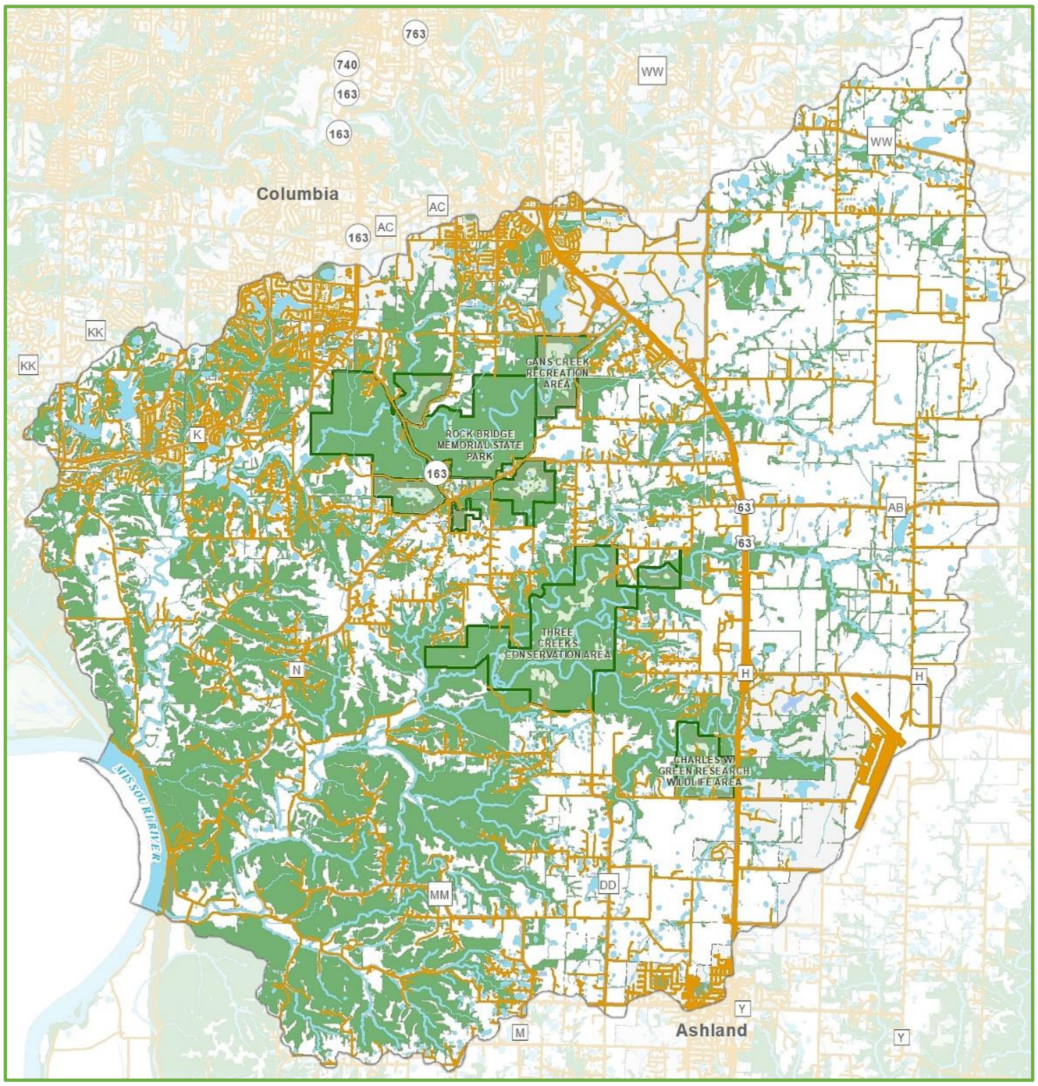
GREATER BONNE FEMME WATERSHED-BASED PLAN
- APPENDICES -

July 31, 2022



To address impairments in:
Bass Creek, Bonne Femme Creek and Turkey Creek – HUC: 10300102-0902
Gans Creek and Little Bonne Femme Creek – HUC: 10300102-0903

Prepared by Boone County Resource Management and Project Partners

Acknowledgements

USDA / ARS, and specifically Dr. Robert Lerch, for supporting this project from the beginning. Dr. Lerch was involved with the Greater Bonne Femme Watershed (GBFW) for many years. He conducted water quality monitoring at 10 sites in the GBFW over an extended period of time, giving us a baseline for levels of various constituents as discussed in this watershed-based plan (WBP). Bob was also instrumental in developing the water quality QAPP for this project. The project partners are grateful for his contributions and insight.

Roxie Campbell, Park Naturalist for Rock Bridge Memorial State Park, who has been involved with stewardship of this watershed for decades.

Boone County Regional Sewer District for the use of their laboratory for *E. coli* analysis.

The Technical Advisory Team, comprised of local, state and federal government and agency partners, as well as local landowners and non-governmental organizations, was instrumental in assisting project partners with evaluating the impaired waters in the GBFW and determining the path forward for drafting and implementation of the watershed-based plan. The Steering Committee consists of local government partners who have and will continue to provide policy support to facilitate implementation of the WBP. Members of the Technical Advisory Team and Steering Committees are listed below:

Amelia Cottle, landowner
Bryan Mayhan, University of Missouri and private soil scientist
Boone County Commission
Boone County Regional Sewer District
Boone County Soil and Water Conservation District
City of Ashland, Missouri
City of Columbia, Missouri
Columbia / Boone County Health Department
Emily Wright, local producer and Board Member of Greenbelt Land Trust
Greenbelt Land Trust
Missouri Department of Conservation
Missouri Department of Natural Resources / Section 319 and TMDL Teams
Missouri Stream Teams
Fred Parry, former Boone County Southern District Commissioner
Rock Bridge Memorial State Park
University of Missouri Extension
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United States Geological Survey / Columbia Education and Research Facility
University of Missouri-Columbia

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MISSOURI DEPARTMENT OF NATURAL RESOURCES

List of Appendices

Appendix A: Existing Environmental Protections

Greater Bonne Femme Watershed-based Plan: Appendix A
Existing Environmental Protections

Protective measures primarily exist in the form of local government regulations. The Missouri Department of Natural Resources (MDNR), as mandated by the Environmental Protection Agency, regulates small municipal separate storm sewer systems (MS4s). The University of Missouri (MU), City of Columbia, and Boone County are jointly permitted as an MS4. The MDNR defines a municipal separate storm sewer system as a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains, etc.) that are owned or operated by a public entity.

The City of Columbia and Boone County have adopted comprehensive stormwater management regulations. Those regulations address land disturbance, post development stormwater management and illicit discharges of pollutants into waterways within their jurisdictions. MU also has a comprehensive stormwater program. Unlike the City and County, MU does not have the authority or need to adopt ordinances. Instead, the University relies on administrative policy to enact stormwater controls.

Stream Buffer Regulations
New and redevelopment within unincorporated Boone County, and new development within the City of Columbia, are required to set aside land which borders streams having at least 50 acres draining to them. Both the City and County measure their buffers from the ordinary high-water mark of the channel which then extends a certain distance outward on both sides of the stream depending on stream type. Stream type is determined by the manner in which the stream is depicted on a United States Geological Survey 7.5 minute series topographical map. Additional buffer width may be added due to adjacent slope steepness (see table below).

The stream buffer is divided into two sections: the streamside zone and outer zone. The function of the streamside zone is to protect the physical, biological, and ecological integrity of the stream ecosystem. The outer zone prevents encroachment into the streamside zone and filters runoff from development.

City of Columbia and Boone County Stream Buffer Ordinances						
	Streamside Zone			**Outer Zone****		
Stream Types	Type I*	Type II*	Type III*	Type I*	Type II*	Type III*
Width	50	25	15	50	25	15
Vegetation	Native Vegetation			Type I - Native Vegetation Type II - Managed Lawns Permissible Type III - Managed Lawns Permissible		
Uses	Flood control, foot and bicycle paths, road crossings, utility crossings, stream or stream bank restoration and restoration of native vegetation			All uses allowed in the Streamside Zone, hard-surfaced biking/hiking paths, detention/retention structures, utility corridors, stormwater BMPs, residential yards, landscaped areas		
Function	Protect the physical and ecological integrity of the stream ecosystem			Protect key components of the stream and filter and slow velocity of water runoff		

* Type 1 = perennial streams symbolized by a solid blue line; Type 2 = intermittent streams symbolized by a dashed blue line; Type 3 = drainages not symbolized on 7.5' USGS topographical quadrangle maps, but have drainage areas greater than 50 acres.
**The outer zone may increase up to 50 feet for slopes greater than 25%.

Overview of Boone County's Stormwater Management Ordinance

Boone County adopted a stormwater management ordinance and stormwater design manual, which was effective April 15, 2010. Boone County Resource Management is responsible for enforcement of the County's stream buffer and stormwater ordinances. Long-term stormwater management in the County includes maintenance, inspection, and water quality management procedures for post-construction best management practices (BMPs). As property is developed, covenants, easements, and maintenance agreements are required to be in place prior to recording any final plats.

Section 4.6 of the stormwater ordinance provides enhanced criteria for environmentally sensitive areas. The land disturbance threshold is lowered to 3,000 square feet and additional protections are required for development near sinkholes, springs, caves, Type I streams per the stream buffer ordinance, gaining/losing streams, Outstanding State Resource Waters, and jurisdictional wetlands.

Boone County's stormwater ordinance establishes minimum stormwater management requirements and controls to protect and safeguard the general health, safety, and welfare of the public. This ordinance is intended to meet that purpose through the following objectives:

(1) Minimize increases in stormwater runoff from any development in order to reduce flooding, siltation and stream bank erosion and stream channel degradation.
(2) Minimize increases in nonpoint source pollution caused by stormwater runoff from development which would otherwise degrade local water quality.
(3) Minimize the total annual volume of surface water runoff which flows from any specific site during and following development to not exceed the predevelopment hydrologic regime to the maximum extent practicable.
(4) Reduce stormwater runoff rates and volumes, soil erosion and nonpoint source pollution, wherever possible, through stormwater management controls and to ensure that these management controls are properly maintained and pose no threat to public safety.

Overview of the City of Columbia's Stormwater Management Ordinance
The City of Columbia's stormwater ordinance passed in March 2007 and took effect in September 2007, along with The City of Columbia's Stormwater Management and Water Quality Manual.

[The purpose of the City of Columbia's stormwater ordinance is to:

- Protect the health, safety, and property of the people of Columbia by regulating the disturbance of land surface areas by preserving trees, preventing erosion on disturbed areas, and controlling stormwater drainage.
- Assure that consideration is given to the preservation and restoration of natural features in the grading or development of public and private land.
- Assure that proper provisions are made regarding control of sediments resulting from rainfall on graded areas, and that adequate facilities are constructed for the management of stormwater.
- Assure the movement of emergency vehicles during storm periods.
- Protect the public from rapidly flowing water and flash floods.
- Minimize storm and flood losses resulting from uncontrolled runoff.
- Establish requirements for construction of stormwater management facilities in newly developed areas.
- Establish reasonable stormwater utility charges to enable the stormwater utility to develop and maintain a stormwater management system.][1]

The City of Columbia also promulgates rules to protect water quality and prevent stream degradation in new and redevelopment.

The City of Columbia Stormwater Management and Water Quality Manual provides flexibility to allow stormwater management plans to be tailored to specific conditions in various Columbia watersheds for both development and redevelopment projects. The City's Community Development Department enforces the City's stream buffer ordinance and stormwater quality management for new development. The Community Development Department also requires covenants and maintenance agreements for post-construction BMPs to be recorded in the County land records. The City's Stormwater Utility receives and tracks annual inspection information for post-construction best management practices.

Overview of the City of Columbia's "Our Columbia Waters" Integrated Management Plan for Wastewater and Stormwater
In 2019, the City of Columbia submitted the *Our Columbia Waters Integrated Management Plan for Wastewater and Stormwater* to the Missouri Department of Natural Resources for final approval. The goal of the Our Columbia Waters Plan is to develop adaptable and affordable long-term recommendations that meet Columbia's wastewater and stormwater management needs and address Clean Water Act obligations to protect and improve our community waterways. The complete plan may be viewed at como.gov/utilities/sewer/imp/report/.

Overview of the University of Missouri-Columbia's Stormwater Guidelines
The University of Missouri's stormwater guidelines and Stormwater Master Plan were completed in late 2012 and were presented publicly in 2013. At MU, all construction projects are designed and reviewed by the MU's Campus Facilities – Planning, Design & Construction (CF-PDC) department using the PDC "Sustainable Design Policy." This policy incorporates sustainability principles and concepts in the design

of all facilities and infrastructure projects to the fullest extent possible, while being consistent with budget constraints, appropriate life cycle cost analysis, and customer priorities. The policy directs MU to meet or exceed MDNR best management practices for erosion and sedimentation control standards and implement innovative stormwater management. MU delegates authority to its Environmental Health and Safety department to implement compliance with the MS4 (Municipal Separate Storm Sewer System) permit. This delegation of authority is found in Section 7:001 (Delegation of Responsibility) of the University of Missouri Business Policy and Procedures manual.

Two MU research farms, Bradford Farm and South Farm, are located within the Greater Bonne Femme watershed. Approximately 90% of the stormwater runoff on Bradford Farm is collected in three lakes on the farm. This allows stormwater runoff and nutrients to be captured and used for irrigation purposes. South Farm utilizes animal lagoons to capture manure. These lagoons are maintained and pumped down onto fields when conditions are dry enough for water to soak in, which minimizes or eliminates animal manure runoff.

Overview of the City of Ashland's Stormwater Regulations
The City of Ashland's stormwater regulations passed July 26, 2011, along with their Stormwater Management and Water Quality Manual. The City is currently working with a consultant to update their stormwater regulations and water quality manual.

[The purpose of the City of Ashland's stormwater regulation is to lessen or avoid hazards to persons and property caused by uncontrolled stormwater runoff or by obstructions to drainage and to lessen the degradation of the quality of surface runoff.][2]

[The City of Ashland's Design Criteria for Stormwater Drainage Facilities establishes standard methods and principals for the design and construction of surface collection and drainage systems, storm water detention and retention systems and erosion control systems within the City of Ashland, Missouri. The City's Administrative Officer enforces the City's stormwater regulations.][3]

Other Stormwater and Water-Related Permits Required by the Missouri Department of Natural Resources (MDNR) or Army Corps of Engineers
[The Missouri Department of Natural Resources (MDNR) Water Protection Program issues site specific, general, and stormwater permits for multiple activities such as:

- General construction or land disturbance activity disturbing one acre or more.
- Discharges from regulated small (Phase II) Municipal Separate Storm Sewer Systems (MS4).
- Construction or land disturbance activity that are performed by or under contract to a city, county or other governmental jurisdiction that has a Stormwater control program for land disturbance activities that has been approved by the Missouri Department of Natural Resources.
- Stormwater discharges from production of paper and allied products, textiles, and apparel products, and, printing and publishing operations, and paper-only recycling, food, and kindred products manufacturing operations.
- Ferrous and Nonferrous foundries, casting, extrusion, rolling, galvanizing, and finishing, structural steel production, light metal fabrication, electrical equipment manufacturing.
- Stormwater run-off discharges from Primary Lumber and Wood Products Industries.
- Stormwater runoff from facilities engaged in wood treating operations.

- Stormwater runoff from facilities engaged in secondary processing and manufacturing of lumber and wood products.
- Chemical and Lubricant Manufacturing - Stormwater runoff only.
- Plastics and Rubber Manufacturing and Molding - Stormwater runoff only and Plastics and Rubber Recycling Operations.
- Biodiesel manufacturing facilities that are required to obtain a Stormwater permit.
- Agrichemical facilities - Containment water from bulk fertilizer and bulk pesticide facilities.
- Motor vehicle salvage yards and scrap metal recycling operations.
- Firms engaged in motor freight, watercraft transportation, warehousing activities, and U.S. Postal Service maintenance facilities.
- Stormwater runoff from airports that use deicers or conduct uncovered vehicle or aircraft maintenance, washing or fueling.
- Solid waste transfer stations, SIC 4953; and solid waste recovery facilities, SIC 5093.][4]

[Most construction activities involving work in Waters of the United States or Missouri's Waters of the State require authorization from the U.S. Army Corps of Engineers, also known as the Corps, or MDNR. Individuals, companies, corporations, federal and state agencies and local governments planning construction activities in a stream, river, lake, or wetland should contact the Corps or MDNR before any work begins. Such construction activities may require a permit from one or both agencies.][5] These permits include Dam Safety Permits, Sand and Gravel Mining Permits, and 401 Certification from MDNR and a 404 Permit from the Corps when placing material, or fill, into a jurisdictional water.

Boone County Wastewater Treatment Ordinance

[On-site sewage disposal problems in Boone County are the result of decades of growth in the unincorporated areas of the county. For most of these years, there were no regulations which covered how on-site sewage disposal systems were designed and built. The zoning and building regulations presently in effect were nonexistent in earlier years. State regulations were not completely effective and did not address existing conditions. Many of the soils in Boone County are incompatible or undesirable for septic systems, and many of these systems did not have the required lateral fields. Boone County Zoning and Subdivision regulations became effective in 1973. In 1987 Boone County began requiring building permits, alleviating some of these problems.

The Boone County Commission adopted an ordinance in 1993 for the construction of new on-site sewage treatment facilities construction and for remodeling or repairs of older systems so that eventually the disposal problems in Boone County can meet modern public health standards.][6] At this time, the ordinance does not require wastewater maintenance contracts.

Boone County residents constructing new wastewater systems or renovating existing systems must apply for a wastewater permit. Proposed plans for the wastewater system are reviewed by the Environmental Health and Safety Division of the Department of Public Health & Human Services, and a site inspection is conducted. The State of Missouri requires septic tank disposal systems, lagoon disposal systems, and alternative design systems to follow specific design criteria. A certified wastewater installer and certified soil scientist are required to evaluate site and soil conditions.

Appendix B: History of Water Pollution and Protection for Devil's Icebox Cave and Bonne Femme Watershed Streams

Greater Bonne Femme Watershed-based Plan: Appendix B
History of Water Pollution and Protection for Devil's Icebox Cave and Bonne Femme Watershed Streams
By Roxie Campbell, Park Naturalist, Rock Bridge Memorial State Park, October 6, 2020

Pollution events and the desire to prevent them has motivated action throughout the years especially in regard to Devil's Icebox Cave and its stream, which were recognized as significant karst resources. It started quite early in local history as indicated in an 1857 land deed. James McConathy who owned the whiskey distillery, tan yard and hog operations at Rockbridge Mills sold a portion of his land that was downstream of the mills to Briant Cariender and in the land deed put a caveat that Cariender agree to never sue over the nuisance of having "slop and filth" from the mills running in the creek and through the land. Legend has it that Cariender got a lifetime of free whiskey out of the deal.

For many years in the 1800s and early 1900s, land in the Bonne Femme watershed was farmed and animal waste was common, but generally not recognized as a water quality problem. Sinkholes were not very usable for farmers, so usually that's where they put dead hogs and other animals and where they put junk and trash that they couldn't burn. That's how some caves came to have names like "Hog's Graveyard Cave" and "Hoglot Cave," and, why years later, truckloads of metal and glass trash have either been removed from sinkholes by volunteers or still remain, slowly making their way into underground openings.

In the 1950s, exploring Devil's Icebox Cave became popular among University of Missouri-Columbia (UMC) students who formed a chapter of the Missouri Speleological Society called Chouteau Grotto. Cavers noticed a certain dome, where water drips in from the land surface, always had a sewage smell, so they dubbed it "Smelly Dome." When exploring inside the cave about 100 feet below the surface, it's easy to understand the connection: to understand that water from the surface flows without resistance or filtering through cracks in the limestone rock and pours into the underground river known as Devil's Icebox Cave Branch. Cavers regularly waded to thigh and chest deep in that water so, they became concerned about their health and safety and that of cave animals like the pink planarian that lived in the cave stream. The pink planarian was found to live nowhere else on earth, it was endemic to Devil's Icebox Cave. Thus, the entire population was vulnerable to extinction should the cave stream become too polluted.

In 1963, Eugene Hargrove, a freshman English major at UMC went on his first cave exploring trip in Devil's Icebox Cave. Then, he was hooked and became so passionate about caves and the need to protect them that he became an outspoken advocate for Devil's Icebox Cave in the community and opposed the approval of a subdivision that he believed would threaten water quality in the cave. Hargrove and other cavers raised awareness through local media and among local officials and the subdivision was not approved. Hargrove had changed his major to philosophy and became a pioneer in the new field of environmental ethics. His experiences with arguments about the protection of Devil's Icebox Cave became a case study that he included in his book entitled *Foundations of Environmental Ethics*. His life is a testament to the impact that experiencing the mystery and allure of a cave can have on an individual.

Hargrove formed the Devil's Icebox-Rock Bridge Park Conservation Task Force, submitted a report published in Missouri Speleology and corresponded with the Missouri State Park Board (MSPB), the Missouri Clean Water Commission, the Missouri Geological Survey and Governor Bond. Thus began a multi-agency cooperative effort that continues to date. A project to test water samples was conducted by staff of the UMC and U.S. Fish and Wildlife Service (USFWS). Water samples collected and analyzed in 1973 and 1974 provided evidence (phosphorus, chloride and organic carbon levels) that sewage contamination was indeed happening at locations such as Smelly Dome, however, large scale pollution was not found. In 1973, Boone County was considering a permanent zoning plan. Then director of the Missouri State Park Board (MSPB), James L. Wilson corresponded with Judge Butcher of Boone County. The result was that Boone County granted the MSPB request that zoning for the sinkhole plain be restricted to A-1 (one home per 10 acres) for much of the sinkhole plain and MSPB followed through with their stated goal by purchasing about 380 acres of sinkhole plain and adding them to the park. This included the Grassland Trail, Karst Trail and Community Trail areas.

Therefore, what we saw locally in the 1970s as Earth Day began across the county, was that an increased awareness of the need to protect Devil's Icebox Cave coupled with increased development pressure in the sinkhole plain, produced inter-governmental cooperation and actions to protect the cave. Pollution events that occurred in the early 1980s further emphasized the need and increased the efforts.

For sixteen years, personnel with the USFWS's Columbia National Fisheries Research Laboratory had been collecting an amphipod, *Gammarus pseudolinnaeus* (G.p.), every two months from the creek outside of Devil's Icebox Cave as their principal invertebrate toxicity test organism. When personnel went to collect on July 9, 1981, this amphipod that normally occurred in the thousands, could not be found! Further investigation found no surviving G. p. and also found pink planarians and snails absent where they normally were present. Two days later, about 200 yards inside Devil's Icebox Cave, dead bats were discovered in the cave stream. Analysis of the dead bats and dead G.p. amphipods found high levels of the pesticide Dieldrin (57 ppm in the amphipods). Dieldrin had been banned by the U. S. Environmental Protection Agency in 1974. Amphipods are known to feed on dead animals, so it is thought that the bats died first and then the amphipods fed on the bats and died from ingesting the pesticide. Yet investigators were not able to answer some questions. Why were isopods present (in numbers double that of normal) when they are known to be sensitive to Dieldrin? A possible answer is that some didn't feed on the bats and since other organisms were absent from the stream, more food existed to support their greater numbers. Why did snails die when they are fairly tolerant of Dieldrin? Possible answer is that another chemical was also involved. Since bats collected the previous year from Hunter's Cave also tested high for Dieldrin and it's thought that the same bat colony moves between the two caves, why didn't amphipods die that year? While investigators pointed to Dieldrin as the probable cause, they lacked confidence to be conclusive. The investigation itself was another exercise in inter-agency cooperation as staff from these agencies worked together: USFWS, Missouri Department of Natural Resources' (MDNR) Divisions of State Parks and Environmental Quality and the Missouri Department of Conservation (MDC). The amphipod G. p. which had been the dominant organism in the creek, never recovered and has remained absent to this date.

Pollution events drove the protection efforts where concerned individuals came together to form a group known as the Devil's Icebox Task Force. The task force was made up of different people at different periods of time, resurrected whenever there was renewed concern. The first one was started by Eugene Hargrove in the 1970's. In October, 1981, Park Superintendent Scott W. Schulte wrote a memo to Missouri State Park Director John Karel requesting that the current Devil's Icebox Task Force be continued and augmented with a representative from MDNR's Division of Geology and Land Survey and that the MDNR divisions be enabled to make the task force a priority. Specifically, he recommended that MDNR support a two-year water quality study and a dye tracing study. These requests were granted and the studies were conducted. The dye tracing study revealed that not only did the 1200 acre Pierpont Karst Sinkhole Plain contribute water to Devil's Icebox Cave, but also a large portion of its water was coming from a losing stream, Bonne Femme Creek. A losing section of the stream located above the Highway 163 bridge drained about 7,300 acres. This revelation was very significant and helped people to realize two things: 1) hundreds of acres of farmland that lacks sinkholes affects the water quality inside the cave and 2) the recharge area (land that drains into the cave) is much larger than previously thought.

A water quality study was indeed funded and supported by MDNR, MDC and the UMC Vet Diagnostic Lab. From June 1982 to July 1984, water samples were collected weekly from just outside the cave and monthly from three sites inside Devil's Icebox Cave and tested for 22 parameters that included bacteria, several chemicals, turbidity, dissolved oxygen, pH and temperature. They accomplished three objectives to: 1) determine water quality of water in Devil's icebox Cave system, 2) establish baseline data for future reference and 3) establish differences between feeder streams within the cave. The overall water quality as shown by the site outside of the cave, indicated periodic high levels of bacteria and measurable but not conspicuous levels of pollution from some chemicals. Nitrates which, are a good indicator of contamination from either organic wastes or chemical fertilizers, averaged 2.1 mg/L which was below the Missouri Public Drinking Water Standard of that time (10 mg/L). Again, this indicated that some contaminants were entering the cave stream but not at high levels. From within the cave, the feeder stream with the highest bacteria levels was the Left Fork (samples collected from 2200 meters in on the left) which implicated septic effluent from homes East of Pierpont. The study concluded that the fairly consistent high bacteria readings were likely from human sources while occasional spikes were likely due to heavy rain washing animal wastes off the land.

In 1980, Scott W. Schulte and John Willenberg, staff of Rock Bridge Memorial State Park, started offering and guiding Wild Cave Tours in Devil's Icebox Cave. These six-hour adventure trips became very popular and provided the opportunity for about 300 people a year to see first-hand the extraordinary cave resources that lie so quietly only 100 ft. below the surface. People waded in and learned about Devil's Icebox Cave Branch which flowed 3.5 miles underground before exiting at the scenic Devil's Icebox trail destination. The wild cave tours continued for 30 years, until 2010 when tours were stopped to protect bats. A new disease, White Nose Syndrome, which began in New York in 2006 and spread westward, killed over 6 million bats in the eastern U. S. For a number of years, free tours were offered to those who lived in the watershed/recharge area of the cave. After going on a tour in 1996, watershed resident Jay Franssen wrote "It makes you realize that what you do on top of the earth affects the bottom and beyond." Carol Franssen wrote "This huge experience will be treasured, just as we hope the Icebox will be treasured by all who impact this natural beauty."

Devil's Icebox Cave Branch and its life were not the only aquatic resources at risk in the area which, became abundantly clear when an ammonia spill killed an estimated 17,217 fish valued at $3,061 in four miles of Gans Creek and 3.5 miles of Little Bonne Femme Creek between October 21 and November 1, 1985. Investigators with the Missouri Department of Conservation reported this as a conservative estimate. Also dead were crayfish, frogs and aquatic invertebrates. The cause was a leak in a pipeline carrying a liquid fertilizer, urea ammonium nitrate, which unknowingly placed 5,000 gallons of fertilizer into a containment basin which was drained prior to the leak being detected. The ammonia was released from the Williams Brothers Pipeline Co. adjacent to Hwy. 63 into a tributary of Gans Creek. On November 1, 1985 at the Hwy. 163 bridge, the ammonia level was greater than 100 ppm. Efforts to clean up the spill were hampered by rain and high water.

For each of three years, 1996, 1997 and 1998, Roxie Campbell, Park Naturalist of Rock Bridge Memorial State Park sponsored outreach programs about water and cave protection. Invitation letters were mailed to residents who owned land in the Devil's Icebox Cave watershed/recharge area. About 40 to 75 people attended each program and some participated in wild cave tours. Campbell arranged several speakers who had affiliations with the following agencies or organizations: University of Missouri-Columbia, Boone County Department of Health, Soil and Water Conservation District, Show-Me Clean Streams, Friends of Rock Bridge, Missouri Department of Natural Resources and Missouri Department of Conservation. Again, this brought together people who had a common interest in protecting water quality in the area. Conversations led to the idea of meeting regularly and forming a work group. Jim Davis with Show-Me Clean Streams led the way by writing a grant application. This time, the group broadened its view to include all of the streams of the greater Bonne Femme Creek watershed. It also broadened its membership to include wide variety of local landowners and residents.

During the years of 1998-2002, the Bonne Femme Watershed Partnership found funding from two sources: Boone County Soil and Water Conservation District in the form of an Agricultural Nonpoint Source Special Area Land Treatment Project (SALT Project) and an Environmental Protection Agency (EPA) Section 319 mini-grant. The partnership focused on providing education and cost-share for landowners. These went hand-in-hand. For example, cattle producer Donnie Wren found cost-share and technical assistance through the Missouri Department of Conservation and the U.S. Fish & Wildlife Service for fencing nearly two miles of stream and developing alternative water sources for his cattle. Then, the partnership sponsored a field day where others came to see and learn about this best management practice (BMP). Other field days displayed innovative on-site sewage systems. A 2001 forum designed for developers promoted such things as planned cluster developments that protected a site's natural resources and stormwater practices new at the time such as detention basins and stream buffers. In 2000, a watershed friendly lawn care demonstration and wayside exhibit sign was installed at the Hickam Cabin at Rock Bridge Memorial State Park. Educations efforts included: newsletters mailed to over 2,000 residents, annual meetings, an annual children's watershed festival for about 400 local 5th grade students and a water festival for the public. Volunteers helped with stream clean-ups, tree plantings and water quality monitoring.

Augmenting the local level movement was new stormwater regulations from the Environmental Protection Agency (EPA) which was a factor in the development of the Community Stormwater Project, a collaboration between the City of Columbia, Boone County, University of Missouri and Show-Me Clean Streams, which conducted a survey of more than 50 residents and produced a report in 2001 that assessed storm water problems.

In 2005, the Missouri Department of Conservation led a number of partners in a series of meetings the result of which was the formation of the Bonne Femme Karst Conservation Opportunity Area (COA). This status carried with it recognition for the high value of the natural resources of the area and the process fostered partnerships.

The population in the Bonne Femme Watershed grew by 40% in the 10-year period between 1990 and 2000. And, water quality data was showing consistently high fecal bacteria levels suggesting on-site sewers and poor livestock management were the most likely sources. In response, Stephen M. Mahfood, Director of the Missouri Department of Natural Resources talked with Jerry Conley, Director of the Missouri Department of Conservation and they agreed to devote staff to investigate ways to protect the caves and streams of the Bonne Femme Watershed. They, along with Bill Florea of Boone County, Robert N. Lerch of USDA-Agricultural Research Service and others, formed the Southern Boone County Karst Team. Since most of the watershed is in Boone County's jurisdiction, the Karst Team invited county staff to participate on the team, and asked the county commission to sponsor a Section 319 grant. In

November 2001, the Boone County Commission formally applied for the grant, which was to be administered by its Planning and Building Inspection Department. The grant provided funding for the County to hire a full time temporary employee, Terry Frueh, as an Urban Conservationist who would be dedicated staff for the project. The cities of Columbia and Ashland agreed to be listed as partners in the grant application. The 319 grant funded the Bonne Femme Watershed Project from 2003 through 2007.

After the grant was awarded, several members of the Southern Boone County Karst Team became the Project's Steering committee. They formulated the project mission statement: use watershed planning as a tool to prevent further water resources degradation in order to maintain their long-term quality within the Bonne Femme watershed. To facilitate the plan's development, the Bonne Femme Watershed Project was organized into three committees: Steering, Policy, and Stakeholder. From the beginning of the project, the Steering Committee felt that strong community input was crucial to the plan's success. So, the Steering Committee delegated responsibility for development of the watershed plan to the Stakeholder Committee, and in the process, it adopted a support role by providing education, technical advice, and facilitation of Stakeholder meetings. The Policy Committee aided the Stakeholders by providing a political and legal perspective.

The Policy Committee consisted of the following agencies and entities: Boone County Commission, Boone County Planning and Zoning Commission, Boone County Regional Sewer District, Boone County Water District #9, City of Ashland, Columbia City Council, Columbia Planning and Zoning Commission, Consolidated Public Water Supply District #1, and the University of Missouri-Columbia. This Committee performed several key functions throughout the life of the Project. They established the make-up of the Stakeholder Committee and acted as liaisons with their agencies to educate and support project goals. Since the watershed lies in many different jurisdictions, interagency coordination was important to ensure that efforts were synergistic and not counterproductive, while providing interagency communication regarding actions or planned actions within the Bonne Femme Watershed. Members provided input on the legal and political feasibility of the watershed plan's recommendations.

The Policy Committee followed three Steering Committee recommendations when choosing the Stakeholders:

1. Select some people who do not own watershed land, but have a vested interest in the watershed because of development, recreation, or environmental protection;
2. Include diverse, even adversarial, interests to provide a necessary spectrum of ideas to be considered;
3. Have a Stakeholder Committee of eighteen people, with three general groups represented: business/construction, environmental and landowner.

With such a makeup, the diverse interests were well represented, and the Stakeholder Committee had the needed balance to complete a plan that reflected the values of the community. Representing the business group were individuals from construction, development, real estate, engineering, banking, and other businesses. The environmental group was represented by educators, recreators, and local watershed and environmental organizations. The third group represented watershed landowners, including farmers, and homeowners. It should be noted that the three general groups often had overlapping interests, and thus it was somewhat artificial to place each Stakeholder into a single interest "box."

The Stakeholders held their first meeting in June 2004, and continued to meet on a monthly basis until completion of the plan in February 2007. To reinforce their autonomy, the Steering Committee recommended that the Stakeholders elect two co-chairs, who ran the meetings, and decide amongst themselves how to organize their meetings and establish voting procedures to be followed. Stakeholders were given full control over the plan content. Key factors in the success of the Stakeholder Committee were their willingness to commit their time and energy to the project and their willingness to have open dialog and work through differences of opinion and form consensus.

The Bonne Femme Watershed Plan was unanimously adopted in November, 2007 by the three local governmental entities that have jurisdiction over most of the watershed – Boone County Commission, City of Columbia, and the City of Ashland. The plan and its recommendations can be viewed on the project's website, www.CaveWatershed.org.

Appendix C: Dr. Robert Lerch's Full Water Quality Report

Water Quality

Water quality monitoring has been periodically conducted at 10 subwatershed sites since 2003 to capture the differences in land use that impact water quality across the Greater Bonne Femme Watershed. Sampling campaigns, with the same sampling frequency, occurred from 2003 to 2007 and again from 2016 through 2019, with some limited *E. coli* sampling in 2020. The focus of the monitoring has been bacteria, nutrients, and herbicides. These non-point source contaminants are good indicators of overall water quality as multiple sources within the subwatersheds may contribute. These sources may include agricultural lands (hay and grazed pastures and cropland), turf (residential and business), forests (wildlife) and on-site wastewater systems. The following discussion is a comparison between the 2003-2007 and 2016-2020 data in an effort to assess changes in water quality in the GBFW over time. Note that the methods for bacterial analysis were different between the two datasets; the 2003-07 data are expressed in colony forming units (cfu)/100 mL and the 2016-20 in most probable number (MPN)/100 mL. Both methods measure the fecal coliform bacteria, *E. coli*, which is the indicator species for fecal contamination of water. The water quality standard for whole-body contact (WBC A) is 126 cfu or MPN/100 mL, and the water quality standard for WBC B is 206 cfu or MPN/100 mL. Of the nutrients measured, only ammonium-N (NH_4-N) has established chronic (0.1-10.8 mg/L) and acute (0.8-48.8 mg/L) water quality standards for streams in Missouri (https://dnr.mo.gov/env/wpp/wqstandards/index.html); there are currently no concentration standards for nitrate-N (NO_3-N), orthophosphate-P (PO_4-P), and herbicides in streams. There are standards for drinking water, i.e., treated water, for NO_3-N (10 mg/L), and for herbicides, such as the atrazine maximum contaminant level (MCL) of 3 µg/L.

Bacteria

Data for the Greater Bonne Femme sites showed that six sites had increases in the median *E. coli* levels from 2016-20 compared to 2003-07 (Figure 1), but there was a statistically significant increase at only one site, Hunters Cave. Four sites showed decreased median *E. coli* levels over time, and Fox Hollow significantly decreased from a median of 170 cfu/100mL to 74 MPN/100 mL. Median *E. coli* levels did not exceed the whole-body contact standards at six of ten sites, meaning that most sites exceeded the standard <50% of the time. Two sites that consistently exceeded the standard from 2003-07 – Devils Icebox Spring Branch and Turkey Creek – continue to exceed it >50% of the time from 2016-20. On the other hand, Fox Hollow Branch showed the biggest decline over time of any site. Based on observation from 2003-07, cattle were commonly

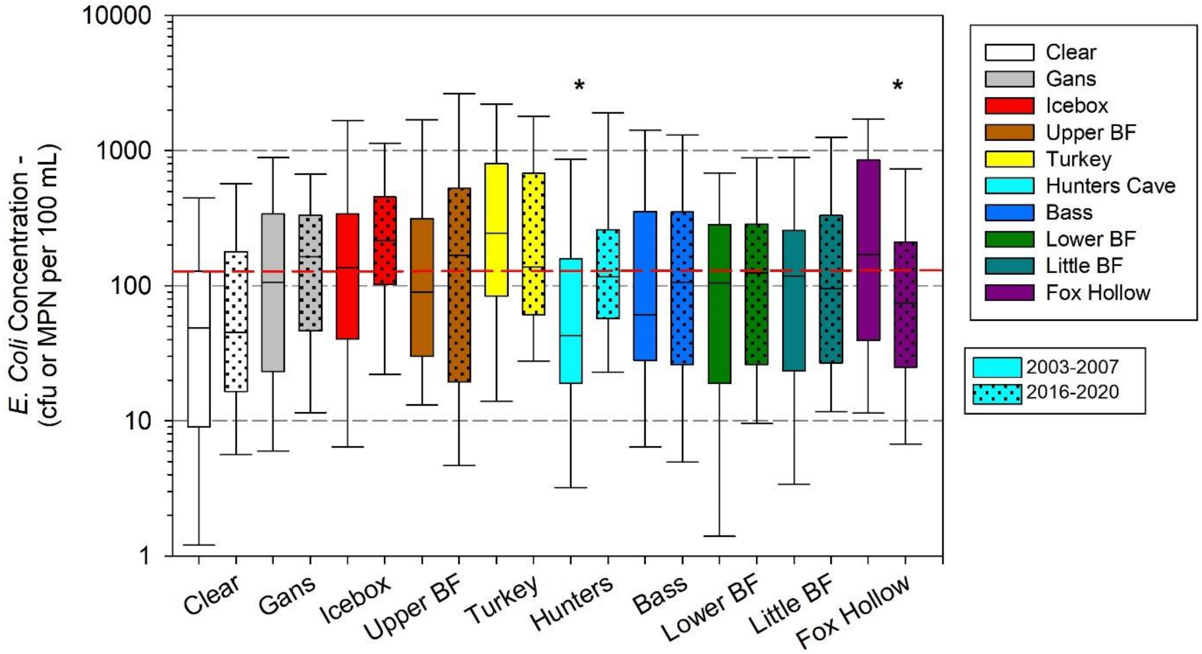


Figure 1. Comparison of *E. Coli* concentrations over time in the Bonne Femme sub-watersheds. Outer bars are 5th and 95th percentiles; boxes are 25th to 75th percentiles with median. *within site significant difference. Dashed red line indicates whole body contact standard (126 cfu or MPN/100 mL).

in the stream and manure was stockpiled adjacent to it. By 2016-20, cattle were observed only once in the stream and manure is no longer stockpiled. Results of MST indicated that ruminant and human DNA were the two most common sources of *E. coli*. Human sources were detected at low levels, and ruminant sources were more often detected at higher levels. Cattle and deer would be the most common ruminants within these watersheds, and goats have commonly been present in Fox Hollow Branch.

