North and Middle Fabius Nonpoint Source Watershed Management Plan

Written by:
Schuyler Soil and Water Conservation District
and
Missouri Department of Natural Resources

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Acknowledgements

This North and Middle Fabius Nonpoint Source Watershed Management Plan (WMP) was completed with assistance from several partners, including representatives from federal, state and local governments, watershed organizations and citizens of the watershed.

Soil and Water Conservation Districts
The Schuyler, Scotland, Clark, Lewis, Marion, Knox, and Adair County Soil and Water Conservation Districts (SWCDs) assist landowners and producers in the protection and improvement of soil and water resources in the North Fabius watershed. The SWCDs offer cost-share programs and technical assistance through best management practices (BMPs) such as terraces, dry-hole systems, waterways, well decommissioning, pasture land management, and many others. Members of the county boards contribute input on BMP effectiveness and preferences and contribute information about land and landowners in the watershed.

University of Missouri Extension Councils
University of Missouri Extension Councils consist of elected and appointed members who represent a diverse and comprehensive part of each community. Extension councils market programs and give input on issues affecting citizens. Councils work with University of Missouri (MU) specialists to identify and address unmet needs. Darla Campbell, MU Extension Agricultural Business and County Engagement Specialist, continues to be the local project manager working with the Extension councils in Schuyler, Scotland, Clark, Lewis, Knox, Marion, and Adair counties.

University of Missouri - Columbia
The University of Missouri –Columbia conducted modeling of the North Fabius watershed to help with understanding baseline sediment loading and the sediment load reductions that would occur from implementation of various BMPs throughout the watershed. An ArcGIS Interface for Soil and Water Assessment Tool was used for the model.

County Residents and Landowners in all Seven Counties
Landowners and residents have taken part in the planning process in various ways, including attending planning meetings, participating in the steering committee, and providing information and input during the planning process.

County Commissions for all Seven Counties
The County Commissioners have attended public meetings, reviewed existing plan, and provided input on the plan.

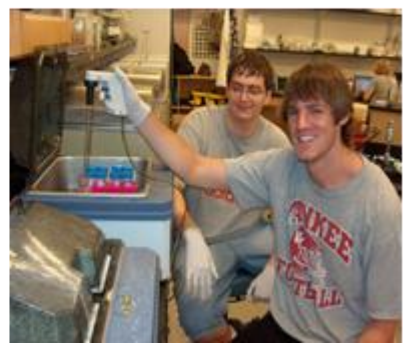
Missouri Department of Natural Resources
The Missouri Department of Natural Resources (MDNR) has been instrumental in providing technical assistance through the Water Protection and Soil and Water Conservation Programs. The Nonpoint Source (NPS) Project Manager, John Johnson, reviewed each draft of the plan and provided guidance in meeting Environmental Protection Agency (EPA) requirements. The MDNR serves as administrator for the 319 grant funds received from the EPA through the Clean Water Act. MDNR staff provided comments, recommendations and revisions, as needed, to address EPA's required nine planning elements. Pollutant Load Duration Curves were developed and STEPL modeling conducted to estimate pollutant loading, obtain the water quality goals, identify target/critical areas, and calculate BMP load reductions needed to address the stream water quality impairment and other pollutants of concern.

Natural Resources Conservation Service
The Natural Resources Conservation Service (NRCS), under the U.S. Department of Agriculture (USDA) provides financial, technical, and educational assistance to implement conservation practices on privately owned land. The NRCS provided assistance on this project with mapping, load reductions, and technical data on structural practices.

Missouri Department of Conservation
The Missouri Department of Conservation (MDC) allowed the use of technical data collected by their department to be cited in the watershed management plan.

Dr. Cynthia Cooper, PhD., Department of Biology, Truman State University
Dr. Cynthia Cooper PhD, from the Department of Biology (now retired) at Truman State University (Kirksville, Missouri) and her students assisted with the collection of water samples from five sites on the North and Middle Fabius Rivers. The North Fabius Watershed Management Steering Committee and the Schuyler County Soil and Water District Board are very appreciative for the assistance of Dr. Cooper and her students for collecting the grab samples that will be used as screening level/baseline data.

Students from Truman State University taking water samples and conducting lab test for water quality.



Executive Summary

Purpose

In 2010, Schuyler County Soil and Water Conservation District received a Section 319 Nonpoint Source Implementation Grant from the Missouri Department of Natural Resources to develop a Watershed Plan for the North and Middle Fabius River watersheds. The intent was to fully analyze the watersheds, make recommendations toward improving water quality, and provide watershed-level recommendations for surface water management. The plan was developed in response to the North Fabius River (WBID 56) being listed on Missouri's 1998 and 2002 303(d) lists of impaired waters due to sediment pollution from agricultural nonpoint sources. The plan was updated in 2020 and addresses nonpoint source pollutants of concern that were identified by local stakeholders.

Introduction - North Fabius Subbasin

The North Fabius Subbasin encompasses the North Fabius River (WBID 56) and Middle Fabius River (WBID 63), which are both surrounded by long, narrow drainage areas in northeastern Missouri that extend southeastward from Iowa across several Missouri counties and outlets near the Mississippi River in northeastern Marion County, Missouri (Figure 1). Missouri counties located within the watershed include Schuyler, Scotland, Adair, Clark, Knox, Lewis, and Marion. The North Fabius subbasin is a subset of the larger Upper Mississippi River Basin encompasses about 585,736 acres (915 sq. miles).

The North and Middle Fabius project area contains twenty-five subwatersheds that are delineated at the HUC 12 scale. "HUC" stands for Hydrologic Unit Code, which is a number that identifies the general location and size of the watershed. Many of the issues identified in the watershed are assessed at these subwatershed levels. The HUC12 subwatersheds within the North Fabius and Middle Fabius watersheds are:

North Fabius River

071100020101	South Fork North Fabius River
071100020102	Headwaters North Fabius River
071100020103	Carter Creek
071100020104	North Fork North Fabius River
071100020105	Downing Reservoir
071100020106	Gunns Branch
071100020107	Indian Creek
071100020108	Memphis Reservoir
071100020401	Bear Creek
071100020402	Long Branch
071100020403	Cooper Branch
071100020404	Town of Weber
071100020405	North Fabius River

Middle Fabius River

071100020201	Bridge Creek
071100020202	Headwaters North Fork Middle Fabius River
071100020203	Brushy Creek
071100020204	Headwaters South Fork Middle Fabius River
071100020205	North Middle Fork Fabius River
071100020206	South Fork Middle Fabius River
071100020301	Tobin Creek
071100020302	City of Baring - Bridge Creek
071100020303	Little Bridge Creek - Bridge Creek
071100020304	Sand Hill Branch
071100020305	Reddish Branch
071100020306	Middle Fabius River

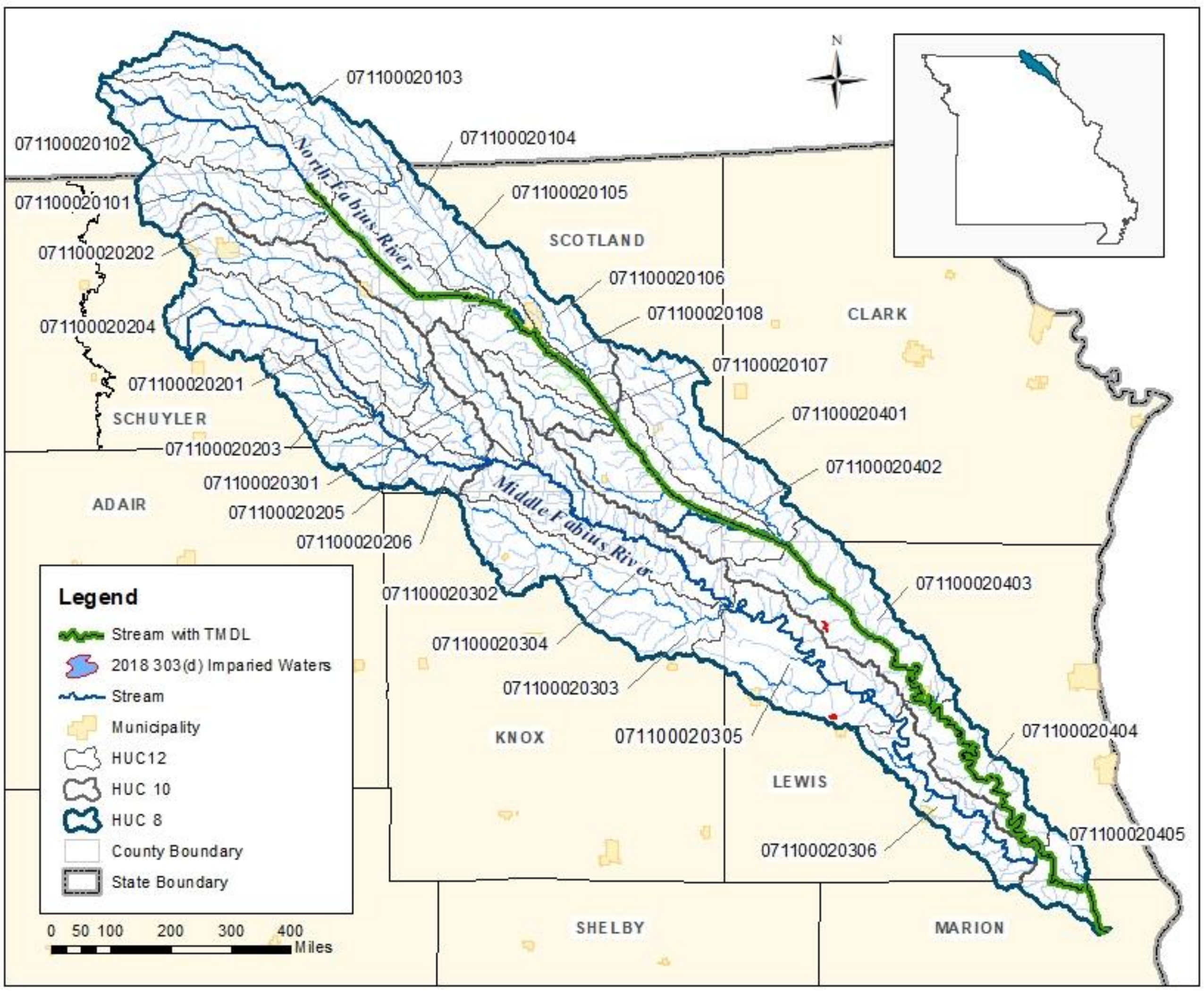


Figure 1. North Fabius Subbasin (HUC 07110002) containing North Fabius and Middle Fabius Rivers.

The land uses and covers throughout the subbasin are mostly rural and agricultural. Farming is the major land use in the watershed. The 2017 agriculture census data reported a range of 116,941 to 267,920 acres farmed across Adair, Clark, Knox, Lewis, Marion, Schuyler, and Scotland counties. Hay/pastureland makeup 43% and cropland makes up about twenty-seven percent of the area.

Water Quality Concerns

Water quality concerns in the North Fabius planning area include high concentrations of pollutant loading, such as sediment, nutrient, chemicals, and pathogens. Nonpoint sources of these pollutants are mainly from alterations to streambanks, row crop agricultural practices, and animal agricultural practices. Stream channelization, bank clearing, and channel widening have resulted in loss of total stream area and usable habitat and increased streambank and streambed erosion. The increase in land conversion to row crop agriculture, especially when management practices do not incorporate soil health practices and nutrient management plans, has resulted in sheet and rill erosion, gully erosion, and nutrient runoff. The increase in land conversion from pasture and hay land to row crops has also resulted in increased use of herbicides and pesticides.

Improper application of animal nutrients to crop and pastureland may also contribute to nutrient loading in waterbodies. Poor grazing land health where pasture and hay land is not properly managed can also facilitate soil erosion and nutrients and pathogens in surface runoff. Livestock that have direct access to streams also contribute to water quality issues by trampling riparian corridors, degrading streambanks, and depositing waste directly in the waterbody.

Water Quality Targets

The North Fabius River (WBID 56) was included on the 1998 and 2002 303(d) list of impaired waters. The waterbody was listed because the Protection of Warm Water Aquatic Life Use did not meet Narrative Criteria due to sediment pollution from agricultural nonpoint sources. Per Missouri's Water Quality Standards (WQS), all waters of the state must provide suitable physical habitat and water quality for aquatic life.

A Total Maximum Daily Load was written to address the sediment impairment in the North Fabius River and approved by the EPA in September 2006, which is required by Section 303(d) of the federal Clean Water Act for waterbodies not meeting a state's WQS. The 2006 North Fabius TMDL suggested simply that an 87% reduction was needed to reduce suspended solids (TSS)/sediment loading to the level the waterbody could assimilate and still meet WQS. However, for the 2020 revision of the North and Middle Fabius NPS watershed management plan, the TSS Load Duration Curve was recalculated using more current data and recommended that at the mid-range flow an average TSS reduction of 52% or 16 tons per day is needed. The overall goal of this watershed management plan is to implement the TMDL, restore aquatic habitats, and bring the North Fabius River to the State's Water Quality Standards.

In addition the sediment impairment, additional pollutants of concern that show trends in becoming a future threat to water quality will also be addressed with the watershed plan, such as nutrients (nitrogen, phosphorus) and bacteria (*E.coli*). With assistance from MDNR, load reduction goals for total nitrogen (TN), total phosphorus (TP), and bacteria were also developed using a load duration curve model. Targets for TN and TP were based on RTAG benchmark values of 0.9 mg/L and 0.075 mg/L, respectively. Based on water quality data collected from the North and Middle Fabius Rivers since March 2006, an average 23% reduction in TN and a 31% reduction in TP were estimated for the planning area. The *E. coli* target for the watershed plan is based on Missouri's Water Quality Standards and uses the criterion of 206 bacterial counts per 100mL for the protection of Whole Body Contact -B Use. Across the entire range of flows, the average *E. coli* load reduction goal is calculated at 35%.

Watershed Plan Goals and Objectives

The plan promotes a functioning, healthy watershed and guides the development, enhancement, and implementation of actions to achieve these goals:

- Goal I: Implement an Information/Education and Outreach Program targeting North Fabius watershed stakeholders to inform and educate conservation measures to improve water quality.
- Goal II: Use BMPs implementation to address the stream impairments and improve water quality to TMDL or Water Quality Standards limits.
- Goal III: Conduct yearly monitoring and modeling in the North Fabius Watershed to track water quality improvement over time.

These Objectives will be implemented to meet the goals:

- Create public awareness and involvement in water quality issues.
- Provide information about water quality issues and how all community sectors, partners, and stakeholders affect water quality within the watershed.
- Promote relationships and networks among local leaders, agricultural producers, landowners, and residents to promote watershed management programs targeting the following concerns; erosion and sedimentation, nutrient and chemical runoff, loss of fish and wildlife resources, and maintenance of water quality for recreational use.
- Target practices to geographical areas that will be most effective in reducing soil erosion and improving water quality as reflected through load reductions BMP implementation include strategies for Cropland Management, Livestock Management, Groundwater Quality and Riparian Improvement and Stream Protection.
- Evaluate past and present conservation practices to determine effectiveness after implementation.

Critical Areas and Priority Areas

Identifying the critical source areas is a major part of the planning process and a key part to meeting the load reduction targets set by a Watershed Management Plan or Total Maximum Daily Load. The critical areas are those areas where the conservation measures or best management practices should be placed for the greatest pollutant load reduction to address the stream water quality problems. They are identified through modeling or land use assessment as areas that likely contribute the greatest amount of a nonpoint source pollutant. The entire watershed management planning area was then divided into three Priority area tiers to help prioritize implementation efforts. Sediment loading from the North and Middle Fabius watersheds was assessed at the HUC 12 subwatershed scale and estimated using the U.S. Environmental Protection Agency's Spreadsheet Tool for Estimating Pollutant Loads (STEPL), Sediment loading within each of the twenty-five subwatersheds in the watershed management planning area was estimated after considering land use coverage, BMPs recently implemented, and an aerial assessment of gully and streambank erosion. Based on total STEPL-estimated annual sediment loading, the HUC 12s were ranked and assigned to a priority tier where the top eight subwatershed with the greatest average annual sediment loading were designated as Priority 1.

BMP Implementation

Conservation management measures or BMPs selected for the plan are commonly used practices in the watershed that landowners are willing to implement. Implemented BMPs that are placed in one of the critical areas will be most effective in reducing the nonpoint source pollutants of concern and addressing the stream water quality impairment. Aside from the practices selected for implementation that are commonly used by landowners, additional agriculture BMPs that address the stream impairment will be promoted through information/education and BMP demonstration activities. State cost-share agriculture practices available through the Soil and Water Conservation Program (SWCP) and any other BMP that addresses sediment, nutrient and bacteria pollutants will be eligible for use to improve the stream water quality.

The BMPs scheduled for implementation during the watershed plan 20 year period to address the stream impairment and other nonpoint source pollutants of concern consist of Cropland Management, Livestock Management, Groundwater Quality, and Riparian Improvement and Stream Protection practices and include:

- 400 Terrace System (DSL-44)
- 40 Diversion (DSL-5)
- 20 Permanent Vegetative Cover - Critical Area (DSL-11)
- 360 Cover Crop (N340)
- 400 Water Impoundment Reservoir (DWC-1)
- 180 Sediment Retention, Erosion or Water Control Structure (DWP-1)
- 20 Sod Waterway (DWP-3)
- 20 Nutrient Management Plans (N590)
- 80 Pest Management Plans (N595)
- 100 Permanent Vegetative Cover Establishment (DSL-1)
- 20 Permanent Vegetative Cover Enhancement (DSP-02)
- 200 Permanent Vegetative Cover Improvement (DSL-2)
- 20 Grazing Systems (DSP- 03)
- 140 Well Decommissioning (N351)
- 20 Field Border (N386)
- 20 Filter Strip (N393)
- 60 Livestock Exclusion (N472)
- 20 Stream Protection (WQ-10)

Estimated Pollutant Load Reduction

Pollutant load reductions from the implementation of management measures or best management practices are estimated with modeling or by applying known pollutant reduction efficiencies. Pollutant load reduction efficiencies for SWCP cost-share practices were estimated using STEPL's BMP Calculator by simulating as best as possible the combined effect of the various structures and practices that make up each state cost-share practice. These BMP efficiencies were then applied to the suite of cost-share practices scheduled in the watershed management plan to estimate an annual pollutant load reduction. Included in the estimated reduction were practices not yet implemented in the subbasin: riparian forest buffer, streambank stabilization, and field borders. The riparian forest buffer and streambank stabilization practices were especially included because stabilizing the streambanks and securing them with vegetation, in addition to stream access by livestock, will greatly reduce sediment, nutrient, and bacteria loading to the North and Middle Fabius Rivers.

Annual pollutant load reductions estimated in the plan are also expanded to represent the short-term (years 1-5), mid-term (years 6-10), and long-term (years 11-20) reductions that will be achieved during the 20 year plan period if all scheduled practices are implemented.

Information, Education and Outreach

Education programs that focus on informing and educating the general public about water quality issues in the watershed will be implemented. Programs will focus on informing about practical and affordable conservation practices that landowners can adopt to reduce nonpoint source pollution. Information will be distributed to the general public in the form of brochures, public service announcements, and newsletters. In addition, workshops, tours and field days will be organized to increase public perception on utilizing conservation practices for reducing sediment runoff and improving stream water quality.

Technical and Financial Assistance - Funding Options

The implementation of the watershed plan will depend on the availability of the technical and financial assistance needed to apply the conservation measures. Technical assistance for agriculture BMP installation can be provided by agencies and organizations such as NRCS, MDNR, SWCD, University of Missouri Extension, or MDC. The use of federal, state, local, and private funds or resources from other conservation partners will be utilized when available. Cost estimates for each cost-share practice were determined using the average cost of conservation practices implemented in the North and Middle Fabius watersheds from July 2009 to June 2020.

Watershed Plan Evaluation and Performance

Progress in achieving the goals and objectives of this plan will be evaluated using the number of BMPs implemented to estimate load reductions with modeling and monitoring to capture water quality improvements. Performance evaluation will also occur through gathering input from participants at field days, demonstrations, or other events, such as grazing schools.

Within 5 years from the beginning of implementing the North and Middle Fabius Nonpoint Source Watershed Management Plan, partners and stakeholders will evaluate the progress made toward achieving the BMP implementation schedule and water quality goals**.** If water quality goals are not on pace to be met within the first 5 year period, partners will discuss the feasibility of increasing the number of BMPs installed. If modeling and/or monitoring indicates that water quality goals will most likely not be met through further implementation, water quality partners will discuss revising strategies toward the achievement of plan goals. **Schuyler County SWCD will have primary responsibility for the updating process, including contact with all major stakeholders and gathering data and input.**

Chapter 1: Introduction

Mission

The mission of the North and Middle Fabius Nonpoint Source Watershed Management Plan is to create an on-going plan that engages local citizens concerning their goals and objectives for water resource protection, management and development.

Project Vision

The North Fabius subbasin is an exceptional natural resource that provides for economic, agricultural, residential, and recreational needs and should be managed in a balanced and sustainable way. The development and implementation of a watershed plan will help improve and protect the land and water resources in the North Fabius River and Middle Fabius River watersheds.

Project Overview

2010 North and Middle Fabius Nonpoint Source Watershed Management Plan[1]

In September 2006, the North Fabius River (WBID 56) Total Maximum Daily Load (TMDL) for sediment established in accordance with Section 303(d) of the Clean Water Act, because the State of Missouri determined on the 1998 and 2002 303(d) lists of impaired waters that the water quality standards (WQS) for North Fabius River were exceeded due to sediment.

The TMDL stated that a combination of natural geology and land use in the prairie portions of the state where the North Fabius River is located is believed to have reduced the amount and impaired the quality of habitat for aquatic life. The major problems are excessive rates of sediment deposition due to stream bank erosion and sheet erosion from agricultural lands, loss of stream length and loss of stream channel heterogeneity due to channelization, and changes in basin hydrology that have increased flood flows and prolonged low flow conditions. Loss of tree cover in riparian zones caused elevated water temperatures in summer and a reduction in woody debris, which is a critical aquatic habitat component in prairie streams. The most compelling evidence of loss or impairment of aquatic habitat is the change in the historical distribution of fishes in Missouri[2].

In an attempt to gain input about North and Middle Fabius watershed concerns, Schuyler County SWCD staff solicited input from landowners, Special Area Land Treatment (SALT) steering

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[1] 2010 North and Middle Fabius Nonpoint Source Watershed Management Plan https://dnr.mo.gov/env/swcp/nps/319applicationresourcetools.htm
[2] MDNR. Water Protection Program. For Streams with Aquatic Habitat Loss that are Listed for Sediment. https://dnr.mo.gov/env/wpp/tmdl/info/docs/sediment-info.pdf

committee members, district board members, contractors, and the University of Missouri Extension Council. The SWCD was given a consistent, recurring message—water quality issues must be addressed in a sustainable way. With that in mind, and because of the water quality impairment concerns and Total Maximum Daily Load development for the North Fabius River, the Schuyler County SWCD decided to develop a plan to address the sediment impairment and restore the water quality in the North Fabius Subbasin.

In April 2007, a Section 319 subgrant in the amount of $15,000 from the Missouri Department of Natural Resources was awarded to the Schuyler County Soil and Water Conservation District to develop a watershed plan for the North and Middle Fabius Watershed. The funds supported the project from April 15, 2007 through April 14, 2009. The Schuyler County SWCD also provided $4,741 of the required match and the remaining $5,259 was provided through the MDNR's Soil and Water Conservation Program with revenue generated from the Missouri Parks and Soil Sales Tax. The total project cost was $25,000.

The grant project funds were used to develop a watershed management plan that contains the Environmental Protection Agency's nine critical planning elements for the greater North Fabius (HUC 07110002) subbasin, which includes Schuyler, Scotland, Knox, Lewis, Clark, Marion, and Adair counties. The plan would help protect and improve water quality in the North Fabius Subbasin by identifying pollutant sources, identifying best management practices (BMPs) to be implemented, setting reachable goals and a timeline for implementation, and establishing an evaluation and monitoring program. By applying BMPs at strategic locations within the planning area, the Schuyler County SWCD hoped to reduce the impact of pollution on the North Fabius and Middle Fabius Rivers.

Plan Development through Public Engagement

The Schuyler County SWCD used a planning process that encourages local stakeholder participation and support. They worked with the local conservation partners and watershed stakeholders to assist and coordinate planning efforts in developing the 2010 plan. A steering committee made up of key stakeholders, was formed to oversee the development of the watershed management plan (WMP) that contains EPA's nine critical elements. Partners in the project included the Knox County SWCD, Knox County University Extension, Lewis County SWCD, Lewis County Extension, Clark County SWCD, Clark County Extension, Marion County SWCD, Marion County Extension, Schuyler University Extension, Scotland County Extension, Scotland County SWCD, Northeast Missouri Resource Conservation and Development, Adair County SWCD, Adair County Extension, and the city and county governments in the watershed.

Throughout the process, partnering agencies/organizations and stakeholders meetings were held to identify watershed problems, major pollutant sources, and management measures to be implemented. Meetings were held with each of the SWCD Boards and University Extension Councils in the seven counties to gather information on perceived problems, goals, and activities in the watershed. The meetings also served to introduce the agencies and individuals currently working within the watershed to various land use, water quality, and quantity issues. The meetings resulted in a number of objectives being defined and identifying strategies for meeting these objectives. The data and information obtained from meetings, research, and assessment was compiled and used to complete a draft plan.

During the plan development process, high interest was expressed in improving water quality by controlling erosion and sedimentation, as well as surface runoff of chemicals and nutrients. Streambank erosion due to channelization, livestock access to the stream, and lack of adequate vegetative buffers between streams and agricultural land generated much discussion on how these concerns should be addressed. Education, promotion and implementation of BMPs were most often cited as the best way to address the concerns. Sites of concern within the North and Middle Fabius watersheds were identified in Schuyler and Scotland counties (Figure 2).

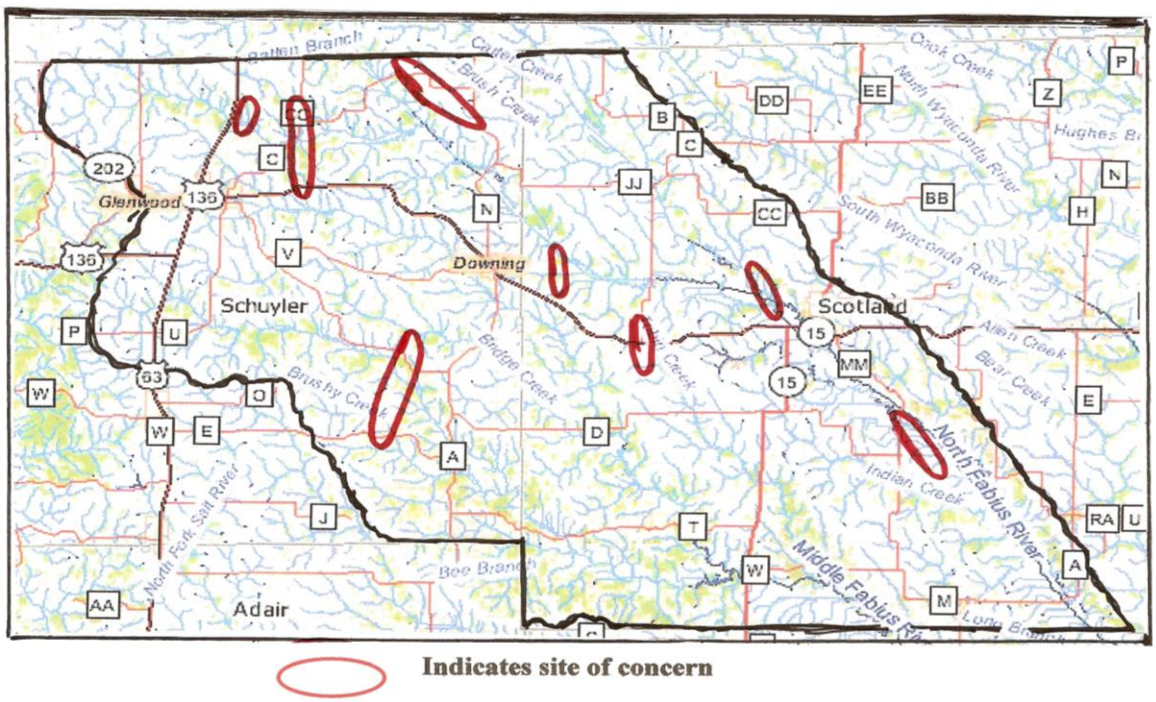

Figure 2. Sites of concern along the North and Middle Fabius Rivers identified in the 2010 watershed management plan.

The Scotland/Schuyler North Fabius steering committee reviewed the plan objectives and strategies, nonpoint source (NPS) Management Measures, and Schedule for BMP Implementation and made revisions, as needed, before the final draft was distributed for public comments.

A copy of the draft watershed management plan was distributed at a public meeting at the Nutrition Center in Lancaster, and notices asking for public comment were placed in the Scotland and Schuyler County newspapers and on local radio stations. A final review of the plan was held by steering committee and numerous revisions in project numbers and funding were made before the plan was finalized and adopted. **The completed plan was approved by MDNR in March 2010.**

The 2010 North and Middle Fabius Nonpoint Source Watershed Management Plan (2010 WMP) was intended to serve as an overall strategy to guide complete watershed restoration and protection efforts by individuals, organizations, and local, state and federal agencies. The plan provided the watershed stakeholders with the capability, capacity, and confidence to make decisions that will restore and protect the water quality and watershed conditions of the North and Middle Fabius watersheds. It was to be used as a guide to monitor current conditions and improve management of the watershed's natural resources through education and voluntary cooperation of partners and stakeholders. The plan also established watershed goals, scheduled watershed activities, and identified BMPs for improving and conserving the watershed's natural resources. One long-term goal of the 2010 plan was to improve habitat conditions on sections of the North Fabius River that scored below or at 75%, as recommended in the Biological Assessment and Habitat Study Report developed by MDNR[3].

Sites of Concern and BMP Solutions

Problem areas in the watershed were identified through public input and visual survey. These areas include: 1) those areas where livestock have direct access to streams, causing eroded streambanks and waste deposited directly into the waterway; 2) farm fields with little or no buffer along the waterway; and 3) areas with inadequate vegetative cover that result in wind and water erosion. The following NPS pollutants were identified and prioritized with input from the Scotland and Schuyler County Soil and Water Conservation District Boards, Farm Service Agency County Committees, and landowner/operators:

Pollutant	Priority
Sediment	High
Streambank degradation (Livestock access)	High
Streambank degradation (Agricultural practices)	High
Nutrients	Moderate
Pesticides	Moderate

Solutions for addressing NPS pollutants included implementing more stream bank protection and continued use of ponds, terraces, and dry hole systems to address gully and rill erosion[4]. The plan also encouraged the use of buffer strips, cover crops, conservation tillage, and pasture improvement to try to keep steeper sloped land in grass. Well decommissioning was also promoted in an effort to protect groundwater. Informing landowners about problems and solutions were accomplished through information/education activities and landowners networking.

[3] Missouri Department of Natural Recourses, Environmental Services Program. Biological Assessment and Habitat Study Report for the North Fabius River. https://dnr.mo.gov/env/esp/docs/North_Fabius_River_Final_Report.pdf

Information and Education

All planning partners recognized that no project can be successful without the cooperation and involvement of the communities and residents of the areas involved. The 2010 WMP included an educational component in order to encourage community participation in watershed restoration and protection activities. Media outlets, such as radio and local newspapers, were utilized to encourage stakeholders to identify with the watershed and to promote stewardship of the water resources it contains. These same media resources were used to report progress of the projects and solicit additional public comment. Partners, such as the Soil and Water District Boards, served as area representatives for local watersheds in their county with Extension Councils serving as representatives for landowner/operators within the watershed. Meetings of these organizations also provided opportunities for progress to be reported.

Plan Implementation

North Fabius Watershed Quality Improvement Project (Phase I)

In 2008, the Schuyler County Soil and Water Conservation District received a Section 319 Nonpoint Source Implementation Grant from Missouri Department of Natural Resources for $543,094 to assist with addressing watershed concerns. The North Fabius Water Quality Improvement Project started March 1, 2008 and ended August 31, 2013. The goal of the North Fabius Water Quality Improvement Project was to protect and improve the quality of water in the entire watershed; however, the project was focused mainly in Schuyler County.

Some of the water quality concerns in the watershed included chemical runoff, animal waste sources, poor pastureland, erosion from cropland, and streambank degradation caused by conventional cropland and agricultural livestock operations. The project started the implementation of the conservation measures identified in the 2010 WMP and helped to fund BMPs to address the watershed quality concerns. The BMPs implemented consisted of alternative livestock watering sources, management intensive grazing systems, bank vegetative buffers, nutrient/pest management plans, dry-hole systems, decommissioning private wells, and constructing animal waste facilities.

The major objectives of the project were:

- Reduce sheet and rill erosion and control pests on cropland.
- Demonstrate the benefits to water quality by improving manure distribution and reducing erosion by maintaining vegetative cover.
- Demonstrate the water quality and soil conservation benefits of excluding livestock from streams.
- Reduce erosion, thereby decreasing sediment, nutrient and chemical runoff through the installation of riparian buffers.
- Reduce sediment delivered into the river and its tributaries by 25% through construction of terraces and dry-hole systems.
- Reduce chemical and animal waste runoff by 20% through promotion of proper application of lime and fertilizer to increase pasture production.
- Control animal waste runoff and increase infiltration by constructing an animal waste

facility.
- Prevent groundwater contamination by decommissioning abandoned wells.

Numerous BMPs were implemented and activities accomplished, including: writing over 100 crop rotation plans, implementing two nutrient management plans for confined animal feeding operations, installing 12.4 miles of fence along stream riparian corridor to exclude cattle access, constructing dry-hole sediment structures, decommissioning abandoned wells, and improving 1,231 acres of poor to marginal pastureland with inter-seed grass mixtures. In addition, the project information and education activities implemented included: collecting water quality samples at five test sites; hosting two well decommissioning demonstrations; conducting pest/nutrient management workshops; organizing intensive grazing schools; holding contractor and steering committee meetings; and participating in radio and television interviews.

North Fabius Watershed Quality Improvement Project - Phase II

The North Fabius Watershed Quality Project – Phase II is a continuation of the successfully completed North Fabius Water Quality Improvement Project (Phase I). The Schuyler County Soil and Water Conservation District received a $266,813 federal Section 319 Nonpoint Source Implementation Grant award to support the project from March 1, 2014 to October 31, 2020. The purpose of the project was to implement more conservation measures to improve water quality, decrease soil erosion, and improve aquatic life an according to the MDNR's accepted March 2010 North and Middle Fabius Nonpoint Source Watershed Management Plan. Four HUC12 subwatersheds in Schuyler County (Brushy Creek, Downing Reservoir – North Fabius, Headwaters of South Fork Middle Fabius River, and North Fork North Fabius River) were the primary focus areas for the project.

The Phase II project continued to implement the goals of the Phase I project, which were to reduce impairments to the North Fabius River by implementing BMPs, by again focusing on agricultural practices by utilizing the Soil and Water Conservation Program's (SWCP) Practice Standards[4]. Specifically, grant funding was used to install stream protection practices and management intensive grazing systems. Terraces and dry hole systems were implemented with bubble up outlets, grassed waterways, and additional buffer area between the terraces or the receiving creek/stream to minimize sediment input into the North and Middle Fabius Rivers.

The project also included a water quality monitoring and modeling component, which were intended to create a greater understanding of the impacts of agricultural, and/or stormwater runoff on water quality within the watershed and to support updating the nine planning elements of the 2010 WMP. Water quality monitoring was conducted by Dr. Cynthia Cooper, from the Department of Biology at Truman State University (Kirksville, Missouri), and her students to obtain baseline water quality data. More details about their monitoring efforts are presented in Chapter 2 of this plan. A watershed model called Soil and Water Assessment Tool (SWAT) was used by the University of Missouri to estimate sediment loading within the watershed and determine the locations of the critical areas of the watershed where management measures are needed to improve the water quality. More information about the SWAT model and results are provided in Chapter 2, Appendix G, and elsewhere throughout this plan.

[4]MDNR. Soil and Water Conservation Program. Cost-Share Handbook https://mosoilandwater.land/internal/cost-share-handbook

Best Management Practice Implementation

Since the 2010 WMP development, numerous BMPs have been implemented in the North Fabius and Middle Fabius watersheds between FY2009 and FY2020 to achieve the goals and objectives of the watershed plan and address the pollutants of concern (Table 1). Staff from MDNR

employed a commonly used spreadsheet model that is supported by the EPA called the Spreadsheet Tool for Estimating Pollutant Loads (STEPL) to simulate the impact state cost-share BMPs had on reducing sediment and nutrient loading to the North and Middle Fabius Rivers (Appendix E). The BMPs implemented between FY2009 and FY2020 resulted in a total estimated sediment reduction of 34,664 tons (Table 2). Nutrient load reductions during this same time period were estimated at 471,085 lbs of nitrogen and 120,759 lbs of phosphorus (Table 2).

Table 1. Missouri cost-share practices implemented in the North Fabius subbasin and dollars spent between FY2009 and FY2020.

Management Strategies	Management Measures (milestones)	Milestone Quantity FY2009 - FY2020	Total Acres	Cost-share Dollars Spent	Technical Assistance
Crop Management Strategies: ***Nutrient & Pest Management***	Pest Management (N595)	44 practices	7436	$73,450.00	NRCS/SWCD / Private Landowners
	Nutrient Management (N590)	9 practices	1061	$22,897.00	NRCS/SWCD / Private Landowners
Implementation of Sediment Control Structures	Terrace Systems (DSL-04)	2 systems	15	$9,106.87	NRCS/SWCD / Private Landowners
	Terrace Systems with Tile (DSL-44)	297 systems	3958	$3,199,746.88	NRCS/SWCD / Private Landowners
	Diversions (DSL-5)	20 practices	531	$124,001.47	
	Water Impoundment Reservoir (Pond) (DWC-1)	250 reservoirs	3864	$2,515,939.58	NRCS/SWCD / Private Landowners
	Sediment Retention Control Structure (Dry Holes) (DWP-1)	120 structures	1914	$828,746.62	NRCS/SWCD / Private Landowners

Management Strategies	Management Measures (milestones)	Milestone Quantity FY2009 - FY2020	Total Acres	Cost-share Dollars Spent	Technical Assistance
	Permanent Vegetative Cover Critical Area (DSL -11)	1 practice	1	$322.30	NRCS/SWCD / Private Landowners
Implementation of Runoff Filtration Practices	Sod Waterways (DWP-3)	7 practices	153	$32,079.41	NRCS/SWCD / Private Landowners
	Filter Strips (N393)	3 practices	79	$28,732.78	NRCS/SWCD / Private Landowners
	Field Border (N386)	1 practice	6	$5,616.15	NRCS/SWCD / Private Landowners
	Cover Crops (N340)	247 practices	18261	$583,916.19	NRCS/SWCD / Private Landowners
Livestock Management Strategies: ***Implementation of Grazing Systems***	Permanent Vegetative Cover Establishment (DSL-1)	21 practices	629	$88,606.17	NRCS/SWCD / University/Private Landowners
	Permanent Vegetative Cover Improvement (DSL-2)	29 practices	1801	$127,536.20	NRCS/SWCD / University/Private Landowners
	Permanent Vegetative Cover Enhancement (DSL-02)	3 practices	180	$10,382.39	NRCS/SWCD / University/Private Landowners
	Grazing Systems (DSP-3)	15 systems	1168	$51,301.84	NRCS/SWCD / Private Landowners
Ground Water Quality: ***Implementation of Well Decommissioning***	Well Decommissioning (N351)	85 practices	10	$44,400.00	NRCS/SWCD / Private Landowners

Management Strategies	Management Measures (milestones)	Milestone Quantity FY2009 - FY2020	Total Acres	Cost-share Dollars Spent	Technical Assistance
Riparian Improvement and Stream Protection:	Stream Protection (WQ-10)	15 practices	136	$137,927.84	NRCS/SWCD / Private Landowners
Implementation of Stream Protection, Riparian Buffers, and Alternative Water Sources	Livestock Exclusion (N472)	23 practices	194	$41,574.26	NRCS/SWCD / Private Landowners

Table 2. STEPL-estimated sediment, total nitrogen (TN), and total phosphorus (TP) load reductions for each HUC12 and totaled for the North Fabius subbasin due to implementation of cost-share practices between FY2009 and FY2020.

Waterbody	HUC 12	Sediment Reduction (tons)	TN Reduction (lbs)	TP Reduction (lbs)
North Fabius River	071100020101	242	6713	1224
	071100020102	16	447	77
	071100020103	190	6436	1503
	071100020104	2344	34664	6517
	071100020105	2193	28158	5183
	071100020106	930	12750	2170
	071100020107	1693	19254	3811
	071100020108	1663	20851	3964
	071100020401	4441	54154	13761
	071100020402	385	8061	2270
	071100020403	2918	35230	12266
	071100020404	3230	36615	12467
	071100020405	2574	28280	9885
Middle Fabius River	071100020201	448	13250	2442
	071100020202	422	10918	2013
	071100020203	115	3152	722
	071100020204	134	5210	709
	071100020205	691	8725	1506

	071100020206	1169	19215	3470
	071100020301	3315	40041	8660
	071100020302	1201	17390	6056
	071100020303	785	12080	4097
	071100020304	1122	18948	5793
	071100020305	1795	22671	7661
	071100020306	647	7870	2534
	Total	**34,664**	**471,085**	**120,759**

2020 North and Middle Fabius Nonpoint Source Watershed Management Plan

A watershed plan is a living document to be evaluated on a regular basis and revised as new information becomes available to keep the plan current. As BMPs and other management measures and activities are implemented, a periodic review of the implementation activities, comparison of implementation results with milestone goals, and revisions to the WMP must be conducted.

In 2020, through a Section 319 Nonpoint Source Implementation Grant from the MDNR, the Schuyler County SWCD updated the original 2010 WMP. In preserving the spirit of the 2010 plan, the 2020 North and Middle Fabius Nonpoint Source Watershed Management Plan (2020 WMP) will continue the goals and efforts of the previous plan by sustaining ongoing engagement with local citizens to implement measures for water protection, management, and development.

This revised plan will also identify and outline new goals and actions for restoring and protecting water quality in the watershed. The 2020 WMP includes management measures that will assist in improving surface waters that do not meet Missouri's Water Quality Standards[5] and addressing areas of the watershed that need improvement in habitat land management or other attributes. The plan will be evaluated yearly, as needed, and updated every five years, using the most current water quality monitoring data and watershed modeling tools.

The Nine Critical Elements for a watershed based plan, as suggested by the EPA and MDNR, ensure a successful watershed management plan. This approach satisfies both regulatory purposes and public concerns about the watershed. The nine elements also act as a framework for the management plan.

The following nine critical elements are described in more detail in Appendix A:

A. Identify the sources that will need to be controlled to reduce pollution levels.

[5] Missouri Water Quality Standards. January 29, 2019. https://s1.sos.mo.gov/cmsimages/adrules/csr/current/10csr/10c20-7a.pdf

B. An estimate of the load reductions expected from the management measures.
C. Describe the management measures needed to achieve the pollution reductions.
D. Estimate the amounts of technical and financial assistance needed.
E. An information and education component.
F. Schedule or timeline for implementing the nonpoint source management measures.
G. Description of the interim measurable milestones.
H. Set of criteria to be used to determine if load reductions are being achieved.
I. Monitoring component to evaluate the effectiveness of the implemented measures.

Description of the North Fabius Subbasin

The North Fabius Subbasin (HUC 07110002) is part of the larger Upper Mississippi River Basin. This watershed management plan covers the majority of the North Fabius subbasin, which includes within it the same geographical area as the 2006 North Fabius TMDL. Encompassing the North Fabius River (WBID 56) and Middle Fabius River (WBID 63) watersheds, this long, narrow drainage area extends southeastward from Appanoose and Davis counties of Iowa across several Missouri counties and outlets near the Mississippi River in northeastern Marion County, Missouri. Missouri counties located within the watershed include Schuyler, Scotland, Adair, Clark, Knox, Lewis, and Marion. The North Fabius River watershed is 315,512 acres (493 sq. miles) and the Middle Fabius River watershed drains 270,223 acres (422 sq. miles). Therefore, the entire North Fabius subbasin and 2020 WMP area is about 585,736 acres (915 sq. miles).

According to Chapter 7 of the State of Missouri Water Quality Standards (10 CSR 20-7.031), the North Fabius River segment is 92-miles from sec. 26, T. 67 N., R. 14 W.[6] to its confluence with the South Fabius at sec. 24, T. 59 N., R. 6 W. It is designated as a Class "P" stream, which are streams that maintain permanent flow during drought conditions. Designated uses are for the protection of warm water aquatic life, human health (fish consumption), irrigation, livestock and wildlife watering, secondary contact recreation, and as a drinking water supply. As defined in Missouri's Water Quality Standards (WQS), secondary contact recreation uses "include fishing, wading, commercial and recreational boating, any limited contact incidental to shoreline activities, and activities in which users do not swim or float in the water. These recreational activities may result in contact with the water that is either incidental or accidental and the probability of ingesting appreciable quantities of water is minimal."

The Middle Fabius River segment extends 75.7 miles starting from sec. 22, T. 64 N., R. 12 W. It is also classified as a Class "P" stream. Similar to the N. Fabius segment, use designations are for the protection of warm water aquatic life, human health (fish consumption), irrigation, livestock and wildlife watering, secondary contact recreation, and as a drinking water supply.

[6] Information about Missouri's Water Quality Standards for classified waterbodies can be easily accessed via an interactive Water Quality Standards Map Viewer.

There are several small lakes in the subbasin. Lewistown Lake (WBID 7020) is approximately 0.7 sq. miles and the downstream portion resides at sec NW SW 08, T. 61 N., R. 08 W. The lake is classified as an L1 lake, which means it is used primarily as a public drinking water supply. Use designations are for protection of warm water habitat, human health (fish consumption), irrigation, livestock and wildlife watering, secondary contact recreation, and as a drinking water supply. Lewistown Lake has been on the 303(d) list of impaired waters since 2002 for atrazine pollution from rural nonpoint source pollution. While the city of Lewistown discontinued the use of Lewistown Lake as a drinking water supply in 2002, the lake is still protected as a drinking water source. The lake's assessment for the 2020 303(d) list states that existing data is insufficient to show "good cause" for delisting[7].

Physiographic Region[8 and 9]

The topography of the region is dominated by a very distinct series of parallel ridges and valleys, cut by the postglacial stream network that runs the length of the subbasin. Within this ridge and valley setting, the subbasin physiography substantially changes from the rolling uplands encompassing the headwaters of the North Fabius River to the steeper relief of the dissected valleys approaching the Mississippi River.

In Schuyler County, an elevated plateau known as the Grand Divide runs quite irregularly from north to south. It is part of the divide between the Mississippi and Missouri Rivers and the watershed between the Mississippi and Chariton Rivers. The county is watered on the west side of the Grand Divide by the Chariton River and the streams that flow into it from the east; and the east side of the Grand Divide is watered by the North Fabius, Middle Fabius, South Fork of Middle Fabius, South Fabius, Salt River, and their tributaries. All of these streams flow in a southeasterly direction and empty into the Mississippi River, while the Chariton River and streams flowing into it from the east empty into the Missouri River.

In Scotland County, the land ranges from broad, nearly level upland flats to steep, wooded slopes with occasional areas of level flood plains. Drainage is provided by several large streams and rivers, including the Fabius River and its various forks, the Wyaconda and Little Fox Rivers. Both Schuyler and Scotland counties lie within the state's Northeast Prairie climatological region with a moist continental climate. Most of the annual precipitation events occur during the spring, summer and fall months, and weather conditions change frequently.

The upper third of the subbasin, which is concentrated in Appanoose and Davis Counties in Iowa and Schuyler County in Missouri and the western edge of Scotland County in Missouri, consists of broad ridges separating a sub-parallel stream network that trends northwest to southeast. With local relief averaging around 100 feet, the stream valleys are gently sloping and slightly dissected. Thick deposits of glacial till with a thin cap of loess cover alternating layers of

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[7] MDNR. Missouri Water Quality, 303(d) lists. https://dnr.mo.gov/env/wpp/waterquality/303d/303d.htm
[8] Missouri Department of Conservation. 1999. "North Fabius Rapid Watershed Assessment" https://missouriconservation.org/sites/default/files/watersheds/FabiusWatershed110.pdf
[9] USDA-NRCS. 2008. 'North Fabius River Rabid Watershed Assessment" https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_011187.pdf

Pennsylvanian age limestone, sandstone, and shale bedrock. Pre-settlement vegetation consisted of prairie grasses on the broad interfluves grading into oak (*Quercus spp.*) savannas and woodlands on the valley sides.

The parallel ridges and valley topography continues into the middle section of the subbasin, covering about two-thirds of Schuyler and Scotland Counties and the northeast corner of Knox County. Local relief drops to less than fifty feet on average as the broad interfluves flatten to form a more gently rolling surface in loess covered glacial till.

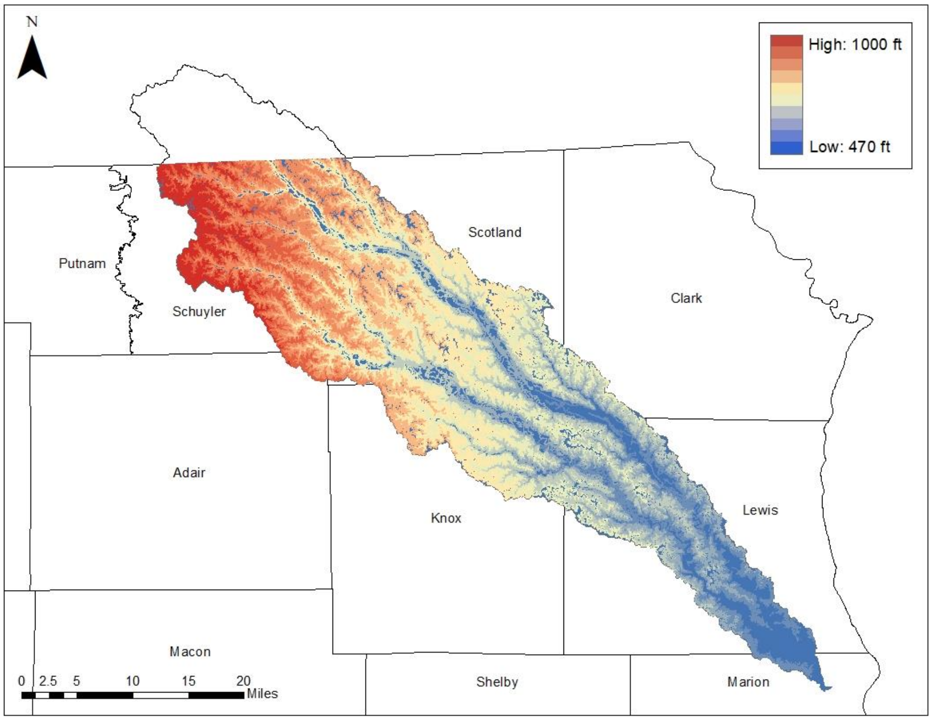

Figure 3. Map showing elevation across the Missouri portion of North Fabius Subbasin.

The shaded elevation map of the subbasin depicts land elevation across the subbasin ranges from about 470 ft to 1000 ft above sea level (Figure 3). In the rolling uplands that form the headwaters of the North and Middle Fabius Rivers, local relief averages around 100 ft. Southeastward into the middle reaches of the North and Middle Fabius Rivers, the elevation drops and local relief across the flat to gently rolling hills and shallow valleys is typically less than 50 ft. The moderately dissected valleys and broad divides covering the lower portion of the subbasin push the average local relief to greater than 100 ft.[8]

The lower third of the subbasin is located in Clark, Lewis, and Marion counties. The southeast trending broad divides gives way to steeper valleys with local relief ranging from 100 to 150 ft as the subbasin narrows to its confluence with the South Fabius and Fabius Rivers. The depth of the glacial till thins on the lower slopes, exposing Mississippian age limestone along the valley sides and streambeds.

The Fabius River basin lies in the eastern section of the Glaciated Plains Division of Missouri[10] (Thom and Wilson 1980), also known as the Dissected Till Plains. The Till Plains were formed by glaciers that deposited drift composed mostly of clay with some rock, gravel and sand lenses (MDNR, unpublished). Geologically, the basin changes significantly from northwest to southeast. Glacial till up to 200 feet thick on ridge tops is found in the upper portions of the basin, mainly the upper North and Middle Fabius watersheds. It thins only slightly on gentle slopes and in broad valleys. Four to eight feet of wind-deposited loess overlies this till. Beneath it is a thin layer of sand and gravel and then a layer up to 400 feet thick of alternating deposits of Pennsylvanian age sandstone, siltstone, shale, limestone, and coal.

In the middle and lower portions of the basin the topography grades from broad plains to steep, abrupt valleys with high relief. The till shallows quickly on the lower slopes to expose Mississippian age limestone in the valley walls and streambeds. Loess deposits are usually less than four feet deep in lower North and Middle Fabius watershed and in the South Fabius drainage. This region of thin glacial soils and exposed limestone is roughly defined as the area downstream of Route E in Lewis County in the North Fabius subbasin, downstream of the Scotland-Knox county line in the Middle Fabius drainage. The basin flattens as it enters the Mississippi River floodplain, and the substratum turns to fine alluvium.

The majority of the subbasin is located in the Central Claypan region[11]. Soils of this region are formed in glacial till or loess parent material or both**.** They generally have a silt loam surface of moderate to high erosion potential overlying a silty clay subsoil of low permeability. Once home to native prairie grasses, most of this fertile region is now considered excellent farmland. Deep loess soils occur in the upper North and Middle Fabius drainages, and soils of the Central Mississippi Valley wooded slopes are found on steep hills and some ridgetops primarily in the lower part of the basin. Silty loam alluvial soils are limited to stream floodplains. Due to the clay content of the till and the underlying shales and limestone, vertical movement of water from the surface to groundwater is minimal throughout the basin (MDNR, unpublished).

Major Land Resource Areas (MLRA) are areas defined by their soil capabilities and agricultural potentials. A MLRA is further divided into Common Resource Areas (CRA) that are areas having similar resource concerns and treatment requirements. The two CRAs within the North Fabius subbasin are[12]:

Fox-Wyaconda River Dissected Till Plain

The Fox-Wyaconda River Dissected Till Plain is a gently sloping to steep area that consists of a slightly dissected till plain. Although relief is usually less than 150 feet, little of the flat till plain surface remains. Native vegetation was a mix of prairie grasses and deciduous trees. Presently, most of this area is a mix of cropland and pasture. Corn, soybeans, and forage crops are the most common crops. Resource concerns are water erosion, nutrient management, and pasture management.

