Black Creek Watershed
Shelby County, Missouri
Watershed-based Plan

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

Executive Summary

The purpose of this ten-year Watershed-based Plan (WBP) for the Black Creek watershed (BCW) is to outline the restoration and protection goals and actions for surface waters in the watershed. Watershed goals are characterized as either “restoration” or “protection.” Watershed restoration is conducted for surface waters that do not meet water quality standards and for areas of the watershed that need improvements in habitat, land management, or other attributes. Watershed protection is conducted for surface waters that currently meet water quality standards, but are in need of protection from future degradation.

The WBP development process involves the local community and governmental agencies working together toward the common goal of a healthy environment. Local participants or stakeholders provide valuable grass roots leadership and responsible management of resources. The local community has the most “at stake” in restoring and protecting the water quality in their watershed and in ensuring that runoff from their land is of acceptable quality for use by their downstream neighbors and municipalities.

State and federal agencies support watershed restoration and protection efforts by working together with local communities to build awareness, provide public information and education, engage local leadership in monitoring and evaluating watershed conditions, and planning and implementing the watershed based plan. Watershed based management plan goals are to provide a sustainable water source for recreational and domestic use while preserving food and fiber production. The ultimate goal is watershed restoration and protection that will be “locally-led and driven” in conjunction with government agencies.

This WBP is intended to serve as an overall strategy to guide watershed restoration and protection efforts by individuals, and local, state, and federal agencies and organizations that will benefit not just local users but neighbors up and downstream. This WBP will also provide guidance to the local stakeholders as they make decisions that will help to restore and protect water quality on lands they own in Black Creek Watershed. The Steering Committee, listed below, met regularly and was instrumental in guiding the planning project. Consisting of individuals from a variety of backgrounds, the committee provided valuable information on such things as land use issues as well as feedback, evaluation and prioritization of uses, concerns, Best Management Practices (BMPs), goals, objectives, and other important components of the actual management plan. The Steering Committee recommends the plan length be ten years. They feel that this will provide sufficient time to secure funding and to allow sufficient time for the goals of this plan to be met.

High levels of *E. coli* bacteria and low dissolved oxygen due mainly to runoff from agricultural areas impair Black Creek Watershed. The most likely nonpoint source pollution problems in the watershed are sediment from eroding crop and grazing lands and excess nutrients from agricultural runoff which can contribute to the overgrowth of nuisance algae, and the subsequent breakdown of the algae causing dissolved oxygen levels to decrease in Black Creek

By installing cropland and grazing land BMPs the amount of erosion will be reduced which in turn will reduce sediment and nutrient loading to streams. Because phosphorus and nitrogen typically binds to soil particles, practices that reduce soil erosion assist with controlling nutrient loading. In addition, implementing pasture BMPs will increase the density of vegetation, which will help to reduce the volume of runoff and the transport of soil, nutrients and bacteria into Black Creek. Implementing BMPs to protect the riparian corridor such as live stock exclusion, woodland protection and alternative water sources will help in keeping livestock out of the stream and reduce bacteria loading.

The U.S. Department of Agriculture's Conservation Effects Assessment Project (CEAP) has undertaken a series of studies designed to quantify the effects of conservation practices on cultivated cropland in the contiguous 48 States. The first study in this series was on the Upper Mississippi River Basin (UMRB), which includes the Black Creek Watershed. The assessment uses a statistical sampling and modeling approach to estimate the effects of conservation practices. The study showed that voluntary, incentives based conservation approaches are achieving results. Farmers have reduced sediment, nutrient, and pesticide losses from farm fields through conservation practice adoption. Conservation practices in place from 2003 to 2006 showed a 61% reduction in sediment runoff, a 45% reduction of nitrogen in runoff and a 44% reduction of total phosphorus in runoff.

The study goes on to show that by using a suite of conservation practices, such as those that will be proposed in this plan, there is a potential for further reductions in edge of field losses of sediment and nutrients. It is possible to have an additional 76% reduction in sediment in runoff, 58%of nitrogen in runoff and 45% of phosphorus in runoff.