Nutrients

Median nitrate (NO_3-N) concentrations decreased at all sites, except Little Bonne Femme Creek, but the decreases were significant only at Clear Creek and Fox Hollow Branch (Figure 2). At five of the sites, median concentrations have remained low (<0.5 mg/L) over time. The Devils

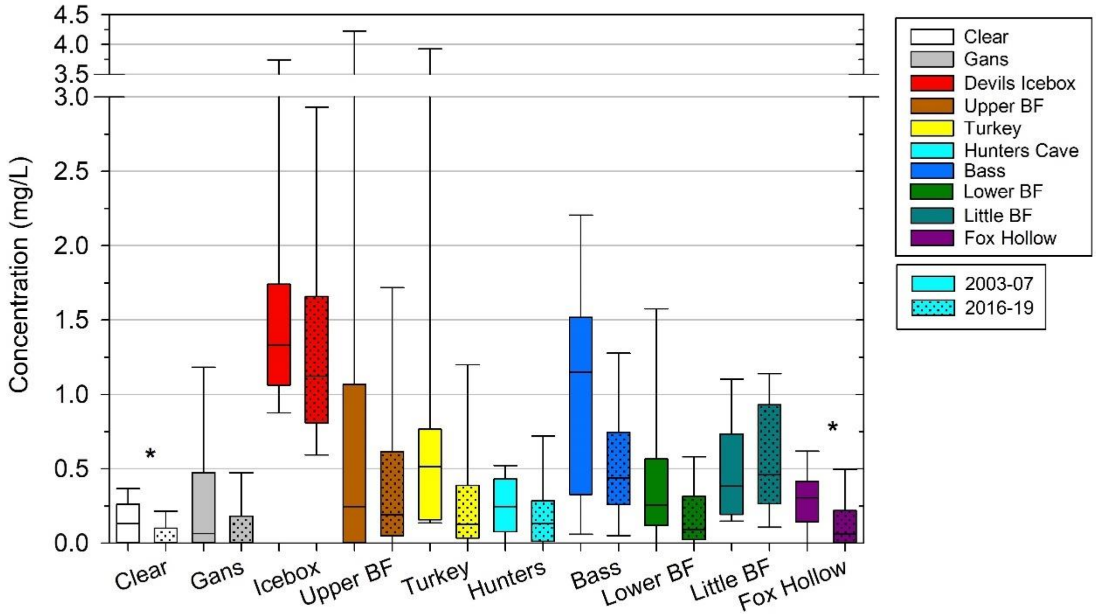


Figure 2. Comparison of nitrate-N (NO_3-N) concentrations over time in the Bonne Femme sub-watersheds. Outer bars are 5th and 95th percentiles; boxes are 25th to 75th percentiles with median. *within site significant difference.

Icebox Spring Branch consistently had the highest NO_3-N levels of any subwatershed, with median concentrations of 1.33 mg/L from 2003-07 and 1.12 mg/L from 2016-20, while none of the other sites currently have median concentrations >0.5 mg/L.

In contrast, PO_4-P concentrations increased at 8 of 10 sites, but the increase was significant only at Little Bonne Femme Creek (Figure 3). Clear Creek slightly decreased while Turkey Creek remained unchanged in median PO_4-P concentrations. At seven sites, median PO_4-P concentrations were $\leq$ 0.05 mg/L, but Devils Icebox Spring Branch, Upper Bonne Femme Creek, and Little Bonne Femme Creek had medians of approximately 0.1 mg/L. From 2016-20, 75th percentile concentrations were 0.243 mg/L at the Devils Icebox Spring Branch and 0.383 mg/L at Upper Bonne Femme Creek – i.e., 25% of samples exceeded those concentrations at these two sites.

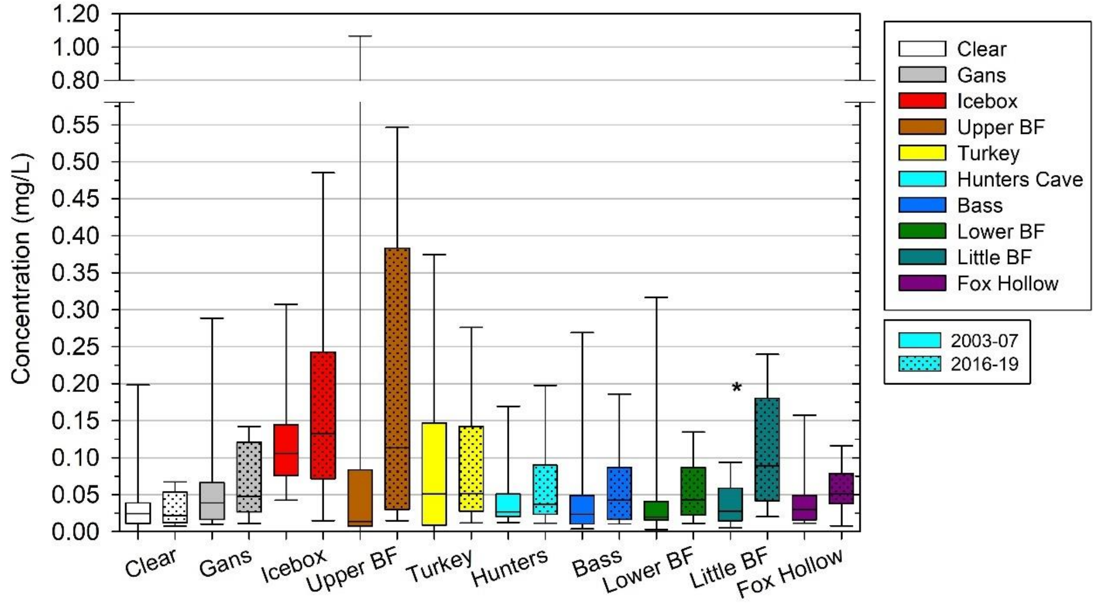


Figure 3. Comparison of orthophosphate-P (PO_4-P) concentrations over time in the Bonne Femme sub-watersheds. Outer bars are 5th and 95th percentiles; boxes are 25th to 75th percentiles with median. *within site significant difference.

Changes in median NH_4-N concentrations over time (Figure 4) were generally minimal except the approximately 50% decreases observed at Upper Bonne Femme and Turkey Creeks, and the increases of Clear Creek and Hunters Cave from non-detectable in 2003-07 to 0.013 to 0.015 mg/L from 2016-20. However, differences over time were minor at the remaining six sites, and there were no statistically significant changes in NH_4-N concentrations at any site.

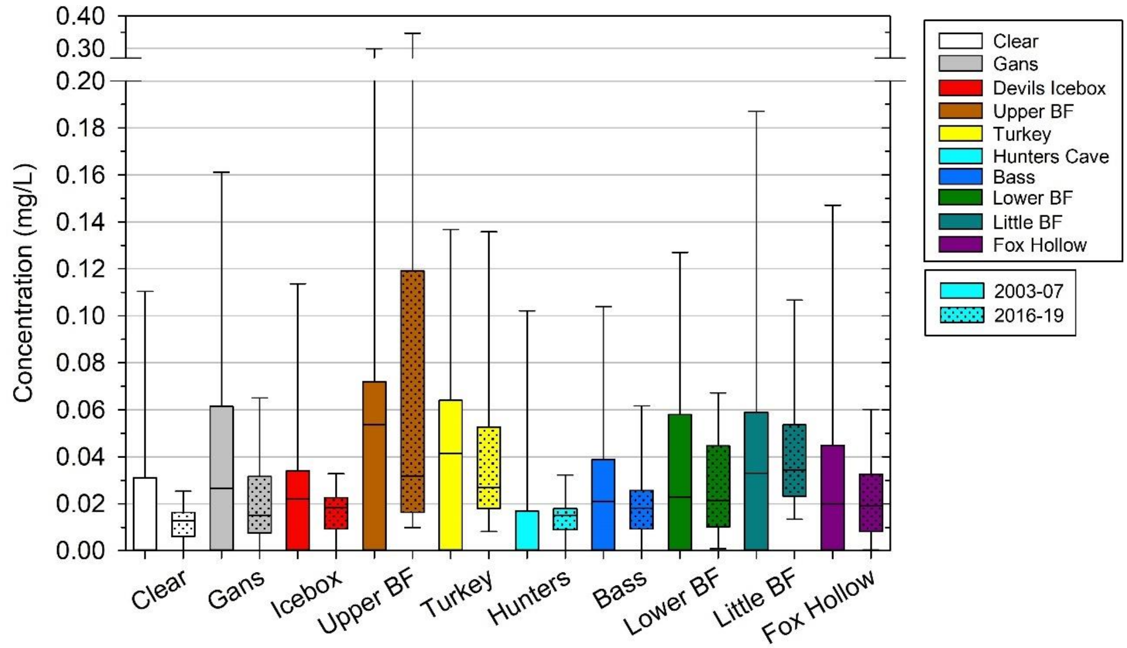


Figure 4. Comparison of ammonium-N (NH_4-N) concentrations over time in the Bonne Femme sub-watersheds. Outer bars are 5th and 95th percentiles; boxes are 25th to 75th percentiles with median.

Herbicides

Five corn and soybean herbicides – atrazine, alachlor, acetochlor, metolachlor, and metribuzin – and two breakdown products of atrazine – DEA and DIA – have been included as part of the monitoring, and in 2016-19, simazine was added. Median herbicide concentrations in spring and summer decreased over time for atrazine, DEA, DIA, and acetochlor, but increased for metolachlor and metribuzin (Table A). Herbicides were detected previously and currently, with atrazine, DEA, and metolachlor most often detected from 2003-07 and from 2017-19. Simazine was detected in 94% of samples from 2017-2019 compared to earlier. Of the herbicides monitored, atrazine was most often detected and at the highest levels, but comparison among sites showed that median atrazine concentrations decreased at every site except Clear Creek and Devils Icebox Spring Branch, where concentrations remained essentially unchanged over time (Figure 5). Major declines were observed at Upper Bonne Femme, Turkey, Bass and Lower Bonne Femme Creeks, and Hunters Cave. From 2017-19, only the Devils Icebox Spring Branch had a median atrazine concentration >1.00 µg/L.

Table A. Herbicide concentrations and frequency of detections over time.

	Atrazine	DEA	DIA	Acetochlor	Alachlor	Metolachlor	Metribuzin	Simazine
	--2003-2007†							--
Median, µg/L	0.632	0.306	0.155	0.016	<0.004	0.009	<0.004	–
Max, µg/L	10.5	4.26	1.93	1.57	0.730	1.47	0.034	–
% Detection	100	100	63	65	23	75	20	–
	--2016-2019							--
Median, µg/L	0.213	0.122	0.118	0.010	<0.004	0.221	0.019	0.007
Max, µg/L	33.3	6.41	4.50	2.00	<0.004	8.33	0.780	1.31
% Detection	100	99	81	81	0.0	99	78	94

†Data from May, June, and July 2003-2006 and 2017-2019 and pooled from all sites.

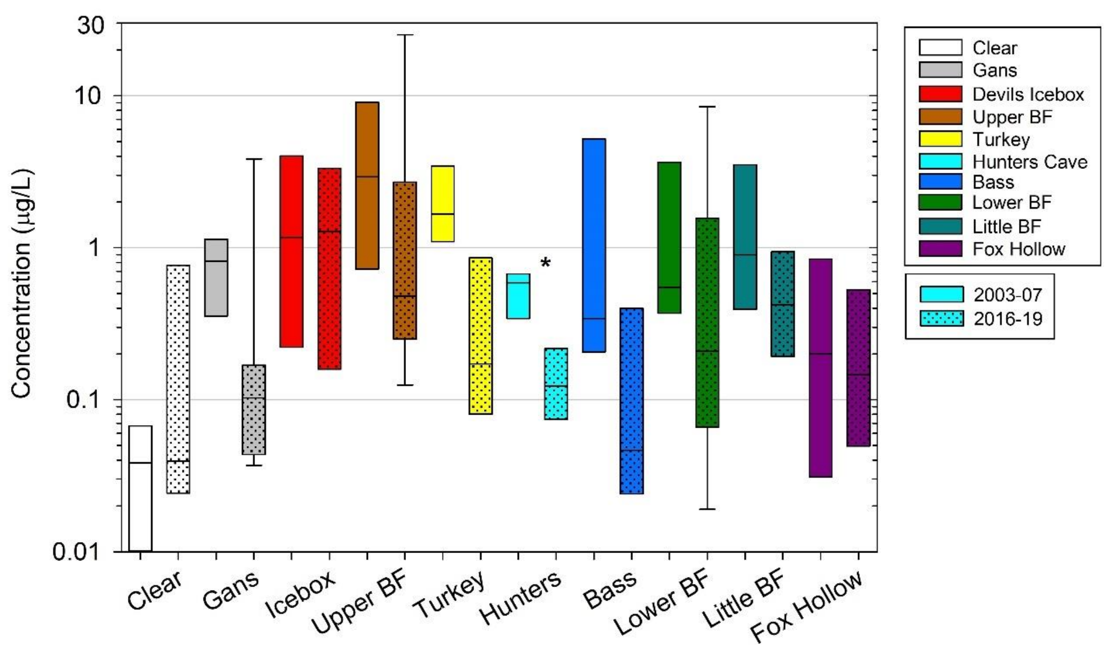


Figure 5. Comparison of atrazine concentrations over time in the Bonne Femme sub-watersheds. Outer bars are 5th and 95th percentiles; boxes are 25th to 75th percentiles with median. *within site significant difference.

Summary and Conclusions

Levels of *E. coli*, nutrients, and herbicides in GBFW subwatersheds showed minor changes in water quality over the last 13 years. However, exceedance of the *E. coli* whole-body contact criteria now occurs less frequently in the majority of subwatersheds, but high levels continue to occur under conditions of high flow during the 2nd and 3rd quarters of the year. With the exception of the Devils Icebox Spring Branch and Upper Bonne Femme Creek, nutrient levels in most subwatersheds were in the lower range reported for agricultural watersheds throughout the US Corn Belt (Lerch et al., 2015a). Nutrient and herbicide concentrations in the Devils Icebox Spring Branch and Hunters Cave subwatersheds remained similar to data from 1999 to 2002 for these two sub-watersheds (Lerch, 2011; Lerch et al., 2015b; see Appendix 7 for link to this data). The higher nutrient concentrations in the Devils Icebox Spring Branch and Upper Bonne Femme Creek reflected more intensive agricultural land uses within these subwatersheds, and their nutrient concentrations were in the upper range reported for northeastern Missouri streams (Blanchard and Lerch, 2000; Lerch et al., 2015a) and the Central Irregular Plains ecoregion, which includes the GBFW. While there are no Missouri WQS for nutrient concentrations in streams, and nutrient levels did not approach exceedance of the criteria range recommended by EPA for WQS for this ecoregion, all sites have chronic low-level contamination at concentrations known to impair aquatic ecosystems (Dodd and Welch, 2000; US EPA, 2000). Dissolved nutrient concentrations that can cause water quality degradation via ecological impairment or creation of nuisance conditions can occur at concentrations as low as 0.025 mg/L for NO_3-N, 0.002 mg/L for PO_4-P, and 0.005 mg/L for NH_4-N (Dodds and Welch, 2000; US EPA, 2000). While herbicides were frequently detected they generally remain at low levels, with the exception of atrazine. From 2017-19, peak atrazine concentrations were >10 µg/L at three sites – Devils Icebox Spring Branch (14.8 µg/L), Upper Bonne Femme Creek (25.2 µg/L), and Turkey Creek (33.3 µg/L), and these concentrations have been documented to exceed the level of concern for impairment of aquatic ecosystems (US EPA, 2016). Based on this assessment, water quality in the GBFW has not significantly improved nor degraded since 2003, and chronic nonpoint source contamination remains a problem.

Citations are listed in the References section.

Appendix D: Missouri Agriculture – 2016 Economic Contributions of Agriculture and Forestry

MISSOURI AGRICULTURE

2016 Economic Contributions of Agriculture & Forestry

Agriculture.Mo.Gov

BOONE COUNTY

Economic Contributions of Agriculture, Forestry & Related Industries:

Sales: $1.0 billion

Jobs: 5,819

Value-Added: $344.8 million

Labor Income: $201.9 million

Inputs: $667.0 million

Taxes: $74.4 million

Sales: The broadest measure of economic activity - often referred to as "output"; **Employment (Jobs):** A measure of job positions without regard to whether they are full-time equivalents; **Value-Added:** Sales (output) minus the cost of inputs; **Taxes:** Includes taxes paid at the federal, state and local levels.

Economic Contributions						
	Inputs ($M)	+	Value-Added ($M)	=	Sales ($M)	Employment
Ag Inputs & Services	$47.3		$61.7		$108.9	1,534
Crops, Livestock, Forestry, & Fisheries Production	$45.7		$54.9		$100.6	1,587
Food & Kindred Products Manufacturing	$546.0		$214.8		$760.9	2,543
Forestry Products Manufacturing	$27.9		$13.4		$41.3	156
Total	$667.0		$344.8		$1,011.8	5,819

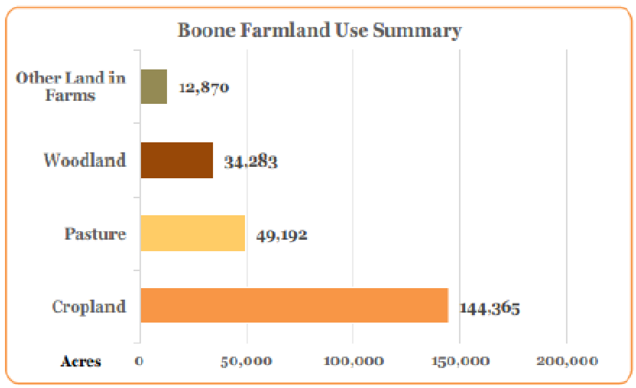
Number of Farms: 1,171 farms

Average Size of Farm: 206 acres

Total Land Area: 438,739 acres

Total Land in Farms: 240,710 acres

Population (2015): 174,974



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MO Dept of Ag | MO Farm Bureau | MASBDA | DIS

Missouri Agriculture – 2016 Economic Contributions of Agriculture and Forestry

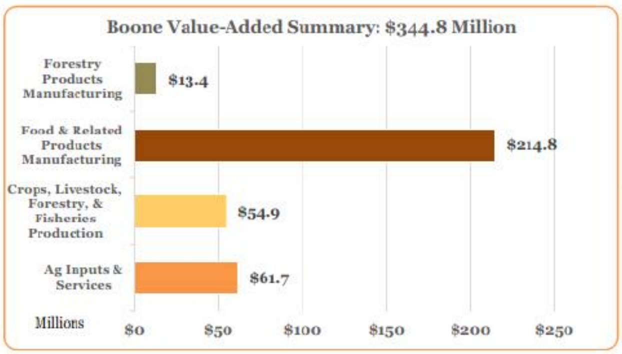
MISSOURI AGRICULTURE

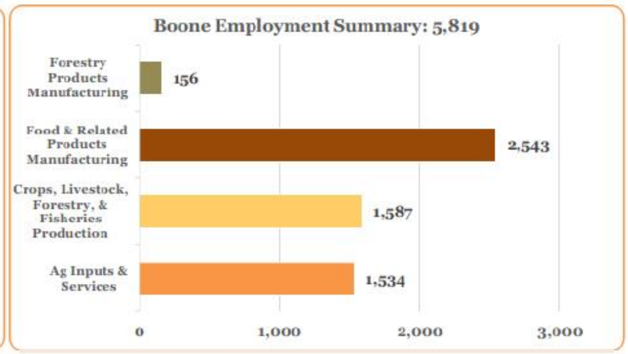
2016 Economic Contributions of Agriculture & Forestry

Agriculture.Mo.Gov

BOONE COUNTY

Overall Top Three Contributors (Ranked by Value-Added)						
	Inputs ($M)	+	Value-Added ($M)	=	Sales ($M)	Employment
Landscape and horticultural services	$29.7		$45.3		$75.0	1,182
All other food manufacturing	$95.6		$41.3		$136.9	587
Meat processed from carcasses	$122.1		$35.5		$157.6	461





Crops, Livestock, Forestry & Fishery Production - Top Three Contributors (Ranked by Value-Added)						
	Inputs ($M)	+	Value-Added ($M)	=	Sales ($M)	Employment
Oilseed farming	$7.3		$18.1		$25.4	156
Beef cattle ranching and farming	$8.8		$8.7		$17.5	335
Hogs	$2.7		$6.8		$9.5	295

Note: Totals in tables may not sum due to rounding.

Overall Contributions to Boone County

Agricultural, forestry, and related industries support 5,819 jobs in Boone County. Additionally, these industries contribute $1.0 billion in sales, which translates to $344.8 million in added value to the area after $667.0 million worth of inputs are purchased. Of this $344.8 million, $201.9 million is comprised of labor income. Tax revenues generated by the agricultural, forestry, and related industries in Boone County are $74.4 million.

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Appendix E: 2007 Watershed Management Plan Goals

Goal	Strategies	Recommendations
Ensure that structures are not built in places that will flood	Updated 100 year floodplain maps and regulations	Political subdivisions should consider complete hydrologic modeling to determine where the 100-year floodplain would be under full build-out conditions and locate it more accurately on floodplain maps. This modeling should be limited to development areas to keep costs down. Allow no construction of structures for occupancy in the re-delineated 100-year floodplain.
	Zoning – Streamside buffer ordinance	Adopt a stream buffer ordinance that limits construction within its boundaries
	Design manual	Do not permit new development to increase peak flows downstream so that flooding is not exacerbated.
	Purchase structures that flood now	City or County may offer to purchase a structure, at prevailing market rate, to correct a flooding problem in an existing neighborhood, if the cost of correcting the problem exceeds the value of the structure.

Goal	Strategies	Recommendations
Conserve recharge & karst areas with special protections	Design manual/ Performance based goals	The *level of service* (following Columbia's stormwater manual and ordinance) will be more restrictive (e.g. by one or two points on the level of service scale) in karst and recharge areas than in other areas. Local governments will adopt similar, compatible stormwater ordinances and design manuals.
	Zoning	Zoning ordinances will establish specific criteria for development in karst recharge areas. These should include defining levels of stormwater quantity and quality and limiting new sanitary sewers to *no discharge systems*.
	Land purchase	Local governments may purchase land from willing sellers in karst recharge areas, but other options for protecting water quality should be explored first. Create management plans for this purchased land with a primary goal to protect water quality. (Government takings of eminent domain should not be used for acquiring land for this purpose)
	TDRs & conservation easements	Transfer of development rights (TDR) should be established county-wide, with sensitive areas (such as karst recharge areas and steep slopes) being primary sending areas. This program should enable the cities and the county to have joint program reciprocity. TDR and conservation easements should be economically and logistically feasible options for use by landowners and developers.
	Tax relief	Create incentives to encourage conservation in karst recharge areas.
	Zoning and Subdivision regulations; Design manual	Consider a plan to provide special protections to karst and recharge areas.
	Further scientific study and monitoring	More scientific analysis should be done to further delineate karst recharge and other environmentally sensitive areas, and more definitively identify sources of contamination.

Goal	Strategies	Recommendations
Ensure that changes in land use do not increase downstream flooding or channel instability, or decrease water quality	Design manual	The *level of service* (following Columbia's stormwater ordinance and manual) for stormwater runoff flow characteristics post-development shall be no less than pre-development. Similarly, stormwater quality should have the same or better characteristics for post-development as it had pre-development. Local governments should adopt similar, compatible stormwater ordinances and design manuals.
	Encourage *low impact development (LID)*	Local governments should establish additional zoning and subdivision regulations that allow LID as a *matter of right* (i.e. approval will be expedited). This avoids the problems associated with the planned development process and encourages LID.
	Education	Make new stormwater manuals and ordinances widely available and familiar to the public through a public outreach and education effort.
	Develop funding mechanisms	New sources of funding should be pursued to assist landowners in implementing stream-protection *best management practices (BMPs)*. Compile a list of available sources of funding and provide to landowners and developers.
	Financing of storm water program	Secure sustainable, adequate funding for stormwater programs.

Goal	Strategies	Recommendations
Encourage low impact development as a way to maintain or improve water quality	Education	Implement a comprehensive educational program for the general public, landowners, and developers to encourage LID.
	Design manual	Revise local governments' development regulations to promote environmentally sensitive design and maintenance. The level of service (following Columbia's stormwater manual and ordinance) will be more restrictive (e.g. by one or two points on the level of service scale) in susceptible watersheds (following maps 6.0E, 7.3E and 8.2B of the Subwatershed Sensitivity Analysis) than in less susceptible watersheds. Local governments will adopt similar, compatible stormwater ordinances and design manuals.
	Tax relief, funding, Economic development	Create economic incentives to encourage developers to implement LID.

Goal	Strategies	Recommendations
In order to maintain quality of life, encourage parks, healthy streams, LID, and municipal services	Land purchase, Develop funding mechanisms, Economic incentives	Provide mechanisms and/or incentives to set aside land in non-LID developments for land to be set aside for parks or green space, especially in conjunction with a stream buffer. Encourage these features in other new, as well as preexisting, neighborhoods.

Goal	Strategies	Recommendations
Maintain the economic viability of the community while protecting clean streams	Education	Include information on protecting clean streams in development information distributed by the city and county (through web, forms, brochures). Develop a map that shows protected areas and include this in all literature related to development.
	Design manual	Local governments should adopt similar, compatible stormwater ordinances and design manuals that have stream protection information and requirements.
	Zoning	Address zoning where protection is necessary.

Goal	Strategies	Recommendations
Enhance healthy streams in parks	Education	Make stream protection a central part of park management. Establish park definitions to include stream protection goals. BMPs should be used on property owned by local governments.

Goal	Strategies	Recommendations
Maintain clean water without unnecessarily restricting property rights	Design manual	Give detailed design information to developers and engineers to assist them in controlling runoff quality and quantity from development.
	Zoning	Use voluntary zoning changes to direct density, and therefore higher runoff, to the most appropriate areas.
	Subdivision and zoning regulations	Revise local governments' ordinances and design manuals to enable reductions in impervious surface by allowing flexibility in street width, sidewalks, etc.
	Education	Expand public education newsletters and mail them more frequently.
	Develop funding mechanisms	Secure sustainable public funding for the operation and maintenance of BMPs, especially those funded by government agencies.
	TDRs and conservation easements	Encourage landowners to use various economic incentives (e.g. conservation easements and TDR).

Goal	Strategies	Recommendations
Have policies which boost jobs, retail, tax base, and local economics	Zoning	Locate retail, by appropriate zoning, to areas that will allow the most efficient use of infrastructure and the least hazard of stream pollution.
	Economic incentives	Consider reduction in fees and other expenses paid by developers of commercial property, in preference to the creation of additional special transportation districts. For locally-owned businesses, give economic incentives to help implement LID. Use tax incentives for owners of LID-style commercial/retail structures.
	Zoning	Exempt agricultural land from restrictions and stream buffers to maintain and enhance maximum economic opportunity for farmers and related agricultural activities, as well as to keep land in agricultural use.

Goal	Strategies	Recommendations
The impacts of upstream urbanization should be mitigated to prevent increased costs to agricultural and other downstream property owners.	Performance based goals/ Design manual	1) Determine baseline conditions for the establishment of monitoring programs. These conditions should include stream water quality, amount of stormwater discharge, *stream cross-sections*. 2) Publicly monitor at specified time periods at specific locations to determine effectiveness of currently implemented plan.
	Develop funding mechanisms	Ensure that local governments provide adequate funding for their stormwater programs via a stormwater utility fee.
	TDR & conservation easements	Use land purchase, TDRs, conservation easements, etc. where applicable to encourage conservation in appropriate areas.

Goal	Strategies	Recommendations
Ensure that BMPs do not unreasonable affect housing affordability.	Education	Publicize information on cost-effective BMPs.
	Zoning	Amend zoning regulations to allow for increased density in exchange for improved stormwater quality and quantity management.

Goal	Strategies	Recommendations
Ensure that certain areas receive special protections while maintaining the economics of urbanization.	Zoning	Zoning regulations will reflect the sensitivity of the watershed/ subwatershed. This will allow for economic growth while protecting sensitive subwatersheds.
	Design manual	Review local governments' stormwater design manuals with specific design criteria for sensitive subwatersheds.

Appendix F: Integrating the Greater Bonne Femme Watershed-based Plan into the Boone County, City of Columbia, University of Missouri MS4

Greater Bonne Femme Watershed-based Plan: Appendix F
Integrating the Greater Bonne Femme Watershed-based Plan into the Boone County, City of Columbia, University of Missouri MS4

Content primarily taken from the Columbia, Boone County and University of Missouri-Columbia joint MS4 Program, Permit MO-0136557[7,8]

The City of Columbia, Boone County, and University of Missouri-Columbia (MU) developed a joint stormwater management program, Show-me Stormwater Management, to effectively minimize stormwater pollution runoff and meet NPDES Stormwater Phase II permit requirements for municipal separate storm sewer systems (MS4s). MU has been designated the coordinating authority to give Missouri Department of Natural Resources (MDNR) a single point of contact for issues arising out of this joint permit application. However, the Director of Utilities for the City of Columbia, the Director of Resource Management for Boone County, and the Director of Environmental Health and Safety for MU are responsible for the management and implementation of the joint permit. While each permitted entity can rely on partnering to achieve regulatory compliance in the most cost-efficient manner, each entity is ultimately responsible individually for regulatory compliance. The permittees will maintain these programs as outlined in the joint Stormwater Management Plan (SWMP), and as appropriate, will develop and add new programs for the six minimum control measures (MCMs).

Implementation of this watershed-based plan will be a combined effort involving multiple groups, individuals, and organizations. The MS4 partnership and additional partnerships yet to be created will provide more opportunities and resources to coordinate with planned watershed activities, programs, and projects that would otherwise be infeasible. This watershed-based plan will be incorporated into each of the six MCMs listed below. The SWMP will be updated to reflect any stormwater management actions taken in accordance to the watershed-based plan. MS4 reports will track progress made on milestones throughout the implementation phase of the watershed project. Any stormwater-related activities funded through the MDNR 319 Program will be above and beyond any MS4 permit requirements.

Public Education and Outreach (MCM 1)
Raising citizen's understanding and awareness of stormwater impacts and issues is the primary goal of MCM 1 and the permittee's level of commitment to education and outreach programs is significant. The permittees are satisfying their permit requirements by implementing a coordinated public education program, maintaining a list of all education and outreach programs conducted yearly, developing and distributing education and outreach materials, conducting education and outreach activities, maintaining dedicated stormwater resource websites, and holding coordinated household hazardous waste collection events.

The joint MS4 permit requires the permittees to implement a coordinated public education program which involves the distribution of educational materials to the community, or equivalent outreach activities about the impacts of stormwater discharges on water bodies and steps the public can take to reduce pollutants in stormwater runoff. The three entities have cooperated in developing stormwater public education and outreach programs. A Stormwater Coordination Committee meets monthly to discuss educational issues.

The GBFW project will conduct information and outreach activities and distribute outreach materials to residents and visitors in the GBFW, as noted in Section VI. Boone County will maintain www.cavewatershed.org, where the community can find information about the watershed, GBFW project, and upcoming activities/events. The Information and Outreach subcommittee of the GBFW project's Technical Advisory Team will help develop and revise the project's outreach goals and strategies (Appendix 11) using adaptive management techniques. A yearly update of the project's progress will be provided in the MS4 Annual Report.

Public Involvement and Participation (MCM 2)
This MCM has the goal of transforming public education into action and involving the public in the development of stormwater management policies by allowing the public to participate through public hearings and public meetings.

The permittees satisfy this portion of their MS4 permit by implementing effective public involvement/participation programs that allow citizens and civic groups to provide input concerning policies and complies with state and local public notice requirements, promoting Adopt-A-Spot/Adopt-A-Road programs, public service announcements, community clean-up events, and holding coordinated household hazardous waste collection events.

The GBFW project will provide opportunities for public input at public meetings, volunteer clean-up and monitoring events, and voluntary participation of BMP installation and maintenance by property owners in the watershed. A yearly progress update will be provided in the MS4 Annual Report.

Illicit Discharge Detection and Elimination (IDDE) (MCM 3)
Illicit discharges enter the system through either direct or indirect connections. Direct connections are usually vehicular accidents, and first responders continue to be educated on clean up techniques. Other direct connections happen mistakenly and require education on the spot. A robust program to detect and address indirect wastewater connections is underway. The necessary legal measures are in place to prohibit and pursue enforcement on illicit discharges. Addressing indirect wastewater connections and educating the public continue to be primary activities for this measure.

Columbia, Boone County and MU are required to develop, implement, and enforce a program to detect and eliminate illicit discharges into the regulated MS4.

Each permittee has documented the location of all new and existing stormwater outfalls, pipes, inlets, and other associated attributes for locational and logistical reference. A geospatial tool helps the permittees understand the impacts of illicit discharges to the MS4 area. The permittees, through IDDE ordinances or other IDDE regulatory mechanisms, maintain water quality by restricting certain discharges into the stormwater drainage system, and implement appropriate enforcement procedures and actions. Incidental non-stormwater discharges are addressed on a case-by-case basis to determine whether such discharges may appropriately be directed to the storm sewer system. Permitted MS4 outfalls are inspected each year on a rotating basis to detect cross connections in the sanitary sewer system and other discharge to the MS4 area. Methods used for detection may include on-site visual inspections, smoke and dye testing, closed circuit television inspections as well as public watch and reporting programs with established hotlines.

The GBFW project will continue to use microbial source tracking (MST) to track *E. coli* loading sources within the watershed. Although failing on-site wastewater systems were not found to be a major contributor to the *E. coli* loading in streams in the GBFW through previous MST, on-site wastewater system BMPs will be offered for existing on-site wastewater systems through an outreach program that requires nonpoint source/water quality workshop participation to qualify for a septic pump-out rebate.

The City of Columbia's *Our Columbia Waters Integrated Management Plan for Wastewater and Stormwater* will help develop affordable and adaptable long-term recommendations to meet Columbia's wastewater needs within the watershed. The Environmental Health and Safety Division of the City of Columbia/Boone County Department of Public Health and Human Services reviews all plans for new and renovated on-site wastewater systems and performs site inspections for compliance. Failing systems can be required to be upgraded if noncompliance is discovered, however, these inspections are usually complaint driven.

Construction Site Stormwater Runoff Control (MCM 4)
Construction site runoff is a publicly visible element of the stormwater management program. Regulatory mechanisms are in place to control construction site runoff. Site plan review and inspections for construction site runoff control are ongoing. The purpose of this MCM is to prevent soil, construction material, and other materials from leaving the construction site and entering the stormwater drainage system.

The joint MS4 permit requires the permittees to develop, implement and enforce a program that reduces pollutants in stormwater runoff to the MS4 from construction activities that result in a land disturbance of greater than or equal to one acre. These construction activities have the potential to contribute more pollutants to local waterways. The permittees meet this requirement by tracking the number of land disturbance permits issued each year, maintaining and enforcing erosion and sedimentation/land disturbance ordinances/regulatory mechanisms, implementing and maintaining stormwater design manuals, requiring stormwater pollution prevention plans (SWPPPs) for waste and erosion control on sites, maintaining websites and hotline phone numbers for public concerns, and conducting site inspections for compliance.

Many of the BMPs assessed and selected for potential implementation in the GBFW (WBP Sections IV and V) are designed for use on private agricultural land. Agricultural activities are exempted from the City of Columbia land preservation requirements and the Boone County zoning regulations. BMPs will be installed on a voluntary basis.

Post-construction Stormwater Management in New Development and Redevelopment (MCM 5)
Maintenance of structural best management practices is a critical component to the success of post-construction runoff controls. Inventory and inspection of BMPs encourages proper maintenance which supports pollutant and runoff reductions.

Each permittee is required by the MS4 permit to develop, implement, and enforce a program to address the quality of stormwater runoff from new and redevelopment projects that disturb greater than or equal to one acre. This includes projects less than one acre that are part of a larger common plan for development or sale that discharge into the regulated MS4. The MDNR requires any portion of a common plan for development or sale sold to a developer for commercial, industrial, or residential use to obtain a permit before conducting any land disturbance activity, regardless of size. While the sold portion remains part of the common plan of development or sale, it is no longer under the original permit coverage.

This permit requirement is met by the permittees by implementing and tracking water quality improvement projects, BMP monitoring projects, LEED building standards, and tracking permits for installation of private BMPs for new and redevelopment projects within the City of Columbia and unincorporated Boone County. All stormwater and stream buffer ordinances, stormwater design manuals and MU Stormwater Master Plan are reviewed and revised, as necessary. Downstream water quality is improved by inspection and maintenance of post-construction stormwater controls. A coordinated household hazardous waste event is held annually to provide the public with proper, publicly announced disposal opportunities to minimize the presence of chemicals in local waterways.

BMPs installed in the GBFW during the implementation phase will be monitored for effectiveness. With landowner permission, edge-of-field monitoring will be considered pre- and post-installation. Stream monitoring and water quality sampling will continue to take place. Effectiveness of installed BMPs will be reviewed at three-, five-, and seven-year intervals. For more information on monitoring, see Section VII of the WBP.

Pollution Prevention/Good Housekeeping for Municipal Operations (MCM 6)
All permittees' employees receive regular training on maintaining facilities and properly using and storing potential pollutants. In addition to training, operations personnel continue to improve road salt application methods, street sweeping procedures, and site maintenance to reduce pollutants to our waterways. Pollution prevention opportunities are extended to the greater community through household hazardous waste drop offs, recycling programs, and education and outreach efforts.

Permittees are required to develop and implement an operation and maintenance program that includes a training component and has the goal of preventing and/or reducing polluted runoff from municipal operations, including those not currently required to be permitted as associated with industrial activities. The program must include employee training to prevent and reduce stormwater pollution from activities such as park and open space maintenance, fleet and building maintenance, new construction and land disturbances, and stormwater system maintenance.

The permittees are meeting this requirement by maintaining operation and maintenance training schedules, training all impacted employees, reviewing, updating, and scheduling pollution prevention/good housekeeping training presentations, and conducting coordinated household hazardous waste collection events.

Employees of the co-permittees receive annual training about stormwater runoff and pollution prevention. Employees will receive periodic status updates about the implementation of the GBFW project and environmentally sensitive area protections.

In the event the Greater Bonne Femme Watershed-based Plan cannot be used in lieu of Total Maximum Daily Loads (TMDLs) to reduce *E. coli* in the watershed, a TMDL Assumptions and Requirement Attainment Plan (ARAP) will be developed to address the TMDL's assumptions and requirements in accordance with State law. Additionally, a summary of controls listing BMPs, expected results of those BMPs, how measurable goals will be utilized to document the effectiveness of those BMPs, and the status of those measurable goals will be listed in the MS4's annual report.