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[10] Thom, R., & Wilson, J. 1983. The Natural Divisions of Missouri. *Natural Areas Journal, 3*(2), 44-51.
[11] Allgood and Persinger. 1979. Missouri General Soil Map & Soil Association Descriptions.
[12] Nigh and Schroeder. 2002. The Atlas of Missouri Ecoregions

Clay Pan Till Plains

The Clay Pan Till Plains are nearly level and gently sloping, well-developed claypan soils on a flat glacial till plain. Light to moderately dark colored, poorly drained, and somewhat poorly drained soils formed primarily in loess. Loess thickness generally ranges from greater than six feet in the western part to about three feet in the eastern part. The low clay content of the surface soil abruptly changes to high clay content subsoil. The area is intensively cropped with row crops and small grain. Sodium affected soils are predominate throughout the area and occur in an intricate pattern with soils not affected by sodium. The more sloping areas adjacent to the streams are more commonly used for pasture or remain in woodland. Postglacial stream erosion has made little progress and most of the surface is flat or gently rolling with local relief less than 100 feet. Bedrock exposures are rare.

Waterbody Characteristics

The gradient of a stream is the change in elevation over a distance, or its steepness. The gradient is a major factor in a stream's velocity and subsequent erosive forces. Stream order describes the size of stream that has year-round water. The smallest stream with no tributaries is called a first order stream. When two first-ordered streams merge they create a second order stream. Therefore, third order streams occur where two second-ordered streams merge, and so on.

Channel gradients were determined by MDC for all third-order and larger streams[8] (Tables 3 and 4). Gradient is very low in the lower-most reaches of the North Fabius and Middle Fabius Rivers (2.0-2.8 feet/mile). Gradients in fifth-order reaches of watershed streams range from 2.6 feet/mile in the Middle Fabius River to 5.0 feet/mile in the south fork of the Middle Fabius. Because of their higher gradients, the latter two streams exhibit better riffle/pool development than many lower-gradient prairie streams of similar size. Riffles and pools provide optimal habitats for a range of aquatic species. Gradients in fourth-order reaches of the subbasin streams range from 3.9 to 11.5 feet/mile. While third-order reaches of basin streams have wide-ranging gradients, the slopes of some short, third-order streams are strikingly high. For instance, gradient exceeds 90 feet/mile in an unnamed tributary in the lower portion of the North Fabius River sub-basin. This and other high-gradient streams are generally located in the middle and lower portions of the basin as the watershed enters the region of steep, narrow valleys with shallow till and exposed limestone.

Table 3. Assessment of third-order and larger streams in the North Fabius watershed. S T R indicates section, township, and range at the mouth. An asterisk (*) indicates a stream length too short to measure gradient. *(Table adapted from MDC, 1999 report[8])*

Stream Name	HUC 12 (last 3 digits)	Location S T R	Total Length (mi)	Percent Channelized	Stream Order at Mouth	Gradient By Stream Order (ft/mi)			
						6	5	4	3
North Fabius		21 59n 8w	104.9	59	6	2.8	3.3	6.7	10.3
Unnamed trib.	-404	22 61n 7w	1.1	0	3				*
Unnamed trib.	-404	8 61n 7w	1.8	0	3				*
Forsee Branch	-403	5 62n 8w	3.6	0	3				18.2
Cooper Branch	-403	6 62n 8w	9.9	0	3				6.6
Bear Creek	-401	23 63n 9w	26.2	0	4			5.5	6.2
Long Branch	-402	33 64n 10w	12.5	0	3				13.3
Indian Creek	-107	12 64n 11w	12.4	0	3				10
Gunns Branch	-106	34 65n 11w	13.2	0	3				9.7
Cooper Branch	-403	12 65n 12w	4.7	0	3				19.5
N. Fk. N. Fabius	-104	2 65n 12w	19.9	69	4			3.9	6.5
Unnamed trib.	-108	3 65n 12w	3	0	3				11.4
S. Fk. N. Fabius	-101	1 66n 14w	15.1	0	4			10.1	9.1
Unnamed trib.	-101	1 66n 14w	3.7	0	3				13.1
Batten Branch	-102	15 67n 14w	3.7	0	3				22.2
Carter Creek	-103	27 67n 13w	24.5	37	3				6.9
Unnamed trib.	-103	33 68n 15w	3.5	0	3				15.2
Unnamed trib.	-103	5 67n 14w	8.1	23	3				12.8

Table 4. Assessment of third-order and larger streams in the Middle Fabius watershed. S T R indicates section, township, and range at the mouth. An asterisk (*) indicates a stream length too short to measure gradient. *(Table adapted from MDC report[8])*

Stream Name	HUC 12 (last 3 digits)	Location S T R	Total Length (mi)	Percent Channelized	Stream Order at Mouth	Gradient By Stream Order (ft/mi)			
						6	5	4	3
Middle Fabius		29 60n 6w	74.5	0	5		2.6		
Unnamed trib.	-306	5 60n 7w	2	0	3				30.7
Unnamed trib.	-306	30 61n 7w	5.2	0	3				23.3
Reddish Branch	-305	31 62n 8w	11.8	0	3				15.1
Bridge Creek	-303	6 62n 9w	30.2	0	4			6	5.2
L. Bridge Creek	-303	10 62n 10w	9.7	0	3				12.3
Tobin Creek	-301	30 64n 11w	14.5	0	3				7
N. Fk. Middle Fabius	-205	27 64n 12w	35	0	4			6.3	6.1
Bridge Creek	-201	36 65n 13w	16.3	0	3				8
S. Fk. Middle Fabius	-206	27 64n 12w	30.3	0	5		5	8	13.7
N. Bridge Creek	-206	23 64n 13w	7.2	0	4			11.5	14.6
Bee Branch	-206	22 64n 13w	4.2	0	3				16.2
Brushy Creek	-203	9 64n 13w	9.4	0	4			9.3	14.1
Tipp Creek	-204	8 65n 14w	6.1	0	3				12.5

Base flows throughout the basin are not sustained by groundwater inflow during dry weather due to the low conductivity of the underlying clays and rock. Since no significant springs exist, stream flow is largely dependent on surface runoff[7]. Both subbasin streams are considered to be permanently flowing. Most other fourth and fifth-order streams have only short reaches are considered intermittent. Many third-order streams are intermittent their entire length. Small precipitation events cause rapid increases in stream flow; most water runs off quickly due to the low permeability of underlying strata.

Since November 2005, a newly installed stream gauge on the North Fabius River near Ewing, MO (USGS 05497150; Lat 40°01'08", Long 91°37'19") has been recording daily stream flow[13]. For this revised WMP, the MDNR's Water Protection Program created a flow duration curve (FDC) with data from the new USGS gauge (Figure 4). The FDC used about fifteen years of continuous flow measurements and ranked them to show the portion of time a particular flow level is met or exceeded. Data points along the graph represent the percent of time stream flow (cfs) equals or exceeds that value. For example, 80% of the time, stream flow is greater than or equal to 33.2 cfs.

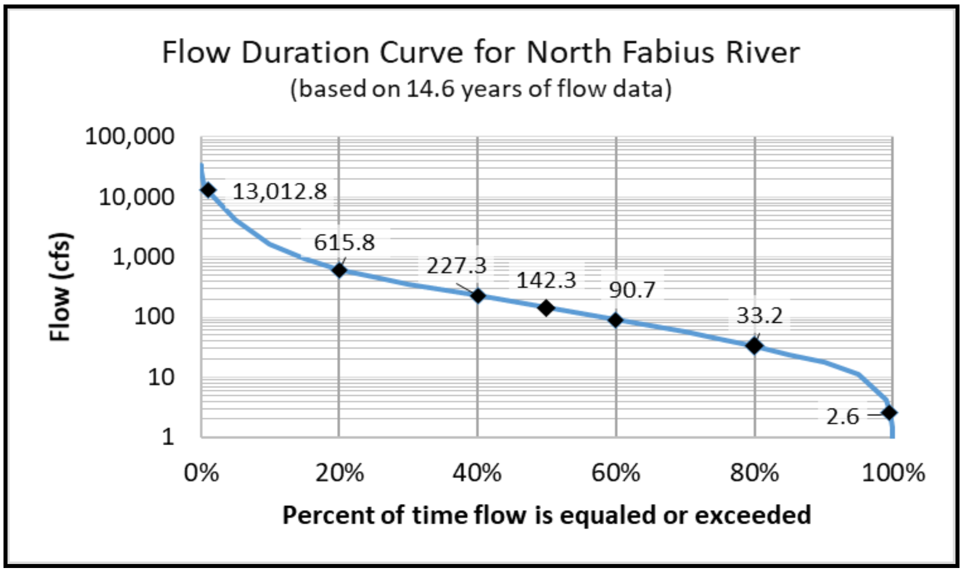

Figure 4. Flow duration curve shows the range of flows (cfs) measured on the North Fabius River.

Historic and Current Land Use

The original inhabitants of the area were Native Americans of the Missouri, Osage, Fox, and Sac tribes who hunted in the area and depended upon the abundant wildlife resources. The first white settlers of Missouri, the French, claimed much of the area in 1712, and the United States took ownership in 1803 as part of the Louisiana Purchase. The Fabius River was named around 1800 by a Spanish surveyor named Don Antonio Soulard. Treaties signed with native tribes in 1804

[13] USGS. National Water Information System. USGS 05497150 North Fabius River near Ewing, MO. https://waterdata.usgs.gov/nwis/inventory/?site_no=05497150

and 1816 designated the area north of the Fabius River and 30 miles west of the mouth of the river as Indian Territory. The last treaty in 1824 permanently turned the region over to the United States. Settlers from Kentucky, Indiana, Ohio, Tennessee, Pennsylvania, and Virginia were already arriving by the 1940's and quickly established farming as the region's economic base.

Present boundaries for the counties in the basin were established between 1825 and 1845. Human population in the region grew rapidly from 1840 to 1920, and then declined. For example, the population of Schuyler County increased from 3,287 in 1850 to 10,470 in 1880. In 2019, Schuyler county population was 4,514 and reported as 100 % rural. In Scotland County, the 2019 population was recorded as 4,963 and also reported as 100 % rural.[14] Other basin counties exhibited similar demographic trends, except Marion County, where the population has been relatively stable since 1900.

Much of the pre-settlement landscape of the basin was prairie[15]. The proportion of prairie land in Lewis, Knox, Scotland, and Schuyler counties ranged between 30% and 55%. Prairies of the basin were usually long and narrow since they were located on the narrow uplands or ridges along the three main, parallel-flowing streams. Wet, bottomland prairies occurred on nearly all floodplains. Wooded areas were found across the steeper rolling hills and adjacent to streams.[8]

Like the upper reaches of the subbasin, the pre-settlement tall grass prairies were predominantly replaced with cropland and cool-season pastures for hay. The prevailing land uses and covers throughout the subbasin are rural and agricultural (Figure 5 and Table 5)[16]. Across the 2020 WMP planning area, hay/pasture land make 43% of the area and cropland makes up about twenty-seven percent of the area. Cultivated cropland is largely planted to soybeans, followed by corn for grain, wheat for grain, and grain sorghum. The third largest land cover/use acreage is forest land at almost nineteen percent. Developed areas cover only about four percent of the area.

Changes in farmland numbers and acreage between 1850 and 2017 for each county in the subbasin are presented in Table 5. Agricultural census[17] data show that the number of farms have decreased during this time range within each county. Across all counties, the number of farms in 1880 census ranged from 1,350 to 2,002 and in 2017 ranged from 541 to 816 farms. However, the number of acres farmed has remained relative the same, with exception. Data from 1880 reported a range of 110,504 to 309,506 acres farmed, and data from 2017 reported a range of 116,941 to 267,920 acres across Adair, Clark, Knox, Lewis, Marion, Schuyler, and Scotland counties.

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[14] John Clements. 1991. Missouri Facts: A Comprehensive Look at Missouri Today: County by County. Dallas, TX. p. 323-326.
[15] Schroeder W. A. 1982. Presettlement Prairie of Missouri. Missouri Department of Conservation, Natural History Series 2. Jefferson City, Missouri.
[16] Multi-Resolution Land Characteristics Consortium (MRLC). 2018. National Land Cover Database (NLCD) 2011. https://data.nal.usda.gov/dataset/national-land-cover-database-2011-nlcd-2011
[17] USDA. National Agricultural Statistics Service. Census of Agriculture. https://www.nass.usda.gov/AgCensus/

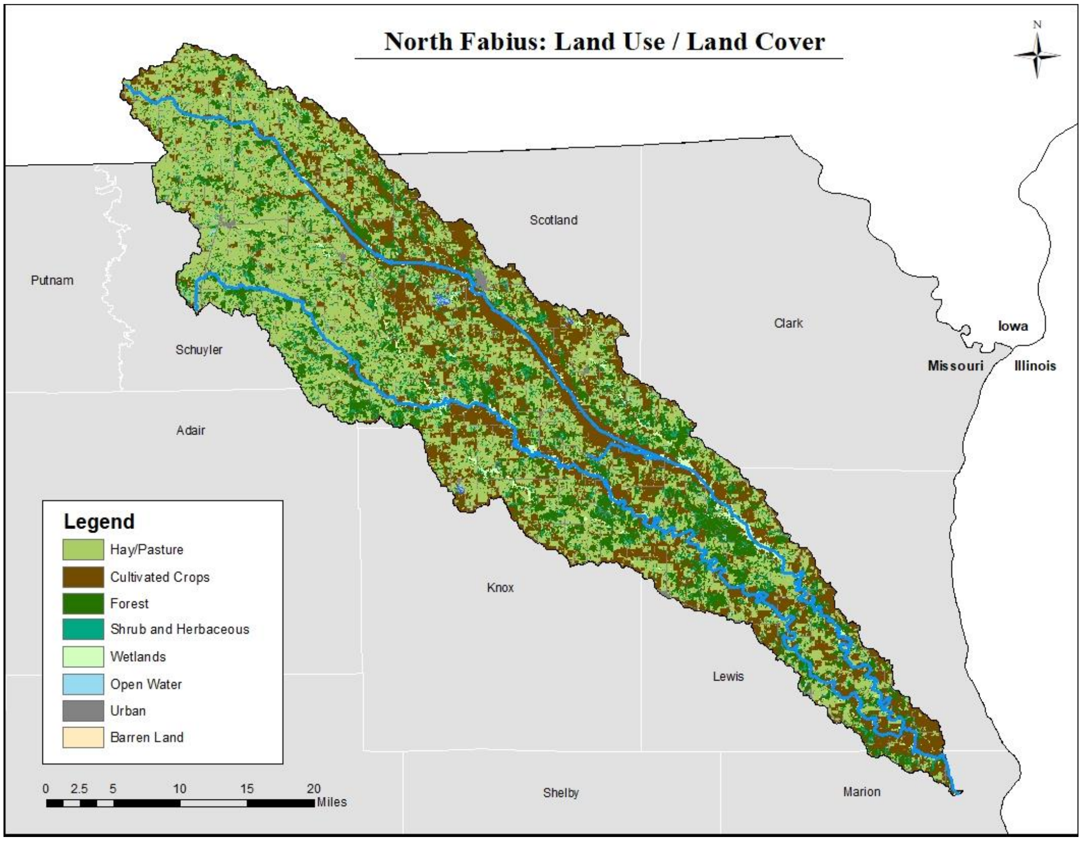

Figure 5. Land cover across the North Fabius Subbasin[16].

Table 5. Area and portion of land covers in the North Fabius Subbasin[16].

Land Cover	North Fabius River	Middle Fabius River	Total Planning Area	
	---------- acres	----------	acres	%
Hay / Pasture	124052	121772	245824	35
Cropland	95372	58546	153918	22
Forest	51103	56534	107637	15
Shrub / Herbaceous	11298	12858	24156	3
Wetland	8125	6952	15077	2
Open Water	2094	1403	3497	1
Urban / Impervious	135350	11990	147339	21
Barren / Sparsely Vegetated	65	37	103	0.01

Table 6. Number of farms and acreage usage in counties of northeastern Missouri[17].

County	# of Farms	Acres Farmed	Pasture Acres	Cropland Acres (All Crops)
Adair County				
1850	Unknown	44,081	Unknown	Unknown
1880	1,942	265,624	Unknown	65,581
1950	1,926	324,350	178,763	161,597
2007	944	279,855	19,223	144,379
2012	822	273,155	Unknown	134,006
2017	816	267,920	Unknown	141,865
Clark County				
1850	Unknown	108,585	Unknown	Unknown
1880	2,048	267,706	Unknown	88,247
1950	1,398	295,253	137,067	165,600
2007	709	262,937	17,415	181,657
2012	673	241,121	Unknown	150,888
2017	547	255,994	Unknown	193,841
Knox County				
1850	Unknown	73,963	Unknown	Unknown
1880	1,874	309,506	Unknown	85,700
1950	1,392	308,284	148,452	184,161
2007	696	253,679	20,112	170,179
2012	695	280,980	Unknown	193,295
2017	637	235,398	Unknown	161,661
Lewis County				
1850	Unknown	110,554	Unknown	Unknown
1880	2,003	288,097	Unknown	81,434
1950	1,350	290,817	132,454	164,035
2007	750	261,299	30,001	178,257
2012	729	284,283	Unknown	201,259
2017	636	213,678	Unknown	152,958
Marion County				
1850	Unknown	184,393	Unknown	Unknown
1880	1,787	246,005	Unknown	75,963
1950	1,431	280,622	181,393	94,135
2007	749	237,016	9,234	166,178
2012	704	221,469	Unknown	157,511
2017	587	232,558	Unknown	182,528
Schuyler County				
1850	Unknown	51,949	Unknown	Unknown
1880	1,407	110,504	Unknown	45,808
1950	841	181,713	112,389	55,774
2007	544	152,378	73,299	78,971
2012	516	159,378	Unknown	83,792
2017	541	166,941	56,760	80,132
Scotland County				
1850	334	81,430	Unknown	Unknown
1880	1,994	206,274	Unknown	81,959
1950	1,052	262,808	139,032	104,224
2007	716	231,697	53,323	148,298
2012	674	244,169	Unknown	158,418
2017	713	250,189	30,023	182,264

Chapter 2: Element A. - Identifying Impairment

Watershed Inventory

The North Fabius River (WBID 56) was included on the 1998 and 2002 303(d) list of impaired waters. From 24, 59N, 6W to 26, 67N, 14, 82 miles of the waterbody was listed because the Protection of Warm Water Aquatic Life Use did not meet Narrative Criteria due to sediment pollution from agricultural nonpoint sources. Per Missouri's WQS, all waters of the state must provide suitable physical habitat and water quality for aquatic life[5]. Even though the 303(d) list does not include habitat problems as an impairment, much of the North Fabius River had poor habitat due to poor riparian zones, steep and bare banks, and extensive channelization. When the water quality standard is expressed as a narrative criteria, a measurable indicator of the pollutant may be selected to express the narrative as a numeric value. There are many quantitative indicators of sediment, such as, total suspended solids (TSS), turbidity, and bed-load sediment, all of which are appropriate to describe sediment in rivers and streams.

Historic Stream Assessments

Fabius River Watershed Inventory and Assessment[8]

The Fabius River Watershed Inventory and Assessment is a report that was published by MDC in 1999 in order to present the findings of watershed and aquatic life surveys. Due to the adverse impacts of channelization, especially from bank clearing and channel widening, there was a concern that loss of total stream area and usable habitat, increased streambank and streambed erosion, and a homogenous habitat would be supporting less aquatic life within the Fabius River basin. Even on reaches of stream not impacted by channelization, accelerated streambank erosion was occurring where protective forested corridors had been removed. In such cases, vertical banks up to 15 feet high had developed. Maintaining diversity of water depth is difficult, if not impossible, in areas where streambanks are unstable. Stream fish habitat in many small tributaries had been severely degraded by grazing livestock that trample streambanks and streambeds, increasing erosion and turbidity and destroying instream cover. Problems stemming from instream sand and gravel removal were locally significant but minor compared with problems resulting from stream channelization and watershed erosion.

In 1999, MDC compiled basin surveys and project data into a report. The main objectives of the report were: 1) to summarize the widely scattered physical, chemical, and biological information most relevant to the stream fishery of the Fabius River watershed, and 2) to identify opportunities for conserving (wisely managing) Fabius River basin streams on a watershed scale. In addition to providing guidance for MDC operations, the document was also intended to facilitate citizen-led initiatives to manage the watershed in a way that will benefit the fisheries, the rural economy in general, and future generations who will inherit the legacy.

While parts of the Middle Fabius River (WBID 63) were named as Significant Aquatic Areas in the Missouri Natural Features Inventory[18], there was basin-wide concern about the impacts increased sedimentation had on aquatic habitats. Fish community data were collected by MDC staff throughout the basin during 1988-1989, which revealed the loss or decline of several fish species that are known to be intolerant of turbid or silty streams and the presence of species not previously seen that are known to be tolerant of high turbidity. There were limited surveys on mussel species, crayfish, and other aquatic invertebrate communities during this time period. Data on aquatic insects presented in the report were quantified by MDNR in 1992 in the Middle Fabius River.

In summary and in addition to several monitoring suggestions, the report states that:

"Stream fish communities in the Fabius River watershed seem to be imbalanced. Surveys have revealed the existence of relatively few fish-eating predators (flathead catfish, black bass, or walleye/sauger) but large numbers of insect-eating bottom feeders (channel catfish, river carpsuckers, freshwater drum, common carp, and a variety of native minnow species). Non-game fishes are represented mostly by species tolerant of the shallow depths and shifting substrates caused by excessive watershed erosion and subsequent stream channel sedimentation. Shifting substrates dramatically reduce biological productivity, so in channelized streams the large populations of insect-eating fish are almost entirely dependent upon terrestrial inputs or whatever invertebrate production occurs on in-channel woody debris. There are not enough predatory fish to control the abundant insect-eating fish. Degraded habitat may be the main factor limiting predator abundance and thereby preventing ecosystem balance."

Biological Assessment and Habitat Study[19]

Between Fall of 2005 and Spring of 2006, the Missouri Department of Natural Resources' Environmental Services Program conducted a biological assessment and habitat study of the North Fabius River to determine if macroinvertebrate community and/or aquatic habitat were impaired and, if so, determine the sources of impairment. The objectives of the study were to assess aquatic habitat characteristics, water quality characteristics, macroinvertebrate communities, stream sinuosity, and riparian coverage. Sampling results from sixteen sampling stations along the North Fabius River were compared to the Little Fox River, a bio-reference (BIOREF) stream within the same EDU (Figure 7).

The North Fabius Subbasin is within the EDU named 'Plains/ MS Tribs between Des Moines and MO Rivers/Des Moines Drainage'. Ecologic Drainage Units (EDU) are aquatic ecoregions where major watersheds with similar watershed and hydrological characteristics have been consolidated based on proximity.

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[18]Anderson, J. 1983. Addition to the eight-county natural features inventory. Missouri Department of Conservation. Jefferson City, Missouri
[19] Missouri Department of Natural Recourses, Environmental Services Program. Biological Assessment and Habitat Study Report for the North Fabius River. https://dnr.mo.gov/env/esp/docs/North_Fabius_River_Final_Report.pdf

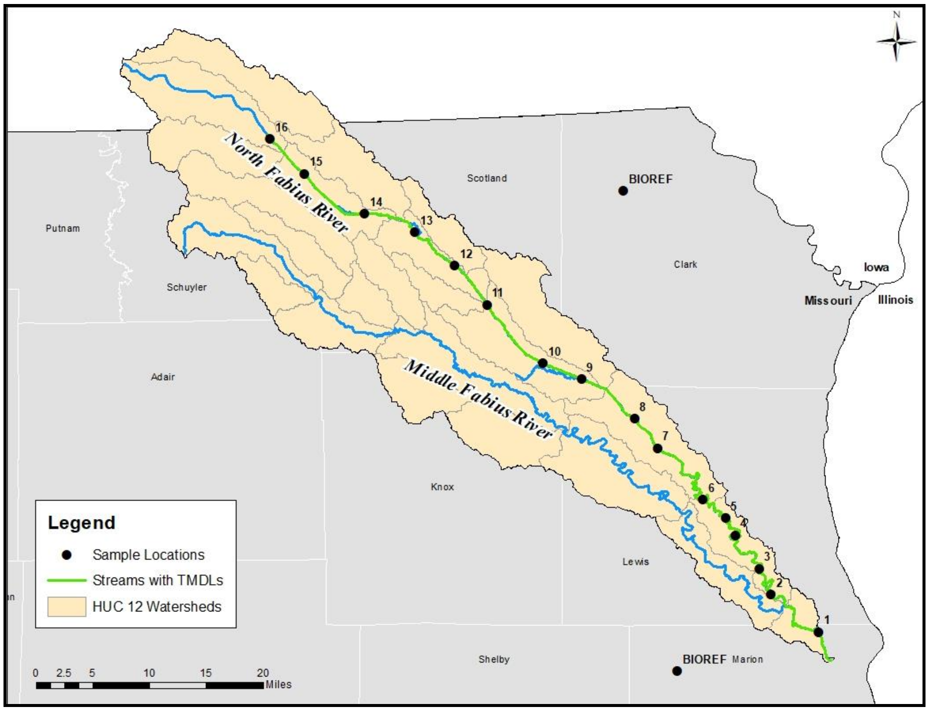

Figure 6. Sampling locations along the North Fabius River and two bioreference locations as part of the Missouri Department of Natural Resources' Biological Assessment and Habitat Study.

Habitat assessment scores were recorded for each sampling station. According to the project procedure guidance, the total score from the physical habitat assessment should be at least 75% similar to the total score of the study site to be assumed to be supporting a biological community. Habitat assessment results from Fall 2005 showed that five sites were less than 75% similar to the reference site and could not be assumed to have adequate habitat to sustain similar biological communities (Table 7). However, the biological assessment failed to indicate an overall habitat impairment in spite of seven of the sixteen North Fabius stations with scores that were at or below the acceptable 75% threshold.

Sinuosity was also calculated for each station. Sinuosity describes the degree in which a stream channel is meandering and is used as a rough indicator of the amount of channelization that has occurred. Sinuosity ratios were calculated by comparing the stream length between two sampling sites that were approximately two miles apart to the direct distance between the sites. The higher the sinuosity ratio the less likely the stream segment is channelized. The sinuosity ratio of 1.24 on the Little Fox was used for comparison. Sinuosity ratio on the North Fabius River for Stations 2 through 6 ranged from 1.62 to 2.06, indicating a lack of channelization. Sinuosity of Stations 7 through 16 ranged from 1.01 to 1.09, indicating extensive channelization along a substantial length of the upper stream length. Habitat degradation can be seen in the evidence of historic channelization from Station 7 upstream through the extent of the study. A lack of abundant woody debris was evident in the North Fabius, which is typical of channelized streams. Further, three of the sixteen sites had poor riparian coverage while the other sites ranged from mixed to very good riparian coverage (Table 8).

Table 7. Fall 2005 Habitat Scores from North Fabius River compared with Little Fox River. The South Fabius River was not compared with North Fabius stations biologically. *(Table adapted from report[19])*

BIOREF Stream	Habitat Score	North Fabius Station #	Habitat Score	% of L. Fox BIOREF
Little Fox	**99**	1	98	99
South Fabius	136	2	108	109
		3	125	93
		4	97	98
		5	95	96
		6	92	93
		7	70	**71***
		8	65	**66***
		9	81	82
		10	81	82
		11	72	**73***
		12	74	75
		13	83	84
		14	74	75
		15	62	**63***
*<75%		16	72	**73***

Table 8. Sinuosity and Riparian zone conditions conducted in the Fall 2005 at each sampling station ranged from poor to very good. *(Table adapted from report[19])*

Station	Sinuosity*	Likely to be Channelized	Riparian Zone Condition
North Fabius			
1	-	-	**Poor**
2	1.62	No	**Poor**
3	1.77	No	Good
4	2.06	No	Good
5	1.97	No	Very Good
6	1.62	No	Good
7	**1.06**	**Yes**	Mixed*
8	**1.08**	**Yes**	Mixed
9	**1.04**	**Yes**	Very Good
10	**1.07**	**Yes**	Mixed
11	**1.03**	**Yes**	**Poor**
12	**1.03**	**Yes**	Mixed
13	**1.09**	**Yes**	Mixed
14	**1.01**	**Yes**	Good
15	**1.03**	**Yes**	Mixed
16	**1.03**	**Yes**	Mixed
South Fabius R.	1.40	No	Mixed
Little Fox R.	1.24	No	Very Good

*Left descending bank rated poor; right descending bank rated very good

Channel dimension measurements provide further evidence of habitat impairment, especially the wetted width/depth ratios showing wide and shallow flow. The wetted width refers to the points where the water surface touches each side of the bank, whereas the channel width (also referred to as bankful [channel] width) is the distance between top edges of opposite streambanks. Maximum depths in the BIOREF stations were higher than those in the North Fabius and greater standard deviations for depths in the BIOREF stations indicate lower depth heterogeneity in the North Fabius. At some stations there were also high channel width/wetted width ratios. For example, Station 8 where the channel to wetted width ratio was 3.00, there were very large in-channel deposits of loose sandbars that were near, or exceeded, widths of 100 feet in seven of the ten transects. Some of these sandbars reached as high as approximately three to four feet above the water surface next to the wetted bank.

Macroinvertebrate Stream Condition Index sustainability scores for all sites during fall and spring sampling show all sites are fully sustaining of aquatic life. While there was significant physical alteration to the stream, the study concluded the North Fabius River did not appear to be biologically impaired by sediment and was maintaining a healthy macroinvertebrate community. However, although the macroinvertebrate evaluation showed full sustainability during both seasons in the North Fabius, this may not necessarily give the full assessment of the overall quality of the stream. Macroinvertebrate assessments tend to be more suitable for water and substrate quality studies. The MDNR report recommended that streams that are extensively channelized should also be evaluated for fish communities.

Water quality data collected during fall and spring seasons included temperature, pH, conductivity, dissolved oxygen, and nutrient and chloride concentrations. These data are presented in the study report[19]. Turbidity measurements were included in the data collection and is a measure of light reflectance as a function of the amount and properties of particles in the water column. An increase in nephelometric turbidity units (NTU) indicates increased cloudiness. Turbidity levels during Fall 2005 were somewhat consistent with a few higher values measured shortly after precipitation events. During the Spring 2006 sampling, turbidity values were more varied and reached as high as 222 NTU at Station 13 and 257 NTU at Station 12. Some of the spring sampling was conducted during snowmelt runoff and after rain events. Overall, water quality measurements revealed few definitive trends other than seasonal differences.

Total Maximum Daily Load (TMDL) Study and Report

In accordance with Section 303(d) of the federal Clean Water Act[20], a TMDL study must be conducted and a report written for waterbodies not meeting a state's Water Quality Standards (WQS). The study identifies potential point and nonpoint sources of a specific pollutant to a waterbody that is assessed as impaired. The TMDL determines the pollutant loading a waterbody can assimilate without exceeding the WQS for that pollutant and, based on the relationship between pollutant sources and in-stream water quality conditions, establishes the pollutant load allocation necessary to meet the WQS established for each waterbody. The TMDL consists of a wasteload allocation (WLA), a load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL that accounts for the uncertainty associated with the model assumption and data inadequacies.

The North Fabius River, Marion County, Missouri TMDL was written and approved by the EPA in September 2006[21]. The TMDL cited MDNR's "Information Sheet For Streams with Aquatic Habitat Loss"[2] when describing the conditions across the watershed, namely excessive rates of sediment deposition that had reduced or degraded aquatic habitats in the North Fabius River. However, TMDLs do not address habitat but are written to correct a water quality condition. The TMDL report selected total suspended solids (TSS) as the numeric target, determined the sediment load the waterbody can assimilate without exceeding Missouri's WQS, and allocated portions of the loading capacity between nonpoint sources and a margin of safety. The TMDL study determined that point sources do not contribute to the water quality impairment relative to sediment impacts on stream biology and were given a zero percent net reduction in sediment load. With 10% of the loading capacity reserved for a margin of error, the remaining 90% of allowable sediment loading was assigned to nonpoint sources.

Sediment targets were based on EDU information, where the TSS target for maximum allowable pollutant loading is the 25th percentile calculated from all data available within the EDU in which the waterbody is located. A sediment Load Duration Curve (LDC) model was developed using a synthesized flow range that was created using data from a group of USGS gauges within the EDU and a TSS 25th Percentile target. Therefore, based on TSS concentrations measured across a range of flows, the 2006 TMDL estimated a needed 87% reduction in sediment loading from nonpoint sources at the outlet of the watershed.

[20] Federal Water Pollution Control Act. November 27, 2002. https://www.epa.gov/sites/production/files/2017-08/documents/federal-water-pollution-control-act-508full.pdf
[21] U.S.EPA Region 7. "North Fabius River Marion County, Missouri, Total Maximum Daily Load". September 2006. https://dnr.mo.gov/env/wpp/tmdl/docs/0056-n-fabius-r-tmdl.pdf

Recent Stream Assessments

Watershed modeling or water quality modeling is used to estimate the amount of pollutants affecting the waterbody and the amount of load reductions expected from implementing best management practices throughout the watershed to address the stream impairment. Watershed modeling essentially describes the natural or man-made process in the watershed system, such as runoff or stream transport, and forecasts or estimates future conditions that might occur under various conditions.

Sediment Pollution

For this 2020 WMP, addressing and reducing soil erosion and streambank degradation remains a high priority, just as it was for stakeholders surrounding the development of the 2010 North and Middle Fabius NPS Watershed Management Plan. Since the 2010 WMP, several water quality models were employed to estimate sediment loading in the planning area.

Total Suspended Solids Load Duration Curve

For the revision of this 2020 WMP, MDNR's Water Protection Program revised the TSS LDC that was created for the 2006 North Fabius TMDL (Figure 7). Since site-specific gauge data wasn't available at the time the TMDL was developed, the TSS LCD was created using a synthetic flow developed with discharge data from USGS stream gauges within the EDU. However, a newly installed stream gauge on the North Fabius River near Ewing, MO (USGS 05497150[13]) has been collecting continuous discharge measurements since November 2005. The flow duration curve (Figure 4) and revised TSS LDC have been updated with this recent discharge data to assess the range of flow conditions on the North Fabius River. The TSS water quality data used in the TMDL LDC was collected across the EDU by USGS between 1979 and 1997; however, newer TSS data collected between 2009 and 2018 were plotted on the revised LDC (Data presented in Appendix D).

The selection of the TSS allowable load target for the revised LDC was completed using the same approach and sample locations as those used in the TMDL, which is the 25th percentile calculated from all data available within the EDU. However unlike the TMDL, the revised TSS curve assumes a constant target across all flow conditions. For unknown reasons, the TMDL curve maintained the same constant target of 30 mg/L for most of the low and dry flow conditions, but then the target appeared to increase at higher flows. For this revised LDC, a TSS 25th percentile target of 30mg/L assumes a constant target across all flow conditions and is as stringent as the TMDL was at lower flows, but more so at higher flows.

The LCD in Figure 7 presents discharge levels at the time TSS samples were collected. With the recent flow and TSS data, the revised LDC shows most of the TSS exceedances occurred during moist and high flow conditions. See the flow duration curve for discharge (cfs) values associated with each flow range (Figure 4). Further, see the 2006 TMDL[21] and Appendix D of this plan for a more detailed explanation about the development and interpretation of LDCs for modeling water quality data with stream flow data.

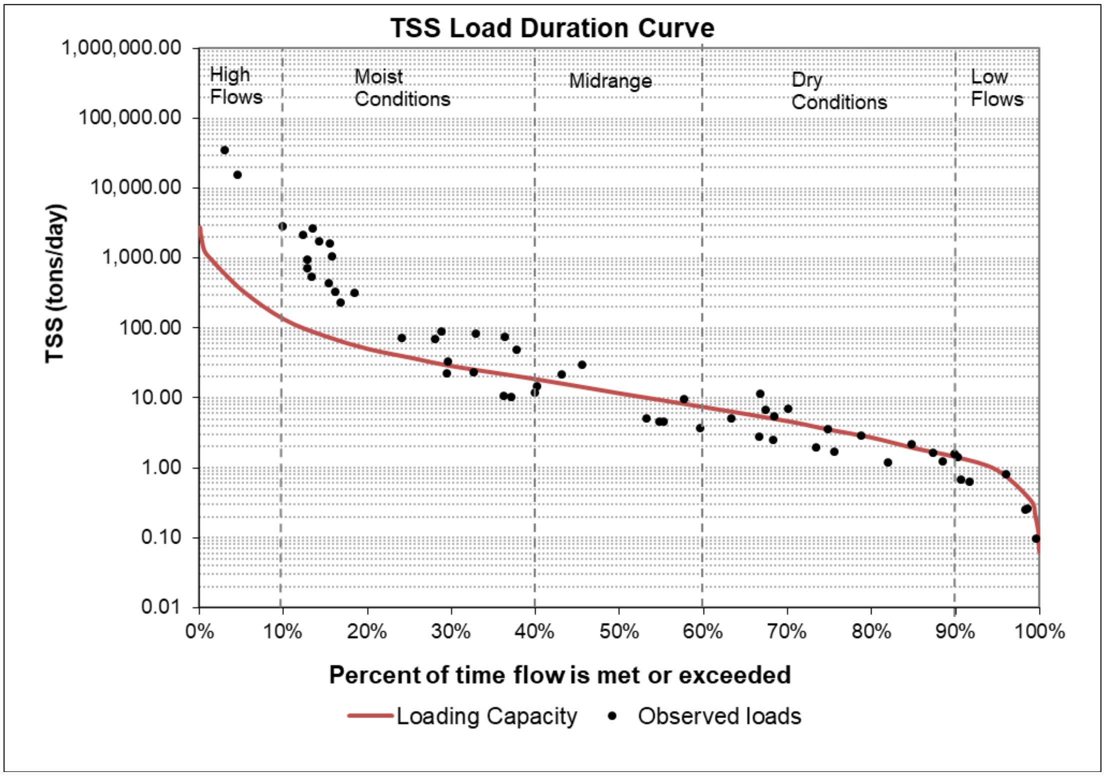

Figure 7. Total suspended solids (TSS) load duration curve compares TSS data collected across a range of flow conditions with the allowable amount of TSS loading (red line) required to meet WQS.

<u>Soil and Water Assessment Tool (SWAT) model</u>

In 2015, through a contract agreement with the University of Missouri – Columbia, the Schuyler County Soil and Water Conservation District obtained the services of Dr. Allen Thompson and a graduate student, whom Dr. Thompson supervised, to implement watershed modeling in the North Fabius River watershed. The modeling project was funded by Section 319 Nonpoint Source Implementation Grant as part of the North and Middle Fabius Water Quality Improvement Project – Phase II and was completed December 2019. The modeling was used to obtain technical information needed to update the North Fabius watershed plan.

An ArcGIS Interface for Soil and Water Assessment Tool (ArcSWAT) was used to analyze sediment loading and determine critical areas for the North Fabius River (WBID 56), and did not include the Middle Fabius River (WBID 63) in the analysis. The ArcSWAT model utilized current water quality data, land use, soil, agriculture crop history and other watershed information. Water data included daily flow data from January 2000 to December 2015 and sediment data from grab samples collected every two months during the same time period from USGS Gauge 05497150, near Ewing, Missouri.

The modeled portion of the North Fabius HUC8 subbasin (HUC07110002) comprised of twelve HUC12 subwatersheds within the North Fabius River watershed:

12-digit HUC	*HUC Name*
071100020101	*South Fork North Fabius River*
071100020102	*Headwaters North Fabius River*
071100020103	*Carter Creek North Fork North Fabius River*
071100020104	*North Fork North Fabius River*
071100020105	*Downing Reservoir-North Fabius River*
071100020106	*Gunns Branch*
071100020107	*Indian Creek*
071100020108	*Memphis Reservoir-North Fabius River*
071100020401	*Bear Creek*
071100020402	*Long Branch-North Fabius River*
071100020403	*Cooper Branch-North Fabius River*
071100020404	*Town of Weber-North Fabius River*

The SWAT model delineated the 12 HUC12s into 291 catchments that were each associated with a stream reach. Then, the catchments were further divided into a total of 9,074 hydrologic response units (HRUs), which were made up of a distinct land use, soil, and slope combinations. Perdue's LOADEST online calculator was used to estimate monthly and daily sediment yields[22].

Model baseline inputs, which included state cost-share BMPs that were implemented between FY2009 and FY2017, calibration and validation processes, and other information about how the SWAT model was set-up are detailed in Appendix G.

[22] Runkel, R.L., C.G. Crawford, and T.A. Cohn. 2004. Load Estimator (LOADEST): A FORTRAN Program or Estimating Constituent Loads in Streams and Rivers. Techniques and Methods Book 4, Chapter 5. U.S. Geological Survey. https://pubs.usgs.gov/tm/2005/tm4A5/pdf/508final.pdf

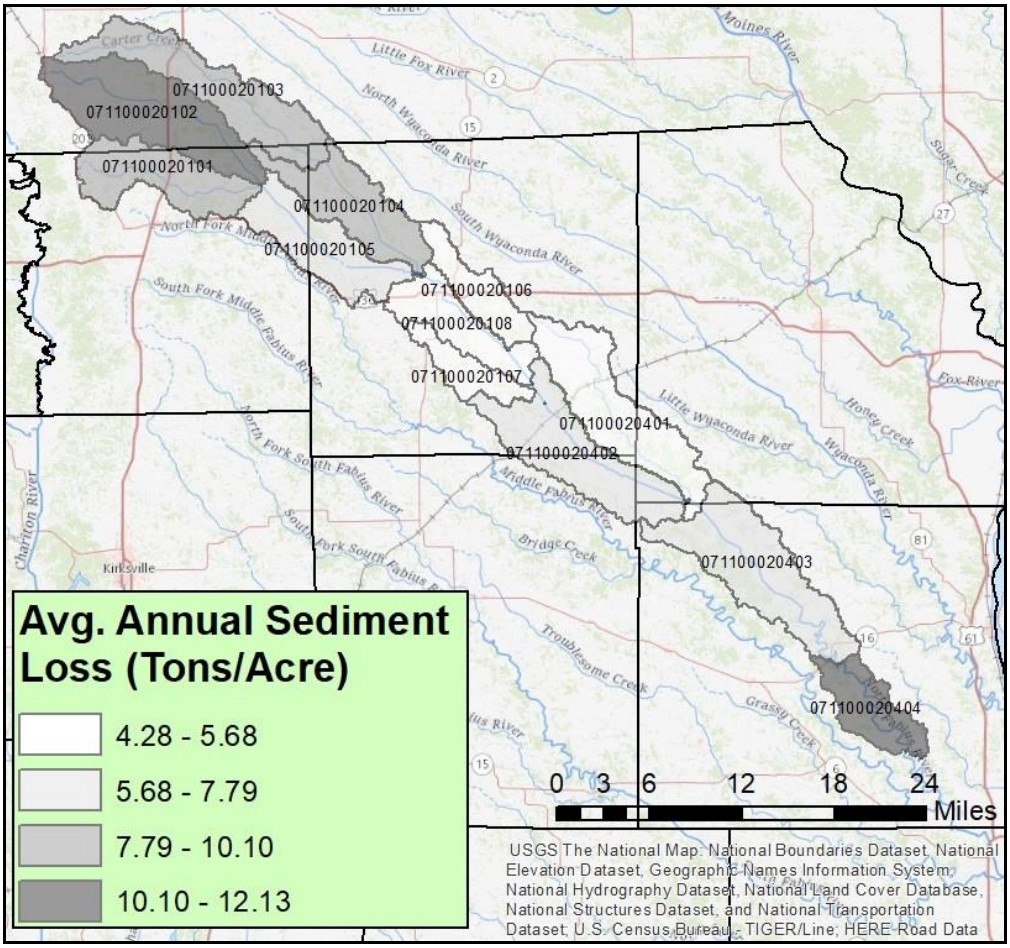

Figure 8. Average annual sediment loss (tons/acre) estimated by SWAT for each HUC12 subwatershed in the North Fabius River watershed.

As seen in Figure 8, there are varying levels of contribution from the 12 subwatersheds, with the greatest sediment loss occurring at both the top and bottom of the North Fabius River watershed. SWAT model results estimated an average sediment loss of 545 tons per day when the North Fabius River flow was at 75% flow rate of about 418 cfs[23]. <u>The average annual watershed value for sediment loading at USGS Gauge 05497150 was given as 8.15 tons of sediment per acre (20.145 tons/hectare).</u>

[23] For comparison, the Flow Duration Curve in Figure 4 is similar and estimates this flow range at 462 cfs.

Spreadsheet Tool for Estimating Pollutant Loads (STEPL)[24]

The STEPL model commonly used by the EPA and other states is an excel-based model that calculates nutrient and sediment loads from different land uses based on watershed characteristics. It also estimates the reductions in nutrient and sediment loading from the implementation of BMPs. A STEPL model for each HUC12 subwatershed within the North Fabius and Middle Fabius watersheds was set up by staff in MDNR's Section 319 NPS Program. See Appendix E for information on model inputs and assumptions.

Table 9 presents the 'background' sediment loads that were estimated based on land use and land management across each subwatershed. Different from the SWAT model, the number and size of gullies and eroding streambanks along the perennial segment of each stream was also included in the STEPL model, as these are likely the contribute a large portion of sediment to the North Fabius and Middle Fabius Rivers[25].

Total annual background sediment loading for the entire planning area was estimated at an average of 456,033 tons per year. Since the 2010 WMP, a total of 1,054 cost-share practices that would decrease soil erosion or protect streambanks were implemented across the planning area (Table 1). The implementation of these BMPs between FY 2009 and FY2020 were estimated to have reduced sediment loading by 34,664 tons over 12 years. This reduction calculates to about 2,889 tons of sediment per year (8 tons/day) during this time period. As shown in Table 9, the percent sediment load reduction varies for each HUC12 and ranges from a 0.1% to 19% decrease. Altogether, total estimated sediment load reductions results in an 8% decrease for the planning area. Current average annual sediment loading, which will also be referred to as the Baseline loading, is estimated at 421,370 tons per year.

[24] Environmental Protection Agency. Polluted Runoff: Nonpoint Source Pollution. Spreadsheet Tool for Estimating Pollutant Loads. https://www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl

[25] Willet, C.D., R.N. Lerch, R.C. Schultz, S.A. Berges, R.D. Peacher, and T.M. Isenhart. 2012. Streambank erosion in two watersheds of the central claypan region of Missouri, United States. Journal of Soil and Water Conservation 67(4): 249-263. https://www.jswconline.org/content/67/4/249.short

Table 9. STEPL-estimated Sediment loading (tons/yr) by HUC12 and totaled for the greater planning area and load reductions from FY2009-FY2020 cost-share practices.

Waterbody	HUC12	Background Sediment Load	Sediment Reduction FY2009-FY2020 BMPs	Baseline Sediment Load (after BMPs)	% Sediment Reduction
		- - - - - - - - - - - tons/yr - - - - - - - - - - -			
North Fabius River	071100020101	10835	242	10592	2%
	071100020102	15566	16	15550	0.1%
	071100020103	14789	190	14599	1%
	071100020104	33184	2344	30839	7%
	071100020105	35396	2193	33203	6%
	071100020106	17360	930	16430	5%
	071100020107	15050	1693	13357	11%
	071100020108	39846	1663	38183	4%
	071100020401	29347	4441	24906	15%
	071100020402	25917	385	25532	1%
	071100020403	20576	2918	17659	14%
	071100020404	19809	3230	16579	16%
	071100020405	13927	2574	11352	18%
Middle Fabius River	071100020201	5707	448	5260	8%
	071100020202	9897	422	9475	4%
	071100020203	3364	115	3250	3%
	071100020204	10149	134	10016	1%
	071100020205	9346	691	8656	7%
	071100020206	16449	1169	15280	7%
	071100020301	17475	3315	14160	19%
	071100020302	10242	1201	9041	12%
	071100020303	10528	785	9744	7%
	071100020304	25630	1122	24507	4%
	071100020305	25044	1795	23249	7%
	071100020306	20599	647	19952	3%
	Total	**456,033**	**34,664**	**421,370**	**8%**

Nutrient and Chemical Pollution

During public meetings, stakeholders also expressed a concern about nutrient and chemical pollution. These pollutants of concern were categorized as a medium priority. Many of the state cost-share practices that address sediment control also help to reduce nutrient and chemical loading by keeping them on-site to be utilized by plants and soil microorganisms or become filtered through the soil profile before reaching the nearby waterbody. Pesticide/herbicide loading is not currently extensively monitored or being modeled. Total nitrogen and total phosphorus stream concentrations from water quality monitoring were assessed with load duration curves, and the reduction in nitrogen and phosphorus loading from cost-share practices were captured in the STEPL modeling efforts.

Total Nitrogen and Total Phosphorus Load Duration Curves

Water quality data was collected from the North and Middle Fabius watersheds by MDNR and USGS. Load duration curves for TN and TP were plotted using the same flow data from the stream gauge on the North Fabius River near Ewing, MO (USGS 05497150[13]). Since the gauge has been collecting continuous discharge measurements since November 2005, water quality data collected since then were used, which spans from March 2006 to October 2018.

Missouri does not have specific numeric criteria for nutrients in streams, therefore loading targets are based on the Regional Technical Assistance Group (RTAG) benchmark values for nutrients, which is a group consisting of state, federal, tribal, and academic members that formed in 1999. RTAG developed nutrient benchmark concentrations for streams in Missouri, Kansas, Nebraska, and Iowa, which are surrogate criteria designed to protect aquatic life against nutrient concentrations beyond natural levels (Table 10).[26] Per EPA Region 7, the benchmark values developed by RTAG are consistent with the Clean Water Act and its implementing regulations at 40 CFR 131.11(a) as being protective of designated uses, are scientifically defensible, and may be used as numeric translators of narrative criteria in lieu of the ecoregional values.[27] These recommended criteria are not laws or regulations; they are guidance that states and tribes may use as a starting point for criteria development for their water quality standards. Water quality goals would be to achieve a value below or at a percentage better than the benchmarks (e.g. 10%).

Table 10. EPA Region 7 RTAG Nutrient Benchmarks (*adapted from report*[26])

Nutrient Parameter	Regional Technical Assistance Group Benchmarks
Total Phosphorus (TP) mg/L	0.075
Total Nitrogen (TN) mg/L	0.90

[26] USEPA Region 7 RTAG Members. January 14, 2009. Nutrient Reference Conditions Identification and Ambient Water Quality Benchmark Development Process.
https://www.ok.gov/conservation/documents/Huggins%20SOQ%20addendum%202.pdf

[27] U.S. Environmental Protection Agency, Region 7 (USEPA). 2019. Memorandum: Surface Water Nutrient Criteria Document. October 14, 2019.

Figures 9 and 10 present the TN LDC and TP LDC, respectively. Both curves assume a constant target across all flow conditions using RTAG benchmark targets (Table 10). The LCDs also present stream discharge levels at the time water quality samples were collected. While there were a few TN exceedances during low and dry flow conditions, most of the samples that exceeded concentration of 0.9 mg TN/ L occurred during moist and high flow conditions. While most of TP samples collected during moist and high flow conditions exceeded the target value of 0.075 mg TP/L, several TP measurements taken during midrange and dry flow conditions also exceeded the target. See the flow duration curve in Figure 4 for discharge (cfs) values associated with each flow range and Appendix D of this plan for a more detailed explanation about the development and interpretation of LDCs for modeling water quality data with stream flow data.

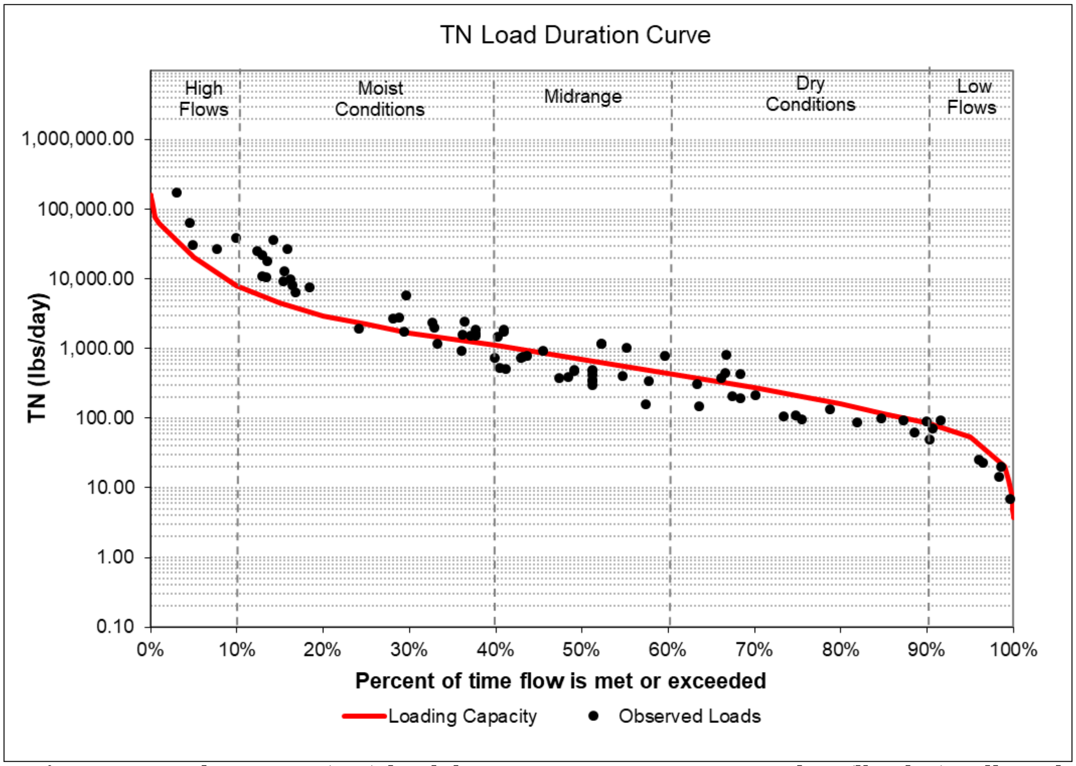

Figure 9. Total nitrogen (TN) load duration curve compares TN data (lbs/day) collected across a range of flow conditions with the red line indicating the RTAG value of 0.9 mg/l as the maximum target amount for TN loading.

