Des Moines River Basin Restoration and Protection Strategies Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Contents

Key terms and abbreviations

Altered hydrology (USGS 2019a): Changes in the amount of and way that water moves through the landscape. Examples of altered hydrology include changes in: river flow, precipitation, subsurface drainage, impervious surfaces, wetlands, river paths, vegetation, and soil conditions. These changes can be climate- or human-caused.

Animal Units (AU): A term typically used in feedlot regulatory language. One animal unit is roughly equivalent to 1,000 pounds of animal, but varies depending on the specific animal.

Assessment Unit Identifier (AUID): The unique waterbody identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if *E. coli* standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus and either chlorophyll-*a* or Secchi disc depth standards are not met.

Biological Impairment (bio-impaired): A biological impairment is an impairment to the aquatic life beneficial use due to a low fish and/or aquatic macroinvertebrate (bug) IBI score.

Civic Engagement (CE): CE is a subset of public participation (EPA 2018b) where decision makers involve, collaborate, or empower citizens in the decision-making process. The University of Minnesota Extension (2013) provides information on CE and defines CE as "Making resourceful decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration."

Designated (or Beneficial) Use: Waterbodies are assigned a designated use based on how the waterbody is used. Typical beneficial uses include: drinking, swimming, fishing, fish consumption, agricultural uses, and limited uses. Water quality standards for pollutants or other parameters are developed to determine if waterbodies are meeting their designated use.

Flow-weighted Mean Concentration (FWMC): The total mass of a pollutant delivered (by water) over a set period of time by the total volume of water over that same period of time. Typical units are mg/L.

Geographic Information Systems (GIS; ESRI 2019): A system designed to capture, store, manipulate, analyze, manage, and present spatial or geographical data.

Hydrologic Unit Code (HUC): A HUC is assigned to a watershed or groups of watersheds by the USGS. HUCs are organized in a nested hierarchy by size. For example, the Des Moines River Basin is assigned a HUC-4 of 0710 and the East Fork Des Moines River Watershed is assigned a HUC-8 of 07100003.

Impairment: Waterbodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic Integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Nonpoint source pollutants: Pollutants that are from diffuse sources; most of these sources are not regulated. Nonpoint sources include: agricultural field run-off, agricultural drain tile discharge, storm water from smaller cities and roads, bank, bluff, and ravine failures, atmospheric deposition, failing septic systems, animals, and other sources.

Point Source Pollutant: Pollutants that can be directly attributed to one location; generally, these sources are regulated by permits. Point sources include: waste water treatment plants, industrial dischargers, storm water discharge from MS4 (larger) cities (MPCA 2019g), and construction stormwater (MPCA 2019b).

Pollutant: Parameters (e.g. bacteria, total suspended solids, etc.) that have a water quality standard and can be tested for directly. Pollutants affect all beneficial uses.

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or pollutant source): Actions, places, or entities that deliver/discharge pollutants.

Stream Class: a classification system for streams to specify the stream's beneficial or designated uses. Modified use classification refers to streams that have been extensively altered and currently exhibit legacy physical modifications and have been determined to be in nonattainment of the general use biological criteria.

> **Stream Class 2B**: The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable.
>
> **Stream Class 2C**: The quality of Class 2C surface waters shall be such as to permit the propagation and maintenance of a healthy community of indigenous fish and associated aquatic life and their habitats. These waters shall be suitable for boating and other forms of aquatic recreation for which the waters may be usable.
>
> **Stream Class 7 waters**: The quality of Class 7 waters of the state shall be such as to protect aesthetic qualities, secondary body contact use, and groundwater for use as a potable water supply.

Stream reach: "A section of a stream or river along which similar hydrologic conditions exist, such as discharge, depth, area, and slope… The term is often used by hydrologists when they're referring to a small section of a stream or river rather than its entire length." (USGS, 2019b)

Stressor (or biological stressor): A term for the parameters (e.g., altered hydrology, dams preventing fish passage, etc.) that were identified as adversely impacting aquatic life in a biologically-impaired stream reach or lake.

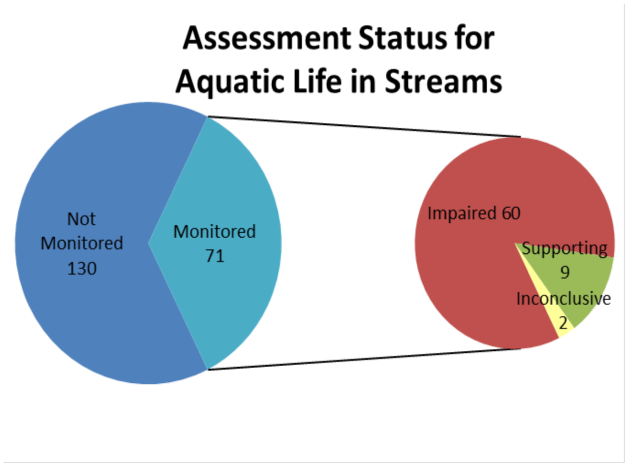
Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

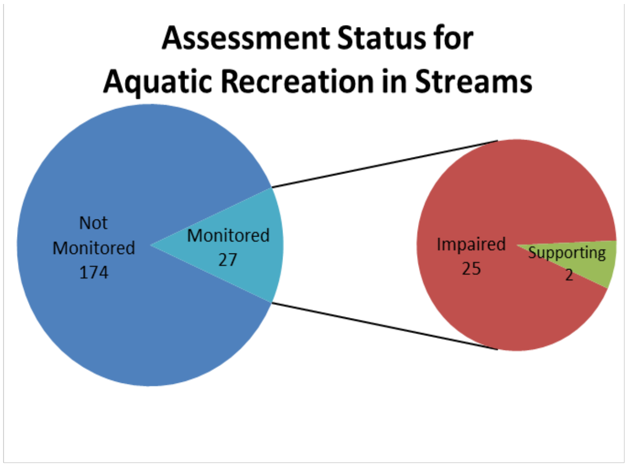
Yield (water, pollutant, crop, etc.): The amount of mass, volume, or depth per unit land area (e.g. lbs/ac, in/ac).

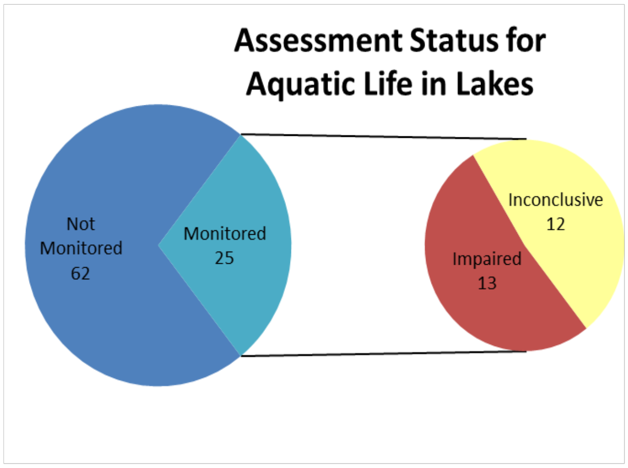
Executive summary

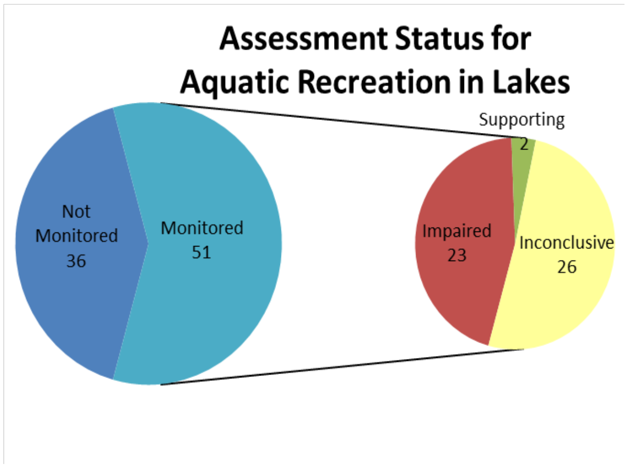
The State of Minnesota uses a “Watershed Approach” to assess and address the water quality of each of the state’s 80 major watersheds on a 10-year cycle. This report summarizes the Minnesota Pollution Control Agency’s (MPCA) Watershed Approach work findings, addressing the fishable, swimmable status of surface waters in the Des Moines River Basin. This work relied on a scientific approach by MPCA staff, but also developed and vetted results using a team of local watershed partners (Soil and Water Conservation Districts (SWCDs), counties, a Watershed District, and other state agencies). Another important aspect of this work was the civic engagement process, which identified challenges, opportunities, and recommendations to achieve higher adoption of conservation practices within the watersheds.

The majority of monitored stream reaches and lakes in the Des Moines River Basin are not meeting water quality standards for aquatic life (fishing) and aquatic recreation (swimming), as illustrated in the pie charts below.


Assessment Status for Aquatic Life in Streams


Assessment Status for Aquatic Recreation in Streams


Assessment Status for Aquatic Life in Lakes


Assessment Status for Aquatic Recreation in Lakes

These impairments to aquatic recreation and aquatic life are caused by multiple parameters (pollutants and stressors). A source assessment, goals, and 10-year targets were developed for each parameter. The parameters along with their goals and 10-year targets are summarized in the following table.

Parameter (Pollutant/ Stressor)	**Basin-Wide Goal** (average/surrogate for watershed)	**Range of Subwatershed Goals** (Estimated only when TMDL or MSHA data available)	**10-year Target** (for 2030)	**Years to Reach Goal** (from 2020)
Degraded Habitat	45% increase in MSHA habitat score	Protection and up to a 214% increase	20%↑	40
Phosphorus/ Eutrophication	45% reduction in lake and stream concentrations/loads	Protection and up to a 76% reduction	Lakes - 7%↓ Streams - 15%↓	Lakes - 50 Streams - 40
Sediment	30% reduction in stream concentrations/loads	Protection and up to a 80% reduction	5%↓	60
Nitrogen	30% reduction in stream concentrations/loads	Not estimated (TMDLs not completed on this parameter)	10%↓	40
Altered Hydrology	20% reduction in peak & annual stream flow	Not estimated (TMDLs not completed on this parameter)	2.5%↓	100
	Increase dry season stream base flow where ID'd in SID by enough to support aquatic life		Small Improvement	50
Connectivity	Address human-caused issues (dams, culverts) as identified in SID and where practical/feasible	Not estimated (TMDLs not completed on this parameter)	6 Barriers Removed	20
Bacteria	50% reduction in stream concentrations/loads	Protection and up to a 86% reduction	10%↓	50
Chloride	Protect (restore the one impaired reach)	Protection and up to a 33% reduction	Meet permit requirements (impaired reach is point source driven)	
Parameters that are impacted/addressed by the above pollutants and stressors				
Fish (F-IBI)	Each parameter's goal is to meet the water quality standard and support downstream goals. Because these parameters are a response to (caused by) the above pollutants/stressors, the above watershed-wide goals are the (indirect) goals for these parameters.	Not estimated (TMDLs not completed on these parameters)	Meet other 10-year targets	60
Macroinverts (M-IBI)				60
DO				40
pH				50

Strategies were developed to address the identified goals and 10-year targets. **Strategies Table A** (Table 21, Page 80) provides a high-level narrative estimate of the total changes necessary for all waters to be restored and protected, and **Strategies Table B** (Table 22, Page 81) presents a suite of strategies and numeric adoption rates to meet the 10-year targets. Cultivated crops represent 82% of the land use in Minnesota’s portion of the Des Moines River Basin. Therefore, cultivated crops are the largest land management opportunity for water quality improvement in the watershed. However, nearly all land uses and sources require improvements to meet goals, including cultivated crops, feedlots, manure application, pastures, streams (including ditches and riparian areas), lakes (including wetlands and shoreland), cities and residential, septic systems, and point sources.

Watershed restoration depends on higher adoption of best management practices (BMPs), including the following, high priority practices: cover crops, decreased tillage, decreased fertilizer use, cropland surface runoff treatment, crop diversification, cropland tile drainage treatment, and improved manure application. Social strategies to accelerate BMP adoption include improving programs and funding, increasing education and outreach, leveraging collaborations and networks, and developing or enforcing rules or ordinances. High priority strategies for protecting waters include maintaining perennial vegetation and BMPs on the landscape and mitigating future changes to hydrology.

Priority areas to restore and protect surface water quality are summarized in the Priorities Table (Table 23, Page 84). Local partners will further prioritize and target during the One Watershed-One Plan process, to integrate surface water quality with other local priorities to identify multiple-benefit priority areas. Identified priorities from the WRAPS Local Work Group (LWG) include: protection of supporting waters, waters that are barely impaired, connectivity/fish passage barriers, measurable waters, dirtiest watersheds or waters, highly hydrologically altered waterbodies, drinking water and ground water, wildlife habitat, and popular recreational waterbodies.

The biophysical means to restore and protect the watershed (i.e. the physical strategies) are fairly well understood. However, the transition to these sustainable practices is limited by social-based challenges. Identifying potential social strategies, civic engagement, and public participation were a major focus during the Des Moines River Basin Watershed Approach. The MPCA worked collaboratively with county and SWCD staff, the Heron Lake Watershed District, consultants, citizens, and other state agency staff on two civic engagement projects in the Des Moines River Basin. The collective work (summarized in Section 3.2) was integrated into the strategies table, but independently serves as a representation of citizen recommended work and next steps for local conservation planning. Ultimately, this work will help identify land management options for the purposes of surface water quality restoration and protection within the Des Moines River Basin.

1. Introduction and Background

1.1 Watershed Approach and WRAPS

The State of Minnesota uses a “Watershed Approach” (MPCA 2015e) to assess and address the water quality of each of the state’s 80 major watersheds on a 10-year cycle. In each cycle of the Watershed Approach, waterbodies across the watershed are monitored and assessed, restoration and protection strategies and local plans are developed and updated, and conservation practices are implemented. Watershed Approach assessment work started in the Des Moines River Basin in 2014 (Figure 1).

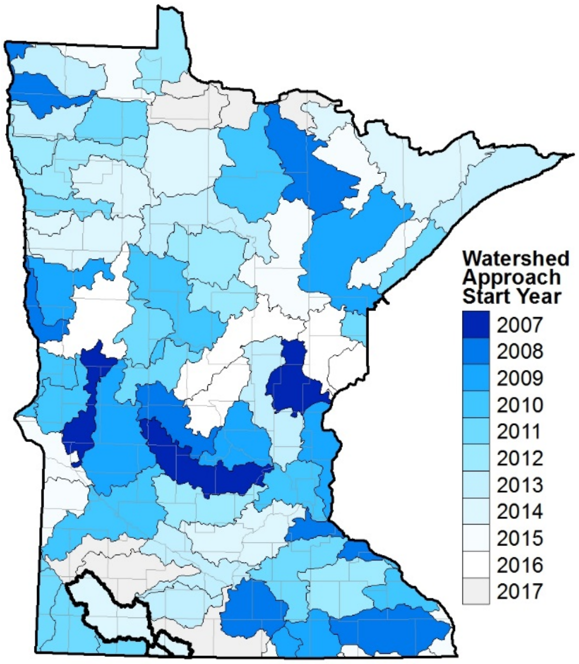


Figure 1: Watershed Approach work in the Des Moines River Basin (outlined in bold) started in 2014 with stream and lake monitoring.

Much of the information presented in this Watershed Restoration and Protection Strategies (WRAPS) report was produced in earlier Watershed Approach work. However, this report presents additional data and analyses. To ensure the WRAPS strategies and other analyses appropriately represent the Des Moines River Basin, local and state natural resources and conservation professionals (referred to as the WRAPS LWG) were convened to inform the report and advise on technical analyses.

Two key products of this WRAPS report are the Strategies Table and the Priorities Table, each developed with the WRAPS LWG. The Strategies Table outlines high-level strategies and estimated adoption rates necessary to restore and protect water quality in the Des Moines River Basin, including social strategies that are key to achieving the physical strategies. The Priorities Table presents criteria to identify priority areas for water quality improvement, including specific examples of waterbodies and areas that meet the prioritizing criteria. Additional tools and data layers can be used to refine priority areas and target strategies within those priority areas are listed in Appendix 4.

In summary, the ***purpose*** of the WRAPS report is to summarize work, including strategy development, completed in this first cycle of the Watershed Approach in the Des Moines River Basin, which started in 2014. The ***scope*** of the report is surface waterbodies and their aquatic life and aquatic recreation beneficial uses as currently assessed by the MPCA. The primary ***audience*** for the WRAPS report is local planners, decision makers, and conservation practice implementers; watershed residents, neighboring downstream states, agricultural business, governmental agencies, and other stakeholders are the secondary audience.

This WRAPS report is not a regulatory document but is legislatively required per the (updated) Clean Water Legacy legislation on Watershed Restoration and Protection Strategy (WRAPS) (ROS 2019). This report has been designed to meet these requirements, including an opportunity for public comment, which was provided via a public notice in the State Register from December 7, 2020 to January 6, 2021. The WRAPS report concisely summarizes an extensive amount of information. The reader may want to review the supplementary information provided (links and references in document) to fully understand the summaries and recommendations made within this document.

1.2 Watershed Description

The Minnesota portion of the Des Moines River Basin contains all or parts of three major (HUC-8) watersheds in southwest Minnesota. These include the Des Moines River – Headwaters (HUC 07100001), Lower Des Moines River (HUC 07100002), and the East Fork Des Moines River (HUC 07100003) watersheds (Figure 2). The Des Moines River – Headwaters flows into the Lower Des Moines River and combined are considered the West Fork Des Moines River Watershed. The East Fork Des Moines River flows across the Minnesota border and into the Des Moines River in Iowa. The Des Moines River continues to flow southeast to the confluence with the Mississippi River at Keokuk, Iowa.

In total, the 3 watersheds drain 983,719 acres from 7 counties in Minnesota (Cottonwood, Jackson, Martin, Murray, Nobles, Lyon, and Pipestone). A total of 25 towns and cities are either completely or partially located within the Des Moines River Basin. The total population of the three watersheds is approximately 34,000 people.

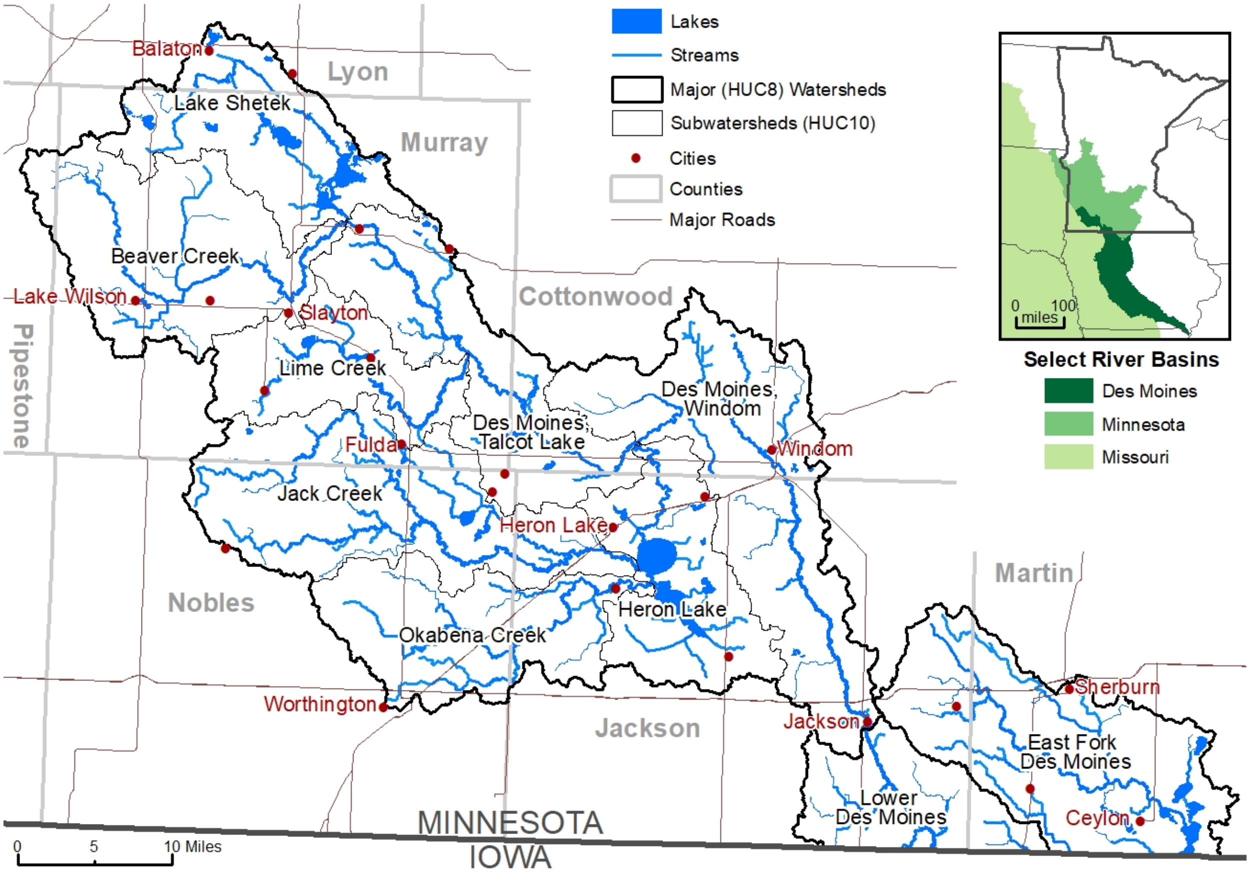


Figure 2: The Des Moines River Basin include the Des Moines River Headwaters, Lower Des Moines River, and the East Fork Des Moines River watersheds. The stream line sizes in this image are used to indicate the estimated average stream flow (thicker lines indicate more flow).

The Des Moines River Basin is located within two ecoregions (EPA 2018a). The northwestern portion is located in the Northern Glaciated Plains, while the remaining area is located in the Western Corn Belt Plains. Land use is dominated by agriculture and has limited development (Figure 3). The majority of the agricultural land is used for growing corn and soybeans with small areas of herbaceous and hay/pasture lands. The remaining portion of the land is developed, undeveloped (forest/shrub and herbaceous), wetlands and open water.

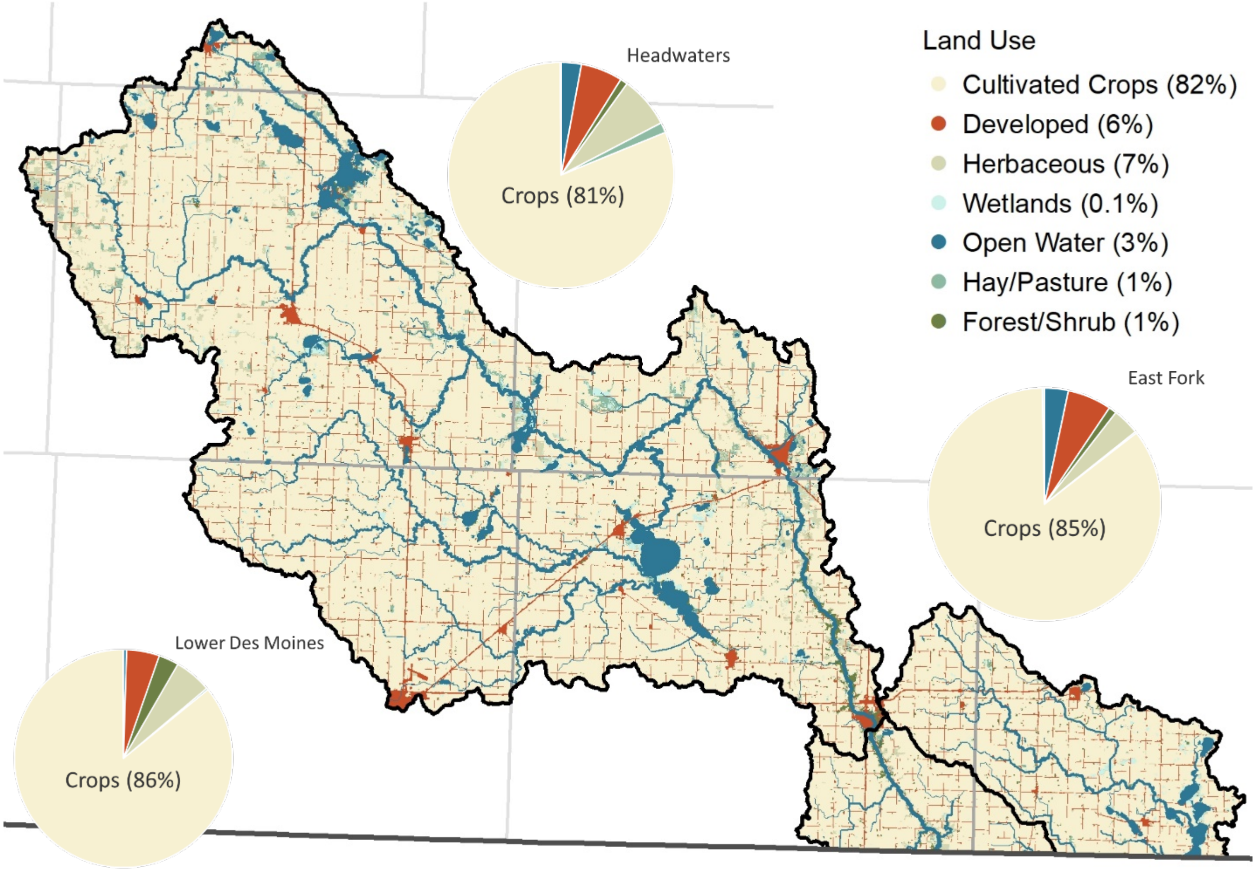


Figure 3: Land use in the Des Moines River Basin is dominated by cultivated crops.

The Buffalo Ridge separates the western border of the Des Moines River Headwaters Watershed from the Missouri River basin. This ridge is in the southeastern part of the larger Coteau de Prairies geologic feature. The Coteau de Prairies is a plateau where two glacial lobes, James on the west and Des Moines on the east, parted around it (Lusardi and Dengler 2017). From this ridge moving east, the land falls to the lowest point in the East Fork Des Moines Watershed (Figure 4).

There are currently no American Indian areas in the Minnesota portion of the Des Moines River Basin in Minnesota (USCB 2018). However, the counties of Cottonwood, Jackson, Lyon, Martin, Murray, Nobles, and Pipestone are designated as counties of interest for the Lower Sioux Indian Community of Minnesota (MPCA 2020c).

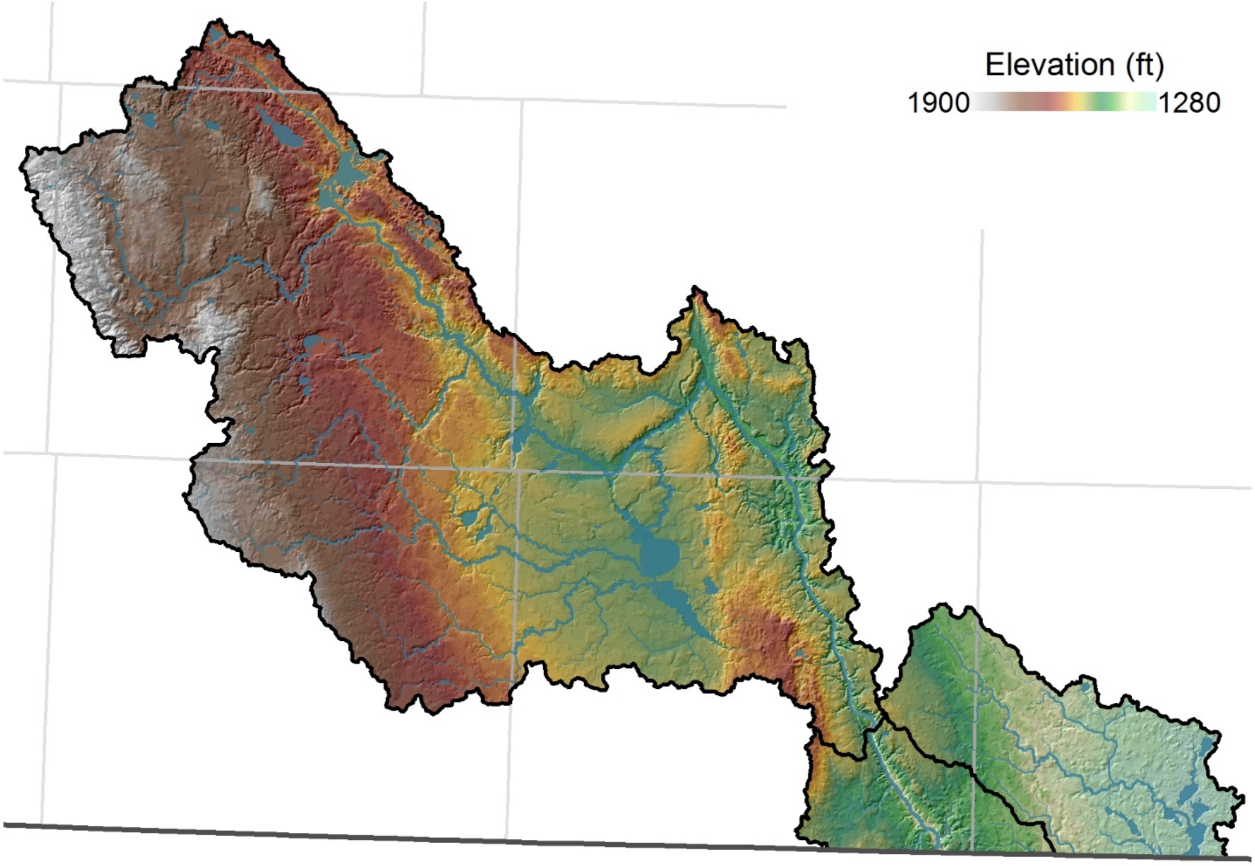


Figure 4: Elevation in the Des Moines River Basin drops roughly 600 feet from the Buffalo Ridge in the northwestern part of the Des Moines River – Headwaters Watershed to the Iowa/Minnesota boundary in the Lower Des Moines River and East Fork Des Moines River Watersheds.

More background information on the Des Moines River Basin can be found at:

Rapid Watershed Assessment (USDA-NRCS 2018)

Watershed Health Assessment Framework (DNR 2020)

1.3 Assessing Water Quality

Assessing water quality is a complex process with many steps including: developing water quality standards, monitoring the water, ensuring the monitoring data set is comprehensive and accurately represents the water, and local professional review. A summary of some process information and steps is below.

Water Quality Standards

Water quality is not expected to be as clean as it would be under undisturbed, "natural background" conditions. However, waterbodies are expected to support designated (or beneficial) uses including: fishing (aquatic life), swimming (aquatic recreation), and eating fish (aquatic consumption). Water quality standards (MPCA 2015d; also referred to as "standards") are set after extensive review of data about the pollutant concentrations that support different designated uses and include natural background conditions.

Water Quality Monitoring and Assessment

To determine if water quality is supporting its designated use, data on the waterbody are compared to relevant standards. When pollutants/parameters in a waterbody exceed the water quality standard, the waterbody is considered impaired (MPCA 2011a). When pollutants/parameters in a waterbody meet the standard (usually when the monitored water quality is cleaner than the water quality standard), the waterbody is considered supporting (of designated uses). If the monitoring data sample size is not robust enough to ensure that the data adequately represent the waterbody, or if monitoring results seem unclear regarding the condition of the waterbody, an assessment is delayed until further data are collected; this is referred to as an inconclusive or insufficient finding.

Several different parameters are considered for the assessment of each designated use. For aquatic recreation assessment, streams are monitored for bacteria and lakes are monitored for clarity and algae-fueling phosphorus. For aquatic life assessment, streams are monitored for both aquatic life populations and pollutants that are harmful to these populations. Lakes are monitored for aquatic life populations (fish populations). A water is considered as having impaired aquatic life populations (referred to as "bio-impaired") when low or imbalanced fish or bug populations are found (as determined by the Index of Biological Integrity [IBI] score).

This WRAPS report summarizes the assessment results; however, the full report is available at *Des Moines River Watersheds in Minnesota Monitoring and Assessment Report* (MPCA 2017a).

Stressor Identification

When streams are found to be bio-impaired, the cause of bio-impairment is studied and identified in a process called stressor identification (SID). SID identifies the parameters negatively affecting the aquatic life populations, referred to as "stressors". Stressors can be pollutants like nitrate, phosphorus, or sediment, or nonpollutants like degraded habitat or high flow. Stressors are identified using the *Causal Analysis/Diagnosis Decision Information System* (CADDIS; EPA 2019c) process. In short, stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. This WRAPS report summarizes the SID results, but the full report is available at *Des Moines River Watershed Stressor Identification Report* (MPCA 2018c).

Summary of Beneficial Uses, Pollutants, and Stressors

Pollutants and stressors both affect the beneficial uses and must be addressed to bring waters to a supporting status. However, they are identified in different ways: pollutants are compared to the water quality standards directly, while stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. Often times, pollutants and stressors can be complex and interconnected. Furthermore, an identified stressor can be more of an effect than a cause, and will therefore have additional stressors and/or sources driving the problem. The difference between a pollutant and a stressor and a brief summary of how pollutants and stressors are identified is illustrated in Figure 5.

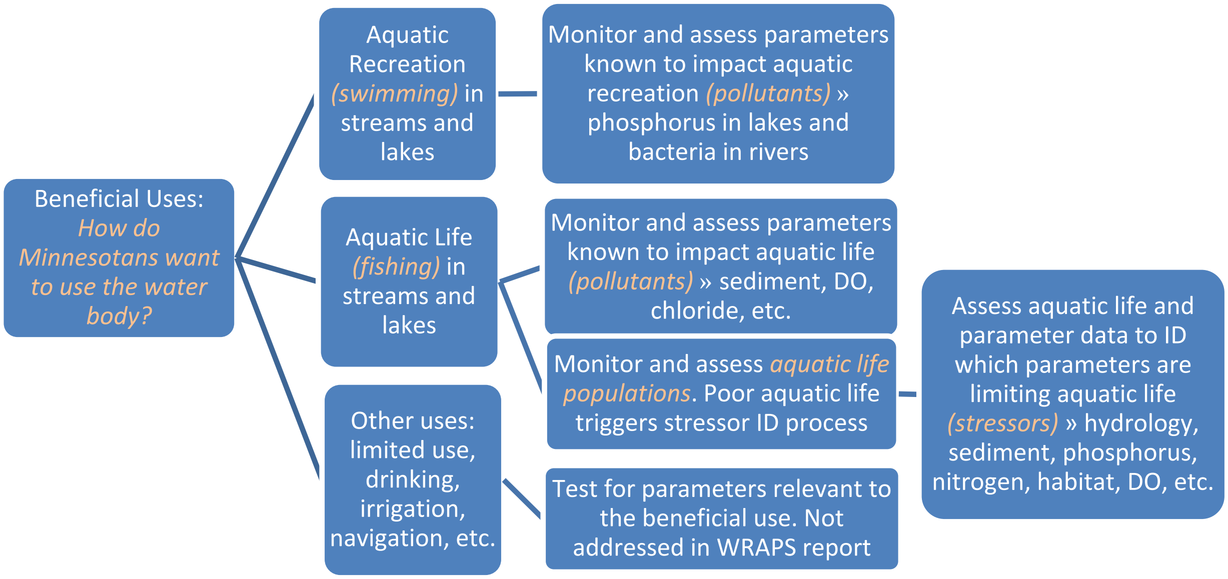


Figure 5: Pollutant and stressors are identified through different processes. Pollutants are parameters that are analyzed directly and the level of the parameter can be compared directly to a pre-developed numeric water quality standard. Stressors are parameters that are assessed only when aquatic life populations are monitored and assessed and found to be low or imbalanced (using the IBI score). Then, the SID process is triggered to determine which parameters are impacting the aquatic life populations. Both pollutants and stressors must be addressed to restore and protect water quality beneficial uses such as swimming and fishing.

Monitoring Plan

Data from three water quality monitoring programs enable water quality assessment and create a long-term data set to track progress towards water quality goals. These programs will continue to collect and analyze data in the Des Moines River Basin as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011b). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. Combined, these programs collect data at dozens of locations around the basin (Figure 6). The parameters collected at each monitoring site can vary. Local partners collect additional data to supplement MPCA programs. These monitoring programs are summarized below:

Intensive Watershed Monitoring (IWM; MPCA 2012) data provide a periodic but intensive "snapshot" of water quality conditions throughout the watershed. This program collects water quality and aquatic life (fish and macroinvertebrate community) data (including Surface Water Assessment Grants referred to as 10X sites) at numerous stream and lake monitoring stations in 1 or 2 years, every 10 years. Monitoring sites are generally selected to provide comprehensive coverage of watersheds. This work is scheduled to start its second iteration in the Des Moines River Basin in 2025.

Watershed Pollutant Load Monitoring Network (WPLMN; MPCA 2015f) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment, and nutrient loads. In the Des Moines River Basin, there is one continuous site on the Des Moines River at Jackson and a seasonal site on the Des Moines River near Avoca. The East Fork Des Moines River currently does not have a WPLMN site located within its watershed.

Citizen Stream and Lake Monitoring Program (MPCA 2015c) data provide a continuous record of waterbody transparency. This program relies on a network of volunteers who make monthly lake and river measurements. In the last 10 years, there have been 16 volunteer-monitored sites throughout the basin. This has declined to five volunteer-monitored stream locations and no lake locations in 2017. Citizen data are not as rigorous but provide a long-term data set.

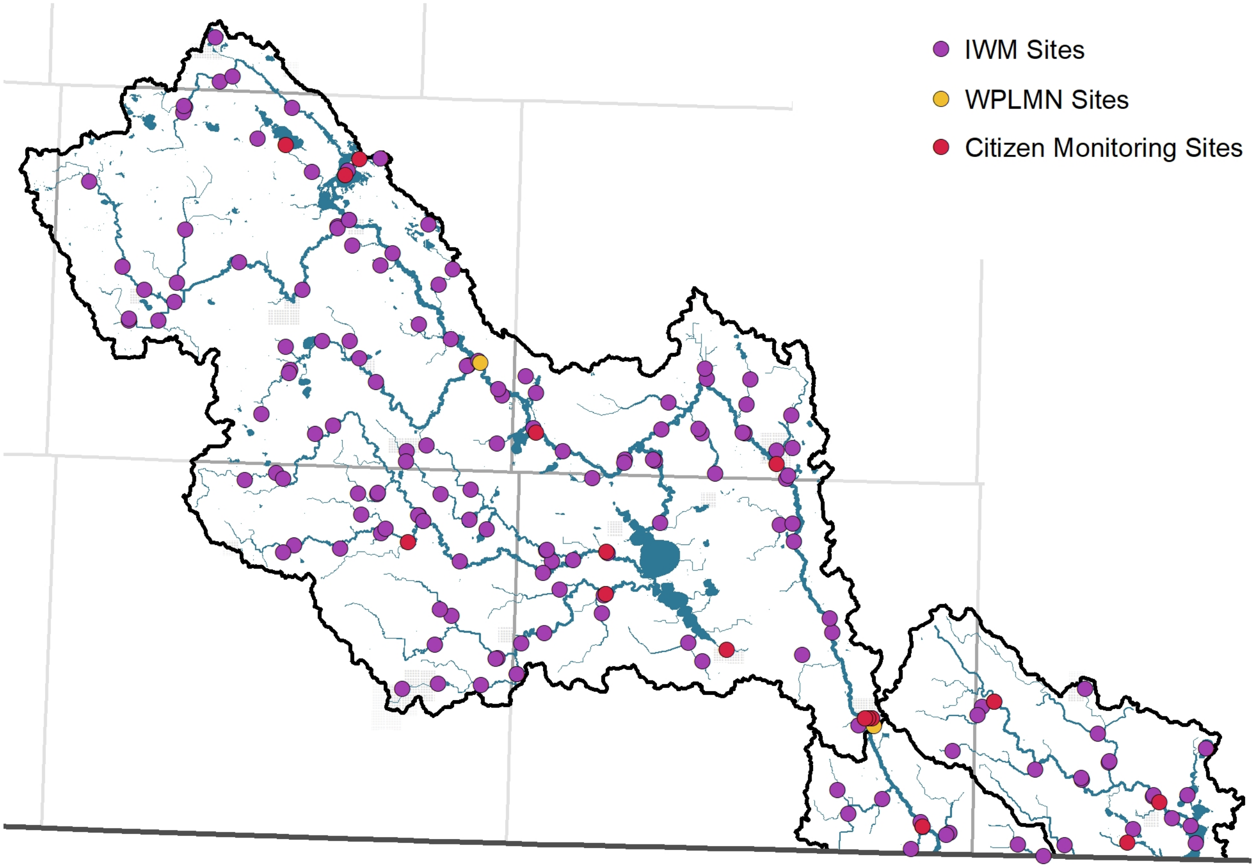


Figure 6: Dozens of stream and lake sites have been monitored in the Des Moines River Basin over the last 10 years. Data from these sites were used to assess waterbodies for their ability to meet fishable and swimmable water quality standards.

Computer Modeling

With the Watershed Approach, monitoring for pollutants and stressors is generally extensive, but not every stream or lake can be monitored due to financial and logistical constraints. Computer modeling can extrapolate the known conditions of the watershed to areas with less monitoring data. Computer models, such as Hydrological Simulation Program – FORTRAN (HSPF; USGS 2014), represent complex natural phenomena with numeric estimates and equations of natural features and processes. HSPF incorporates data including stream pollutant monitoring, land use, weather, soil type, etc. to estimate flow, sediment, and nutrient conditions within the watershed. *Building a Picture of a Watershed* (MPCA 2014a) explains the model's uses and development. Information on the HSPF development, calibration, and validation in the Des Moines River Basin are available in the *Des Moines… Model Report* (Tetra Tech 2016).

HSPF model data provide a reasonable estimate of pollutant concentrations across watersheds. The output can be used for source assessment, TMDL calculations, and prioritizing and targeting conservation efforts. However, these data are not used for impairment assessments since monitoring data are required for those assessments. Modeled pollutant concentration yields are presented in Section 2.2 within the Sources subsection for each pollutant. Modeled yields are presented in Appendix 2 under HSPF Estimated Subwatershed Yields. Modeled landscape and practice changes (referred to as scenarios) are discussed in Section 3.1 and summarized in Appendix 4 under Model Summary.

2. Watershed Conditions

This section summarizes condition information including water quality data and associated impairments. The "condition" refers to the waterbodies' condition compared to fishable and swimmable water quality standards. For waterbodies found not able to support fishable and/or swimmable standards, the reason for these poor conditions – the pollutants and/or stressors – are identified. This report covers only impairments to aquatic recreation and aquatic life. Several lakes and stream reaches are impaired for aquatic consumption with information available at the links below.

2.1 Conditions Overview

This section provides a general overview of watershed conditions and basic information to orient the reader to Section 2.2, where the status, sources, and goals are presented for each of the identified pollutants and stressors.

More information on the conditions of the Des Moines River Basin can be found at:

Des Moines River Basin Monitoring and Assessment Report (MPCA 2017a)

Des Moines River Watershed Stressor ID (MPCA 2018c)

Des Moines River Watershed Characterization Report (DNR 2016)

Environmental Data Application (MPCA 2019d)

Watershed Health Assessment Framework (DNR 2020)

Statewide Mercury TMDL (MPCA 2019h)

Fish Consumption Guidance (MDH 2019a)

Status Overview

A breakdown of the total number of waterbodies (monitored and not monitored in blue) and the assessment results by designated use (impaired, supporting, or inconclusive) are presented in Figure 7. See Appendix 1 for a table of monitoring and assessment results by stream reach and by lake.

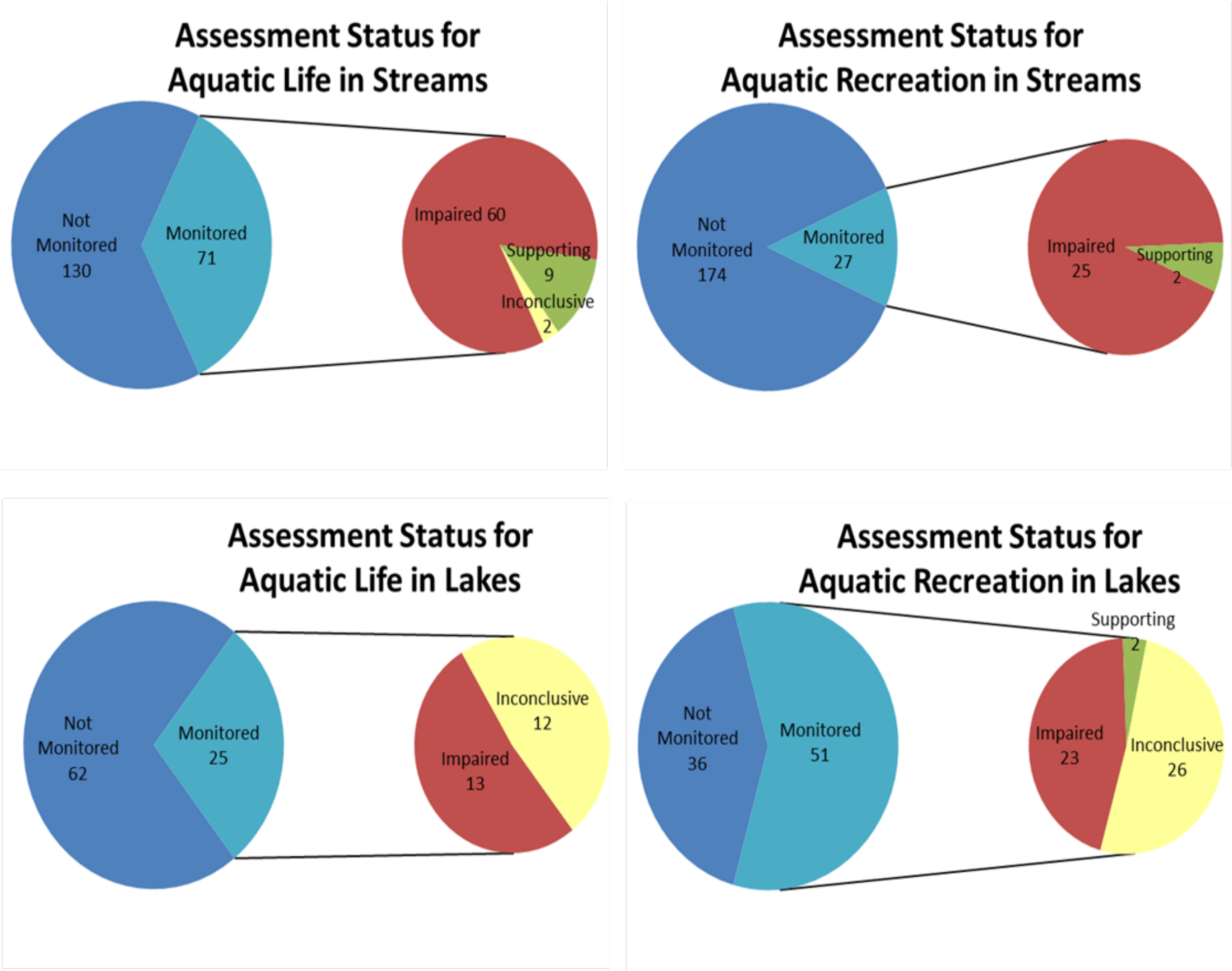


Figure 7: Waterbodies are monitored for specific parameters to make a designated use assessment. For aquatic recreation assessment, streams are monitored for bacteria and lakes are monitored for clarity and algae-fueling phosphorus. For aquatic life assessment, streams are monitored for both aquatic life populations and pollutants that are harmful to these populations. When monitored parameters (bacteria, phosphorus, fish populations, etc.) do not meet the water quality standards, the waterbody is impaired.

Assessment results of aquatic life and aquatic recreation in individual lakes and stream reaches in the Des Moines River Basin are illustrated in Figure 8. The majority of monitored streams and lakes are impaired (red). Nine stream reaches support aquatic life, two stream reaches support aquatic recreation, and two lakes support aquatic recreation (green). Two stream reaches and several lakes need more data to make a scientifically conclusive finding (yellow).

The SID process was conducted on streams and lakes found to have aquatic life impairments based on biological impairments. Several stream reaches with an aquatic life impairment were impaired due to low or imbalanced fish or macroinvertebrate populations. The identified stressors for streams are: lack of habitat, high phosphorus causing eutrophication, high total suspended solids (TSS), low dissolved oxygen (DO), high nitrates, altered hydrology, and lack of connectivity. Lakes were found to have an aquatic life impairment due to low or imbalanced fish populations. Candidate causes of biological stress based on SID in lakes include eutrophication, poor shoreline habitat, lack of plant habitat and abundance of carp and bullhead. See Appendix 1 for a more detailed summary of SID results by waterbody.

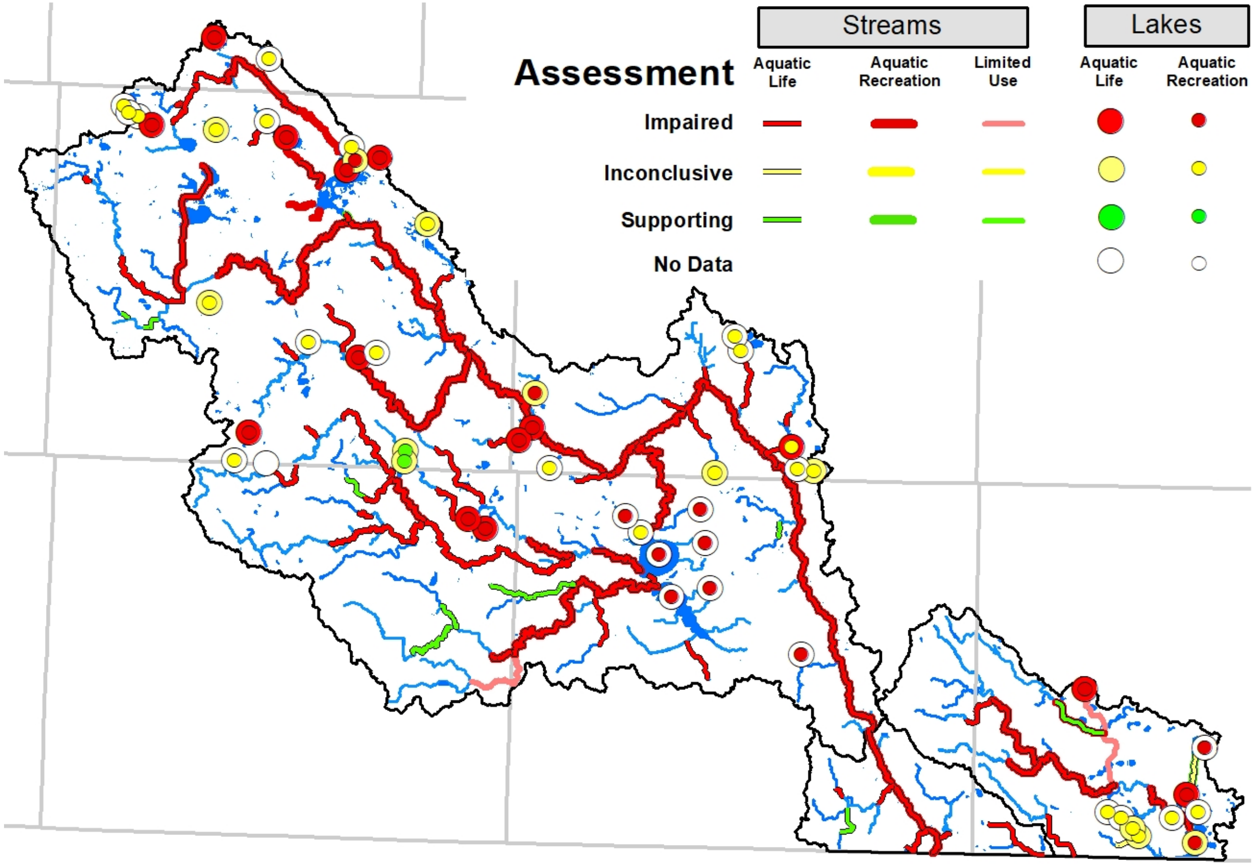


Figure 8: Impairments (shades of red) of the beneficial uses of aquatic life and aquatic recreation dominate the monitored stream reaches across the Des Moines River Basin. Just a handful of stream reaches are supporting (shades of green) these beneficial uses. Similarly, many of the monitored lakes in the basin are impaired (shades of red). Only two lakes are supporting these beneficial uses (shades of green). In this image, stream assessments results are indicated by lines with the inside line color indicating the aquatic life assessment and the outside line color indicating the aquatic recreation assessment. Lake assessment results are indicated by circles, where the inside circle color indicates aquatic recreation assessment and the outside circle color indicates the aquatic life assessment.

Trends Overview

Statistical trends in pollutant concentrations at three locations in the Des Moines River Basin were reported in the *Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites* (MPCA 2014c; Table 1). Both longer-term trends (40+ years of data) and short-term trends (15 years of data) were analyzed for TSS, total phosphorus (TP), and nitrite/nitrate (NO_2/NO_3) using the Seasonal Kendall test. Longer-term trends indicate a decrease (improvement) in TP for the East Fork Des Moines River, an increase (degradation) in NO2/NO3 for both the West Fork Des Moines River and Okabena Creek, and a decrease (improvement) in TSS at both the East Fork Des Moines River and Okabena Creek. Shorter-term trends indicate a decrease in sediment and TP in Okabena Creek.

Table 1: Pollutant concentration trends in the Des Moines River Basin show mixed results: TSS and TP concentrations show no trend to some improvement, while nitrite/nitrate concentrations show no trend to some degradation.

Location	Years of Data	TSS	TP	NO_2/NO_3
East Fork Des Moines River near Ceylon	1995-2009	No Trend	No Trend	No Trend
	1967-2009	-1.2%	-2.0%	No Trend
West Fork Des Moines River near Petersburg	1995-2009	No Trend	No Trend	No Trend
	1967-2009	No Trend	No Trend	1.9%
Okabena Creek near Brewster	1995-2009	-8.5%	-20.1%	No Trend
	1973-2009	-4.9%	No Trend	6.0%

The annual flow of the Des Moines River has roughly doubled over the past 80 years, and annual precipitation has modestly increased (Figure 9). Annual flow has increased at a greater rate than precipitation, as illustrated by the linear (dotted) trend lines in Figure 9. Furthermore, since 1980, the river has more flow from each inch of precipitation as reported in the DNR *Des Moines River Watershed Characterization* Report (2016). This trend in increasing flow versus precipitation is visible in Figure 9 by how the river flow and precipitation begin to “cross” after 1980.

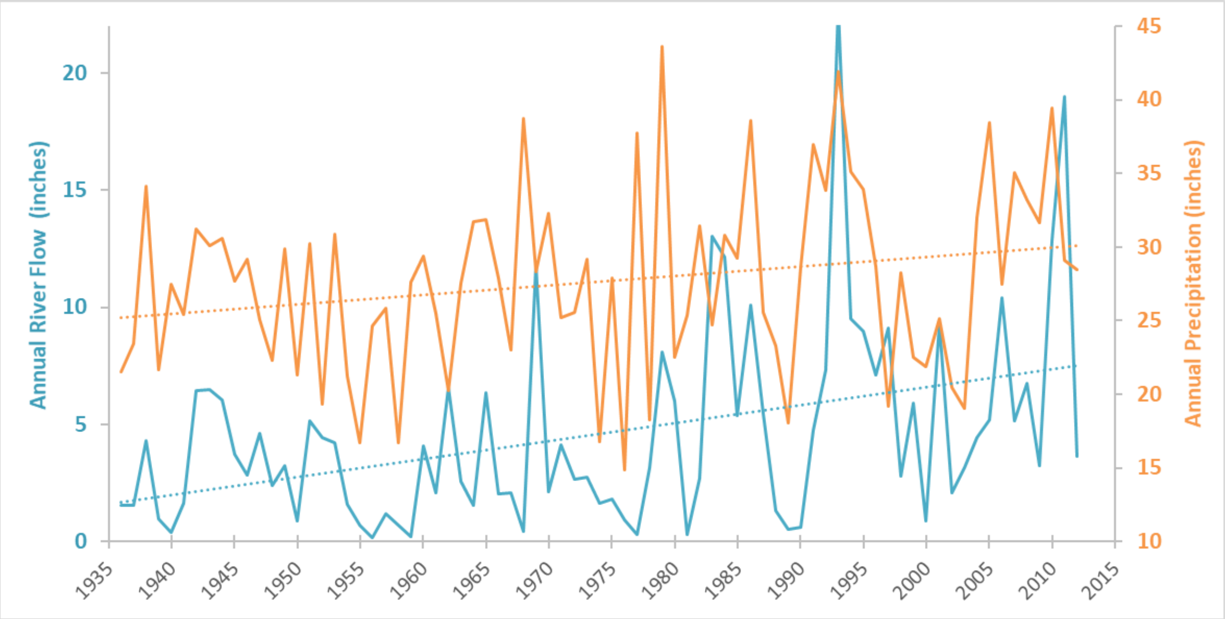


Figure 9: The Des Moines River’s flow at Jackson between 1936 and 2012 has increased more substantially than precipitation during this time.

Increases in river flow are important context for pollutant concentration trends. While TSS and TP concentrations show some improvement as mentioned above, the total amount of water moving through the Des Moines River has increased. Since the pollutant load is the product of flow and concentration and the total flow has increased, the total pollutant load delivered by the river may have increased. No load data is available for this long period of record to review for load trends.

Clarity is recorded for several lakes in the basin as shown in Table 2. First Fulda, Sarah, and Wilson lakes showed statistically significant improving transparency trends (green). Shetek and Summit lakes showed statistically significant declining transparency trends (pink). Yankton Lake showed a declining trend;

however, the trend was not statistically significant. Lakes not listed in the table did not have sufficient data to calculate a trend.