Appendix G: Greater Bonne Femme Watershed Modeling Report

Greater Bonne Femme Watershed Modeling Report

Submitted to

Boone County, Missouri
Missouri Department of Natural Resources

Prepared by:

Geosyntec consultants

engineers | scientists | innovators

June 21, 2023

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FIGURES

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ACRONYMS AND ABBREVIATIONS

ACRONYM	DEFINITION
AWMS	Animal Waste Management System
BMP	Best Management Practice
CBP	Chesapeake Bay Program
cfu/100mL	Colony forming units per 100 milliliters
CPI	Catchment Prioritization Index
DEM	Digital Elevation Model
E. coli	Escherichia coli
GBFW	Greater Bonne Femme Watershed
HUC	Hydrological Unit Code
LDC	Load Duration Curve
MDA	Minnesota Department of Agriculture
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
MST	Microbial Source Tracking
NAVD83	North American Vertical Datum of 1983
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NPS	Non-point Sources
NRCS	Natural Resources Conservation Service
PCPI	Pollutant Catchment Prioritization Index
POC	Pollutant of Concern
QAPP	Quality Assurance Project Plan
SELECT	Spatially Explicit Load Enrichment Calculation Tool
STEPL	Spreadsheet Tool for Estimating Pollutant Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids

ACRONYM	DEFINITION
US EPA	US Environmental Protection Agency
USDA	United States Department of Agriculture
USLE	Universal Soil Loss Equation
WBC	Whole Body Contact
WBID	Water Body Identification
WBP	Watershed-based Plan
WSS	Web Soil Survey
WQS	Water Quality Standards

SECTION 1

INTRODUCTION

1.1 Background and Problem Definition

The Greater Bonne Femme Watershed (GBFW) is comprised of 92.4 square miles of mixed-land use including: row cropping, livestock, residential development, and recreation. The GBFW is located between the rapidly developing cities of Ashland (south) and Columbia, Missouri (north), where population growth has increased by 40 percent over the last 10 years.

The Bonne Femme and Little Bonne Femme Creeks, along with their tributaries - Bass Creek, Turkey Creek, Fox Hollow Branch, Smith Branch, Devil's Icebox Spring Branch, Gans Creek, Clear Creek, and Mayhan Creek - are the focus of development of watershed models of the GBFW (Figure 1). The watershed contains sensitive karst habitats, Outstanding State Resource Waters, and losing stream hydrology that are vulnerable to water quality degradation. Consequently, land-use and management practices have significant impacts on these unique ecosystems. Threats to these ecosystems include riparian area deforestation, failing on-site sewage systems, nutrients, pesticides, sediment in stormwater runoff from commercial and residential sites, and animal waste.

Water quality parameters of concern in the GBFW streams include *Escherichia coli* (*E. coli)*, nutrients, and total suspended solids (TSS). These are summarized below:

- The GBFW streams have elevated levels of microbial contamination as measured by *E. coli* bacteria. *E. coli* levels have exceeded the recreational season (April 1 through October 31) geometric mean criterion for whole body contact "A" (126 colony forming units per 100 milliliters, cfu/100 mL) and whole-body contact "B" (206 cfu/100 mL). The Missouri Department of Natural Resources (MDNR) has listed six stream segments in the GBFW as being impaired for *E. coli* on the state's 303(d) list of impaired waters. These include Little Bonne Femme Creek - Water Body Identification number [WBID] 1003; Gans Creek - WBID 1004; Bonne Femme Creek - WBID 750 and 753; Turkey Creek - WBID 751; and Bass Creek WBID 752. The locations of impaired stream segments are shown in Figure 1. Total maximum daily loads (TMDLs) have not been developed for these WBIDs.
- Missouri has not yet adopted instream criteria for nutrients. Water quality monitoring data from 2001 to 2006 collected as part of the previous watershed-based plan (WBP) show that reported total nitrogen (TN) and nitrate concentrations in several subwatersheds are higher than the lower end of the nutrient criteria range recommended by the US Environmental Protection Agency (US EPA) in 2000 (Appendix G, BFSC, 2007). The targets are not water quality standards but were established by US EPA to be protective of aquatic invertebrate density, nuisance algal growth, and eutrophication.

- Elevated levels for phosphorus have been reported in Upper Bonne Femme Creek, Little Bonne Femme, and Fox Hollow Branch over the last decade by the US Department of Agriculture, Agricultural Research Service (USDA-ARS). A previous watershed plan indicated several sites in the watershed had some level of nuisance algal growth associated with nutrient pollution (Appendix G, BFSC, 2007).
- High turbidity levels have been reported in the streams during wet weather indicating wash off of sediment from land (BFSC, 2007).

A previous watershed-based plan (WBP) for the GBFW was completed in 2007 and was approved by Boone County, the City of Columbia, the City of Ashland and the MDNR (BFSC, 2007). The 2007 WBP provided goals and general recommendations to preserve sensitive ecosystems, promote best management practices (BMPs), and maintain water quality while supporting economic development. This plan has led to improvements in the watershed; however, a more prescriptive 9-element watershed plan is needed to effectively restore water quality, protect the watershed and reduce pollutant loading to GBFW streams. Boone County is developing a 9-element WBP which will provide a road map towards achieving GBFW water quality improvement goals and be protective of the existing conditions in the watershed. The WBP will include recommendations for BMP implementation to strategically reduce impacts of non-point sources (NPS) on the stream water quality in the watershed.

Boone County engaged Geosyntec Consultants (Geosyntec) to develop pollutant loading/load reduction estimates to meet US EPA requirements for 9-element WBPs as identified by MDNR staff, specifically elements a-6 and b-1 through b-3 of US EPA’s 9 required elements for a WBP (Westin, 2019). These elements state:

> “Causes of impairment are broken down by source and quantified by load, percentage, priority, or other method to identify the extent of the source treated (such as x number of animal feeding operations within segment y).” (Element a-6)
>
> “The watershed-based plan includes load reductions needed to meet water quality criteria or standards [for the 303(d) list or TMDL] in impaired streams and achieve the environmental goal.” (Element b-1)
>
> “The source of the load reduction information (TMDL, modeling, monitoring) is identified to estimate pollutant load reductions (assumptions and limitations should be stated).” (Element b-2)
>
> “The plan provides estimates of potential load reductions for each pollutants cause/source, or groups of similar sources that need to be managed.” (Element b-3)

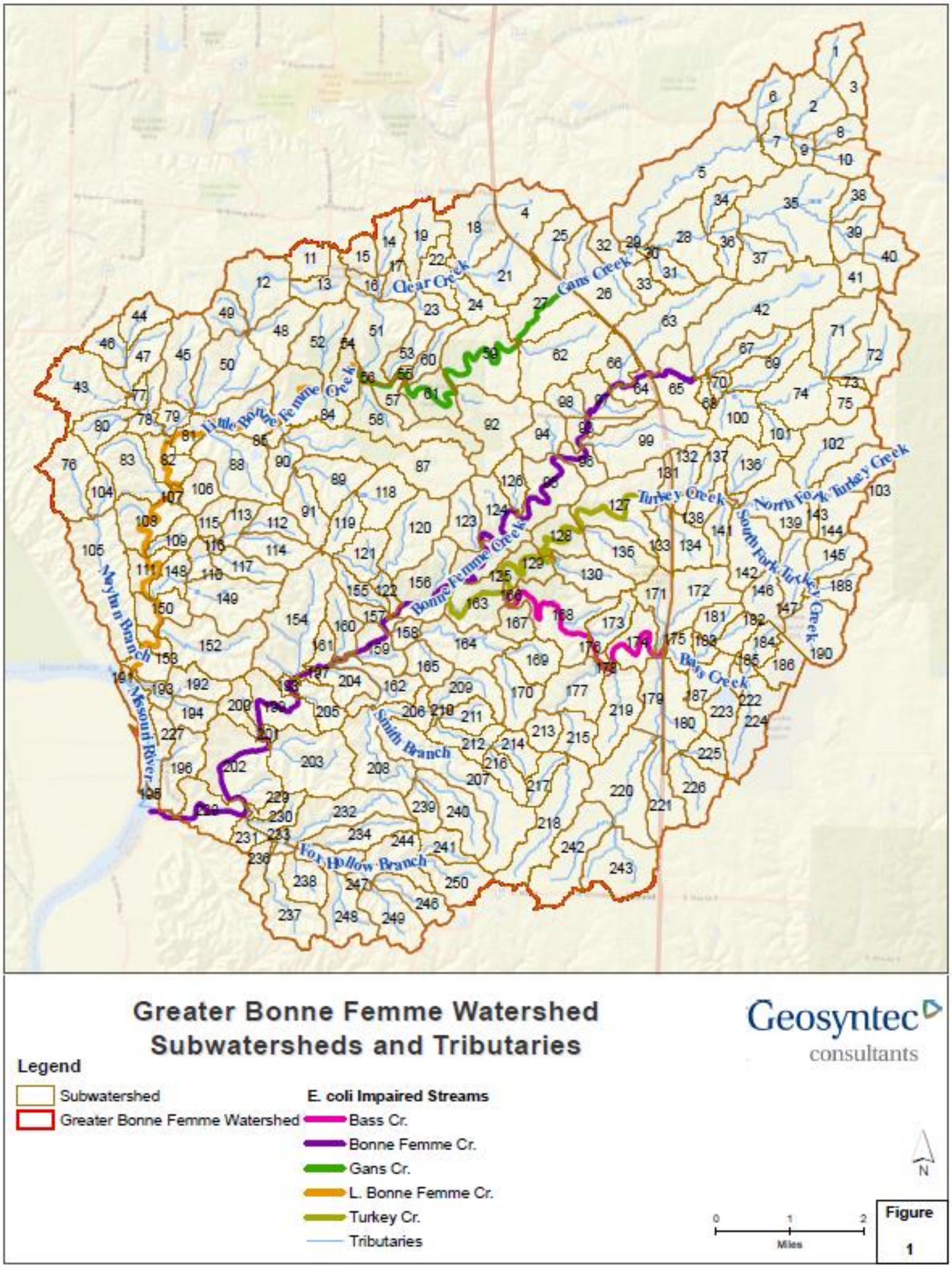
This GBFW Modeling Report is submitted in support of Boone County’s need for specific information to develop a 9-element WBP.

1.2 Modeling Objectives

The reason for developing watershed models is to generate information to support the development of a 9-element WBP. This information includes:

- Maps showing specific NPS which result in *E. coli* (by area category, facility type, etc.) impairments in the watershed (Element a-4).
- Existing condition load estimates for nutrients, total suspended solids, and *E. coli* from each land use in the watershed (Element a-6).
- Maps that identify specific, critical/targeted areas within the watershed for BMP implementation to mitigate NPS pollution, and to estimate the areas and/or length of their extent (Element a-7).
- List of recommendations for BMPs in the critical areas to reduce pollutant loading corresponding to land use practices in the critical areas, including prioritization of areas for implementation and rationale for BMP selection as optimal for *E. coli* loading mitigation (Elements c-1 and c-2).
- Documentation of locations where streambank erosion and riparian corridor degradation are concerns (Assessed as part of previous WBP).
- Documentation of pollutant load reduction estimates through the implementation of proposed BMPs at different implementation levels to improve water quality in the watershed and ultimately achieve instream water quality standards for *E. coli* (Element c-3).
- Report documenting data, assumptions, and literature sources for watershed model development; critical area identification; BMP selection; and estimation of load reductions from BMPs at different implementation levels.

Figure 1: Greater Bonne Femme Watershed and Tributaries



SECTION 2

MODEL FRAMEWORK

Two watershed models were developed and applied to meet the objectives of the project – one for nutrients and TSS and another for *E. coli*. Brief descriptions of the modeling frameworks are provided below.

2.1 Nutrients and TSS Model

Geosyntec developed the watershed model for nutrients and TSS using the US EPA Spreadsheet Tool for Estimating Pollutant Loads (STEPL) version 4.4 (TetraTech, 2018). STEPL simulates annualized estimates of total runoff volume and nutrient and TSS loads based on the Universal Soil Loss Equation (USLE), watershed characteristics (both default and user-specified), BMP implementation, and meteorology. STEPL has been used by MDNR to estimate NPS pollutant loads for several WBPs. STEPL currently does not simulate *E. coli*.

2.2 *E. coli* Model

Geosyntec simulated *E. coli* loads using the methodology of the Spatially Explicit Load Enrichment Calculation Tool (SELECT) developed by the Spatial Sciences Laboratory and the Biological and Agricultural Engineering Department at Texas A&M University (Teague et. al, 2009). SELECT has been applied to assess sources of bacteria contamination for WBPs and TMDL projects (Riebschleager et al., 2012; Borel et al., 2012; Borel et al., 2015; Roberts et. al, 2015; NTMWD et al., 2017; Glen et al., 2017). The methodology is consistent with the guidance provided by US EPA to estimate *E. coli* loading from NPS (US EPA, 2001). This methodology was selected for application in the GBFW since it is less data intensive and requires less effort as compared to complex mechanistic models such as HSPF and SWAT, but still provides information suitable for watershed planning purposes, similar to STEPL. A description of SELECT's methodology is provided below.

Daily *E. coli* loading from potential *E. coli* sources were estimated for each subwatershed using equations in Table 1. *E. coli* production rates are based on literature reported values from US EPA for fecal coliform (US EPA, 2001). A conversion factor was applied to convert the fecal coliform loading rate to an *E. coli* loading rate, which was estimated using water quality data from the GBFW. This methodology did not account for die-off of *E. coli* and hence provides a conservative estimate of loading. The calculation of loads for each potential source in the GBFW is described below.

Livestock
Livestock in the GBFW contributing to the *E. coli* impairment include cows and potentially other livestock included in the ruminant category consisting of sheep and goats based on the results of

microbial source tracking (MST) results conducted by Boone County. Daily *E. coli* loads for livestock were calculated using equations in Table 1.

Wildlife

Wildlife in the GBFW contributing to the *E. coli* impairment was identified as deer (listed in the ruminant category) based on information from the Missouri Department of Conservation (MDC) and MST results conducted by Boone County. The MST results did not indicate contamination from geese. Although habitat in the GBFW is suitable for coyotes, markers were not available at the time the MST analyses were done that would distinguish *E. coli* from coyotes from *E. coli* from domestic dogs. Daily *E. coli* loads for wildlife were calculated using the equation for deer in Table 1.

On-Site Wastewater Systems

Daily *E. coli* loading from failing on-site wastewater systems was calculated using the equation in Table 1. An average number of three people per household is assumed based on the STEPL data server input. The model assumes 60 gallons of sewer volume is generated per person per day. The areas of the GBFW not served by sewer systems were mapped by Boone County GIS department to identify the residential areas using the on-site wastewater systems.

Table 1: Equations for Estimating E. coli Load from Different Sources

Source	*E. coli* Load (colony forming units per day or cfu/day)
Cattle	(#Cattle) * (10^{11} cfu/day/Cattle) * f^1
Goats	(#Goats) * ($1.2*10^{10}$ cfu/day/Goat) * f^1
Sheep	(#Sheep) * ($1.2*10^{10}$ cfu/day/Sheep) * f^1
Deer	(#Deer) * ($3.5*10^8$ cfu/day/Deer) * f^1
On-site septic wastewater systems	(#Households) * Malfunction Rate * (#Average people/household) * (Volume generated/person/day) * (10^4cfu/100mL) * (3758.2mL/gallon) * f^1

f^1- conversion factor to convert fecal coliform loading rate to *E. coli*

SECTION 3

MODEL DEVELOPMENT AND APPLICATION

The watershed model for the GBFW was developed as per the methodology described in approved modeling Quality Assurance Project Plan or QAPP (Geosyntec, 2020). Minor deviations from the approved QAPP were communicated to the Boone County Project Manager and MDNR, and subsequently approved. They are documented in this report, wherever applicable, along with the discussion of the effect of the deviation on model quality. This section documents the data, assumptions, and methodology used to develop and apply the watershed model for the GBFW.

3.1 Existing Data Sources

The existing data utilized for the development of the watershed model for GBFW are summarized in Table 2 along with the data sources. Where available, data from Boone County and other local agencies in the watershed were used for model development to help ensure that model results are reflective of the existing conditions of GBFW. A brief description of each data type is also provided below.

3.1.1 Hydrology

Hydrology information for the GBFW such as Hydrological Unit Codes (HUCs), rivers, and streams were obtained from the United States Geological Survey (USGS) National Hydrography Dataset (NHD/NHD Plus, USGS, 2019). These data were used for delineation of GBFW into smaller subwatersheds.

3.1.2 Land Cover

The land cover data was downloaded from National Land Cover Database (NLCD, 2016). Table 3 shows the breakdown of the land use in the GBFW. Review of the land cover data shows that most of the watershed is rural and forested, with most development occurring close to cities of Ashland (south) and Columbia, Missouri (north), and some along the Highway 63 corridor (Figure 2). About 13% of the watershed is cropland, primarily east of Highway 63, where there is flatter land and deep soils. Pasture is about 33% of the total watershed area, spread throughout the watershed. Various forest types cover an additional 44%, most of it occurring west of Highway 63 in the areas with steeper terrain. Suburban and commercial development cover about 9% of the total watershed area. Other land use (open water, wetlands, shrub, grassland and barren land) covers about 2% of the total watershed area.

The land cover for the GBFW, presented in Table 3, was categorized as urban, cultivated crops, pasture/hay, forest and other based on land use categorizes defined in STEPL model. Other land use includes all land uses that do not fit into urban, cultivated crops, pasture/hay or forest. The acreage for open water was not included in the watershed model as open water was assumed to not contribute to pollutant loading.

Table 2: Existing Data Sources for Development of Watershed Models

Category	Required Data	Data Source
Hydrology	Watershed boundaries	National Hydrography Dataset National Hydrography Dataset Plus
	Rivers	
	Streams	
Land Use / Land Cover	Parcel GIS data with land use/land cover information	National Land Cover Database
	Land use zoning map (for urban land use distribution)	Boone County Zoning Information Viewer
Topography / DEM	Lidar	USGS 3D Digital Elevation Program (1 m resolution)
Soil Data	Soil coverage	SSURGO dataset
Meteorological	Temperature, cloud cover, dewpoint temperature, precipitation, solar radiation, wind, potential evapotranspiration	National Climatic Data Centre, Missouri Mesonet
Impairments	Impaired streams	Missouri Department of Natural Resources
Event Mean Concentration	Event mean concentration for nutrients and TSS associated with different land use	STEPL default values
Sediment wash off parameters	Universal Soil Loss Parameters	Default parameters in STEPL for Boone County, Missouri
On-site Wastewater System Information	Population per on-site wastewater system, septic failure rate	Columbia/Boone County Public Health & Human Services
Fecal production rates	Daily fecal production rates from different sources	US EPA (2001)
Animal Populations	Livestock and wildlife animal population	Boone County/MDC

Table 3: Existing Land Cover Breakdown for the GBFW

Land Use	Percent Land Use (%)
Urban	9
Cultivated Crops	13
Pasture/Hay	33
Forest	43
Other	2

3.1.3 Topography

A high resolution one-meter Digital Elevation Model (DEM) for GBFW downloaded through the USGS 3D Elevation Program, was used for watershed delineation. The DEM uses the North American Vertical Datum of 1983 (NAVD83).

3.1.4 Soils

The soils data for the GBFW were extracted using the Web Soil Survey (WSS) application by USDA NRCS (USDA, 2019). The soils data extracted as GIS shapefiles were used to identify the type of soil and assign hydrologic soil group to each of the delineated subwatersheds. The majority of GBFW consists of soil in hydrologic soil group D (Figure 3), characterized as soils having a very slow infiltration rate, high runoff potential and very slow rate of water transmission.

3.1.5 Meteorology

For the GBFW, the STEPL model uses mean meteorological data from Columbia Regional Airport weather station (Station Id: GHCND: USW00003945, latitude/longitude: 38.8169/-92.2183). The location of the weather station is shown in Figure 2.

3.1.6 Septic Systems

A non-sewered parcel layer and building location point shapefile received from Boone County was used to determine number of households in Boone County that rely on on-site wastewater systems. The areas of the GBFW not served by sewer systems were mapped by Boone County GIS department to identify the residential areas using the on-site wastewater systems (Figure 4). Boone County also provided building location and use data. The building uses of residential 1- and 2-family houses, house, mobile home, livestock operation home, farm in use & farm residential, double wide on acreage, and residential structures in the non-sewered parcels were assumed to be on-site wastewater systems. The number of households were determined to be 1,498 using this information. The use of building data for determining the number of households represents a minor deviation from the approved QAPP, which included the use of Census data for this purpose. Geosyntec determined that Census data were too coarse for application at the subwatershed level. The use of building data provided a more accurate estimate of number of households using on-site wastewater systems, which improved the quality of model.

An average of three persons per on-site wastewater system was used based on the STEPL data input server. A septic failure rate of 10 percent was assumed for the GBFW based on the results of MST which indicated a very low signature of human source in *E. coli* measurements.

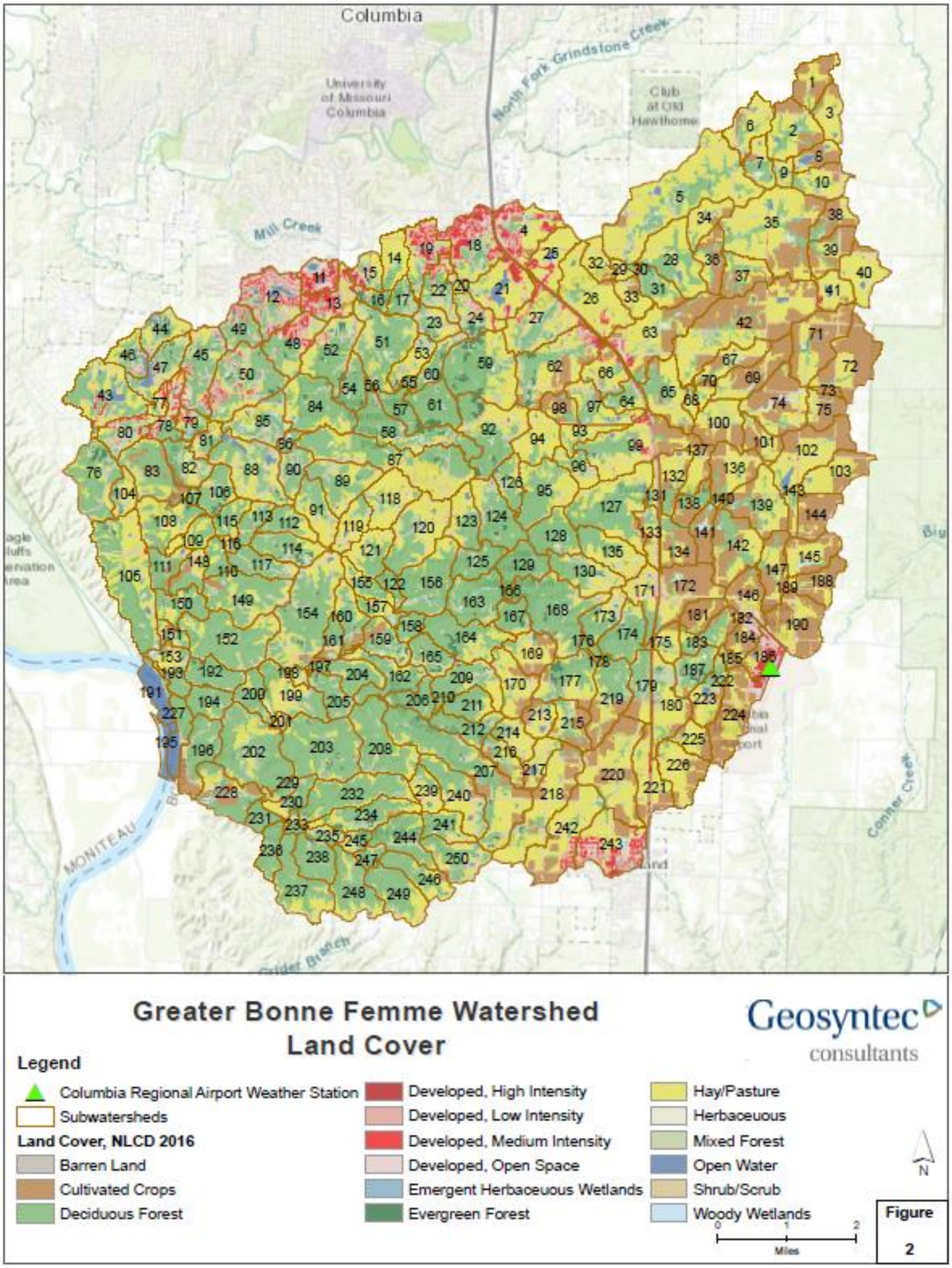


Figure 2: Greater Bonne Femme Watershed Land Cover

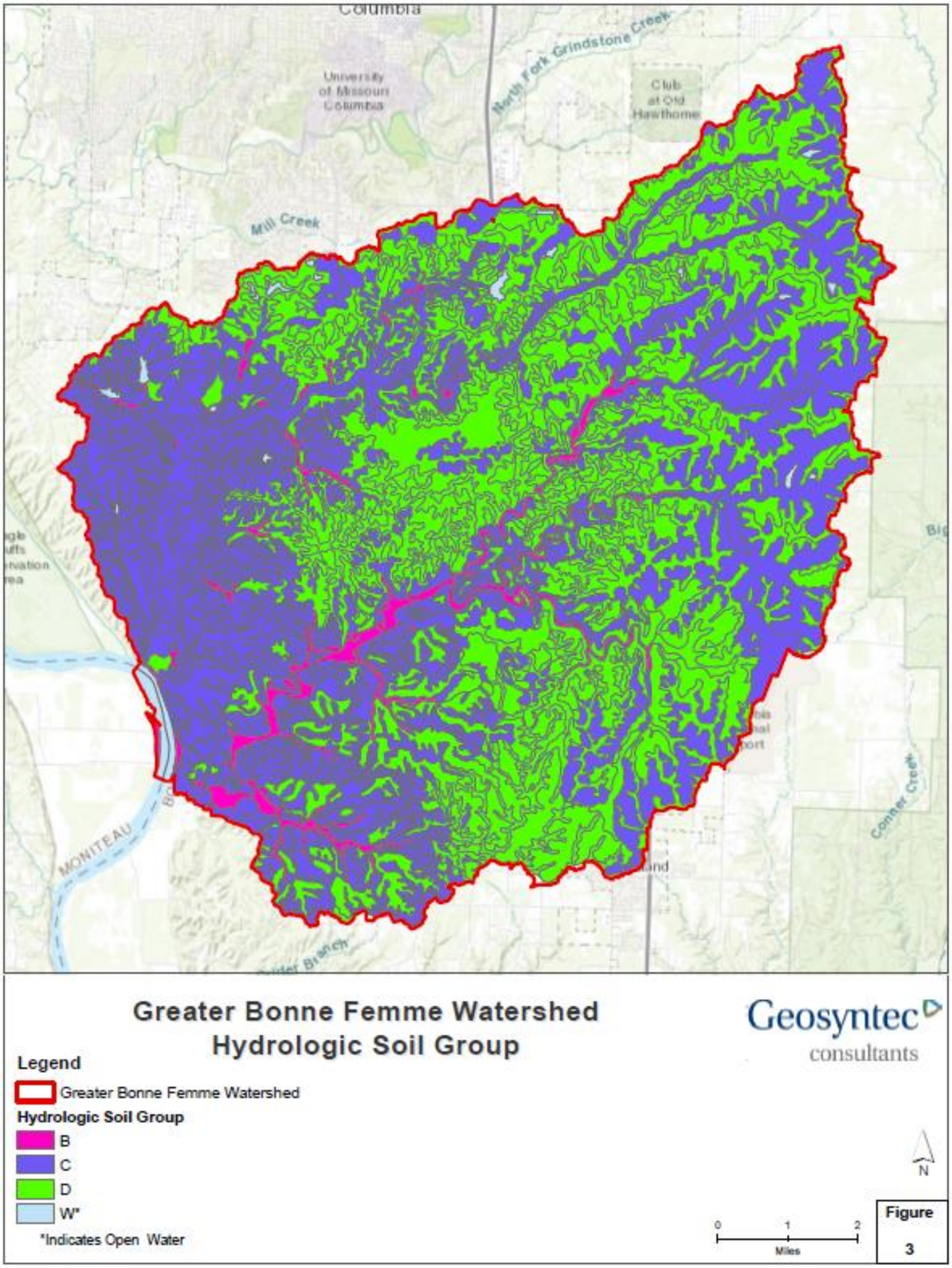


Figure 3: Greater Bonne Femme Watershed Hydrologic Soil Group

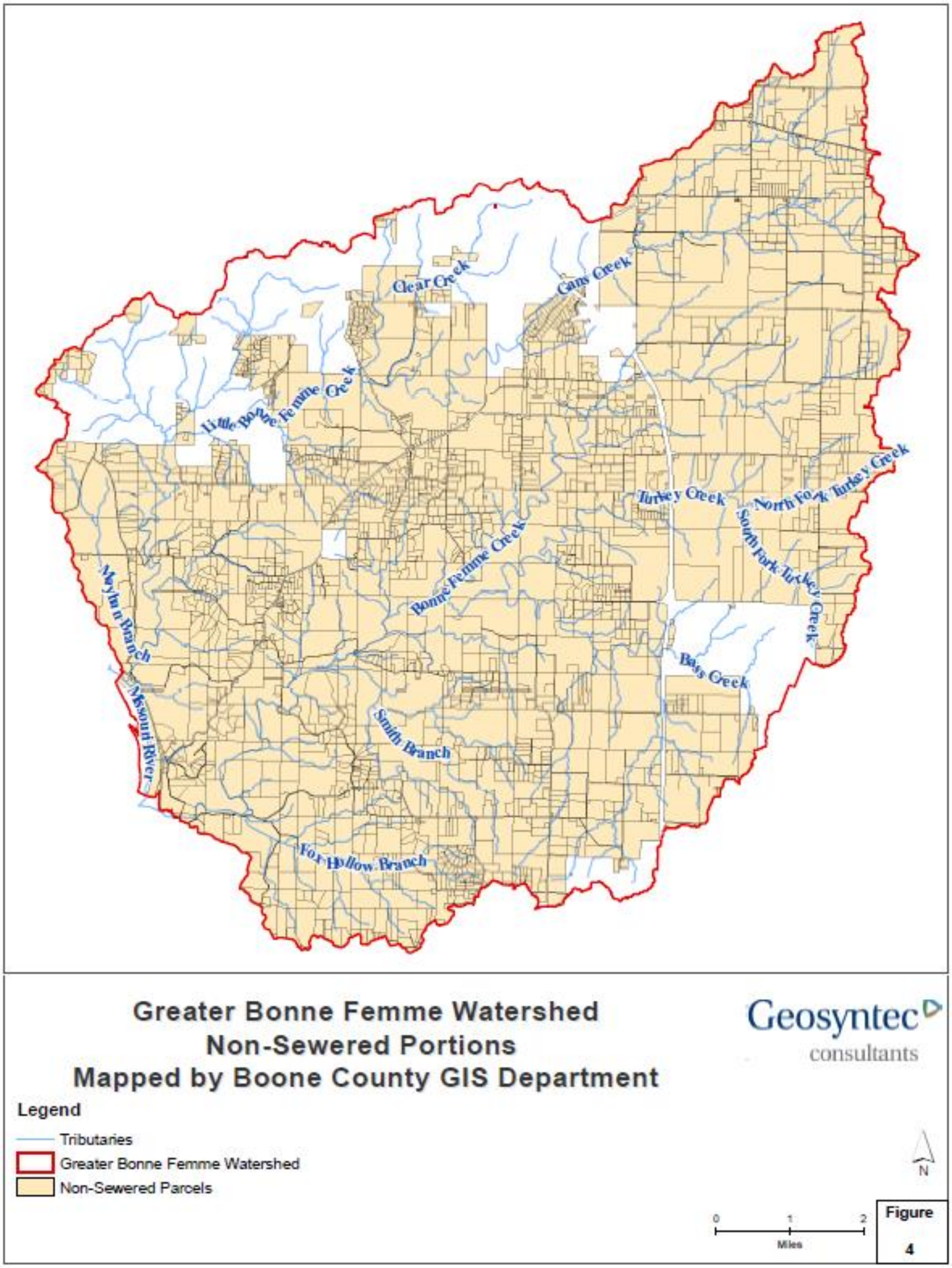


Figure 4: Non-Sewered Portions of Greater Bonne Femme Watershed Mapped by Boone County GIS Department

3.1.7 Animal Population

Boone County has geographically referenced count data for cattle, goat and sheep[1] for the calendar years 2017 and 2018. The average of livestock counts from 2017 and 2018 were used to calculate *E. coli*, nutrient, and TSS loads from livestock for each subwatershed.

The deer population for Boone County was calculated using an estimate of 36 deer per square mile provided by Missouri Department of Conservation (MDC) for Boone County (per email correspondence with Jason Isabelle, the Cervid Program Manager at MDC on July 23, 2020).

3.2 Identification and Mapping of *E. coli* Pollutant Sources

Major potential NPS of *E. coli* pollutant loading were identified and mapped (element a-4 of the WBP). The NPS of *E. coli* that were investigated include livestock (cows, sheep and goat) and wildlife (deer), and failing on-site wastewater systems. MST results from Boone County were used with other information such as land use and animal density to map specific NPS of *E. coli* (by area category, facility type etc.) in the GBFW. Based on this investigation, the detectable sources of *E. coli* in the GBFW are livestock, wildlife, and failing on-site wastewater systems, which are mapped in Figure 5.

3.3 Watershed Delineation

The GBFW was delineated into subwatersheds using the Arc Hydro Tool in GIS. The delineation for the watershed consisting of 250 subwatersheds is shown in Figure 6. Subwatersheds with areas less than 10 acres were merged with adjoining subwatersheds based on drainage pattern to avoid very small subwatersheds. This is a minor deviation from the MDNR approved QAPP (Geosyntec, 2020) and was done to ensure that subwatersheds do not show up as critical hotspots for load per acre because of their size. The area of the delineated subwatersheds ranges from 11 acres to 1,097 acres. The average subwatershed area is 240 acres. The estimation of pollutant load at the fine resolution subwatershed level allowed better identification of critical areas with greatest load generating potential.

3.4 Watershed Modeling of Baseline

Geosyntec developed watershed models to estimate the existing loads for *E. coli*, nutrients, and TSS (element a-4 of WBP). Pollutant loads were estimated for each of the subwatersheds shown in Figure 6. Nutrient and TSS loads were estimated using US EPA's STEPL framework version 4.4 (TetraTech, 2018). *E. coli* loads were simulated using the methodology of SELECT. SELECT simulates the annualized loading of *E. coli* from various sources within a mixed land use watershed

[1] Boone County reported data for lambs and ewes and llamas. The count of ewes and llamas was used for sheep and lamb count was used for goat

based on spatial inputs such as, animal population density and septic systems. Additional details about STEPL and SELECT are provided in Section 2.1.

3.4.1 Nutrients and TSS

The STEPL model Excel workbook can only simulate 50 subwatersheds at a time. Hence 5 STEPL workbooks were set up for the 250 delineated subwatersheds. The simulated loading results for nutrients and TSS were combined from the 5 STEPL workbooks with 50 subwatersheds each. Existing BMPs provided by City of Columbia, Boone County and University of Missouri were also input into the BMP input for the GBFW model. Default model input data, such as BMP treatment efficiency, event mean concentrations, and sediment wash off parameters, were checked for applicability in GBFW based on values reported in peer reviewed studies in the Midwestern US (Section 3.7). Electronic files for model inputs and STEPL models are provided with this report (Appendix A).

3.4.2 *E. coli*

The methodology described in Section 2.2 was implemented in a single Excel spreadsheet for 250 subwatersheds to calculate the E. coli daily loading for each subwatershed. Potential NPS of E. coli pollutant loading that are likely causing the water quality impairment are shown in Figure 5. The subwatersheds with reported livestock are shown in Figure 7. These subwatersheds are generalized because livestock are often set out to graze in rotational patterns between paddocks and their precise location cannot be identified. The contribution of different potential sources to the total E. coli loading was determined using the SELECT model. The E. coli model calculated the loads on a subwatershed basis. This approach was described in the QAPP that was approved by MDNR. An electronic file for the E. coli model is provided in Appendix B.