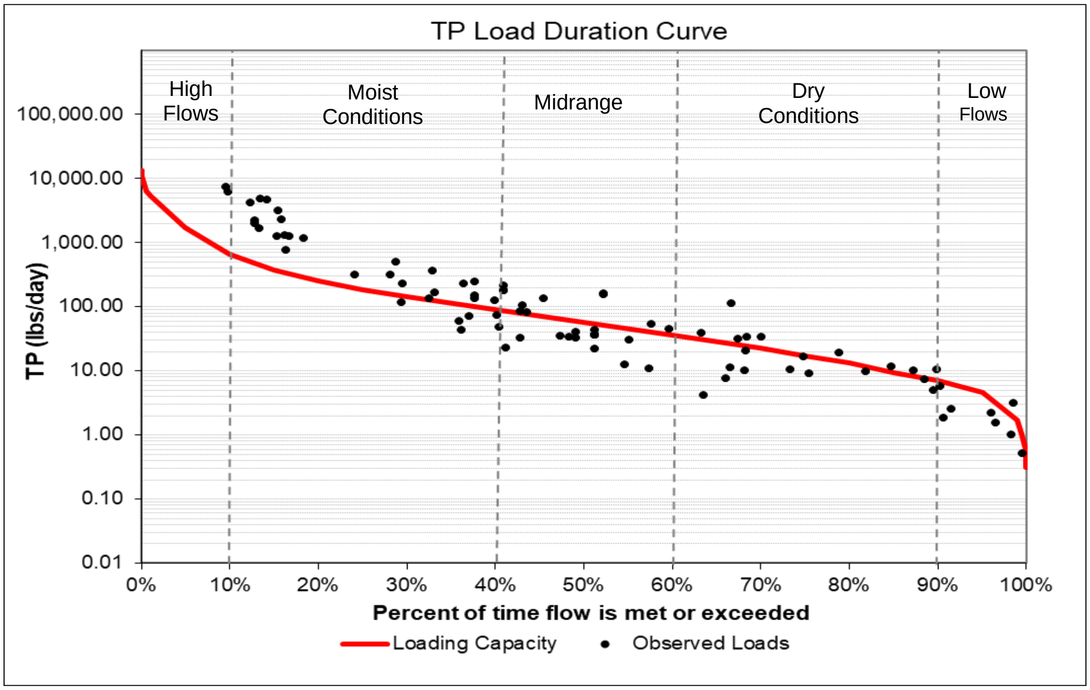

Figure 10. Total phosphorus (TP) load duration curve compares TP data (lbs/day) collected across a range of flow conditions with the red line indicating the RTAG value of 0.075 mg/l as the maximum target amount for TP loading.

<u>Spreadsheet Tool for Estimating Pollutant Loads</u>

The STEPL model, described above and in Appendix E, that was set up for estimating sediment loading for each HUC12 subwatershed within the 2020 WMP area was also used to estimated annual total nitrogen (TN) and total phosphorus (TP) loading before and after cost-share BMPs were implemented.

Total 'background' TN loading for the entire planning area was estimated at an average of 7,830,049 lbs per year. Since the 2010 WMP, the implementation of state cost-share practices between FY2009 and FY2020 were estimated to have reduced TN loading by 471,085 lbs over 12 years. This reduction calculates to about 39,257 lbs of nitrogen per year (108 lbs/day) during this time period. As shown in Table 11, the percent TN load reduction varies for each HUC12 and ranges from a 0.1% to 16% decrease. Altogether, total estimated TN load reductions results in a 6% decrease in TN loading for the planning area. Current TN average annual loading, or Baseline loading, is estimated at 7,358,964 lbs per year.

Total 'background' TP loading for the entire planning area was estimated at an average of 1,487,875 lbs per year. Since the 2010 WMP, the implementation of state cost-share practices between FY2009 and FY2020 were estimated to have reduced TP loading by 120,759 lbs over 12 years. This reduction calculates to about 10,063 lbs of phosphorus per year (28 lbs/day) during this time period. As shown in Table 12, the percent TP load reduction varies for each HUC12 and ranges from a 0.1% to 19% decrease. Altogether, total estimated TP load reductions results in an 8% decrease in TP loading for the planning area. Current baseline TP loading is estimated at 1,367,116 lbs per year.

Table 11. STEPL-estimated total nitrogen (TN) loading (lbs/yr) by HUC12 and totaled for the greater planning area and load reductions from FY2009-FY2020 cost-share practices.

Waterbody	HUC12	Background TN Load	TN Reduction FY2009-FY2020 BMPs	Baseline TN Load (after BMPs)	% TN Reduction
		- - - - - - - - - - -	lbs/yr	- - - - - - - - - -	
North Fabius River	071100020101	190989	6713	184276	4%
	071100020102	359803	447	359356	0.1%
	071100020103	393396	6436	386960	2%
	071100020104	565638	34664	530974	6%
	071100020105	432279	28158	404121	7%
	071100020106	265733	12750	252983	5%
	071100020107	213570	19254	194316	9%
	071100020108	457230	20851	436380	5%
	071100020401	516054	54154	461900	10%
	071100020402	407590	8061	399530	2%
	071100020403	394234	35230	359004	9%
	071100020404	291792	36615	255177	13%
	071100020405	176039	28280	147760	16%
Middle Fabius River	071100020201	158972	13250	145722	8%
	071100020202	267207	10918	256288	4%
	071100020203	84013	3152	80861	4%
	071100020204	239112	5210	233902	2%
	071100020205	147620	8725	138896	6%
	071100020206	249514	19215	230299	8%
	071100020301	273846	40041	233805	15%
	071100020302	226430	17390	209040	8%
	071100020303	241946	12080	229866	5%
	071100020304	489329	18948	470381	4%
	071100020305	472090	22671	449419	5%
	071100020306	315618	7870	307748	2%
	Total	**7,830,049**	**471,085**	**7,358,964**	6%

Table 12. STEPL-estimated total phosphorus (TP) loading (lbs/yr) by HUC12 and totaled for the greater planning area and load reductions from FY2009-FY2020 cost-share practices.

Waterbody	HUC12	Background TP Load	TP Reduction FY2009-FY2020 BMPs	Baseline TP Load (after BMPs)	% TP Reduction
		- - - - - - - - - - - lbs/yr	- - - - - - - - - -		
North Fabius River	071100020101	30429	1224	29205	4%
	071100020102	63810	77	63734	0.1%
	071100020103	64800	1503	63297	2%
	071100020104	90817	6517	84300	7%
	071100020105	70367	5183	65185	7%
	071100020106	44410	2170	42240	5%
	071100020107	34469	3811	30659	11%
	071100020108	77834	3964	73869	5%
	071100020401	100236	13761	86475	14%
	071100020402	82290	2270	80020	3%
	071100020403	91481	12266	79215	13%
	071100020404	72598	12467	60131	17%
	071100020405	52258	9885	42373	19%
Middle Fabius River	071100020201	21737	2442	19295	11%
	071100020202	36269	2013	34257	6%
	071100020203	10072	722	9351	7%
	071100020204	30065	709	29355	2%
	071100020205	22232	1506	20726	7%
	071100020206	41812	3470	38342	8%
	071100020301	45049	8660	36389	19%
	071100020302	52649	6056	46593	12%
	071100020303	55299	4097	51202	7%
	071100020304	110530	5793	104737	5%
	071100020305	109869	7661	102207	7%
	071100020306	76494	2534	73959	3%
	Total	**1,487,875**	**120,759**	**1,367,116**	8%

Escherichia coli (E. coli) Pollution

E. *coli* loading to waterbodies was not listed as a nonpoint source pollution of concern surrounding the development of the 2010 WMP. However, more recent screening level monitoring data collected by Truman State University and MDNR show trends toward a water impairment; therefore, this revised plan also addresses E. *coli* pollution. High counts of *E. coli* may be an indication of fecal contamination and an increased risk of pathogen-induced illness to humans. *E. coli* are bacteria found in the intestines of humans and warm-blooded animals and are used as indicators of the risk of waterborne disease from pathogenic bacteria or viruses. Infections due to pathogen-contaminated waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases.

In rural areas, stormwater runoff from onsite wastewater treatment systems (septic systems) and from lands used for agricultural purposes are sources of bacterial loading to water bodies. Activities associated with agricultural land uses that may contribute bacteria to a water body include manure fertilization of croplands or pastures and livestock grazing. Septic systems that are properly designed and maintained should not be a source of contamination to surface waters; however, system can fail hydraulically from surface breakout or hydrogeologically where there is inadequate soil filtration.

<u>North Fabius Water Quality Improvement Project</u>

With financial support from a Section 319 Nonpoint Source Implementation Grant under the North Fabius Water Quality Improvement Project, a student team from Truman State University, led by Dr. Cynthia Cooper in the Department of Biology, assisted on the visual survey and collection of water samples from five sites on the Middle and North Fabius Rivers (Figure 11). Samples were collected five times within a 30-day period with the first grab sample taken on June 10, 2008. This was Phase 1 of a 2-Phase study to gather baseline water quality data. Analyses included air and water temperature, dissolved oxygen, pH, nitrate levels, turbidity, micro-invertebrate count, and *E. coli*. Water quality results were compared to Missouri’s Water Quality Standards.

As part of Phase 2 of the Fabius Water Quality Improvement Project, monitoring at the five sites continued from 2014 to 2016. Results from Phase 1 and 2 sampling show two trends in the *E. coli* data (Table 13 and Figure 12). First, two sites show a significant trend of increasing bacteriological counts (Sites 3 and 8) while the other two sites show more gradual trends of slightly upward (Site 2) and slightly downward (Site 7). While Site 2 did trend up between 2008 and 2014, there was no further increase after that. Although none of these sites have a designated use by which *E. coli* criteria can be applied, using the most generous criteria for casual recreational use, it is best to avoid an *E. coli* level higher than 1,134 bacterial counts per 100 ml. Most of the sample values exceeded this limit.

Water quality data collected as part of the Fabius Water Quality Improvement Project were not used by MDNR for assessment against Missouri’s WQS when determining if a waterbody is supporting its designated used. However, these data serve as valuable screening level data as to where excessive *E. coli* loading may be occuring in the upper portions of the North Fabius and Middle Fabius Rivers.

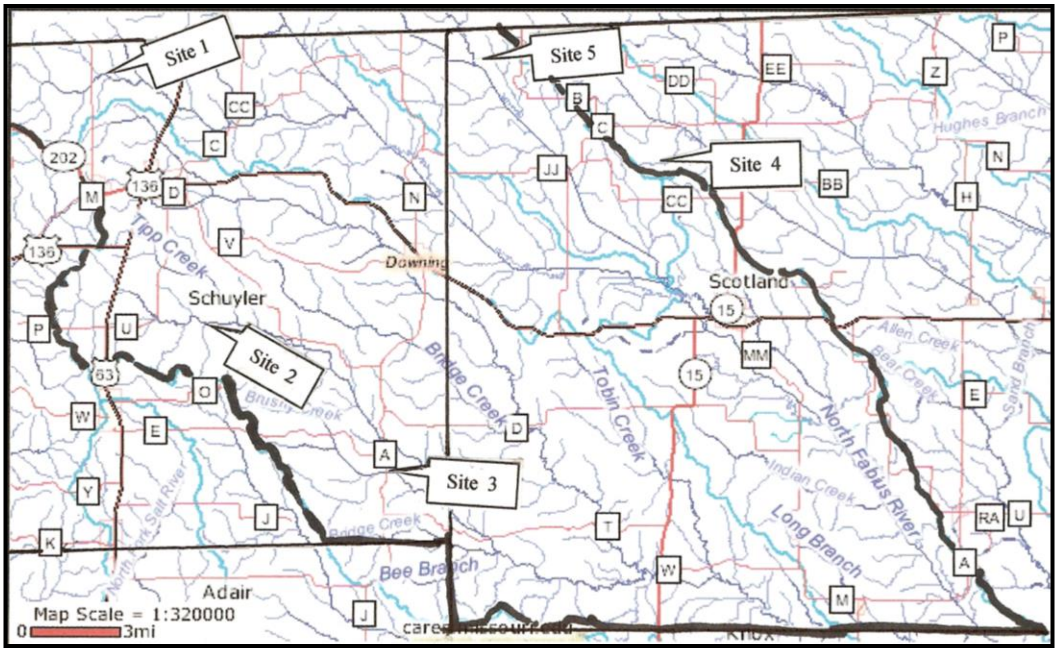

Figure 11. Sampling locations along the North and Middle Fabius Rivers in Schuyler and Scotland counties: Site 1. Route M north of Glenwood – South fork of North Fabius River

Site 2. Route O & Route D – Mark Bushnell – Middle Fabius River
Site 3. Route A – Big bridge, Public Access – Middle Fabius
Site 4. 3 Miles east of Crawford – David Myers – North Fabius River
Site 5. Route B north and west in Scotland County – North Fabius River

Table 13. Range of *E. coli* values for four sites in Schuyler County. Most Probable Number (MPN/100ml) by the IDEXX Method (www.idexx.com)[28]. Values that exceeded the recommended criterion for secondary contact recreation are underlined (1134 MPN/100 ml).

River or Stream (Site #)	GPS Location	Date 3/192016	Date 3/202016	Date 4/24 2016	Date 5/26 2016	Date 6/25 2016	Date 7/16 2016	Date 7/30 2016	Date 8/20 2016	Date 9/17 2016	Geo-Mean
S Fork Middle Fabius (FWQIP2)	40.452717 -92.473767	N.D.	N.D.	387	6,867	5,172	1,046	4,611	1,414	4,884	2,400
S Fork Middle Fabius (FWQIP3)	40.398215 -92.392707	N.D.	N.D.	2,755	12,997	6,131	N.D.	10,462	5,172	6,488	6,524
North Fabius River (FWQIP7)	40.532438 -92.373554	N.D.	N.D.	461	2,282	649	1,733	816	N.D.	292	810
Brushy Creek (FWQIP8)	40.389900 -92.418817	N.D.	N.D.	580	5,794	1,553	N.D.	Dry Bed	4,884	6,867	2,809
7-Day Rainfall (inches)		0.62	0.62	0.79	0.42	0.52	0.97	0.38	0.37	0.51	0.55

[28] MDNR. Environmental Services Program-109 (2014). *Analysis of Escherichia coli and Total Coliforms Using the IDEXX Colilert and Quanti-Tray Test Method,* Standard Operating Procedure

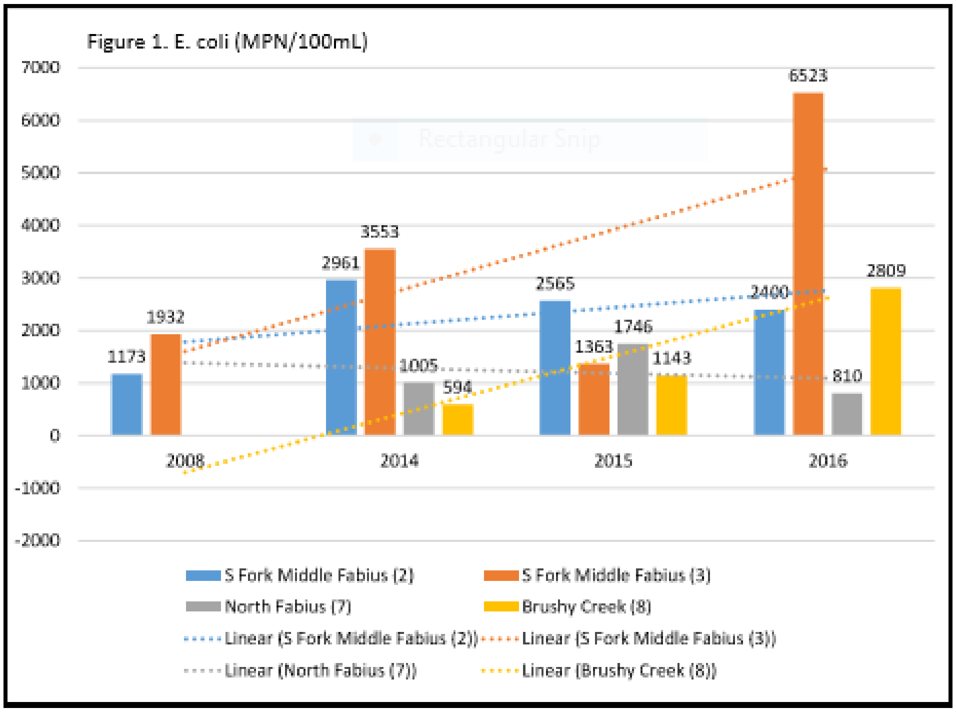

Figure 12. Average *E. coli* counts (MPN/100ml) at four sites in Schuyler county sampled in 2008, and between 2014 and 2016.

<u>*E. coli* Load Duration Curve</u>

MDNR's Water Protection Program developed an *E. coli* LDC using data collected by USGS and MDNR between 2009 and 2018 at the stream gauge site on the North Fabius River near Ewing, MO (Figure 13; data presented in Appendix D). However, since land use and land cover are about the same for the Middle Fabius and North Fabius watersheds, it is assumed that the LDC information presented here can be used as a guide to target *E. coli* load reductions to the Middle Fabius River. It is recommended that future E. coli monitoring occur within both watersheds.

The *E. coli* target for the 2020 WMP is based on Missouri's Water Quality Standards and uses the criterion of 206 bacterial counts per 100mL for the protection of Whole Body Contact -B Use[5]. The LDC shows *E. coli* concentrations in the waterbodies generally exceeded WQS during wet and high flow conditions, which are shown in the flow duration curve (Figure 4) to be flow conditions that range from about 227 cfs to 13,013 cfs. However, exceedances also occur during dry and low flow conditions. Exceedances during high flow conditions generally represent loading from runoff while exceedances during dry conditions suggest a point or nonpoint source discharging directly into the waterbody.

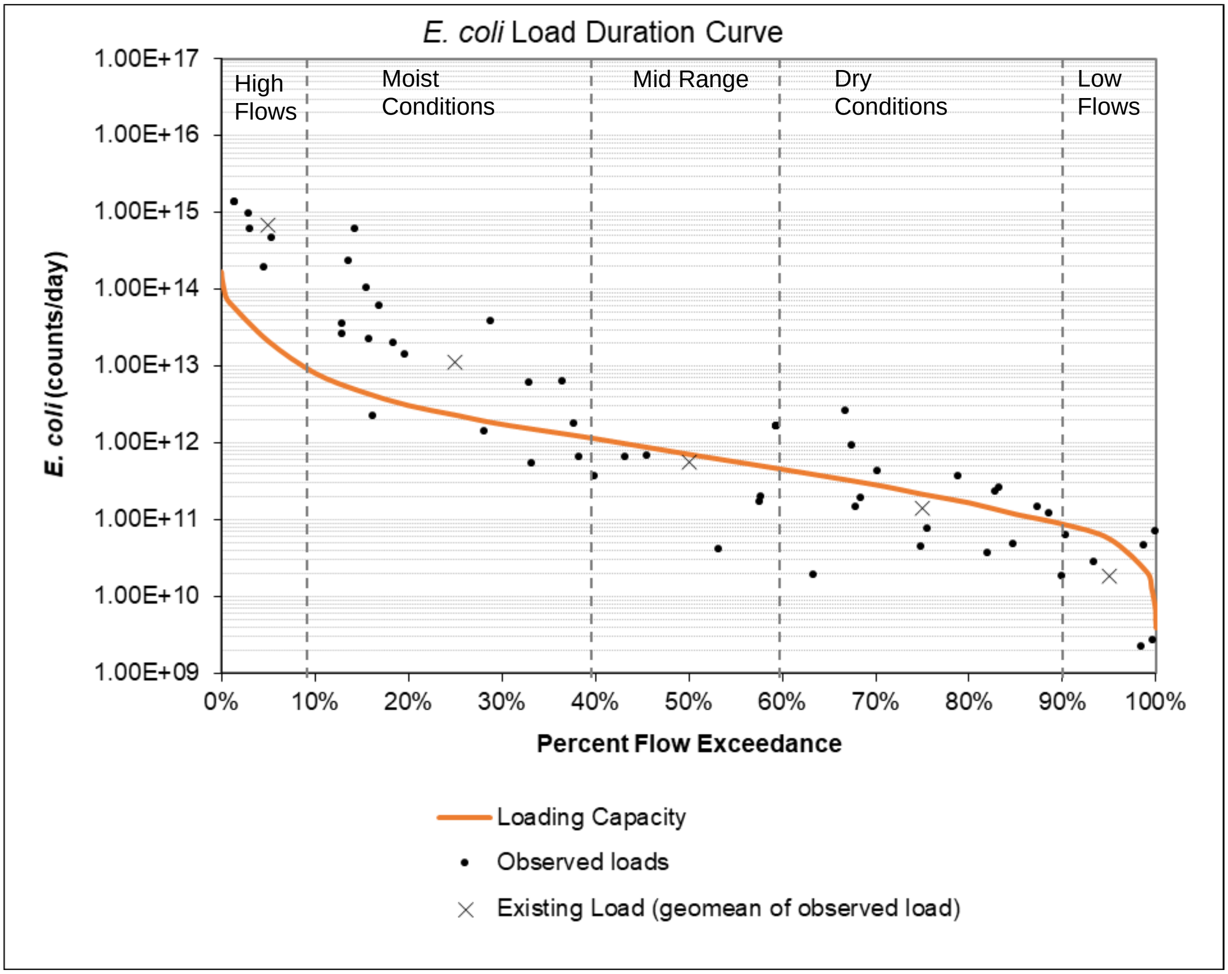

Figure 13. *Escherichia coli* load duration curve compares *E. coli* data collected across a range of flow conditions with the allowable geometric mean of *E. coli* loading (red line) during the recreational season required to meet WQS.

Identifying Nonpoint Source Stressors

Nonpoint source pollution refers to pollution from diffuse, non-permitted sources that typically cannot be identified as entering a water body at a single location and includes all categories of pollution not classified as being from a point source. These sources involve stormwater runoff over land and are minor or typically negligible under low-flow conditions. Nonpoint sources of pollution having the potential to influence water quality include various sources associated with runoff from agricultural lands and permitted urban areas, on-site wastewater treatment systems, and areas having poor riparian corridor conditions.

Water quality concerns in the North Fabius include sediment, nutrient, chemical, and pathogen loading, turbidity from organic and inorganic particles, and loss of aquatic habitat. Causes for these concerns are from streambank alterations, streambank erosion, poor riparian corridors, poor grazing land health, livestock watering out of the river due to lack of livestock exclusions or alternative watering sources, an increased number of feedlots without proper waste management systems, improper application of animal nutrients to crop and pastureland, runoff from row crop production, and sheet and rill erosion. Sedimentation and turbidity are the watershed's most severe problems. Excessive sedimentation not only reduces the useful life of ponds, lakes, reservoirs, and wetlands, it can increase the severity and frequency of flooding by reducing the water carrying capacity of streams and rivers.

Sediment and nutrients, such as nitrogen and phosphorus, support the growth of algae and other aquatic plants. This contributes to water quality issues due to the depletion of dissolved oxygen concentrations as oxygen is used to facilitate the biochemical processes of decomposition. In the presence of organic sediment and nutrients, dissolved oxygen in the stream becomes consumed faster than it can be replenished through atmospheric oxygen exchange and aquatic organism photosynthesis. The resulting low dissolved oxygen concentrations can harm aquatic life.

Turbid waters also create low dissolved oxygen concentrations in water bodies through increasing water temperatures by absorbing more radiant heat and reducing photosynthetic rates by reducing the amount of light penetrating the water column. Further, suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development.

Channel Alterations and Habitat Problems

As of 1999, most of the North Fabius River had been channelized, but the Middle Fabius River remained largely unaltered. The North Fabius River has been completely channelized upstream of Monticello, Missouri, resulting in ongoing, severe head-cutting in upper reaches of the watershed. The Middle Fabius River is one of only a few northern Missouri streams that have not been extensively channelized. According to the MDC's 1999 assessment[8], this stream offers a wide variety of habitat types since it flows through two distinct regions - one of glacial till with sand and silt substrates and another of rock outcroppings with gravel, cobble, and bedrock substrates. Compared to most other northern Missouri streams, the banks of the Middle Fabius

River are relatively low, and the streambed is stable. Often times, very short channelized sections are usually associated with bridge crossings. Less of the North Fabius watershed lies in the region of thin till and exposed rock than the Middle Fabius, and it has been more severely degraded. Small sections of several tributary streams across the watersheds have been altered also, usually by private landowners and local governments.

Channelization, or the straightening of a stream, also includes bank clearing and widening of the channel. This results in a loss of total stream area and usable habitat, increases streambank and streambed erosion, and a homogenous habitat that supports far less aquatic life. Even on reaches of stream not impacted by channelization, accelerated stream bank erosion occurs where protective forested corridors have been removed. In such cases, vertical banks up to 15 feet high have developed. Maintaining diversity of water depth is difficult, if not impossible, in areas where stream banks are unstable. Further, stream fish habitat in many small tributaries have been severely degraded by grazing livestock that trample stream banks and streambeds, which increases turbidity and erosion and destroys stream cover. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and other beneficial macroinvertebrates. Additional problems stemming from in-stream sand and gravel removal are locally insignificant compared with problems resulting from stream channelization and watershed erosion.

Riparian Corridor Conditions

Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal, and assimilation of pollutants in runoff. Land use changes or land clearing for grazing or row crop production can include complete removal of riparian vegetation or a decrease in width. Loss of tree cover in riparian zones facilitates elevated water temperatures in summer and an overall reduction in woody debris, which is a critical aquatic habitat component in prairie streams. Removal of riparian vegetation leaves streambanks more susceptible to erosion.

Table 14 presents the distribution of land cover types within a 100-ft buffer zone along the North Fabius River, Middle Fabius River, which includes their tributaries, and the total area for the watershed management planning area. Across the entire planning area, forested land cover makes up 33% of the riparian corridor, although the forest cover does not always extend the entire 100-ft width. The North and Middle Fabius watersheds have a similar amount of forested riparian area. Similarly, the number of acres of the riparian zone under Grassland and Pasture management for each watershed are almost equivalent, which combined accounts for 27% for the entire planning area. The amount of riparian zone as Cropland makes up about nineteen percent for the entire planning area. However, the North Fabius watershed, which is larger than the Middle Fabius watershed, has more acres of riparian land under cultivation. The amount of cropland within the 100-ft buffer zone in the North Fabius watershed is about 4,256 acres, compared to 1,882 acres within the Middle Fabius watershed. The combined agricultural land uses total about 14,910 acres adjacent to surface waters available for BMP implementation that would intercept pollutants before entering the stream.

Table 14. Land cover within a 100-ft buffer corridor along the North and Middle Fabius Rivers and tributaries.

Land Use	Riparian Corridor Land Cover Type Area			
	North Fabius	**Middle Fabius**	**Total Acres**	**Percentage**
	- - - - - - - acres - - - - - - -			
Grassland and Pasture	4395	4377	**8771**	**27%**
Cropland	4256	1882	**6138**	**19%**
Forest	5403	5438	**10841**	**33%**
Shrub and Herbaceous	453	544	**997**	**3%**
Wetlands	2644	2391	**5034**	**15%**
Urban/Impervious	442	323	**765**	**2%**
Barren or Sparsely Vegetated	11	2	**13**	**0.04%**
Total	**17603**	**14957**	**32560**	**100%**

Agriculture Areas

The majority the North and Middle Fabius watershed management planning area is under some type of agricultural management. As previously shown in Table 5, grasslands and pastures extend about thirty-five percent of the planning area, or about 246,000 acres, and cropland covers about twenty-two percent, or 154,000 acres. Pasture and hay land have been converted to row crops and the conversion from continuous grazing to manage intensive grazing systems on the existing grazing land has slowly increased. Row crops across the planning area are grown on a variety of topography from the bottomlands to the 30% slopes. Major crops grown are soybeans, corn, hay, and winter wheat with a growing number of producers including the use of cover crops. The price of land has escalated, along with competition for both row crop and pasture. Many acres of marginal land are coming out of CRP and being converted into cropland, many of which are on steeply sloped and highly erodible lands.

Soil erosion is tied closely with water quality and is a major concern of landowners and producers. Soils that are disturbed, such as from tillage or excavation, and left bare are highly susceptible to water and wind erosion (Figure 14). Soil erosion primarily occurs from agricultural sources, especially due to practices that do not follow soil health principles. Rainfalls that contribute to sheet and rill erosion occur after spring planting but before crops emerge, after fall plowing of land, and where marginal lands are cultivated.

Figure 14. Soil erosion occurs on sloped cropland without best management practices that cover and protect the soil.

In addition to soil loss from wind and water erosion, nonpoint source pollutants that are often transported in overland flows from residential properties, croplands, pasturelands, and low-density animal feeding operations, such as nutrients, chemicals, and pathogens, are either attached to mineral soil particles and organic materials or dissolved in runoff waters. Sources include areas fertilized with animal manure and where livestock are present. Polluted runoff can result from intense precipitation events or excessive irrigation of these areas.

Fertilizer usage in the area has increased as more hog confinements have been built. Hog manure has a high nitrogen content, which is the primary nutrient by nearly 2:1. However, concerns about phosphorus buildup in the soils are increasing. Microbes, parasites and nitrate levels have not been extensively tested, but are concerns since hog facilities from Iowa and Missouri are draining into the watershed. The Missouri Department of Natural Resources does not regulate animal waste that is applied on areas not under the direct control of a permitted CAFO. Likewise, MDNR does not regulate manure fertilizers that originate from locations outside the watersheds, which may be imported and applied to unregulated areas. For these reasons, nutrient and bacteria contributions to the water body from manure applications could be significant due to the large extent of land in this watershed under agricultural uses.

Although grazing areas are typically well vegetated, livestock congregate near feeding and watering areas and create barren areas that are susceptible to erosion. Additionally, livestock that are not excluded from streams deposit manure and thus bacteria directly into waterways (Figure 15). Areas where nutrient management plans that guide manure application and where BMPs are used to reduce soil erosion contribute less bacteria to surface waters than unmanaged areas.

Figure 15. Cattle often have direct access to streams within the North Fabius subbasin.

The increase in land conversion from pasture and hay land to row crops has resulted in increased use of herbicides and pesticides. The leading chemical used for pests is Permethrin. Atrazine is the leading component for herbicides, which has been identified by the EPA as a potential human carcinogen. Many pesticides and herbicides destroy plant and insect species other than the "targeted" ones and this disrupts the food chain and alters ecosystems. The over-application or misuse of pesticides and herbicides, especially in riparian areas and/or areas with insufficient erosion control practices, can allow these chemicals to enter surface and ground water (via runoff or leaching) where they pose a significant risk to human health, aquatic habitat (both flora and fauna), and wildlife.

Field runoff is the primary mechanism for chemical transport from fields to streams. A study on herbicide contamination and transport in northern Missouri/southern Iowa streams found the maximum herbicide concentrations and frequency of detection in streams follows spring applications due to the intensity of spring rainfall.[29] The study found that total herbicide loss for a watershed increased with the increase in runoff potential of soils, namely soils that have a restrictive layer such as those with claypans or pronounced argillic horizons. Runoff potential of a watershed's soils is primarily due to soil texture and topography; therefore, a watershed's hydrologic soil groups (HSG) are valid indicators of regional hydrology and vulnerability.

Table 15 shows the types and distribution of HSGs for each subwatershed within the 2020 WMP area. Hydrologic soil groups categorize soils based on infiltration rates (when thoroughly wet) and runoff potentials, which are a function of soil texture, soil structure, clay mineralogy, organic matter content, and the depth to a restrictive layer (e.g. claypan, bedrock) or the water table.[30] Slope is not a factor that is considered in hydrologic soil groupings. Soils designated as HSG-A have high infiltration rates at saturation (also referred to as saturated hydraulic conductivity) and low runoff potentials. Soils designated as HSG-D have low saturated hydraulic conductivity rates and high runoff potentials. Dual listed soils (e.g. B/D or C/D) may have good infiltration rates

[29] Learch, Robert and Paul Blanchard. May 2006. Herbicide Contamination and Transport in Northern Missouri and Southern Iowa Streams. https://www.ars.usda.gov/ARSUserFiles/50701000/ARS_588_lerch.pdf
[30] USDA-NRCS. May 2007. Part 630 Hydrology, National Engineering Handbook. Ch7 Hydrologic Soil Groups. Available at https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba

but have a shallow depth to the water table, therefore their designation indicates the drained /undrained characteristics of the soil.

Table 15. Hydrologic soil group distribution across the North and Middle Fabius NPS WMP area.

HUC 12 -Subwatershed Name		Hydrologic Soil Group					
	North Fabius Watershed	**A**	B	B/D	C	C/D	D
71100020101	South Fork North Fabius River	-	5%	19%	17%	31%	28%
71100020102	Headwaters North Fabius River	-	7%	9%	15%	36%	32%
71100020103	Carter Creek-North Fork North Fabius River	-	5%	2%	26%	33%	34%
71100020104	North Fork North Fabius River	-	0.4%	7%	37%	22%	34%
71100020105	Downing Reservoir-North Fabius River	-	4%	9%	28%	33%	27%
71100020106	Gunns Branch	-	-	7%	32%	25%	36%
71100020107	Indian Creek	-	-	7%	36%	28%	29%
71100020108	Memphis Reservoir-North Fabius River	-	0.02%	0.2%	2.9%	2%	95%
71100020401	Bear Creek	2%	-	4%	35%	33%	27%
71100020402	Long Branch-North Fabius River	2%	0.5%	3%	37%	38%	20%
71100020403	Cooper Branch-North Fabius River	-	7%	6%	24%	27%	35%
71100020404	Town of Weber-North Fabius River	-	7%	1%	33%	24%	36%
71100020405	North Fabius River	-	8%	4%	73%	10%	5%
	Middle Fabius Watershed						
71100020201	Bridge Creek	-	2%	4%	30%	39%	25%
71100020202	Headwaters North Fork Middle Fabius River	-	2%	9%	27%	36%	25%
71100020203	Brushy Creek	-	3%	22%	20%	35%	20%
71100020204	Headwaters South Fork Middle Fabius River	-	3%	9%	19%	42%	27%
71100020205	North Fork Middle Fabius River	-	0%	4%	36%	36%	24%
71100020206	South Fork Middle Fabius River	-	2%	5%	48%	21%	24%
71100020301	Tobin Creek	-	0%	7%	38%	19%	36%
71100020302	City of Baring-Bridge Creek	-	0%	10%	14%	50%	26%
71100020303	Little Bridge Creek-Bridge Creek	-	0%	12%	44%	31%	12%
71100020304	Sand Hill Branch-Middle Fabius River	-	1%	2%	32%	48%	16%
71100020305	Reddish Branch-Middle Fabius River	-	2%	2%	35%	37%	25%
71100020306	Middle Fabius River	-	4%	1%	35%	27%	33%
	Total		**2%**	**7%**	**33%**	**33%**	**25%**

Identifying Point Source Stressors

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit Program. Point sources include any discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, or conduit, by which pollutants are transported to a water body. Under this definition, permitted point sources include permitted municipal and domestic wastewater dischargers, site-specific permitted industrial, and non-domestic wastewater dischargers, concentrated animal feeding operations, municipal separate storm sewer systems, and general wastewater and stormwater permitted entities. In addition to these permitted sources, illicit straight pipe discharges, which are illegal and therefore unpermitted, are also point sources.

Concentrated animal feeding operations (CAFOs) are operations in which animals are confined to areas that are totally roofed. The facilities typically utilize earthen or concrete structures to contain and store manure prior to land application. National Pollutant Discharge Elimination System (NPDES) permits, non-discharging, are issued for facilities with more than 1,000 animal units. All permitted livestock facilities have waste management systems designed to minimize runoff entering their operations or detaining runoff emanating from their areas. Such systems are designed for the 25 year, 24-hour rainfall/runoff event. Total potential animal units (AU) for all facilities are approximately 1,920 AU. The actual number of AUs on site is variable, but typically less than potential numbers.

As of August 2020, there were twelve permitted CAFOs in the planning area (Table 16 and Figure 16). All twelve facilities are hog finishing operations. Slurry produced by these CAFOs is rich in nitrogen and phosphorus and is applied to cropland and pastures as fertilizer. Water quality problems related to runoff and leaching from cropland and pastures treated with animal waste include excessive algae growth in streams and ponds, reduced dissolved oxygen levels, habitat loss, and fish kills.

Under NPDES general permit, CAFO facilities are not allowed to discharge for any reason, without exception, and any discharge is a violation. The 2006 North Fabius TMDL reported that point sources in the watershed, including CAFOs, were not considered sources of sediment loading to the waterbody and were not allocated a waste load reduction. Also due to NPDES permit restrictions, CAFOs are not expected to contribute nutrient and bacteria loads to streams in the North Fabius watershed as a result of direct wastewater discharges. However, a potential source for nutrient and bacteria loading from these operations is runoff from areas where animal wastes are land applied as fertilizer. Land applications occurring on areas under the control of a CAFO are subject to conditions found in the permit and the required nutrient management plan developed by the facility. For these reasons, land applications conducted by the CAFO facilities in compliance with permitted conditions should not be contributing significant nutrient and bacteria loads to water bodies in the North Fabius watershed.

Table 16. List of confined animal feeding operations (CAFO) in the North Fabius Subbasin.

CAFO Facilities	Permit Number	Description	County	Class*	Animal Units
Michael Sensenig	MO-GS10321	Hogs	Scotland	Class IC	360
Michael Sensenig	MO-GS10321	Hogs	Scotland	Class IC	1760
County Line Pork	MO-GS10504	Hogs	Lewis	Class IB	3006
Parks Finishing C9, LLC	MO-GS10459	Hogs	Schuyler	Class IC	1960
Miller Farms Pork Production AA	MO-GS10290	Hogs	Knox	Class IC	1920
Doug Ruth	MO-GS10408	Hogs	Schuyler	Class IC	1992
S and K Custom Work Inc	MO-GS10018	Hogs	Lewis	Class IC	1920
Elise Toohill	MO-GS10545	Hogs	Schuyler	Class IC	1440
Ruth Pork LLC	MO-GS10166	Hogs	Scotland	Class IC	1920
Aeschliman Finishing Farm	MO-GS10024	Hogs	Schuyler	Class IC	1984
Newland Finishing Farm	MO-GS10111	Hogs	Scotland	Class IC	1920
Denver Oberholtzer	MO-GS10319	Hogs	Scotland	Class IC	1920

***Class:** An operation's "class size" is a category that is based upon the total number of animal units confined at an operation. The Class IC, IB and IA are categories that start at 1,000, 3,000 and 7,000 animal units respectively, and are required by state regulation to obtain a permit. (1,000 animal units is equal to 2,500 swine; 100,000 broilers; 700 dairy cows; or 1,000 beef steers).

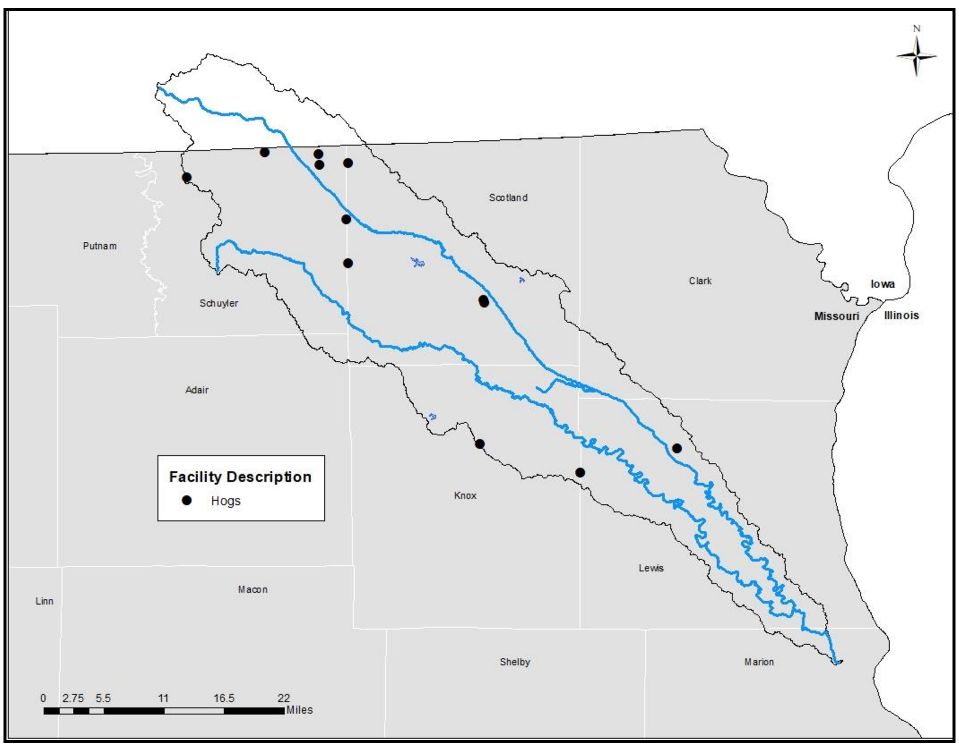

Figure 16. Locations of CAFOs across the North Fabius subbasin.

Identifying Critical Source Areas

Under the goals and objectives of improving water quality and quantity, which includes restoring and protecting designated beneficial uses of waters, the implementation of nonpoint source management practices will be most effective with proper planning. Identifying the critical source areas, or critical areas, is a major part of the planning process and a key part to meeting the load reduction targets set by a Watershed Management Plan or Total Maximum Daily Load report. Critical source areas are identified through modeling or visual assessment as areas that contribute the greatest amount of a nonpoint source pollutant. These are areas where there is an adverse overlap between the amount of pollutant source and transport potential; therefore, targeting the source and/or the transport of a pollutant will reduce pollutant loading[31].

Sediment loading causing high turbidity in waterbodies across the North Fabius subbasin is the main pollutant of concern. Improving water quality by addressing the sources of soil is the number one priority for stakeholders in these planning areas. The SWAT modeling that was conducted for the North Fabius River watershed identified the current critical source areas of sediment after adding to the model the BMPs that had already being implemented in the watershed. The SWAT model divided each HUC12 subwatershed into catchments and was able to identify critical source areas at the catchment level. See Appendix G for the SWAT model report and critical area maps.

Since the recent SWAT modeling only assessed a portion of the North Fabius River watershed, which is about half the WMP area, an additional water quality model was employed to estimate sediment loading across the planning area within the North and Middle Fabius River watersheds. The STEPL model incorporates various land use, land cover, management practices, and soil data when estimating sediment and nutrient loading. Since gully erosion and streambank degradation are identified as major sources of sediment loading to waterbodies, an estimate of gullies and failing streambanks was also included in the STEPL assessment for each HUC12 subwatershed. Including sediment contribution from gullies and streambanks greatly increases the estimated sediment loading across the planning area and results in a different prioritization of HUC12 subwatersheds than was identified by the SWAT model. See Appendix E for more detailed information about the STEPL modeling.

Critical Source Areas

The Critical Areas identified for the planning area within this 2020 WMP are closely linked to land characteristics that influence runoff volume and quality, soil erosion, and sediment loading. The major factors considered in designating critical areas were: 1) streams bordering agricultural lands with none to minimal riparian corridor, 2) soils that have high runoff potentials due to low rates of water infiltration and percolation during saturated conditions (also known as saturated hydraulic conductivity), or a shallow depth to an impermeable layer or the water table, and

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[31] EPA. July 2018. Critical Source Area Identification and BMP Selection: Supplement to Watershed Planning Handbook. Available at https://www.epa.gov/sites/production/files/2018-08/documents/critical_source_area_identification_and_bmp_selection_final_5-11-18cover.pdf

3) agricultural practices on land with slopes greater than or equal to 3%. Riparian corridors/buffer zones not only slow down surface runoff, promote water infiltration, and slow down flood waters, the roots of riparian vegetation along the streambank help to stabilize the bank by holding soil in place. Additionally, soils characteristics vary widely across a landscape depending on landscape position, inherent properties and management practices, all of which influence the rate at which water infiltrates into the soil and percolates through the soil profile. The depth to an impermeable layer, such as a claypan or bedrock, or to the water table also influences the capacity of a soil to hold and transport water before pooling or runoff occurs. Further, land with slopes greater than 3% are likely to experience sheet, rill and gully erosion, especially where management practices, inherent soil properties and poor soil health decrease water infiltration rates and water holding capacity of a soil. Given the above considerations, three types of critical source areas were designated (Figure 17).

Critical Area 1 – Designates a 100 ft stream buffer along stream segments that are bordered by agricultural lands (this includes areas where there may be some type of perennial buffer already established, but buffer widths were less than 100 ft).

Critical Area 2 – Targets areas of land under agricultural land uses with a slope greater than 3% and with hydrologic soil groups D and dual-listed D/C soils.

Critical Area 3 - Designates any remaining land under agricultural land use with a slope greater than 3%, regardless of hydrologic soil group designation.

Critical Area 4 – (not mapped) Addresses stakeholder concerns for nutrient and chemicals in runoff from agricultural lands and supports nutrient and pest management plans for all agricultural lands, regardless of slope.

Critical area maps for each of the 25 HUC12 subwatersheds across the planning area are provided in Appendix F.

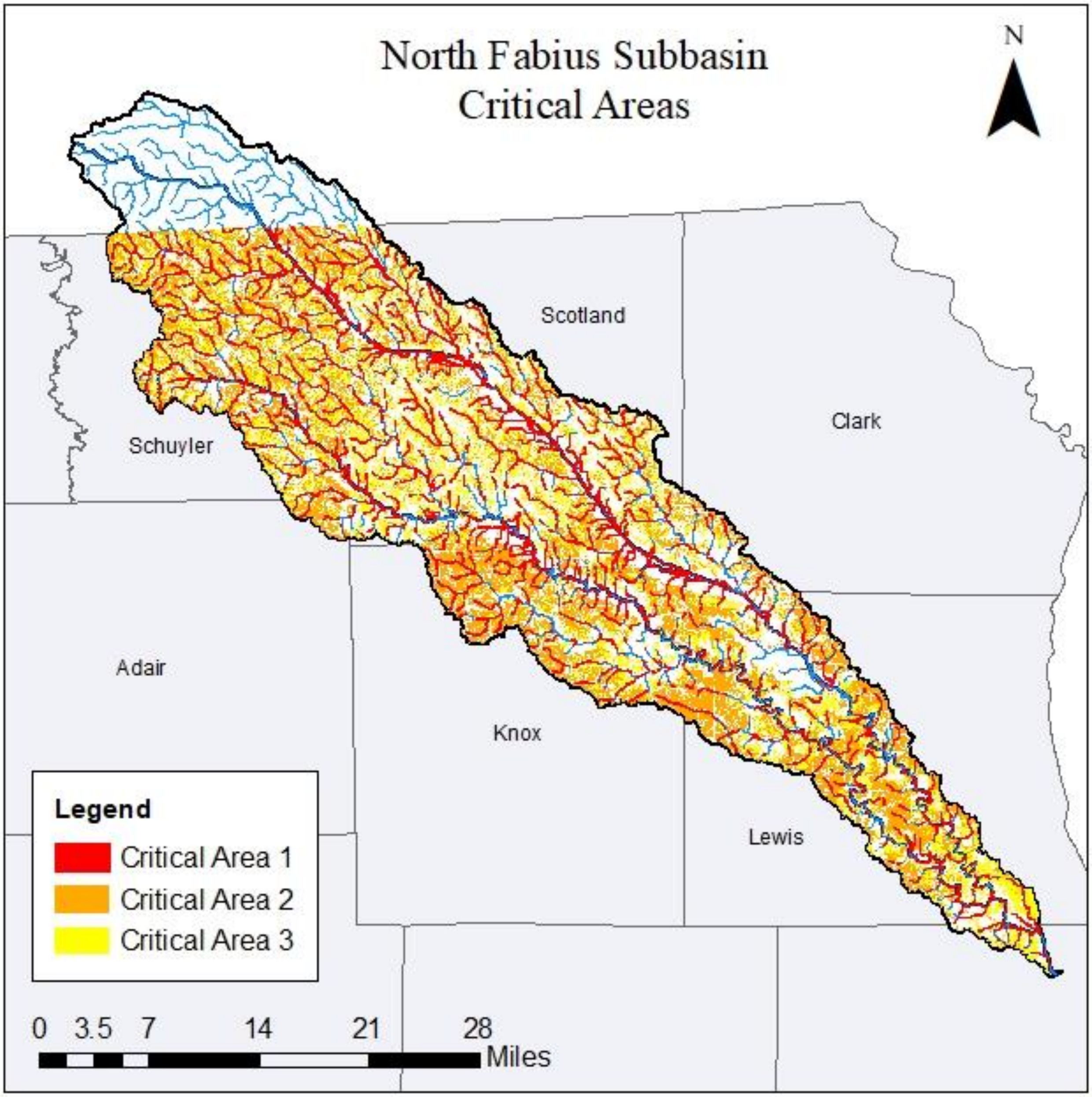

Figure 17. Critical source areas identified across the North Fabius subbasin as target areas for implementation of best management practices in order to reduce pollutant loading.

Priority Areas

After determining the critical source areas for the 2020 WMP area, the 25 HUC12 subwatersheds were prioritized into three **Priority tiers** in order to effectively target implementation efforts (Figure 18). The subwatersheds were ranked according to average annual sediment loading, as determined by the STEPL modeling, after FY2009-FY2020 cost-share BMPs were added to the model. All subwatersheds within the planning area were assigned to one of three priority tiers where the top eight HUC12s with the greatest estimated sediment loading were set as Priority 1 Areas and will be targeted for implementation within the first 5 years of the 2020 WMP (Table F1 of the Appendix). The three priority area tiers sets a general schedule for rotating implementation efforts around the watershed:

Priority 1 – Years 1 to 5 (Calendar years 2021–2025) - Short-term goals

Priority 2 – Years 6 to 10 (Calendar years 2026 –2030) - Mid-term goals

Priority 3 – Years 11 to 20 (Calendar years 2031–2040) - Long-term goals

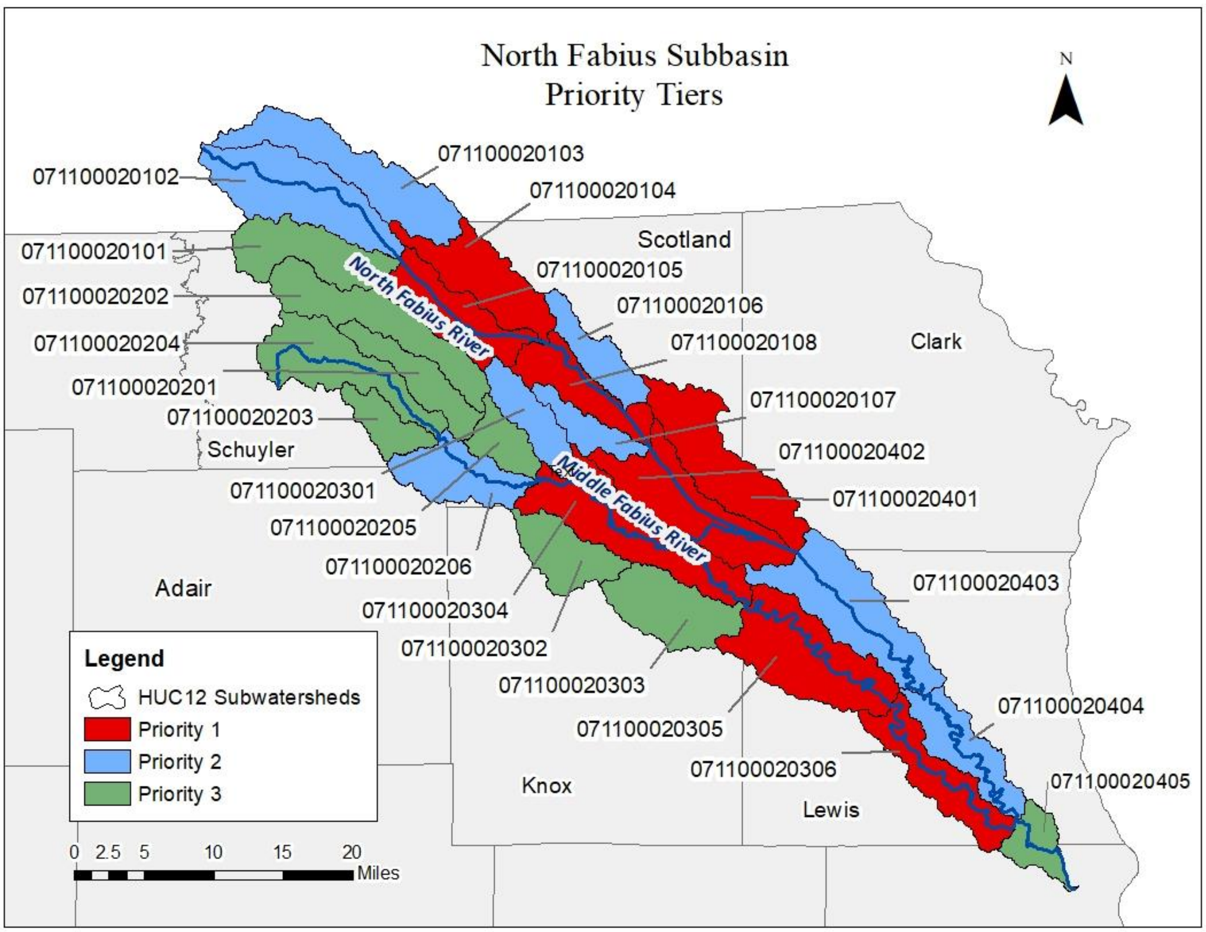

Figure 18. HUC12 subwatersheds were divided into three priority tiers based on the total annual amount of STEPL-estimated sediment loading.

Chapter 3: Element B. - Estimating Load Reductions

The load reductions needed are calculated or estimated based upon monitoring data and serve as targets intended to bring the waterbody back to meeting water quality standards. The load reductions expected are estimated with modeling or by applying known pollutant reduction efficiencies to simulate the impacts of management measures or best management practices that are scheduled and/or suggested for implementation during time period of the watershed management plan. A TMDL may address a particular pollutant of concern, but may not address all the pollutants of concern within the watershed.

Calculating Load Reductions

Sediment Load Reductions Needed

The 2006 North Fabius TMDL suggested broadly that an 87% reduction is needed in order to reduce suspended solids/sediment loading to the level the waterbody could assimilate and still meet WQS. Based on the revised TSS LDC with more current discharge and water quality data, the estimated TSS load reductions needed were assessed across the range of flow conditions and apply to the outlet of the North Fabius River (Table 17). Across the entire range of flows, the average water quality load reduction goal is calculated at 34%. However, as shown in the revised TSS LDC in Figure 7, the majority of the exceedances occur during wet and high flow conditions, which would need an average reduction of 2,608 to 34,609 tons TSS per day or a 97 - 98% reduction. At the mid-range flow, a 52% or an average of 16 tons per day TSS reduction is needed.

Table 17. Estimates of needed percent and quantity (tons/day) of TSS load reductions across the range of flows based on the target of 30 mg/l.

Flow Condition	Flow range (cfs)	Max Reduction Required (%)	Max Reduction Required (tons/day)
High Flow	1,632 - 13,013	98%	34,609
Moist Conditions	228 - 1,631	97%	2,608
Mid-range	91 - 227	52%	16
Dry Conditions	18 - 90	3%	0.05
Low Flow	3 - 17	0%	0
Avg. Reduction =		**34%**	

Nutrient Load Reductions

The Missouri Nutrient Loss Reduction Strategy aims to reduce point and nonpoint source nutrient pollution in order to improve local water quality across Missouri and the amount of nutrients transported downstream. Best management practices that are implemented to address the source of soil erosion and reduce the transport of soil and nutrients in runoff not only meets the goals of this WMP, but also addresses Missouri's 2020-2025 Nonpoint Source Management Plan[32] and Missouri's Nutrient Loss Reduction Strategy[33].

