Watershed

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Shell Rock River Watershed Restoration and Protection Strategy Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Cover photo descriptions (clockwise, from upper left):

Shell Rock River near Gordonsville, Minnesota

Agricultural drainage ditch in the Peter Lund Creek Subwatershed

Jerad Stricker of the Shell Rock River Watershed District takes a water elevation measurement from the bridge over the channel between Fountain and Albert Lea lakes.

City of Albert Lea's wastewater treatment plant outfall to the Shell Rock River

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Acronyms

1W1P	One Watershed, One Plan
AFO	animal feeding operation
BMP	Best management practice
BWSR	Board of Water and Soil Resources
CAFO	Concentrated animal feeding operations
CBOD	Carbonaceous biochemical oxygen demand
CD	County Ditch
CDL	Crop data layer
Chl-*a*	Chlorophyll-a
CTIC	Conservation Technology Information Center
CV	coefficient of variation
DNR	Minnesota Department of Natural Resources
DO	Dissolved oxygen
DOP	Dissolved orthophosphate
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
FIBI	Fish Index of Biological Integrity
FWMC	Flow weighted mean concentration
GIS	Geographic Information System
GHG	Green House Gas
HEL	Highly erodible land
HSPF	Hydrologic Simulation Program-Fortran
HUC	Hydrologic unit code
IBI	Index of Biological Integrity
ITPHS	Imminent threat to public health or safety
IWM	Intensive watershed monitoring
JD	Judicial Ditch
lb	pound
lb/day	pounds per day
lb/yr	pounds per year

LGU	Local Government Unit
m	meter
MAWQCP	Minnesota Agricultural Water Quality Certification Program
mg/L	milligrams per liter
MGD	million gallons per day
MIBI	Macroinvertebrate Index of Biological Integrity
mL	milliliter
MDA	Minnesota Department of Agriculture
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
MT	Metric ton
NO3-N	Nitrate
NPDES	National Pollutant Discharge Elimination System
NRS	Nutrient Reduction Strategy
NRCS	Natural Resources Conservation Service
OP	Inorganic orthophosphate
RIM	Reinvest in Minnesota Program
SDT	Secchi disk transparency
SDS	State Disposal System
SID	Stressor Identification
SOM	soil organic matter
SRRW	Shell Rock River Watershed
SRRWD	Shell Rock River Watershed District
SSTS	Subsurface sewage treatment systems
SWAT	Soil and Water Assessment Tool
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Pollution Prevention Plan
TALU	Tiered Aquatic Life Use
TN	Total Nitrogen
TMDL	total maximum daily load
TP	Total phosphorus

TSS	total suspended solids
USDA	United States Department of Agriculture
USLE	Universal Soil Loss Equation
VSS	volatile suspended solids
WID	waterbody identification number
WLA	wasteload allocation
WCBP	Western Corn Belt Plains (Ecoregion)
WHAF	Watershed Health Assessment Framework
WQS	Water Quality Standard
WRAPS	Watershed Restoration and Protection Strategy
WRP	Wetland Reserve Program
WWTP	Treatment Plant
WWTF	Wastewater Treatment Facility

Executive summary

The State of Minnesota has adopted a watershed approach to address water quality within the state's 80 major watersheds. The watershed approach follows a 10-year cycle where water bodies are 1) monitored for chemistry and biology, and assessed to determine if they are fishable and swimmable, 2) pollutants and stressors, and their sources are identified, and then local partners and citizens are engaged to help 3) develop strategies to restore and protect water bodies, and 4) plan and implement restoration and protection projects. The Shell Rock River Watershed (SRRW) Restoration and Protection Strategy (WRAPS) Report summarizes work done in Steps 1 to 3 above in this first cycle of the Watershed Approach.

Surface water quality in the SRRW is negatively affected by both nonpoint and point pollution sources. The Shell Rock River is impaired by low dissolved oxygen (DO), *E. coli* (MPCA 2006*)*, pH, turbidity, eutrophication, and has impaired fish and macroinvertebrate communities (as measured by Fish Index of Biotic Integrity (FIBI) and Macroinvertebrate Index of Biotic Integrity (MIBI)). Biota in the Shell Rock River are compromised due to the impairments above, as well as nitrate-nitrogen (NO3-N) and altered hydrology. Bacteria (*E. coli*) impairments are also present on Bancroft Creek and Wedge Creek. Shoff Creek is not meeting aquatic life standards for total suspended solids (TSS) and river eutrophication.

Five lakes are not meeting water quality standards (WQS) for shallow Southern Minnesota lakes. These lakes are Fountain Lake (East Bay and West Bay), Albert Lea Lake, Pickeral Lake, and White Lake. There are other lakes in the watershed that are also important water resources including School Section Lake, Sugar Lake, Eberhart Lake, Church Lake, Goose Lake, Halls Lake, and Upper and Lower Twin Lakes. These lakes have not been assessed by the Minnesota Pollution Control Agency (MPCA) for meeting WQSs.

During intensive watershed monitoring (IWM), 16 of 17 stream reaches were monitored for fish and macroinvertebrates, and then deferred from FIBI and MIBI assessment due to channelization. Reaches that have poor habitat and are over 50% channelized do not have the same biological standards as more natural channels with aquatic habitat. Due to these deferrals, only the Shell Rock River was assessed, with the determination being that FIBI and MIBI are not meeting their respective goals. Thus the follow-up Stressor Identification (SID) process and report focused on the Shell Rock River. After monitoring work by both the MPCA and the Shell Rock River Watershed District (SRRWD), it was determined that the following factors were negatively affecting Shell Rock River's biology: algal productivity (Chlorophyll-a), DO, habitat, NO3-N, pH, phosphorus, and TSS. Discussion on assessment for these deferred reaches is found in Section 2.

Impairments in the SRRW are addressed by Total Maximum Daily Load (TMDL) computations. The companion TMDLs report details the pollutant allocations and reductions for each listed water resource. The TMDL includes five lake total phosphorus (TP) TMDLs, two river TP TMDLs, two *E. coli* TMDLs, two TSS TMDLs, and one DO TMDL.

General reductions from the TMDL report for multiple waters per impairment type are summarized as:

Lake water quality	TP reductions 46% to 71% to meet WQS
Bacteria	Aquatic recreation standard is exceeded by 20% to 88% (flow zone dependent)

Total suspended solids	Aquatic life standard is exceeded from 33% to 59% (flow zone dependent)
Stream water quality	Shell Rock River exceeds the phosphorus loading capacity by 75%
	Shell Rock River exceeds the oxygen demand allowable load by 70%
	Shell Rock River exceeds high pH; a result of high phosphorus load.
	Shell Rock River biota (TMDLs for above parameters address biota)

In addition to the specific TMDL reduction values, Minnesota's nutrient reduction strategy ([NRS] MPCA 2014) for the SRRW calls for reductions in the phosphorus and nitrogen loads exported from the watershed, with milestone reductions in 2025 and 2045.

Restoration of water quality in the SRRW is the focus of this report. While there are promising trends in water quality improvement (Table 22), continued support for comprehensive and sustainable implementation is needed to further improve and restore surface water quality. Sustained citizen outreach and landowner involvement are also key elements for this restoration effort. Currently, the Shell Rock – Winnebago One Watershed, One Plan (1W1P) process is underway, being led by SRRWD staff and includes Freeborn SWCD, Freeborn County, and the City of Albert Lea. Partnerships established through the development of 1W1P will be another critical component of restoration progress.

The watershed restoration strategies are provided in Section 3.4, and are mostly contained within a series of tables. A general approach was followed that focused on the most critical factors affecting water quality, and providing a set of "high-level" strategies and BMP examples, to significantly improve water quality. In some cases, specific adoption targets (rates, acres treated) are suggested. Many of the suggested practices build upon and expand the solid upper watershed conservation work that is ongoing.

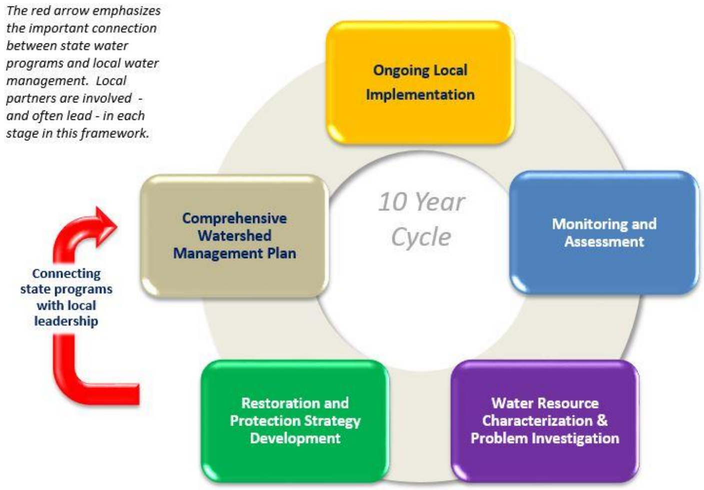
General strategies recommended for the SRRW include:

- Reducing nutrients (particularly phosphorus) from point sources (WWTPs and city storm drains) through facility improvements and urban stormwater management;
- Reducing nutrients (phosphorus and nitrogen) from nonpoint sources (agricultural fields) through nutrient management and conservation practices (i.e. reduced tillage and cover crops);
- Increase watershed water storage through wetland restorations, controlled drainage structures and soil health practices;
- Address failing septic systems, improve animal manure management and ensure animal feedlot compliance; and
- Continue to implement lake management strategies for shallow lakes (rough fish control, native aquatic plant restorations, and drawdowns).

The information in this WRAPS report adds support to work and efforts already in place by watershed partners. This includes tools for additional geographic targeting, reduction goals and examples of strategies to accomplish restoration. These resources aim to further local water quality efforts and provide support to the mission of local watershed groups.

What is the WRAPS Report?

Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota watershed approach incorporates **water quality assessment, watershed analysis, public participation, planning, implementation, and measurement of results** into a 10-year cycle that addresses both restoration and protection.



The red arrow emphasizes the important connection between state water programs and local water management. Local partners are involved - and often lead - in each stage in this framework.

As part of the watershed approach, the MPCA developed a process to identify and address threats to water quality in each of these major watersheds. This process is called Watershed Restoration and Protection Strategy (WRAPS) development. WRAPS reports have two parts: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and TMDL studies are developed for them. TMDLs are incorporated into WRAPS. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves as the basis for addressing the U.S. Environmental Protection Agency's (EPA) Nine Minimum Elements of watershed plans, to help qualify applicants for eligibility for Clean Water Act Section 319 implementation funds.

Purpose	•Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning •Summarize watershed approach work done to date including the following reports: •*Shell Rock River Watershed Monitoring and Assessment* •*Shell Rock River Watershed Biotic Stressor Identification* •*Shell Rock River Watershed Total Maximum Daily Load*
Scope	•Impacts to aquatic recreation and impacts to aquatic life in streams •Impacts to aquatic recreation in lakes
Audience	•Local working groups (SWCDs, watershed district, etc.) •State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed background and description

The SRRW (hydrologic unit code [HUC]-8: 07080202) in Minnesota encompasses a drainage area of about 246 square miles, and is located entirely within Freeborn County. All surface waters are connected through stream channels, ditches and a chain of lakes. This series of surface waters all drain to, or eventually become, the Shell Rock River. Upon entering Iowa, the Shell Rock River flows across portions of Worth, Cerro Gordo, Floyd, and Butler Counties, where it joins the Cedar River northwest of Waterloo. The overall length of the Shell Rock River is 113 miles. The river is named for the fossilized shells found along its banks (DNR 2018).

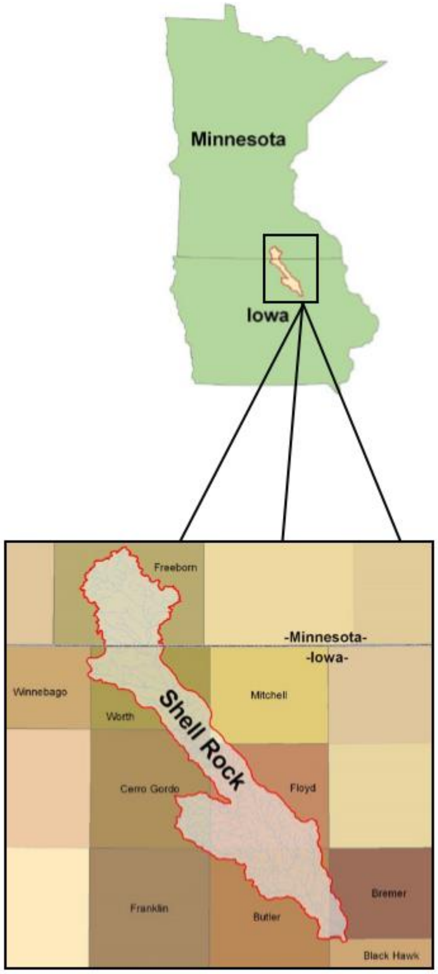


Figure 1. Overview of the Shell Rock River Watershed (USDA-NRCS 2007).

Additional Shell Rock River Watershed Resources:

MPCA Shell Rock River Watershed reports referenced in this watershed report are available at the Shell Rock River Watershed webpage: https://www.pca.state.mn.us/water/watersheds/shell-rock-river

Shell Rock River Rapid Watershed Assessment Report. (USDA-NRCS): https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_006675.pdf

Shell Rock River Watershed P-balance Study *(Watershed-scale phosphorus balances to establish reasonable water quality expectations):* https://dl.sciencesocieties.org/publications/cns/pdfs/51/3/10

1.1 Watershed Characteristics

1.1.1. Ecological Classifications

There are several ways to characterize various physical and vegetative features of the SRRW. Several classifications and descriptions are provided to enable an understanding of soils, land characteristics, and vegetation types that existed pre-European settlement. These help interpret the more recent land use and land management characteristics within a broader ecological framework.

Ecoregions are areas of land defined by major climate zones, native vegetation and biomes. The SRRW lies in Minnesota's Drift Plains portion of the Western Corn Belt Plains Ecoregion (USDA-NRCS 2007). The soils in this Ecoregion are comprised of glacial tills of the Central Iowa and Minnesota Till Prairies and Eastern Iowa and Minnesota Till Prairies. Albert Lea Lake and smaller lakes near it were formed by glacial drift deposits and dammed depressions (Waters 1980). The SRRW lies within two subsections: 92.2% Oak Savanna (92.2%) and Minnesota River Prairie (7.8%) (Figure 2).

The United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS) rapid watershed assessment includes maps and tables with soils, land use, crop production and resource concerns (USDA-NRCS 2007). About 23% of the entire SRRW is in Minnesota. Minnesota's portion of the watershed is predominately within the common resource area called the Iowa and Minnesota Rolling Prairie/Forest Moraines. These lands are primarily loamy glacial till soils with some wetland potholes, outwash and floodplains. The topography is gently undulating to rolling with relatively short, complex slopes. Native vegetation was dominantly mixed tall grass prairie and deciduous trees.

Figure 2. Land types of the Shell Rock River Watershed (DNR 2019).

Before the time of European settlement, the land cover in the area of the SRRW included oak openings and barrens, prairie, wet prairie, lakes and hardwood forest (DNR 2019). Myre-Big Island State Park on the north side of Albert Lea Lake may represent what much of the area may have looked like during that time period. During the early 1900s, much of the wetlands and smaller lakes within the WCBP were ditched and tile-drained for agricultural production and transportation (Timmerman 2001). Today, the thick prairie and drained wetland soils of the WCBP provide high percentages of organic matter making the soils of the SRRW some the most productive farmland in the world (EPA 2000).

1.1.2. Climate

The long-term average annual watershed precipitation throughout the basin ranges from 31 to 33 inches. IWM was conducted by MPCA in both 2009 and 2010. During this timeframe, annual precipitation was 33 inches in 2009, with about 2.6 inches of runoff. 2010 was a wetter year, with 36.6 inches of annual precipitation, and a significantly higher runoff of 7.8 inches. According to Minnesota Department of Natural Resources (DNR) climate trends, Minnesota has warmed by 2.9 degrees Fahrenheit between 1895 and 2017, while getting an average of 3.4 inches wetter. While Minnesota has gotten warmer and wetter since 1895, the most dramatic changes have come in the past several decades. Compared to 20th century averages, all but two years since 1970 have been some combination of warm and wet, and each of the top-10 combined warmest and wettest years on record occurred between 1998 and 2017 (DNR 2019a). Climate conditions vary from year to year, but it is expected that these increases will continue through the 21st century (DNR 2020). While warmer and wetter conditions are expected in the future, pronounced periods of low water and dry conditions are also expected.

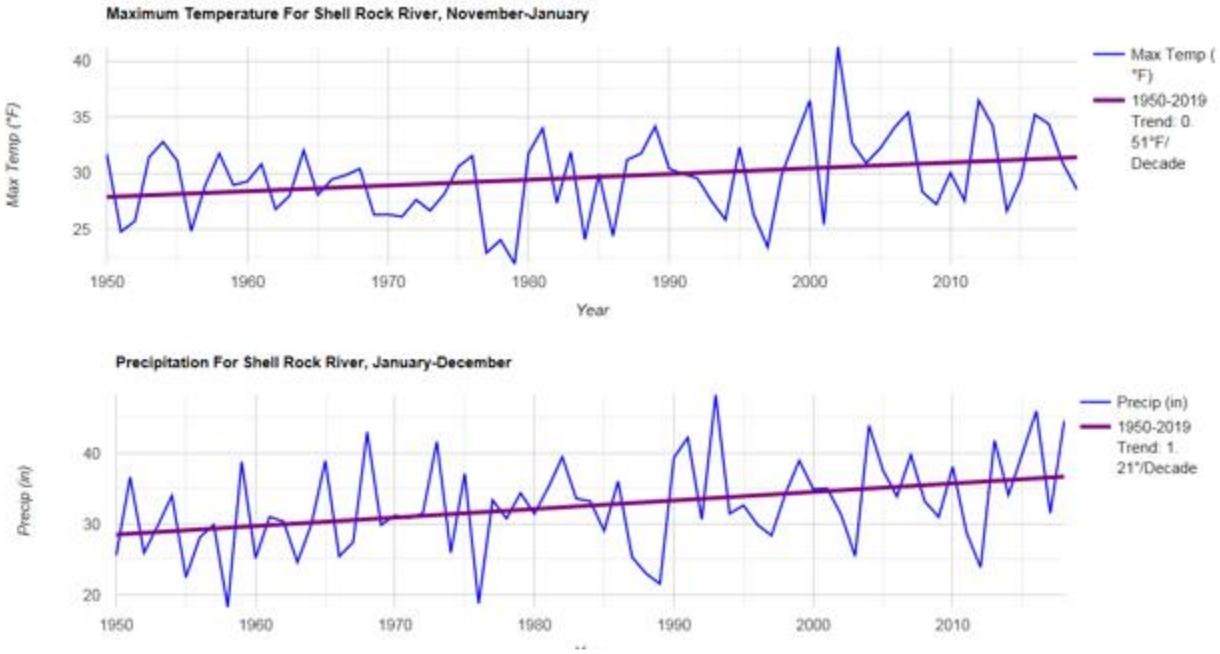


Figure 3. Climate trends for the SRRW 1950 - 2019.

1.1.3. Topography and Soils

Land slope is an important factor in watershed hydrology, soil erosion, and pollutant mobilization and transport. Certain land uses can accelerate pollutant loading, especially on land with 5% or more slope. Areas in the SRRW with 5% or greater land slope is presented in Figure 5. About 18% of the land in the watershed has slopes greater than 5%. Depending upon land use and land management, those areas with higher land slopes can be more prone to erosion. Soil erosion from the land surface can be sheet and rill erosion, ephemeral gully erosion, and/or classic gully erosion.

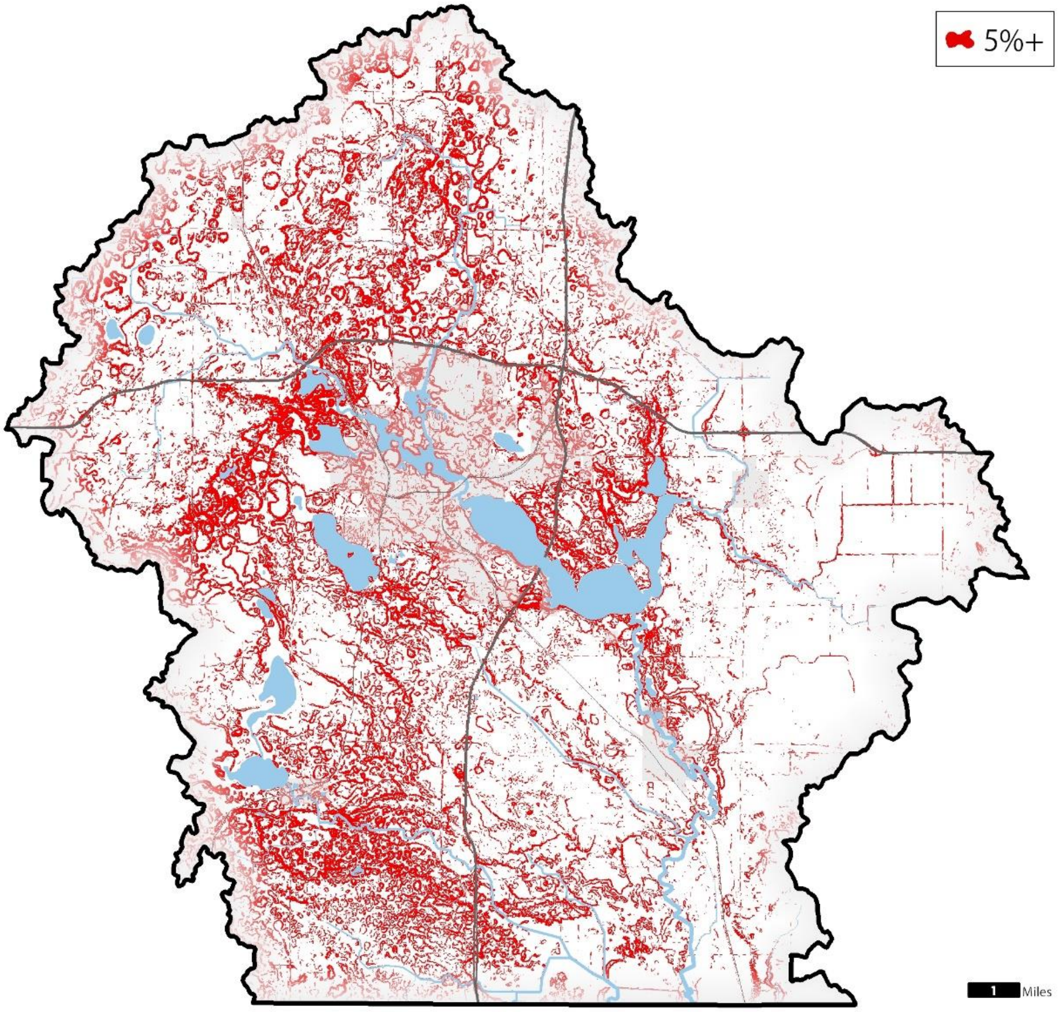


Figure 4. Areas in the SRRW where land slope is greater than 5%.

Dominant soil drainage classes are displayed in Figure 5, based on a quarter section (40-acre) scale. Soil drainage class refers to the natural soil drainage and does not take into account alterations by human activity, like field drainage tile. Soil drainage classes are often used as surrogates to estimate what soils have likely been tile-drained for agricultural production (i.e. poorly drained and very poorly drained soils). This has consequences to the watershed’s hydrology as described in Section 1.1.6.

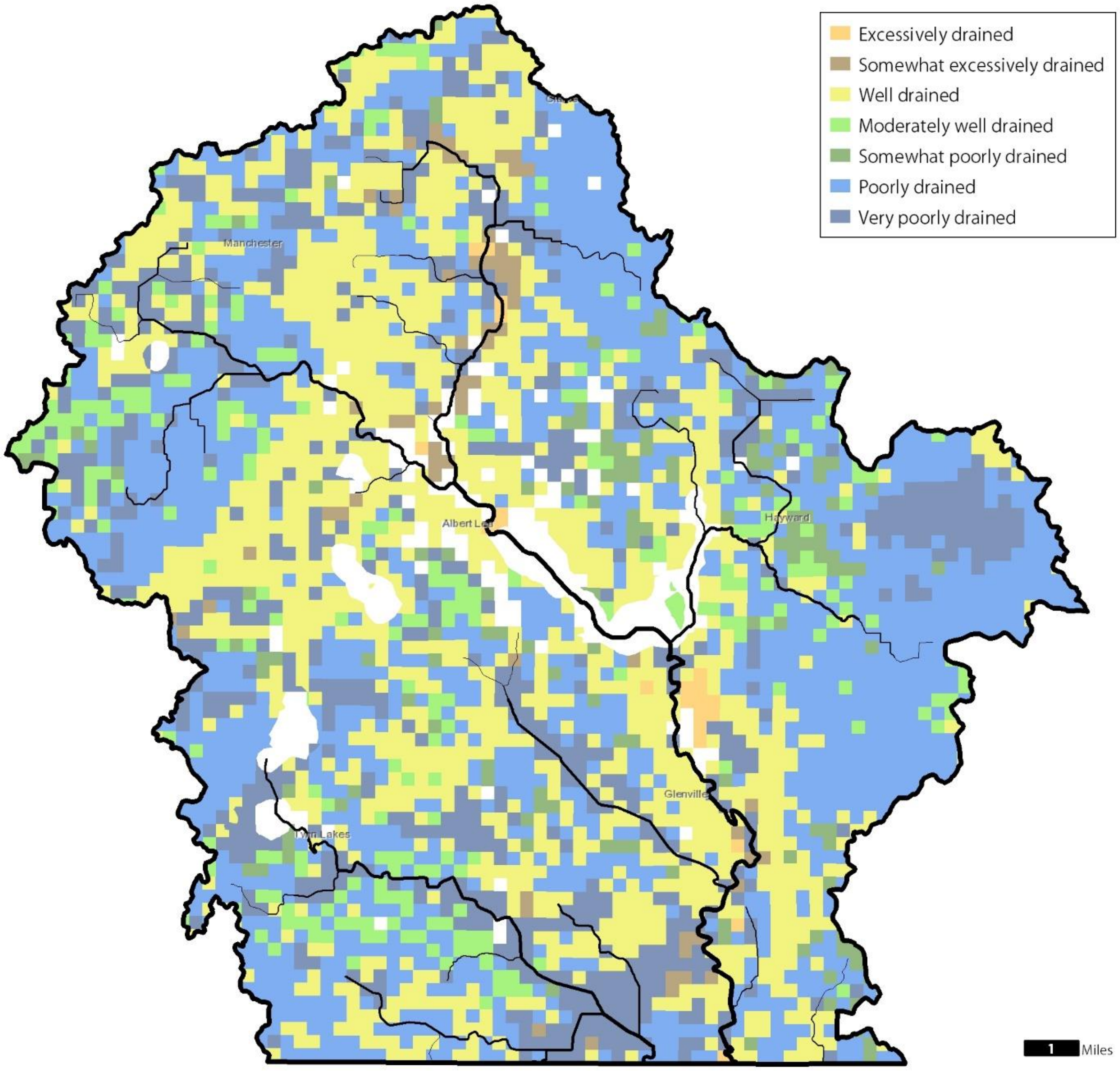


Figure 5. Soil drainage class by 40 acre parcels (SSURGO soils data, USDA).

The majority of the watershed is either in a poorly drained or well drained class. The poorly and very poorly drained region in the Peter Lund Creek Subwatershed (eastern-most area) corresponds with Figure 17 (wetland land cover) and Figure 16 (drainage system locations). Significant portions of the upper watershed have well drained soils, especially in the Bancroft Creek Subwatershed.

Soil organic matter (SOM) is important for water infiltration into the soil profile, and the amount of runoff that is produced during a rainstorm event. The general distribution of SOM in the watershed is displayed in Figure 6 with SOM ranging from less than 0.05% to greater than 5%.

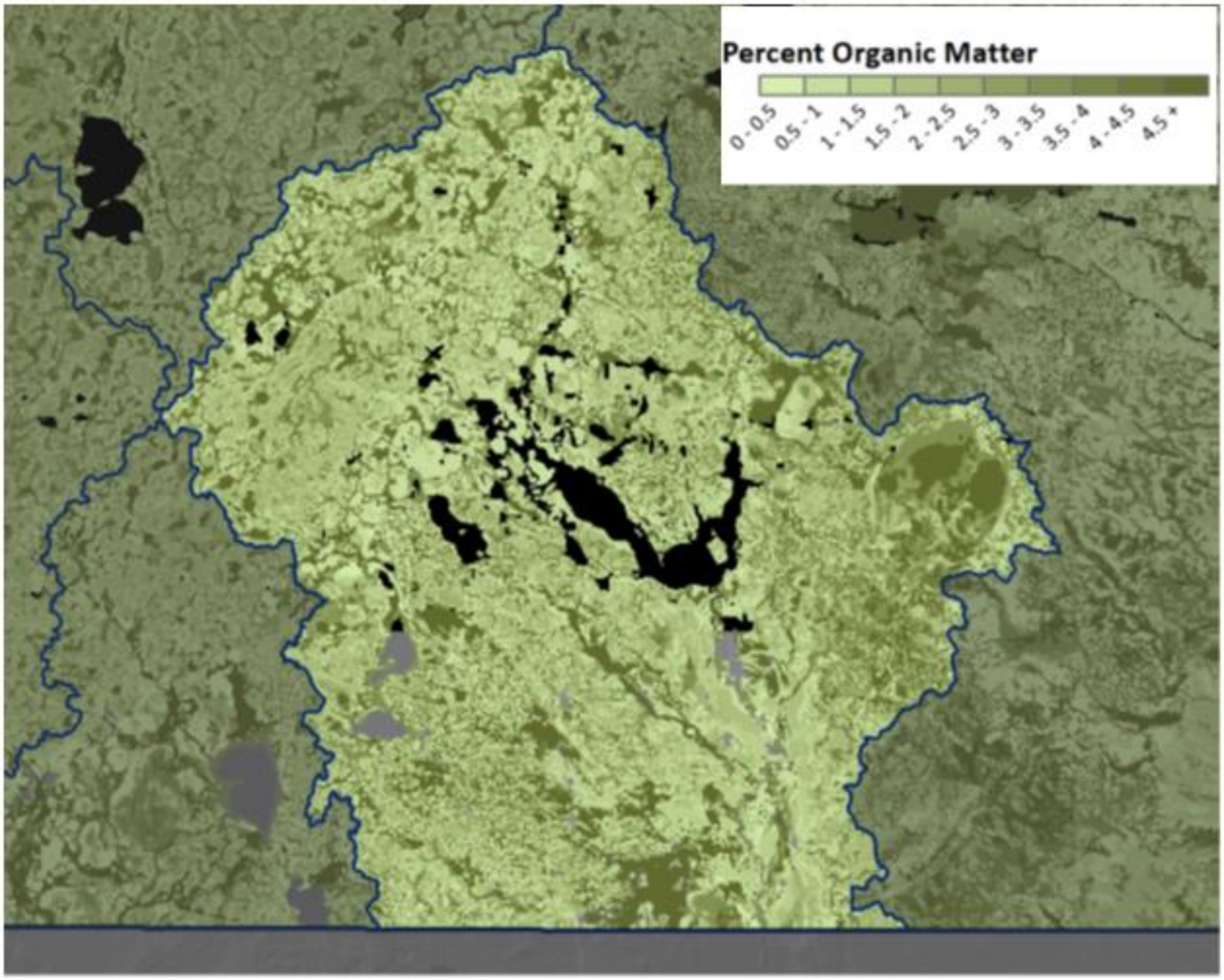
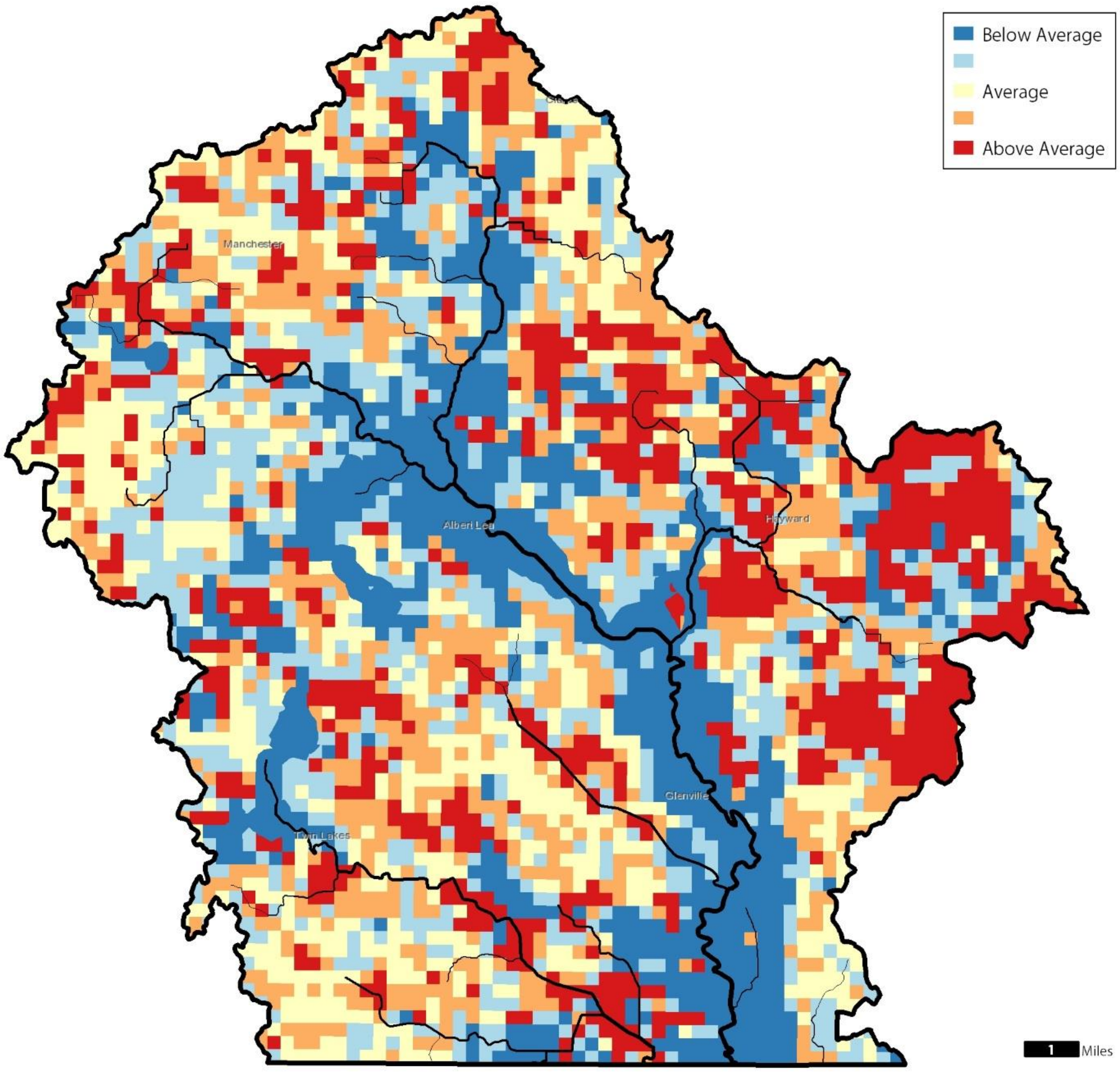


Figure 6. Percent soil organic matter in the Shell Rock River Watershed; DNR 2019.

In an agricultural context, highly erodible land (HEL) is any land that can erode at excessive rates because of its soil properties. HEL is designated by field and based on the proportion of the total field acreage that contains highly erodible soils (USDA 2017a). A soil erodibility factor (K-factor) represents the effect of soil properties and soil profile characteristics on soil loss and takes into account soil texture, structure, permeability, and organic matter content (Figure 7). Values of K range from 0.02 (lowest erodibility – "below average") to 0.69 (highest erodibility – "above average"). In general, the higher the K value, the greater the susceptibility of the soil to rill and sheet erosion by rainfall.



Key: Blue = 0.00 – 0.26, Light blue = 0.27-0.31, Yellow = 0.32, Orange: 0.33, Red: 0.34 – 0.49
Figure 7. Whole soil K-factor for the Shell Rock River Watershed.

Regarding erosion prone soil types, the Freeborn County Soil Survey (USDA 1980) indicates that soil erosion is a concern on about 10% of the cropland and pasture in the county. Soil productivity is reduced as the surface layers are damaged by erosion. Several studies in the Upper Midwest indicate that yield loss in corn can be up to 18% (i.e. fields with severe erosion are compared to slightly eroded fields) and soybean yield loss up to 24% (USDA-NRCS 1998). These studies noted that erosion reduced SOM, which negatively affected aggregate stability, moisture holding capacity, and cation exchange capacity.

Geology of the SRRW includes some areas with high pollution sensitivity of near surface materials, and smaller locations with active karst (Figure 8). The remaining lands have glacial till coverage of more than 100 feet with moderate pollution sensitivity.

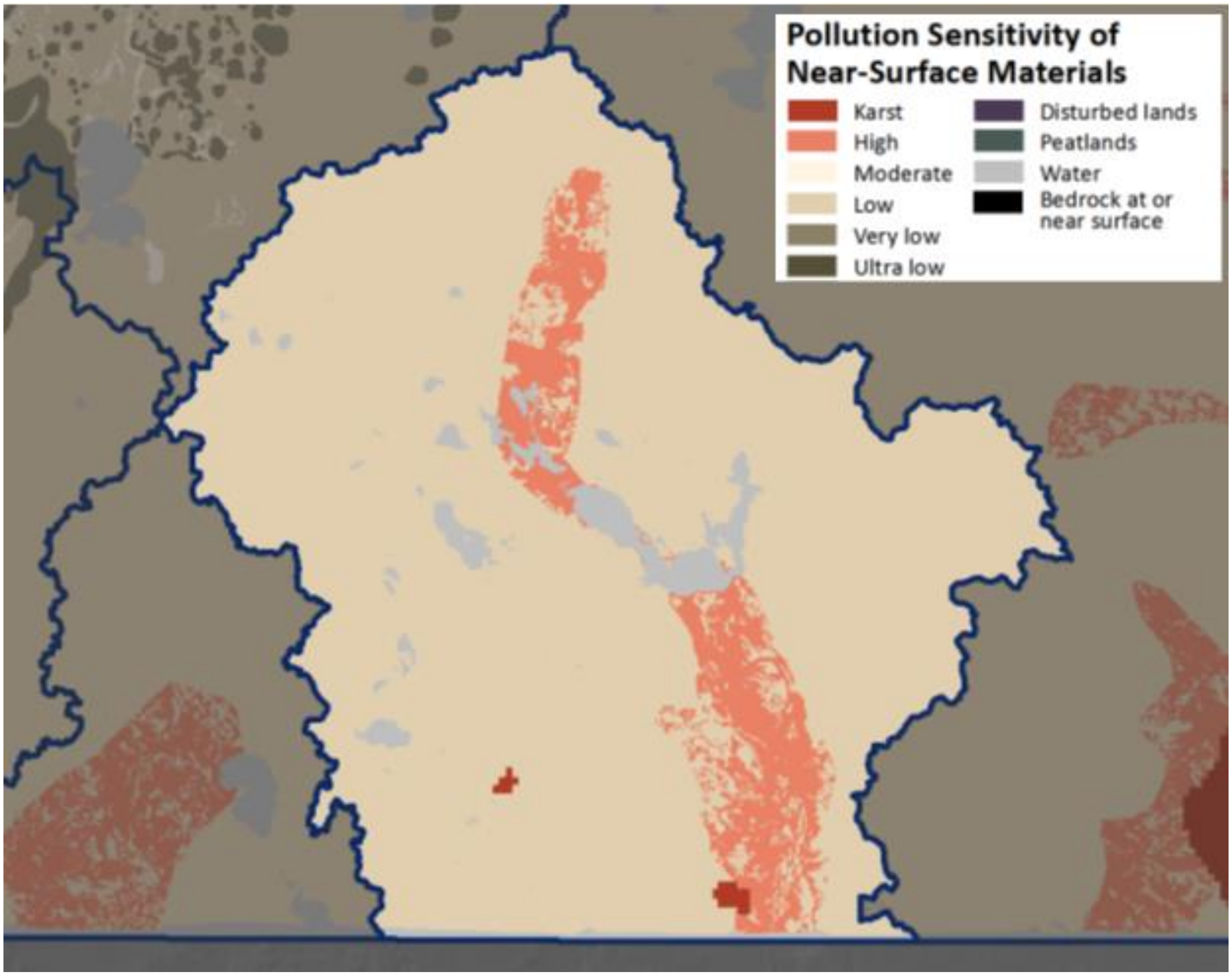


Figure 8. Pollution sensitivity of near-surface materials (DNR 2019).

1.1.4. Land Use

The dominant land use in the SRRW is cultivated crops; covering over 70% of the watershed (DNR 2019). Open water, wetlands and developed land uses combined cover approximately 18.5% of the watershed. Forest, barren lands and pasture make up the remaining watershed land covers.

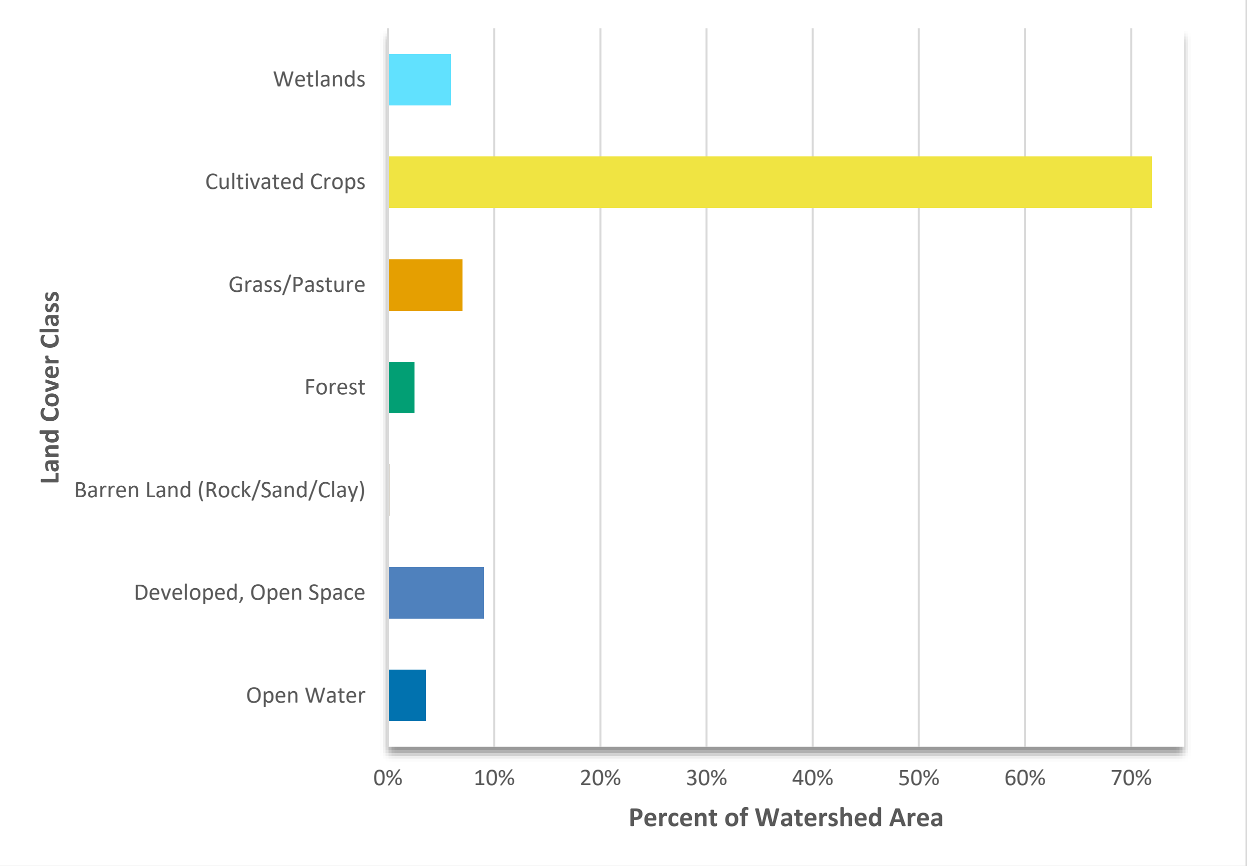


Figure 9. Land use cover classes of the SRRW (NLCD 2016).

1.1.5. Agriculture

Distribution of agricultural land use throughout the watershed are shown in Figure 10 and Figure 11. The USDA-NRCS assessed the agricultural conditions in the larger (Minnesota and Iowa) SRRW. While data are combined for watershed areas in both states in this report, the number of farms in Minnesota's portion of the watershed is likely around 400. Farm size distribution for 2017 in Freeborn County (USDA 2017) is:

Table 1. Farm size distribution in Freeborn County.

Farm size (acres)	Number of farms (%)
1 to 49 acres	381 (35%)
50 to 499 acres	431 (40%)
500 to 999 acres	137 (13%)
Over 1000 acres	127 (12%)

According to USDA (2017), 1,076 farms are located in Freeborn County with an average size of 366 acres. The SRRW makes up approximately 34% of Freeborn County. For the remainder of this report, the SRRW is being referred to as the Minnesota portion of the watershed.

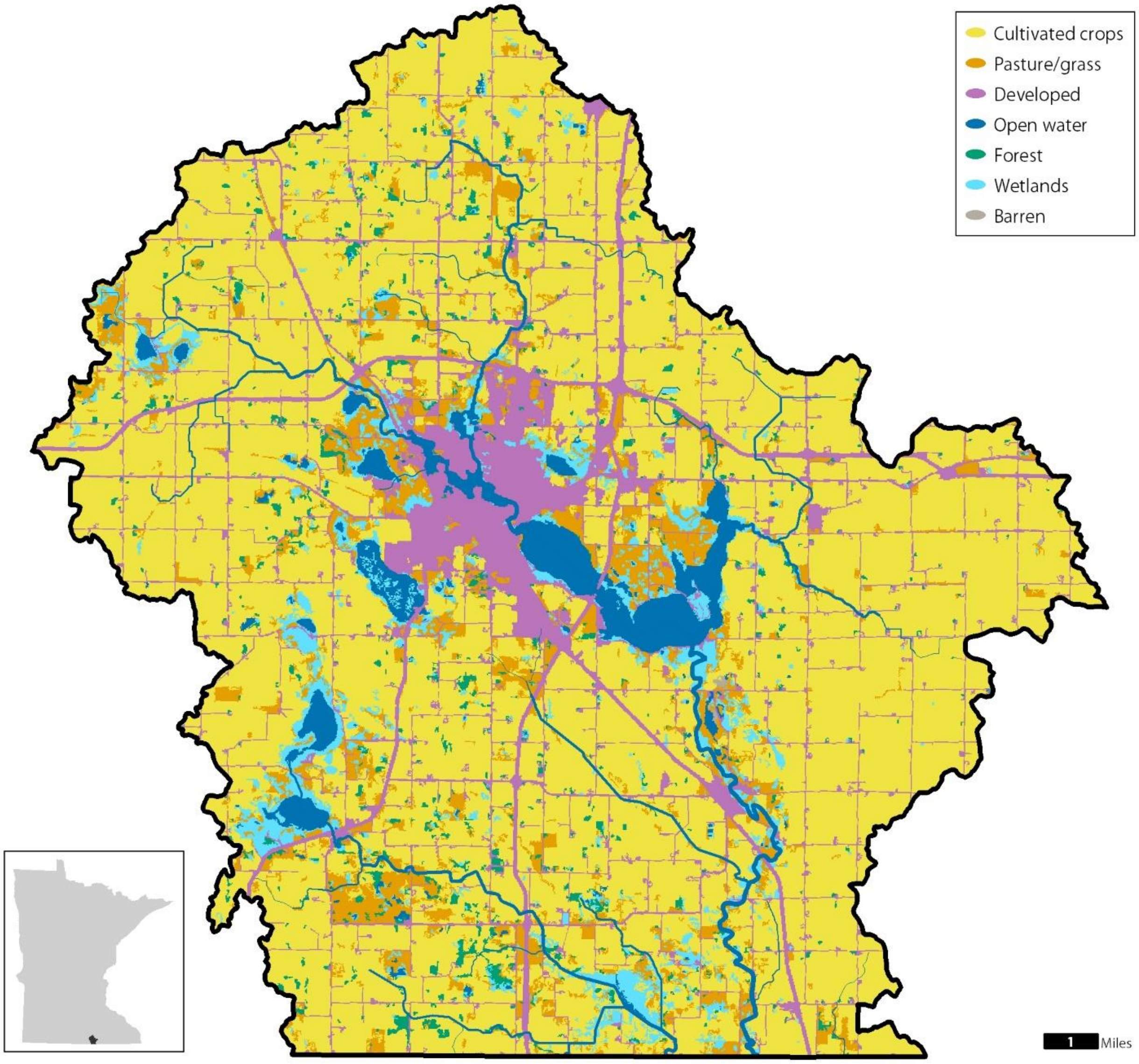


Figure 10. Land cover class of SRRW.

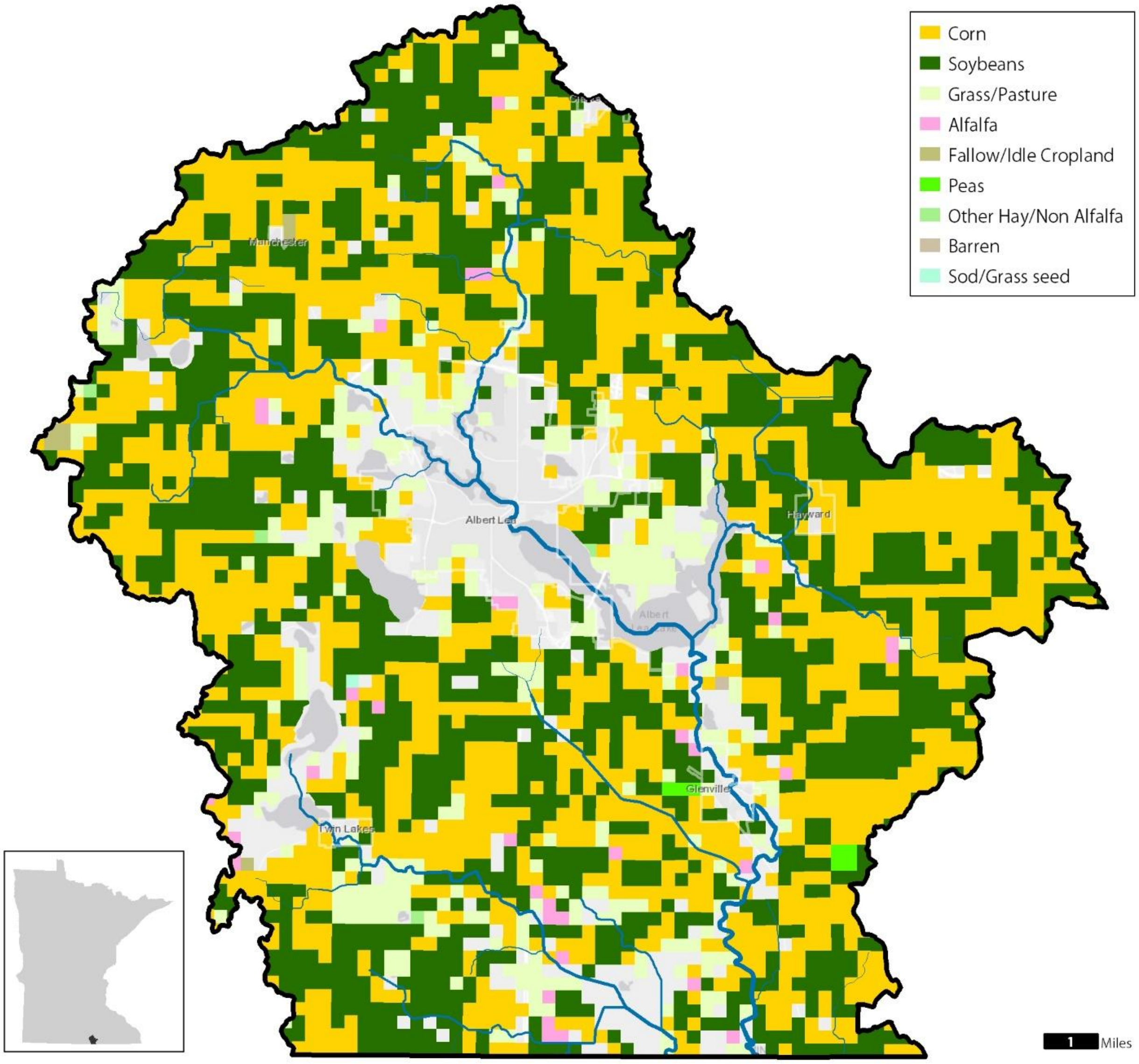


Figure 11. Crop Data Layer (USDA) of the SRRW; USDA 2019.

Data from 2009 to 2018 for Freeborn County shows that corn acres account for an average of 35% of the planted acres, soybeans 26%, pastures 13% and other (including alfalfa) 1%. During the 2009 through 2018 timeframe, acres planted to hay averaged about 4,500 acres, while acres planted to oats averaged 2,000 acres. (Crop Data Layer [CDL], Freeborn County Minnesota). Corn and soybean acres in Freeborn County consistently total about 330,000 acres for these years, with the exception of 2013, when an extremely wet spring prevented about 100,000 acres of these crops from being planted.

Table 2. Acres and percentages of crops grown in Freebon County (CDL 2019).

Year	Corn (ac)	Corn (%)	Soybeans (ac)	Soybeans (%)	Grass / Pasture (ac)	Grass / Pasture (%)	Alfalfa (ac)	Alfalfa (%)	Everything Else (ac)	Everything Else (%)	Total (acres)	Total (%)
2010	53,398	34	42,057	27	23,569	15	1,311	1	37,510	24	157,845	100
2011	54,501	35	41,392	26	24,282	15	1,265	1	36,404	23	157,844	100
2012	59,483	38	36,773	23	21,569	14	1,686	1	38,334	24	157,845	100
2013	49,798	32	32,069	20	32,183	20	1,313	1	42,481	27	157,844	100
2014	60,006	38	38,114	24	20,899	13	901	1	37,924	24	157,844	100
2015	49,931	32	49,069	31	14,712	9	1,264	1	42,868	27	157,844	100
2016	59,556	38	39,141	25	16,538	11	1,206	1	41,403	26	157,844	100
2017	54,321	34	45,683	29	16,992	11	1,512	1	39,337	25	157,845	100
2018	51,095	32	48,450	31	13,905	9	1,853	1	42,541	27	157,844	100
Average	**54,677**	**35**	**41,417**	**26**	**20,516**	**13**	**1,368**	**1**	**39,867**	**25**	**157,844**	**100**
Min	**49,798**	**32**	**32,069**	**20**	**13,905**	**9**	**901**	**1**	**36,404**	**23**	**157,844**	**100**
Max	**60,006**	**38**	**49,069**	**31**	**32,183**	**20**	**1,853**	**1**	**42,868**	**27**	**157,844**	**100**

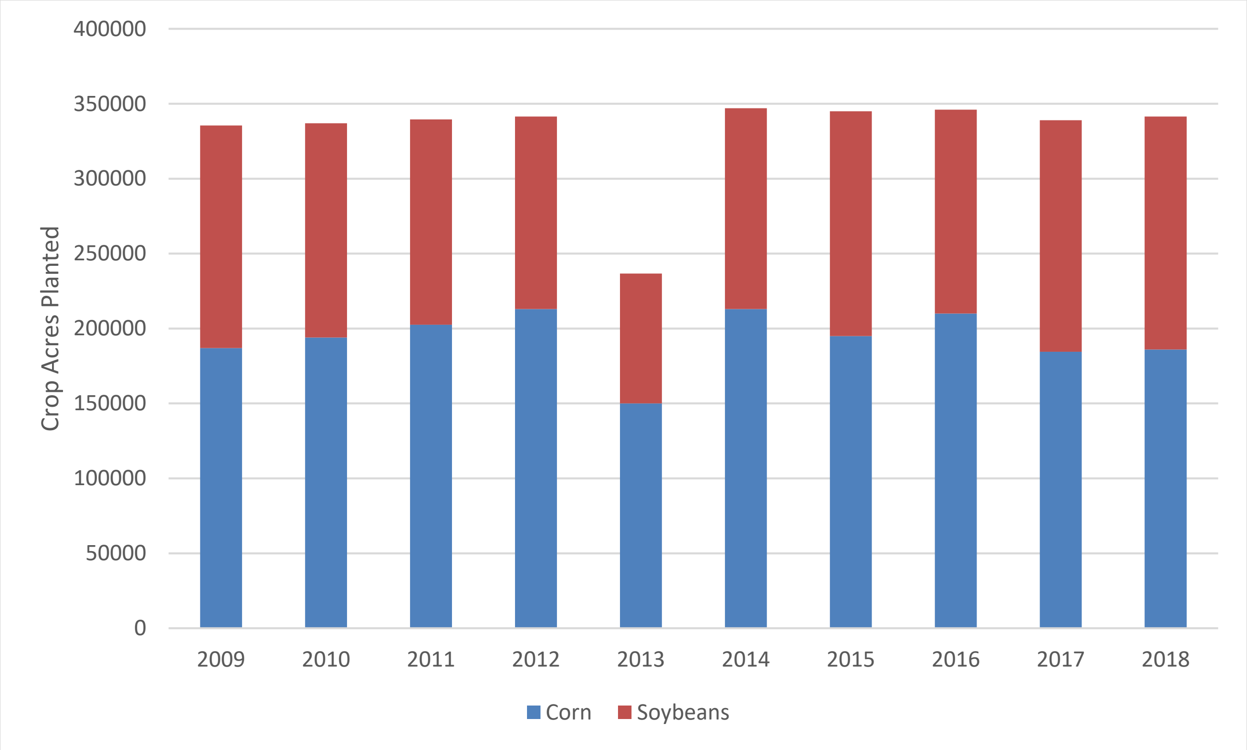


Figure 12. Crop acres planted to corn and soybeans in Freeborn County, 2009-2018.

Roadside field surveys in the SRRW have been conducted in the spring by Freeborn County SWCD staff following planting and before the crop canopy covers field surface from view. From 1996 to 2007, the crop residue surveys were the standard survey, with USDA-NRCS, Board of Water and Soil Resources (BWSR) and/or Conservation Technology Information Center (CTIC) support. After these sources of support ended, the SWCD continued crop residue survey data collection from 2009 through 2015.

For reference, definitions for crop residues and tillage from the CTIC (2002) are:

Conventional tillage: < 15% crop residue after planting, full-width tillage.

Reduced tillage: 15% to 30% crop residue after planting, full-width tillage.

Conservation tillage: any tillage and planting system that covers > 30% of the soil surface with crop residue after planting.

The amount of plant residue left on the field surface is affected by several factors – tillage (type and amount), previous crop grown and use of cover crops. The majority of the fields within the watershed have a crop rotation of corn and soybeans. Distinct difference in crop residue amounts were noted in fields planted for corn when compared to fields planted for soybeans (Figure 13). Soybeans generally provide limited crop residue after harvest and when combined with even limited amounts of tillage will result in crop residue amounts of less than 15% in the next growing season. To achieve higher residue amounts, practices such as no till, strip till or the use of cover crops will be required. See Restoration Strategies Section 3.3, Table 39, for more discussion on recommended implementation goals.

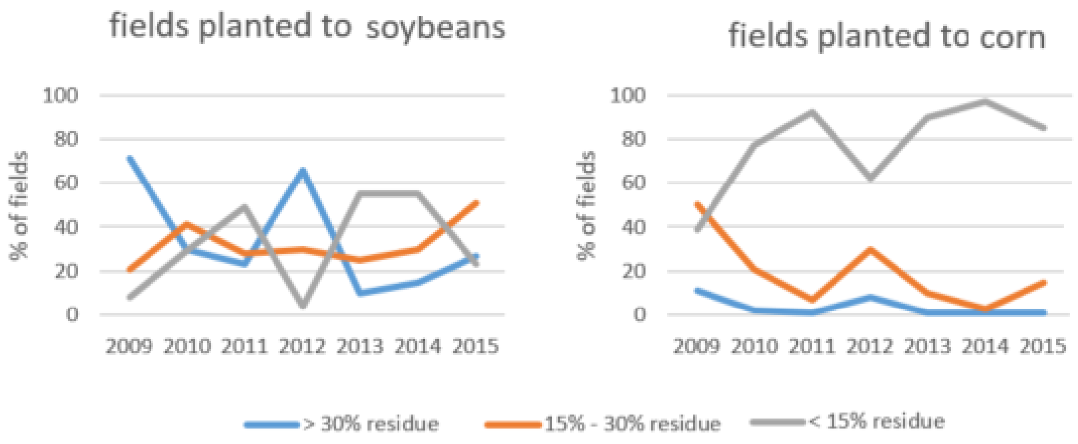


Figure 13. Percent crop residue from SRRW field surveys.

Freeborn County tillage data are displayed in Figure 14 for 14 years, as a percentage of the total planted acres.

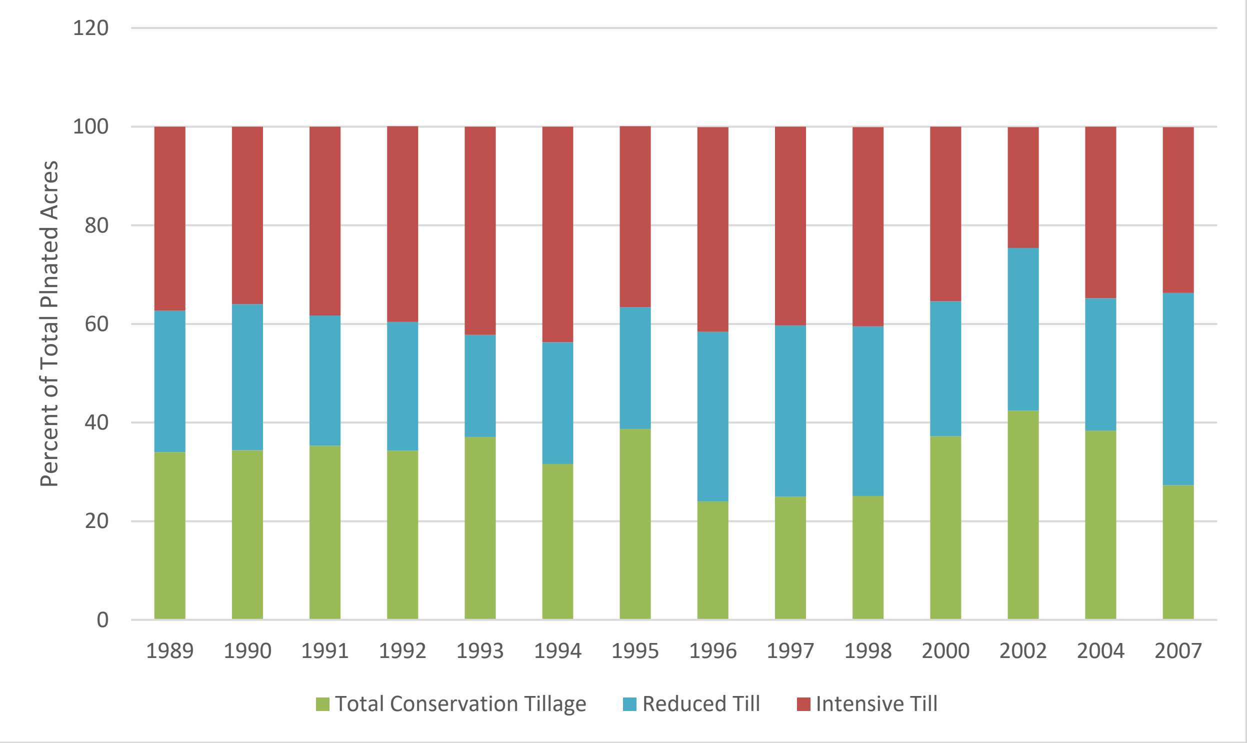


Figure 14. Freeborn County tillage practice survey results (1989-2007).

1.1.6. Altered Watercourses

A majority of waters within the SRRW have been altered from their natural state. Examples of these alterations include installing public and private drainage ditches, agricultural tile on farm fields, and dams on lakes and rivers (MPCA 2011 and DNR 2019). There are areas of the SRRW were natural water courses exist (Figure 15). Many of these are wetlands and are targeted areas of protection; see Section 2.5.

Table 3. Drainage classes in the SRRW.

Class	Length of miles	Percentage
Natural	26.4 mi.	11%
Altered	182.6 mi.	70%
Impounded (dams)	18.4 mi	7%
No Definable Channel	29.5 mi.	12%

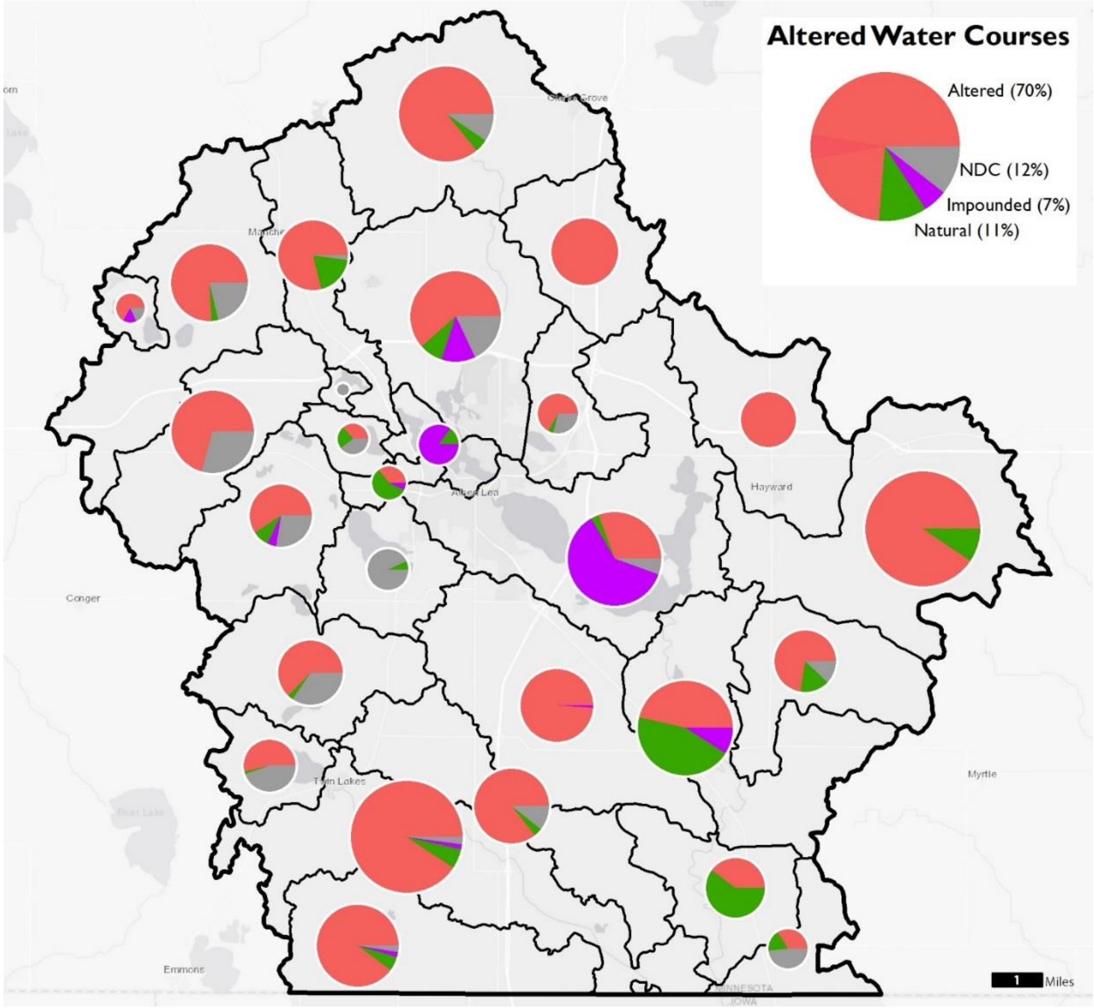


Figure 15. Altered water courses of the SRRW.

The agricultural drainage network is a significant feature in the SRRW. This vast network includes field scale tile systems, open ditch channels, and larger diameter "collector" tiles. This critical infrastructure is privately owned, and either managed by Freeborn County, or by private individuals and landowner groups. In other words, publically-managed systems are privately owned, and the "public" name refers to the administration, by a public entity such as a county or watershed district, acting within Minnesota Statutes 103E (The Drainage Code or Law). Public ditch systems within the SRRW are under the jurisdiction of Freeborn County.

Appendix H contains additional information about the publically-managed systems. In the SRRW, there are 29 public drainage systems, with drainage areas from 0.8 to 30.6 square miles. Together these 25 county ditches (CD) and four judicial ditches (JD) drain a total of 178.5 square miles, or 56% of the watershed (SRRWD 2004). When considering all publically-administered drainage systems, there are 145 miles of system tile, and 123 miles of drainage ditches. The smallest system based on drainage area is CD-70, and the largest is CD-55. The median drainage area is 3.8 square miles, or about 2,400 acres. Four of these systems consist of only tile (no open channel drainage ditch), while one system consists of only an open ditch. The other 24 systems are a combination of open channel drainage ditch and tile (larger diameter tiles, not field tiles). Table 4 displays the number of systems by percent open ditch (ditch miles divided by ditch plus tile miles).

Table 4. Number of public drainage systems and associated percent of open ditch.

Percent Open Ditch (by miles)	Number of public drainage systems
0%	4
< 25%	5
25% to 50%	9
50% to 75%	6
>75%	5

Note: this is based on miles of ditch and tile in the M.S. 103E management system, for 1993. There are five drainage systems with less than 25% open channel mileage, and thus they consist of more than 75% 'public' tile.

This type of categorization may be helpful to guide drainage system planning. Those systems that are either all tile, or are more than 75% tile (by total mileage), could be prioritized for targeted water storage efforts. For example, avoiding a potentially costly tile to open ditch conversion project could provide multipurpose benefits, such as decreased downstream pollutant loading and a more stable channel below the outlet.

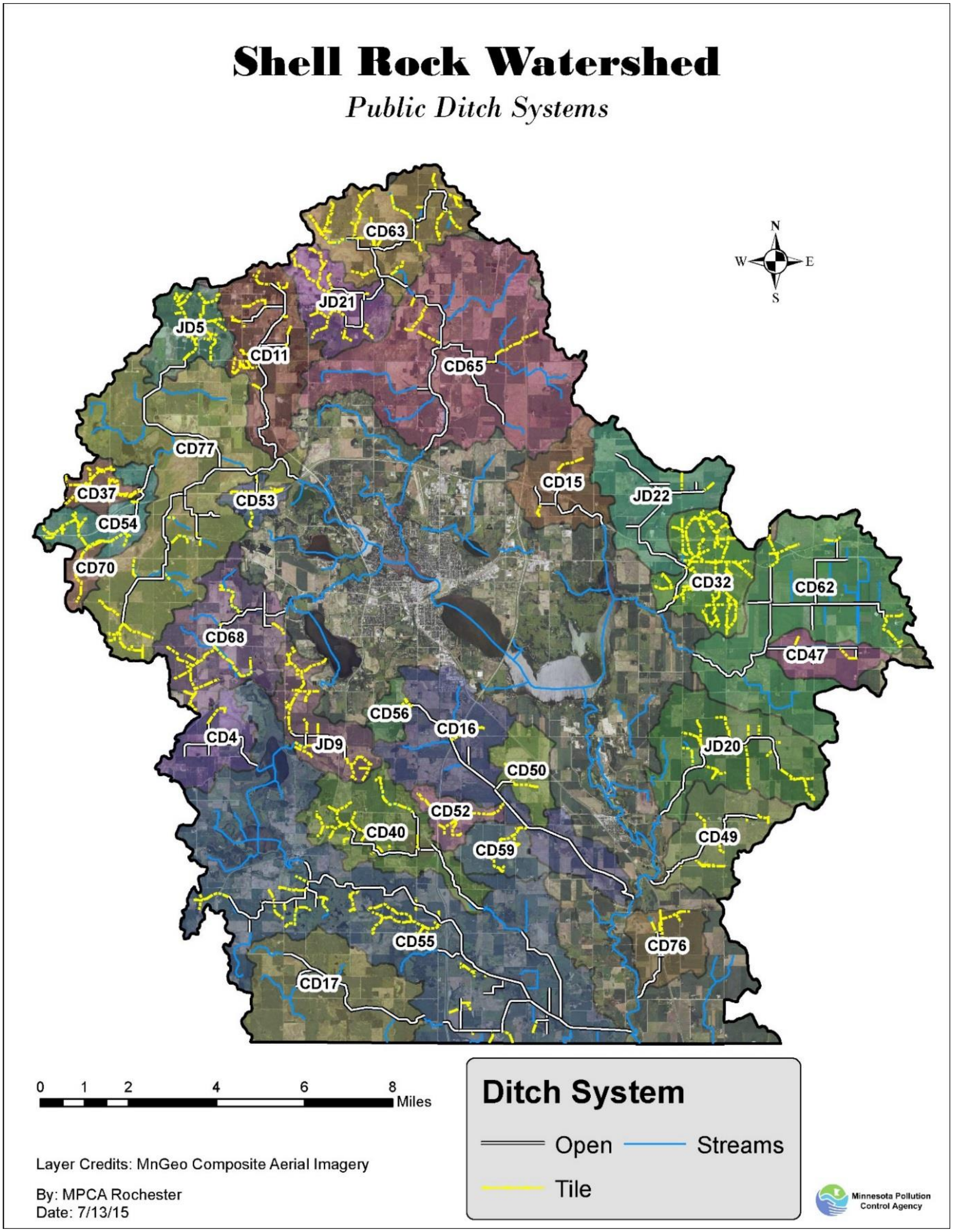


Figure 16. Public ditch system of the SRRW.

Wetland drainage began in the early 1900s, to facilitate transportation and agricultural production. Determining how much wetland loss has occurred since European settlement is estimated by measuring the extent of hydric soils. Hydric soils form when the soil is saturated for a long enough period of time during the growing season to create an anaerobic condition. In the SRRW, 131.5 sq. mi. (53.3%) of the watershed is covered with hydric soils (historic wetlands). Currently, wetlands make up 15.4 sq. mi. (5.89%) of the watershed. Wetland losses range from 69% to 89% for the SRRW’s main subwatersheds (MPCA 2016b). To illustrate this for the Wedge Creek Subwatershed, the historical wetlands accounted for about 11,500 acres, and wetlands in 2014 are about 1,250 acres. Across the entire SRRW, wetland loss is estimated to be about 83% (MPCA 2016b).

Of the wetlands that exist now in the SRRW, about 56% are considered emergent herbaceous wetlands, and would include wetland plant communities such as shallow and deep marshes. Regarding the quality of the wetlands based on the plant communities present, the majority are in poor condition (52.8%), with 41.7% rated as fair, and only 6% of the wetlands classified as being in good condition (MPCA 2016b).

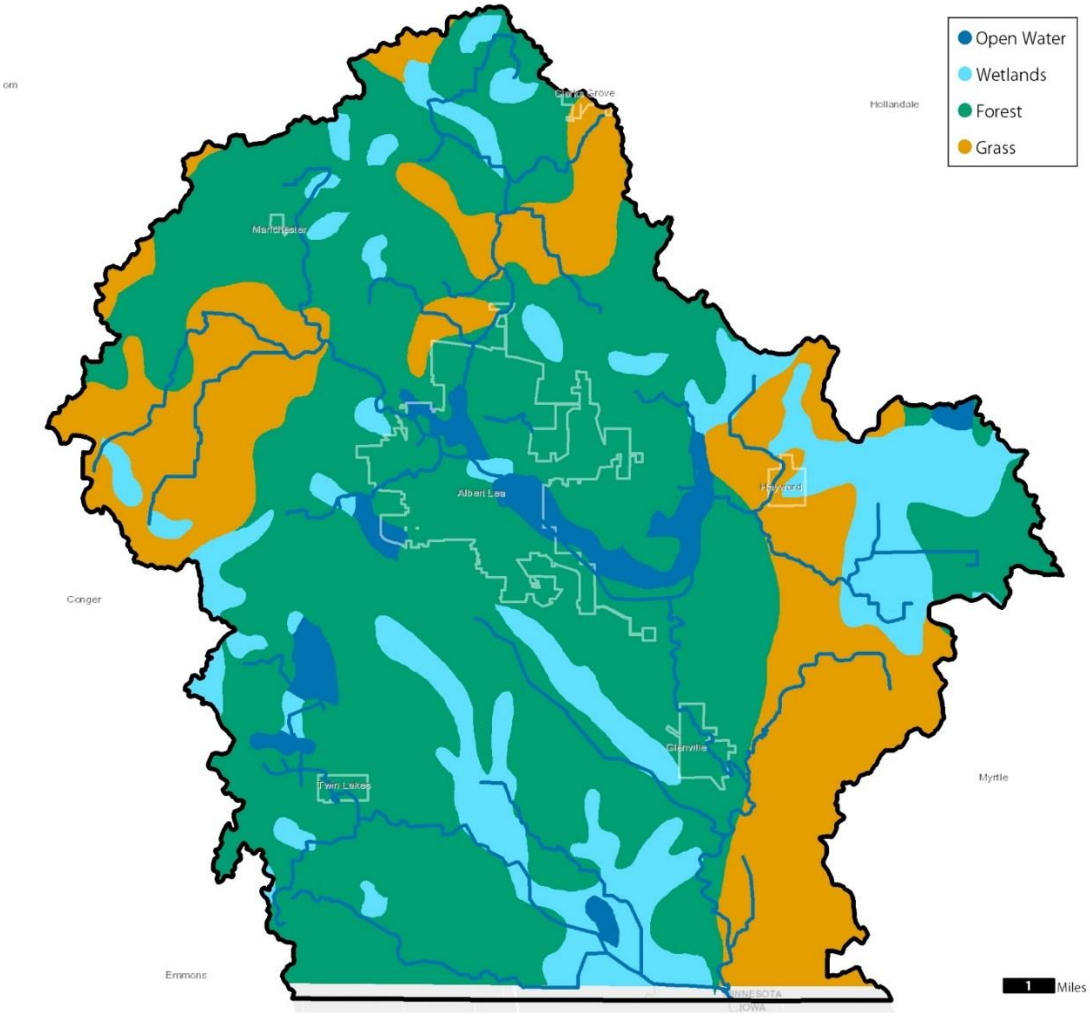


Figure 17. Historic land cover (DNR 2014) including Wetlands in the Shell Rock River Watershed.

The SRRW is reported as having approximately 16 acres in the Wetland Reserve Program (WRP) and 2,440 acres in Reinvest in Minnesota – Wetland Reserve Program (RIM-WRP). Wetland restoration is used to enhance environmental quality, provide water storage and habitat, and improve water quality. A detailed report on the status and quality of wetlands was completed by the MPCA in 2016, and is called the Shell Rock Watershed Wetland Condition Support document (MPCA 2016b). A view of historical wetlands and land use change for Freeborn County and this watershed, can be reviewed in Morriem (1972). Recommendations for wetland restoration can also be found in MPCA's Shell Rock River Watershed Wetland Condition Support Report (MPCA, 2016b). A map taken from this report identifies the subwatersheds of Wedge, Bancroft and Shell Rock River as high priorities for wetland restoration (Figure 18).