Table 2: Lake transparency trends in the Des Moines River Basin (of lakes with adequate data to assess trends) show mixed results; three lakes show improving trends and three lakes show declining trends

Name	Years of data	Transparency Trend (ft/yr)
First Fulda	1987-2014	0.07
Sarah	1980-2013	0.02
Shetek	1973-2015	-0.02
Summit	1988-2012	-0.11
Wilson	1987-2010	0.08
Yankton	1985-2014	-0.01

Sources Overview

This section orients readers to the array of sources of pollutants and stressors in the Des Moines River Basin. Sources of pollutants and stressors can be grouped into either point sources (NOAA 2008), which discharge directly from a discrete point, and nonpoint sources (MPCA 2013b), which is runoff and drainage from diffuse areas. Examples of point sources are wastewater plants and industry discharges. Nonpoint source examples include overland runoff, farm drainage, and urban runoff. Generally, point sources are regulated to ensure any discharge supports water quality standards, while nonpoint sources are not or are minimally regulated.

Within Section 2.2, a detailed source assessment will be presented for each pollutant and stressor. These source assessments were developed after analyzing multiple lines of evidence (see Appendix 2). These lines of evidence include state and basin-level reports, model studies, TMDLs, field-scale data, and watershed data. The WRAPS LWG was asked to review and use this information, applying their professional judgment and local knowledge, to ensure source assessments reflected recent conditions in the Des Moines River Basin. The Watershed Approach starts a new iteration every 10 years, each time striving for more refined analysis. Therefore, source assessments will be revisited and revised with each iteration to ensure that new data and science are incorporated.

Point Sources

Point sources are regulated through National Pollutant Discharge Elimination System (NPDES; EPA 2019b) permits. Depending on the type of point source, regulatory requirements vary. Some point sources are not allowed to discharge; some are allowed to discharge but must treat and measure discharged pollutants to ensure permit requirements are met; and some are allowed to discharge under special circumstances or are required to use BMPs to reduce pollutants.

Municipal and Industrial Wastewater

Municipal and industrial wastewater point sources have discharge and monitoring requirements specified in the facility permits to ensure pollutant levels in their discharge support water quality goals. Municipal point sources that discharge to waterbodies in the Des Moines River Basin are listed in Table 3 and industrial point sources are listed in Table 4. Because these systems often require monitoring, their total contributions can be calculated. The estimated 2008 through 2016 contributions (percent of total load over time period) of these facilities to the total loads delivered by the Des Moines River Basin are 7% of nitrogen, 9% of phosphorus, and 0.2% of TSS (see data and calculations in Appendix 2).

While the impact of these point sources on the total pollutant loads is minimal, they can be substantial sources at times of low flow. Refer to the TMDLs (links provided in Goals and Targets Overview section) for more information on the impact of point sources on impaired reaches.

Table 4: Nineteen municipal wastewater treatment plants (WWTPs) have NPDES permits to discharge into the Des Moines River Basin.

Municipal Facility	County	Watershed
Avoca & Iona WWTP	Murray	7100001
Brewster WWTP	Nobles	7100001
Currie WWTP	Murray	7100001
Dundee WWTP	Nobles	7100001
Fulda WWTP	Murray	7100001
Heron Lake WWTP	Jackson	7100001
Jackson WWTP	Jackson	7100001
Lake Wilson WWTP	Murray	7100001
Lakefield WWTP	Jackson	7100001
Okabena WWTP	Jackson	7100001

Municipal Facility	County	Watershed
Red Rock Rural WS - Windom WTP No 1	Cottonwood	7100001
Shetek Area Water & Sewer District WWTP	Murray	7100001
Slayton WWTP	Murray	7100001
Windom WWTP	Cottonwood	7100001
Worthington WWTP	Nobles	7100001
Alpha WTP	Jackson	7100003
Ceylon WWTP	Martin	7100003
Dunnell WWTP	Martin	7100003
Sherburn WWTP	Martin	7100003

Table 3: Three industries have NPDES permits to discharge into the Des Moines River Basin.

Industrial Facility	County	Watershed
Heron Lake BioEnergy LLC	Jackson	7100001
Hubbard Feeds Inc - Worthington	Nobles	7100001
Worthington Industrial WWTP	Nobles	7100001

Urban, Construction and Industrial Stormwater

Large urban areas are regulated under the Municipal Separate Storm Sewer System (MS4; MPCA 2019g) program, which requires the use of BMPs to reduce pollutants. The City of Worthington is the only community within the Des Moines River Basin that is a permitted MS4.

Construction projects disturbing more than one acre require an NPDES permit. These projects are required to use BMPs to reduce pollutant runoff. County estimates for construction stormwater areas indicate less than 0.1% of the Des Moines River Basin land area is impacted by construction projects at any given time.

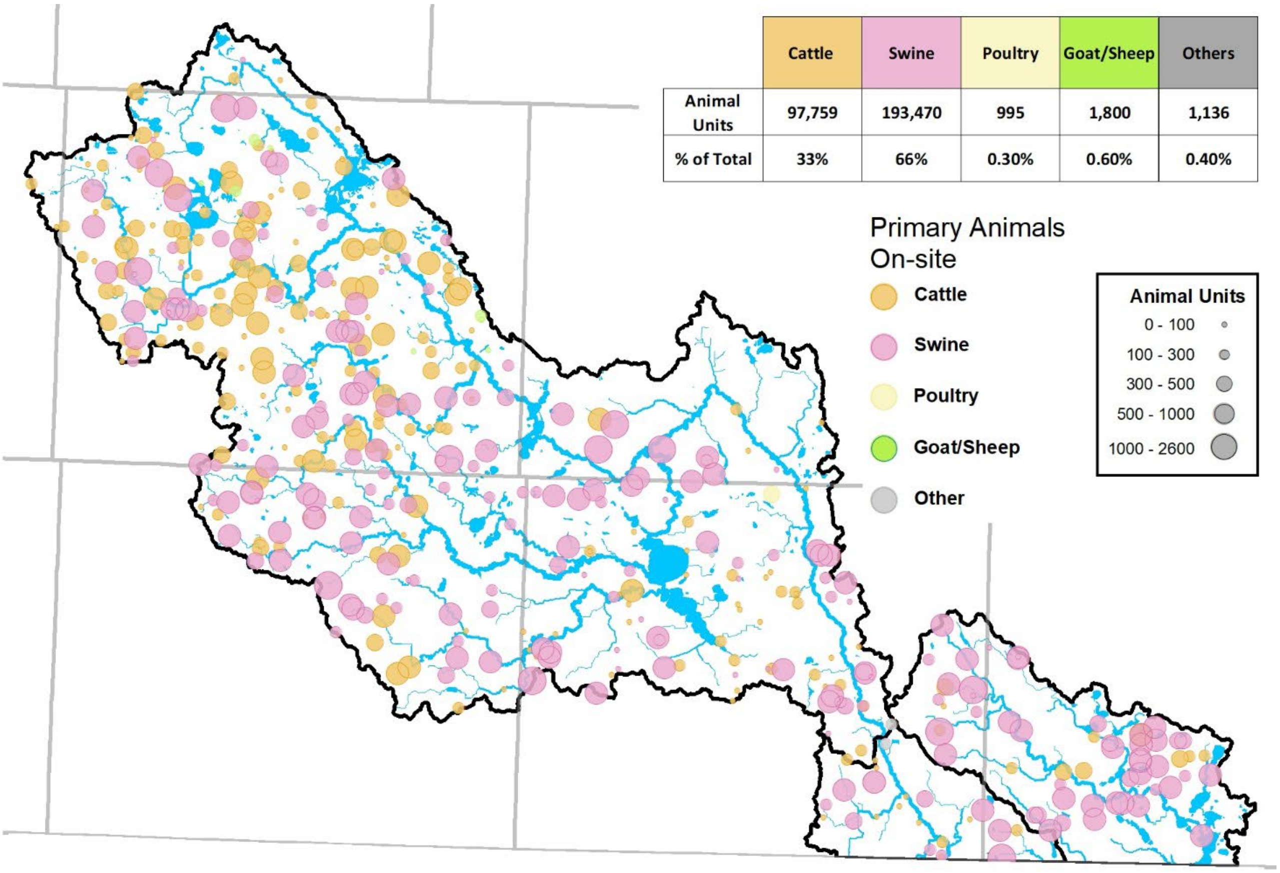
Similar to large urban areas and large construction projects, industrial stormwater (MPCA 2019e) is regulated through the NPDES program. Industrial facilities must have either no discharge or manage discharge with sufficient BMPs to protect water quality.

CAFO Feedlots

Feedlots (MPCA 2017b) are animal operations (either open lots or buildings) used in intensive animal farming where manure accumulates and vegetative cover cannot be maintained. Manure contains high levels of bacteria and nutrients, and therefore, feedlot and manure management have a potential to impact water quality. Large feedlots are regulated as point sources and discussed here. Other animal operations and land-applied feedlot manure are considered nonpoint sources and discussed in the nonpoint source section below. In total, approximately 295,000 animal units (AUs; see feedlots link above for conversions of animal types to AUs) in 647 feedlots are located within Des Moines River Basin (Figure 10). On average, this translates to roughly 300 AUs per 1,000 acres. 107,004 (36%) AUs reside in

84 concentrated animal feeding operations (CAFOs), and are regulated as point sources (list available in Appendix 2).

NPDES permits are required for facilities that meet the definition of a Large CAFO (EPA 2015b) and have discharged. Either a State Disposal System (SDS) or NPDES permit is required by state rule for feedlots with 1,000 AUs or more. 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 an NPDES permit, even if discharges have not occurred in the past at the facility. Considering large CAFOs are not allowed to discharge, their impact on the total pollutant loads is minimal.



	Cattle	Swine	Poultry	Goat/Sheep	Others
Animal Units	97,759	193,470	995	1,800	1,136
% of Total	33%	66%	0.30%	0.60%	0.40%

Figure 10: Over 295,000 animal units are registered within the Des Moines River Basin. See the Animal Unit Calculator (MPCA 2016a) for conversions of animal numbers to units. The number of feedlot animal units per region, along with additional information, can indicate the likeliness that feedlot-produced manure is making substantial contributions of bacteria and nutrients to waterbodies.

Nonpoint Sources

With a generally low input of pollutants/stressors from point sources, nonpoint sources are the dominant source of pollutants/stressors in the Des Moines River Basin. Nonpoint sources of pollutants/stressors are products of the way that land is used and how well human impacts are managed/mitigated with BMPs. This section summarizes the types of nonpoint sources.

Nonpoint sources of pollutants/stressors typically travel to a waterbody from the land around the waterbody (watershed) in response to precipitation. Once the area where precipitation falls cannot hold more water, water along with the pollutants/stressors it carries will move via surface runoff, artificial drainage networks, or groundwater pathways to streams and lakes. The pollutants/stressors can be of natural origin (like tree leaves breaking down), human-accelerated natural origin (like excessive streambank erosion from altered hydrology), or of human origin (like fertilizer applied on fields and lawns).

Farm and City Runoff

Typically, highly manipulated land uses contribute higher levels of pollutants/stressors compared to more naturalized areas. Grasslands and forests tend to have lower contributions of pollutants/stressors compared to many cultivated crops, urban developments, and over-grazed pastures.

While highly manipulated (urban and agricultural) land often does contribute higher levels of pollutants/stressors, the impacts can be reduced by adequately-managing/mitigating with sufficient BMPs. As demonstrated by sustainable agriculture (UCS 2019), farming and clean water do not have to be mutually exclusive. For instance, a farm that incorporates nutrient management practices, conservation tillage, cover crops, grassed waterways, and buffers will contribute substantially less pollutants/stressors than if those BMPs were not used. Likewise, city stormwater systems can be designed and built for zero or minimal runoff (depending on the size and intensity of the rain event).

When land uses such as cultivated crops do not adhere to industry recommendations (for instance the over application of fertilizer/manure as documented in the *Commercial Nitrogen and Manure Fertilizer… Management Practices* [MDA 2014]), contributions of pollutants and stressors can be further accelerated. One example of this was tested and documented by the MDA (2016), who found much larger exports of nutrients, sediment, and water runoff on a corn plot compared to a prairie plot. The Des Moines River Basin is dominated by cultivated crop production (refer to land use in background section) and accordingly have a large potential to impact water quality.

While some agricultural and urban runoff has been reduced using sufficient BMPs, substantial additional BMPs need to be adopted to achieve clean water. The new MPCA Healthier Watersheds Accountability Report (MPCA 2018a) shows that 2,197 BMPs have been installed in the Des Moines River Basin since 2004. In addition, the Agricultural Water Quality Certification Program (MDA 2019) has certified more than 25,209 acres (2%) in the Des Moines River Basin as of November 2020. These farms are certified that impacts to water quality are adequately managed/mitigated. While these producers and others have incorporated sufficient BMPs to protect water quality, much of the remaining cultivated crops, pastures, urban development, and residential landscape are not adequately managed/mitigated with BMPs.

Subsurface Drainage

In addition to surface runoff pathways, subsurface drainage pathways also deliver pollutants/stressors to waterbodies. In urban settings, subsurface drainage occurs via storm sewers. Up to 6% of the Des Moines River Basin is serviced by storm sewers, based on land use statistics. In agricultural settings, subsurface drainage occurs via subsurface tile drainage systems (crop tile) and crop groundwater (not tile drained). Based on a Geographic Information System (GIS) analysis using land use, slope, and soil type data, 30% of the Des Moines River Basin's area is likely tile drained, and an additional 37% of the area may be tile drained (Figure 11).

Tile drainage has been identified as a primary cause of stream flow changes in heavily tiled landscapes. Several research papers found that roughly 60% or more of stream flow increases between mid- and late-20th century in heavily-tiled areas of the Midwest and Southern Minnesota is due to agricultural drainage changes: *Twentieth Century Agricultural Drainage Creates More Erosive Rivers* (Schottler et al., 2013), *Temporal Changes in Stream Flow and Attribution of Changes…* (Gyawali, Greb, and Block, 2015), and *Quantifying the Relative Contribution of the Climate and Direct Human Impacts…* (Wang and Hejazi 2011). The rest of the increase in stream flow is attributed to crop and climate changes.

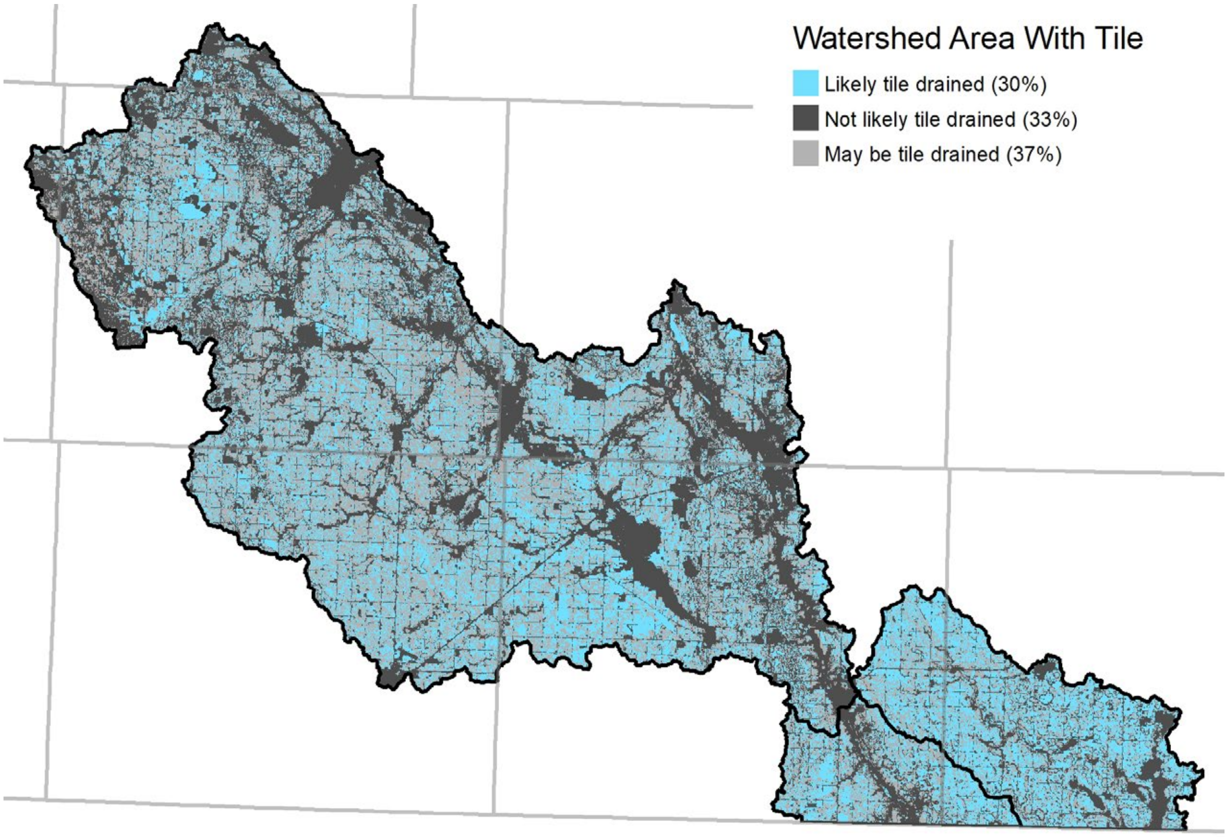


Figure 11: Similar to many parts of southern Minnesota, large portions of agricultural lands within the Des Moines River Basin are tile drained. According to a GIS analysis, the northern portion of the area likely has a lower density of tile drainage, while the East Fork Des Moines River Watershed likely has a higher density of tile drainage.

Other Feedlots, Manure Application, and Pastures

Only the largest feedlots are regulated as point sources (discussed in section above). Roughly 188,000 (64%) AUs in 563 feedlots are not regulated as point sources (feedlots not meeting Large CAFO criteria). However, these facilities are still regulated and may only have discharge/runoff that meets a maximum pollutant concentration (using a designated estimation tool). Small animal operations (<10 AUs in shoreland or <50 AUs elsewhere) are not considered feedlots and are not regulated. AU counts associated with the nonregulated operations are not available but can be presumed to be relatively small.

Feedlots within close proximity to waterbodies (referred to as shoreland) may pose a disproportionately high risk to water quality if runoff is not prevented or treated. In the Des Moines River Basin, approximately 13,503 (4%) AUs in 52 feedlots are within shoreland, including 45 open lot facilities. Open lots can be particularly high risk, because manure is not contained within a structure and may more readily run off.

Because most feedlots are regulated to have minimal runoff, the largest water quality risk associated with feedlots is from the land-applied manure. Like other types of fertilizer application, the location, method, rate, and timing of manure application are important considerations to estimate the impact and likelihood of runoff. Some inferences can be made based on the animal statistics as discussed below. Additional interpretation is offered in Appendix 2.

Manure that is injected versus surface-applied is generally considered less likely to produce runoff. Manure from roughly 60% of the AUs in the basin is likely injected and incorporated manure (swine manure for facilities with more than 300 AU). Thirty-three percent of the AUs in the basin are cattle and poultry. This manure is generally handled as solid manure and may not be immediately incorporated.

Perennial vegetation, like that of hay or pasture, typically provides an overall benefit to water quality compared to inadequately managed/mitigated urban and cultivated cropland uses. However, when pastures are overgrazed (indicated by too little vegetation), especially adjacent to a waterbody, these areas can be sources of pollutants/stressors. Furthermore, when cattle access streams, the delicate streambank habitat is trampled, the stream geomorphology (DNR 2017) is negatively impacted, streambank erosion is accelerated and fecal matter containing nutrients and bacteria are deposited directly into the water.

Septic Systems and Unsewered Communities

Well-functioning individual and small community wastewater treatment systems generally pose little risk to waters. When these systems fail or do not offer ample treatment, these systems can pose a risk to water quality.

Based on the estimates provided by counties, there are between one and five failing septic systems (subsurface treatment system, SSTS) per 1,000 acres in the Des Moines River Basin (Figure 12). At this concentration, failing septic systems are unlikely to contribute substantial amounts of pollutants/stressors to the total annual loads. However, the impacts of failing SSTS on water quality may be pronounced in areas with high concentrations of failing SSTS or at times of low precipitation and/or flow.

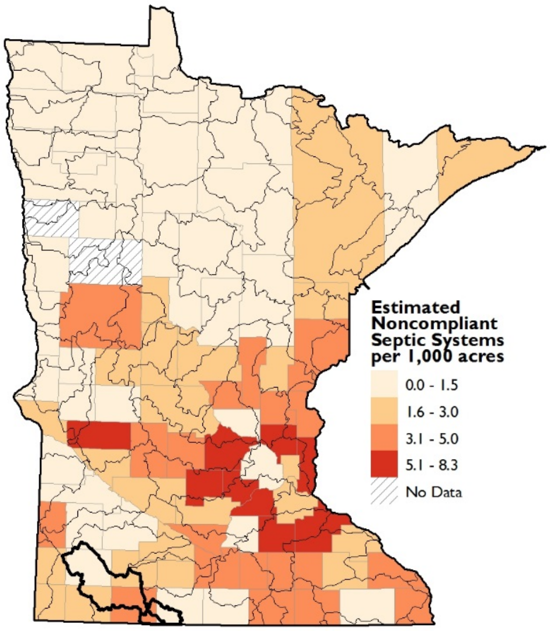


Figure 12: The Des Moines River Basin has an estimated average of one to five failing septic systems per 1,000 acres.

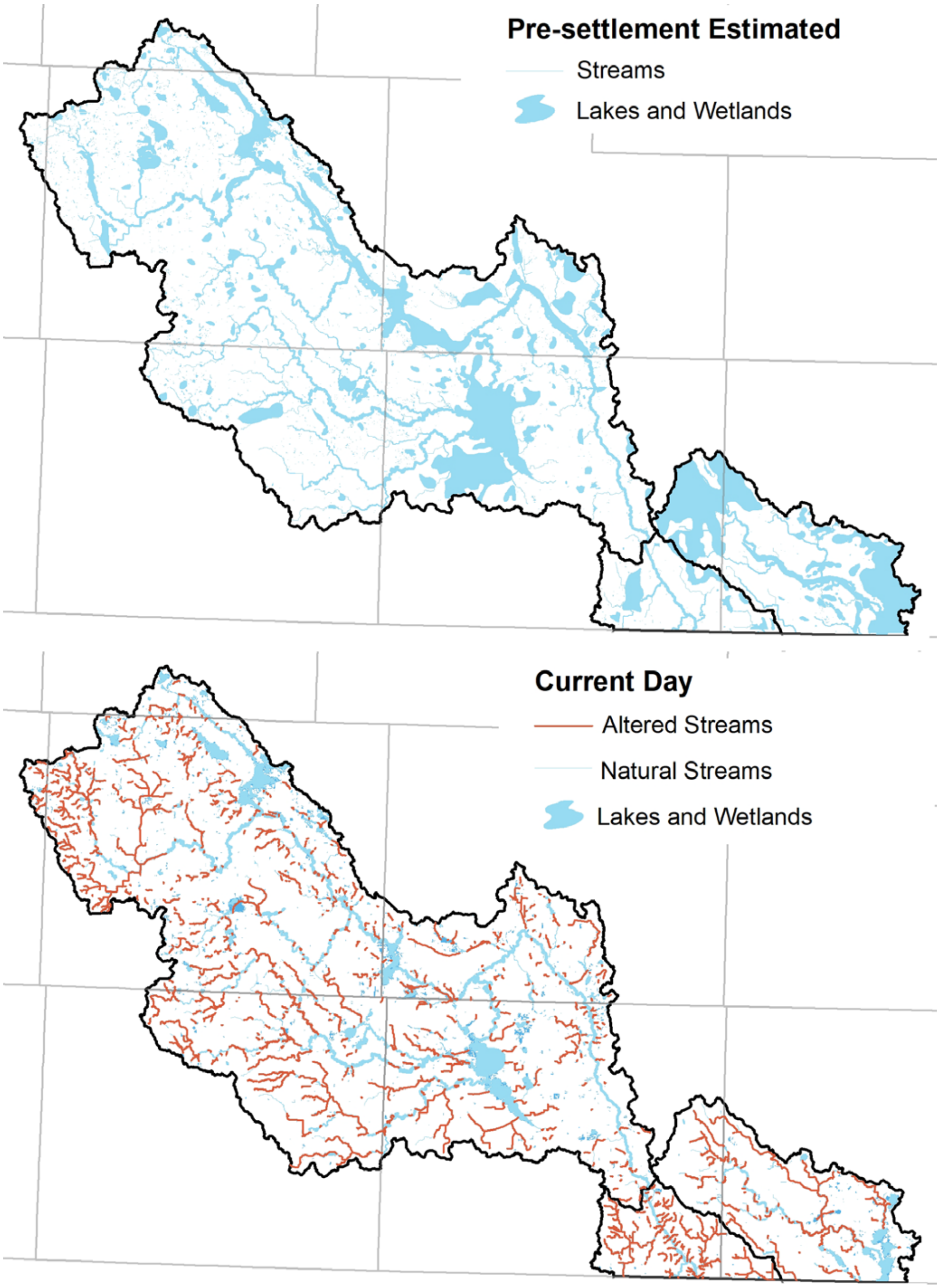
Unsewered or undersewered communities (MPCA 2019) are clusters of five or more homes or businesses on small lots where individual or small community systems do not provide sufficient sewage treatment (including straight pipes). Many of these have been upgraded, but a handful of unsewered or undersewered areas still exist in the Des Moines River Basin, including Kinbrae and Petersburg.

High Risk Areas

While some highly manipulated land uses can adequately manage pollutant contributions by adopting sufficient BMPs, some areas within a landscape are particularly sensitive from a water quality perspective. For instance, the area or buffer around waterbodies is particularly sensitive. Crops or lawn turf directly adjacent to a stream or lake can cause more pollutants/stressors to enter waterbodies, accelerate erosion, and destroy sensitive habitat. On the contrary, a high quality, naturalized vegetative buffer adjacent to a waterbody can help capture pollutants/stressors, stabilize the streambank, and provide habitat to sensitive aquatic species. Other particularly sensitive areas include flood plains, high slope areas, and areas with highly erodible soils.

Historical Changes

Understanding landscape conditions prior to European settlement, and the changes that took place between then and now, provides context for today's water quality conditions and sources. The landscape in the Des Moines River Basin has been highly manipulated since European settlement. Figure 13 compares the estimated streams, lakes, and wetlands of pre-European settlement to those of today. Prior to European settlement, portions of the Des Moines River Basin were covered by prairie and speckled with prairie potholes (EPA 2015a). These potholes and the rich, healthy, prairie soils provided water storage, nutrient recycling, and superior erosion protection across the landscape.



Pre-settlement Estimated

Current Day

Figure 13: The areas covered by wetlands, lakes, and streams has changed substantially between the mid-19th century and today. The Des Moines River Basin likely had substantial amounts of wetlands to hold, infiltrate, and evapotranspirate water. This image is for illustrative purposes only. See Appendix 2 for data sources.

Grasslands and wetlands provided water storage and kept most precipitation on the landscape to be used by plants or to recharge groundwater and resulted in relatively fewer streams. Today, most of the grasslands have been converted to crops and cities, streams have been ditched or straightened, ditches have been added to the landscape, and prairie potholes have been drained or highly altered. The drainage networks that replaced prairies and wetlands have created a “short-circuit” in hydrologic conditions.

Since European settlement, the diversity of vegetation and crops on the landscape has continued to decline. The grasslands were first replaced by diverse crops and rural development. Then between the mid- to late-20th century, the diverse crops - including substantial amounts of small grains and hay - were replaced by a dominance of corn and soybeans (Figure 14). The changes in land use and crops have resulted in impacts to hydrology: less evapotranspiration (ET) in spring and more ET in mid-summer (Figure 15), resulting in more precipitation entering rivers in spring and less entering in mid-summer.

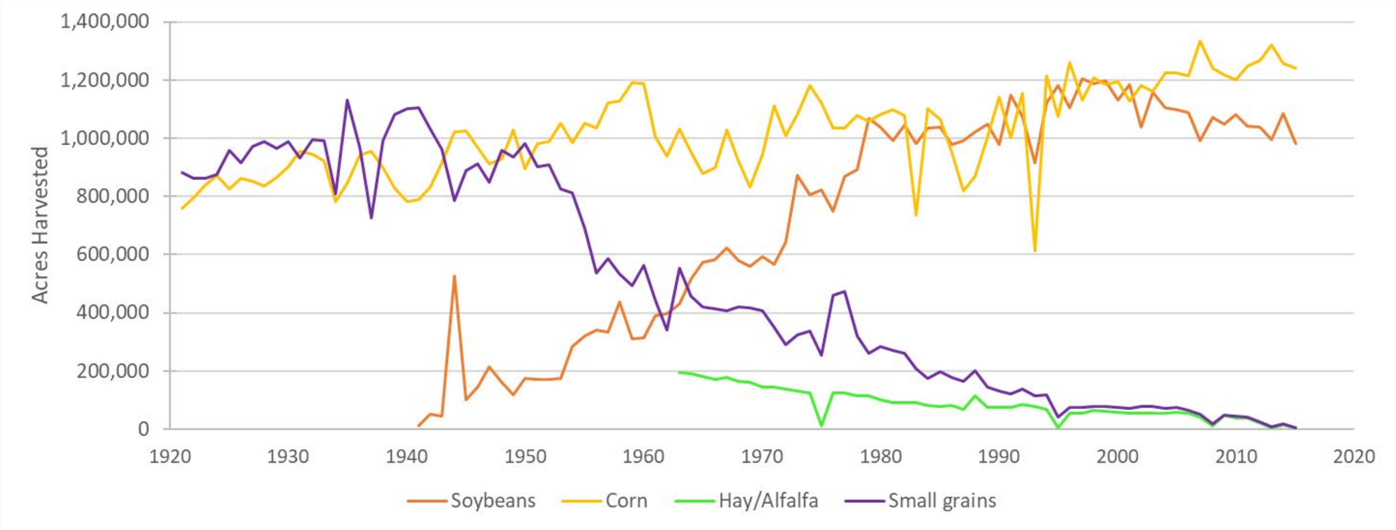


Figure 14: The harvested acres of corn, soybeans, hay, and small grains in the dominant counties of the Des Moines River Basin illustrate how small grains and hay were replaced through time by soybeans and corn.

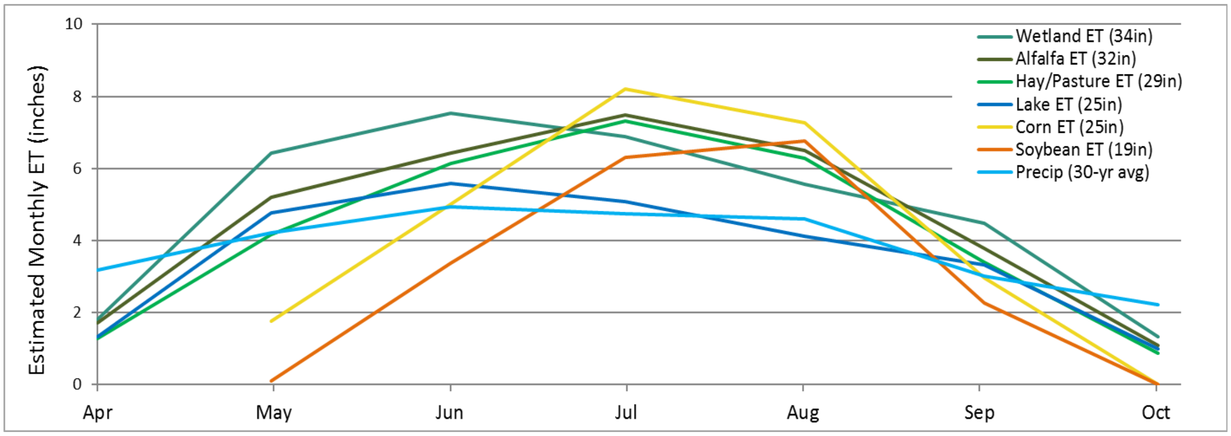


Figure 15: Since European settlement, prairies and wetlands were replaced first by diverse crops and then by corn and soybeans. The total annual ET rates (indicated in the figure legend) of these replacement crops are smaller and the timing of ET through the year has shifted. These changes affect the hydrology of the basin. See Appendix 2 for data sources and calculations.

While agricultural and urban drainage can negatively affect water resources, the historical perspective of agricultural and infrastructural benefits of drainage are important to recognize. European settlers drained wetlands to settle and farm lands. For decades, the government further encouraged drainage to reduce pests, increase farmable lands, and clear lands for roads and infrastructure. Today, drainage is still encouraged by some agricultural interests to increase crop production. Drainage is necessary for crop production and development in certain circumstances; however, drainage impacts can be better managed/mitigated to reduce impacts to waterbodies.

Goals and Targets Overview

Water quality goals for the Des Moines River Basin (Table 5) are intended to help waterbodies meet water quality goals both within and downstream of the basin (e.g. Gulf Hypoxia goals). These goals were set after analyzing Total Maximum Daily Load (TMDL; MPCA 2013c) studies, statewide reduction goals, WPLMN data, and HSPF model data. The selected goals integrate multiple levels of goals into one basin-wide goal for the major watersheds, along with goals for smaller subwatersheds when TMDL data are available. The TMDL studies include the Des Moines Basin TMDL and Des Moines River Headwaters Watershed River Eutrophication TMDL, both developed concurrently with this WRAPS report, and the West Fork Des Moines River TMDL (MPCA 2008).

The specific goal for every lake and stream reach is to meet water quality standards for all relevant parameters and to support downstream water quality goals. However, to better communicate water quality goals and to make the identification of strategies and adoption rates more straightforward, the multiple levels of goals were integrated into one average or “surrogate” basin-wide goal for all of the watersheds in the Des Moines River Basin. The goals only apply to the portion of the East Fork Des Moines River and Lower Des Moines River Watersheds that are located in Minnesota. Likewise, because water quality standards do not include a specific method to calculate a reduction, surrogate goals for individual streams and lakes were calculated from TMDL data. A summary of the WRAPS report calculation methods and results are in Appendix 3.

For parameters that are the effect of other pollutants/stressors (F-IBI, M-IBI, DO, and pH), a numeric goal for the identified pollutants/stressors was not estimated. For instance, in the case of bio-impaired streams (where the aquatic life impairment was due to a low F-IBI or M-IBI score) and lakes (where the aquatic life impairment was due to a low F-IBI score) , the goal for F-IBI and/or bug IBI scores is to meet the numeric thresholds. However, no tool or model is available to estimate the magnitude of change needed to meet this threshold. Therefore, numeric goals for the stressors causing the biological impairments in streams (altered hydrology, sediment, nitrogen, etc.) are the surrogate goal. Goals to address F-IBI impairments in lakes will use the eutrophication numeric goal as a surrogate.

Within Section 2.2, goals for each pollutant and stressor are illustrated in a “goals map”. The subwatershed area of each waterbody is colored according to its goal: the darker the gray shading, the larger the reduction goal. White indicates areas of protection. Stream reaches where fish and bugs are supporting are illustrated in lime green. Subwatersheds associated with supporting stream reaches are indicated by hash marks. The basin-wide goal underlays the subwatershed goals. The basin-wide goal is also the default goal for any area that does not have sufficient data to calculate an individual subwatershed goal.

Interim water quality “10-year targets” were selected via average consensus by the WRAPS LWG, and allow opportunities to adaptively manage implementation efforts. With each iteration of the Watershed Approach, progress will be measured, goals will be reassessed, and updated 10-year targets will be set. Future efforts should consider changes in waterbody conditions reflected by new data or due to changes in standards, statewide goals, and calculation methods.

Table 5: Goals and 10-year targets by parameter for the Des Moines River Basin.

Parameter (Pollutant/ Stressor)	**Basin-Wide Goal** (average/surrogate for watershed)	**Range of Subwatershed Goals** (Estimated only when TMDL or MSHA data available)	**10-year Target** (for 2030)	**Years to Reach Goal** (from 2020)
Degraded Habitat	45% increase in MSHA habitat score	Protection and up to a 214% increase	20%↑	40
Phosphorus/ Eutrophication	45% reduction in lake and stream concentrations/loads	Protection and up to a 76% reduction	Lakes - 7%↓ Streams - 15%↓	Lakes - 50 Streams - 40
Sediment	30% reduction in stream concentrations/loads	Protection and up to a 80% reduction	5%↓	60
Nitrogen	30% reduction in stream concentrations/loads	Not estimated (TMDLs not completed on this parameter)	10%↓	40
Altered Hydrology	20% reduction in peak & annual stream flow	Not estimated (TMDLs not completed on this parameter)	2.5%↓	100
	Increase dry season stream base flow where ID'd in SID by enough to support aquatic life		Small Improvement	50
Connectivity	Address human-caused issues (dams, culverts) as identified in SID and where practical/feasible	Not estimated (TMDLs not completed on this parameter)	6 Barriers Removed	20
Bacteria	50% reduction in stream concentrations/loads	Protection and up to a 86% reduction	10%↓	50
Chloride	Protect (restore the one impaired reach)	Protection and up to a 33% reduction	Meet permit requirements (impaired reach is point source driven)	
Parameters that are impacted/addressed by the above pollutants and stressors				
Fish (F-IBI)	Each parameter's goal is to meet the water quality standard and support downstream goals. Because these parameters are a response to (caused by) the above pollutants/stressors, the above watershed-wide goals are the (indirect) goals for these parameters.	Not estimated (TMDLs not completed on these parameters)	Meet other 10-year targets	60
Macroinverts (M-IBI)				60
DO				40
pH				50

2.2 Identified Pollutants and Stressors

This section looks at each of the identified pollutants and stressors in detail, describing/illustrating:

- the streams and lakes known to be impaired or stressed by the pollutant/stressor
- a detailed source assessment
- estimated reductions necessary to meet water quality goals in and downstream of the Des Moines River Basin
- priority areas based on estimated reductions, areas of protection, and model data

Refer to the Conditions Overview Section 2.1 for a broad summary and methods relevant to multiple parameters. Refer to the Assessing Water Quality Section 1.3 for a summary of how waterbodies are monitored and assessed, the SID process, and the difference between a pollutant and stressor.

Habitat

Habitat, as identified in this report, refers to the physical stream habitat. Important habitat components include: stream size, channel dimension, slope, substrate, habitat complexity, and vegetation cover. Degraded habitat reduces aquatic life's ability to feed, shelter, and reproduce which results in altered behavior, increased mortality, and decreased populations.

The MPCA Stream Habitat Assessment (MSHA; MPCA 2014b) is used to score habitat. The assessment considers floodplain, riparian, instream, and channel morphology attributes. MSHA scores above 65 are "good"; scores between 45 and 65 are fair, and scores below 45 are poor. The MSHA score is an important factor used to assess if degraded habitat is a stressor to bio-impaired streams.

Status

Of the bio-impaired stream reaches, degraded habitat was the most identified stressor in the Des Moines River Basin. Of the 56 bio-impaired stream reaches, degraded habitat was identified as a stressor in 51, ruled out in 4, and inconclusive in 1. The habitat assessment results are illustrated in Figure 16 and tabulated in Table 6.

Table 6: Assessment results for degraded habitat as a stressor in stream reaches in the Des Moines River Basin.

Major Watershed	Stream Name	AUID-3	Habitat Stressor Assessment
Des Moines Headwaters	Des Moines River	501	x
	County Ditch 20	504	x
	Lower Lake Sarah Outlet	508	+
	Jack Creek	514	X
	Unnamed creek	518	X
	Judicial Ditch 26	523	X
	Des Moines River	524	X
	Heron Lake Outlet	527	X
	Des Moines River	533	X
	Lime Creek	535	X
	Perkins Creek	544	X
	Des Moines River	545	X
	Des Moines River	546	X
	Jack Creek	549	X
	Unnamed creek	551	X
	County Ditch 43 (Scheldorf Creek)	552	X
	Unnamed creek	563	X
	Unnamed creek	564	X
	Okabena Creek	602	X
	Unnamed creek	613	X
	Unnamed creek	614	X
	Unnamed creek	618	X
	Unnamed creek	619	X
	Unnamed creek	621	X
	Unnamed creek	624	X
	Unnamed creek	625	X
	Unnamed creek	626	X
	Unnamed creek	628	X
Des Moines Headwaters	Unnamed creek	632	X
	Unnamed creek	637	X
	Lake Shetek Inlet	641	X
	Lake Shetek Inlet	642	X
	Lake Shetek Inlet	643	X
	Beaver Creek	646	X
	Jack Creek	649	X
	Jack Creek	652	X
	Elk Creek	656	X
	Jack Creek	658	X
	Unnamed creek	661	X
	Beaver Creek	663	X
	Beaver Creek	664	X
	Judicial Ditch 12	666	X
	Devils Run Creek	668	X
	Unnamed creek	670	+
	Unnamed creek	672	X
Lower Des Moines	Des Moines River	501	?
	Brown Creek (Judicial Ditch 10)	502	X
	Unnamed creek	504	+
	Judicial Ditch 56	505	X
	Story Brook	507	+
	Unnamed ditch	510	X
East Fork Des Moines	County Ditch 53	506	X
	Fourmile Creek	510	X
	Des Moines River, East Branch	525	X
	Des Moines River	527	X
	Unnamed creek	529	X

X = stressor
? = inconclusive (need more data)
\+ = not a stressor

Figure 16 also illustrates the MSHA scores in the basin. Average MSHA scores for habitat in the Des Moines River Basin are 49 for general use (Class 2B) streams and 39 for modified and limited use (class 2Bm and 7) streams.

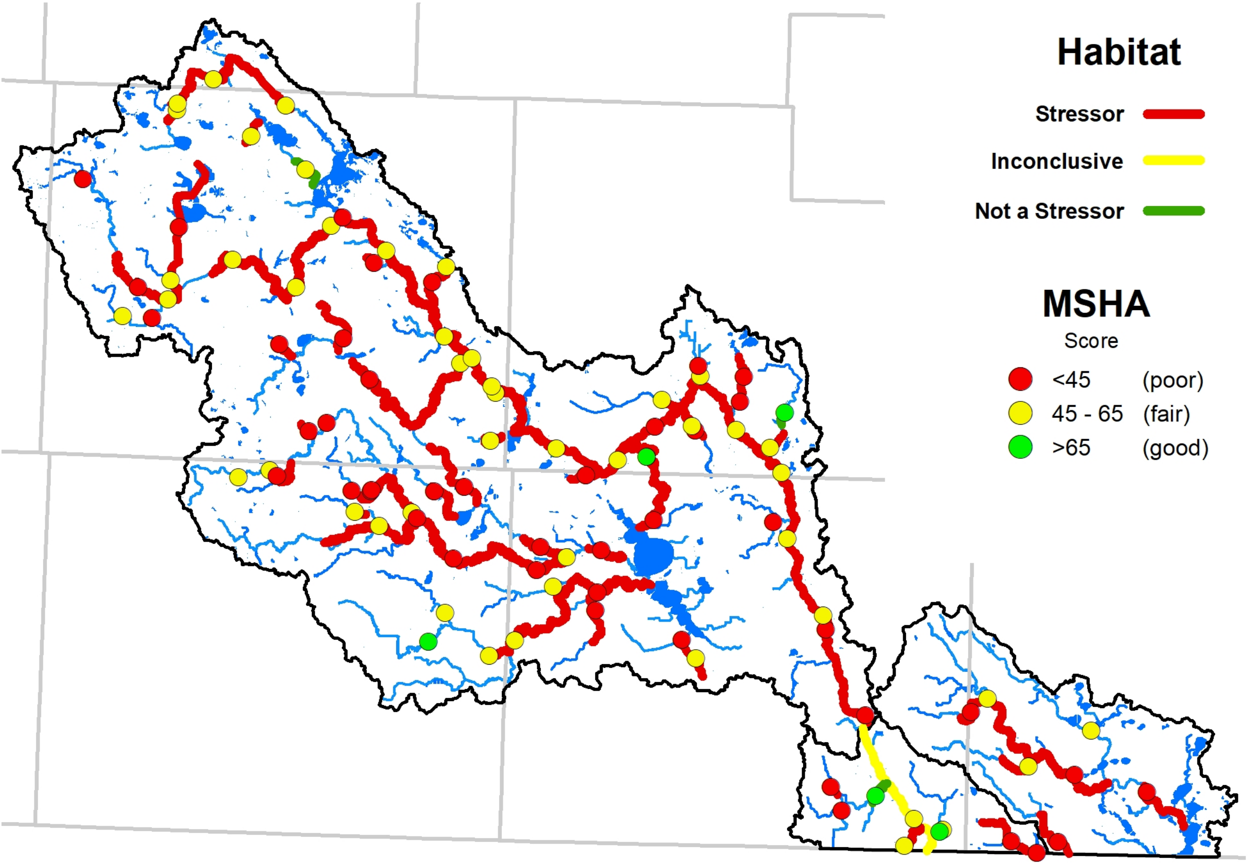


Figure 16: Both the stressor assessment results and the MSHA habitat scores are illustrated in this map. Assessment results (colored stream lines) show that generally, degraded habitat is stressing many of the streams in the Des Moines River Basin: red indicates a stressor (habitat is problematic in that reach); green indicates habitat is not a stressor (habitat is not problematic in that reach), and yellow indicates that more data are needed to assess habitat as a stressor. These assessments apply to the stream reach as a whole. The MSHA habitat scores apply to only a discrete site and not the whole reach. Therefore, a reach may be stressed by degraded habitat but have some locations with good habitat.

Sources

The specific habitat issues identified in the Des Moines River Basin SID Report show a complex, interconnected set of factors that are driven by primarily the stressors of altered hydrology and degraded riparian/vegetation.

Table 7 summarizes SID results within the basin. Issues leading to excess sediment (bedded sediment and erosion) are often due to unstable channel morphology, which is typically caused by altered hydrology. Degraded riparian issues are related to insufficient vegetation due to cropping/other land use too close to the stream, pasturing on the stream bank, and excessive stream bank erosion (accelerated by altered hydrology). Without an adequate riparian buffer, issues such as excessive flow, which causes stream instability and sediment issues, are magnified because the stream banks lack the strength to resist erosion.

Table 7: Specifics on the degraded habitat of bio-impaired stream reaches were identified in the Des Moines River Basin SID Report and summarized here.

			Stresssor Source				
Major Watershed	**AUID-3**	**Stream Name**	Pasturing/Lack of Riparian	Channel Morphology	Bedded Sediment	Erosion	Habitat diversity
Des Moines Headwaters	501	Des Moines River	●	●	●	●	●
	504	County Ditch 20	●	●	●	●	●
	514	Jack Creek	●	●	●	●	●
	518	Unnamed Creek		●	●	○	●
	523	Judicial Ditch 26	●	●	●		●
	524	Des Moines River	●	●	●	●	●
	527	Heron Lake Outlet	●	●	●	●	●
	533	Des Moines River	●		●	●	○
	535	Lime Creek	○	●	●	●	●
	544	Perkins Creek	●	●	●	●	●
	545	Des Moines River			●	●	●
	546	Des Moines River	○	○	●	●	●
	549	Jack Creek	●	●	●	●	●
	551	Unnamed Creek		●	●	●	●
	552	County Ditch 43/Scheldorf Creek		●	●		●
	563	Unnamed Creek		●	●		●
	564	Unnamed Creek	○	●	●	○	●
	602	Okabena Creek	●	●	●	●	●
	613	Unnamed Creek		○	●		○
	614	Unnamed Creek	●		●		●
	618	Unnamed Creek		●	●		●
	619	Unnamed Creek	●	●	●	●	●
	621	Unnamed Creek	●	●	●	○	●
	624	Unnamed Creek	●	●	●	○	●
	625	Unnamed Creek		●	○	●	●
Des Moines Headwaters	626	Unnamed Creek	●		●	○	○
	628	Unnamed Creek	●	●	●	●	○
	632	Unnamed Creek	●		●		●
	637	Unnamed Creek	●	●	●		
	641	Lake Shetek Inlet			●	●	○
	642	Lake Shetek Inlet	●		●	●	●
	643	Lake Shetek Inlet	●		●	●	●
	646	Beaver Creek	●	●	●	●	●
	649	Jack Creek, North Branch	●	●	●	●	●
	652	Jack Creek, North Branch	○	○	●	○	○
	656	Elk Creek	○	○	●	●	●
	658	Jack Creek	○	●	●	●	○
	661	Unnamed Creek	●	●	●	●	○
	663	Beaver Creek	●	●	●	●	●
	664	Beaver Creek	○	●	●		●
	666	Judicial Ditch 12	●	●	●	○	●
	668	Devils Run Creek	●	○	●		●
	672	Unnamed Creek	●		●		○
Lower Des Moines	502	Brown Creek/Judicial Ditch 10	●	●	●		●
	505	Judicial Ditch 56	●	●	●	●	●
	510	Unnamed ditch	●	●	●		○
East Fork Des Moines	506	County Ditch 53	●	●	●	●	●
	510	Fourmile Creek	○	○	●	●	○
	525	Des Moines River, East Branch	●	●	●	●	●
	527	Des Moines River, East Branch	○	●	●	●	●
	529	Unnamed Creek	●	●	●	●	●

●=source, ○=potential source, <blank>= not a source

Goal and 10-year Target

The basin-wide habitat goal is a 45% increase in the MSHA habitat score (Figure 17). The 10-year habitat target selected by the LWG is a 20% increase in the MSHA habitat score. The goal was calculated based on the MSHA scores, to achieve an average MSHA score of 65. Individual stream reach improvements may be more or less than the basin-wide goal based on specific stream conditions.

Site-specific goals (circles on Figure 17) were based on the stream's use class and calculated from the site-specific MSHA score. The goal for general use streams is to achieve an MSHA score of 65 or greater, and the goal for modified and limited use streams is to achieve an MSHA score of 45 or greater. Stream reaches exceeding the MSHA score goal have a protection goal. Because low habitat scores are mostly driven by degraded riparian vegetation and altered hydrology, these factors are the focus of restoration and protection efforts.

The goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address habitat are summarized in Section 3.

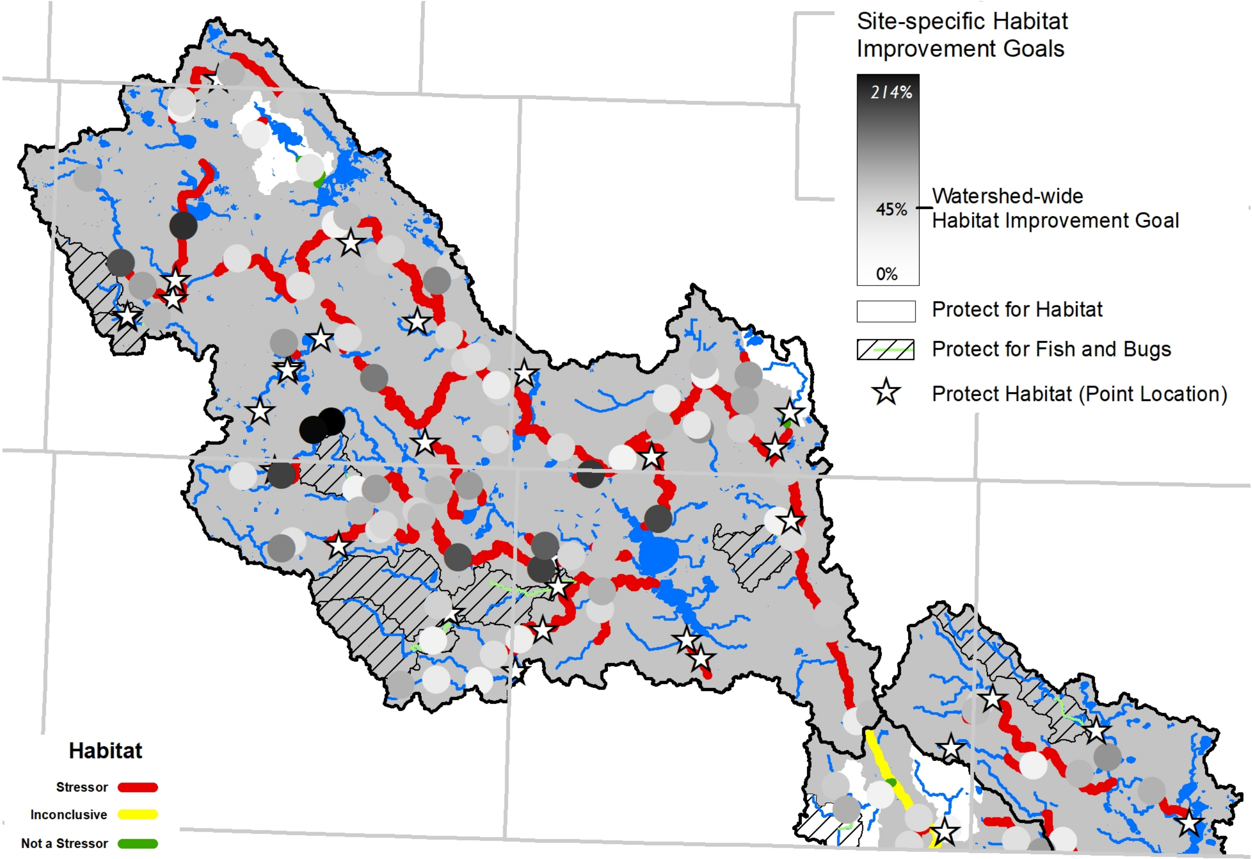


Figure 17: The habitat goal for the Des Moines River Basin is to increase the average MSHA score in the watershed for modified and Class 7 streams to 45 (fair) or greater and a score of 65 (good) or greater for general use streams. The relative amount of change needed at a location can be estimated by the color located on the stream reach; the darker the circle indicates the need for more extensive changes at these sampling sites. Stars indicate good habitat at sampling sites and have a protection goal. Sample sites may not be indicative of overall stream reach habitat quality.

Phosphorus/Eutrophication

Phosphorus is a nutrient that fuels algae and plant growth. While not directly harmful to aquatic life, excess phosphorus in waterbodies can lead to excessive algae growth and eutrophication (Chislock et al. 2013). Eutrophic responses to excess phosphorus affect aquatic life by changing food chain dynamics, affecting fish growth and development, and decreasing DO when algae/plant growth decomposes. Phosphorus also affects aquatic recreation in lakes by fueling algae growth, making waters undesirable or even dangerous to swim in due to the potential presence of toxic blue-green algae.

High phosphorus conditions alone do not necessitate its identification as a pollutant or stressor: eutrophic response conditions must also be observed. Because of this, some waterbodies may have high phosphorus concentrations but are not identified as impaired or stressed. In these cases, reducing phosphorus is still typically necessary to support downstream goals.

Status

Of the lakes monitored to determine if phosphorus/eutrophication (P/E) is a pollutant, 24 were impaired, 2 were supporting, and 25 were inconclusive. Of the bio-impaired stream reaches, P/E was identified as a stressor in 49, ruled out in 2, and inconclusive in 5. Of the 67 stream reaches assessed for P/E, 2 were impaired, 0 were supporting, and 65 were inconclusive. Figure 18 illustrates the stream reaches and lakes that were assessed for P/E, and Table 8 and Table 9 tabulate assessment results and lake clarity trends (which reflect eutrophic conditions).

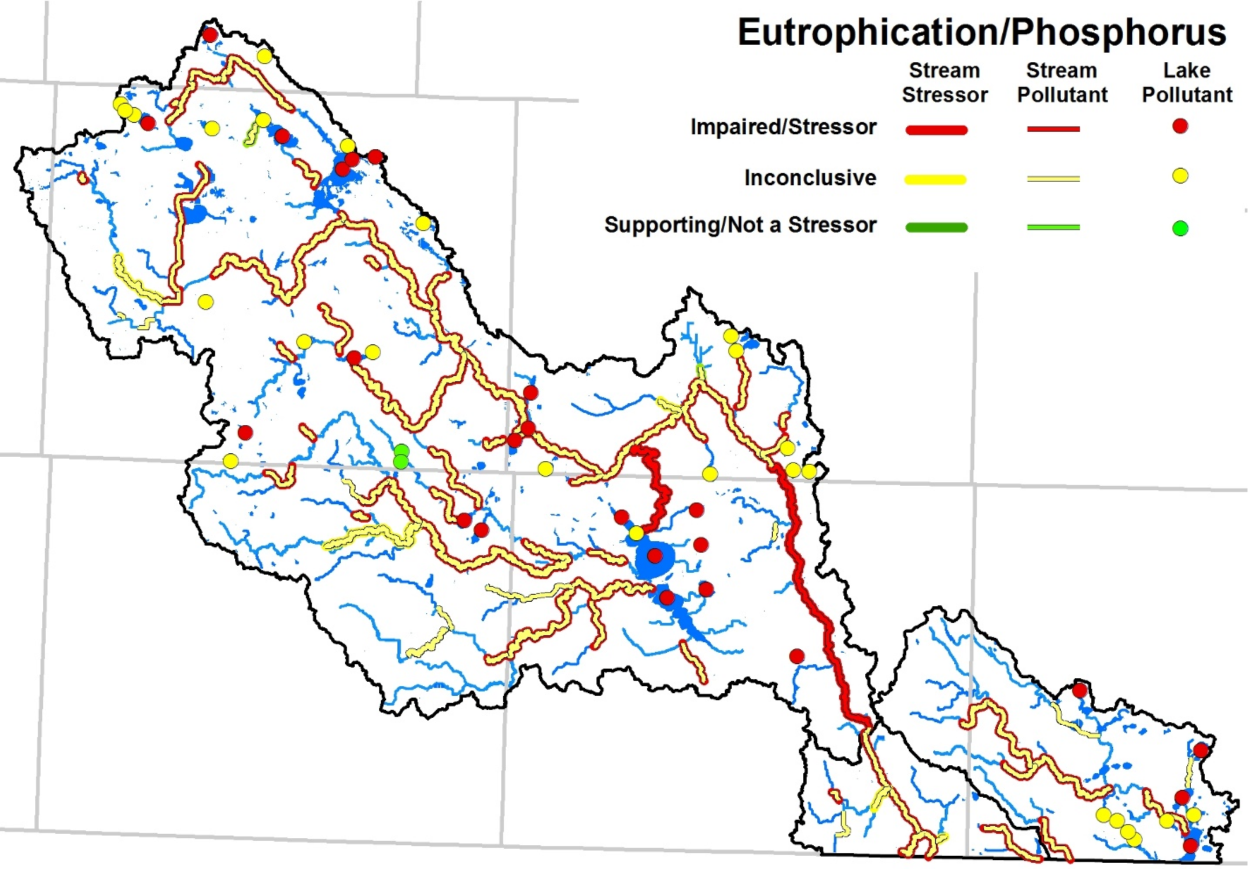


Figure 18: Assessment results indicate that P/E is stressing the majority of the stream reaches and is a pollutant in about half of the lakes and two stream reaches in the Des Moines River Basin. P/E is inconclusive in majority of the streams due to a lack of response variable data as a pollutant. Red indicates phosphorus was identified as a stressor/pollutant; green indicates phosphorus is not a stressor/pollutant, and yellow indicates that more data are needed to assess P/E.