The TN LDC and TP LDC presented in Chapter 2 were used to estimate the loading reductions needed for the planning area across the range of flow conditions. Table 18 shows the maximum TN load reduction needed to meet the RTAG target of 0.9 mg/l for each flow condition, which is based on observed data. Across the entire range of flows, the average TN load reduction goal is calculated at 23%. However, as shown in the TN LDC in Figure 9, the majority of the exceedances occur during wet and high flow conditions, which would need an average reduction of 30,574 to 32,008 lbs TN per day, or a 79% - 87% reduction. At the mid-range flow, a 47% or an average TN reduction of 532 lbs per day is needed.

Table 19 shows the maximum TP load reduction needed to meet a target of 0.075 mg/l for each flow condition. Across the entire range of flows, the average TP load reduction goal is calculated at 31%. As shown in the LDC in Figure 10, the TP exceedances occur at all flow conditions. At the mid-range flow, a 67% or an average TP reduction of 108 lbs per day is needed.

Table 18. Estimates of needed percent and quantity (lbs/day) of TN load reductions across the range of flows based on the target of 0.9 mg/l.

Flow Condition	Flow range (cfs)	Max Reduction Required (%)	Max Reduction Required (lbs/day)
High Flow	1,632 - 13,013	79%	30,574
Moist Conditions	228 - 1,631	87%	32,008
Mid-range	91 - 227	47%	532
Dry Conditions	18 - 90	59%	477
Low Flow	3 - 17	18%	17
	Avg. Reduction =	**23%**	

[32] MDNR. 2020-2025 Missouri Nonpoint Source Management Plan [insert link when available]
[33] MDNR. Missouri Nutrient Reduction Strategy. https://dnr.mo.gov/env/wpp/mnrsc/index.htm

Table 19. Estimates of needed percent and quantity (lbs/day) of TP load reductions across the range of flows based on the target of 0.075 mg/l.

Flow Condition	Flow range (cfs)	Max Reduction Required (%)	Max Reduction Required (lbs/day)
High Flow	1,632 - 13,013	95%	56,733
Moist Conditions	228 - 1,631	91%	4,318
Mid-range	91 - 227	67%	108
Dry Conditions	18 - 90	76%	86
Low Flow	3 - 17	32%	1
	Avg. Reduction =	**31%**	

E. coli Load Reductions Needed

The E. coli loading target is based on Missouri's Water Quality Standards and uses the criterion of 206 bacterial counts per 100mL for the protection of Whole Body Contact -B Use. Table 20 shows the E. coli loading capacity (colonies/100 ml) calculated at the median flow of each flow condition based on a target criterion. The percent E. coli reduction needed was calculated by comparing the geometric mean of all samples observed within each flow range, as noted in Figure 13 as the Existing Load, with each loading capacity. Across the entire range of flows, the average *E. coli* load reduction goal is calculated at 35%. However, as shown in the *E. coli* LDC, exceedances of individual samples occur across all flows. The geometric mean of sample data shows that a 79% and 97% reduction is needed for the moist and high flows. Overall, more water quality monitoring is needed over time to determine water quality changes.

Table 20. *E. coli* loading reductions needed for various flow conditions and an overall average based on the WQS target of 206 colonies/100ml and the geometric mean of sample data for each condition.

Flow Condition of Existing Loading	Flow range (cfs)	Loading Capacity at median flow (colonies/100ml)	% Reduction Needed
High Flows	1,632 - 13,013	2.14E+13	97%
Moist Conditions	228 - 1,631	2.33E+12	79%
Midrange	91 - 227	7.17E+11	0%
Dry Conditions	18 - 90	2.16E+11	0%
Low Flows	3 - 17	5.68E+10	0%
		Avg. Reduction =	**35%**

Chapter 4: Element C. - Management Measures

Choosing Best Management Measures or Practices

Conservation management measures and best management practices selected for the 2020 WMP are practices commonly used in the North Fabius subbasin that landowners have historically implemented. The cost-share practices selected for the watershed plan implementation are commonly accepted by landowners; however, additional cost-share BMPs that also address the stream impairment were included in the implementation schedule and will be promoted through information/education and BMP demonstration activities. In addition to the SWCP cost-share practices listed below, any other agricultural BMP that improves water quality through addressing sediment, nutrient, and bacterial pollution are also acceptable for implementation. Agricultural practices that improve soil health, such as the use of cover crops to keep the soil covered and increase biodiversity and managed grazing practices, are especially sought after due to the benefits that healthy soils have on water quality. The Missouri Nonpoint Source Management Plan (2020-2025) lists additional conservation practices that are also eligible for implementation[32]. A list of BMPs commonly used in urban settings is included in Appendix C. The planned management measures or any other BMP that is implemented will be most effective in addressing the pollutants of concern if practices first target critical areas.

Soil and Water Conservation Program Practices

The following are the management strategies and descriptions of the SWCP cost-share BMPs that will be implemented or promoted in order to address the stream impairment and other pollutants of concern. The critical source areas that each cost-share BMPs addresses are specified on the BMP Implement Schedule in Chapter 7; the estimated annual load reductions for each practice are presented below in Table 23. See Appendix B for a more information about Missouri SWCP's cost-share practices.

Crop Management Strategies

Implementation of sediment control structures to reduce and prevent sediment runoff on cropland areas of the watershed:

> Terrace Systems (DSL- 4, DSL- 44) - Reduces the erosive force of water by decreasing slope length and placing embankments in order to slow water runoff and increase water absorption on crop land that is experiencing significant erosion.
>
> Diversion (DSL- 05) - Controls erosion and reduces or prevents pollution of land, water or air from agricultural nonpoint sources by directing rainwater to less sloping areas of the landscape and allowing it to dissipate or run off at a lower velocity, which encourages infiltration into the soil.

Permanent Vegetative Cover – Critical Area (DSL-11) - Establishes a permanent vegetative cover on small critical areas such as gullies and steep banks to reduce erosion and protect water quality.

Cover Crops (N340) - Reduces soil erosion, reduces nutrient runoff by immobilizing excess available nutrients in the soil and slowly releasing them to the crops through decay processes, and improves soil health.

Water Impoundment Reservoir (Pond) (DWC-1) - Controls erosion and protects water quality by constructing ponds that catch sediment and prevent it from leaving fields; ideal for land that is experiencing significant active erosion.

Sediment Retention Control Structure (Dry Holes) (DWP-1) - Temporarily retains water to control the release of runoff water and allows soil particles and nutrients to settle out. This practice is applicable to areas on farms where the runoff contains substantial amounts of sediment, chemicals, or nutrients that constitute a significant pollution hazard.

Sod Waterway (DWP-03) - Prevents or reduces existing erosion and land or water pollution from agricultural nonpoint sources by using sod-forming grasses to protect soil within waterways.

Nutrient/Pest Management to reduce and prevent nutrient and chemical runoff on cropland areas of the watershed:

Nutrient Management (N590) - Follows an approved nutrient management plan to improve soil fertility and crop production. Planning is based on soil or plant nutrient testing to ensure adequate fertility without excess nutrient runoff. A nutrient management plan is used to determine the correct amount and form of plant nutrients needed to achieve optimum yields and, at the same time, prevent excess nutrients from impacting waterways.

Pest Management (N595) – To minimize entry of chemical contaminants in ground and surface water a pest management plan will be developed and followed. The pest management plan will assist the operator in determining whether, when, and how an application of pesticides (herbicide, fungicide, insecticide) should occur for the crop. Planning is based on soil or plant nutrient testing to ensure adequate fertility without excess nutrient runoff.

Livestock Management Strategies

Implementation of grazing systems to properly management agriculture pastureland to prevent or reduce soil erosion and nutrient runoff:

Permanent Vegetative Cover Establishment (DSL-1) - Establishes a permanent vegetative cover to stabilize soil on land that is experiencing significant erosion.

Permanent Vegetative Cover Enhancement (DSP-02) - Applies to pastureland and hay land only where non-woody, permanent vegetative cover is in poor or very poor condition. Improves the vegetative cover on pastures by introducing legumes into the grass base using no-till technology. Improving the plant community health protects the soil by reducing erosion and prevents water pollution.

Permanent Vegetative Cover Improvement (DSL-2) - Improves plant health and diversity by introducing legumes into established grass communities to protect soil on land that is experiencing significant erosion

Grazing Systems (DSP-3) - Practices are designed to promote economically and environmentally sound agricultural land management on pastureland by demonstrating the best use of soil and water resources through the use of rotational grazing. It improves the plant community health and protects the soil by reducing erosion and prevent water pollution.

Ground Water Quality

Implementation of well decommissioning to protect ground water from NPS pollution:

Well Decommissioning (N351) **-** Abandoned wells present a direct connection to the groundwater aquifer as well as a safety hazard. Wells that are properly treated, filled and sealed eliminate the safety hazard and protect the groundwater resource from possible pollution.

Riparian Improvement and Stream Protection

Implementation of stream protection, riparian buffers and alternative water sources to reduce sediment, nutrient and bacteria loading to the stream:

Field Border (N386) - Establishes a permanent grass buffer along the edge of crop field to trap pesticide and fertilizer runoff. This practice reduces soil loss and improves water quality by preventing excess sediment and nutrients from entering streams.

Filter Strip (N393) - Establishes permanent grass filter strips below crop, hay, and grazing land. Prevents sediment, chemicals, and nutrients from entering sensitive areas or water bodies.

Riparian Forest Buffer (N391) - Protects soil and shallow groundwater from contamination by sediments, nutrients, chemicals, and organic matter and protect streambanks from erosion by planting woody species along the stream course and protecting the buffer area from trampling and grazing.

Livestock Exclusion (N472) - Installs exclusion fences around existing ponds, woodlands, sinkholes, streams, or sensitive areas where vegetation, soil condition, and water quality are in need of protection from livestock.

Stream Protection (WQ-10) - Excludes livestock from stream corridors to allow revegetation with grasses and trees on the streambank. This also provides a filter to trap sediments, chemicals, and nutrients.

Streambank Stabilization (C650) - Uses large stones, anchored cedar trees, or other designs as a mechanical protection of highly eroded streambanks. Also provides a stable area to establish grasses or other vegetation to protect the soil and water resource from additional erosion losses and contamination.

BMP Pollutant Reduction Efficiencies

Pollutant reduction efficiencies for SWCP cost-share practices were estimated using STEPL's BMP Calculator[34] by simulating as best as possible the combined effect of the various structures and practices that make up each state cost-share practice (Table 21). See Appendix E for the crosswalk from SWCP cost-share practices to STEPL BMP-combinations. Since BMP efficiencies in STEPL are based on national averages, the load reduction efficiencies for sediment, total nitrogen, and total phosphorus presented in Table 21 are general estimates. The impact of specific practices on pollutant reduction varies and actual reductions will differ based on site- and regional-specific conditions. Further, normal climate variations, such as the timing and amount of precipitation events, temperature, and wind will influence year-to-year variations in load reductions.

At this time, there are no data for estimating *E. coli* load reduction from SWCP cost-share practices. While Table 22 focuses on Atrazine reduction, the table is included to help guide practice selection for reducing runoff of various chemicals that are commonly used in agricultural production, especially from soils with high runoff potentials. BMPs that focus on erosion control and promoting water infiltration before runoff reaches a waterbody will also reduce *E. coli* loading; however, BMPs that exclude livestock from direct access to waterbodies or proper management of septic systems will greater reduce *E. coli* pollution.

[34] EPA. Spreadsheet Tool for Estimating Pollutant Loads (STEPL). Model Download and Documentation – STEPL 4.4 BMP Calculator. https://www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl#doc

Table 21. Sediment, total nitrogen (TN), and total phosphorus (TP) load reduction efficiencies (range 0-1) of Soils and Water Conservation Program (SWCP) cost-share practices as estimated by STEPL's BMP Calculator.

SWCP Cost-Share Practices	Sediment Reduction	TN Reduction	TP Reduction
Crop Management Strategies			
DSL-04 Terrace System	0.771	0.556	0.667
DSL-44 Terrace System with Tile	0.771	0.728	0.783
DSL-05 Diversion	0.42	0.495	0.48
DSL-11 Permanent Vegetative Cover - Critical Area	0.909	0.672	0.546
N340 Cover Crop	0.793	0.397	0.709
DWC-01 Water Impoundment Reservoir	0.926	0.715	0.598
DWP-01 Sediment Retention, Erosion or Water Control Structure	0.909	0.799	0.705
DWP-03 Sod Waterway	0.729	0.553	0.616
N590 Nutrient Management	0	0.247	0.56
Livestock Management Strategies			
DSL-01 Permanent Vegetative Cover Establishment	0.42	0.324	0.32
DSP-02 Permanent Vegetative Cover Enhancement	0.333	0.515	0.343
DSL-02 Permanent Vegetative Cover Improvement	0.613	0.6	0.474
DSP 3.1 Grazing System Water Development	0.951	0.831	0.689
DSP 3.2 Grazing System Water Distribution	0.794	0.591	0.524
DSP 3.3 Grazing System Fence	0.747	0.528	0.462
DSP 3.4 Grazing System Lime	0.333	0.408	0.227
DSP 3.5 Grazing System Seed	0.333	0.515	0.343
Riparian Improvement and Stream Protection			
N386 Field Border	0.729	0.553	0.616
N393 Filter Strip	0.958	0.783	0.743
N391-Riparian Forest Buffer	0.791	0.714	0.962
N472 Livestock Exclusion	0.844	0.514	0.332
WQ10 Stream Protection	0.926	0.715	0.598
C650 Streambank Stabilization	0.952	0.916	0.856

Table 22. Relative effectiveness of management practices to reduce field losses of Atrazine and reduce soil erosion from runoff water. *(Table adapted from NebGuide[35]).*

Practice	Action	In Runoff Water	With Soil Erosion
Relative impact on Reducing Atrazine Losses			
Crop rotation	Eliminates atrazine use in some years	High	Medium-High
Integrated Pest Management	Reduces atrazine use	Medium-High	Medium
Atrazine Combination	Reduces amount applied	Medium-High	Medium
Mechanical weed control	Reduces atrazine use	Medium-High	Medium
Match rates to weed pressure	Reduces total application	Medium	Medium

Estimated Pollutant Load Reductions from BMPs

Management measures and milestones for the 2020 North Fabius NPS WMP are presented in Table 28 of Chapter 7. The types and number of practices included in Table 28 are based on cost-share practices that have been historically implemented across the North Fabius subbasin and are reasonably expected to continue to be accepted by landowners. Also included in the schedule are BMPs that have not historically been implemented, such as streambank stabilization and riparian forest corridor, but are included for information/education and demonstration purposes. These practices that directly focus on improving poor riparian zones, stabilizing actively eroding streambanks, and excluding livestock from streams will largely contribute to reducing sediment loading to the North Fabius and Middle Fabius Rivers if they are adopted across the subbasin.

Estimated Sediment and Nutrient Reductions

<u>STEPL BMP Reductions</u>

After modeling load reductions from cost-share practices implemented between FY2009 and FY2020, the SWCP cost-share practices selected for the 2020 WMP were simulated in STEPL to estimate the benefits in load reductions if all practices were implemented annually (Table 23). See Appendix E for more detailed information about the STEPL model setup. Based on the average annual number of each practice that has been historically implemented and the average area addressed by each practice, annual sediment, nitrogen, and phosphorus load reductions were estimated by STEPL using the BMP efficiencies in Table 21.

[35] NebGuide. October 1996. “Agricultural Management Practices to Reduce Atrazine in Surface Water” Published by Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Also included in Table 23 are the estimated pollutant load reductions from practices not yet implemented in the subbasin: riparian forest buffers, streambank stabilizations, and field borders. The riparian forest buffer and streambank stabilization practices were especially included because stabilizing the streambanks and securing them with vegetation will likely reduce as much sediment loading, if not more, to the North and Middle Fabius Rivers than other field BMPs. Because of the beneficial impact these practices can have on reducing sediment and nutrient loading, it is recommended that riparian forest buffers, streambank stabilizations, and field borders be introduced and promoted through demonstration activities.

An analysis conducted by MDNR comparing 2012/2013 aerial imagery with 2015/2016 aerial imagery of the subbasin, as part of the STEPL modeling exercise, assessed streambanks along perennial stream segments within each HUC12 and the presence of gullies directly connected to those streambanks. This aerial assessment, which was limited in scope to areas without vegetative cover, identified approximately 373 gullies and at over 1,000 moderate, severe, or very severely eroding streambanks of various lengths and heights (Appendix E). The identified gullies and eroding streambanks occurred mainly where there was none to minimal riparian vegetation, where row crop cultivation occurred along streambank, and where livestock were directly accessing the streams.

The Field border practice was modeled as a 30-ft wide buffer surrounding a 10-acre field (500 ft by 871 ft). The Riparian forest buffer was modeled as a 100-ft wide buffer along a 500 ft streambank. The streambank was modeled with the dimensions of 500 ft long and 8 ft in height and then simulated as combinations of severe and severely eroding with either silt loam or silty clay loam soils. The load reduction values presented below are the average of the four possible erosion category-soil type combinations that describe an average eroding streambank in the subbasin.

Total estimated annual pollutant load reductions for each implementation year are presented in Table 24. Short-term (year 1-5), mid-tem (years 6-10), and long-term (years 11-20) reductions are also calculated to show total reduction for each milestone. <u>If the scheduled management measures/BMPs were implemented each year, then 3,491 tons of sediment (1% reduction), 71,663 lbs of nitrogen (1% reduction), and 19,546 lbs of phosphorus (1% reduction) are estimated to be reduced each year. After 20 years, these reductions are estimated at a 17% reduction in sediment, 19% reduction in nitrogen, and 29% reduction in phosphorus loading.</u>

The revised TSS LDC estimated an average needed sediment load reduction of 34 % (Table 17). The average needed reduction in nutrients, as estimated by nutrient LDCs, is 23% for TN and 31% for TP (Tables 18 and 19). As scheduled, the current list of BMPs is estimated to only address half the amount of sediment reduction needed. The projected reduction in nitrogen and phosphorus are close to the target reduction, however they also are estimated at less than needed. Therefore, implementation activities beyond the scheduled practices is needed. Focusing additional implementation efforts on Critical Areas 1 (Figure 17) with practices that improve riparian vegetation and repair degraded streambanks will contribute greatly to the needed reductions in sediment and nutrient loading, especially since the greatest load reductions needed are during wet and high flow conditions.

Table 23. STEPL-estimated sediment, total nitrogen (TN), and total phosphorus (TP) annual load reductions from SWCP cost-share practices scheduled for implementation or suggested for demonstration.

Practice	**Acres per Practice** (historic avg.)	**# Practices Modeled*** (historic avg/yr)	**Sediment Reduced** tons/yr	**TN Reduced** lbs/yr	**TP Reduced** lbs/yr	**Sediment Reduced** %	**TN Reduced** %	**TP Reduced** %
Nutrient Management (N590)	177	1	-	553	289	-	0.01	0.03
Terrace Systems (DSL-44)	25	20	263	6718	1622	0.16	0.11	0.15
Diversions (DSL-5)	17	2	11	330	74	0.01	0.01	0.01
Water Impoundment Reservoir (Pond) (DWC-1)	20	20	49	2495	219	0.03	0.04	0.02
Sediment Retention Control Structure (Dry Holes) (DWP-1)	21	9	119	2899	611	0.07	0.05	0.06
Permanent Vegetative Cover – Critical Area (DSL-11)	1	1	1	13	3	<0.001	<0.001	<0.001
Sod Waterways (DWP-3)	79	1	38	842	207	0.02	0.01	0.02
Filter Strips (N393)	23	1	13	291	64	0.01	0.00	0.01
Field Border (N386)***	1.9	1	0.1	2.1	0.5	<0.001	<0.001	<0.001
Cover Crops (N340)	170	30	2,768	47,398	15,600	1.65	0.79	1.42
Permanent Vegetative Cover Establishment (DSL-1)	39	5	11	532	52	0.01	0.01	0.005
Permanent Vegetative Cover Enhancement (DSP-02)	74	1	3	293	19	0.002	0.005	0.002
Permanent Vegetative Cover Improvement (DSL-2)	80	20	135	8348	667	0.08	0.14	0.06
Grazing Systems (DSP-3.1)*	42	1	6	335	28	0.004	0.006	0.003
Grazing Systems (DSP-3.2)*	49	1	5	244	22	0.003	0.004	0.002
Grazing Systems (DSP-3.3)*	93	1	9	440	40	0.01	0.01	0.004
Grazing Systems (DSP-3.4)*	159	1	7	554	33	0.004	0.01	0.003

Avg. Grazing system (DSP-3)**			7	393	31	0.004	0.01	0.003
Practice	**Acres per Practice** historic avg.	**# Practices Modeled*** historic avg/yr	**Sediment Reduced** tons/yr	**TN Reduced** lbs/yr	**TP Reduced** lbs/yr	**Sediment Reduced** %	**TN Reduced** %	**TP Reduced** %
Livestock Exclusion (N472)	8	3	3	110	9	0.002	0.002	0.001
Riparian Forest Buffer (N391)***	1.2	1	1	16	3	<0.001	<0.001	<0.001
Stream Protection (WQ-10)	10	1	3	147	13	0.002	0.002	0.001
Streambank Stabilization (650)***	-	1	67	283	64	-	-	-

* Number of practices not based on historic average; simulated as 1 per year with avg. acres based on historical average

**Only values from Avg. Grazing System are included in Annual totals in Table 23.

***Since practices are not historically used, modeled as 1 per year each with avg. acres based on avg. 500 ft length of impaired streambanks (Riparian Buffer, Streambank Stabilization) or 10-acre field (Field Border)

Table 24. Total estimated sediment, total nitrogen (TN), and total phosphorus (TP) load reduction for annual, short-tem (Yrs. 1-5), mid-term (Yrs. 6-10), and long-term (Yrs. 11-20) implementation goals.

Total estimated annual load reduction if all practiced were implemented:	Sediment Reduced (tons)	TN Reduced (lbs)	TP Reduced (lbs)	% Sediment Reduced	% TN Reduced	% TP Reduced
Annual	3,491	71,663	19,546	1	1	1
Yrs. 1-5	17,454	358,317	97,731	4	5	7
Yrs. 6-10	17454	358,317	97,731	4	5	7
Yrs. 11-20	34,907	716,634	195,462	9	10	15
Total for 20-yr Plan	69,815	1,433,268	390,925	17	19	29

SWAT BMP Scenarios

The SWAT modeling conducted for a portion of the North Fabius River watershed simulated the best-case scenario in which various BMPs were placed throughout the watershed by targeting catchments with greater sediment loading (e.g. target dry-holes) or to the maximum extent possible (e.g. vegetated buffer strips). The SWAT model did not include actively eroding streambanks as a source of sediment loading; therefore, the HUC12s identified by the model as contributing the greatest sediment loading differ from the Priority Area 1 HUCs identified by the STEPL modeling. SWAT model results presented here are intended to provide greater insight to the benefit of implementing BMPs across the planning area. While this model focused solely on the North Fabius watershed, it is assumed that the reduction impacts from the simulated BMPs would be similar for the Middle Fabius watershed since the two watersheds' land use coverage are similar. Best management practices simulated in the SWAT model include vegetated buffer strips, terracing, targeted and untargeted dry-holes, and re-vegetation practices. The process and decision making behind choosing where to model BMPs across the watershed are described in detail in Appendix G. Starting with the SWAT-estimated baseline average annual loading of 8.15 tons of sediment per acre (20.145 tons/hectare) at USGS Gauge 05497150, each BMP scenario was simulated separately and then altogether to generate a combined load reduction. A summary of estimated sediment reductions from each BMP simulated in the SWAT modeling exercise are provide below in Table 25.

Vegetated buffers -

While the North Fabius River appeared to generally be well buffered, the vegetated buffer scenario looked at a best-case scenario by buffering the portion of the watershed in Missouri where there were no buffers or where the ratio of the filter strip and the field that is being buffered was less than 40. The vegetated buffers scenario resulted in an average annual watershed sediment loading of 7.8 tons per acre (19.281 tons/hectare). This is a reduction of 4.3 % from the baseline sediment loading (Figures G19 and G20 of the Appendix).

Dry Hole installations were modeled as two different scenarios: **random and targeted placement**.

- In the first scenario, the **random dry-hole placement** of an equal sized dry hole into every subbasin located in Missouri was modeled. It was determined by local experts that it was reasonable to increase the dry holes by around 50%. Using local average drainage areas for dry holes and estimates on drainage acres served by dry holes that were paid for with cost-share between 2009 and 2017, it was determined that there were 37.5 dry hole acres to be added. Equally adding these dry holes to the 234 Missouri catchments (excluding catchments in Iowa) resulted in an addition of 0.16 surface acres of dry holes and 4.8 acres draining into dry holes in every catchment. <u>The random dry hole placement scenario resulted in an average annual watershed sediment loading of 8.13 tons per acre (20.1 tons/hectare). This is a reduction of 0.4%</u>.

- In the second dry hole scenario referred to as **targeted dry-hole placement**, the dry holes were placed only in catchments that were shown to contribute the greatest rates of sediment according to the Jenks natural breaks method. The 37.5 dry hole acres were divided amongst nineteen catchments by area weighting the catchments. <u>The targeted placement of dry holes resulted in an average annual watershed sediment loading of 8.08 tons per acre (19.972 tons/hectare). This is a reduction of 0.9%.</u> Thus, by targeting dry hole placement more specifically using the model results to identify the catchments with the greatest sediment loading, the sediment reduction is more than twice as great compared to randomly assigning dry holes everywhere.

Terraces –

During the terrace scenario, the baseline model used aerial satellite imagery to estimate a total of about 20,761 acres of terraced land found within the modeled portion of the North Fabius watershed. It was recommended by local experts that it would be reasonable to increase this acreage by about 2/3 in the future. Thus, the terrace scenario simulated an additional 13,691 acres of terraced land, which was targeted by selecting the catchments with the highest sediment loading concentration and then by choosing the agricultural HRUs with a slope greater than or equal to 3%. When it was found that there were not sufficient acres within these HRUs for the nineteen highest contributing catchments, additional HRUs were selected from the next highest contributing catchment. This process was repeated until sufficient acreage had been selected. <u>The terrace scenario resulted in an average annual watershed sediment loading of 7.08 tons per acre (17.485 tons/hectare). This is a reduction of 13.2% at the watershed scale.</u>

Improved grazing –

In **the improved grazing scenario,** the model was adjusted to reflect a 10% increase in the practice of inter-seeding legumes into pasture and a 5% increase in management intensive grazing. This scenario makes the assumption that these grazing changes would also be adopted by neighboring farmers in Iowa. Because there is not spatial information to place the management intensive grazing practices, the increase in management intensive grazing causes a slight increase in stocking rates across the entire watershed. <u>The improved</u>

grazing scenario resulted in an average annual watershed sediment loading of 8.22 tons per acre (20.308 tons/hectare). This is actually an increase of 0.8% at the watershed scale.

Combined BMPs –

The combined BMP scenario simulated the inputs from the vegetated buffer, targeted dry hole, increased terracing, and improved grazing scenarios in order to represent a best-case scenario for the watershed and better understand how these management decisions impact each other. The combined BMP scenario resulted in an average annual watershed sediment loading of 6.83 tons per acre (16.874 tons/hectare). This is a reduction of 16.2% at the watershed scale. This reduction is mostly explained by the vegetated buffer and terracing scenarios, which provide the largest reductions of the BMP scenarios.

Table 25. SWAT-estimated sediment reduction (%) from best management practices simulated at the watershed scale for the North Fabius watershed.

SWAT model of North Fabius Watershed	
Practice	**Sediment Reduction**
Vegetated buffer	4.30%
Dry-holes:	
random placement	0.40%
targeted placement	0.90%
Terracing	13.20%
Improved grazing	0.80%
Combined BMPs	16.20%

Chapter 5: Element D. - Technical & Financial Assistance

The implementation of the watershed plan will depend on the availability of the technical and financial assistance that is needed to apply the conservation measures. The use of federal, state, local, and private funds or resources from other conservation partners will be utilized when available. Technical assistance for agriculture BMP installation can be provided by agencies and organizations such as NRCS, MDNR, SWCD, University of Missouri Extension, or MDC.

Cost estimates of financial needed to support BMP implementation are presented in Table 26. Cost estimates for each cost-share practice were determined using the average cost of conservation practices implemented in the North Fabius watershed from July 2009 to June 2020. The cost of the conservation measures will be borne by the private property owner and cost-shared or grant funding assistance programs when available. Potential funding sources include Section 319-Grants, 604(b) Water Quality Planning Grants, Soil and Water Conservation Cost Share Program, Conservation Reserve Program (CRP), Conservation Easement Program (NRCS), Environmental Quality Incentives Program (EQIP), and Conservation Stewardship Program.

Table 26. Cost estimates needed to support implementation of best management practices.

BMP Type	Unit Per Year	Technical Assistance Services	Estimated Cost Per Year	Total Cost (0-5 Years)	Total Cost (6-10 Years)	Total Cost (11-20 Years)
Cropland Management						
Terrace System	20 systems	One-on-one assistance with producers	$450,000	$2,250,000	$2,250,000	$4,500,000
Water Impoundment Reservoir	20 structures		$450,000	$2,250,000	$2,250,000	$4,500,000
Sediment Retention Control Structure	9 structures		$160,000	$800,000	$800,000	$1,600,000
Diversions	2 practices	Conservation plans development	$6,256	$31,280	$31,280	$62,560
Sod Waterways	1 practice	Technical design, installation	$4,583	$22,915	$22,915	$45,830
Nutrient Management	1 practice	Technical design, installation and checkout	$1,908	$9,540	$9,540	$19,080
Permanent Vegetative Cover Critical Area	1 practice		$322	$1,610	$1,610	$3,220

BMP Type	Unit Per Year	Technical Assistance Services	Estimated Cost Per Year	Total Cost (0-5 Years)	Total Cost (6-10 Years)	Total Cost (11-20 Years)
Cover Crops	30 practices	Technical design, installation and checkout	$45,900	$229,500	$229,500	$459,000
Field Border	1 practice		$5,616	$28,080	$28,080	$56,160
Filter Strips	3 practices		$28,733	$143,665	$143,665	$287,330
Pest Management	4 practices		$6,677	$33,385	$33,385	$66,770
Livestock Management						
Permanent Vegetative Cover Establishment	5 practices	One-on-one assistance for livestock producers	$75,000	$375,000	$375,000	$750,000
Permanent Vegetative Cover Enhancement	1 practice	Technical assistance and checkout	$3,461	$17,305	$17,305	$34,610
Permanent Vegetative Cover Improvement	10 practices	Conservation and nutrient management planning	$150,000	$750,000	$750,000	$1,500,000
Grazing Systems	1 system		$30,000	$150,000	$150,000	$300,000
Ground Water Quality						
Well Decommissioning	7 practices	Technical design and Installation of practice	$3,200	$16,000	$16,000	$32,000
Riparian Improvement and Stream Protection						
Livestock Exclusion	3 practices	Technical Design and Installation of practice	$12,000	$60,000	$60,000	$120,000
Stream Protection	1 practice	One -on-one assistance with producer	$10,000	$50,000	$50,000	$100,000

Chapter 6: Element E. - Public Information & Education

A public information/education program will be implemented that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

The SWCD boards in the watershed will have the opportunity to give input on updates and serve as an ongoing steering committee. Demonstrations of BMPs will be combined with other related events, such as a management intensive grazing school. Besides grazing school, educational workshops will include Private Pesticide Applicator Training (PPAT) and Soil Health education. Newsletters through the SWCDs will promote water quality.

Education programs that focus on informing and educating the general public about water quality issues in the watershed will be implemented (Table 27). Programs will inform about practical and affordable conservation practices that landowners can adopt to reduce nonpoint source pollution. Information will be distributed to the general public in the form of brochures, public service announcements, and newsletters. In addition, workshops, tours, and field days will be organized to increase public perception on utilizing conservation practices for reducing sediment and nutrient runoff and improving water quality.

Due to high sediment loading from erodible streambanks, streambank stabilization and riparian forest buffers will be encouraged as demonstration projects to increase agriculture landowner’s education and awareness of these practices and their benefits with improving water quality.

All programs conducting information and education activities will include an evaluation component to identify participant behavior changes or other outcomes that are expected to result from the activity.

Specific evaluation tools or methods may include (but are not limited to):

- Feedback forms allowing participants to provide rankings of the content, presenters, and usefulness of information, etc.

- Pre- and post- surveys to determine the amount of knowledge gained, anticipated behavioral changes, need for further learning, etc.

- Follow-up interviews (one-on-one contacts, phone calls, e-mails) with selected participants to gather more in-depth input regarding the effectiveness of the activity.

- Written evaluation of information and education activity to summarize how successful the activities were in achieving the learning objectives, and how the activities contributed to achieving the long-term watershed goals and/or objectives for pollution reduction.

Activities	Schedule	Technical Assistance	Completion Date	Estimated Cost
SWCDs Newsletter	Annually	Watershed Counties SWCD Boards	Ongoing	No cost
News Release or Public Announcements	Annually	Watershed Counties SWCD Boards	Ongoing	Staff Assistance
Educational Workshops, field days, conservation tour and Grazing School	Annually	MU Extension NRCS	2020-2023	$350.00 per event
BMP Demonstrations (streambank stabilization and riparian forest buffers)	Minimum one per year	NRCS, SWCDs, MU Extension	Ongoing	Based on Cost/share Program State average cost
Individual Contacts	Weekly	NRCS, SWCDs, MU Extension	Ongoing	No cost
Website updates, social media updates (Facebook, Twitter, etc.)	As needed	SWCDs	Ongoing	Staff assistance
Education Material (brochure, factsheets, flyers, signage)	As needed	SWCDs, NRCS	Ongoing	SWCD's staff and partner agencies volunteer assistance
Public Group meetings • Stakeholders • Committees • Key partners • Board Meetings	Quarterly or twice yearly	SWCDs, NRCS, Partners, Stakeholders	Ongoing	No cost, virtual meeting or partner donated facility
Develop and/or Support local Missouri Stream Team activities and Youth Day events	Yearly	SWCDs, Partners, Stakeholders	Ongoing	Volunteer

Table 27. Implementation Schedule for Information and Education Activities

Chapter 7: Element F. - Schedule

A successful watershed management plan requires participation from the people who live, work, and play in the watershed. The nonpoint source pollutants of concern that exist in the subbasin are primarily ones that can be significantly improved or eliminated through implementation of BMPs. Emphasis should also be given to preventing future problems through information and educational activities (Table 27).

A 20-year BMP implementation schedule has been developed, though it is anticipated that through the plan implementation period changes to this schedule may be made. These changes may be based on watershed needs, effectiveness of the BMPs, monitoring results, and changes in funding sources. Time frame for implementation is estimated and estimated completion dates may be moved up or back as indicated by stakeholder commitment and funding (Table 28). Projections are based on landowner and producer input, as well as, the previous 11 years of actual BMP implementation.

Conservation practices like field borders, riparian forest buffers, and streambank stabilization, although not historically implemented in this subbasin, are highly recommended for this watershed plan. Implementing beyond the extent that is scheduled will be needed to help achieve the load reduction goals of the plan. By implementing these types of practices, sediment loading from streambank erosion will be addressed and pollutants in runoff will be intercepted by riparian vegetation, greatly reducing the amount entering the stream.

Table 28. Best Management Practice Implementation Schedule (2021 – 2040).

Management Strategies	Management Measures (milestones)	Milestone Quantity (per year)	20 Year Timeframe: FY2021-FY2040	Technical Assistance	Load Reduction (lbs/yr)*	Critical Source Areas**
Crop Management Strategies: ***Nutrient/Pest Management***	Pest Management (N595)	4 plans	80 plans	NRCS, SWCD, Private Landowners		Critical Area 2, 3, 4
	Nutrient Management (N590)	1 plan	20 plans	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2, 3, 4
Runoff and Sediment Control Structures	Terrace Systems (DSL-44)	20 systems	400 systems	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2,3

	Diversions (DSL-5)	2 practices	40 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2,3
	Water Impoundment Reservoir (Pond) (DWC-1)	20 structures	400 structures	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2,3
	Sediment Retention Control Structure (Dry Holes) (DWP-1)	9 structures	180 structures	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2, 3
	Permanent Vegetative Cover - Critical Area (DSL -11)	1 practice	20 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2, 3
	Sod Waterways (DWP-3)	1 practice	20 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2,3
	Filter Strips (N393)	1 practice	20 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2,3
	Field Border (N386)	1 practice	20 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2,3
	Cover Crops (N340)	30 practice	600 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP	Critical Area 2,3
Livestock Management Strategies:	Permanent Vegetative Cover Establishment (DSL-1)	5 practices	100 practices	NRCS, SWCD, University, Private Landowners	Sediment, TN, TP	Critical Area 1, 2, 3

Implementation of Grazing Systems	Permanent Vegetative Cover Enhancement (DSP-2)	1 practice	20 practices	NRCS, SWCD, University, Private Landowners	Sediment, TN, TP	Critical Area 1, 2, 3
	Permanent Vegetative Cover Improvement (DSL-2)	10 practices	200 practices	NRCS, SWCD, University, Private Landowners	Sediment, TN, TP	Critical Area 1, 2, 3
	Grazing Systems (DSP-3)	1 system	20 systems	NRCS, SWCD, University, Private Landowners	Sediment, TN, TP	Critical Area 1, 2, 3
Ground Water Quality: ***Implementation of Well Decommissioning***	Well Decommissioning (N351)	7 practices	140 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP, *E.coli*	Critical Area 2,3
Riparian Improvement and Stream Protection:	Livestock Exclusion (N472)	3 practices	60 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP, *E.coli*	Critical Area 1, 2, 3
Stream Protection, Riparian Buffers and Alternative Water Sources	Stream Protection (WQ-10)	1 practice	20 practices	NRCS, SWCD, Private Landowners	Sediment, TN, TP, *E.coli*	Critical Area 1, 2, 3

*Annual sediment, TN, and TP load reductions for each practice are reported in Table 20.
*Critical Area described in more detail in Chapter 2:
Critical Area 1 - Riparian corridors with buffer areas less than 100 ft. width
Critical Area 2 - Agricultural lands with slopes at 3% or greater and hydrologic soil groups D and C/D
Critical Area 3 - Agricultural lands with slopes at 3% or greater not included in Critical Areas 2
Critical Area 4 - Nutrient and chemical pesticide management for all agricultural lands

Chapter 8: Element G. – Milestones

Short-, mid-, and long-term goals for watershed management will be contingent on available funding and personnel. Cost-share programs, such as those provided through the Soil and Water Districts, and grants provided through MDNR programs will be vital in achieving these goals.

The long-term goal of restoring water quality will be done through implementing BMPs, which will also be implementing a Total Maximum Daily Load or removing streams from Missouri's Section 303(d) list. The 2020 WMP's overall water quality goal is a 34% sediment reduction to address the stream impairment and a 23% reduction in TN, 31% reduction in TP, and a 35% reduction for E. *coli* in order to prevent future water quality issues. However, more specific goals and objectives have been developed in order to ensure success in meeting the overreaching goals stated above along with achieving nutrient and E. *coli* pollutant reductions. Estimated pollutant load reduction efficiencies by BMPs are indicated in Tables 21 and 22 of Chapter 4. As it stands, and without considering the additional impact from information/education programs and demonstration activities, the BMP implementation plan is estimated to achieve a 17% sediment, 19% TN. and 29% TP reduction after 20 years. These goals and objectives are shown for the total 20-years watershed plan implementation period as follows:

<u>Goal I:</u> Implement an Information/Education and Outreach Program targeting North Fabius watershed stakeholders to inform and educate about conservation measures that improve water quality.

A. ***Objective 1:*** Create public awareness and involvement in water quality issues.

Milestones:

- Conduct targeted mailings/emails to stakeholders informing them of meetings and workshops.
- Develop and distribute press releases/public service announcements to inform public about upcoming project events and status of watershed plan implementation.
- Develop and publish news articles and feature stories about the water quality and conservation project quarterly.
- Maintain and update SWCD's website with project and BMP information.
- Develop and publish quarterly newsletters.

B. ***Objective 2*:** Provide information about water quality issues and how all community sectors, partners, and stakeholders affect water quality within the watershed.

Milestones:

- Hold field days, demonstrations, and/or grazing school to promote best management practices, like soil sampling, terraces, dry holes, cover crops, nutrient management, rotation

grazing system, streambank stabilization, well decommissioning, and riparian forest buffers.
- Educate livestock producers on pasture management and improved grazing systems through development and distribution of quarterly newsletters.
- Develop curriculum/agenda and presentations for riparian corridor stream dynamics workshops.
- Design and install informational and demonstration signs for BMP demonstration sites.
- Educate the local youth, including future farmers, about available methods of water quality area protection; provide local youth with the opportunity to learn about and implement their own BMP projects through education events like Earth Day and stream cleanups.
- Use social media (Facebook, Twitter, etc.) to announce conservation events, public meetings, and conservation practice information.

C. ***Objective 3*:** Promote relationships and networks among local leaders, agricultural producers, landowners, and residents to promote watershed management programs targeting the following concerns: 1) Erosion and sedimentation, 2) Nutrient and chemical runoff, 3) Loss of fish and wildlife resources, and 4) Maintenance of water quality for recreational use.

Milestones:
- Hold quarterly Project Meetings with key Partners (SWCD, NRCS, etc.).
- Provide news article for partner agencies and organization newsletter webpages.
- Promote the watershed plan implementation at partner agency organizations meetings.
- Participate in conservation events with partners to promote conservation practices.
- Develop a Watershed Committee to oversee implementation and updates of the watershed plan.
- Work with local conservation agencies and organizations to seek funding opportunities through State and Federal grants, cost-share and loan programs.

<u>Goal II</u>*:* Use BMP Implementation to address the stream impairments and improve water quality to TMDL limits or Water Quality Standards.

D. ***Objective 4***: Target practices to geographical areas that will be most effective in improving water quality by reducing soil erosion and nutrient and sediment runoff, as reflected through pollutant load reductions.

1. Crop Management Strategies 1: Implementation of terraces or other sediment control structures to reduce and prevent sediment runoff from agricultural lands.

Milestones
- Install 20 terrace systems.
- Increase the use of cover crop practices by installing 360 practices.
- Construct 40 diversion practices.
- Establish 20 permanent vegetative cover (critical areas) practices.
- Install 400 water impoundment reservoirs (ponds).
- Construct 180 sediment retention control structures (dry holes).
- Install 20 sod waterway practices.
- Establish 20 permanent grass field borders along the edges of crop fields.

- Establish 20 permanent filter strip practices to prevent pollutants from entering sensitive areas or stream.

2. **Crop Management Strategies 2:** Implement Nutrient/Pest Management to reduce and prevent nutrient and chemical runoff from agricultural lands.
   Milestones:
   - Develop and implement 20 nutrient management plans.
   - Promote the use of pest management by implementing 80 pest management plans.

3. **Livestock Management Strategies:** Implementation of Grazing Systems to properly manage agriculture pastureland to reduce and prevent soil erosion and nutrient runoff.
   Milestones:
   - Establish 100 permanent vegetative cover establishment practices.
   - Establish 20 permanent vegetative cover enhancement practices.
   - Establish 200 permanent vegetative cover improvement practices.
   - Install 20 grazing systems practices.

4. **Ground Water Quality Strategies:** Implementation of Well Decommissioning to protect ground water from NPS pollution.
   Milestones
   - Implement 140 abandon well decommissioning practices.

5. **Riparian Improvement and Stream Protection:** Implementation of Stream Protection, Riparian Buffers, and Alternative Water Sources to reduce sediment, nutrient and bacteria loading to the stream.
   Milestones
   - Implement 60 livestock exclusion practices to protect stream water quality.
   - Install 20 stream protection practices to exclude livestock from stream riparian corridor.

Goal III: Conduct Yearly Monitoring and Modeling in the North Fabius Watershed to track water quality improvement over time.

E. ***Objective 5***: Evaluate past and present conservation practices to determine effectiveness after BMP implementation and track water quality changes.

Milestones:
- Work with MDNR to continue the current monitoring program in watershed.
- Support Missouri Stream Team monitoring and participate in stream clean-up activities.
- Use current monitoring data to inform the watershed stakeholders of improvement in stream water quality through yearly progress reports.
- Calculate pollutant load reductions due to BMP implementation using a simple model like RUSLE, STEPL, and load duration curves.

Chapter 9: Element H. - Performance

Progress in achieving the goals and objectives of this plan will be evaluated based on BMP implementation, load reductions, and monitoring improvement in water quality conditions. Improvement in water quality conditions will be determined by reduction of pollutant concentrations in the water bodies such that progress in attaining water quality goals can be documented.

In order to understand the impact of agricultural runoff on rural streams, water quality analyses must be conducted over time. Stream monitoring and watershed modeling will be used to evaluate the effectiveness of the management measures or BMP installed.

The number of BMPs implemented throughout the watershed will be used to evaluate the success of the plan. Load reductions will be calculated and visual assessments taken. Input will be gathered from participants at field days, demonstrations, or grazing schools.

Evaluation criteria used will include:

- ✓ Number of BMPs installed in critical areas.
- ✓ Tons/year of sediment load reduction assessed through modeling.
- ✓ Lbs/year of nitrogen load reduction assessed through modeling.
- ✓ Lbs/year of phosphorus load reduction assessed through modeling.
- ✓ E. coli load reduction assessed through modeling.
- ✓ Number of acres impacted calculated.

Chapter 10: Element I. - Monitoring

Water quality monitoring on North Fabius will continue as funding is available, in order to evaluate the changes over time throughout the watershed plan implementation period. Milestones for water quality changes (improvement) will be determined through the local and state's water quality monitoring programs. Water quality sampling parameters will include air and water temperature, DO, pH, nitrate levels, turbidity, TSS, macro-invertebrate count, and bacteria. Long-term monitoring of BMP effectiveness will be done based on water quality data collected by partners, including Missouri Department of Natural Resources and United States Geological Survey (Figure 19). See Appendix H for Missouri's Water Quality Monitoring strategy.

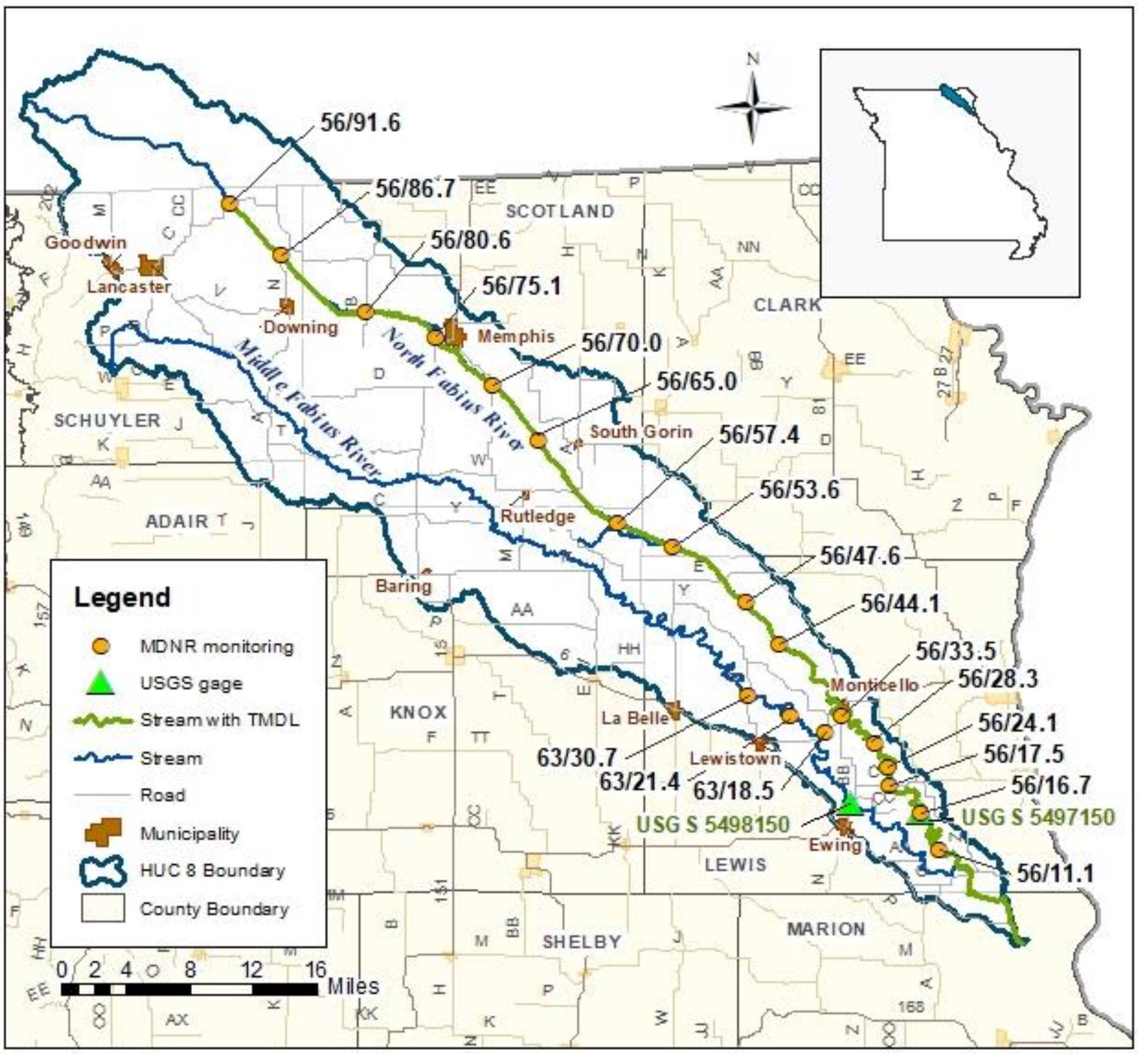

Figure 19. Water quality and stream discharge monitoring sites along the North Fabius River (WBID 56) and Middle Fabius River (WBID 63).

Within 5 years of the beginning of implementation of the North and Middle Fabius Nonpoint Source Watershed Management Plan, partners and stakeholders will evaluate the progress made towards achievement of the BMP implementation schedule and water quality goals**.** If water quality goals are not on pace to be met within the first 5 year period, partners will discuss the feasibility of increasing the number of BMPs installed. If modeling and/or monitoring indicates that water quality goals will most likely not be met through increased implementation, water quality partners will discuss revising strategies towards achieving the plan's goals. Schuyler County SWCD will have primary responsibility for the updating process, including contact with all major stakeholders, and gathering data and input.

Appendix A – Nine Elements of a Watershed-based Plan

Minimum Elements of a Watershed-based Plan

Although many different elements may be included in a watershed plan, EPA has identified nine minimum elements that are critical for achieving improvements in water quality. In general, EPA requires that nine-element watershed-based plans (WBPs), also referred to as a watershed management plan (WMP), be developed prior to implementing project(s) funded with 319 watershed project funding. In many cases, state and local groups have already developed watershed plans and strategies for their rivers, lakes, streams, wetlands, estuaries, and coastal waters that address some or all of the nine elements. EPA encourages states to use these plans and strategies, where appropriate, as building blocks for developing and implementing WBPs. If these existing plans contain all nine elements listed below, they can be used to fulfill the WBP requirement for watershed projects. If the existing plans do not address all nine elements or do not include the entire watershed planning area, they can still provide valuable components to inform, develop, and update WBPs.

For example, some watershed management plans contain information on hydrology, topography, soils, climate, land uses, water quality problems, and management practices needed to address water quality problems but lack the quantitative analysis of current pollutant loads or expected load reductions from proposed management practices. In this case, the WBP developer could incorporate such existing information into the plan to help fulfill the nine WBP elements. If separate documents contain information that help meet the nine WBP elements listed below but are too lengthy to be included in the WBP, they can be summarized and referenced in the appropriate sections of the plan, as long as the information is readily available.

Nine Elements of Watershed-based Plans (WBPs)
The nine elements, as well as short explanations of how each element fits in the context of the broader WBP, are provided below. Although they are listed as *A* through *I*, they do not necessarily take place sequentially. For example, element *D* asks for a description of the technical and financial assistance that will be needed to implement the WBP, but this can be done only after you have addressed elements *E* and *I*.

The level of detail needed to address the nine elements of WBPs will vary in proportion to the homogeneity or similarity of land use types and variety and complexity of pollution sources. For example, densely developed urban and suburban watersheds often have multiples sources of pollution from historic and current activities (Superfund sites, point sources, solid waste disposal, leakage from road salt storage, oil handling, stormwater-caused erosion, road maintenance, etc.) in addition to some agricultural activities. Plans will be more complex than in predominantly rural settings in these cases. For this reason, plans for urban and suburban watersheds may need to be developed and implemented at a smaller scale than watersheds with agricultural lands of a similar character.

Element A. **Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).**

What does this mean?
Your WBP source assessment should encompass the watershed of the impaired waterbody(ies) throughout the watershed, and include map(s) of the watershed that locates the major cause(s) and source(s) of impairment in the planning area. To address these impairments, you will set goals to meet (or exceed) the appropriate water quality standards for pollutant(s) that threaten or impair the physical, chemical, or biological integrity of the watershed covered in the plan.

This element will usually include an accounting of the significant point and nonpoint sources in addition to the natural background levels that make up the pollutant loads causing problems in the watershed. If a TMDL or TMDLs exist for the waters under consideration, this element may be adequately addressed in those documents. If not, you will need to conduct a similar analysis (which may involve mapping, modeling, monitoring, and field assessments) to make the link between the sources of pollution and the extent to which they cause the water to exceed relevant water quality standards.

Element B. **An estimate of the load reductions expected from management measures.**

What does this mean?
On the basis of the existing source loads estimated for element *A*, you will similarly determine the reductions needed to meet water quality standards. After identifying the various management measures that will help to reduce the pollutant loads (see element *C* below), you will estimate the load reductions expected as a result of implementing these management measures, recognizing the difficulty in precisely predicting the performance of management measures over time.

Estimates should be provided at the same level as that required in the scale and scope described in element *A* (e.g., the total load reduction expected for dairy cattle feedlots, row crops, eroded streambanks, or implementation of a specific stormwater management practice). For waters for which TMDLs have been approved or are being developed, the plan should identify and incorporate the TMDLs; the plan needs to be designed to achieve the applicable load reductions in the TMDLs. Applicable loads for downstream waters should be included so that water delivered to a downstream or adjacent segment does not exceed the water quality standards for the pollutant of concern at the water segment boundary. The estimate should account for reductions in pollutant loads from point and nonpoint sources identified in the TMDL as necessary to attain the applicable water quality standards.