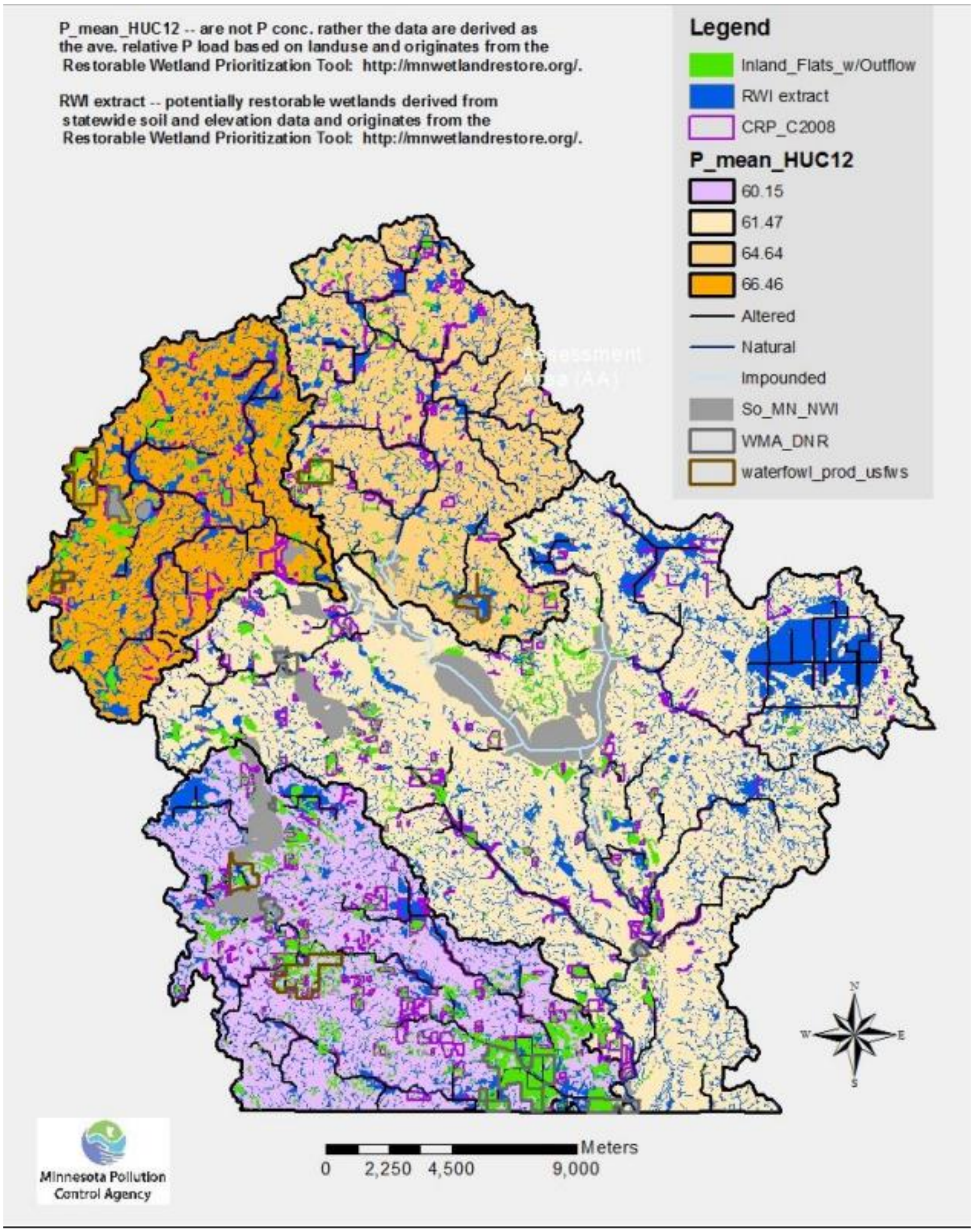


Figure 18. Priority subwatersheds for wetland restoration (MPCA 2016b).

Dams have been installed on Fountain and Albert Lea Lake to maintain stable water levels. In 1864, a fixed-crest dam was constructed on the south side of Albert Lea Lake to enlarge and deepen the lake (Albert Lea Lake Technical Committee 2000). Recent lake management in the SRRW occurred on Pickeral Lake (drawdown and fish ladder installation) and Albert Lea Lake (drawdown and fish barrier installation). The SRRWD maintains electric fish barriers on Wedge Creek, White Lake, Pickeral Lake, Albert Lea Lake, and Goose Lake. SRRWD also maintains a mechanical fish barrier on Fountain Lake. A new culvert/rock barrier has recently been installed on Lower Twin Lake.

1.1.7. Developed Areas

The City of Albert Lea is a regional community center of significance in the SRRW, and is the county seat of Freeborn County. Albert Lea lies "between the lakes" – which are Fountain Lake and Albert Lea Lake. The city encompasses the entire immediate watershed area of Fountain Lake, as well as the much of the western bay of Albert Lea Lake. The water resources are an integral part of the city of Albert Lea. Albert Lea has a population of 18,016 and land area of 14 square miles. There are several small towns located in the SRRW including Clarks Grove, Glenville, Gordonsville, Hayward, Manchester, and Twin Lakes. The human population in the SRRW is estimated at 23,357 based on the 2010 census (DNR 2019).

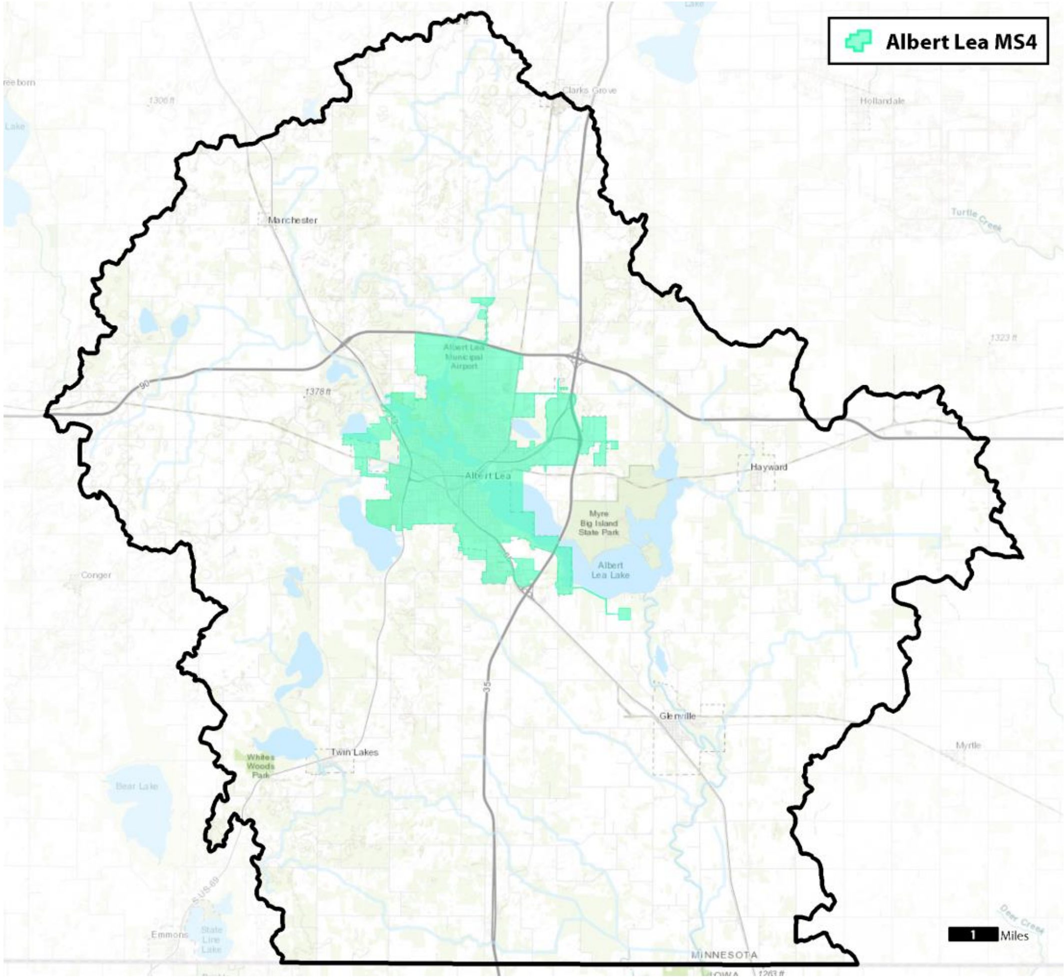


Figure 19. City of Albert Lea MS4 boundary in Shell Rock River Watershed.

Albert Lea is the only permitted municipal separate storm sewer system (MS4) in the watershed. As an MS4 community, Albert Lea is required to manage stormwater and improve runoff water quality through maintenance activities, installing implementation practices, and education. For example, numerous runoff control and treatment practices have been funded and installed, in collaboration with the SRRWD. See Section 2.3.4.2 for additional information on Albert Lea's MS4 Permit (#MS400263) allocations and stormwater management conditions.

1.1.8. Myre-Big Island State Park

Myre-Big Island State Park is a significant state resource in the SRRW. The park was created in 1947 and encompasses over 1,700 acres of gently rolling tallgrass prairie, oak savannas and maple basswood forests along the shores of Albert Lea Lake, including the 116 acre Big Island. Several areas within the park have produced artifacts indicating that humans have occupied the shores of Albert Lea Lake for over 9,000 years. The park has 93 drive-in campsites in addition to four backpack sites and has long been a popular destination for canoers, kayakers, anglers, and birders. The park falls along the Shell Rock River State Water Trail, a 20-mile route that starts at Fountain Lake and extends south to the Iowa border. The park is named for former state senator, Helmer Myre.

1.2 Subwatersheds

Three HUC-11 subwatersheds make up the SRRW: Fountain Lake, Shell Rock River, and Goose Creek. HUC-11 scales are not typically used, but since this was the scale used in the Monitoring and Assessment Report (MPCA 2012) the WRAPS will carry forward the same approach.

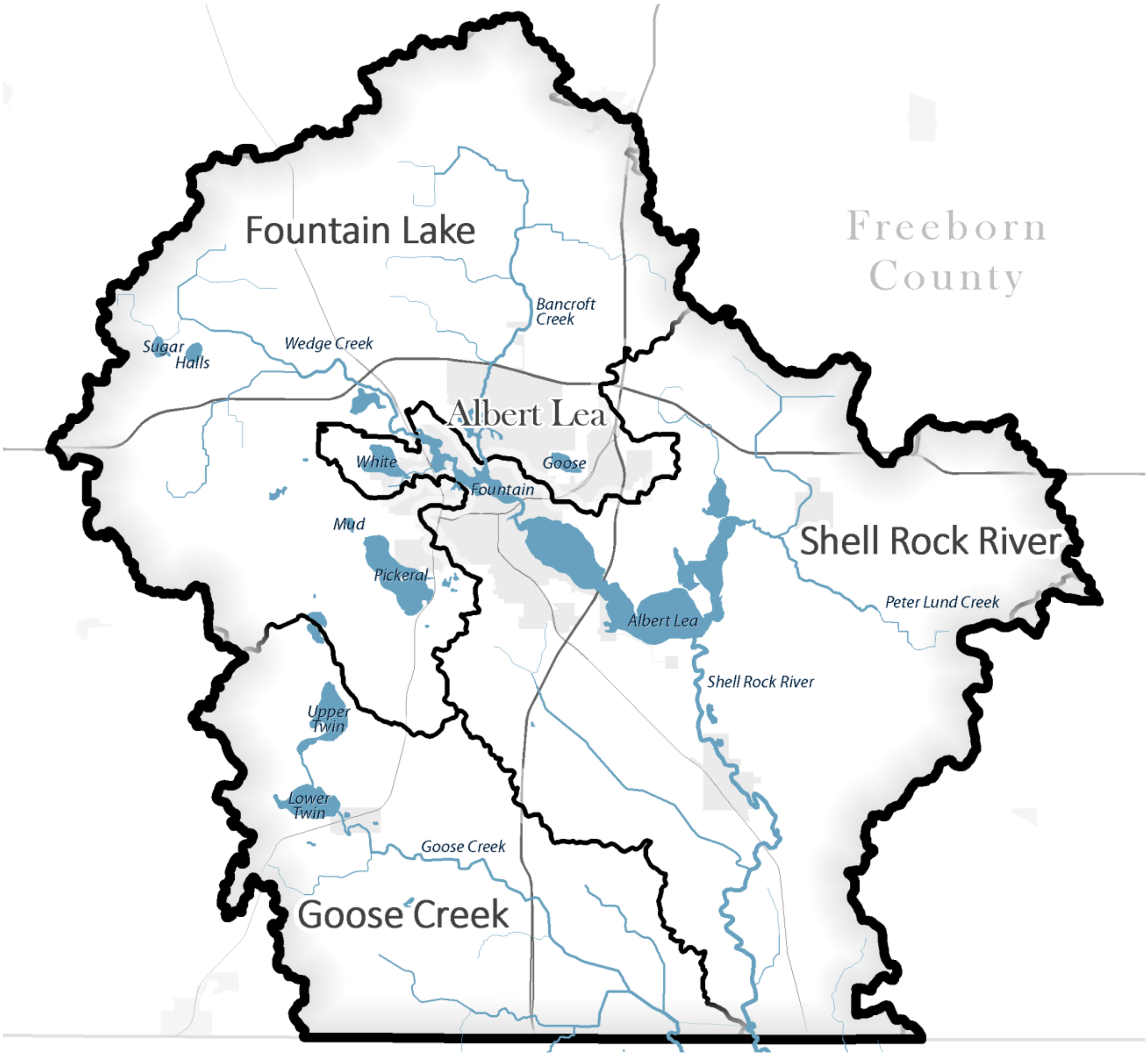


Figure 20. HUC-11 subwatersheds of the Shell Rock River Watershed.

Fountain Lake Subwatershed

The Fountain Lake Subwatershed is second largest subwatershed in the SRRW draining 95 square miles. The subwatershed is located on the northwestern side of the city of Albert Lea and includes the city of Manchester. Nine lakes lie within the watershed (Goose, Sugar, Halls, School Section, Mud, Pickeral, North Bay of Fountain, and two that are unnamed). The headwaters of the Fountain Lake Subwatershed begin as a series of channelized streams and wetlands that drain into a number of small lakes (MPCA 2012). The outflows of these lakes are a series of natural and channelized tributaries which eventually pour into Fountain Lake.

Shell Rock River Subwatershed

In Minnesota, the Shell Rock River is 12 miles in length (prior to entering Iowa), and is classified as a warm-water (class 2B) resource. This 12 mile stretch of the Shell Rock River is one WID (-501).

The river begins at the outlet of Albert Lea Lake, and is essentially flowing lake water, derived from the lake’s 145.9 square mile watershed. It is a low-gradient stream, and lacks distinct riffle areas, and has minimal pool habitat. In 2014, DNR staff conducted a geomorphic survey of the first 1,000 feet of river channel (known as Juglans Woods Aquatic Management Area). The geomorphology report (DNR 2015) describes a channel slope of 0.005%, a water depth range from 1.1 to 2.2 feet, and a sinuosity of 1.79. These and other geomorphic statistics classify the initial river reach as a C5c-stream type, which means it is a sinuous sand-bed river with a high width/depth ratio and good floodplain connectivity. The DNR further notes that the river channel has widened somewhat since 1938. For the full DNR geomorphology report, follow the link at DNR (2015).

Goose Creek Subwatershed

The Goose Creek Watershed Unit is the smallest subwatershed draining 48 square miles in the southwest corner of the SRRW. Goose Creek runs 11 miles before flowing into the Shell Rock River, 1 mile north of the Minnesota-Iowa border (MPCA 2012).

1.3 Lake Characteristics

The SRRW contains several lakes that serve multiple recreational uses. These include natural environment lakes managed primarily for wildlife, and general recreation lakes for uses such as swimming, fishing, and boating.

Table 5. Shell Rock River Watershed lakes.

Lake ID	Lake Name	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral	Mean Depth (m)	Support Status
24-0017-00	Goose	32.17	---	1343	---	---	NA
24-0025-00	Pickeral	201.51	1.22	1498	100	0.96	NS
24-0037-00	Sugar	24.89	0.46	4149	100	0.25*	IF
24-0038-00	Halls	21.69	0.91	412	100	0.50*	IF
24-0040-00	School Section	6.96	---	143	---	0.59	IF
24-0068-00	Mud	6.8	---	3645	---	---	IF
24-0014-00	Albert Lea	1074.69	1.83	38047	100	0.53	NS
24-0018-01	Fountain (East Bay)	94.68	4.27	10058	100	1.72	NS
24-0018-02	Fountain (West Bay)	57.54	2.44	21261	100	1.57	NS
24-0024-00	White	63.82	1.07	468	100	35	NS
24-0027-00	Lower Twin	111.55	0.76	3320	100	29	IF
24-0031-00	Upper Twin	33.87	0.76	2325	100	0.29*	IF

Key: **NS** – NonSupport, **IF** – Insufficient Information, **NA** – Not Assessed, *Depths estimated by MPCA Staff

Lakes within the SRRW can be generally characterized as shallow lakes. Shallow lakes have permanent or semi-permanent water regimes and are typically dominated by wetland habitat (less than 15 feet deep) (DNR 2019b). Although water quality degradation, altered watersheds, modified outlets, urban development, intensive agriculture and exotic species have impacted many of these shallow lakes (both statewide and within the SRRW), wildlife benefits remain a critical habitat component for Minnesota's shallow lakes. Although the water quality of shallow lakes have been impacted by many things (development, altered hydrology, exotic species, etc.) they remain critically important for wildlife.

2. Watershed conditions

"Water quality" is a comprehensive term that covers the physical, chemical and biological conditions in a stream or lake. Since those three components are all related, water quality represents the integration of those elements. Water quality varies with time (day, night, seasons, etc.), and with space (upper watershed ditch or stream, downstream lake, or larger river). This water quality concept is well engrained in the SRRW, where physical factors, such as water flow and temperature, affect nutrient concentrations and loads, or DO levels. These in turn impact aquatic plants, algae, macroinvertebrates, fish, and human interactions with the aquatic environment.

Initiatives monitoring water quality in the SRRW have been supported by local, state and federal entities for many years. The SRRWD has collected stream and lake water quality data since 2005, summarized in annual reports available on their webpage (https://www.shellrock.org/reports). State departments including the Department of Health (groundwater public and private wells), Department of Agriculture (groundwater, pesticides), DNR (stream flow, fish, aquatic plants, stream geomorphology) and MPCA (chemical, sediment, and biota monitoring) routinely collect water quality data. Federal agencies have also contributed to critical longer-term data sets for this watershed, including weather data (National Weather Service), and the initiation of stream flows and stream sediment monitoring (U.S. Geological Survey [USGS]). The USGS initiated the stream flow gage for the Shell Rock River at Gordonsville, Minnesota and maintains many stream flow gages in Iowa, on the Shell Rock and Cedar Rivers. For example, the Shell Rock River at Shell Rock, Iowa is USGS gage 05462000, where flow monitoring has been provided continuously since 1953 (USGS 2020).

These data collection efforts have led to a greater ability to apply predictive modeling in the SRRW, allowing more accurate trend analysis and effective water quality improvement plan development. This background is important to be aware of, as this solid framework will continue to serve the SRRW in the future.

DNR Watershed Health Assessment Framework (WHAF) scores the health of watershed biology, stream geomorphology, hydrology, connectivity and water quality. Scores are scaled 0 (least healthy) to 100 (best health). The overall WHAF score for the SRRW is 43. For more information about WHAF and the scored components, visit: https://www.dnr.state.mn.us/whaf/about/scores/index.html.

Table 6. Watershed Health Index Scores for the SRRW (DNR 2019).

Component	Index Avg. Score
Hydrology	56
Geomorphology	68
Biology	34
Connectivity	18
Water quality	39

Tiered Aquatic Life Use Summary

Biological monitoring in the SRRW began in 2009, before the establishment of MPCA's Tiered Aquatic Life Use (TALU) Framework. The TALU Framework is based on aquatic life index of biotic integrity (IBI) scores and gives different biotic community scores for Class 2 streams in Exceptional, General, and Modified Use classifications. Each of these three classifications have different expectations and criteria for fish and invertebrates. This allows for the protection of exceptional waters while also setting attainable goals for waters affected by past activities such as ditching. For more information about MPCA's TALU Framework, refer to the TALU fact sheet: https://www.pca.state.mn.us/sites/default/files/wq-s6-36.pdf.

Because the TALU framework and IBI scores for waters classified as modified use were under development, much of the fish and macroinvertebrate data collected in the headwater areas of the SRRW was deferred from the 2012 assessment. Only the Shell Rock River and Wedge Creek met available aquatic life assessment criteria (MPCA 2012). The remaining channel reaches were deferred until the TALU rules could be formally adopted. Adoption of the TALU framework occurred in 2017 and since then, deferred stream reaches in the SRRW have been assessed for aquatic life (see Section 2.0.2).

It is important to note that TALU designations do not affect chemical, physical, or bacteria-related water quality standards. A stream WQS for DO, TP, or bacteria is not part of the TALU approach. The current (2018) impaired waters list includes these assessments. The companion TMDL report addresses the biological impairments in the Shell Rock River, and does not include the deferred reaches referenced in this section.

Table 7 and Table 8 below summarize the stream reaches proposed for general or modified use TALU classifications in the SRRW. No exceptional use reaches are being recommended in the watershed. The reaches with a "new-split" note where a long reach was "split" or subdivided, to better reflect the stream conditions and water quality potential. These designations are subject to change, both before and during rule-making. Final designations will be published in Minn. R. ch. 7050. Following a period of public comment. Use designations are expected to be adopted in 2026, but future assessments will likely use proposed designations to assess for aquatic life.

Table 7. General Use - Preliminary Draft Use Designations under TALU.

Reach WID	Name	Length (miles)
07080202-513	County Ditch 16	2.46
07080202-516	Unnamed creek (Shoff Ck)	3.12
07080202-527	County Ditch 66	1.64
07080202-529	County Ditch 65	1.04
07080202-531	Unnamed creek (Wedge Ck)	1.46
07080202-534	Peter Lund Creek	2.84
07080202-548	Bancroft Creek (CD-63)	new - split
07080202-550	Bancroft Creek (CD-63)	new - split
07080202-552	Judicial Ditch 20	new - split

Table 8. Modified Use – Preliminary Draft Use Designations under TALU.

Reach WID	Name	Length (miles)
07080202-508	County Ditch 16	5.93
07080202-510	County Ditch 17	1.6

Reach WID	Name	Length (miles)
07080202-526	County Ditch 9	2.02
07080202-532	County Ditch 40	6.11
07080202-533	Judicial Ditch 20	6.09
07080202-535	County Ditch 32	3.95
07080202-549	Bancroft Creek (CD-63)	new - split

Watershed Assessment Summary

The MPCA assesses surface waters for meeting aquatic recreation and aquatic life use standards. In lakes, aquatic recreation includes eutrophication standards (TP, chl-*a,* and secchi). In streams, aquatic recreation includes an *E. coli* standard. Aquatic life standards are used in streams and include FIBI, MIBI, and associated chemical indicators.

The water quality conditions discussed in the following section come from the 2012 SRRW monitoring and assessment report (MPCA 2012). Waters with monitoring data that were pending use classification designation in 2012 (Table 7 and

Table 8) are not discussed in the report. Since the 2012 assessment, an "opt-in" assessment was conducted in 2018 to preliminarily assess whether waters will meet their proposed designated uses. Once proposed designated uses are finalized, the opt-in assessment decisions will determine whether a surface water will be placed on a future impaired waters list.

Table 9 summarizes all stream reaches monitored and assessed to date. Table 17 in Section 2.1.2 summarizes lakes monitored and assessed to date.

Fountain Lake HUC-11:

Bancroft Creek (-507) and Unnamed Creek, "Wedge Ck" (-531) were the two waterbody identification numbers (WIDs) assessed for aquatic recreation standards in the Fountain Lake Subwatershed. Both WIDs are impaired for aquatic recreation. Due to the channelized conditions, Bancroft Creek was deferred for aquatic life assessment. Unnamed Creek (Wedge) did not have enough information to complete a FIBI or MIBI assessment, but was assessed for TSS and found to be impaired.

Shell Rock River HUC-11:

One WID (Shell Rock River -501) was assessed for aquatic recreation and aquatic life. Shell Rock River (-501) was found to be impaired for both aquatic recreation and aquatic life. County Ditch 16 (-508) was not assessed for aquatic recreation and was deferred from being assessed for aquatic life due to channelization. There were eight reaches in the Shell Rock River HUC-11 that were not assessed for aquatic recreation, aquatic life or both, totaling 22.6 miles.

Goose Creek HUC-11:

None of the lakes within the subwatershed (Lower Twin, Upper Twin, Church, and two small unnamed lakes) were assessed for WQSs (see Table 17). Goose Creek (-510) is the only stream monitored for aquatic life and aquatic recreation. The stream was not assessed for aquatic life and had insufficient data to complete an aquatic recreation assessment.

In the following Section 2.1, the water quality data used in these assessments is summarized and discussed in more detail.

Table 9. Assessment summary of streams in the SRRW.

WID - last 3 digits	Stream	Reach Description	Stream Class	Beneficial Use and Associated Biology, Stressors, and Pollutant Assessment																						
				Aquatic Life																		Aquatic Recreation		Lim Use		
							Indicators							Stressors									Pollutant		Pollutant	
				Assessment	F-IBI	M-IBI	DO	TSS	Chloride	pH	NH3	TP	Pesticides	Habitat	Hydrology	NO3-N	TSS	Connectivity	DO	Eutrophication (TP)	Chloride	Assessment*	Bacteria	Assessment*	Bacteria	DO
501	Shell Rock River	Albert Lea Lk to Goose Cr	2B	x	x	x	x	x	+	x	+		-	X		X	X		X	X		x_1	x_1			
504	Shell Rock River	Fountain Lk to Albert Lea Lk	2Bg, 3C	NA																		NA	-			
505	Goose Creek (County Ditch 10)	Headwaters to Shell Rock R	7	IF																				IF	-	-
507	Bancroft Creek (County Ditch 63)	Unnamed ditch to Fountain Lk	2Bg, 3C	IF	+	x	?	?	-	+	-		-									x	x			
508	County Ditch 16	Unnamed ditch to Shell Rock R	*2Bm	x**	x**	x**	IF	NA	-	NA	NA		NA									NA	-			
509	County Ditch 63	Headwaters to Bancroft Cr	2Bg, 3C	IF																		NA	-			
510	County Ditch 17	Unnamed ditch to Goose Cr	*2Bm	$+^a$	+	+	NA	NA	-	NA	NA		NA									NA	-	IF	+	-
511	County Ditch 16	Headwaters to Unnamed ditch	2Bg, 3C	NA																		NA	-			
512	Peter Lund Creek	CD 32 to Albert Lea Lk	2Bg, 3C	IF																		NA	-			
513	County Ditch 16	Unnamed ditch to Albert Lea Lk	2Bg, 3C	$+^a$	x	+																				
514	County Ditch 68	Unnamed ditch to Mud Lk	2Bg, 3C	IF																						
516	Unnamed creek (Shoff)	Mud Lk to Fountain Lk	2Bg, 3C	x	x**	x**	-	x	-	IF	-		-									NA	-			
524	County Ditch 11	Headwaters to Unnamed ditch	7	NA																				NA		
526	County Ditch 9	Unnamed ditch to Unnamed ditch	*2Bm	x**	x**	x**																NA				
527	County Ditch 66	Unnamed ditch to CD 9	2Bg, 3C	x**	x**	x**																NA				
529	County Ditch 65	Unnamed ditch to CD 63	2Bg, 3C	x**	x**	x**																				
531	Unnamed creek (Wedge)	T103 R22W S36, north line to Unnamed ditch	2Bg, 3C	x**	x**	+	+	x	-	+	-											x	x			
532	County Ditch 40	Unnamed ditch to Goose Cr	*2Bm	$+^a$	+	+																NA				
533	Judicial Ditch 20	Headwaters to Shell Rock River	*2Bm	IF																		NA				
534	Peter Lund Creek	CD 12/47 to CD 32	2Bg, 3C	$+^a$	+	+																NA				
535	County Ditch 32	Unnamed ditch to Peter Lund Cr	*2Bm	$+^a$	+	x																NA				

WID - last 3 digits	Stream	Reach Description	Stream Class	Beneficial Use and Associated Biology, Stressors, and Pollutant Assessment																						
				Aquatic Life																		Aquatic Recreation		Lim Use		
							Indicators							Stressors									Pollutant		Pollutant	
				Assessment	F-IBI	M-IBI	DO	TSS	Chloride	pH	NH3	TP	Pesticides	Habitat	Hydrology	NO3-N	TSS	Connectivity	DO	Eutrophication (TP)	Chloride	Assessment*	Bacteria	Assessment*	Bacteria	DO
536	County Ditch 66	Headwaters to Unnamed ditch	2Bg, 3C	IF																		NA				
537	Unnamed creek	Goose Lk to Fountain Lk	2Bg, 3C	IF																		NA				
548	Bancroft Creek (County Ditch 63)	CD 63 to 270th St (new split)	2Bg, 3C	x**	x**	x**																IF				
549	Bancroft Creek (County Ditch 63)	270th St to -93.366 43.695	*2Bm	x**	x**	x**																IF				
550	Bancroft Creek (County Ditch 63)	-93.366 43.695 to Fountain Lk (new split)	2Bg, 3C	x**	-	x**																x[2]	x[2]			
552	Judicial Ditch 20	-93.254 43.579 to Shell Rock R (new split)	*2Bg	+[a]	+	+																NA				

* Proposed designated use change.

**Opt-in assessment 2018 - 2020 impaired water listing.

1 = 2012 TMDL.

2 = *E. coli* TMDL expected in 2020.

a = Assessment done in 2018 opt-in. Results will be summarized in Cycle II Assessment (Spring 2021).

X = impaired

? = inconclusive (need more data)

\+ = meets standard

\- = not applicable

□ = no data

2.1 Water Quality Conditions

Watershed wide sampling by MPCA's watershed approach occurred in 2009. As described in the Shell Rock River Monitoring and Assessment Report (MPCA 2012), all data collected during a 10-year window was used for assessment. Water quality assessment is a process of evaluating whether a surface water is meeting its designed use by comparing water quality data to Minnesota WQSs (Minn. R. ch. 7050). Of the waters assessed in 2012, none were found to be meeting WQSs and thus all were given an impaired status. Impaired does not mean a water is un-fishable or un-swimmable, rather, it means that a water is not fully supporting its designated use(s) and thus can be improved. Since the 2012 assessment, several reaches underwent an aquatic life (AQL) opt-in 2018 assessment (indicated in Table 9). Conclusions on this opt-in assessment will be captured in the next Monitoring and Assessment Report (expected in 2021/2022).

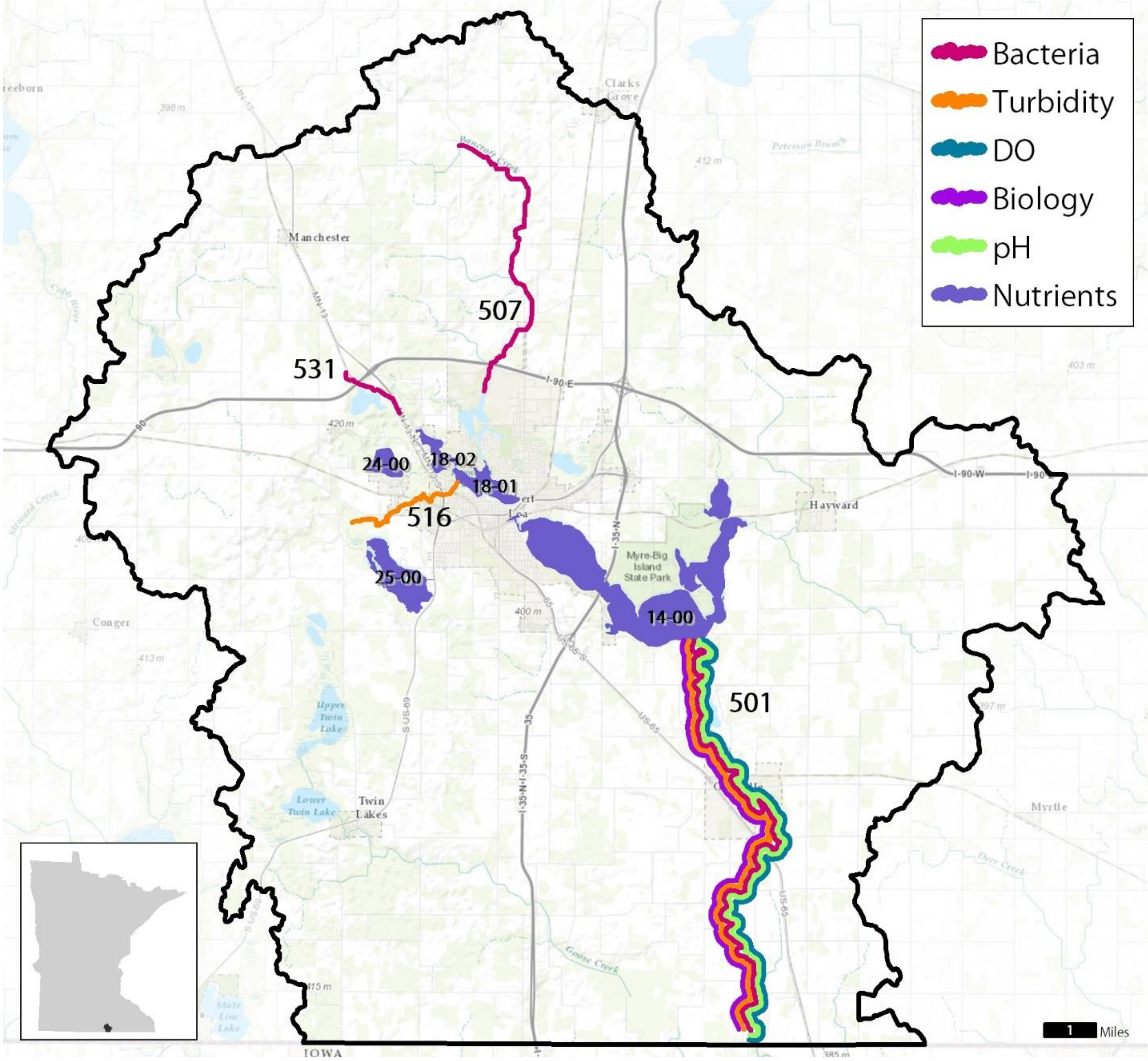
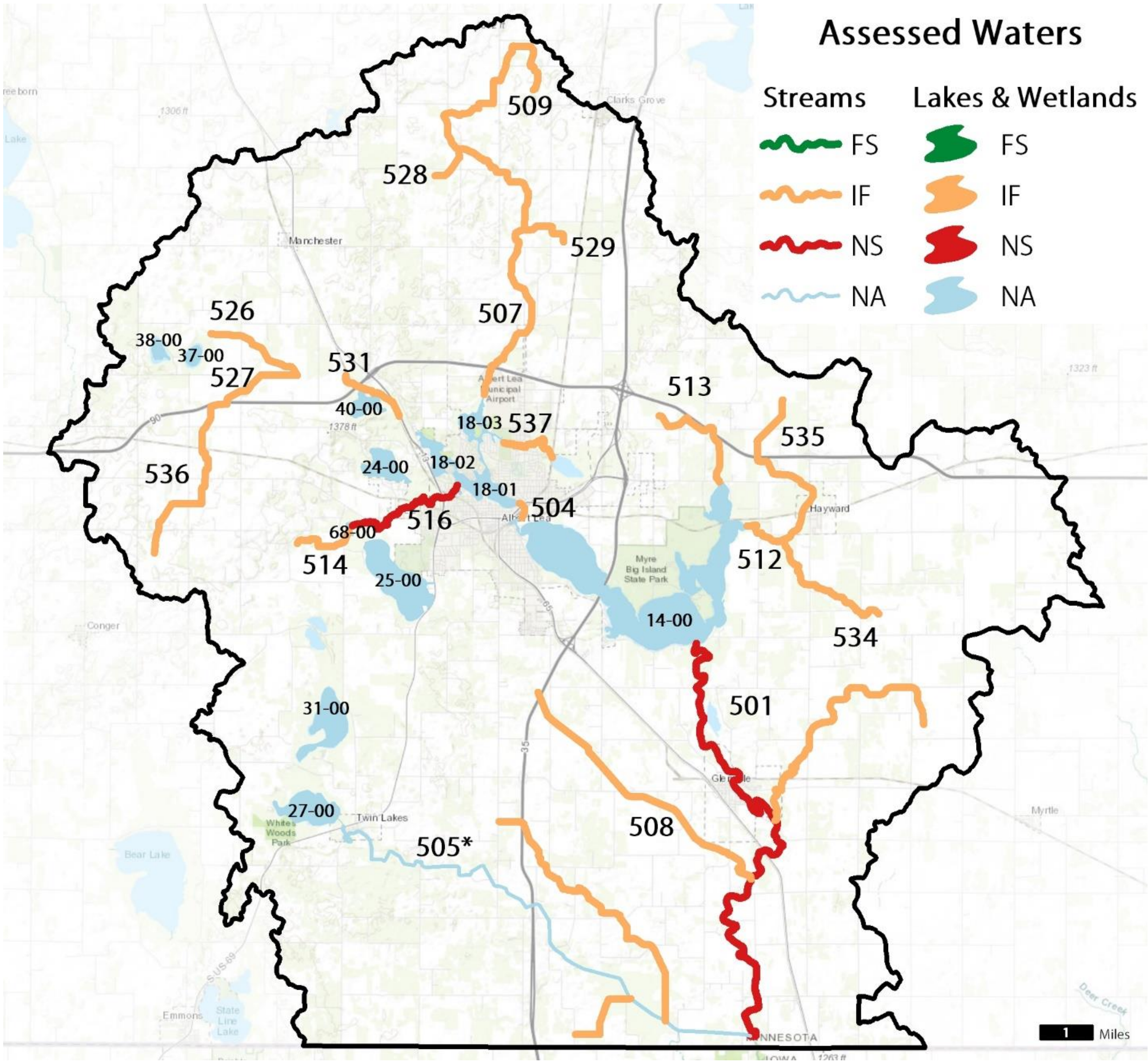


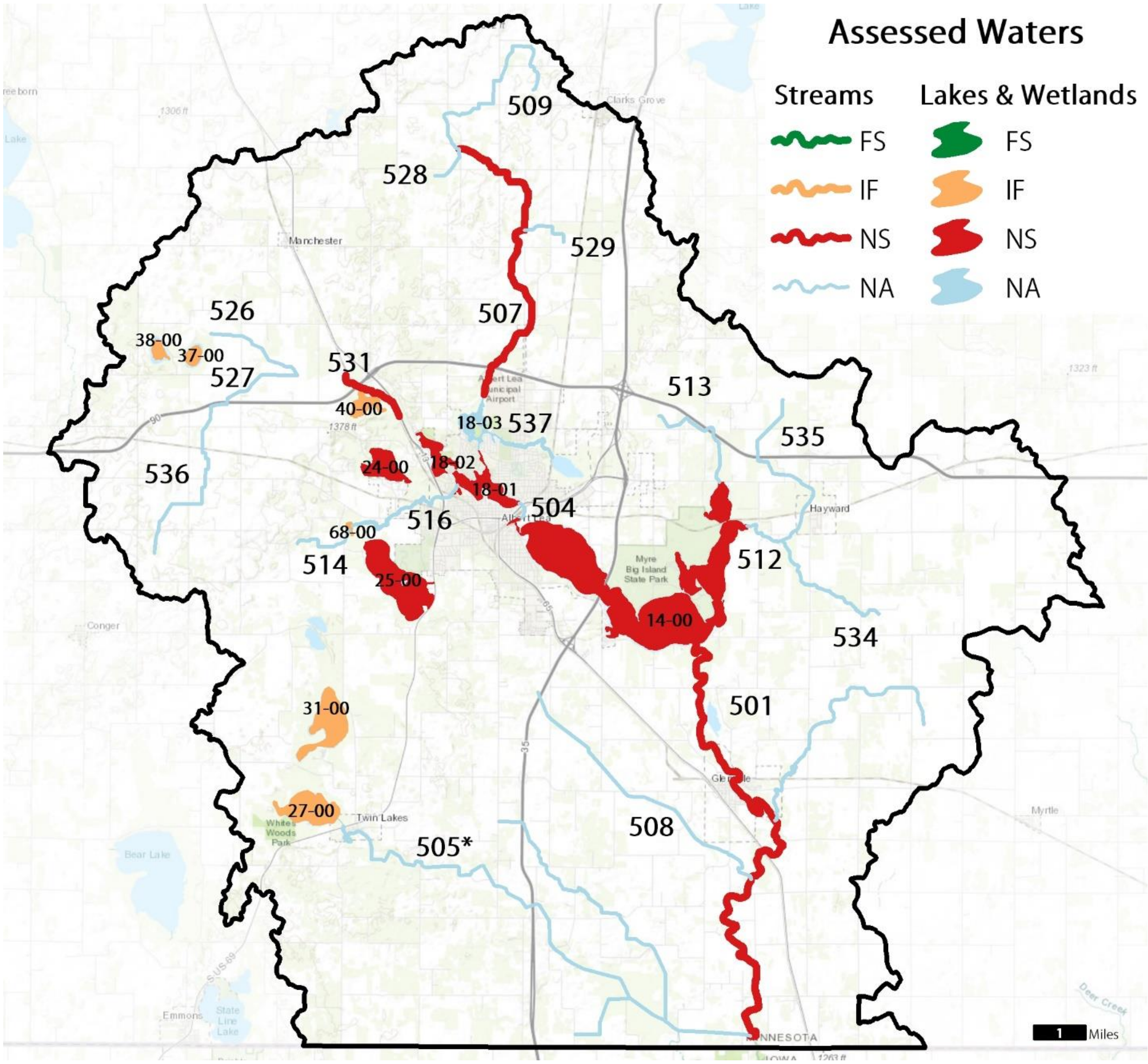
Figure 21. Water quality impairments in the SRRW from 2012 assessment.



FS: Full support of standards	NS: Not supportive of standards
IF: Insufficient information for assessment	NA: Not assessed

* Class 7 water; no AQL standards

Figure 22. SRRW surface waters assessed for Aquatic Life (AQL) in 2012.



FS: Full support of standards NS: Not supportive of standards
IF: Insufficient information for assessment NA: Not assessed
* Class 7 water; no AQL standards

Figure 23. SRRW surface waters assed for Aquatic Recreation (AQR) in 2012.

2.1.1. Streams

The following section discusses the water quality condition of streams in the SRRW by pollutant parameter. The Shell Rock River is addressed to a greater degree because of its multiple impairments, and deferment of assessments on upper watershed streams. A comprehensive watershed approach for restoration is put forward in Section 3, which includes all waters in the SRRW, regardless of assessment status.

Water quality assessments in Minnesota are made for individual waterbodies. A stream or river assessment unit usually extends from one significant tributary stream to another or from the headwaters to the first tributary. Therefore, a stream or river is often segmented into multiple assessment units that are variable in length. Multiple assessment units are identified by different water identification numbers, called WIDs. For the Shell Rock River, the entire 12 mile reach in Minnesota is considered one WID (-501).

Aquatic life standards call for the maintenance of a healthy biological community of aquatic life. FIBI and MIBI provide a measurement tool to assess the health of the aquatic communities. Index of Biological Integrity (IBI) scores higher than the impairment threshold indicate that the stream reach supports aquatic life. Contrarily, scores below the impairment threshold indicate that the stream reach does not support aquatic life. Confidence limits around the impairment threshold help to ascertain where additional information may be considered to help inform the impairment decision. When IBI scores fall within the confidence interval, interpretation and assessment of waterbody condition involves consideration of potential stressors, and draws upon additional information regarding water chemistry, physical habitat, land use activities, etc. Other metrics, besides just those used in the IBI, will also be discussed in this report, as they are often more closely tied to individual stressors (MPCA 2014a). The fish and macroinvertebrate IBI thresholds, confidence intervals and scores are shown in Appendix C.

Seven sections of streams were assessed for WQS in the SRRW. Of the seven stream sections assessed, four are impaired and three had insufficient information for assessment. Of the four impaired streams sections, impairment listings for DO, eutrophication (P), turbidity (TSS) and *E. coli* are addressed via TMDLs. The Shell Rock River impairments for pH, FIBI and MIBI are conclusively linked to DO and/or phosphorus and will be addressed through those TMDLs. See Appendix A for additional information on stream sections monitored.

Table 10. Assessed streams in the SRRW.

Waterbody Name	WID (07080202)-	Affected Use	Impaired Waters Listing
Shell Rock River	-501	Aquatic Life	DO
			Nutrients/Eutrophication
			Macroinvertebrate bioassessment (MIBI)
			Fish bioassessment (FIBI)
			Turbidity
			pH
		Aquatic Recreation	*E. coli*
Bancroft Creek (County Ditch 63)	-507	Aquatic Recreation	*E. coli*
Unnamed Creek (Shoff)	-516	Aquatic Life	Nutrients/Eutrophication
			Turbidity
Unnamed Creek (Wedge)	-531	Aquatic Recreation	*E. coli*

Shell Rock River overview

The Shell Rock River (WID -501) is impaired by DO, TSS, bacteria, FIBI, MIBI, river eutrophication, and pH. It is the only surface water in the SRRW that was assessed for both aquatic recreation and aquatic life standards, due to TALU classification (see section 2.0.1). Table 11 displays the biological impairments for the Shell Rock River based on the seven monitoring sites in this reach.

Table 11: Assessment status of stream reaches in the Shell Rock River, presented from upstream to downstream for the 12 river miles in WID 07080202-501.

AUID **Reach Name** *Reach Description*	**Biological Station ID**	**Location of biological station**	**Aquatic Life Indicators**							**Bacteria**	**Aquatic Life**	**Aquatic Recreation**
			Fish Index of biotic integrity	**Macroinvertebrate index of biotic integrity**	**Dissolved oxygen**	**Turbidity/TSS**	**pH**	**Chloride**	**NH_3**			
07080202-501 **Shell Rock River** *Albert Lea Lake to Iowa*	04CD037	1 mile downstream of A.L. Lk	**EXS**	**EXS**	**EXP**	**EXP**	**EXP**	**MTS**	**MTS**	**EX**	**NS**	**NS**
	09CD087	Upstream of 170th Street										
	04CD017	At Hwy 13 bridge, Glenville										
	09CD088	Downstream of Hwy. 65										
	11CD001	Downstream of 130th Street										
	04CD015	Downstream of Hwy. 7										
	09CD089	Upstream of CSAH 1, west of Gordonsville, MN										

EXS: Exceeds criteria; potential severe impairment
EXP: Exceeds criteria; potential impairment
MTS: Meets criteria
NS: Not supporting
Key for color: ■ = new impairment □ = Existing impairment; listed prior to 2012 reporting cycle.

Shell Rock River Watershed flow gage

Stream flow for the Shell Rock River is continuously collected by a DNR cooperative river flow gaging station known as “Shell Rock River near Gordonsville” (ID: H49009001). This is the main river flow gaging site for the Shell Rock River in Minnesota, with both flow and water quality data collection at the location. Daily streamflow from this station is displayed in Figure 24. The drainage area for the DNR river gaging station H49009001 is 191 square miles. While river flows are moderated by the upstream lakes in the watershed, numerous peak flows can be observed during this timeframe, when flow increases fairly rapidly by a factor of two to three times above a baseflow condition.

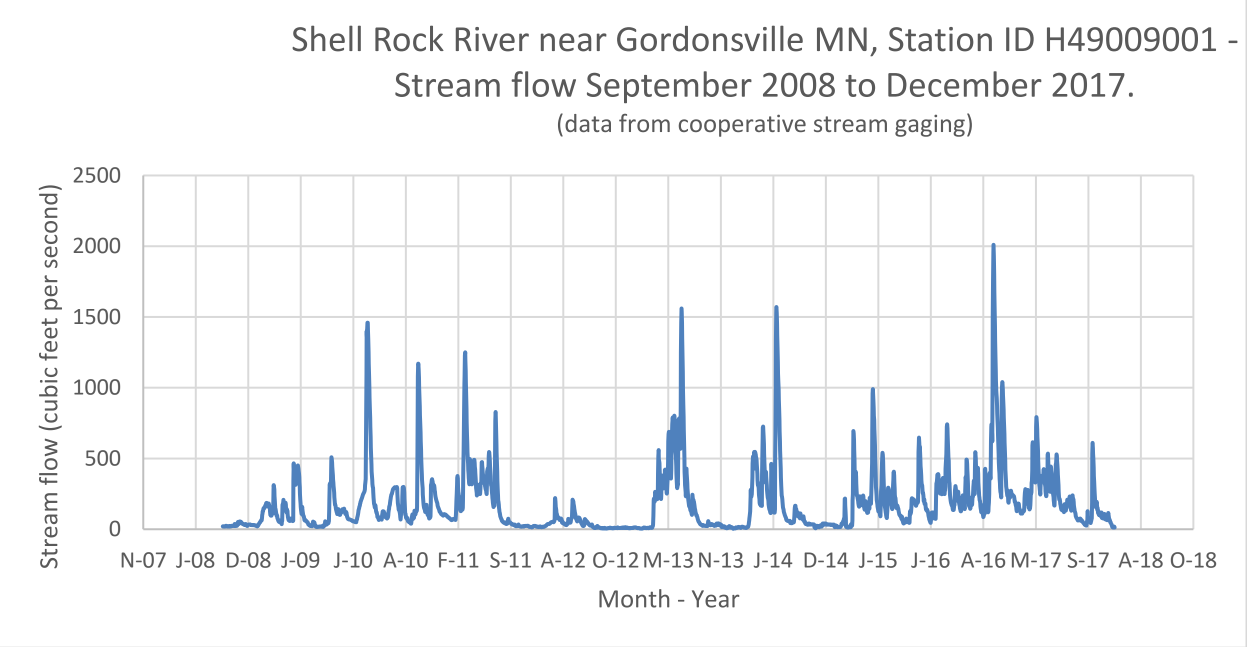


Figure 24. Shell Rock River streamflow at Gordonsville, MN 2008-2017.

Annual measured streamflow in the Shell Rock River shows significant variability (Figure 25). Flows in 2012 were at critical low flow conditions, and 2016 having an annual flow nearly 10 times higher than 2012 annual flows. The remaining annual flows fall between 2012 and 2016 values.

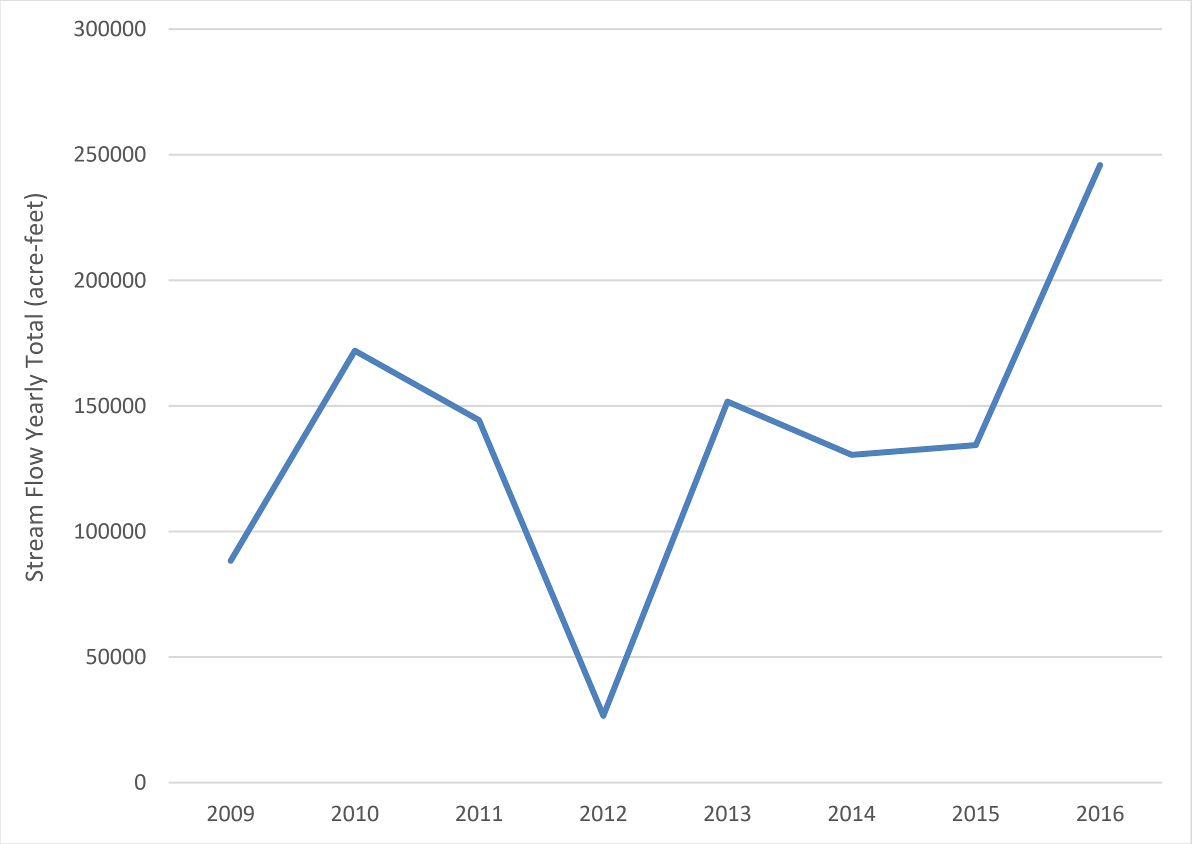


Figure 25. Yearly stream flow for the Shell Rock River at Gordonsville, MN (2009-2016).

Pollutants contributing to impairments:

Pollutants driving the Shell Rock River's water quality impairments are TP and TSS. These two pollutant parameters contribute to responses such as low DO levels and high algal growth (expressed as chl-*a*). The other pollutant data included in Table 12 and Table 13 include NO3-N, total kjeldahl nitrogen (TKN), dissolved orthophosphosphate (DOP), and *E. coli* from the main monitoring station at Gordonsville (S004-084).

Table 12. Mean and median pollutant concentrations in the Shell Rock River.

	TSS	TP (mg/L)	N03-N (mg/L)**	TKN (mg/L)	Indicator Bacteria*
Total # years	10 (2009-2018)	12 (2009-2020)	8 (2009-2016)	8 (2009-2016)	5 (2001-2010)
Total # samples	294	236	286	278	47
Mean	24 mg/L	0.48 mg/L	3.6 mg/L	1.9 mg/L	194 org/100 mL
median	25 mg/L	0.33 mg/L	3.3 mg/L	1.8 mg/L	91 org/100 mL

**E. coli* TMDL approved in 2002. Data summary includes these years 2001, 2004, 2006, 2009, and 2010.
**No impairment listing for nitrate.

Table 13. Pollutant flow-weighted mean concentrations and mass in the Shell Rock River (average for 2009-2016).

Pollutant	Years	FWMC	Mass (kg)
DOP	2013-2015	0.21	34,571
TP	2009-2011, 2014-2016*	0.34	60,734
NO3-N	2009-2016	3.60	633,952
TKN	2009-2016	1.88	297,663
TSS	2009-2016	24.00	3,659,120

*2 years of TP data were not available in 2012 and 2013, due to data quality assurance factors.

Phosphorus

Phosphorus in water is present in several soluble and particulate forms, including organically-bound phosphorus, inorganic polyphosphates, and inorganic orthophosphates. DOP is the nonfilterable component of TP, defined by the analytical method, and considered to be most readily available to stimulate excessive production (of algae) and eutrophication (Lind 1979). DOP is also called soluble reactive phosphorus, and is often used with the word “inorganic” to distinguish it from the organic forms of dissolved phosphate. TP uses methods to account for all forms of phosphorus, including both dissolved and particulate (including phosphorus in algae). For a more complete discussion about phosphorus forms, see Barr 2004.

Phosphorus that is “bioavailable,” is in a form that can be readily used by algae (see Sharpley etal. 1994). Phosphorus is most frequently the limiting nutrient in freshwater aquatic systems, especially when conditions favor the growth of blue green algae, which can fix nitrogen (thus overcome any nitrogen limitations). Wastewater treatment facilities (WWTF) can be a major source of DOP, affecting the critical conditions in streams, especially when stream flows are lower, and water temperatures are higher.

In the SRRW, having a good understanding of phosphorus is critical. Factors such as the amount, forms and timing of phosphorus loads into lakes and rivers are all important consequences to water quality. This can also be a difficult set of information to grasp, since phosphorus parameters for a crop field, or turf grass – are very different than phosphorus factors in a river, reservoir or lake. Also, while Minnesota’s WQS for lakes and streams are defined in terms of TP, having an understanding of what “makes up” the TP, is also important. Over the past several decades, there has been a change in how many scientists view phosphorus transport. The initial view was that the majority of phosphorus is transported as attached phosphorus (particulate) via surface runoff. The more recent approach is to consider phosphorus loss to include both surface and subsurface pathways. As rainfall infiltrates and percolates through the soil, there can be dissolved phosphorus moving into shallow ground water, and/or tile lines. Baker (2011) describes these changing views, and how about 95% of the dissolved phosphorus is bioavailable to algae, compared to about 30% for particulate phosphorus.

Shell Rock River Phosphorus

For 2014 and 2015, the flow weighted mean concentration (FWMC) of DOP and TP displays considerable variation, but the ratio of DOP to TP remains about two-thirds (Table 14). This level of DOP in the SRR is similar to what has been measured in the upper watershed tributaries that flow into Fountain and Albert Lea Lakes (see Ulrich 2014). When other environmental factors such as water temperature and light availability are conducive for algal production, these high levels of DOP can result in more primary production by algae (algae bloom).

Point source phosphorus in the SRR is a critical factor affecting the overall health and water quality of the river, particularly during low flow periods. While the Albert Lea WWTP has been operated and maintained appropriately, there have been no effluent limits on phosphorus. The WWTP currently does have effluent limits on other important parameters, such as CBOD5, TSS, and ammonia nitrogen. The average TP effluent concentration is 5.8 mg/L and at least 82% of that TP is in a dissolved form. This ongoing and consistent point source loading of phosphorus into the SRR is an important focus of the TMDL Report (RESPEC 2020), and an 89% reduction (in effluent concentration) has been determined to be required to meet WQS in the SRR.

Table 14. Flow-weighted mean dissolved orthophosphate and total phosphorus concentrations in the Shell Rock River, 2013 to 2015, with DOP/TP ratios.

Year	Dissolved orthophosphate (DOP) mg/L	Total phosphorus (TP) mg/L	DOP:TP ratio
2013	0.144	NA*	NA
2014	0.297	0.403	0.74
2015	0.174	0.277	0.63

* TP data are not available in 2013, due to MDH lab quality control issues.

Total phosphorus for the Shell Rock River at Gordonsville is displayed as a flow-weighted mean concentration in Figure 26 (Watershed Pollutant Load monitoring site S004-084). TP values average about twice the river eutrophication standard (RES) of 0.150 mg/L.

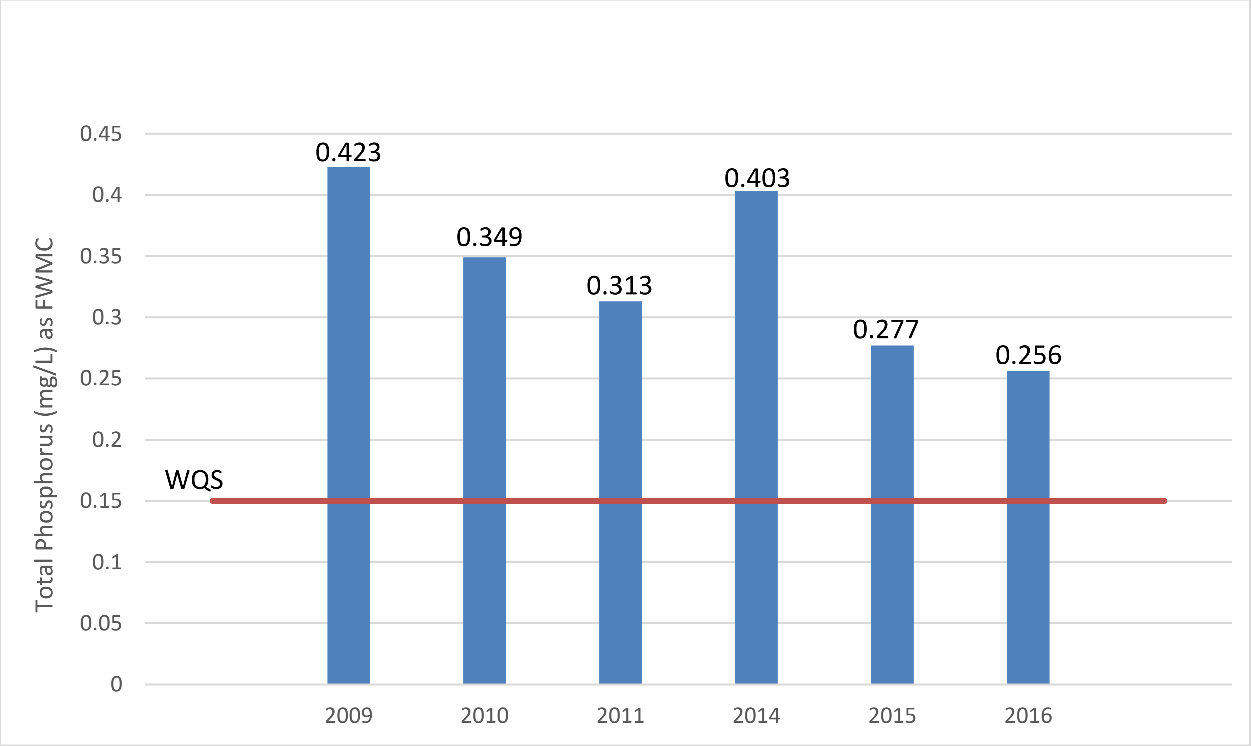


Figure 26. Shell Rock River Flow Weighted Mean Concentration of TP.

DOP concentrations generally have an inverse relationship to stream flow in the Shell Rock River. High flows dilute concentrations of DOP while low flow conditions have more concentrated DOP (Figure 27).

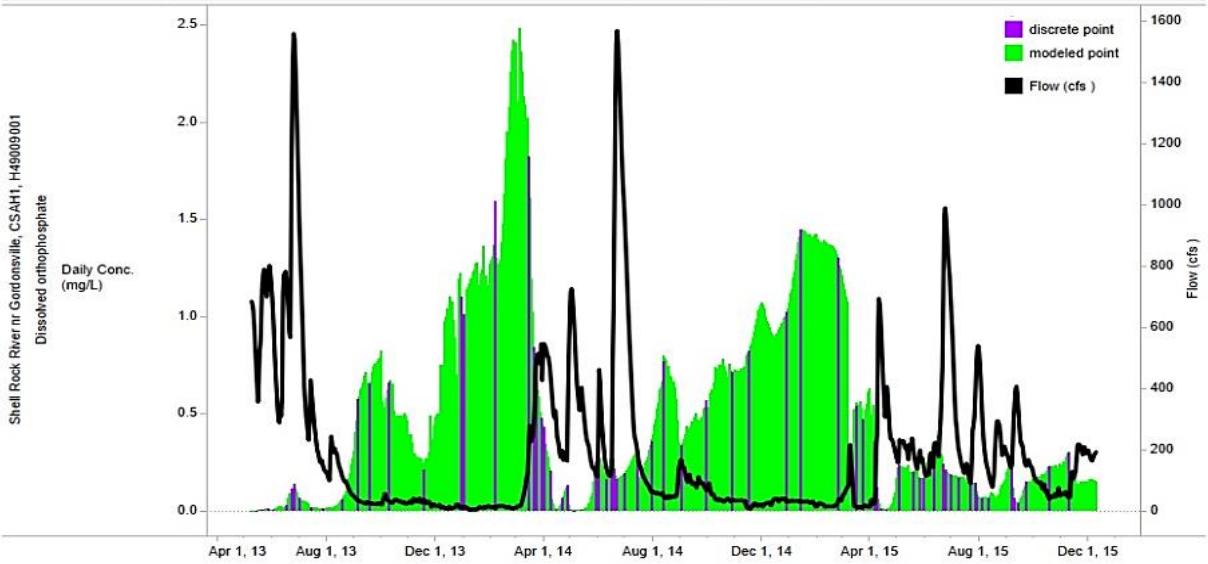
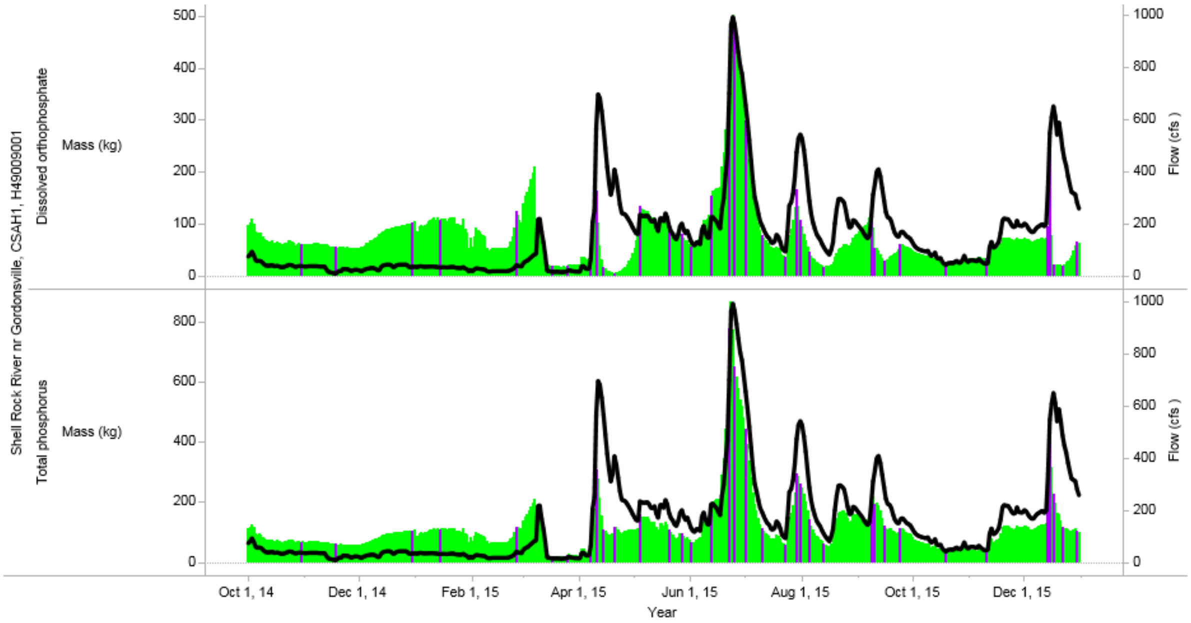


Figure 27. Modeled and measured dissolved orthophosphate concentrations, and streamflow, in the Shell Rock River WPLMN site (December 2012 – December 2015).

TP load data for 2015 was compared against the river's hydrograph (Figure 28). Year 2015 was selected because several spring and summer runoff events occurred, and the overall annual water runoff was similar to other more "mid-range" flow years, within the current dataset.



Note: Green color indicates model-simulated phosphorus concentration. Purple indicates measured phosphorus concentration. Black indicates river flow.

Figure 28. Shell Rock River dissolved orthophosphate and total phosphorus loads, with stream flow for October 2014 to December 2015.

An analysis of several storm runoff events provides further information related to phosphorus and stream flow dynamics in the Shell Rock River. In April of 2015 (Figure 29), an event beginning on April 7th peaked about one week later, with a peak flow of 694 cfs. As the runoff event began, the DOP concentration made up about 77% of the TP. Both TP and DOP increased in concentration during the rising limb of the stream hydrograph, and peaked as the stream was still rising. Also, both phosphorus parameters showed a similar rate of decline, as the stream continued to rise. At the time of peak stream flow, TP leveled off, and slowly increased. The DOP dropped slightly, then increased at a faster rate, so that when the stream flows receded, the DOP made up about 84% of the TP.

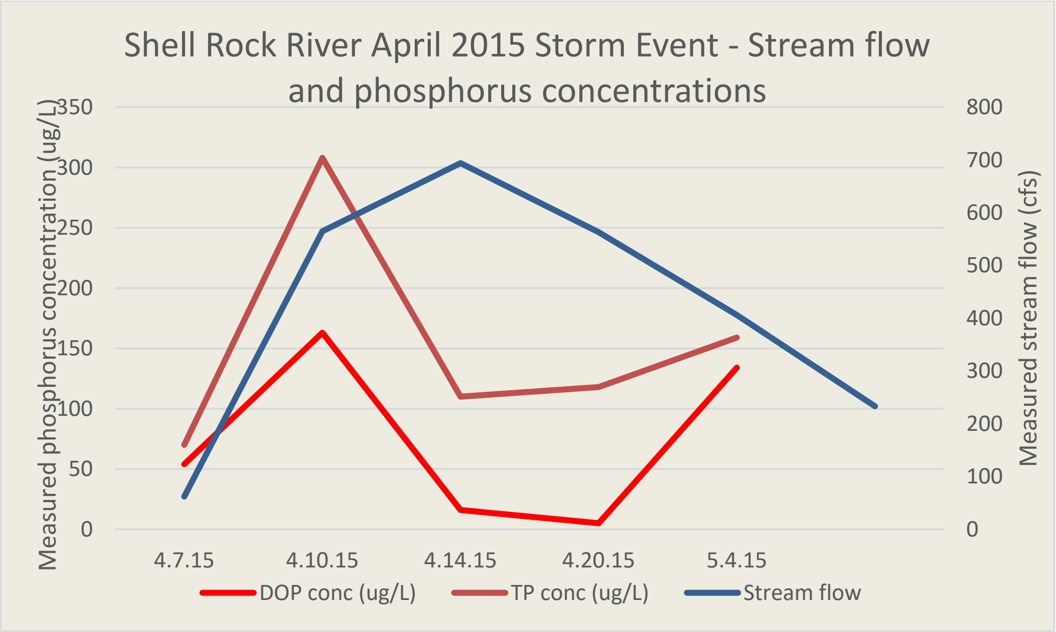


Figure 29. April 2015 storm event with phosphorus concentrations and stream flow in the Shell Rock River.

A storm runoff event in June of 2015 (Figure 30) illustrates a different phosphorus concentration response. While both the TP and DOP concentration peaks occur on the rising limb of the hydrograph, the DOP peak trails the TP peak, by about a week. Both DOP and TP decline at a similar rate, with the DOP always making up from about 50% to 80% of the TP. While both of these illustrated events occurred over a three to four week period, the June event had higher concentrations, higher phosphorus loads, and a higher percentage of DOP throughout the event, compared to the April event. With warmer water temperature in June than in April, this points to a greater likelihood of more algal production in downstream water resources.

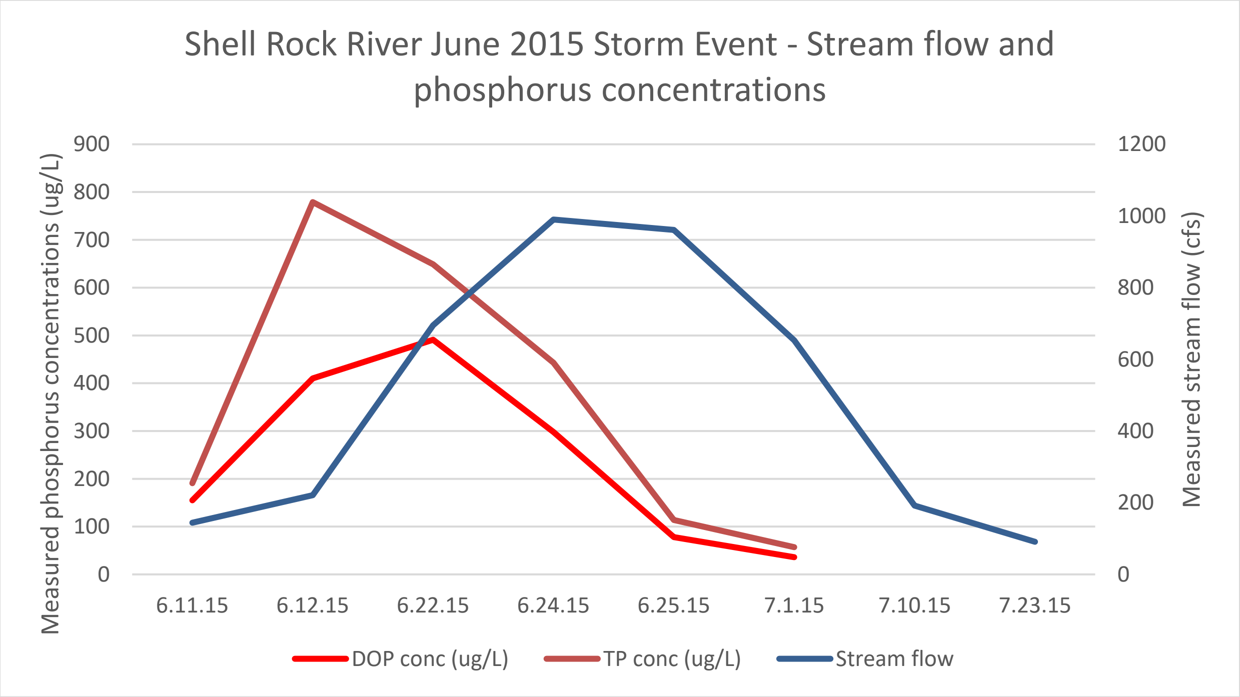


Figure 30. June 2015 storm event with phosphorus concentrations and stream flow in the Shell Rock River.

Across the months of June through September 2015 (when the TP WQS of 150 µg/L applies) monitored data show a TP concentration range of 170 to 460 µg/L. The average TP concentration (280 µg/L) exceeds the WQS by a factor of 1.8 (RESPEC 2020).

Assessing the sources of phosphorus for the Shell Rock River requires an evaluation of point sources, nonpoint sources and the impact of seasonal variability. This assessment is discussed in Section 2.3.

The Shell Rock River phosphorus dynamics can be summarized as follows:

- The DOP can constitute a large proportion of the TP in the Shell Rock River.
- Stream flow changes that increase silt and clay transport, will result in higher TP loads associated with the particulate component.
    - There is a strong point source "signature" in the Shell Rock River, as both TP and DOP concentrations show a general inverse relationship to stream flow. Phosphorus loading increases with larger storm runoff events, as watershed-derived phosphorus is added to the system. See Section 2.3 for additional sources discussion.
- Timing is critical for several key parameters, in regards to how phosphorus will affect the river and downstream water resources. The worst case is when more biologically-available phosphorus is "delivered" into a warmer water condition where there is adequate light to grow algae. The typical case for this is wastewater discharge at lower stream flows during warmer summer weather. This set of conditions will affect more algal growth, lower diurnal DO minimums, and higher DO swings between day and night.
- Reducing phosphorus loads from both the watershed and point sources is critical to improving water quality throughout the system.

Total Suspended Solids

TSS consists of both organic and inorganic particles suspended in the water column. Organic, or nonmineral suspended particles, include living or decaying algae and aquatic plants, and what is called "detritus," which is a catch-all term for plant and animal material that is in some state of decomposition. Inorganic particles are soil and mineral-derived substances, most frequently silts, clays, and fine sands. The "suspended" term means that these materials are in the water column, and above the stream or channel bed. Overall in the SRRW, TSS levels in tributary streams and the Shell Rock River are frequently meeting standards, with the exception of Shoff Creek. Algae can play a larger role during low flows, especially below eutrophic lakes. Tributary streams above the lakes can have higher TSS levels, which are more due to soil erosion.

Shell Rock River TSS

Average flow-weighed mean concentrations of TSS in the Shell Rock River were determined from data collected from 2009 through 2016. The highest concentration occurred during very low flows of 2012. A likely conclusion is that a majority of TSS is derived from organic sources because runoff events that transport inorganic silts/clays into the Shell Rock River did not occur frequently in 2012. TSS flow-weighted mean concentrations are displayed in Figure 31. All concentrations are below the southern Minnesota TSS WQS (65 mg/L).

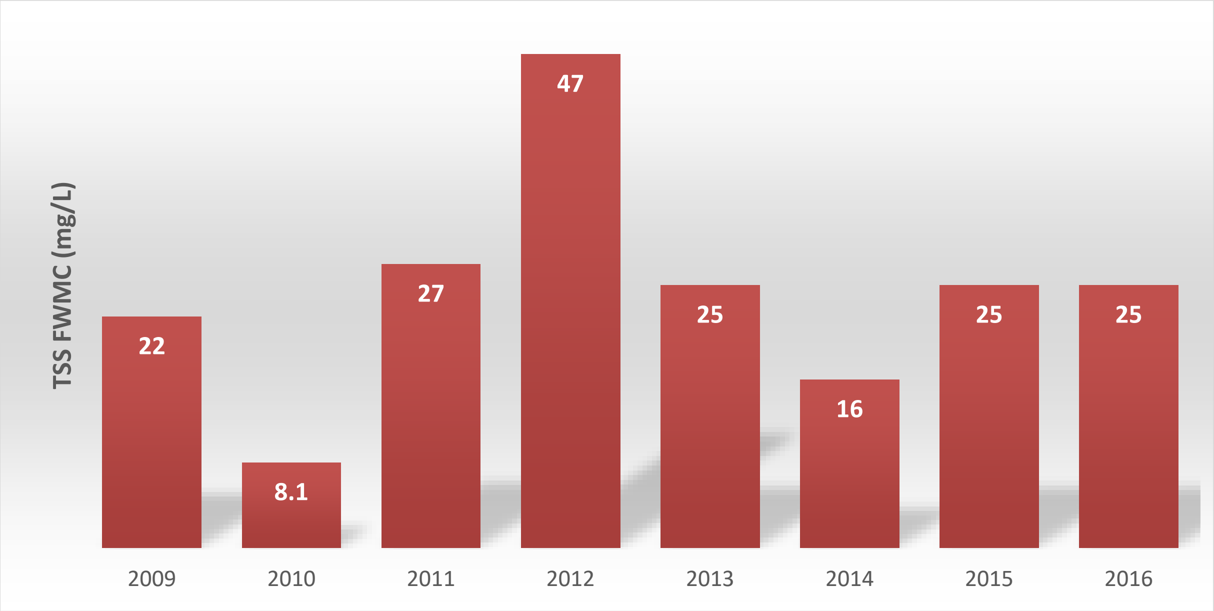


Figure 31. TSS flow weighted mean concentrations for the Shell Rock River.

Daily Shell Rock River TSS loads (kilograms) are shown in Figure 32 for the 2015 calendar year. Seasonal differences are apparent between the runoff events in mid-April, June, and December. For example, a three-fold increase in streamflow in December results in only small load changes, when compared to months in the spring. Sediment mobilization and transport conditions, as well as algal introduction from upstream, are the most likely reasons for the load data from June 2015. Model simulated values mirror the measured data, with the exception of the June event when only one sample was collected near the peak of the runoff hydrograph. This dramatic rise and fall of the hydrograph in June is due to a large storm event.

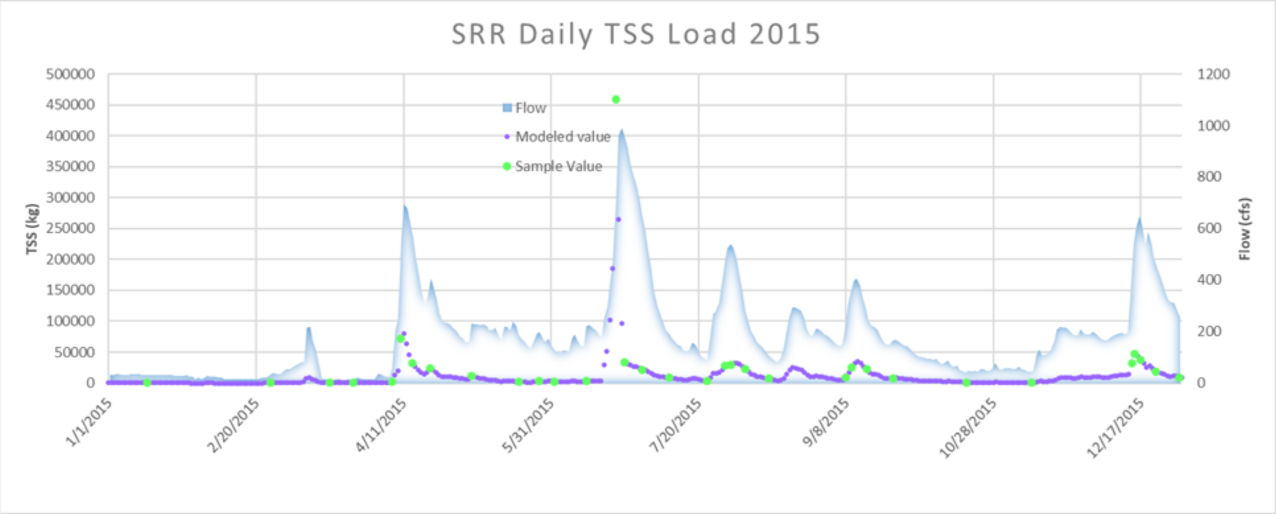


Figure 32. Daily TSS loads for the Shell Rock River in 2015.