Table 8: Assessment results of phosphorus/eutrophication as a pollutant and stressor in streams in the Des Moines River Basin.

Major Watershed	Stream Name	AUID-3	P/E Stressor Assessment	P/E Pollutant Assessment
Des Moines Headwaters	Des Moines River	501	x	X
	County Ditch 20	504	x	?
	Lower Lake Sarah Outlet	508	X	?
	Jack Creek	514	X	?
	Judicial Ditch 76	515		?
	Unnamed creek	518	X	?
	Judicial Ditch 26	523	X	?
	Des Moines River	524	X	?
	Heron Lake Outlet	527	X	X
	Des Moines River	533	X	?
	Lime Creek	535	X	?
	Des Moines River	541		?
	Perkins Creek	544	X	?
	Des Moines River	545	X	?
	Des Moines River	546	X	?
	Jack Creek	549	?	?
	Unnamed creek	551	X	?
	County Ditch 43 (Scheldorf Creek)	552	+	?
	Unnamed creek	563	X	?
	Unnamed creek	564	X	?
	Judicial Ditch 14	589		?
	Unnamed ditch	594		?
	Okabena Creek	602	X	?
	Unnamed creek	608		?
	Unnamed creek	613	?	?
	Unnamed creek	614	X	?
	Unnamed creek	615		?
	Unnamed creek	618	X	?
	Unnamed creek	619	X	?
	Unnamed creek	621	X	?
	Unnamed creek	624	X	?
	Unnamed creek	625	X	?
	Unnamed creek	626	X	?

Major Watershed	Stream Name	AUID-3	P/E Stressor Assessment	P/E Pollutant Assessment
Des Moines Headwaters	Unnamed creek	628	X	?
	Unnamed creek	632	+	?
	Unnamed creek	637	X	?
	Lake Shetek Inlet	641	X	?
	Lake Shetek Inlet	642	X	?
	Lake Shetek Inlet	643	X	?
	Beaver Creek	646	X	?
	Jack Creek	649	X	?
	Jack Creek	652	X	?
	Elk Creek	654		?
	Elk Creek	656	X	?
	Jack Creek	658	X	?
	Unnamed creek	661	X	?
	Beaver Creek	663	?	?
	Beaver Creek	664	X	?
	Judicial Ditch 12	665		?
	Judicial Ditch 12	666	X	?
	Devils Run Creek	668	X	?
	Unnamed creek	670	X	?
	Unnamed creek	672	X	?
Lower Des Moines	Des Moines River	501	X	?
	Brown Creek (Judicial Ditch 10)	502	X	?
	Unnamed creek	504	?	?
	Judicial Ditch 56	505	X	?
	Story Brook	507	?	?
	Unnamed ditch	510	X	?
	Judicial Ditch 6	513		?
East Fork Des Moines	County Ditch 53	506	X	?
	Fourmile Creek	510	X	?
	County Ditch 1/Judicial Ditch 50	515		?
	Mud Slough	516		?
	Des Moines River, East Branch	525	X	?
	Des Moines River	527	X	?
	Unnamed creek	529	X	?

+ = supporting/not a stressor
? = inconclusive (need more data)
X = impaired/stressor
<blank> = not monitored/assessed

Table 9: Assessment results for phosphorus/eutrophication, clarity trends and aquatic life for lakes in the Des Moines River Basin.

Major Watershed	Lake ID	Lake Name	Phosphorus Assessment	Clarity Trend	Aquatic Life Assessment
Des Moines Headwater	51-0045-00	Armstrong Slough		?	
	51-0105-00	Big Slough	?	?	
	51-0040-00	Bloody	X	--	?
	32-0015-00	Boot	X	?	
	51-0018-00	Buffalo	?	?	?
	51-0011-00	Corabelle	X	?	X
	17-0022-00	Cottonwood	?	?	X
	51-0082-00	Currant	X	--	X
	51-0090-00	Current Lake Marsh	?	?	
	53-0020-00	East Graham	X	?	X
	51-0021-00	First Fulda	+	+	?
	32-0045-00	Flahtery	X	?	
	51-0043-00	Fox	X	?	X
	51-0039-00	Fremont	?	?	
	17-0031-00	Harder	?	?	
	32-0057-02	Heron (Duck)	X	?	
	32-0057-05	Heron (North Heron)	X	?	
	32-0057-01	Heron (North Marsh)	?	?	
	32-0057-07	Heron (South Heron)	X	?	
	51-0089-02	Hjermstad Slough	?	?	
	51-0079-00	Iron	?	?	?
	53-0016-00	Kinbrae		?	
	53-0018-00	Kinbrae Slough		?	
	42-0032-00	Lake of the Hill	?	?	
	51-0024-00	Lime	X	?	X
	51-0062-00	Maria	?	?	
	51-0050-00	North Badger		?	
	51-0089-01	North Marsh	?	?	?
Des Moines Headwater	17-0044-00	North Oaks	X	?	?
	51-0063-00	Sarah	X	+	X
	51-0020-00	Second Fulda	+	?	?
	51-0046-00	Shetek	X	X	X
	51-0049-00	South Badger		?	
	17-0041-00	South Clear	?		
	17-0024-00	String	?	?	?
	17-0073-00	Summit	?	?	?
	51-0068-00	Summit	?	X	?
	17-0060-00	Talcot	X	?	
	32-0053-00	Teal	X	?	
	32-0058-00	Timber	X	?	
	17-0030-00	Unnamed	?	?	
	51-0104-00	Unnamed	?	?	
	51-0023-00	Unnamed	?	?	
	53-0021-00	West Graham	X	?	X
	17-0013-00	Wolf	?	?	
	42-0047-00	Yankton	X	--	X
East Fork Des Moines	46-0052-00	Bright	X	?	X
	46-0061-00	Clayton	?	?	
	46-0096-00	Clear	?	X	?
	46-0098-00	Dutton Slough	?	?	?
	46-0095-00	Fish	?	?	
	46-0088-00	Little Tuttle	?	?	
	46-0051-00	Okamanpeedan	X	?	?
	46-0076-00	Pierce	X	?	
	46-0094-00	Susan	?	?	
	46-0103-00	Temperance	X	?	X

x	=	impaired/declining trend
?	=	inconclusive (need more data)
+	=	supporting/improving trend
--	=	no trend detected
<blank>	=	no data

From a statewide perspective, the Des Moines River Headwaters Watershed phosphorus concentrations and yields are moderate to high (Figure 19). WPLMN monitoring data was not available for the Lower Des Moines River and East Fork Des Moines River Watersheds.

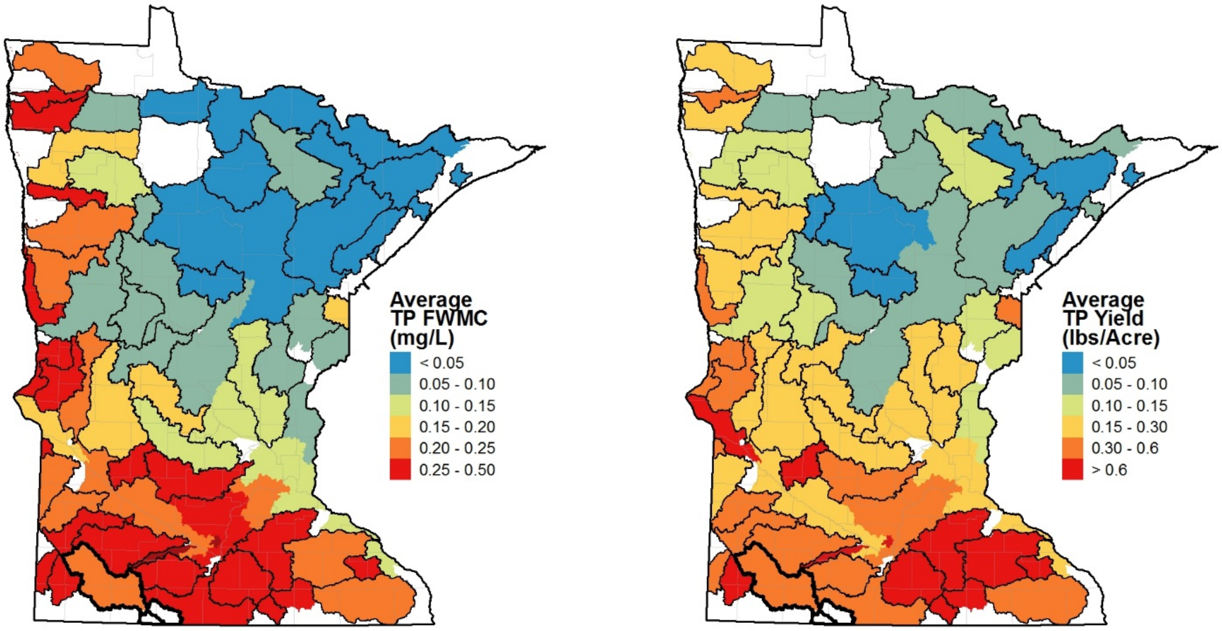


Figure 19: The Des Moines River Headwaters Watershed has a higher annual total phosphorus yield compared to many other watersheds throughout the state.

An HSPF model was developed for the Des Moines River Basin. The models estimated flow-weighted mean concentration (FWMC) for the years 1994 through 2014 is illustrated in Figure 20. This model data can be used to estimate conditions in stream reaches that have not been monitored.

Continuous data provided by the WPLMN illustrate the timing of phosphorus loads by month. Over the years of 2008 through 2018 at the Des Moines River at Jackson, the months of March, April, June, and July each accounted for 12% to 20% of the load (Figure 20). The timing of loads is useful for identifying sources and strategies. More information and interpretation of the WPLMN phosphorus data is in Appendix 2.

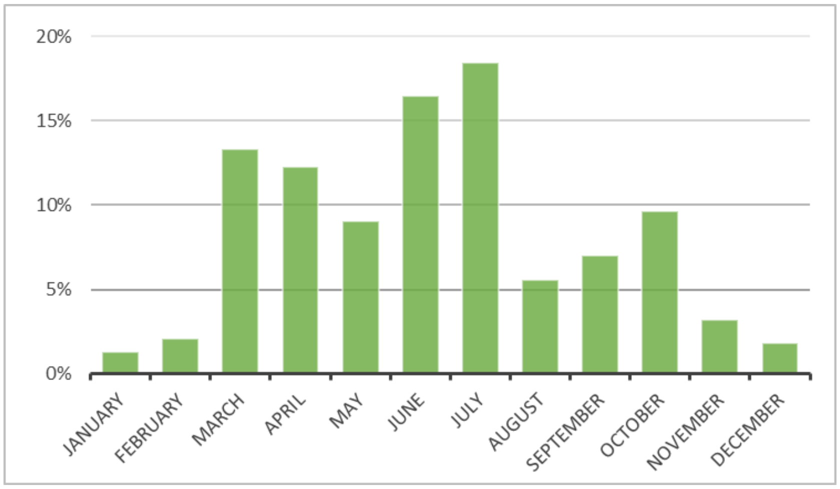


Figure 20: 2008-2018 total phosphorus WPLMN load data from the Des Moines River at Jackson illustrate the timing of phosphorus loads. The load over these years was heaviest in March, April, June, and July, each delivering 12-20% of the load. Moderate loads (roughly 5% of the load) were delivered from the months of August through November. Minimal loads (<3% of the load) were delivered in the winter months.

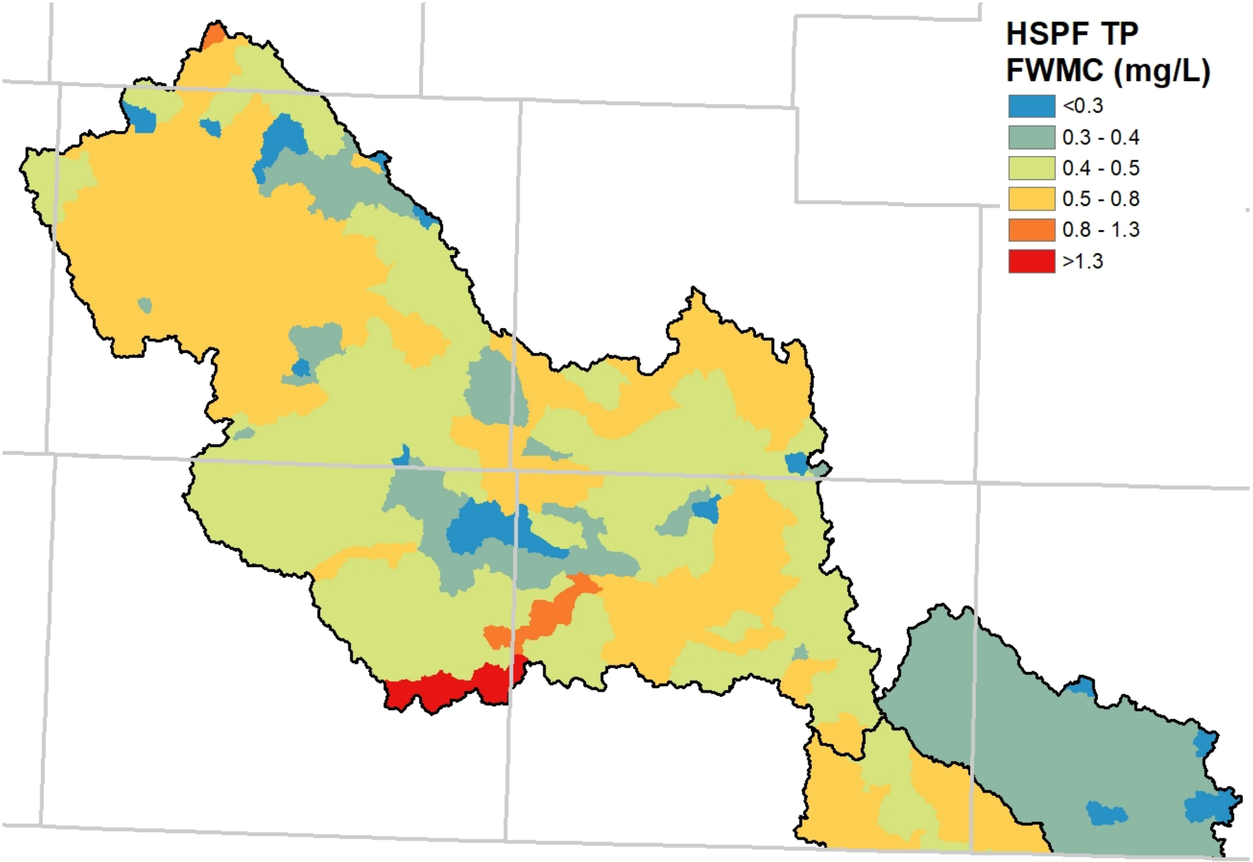


Figure 21: HSPF model data estimate the FWMC of total phosphorus for the years 1994-2014.

Sources

Phosphorus contributions are dominated by nonpoint sources in the Des Moines River Basin. Point source contributions for the years 2008 through 2016 are estimated to total 9% of the phosphorus load in the Des Moines River Basin (Appendix 2).

A numeric estimate of the Des Moines River Basin's phosphorus sources is presented in Figure 22. Refer to the Sources Overview in Section 2.1 for more details. Crop surface and tile discharge were estimated to be the largest sources of phosphorus. Much of this crop phosphorus source is from applied fertilizer and manure, while some is from phosphorus native to the soil.

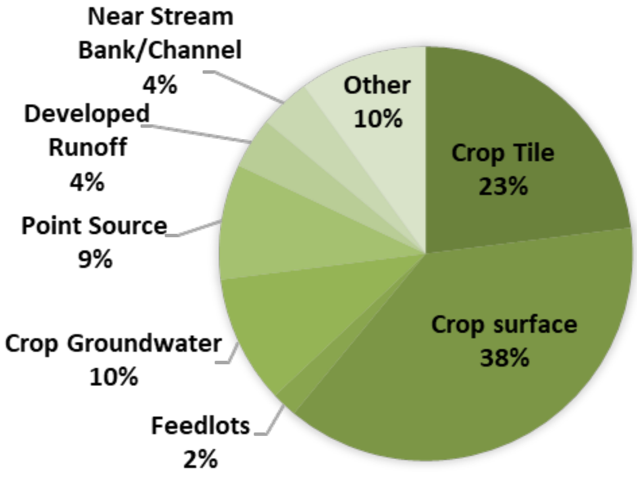


Figure 22: Source assessment work in the Des Moines River Basin estimates that crop surface runoff and tile drainage account for more than 60% of the phosphorus. The other 40% of phosphorus comes from varied sources including point sources and stream banks.

Internal phosphorus loads in lakes are not explicitly accounted for in the source assessment. Internal loads are a product of excessive, legacy phosphorus contributions from a lake's watershed, and little of the internal load is natural. The strategies presented in Section 3.3 focus mainly on external load. When planning for lake restoration, however, knowing the magnitude of internal load is important in developing the specific strategies to address the impairment. Planners should consult the TMDL or additional lake modeling or studies to estimate the internal load accordingly.

Goal and 10-year Target

The basin-wide phosphorus goal is a 45% reduction (Figure 23). The 10-year phosphorus target selected by the WRAPS LWG is a 7% reduction in lakes and a 15% reduction in streams. The basin-wide goal was set after reviewing phosphorus data from lakes and streams in the basin, WPLMN data, the *Minnesota Nutrient Reduction Strategy* (MPCA 2013a) goals, and lake and stream standards. Individual stream reach and lake reductions may be more or less than the basin-wide goal based on specific conditions.

Individual subwatershed reduction goals were calculated for lakes and streams that required a TMDL. Goals for these subwatersheds ranged from 16 to 80% phosphorus reduction. Two stream reaches that identified phosphorus not being a stressor and two lakes that are in full support have a phosphorus protection goal. Refer to the TMDL summary in Appendix 3 for lake and stream subwatershed reduction goals and calculation methods.

These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for phosphorus reductions are summarized in Section 3.

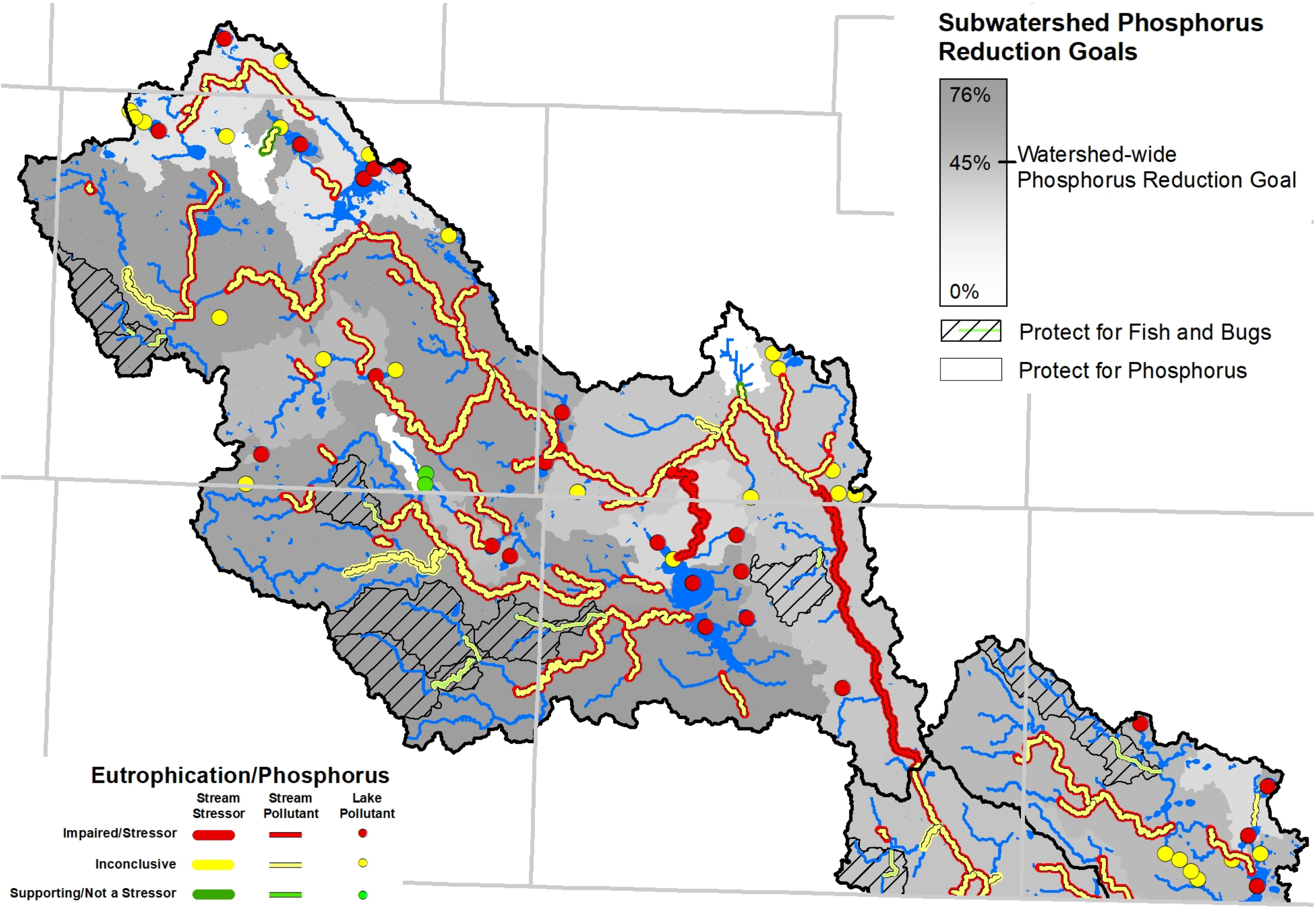


Figure 23: The basin-wide phosphorus goal for the Des Moines River Basin is a 45% reduction. Reduction goals were calculated for subwatersheds with TMDL data.

Sediment/TSS

TSS are material suspended in the water. This material is often dominated by sediment, but also includes algae (especially in eutrophic streams) and other solids. Suspended sediment and streambed sediment are closely related because they have similar sources but affect aquatic life differently. Due to the inter-related nature of these parameters, they are grouped together in this report. Furthermore, sediment is the focus of this section and issues related to the algae-portion of TSS are addressed in the phosphorus/eutrophication section.

TSS impacts aquatic life by reducing visibility, which reduces feeding, clogging gills, which reduces respiration, and smothering substrate, which limits reproduction. Excessive TSS can reduce the penetration of sunlight, limit plant growth, and increase water temperatures. Sediment also affects downstream waters used for navigation (larger rivers) and recreation (lakes) by filling in waterbodies.

Status

Of the stream reaches monitored to assess TSS as a pollutant, 19 were impaired, 2 were supporting, and 50 were inconclusive. Of the bio-impaired stream reaches, TSS was identified as a stressor in 22, ruled out in 28, and inconclusive in 6. Figure 24 illustrates the stream reaches that were assessed for sediment, and Table 10 tabulates those results.

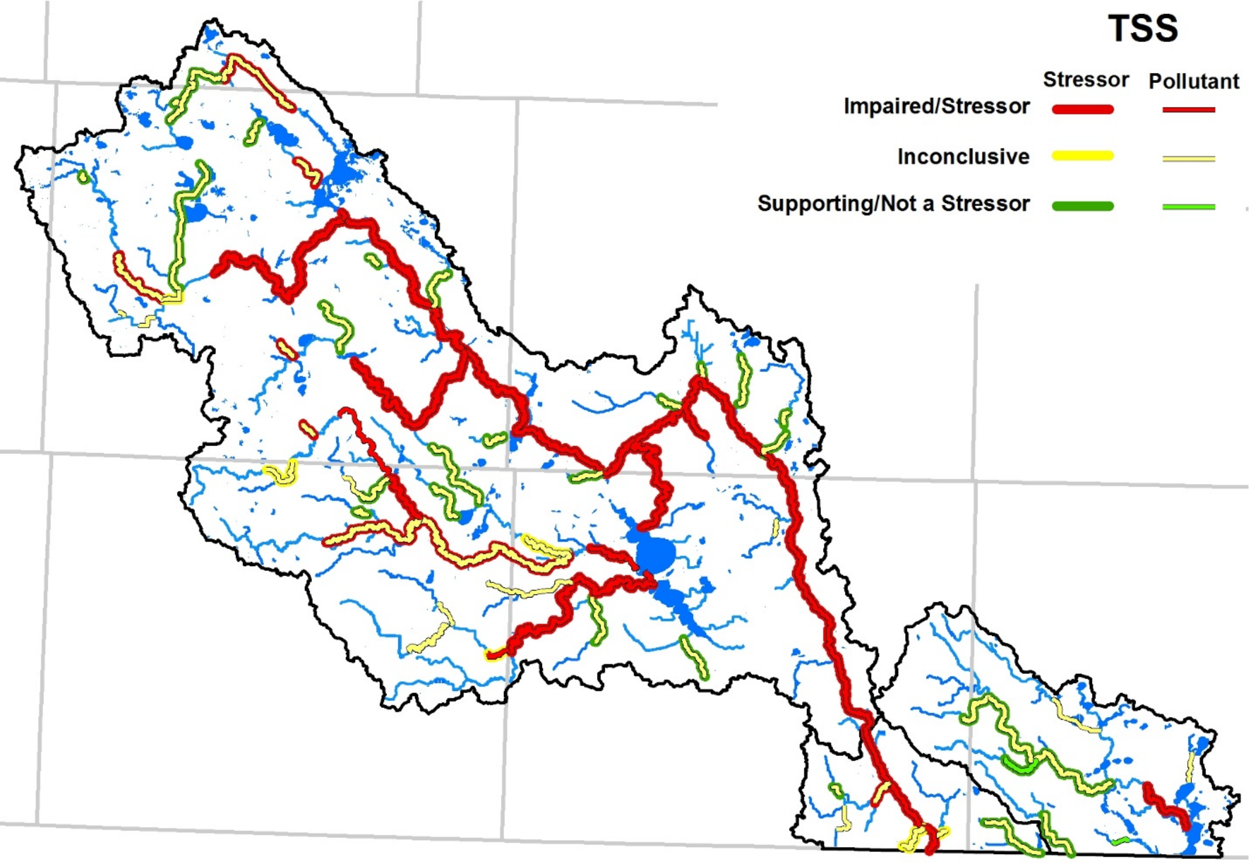


Figure 24: Assessment results show that TSS is a pollutant or stressor in many of the stream reaches in the Des Moines River Basin. Red indicates TSS was identified as a pollutant/stressor (TSS is problematic in that reach); green indicates TSS is not a pollutant/stressor (TSS is not problematic in that reach), and yellow indicates that more data are needed to assess TSS.

Table 10: Assessment results for TSS as a pollutant and/or stressor for stream reaches in the Des Moines Basin.

Major Watershed	Stream Name	AUID-3	TSS Stressor Assessment	TSS Pollutant Assessment
Des Moines Headwater	Des Moines River	501	X	X
	County Ditch 20	504	+	?
	Lower Lake Sarah Outlet	508	X	?
	Jack Creek	514	X	?
	Judicial Ditch 76	515		?
	Unnamed creek	518	+	?
	Judicial Ditch 26	523	+	?
	Des Moines River	524	X	X
	Heron Lake Outlet	527	X	X
	Division Creek	529		X
	Des Moines River	533	X	X
	Lime Creek	535	X	X
	Des Moines River	541		X
	Perkins Creek	544	+	?
	Des Moines River	545	X	X
	Des Moines River	546	X	X
	Jack Creek	549	X	?
	Unnamed creek	551	X	X
	County Ditch 43 (Scheldorf Creek)	552	+	?
	Unnamed creek	563	+	?
	Unnamed creek	564	?	?
	Judicial Ditch 14	589		?
	Unnamed ditch	594		?
	Okabena Creek	602	X	X
	Unnamed creek	608		?
	Unnamed creek	613	+	?
	Unnamed creek	614	+	?
	Unnamed creek	615		?
	Unnamed creek	618	+	?
	Unnamed creek	619	X	?
	Unnamed creek	621	+	?
	Unnamed creek	624	+	?
	Unnamed creek	625	X	?
	Unnamed creek	626	+	?
	Unnamed creek	628	+	?
Des Moines Headwater	Unnamed creek	632	+	?
	Unnamed creek	637	+	?
	Lake Shetek Inlet	641	+	?
	Lake Shetek Inlet	642	+	?
	Lake Shetek Inlet	643	X	?
	Beaver Creek	646	X	X
	Jack Creek	649	?	?
	Jack Creek, North Branch	651		X
	Jack Creek	652	X	X
	Elk Creek	654		?
	Elk Creek	656	?	X
	Jack Creek	658	X	X
	Jack Creek	659		X
	Unnamed creek	661	+	?
	Beaver Creek	663	X	?
	Beaver Creek	664	?	?
	Judicial Ditch 12	665		?
	Judicial Ditch 12	666	+	?
	Devils Run Creek	668	+	?
	Unnamed creek	670	+	?
	Unnamed creek	672	+	?
Lower Des Moines	Des Moines River	501	X	X
	Brown Creek (Judicial Ditch 10)	502	+	?
	Unnamed creek	504	?	?
	Judicial Ditch 56	505	?	?
	Story Brook	507	X	?
	Unnamed ditch	510	+	?
	Judicial Ditch 6	513		?
East Fork Des Moines	County Ditch 53	506	+	?
	Fourmile Creek	510	+	+
	County Ditch 1/Judicial Ditch 50	515		?
	Mud Slough	516		?
	Unnamed creek	521		+
	Des Moines River, East Branch	525	+	?
	Des Moines River	527	X	X
	Unnamed creek	529	+	?

+	=	supporting/not a stressor
?	=	inconclusive (need more data)
X	=	impaired/stressor
<blank>	=	not monitored/assessed

From a statewide perspective, the Des Moines River Headwaters Watershed has a medium-high yield and FWMC of TSS (Figure 25). Data from the WPLMN show that the Des Moines River Headwaters Watershed's concentrations often spike above the 65 mg/L standard. WPLMN monitoring data was not available for the Lower Des Moines River and East Fork Des Moines River Watersheds.

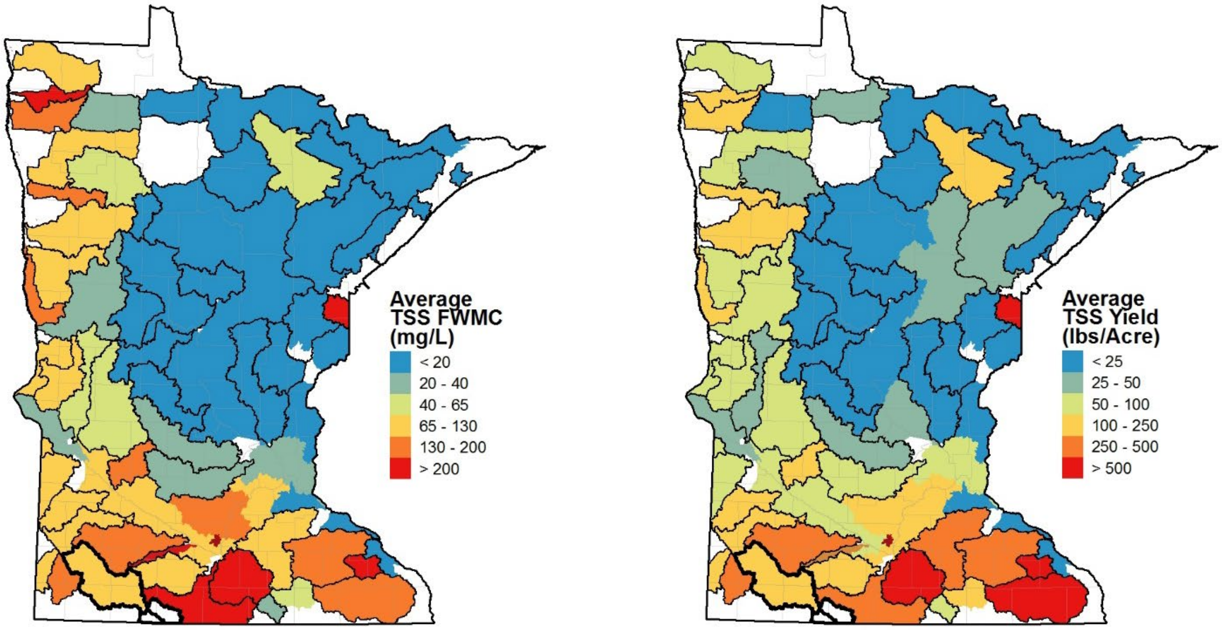


Figure 25: The Des Moines River Headwaters Watershed has a high annual sediment yield compared to many other watersheds throughout the state.

An HSPF model was developed for the Des Moines River Basin, which estimated the FWMC for the years 1994 through 2014 as illustrated in Figure 26. This model data can be used to estimate conditions in stream reaches that have not been monitored.

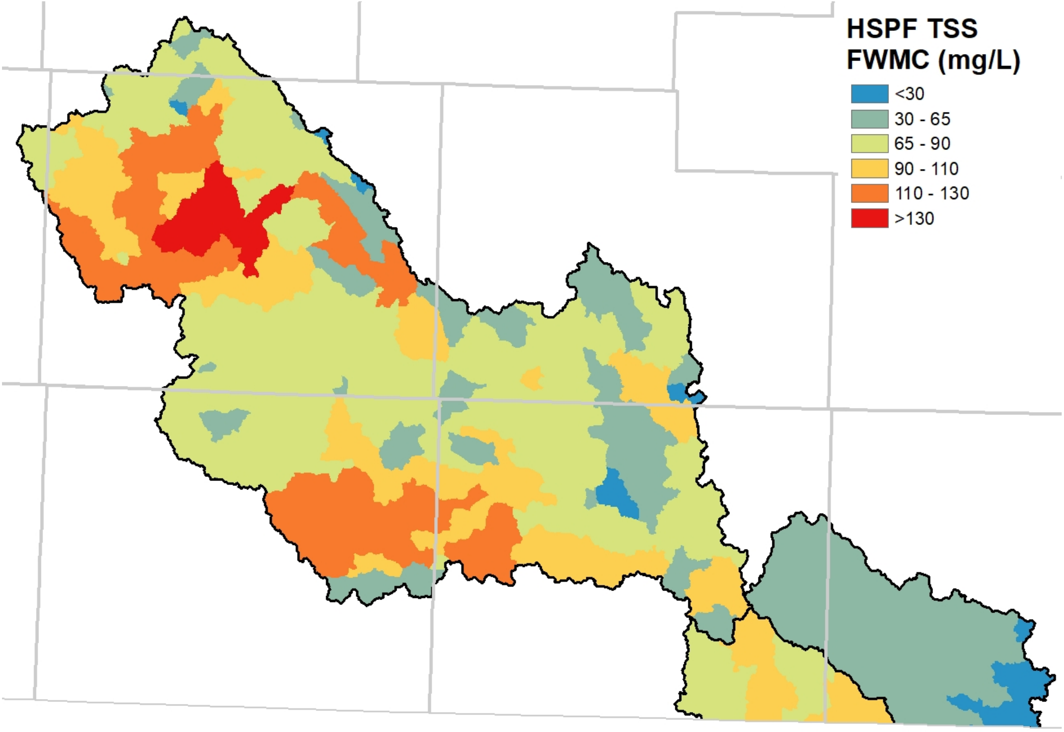


Figure 26: HSPF model data estimate the FWMC of TSS for the years 1994-2014.

Continuous data provided by the WPLMN illustrate the timing of TSS loads by month. Over the years of 2008 through 2018 at the Des Moines River at Jackson, the months of May, June, and July produced the largest loads (Figure 27), with June alone representing 24% of the TSS load. The timing of loads is useful for identifying sources and strategies. More information and interpretation of the WPLMN phosphorus data is in Appendix 2.

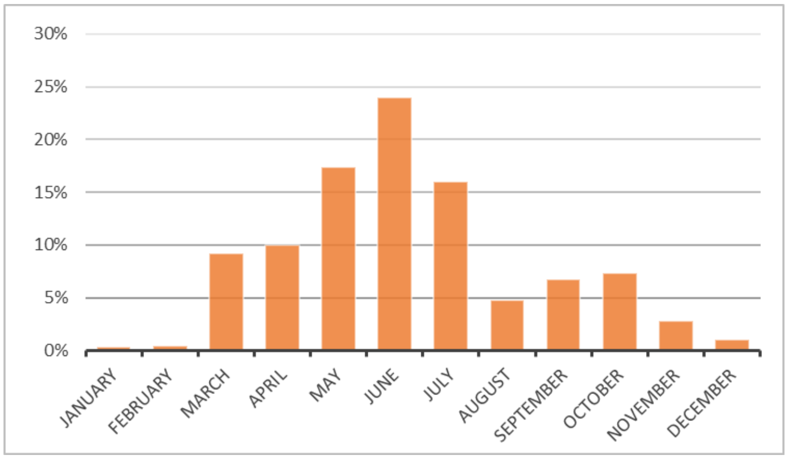


Figure 27: 2008-2018 TSS WPLMN load data from the Des Moines River at Jackson illustrate the timing of TSS loads. The load over these years was heaviest in May, June, and July, each delivering more than 15% of the load. Moderate loads (roughly 10% of the load) were delivered from March and April. Low loads (~5% of the load) were delivered in August through November, and very low loads were delivered in the winter months.

Sources

Point source contributions of sediment are minimal with contributions for the years of 2008 through 2016 estimated at 0.2% of the Des Moines River Basin sediment load (Appendix 2).

The primary nonpoint sources of sediment can be broken into two groups: upland and channel. Upland erosion includes farm field surface and gully erosion, sediment that is washed away from roads and developed areas, and surface erosion from other areas. Upland sediment contributions typically happen when bare soils erode during rains or snowmelt.

Channel sediment contributions are dominated by stream and ditch bank erosion but also include channel bed and other material in or directly adjacent to the waterbody. While some amount of channel migration and associated bank/bluff erosion is natural, altered hydrology has likely increased stream flow, contributing to excessive bank/bluff erosion. The DNR (2010) discusses the multiple causes of streambank erosion, including how altered hydrology influences streambank erosion.

A numeric estimate of the Des Moines River Basin's sediment sources is presented in Figure 28. Cultivated crop surface runoff and streambank/streambed (channel) erosion are the dominant sources throughout the Des Moines River Basin. Refer to the Sources Overview in Section 2.1 for more details about sediment sources.

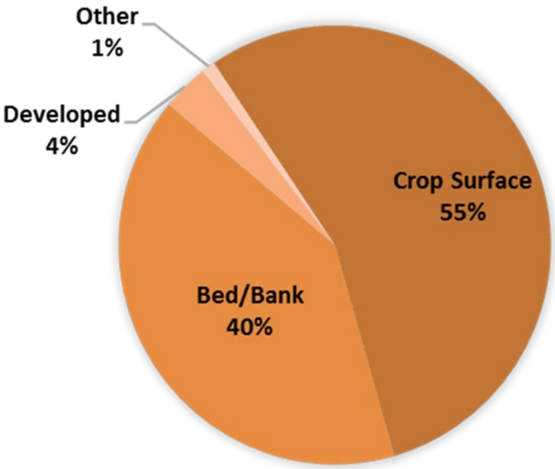


Figure 28: TSS source assessment in the Des Moines River Basin estimates that the largest sources of sediment are from channel (bed/bank) erosion and crop surface runoff.

The upstream watershed is estimated to have a higher portion of sediment from upland sources, and conversely, the downstream portion of the watershed has a higher portion of sediment from channel sources (see Appendix 2 for more details).

While some streambank erosion is part of the natural channel evolution process, streambank erosion due to unstable streams is common in the Des Moines River Basin, especially in the Des Moines River Headwaters and Lower Des Moines River, as discussed in the *Des Moines River Watershed Characterization Report* (DNR 2016). According to this report, most stream instability in this area is from poor riparian vegetation management and altered hydrology (higher flows due to losses in water storage and ET and decreased channel residence times due to stream straightening). Sites with good riparian vegetation appeared more resilent than those without dense, deep-rooted vegetation.

Some streams contain enough instream production of algae that it may be a suspended solids source of concern. At the basin-wide scale, this contribution is minimal. In-stream algae production is due to excessive phosphorus contributions and stagnant flow conditions creating eutrophic conditions. Therefore, issues related to instream algae production are handled in this report in the Phosphorus/Eutrophication and Altered Hydrology sections.

Goal and 10-year Target

The basin-wide TSS goal is a 30% reduction (Figure 29). The TSS 10-year target selected by the WRAPS LWG is a 5% reduction. The basin-wide goal was set after analyzing TMDL and WPLMN data. Individual stream reach reductions may be more or less than the basin-wide goal based on specific stream conditions.

Individual subwatershed reduction goals were calculated for streams that required a TMDL. Subwatershed reduction goals range from a 30% to an 80% reduction. The reaches not stressed or impaired by sediment have a protection goal. Refer to the TMDL summary in Appendix 3 for subwatershed reduction goals and calculation methods.

These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for sediment reductions are summarized in Section 3.

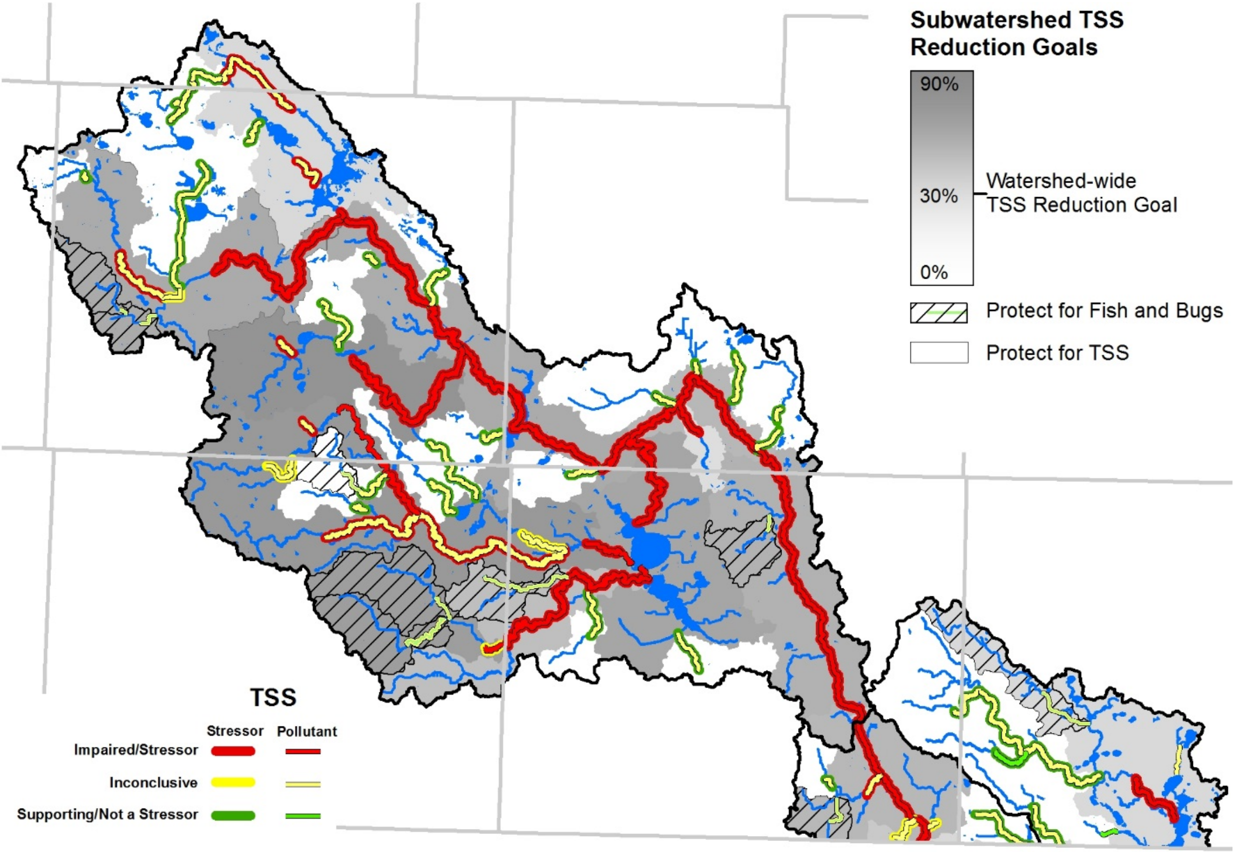


Figure 29: The basin-wide sediment goal for the Des Moines River Basin is a 30% reduction. The individual subwatershed goals range from protection up to an 80% reduction.

Dissolved Oxygen

DO is oxygen gas within water. Low or highly fluctuating DO concentrations affect aquatic life primarily by limiting respiration, which contributes to stress and disease. If DO concentrations become limited or fluctuate dramatically, aquatic life can experience reduced growth or fatality.

Status

Of the stream reaches monitored to assess DO as a pollutant, 2 were impaired, 2 were supporting, and 65 were inconclusive. Of the bio-impaired stream reaches, DO was identified as a stressor in 37, ruled out in 8, and inconclusive in 11. Figure 30 illustrates the stream reaches assessed for DO, and Table 11 tabulates those results.

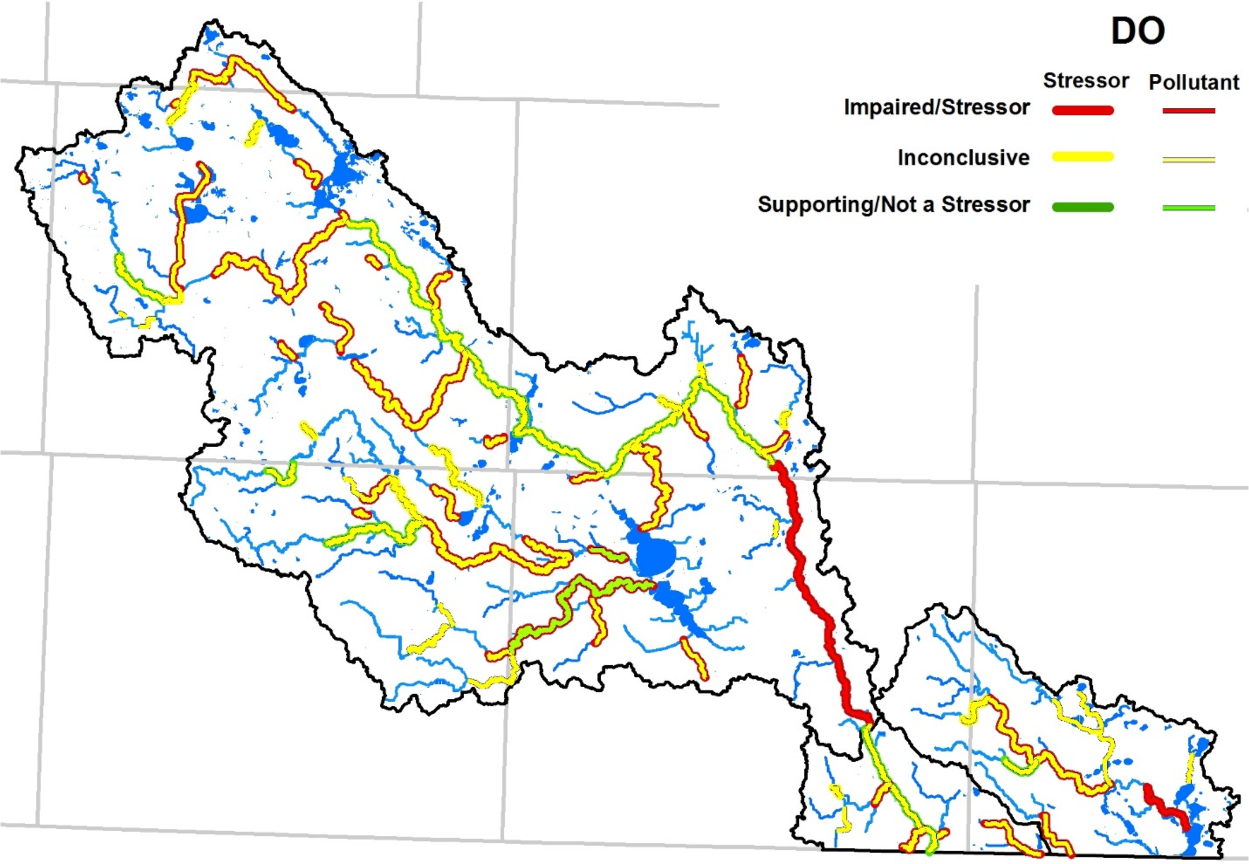


Figure 30: DO is stressing many stream reaches throughout the Des Moines River Basin. Two stream reaches were assessed as impaired by DO as a pollutant, one in the Headwaters and one in the East Fork. Red indicates DO was identified as a pollutant/stressor (DO is problematic in that reach); green indicates DO is not a pollutant/stressor (DO is not problematic in that reach), and yellow indicates that more data are needed to assess DO.

Table 11: Assessment results for DO as a pollutant and/or stressor for stream reaches in the Des Moines Basin.

Major Watershed	Stream Name	AUID-3	Dissolved Oxygen Stressor Assessment	Disolved Oxygen Pollutant Assessment
Des Moines Headwaters	Des Moines River	501	X	X
	County Ditch 20	504	X	?
	Lower Lake Sarah Outlet	508	X	?
	Okabena Creek	512		?
	Jack Creek	514	X	?
	Judicial Ditch 76	515		?
	Unnamed creek	518	X	?
	Judicial Ditch 26	523	?	?
	Des Moines River	524	+	?
	Heron Lake Outlet	527	X	?
	Des Moines River	533	+	?
	Lime Creek	535	X	?
	Des Moines River	541		?
	Perkins Creek	544	X	?
	Des Moines River	545	X	?
	Des Moines River	546	+	?
	Jack Creek	549	+	?
	Unnamed creek	551	X	?
	County Ditch 43 (Scheldorf Creek)	552	?	?
	Unnamed creek	563	X	?
	Unnamed creek	564	X	?
	Judicial Ditch 14	589		?
	Unnamed ditch	594		?
	Okabena Creek	602	X	+
	Unnamed creek	608		?
	Unnamed creek	613	?	?
	Unnamed creek	614	X	?
	Unnamed creek	615		?
	Unnamed creek	618	X	?
	Unnamed creek	619	?	?
	Unnamed creek	621	X	?
	Unnamed creek	624	X	?
	Unnamed creek	625	X	?
	Unnamed creek	626	X	?

Major Watershed	Stream Name	AUID-3	Dissolved Oxygen Stressor Assessment	Disolved Oxygen Pollutant Assessment
Des Moines Headwaters	Unnamed creek	628	X	?
	Unnamed creek	632	?	?
	Unnamed creek	637	X	?
	Lake Shetek Inlet	641	?	?
	Lake Shetek Inlet	642	X	?
	Lake Shetek Inlet	643	X	?
	Beaver Creek	646	X	?
	Jack Creek	649	+	?
	Jack Creek	652	?	?
	Elk Creek	654		?
	Elk Creek	656	X	?
	Jack Creek	658	X	+
	Unnamed creek	661	X	?
	Beaver Creek	663	+	?
	Beaver Creek	664	?	?
	Judicial Ditch 12	665		?
	Judicial Ditch 12	666	X	?
	Devils Run Creek	668	X	?
	Unnamed creek	670	?	?
	Unnamed creek	672	X	?
Lower Des Moines	Des Moines River	501	+	?
	Brown Creek (Judicial Ditch 10)	502	X	?
	Unnamed creek	504	X	?
	Judicial Ditch 56	505	X	?
	Story Brook	507	X	?
	Unnamed ditch	510	?	?
	Judicial Ditch 6	513		?
East Fork Des Moines	County Ditch 11	503		?
	County Ditch 53	506	X	?
	Fourmile Creek	510	+	?
	County Ditch 1/Judicial Ditch 50	515		?
	Mud Slough	516		?
	Des Moines River, East Branch	525	X	?
	Des Moines River	527	X	X
	Unnamed creek	529	?	?

+ = supporting/not a stressor
? = inconclusive (need more data)
X = impaired/stressor
<blank> = not monitored/assessed

Sources

Low DO in waterbodies is caused by: 1) *excessive oxygen consumption*, which is often caused by the decomposition of algae, and plants whose growth is fueled by excess phosphorus and/or 2) *too little re-oxygenation*, which is often caused by minimal turbulence from low flow conditions or high water temperatures. Highly fluctuating diurnal DO levels indicate that high levels of plant respiration are occurring during daylight, but excessive oxygen consumption (from plant matter decomposition) occurs at night. Table 12 summarizes the Stressor ID report's DO source assessment findings.

Table 12: Sources of low or fluctuating DO concentrations in bio-impaired stream reaches were identified in the Des Moines River Basin Stressor ID report.

Major Watershed	AUID-3	Stream Name	Stressor Sources			
			Plant Respiration	Lack of flow	Wetland influcence	Unidentified
Des Moines Headwaters	501	Des Moines River	●			
	504	County Ditch 20	●			
	508	Lower Lake Sarah Outlet	●			
	514	Jack Creek	●			
	518	Unnamed Creek	●	●		
	527	Heron Lake Outlet	●			
	535	Lime Creek	●			
	544	Perkins Creek				●
	545	Des Moines River	●			
	551	Unnamed Creek	○			
	563	Unnamed Creek	●	○		
	564	Unnamed Creek	●	○		
	602	Okabena Creek	●			
	614	Unnamed Creek	●	○		
	618	Unnamed Creek	○	●		
	621	Unnamed Creek	●	○		
	624	Unnamed Creek	●			
	625	Unnamed Creek	○	○		●

●=source, ○=potential source, <blank>= not a source

Major Watershed	AUID-3	Stream Name	Stressor Sources			
			Plant Respiration	Lack of flow	Wetland influcence	Unidentified
Des Moines Headwaters	626	Unnamed Creek	○	○		
	628	Unnamed Creek	○	●		
	637	Unnamed Creek	○			●
	642	Lake Shetek Inlet	●	○		
	643	Lake Shetek Inlet	●			
	646	Beaver Creek	○			●
	656	Elk Creek	●			
	658	Jack Creek	●			
	661	Unnamed Creek	●	○		
	666	Judicial Ditch 12	○	○		
	668	Devils Run Creek	●	○		
	672	Unnamed Creek	●	○		
Lower Des Moines	504	Unnamed Creek				●
	502	Brown Creek/Judicial Ditch 10	●	○		
	505	Judicial Ditch 56	●			
	507	Story Brook				●
East Fork Des Moines	506	County Ditch 53	●	○		
	525	Des Moines River, East Branch	○			
	527	Des Moines River, East Branch	○			

Goal and 10-year Target

The basin-wide DO goal and 10-year target are to meet the altered hydrology, phosphorus, and habitat goals and 10-year targets. Specifically, the DO goal is to reach 5 mg/L or greater and for diurnal DO flux to be less than 4.5 mg/L. However, since DO is a response to (caused by) other pollutants and stressors, these parameters' goals are used as the indirect DO goal. Strategies and methods to prioritize regions to address altered hydrology, phosphorus, and habitat are summarized in Section 3.

Nitrogen

Nitrogen can be present in waterbodies in several forms including ammonia, nitrite, and nitrate. The sum of all forms is referred to as total nitrogen (TN). Ammonia, the most toxic nitrogen form, is converted to nitrite and then to nitrate through a process called the nitrogen cycle. While ammonia is the most toxic, it is typically converted to the less toxic nitrate very quickly, and hence, is rarely identified as a pollutant. Nitrate, while less toxic, is typically the parameter of concern because the conversion of nitrate to nitrogen gas (denitrification) is a relatively slow process that must occur in anaerobic conditions. This results in the accumulation of nitrate to concentrations that are toxic to aquatic life. Additional information on nitrogen in surface waters is provided by the MPCA (2013d).

High nitrogen concentrations in waters affect aquatic life, humans, and downstream waters. Ammonia affects fish growth and gill conditions, and at higher concentrations, causes death. Nitrate affects aquatic life by limiting its ability to carry oxygen, which contributes to disease susceptibility and death. Nitrate is also a major concern to human health. Excessive nitrate in drinking water causes methemoglobinemia, also known as blue baby syndrome (MDH 2019b). Due to this health risk, excessive nitrogen in drinking water can necessitate expensive treatments. The Des Moines River is a drinking water source for downstream communities in Iowa and currently has a TMDL for nitrate due to drinking water impairments (IA DNR 2009). Minnesota currently has a standard for drinking water; however, no streams with a drinking water beneficial use were assessed for nitrate in the Minnesota portion of the Des Moines River Basin. Nitrate was evaluated as a stressor for biologically impaired streams. Finally, eutrophication causing the Gulf Hypoxic Zone (NOAA 2015) is due to excessive nitrogen contributions from the Mississippi River Basin, which includes the Des Moines River Basin.

Status

Nitrate was identified as a stressor in 36 stream reaches, ruled out in 33, and inconclusive in 56. Figure 31 illustrates the stream reaches assessed for nitrate as a stressor, and Table 13 tabulates those results. County Ditch 43 (reach 1-552), a cold water reach, was assessed for nitrate as a pollutant and found inconclusive.