***Element C.* A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in element *B* and a description of the critical areas in which those measures will be needed to implement this plan.**

What does this mean?
The plan should describe the management measures that need to be implemented to achieve the load reductions estimated under element *B*, as well as to achieve any additional pollution prevention goals outlined in the watershed plan (e.g., habitat conservation and protection). Pollutant loads will vary even within land use types, so the plan should also identify the critical areas in which those measures will be needed to implement the plan. This description should be detailed enough to guide needed implementation activities throughout the watershed and can be greatly enhanced by developing an accompanying map with priority areas and practices. Thought should also be given to the possible use of measures that protect important habitats (e.g. wetlands, vegetated buffers, and forest corridors) and other non-polluting areas of the watershed. In this way, waterbodies would not continue to degrade in some areas of the watershed while other parts are being restored.

***Element D.* Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.**

What does this mean?
You should estimate the financial and technical assistance needed to implement the entire plan. This includes implementation and long-term operation and maintenance of management measures, information/education (I/E) activities, monitoring, and evaluation activities. You should also document which relevant authorities might play a role in implementing the plan. Plan sponsors should consider the use of federal, state, local, and private funds or resources that might be available to assist in implementing the plan. Shortfalls between needs and available resources should be identified and addressed in the plan.

***Element E.* An information and education component used to enhance public understanding of the plan and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.**

What does this mean?
The plan should include an I/E component that identifies the education and outreach activities or actions that will be used to implement the plan. These I/E activities may support the adoption and long-term operation and maintenance of management practices and support stakeholder involvement efforts.

***Element F.* Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.**

What does this mean?
You should include a schedule for implementing the management measures outlined in your watershed plan. The schedule should reflect the milestones you develop in *G* and you should

begin implementation as soon as possible. Conducting baseline monitoring and outreach for implementing water quality projects are examples of activities that can start right away. It is important that schedules not be "shelved" for lack of funds or program authorities; instead they should identify steps towards obtaining needed funds as feasible.

***Element G.* A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.**

What does this mean?
The WBP should include interim, measurable implementation milestones to measure progress in implementing the management measures. These milestones will be used to track implementation of the management measures, such as whether they are being implemented according to the schedule outlined in element *F*, whereas element *H* (see below) will develop criteria to measure the effectiveness of the management measures by, for example, documenting improvements in water quality. For example, a watershed plan may include milestones for a problem pesticide found at high levels in a stream. An initial milestone may be a 30% reduction in measured stream concentrations of that pesticide after 5 years and 50% of the users in the watershed have implemented Integrated Pest Management (IPM). The next milestone could be a 40% reduction after 7 years, when 80% of pesticide users are using IPM. The final goal, which achieves the water quality standard for that stream, may require a 50% reduction in 10 years. Having these waypoints lets the watershed managers know if they are on track to meet their goals, or if they need to re-evaluate treatment levels or timelines.

***Element H.* A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.**

What does this mean?
As projects are implemented in the watershed, you will need water quality benchmarks to track progress towards attaining water quality standards. The *criteria* in element *H* (not to be confused with *water quality criteria* in state regulations) are the benchmarks or waypoints to measure against through monitoring. These interim targets can be direct measurements (e.g., fecal coliform concentrations, nutrient loads) or indirect indicators of load reduction (e.g., number of beach closings). These criteria should reflect the time it takes to implement pollution control measures, as well as the time needed for water quality indicators to respond, including lag times (e.g., water quality response as it is influenced by ground water sources that move slowly or the extra time it takes for sediment bound pollutants to break down, degrade or otherwise be isolated from the water column). Appendix B of these guidelines, "Measures and Indicators of Progress and Success," although intended as measures for program success, may provide some examples that may be useful. You should also indicate how you will determine whether the WBP needs to be revised if interim targets are not met. These revisions could involve changing management practices, updating the loading analyses, and reassessing the time it takes for pollution concentrations to respond to treatment.

***Element I.* A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under element H.**

What does this mean?
The WBP should include a monitoring component to determine whether progress is being made toward attaining or maintaining the applicable water quality standards for the waterbody(ies) addressed in the plan. The monitoring program should be fully integrated with the established schedule and interim milestone criteria identified above. The monitoring component should be designed to assess progress in achieving loading reductions and meeting water quality standards. Watershed-scale monitoring can be used to measure the effects of multiple programs, projects, and trends over time. Instream monitoring does not have to be conducted for individual BMPs unless that type of monitoring is particularly relevant to the project.

For more detailed information on developing watershed-based plans, please see *A Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, U.S. EPA, EPA 841-B-08-002 March 2008, (water.epa.gov/polwaste/nps/handbook_index.cfm). Other resources for watershed planning are available on the Watershed Central website - including the Watershed Central Wiki and Plan Builder tool at (water.epa.gov/type/watersheds/datait/watershedcentral/index.cfm).

Appendix B – Missouri SWCP Cost-share Practices

Missouri Soil and Water Conservation Program		**Practice Mode of Action***			**Pollutants Addressed**			
Resource Concerns and Associated Cost-Share Practices		**Avoid**	**Control**	**Trap**	**Sediment**	**Nutrients**	**E. coli**	**Pesticide**
SWCP Cost-Share #	Sheet/Rill and Gully Erosion	Sheet/Rill and Gully Erosion						
DSL-01	Permanent Vegetative Cover Establishment	x	x	x	x	x	x	x
DSL-02	Permanent Vegetative Cover Improvement	x	x	x	x	x	x	x
DSL-04	Terrace System		x	x	x	x		x
DSL-44	Terrace System with Tile		x		x	x		
DSL-05	Diversion		x		x	x		x
DSL-11	Permanent Vegetative Cover - Critical Area	x	x	x	x	x		x
DSL-111	Permanent Vegetative Cover - Critical Area: Confined Animal Feedlot	x	x	x	x	x	x	
DSL-15	No-Till System	x	x	x	x	x		x
DWC-01	Water Impoundment Reservoir		x	x	x	x		x
DWP-01	Sediment Retention, Erosion or Water Control Structure		x	x	x	x		x
DWP-03	Sod Waterway	x	x	x	x	x		x
N332	Contour Buffer Strips	x	x	x	x	x		x
N340	Cover Crop	x	x	x	x	x	x	x
N380	Windbreak/Shelterbelt Establishment	x	x	x	x	x		x
N410	Drop Pipe		x	x	x	x		
N585	Contour Stripcropping		x	x	x	x	x	x
Cost-Share #	Grazing Management	Grazing Management						
DSP-02	Permanent Vegetative Cover Enhancement	x	x	x	x	x	x	
DSP 3.1	Grazing System Water Development		x		x	x	x	
DSP 3.2	Grazing System Water Distribution		x		x	x	x	

DSP 3.3	Grazing System Fence	x	x		x	x	x	
DSP 3.4	Grazing System Lime		x			x		
DSP 3.5	Grazing System Seed	x	x	x	x	x	x	
	-							
Cost-Share #	[Irrigation Management]()	Irrigation Management						
N430	Irrigation Water Conveyance		x		x	x		x
N442	Irrigation System, Sprinkler	x			x	x		x
N443	Irrigation System, Surface and Subsurface		x		x	x		x
N447	Irrigation System, Tail Water Recovery		x		x	x		x
N554	Drainage Water Management		x	x	x	x		x
N587	Structure for Water Control		x	x	x	x		x
	-							
Cost-Share #	[Animal Waste Management]()	Animal Waste Management						
N312	Beef Waste Management System	x	x			x	x	
N312	Dairy Waste Management System	x	x			x	x	
N312	Poultry Waste Management	x	x			x	x	
N312	Swine Waste Management	x	x			x	x	
N316	Incinerator	x	x			x	x	
N317	Composting Facility	x	x			x	x	
Cost-Share #	[Nutrient and Pest Management]()	Nutrient and Pest Management						
N590	Nutrient Management	x	x		x	x	(x)	
N595	Pest Management	x	x					x
Cost-Share #	[Sensitive Areas]()	Sensitive Areas						
C650	Streambank Stabilization		x	x	x	x	x	
DSP-31	Sinkhole Improvement		x	x	x	x	x	x

BDSP-31	Buffer Sinkhole Improvement		x	x	x	x	x	x
N351	Well Decommissioning	x			x	x	x	x
N380	Windbreak/Shelterbelt Establishment	x	x	x	x	x		x
N386	Field Border		x	x	x	x	x	x
N391	Riparian Forest Buffer		x	x	x	x		
N393	Filter Strip		x	x	x	x	x	x
N574	Spring Development	x			x	x	x	
N725	Sinkhole Treatment	x	x	x	x	x	x	x
WQ10	Stream Protection	x	x	x	x	x	x	x
Cost-Share #	Woodland Erosion	Woodland Erosion						
C100	Timber Harvest Plan	x			x	x		
DFR-04	Forest Plantation	x			x	x		
N472	Livestock Exclusion	x			x	x	x	
N655	Restoration of Skid Trails, Logging Roads, Stream Crossings and Log Landings		x	x	x	x		
	Resource Concern and Associated Cost-Share Practices	**Avoid**	**Control**	**Trap**	**Sediment**	**Nutrients**	**E. coli**	**Pesticide**
Note: The above table is meant to provide examples of the most commonly accepted practices employed in Missouri. It is not meant to preclude other practices that may be appropriate to specific projects or site conditions.		**Practice Mode of Action***			**Pollutants Addressed**			

*Additional information can be found at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1187023.pdf

(x) count if management plan is for animal waste

Appendix C – Common Urban Best Management Practices

Common Urban Land Management Practices	Practice Mode of Action			Pollutants Addressed			
	Avoid	Control	Trap	Sediment	Nutrients	E. coli	Pesticide
Urban	**Urban**						
Bioswale		x	x	x	x	x	
Detention basin		x	x	x	x	x	
Fertilizer management	x	x			x		
Enhanced infiltration (soil amendment)	x	x	x	x	x		
Irrigation management	x	x			x	x	x
Low impact landscaping	x			x	x		x
Pest management							x
Porous pavement		x	x		x	x	x
Rain garden		x	x	x	x	x	x
Rain water harvesting	x	x		x	x	x	
Other	**Other**						
Alum application		x	x		x		
Filter/buffer strip		x	x	x	x	x	x
Grade stabilization structure		x		x			
Grass seeding	x	x		x	x		
Habitat improvement	x	x		x	x	x	
On-site wastewater system upgrade		x			x	x	
Riparian restoration	x	x	x	x	x	x	x

Sediment control basin		x	x	x	x	x	
Common Urban Land Management Practices	Practice Mode of Action			Pollutants Addressed			
	Avoid	Control	Avoid	Control	Avoid	Control	Avoid
Sediment removal		x		x	x		
Shoreline stabilization		x		x	x		
Stream bank stabilization		x		x	x	x	
Water diversion	x	x		x	x		
Water retention basin		x	x	x	x	x	x
Well decommissioning	x				x	x	x
Wetland Restoration/Construction		x	x	x	x	x	x
Practice Facilitation	Practice Facilitation						
Conservation consultant							
Crop production deferment	x	x		x	x		x
Common Practices	Avoid	Control	Trap	Sediment	Nutrients	E. coli	Pesticide
	Practice Mode of Action			Pollutants Addressed			

** Note: The above table is meant to provide examples of the most commonly accepted practices employed in Nebraska. It is not meant to preclude other practices that that may be appropriate to specific projects or site conditions.*

Appendix D – Load Duration Curves

As described by the U.S. Environmental Protection Agency *"A load duration curve approach allows the characterization of water quality concentrations (or water quality data) at different flow regimes. The method provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, the frequency and magnitude of water quality standard exceedances, allowable loadings, and size of load reductions are easily presented and can be better understood*

Load Duration Curve Explanation

In general, a load duration curve is a visual communication tool that organizes information in a way that is useful for watershed planning. A load duration curve provides 1) a visual representation of a water quality concern and how it relates to stream flow conditions (e.g. low, medium, and high), 2) indicates if point sources or other continuous input sources (e.g. failing septic systems, livestock access to the stream) are contributing to the concern, and 3) helps determine the types of best management practices that would be most effective.

Figure C1 provides an example of a load duration curve for *E. coli*. The x-axis, the flow duration interval, illustrates the full range of stream flow conditions for the water body segment (≤ 10 represents the percent of time the stream is at the highest flow conditions (flood), and ≥ 90 represents the percent of time the stream is at the lowest flow conditions (drought)). The x-axis represents the frequency for which a particular flow is met or exceeded. Whereas, lower flows are equaled or exceeded more frequently than higher flows. The y-axis describes bacteria loading as counts per day. Individually measured data have been converted to instantaneous loads and are plotted as points on the graph. The solid line represents the maximum pollutant loading across the different flow scenarios in which the water body can still meet the state's water quality standards. This line also corresponds to the water quality criterion concentration applicable for attaining the water body's designated whole body contact recreational use. Any data point above the solid line reflects a water quality excursion and possible exceedance.

The information provided in Figure C1 below indicates the frequency of *E. coli* excursions, which start occurring at the mid-range flow conditions (2 of 8 observations occur above the red line) and become more frequent through moist and high flow conditions (18 of 20 observations above the red line). The goal of a watershed management plan is to implement land management practices to address excursions or exceedances occurring during moist and mid-range conditions (runoff conditions), and dry and low flow condition (non-runoff conditions) in an effort to decrease the frequency and magnitude of the water quality excursions. Decreasing the frequency and magnitude of excursions would aid in bring the water body back into compliance and allow it to meet its designated recreational use(s) (e.g. whole body contact A or B recreation; and secondary contact recreation).

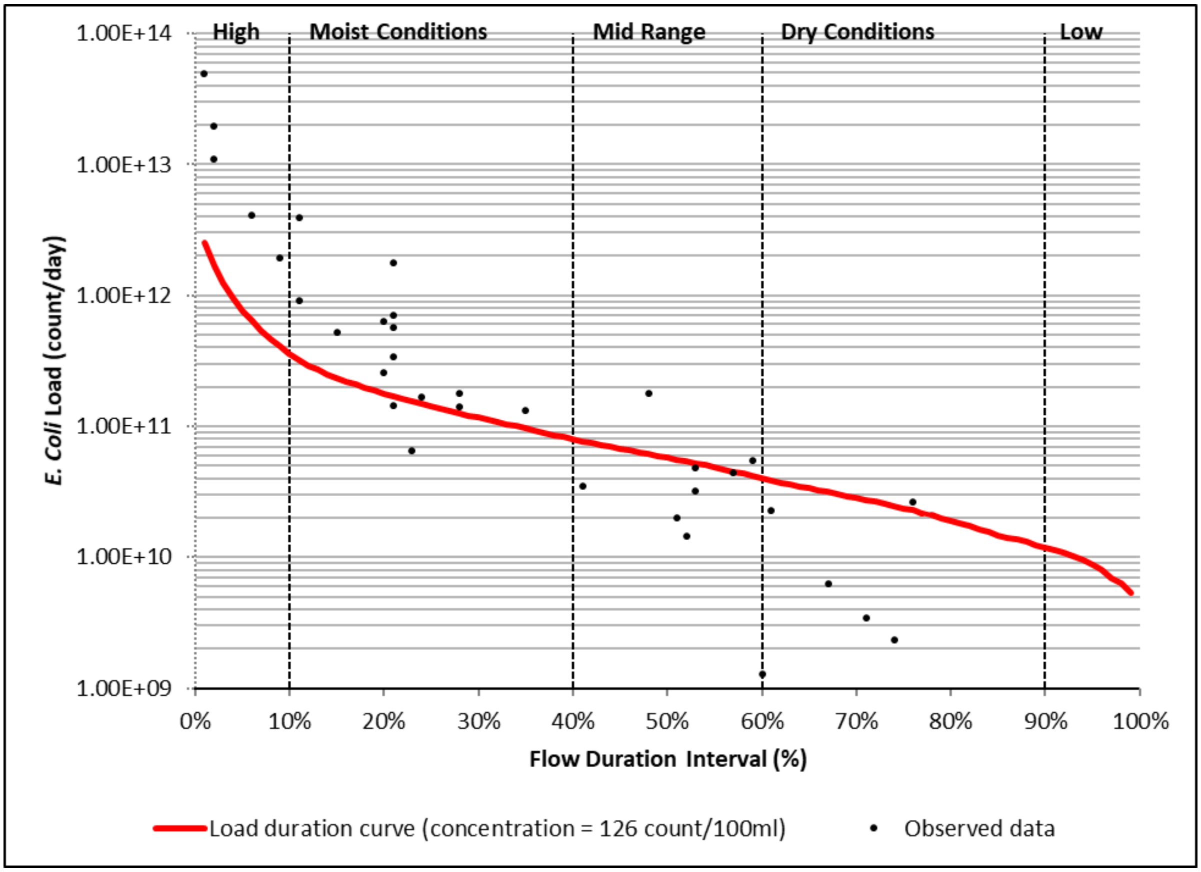

Figure C1. Example Load Duration Curve

Load Duration Curve Data

The 2006 TMDL that was written by EPA used TSS data collected from within the same EDU to develop the target TSS load since data from the North Fabius watershed was limited. Any interest in reviewing this data can be directed at MDNR's Water Protection Program[36]. Below are the total suspended solids (TSS; Table C1), total nitrogen (TN) and total phosphorus (TP)(Table C2), and *E. coli* (Table C3) data used in the LDCs presented in this 2020 North Fabius Nonpoint Source Watershed Management Plan. These TSS and *E. coli* data were collected more recently by USGS at USGS 05497150 gauge site on the North Fabius River near Ewing, MO between 2009 and 2018. Additionally, some of the *E. coli* data were also collected by MDNR at the same location.

Table C1. North Fabius (WBID 56) and Middle Fabius (WBID 63) total suspended solids (TSS) data used in load duration curve.

Org	Site Code	Site Name	Date	TSS (mg/l)	Qualifier
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/6/2009	28	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/17/2009	182	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/4/2009	312	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/28/2009	36	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/1/2009	102	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/14/2009	90	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/12/2010	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/3/2010	23	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/25/2010	144	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/8/2010	1610	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/13/2010	925	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/4/2011	34	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/7/2011	648	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/2/2011	67	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/11/2011	19	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/6/2011	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/11/2011	24	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/10/2012	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/5/2012	24	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/1/2012	657	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/17/2012	34	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/4/2012	30	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/2/2012	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/7/2013	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/4/2013	15	<

[36] Water Protection Program, PO BOX 176, Jefferson City, MO 65102; phone 800-361-4827 or 573-751-1300

USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/7/2013	234	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/30/2013	39	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/19/2013	31	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/29/2013	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/27/2014	30	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/25/2014	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/27/2014	30	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/7/2014	680	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/9/2014	46	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/6/2014	167	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/20/2015	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/9/2015	182	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/27/2015	462	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/21/2015	1130	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/14/2015	103	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/19/2015	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/25/2016	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/15/2016	56	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/23/2016	42	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/25/2016	71	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/12/2016	63	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/17/2016	30	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/9/2017	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/21/2017	15	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	6/5/2017	33	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/24/2017	33	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/18/2017	62	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/24/2018	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/27/2018	632	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/7/2018	24	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/10/2018	18	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/17/2018	15	<
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/15/2018	108	

Table C2. North Fabius (WBID 56) and Middle Fabius (WBID 63) total nitrogen (TN) and total phosphorus (TP) data used in load duration curves.

Org	Site Code	Site Name	Date	TN (mg/l)	TP (mg/l)
MDNR	56/70.0	N. Fabius R. @Hwy MM	3/28/2006	1.69	0.23
MDNR	56/75.1	N. Fabius R. @Hwy 136, Memphis	3/28/2006	1.71	0.22
MDNR	56/53.6	N. Fabius R. W. of Williamstown	3/29/2006	1.51	0.15
MDNR	56/57.4	N. Fabius R. N. of Colony	3/29/2006	1.59	0.18
MDNR	56/65.0	N. Fabius R. W. of Gorin	3/29/2006	1.56	0.15
MDNR	56/44.1	N. Fabius R. @Deer Ridge CA (lower)	3/30/2006	1.21	0.11
MDNR	56/47.6	N. Fabius R. @Deer Ridge CA(upper)	3/30/2006	1.13	0.10
MDNR	56/28.3	N. Fabius R. @CR 513 (Juniper Ave)	4/11/2006	0.62	0.05
MDNR	56/33.5	N. Fabius R. @Hwy 16, Monticello	4/11/2006	0.59	0.04
MDNR	56/11.1	N. Fabius R. @CR 588	4/12/2006	0.69	0.05
MDNR	56/16.7	N. Fabius R. @Napa Street	4/12/2006	0.66	0.06
MDNR	56/24.1	N. Fabius R. @CR 532	4/12/2006	0.58	0.05
MDNR	56/80.6	N. Fabius R. @Hwy B	4/12/2006	0.48	0.05
MDNR	56/86.7	N. Fabius R. @ Hwy. N	4/12/2006	0.42	0.05
MDNR	56/91.6	N. Fabius R. @ Hwy. C (Schuyler Co.)	4/12/2006	0.49	0.03
MDNR	63/18.5	M. Fabius R. 2 mi. W. of Monticello	5/16/2006	0.41	0.03
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/6/2009	1.40	0.08
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/17/2009	1.90	0.26
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/4/2009	1.80	0.36
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/28/2009	<0.63	0.10
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/1/2009	1.20	0.22
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/14/2009	1.40	0.25
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/12/2010	1.10	E0.03
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/3/2010	0.89	0.06
MDNR	63/21.4	M. Fabius R. nr. Monticello	4/20/2010	0.32	E0.03
MDNR	63/21.4	M. Fabius R. nr. Monticello	5/10/2010	2.10	0.78
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/25/2010	2.20	0.29
MDNR	63/21.4	M. Fabius R. nr. Monticello	6/16/2010	1.21	0.26
MDNR	63/21.4	M. Fabius R. nr. Monticello	6/16/2010	1.42	0.31
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/8/2010	4.00	1.37
MDNR	63/21.4	M. Fabius R. nr. Monticello	7/26/2010	1.66	0.32
MDNR	63/21.4	M. Fabius R. nr. Monticello	8/11/2010	0.70	0.08
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/13/2010	3.10	0.82
MDNR	63/21.4	M. Fabius R. nr. Monticello	9/27/2010	1.34	0.40
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/4/2010	0.71	0.10
MDNR	63/21.4	M. Fabius R. nr. Monticello	10/13/2010	0.43	0.04
MDNR	63/21.4	M. Fabius R. nr. Monticello	11/9/2010	0.29	0.02
MDNR	63/21.4	M. Fabius R. nr. Monticello	12/10/2010	0.36	0.01
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/4/2011	3.00	0.12
MDNR	63/21.4	M. Fabius R. nr. Monticello	1/26/2011	0.99	0.02
MDNR	63/21.4	M. Fabius R. nr. Monticello	2/15/2011	1.85	0.17
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/7/2011	3.80	0.62
MDNR	63/21.4	M. Fabius R. nr. Monticello	3/22/2011	0.45	E0.02
MDNR	63/21.4	M. Fabius R. nr. Monticello	4/7/2011	0.44	E0.04
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/2/2011	1.30	0.15
MDNR	63/21.4	M. Fabius R. nr. Monticello	5/12/2011	0.47	0.04

MDNR	63/21.4	M. Fabius R. nr. Monticello	6/23/2011	2.08	0.29
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/11/2011	<0.59	0.10
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/6/2011	<0.54	0.06
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/11/2011	<0.60	0.07
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/10/2012	1.20	0.03
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/5/2012	1.20	0.06
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/1/2012	6.90	0.88
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/17/2012	<0.76	0.09
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/4/2012	<0.84	0.09
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/2/2012	<0.54	0.04
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/7/2013	1.10	0.03
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/4/2013	1.70	0.05
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/7/2013	3.60	0.32
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/30/2013	<0.59	0.09
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/19/2013	<0.53	0.06
MDNR	63/21.4	M. Fabius R. nr. Monticello	10/2/2013	0.45	0.03
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/29/2013	<0.43	0.03
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/27/2014	0.47	0.04
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/25/2014	1.60	0.09
MDNR	63/21.4	M. Fabius R. nr. Monticello	4/7/2014	0.77	0.08
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/27/2014	<0.71	0.10
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/7/2014	2.70	0.65
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/9/2014	<0.71	0.11
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/6/2014	2.00	0.30
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/20/2015	0.66	0.02
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/9/2015	1.80	0.28
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/27/2015	5.80	0.49
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/21/2015	2.30	0.93
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/14/2015	1.70	0.16
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/19/2015	<0.42	0.04
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/25/2016	1.10	0.05
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/15/2016	0.75	0.12
MDNR	63/30.7	M. Fk. Fabius R. ab. Hwy. H	4/7/2016	0.64	0.04
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/23/2016	0.74	0.10
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/25/2016	1.40	0.18
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	9/12/2016	0.98	0.14
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/17/2016	<0.47	0.07
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/9/2017	0.78	0.02
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/21/2017	<0.41	0.04
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	6/5/2017	<0.59	0.10
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/24/2017	<0.95	0.11
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/18/2017	2.20	0.31
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	1/24/2018	1.30	0.06
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	3/27/2018	4.30	0.69
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	5/7/2018	<0.72	0.09
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	7/10/2018	<0.71	0.11
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	10/15/2018	1.50	0.29

Table C3. North Fabius River (WBID 56) E. coli data used in load duration curve.

Org	Site Code	Site Name	Sample Type	Date	Rec Seas?	Escherichia coli (#/100ml)	Qualifier
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/4/2009	Y	950	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/28/2009	Y	84	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/1/2009	Y	840	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/14/2009	Y	4300	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/25/2010	Y	110	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/8/2010	Y	3200.00	>
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/13/2010	Y	9000	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/4/2010	Y	74	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/2/2011	Y	150	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/11/2011	Y	66	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/6/2011	Y	52	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/11/2011	Y	260	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/1/2012	Y	26000	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/17/2012	Y	84	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/4/2012	Y	300	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/2/2012	Y	47	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/7/2013	Y	1300	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/30/2013	Y	590	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/19/2013	Y	150	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/29/2013	Y	15	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/27/2014	Y	430	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/7/2014	Y	4800	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/9/2014	Y	310	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/6/2014	Y	1200	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/27/2015	Y	1100	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/21/2015	Y	1600	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/14/2015	Y	1000	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/19/2015	Y	77	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/23/2016	Y	140	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	FieldDupl	7/21/2016	Y	727	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	FieldDupl	7/21/2016	Y	727	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	FieldDupl	7/21/2016	Y	727	

MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	FieldDupl	7/21/2016	Y	727	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/25/2016	Y	290	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/12/2016	Y	160	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/15/2016	Y	95.9	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/17/2016	Y	42	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	FieldDupl	4/6/2017	Y	4839.2	>
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	FieldDupl	4/6/2017	Y	4839.2	>
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/9/2017	Y	111.2	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	6/5/2017	Y	130	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/6/2017	Y	410.6	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/24/2017	Y	43	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	8/1/2017	Y	86.2	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	8/31/2017	Y	344.8	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/18/2017	Y	1600	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	5/7/2018	Y	10	E
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	7/10/2018	Y	360	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	8/16/2018	Y	1986.3	
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	8/29/2018	Y	4839.2	>
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/11/2018	Y	920.8	
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	9/17/2018	Y	14	E
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/10/2018	Y	4839.2	>
USGS	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/15/2018	Y	3200	>
MDNR	56/17.5	N. Fabius R. 3 mi. NE of Ewing	Grab	10/30/2018	Y	71.2	

Appendix E – STEPL Model Report

STEPL Modeling for North Fabius and Middle Fabius Rivers

The Spreadsheet Tool for the Estimation of Pollutant Load (STEPL, Version 4.4)[37] was used to estimate sediment, total nitrogen (TN), and total phosphorus (TP) load reductions from Missouri's Soil and Water Conservation Program (SWCP) cost-share practices. The reduction efficiencies for each SWCP practice were calculated using STEPL's BMP Calculator. For the revision of the 2010 North and Middle Fabius Nonpoint Source Watershed Management Plan (WMP), pollutant load reductions from cost-share best management practices (BMPs) that were implemented from FY2009 to FY2020 were estimated for each HUC12 subwatershed within the planning area. After the benefits of these practices were accounted for in the models in order to create a Baseline loading for the current revised WMP, STEPL was used to estimate the additional annual, short-term (yrs.1-5), mid-term (yrs. 6-10), and long-term (yrs. 11-20) pollutant load reductions from BMPs scheduled in the 2020 North Fabius Nonpoint Source Watershed Management Plan.

Overview

STEPL is an EPA supported model and was selected because it is easy to customize and generates the data needed to fulfill the requirements of a Nine Element Watershed Management Plan. The STEPL model is a spreadsheet-based tool that utilizes simple algorithms and a Visual Basic interface within Microsoft Excel. Annual sediment and nutrient loads from surface runoff and in groundwater are calculated based on watershed characteristics and management, such as land use coverage, local/regional climate data, soil data, runoff quantity and quality, and management practices within each land use type. The annual sediment load from sheet and rill erosion is calculated from the Universal Soil Loss Equation (USLE) and sediment delivery ratio. The sediment loads from gully and streambank erosion are optional inputs, which were included in this modeling exercise. The STEPL analysis of the greater North Fabius subbasin for the 2020 WMP focused on cropland and pasture land uses and corresponding BMPs.

Model Setup

A STEPL spreadsheet was set up for each of the 25 HUC12 subwatersheds in the North Fabius planning area. Several HUC12-specific inputs were downloaded using EPA's STEPL Model Input Data Server[38] and the remaining county- or HUC12-specific inputs were retrieved or calculated from a variety of data sources. After the models were set up in order to generate a background loading, annual pollutant load reductions from FY2009 through FY2020 cost-share practices were assessed on a HUC12-basis. Loading from each HUC12 subwatershed were then summed to represent the Baseline loading for entire planning area for the 2020 WMP. Annual load reductions from BMPs planned as part of the 2020 WMP implementation goals were generated from a single STEPL spreadsheet set up to represent the entire planning.

[37] EPA. Polluted Runoff: Nonpoint Source (NPS) Pollution. Spreadsheet Tool for Estimating Pollutant Loads (STEPL). Developed by Tetra Tech Inc. https://www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl
[38] EPA. STEPL Input Data Server. http://it.tetratech-ffx.com/steplweb/steplweb.html

STEPL Data Inputs

Data inputs within STEPL or queried at subwatershed (HUC12) level from STEPL's on-line data access system:

- State and County boundaries.
- Watershed boundary dataset (HUC12, HUC10, HUC8, HUC6, HUC4, and HUC2).
- NHDplus catchments.
- NHDplus flowlines and waterbodies.
- **Meteorological data** - data obtained from NOAA's National Climatic Data Center[39] data sources from weather stations with at least 30 years of data.
- **Land use area distribution** - based on 2011 National Land Cover Database (NLCD)[40] and USDA Cropland Data Layer (CDL)[41].
- **Agricultural animal count –** based on 2012, USDA Census of Agriculture.
- **Septic system data** - based on septic system surveys by National Small Flows Clearinghouse, 1992 and 1998.

STEPL input default parameters not changed:

- Feedlot percent Paved kept at 0-24% for all subwatersheds.
- Runoff nutrient concentrations.
- USLE parameters.

Data inputs from other sources:

- **Gullies and Streambanks** – The number of eroding streambanks and the number of gullies intersecting streambanks along perennial stream segments were tabulated per HUC12 and the dimensions for each were estimated/measured using 2015/2016 aerial images in Google Earth Pro. The number of formation years for each gully was estimated using all available historic images within Google Earth. Erosion rates of streambanks were estimated as best as possible by comparing 2012/2013 imagery with 2015/2016 imagery, and then the streambank was categorized based on STEPL categories (Table E1). Only Moderate (if able to identify), Severe, and Very Severely eroding streambanks were noted, which were identified based on lateral recession rate using the digital measuring tool. This analysis was limited to streambanks without vegetative cover. Also, STEPL setup limits the quantity of each feature to 100; a few HUC12s showed more than 100 eroding streambanks. The location of each streambank and gully identified in Google Earth was compared to Natural Resources Conservation Service - State Soil Geographic (STATSGO) database in ArcMap (ESRI, v10.7.1) to identify the corresponding soil textural class.

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[39] NOAA. National Centers for Environmental Information. https://www.ncdc.noaa.gov/
[40] USGS. National Land Cover Database. 2011. https://www.mrlc.gov/data/nlcd-2011-land-cover-conus-0
[41] USDA. National Agricultural Statistics Service. Cropland Data Layer. 2011 https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php

Table E1. STEPL categories for range of streambank erosion conditions.

Category	Description	Lateral Recession Rate (ft/yr)
Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.	0.01 - 0.05
Moderate	Bank is predominantly bare with some rills and vegetative overhang.	0.06 - 0.2
Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross-section becomes more U-shaped as opposed to V-shaped.	0.3 - 0.5
Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and stream course or gully may be meandering.	0.5+

- **Manure applications** (Number of months applied to Cropland, Pastureland) - It was assumed that manure is applied to cropland during growing season (6 months) and applied to Pastureland throughout the year from live animals or by land application from feedlots.

- **Hydrological soil group (HSG)** based on STATSGO database - HSG for each HUC12 was set to D; the sum of HSG D and dual listed C/D and B/D soils consisted the majority of the area for all HUC12s.

- **Soil chemical properties** - Average total nitrogen and phosphorus soil data was provided for each county in planning area by the University of Missouri's Soil Health Assessment Center[42]. Soils used in their analyses were part of MDNR's cover crop cost-share program and were sampled before or at the same time a farmer plants winter covers for the first time. Soils are sampled from fields with a range of management practice, soil textures, and landscape positions. Average data for each county was from soil samples submitted to the lab from 2015-2017; values were area-weighted by county for each HUC12.

[42] Soils Health Assessment Center, University of Missouri, Columbia, Mo. https://cafnr.missouri.edu/soil-health/

- **Irrigation** - The number of irrigated acres was obtained from 2017 Census of Agriculture[43] for each county, then area-weighted for each HUC12 subwatershed containing multiple counties. Data from the 2018 Irrigation and Water Management Survey (a follow-on to the 2017 Ag Census) for Missouri and the HUC 6 basin (071100) was used to convert average acre-feet of irrigation water applied per acre to gallons per acre. The medium irrigation depth suggested by the Woodruff Irrigation Model[44] was 1.5 inches based on soy/corn crops, various soil textures, and counties in the planning area. Using the total gallons irrigated, gallons per acre applied, and the number of gallons of water in an acre-1.5 inch, an irrigation frequency for Missouri and the HUC6 was calculated at 4 and 6 times per year, respectively. Therefore, an average irrigation frequency of 5 times per year was used in STEPL model for all simulations.

STEPL Assumptions

STEPL assumes that all BMPs are implemented in parallel orientation to the waterbody, unless otherwise estimated using the BMP Calculator to simulate nested practices (just as the SWCP cost-share BMP efficiencies were generated).

BMP Efficiencies

Missouri SWCP cost-share practices each consist of a combination of practices and structures that are installed or applied based on NRCS standards and specifications. A combined pollutant reduction efficiency for each cost-share practice was calculated as best as possible using the BMPs listed in STEPL's BMP Calculator (Table E2). The pollutant reduction efficiencies of each STEPL BMP are based on a national average and it is unclear how these values compare to local or regional efficiencies.

Table E2. List of STEPL BMPs used in STEPL's BMP calculator to estimate the combined efficiency of the various practices that make up Missouri's Soil and Water Conservation Program (SWCP) cost-share practices.

SWCP practices	NRCS Equivalent	STEPL BMP Equivalent
Crop Management Strategies		
DSL-04 Terrace System	342, 723, 600	Terrace, Critical Area Planting, Contour Farming
DSL-44 Terrace System with Tile	342, 723, 600, 620	Terrace, Critical Area Planting, Contour Farming, Controlled Drainage
DSL-05 Diversion	342, 723, 348, 362, 378, 410, 606, 620	Critical Area Planting, Controlled Drainage
DSL-11 Permanent Vegetative Cover - Critical Area	342, 723, 382, 472	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting), Livestock Exclusion Fencing, Use Exclusion

43 USDA. National Agricultural Statistics Service. Census of Agriculture. https://www.nass.usda.gov/AgCensus/
44 University of Missouri Extension. Woodruff Irrigation Charts. http://agebb.missouri.edu/irrigate/woodruff/

N340 Cover Crop	328, 340	Cover Crop 2 (Group A Traditional Normal Planting Time) (High Till only for TP and Sediment), Conservation Tillage 2 (equal or more than 60% Residue)
DWC-01 Water Impoundment Reservoir	342, 723, 378, 382, 410, 472, 516, 614	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting), Alternative Water Supply, Use Exclusion, Livestock Exclusion Fencing
DWP-01 Sediment Retention, Erosion or Water Control Structure	342, 723, 382, 410, 472, 638	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting), Controlled Drainage, Use Exclusion, Livestock Exclusion Fencing
DWP-03 Sod Waterway	342, 723, 412, 468	Buffer - Grass (35ft wide), Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting)
N590 Nutrient Management	590	Nutrient Management 2 (Determined Rate Plus Additional Considerations)
Livestock Management Strategies		
DSL-01 Permanent Vegetative Cover Establishment	512, 723	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting)
DSP-02 Permanent Vegetative Cover Enhancement	512, 528, 723	Pasture and Hayland Planting (also called Forage Planting), Prescribed Grazing
DSL-02 Permanent Vegetative Cover Improvement	512, 723, 528	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting), Prescribed Grazing
DSP 3.1 Grazing System Water Development	342, 723, 378, 382, 472, 528, 642	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting), Prescribed Grazing, Alternative Water Supply, Livestock Exclusion Fencing, Use Exclusion
DSP 3.2 Grazing System Water Distribution	516, 528, 578, 614	Prescribed Grazing, Alternative Water Supply, Livestock Exclusion Fencing
DSP 3.3 Grazing System Fence	382, 528	Livestock Exclusion Fencing, Prescribed Grazing
DSP 3.4 Grazing System Lime	528, 590	Prescribed Grazing
DSP 3.5 Grazing System Seed	512, 723, 528	Pasture and Hayland Planting (also called Forage Planting), Prescribed Grazing
Riparian Improvement and Stream Protection		
N386 Field Border	342, 723, 386, 511	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting), Buffer - Grass (35ft wide)
N393 Filter Strip	342, 723, 382, 393, 472, 511	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting), Buffer - Grass (35ft wide), Livestock Exclusion Fencing, Use Exclusion
N391 - Riparian Forest Buffer	382, 391, 723, 472, 490, 516, 578, 612, 614, 642	Alternative Water Supply, Livestock Exclusion Fencing, Use Exclusion, Pasture and Hayland Planting (also called Forage Planting), Streambank protection w/o fencing, Cropland - Buffer -Forest (100 ft wide)
N472 Livestock Exclusion	382, 472	Livestock Exclusion Fencing
WQ10 Stream Protection	342, 723, 378, 382, 472, 516, 578, 614, 642	Critical Area Planting, Pasture and Hayland Planting (also called Forage Planting), Livestock Exclusion Fencing, Use Exclusion, Alternative Water Supply
C650 Streambank Stabilization	382, 472, 490, 580, 612	Streambank Stabilization and Fencing, Use Exclusion, Forest Buffer (minimum 35 feet wide)

Model Processing Steps and Results

Background Loads

A separate STEPL model was set up for each HUC12 subwatershed in the planning area using the retrieved and calculated input data, including gully and streambank information.

FY2009-FY2020 Annual Load Reductions

SWCP cost-share practices implemented within each HUC12 subwatershed between FY2009 and FY2020 were added to the models to generate total sediment, TN, and TP load reductions for each HUC12. Cost-share practices implemented between FY2009 and FY2013 were recorded at the HUC14 scale, but for the modeling exercise these practices were assigned to the associated HUC12. Where there were more than one HUC12s intersecting the HUC14, the implemented practices were assigned to one HUC12 as presented in Table E3. The estimated loading for each subwatershed after the BMPs were added to the models was totaled and considered the Baseline loading for the 2020 WMP planning area.

2020 WMP Annual Load Reductions

SWCP cost-share practices listed in the 2020 WMP Implementation Schedule were identified as the reasonable amount of the various BMPs that could be expected to be adapted by private landowners or implemented as a demonstration project. To estimate the annual pollutant load of these practices, a STEPL model was set up to represent the entire 2020 WMP planning area. To set up the model, watershed input data from each HUC12 STEPL model were either summed, averaged, or area-weighted, as applicable, to represent a greater North Fabius planning area. Due to the STEPL's limit in number of streambanks and gullies entered, the observed features were not added to the subbasin model. Since STEPL estimates loading from gullies and streambanks separate from land uses, only one streambank was simulated using average parameters (500 ft length and 8 ft height) and a variety of conditions observed in the streambank analysis in order to find the average load reduction from a streambank stabilization project with a 90% load reduction efficiency, which is the average of the reduction efficiencies for sediment, TN, and TP (Table E4a and b).

The total annual pollutant load reductions from all BMPs were expanded to estimate load reductions for the WMP's short-, mid- and long-term goals. STEPL estimates a percent load reduction for each simulated BMP. To estimate the percent reduction for sediment, TN, and TP for each milestone time period, the total revised BMP pollutant load reductions were compared to the 2020 WMP Baseline Loading (estimated after incorporation of FY2009-FY2020 cost-share practices):

Sediment Load (tons/yr)	TN Load (lbs/yr)	TP Load (lbs/yr)
421,370	**7,358,964**	**1,367,116**

Table E3. Crosswalk from HUC14 to HUC12 subwatersheds for assigning cost-share practices implemented between FY2009 and FY2013.

HUC 14	Intersecting HUC12s	Assigned HUC12
07110002-020002	071100020104	071100020104
07110002-030002	071100020101	071100020101
07110002-020003	071100020105 071100020102 071100020108	071100020105
07110002-060001	071100020401	071100020401
07110002-070001	071100020106	071100020106
07110002-070002	071100020108	071100020108
07110002-070003	071100020107	071100020107
07110002-070004	071100020402	071100020402
07110002-080001	071100020202	071100020202
07110002-080002	071100020204	071100020204
07110002-080003	071100020201 071100020202	071100020201
07110002-080004	071100020206 071100020203	071100020206
07110002-080005	071100020301	071100020301
07110002-080006	071100020205	071100020205
07110002-080007	071100020304	071100020304
07110002-090001	071100020303 071100020302	071100020303
07110002-090002	071100020305	071100020305
07110002-090003	071100020306	071100020306
07110002-100001	071100020403	071100020403
07110002-100002	071100020404 071100020405	071100020404

Table E4. Average annual sediment, nitrogen (N), and phosphorus (P) loading and load reductions from a streambank stabilization project with a 90% reduction efficiency simulated on streambanks with a variety of conditions and soils in subbasin.

a)

Streambank simulations						Load before BMP			
#	Length (ft)	Height (ft)	Lateral Recession	Avg. Erosion Rate (ft/yr)	Soil Texture Class*	Soil Dry Weight (ton/ft^3)	Sediment Load (ton/yr)	N Load (lbs/yr)	P Load (lbs/yr)
1	500	8	Severe	0.4	SiL	0.0425	68	259	59
2	500	8	Very Severe	0.5	SiL	0.0425	85	324	74
3	500	8	Severe	0.4	SiCL, SiC	0.04	64	244	56
4	500	8	Very Severe	0.5	SiCL, SiC	0.04	80	305	69
						Average loads	**74**	**283**	**64**

*SiL = Silt Loam; SiCL =Silty clay loam; SiC = Silty clay

b)

BMP Reduction					Load after BMP		
#	BMP Efficiency (0-1)	Sediment Reduction (ton)	N Reduction (lbs)	P Reduction (lbs)	Sediment Load (t/yr)	Soil N Load (lbs)	Soil P Load (lbs)
1	0.9	61	233	53	7	26	6
2	0.9	77	292	66	9	32	7
3	0.9	58	220	50	6	24	6
4	0.9	72	275	62	8	31	7
	Average loads	**67**	**255**	**58**	**7**	**28**	**6**

Appendix F – Critical Area Maps

Critical Area Determination

Critical Areas for the 2020 North Fabius Nonpoint Source Watershed Management Plan were developed based on four criteria and several data sources that were analyzed within ArcMap 10.7.1 (ArcGIS® software by Esri) based on the critical area criteria.

Data Inputs

Multi-Resolution Land Characteristics Consortium (MRLC). (2018). National Land Cover Database 2011 (NLCD 2011). Multi-Resolution Land Characteristics Consortium (MRLC). https://data.nal.usda.gov/dataset/national-land-cover-database-2011-nlcd-2011.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at https://websoilsurvey.nrcs.usda.gov/.

U.S. Geological Survey. (2019). National Hydrography Dataset (ver. USGS National Hydrography Dataset Best Resolution (NHD) for Hydrologic Unit (HU) 4 - 2001 (published 20191002)), accessed October 23, 2019 at URL https://www.usgs.gov/core-science-systems/ngp/national-hydrography/access-national-hydrography-products

Watershed Boundary Dataset. Coordinated effort between the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA). The Watershed Boundary Dataset (WBD) was created from a variety of sources from each state and aggregated into a standard national layer for use in strategic planning and accountability. Watershed Boundary Dataset for North Fabius Subbasin, Missouri. Available at https://datagateway.nrcs.usda.gov/

Critical Areas

Critical Area 1 - Designates a 100 ft stream buffer along any stream segments that flows through agricultural lands (this includes areas where there may be some type of perennial buffer already established, but buffer widths were less than 100 ft).

Critical Area 2 - Designates agricultural land with a slope greater than 3% and poorly draining soils that fall within the hydrologic soil groups D or dual listed D/C.

Critical Area 3 - Designates any remaining agricultural land with a slope greater than 3% regardless of soil type.

Critical Area 4 - (not mapped) Addresses stakeholder concerns for nutrient and chemical pesticides in runoff from agricultural lands and supports nutrient and pest management plans on any agricultural land.

Priority Area Determination

After determining the critical areas for the HUC 8 subbasin, the 25 subwatersheds were prioritized into three **Priority tiers** in order to effectively target implementation efforts. The subwatersheds were ranked according to average annual sediment loading, as determined by the STEPL modeling, after FY2009-FY2020 cost-share BMPs were added to the model. All subwatersheds within the planning area were assigned to one of three priority tiers where the top 8 HUC12s with the greatest estimated sediment loading will be targeted as Priority 1 for implementation (Table F1). Priority tiers are:

Priority 1 – Short-term (years 1 – 5)
Priority 2 – Mid-term (years 6 – 10)
Priority 3 – Long-term (years 11 – 20)

Table F1. Priority tiers for BMP implementation based on STEPL-estimated average annual sediment loading (tons/year) in the North Fabius subbasin.

Tier	HUC12	Subwatershed Name	Estimated Avg. Sediment Load (tons/yr)
Priority 1	071100020108	Memphis Reservoir - N. Fabius River	38183
Years 1-5	071100020105	Downing Reservoir - N. Fabius River	33203
	071100020104	North Fork - N. Fabius River	30839
	071100020402	Long Branch - N. Fabius River	25532
	071100020401	Bear Creek - N. Fabius River	24906
	071100020304	Sand Hill Branch - M. Fabius River	24507
	071100020305	Reddish Branch - M. Fabius River	23249
	071100020306	Middle Fabius River	19952
Priority 2	071100020403	Cooper Branch - N. Fabius River	17659
Years 6-10	071100020404	Town of Weber - N. Fabius River	16579
	071100020106	Gunns Branch - N. Fabius River	16430
	071100020102	Headwaters North Fabius River	15550
	071100020206	South Fork Middle Fabius River	15280
	071100020103	Carter Creek- North Fork N. Fabius River	14599
	071100020301	Tobin Creek - M. Fabius River	14160
	071100020107	Indian Creek - N. Fabius River	13357
Priority 3	071100020405	North Fabius River	11352
	071100020101	South Fork North Fabius River	10592
Years 11-20	071100020204	Headwaters South Fork M. Fabius River	10016
	071100020303	Little Bridge Creek - Bridge Creek	9744
	071100020202	Headwaters North Fork M. Fabius River	9475
	071100020302	City of Baring - Bridge Creek	9041
	071100020205	North Fork Middle Fabius River	8656
	071100020201	Bridge Creek - M. Fabius River	5260
	071100020203	Brushy Creek - M. Fabius River	3250

Priority 1 Subwatersheds

Priority 1 subwatersheds are those HUC12s that the STEPL model estimates to have the greatest annual sediment loading and are prioritized for implementation during Years 1 through 5 (calendar years 2021-2025) of this WMP (Figure F1). The estimated annual sediment loads for this tier ranged from an average of 19,952 to 38,183 tons per year (Table F1). Figures F2 through F9 present each HUC12 subwatershed and the extent of Critical Areas 1 through.

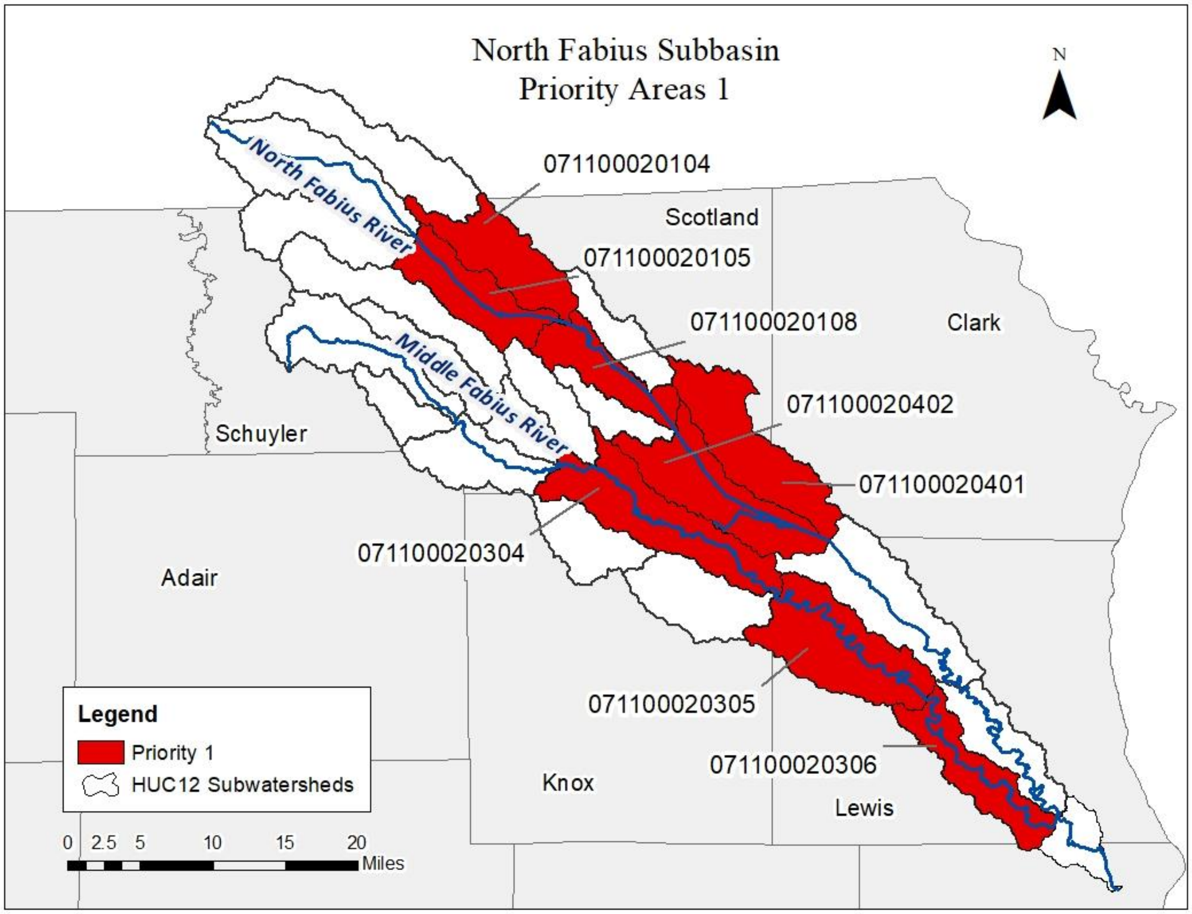

Figure F1. Priority 1 subwatersheds are shown in red.

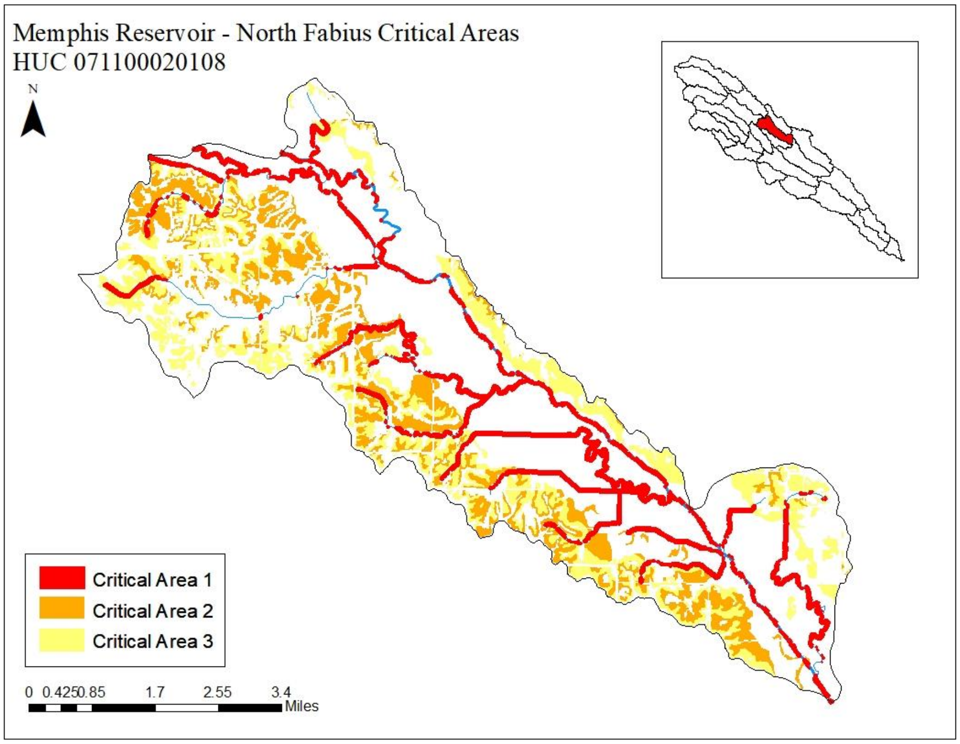

Figure F2. Critical areas 1-3 targeted for BMP implementation within Memphis Reservoir - North Fabius River subwatershed (HUC 071100020108).