Modeling done for this plan shows the percent reduction for each BMP that can be expected for sediment, nitrogen and phosphorus at the outlet of Black Creek (see table 8). Work done in Kansas and presented in the document Cost-effective Water Quality Protection in the Midwest, shows expected load reduction from using certain BMPS. It shows that using a vegetative buffer strip would reduce sediment by 50%, total nitrogen by 35%, and total phosphorus by 50%. Terrace with tile outlets would result in a reduction of sediment by 30%, total nitrogen by 10% and total phosphorus by 30%. Implementing terraces using grass water ways as outlets would give a reduction in sediment of 30%, of total nitrogen of 30% and total phosphorus by 30%. These practices are part of the suite of conservation practices proposed in this plan.

The Steering Committee assumes that producers will be willing to implement more than one conservation practice and have set the overall goal of this WBP to reduce the sediment loading by 50% and nutrient loading by 60% which should help improve the low dissolved oxygen problem. The goal for E-coli bacteria is to have bacteria levels reduced to Class B recreational water quality standards. That goal is no more than 206 Colonies/100ml between April 1 and October 31. This will be achieved by using a holistic approach of promoting BMPs that reduce the amount of sediment by 50%, phosphorous by 30% and nitrogen by 30% that reach the stream.

The Best Management Practices that will be implemented to help achieve these goals are as follows; terraces, nutrient management, filter strips, field borders, cover crops, grass waterways, reduced tillage, interseeding, stream exclusion, woodland protection, and alternate water sources. The Steering Committee consists of the following: John Broughton, land owner, Farm Service Agency County Committee Member, Shelby County Rural Water District Board Member, Kenny Latimer, land owner, Rick Stevenson, land owner, Dan Ballow, land owner, Scot Shively, land owner, Charlie Watts, land owner, Max Glover, University of Missouri Extension, Glen Eagan, Shelby County Presiding Commissioner, Carol Hubbard, Shelby County Soil and Water Conservation District Manager and Mitch Kruger, Natural Resources Conservation Service District Conservationist. Also the Project Manager has formed an Advisory Committee to advise and provide suggestions. Those members are Robert Broz, Extension Assistant Professor, Darla Campbell, Agri Business Specialist and County Program Director, Ted Sieler, Missouri Department of Conservation, Private Lands Conservationist and the Northeast Missouri Resource Conservation and Development Council.

CHAPTER I. Introduction

Section 303(d) of the federal Clean Water Act requires each state to identify waters not meeting water quality standards and waters where water pollution controls are not stringent enough to meet those standards. Water quality standards protect beneficial uses of water such as whole body contact (i.e. swimming), maintaining fish and other aquatic life, and providing drinking water for people, livestock and wildlife. The 303(d) list of impaired waters, **(http://www.dnr.mo.gov/env/wpp/waterquality/303d.htm),** identifies impaired waters that need attention and help in addressing water quality problems. Black Creek in Shelby County is currently on the state's 2012 303(d) List for excess levels of *E. coli* bacteria, from unknown nonpoint source pollution (NPS) and the Shelbyville wastewater treatment facility cited as a potential point source.

Nonpoint source pollution refers to contaminants that do not come from specific conveyances, such as pipes or other permitted sources. It includes contaminants carried in runoff from fields, roads, parking lots, etc., as well as more specific sources such as improperly functioning on-site wastewater treatment systems. In Missouri, agriculture is a common source of NPS pollution, although urban areas and abandoned mine lands can also be significant sources.

Point sources are regulated under the Clean Water Act and are usually subject to permit requirements that focus on water quality protection. However, most nonpoint sources of pollution are typically unregulated and are addressed by citizens, farmers and educators on a voluntary basis. The responsible parties may include citizens, industries, agribusinesses, commercial businesses or homeowners.

"The Nonpoint Source Program and Grants Guidelines for States and Territories for FY 2004 and Beyond" requires a WBP to be completed prior to implementation using incremental funds. This guidance defines the nine key elements to be addressed in a WBP. These elements include: 1) identification of causes and sources that will need to be controlled to achieve load reductions; 2) estimate of load reductions expected from the management measures described; 3) a description of the management measures that will need to be implemented to achieve load reductions; 4) an estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources or authorities who will bear responsibility; 5) an information/education component that will be used to enhance public understanding of the project and encourage early participation in the overall program; 6) a schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious; 7) a description of interim, measurable milestones for determining whether control actions are being implemented; 8) a set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made or whether the Watershed Plan or Load Duration Curve (LDC) needs to be revised, and 9) a monitoring component to evaluate the effectiveness of the implementation efforts over time.

