometric mean for all samples collected in a month must not exceed 200 cfu/100 mL fecal coliform bacteria.

The *E. coli* concentration standard of 126 organisms per 100 mL was considered reasonably equivalent to the previous fecal coliform standard of 200 organisms per 100 mL from a public health protection standpoint. The SONAR section that supports this rationale uses a log plot that shows a good relationship between these two parameters. The following regression equation was deemed reasonable to convert any data reported in fecal coliform to *E. coli* equivalents:

E. coli concentration (equivalents) = 1.80 x (fecal coliform concentration)

It should also be noted that most analytical laboratories report *E. coli* in terms of cfu/100 mL, not organisms per 100 mL. This TMDL report will present *E. coli* data in cfu/100 mL since all of the monitored data collected for this TMDL were reported in these units. Bacteria TMDLs were written to achieve the bacteria water quality standard of 126 org/100 mL.

There are three NPDES-permitted WWTPs whose surface discharge stations fall within the direct drainage of an *E. coli* impaired stream. These WWTPs are pond systems with intermittent discharges and must disinfect from May to October. Bacteria loads from NPDES-permitted WWTP are estimated based on the design flow and permitted bacteria effluent limit of 200 cfu/100 mL (Table 47). There are no WWTPs contributing to the Unnamed Creek (07020002-547) drainage.

Table 47. WWTP design flows and permitted bacteria loads.

Impaired Reach (AUID)	Facility Name, Permit #	Surface Discharge Station	Design Flow (mgd)	Permitted Bacteria Load as Fecal Coliform: 200 cfu/ 100 mL (billion cfu/day)	Equivalent Bacteria Load as *E. coli*: 126 cfu / 100 mL (billion cfu/day)
Pelican Creek (07020002-506)	Ashby WWTP, MNG580087	SD-001	0.101	0.76	0.48
Muddy Creek (07020002-511)	Alberta WWTP, MNG580002	SD-001	0.023	0.17	0.11
Muddy Creek (07020002-511)	Chokio WWTP, MNG580007	SD-001	0.098	0.47	0.74

Note: There is no WWTP in the unnamed creek (07020002-547).

4.3.4 Margin of safety

The MOS accounts for uncertainty about pollutant loadings and water body response. It reflects the degree of characterization and accuracy of the estimates of the source loads and the level of confidence in the analysis of the relationship between the source loads and the impact upon the receiving water. In concept, it ensures attainment and maintenance of water quality standards for the allocated pollutant. As such, it reduces the remaining pollutant allocation to nonpoint and point sources.

An explicit MOS equal to 10% of the LC was used for the stream TMDLs based on the following considerations:

- Sufficient monitoring data available for the impaired reaches
- Adequate calibration and validation of the HSPF model

- Some inherent uncertainty in flow estimates by HSPF-SAM models
- Allocations that are a function of flow, which vary from high to low flows
- Bacteria re-growth in sediments, die-off, and natural background levels that are not accounted for in the LDC methodology
- Best professional judgement of the overall TMDL development
- Reasonable and achievable WLAs

In addition to the explicit MOS, an implicit MOS is factored into the TMDL through the use of critical conditions and seasonal variability in the establishment of water quality standards by the State of Minnesota and the use of conservative assumptions in the determination of critical conditions using the monitoring data and other statewide databases to determine the contribution of *E. coli* from point and nonpoint sources.

4.3.5 Seasonal variation and critical conditions

Use of these water bodies for aquatic recreation occurs from April through October, which includes all or portions of the spring, summer, and fall seasons. *E. coli* loading varies with the flow regime and season. Spring is associated with large flows from snowmelt, the summer is associated with the growing season as well as periodic storm events and receding streamflows, and the fall brings increasing precipitation and rapidly changing agricultural landscapes.

Critical conditions and seasonal variation are addressed in this TMDL through several mechanisms. The *E. coli* standard applies during the recreational period, and data were collected throughout this period. The water quality analysis conducted on these data evaluated variability in flow through the use of five flow regimes: from high flows, such as flood events, to low flows, such as baseflow. Through the use of LDCs and monthly summary figures, *E. coli* loading was evaluated at actual flow conditions at the time of sampling (and by month), and monthly *E. coli* concentrations were evaluated against precipitation and streamflow.

4.3.6 Percent reduction

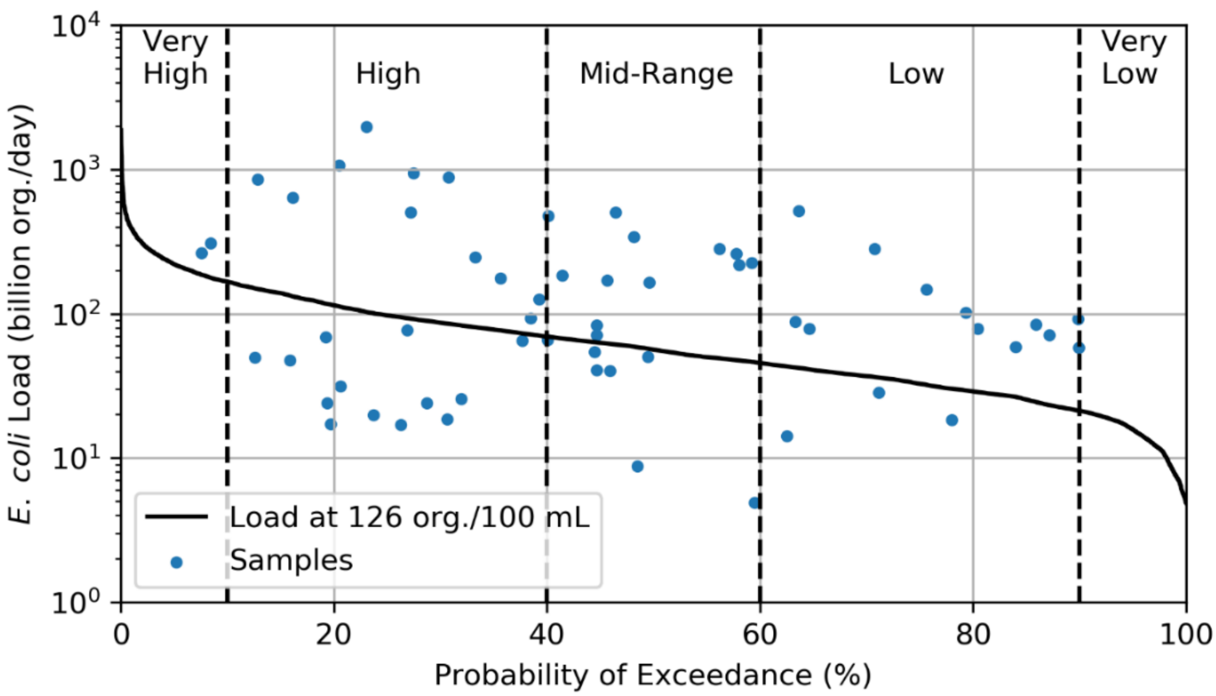
E. coli load reductions were calculated based on the mid-point of the existing *E. coli* load and the mid-point of the LC within each flow regime. The estimated percent reductions provide a rough approximation of the overall reduction needed for the water body to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce *E. coli* loads in the watershed. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount.

4.3.7 TMDL summary

4.3.7.1 *E. coli* TMDL: Pelican Creek, T130 R41W S4, north line to Pomme de Terre R. (07020002-506)

- 303(d) listing year: 2020
- Baseline year(s): 2013, based on the mid-range year of the existing monitoring data used to determine the *E. coli* load reduction (2010 through 2016)
- Numeric standard used to calculate TMDL: 126 org./100 mL *E. coli*
- Sample points indicate a pervasive impairment in all flow zones where samples were taken this suggests a variety of sources are responsible for the impairment

Figure 37. Pelican Creek (07020002-506) *E. coli* load duration curve.



Continuous flow based on HSPF-SAM reach A840 simulated for 1996 through 2016. Existing *E. coli* loads were based on *E. coli* concentration data from monitoring station S004-410 collected during the 10-year TMDL time-period of 2009 through 2018.

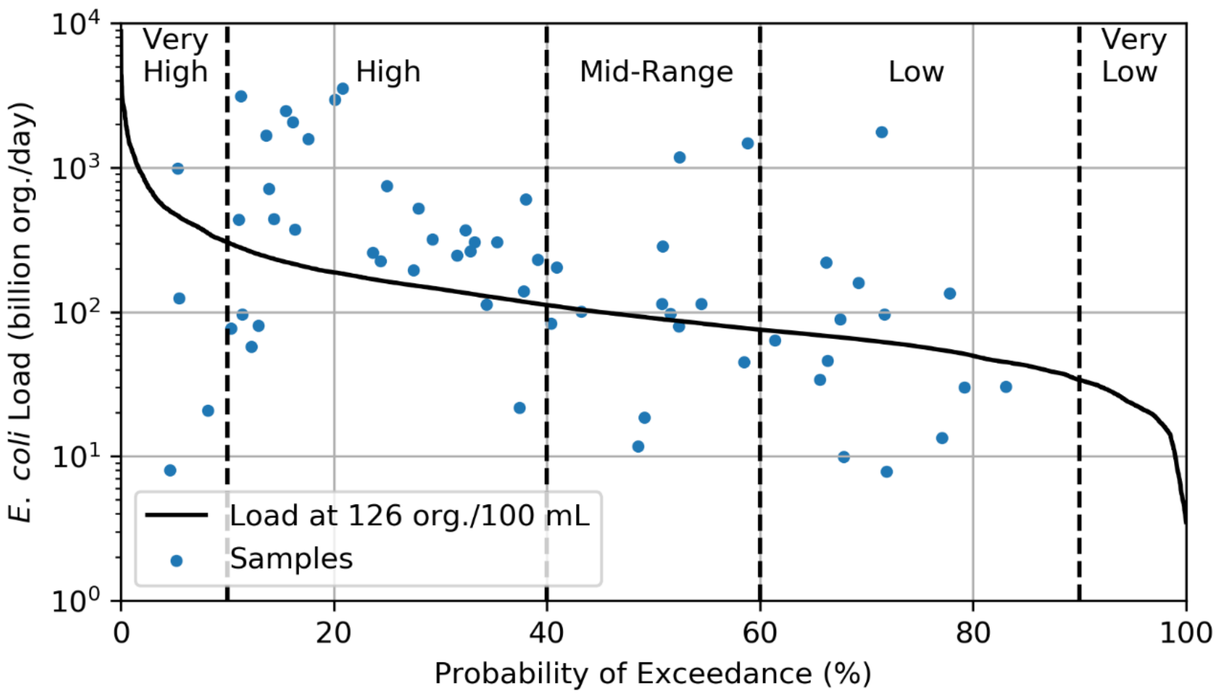
Table 48. Pelican Creek (07020002-506) *E. coli* TMDL and allocations.