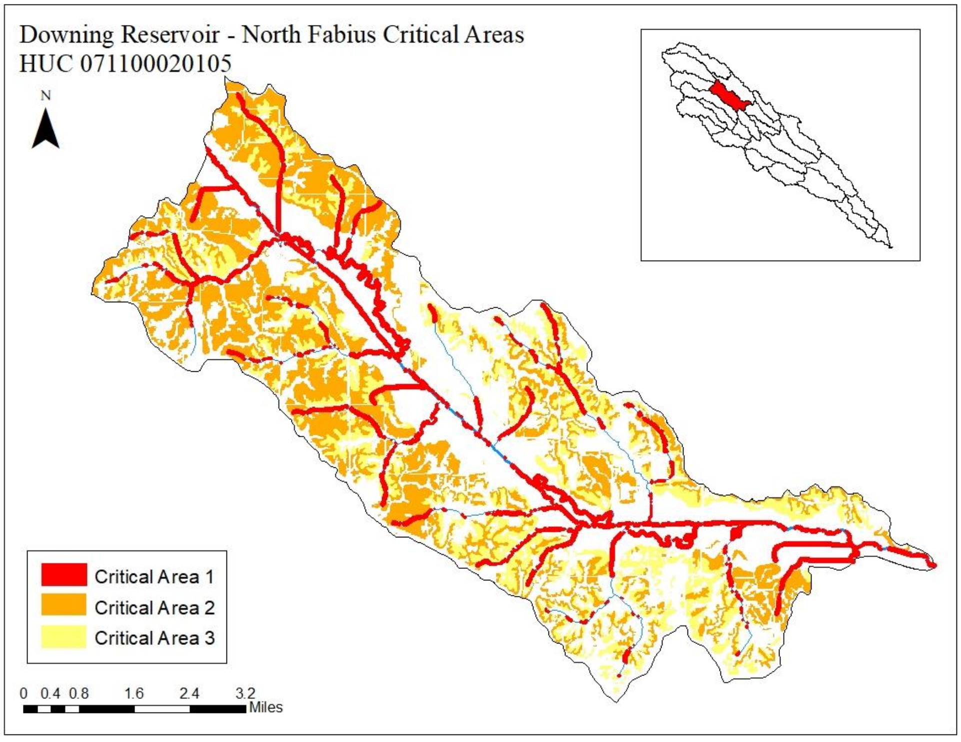

Figure F3. Critical areas 1-3 targeted for BMP implementation in Downing Reservoir - North Fabius River subwatershed (HUC 071100020105).

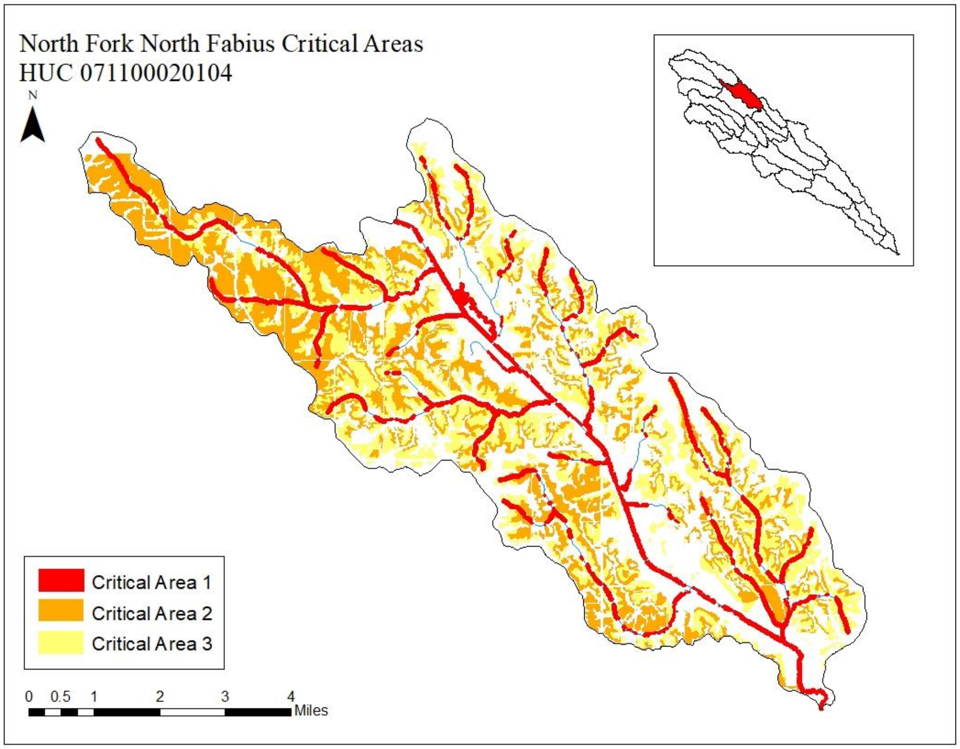

Figure F4. Critical areas 1-3 targeted for BMP implementation within North Fork - North Fabius River subwatershed (HUC 071100020104).

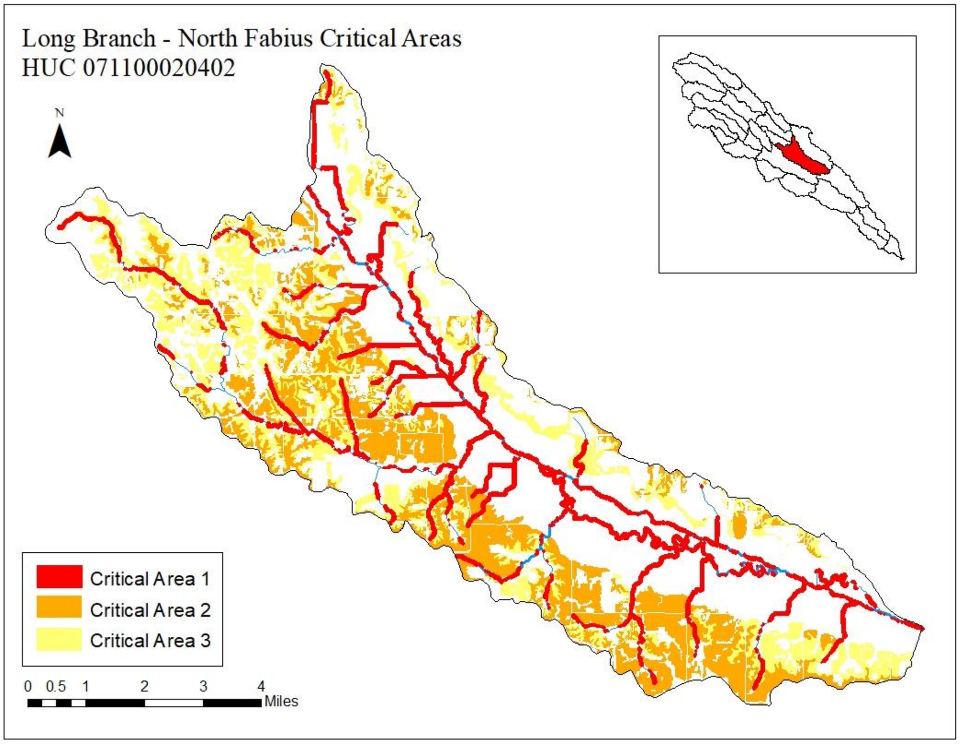

Figure F5. Critical areas 1-3 targeted for BMP implementation Long Branch - North Fabius River subwatershed (HUC 071100020402).

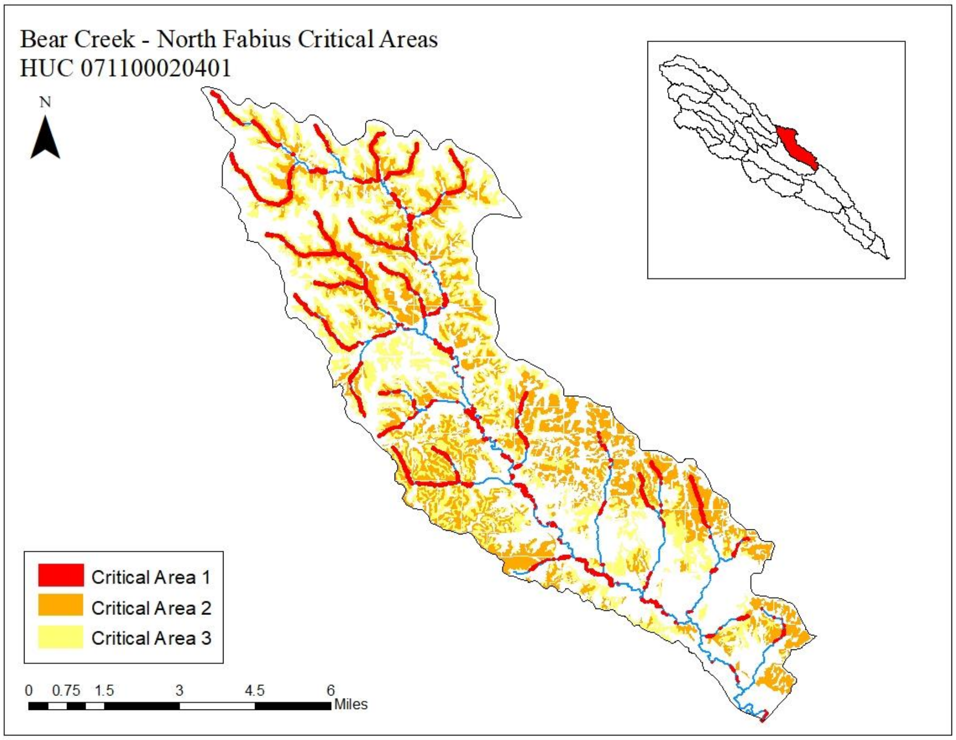

Figure F6. Critical areas 1-3 targeted for BMP implementation in Bear Creek - North Fabius River subwatershed (HUC 071100020401).

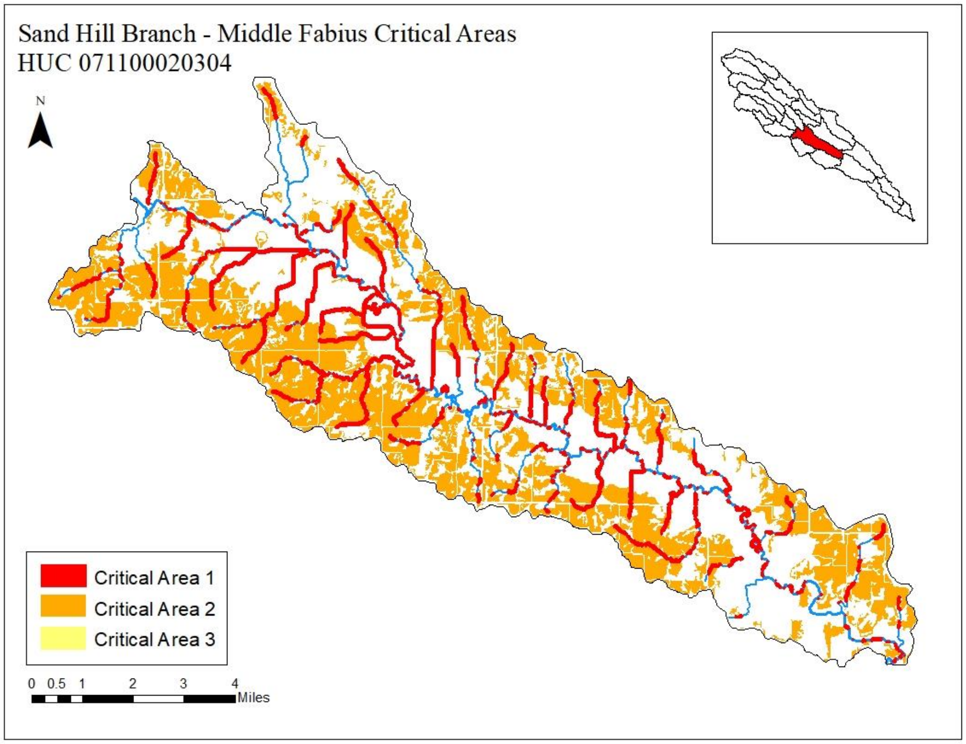

Figure F7. Critical areas 1-3 targeted for BMP implementation in Sand Hill Branch- Middle Fabius River subwatershed (HUC 071100020304).

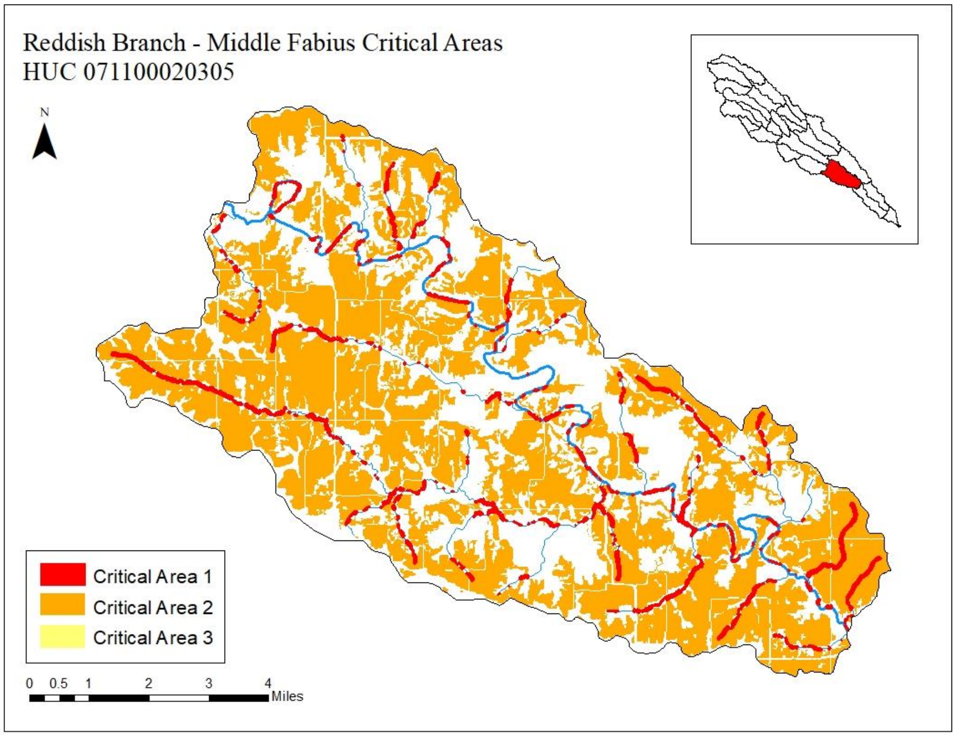

Figure F8. Critical areas 1-3 targeted for BMP implementation in Reddish Branch - Middle Fabius River subwatershed (HUC 071100020305).

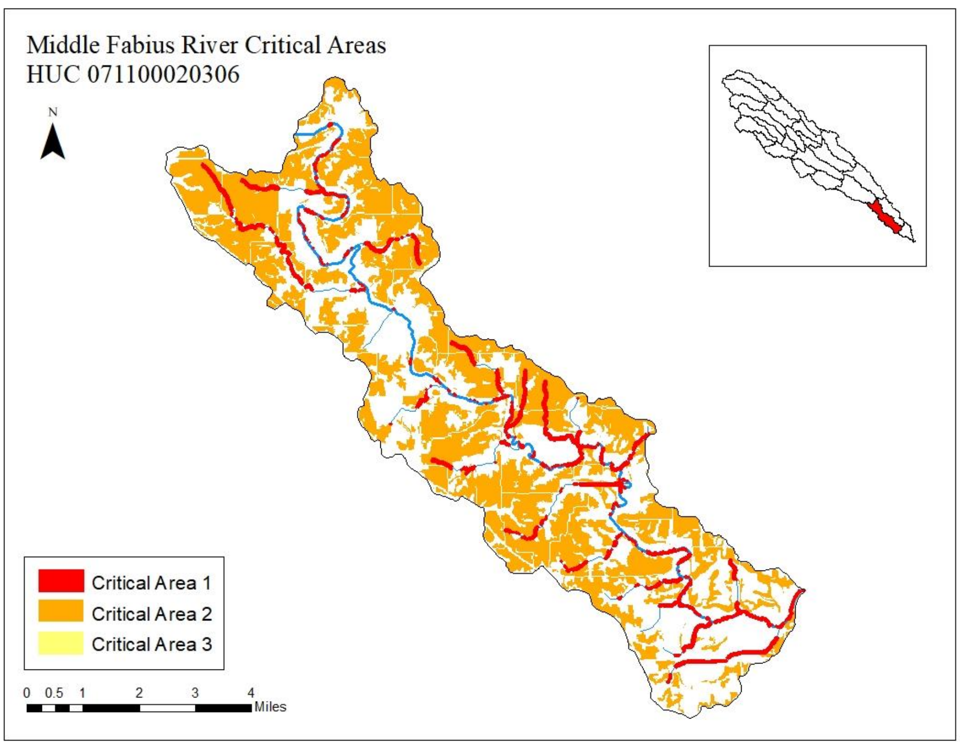

Figure F9. Critical areas 1-3 targeted for BMP implementation in Middle Fabius River subwatershed (HUC 071100020306).

Priority 2 Subwatersheds

Priority 2 subwatersheds are those HUC12s that the STEPL model estimates to have the second greatest annual sediment loading and are prioritized for implementation during Years 6 through 10 (calendar years 2026-2030) of this WMP (Figure F10). The estimated annual sediment loads for this tier ranged from an average of 13,357 to 17,659 tons per year (Table F1). Figures F11 through F18 present each HUC12 subwatershed and the extent of Critical Areas 1 through 3.

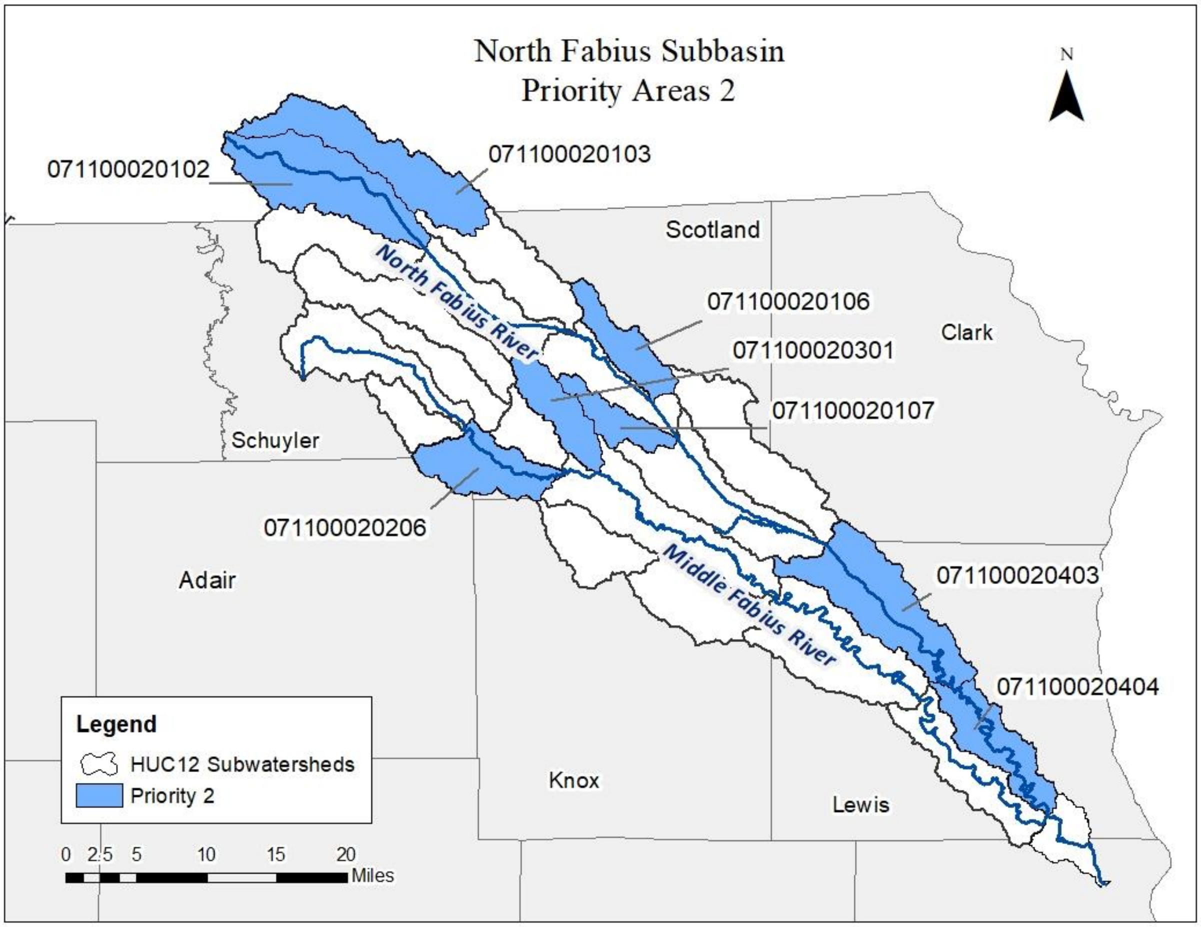

Figure F10. Priority 2 subwatersheds are shown in blue.

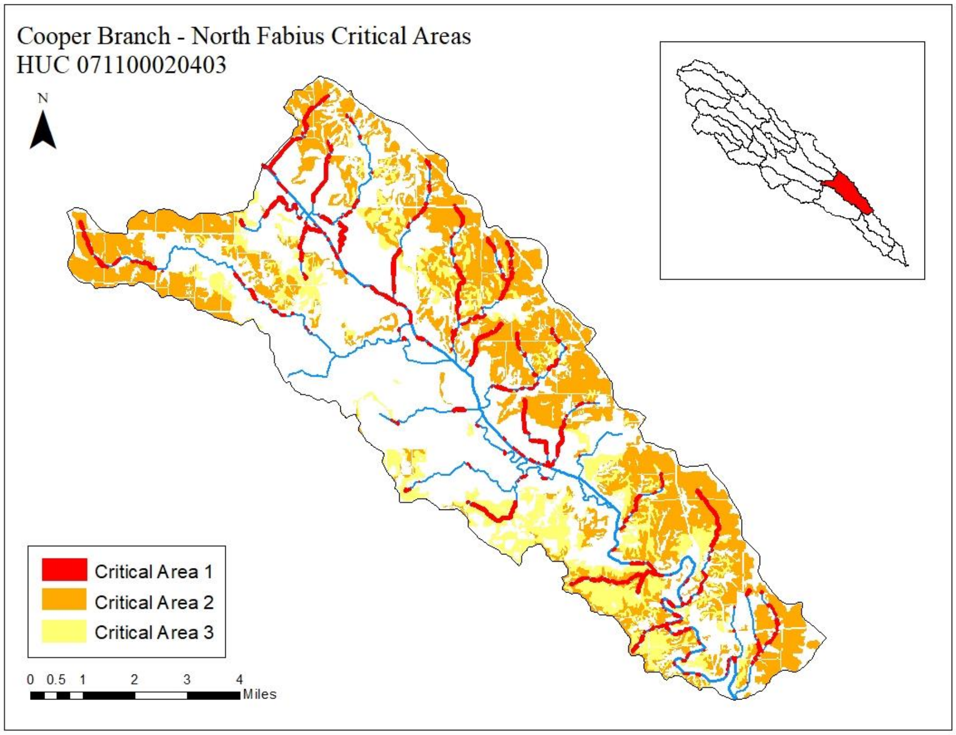

Figure F11. Critical areas 1-3 targeted for BMP implementation in Cooper Branch - North Fabius River subwatershed (HUC 071100020403).

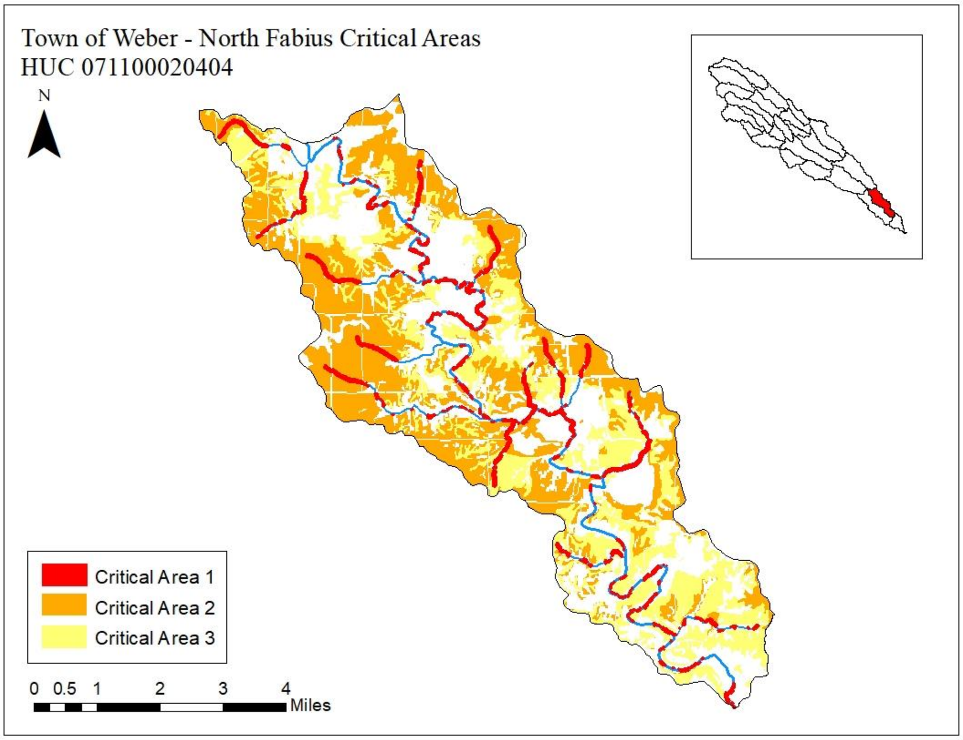

Figure F12. Critical areas 1-3 targeted for BMP implementation in Town of Weber - North Fabius River subwatershed (HUC 071100020404).

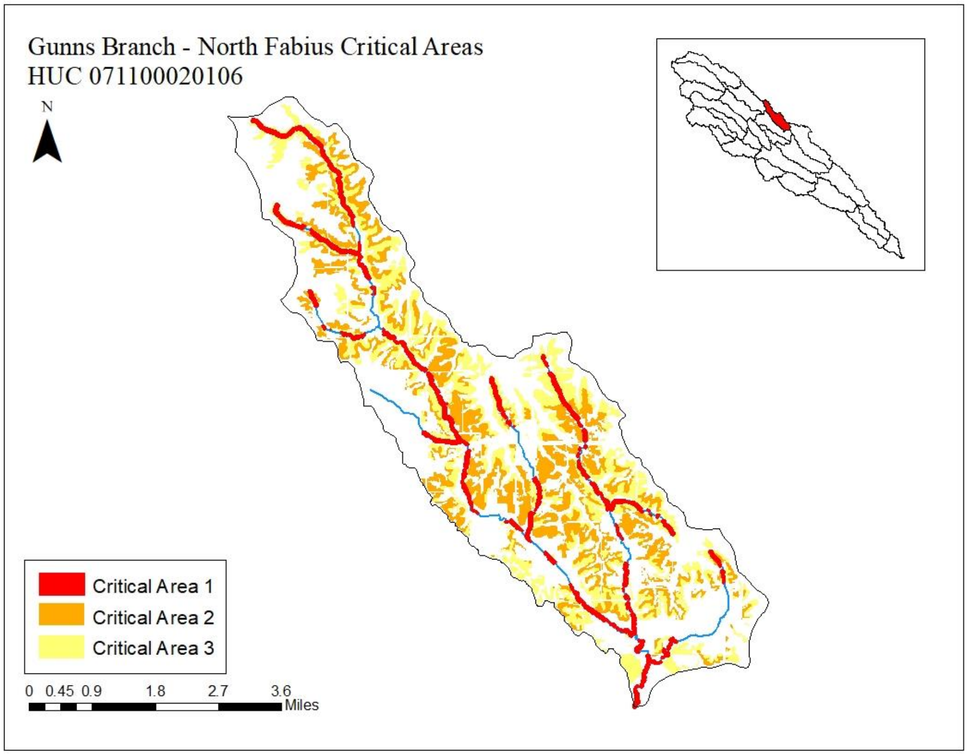

Figure F13. Critical areas 1-3 targeted for BMP implementation in Gunns Branch **-** North Fabius River subwatershed (HUC 071100020106).

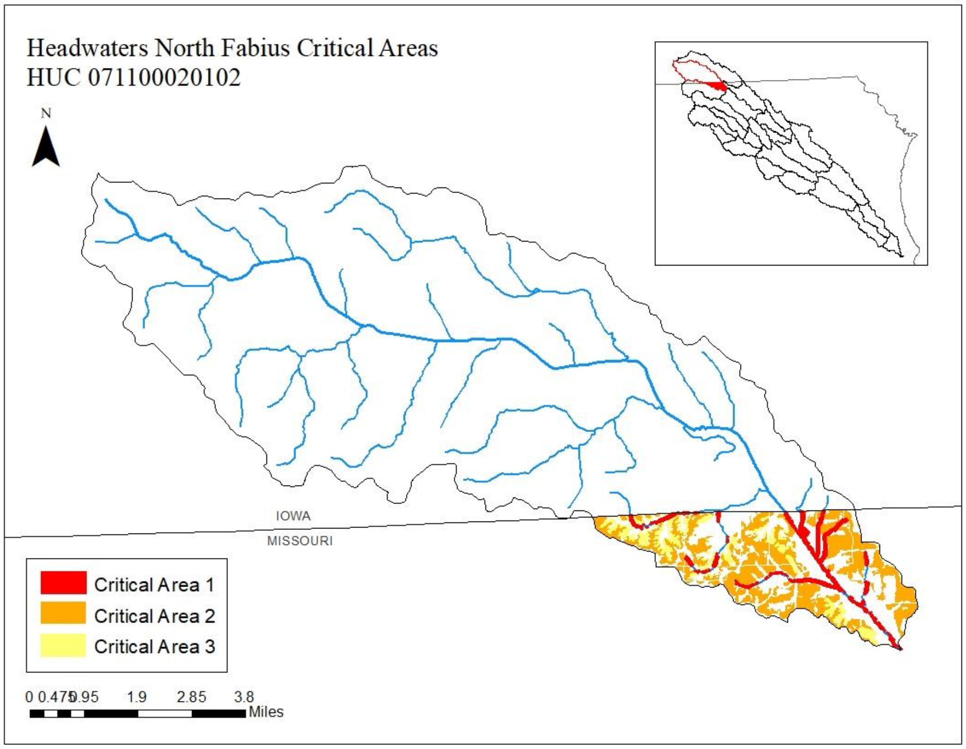

Figure F14. Critical areas 1-3 targeted for BMP implementation in Headwaters North Fabius River subwatershed (HUC 071100020102).

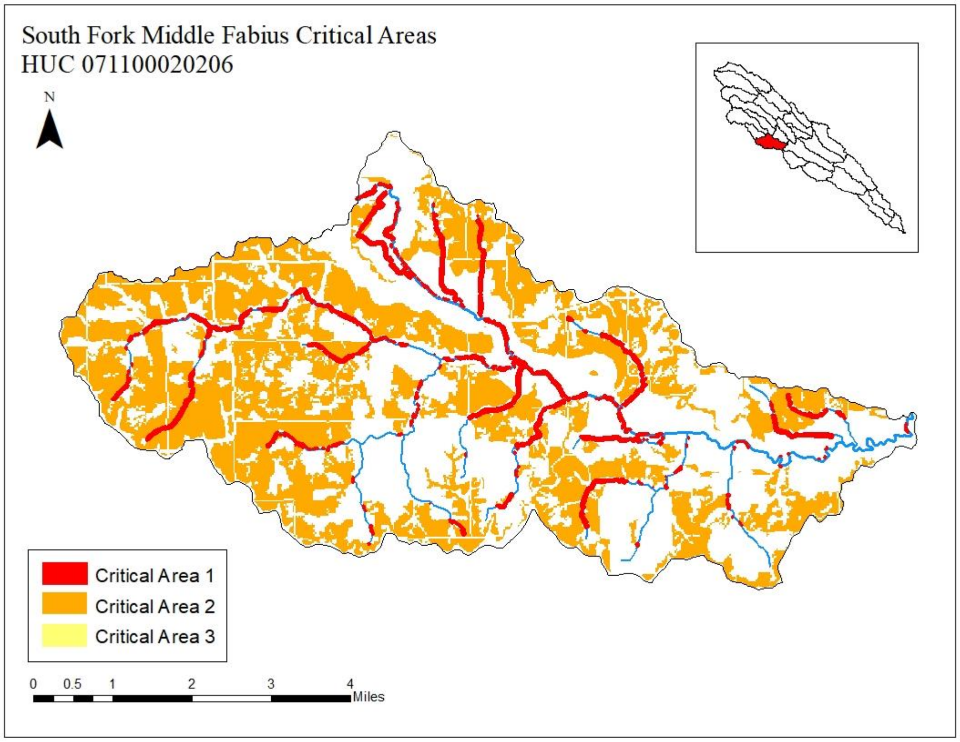

Figure F15. Critical areas 1-3 targeted for BMP implementation in South Fork Middle Fabius River subwatershed (HUC 071100020206).

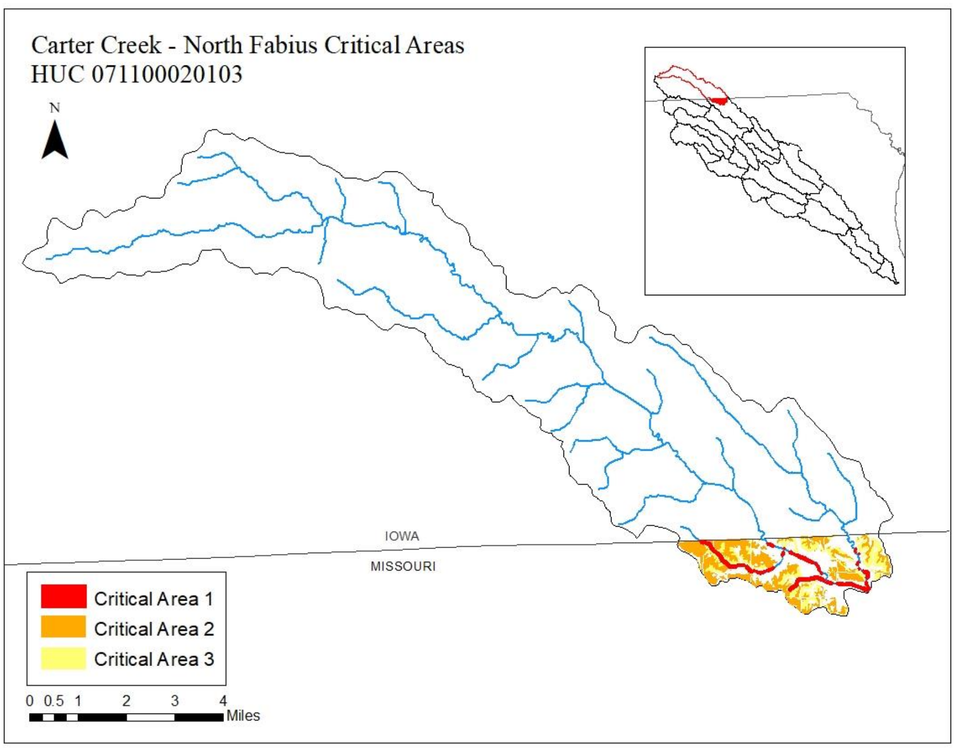

Figure F16. Critical areas 1-3 targeted for BMP implementation in Carter Creek - North Fabius River subwatershed (HUC 071100020103).

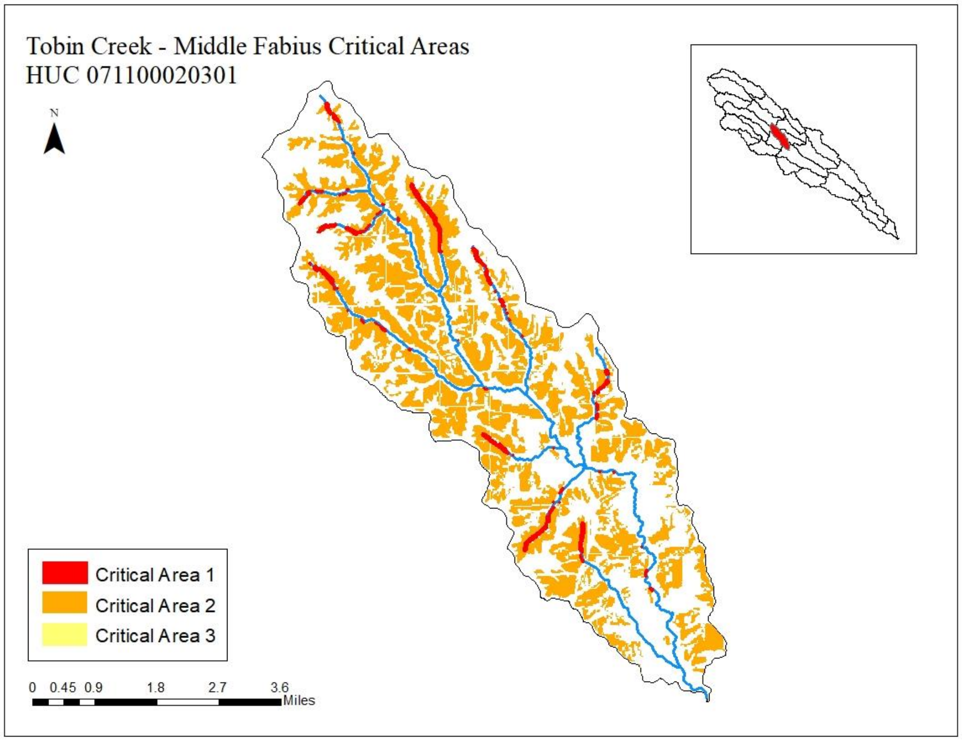

Figure F17. Critical areas 1-3 targeted for BMP implementation in Tobin Creek - Middle Fabius River subwatershed (HUC 071100020301).

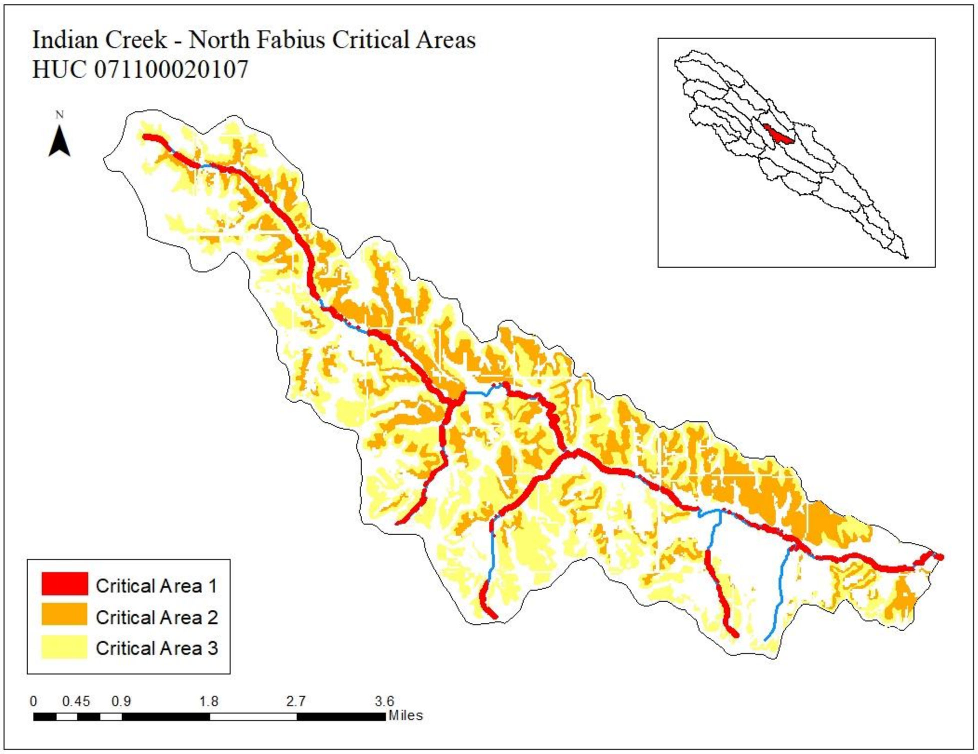

Figure F18. Critical areas 1-3 targeted for BMP implementation in Indian Creek - North Fabius River subwatershed (HUC 071100020107).

Priority 3 Subwatersheds

Priority 3 subwatersheds are the eight HUC12s that the STEPL model estimated to have the least annual sediment loading. These subwatersheds are prioritized for implementation during Years 11 through 20 (calendar years 2031-2040) of this WMP (Figure F19). The estimated annual sediment loads for this tier ranged from an average of 3,250 to 11,352 tons per year (Table F1). Figures F20 through F28 present each HUC12 subwatershed and the extent of Critical Areas 1 through 3.

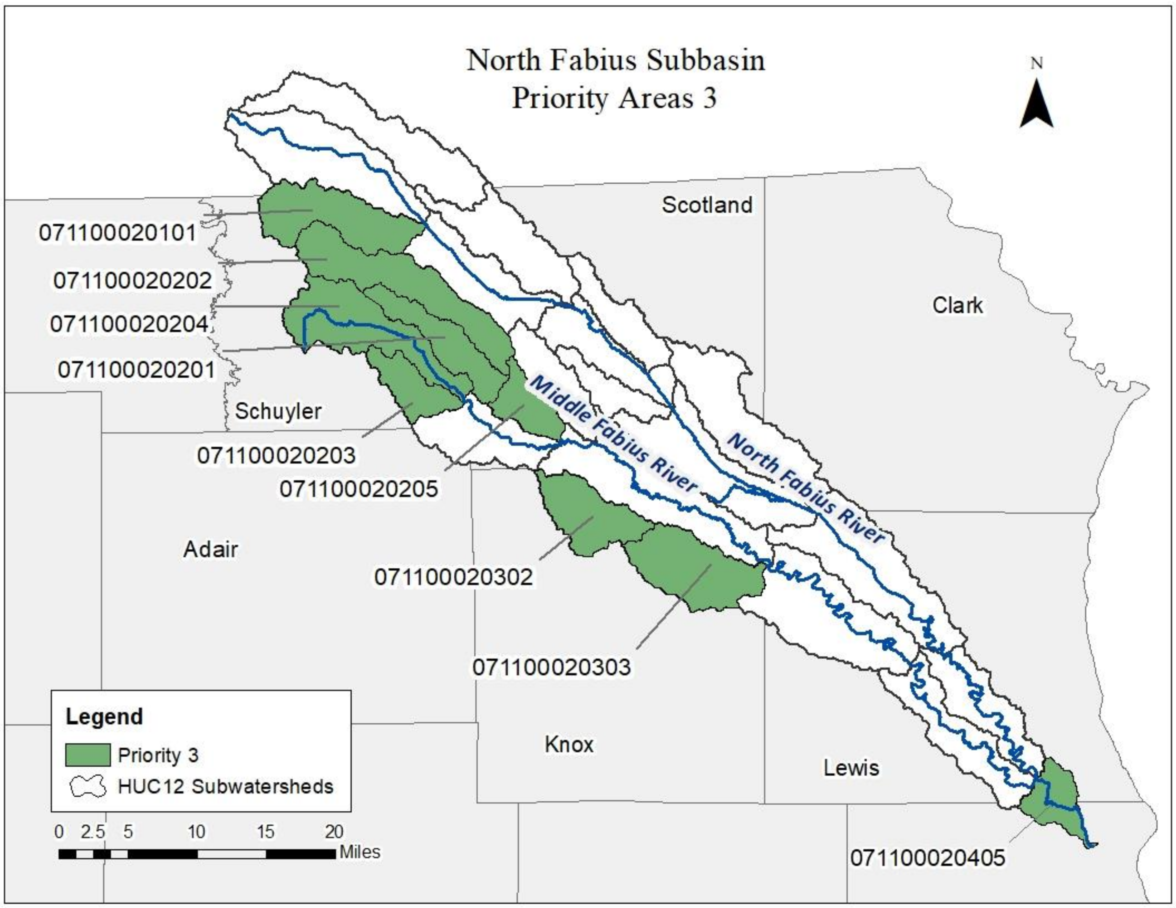

Figure F19. Priority 3 subwatersheds are shown in green.

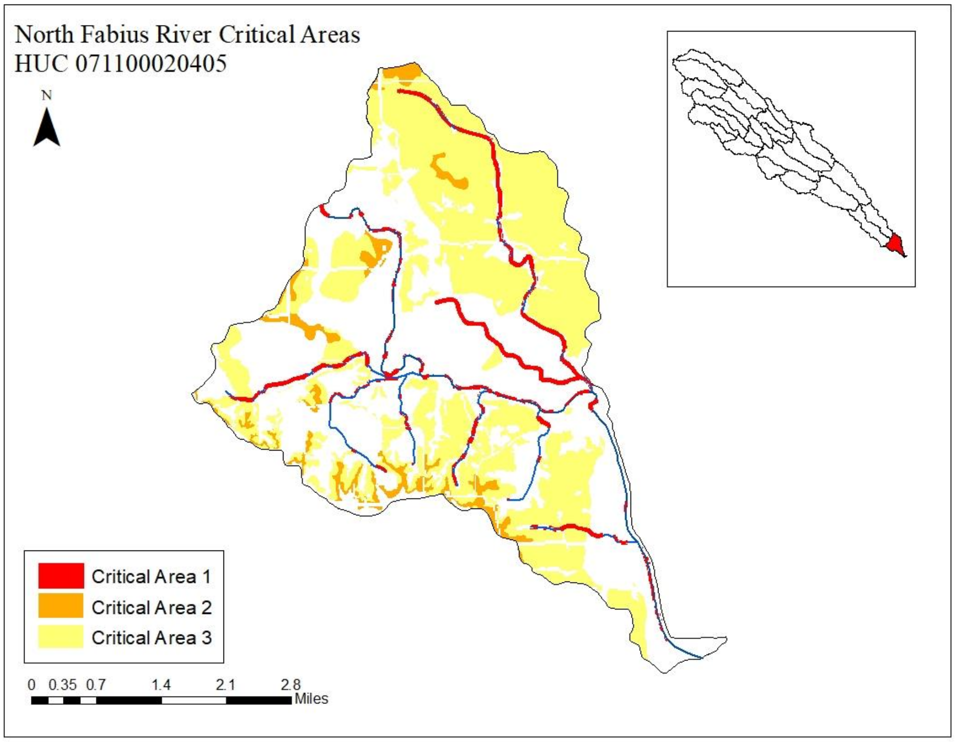

Figure F20. Critical areas 1-3 targeted for BMP implementation in North Fabius River subwatershed (HUC 071100020405).

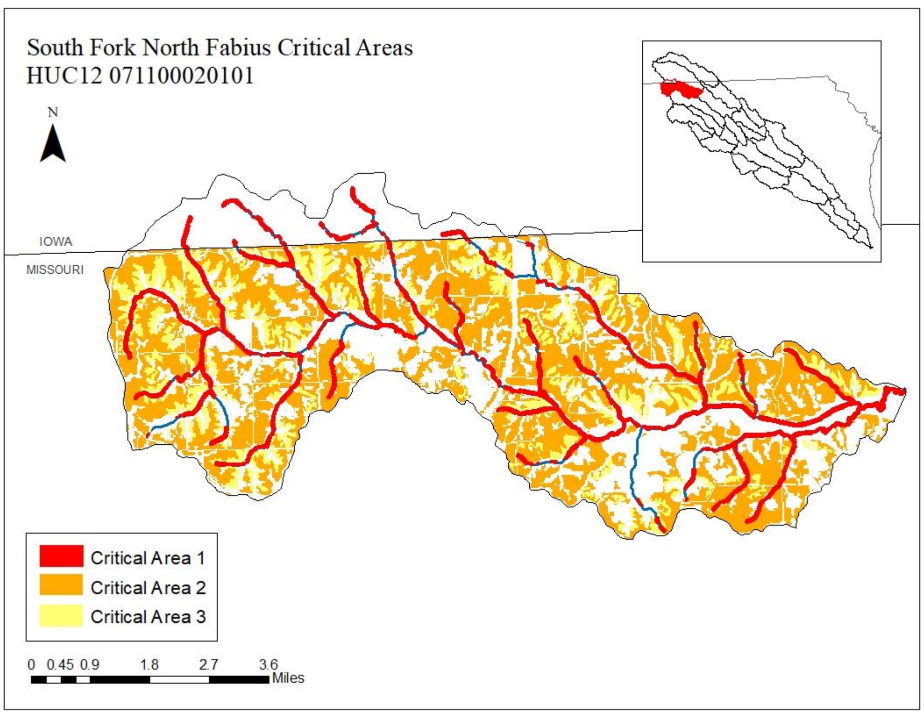

Figure F21. Critical areas 1-3 targeted for BMP implementation in South Fork North Fabius River subwatershed (HUC 071100020101).

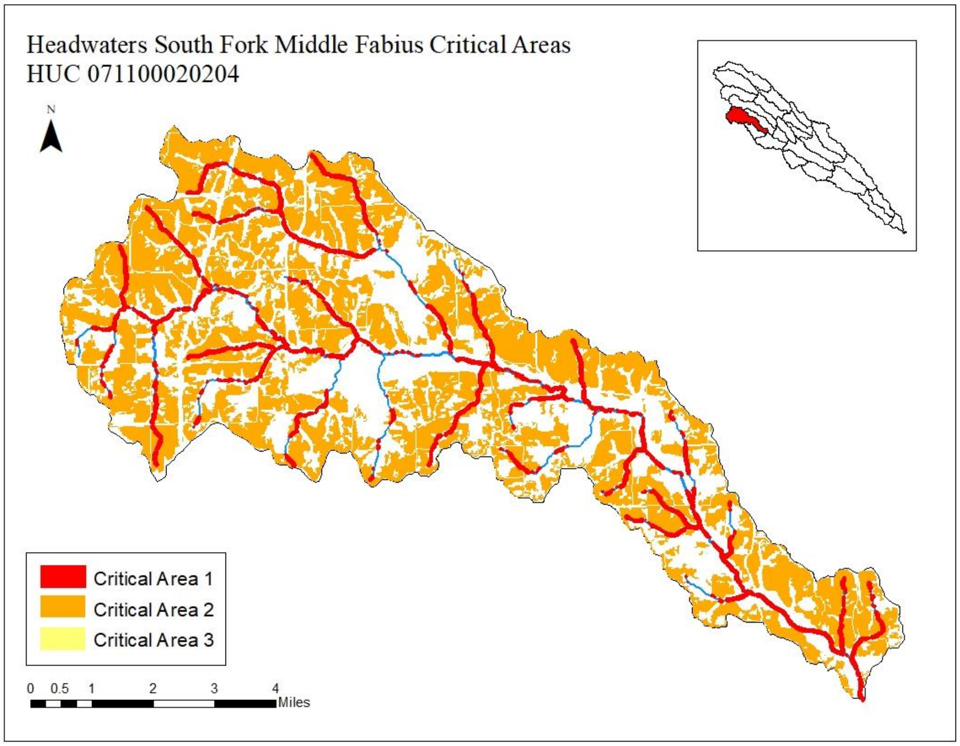

Figure F22. Critical areas 1-3 targeted for BMP implementation in Headwaters South Fork Middle Fabius River subwatershed (HUC 071100020204).

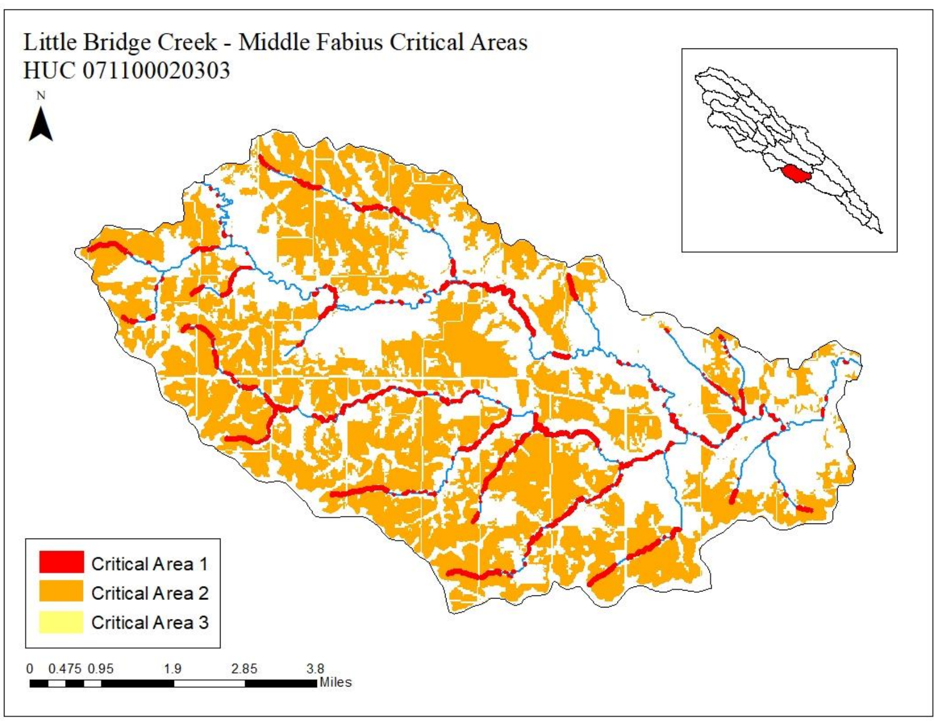

Figure F23. Critical areas 1-3 targeted for BMP implementation in Little Bridge Creek - Bridge Creek subwatershed (HUC 071100020303).

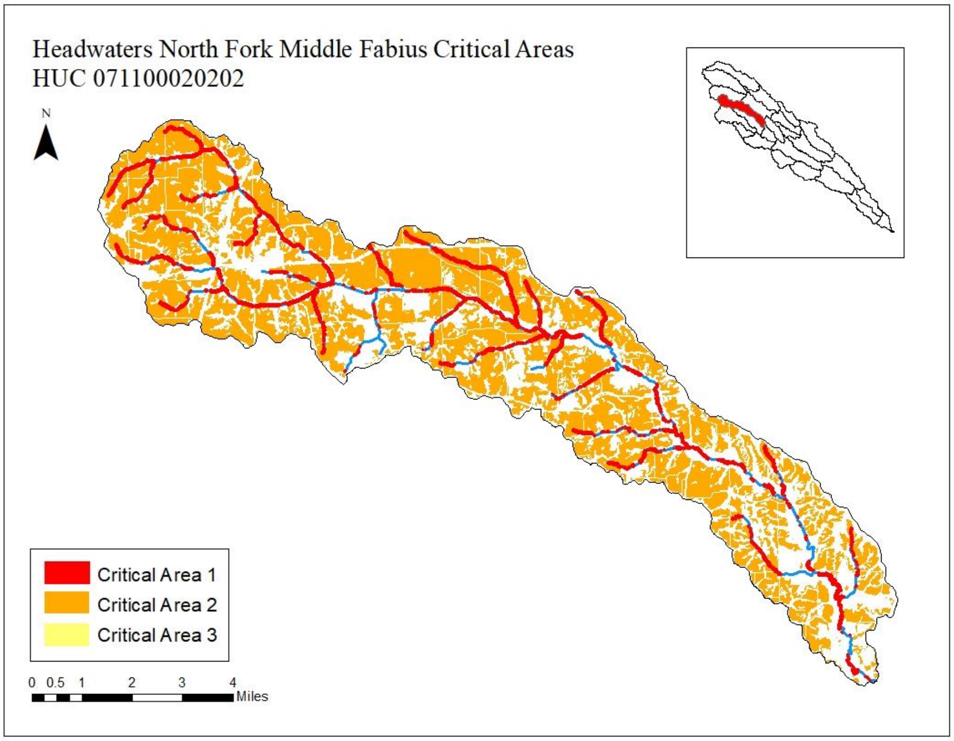

Figure F24. Critical areas 1-3 targeted for BMP implementation in Headwaters North Fork Middle Fabius River subwatershed (HUC 071100020202).