The overall goal of the Black Creek WBP is to provide guidance to the Shelby County Soil and Water Conservation District (SWCD), local stakeholders, and government agencies as they move forward in the impairments that have resulted in Black Creek being listed on the state's 303d list. The overall goal of this WBP is to reduce the sediment loading by 50% which should help reduce *E-coli* bacteria levels to recreational water quality standards. This will be achieved by using a holistic approach of promoting BMPs that reduce the amount of sediment and nutrients that reach the stream. In order for a WBP to become an effective tool, it must be amenable to revision and update. The Black Creek WBP has been developed as a dynamic document that will be revised to incorporate the latest information, address new strategies, and define new partnerships between watershed stakeholders. It is anticipated that at least biennial revisions may be necessary and that the responsibility for such revisions will rest primarily with the Black Creek Watershed Steering Committee in consultation with the Missouri DNR. Copies of the plan and revision will be provided to local and county agencies and made available to any entity that would have an interest in improving water quality.

Watershed Characterization

The BCW is located in Shelby County in northeast Missouri. The watershed includes the 12-digit Hydrologic Unit Codes (HUC) 071100050201 and 071100050202 (See Figure 1). This WBP will target HUC 071100050202 only. Black Creek is a tributary of the North Fork of the Salt River which is part of the Mark Twain Lake watershed. Figure two shows the location of the BCW and its relationship to the Mark Twain watershed (See Figure 2).

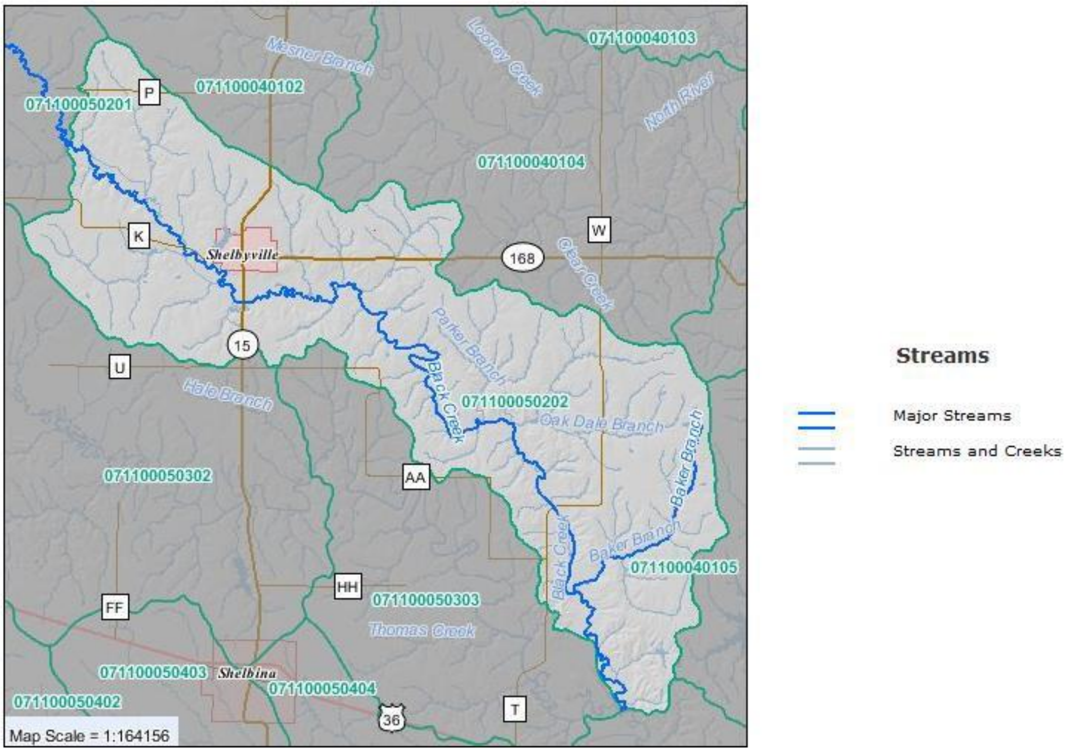


Figure 1. Black Creek Watershed.