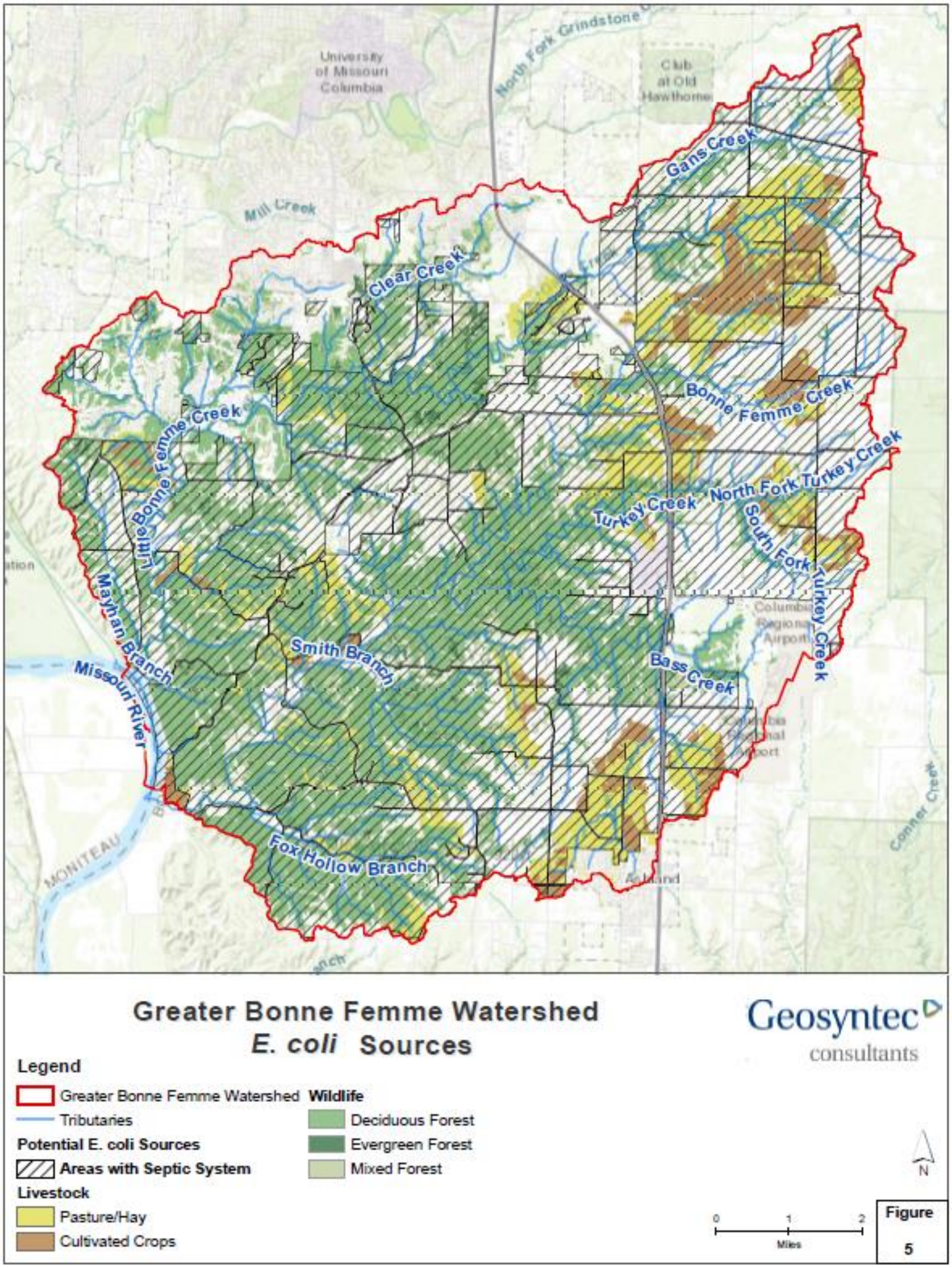


Figure 5: Major Potential NPS of E. coli Pollutant Loading

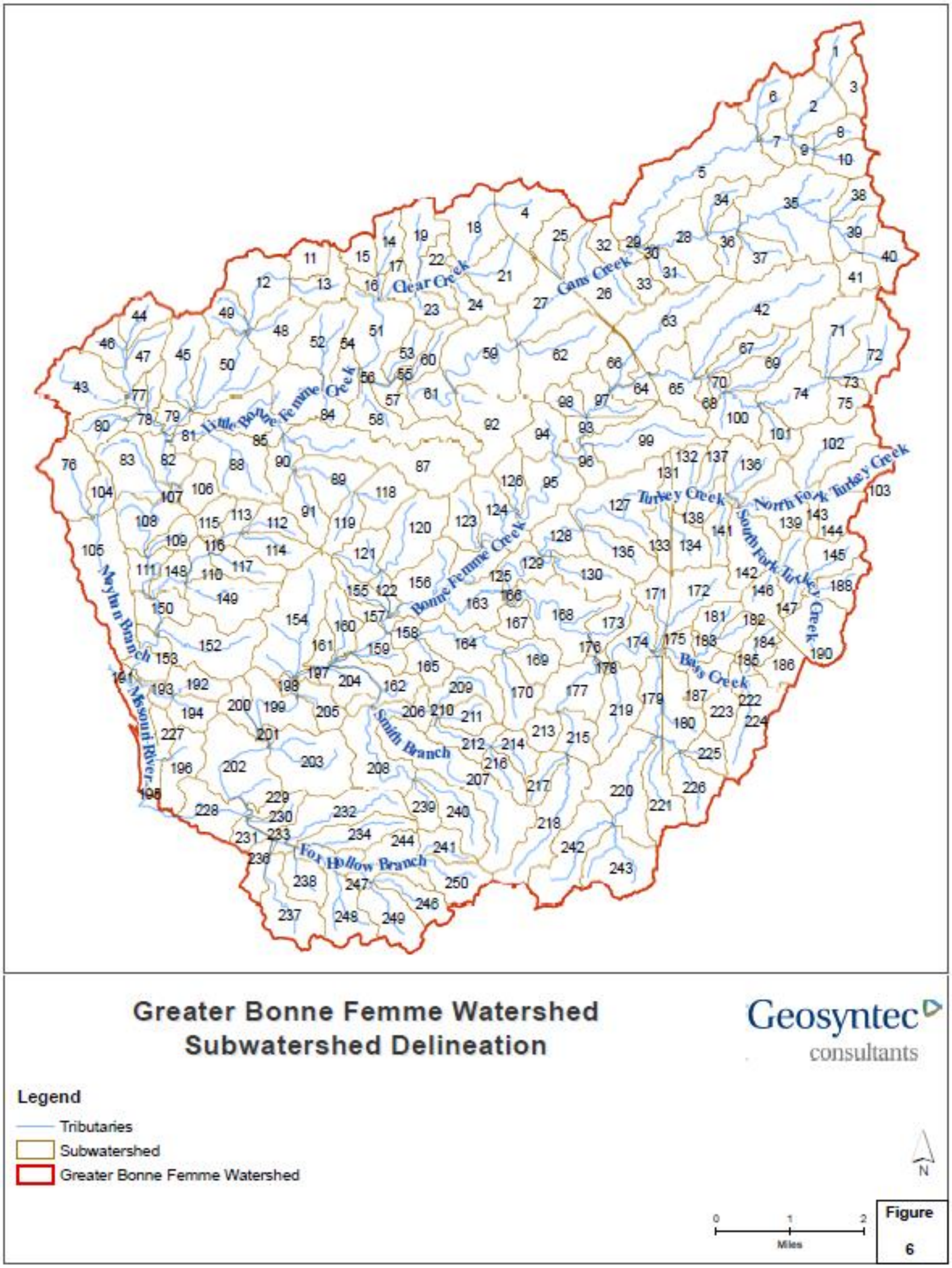


Figure 6: Subwatershed Delineation for GBFW

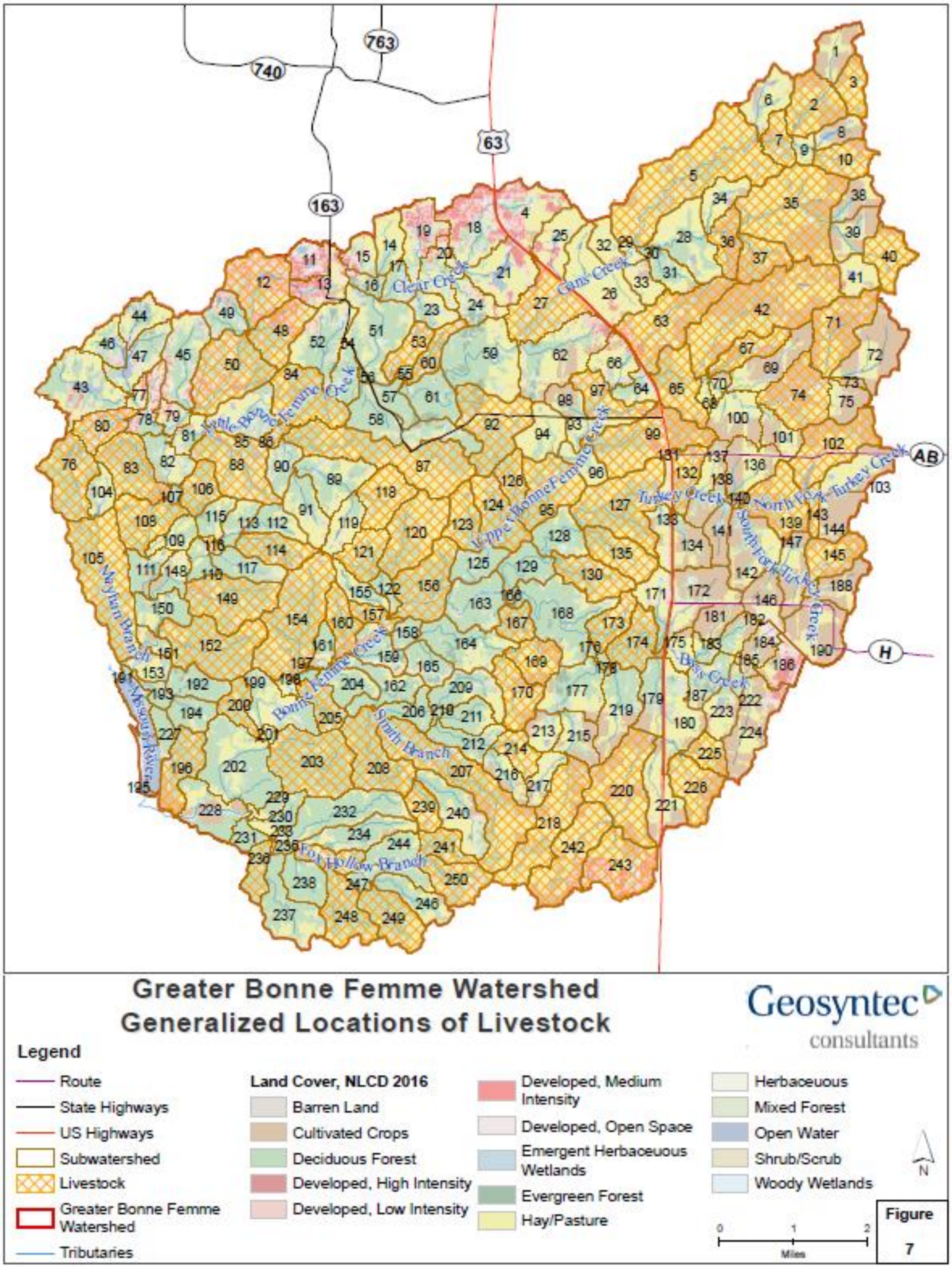


Figure 7: Generalized location of livestock in Greater-Bonne Femme Watershed

3.5 Identification of Critical Areas

Critical areas in the GBFW for BMP implementation were identified, prioritized, and mapped as per the guidance from US EPA (US EPA, 2018) to satisfy the requirements of a 9-element WBP (elements a-7 and c-1 of WBP).

Geosyntec applied a Catchment Prioritization Index (CPI) that was developed for watershed planning. The CPI prioritizes BMPs when addressing multiple pollutants (Geosyntec, 2006) to identify critical areas for BMP implementation. A CPI was calculated for the subwatersheds shown in Figure 6 based on pollutants of concern, pollutant loading, and impairments. A higher CPI score would indicate higher priority of a subwatershed for BMP implementation.

The steps for calculating the CPI are:

1. For each pollutant of concern (POC), i.e., *E. coli*, TN, total phosphorus (TP), and TSS, the pollutant catchment prioritization index ($PCPI_s^i$) was calculated using the following equation:

$$PCPI_s^i = \frac{L_s^i}{Max(L_s^i)}$$

   where, L_s^i is the estimated unit acre load for subwatershed s and pollutant of concern i.

2. PCPIs were weighted by a weighting factor for each POC and summed to calculate the Total PCPI for each subwatershed. Proposed weighting factors for different pollutants of concern are provided in **Error! Not a valid bookmark self-reference.** below. The use of the selected weighting factors in Table 4 puts the strongest emphasis on addressing the *E. coli* impairments, with a secondary emphasis on optimizing TSS and nutrient load reductions.

$$Total\ PCPI_s = \sum_{i}^{N}(PCPI_s^i \times F)$$

Table 4: Proposed Weighting Factors for Pollutants of Concern

Pollutant of Concern	Weighting Factor (F)
E. Coli	10
Total Nitrogen	3
Total Phosphorus	1
TSS	1

3. For subwatersheds with downstream impairments, the Total PCPI are multiplied by a factor for each downstream impairment. A sensitivity analysis was conducted to assess the impact of magnitude of downstream impairment factor and location of downstream impairment on the prioritization of subwatersheds. A factor of 1.1 was deemed appropriate for Bonne Femme watershed in consultation with MDNR and Boone County. This is a minor deviation from the approved QAPP, which included using a factor of 2 for each downstream impairment. The change was necessitated because using a factor of 2 was resulting in higher weighting of subwatersheds with low simulated loads but located upstream of multiple impaired streams. The use of a factor of 1.1 prioritized subwatersheds with higher simulated pollutant loading located downstream of the impaired streams. This change improved the identification and prioritization of subwatersheds for BMP implementation

4. The CPI for each subwatershed is calculated by normalizing the Total PCPI, scaling by five (5), and rounding to nearest integer:

$$CPI_s = \text{Round}\left(\frac{Total\ PCPI_s}{Max(Total\ PCPI_s\ )} \times 5\right)$$

The normalization and scaling of CPI results in binning of subwatersheds with CPI scores in the range of 1 to 5. This approach provides the stakeholders with more options for BMP implementation in the critical areas corresponding to higher CPI bins.

Subwatersheds with the highest CPIs are identified as critical areas for BMP implementation. The use of the CPI scoring approach allowed subwatershed prioritization for implementation of BMPs.

Other critical areas in the watershed include areas that are particularly sensitive to runoff and erosion. These areas were identified using the sensitivity analysis conducted as part of the previous WBP (BFSC, 2007). These critical areas were mapped along with the critical areas identified using the CPI methodology described above.

3.6 BMP Selection

A BMP is defined as an environmental protection practice used to control pollutants. For the critical areas identified using the methodology described above, the feasibility and effectiveness of cropland, pastureland, streambank, on-site wastewater systems, and urban BMPs were assessed. The POC in the GBFW include *E. coli*, TN, TP, and TSS. Although the primary focus of the BMPs selected for this report reduce *E. coli* loading, many of the BMPs selected have a positive effect on reducing the loading of multiple POCs. The BMP selection for this project was based upon the recommendations from MDNR and Missouri Soil and Water Conservation Program (SWCP), which is included in Appendix C. A brief description of example BMPs assessed for implementation in the GBFW is provided below.

3.6.1 Cropland BMPs

Cropland BMPs control the runoff from agriculture fields resulting in reduced sediment and nutrient loading. Given the size of the subwatersheds used in the models, the use of cropland BMPs would also manage any runoff from adjacent land use types or subwatersheds. This would result in reduced loading of other POCs which could include *E. coli* given the proximity of some of the cropland to pastureland in the GBFW. Seven types of BMPs were assessed for implementation in the cropland areas of the GBFW:

- **Cover Crops** are short-term crops grown after the main cropping season to reduce POC loading from the farm fields or adjacent areas.
- **Nutrient Management** helps the farmer maximize profits by balancing crop yields and nutrient inputs. Using a nutrient management plan, farmers can optimize the economic returns from nutrients used in production, minimize nutrient loss and improve water quality at the same time.
- **Conservation Tillage** involves the planting, growing, and harvesting of crops with minimal disturbance to the soil. This practice uses seeders and techniques that are more precise and require fewer passes, reducing the amount of fuel used for farm equipment in addition to reducing POC loading.
- **Terraces** are earth embankments and/or channels constructed across the slope of the field to intercept runoff and trap POCs contained in runoff.
- **Vegetated Buffers** are areas of crop fields maintained in permanent vegetation to help reduce POC loading from the farm fields or adjacent areas.
- **Retention Ponds** trap POCs in runoff and provide habitat for wildlife.
- **Regenerative Agriculture** is a holistic approach for agriculture that focuses on practices that involve minimizing soil disturbance, keeping soil coverage, increased plant diversity, keeping living root in the soil as much as possible and integrating animals into the farm. Example of regenerative agriculture practices include diverse crop rotation, multi species cover crop, no-till and low till farming, soil management, prairie strips and rotational grazing.

3.6.2 Pastureland BMPs

Six types of pastureland BMPs were assessed for implementation in the pasture areas of the GBFW. Some of these BMPs limit the source of POC from feeding operations and others reduce the pathways for the POC to enter the adjacent waterbodies.

- **Manure Management** or animal waste management systems involve manure storage, transportation off-site, and improvements in manure recoverability. This practice reduces the source of nutrients and bacteria in the runoff.

- **Grazing Management** involves controlling the movement of animals on the field. Grazing, movement and manure deposition by the animals encourages growth of pasture vegetation. However, animals can overgraze a pasture if they are not moved to a fresh area frequently enough. By rotating animals to other areas or pastures, the recently grazed vegetation has an opportunity to regrow, which impedes flow of runoff across the pasture and improves the soil nutrient content. The improved soil nutrient content reduces the need for fertilizer application in the field and reduces nutrient loading
- **Fencing** of streams and other waterbodies is designed to prevent livestock from entering the waterbody. This prevents livestock from depositing manure directly into the waterway and from damaging streambanks.
- **Vegetative Filter Strips** are vegetated areas that receive stormwater runoff from a pastureland with animal feeding operations.
- **Livestock Exclusion / Alternative Sources of Water** involves fencing of streams and other waterbodies to prevent livestock from entering the waterbody, coupled with providing alternative sources of water.
- **Wetland restoration or creation** projects on pastureland provides numerous crucial environmental functions such as wildlife habitat, flood protection, and water quality improvements.

3.6.3 Streambank BMPs

Streambank BMPs are installed along the banks of streams to reduce POC loadings into the receiving streams, improve water quality, and improve the biological condition along the stream bank. Two types of streambank BMPs were considered for implementation in the GBFW:

- **Stream Restoration** includes natural channel design, regenerative stream channel projects, and legacy sediment removal. These approaches are carefully designed interventions to improve the hydrologic, hydraulic, geomorphic, water quality, and biological condition of degraded streams.
- **Streambank Buffers** includes riparian buffer, vegetative buffer or reinforcing the existing tree line in the vicinity of stream bank, sometimes implemented with stream exclusion fencing to restrict animal access to the stream, to improve the biological condition of the streambank. US Department of Agriculture provides cost share for stream buffer practices through federal programs such as the Conservation Reserve Program, Environmental Quality Incentives Program and Wildlife Habitat Incentives Program.

3.6.4 On-site Wastewater System BMPs

On-site wastewater system BMPs address the POC loading from failing on-site wastewater systems that leak bacteria or nutrients into surface water and groundwater. This practice involves replacing old systems with more reliable systems and/or repairing malfunctioning treatment systems, failing drain fields, or waste lagoon systems.

3.6.5 Urban BMPs

Urban BMPs are designed to reduce the quantity and improve the quality of stormwater runoff from impervious surfaces in urban areas. The selection and implementation of urban BMPs are subject to site-specific constraints such as local hydrology, soil infiltration feasibility, and space restrictions. Four commonly used urban BMPs assessed for implementation in GBFW include:

- **Bioretention systems** consist of a soil bed planted with suitable native vegetation. Stormwater runoff entering the bioretention system is filtered through the soil planting bed before being discharged downstream.
- **Grass swales,** or ditches, can be placed in residential areas or along major roadways to help reduce peak runoff through infiltration and storage.
- **Wetland basins** are man-made systems engineered to approximate the water-cleansing process of natural wetlands. They are used to filter runoff from urban impervious areas and provide habitat for some wildlife.
- **Detention ponds** hold stormwater runoff until pollutants settle to the bottom. The water is then released slowly into the stream, reducing flooding and POCs in the discharge.

In addition to recommending the installation of new BMPs where applicable, Table 5 also lists maintenance of existing BMPs under a stormwater management plan for a commercial area in the GBFW.

3.7 Pollutant Load Reduction and Feasibility Assessment

The effectiveness of load reduction and feasibility of implementation of the BMP types selected in Section 3.6 are described below.

3.7.1 BMP Pollutant Load Reduction Effectiveness

Percent load reduction efficiency data were extracted from literature review to estimate the load reduction of the selected BMPs for the GBFW. The literature review includes summaries of paired watershed case studies, watershed plans for similar watersheds and agricultural BMP reference guides. Percent load reduction was extracted for each BMP to reduce the load for each POC in the GBFW.

3.7.1.1 Literature Review

A literature review was conducted to estimate the BMP percent removal efficiencies for the four POCs in the GBFW. Due to the limited performance data available for *E. coli* treatment and agricultural BMPs in general, no single source of data covers the performance of all types of BMPs listed in Section 3.6. Six sources of data were analyzed, from which BMP performance data is extracted:

a) Spring River Nonpoint Source Watershed Plan

The WBP was written for the Spring River Watershed to address impairments caused by nutrients and sediment (MDNR, 2015). The list of considered BMPs in the Spring River Watershed study is similar to the list presented in Section 3.6 for the GBFW, including urban, agricultural, streambank and on-site wastewater system BMPs. The BMP removal efficiency data for nutrients and sediment from this WBP were utilized for this project, where applicable.

b) International Stormwater BMP Database 2016 Summary Statistics

The International Stormwater BMP Database (the Database) is a publicly accessible repository for BMP performance, design, and cost information. Since the initial development of the BMP Database in 1996, a portfolio of more than $200 million in water quality research is represented in the Database. The 2016 summary statistics of the Database include treatment performance of urban BMPs for TN, TP, and TSS (Clary. J. et al. 2017). The median removal percentage for each BMP-POC pairing for all case studies in the Database was extracted from the report and used in this evaluation to estimate load reductions.

c) Effectiveness of BMPs for Bacteria Removal Developed for the Upper Mississippi River Bacteria TMDL

A literature review was conducted to inform the selection of the most practical and effective implementation strategies to improve water quality in the Upper Mississippi River Bacteria TMDL project area in the state of Minnesota (Tilman, L. et al., 2011). This literature review evaluated research findings regarding the effectiveness of various BMPs to reduce bacteria loading to surface waters. Only a limited number of BMPs were reviewed in this data source, but multiple studies were analyzed for each type of BMP. The median load reduction performance for indicator bacteria from all studies included in the data source for each type of BMP was extracted and used in this project for calculating *E. coli* load reduction.

d) The Agricultural BMP Handbook for Minnesota

This literature review, published by the Minnesota Department of Agriculture (MDA), included empirical research on the effectiveness of 30 conservation practices, i.e., agricultural BMPs (MDA, 2012). Nutrient, sediment, and limited bacteria removal performance data for the 30 BMPs is available in this data source.

e) Chesapeake Bay Quick Reference Guide for BMPs

The Chesapeake Bay Program (CBP) is a regional partnership that leads and directs Chesapeake Bay restoration and protection. This reference guide provides summarized profiles for each CBP-approved BMP, including the effectiveness in pollutant load removal, cost and feasibility of implementation (CBP, 2018). In this data source, BMP load reduction percentages are often summarized for specific land use, crop types, or sub-type of the BMP. For the purpose of this project, the median value of the load reduction for each BMP-POC pairing was extracted from this reference guide.

3.7.1.2 POC Load Reduction Efficiencies

Table 5 summarizes the load reduction percentage of each BMP listed in Section 3.6 for *E. Coli*, TN, TP, and TSS and the corresponding source of data from the six sources listed in Section 3.7.1.1.

Table 5: BMP Pollutant Load Reduction Efficiencies Used for Calculating Load Reductions through BMPs

BMP Type	BMP	*E. Coli*	TN	TP	TSS
Cropland	Cover Crops	0 [e]	0.23 [e]	0.07 [e]	0.1 [e]
	Nutrient Management	0 [e]	0.05 [e]	0.05 [e]	0.25 [b]
	Conservation Tillage	0 [e]	0.08 [e]	0.35 [e]	0.47 [e]
	Terrace	0 [e]	0.38 [b]	0.3 [b]	0.36 [b]
	Vegetated Buffer	0.59 [d]	0.36 [b]	0.5 [b]	0.5 [b]
	Retention Pond	0.7 [c]	0.5 [b]	0.5 [b]	0.5 [b]
Pastureland	Manure Management	TP, TN and *E. Coli* removal based on percent of manure removed from the feedlot.			
	Grazing Management	0.3 [d]	0.09 [d]	0.24 [d]	0.3 [d]
	Fencing	0.35 [c]	0.34 [e]	0.42 [e]	0.56 [e]
	Vegetative Filter Strip	0.7 [c]	0.32 [e]	0.5 [b]	0.56 [e]
	Livestock Exclusion/Alternative sources of water	0.35 [c]	0.34 [e]	0.42 [e]	0.56 [e]
	Wetland	0.78 [c]	0.42 [e]	0.4 [e]	0.31 [e]
Streambank	Streambank Stabilization	0 [e]	0.075 lbs/ft/yr [e]	0.068 lbs/ft/yr [e]	248 lbs/ft/yr [e]
	Streambank Buffer	0.7 [c]	0.34 [e]	0.42 [e]	0.56 [e]
	Vegetated Buffer with Trees	0.7 [c]	0.34 [e]	0.42 [e]	0.56 [e]
	Permanent vegetation establishment in riparian buffer	0.7 [c]	0.34 [e]	0.42 [e]	0.56 [e]
Urban	Bioretention	0.8 [a]	0.16 [a]	0 [a]	0.75 [a]
	Grass Swale	0 [a]	0 [a]	0 [a]	0.16 [a]
	Wetland Basin	0.64 [a]	0.04 [a]	0.25 [a]	0.55 [a]
	Detention Pond	0.64 [a]	0 [a]	0.17 [a]	0.64 [a]

	Maintain existing BMPs in accordance with the SWPP (Retention Pond)	0.7 [c]	0.5 [b]	0.5 [b]	0.5 [b]
On-site Wastewater	Repair/Replace program	TN, TP and TSS removal based on percent of on-site wastewater system repaired/replaced			

The data source for the load reduction rate for each BMP-POC pairing is from one of the six data sources listed in Section 3.8.1.1:

a - International Stormwater BMP Database 2016 Summary Statistics;

b – Spring River Nonpoint Source Watershed Plan;

c - Effectiveness of BMP for Bacteria Removal Developed for the Upper Mississippi River Bacteria TMDL;

d – The Agricultural BMP Handbook for Minnesota;

e – Chesapeake Bay Quick Reference Guide for BMP;

As shown in Table 5, load reduction percentage of all BMPs listed in Section 3.6 for each of the four POCs are extracted from the literature review, except for manure management, streambank stabilization, and on-site wastewater system BMPs. The load reduction resulting from manure management depends on the amount of manure collected, stored, transferred, or removed from the feedlot. The load reduction resulting from streambank stabilization is a function of the length of streambank stabilized. The load reduction resulting from on-site wastewater system BMPs is a function of the percentage of on-site wastewater systems repaired or replaced. As a result, the load reduction of these three types of BMPs cannot be represented as percent of load removal from the BMPs' tributary areas.

3.7.2 BMP Implementation Feasibility Assessment

In addition to selecting the appropriate types of BMPs most effective for the POC in the GBFW, the location for each type of BMP implementation was also assessed. The feasibility of implementing a certain type of BMP in a subwatershed was assessed based on factors including the land use, space constraint, slope and vegetation of the subwatershed, proximity of the source of POC to the stream, cost-effectiveness and stakeholder involvement. The feasibility assessment process is summarized below:

3.7.2.1 Cropland BMPs

Cropland BMPs are feasible for locations with a larger proportion of cropland land use. Cover crops, nutrient management, conservation tillage and regenerative agriculture can generally be implemented in cropland areas of the watershed without space constraints since these BMPs do not reduce the existing footprint of the cropland. However, there are currently not data available to quantify *E. coli* load reduction from implementation of these practices. Terraces, vegetated buffers, and retention ponds require extra space to implement but can result in reduction of *E. coli* load. In addition, terraces are typically implemented in cropland areas with moderate to high slopes which may already be difficult to farm.

3.7.2.2 Pastureland BMPs

Pastureland BMPs are suitable for locations with dominant pasture/hay land use. Manure management requires construction of structures designed for collection, transfer, and storage of manures and associated wastes. As a result, the practice requires space for the facility, including operation and maintenance. Grazing management involves rotating paddocks which requires sufficient pastureland area relative to the animal population in the subwatershed, along with fencing and water sources for each paddock. Vegetative filter strips and wetlands also require extra space to be installed adjacent to the pastureland, while livestock exclusion fencing requires a limited amount of space for implementation, but often requires infrastructure to provide alternative water sources.

3.7.2.3 Streambank BMPs

Streambank restoration projects are feasible for stream segments that are eroded severely or composed with karst formation in the streambed. Streambank restoration usually requires the services of an engineer, which can make this type of BMP more expensive for landowners. The Subwatershed Sensitivity Analysis done as part of the previous WBP (BFSC, 2007) was used to identify areas that are suitable for streambank restoration projects, which include:

- Clear Creek
- Upper Little Bonne Femme Creek before confluence with Clear Creek
- Mayhan Branch
- Bonne Femme Creek between U.S. Route 63 and confluence with Turkey Creek
- Turkey Creek
- Lower Bass Creek between U.S. Route 63 and confluence with Turkey Creek
- Fox Hollow Branch

The feasibility of implementing streambank buffers in a subwatershed depends on the distance from the source of pollutants (e.g., animals) to the waterbody and whether vegetation already exists adjacent to the waterbody which can be enhanced for implementation of the practice.

3.7.2.4 On-site wastewater System BMPs

On-site wastewater system BMPs are suitable for areas with existing on-site wastewater system with indications of failure.

3.7.2.5 Urban BMPs

Urban BMPs are feasible for subwatersheds with a significant amount of stormwater runoff from impervious surfaces. Space, soil infiltration capacity, local hydrology, and stormwater regulatory requirements are some of the major factors that affect the feasibility and design of urban BMPs. Urban areas in the GBFW watershed include the southern part of the City of Columbia, the northern part of the City of Ashland, the Columbia Regional Airport, and the Community of Deer Park along U.S. Route 63.

SECTION 4

RESULTS

This section documents the estimated baseline loading, identified critical areas, recommended BMP strategy and estimated load reduction from the implementation of recommended BMPs in the GBFW.

4.1 Baseline Loads

Baseline unit loads (per unit acre per day or year) were estimated using the two watershed models, STEPL and SELECT, for each subwatershed as described in the following sections.

4.1.1 *E. coli*

The potential sources of *E. coli* loading in the GBFW include livestock, wildlife, and failing on-site wastewater systems. Daily *E. coli* unit loads simulated using the SELECT modeling approach are shown in Figure 8 for each subwatershed. The daily *E. coli* unit load ranges from 0 to 4.91 x 10^{10} cfu/per acre/per day. Loading from livestock (specifically cows) constitutes the largest proportion of simulated loads. Failing on-site wastewater and wildlife contribute a small portion of the simulated *E. coli* unit loads. These results are in agreement with the results of MST conducted by Boone County.

4.1.2 Total Nitrogen

TN is commonly found in surface waters and serves as a primary nutrient for aquatic species. Major anthropogenic sources that deliver TN to streams within GBFW include runoff from agricultural fields, on-site wastewater systems, urban runoff, and animal agriculture.

Yearly TN unit loads were simulated using the STEPL model and are mapped in Figure 9. The TN unit loads in the GBFW range from 0.7 to 47.4 lb/acre/year. The subwatersheds with maximum loading for TN have pastureland and cropland as their dominant landuses. Hence, the greatest reduction in TN nutrient loading would be achieved by implementing BMPs in subwatersheds with a majority of pastureland and cropland.

4.1.3 Total Phosphorus

Similar to TN, TP serves as a primary nutrient for aquatic species. Major anthropogenic sources that deliver TP to streams within the GBFW include fertilizer loss from croplands, agricultural fields, on-site wastewater systems, urban runoff, and animal agriculture.

Yearly TP unit loads simulated using the STEPL model are mapped in Figure 10. The TP unit loads range from 0.2 to 10.1 lb/acre/year. Similar to TN, the subwatersheds with maximum loading for TP have pastureland and cropland as their dominant landuses.

4.1.4 Total Suspended Solids

Major sources that deliver TSS to streams within GBFW include cultivated areas, areas undergoing development, and highly impervious land uses such as roads, industrial, residential, and urban areas.

Yearly TSS unit loads simulated using the STEPL model are mapped in Figure 11. The TSS unit loads range from 0.1 to 5.8 tons/acre/year. The figure suggests that the greatest reduction in TSS would be achieved by implementing BMPs in watersheds with a majority of cultivated crop and transportation land use.