Ammonia was identified as a pollutant in 1 reach, ruled out in 19, and was inconclusive in 49. Since the identification of ammonia as a pollutant in the Des Moines River (reach 1-501) in 1994, restoration activities have occurred. Preliminary monitoring data suggests that ammonia is no longer exceeding standards, but more data is needed to pursue the formal delisting process.

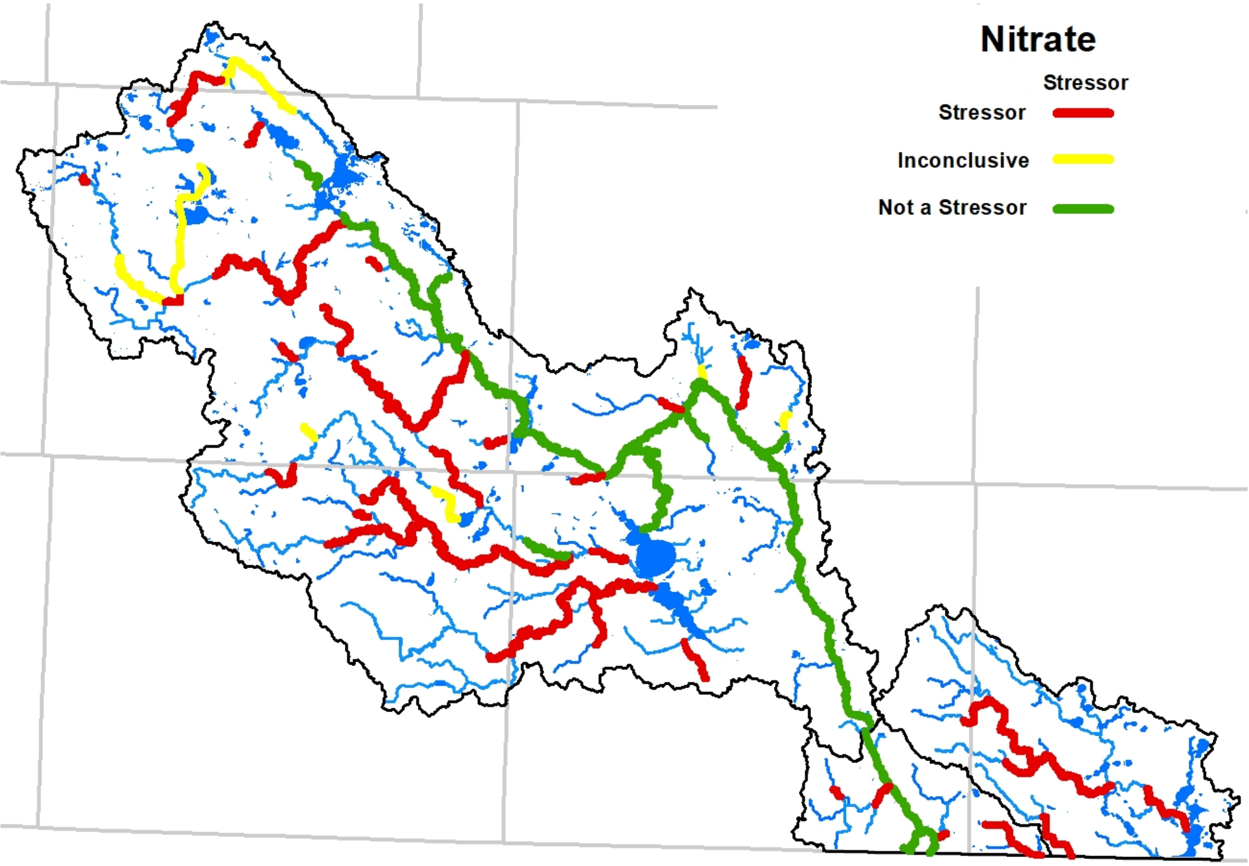


Figure 31: Nitrate was identified as a stressor throughout the Des Moines River Basin, but not on the main stem of the Des Moines River. Red indicates nitrate was identified as a stressor (nitrate is problematic in that reach); green indicates nitrate is not a stressor (nitrate is not problematic in that reach), and yellow indicates that more data are needed to assess nitrate as a stressor.

Table 13: Assessment results for nitrate as a stressor and ammonia as a pollutant for stream reaches in the Des Moines Basin.

Major Watershed	Stream Name	AUID-3	Nitrate Stressor Assessment	Ammonia Pollutant Assessment
Des Moines Headwaters	Des Moines River	501	+	X
	County Ditch 20	504	?	?
	Lower Lake Sarah Outlet	508	+	?
	Okabena Creek	512		+
	Jack Creek	514	X	?
	Judicial Ditch 76	515		?
	Unnamed creek	518	X	?
	Judicial Ditch 26	523	X	?
	Des Moines River	524	+	+
	Heron Lake Outlet	527	+	?
	Des Moines River	533	+	+
	Lime Creek	535	X	+
	Des Moines River	541		+
	Perkins Creek	544	+	?
	Des Moines River	545	+	+
	Des Moines River	546	+	?
	Jack Creek	549	X	?
	Unnamed creek	551	+	?
	County Ditch 43 (Scheldorf Creek)	552	?	?
	Unnamed creek	563	X	?
	Unnamed creek	564	+	+
	Judicial Ditch 14	589		?
	Unnamed ditch	594		?
	Okabena Creek	602	X	+
	Unnamed creek	608		?
	Unnamed creek	613	X	?
	Unnamed creek	614	X	?
	Unnamed creek	615		?
	Unnamed creek	618	X	?
	Unnamed creek	619	?	?
	Unnamed creek	621	X	?
	Unnamed creek	624	X	?
	Unnamed creek	625	X	?
	Unnamed creek	626	X	?
Des Moines Headwaters	Unnamed creek	628	X	?
	Unnamed creek	632	X	?
	Unnamed creek	637	X	?
	Lake Shetek Inlet	641	X	?
	Lake Shetek Inlet	642	X	?
	Lake Shetek Inlet	643	?	?
	Beaver Creek	646	X	+
	Jack Creek	649	X	?
	Jack Creek	652	X	+
	Elk Creek	654		?
	Elk Creek	656	X	+
	Jack Creek	658	X	+
	Unnamed creek	661	?	?
	Beaver Creek	663	?	?
	Beaver Creek	664	X	?
	Judicial Ditch 12	665		?
	Judicial Ditch 12	666	X	?
	Devils Run Creek	668	+	?
	Unnamed creek	670	?	?
	Unnamed creek	672	X	?
Lower Des Moines	Des Moines River	501	+	+
	Brown Creek (Judicial Ditch 10)	502	X	?
	Unnamed creek	504	X	?
	Judicial Ditch 56	505	+	?
	Story Brook	507	X	?
	Unnamed ditch	510	X	?
	Judicial Ditch 6	513		?
East Fork Des Moines	County Ditch 11	503		+
	County Ditch 53	506	X	?
	Fourmile Creek	510	X	+
	County Ditch 1/Judicial Ditch 50	515		+
	Mud Slough	516		+
	Des Moines River, East Branch	525	X	+
	Des Moines River	527	X	+
	Unnamed creek	529	X	?

+	=	supporting/not a stressor
?	=	inconclusive (need more data)
X	=	impaired/stressor
<blank>	=	not monitored/assessed

From a statewide perspective, the Des Moines River Headwaters Watershed has a moderate to high FWMC and yield of nitrogen (Figure 32). WPLMN monitoring data was not available for the Lower Des Moines River and East Fork Des Moines River Watersheds.

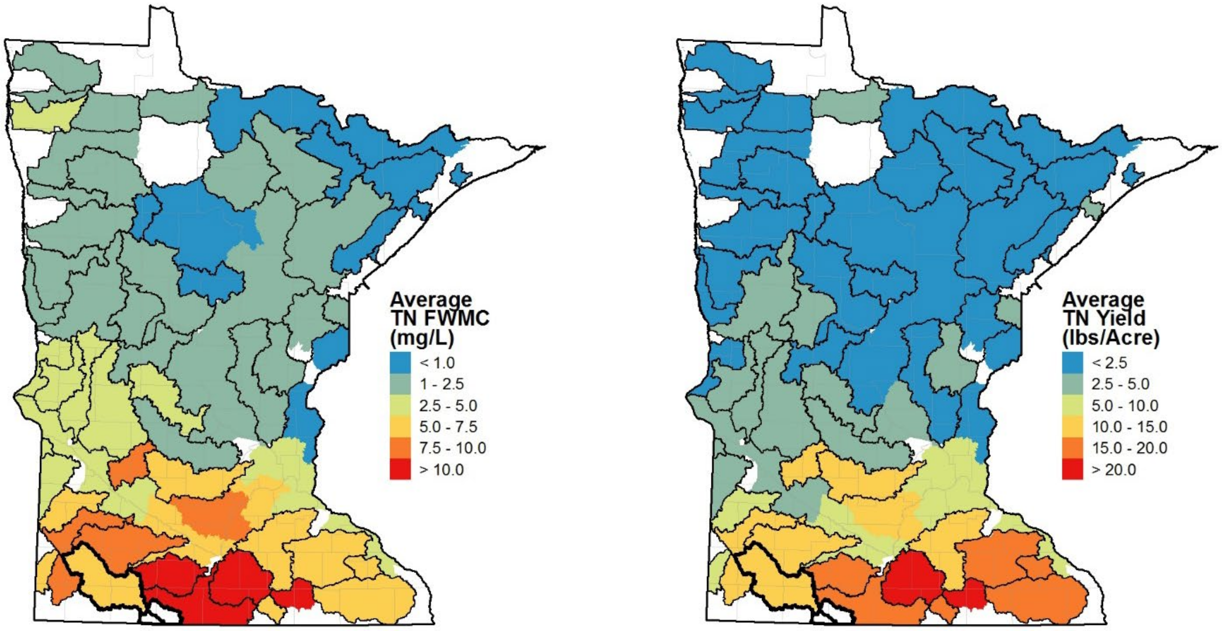


Figure 32: The Des Moines River Headwaters Watershed has a moderate to high FWMC and yield of TN compared to the rest of the state. Data are from the WPLMN.

An HSPF model was developed for the Des Moines River Basin. The model's estimated FWMCs for the years 1994 through 2014 are illustrated in Figure 33. This model data can be used to estimate conditions in stream reaches that have not been monitored.

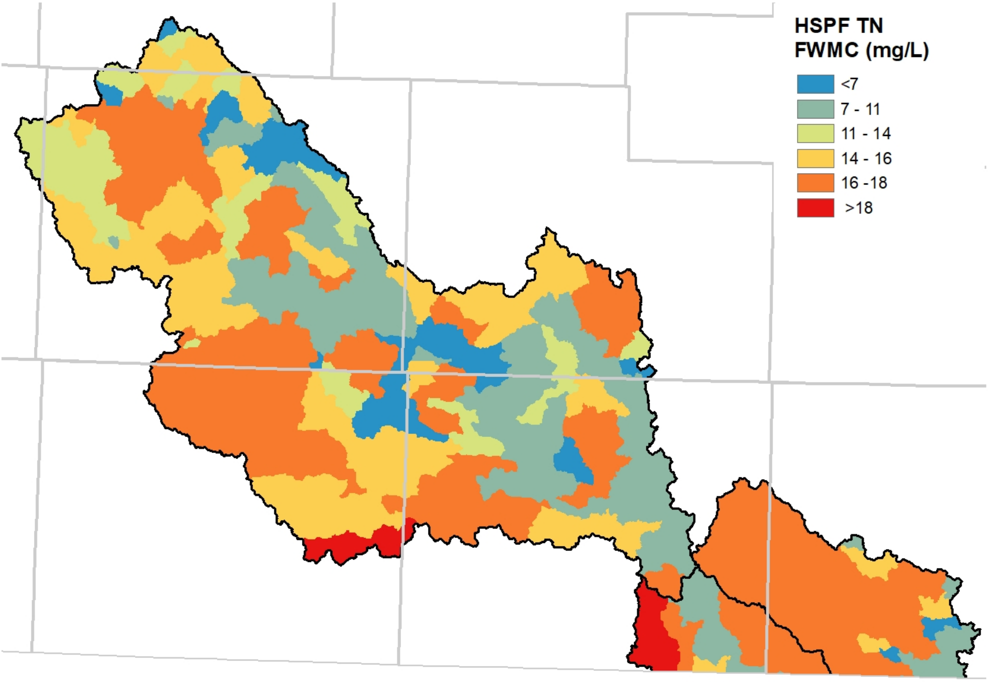


Figure 33: HSPF model data estimates the FWMC of TN from 1994-2014.

Continuous data provided by the WPLMN illustrate the timing of combined nitrate and nitrite loads by month. Over the years of 2008 through 2018 at the Des Moines River at Jackson, June alone accounted for 20% of the TN load, and the months of March, April, and May each represented over 10% of the load (Figure 34). The timing of loads is useful for identifying sources and strategies. More information and interpretation of the WPLMN nitrogen data is in Appendix 2.

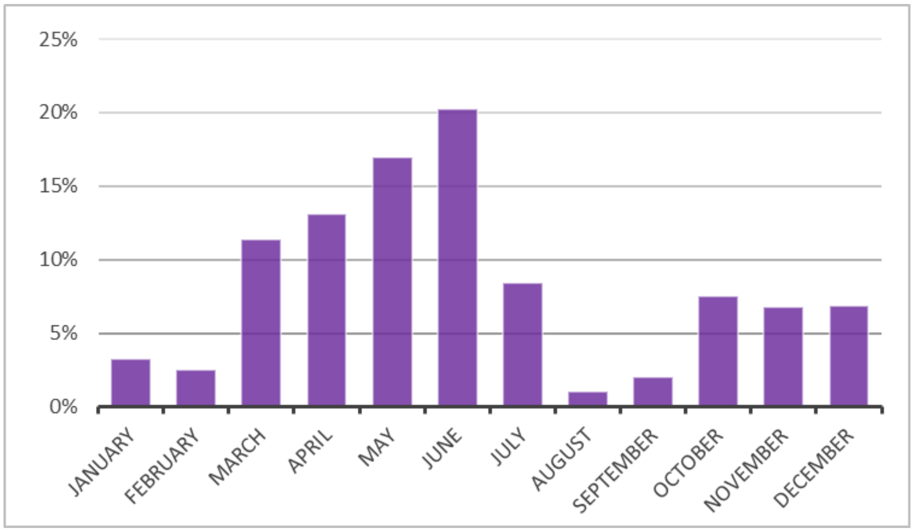


Figure 34: 2008-2018 nitrate/nitrite WPLMN load data from the Des Moines River at Jackson illustrate the timing of nitrogen loads. The load over these years was heaviest in June, delivering more than 20% of the load. Moderate loads (10-17% of the load) were delivered in each month March through May. Very low loads (<5% of the load) were delivered in August through September and again in January and February.

Sources

In the Des Moines River Basin, most nitrogen that reaches waterbodies is from nonpoint sources. Point source contributions for the years of 2008 through 2016 are estimated to total about 7% of the Des Moines River Basin total nitrogen load (Appendix 2).

A numeric estimate of the Des Moines River Basin nitrogen sources is presented in Figure 35; refer to the Sources Overview in Section 2.1 for more details. Crop drainage and agricultural groundwater dominate nitrogen contributions to waterbodies. Application of manure, chemical fertilizer and nitrogen native to the soil are significant sources of nitrogen through the crop drainage and crop ground water pathways when timing and application rates are not optimal.

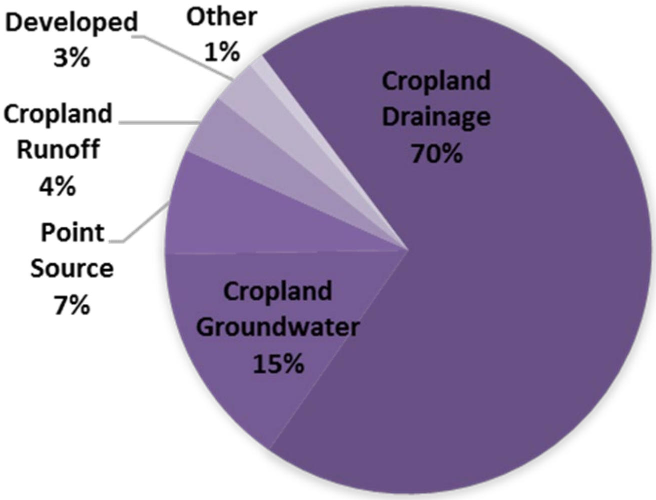


Figure 35: Source assessment in the Des Moines River Basin estimate nitrogen sources are dominated by crop drainage and crop groundwater contributions. The nitrogen leaving crops is mostly from applied fertilizer or manure.

Goal and 10-year Target

The basin-wide nitrogen goal is a 30% reduction (Figure 36). The nitrogen 10-year target selected by the WRAPS LWG is a 15% reduction. The goal equates to achieving a FWMC of 5 mg/L. Multiple data and goals were considered to set the basin-wide reduction goal: the proposed aquatic life toxicity standard (MPCA 2010b; 4.9 mg/L), the *Minnesota Nutrient Reduction Strategy* (MPCA 2013a), WPLMN data and the Iowa DNR Des Moines River Nitrate TMDL (IA DNR 2009). Individual stream reach reductions may be more or less than the basin-wide goal based on specific stream conditions. However, individual stream reduction goals were not calculated because no nitrate TMDLs were completed. Areas designated as "protect for nitrate" have a 15% reduction goal in order to help achieve goals statewide as part of the nutrient reduction strategy plan.

These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for nitrogen reductions are summarized in Section 3.

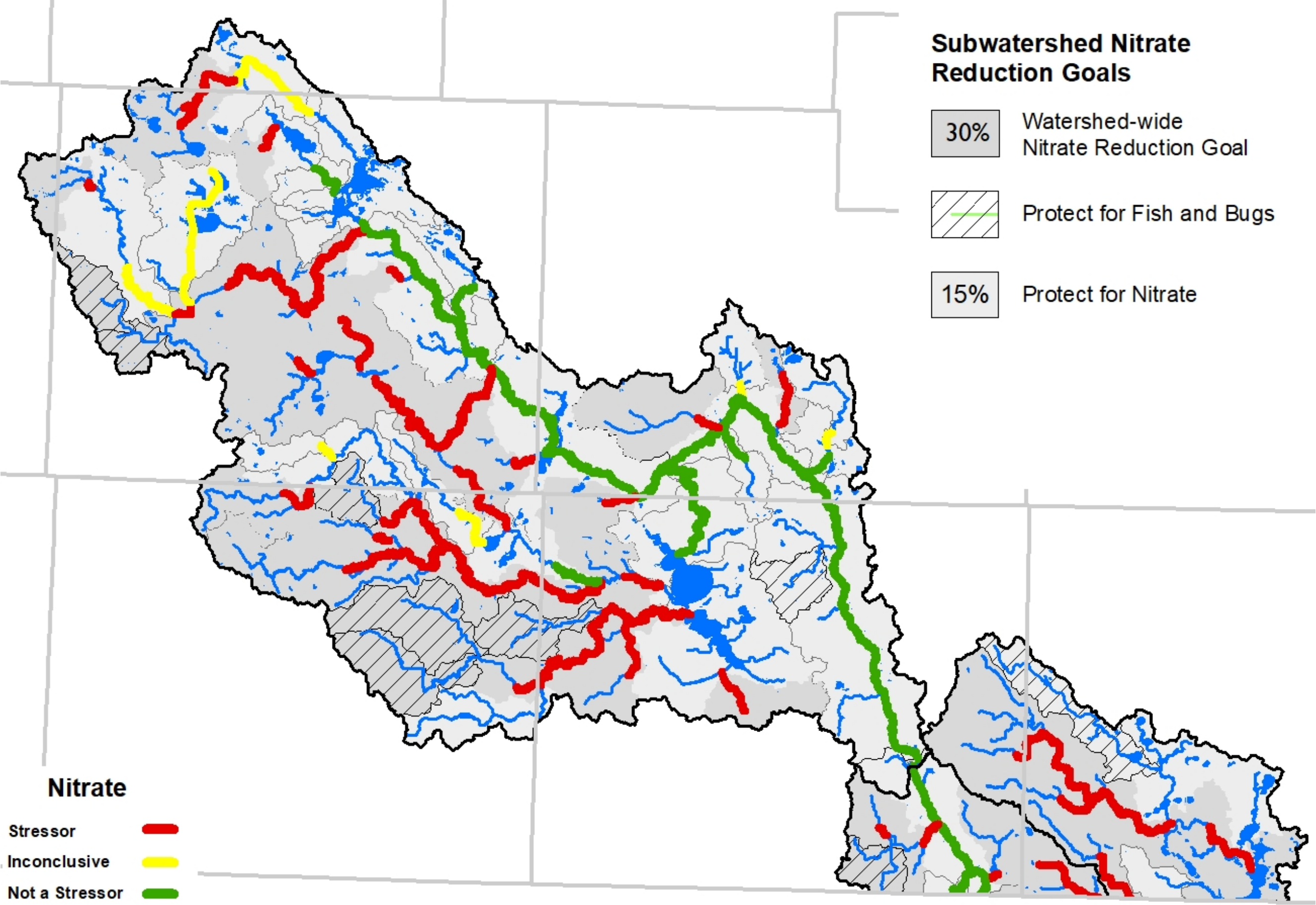


Figure 36: The basin-wide nitrogen reduction goal in the Des Moines River Basin is a 30% reduction. Streams with protection goals need a nitrogen reduction of 15% to support state nutrient reduction goals.

Altered Hydrology

Altered hydrology (USGS 2019a) in general refers to changes in hydrologic parameters including stream flow, precipitation, drainage, impervious surfaces, wetlands, stream paths, vegetation, soil conditions, etc. Altered hydrology as an identified stressor more specifically refers to changes in the amount and timing of stream flow. Both too much and too little stream flow directly harm aquatic life by creating excessive speed and force of water or reducing the amount of water. Altered hydrology also indirectly harms aquatic life because it increases the amount and transport of pollutants and stressors to waterbodies.

Status

Altered hydrology was identified as a stressor in 36 stream reaches, ruled out in 5, and inconclusive in 15. Figure 37 illustrates the stream reaches assessed for altered hydrology, and Table 14 tabulates those results.

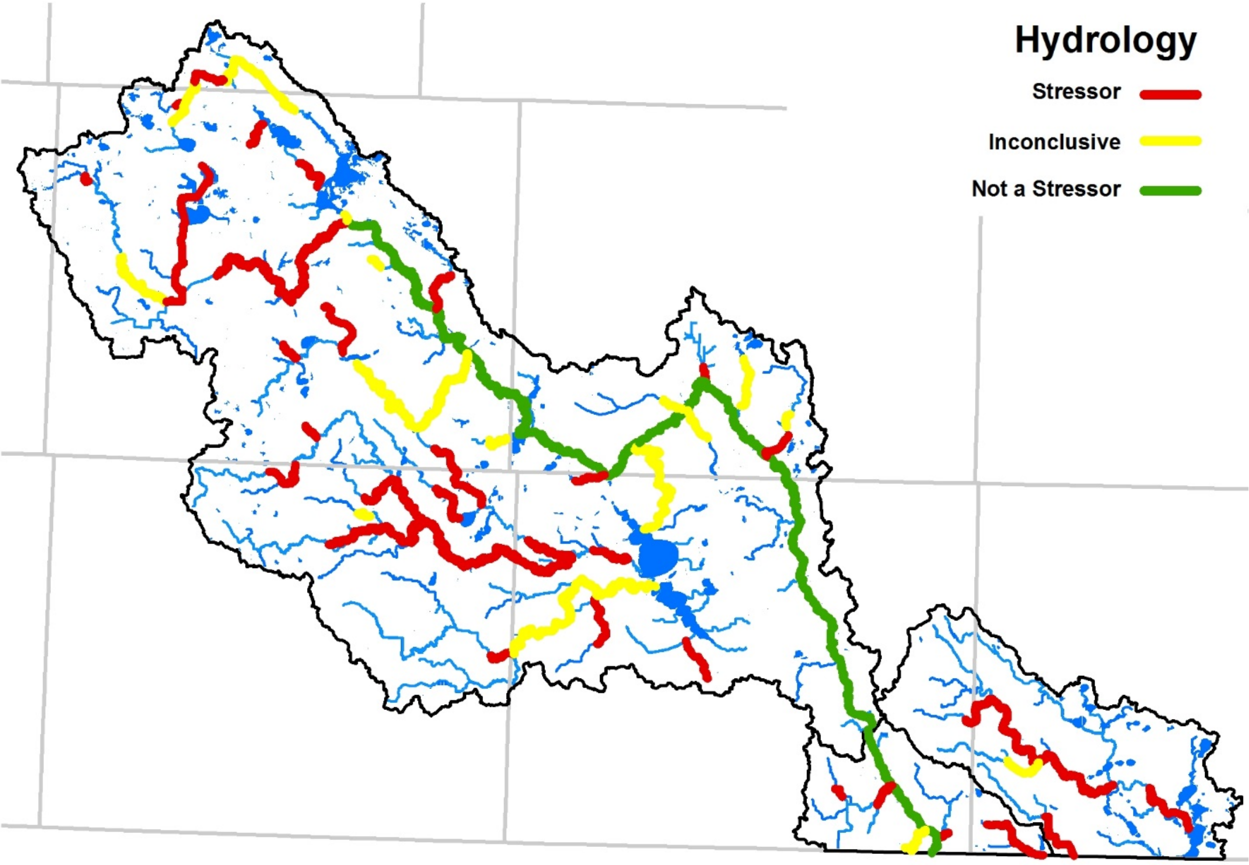


Figure 37: Assessment results show that altered hydrology is stressing aquatic life throughout the Des Moines River Basin. Red indicates a stressor (altered hydrology is problematic in that reach); green indicates altered hydrology is not a stressor (altered hydrology is not a problem), and yellow indicates that more data are needed to assess altered hydrology as a stressor.

Table 14: Altered hydrology assessment results for stream reaches in the Des Moines River Basin.

Major Watershed	Stream Name	AUID-3	Altered Hydrology Stressor Assessment
Des Moines Headwaters	Des Moines River	501	+
	County Ditch 20	504	X
	Lower Lake Sarah Outlet	508	X
	Jack Creek	514	X
	Unnamed creek	518	X
	Judicial Ditch 26	523	X
	Des Moines River	524	+
	Heron Lake Outlet	527	?
	Des Moines River	533	+
	Lime Creek	535	?
	Perkins Creek	544	X
	Des Moines River	545	?
	Des Moines River	546	+
	Jack Creek	549	X
	Unnamed creek	551	?
	County Ditch 43 (Scheldorf Creek)	552	X
	Unnamed creek	563	?
	Unnamed creek	564	X
	Okabena Creek	602	?
	Unnamed creek	613	?
	Unnamed creek	614	X
	Unnamed creek	618	?
	Unnamed creek	619	X
	Unnamed creek	621	X
	Unnamed creek	624	X
	Unnamed creek	625	X
	Unnamed creek	626	?
	Unnamed creek	628	X
Des Moines Headwaters	Unnamed creek	632	X
	Unnamed creek	637	X
	Lake Shetek Inlet	641	?
	Lake Shetek Inlet	642	X
	Lake Shetek Inlet	643	?
	Beaver Creek	646	X
	Jack Creek	649	X
	Jack Creek	652	X
	Elk Creek	656	X
	Jack Creek	658	X
	Unnamed creek	661	X
	Beaver Creek	663	?
	Beaver Creek	664	X
	Judicial Ditch 12	666	X
	Devils Run Creek	668	X
	Unnamed creek	670	?
	Unnamed creek	672	X
Lower Des Moines	Des Moines River	501	+
	Brown Creek (Judicial Ditch 10)	502	X
	Unnamed creek	504	X
	Judicial Ditch 56	505	?
	Story Brook	507	X
	Unnamed ditch	510	X
East Fork Des Moines	County Ditch 53	506	X
	Fourmile Creek	510	?
	Des Moines River, East Branch	525	X
	Des Moines River	527	X
	Unnamed creek	529	X

X = Stressor

? = Inconclusive (need more data)

\+ = Not a Stressor

Continuous data provided by the WPLMN illustrate the timing of river flow by month. Over the years of 2008 through 2018 at the Des Moines River at Jackson, June, and then July were the highest flow months, accounting for 17% and 16% of the river flow respectively (Figure 38). The timing of flow is useful for identifying sources and strategies. More information and interpretation of the WPLMN flow data is in Appendix 2.

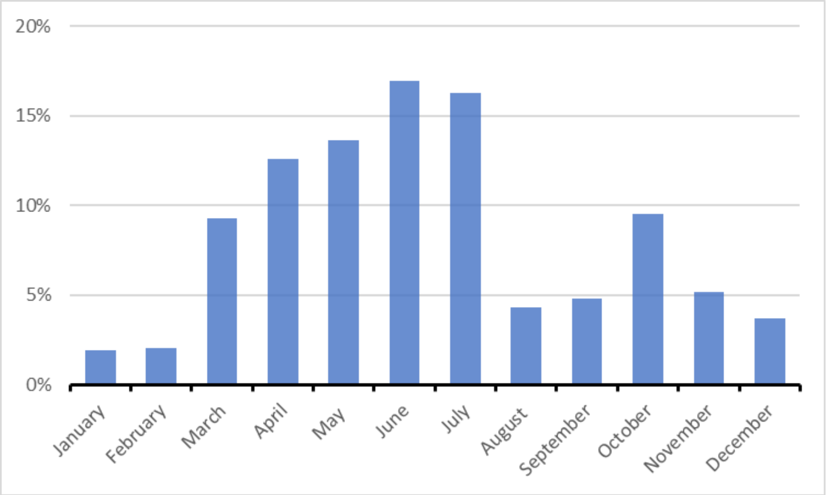


Figure 38: 2008-2018 WPLMN river flow data from the Des Moines River at Jackson illustrate the timing of flows. June and July had the highest flows, accounting for 17% and 16% respectively. The spring months (March, April, and May) each accounted for 9-14% of the flow. The lowest flows occurred during January and February.

Sources

A surface water's hydrology is interconnected to its landscape; when changes are made to one hydrologic parameter, other hydrologic parameters respond. For instance, tile drainage quickly removes water from the soil profile, increasing the total volume and timing of water inputs to rivers. Changes in stream flow are symptoms of changes in hydrologic parameters.

Altered hydrology is common throughout the Des Moines River Basin, ranging from landscape and climate changes, to crop and vegetative changes, to soil and drainage changes. Rather than attempting to numerically estimate the magnitude of change in river flow from the varied forms of altered hydrology, source assessment work focuses on the land use and pathway that water travels after being received as precipitation.

While most precipitation is returned to the atmosphere by ET, the remaining water travels to waterbodies via different pathways. Pathways for water to travel to waterbodies include: surface runoff, groundwater flow, or artificial subsurface drainage such as drainage tile or storm sewer networks. Numeric estimates of contributions of water to waterbodies by land use in the Des Moines River Basin were estimated using a water portioning calculator (Appendix 2) and are presented in Figure 39.

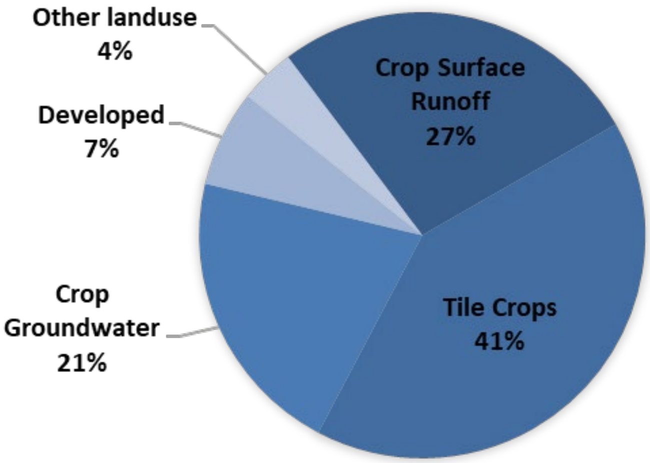


Figure 39: Source assessment estimates cultivated crops are the pathway for most water that enters waterbodies in the Des Moines River Basin.

Goal and 10-year Target

The basin-wide altered hydrology goal is a 20% reduction of annual and peak flow and an increase in base flow (Figure 40). The 10-year target selected by the WRAPS LWG is a 2.5% reduction in annual and peak flows and a small improvement in base flow. Individual stream reach goals may be more or less than the basin-wide goal based on specific stream conditions.

The altered hydrology goal was set after considering multiple lines of evidence including the long-term flow data (refer to Trends Overview section), which indicates that flow has roughly doubled over the last 80 years. Despite the observed flow increase, high flows were not found to be stressing aquatic communities in most of the Des Moines River's main stem. However, habitat was identified as a stressor to aquatic communities in the main stem, which was due to sedimentation from upstream erosion caused by altered hydrology. This chain reaction, along with the prevalence of altered hydrology as an identified stressor throughout the watersheds, warranted a basin-wide reduction goal. As an additional line of evidence, data and goals for altered hydrology from other southwestern Minnesota watersheds were considered. Currently, the necessary base flow needed to support aquatic life has not been modeled, no correlations have been made, and no numeric understanding has been established, thus a numeric goal was not set for base flow increases.

This goal is revisable and will be revisited in the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address altered hydrology are summarized in Section 3.

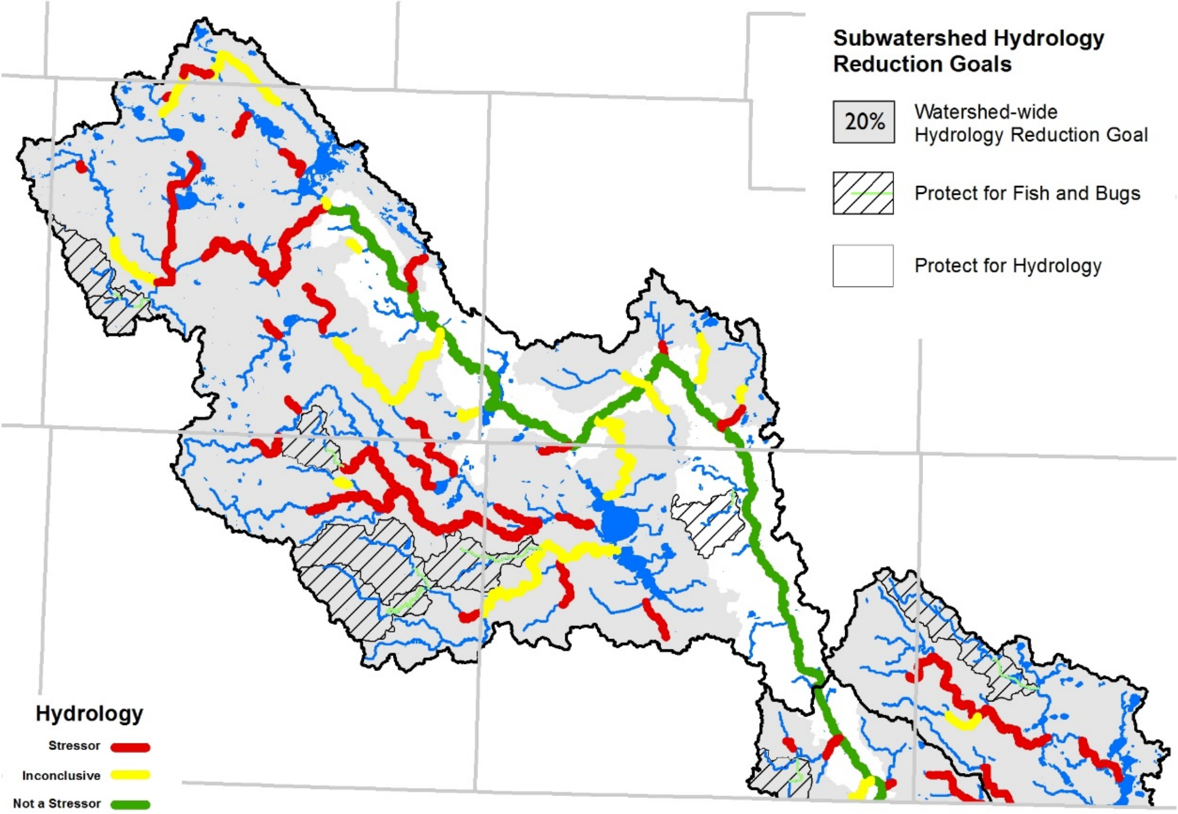


Figure 40: The basin-wide altered hydrology goal is a 20% reduction in peak and annual flow. Base flow also needs to be increased in some areas of the basin.

Connectivity

Connectivity, as identified in this report, refers to the longitudinal connectivity of a stream, or the upstream to downstream connectedness of a stream. A lack of connectivity is typically due to dams, waterfalls, perched culverts, and improperly sized bridges and culverts. A lack of connectivity can obstruct the movement of migratory fish and macroinvertebrates (mussels), decreasing or eliminating the population and community structure. Furthermore, lack of connectivity can cause changes in flow, sediment, habitat, and chemical characteristics of a waterbody, further affecting aquatic life.

Status

Connectivity was identified as a stressor in 9 stream reaches, ruled out in 36, and inconclusive in 11. Figure 41 illustrates the stream reaches assessed for connectivity, and Table 15 tabulates those results.

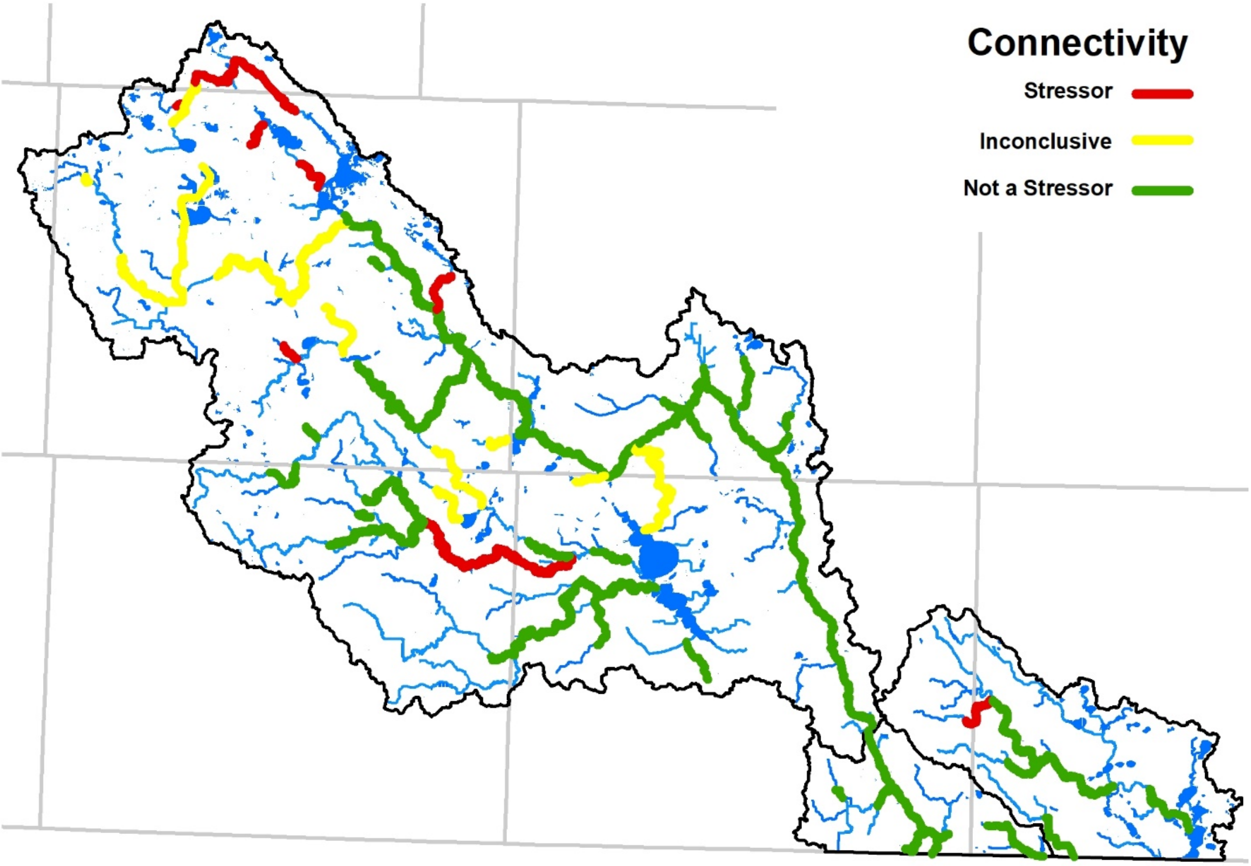


Figure 41: Assessment results show that connectivity is stressing aquatic life in less than a quarter of the stream reaches assessed in the Des Moines River Basin. Red indicates a stressor (connectivity is problematic in that reach); green indicates connectivity is not a stressor (connectivity is not a problem), and yellow indicates that more data are needed to assess connectivity as a stressor.

Table 15: Connectivity assessment results for stream reaches in the Des Moines River Basin.

Major Watershed	Stream Name	AUID-3	Connectivity Stressor Assessment
Des Moines Headwaters	Des Moines River	501	+
	County Ditch 20	504	?
	Lower Lake Sarah Outlet	508	X
	Jack Creek	514	X
	Unnamed creek	518	+
	Judicial Ditch 26	523	?
	Des Moines River	524	+
	Heron Lake Outlet	527	?
	Des Moines River	533	+
	Lime Creek	535	+
	Perkins Creek	544	+
	Des Moines River	545	+
	Des Moines River	546	+
	Jack Creek	549	+
	Unnamed creek	551	+
	County Ditch 43 (Scheldorf Creek)	552	+
	Unnamed creek	563	+
	Unnamed creek	564	+
	Okabena Creek	602	+
	Unnamed creek	613	+
	Unnamed creek	614	+
	Unnamed creek	618	+
	Unnamed creek	619	+
	Unnamed creek	621	?
	Unnamed creek	624	?
	Unnamed creek	625	X
	Unnamed creek	626	+
	Unnamed creek	628	?
Des Moines Headwaters	Unnamed creek	632	X
	Unnamed creek	637	X
	Lake Shetek Inlet	641	?
	Lake Shetek Inlet	642	X
	Lake Shetek Inlet	643	X
	Beaver Creek	646	?
	Jack Creek	649	+
	Jack Creek	652	+
	Elk Creek	656	+
	Jack Creek	658	+
	Unnamed creek	661	?
	Beaver Creek	663	?
	Beaver Creek	664	?
	Judicial Ditch 12	666	+
	Devils Run Creek	668	X
	Unnamed creek	670	+
	Unnamed creek	672	?
Lower Des Moines	Des Moines River	501	+
	Brown Creek (Judicial Ditch 10)	502	+
	Unnamed creek	504	+
	Judicial Ditch 56	505	+
	Story Brook	507	+
	Unnamed ditch	510	+
East Fork Des Moines	County Ditch 53	506	+
	Fourmile Creek	510	+
	Des Moines River, East Branch	525	+
	Des Moines River	527	+
	Unnamed creek	529	X

x = Stressor
? = Inconclusive
\+ = Not a Stressor

Sources

The connectivity issues identified in the Stressor ID report include human causes like dams and perched culverts, and natural causes like beaver dams (Table 16). Sources were determined by both field observation and GIS analysis. The bridge and culvert analysis utilized the Minnesota Department of Transportation bridge and culvert and streams layer. This information is available in the DNR Watershed Health Assessment Framework tool (DNR 2020).

Table 16: Connectivity problems of bio-impaired stream reaches as identified in the Des Moines River Basin Stressor ID report.

Major Watershed	AUID	Stream Name	Stressor Sources		
			Dams/Impoundments	Road Crossings/Perched Culverts	Beaver Dams
Des Moines Headwaters	504	County Ditch 20		○	
	508	Lower Lake Sarah Outlet	●	○	
	514	Jack Creek			●
	523	Judicial Ditch 26	○		
	527	Heron Lake Outlet	○		
	621	Unnamed Creek		○	
	624	Unnamed Creek		○	
	625	Unnamed Creek		●	
	628	Unnamed Creek		○	
	632	Unnamed Creek	●	○	
Des Moines Headwaters	637	Unnamed Creek	●	○	●
	642	Lake Shetek Inlet	●	○	
	643	Lake Shetek Inlet	●	○	
	646	Beaver Creek		○	
	661	Unnamed Creek	○		
	664	Beaver Creek		○	
	668	Devils Run Creek		●	
	672	Unnamed Creek		○	
East Fork Des Moines	529	Unnamed Creek		●	

●=source, ○=potential source, <blank>= not a source

Goal and 10-year Target

The connectivity goal for the Des Moines River Basin is to mitigate or remove connectivity issues where relevant and feasible. The 10-year target selected by the WRAPS LWG is to remove six barriers. These barriers include culverts and dams. Road crossings and culverts should be assessed to determine feasibility of repair, and dams and impoundments should be assessed on a case-by-case basis for opportunities to mitigate fish community impacts. Prior to restoration work, the impact of connectivity relative to other stressors (altered hydrology, nutrients, habitat, etc.) should be assessed. Restoration or mitigation may best be delayed if other stressors are having larger impacts on the aquatic communities.

This goal is revisable and will be revisited in the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address connectivity are summarized in Section 3.

Bacteria

Escherichia coli (*E. coli*) and fecal coliform, referred to as bacteria in this report, are indicators of animal or human fecal matter in waters. Contact with fecal matter can lead to potentially severe illnesses, making aquatic recreation unsafe when bacteria are present at high levels. Bacteria are living organisms that can die as they travel downstream. Therefore, they can be present in upstream locations, yet die before reaching downstream waters where they may not be detected.

Status

Of the 29 stream reaches assessed for bacteria, 27 were impaired, 2 were supporting, and 0 were inconclusive. Figure 42 illustrates the stream reaches assessed for bacteria, and Table 17 tabulates those results.

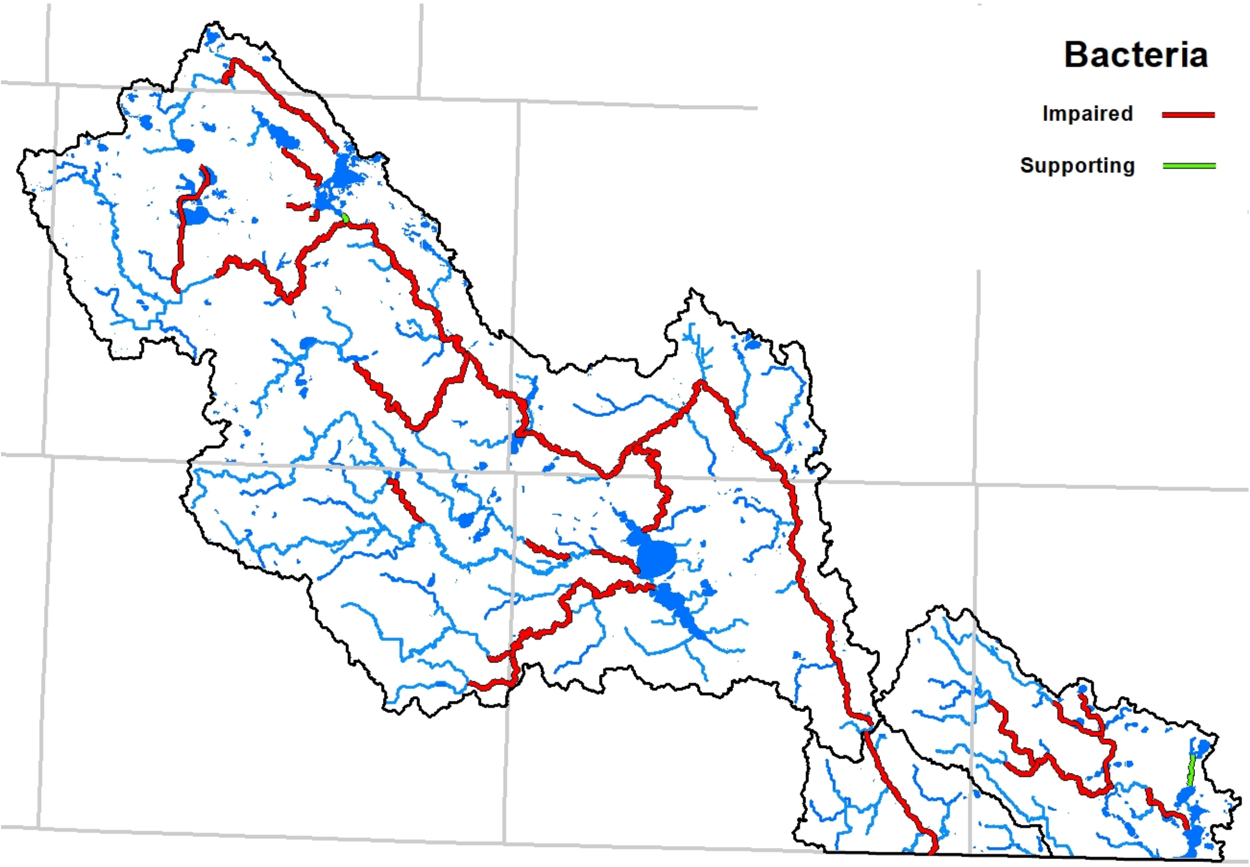


Figure 42: Assessment results show that bacteria are a pollutant across much of the Des Moines River Basin. Red indicates an impairment (bacteria is problematic in that reach); and green indicates support (bacteria is not a problem).

Table 17: Assessment results for bacteria as a pollutant in stream reaches in the Des Moines River Basin.

Major Watershed	Stream Name	AUID-3	Bacteria Pollutant Assessment
Des Moines Headwaters	Des Moines River	501	X
	County Ditch 20	504	X
	Lower Lake Sarah Outlet	508	X
	Okabena Creek	512	X
	Upper Lake Sarah Outlet	513	X
	Unnamed creek	517	X
	Unnamed creek	519	X
	Des Moines River	524	X
	Heron Lake Outlet	527	X
	Des Moines River	533	X
	Lime Creek	535	X
	Des Moines River	545	+
	Des Moines River	546	X
	Unnamed creek	564	X

Major Watershed	Stream Name	AUID-3	Bacteria Pollutant Assessment
Des Moines Headwaters	Okabena Creek	602	X
	Lake Shetek Inlet	643	X
	Lake Shetek Inlet	644	X
	Beaver Creek	646	X
	Jack Creek	652	X
	Elk Creek	656	X
	Jack Creek	658	X
	Jack Creek	659	X
Lower Des Moines	Des Moines River	501	X
East Fork Des Moines	County Ditch 11	503	X
	Fourmile Creek	510	X
	County Ditch 1/Judicial Ditch 50	515	X
	Mud Slough	516	+
	Des Moines River, East Branch	525	X
	Des Moines River	527	X

+ = Supporting
? = Inconclusive (need more data)
X = Impaired

Sources

Fecal bacteria contributions are dominated by nonpoint sources. However, specific source assessment is difficult due to the dynamic and living attributes of bacteria. Bacteria sourcing can be difficult due to the bacteria's ability to persist, reproduce, and migrate in unpredictable ways. Therefore, the factors associated with bacterial presence provide some confidence to bacterial source estimates. Emmons & Olivier Resources (2009) conducted a *Literature Summary of Bacteria* for the MPCA to develop a relationship between these factors and fecal bacterial contamination (Table 18).

Table 18: Summarized factors from literature review explaining fecal bacteria contamination in streams. The literature review summarized factors that have either a strong or a weak positive relationship to fecal bacterial contamination in streams.

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 present • Presence of waterfowl or other wildlife • Conductivity

Fecal bacteria source identification is further confounded by some bacteria being able to survive and reproduce in streams as reported in Chandrasekaran et al., 2015 study of a Middle Minnesota River stream, Seven-mile Creek. This study and a small but growing body of evidence suggests that environmental propagation of bacteria is likely in at least some systems. However, the magnitude of the population from this source type is not well understood as of yet. In order to acknowledge this source type, but without certainty, the authors of this report are assigning an assumed 10% of the basin's bacteria population to this source type.

A numeric estimate of the Des Moines River Basin fecal bacteria sources is presented in Figure 43. This source assessment was calculated based on the amount of fecal matter produced by source type and estimated delivery ratios (see calculations in Appendix 2). The single largest fecal bacteria source in the Des Moines River Basin was estimated as crop surface runoff where manure has not been incorporated. Most of the manure that is applied to fields originates from feedlot operations. Refer to Section 2.1 for more information on feedlots in the Des Moines River Basin. The "humans" category is the combination of septic system and wastewater treatment facility contributions.

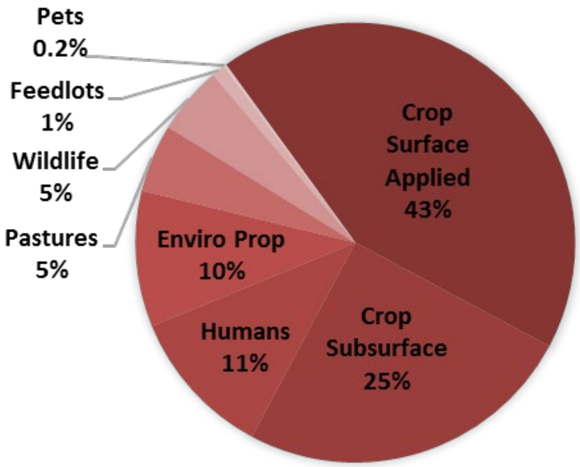


Figure 43: Source assessments in the Des Moines River Basin estimate that crop runoff of surface applied manure is the biggest land use and pathway of bacteria in the basin.

Goal and 10-year Target

The basin-wide bacteria goal for the Des Moines River Basin is a 50% reduction (Figure 44). The 10-year target selected by the WRAPS LWG is a 10% reduction. Individual stream reach reductions may be more or less than the basin-wide goal based on specific stream conditions.

Individual subwatershed reduction goals were calculated for streams that required a TMDL. Subwatershed reduction goals range from a 35% to a 90% reduction. The stream reaches supporting bacteria have a protection goal, as indicated by the white subwatershed in Figure 44. Refer to the TMDL summary in Appendix 3 for subwatershed reduction goals and calculation methods.

Strategies to meet the goals and 10-year targets and methods to prioritize regions for bacteria reductions are summarized in Section 3.

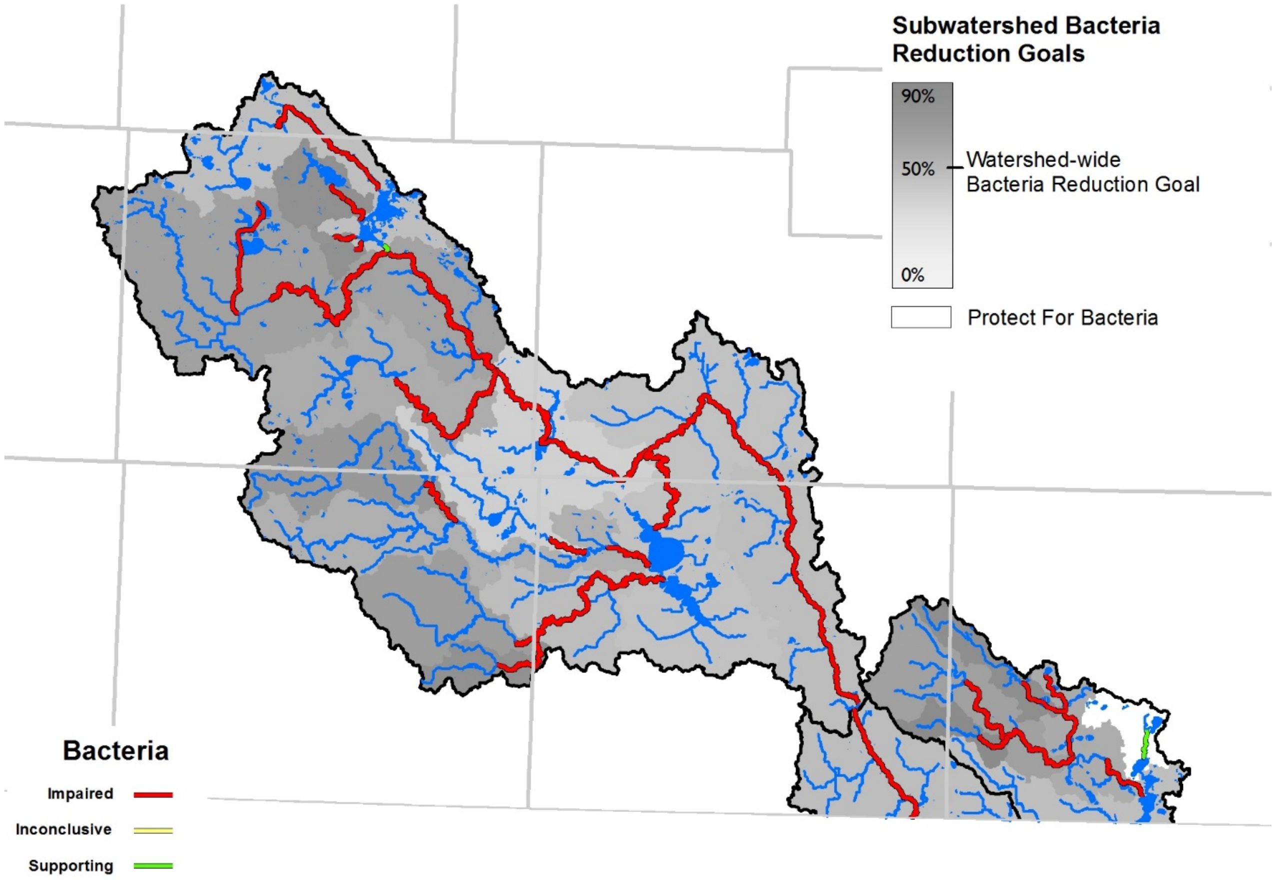


Figure 44: The basin-wide bacteria goal in the Des Moines River Basin is a 50% reduction. Subwatershed bacteria goals ranged from protection to a 90% reduction.

pH

pH is a measurement of how acidic or basic water is. pH values range from zero (the most acidic), to 14 (the most basic), with 7 being neutral. Depending on the specific species, pH values between 6.5 and 9 are generally tolerable to aquatic life. Excessively high or low pH affects aquatic life by: decreasing growth and reproduction; damaging skin, gills, eyes, and organs; or even causing death. pH also indirectly impacts aquatic life by affecting chemical processes within water.