Another method that uses streamflow data for the Shell Rock River, along with a suspended sediment statistical ratio, is presented in Figure 33. The statistical ratio uses an organic form of suspended solids, known as volatile suspended solids (VSS). VSS can be plant matter produced in-stream and/or introduced into the surface water system from runoff. In the lab analysis process for a water sample, the nonmineral parts like algal cells and plant materials are "volatilized" by heat, hence the descriptive term "VSS." Since the VSS is part of the TSS, using the ratio, or percentage of VSS in each water sample, provides some indicators of potential sources and pathways. A VSS:TSS ratio of 0.5 means that 50% of the TSS are organic and volatile in nature, and 50% are inorganic, most often silt and clay particles. This ratio is plotted against the flow exceedance percent (horizontal axis), with the highest stream flows on the left (i.e. exceeded less frequently, or at a low percentage), and the lowest stream flows on the right. For the Shell Rock River at Gordonsville (Site SSR03, or S000-084), there is no pattern of flow to the VSS:TSS ratio, for the 10-year period that is plotted. This is based on the methods used for sample collection and analysis – and a sample size of 98. High flows did not affect any trend for either low, or high VSS. Low river flows display a nominally higher ratio, indicating more organic compounds than mineral sediment, which is a function of decreasing stream transport capacity of the heavier mineral particles, with lower water levels and slower stream velocity. Lower flows and decreased stream velocity increase the residence time, as water moves down the 12-mile river reach in Minnesota. Over 90% of these data have a ratio greater than 35%, indicating that a sustained occurrence of organic materials is present. The majority of these data fall within a ratio range of 45% to 80%. The relatively higher ratios indicate that material is being "washed in" from upland areas, scoured from the stream channel itself, and/or is associated with algal washout, from upstream lakes or wetlands. The values at the top of the graph (i.e. ratio of 1.0, or 100% is volatile) tended to be samples with low TSS concentrations.

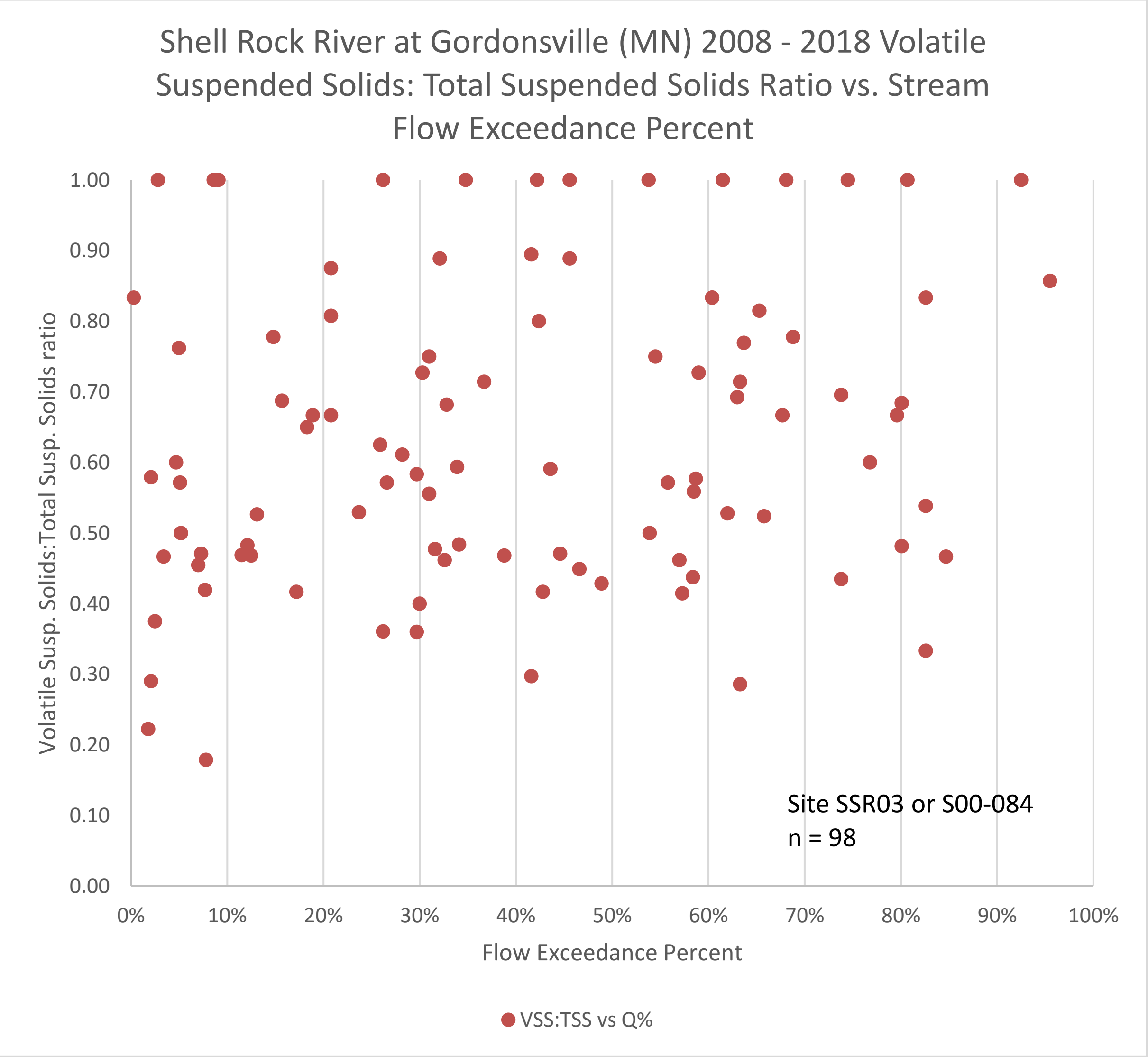


Figure 33. Shell Rock River at Gordonsville VSS:TSS ratio versus stream flow exceedance percent 2008-2018 (2018 flow data are provisional – from DNR).

The TSS data set for the Shell Rock River (about 519 water quality samples) as organized on a monthly timeframe over nine years is shown in Figure 34. Data are plotted in the month the sample was collected as TSS concentrations (not flow-weighted). When exceedances of the TSS WQS do occur, they tend to be in the warmer months of May thru July but may also occur in September.

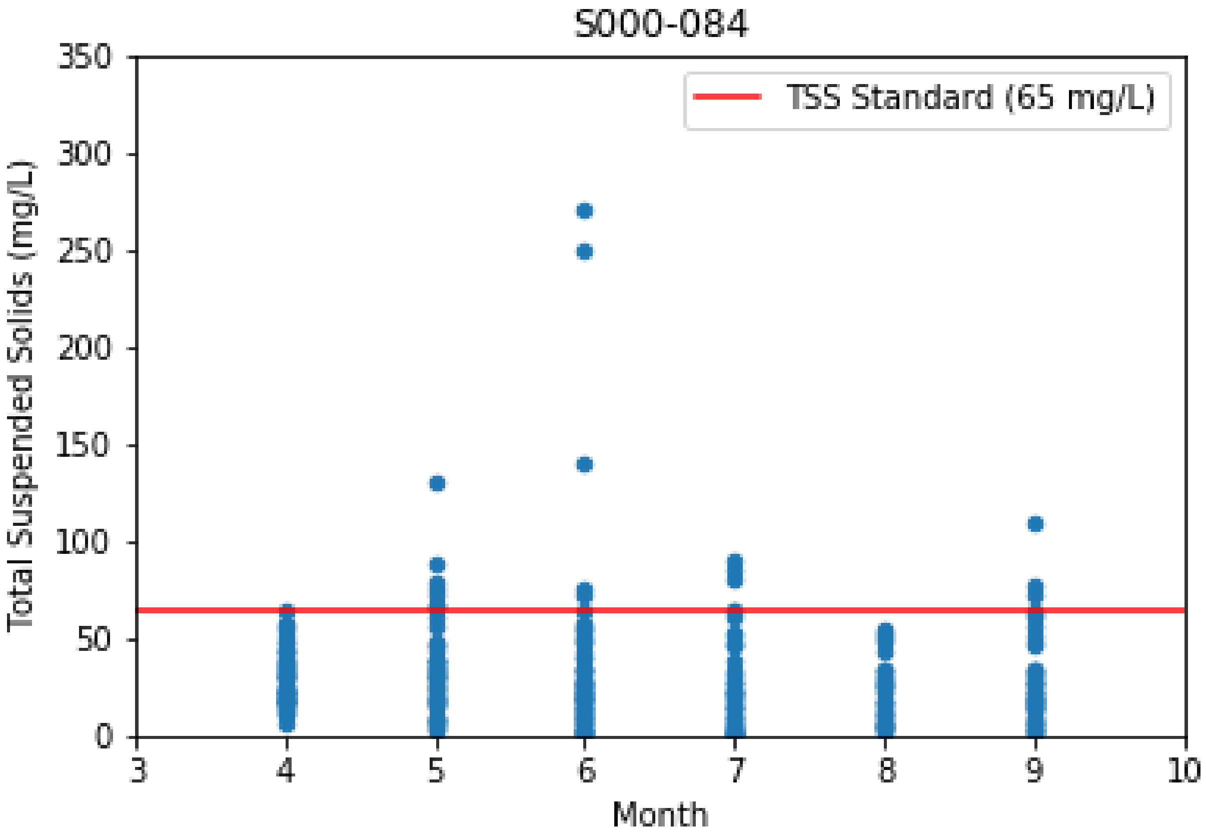


Figure 34. Shell Rock River TSS by month at station “S000-084” from 2009 to 2018.

In a system like the SRRW, with many interconnected stream and lakes, algal cells can become a significant part of the “organic TSS.” The algal pigment chl-*a* is used as an indirect measure of the amount of algae in the water column; higher chl-*a* values equates to more algae. Since algae are mostly made of organic compounds, the quantity of algal cells can directly affect the organic (volatile) component of TSS. Median (50th percentile) values chl-*a* from June through September range between 25 to 60 µg/L (Figure 35). The river eutrophication standard for chl-*a* is 40 µg/L (red line).The August median is well above that threshold, when applying these statistics.

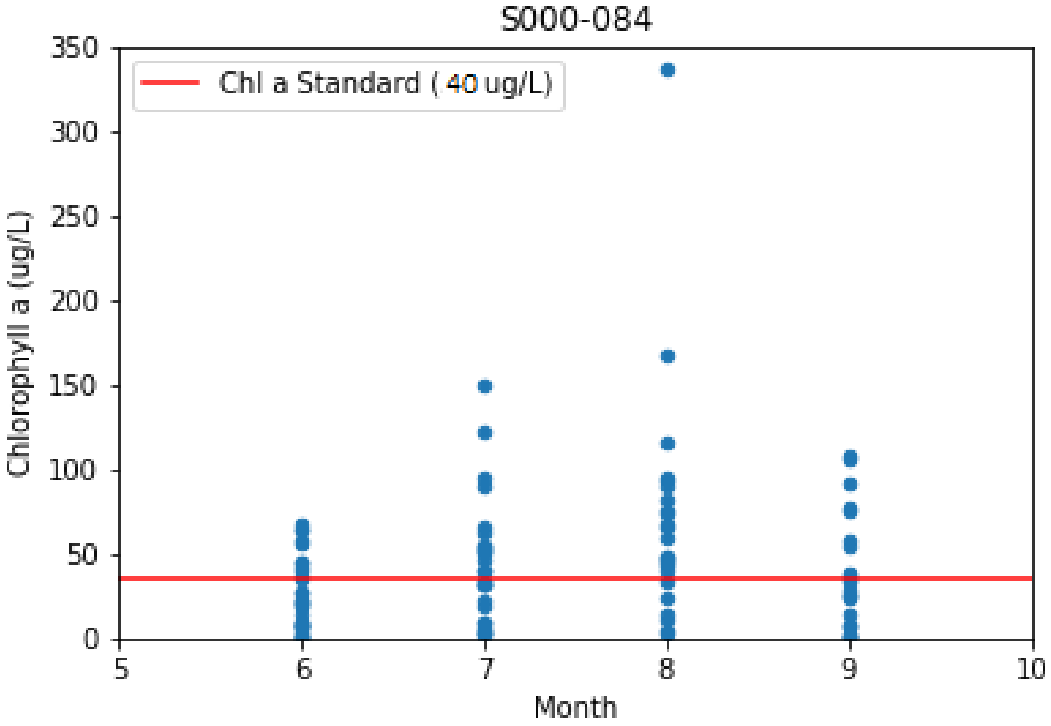


Figure 35. Shell Rock River chl-a by month at station "S000-084" from 2009 to 2018.

Comparing monthly TSS and chl-*a* data indicates that chl-*a* concentrations are not the only factor affecting the TSS concentrations. The TSS median concentrations are fairly constant for the months April through September, while the chl-*a* concentrations are notably higher during the month of August.

The last approach in summarizing the suspended solids data in the Shell Rock River is presented in Figure 36. This analysis uses both "forms" of suspended sediment data, the total form (inorganic + organic) as TSS, and the organic form, as VSS. Figure 36 is a seasonal analysis with the VSS:TSS ratios aggregated by month for three monitoring sites, using 10 years of data provided by the SRRWD. The VSS typically makes up over 50% of the TSS, at all Shell Rock River monitoring sites. There are numerous occasions at all the monitoring sites when the VSS accounts for all of the TSS (i.e. ratio = 1.0), and it was observed this happens most frequently with TSS concentrations less than about 10 mg/L. There is an increase seasonally with warmer water temperatures and greater plant and algae production, peaking in August or September. The combined data for June and September show somewhat higher VSS at the site just downstream of Albert Lea Lake (SSR01). Several factors in Albert Lea Lake affect this, including the washout of lake-produced algae, and transport of "soft" bottom materials, re-suspended by wind-driven currents. There are four months (April, May, July, and August) that indicate an accumulating trend of VSS, from upstream to downstream along the 12-mile reach of the Shell Rock River. Nutrient enrichment that promotes plant and algal growth is a factor in this phenomenon. The suspended organics, as estimated with the VSS parameter, also play a role for bacterial decomposition and DO dynamics in the river.

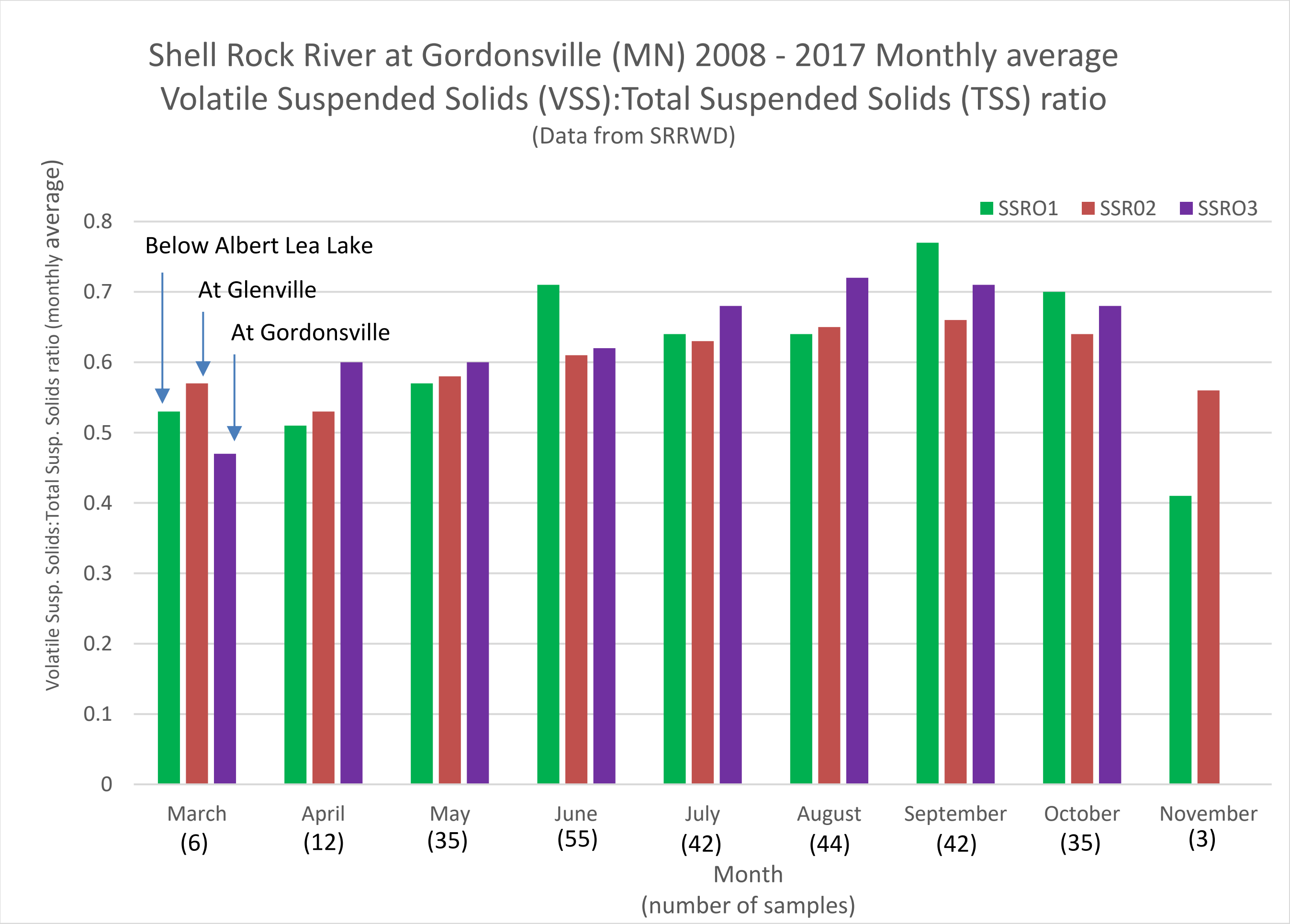


Figure 36. Shell Rock River monthly VSS:TSS ratio 2008 through 2017; sites listed upstream to downstream.

Based on a robust data set for the months of April, May, July, and August – the volatile component does not decline for the 12 river miles, from Albert Lea Lake to Gordonsville. Of these four months, July and August tend toward slower stream velocities, lower stream flows, and higher residence times. These types of conditions can allow for more in-stream primary production (both algal and aquatic plant).

Unnamed (Shoff) Creek TSS

This relationship between algae and TSS addressed for the Shell Rock River is also present for Shoff Creek (-516). Shoff Creek receives water from Pickeral Lake. This relationship is illustrated in Figure 37 with data from the fall of 2008 into the early fall of 2010. A direct relationship is frequently present, and is especially evident in late 2009 and 2010. Shoff Creek is impaired by both TSS and TP, and therefore is included in the SRRW TMDL Report.

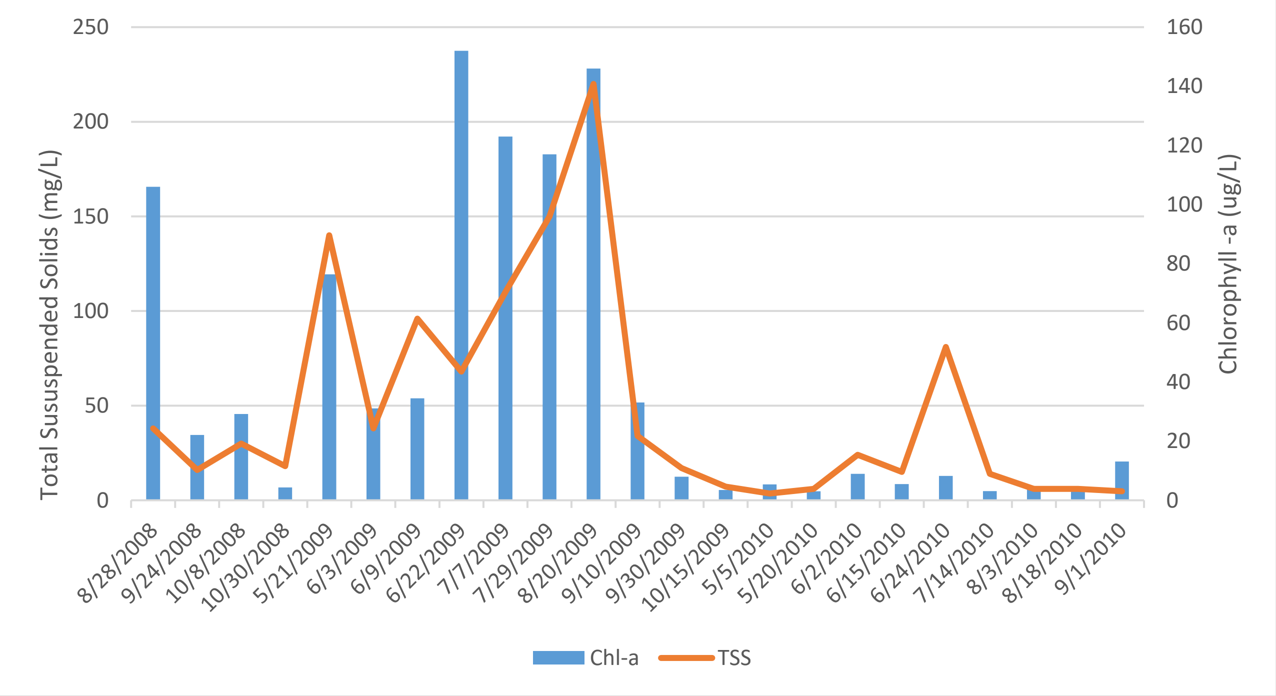


Figure 37. Shoff Creek TSS and chl-*a* concentrations, Aug. 2008 - Sept 2010.

Other SRRW Tributary TSS summaries:

Tributary TSS concentrations are provided in Table 15, along with stream reach and monitoring site information (see Figure 22 for tributary locations). These data are derived from the SRRWD's robust water quality monitoring program, where grab samples are collected from a network of sites, for six to seven months/year (typically three samples/month, April to October). The values in Table 15 include all of these direct TSS concentration values, and are not flow-weighted.

Table 15. Total suspended solid data summary from other streams and tributaries.

					Total suspended solids				
Stream name	WID (last 3)	SRRWD Site #	MPCA Site #	Length (miles)	Data time frame	Sample count	Average (mg/L)	Median (mg/L)	# samples > 65 mg/L
Bancroft Creek	-507	SBC01	S004-120	6.6	2005-2018	197	22.5	7	10
County Ditch 16	-508	SCD16	S005-096	5.9	2008-2018	120	14.7	6	3
Northeast Creek	-513	SNE01	S004-116	2.5	2005-2018	163	20.4	7	10
Peter Lund Creek	-534	SPL01B	S005-772	2.8	2009-2018	123	16.3	8	5
County Ditch 30	-535	SPL02	S005-773	4.0	2009-2018	119	26.4	5	6
Wedge Creek	-531	SWC01	S005-010	1.5	2005-2018	186	30.6	9	17

Wedge Creek TSS concentrations are somewhat higher than the other tributary sites, and show a higher number of values exceeding the WQS of 65 mg/L TSS. For Wedge Creek, a range from 65 mg/L to 660 mg/L is present for those samples exceeding the WQS, and 53% of those exceedances occurred during the month of June. Lower average TSS values were observed in Peter Lund Creek and CD 16.

For all of the tributaries, the average TSS values are within a range of about 15 to 30 mg/L. Grab sampling and laboratory analysis using standard TSS procedures (such as employed here) are known to underestimate a more representative and "truer" suspended sediment concentration. The degree of the underestimation is a function of seasonal and stream flow factors, and can be as high as 50%. What this means is that heavier sediment particles, such as fine sands, are frequently not "captured" with these monitoring and analytical techniques. This important condition also exists in the MPCA's monitoring protocols as well, and more information is available at Ellison etal (2015).

Total Nitrogen

Nitrogen exists in the environment and water in numerous forms, including ammonia, nitrate (NO_3) and nitrite (NO_2) (inorganic N) and organic/TKN fractions. Transformations among the different forms of nitrogen occur constantly in the water cycle. Because of this cycling, nitrogen is often considered in totality as total nitrogen (TN). TN is a combination of TKN, NO_3-N and ammonia N. While there is no NO_3-N standard for 2B waters, biology in the Shell Rock River is being stressed by NO_3-N concentrations. While the drinking water standard of 10 mg/L NO_3-N is frequently used as a marker for nitrogen concentrations, it is noted that concentrations below the 10 mg/L "marker" for NO_3-N can negatively affect stream biology.

Approximately 350 water quality samples were analyzed for nitrogen parameters in the Shell Rock River (-501). Resulting TN was calculated. The higher TN concentrations presented in Figure 38 come from years with lower stream flows. Low stream flow reduces the river's ability to dilute higher concentrations of TN. This is illustrated in 2012; a year of low precipitation, low runoff, and very low stream flows. The following year (2013) had a combination of more NO_3-N leaching and lower crop demand, due to a wet spring, resulting in the highest annual FWMC of 8.3 mg/L TN. At this monitoring location, NO_3-N makes up from 48% to 73% of the TN, with 2013 associated with the high end of that range.

Elevated NO_3-N concentrations can negatively affect the biota. There is variation among nitrogen sources and the observed concentrations. In 2012, with low runoff and low NO_3-N leaching from fields, the Albert Lea WWTP heavily influenced the nitrogen dynamics in the SRR. However, under the wet conditions of 2013, nitrogen loss from agricultural fields was the dominant factor for NO_3-N concentrations.

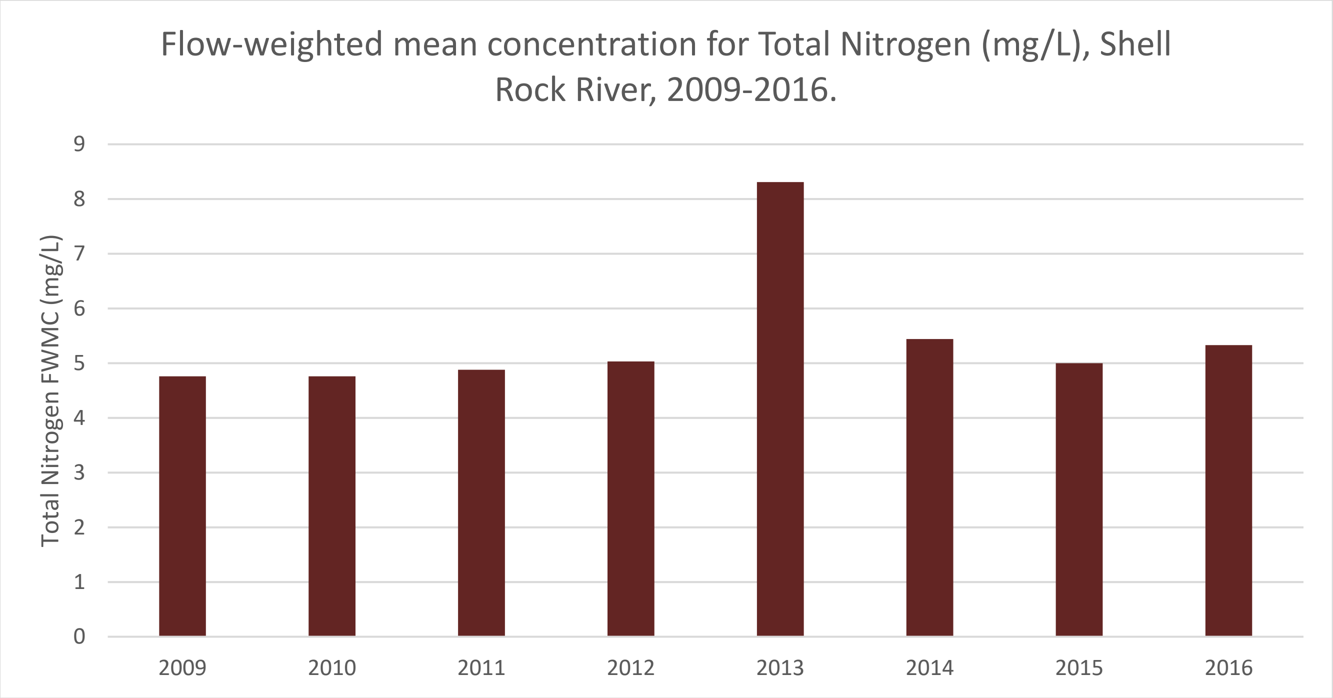


Figure 38. Flow weighted mean concentrations of total nitrogen; Shell Rock River (-501).

Measured and modeled nitrogen loads are displayed in Figure 39 alongside Shell Rock River's hydrograph for 2015 (plot begins in Fall of 2014). The top graph is the nitrate + nitrite-N (NO_3 + NO_2) load, and the bottom graph is the TKN load. This pair of graphs are set up with different scales on the vertical axis, as the NO_3 + NO_2 loads are higher than the TKN loads, but with the same stream flow scales. The purple bars are discrete measured data, and the green bars represent modeled estimates of the nitrogen loads.

The overall increase in nitrogen loads that occurs with stream flow increases is well displayed for both parameters, comparing the low flow conditions of the fall of 2014, with the spring and summer of 2015. The loadings associated with the highest stream flows of this time period (occurred on June 25, 2015) was estimated to be 12,700 kg NO_3 + NO_2, and 5,460 kg of TKN, for a sum of 18,160 kg of TN, or about 20 tons of TN. Looking at the Fall of 2015, NO_3 + NO_2 losses are reduced, with a decrease in leaching from agricultural fields, with the TKN loads representing a higher amount of the overall TN load. A second NO_3 + NO_2 loading event occurred in December of 2015, and was estimated with a solid set of measured data.

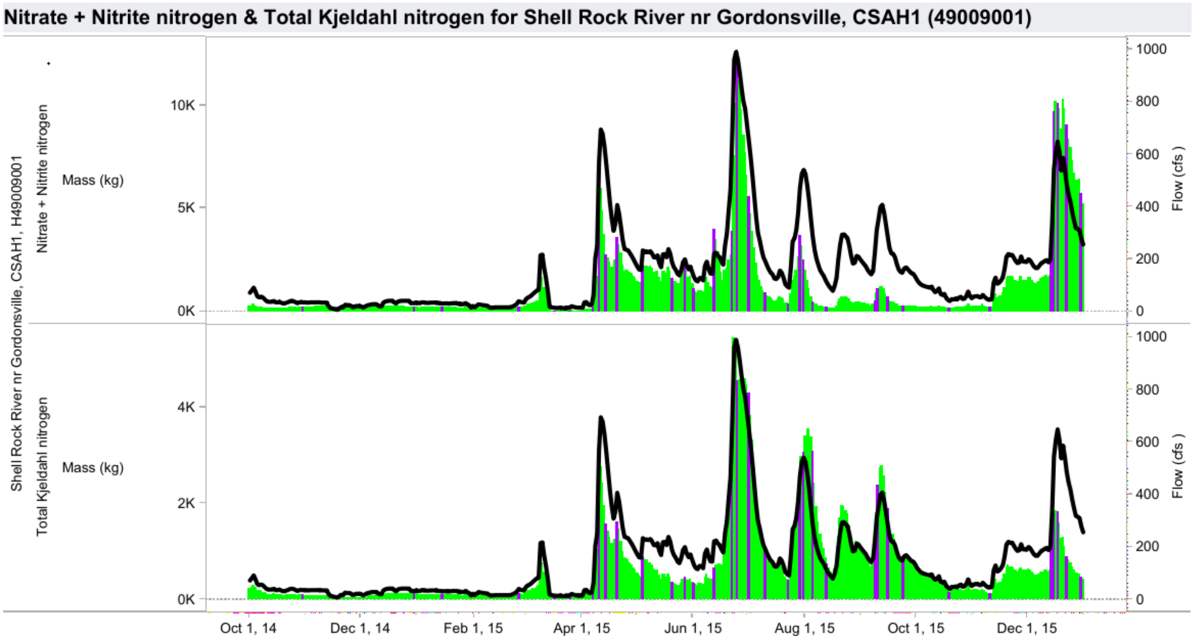


Figure 39. Shell Rock River Nitrogen Loads (Nitrate + Nitrite-N; and Total Kjeldahl Nitrogen) for October 1, 2014 to December 31, 2015.

Bacteria

The new bacteria impairments addressed in the TMDL and WRAPS reports are for Bancroft Creek and Wedge Creek, two headwater streams in the upper SRRW. Table 16 includes a summary of 2009 through 2018 *E. coli* indicator bacteria data for those sites. Geometric means for each month June through September exceeded the water quality standard and August showed the highest indicator bacteria concentrations for both streams. The WQS for *E. coli* has both a geometric mean standard (126 colony forming units per 100 milliliters of water (cfu/100 mL)) and an individual sample maximum value (1,260 cfu/100 mL).

Table 16. *E. coli* concentrations for Bancroft Creek and Wedge Creek.

Stream Name	WID # -	Station #	*E. coli* geomean (cfu/100 ml)			Maximum Concentration Sampled
			June	July	August	
Bancroft Creek	507	S004-120	307	298	424	>2400
Wedge Creek	531	S004-121	295	208	494	>2400

2.1.2. Lakes

Understanding lake ecology begins with the collection of monitoring data. The primary focus of MPCA lake monitoring is to sample large lakes (greater than 500 acres), but also small lakes (100 to 499 acres). Because monitoring resources are limited, lakes with greatest aquatic recreational opportunities are targeted for monitoring and assessment. For additional information about MPCA's goal for lake monitoring, see Minnesota's Water Quality Monitoring Strategy (MPCA 2011b). The SRRWD has developed a robust lake water quality data set, which has been used by the MPCA. Additional information about those data and the SRRW lakes, can be found in the SRRW TMDL (RESPEC 2020), and the SRRWD webpage.

The five lakes in the SRRW have impaired aquatic recreation due to eutrophication. The aquatic recreation eutrophication standard for lakes in the SRRW comes from Minn. R. ch. 7050.0222, subp. 3. The standard includes three parameters: TP (90 µg/L), chl-*a* (30 µg/L) and secchi disk transparency ([SDT] 0.7 meters/2.1 feet). TP is the causal variable and affects the two response variables: chl-*a* and SDT. These response parameter standards reflect what is suitable for Shallow Lakes in WCBP and Northern Glaciated Plains Ecoregions. To be listed as impaired, monitoring data must show that the TP concentration exceeds 90 µg/L, and that either the chl-*a* or transparency thresholds are exceeded. White Lake was listed as impaired in 2012; all other lakes were listed in 2008. While TP, chl-*a* and transparency are highlighted water quality parameters, there are a mix of chemical, physical and biological factors at play that affect the observed lake quality conditions. {Note on concentrations for parameters like phosphorus and chlorophyll: this section uses both micrograms per liter (µg/L) and milligrams per liter (mg/L); 90 µg/L = 0.090 mg/L (for P), and 30 µg/L = 0.030 mg/L (for chl-*a*).}

Table 17. Assessment status of lakes in the Shell Rock River Watershed.

Lake ID	Lake Name	Aquatic Rec. (Phosphorus)
24-0014-00	Albert Lea	Impaired
24-0018-01	Fountain (East Bay)	Impaired
24-0018-02	Fountain (West Bay)	Impaired
24-0018-03	Fountain (North Bay)	Impaired
24-0024-00	White Lake	Impaired
24-0025-00	Pickeral Lake	Impaired
24-0027-00	Lower Twin Lake	Insufficient information to assess
24-0031-00	Upper Twin Lake	Insufficient information to assess
24-0037-00	Sugar Lake	Insufficient information to assess
24-0038-00	Halls Lake	Insufficient information to assess
24-0040-00	School Section Lake	Insufficient information to assess
24-0068-00	Mud Lake	Insufficient information to assess
24-0017-00	Goose Lake	Not assessed

Fountain Lake

SRRWD collected TP concentrations for the June thru September growing season in Fountain Lake (East Bay and West Bay). Average TP concentration is 265 µg/L over a 10-year timespan (2009 through 2018) with maximum values reaching three to four times the mean values. These data, plus additional data from years 2005 through 2008, are displayed in Figure 40 and Figure 41. . Both the East and West bays of Fountain Lake show higher average TP concentrations for 2011 and 2012, due primarily to a drought that reduced the flushing rate, elevated water temperatures, and increased internal nutrient loading. Water quality response variables affected by the TP include chl-*a* and SDT (Table 18).

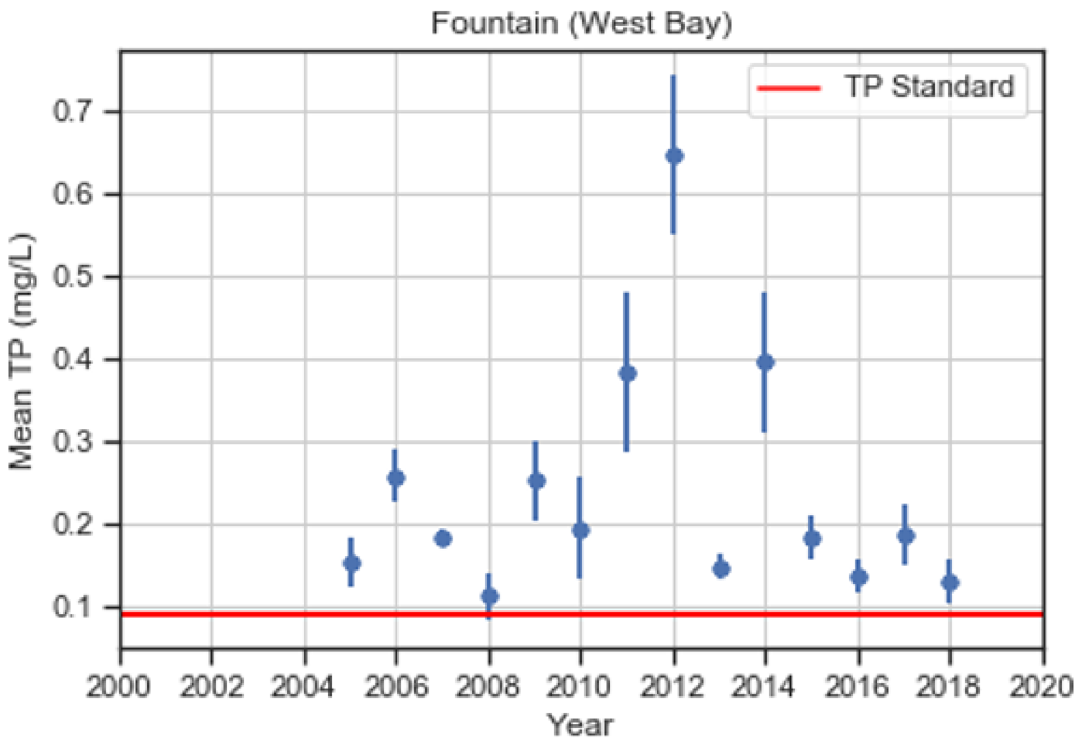


Figure 40. Total phosphorus mean concentration 2005 – 2018 for Fountain Lake (West Bay; RESPEC 2020).

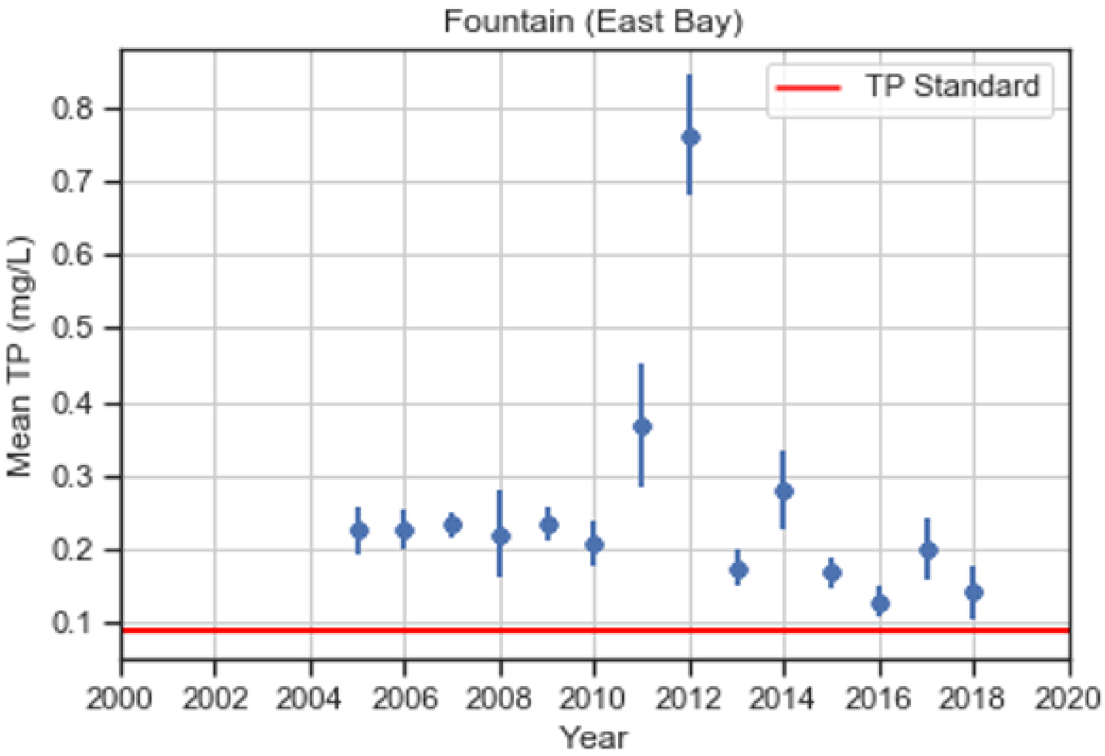


Figure 41. Total phosphorus mean concentration 2005 – 2018 for Fountain Lake (East Bay; RESPEC 2020).

Table 18. Fountain Lake growing season means for chl-*a* and secchi disk transparency.

Fountain Lake	Chlorophyll a (WQS: 30 µg/L)			Secchi Disk Transparency (WQS: 0.7 m.)		
	Minimum (µg/L)	Mean (µg/L)	Maximum (µg/L)	Minimum (m.)	Mean (m.)	Maximum (m.)
East Bay	1.1	65.9	256	0.18	0.71	1.68
West Bay	1.0	39.6	167	0.18	0.73	2.07

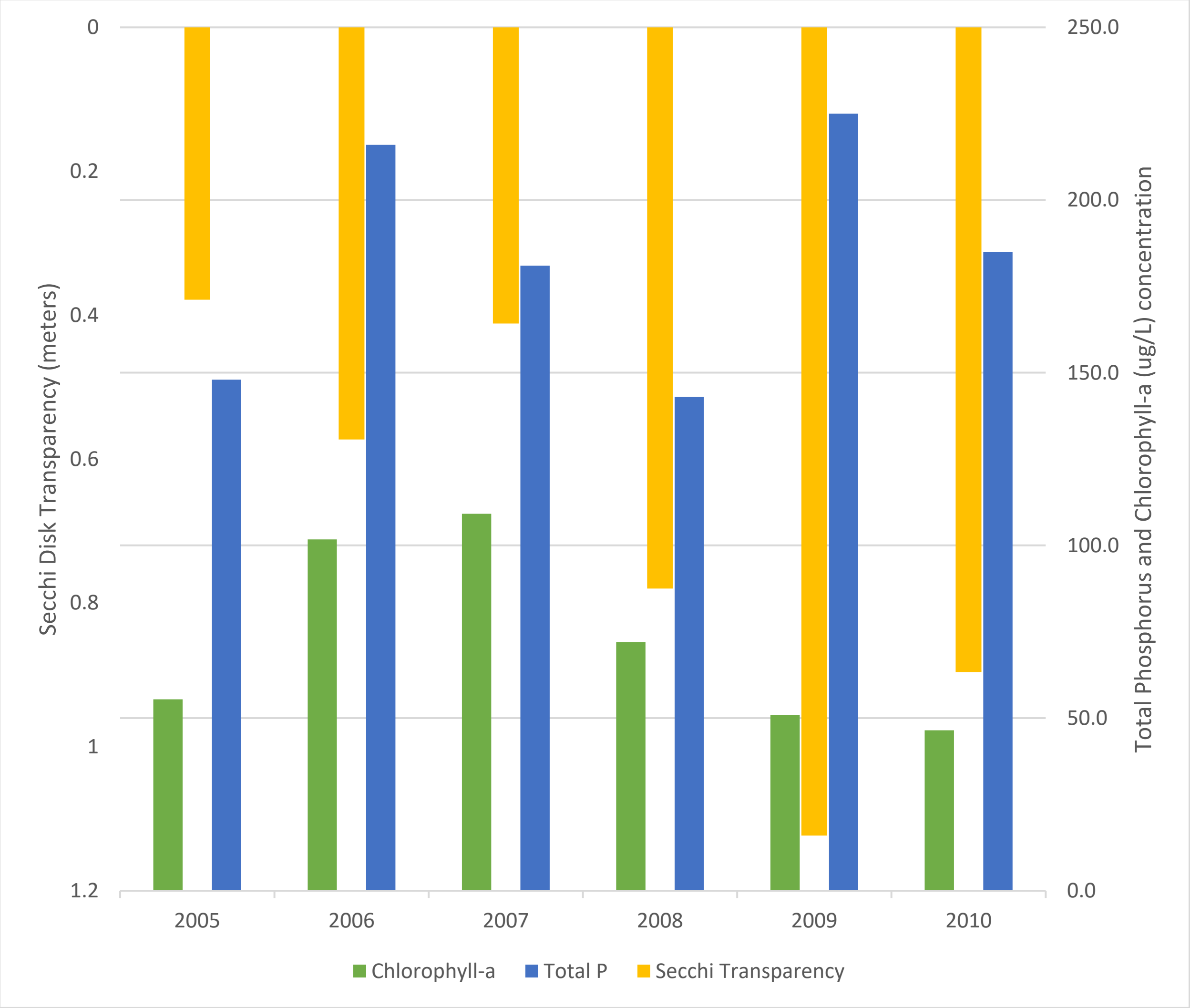


Figure 42. Fountain Lake (West Bay) Water Quality Data trend data 2005 – 2010 (June -September averages).

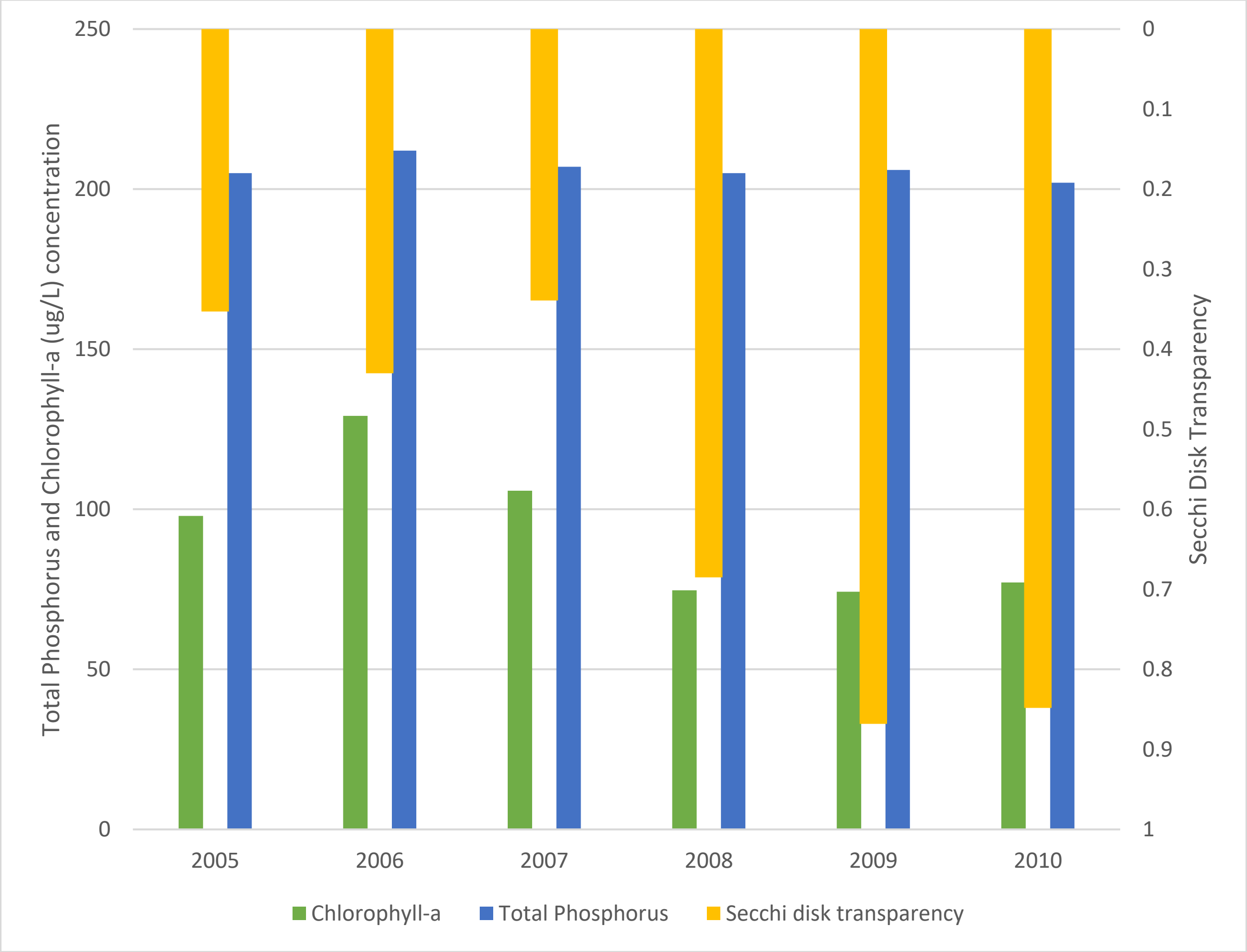


Figure 43. Fountain Lake (East Bay) Water Quality Data trend data 2005 – 2010 (June -September averages).

Average chl-*a* and transparency values largely exceed their respective standards. Many factors influence the lake water quality response variables, including nutrient loading, fish dynamics, materials suspended in the water column that “shade” algae, and physical factors such as wind and water temperature.

Albert Lea Lake

A 14-year record of Albert Lea Lake water quality data has been established averaging over the growing season of June through September (Figure 44). This figure displays TP, chl-a, and SDT data for Albert Lea Lake's west basin (SRRWD site LAL01).

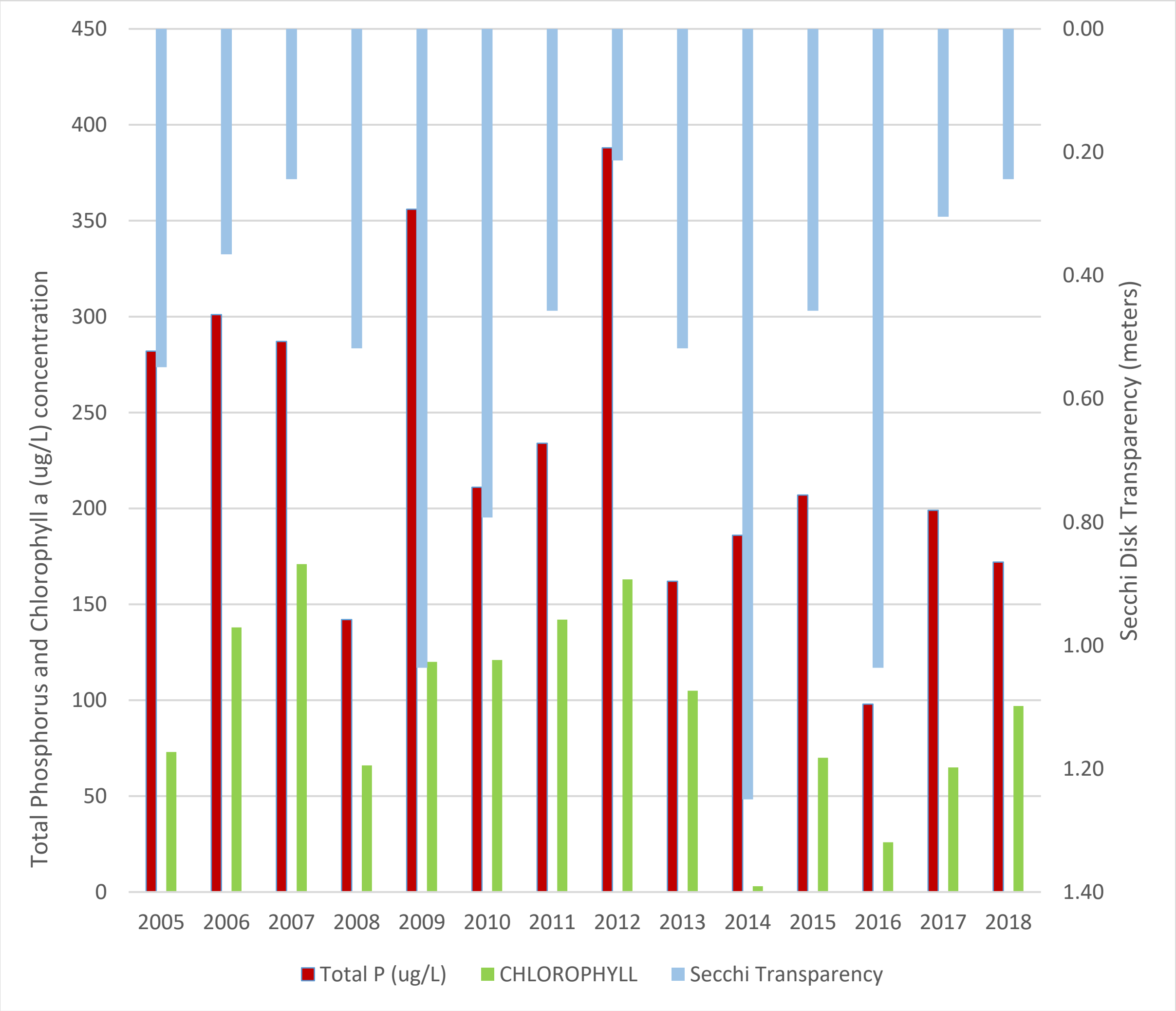


Figure 44. Albert Lea Lake Water Qualtiy Data trend data 2005 – 2018 (Site LAL01, June – Sept. average) – Data from SRRWD.

While chl-*a* values are often in the 50 to 100 µg/L range, in 2014 and 2016, Albert Lea Lake had significantly lower chl-*a* concentrations. Improved SDT conditions were in the 1.0 to 1.2 meter range.

Years with higher TP often have poorer water transparency; 2012 for example. But, other factors, such as wind-driven sediment resuspension, can also negatively affect water clarity, which might be an important factor in 2017. The length of time water remains in Albert Lea Lake, which is known as residence time, is another important factor that affects these lake water quality parameters. The years 2009 and 2010 display relatively good water clarity, with fairly high TP levels, and so a shorter lake residence time could have been a factor. Residence time calculations for SRRW lakes can be found in the SRRW TMDL Appendices A thru D.

TP concentrations found in three lake areas of Albert Lea Lake from 2005 through 2018 are shown below. All mean values exceed the standard. The minimum and average values are similar for west, central and east areas of this large lake. The central zone of Albert Lea Lake has a lower average maximum TP concentration, over this timeframe. Corresponding chl-*a* and SDT values generally exceed their respective standards (Table 18). These water quality data for Albert Lea Lake are quite variable, with many factors impacting data parameters including hydrology, wind, temperature, and fish communities.

Table 19. Albert Lea Lake growing for chlorophyll a and secchi disk transparency.

Albert Lea Lake Area	Chlorophyll a (WQS: 30 µg/L)			Secchi Disk Transparency (WQS: 0.7 m.)		
	Minimum (µg/L)	Mean (µg/L)	Maximum (µg/L)	Minimum (m.)	Mean (m.)	Maximum (m.)
West	1.1	88.3	626	0.15	0.68	1.77
Central	1	71.1	433	0.15	0.77	1.83
East	1.1	74.6	277	0.12	0.49	1.37

Pickeral Lake

TP concentrations for Pickeral Lake were collected between 2005 and 2018 growing season months. A total fish reclamation project took place in 2009, affecting significant decreases in TP in the lake water.

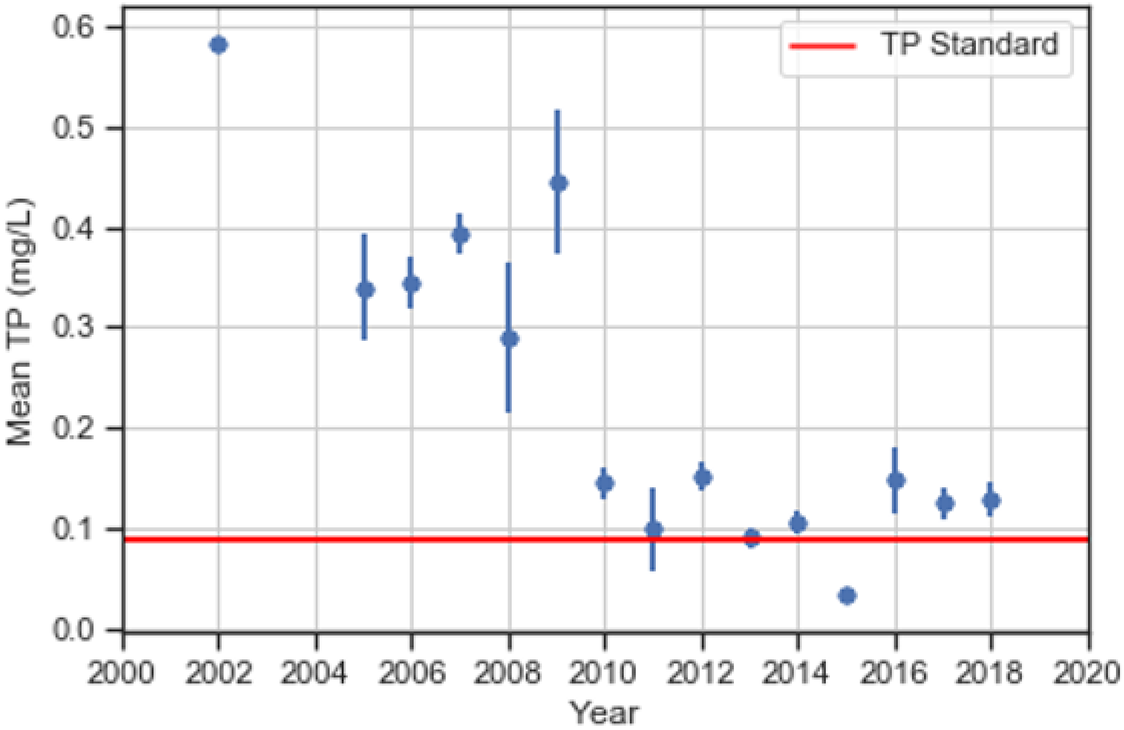


Figure 45. Mean total phosphorus concentrations for Pickeral Lake, 2005 – 2018 growing seasons; RESPEC 2020.

Table 20. Pickeral Lake growing season means for chlorophyll a and secchi disk transparency (2009-2018).

Pickeral Lake	Chl-*a* (WQS: 30 µg /L)			Secchi Disk Transparency (WQS: 0.7 m)		
	Minimum (µg/L)	Mean (µg/L)	Maximum (µg/L)	Minimum (m)	Mean (m)	Maximum (m)
	1.0	34.6	300	0.15	1.02	1.68

Pickeral Lake is an important lake resource in the SRRW, and an important “case study” lake. In 2009, a fish reclamation (i.e. fish kill) project was launched to manage rough fish in Pickeral Lake. Success of the rough fish removal in Pickeral Lake is evident in Figure 46 by looking at the lake’s water quality trends.

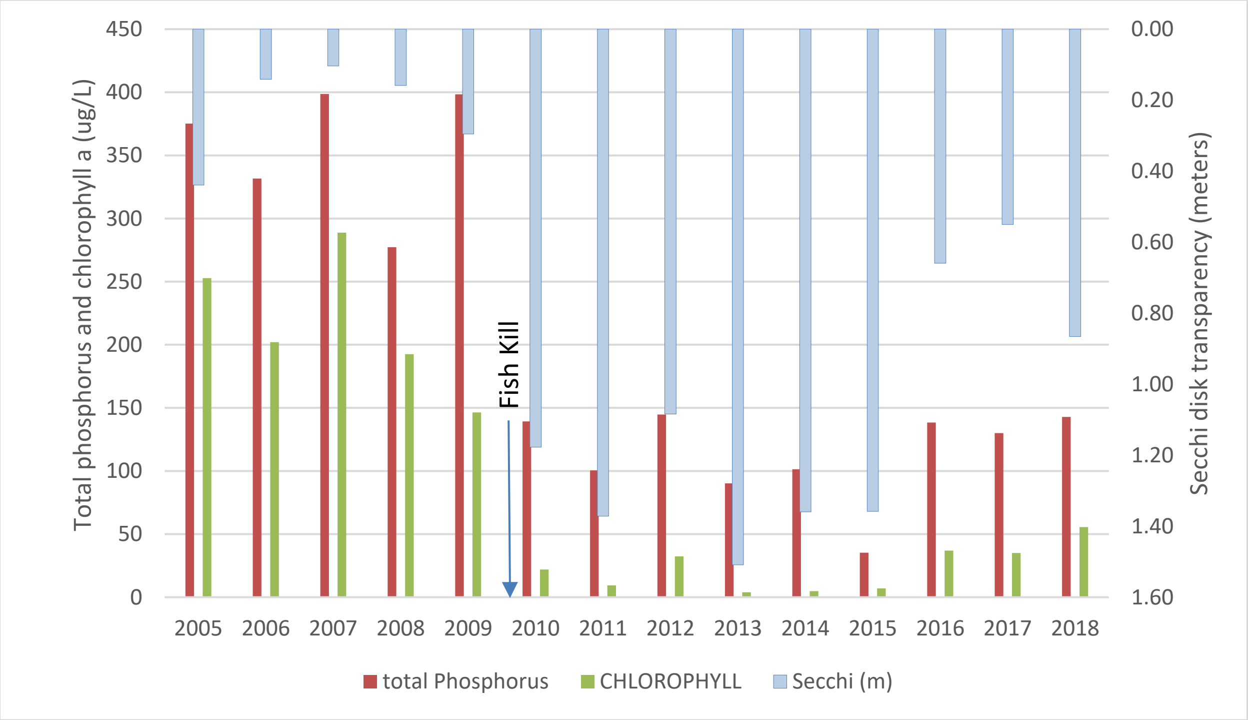


Figure 46. Total phosphorus, chl-*a*, and secchi disk transparency trends for Pickeral Lake (2005-2018).

In 2016, TP levels seemed to stabilize at around 140 µg/L, chl-*a* levels exceeded the WQS of 30 µg/L, and transparency declined from the improved levels of the previous six years. Concentrations of chl-*a* have dropped from a range of 150 to 250 µg/L (pre-fish kill) to low concentrations (less than about 40 µg/L). Recent data collected by SRRWD show TP and chl-*a* concentrations that have exceeded WQS, and SDT values have declined. Trap netting by DNR Fisheries personnel in both 2018 and 2019 resulted in pike, perch, black bullhead, and some walleye being caught, but no carp. The shallow and dynamic nature of shallow lakes such as Pickeral Lake do not lend themselves to a more standard fishery assessment method (Soupir 2020).

White Lake

Seventy-nine samples from White Lake were collected and analyzed for TP between 2005 and 2018 growing season months. The average TP concentrations in White Lake for June thru September range from 0.109 to 0.224 mg/L. In 2009 a fish barrier was installed to prevent rough fish migration into White Lake. The lower mean TP concentrations in the more recent years likely are the result of winterkills of fish, which translated into improved lake water quality (SRRWD 2018).

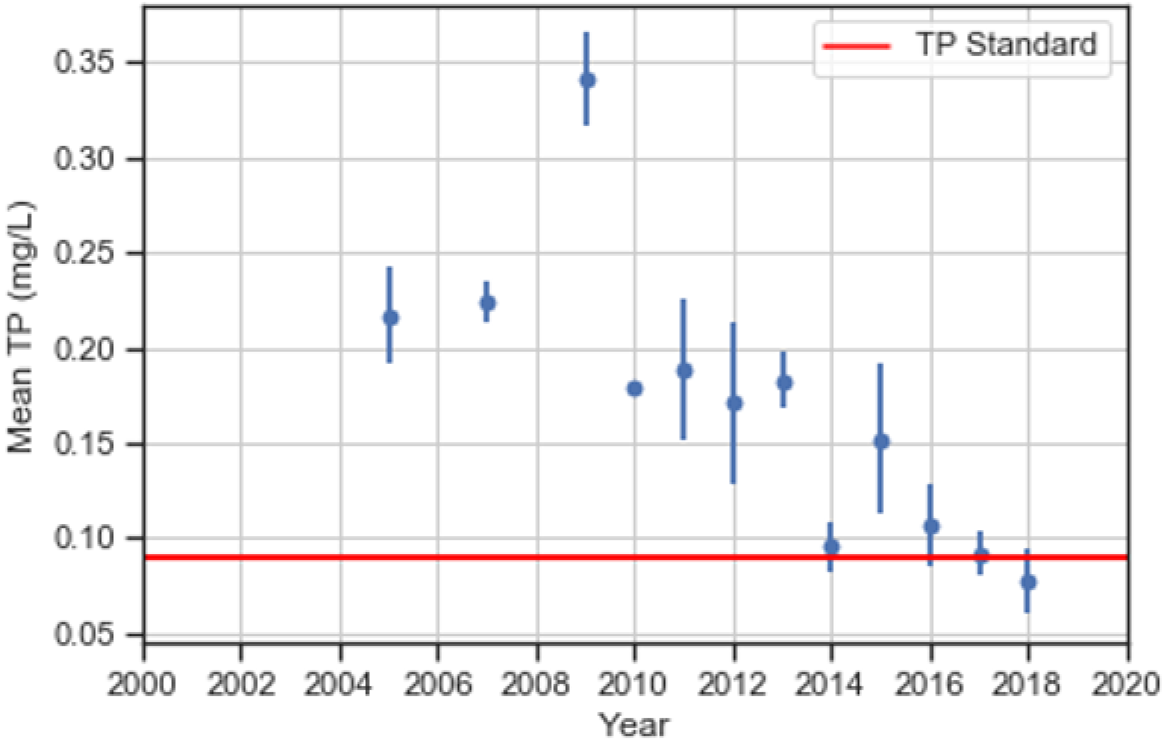


Figure 47. Mean total phosphorus concentrations for White Lake, 2005 – 2018; RESPEC 2020.

Table 21. White Lake growing season means for chlorophyll a and secchi disk transparency (2009-2018).

White Lake	**Chlorophyll a (WQS: 30 µg /L)**			**Secchi Disk Transparency (WQS: 0.7 m)**		
	Minimum (µg)	**Mean (µg)**	**Maximum (µg)**	**Minimum (m)**	**Mean (m)**	**Maximum (m)**
	1.0	**71.5**	**267**	**.12**	**.56**	**2.13**

In summary, the lakes assessed in the SRRW are clearly impaired by eutrophication. These lakes are enriched with excess phosphorus and are subject to frequent algae blooms as evidenced by chl-*a* concentrations, along with reduced SDT. Pickeral and White Lakes have shown positive water quality responses to fisheries management strategies. Subsequent Section 2.3 will further discuss the sources of phosphorus and Section 3.4 describes goals for lake restoration. Post 2012 lake monitoring data are indicating an optimistic trend: a majority of SRRW lakes are improving since the 2012 assessment. Incorporating these recent data into the next round of water quality assessments (Spring 2021) will allow MPCA to determine each lake's progress toward meeting WQSs.

2.2 Water quality trends

The MPCA completes trend analysis for various parameters for lakes and streams across the state. A trend assessment for the SRRW was conducted by the MPCA (2014b). Trends cover nearly five decades of water quality data for the monitoring site located near Gordonsville, Minnesota. The trends are assessed over a 1961 through 2009 period, and a more recent timeframe (1995 through 2009). A designation of "no trend" means that a statistically significant trend has not been found; this may simply be the result of insufficient data. Concentrations are median summer (June through August) values, except for chlorides, which are median year-round values.

Table 22. Trends in the Shell Rock River Watershed for Monitoring Station S000-084; At bridge on CSAH-1, 1 mile west of Gordonsville (SR-1.2), 1961-2009. From MPCA 2014c.

	TSS (mg/L)	TP (mg/L)	NO3-N (mg/L)	Ammonia (mg/L)	Biochemical Oxygen Demand (mg/L)	Chloride (mg/L)
overall trend (1961-2009)	**decrease**	**decrease**	**increase**	**decrease**	**decrease**	**increase**
average annual change	-1.9%	-1.0%	4.6%	-0.9%	-2.9%	1.5%
total change	**-60%**	**-38%**	**563%**	**-37%**	**-77%**	**106%**
Recent trend (1995 – 2009)	**no trend**	**no trend**	**no trend**	**no trend**	**no trend**	Not assessable.
average annual change	--	--	--	--	--	--
total change	--	--	--	--	--	--
Median concentrations first 10 years	**99**	**0.5**	**1**	**0.10**	**14.5**	**35**
Median concentrations most recent 10 years	**54**	**0.4**	**2**	**<.05**	**6.6**	**43**

Overall trends for the Shell Rock River are similar to what has been observed in other Southern Minnesota streams: increasing NO3-N and chloride concentration; decreases in TSS and P. For the more recent trend timeframe (1995 through 2009), no pollutant trends were detected.

Lake water quality trends can be assessed in several ways. Longer-term trends are more qualitative and anecdotal in nature, and for Albert Lea Lake, go back about eight decades. Analytical methods that make use of data that ranges from one to three decades in duration, can be more quantitative, due to the greater degree of monitored lake water quality data available, that includes consistent methodology and chemical analysis.

The longer-term data for Albert Lea Lake reflects the high pollutant loads from both municipal and industrial wastewater sources, which were discharged into the lake in the earlier decades. Because of the longer history for Albert Lea Lake, an extended narrative on the historical context for lake restoration is included in Appendix I.

A formal trend analysis for lake water quality parameters, which utilizes all QA-inspected data, has not been accomplished for the lakes in the SRRW. A partial analysis by the MPCA for water clarity (SDT) found no trend for Albert Lea Lake or Fountain Lake East (MPCA 2019). This partial analysis did not have access to the additional data from the SRRWD, which was provided during 2019. Additional analysis and the determination of trends, using the proper statistical methods, on a larger data set is now feasible. This will be captured in future water quality condition reports.

2.3 Stressors and pollutant sources

In the two previous report sections, the water quality conditions and water quality trends were summarized for the SRRW's surface water resources. This section will examine, and generally identify, the stressors and pollutant sources most associated with the conditions and trends.

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or pollutant sources impacting or threatening them must be identified and evaluated. Biological SID is conducted for streams with fish and/or macroinvertebrate biota impairments. SID encompasses the evaluation of both pollutant and nonpollutant factors as potential stressors on biology. Source assessments are done where the SID process identifies a pollutant as a stressor. The following sections will discuss stressors to biology, pollutants contributing to impairments, and likely origins of pollutants from both point and nonpoint sources.

2.3.1. Stressors of biologically-impaired stream reaches

The Shell Rock River is the only listed biology-impaired river in the SRRW, at the writing of this report. As discussed previously, examination of potential stressors of biota in other stream and river reaches in the SRRW is underway.

Table 23. Primary stressors to aquatic life in the biologically impaired reach of the Shell Rock River (MPCA 2014b).

Stream/River	WID (Last 3 digits)	Reach description	Biological impairment	Identified Stressors								
				Dissolved oxygen	Nitrate	Phosphorus	Suspended Solids	Chl-*a*	pH	Habitat	Temperature	Specific Conductance
Shell Rock River	-501	A.L. Lk outlet to Iowa border	Fish and invertebrates	X	X	X	X	X	X	X	ID	ID

ID = Indirect stressor

The most prominent stressors to biology in the Shell Rock River are elevated nitrates, phosphorus, pH and chl-*a* levels and resulting DO fluctuations (MPCA 2014a). Other indirect stressors to the fish and invertebrates are stream flow (altered hydrology), temperature and specific conductance.

Bancroft Creek was noted in the SID Report as being deferred from aquatic life assessment due to stream channel modifications. However, because of the importance of the subwatershed, chemistry data collected was summarized in the SID Report. Though the biology of Bancroft Creek is not listed as impaired, evidence suggests that DO and nitrogen are stressing the macroinvertebrate community.

2.3.2. Pollutants and sources

As summarized in Table 10, the main pollutants of concern in the SRRW are nutrients and sediment. Pollutants are subdivided by their origin as either point source or nonpoint source. Point source pollution sources include industrial and municipal wastewater, and construction, industrial and municipal stormwater. These point sources are directly addressed in the TMDL report. Nonpoint source pollution categories are associated with the variety of land uses within the watershed. There are many agricultural land uses, which differ from pollutant sources associated with land that is forested, a wetland, or a highway system. A framework to identify and develop estimates for this complex set of conditions includes the application of mapping and modeling tools, as well as critical input from local land managers, resource management personnel, and conservation leaders.

Information from the SRRWD (2015) water management plan provides a general summary of nonpoint pollutant factors that pertain to the watershed:

> *"Pollutant source contributions vary considerably from one runoff event to the next depending on factors such as tree and vegetation cover, soil moisture, and precipitation depth and precipitation intensity. In urban and agricultural settings, drainage systems efficiently deliver pollutants to streams, lakes and wetlands through stormwater and agricultural runoff. Additionally, surface erosion and instream sediment concentrations increase following high intensity rain events in the spring prior to vegetation development and leaf out as opposed to later in the year where mature vegetation can absorb a significant amount of rainfall before runoff occurs."*

Using this general statement from local on-the-ground practitioners provides guidance on how best to apply some mapping and watershed pollutant modeling techniques. Sources of sediment, phosphorus, and nitrogen in the SRRW were estimated using MPCA's Hydrologic Simulation Program–Fortran (HSPF) model. Additional studies that took place in the watershed, or in close proximity, were also used to inform the HSPF model. This framework starts with local input and expertise, and builds upon both land and water data sets - making use of predictive models, special studies, and qualified regional information.

HSPF is a comprehensive model of watershed hydrology and water quality that was used in the SRRW. This model allows the integrated simulation of point sources, land and soil contaminant runoff processes, and in-stream hydraulic and sediment-chemical interactions. Within each subwatershed, the upland areas are separated into multiple land use categories. The model evaluated both permitted and nonpermitted sources of pollutants, including watershed runoff, and wastewater point sources. HSPF was also used to quantify upland loading rates for TSS, TP, and TN by model catchment. Upland loads include rill, sheet, and gully erosion to estimate TSS. Model development and calibration is based on the best available information, but as with all models, uncertainties do exist while still providing useful information. Model documentation contains additional details about the model development and calibration (RESPEC 2019). An understanding of that background on HSPF is critical to also knowing that this model does not explicitly determine pollutant sources. As noted in the referenced documents for the SRRW HSPF model, user inputs with model adjustments and calibration are required, and the model then simulates pollutant transport from the various possible sources. And lastly, because the model is set up on a subwatershed basis, a helpful accounting system is also available.

The MPCA (1987) 'Lakes Protocol' document includes a detailed description of the network of empirical models generally known as "BATHTUB." This model was developed by Walker (1985) for the U.S. Army Corps of Engineers, and includes nutrient balance and eutrophication response components. Data from many lakes (and reservoirs) is gathered together to develop this modeling package, and includes statistical relationships about water flow, basin characteristics, and water quality parameters. These models allow for input of monitored tributary flow and pollutant concentration data. Loading estimates can be predicted that are consistent with water quality objectives.

The lake-modeling software BATHTUB (Version 6.1) integrates watershed runoff with lake-water quality. This publicly available, peer-reviewed model has been successfully implemented in lake studies throughout the U.S. for more than 30 years and uses steady-state annual water and nutrient mass balances to model advective and diffusive transport and nutrient sedimentation (Walker 2006). Lake responses (e.g., chl-*a* or SDT) are predicted via empirical relationships (Walker 1985). BATHTUB allows its users to specify single lake segments (lake bays) or multiple segments with complicated flow routing, and calculates the lake response for each segment from morphometry and user-supplied lake fetch (lake length is an example for wind calculations) data. The cumulative annual phosphorus load of all of the external watershed and internal lake sources can be empirically related to the lake recreation period (e.g., growing-season) conditions (Walker 1996) and expressed as the average summer TP, chl-*a*, and Secchi disk depth. This predictive model includes statistical analyses to account for variability and uncertainty.

A description of how the BATHTUB lake model was used for the lakes in the SRRW is included in Section 4.8.1 of the TMDL Report, and more detailed listing of modeling coefficients included in Appendix F of the TMDL. The time period for the modeling was 2009 through 2018. The HSPF model was used to derive average annual water and phosphorus input datasets, for each lake.

Bacteria are a complicated pollutant to surface waters, and both Wedge Creek and Bancroft Creek are impaired by *E. coli*. The HSPF model described above does not address bacteria, as sources and population growth are both highly variable across the landscape and seasonally. Potential sources of *E. coli* in the watershed are based on the best available data and those methods are further described in the SRRW TMDL. These commonly applied techniques form the basis of the bacterial source assessment below.

Sediment

TSS are materials suspended in the water. These materials are often primarily sediment but also includes algae and other solids. TSS directly affects aquatic life by reducing visibility, clogging gills, and smothering substrate which limits reproduction. Excessive TSS indirectly affects aquatic life by reducing the penetration of sunlight, limiting plant growth, and increasing water temperatures. Organic particles include algae and detritus (mostly material from plant breakdown). Inorganic materials are most frequently silts and clays.

Sediment is also affecting habitat quality and availability for fish and invertebrates in the Shell Rock River (from both near-channel and upland sources). Suspended sediments that are deposited onto the stream bottom can fill-in coarser substrates, and become “bedded,” and thus negatively affect habitats and stream biota.

Soil erosion from upland sources is an important condition in the SRRW. The NRCS estimated water erosion soil loss for four years using the Universal Soil Loss Equation (USLE) for the SRRW and found rates varied from around 300,000 ton/year (in 1982, 1987, and 1992) to 825,000 tons/year (in 1997), (USDA 2017a). The large difference between 1997 and the other years for estimated soil loss from water erosion is most likely due to the variable effects of rainfall, and factors associated with land use or land management. USDA-NRCS (2016) notes that the rainfall time, amount, intensity and distribution are all important factors, as are soil conditions such as structure, texture, and organic matter.

Another method to assess soil erosion is with the Daily Erosion Project (DEP), which is a tested and proven soil erosion model that employs USDA’s Watershed Erosion Prediction Model. Developed by researchers at Iowa State University, this analysis uses soils data, LiDAR and satellite imagery for crop management and field boundaries (Iowa State University, https://www.dailyerosion.org/). It allows for both daily and yearly runoff and hillslope soil loss estimations, and is available to some regions of Minnesota, including the SRRW.