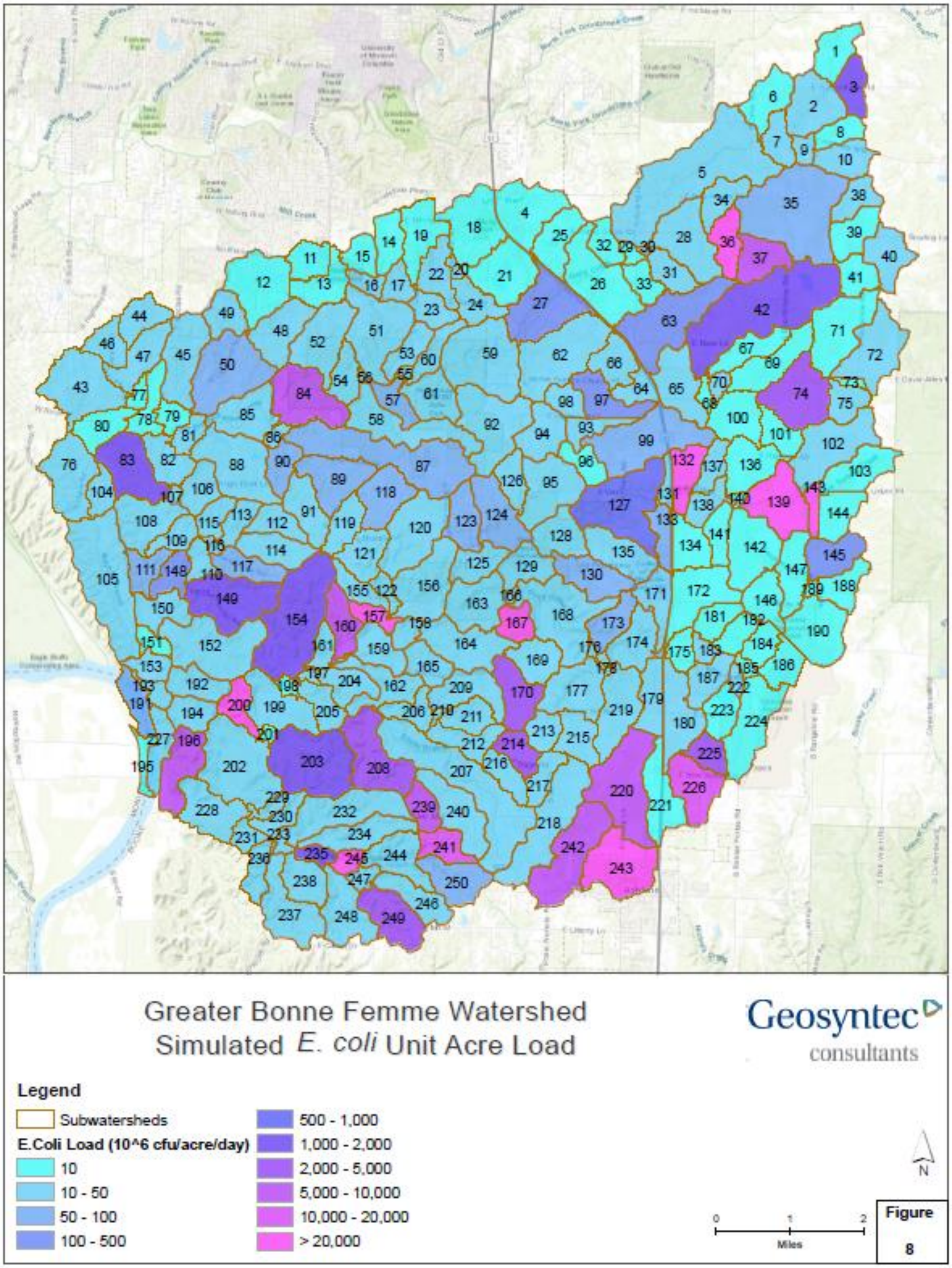


Figure 8: Simulated E. Coli Unit Area Loads for GBFW

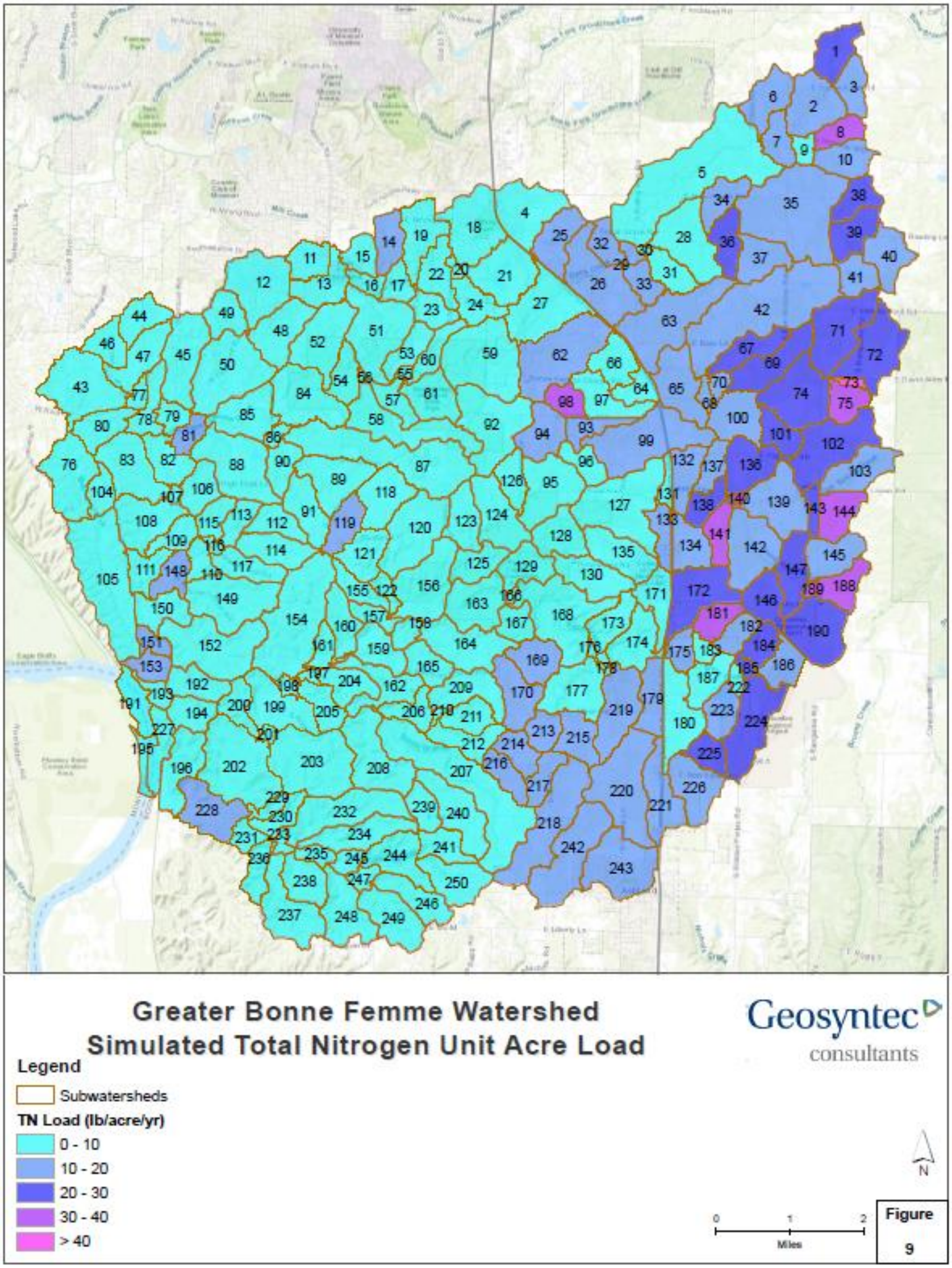


Figure 9: Simulated Total Nitrogen Unit Acre Load for GBFW

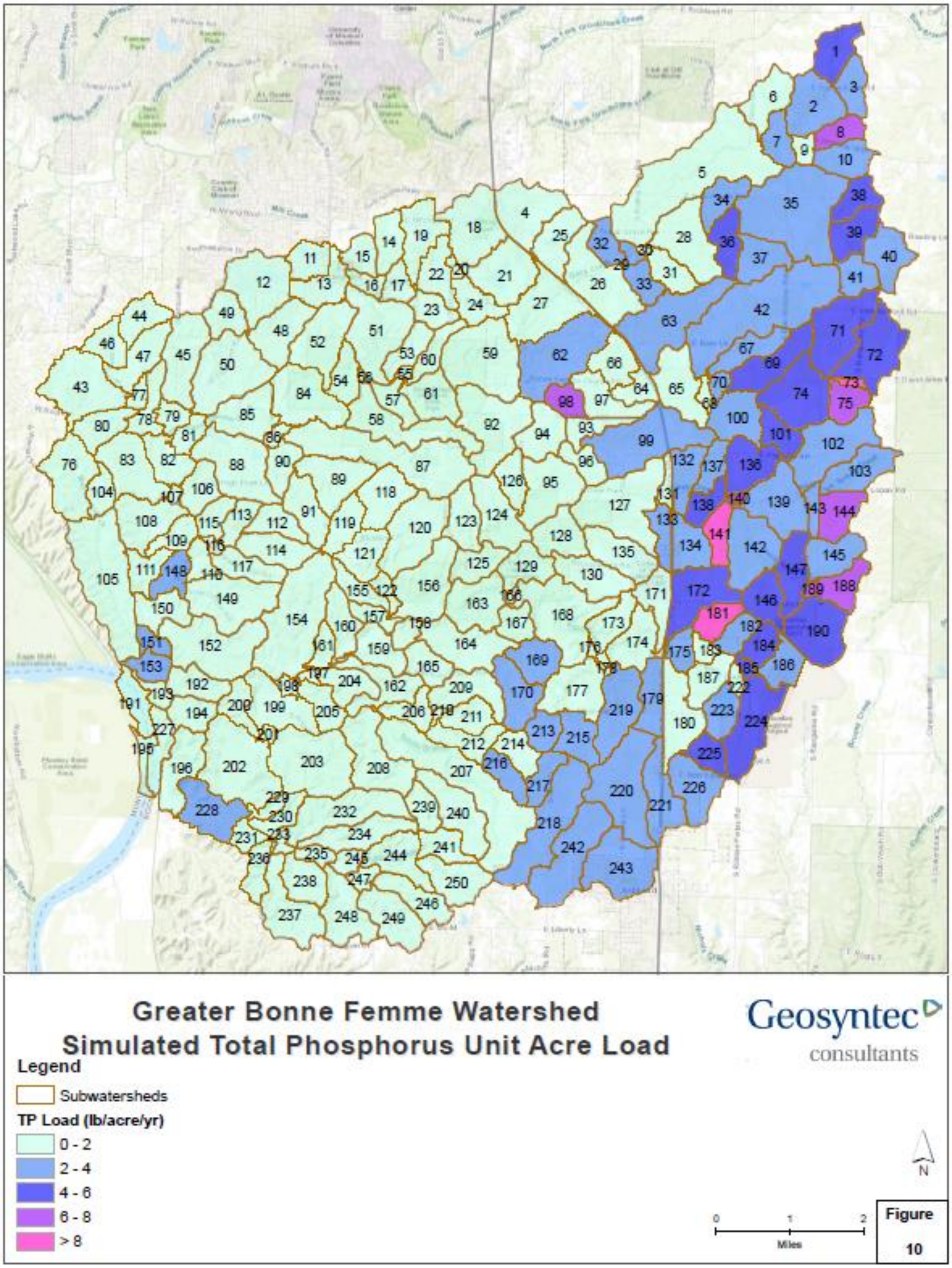


Figure 10: Simulated Total Phosphorus Unit Acre Load for GBFW

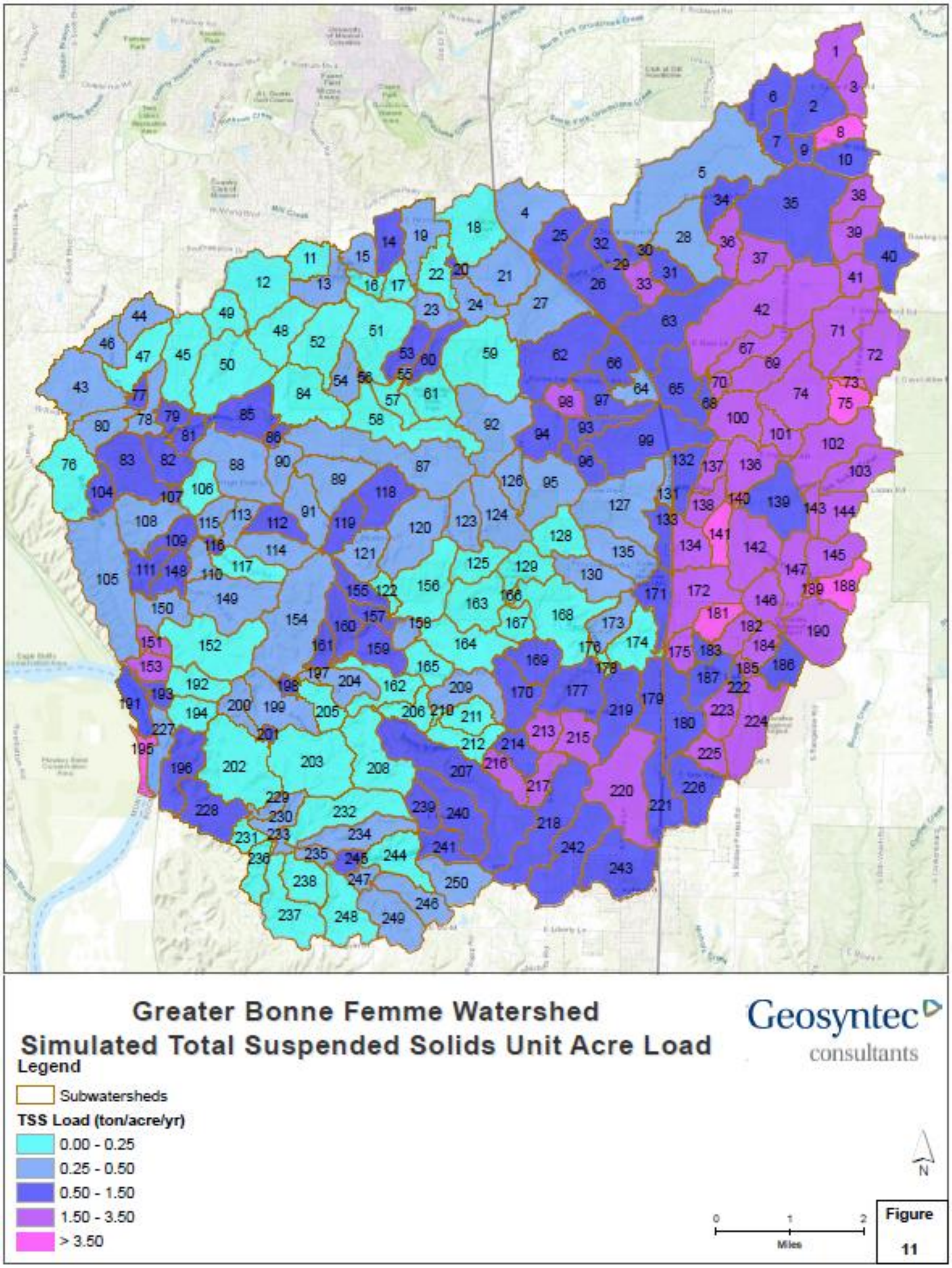


Figure 11: Simulated Total Suspended Solids Unit Acre Load for GBFW

4.2 Identified Critical Areas

The CPI was calculated for each subwatershed using the methodology described in Section 3.5. The calculated CPIs are shown in Figure 12. The CPI scores range from 1 to 5, and a higher CPI indicates a higher priority for the subwatershed. The subwatershed with the largest CPI score drains to Bass Creek. Twenty-four subwatersheds had CPIs equal to or greater than 2 – these were identified as critical areas for BMP implementation in the GBFW. The POCs for each of the identified critical subwatershed and the downstream impaired stream are shown in Table 6. Eighteen priority subwatersheds, with CPI score ranging from 5 to 2, have *E. coli* as the primary POC. The area of these eighteen subwatersheds constitutes about 90 percent of total area of prioritized subwatersheds. Six of the twenty-four priority subwatersheds (Subwatershed 73, 140, 181, 185, 188,189) have a CPI score of 2 with zero *E. coli* loading. The implementation of BMPs in these six watersheds would be geared towards reducing nutrient loading and TSS to work toward the protection component of the watershed-based plan being developed by Boone County.

Table 6: Pollutants of Concern in Critical Areas

Subwatershed ID	Area (ac)	CPI Score**	Downstream Impaired Stream	Pollutant*			
				TN	TP	TSS	*E. coli*
8	114	2	Gans Cr.	x	x	x	x
36	185	5	Gans Cr.	x	x	x	x
73	25	2	Bonne Femme Cr.	x	x	x	
75	156	2	Bonne Femme Cr.	x	x	x	x
98	124	2	Bonne Femme Cr.	x	x	x	x
132	189	4	Turkey Cr. & Bonne Femme Cr.	x	x	x	x
139	356	4	N. Fork Turkey Cr.	x	x	x	x
140	20	2	Turkey Cr. & Bonne Femme Cr.	x	x	x	
141	143	2	Turkey Cr. & Bonne Femme Cr.	x	x	x	x
143	70	4	N. Fork Turkey Cr.	x	x	x	x
144	202	2	N. Fork Turkey Cr.	x	x	x	x
157	97	2	Bonne Femme Cr.	x	x	x	x
167	135	3	Bass Cr.	x	x	x	x
181	145	2	Bass Cr.	x	x	x	
185	37	2	Bass Cr.	x	x	x	
188	177	2	S. Fork Turkey Cr.	x	x	x	
189	23	2	S. Fork Turkey Cr.	x	x	x	
200	144	4	Bonne Femme Cr.	x	x	x	x
220	560	2	Bass Cr.	x	x	x	x
226	288	3	Bass Cr.	x	x	x	x
241	159	2	Fox Hollow Br.	x	x	x	x
242	487	2	Bass Cr.	x	x	x	x
243	429	3	Bass Cr.	x	x	x	x
245	75	2	Fox Hollow Br.	x	x	x	x

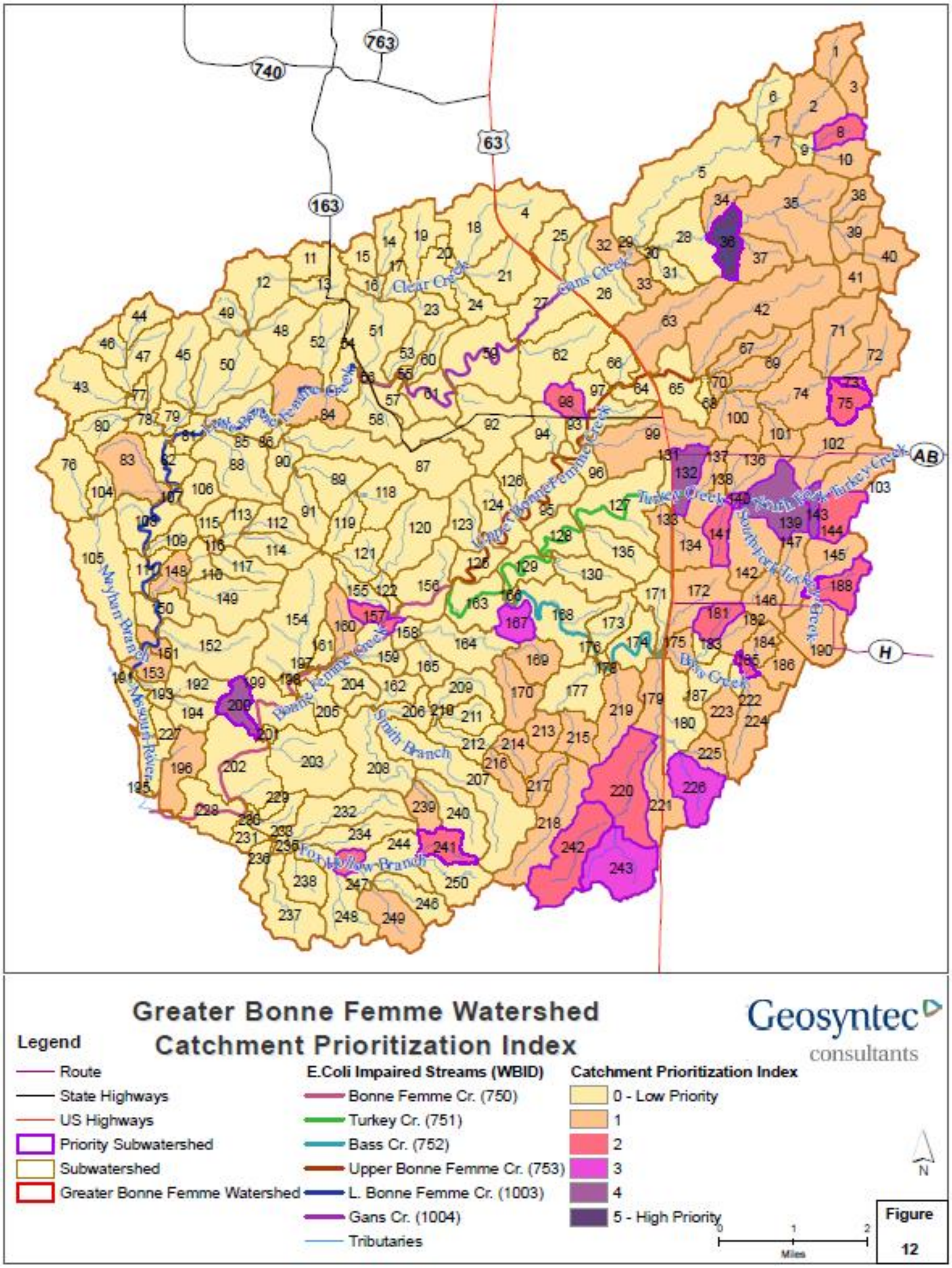


Figure 12: Catchment Prioritization Index

4.3 Recommended BMP Implementation Strategy

Watershed-wide BMP implementation was recommended for the critical areas in the GBFW. Watershed-wide BMPs represent future potential projects whose location is not specifically identified in the WBP. The BMPs may be implemented at any appropriate location in the subwatershed at the discretion of Boone County and other stakeholders.

One primary BMP and one alternative BMP are proposed for each of the 24 identified critical subwatersheds in GBFW, based on the loading analysis. The BMP types are selected based on the POC and the land use in the subwatershed. For primary and alternate BMPs, priority was given to the BMP types that result in *E. coli* load reduction. Additional BMPs that could be considered for implementation in the critical subwatersheds were also listed to provide additional options for landowners participating in BMP implementation. The BMP recommendations for subwatersheds located in sensitive karst areas were tailored based on recommendations from the Missouri SWCP. Table 7 shows the recommended watershed wide BMPs and the corresponding land use types where they would be appropriate for the identified critical area subwatersheds.

For this project, load reduction resulting from the proposed watershed wide BMPs were estimated for three implementation milestones

1) 7-Year Implementation Milestone: selected BMPs are implemented at 30% of the applicable land use area or stream length in the subwatershed.
2) 14-Year Implementation Milestone: selected BMPs are implemented at 60% of the applicable land use area or stream length in the subwatershed.
3) 21-Year Implementation Milestone: selected BMPs are implemented at 90% of the applicable land use area or stream length in the subwatershed.

Table 7: Watershed-Wide BMP Recommendations

Subwatershed ID	Area (ac)	CPI Score	Watershed-Wide BMP Recommendation (Applicable location in subwatershed[2])	Alternate Watershed-Wide BMP Recommendation	Additional BMPs
8	114	2	Livestock exclusion/Alternative source of water (P)	Permanent vegetation establishment in riparian buffer (S)	Regenerative Agriculture (C)
36	185	5	Fencing (P)	Grazing Management (P)	Regenerative Agriculture (C)
73	25	2	Vegetated Buffer (C, S)	Streambank buffer[1] (S)	
75	156	2	Streambank buffer[1] (S)	Vegetated buffer (C, S)	
98	124	2	Streambank buffer[1] (S)	Vegetated buffer (S)	
132	189	4	Grazing management (P)	Fencing (P)	
139	356	4	Fencing (P)	Grazing Management (P)	
140	20	2	Vegetated Buffer (C)	Retention pond (C)	Regenerative Agriculture (C)
141	143	2	Vegetated Buffer with Trees (S)	Streambank buffer[1] (S)	Regenerative Agriculture (C)
143	70	4	Grazing management (P)	Fencing (P)	
144	202	2	Livestock exclusion/Alternative source of water (P)	Permanent vegetation establishment in riparian buffer (S)	Regenerative Agriculture (C)
157	97	2	Grazing management (P)	Fencing (P)	
167	135	3	Grazing management (P)	Fencing (P)	
181	145	2	Vegetated Buffer (C)	Maintain existing BMPs in accordance with the SWPP (U)	
185	37	2	Vegetated Buffer (C)	Retention pond (C)	Regenerative Agriculture (C)
188	177	2	Vegetated Buffer (C)	Retention pond (C)	Regenerative Agriculture (C)

Subwatershed ID	Area (ac)	CPI Score	Watershed-Wide BMP Recommendation (Applicable location in subwatershed[2])	Alternate Watershed-Wide BMP Recommendation	Additional BMPs
189	23	2	Vegetated Buffer (C)	Retention pond (C)	Regenerative Agriculture (C)
200	144	4	Grazing management (P)	Fencing (P)	
220	560	2	Vegetative filter strip (P)	Livestock exclusion/Alternative source of water (P, S)	
226	288	3	Vegetative filter strip (P)	Livestock exclusion/Alternative source of water (P, S)	
241	159	2	Grazing management (P)	Fencing (P)	
242	487	2	Vegetative filter strip (P)	Livestock exclusion/Alternative source of water (P)	
243	429	3	Bioretention Basin (U)	Detention Pond (U)	
245	75	2	Grazing Management (P)	Fencing (P)	

[1] This may be a riparian buffer, vegetative buffer or reinforcing the existing tree line in the vicinity of stream bank.
[2] Applicable location in watershed – C: Cropland, P: Pasture, S-Stream bank, U - Urban

4.4 Pollutant Load Reduction Estimation

The pollutant load reductions from the implementation of recommended primary and alternative watershed wide BMPs were estimated using the methodology in Section 3.7.

4.4.1 Watershed-Wide BMPs

To estimate the load reduction from watershed wide BMPs for TP, TN and TSS, the loadings from each type of land use in each of the 24 identified critical subwatersheds were extracted from the STEPL models. For each subwatershed, the load reduction from the selected BMP for a POC is calculated using the following equation, with exception of streambank restoration and manure management:

$$Load\ Reduction_{WS,\ POC}$$

$$= BMP\ Removal\ \%_{POC} \times BMP\ Adoption\ \%_{WS} \times Load\ from\ Applicable\ Land\ Use_{WS,POC}$$

Where ***WS*** is the subwatershed ID;

POC is the pollutant of concern (TP, TN or TSS);

BMP Removal % $_{POC}$ is the load reduction efficiency of the BMP for a certain type of POC from Table 5;

BMP Adoption % $_{WS}$ is the percent of the applicable land use in the area that implements the watershed-wide BMP; and

Load from Applicable Land Use $_{WS,\ POC}$ is the total loading of a certain type of POC in a type of land use where the watershed wide BMPs would be implemented.

Streambank stabilization is implemented at the stream waterbody instead of on a certain type of land use. To estimate the load reduction from streambank restoration, the length of streambank that is proposed to be restored in the subwatershed is multiplied by the unit-length POC load removal rates of implementing streambank restoration.

Manure management reduces TN and TP loading by eliminating the source of these POCs in the animal waste. As a result, the load reduction resulting from manure management is a function of the percentage of manure removed from the feedlot and it is not estimated in this project.

To estimate the load reduction from watershed wide BMPs for *E. coli*, the loading in each subwatershed is extracted from the *E. coli* loading model. Based on the result of the *E. coli* model, the largest proportion of the *E. coli* loading in the GBFW is from animals instead of from a specific type of land use. For each subwatershed, the load reduction for *E. coli* is calculated by multiplying the total *E. coli* load by the removal rate of the selected BMP in Table 5.

Table 8 to 10 summarize the load reduction and percent load reduction from primary watershed wide BMPs for each POC in each subwatershed in the GBFW that was identified as a critical area under three levels of BMP implementation as described in Section 4.3.1. Table 11 summarizes the load reduction and percent load reduction from alternative watershed-wide BMPs for each POC in each subwatershed in the GBFW that was identified as a critical area in 90% implementation level (21-Year milestone)

Table 8: Primary Watershed-Wide BMPs Load Reduction Summary in 30% Implementation Scenario (7-Year Implementation Milestone)

Subwatershed	Watershed-Wide BMP Recommendation (Applicable location in subwatershed[2])	*E. coli*		TN		TP		TSS	
		Load Reduction (cfu/day)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction
8	Livestock exclusion/Alternative source of water (P)	6.53E+07	11%	56	2%	9	1%	13,482	2%
36	Fencing (P)	7.69E+11	11%	74	2%	13	1%	19,883	2%
73	Vegetated Buffer (C, S)	0.00E+00[1]	0%	128	11%	38	15%	43,357	15%
75	Streambank buffer (S)	4.60E+08	21%	522	10%	135	13%	191,533	17%
98	Streambank buffer (S)	1.11E+09	21%	395	10%	102	13%	146,201	17%
132	Grazing management (P)	5.47E+11	9%	27	1%	11	2%	17,610	3%
139	Fencing (P)	9.66E+11	11%	208	4%	30	3%	37,028	4%
140	Vegetated Buffer (C)	0.00E+00	0%	59	9%	18	13%	20,680	12%
141	Vegetated Buffer with Trees (S)	6.76E+07	21%	539	10%	144	13%	226,133	17%
143	Grazing management (P)	1.91E+11	9%	13	1%	5	2%	6,435	2%
144	Livestock exclusion/Alternative source of water (P)	1.96E+08	11%	29	0%	4	0%	5,625	0%
157	Grazing management (P)	2.15E+11	9%	16	2%	6	5%	7,688	6%
167	Grazing management (P)	3.31E+11	9%	3	1%	1	2%	1,619	4%
181	Vegetated Buffer (C)	0.00E+00[1]	0%	553	10%	168	14%	179,110	14%
185	Vegetated Buffer (C)	0.00E+00[1]	0%	91	9%	27	13%	30,902	13%
188	Vegetated Buffer (C)	0.00E+00[1]	0%	557	10%	168	14%	192,582	14%
189	Vegetated Buffer (C)	0.00E+00[1]	0%	80	9%	24	13%	27,859	13%
200	Grazing management (P)	6.38E+11	9%	7	1%	2	3%	3,127	4%
220	Vegetative filter strip (P)	8.71E+11	21%	266	3%	51	3%	56,212	3%
226	Vegetative filter strip (P)	1.20E+12	21%	191	4%	38	5%	43,863	5%
241	Grazing management (P)	2.33E+11	9%	23	2%	8	5%	10,692	7%
242	Vegetative filter strip (P)	8.71E+11	21%	282	4%	55	5%	60,794	6%
243	Bioretention Basin (U)	2.25E+12	24%	88	2%	0	0%	19,312	4%
245	Grazing Management (P)	1.66E+11	9%	9	2%	4	6%	6,057	8%

[1] Estimated load reduction is zero since the estimated E. coli loading for the subwatershed is 0

[2] Applicable location in watershed – C: Cropland, P: Pasture, S-Stream bank, U - Urban

Table 9: Primary Watershed-Wide BMPs Load Reduction Summary in 60% Implementation Scenario (14-Year Implementation Milestone)

Subwatershed	Watershed-Wide BMP Recommendation (Applicable location in subwatershed[2])	*E. coli*		TN		TP		TSS	
		Load Reduction (cfu/day)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction
8	Livestock exclusion/Alternative source of water (P)	1.31E+08	21%	112	3%	18	2%	26,964	3%
36	Fencing (P)	1.54E+12	21%	149	3%	26	3%	39,765	4%
73	Vegetated Buffer (C, S)	0.00E+00[1]	0%	255	22%	76	30%	86,713	30%
75	Streambank buffer (S)	9.19E+08	42%	1,044	20%	270	25%	383,066	34%
98	Streambank buffer (S)	2.23E+09	42%	790	20%	205	25%	292,402	34%
132	Grazing management (P)	1.09E+12	18%	53	2%	22	5%	35,219	7%
139	Fencing (P)	1.93E+12	21%	416	7%	61	6%	74,056	7%
140	Vegetated Buffer (C)	0.00E+00[1]	0%	119	18%	36	25%	41,360	24%
141	Vegetated Buffer with Trees (S)	1.35E+08	42%	1,078	20%	289	25%	452,266	34%
143	Grazing management (P)	3.82E+11	18%	26	2%	9	3%	12,869	5%
144	Livestock exclusion/Alternative source of water (P)	3.92E+08	21%	59	1%	9	1%	11,250	1%
157	Grazing management (P)	4.31E+11	18%	31	4%	11	10%	15,376	12%
167	Grazing management (P)	6.63E+11	18%	7	3%	2	4%	3,239	8%
181	Vegetated Buffer (C)	0.00E+00[1]	0%	1,107	20%	335	29%	358,220	29%
185	Vegetated Buffer (C)	0.00E+00[1]	0%	181	17%	55	26%	61,804	26%
188	Vegetated Buffer (C)	0.00E+00[1]	0%	1,114	20%	336	28%	385,164	28%
189	Vegetated Buffer (C)	0.00E+00[1]	0%	161	18%	49	27%	55,717	27%
200	Grazing management (P)	1.28E+12	18%	13	3%	5	5%	6,254	8%
220	Vegetative filter strip (P)	1.74E+12	42%	531	6%	102	6%	112,424	7%
226	Vegetative filter strip (P)	2.40E+12	42%	383	8%	76	9%	87,726	10%
241	Grazing management (P)	4.66E+11	18%	45	4%	16	10%	21,384	13%
242	Vegetative filter strip (P)	1.74E+12	42%	565	9%	109	10%	121,588	12%
243	Bioretention Basin (U)	4.51E+12	48%	175	3%	0	0%	38,624	7%
245	Grazing Management (P)	3.31E+11	18%	17	5%	7	12%	12,113	16%

[1] Estimated load reduction is zero since the estimated E. coli loading for the subwatershed is 0

[2] Applicable location in watershed – C: Cropland, P: Pasture, S-Stream bank, U - Urban

Table 10: Primary Watershed-Wide BMPs Load Reduction Summary in 90% Implementation Scenario (21-Year Implementation Milestone)

Subwatershed	Watershed-Wide BMP Recommendation (Applicable location in subwatershed[2])	*E. coli*		TN		TP		TSS	
		Load Reduction (cfu/day)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction
8	Livestock exclusion/Alternative source of water (P)	1.96E+08	32%	169	5%	28	4%	40,446	5%
36	Fencing (P)	2.31E+12	32%	223	5%	39	4%	59,648	6%
73	Vegetated Buffer (C, S)	0.00E+00[1]	0%	383	32%	114	45%	130,070	45%
75	Streambank buffer (S)	1.38E+09	63%	1,566	31%	405	38%	574,598	50%
98	Streambank buffer (S)	3.34E+09	63%	1,184	31%	307	38%	438,603	50%
132	Grazing management (P)	1.64E+12	27%	80	3%	33	7%	52,829	10%
139	Fencing (P)	2.90E+12	32%	624	11%	91	8%	111,084	11%
140	Vegetated Buffer (C)	0.00E+00[1]	0%	178	28%	54	38%	62,040	37%
141	Vegetated Buffer with Trees (S)	2.03E+08	63%	1,617	31%	433	38%	678,399	50%
143	Grazing management (P)	5.72E+11	27%	38	3%	14	5%	19,304	7%
144	Livestock exclusion/Alternative source of water (P)	5.88E+08	32%	88	1%	13	1%	16,875	1%
157	Grazing management (P)	6.46E+11	27%	47	7%	17	15%	23,064	19%
167	Grazing management (P)	9.94E+11	27%	10	4%	4	7%	4,858	12%
181	Vegetated Buffer (C)	0.00E+00[1]	0%	1,660	30%	503	43%	537,331	43%
185	Vegetated Buffer (C)	0.00E+00[1]	0%	272	26%	82	39%	92,706	39%
188	Vegetated Buffer (C)	0.00E+00[1]	0%	1,672	30%	505	42%	577,746	43%
189	Vegetated Buffer (C)	0.00E+00[1]	0%	241	27%	73	40%	83,576	40%
200	Grazing management (P)	1.91E+12	27%	20	4%	7	8%	9,381	12%
220	Vegetative filter strip (P)	2.61E+12	63%	797	9%	153	9%	168,635	10%
226	Vegetative filter strip (P)	3.59E+12	63%	574	12%	114	14%	131,590	16%
241	Grazing management (P)	6.99E+11	27%	68	7%	24	15%	32,075	20%
242	Vegetative filter strip (P)	2.61E+12	63%	847	13%	164	15%	182,381	18%
243	Bioretention Basin (U)	6.76E+12	72%	263	5%	0	0%	57,936	11%
245	Grazing Management (P)	4.97E+11	27%	26	7%	11	18%	18,170	24%

[1] Estimated load reduction is zero since the estimated E. coli loading for the subwatershed is 0

[2] Applicable location in watershed – C: Cropland, P: Pasture, S-Stream bank, U - Urban

Table 11: Alternative Watershed-Wide BMPs Load Reduction Summary in 90% Implementation Scenario (21-Year Implementation Milestone)

Subwatershed	Watershed-Wide BMP Recommendation (Applicable location in subwatershed[2])	*E. coli*		TN		TP		TSS	
		Load Reduction (cfu/day)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction	Load Reduction (lb/yr)	Percent Reduction
8	Permanent vegetation establishment in riparian buffer (S)	3.92E+08	63%	169	5%	28	4%	40,446	5%
36	Grazing Management (P)	1.98E+12	27%	59	1%	22	2%	31,954	3%
73	Streambank buffer (S)	0.00E+00[1]	0%	361	31%	95	38%	145,678	50%
75	Vegetated buffer (C, S)	1.16E+09	53%	1,658	32%	482	45%	513,034	45%
98	Vegetated buffer (S)	2.81E+09	53%	1,254	32%	366	45%	391,610	45%
132	Fencing (P)	1.91E+12	32%	300	12%	57	12%	98,613	19%
139	Grazing Management (P)	2.49E+12	27%	165	3%	52	5%	59,509	6%
140	Retention pond (C)	0.00E+00[1]	0%	247	38%	54	38%	62,040	37%
141	Streambank buffer (S)	2.03E+08	63%	1,617	31%	433	38%	678,399	50%
143	Fencing (P)	6.68E+11	32%	145	10%	24	9%	36,034	14%
144	Permanent vegetation establishment in riparian buffer (S)	1.18E+09	63%	1,977	31%	523	38%	651,694	50%
157	Fencing (P)	7.54E+11	32%	177	25%	29	26%	43,052	35%
167	Fencing (P)	1.16E+12	32%	38	14%	6	11%	9,068	23%
181	Maintain existing BMPs in accordance with the SWPP (U)	0.00E+00[1]	0%	2,306	42%	503	43%	537,331	43%
185	Retention pond (C)	0.00E+00[1]	0%	378	36%	82	39%	92,706	39%
188	Retention pond (C)	0.00E+00[1]	0%	2,322	41%	505	42%	577,746	43%
189	Retention pond (C)	0.00E+00[1]	0%	335	37%	73	40%	83,576	40%
200	Fencing (P)	2.23E+12	32%	74	16%	12	14%	17,512	22%
220	Livestock exclusion/Alternative source of water (P, S)	1.31E+12	32%	847	9%	129	7%	168,635	10%
226	Livestock exclusion/Alternative source of water (P, S)	1.80E+12	32%	610	13%	96	11%	131,590	16%
241	Fencing (P)	8.15E+11	32%	256	25%	42	26%	59,874	38%
242	Livestock exclusion/Alternative source of water (P)	1.31E+12	32%	900	14%	138	13%	182,381	18%
243	Detention Pond (U)	5.41E+12	58%	0	0%	49	6%	49,399	9%
245	Fencing (P)	5.80E+11	32%	99	27%	19	31%	33,917	45%

[1] Estimated load reduction is zero since the estimated E. coli loading for the subwatershed is 0

[2] Applicable location in watershed – C: Cropland, P: Pasture, S-Stream bank, U - Urban

4.4.2 Compliance with Water Quality Standards

MDNR requires demonstration of compliance with instream water quality standards (WQS) for *E. coli* through the implementation of recommended BMPs in the watershed plan. MDNR had calculated updated load duration curves (LDCs) for *E. coli* using the estimated flow and measured *E. coli* concentration for the impaired streams in the GBFW (provided by Karen Westin to Lynne Hooper via email correspondence on August 31, 2021). MDNR recommended comparing the LDC values at WQS with estimated load reduction post-BMP implementation to demonstrate compliance with WQS. However, this approach was not valid for the current analysis because of following reasons

- The LDC was calculated using estimated flows from two reference watersheds. A comparison of measured flows by Boone County and MDNR estimated flows for the GBFW streams showed that flows are underpredicted by this method, sometimes even by an order of magnitude of 2.
- The existing daily loads calculated using the LDC methodology and the SELECT model differ by an order of magnitude of 2. The difference of two-order of magnitude between existing load calculated by LDC methodology and SELECT model can be explained by the fact that LDC method uses underpredicted flows.

A comparison of target load reduction from MDNR LDCs with estimated load reduction for all the impaired WBIDs was made to demonstrate compliance with WQS through the implementation of proposed BMPs in the GBFW. The range of target load reduction provided by MDNR for different flow conditions was compared to the estimated load reduction. This approach was discussed with MDNR and subsequently approved. (per Boone County's email correspondence with Mike Kruse, MDNR TMDL Unit Chief on September 11, 2020). The estimated load reduction for the recommended BMPs is achieved the required the load reduction target under the 90% implementation scenario. The highest load reduction is required for high flow conditions which occur only 5 % of time. (Table 12). This analysis shows that WQS for *E. coli* will likely be met over time through the implementation of recommended BMPs in the GBFW.

Table 12: Comparison of Target Load Reduction with Estimated Load Reduction for E. coli through the implementation of recommended BMPs

WBID	WB Name	Target Load Reduction Range, cfu/day	Scenario	Estimated Load Reduction for Primary BMPs, cfu/day	Estimated Load Reduction for Alternative BMPs, cfu/day
750	Bonne Femme Cr.	1.15E+09 to 1.45E+13	30% Implementation of Watershed Wide BMP	8.48E+12	6.81E+12
			60% Implementation of Watershed Wide BMP	1.70E+13	1.36E+13
			90% Implementation of Watershed Wide BMP	2.54E+13	2.04E+13
751	Turkey Cr.	1.21E+09 to 2.71E+12	30% Implementation of Watershed Wide BMP	7.23E+12	5.35E+12
			60% Implementation of Watershed Wide BMP	1.45E+13	1.07E+13
			90% Implementation of Watershed Wide BMP	2.17E+13	1.60E+13
752	Bass Cr.	4.34E+09 to 1.96E+12	30% Implementation of Watershed Wide BMP	5.52E+12	3.66E+12
			60% Implementation of Watershed Wide BMP	1.10E+13	7.32E+12
			90% Implementation of Watershed Wide BMP	1.66E+13	1.10E+13
1003	Little Bonne Femme Cr.	1.34E+11 to 1.31E+12	30% Implementation of Watershed Wide BMP	7.69E+11	6.59E+11
			60% Implementation of Watershed Wide BMP	1.54E+12	1.32E+12
			90% Implementation of Watershed Wide BMP	2.31E+12	1.98E+12
1004	Gans Cr.	4.43E+08 to 4.07E+11	30% Implementation of Watershed Wide BMP	7.69E+11	6.59E+11
			60% Implementation of Watershed Wide BMP	1.54E+12	1.32E+12
			90% Implementation of Watershed Wide BMP	2.31E+12	1.98E+12
753	Bonne Femme Cr. (Upper)	2.94E+07 to 4.11E+07	30% Implementation of Watershed Wide BMP	1.57E+09	1.33E+09
			60% Implementation of Watershed Wide BMP	3.15E+09	2.65E+09
			90% Implementation of Watershed Wide BMP	4.72E+09	3.98E+09

SECTION 5

SUMMARY

Geosyntec developed a watershed model for the GBFW to estimate TN, TP, TSS, and *E. coli* average annual loads in 250 subwatersheds. The loads for TN, TP, and TSS were estimated using STEPL and loads for *E. coli* were estimated using the SELECT methodology. The estimated loading per unit acre was used to calculate a CPI. Subwatersheds with a CPI of two or higher were identified as critical areas for a BMP implementation. A BMP implementation strategy consisting of watershed wide BMPs was recommended based on the POCs and landuses in the critical subwatersheds. The watershed BMPs are recommended to be implemented over a 21-year period with two interim milestones. Pollutant load reductions were estimated for the recommended BMPs in the GBFW. These recommended BMPs would serve to eliminate the *E. coli* impairments in the GBFW streams and be protective of the existing condition for nutrients and TSS in the affected subwatersheds.

SECTION 6

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APPENDIX A: ELECTRONIC FILES FOR MODEL INPUTS AND STEPL MODELS

APPENDIX B: ELECTRONIC FILE FOR *E. COLI* MODEL

APPENDIX C: BMP RECOMMENDATIONS FOR MISSOURI

Appendix H: Agricultural BMP Mode of Action and Pollutants Addressed

Greater Bonne Femme Watershed-based Plan: Appendix H:
Agricultural BMP Mode of Action and Pollutants Addressed

Missouri Soil and Water Conservation Program		Practice Mode of			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 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

Prepared by: Water Protection Program, Watershed Protection Section

Appendix I: Load Duration Curves and Pollutant Reduction Estimates for Six Impaired Streams in Boone County, Missouri

Prepared by: Water Protection Program, Watershed Protection Section

LOAD DURATION CURVES AND POLLUTANT REDUCTION ESTIMATES FOR SIX BACTERIA IMPAIRED STREAMS IN BOONE COUNTY

Completed
June 22, 2022

Prepared by: Water Protection Program, Watershed Protection Section

Load Duration Curves and Reduction Estimates for *E. coli* Impaired Streams in southern Boone County

Introduction

The Missouri Department of Natural Resources Watershed Protection Section calculated the load duration curves and pollutant reduction estimates in this document to support the development and implementation of the Greater Bonne Femme Watershed Based Plan, which is funded, in part, by the U.S. Environmental Protection Agency, Region 7, through the Department under Section 319 of the Clean Water Act. Flow records used to develop the load duration curves are based on available U.S. Geological Survey stream gage data from representative watersheds near the Greater Bonne Femme Watershed, and with assistance from the EPA Region 7.[2] When achieved, these loading targets and estimated reductions are expected to result in attainment of water quality standards. For this reason, incorporation of these loading targets into a nine-element watershed-based plan, and expected implementation of that plan, may serve as an alternative restoration approach that is more beneficial or practicable for restoring water quality than the immediate development of a total maximum daily load (TMDL). The department may subcategorize impairments addressed by alternative restoration approaches as Category 5-alt on Missouri's Section 303(d) list of impaired waters. Impairments subcategorized as 5-alt remain on the 303(d) list, but are considered low priority for TMDL development.

The following sections explain the load duration curve approach and provide estimates of existing bacteria loading and needed reductions for attaining water quality standards in six bacteria impaired streams in Boone County. Although the Department has only identified these streams as being impaired by *Escherichia coli* (*E. coli*), additional nutrient (nitrogen and phosphorus) and sediment (total suspended solids) load duration curves are provided for the two subwatersheds being addressed by the Greater Bonne Femme watershed-based plan. Estimates of existing loading and needed reductions for these other pollutants are provided where data is available.

Load duration curves were developed for the following stream segments:

- Water Body ID 750 – Bonne Femme Creek;
- Water Body ID 751 – Turkey Creek;
- Water Body ID 752 – Bass Creek;
- Water Body ID 753 – Bonne Femme Creek;
- Water Body ID 1003 – Little Bonne Femme Creek; and
- Water Body ID 1004 – Gans Creek.

A map showing the locations of the impaired streams and their watersheds within Boone County is provided on the next page in Figure 1.

[2] Flow records provided via email by Steven Wang, EPA Region 7 on Aug. 9, 2021.