Status

Of the 69 stream reaches assessed for pH as a pollutant, 1 was impaired, 18 were supporting, and 50 were inconclusive. Figure 45 illustrates the stream reaches assessed for pH, and Table 19 tabulates those results.

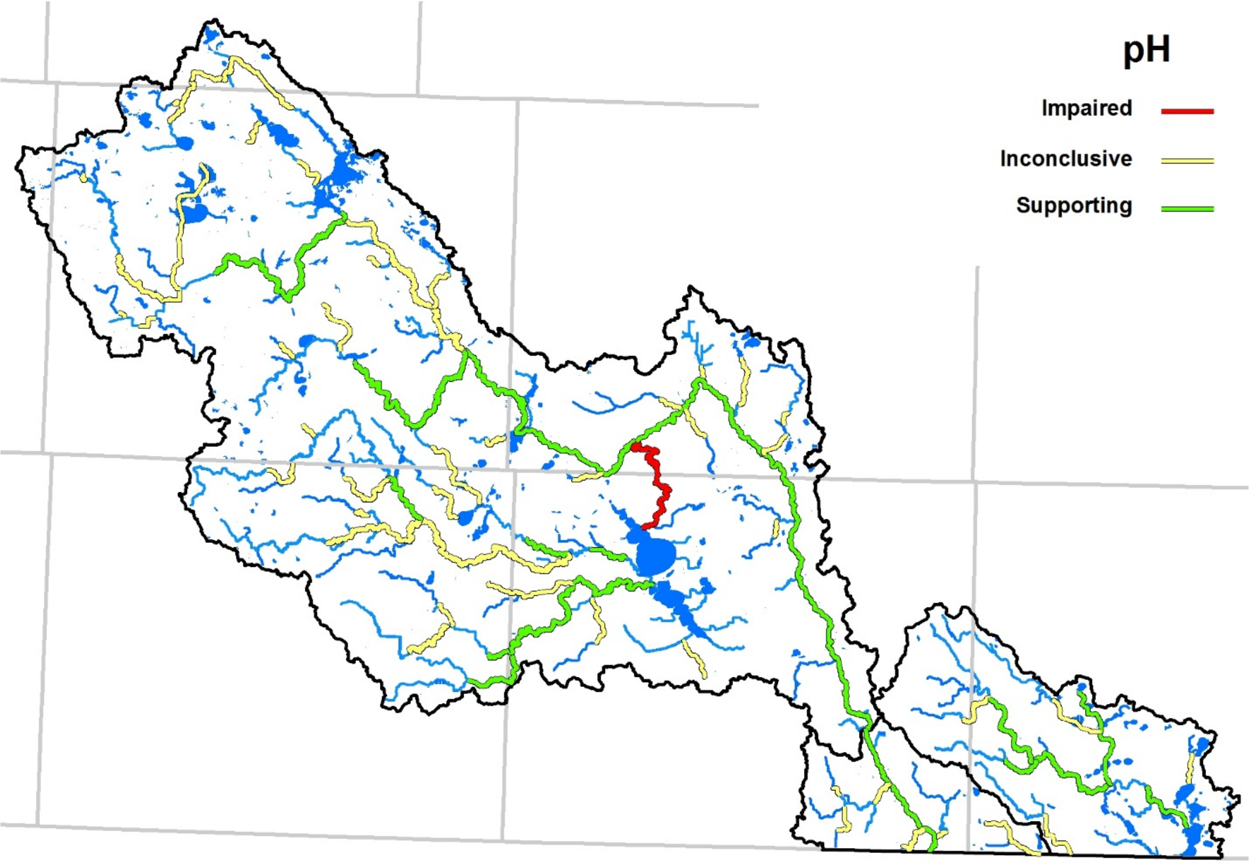


Figure 45: The majority of stream reaches monitored for pH in the Des Moines River Basin are supporting. The Heron Lake Outlet is impaired indicated by red (pH is problematic in that reach). Green indicates support (pH is not a problem) and yellow indicates that more data are needed to assess.

Table 19: Assessment results for pH as a pollutant in stream reaches in the Des Moines River Basin.

Major Watershed	Stream Name	AUID-3	pH
Des Moines Headwaters	Des Moines River	501	+
	County Ditch 20	504	?
	Lower Lake Sarah Outlet	508	?
	Okabena Creek	512	+
	Jack Creek	514	?
	Judicial Ditch 76	515	?
	Unnamed creek	518	?
	Judicial Ditch 26	523	?
	Des Moines River	524	+
	Heron Lake Outlet	527	X
	Des Moines River	533	+
	Lime Creek	535	+
	Des Moines River	541	+
	Perkins Creek	544	?
	Des Moines River	545	+
	Des Moines River	546	?
	Jack Creek	549	?
	Unnamed creek	551	?
	County Ditch 43 (Scheldorf Creek)	552	?
	Unnamed creek	563	?
	Unnamed creek	564	+
	Judicial Ditch 14	589	?
	Unnamed ditch	594	?
	Okabena Creek	602	+
	Unnamed creek	608	?
	Unnamed creek	613	?
	Unnamed creek	614	?
	Unnamed creek	615	?
	Unnamed creek	618	?
	Unnamed creek	619	?
	Unnamed creek	621	?
	Unnamed creek	624	?
	Unnamed creek	625	?
	Unnamed creek	626	?
Des Moines Headwaters	Unnamed creek	628	?
	Unnamed creek	632	?
	Unnamed creek	637	?
	Lake Shetek Inlet	641	?
	Lake Shetek Inlet	642	?
	Lake Shetek Inlet	643	?
	Beaver Creek	646	+
	Jack Creek	649	?
	Jack Creek	652	+
	Elk Creek	654	?
	Elk Creek	656	+
	Jack Creek	658	+
	Unnamed creek	661	?
	Beaver Creek	663	?
	Beaver Creek	664	?
	Judicial Ditch 12	665	?
	Judicial Ditch 12	666	?
	Devils Run Creek	668	?
	Unnamed creek	670	?
	Unnamed creek	672	?
Lower Des Moines	Des Moines River	501	+
	Brown Creek (Judicial Ditch 10)	502	?
	Unnamed creek	504	?
	Judicial Ditch 56	505	?
	Story Brook	507	?
	Unnamed ditch	510	?
	Judicial Ditch 6	513	?
East Fork Des Moines	County Ditch 11	503	+
	County Ditch 53	506	?
	Fourmile Creek	510	+
	County Ditch 1/Judicial Ditch 50	515	?
	Mud Slough	516	?
	Des Moines River, East Branch	525	+
	Des Moines River	527	+
	Unnamed creek	529	?

+ = Supporting
? = Inconclusive (need more data)
X = Impaired

Sources

According to the *West Fork Des Moines River Watershed Total Maximum Daily Load Final Report* (MPCA 2008), the high pH values in the Heron Lake Outlet are directly related to the eutrophic status of the upstream lakes, North Heron Lake and South Heron Lake. To address the pH impairment, the eutrophication of the lakes must be addressed (refer to the Phosphorus/Eutrophication section above).

Goal and 10-year Target

The goal for pH is to meet the water quality standard and support downstream goals. Since this parameter is a response to (caused by) the eutrophication, the TP basin-wide and subwatershed goals and 10-year targets are indirect goals and targets of the pH goal. Strategies to meet the goals and 10-year targets and methods to prioritize regions are summarized in Section 3.

Chloride

Chloride (MPCA 2019a) is one of two ions that form salt (sodium chloride) and a defining characteristic of marine (salt-water) systems. However, chloride is toxic to freshwater systems at relatively low concentrations. Excessive chloride concentrations disrupt the osmoregulation (Britannica 2019) of aquatic life, preventing growth and reproduction or causing death. Chloride also alters lake functions and can contaminate ground water. Removing chloride from waterbodies is typically cost prohibitive if not impossible. Because of this, prevention and source reduction are critical to protecting waterbodies.

Status

Chloride was assessed as a pollutant on 16 stream reaches in the Des Moines River Basin. Of these, 1 stream reach was impaired, 15 were supporting, and 0 were inconclusive. Figure 46 illustrates the stream reaches assessed for chloride, and Table 20 tabulates those results.

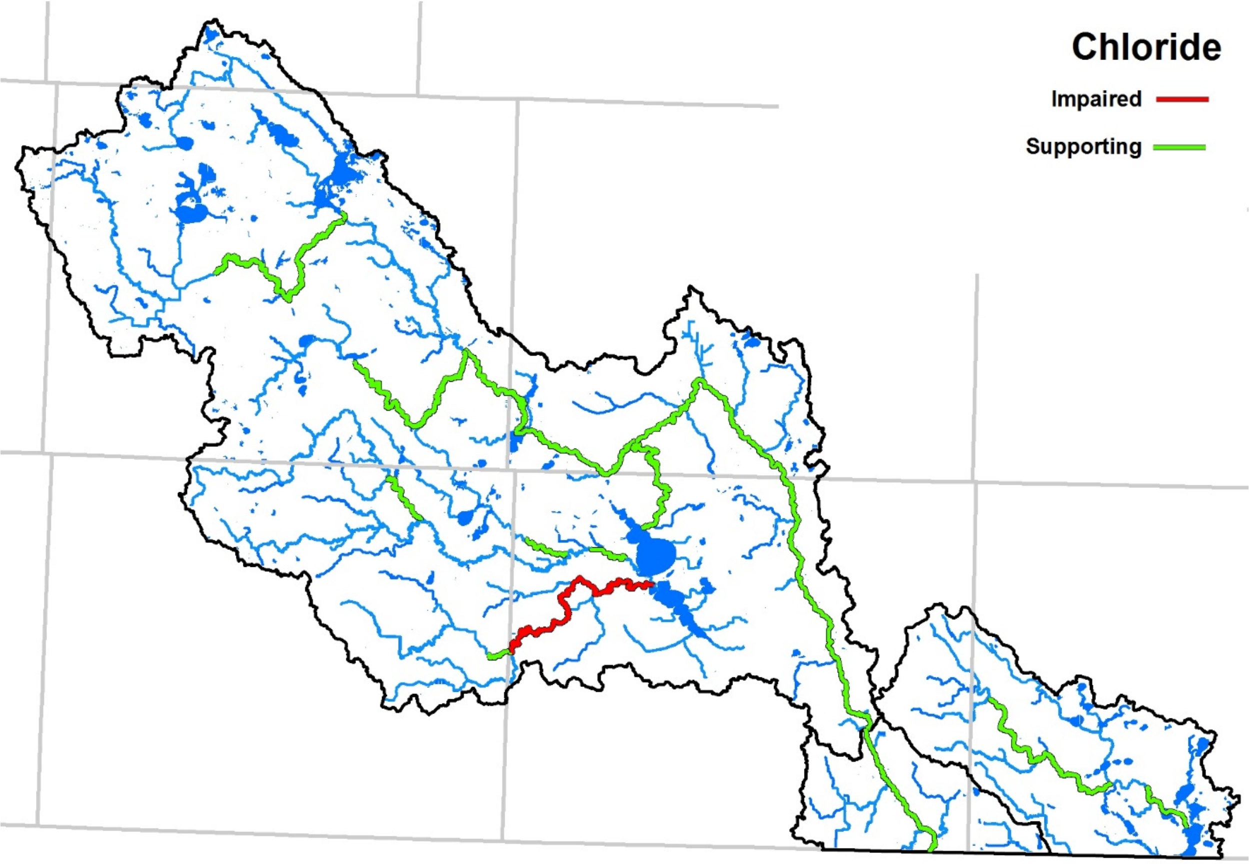


Figure 46: The majority of the stream reaches monitored for chloride in the Des Moines River Basin are supporting. The one impaired reach is on Okabena Creek, indicated by red (chloride is problematic in that reach). Green indicates support (chloride is not problematic).

Table 20: Assessment results for chloride as a pollutant in stream reaches in the Des Moines River Basin.

Major Watershed	Stream Name	AUID-3	Chloride Pollutant Assessment
Des Moines Headwaters	Des Moines River	501	+
	Des Moines River	524	+
	Heron Lake Outlet	527	+
	Des Moines River	533	+
	Lime Creek	535	+
	Des Moines River	541	+
	Des Moines River	545	+
	Unnamed creek	564	+
	Okabena Creek	602	X
	Beaver Creek	646	+
	Jack Creek	652	+
	Elk Creek	656	+
	Jack Creek	658	+
Lower Des Moines	Des Moines River	501	+
East Fork Des Moines	Des Moines River, East Branch	525	+
	Des Moines River	527	+

+ = Supporting
X = Impaired

Sources

Chloride can come from both point and nonpoint sources. Nonpoint sources of chloride include runoff from road and sidewalk salts and runoff from croplands where potassium chloride fertilizer has been applied. Point sources of chloride include municipal and industrial wastewater, which may have high chloride concentrations because of high levels of softener or industrially-used salt.

In the case of the one impaired reach, flow, precipitation, and chloride concentration data were analyzed in the TMDL (MPCA 2020a) for source assessment. This data indicates that elevated chloride concentrations occur during low flow conditions in the fall of the year, when precipitation and resulting runoff were minimal. Therefore, contributions of the chloride to Okabena Creek are dominated by point sources, and strategies should focus on the point source permitting processes.

Goal and 10-year Target

The basin-wide chloride goal is protection. Only Okabena Creek has a reduction goal. The chloride goal for this reach is an overall reduction of 4.6% and a 33% reduction during the critical, low-flow condition based on the TMDL (MPCA 2020a).

3. Restoration and Protection

This section presents a summary of scientifically and socially supported strategies to restore and protect waters, presented in "Strategies Tables", and a "Priorities Table". The content in these tables was primarily developed by the WRAPS LWG. The Strategies Tables provide high-level information on the changes necessary to restore and protect waters within the Des Moines River Basin. The Priorities Table provides subwatersheds that are high priority using multiple water quality and multiple benefits prioritizing criteria. These two high-level tools, along with civic engagement project findings, provide a solid foundation for local water resource planning.

3.1 Scientifically-Supported Strategies to Restore and Protect Waters

This section summarizes studies and data on land management and BMP effects on water quality. Supplementary and detailed information relevant to this section is included in Appendix 4.

To address the widespread water quality impairments, comprehensive and layered BMP suites are likely necessary. This comprehensive and layered BMP adoption calls for a paradigm shift in land management, particularly in the agricultural lands that dominate the Des Moines River Basin. However, these same principles should be applied to all land uses.

A conceptual model displaying this layered approach is presented by Tomer et al. (2013; Figure 47). Another model to address widespread nutrient problems is presented in the *Minnesota Nutrient Reduction Strategy* (MPCA 2015a), which calls for four major steps involving millions of acres statewide: 1) increase fertilizer use efficiencies, 2) increase and target living cover, 3) increase field erosion control and 4) increase drainage water retention.

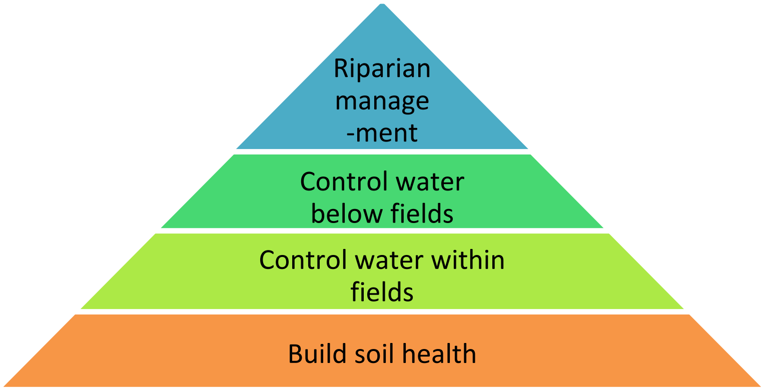


Figure 47: This conceptual model to address water quality in agricultural watersheds uses 1) soil health principles as a base: nutrient management, reduced tillage, crop rotation, etc., then 2) in-field water control: grassed waterways, controlled drainage, filter strips, etc., then 3) below-field water controls: wetlands, impounds, etc., and then 4) riparian management: buffers, stabilization, restoration, etc.

A third example of a comprehensive, layered approach is being demonstrated with a "Treatment Train" approach in the Elm Creek Watershed (BWSR 2018), which has demonstrated layered strategies including: 1) upland: cover crops and nutrient management, 2) tile treatment: treatment wetlands and controlled drainage and 3) in-stream: woody debris and stream geomorphology restoration.

Agricultural BMPs

Since the Des Moines River Basin's land use and pollutant sources are generally dominated by agriculture, reducing pollutant/stressor contributions from agricultural sources is a high priority. A comprehensive resource for agricultural BMPs is *The Agricultural BMP Handbook for Minnesota (2017 Revision)* (MDA 2017).

Several tools to estimate the types and amounts of BMPs that meet pollutant and stressor reduction goals are presented in Appendix 4. Additional field data has been compiled by Iowa and Minnesota for review in their respective state nutrient reduction strategies. This information is included in Appendix 4.

Urban and Residential BMPs

Cities and watershed residents also impact water quality. A comprehensive resource for urban and residential BMPs is the *Minnesota Stormwater Manual* (MPCA 2019f). This resource is in electronic format and includes links to studies, calculators, and special considerations for Minnesota regarding industrial and stormwater programs. Failing and unmaintained septic systems in unincorporated and rural areas can also pollute waters. Information and BMPs for Septic Systems are provided by EPA (2014).

Stream and Ravine Erosion Control

Wide-scale stabilization of eroding streambanks and ravines is cost-prohibitive. Instead, first addressing altered hydrology (e.g. excessive, concentrated flows) within the landscape decreases wide-scale stream and ravine erosion problems, as discussed in *the Minnesota River Valley Ravine Stabilization Charrette* (Emmons & Oliver Resources 2011) and the *Minnesota River Basin Sediment Reduction Strategy* (MPCA 2015b). Improving practices directly adjacent to the stream/ravine (e.g. buffers) can also decrease erosion as summarized in *The River Restoration Toolbox* (IA DNR 2019). In some cases, however, infrastructure may need to be protected or a ravine/streambank may be experiencing such severe erosion that stabilizing the streambank or ravine is deemed necessary.

Lake Watershed Improvement

Strategies to protect and restore lakes include both 1) strategies to minimize pollutant contributions from the watershed and 2) strategies to implement adjacent to and in the lake (refer to summary in Appendix 4). Strategies to minimize pollutant contributions from the watershed focus mostly on agricultural and/or stormwater BMPs, depending on the land use and pollutant sources in the watershed. The DNR (2014) supplies detailed information on strategies to implement adjacent to and in the lake through the Shoreland Management guidance. Another reference guide for managing and reducing internal phosphorus contributions is The Minnesota State and Regional Government Review of Internal Phosphorus Load Control (MPCA 2020b).

Computer Model Scenarios

Computer models provide a scientifically-based estimate of the pollutant reduction effectiveness of land management and BMPs. Models represent complex natural phenomena with equations and numeric estimates of natural features, which can vary substantially between models. Because of these varying assumptions and estimates, each model has its strengths and weaknesses and can provide differing results. For these reasons, multiple model results were used as multiple lines of evidence when developing the strategies tables. N-BMP, P-BMP, HSPF SAM, and other scenarios are summarized in Appendix 4.

Culverts, Bridges, and Connectivity Barriers

Strategies to address connectivity barriers need to be assessed on a case-by-case basis and include correctly sizing, removing, or otherwise mitigating the connectivity barriers. Bridges and culverts should be sized using flow regime and stream properties using a resource such as Hillman's (2015) stream crossing inventory and barrier ranking guidelines. The effects of dams and impoundments can be mitigated to minimize impacts to aquatic life. Overall system health should be considered; restoring connectivity may not be cost effective if other stressors are creating significant impacts to aquatic communities.

3.2 Social Dimension of Restoration and Protection

Most of the changes that must occur to improve and protect water resources are voluntary; therefore, communities and individuals ultimately hold the power to restore and protect waters in the Des Moines River Basin. For this reason, the Clean Water Council (MPCA 2018b) recommended that agencies integrate civic engagement in watershed projects (MPCA 2010a).

A growing body of evidence detailed in *Pathways for Getting to Better Water Quality: The Citizen Effect* (Morton and Brown 2011) suggests that to achieve clean water with the voluntary-adoption system in place, a citizen-based approach is likely the most feasible means to success. Specifically, the transition to more sustainable practices must be developed, demonstrated, and spread by trusted leaders within the community. When leaders embrace a transition, communities are more likely to accept and adopt the transition. When leaders and communities develop solutions, they are likely to intertwine financial security and environmental stewardship, instead of viewing them as conflicting goals. In this way, the community is more likely to improve water quality while securing sustainable farms and cities for future generations. If this pathway to water quality improvement is to be embraced, however, one of the most important uses for limited resources is to further develop and support local leaders to take on this challenging work.

Civic engagement and public participation were a major focus during the Des Moines River Basin Watershed Approach from 2014 through the summer of 2018. The MPCA worked with county and SWCD staff, the Heron Lake Watershed District, consultants, citizens, and other state agency staff on two projects. The two projects were the 1) East Fork Des Moines River Watershed Priority Management Zone Strategy, and 2) West Fork Des Moines River Major Watershed Project. These projects were tailored to local partner interest and capacity.

A brief summary of and results from each project are included below. The end of this section contains a summary of opportunities and constraints to water quality improvement synthesized from these projects. Detailed project information including project reports and attachments can be found in the *Des Moines River Watersheds Civic Engagement Project Summary* (MPCA 2019c).

East Fork Des Moines River Watershed Priority Management Zone Strategy

The goals of this project were to 1) identify community/landowner opportunities, obstacles, and opinions on land management and water quality, 2) inform watershed restoration and protection strategies using identified community goals and interests, 3) assist in data collection in the East and West Fork Des Moines River Watersheds, and 4) develop TMDL reports for impaired waterbodies in the Des Moines River Basin. This project was a collaboration between Martin and Jackson County and SWCD staff, Minnesota State University, Mankato (MNSU), the MPCA, and Houston Engineering.

West Fork Des Moines River Major Watershed Project

The goals of this project were to 1) develop a citizen advisory group for input on gathering public values, restoration activities, and educating the public and 2) develop and implement a public education campaign. This project was a collaboration between Heron Lake Watershed District, County and SWCD staff, and the MPCA. A primary finding of the project was that additional education is needed on multiple topics related to water quality restoration and protection.

The citizen advisory group developed three actions to complete through the project: 1) develop a survey to gather public input and a poster to promote clean water, 2) develop a Facebook page, and 3) connect with other civic organizations and events to distribute surveys and discuss watershed issues. The survey was completed by 142 participants from throughout the watershed, ranging in ages from 18 to over 71, and representing many sectors (i.e. agriculture businesses, rural residents and city residents). The Facebook page was developed to share information with the public.

The public education campaign was multi-faceted. Six educational events were held throughout the watershed, drawing 184 attendees. A public official's summit was held. Youth education occurred with the Prairie Ecology Bus. The West Fork Des Moines River Story Map (HLWD 2018) was developed to help share water quality, landscape change, and other watershed information.

Opportunities, Constraints, and Recommendations for Future Work

Constraints and opportunities for water quality improvements were identified from the two projects. From these, additional civic engagement work recommendations are presented.

The identified opportunities include:

- Citizens were interested in slowing the flow of water, as well as working towards eliminating surface water ponding and keeping water on the landscape upstream
- Participants wanted more information about baseline water quality levels and what is being done to regulate runoff from municipalities
- Interest in ditch channel storage, holding ponds and two stage ditches
- Need for existing storage areas to be cleaned out more often
- Respondents were more interested in conservation tillage than nutrient management
- Interest is growing in cover crops and programs are starting that provide cost share money in this watershed for residents to try cover crops
- Restoration efforts should target specific key areas
- There is interest in reduced tillage, nutrient application/timing, crop rotation, feedlot compliance and groundwater protection
- It is believed that water resources are important and that landowners are the most responsible for the water quality in the watershed
- The water resources are important for both agricultural production (drainage and livestock watering) and recreational use such as hunting and fishing to boating and swimming

- There is interest in additional training events that include implementation opportunities in the watersheds and implementation policies

The identified constraints include:

- In general, people felt existing programs, such as CRP and cover crops, were too restrictive and had too long of timeframes
- Not enough controlled drainage
- Not enough education of BMP implementation
- Frustration with existing programs, such as CRP and cover crops, finding enough cooperators
- Research findings have not been presented to groups
- Financial incentives have not been adequate
- Not one size fits all to find solutions
- The largest obstacle to implementing conservation BMPs are the associated costs
- Concern about the loss of agricultural production acres
- Some citizens do not believe a water quality problem exists

Some of the identified constraints can be addressed through additional civic engagement work, which will require cooperation among many partners. The following are some examples of what could be done locally.

- Local partners work with community leaders to start building leadership and create a unified vision around water quality issues of importance.
- Local partners, community leaders, state agency staff, and local business partners could work together to develop new funding opportunities to address costs.
- Local partners and agency staff could work together to develop easier and efficient programs to suit landowner interest and need, which would help alleviate program restrictions.
- Local partners could seek new opportunities focused on subwatersheds based on local priorities and landowner interest. Exploring future opportunities to expand face-to-face conversations and education activities regarding water quality to reach a new audience and provide missing information to existing ones. Conversations during the civic engagement projects like these lead to greater interest and involvement in local conservation programs.

3.3 Restoration and Protection Strategies

The presented strategies tables show the types of practices and associated adoption rates estimated to meet: A) the full water quality goals (Table 21) and B) 10-year water quality targets (Table 22) for the Des Moines River Basin. The strategies need to be refined in local planning processes to determine specific locations and means to get these types of strategies “on the ground”.

Strategies Table A (Table 21) summarizes the water quality conditions, goals, and high-level strategies and adoption rates at the basin-scale. The basis for these goals was derived from the Model Summary presented in Appendix 4 and best professional judgement. Recommending specific suites of practices cumulatively capable of achieving all water quality goals is not practical. Challenges including the vast amount of change needed to meet water quality goals and the needed changes in technologies, programs, markets, and other whole-scale drivers will likely result in this work taking decades. Instead, high-level, narrative strategies and adoption rates were deemed more practical.

Strategies Table B (Table 22) presents specific strategies and numeric adoption rates estimated to meet the 10-year water quality targets. This strategies table is intended to be more helpful for local planning efforts, which typically work on a 10-year revision schedule. These strategies were proposed and ranked (highest to lowest adoption) by the WRAPS LWG. The numeric adoption rates were then calculated to meet the 10-year water quality targets, using the developed source assessment, with a spreadsheet tool (notes and assumptions in Appendix 4) and reviewed to ensure consistency with computer model information (Model Summary in Appendix 4).

The strategies presented need to be implemented across the basin, in all subwatersheds with impaired waterbodies or supporting waterbodies with declining trends (any area shown in gray in the goals maps presented in Section 2.2). However, the adoption rates in any one region will not necessarily match the basin-wide adoption rates due to regional differences. Furthermore, not all strategies are appropriate for all locations. The strategies and regional adoption rates need to be customized during local planning efforts.

Protection Considerations

Waterbodies that meet water quality standards should be protected to maintain or improve water quality. Furthermore, waterbodies that have not been assessed should not be allowed to degrade. The strategies presented in Table 21 and Table 22 - set at the basin scale - are intended to not only restore but also protect waters in the Des Moines River Basin. Strategies that are high priority for protection efforts are noted with a pink cross symbol. Similar to customizing regional adoption rates of the basin-wide strategies, strategies and adoption rates should reflect the relative amount of protection needed and any site-specific considerations.

The highest priority aspects of water quality protection in the Des Moines River Basin include:

- Mitigate new agricultural drainage projects by adding basin/wetland storage such as the wetland-trading program.
- Maintain existing BMPs, CRP, RIM and endemic land uses like wetlands, prairies, and forests.
- Add new checkpoints to prevent aquatic invasive species spread.

Additional protection concerns in the basin relate to groundwater and drinking water protection. The main supply of drinking water to the residents and businesses in the Des Moines River Basin is groundwater – either from private wells, community wells or a rural water supplier.

The communities of Alpha, Balaton, Lake Wilson and Windom have vulnerable drinking water systems that indicate a connection and influence from surface water in the watershed. Red Rock Rural Water's Lake Augusta, Great Bend, and Lindstrom wellfields are also highly vulnerable with a highly vulnerable surface water contribution area. Contaminants on the surface can move into the drinking water aquifers more quickly in these areas and are directly connected to the surface water resources in the watershed. The ground water and surface water interactions in the Des Moines River near Windom are further described in the Hydrogeology and Ground-Water/Surface-Water Interactions Report (USGS 2005).

The communities of Ceylon, Dunnell, Fulda, Iona, Jackson, Lakefield, and Sherburn have low vulnerability to contamination which means that in those areas the deep aquifers are fairly well protected. There is also the potential for contamination through unused and abandoned wells. Ensuring abundant and high quality supplies of groundwater is critical, especially in light of altered hydrology and the impacts on groundwater recharge.

Table 21, Strategies Table A: This portion of the strategies table summarizes the conditions, goals, 10-year targets, proposed years to reach the goals, and the strategies and estimated adoption rates needed to achieve the goals in the Des Moines River Watersheds. The strategies and estimated adoption rates are presented in narrative form. The high-level strategies and rough estimate adoption rates are intentionally used to reflect the variety of practices, corresponding differences in practice efficiencies, and uncertainty in the exact practices and adoption rates that will be needed to achieve water quality goals throughout the watershed. These strategies and adoption rates were estimated after reviewing multiple model results (available in Appendix 4), the identified sources of pollutants and stressors in the Des Moines River Watersheds, the SID and Geomorphology/Hydrology reports, and using best professional judgement. Strategies, practices, and specific adoption rates to meet the 10-year targets are identified in Table 22.

Parameter	Identified Conditions	Water Quality Goal (summarized)	Basin-wide Goal (average/surrogate for watershed)	10-yr Target (meet by 2030)	Years to Reach Goal (from 2020)	Restoration and Protection Strategies See key in Appendix 4 for BMPs associated with strategies Estimated Adoption Rates: All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10% Adoption rates indicate the final landscape outcome and include any practices already in place.
Degraded Habitat	•51 stream reaches stressed •4 stream reaches not stressed •Likely stressor of lake aquatic life	Aquatic life populations are not stressed by degraded or lack of habitat.	45% increase in MSHA habitat score	20% ↑	40	All streams and ditches have a restored riparian area/shoreland. Most ditches reduce impacts. Many stream/ditch channels, banks, and floodplains are improved. Few marginally productive/high risk land uses are converted for critical habitat (wetlands, CRP, etc.). Most lake and wetland shorelands are restored/protected. Altered hydrology and sediment are addressed.
Phosphorus/ Eutrophication	•49 stream reaches and 23 lakes stressed/impaired •2 stream reaches and 2 lakes not stressed/supporting •Reductions needed to meet downstream goals	Summer lake mean TP concentration is less than 0.09 mg/L and aquatic life populations are not stressed by eutrophication. Support statewide and downstream reduction goals.	45% reduction in lake and stream concentrations/loads	Lakes 7% ↓ Streams 15% ↓	Lakes 50 Streams 40	All croplands improve soil health by decreasing fertilizer use, adding cover crops, decreasing tillage, and/or diversifying crops. Most croplands reduce and treat cropland surface runoff. All streams and ditches have riparian buffer. All residential/urban areas reduce and treat runoff. Some stream/ditch channels, banks, and floodplains are improved. All WWTPs and septic systems are providing adequate treatment.
Sediment	•27 stream reaches stressed/impaired •29 stream reaches not stressed/supporting •Sediment reductions needed to meet downstream needs •Contributing to other stressor (habitat)	90% of stream concentrations are below 65 mg/L. Aquatic life populations are not stressed by sediment.	30% reduction	5% ↓	60	All croplands improve soil health by adding cover crops, decreasing tillage, and/or diversifying crops. Most croplands reduce and treat cropland surface runoff. All streams and ditches have riparian buffer. All residential/urban areas reduce and treat runoff. Some stream/ditch channels, banks, and floodplains are improved. Impacts from most ditches are reduced.
Nitrogen	•36 stream reaches stressed/impaired •13 stream reaches not stressed •Reductions needed to meet downstream goals	Aquatic life populations are not stressed by nitrogen. Support statewide and downstream reduction goals.	30% reduction in river concentrations/loads	10% ↓	40	All croplands improve soil health by decreasing fertilizer use, adding cover crops, decreasing tillage, and/or diversifying crops. Most croplands reduce and treat cropland tile drainage. All streams and ditches have riparian buffer. All residential/urban areas reduce and treat runoff. All WWTPs and septic systems are providing adequate treatment.
Altered Hydrology	•36 stream reaches stressed •5 stream reaches not stressed •Source of other stressors (sediment, degraded habitat)	Aquatic life populations are not stressed by altered hydrology (too high or too low river flow). Hydrology is not creating problems with other parameters (habitat, sediment, nitrogen, phosphorus, etc.).	20% reduction in peak & annual river flow	2.5% ↓	100	All croplands improve soil health by adding cover crops, decreasing tillage, and/or diversifying crops. Most croplands reduce and treat surface runoff and reduce and treat tile drainage. Few (marginally productive/high risk) areas are converted for critical habitat (wetlands, CRP, etc.). All residential/urban areas reduce and treat runoff. Some stream/ditch channels, banks, and floodplains are improved.
			Increase dry season river base flow by enough to support aquatic life	small increase	50	
Connect- ivity	•9 stream reaches stressed •36 stream reaches not stressed	Aquatic life populations are not stressed by human-caused connectivity barriers.	Address human-caused barriers as identified in SID and where practical	6 barriers removed	20	Fish barriers are addressed.
Bacteria	•27 stream reaches impaired •2 stream reaches supporting	Average monthly geomean of stream samples is below 126 cfu/100mL to support aquatic recreation or 630 to support limited use (Class 7) streams.	50% reduction in river concentrations/loads	10% ↓	50	All WWTPs and septic systems are providing adequate treatment. All feedlot-produced manure is applied to cropland using improved application practices. All croplands improve soil health by adding cover crops, decreasing tillage, and/or diversifying crops. Most manured croplands reduce and treat cropland surface runoff. All feedlots optimize manure storage and siting. All pastures improve livestock and manure management by improving grazing practices and restricting livestock access to water bodies. Some livestock are integrated onto the landscape.
Chloride	•1 stream reach impaired •15 stream reaches supporting	Stream concentrations are below 230 mg/L.	Protect (restore the 1 imparied reach)	Meet permit requirements		Reduce chloride at the source by either upgrading water softeners, changing or treating source water, and/or eliminating or treating industrial or point sources. Reduce road salt use. Utilize State Chloride Management Plan.
Parameters that are impacted/addressed by the above pollutants and stressors						
F-IBI	•48 stream reaches impaired •9 stream reaches supporting	Aquatic life populations (scored with the IBI) meet thresholds based on stream class/use.	Each parameter's goal is to meet the water quality standard and support downstream goals. Because these parameters are a response to (caused by) the above pollutants/stressors, the above watershed-wide goals are the (indirect) goals for these parameters.	meet other 10-year targets	60	The above strategies are implemented.
M-IBI	•40 stream reaches impaired •16 stream reaches supporting					
DO	•37 stream reaches stressed/impaired •10 stream reaches not stressed/supporting	Stream concentrations are above 5 mg/L and DO flux is not excessive.			40	
pH	•1 stream reach impaired •18 stream reaches supporting	Stream concentrations are between 6.5 and 9.0 mg/L.			50	

Table 22, Strategies Table B (page 1 of 2): This table presents a suite of strategies and practices that are cumulatively capable of meeting the 10-year targets for the Des Moines River Watersheds. The strategies are presented by land use and provide target adoption rates by both watershed area and the equivalent number of acres. This level of new adoption progresses the landscape and water bodies towards clean water consistent with the total years to achieve watershed restoration as presented in Table 21. Adoption rates are for new projects and assume existing practices will be maintained. Information on the conditions, goals, and total timelines is presented in Table 21. Refer to the narrative in Section 3.3 for more information. See Appendix 4 for information on practices and relevant NRCS practice codes.

Land use/ Source Type	**Des Moines River Watersheds Restoration and Protection Strategies and associated BMPs** estimated to meet 10-year targets at specified adoption rates	**Adoption Rate**		**Effectiveness** of practice on parameter per acre comparison							
		Portion of Watershed Area	Watershed Acres	Sediment	Flow	Nitrogen	Phosphorus	Bacteria	Habitat‡	Connectivity	Chloride
Cultivated Crops	**Add cover crops for living cover in fall/spring**: cover crops on corn/beans, cover crops on early-harvest (canning) crops	8%	78,700	**X**	x	**X**	**X**	x	-		
	Decrease tillage: conservation tillage, no-till, strip till, ridge till	5%	49,200	x	-	-	x	x			
	Decrease fertilizer use: nutrient management, reduced rates, targeted/measured application	5%	49,200			x	-				
	Reduce and treat cropland surface runoff*: water and sediment control basins, retention ponds, treatment wetlands, stormwater control structures, field buffers	2%	19,700	**X**	-	-	**X**	x			
	Diversify crops: conversion to small grains, perennial crops, and well-managed pasture	2%	19,700	x	x	**X**	x	x	-		
	Replace or buffer open tile intakes*: blind, rock, sand filter intakes, vegetative buffer	1.5%	14,800	**X**			**X**	**X**			
	Reduce and treat cropland tile drainage*: Bioreactors, treatment wetlands, saturated buffers, limit new tiles	1%	9,800		-	**X**	-				
	Convert/protect land for critical habitat (replacing marginally productive and high risk cropped areas): Restore wetlands, conservation cover/CRP, prairie, habitat management, native shrub hedgerows	0.5%	4,900	**X**	**X**	**X**	**X**	**X**	-		
	Mitigate new ag drainage projects by adding basin/wetland storage (wetland trading program) †	All new projects		n/a							
	Maintain existing BMPs, CRP, RIM †	All current BMPs		n/a							
	Improved programs and program funding: Federal farm program changes, more reduced tillage programs, create programs for new crops, more funding in Ag Water Quality certification program, implement a wetland trading program, flexible funding and insurance coverage for innovative conservation practices, new 30-50 year easement programs	sufficient to achieve the above physical strategies		n/a							
	Education: nutrient management education for agronomists and landowners, cover crop, altered hydrology, and bioreactor education										
	Field trials and monitoring: field trials of cover crops/other conservation practices, tile monitoring to identify volume of water and pollutants										
	Market development: second crop (cover crops), small grains, perennials										
Feedlots	**Optimize siting of manure storage**: rainwater diversion (prevent from entering manure storage system) to water source, feedlot manure storage addition, add farm infrastructure to achieve storage/runoff reduction goals (machinery, buildings, roads)	sufficient to reduce current contributions by 25%				√	√	√			
	Reduce/treat feedlot runoff: targeting smaller and unpermitted facilities					√	√	√			
	Optimize feedlot siting: increase distance between livestock and water, move feedlots out of sensitive areas					√	√	√			
	Smaller facilities and transition to more grazing: encourage small scale facilities and more conservation and cover crop grazing					√	√	√			
Manure Application	**Improve manure application**: improve placement/setbacks, no application draining to open intakes, equipment upgrades to variable applicators	1.5%	14,800		-	x	x	**X**			
	Outreach, education, and support: education on value of manure and better manure use, provide a manure testing incentive, provide variable rate applicator support	sufficient to achieve the above physical strategies		n/a							
Pastures	**Improve pasture/grazing management**: managed/rotational grazing, graze cover crops, remote watering facilities and fencing	0.1%	1,000	**X**			**X**	**X**			
	Restrict livestock access to water bodies: exclusions/fencing, watering facilities	0.1%	1,000	**X**			**X**	**X**			
	Networks and Support: create support systems to encourage innovative pasture conservation, work with groups like Cattleman's Association	sufficient to achieve the above physical strategies		n/a							

Effectiveness was estimated using 1% adoption. While some practices are most effective at 1% adoption, the total effectiveness is limited by the watershed area contributing to the source. For instance, replacing open tile intakes is effective, but only a small percentage of the watershed is served by open intakes. Therefore, the total reduction achievable from this practice is minimal.

Effectiveness Scale - per acre comparison
X x - <blank>
most effective ⟷ least effective
√ = Effective on parameter. No per acre comparison made.

‡ Practices with "x" or "**X**" affect on flow are given a "-" on habitat.

† = protection strategy to prevent current condition degradation. Effectiveness not estimated for protection strategy.

* = strategy footprint is much smaller than treated area (e.g. a grassed waterway treats many more acres than the practice footprint)

Table 22, Strategies Table B (page 2 of 2): This table presents a suite of strategies and practices that are cumulatively capable of meeting the 10-year targets for the Des Moines River Watersheds. The strategies are presented by land use and provide target adoption rates by both watershed area and the equivalent number of acres. This level of new adoption progresses the landscape and water bodies towards clean water consistent with the total years to achieve watershed restoration as presented in Table 21. Adoption rates are for new projects and assume existing practices will be maintained. Information on the conditions, goals, and total timelines is presented in Table 21. Refer to the narrative in Section 3.3 for more information. See Appendix 4 for information on practices and relevant NRCS practice codes.

Land use/ Source Type	Des Moines River Watersheds Restoration and Protection Strategies and associated BMPs estimated to meet 10-year targets at specified adoption rates	Adoption Rate	Pollutants/ Stressor addressed by strategy							
			Sediment	Flow	Nitrogen	Phosphorus	Bacteria	Habitat‡	Connectivity	Chloride
Stream, ditches, & riparian	**Stream channel, bank, and habitat projects**: stream stabilization, re-connect/ restore flood plains, re-meander channelized stream reaches, and/or stream habitat improvement and management on selected locations within assessed stream miles	5% of streams/diches (40 miles)	√	√	√	√	√	√	√	
	Reduce ditch impacts: reduce ditch clean-outs, ditch improvement projects include additional water storage practices to mitigate impacts, 2-stage ditches	100% of ditches	√	√	√	√	√	√		
	Address fish barriers: replace/properly size culverts and bridges (perched culverts and velocity barriers)	5% of culverts replaced							√	
	Enhance/improve buffers: improve required buffers with native plants	100% of stream/ditches have required buffer and 10% are planted to natives	√	√	√	√	√	√		
	Education and outreach: topics to include stream functionality/stability, fish barriers, watershed health; use existing public events for outreach, education field days	sufficient to achieve the above physical strategies	n/a							
	Programs and funding: increased guidance, funding, and flexibility									
	Collaboration: work with drainage authority and engineers to incorporate water storage in ditch projects									
	Rules: create and enforce a maximum drainage coefficient									
Lakes, wetlands, & shoreland	**Restore/protect shoreland**: stabilize/restore shoreline with native vegetation and/or increase distance (buffer) between waterbody and impacts at selected locations within assessed lakes	5 lakes	√			√		√		
	Manage in-lake/wetland: Drawdowns, wetland enhancements	5 lakes/wetlands	√			√		√		
	Remove dams/outlet structures	2 lakes						√	√	
	Prevent AIS spread: add new check points to prevent aquatic invasive species spread †	4 new check points	n/a							
	Education: topics to include AIS prevention, lake dams, economic benefits of restoration	sufficient to achieve the above physical strategies	n/a							
	Funding: create funding source for dam removal									
	Regulations/zoning: enforce shoreland ordinance									
	Collaboration: with lake associations and sportsman's clubs									
Forest & prairies	**Protect and enhance:** areas in natural landuses, increase native populations †	n/a	√	√	√	√	√	√		
City and residential	**Increase stormwater treatment and storage:** Stormwater ponds, swales, rain gardens/barrels, wetlands, applicable parties follow SWPPPs	sufficient adoption to reduce current contributions by 20%	√	√	√	√	√			
	Improve vegetation: Add and diversify trees, native landscaping, rain gardens		√	√	√	√	√	√		
	Improve road management: Road salt management/education, street sweeping, smart snow stockpiling, utilize Statewide Chloride Management Plan		√	√	√	√	√			√
	Nutrient management: Proper/reduced use of lawn fertilizer, pet waste management				√	√	√			
	Water softener upgrades	5% of softeners upgraded								√
	Education and Advertising: on urban BMPs and water softener upgrades through radio, newspapers, fliers; educational events at businesses that sell plants; marking storm drains	sufficient to achieve the above physical strategies	n/a							
	Funding: funding for educational events, cost-share for urban/residential BMPs									
	Ordinance: to require stormwater management									
	Leadership/oversight: create an urban BMP committee to lead educational events, identify ordinance needs, locate proposed project sites, oversee project completion									
Septics/ SSTS	**Eliminate unsewered areas and straight pipes**: systems discharging to streams/land surfaces are redirected per SSTS rules	100% eliminated			√	√	√			
	Maintenance and replacement: scheduled maintenance and replace failing systems	As needed, roughly 30%			√	√	√			
	Funding: cost-share available, including targeted to low income households	sufficient to achieve the above physical strategies	n/a							
Point Sources	**Facility upgrades:** when required by permit	Follow permit requirements			√	√	√			√
	Regulations: follow permitting process		n/a							

* = strategy footprint is much smaller than treated area (e.g. a grassed waterway treats many more acres than the practice footprint)
‡ Practices with "x" affect on flow are given a "-" on habitat. Practices that target riparian zone improvements are given "X" on habitat
√ = practice is effective on parameter. No relative comparison made as no model or calculator was readily available to provide analysis.
† = protection strategy to prevent current condition degradation. Effectiveness not estimated for protection strategy.

3.4 Priority Areas

Conservation implementation plans (i.e. *One Watershed, One Plan* [1W1P; BWSR 2014a] or EPA Section 319 project work plans, etc.) that are developed subsequent the WRAPS report should ***prioritize*** and ***target*** the strategies in this report and set ***measurable*** goals. Figure 48 (BWSR 2014b) represents the prioritized, targeted, and measurable concepts. A broad list of tools for prioritizing and targeting work is in Appendix 4.

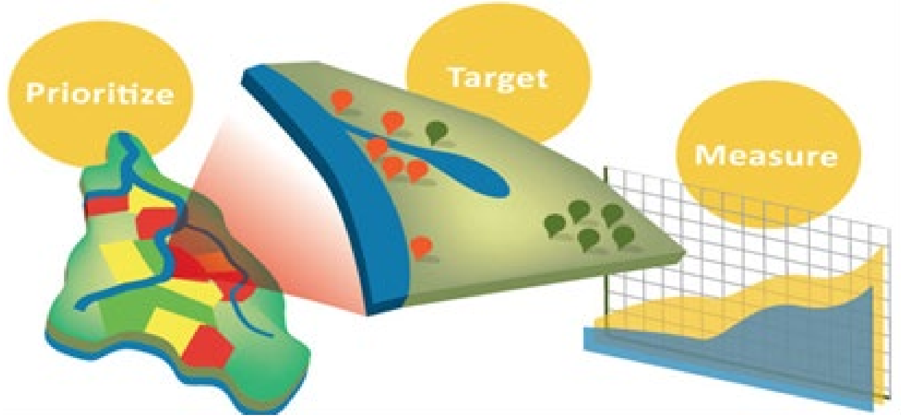


Figure 48: "Prioritized, targeted, and measurable" plans are more likely to improve water quality and be funded, compared to those that are less strategic.

Prioritizing is the process of selecting priority areas or issues based on justified water quality, environmental, or other concerns. Priority areas can be further refined by considering additional information: other water quality, environmental or conservation practice effectiveness models or concerns; ordinances and rules; areas to create habitat corridors; areas of high public interest/value; and many more that can be selected to meet local needs. This report has identified several priority areas throughout, such as the goals maps, the HSPF model maps, and the GIS estimated altered hydrology maps. These and additional priority areas are summarized in Table 23. These priorities were developed in conjunction with the WRAPS LWG.

Targeting is the process of strategically selecting locations on the land (within a priority area) to implement strategies to meet water quality, environmental or other concerns (that were identified in the prioritization process). The WRAPS report is not intended to target practices, rather, the work done as part of the larger Watershed Approach should empower local partners to target practices that satisfy local needs.

Table 23: Priority areas to restore and protect surface water quality are summarized below. The first six rows of this table are priority areas directly from this WRAPS Report and focus on water quality restoration or protection. The bottom three rows of this table are multiple benefit or locally driven priority areas not strictly associated with the WRAPS, but these areas would offer benefits to water quality. Priority areas should be further customized and focused during local planning efforts using additional prioritizing criteria.

"Priority Area" Prioritizing Criteria	Specific Examples	Applicable WRAPS/other data sources	Other considerations
"Protection of Supporting Waters" Water bodies that are currently meeting the water quality standard (beneficial use or for any parameter) or any water body (assessed or not) should have an improving or stable trend in water quality	**First and Second Fulda Lakes** are the only assessed lakes that are meeting aquatic recreation standards. **Mud Slough** (reach 3-516, inlet to Bright Lake) and the Des Moines River, **Shetek Lake outlet** (reach 1-545) are meeting standards for aquatic recreation. Nine assessed stream reaches are supporting aquatic life standards. Several unassessed lakes score more sensitive on the Phosphorus Sensitivity Analysis including **Clear, South Badger, and Summit Lakes**.	The "green" water bodies in the status maps and assessment tables throughout Section 2.2 show the supporting water bodies. While a stream reach may be impaired for a beneficial use, some parameters may be supporting. Refer to Assessment Table in the Appendix 1.	Additional useful prioritizing criteria for protection include: hydrologic alteration, trends, HSPF-modeled yields, phosphorus sensitivity, local pollutant sources, etc. The MPCA Lakes Phosphorus Sensitivity Analysis can be used to prioritize lakes that are estimated to be the most sensitive to additional phosphorus inputs.
"Tipping point: Barely impaired" Water bodies that are impaired but have a relatively smaller reduction or improvement goal or have fewer identified parameters/sources driving the impairment	**Fox, Shetek, Bloody, Currant, Yankton, and Bright Lakes** are the impaired lakes requiring the least estimated phosphorus percent reduction to meet the standard. Few stream reaches appear to meet the barely impaired criteria, based on available data, in that most are estimated to need large reductions to meet standards, and the number of stressors in most reaches is four or more.	Use the goals maps in Section 2.2 (which illustrate the TMDL Summary table in the Appendix) to identify which impaired water bodies require the least reduction. On the goals map, the lighter the gray shading, the less reduction that is required. Aquatic life (IBI) scores are available in the Monitoring and Assessment report. Those that are closer to the threshold are likely more attainable/restorable. Additional details are provided in the SID and the DNR Watershed Characterization reports.	Compared to "dirtier" watersheds, fewer changes are needed to address parameters and can be "easier" to achieve restoration goals. This prioritizing criteria can be especially important if the primary goal of the funding entity is to achieve restoration of impaired water bodies.
"Highly Hydrologically Altered" Subwatersheds or waterbodies identified as highly hydrologically altered	Western portions of **Okabena Creek, Jack Creek, and Heron Lake subwatersheds**, most of the **East Fork Des Moines watershed**, and an area at the divide of **Lake Shetek and Beaver Creek** subwatersheds are the most highly hydrologically altered areas in the watershed.	A GIS analysis of altered hydrology is presented in Section 2.2 in the Altered Hydrology section. Areas with a higher score indicate more alteration. 1855 land survey or other past landscape imagery/analysis can identify drained lakes/wetlands.	Altered hydrology is a commonly identified stressor in the Des Moines River watersheds and a driver of most other stressors like sediment, habitat, and nitrogen.

"Priority Area" Prioritizing Criteria	Specific Examples	Applicable WRAPS/other data sources	Other considerations
"Measurable waters" Water bodies with ample monitoring data to establish baseline conditions prior to work being done and future monitoring data can be used to track changes in water quality	**First Fulda, Sarah, Shetek, Summit, Wilson, and Yankton Lakes** all have sufficient data to calculate trends currently, and therefore, assuming monitoring continues, would have ample data to reflect changes. River sites with sufficient data to calculate trends include the **East Fork** near Ceylon, the **West Fork** near Petersburg, and **Okabena Creek** near Brewster. Stream reaches with aquatic life (IWM) monitoring locations provide a record to compare after implementing projects. In particular, areas that may show a quick response in aquatic life (IBI) scores are those primarily limited by few stressors.	The monitoring locations are illustrated on a map in Section 1.3. The three different types of monitoring locations provide different types of data. Review the data online (link at beginning of Section 2) to determine which parameter could be tracked to compare the conditions before and after BMPs are implemented.	Lakes with small watersheds will probably be the easiest to show changes in. Depending on the kind of work to be done, biological data may change. Solid, long-term data is taken at WPLMN sites, but the watersheds of these sites are very large and substantial changes are likely necessary before water quality improvement will be seen.
"Dirtiest Watersheds or Waters" Watersheds with high pollutant/stressor yields or water bodies that have higher amounts of pollutant/stressor using either: 1) estimated reductions from TMDL data or observed concentrations, or 2) model data (yields or concentrations), 3) total number of identified parameters not supporting water quality goals.	1) **Talcot, Sarah, Pierce, North Oaks, and Temperance Lakes** are the lakes estimated to need the largest phosphorus reductions based on TMDL data. Western and central areas of the watershed (**Jack and Okabena Creeks**, etc.) are estimated to need the largest sediment reductions based on TMDL data. 2) **Beaver Creek, Okabena Creek**, and the south portion of the **Lower Des Moines** subwatersheds are model estimated to have the highest sediment yields. **Beaver Creek** and portions of the **Lower Des Moines** subwatersheds are model estimated to have the highest phosphorus yield. **Okabena Creek and East Fork Des Moines** subwatersheds were model estimated to have the highest nitrogen yields. 3) **Jack Creek** and its tributaries (reaches 1-514, 1-666), **Unnamed** (reach 1-625), **Brown Creek** (3-502) etc. were found to be stressed by all/nearly all potential stressors.	1) The goals maps (Section 2.2 - Goals Subsections) illustrate areas that need pollutant reductions- the darker the grey shading, the more reduction needed from this contributing area. The larger the needed reduction, the "dirtier" the water body (reductions also in the TMDL summary in the Appendix). 2) Data are available online and additional interpretation are available in the SID and the DNR Watershed Characterization reports. 3) HSPF-modeled concentrations are in the status subsections in Section 2.2 and yield maps are presented in Appendix 2.	1) Subwatershed goals maps can be used to estimate the dirtiest areas but are only presented when TMDL data are available which only apply to TSS, TP, and bacteria. Observed data should be corroborated by that parameter being assessed as a pollutant or stressor. 2) Model data are an estimate and may not represent real world conditions and may be limited by model mechanics or assumptions. Coupling model data with additional prioritizing criteria (versus being a single driver in selecting a priority area) is recommended.

"Priority Area" Prioritizing Criteria	Specific Examples	Applicable WRAPS/other data sources	Other considerations
"Connectivity/Fish Passage Barriers" Stream reaches where connectivity was identified as a stressor or other known fish passage barriers	Nine stream reaches were found to be limited by connectivity barriers (see Assessment table, Appendix 1) including the **inlets to Shetek and Sarah Lakes**. None of these reaches had few pollutants and stressors, so this criteria should be considered when other watershed work will be done. In other words, these streams may not respond by only removing the barrier.	Streams stressed by connectivity barriers were identified in the SID report and summarized in the WRAPS. A more comprehensive inventory of fish passage barriers is presented in the DNR Watershed Characterization report.	Work with county and township officials to opportunistically eliminate barriers when culverts or bridges are replaced.
"Drinking water and Ground water" Areas contributing water or risks to drinking and ground water resources	Red Rock Rural Water's Lindstrom Drinking Water Supply Management Area, Red Rock Rural Water Great Bend Drinking Water Supply Management Area, High vulnerability Drinking Water Supply Management Areas	Nitrogen concentration/load observed and modeled data and soils data (course textured and tile drained) can estimate higher yielding areas. MDH also provides information for targeting for drinking water source restoration and protection. A narrative is included in the Protection Considerations section or contact MDH for more info.	
"Wildlife habitat" Areas that provide critical habitat including endangered species and ecologically sensitive areas	**Lake Maria, Lange Marsh, Nelson's Marsh, Big Slough, Hjermstad Slough, Lake Sarah** are "Outstanding Lakes of Biological Significance".	Wetland Management Areas, National Wetland Inventory/Restorable Wetlands, and River Corridors are all data sets useful for identifying and prioritizing habitat. DNR Fisheries Lakes of Biological Significance (2015 GIS layer) identifies high quality lakes based on unique in-lake habitat features.	
"Popular recreational water bodies" Water bodies that are commonly used for recreation	**Lakes Shetek, North and South Heron, East and West Graham, Okamanpeedan, Clear, and Sarah Lakes** are valued for their recreational opportunities.	Civic engagement and the day-to-day work of local partners has identified several priority areas based on local values and special uses, particularly recreation. Many of these are mentioned in the CE work done as part of the Watershed Approach and can be further identified and refined by local staff and citizens.	