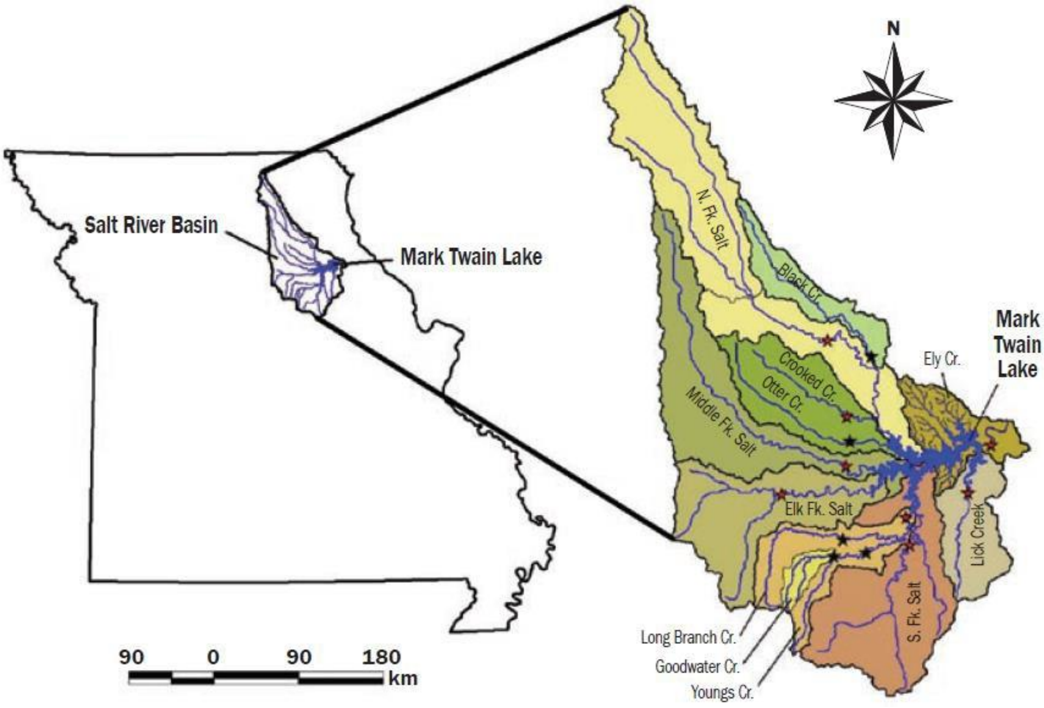


Figure 2. Position of Black Creek Watershed within the Mark Twain Lake Watershed/Salt River Basin

Mark Twain Lake is the drinking water source for the Clarence Cannon Wholesale Water Commission (CCWWC) District which provides three million gallons of drinking water daily, through 325 miles of water transmission lines, to approximately 65,000 people living in 14 counties in northeast Missouri (See Figure 3). As the map shows, those living in the BCW receive their drinking water from Mark Twain Lake through the Shelby County Public Water Supply District Number One (PWSD). A board member of this PWSD is a member of the Steering Committee. The Steering Committee intends to make a copy of the final WBP available to the Clarence Cannon Wholesale Water Commission to be used as a tool for them to promote watershed planning in the other watersheds that drain into Mark Twain Lake.