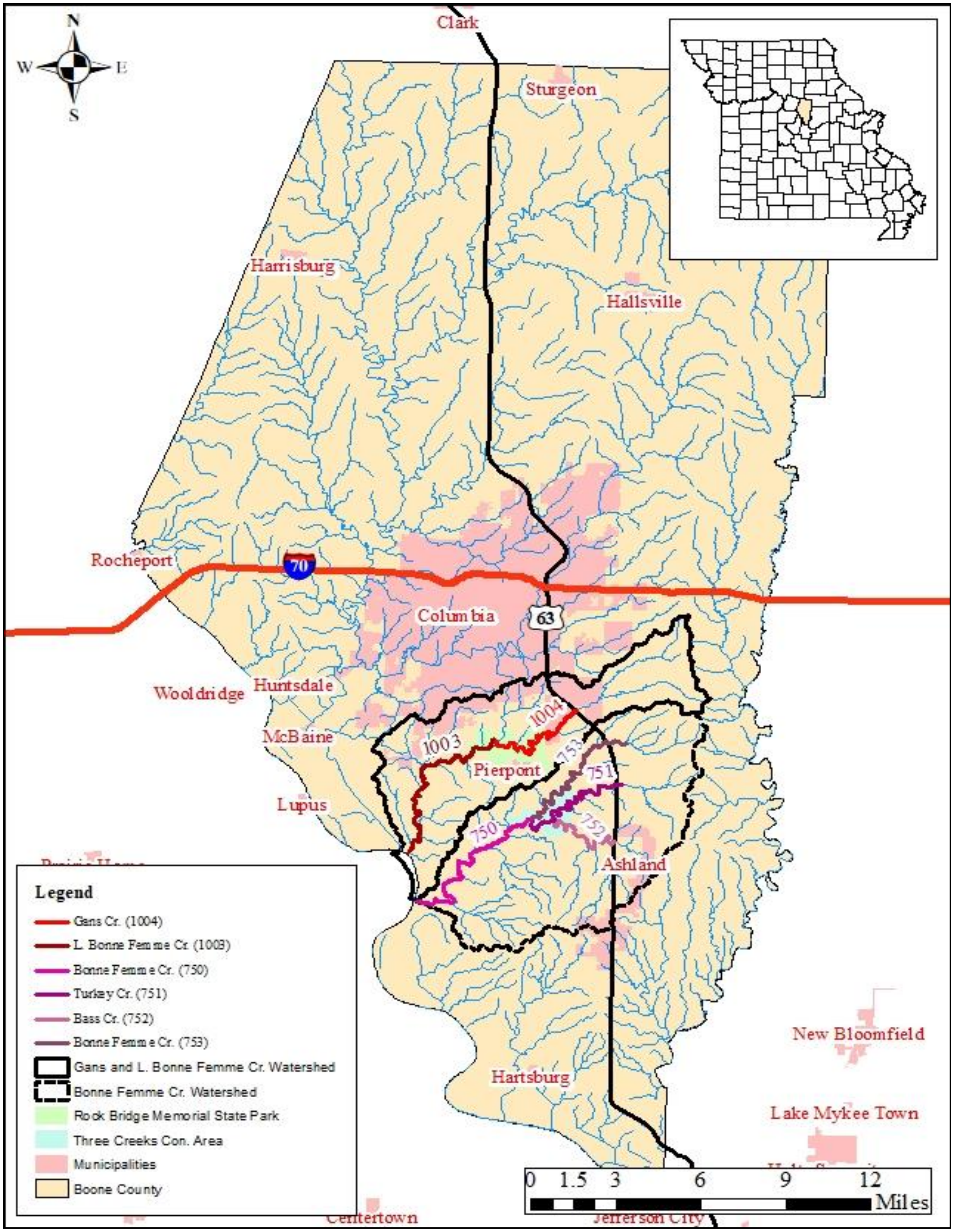

Figure 13. Map showing bacteria impaired streams in Boone County

Explanation of Load Duration Curves

As described by EPA *"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."*

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 represents the relationship between a pollutant and stream flow conditions (e.g., low, dry, mid-range, moist and high). Such a relationship is helpful for determining if excess pollutant loading occurs as a result of stormwater driven sources (i.e., surface runoff from impervious surfaces, bare soil, or soil with low infiltration rates) or from continuous input sources that are more apparent during dry weather conditions (i.e., point source discharges, failing septic systems, or livestock accessing the stream). The information derived from a load duration curve can help determine appropriate best management practices (BMPs). For example, Figure 2 is the *E. coli* load duration curve calculated for Bonne Femme Creek, water body ID 750.

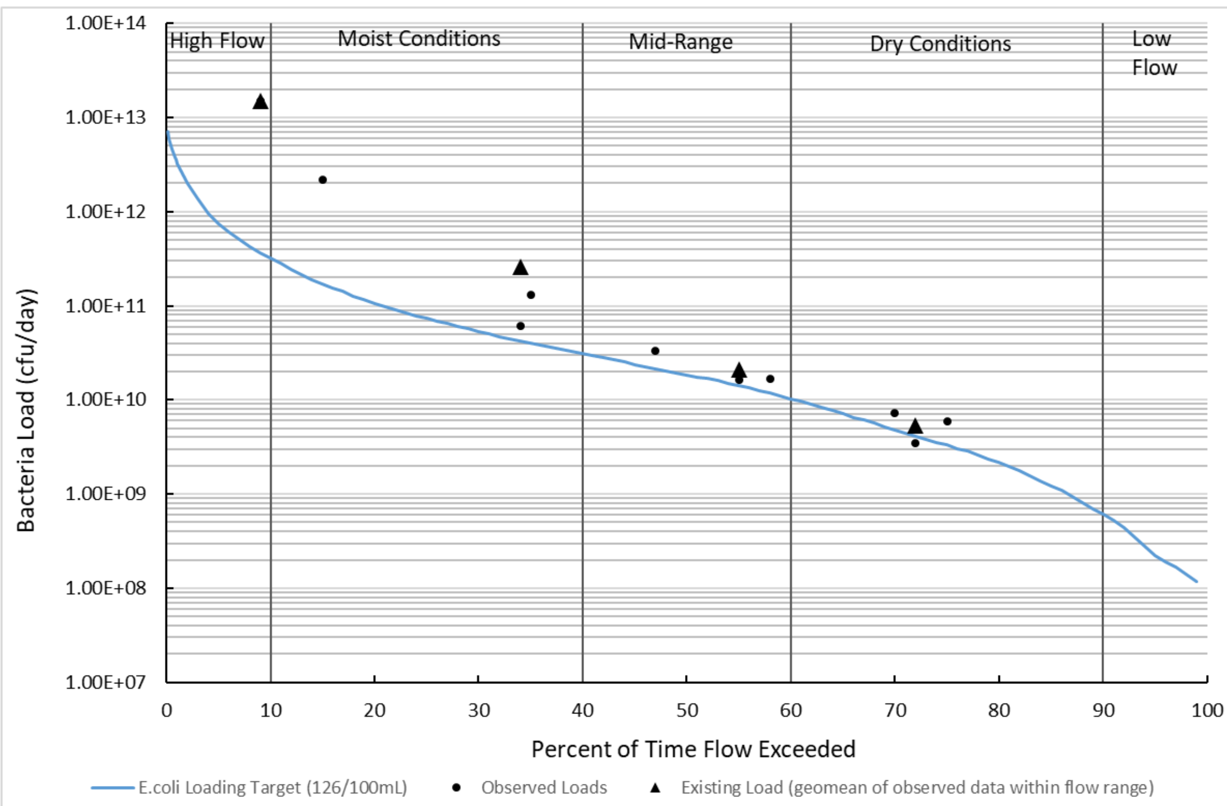

Figure 2. Bonne Femme Creek – WBID 750 E. coli load duration curve

A load duration curve represents the stream's loading capacity, or the maximum amount of the pollutant that the stream can assimilate and still meet water quality standards. In Figure 2, the loading capacity is represented by the solid curve. Water quality impairments occur when existing pollutant loading exceeds a water body's loading capacity. Moving along the curve from high flows to low flows shows the decreasing assimilative capacity of Bonne Femme Creek in terms of the expectation that water quality standards are met at the target *E. coli* concentration of 126 colony forming units per 100 mL of water (126 cfu/100 mL). Although the allowable loading to meet water quality standards changes with flow, the target concentration remains constant. At high flows there is more water and more dilution, therefore the loading capacity is greater. The target *E. coli* concentration chosen for calculation of a load duration curve is based on each stream's designated whole body contact recreational use and the applicable criterion to protect that use (Table 1). Designated uses and criteria can be found in Missouri's Water Quality Standards regulation at 10 CSR 20-7.031. Pollutant loading to an impaired water body must be reduced to levels at or below the loading capacity if it is to meet water quality standards.

Table 13. Whole body contact use designations for Boone County streams

Water Body ID	Name	WBC Designation	Criterion (count/ 100 mL)
750	Bonne Femme Cr.	A	126
751	Turkey Cr.	A	126
752	Bass Cr.	A	126
753	Bonne Femme Cr.*	B	206
1003	L. Bonne Femme Cr.	B	206
1004	Gans Cr.	A	126
*Potential losing stream conditions, 126 count/100mL criterion applied for load duration calculations.			

In the example load duration curve in Figure 2, the x-axis represents the frequency for which a particular flow is met or exceeded. Calculated using multiple years of available flow data, the x-axis represents the full range of possible stream flow conditions expected to occur in the water body. As can be seen from the figure, lower flows are equaled or exceeded more frequently than higher flows. Flows met or exceeded 90 percent of the time or more represent the lowest flow conditions, such as during a drought. Flows met or exceeded 10 percent of the time or less represent the highest flow conditions, such as those occurring during a flood. Table 2 presents the USGS flow gage stations used to derive the flow records used to develop the load duration curves for the Greater Bonne Femme watershed. These gages provide flow data from both rural and urban watersheds, and therefore are appropriate for developing flow records for streams in the Greater Bonne Femme watershed, which contains a mixed land cover.

Table 2. USGS stream gages used for load duration curve development

Gage	Stream	Drainage Area	Data Range
06909500	Moniteau Creek	75.1	1948 – 2019
06910230	Hinkson Creek	69.8 mi2	1990 - 2019

In Figure 2, the y-axis describes *E. coli* loading as cfu per day (cfu/day). Due to the extremely large numbers associated with bacteria loads, this is expressed using scientific notation. To obtain the true numeric loading value, the decimal number is multiplied by 10 to the *n*th power. For example, 1.00E+12 is the same as 1.00 times 10 to the 12th power, which is 1,000,000,000,000 (or 1 trillion) *E.coli* cfu/day. For lab analysis, individual *E. coli* stream samples are reported as a concentration in a volume of water, or cfu/100 mL. Observed bacteria loads are calculated by multiplying the individually measured *E. coli* concentrations by the daily average stream flow record corresponding to the date of sample collection. A conversion factor is also multiplied to obtain daily units. For *E. coli* the conversion factor is 24,465,715. See Equation 1 below. These individual observed loads are represented on the figure by black dots. Any data point above the loading capacity curve reflects a water quality excursion and possible exceedance of the water quality criterion.

Equation 1. $\boldsymbol{Load}\left(\frac{count}{day}\right) = \left[\boldsymbol{Target}\ (\boldsymbol{Observed})\left(\frac{count}{100ml}\right)\right] * \left[\boldsymbol{Flow}\ \left(\frac{feet^3}{second}\right)\right] * [\boldsymbol{Conversion\ Factor}]$

Although Figure 2 shows that individual observed loads above the loading capacity have been measured, because Missouri's water quality criteria for *E. coli* are expressed as geometric means, individual excursions above the criteria concentration do not necessarily indicate a violation of water quality standards. However, these individually observed loads still provide important information regarding the frequency for which excursions above the water quality criterion occur and under what flow conditions that pollutant loading is typically occurring. In order to make a better comparison between the observed data and compliance with the water quality criterion, the geometric means of all observed loads within a specific flow condition were calculated and plotted in the figure as a black triangle. These triangles represent estimates of existing load and provide a better representation of the overall magnitude of excursions occurring during specific flow conditions. These values are also more directly comparable to the loading capacity curve and the geometric mean criterion. Because Missouri's bacteria criteria are expressed as a geometric mean, reductions in both the frequency and magnitude of excursions above the loading capacity will aid in restoring water quality in Bonne Femme Creek.

For watershed planning purposes, a pollutant reduction goal or target is needed for measuring progress towards water quality improvement and for evaluating the effectiveness of restoration activities. To assist in the selection of appropriate BMPs the amount and percentage of pollutant reduction needed is estimated for each specific flow condition for which there is available data. When the existing load exceeds the loading capacity, the amount of reduction needed is calculated as the difference between the existing load and the loading capacity. So in this example, this is calculated as the existing load (triangles) minus the loading capacity (curve) at the same flow. From this, a percent reduction goal can be calculated using Equation 2 below.

Equation 2. $\boldsymbol{Percent\ Reduction\ Needed} = \left[\frac{(Existing - Target\,)}{Existing}\right] * \mathbf{100}$

For other pollutants, such as sediment or nutrients, pollutant loading is presented on the y-axis in units of pounds per day (lbs/day). The target concentration to derive the loading capacity curve is in units of milligrams per liter (mg/L). Unlike *E. coli* which is measured as a geometric mean for compliance with water quality standards, for these other pollutants every individual observed load measured above the load duration curve is considered to be an exceedance of the targeted loading. Reduction targets for these pollutants are based on the highest observed exceedance. It should be noted that Missouri does not have numeric water quality criteria for sediment or nutrients. Therefore reference targets were used to calculate load duration curves. For nutrients, benchmark values derived by the US EPA's Regional Technical Assistance Group (RTAG) were used. For sediment, reference stream total suspended solids (TSS) data were used to estimate a target concentration. Where observed loading shows that no pollutant reductions are necessary, the loading capacity serves as a target for protecting water quality instead of restoring it.

The following pages present *E. coli* load duration curves for each bacteria impaired stream included on Missouri's section 2020 303(d) List. Supplemental tables are also provided to show specific loading targets under various flow conditions, as well as estimates of needed pollutant load reduction to attain water quality standards. Additional nutrient and sediment load duration curves are also provided for Little Bonne Femme Creek and Bonne Femme Creek to assist watershed planning activities in those watersheds.

To provide further assistance for watershed planning, a map of critical areas for implementing BMPs is provided in Appendix A. Critical areas were identified through geographic information system analysis comparing soil runoff potential with areas associated with agricultural land uses. The areas presented in these maps are expected to be highly responsive to BMPs. However, this information should be supplemented with local knowledge of the watershed in order to better refine critical areas and appropriate BMPs.

Appendix B presents individual *E. coli* measurements used for plotting observed loads on the load duration curve figures. Appendix C presents present all available total suspended solids, total nitrogen, and total phosphorus data plotted on load duration curves.

Little Bonne Femme Creek (WBID 1003) and Gans Creek (WBID 1004)

Summary:
The Little Bonne Femme and Gans Creek watershed is approximately 41.13 square miles (106.53 square kilometers) and includes portions of the municipalities of Pierpont and Columbia. Gans Creek originates east of the City of Columbia and flows approximately 5.5 miles (8.85 kilometers) until it enters Little Bonne Femme Creek in Rock Bridge Memorial State Park. The entire stream reach of Gans Creek from U.S. Highway 63 to its confluence with Little Bonne Femme Creek is listed as impaired due to exceedances of the state's *E. coli* water quality criteria for the protection of Whole Body Contact Recreation Category A (swimming) and Secondary Contact Recreation (wading and fishing). The entire length of Little Bonne Femme Creek, downstream of the confluence with Gans Creek to the Missouri River (approximately 9 miles [14.48 km]), is listed as impaired due to exceedances of the state's *E. coli* water quality criteria for the protection of Whole Body Contact Recreation Category B and Secondary Contact Recreation. All municipal and domestic wastewater dischargers in the watershed disinfect their effluent, are scheduled to disinfect, or have established *E. coli* permit limits. There are no concentrated animal feeding operations (CAFOs) in this watershed. Other permitted facilities operating in compliance with site-specific industrial, general wastewater, or general stormwater permits are not expected to contribute bacteria loads above negligible levels.

Table 3. Land Cover in the Little Bonne Femme and Gans Creek Watershed

Land Cover Type	Area acre (hectare)	Area mi^2 (km^2)	Percent (%)
Developed, High Intensity	68 (28)	0.11 (0.28)	0.26
Developed, Medium Intensity	648 (262)	1.01 (2.62)	2.46
Developed, Low Intensity	1,114 (451)	1.74 (4.51)	4.23
Developed, Open Space	1,322 (535)	2.07 (5.35)	5.02
Barren Land	44 (18)	0.07 (0.18)	0.17
Cultivated Crops	1,630 (660)	2.55 (6.60)	6.19
Hay/Pasture	9,187 (3,718)	14.36 (37.18)	34.90
Deciduous Forest	10,387 (4,203)	16.23 (42.03)	39.46
Evergreen Forest	491 (199)	0.77 (1.99)	1.87
Mixed Forest	252 (102)	0.39 (1.02)	0.96
Shrub/Scrub	62 (25)	0.10 (0.25)	0.25
Herbaceous	374 (151)	0.58 (1.51)	1.42
Woody Wetlands	163 (66)	0.26 (0.66)	0.62
Emergent Herbaceous Wetlands	4 (2)	0.01 (0.02)	0.01
Open Water	578 (234)	0.90 (2.34)	2.19
Totals =	26,325 (10,653)	41.13 (106.53)	100.00

Load Duration Curves for Little Bonne Femme Creek – WBID 1003

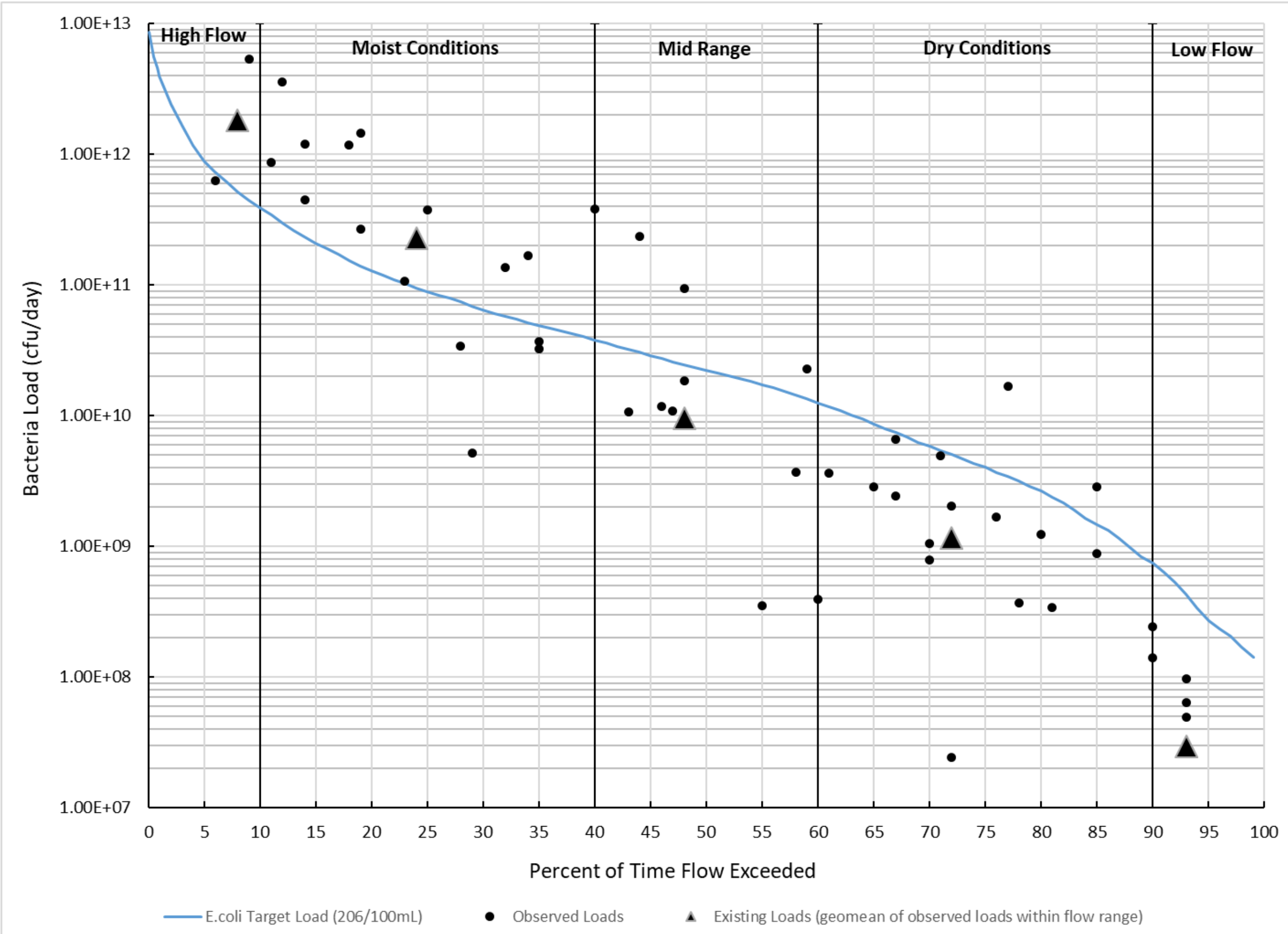

Figure 3. E. coli load duration curve for Little Bonne Femme Creek – WBID 1003. Target E. coli concentration = 206 counts/100mL

Table 4. E. coli loads at specific flow exceedance percentiles for Little Bonne Femme Creek and percent reductions required to meet water quality targets – WBID 1003.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (cfu/day)	Existing Load (cfu/day)	Percent Reductions to meet WQ Targets
93	Low Flow	0.09	4.29E+08	2.94E+07	0.00%
72	Dry Conditions	1.00	5.02E+09	1.15E+09	0.00%
48	Mid Range	4.85	2.45E+10	9.58E+09	0.00%
24	Moist Conditions	18.80	9.48E+10	2.29E+11	58.57%
8	High Flow	102.24	5.15E+11	1.82E+12	71.74%

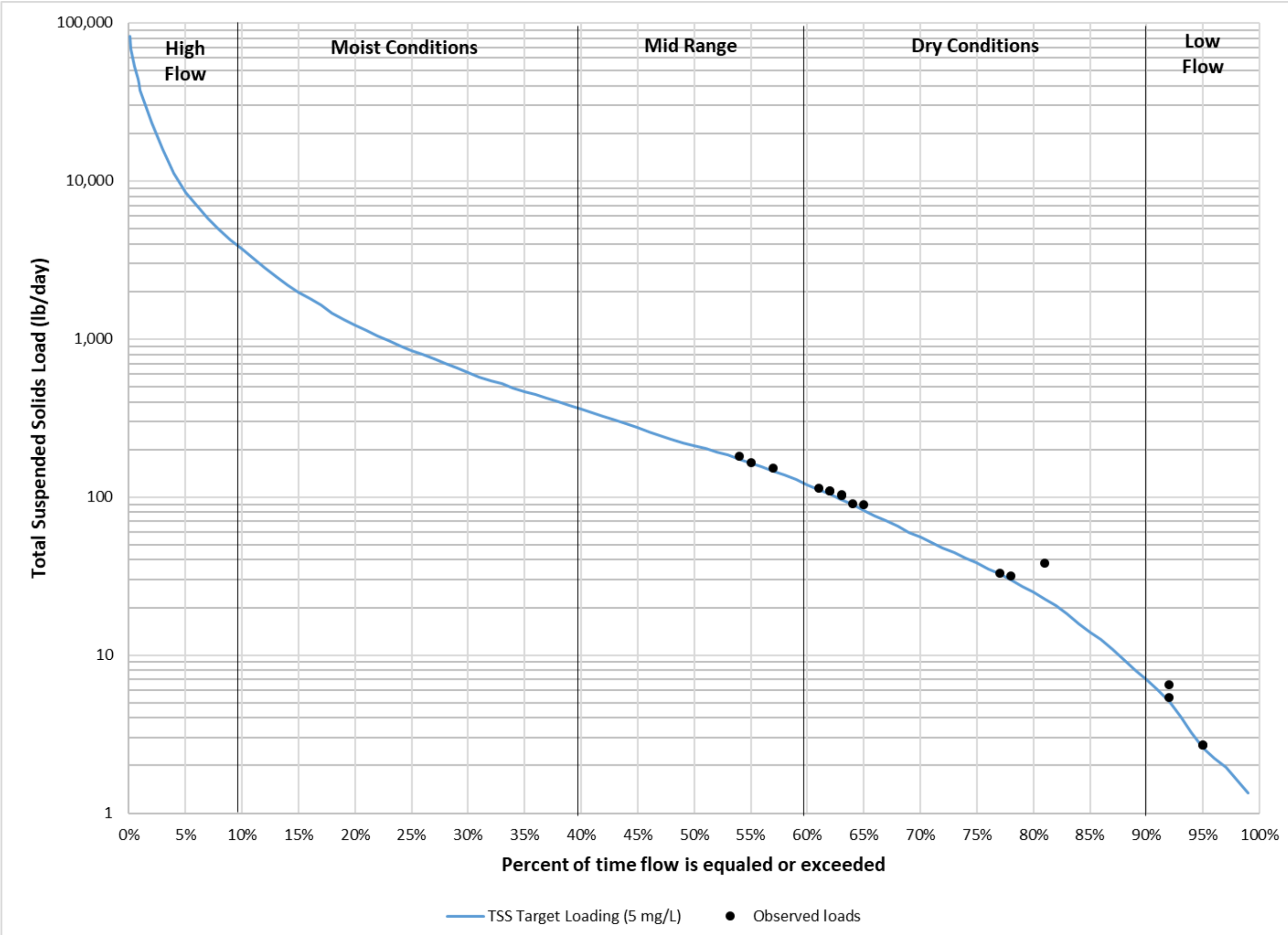

Figure 4. TSS load duration curve for Little Bonne Femme Creek – WBID 1003.

Table 5. TSS loads at specific flow conditions for Little Bonne Femme Creek – WBID 1003.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (lbs/day)	Existing Load (lbs/day)	% Reduction Needed
92%	Low Flow	0.19	0.31	6.47	95%
61%	Dry Conditions	4.15	6.94	113.05	94%
54%	Mid Range	6.43	10.76	182.22	94%
25%	Moist Conditions	31.29	52.32	No data	No data
5%	High Flow	314.95	526.63	No data	No data

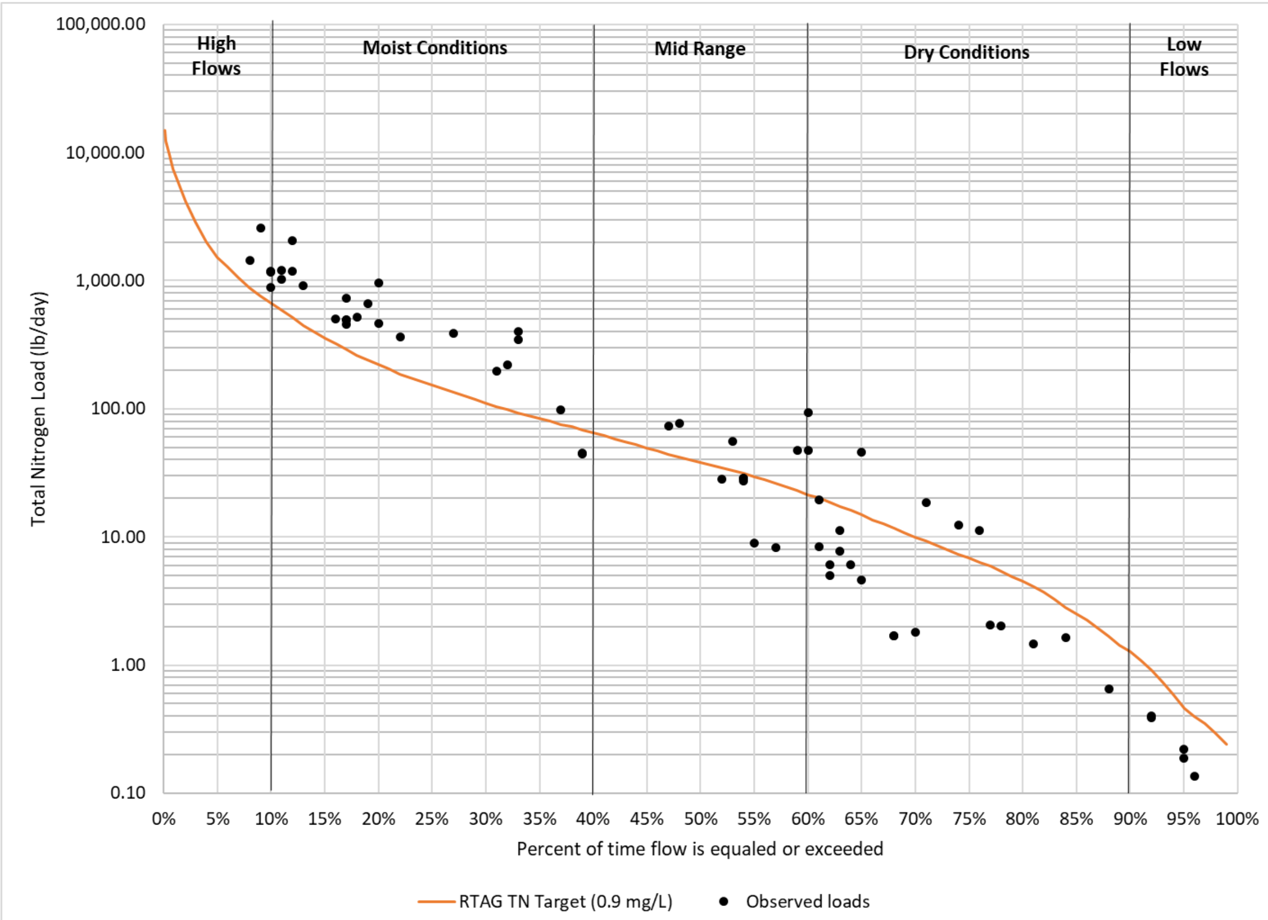

Figure 5. Total nitrogen (TN) load duration curve for Little Bonne Femme Creek – WBID 1003.

Table 6. TN loads at specific flow conditions for Little Bonne Femme Creek – WBID 1003.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (lbs/day)	Existing Load (lbs/day)	% Needed Reduction
92%	Low Flow	0.19	0.91	0.40	0%
65%	Dry Conditions	3.05	14.83	45.61	67%
60%	Mid Range	4.40	21.34	93.51	77%
12%	Moist Conditions	105.28	511.10	2,064.82	75%
9%	High Flow	156.43	759.43	2,592.36	71%

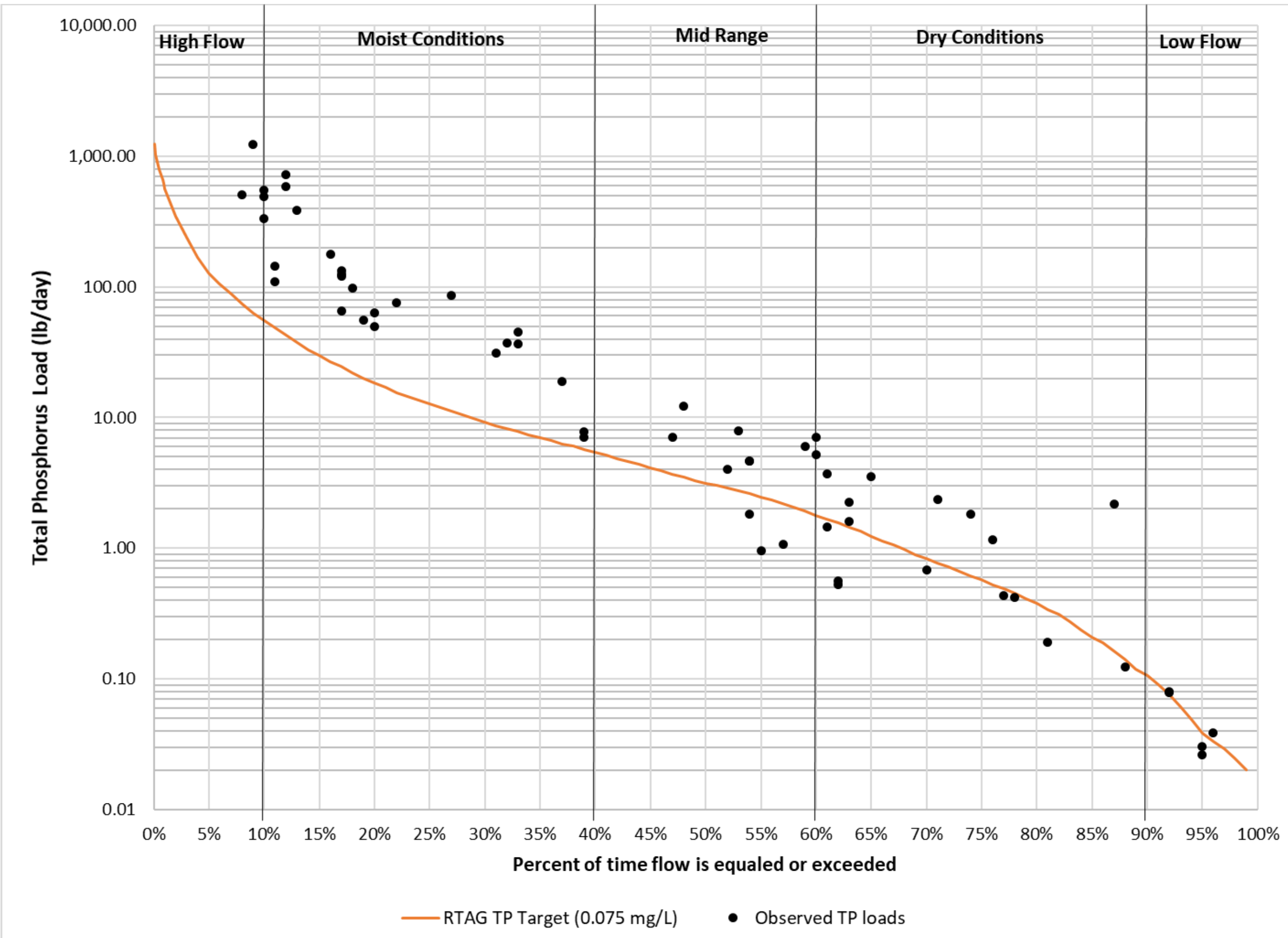

Figure 6. Total phosphorus (TP) load duration curve for Little Bonne Femme Creek – WBID 1003.

Table 7. TP loads at specific flow conditions for Little Bonne Femme Creek – WBID 1003.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (lbs/day)	Existing Load (lbs/day)	% Needed Reduction
92%	Low Flow	0.19	0.08	0.08	5%
61%	Dry Conditions	4.15	1.68	3.69	55%
48%	Mid Range	8.63	3.49	12.31	72%
12%	Moist Conditions	105.28	42.59	724.95	94%
9%	High Flow	156.43	63.29	1,233.07	95%

Load Duration Curves for Gans Creek – WBID 1004

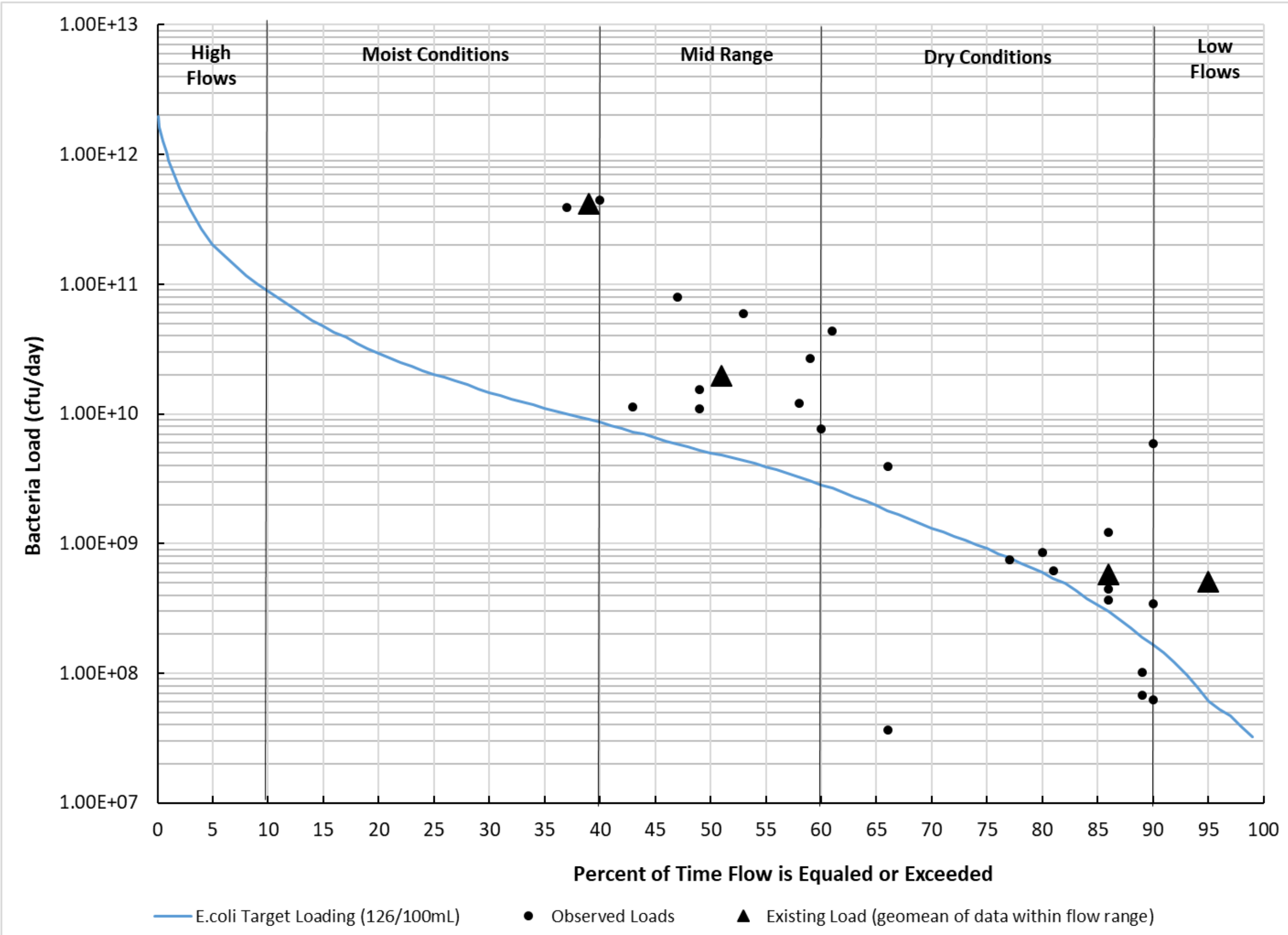

Figure 7. E. coli load duration curve for Gans Creek – WBID 1004.

Table 8. E. coli loads at specific flow conditions for Gans Creek– WBID 1004.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (cfu/day)	Existing Load (cfu/day)	Percent Reductions to meet WQ Targets
95	Low Flow	0.01	6.11E+07	5.04E+08	87.90%
86	Dry Conditions	0.07	2.99E+08	5.76E+08	48.05%
51	Mid Range	1.48	4.84E+09	1.96E+10	75.38%
39	Moist Conditions	2.81	9.08E+09	4.16E+11	97.82%
5	High Flow	66.79	2.02E+11	No data	No data

Bonne Femme Creek (WBID 750), Turkey Creek (WBID 751), Bass Creek (WBID 752), and Bonne Femme Creek (WBID 753)

Summary:
The Bonne Femme Creek watershed is approximately 52.8 square miles. The watershed includes a portion of the municipality of Ashland, as well as a portion of Three Creeks Conservation Area. Bonne Femme Creek is a 14.8 mi (23.8 km) tributary to the Missouri River. The entire approximately 7.8 mi (12.6 km) lower reach of Bonne Femme Creek (WBID 750) is listed as impaired due to exceedances of the state's *E. coli* water quality criteria for the protection of Whole Body Contact Recreation Category A. Approximately 7.0 mi (11.3 km) of the upper reach of Bonne Femme Creek (WBID 753) is listed as impaired due to exceedances of the state's *E. coli* water quality criteria for the protection of Whole Body Contact Recreation Category B. Turkey Creek is a 6.3 mi (10.1 km) tributary to Bonne Femme Creek. The entire reach of Turkey Creek (WBID 751) is listed as impaired due to exceedances of the state's *E. coli* water quality criteria for the protection of Whole Body Contact Recreation Category A. Bass Creek is a 4.4 mi (7.0 km) tributary to Bonne Femme Creek. The entire reach of Bass Creek (WBID 752) is listed as impaired due to exceedances of the state's *E. coli* water quality criteria for the protection of Whole Body Contact Recreation Category A. There are no permitted CAFOs in the Bonne Femme Creek watershed; there is one general land application permit and one minor municipal permit, which surface irrigates. For these reasons, point sources are not expected to contribute bacteria loading above negligible concentrations and no pollutant reductions from point sources are necessary to achieve the specified loading targets.