Pelican Creek (07020002-506)		Flow Regime				
		Very High (cfs)	**High (cfs)**	**Mid-Range (cfs)**	**Low (cfs)**	**Very Low (cfs)**
		71.4	**31.6**	**18.3**	**10.6**	**5.1**
TMDL Parameter		***E. coli* (billion organisms per day)**				
Existing Load		**285.9**	**73.0**	**165.5**	**78.5**	**NA**
Wasteload Allocations	*Ashby WWTP (MNG580087)*	0.5	0.5	0.5	0.5	0.5
	Total WLA	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Load Allocations	*Direct drainage runoff*	197.5	87.2	50.2	28.9	13.7
	Total LA	**197.5**	**87.2**	**50.2**	**28.9**	**13.7**
10% Margin of Safety		22.0	9.7	5.6	3.3	1.6
Total Loading Capacity		**220.0**	**97.4**	**56.3**	**32.7**	**15.8**
Estimated Load Reduction		*65.90*	*NA*	*109.2*	*45.8*	*NA*
		23%	*NA*	*66%*	*58%*	*NA*

4.3.7.2 *E. coli* TMDL: Muddy Creek, T124 R44W S3, west line to Pomme de Terre R. (07020002-511)

- 303(d) listing year: 2020
- Baseline year(s): 2013, based on the mid-range year of the existing monitoring data used to determine the *E. coli* load reduction (2010 through 2016)
- Numeric standard used to calculate TMDL: 126 org./100 mL *E. coli*
- Aside from the very high and the very low flow ranges, the evidence points to a clear *E. coli* impairment. The prevalence of high *E. coli* loads in low, mid and high range flows suggests a variety of sources are responsible for the impairment.

Figure 38. Muddy Creek (07020002-511) *E. coli* load duration curve.



Continuous flow is based on HSPF-SAM reach A310 simulated for 1996 through 2016. Existing *E. coli* loads were based on *E. coli* concentration data from monitoring station S004-412 collected during the 10-year TMDL time-period of 2009 through 2018.

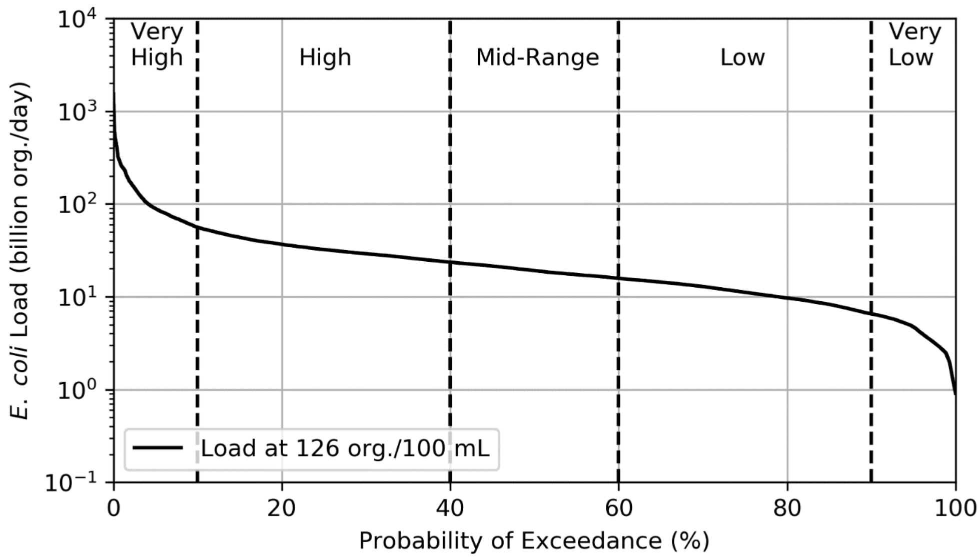
Table 49. Muddy Creek (07020002-511) *E. coli* TMDL and allocations.

Muddy Creek 07020002-511		Flow Regime				
		Very High (cfs)	High (cfs)	Mid - Range (cfs)	Low (cfs)	Very Low (cfs)
		155.8	52.7	29.4	18.6	7.5
TMDL Parameter		*E. coli* (billion organisms per day)				
Existing Load		**73.1**	**320.3**	**100.4**	**54.8**	**NA**
Wasteload Allocation	*Loren Schmidgall Farm - Site 1 (MNG440002)*	0	0	0	0	0
	Farmco Supply LLP - Sec 5 (MNG440270)	0	0	0	0	0
	Martys Swine Systems Inc - East Site (MNG440830)	0	0	0	0	0
	Martys Swine Systems Inc - West Side (MNG440831)	0	0	0	0	0
	West Line Pork (MNG441061)	0	0	0	0	0
	Riverview LLP - Baker Dairy (not available)	0	0	0	0	0
	Alberta WWTP (MNG580002)	0.1	0.1	0.1	0.1	0.1
	Chokio WWTP (MNG580007)	0.5	0.5	0.5	0.5	0.5
	Total WLA	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
Load Allocations	*Direct drainage runoff*	431.8	145.5	80.8	51.1	20.2
	Total LA	**431.8**	**145.5**	**80.8**	**51.1**	**20.2**
10% Margin of Safety		48.0	16.2	9.1	5.7	2.3
Total Loading Capacity		**480.4**	**162.3**	**90.5**	**57.4**	**23.1**
Estimated Load Reduction		*NA*	*158.0*	*9.9*	*NA*	*NA*
		NA	*49%*	*10%*	*NA*	*NA*

4.3.7.3 *E. coli* TMDL: Unnamed Creek, Unnamed Creek to Pomme de Terre R. (07020002-547)

- 303(d) listing year: 2024
- Baseline year(s): 2017, based on the mid-range year of the existing monitoring data used to determine the *E. coli* concentration reduction (2017 through 2018)
- Numeric standard used to calculate TMDL: 126 org./100 mL *E. coli*

Figure 39. Unnamed Creek (07020002-547) *E. coli* load duration curve.



Continuous flow records were based on area-weighting flow contributions from the HSPF-SAM subbasin A30 (that is to say, excluding flows from the upstream HSPF-SAM reaches) to the drainage area of Unnamed Creek (07020002-547). No *E. coli* concentration data were collected from Unnamed Creek (07020002-547) during the HSPF-SAM model time-period (1996 through 2016) to calculate existing *E. coli* loads. Samples collected for the assessment were collected in 2017 and 2018 and therefore do not appear as a reference on the LDC.

Table 50. Unnamed Creek (07020002-547) *E. coli* TMDL allocations.

Unnamed Creek (07020002-547)		Flow Regime				
		Very High	High	Mid - Range	Low	Very Low
		28.9	10.5	6.2	3.6	1.5
TMDL Parameter		***E. coli* (billion organisms per day)**				
Existing Load*		**NA**	**NA**	**NA**	**NA**	**NA**
Wasteload Allocations (WLA)	*Outback Five Inc. (MNG440126)*	*0*	*0*	*0*	*0*	*0*
	Farmco Supply LLP - Sec 34 (MNG440548)	*0*	*0*	*0*	*0*	*0*
	District 45 Dairy (MNG440749)	*0*	*0*	*0*	*0*	*0*
	Fairfield Hog Farm (MNG441057)	*0*	*0*	*0*	*0*	*0*
	Total WLA	**0**	**0**	**0**	**0**	**0**
Load Allocations (LA)	*Direct drainage runoff*	*80.2*	*29.1*	*17.2*	*10.0*	*4.2*
	Total LA	**80.2**	**29.1**	**17.2**	**10.0**	**4.2**
10% Margin of Safety		8.9	3.2	1.9	1.1	0.5
Total Loading Capacity		**89.1**	**32.3**	**19.1**	**11.1**	**4.7**
Existing average monthly geometric mean *E. coli* concentration (org/100 mL)**		1,802				
Percent reduction to achieve 126 org/100 mL *E. coli* standard***		93%				

* Water quality data collected after HSPF model simulation so there are no paired flow regimes to list as existing loads.

**Derived from 2017-2018 assessment data.

*** The percent reduction needed to meet the standard was calculated as the maximum monthly observed geometric mean concentration minus the geometric mean standard (126 org/100 mL) divided by the maximum monthly observed geometric mean concentration.

5. Future growth considerations

The top economic activity in the Pomme de Terre River Watershed is agriculture. Land use is not expected to change much in the future. In addition, the population in the Pomme de Terre River Watershed has increased only slightly (0.14%) from 2010 through 2020 (U.S. Census Bureau 2020). Large increases in urban or rural population are not expected in this watershed. How changing sources of pollutants may or may not impact TMDL allocations are discussed below, in the event that population and land use in the Pomme de Terre Watershed do change over time.

5.1 New or expanding permitted MS4 WLA transfer process

Future transfer of direct drainage runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries.

1. One or more nonregulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
2. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an urban area at the time the TMDL was completed, but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
3. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL (see sections 4.1.3, 4.2.3, and 4.3.3). In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

5.2 New or expanding wastewater

The MPCA, in coordination with the EPA Region 5, has developed a streamlined process for setting or revising WLAs for new or expanding wastewater discharges to water bodies with an EPA approved TMDL for TSS or *E. coli* (MPCA 2012). This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target and will ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying any and all WLAs will be handled by the MPCA, with input and involvement by the EPA, once a permit request or reissuance is submitted. The overall process will use the permitting public notice process to allow for the public and EPA to comment on the permit changes based on the proposed WLA modification(s). Once any comments or concerns are addressed, and the MPCA determines that the new or expanded wastewater discharge is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made.

For more information on the overall process, visit the MPCA's TMDL Policy and Guidance webpage.

6. Reasonable assurance

"Reasonable assurance" shows that elements are in place, for both permitted and nonpermitted sources, that are making (or will make) progress toward needed pollutant reductions.

6.1 Reduction of permitted sources

6.1.1 Permitted construction stormwater

Regulated construction stormwater was given a categorical WLA is this study. Construction activities disturbing one acre or more are required to obtain NPDES permit coverage through the MPCA. Compliance with TMDL requirements are assumed when a construction site owner/operator meets the conditions of the General Stormwater Permit for Construction Activity (MNR100001) and properly selects, installs, and maintains all BMPs required under the permit, including any applicable additional BMPs required in Section 23 of the Construction General Permit for discharges to impaired waters, or compliance with local construction stormwater requirements if they are more restrictive than those in the State General Permit.

6.1.2 Permitted industrial stormwater

Industrial stormwater was given a categorical WLA in this study. Industrial activities require permit coverage under the state's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS Nonmetallic Mining/Associated Activities General Permit (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS permit and properly selects, installs, and maintains BMPs sufficient to meet the benchmark values in the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report.

6.1.3 Permitted wastewater

All municipal and industrial wastewater NPDES/SDS permits in the watershed will reflect limits consistent with WLAs described herein. Discharge monitoring is conducted by permittees and routinely submitted to the MPCA for review.