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Appendix

Appendix 1 – Assessment and SID Results

Assessment and SID Results by Stream Reach

				Beneficial Use and Associated Biology, Stressor, and Pollutant Assessment																				
				Aquatic Life																	Aq Rec		Lim Use	
					Bio		Stressors								Pollutants							Pol.		Pol.
AUID-3	Stream	Reach Description	Stream Class	Assessment*	Fish IBI	Macro IBI	Habitat	Eutrophication	Dissolved Oxygen	Nitrate	Altered Hydrology	Connectivity	TSS	Chloride	TSS	Dissolved Oxygen	Phosphorus	Chloride	pH	Unionized-Ammonia	Assessment*	Bacteria	Assessment*	Bacteria
07100001-501	Des Moines River	Windom Dam to Jackson Dam	2Bg, 3C	X	X	X	X	X	X	+	+	+	X		X	X	X	+	+	X	X	X	-	
07100001-504	County Ditch 20	Headwaters to Beaver Cr	2Bm, 3C	X	X	+	X	X	X	?	X	?	+		?	?	?		?	?	X	X	-	
07100001-508	Lower Lake Sarah O	First Unnamed cr on Lk Sarah outlet s	2Bg, 3C	X	X	X	+	X	X	+	X	X	X		?	?	?		?	?	X	X	-	
07100001-512	Okabena Creek	Unnamed cr to T102 R38W S6	7	-												?			+	+	-		X	X
07100001-513	Upper Lake Sarah O	Lk Sarah to Unnamed cr	2Bg, 3C																		X	X	-	
07100001-514	Jack Creek	N Br Jack Cr to JD 26	2Bg, 3C	X	X		X	X	X	X	X	X	X		?	?	?		?	?			-	
07100001-515	Judicial Ditch 76	Unnamed cr to Okabena Cr	2Bm, 3C	+	+	+									?	?	?		?	?			-	
07100001-517	Unnamed creek	Unnamed cr to Unnamed cr	2Bg, 3C																		X	X	-	
07100001-518	Unnamed creek	Unnamed cr to JD 3	2Bm, 3C	X	X	X	X	X	X	X	X	+	+		?	?	?		?	?			-	
07100001-519	Unnamed creek	Unnamed cr to Lk Shetek	2Bg, 3C																		X	X	-	
07100001-523	Judicial Ditch 26	Unnamed cr to Jack Lk	2Bm, 3C	X		X	X	X	?	X	X	?	+		?	?	?		?	?			-	
07100001-524	Des Moines River	Heron Lk outlet to Windom Dam	2Bg, 3C	X	X	X	X	X	+	+	+	+	X		X	?	?	+	+	+	X	X	-	
07100001-527	Heron Lake Outlet	Heron Lk (32-0057-01) to Des Moines	2Bg, 3C	X	X	X	X	X	X	+	?	?	X		X	?	X	+	X	?	X	X	-	
07100001-529	Division Creek	Okabena Cr to Heron Lk (32-0057-06)	2Bg, 3C	X											X								-	
07100001-533	Des Moines River	Lime Cr to Heron Lk outlet	2Bg, 3C	X	X	X	X	X	+	+	+	+	X		X	?	?	+	+	+	X	X	-	
07100001-535	Lime Creek	Lime Lk to Des Moines R	2Bg, 3C	X	X	X	X	X	X	X	?	+	X		X	?	?	+	+	+	X	X	-	
07100001-541	Des Moines River	Jackson Dam to JD 66	2Bg, 3C	X											X	?	?	+	+	+			-	
07100001-544	Perkins Creek	Warren Lk to Des Moines R	2Bm, 3C	X		X	X	X	X	+	X	+	+		?	?	?		?	?			-	
07100001-545	Des Moines River	Lk Shetek to Beaver Cr	2Bg, 3C	X	X	X	X	X	X	+	?	+	X		X	?	?	+	+	+	+	+	-	
07100001-546	Des Moines River	Beaver Cr to Lime Cr	2Bg, 3C	X	X	X	X	X	+	+	+	+	X		X	?	?		?	?	X	X	-	
07100001-549	Jack Creek	T104 R40W S31	2Bg, 3C	X	X	X	X	?	+	X	X	+	X		?	?	?		?	?			-	
07100001-551	Unnamed creek	String Lk to Des Moines R	2Bg, 3C	X	X	X	X	X	X	+	?	+	X		X	?	?		?	?			-	
07100001-552	County Ditch 43 (Sc	Unnamed cr to Des Moines R	B, 2Ag, 3	X	X	X	X	+	?	?	X	+	+		?	?	?		?	?			-	
07100001-563	Unnamed creek	Harder Lk to Unnamed cr	2Bg, 3C	X		X	X	X	X	X	?	+	+		?	?	?		?	?			-	
07100001-564	Unnamed creek	Unnamed ditch to Jack Cr	2Bg, 3C	X	X	X	X	X	X	+	X	+	?		?	?	?	+	+	+	X	X	-	
07100001-589	Judicial Ditch 14	Unnamed ditch to Unnamed cr	2Bm, 3C	+	+	+									?	?	?		?	?			-	
07100001-594	Unnamed ditch	Unnamed ditch to Unnamed ditch	2Bm, 3C	+	+	+									?	?	?		?	?			-	
07100001-602	Okabena Creek	Elk Cr to Division Cr	2Bg, 3C	X	X	X	X	X	X	X	?	+	X		X	+	?	X	+	+	X	X	-	
07100001-608	Unnamed creek	Unnamed cr to Unnamed cr	2Bm, 3C	+		+									?	?	?		?	?			-	
07100001-613	Unnamed creek	Unnamed cr to Des Moines R	2Bg, 3C	X	X	+	X	?	?	X	?	+	+		?	?	?		?	?			-	
07100001-614	Unnamed creek	Unnamed cr to JD 84	2Bm, 3C	X		X	X	X	X	X	X	+	+		?	?	?		?	?			-	
07100001-615	Unnamed creek	Unnamed cr to Elk Cr	2Bm, 3C	+	?	+									?	?	?		?	?			-	
07100001-618	Unnamed creek	Unnamed cr to Unnamed lk	2Bg, 3C	X	X	X	X	X	X	X	?	+	+		?	?	?		?	?			-	
07100001-619	Unnamed creek	Unnamed cr to JD 20	2Bg, 3C	X	X		X	X	?	?	X	+	X		?	?	?		?	?			-	

				Beneficial Use and Associated Biology, Stressor, and Pollutant Assessment																				
				Aquatic Life																	Aq Rec		Lim Use	
					Bio		Stressors								Pollutants							Pol.		Pol.
AUID-3	Stream	Reach Description	Stream Class	Assessment*	Fish IBI	Macro IBI	Habitat	Eutrophication	Dissolved Oxygen	Nitrate	Altered Hydrology	Connectivity	TSS	Chloride	TSS	Dissolved Oxygen	Phosphorus	Chloride	pH	Unionized-Ammonia	Assessment*	Bacteria	Assessment*	Bacteria
07100001-621	Unnamed creek	Unnamed lk to Des Moines R	2Bm, 3C	X	+	X	X	X	X	X	X	?	+		?	?	?		?	?			-	
07100001-624	Unnamed creek	Headwaters to Unnamed creek	2Bm, 3C	X	X	X	X	X	X	X	X	?	+		?	?	?		?	?			-	
07100001-625	Unnamed creek	Unnamed cr to unnamed cr	2Bg, 3C	X	X	X	X	X	X	X	X	X	X		?	?	?		?	?			-	
07100001-626	Unnamed creek	Unnamed cr to Unnamed cr	2Bg, 3C	X	X	X	X	X	X	X	?	+	+		?	?	?		?	?			-	
07100001-628	Unnamed creek	Unnamed cr to Unnamed cr	2Bg, 3C	X	X	X	X	X	X	X	X	?	+		?	?	?		?	?			-	
07100001-632	Unnamed creek	Unnamed cr to Lk Maria	2Bg, 3C	X	X	X	X	+	?	X	X	X	+		?	?	?		?	?			-	
07100001-637	Unnamed creek	Unnamed cr to Lk Shetek inlet	2Bg, 3C	X		X	X	X	X	X	X	X	+		?	?	?		?	?			-	
07100001-641	Lake Shetek Inlet	-95.9137 44.1640 to -95.8869 44.2032	2Bg, 3C	X	X	X	X	X	?	X	?	?	+		?	?	?		?	?			-	
07100001-642	Lake Shetek Inlet	-95.8869 44.2032 to -95.8495 44.2061	2Bm, 3C	X	X	+	X	X	X	X	X	X	+		?	?	?		?	?			-	
07100001-643	Lake Shetek Inlet	-95.8495 44.2061 to -95.7553 44.1793	2Bg, 3C	X	X	?	X	X	X	?	?	X	X		?	?	?		?	?	X	X	-	
07100001-644	Lake Shetek Inlet	-95.7553 44.1793 to Lk Shetek	2Bg, 3C																		X	X	-	
07100001-646	Beaver Creek	121st Ave to Des Moines R	2Bg, 3C	X	X	+	X	X	X	X	X	?	X		X	?	?	+	+	+	X	X	-	
07100001-649	Jack Creek	North Branch	2Bm, 3C	X	X		X	X	+	X	X	+	?		?	?	?		?	?			-	
07100001-651	Jack Creek, North B	North Branch, 31st St to JD 12	2Bg, 3C	X											X								-	
07100001-652	Jack Creek	North Branch	2Bg, 3C	X	X	?	X	X	?	X	X	+	X		X	?	?	+	+	+	X	X	-	
07100001-654	Elk Creek	T- 41 to CSAH 3	2Bg, 3C	+	+	+									?	?	?		?	?			-	
07100001-656	Elk Creek	-95.4791 43.6750 to Okabena Cr	2Bg, 3C	X	X	X	X	X	X	X	X	+	?		X	?	?	+	+	+	X	X	-	
07100001-658	Jack Creek	MN Hwy 60 to -93.3062 43.7685	2Bm, 3C	X	X	+	X	X	X	X	X	+	X		X	+	?	+	+	+	X	X	-	
07100001-659	Jack Creek	-93.3062 43.7685 to Heron Lk	2Bg, 3C	X											X						X	X	-	
07100001-661	Unnamed creek	-95.5572 43.8293 to West Graham Lk	2Bg, 3C	X	X	X	X	X	X	?	X	?	+		?	?	?		?	?			-	
07100001-663	Beaver Creek	131st St to JD 14	2Bg, 3C	X	X	X	X	?	+	?	?	?	X		?	?	?		?	?			-	
07100001-664	Beaver Creek	JD 14 to CD 20	2Bm, 3C	X	X	+	X	X	?	X	X	?	?		?	?	?		?	?			-	
07100001-665	Judicial Ditch 12	Unnamed cr to CSAH 18	2Bm, 3C	+	+										?	?	?		?	?			-	
07100001-666	Judicial Ditch 12	CSAH 18 to N Br Jack Cr	2Bg, 3C	X	X	X	X	X	X	X	X	+	+		?	?	?		?	?			-	
07100001-668	Devils Run Creek	Unnamed cr to Des Moines R	2Bg, 3C	X	X	?	X	X	X	+	X	X	+		?	?	?		?	?			-	
07100001-670	Unnamed creek	490th Ave to Warren Lk	2Bg, 3C	X		X	+	X	?	?	?	+	+		?	?	?		?	?			-	
07100001-672	Unnamed creek	21st St to Talcot Lk	2Bg, 3C	X	X	X	X	X	X	X	X	?	+		?	?	?		?	?			-	
07100002-501	Des Moines River	JD 66 to MN/IA border	2Bg, 3C	X	X	X	?	X	+	+	+	+	X		X	?	?	+	+	+	X	X	-	
07100002-502	Brown Creek (Judic	Headwaters to MN/IA border	2Bm, 3C	X	+	X	X	X	X	X	X	+	+		?	?	?		?	?			-	
07100002-504	Unnamed creek	JD 11 to Des Moines R	2Bg, 3C	X	X	X	+	?	X	X	X	+	?		?	?	?		?	?			-	
07100002-505	Judicial Ditch 56	Unnamed cr to Des Moines R	2Bg, 3C	X	X	X	X	X	X	+	?	+	?		?	?	?		?	?			-	
07100002-507	Story Brook	JD 56 to Des Moines R	2Bg, 3C	X	X	X	+	?	X	X	X	+	X		?	?	?		?	?			-	
07100002-510	Unnamed ditch	Unnamed ditch to Unnamed ditch	2Bg, 3C	X	X	?	X	X	?	X	X	+	+		?	?	?		?	?			-	
07100002-513	Judicial Ditch 6	Unnamed ditch to Unnamed ditch	2Bm, 3C	+	+	+									?	?	?		?	?			-	
07100003-503	County Ditch 11	Headwaters to E Fk Des Moines R	7	-												?			+	+	-		X	X
07100003-506	County Ditch 53	Unnamed cr to MN/IA border	2Bm, 3C	X	X	+	X	X	X	X	X	+	+		?	?	?		?	?			-	
07100003-510	Fourmile Creek	JD 105 to Des Moines R	2Bg, 3C	X	X	X	X	X	+	X	?	+	+		+	?	?		+	+	X	X	-	
07100003-515	County Ditch 1/Judi	Unnamed cr to CD 11	2Bm, 3C	+	+	+									?	?	?		?	+	X	X	-	
07100003-516	Mud Slough	Unnamed ditch to Bright Lk	2Bg, 3C	?											?	?	?		?	+	+	+	-	
07100003-521	Unnamed creek	Unnamed cr to Unnamed cr	2Bg, 3C	?											+								-	
07100003-525	Des Moines River, East Branch		2Bg, 3C	X	X	?	X	X	X	X	X	+	+		?	?	?	+	+	+	X	X	-	
07100003-527	Des Moines River		2Bg, 3C	X	X	+	X	X	X	X	X	+	X		X	X	?	+	+	+	X	X	-	
07100003-529	Unnamed creek	-94.8641 43.6264 to Des Moines R	2Bg, 3C	X	X	X	X	X	?	X	X	X	+		?	?	?		?	?			-	

Assessment and SID Results by Lake

Major Watershed	Code	Lake Name	Phosphorus Assessment	Clarity Trend	Fish IBI Assessment	Stressors			
						Eutrophication	Poor shoreline habitat	Lack of plant habitat	Abundant carp/bullhead
Des Moines Headwater	51-0045-00	Armstrong Slough		?					
	51-0105-00	Big Slough	?	?					
	51-0040-00	Bloody	X	--	?				
	32-0015-00	Boot	X	?					
	51-0018-00	Buffalo	?	?	?				
	51-0011-00	Corabelle	X	?	X	X	?	?	?
	17-0022-00	Cottonwood	?	?	X	?	X	?	X
	51-0082-00	Currant	X	--	X	X	?	X	X
	51-0090-00	Current Lake Marsh	?	?					
	53-0020-00	East Graham	X	?	X	X	?	X	X
	51-0021-00	First Fulda	+	+	?				
	32-0045-00	Flahtery	X	?					
	51-0043-00	Fox	X	?	X	X	?	?	X
	51-0039-00	Fremont	?	?					
	17-0031-00	Harder	?	?					
	32-0057-02	Heron (Duck)	X	?					
	32-0057-05	Heron (North Heron)	X	?					
	32-0057-01	Heron (North Marsh)	?	?					
	32-0057-07	Heron (South Heron)	X	?					
	51-0089-02	Hjermstad Slough	?	?					
	51-0079-00	Iron	?	?	?				
	53-0016-00	Kinbrae		?					
	53-0018-00	Kinbrae Slough		?					

Major Watersend	Code	Lake Name	Phosphorus Assessment	Clarity Trend	Fish IBI Assessment	Stressors			
						Eutrophication	Poor shoreline habitat	Lack of plant habitat	Abundant carp/bullhead
Des Moines Headwater	42-0032-00	Lake of the Hill	?	?					
	51-0024-00	Lime	X	?	X	X	?	X	X
	51-0062-00	Maria	?	?					
	51-0050-00	North Badger		?					
	51-0089-01	North Marsh	?	?					
	17-0044-00	North Oaks	X	?	?				
	51-0063-00	Sarah	X	+	X	X	?	X	X
	51-0020-00	Second Fulda	+	?	?				
	51-0046-00	Shetek	X	X	X	X	X	?	X
	51-0049-00	South Badger		?					
	17-0041-00	South Clear	?						
	17-0024-00	String	?	?	?				
	17-0073-00	Summit	?	?	?				
	51-0068-00	Summit	?	X	?				
	17-0060-00	Talcot	X	?	X	X	?	X	X
	32-0053-00	Teal	X	?					
	32-0058-00	Timber	X	?					
	17-0030-00	Unnamed	?	?					
	51-0104-00	Unnamed	?	?					
	51-0023-00	Unnamed	?	?					
	53-0021-00	West Graham	X	?	X	X	?	?	X
	17-0013-00	Wolf	?	?					
	42-0047-00	Yankton	X	--	X	X	?	X	X

Major Watershed	Code	Lake Name	Phosphorus Assessment	Clarity Trend	Fish IBI Assessment	Stressors			
						Eutrophication	Poor shoreline habitat	Lack of plant habitat	Abundant carp/bullhead
East Fork	46-0052-00	Bright	X	?	X	X	?		x
	46-0061-00	Clayton	?	?					
	46-0096-00	Clear	?	X	?				
	46-0098-00	Dutton Slough	?	?	?				
	46-0095-00	Fish	?	?					
	46-0088-00	Little Tuttle	?	?					
	46-0051-00	Okamanpeedan	X	?	?				
	46-0076-00	Pierce	X	?					
	46-0094-00	Susan	?	?					
	46-0103-00	Temperance	X	?	X	X	?	X	X

X	=	Impaired/declining trend/probable stressor
?	=	Inconclusive (need more data)
+	=	Supporting/improving trend/not a stressor
--	=	No trend detected
<blank>	=	No data

Appendix 2 – Source Assessment Supplementary Information

Summary Source Assessment Lines of Evidence

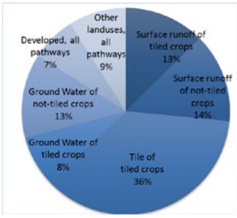
Specific Source Assessment Analyses (including source and applicable area)

HSPF Source Assessment for Des Moines (model years 1994-2014)

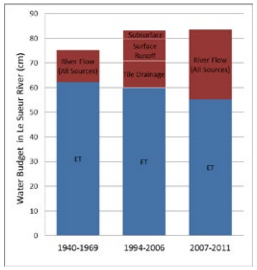
2013-2017 Discovery Farms Data for the tiled farms (BE1, DO1, RE1)

2009-2013 Watershed Pollutant Load Monitoring Network Data

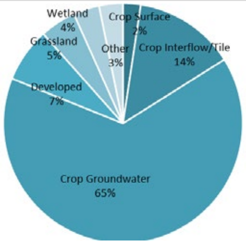
Q

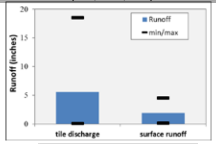


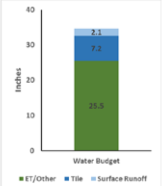
water portioning calculator (boettcher), assumes 60% of watershed tiled



Middle bar of water budget: SWAT modeling of water budget by Folle







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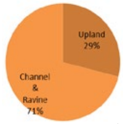
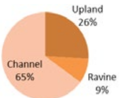
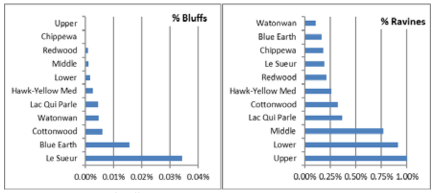
TSS



finger-printing, MN River US from mid mn (schottler)

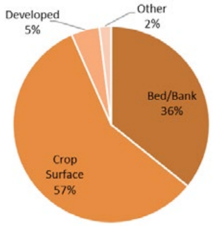


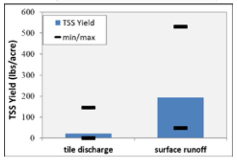
Gran Sediment Budget for Le Sueur River

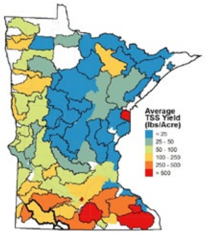


Mulla estimate of bluff and ravine areas per major watershed

MN River Basin Near Stream Sediment Sources (Mulla, 2010)







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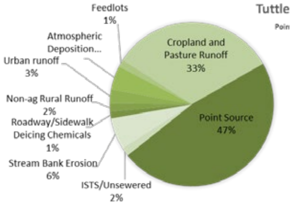


Detailed Assessments of Phosphorus Sources to Minnesota Watersheds

Barr Engineering and the PCA (2003 with 2007 update)

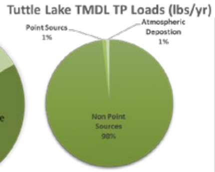
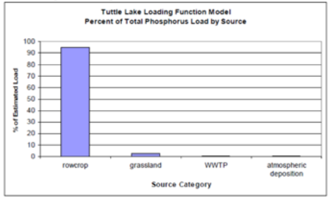
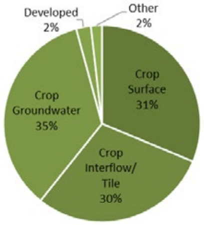


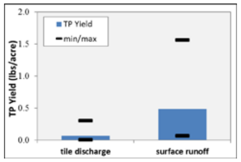
Figure 2. Loading Function Model Source Contributions

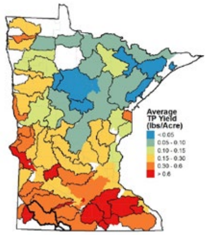


TMDL for Algae and Turbidity Tuttle Lake

Iowa DNR (2004)







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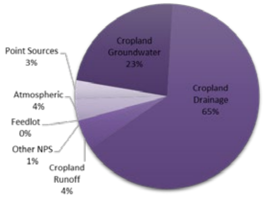
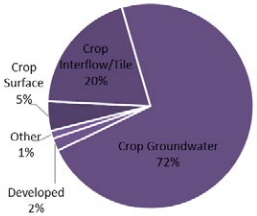
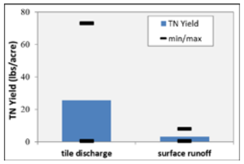
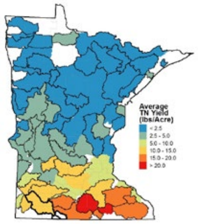


PCA Assessment for DM Basin, avg yr

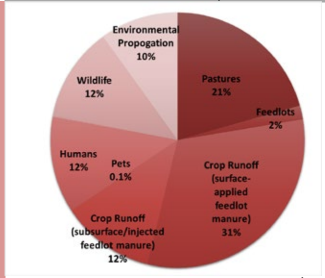


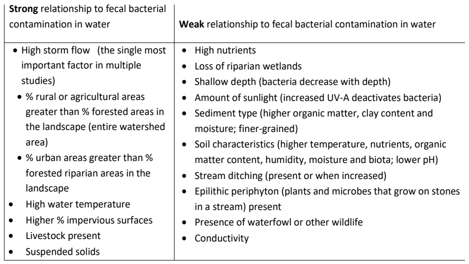




TN

	Specific Source Assessment Analyses (including source and applicable area)	HSPF Source Assessment for Des Moines (model years 1994-2014)	2013-2017 Discovery Farms Data for the tiled farms (BE1, DO1, RE1) http://www.discoveryfarmsmn.org/	2009-2013 Watershed Pollutant Load Monitoring Network Data	
Bacteria					Bacteria





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

PCA/Emmons & Oliver literature summary of bacteria coorelation

Bacteria Calculator, Boettcher

Figure 3.2. Estimated fecal coliform produced by source in Nobles Co.

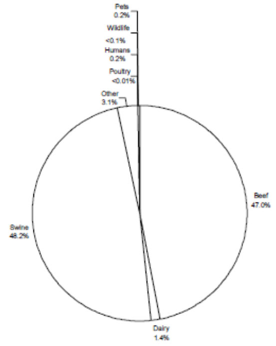


Figure 3.3. Estimated fecal coliform produced by source in Cottonwood Co.

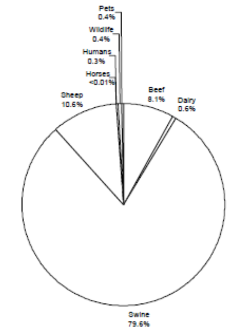


Figure 3.4. Estimated fecal coliform produced by source in Jackson Co.

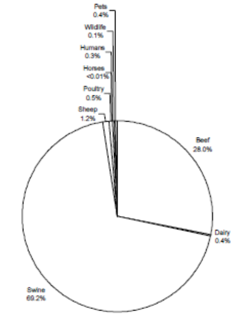
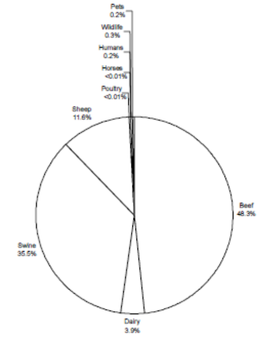


Figure 3.5. Estimated fecal coliform produced by source in Murray Co.



WFDM River Watershed TMDL Final Report: Excess Nutrients (North and South Heron Lake), Turbidity, and Fecal Coliform Bacteria Impairments
Barr Engineering and MPCA (2008)

Bacteria Source Estimate Calculator

Bacteria Source Estimates Calculator

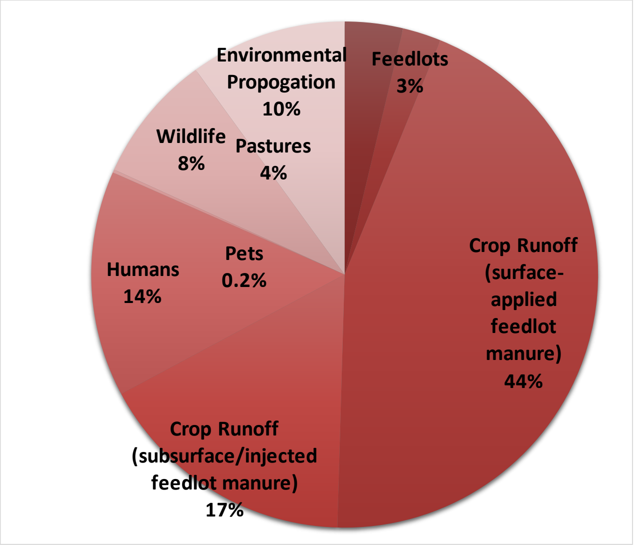
DIRECTIONS : 🟧 = enter value for watershed (known or assumption).

Waterhsed	**wat.**
Total area (ac)	1635152
Total Pasture (ac) with grazing animals (19600 total pasture acres plu	2000
Pasture <1000ft of water body (ac) (should never be greater than B6	2000
Total AUs	193000
% feedlot AUs whose manure stockpiles w/o runoff controls (professional ju	5%
number of pasture acres per 1 grazed AU (on average throughout the year do	4
% Feedlot manure applied Surface • Surface applied manure generally tends	15%
% Feedlot manure applied Subsurface	85%
Pasture >1000 ft (ac)	0
pasture <1000ft AUS	500
pasture >1000ft AUs	0
Feedlot AUs	192500
Feedlot inadequate runoff AUs	9625
Feedlot surface applied AUs	28875
Feedlot subsurface applied AUs	163625
Human population	34000
number of failing septics per 1,000 acres(based on county reportings)	3
number of people per failing septic (avg household size)	2
# humans equivalent to 1 AU (1AU = 1000 lbs steer waste)	7
# acres per 1 wildlife AU of total watershed (right now low)	500
humans per pet (one pet for every x humans)	3
# pets comparable to 1 AU	30
% of total load due to environmental propogation (assumed based on litera	10%
people using failing septics	8176
% of human wastewater inadequatetly treated (on failing septics)	24%
of human wastewater is adequately treated	76%
Human - inadequate treatment AUs	1168
Human - adequate treatment AUs	3689
Pet AUs	378
Wildlife AUs	3270
over time frame	5%
Dry conditions (no active runoff)	95%

Total Livestock AUs data includes pastured animals

each AU produces 1 unit of manure/bacteria

	condition	Pastures adjacent waterways	Other pastures	Pastures	Feedlots	Crop Runoff (surface-applied feedlot	Crop Runoff (subsurface/injected feedlot	Humans	Pets	Wildlife	Environmental Propogation	Human - adequately treated wastewater	Human - inadequately treated wastewater	SUM of Crop applied manure
Delivery ratio (assumed)	wet	5.0%	1.0%		0.5%	3.0%	0.2%		1.0%	3.0%		0.05%	2.0%	
Production x Delivery ratio x % of time		1.3	0.0		2.4	43.3	16.4		0.2	4.9		0.1	1.2	
Delivery ratio (assumed)	dry	0.5%	0.0%		0.0%	0.0%	0.0%		0.0%	0.1%		0.05%	1.0%	
Production x Delivery ratio x % of time		2.4	0.0		0.0	0.0	0.0		0.0	3.1		1.8	11.1	
Total Delivered Units		3.6	0.0	3.6	2.4	43.3	16.4	14.1	0.2	8.0	10	1.8	12.3	59.7
Total Delivered Percentage		3.7%	0.0%	3.7%	2.5%	44.3%	16.7%	14.4%	0.2%	8.2%	10.0%	1.9%	12.5%	61.0%



Calculator by J Boettcher

Calculation method based on GBE fecal TMDL, but with other/additional assumptions and calculation methods

Water Portioning Calculator

Key
this color = known for watershed
this color = assumption, based on other available data where possible
this color = calculated using knows and assumptions
<no color> = known value/used to check calculations, value = 0 or 1

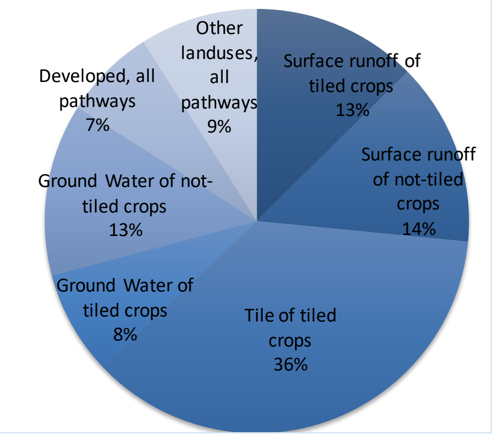
Landuse	% of crops	% of watershed
tiled ag	60%	49.2%
not tiled ag	40%	32.8%
all ag	100%	82%

GIS estimate for tile: 30% likely, 37% may - use 50% of watershed is tiled

Ratios of Water Yields				
The per acre tile water yield ratio for a tiled:not tiled field is	1.0	:	0	untiled field has no tile water path
Assume the surface runoff water yield ratio for a tiled:not tiled field is	0.60	:	1.0	see check numbers below (yellow)
Assume that in a tiled field, the tile:surface water yeild ratio is	2.9	:	1.0	see check numbers below (blue)
Assume that the GW:total ratio of river water for watershed = that of ag ar	0.25	:	1.0	see check numbers below (light blue)
Assume that the per acre GW yield ratio for a tiled:not tiled field is	1.0	:	2.5	
Assume that the per acre yield for all flowpaths ratio for a tiled:not tiled fi	1.40	:	1.0	see check logic below (pink)

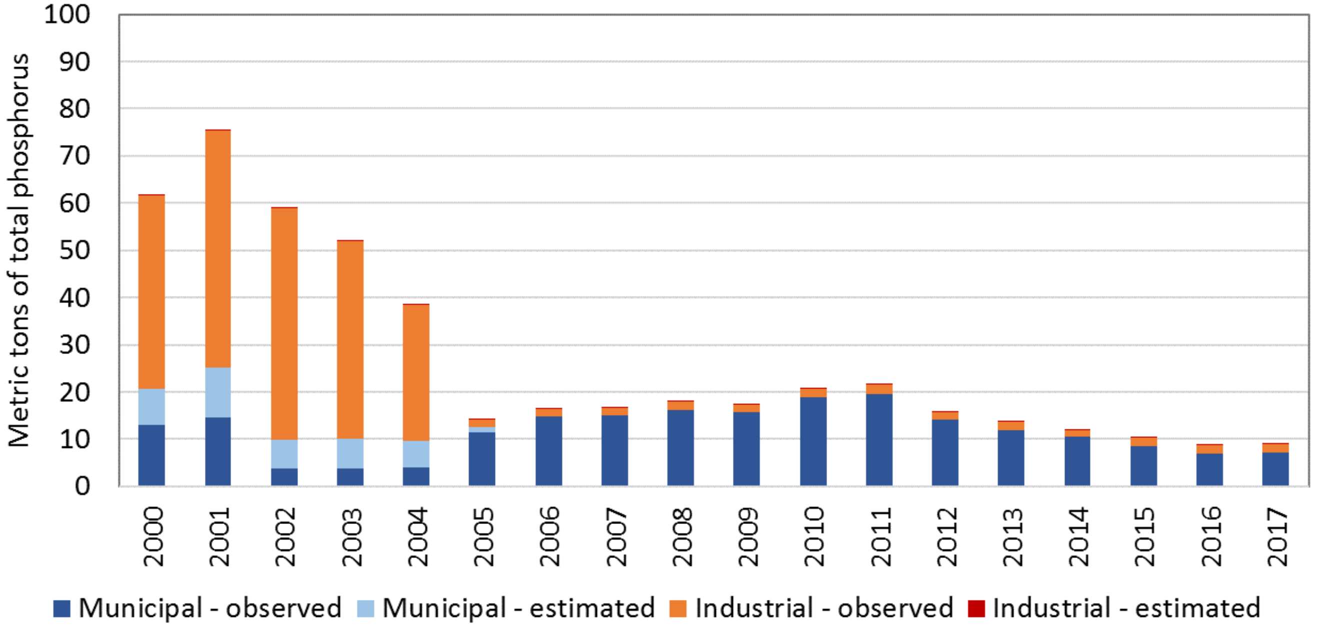
% of water yields by flow path between tiled and untiled land	% of ag water tile yields	% of ag water surface	% of ag water GW yields	% of total water from	% of total watershed
tiled land	100%	47.4%	38%	68%	57%
not tiled land	0%	53%	63%	32%	27%
all ag land	100%	100%	100%	100%	84%

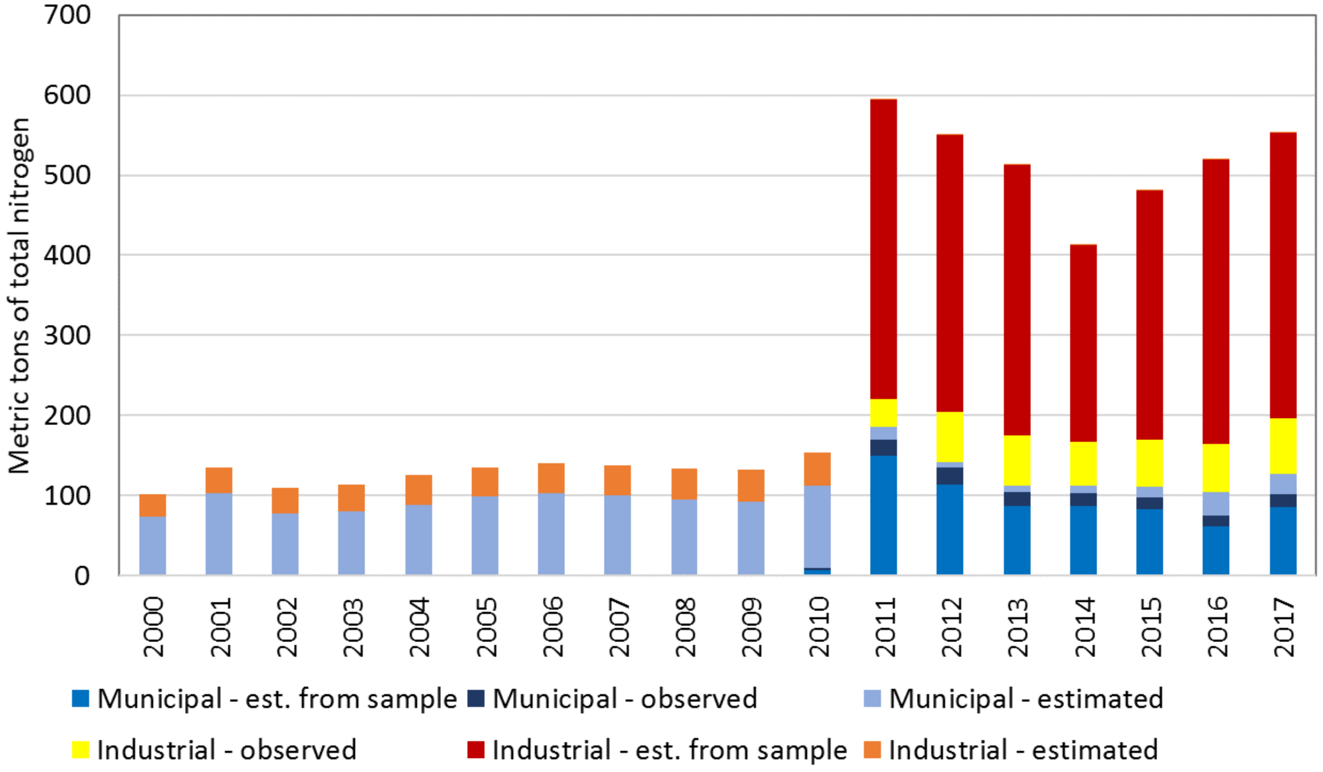
Flow contributions by flow path toward total watershed contributions	tiled ag	not tiled ag	all ag land
% from tile	36%	0%	36%
% from surface	13%	14%	27%
% from GW	8%	13%	21%
% from all ag paths	57%	27%	84%

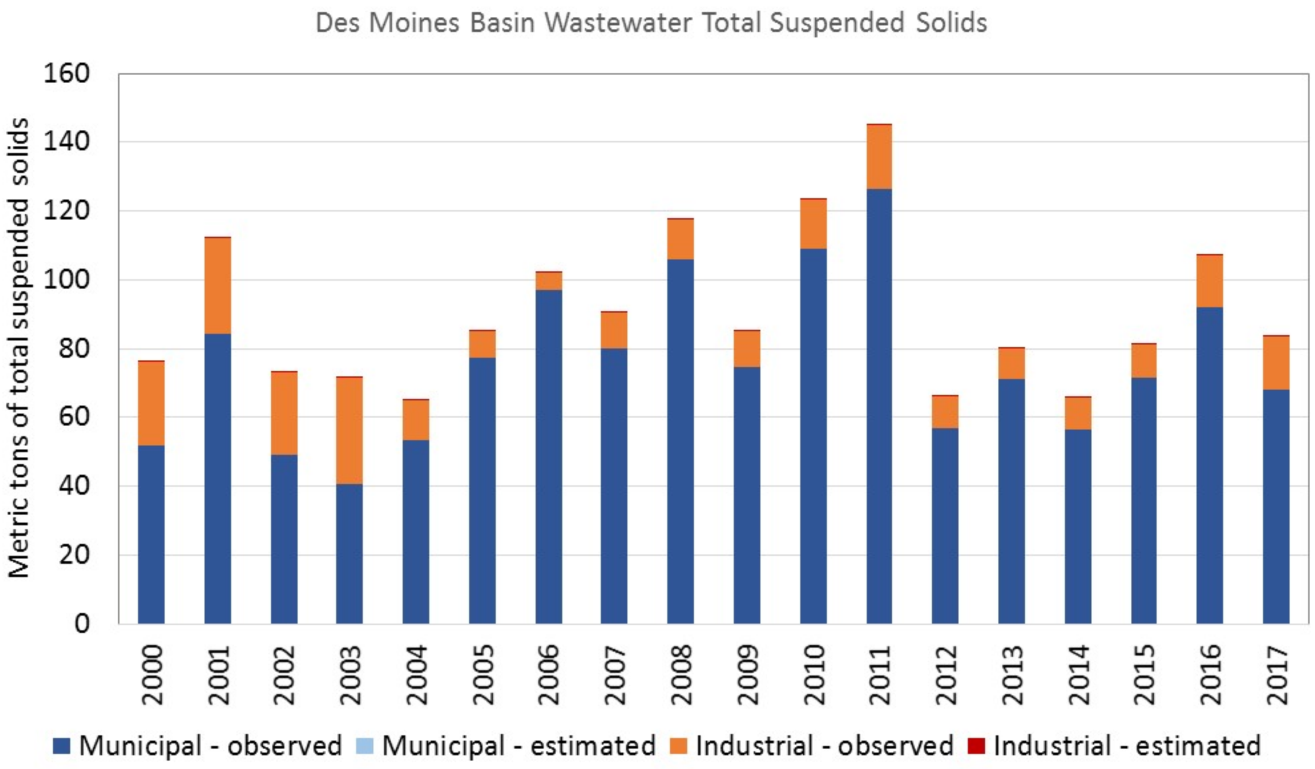


Data and Estimates for Checks in Calculator-recalc values when updated info is available		
Watershed Yield (in) (WPLMN data)	7.5	des moines years through 2016
Change in River flow due to drainage (in) (estimated from Schottler, etc.)	1.8	reported for des moines
Average Surface Runoff from Not-tiled sites (in) (Discovery Farms)	3.0	
Average Surface+Tile from Tiled sites (in) (DiscoveryFarms)	7.5	tiled farms represented by BE1, DO1, and RE1 through 2017
Average Surface+Tile yield ratio for tiled:not tiled (ratio) (Discover Farms)	2.5	
Average surface runoff ratio for a tiled:not tiled (ratio) (Discovery Farms)	0.6	
Average Tile Runoff from Tiled sites (in) (Discovery Farms)	5.6	
Average Surface Runoff from Tiled sites (in) (Discovery Farms)	1.9	
Average Tile:Surface water yield ratio in a tiled field (ratio) (Discovery Farn	2.9	
Estimated Tile Runoff from Tile Drained Areas (in)	3.6	
baseflow estimate/justification - whole watershed	0.20	
baseflow - tiled farm	0.15	
Estimate of % ground water (See Folle)	0.2	
tiled all paths	8.6	
not tiled all paths	6.0	
	1.4	

Point Source Data Summary


Des Moines Basin Wastewater Total Phosphorus


Des Moines Basin Wastewater Total Nitrogen


Des Moines Basin Wastewater Total Suspended Solids
Metric tons of total suspended solids
0
20
40
60
80
100
120
140
160
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Municipal - observed
Municipal - estimated
Industrial - observed
Industrial - estimated

Point Source Contribution to Total Watershed Load Calculation

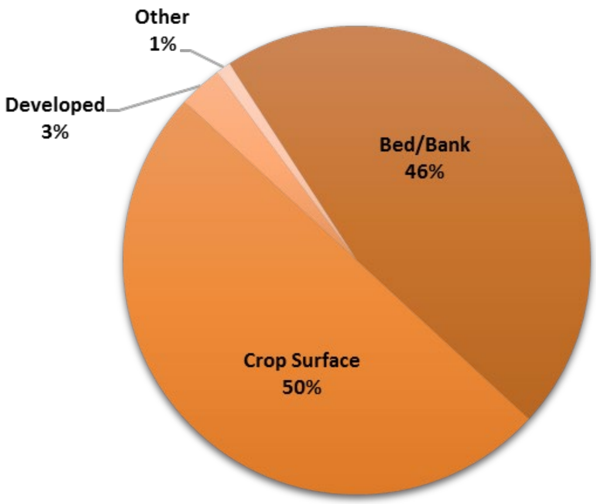
FLX_PARAM	FLX_START	FLX_END	Mass (kg)	2008-2016 kg at Jackson	Extrapolated 2008-2016 kg from MN portion of watershed	Point Source 2008-2016 kg	**Estimated** % Point of Total Watershed Load
TN	1/1/2008	12/31/2008	3027750	38,155,213	46,917,510	3,490,704	7%
TN	1/1/2009	12/31/2009	2118391				
TN	1/1/2010	12/31/2010	7968451				
TN	1/1/2011	12/31/2011	6985088				
TN	1/1/2012	12/31/2012	2173495				
TN	1/1/2013	12/31/2013	2030706				
TN	1/1/2014	12/31/2014	1790378				
TN	1/1/2015	12/31/2015	3805070				
TN	1/1/2016	12/31/2016	8255884				
TP	1/1/2008	12/31/2008	79105	1,183,965	1,455,862	137,705	9%
TP	1/1/2009	12/31/2009	83137				
TP	1/1/2010	12/31/2010	295700				
TP	1/1/2011	12/31/2011	229652				
TP	1/1/2012	12/31/2012	131552				
TP	1/1/2013	12/31/2013	131552				
TP	1/1/2014	12/31/2014	72304				
TP	1/1/2015	12/31/2015	45417				
TP	1/1/2016	12/31/2016	115547				
TSS	1/1/2008	12/31/2008	34490391	383,757,911	471,887,436	871,249	0.2%
TSS	1/1/2009	12/31/2009	24876766				
TSS	1/1/2010	12/31/2010	84054218				
TSS	1/1/2011	12/31/2011	61141224				
TSS	1/1/2012	12/31/2012	47875848				
TSS	1/1/2013	12/31/2013	25669800				
TSS	1/1/2014	12/31/2014	30619640				
TSS	1/1/2015	12/31/2015	23326547				
TSS	1/1/2016	12/31/2016	51703477				

These cells were ESTIMATED USING AVERAGE OF THE ANNUAL MASS FROM 2008-11 AND 2014-16.

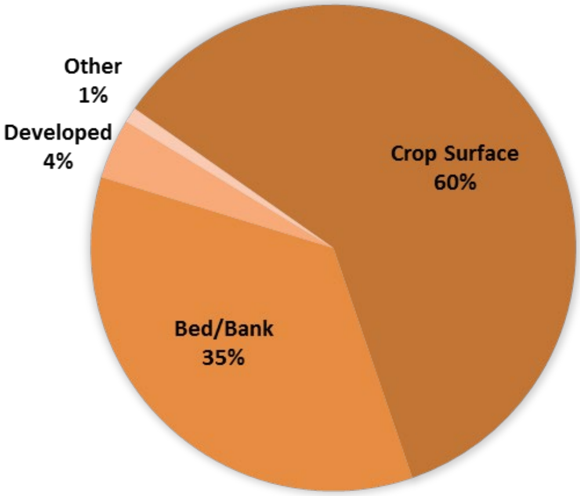
Upstream of Jackson site	800000	
Total Watershed Acres in Minnesota	983719	81%

Source Assessment Workshop Results - TSS

Watershed above Des Moines River near Avoca site:



Watershed below Des Moines River near Avoca site and East Fork Des Moines River



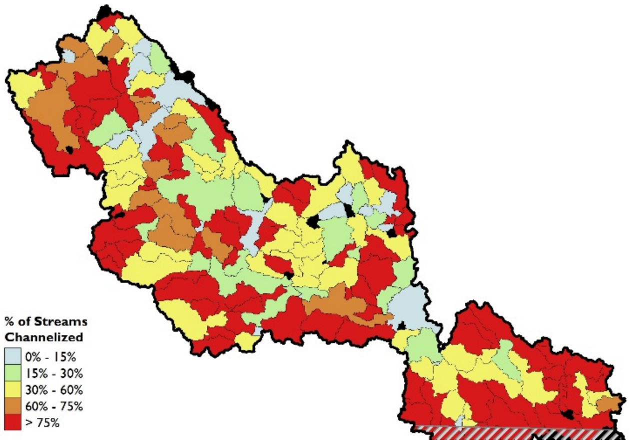
Pre-European Settlement Landscape Map Data Sources

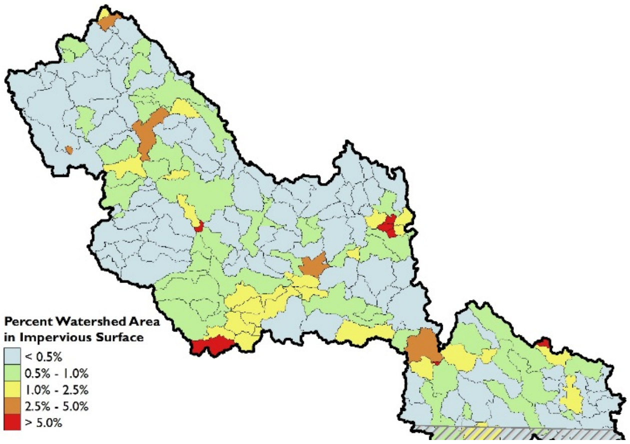
Figure 13 (Section 2.1) is an approximation of the pre-European settlement landscape. It is not intended for numerical analysis, but rather offers a small scale illustration (or paints the picture) of the pre-European settlement, which was predominantly prairie with waterbodies and wetlands (prairie wetlands, some streams, and some forested riparian areas). The pre-settlement landscape was estimated using the following data sources:

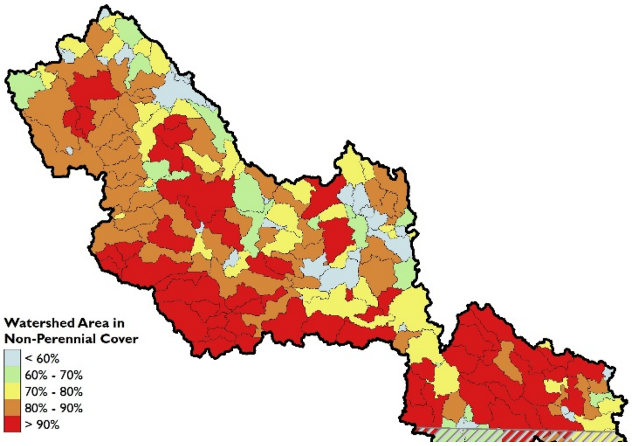
1. A digitized copy of the streams from the U.S. General Land Office Survey survey maps and notes (from 1848 through 1907; MnGeo 2011). Note that this digitization was intended to generally represent the features as captured in the U.S. General Land Office Survey maps and notes as documented 110 to 169 years ago. It cannot be used to calculate miles or to do analysis at a large (close up) scale. The image of this data layer may be used at a smaller (far away) scale, but is not visible at the scale presented.

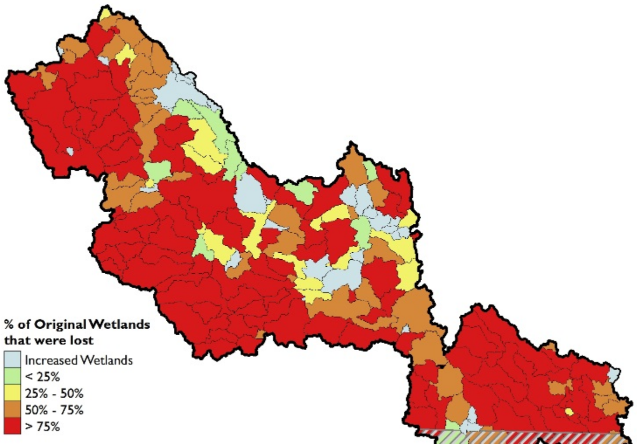
2. Drained wetlands were pulled from the National Wetland Inventory (USFSW 2016) and Restorable Wetlands were pulled from the Restorable Wetland Inventory (USFWS 2009).
3. Additional wetland areas were pulled from Marschner's analysis. The Original Vegetation of Minnesota: data was first compiled in 1930 by F. J. Marschner (of the Office of Agricultural Economics, USDA) from the data created by the U.S. General Land Office Survey notes. In 1974, the Marschner's data was interpreted and mapped by M.L. Heinselman and others at the U.S. Forest Service (North Central Forest Experiment Station in St. Paul). This map was then digitized and modified by the DNR Natural Heritage and Nongame Research Program in the 1980s and later. The original map was done at 1:500,000 and then attributes and geography generalized for display, at approximately 1:1 million, at which the presented map is approximately shown. The purpose of the data is to analyze pre-settlement vegetation patterns for the purpose of determining natural community potential, productivity indexes and patterns of natural disturbance.

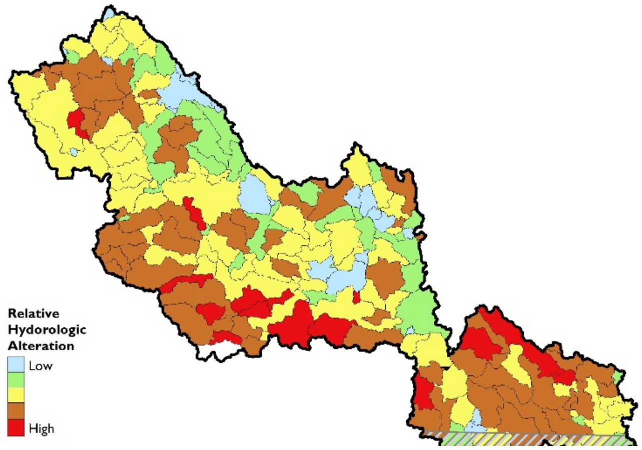
Altered Hydrology GIS Analysis

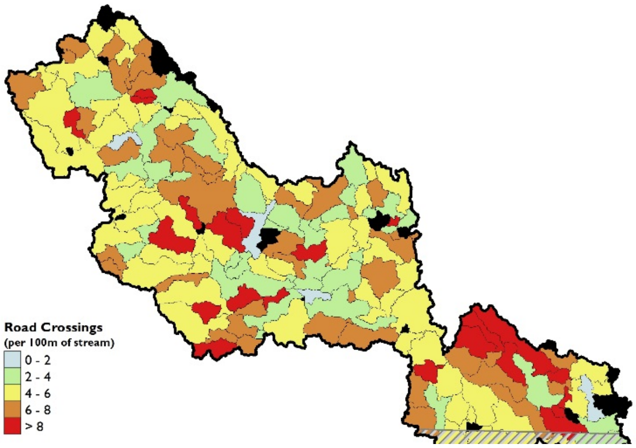


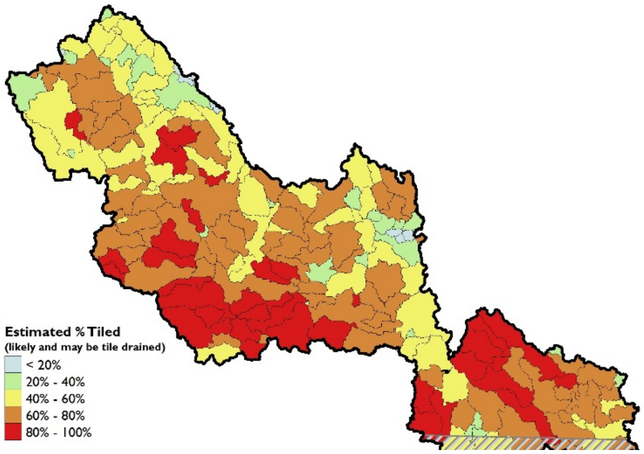












Interpretation of the Feedlot Statistics

Interpretation of feedlot statistics for the Des Moines River Basin were provided by the MPCA feedlot staff.

- Surface applied manure generally tends to come from smaller feedlots or "smaller" dairies or poultry.
- Facilities with <300 AUs generally have limited manure storage so manure application occurs on a more frequent basis and are not required to have a manure management plan or test their soils for P.
- Facilities with <100 AU have even fewer restrictions under the feedlot rules.
- Poultry litter does not follow the general rule of being spread close to a facility. It is generally brokered out to area crop farmers who are willing to pay for the manure. Because of the higher nutrient value and ease at which it can be hauled in a semi, this type of manure is more "mobile" then other manures. Implications of this include:
  - most of the manure is surface applied

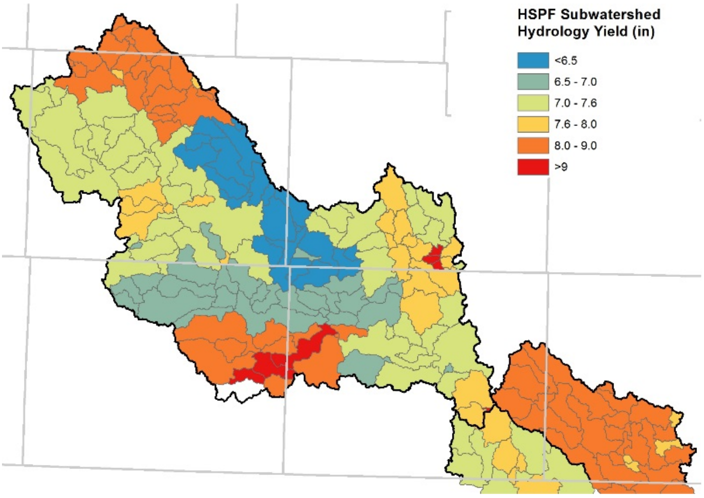
  - generally, manure from these facilities is sold to nonlivestock farmers
  - barns are cleaned out when barns are emptied of mature birds so tends to lead to a significant amount of temporary manure stockpiles in fields which can have their own issues (they must meet setback requirements but generally do not have runoff controls like permanent stockpile sites) since they are exposed to weather extremes
- Most feedlots have to keep records of manure application and the MPCA and/or delegated counties have the authority to request these records but because of a lack staffing generally do not request them. The NPDES permitted sites have to submit annual reports with their manure records but lack of staffing does not allow comprehensive tracking of the acres.