Table 9. Land Cover in the Bonne Femme Creek Watershed

Land Cover Type	Area acre (hectare)	Area mi^2 (km^2)	Percent (%)
Developed, High Intensity	50.36 (20)	0.08 (0.20)	0.15
Developed, Medium Intensity	247.94 (100)	0.39 (1.00)	0.73
Developed, Low Intensity	529.82 (214)	0.83 (2.14)	1.57
Developed, Open Space	1331.79 (539)	2.08 (5.39)	3.94
Barren Land	18.91 (8)	0.03 (0.08)	0.06
Cultivated Crops	5,807 (2,350)	9.07 (23.50)	17.17
Hay/Pasture	11,344.05 (4591)	17.73 (45.91)	33.54
Deciduous Forest	13,004.93 (5,263)	20.32 (52.63)	38.46
Evergreen Forest	401.80 (163)	0.63 (1.63)	1.19
Mixed Forest	227.04 (92)	0.35 (0.92)	0.67
Shrub/Scrub	96.32 (39)	0.15 (0.39)	0.28
Herbaceous	357.88 (154)	0.56 (1.45)	1.06
Woody Wetlands	271.08 (110)	0.42 (1.10)	0.80
Emergent Herbaceous Wetlands	16.44 (7)	0.03 (0.07)	0.05
Open Water	113.12 (46)	0.18 (0.46)	0.33
Totals =	33,818.56 (13,687)	52.84 (136.86)	100.00

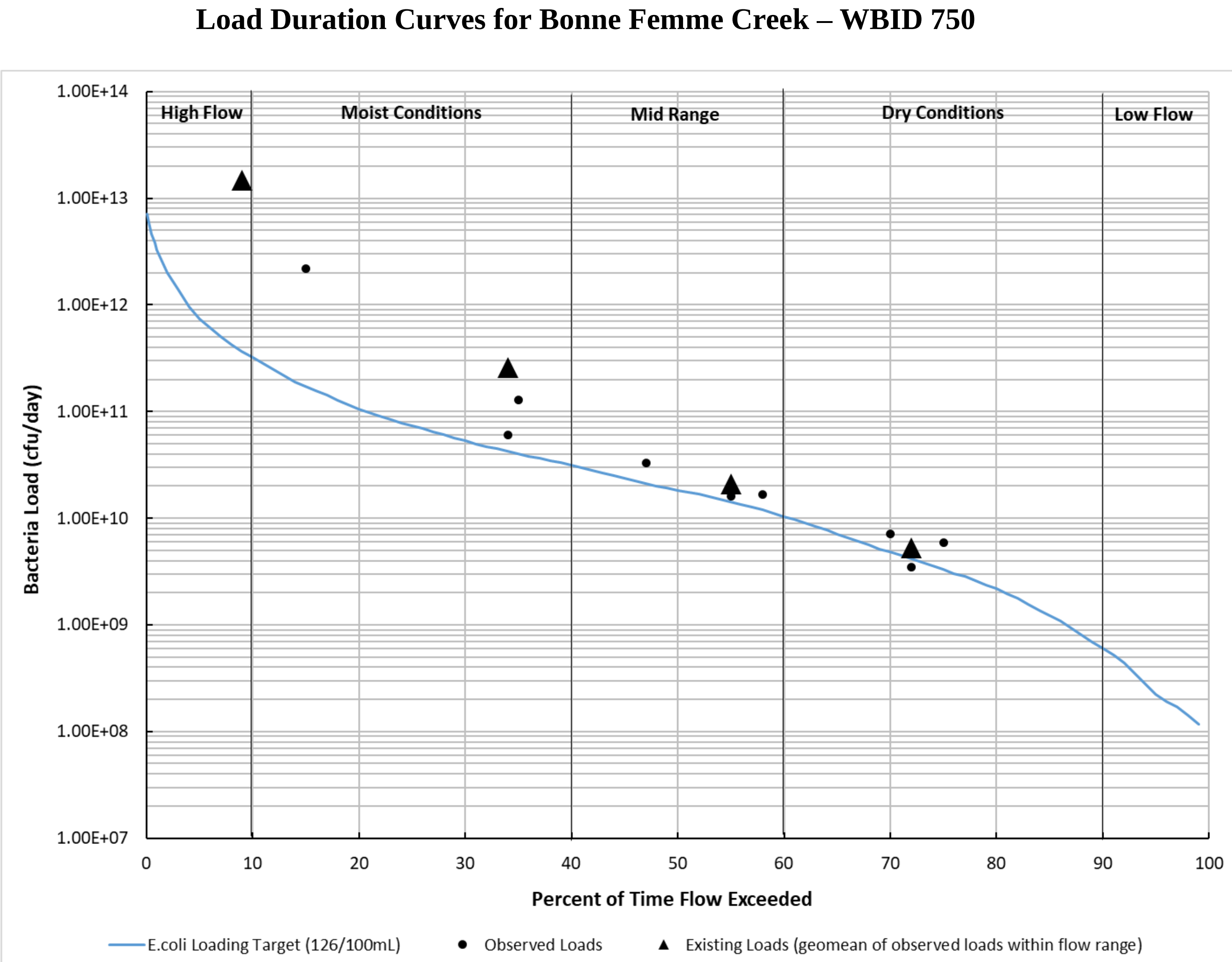

Figure 8. E. coli load duration curve for Bonne Femme Creek – WBID 750.

Table 10. Loads at specific flow conditions for Bonne Femme Creek – WBID 750.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (cfu/day)	Existing Load (cfu/day)	Percent Reductions to meet WQ Targets
95	Low Flow	0.03	2.22E+08	No data	No data
72	Dry Conditions	1.12	4.14E+09	5.29E+09	21.75%
55	Mid Range	4.32	1.42E+10	2.08E+10	31.79%
34	Moist Conditions	13.19	4.24E+10	2.57E+11	83.51%
9	High Flow	121.22	3.65E+11	1.49E+13	97.55%

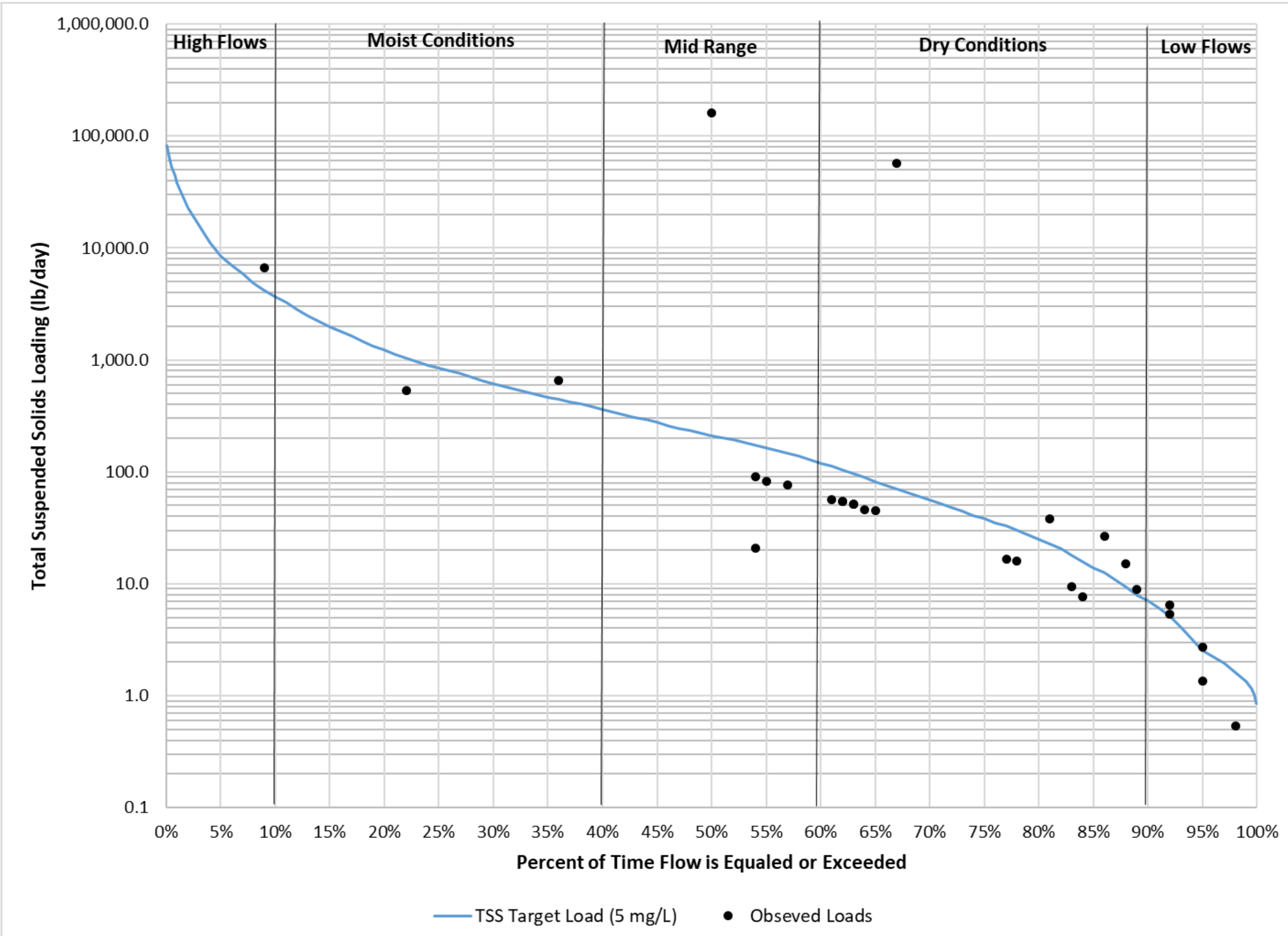

Figure 9. TSS load duration curve for Bonne Femme Creek – WBID 750.

Table 11. TSS loads at specific flow conditions for Bonne Femme Creek – WBID 750.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (lbs/day)	Existing Load (lbs/day)	% Needed Reduction
92%	Low Flow	0.19	0.31	6.47	95.15%
67%	Dry Conditions	2.62	4.37	56,939.06	99.99%
50%	Mid Range	7.80	13.04	162,132.85	99.99%
36%	Moist Conditions	16.41	27.43	650.19	95.78%
9%	High Flow	156.43	261.58	6,607.65	96.04%

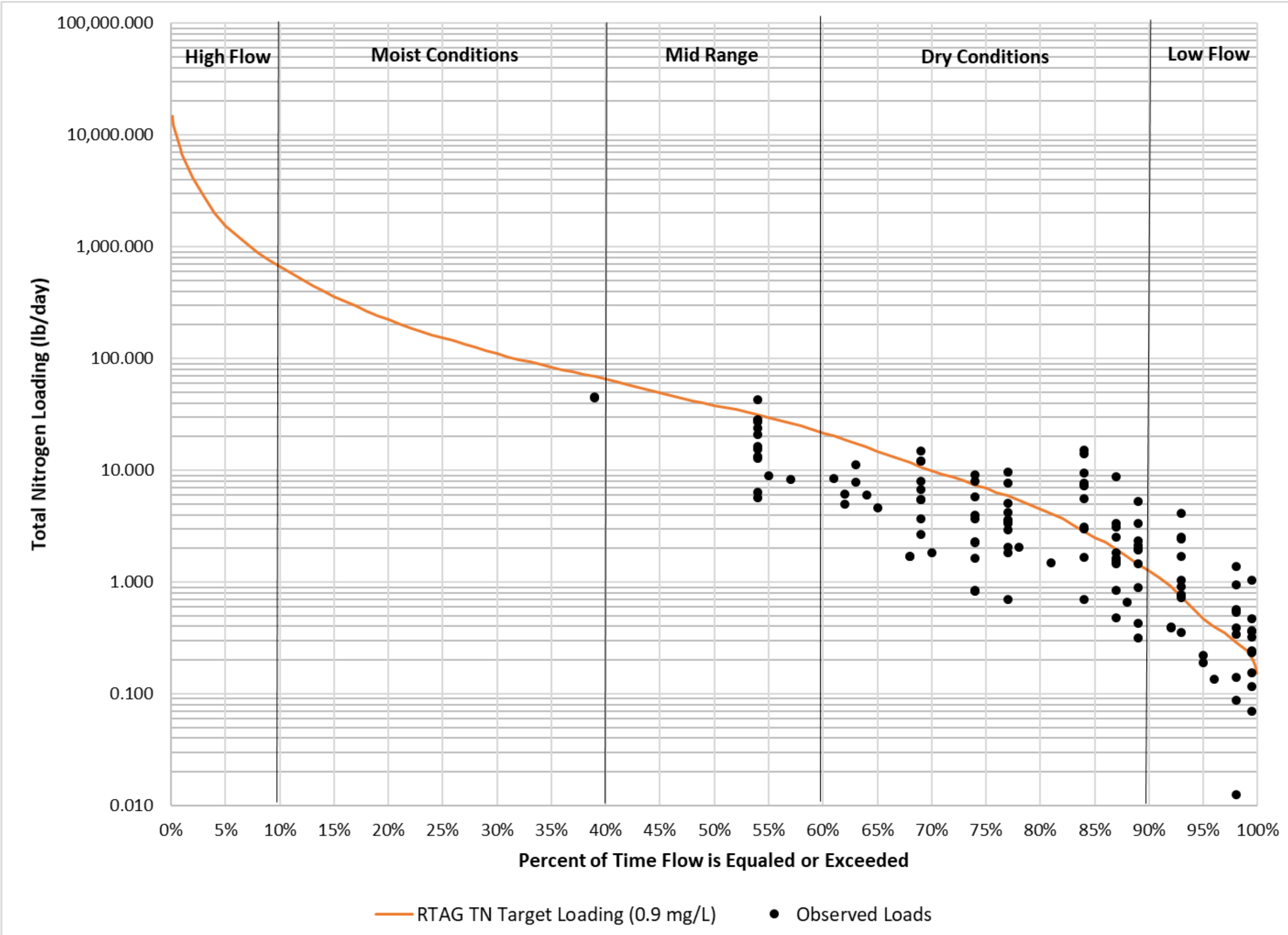

Figure 10. Total nitrogen (TN) load duration curve for Bonne Femme Creek – WBID 750.

Table 12. TN loads at specific flow conditionss for Bonne Femme Creek – WBID 750.*

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (lbs/day)	Existing Load (cfu/day)	Percent Reductions to meet WQ Targets
93%	Low Flow	0.15	0.74	4.14	82%
84%	Dry Conditions	0.58	2.83	15.13	81%
54%	Mid Range	6.43	31.24	42.64	27%
39%	Moist Conditions	14.13	68.61	45.36	0%

** No data at high flows to calculate existing loads or needed reductions*

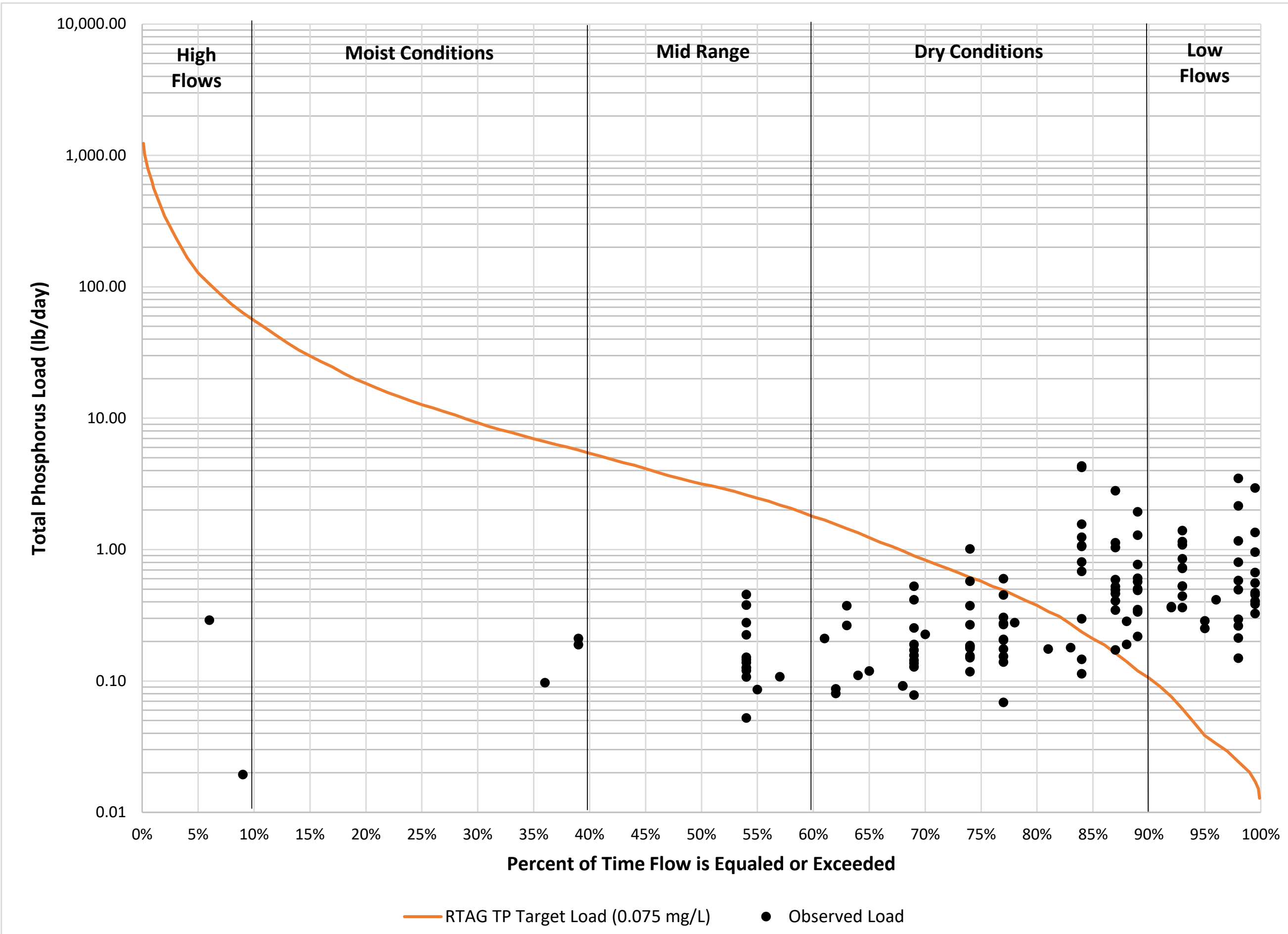

Figure 11. Total phosphorus (TP) load duration curve for Bonne Femme Creek – WBID 750.

Table 13. TP loads at specific flow conditions for Bonne Femme Creek – WBID 750.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (lbs/day)	Existing Load (lbs/day)	Percent Reductions to meet WQ Targets
98%	Low Flow	0.06	0.02	3.49	99.30%
84%	Dry Conditions	0.58	0.24	4.34	94.57%
54%	Mid Range	6.43	2.60	0.46	0.00%
39%	Moist Conditions	14.13	5.72	0.21	0.00%
6%	High Flow	260.49	105.38	0.29	0.00%

Load Duration Curves for Turkey Creek – WBID 751

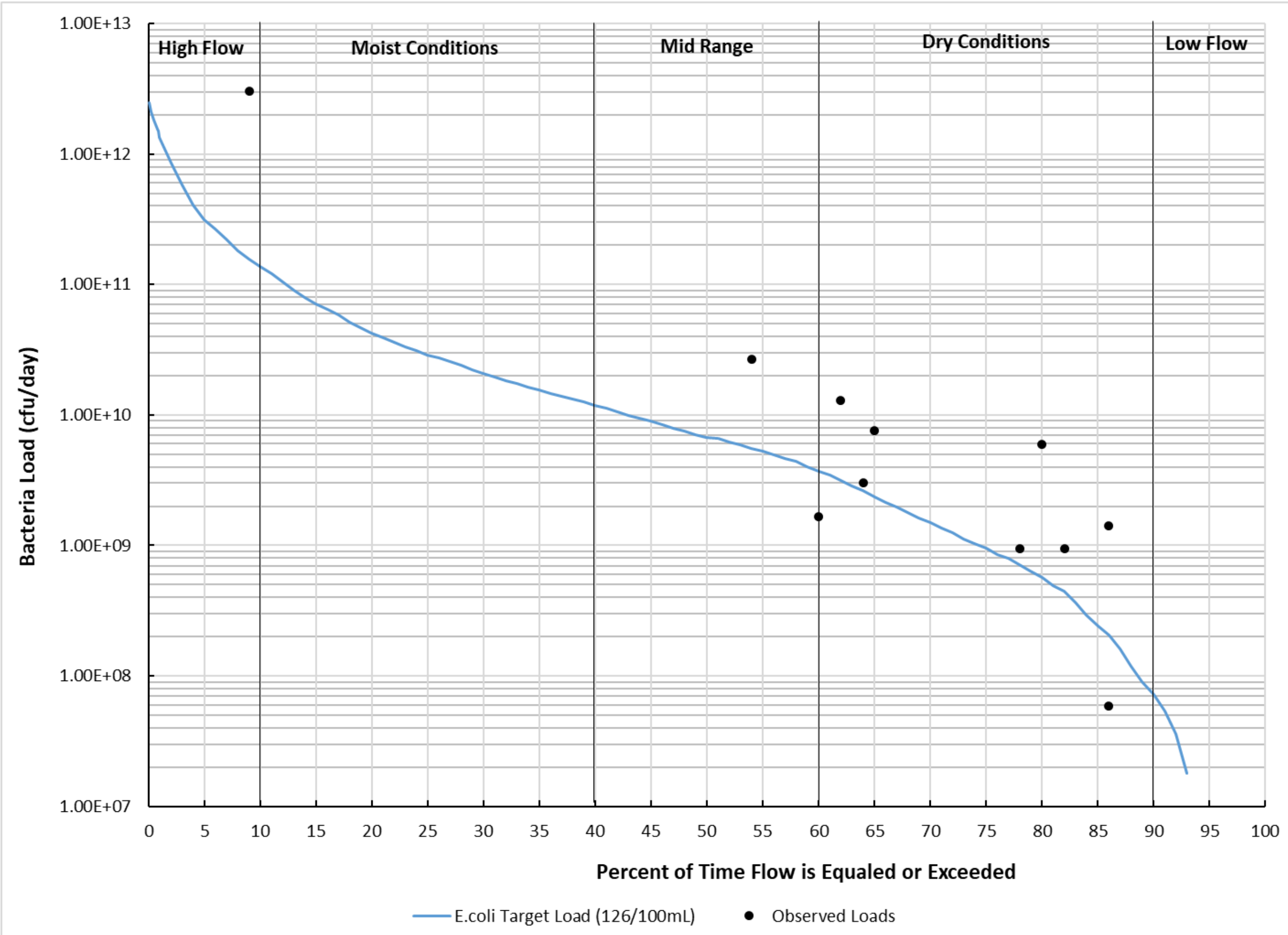

Figure 12. E. coli load duration curve for Turkey Creek – WBID 751.

Table 14. E. coli loads at specific flow conditions for Turkey Creek– WBID 751.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (cfu/day)	Existing Load (cfu/day)	Percent Reductions to meet WQ Targets
95	Low Flow	0.01	0.00E+00	No data	No data
79	Dry Conditions	0.25	6.35E+08	1.84E+09	65.50%
57	Mid Range	1.57	4.61E+09	6.66E+09	30.74%
25	Moist Conditions	9.53	2.89E+10	No data	No data
5	High Flow	99.98	3.12E+11	3.03E+12	89.70%

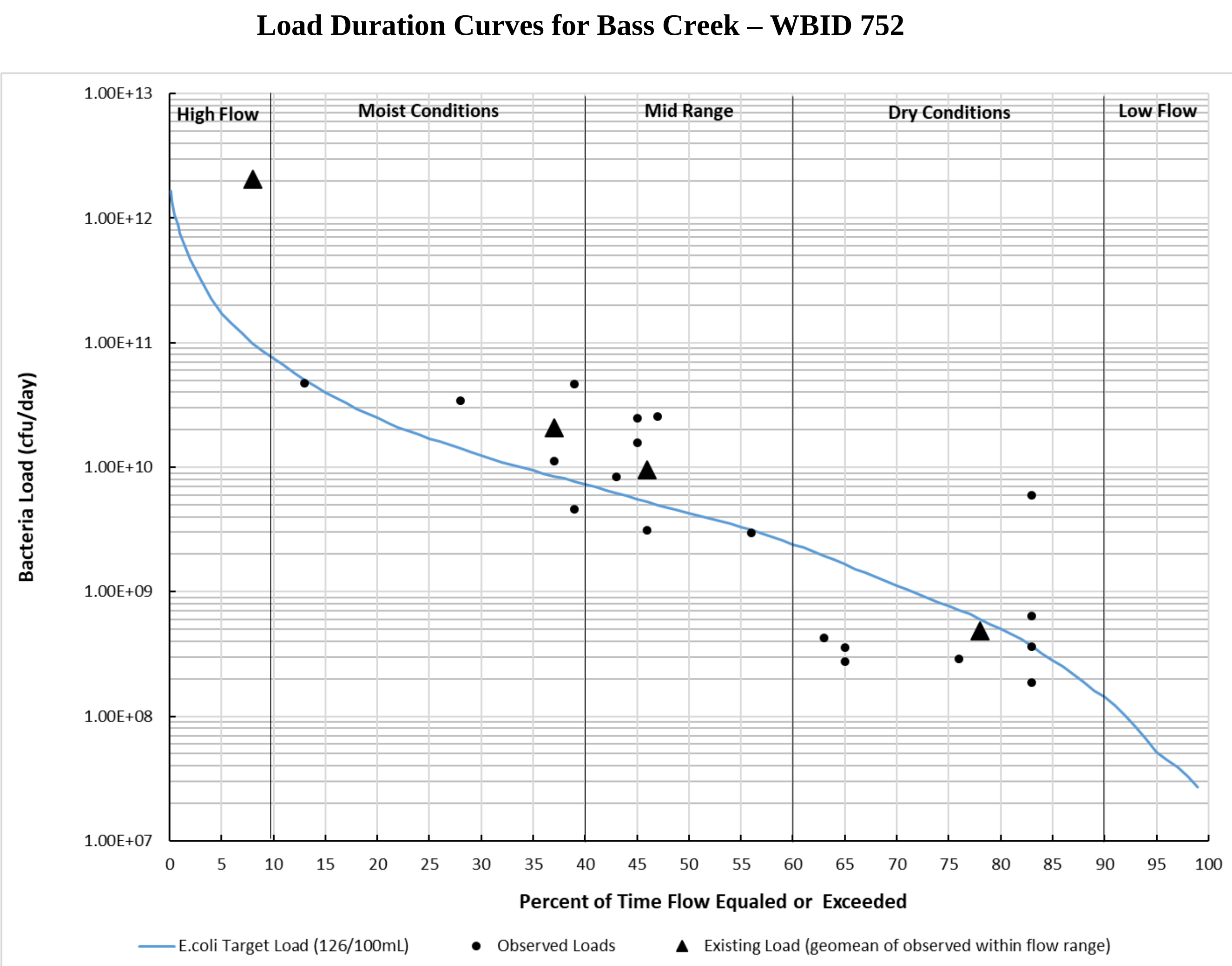

Figure 13. E. coli load duration curve for Bass Creek – WBID 752.

Table 15. E. coli loads at specific flow conditions for Bass Creek – WBID 752.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (cfu/day)	Existing Load (cfu/day)	Percent Reductions to meet WQ Targets
95	Low Flow	0.01	5.17E+07	No data	No data
78	Dry Conditions	0.16	6.04E+08	4.85E+08	0.00%
46	Mid Range	1.60	5.24E+09	9.58E+09	45.31%
37	Moist Conditions	2.62	8.47E+09	2.08E+10	59.23%
8	High Flow	32.87	9.90E+10	2.06E+12	95.19%

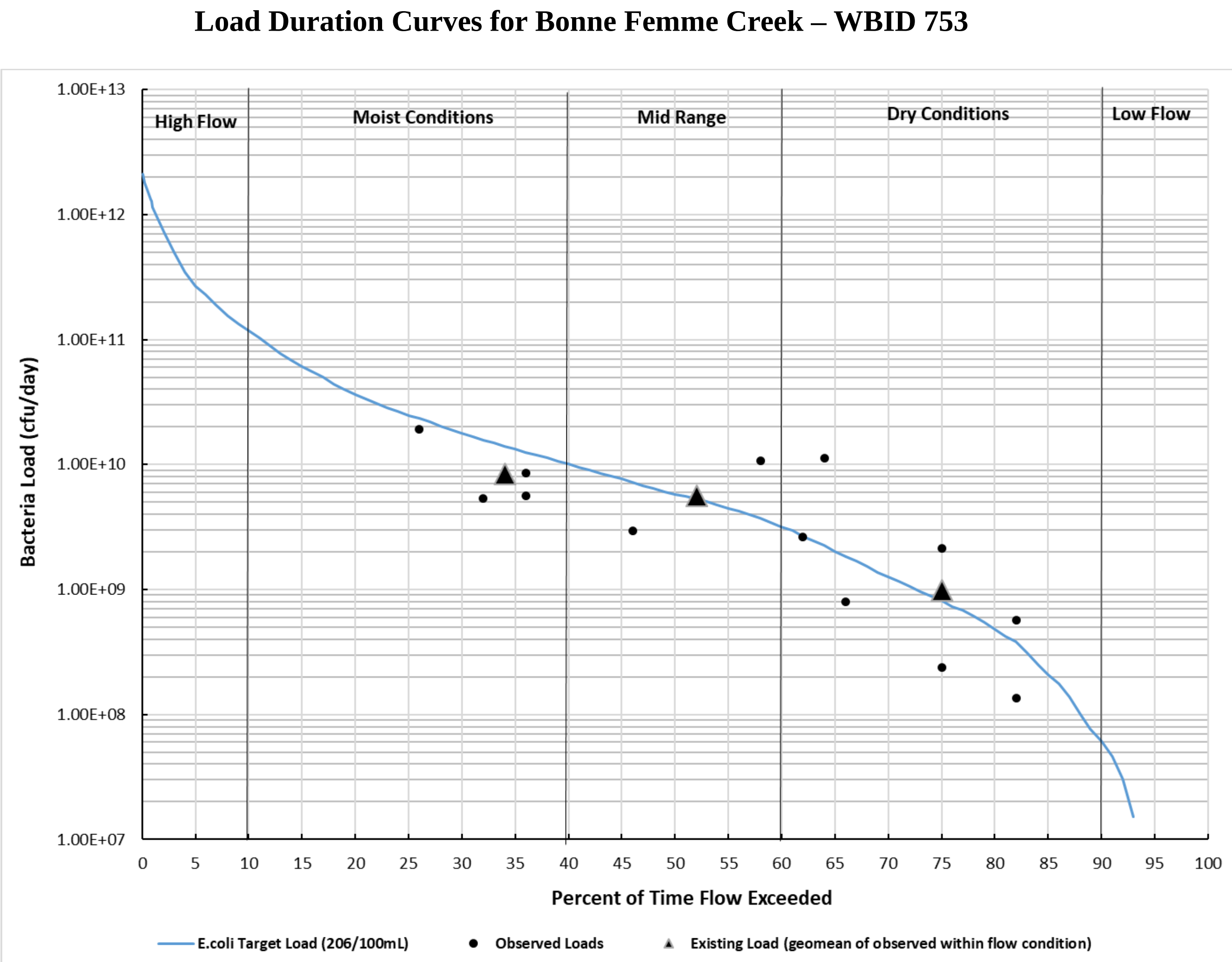

Figure 14. E. coli load duration curve for Bonne Femme Creek – WBID 753.

Table 16. E. coli loads at specific flow conditions for Bonne Femme Creek – WBID 753.

Percent of time flow met or exceeded	Flow Condition	Flow (cfs)	Loading Capacity (cfu/day)	Existing Load (cfu/day)	Percent Reductions to meet WQ Targets
95	Low Flow	0.01	3.13E+07	No data	No data
75	Dry Conditions	0.19	9.59E+08	9.89E+08	2.97%
52	Mid Range	1.10	5.56E+09	5.60E+09	0.73%
34	Moist Conditions	2.84	1.43E+10	8.38E+09	0.00%
5	High Flow	52.28	2.64E+11	No data	No data

Appendix A
12-digit Subwatershed Maps of Critical Areas for Nonpoint Source BMP Implementation

The map on the following page presents critical areas associated with agricultural land uses in the 12-digit hydrologic unit code (HUC) subwatersheds within the Little Bonne Femme and Bonne Femme watersheds. These areas were broadly determined based on available land cover and soils data. The critical areas presented here should be supplemented with local knowledge of the watershed in order to select and appropriately site BMPs.

Figure A.1.	12-digit HUC 103001020903	Little Bonne Femme	41.1 mi^2 (66 km^2)
	12-digit HUC 103001020902	Bonne Femme	52.8 mi^2 (85 km^2)

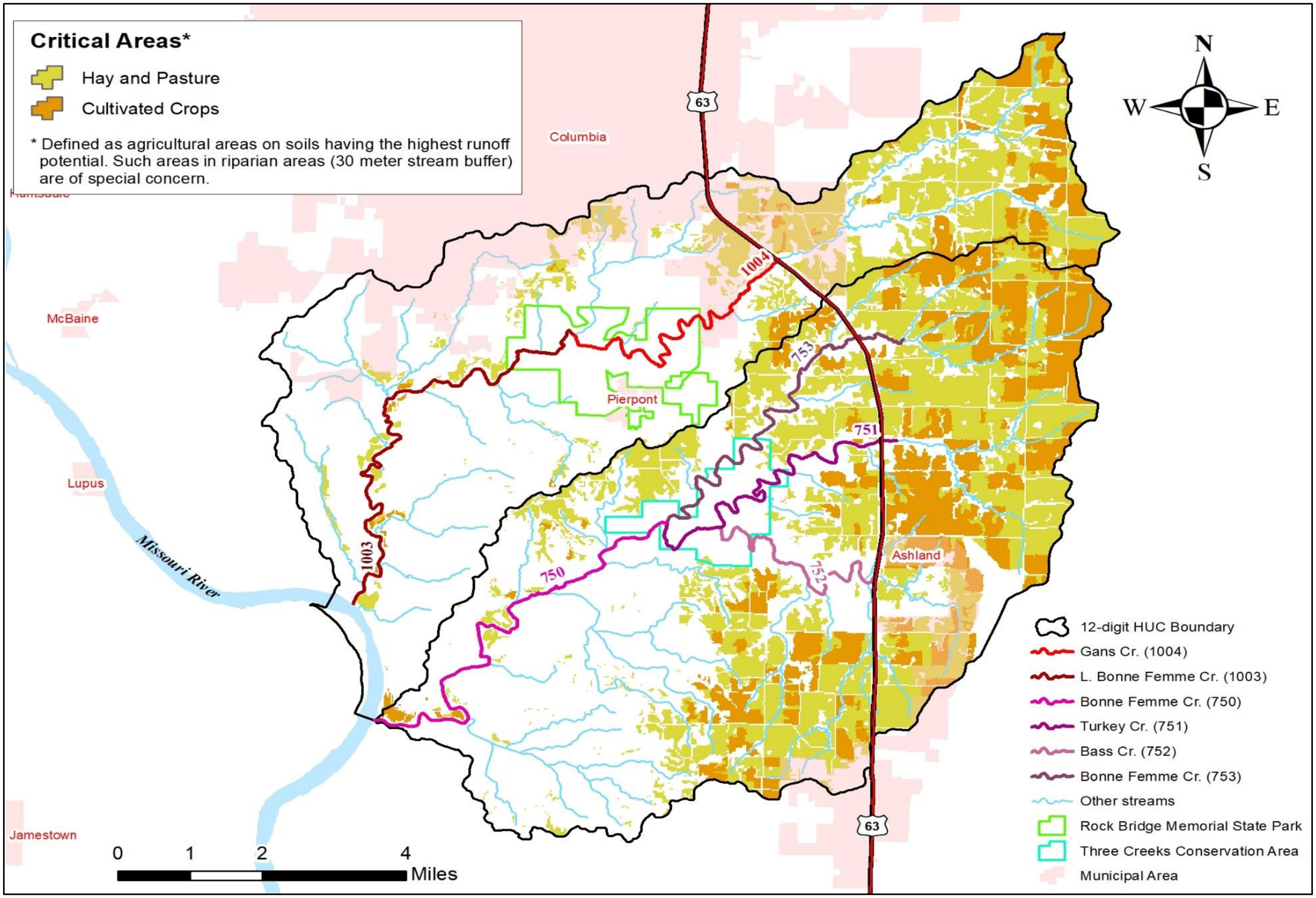

Figure A-1. Bonne Femme Creek (HUC 103001020902) and Little Bonne Femme Creek (HUC 103001020903) critical areas.