NPDES/SDS permits for discharges that may cause or have reasonable potential to cause or contribute to an exceedance of a water quality standard are required to contain water quality-based effluent limits (WQBELs) consistent with the assumptions and requirements of the WLAs in this TMDL report. Attaining the WLAs, as developed and presented in this TMDL report, is assumed to ensure meeting the water quality standards for the relevant impaired waters listings. During the permit issuance or reissuance process, wastewater discharges will be evaluated for the potential to cause or contribute to violations of water quality standards. WQBELs will be developed for facilities whose discharges are found to have a reasonable potential to cause or contribute to pollutants above the water quality standards. The WQBELs will be calculated based on low flow conditions, may vary slightly from the TMDL WLAs, and will include concentration based effluent limitations.

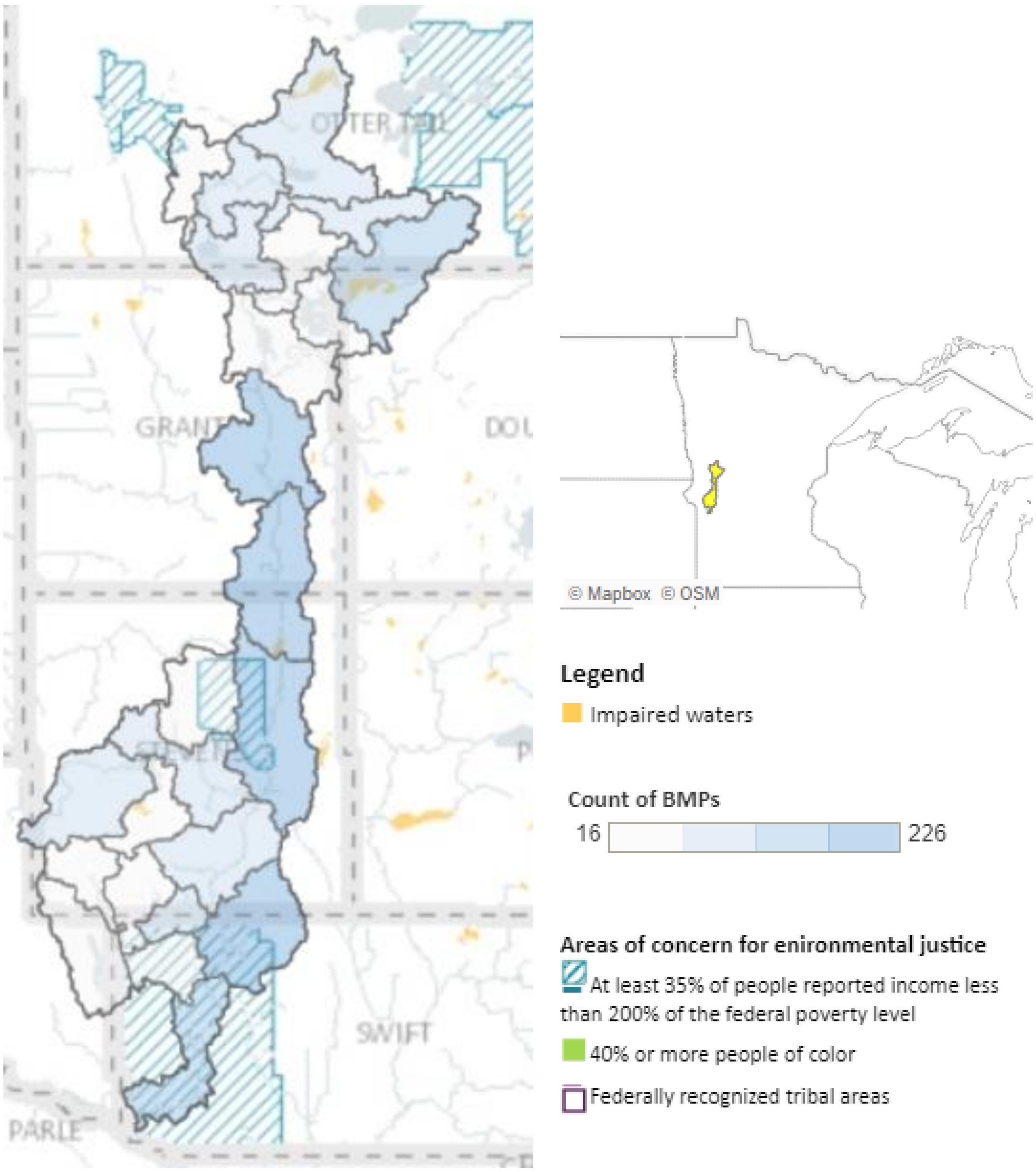
6.1.4 Permitted feedlots

See the discussion of the state's Feedlot Program in Section 6.2.2, which applies to both permitted and nonpermitted feedlots.

6.2 Reduction of nonpermitted sources

Several nonpermitted reduction programs exist to support implementation of nonpoint source reduction BMPs in the Pomme de Terre River Watershed. These programs identify BMPs, provide means of focusing BMPs, and support their implementation via state initiatives, ordinances, and/or dedicated funding. Figure 40 shows the number of BMPs per subwatershed, as tracked on the [MPCA's Healthier Watersheds website]().

Figure 40. Number of BMPs per subwatershed in the Pomme de Terre River Watershed; data from the MPCA's Healthier Watersheds website (April 2024).



The six counties and soil and water conservation districts (SWCDs) founded the PDTRA in 1981 to implement conservation practices in the Pomme de Terre River Watershed. The PDTRA consists of a Technical Advisory Committee (TAC) and a Joint Powers Board (JPB). TAC members are technicians and professionals in the water field that consist of a county and SWCD representative from each of the six counties (Otter Tail, Grant, Douglas, Big Stone, Swift, and Stevens). Similarly, JPB members consist of a county commissioner and SWCD supervisors from each of the six counties. TAC members provided technical guidance for the JPB, which is the governing authority for the association. The association is a watershed project, meaning that they are strictly a voluntary and grant funded/nonconventionally funded organization.

There are many opportunities available through local, county, state, and federal programs to address the pollutant loads in the Pomme de Terre River Watershed. These programs include incentive programs, operations and maintenance programs, a capital improvement program, regulatory and enforcement programs, data collection and monitoring, and outreach and engagement programs. A more detailed description of each of these types of programs is provided in the Pomme de Terre River CWMP (see Section 6.3). Through the PDTRA, local government units in the Pomme de Terre River Watershed utilize joint resources to coordinate programs within the watershed when appropriate. Through the implementation of the Pomme de Terre River CWMP, the PDTRA will continue this coordination and information-sharing platform to effectively remove and/or reduce phosphorus, TSS, and *E. coli* loads going forward.

The following examples describe large-scale programs that have proven to be effective and/or will reduce pollutant loads going forward.

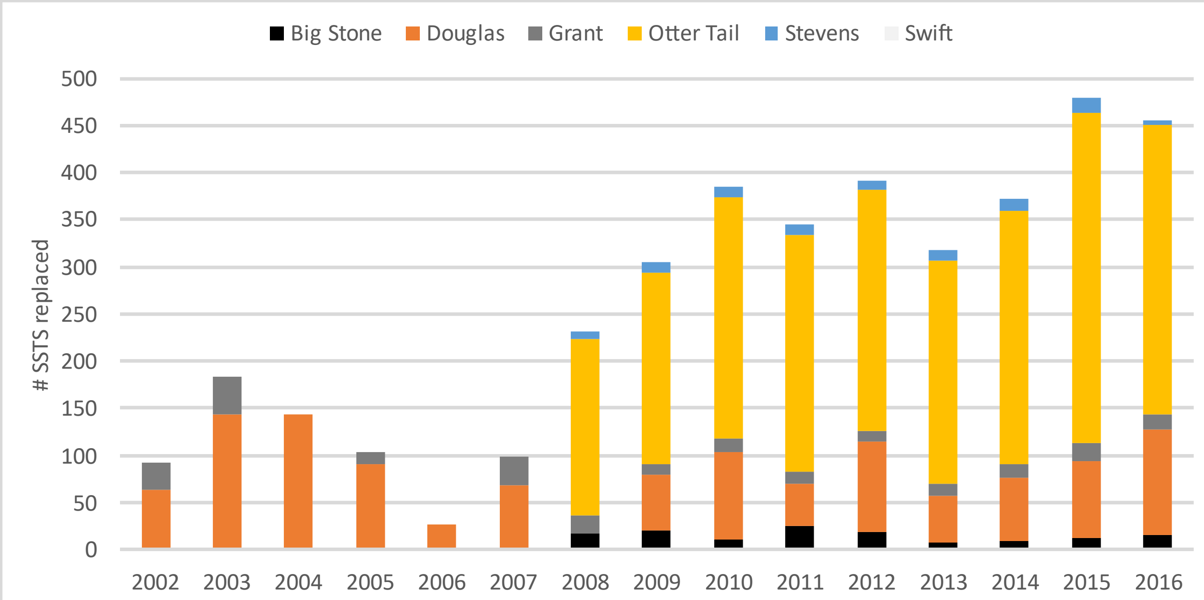
6.2.1 SSTS regulation

SSTS are regulated through Minn. Stat. §§ 115.55 and 115.56. SSTS specific rule requirements can be found in Minn. R. 7080 through 7083. Regulations include the following:

- Minimum technical standards for individual and mid-size SSTS
- A framework for local units of government to administer SSTS programs
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee
- Various ordinances for SSTS installation, maintenance, and inspection

Each county maintains an SSTS ordinance, in accordance with Minn. Stat. and Minn. R., establishing minimum requirements for regulation of SSTS, for the treatment and dispersal of sewage within the applicable jurisdiction of the county, to protect public health and safety, to protect groundwater quality, and to prevent or eliminate the development of public nuisances. Ordinances serve the best interests of the county's citizens by protecting health, safety, general welfare, and natural resources. In addition, each county zoning ordinance prescribes the technical standards that on-site septic systems are required to meet for compliance and outlines the requirements for the upgrade of systems found not to be in compliance. This includes systems subject to inspection at transfer of property, upon the addition of living space that includes a bedroom and/or a bathroom, and at discovery of the failure of an existing system. Between 2002 and 2016, the counties within the drainage area to an impaired lake or stream addressed by this TMDL in the Pomme de Terre River Watershed have, on average, replaced 262 systems per year (Figure 41).

Figure 41. SSTS replacements by county by year.



All known IPHT are recorded in a statewide database by the MPCA. From 2006 to 2019, 797 alleged straight pipes were tracked by the MPCA statewide, 765 of which were abandoned, fixed, or were found not to be a straight pipe system. The remaining known, unfixed, straight pipe systems have received a notice of noncompliance and are currently within the 10-month deadline to be fixed, have been issued Administrative Penalty Orders, or are docketed in court. The MPCA, through the Clean Water Partnership Loan Program, has awarded over $1,000,000 to counties within the Pomme de Terre River Watershed to provide low interest loans for SSTS upgrades since 2010. More information on SSTS financial assistance can be found at the following MPCA's SSTS financial assistance webpage.