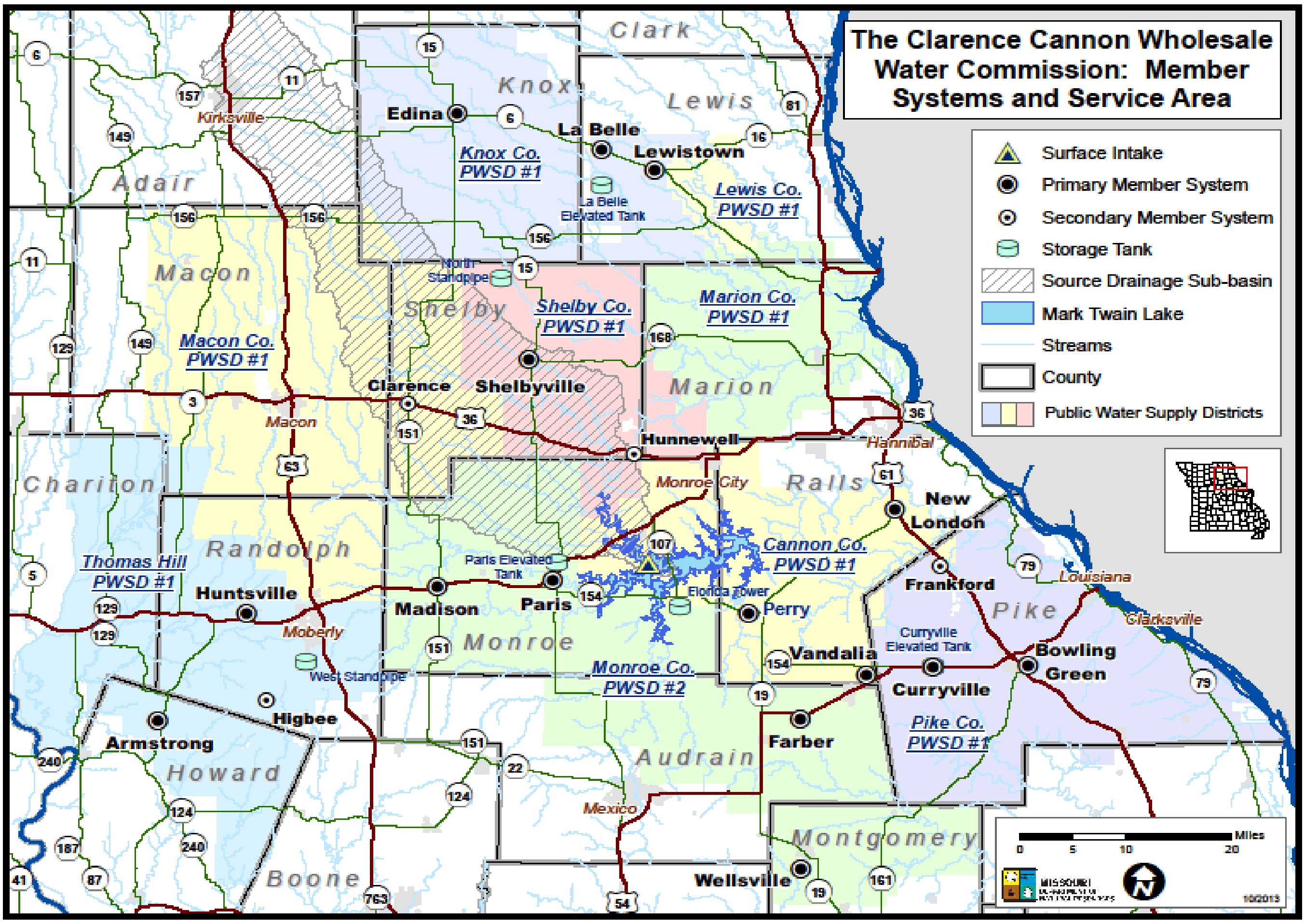


Table 2. Land Slope in Black Creek Watershed.

Slope Range:	0-3%	3-6%	6-10%	10-15%	> 15%	Total
Acres	18,492	11,130	4,070	737	56	34,485
Percent	53.63%	32.27%	11.80%	2.14%	0.16%	100.00%

The Natural Resources Conservation Service (NRCS) Hydrological Soil Groups are divided into four groups, A, B, C and D. Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in. /hr.). Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately course textures. These soils have a moderate rate of water transmission (0.15 to 0.30 in. /hr.). Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately coarse textures. These soils have a moderate rate of water transmission (0.05-0.15 in. /hr.). Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0.00 to 0.05 in. /hr.). Ninety-seven percent of the land falls within Hydrologic Soil Groups C and D which results in a high runoff potential. According to the website **http://nass.usda.gov** annual rainfall averages 38-40 inches per year with spring and summer showers that enhance runoff potential.

Some of the riparian area along Black Creek is degraded by overgrazing or row-crop agriculture. Based on Shelby County NRCS Field Office records, it appears that only 5 percent of the riparian area is protected through the Conservation Reserve Program (CRP) or Wetland Reserve Program (WRP) long-term easements. Other sources of funding to increase the number of acres protected will be explored such as state cost share and 319 program funds. Most of the protected area is at the southern end of the watershed where it merges with the North Fork Salt River. This region periodically backs up during high water levels in Mark Twain Lake. The major streams within BCW are listed in (Table 2) with their stream lengths (miles). These are tributaries of BCW that are of significant size and empty into Black Creek. The location of these tributaries in relation to Black Creek can be seen in (Figure 1).

Table 2. Major streams in Black Creek Watershed.