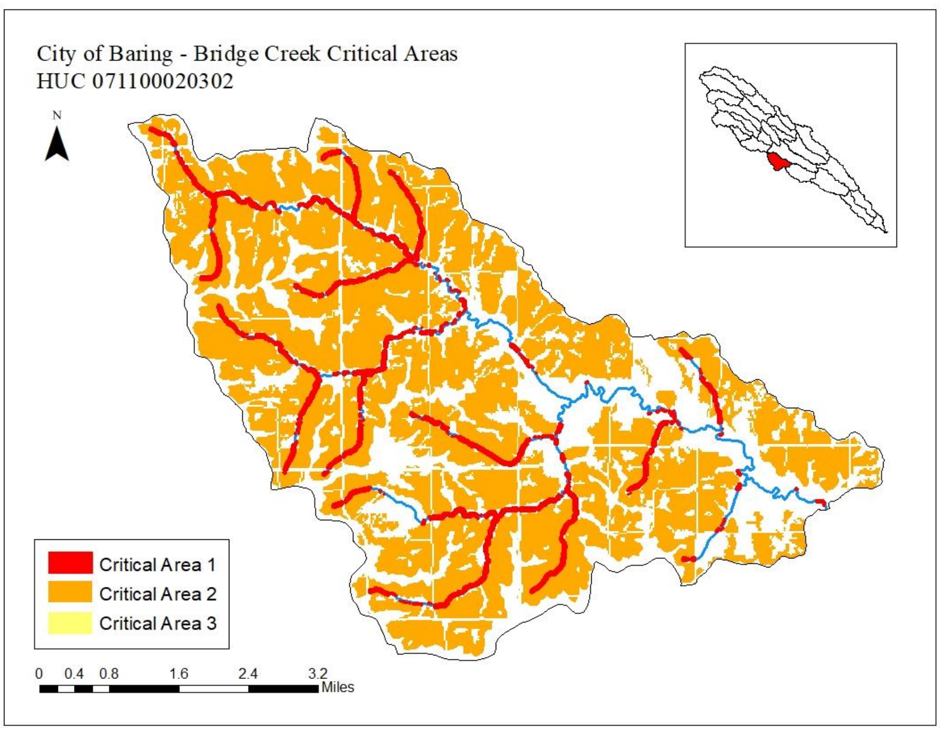

Figure F25. Critical areas 1-3 targeted for BMP implementation in City of Baring - Bridge Creek Middle Fabius River subwatershed (HUC 071100020302).

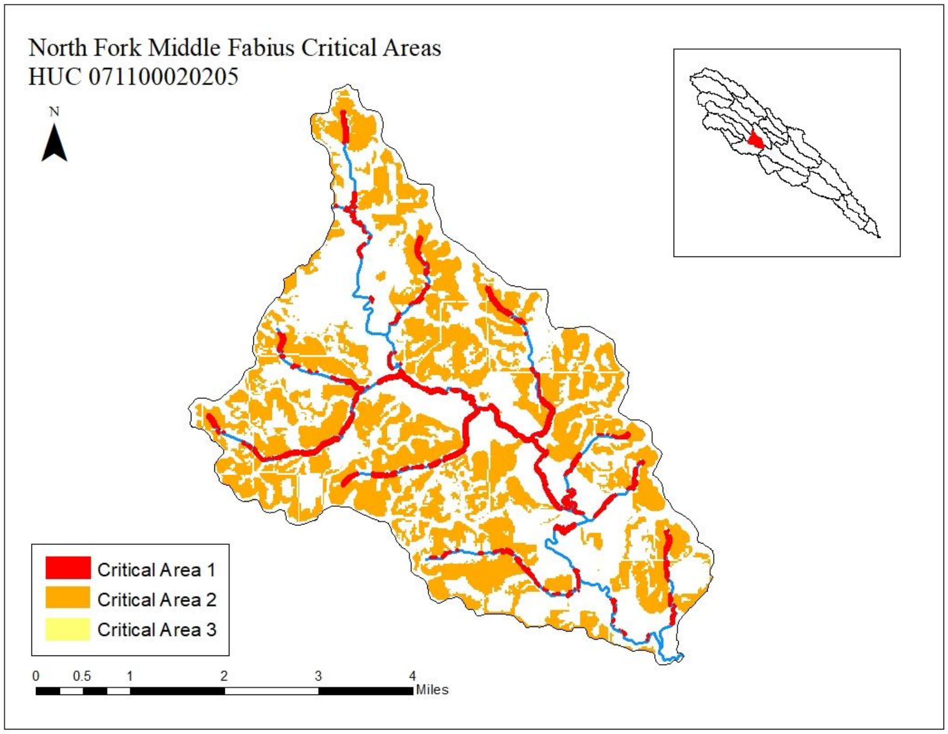

Figure F26. Critical areas 1-3 targeted for BMP implementation in North Fork Middle Fabius River subwatershed (HUC 071100020205).

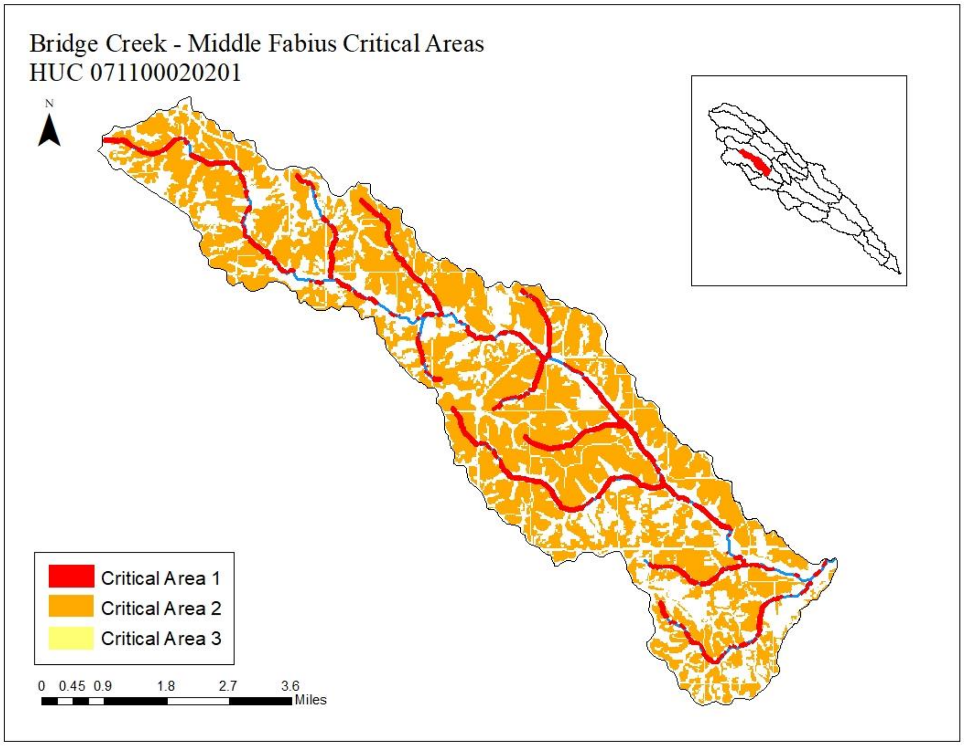

Figure F27. Critical areas 1-3 targeted for BMP implementation in Bridge Creek - Middle Fabius River subwatershed (HUC 071100020201).

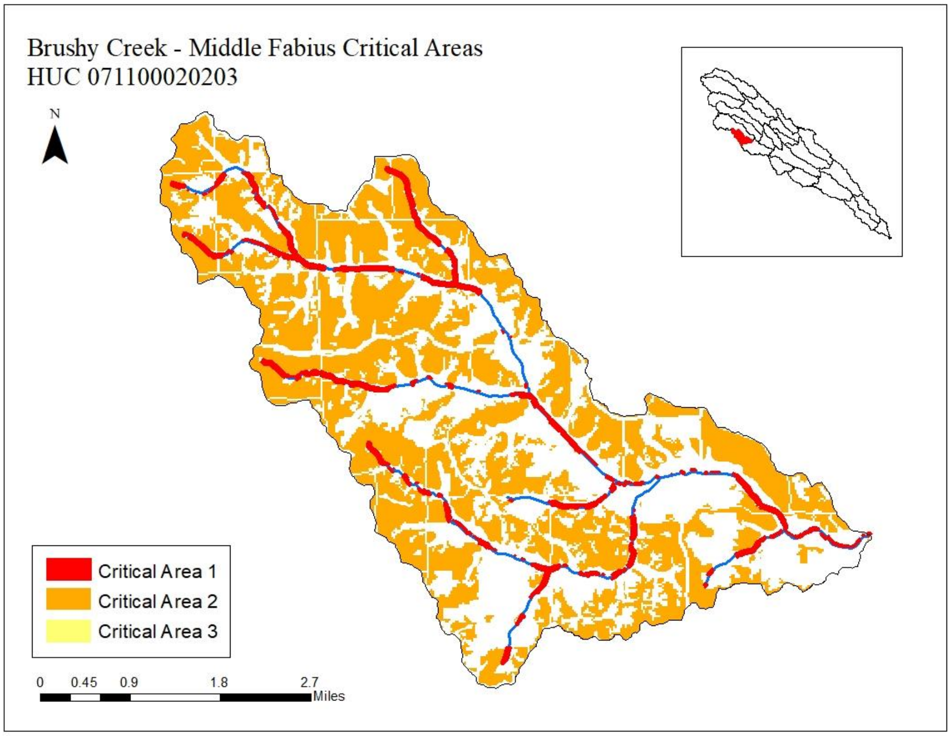

Figure F28. Critical areas 1-3 targeted for BMP implementation in Brushy Creek - Middle Fabius River subwatershed (HUC 071100020203).

Appendix G – SWAT Modeling

The SWAT model was run by a graduate student at the University of Missouri to analyze sediment loading for the North Fabius River (WBID 56). Through a contract agreement with the University of Missouri - Columbia, the Schuyler County Soil and Water Conservation District obtained the services of the university to implement watershed modeling in the North Fabius watershed. The modeling was used to obtain technical information needed to update the North Fabius watershed plan. The modeling was conducted by a University Graduate Student (Austin Davis) with supervision from Dr. Allen Thompson. The purpose of the modeling project included identifying critical areas for sediment loading in the North Fabius Watershed and simulate load reductions that would occur if various BMPs were implemented in these target areas. Over all, the modeling project included:

- Acquiring necessary input data for ArcSWAT model, including DEM, land use, soil, and climate information.
- Building and calibrating ArcSWAT model using data from U.S. Geological Survey (USGS) gauging stations.
- Using the output from ArcSWAT models to delineate priority levels to sub-watersheds based on their pollutant contribution.
- Using Missouri's Water Quality Standards to determine the required load reduction in each parameter for the "high priority" watersheds.
- Estimating the types, locations and cost of BMP installations required to meet Water Quality Standards.

Below is the majority of the modeling report submitted by the modeler. While the critical, priority areas for the entire 2020 WMP planning area differ from those identified in SWAT model. The SWAT output maps are presented here as a resource to help guide BMP placement in the North Fabius Watershed.

Software Descriptions

- ArcMap10.2.1
- ArcSWAT 2012 (32-bit)
- Web-based Load Calculation using LOADEST (version 2012)
- Baseflow Program

North Fabius Watershed Information

The North Fabius watershed is a HUC8 watershed; and the modeled portion of it contains twelve distinct HUC12 subwatersheds. These HUC12 subwatersheds are the focus of the nonpoint source prioritization in this report. There have already been a number of management practices put into place within the North Fabius, so an important part of optimizing future placement is recognizing these past locations. An additional consideration in this report is that the locations of practices prior to 2014 are listed according to HUC14 subwatersheds. HUC14 subwatersheds are approximately equivalent in size to a HUC12, but belong to an older classification scheme, which is no longer in use. Thus, ArcGIS was used to transpose the HUC14 subwatersheds onto the modern HUC12 subwatersheds to determine the relative percentage of each HUC14 located in the modern HUC12 subwatershed. This allowed for the previous practices in the subwatershed to be listed according to HUC12 for the period of 2009-2017.

SWAT Calibration and Methodology

SWAT Model Input Data

The inputs for the ArcSWAT model were obtained from a number of sources depending on the type of data (Table G1). The DEM, or Digital Elevation Model, information was acquired from the 30 meter (1 arc second) USGS survey data available from their Global Data Explorer tool (http://gdex.cr.usgs.gov/gdex/). Soil data was obtained from the Soil Survey Geographic Database (SSURGO). Climate information was gathered from the National Oceanic and Atmospheric Administration (Table G2). Land use was classified into cropland, pasture, forest, and urban components based on the 2011 National Land Cover Database.

Table G1. Model Input Data Sources

Input	Data Source	Data Type/Resolution
Digital Elevation Map	https://gdex.cr.usgs.gov/gdex/	30-m DEM
Land Cover		2011 National Land Cover Database
Soils	http://websoilsurvey.nrcs.usda.gov/	SSURGO
Temperature	https://www.ncdc.noaa.gov/cdo-web/	Daily Temp Data from NOAA Stations
Precipitation		Daily Precip Data from NOAA Stations
Stream Flow	https://waterdata.usgs.gov	Monthly Flow Data from USGS
Water Quality		Sediment Concentration Data from USGS

Table G2. Locations of NOAA weather stations used for temperature and precipitation inputs.

Temperature Stations	Precipitation Stations
Centerville, IA	Downing, MO
Kirksville, MO	Luray 2 N, MO
Memphis, MO	Edina, MO
Steffenville, MO	Centerville, IA
Unionville, MO	Kirksville, MO
Bloomfield 1 WNW, IA	Memphis, MO
Quincy Dam 21, IL	Steffenville, MO
	Bloomfield 1 WNW, IA
	Quincy Dam 21, IL
	Unionville, MO

ArcSWAT 2012

Once the above inputs are supplied to ArcMap 10.2.1, the subwatershed areas will be delineated into smaller catchments based upon the DEM data and the user-inputted threshold size. Threshold size is expected to be selected somewhere between three and five percent, depending on subwatershed characteristics, for efficient modeling while optimizing accuracy of predictions for flow rate, sediment, and nutrients[45]. The SWAT model delineated the North Fabius Watershed into 291 catchments that are each associated with a stream reach. The catchments are further distributed into 9,074 hydrologic response units (HRUs), which assumes a constant soil, land-use, and slope, although this does not necessarily represent a contiguous area. These HRUs represent a percent of a given catchment with these features, but does not necessarily represent a contiguous area.

Water is routed in and out of each catchment through a minimum of one reach following a “bucket method”. This means that the water quality and quantity of one entire reach are calculated, and this water is then moved in its entirety to the next reach, where the next batch of calculations will take place. The soils and land use information is used to determine water behavior within an HRU on its way to the reach, based on its soil curve number and modeled evapotranspiration[46]. Sediment routing out of the catchment is controlled the Modified Universal Soil Loss Equation (MUSLE).

Flow and sediment data was collected at the USGS Gauge 05497150 on the North Fabius River near Ewing, MO. This gauge was chosen because it was the only gauge in the watershed with continuous data for the modeled period of January 2000 to December 2015. Stream flow data was collected on a daily basis with the stream gauge, while suspended sediment data was collected approximately once every two months via grab sample. The sediment and flow data were run through the Purdue LOADEST online calculator in order to estimate monthly sediment yield, which was used for calibration.

[45] (Jha 2004)*reference not listed in modeling report

[46] Arnold, J.G., D. Moriasi, P. Gassman, K. Abbaspour, M. White, and R. Srinivasan. 2012. SWAT: model use, calibration, and validation. Transactions of the ASABE 55:1491-1508.

LOADEST

Water quality data at the USGS gauge 05497150 on the North Fabius River near Ewing, MO was collected approximately once every two months. This necessitated the performance of a regression analysis in order to establish monthly sediment estimates. LOAD ESTimator (LOADEST) is a FORTRAN program developed by the USGS to estimate stream sediment loading given daily stream flow data and the sediment sampling dates and values[47]. An online tool for this program was developed at Purdue University, and this was the regression model used to process the data for this model[48].

Baseflow Program

Baseflow refers to the fraction of stream flow that does not come from direct surface runoff following a precipitation event. Instead, this water enters the stream from ground flow or other delayed sources. The level of baseflow in a watershed is highly dependent on the land use, topography, soil, and even the shape of the basin. The Baseflow Program uses a digital filter technique to approximate this portion of the flow. The outputs from this program were used to select groundwater inputs during the calibration of the model.

Baseline Management Inputs

After following the general procedure of creating the watershed in ArcSWAT using the spatial data and climate tables as shown in Table G1, the watershed inputs were manually refined to further match local land use practices. This process involved land use splits for the creation of HRU that match reality better than that provided by the National Land Cover Database. These land use splits can be found below in Table G3. The corn and soybean management inputs used follow those used in the nearby Goodwater Creek Experimental Watershed, which has previously been modeled using ArcSWAT[49]. Management inputs for hay, pasture, and clover were determined through discussions with local experts and the use of reasonable average values.

It was necessary that there be distinct HRU for the pasture and clover because ArcSWAT does not allow more than one type of plant growth at a given time in a given HRU; however, these are intended to represent an intercropping of 50% clover on 30% of the pasture land in the watershed. It was also determined by local experts that the stocking rate for cattle was about 4 acres per cow-calf pair being used by 90% of producers and another 10% using management intensive grazing systems that utilized about 2 acres per cow-calf pair. Without spatial information to split this up, the stocking rate in the watershed uses the average of these values.

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[47] Runkel, R.L., C.G. Crawford, and T.A. Cohn. 2004. Load Estimator (LOADEST): A FORTRAN Program for Estimating Constituent Loads in Streams and Rivers. Techniques and Methods Book 4, Chapter 5. U.S. Geological Survey. https://pubs.usgs.gov/tm/2005/tm4A5/pdf/508final.pdf

[48] Engel, B., K.J. Lim, J.H. Hunter, I.C. Chaubey, J.E. Quansah, L. Theller, and Y.S. Park. 2014. Web-based LDC Tool: User's Guide. Purdue University. https://engineering.purdue.edu/mapserve/ldc/pldc/help/Load_Duration_Manual_2014.pdf

[49] Baffaut, C., E.J. Sadler, F. Ghidey, and S.H. Anderson. 2015. Long-Term Agroecosystem Research in the Central Mississippi River Basin: SWAT Simulation of Flow and Water Quality in the Goodwater Creek Experimental Watershed. Journal of Environmental Quality 44: 84-96.

Table G3. Land Use Splits for Baseline

National Land Cover Database	Land Use Split	%
Hay	Hay	50
Hay	Pasture	35
Hay	Clover	15
AGRR	Conventional Till Corn	15
AGRR	Conservation Till Corn	15
AGRR	No Till Corn	15
AGRR	Conventional Soybean	27.5
AGRR	Conservation Soybean	13.75
AGRR	No Till Soybean	13.75

Baseline BMP Inputs

In order to correctly calibrate the model baseline it was necessary to provide model inputs to represent the BMPs that are already being used within the watershed. The BMPs modeled in the North Fabius watershed consist of vegetated riparian buffers, dry holes, terraces, and pasture management. While there was some information on the extent of these, it was quite general and uncorroborated with spatial data. As such, the extent of the riparian buffers, dry holes, and terraces in the watershed was determined manually using aerial imagery for all 291 catchments in the model.

Filter strips ratio refers to the ratio between the area of the filter strip and the area of the field. Average filter strip values were estimated by subwatershed and applied to all agricultural land uses in the subwatershed.

Dry holes in the watershed were modeled as ponds following the recommended conservation practice modeling guide for ArcSWAT. As such, the “ponds” in this watershed are used to estimate both permanent ponds and ephemeral dry holes. Additionally, each catchment in ArcSWAT is only able to consider a single pond. Therefore, the pond values used represent a conceptual pond that is actually the aggregate of the ponds and dry holes in the subbasin. Pond principle volumes are estimated using a four-foot depth when surface area is less than 20 acres and a five-foot depth when greater. The emergency spillway surface area was set as equal to the principle spillway surface area in an attempt to better model ponds as dry holes, which are not designed with traditional spillways. Additionally, the pond emergency volumes are input as fifty times larger than the principle spillway so that there is not overflow outside of extreme events. This method follows a similar one performed by Almendinger and Murphy[50] when modeling similar ground depressions as ponds.

Terraces were placed by looking at the estimated percentage of each catchment that was terraced. In catchments that were identified as having terraces, an agricultural HRU was selected to match the total catchment percentage. The RUSLE practice factor and curve number were updated to match the values for terracing on that land use, slope, and soil type according to the SWAT manual. Terrace slope lengths were set equal to 36 meters.

[50] Almendinger, J.E., and Murphy, M.S. 2007. Constructing a SWAT model of the Willow River watershed, western Wisconsin. St. Croix Watershed Research Station, Science Museum of Minnesota. 84 pp.

Grazing practices were set in the land use splits for HRU definition, by splitting the hay into 50% hay, 35% pasture, and 15% clover to represent that 60% of the pasture land is inter-seeded at an equal ratio with clover.

Calibration and Validation

The model was run for a total of 16 years from the period of January 2000 through December 2015. This time frame is then split into three distinct modeling phases. These are the warm-up period, the calibration period, and the validation period. The warm-up period is important for allowing the model to get equilibrated for some number of years prior to the desired results. The calibration period is then used to adjust model parameters in order to fit the modeled data to the observed data. Finally, the validation period is checked in order to ensure that the model is working properly. If the model parameters are chosen properly during the calibration period, then it should hold true, and the validation period should also be satisfactory. This model used a 6 year warm-up period, thus the results are from January 2006 through December 2015. This is broken into a 5 year calibration period from 2006 through 2010, and a validation period from 2011 through 2015.

Model calibration and validation is based on a number of calculated parameters comparing the observed and modeled data. This project used the Nash-Sutcliffe model efficiency coefficient (NS) and the Percent Bias (PBIAS) to compare model effectiveness. The following guidelines were used to describe the goodness-of-fit for the model[51].

Calibration Results

As is shown in Table G4, the results of the monthly flow calibration are firmly within the established “good” criteria. The Nash-Sutcliffe value during the calibration period is 0.74, which is at the top of the range for a “good” model evaluation. The Nash-Sutcliffe compares how well the observed data fits the 1:1 line versus the modeled data. The optimal value for Nash-Sutcliffe is 1, and the value ranges down to $-\infty$. The Percent bias is a reflection of the average tendency of a model to either overestimate or underestimate the observed data. A positive PBIAS is indicative of model underestimation, while a negative PBIAS shows the opposite (Table G5). During the calibration period for the model, it can be seen that the model generally underestimates the model. This flips during the validation period, where the model begins slightly overestimating. It can be seen in Figure G2 that the model generally overestimates periods of extreme low flows while underestimating the highest peak flows. This explains the difference in the PBIAS between the calibration and validation, as the calibration period generally has quite high flows, and the validation period includes the drought of 2012, as well as just exhibiting generally lower flows. However, as seen by the improvement in the Nash-Sutcliffe for the validation period, the model is still managing to match the magnitude of the variance in the observed data.

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[51] Moriasi, D.N., J.G. Arnold, M.W. Van Liew, R.L. Bingner, R.D. Harmel, and T.L. Veith. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE 50(3): 885-900.

Table G4. Goodness-of-fit criteria for the Nash-Sutcliffe Coefficient[35].

Very Good:	0.75 < NSE < 1
Good:	0.65 < NSE < 0.75
Satisfactory:	0.5 < NSE < 0.65

Table G5. Goodness-of-fit criteria for the PBIAS coefficient[35].

	Stream Flow	Sediment
Very Good:	PBIAS < ± 10%	PBIAS < ± 15%
Good:	± 10% < PBIAS < ± 15%	± 15% < PBIAS < ± 30%
Satisfactory:	± 15% < PBIAS < ± 25%	± 30% < PBIAS < ± 55%

Table G6. Monthly Flow Calibration Results

	NSE	PBIAS
Calibration Period (Jan 2006 – Dec 2010)	0.74	13.85%
Validation Period (Jan 2011 – Dec 2015)	0.81	-11.83%
Total Modeling Period (Jan 2006 – Dec 2015)	0.78	3.05%

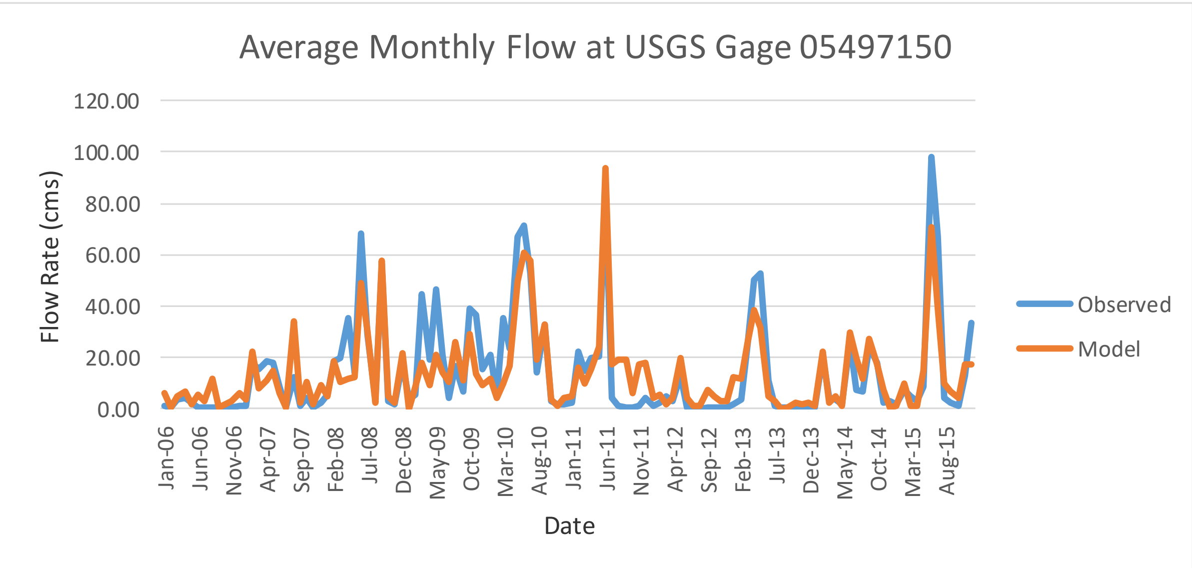

Figure G2. Average Observed and Modeled Monthly Flow Rate at USGS Gauge 05497150

Table G7. Monthly Sediment Yield Calibration Results at USGS Gauge 05497150

	NSE	PBIAS
Calibration Period (Jan 2009 – Dec 2011)	0.82	-27.58%
Validation Period (Jan 2012 – Dec 2014)	0.60	-16.09%
Total Modeling Period (Oct 2008 – Dec 2015)	0.74	-17.54%

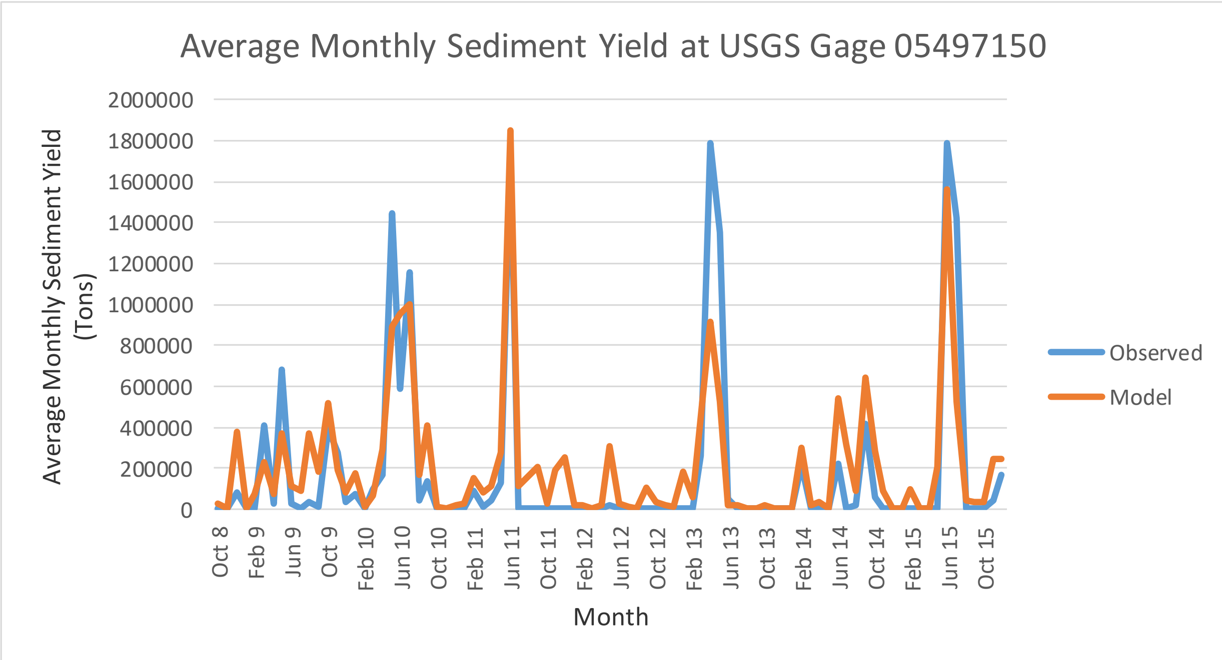

Figure G3. Average Observed and Modeled Monthly Sediment Yield at USGS Gauge 05497150.

As can be seen in Table G7, the sediment calibration for the watershed is satisfactory using a calibration period of January 2009 through December 2011 and a validation period from January 2012 through December 2014. The calibration and validation periods differ from the flow due to a lack of water quality data to match the flow period. Thus these 3 year periods were selected as the maximum length of time that could be adequately compared without including seasonal variation.

Figure G3 demonstrates that the model is better at matching the sediment yield peaks, which it tends to either match quite well or slightly underestimate. When sediment yields are very low, the model tends to overestimate the sediment yield. This is reasonable, as most sediment gets transported at higher flows. This can also be noticed in Table G7 in the difference to how the model responds with the Nash-Sutcliffe and PBIAS values for the calibration and validation. During the calibration period, which experiences higher rainfall and greater volatility, the Nash-Sutcliffe value is “very good” as the model is matching the magnitude of change well. However, the PBIAS is only considered “good”, as the model is consistently providing a slight overestimation. That overestimation is exaggerated during the second half of 2011, which corresponds with a dry period of especially low flows. The opposite is found during the validation period, where the PBIAS is found to be “good”, and the Nash-Sutcliffe is found to be “satisfactory”. This makes some sense due to the differences in the precipitation and flow during the validation period, which has much lower flows in general and fewer peak events. The peak events that do occur during the validation period are well matched.

It is important to consider that the monthly sediment yield has to be estimated using the LOADEST program, which can only be as accurate as the data provided. In this instance, monthly sediment yield estimates are based on daily flow data and sediment grab samples that represent a single moment in time and are collected approximately once every two months. Therefore, it is quite possible that there was greater sediment yield taking place during the period of June 2011 through January 2013 than was captured by LOADEST and these particular grab samples. The same consideration must be had for the extreme peaks that occur in 2010, 2011, 2013, and 2015. There is a reasonable chance that these values could be greatly affected by a particular grab sample. Greater data collection is required for improved model trust.

Baseline Sediment Yield Results

The average annual watershed value for sediment loading at USGS Gauge 05497150 was given as 20.145 tons of sediment per hectare. This is the value that the model calculates as the annual average at the outlet. Baseline model outputs for each subwatershed are provided below in Figures G4 - G18. Table G12 at the end of this report lists the baseline BMP inputs for each catchment. For planning purposes, the annual sediment yield was averaged for each of the twelve HUC12 watersheds found within the North Fabius HUC8. The HUCs shown below are comprised only of complete subwatersheds, and as such, may have slight differences in shape compared to the USGS data layer. The congruity between the subbasin-mosaic HUC8s and the USGS HUC8s points to an accurate delineation of subwatersheds in the watershed.

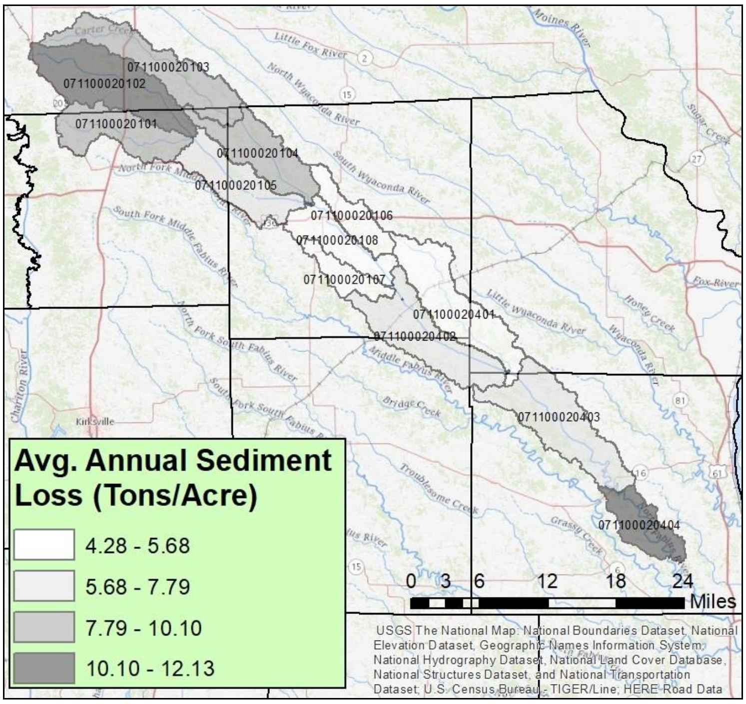

Figure G4. Extent of Modeled Area labeled by HUC12 within the North Fabius watershed

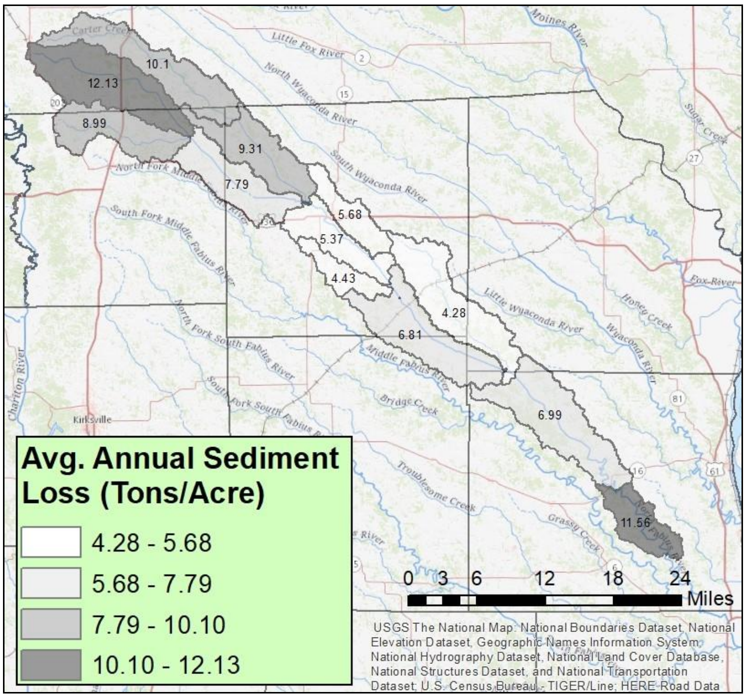

Figure G5. Average Annual Sediment Yield by HUC12 - Baseline

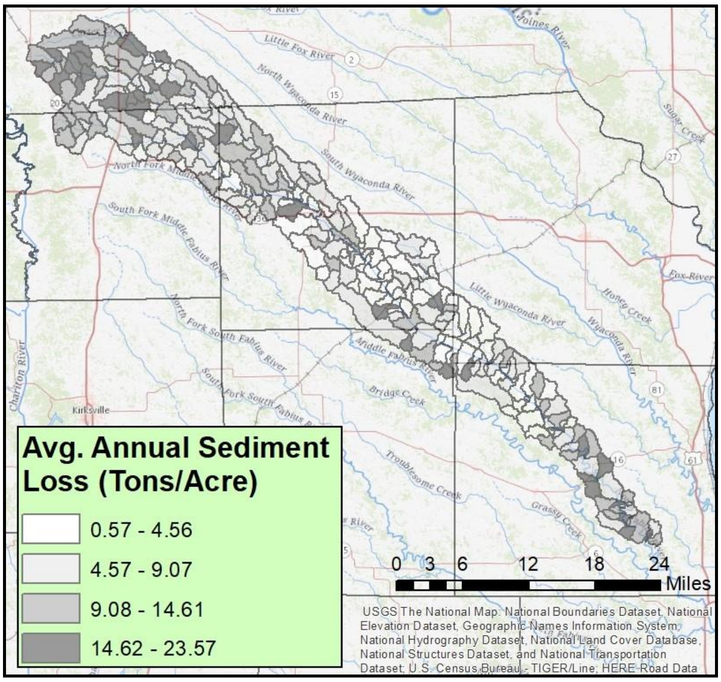

Figure G6. Average Annual Sediment Yield by ArcSWAT catchment - Baseline

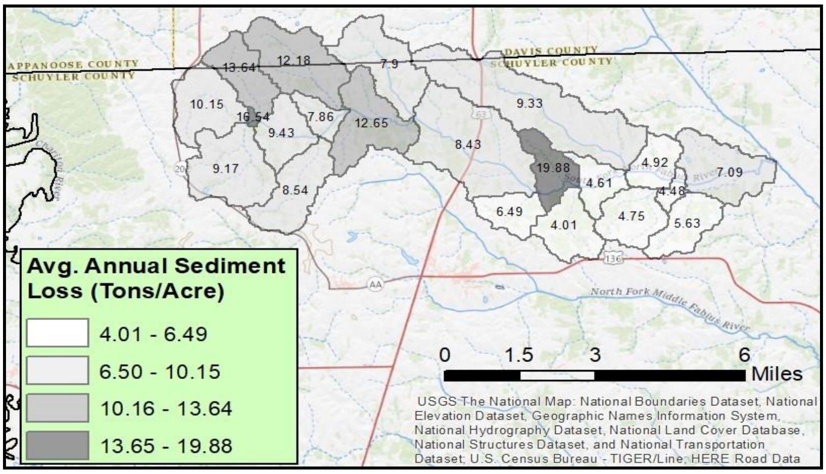

Figure G7. Average Annual Sediment Yield in the South Fork North Fabius River (HUC 071100020101) - Baseline

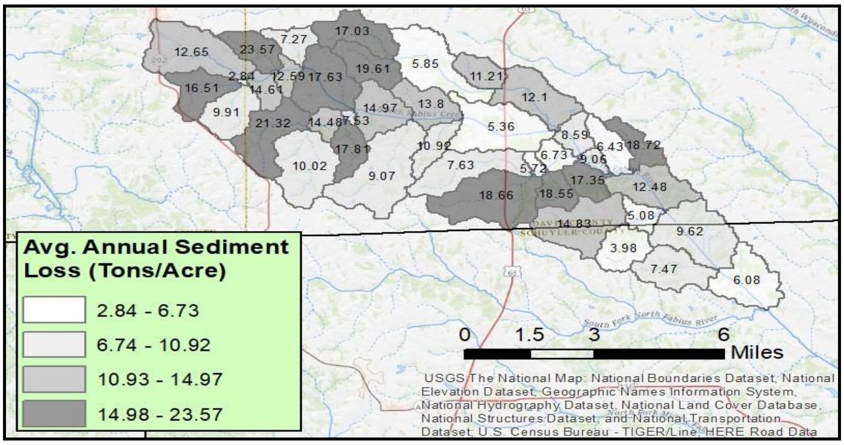

Figure G8. Average Annual Sediment Yield in the Headwaters of North Fabius River (HUC 071100020102) - Baseline

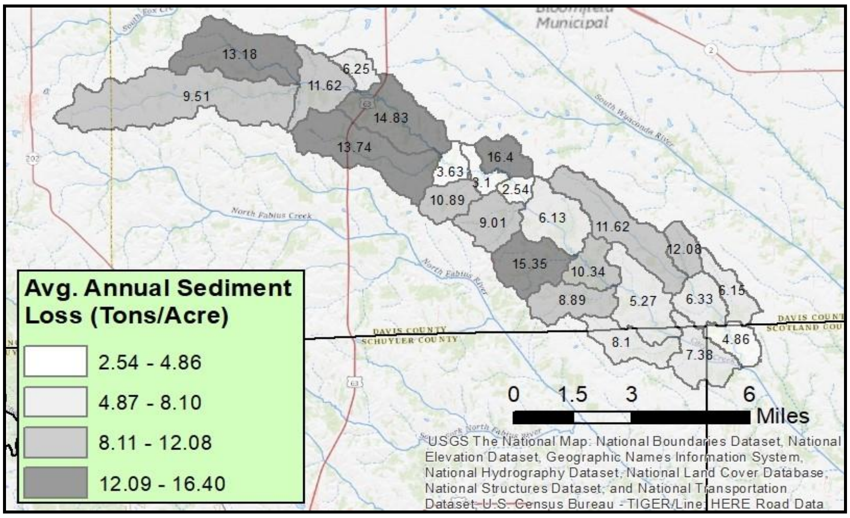

Figure G9. Average Annual Sediment Yield in the Carter Creek - North Fork North Fabius River (HUC 071100020103) - Baseline

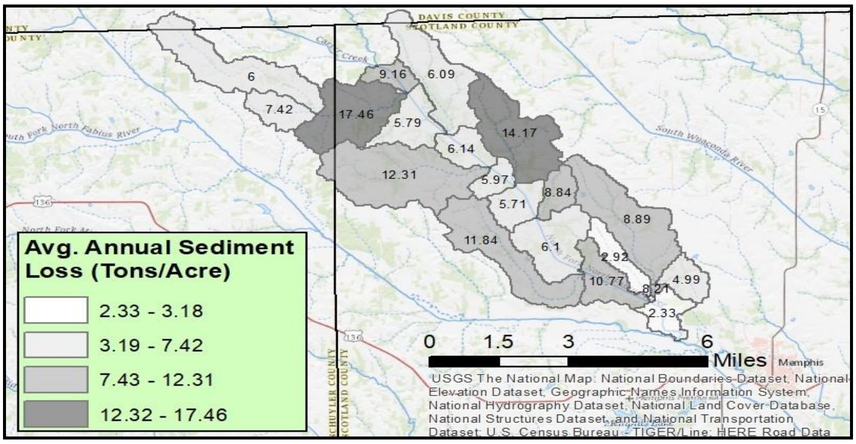

Figure G10. Average Annual Sediment Yield in the North Fork North Fabius River (HUC 071100020104) - Baseline

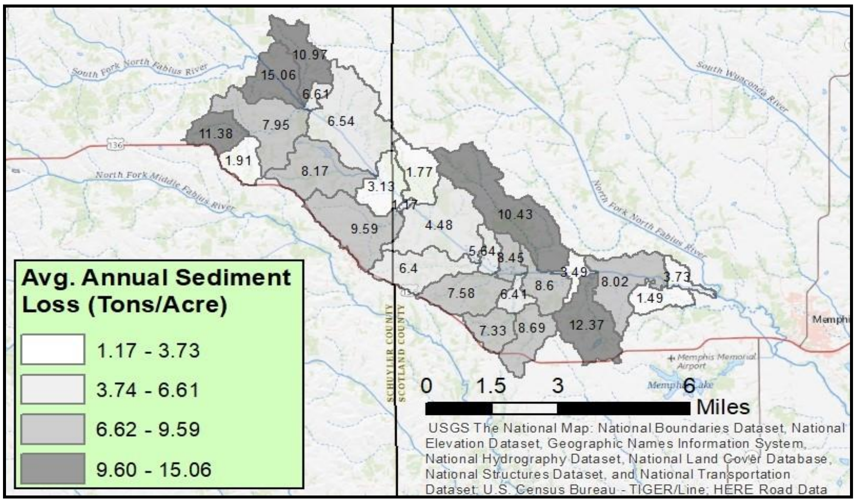

Figure G11. Average Annual Sediment Yield in the Downing Reservoir - North Fabius River (HUC 071100020105) - Baseline

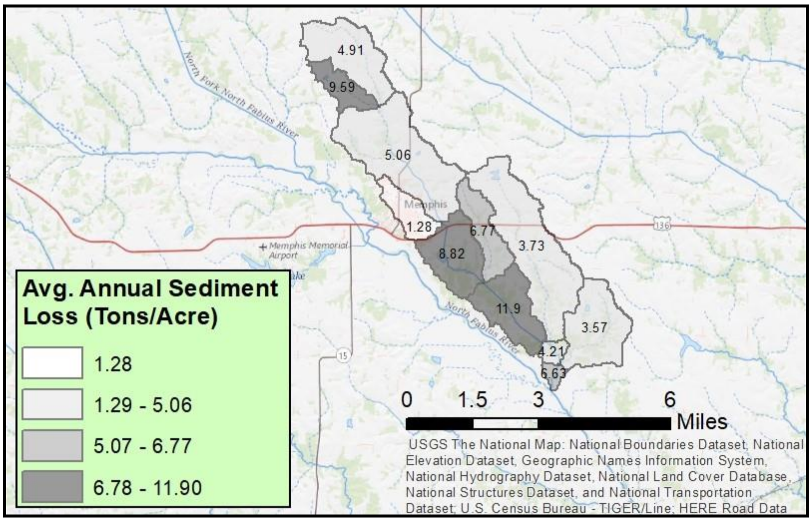

Figure G12. Average Annual Sediment Yield in the Gunns Branch (HUC 071100020106) - Baseline

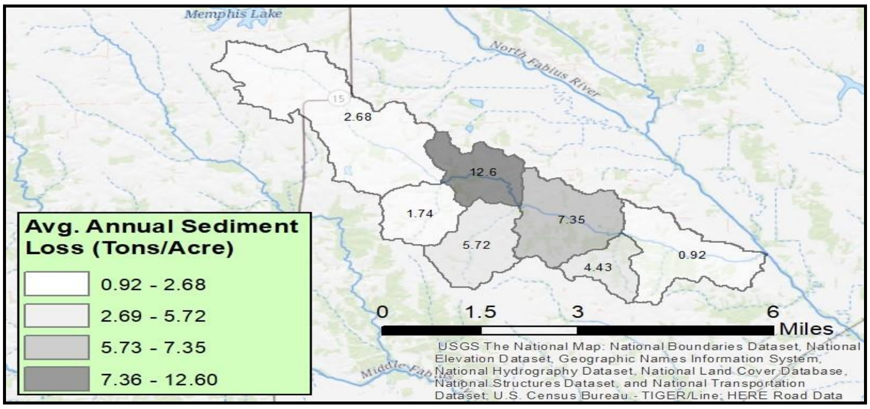

Figure G13. Average Annual Sediment Yield in Indian Creek (HUC 071100020107) - Baseline

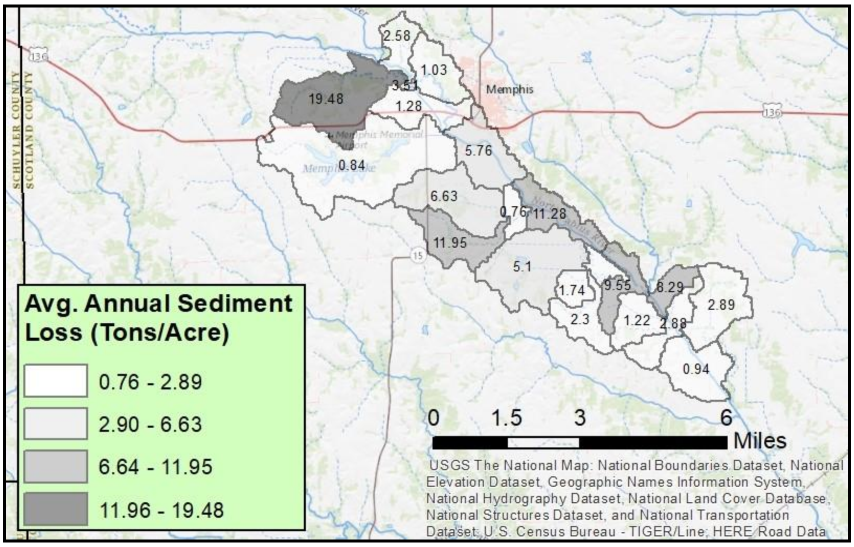

Figure G14. Average Annual Sediment Yield in the Memphis Reservoir - North Fabius River (HUC 071100020108) - Baseline

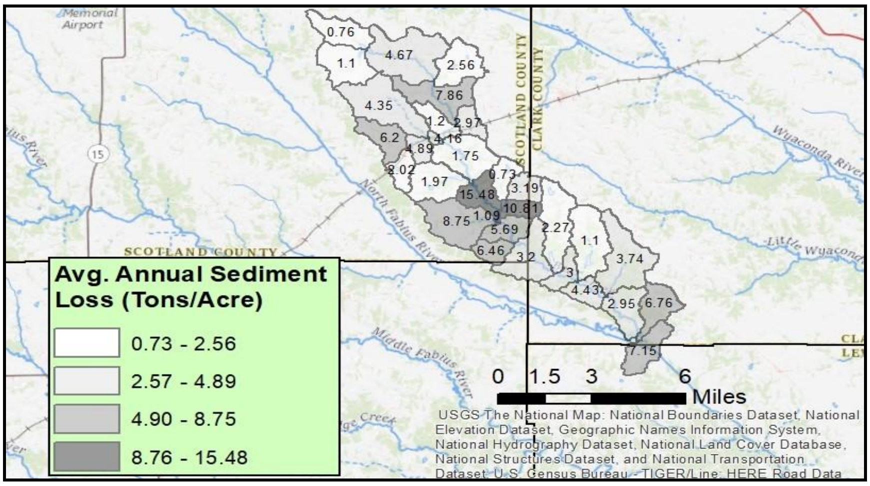

Figure G15. Average Annual Sediment Yield in Bear Creek (HUC 071100020401) - Baseline

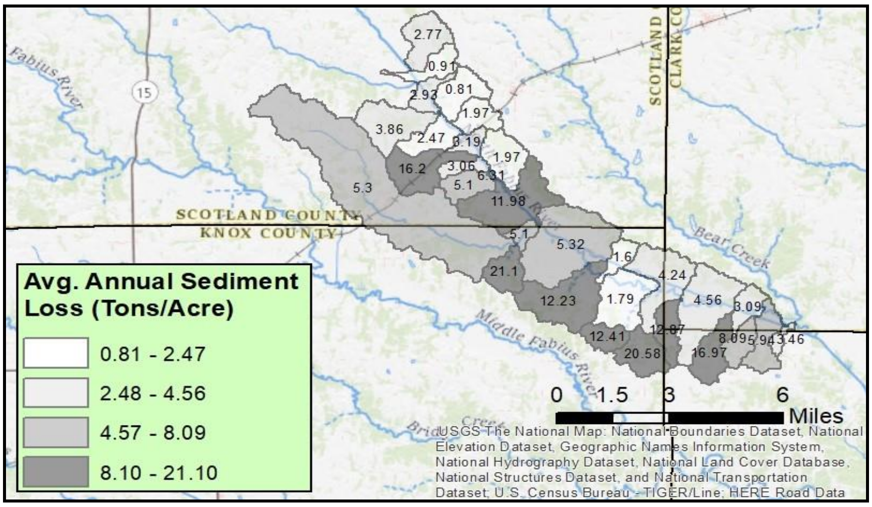

Figure G16. Average Annual Sediment Yield in the Long Branch - North Fabius River (HUC 071100020402) - Baseline

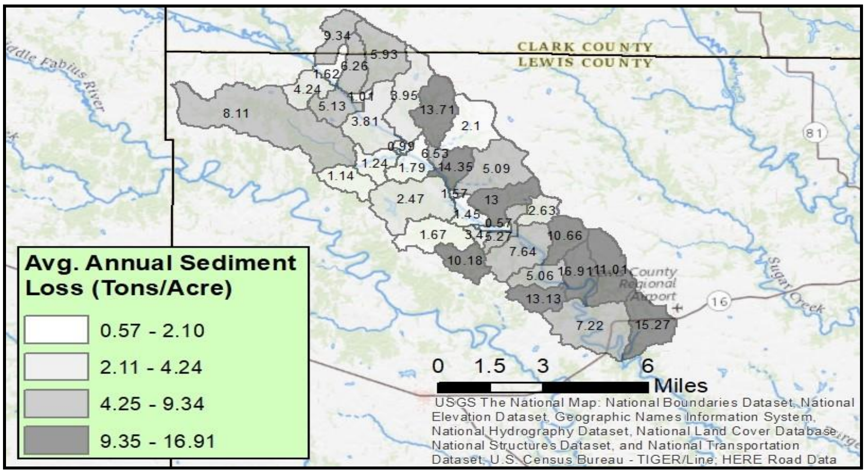

Figure G17. Average Annual Sediment Yield in the Cooper Branch - North Fabius River (HUC 071100020403) - Baseline.

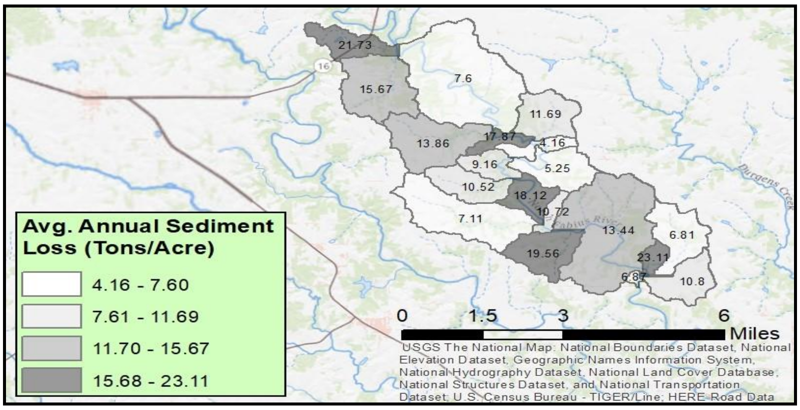

Figure G18. Average Annual Sediment Yield in the Town of Weber - North Fabius River (HUC 071100020404) - Baseline

Vegetated Buffer Scenario

Vegetated buffers help to trap sediment and nutrients before they enter the water stream. ArcSWAT represents vegetated buffers using the ratio between the filter strip and the field that is being buffered and considering effects of channelized flow. It is recommended that you would typically have vegetated buffers with a ratio between 30 and 60, with a default value of 40. It was found that the North Fabius is already generally very well buffered, but this scenario looks at a best case scenario for buffering in the watershed.