6.2.2 Feedlot Program

The MPCA's Feedlot Program addresses both permitted and nonpermitted feedlots. The Feedlot Program implements rules governing the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation wastes. Minn. R. ch. 7020 regulates feedlots in the state of Minnesota. All feedlots are subject to this rule. The focus of the rule is on animal feedlots and manure storage areas that have the greatest potential for environmental impact.

The Feedlot Program is implemented through cooperation between MPCA and delegated county governments in 50 counties in the state. The MPCA works with county representatives to provide training, program oversight, policy and technical support, and formal enforcement support when needed. A county participating in the program has been delegated authority by the MPCA to administer the Feedlot Program. These delegated counties receive state grants to help fund their feedlot programs based on the number of feedlots in the county and the level of inspections they complete. In recent years, annual grants given to these counties statewide totaled about two million dollars (MPCA 2017). The delegated counties in the project area for this report are Big Stone, Douglas, Stevens, Swift, and the counties that are not delegated are Grant and Otter Tail. In the counties that are not delegated, the MPCA is tasked with running the Feedlot Program.

From 2010 through December 2023, there were 107 feedlot facility inspections in the Pomme de Terre River Watershed, with 82 of those inspections occurring at non-CAFO facilities and 25 at CAFO facilities.

6.2.3 Minnesota buffer law

Minnesota's buffer law (Minn. Stat. § 103F.48) requires perennial vegetative buffers of up to 50 feet along lakes, rivers, and streams and buffers of 16.5 feet along ditches. These buffers help filter out phosphorus, nitrogen, and sediment. Alternative practices are allowed in place of a perennial buffer in some cases. Amendments enacted in 2017 clarify the application of the buffer requirement to public waters, provide additional statutory authority for alternative practices, address concerns over the potential spread of invasive species through buffer establishment, establish a riparian protection aid program to fund local government buffer law enforcement and implementation, and allowed landowners to be granted a compliance waiver until July 1, 2018, when they filed a compliance plan with the appropriate SWCD.

The Board of Water and Soil Resources (BWSR) provides oversight of the buffer program, which is primarily administered at the local level. Compliance with the buffer law ranges from 94% to 100% for counties in the impaired lake and stream drainage areas addressed by this TMDL study in the Pomme de Terre River Watershed as of January 2023 (Table 51).

Table 51. Compliance with Minnesota buffer law as of January 2023 (data from BWSR, available on https://bwsr.state.mn.us/ under Buffer Program Update).

County	Compliance with buffer law (%)
Douglas	94%-100%
Grant	94%-100%
Otter Tail	94%-100%
Stevens	94%-100%
Swift	94%-100%
Big stone	94%-100%

6.2.4 Minnesota Agricultural Water Quality Certification Program

The Minnesota Agricultural Water Quality Certification Program (MAWQCP) is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Those who implement and maintain approved farm management practices will be certified and, in turn, obtain regulatory certainty for a period of 10 years.

Through this program, certified producers receive:

- Regulatory certainty: certified producers are deemed to be in compliance with any new water quality rules or laws during the period of certification.
- Recognition: certified producers may use their status to promote their business as protective of water quality
- Priority for technical assistance: producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality

Through this program, the public receives assurance that certified producers are using conservation practices to protect Minnesota's lakes, rivers, and streams. Since the start of the program in 2014, the program has achieved the following (estimates as of April 2024):

- Enrolled 1,070,586 acres

- Included 1,487 producers
- Added 2,887 new conservation practices
- Kept over 48,217 tons of sediment out of Minnesota rivers
- Saved 144,006 tons of soil and 60,299 lb of phosphorus on farms per year
- Up to 48% reduction in Nitrogen loss
- Cut greenhouse gas emissions by 52,570 tons annually

Approximately 13,985 acres in the Pomme de Terre River Watershed are certified under the MAWQCP (through June, 2021).

6.2.5 Minnesota Nutrient Reduction Strategy

The Minnesota Nutrient Reduction Strategy (MPCA 2014) and the Five-Year Progress Report on Minnesota's Nutrient Reduction Strategy (MPCA 2020) guide activities that support nitrogen and phosphorus reductions in Minnesota water bodies and those water bodies downstream of the state (e.g., Lake Winnipeg, Lake Superior, and the Gulf of Mexico). The Nutrient Reduction Strategy was developed by an interagency coordination team with help from public input. Fundamental elements of the Nutrient Reduction Strategy include:

- Defining progress with clear goals
- Building on current strategies and success
- Prioritizing problems and solutions
- Supporting local planning and implementation
- Improving tracking and accountability

Included within the strategy discussion are alternatives and tools for consideration by drainage authorities, information on available tools and approaches for identifying areas of phosphorus and nitrogen loading and tracking efforts within a watershed, and additional research priorities. The Nutrient Reduction Strategy is focused on incremental progress and provides meaningful and achievable nutrient load reduction milestones that allow for better understanding of incremental and adaptive progress toward final goals. The strategy has set a reduction of 45% for both phosphorus and nitrogen in the Mississippi River (relative to average 1980 to 1996 conditions).

Successful implementation of the Nutrient Reduction Strategy will require broad support, coordination, and collaboration among agencies, academia, local government, and private industry. The MPCA is implementing a framework to integrate its water quality management programs on a major watershed scale, a process that includes:

- IWM
- Assessment of watershed health
- Development of WRAPS reports
- Management of NPDES and other regulatory and assistance programs

This framework will result in nutrient reduction for the basin as a whole and the major watersheds within the basin. Minnesota's NRS is currently undergoing an update to be completed in late 2025 that will include a focus on strategies to increase adoption of BMPs.

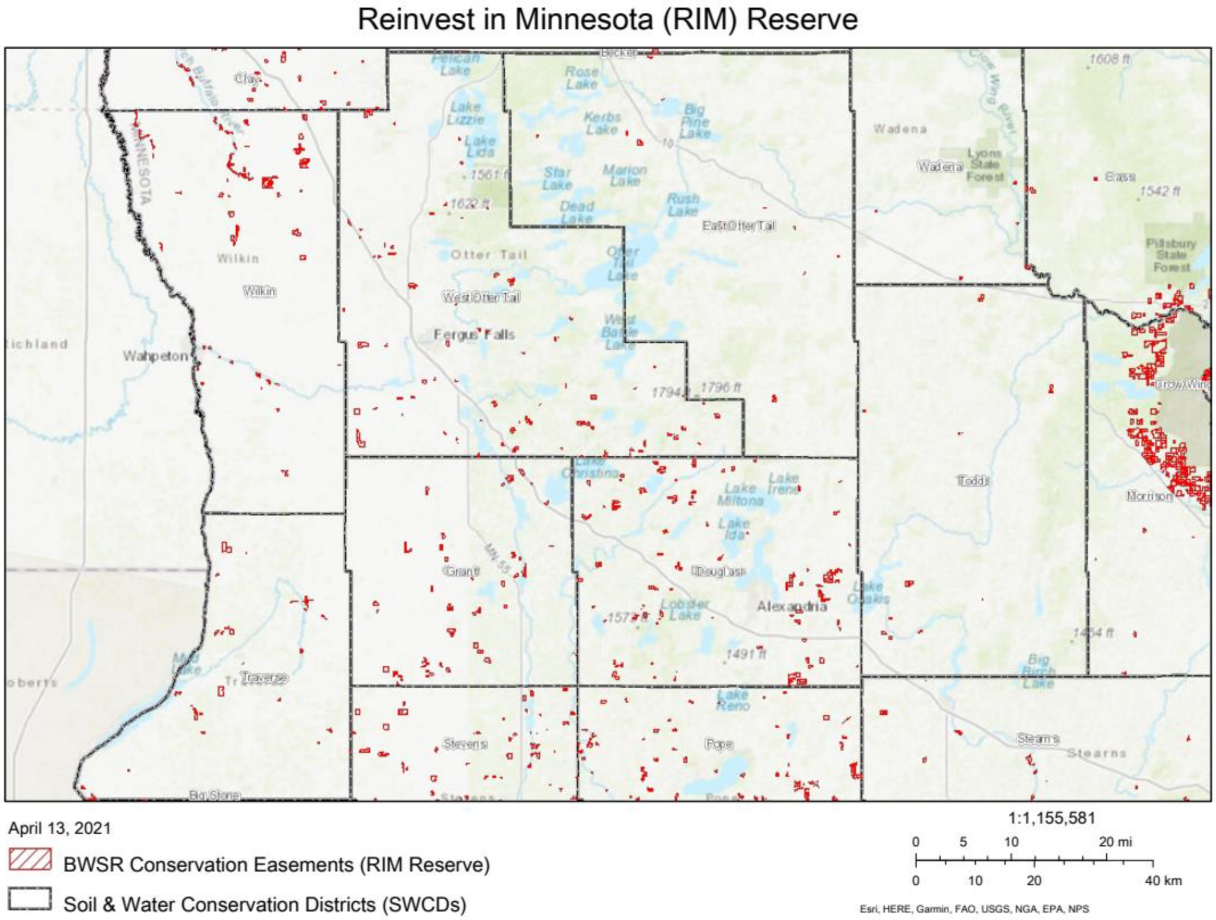
6.2.6 Conservation easements

Conservation easements are a critical component of the state's efforts to improve water quality by reducing soil erosion, reducing phosphorus and nitrogen loading, and improving wildlife habitat and flood attenuation on private lands. Easements protect the state's water and soil resources by permanently restoring wetlands, adjacent native grassland wildlife habitat complexes, and permanent riparian buffers. In cooperation with county SWCDs, State and Federal programs compensate landowners for granting conservation easements and establishing native vegetation habitat on economically marginal, flood prone, environmentally sensitive, or highly erodible lands. These easements vary in length of time from 10 years to permanent/perpetual easements. Types of conservation easements in Minnesota include Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Reinvest in Minnesota (RIM), and the Wetland Reserve Program (WRP) or Permanent Wetland Preserve (PWP). As of August 2020, in the three counties in the impaired lake and stream drainage areas addressed by this TMDL report in the Pomme de Terre River Watershed, there were 88,069 acres of short-term conservation easements such as CRP and 16,140 acres of long term or permanent easements (CREP, RIM, WRP) (Table 52).

Table 52. Conservation lands summary as of August 2020 for the counties that are located in the impaired lake and stream drainage areas addressed by this TMDL report in the Pomme de Terre River Watershed (data from BWSR).

County	Conservation Lands Enrollment (acres)					County Area
	CRP	CREP	RIM	RIM WRP	WRP	
Douglas	17,332	2,306	1,647	1,501	914	460,928
Grant	24,845	507	1,175	1,247	1,214	368,557
Otter Tail	45,892	1,085	2,303	1,027	1,214	1,423,923
Total	**88,069**	**3,898**	**5,125**	**3,775**	**3,342**	**2,253,408**

Figure 42. Reinvest In Minnesota by county.