Thirteen years of hillslope soil loss estimates in tons/acre, for both Bancroft Creek and Wedge Creek subwatersheds are displayed in Figure 48. Low precipitation years like 2012 produce a lower number of runoff events (23), and lower soil loss estimates. High precipitation years such as 2010 (36.63" precipitation) and 2013 (43.4" precipitation) can produce more runoff events, which can result in more soil loss. Because timing and land conditions are so critical to these estimates, a year with similarly high precipitation such as 2018 (44.3" precipitation), and a high number of runoff events (66), resulted in lower soil loss, especially for the Wedge Creek Subwatershed. Figure 48 shows significant soil loss variation within these 13 years, as well as estimates that show more soil loss from either Wedge Creek, or Bancroft Creek. There are five years where these soil loss estimates between the two subwatersheds are essentially the same (2009, 2012, 2016, 2017, and 2019).

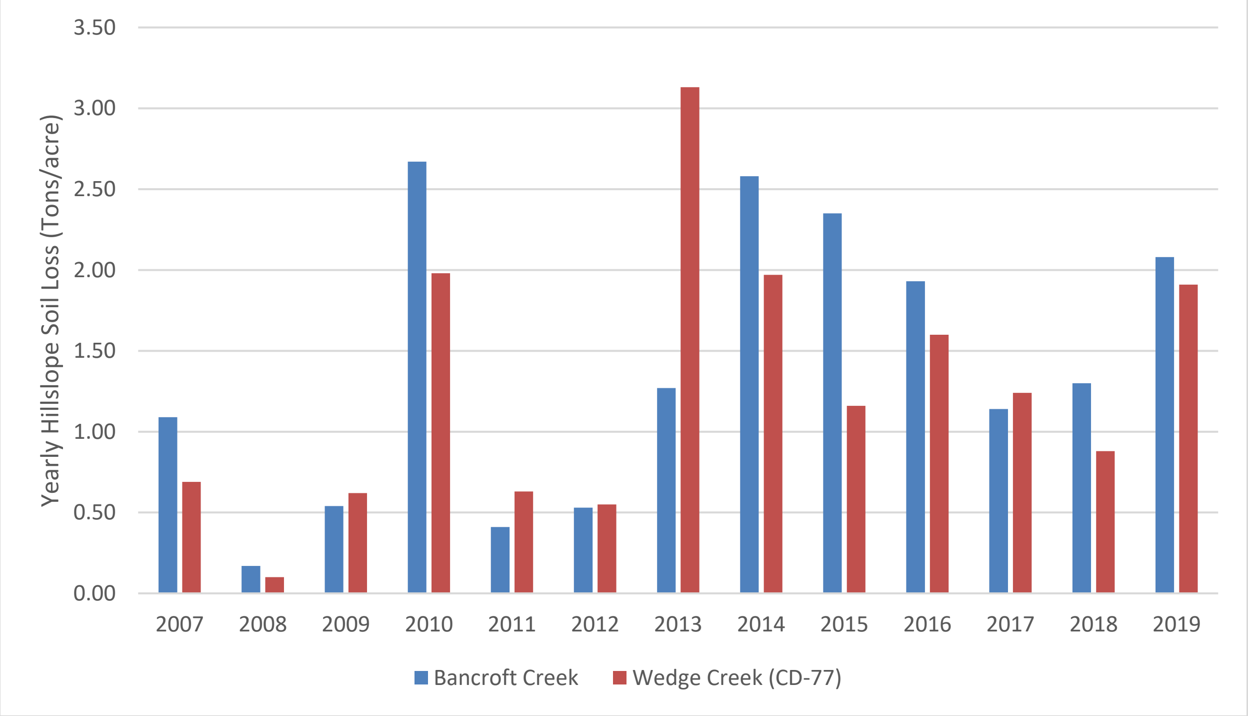
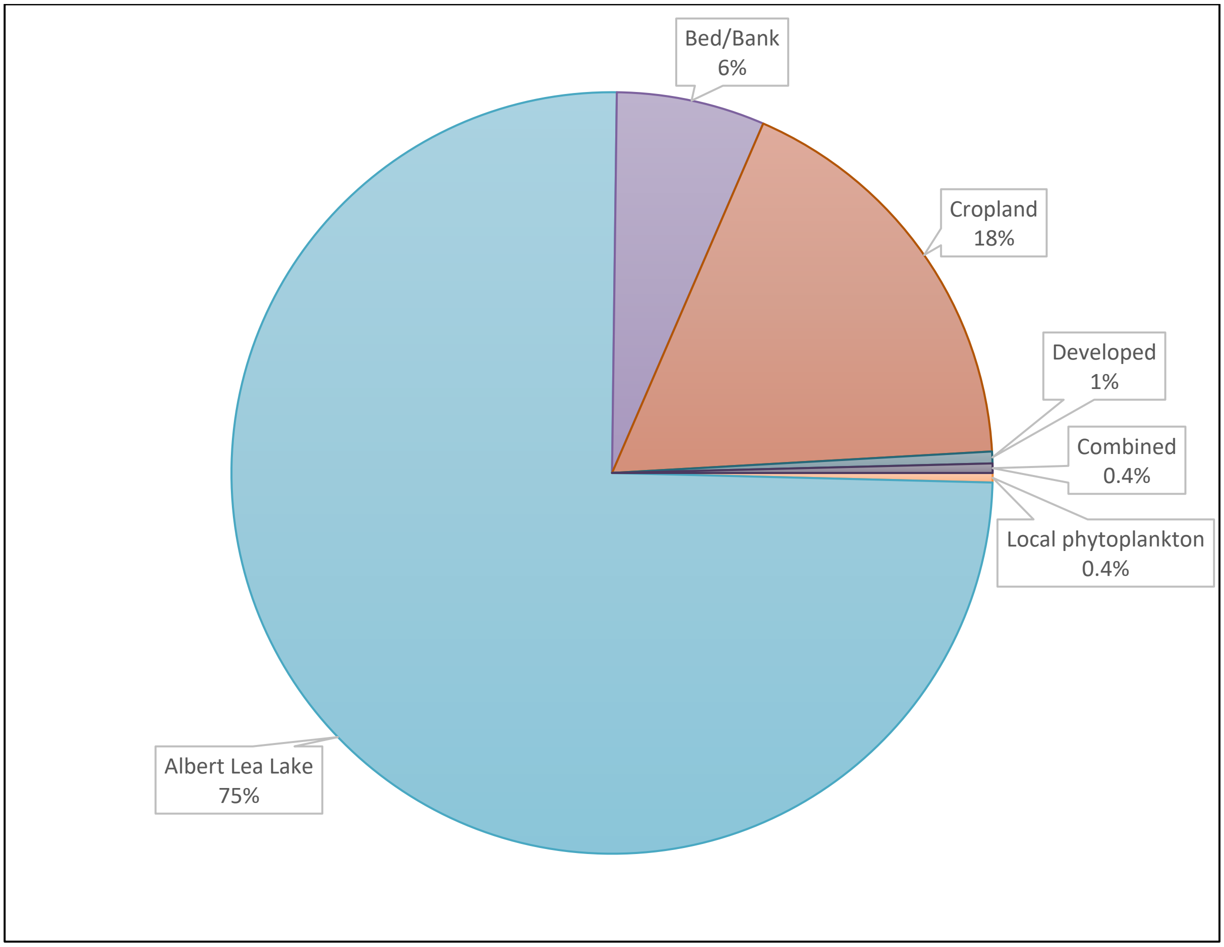


Figure 48. Hillslope soil loss estimates for Bancroft Creek and Wedge Creek, 2007-2019 (Iowa State University, Daily Erosion Project).

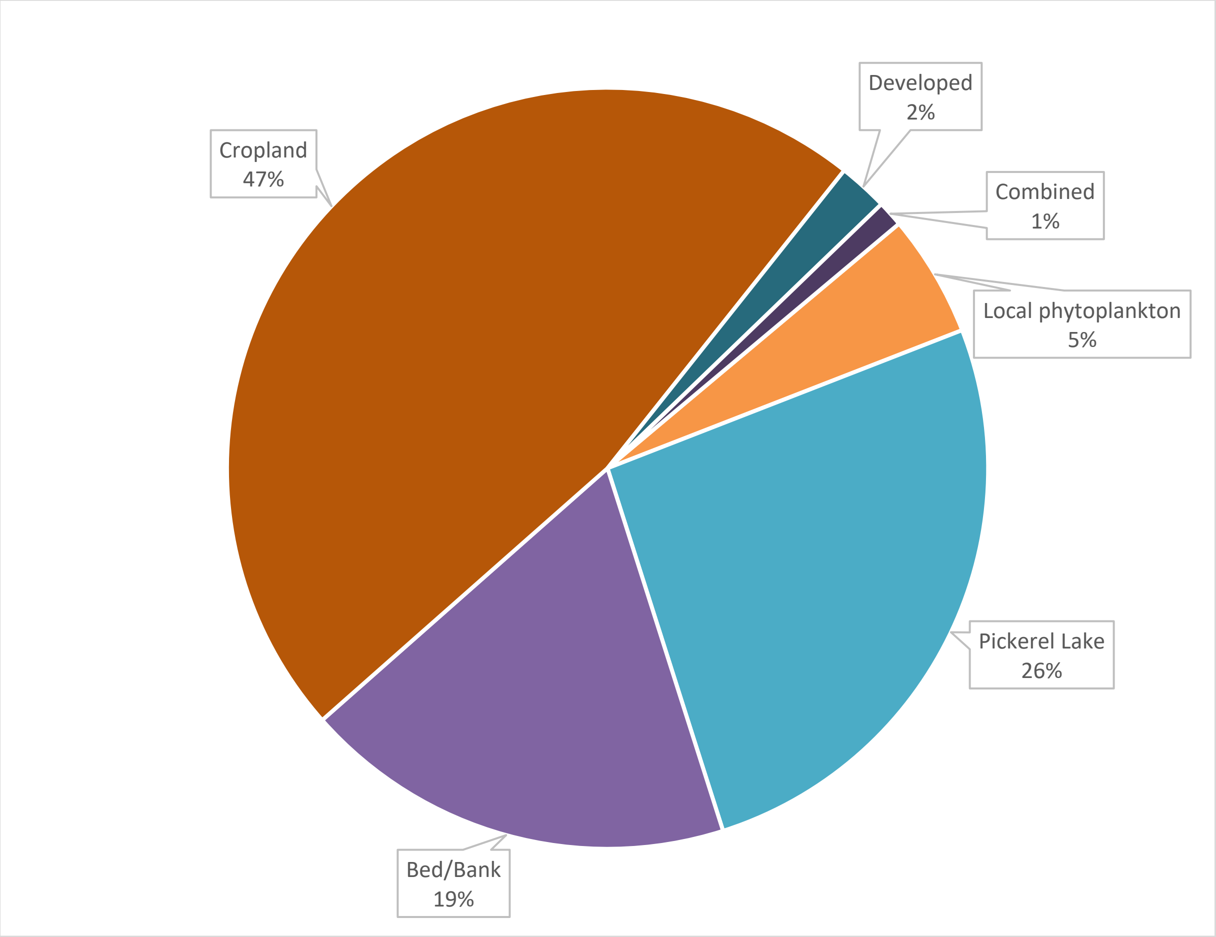
Considering only the Shell Rock River, which begins essentially as 'flowing lake water' at the outlet of Albert Lea Lake, the model predicts that 75% of the TSS is from the lake (Figure 49). This "Total TSS" is made up of a seasonal mix of organic TSS (algae and detrital matter), and any fine particles that are in suspension near the lake outlet. These data were presented in Section 2.1.1, including data on the initial monitoring site on the Shell Rock River, directly below Albert Lea Lake. The model predictions presented here align with the observed data (volatile solids: total solids) presented in Figure 33. The organic TSS component generally exceeds the clay and silt component (in other words, the organic TSS is most dominant form, "explaining" 70% of the observed variation in total TSS). The secondary TSS source for the Shell Rock River is from local cropland, which is the dominant land use in the watershed Sediment sourced from streambeds and streambanks is estimated at 6% for the SRR. While this estimation may seem low, when compared with other Southern Minnesota watersheds, the SRR is positioned below the lakes, with more gradual stream gradients. For perspective, the current load of TSS at the end of the Shell Rock River reach, calculated as a daily average for the TMDL, is 327 tons/day (RESPEC 2020).



Note: *Combined* % (0.4%) is sum of point sources, pasture, grasslands and feedlots.

Figure 49. TSS source-assessment modeling results in impaired Shell Rock River Reach 501. (RESPEC 2020).

TSS source assessments for Shoff Creek (Figure 50) are somewhat different than the Shell Rock River. The ‘Pickeral-Shoff system’ is at a much smaller scale that the ‘Albert Lea Lake-Shell Rock River’ system for all components (i.e. the current TSS load at the Shell Rock River is about fourteen times more than for Shoff Creek). While the Pickeral Lake to Shoff Creek Subwatershed is small, sediment from cropland sources is more important in Shoff Creek. Pickeral Lake is the dominant feature in the subwatershed, but is relatively less effective at retaining watershed-derived sediments (than a much larger Albert Lea Lake). Some smaller direct drainage agricultural fields may also help account for the higher TSS load fate for Shoff Creek, as cropland accounts for about 46% of the TSS. The current TSS load, calculated for the TMDL as a daily average, at the end of the Shoff Creek reach is 23 tons/day (RESPEC 2020).



Note: Combined is the sum of feedlots, point sources, forest, grasslands and pasture.

Figure 50. TSS source-assessment modeling results in impaired Shoff Creek Reach 516. (RESPEC 2020).

Nitrogen

Nitrogen exists in the environment and water in numerous forms, including ammonia, nitrite and nitrate. Organic nitrogen exists naturally in the environment as SOM and/or decaying plant residue. The nitrogen cycle is the process in which nitrogen changes from one form to another, allowing particular forms of nitrogen to move easier within the environment. Nitrate (NO_3-N) is the form of nitrogen of most concern in water. Nitrates pose risks to humans in drinking water such as the risk of methemoglobinemia in infants (i.e., “blue baby syndrome”) and susceptible adults. In the freshwater environment, nitrates are toxic to aquatic life at variable concentrations. In the marine environment, NO_3-N have contributed to low oxygen, or hypoxic conditions, in coastal areas such as the Gulf of Mexico. Transformations among the different forms of nitrogen occur constantly in the nitrogen cycle.

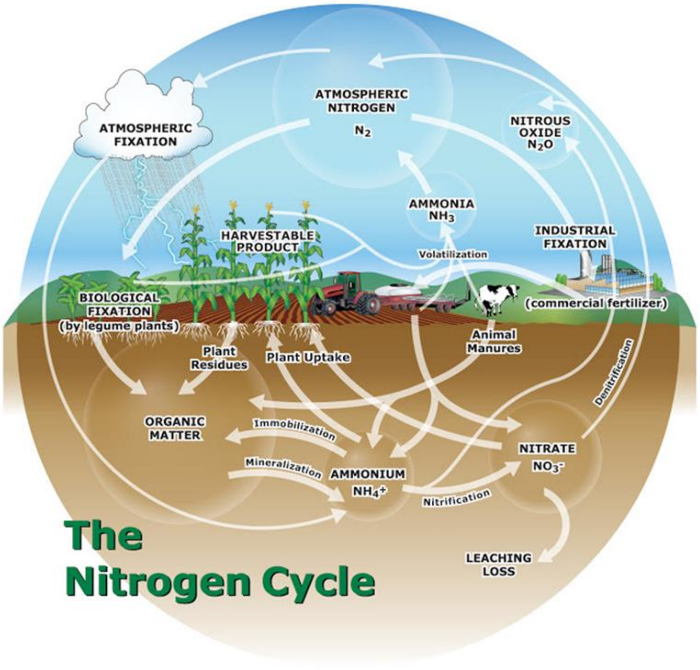


Figure 51. The nitrogen cycle; Cates 2019.

The State of Minnesota has diligently studied nitrogen and its impact to the environment. Minnesota's NRS, as called for in the 2008 Gulf of Mexico Hypoxia Action Plan, was completed in 2014. Minnesota contributes the sixth highest nitrogen load among all states to the Gulf of Mexico, and is 1 of 12 member states serving on the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. The scientific foundation of information for the nitrogen component of the NRS is represented in the 2013 report, "Nitrogen in Minnesota Surface Waters" (The Nitrogen Study). This document will continue to be useful as the MPCA and other state and federal organizations further their nitrogen-related work, and also as local governments consider how high nitrogen levels might be reduced in their watersheds.

The Nitrogen Study and the NRS state that cropland nitrogen losses through agricultural tile drainage and agricultural groundwater (leaching loss from cropland to local groundwater) make up the majority of nitrogen sources in Minnesota. These conclusions are critical when considering appropriate tools and strategies for managing nitrogen.

During the SID monitoring, NO_3-N was found to be a stressor to the biological community in the Shell Rock River. In the upstream tributaries to the Shell Rock River, average NO_3-N values are highest in the Bancroft Creek and Peter Lund Creek systems, with the highest average (11.07 mg/L) at CD 32 (tributary to Peter Lund) (MPCA 2014).

In the Shell Rock River (at Gordonsville, Minnesota) the nitrate + nitrite flow-weighted mean concentrations from 2009 to 2016 range from 2.4 to 6.1 mg/L, and average 3.6 mg/L. Nitrate + nitrite yields also vary considerably with weather and land use and soil conditions, with a range of 1.4 lbs/acre in a drought year (2012) to 20.7 lbs/acre (2013 and 2016). The leaching of NO_3-N from agricultural fields is a major factor affecting these variable yields. A reduction in crop uptake from 2012 allowed for an excess of NO_3-N to be present in the spring of 2013. The excessively wet spring of 2013 increased NO_3-N leaching, with transport occurring predominately via tile lines, to nearby ditches and streams. This points to the dynamic and complex nature of nitrogen in the SRRW, and the importance of continuing monitoring and modeling efforts – for both land where nitrogen is applied, and water where nitrogen has negative effects.

A majority of nitrogen sources in the SRRW come from nonpoint sources; primarily from cultivated land acres (Figure 52). Nitrogen from cropland groundwater, drainage and runoff originates from a variety of sources. Assessing nitrogen sources statewide, the MPCA (2013) determined that commercial fertilizer represents the largest source of nitrogen that is added to soil. Manure, legumes, and atmospheric deposition are also significant sources, and when added together provide similar nitrogen amounts as the fertilizer additions. SOM mineralization is not a nitrogen source in itself, but rather a process that mobilizes large quantities of nitrogen from the soil bank. While mineralization is an ongoing natural phenomenon, the increase in tile drainage has resulted in an increased transport of this nitrogen to surface waters. Septic systems, lawn fertilizers and municipal biosolids add comparatively small amounts of nitrogen to soils statewide (less than 1% of added nitrogen). Overall, the majority of nitrogen introduced into surface and ground waters originates from cultivated acres.

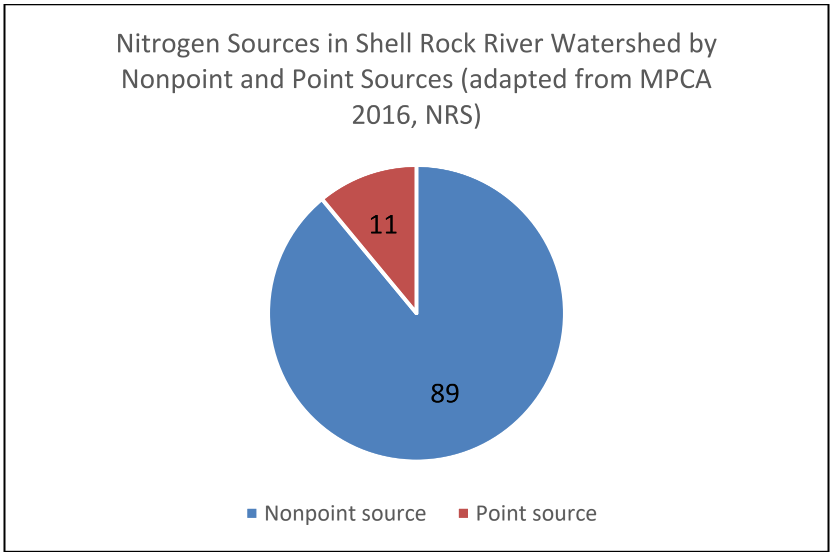


Figure 52. Nitrogen sources in the Shell Rock River Watershed by nonpoint and point sources.

The Minnesota Department of Agriculture (MDA) conducted a survey asking farmers about commercial nitrogen applications on corn and manure use practices (MDA 2017). Responses included information about rates, applications, incorporations, types of manure and other management decisions based on manure use on corn acres. In Freeborn County, 47 participants operating about 15,000 acres responded to the survey. Average commercial nitrogen fertilizer application rate for corn following soybeans was 155 lbs/acre; 167 lbs/acres for corn following corn.

Agricultural tile provides a pathway for the nitrogen to reach streams (Figure 53). In the greater Cedar River Basin (which the SRRW is a part of) 51% of the NO_3-N reaches surface waters through cropland tile drainage. Together with cropland groundwater, these two sources account for about 90% of the nitrogen reaching streams. This emphasizes that nitrogen loading to surface water is not a runoff issue, but rather a leaching issue, as nitrogen is lost vertically “downward” from cultivated acres to tiles and shallow groundwater.

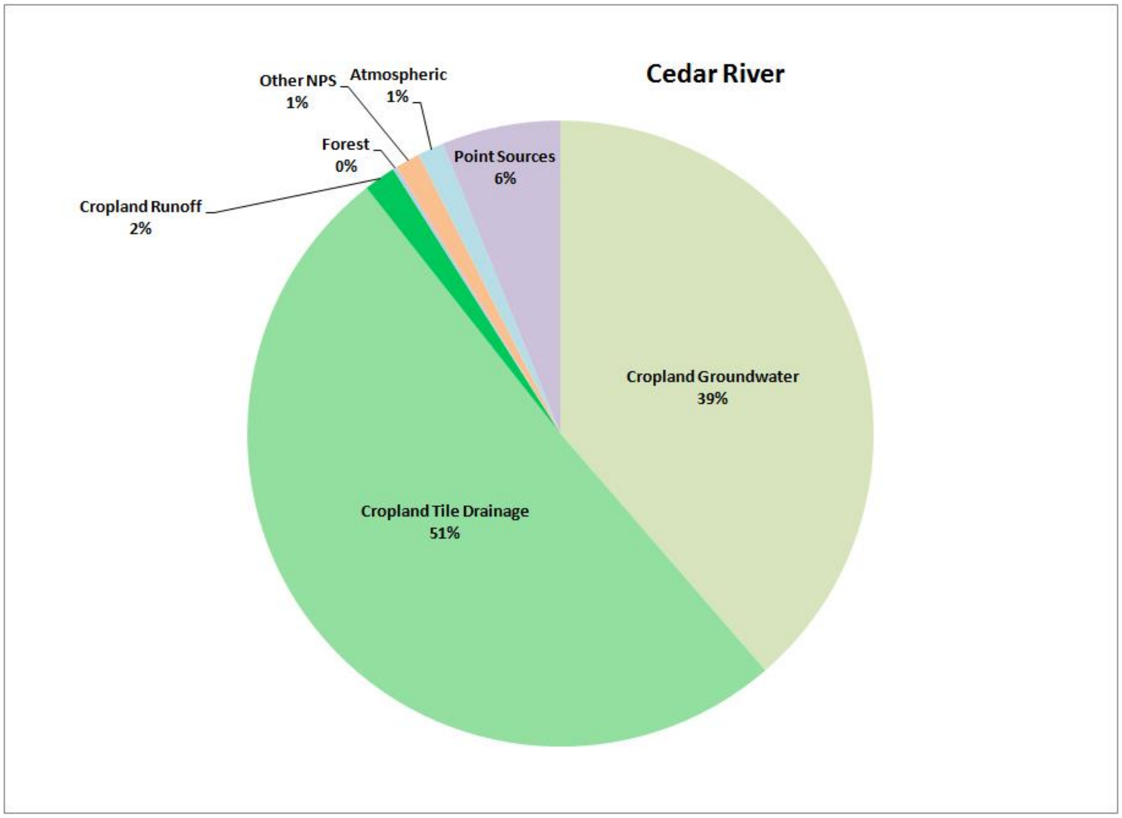


Figure 53. Nitrogen sources in the Cedar River Basin; MPCA 2013.

The State of Minnesota regulates animal manure by using land application rate recommendations and location restrictions though Feedlot Rules (Minn. R. ch. 7020). Rate recommendations for manure follow the University of Minnesota's recommendations for nitrogen. Minn. R. ch. 7020 requires appropriate crediting of all nitrogen inputs when manure is land applied. This includes carry over nitrogen from previous year manure applications and commercial nitrogen fertilizer. Nitrogen crediting from manure application is critical when determining additional nitrogen fertilizer application rates in order to avoid over-application and leaching of nitrogen.

The State of Iowa developed a Cedar River nitrate TMDL in 2006, which calls for a 65% reduction of NO_3-N (IDNR 2006). Iowa's approach was to use the drinking water concentration of 10 mg/L NO_3-N as the target WQS, since cities such as Cedar Rapids use shallow wells that are directly influenced by the river. Iowa's Cedar River nitrate TMDL clearly calls for critical nitrate loading reductions in Minnesota. For the SRRW (in Minnesota), an 18% reduction in nitrogen load (i.e. reduce Minnesota's load from 1,653 tons nitrogen/year to 1,075 tons nitrogen/year) is noted (overall, Minnesota's reduction is noted at 35%, which includes both the Cedar and Shell Rock watersheds). Continued discussion on nitrogen reduction strategies is found in Section 3.4.

Phosphorus in streams

As discussed in Section 2.1, phosphorus in water is present in different forms. The different forms of phosphorus present in the system provide some information about both source and effects. For example, sediment-attached phosphorus is linked to soil erosion. Alternately, a phosphorus load with a high DOP component was likely from either subsurface leaching in fields, or municipal wastewater. The higher the DOP levels, the greater the risk that algal growth will be stimulated in lakes and streams.

Data and information are presented below, and in Table 32 and Figure 54, that focus on the importance of phosphorus from municipal wastewater. Approximately 82% of the TP in treated municipal wastewater effluent is DOP (Barr 2004 – see especially Appendix K). Further analysis of these data showed that the Albert Lea WWTP discharges phosphorus that is 93% bioavailable (i.e. total bioavailable fraction). The consistent discharge (average of 617 lbs/day of TP) of these point source pollutant loads is a foundational cause of the SRR eutrophication issues.

For the nonpoint source load of phosphorus to the SRR (see Figure 54), another important pathway of phosphorus to surface waters is through surface erosion. Molecular bonds adhere phosphorus to sediment and allow movement of phosphorus in stormwater runoff during precipitation events or snowmelt. Phosphorus is commonly applied to cropland as a supplemental fertilizer, in the form of animal manure or commercial fertilizer. Phosphorus from cropland can enter surface waters through two general pathways: surface runoff and subsurface (drain tile) discharge. Historically, surface runoff was considered to be the main pathway for phosphorus movement, with phosphorus moving similarly to sediment. But in the past fifteen years, more attention has been applied to phosphorus transport via subsurface tile and drainage network pathways. This has been comprehensively assessed for some tributary watersheds to Lake Erie (Heidelberg University 2020), and also at selected edge-of-field monitoring sites in Minnesota (Minnesota Discovery Farms 2020). Understanding both surface and subsurface pathways for phosphorus transport in the agricultural land uses of the SRRW will provide a balanced strategy for water quality improvement.

Phosphorus sources are also present in urban settings, with stormwater runoff coming directly into lakes, drainage ditches, and streams. Monitoring urban stormwater runoff, reducing the rate of runoff, and mitigating nutrient loads are all aspects of the City of Albert Lea’s MS4 stormwater management program (see RESPEC 2020).

The two streams/rivers listed as impaired by phosphorus are Shoff Creek (-516) and the Shell Rock River (-501). Each stream reach is discussed separately below. It is noted that both streams underwent a similar phosphorus source assessment, as completed for the TMDL (RESPEC 2020). Overall, measured monitoring data (from stream sites, or point source discharge reports) are used to develop and apply a watershed simulation model (i.e. the monitoring program is coordinated with the model). This common method included using modelled HSPF outputs to help examine likely TP sources.

Shell Rock River Phosphorus Sources:

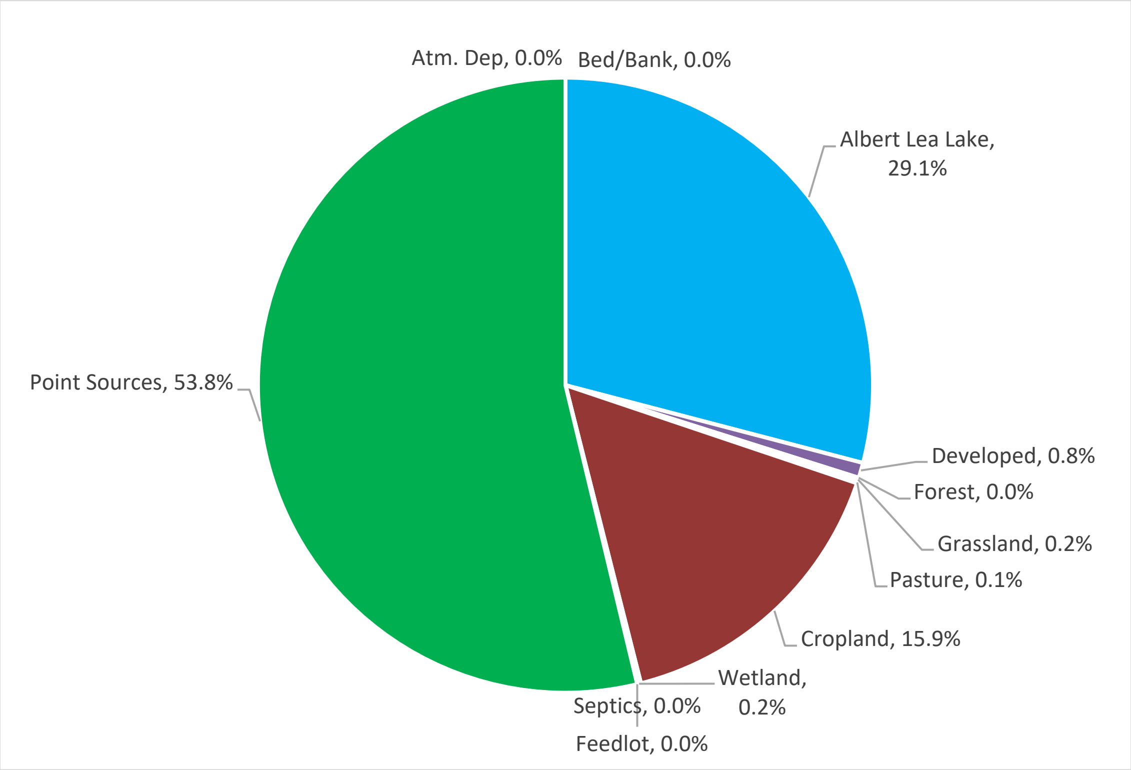


Figure 54. Shell Rock River Watershed Reach 501 annual total phosphorus source summary estimated by HSPF modeling. (RESPEC 2020).

Based on the SRRW HSPF model, the Shell Rock River's (Reach 501) top TP sources are (in order) permitted point sources (53.8%) and the Albert Lea Lake outflow (29.1%). Albert Lea Lake has an "aggregating function," in that the upstream lakes and tributaries eventually flow through it. The TP from cropland within the lower SRRW accounts for just under one-quarter of the total load (15.8%), at Gordonsville. TP from the bed and bank of the stream channel is not a significant source.

The major point source for the Shell Rock River is the City of Albert Lea's WWTP. Average TP concentration for Albert Lea WWTP effluent between 2003 through 2019 was 5.8 mg/L. This translates into an average yearly TP load of 34.2 tons/year discharged to the Shell Rock River. While monitoring for dissolved phosphorus is not an effluent permit requirement for the Albert Lea WWTP, Barr (2004) estimated that for similar mechanical WWTFs, approximately 82% of the TP in treated effluent is OP. This was confirmed in October 2003, when the Albert Lea WWTP was monitored for both TP and OP. Approximately 81% of the TP in effluent was DOP (5.32 mg/L TP and 4.31 mg/L OP). Further calculations were done for the Albert Lea WWTP, as part of the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds Report (Barr 2004). These calculations found that the OP load was available for plant and algal growth ("bioavailable") within 30 days of discharge. When these estimates are extended beyond 30 days, it was estimated that about 93% of the phosphorus in the treated wastewater was defined as being bioavailable. While variable conditions such as stream flow, temperature and sunlight impact the bioavailability of phosphorus in the Shell Rock River, the WWTP provides a significant load of phosphorus that can increase algal growth.

It is noted that bed/bank was estimated as contributing 0% of phosphorus to the Shell Rock River. While stream bed/bank can be a significant net sources of sediment (Figure 49), they are generally not net sources of phosphorus (Figure 54). This is because while there may be some amount of phosphorus introduced into a stream due to stream bank/bed erosion, a much greater amount of phosphorus is lost within the stream channel due to algal uptake. Therefore the stream bed/bank is not a net source of phosphorus. Further discussion of phosphorus sources and their impact on SRRW water quality can be found in Section 2.3.4.

Based on an assessment of only measured water quality and flow monitoring data, Figure 55 shows the mass of TP discharged at the Albert Lea WWTP, and the mass of TP that passes the monitoring station at Gordonsville, Minnesota. The entire reach of the Shell Rock River (-501) is 12.1 miles, with the WWTP discharge at mile 0.9, and the WPLMN monitoring site at mile 11.2. While there are TP losses and gains in the intervening stream miles, using just these statistics shows that the Albert Lea WWTP contributes from about one-third to three-fourths of the TP load, as the water is discharged to Iowa. There is a smaller (< 5%) of TP that is from the Glenville WWTP, discharged at mile 5.2, which is not explicitly included in this figure, but is included in the waste load allocation of the TP TMDL (RESPEC 2020), where additional information is available.

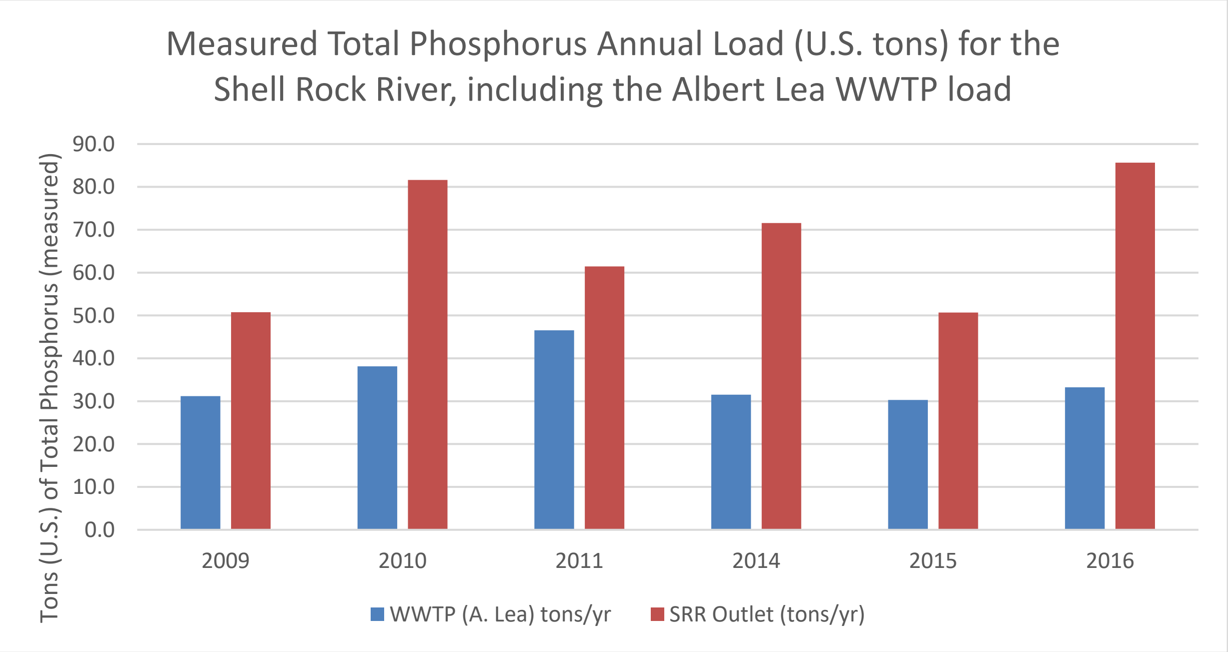


Figure 55. Measured TP Annual load for six years for the Shell Rock River and the Albert Lea WWTP. 2012 and 2013 data excluded due to quality assurance/quality control issues.

Shoff Creek Phosphorus Sources:

In Shoff Creek, the top TP sources that are included in the TP contributions pie chart (Figure 56) are cropland (71%) and the outflow from Pickeral Lake (18%). Because there are some parts of the city of Albert Lea in this subwatershed, a small relative percentage of the TP comes from developed land uses. Because Shoff Creek is the outflow of Pickeral Lake, the TP at the start of this 3.1 mile reach is nearly all derived from the lake. Significant improvements in lake water quality have occurred in Pickeral Lake (see Section 2.1.2) which directly impact the water quality of Shoff Creek. Important work is ongoing in the upper watershed which will continue to improve nonpoint source impacts to Shoff Creek. Like the Shell Rock River, bed/bank contributions to phosphorus in Shoff Creek are estimated as contributing 0%. This means that bed/bank of Shoff Creek are not net sources of phosphorus.

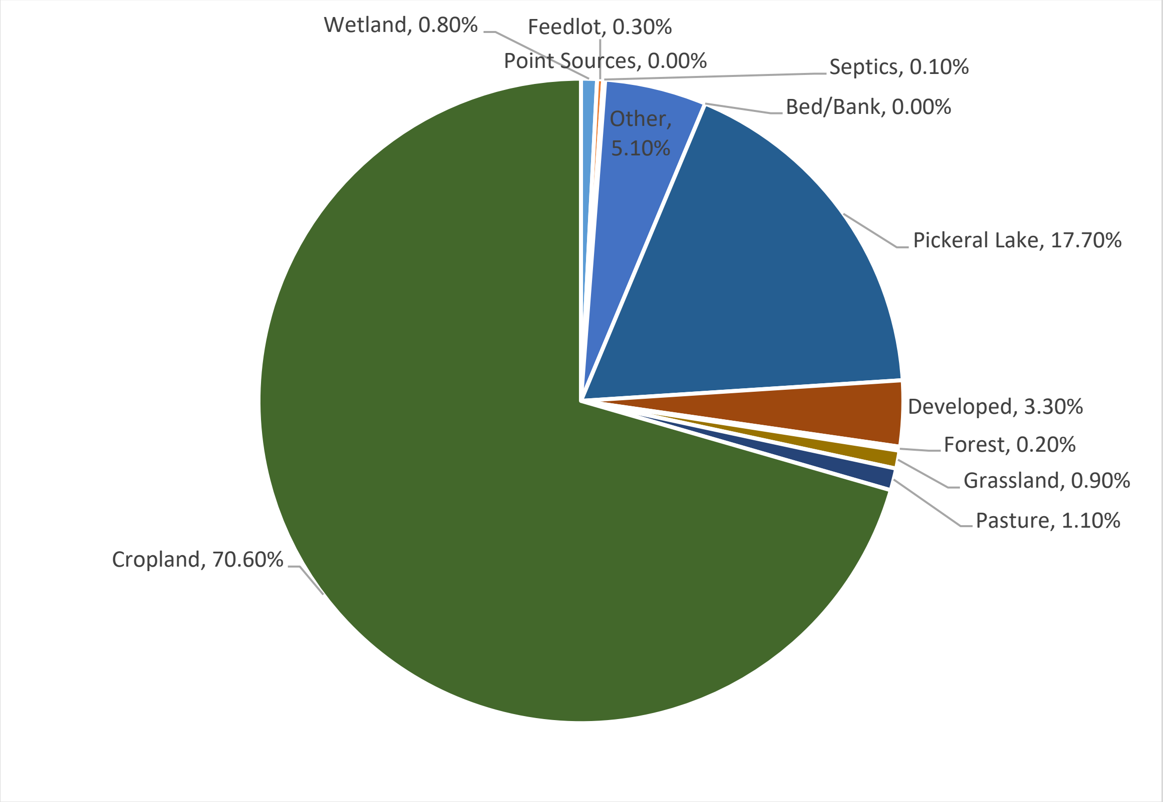
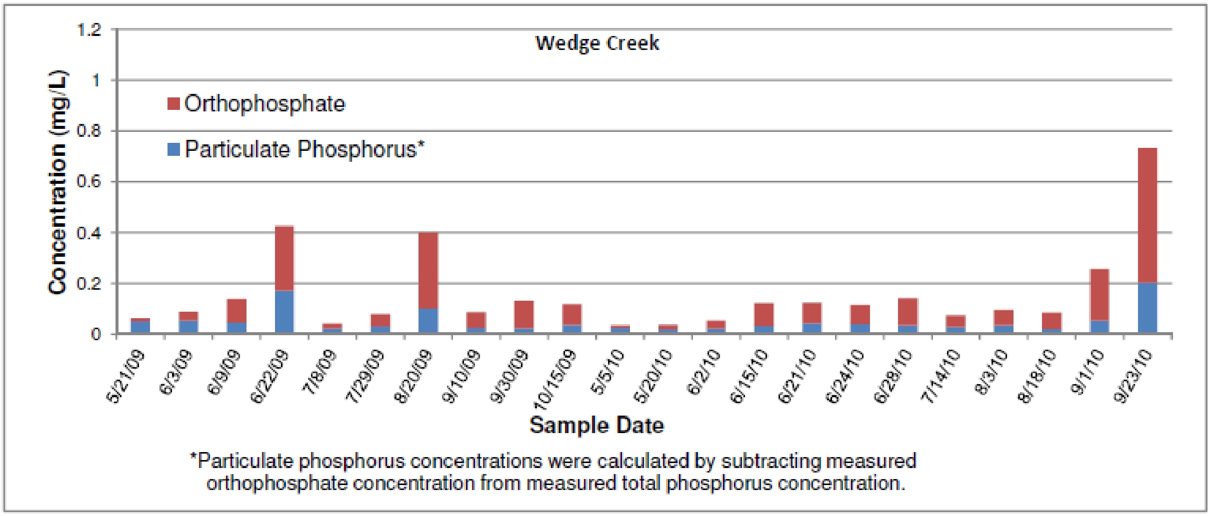


Figure 56. Total phosphorus source-assessment modeling results in impaired Shoff Creek Reach 516. (RESPEC 2020).

As previously mentioned, identifying the form of phosphorus in a waterbody can indicate a future environmental response. In 2009 and 2010 the SRRWD conducted water quality monitoring in the Wedge Creek Subwatershed, including monitoring two forms of phosphorus: TP and OP. This monitoring included three agricultural drainage ditches that are tributaries to Wedge Creek. Data analysis provided in SRRWD 2013 show that DOP is a high proportion of the TP load. The water originating from subsurface drainage systems also contains mostly OP (SRRWD 2013). Concentrations for both phosphorus components, by sampling date are displayed in Figure 57. Identifying OP as the primary form of phosphorus means that algae and aquatic plants can readily take advantage of this nutrient. Wedge Creek flows into Fountain Lake, and elevated OPs can affect severe algae blooms. Similar graphs for Bancroft Creek, Shoff Creek, and Goose Creek are in SRRWD 2013 and can be accessed on the SRRWD's website (www.shellrock.org).



*Particulate phosphorus concentrations were calculated by subtracting measured orthophosphate concentration from measured total phosphorus concentration.

Figure 57. Grab sample phosphorus concentrations for Wedge Creek (SRRWD 2013).

These types of phosphorus factors have been studied in other upper Midwestern regions. Schilling et al (2017) assessed rivers and watersheds in Iowa, specifically for OP and TP concentrations and loads. The annual mean ratios of OP to TP for 12 Iowa rivers were greater than 60% in two tile-drained watersheds of the Des Moines lobe, whereas the ratios were less than 30% in rivers from the southern and western portions of the State. Similar to the SRRW, understanding the dominant form and transport pathways of phosphorus was an important first step in determining the appropriate conservation practices to reduce phosphorus loads.

Whole watershed Phosphorus Balance for the Albert Lea Region:

The SRRWD and the University of Minnesota (Department of Bioproducts and Biosystems Engineering, BBE) coordinated on an informative project called, “The Whole Watershed Phosphorus Balance,” resulting in the publication of a SRRW case study, “Agricultural Phosphorus Balance Calculator: A tool for watershed planning.” (Peterson et al 2017). This unique project developed a comprehensive phosphorus balance, using both measured and estimated phosphorus input and phosphorus export data, for the entire upper portion of the SRRW. The objectives of this project included determining the phosphorus-use efficiency of crop and livestock sectors, and to prioritize nonpoint source reduction efforts, at the watershed scale. The SRRW was a good watershed for such as “case study,” with a robust dataset for water quality monitoring, and cooperative partners and landowners. The project was supported by the SRRWD, Freeborn County, the MDA, and the UMN-BBE, with CWA Section 319 program grant support from the MPCA.

Previously developed methods by Schussler et al. (2007) for whole-system phosphorus balances for lake watersheds in northcentral Minnesota were also used for the Shell Rock Watershed.

Several key items to consider with this comprehensive project are that 2010 was the year selected for the phosphorus balance analysis timeframe. However, data from 2009 and 2011 were also used in parts of this effort. The timeframes are important, as this relates to both the use of water data, and the 2010 cropland data layer. A significant effort was placed on interviewing farmers about their phosphorusmanagement. This included 88 on-farm interviews by the MDA staff, and an additional 20 interviews with feedlot permittees to better understand any differences between permitted livestock numbers and actual onsite livestock numbers in 2010.

While the results of this project are extensive, five key conclusions can assist in future watershed management efforts are:

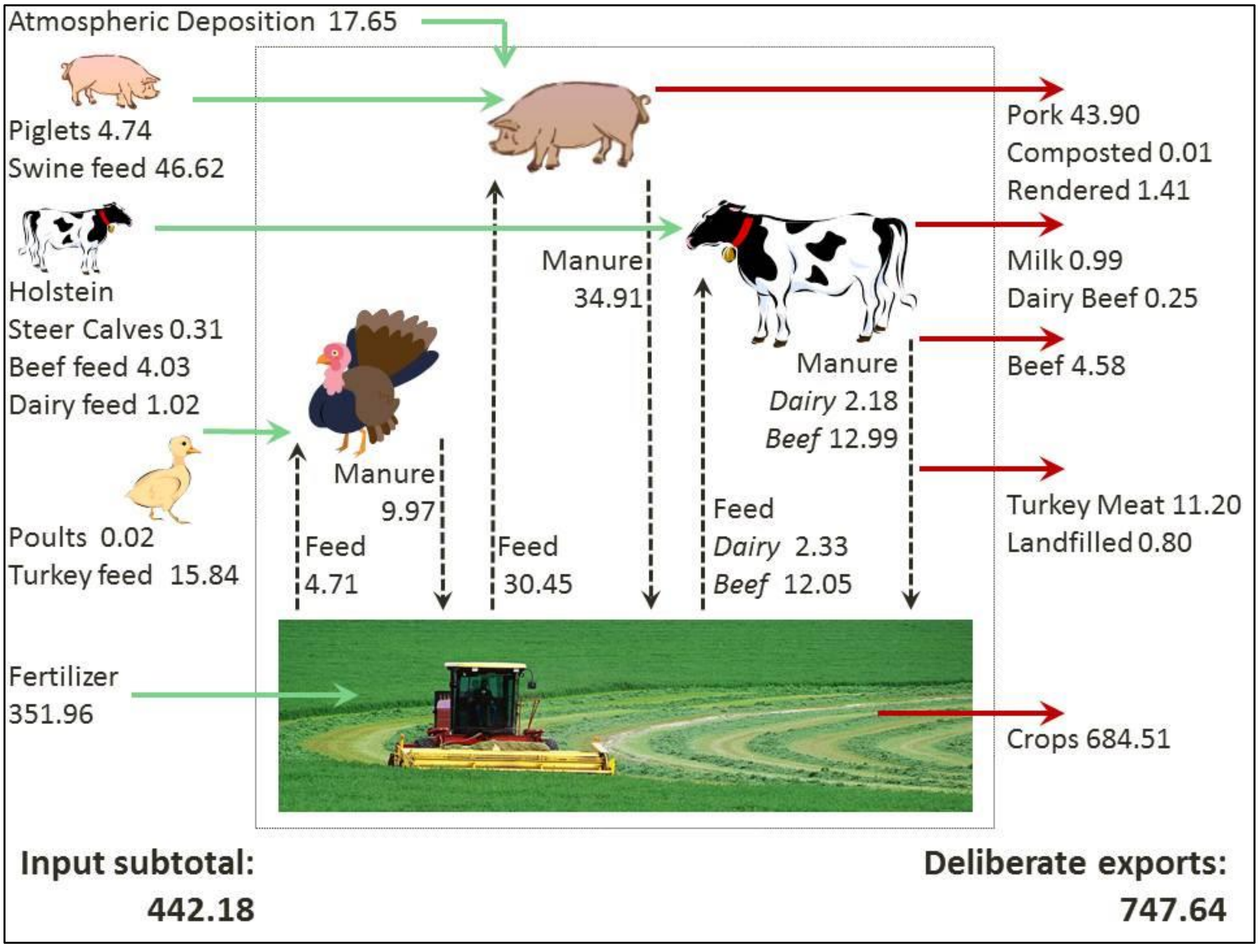
1. **Four of the six lake tributaries had an orthophosphorus (dissolved reactive P) to TP ratio of at least 0.61.** This means that for these three years, the DOP load, which is not attached to sediments such as silts and clays, accounts for more than one-half of the total pollutant load for phosphorus, to the affected downstream waters. Dissolved phosphorus is more readily available for uptake by algae. Table 24 includes these ratios, and the coefficient of variation (CV), a statistic that addresses the variation in loads among the three years. The CV is the standard deviation divided by the mean (a higher CV statistic means a higher degree of variation). The 2010 year had a higher total precipitation amount than the other two years, and phosphorus loads for both Bancroft Creek and Wedge Creek were subsequently higher in 2010. Peter Lund Creek did not show the same "pattern" in loading values (when contrasted to Bancroft Creek and Wedge Creek) for these years, with more consistent loading values for all three years (thus the lower CV statistics for Peter Lund Creek).

Table 24. Orthophosphorus: Total Phosphorus ratios for six tributaries in the SRRW, 2009-2011; Ulrich 2014.

Tributary	Orthophosphorus : Total Phosphorus Ratio*	Coefficients of Variation (for loads, kg/yr)	
		TP	OP
Bancroft Creek	0.74	0.56	0.25
Wedge Creek	0.61	0.56	0.28
Peter Lund Creek	0.64	0.17	.14
Shoff Creek	0.36	0.25	0.27
North East Tributary	0.67	0.43	0.43
Goose Creek	0.35	0.44	0.37

*As a ratio, this has no units.

2. **At the whole watershed scale, there was a P-use efficiency of 1.7.** This means that more phosphorus is being deliberately exported (as crops, animal products, etc) than is being deliberately imported as fertilizer, feed and animals. See Figure 58 for the illustration of this P-use efficiency. A P-use efficiency of 1.0 would mean that deliberate imports and exports were the same, and thus balanced.



Units in 1,000 kg/yr.

Figure 58. Summary phosphorus balance for the agricultural watersheds; Baker etal 2014a.

3. Because the research team suggests that this level of phosphorus-use efficiency could mean a “draw-down” of phosphorus in cropland soils, **ongoing soil testing for phosphorus (soil test phosphorus) is strongly suggested at the field and farm scales.**

4. **Understanding nutrient cycling in the watershed is critical for meeting load reduction goals.** Using a phosphorus-balance approach and dealing with “…nutrient impairment through source reduction is an economical and long-term best management approach.” (Peterson etal. 2017).

5. **In assessing stream phosphorus export, the research team suggested that there could be a “legacy effect” occurring.** They suggested that areas in the watershed that have accumulated phosphorus (and especially forms that are more readily available phosphorus), could contribute phosphorus through erosion or desorption processes. A second suggestion regarding higher stream phosphorus export was that at smaller scales, there is a highly disproportionate geographic distribution of areas where phosphorus inputs are rather high, compared to phosphorus exports (i.e. animals, crops). Given an available pathway for phosphorus transport, this could result in more substantial mobilization of phosphorus, to downstream waters. Suggestions were also made for additional future research in this area.

Phosphorus from animal manure

The application of animal manure onto crop fields in the watershed represents a potential source of phosphorus to surface waters. The MPCA staff developed estimates of the manure type, quantity, nutrient value, and if the manure was directly incorporated into the soils after application. These data are provided for Wedge Creek (Table 25) and Bancroft Creek (Table 26), but do not include an application rate to the land. Manure production from swine operations is located mostly in the Wedge Creek Subwatershed, and manures are applied with incorporation. Solid manure originating from beef, sheep, or turkey operations are broadcast onto crop fields, and generally delayed incorporated or not incorporated.

Table 25. Wedge Creek Subwatershed estimated manure production and estimated phosphorus nutrient value.

Manure Type	Annual Manure Production	P_20_5 Nutrient Value (lbs)	Incorporated
Liquid	**7.5 million gallons**	**170,378**	**Yes**
Solid	**11,790 Tons**	**96,879**	**No**

Table 26. Bancroft Creek Subwatershed estimated manure production and estimated phosphorus nutrient value.

Manure Type	Annual Manure Production	P_20_5 Nutrient Value (lbs)	Incorporated
Liquid	**283,500 gallons**	**5,387**	**Yes**
Solid	**2,024 Tons**	**93,665**	**No**

Animal feedlot sites themselves can also be a source of phosphorus to surface waters. The number of open lots with polluted runoff issues have been reduced over the last several decades, with various implementation efforts at the local, regional and state scales. The feedlot number in the Wedge Creek Subwatershed is 24, with about one-third as open lots. Two operations in Wedge Creek are CAFOs. Bancroft Creek has 8 feedlots, with 2 open lots. The Peter Lund Creek Subwatershed has 14 feedlots, with 6 open lots, while subwatersheds along the lower Shell Rock River include 13 feedlots. The Pickeral Lake Subwatershed has 2 feedlots.

Using a broader source of information, Barr (2003) assessed annual phosphorus generated from noncompliant feedlots, and estimated that about 30% of the open feedlots contributed about 2% of the annual phosphorus loading for the Lower Mississippi Basin (which includes the SRRW). The average annual runoff used in this estimation method was 9.8”. There are additional data and information on feedlots contained in report Section 2.3.4.1, as a nonpoint source.

Phosphorus in lakes

The five impaired lakes within the SRRW have excess phosphorus concentrations. The following graphs, produced by utilizing HSPF and BATHTUB modeled outputs, identify nonpoint sources as the most likely contributor of phosphorus to watershed lakes (RESPEC 2020). Refer to the SRRW TMDL (RESPEC 2020) Section 4.3.1 for more information on lake model methodology. Across all impaired lakes, nonpoint sources are estimated to contribute at least 50% of phosphorus loads.

The phosphorus contributions for Pickeral Lake (Figure 59) have been reduced, following the 2009 fish reclamation project, and the removal of carp reduced the internal phosphorus load. The dynamics associated with the Pickeral Lake fish reclamation have not been entirely captured in the modeling methods applied thus far.

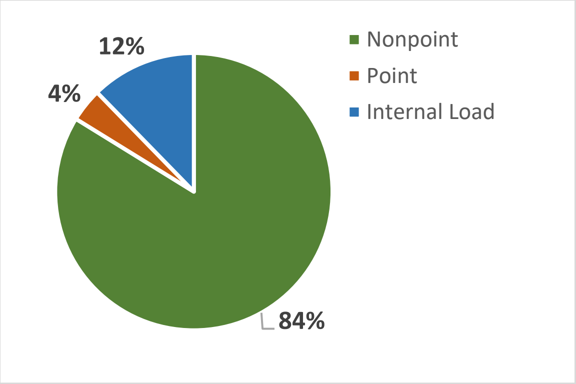


Figure 59. Modeled existing total phosphorus load sources for Pickeral Lake.

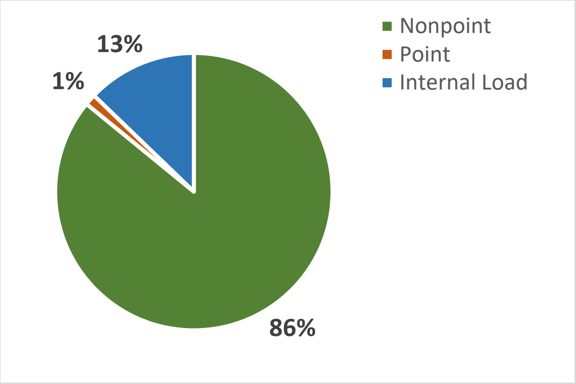


Figure 60. Modeled existing total phosphorus load sources for Albert Lea Lake.

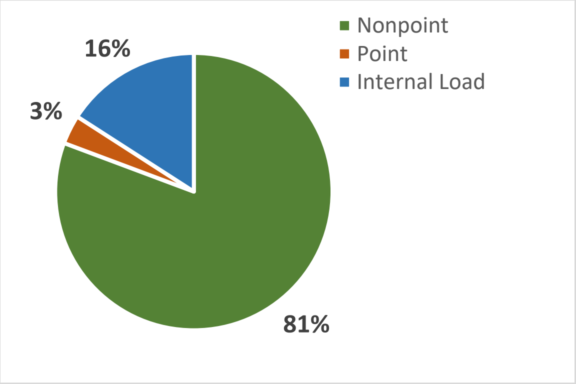


Figure 61. Modeled existing total phosphorus load sources for Fountain Lake (East).

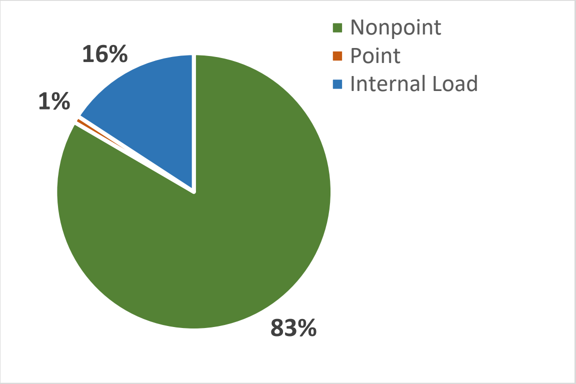


Figure 62. Modeled existing total phosphorus load sources for Fountain Lake (West).

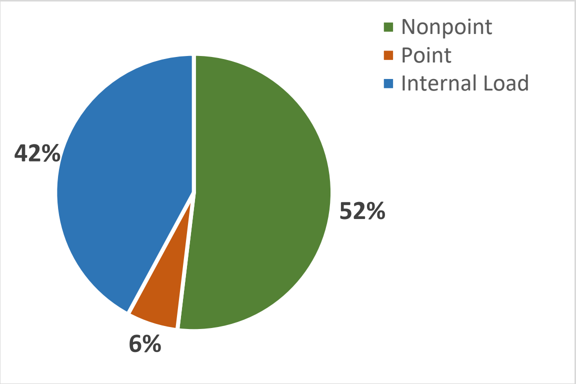


Figure 63. Modeled existing total phosphorus load sources for White Lake.

Internal Phosphorus Loading:

Since the limiting nutrient in most lakes is phosphorus, the issue of phosphorus loading and lake water quality is very pertinent. Phosphorus loads (mass or quantity) come from permitted point sources, watershed runoff (including MS4 runoff), atmospheric deposition, and from internal (within the lake itself) sources. In shallow lakes such as those in the SRRW, the measurement and prediction of internal phosphorus load is difficult, and involves many factors, including the lake basin shape, lake depth, fish and aquatic plants, DO conditions in the lake water, and sediment chemistry. While direct measurements are very important for this work, lake water quality models are also used to help address uncertainties and make predictions of future conditions. See Section 3.4, Table 42, for recommended strategies addressing internal phosphorus loading.

A technical review of this subject was completed by Nurnberg (2009). In another standard reference on this topic, Wetzel (1975) notes that the phosphorus content in the sediment can be much greater than the phosphorus in the overlying waters, and that there is little correlation between the two. The most important factors are the ability of the sediments to retain phosphorus, the condition of the overlying water, and the biota that alter the exchange equilibria and effect phosphorus transport back to the water.

In Minnesota, several important recent efforts have helped address this topic. First, an interagency team of scientists will finalize a report in 2020 titled “Minnesota State Government Review of Internal Phosphorus Load Control.” The objective of this effort is to provide practitioners a reference for investigating different methods of reducing internal phosphorus loads, and to overview the most common practices in Minnesota (Minnesota State Government 2020).

Secondly, a study in Southern Minnesota was completed by the St. Croix Watershed Research Station/Science Museum of Minnesota (2019) for lakes in the Cannon River Watershed. This project collected sediment cores from 16 nutrient-impaired lakes, developed phosphorus budgets for all lakes, as well as historical lake reconstructions for four lakes. This study also utilized reported TMDL load reductions, to assess the recoverability of the lakes. In one scenario involving a reduction in external loads, they suggested that a depletion of phosphorus "stores" in the surface sediments would ultimately result in a reduction of internal phosphorus loading. This study also considered that with only small external load reductions, the "legacy" phosphorus in the sediments might overwhelm the watershed restoration efforts for many years. These researchers also reinforced what many lake scientists have confirmed for southern Minnesota lakes: understanding this "unaccounted for" phosphorus load is very challenging. They further cautioned that adjusting the models upward to match observed lake water quality values, based on only internal loading, maybe underestimating the quantity and effects of the external load.

For direct internal loading efforts in the SRRW, a study in 2009 by Barr Engineering collected and analyzed sediment cores (for phosphorus fractions, iron, etc.) from numerous locations in Albert Lea, Fountain, Pickeral and White lakes. Using a relationship between mobile phosphorus in the sediments and the sediment phosphorus release rates (Barr 2009), estimates were made of the sediment release rates, and model calibration factors were checked. For Albert Lea Lake, these data suggest higher internal loading rates in the eastern and western portions of the basin, compared to the central basin of the lake (Barr 2009). These data and estimates, as well as more detailed work during the development of the Fountain Lake dredging project, have been utilized by local and regional lake managers. For more information about the Fountain Lake Dredging project, contact SRRWD staff or website (www.shellrock.org).

The companion TMDL report estimates the internal load for each impaired lake in the SRRW, with values provided in each lake's phosphorus allocation table.

Table 27. Lake internal load allocations for Shell Rock River Watershed TMDL (RESPEC 2020).

Lake	Internal Load (lb/yr)	% of daily load
Pickeral	**435**	**12.3**
White	**385**	**42.1**
Fountain West	**3,331**	**15.8**
Fountain East	**8,529**	**15.9**
Albert Lea	**10,605**	**12.8**

These estimates are derived using both monitoring data (measured stream flow and phosphorus concentrations, and calculated phosphorus loads), and modeling methods (BATHTUB lake model), for a 2009 through 2018 timeframe. With the exception of White Lake, internal phosphorus modeled outputs makes up less than 20% of phosphorus loads. Further details and methods regarding internal loading calculations and procedures are contained in Section 4.8.2 of the TMDL Report (RESPEC 2020). While internal loading will always be an important component in the lake water quality assessments and management, this analysis supports that primary strategies should focus on comprehensive external phosphorus load reductions from the watershed.

Internal load management practices may include alum addition (in-lake treatments), fish management, aquatic vegetation management, lake level management, and watercraft restrictions. Fish management in the SRRW has been a very significant management effort for many years. Numerous sophisticated fish barriers are in place and maintained by the SRRWD to limit rough fish migrations. An overall strategy for carp management for Albert Lea and Fountain Lakes is referenced the SRRWD's Watershed Management Plan (SRRWD 2015). In 2009 a fish reclamation project was implemented on Pickeral Lake, and results have been reported by the SRRWD. The SRRWD is continuing a lake dredging management and implementation project on Fountain Lake; with 250,000 cubic yards of material removed in 2018. Dredging plan progress for 2019 and 2020 will be reported on the SRRWD's website.

Moving forward for the next 20 to 30 years, lake improvements in the SRRW will mean ongoing coordination of both lake managers and technicians, with landowners and watershed managers in the upper watershed areas. This basic strategy of sequencing pollutant load reduction efforts, with in-lake and downstream management actions can provide a cost effective, complementary, and sustainable framework.

E. coli

Fecal coliform and *E. coli* are two bacterial indicator parameters used to determine the presence of disease-producing organisms (pathogens). Bacteria mainly come from sources such as failing septic systems, wastewater treatment plant (WWTP) releases, livestock, and urban stormwater (MPCA 2021). Waste from pets and wildlife is another source, but typically very minimal. *E. coli* is a subgroup of fecal coliform and is almost always present with fecal coliform. Currently, the State of Minnesota has two standards for *E. coli*: a monthly average standard (geomean) and a maximum concentration standard. The concentration of fecal coliform and *E. coli* have a complex relationship with land use and precipitation but can be linked to certain factors (Table 28).

Table 28. Factors associated with bacterial presence (MPCA 2015).

Strong relationship to fecal bacterial contamination in water	**Weak** relationship to fecal bacterial contamination in water
• High storm flow (the single most important factor in multiple studies) • % rural or agricultural areas greater than % forested areas in the landscape (entire watershed area) • % urban areas greater than % forested riparian areas in the landscape • High water temperature • Higher % impervious surfaces • Livestock present • Suspended solids	• High nutrients • Loss of riparian wetlands • Shallow depth (bacteria decrease with depth) • Amount of sunlight (increased UV-A deactivates bacteria) • Sediment type (higher organic matter, clay content and moisture; finer-grained) • Soil characteristics (higher temperature, nutrients, organic matter content, humidity, moisture and biota; lower pH) • Stream ditching (present or when increased) • Epilithic periphyton (plants and microbes that grow on stones in a stream) present • Presence of waterfowl or other wildlife • Conductivity

The following text, which provides an overview of nonpoint sources of fecal coliform and *E. coli* bacteria and associated pathogens, is excerpted and adapted with new information from the Revised Regional TMDL Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota (MPCA 2006). At the time the 2006 MPCA study was conducted, Minnesota's WQS was based on fecal coliform as indicators of fecal pathogens; the standard has since changed and is now based on *E. coli* counts.

> *"The relationship between land use and fecal coliform concentrations found in streams is complex, involving both pollutant transport and rate of survival in different types of aquatic environments. Intensive sampling at numerous sites in southeastern Minnesota shows strong positive correlations among stream flow, precipitation, and fecal coliform bacteria concentrations. In the Vermillion River Watershed, storm-event samples often showed concentrations in the thousands of organisms per 100 mL, far above nonstorm-event samples. A study of the Straight River Watershed divided sources into continuous (failing subsurface sewage treatment systems, unsewered communities, industrial and institutional sources, WWTFs) and weather-driven (feedlot runoff, manured fields, urban stormwater) categories. The study hypothesized that when precipitation and stream flows are high, the influence of continuous sources is overshadowed by weather-driven sources, which generate extremely high fecal coliform concentrations. However, the study indicated that during drought, continuous sources can generate high concentrations of fecal coliform. Besides precipitation and flow, factors such as temperature, livestock management practices, wildlife activity, fecal deposit storage, and channel and bank storage also affect fecal bacterial concentrations in runoff,"* (Baxter-Potter and Gilliland 1988).

In the rural portions of the watershed, there are deer, waterfowl, and other animals, with greater numbers in conservation and remnant natural areas, wetlands and lakes, and river and stream corridors that may be contributing to *E. coli* impairments. Urbanized areas of the watersheds can have higher densities of pets and a higher delivery of pet waste to surface waters due to connected impervious surfaces. Wildlife and pet *E. coli* contributions were estimated for the SRRWD as part of the *E. coli* TMDL report. When compared to human and livestock populations, it appears unlikely that the production of *E. coli* from wildlife and pets substantially contributes to *E. coli* impairments.

Research in the last 15 years has found the persistence of *E. coli* in soil, beach sand, sediments, and algal mats throughout the year in the north-central United States without the continuous presence of sewage or mammalian sources. An Alaskan study [Adhikari et al. 2007] found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions. An MPCA study of cold-water streams in southeastern Minnesota discovered the resuspension of *E. coli* in the stream-water column due to stream sediment disturbance [MPCA 2019a]. A recent 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. Fecal coliform survival and growth have been documented in storm sewer sediment in Michigan [Marino and Gannon 1991].

Despite the complexity of the relationship between sources and in-stream concentrations of fecal coliform, SSTS, animal feedlots, and land applied manure are likely source categories in the SRRW. Discussion of these sources is continued in subsequent Section 2.3.4.1.

Temperature

Stream temperature naturally varies due to air temperature, precipitation, geology, shading, and the inputs from tributaries and springs. Riparian land cover alteration and increasing channel width are both occurring in the Shell Rock River, contributing to higher water temperatures. Increased temperatures can influence predator-prey dynamics, but this is hard to quantify. Warmer lake waters due to climate change can alter oxygen regimes, redox potential, lake stratification, mixing rates, and the metabolism of plant and animal species (Kundzewicz etal. 2007). Temperature has been found to be an indirect stressor to biology in the Shell Rock River; a consequence of low summer precipitation and low summer outflows from Albert Lea Lake.

Specific conductance

Specific conductivity was also found to be an indirect stressor to biology in the SRRW. Specific conductance refers to the collective amount of ions in the water. In general, the higher the level of dissolved minerals in a volume of water, the more electrical current (or conductance) can be transmitted through that water. The presence of dissolved salts and minerals in surface waters does occur naturally, and biota are adapted to a natural range of ionic strengths. However, industry runoff and discharges, road salt, urban stormwater drainage, agricultural drainage, WWTP effluent, and other point sources can increase ions in downstream waters. Biological effects of specific conductivity are difficult to quantify. Increased ionic strength can cause an increase in ion tolerant taxa, causing fish and invert impairments, but it is difficult to separate this effect from other stressors (MPCA 2014a). Generally, as salinity increases, macroinvertebrate taxa richness has been found to decrease. A study of Minnesota biological data and stressor linkages found that sites with conductivities higher than 1,000 µS/cm rarely meet the biological thresholds for general use streams (MBI 2012).

2.3.3. Nonpollutants and sources – Altered Hydrology/Flow Alteration and Habitat

Flow alteration is the change of a stream's flow volume and/or flow pattern (low flows, intermittent flows, increased surface runoff, and highly variable flows) typically caused by human activities. These activities can include physically altering watercourses, water withdrawals, land cover alteration and urban stormwater runoff. Section 1.1.6 provided some of the background information about altered watercourses in the SRRW. About 182 miles, or 70% of the water courses are altered, which often means that a channelization activity has taken place.

Altered hydrology is a change in the water conveyance (including flow) and/or water storage characteristics of the water cycle caused by shifts in climate and land use practices. With any discussion of altered hydrology, there must be information about the time scale or time period used as a reference, as well as the spatial scales that are being considered. Changes caused by climate shifts as well as changes affected by humans are both to be considered, as the two are closely entwined.

An outline (Figure 64) summarizes the components of altered hydrology. The changes in evaporation (from the land surface) and transpiration (by plants), a hybrid phrase called "evapotranspiration," is a key water conveyance aspect of altered hydrology.

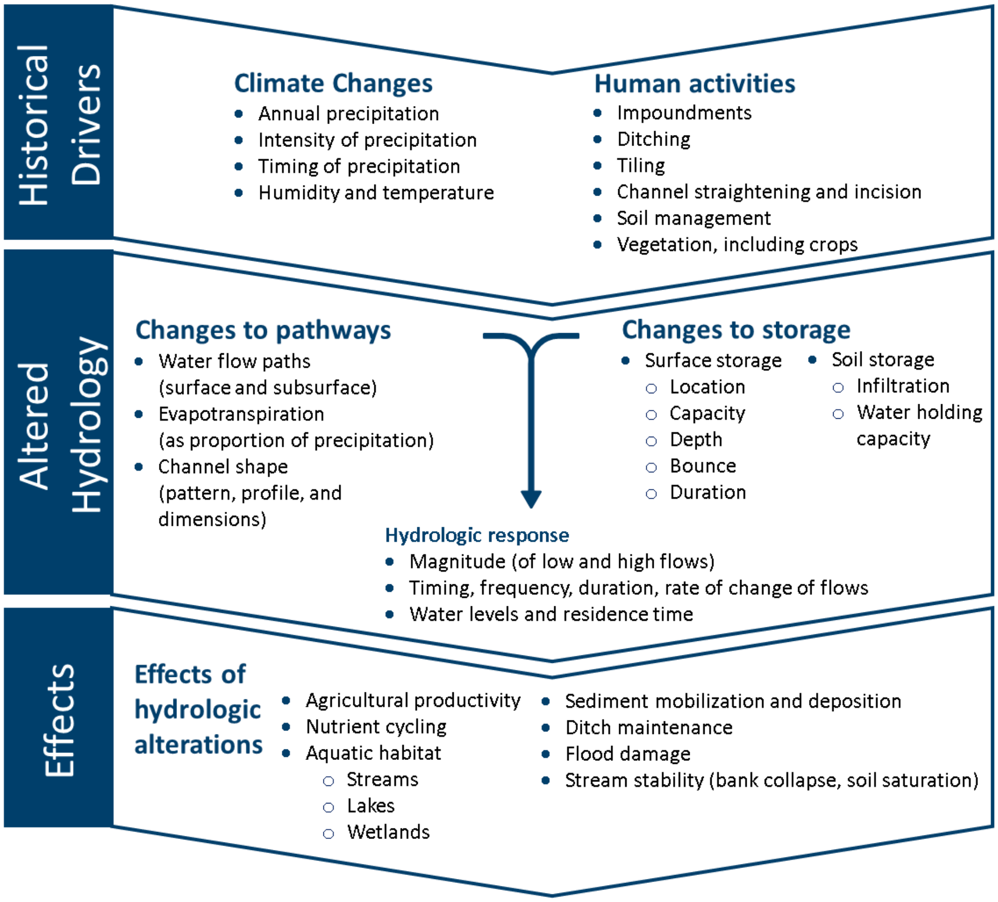


Figure 64. The relationship between altered hydrology and its causes and impacts (Minnesota Drainage Management Team 2020).

A study of southern Minnesota watersheds (Schottler et al. 2013) found human-caused changes, including agricultural drainage and crop changes, as the primary cause of increased flows. This study also estimated that in agriculturally-dominated watersheds, such as the SRRW, more than 50% of the increase in flow between the mid and late 20th century was caused by changes in agricultural drainage. While the SRRW is not part of this study, several neighboring watersheds were included, which have some of the same conditions that exist in the SRRW.

A concept that captures several important conditions involved with the water cycle and human use of the land is runoff ratio. It is the amount of runoff, per unit of precipitation. Over a longer timeframe, if the amount of runoff, per inch of rain, has increased – then it would point toward other factors influencing the runoff amounts. It is clear that having long term data sets for weather, climate, land use and water is required to assess runoff ratios. Standardizing stream runoff data using precipitation allows for a more appropriate understanding of trends for the watershed. In the SRRW, Baker etal (2014b) found that Wedge Creek and Bancroft Creek had higher runoff ratios than Peter Lund Creek (0.39, 0.37, and 0.29 respectively). These data are useful to understand pollutant transport, and in prioritizing implementation.

2.3.4. Summary of nonpoint and point sources

Section 2.3.4.1 covers the primary nonpoint pollution sources in the SRRW. Nonpoint sources include animal feeding operations (AFOs), subsurface sewage treatment, and general land use sources. A similar summary of point sources follows in Section 2.3.4.2, including a table of municipal, industrial and stormwater dischargers.

2.3.4.1. Nonpoint sources

As mentioned in previous sections, nonpoint sources make significant contributions to the impairments of surface waters in the SRRW. Table 29 provides a three-tier ranking of the relative magnitude of nonpoint sources. These rankings were based on the MPCA staff professional judgement and vetted by local partners through review and discussion. Emphasis has been placed on the primary prevention of NPS pollution, with priority for upper watershed work that will have multiple benefits downstream. Further information on this approach is provided in Section 3.

Table 29: Nonpoint sources in the Shell Rock River Watershed. Relative magnitudes of contributing sources are indicated.

Stream/Reach or Lake Name	Pollutant	Fertilizer & manure run-off	Nutrient movement to subsurface	Failing septic systems	Wildlife/Pets	Bacterial loss to subsurface	Upland soil erosion	In-channel sediments	Internal remobilization *	Naturalized populations	Lake Algae as TSS
Bancroft Creek	Bacteria	●		⭘	○	⭘	●			⭘	
Wedge Creek	Bacteria	●		⭘	○	⭘	●			⭘	
White, Fountain, and Pickeral Lakes	TSS						●	⭘			
	TP	⭘	●						⭘		
	Bacteria	●		⭘	○	⭘	●			⭘	
Shoff Creek	TP	⭘							⭘		
	TSS						●	⭘			●
Shell Rock River	N	●	●								
	TP	⭘	⭘						⭘		
	TSS						●	⭘			●
	Bacteria	●		⭘	○	⭘	●			⭘	
Albert Lea Lake	TP	⭘	●						⭘		

Key: ● = High ⭘ = Moderate ○ = Low

*Internal mobilization includes phosphorus release from anoxic sediments, as well as from physical and biotic factors in lakes, drainage ditches, and/or streams. Example conditions involving internal mobilization are wind and carp effects on a lake, low DO in over-lying waters, and senescence of aquatic plants.

Animal feeding operations and manure application

AFOs are potential sources of fecal bacteria to streams in the SRRW, particularly when direct animal access is not restricted or where noncompliant discharges from AFOs reach surface waters.

Concentrated animal feeding operations (CAFOs) are 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 National Pollutant Discharge Elimination System (NPDES) Permit or a state issued State Disposal System (SDS) Permit: a) all federally defined CAFOs that have had a discharge, some of which are under 1,000 AUs in size; and b) all CAFOs and nonCAFOs that have 1,000 or more AUs.

CAFOs and AFOs operating under a NPDES or SDS permit must be designed to contain all manure and manure contaminated runoff from precipitation events of less than 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 (approximately 5.3” in 24 hours) and the discharge does not contribute to a water quality impairment. Large CAFOs permitted with an SDS permit or those not covered by a permit must contain 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.

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 with an appropriate mix of field inspections, offsite monitoring and compliance assistance. Facilities that are permit compliant are not considered to be a substantial pollutant source to surface waters. In the past three years, MPCA feedlot inspections have prioritized facilities located in impaired watersheds.

AFOs under 1,000 AUs and those that are not federally defined as CAFOs do not operate under a NPDES permit. However, the facilities must operate in compliance with applicable portions of Minn. R. 7020. Animal waste from nonNPDES feedlots can be delivered to surface waters from facility components (open lots) or from fields with land applied manure. 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 (Ginting etal. 1998a; Ginting etal. 1998b; MPCA 2018).

Of the 218 registered feedlots in the SRRW (as of 2/18/20), most (53%) are beef operations followed by swine facilities (23%). Fifteen percent of the feedlots are “Other,” raising turkey, horse, goat, sheep, bison, or elk. Eight percent of the registered feedlots are dairies. Almost no feedlots are located in shoreland; only one feedlot is documented as being within 1,000 feet of a surface water. Approximately 57% of feedlots in the SRRW utilize pastures in their operations; mostly used by beef livestock. Open lots are a component of 76% of registered feedlots. Three swine CAFOs are located in SRRW; all within the Wedge Creek Subwatershed. Of all registered animal numbers, swine make about 61% of the livestock population (Table 30).

Table 30. Animal units and animal count of registered feedlots in SRRW.