All catchments in Iowa were completely unchanged. They are included in the model due to having a downstream effect, and only Missouri catchments were changed in regards to their vegetated buffers in this scenario. Missouri catchments also remained unchanged if they already have vegetated buffers with a ratio of less than the default of 40. Any Missouri catchments that had vegetated buffers with a ratio of greater than 40 or no vegetated buffer are given a vegetated buffer with the default ratio of 40. This scenario resulted in an average annual watershed sediment loading of 19.281 tons per hectare. This is a reduction of 4.3%. Spatial results at the HUC and catchment level can be found in Figures G19 and G20.

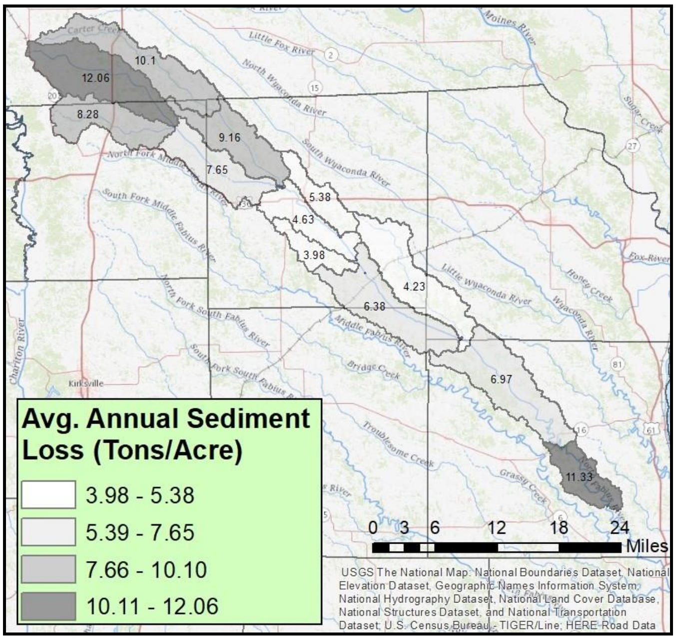

Figure G19. Average Annual Sediment Yield by HUC12 - Expanded Vegetated Buffers

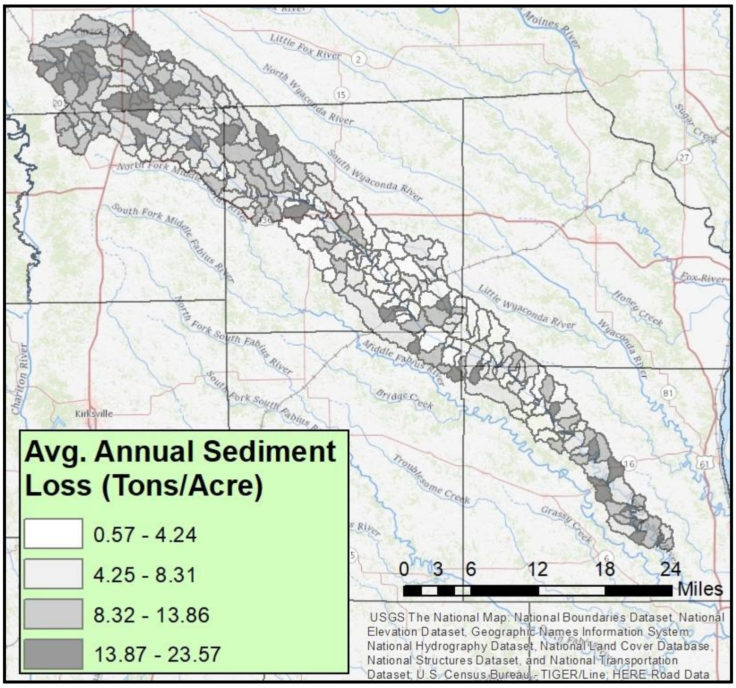

Figure G20. Average Annual Sediment Yield by Catchment - Expanded Vegetated Buffers

Untargeted Dry Hole Scenario

In order to look at the difference in effects between random and targeted placement for BMPs, two different dry hole scenarios were modeled. The first was untargeted placement of an equal sized dry hole into every catchment located in Missouri. Once again, no changes were made to catchments located in Iowa.

Local experts determined that it was reasonable to increase the dry holes by around 50%. Using local average drainage areas for dry holes and estimates on drainage acres served by dry holes that were paid for with cost-share between 2009 and 2017, it was determined that there was 37.5 dry hole acres to be added. Equally adding these dry holes to the 234 Missouri catchments resulted in an addition of 0.16 surface acres of dry holes and 4.8 acres draining into dry holes in every catchment. The fraction draining to ponds/dry holes was determined using the area of each catchment.

This scenario resulted in an average annual basin sediment loading of 20.063 tons per hectare. This is a reduction of 0.4%. Spatial results at the HUC and catchment levels can be found below in Figures G21 and G22.

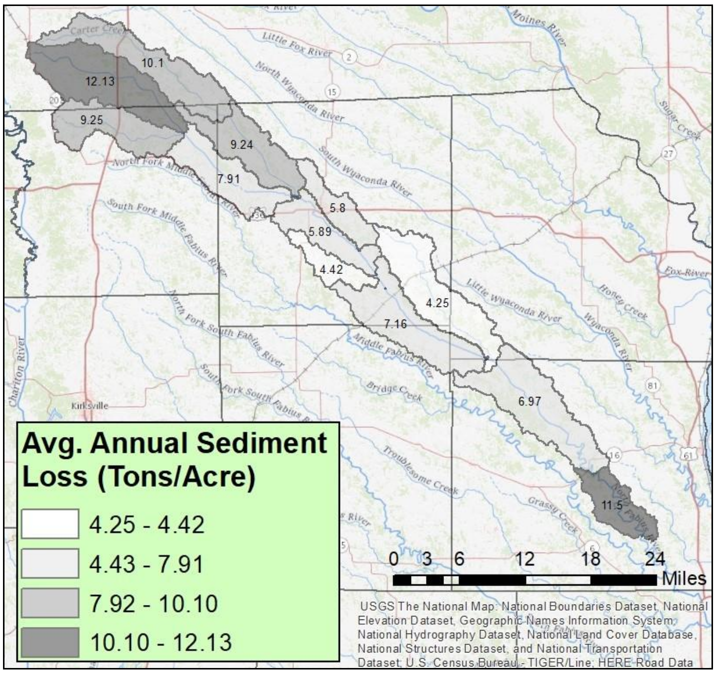

Figure G21. Average Annual Sediment Yield by HUC12 - Untargeted Dry Holes

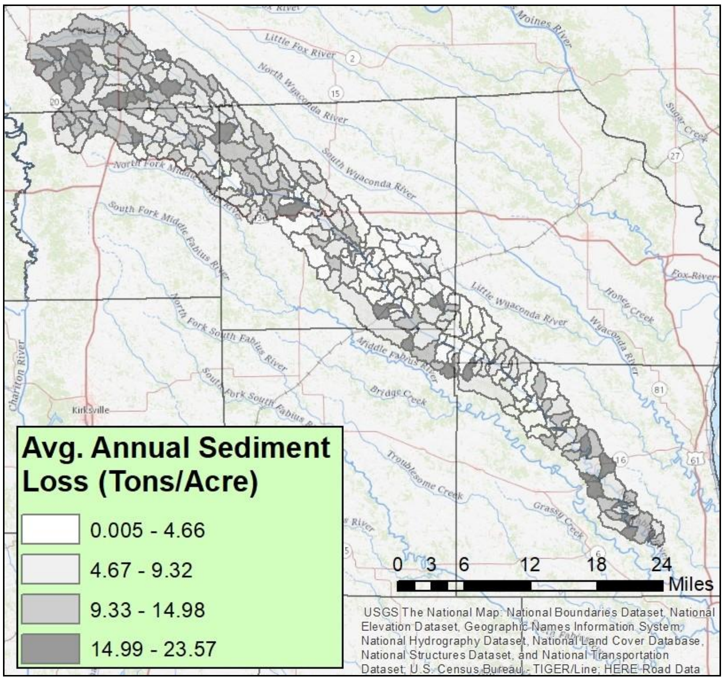

Figure G22. Average Annual Sediment Yield by Catchment - Untargeted Dry Holes

Targeted Dry Hole Scenario

In the second dry hole scenario, the dry holes are placed only in the catchments that were shown to contribute the greatest rates of sediment according to the Jenks natural breaks method. The 37.5 dry hole acres were divided amongst these nineteen catchments by area weighting the catchments (Table G8). Once again, there were no changes made to catchments located in Iowa.

This scenario resulted in an average annual basin sediment loading of 19.972 tons per hectare. This is a reduction of 0.9%. Thus, by targeting dry hole placement more specifically using the model results the sediment reduction is more than twice as great compared to randomly assigning dry holes everywhere. Spatial results for both the HUC and catchment level are presented in Figures G23 and G24.

Table G8. Targeted Dry Hole Changes by Catchment

Catchment	Original Dry Hole Surface Acres	New Dry Hole Surface Acres
58	16.06	19.62
69	0.00	0.10
76	18.29	22.44
87	4.69	6.33
92	5.44	7.49
140	21.25	24.93
200	7.66	10.33
201	8.65	10.65
216	7.17	8.65
233	4.20	6.08
234	9.88	11.74
269	4.69	6.87
272	1.98	4.94
273	15.57	16.75
274	4.69	7.31
277	0.00	0.49
283	2.97	3.93
286	3.71	5.30
289	0.00	0.45

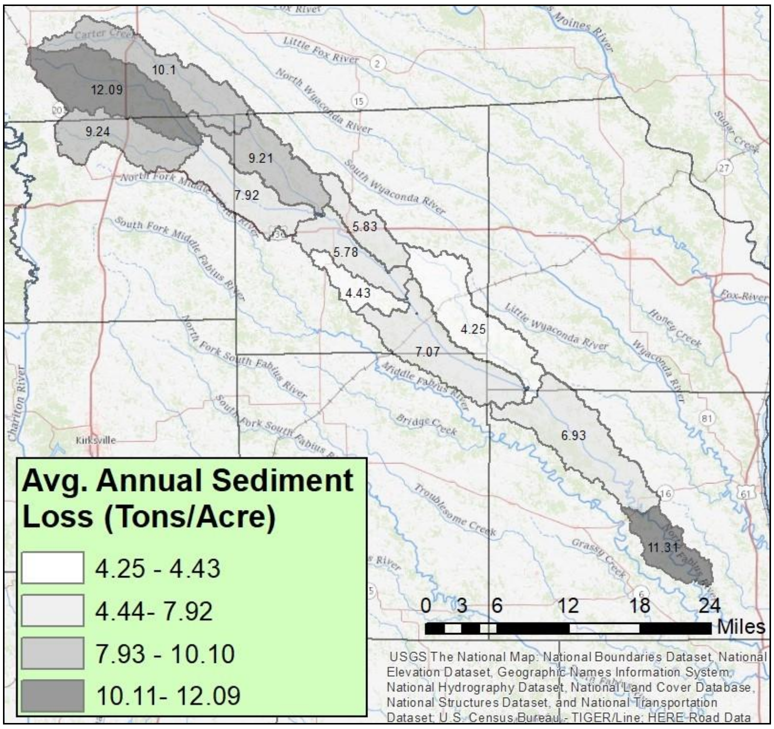

Figure G23. Average Annual Sediment Yield by HUC12 - Targeted Dry Holes

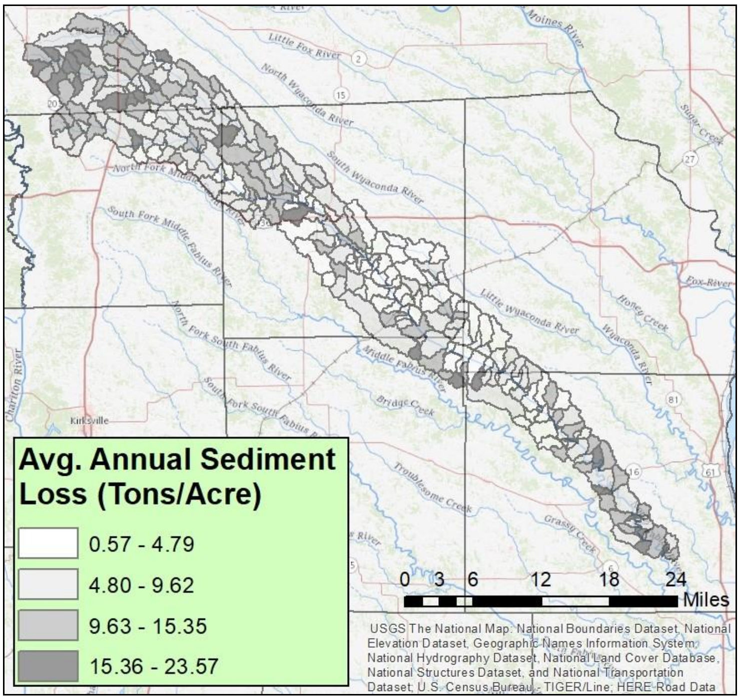

Figure G24. Average Annual Sediment Yield by Catchment - Targeted Dry Holes

Terrace Scenario

The baseline model used aerial satellite imagery to estimate a total of about 20,761 acres of terraced land found within the modeled portion of the North Fabius watershed. It was recommended by local experts that it would be reasonable to increase this acreage by about 2/3 in the future. Thus, the terrace scenario contains an additional 13,691 acres of terraced land. Again, there were no changes to the Iowa catchments.

This land was targeted by selecting the catchments with the highest sediment loading concentration, similarly to the targeted pond scenario (Table G9). However, with terracing it was necessary to also select individual HRUs to terrace, and these were selected by choosing the agricultural HRUs with a slope greater than or equal to 3%. When it was found that there were not sufficient acres within these HRUs for the nineteen highest contributing catchments, additional HRUs were selected from the next highest contributing catchments. This process was repeated until sufficient acreage had been selected.

Table G9. Terraced Acres Added for Expanded Terrace Scenario

Catchments	Terraced Acres
58	1403
67	283
69	30
76	1538
87	490
92	420
99	998
140	1106
200	1006
201	476
216	402
233	568
234	408
245	650
253	298
269	597
272	510
273	308
274	650
276	665
277	74
283	222
286	462
289	128

This scenario resulted in an average annual sediment loading of 17.485 tons per hectare. This is a reduction of 13.2% at the watershed scale. At a localized scale for the catchments where the terraces are added, the savings are even greater. Spatial results at the HUC and catchment levels can be found in Figures G25 and G26.

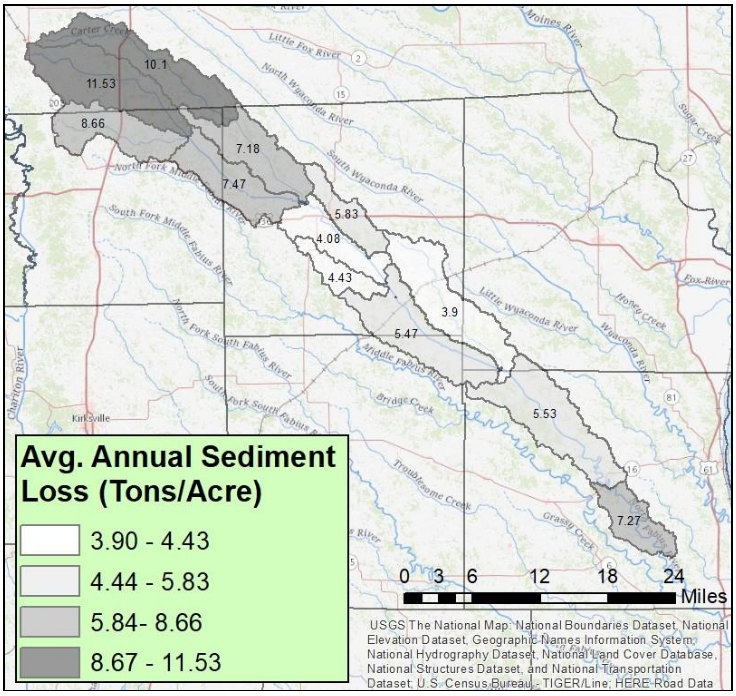

Figure G25. Average Annual Sediment Yield by HUC12 - Expanded Terraces

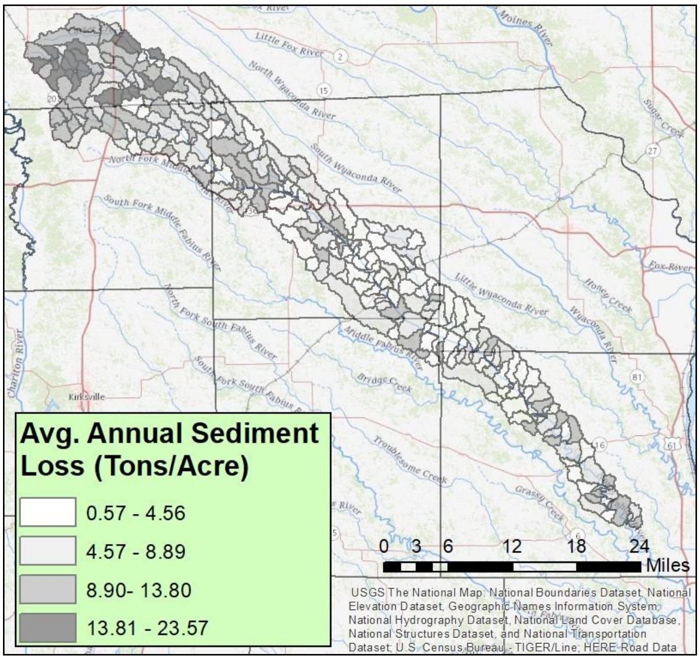

Figure G26. Average Annual Sediment Yield by Catchment - Expanded Terraces

Improved Grazing Scenario

In the improved grazing scenario, the model was adjusted to reflect a 10% increase in the practice of inter-seeding legumes into pasture and a 5% increase in management intensive grazing. In order to make these changes to the model, it was necessary to create new HRUs for the model. Thus, the baseline model was copied, pasted, and then renamed on the hard drive to create a second model using the same inputs as the baseline. HRUs were then reprocessed on this version using the land use splits found in Table G10 in order to update the amount of legume inter-seeding. Unfortunately, there is no way to make this change in the model without also affecting the catchments in Iowa. Thus, this scenario makes the assumption that these grazing changes would also be adopted by neighboring farmers in Iowa. Because there is not spatial information to place the management intensive grazing practices, the increase in management intensive grazing causes a slight increase in stocking rates across the entire watershed.

Table G10. Land Use Splits for Improved Grazing Scenario

National Land Cover Database	Land Use Split	%
Hay	Hay	50
Hay	Pasture	32.5
Hay	Clover	17.5
AGRR	Conventional Till Corn	15
AGRR	Conservation Till Corn	15
AGRR	No Till Corn	15
AGRR	Conventional Soybean	27.5
AGRR	Conservation Soybean	13.75
AGRR	No Till Soybean	13.75

This scenario resulted in an average annual basin sediment loading of 20.308 tons per hectare. This is an increase of 0.8% at the basin scale. This is because the method of assigning cattle grazing was not spatially explicit due to a lack of spatial information on the watershed. Therefore, increasing the management intensive grazing is simply represented as a generalized increase in grazing, trampling, and manure rates in the model. The increase in clover was unable to make up for the increase in stocking rate in the model. Future efforts would need to confirm spatially explicit pasture rotations in order to better understand these effects. Spatial results at the HUC and catchment levels can be found in Figures G27 and G28.

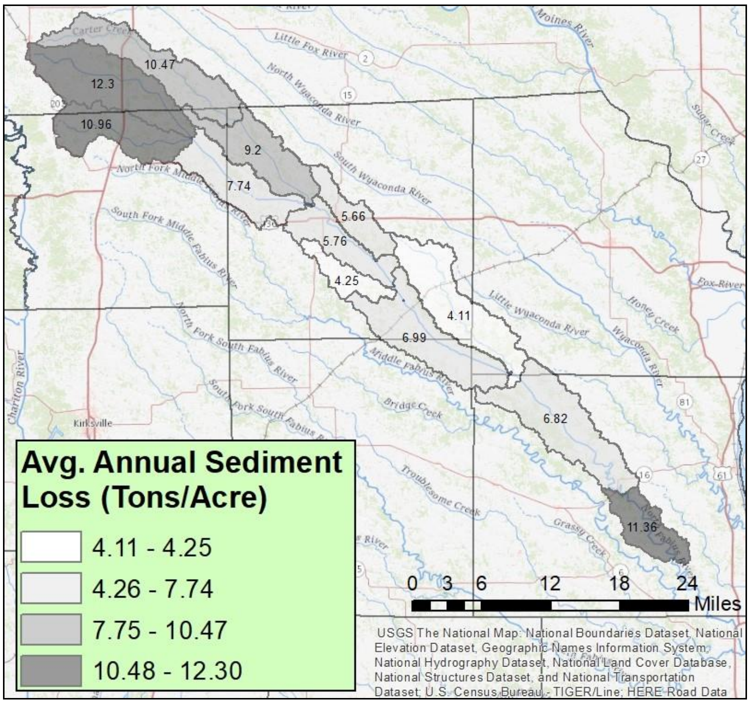

Figure G27. Average Annual Sediment Yield by HUC12 - Improved Pasture

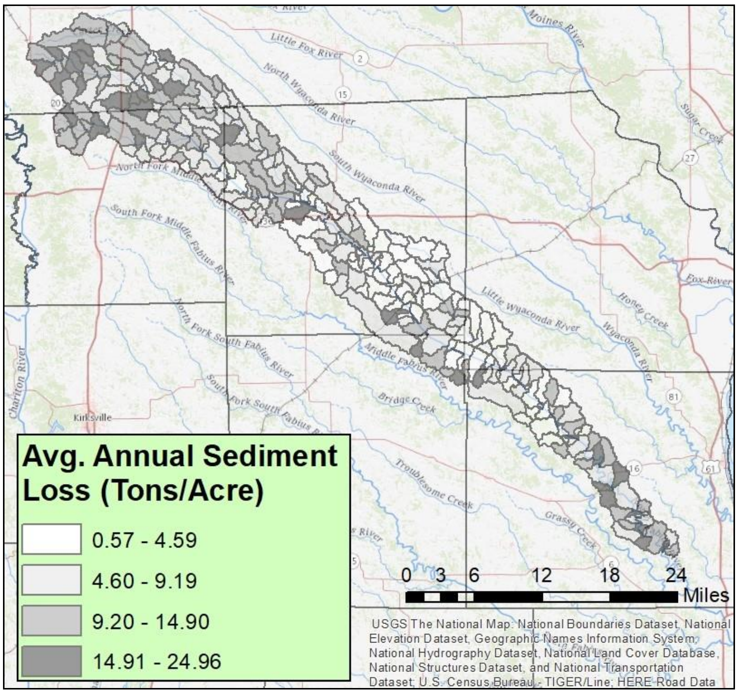

Figure G28. Average Annual Sediment Yield by Catchment **-** Improved Pasture

All BMP Scenarios

This scenario combined the BMP inputs from the vegetated buffer, targeted dry hole, increased terracing, and improved grazing scenarios. This was to represent a best-case scenario for the watershed, and help to understand better, how these management decisions impact each other. This scenario resulted in an average annual watershed sediment loading of 16.874 tons per hectare. This is a reduction of 16.2% at the watershed scale. This reduction is basically explained by the vegetated buffer and terracing scenarios, which provide the largest reductions of the BMP scenarios. Increased data collection and spatially explicit modeling would be required to better understand the impacts of dry holes and grazing in the watershed. Spatial results at the HUC and catchment levels can be found in Figures G29 and G30.

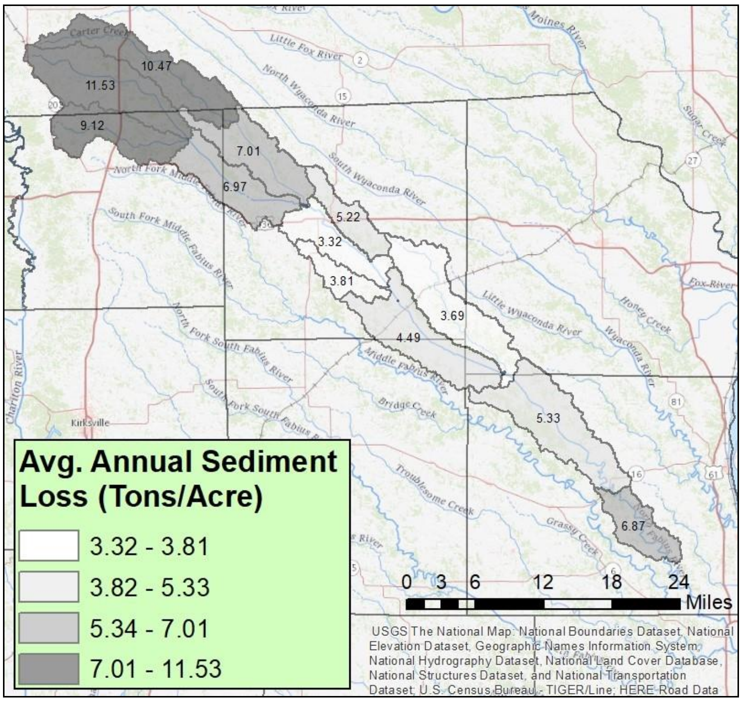

Figure G29. Average Annual Sediment Yield by HUC12 - All BMPs

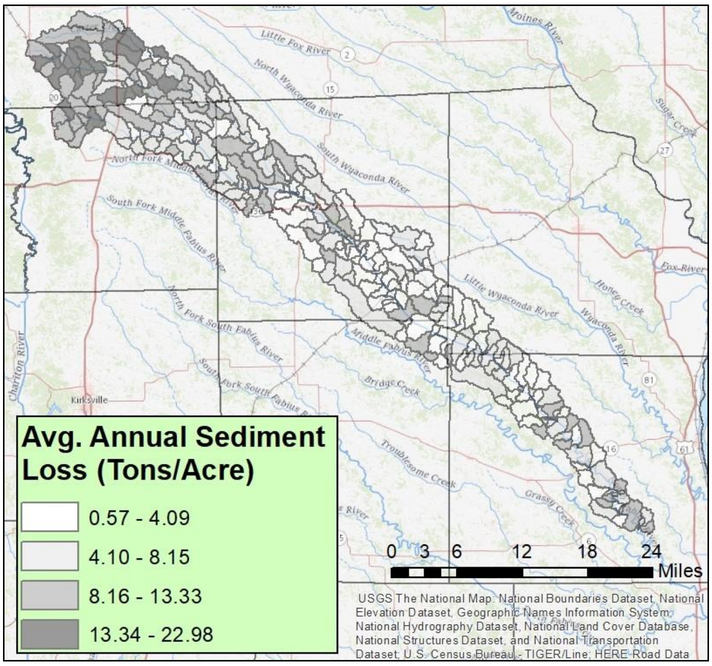

Figure G30. Average Annual Sediment Yield by Catchment - All BMPs

Increased Conventional Tillage

It was noted by local experts that there may be an increase in conventional tillage found in the watershed moving forward. To better understand the impacts of this possibility, one last scenario was modeled such that 25% of conservation tillage acres and 25% of no till acres were converted to conventional tillage. Thus, the land use splits were as follows in Table G11. Once again, changing the land use splits necessitates recreating the HRUs in the model. This means that the catchments in Iowa are also affected by this change. Other than the land use splits, this scenario matched the baseline inputs. This scenario resulted in an average annual watershed sediment loading of 20.799 tons per hectare. This is an increase of 3.2% at the watershed scale. This increase is expected, as conservation tillage and no till are both management decisions that help to reduce sediment erosion. Spatial results at the HUC and catchment level are presented in Figures G31 and G32.

Table G11. Land Use Splits for Increased Conventional Tillage Scenario

National Land Cover Database	Land Use Split	%
Hay	Hay	50
Hay	Pasture	35
Hay	Clover	15
AGRR	Conventional Till Corn	22.5
AGRR	Conservation Till Corn	11.25
AGRR	No Till Corn	11.25
AGRR	Conventional Soybean	34.375
AGRR	Conservation Soybean	10.3125
AGRR	No Till Soybean	10.3125

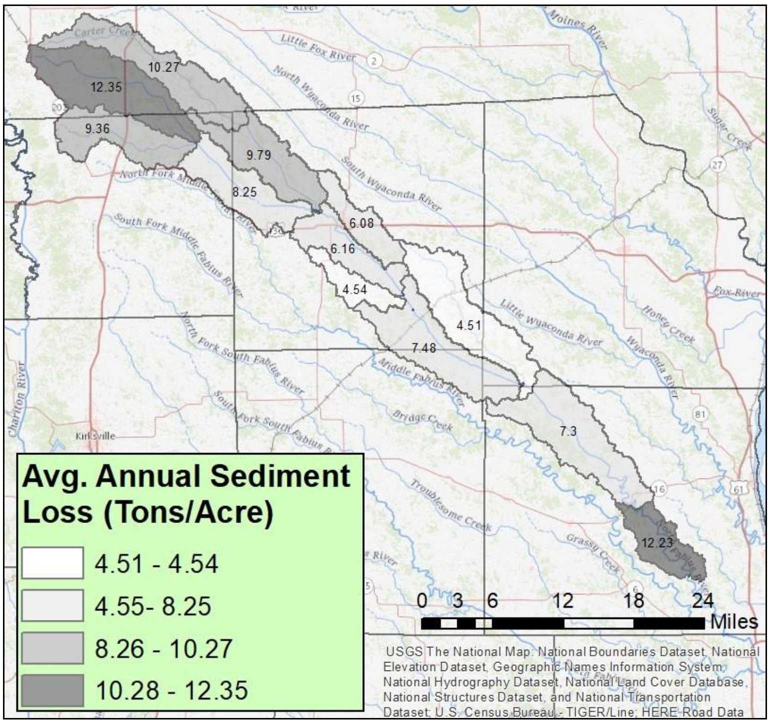

Figure G31. Average Annual Sediment Yield by HUC12 - Increased Conventional Tillage

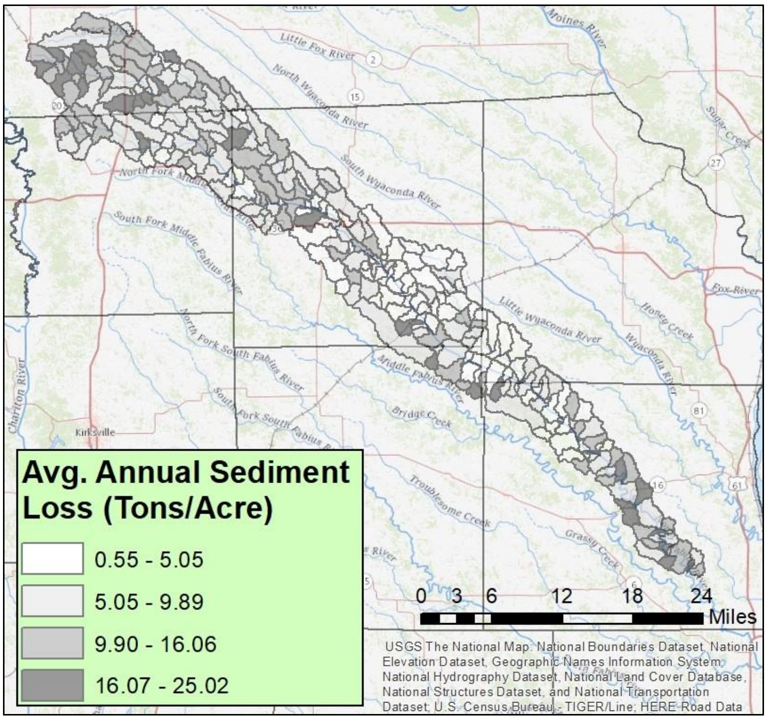

Figure G32. Average Annual Sediment Yield by Catchment - Increased Conventional Tillage

Baseline BMP Inputs

Table G12. Baseline BMP inputs for each catchment.

Catchment	Filter Strip Ratio	Fraction Draining to Pond	Pond Principle SA (hectares)	Pond Principle Vol. (m^3)	Pond Emergency SA (hectares)	Pond Emergency Vol. (m^3)	% Terraced
1	35	0.08	6.1	7.5	6.1	375	0
2	30	0.05	4.9	6	4.9	300	0
3	20	0.1	1.8	2.2	1.8	110	0
4	30	0.2	1.8	2.2	1.8	110	0
5	40	0.05	4.9	6	4.9	300	0
6	39	0.05	2.6	3.1	2.6	155	0
7	25	0.05	0.6	0.7	0.6	35	0
8	82	0.05	1	1.2	1	60	0
9	60	0.05	1.1	1.4	1.1	70	0
10	20	0.08	0.5	0.6	0.5	30	0
11	40	0.03	3.2	3.9	3.2	195	0
12	50	0.05	1.1	1.3	1.1	65	0
13	60	0.05	1.9	2.3	1.9	115	0
14	73	0.1	40.7	62.1	40.7	3105	0
15	200	0.05	1.1	1.3	1.1	65	0
16	60	0.15	1.8	2.2	1.8	110	0
17	20	0	0	0	0	0	0
18	30	0.08	2.3	2.8	2.3	140	0
19	20	0.005	0.1	0.1	0.1	5	0
20	30	0.03	2.3	2.8	2.3	140	0
21	30	0.3	4.5	5.5	4.5	275	0
22	25	0.05	1.5	1.8	1.5	90	0
23	25	0.03	0.6	0.7	0.6	35	0
24	25	0.08	2.2	2.7	2.2	135	0
25	30	0.05	4.1	5	4.1	250	0
26	15	0.18	0.1	0.1	0.1	5	0
27	20	0.03	1.7	2	1.7	100	0
28	29	0.1	2.9	3.6	2.9	180	0
29	20	0.08	1.6	1.9	1.6	95	0
30	20	0.05	0.9	1.1	0.9	55	0
31	30	0.05	3.5	4.3	3.5	215	0
32	40	0.03	0.5	0.6	0.5	30	0
33	50	0.08	5.3	6.4	5.3	320	0
34	40	0.03	3.7	4.5	3.7	225	0
35	80	0.05	6.7	8.2	6.7	410	0
36	25	0.05	1.6	1.9	1.6	95	0
37	30	0.08	4.6	5.6	4.6	280	0
38	25	0.03	0.5	0.6	0.5	30	0

Catchment	Filter Strip Ratio	Fraction Draining to Pond	Pond Principle SA (hectares)	Pond Principle Vol. (m^3)	Pond Emergency SA (hectares)	Pond Emergency Vol. (m^3)	% Terraced
39	25	0.18	0.9	1	0.9	50	0
40	45	0.02	0.9	1.1	0.9	55	0
41	60	0.03	3.6	4.4	3.6	220	0
42	20	0.03	1.2	1.5	1.2	75	0
43	40	0.03	1.6	2	1.6	100	0
44	35	0.03	3.6	4.4	3.6	220	0
45	40	0.03	9.4	14.3	9.4	715	0
46	30	0.12	1.3	1.6	1.3	80	0
47	30	0.08	5.5	6.7	5.5	335	0
48	30	0.03	1.4	1.7	1.4	85	0
49	30	0.03	2.8	3.4	2.8	170	0
50	40	0.08	9.6	14.6	9.6	730	0
51	30	0.05	3.1	3.7	3.1	185	0
52	45	0.03	4.5	5.4	4.5	270	0
53	30	0.02	3.1	3.8	3.1	190	0
54	45	0.05	3.1	3.8	3.1	190	0
55	60	0.05	2.7	3.2	2.7	160	0
56	20	0.03	0.8	1	0.8	50	0
57	60	0.05	4.6	5.6	4.6	280	0
58	45	0.05	6.5	7.9	6.5	395	0
59	20	0.03	2.6	3.1	2.6	155	0
60	35	0.03	4.6	5.6	4.6	280	0
61	30	0.03	4.1	5	4.1	250	0
62	25	0.1	2.7	3.3	2.7	165	0
63	80	0.08	4.3	5.3	4.3	265	0
64	50	0.03	4.2	5.1	4.2	255	0
65	60	0.03	6.6	8	6.6	400	0
66	60	0.05	4	4.9	4	245	0
67	80	0.05	1.9	2.3	1.9	115	0
68	50	0.08	3.5	4.3	3.5	215	0
69	200	0	0	0	0	0	0
70	50	0.08	4.5	5.5	4.5	275	0
71	20	0.02	1	1.2	1	60	0
72	45	0.05	1.4	1.7	1.4	85	0
73	200	0.02	0.5	0.6	0.5	30	0
74	50	0.03	2.8	3.4	2.8	170	0
75	50	0.01	4.4	5.4	4.4	270	0
76	50	0.03	7.4	9.1	7.4	455	0
77	80	0.02	2.3	2.8	2.3	140	0
78	30	0.08	7.9	9.6	7.9	480	0
79	45	0.15	13.3	20.2	13.3	1010	0

Catchment	Filter Strip Ratio	Fraction Draining to Pond	Pond Principle SA (hectares)	Pond Principle Vol. (m^3)	Pond Emergency SA (hectares)	Pond Emergency Vol. (m^3)	% Terraced
80	20	0.0025	0.7	0.8	0.7	40	0
81	20	0.01	4.5	5.5	4.5	275	0
82	200	0.03	2.9	3.6	2.9	180	0
83	45	0.05	2.5	3	2.5	150	0
84	45	0.15	4.1	5	4.1	250	0
85	200	0.08	8.2	12.4	8.2	620	0
86	200	0.03	5	6.1	5	305	0
87	80	0.03	1.9	2.3	1.9	115	0
88	30	0.12	5.7	7	5.7	350	0
89	35	0.03	1.6	2	1.6	100	0
90	40	0.08	4	4.9	4	245	0
91	40	0.03	1.8	2.2	1.8	110	0
92	20	0.02	2.2	2.6	2.2	130	0
93	35	0.03	4	4.9	4	245	0
94	20	0.04	0.9	1.1	0.9	55	0
95	20	0.03	1.3	1.6	1.3	80	0
96	40	0.1	0.6	0.7	0.6	35	0
97	45	0.015	6.3	7.7	6.3	385	0
98	20	0.2	2.5	3	2.5	150	0
99	25	0.015	4.3	5.2	4.3	260	0
100	15	0.05	5.6	6.8	5.6	340	0
101	40	0.02	4.7	5.7	4.7	285	0
102	15	0.5	4.2	5.1	4.2	255	0
103	25	0.02	1.2	1.5	1.2	75	0
104	20	0.01	0.7	0.8	0.7	40	0
105	20	0.02	4.4	5.3	4.4	265	0
106	30	0.01	3.8	4.7	3.8	235	0
107	40	0.03	0.8	1	0.8	50	0
108	15	0.02	2	2.5	2	125	0
109	12	0	0	0	0	0	0
110	30	0.01	2.6	3.1	2.6	155	0
111	50	0.05	9	13.7	9	685	0
112	200	0.0025	0.3	0.4	0.3	20	0
113	80	0.0025	0.9	1.1	0.9	55	0
114	35	0.01	4.2	5.1	4.2	255	0
115	20	0.015	2.2	2.7	2.2	135	25
116	40	0.02	2.1	2.5	2.1	125	50
117	20	0.05	0.7	0.9	0.7	45	0
118	40	0.05	14.3	21.7	14.3	1085	0
119	60	0.01	1.4	1.7	1.4	85	0
120	20	0	0	0	0	0	0

Catchment	Filter Strip Ratio	Fraction Draining to Pond	Pond Principle SA (hectares)	Pond Principle Vol. (m^3)	Pond Emergency SA (hectares)	Pond Emergency Vol. (m^3)	% Terraced
121	25	0.02	3.5	4.2	3.5	210	0
122	20	0.02	2.5	3	2.5	150	0
123	25	0.03	8.8	13.3	8.8	665	0
124	200	0.01	0.6	0.7	0.6	35	0
125	18	0.0025	0.1	0.1	0.1	5	0
126	25	0.05	1.3	1.5	1.3	75	0
127	200	0.01	0.4	0.5	0.4	25	0
128	30	0.02	3.6	4.3	3.6	215	0
129	200	0.05	8.7	13.3	8.7	665	0
130	200	0.02	1.2	1.4	1.2	70	0
131	60	0.01	0.8	0.9	0.8	45	33
132	60	0.05	1.1	1.3	1.1	65	50
133	20	0.02	0.6	0.7	0.6	35	0
134	200	0.01	0.6	0.7	0.6	35	0
135	200	0	0	0	0	0	0
136	25	0.02	2.3	2.7	2.3	135	0
137	16	0.02	2.5	3	2.5	150	0
138	20	0.05	7.8	9.5	7.8	475	0
139	20	0.03	1.8	2.2	1.8	110	0
140	200	0.03	8.6	13	8.6	650	0
141	40	0.02	10.4	15.8	10.4	790	33
142	200	0.01	1.2	1.5	1.2	75	0
143	200	0.01	1.8	2.1	1.8	105	33
144	200	0.015	8.4	12.8	8.4	640	50
145	20	0.04	11.6	17.7	11.6	885	0
146	80	0.03	2.9	3.5	2.9	175	33
147	200	0.01	1	1.2	1	60	0
148	200	0	0	0	0	0	0
149	45	0.02	2.1	2.5	2.1	125	33
150	40	0.015	2.6	3.2	2.6	160	0
151	100	0.02	12.3	18.7	12.3	935	50
152	45	0.04	2.5	3	2.5	150	66
153	35	0.05	3.1	3.7	3.1	185	0
154	100	0.015	2.2	2.7	2.2	135	0
155	15	0.01	0.2	0.3	0.2	15	0
156	20	0.01	3	3.7	3	185	0
157	60	0.05	7.9	9.6	7.9	480	0
158	100	0	0	0	0	0	25
159	45	0.03	2	2.4	2	120	66
160	100	0.02	1.9	2.3	1.9	115	0
161	25	0	0	0	0	0	0

Catchment	Filter Strip Ratio	Fraction Draining to Pond	Pond Principle SA (hectares)	Pond Principle Vol. (m^3)	Pond Emergency SA (hectares)	Pond Emergency Vol. (m^3)	% Terraced
162	30	0.04	6.4	7.8	6.4	390	50
163	100	0.02	8	9.7	8	485	66
164	100	0.1	10.2	15.5	10.2	775	50
165	57	0.005	0.3	0.4	0.3	20	0
166	60	0	0	0	0	0	0
167	30	0.0025	0.2	0.2	0.2	10	15
168	60	0.03	3.8	4.6	3.8	230	0
169	100	0.02	8.6	13.1	8.6	655	33
170	80	0.005	1.3	1.6	1.3	80	33
171	40	0.02	2.3	2.8	2.3	140	66
172	30	0.05	5.9	7.2	5.9	360	0
173	50	0.03	2.3	2.8	2.3	140	66
174	80	0.03	4.6	5.6	4.6	280	33
175	40	0.03	1.4	1.7	1.4	85	50
176	30	0.02	2.2	2.7	2.2	135	0
177	50	0.04	10.7	16.3	10.7	815	50
178	100	0.04	5	6.1	5	305	50
179	30	0.02	0.3	0.4	0.3	20	0
180	50	0.08	2.3	2.8	2.3	140	33
181	20	0.01	1	1.3	1	65	0
182	200	0.03	1.6	1.9	1.6	95	0
183	40	0.03	2.3	2.8	2.3	140	15
184	45	0.05	7	8.5	7	425	0
185	70	0.0025	1.1	1.4	1.1	70	33
186	60	0.4	5.3	6.5	5.3	325	50
187	100	0	0	0	0	0	50
188	100	0.07	7	8.5	7	425	20
189	200	0	0	0	0	0	0
190	20	0.03	5.5	6.7	5.5	335	10
191	20	0.6	19.6	29.8	19.6	1490	15
192	20	0.01	2.9	3.5	2.9	175	50
193	200	0.0025	0.4	0.5	0.4	25	15
194	200	0.0025	0.4	0.5	0.4	25	10
195	25	0.25	5.2	6.3	5.2	315	66
196	25	0.15	1.5	1.8	1.5	90	0
197	200	0	0	0	0	0	0
198	200	0.01	0.4	0.4	0.4	20	0
199	25	0.005	0.7	0.8	0.7	40	0
200	30	0.02	3.1	3.7	3.1	185	0
201	25	0.05	3.5	4.3	3.5	215	0
202	200	0	0	0	0	0	0

Catchment	Filter Strip Ratio	Fraction Draining to Pond	Pond Principle SA (hectares)	Pond Principle Vol. (m^3)	Pond Emergency SA (hectares)	Pond Emergency Vol. (m^3)	% Terraced
203	20	0	0	0	0	0	0
204	30	0.05	2.9	3.5	2.9	175	0
205	30	0.03	4.4	5.3	4.4	265	10
206	200	0.005	0.7	0.8	0.7	40	0
207	20	0.05	2.5	3.1	2.5	155	0
208	20	0.03	2.3	2.8	2.3	140	0
209	200	0.03	6.2	7.5	6.2	375	0
210	20	0.03	6.9	8.4	6.9	420	10
211	20	0.015	3.3	4	3.3	200	0
212	200	0	0	0	0	0	0
213	60	0.01	18.8	28.6	18.8	1430	10
214	20	0.2	6.8	8.3	6.8	415	20
215	20	0.2	9.5	14.4	9.5	720	33
216	30	0.03	2.9	3.6	2.9	180	20
217	200	0.015	4.3	5.2	4.3	260	10
218	59	0	0	0	0	0	0
219	20	0.015	6.3	7.7	6.3	385	0
220	15	0.04	1.9	2.4	1.9	120	0
221	100	0.0025	0.5	0.7	0.5	35	0
222	45	0.005	2.9	3.6	2.9	180	10
223	100	0.015	1.1	1.3	1.1	65	0
224	35	0.02	3	3.7	3	185	0
225	200	0.02	0.7	0.8	0.7	40	0
226	42	0.08	2.4	2.9	2.4	145	0
227	40	0.01	0.7	0.9	0.7	45	0
228	20	0.01	2.4	2.9	2.4	145	0
229	30	0	0	0	0	0	0
230	20	0.05	7	8.5	7	425	0
231	100	0.01	1.5	1.8	1.5	90	0
232	40	0.05	3.2	3.9	3.2	195	0
233	30	0.02	1.7	2.1	1.7	105	0
234	50	0.03	4	4.9	4	245	0
235	33	0.01	1.5	1.8	1.5	90	0
236	70	0.03	1.3	1.6	1.3	80	10
237	25	0	0	0	0	0	20
238	20	0.03	2.4	2.9	2.4	145	0
239	40	0.02	0.8	0.9	0.8	45	0
240	20	0.03	3.1	3.7	3.1	185	0
241	20	0.2	9.6	14.7	9.6	735	0
242	20	0	0	0	0	0	0
243	30	0.005	1.5	1.9	1.5	95	0

Catchment	Filter Strip Ratio	Fraction Draining to Pond	Pond Principle SA (hectares)	Pond Principle Vol. (m^3)	Pond Emergency SA (hectares)	Pond Emergency Vol. (m^3)	% Terraced
244	25	0.2	6.4	7.8	6.4	390	0
245	20	0.015	2	2.5	2	125	15
246	30	0.05	2.7	3.3	2.7	165	20
247	20	0	0	0	0	0	0
248	25	0.08	14.2	21.7	14.2	1085	0
249	20	0	0	0	0	0	33
250	20	0	0	0	0	0	0
251	20	0	0	0	0	0	0
252	20	0.005	0.2	0.3	0.2	15	0
253	20	0.03	0.6	0.7	0.6	35	0
254	20	0.02	4	4.9	4	245	0
255	1	0	0	0	0	0	0
256	15	0.0025	1	1.2	1	60	0
257	25	0.04	6.5	7.9	6.5	395	0
258	30	0.02	2.2	2.6	2.2	130	0
259	20	0	0	0	0	0	0
260	20	0.005	0.2	0.3	0.2	15	0
261	15	0.005	0.2	0.2	0.2	10	0
262	15	0	0	0	0	0	0
263	15	0.015	1.9	2.3	1.9	115	0
264	20	0.015	2.1	2.6	2.1	130	0
265	20	0.04	6.6	8	6.6	400	0
266	25	0.015	1	1.2	1	60	0
267	25	0.1	2.9	3.6	2.9	180	0
268	50	0.15	5.1	6.2	5.1	310	0
269	25	0.02	1.9	2.3	1.9	115	0
270	40	0.015	3.8	4.6	3.8	230	0
271	20	0.015	4.4	5.4	4.4	270	0
272	25	0.0025	0.8	1	0.8	50	0
273	20	0.15	6.3	7.7	6.3	385	0
274	20	0.02	1.9	2.4	1.9	120	0
275	20	0.02	7.4	9	7.4	450	0
276	30	0.01	1.4	1.7	1.4	85	0
277	200	0	0	0	0	0	0
278	30	0.04	2.5	3	2.5	150	0
279	35	0	0	0	0	0	0
280	35	0.08	2.8	3.5	2.8	175	0
281	15	0.01	0.5	0.7	0.5	35	0
282	20	0.01	1.2	1.5	1.2	75	0
283	25	0.03	1.2	1.5	1.2	75	0
284	20	0.05	2.8	3.4	2.8	170	0

Catchment	Filter Strip Ratio	Fraction Draining to Pond	Pond Principle SA (hectares)	Pond Principle Vol. (m^3)	Pond Emergency SA (hectares)	Pond Emergency Vol. (m^3)	% Terraced
285	100	0.01	0.3	0.4	0.3	20	0
286	40	0.05	1.5	1.8	1.5	90	0
287	60	0.1	11.6	17.6	11.6	880	0
288	40	0.03	1.5	1.8	1.5	90	0
289	40	0	0	0	0	0	0
290	50	0.02	1	1.2	1	60	0
291	15	0.1	0.4	0.5	0.4	25	0

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Appendix H – Water Quality Monitoring

Missouri's Water Quality Monitoring Strategy

Missouri's objectives reflect the needs of the Clean Water Act (CWA), the Safe Drinking Water Act, and other water management activities. Water quality monitoring provides the data to characterize waters and identify changes or trends in water quality over time. The collection of monitoring data enables Missouri to identify existing or emerging water quality problems, and determine whether current pollution control measures are effective in complying with the regulations. The CWA requires each state to monitor and assess the health of all waters and report their findings every two years to the EPA. The list of data and findings are discussed in a 305(b) Integrated Report (also known as the 305(b) report or water quality report) and is available from the Missouri Department of Natural Resources website at URL: http://dnr.mo.gov/env/wpp/waterquality/303d/303d.htm.

Monitoring Objectives

Missouri's overall objective of a monitoring program is to provide sufficient data to allow a water quality assessment of all waters of the state where data is available in both quantity and quality. The specific objectives for Missouri's monitoring program are described A Proposal for A Water Quality Monitoring Strategy for Missouri.

Assessing Water Quality Conditions

For assessing present conditions, more recent data are preferable; however, older data may be used to assess present conditions if the data remains representative of present conditions.

- If the department uses data older than seven years to make a Section 303(d) list decision a written justification for the use of such data will be provided.
- If a water body has not been listed previously and all data indicating an impairment is older than 7 years, then the water body shall be placed into the 303(d) Listing Category 2B or 3B and prioritized for future sampling.
- A second consideration is the age of the data relative to significant events that may have an effect on water quality. Data collected prior to the initiation, closure, or significant change in a wastewater discharge, or prior to a large spill event or the reclamation of a mining or hazardous waste site, for example, may not be representative of present conditions. Such data would not be used to assess present conditions even if it was less than seven years old. Such "pre-event" data can be used to determine changes in water quality before and after the event or to show water quality trends.

Core Water Quality Indicators

The table below describes MDNR's core and supplemental indicators utilized by the state for the determination of water quality decision needs. The process includes assessing water quality standards attainments and designated use support, identifying needed changes to water quality standards, describing causes and sources of impairments, developing water quality-based source controls, and assessing whether physical, chemical and biological integrity are supported. Details of MDNR's assessment methods and processes are described in Methodology for the Development of the Section 303(d).

List and Missouri Water Quality (305(b)) Integrated Report. Reference the MDNR website: http://www.dnr.mo.gov/env/wpp/waterquality/index.html for additional information.

Table B1. Details of Proposed Core and Supplemental Indicators

	Protection of Aquatic Life	Recreation	Drinking Water Supply	Fish and Shellfish Consumption
Core Indicators	• Quantitative Sampling of Aq. Invertebrates • Quantitative Sampling of Fish • Qualitative Sampling of Invertebrates and Fish • Habitat Assessment • Flow • Water Temperature • Dissolved Oxygen • pH • Conductivity • Sulfate • Chloride • TKN, NH^3N,NO^2+NO^3N • Total P • Diss. Al, Cd, Cu, Fe, Pb, Zn	• Fecal Coliform/E. coli • Total N, Total P **For lakes only:** • Secchi depth • Chlorophyll • VSS • NVSS	• Diss. As, Cd, Cu, Pb, Zn • NO^2+NO^3N • Dissolved Solids **For lakes only:** • Chlorophyll • VSS • NVSS • Total N, Total P	• Pesticides • PCBs • Hg, Pb • Dioxins • Dibenzo Furans
Supplemental Indicators	• Diss. Co, Ni, Cr, Th • Bioassay toxicity • Pesticides	• Hazardous chemicals	• Taste and odor causing substances • Diss. Fe, Mn	• Heavy metals, PAHs

Quality Assurance

MDNR has an EPA approved quality assurance (QA) management program in place and describes the processes to be followed for all MDNR environmental monitoring activities. All internal water quality monitoring completed by the department's Division of Environmental Quality must be done under a QAPP with the MDNR Environmental Services Program laboratory and approved by the MDNR QA manager. Environmental monitoring contracted to those outside of the department requires the contractor to also develop a QAPP that must be reviewed and approved by MDNR. Data generated in the absence of an MDNR approved QAPP may be used if the department determines the data is scientifically defensible after making a review of the quality assurance procedures used by the data generator. This review includes 1) names of all persons involved in the monitoring program, their duties and a description of training and work related experience; 2) all written procedures, standard operation procedures, or QAPPs pertaining to the monitoring effort; 3) a description of all the field methods used, brand names and model number of any equipment and description of calibration and maintenance procedures; and 4) a description of laboratory analytical methods.