6.3 Summary of local plans

Minnesota has a long history of water management by local government, which included developing water management plans along county boundaries since the 1980s. The BWSR-led One Watershed, One Plan (1W1P) program is rooted in work initiated by the Local Government Water Roundtable (Association of Minnesota Counties, Minnesota Association of Watershed Districts, and Minnesota Association of SWCDs). The Roundtable recommended that local governments organize to develop focused implementation plans based on watershed boundaries. That recommendation was followed by the legislation (Minn. Stat. § 103B.801) that would establish the 1W1P program, which provides policy, guidance, and support for developing CWMPs:

- Align local water planning purposes and procedures on watershed boundaries to create a systematic, watershed-wide, science-based approach to watershed management.
- Acknowledge and build off existing local government structure, water plan services, and local capacity.
- Incorporate and make use of data and information, including watershed restoration and protection strategies.
- Solicit input and engage experts from agencies, citizens, and stakeholder groups; focus on implementation of prioritized and targeted actions capable of achieving measurable progress.

- Serve as a substitute for a comprehensive plan, local water management plan, or watershed management plan developed or amended, approved, and adopted.

The PDTRA completed a CWMP as part of the BWSR 1W1P program. The Pomme de Terre River Watershed CWMP was approved by the BWSR on August 26, 2020. The goal of the CWMP is to develop a systematic, watershed-wide, science-based approach to watershed management. Since the CWMP was approved the PDTRA has been awarded $1,673,367 in Watershed Based Implementation Funding (WBIF).

The 1W1P for the Pomme de Terre River Watershed developed a framework to prioritize issues and areas in the watershed for the next ten-year timeframe (2021 through 2030). The Plan identifies five priority areas where the majority of the work will be completed in the next 10 years (see Section 2.4 Prioritizing Issues and Resources of the CWMP). These priority areas were identified using local values; high-level priorities identified in the state's Nonpoint Priority Funding plan; various modeling tools (e.g., Zonation conservation model and watershed pollutant loading model results) and current impairment results. The five priority areas include (from north to south, Figure 43): Northern Lakes Area, Christina/Pelican Lakes Area, Pomme de Terre River Lakes Chain Area (which includes Barrett Lake), Pomme de Terre River Corridor (which includes Unnamed Creek), and the Drywood Creek Area (which includes Unnamed Creek and North and South Drywood Lakes). Mud Creek and Pelican Creek are not included in any of the priority areas and therefore will not be a priority during the next 10-years (2021 through 2030). However, the 1W1P includes watershed-wide goals that will benefit Mud Creek and Pelican Creek.

Through public input and the review of previous reports of the watershed, the Plan identified 11 priority issues that address:

- Drinking Water Protection,
- Groundwater Conservation,
- Altered Hydrology,
- Poor Quality Lakes,
- High Quality Lakes,
- Protect and Restore Perennial Cover and Shallow Basins,
- Excess Pollutants,
- Loss of In-Stream Habitat,
- Aquatic Invasive Species,
- Watershed Outreach, and
- Lakeshore Owner Education.

Some priority issues are unique to a priority area and others are an issue for the entire watershed. The Plan identified 20 measurable goals, which were developed to address the priority issues in the 10-year timeframe of the plan. Specific and targeted implementation activities were identified that are needed to achieve plan goals.

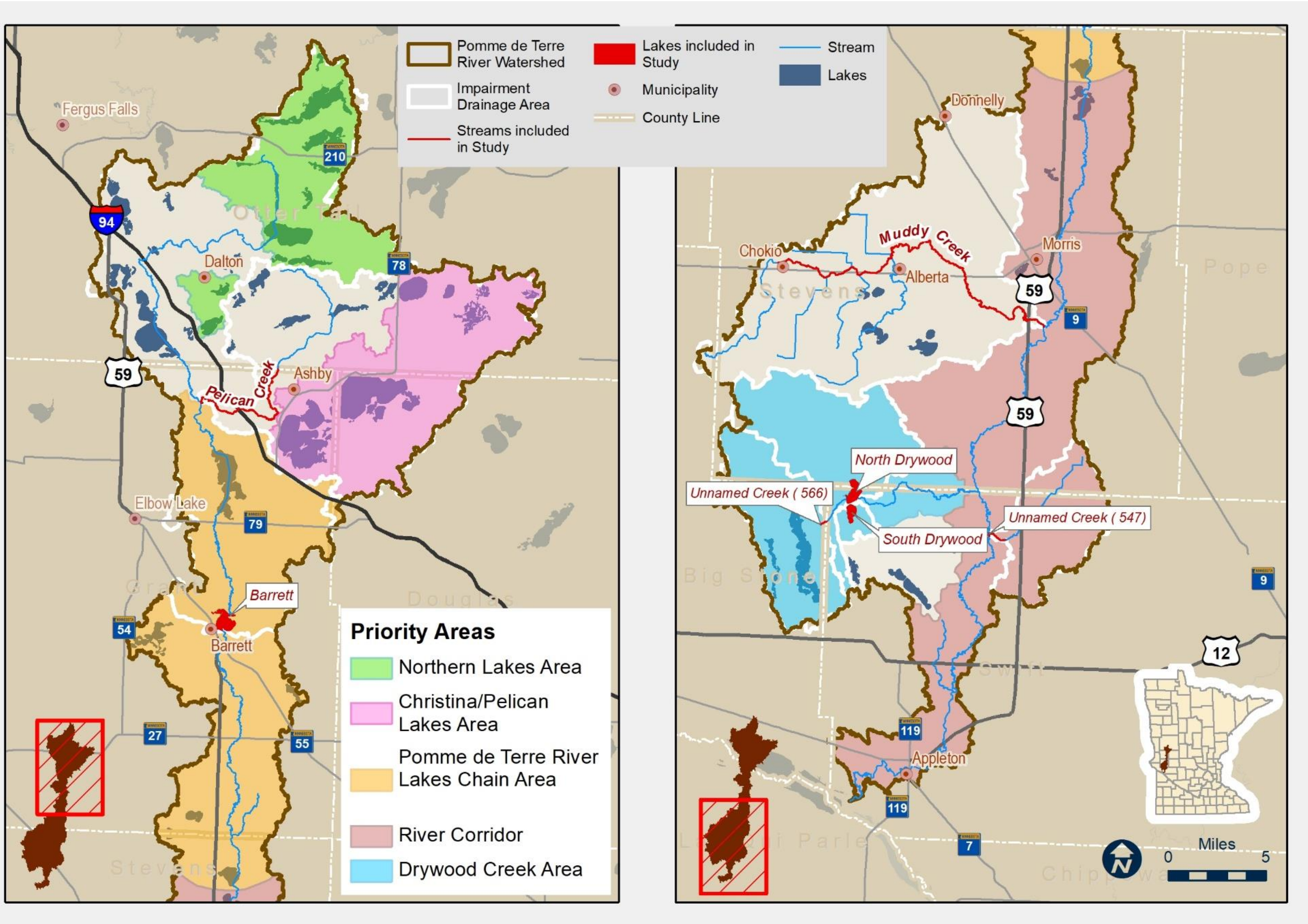
Three of these issues, Altered Hydrology, Poor Quality Lakes, and Excess Pollutants have measurable goals and implementation strategies that will directly benefit impaired waters in this TMDL.

- Altered Hydrology is a watershed-wide issue that is being addressed in the 1W1P with the overall goal of returning the hydrology of the watershed to a more natural state by reducing the annual runoff in the watershed. The long-term goal is to reduce annual runoff by 0.5 inches over the entire watershed. Restoring the hydrologic conditions will directly improve impairments in the watershed by limiting the amount of runoff from the landscape that carries TSS, *E. coli*, and TP to impaired water bodies.
- Poor Quality Lakes are defined by specific lakes that are impaired by eutrophication and will be prioritized first. The long-term goal for these lakes is to reduce the load below the TMDL. Barrett Lake is one of the priority lakes. The North and South Drywood Lakes are not a priority for the next 10-year timeframe. However, practices built within the subwatershed to Artichoke Lake, a priority lake upstream of the Drywood Lakes, will reduce loads to Drywood Lake.
- The Excess Pollutants issue is focused on the stream corridors of the Pomme de Terre River and Drywood Creek Areas. In these areas excess pollutants are causing sediment and eutrophication problems in streams, including Unnamed Creek. As part of this issue, the long-term goal for phosphorus is based on the 2014 Minnesota Nutrient Reduction Strategy goals to reduce phosphorus pollution by 12% by 2025 from baseline conditions (mid-1990s). This goal will directly benefit Unnamed Creek and Drywood Lakes by implementing practices in the watershed that will reduce phosphorus loads from the watershed.

For each issue in the CWMP, measurable goals were identified and a targeted implementation schedule was developed to define when and where actions will be implemented in the Pomme de Terre River Watershed. The targeted implementation schedule includes both structural and programmatic elements to achieve the goals of the plan. The targeted implementation schedule includes the following information:

- Implementation activities for the priority issues and concerns (actions)
- Link to the corresponding priority concern(s) and goal(s)
- Location targeting where action will occur
- Estimated cost
- Estimated time when implementation of the activity will occur within the 10-year timeframe of the Plan
- Project lead and project partners
- Description of how outcomes of the action will be measured

Figure 43. Pomme de Terre River Watershed CWMP priority areas.



6.4 Examples of pollution reduction efforts

The PDTRA promotes conservation by providing design work, construction, and partial funding for BMPs and many conservation practices that have proven to be effective and/or will reduce pollutant loads going forward, such as rain gardens, alternative tile intakes, water and sediment control basins (WASCOB), shoreline restorations, stream barbs, cattle exclusions, and enrollment of land in CRPs. Between 2011 and 2021, PDTRA has been able to bring $2.5 million in tax-generated grant funds for the benefit of improving water resources through project implementation (Table 53), resulting in an estimated TP reduction of 89,368 lb/yr and a total sediment reduction of 74,422 tons/yr.

Table 53. Pomme de Terre River Watershed BMP and conservation practice implementation grants since 2011-2021.