Primary Stock	AU	Animals
Beef Cattle - Calf	0	0
Beef Cattle - Feeder/heifer	1351	1,930
Beef Cattle - Cow and calf pair	915.6	763
Beef Cattle - Slaughter/Stock	2,751	2,751
Total Beef Cattle	**5,017.6**	**5,444**
Dairy Cattle - Calf	79	395
Dairy Cattle - Heifer	33.6	48
Dairy Cattle <1000 lb	0	0
Dairy Cattle >1000 lb	2,175.6	1,554
Total Dairy Cattle	**2,288.2**	**1,997**
Swine < 55 lbs	545	10,900
Swine 55-300 lbs	12,765.9	42,553
Swine > 300 lbs	78	195
Total Swine	**13,388.9**	**53,648**
Total Sheep, lambs or goats	**140.2**	**1,402**
Total Horses	**239**	**239**
Bison	**15.5**	**115**
Turkey (over 5 lbs)	**934.9**	**51,940**
Total	**22,024.3**	**114,785**

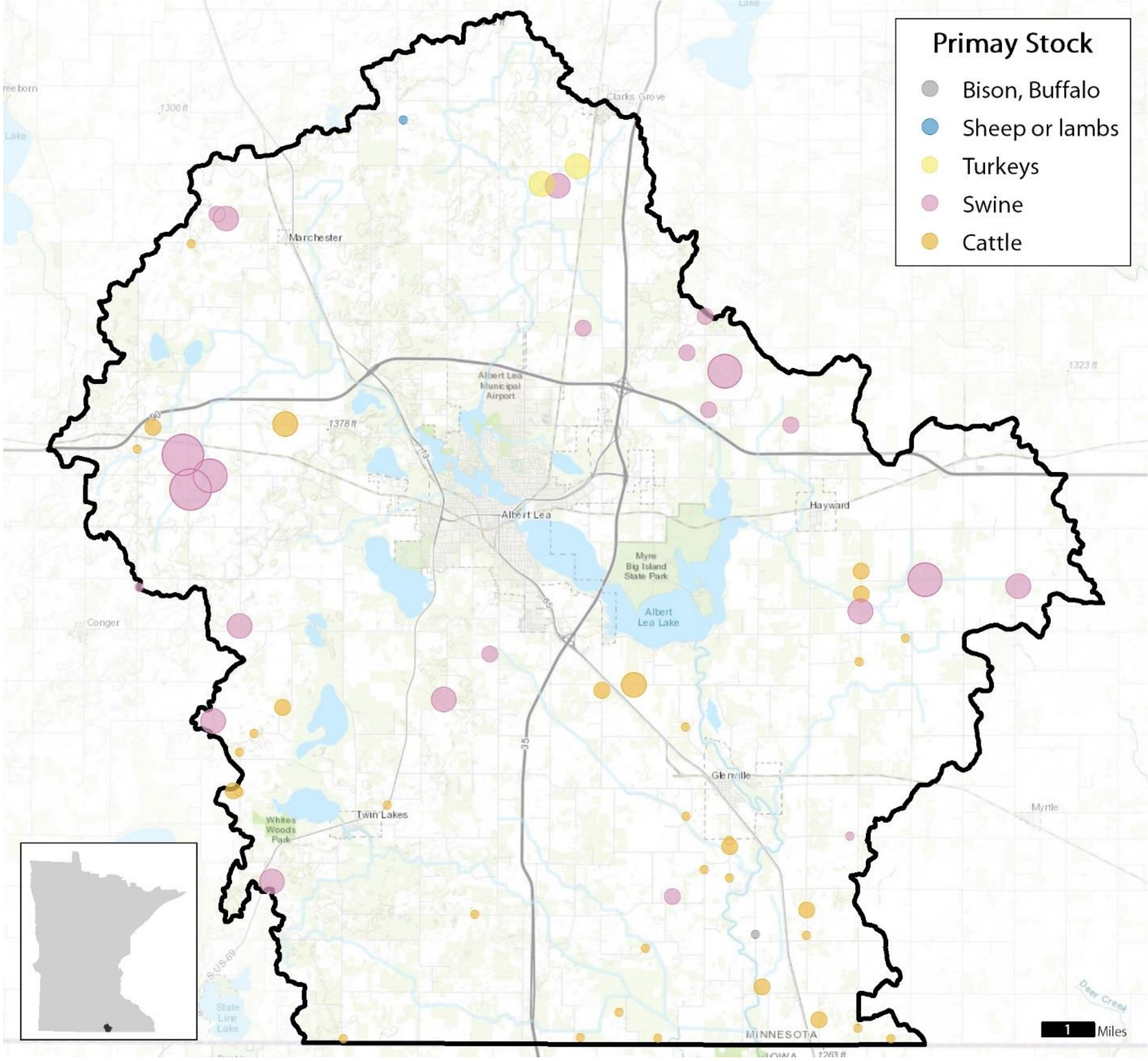


Figure 65. Feedlot locations in the SRRW by relative size (by AU) and primary stock.

Manure application sites may be pollutant sources due to surface runoff, or leaching of nutrients and bacterial transport via subsurface pathways. Feedlot operators with facilities either within or outside the SRRW boundary, may apply manure to fields within the watershed.

Since 2006, feedlot compliance staff conducted 37 inspections. During that time, compliance staff deemed two feedlot facilities with minor noncompliance for failing to keep adequate manure application records, and one with major noncompliance for not meeting water quality discharge standards. Four manure application inspections were documented within this timeframe. All were found to be compliant.

Subsurface Septic Treatment Systems

SSTSs that are failing can contribute *E. coli* to nearby waters. SSTS can fail for a variety of reasons, including excessive water use, poor design, physical damage, and lack of maintenance. Common limitations that contribute to failure include a seasonal high water table, fine-grained soils, shallow bedrock, and fragipan (i.e., altered subsurface soil layer that restricts water flow and root penetration).

Septic systems can fail hydraulically through surface breakouts or hydrogeologically from inadequate soil filtration. Most SSTS systems within the SRRW are used for individual homes and residences.

Septic systems that discharge untreated sewage to the land surface or directly to streams are considered imminent public health threats (IPHTs). IPHT typically include straight pipes, effluent ponding at ground surface, effluent backing up into home, unsafe tank lids, electrical hazards, or any other unsafe condition deemed by certified SSTS inspector. Therefore, it should be noted that not all of the IPHTs discharge pollutants directly to surface waters.

Annual SSTS reports for Freeborn estimate the compliance of SSTS across the county. SSTS compliance has remained fairly consistent for Freeborn County in the last few years. Since 2006, overall estimated percentages of IPHT are low, approximately 15% of total systems reported (Figure 66). The 2018 SSTS Annual Report from Freeborn County estimated that 26% of septic systems were failing to protect groundwater and 14% were an imminent threat to public health or safety (ITPHS) in Freeborn County [MPCA 2018b]. From 2008 through 2016, an average of 95 SSTS were replaced each year (Figure 67).

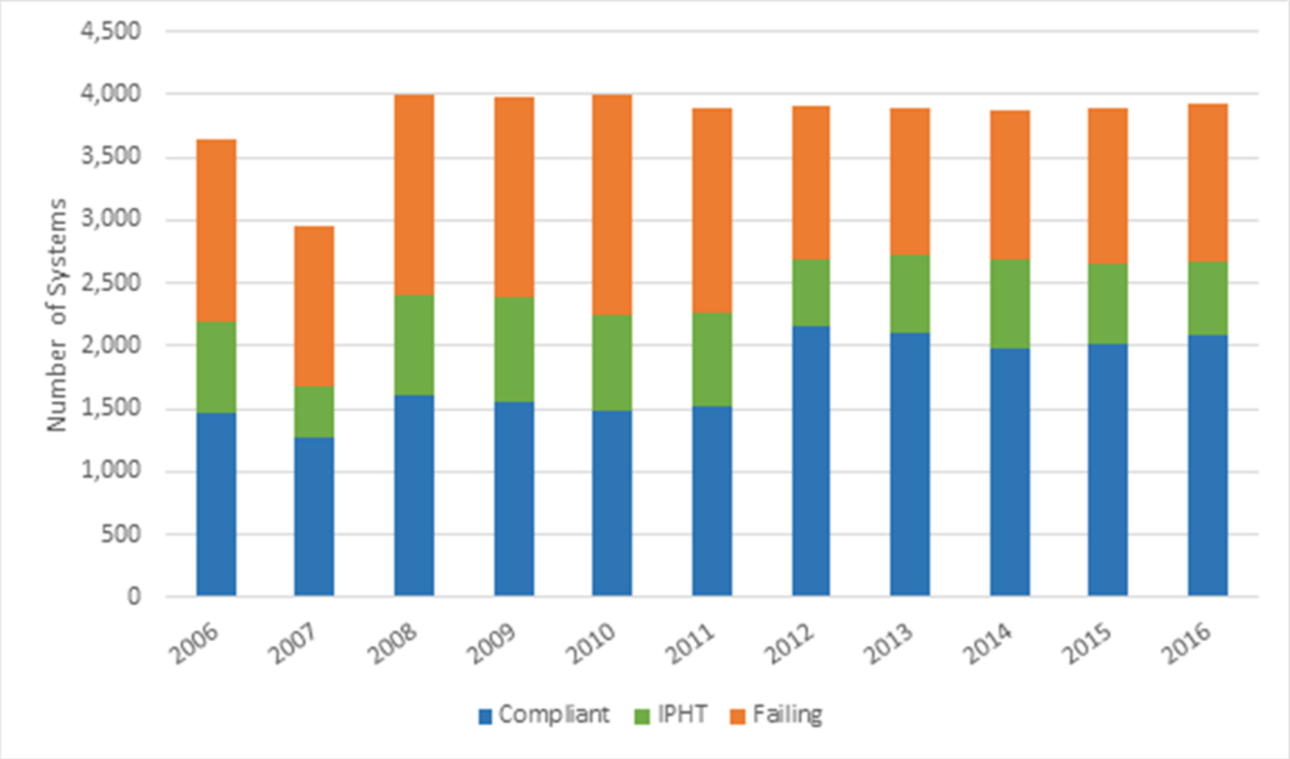


Figure 66. SSTS compliance reported from Freeborn County 2000-2016.

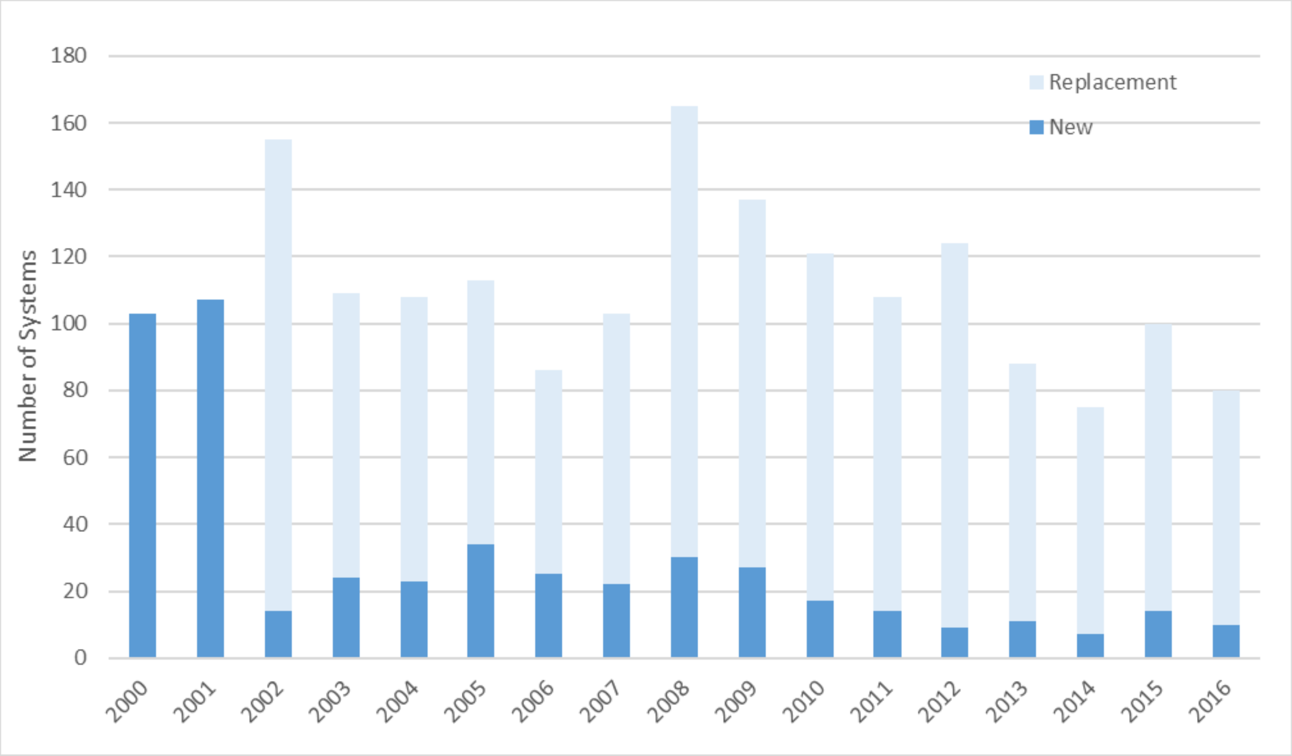


Figure 67. New and replaced SSTS reported for Freeborn County 2000-2016.

2.3.4.2. NPDES permitted point sources:

NPDES-permitted point sources (not including NPDES-permitted feedlots) in the SRRW are included in Table 31 and Figure 68. The most significant municipal point source in the watershed is the City of Albert Lea's WWTP, which discharges to the Shell Rock River below Albert Lea Lake. Other smaller domestic wastewater dischargers are Clarks Grove, Hayward, Glenville, Twin Lakes, and Myre Big Island State Park. There are three industrial point source dischargers in the SRRW as well.

Table 31. Point sources in the Shell Rock River Watershed.

HUC-10 Subwatershed	Point source		
	Name	**Permit #**	**Type**
Fountain Lake	Clarks Grove WWTF	MNG580067	Municipal wastewater
Shell Rock River	Glenville WWTF	MN0021245	Municipal wastewater
Shell Rock River	Albert Lea WWTF	MN0041092	Municipal wastewater
Albert Lea Lake	Hayward WWTF	MN0041122	Municipal wastewater
Albert Lea Lake	Myre-Big Island State Park	MN0033740	Domestic wastewater
Albert Lea Lake	Albert Lea WTP SD001	MNG64002	Municipal drinking water
Albert Lea Lake	Cargill Value Added Meats	MNG255077	Industrial wastewater
Fountain Lake, Albert Lea Lake and Shell Rock River	City of Albert Lea MS4	MS400263	Municipal stormwater
Fountain Lake, Albert Lea Lake, and Shell Rock River	Combined CSW and ISW		Construction and Industrial stormwater

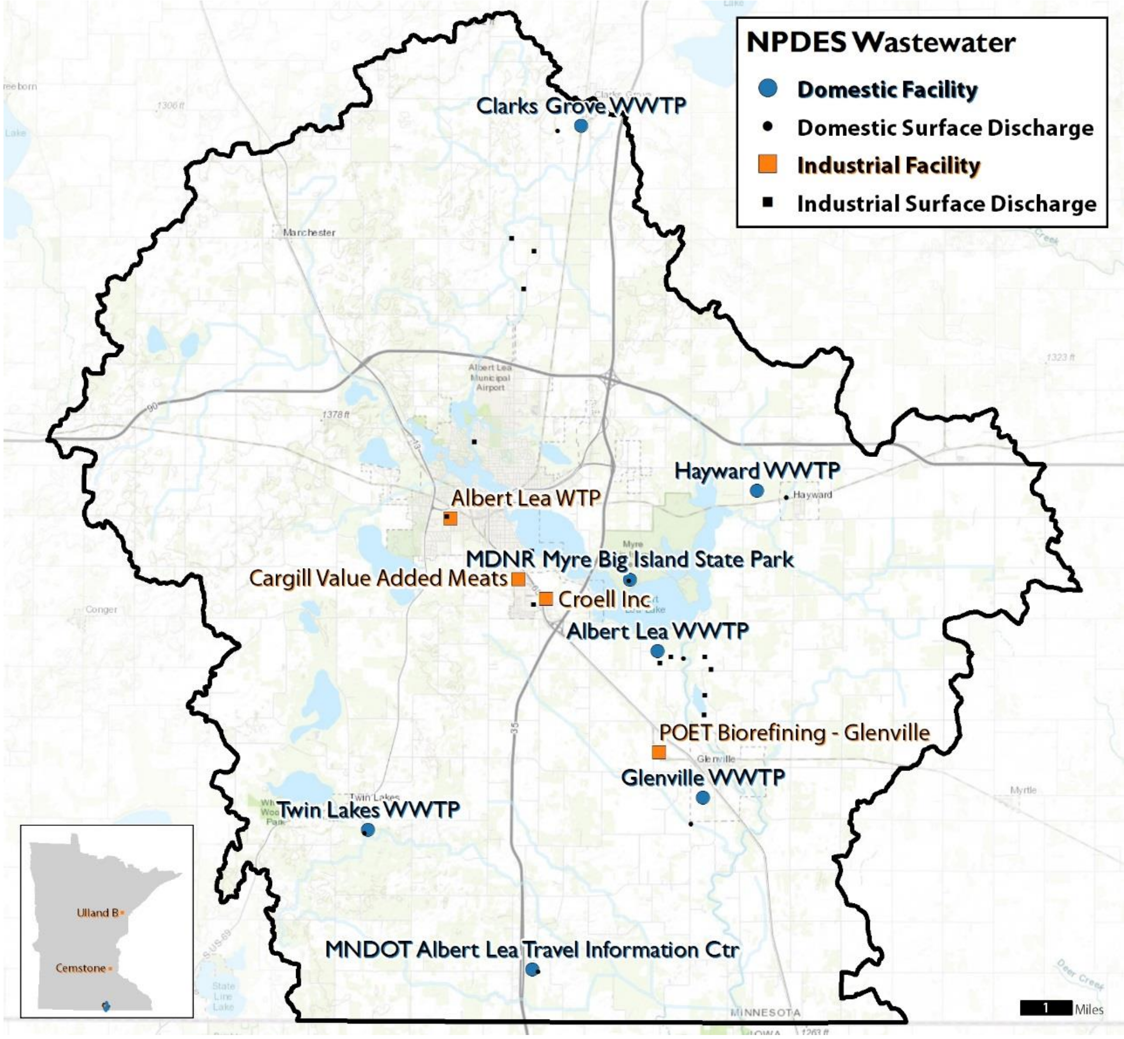


Figure 68. NPDES-permitted point sources in the Shell Rock River (excluding feedlots).

Wastewater Treatment Facilities:

Five WWTFs operate in the SRRW. WWTFs can contribute to phosphorus, TSS, carbonaceous biochemical oxygen demand (CBOD) and nitrogen loads to surface waters through their facility discharge. Maximum quantities of pollutants are established through permit conditions. Monitoring and reporting pollutant concentrations of facility discharge is a permit condition for WWTFs.

The parameter loads (Table 32) for the Albert Lea WWTF are understandably much larger than those of the smaller nearby towns, due to the human population and industrial effluents in Albert Lea. The annual phosphorus load for Albert Lea's WWTP ranges from 154 – 255 lbs/day (converted from kilograms) – and the allowable load per the TMDL is 48.4 lbs/day. The proposed phosphorus TMDL wasteload allocation (WLA) for Glenville, for comparison, is 2.7 lbs/day, while the Albert Lea Stormwater MS4 is 0.3 lbs/day. The Albert Lea WWTP has operated at an effluent flow rate of about 4.04 MGD, and the dry weather design flow for the facility is 9.125 MGD (RESPEC 2020). The consistent wastewater discharge at high phosphorus concentrations leads to high phosphorus pollutant loads in the SRR, and is the significant factor for poor river water quality conditions at low to moderate stream flows.

WWTP progress toward pollutant load reductions are reported on the MPCA's "Healthier Watershed" website (https://www.pca.state.mn.us/water/wastewater-treatment-plant-progress). Loads are derived by multiplying the monthly average concentrations and monthly total flow. The resulting loads may vary slightly from mass reported on discharge monitoring reports due to calculation methods. Calculated loads below can be used for informational and planning purposes.

Since 2003, yearly phosphorus loads for the Albert Lea WWTP have been measured between 25,000 to 42,000 kg (Table 31), and while there is variability between years, the loads have not declined. Annual loads for TP, TSS, CBOD, and nitrogen from each of the five WWTFs are included in Appendix L.

Table 32. Range of annual reported parameter loads from SRRW wastewater treatment facilities.

Wastewater facility	Annual phosphorus load (kg)	Annual TSS load (kg)	Annual CBOD load (kg)	Annual Nitrogen load (kg)
Albert Lea WWTF	25,557– 42,227	5,406 – 69,965	5,385 – 9,475	9,634 – 27,804*
Clarks Grove WWTF	23 – 293	606 – 7,597	266 – 1,648	304 – 1,303**
Glenville WWTF	9.1 – 137**	38 – 1,778	19 – 791	26 – 183
Hayward WWTF***	15 – 30	176 – 435	88 – 206	181 - 254
Twin Lakes WWTF	3 – 67**	7 – 904	5 – 268	43 – 214**

***Observed data from 2010 – 2019.**
****Includes estimated data.**

Albert Lea Municipal Separate Storm Sewer System

The Albert Lea City Municipal Separate Storm Sewer System (MS4) is located primarily in the SRR drainage but, also overlaps the watersheds of Bancroft Creek (CD 63) and Shoff Creek (Table 33).

Table 33. Albert Lea MS4 contributions to impaired streams in the Shell Rock River Watershed.

Impaired reach (Reach)	MS4 Acres (% subwatershed)	Pollutant	Estimated existing load
Bancroft Ck/CD 63 (-507)	535.95 (5%)	*E. coli*	2.13 billion org/day* (mid-flow zone)
Shoff Ck (-516)	250.86 (33%)	TSS	12.93 tons/year
		TP	110.89 lbs/year
Shell Rock River (-501)	209.05 (1%)	TSS	5.67 tons/year
		TP	61.56 lbs/year

* No estimated load contributions modeled; existing load references TMDL wasteload allocation.

Municipal stormwater permits are required for specified Phase II cities that are defined as MS4s by MPCA's General Permit Authorization to Discharge Stormwater Associated with small MS4s under the NPDES/SDS Permit (MNR040000). The MPCA defines MS4s as conveyance systems (roads with drainage systems, municipal streets, catch basin, curb gutters, ditches, man-made channels, and storm drains) that are owned or operated by a public entity, such as a city, town, county, district, state, or other public body that has jurisdiction. Phase II MS4 NPDES-permitted stormwater communities are required by permit General MS4 Permit MNR040000 to develop and implement a Stormwater Pollution Prevention Plan (SWPPP). The General Permit also requires MS4s to develop regulatory mechanisms, inventory and mapping of storm sewer system, public participation/involvement and illicit discharge detection and elimination. For more information on the City of Albert Lea MS4 program, visit the City of Albert Lea website and/or the SRRW TMDL (RESPEC 2020).

2.4 TMDL summary

The impaired waters with completed TMDLs in the SRRW are listed in Table 34. The Shell Rock River's 12-mile reach in Minnesota has multiple pollutant-caused impairments, including for both fish and macroinvertebrates. The detailed information for the Shell Rock River, and the other bacteria, TSS, and phosphorus TMDLs is located in the companion TMDL report (RESPEC 2020).

Table 34. TMDLs developed for impaired waters on the SRRW.

HUC-8	Waterbody Name	WID (HUC-8)	Use Class	Affected Use	Year Added to List	Proposed EPA Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in This Report
Shell Rock River (07080202)	Shell Rock River	-501	2Bg, 3C	Aquatic Life	2012	4A	DO	DO	**Yes:** Oxygen Demand
					2016	4A	Nutrients/Eutrophication	Phosphorus	**Yes:** Total phosphorus
					2012	5	Macroinvertebrate bioassessment (MIBI)	Nitrate Algal productivity (Chlorophyll-a) pH Phosphorus Habitat DO	**No:** Nitrate standard not applicable **No:** TP TMDL for RES will address. **No:** TP TMDL for RES will address. **No:** TP TMDL for RES will address. **No:** nonpollutant stressor **Yes**: Oxygen Demand TMDL will address.
					2012	5	Fish bioassessment (FIBI)		
					2002	4A	Turbidity	TSS	**Yes:** TSS
					2008	4A	pH	pH	**No:** TP TMDL for RES will address.
				Aquatic Recreation	1994	4A	*E. coli*	*E. coli*	**No:** 2002 TMDL approved
	Bancroft Creek (County Ditch 63)	-507	2Bg, 3C	Aquatic Recreation	2012	4A	*E. coli*	*E. coli*	**Yes:** *E. coli*
	Unnamed Creek (Shoff)	-516	2Bg, 3C	Aquatic Life	2016	4A	Nutrients/Eutrophication	Total phosphorus	**Yes:** Total phosphorus
					2010	4A	Turbidity	TSS	**Yes:** TSS

HUC-8	Waterbody Name	WID (HUC-8)	Use Class	Affected Use	Year Added to List	Proposed EPA Category	Impaired Waters Listing	Pollutant or Stressor	TMDL Developed in This Report
	Unnamed Creek (Wedge)	-531	2Bg, 3C	Aquatic Recreation	2012	4A	*E. coli*	*E. coli*	**Yes:** *E. coli*
	Albert Lea Lake	24-0014-00	2B, 3C	Aquatic Recreation	2008	4A	Nutrients/Eutrophication	Total phosphorus	**Yes:** Total phosphorus
	Fountain Lake (East Bay)	24-0018-01	2B, 3C	Aquatic Recreation	2008	4A	Nutrients/Eutrophication	Total phosphorus	**Yes:** Total phosphorus
	Fountain Lake (West Bay)	24-0018-02	2B, 3C	Aquatic Recreation	2008	4A	Nutrients/Eutrophication	Total phosphorus	**Yes:** Total phosphorus
	White Lake	24-0024-00	2B, 3C	Aquatic Recreation	2008	4A	Nutrients/Eutrophication	Total phosphorus	**Yes:** Total phosphorus
	Pickeral Lake	24-0025-00	2B, 3C	Aquatic Recreation	2008	4A	Nutrients/Eutrophication	Total phosphorus	**Yes:** Total phosphorus

The lake TP TMDLs require significant load reductions, at a time when storm-event driven external loading of TP is frequently increasing. Large drainage areas also increase the complexity for the major lakes in the SRRW, and point to the need for a comprehensive and sustained effort to reduce external loads. Table 35 below summarizes permitted wastewater facilities in the SRRW and their associated WLAs described in the SRRW TMDL. In some cases, reductions outlined in the TMDLs will be translated into future permit limits. See Section 7.2.4 of the TMDL for additional information.

Table 35. Permitted point sources and associated TMDL wasteload allocations.

HUC-10 Subwatershed	Point source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
Fountain Lake (Bancroft Ck)	Clarks Grove WWTF	MNG580067	Municipal wastewater	No	*E. coli* WLA
Shell Rock River	Glenville WWTF	MN0021245	Municipal wastewater	Yes (TP) No (TSS)	TP concentration of 2.00 mg/L and WLA of 2.7 lbs/day*
Shell Rock River	Albert Lea WWTF	MN0041092	Municipal wastewater	Yes (TP) No (TSS)	TP concentration of 0.636 mg/L and WLA of 48.4 lbs/day*
Albert Lea Lake	Hayward WWTF	MN0041122	Municipal wastewater	No	TP WLA of 0.375 lbs/day is for current design/operations
Albert Lea Lake	DNR Myre Big Isl. St. Pk	MN0033740	Domestic wastewater from St. Pk.	No	TP WLA of 0.08 lbs/day is for current design/operations
Albert Lea Lake	Albert Lea WTP SD001	MNG64002	Municipal drinking water	No	TP WLA of 0.17 lbs/day is for current design/operations
Albert Lea Lake	Cargill Value Added Meats	MNG255077	Industrial wastewater	No	TP WLA of 0.25 lbs/day is for current design / operation
Fountain Lake and Shell Rock River	City of Albert Lea MS4	MS400263	Municipal stormwater	Yes	MS4 drains to all five lakes and to Shell Rock River. See TMDL (RESPEC 2020) for WLAs.
Fountain Lake, Albert Lea Lake, and Shell Rock River	Combined CSW and ISW		Construction and Industrial stormwater	No	0.6 lb/day of waste load for oxygen and 0.4 lb/day phosphorus

* Permit limit to be established following the approval of TMDL (see TMDL Section 7.2.4).

2.5 Protection considerations

While there are no streams or lakes in the SRRW that can presently be considered for protection status, there are some remaining wetlands that are in good condition. In 2016, a field assessment and analysis of wetlands in the SRRW was completed by MPCA wetland scientists (MPCA 2016). As of 2019, there are about 12,300 acres of wetlands in the watershed, excluding deepwater habitats. Historical wetland drainage was estimated to be about 83% of the original wetland extent (i.e. prior to European settlement). Field data were collected on the condition of the plant community in a selection of wetlands in the watershed. Six percent of the wetland communities assessed were in good condition. The other wetlands were either classified as being in poor (53%) or fair (42%) condition regarding the plants present at the time of data collection. The wetland along the eastern fringe of Lower Twin Lake (15FREE022) was classified in good condition, and it is recommended to be protected and enhanced.

3. Prioritizing and implementing restoration

The intention of the WRAPS report is to assemble and highlight relevant data, information and technical resources to inform subsequent local planning efforts. Priority geographic areas and recommended strategies are suggested in this report. The act of prioritizing actions is the focus of the local water planning process, and directly involves individual land managers and citizens in the SRRW.

Many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed. As such, it is imperative to foster social capital (trust, networks and positive relationships) with those who will be needed to voluntarily implement the best management practices (BMPs). Continuing effective public participation and civic engagement is a part of the overall plan for moving forward. Section 3.3 provides further information on the civic engagement process used thus far.

The prioritization and implementation strategies provided in this section are the result of water monitoring, watershed and lake modeling, applied phosphorus and nitrogen research, and assessments by local and regional resource personnel. Watershed modeling efforts included watershed simulation models (Soil and Water Assessment Tool [SWAT] and HSPF), lake water quality models (BATHTUB), the phosphorus-BMP Tool, and the nitrogen BMP tool. The models and tools were developed using monitoring data, which were available at the time of model development. Table 36 below provides basic information about the models, tools and research that were used to assess and develop strategies for this watershed. These tools are available for use in subsequent planning efforts and other natural resources work as needed.

Table 36. Models, tools and applied research - Shell Rock River Watershed.

Model/Tool	Scale/ Timeframe	Objectives	Pertinent Notes:	Web links
HSPF	**1996-2018**	**Partner-led nonpoint reduction HSPF scenarios**	**Done with watershed partner input**	**https://www.pca.state.mn.us/water/watersheds/shell-rock-river**
HSPF	**1996 - 2018**	**Water quality predictions**	**Extended modeled outputs for subwatersheds**	**https://wrl.mnpals.net/islandora/object/WRLrepository%3A3525**
HSPF	**1996-2018**	**Permitted wastewater effluent limits**	**Under development**	**https://public.tableau.com/profile/mpca.data.services#!/vizhome/Wastewater-WatershedPhosphorusReviews/Watershedreview**
SWAT	**2008 – 2010 growing seasons**	**Agricultural land uses**	**165 modeling subbasins**	**https://www.pca.state.mn.us/sites/default/files/wq-iw7-46f.pdf**

Model/Tool	Scale/ Timeframe	Objectives	Pertinent Notes:	Web links
BATHTUB	**Lake-basin scale 2008-2018**	**Lake water quality; tributary loadings, and water balance**	**Used for impaired lakes**	**Request from MPCA.**
P-BMP	**HUC-8 large scale**	**P load reductions by BMP**	**Done with watershed partner input**	**http://wlazarus.cfans.umn.edu/nbmp-xlsm-spreadsheet-downloads**
P-Balance	**Watersheds above Albert Lea Lake**	**Phosphorus sources, accounting/balance**	**Peterson etal. 2014 J. Soil and Water Conservation: 72(4):395-404.**	**https://www.jswconline.org/content/72/4/395**
N-BMP	**HUC-8 large scale**	**N load reductions by BMP**	**Done with watershed partner input**	**http://wlazarus.cfans.umn.edu/nbmp-xlsm-spreadsheet-downloads**
DELFT3D	**2006, 2013**	**Mechanistic lake model / SRRWD and contractors (Barr 2009)**	**Track water quality** **Lake sediment interactions** **Assess dredging parameters**	**https://www.shellrock.org/vertical/sites/%7B9804AD9D-40CA-46B1-8F91-CC0257E7304A%7D/uploads/Final_Preliminary_Engineering_Report_April2017.pdf**

The goals of watershed simulation models in the SRRW were to better understand the impacts of management actions, support the TMDL and WRAPS efforts, and to provide actionable information to local government partners and watershed implementation planning efforts for improved water quality.

To address that goal comprehensively, a whole watershed approach to water quality improvement is to be pursued. While many implementation actions have been undertaken, at a variety of scales, the need to prioritize actions to promote efficiency and longer-term sustainability is critical. Also, because the watershed contains both rural and city land uses, pollutant load allocations need to be understandable and unbiased.

Any watershed simulation model contains inherent strengths and weaknesses. Understanding these factors, and using multiple models allows for better quality information to inform management decisions. Models rely upon land and water data sets in order to be usable. And, on the "flip side," models can provide guidance and direction to monitoring programs, and help adjust how monitoring is done. Models are helpful when seeking to examine longer timeframes, year-to-year variability, and the effects of both point source and nonpoint source management together. In summary, the ability to predict how future implementation efforts will affect water quality, at various scales, is critical for assessing and adjusting management actions, for sustainable and long-run outcomes.

3.1 Comprehensive Local BMP Assessments

Four efforts from watersheds in close proximity to the SRRW were reviewed to better understand how various BMP scenarios affected hydrology and water quality. While there are some water quality modeling predictions for the lower Shell Rock River available, it is helpful to also learn from the results of nearby watersheds, where broader nonpoint source scenarios were developed and modeled. While the results from these nearby watersheds are not directly transferrable to the SRRW, many of the implementation strategies do have carry-over to some areas in the SRRW. The objective of this section is to present general observations for watershed partners' knowledge. At the writing of this report, a MPCA-supported project is underway to model nitrogen, phosphorus and TSS reductions under various BMP implementation scenarios using HSPF-SAM. Outputs from this in-progress project, as well as findings from studies below, can be used to target geographic areas in the SRRW for restoration. The combination of targeting tools, field reconnaissance and verification, and local experience and technical expertise will result in positive water management and water quality outcomes.

The priorities for water quality improvements presented and discussed in this section are recommendations from MPCA staff based on the major water resource assessments, associated impairments, and standard practices for long term comprehensive nonpoint source reduction efforts. Various recommended priority areas for phosphorus reduction (Figure 69) are:

- areas of **Wedge and Bancroft Creeks** are recommended as higher priority areas for Fountain Lake;
- **Peter Lund Creek (E2)** is a recommended as a higher priority area for Albert Lea Lake; and
- **direct drainage area (B2**) of the Shell Rock River is a recommended as a higher priority for the Shell Rock River.

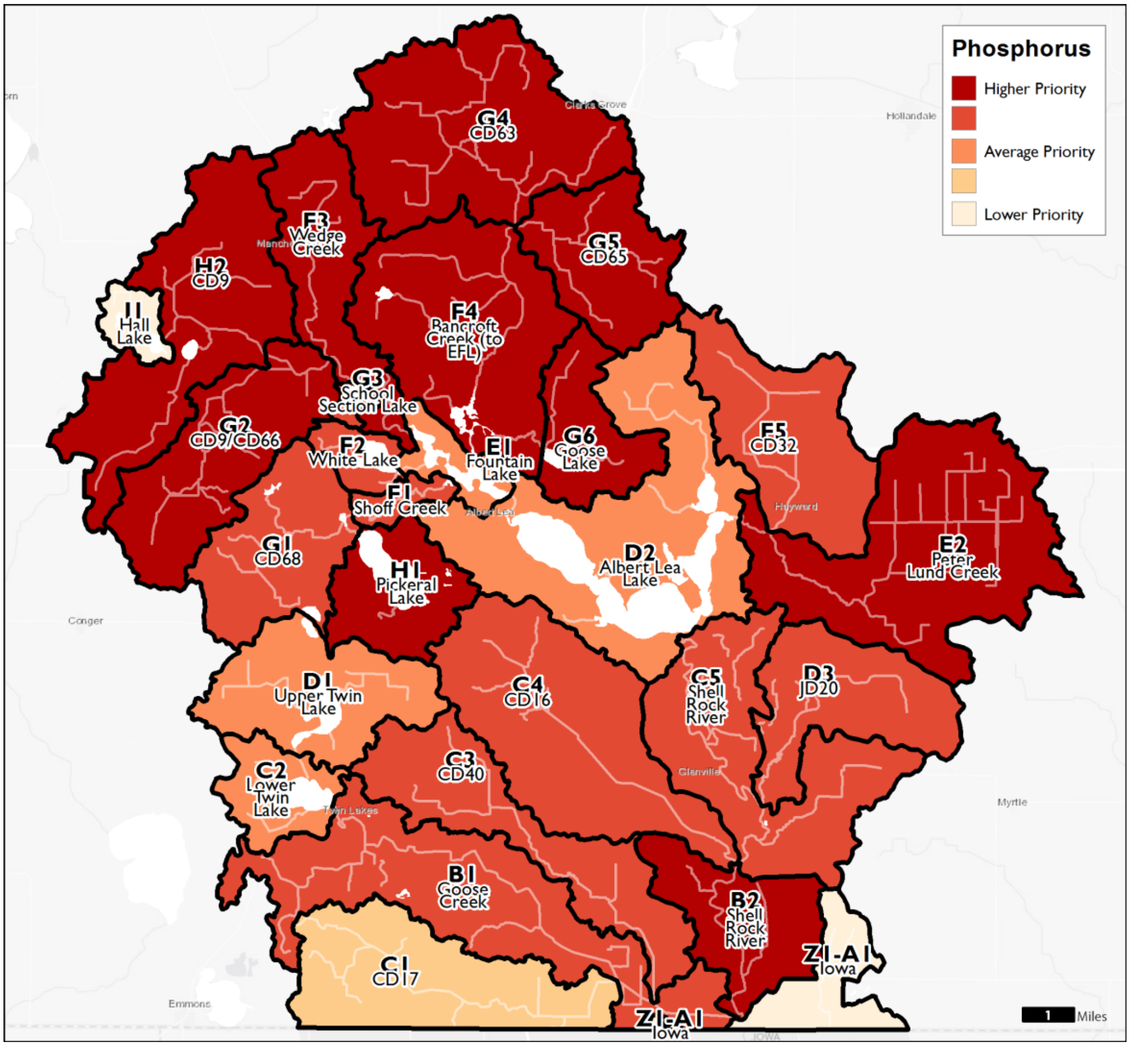


Figure 69. Priority areas in the SRRW for phosphorus reduction.

Priority areas may also vary by timing, as well as by location. Seasonal conditions for large zones with agricultural fields is an example of this situation. When implementation efforts are carefully assessed and planned for a priority area, the improvements will positively affect both the specific area, and also the downstream water resources. An example of this situation includes cooperative implementation to improve a multi-farm drainage system, where water storage and multipurpose drainage benefits are built-into a project, along with the planned ditch maintenance. Another example would be comprehensive stormwater management in the urban areas, to both mitigate altered hydrology and the downstream transport of pollution. From a long-term resource management perspective for working lands, priority areas above sensitive surface water resources will always need active management and practice maintenance. Priority area maps in the SRRW for bacteria, habitat, biology, hydrology, sediment, DO and nitrogen can be found in Appendix K.

3.2.1. HSPF

HSPF is a large-basin, watershed model that simulates runoff and water quality in urban and rural landscapes. The initial HSPF watershed model was created for the SRRW for use with TMDL analyses, and covered 1996 through 2012. The model was recently updated to include water quality data and climate data through 2018. Incorporating additional years into the model accounts for variation in rainfall-runoff conditions, and thus pollutant loading and water resources conditions. A selection of pertinent HSPF information is also included in Appendix G.

HSPF focuses on a generalized, larger scale perspective of watershed processes. One of the HSPF model values lies in using existing water quality and quantity data to simulate river flows and water quality in areas where limited or no observed data have been collected. It also provides estimations of the locations and proportions of watershed sources -- specific combinations of land use, slopes and soils -- comprising pollutant loading at downstream locations where more substantial observed data are available. All modeling reports, data, and files are available from the MPCA. The most recent model development and calibration report for the HSPF model is part of a memo from RESPEC (2019).

HSPF Yield Maps

The SRRW is divided into 59 modeling subwatersheds, called reach segments. These vary significantly in size, from less than 100 acres, to 14,300 acres. For each major pollutant (sediment, phosphorus and nitrogen), a pollutant yield map was produced with the HUC-12 subwatershed boundaries outlined. These yield maps display pollutant mass divided by subwatershed area and provide a means to make comparisons across the entire SRRW. A water yield map was also produced showing the total water volume (inches) is estimated over the entire watershed area. The averaging timeframe for all yield maps is 2009 through 2018. Outputs of the SRRW HSPF modelled pollutant and water yields are displayed in Figure 70, Figure 71, Figure 72, and Figure 73.

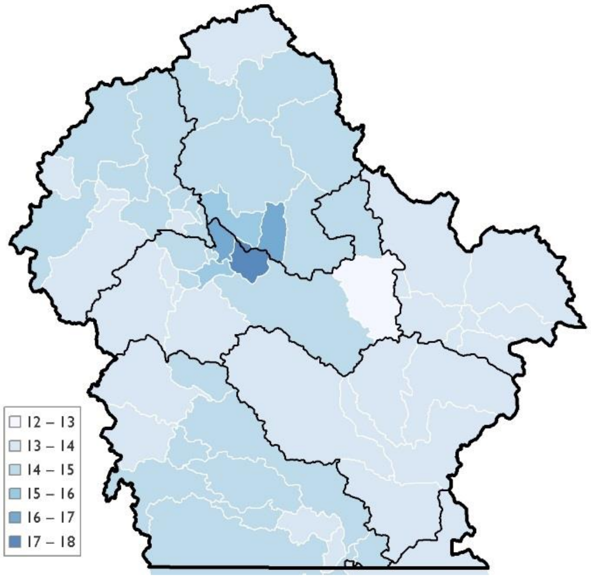


Figure 70. HSPF average annual water yield in inches for the SRRW, 2009 - 2018.

Water yields across the SRRW are typically about 13 to 15 inches per year. The urbanized subwatersheds of Albert Lea have higher water yields, due to the degree of impervious areas present. The subwatershed with the lowest water yield, along the northeast portion of Albert Lea Lake, may have soil conditions that increase water infiltration, and thus reduce modeled surface water yields.

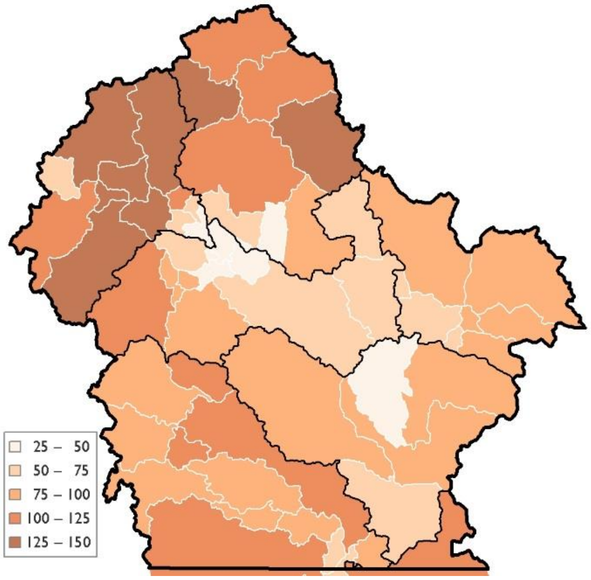


Figure 71. HSPF average annual nonpoint delivered sediment yield in pounds per acre in the SRRW, 2009-2018.

While average sediment yields vary from 25 to 150 lbs/acre, higher sediment yields in the upper subwatersheds of Wedge Creek and Bancroft Creek are shown in Figure 71. These subwatersheds have intensive row-cropping land use, and hydrologic alterations that have resulted from wetland loss, the construction and maintenance of ditch channels, and stream channelization. When higher sediment levels are delivered to the outlet point of a modeling subwatershed, it increases the likelihood of downstream sediment transport.

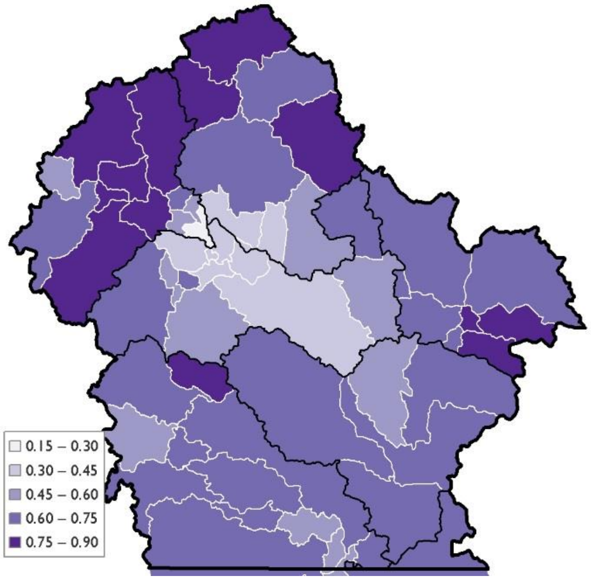


Figure 72. HSPF average annual nonpoint delivered phosphorus yield in pounds per acre in the SRRW, 2009-2018.

A watershed map (Figure 72) illustrates the mean annual HSPF-simulated TP yields from all subwatersheds. This map only includes contributions from local nonpoint sources; it does not include loads from point sources, atmospheric deposition or upstream sources. The phosphorus yield map (Figure 72) includes load contributions from all of the dissolved inorganic, sediment-bound inorganic, and organic forms simulated by HSPF. This analysis does not include channel sources, such as scouring of the channel bed, or streambank erosion. As such, these phosphorus yield estimates are what moves from an upland source area, to a defined channel.

This phosphorus yield shows some similarities to the sediment yield, which can be explained by the fact that phosphorus can attach to fine sediment particles (silts and clays), which are frequently mobilized and transported during precipitation-driven runoff events. However, information from observed water quality monitoring data and from Baker (2014a) indicate that approximately 60% of the TP load is in the dissolved inorganic (orthophosphate) form.

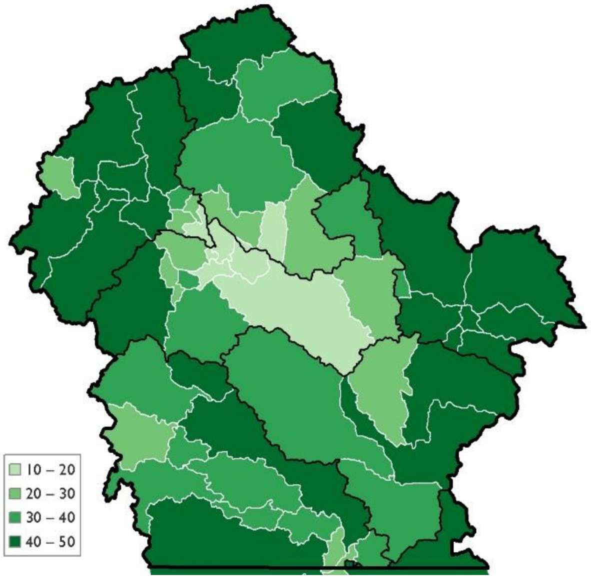


Figure 73. HSPF average annual nonpoint delivered nitrogen yield in pounds per acre in the SRRW, 2009-2018.

TN yields in the SRRW range mostly from 20 to 40 pounds per acre. The central portion of the watershed, dominated by the chain of lakes, shows lower nitrogen yields. The nitrogen yields are mostly a function of cropland acres (cropland tile drainage, cropland groundwater and cropland runoff) present within each modeling subwatershed, and affected by nitrogen leaching in the soils. Associating this N-yield map, with Figure 5 (soil drainage classes), the subwatersheds along the outer boundary of the SRRW tend to have poorly drained, or very poorly drained soils, which increases the placement of subsurface drain tiles into those soils, for crop production.

Partner-led Nonpoint reduction HSPF Scenarios

The MPCA has provided funding for additional HSPF scenario work to benefit local watershed planning efforts. In addition to HSPF, the Scenario Application Manager (SAM) was applied to convert the highly technical results of HSPF into applied analysis for planning and implementing targeted actions to restore or protect water quality in a specific geographic area. SAM provides results at a watershed scale but efforts have been made to develop methods to integrate higher resolution terrain analysis to develop more localized implementation strategies. For this project, a specified set of scenarios were simulated in HSPF-SAM for the Shell Rock and Winnebago River watersheds. The scenario results will identify the most cost-effective subwatersheds and higher resolution areas based on the terrain component for the scenario BMPs to be implemented. The terrain analyses redistributes subbasin-wide SAM loading rates at a higher resolution for localized targeting of more critical and cost-effective source areas. At the writing of this report, this partner led HSPF scenario project was still in draft. A final version of the project results will be available on the MPCA watershed webpages for the SRRW and the Winnebago River Watershed.

3.2.2. SWAT

The Surface Water Assessment Tool (SWAT) is a physically-based watershed model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS) in Temple, Texas (Arnold etal. 1993). SWAT was developed to predict the impact of land management practices on water, sediment, nutrients, DO, and agricultural chemical yields in large watersheds with varying soils, land use, and management conditions over long periods of time. SWAT is noted for accuracy in agricultural land management simulations. SWAT explicitly simulates crop management practices and urban impervious runoff. For more detailed information and documentation on SWAT, see Appendix F, as well as http://blackland.tamu.edu/models/swat/.

The initial SWAT models for this project area were set up in 2011 and 2012 by Barr Engineering, for both the Shell Rock Watershed and the Cedar River Watershed, in Minnesota (Barr 2012b). The SWAT model was initially selected because the dominant land use in the watershed is agriculture, and the SWAT model accommodated various land management practices in a more robust fashion than other watershed simulation models at the time.

Modeled land cover was derived from using 2008 through 2010 USDA-NASS CDL coverage in a Geographic Information Systems (GIS). By using these three years, a better approximation of crop rotation could be derived, with subdivisions for corn, soybeans and alfalfa during each year when watershed stream and lake monitoring occurred.

There was a total of 165 subbasins set up for the SRRW SWAT model. Hydrologic Response Units (HRUs) were developed by overlaying soil type, slope and land cover. These HRUs are somewhat counterintuitive, in that they are not defined by a flow direction, and do not influence sediment loading to the stream. During initial model setup, there were multiple thousands of HRUs, and therefore a routine was conducted to refine the HRUs (i.e. limit or reduce the total number) by setting criteria at 5% minimum of a land use and a soil type that occupied at least 20% of a subbasin. This reduced the total HRU count, and allowed for faster computational times. This technique resulted in 1,998 HRUs in the SRRW. Further consolidation brought the HRC count to 165 in the SRRW.

Precipitation data from the National Weather Service's site in Albert Lea were used, with some modifications for the Wedge Creek, Bancroft Creek, and Peter Lund Creek drainage areas. Flow and water quality data from Wedge Creek, Bancroft Creek, Peter Lund Creek, and the Shell Rock River below Albert Lea Lake, were all used. These data were generated by the SRRWD and the TMDL monitoring project.

The MPCA staff conducted further development and analysis of the SWAT data to better assess and organize the upper watershed, with a focus on phosphorus and sediment conditions. The pollutant loads presented are three year growing season (April 1 to September 30) averages for 2008 through 2010. Pollutant loads in 2010 were four to five times higher than the previous two years that are included in the averages.

Results of the SWAT model for TP and TSS loads are highlighted in this section for the SRRW and Fountain Lake Subbasin. A similar suite of results for the Albert Lea Lake Watershed are located in Appendix F.

The entire SRRW as subdivided for the SWAT model is displayed in Figure 74. Top numbers displayed in each subwatershed represent the SWAT reach number. Bottom numbers represent the growing season upland TP load in pounds. For example, the area in upper Wedge Creek on the west side of the SRRW is modeling subwatershed 85, with a TP load of 4,643 pounds. This provides some relative targeting, as the green-color modeling subwatersheds are at least 10 times lower in upland TP load, compared to the red-colored ones. Land slope, soil types, and land uses all are important factors that help determine the TP loads across the watershed.

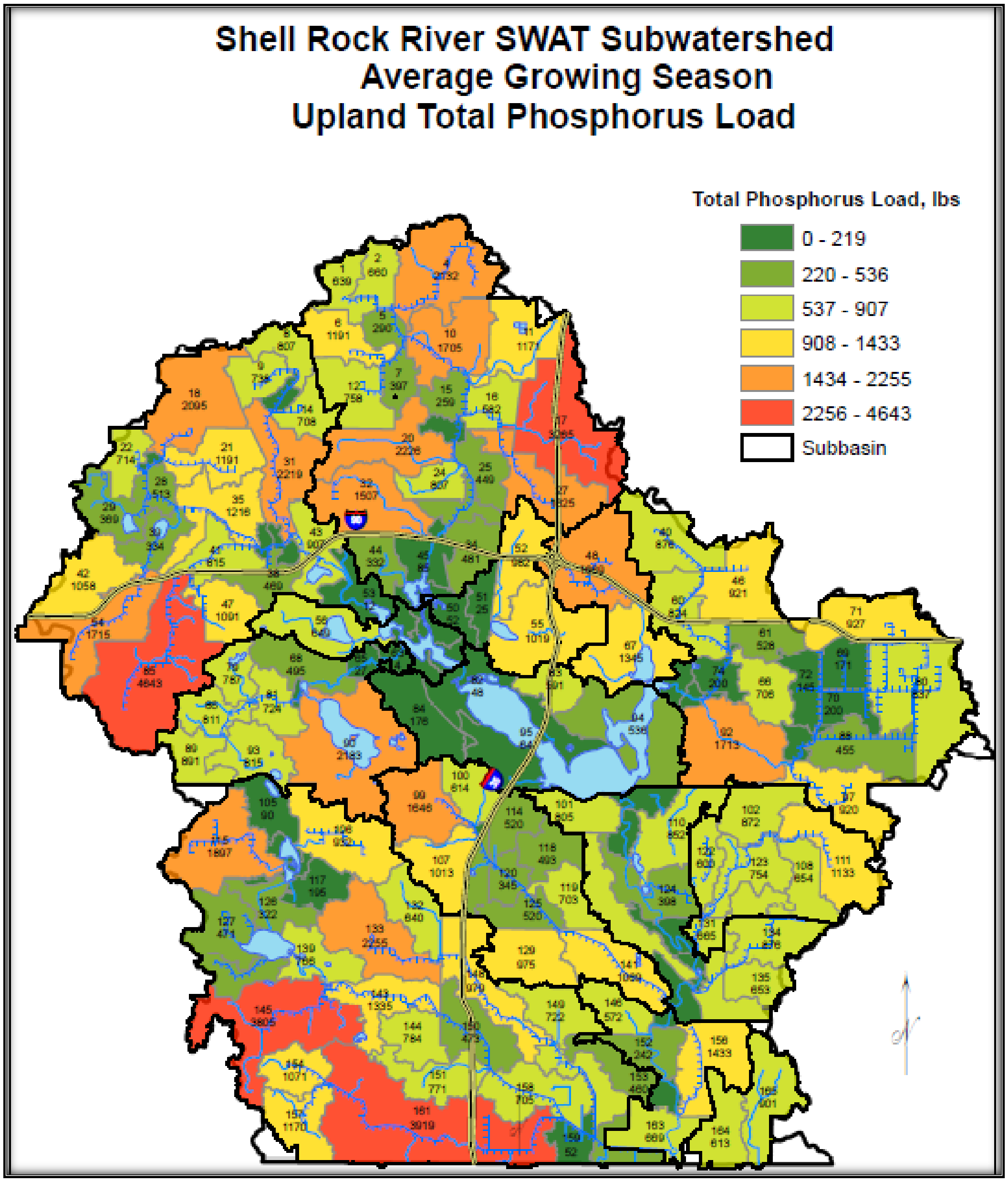


Figure 74. Shell Rock River SWAT Subwatershed average growing season upland total phosphorus load (2008-2010).

The average growing season upland sediment loads (2008 through 2010) are in Figure 75, with units of tons, and mapped for six categories. The dominance of the mineral phosphorus component helps explain why the TP and TSS load maps look similar. The version of the SWAT model developed in the SRRW, does not explicitly model phosphorus transport via subsurface pathways including tile drainage systems. Therefore surface erosion, with sediment-bound phosphorus, is the main factor affecting model output. For an assessment of Figure 74 (SWAT with TP load) to Figure 72 (HSPF with TP yield), it can be seen that certain areas of both upper Wedge Creek, and the northeast portion of Bancroft Creek, are relatively higher on both maps. With an understanding that there are different timeframes and modeling routines involved, there are some good correlations between the two models, which improves confidence in the ability to target critical areas. To conclude, the SWAT model provides a means of relative targeting for TP and sediment, across the SRRW.

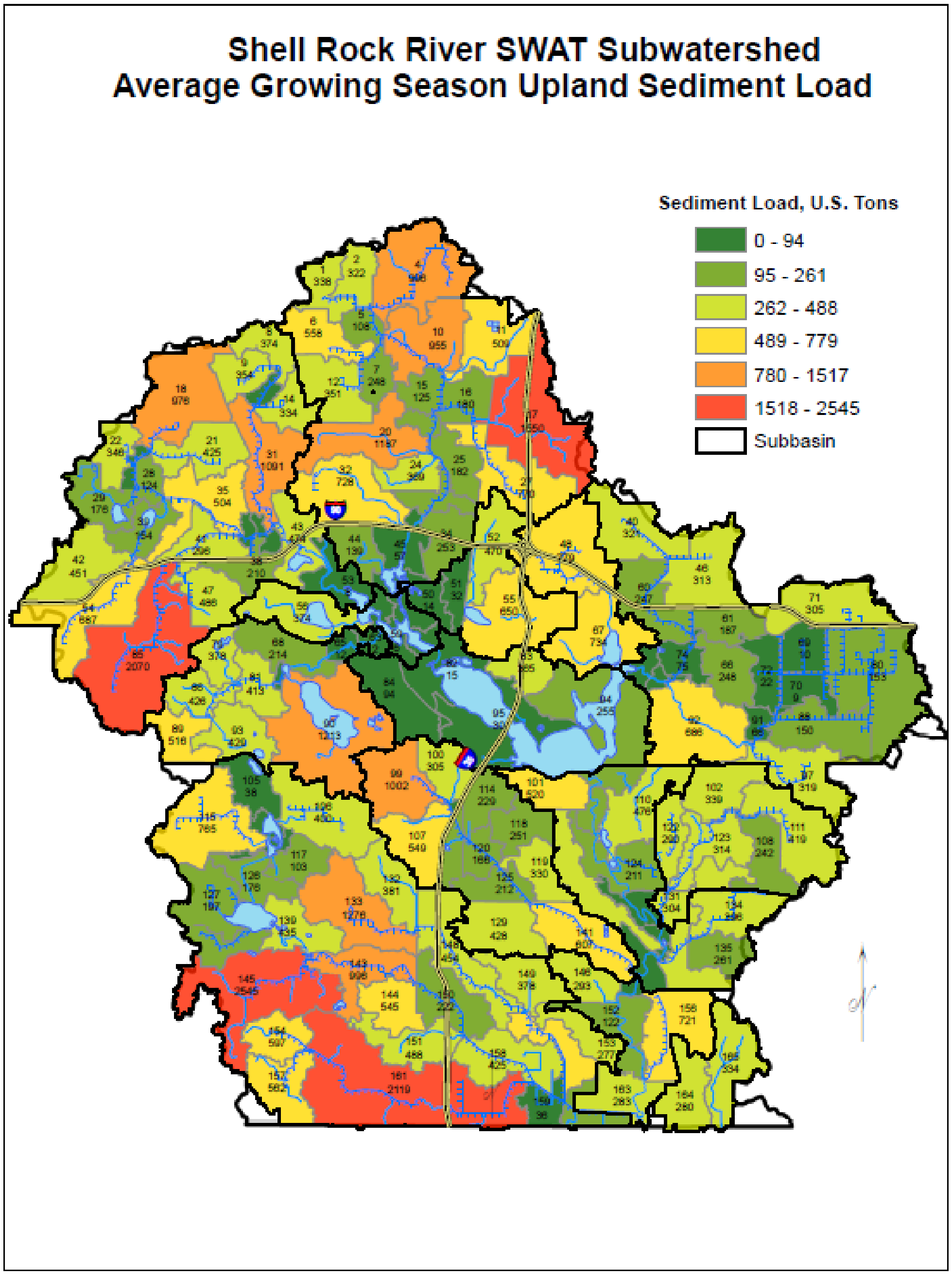


Figure 75. Shell Rock River SWAT Subwatershed average growing season upland sediment load (2008-2010).

Soil and Water Assessment Tool Modeling for Fountain Lake Subbasin:

Pollutant load and yield data for the Fountain Lake Subbasin is presented in Table 37. The SWAT model provides a subdivision for phosphorus, into mineral phosphorus and organic phosphorus. Tabulated data for phosphorus load and sediment load, are shown Figure 76 and Figure 77 respectively. These figures show both the load proportions (as green pie slices, that add to 100%), and pollutant yields (load mass/land area).

Table 37. Fountain Lake subbasin average growing season loads and yields – SWAT outputs.

		Subbasin				
Parameter		Goose Lake	Bancroft Creek	Wedge Creek	Pickeral Lake	Fountain Lake Local
	Land Area, acres	4,070	22,986	22,712	8,277	2,111
Sediment	Load, U.S. Tons	874	4,099	4,368	405	390
	Yield, Tons/acre	0.21	0.18	0.19	0.05	0.18
Mineral Phosphorus	Load, U.S. Tons	364	9801	9053	1743	99
	% Load	1.7	46.5	43.0	8.3	0.5
	Yield, lbs/acre	0.09	0.43	0.40	0.21	0.05
Organic Phosphorus	Load, U.S. Tons	687	1910	2699	792	586
	% Load	10.3	28.6	40.4	11.9	8.8
	Yield, lbs/acre	0.17	0.08	0.12	0.10	0.28
Total Phosphorus	Load, lbs	1050	11711	11752	2535	685
	% Load	3.8	42.2	42.4	9.1	2.5
	Yield, lbs/acre	0.26	0.51	0.52	0.31	0.32

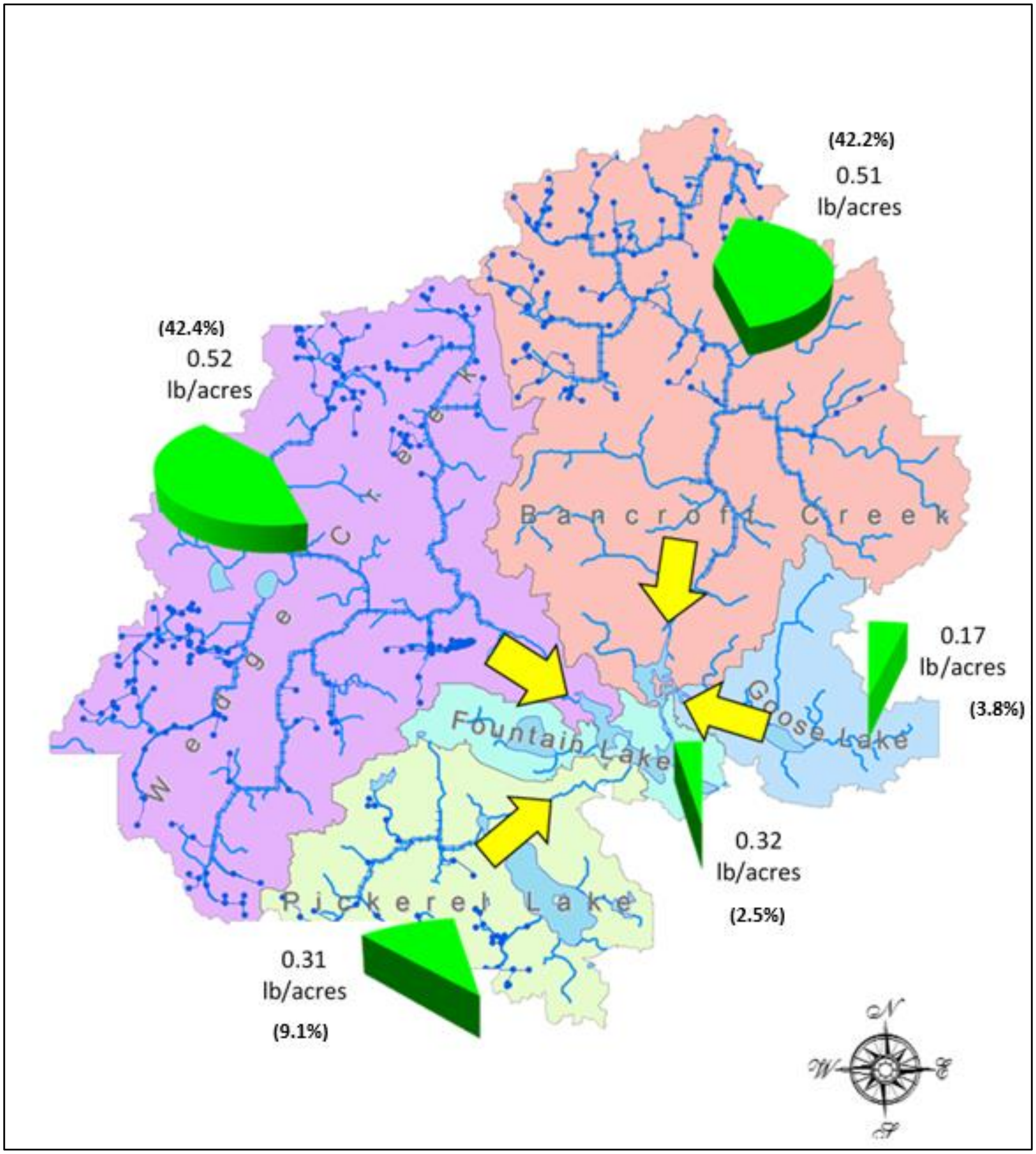


Figure 76. Fountain Lake Subbasin SWAT total phosphorus load proportions and yields (2008-2010).

Wedge Creek and Bancroft Creek together account for about 84% of the total external phosphorus load to Fountain Lake (Figure 76). Both of these important lake tributaries have similar TP yields and loads, and they are significantly higher than the other smaller subwatersheds. The Fountain Lake Subbasin map also depicts the extensive drainage network that is part of the transport system for P.

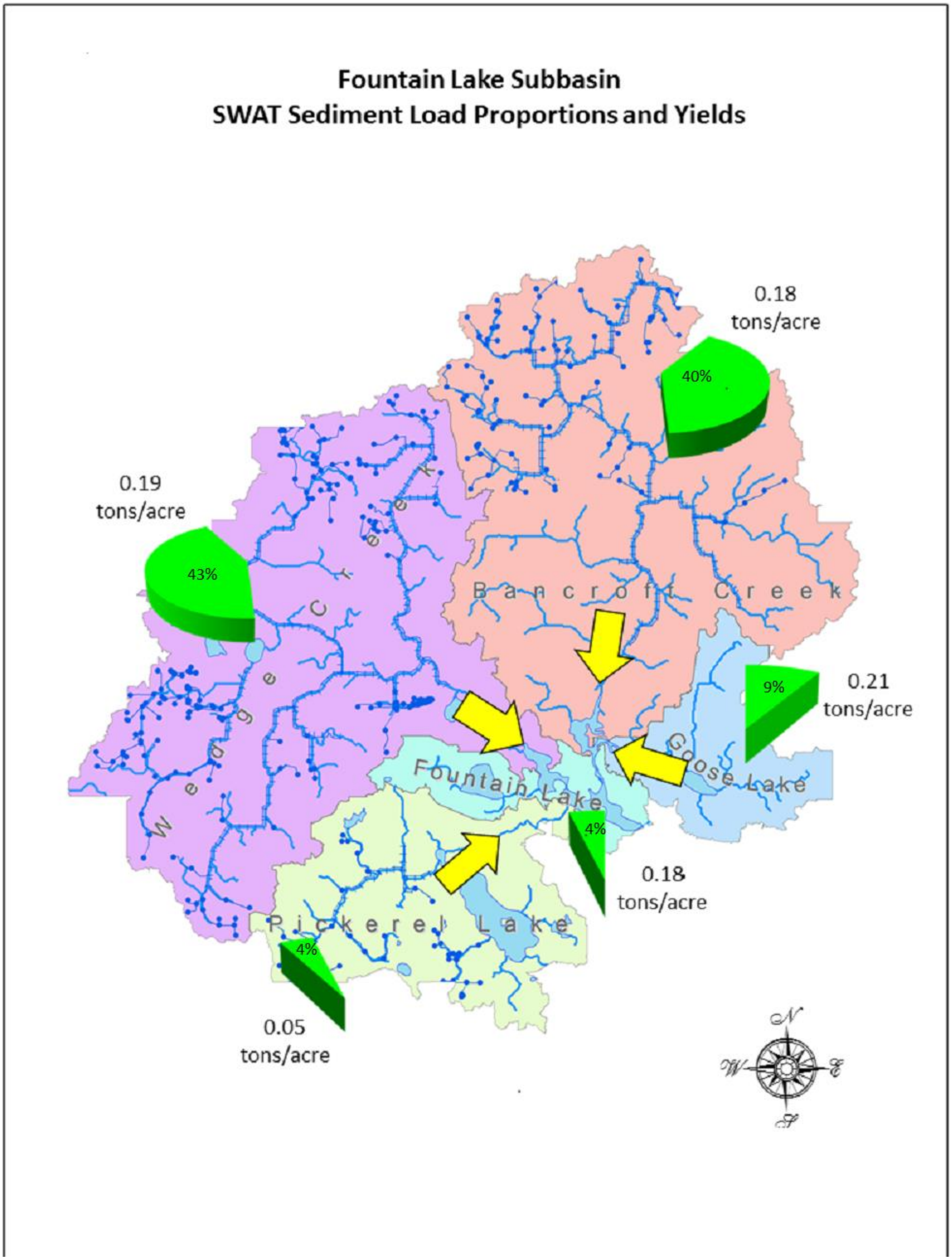


Figure 77. Fountain Lake subbasin SWAT sediment load proportions and yields (2008-2010).

3.2.3. Nitrogen and Phosphorus-BMP Tools

As part of the engagement component of the WRAPS process, a working group meeting was held with watershed partners from local government units to discuss and formulate examples of how to best meet statewide nutrient reduction goals for phosphorus and nitrogen for the SRRW. Examples of practice combinations developed by SWCD, county and watershed district personnel using the nitrogen and phosphorus BMP Tools to meet reduction goals are shown in Figure 78 and Figure 79. For nitrogen, the 10-year reduction target is 20% with a watershed-wide goal of 45% reduction (137 tons/year). The 10-year reduction target for phosphorus is 36% with a watershed wide goal of 45% by 2040. The nitrogen and phosphorus BMP Tools were developed by the University of Minnesota to assist resource managers in better understanding the feasibility and cost of various BMPs in reducing nutrients from Minnesota cropland. The tool also translates "percent adoption rates" for specific BMPs into numbers of "acres treated" based on the number of acres suitable for the practice. Partners could utilize these acre and adoption goals for grants and other incentives for landowners to implement these practices. Estimated adoption rates represent the cumulative adoption rates of BMPs to achieve water quality goals and have been vetted by local government unit staff.

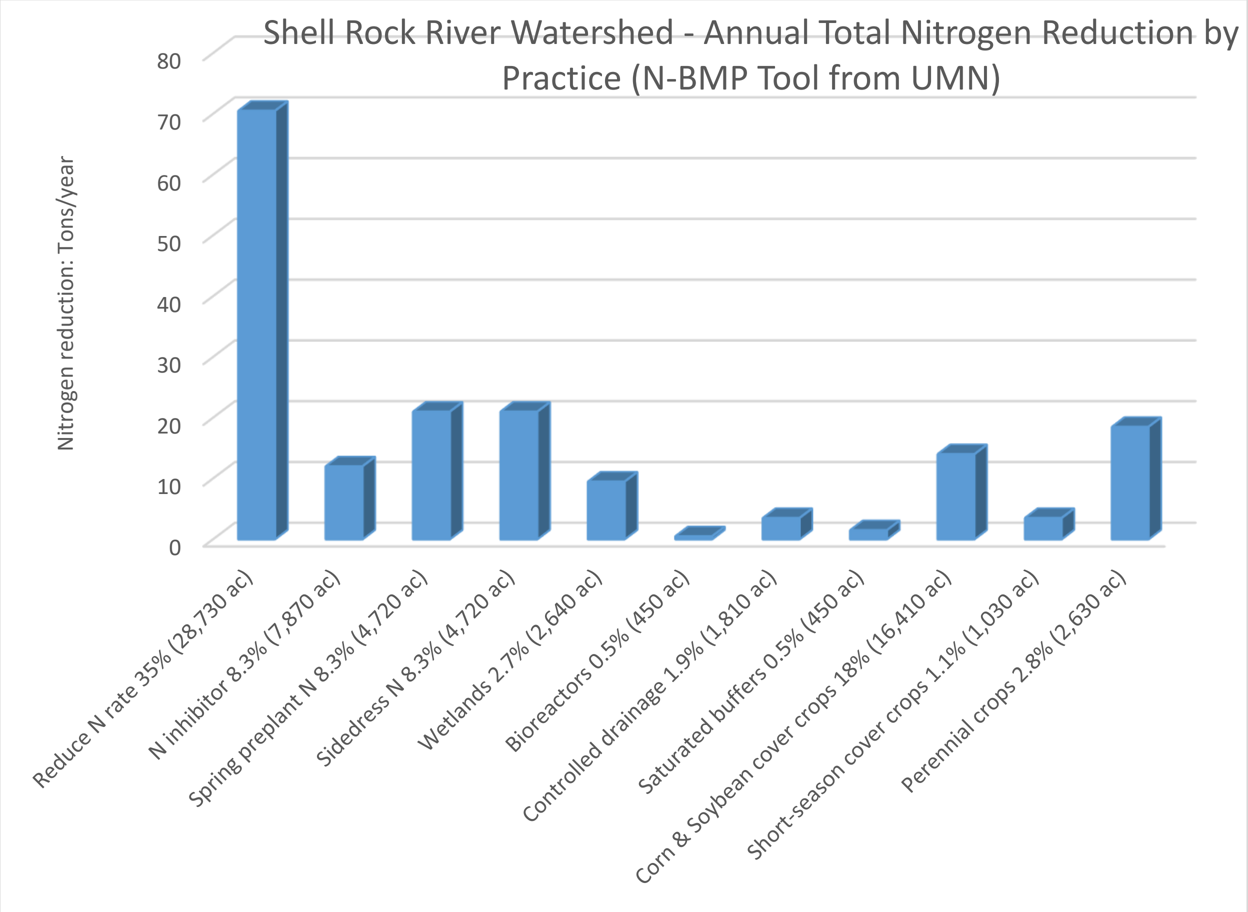


Figure 78. Example nitrogen reductions in tons/year from BMP implementation rates (as % adopted) and estimated treated land (acres).

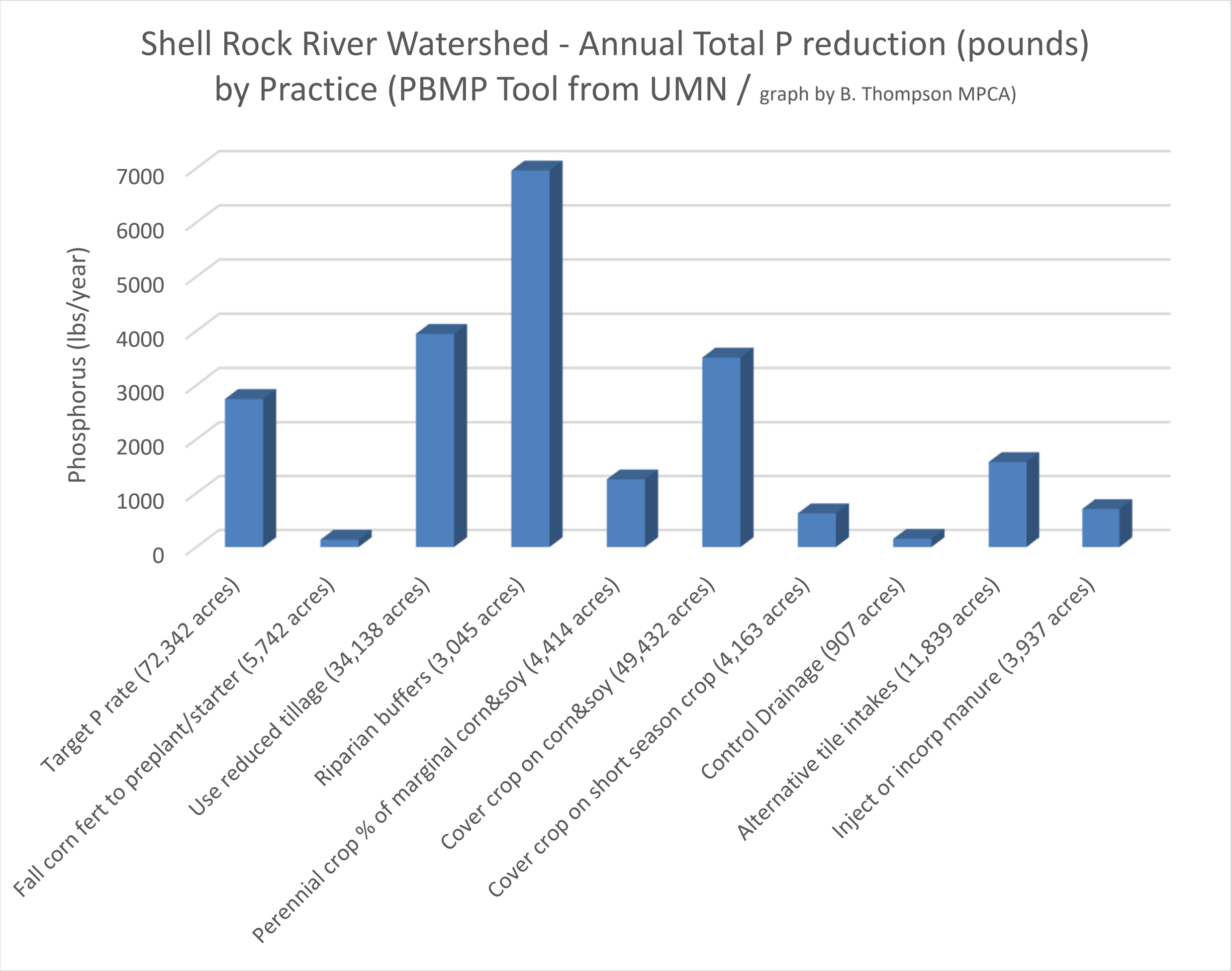


Figure 79. Example phosphorus reductions from BMP implementation percentages, as percent adopted (with acres treated).

3.2.4. Whole Watershed Phosphorus Balance for the Albert Lea Region:

The primary purpose of this phosphorus study was to characterize the phosphorus in the Upper SRRW. However, this study can also be used to help prioritize areas for targeted phosphorus reductions. Wedge Creek was identified as a priority for TP yield reductions:
TP yields from Wedge Creek were the highest (0.79lb/ac), while the other four tributary subwatersheds ranged from 0.54 to 0.63 lb/acre.

Other nonpublished reports and resources useful for prioritization are accessible through the watershed P-balance study Appendix including: User's Manual: phosphorus and Water Balance Tools for TMDL Plans, Agricultural phosphorus Calculator (Excel spreadsheet),phosphorus Balance Spreadsheet Calculator – Urban System Component (Excel spreadsheet), FANMAP (farm survey) for Albert Lea Lake Watershed, Albert Lea Agricultural phosphorus Balance, and Phosphorus Balance for the Albert Lea Region – Summary Report to the SRRWD. See Peterson et al (2017) and Baker etal (2014b).

3.2.5. SRRWD's TMDL Implementation Plan Report

SRRWD's TMDL Implementation Plan (IP) Report was drafted in 2013. The IP includes general characteristics about the water resources, pollutants and pollutant sources. Nonpermitted and permitted external and internal lake phosphorus are also included for all watershed lakes. Restorative measures and BMP descriptions for each lake are summarized in a major table titled, “Summary of Potential BMPs….,” which is accompanied by a map showing potential BMP locations. A wide diversity of BMPs are included, which cover urban, rural residential, and agricultural areas, as well as lakes, streams, and ditches. Many of the BMPs have a cost effectiveness range, in dollars per pound of phosphorus removed per year.