Appendix B – E. coli Data

Site	Date	E. coli (cfu/100mL)
1003/2.4	7/18/2013	35.5
1003/2.4	8/8/2013	62.0
1003/2.4	8/28/2013	1.0
1003/2.4	8/28/2013	9.8
1003/2.4	9/18/2013	83.3
1003/2.4	10/9/2013	23.8
1003/2.4	10/9/2013	1.0
1003/2.4	4/2/2014	1,011.2
1003/2.4	4/22/2014	461.1
1003/2.4	5/14/2014	2,419.6
1003/2.4	6/3/2014	26.9
1003/2.4	7/14/2014	84.5
1003/2.4	8/6/2014	6.3
1003/2.4	8/21/2014	25.9
1003/2.4	9/16/2014	93.3
1003/2.4	10/6/2014	648.8
1003/2.4	4/6/2015	488.4
1003/2.4	4/22/2015	365.4
1003/2.4	5/12/2015	133.3
1003/2.4	5/12/2015	150.0
1003/2.4	6/2/2015	866.4
1003/2.4	6/22/2015	387.3
1003/2.4	7/14/2015	209.8
1003/2.4	8/4/2015	93.4
1003/2.4	8/24/2015	1,553.1
1003/2.4	9/15/2015	128.1
1003/2.4	10/6/2015	178.5
1003/2.4	4/4/2016	67.0
1003/2.4	4/25/2016	84.2
1003/2.4	5/18/2016	770.1
1003/2.4	6/28/2016	63.8
1003/2.4	7/12/2016	980.4
1003/2.4	8/2/2016	1,553.1
1003/2.4	8/2/2016	1,986.3
1003/2.4	8/22/2016	34.1
1003/2.4	9/12/2016	365.4

Site	Date	E. coli (cfu/100mL)
1003/2.4	10/3/2016	64.4
1003/2.4	4/6/2017	1,986.3
1003/2.4	4/27/2017	2,419.6
1003/2.4	5/15/2017	84.5
1003/2.4	6/6/2017	151.5
1003/2.4	6/27/2017	184.2
1003/2.4	6/27/2017	1.0
1003/2.4	7/11/2017	120.1
1003/2.4	8/2/2017	27.9
1003/2.4	8/24/2017	325.5
1003/2.4	9/14/2017	45.9
1003/2.4	9/14/2017	1.0
1003/2.4	10/2/2017	20.3
1003/2.4	4/4/2018	50.4
1003/2.4	4/24/2018	4.1
1003/2.4	5/16/2018	78.5
1003/2.4	6/5/2018	88.4
1003/2.4	6/25/2018	45.0
1003/2.4	7/10/2018	39.5
1003/2.4	8/2/2018	64.4
1003/2.4	8/21/2018	37.3
1003/2.4	9/10/2018	14.6
1003/2.4	9/10/2018	1.0
1003/2.4	10/2/2018	159.7
1004/0.4	7/18/2013	24.1
1004/0.4	7/18/2013	36.4
1004/0.4	8/8/2013	141.4
1004/0.4	4/2/2014	2,419.6
1004/0.4	4/22/2014	62.7
1004/0.4	5/14/2014	1,732.9
1004/0.4	6/3/2014	25.6
1004/0.4	6/26/2014	167.0
1004/0.4	7/14/2014	613.1
1004/0.4	8/21/2014	2,419.6
1004/0.4	9/16/2014	248.9
1004/0.4	10/6/2014	613.1
1004/0.4	4/6/2015	95.9
1004/0.4	4/22/2015	410.6
1004/0.4	5/12/2015	1.0
1004/0.4	5/12/2015	107.1

Site	Date	E. coli (cfu/100mL)
1004/0.4	6/2/2015	70.3
1004/0.4	6/22/2015	131.7
1004/0.4	7/14/2015	125.9
1004/0.4	8/4/2015	90.8
1004/0.4	8/4/2015	75.4
1004/0.4	8/24/2015	770.1
1004/0.4	4/4/2016	51.2
1004/0.4	4/25/2016	81.6
1004/0.4	5/18/2016	2,419.6
750/4.2	9/2/2009	121.0
750/4.2	10/7/2009	261.0
750/4.2	4/7/2010	4,839.0
750/4.2	5/5/2010	185.0
750/4.2	6/2/2010	1,553.0
750/4.2	8/4/2010	201.4
750/4.2	9/8/2010	206.4
750/4.2	4/6/2011	410.6
750/4.2	5/12/2011	185.0
750/4.2	6/9/2011	146.7
751/3.3	4/3/2014	2,419.6
751/3.3	4/15/2014	91.1
751/3.3	5/12/2014	1,119.9
751/3.3	6/4/2014	2,419.6
751/3.3	6/25/2014	461.1
751/3.3	4/22/2015	344.8
751/3.3	5/12/2015	24.1
751/3.3	6/3/2015	52.0
751/3.3	6/23/2015	127.4
751/3.3	7/15/2015	193.5
751/3.3	8/5/2015	579.4
751/3.3	8/24/2015	547.5
751/3.3	4/7/2016	129.1
751/3.3	5/19/2016	980.4
752/0.2	4/3/2014	2,419.6
752/0.2	4/15/2014	172.3
752/0.2	5/12/2014	75.4
752/0.2	6/4/2014	2,419.6
752/0.2	6/25/2014	178.5
752/0.2	8/7/2014	2,419.6
752/0.2	9/18/2014	148.3

Site	Date	E. coli (cfu/100mL)
752/0.2	10/6/2014	203.5
752/0.2	4/6/2015	103.9
752/0.2	4/22/2015	307.6
752/0.2	5/12/2015	29.2
752/0.2	6/3/2015	74.9
752/0.2	6/23/2015	770.1
752/0.2	7/15/2015	122.3
752/0.2	8/5/2015	59.4
752/0.2	8/24/2015	365.4
752/0.2	8/24/2015	579.4
752/0.2	9/15/2015	1.0
752/0.2	4/7/2016	28.8
752/0.2	4/25/2016	23.3
752/0.2	5/19/2016	686.7
752/0.2	6/8/2016	75.9
752/0.2	6/29/2016	261.3
753/0.2	6/3/2015	547.5
753/0.2	6/23/2015	79.8
753/0.2	7/15/2015	55.6
753/0.2	8/5/2015	231.0
753/0.2	8/24/2015	920.8
753/0.2	4/8/2016	81.6
753/0.2	4/8/2016	68.9
753/0.2	4/25/2016	86.2
753/0.2	4/25/2016	131.7
753/0.2	5/19/2016	162.4
753/0.2	5/19/2016	48.8
753/0.2	6/8/2016	178.5
753/0.2	6/29/2016	435.2
753/0.2	9/12/2016	1.0

Appendix C – Nutrient and Sediment Data

Site Code	Date (mo/day/year)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Total suspended solids (mg/L)
1004/0.1/0.4	5/15/1999	0.22	1.73	
1004/0.1/0.4	5/19/1999	0.22	3.94	
1004/0.1/0.4	7/26/1999	0.1	1.69	
1004/0.1/0.4	8/11/1999	0.09	1.72	
1004/0.1/0.4	8/27/1999	0.09	1.77	
1004/0.1/0.4	2/25/2000	0.88	4.09	
1004/0.1/0.4	2/25/2000			
1004/0.1/0.4	2/26/2000			
1004/0.1/0.4	2/26/2000	0.34	3.22	
1004/0.1/0.4	2/26/2000	0.42	3.69	
1004/0.1/0.4	7/14/2000	0.14	1.35	
1004/0.1/0.4	8/7/2000	0.28	1.87	
1004/0.1/0.4	8/7/2000	0.26	1.62	
1004/0.1/0.4	8/7/2000	0.26	1.62	
1004/0.1/0.4	8/7/2000	0.33	1.77	
1004/0.1/0.4	8/7/2000	1.12	3.19	
1004/0.1/0.4	8/8/2000	1.27	2.67	
1004/0.1/0.4	8/8/2000	0.46	1.29	
1004/0.1/0.4	8/8/2000	0.44	1.17	
1004/0.1/0.4	8/9/2000	0.16	0.84	
1004/0.1/0.4	1/28/2001	0.2	2.57	
1004/0.1/0.4	1/28/2001	0.21	2.47	
1004/0.1/0.4	1/29/2001	0.95	1.92	
1004/0.1/0.4	1/29/2001	0.7	1.65	
1004/0.1/0.4	1/29/2001	0.64	1.51	
1004/0.1/0.4	1/29/2001	0.34	1.39	
1004/0.1/0.4	1/29/2001	0.74	1.58	
1004/0.1/0.4	1/29/2001	0.48	1.36	
1004/0.1/0.4	1/30/2001	0.36	1.74	
1004/0.1/0.4	1/30/2001	0.33	1.93	
1004/0.1/0.4	6/3/2001	0.2	3.85	
1004/0.1/0.4	6/3/2001	0.19	2.11	
1004/0.1/0.4	6/3/2001	0.57	2.58	
1004/0.1/0.4	6/4/2001	0.38	1.38	
1004/0.1/0.4	6/4/2001	0.25	1.83	
1004/0.1/0.4	6/4/2001	0.22	1.56	
1004/0.1/0.4	6/6/2001	0.4	1.47	
1004/0.1/0.4	6/6/2001	0.22	1.14	

Site Code	Date (mo/day/year)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Total suspended solids (mg/L)
1004/0.1/0.4	6/6/2001	0.16	1.76	
1004/0.1/0.4	6/15/2001	0.11	1.21	
1004/0.1/0.4	6/22/2001	0.1	1.15	
1004/0.1/0.4	6/29/2001	0.12	1.53	
1004/0.1/0.4	3/6/2002	0.21	1.48	
1004/0.1/0.4	3/6/2002	0.14	1.45	
1004/0.1/0.4	3/7/2002	0.23	1.82	
1004/0.1/0.4	3/12/2002	0.22	1.49	
1004/0.1/0.4	3/13/2002	0.16	1.56	
1004/0.1/0.4	5/12/2010	0.2	1.04	151
1004/0.5	4/1/2004	0.1	0.7	
750/5.8	9/24/2001		0.47	
750/5.8	3/21/2002		0.12	
750/5.8	9/24/2003	0.130	0.77	
750/5.8	4/2/2004	0.090	0.57	
750/5.8	10/12/2012		0.36	19
750/5.8	3/19/2013	0.050	0.78	<5
750/5.8	4/1/2014		0.33	<5
750/5.8	10/8/2014	0.078	0.54	<5
750/5.8	4/1/2015	0.029	0.27	<5
750/5.8	4/1/2015	0.035	0.27	<5
750/5.8	10/1/2015	0.049	0.35	5
750/5.8	10/1/2015	0.056	0.41	<5
750/5.8	4/6/2016	0.024	0.28	<5
750/5.8	4/6/2016	0.026	0.23	<5
750/5.8	10/4/2016	0.066	0.31	<5
750/5.8	10/4/2016	0.066	0.32	<5
750/5.8	4/13/2017	0.064	0.37	<5
750/5.8	9/28/2017	0.073	0.36	5
750/5.8	9/28/2017	0.074	0.37	6
750/5.9	9/24/2001	0.060	0.32	
750/5.9	3/21/2002		0.12	
750/5.9	9/24/2003	0.130	0.8	
750/5.9	4/2/2004	0.100	0.58	
750/5.9	7/28/2004	0.040	0.26	7
750/5.9	12/15/2004	0.050	0.57	7
750/5.9	5/11/2005	0.040	0.29	7
750/5.9	10/17/2005	0.050	0.34	12
750/5.9	12/13/2005	0.040	0.22	<5
750/5.9	2/27/2006	0.040	0.31	8

Site Code	Date (mo/day/year)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Total suspended solids (mg/L)
750/5.9	4/3/2012	0.110	0.38	<5
750/6.1	4/1/2014		0.26	<5
751/0.7	9/24/2001	0.080	0.28	
751/0.7	3/21/2002	0.060	0.16	

Appendix J: WBP Implementation Budget Summary and Cost Estimate Calculations

Greater Bonne Femme Watershed-based Plan Budget Summary

High-end values are used on cost ranges from breakdown worksheets to be conservative.

Implementation Cost Category	Phase 1 Years 1-7	Phase 2 Years 8-14	Phase 3 Years 15-21	Total Estimated Cost
Watershed-wide BMP Installation	$121,517.00	$121,517.00	$121,517.00	$364,551.00
Cover Crops Pilot Subwatershed 42	$14,700.00	$29,400.00	$44,100.00	$88,200.00
Demonstration Project	$30,000.00			$30,000.00
Information and Outreach	$119,950.00	$204,950.00	$89,950.00	$414,850.00
Septic Pump-out Program	$6,000.00	$6,000.00	$6,000.00	$18,000.00
Monitoring	$68,296.20	$68,296.20	$68,296.20	$204,888.60
Administrative	$28,000.00	$28,000.00	$28,000.00	$84,000.00
Total Estimated Cost	**$535,463.20**	**$752,163.20**	**$798,863.20**	**$2,086,489.60**

Urban BMP	Area	Cost	Total
Bioretention Basin	7.3 acres (317998 sq ft)	$14.68/sq ft	$4,668,064.00
Detention Pond	4.4 acres (191664 sq ft)	Variable**	Variable**

**According to the EPA, typical costs for wet detention ponds range from $17.50-$35.00 per cubic meter ($0.50-$1.00 per cubic foot) of storage area. Dry detention basins typically cost around $10 per square meter ($0.30 per cubic foot) for smaller basins and $5 per square meter ($0.15 per cubic foot) for larger basins. However, the total cost for a pond or detention basin needs to include allowances for permitting, design and construction, and maintenance costs. Permitting costs may vary depending on state and local regulations.

Cost Calculations for Practices Supported by Boone County Soil and Water Conservation District (SWCD)

BMP Type	BMP Recommended in Geosyntec Report	Corresponding SWCD Practice Name*	Units for Cost Calculation	State Average Cost Estimate**	Cost-Share Payment Rate***
Cropland	Field Border (replace vegetated buffer)	N386 Field Border (+ $500/ac for 10-year renewal)	Acre	$557.20	$1,017.90
	Retention pond (WASCOB)	DWP-01 Sediment Retention, Erosion, or Water Control Structure	Past Contracts Project Avg	$10,878.61	$8,158.96
Pastureland	Grazing Management	Extremely variable across species, system size, and components - going with max / acre			
	Permanent Fencing	DSP 3.3 Grazing System Fence - Dependent on Species	Acre		$70.00 Maximum per Acre
	Water Development (not often needed as water source already present)	DSP 3.1 Grazing System Water Development	Acre		$110.00 Maximum per Acre
	Water Distribution	DSP 3.2 Grazing System Water Distribution	Acre		$120.00 Maximum per Acre
	WQ 10 (replace livestock exclusion)	WQ10 Stream Protection****	Acre	$200.00	$750.00
	N393 Vegetative filter strip (only appropriate adjacent to streams)	N393 Filter Strip	Acre	$557.20	$1,417.90
	N472 Livestock Exclusion (replace fencing)	N472 Livestock Exclusion - Dependent on Species (will go with max here)	Feet of Fence	$1.10-$1.79/foot (electric)	$0.82-$1.34/foot (electric)
Streambank	Streambank buffer (must be adjacent to agricultural land)	N393 Filter Strip (a riparian buffer, vegetative buffer or reinforcing the existing tree line)	Acre	$557.20	$1,417.90
	Vegetated buffer with trees (must be adjacent to agricultural land)	N391 Riparian Forest Buffer (NRCS practice)	Acre	$1,914.01	$2,635.51
Urban	Bioretention	urban practice	cost-share funding not available - will work with municipal partners		
	Detention pond	urban practice	cost-share funding not available - will work with municipal partners		
	Maintain existing BMPs in accordace with the SWPPP	landowner responsibility	landowner responsibility		

* Boone County staff worked with Boone County Soil and Water Conservation District staff to determine which SWCD practice most closely corresponded to practices recommended by Geosyntec in their modeling report

** State Average Cost Estimate is based on SWCD receipts collected from cooperators the year prior for all practices, and actual costs are averaged to come up with the Average, and SWCD payments to cooperators are based off of those. New State Average Costs are calculated annually by DNR-SWCP.

*** Cost-share payment rate is determined periodically for certain practices funded by SWCD.

****Includes fencing, water distribution, Out of Production Incentive, etc.

A description of eligible Missouri Soil and Water Conservation Program cost-share practices can be found here: https://mosoilandwater.land/sites/mosoilandwater/files/internal-07-V-eligible-practices.pdf.

Cost Estimate Calculation for Primary BMP Recommendations from Geosyntec

All costs are taken from the BCSWCD costs tab for the practice numbers noted.

WBID	BMP Recommendation from Geosyntec	Applicable BCWCD Practice	Applicable Location	Area (Acres) or Length (ft) of BMP (Geosyntec)	Units (Geosyntec)	Unit Conversion (to acres of practice)*	Cost-share Payment Rate	Cost per Unit	Cost / Cost Range
8	Livestock exclusion/Alternative source of water	WQ10 Stream Protection****	Pasture	3341.7	ft	2.3	$750.00		$1,725.00
36	Fencing	N472 Livestock Exclusion*****	Pasture	5073.2	ft		$0.82-$1.34/foot (electric)		$4160.02-$6798.09
73	Vegetated Buffer	N386 Field Border (+ $500/ac for 10-year renewal)***	Streambank	747.5	ft	0.51	$1017.90 + $500/ac for 10-year renewal		$1,029.13
75	Streambank Buffer	N393 Filter Strip / N391 Riparian Forest Buffer	Streambank	118.2	ft	0.08	$1417.90-$2635.51		$113.43-$210.84
98	Streambank Buffer	N393 Filter Strip / N391 Riparian Forest Buffer	Streambank	2664.4	ft	1.83	$1417.90-$2635.51		$2594.76-$4822.98
132	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species DSP 3.1 Grazing System Water Development** DSP 3.2 Grazing System Water Distribution	Pasture	86.3	ac		$70.00 Maximum per Acre $110.00 Maximum per Acre $120.00 Maximum per Acre	$300.00	$25,890.00
139	Fencing	N472 Livestock Exclusion*****	Pasture	7537.6	ft		$0.82-$1.34/foot (electric)		$6180.83-$10100.38
140	Vegetated Buffer	N386 Field Border (+ $500/ac for 10-year renewal)***	Cropland	1.2	ac		$1017.90 + $500/ac for 10-year renewal		$2,421.48
141	Vegetated Buffer with Trees	N391 Riparian Forest Buffer	Streambank	4177.5	ft	2.88	$2,635.51		$7,590.27
143	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species DSP 3.1 Grazing System Water Development** DSP 3.2 Grazing System Water Distribution	Pasture	27.8	ac		$70.00 Maximum per Acre $110.00 Maximum per Acre $120.00 Maximum per Acre	$300.00	$8,340.00
144	Livestock exclusion/Alternative source of water	WQ10 Stream Protection****	Pasture	1356	ft	0.93	$750.00		$697.50
157	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species DSP 3.1 Grazing System Water Development** DSP 3.2 Grazing System Water Distribution	Pasture	34.6	ac		$70.00 Maximum per Acre $110.00 Maximum per Acre $120.00 Maximum per Acre	$300.00	$10,380.00
167	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species DSP 3.1 Grazing System Water Development** DSP 3.2 Grazing System Water Distribution	Pasture	7.6	ac		$70.00 Maximum per Acre $110.00 Maximum per Acre $120.00 Maximum per Acre	$300.00	$2,280.00
181	Vegetated Buffer	N386 Field Border (+ $500/ac for 10-year renewal)***	Cropland	12.7	ac		$1017.90 + $500/ac for 10-year renewal		$25,627.33
185	Vegetated Buffer	N386 Field Border (+ $500/ac for 10-year renewal)***	Cropland	1.9	ac		$1017.90 + $500/ac for 10-year renewal		$3,834.01
188	Vegetated Buffer	N386 Field Border (+ $500/ac for 10-year renewal)***	Cropland	14	ac		$1017.90 + $500/ac for 10-year renewal		$28,250.60
189	Vegetated Buffer	N386 Field Border (+ $500/ac for 10-year renewal)***	Cropland	1.6	ac		$1017.90 + $500/ac for 10-year renewal		$3,228.64
200	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species DSP 3.1 Grazing System Water Development** DSP 3.2 Grazing System Water Distribution	Pasture	14.8	ac		$70.00 Maximum per Acre $110.00 Maximum per Acre $120.00 Maximum per Acre	$300.00	$4,400.00
220	Vegetative Filter Strip	N393 Filter Strip	Pasture	9902.5	ft	6.8	$1,417.90		$9,641.72
226	Vegetative Filter Strip	N393 Filter Strip	Pasture	5305.9	ft	3.7	$1,417.90		$5,246.23
241	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species DSP 3.1 Grazing System Water Development** DSP 3.2 Grazing System Water Distribution	Pasture	51.2	ac		$70.00 Maximum per Acre $110.00 Maximum per Acre $120.00 Maximum per Acre	$300.00	$15,360.00
242	Vegetative Filter Strip	N393 Filter Strip	Pasture	8024.3	ft	5.5	$1,417.90		$7,798.45
243	Bioretention basin	urban practice - cost-share funding not available******	Urban	7.3	ac			$14.68/sq ft	
245	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species DSP 3.1 Grazing System Water Development** DSP 3.2 Grazing System Water Distribution	Pasture	26.4	ac		$70.00 Maximum per Acre $110.00 Maximum per Acre $120.00 Maximum per Acre	$300.00	$7,920.00

*where applicable: 30 foot width from Type 3 buffer, Boone County regulations, by # of feet
**water development may not be needed - included in cost estimate to be conservative
***included two 10-year renewal bonuses per acre for the 21 years of milestones
****includes fencing, water distribution, Out of Production Incentive, etc.
*****cost dependent on species
******will work with municipal partners for funding

Cost Range Low	$184,709.40	30% of Low Range	$55,412.82
Cost Range High	$193,592.65	30% of High Range	$58,077.80

A description of eligible Missouri Soil and Water Conservation Program cost-share practices can be found here: https://mosoilandwater.land/sites/mosoilandwater/files/internal-07-V-eligible-practices.pdf.

Cost Estimate Calculation for Alternative BMP Recommendations from Geosyntec

All costs are taken from the BCSWCD costs tab for the practice numbers noted.

WBID	BMP Recommendation from Geosyntec	Applicable BCSWCD Practice	Applicable Location	Area (Acres) or Length (ft) of BMP (Geosyntec)	Units (Geosyntec)	Unit Conversion (to acres of practice)*	Cost-share Payment Rate	Cost per Unit	Cost / Cost Range
8	Permanent vegetation establishment in riparian buffer	N393 Filter Strip / N391 Riparian Forest Buffer	Pasture	3341.7	ft	2.3	$1417.90-$2635.51		$3261.17-$6061.67
36	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species	Pasture	52	ac		$70.00 Maximum per Acre	$300.00	$15,600.00
		DSP 3.1 Grazing System Water Development**					$110.00 Maximum per Acre		
		DSP 3.2 Grazing System Water Distribution					$120.00 Maximum per Acre		
73	Streambank Buffer	N393 Filter Strip / N391 Riparian Forest Buffer	Streambank	747.5	ft	0.51	$1417.90-$2635.51		$723.13-$1344.11
75	Vegetated Buffer	N386 Field Border (+ $500/ac for 10-year renewal)***	Streambank	118.2	ft	0.08	$1017.90 + $500/ac for 10-year renewal		$161.43
98	Vegetated Buffer	N386 Field Border (+ $500/ac for 10-year renewal)***	Streambank	2664.4	ft	1.83	$1017.90 + $500/ac for 10-year renewal		$3,692.76
132	Fencing	N472 Livestock Exclusion*****	Pasture	4243.6	ft		$0.82-$1.34/foot (electric)		$3479.75-$5686.42
139	Grazing Management	DSP 3.3 Grazing System Fence - Dependent on Species	Pasture	146.3	ac		$70.00 Maximum per Acre	$300.00	$43,890.00
		DSP 3.1 Grazing System Water Development**					$110.00 Maximum per Acre		
		DSP 3.2 Grazing System Water Distribution					$120.00 Maximum per Acre		
140	Retention Pond	DWP-01 Sediment Retention, Erosion, or Water Control Structure	Cropland	9.2	ac treated	10 ac land / 1 ac pool	$18,000.00 / 1 ac pool - 1 pond	$18,000.00	$18,000.00
141	Streambank Buffer	N393 Filter Strip / N391 Riparian Forest Buffer	Streambank	4177.5	ft	2.88	$1417.90-$2635.51		$4083.55-$7590.27
143	Fencing	N472 Livestock Exclusion*****	Pasture	1983.2	ft		$0.82-$1.34/foot (electric)		$1626.22-$2657.49
144	Permanent vegetation establishment in riprarian buffer	N393 Filter Strip / N391 Riparian Forest Buffer	Streambank	1356	ft	0.93	$1417.90-$2635.51		$1318.65-$2451.02
157	Fencing	N472 Livestock Exclusion*****	Pasture	1672.2	ft		$0.82-$1.34/foot (electric)		$1371.20-$2240.75
167	Fencing	N472 Livestock Exclusion*****	Pasture	279.2	ft		$0.82-$1.34/foot (electric)		$228.94-$374.13
181	Maintain existing BMPs in accordance with the SWPP	Landowner responsibility	Cropland	20.4	ac				
185	Retention Pond	DWP-01 Sediment Retention, Erosion, or Water Control Structure	Cropland	14.5	ac treated	10 ac land / 1 ac pool	$18,000.00 / 1 ac pool - 2 ponds	$18,000.00	$36,000.00
188	Retention Pond	DWP-01 Sediment Retention, Erosion, or Water Control Structure	Cropland	114	ac treated	10 ac land / 1 ac pool	$18,000.00 / 1 ac pool - 12 ponds	$18,000.00	$216,000.00
189	Retention Pond	DWP-01 Sediment Retention, Erosion, or Water Control Structure	Cropland	12.6	ac treated	10 ac land / 1 ac pool	$18,000.00 / 1 ac pool - 1 pond	$18,000.00	$18,000.00
200	Fencing	N472 Livestock Exclusion*****	Pasture	2839.1	ft		$0.82-$1.34/foot (electric)		$2328.06-$3804.39
220	Livestock exclusion/Alternative source of water	WQ10 Stream Protection****	Pasture	9902.5	ft	6.82	$750.00		$5,115.00
226	Livestock exclusion/Alternative source of water	WQ10 Stream Protection****	Pasture	5305.9	ft	3.65	$750.00		$2,737.50
241	Fencing	N472 Livestock Exclusion*****	Pasture	4389.2	ft		$0.82-$1.34/foot (electric)		$3599.14-$5881.53
242	Livestock exclusion/Alternative source of water	WQ10 Stream Protection****	Pasture	8024.3	ft	5.5	$750.00		$4,125.00
243	Detention Pond	urban practice - cost-share funding not available******	Urban	4.4	ac				
245	Fencing	N472 Livestock Exclusion*****	Pasture	2718.9	ft		$0.82-$1.34/foot (electric)		$2229.50-3643.33

*where applicable: 30 foot width from Type 3 buffer, Boone County regulations, by # of feet, converted to acres

**water development may not be needed - included in cost estimate

***included two 10-year renewal bonuses per acre for the 21 years of milestones

****includes fencing, water distribution, Out of Production Incentive, etc.

*****cost dependent on species

******will work with municipal partners for funding

Cost Range Low:	$387,571.00	30% of Low:	$116,271.30
Cost Range High:	$405,056.80	30% of High:	$121,517.04

A description of eligible Missouri Soil and Water Conservation Program cost-share practices can be found here: https://mosoilandwater.land/sites/mosoilandwater/files/internal-07-V-eligible-practices.pdf.

Cover Crop Pilot Program Cost Estimate:

	Phase 1 (Years 1-7)	Phase 2 (Years 8-14)	Phase 3 (Years 15-21)	21-Year Total
Cover Crop Acres	70	140	210	210
Annual Cost-share Cost	$2,100	$4,200	$6,300	$12,600
Total Cost	$14,700	$29,400	$44,100	$88,200

Subwatershed 42 Cover Crop Pilot Program:

- Total subwatershed row crop production acres: 427.9
- Project goal: Implement cover crops in roughly 1/2 of the row crop acreage in subwatershed
- Cover crop unit cost = $30/ac (based on BCSWCD costs in the county)
- Considers the lifetime allowable cost-share maximum for practice for any landowner is $20,000

Information and Outreach Program Costs Estimate (excluding Septic Program):

Event/Program	Annual Cost	Source of Cost Estimation and Description
Monitoring Blitz Lunches	$500	previous events; 2 events/year at $250 per event ($5/person max with 50 people/event)
Water Festival	$500	previous events / estimate for expansion
Land Management Workshop (with partner, once per year)	$4,000	previous events; Understanding Ag consultant
	$1,000	previous events; food, mailings, speaker gifts, other supplies
	$500	previous events; space at Bradford Farms
Producer scholarships to attend training workshops	$1,000	selected limit; 10 scholarships/year at $100 each
Producer field day with Understanding Ag	$4,000	Understanding Ag costs menu; field consultation farm day with producer attendees
Watershed Signs Replacement	$150	previous sign costs with vendor / no setup cost
Demonstration and Field Day signage	$1,200	internet search / estimate; temp. signs for field days and perm. signs for demonstration sites
TOTAL ANNUAL COST	$12,850	

Additional Costs	Cost	Source of Cost Estimation and Description
Return on Environment Study	$115,000.00	cost calculated based on previous study with similar research intensity / discussion with other entity that has done similar work / internet search for graphic work
Social Marketing Training and Assistance	$30,000	vendor internet search; suitable vendor - expected in year 1 or 2 of Phase 1

Total Information and Outreach Program Costs:

	Phase 1 (Years 1-7)	Phase 2 (Years 8-14)	Phase 3 (Years 15-21)	21-Year Total
Annual Information and Outreach Program Costs	89,950	89,950	89,950	269,850
Additional Costs	30,000	115,000		145,000
TOTAL COSTS	119,950	204,950	89,950	414,850

Septic Pumpout and Awareness Program Cost Estimate:

	Phase 1 (Years 1-7)	Phase 2 (Years 8-14)	Phase 3 (Years 15-21)	21-Year Total
Septic Pump-out Program	$6,000	$6,000	$6,000	$18,000

The septic pump-out program will offer $200 per household for a septic system pump-out one time during the implementation phase timeframe. A previous program (2007) offered homeowners $100 per household for a septic system pump-out and the cost has increased substantially since that time - this is why we chose $200/household. We are unable to break this down on an annual basis because we do not know how many of the pump-outs will be used each year. We do, however, anticipate "selling out" of the pump-outs the first year of each 7-year phase as this program was very popular last time.

In order to receive the payment for the septic system pump-out, participants will need to attend an online webinar program offered by the County (there is no cost associated with the creation of this webinar program) and present a receipt for their cost for the septic system pump-out.

Watershed-based Plan Monitoring Component Cost Estimate:

> Please see "Annual *E. coli* Monitoring" and "Annual Nutrient Monitoring" tabs for more detailed breakdown of sampling costs.

Constituent	per year	Years 1-7	Years 8-14	Years 15-21	Total for project
E. coli	$ 3,171.00	$22,197.00	$22,197.00	$22,197.00	$ 66,591.00
TN, TP, TSS (WRO)	$ 4,281.47	$29,970.29	$29,970.29	$29,970.29	$ 89,910.87
TN, TP, TSS (Limnology Lab) - separating Organic from Inorganic in TSS	$ 6,585.60	$46,099.20	$46,099.20	$46,099.20	$ 138,297.60
TN, TP, TSS (Limnology Lab) - no separation of TSS	$ 5,913.60	$41,395.20	$41,395.20	$41,395.20	$ 124,185.60
Total monitoring cost, low end	$ 7,452.47	$52,167.29	$52,167.29	$52,167.29	$ 156,501.87
Total monitoring cost, high end	$ 9,756.60	$68,296.20	$68,296.20	$68,296.20	$ 204,888.60

The costs for monitoring includes 7 samples for each constituent per week for four weeks during each quarter, for a total of 28 samples per quarter and 112 samples per year.

Annual *E. coli* Monitoring Cost Estimate:

Quarter	Number of samples (7 sites, one sample per site) Week 1	Week 2	Week 3	Week 4	Number of diluted samples per quarter	Cost per sample (non-diluted)	Cost per sample (diluted)	Cost Summary
1Q	7	7	7	7	0	28 @ $23.00 / sample		$ 644.00
2Q	7	7	7	7	28		28 @ $31.50 / sample	$ 882.00
3Q	7	7	7	7	28		28 @ $31.50 / sample	$ 882.00
4Q	7	7	7	7	14	16 @ $23.00 / sample	14 @ $31.50 / sample	$ 763.00
							Total per year:	$3,171.00

> Dilution is required during the recreational season (April 1 through October 31 of each year) to ensure that the E. coli concentration estimate is the most accurate available using the IDEXX method.

> See Monitoring-ALL tab for total monitoring costs by implementation phase

Annual Nutrient and Sediment Monitoring Cost Estimate:

WRO, Lincoln University, Nutrient Analysis			
Constituent	**per sample**	**per quarter**	**per year**
Personnel cost			
personnel at $12/hr	$13.71	$384.00	$1,536.00
subtotal			$1,536.00
Materials and supplies			
TN	$3.58	$100.31	$401.25
TP	$4.83	$135.31	$541.25
Gravimetrics	$8.05	$225.50	$902.00
subtotal			$1,844.50
Other direct costs			
Shipping and handling	$1.32	$37.06	$148.26
surcharge 5%	$0.82	$23.05	$92.23
subtotal			$240.49
F&A/Indirect			
F&A/Indirect (43% of personnel)	$5.89	$165.12	$660.48
subtotal			$660.48
grand total*			$4,281.47
Total overhead cost per sample	$21.74	$609.23	$2,436.97

University of Missouri, Limnology Lab, Nutrient Analysis			
Constituent	**per sample**	**per quarter**	**per year**
E. coli			
TN	**18.3**	512.4	2049.6
TP	**15.2**	425.6	1702.4
TSS[1]	**25.3**	708.4	2833.6
Total for Nutrients			6585.6

[1] Includes breakdown of organics / inorganics

University of Missouri, Limnology Lab, Nutrient Analysis			
Constituent	**per sample**	**per quarter**	**per year**
E. coli			
TN	**18.3**	512.4	2049.6
TP	**15.2**	425.6	1702.4
TSS	**19.3**	540.4	2161.6
Total for Nutrients			5913.6

> This quote is a yearly estimate based on TN, TP, TSS analysis for 7 sites, 4 weeks, and 4 quarters. Additional years would be subject to additional surcharge given that materials and supplies increase in price each year. (2022-2023)

> See Monitoring-ALL tab for total monitoring costs by implementation phase.

Appendix K: Information and Outreach Strategies and Examples

Greater Bonne Femme Watershed-based Plan: Appendix K
Information and Outreach Strategies and Examples

Reaching the goals outlined in the watershed-based plan will require outreach strategies. Education, outreach, and information activities and strategies are categorized by goal. Each goal and corresponding table of strategies, examples, and evaluations are found below, and the corresponding evaluation must be completed for each strategy that is used with an accompanying assessment. A minimum of one strategy for each of the WBP's Information and Outreach goals must be completed each year.

Table 1. Goal: Increase awareness about water quality and watersheds.

Strategies	***Examples***	***Evaluation***
Informational Signs	• Watershed delineation (install in high traffic areas) • Storm drain marking • Stream signs • Demonstration information • Added signage to increase awareness and information at places such as demonstration sites, BMP indicators, topographic information, and local projects	• Number of signs installed • Number of storm drains marked
Public Speaking	• Government organizations • Schools • Churches • Clubs • Virtual presentations on website, social media, or other outlets	• Number of public speaking events • Based on evaluations, whether attendees received information from the presentation
Diversify Outreach	• Engage with a new community • Partner with a local organization • Translate education material to additional languages	• Survey
Community Events	• Watershed Festival • Picnics or Fairs • Open house • Watershed tour • Day at the stream • Educational hikes • Scavenger hunts • Virtual community events (ex. photo check ins, exploration trail shares, etc.) • Display booths at non-sponsored events	• Number of people who attend • Exit survey to gauge enjoyment of event

Student-Focused Activities	• Rockbridge Memorial State Park • Boone County Nature School • Local public and private schools • Virtual or digital programming • Day Camps	• Number of presentations held • Number of students attending • Trend of number of students attending over time • Exit survey to gauge enjoyment of event
Multimedia Campaigns	Develop a marketing campaign. A marketing company may be used for marketing development and instruction during WBP implementation. • Classes for social and digital marketing Informational Materials • Marketing Materials	• Number of hits on County website before and after marketing campaign • Number of views for social posts • Number of times that partners' posts are shared
Informational Materials	• Slide shows • Handouts or Flyers • Mailers • Websites • Videos • Brochures	• Pre and post evaluation of the watershed population
Programs and Workshops	• Land management workshops • Panel discussions for agricultural producers, homeowners, and/or developers. In person or virtual presentations. • BMP tours and/or displays • Public hearings and meetings	• Number of people attending
Competitions	• Art and design competitions with rewards and recognitions for winners • Education campaigns and PSAs with rewards and recognitions for winners	• Number of people who participate • Change in survey results
Giveaways	• To promote the project and general water quality awareness (examples: seed packets, stickers, gift cards for BMP material, T-shirts, calendars, beverage holders, reusable water bottles, etc.)	• Return on Environment surveys • Pre-event or workshop survey responses
Online and Virtual Resources	• Website development • Online training tools • Interactive pages	• Number of people who visit the website

	• Resource pages for public and educators • Virtual place-based education hub	
Food Production	• Peer presentation • Perennial edible ID • Cultivation • Market education • Farm to Table meal • Farm tours	• Number of people who participate • The continuations rate of people who go on to attend workshops or apply for scholarships

Table 2. Goal: Strengthen understanding among stakeholders of how land use activities are connected to water quality and flooding.

Strategies	***Recommendation***	***Evaluation***
Monitoring Events	• Monitoring Blitz at Rock Bridge Memorial State Park • Regular monitoring of streams • Volunteer monitoring and stream adoption • School group or clubs monitoring • Rain monitoring	• Number of people who attend • Number of VWQM data sheets submitted for GBFW streams • Number of streams adopted for monitoring in the GBFW • Number of groups monitoring
Modeling and Demonstration Tools	• Stream table • Floodplain simulation • Other demonstration tools such as the enviroscape, erosion control	• Number of people who attend • People who sign up for contact list • Post-demonstration survey
Demonstration Projects	Demonstration projects will be incorporated into WBP implementation projects; signage, field days and tours will be included. Examples of potential BMPs to demonstrate: • Bioretention basins • Cropland BMPs (ex. nutrient management plan, cover crops, vegetative buffer, grassed waterways, etc.) • Livestock BMPs (ex. rotational grazing, relocation of pasture feeding sites, grazing management plan, fencing off streams, vegetative filter strips, etc.)	• Pre- and post-evaluation of the population in the watershed • Pre- and post-survey of attendees • Number of people who request information for cost share and funding through partner organization

	• Urban (ex. bioswale, permanent vegetation, invasive species removal, etc.) • Streambanks (ex. riparian restoration, stabilization, etc.)	
Clean Up Events	• Stream clean ups • Watershed land clean up • Native plantings • Restoration workdays • Invasive species removal	• Number of people who participate • Number of road segments in the watershed adopted • Number of activities that occur
Watershed Tours	• Stakeholder tour • Scavenger hunt • Farm tours • Rain Catchers – go out while it is raining and get flow and rainfall information	• Number of people who participate • Change in survey results • Number of actives that occur
Workshops	• Land management workshops • Panel discussions for agricultural producers, homeowners, or developers. In person or virtual presentations • BMP tours or displays	• Number of people who attend • People who sign up for contact list • Post-activity survey
Wet Feet Activities	• Day at the stream • Exploration and education hikes	• Number of people who attend • People who sign up for contact list • Post-activity survey

Table 3: Goal: Encourage BMP implementation for the protection and improvement of water quality.

Strategies	***Recommendation***	***Evaluation***
Recognition and/or Reward Program	Stormwater Champions – marketing and recognition program for incentivizing online or in-person training for the use of BMPs to promote water quality protection and improvement. • Green snow removal • Agriculture • Residents • Schools • Construction • Development	• Number of people who take part in the training and certification practice • Interview random citizens to see if they are more likely to support an organization that has a Stormwater Champion recognition • Pre- and post-program survey of the recipients

	• Schools • Organizations	
How-to Field Guides	• Handouts • Videos • Online Content	• Number of people who view or download resource
Low Impact Development	• Developers forum • LEED certification recognition • Contractor and engineer workshops	• Number of forums and/or workshops held • Number of people who attend • Number of new buildings that are LEED
Soil Health, Agroforestry, and Regenerative Agriculture	• Scholarships for training • Landscape coaching • Town halls • Farmer forums • Demonstration tours • Resources webpage for implementation • Land management workshops • Demonstration sites • Perennial production education	• Reduction in E. *coli* from livestock and nutrients and sediment in watershed streams • Number of Soil and Water District funded projects in watershed • Pre- and post-program survey
Good Housekeeping	• Trash clean up • Snow and ice removal • Fertilizer and pesticide usage • Pet waste removal • Car washing	• Reduction in reported illicit discharges
BMP Hands-on Activities	• Rain barrel workshops • Rain scaping • Invasive species removal • Native planting • Tips and tours for maintaining BMPs	• Number of people who attend • Pre- and post-program Survey
Wastewater	• Septic pumping and maintenance rebate • Policy maker tours • Partnering with Boone County Regional Sewer District and Boone County Health Department • Maintenance guides and manuals	• Number of septic program workshop attendees • Number of septic pumpouts • Amount of human E. *coli* in streams

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