Project	Grant Dollars	Leveraged Funds Including Local Match	Phosphorus Reduction (lb/yr)	Sediment Reduction (ton/yr)
2011 Pomme de Terre Watershed BMPs	$257,610	$1,344,594	39,283	39,247
2012 Pomme de Terre River Watershed BMPS – Phase II	$350,470	$169,671	20,426	20,441
2013 Pomme de Terre River Watershed BMP Implementation Initiative	$480,228	$149,617	9,914	9,948
2014 Pomme de Terre River Watershed BMP Implementation Project	$274,815	$333,132	1,733	1,971
2015 Pomme de Terre River WRAPS Implementation Plan	$387,146	$1,740,154	17,799	2,602
2017 Pomme de Terre WRAPS Implementation Plan	$302,171	$129,416	213	213
2019 Pomme de Terre WRAPS Implementation Plan	$541,775	TBD	TBD	TBD
TOTAL	**$2,594,214**	**$3,866,584**	**89,368**	**74,422**

Below are practice descriptions and the total projects completed by the PDTRA for each practice:

- **Rain Gardens**: Rain gardens help reduce the amount of urban storm runoff entering surface waters. Their design diverts water from a building's downspouts and/or captures runoff from steep or impenetrable areas like parking lots or sidewalks. The water is diverted into shallow basins planted with native plants, which allow the water to slowly penetrate the ground. Ninety-one rain gardens have been installed since 2010.
- **Alternative Tile Intakes**: Surface inlets are sometimes used to remove excess water in agricultural fields. However, this creates a direct path for sediments and nutrients to enter surface waters. An alternative tile intake is buried under sand and gravel, which allows particulates to be filtered out of the water. 205 alternative tile intakes have been installed since 2010.

- **Water and Sediment Control Basins**: WASCOBs are used to fix gully erosion on agricultural fields. Essentially, the gully is filled in and a dam structure installed. On the upslope side of the structure, a special tile inlet is placed to slowly drain any water collected by the newly constructed basin. This allows particulates to settle out and prevents the water from running across the surface of the field. One hundred sixty-seven WASCOBs have been installed within the Pomme de Terre Watershed.
- **Shoreline Restorations**: Native plants go a long way in protecting our lakes. Planting native species along shorelines mitigates bank erosion and reduces the amount of pollutants entering the lakes. Native grasses and wildflowers also provide food and habitat for birds and wildlife. That's why the PDTRA provides cost-share for the restoration of shorelines around lakes. It is very important to keep nutrients and sediment where it belongs – on the shoreline, not in the lake. Seventeen shorelines and streambanks have been restored or protected to date with the help of PDTRA.
- **Stream Barbs**: Stream barbs are low profile, sloping stone sill projecting out from a stream bank. Their purpose is to redirect the stream currents away from an exposed, eroding bank, and they also protect riparian vegetation. The Stone's Mill Stream Barb was constructed in 2012 with Clean Water Funds.
- **Cattle Exclusions**: In areas where livestock have easy access to surface waters and may impact water quality, a livestock exclusion fence can aid in keeping cattle away from the water. By implementing an exclusion fence and providing another water source for cattle, critical shoreline areas benefit from reduced soil erosion, less sedimentation running into the water, and lower *E. coli* levels. Eleven cattle exclusions have been constructed to date by PDTRA.
- **Filter Strips and Wetlands (CRP and CCRP)**: Some grant funds have been used to recruit landowners into enrolling in federal programs, such as the CRP and the Continuous Conservation Reserve Program (CCRP). These programs temporarily retire cultivated/agricultural land and provide beneficial buffers and wildlife habitat to the watershed. For more information on these federal programs, visit the USDA Farm Service Agency website here. The Pomme de Terre River Watershed has enrolled 6,753 acres into these programs.

6.5 Funding

Funding sources to implement TMDLs can come from local, state, federal, and/or private sources. Examples include BWSR's Watershed-based Implementation Funding, Clean Water Fund Competitive Grants (e.g., Projects and Practices), and conservation funds from Natural Resources Conservation Service (NRCS) (e.g., Environmental Quality Incentives Program and Conservation Stewardship Program).

Watershed-based implementation funding is a noncompetitive process to fund water quality improvement and protection projects for lakes, rivers/streams, and groundwater. This funding allows collaborating local governments to pursue timely solutions based on a watershed's highest priority needs. The approach depends on the completion of a CWMP developed under the 1W1P program or the Metropolitan Surface Water framework to provide assurance that actions are prioritized, targeted, and measurable.

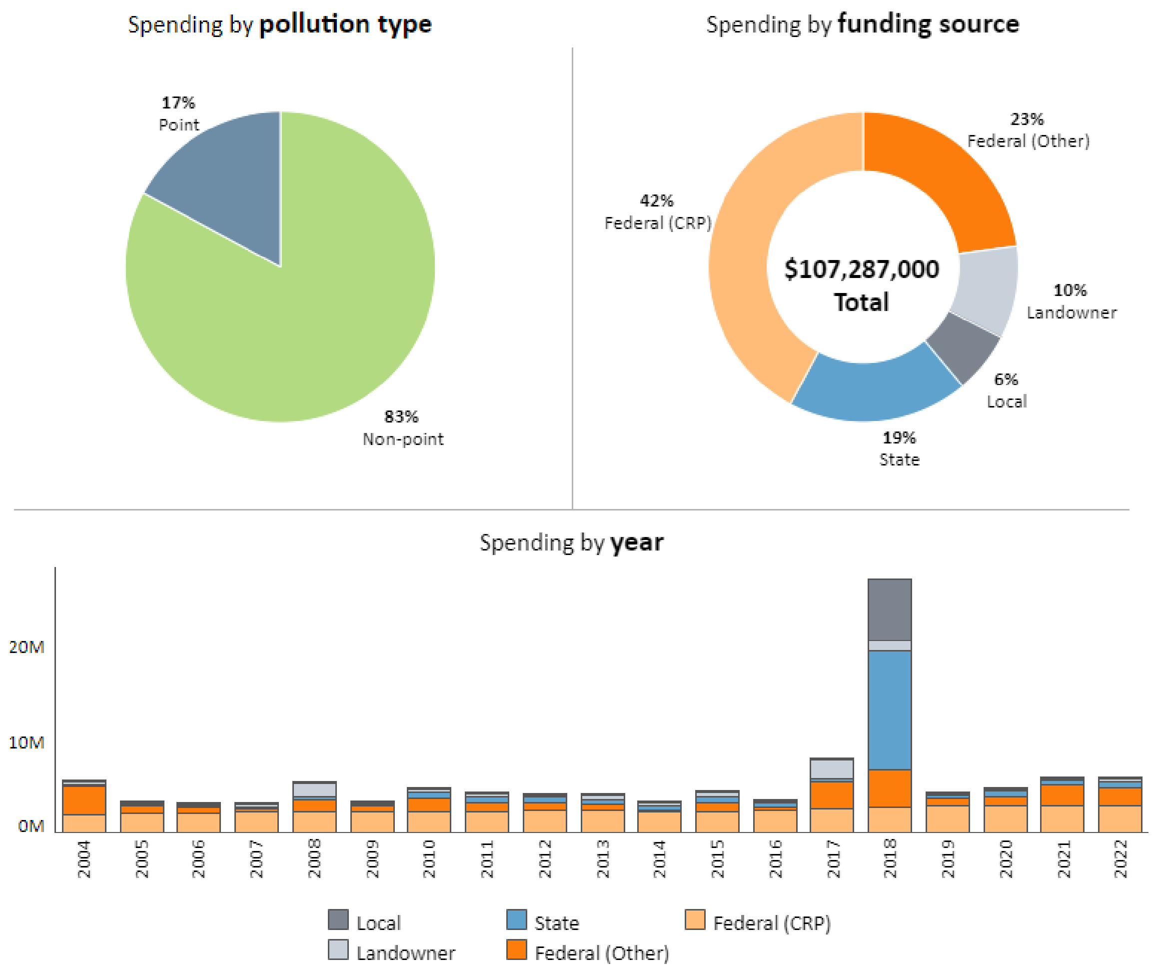
BWSR has begun the transition of moving toward watershed-based implementation funding to accelerate water management outcomes, enhance accountability, and improve consistency and efficiency across the state. This approach allows more clean water projects to be implemented and helps local governments spend limited resources where they are most needed.

Watershed-based implementation funding assurance measures are based on fiscal integrity and accountability for achieving measurable progress towards water quality elements of CWMPs. Assurance measures will be used as a means to help grantees meaningfully assess, track, and describe use of these grant funds to achieve clean water goals through prioritized, targeted, and measurable implementation. The following assurance measures are supplemental to existing reporting and on-going grant monitoring efforts:

- Understand contributions of prioritized, targeted, and measurable work in achieving clean water goals
- Review progress of programs, projects, and practices implemented in identified priority areas
- Complete Clean Water Fund grant work on schedule and on budget
- Leverage funds beyond the state grant

Over $107,287,000 has been spent on watershed implementation projects in the Pomme de Terre River Watershed since 2004 (Figure 44).

Figure 44. Spending for watershed implementation projects in the Pomme de Terre River Watershed 2004-2024; data from the MPCA's Healthier Watersheds website (April 2024).



6.6 Other partners and organizations

The Pomme de Terre River Watershed CMP partners expect to continue and build on existing collaboration with others when opportunities exist that align with plan objectives, including nongovernmental organizations, while implementing this plan. Current and potential future partnerships include, but are not limited to the Minnesota Land Trust, Pheasants Forever, Ducks Unlimited, University of Minnesota Extension, local sporting groups, local service clubs, lake associations, Corn Growers, Soybean Growers, Farm Bureau, Farmers Union, and others. See Section 6.3.1 of the Pomme de Terre River Watershed Comprehensive Management Plan (EOR Inc. 2019).

6.7 Reasonable assurance conclusion

In summary, significant time and resources have been devoted to identifying the best BMPs, providing means of focusing them in the Pomme de Terre River Watershed, and supporting their implementation via state initiatives and dedicated funding. The Pomme de Terre River Watershed WRAPS and TMDLs process engaged partners to arrive at reasonable examples of BMP combinations that attain pollutant reduction goals. Minnesota is a leader in watershed planning as well as monitoring and tracking progress toward water quality goals and pollutant load reductions.

7. Monitoring

There are numerous, local, state, and federal monitoring and data collection activities within the Pomme de Terre River Watershed. Monitoring programs were described previously in detail in the Pomme de Terre CWMP, see Section 5.6 (EOR Inc. 2019).

Data from three MPCA water quality monitoring programs enable water quality condition assessment and creates a long-term data set to track progress towards water quality goals. BMPs implemented by local government units (LGUs) will continue to be tracked through BWSR's e-Link system. These programs will continue to collect and analyze data in the Pomme de Terre River Watershed as part of Minnesota's Water Quality Monitoring Strategy 2021 – 2031 (MPCA 2021). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. These monitoring programs are summarized below:

IWM (MPCA 2021) data provides a periodic but intensive "snapshot" of water quality throughout the watershed. This program collects water quality and biological data at roughly 100 stream and 50 lake monitoring stations across the watershed for 1 to 2 years, every 10 years. To measure pollutants across the watershed the MPCA will revisit and reassess the watershed, as well as have capacity to visit new sites in areas with BMP implementation activity.

Watershed Pollutant Load Monitoring Network data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment, and nutrient loads. In the Pomme de Terre River Watershed, there is year-round site near the outlet of the Pomme de Terre River in Appleton and one seasonal (spring through fall) subwatershed site on the Pomme de Terre River at County Road 76 in Grant County.