Section 3.1.2 of the IP provides a framework for the phasing of restorative practices and BMPs, as well as prioritization criteria. The framework suggested by the SRRWD includes:

Category	Description
Phase I	**First priority BMPs, either completed since 2009, when the TMDL began, or ongoing BMPs.**
Phase II	**Second priority BMPs. These practices would be considered, based upon monitoring of the lake, and an assessment of the necessary reductions.**
Reserve	**Practices to be considered following Phase I and Phase II implementation.**

Many of the implementation measures contained in the TMDL IP involve structural engineering practices. An example of this would be an iron-enhanced sand filter in the Wedge Creek Subwatershed (FLEB-33, cost estimates $343,000 to $686,000, to remove 27 to 40 lbs of P). This was set as a Phase II project. An example of a “Reserve” project is the alum treatment facility of CD 68, which could cost from $1.05 to 2.10 million dollars, and would treat 140 to 170 lbs of P.

There are also nonstructural practices that involve LGUs ongoing work on programs for stormwater (city), SSTS (county) and public drainage system management (county and landowners). While there are some potential restorative measures on agricultural lands, such as grassed waterways or vegetative buffer strips, a majority of referenced practices involve a more structural engineered approach.

The SRRWD TMDL IP is a helpful guide, especially related to structural engineering practices, including locational and cost estimate data.

Due to the altered hydrology in the SRRW, a focus on agricultural drainage-related projects that are either included in the TMDL IP, or are suggested by the Freeborn County Drainage Department, is recommended. While some projects can occur when the opportunities arise, most will require detailed planning, data collection (surveys), and design efforts. The suggested approach is to intentionally develop those drainage system changes into a comprehensive package of efforts that the County, the landowners, and the SRRWD would pursue, during a 20 to 30 year timeline. This will call for up-front assessment and planning for a prioritized list of public drainage systems. Data collection and planning will be needed to take advantage of multi-purpose drainage water management. Freeborn County has some excellent examples which include some projects in the Winnebago Watershed, and also site-specific work when ditch repairs are initiated. Public drainage system managers in other nearby counties are also working in this direction, and thereby a great deal can be learned through regional cooperation.

The SRRWD TMDL IP is a resource that can pair well with future watershed planning documents, including future 1W1P IPs. Recommended structural practices within the IP can complement upland watershed targeted implementation, resulting in a comprehensive watershed approach to meeting surface water quality goals.

3.2.6. Existing BMP Inventory

The MPCA has developed a system to track the actions taken within the state to achieve healthier watersheds. Actions taken to reduce polluted runoff from agricultural and rural lands are provided in Figure 80. These numbers represent only the BMPs that have been funded through federal and state programs and reported to the MPCA. Actual implementation is likely higher.

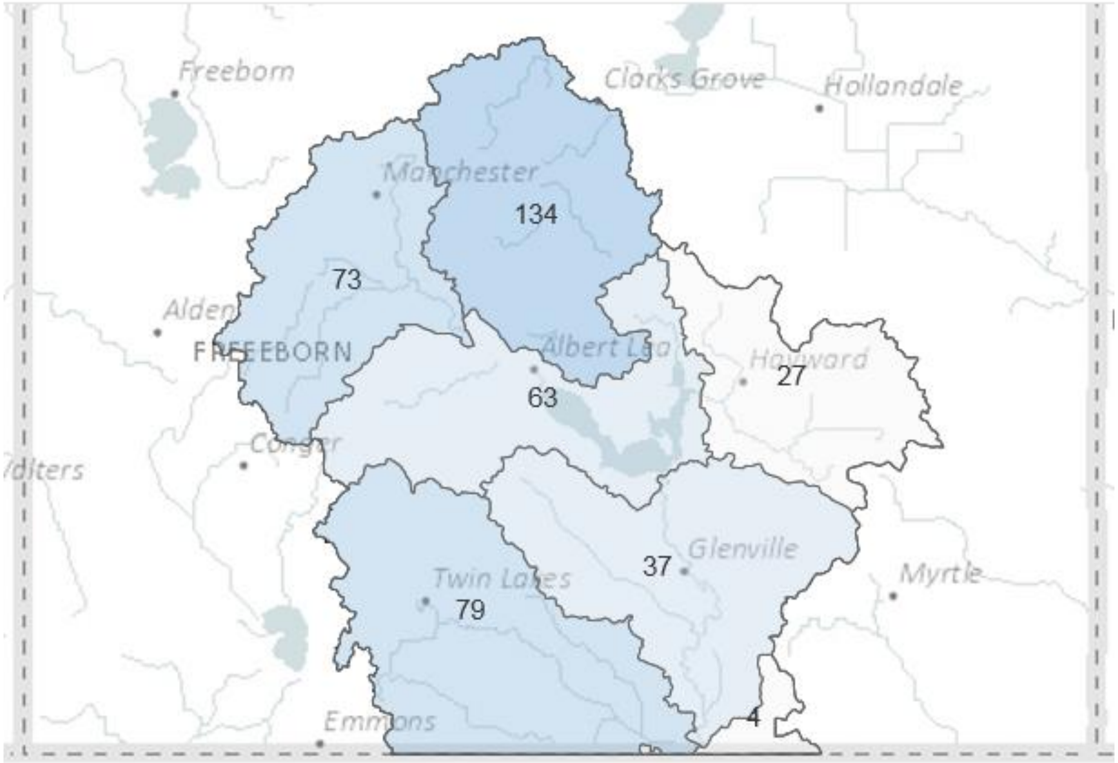


Figure 80. BMP implementation reported on MPCA's Healthier Watersheds webpage (2004-2018).

In addition to data reported to MPCA, SRRWD, and Freeborn County staff provided past (last five years), existing and planned BMPs funded by their organizations (Figure 81).

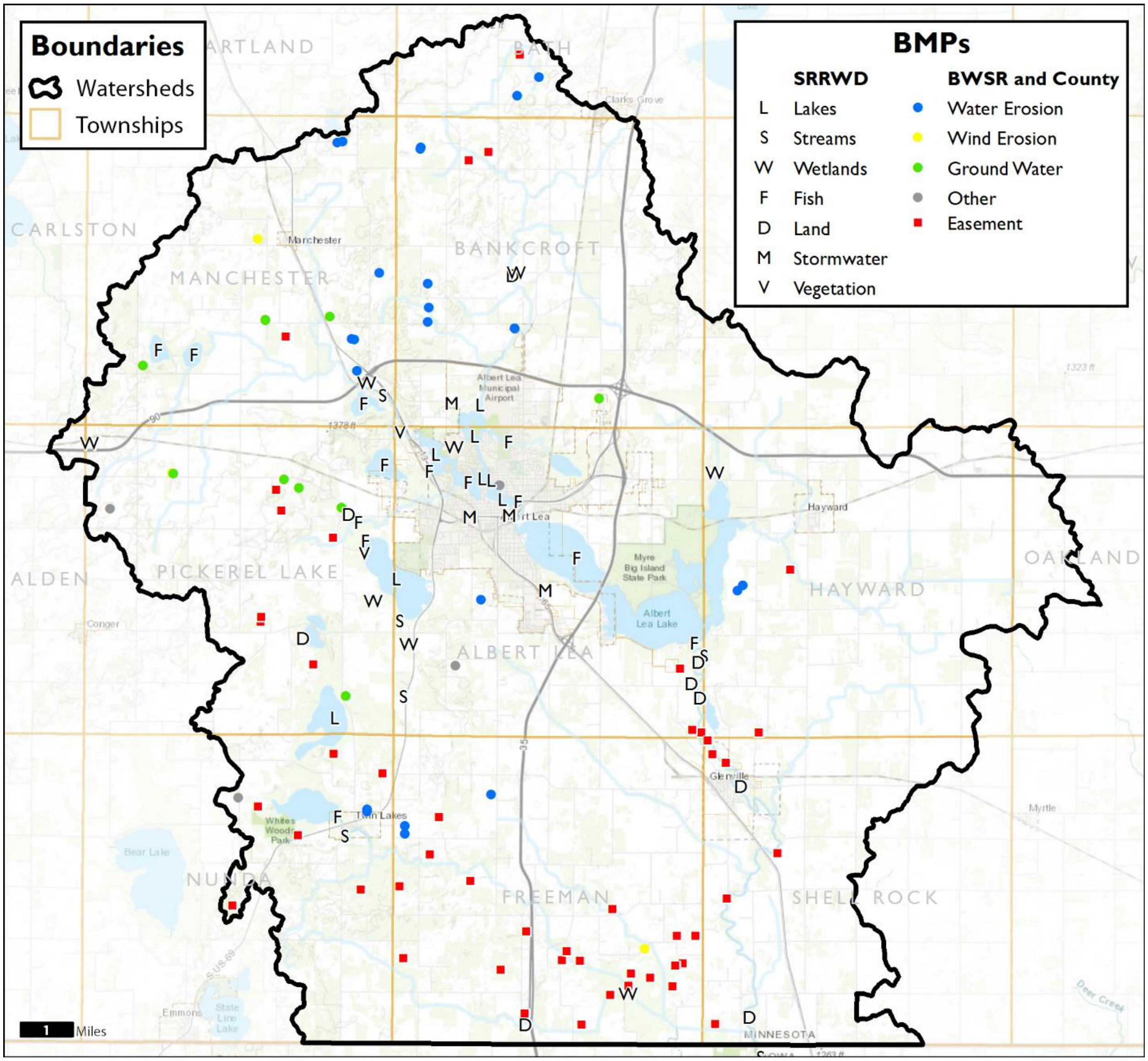


Figure 81. BMPs in the SRRW (2019), including past, current and planned BMPs from the Shell Rock River Watershed District, and Freeborn SWCD.

3.2.7. Climate protection co-benefit of strategies

Many agricultural BMPs which reduce the load of nutrients and sediment to receiving waters also act to decrease emissions of greenhouse gases (GHGs) to the air. Agriculture is the third largest emitting sector of GHGs in Minnesota. Important sources of GHGs from crop production include the application of manure and nitrogen fertilizer to cropland, soil organic carbon oxidation resulting from cropland tillage, and carbon dioxide emissions from fossil fuel used to power agricultural machinery or in the production of agricultural chemicals. Reduction in the application of nitrogen to cropland through optimized fertilizer application rates, timing, and placement is a source reduction strategy; while conservation cover, riparian buffers, vegetative filter strips, field borders, and cover crops reduce GHG emissions as compared to cropland with conventional tillage. Additional information about GHG emission reduction from agricultural BMPs is summarized in MPCA report: https://www.pca.state.mn.us/air/agriculture-and-climate-change-minnesota.

The USDA Natural Resources Conservation Service (NRCS) developed Comet Planner, a ranking tool for cropland BMPs that can be used by local units of government to consider ancillary GHG effects when selecting BMPs for nutrient and sediment control (http://www.comet-planner.com/). Practices with a high potential for GHG avoidance include: conservation cover, forage and biomass planting, no-till and strip-till tillage, multi-story cropping, nutrient management, silvopasture establishment, other tree and shrub establishment, and shelterbelt establishment. Practices with a medium-high potential to mitigate GHG emissions include: contour buffer strips, riparian forest buffers, vegetative buffers and shelterbelt renovation. The following cropland BMPs with ancillary GHG benefits were selected for implementation in the SRR WRAPS:

- Conservation cover
- No-till and strip-till tillage
- Nutrient management
- Contour buffer strips
- Riparian buffers

A longer, more detailed assessment of cropland BMP effects on GHG emission can be found at http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf.

3.2 Civic engagement, accomplishments and public participation

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement and public participation.

Accomplishments and future plans

Currently, significant civic engagement is being conducted in the SRRW as part of the Shell Rock-Winnebago 1W1P development. These engagement efforts are being led by the SRRWD. During the development of the WRAPS report, engagement with local government staff allowed for sharing of information and establishment of priorities. Public engagement will take the form of public meetings informing watershed citizens on the WRAPS and corresponding TMDL reports as well as highlighting the public review and comment period.

One Watershed, One Plan development

During the development of the Shell Rock River WRAPS, three committees were formed to steer and develop the 1W1P: steering, advisory, and policy committees. These committees included representatives from SWCDs, municipalities, state, local governments, agricultural groups, conservation groups, and county commissioners. The committees are meeting regularly to discuss plan development.

In addition to the committee meetings, several public outreach events were held to identify and prioritize resource concerns and applicable actions to address those concerns. More information on civic engagement activities during the 1W1P process, including their stakeholder engagement plan, is available on the SRRWD website.

Freeborn County Area Soil Health Team

The mission of the Freeborn Area Soil Health Team is to facilitate local collaboration that encourages, educates, and demonstrates how to improve area soil health and water quality while improving productivity, profitability and sustainability of natural resources. Recent civic engagement events in Freeborn County included a September 7, 2019, soil health tour where local farmers and see and discuss examples of reduced tillage and cover crop practices.

Freeborn County

Freeborn County Environmental Services is the lead for the SSTS program, private well testing (upon request) for nitrate/nitrite and fecal coliform, Feedlots, Wetland Conservation Act (WCA), Shoreland, zoning, Buffer enforcement and Household Hazardous Waste/Recycling. On-going and future civic engagement plans for the SRRW includes a SSTS inventory (on-going until 2029). Freeborn County is also the drainage authority responsible for maintaining public ditches.

Freeborn County SWCD

The Freeborn County Soil and Water Conservation District (SWCD) conducts outreach and civic engagement through regular work including:

- Volunteer Well Monitoring Network;
- Conservation Reserve Enhancement Program (CREP) and Conservation Reserve Program (CRP) acre enrollment;
- Tree sales;
- No-till drill rental;
- Volunteer conservation guidance (BMPs: waterways);
- Monitoring and assessing public water/ditch buffers every three years;
- Volunteer rain gage readers (state climatology);
- Assists with administering Minnesota Agricultural Water Quality Certification Program (MAWQCP).

Shell Rock River Watershed District

Established in 2003, the SRRWD leads efforts to improve water quality in the watershed. The SRRWD has active partnerships with the City of Albert Lea and several citizen groups including Albert Lea Anglers, Albert Lea Lakes Foundation, Pheasants Forever and Ducks Unlimited. SRRWD routinely holds civic engagement events. In 2019, this included Enviroscape demonstrations to youth, Service Club presentations and weekly watershed emails. 1W1P efforts are also being led by SRRWD staff.

City of Albert Lea

As a permitted MS4, the City of Albert Lea conducts several public engagement events to discuss stormwater. On an annual basis, the City holds a public meeting to present their SWPPP, educate citizens on SWPPP efforts, and receive input on the SWPPP content. The City also holds public meetings for its Wellhead Protection Plan and DNR Local Water Supply Plan. Information regarding these local plans can be made available by contacting City of Albert Lea staff.

WRAPS and TMDL reports

Throughout the development of the WRAPS and TMDL reports, several meetings were held with local stakeholders including local government staff and/or elected officials, as well as regional staff from DNR.

Table 38. Meetings conducted between MPCA and SRRW stakeholders for WRAPS/TMDL report development.

Date	Meeting/Event	Topics
Jan. 10, 2012	SRRWD	TMDL
Feb. 9, 2012	City of Albert Lea, City Council Work Session	TMDL, Stormwater
Feb. 9, 2012	Freeborn SWCD	TMDL
Dec. 6, 2012	Freeborn County Board work session	TMDL
July 22, 2015	TMDL/WRAPS committee	WRAPS development meeting #1
Apr. 13, 2016	TMDL/WRAPS committee	WRAPS development meeting #2 and SRRW wetlands
Jan. 15, 2019	TMDL Discussion	Discussion of modeling results and took input for future modeling scenarios.
Aug. 6, 2019	WRAPS working meeting	Assign nitrogen and phosphorus reduction scenarios
Oct. 22, 2019	WRAPS working group meeting	Review and determine watershed priorities
Nov. 12, 2019	TMDL discussion	Discuss the draft Shell Rock TMDL and the updated modeling/associated documentation.
Dec. 12, 2019	WRAPS working group meeting	Review preliminary WRAPS report

The MPCA staff are members of the Shell Rock-Winnebago 1W1P Advisory Committee, which are meeting to develop the future 1W1P.

Public notice for comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from July 27, 2020 to September 25, 2020. There were eight comment letters received and responded to as a result of the notice.

The MPCA presented information on the WRAPS/TMDL and facilitated public comments/questions at the following public meetings during the public notice:

- MPCA Webex public meeting; August 4, 2020
- City of Albert Lea Council Meeting; August 24, 2020

In addition, an informational presentation on the WRAPS/TMDL was recorded and published on MPCA's SRRW webpage.

3.3 Restoration strategies

This section provides a general approach for water quality restoration in the SRRW. This approach includes input from LGUs and regional partners. This less prescriptive method also makes use of what has been employed in other Southern Minnesota watersheds. The strategies outlined below are subject to adaptive management, which is an iterative and community-based approach of implementation, evaluation and course correction. This section provides a foundation for more refined conservation practice implementation, which will be developed in the 1W1P process.

A general guide to this section is to utilize the priority area maps of Section 3.2 and Appendix K for general orientation on water quality by subwatershed. The strategies are provided in three tables, and it is recommended to work through Table 39, Table 40, and Table 41 – in a sequential fashion. Table 40 provides direction on important factors and pollutants by impaired lake or stream. Factors include altered hydrology and aquatic habitat. Pollutants include TP, N, sediment, and bacteria. A general ranking is suggested, and not all water resources are ranked for each factor or pollutant. The capacity to distinguish between the four pollutants and the two factors that are present in Table 39 is limited. To fully complete the ranking, and provide adequate justification, additional data collection would be required. In the interim, a general ranking provides a substantial focus for implementation. When future water quality data sets are developed, refinements to this approach can be taken. The general method employed in this series of tables is to focus attention on the most critical factors for a water resource. There are multiple benefits that will occur, as working on one set of strategies can also help improve conditions for a second or third pollutant or condition.

To further introduce this sequence of strategy tables, the table title and number are:

Table 39. Shell Rock River Watershed - Impaired Water Resources, General water quality and ranked factors affecting water quality

Table 40. SRRW high level Watershed Restoration and Protection Strategies

Table 41. SRRW conservation practices and BMP examples by strategy type with general adoption rate estimates

Included below each table are a set of explanations and a key.

For example, the Shell Rock River is noted in Table 39 to have phosphorus, DO, bacteria, sediment, pH, and biological issues. TP and altered hydrology are considered as the two highest ranking factors affecting Shell Rock River conditions. Table 40 has rows for each of the ranked factors, with general water quality conditions, goals, targets, and recommended strategy groups. Information on upper watershed goals is included, since pollutant reductions in the upper watershed will improve conditions throughout the system. The last column of Table 40 lists restoration strategies, by group, to address the factor or pollutant. This leads to Table 41, where the strategy group is further developed to recommend BMPs, the scale where implementation occurs, general adoption rates that will be required, and any additional notes to inform the watershed planning and implementation process. A similar sequential process is used for the other impaired streams, and the impaired lakes.

Table 39. Shell Rock River Watershed - Impaired Water Resources, General water quality and ranked factors affecting water quality.

Water Body Name	WID Streams (07080202-*ZZZ*) Lake (DNR #)	General Location	Current Water Quality Condition Summary (see TMDL for statistics)	Factors / Pollutants Affecting Resource Ranked in priority order* 1 = highest priority for WQ						
				TP	N	Sediment	Bacteria	AH	Habitat	DO
Shell Rock River	-501	Albert Lea Lk. To Iowa border	High TP, periods of Low DO with periods of high DO variation, limited habitat and stressed by nitrate, TSS and pH, with biota impairments due to the accumulated effects of above pollutants and stressors. Bacterial impairment. Channel gradient and habitat constraints are also present in this 12-mile reach.	1	6	4	5	3	7	2
Bancroft Creek	-507	Upper subshed, tributary to Fountain East	Moderate TP, but a high level is DOP, high channelization and poor habitat, with bacterial impairment	1	--	--	2	3	4	--
Wedge Creek	-531	Upper subshed, and tributary to Fountain West	Highly channelized system, with excess sediment transport. Bacterial impairment. Moderate TP, but a high level is DOP.	1	--	2	4	3	5	--
Shoff Creek	-516	Subshed with Pickeral lake, tributary to Fountain West	Both RES and TSS impairments, due mainly to proximity below eutrophic Pickeral Lake. Smaller subshed, but altered hydrology and wetland losses have occurred.	2	--	1	--	3	--	--
White Lake	24-0024-00	Upper subshed	High TP and lake WQ response variables	1	--	--	--	--	--	--
Fountain Lake W.	24-0018-02	Wedge Creek subshed. West Albert Lea city	Eutrophication and sedimentation from highly altered upper subwatershed	1	--	--	--	2	--	--
Fountain Lake E.	24-0018-01	Between Fountain Lk. W. and Albert Lea Lake. Central Albert Lea city.	Eutrophication and sedimentation from highly altered upper subwatersheds	1	--	--	--	2	--	--
Albert Lea Lake	24-0014-00	Receives flow from Fountain Lk. W. and Peter Lund Creek. SE of Albert Lea.	Eutrophication and sedimentation from highly altered upper subwatersheds	1	--	--	--	2	--	--

Water Body Name	WID Streams (07080202-ZZZ) Lake (DNR #)	General Location	Current Water Quality Condition Summary (see TMDL for statistics)	Factors / Pollutants Affecting Resource Ranked in priority order* 1 = highest priority for WQ						
				TP	N	Sediment	Bacteria	AH	Habitat	DO
Pickeral Lake	24-0025-00	Upper subshed, SW Albert Lea city	Eutrophication and poor water quality. Fish reclamation project in 2009 improved conditions for some years.	1	--	--	--	2	--	--

*** Table 39 key and explanations:**

-- = Not currently considered a critical priority (i.e. no specific numeric ranking, and pending additional data collection/analysis)

Priority ranking is based on a review of the current resource water quality, impairments, and how the resource affects other downstream water resources, especially those in the SRRW. Best professional judgement is also a factor that was used for estimating rankings. (For example: Wedge Creek has a bacterial impairment, as well as sediment and phosphorus problems. The bacterial pollution can affect how people use the creek itself, and the downstream lake resources. But, in this assessment - the downstream effects of sediment and phosphorus transport from Wedge Creek into the lakes, translate that TP and sediment are ranked somewhat higher, than bacteria).

Key:

AH	Altered Hydrology
DO	Dissolved Oxygen
N	Nitrogen
TP	Total Phosphorus
WQ	Water quality

Table 40. SRRW High Level Watershed Restoration and Protection Strategies

Parameter	Identified Condition	WQ Goal (s)	Watershed-wide goal	Upper Watershed* goal	10-year target (meet by 2030)	Restoration and Protection Strategies
Phosphorus	Five impaired lakes (TP: 0.175-0.300 range)	**Lakes:** summer mean TP < 0.90 mg/L	Lake TMDL TP reduction: Pickeral: -46% White: -55% Fountain W: -71% Fountain E: -69% Albert Lea: -63%	Lakes: responding to stream reductions, show a downward trend	Lakes: downward trends for TP and chlorophyll. Upward trend for secchi transparency. Decrease algae bloom frequency and severity.	Feedlot runoff control Nutrient management Point source reductions Drainage practices – fields Drainage practices - systems In-lake management
	Two impaired streams: **Shell Rock River** avg 0.40 mg/L. **Shoff Creek** avg 0.22 mg/L.	**Streams**: summer mean TP < 0.150 mg/L	NRS goal: 45% reduction (2040)	Streams: -5 to -10% of TP load Focus on DOP component of TP	Streams: -3 to -5% TP reduction	
		Tributaries meet TP TMDL allocations			-36% (19,000 lb/yr) watershed phosphorus load reduction	
Nitrogen	Primary stressor in Shell Rock River	FIBI scores > 46.8	-40% reduction watershed nitrogen load (137 tons/year)	Prioritize Bancroft Ck and Peter Lund Ck subwatersheds	12% reduction in nitrogen	Vegetative changes fertilizer optimization Drainage practices
	1,025 T/yr TN average load	MIBI scores > 45	Iowa N03-N goal -18% load reduction			
	3.6 mg/L FWMC	Meet downstream NRS goals				
Sediment	Primary stressor in Shell Rock River	TSS values < 65 mg/L WQS (includes algal form and sediment particles)	Improved habitats (see Habitat)	Shoff Creek: June and August reductions affecting downward trend.		Erosion control Open tile and side inlets Tillage and residue Rural water storage
			Shell Rock River: -56% at very high flows (184 T/day)			
	Shoff Creek: seasonal means normally > WQS		Shoff Creek: -45% at very high flow (10.5 T/day)	Bancroft and Wedge Creek flow mitigation and		

Parameter	Identified Condition	WQ Goal (s)	Watershed-wide goal	Upper Watershed* goal	10-year target (meet by 2030)	Restoration and Protection Strategies
	Seasonal means for Shell Rock River > WQS		Reduced lake-filling	load reductions affecting downward trend		
Bacteria	Wedge Creek geomean 200-500 cfu/100 mL	< 126 cfu/100 mL in streams (monthly geomean)	Meet TMDL allocations.	Meet indicator bacteria WQS.		Urban stormwater management Feedlot runoff control Nutrient management SSTS
	Bancroft Creek geomean 300-430 cfu/100 mL	<1,260 cfu/100 mL (single sample)	Reduce primary contact risks from pathogens.			
	Shell Rock River – 2006 TMDL					
Altered Hydrology	Flashy stream hydrographs	Runoff and stream flow reductions to complement pollutant allocation reductions in TMDL	Trend to reduce runoff ratio[a] over the mid-term		15% reduction of peak stream flows for spring and fall rainfall-runoff events	Rural water storage Soil health buildup Water retention for drainage systems (public and private) Urban stormwater management
	Decline in low base flows					
	Total flow volume affects pollutants and habitat					
	Stream flow timing at downstream end of larger tributaries					
Habitat	Degraded stream habitats due to pollution and channelization	MSHA score > 66	Improve conditions in existing wetlands		Improve degraded wetlands	Riparian area management Rural water storage Restorations using natural channel designs Support WMA and AMA projects
	Average MSHA scores: Fountain Lk HUC-11: 53.5 Shell Rock R HUC-11: 47 Goose Ck HUC-11: 31		Targeted wetland restorations to improve water storage			
	Degraded wetlands: 53% poor, 42 % fair, 6% good.					

Parameter	Identified Condition	WQ Goal (s)	Watershed-wide goal	Upper Watershed* goal	10-year target (meet by 2030)	Restoration and Protection Strategies
Aquatic biology	Shell Rock River poor average IBI scores: FIBI: 44.1 MIBI: 36.7	Biological indices are trending upward				Riparian area management Rural water storage Channel restorations Native aquatic plants
		FIBI scores > 46.8				
		MIBI scores > 45				
Dissolved Oxygen	Shell Rock River listed as impaired by DO and DO flux.	Maintain minimum of 5 mg/L DO WQS	DO TMDL reductions	Albert Lea Lake WQS to be attained – which relies on upper watershed improvements.		See strategies for phosphorus Rural water storage
	DO <5 mg/L in 6/10 years (mostly summer months with high DO flux).	Meet DO flux WQS (≤5 mg/L)	TP TMDL reductions			
	Oxygen demand exceeds allowable load by 70%.	See TP reductions for streams and lakes	Altered hydrology objectives.			
pH	Shell Rock River impaired by high pH (>9.0)	Reduce pH to WQS: 9.0 < pH > 6.5	Meet lake TP allocations and Shell Rock River allocations to reduce overall eutrophication	Tributary nutrient reductions leading to improved lake WQ		See strategies for phosphorus Lake WQ improvement
	7/10 years have pH > 9.0					

*Upper watershed: Wedge Creek, Bancroft Creek, Shoff/Pickeral, and Peter Lund Creek Subwatersheds, above Fountain and Albert Lea Lakes.

a. Runoff ratio (from Altered Hydrology) parameter means the amount of runoff per unit of precipitation. It is a means of normalizing runoff statistics, based on the reality of variable precipitation across a watershed and from year to year.

Table 40 explanations:

- This summary table includes the 10-year targets and adoption rates described in general terms. The table also includes general strategies (only), without defining a list of specific BMPs. See Table 41 for more specific practice types and BMPs, within the stated strategies.
- The water quality goals are consistent with the Minnesota WQSs. The watershed-wide goals are from the TMDL and the Minnesota NRS. The 10-year targets are reasonable estimates to help define a decade of continued progress.
- Aquatic biology and pH are included column 1. Aquatic biology is an overall water quality condition, for both lake and stream resources. For lakes, there is no WQS for aquatic biology. For streams, there are numeric criteria for fish and macroinvertebrates (see Section 2.3). Both of these are components for high level strategies, and so were included here, while not explicitly noted in Table 40.

- Downward trend: despite the inevitable year-to-year variability, a trend over several decades will be moving downward (e.g. runoff ratio can show a downward trend over 20 years).
- Upward trend: despite the inevitable year-to-year variability, a trend over several decades will be moving upward, using an appropriate statistical methods (e.g.: the stream MIBI is showing an improvement and trending upward, over the last 20 years.)

Key for Table 40.

AMA	Aquatic management area
cfu	colony-forming unit
DO	Dissolved oxygen (and DO flux is the variation between the highest and lowest values in 1 day)
DOP	Dissolved phosphorus (form readily available to algae)
FIBI	Fish Index of Biotic Integrity
MIBI	Macroinvertebrate Index of Biotic Integrity
NO3-N	Nitrate-nitrogen concentration, the main dissolved form of nitrogen
mg/L	Pollutant concentration in weight by water volume, milligram (mg) pollutant in a liter (L) of water
NRS	Minnesota Nutrient Reduction Strategy
Runoff ratio	Stream flows normalized to precipitation
Shell Rock River	Shell Rock River (WID-501, 12-mile stream reach)
T/day	Tons (U.S. 2000 lbs.)/day
TN	Total nitrogen (inorganic + organic)
TP	Total phosphorus, such as a concentration in a lake, or either concentration of load for a river
WMA	Wildlife management area
WQS	Water quality standard

Table 41. SRRW conservation practices and BMP examples by strategy type with general adoption rate estimates.

Restoration and Protection Strategies	Common scale for BMPs	Example BMPs for strategy type	Adoption rate estimates (general, % range, acres)	Notes and additional factors for consideration
Agricultural tile drainage water treatment	Farm fields	Open tile inlet alternatives Ditch channel side inlets Saturated buffer Controlled drainage Bioreactors	All (90%) = 11,840 acres	Utilize MPDWM grants for side inlet projects See side inlet notes below.
	Open channel ditches		Many (30-50%) = 50 miles	
	Field tile outlets		Few (5-10%) = 450 acres	
	Flatter fields		Some (10-15%) = 910 acres	
	Tile outlets		Few (5-10%) = 450 acres	
Agricultural ditch Management	County ditch system	Water retention for ditch projects Two-stage ditch channels naturalized and designed Off-channel water storage	Most (> 60% for major projects and all improvements)	For both publicly-administered drainage systems (MS 103E) and private multi-farm systems
	Private ditch system		Some, strategically placed and designed	
Riparian area management	Field or pasture edge intersecting with channel or stream	Re-vegetate with perennials	Most (60 – 70%) 660 acres	Strategically widen buffers for floodplain and channel stability
		Widen existing buffer	All (>90%) 3,050 acres	
		Expand buffers in pastured areas	Many (30-50%) 1,300 acres	
Vegetative changes	Row crop fields Marginal fields	Cover crops on corn and soybean	Most (60-70%) = 49,430 acres	Wetland restorations for flood-out or freeze-out acres
		Cover crops after early harvest	Most (70-80%) = 4,160 acres	
		Perennial crops	Many (40-60%) = 4,410 acres	
		Wetlands restorations	Some (15-25%) = 1,980 acres	
Fertilizer optimization	Field scales	Reduce N-rate 30%	Most (30-60%) = 27,210 acres	Utilize MAWQCP and private sector TA
		Use N-inhibitor	Some (10-20%) = 7,870 acres	
		Spring pre-plant nitrogen	Few (10%) = 5,900 acres	
		Sidedress nitrogen	Few (10%) = 4,720 acres	
		Target phosphorus rate	Most (60-90%) = 72,340 acres	
		Spring pre-plant P	Many (40-50%) = 5,740 acres	
Feedlot runoff control	Feedlot sites	Manure storage runoff	All (>90%) 61 feedlot sites	
		Open lot runoff reduction/treatment		
		Feed storage runoff reduction/treatment		
		Feedlot relocation	Few: only if BMPs will not work	
Nutrient Management	Row crop fields	4Rs: Rate, form, placement, timing	Most (X%) = 44,161 acres	
		Inject/incorporate manure	All (95%) = 3,940 acres	
		Manure spreader calibration	Some	
		Precision nutrient management	As many as possible	

Restoration and Protection Strategies	Common scale for BMPs	Example BMPs included in the strategy	Adoption rate estimates (general, % range, acres)	Notes and additional factors for consideration
Erosion Control	Row crop fields	Water and sediment control basins Terrace Grassed waterway Filter strips Stripcropping	Most (60-75%), based on SWCD survey and TA	
Rural water storage	Row crop fields	Soil health buildup	Many (25-35%) = 20,550 acres	
		Wetland restoration	Selected few (<5%) = 1,980 acres	
		Wetland construction	Few (<5%) = 910 acres	
		Controlled drainage		
		Water storage pond		
Tillage and residue	Row crop fields	Conservation tillage No-till Ridge till Contour tillage/farming	Most (75%) = 34,140 acres (using one example BMP)	
SSTS	Rural residences	Inspection	Most	
		Maintenance		
		Replacement/Upgrade	All (100%) if failing/ ITPHS	
Soil health buildup	Fields and farms	See expanded Table 43 below		
Natural channel restoration	Stream segments	Small-scale restorations	Some: selected/surveyed/designed projects	Reduce near-channel sediment sources
		Larger-scale channel projects		
Urban Stormwater management	Residential yards to subsheds in urban and suburban areas	Infiltration BMPs	Most	See MPCA's Stormwater Manual FMI
		Construction sites Pond treatments	All	
In-lake management	Lake watersheds and lake basins	Native aquatic plants (maintain support)	As planned by DNR and SRRWD	Internal load references: Cooke et al (1994), and footnote; Minnesota State Government, 2020
		Continue carp and goldfish population estimates		
		Biomanipulation		
Point source reductions	Cities, Industrial sectors, and individual business			TMDL and point source regulatory program approach.

		Municipal and industrial wastewater treatment upgrades and enhancements		Point source/nonpoint source pollutant trading options.

Table 41 explanations

- The restoration and protection strategies that are here in column 1, match those in Table 40 column 5.
- Adoption rates and associated acres come from NBMP and PBMP developed by U of MN (2019). When both the NBMP and PBMP tools employed a specific practice, the tool that provided the higher adoption rate and acreage involved was selected. The adoption rate estimates and example BMPs within a given strategy "line-up" as rows, if there are multiple entries. For example, within the fertilizer optimization strategy row, there are six example BMPs listed, with 6 corresponding adoption rate estimates. The NBMP tool and the PBMP tool are referenced as University of Minnesota (2019).
- There is some redundancy in Table 41, as for example, Rural Water Storage has Soil Health Buildup as a set of practices and BMPs, and cover crops are also part of the Vegetative Change Category. This is deemed appropriate because several strategies may incorporate some common BMPs.
- Drainage ditches - Side Inlet information. The number of side inlets per mile of open channel drainage ditch varies with the topography, soils and land slopes. Estimates from Bailey (2020) and Fox (2020) are about 4-5 side inlets/ditch mile. The practice life span is about 25 years, and in Freeborn County, about 50 need to be installed initially, and others repaired (Fox 2020). An alternative side inlet calculator is available at Greater Blue Earth River Basin's website (GBERBA 2020). Alternative side inlets allow for temporary ponding behind a dike, and reduced sediment delivery to the ditch channel.
- In-lake management - There are numerous other reports and publications available to provide background information, research results, and case study analysis about internal loading. The book titled "Restoration and Management of Lakes and Reservoirs" by Cooke et al (1994) is a standard reference that covers basic limnology, algal biomass control, macrophyte biomass control, and multiple benefit treatments. Multiple benefit treatments can include hypolimnetic aeration, artificial circulation, and sediment removal. Nutrient control by sediment removal is addressed by Cooke et al (1994); when significant nutrient loading from sediments can be documented, this practice might be expected to improve overall lake and water quality conditions.

Table 41 Key:

AP	Aquatic plants
IPHT	Imminent public health threat
MAWQCP	Minnesota Agriculture Water Quality Certification Program
MPDWM	Multi-purpose drainage water management program (BWSR)
TA	Technical assistance

The following words are used to estimate adoption rates:

All	> 90%
Most	> 60%
Many or much	>30%
Some	>10%
Few	<10%

The rural water storage strategy is especially critical, due to altered hydrology, precipitation and runoff events, and land use. Several tools and regional watershed examples are now available to use. The Conservation Market Place has developed workbooks to assess watershed-scale results from vegetative cover practices, surface impoundments, and increased SOM (https://www.conservationmarketplacemidwest.org/linking-water-storage). The Minnesota Public Drainage Manual was updated in 2016, and includes a useful chapter on BMPs. Importantly, this update include BMPs in both "on-system" and "off-system" locations (i.e. on the ditch versus in the drainage area of a ditch system). Water storage via wetland impoundments can be either on-system or off-system (BWSR 2016).

The Minnesota NRS (MPCA 2016) also provides BMP lists to achieve phosphorus and nitrogen reductions, including categories for core practices and supporting practices. Within each main category, there are practices for avoiding, controlling, and trapping pollutants. For agricultural land uses, the recommended high priority practices for the SRRW in both categories are:

Table 42. Avoiding, controlling and trapping BMP examples.

Practice Category	Avoiding	Controlling	Trapping
Core Practice	Cover crops	Residue and tillage	Filter strips
	Nutrient management	Grassed waterways	Constructed wetlands
	Crop rotation	Drainage water management	Wetland restorations
Supporting practices	Manure storage	Diversion	Critical area planting
	Conservation cover	Water control structures	WASCOB*

***WASCOB = water and sediment control basin, NRCS practice 638.**

Soil health "build-up" is a category of BMPs and conservation practices for agricultural lands. It is included in several of the strategies noted in Table 41 (see: rural water storage, and nutrient reduction). The main NRCS conservation practice standard for cover crops (# 340) includes grasses, legumes, or forbs that are planted to provide seasonal cover on cropland when the soil would be bare. Table 43 shows the other related conservation practices that are included in this "build-up" approach to reinforce their broad adoption to provide multiple benefits. Some of these practices are in common use for the control of soil erosion on farms in the SRRW.

Table 43. Soil health build up conservation practices.

NRCS Conservation Practice Standard #	Practice
340	Cover Crop
345	Residue and tillage management
329	No-till
346	Ridge Till
332	Contour buffer strips
585	Stripcropping
342	Critical area planting
512	Forage and biomass planting
327, 612	Conservation crop perennials
328	Conservation crop rotation
412	Grassed waterway

3.4.1. Suggestions for Comprehensive Drainage and Watershed Management

Several sections of the WRAPS report have noted the importance of agricultural drainage management. Section 1.2 provides an overview of the types of publically-administered drainage systems present in the watershed. There are also additional data tables, maps and figures that relate to available agricultural drainage information in Appendix H.

While there are always significant details about each drainage system, there are also some common themes or strategies across these systems, that may serve to commonly improve both drainage management and comprehensive watershed management. To continue this approach, there are seven suggestions in this section, for drainage practitioners, and resource managers to consider together.

- **Develop a common set of terms, concepts, scales and understanding:** To update the agricultural drainage network for both agricultural production and water management at larger scales, a set of commonly understood terms and concepts is needed. The University of Minnesota's 'Fields to Streams' publication (UMN/WRC 2015) has several excellent sections on agricultural drainage that can help provide the background for a common understanding of these complex issues.
- **Invest in pre-petition data collection and information analysis:** Conduct pre-petition planning on public drainage systems. Assess where potential "mitigation projects" could occur, so that if an improvement project does occur, there are some potential projects that can be further studied. For example, a project that would increase drainage capacity (ex. a change or conversion of a tile system to an open ditch channel) will likely increase downstream pollutant loading (NO_3-N, TP) if no mitigating projects are included.

- **Use the updated Minnesota Public Drainage Manual:** Take advantage of Minnesota Public Drainage Manual (BWSR 2016), especially Chapter 5 which includes BMPs for both on-system (ex. side inlets on a ditch) and off-system (field-scale conservation practices that can reduce downstream effects).

- **Merge land conservation work and drainage system efforts together:** Utilize BWSR's multi-Purpose drainage water management grant program. This program involves both the drainage authority and the SWCD for 103E systems. It provides project grant funding for the combination of drainage system and farmland conservation management, for improved outcomes.

- **Consider alternative option on how to pay for repairs on public systems.** This option allows drainage authorities to incentivize conservation activities on the farm and field scales, and also reduce repair frequency (for the ditch) and downstream effects. This option for public drainage systems is found in Minn. Stat. 103E.729 (Apportioning repair costs; alternative option. https://www.revisor.mn.gov/statutes/cite/103E.729). In general, the drainage authority may use relative runoff and relative sediment delivery, when apportioning the costs of repair to those landowners benefitting from the system. If a parcel of land in the drainage system is managed so that less runoff and sediment comes off of the land, the drainage authority can reduce the repair cost assessment charged to that parcel. The redetermination of benefits for public drainage systems is another useful technique to update the lists of benefited lands within a system, and thereby set the stage for any future projects. https://bwsr.state.mn.us/sites/default/files/2019-01/Redetermination_of_Benefits_and_Damages_Brochure.pdf

- **Work for improving conditions at several scales, while acknowledging complexity:** Nutrient reductions from highly drained agricultural systems is a challenging effort that will require comprehensive and sustainable management at many scales. Fields, farms, tile systems, drainage ditches, wetlands (natural and constructed), water storage basins, and downstream lakes and rivers are all involved. There are some 'trade-offs' regarding some conservation practices – in that subsurface tile installation can reduce some surface runoff and erosion-driven phosphorus loading (i.e. sediment attached), but a higher dissolved phosphorus load may result from some fields. Dissolved phosphorus may also be released from accumulated ditch channel sediments, under low oxygen conditions. Overall, these conditions point to the need to address and manage for all forms of P.

- **Build water storage into all of the work and plans you develop:** Comprehensive watershed management plans are required to define water storage goals. Assess larger watershed goals with data and information from all of the smaller systems within your HUC-8. Build a comprehensive management system with current data for all agricultural drainage systems in your larger watershed. Consider how project scheduling and sequencing over the mid-term timeframes can be accomplished, using both the 103E process, and cooperative management for non103E systems.

3.4.2. Goals for the Shell Rock River Watershed

Minnesota's Nutrient Reduction Strategy (MPCA 2014)

The reduction of nutrients in the SRRW is required to meet goals and thresholds for water quality improvement within the watershed. All of Minnesota's HUC-8 watersheds, including the SRRW, have also been included in statewide assessments and efforts to reduce nutrient pollution that moves further downstream. These downstream waters include the Shell Rock River in Iowa, the Cedar River in Iowa, the Mississippi River in Iowa and downstream, and the Gulf of Mexico.

Minnesota's NRS further defines the nitrogen reduction for the SRRW as 272 metric tons/year, of which 123 metric tons/year are from cropland sources. The timeframes within the NRS include an interim milestone at year 2025 (- 45% for phosphorus, and -20% for N), and then the final reduction goal in 2040 (maintain reductions and also reduce another -25% for N).

Table 44. General reduction targets for phosphorus and nitrogen in the SRRW - MN NRS.

Condition	Phosphorus (MT)		Nitrogen (MT)	
	Load	Reduction	Load	Reduction
Existing	**57.6**	**6.9**	**1,359.4**	**271.9**
Load reduction from croplands	**3.1**		**123.4**	
% reduction needed from croplands (by 2045)		**45%**		**45%**

Metric tons/year (Sparrow modeled loads at the HUC-8 outlet, and based on the years 2000-2002.. See Table E-2, and E-3, NRS).

As described in Section 2.3.2, the State of Iowa's Cedar River nitrate TMDL calls for a NO3-N concentration reduction from a current value of 14.7 mg/L to 9.5 mg/L (IDNR 2006). For the Shell Rock River in Minnesota, an 18% reduction in nitrogen load is called for, which would equate to a load of 1,075 tons N/year. Further information is provided in the linked report (IDNR 2006), and from IDNR water quality personnel.

Downstream Goals

Downstream water quality and water resource goals are an important element in Minnesota's Watershed Approach. For Minnesota's Cedar River Basin (Shell Rock and Cedar Rivers), Iowa does indeed "live downstream," and looks northward with expectations that we will do our part. Iowa's approach on the Upper Cedar River Watershed has had a focus on both hydrology (flooding), and NO3-N. Frequent flooding of lands and towns in Iowa has resulted in a local-state-federal partnership to mitigate flood damages and improve resiliency. Water quality improvements have been another important management component in Iowa, and this is especially true for nitrates in surface waters. IDNR (2006) developed a nitrate TMDL for the Cedar River, which specifically calls for a reduction in N-loading from the Shell Rock River (from 1,653 tons N/year to 1,075 tons N/year), which is an 18% reduction. Phosphorus transported from Minnesota is also an issue, being responsible for further degrading water quality in Iowa. The IDNR maintains an ambient surface water monitoring site (#

10120001) on the Shell Rock River at the town of Shell Rock near Waverly, and is also seeking to improve stream conditions for aquatic life, including fish and freshwater mussels. Cooperation and collaboration is strong between Minnesota and Iowa, with each State working toward common clean water goals.

General Guidelines and Project Benchmarks Suggestions

It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. Accordingly, as a very general guideline, progress benchmarks can be established for this watershed that implement activities and practices which will result in a water quality pollutant load decline, as a mid-term to longer-term trend (15 to 30 years). For example, sediment load reductions in the high flow zone will be a function of many factors, including rainfall, runoff, land use, cropping patterns, and numerous management actions across the watershed. Having an alignment of positive trends for all of these, on a yearly basis, would not be practical. However, over a 15 to 20 year timeframe at the HUC-11 scale, a significant level of BMP adoption and sustained implementation can occur, which can result in a decreasing trend (improvement) in pollutant loads. It is acknowledged that larger rainfall-runoff events, as monitored at the larger scales (i.e. Lower tributary reaches), will remain a challenge for decades to come. Factors that may mean slower progress include: limits in funding or landowner acceptance, challenging fixes (e.g., unstable ravines, invasive species) and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters, especially where some higher-impact fixes are slated to occur. However, sustained soil and water management improvements at all of the lower, smaller scales will over time accrue and promote improving trends for both hydrology and pollutant loading. Additional recommendations, related to monitoring, are discussed in Section 4.

4. Monitoring plan

The collection of current land and water data is an important component to both assess progress, and inform management and decision-making. For comprehensive watershed management to progress in the SRRW, there needs to be reliable data that can be used to generate information. The basic needs include an understanding of variability, scale, confidence, and associated risk levels. For example, the scale of the Shell Rock River at Gordonsville, and the requirement of reliable stream hydrology data, is different than the need for data on land uses, phosphorus, and bacteria for the Bancroft Creek Subwatershed. Monitoring of both land and water components is needed and data can then be used to inform and calibrate watershed models. Monitoring data that is assessed for quality, and "condensed down" into informative summary statements and/or maps, can then be used by many people and groups. Such people and groups can then use current land and water information, as they determine plans and make management decisions. Section 8 of the SRRW TMDL also includes information on monitoring. The SRRWD is actively involved in many aspects of monitoring, including a robust tributary and lake monitoring program.

Land information includes the following, and is critical for interpreting any water monitoring data:

- Land use and land cover;
- Existing conservation practices;
  - Agricultural (erosion control, nutrient management, tillage, and cover cropping)
  - Urban (storm water management, erosion control, rate control practices)
- Crop residue levels (including new satellite imagery methods being developed by BWSR);
- Culvert and bridge projects; and
- Ditch channels and drainage system projects (rural and urban).

Water information includes current data and actionable reports about:

- Water quality (chemical, biological, sediment);
- Precipitation;
- Stream geomorphology;
- Stream hydrology (continuous flow at selected sites at a variety of scales);
- Point source pollutant monitoring;
- Pollutant source assessment for nonpoint sources; and
- Stormwater management activities.

Future monitoring recommended by watershed partners include: Shell Rock River periphyton, continuous DO, and tillage and crop residue surveys. Additionally, lakes and streams with insufficient information to perform an assessment should be prioritized for monitoring. It may also be beneficial to conduct future monitoring of lake sediment phosphorus to better measure lake internal phosphorus concentrations.

Data from numerous monitoring programs will continue to be collected and analyzed for the SRRW. Monitoring is conducted by local, state and federal departments, and also special projects that include a monitoring component can be especially helpful.

Local Monitoring Programs

- **SWCDs and private citizens** – rain gauge networks
- **WWTPs** – City discharges of treatment wastewater
- **MS4 City (Albert Lea)** – Stormwater management
- **County** – Feedlots, SSTS, planning and zoning, and public drainage system administration
- **Watershed District (Shell Rock)** – River, stream and lake monitoring. Carp population estimates and distribution. Bridge and culvert replacements.

All data collected locally is encouraged to be submitted regularly to the MPCA for entry into the Environmental Quality Information System (EQuIS) database system. http://www.pca.state.mn.us/index.php/data/surface-water.html

State Programs

- **MPCA - Intensive Watershed Monitoring** collects water quality and biological data throughout each major watershed, once every 10 years. Cycle 2 IWM in the Shell Rock River began in 2019. This second round of monitoring included eight sites for biology and three sites for water chemistry. SRRWD is the lead for the chemistry sampling and MPCA is the lead for the biological sampling. Chemistry samples were collected on Goose Creek, Wedge Creek, and Bancroft Creek, while biology measurements were taken on Goose Creek, Wedge Creek, Bancroft Creek, Shoff Creek, County Ditch 16, Peter Lund Creek, and the Shell Rock River. There is a remaining fish site on Goose Creek that will be sampled in 2021; delayed because of restrictions due to the Corona Virus. This data provides a periodic but intensive "snapshot" of water quality throughout the watershed. http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/water-quality-condition-monitoring/watershed-sampling-design-intensive-watershed-monitoring.html
- **MPCA - Watershed Pollutant Load Monitoring Network** intensively collects pollutant samples and flow data to calculate daily sediment and nutrient loads on an annual or seasonal (no-ice) basis. In the SRRW, there is one subwatershed pollutant load monitoring sites. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/streams-and-rivers/watershed-pollutant-load-monitoring-network.html
- **MPCA - Citizen Surface Water Monitoring Program** is a network of volunteers who make monthly lake and river transparency readings. There are data collection locations in the SRRW that need citizen volunteers. These data provide a continuous record of water transparency measurements (for streams) or secchi depth measurements (for lakes) throughout much of the watershed. http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/volunteer-water-monitoring/volunteer-surface-water-monitoring.html
- **DNR/MPCA Cooperative Stream Gaging** – Shell Rock River at Gordonsville

- **MPCA - Healthier Watersheds and Clean Water Accountability** is an effort to gather and display data on BMP implementation at the watershed scale. This includes agricultural BMPs and progress for wastewater treatment, using data from local, State and Federal sources. https://www.pca.state.mn.us/water/best-management-practices-implemented-watershed.

Federal Programs

- **USGS Sites -** (Shell Rock River flow monitoring sites downstream in Iowa/current site is at Shell Rock, Iowa)
- **National Weather Service –** Precipitation, weather and climate measurements at Albert Lea.

5. References and further information

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6. Appendix

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Appendix A. Watershed wide Stream Assessment

Source: Appendix 3.1 of Shell Rock River Watershed Monitoring & Assessment Report (MPCA 2012).

AUID DESCRIPTIONS				USES					BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS									ECOREGION EXPECTATIONS		
National Hydrography Dataset (NHD) Assessment Segment AUID	Stream Segment Name	Segment Description	NHD Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Aquatic Consumption	Class 7	Fish	Macroinvertebrates	Acetochlor	Alachlor	Atrazine	Chloride	Bacteria (Aquatic Recreation)	Dissolved Oxygen	pH	Turbidity/T-Tube/TSS	Un-ionized ammonia	Nitrite/Nitrate	Total Phosphorous	Suspended Solids
HUC 11: 07080202010 (Fountain Lake Watershed)																						
07080202-509	County Ditch 63	Headwaters to Bancroft Cr	4.5	2C	NA	NA														EXN	MTN	
07080202-528	Judicial Ditch 21	Unnamed ditch to CD 63	0.8	2B	NA	NA														EXN	MTN	
07080202-529	County Ditch 65	Unnamed ditch to CD 63	1	2B	NA	NA			NA	NA										EXN	MTN	
07080202-536	County Ditch 66	Headwaters to Unnamed ditch	4	2B	NA	NA			NA													
07080202-507	Bancroft Creek (County Ditch 63)	CD 63 to Fountain Lk	6.6	2C	IF*	NS			MTS	EXS					EX	IF	MTS	EXP		EXN	MTN	EXP
07080202-527	Unnamed ditch	CD 66 to CD 9	1.6	2B	NA	NA			NA	NA										EXN	EXN	
07080202-526	County Ditch 9	Unnamed ditch to Unnamed ditch	2	2B	NA	NA			NA	NA										EXN	MTN	
07080202-524	County Ditch 11	Headwaters to Unnamed cr	5.5	7	NA	NA		NA	NA	NA												
07080202-531	Unnamed creek	T103 R22W S36, north line to Unnamed ditch	1.5	2B	IF*	NS			NA	NA					EX	MTS	MTS	EXP		EXN	MTN	EXP
07080202-514	County Ditch 68	Unnamed ditch to Mud Lk	1.3	2B	IF	NA										IF	MTS	MTS		EXN	MTN	MTS
07080202-516	Unnamed creek	Mud Lk to Fountain Lk	3.1	2B	NS	NA										IF	MTS	EXS			EXN	EXS
07080202-537	Unnamed creek	Goose Lk to Fountain Lk	1.9	2B	NA	NA										NA†	NA†	NA†			EXN	MTS

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets standards or ecoregion expectations (MT/MTS), Potential Exceedence (EXP), Exceeds standards or ecoregion expectations (EX/EXS). Key for Cell Shading: ▢= existing impairment listed prior to 2012 reporting cycle; ■= new impairment. *Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50 percent) channelized or having biological data limited to a station occurring on a channelized portion of the stream. † The condition of the waterbody where sampled was not appropriate for stream assessment (e.g., wetland flowage, lake effect).

AUID DESCRIPTIONS				USES					BIOLOGICAL CRITERIA		WATER QUALITY STANDARDS									ECOREGION EXPECTATIONS		
National Hydrography Dataset (NHD) Assessment Segment AUID	Stream Segment Name	Segment Description	NHD Length (Miles)	Use Class	Aquatic Life	Aquatic Recreation	Aquatic Consumption	Class 7	Fish	Macroinvertebrates	Acetochlor	Alachlor	Atrazine	Chloride	Bacteria (Aquatic Recreation)	Dissolved Oxygen	pH	Turbidity/T-Tube/TSS	Un-ionized ammonia	Nitrite/Nitrate	Total Phosphorous	Suspended Solids
HUC 11: 07080202020 (Shell Rock River Watershed)																						
07080202-504	Shell Rock River	Fountain Lk to Albert Lea Lk	0.3	2B	NA	NA										IF	EXP	EXP			EXN	EXP
07080202-513	County Ditch 16	Unnamed ditch to Albert Lea Lk	2.5	2B	IF*	NA			NA	NA						IF	MTS	MTS		EXN	MTN	MTS
07080202-534	Peter Lund Creek	CD 12/47 to CD 32	2.8	2B	NA*	NA			NA	NA											EXN	
07080202-535	County Ditch 32	Unnamed ditch to Peter Lund Cr	4	2B	NA*	NA			NA	NA											MTN	
07080202-512	Peter Lund Creek	CD 32 to Albert Lea Lk	0.9	2B	NA*	NA										IF	MTS	EXP			EXN	EXP
07080202-533	Judicial Ditch 20	Headwaters to Shell Rock R	6.1	2B	NA*	NA			NA	NA												
07080202-511	Unnamed ditch (County Ditch 16)	Headwaters to Unnamed ditch	1.3	2B	NA*	NA			NA	NA												
07080202-508	County Ditch 16	Unnamed ditch to Shell Rock R	5.9	2B	IF*	NA			NA	NA						EXP	MTS	MTS		MTN	EXN	MTS
07080202-501	Shell Rock River	Albert Lea Lk to Goose Cr	12.1	2B	NS	NS			EXS	EXS					EX	IF	EXP	EXP		MTN	EXN	EXP
HUC 11: 07080202030 (Goose Creek Watershed)																						
07080202-510	County Ditch 17	Unnamed ditch to Goose Cr	1.6	2B	NA*	NA			NA	NA												
07080202-532	County Ditch 40	Unnamed ditch to Goose Cr	6.1	2B	NA*	NA			NA	NA												
07080202-505	Goose Creek (County Ditch 10)	Headwaters to Shell Rock R	11	7	NA*	NA		IF	NA	NA				MTS	MTS				MTS			

Full Support (FS); Not Supporting (NS); Insufficient Data (IF); Not Assessed (NA); Meets standards or ecoregion expectations (MT/MTS), Potential Exceedence (EXP), Exceeds standards or ecoregion expectations (EX/EXS). Key for Cell Shading: ☐= existing impairment listed prior to 2012 reporting cycle; ■ = new impairment. *Aquatic Life assessment and/or impairments have been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID being predominantly (>50 percent) channelized or having biological data limited to a station occurring on a channelized portion of the stream.

Appendix B. Lakes Assessment

Source: Appendix 3.2 of Shell Rock River Watershed Monitoring & Assessment Report (MPCA 2012).

Lake ID	Lake Name	County	HUC-11	Ecoregion	Lake Area (ha)	Max Depth (m)	Watershed Area (ha)	% Littoral	Mean Depth (m)	Support Status
24-0017-00	Goose	Freeborn	07080202010	WCBP	32.17	---	1343	---	---	N/A
24-0025-00	Pickeral	Freeborn	07080202010	WCBP	201.51	1.22	1498	100.0	0.96	NS
24-0037-00	Sugar	Freeborn	07080202010	WCBP	24.89	0.46	4149	100.0	0.25*	IF
24-0038-00	Halls	Freeborn	07080202010	WCBP	21.69	0.91	412	100.0	0.50*	IF
24-0040-00	School Section	Freeborn	07080202010	WCBP	6.96	---	143	---	0.59	IF
24-0068-00	Mud	Freeborn	07080202010	WCBP	6.8	---	3645	---	---	IF
24-0014-00	Albert Lea	Freeborn	07080202020	WCBP	1074.69	1.83	38047	100.0	0.53	NS
24-0018-01	Fountain (East Bay)	Freeborn	07080202020	WCBP	94.68	4.27	10058	100.0	1.72	NS
24-0018-02	Fountain (West Bay)	Freeborn	07080202020	WCBP	57.54	2.44	21261	100.0	1.57	NS
24-0024-00	White	Freeborn	07080202020	WCBP	63.82	1.07	468	100.0	0.35	NS
24-0027-00	Lower Twin	Freeborn	07080202030	WCBP	111.55	0.76	3320	100.0	0.29	IF
24-0031-00	Upper Twin	Freeborn	07080202030	WCBP	33.87	0.76	2325	100.0	0.29*	IF

Abbreviations:
FS – Full Support
NS – Non-Support
IF – Insufficient Information
N/A – Not Assessed

Key for Cell Shading: ▢ = existing impairment listed prior to 2012 reporting cycle; ■ = new impairment.

*These depths were created by MPCA Staff.

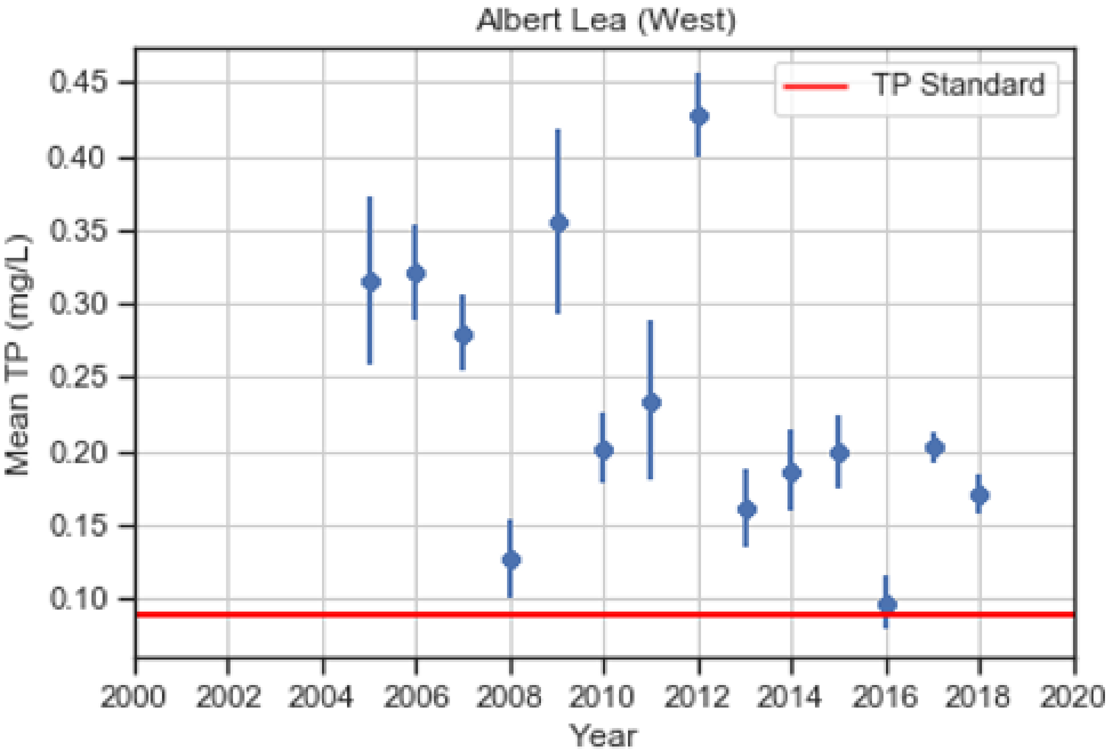


Figure 1. Total phosphorus mean concentrations 2005 – 2018 for Albert Lea Lake (West; RESPEC 2020).

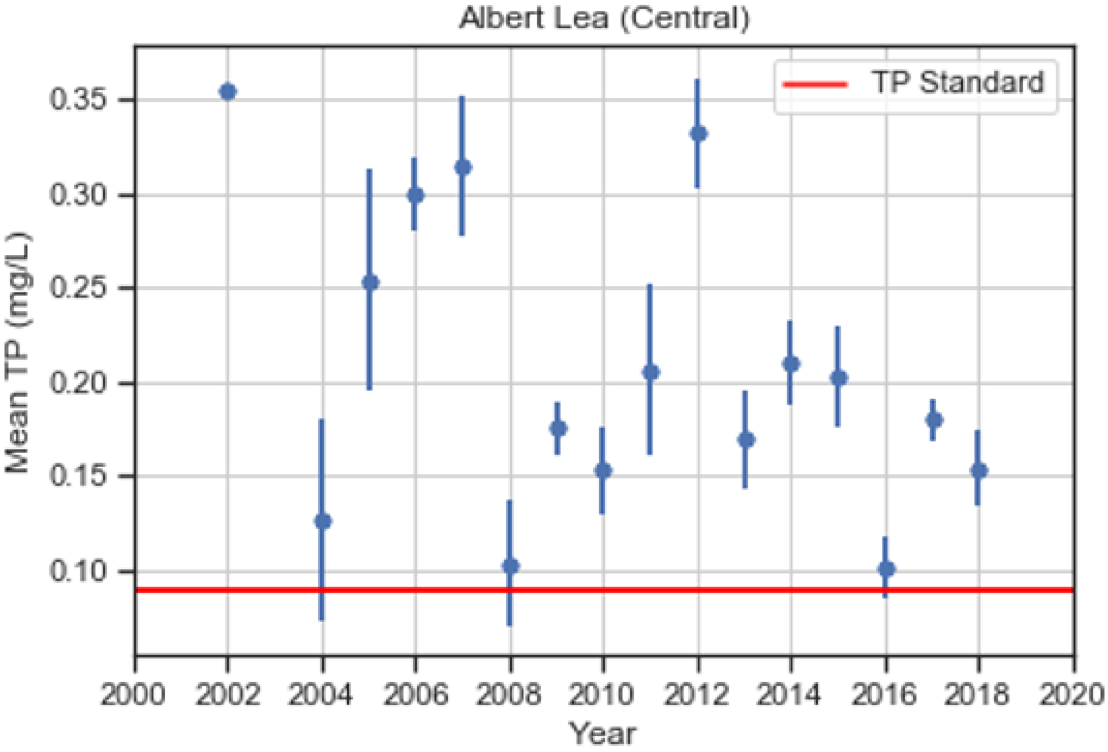


Figure 2. Total phosphorus mean concentrations 2005 – 2018 for Albert Lea Lake (Central; RESPEC 2020).

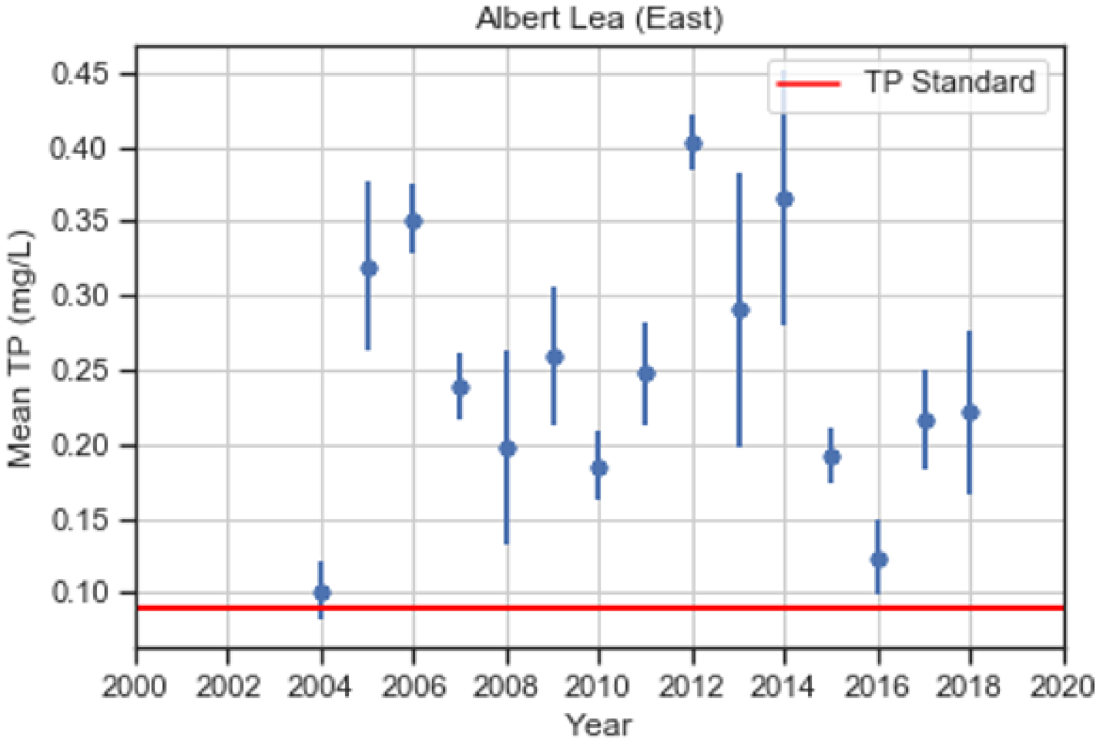
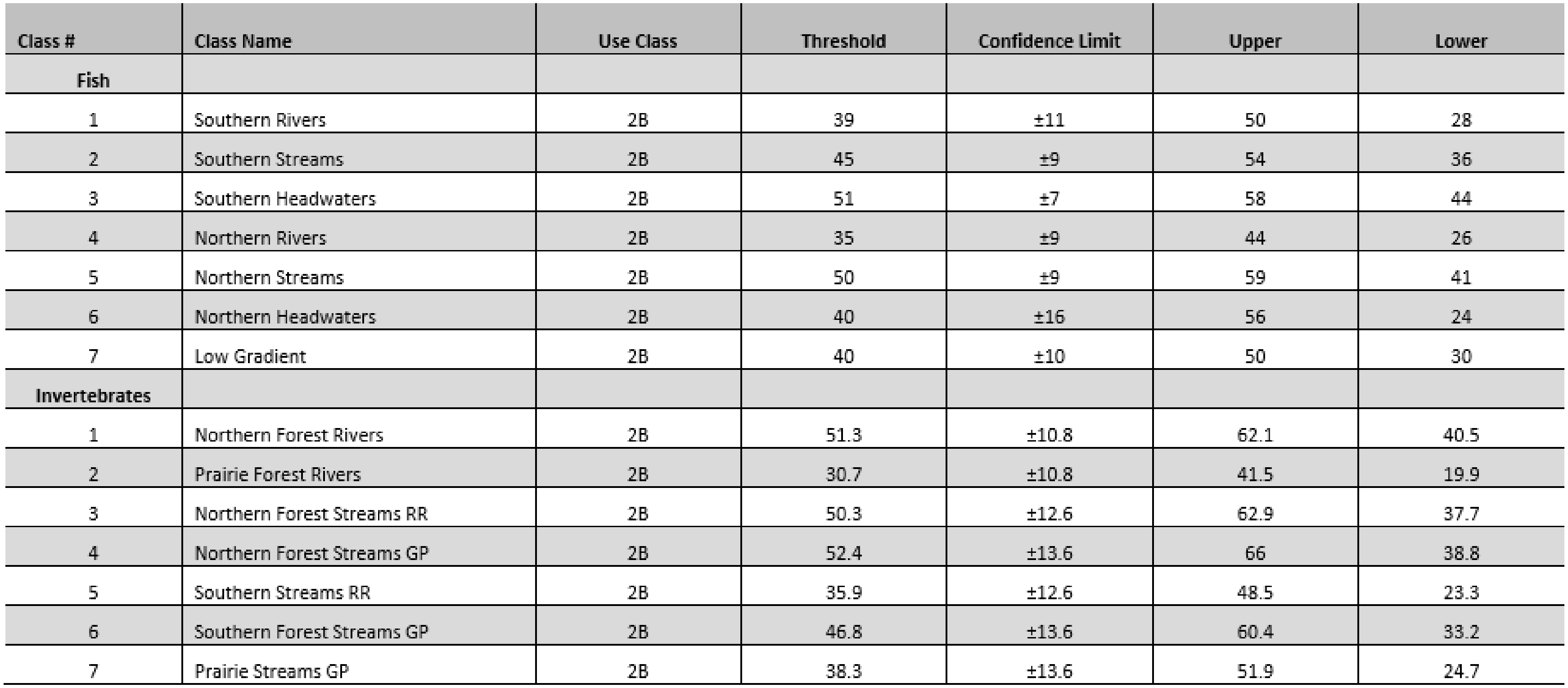


Figure 3. Total phosphorus mean concentrations from 2005 – 2018 for Albert Lea Lake (East; RESPEC 2020).

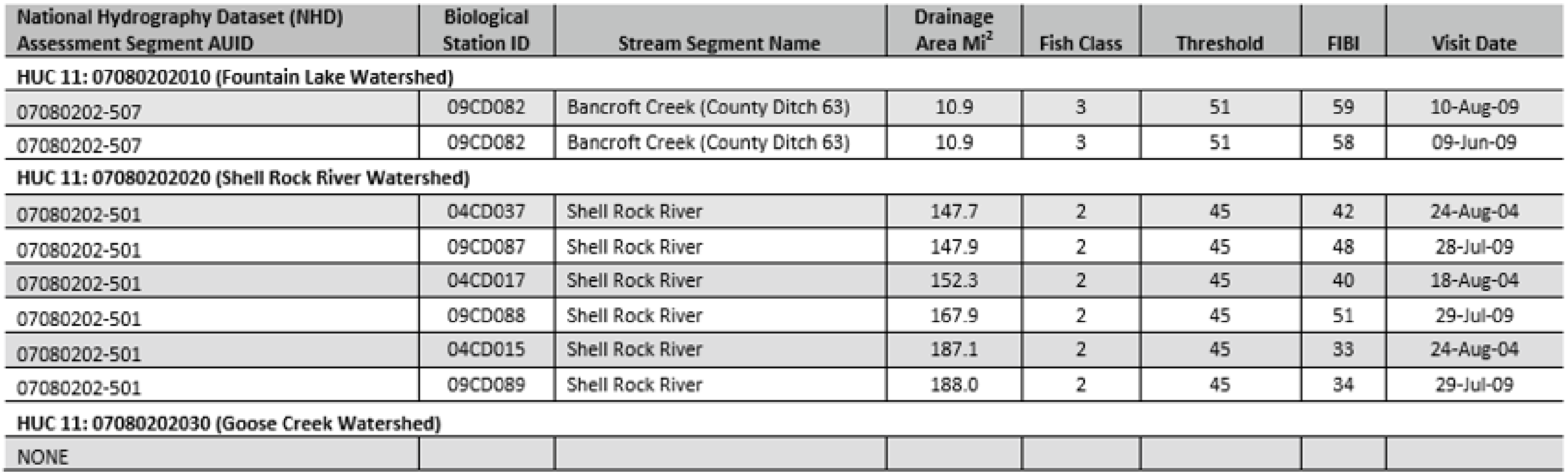
Appendix C. IBI Details from Monitoring and Assessment Report

Source: Appendix 4.1 of Shell Rock River Watershed Monitoring & Assessment Report (MPCA 2012).



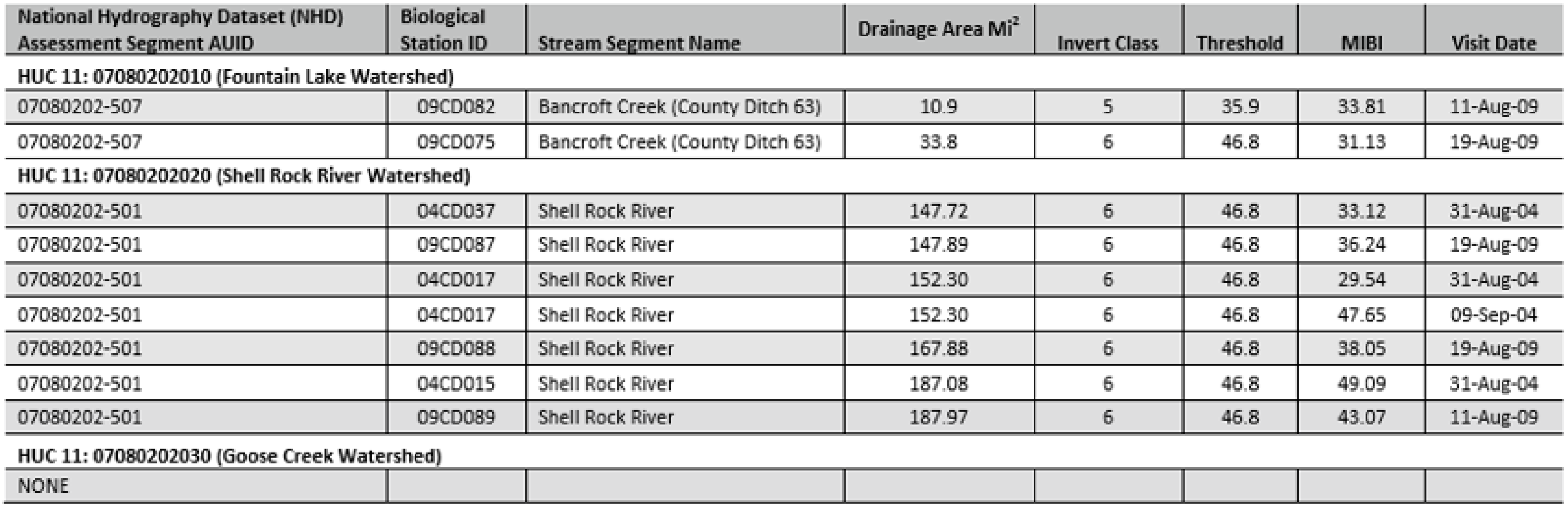
Class #	Class Name	Use Class	Threshold	Confidence Limit	Upper	Lower
Fish						
1	Southern Rivers	2B	39	±11	50	28
2	Southern Streams	2B	45	±9	54	36
3	Southern Headwaters	2B	51	±7	58	44
4	Northern Rivers	2B	35	±9	44	26
5	Northern Streams	2B	50	±9	59	41
6	Northern Headwaters	2B	40	±16	56	24
7	Low Gradient	2B	40	±10	50	30
Invertebrates						
1	Northern Forest Rivers	2B	51.3	±10.8	62.1	40.5
2	Prairie Forest Rivers	2B	30.7	±10.8	41.5	19.9
3	Northern Forest Streams RR	2B	50.3	±12.6	62.9	37.7
4	Northern Forest Streams GP	2B	52.4	±13.6	66	38.8
5	Southern Streams RR	2B	35.9	±12.6	48.5	23.3
6	Southern Forest Streams GP	2B	46.8	±13.6	60.4	33.2
7	Prairie Streams GP	2B	38.3	±13.6	51.9	24.7

Figure 4. Minnesota statewide IBI thresholds and confidence limits.



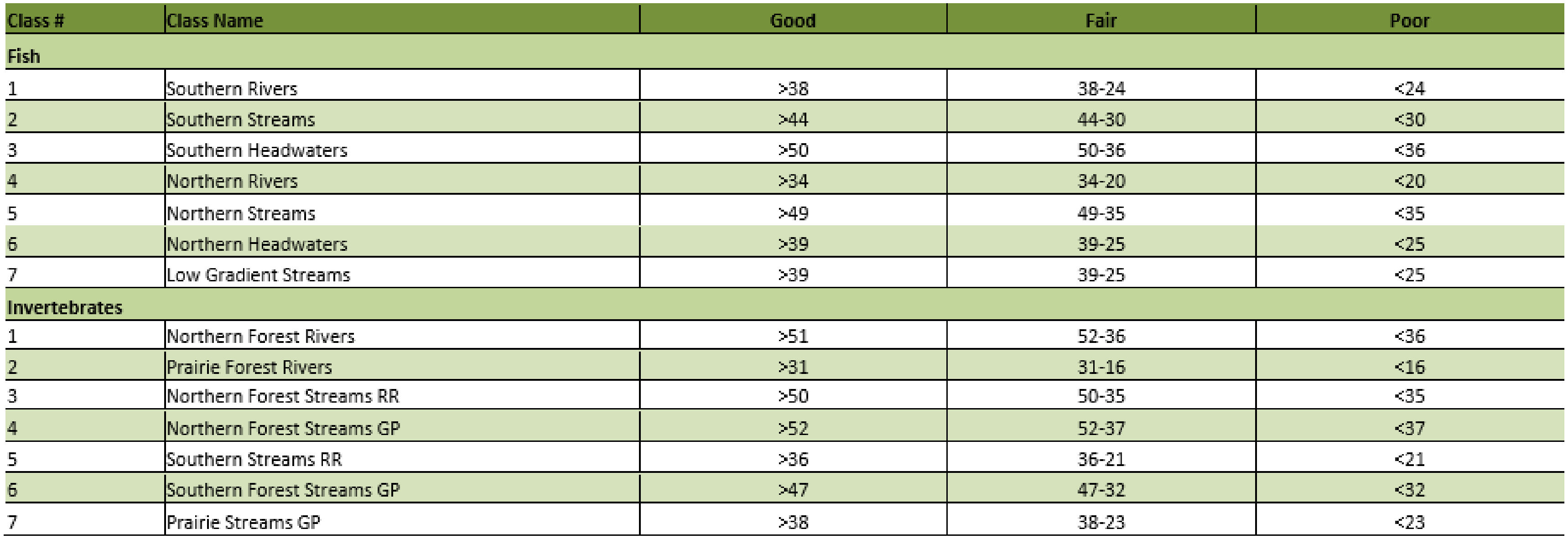
National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Threshold	FIBI	Visit Date
HUC 11: 07080202010 (Fountain Lake Watershed)							
07080202-507	09CD082	Bancroft Creek (County Ditch 63)	10.9	3	51	59	10-Aug-09
07080202-507	09CD082	Bancroft Creek (County Ditch 63)	10.9	3	51	58	09-Jun-09
HUC 11: 07080202020 (Shell Rock River Watershed)							
07080202-501	04CD037	Shell Rock River	147.7	2	45	42	24-Aug-04
07080202-501	09CD087	Shell Rock River	147.9	2	45	48	28-Jul-09
07080202-501	04CD017	Shell Rock River	152.3	2	45	40	18-Aug-04
07080202-501	09CD088	Shell Rock River	167.9	2	45	51	29-Jul-09
07080202-501	04CD015	Shell Rock River	187.1	2	45	33	24-Aug-04
07080202-501	09CD089	Shell Rock River	188.0	2	45	34	29-Jul-09
HUC 11: 07080202030 (Goose Creek Watershed)							
NONE							

Figure 5. Biological monitoring results - fish IBI (assessable reaches).