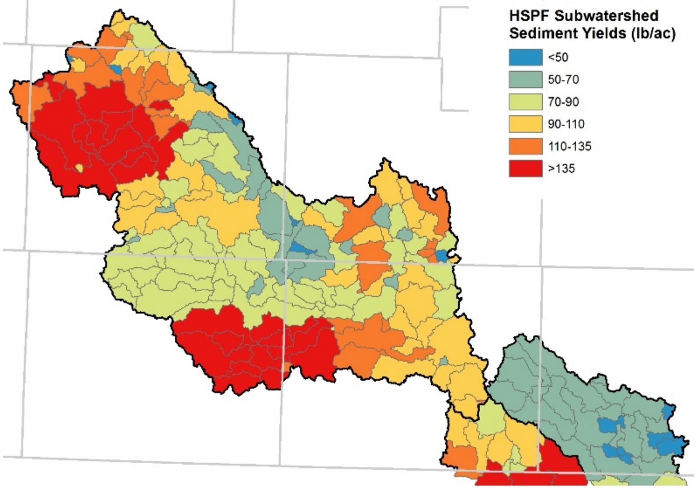
Feedlots with NPDES Permits

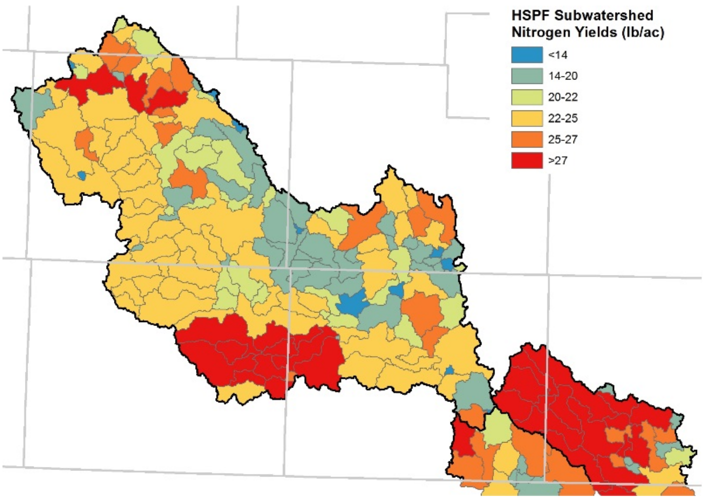
	Name	County
Des Moines River - Headwaters	Christensen Farms Site C013	Cottonwood
	Triple X Swine LLP	Cottonwood
	Christensen Farms Site F077	Cottonwood
	Christensen Farms Site - F132	Cottonwood
	Brian Majerus Farm - Farmland Site	Jackson
	Brewster Finisher	Jackson
	Lake Shore Pork	Jackson
	Brian & Mark Soleta Farm	Jackson
	Salentiny Brothers Farm	Jackson
	Paul Henning Farm	Jackson
	GED Farms	Jackson
	Larry & Wayne Christopher Farm	Jackson
	Schwartz Farms Inc - Brewster	Jackson
	Brian & Mark Soleta Farm - Sec 16	Jackson
	Farm 277 - Burnham	Jackson
	Buldhaupt Farms	Murray
	VanderPoel Hog Properties	Murray
	Schultz Hog Farms Inc	Murray
	Faccendiere - Tutt Site	Murray
	Gervais Brothers II	Murray
	Kramer Swine Finishing	Murray
	Adam Miller Farm	Murray
	Todd Miller Farm	Murray
	Phil Gervais Farm	Murray
	MW Gervais Farms LLC	Murray
	G & K Kramer Inc	Murray
	Chad Swenson Swine Facility	Murray
	Mike Haupert Farm	Murray
	Keith Doeden Farm	Murray
	Birch Lawn Farms Inc	Murray
	G & K Kramer Inc - Sec 21	Murray
	Doug & Jerry Brake	Murray
	Grant Prins - Sec 35	Murray
	Hurd Hog Farm Inc	Murray
	Robert Ford Farm - Dennis Site	Murray
	Darin Henning Feedlot	Murray
	Oscar Carlson Farm	Murray
	Faccendiere-Gilbertson	Murray
	507 Feeders LLC	Murray
	Brake Feedyards LP	Nobles
	Multi-Site - Double K Inc	Nobles
	Multi-Site - Double K Inc	Nobles

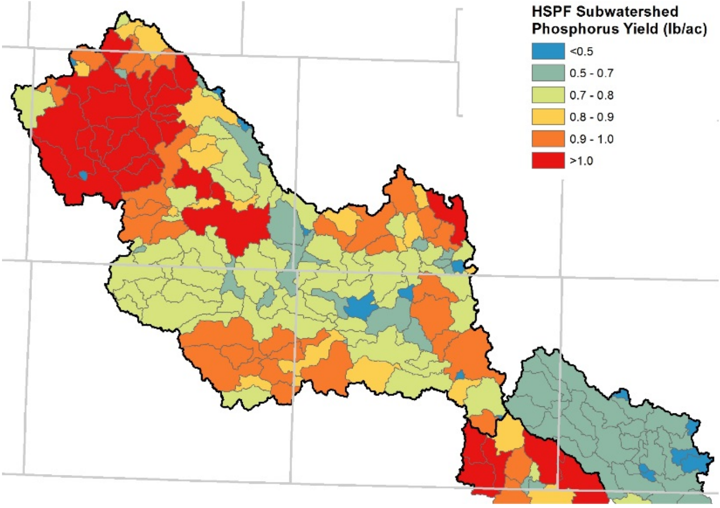
	Name	County
Des Moines River - Headwaters	Paradise Pork	Nobles
	Southwest Prairie Pork - Wilmont 13	Nobles
	Randy Hein Farm	Nobles
	Russ Penning Farm - Sec 4	Nobles
	Wilmont Finishers	Nobles
	Andy Henning Farm - Sec 9	Nobles
	Nick Henning Farm - Sundberg Site	Nobles
Lower Des Moines River	Rolling Hills Pork - Sec 5	Jackson
	Airborne Pork, LLC	Jackson
	Christensen Farms Site C014/C024	Martin
	Leroy Forsberg Farm - Sec 35	Martin
East Fork Des Moines River	Earl Tusa & Sons Inc	Jackson
	Farm 10 - Benda	Jackson
	Art Benda Farms - Sec 23	Jackson
	Farm 152 - Theilhorn	Jackson
	Farm 133 - Simmons	Jackson
	Kevin Schmidt Farm	Martin
	Hawkeye Two LLP	Martin
	Clair Schmidt Jr Farm	Martin
	Gerhardt West	Martin
	Gerhardt North	Martin
	Gerhardt East	Martin
	Truesdell Finisher	Martin
	Whitehead Finishing Site	Martin
	Terry Wagenman Finishers	Martin
	Don Schley Finisher	Martin
	Pro Pork Inc	Martin
	Windmill Farms West	Martin
	Miller Pork	Martin
	Jacob Brolsma Farm - Sec 35	Martin
	Manyaska	Martin
	Farm 163 - Floyd	Martin
	Janssen Finisher	Martin
	Christensen Farms Site F053	Martin
	Farm 199 - Stephan	Martin
	Brad & Meg Freking Farm - NFP 197 Truesdel	Martin
	Christensen Farms Site F124-Lake Fremont 7	Martin
	Truesdell Finisher	Martin
	Hilltop Pork	Martin
	Farm 209 - Finke	Martin
	Kyle Gustafson Farm - Sec 23	Martin
	Farm 288 - Zebedee	Martin

HSPF Estimated Subwatershed Yields









ET Rate Data & Calculation

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

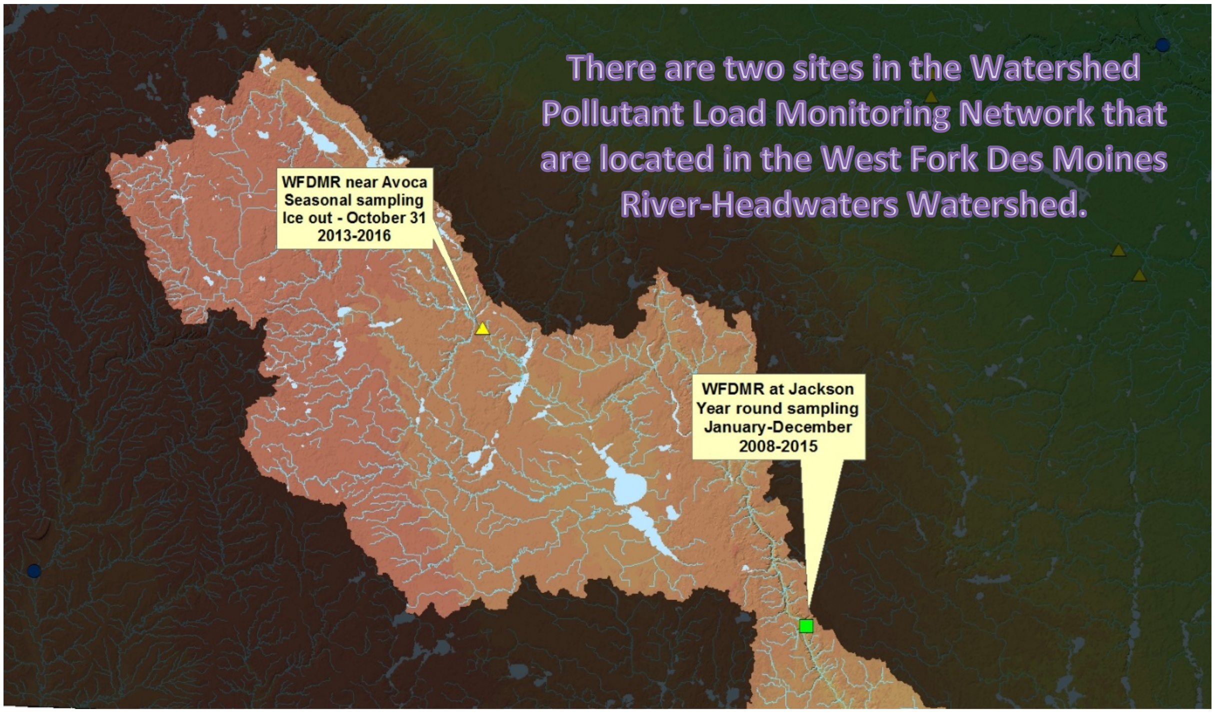
ET rate	Formula/specifics	Reference	Applicable Data
Wetland	$ET_W = 0.9 * ET_{pan}$	Wallace, Nivala, and Parkin (2005)	Waseca station pan ET 1989-2008 average
Lake	$ET_L = 0.7 * ET_{pan}$	Dadaser-Celik and Heinz (2008)	
Crops	Crop ET, Climate II	NRCS (1977)	Table from source

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:

Methodology, data	Source	May-Sept 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

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 noncrop ET rates, and 3) error associated with pan ET rates could result in exaggerated differences between estimated wetland/lake ET and crop ET.

WPLMN TSS Data Interpretation



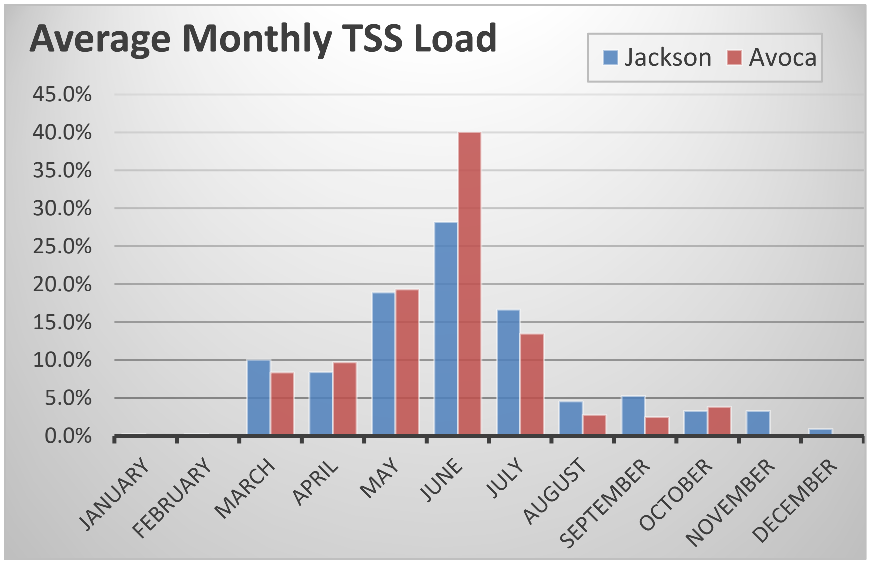
What does the data tell us?

At Jackson:

- 64% of the average annual TSS load passed this site from May through the end of July. June has the highest TSS load (28%).
- 49% of the stream flow passed this site during the same period, 36% in June and July alone.

At Avoca:

- 73% of the average seasonal TSS load passed this site from May through July. June is the heaviest loading month (40%).
- Similar to TSS loads, most of the average seasonal flow volume passed this site during the same period. June alone accounted for 38% of the total seasonal flow volume.



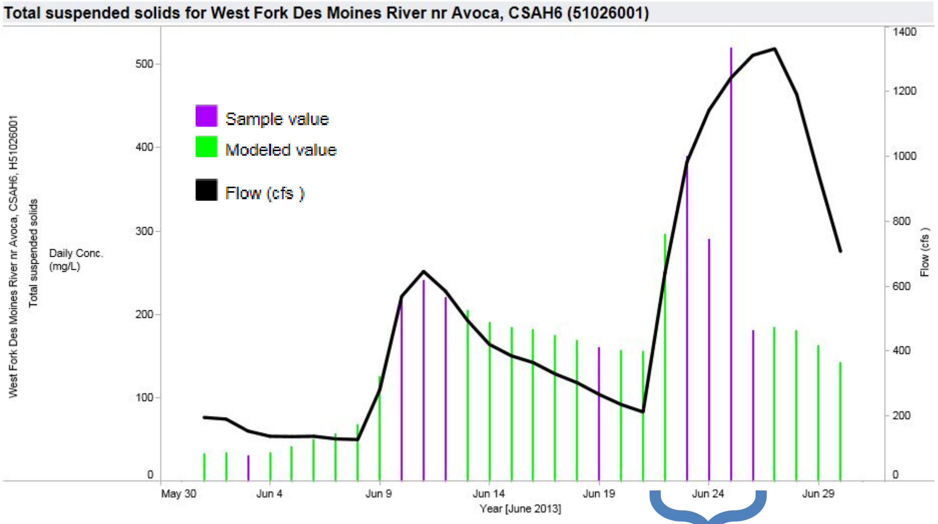
What does this mean?

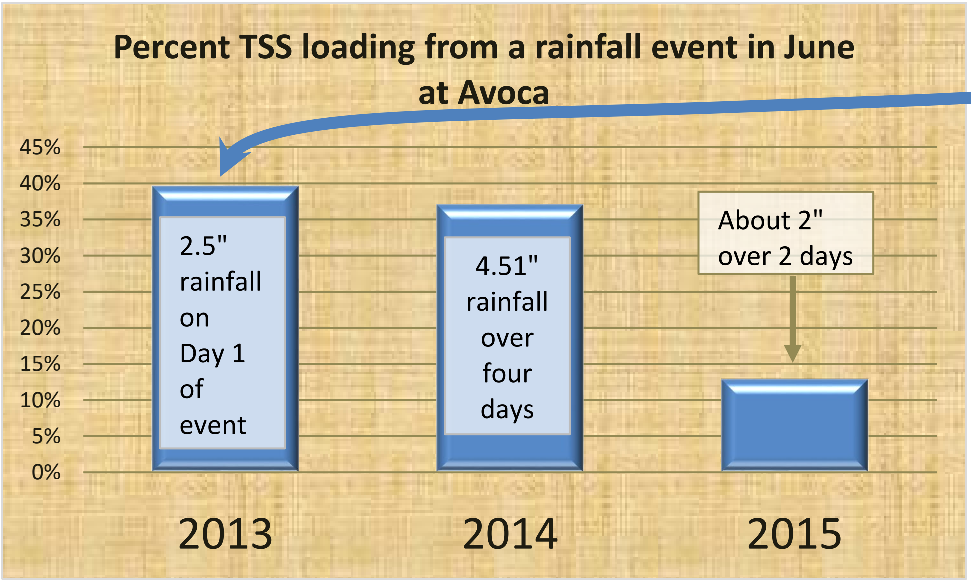
June is a potent month!

July has a fairly high TSS load.

What is happening during this time?

Our streams and rivers respond to high intensity storms with higher TSS concentrations.





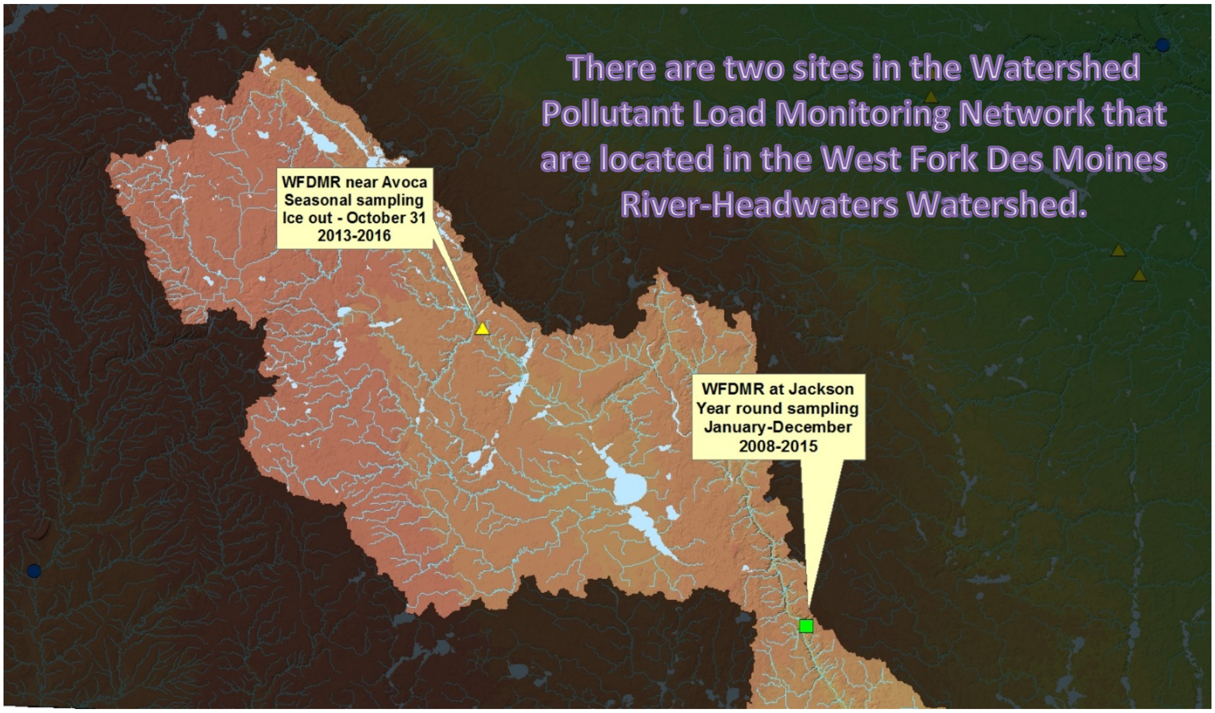
Looking at the largest June rainfall events each year, rising limb TSS loads account for 13% to 40% of the entire seasonal load. Rising limb durations are typically only 5-6 days.

TSS also includes algae which is fueled by excess phosphorus during warmer weather, resulting in hypereutrophic conditions.


July 2015

July 2015

WPLMN TP Data Interpretation



There are two sites in the Watershed Pollutant Load Monitoring Network that are located in the West Fork Des Moines River-Headwaters Watershed.

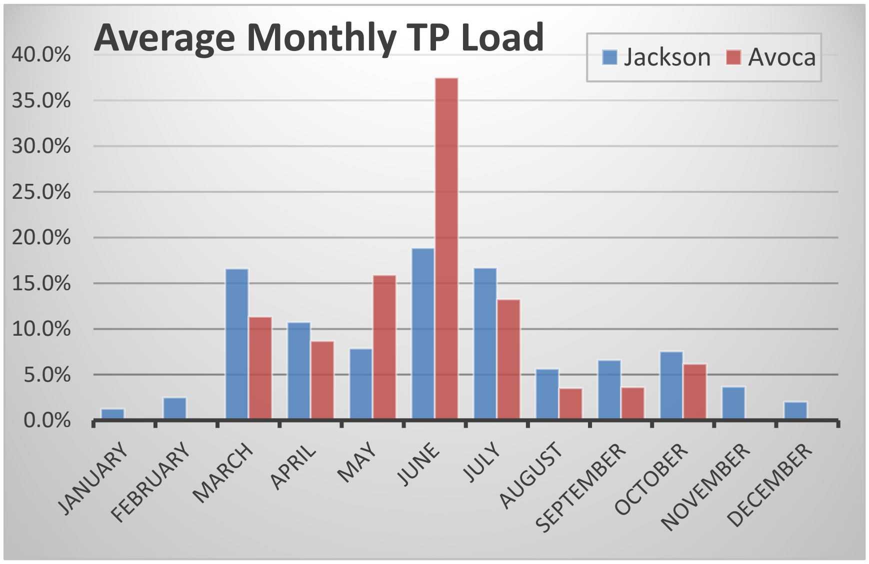
WFDMR near Avoca
Seasonal sampling
Ice out - October 31
2013-2016

WFDMR at Jackson
Year round sampling
January-December
2008-2015

What does the data tell us?

At Jackson:

- Most of the TP load moves through in March, June and July.
- Unlike TSS and NO_3-NO_2-N, TP monthly loads are more evenly distributed during the open water season.
- 62% of the stream flow passed this site from April to the end of July, 36% in June and July alone.



At Avoca:

- 67% of the average seasonal TP load passed this site from May through July. June has the highest TP load (37%).
- Similar to TP loads, most of the average seasonal flow volume passed this site during the same period. June alone accounted for 38% of the total seasonal flow volume.

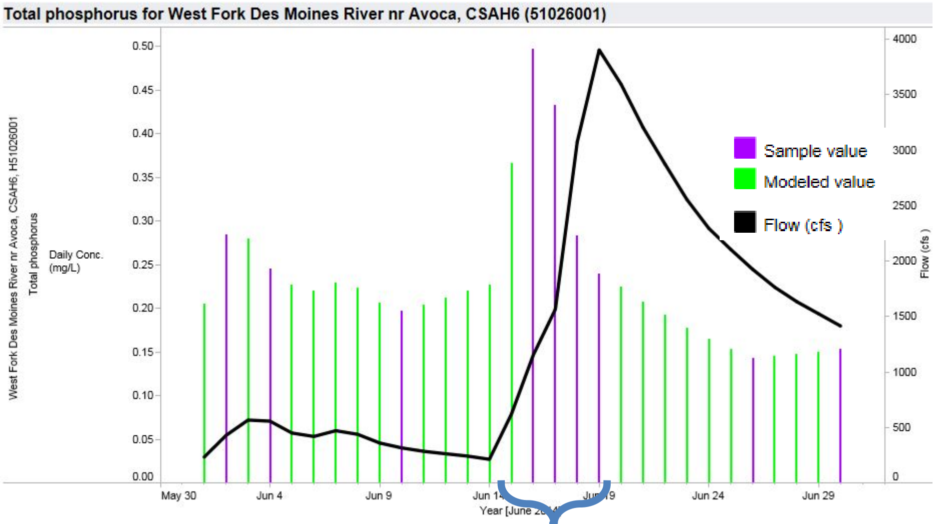
What does this mean?

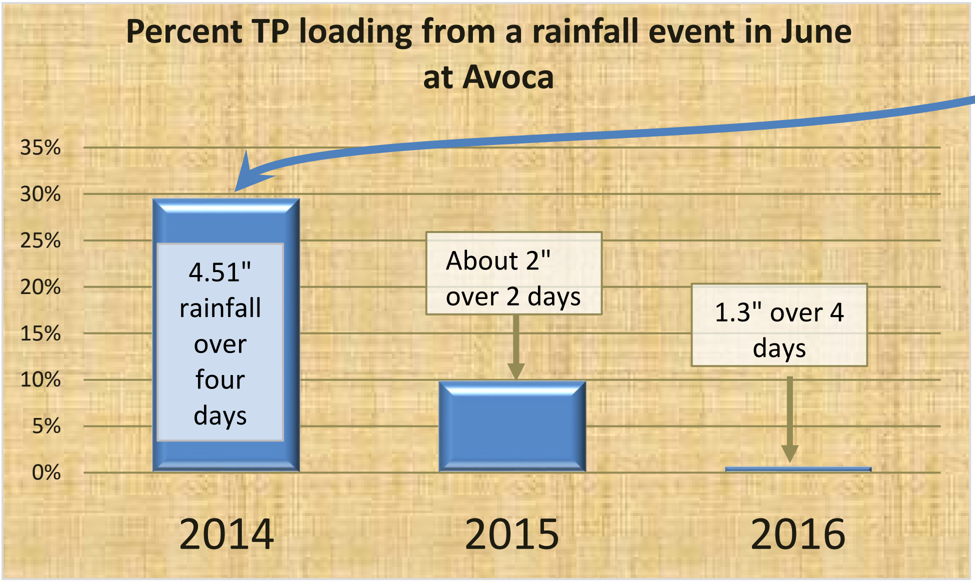
June is a potent month!

TP is present throughout the year.

What is happening during this time?

Our streams and rivers respond to intense storms with higher TP concentrations.

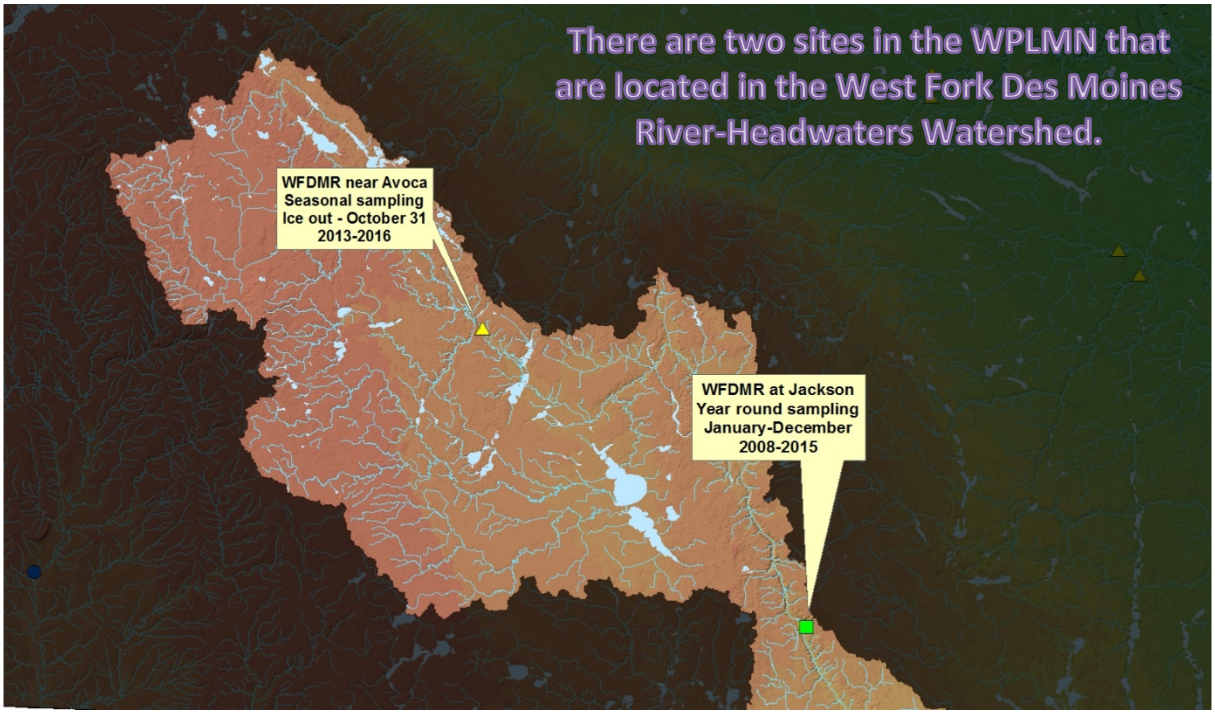




Looking at the largest June rainfall events each year, rising limb TP loads account up to 28% of the entire seasonal load. Rising limb durations are typically only 5 to 6 days.

Some TP loading may be from the hypereutrophic lake inputs from Shetek, Talcot, and Heron.

WPLMN NOx Data Interpretation



There are two sites in the WPLMN that are located in the West Fork Des Moines River-Headwaters Watershed.

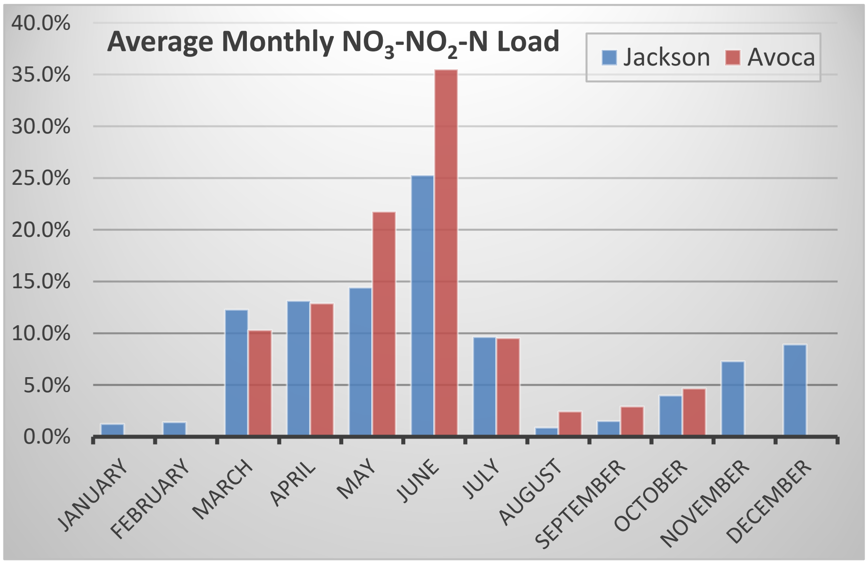
WFDMR near Avoca
Seasonal sampling
Ice out - October 31
2013-2016

WFDMR at Jackson
Year round sampling
January-December
2008-2015

What does the data tell us?

At Jackson:

- 75% of the average annual nitrate-nitrite nitrogen (NO_3-NO_2-N) load passed this site from March through July. June has the highest load (25%).
- Unlike TSS and TP, NO_3-NO_2-N loads increase from early fall through the end of the year.
- 73% of the stream flow passed this site from March to the end of July, 36% in June and July alone.



At Avoca:

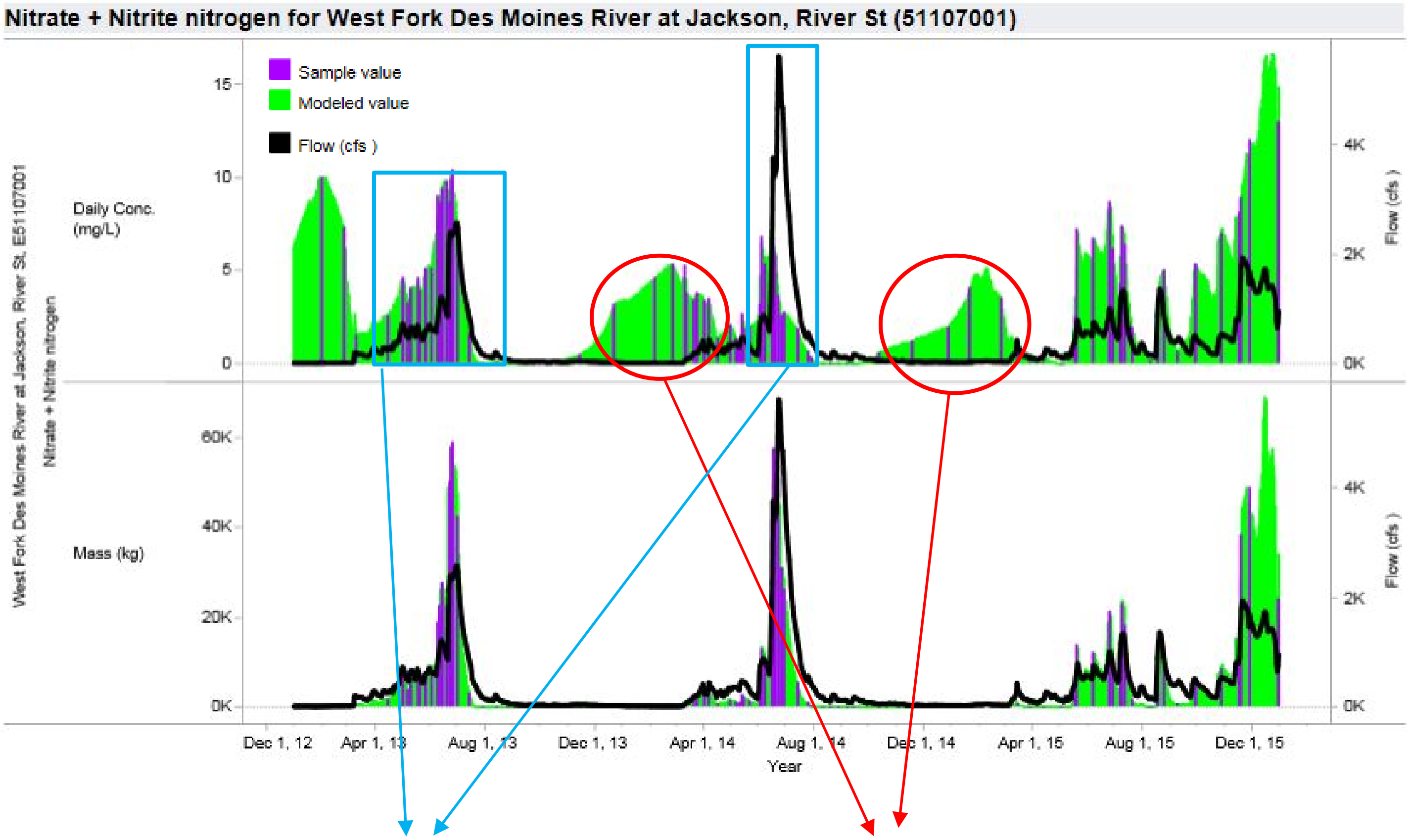
- 90% of the average seasonal NO_3-NO_2-N load passed this site from March through July. June is the heaviest loading month (36%).
- Similar to NO_3-NO_2-N loads, most of the average seasonal flow volume passed this site during the same period. June alone accounted for 38% of the total seasonal flow volume.

What does this mean?

NO_3-NO_2-N load is strongly correlated with flow volume.

NO_3-NO_2-N has strong seasonal influence.

What is happening?



- Under moderate and high flow conditions, concentrations are highest. However, the range in concentrations is fairly narrow under these conditions, thus making daily loads largely a function of daily discharge.
- By late July, NO_3-NO_2-N concentrations decrease and remain insignificant until fall.

- The daily concentrations are elevated during lower flow conditions. The two circled areas are October through December when this is evident.

Appendix 3 – Water Quality Goals Supplementary Information

TMDL Summary

	Phosphorus (Standard Jun-Sept)								
	Whole Data Set								
			Consultant method 1: midpoints of flow regime using existing loads, loading capacity and the difference between the two					Consultant method 2:	WRAPS Method
Reach	Months with Data	Years with Data	Very High	High	Mid-Range	Low	Very Low	Average of seasonal average TP con. of yrs	**Observed Load Sum compared to Standard Load Sum
1-501	June - Sept	2005-2014	40%	31%	39%	41%	nd	55%	44%
1-527	June - Sept	2005-2014	32%	29%	52%	58%	48%	50%	31%
Average			36%	30%	45%	49%	48%	53%	38%

ND = No Data

** Method used in WRAPS Report

Lake Phosphorus Reduction Calculation Methods & Results

Lake Name	Method 1: Mean of all Jun-Sept samples (all years)	Modeled TP Load reduction to meet standard (modeled to mean of all Jun-Sep data)	Method 3: **Averaging Months then Averaging Years (for Jun-Sep recent data only)	Months (POR for Method 3)	Years (POR for Method 3)
Bloody	12%	15%	25%	Jun-Sept	7
Boot	57%	68%	56%	Jun-Sept	14--15
Bright	39%	46%	27%	Jun-Sept	14--15
Corabelle	50%	41%	51%	Jun-Sept	09--10
Currant	35%	51%	26%	Jun, Sept	06,07,11
East Graham	48%	49%	36%	Jun-Sept	06,09,10,14,16
Flahtery	53%	67%	56%	Jun-Sept	07--08
Fox	7%	9%	16%	Jun-Sept	06,14--15
Heron (Duck)	58%	69%	41%	Jun-Sept	9
Lime	58%	57%	54%	Jun-Sept	07,14
North Oaks	64%	77%	64%	Jun-Sept	14--15
Okamanpeedan	58%	56%	53%	Jun-Sept	07,14
Pierce	66%	23%	66%	Jun-Sept	14--15
Sarah	32%	46%	68%	Aug, Sept	06--07
Shetek	26%	34%	22%	Jun-Sept	06,07,14
Talcot	78%	31%	73%	Jun-Sept	07,14
Teal	59%	62%	56%	Jun-Sept	09--11
Temperance	61%	70%	61%	Jun-Sept	14--15
Timber	54%	61%	57%	Jun-Sept	09--10
West Graham	48%	52%	49%	Jun-Sept	06,09,10,14,16
Yankton	32%	51%	26%	Jun-Sept	07,14
North Heron	71%	TMDL did not use a model to calculate reduction.	71%	Jun-Sept	06,09,10,16
South Heron	75%		76%	Jun-Sept	06,09,10,16
Average	50%	49%	49%		

**Method used in WRAPS Report

	TSS % Reductions (Standard Apr-Sep)															
	Whole Data Set														Summer Data only	
			Consultant method: excel estimated 90% concentration using obs conc per flow regime compared to standard					WFDMR Method - "mid point of flow regime" original analysis not located, just numbers pulled from the report							WRAPS method **where able to calculate**	
Reach	Months with Data (in which Std applies)	Years with Data	Very High	High	Mid-Range	Low	Very Low	High	Moist	Mid**	Dry	Low	Observed Load Sum compared to Standard Load Sum	Average concentration compared to standard	**Observed Load Sum compared to Standard Load Sum	Average concentration compared to standard
1-551	5,7-9	2016	0%	42%	28%	21%	nd						4%	16%	25%	24%
2-505	5--9	2016	0%	56%	35%	0%	nd						19%	20%	42%	25%
1-503								95%	75%	65%	nd	nd				
1-545								80%	55%	30%	nd	nd				
1-546								63%	63%	63%	63%	nd				
1-535								83%	83%	83%	83%	83%				
1-533								5%	75%	65%	65%	nd				
1-524								30%	40%	55%	55%	nd				
1-501								40%	80%	60%	60%	nd				
1-541								60%	90%	40%	40%	nd				
1-507								nd	50%	75%	50%	60%				
1-506								90%	70%	50%	75%	25%				
1-505								20%	30%	30%	30%	nd				
1-509								65%	80%	80%	90%	40%				
1-529								20%	40%	70%	70%	75%				
1-527								nd	60%	70%	90%	95%				
2-501								40%	60%	55%	50%	nd				
Average			0%	49%	31%	11%		53%	63%	59%	63%	63%	12%	18%	34%	25%

ND = No Data

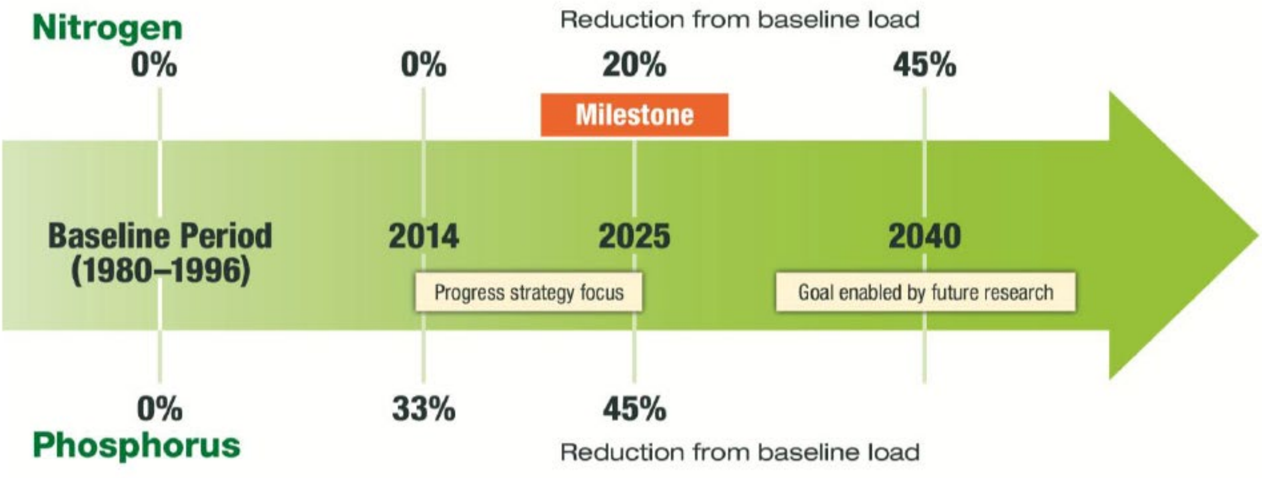
** Method used in WRAPS Report

	Bacteria % Reductions (Standard Applies Apr-Oct)														
	Whole Data set										Summer Data Set				
			Consultant Method: Geomean by flow regime, no data 2015+ included due to no Q model data					WRAPS method for old TMDL only						WRAPS method where able to calculate	
Reach	Months with Data (in which Std applies)	Years with Data	Very High	High	Mid-Range	Low	Very Low	**all data geomean	Avg'd Monthly Geomean	Flow Wt'd Monthly Geomean (include 2015+ data but no 2015+ Q)	Flow Wt'd Monthly Geomean (w/ out 2015)	summer geomean	Avg'd Monthly Geomean	**Flow Wt'd Monthly Geomean (include 2015+ data but no 2015+ Q)	Flow Wt'd Monthly Geomean (w/ out 2015)
1-512	4--10	06,08,14-15	61%	36%	19%	0%	0%	1%	10%	22%	17%	-1%	7%	85%	83%
1-524	6--8	14-15	19%	52%	0%	0%	ND	-47%	-1%	47%	53%	-47%	-1%	47%	53%
1-527	5--10	9-11,14-17	0%	0%	0%	0%	0%	-57%	25%	39%	18%	-20%	-1%	-18%	-41%
1-564	6--8	14-15	0%	65%	0%	0%	ND	-3%	13%	38%	-24%	-3%	13%	38%	-24%
1-652	6--9	14-15	86%	85%	55%	1%	ND	68%	72%	80%	84%	68%	72%	80%	84%
3-503	4--10	08-10,14-15	0%	0%	0%	0%	0%	-201%	-146%	-116%	-99%	-98%	-96%	65%	71%
3-510	4--10	09--10	88%	88%	0%	14%	66%	69%	86%	88%	88%	81%	87%	90%	90%
3-515	4--10	08--09	79%	56%	ND	43%	ND	52%	74%	82%	82%	82%	85%	87%	87%
3-525	6--8	14-15	88%	84%	74%	23%	ND	64%	65%	73%	86%	64%	65%	73%	86%
3-527	4--10	06,08,14-15	48%	59%	28%	9%	9%	37%	30%	41%	50%	55%	56%	63%	70%
1-646								74%							
1-508								86%							
1-517								84%							
1-519								86%							
1-546								71%							
1-535								63%							
1-533								35%							
1-602								51%							
1-658								62%							
1-659								62%							
1-656								76%							
2-501								52%							
Average			47%	53%	20%	9%	15%	36%	23%	39%	36%	18%	29%	61%	56%

ND = No Data
** Method used in WRAPS Report

Minnesota State Nutrient Reduction Strategy

https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf



The phosphorus strategy calls for an additional 12% reduction (in addition to the already reached 33% reduction) between a 1980 through 1996 baseline period and 2025. To calculate what percent-reduction this equates to between the current (2014) loads and the total goal, the 33% reduction already made must be factored into the reduction calculation.

The percent reduction calculation is illustrated by assigning the baseline period a load equal to 100 units. The total goal is to reduce this by 45% (45 units), which means the goal is to reach 100units-45units=55 units. Since a 33% (33 unit) reduction in baseline levels was already achieved, the 2014 load equals 100units-33units=67 units. The reduction from 2014 to the final goal is (67units-55units)/67units = 18% reduction. This goal is for the Mississippi River basin as a whole, whereas the Minnesota River Basin is a much higher yielding area; therefore, the total goals for major watersheds in the Minnesota River Basin will likely be higher than the that the Mississippi River Basin reduction goal.

Appendix 4 – Strategies and Priorities Supplementary Information

Model Summary

				Reduction in Parameter			
Model(s) & Reference	Summary & Notes	Scenario	Modeled BMPs/Landscape	Sediment	Phosphorus	Nitrogen	Cost
N-BMP Spreadsheet Tool Minnesota Watershed Nitrogen Reduction Planning Tool (Lazarus et al., 2014)	The BMP scenarios outlined here were developed using the N-BMP spreadsheet tool with inputs specifically for two locations in the Des Moines Watershed for average weather conditions. The areas represented are the East Fork (EF) and the Des Moines Headwaters (DMH). The first/top scenario in each area achieves a 10% N reduction from cropland. The second/bottom scenario achieves a 30% N reduction from cropland. Parameter load reductions are presented as the pounds per treated acre (how many pounds of N reduction are estimated for each acre where the practice is adopted). The costs are represented as the cost per pound of nitrogen removed.	EF 10% N Reduction from Crops	12% of land uses rye cover crop			1.4 lb/ac	$36/lb
			9% of land receives target N fertilizer rate			3 lb/ac	**$-3/lb**
			2% of land receives Fall N inhibitor			2 lb/ac	$3/lb
			2% of land switches from fall to split fertilizer application			5 lb/ac	$4/lb
			2% of land switches from fall to spring fertilizer application			5 lb/ac	**$-0.3/lb**
			2% of land short season crops adopt a rye cover crop			4 lb/ac	$15/lb
			2% of land converts to perennial crop			8 lb/ac	$7/lb
			0.8% of land is treated by tile line bioreactors			1 lb/ac	$30/lb
			0.8% of land adopts controlled drainage			3 lb/ac	$4/lb
			0.8% of land adopts saturated buffers			4 lb/ac	$3/lb
			0.8% of land is drained to treatment wetlands			5 lb/ac	$2/lb
			0.5% of land adopts riparian buffers 50 feet wide			8 lb/ac	$22/lb
		EF 30% N Reduction from Crops	74% of land uses rye cover crop			1.4 lb/ac	$36/lb
			38% of land receives target N fertilizer rate			3 lb/ac	**$-3/lb**
			6% of land switches from fall to spring fertilizer application			5 lb/ac	**$-0.3/lb**
			3% of land is drained to treatment wetlands			5 lb/ac	$2/lb
			3% of land short season crops adopt a rye cover crop			4 lb/ac	$15/lb
			3% of land adopts controlled drainage			3 lb/ac	$4/lb
			2% of land receives Fall N inhibitor			2 lb/ac	$3/lb
			2% of land switches from fall to split fertilizer application			5 lb/ac	$4/lb
			2% of land converts to perennial crop			8 lb/ac	$7/lb
			2% of land adopts saturated buffers			4 lb/ac	$3/lb
			0.8% of land is treated by tile line bioreactors			1 lb/ac	$30/lb
			0.6% of land adopts riparian buffers 50 feet wide			8 lb/ac	$22/lb
		DMH 10% N Reduction from Crops	18% of land uses rye cover crop			1.2 lb/ac	$43/lb
			9% of land receives target N fertilizer rate			3 lb/ac	**$-3/lb**
			2% of land converts to perennial crop			7 lb/ac	$9/lb
			2% of land receives Fall N inhibitor			2 lb/ac	$4/lb
			1% of land switches from fall to split fertilizer application			4 lb/ac	$5/lb
			1% of land switches from fall to spring fertilizer application			4 lb/ac	**$-0.2/lb**
			1% of land short season crops adopt a rye cover crop			4 lb/ac	$15/lb
			0.6% of land is treated by tile line bioreactors			1 lb/ac	$32/lb
			0.6% of land adopts riparian buffers 50 feet wide			7 lb/ac	$25/lb
			0.6% of land adopts controlled drainage			3 lb/ac	$4/lb
			0.6% of land adopts saturated buffers			4 lb/ac	$3/lb
			0.5% of land is drained to treatment wetlands			5 lb/ac	$2/lb
		DMH 30% N Reduction from Crops	83% of land uses rye cover crop			1.2 lb/ac	$43/lb
			43% of land receives target N fertilizer rate			3 lb/ac	**$-3/lb**
			8% of land switches from fall to spring fertilizer application			4 lb/ac	**$-0.2/lb**
			2% of land receives Fall N inhibitor			2 lb/ac	$4/lb
			2% of land switches from fall to split fertilizer application			4 lb/ac	$5/lb
			2% of land short season crops adopt a rye cover crop			4 lb/ac	$15/lb
			2% of land converts to perennial crop			7 lb/ac	$9/lb
			2% of land adopts controlled drainage			3 lb/ac	$4/lb
			2% of land is drained to treatment wetlands			5 lb/ac	$2/lb
			1% of land adopts saturated buffers			4 lb/ac	$3/lb
			0.7% of land adopts riparian buffers 50 feet wide			7 lb/ac	$26/lb
			0.6% of land is treated by tile line bioreactors			1 lb/ac	$32/lb

Model(s) & Reference	Summary & Notes	Scenario	Modeled BMPs/Landscape	Reduction in Parameter			Cost
				Sediment	Phosphorus	Nitrogen	
P-BMP Spreadsheet Tool Minnesota Watershed Phosphorus Reduction Planning Tool (Lazarus et al., 2015)	The BMP scenarios outlined here were developed using the P-BMP spreadsheet tool with inputs specifically for two areas in the Des Moines River Watershed for average weather conditions. The areas represented are the East Fork (EF) and the Des Moines Headwaters (DMH).The first/top scenario achieves a 15% P reduction from cropland. The second/bottom scenario achieves a 45% P reduction from cropland. Parameter load reductions are presented as the pounds per treated acre (how many pounds of P reduction are estimated for each acre where the practice is adopted). The costs are represented as the cost per pound of phosphorus removed.	EF 15% P Reduction from Crops	39% of land adopts reduced P application rate		0.04 lb/ac		$-11/lb
			14% of land (corn & bean crops) uses rye cover crop		0.05 lb/ac		$52/lb
			12% of land adopts alternative tile intakes		0.12 lb/ac		$54/lb
			6% of land (>2% slopes) uses reduced tillage		0.09 lb/ac		$-16/lb
			4% of land switches to preplant/starter fertilizer application		0.02 lb/ac		$23/lb
			2% of land injects/incorporates manure		0.2 lb/ac		$14/lb
			0.7% of land (short season crops) adopt a rye cover crop		0.1 lb/ac		$57/lb
			0.5% of land converts to 50 ft stream buffers		1.24 lb/ac		$91/lb
			0.3% of land converts to perennial crop		0.24 lb/ac		$39/lb
			0.3% of land adopts controlled drainage		0.18 lb/ac		$10/lb
		EF 45% P Reduction from Crops	98% of land adopts reduced P application rate		0.03 lb/ac		$-11/lb
			94% of land (corn & bean crops) uses rye cover crop		0.05 lb/ac		$52/lb
			31% of land (>2% slopes) uses reduced tillage		0.1 lb/ac		$-16/lb
			24% of land adopts alternative tile intakes		0.12 lb/ac		$0.54/lb
			14% of land switches to preplant/starter fertilizer application		0.02 lb/ac		$23/lb
			4% of land injects/incorporates manure		0.2 lb/ac		$14/lb
			3% of land adopts controlled drainage		0.18 lb/ac		$10/lb
			3% of land (short season crops) adopt a rye cover crop		0.1 lb/ac		$57/lb
			2% of land converts to 50 ft stream buffers		1.24 lb/ac		$106/lb
			1% of land converts to perennial crop		0.24 lb/ac		$39/lb
		DMH 15% P Reduction from Cro	48% of land adopts reduced P application rate		0.03 lb/ac		$-8/lb
			14% of land (corn & bean crops) uses rye cover crop		0.05 lb/ac		$52/lb
			12% of land adopts alternative tile intakes		0.13 lb/ac		$60/lb
			6% of land (>2% slopes) uses reduced tillage		0.1 lb/ac		$-16/lb
			4% of land switches to preplant/starter fertilizer application		0.02 lb/ac		$23/lb
			2% of land injects/incorporates manure		0.2 lb/ac		$10/lb
			0.8% of land adopts controlled drainage		0.18 lb/ac		$10/lb
			0.7% of land converts to perennial crop		0.25 lb/ac		$47/lb
			0.5% of land (short season crops) adopt a rye cover crop		0.1 lb/ac		$57/lb
			0.5% of land converts to 50 ft stream buffers		1.10 lb/ac		$83/lb
		DMH 45% P Reduction from Crop	97% of land adopts reduced P application rate		0.03 lb/ac		$-8/lb
			93% of land (corn & bean crops) uses rye cover crop		0.1 lb/ac		$-16/lb
			31% of land (>2% slopes) uses reduced tillage		0.05 lb/ac		$52/lb
			17% of land adopts alternative tile intakes		0.13 lb/ac		$0.6/lb
			14% of land switches to preplant/starter fertilizer application		0.2 lb/ac		$14/lb
			12% of land adopts controlled drainage		0.02 lb/ac		$23/lb
			5% of land injects/incorporates manure		0.2 lb/ac		$14/lb
			3% of land converts to 50 ft buffers		0.2 lb/ac		$41/lb
			3% of land converts to perennial crop		0.18 lb/ac		$10/lb
			2% of land (short season crops) adopt a rye cover crop		1.10 lb/ac		$107/lb

Model(s) & Reference	Summary & Notes	Scenario	Modeled BMPs/Landscape		Reduction in Parameter			Cost
					Sediment	Phosphorus	Nitrogen	
HSPF SAM Scenarios https://www.respec.com/sam-file-sharing/	6 scenarios ran in the East Fork Des Moines (EF) watershed. 3 Scenarios cost optimized to meet (roughly) the 10-year targets for N (10%), P (15%), and Sediment (5%) and 3 Scenarios cost optimized to meet (roughly) the full goal for N (30%), P (45%), and Sediment (30%). All scenarios ran for load reduction at the subwatershed outlet. Each scenario had multiple BMPs to choose from, and those selected by the program created the lowest cost option to meet the specified water quality reduction. Current SAM default values were used in all cases except for alternative tile intakes. In some cases, the scenario does not represent feasible options, as SAM allows multiple BMPs to be applied on the same land. SAM model summary reports are available by request.	EF 15%	15%	of area adopts Water and Sediment Control Basins	16%	9%	15%	$1.5M $11/ac/yr
			13%	of area adopts Reduced Tillage (30%+ residue cover)				
			7%	of area adopts 16' buffers				
		EF 45% TP	51%	of area adopts Conservation Cover Perennials	40%	25%	50%	$9.3M $70/ac/yr
			19%	of area adopts Restore Tiled Wetlands (Cropland)				
			13%	of area adopts Reduced Tillage (no till)				
			10%	of area adopts 50' buffer				
			4%	of area adopts Nutrient Management				
			4%	of area adopts Corn & Soybeans with Cover Crop				
			4%	of area adopts Corn & Soybeans to Rotational Grazing				
			3%	of area adopts Alternative Tile Intakes				
		EF 10% TN	38%	of area adopts Nutrient Management	7%	4%	10%	$0.7M $6.2/ac/yr
			12%	of area adopts Reduced Tillage (30%+ residue cover)				
			7%	of area adopts 16' buffer				
			1%	of area adopts Tile Line Bioreactors				
		EF 30% TN	43%	of area adopts Nutrient Management	24%	14%	29%	$2.8M $21/ac/yr
			17%	of area adopts Restore Tiled Wetlands (Cropland)				
			13%	of area adopts Reduced Tillage (no till)				
			10%	of area adopts 50' buffer				
			4%	of area adopts Corn & Soybeans to Rotational Grazing				
			4%	of area adopts Conservation Cover Perennials				
			1%	of area adopts Tile Line Bioreactors				
		EF 5%	6%	of area adopts 16' buffer	5%	3%	4%	$0.1M $1/ac/yr
			1%	of area adopts Reduced Tillage (30%+ residue cover)				
			1%	of area adopts Water and Sediment Control Basin (Cropland)				
		EF 30% TSS	24%	of area adopts Corn & Soybeans with Cover Crop	35%	21%	38%	$4.7M $35/ac/yr
			17%	of area adopts Restore Tiled Wetlands (Cropland)				
			14%	of area adopts Water and Sediment Control Basin (Cropland)				
			9%	of area adopts 50' buffer				
			13%	of area adopts Reduced Tillage (no till)				
			4%	of area adopts Conservation Cover Perennials				
			4%	of area adopts Corn & Soybeans to Rotational Grazing				
			1%	of area adopts Alternative Tile Intakes				
			0%	of area adopts Constructed Stormwater Pond				

Model(s) & Reference	Summary & Notes	Scenario	Modeled BMPs/Landscape		Reduction in Parameter			Cost
					Sediment	Phosphorus	Nitrogen	
HSPF SAM Scenarios https://www.respec.com/sam-file-sharing/	5 scenarios ran in the Des Moines, upstream of Avoca (Includes Lime Creek, Beaver Creek, and the Headwaters). 3 Scenarios cost optimized to meet (roughly) the 10-year targets for N (10%), P (15%), and Sediment (5%) and 3 Scenarios cost optimized to meet (roughly) the full goal for N (30%) and Sediment (30%). All scenarios ran for load reduction at the subwatershed outlet. Each scenario had multiple BMPs to choose from, and those selected by the program created the lowest cost option to meet the specified water quality reduction. Current SAM default values were used in all cases except for alternative tile intakes. In some cases, the scenario does not represent feasible options, as SAM allows multiple BMPs to be applied on the same land. SAM model summary reports are available by request.	A 15% TP	28%	of area adopts Reduced Tillage (30%+ residue cover)	19%	13%	13%	$2.4M $10/ac/yr
			9%	of area adopts 16' buffer				
			8%	of area adopts Corn & Soybeans with Cover Crop				
			0%	of area adopts Alternative Tile Intakes				
		A 10% TN	20%	of area adopts Nutrient Management	9%	8%	10%	$1M $4/ac/yr
			10%	of area adopts Reduced Tillage (30%+ residue cover)				
			9%	of area adopts 16' buffer				
		A 30% TN	30%	of area adopts Reduced Tillage (no till)	27%	25%	31%	$1.9M $8/ac/yr
			14%	of area adopts Nutrient Management				
			11%	of area adopts 50' buffer				
			7%	of area adopts Restore Tiled Wetlands (Cropland)				
		5% TSS	7%	of area adopts 16' buffer	4%	3%	3%	$0.1M $0.5/ac/yr
		A 30% TSS	31%	of area adopts Reduced Tillage (no till)	32%	29%	34%	$2.4M $10/ac/yr
			11%	of area adopts 50' buffer				
			8%	of area adopts Water and Sediment Control Basin (Cropland)				
			5%	of area adopts Restore Tiled Wetlands (Cropland)				

Model(s) & Reference	Summary & Notes	Scenario	Modeled BMPs/Landscape		Reduction in Parameter			Cost
					Sediment	Phosphorus	Nitrogen	
HSPF SAM Scenarios https://www.respec.com/sam-file-sharing/	6 scenarios ran in the Jack Creek subwatershed (J). 3 Scenarios cost optimized to meet (roughly) the 10-year targets for N (10%), P (15%), and Sediment (5%) and 3 Scenarios cost optimized to meet (roughly) the full goal for N (30%), P (45%), and Sediment (30%). All scenarios ran for load reduction at the subwatershed outlet. Each scenario had multiple BMPs to choose from, and those selected by the program created the lowest cost option to meet the specified water quality reduction. Current SAM default values were used in all cases except for alternative tile intakes. In some cases, the scenario does not represent feasible options, as SAM allows multiple BMPs to be applied on the same land. SAM model summary reports are available by request.	J 15% TP	20%	of area adopts Corn & Soybeans with Cover Crop	16%	15%	14%	$1.8M $14/ac/yr
			13%	of area adopts 16' buffer				
			11%	of area adopts Reduced Tillage (30%+ residue cover)				
			10%	of area adopts Nutrient Management				
			6%	of area adopts Alternative Tile Intakes				
		J 45% TP	25%	of area adopts Conservation Cover Perennials	32%	45%	46%	$5.9M $44/ac/yr
			19%	of area adopts 50' buffer				
			13%	of area adopts Restore Tiled Wetlands (Cropland)				
			12%	of area adopts Water and Sediment Control Basin (Cropland)				
			11%	of area adopts Reduced Tillage (no till)				
			4%	of area adopts Corn & Soybeans with Cover Crop				
			2%	of area adopts Alternative Tile Intakes				
			2%	of area adopts Nutrient Management				
			2%	of area adopts Corn & Soybeans to Rotational Grazing				
		J 10% TN	35%	of area adopts Nutrient Management	7%	8%	10%	$0.6M $5/ac/yr
			12%	of area adopts 16' buffer				
			5%	of area adopts Reduced Tillage (30%+ residue cover)				
		J 30% TN	71%	of area adopts Nutrient Management	18%	25%	30%	$2.3M $17/ac/yr
			18%	of area adopts 50' buffer				
			12%	of area adopts Restore Tiled Wetlands (Cropland)				
			11%	of area adopts Reduced Tillage (no till)				
			3%	of area adopts Tile Line Bioreactors				
			3%	of area adopts Conservation Cover Perennials				
		J 5% TSS	9%	of area adopts 16' buffer	4%	4%	3%	$0.08M $0.6/ac/yr
		J 30% TSS	18%	of area adopts 50' buffer	31%	37%	36%	$1.8M $14/ac/yr
			18%	of area adopts Filter Strips, 50 ft wide (Cropland field edge)				
			12%	of area adopts Restore Tiled Wetlands (Cropland)				
			11%	of area adopts Reduced Tillage (no till)				
			6%	of area adopts Restore Tiled Wetlands (Cropland)				
			2%	of area adopts Corn & Soybeans with Cover Crop				

Model(s) & Reference	Summary & Notes		Scenario	Modeled BMPs/Landscape									Reduction in Parameter Sediment	 Phosphorus	 Nitrogen	Cost
SWAT, InVEST, Sediment Rating Curve Regression, and Optimization Lake Pepin Watershed Full Cost Accounting (Dalzell et al., 2012)	Models 6 BMPs in the 7-mile Creek watershed either: **1**) placed by rule of thumb recommendations (not optimal) or **2**) to maximize TSS reduction for dollars spent (optimal). Completed economic analyses including: **A**) current market value only (using 2011 $) and **B**) integrated, which adds a valuation of ecosystem services (relatively modest value). Does not allow multiple BMPs on same pixel of land. Scenarios are described by percentages of land in each land use. Analysis of 2002-2008 data.	Land uses:		Normal til	Cons til	1/2 P fert	Pasture	Grass	Forest	Wetland	Water	Urban				
		Baseline		83%	0%	0%	2%	0%	4%	5%	1%	5%	0%	0%		0%
		2A	A	3%	14%	64%	3%	1%	5%	5%	1%	5%	4%	-1%		-4%
			B	35%	1%	38%	10%	1%	4%	5%	1%	5%	25%	22%		4%
			C	8%	0%	35%	32%	10%	4%	5%	1%	5%	50%	46%		21%
			D	2%	0%	10%	43%	29%	4%	5%	1%	5%	76%	69%		51%
		2B	a	30%	1%	44%	2%	0%	11%	5%	1%	5%	15%	19%		-8%
			b	26%	0%	41%	13%	1%	7%	5%	1%	5%	25%	28%		-7%
			c	13%	0%	29%	38%	2%	7%	5%	1%	5%	50%	48%		0%
			d	3%	0%	8%	68%	3%	6%	5%	1%	5%	76%	70%		19%
		1A	F	25m grass buffers around waterways									3%	3%		4%
			G	250m grass buffers around waterways									15%	15%		28%
			H	Converting highly erodible lands to grasslands									15%	17%		10%
SPARROW The Minnesota Nutrient Reduction Strategy (draft) (PCA, 2013i)	Statewide nutrient reduction goals and strategies are developed for the three major drainage basins in Minnesota. For the Mississippi River basin, the milestones (interim targets) between 2014 and 2025 are 20% reduction in N and 8% reduction in P. The scenario to meet those reductions is summarized.		20% N, 8% P Redu	43% of total area (80% of suitable area) uses target N fertilizer rates 6% of total area (90% of suitable area) uses P test and soil banding 1% of total area (10% of suitable area) in cover crops 1% of total area (25% of suitable area) in riparian buffers 25% of total area (91% of suitable area) in conservation tillage 4% of total area (18% of suitable area) uses wetlands or controlled drainage										8%	20%	
HSPF Minnesota River Basin Turbidity Scenario Report (Tetra Tech, 2009)	5 scenarios (BMP suites) evaluated for effect on TSS and TP in MN River tributaries and mainstem. Scenarios 1, 2 were minimally effective. Scenarios 3, 4, & 5 are summarized here. Analysis on 2001-2005 data.		3	20% land in pasture (perennial veg), targeting steepest land 75% of >3% slope land in cons. tillage (30% residue) and cover crop 50% of surface inlets eliminated Comprehensive nutrient management Drop structures installed on eroding ravines Effluent max P of 0.3mg/L for mechanical facilities For MS4 cities, install ponds to hold and treat 1" of runoff									~20% (Le Sueur watershed)	17% (MN basin)		
			4	All BMPs in Scenario 3 with these additions: Target (20% land in) pasture to knickpoint regions as well Increase residue (on 75% of >3% slope land) to 37.5% Increase eliminated surface inlets to 100% Controlled drainage on land with <1% slope Water basins to store 1" of runoff Minor bank/bluff improvements Eliminate baseflow sediment load									50% (Yellow Med watershed)	26% (MN basin)		
			5	All BMPs in Scenarios 3&4 with these additions: Improved management of the pasture land (CRP) Very major bluff/bank improvements Urban (outside MS4s) source reductions of 50-85%									87% (MN basin)	49% (MN basin)		

Lake Restoration and Protection Strategies

This is a summary of strategies and not an exhaustive list. Not all strategies are applicable or appropriate for all lakes or regions.