Volunteer Stream and Lake Monitoring Program data provide a continuous record of water body transparency throughout much of the watershed. This program relies on a network of volunteers who make monthly lake and river measurements throughout the year. There are approximately eighteen active volunteer monitoring locations in the Pomme de Terre River Watershed.

8. Implementation strategy summary

8.1 Permitted sources

8.1.1 Construction stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre expected to be active in the watershed at any one time, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in Minnesota's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs, and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Section 23 of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. Construction activity must also meet all local government construction stormwater requirements.

8.1.2 Industrial stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES industrial stormwater permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. Minnesota's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) and NPDES/SDS Nonmetallic Mining/Associated Activities General Permit (MNG490000) establish benchmark concentrations for pollutants in industrial stormwater discharges. If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs, and maintains BMPs sufficient to meet the benchmark values in the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report. Industrial activity must also meet all local government stormwater requirements.

8.1.3 Wastewater

The MPCA issues permits for wastewater treatment facilities that discharge into waters of the state. The permits have site specific limits that are based on water quality standards. Permits regulate discharges with the goals of: (1) protecting public health and aquatic life, and (2) assuring that every facility treats wastewater. In addition, SDS permits set limits and establish controls for land application of sewage. Current wastewater permits comply with allocations in this TMDL study.

8.2 Nonpermitted sources

Targeted implementation activities were identified in Section 4 the Pomme de Terre River Watershed Comprehensive Management Plan (EOR Inc. 2019) that will make progress towards the nonpermitted source load reduction goals identified in this TMDL report.

Targeted implementation activities identified to address poor quality lakes include:

- Conduct 123 hours per year of SSTS inspections and update 23 Septic Systems found noncompliant through SSTS inspections per year.
- Update septic systems found noncompliant through SSTS inspections.
- Conduct shoreline condition inventories on a parcel-by-parcel basis using a uniform process. Work has already begun on North Turtle. In 2022, inventories were done on Pomme de Terre and Barrett. In 2028, inventories will be done on Christina, Artichoke, and Perkins.
- Implement shoreline restoration projects for erosion control based on shoreline inventories.
- Implement structural agricultural BMPs based on PTMApp and best professional judgment within the lakesheds.
- Implement nonstructural BMPs based on PTMApp and best professional judgment within the lakesheds.
- Conduct a series of lake outreach meetings to identify possible in-lake management and engage affected landowners in lake water quality management.

Targeted implementation activities identified to address excess pollutants in streams include:

- One-on-one conversations with landowners of top-ranked structural and nonstructural practices (from PTMApp) to enroll in cost-share programs.
- Implement structural agricultural BMPs based on PTMApp and best professional judgment within Drywood Creek Area and the Pomme de Terre River Corridor Priority Areas.
- Implement nonstructural BMPs based on PTMApp and best professional judgment within Drywood Creek Area and the Pomme de Terre River Corridor Priority Areas.
- Complete 20 wetland restorations.
- Implement 4 nutrient management plans per year.
- Implement 4 pit closures over 10 years.

Although there is evidence that internal phosphorus recycling occurs within the impaired lakes, it is assumed that the rate of recycling will decrease as the lake and sediments equilibrate to lower external phosphorus loads. Implementation strategies to decrease internal phosphorus recycling could be considered if in-lake TP and eutrophication response variables do not improve, or are slow to improve, after significant watershed reductions are achieved. The MPCA recommends feasibility studies for any lake in which major in-lake management strategies are proposed. In-lake management activities could include, but are not limited to:

- Carp harvesting and control
- Aquatic plant management
- water level drawdown
- sediment dredging
- sediment phosphorus immobilization or chemical treatment (e.g., alum)

More information about in-lake management activities is provided in the [Minnesota State and Regional Government Review of Internal Phosphorus Load Control Report]().

A summary of BMPs and their primary targeted pollutants that can be used to achieve nonpermitted source load reductions in the drainage area of the impaired lakes and streams addressed in this TMDL report is included in Table 54.

Table 54. Summary of BMPs and their primary targeted pollutants.

BMP (NRCS standard, if applicable)	Targeted Pollutant		
	E. coli	Phosphorus	TSS
Filter strips (636)	X	X	X
Riparian buffers (390)	X	X	X
Clean water diversion (362)	X	X	X
Access control/fencing (472 and 382)	X	X	X
Waste storage facilities (313) and nutrient management (590)	X	X	
Grassed waterways (412)		X	X
Water and sediment control basins (638)		X	X
Conservation cover (327)		X	X
Conservation/reduced tillage (329 and 345)		X	X
Cover crops (340)		X	X
Carp harvesting and control		X	
Aquatic plant management		X	
Lake alum treatment		X	

8.3 Cost

The phosphorus and sediment reductions required to achieve the standards as detailed by the TMDL's in this report were applied using the MPCA's Watershed Pollutant Load Reduction Calculator. The MPCA's Watershed Pollutant Load Reduction Calculator uses the HSPF model to approximate nitrogen, phosphorus and sediment load reductions resulting from BMPs in the Pomme de Terre River Watershed. A suite of BMPs was chosen based on local preferences and cost effectiveness. BMP costs were based on twice the federal 2021 EQIP rates.

Depending on the BMPs chosen, the cost to achieve the watershed portion of the water quality standards for the TMDLs documented in this report range between $11,173,336 and $21,915,815. Addressing internal loading of phosphorus in the lakes may cost an additional 10 to 15 million dollars depending on the practices chosen.

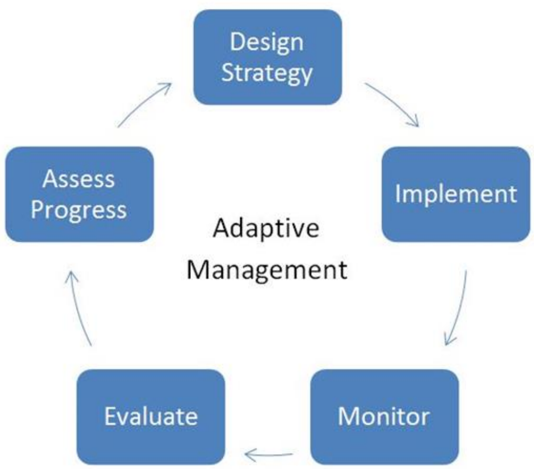
There is considerable overlap between the TMDLs in this report and efforts called for in the Pomme de Terre River CWMP (EOR Inc. 2019). This will likely result in cost savings. BMPs will benefit reductions called for in both documents.

To achieve the goals in the Pomme de Terre River CWMP (EOR Inc. 2019), the county, SWCDs, and the PDTRA plan to spend $64,761,923 over the next 10-year period. This money will contribute to projects that will reduce loads to the impaired water bodies in the Pomme de Terre River Watershed.

The CWLA requires that a TMDL report include an overall approximation of the cost to implement a TMDL [Minn. Stat. 2007 § 114D.25]. The costs to implement the activities outlined in the Pomme de Terre WRAPS Update 2024 (MPCA 2024b) are approximately $120 to $320 million over the next 20 years. This range reflects the level of uncertainty in the source assessment and addresses the high priority sources identified in Section 3.5. The cost includes increasing local capacity to oversee implementation in the watershed and the voluntary actions needed to achieve reductions. Required buffer installation and replacement of ITPHS systems are not included.

8.4 Adaptive management

Figure 45. Adaptive management.



Adaptive management for the Pomme de Terre River Watershed consists of five implementation elements and the more detailed Pomme de Terre River CWMP (EOR Inc. 2019) focuses on adaptive management (Figure 45). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water bodies.

9. Public participation

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from May 28, 2024 through June 27, 2024. There were no comment letters received as a result of the public comment period.

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Appendix A. BATHTUB supporting information

Table 55. Barrett Lake Calibrated Existing Conditions BATHTUB Model Output Files

Barrett Lake

File: **X:\Clients_State\172_MPCA\0109_PdT_PH2_TMDL\07_Modeling\BATHTUB\Barrett_existing.btb**

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: **1** **Barrett Lake**

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	65.0	0.18	63.3%	65.0	0.10	63.3%

Overall Water & Nutrient Balances

Overall Water Balance **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Direct Dra	58.9	5.3	1.11E+00	0.20	0.09
2	1	1	Lake Pomr	799.4	66.5	1.77E+02	0.20	0.08
PRECIPITATION				2.1	1.6	2.45E-02	0.10	0.73
TRIBUTARY INFLOW				858.3	71.7	1.78E+02	0.19	0.08
***TOTAL INFLOW				860.4	73.3	1.78E+02	0.18	0.09
ADVECTIVE OUTFLOW				860.4	72.0	1.78E+02	0.19	0.08
***TOTAL OUTFLOW				860.4	72.0	1.78E+02	0.19	0.08
***EVAPORATION					1.3	1.70E-02	0.10	

Overall Mass Balance Based Upon Component: **Predicted TOTAL P** **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Direct Dra	2544.2	41.6%	5.18E+05	38.2%	0.28	483.8	43.2
2	1	1	Lake Pomr	3230.9	52.8%	8.35E+05	61.6%	0.28	48.6	4.0
PRECIPITATION				89.4	1.5%	2.00E+03	0.1%	0.50	57.0	41.7
INTERNAL LOAD				258.3	4.2%	0.00E+00		0.00		
TRIBUTARY INFLOW				5775.1	94.3%	1.35E+06	99.9%	0.20	80.5	6.7
***TOTAL INFLOW				6122.8	100.0%	1.35E+06	100.0%	0.19	83.5	7.1
ADVECTIVE OUTFLOW				4677.2	76.4%	1.10E+06		0.22	65.0	5.4
***TOTAL OUTFLOW				4677.2	76.4%	1.10E+06		0.22	65.0	5.4
***RETENTION				1445.6	23.6%	3.34E+05		0.40		

Overflow Rate (m/yr)	33.6	Nutrient Resid. Time (yrs)	0.0589
Hydraulic Resid. Time (yrs)	0.0771	Turnover Ratio	17.0
Reservoir Conc (mg/m3)	65	Retention Coef.	0.236

Table 56. Barrett Lake TMDL Scenario BATHTUB Model Output Files

Barrett Lake

File: **X:\Clients_State\172_MPCA\0109_PdT_PH2_TMDL\07_Modeling\BATHTUB\Barrett_goal.btb**

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: **1** **Barrett Lake**

	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P	39.9	0.17	41.9%	65.0	0.10	63.3%