National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Threshold	MIBI	Visit Date
HUC 11: 07080202010 (Fountain Lake Watershed)							
07080202-507	09CD082	Bancroft Creek (County Ditch 63)	10.9	5	35.9	33.81	11-Aug-09
07080202-507	09CD075	Bancroft Creek (County Ditch 63)	33.8	6	46.8	31.13	19-Aug-09
HUC 11: 07080202020 (Shell Rock River Watershed)							
07080202-501	04CD037	Shell Rock River	147.72	6	46.8	33.12	31-Aug-04
07080202-501	09CD087	Shell Rock River	147.89	6	46.8	36.24	19-Aug-09
07080202-501	04CD017	Shell Rock River	152.30	6	46.8	29.54	31-Aug-04
07080202-501	04CD017	Shell Rock River	152.30	6	46.8	47.65	09-Sep-04
07080202-501	09CD088	Shell Rock River	167.88	6	46.8	38.05	19-Aug-09
07080202-501	04CD015	Shell Rock River	187.08	6	46.8	49.09	31-Aug-04
07080202-501	09CD089	Shell Rock River	187.97	6	46.8	43.07	11-Aug-09
HUC 11: 07080202030 (Goose Creek Watershed)							
NONE							

Figure 6. Biological monitoring results - macroinvertebrate IBI (assessable reaches).



Class #	Class Name	Good	Fair	Poor
Fish				
1	Southern Rivers	>38	38-24	<24
2	Southern Streams	>44	44-30	<30
3	Southern Headwaters	>50	50-36	<36
4	Northern Rivers	>34	34-20	<20
5	Northern Streams	>49	49-35	<35
6	Northern Headwaters	>39	39-25	<25
7	Low Gradient Streams	>39	39-25	<25
Invertebrates				
1	Northern Forest Rivers	>51	52-36	<36
2	Prairie Forest Rivers	>31	31-16	<16
3	Northern Forest Streams RR	>50	50-35	<35
4	Northern Forest Streams GP	>52	52-37	<37
5	Southern Streams RR	>36	36-21	<21
6	Southern Forest Streams GP	>47	47-32	<32
7	Prairie Streams GP	>38	38-23	<23

Figure 7. Good/fair/poor thresholds for biological stations on non-assessed channelized AUIDs

Appendix D. Shell Rock River Primary stressors

Source: Shell Rock River Watershed Biotic Stressor Identification Report (MPCA 2014a).

Stressors	Shell Rock River
Ammonia	No
Chloride	Possible
Chlorophyll-a	Yes
Connectivity	Limited data
Dissolved Oxygen	Yes
Habitat	Yes
Ionic strength	Possible
Low flow	Possible
Nitrate	Yes
Parasitism	Not likely
Predation	Limited data
Pesticides	Inconclusive
pH	Yes
Phosphorus	Yes
Physical crushing and trampling	No
Temperature	Possible
TSS	Yes
TSVS	Possible

Appendix E. Evapotranspiration (ET) Rate Data and Calculation

The presented ET rates are from the following sources/methodologies:

ET rate	Formula/specifics	Reference	Applicable Data
Wetland	$ET_W = 0.9 * ET_{pan}$	Wallace, Nivala, and Parkin (2005)	Waseca station pan ET 1989-2008 average
Lake	$ET_L = 0.7 * ET_{pan}$	Dadaser-Celik and Heinz (2008)	
Crops	Crop ET, Climate II	NRCS (1977)	Table from source

The NRCS crop ET source, despite the source age, was selected because it provided the highest estimates of crop ET. To illustrate this point, the seasonal corn ET rates, as determined from several sources, are presented below:

Using the highest crop ET rates for comparison was desired for multiple reasons: 1) pan coefficients were developed using older data sets and it is likely that corn, with higher crop densities and larger plant sizes, uses more water today than it did when the coefficients were determined, 2) using lower crop ET rates may appear to exaggerate the difference between crop and non-crop ET rates, and 3) error associated with pan ET rates could result in exaggerated differences between estimated wetland/lake ET and crop ET. More information on calculating ET rates is available here: http://deepcreekanswers.com/info/evaporation/ET_water_surf.pdf.

Methodology, data	Source	May-September Corn ET
1. Irrigation table	NRCS (1977)	64 cm
2. SWAT modeling in the Lake Pepin Full Cost Accounting	Dalzell et al. (2012)	54 cm
3. MN Irrigation Scheduling Checkbook, Waseca station temp	NDSU (2012)	42 cm
4. MN Crop Coefficient Curve for Pan ET, Waseca station pan ET	Seeley and Spoden (1982)	39 cm

Appendix F. Soil and Water Assessment Tool (SWAT) watershed modeling

Appendix Format: This appendix includes a background information summary, SWAT model set-up information, 7 figures and 18 data tables. The final section of this appendix includes 21 specific notes that were documented about the SWAT data and model (Gervino 2019).

Background Information: Simulated hydrologic processes include surface runoff, tile drainage, snow-melt runoff, infiltration, subsurface flow and plant uptake. The model allows for consideration of reservoirs and ponds/wetlands, as well as inputs from point sources.

The basic elements for the SWAT model include:

- Explicitly simulates crop management practices.
- Lumps soil type, vegetation, and hydrology into hydrologic response units (HRUs).
- Incorporates climate generator.
- Uses Stormwater Management Model (SWMM) functions for urban impervious runoff.
- Daily timestep.
- Simple channel and reservoir routing.

Specific Methods for Shell Rock River Watershed:

Initial SWAT model set-up information is provided in the Table 1 below.

Table 1. SRRW SWAT model set-up.

Model Factor	SRRW Details
Modeling contractor	Barr Engineering Company
Modeling personnel	Greg Wilson, Senior water resources engineer
Model version	2009.93.6 Revision 477
Land cover	2010 USDA NASS crop data layer
Soils	NRCS SSURGO
Crops	96 % row crops (of which….55% was corn and 45% was soybeans)
Conservation tillage	Corn (4%) and Soybeans (33%)…. % acres > 30% crop residues
Crop fertilization	Enough 28-03-00 applied to account for harvest and loss from leaching/runoff
Simulation period	1999-2007
Calibration period	2009-2010
Growing season months	April - September
Parameterization	Global
Sensitivity analysis	None conducted

The SWAT model calibration for April through September 2009 was used for comparisons to phosphorus loadings and flow-weighted mean concentrations. Since the partial year water monitoring programs do not account for all phosphorus passing a given monitoring site, a modeling objective was to have good agreement (modeling vs. monitoring) for lower flow conditions, and to overestimate phosphorus loads under higher flows. When this was accomplished for the 2009 growing season, the phosphorus load estimates ranged from 2% to 53% higher than the monitoring data alone indicated.

Agricultural lands likely to have tile drainage were estimated by intersecting hydrologic soil groups “C” and “D” (poorly and very poorly drained soils, respectively) with the cultivated croplands. A revised SWAT model was done when the NRCS reclassified the hydrologic soil group characteristics. This revision was also completed by Barr Engineering. This increased the row crops with tile drainage to about 50% to 60% of the total acres in the SRW, reducing row crop acres without tile drainage into the 10% to 20% range.

A final application of the SWAT model was undertaken by the MPCA staff. The objectives of this effort was to build from the initial SWAT developments, and to utilize the model for a subbasin analysis of the main drainage areas above the impaired lakes. It was also an objective to use the model to prioritize subwatersheds within a subbasin, for targeted BMP implementation efforts. Both total phosphorus loads and yields, and sediment loads and yields, were used in this effort. It is noted that the larger subbasin scale include Bancroft Creek, Wedge Creek, Peter Lund Creek, Pickeral Lake, County Ditch 16, County Ditch 55, County Ditch 15, Judicial Ditch 20, the Upper Shell Rock River, and the Lower Shell Rock River. The smaller subwatersheds fit within a given subbasin, and are designated with a subwatershed number. This application of the SWAT model in the SRRW was conducted in 2017-2018 by Nick Gervino, Senior Engineer, Watershed Division, St. Paul, MPCA.

For each contributing subbasin, a SWAT outlet subwatershed was selected, and the associated reach outlet daily organic and mineral phosphorus load was summed for the growing season. For the local surrounding watershed of each lake, the SWAT subwatershed upland dissolved and sediment adsorbed phosphorus load was summed to determine the mineral phosphorus load to the lake, and the organic phosphorus load was added to determine the total phosphorus load. ESRI ArcMap feature classes were used to determine the subbasin outlets. A Microsoft Access database of SWAT output was queried to obtain the output information, and Microsoft Excel spreadsheets were used to perform calculations.

SWAT Modeling Results for the Shell Rock River Watershed:

General Modeling Output Assessment: The sediment yield is constant for four of the subbasins discharging to Fountain Lake. Pickerel Lake has a much lower sediment yield than the other four watersheds. This may be due to the scattering of ponds in the subwatershed and the presence of noncropland along a major portion of the main channel which discharges to Fountain Lake. Also of note is the relatively high comparable mineral phosphorus yields to Fountain Lake from the Wedge Creek and Bancroft Creek Subbasins.

Table 2. Albert Lea Lake subbasin average growing season loads and yields - SWAT outputs.

Parameter		Subbasin			
		County Ditch No. 15	Fountain Lake	Peter Lund Creek	Albert Lea Lake Local
	Land Area, acres	3,832	60,155	18,321	6,198
Sediment	Load, U.S. Tons	1,197	8,342	1,378	727
	Yield, Tons/acre	0.31	0.14	0.08	0.12
Mineral Phosphorus	Load, U.S. Tons	113	24,264	4,679	129
	% Load	0.4	83.1	16.0	0.4
	Yield, lbs/acre	0.03	0.40	0.26	0.02
Organic Phosphorus	Load, U.S. Tons	1,628	2,382	1,466	1,142
	% Load	24.6	36.0	22.1	17.3
	Yield, lbs/acre	0.42	0.04	0.08	0.18
Total Phosphorus	Load, U.S. Tons	1,742	26,646	6,144	1,270
	% Load	4.9	74.4	17.2	3.5
	Yield, lbs/acre	0.45	0.44	0.34	0.20

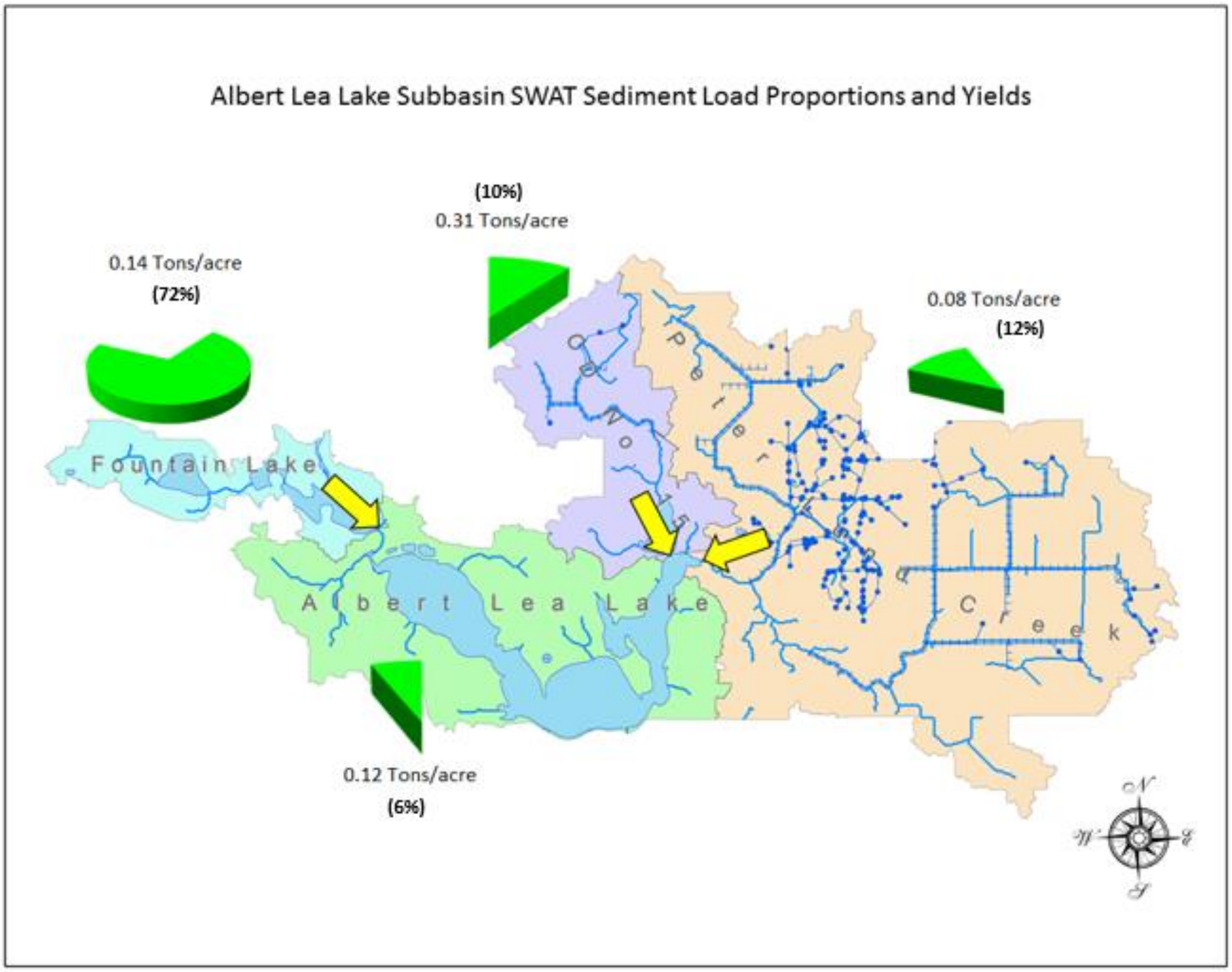


Figure 8. Albert Lea Lake Subbasin SWAT sediment load proportions and yields.

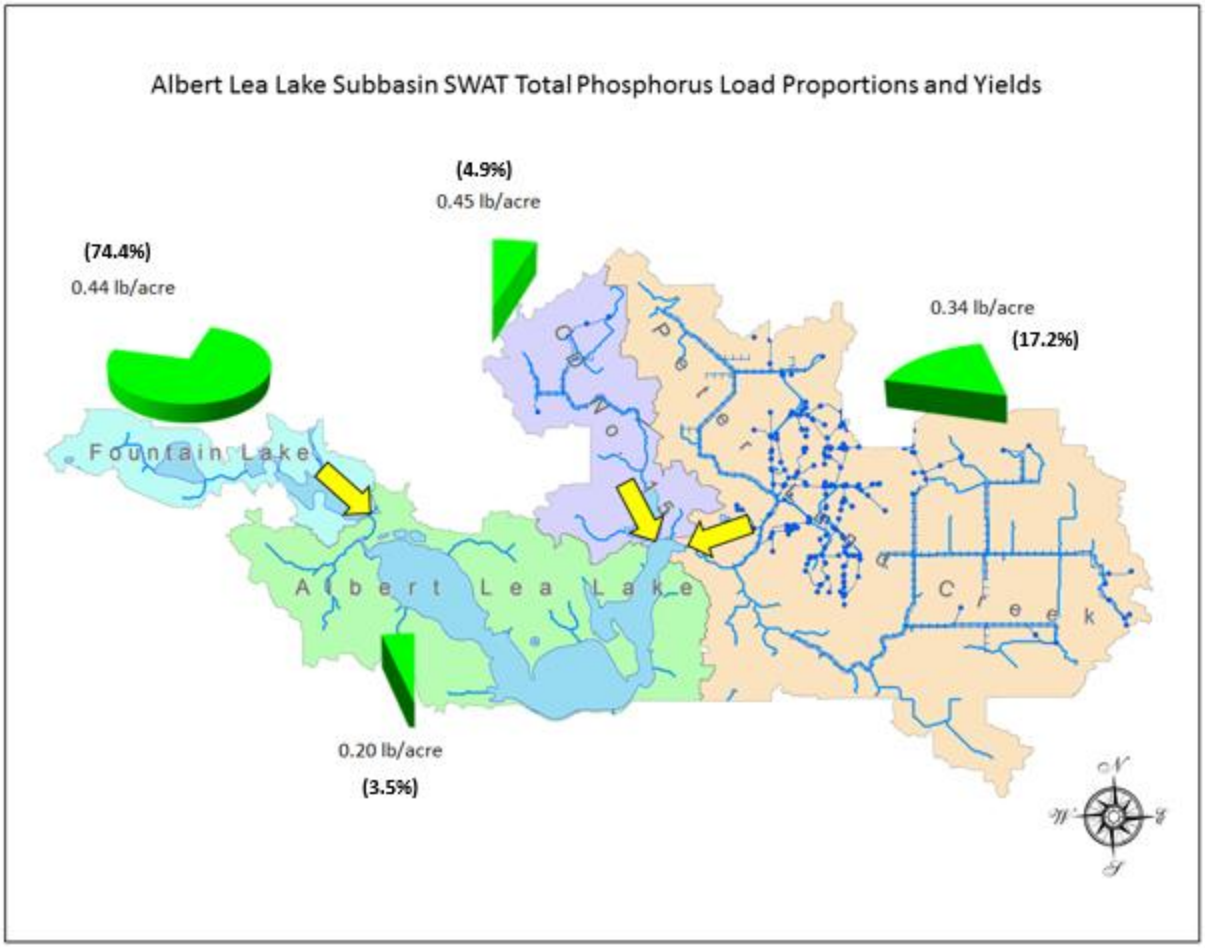


Figure 9. Albert Lea Lake Subbasin SWAT total phosphorus load proportions and yields.

The highest yield of sediment to Albert Lea Lake is from the northern subwatershed that drains to the northeast bay. The yield and load proportion for Peter Lund Creek is lower, reflecting flatter topographic relief. Water flowing from Fountain Lake provides the largest sediment load, even though the yield on a per acre basis is lower than the northeastern tributary.

While the total phosphorus yields are fairly similar for the main portions of the Albert Lea Lake Watershed, a significant portion is from the eastern Peter Lund Creek Subwatershed. The SWAT analysis also confirms the highest load proportion enters Albert Lea Lake from the channel with Fountain Lake.

Comparing loading values for both the Fountain Lake and Albert Lea Lake systems, TP and sediment loads seem to “line-up” together for Wedge, Bancroft, CD-15, the local watersheds, and the channel (between Fountain and Albert Lea Lake). Phosphorus load values plot higher for Peter Lund Creek, and Pickerel/Schoff/Mud systems, and this might point toward a higher dissolved P fraction that is present.

Shell Rock River Watershed Data Tables by Subbasin

Table 3. SWAT Model subwatershed average growing season upland phosphorus and sediment loads, April 1 - Sept. 30th.

Wedge Creek						
SWAT Subwatershed	**Area, acres**	**Organic Phosphorus Load, lbs**	**Soluble Phosphorus Load, lbs**	**Sediment-Adsorbed P Load, lbs**	**Total Phosphorus Load, lbs**	**Sediment Load, U.S. tons**
8	640	711	3.5	92	807	374
9	679	644	3.9	90	738	354
13	211	183	1.6	20	205	72
14	659	621	3.6	83	708	334
18	2093	1833	10.9	251	2095	976
21	1163	1066	6.7	118	1191	425
22	642	627	3.1	83	714	346
23	76	39	0.5	2	42	6
26	98	321	0.8	25	347	93
28	356	470	2.8	40	513	124
29	966	324	2.2	42	369	176
31	1583	1954	9.3	256	2219	1091
35	1427	1072	7.7	136	1216	504
36	200	102	1.1	16	119	52
37	137	84	0.7	11	96	36
38	636	409	5.3	54	469	210
39	715	291	4.3	39	334	154
41	857	724	6.4	85	815	296
42	1418	933	6.2	119	1058	451
43	1024	792	4.6	110	907	474
47	934	962	5.3	123	1091	486
53	810	9	0.7	2	12	8
54	1899	1518	11.1	187	1715	687
85	3743	4101	22.1	520	4643	2070

Albert Lea Lake						
SWAT Subwatershed	**Area, acres**	**Organic Phosphorus Load, lbs**	**Soluble Phosphorus Load, lbs**	**Sediment-Adsorbed P Load, lbs**	**Total Phosphorus Load, lbs**	**Sediment Load, U.S. tons**
82	1222	26	15.7	6	48	15
83	641	510	3.8	78	591	365
84	1252	139	12.9	24	176	94
94	2462	467	3.7	65	536	255
95	3017	55	2.9	6	64	30
96	54	0	0	0	0	0
Fountain Lake						
56	1474	568	4.9	76	649	374
57	231	1	1.4	0	3	1
58	317	5	3.6	1	9	4
59	262	5	4.2	2	11	6
64	259	7	4.7	2	13	5
Goose Lake						
50	420	41	5.9	5	52	14
51	460	9	7.2	9	25	32
52	1199	853	5.6	123	982	470
55	2093	874	8.8	136	1019	650
Pickerel Lake						
63	221	2	1.8	0	4	2
65	253	23	0.8	3	27	12
68	1064	431	5.3	58	495	214
78	70	21	0.2	4	25	16
79	630	699	2.7	86	787	378
81	719	621	4.9	97	724	413
86	748	710	3.0	98	811	426
89	790	781	5.0	105	891	516
90	3415	1883	11.8	288	2183	1213
93	999	702	5.4	108	815	429
County Ditch 15						
48	2235	1447	10.6	212	1669	779
67	1760	1167	7.9	170	1345	734

Judicial Ditch 20						
102	1019	779	4.7	88	872	339
103	4	9	0	1	10	5
108	919	581	4.7	68	654	242
111	1709	1008	7.6	117	1133	419
122	689	521	3.5	76	600	290
123	1080	667	4.3	82	754	314
131	779	583	4.4	78	665	304
Upper Shell Rock River						
SWAT Subwatershed	**Area, acres**	**Organic Phosphorus Load, lbs**	**Soluble Phosphorus Load, lbs**	**Sediment-Adsorbed P Load, lbs**	**Total Phosphorus Load, lbs**	**Sediment Load, U.S. tons**
98	398	135	0.9	26	163	125
101	815	694	3.4	108	805	520
109	289	162	1.3	25	188	119
110	1380	725	7.6	119	852	476
124	1118	338	6.0	54	398	211
130	404	73	2.5	10	85	43
134	1090	763	5.8	107	876	396
135	683	581	3.4	68	653	261
136	113	32	0.6	5	37	19
137	1117	657	6.6	97	761	373
138	49	8	0.1	2	10	6
140	777	567	4.6	82	653	313
142	424	72	1.8	14	88	52
County Ditch 16						
99	1379	1427	6.5	212	1646	1002
100	800	540	7.3	67	614	305
104	36	1	0.3	0	1	0
107	1153	875	5.1	133	1013	549
113	446	235	5.4	32	273	121
114	699	454	5.1	61	520	229
118	787	425	3.0	65	493	251
119	693	617	3.2	82	703	330
120	475	300	2.2	43	345	166

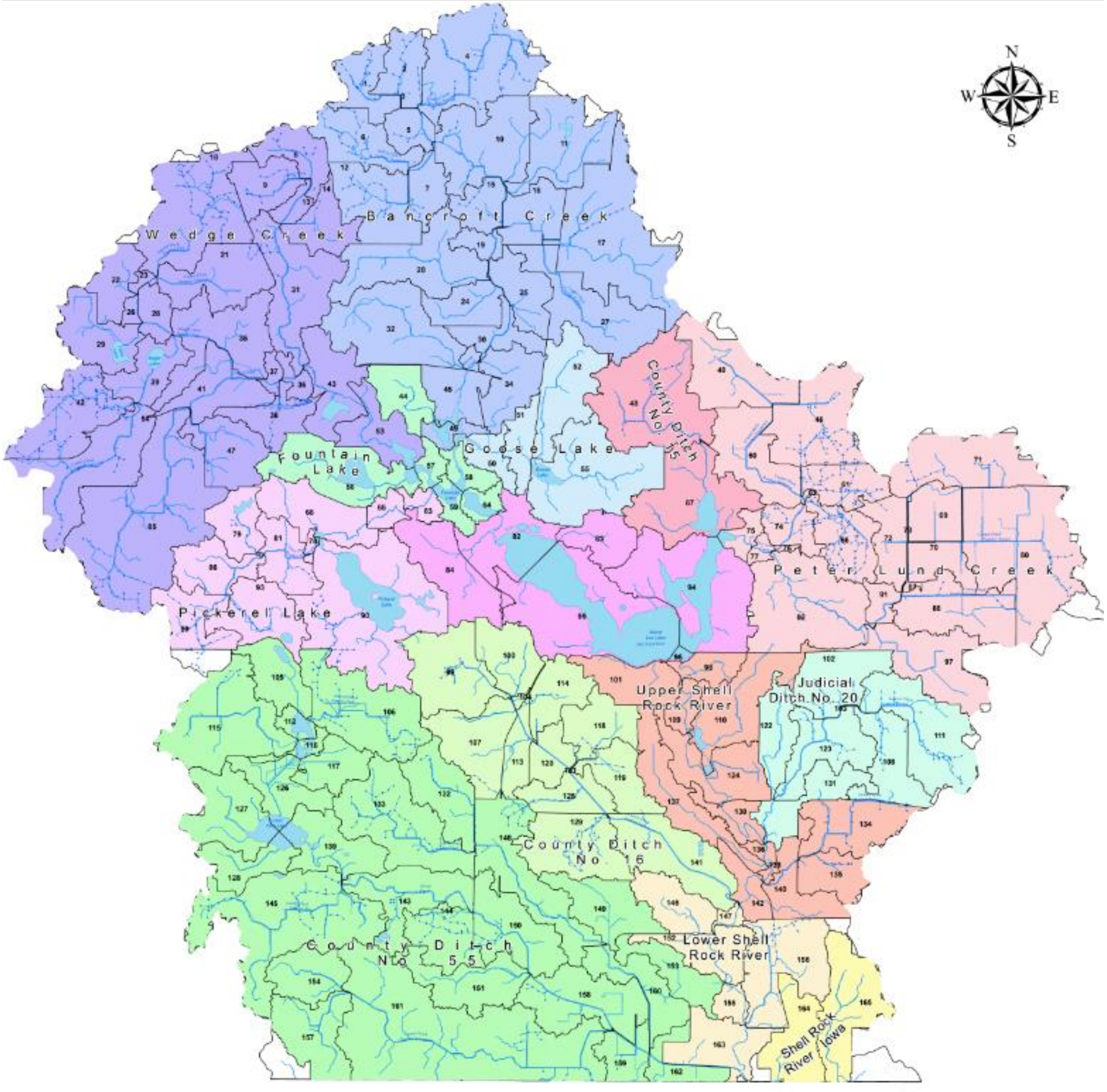
121	1	0	0	0	0	0
125	664	460	3.8	57	520	212
129	1294	855	5.4	115	975	428
141	1429	917	6.1	147	1069	607
Bancroft Creek						
SWAT Subwatershed	**Area, acres**	**Organic Phosphorus Load, lbs**	**Soluble Phosphorus Load, lbs**	**Sediment-Adsorbed P Load, lbs**	**Total Phosphorus Load, lbs**	**Sediment Load, U.S. tons**
1	654	560	2.9	76	639	338
2	625	580	3.1	77	660	322
3	2	3	0	0	3	0
4	2183	1855	15.2	262	2132	996
5	396	258	2.4	30	290	108
6	922	1048	5.3	138	1191	558
7	491	345	2.2	50	397	248
10	1592	1480	7.2	218	1705	955
11	1397	1023	9.6	139	1171	509
12	1182	667	5.3	85	758	351
15	492	224	2.9	31	259	125
16	731	527	5.0	49	582	180
17	2836	2853	18.9	393	3265	1550
19	258	1833	10.9	251	2095	976
20	1600	190	1.8	27	219	114
24	629	713	3.7	90	807	369
25	713	391	4.2	54	449	182
27	1588	1415	9.7	201	1625	770
30	502	239	3.6	37	279	138
32	1806	1316	7.6	184	1507	728
33	83	70	0.5	10	80	43
34	848	412	8.1	60	481	253
44	669	290	3.4	38	332	139
45	692	65	2.8	17	85	57
49	232	8	0.5	1	9	4
Shell Rock River – Iowa						
164	1025	527	6.6	80	613	280

165	1384	803	6.6	92	901	334
Lower Shell Rock River						
146	749	495	3.3	73	572	293
147	111	21	0.6	3	24	11
152	778	205	4.2	33	242	122
155	240	130	1.2	25	157	102
156	1564	1245	8.3	180	1433	721
163	966	592	5.9	71	669	283
County Ditch 55						
SWAT Subwatershed	**Area, acres**	**Organic Phosphorus Load, lbs**	**Soluble Phosphorus Load, lbs**	**Sediment-Adsorbed P Load, lbs**	**Total Phosphorus Load, lbs**	**Sediment Load, U.S. tons**
105	743	73	4.8	12	90	38
106	1809	820	12.3	100	932	400
112	194	8	0.2	4	12	18
115	1998	1679	11.0	207	1897	765
116	181	14	0.2	2	16	7
117	624	168	1.2	26	195	103
126	788	276	2.3	43	322	176
127	1213	411	5.8	54	471	197
128	646	301	2.2	38	341	158
132	1007	551	3.7	85	640	381
133	1872	1962	8.9	284	2255	1276
139	1011	663	4.3	99	766	435
143	1216	1140	5.6	190	1335	996
144	833	680	4.0	100	784	545
145	2997	3264	15.4	525	3805	2545
148	1658	851	10.4	118	979	454
149	1006	626	3.6	93	722	378
150	1221	408	8.1	57	473	222
151	1058	668	4.0	99	771	488
153	699	392	3.1	65	460	277
154	778	929	4.4	138	1071	597
157	1086	1019	6.2	146	1170	562
158	1402	610	6.5	89	705	425

159	508	42	2.4	8	52	36
160	828	601	4.0	102	708	530
161	4788	3398	27.1	494	3919	2119
162	459	229	3.0	31	263	136
Peter Lund Creek						
SWAT Subwatershed	**Area, acres**	**Organic Phosphorus Load, lbs**	**Soluble Phosphorus Load, lbs**	**Sediment-Adsorbed P Load, lbs**	**Total Phosphorus Load, lbs**	**Sediment Load, U.S. tons**
40	1453	780	10.0	85	876	321
46	1615	814	8.9	99	921	313
60	1246	745	8.8	71	824	247
61	690	468	5.1	54	528	187
62	22	11	0.1	1	12	4
66	895	628	5.2	73	706	248
69	648	161	4.7	5	171	10
70	524	191	3.5	5	200	9
71	1607	822	11.4	94	927	305
72	656	133	4.8	8	145	22
73	18	28	0.1	2	30	13
74	472	174	3.4	23	200	75
75	276	119	0.9	15	135	58
76	34	12	0.2	1	14	4
77	118	29	0.5	3	32	12
80	2857	767	19.8	51	837	153
87	38	15	0.1	2	17	6
88	1337	396	7.5	51	455	150
91	261	178	1.5	20	200	66
92	2178	1518	10.1	185	1713	686
97	1416	818	6.8	96	920	319

Additional Results and Products of the SWAT Modeling in the Shell Rock River Watershed

Additional figures from the SWAT modeling effort not included in the WRAPS report are included below:



Shell Rock River SWAT Subwatersheds

Figure 10. Shell Rock River SWAT Subwatersheds.

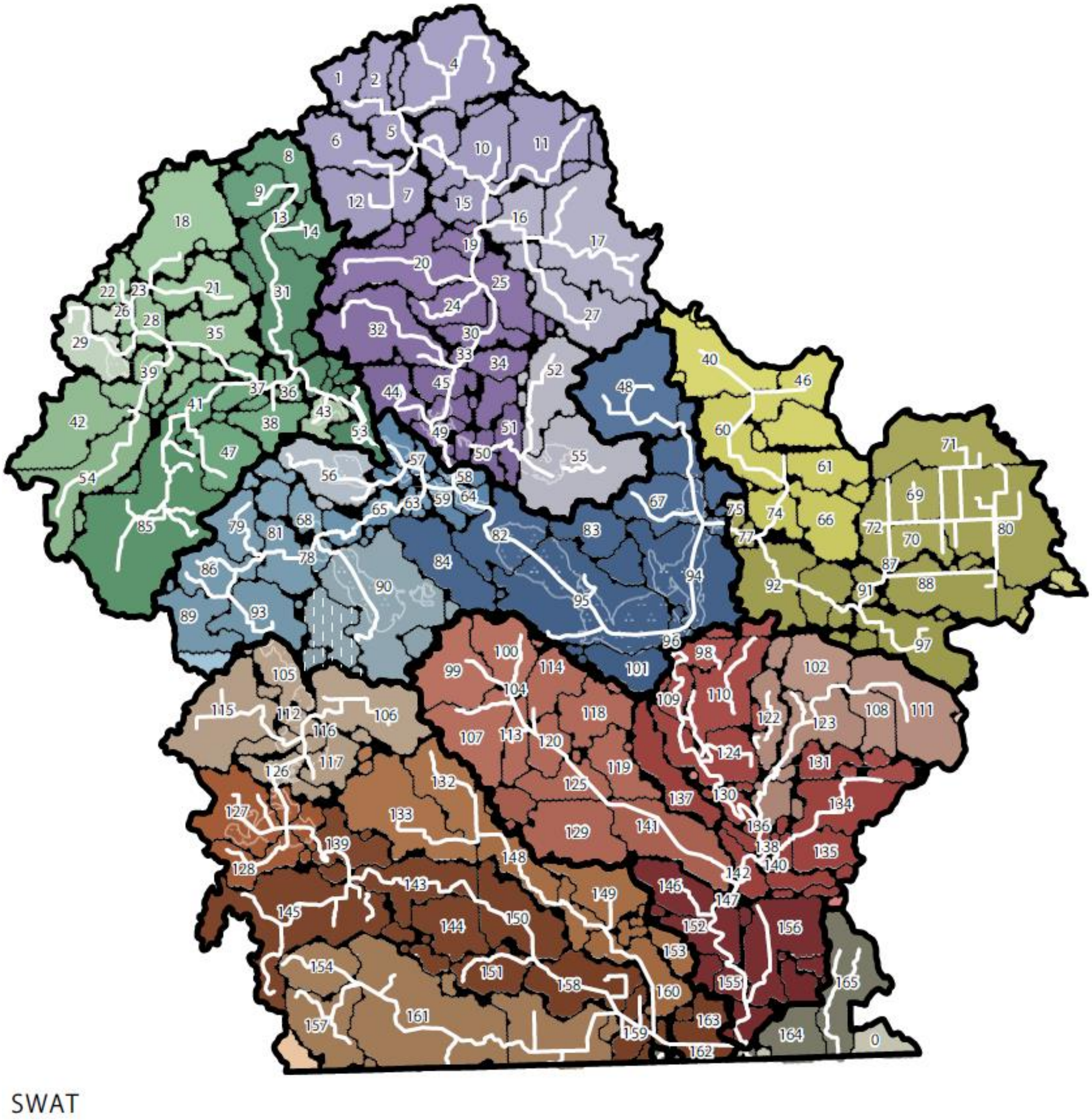


Figure 11. Shell Rock River SWAT subwatersheds with color-coded HUCs.

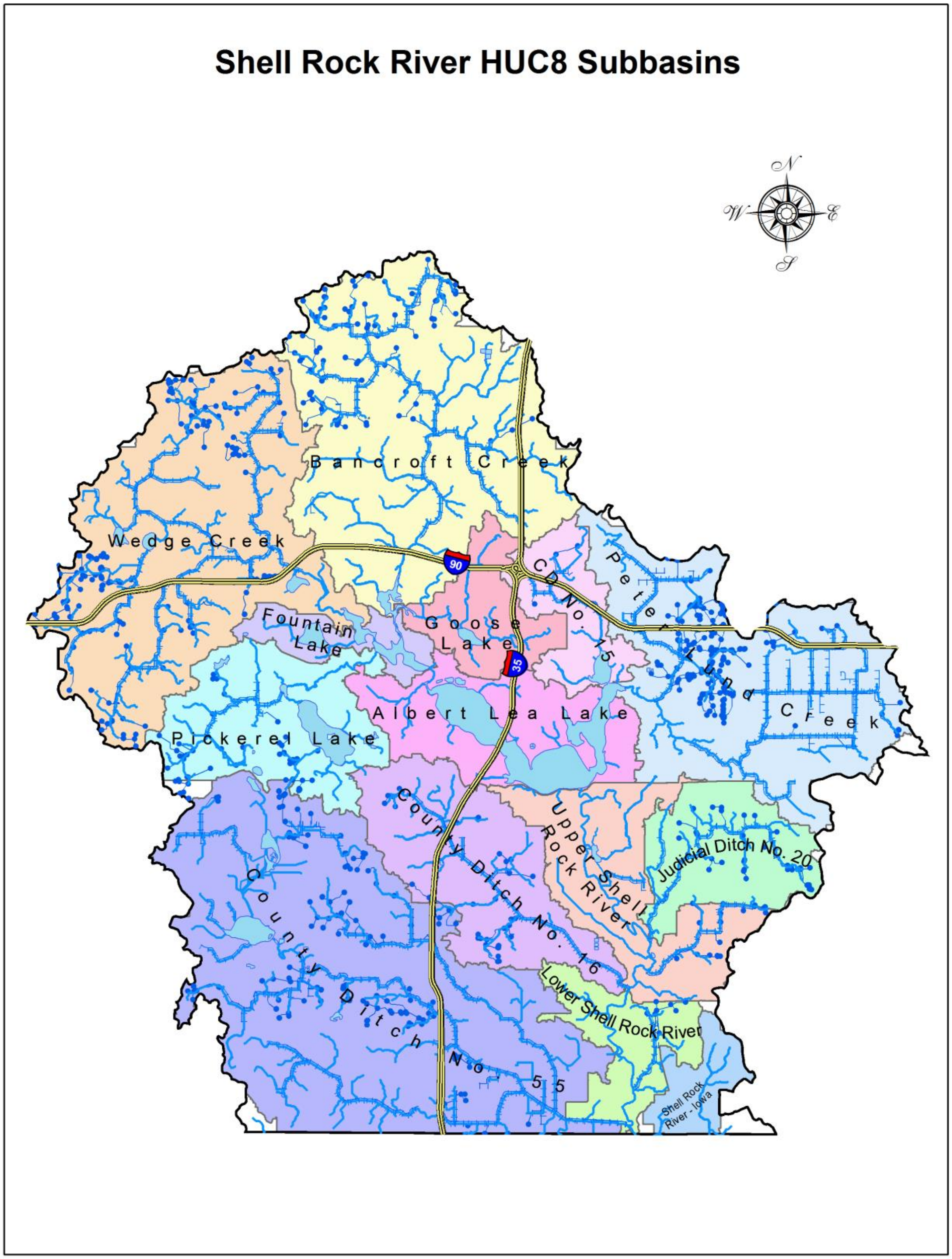


Figure 12. Shell Rock River HUC 8 Subbasins.

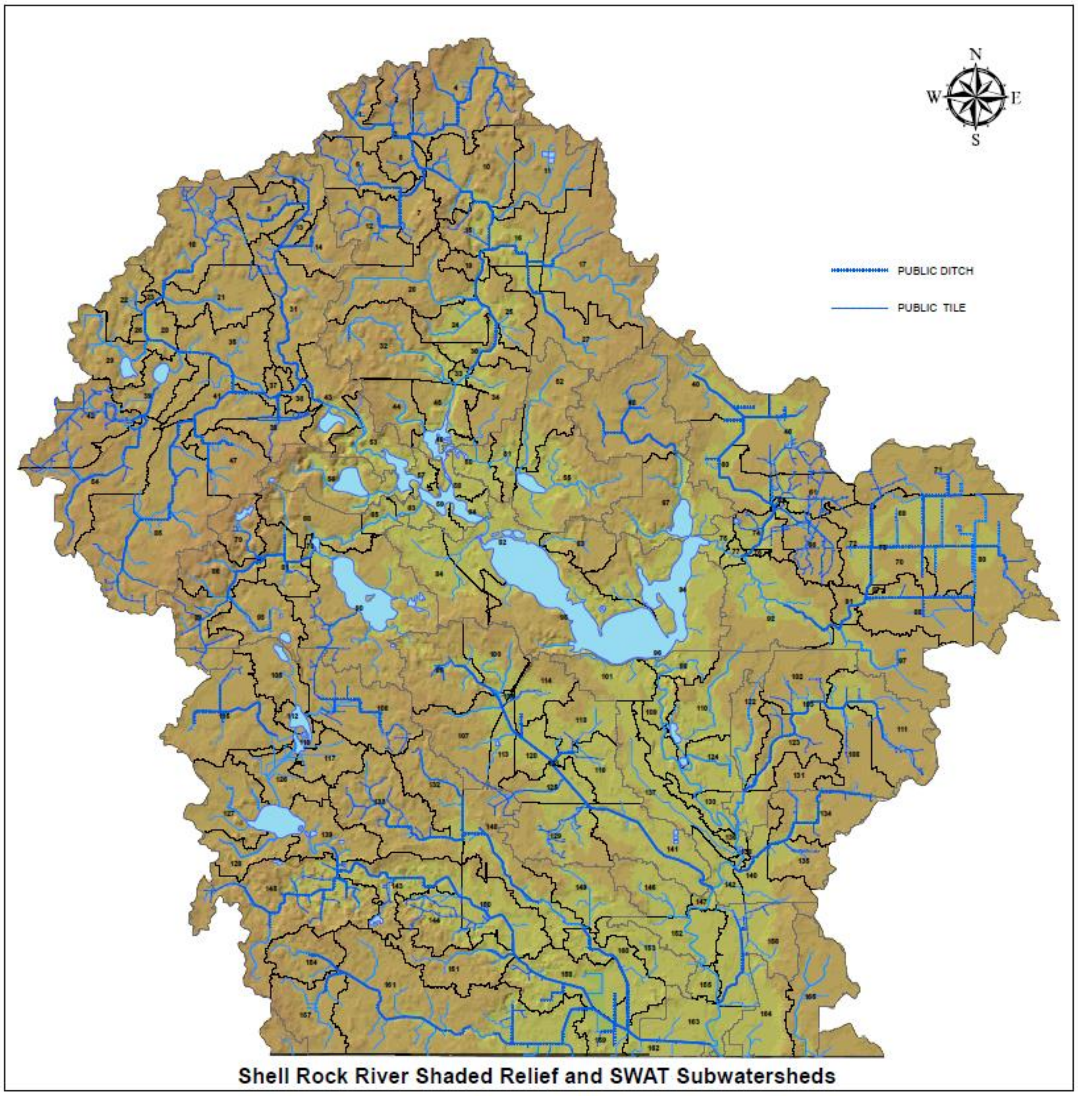


Figure 13. Shell Rock River Watershed shaded relief with SWAT subwatersheds and public ditches and tiles.

Figure 14 below displays this total sediment vs. total phosphorus relationship for 10 selected SWAT subwatersheds in the SRRW. Six of these subwatersheds were in the Wedge and Bancroft Creek Subbasins. These were selected as being in the higher loading categories for both pollutants. From this selected subset, a fairly tight relationship exists when TP loads are less than about 2,500 pounds. More variation exists as the TP loads are doubled, however an R-squared of 0.84 suggests a direct relationship of increasing TP with increasing sediment, and within the confines of these modeling data.

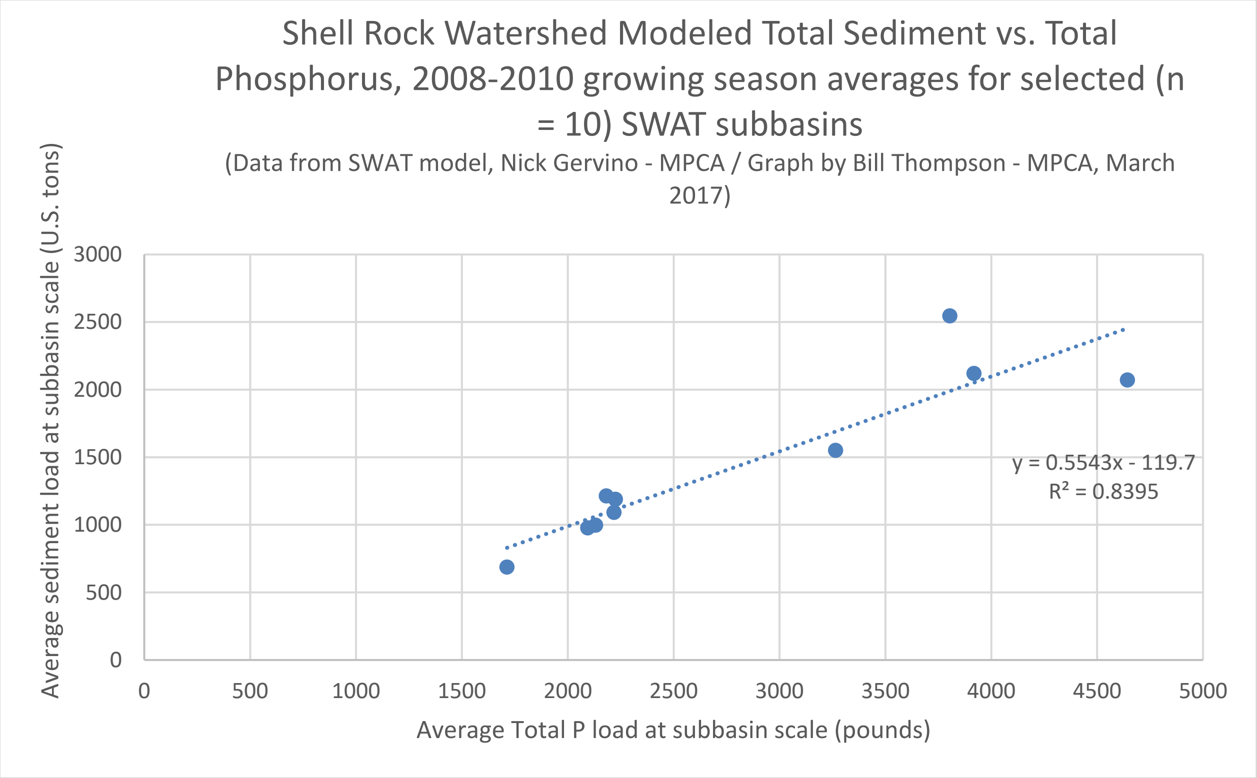


Figure 14. Shell Rock River Watershed modeled total sediment versus total phosphorus for selected SWAT subbasins (2008 – 2010).

Table 4 and Table 5 below present the average growing season mineral and total phosphorus loadings to Fountain Lake and Albert Lea Lake, respectively, from the watershed subbasins illustrated in the appendix figures above. The loadings are an average of the April 1 through September 30 growing season loads for 2008 through 2010 predicted by the Soil and Water Assessment Tool. For each contributing subbasin, a SWAT outlet subwatershed was selected, and the associated reach outlet daily organic and mineral phosphorus load was summed for the growing season. For the local surrounding watershed of each lake, the SWAT subwatershed upland dissolved and sediment adsorbed phosphorus load was summed to determine the mineral phosphorus load to the lake, and the organic phosphorus load was added to determine the total phosphorus load. ESRI ArcMap feature classes were used to determine the subbasin outlets. A Microsoft Access database of SWAT output was queried to obtain the output information, and Microsoft Excel spreadsheets were used to perform calculations.

Table 4. Average growing season sediment and phosphorus loadings by subbasin – Fountain Lake.

Subbasin	Area, Acres	Sediment Load, U.S. Tons	Mineral Phosphorus Load, lbs	Mineral Phosphorus Load, %	Total Phosphorus Load, lbs	Total Phosphorus Load, %
Goose Lake	4,172	874	364	1.7%	1050	3.8%
Bancroft Creek	23,127	4,099	9801	46.5%	11711	42.2%
Wedge Creek	22,965	4,368	9053	43.0%	11752	42.4%
Pickeral Lake	8,909	405	1743	8.3%	2535	9.1%
Fountain Lake Local	2,544	390	99	0.5%	685	2.5%

Table 5. Average growing season sediment and phosphorus loadings by subbasin – Albert Lea Lake.

Subbasin	Area, Acres	Sediment Load, U.S. Tons	Mineral Phosphorus Load, lbs	Mineral Phosphorus Load, %	Total Phosphorus Load, lbs	Total Phosphorus Load, %
County Ditch No. 15	3,995	1,197	113	0.4%	1,742	4.9%
Fountain Lake	61,717	8,342	24,264	83.1%	26,646	74.4%
Peter Lund Creek	18,361	1,378	4,679	16.0%	6,144	17.2%
Albert Lea Lake Local	8,647	727	129	0.4%	1,270	3.5%

It should be noted that these loading data are averaged over three years, 2008, 2009, and 2010. The predicted loads for 2010 were four to five times higher, than those for the other two years.

From a total phosphorus loading perspective, Bancroft Creek and Wedge Creek are many times more significant than the other three, smaller subbasins. These modeled data indicate that total phosphorus and sediment loads from Bancroft Creek and Wedge Creek, to Fountain Lake, are very similar.

For Albert Lea Lake, about 75% of the total phosphorus loads enters the lake from the channel from Fountain Lake. A secondary source of phosphorus (about 17%) that enters from into the northeastern arm of Albert Lea Lake originates within the Peter Lund Creek drainage area, which is 8,647 acres. The small town of Hayward is within the Peter Lund Creek subbasin.

Shell Rock River SWAT Modeling Appendix Notes:

- Used overlays of HUC12 boundaries, SWAT subwatershed boundaries, DNR minor watersheds, NHD streams, and a Ditch layer to group SWAT subwatersheds into subbasins. Subbasins creation greatly aided locating unselected SWAT subwatersheds.
- SWAT subbasin 53, which has zero TP yield as the outlet of the subwatershed, is a forebay lake of Fountain Lake. In addition, this subwatershed is divided into two different minor watersheds – Wedge Creek, and Fountain/Albert Lea Lakes.
- SWAT subwatershed 21 was not included in Wedge Creek Subwatershed.

- SWAT subwatershed 3 is 1 hectare in size, and is a linear boundary between subwatersheds 1, 2, and 5. The subwatershed is 2/3 of the length of a ditch which feeds Bancroft Creek, and has a load of 0.65 lbs TP/acre/year.
- Subbasin 56 is located in the Albert Lea Lake minor watershed, and is not in the Pickeral Lake subwatershed.
- SWAT subwatershed 90 excludes the lake area of Pickeral Lake, but includes the island in Pickeral Lake.
- Using the ditch_tile layer, it appears that SWAT subwatershed 46 is actually two subwatersheds, one flowing west into County Ditch 22, and another flowing south into subwatershed 61.
- SWAT subwatersheds 73 and 87 are linear ditch subwatersheds in the Peter Lund Creek Watershed which isolates County Ditch Number 12 and an unnamed ditch. .
- SWAT subwatersheds 62, 73, and 76 were not included in the Peter Lund Creek Watershed or any other watershed.
- A portion of the Albert Lea Lake basin south of SWAT subwatershed 89 was left out of the SWAT model.
- SWAT subwatershed 108 is divided between two minor watersheds: Judicial Ditch Number 20 and County Ditch Number 49.
- SWAT subwatershed 131 has two lobes. The two lobes are in different HUC14 subwatersheds.
- SWAT subwatershed 163 is divided between Goose Creek minor watershed and the Shell Rock River minor watershed.
- SWAT subwatershed 164 is divided between the Lower Shell Rock River minor subwatershed and the portion of the Shell Rock River watershed which connects with the Shell Rock River in Iowa (Shell Rock – Iowa).
- SWAT subwatershed 103 is a linear 4 acre subwatershed that isolates a section of Judicial Ditch number 20.
- The subbasin map contains some very small land areas that are not colored. The map is made up of SWAT subwatersheds, and these small areas were not contained within a SWAT subwatershed.
- SWAT subwatershed 101 discharges to SWAT subwatershed 109 below the Albert Lea Lake dam, and therefore is not part of the Albert Lea Lake. However, the DNR minor watersheds coverage shows SWAT subwatershed 101 as being part of the Albert Lea Lake drainage area. Changing the drainage would require editing the input file and rerunning the model. SWAT subwatershed 101 was added to the Upper Shell Rock River agglomeration.
- In the SWAT model subwatershed 34 flows to Bancroft Creek in subwatershed 33. The DNR catchment flowlines layer shows that the northern portion of SWAT subwatershed 34 flows as modeled, but the southern half of the subwatershed flows into SWAT subwatershed 50.

- SWAT subwatershed 44 flows directly into Fountain Lake and does not flow into Bancroft Creek.
- SWAT subwatersheds 50, 51, 52, and 55 do not flow into Bancroft Creek, and flow into Fountain Lake. A new subwatershed “Goose Lake” was created.
- SWAT subwatershed 148 drains into SWAT subwatershed 160 in the County Ditch Number 55 watershed. The hydrography illustrates that the northeastern portion of SWAT subwatershed 148 drains into SWAT subwatershed 125, which is part of the County Ditch No. 16 watershed.

*The term “*agglomeration”* is used in this exercise to denote how the SWAT modeling subbasins were combined, aggregated, or agglomerated together, to assess broader geographic scales affecting lakes and downstream water resources.

References Appendix F:

Gervino, N. 2019. Shell Rock River Watershed SWAT Modeling Analysis and Presentation. (Data and modeling files available at MPCA-St. Paul). Senior Water Resources Engineer, MPCA-St. Paul, Watershed Division.

Appendix G. Hydrologic Systems Program - Fortran (HSPF) watershed

Appendix Purpose:

The purpose of this appendix to the SRRW WRAPS is to provide a selection of additional information on the HSPF model, with some pertinent context and history related to this watershed. Additional references for the model itself, and for specific report documents, are provided for the readers who desire more information. This appendix content is not meant to provide an exhaustive review and appraisal of the application of the HSPF model to this watershed. Any reader who desires detailed technical information about the model and its application to this watershed can review the technical development and calibration memos, and discuss issues with trained modeling professionals.

HSPF Model:

While initially released as a watershed simulation model in 1980, the routines and background for this HSPF model date back to the 1970s. There were four predecessor models to HSPF, which addressed simulation programming, nonpoint sources, agricultural runoff, and sediment transport (Aqua Terra 2001).

During the subsequent decades, the HSPF model was widely used, and became part of the EPA's BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) products. HSPF is one of numerous models within this multipurpose environmental analysis system developed and supported by the EPA. EPA (2019) describes HSPF as a comprehensive package for the simulation of watershed hydrology and water quality. HSPF incorporates watershed-scale agricultural runoff models (ARM) and nonpoint source (NPS) models into a basin-scale analysis framework. The model provides runoff flow rates, sediment load, and nutrient concentrations at points in the watershed.

For a general description of why a computer simulation model is used, see "Building a picture of a watershed," MPCA (2004). This fact sheet describes how spatial data from GIS is used with water quality data, stream flow records, meteorological data, with point source data to begin model development.

In 1986, the EPA required the MPCA to develop a waste load allocation for the lower Minnesota River to address low dissolved oxygen concentrations. The MPCA convened a team of technical experts including modelers from the USGS and EPA. The team recommended the use of HSPF to determine the wasteload allocation. By 1994 HSPF initial HSPF applications were constructed for the Minnesota River Basin from the Chippewa River Watershed downstream to the Lower Minnesota River Watershed. In 2007, the MPCA decided to apply HSPF throughout most of the state of Minnesota to support TMDL development and point source permitting. The overall approach which includes watershed model development, application, and updating/maintenance, is within the Minnesota Water Management Framework (State of Minnesota 2014).

The Minnesota Department of Agriculture (2016) hosted an important symposium on water quality modeling and tools, and this included a summary of the HSPF model.

Another helpful set of information has been developed by BWSR (2019) for water quality tools and models. Included in this inventory of models and tools is the HSPF-Scenario Application Manager (RESPEC 2019), which includes the Shell Rock Watershed (up to 12/31/2012). This Scenario Application

Manager (SAM) is a graphical interface to HSPF, which allows for the evaluation of BMP implementation, or deterioration in watershed composition, in terms of water quality.

More recently, the HSPF model was used as part of the Working Lands Watershed Restoration Feasibility Study and Program Plan (BWSR 2018). In that effort, the HSPF model was used to provide an estimate of the potential water quality benefits of several different restoration scenarios for six study watersheds. The capability of modeling extended timeframes (11 to 13 years) allowed for obtaining annual average data with historical land cover and climate information.

Background / Model Context:

There are two main phases for HSPF modeling in the SRRW. The first phase was model development with a simulated timeframe of 1995 to 2012. The second phase extended the timeframe to 2018. Each phase is overviewed below.

Phase 1: 1995 – 2012. The MPCA initiated the development of the first HSPF model for the SRRW in 2014. At that point, a combined model development effort included the Minnesota portions of the Cedar River Watershed, the Shell Rock River Watershed, and the Winnebago River Watershed (RESPEC 2014a and RESPEC 2014b). The HSPF model for the Shell Rock and Winnebago River watersheds were done together, and apart for the Cedar watershed areas (i.e. two distinct HSPF models were completed, under one contract). This version of the HSPF model was used by MPCA staff in TMDL development and point source permitting work for several years. During this timeframe, MPCA staff made several changes to the model, to allow for more realistic predictions of river water quality. The referenced memo describes how the User Control Input (UCI) and Watershed Data Management Files (WDM) files were completed. Significant details from this first modeling phase in the SRRW include:

- Modeling reaches (subwatersheds of various sizes) were set up, using the watershed drainage network and numbering with a specific I.D. from upstream to downstream.
- A simulation time period of 1995 through 2012 was done.
- Lake contours were provided by the SRRWD and the DNR. These data are important to use when calculating discharge over a range of depths, from a modeling reach that includes a lake.
- Stream cross-sectional data was obtained from the SRRWD, USGS, and MPCA – and used in model setup.
- Other reach stream cross sections were developed from 1-meter LiDAR, using the 3D Analyst in ArcGIS.
- A Manning’s roughness coefficient of 0.035 was used for the channels.
- A Manning’s roughness coefficient of 0.045 was used for the floodplain.
- Stream discharge data was obtained for calibration purposes from the USGS, DNR and SRRWD.
- The 2011 National Land Cover Database (NLCD) was the source of land cover distribution data.
- Soils data was obtained from the NRCS’s Soil Survey Geographic (SSURGO) database.

- Tillage data from the MN Tillage Transect Survey data center (<2007) and from Freeborn SWCD (2009 through 2012) was used, with a 30% crop residue threshold (at planting), between conventional tillage and conservation tillage. Tillage was used as an explicit representation in the model, because of the influence on hydrologic and water quality processes.
- Since Albert Lea is an MS4 stormwater city, additional model formulations were developed to track flow and loads, in separate mass links.
- Animal feeding operations data was obtained from the MPCA, with spatial location, animal type and animal counts.
- Appendix C from RESPEC (2014a) contains the Shell Rock River / Winnebago River water quality calibration figures. (This includes 33 figures which have both observed and simulated data plotted together).

MPCA HSPF Scenarios:

Three scenarios were executed by the MPCA staff determine the extent potential nonpoint source sediment and nutrient reductions that could be expected if certain changes were made in the watershed. These scenarios are described on page 114 of the Shell Rock River WRAPS Report. The first scenario involved converting restorable wetland acres from rowcropped to wetland land areas. A relatively low number of acres in the row-crop land use category were deemed suitable, and therefore only minimal water quality improvements were predicted."

The second scenario simulated the conversion of 75% of all high till rowcropped acres to low till rowcropped acres. This scenario resulted more significant water quality loading reductions. The third scenario simulated the conversion of marginal rowcropped acres to perennial vegetation. As in the case of the first scenario, the third scenario resulted in minimal sediment and nutrient loading reduction, as there are relatively few marginal rowcropped acres in the Shell Rock River Watershed. Bar charts for nitrogen, phosphorus, sediment and water – all follow below.

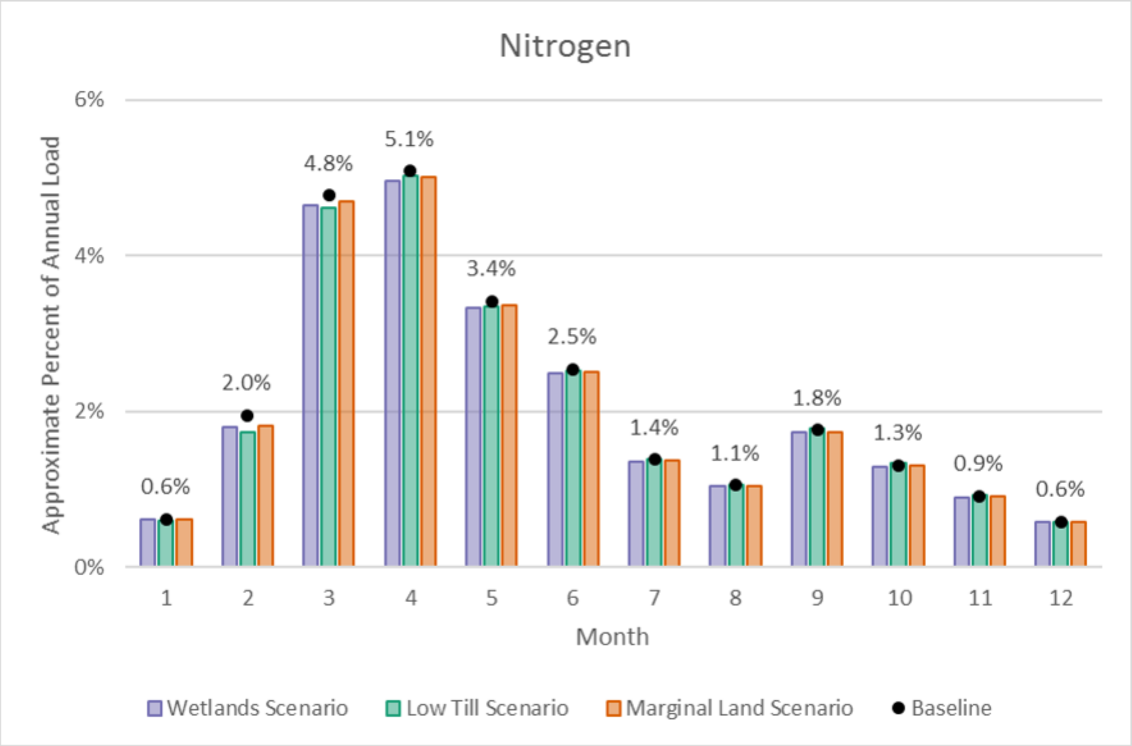


Figure 15. Nitrogen results.

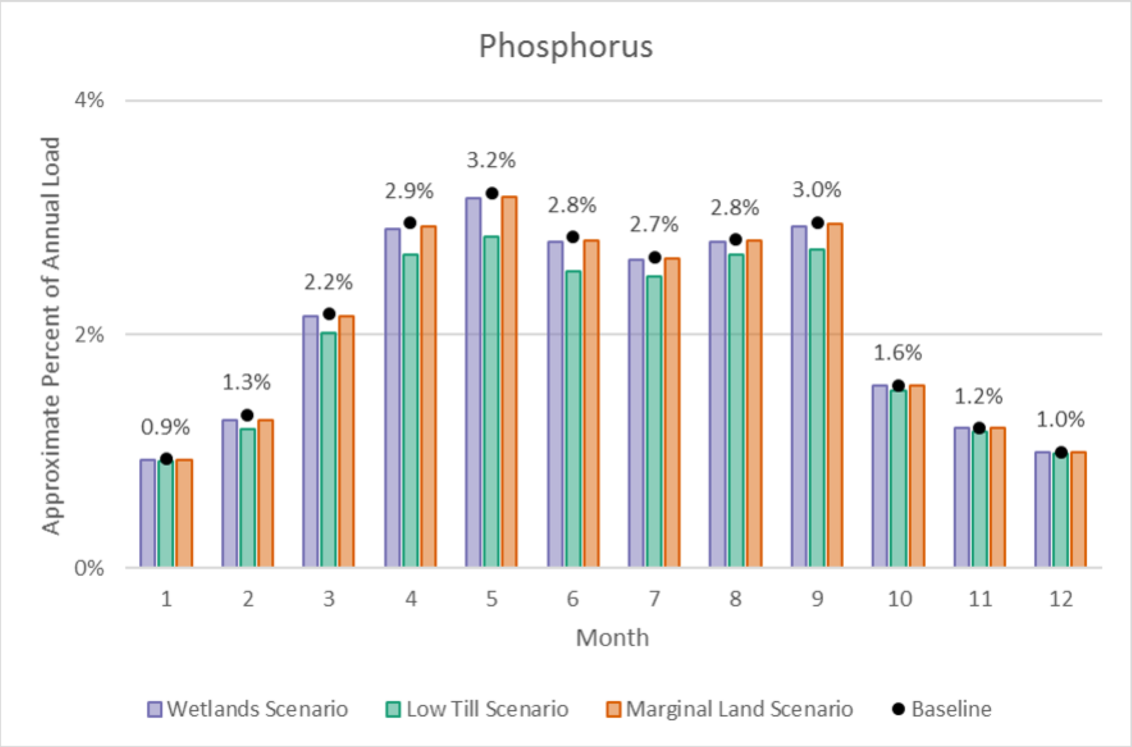


Figure 16. Phosphorus results.

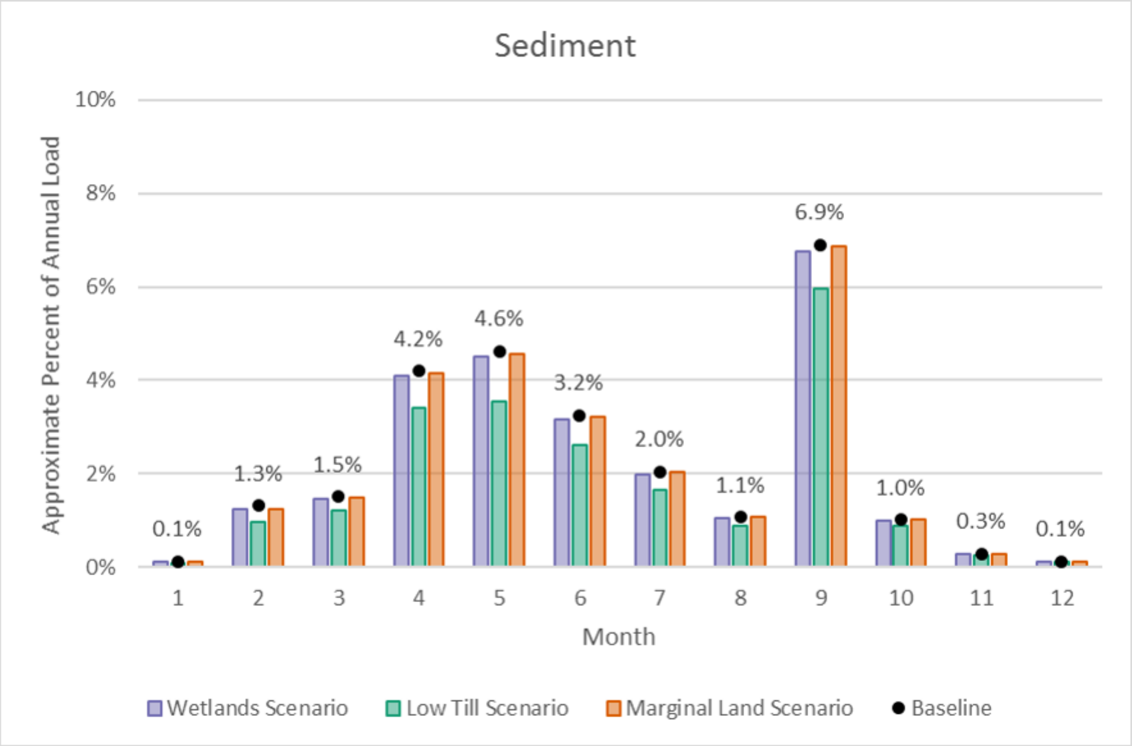


Figure 17. Sediment results.

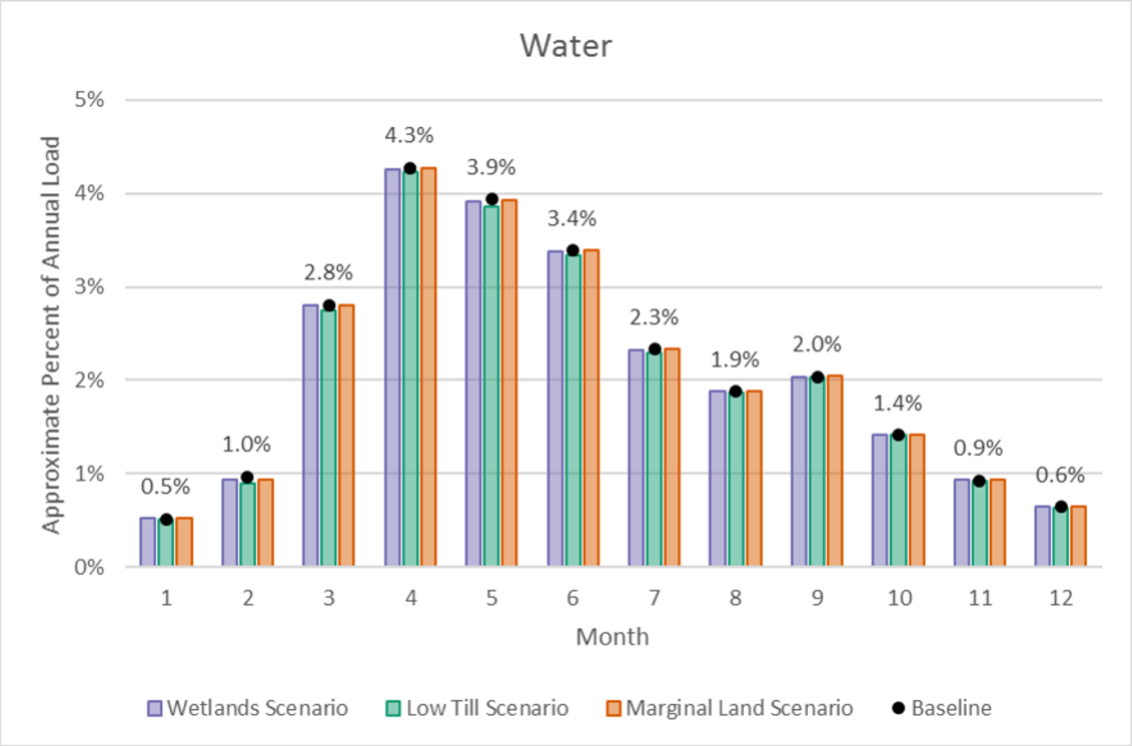


Figure 18. Water yield results.

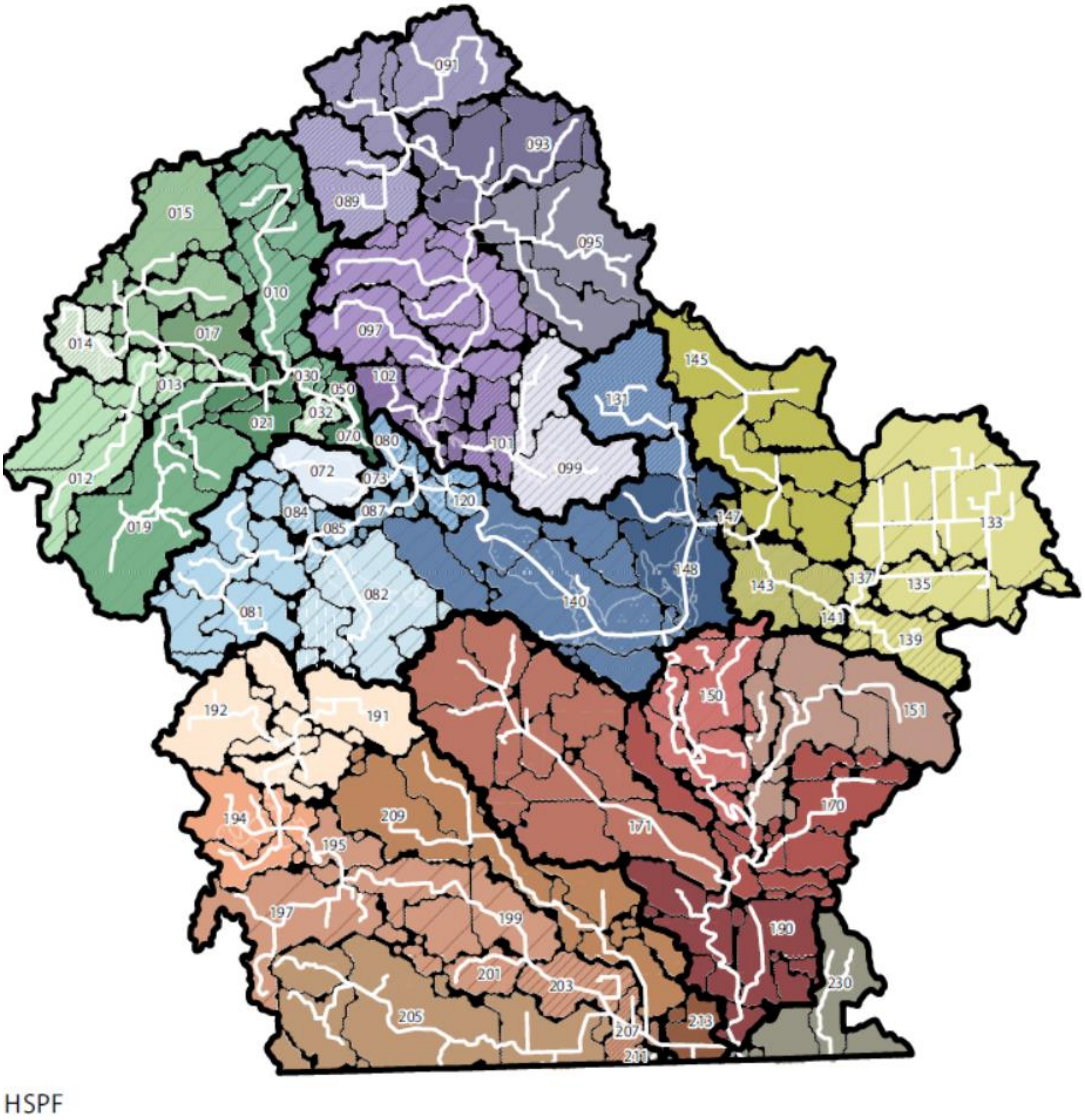


Figure 19. HSPF modeling subwatersheds of the Shell Rock River Watershed.

***Phase 2. Model extension to 2018*.** When additional water quality and water quantity data became available from the SRRWD, the decision was made to extend the initial model from 2012 to 2018. The MPCA initiated a work order with RESPEC to complete this work, with the details provided in Lupo (2019). A selection of information that was used during the model extension effort includes:

- Updated point source information (chemical, flows, etc.) for one major point source (City of Albert Lea WWTP) and fifteen minor point sources.

- Extended time-series data for precipitation, air temperature, wind speed, cloud cover, dew point and potential evaporation.
- The 10-year timeframe of 2009 through 2018 was in scenario analysis and for the TMDL.
- Recalibrated HSPF model for hydrology, with an analysis at HSPF Reach 190 (most downstream reach on the Shell Rock River by Gordonsville Minnesota) showed a small difference in runoff volumes between observed (12.78") and simulated (12.97"). The "Storm Percent Errors" were -1.12% for volume, and -8.78% for peak.
- The calibration of the HSPF model was refined to include the water quality data that was collected from 2013-2018.
- The HSPF model represents lakes as a completely homogenous system. To address internal loading of phosphorus, the MONTH-DATA block was used to add phosphorus, as a monthly time series to lakes.
- A sensitivity analysis was conducted on 17 parameters, to see how the parameters at minimum and maximum values affected DO and TP.
- A set of five final scenarios were developed and run with the HSPF model. These scenarios (#) were:
    - 2009 through 2018 Base scenario (1)
    - Albert Lea Lake compliance with lake eutrophication standards (2)
    - Local (tributaries to Shell Rock River) load allocation compliance (3)
    - Albert Lea WWTF dissolved oxygen scenario (4)
    - Albert Lea WWTF total phosphorus scenario. (5)
- Scenario 5 (Albert Lea WWTF total phosphorus scenario) met the TP RES standard of 0.150 mg/L and maintained the stream DO above the 5.0 mg/L instream standard.
- The extended and revised HSPF model is being used in 2019 for both the TMDL and point source permitting.
- The Lupo (2019) memo included three attachments:
    - Attachment A: Hydrology results for Reach 190 in the Shell Rock River Watershed model application
    - Attachment B: Observed water quality data and locations for the Shell Rock River Watershed model application
    - Attachment C: Water quality calibration figures for Reach 190 the Shell Rock River Watershed model application

A map from Lupo (2019) showing the subwatersheds and modeling reaches is included below.

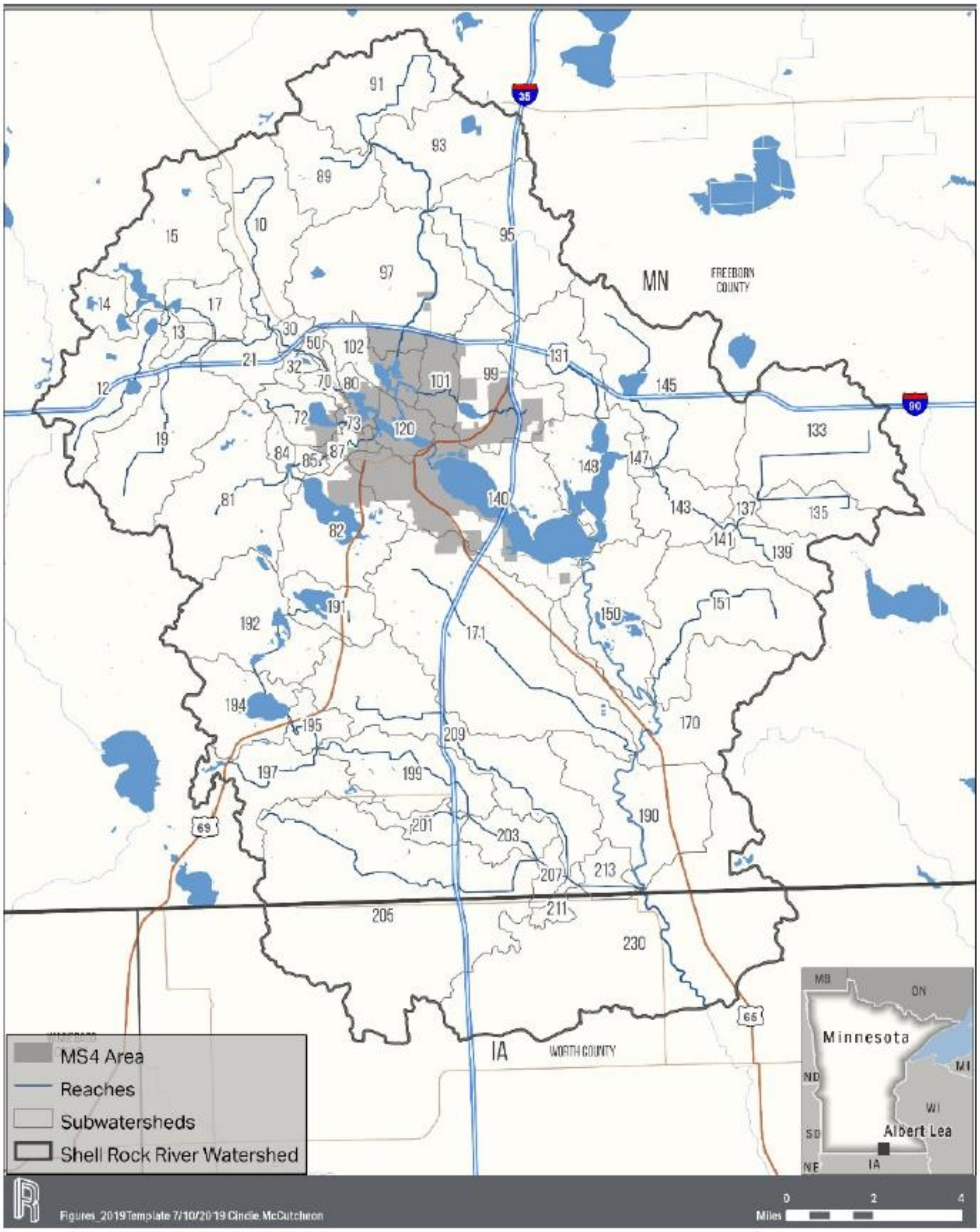


Figure 20. HSPF reaches and subwatersheds.