Watershed Strategies – These strategies reduce phosphorus delivered to a lake and are the basis for any restoration work.

- **Manage nutrients** – carefully planning for and applying phosphorus fertilizers decreases the total amount of phosphorus runoff from cities and fields.
    - Examples: crop nutrient management, city rules on phosphorus fertilizer use, etc.
- **Reduce erosion** – preventing erosion keeps sediment (and attached phosphorus) in place.
    - Examples: construction controls, vegetation (see below)
- **Increase vegetation** – more vegetative cover on the ground uses more water and phosphorus and decreases the total amount of runoff coming from fields and cities.
    - Examples: cover crops, grass buffers, wetlands, prairie gardens/restorations, channel vegetation, etc.
- **Install/restore basins** – capturing runoff and decreasing peak flows in a basin allows the sediment (and attached phosphorus) to settle out.
    - Examples: water and sediment control basins, wetlands, etc.
- **Improve soil health** – soils that are healthy need less fertilizer and hold more water.
    - Examples: reduce/no-till fields, diversified plants in fields and yards

Lake Shore-specific Strategies – These strategies are a subset of watershed strategies that can be directly implemented by lake-shore residents.

- **Eco-friendly landscaping** – poor landscape design and impervious surfaces increase runoff and loading of nutrients into lakes.
    - Examples: aerate, rain barrels or cisterns, rain gardens, permeable pavers, sprinkler and drainage systems, maintain septic systems, etc.
- **Manage upland buffer zone vegetation** – Upland buffer zone vegetation selection can greatly affect nutrient absorbance, watering needs, erosion potential, need for drainage, etc.
    - Examples: properly landscape, maintain canopy and address terrestrial invasive species that may prevent regeneration of native trees, proper turf grass, no mow lawns in highly utilized areas and planting native grasses and forbs with deep root systems in underutilized areas of lawn, reduce watering needs, controlled fertilization and grass clippings.
- **Naturalize transition buffer zone** – a natural transition buffer zone increases absorption of nutrients and decreases erosion potential of the water-shore interface.
    - Examples: balance natural landscaping by minimizing recreational impact area, utilize natural materials for erosion control bioengineering using wood or biodegradable materials in combination with stabilizing native vegetation to restore a shoreline, minimize beach

blankets, draw down water levels for consecutive seasons to allow existing seed banks to develop deep rooted native vegetation or plant diverse mixes of grasses, sedges, forbs, shrubs and trees to create a complex root mass to hold the bank soils, preserve and restore native emergent aquatic vegetation sedges, rushes, forbs, shrubs and trees, do not remove natural wood features that supply cover and food sources for aquatic species and invertebrates while serving as a wave break along the shoreline.

- **Preserve aquatic buffer zone** – The aquatic buffer zone is difficult to restore, so the best approach is preservation and providing best opportunity for aquatic plants through watershed improvements to increase water quality. Draw down water levels to allow natural seed banks of emergent and aquatic vegetation to establish naturally, supplement more plant diversity with lower water levels as restoration of emergent and aquatic vegetation have higher success rates.
    - Examples: reduce recreational impact area, minimize control of aquatic plants, reduce dock footprint, preserve and/or restore native emergent and floating-leaf aquatic plants.

In-Lake Strategies – These strategies use, remove, or seal internal phosphorus (from within the lake). These strategies are only effective if external phosphorus sources are first minimized to the point that water quality of incoming water is not the limiting factor in order to meet water quality standards. Incorporating Lake Shore specific strategies is also essential for long term success.

- **Biomanipulation** – changing the fish population. Rough fish are generally bottom feeders and through feeding activity re-suspend sediments and decrease water clarity; thus, removing rough fish through mechanical or biological methods can improve water clarity, increase aquatic vegetation, and improve water quality overall.
    - Examples: commercial netting (not a standalone tool, implement in conjunction with other fisheries management methods to augment reduced populations for a short term period allowing desirable fish populations to develop adequate size to manage rough fish populations), balanced fish management increasing fish species diversity for a balanced fish population and introducing large predator fish populations, preserve and restore diverse spawning, cover, and feeding habitat that favors specific fish species that maintain a diverse fish population, reclamation (kill all fish and start over) inlets for rough fish should be considered when planning reclamation to prevent immediate re-introduction. In lake shore strategies are essential to incorporate to develop habitat for desirable species of fish once the rough fish population is removed.
- **Invasive species control of plants and/or animals** – invasive species alter the ecology of a lake and can decrease diversity of habitat. Removing native vegetation or incorporating nonnative vegetation into landscaping can allow for invasive species to establish and spread taking over larger blocks of native species that maintain the natural systems health. Therefore, reducing disturbance to near shore habitat is important.
    - Examples: prevention, early detection, lake vegetation management plan (LVMP)
- **Chemical treatment to seal sediments** – re-suspension of nutrients through wind action can cause internal nutrient loading.

  - Examples: alum treatments. Consider the long term effectiveness in shallow lakes that experience wind driven turning, where stratification of the lake does not occur. Incorporating establishment of lake shore habitat is important to absorb phosphorus in the lake as part of a long term approach to phosphorus level management.

- **Dredging** – Sedimentation after years of poor watershed practices increases nutrient laden sediments and decreases depth. Dredging should only be considered when the source of the sediment and the banks of the lake are stable to prevent sediment from redepositing. Dredging can: create channels for access, increase habitat diversity, and accommodate recreational use.

Lake Phosphorus Sensitivity Analysis

Des Moines		
LAKE NAME	Protection Class	Score
Little Tuttle	High	0.00
Harder	High	0.00
First Fulda	High	0.04
Wilson	High	0.06
Fremont	High	0.07
South Clear	High	0.08
Second Fulda	High	0.09
Kinbrae	High	0.10
Maria	High	0.25
Summit	High	0.35
Smith	High	0.65
Buffalo	High	1.02
North Badger	High	1.42
Cottonwood	High	1.73
Hanson March	High	3.16
String	Higher	4.42
Summit	Higher	10.23
South Badger	Higher	10.31
Clear	Highest	14.61
Heron (South Heron)	Impaired	0.00
Talcot	Impaired	0.00
Heron (North Heron)	Impaired	0.00
Lime	Impaired	0.00
Okamanpeedan	Impaired	0.00
North Oaks	Impaired	0.01
Temperance	Impaired	0.01
Heron (Duck)	Impaired	0.02
East Graham	Impaired	0.03
West Graham	Impaired	0.05
Bright	Impaired	0.05
Corabelle	Impaired	0.08
Flahtery	Impaired	0.09
Sarah	Impaired	0.16
Boot	Impaired	0.19
Timber	Impaired	0.60
Current	Impaired	1.35
Yankton	Impaired	1.95
Bloody	Impaired	3.39
Fox	Impaired	7.98
Shetek	Impaired	33.46

Modeled Nutrient Reductions from MN and IA State Reduction Strategy Reports

MN: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient-reduction/nutrient-reduction-strategy.html
IA: http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRS2-141001.pdf

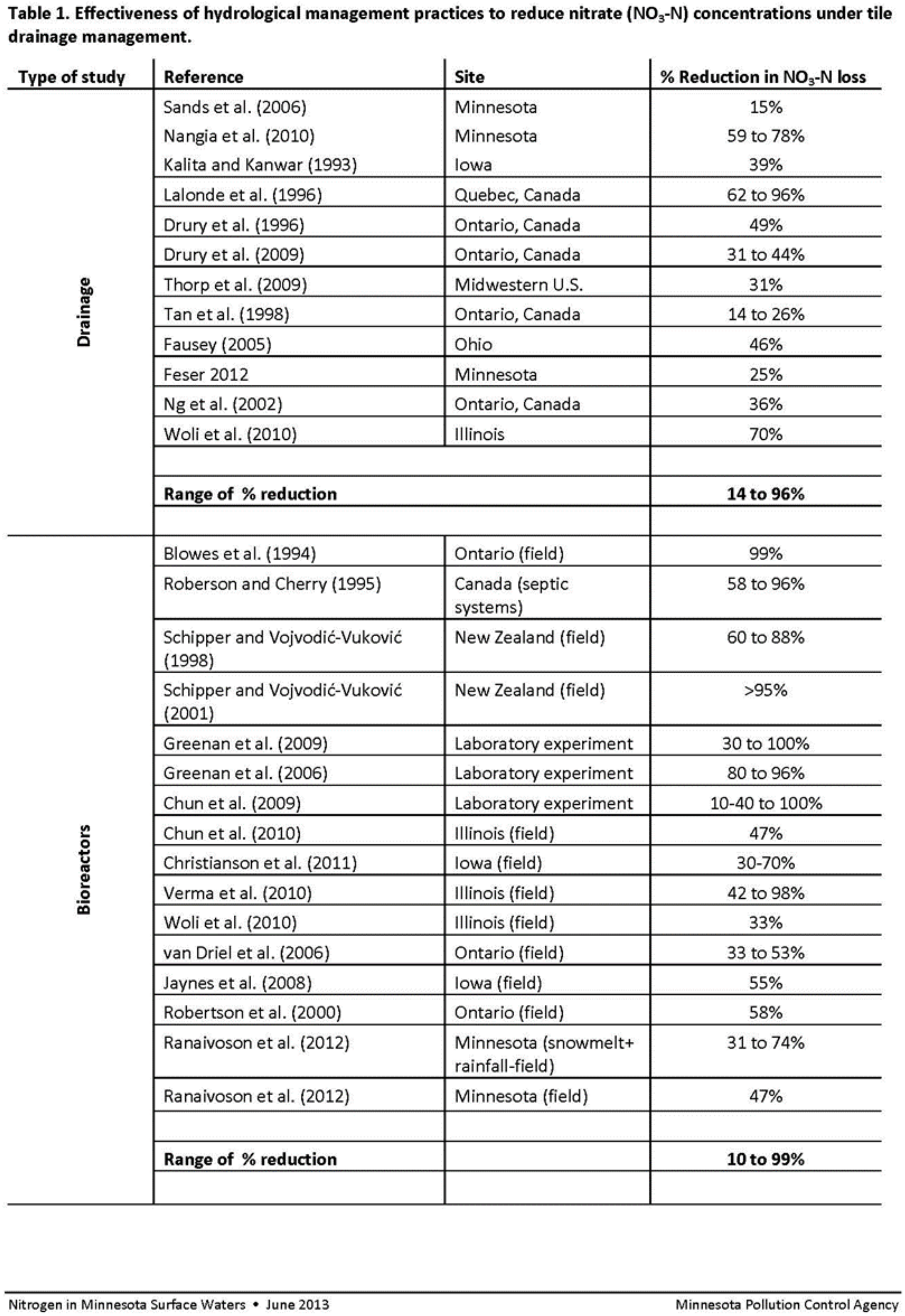


Table 1. Effectiveness of hydrological management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% Reduction in NO_3-N loss
Drainage	Sands et al. (2006)	Minnesota	15%
	Nangia et al. (2010)	Minnesota	59 to 78%
	Kalita and Kanwar (1993)	Iowa	39%
	Lalonde et al. (1996)	Quebec, Canada	62 to 96%
	Drury et al. (1996)	Ontario, Canada	49%
	Drury et al. (2009)	Ontario, Canada	31 to 44%
	Thorp et al. (2009)	Midwestern U.S.	31%
	Tan et al. (1998)	Ontario, Canada	14 to 26%
	Fausey (2005)	Ohio	46%
	Feser 2012	Minnesota	25%
	Ng et al. (2002)	Ontario, Canada	36%
	Woli et al. (2010)	Illinois	70%
	Range of % reduction		**14 to 96%**
Bioreactors	Blowes et al. (1994)	Ontario (field)	99%
	Roberson and Cherry (1995)	Canada (septic systems)	58 to 96%
	Schipper and Vojvodić-Vuković (1998)	New Zealand (field)	60 to 88%
	Schipper and Vojvodić-Vuković (2001)	New Zealand (field)	>95%
	Greenan et al. (2009)	Laboratory experiment	30 to 100%
	Greenan et al. (2006)	Laboratory experiment	80 to 96%
	Chun et al. (2009)	Laboratory experiment	10-40 to 100%
	Chun et al. (2010)	Illinois (field)	47%
	Christianson et al. (2011)	Iowa (field)	30-70%
	Verma et al. (2010)	Illinois (field)	42 to 98%
	Woli et al. (2010)	Illinois (field)	33%
	van Driel et al. (2006)	Ontario (field)	33 to 53%
	Jaynes et al. (2008)	Iowa (field)	55%
	Robertson et al. (2000)	Ontario (field)	58%
	Ranaivoson et al. (2012)	Minnesota (snowmelt+ rainfall-field)	31 to 74%
	Ranaivoson et al. (2012)	Minnesota (field)	47%
	Range of % reduction		**10 to 99%**

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Table 2. Effectiveness of N management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% of Reduction in NO_3-N loss
N rates	Buzicky et al. (1983)	Minnesota	28%
	Nangia et al. (2005a)	Minnesota (model)	12 to 15%
	Gowda et al. (2006)	Minnesota (model)	11 to 14%
	Jaynes et al. (2004a)‡	Iowa	30%
	Baksh et al. (2004)	Iowa	17%
	Nangia et al. (2010)	Minnesota (model)	23%
	Kladivko et al. (2004)†	Indiana	70%
	Range of % reduction		**11 to 70%**
N application time and Inhibitors			
	Smiciklas and Moore (1999)	Illinois	58%
	Randall and Mulla (2001)	Minnesota	36%
	Gowda et al (2006)	Minnesota	34%
	Nangia et al. (2005b)	Minnesota	6%
	Randall et al (2003)	Minnesota	17 to 18%
	Randall and Vetsch (2005)	Minnesota	10 to 14%
	Range of % reduction		**10 to 58%**
Split applications	Randall et al. (2003)	Minnesota	13%
	Jaynes et al. (2004)	Iowa	30%
	Range of % reduction		**13 to 30%**

† This reduction also includes the effect of changing crop rotation and adding cover crops plus changing N rate over time.

‡ This reduction is also related to changing time of application.

Table 3. Effectiveness of landscape diversification management practices to reduce nitrate (NO_3-N) concentrations.

Type of study	Reference	Site	% Reduction NO_3-N
Riparian Buffers*	Barfield et al. (1998)	Kentucky	95 to 98%
	Blanco-Canqui et al (2004a)	Missouri	94%
	Blanco-Canqui et al (2004b)	Missouri	47 to 69%
	Dillaha et al (1989)	Virginia	54 to 77%
	Magette et al. (1989)	Maryland	17 to 72%
	Schmitt et al. (1999)	Nebraska	57 to 91%
	Lowrance and Sheridan (2005)	Georgia	59 to 78 %
	Duff et al (2007)	Minnesota	67 to 99%
	Range of % reduction		**17 to 99%**
Wetlands	Appelboom and Fouss (2006)		37 to 83%
	Kovacic et al. (2000)	Illinois	33 to 55%
	Crumpton et al. (2006)	Iowa	25 to 78%
	Hunt et al. (1999)	North Carolina	70%
	Xue et al. (1999)	Illinois	19 to 59%
	Iovanna et al. (2008)	Iowa	40 to 90%
	Range of % reduction		**19 to 90%**

*Note: none of the riparian buffer studies referenced here were at sites with subsurface tile drainage.

Table 4. Effectiveness of landscape diversification management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% Reduction in NO_3-N loss
Alternative cropping systems	Randall et al. (1997)	Minnesota	7 to 98%
	Boody et al. (2005)	Minnesota	51 to 74%
	Simpkins et al. (2002)	Iowa	5 to 15%
	Range of % reduction		**5 to 98%**
Cover crops			
	Kladivko et al. (2004)	Indiana	<60%
	Feyereisen et al. (2006)	Minnesota	11 to 30%
	Strock et al. (2004)	Minnesota	13%
	Jaynes et al. (2004b)	Iowa	60%
	Kaspar et al. (2007)	Iowa	61%
	Range of % reduction		**11 to 60%**

Table 2. Nitrogen reduction practices – potential impact on nitrate-N reduction and corn yield based on literature review.

	Practice	Comments	% Nitrate-N Reduction[+]	% Corn Yield Change++
			Average (SD*)	Average (SD*)
Nitrogen Management	Timing	Moving from Fall to Spring Pre-plant Application	6 (25)	4 (16)
		Spring pre-plant/sidedress 40-60 split Compared to Fall Applied	5 (28)	10 (7)
		Sidedress - Compared to Pre-plant Application	7 (37)	0 (3)
		Sidedress – Soil Test Based Compared to Pre-plant	4 (20)	13 (22)
	Source	Liquid Swine Manure Compared to Spring Applied Fertilizer	4 (11)	0 (13)
		Poultry Manure Compared to Spring Applied Fertilizer	-3 (20)	-2 (14)
	Nitrogen Application Rate	Reduce to Maximum Return to Nitrogen value 149 kg N/ha (133 lb N/ac) for CS and 213 kg N/ha (190 lb N/ac) for CC	10‡	-1‡‡
	Nitrification Inhibitor	Nitrapyrin – Fall - Compared to Fall-Applied without Nitrapyrin	9 (19)	6 (22)
	Cover Crops	Rye	31 (29)	-6 (7)
		Oat	28 (2)**	-5 (1)
	Living Mulches	e.g. Kura clover - Nitrate-N reduction from one site	41 (16)	-9 (32)
Land Use	Perennial	Energy Crops Compared to Spring- Applied Fertilizer	72 (23)	-100[ɣ]
		Land Retirement (CRP) Compared to Spring- Applied Fertilizer	85 (9)	-100[ɣ]
	Extended Rotations	At least 2 years of alfalfa in a 4 or 5 year rotation	42 (12)	7 (7)
	Grazed Pastures	No pertinent information from Iowa - Assume similar to CRP	85***	NA
Edge-of-Field	Drainage Water Mgmt.	No impact on concentration	33 (32)^	
	Shallow Drainage	No impact on concentration	32 (15)^	
	Wetlands	Targeted Water Quality	52†	
	Bioreactors		43 (21)	
	Buffers	Only for water that interacts with active zone below the buffer - a small fraction of all water that makes it to a stream.	91 (20)	

+ A positive number is nitrate concentration or load reduction and a negative number is increased nitrate.

++ A positive corn yield change is increased yield and a negative number is decreased yield. Soybean yield is not included as the practices are not expected to affect soybean yield.

* SD = standard deviation.

‡ Reduction calculated based on initial application rate for each Major Land Resource Area (MLRA).

‡‡ Calculated based on the Maximum Return to Nitrogen (MRTN) relative yield at the given rates.

** Based on 1 study with 3 years of corn and 2 years of soybean.

*** This number is based on the Land Retirement number – there are no observations to develop a SD.

^ These numbers are based on load reduction since there is no impact on concentration with these practices

† Based on one report looking at multiple wetlands in Iowa (Helmers et al., 2008a).

Table 3. Practices with the largest potential impact on phosphorus load reduction.

Notes: Corn yield impacts associated with each practice also are shown as some practices may be increase or decrease corn production. See text for information on value calculations.

	Practice	Comments	% Phosphorus Load Reduction[a]	% Corn Yield Change[b]
			Average (SD[c])	Average (SD[c])
Phosphorus Management Practices	Phosphorus Application	Applying P based on crop removal - Assuming optimal soil-test P level and P incorporation	0.6[d] [70[e]]	0[f]
		Soil-Test P – Producer does not apply P until soil-test P drops to the optimal level	17[g] [40[h]]	0[f]
		Site-specific P management		0[f]
	Source of Phosphorus	Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application	46 (45)	-1 (13)
		Beef manure compared to commercial fertilizer – Runoff shortly after application	46 (96)	
	Placement of Phosphorus	Broadcast incorporated within one week compared to no incorporation – Same tillage	36 (27)	0[f]
		With Seed or knifed bands compared to surface application without incorporation	24 (46) [35[i]]	0[f]
Erosion Control and Land Use Change Practices	Tillage	Conservation till – chisel plowing compared to moldboard plowing	33 (49)	0 (6)
		No till compared to chisel plowing	90 (17)	-6 (8)
	Crop Choice	Extended rotation	[j]	7 (7)[k]
	Perennial	Energy crops	34 (34)	NA
		Land retirement (CRP)	75	NA
		Grazed pastures	59 (42)	NA
	Terraces		77 (19)	
Edge-of-Field Practices	Wetlands	Targeted water quality	[l]	
	Buffers		58 (32)	
	Sediment Control	Sedimentation basins	85	

a - A positive number is phosphorus reduction and a negative number is increased phosphorus.

b - A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

c - SD = standard deviation.

d - Maximum and average estimated by comparing application of 200 and 125 kg P_2O_5/ha, respectively, to 58 kg P_2O_5/ha (corn-soybean rotation requirements) (Mallarino et al., 2002).

e - This represents the worst case scenario as data is based on runoff events 24 hours after P application. Maximum and average were estimated as application of 200 and 125 kg P_2O_5/ha, respectively, compared to 58 kg P_2O_5/ha (corn-soybean rotation requirements), considering results of two Iowa P rate studies (Allen and Mallarino, 2008; Tabbara, 2003).

f - Indicates no impact on yield should be observed.

g - Maximum and average estimates based on reducing the average STP (Bray-1) of the two highest counties in Iowa and the statewide average STP (Mallarino et al., 2011a), respectively to an optimum level of 20 ppm (Mallarino et al., 2002). Minimum value assumes soil is at the optimum level.

h - Estimates made from unpublished work by Mallarino (2011) in conjunction with the Iowa P Index and Mallarino and Prater (2007). These studies were conducted at several locations and over several years but may, or may not, represent conditions in all Iowa fields.

i - Numbers are from a report by (Dinnes, 2004) and are the author's professional judgment.

j - There is scarce water quality data for P loss on extended rotations in Iowa compared to a corn-soybean rotation.

k - This increase is only seen in the corn year of the rotation – one of five years.

l - Specific conditions are important in wetlands with regards to P as with changing inflow loads.

Table 28. Example Statewide Combination Scenarios that Achieve the Targeted Nitrate-N Reductions, Associated Phosphorous Reductions and Estimated Equal Annualized Costs based on 21.009 Million Acres of Corn-Corn and Corn-Soybean Rotation.

Notes: Research indicates large variation in reductions from practices that is not reflected in this table. Additional costs could be incurred for some of these scenarios due to industry costs or market impacts.

		Nitrate-N	Phosphorus	Cost of N Reduction from baseline ($/lb)	Initial Investment (million $)	Total EAC* Cost (million $/year)	Statewide Average EAC Costs ($/acre)
Name	Practice/Scenario**	% Reduction from baseline					
NCS1	Combined Scenario (MRTN Rate, 60% Acreage with Cover Crop, 27% of ag land treated with wetland and 60% of drained land has bioreactor)	42	30	2.95	3,218	756	36
NCS2	Combined Scenario (MRTN Rate, 100% Acreage with Cover Crop in all MLRAs but 103 and 104, 45% of ag land in MLRA 103 and 104 treated with wetland, and 100% of tile drained land in MLRA 103 and 104 treated with bioreactor)	39	40	2.61	2,357	631	30
NCS3	Combined Scenario (MRTN Rate, 95% of acreage in all MLRAs with Cover Crops, 34% of ag land in MLRA 103 and 104 treated with wetland, and 5% land retirement in all MLRAs)	42	50	4.67	1,222	1,214	58
NCS4	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 85% of all tile drained acres treated with bioreactor, 85% of all applicable land has controlled drainage, 38.25% of ag land treated with a wetland)	42	0	0.88	4,810	225	11
NCS5	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 65% of all tile drained acres treated with bioreactor, 65% of all applicable land has controlled drainage, 29.25% of ag land treated with a wetland, and 15% of corn-soybean and continuous corn acres converted to perennial-based energy crop production)	41	11	5.58	3,678	1,418	67
NCS6	Combined Scenario (MRTN Rate, 25% Acreage with Cover Crop, 25% of acreage with Extended Rotations, 27% of ag land treated with wetland, and 60% of drained land has bioreactor)	41	19	2.13	3,218	542	26
NCS7	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 70% of all tile drained acres treated with bioreactor, 70% of all applicable land has controlled drainage, 31.5% of ag land treated with wetland, and 70% of all agricultural streams have a buffer)	42	20	0.95	4,041	240	11

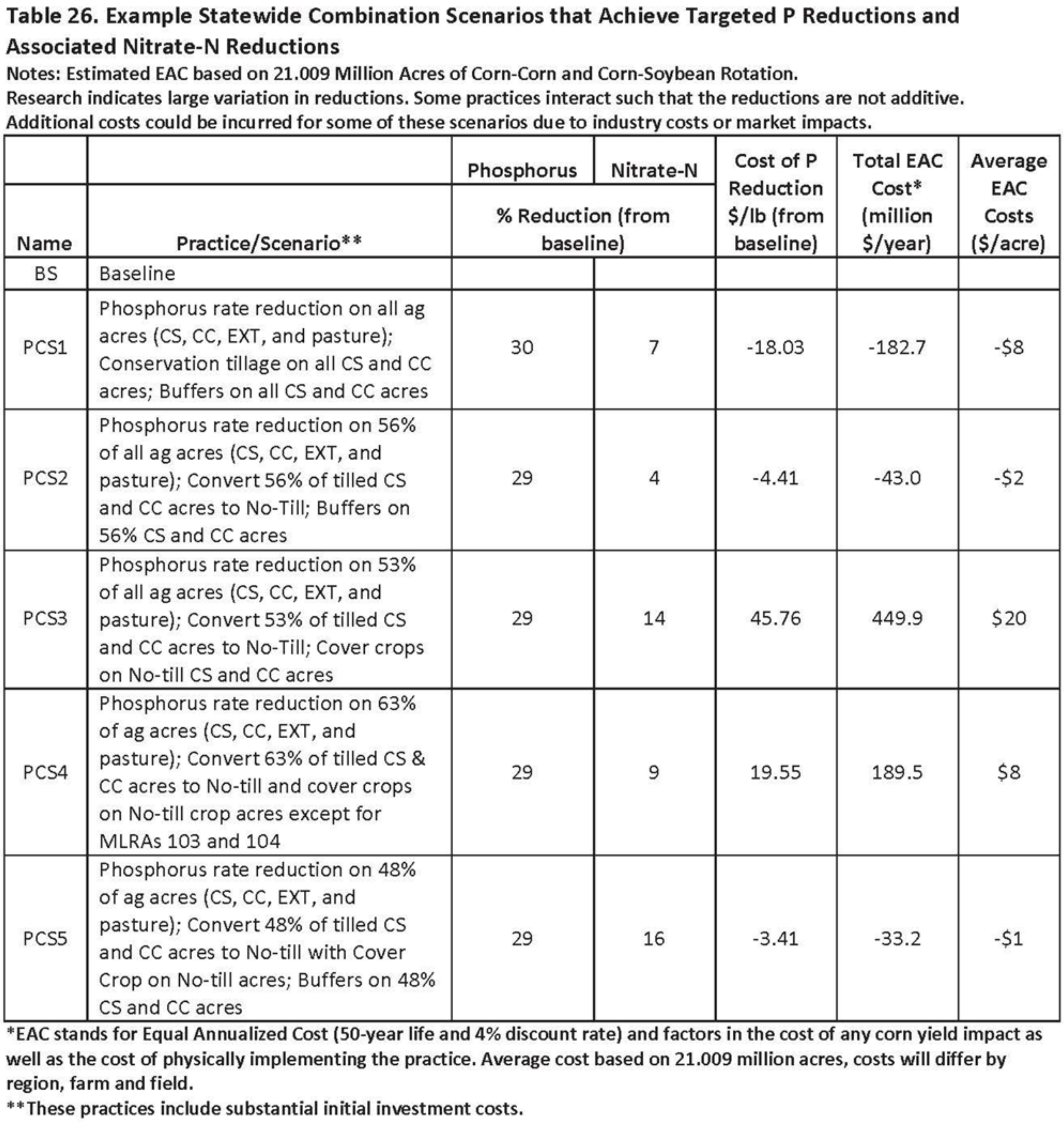

Table 26. Example Statewide Combination Scenarios that Achieve Targeted P Reductions and Associated Nitrate-N Reductions

Notes: Estimated EAC based on 21.009 Million Acres of Corn-Corn and Corn-Soybean Rotation.
Research indicates large variation in reductions. Some practices interact such that the reductions are not additive.
Additional costs could be incurred for some of these scenarios due to industry costs or market impacts.

		Phosphorus	Nitrate-N	Cost of P Reduction $/lb (from baseline)	Total EAC Cost* (million $/year)	Average EAC Costs ($/acre)
Name	Practice/Scenario**	% Reduction (from baseline)				
BS	Baseline					
PCS1	Phosphorus rate reduction on all ag acres (CS, CC, EXT, and pasture); Conservation tillage on all CS and CC acres; Buffers on all CS and CC acres	30	7	-18.03	-182.7	-$8
PCS2	Phosphorus rate reduction on 56% of all ag acres (CS, CC, EXT, and pasture); Convert 56% of tilled CS and CC acres to No-Till; Buffers on 56% CS and CC acres	29	4	-4.41	-43.0	-$2
PCS3	Phosphorus rate reduction on 53% of all ag acres (CS, CC, EXT, and pasture); Convert 53% of tilled CS and CC acres to No-Till; Cover crops on No-till CS and CC acres	29	14	45.76	449.9	$20
PCS4	Phosphorus rate reduction on 63% of ag acres (CS, CC, EXT, and pasture); Convert 63% of tilled CS & CC acres to No-till and cover crops on No-till crop acres except for MLRAs 103 and 104	29	9	19.55	189.5	$8
PCS5	Phosphorus rate reduction on 48% of ag acres (CS, CC, EXT, and pasture); Convert 48% of tilled CS and CC acres to No-till with Cover Crop on No-till acres; Buffers on 48% CS and CC acres	29	16	-3.41	-33.2	-$1

*EAC stands for Equal Annualized Cost (50-year life and 4% discount rate) and factors in the cost of any corn yield impact as well as the cost of physically implementing the practice. Average cost based on 21.009 million acres, costs will differ by region, farm and field.

**These practices include substantial initial investment costs.

Strategies Table Calculator Notes and Assumptions

Landuse (known): 984,000 total acres, 82% cultivated ag, 1% grass/pasture, 6% all developed, 3% open water and wetland.

800 miles of streams/ditches (note: this number is roughly the NHD flow line length).

55% of watershed (67% of crops) is tile drained; none are treating or keeping drained water on the land (all tile water is untreated and drained into ditch/stream).

Source assessments presented in WRAPS report used in calculations with the following refinements of the identified sources:

- 6.1% of watershed equivalent drain to open intakes [6.7% of the watershed (10% of tiled field acres) and 10% have effective control of nutrient/sediment runoff]
- 73% of watershed has nutrient/sediment loss from crop groundwater or crop surface runoff => equivalent of 9% of watershed (11% of crops) prevents nutrient loss to surface runoff and groundwater. This could be for example 11% of crops treating/preventing all runoff or 33% of crops treating/preventing 1/3rd of its runoff: 1/3*33%=11%
- 0.5% of watershed (50% of pastures) are pastures that are contributing nutrients, sediment, and bacteria
- 6% of watershed (7% of crops) gets manure - 4.5% of watershed gets subsurface manure, 1.5% of watershed gets surface manure (60,000 manured acres from the 193,000 AUs)
- 0.4% of land has applied manure traveling through open intakes (=6.7% land serviced by intakes * 6% estimated that gets manure applied)
- When ag-wide control measure goes in, assume manured and nonmanured have same adoption rate as do tiled and untiled (by % of landuse)
- 5% of total watershed sediment load travels through open tile intakes (12.5% of crop surface source travels through this pathway)
- 1% of stream bank erosion is from bank trampling in addition to other pasture sediment contributions
- 1% of P is from pastures
- 5% of watershed load of phosphorus (from crop surface runoff) travels through open tile intakes
- 67% of the watershed (equivalent of) is contributing P through ground water and tile drainage
- 3% of bacteria load travels through open tile intakes (into the tile)

Except a few cases where noted in the calculator, the estimated reduction per strategy adoption is:

Pollutant Reduction from a BMP at a watershed scale
=
(% of watershed to adopt)
X
(% reduction efficiency)
X
(% of load from source type)
/
(% watershed that has that source type)

The primary assumptions of this equation are:

- % reductions in pollutant loads from implementing a BMP result in the same pollutant loading reductions to waterbodies (e.g. 50% less sediment lost from field x results in 50% less sediment contributed to waterbodies by field x)
- The pollutant contributions of land types and efficiencies of BMPs are equivalent throughout the watershed (except where additional treatment occurs as noted in the above assumptions)

- The parameter reductions associated with the strategy assume a mixture of most and least effective BMPs per strategy (a mid-range reduction versus a high or low). So in addition to the the inherent error estimating BMP reduction efficiencies, the estimated reductions could more significantly vary from actual reductions if the least effective or most effective BMPs within a strategy type are adopted. For instance, under the "reduce tillage" strategy type, if no-till is adopted exclusively (or contrarily the basic conservation tillage is adopted exclusively), the reduction from this strategy will likely be higher (contrary case: lower) than the estimated reduction.

Tools for Prioritizing and Targeting

Electronic copy with live hyperlinks available by request.

Tool	Description	Example Uses	Notes for GIS Use	Link to Data/Info
National Hydrography Dataset (NHD) & Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. A specific application of the data set is to identify buffers around riparian areas.	GIS layers are available on the USGS website.	http://nhd.usgs.gov/
Impaired Waterbodies	Data indicates which stream reaches, lakes, and wetlands have been identified as impaired, or not meeting water quality standards. Attribute table includes information on the impairment parameters.	Examples of region/subwatershed prioritization includes: the number of impairments, specific impairment parameter, % of stream miles/lakes that are impaired, immediate subwatersheds of impaired rivers/lakes, identifying reaches with specific impairment parameters, etc. Field-scale targeting examples include: buffering impaired waters.	GIS layers are available on the PCA website.	http://www.pca.state.mn.us/index.php/data/spatial-data.html?show_descr=1
Hydrological Simulation Program – FORTRAN (HSPF)	Simulation of watershed hydrology and water quality. Incorporates point and non-point sources including pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches. The model is typically calibrated with monitoring data to ensure accurate results.	Since the model produces data on a subwatershed scale, the model output can be particularly useful for identifying "priority" subwatersheds. The modeled pollutant or concentrations or total loads include TSS, TP, and TN. Point and non-point contributions can be extracted separately. Can be used to analyze different BMP "scenarios".	PCA models many major watersheds with HSPF. If completed, model data can be obtained from PCA and imported into GIS.	http://water.usgs.gov/software/HSPF/
HSPF - Scenario Application Manager (SAM)	Designed for those without HSPF training to visualize HSPF data and develop non-point and point source BMP scenarios "on the fly" without having to manually manipulate HSPF code	A local county government could develop HSPF scenarios in SAM that would demonstrate BMPs that would reach local WQ goals; this demonstration could then be used to secure funding for BMP placement. This would be done without having to contract out the scenarios with an engineering firm	Can export data from SAM as shapefile for use in GIS	http://www.respec.com/portfolio_project_view.php?project_id=15
1855 Land Survey Data	Data originally created by land surveyors in the mid-to-late 1800s. Surveys were conducted in one-mile grid and indicated the land cover at the time of the survey. This data has been georeferenced and is available for most of the state. This information has been digitized by PCA staff for the GRBERB.	This information could be used to prioritize areas based on changes in the landscape. This information is also helpful to understand landscape limitations (e.g. former lake beds may not be drain well).	Image data is available from MN Geo. Digitized rivers, lakes, and wetlands (in the GBERB only) are available from PCA staff.	http://www.mngeo.state.mn.us/glo/
Drinking Water Supply Management Areas	Drinking water supply management area (DWSMA) is the Minnesota Department of Health (MDH) approved surface and subsurface area surrounding a public water supply well that completely contains the scientifically calculated wellhead protection area and is managed by the entity identified in a wellhead protection plan. The boundaries of the drinking water supply management area are delineated by identifiable physical features, landmarks or political and administrative boundaries.	This dataset was developed with the intention of protecting the public drinking water supply and complies with the federal Safe Drinking Water Act	Contact Minnesota Department Of Health Source Water Protection Unit with questions.	ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_health/water_drinking_water_supply/metadata/drinking_water_supply_management_areas.html
Drinking Water Supply Management Area Vulnerability	Drinking water supply management area (DWSMA) vulnerability is an assessment of the likelihood for a potential contaminant source within the drinking water supply management area to contaminate a public water supply well based on the aquifer's inherent geologic sensitivity; and the chemical and isotopic composition of the groundwater.	This dataset was developed with the intention of protecting the public drinking water supply and complies with the federal Safe Drinking Water Act	Contact Minnesota Department Of Health Source Water Protection Unit with questions.	ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_health/water_drinking_water_supply/metadata/drinking_water_supply_management_area_vulnerability.html
Restorable Depressional Wetland Inventory	A GIS layer representing drained, potentially restorable wetlands in agricultural landscapes. Created primarily through photo-interpretation of 1:40,000 scale color infrared photographs acquired in April and May, 1991 and 1992.	Identify restorable wetland areas with an emphasis on: wildlife habitat, surface and ground water quality, reducing flood damage risk. To see a comprehensive map of restorable wetlands, must display this dataset in conjunction with the USGS National Wetlands Inventory (NWI) polygons that have a 'd' modifier in their NWI classification code	GIS layer is available on the DNR Data Deli website also available from Ducks Unlimited.	http://deli.dnr.state.mn.us/metadata.html?id=L390002730201; http://prairie.ducks.org/index.cfm?&page=minnesota/restorablewetlands/home.htm#downfile

"Altered Hydrology" (PCA Analysis)	GIS layers (results of GIS analysis) of hydrology-influencing parameters indicating the amount of change (since European settlement) including: % tiled, % wetland loss, % stream channelized, % increase in waterway length, % not perennial vegetation, % impervious. Analysis done at the same subwatershed scale as the HSPF modeling was completed to facilitate subwatershed prioritization. Analysis was completed using available GIS data layers.	These 6 layers could be used individually or in combination (using raster calculator) to prioritize subwatersheds to target conservation practices intended to mitigate altered hydrology.	GIS layers are available from PCA staff.	
Altered Watercourse Dataset (Channelized Streams)	Statewide data layer that identifies portions of the National Hydrography Dataset (NHD) that have been visually determined to be hydrologically modified (i.e., ditches, channelized streams and impoundments).	Identifies streams with highly modified stream channels for conservation prioritization. Subwatersheds with high levels of channelized streams may be prioritized for specific conservation practices.	GIS layers are available on the MN Geo website.	http://www.mngeo.state.mn.us/ProjectServices/awat/
Tile Drainage (PCA Analysis)	Data created as an estimate of whether a pixel is tiled or not. Assumes tiled if: row crop, <3% slope, poorly drained soil type	Can be useful for prioritizing highly drained areas to implement BMPs that address altered hydrology.	Data can be obtained from PCA staff	
Light Detection and Ranging (LiDAR)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for: erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the MN Geospatial Information website for most counties.	http://www.mngeo.state.mn.us/chouse/elevation/lidar.html
Stream Power Index (SPI)	SPI, a calculation based on a LiDAR file, describes potential flow erosion at the given point of the topographic surface. As catchment area and slope gradient increase, the amount of water contributed by upslope areas and the velocity of water flow increase. Varying SPI analyses have been done with different resulting qualities depending on the amount of hydrologic conditioning that has been done.	Useful for identifying areas of concentrated flows which can be helpful for targeting practices such as grassed waterways or WASCOBs. Again, the usefulness may depend on the level of hydrologic conditioning that has been done.	This layer has been created by PCA staff with little hydroconditioning for the GBERB and can be obtained from PCA staff.	http://iflorinsky.narod.ru/si.htm
Compound Topographic Index (CTI)	CTI, a calculation based on a LiDAR file, is a steady state wetness index. The CTI is a function of both the slope and the upstream contributing area per unit width orthogonal to the flow direction. CTI was designed for hillslope catenas. Accumulation numbers in flat areas will be very large and CTI will not be a relevant variable.	Identifies likely locations of soil saturation which can be useful for targeting certain practices.	Can be downloaded from ESRI	http://arcscripts.esri.com/details.asp?dbid=11863
NRCS Engineering Toolbox	The free, python based toolsets for ArcGIS 9.3 and 10.0 allow for user friendly use of Lidar Data for field office applications, Hydro-Conditioning, Watershed Delineation, conservation planning and more.	Many uses including siting and preliminary design of BMPs.	Toolbox and training materials available on the MnGeo site.	http://www.mngeo.state.mn.us/chouse/elevation/lidar.html
RUSLE2	RUSLE2 estimates rates of rill and interrill soil erosion caused by rainfall and its associated overland flow. Several data layers and mathematical calculations are used to estimate this erosion.	Estimating erosion to target field sediment controlling practices.		http://www.ars.usda.gov/Research/docs.htm?docid=6016
Crop Land - National Agricultural Statistics Service (NASS)	Data on the crop type for a specific year. Multiple years data sets available.	Identify crop types, including perennial or annual crops and look at crop rotations/changes from year to year. A specific example of a use is to identify locations with a short season crop to target cover crops practice.	Data available for download from the USDA or use the online mapping tool.	http://www.nass.usda.gov/research/Cropland/SARS1a.htm
National Land Cover Database (NLCD) from the MRLC	Data on land use and characteristics of the land surface such as thematic class (urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover.	Identify land uses and target practices based on land use. One example may be to target a residential rain garden/barrel program to an areas with high levels of impervious surfaces.	Data available for download from the MRLC website	http://www.mrlc.gov/
CRP land (2008)	Data on which areas were enrolled in the USDA Conservation Reserve Program. This data is no longer available but may exist at the county level.	Potential uses include targeting areas to create habitat corridors or targeting areas coming out of CRP to implement specific BMPs.		http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp
Soils Data (SSURGO)	Data indicates soil type and properties.	Soil types can be used to determine the acceptableness of a practice based on properties such as permeability or erosvity.	Data can be downloaded or online viewers are available on the NRCS website.	http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627

Feedlot Locations	Data indicates the location of existing feedlots. Some data in this data layer is not accurate and feedlot locations could be mapped at the owner's address or in the center of the quarter quarter.	May be helpful prioritizing areas to implement strategies that address E. coli or nutrients.	Data available on PCA website	ftp://files.pca.state.mn.us/pub/spatialdata/ see "mpca_feedlots_ac.zip"
Land Ownership/ Property Boundaries	Data indicates the owner and property boundary. This data is kept at the county level.	May be helpful for targeting efforts, particularly when a proactive approach is taken (e.g. if areas are targeted for specific practices and land owners are contacted to gauge their interest in a specific practice).	Some data available on the MN Geo website. Not all areas may have data in GIS format. Contact specific counties for more details/information.	http://www.mngeo.state.mn.us/chouse/land_own_property.html
Installed Practices	Data exists in a limited extent at this time. Agencies like BWSR, the NRCS, or County SWCDs may be able to provide some information.	Knowing which areas have had multiple practices installed could indicate more interested landowners or help identify areas to anticipate water quality improvements.	Contact listed agencies to inquire if any data is available.	
Watershed Health Assessment Framework (WHAF)	An online spatial program that displays information at the major and subwatershed scaled. Information includes: hydrology, biology, and water quality.	The online program is helpful for quick viewing and could be used to prioritize subwatersheds based on parameters or criteria in the WHAF.	Online only	http://arcgis.dnr.state.mn.us/ewr/whaf/Explore/
Agricultural Conservation Planning Framework (ACPF; Tomer et al.)	An outlined methodology uses several data layers and established analyses to identify specific locations to target several different BMPs. A "toolbox" is being created to facilitate the use of this methodology in MN.	Targeting specific BMPs (see link).	see demo: https://usdanrcs.adobeconnect.com/p6v40eme1cz/	http://northcentralwater.org/acpf/
Ecological Ranking Tool (Environmental Benefit Index - EBI)	Three GIS layers containing: soil erosion risk, water quality risk, and habitat quality. Locations on each layer are assigned a score from 0-100. The sum of all three layer scores (max of 300) is the EBI score; the higher the score, the higher the value in applying restoration or protection.	Any one of the three layers can be used separately or the sum of the layers (EBI) can be used to identify areas that are in line with local priorities. Raster calculator allows a user to make their own sum of the layers to better reflect local values or to target specific conservation practices.	GIS layers are available on the BWSR website.	http://www.bwsr.state.mn.us/ecological_ranking/
MN Natural Heritage Information System (Rare Features Data)	NHIS contains information about the location and identities of Minnesota's endangered, threatened, special concern, watch list, and species of greatest conservation need (state and federally listed), as well as records of rare native plant communities, Animal aggregations, and geologic features. It is classed as protected data under MN Statute, section 84.0872	This data can be used to prioritize areas for restoration and conservation protection.		http://www.dnr.state.mn.us/nhnrp/nhis.html
MNDNR Native Plant Communities	Classification of Minnesota's remnant land cover types. They are classified by considering vegetation, hydrology, landforms, soils, and natural regimes.	This data can be used to prioritize areas for restoration and conservation protection.		http://www.dnr.state.mn.us/npc/index.html
Protected Lands and Easements	This data is pulled from multiple GIS layers and summarizes fee title and easement lands held by MNDNR, TNC, BWSR, USDA, USFWS, and USFS	This data can be used to prioritize areas for restoration and conservation protection. It gives connection points in the landscape for creating larger blocks of habitat that serve to preserve our diversity.		https://gisdata.mn.gov/
Lakes of Phosphorus Sensitivity Significance	A ranked priority list for Minnesota's unimpaired lakes based on sensitivity to additional phosphorus loading. The most sensitive lakes will likely see substantial declines in water clarity with increased nutrient pollution loading.	Dataset valuable to local governments and state agencies tasked with prioritizing unimpaired lakes for protection efforts.	GIS layer available from Minnesota Geospatial Information Office.	https://gisdata.mn.gov/dataset/env-lakes-phosphorus-sensitivity
Zonation	A values-based framework and software for large-scale spatial conservation prioritization. Allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. Produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites/grid cells. It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process.	Surveys are created and given to targeted audiences to identity their priorities. These survey priorities are then used by the program. The output of Zonation can be used to identify areas that align with the conservation values of the survey respondents.	Zonation results can be exported to GIS. Paul Radomski (DNR) and colleagues have expertise with Zonation.	http://cbig.it.helsinki.fi/software/zonation/

Restorable Wetland Prioritization Tool	The base layer is a restorable wetlands inventory that predicts restorable wetland locations across the landscape. There are also three decision layers including a stress, viability, and benefits layer. The stress and viability decision layers can be weighted differently depending on the users interest in nitrogen and phosphorus reductions and habitat improvement. Lastly, there is a modifying layer with aerial imagery and other supplemental environmental data.	This tool enables one to prioritize wetland restoration by nitrogen or phosphorus removal and/or by habitat. Additional uses include: locating areas most in need of water quality or habitat improvement; prioritizing areas that already are or are most likely to result in high functioning sustainable wetlands; refining prioritizations with aerial imagery and available environmental data.		https://beaver.nrri.umn.edu/MPCAWLPri/
Lakes of Biological Significance	Lakes were identified and classified by DNR subject matter experts on objective criteria for four community types (aquatic plants, fish, amphibians, birds).	Lakes with higher biological signaifcance can be prioritized for restroation and protection.		https://gisdata.mn.gov/dataset/env-lakes-of-biological-signific
National Fish Habitat Partnership Data System	Supports coordinated efforts of scientific assessment and data exchange among the partners and stakeholders of the aquatic habitat community. The system provides data access and visualization tools for authoritative NFHP data products and contributed data from partners. Data sets available include: anthropogenic barrier dataset,			http://ecosystems.usgs.gov/fishhabitat/
Indicators of Hydrologic Alteration (IHA)	The Indicators of Hydrologic Alteration (IHA) is a software program that provides useful information for those trying to understand the hydrologic impacts of human activities or trying to develop environmental flow recommendations for water managers. assess how rivers, lakes and groundwater basins have been affected by human activities over time – or to evaluate future water management scenarios. Assess how rivers, lakes and groundwater basins have been affected by human activities over time – or to evaluate future water management scenarios.	The software program assesses 67 ecologically-relevant statistics derived from daily hydrologic data. For instance, the IHA software can calculate the timing and maximum flow of each year's largest flood or lowest flows, then calculates the mean and variance of these values over some period of time. Comparative analysis can then help statistically describe how these patterns have changed for a particular river or lake, due to abrupt impacts such as dam construction or more gradual trends associated with land- and water-use changes.		https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofHydrologicAlteration/Pages/indicators-hydrologic-alt.aspx
InVEST	InVEST is a suite of software models used to map and value the goods and services from nature that sustain and fulfill human life. InVEST enables decision makers to assess quantified tradeoffs associated with alternative management choices and to identify areas where investment in natural capital can enhance human development and conservation.	InVEST models can be run independently, or as script tools in the ArcGIS Arc Toolbox environment. You will need a mapping software such as QGIS or ArcGIS to view your results. Running InVEST effectively does not require knowledge of Python programming, but it does require basic to intermediate skills in ArcGIS.		http://www.naturalcapitalproject.org/InVEST.html
RIOS	RIOS provides a standardized, science-based approach to watershed management in contexts throughout the world. It combines biophysical, social, and economic data to help users identify the best locations for protection and restoration activities in order to maximize the			http://www.naturalcapitalproject.org/RIOS.html
The Missouri Clipper	This tool will generate a ZIP file containing support files needed for SNMP, MMP and RUSLE2. These support files include aerial photo and topographic map images, soil and watershed shape files, a digital elevation model raster file, and a RUSLE2 GDB file. Soil data is obtained from the NRCS Web Soil Survey and may be limited by availability (see Status Map). To get your data, locate your farm on a map using Google			http://clipper.missouri.edu/index.asp?t=county&state=Minnesota
Map Window GIS + MMP Tools	Map Window GIS + MMP Tools is a free GIS that can be used for the following: 1.As a front-end to MMP when creating nutrient management plans. 2.As a front-end to Irris Scheduler when doing irrigation and nitrogen scheduling. 3.For designing research plots (randomized			http://www.purdue.edu/agsoftware/mapwindow/
Objective Model Custom Weight Tool	A decision support tool designed for USFWS resource managers the ability to make thoughtful and strategic choices about where to spend its limited management resources. This tool makes the processes used to prioritize these management units more transparent, improving the defensibility of management decisions. Originally created for the Morris Wetland Management District (WMD)			http://www.umesc.usgs.gov/management/dss/morris_wmd.html
WARPT: Wetlands-At-Risk Protection Tool	The Wetlands-At-Risk Protection Tool, or WARPT, is a process for local governments and watershed groups that acknowledges the role of wetlands as an important part of their community infrastructure, and is used to develop a plan for protecting at-risk wetlands and their			http://www.wetlandprotection.org/