Overall Water & Nutrient Balances

Overall Water Balance **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Dra	58.9	5.3	1.11E+00	0.20	0.09
2	1	1	Lake Pomr	799.4	66.5	1.77E+02	0.20	0.08
PRECIPITATION				2.1	1.6	2.45E-02	0.10	0.73
TRIBUTARY INFLOW				858.3	71.7	1.78E+02	0.19	0.08
***TOTAL INFLOW				860.4	73.3	1.78E+02	0.18	0.09
ADVECTIVE OUTFLOW				860.4	72.0	1.78E+02	0.19	0.08
***TOTAL OUTFLOW				860.4	72.0	1.78E+02	0.19	0.08
***EVAPORATION					1.3	1.70E-02	0.10	

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**

Component: **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Dra	815.1	22.9%	5.31E+04	8.6%	0.28	155.0	13.8
2	1	1	Lake Pomr	2659.1	74.6%	5.66E+05	91.1%	0.28	40.0	3.3
PRECIPITATION				89.4	2.5%	2.00E+03	0.3%	0.50	57.0	41.7
TRIBUTARY INFLOW				3474.2	97.5%	6.19E+05	99.7%	0.23	48.4	4.0
***TOTAL INFLOW				3563.6	100.0%	6.21E+05	100.0%	0.22	48.6	4.1
ADVECTIVE OUTFLOW				2871.1	80.6%	4.89E+05		0.24	39.9	3.3
***TOTAL OUTFLOW				2871.1	80.6%	4.89E+05		0.24	39.9	3.3
***RETENTION				692.5	19.4%	8.72E+04		0.43		

Overflow Rate (m/yr)	33.6	Nutrient Resid. Time (yrs)	0.0621
Hydraulic Resid. Time (yrs)	0.0771	Turnover Ratio	16.1
Reservoir Conc (mg/m3)	40	Retention Coef.	0.194

Table 57. North Drywood Lake Calibrated Existing Conditions BATHTUB Model Output Files

North Drywood Lake

File: X:\Clients_State\172_MPCA\0109_PdT_PH2_TMDL\07_Modeling\BATHTUB\N_Drywood_existing.btb

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 North Drywood Lake

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	539.9	0.18	99.6%	540.0	0.12	99.6%

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Dra	29.3	4.0	6.29E-01	0.20	0.14
2	1	1	Unnamed	22.3	3.0	8.78E-02	0.10	0.13
3	1	1	Artichoke	155.1	15.7	2.46E+00	0.10	0.10
4	1	1	South Dry	8.3	1.1	1.24E-02	0.10	0.13
PRECIPITATION				1.6	1.1	1.32E-02	0.10	0.73
TRIBUTARY INFLOW				215.1	23.7	3.19E+00	0.08	0.11
***TOTAL INFLOW				216.6	24.9	3.21E+00	0.07	0.11
ADVECTIVE OUTFLOW				216.6	23.9	3.21E+00	0.07	0.11
***TOTAL OUTFLOW				216.6	23.9	3.21E+00	0.07	0.11
***EVAPORATION					1.0	9.11E-03	0.10	

Overall Mass Balance Based Upon Component: **Predicted TOTAL P** — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Dra	3394.2	16.0%	9.22E+05	36.6%	0.28	856.0	115.8
2	1	1	Unnamed	2325.0	10.9%	1.08E+05	4.3%	0.14	784.8	104.2
3	1	1	Artichoke	8354.0	39.3%	1.40E+06	55.4%	0.14	532.3	53.9
4	1	1	South Dry	867.9	4.1%	9.46E+04	3.8%	0.35	780.0	104.6
PRECIPITATION				65.4	0.3%	1.07E+03	0.0%	0.50	57.0	41.7
INTERNAL LOAD				6254.3	29.4%	0.00E+00		0.00		
TRIBUTARY INFLOW				14941.1	70.3%	2.52E+06	100.0%	0.11	629.5	69.5
***TOTAL INFLOW				21260.8	100.0%	2.52E+06	100.0%	0.07	854.5	98.1
ADVECTIVE OUTFLOW				12919.4	60.8%	6.26E+06		0.19	539.9	59.6
***TOTAL OUTFLOW				12919.4	60.8%	6.26E+06		0.19	539.9	59.6
***RETENTION				8341.4	39.2%	5.45E+06		0.28		

Overflow Rate (m/yr)	15.2	Nutrient Resid. Time (yrs)	0.0251
Hydraulic Resid. Time (yrs)	0.0413	Turnover Ratio	39.8
Reservoir Conc (mg/m3)	540	Retention Coef.	0.392

Table 58. North Drywood Lake TMDL Scenario BATHTUB Model Output Files

North Drywood Lake
File: X:\Clients_State\172_MPCA\0109_PdT_PH2_TMDL\07_Modeling\BATHTUB\N_Drywood_goal.btb

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 North Drywood Lake

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	90.0	0.11	75.8%	540.0	0.12	99.6%

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Dra	29.3	4.0	6.29E-01	0.20	0.14
2	1	1	Unnamed	22.3	3.0	8.78E-02	0.10	0.13
3	1	1	Artichoke	155.1	15.7	2.46E+00	0.10	0.10
4	1	1	South Dry	8.3	1.1	1.24E-02	0.10	0.13
PRECIPITATION				1.6	1.1	1.32E-02	0.10	0.73
TRIBUTARY INFLOW				215.1	23.7	3.19E+00	0.08	0.11
***TOTAL INFLOW				216.6	24.9	3.21E+00	0.07	0.11
ADVECTIVE OUTFLOW				216.6	23.9	3.21E+00	0.07	0.11
***TOTAL OUTFLOW				216.6	23.9	3.21E+00	0.07	0.11
***EVAPORATION					1.0	9.11E-03	0.10	

Overall Mass Balance Based Upon Predicted TOTAL P
Component: — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Dra	547.2	20.3%	2.40E+04	30.3%	0.28	138.0	18.7
2	1	1	Unnamed	411.8	15.3%	3.39E+03	4.3%	0.14	139.0	18.5
3	1	1	Artichoke	1569.4	58.3%	4.93E+04	62.4%	0.14	100.0	10.1
4	1	1	South Dry	100.1	3.7%	1.26E+03	1.6%	0.35	90.0	12.1
PRECIPITATION				65.4	2.4%	1.07E+03	1.4%	0.50	57.0	41.7
TRIBUTARY INFLOW				2628.5	97.6%	7.79E+04	98.6%	0.11	110.7	12.2
***TOTAL INFLOW				2694.0	100.0%	7.89E+04	100.0%	0.10	108.3	12.4
ADVECTIVE OUTFLOW				2154.0	80.0%	8.90E+04		0.14	90.0	9.9
***TOTAL OUTFLOW				2154.0	80.0%	8.90E+04		0.14	90.0	9.9
***RETENTION				539.9	20.0%	4.08E+04		0.37		

Overflow Rate (m/yr)	15.2	Nutrient Resid. Time (yrs)	0.0330
Hydraulic Resid. Time (yrs)	0.0413	Turnover Ratio	30.3
Reservoir Conc (mg/m3)	90	Retention Coef.	0.200

Table 59. South Drywood Lake Calibrated Existing Conditions BATHTUB Model Output Files

South Drywood Lake

File: X:\Clients_State\172_MPCA\0109_PdT_PH2_TMDL\07_Modeling\BATHTUB\S_Drywood_existing.btb

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 South Drywood Lake

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	780.0	0.38	99.9%	780.0	0.34	99.9%

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Direct Dra	7.4	1.0	3.98E-02	0.20	0.14
PRECIPITATION				0.9	0.7	4.67E-03	0.10	0.73
TRIBUTARY INFLOW				7.4	1.0	3.98E-02	0.20	0.14
***TOTAL INFLOW				8.3	1.7	4.45E-02	0.13	0.20
ADVECTIVE OUTFLOW				8.3	1.1	4.77E-02	0.20	0.13
***TOTAL OUTFLOW				8.3	1.1	4.77E-02	0.20	0.13
***EVAPORATION					0.6	3.23E-03	0.10	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	Load %Total	Load Variance (kg/yr)^2	Load Variance %Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Direct Dra	852.7	12.3%	5.82E+04	99.3%	0.28	854.7	115.8
PRECIPITATION				39.0	0.6%	3.80E+02	0.6%	0.50	57.0	41.7
INTERNAL LOAD				6053.7	87.2%	0.00E+00		0.00		
TRIBUTARY INFLOW				852.7	12.3%	5.82E+04	99.3%	0.28	854.7	115.8
***TOTAL INFLOW				6945.4	100.0%	5.86E+04	100.0%	0.03	4131.6	836.9
ADVECTIVE OUTFLOW				867.9	12.5%	1.37E+05		0.43	780.0	104.6
***TOTAL OUTFLOW				867.9	12.5%	1.37E+05		0.43	780.0	104.6
***RETENTION				6077.5	87.5%	1.40E+05		0.06		

Overflow Rate (m/yr)	1.2	Nutrient Resid. Time (yrs)	0.0808
Hydraulic Resid. Time (yrs)	0.6469	Turnover Ratio	12.4
Reservoir Conc (mg/m3)	780	Retention Coef.	0.875

Table 60. South Drywood Lake TMDL Scenario BATHTUB Model Output Files

South Drywood Lake
File: X:\Clients_State\172_MPCA\0109_PdT_PH2_TMDL\07_Modeling\BATHTUB\S_Drywood_goal.btb

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 South Drywood Lake

	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	90.0	0.31	75.8%	780.0	0.34	99.9%

Overall Water & Nutrient Balances

Overall Water Balance **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Dra	7.4	1.0	3.98E-02	0.20	0.14
PRECIPITATION				0.9	0.7	4.67E-03	0.10	0.73
TRIBUTARY INFLOW				7.4	1.0	3.98E-02	0.20	0.14
***TOTAL INFLOW				8.3	1.7	4.45E-02	0.13	0.20
ADVECTIVE OUTFLOW				8.3	1.1	4.77E-02	0.20	0.13
***TOTAL OUTFLOW				8.3	1.1	4.77E-02	0.20	0.13
***EVAPORATION					0.6	3.23E-03	0.10	

Overall Mass Balance Based Upon Predicted **Outflow & Reservoir Concentrations**
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Dra	215.5	84.7%	3.72E+03	90.7%	0.28	216.0	29.3
PRECIPITATION				39.0	15.3%	3.80E+02	9.3%	0.50	57.0	41.7
TRIBUTARY INFLOW				215.5	84.7%	3.72E+03	90.7%	0.28	216.0	29.3
***TOTAL INFLOW				254.5	100.0%	4.10E+03	100.0%	0.25	151.4	30.7
ADVECTIVE OUTFLOW				100.2	39.4%	1.46E+03		0.38	90.0	12.1
***TOTAL OUTFLOW				100.2	39.4%	1.46E+03		0.38	90.0	12.1
***RETENTION				154.3	60.6%	2.29E+03		0.31		

Overflow Rate (m/yr)	1.2	Nutrient Resid. Time (yrs)	0.2547
Hydraulic Resid. Time (yrs)	0.6469	Turnover Ratio	3.9
Reservoir Conc (mg/m3)	90	Retention Coef.	0.606