Summary:

The MPCA developed an initial HSPF water quality model at the HUC 8 scale for the SRRW in 2014. An updated and extended HSPF model was completed in 2019, making use of current water and meteorological data. The updated and extended model's timeframe of 2009 through 2018 is being used for completion of both the watershed TMDL and point source permitting.

References Appendix G:

Aqua Terra. 2001. Hydrologic simulation program – fortran (HSPF) version 12 User's Manual (873 page technical manual).

BWSR 2018 . Working Lands Watershed Restoration Feasibility Study and Program Plan. Appendix 4. Water quality modeling results. https://bwsr.state.mn.us/sites/default/files/2018-11/Appendix%204%20-%20Water%20Quality%20Modeling%20Results.pdf

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MPCA 2004. Building a picture of a watershed – modeling with a computer simulation program. 5-page factsheet. https://www.pca.state.mn.us/sites/default/files/wq-ws1-04.pdf

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RESPEC 2014b. Hydrology and water quality calibration of the Cedar River/Little Cedar River and Shell Rock River/Winnebago River HSPF Model Watershed model applications.. [Memo dated 9.30.2014 to Dr. Charles Regan, MPCA, from Staff Engineer Cindie McCutcheon of RESPEC / Project Central File 2428].

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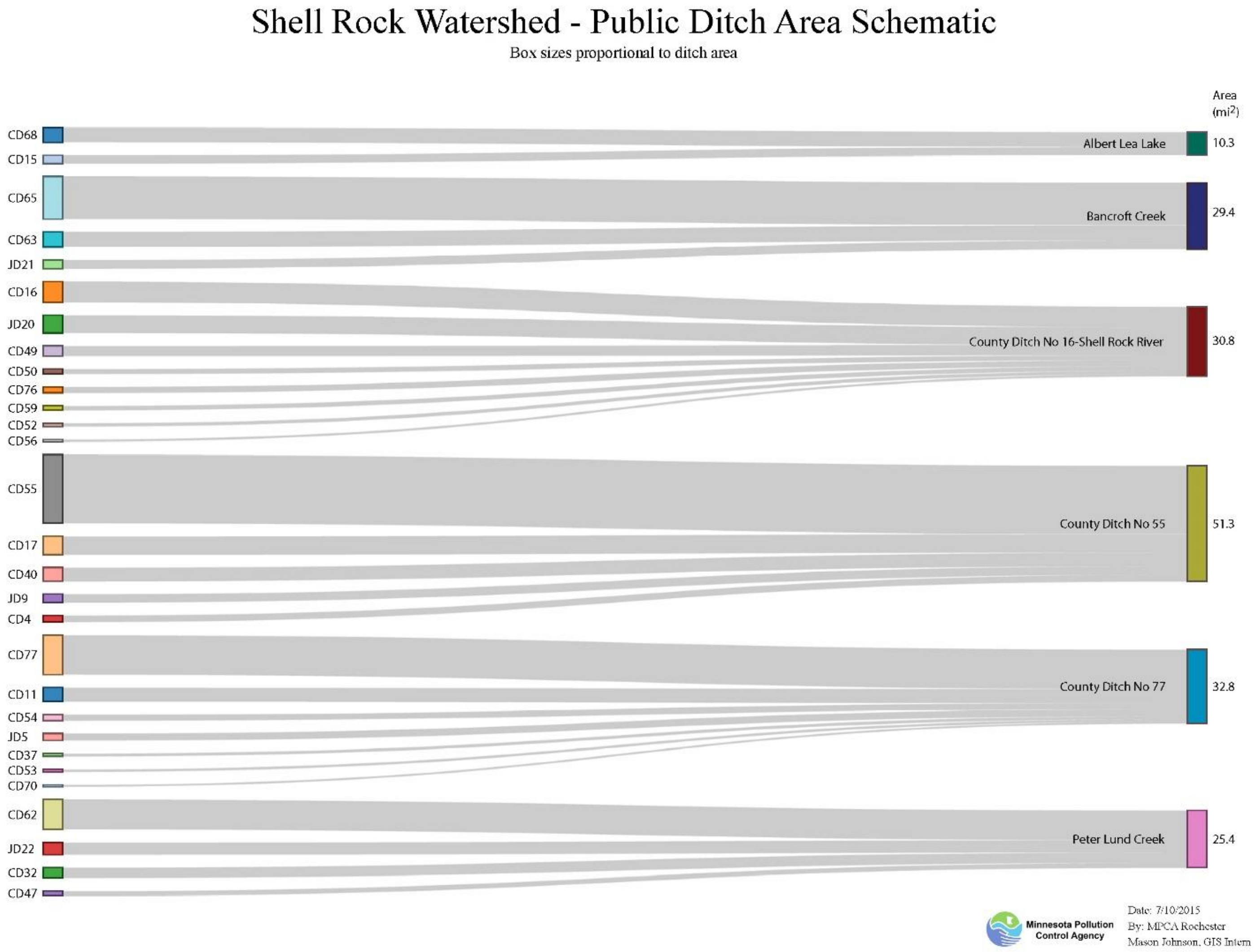
Appendix H. Drainage systems – Additional Information



Date: 7/10/2015
By: MPCA Rochester
Mason Johnson, GIS Intern

Figure 21. Shell Rock River drainage systems ditch area network diagram (johnson 2015).

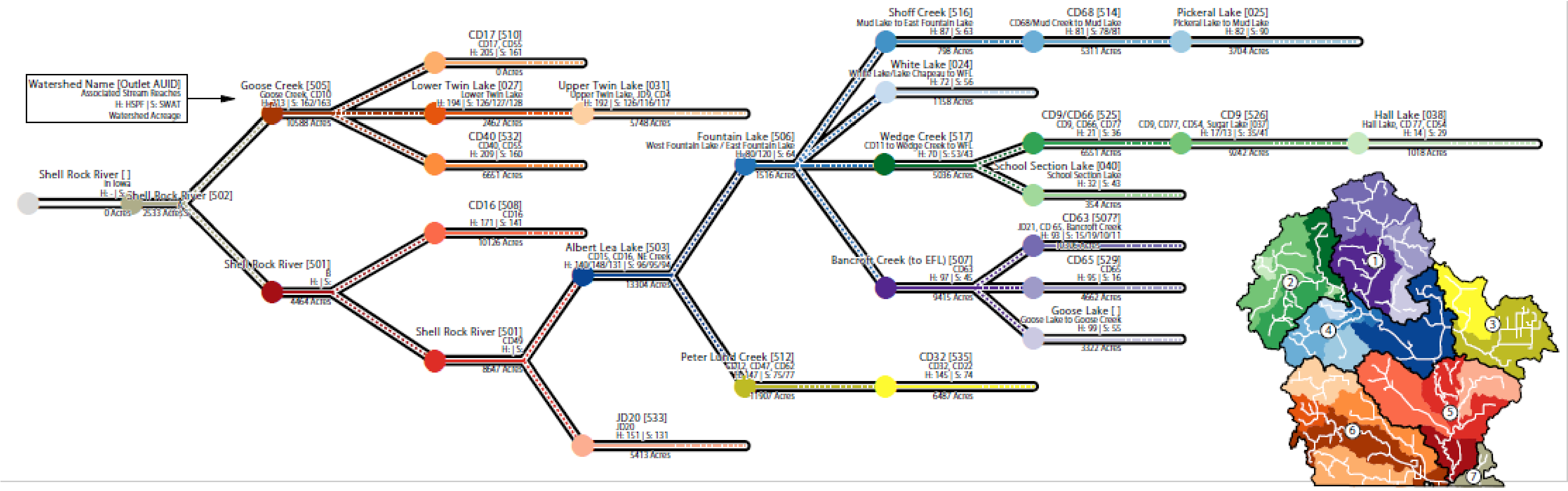


Figure 22. Subwatershed schematic stick diagram (Ignatious 2017).

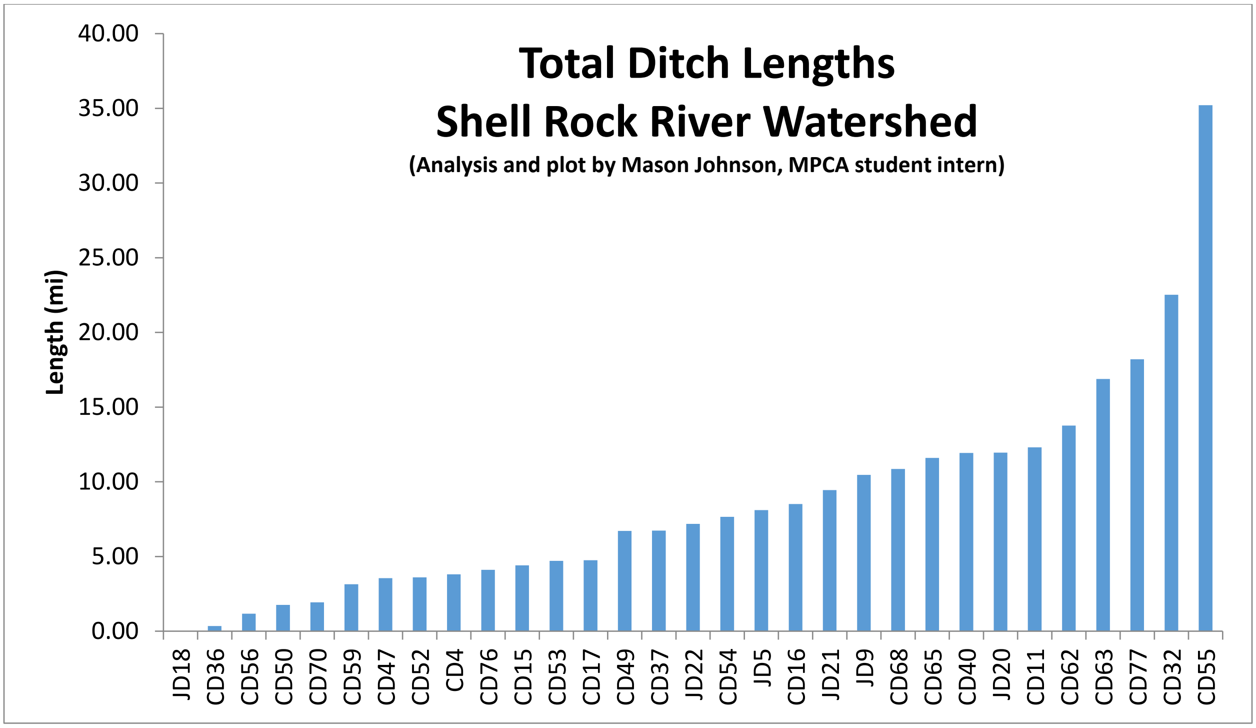
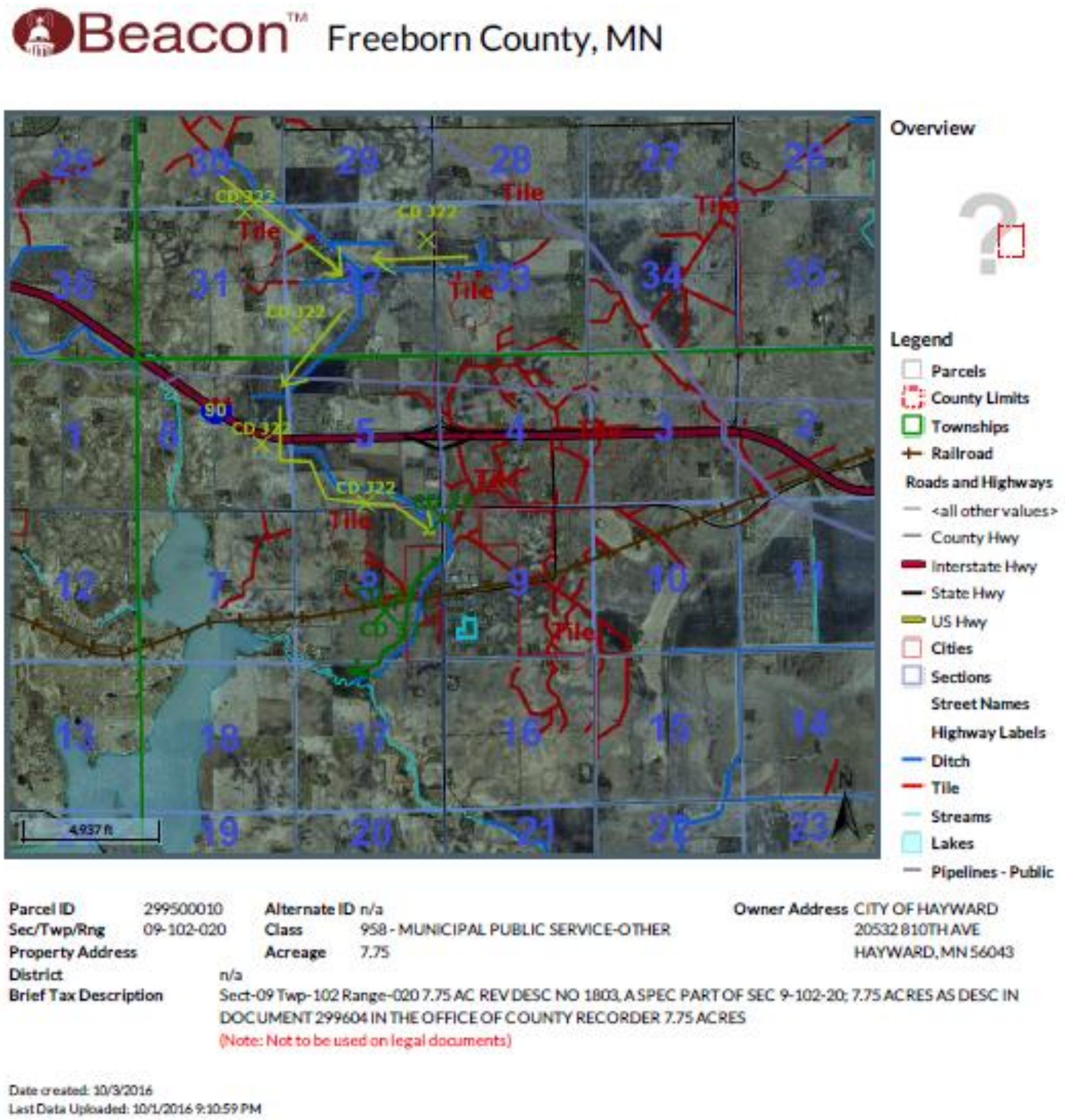


Figure 23. Open ditch lengths, shell rock river watershed.

Table 6. Shell Rock River Watershed public ditch (open & tiled) miles.

DITCH_NAME	PUBLIC DITCH OPEN (miles)	PUBLIC DITCH TILE (miles)	GRAND TOTAL
CD11	6.99	5.32	12.31
CD15	3.13	1.28	4.41
CD16	7.62	0.89	8.51
CD17	4.75	0	4.75
CD32	1.24	21.28	22.52
CD36	0	0.35	0.35
CD37	0	6.74	6.74
CD4	3.1	0.7	3.8
CD40	5.54	6.39	11.93
CD47	2.75	0.8	3.55
CD49	3.61	3.1	6.71
CD50	0.52	1.24	1.76
CD52	0	3.61	3.61
CD53	0.51	4.2	4.71
CD54	1.84	5.81	7.65
CD55	22.27	12.94	35.21
CD56	0	1.17	1.17
CD59	0	3.14	3.14
CD62	10.34	3.42	13.76
CD63	5.51	11.38	16.89
CD65	8.58	3.02	11.6
CD68	3.11	7.75	10.86
CD70	0	1.93	1.93
CD76	1.96	2.15	4.11
CD77	12.55	5.65	18.21
JD18	0	0.02	0.02
JD20	4.7	7.26	11.95
JD21	2.97	6.47	9.44
JD22	6.31	0.87	7.18
JD5	1.06	7.05	8.1
JD9	1.99	8.47	10.47
Grand Total	**122.96**	**144.39**	**267.35**



Parcel ID 299500010
Sec/Twp/Rng 09-102-020
Property Address
District n/a
Brief Tax Description Sect-09 Twp-102 Range-020 7.75 AC REV DESC NO 1803, A SPEC PART OF SEC 9-102-20; 7.75 ACRES AS DESC IN DOCUMENT 299604 IN THE OFFICE OF COUNTY RECORDER 7.75 ACRES
(Note: Not to be used on legal documents)

Alternate ID n/a
Class 958 - MUNICIPAL PUBLIC SERVICE-OTHER
Acreage 7.75

Owner Address CITY OF HAYWARD
20532 810TH AVE
HAYWARD, MN 56043

Date created: 10/3/2016
Last Data Uploaded: 10/1/2016 9:10:59 PM

Figure 24. CD J22, CD J19 and CD 32, northeast of Albert Lea lake (Example to illustrate ditch and tile systems).

Explanation (Biser 2016): CD J22 all flows into CD 32 at the west edge of Hayward on CR 26. Then CD 32 and all of CD J22's water flows into the PLC before entering Albert Lea Lake south of the RR tracks in Hayward Twp sec. 17. CD 62 enters the PLC in sec 21 of Hayward Township

In Sec. 7 of Hayward Township, CD J19 is a tile only system draining only 326 acres directly into Albert Lea Lake just north of the RR tracks.

FYI the outlet of CD J19 could be a location to place a water quality project before this tile water enters into Albert Lea Lake.

Appendix G - References:

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Appendix I. Historical Context for Lake Restoration Efforts: Albert Lea Lake (Bill Thompson, MPCA – Rochester)

Efforts to understand and assess the conditions of Albert Lea Lake (ALL) date back over at least eight decades. A brief summary is presented, to better place this current TMDL report in context, and to learn about, and from, previous efforts.

A lake management report from the Minnesota Department of Conservation was completed in 1945, including historical, physical, chemical and biological information. Some historical perspectives on ALL from about 1850 through 1875 include good fishing reports, but siltation filled the lake soon after that, and fishing declined. Chemical data from the mid-1940s included "soluble or inorganic phosphorus ranging from 0.03 to 0.39 ppm," and BOD values in the upper portion of the lake (by the City of Albert Lea) between 12 to 20 ppm. Submerged aquatic plants were found to be few in kind, but abundant in quantity, with sago pondweed being very common. Test netting of fish found an abundance of common sucker and black bullhead (Department of Conservation 1945).

Several efforts were noted around 1960 that assessed some type of dredging project for ALL. While there were several different scenarios involving dredging depths and coverage, one estimate of dredging the entire lake to a 6' depth found that it would take about 65 years to complete (Tuveson, R. and Lake Study Committee).

The Minnesota Department of Health and Freeborn County Clean Water, Inc. completed a detailed investigation on pollution in ALL and its watershed, in 1962. This project included sampling of lakes, streams, and sediments – with reporting on existing pollution conditions by 'watershed units.' It included specific information on land uses, city and industrial dischargers, and included remedial measures for improvement. Many of the recommendations dealt with industrial and sanitary discharges to streams and lakes. The report was authored by geologist L.E. Richie, Jr. (1962).

In 1972, ALL was included in the EPA's National Eutrophication Survey. This was a broad effort for many lakes, across many States, to assess nutrient conditions, and compare results using some simple lake models. This effort noted that ALL was highly eutrophic, and was receiving 84% of the pollutant load (TP) from industrial and municipal sources (Albert Lea city, Wilson & Company, and Clark's Grove). Nonpoint source phosphorus loading was 16% of the total load, with nutrient export from Peter Lund Creek viewed as "quite high," when compared to other streams in the study (EPA 1974). At this time, significant efforts were underway to upgrade the wastewater facilities.

In 1973, National Biocentric, Inc. (a St. Paul consultant) was hired by the City of Albert Lea and Freeborn County to conduct a thorough eutrophication study of ALL. This project included developing both a water and nutrient budget, and arose from concerns about drastically reduced lake water quality. At the time of this effort, wastewater from the city of Albert Lea was receiving secondary treatment before discharge to ALL. Average TP concentrations were found to be 600 ug/L for ALL, and 180 ug/L for Fountain Lake. This project also noted that for both lakes, there was a net loss of phosphorus to the sediments, and that there was no substantial movement of phosphorus from the sediment into the lake water. By diverting wastewater from the city of Albert Lea, about 72% of the phosphorus loading could be eliminated. The Bancroft Creek Subwatershed was targeted, as contributing about 8% of the TP load, at the time. (National Biocentric 1975). Sediment surveys were also completed for both ALL and Fountain Lake. This significant project concluded that both Fountain Lake and ALL would never have lake characteristics found in northern Minnesota lakes, and beyond nutrient removal through wastewater management, "…remedying the problems of the two lakes becomes much more difficult."

The assessments and studies in the early to mid-1970s led to decisions for Freeborn County (Albert Lea Tribune, 10-19-7X). The debate included costs and feasibility of inlake actions such as sediment dredging, as well as nutrient reduction from wastewater and the watershed.

The EPA awarded a grant for restoration work on Fountain Lake in 1976, with work on ALL postponed until the WWTP could be renovated, with construction grants funding (EPA Report 1977). In 1977, some applied research and testing was conducted to determine if some type of limestone filter might be used to remove phosphorus from tributary streams flowing into the lakes. Five possible "filters" were considered, for Bancroft Creek, Peter Lund Creek, Manchester (Wedge) Creek, Hayward Creek (Peter Lund Creek), and a Pickeral filter (Schoff Creek). Ultimately, these practices were not implemented. The available funds were instead used for "…livestock yard drainage and ditch side filter belts."

In 1992, a lake assessment project was conducted by the MPCA, Freeborn County, and Albert Lea Technical College. The purpose of this effort was to assess the conditions in the lake, nine years after the City of Albert Lea's WWTP discharge was moved from the lake, to the SRR. Total phosphorus levels had improved a good deal, with an average of 230 ug/L – compared to a pre-1978 average TP of 790 ug/L. However, the summer chlorophyll-a levels were high (125 ug/L), and SDT was 1.2 feet – and the lake was classified as eutrophic to hypereutrophic (MPCA 1993).

Through work of the Freeborn County local water planning efforts in the early 1990s, the Albert Lea Lake Improvement committee, that had been active in the early 1970s, was revived. In 1994 this committee was emphasizing long-term solutions for ALL and its watershed (Albert Lea Lake Report 1997). A broad and hard-working committee, involving the City of Albert Lea, Freeborn County, the Chamber of Commerce, DNR and MPCA staff were all involved in assessing, organizing, and presenting seven management alternatives. These seven management scenarios were presented in 1997, and also in 2000 for public information meetings hosted by the Lake Restoration Committee of Freeborn County (Albert Lea Lake Technical Committee 2000).

A local group in Freeborn County called "Save Our Lakes" formed around this time, and developed numerous positions regarding lake and watershed management. This group was formed to foster a lakes stewardship ethic within the community, based upon comprehensive watershed conservation management, environmental protection, and protecting the natural beauty of the lakes (Save Our Lakes 2000).

This was the general historical context for the major lakes in the SRRW, based on available reports and information from about 1960 to 2001. These efforts and events preceded the discussions and formal hearings, which resulted in the formation of the SRRWD in 2003. The purpose of the SRRWD is to conserve and restore water resources for the beneficial use of current and future generations (SRRWD 2016).

Appendix J. Channel Condition and Stability Assessment (CCSI) for SRRW HUC 11s (from Monitoring and Assessment Report, MPCA 2012).

Table 7. Fountain Lake HUC 11 channel condition and stability.

# Visits	Biological Station ID	Reach Name	Upper Banks (43-4)	Lower Banks (46-5)	Bottom Substrate (47-4)	Channel Evolution (11-1)	CCSI Score (147-14)	CCSI Rating
1	09CD085	County Ditch 65	29	9	3	1	42	fairly stable
1	09CD082	Bancroft Creek (County Ditch 63)	16	17	12	5	50	moderately unstable
1	09CD093	Bancroft Creek (County Ditch 10)	21	16	21	7	65	moderately unstable
1	09CD090	County Ditch 11	26	14	11	5	56	moderately unstable
1	09CD084	County Ditch 66	22	8	9	5	44	fairly stable
1	09CD073	County Ditch 9	23	13	13	3	52	moderately unstable
1	09CD072	Trib. to Fountain Lake	17	18	8	5	48	moderately unstable
1	09CD074	Trib. to Fountain Lake	8	16	14	7	45	moderately unstable
Average Channel Stability Results: *Fountain Lake HUC*			**20.3**	**13.9**	**11.4**	**4.8**	**50.3**	**moderately unstable**

Table 8. Shell Rock River HUC 11 channel condition and stability.

# Visits	Biological Station ID	Reach Name	Upper Banks (43-4)	Lower Banks (46-5)	Bottom Substrate (47-4)	Channel Evolution (11-1)	CCSI Score (137-14)	CCSI Rating
1	09CD086	County Ditch 16	16	15	3	1	35	fairly stable
1	09CD079	Peter Lund Creek	21	11	9	5	46	moderately unstable
1	09CD076	County Ditch 32	12	13	9	5	39	fairly stable
1	09CD077	Judicial Ditch 20	8	13	9	3	33	fairly stable
0	04CD004	County Ditch 16	NA	NA	NA	NA	NA	NA
1	09CD078	County Ditch 16	29	9	17	3	58	moderately unstable

# Visits	Biological Station ID	Reach Name	Upper Banks (43-4)	Lower Banks (46-5)	Bottom Substrate (47-4)	Channel Evolution (11-1)	CCSI Score (137-14)	CCSI Rating
1	04CD037	Shell Rock River	NA	NA	NA	NA	NA	NA
1	09CD087	Shell Rock River	4	5	10	1	20	stable
0	04CD017	Shell Rock River	NA	NA	NA	NA	NA	NA
1	09CD088	Shell Rock River	4	9	5	1	19	stable
0	04CD015	Shell Rock River	NA	NA	NA	NA	NA	NA
1	09CD089	Shell Rock River	19	15	19	5	58	moderately unstable
Average Channel Stability Results: ***Shell Rock River HUC***			**14**	**9.5**	**12.8**	**2.5**	**38.8**	**fairly stable**

Table 9. Goose Creek HUC 11 channel condition and stability.

# Visits	Biological Station ID	Reach Name	Upper Banks (43-4)	Lower Banks (46-5)	Bottom Substrate (47-4)	Channel Evolution (11-1)	CCSI Score (147-14)	CCSI Rating
0	04CD028	County Ditch 17	NA	NA	NA	NA	NA	NA
1	07CD002	County Ditch 17	25	8	20	5	58	moderately unstable
1	09CD081	County Ditch 40	24	4	9	1	38	fairly stable
1	09CD071	Goose Creek	29	7	20	3	59	moderately unstable
Average Channel Stability Results: ***Goose Creek 11 HUC***			**26**	**6.3**	**16.3**	**3**	**51.7**	**moderately unstable**

Appendix K. Subwatershed Priority Maps

The following maps identify which drainages in the SRRW are recommended for prioritization based on various pollutant parameters. Level of priority was based on HSPF model outputs.

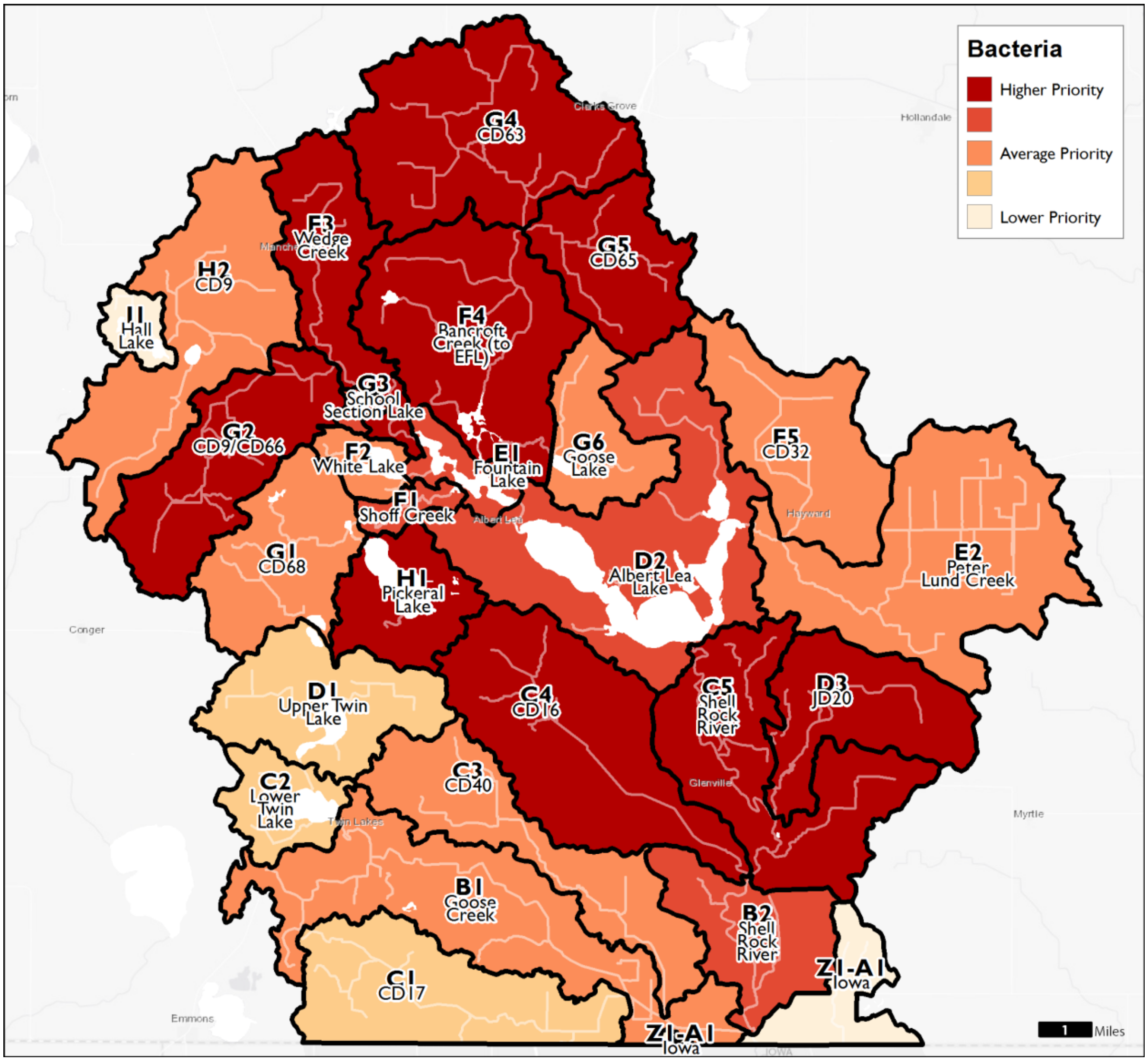

Figure 25. Bacteria priority map.

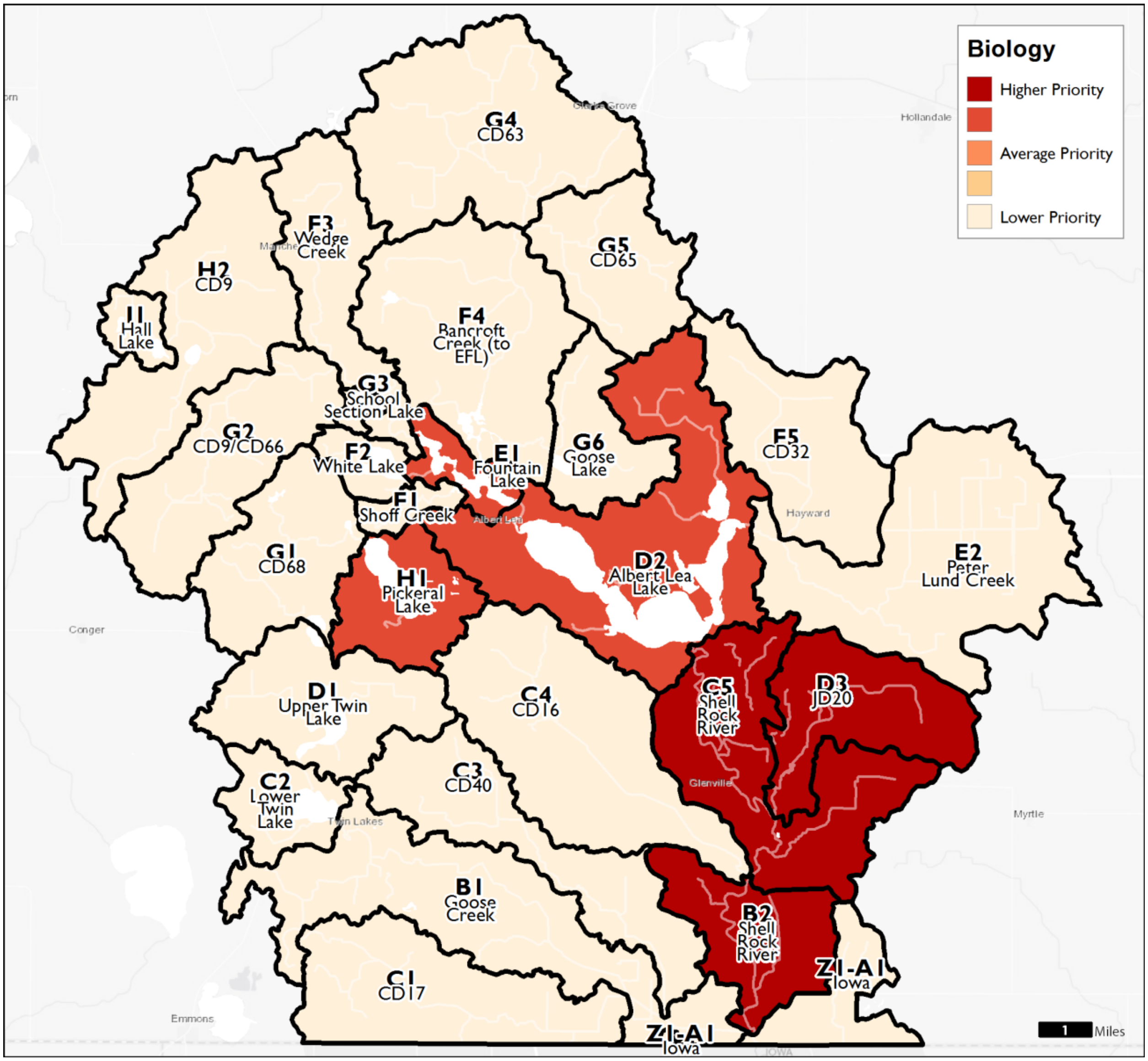

Figure 26. Biology priority map.

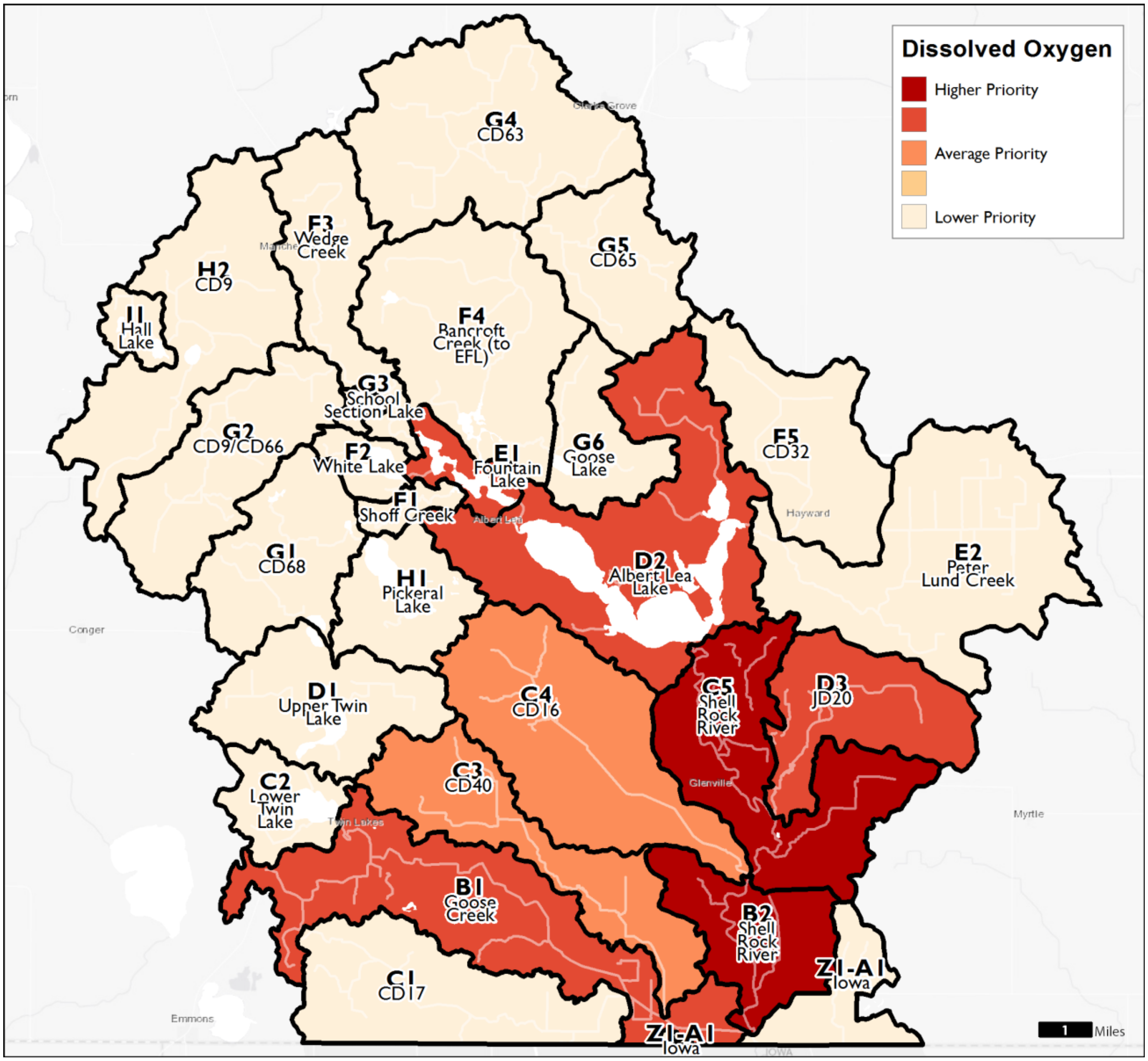

Figure 27. Dissolved oxygen priority map.

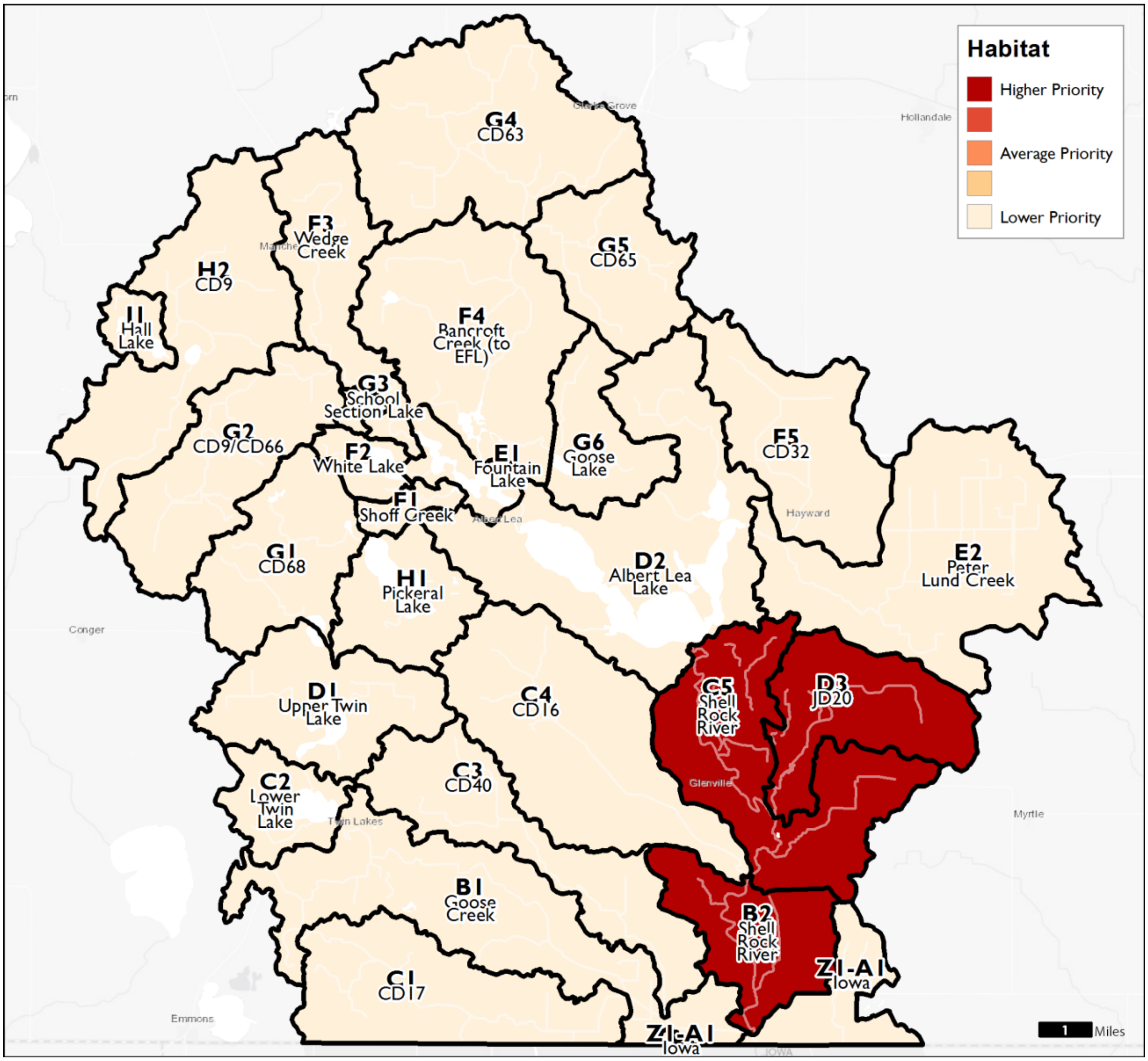

Figure 28. Habitat priority map.

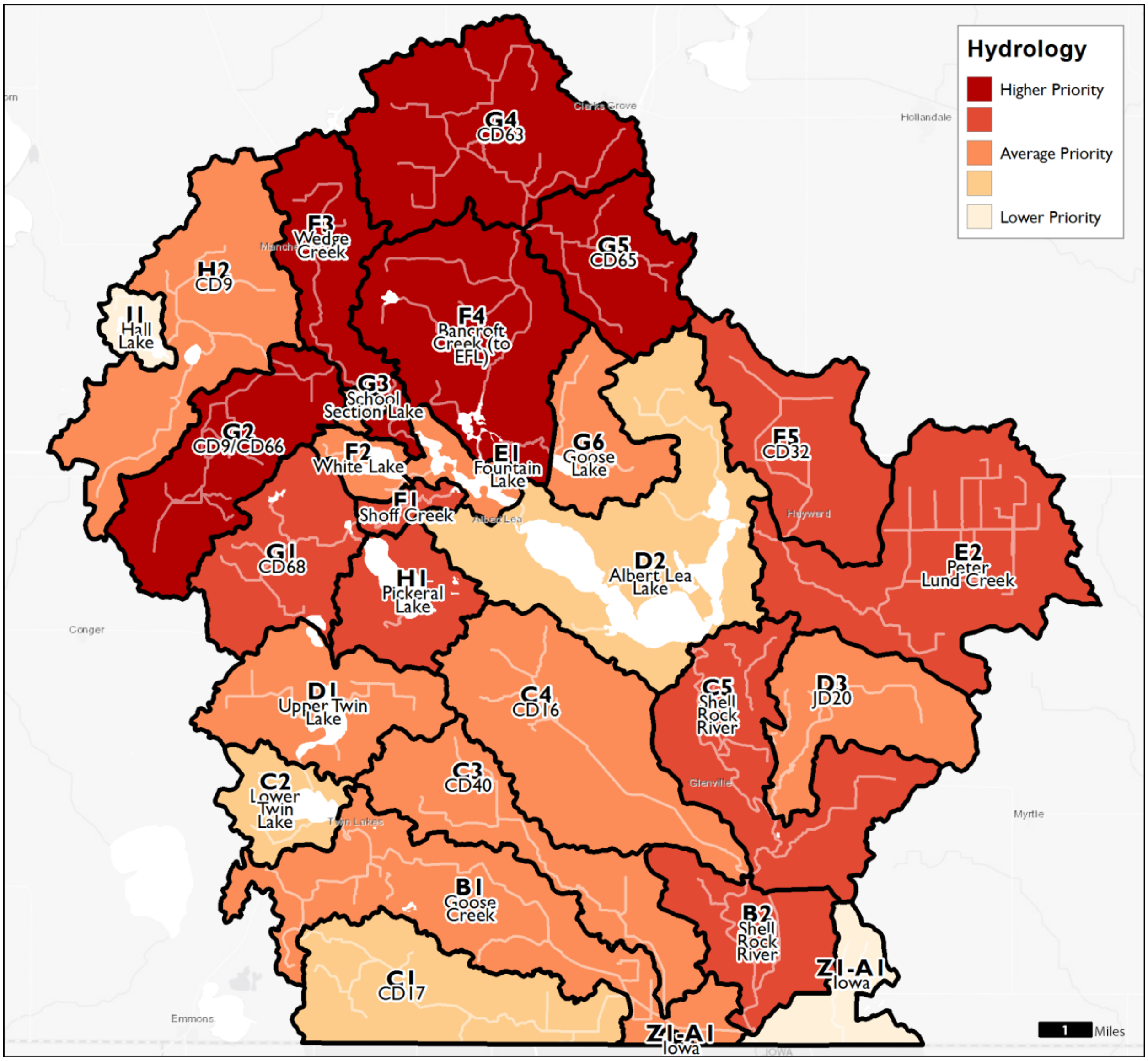

Figure 29. Hydrology priority map.

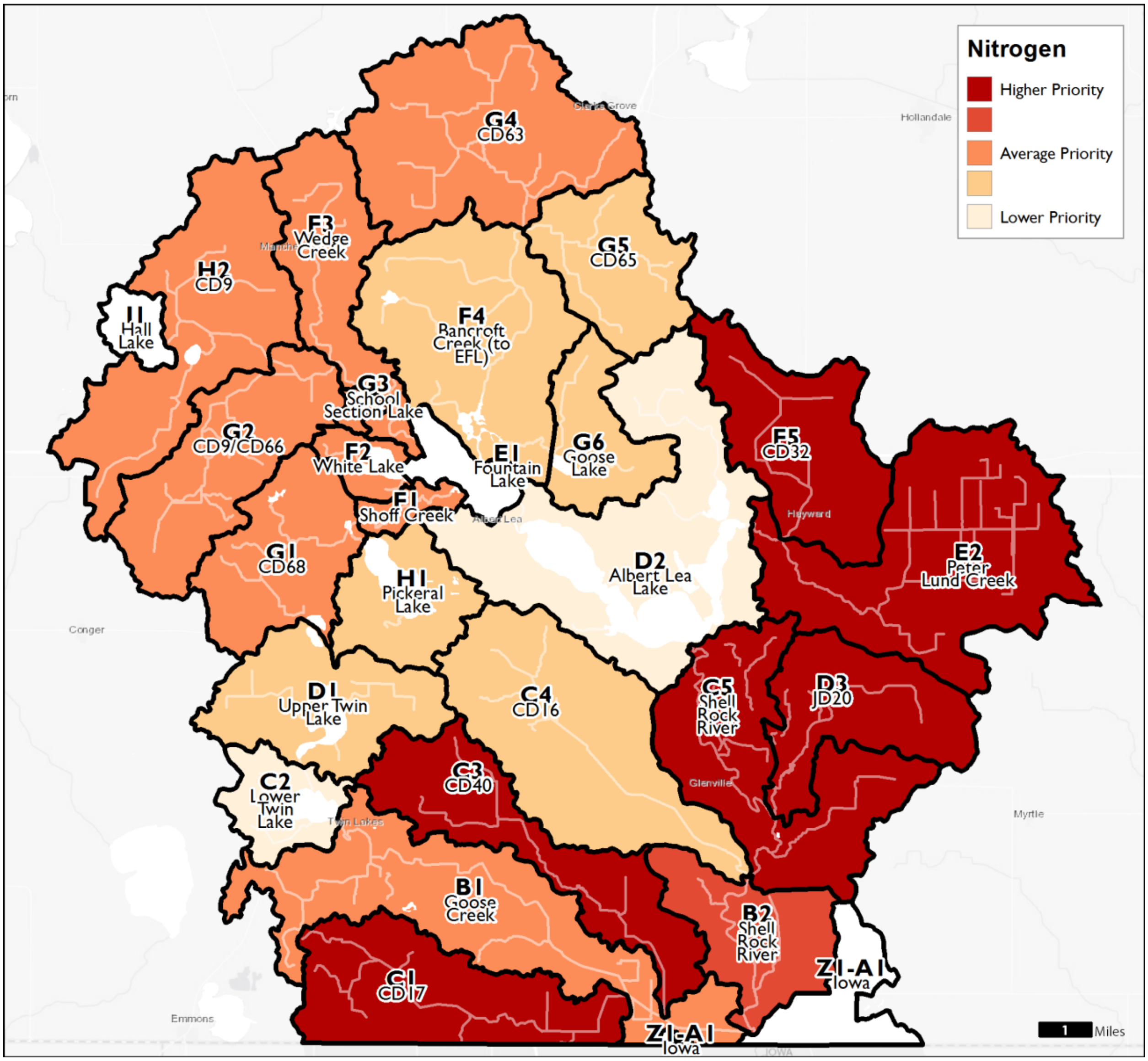

Figure 30. Nitrogen priority map.

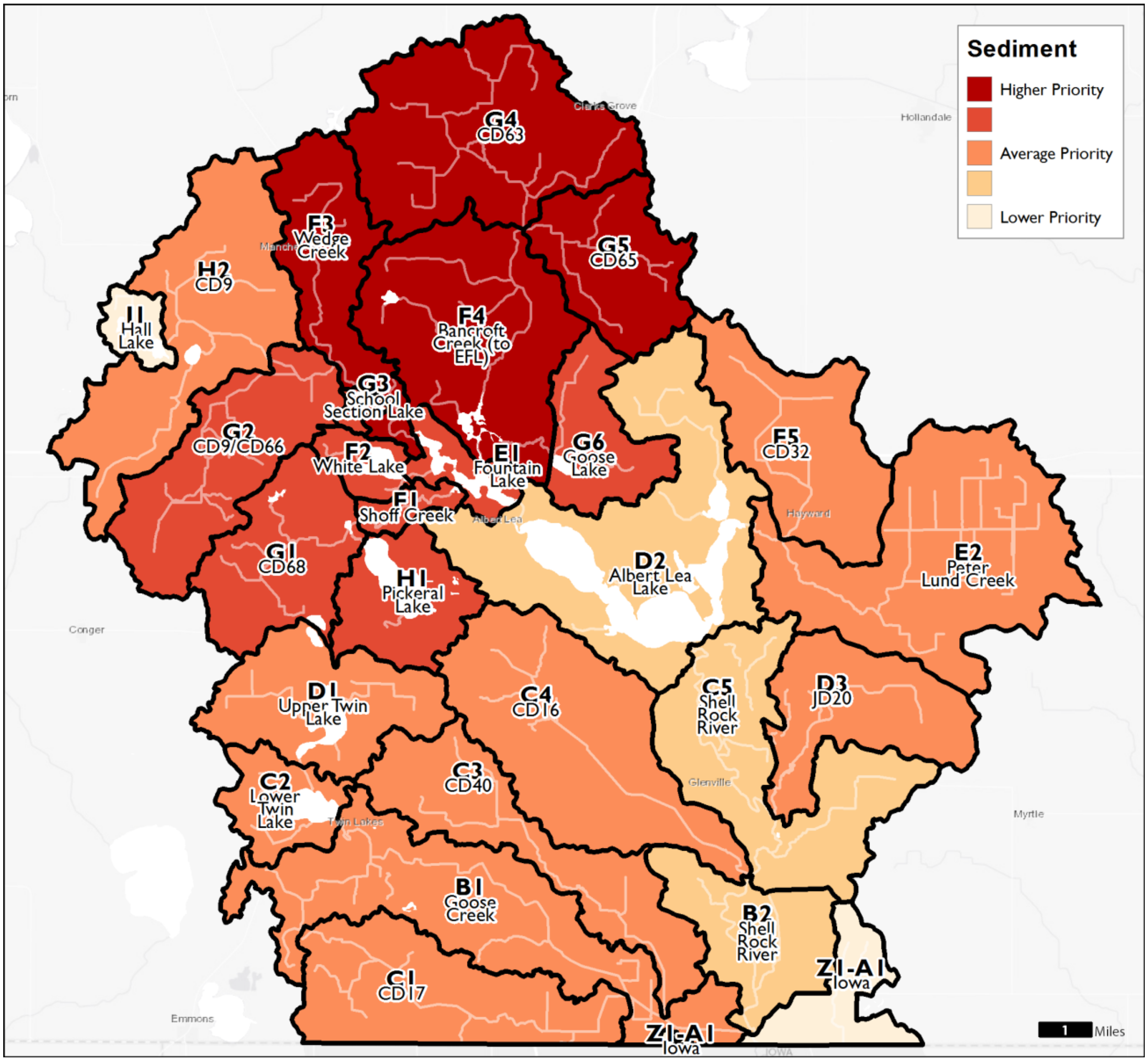

Figure 31. Sediment priority map.

Appendix L. Wastewater Treatment Plant Pollutant Discharges

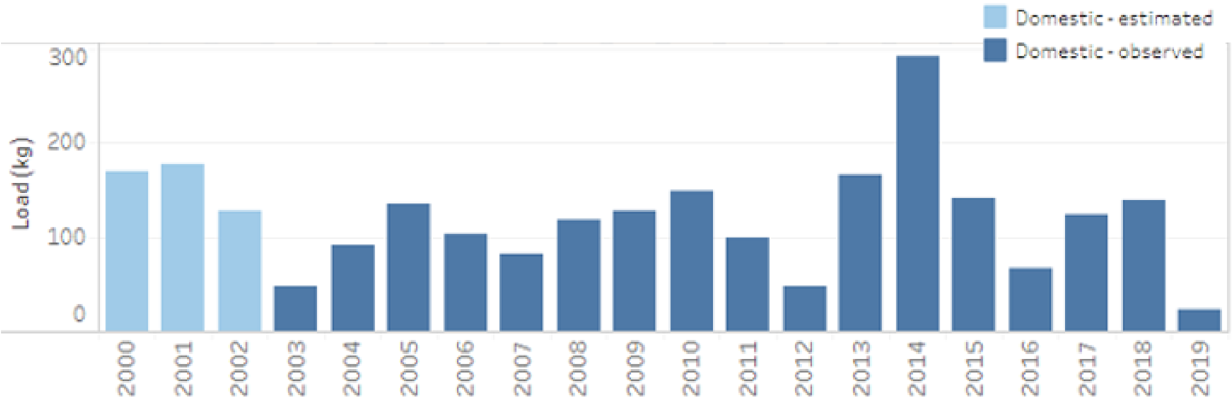

Figure 32. Annual phosphorus loads for Clarks Grove WWTP.

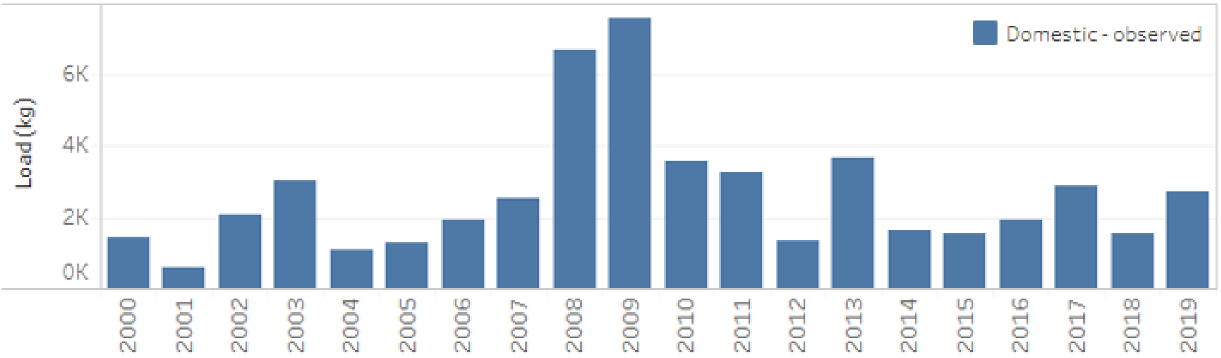

Figure 33. Annual TSS loads for Clarks Grove WWTP.

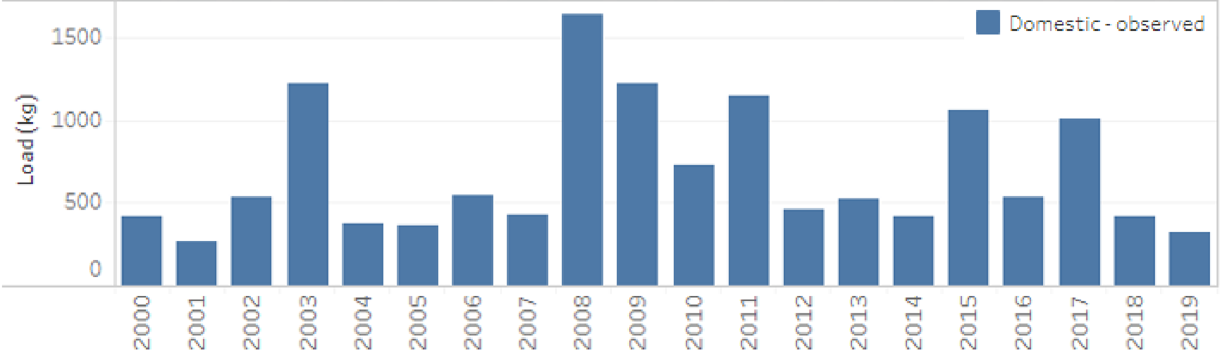

Figure 34. Annual CBOD loads for Clarks Grove WWTP.

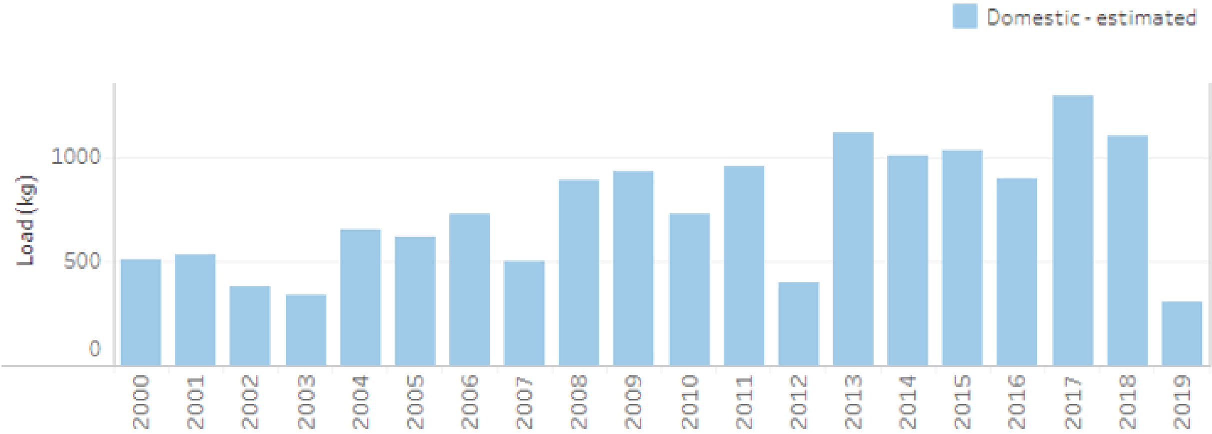

Figure 35. Annual nitrogen loads for Clarks Grove WWTP.

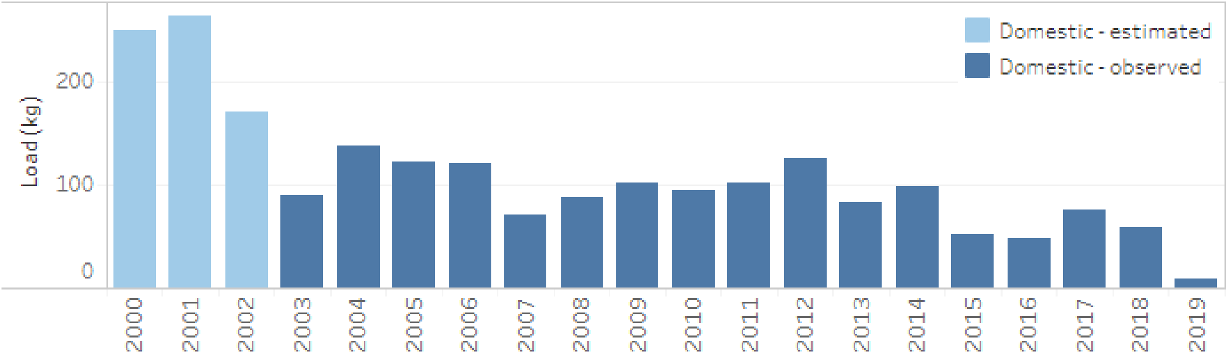

Figure 36. Annual phosphorus loads for Glenville WWTP.

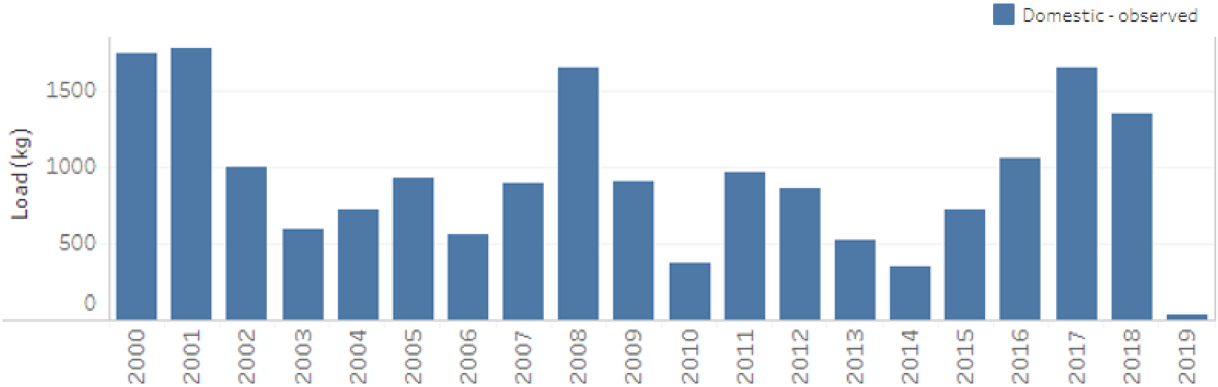

Figure 37. Annual TSS loads for Glenville WWTP.

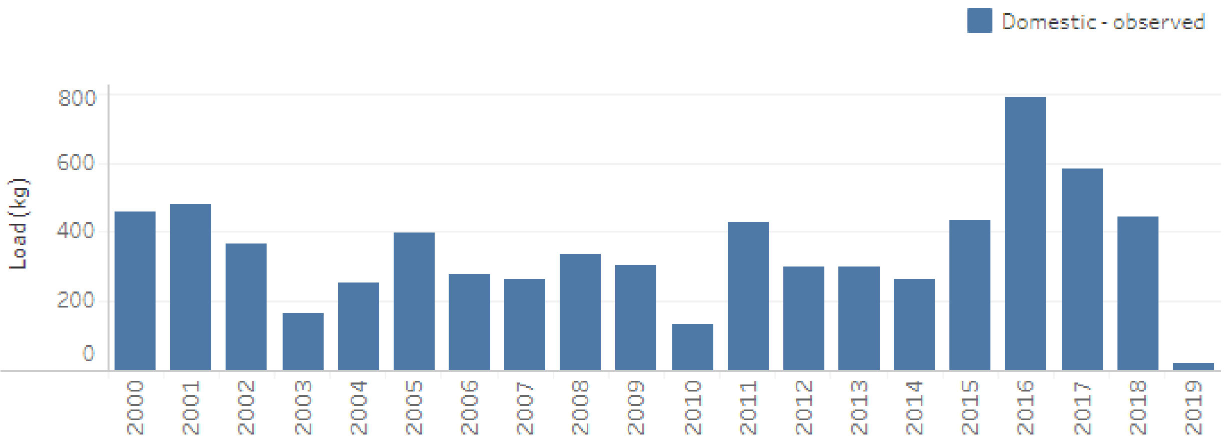

Figure 38. Annual CBOD loads for Glenville WWTP.

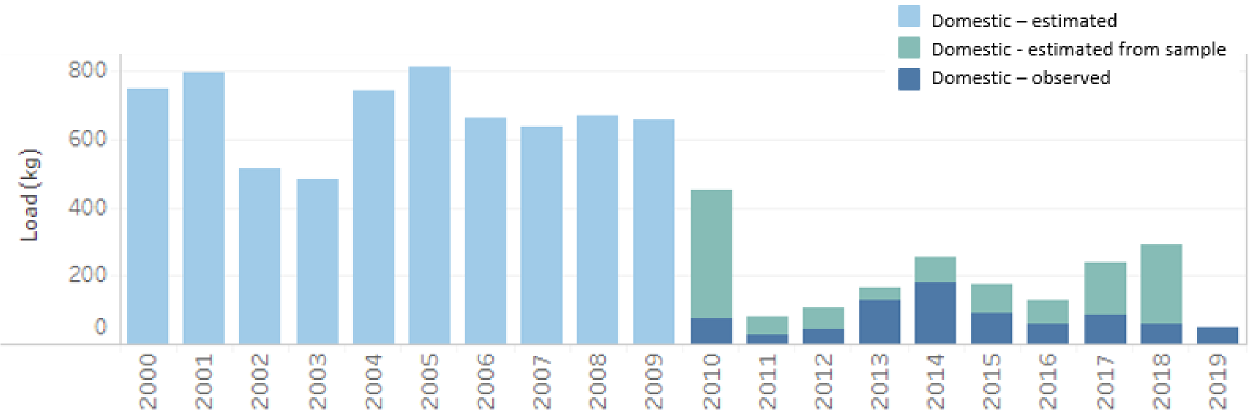

Figure 39. Annual nitrogen loads for Glenville WWTP.

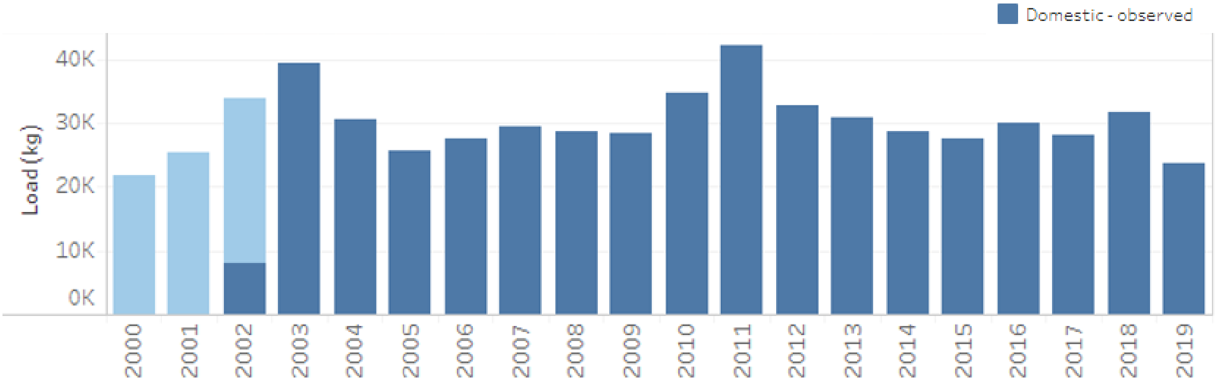

Figure 40. Annual TP loads for Albert Lea WWTP.

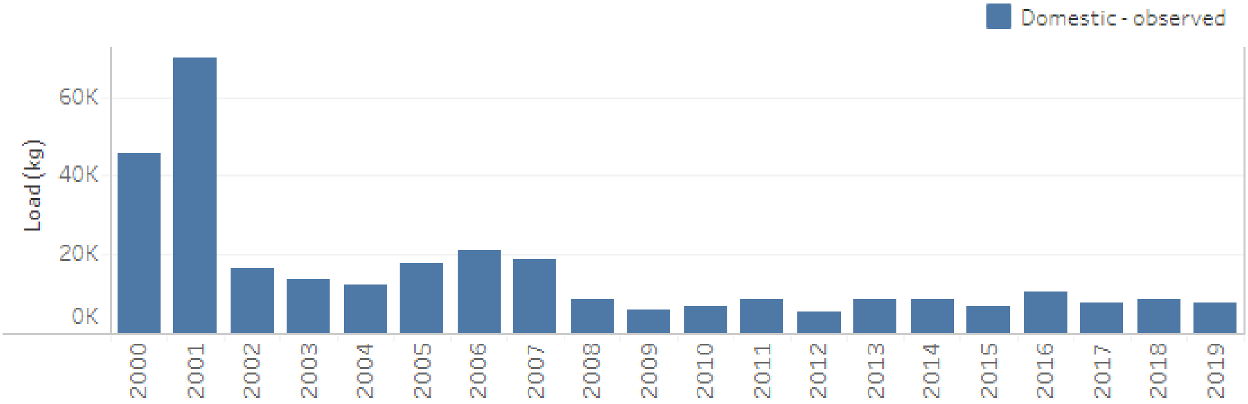

Figure 41. Annual TSS loads for Albert Lea WWTP.

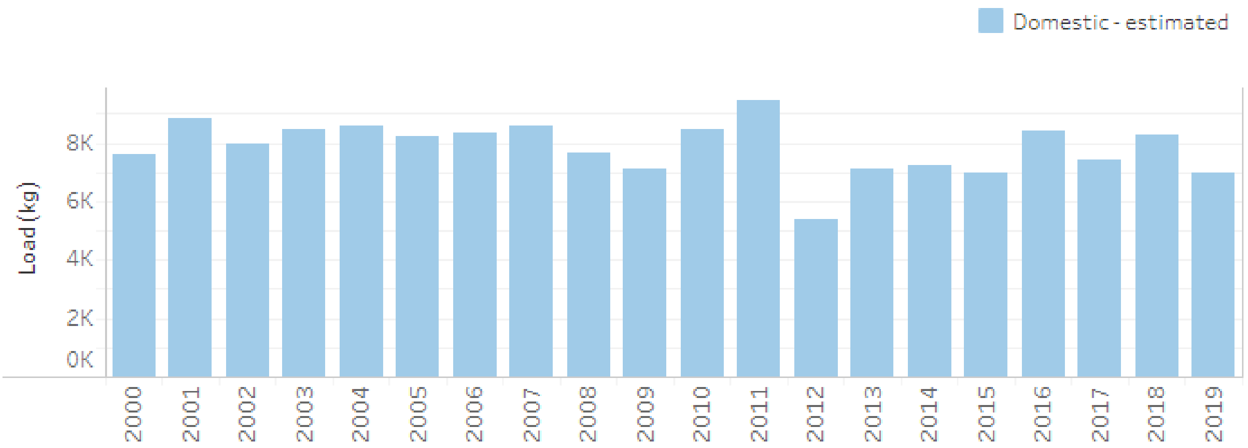

Figure 42. Annual CBOD loads for Albert Lea WWTP.

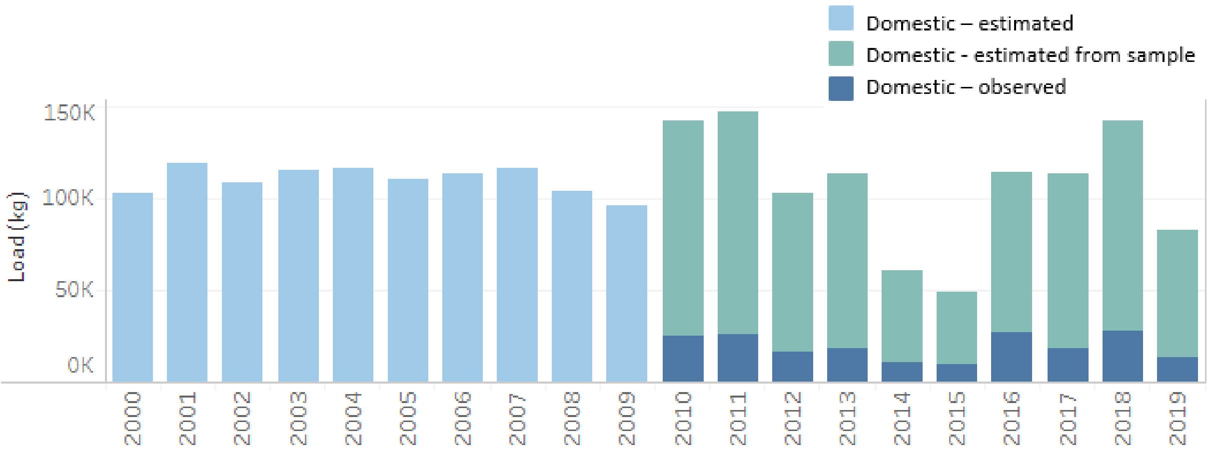

Figure 43. Annual N loads for Albert Lea WWTP.

**Hayward WWTF – not reported in Tableau – contact MPCA staff for annual load data.*

Appendix M. Additional crop statistics

The SRRW covers about 34% of Freeborn County, and some agricultural production statistics (at the county scale) illustrate the significance of row crop agriculture in the region for both environmental and economic conditions (**Error! Reference source not found.**).

Table 10. Freeborn County, Minnesota, corn and soybean crop acres harvested and average yields for 2016 - 2018 (USDA 2019a).

Crop Year	Corn: Acres harvested / yield (bu/ac)	Soybeans: Acres harvested / yield (bu/ac)
2016	206,000 /194	134,900 / 59
2017	182,000 / 212	153,500 / 55
2018	185,300 / 175	153,800 / 54

Crop residue estimates for 2009 through 2015 for the SRRW are displayed for the dominant crop rotation of corn-soybean-corn in Figure 44 below. Residue in fields planted to corn are shown with stacked orange bars, while residue in fields planted to soybeans are shown with stacked purple bars; one pair of bars for each year. The hatched portion of each bar is the estimate of conservation tillage for that year. Conservation tillage represents crop residue greater than 30% after planting. Conservation tillage in fields planted to corn varies in these seven years, but generally makes up less than 10% of the watershed's cropped acres. Fields planted to soybeans (following corn) show expected higher crop residue levels meeting the conservation tillage threshold, with most years in the 45% to 70% range. However, significant variability does exist, with 2009 at about 90% of fields with conservation tillage, and 2013 and 2014 with 40% to 45% of fields.

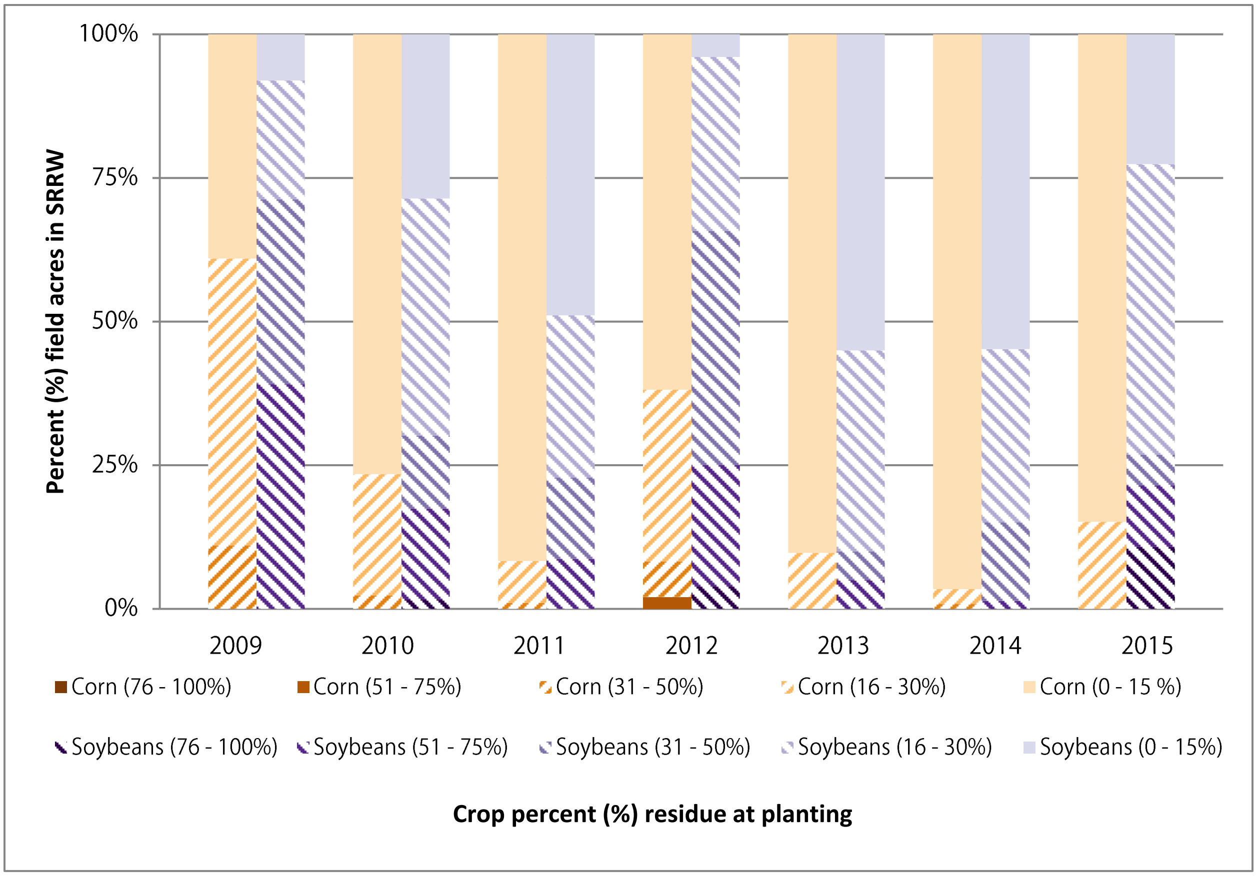

Figure 44. Crop residue estimates for 2009-2015 in the SRRW based on planted crop.