Stream Name	Stream Length (Miles)
Baker Branch	4.82
Black Creek	26.74
Oak Dale Branch	4.46
Parker Branch	3.37
Total	39.39

Historical Land Use

Even though the French laid claim to the area as early as 1682, Native Americans of the Missouri, Osage, Fox and Sac tribes were in undisputed possession of northern Missouri until the United States took ownership in 1803 as part of the Louisiana Purchase. Beginning in 1804, Native Americans entered into a series of treaties that eventually relinquished their claims to land in Missouri. Development of the Salt River Basin, so named because of its numerous salt springs and licks, proceeded rapidly following the War of 1812. White settlers came mostly from Kentucky and Tennessee, and farming quickly became the area's economic base. According to the history section of the 1942 Shelby County Farm Directory crops grown in the 1800’s where wheat, corn, oats and hemp, Livestock flourished grazing on the prairies from spring until June at which time the prairies would be burned off, which would stimulate new growth for the livestock. The Marion County records list Jake’s Creek, the stream which now bears the name of Black Creek. It was originally called Jake’s Creek because in about 1820, a trapper named Jake built a cabin on its banks and trapped and fished there for some time. However, the surveyors who first surveyed that area called it Black Creek, because of the blackness of its water when they first saw it.

Human population in the region grew rapidly until about 1920 and then began to decline. The population of Shelby County from 1900 to 1990 fell from 16,167 to 6,942. The current population based on the 2010 census is 6373.

Land cover in Black Creek Watershed is varied. Figure 4 gives a breakdown according to the U. S. Geological Survey National Land Cover Database. This data is from the 2006.

Land Cover Type	**Acres**	**Percent**
Developed - High Intensity	3	0.01%
Developed - Medium Intensity	24	0.07%
Developed - Low Intensity	242	0.70%
Developed - Open Space	1,354	3.92%
Barren Land	20	0.06%
Deciduous Forest	4,326	12.54%
Evergreen Forest	5	0.01%
Mixed Forest	0	0.00%
Shrub/Scrub	346	1.00%
Grassland/Herbaceous	401	1.16%
Pasture/Hay	10,245	29.69%
Cultivated Crops	16,492	47.80%
Woody Wetlands	700	2.03%
Herbaceous Wetlands	700	2.03%
Water	169	0.49%
Total	34,506	100%

Source: U.S. Geological Survey National Land Cover Database, 2006.

Figure 4. Land use in Black Creek Watershed.

In comparison, the Mark Twain Lake/Salt River Basin Conservation Effects Assessment Project (2007) listed the following land use for BCW. The BCW is one of several smaller watersheds that make up the Salt River Basin. Data was listed for each individual watershed, the following which came from the State Soil Geographic (STATSGO) database, soils for the Salt River Basin pertain only to the BCW, pasture (24.3%), cropland (59.2%), forest (14.4%), developed (1.6%), water (0.50%). This indicates that there has been a conversion of pasture land to cropland which was verified by the Black Creek Steering Committee knowledge of local trends.

Recent data received from the NRCS Field Office, shows that from 2008 to 2012 there was a loss of 47,996 acres of grassland in Shelby County (See Map Appendix E). This data was gathered by the Missouri Department of Conservation from **http://nassgeodata.gmu.edu/CropScape/**.

The major agricultural industry in BCW is crop production, predominately corn and soybeans. Livestock production continues to decline. According to the 1997 Census of Agriculture data for Shelby County, (http://www.agcensus.usda.gov), there were 27,447 head of cows and calves in Shelby County, and 77,893 head of hogs and pigs. The 2012 Census of Agriculture county data shows that the number of cows and calves had declined to 20,434 head and the number of hogs and pigs had declined to 20,663 head (http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level). The Black Creek Watershed Steering Committee is in agreement that this same trend is occurring in the watershed. Based on their knowledge of landowners and operators within the watershed they were able to identify only two hog producers within the watershed. The only urban area within the watershed is the town of Shelbyville which has a population of 552 based on the 2010 Census. The Steering Committee is not aware of any work or studies that have been done to document any impact the town is having on the water quality of Black Creek watershed.

Human Population:

Based on data from CARES the total population for the Black Creek watershed was 821 as of the 2010 census. This was a decline of 265 from the 2000 census. There were 15.24 people per square mile with 57% of the population in the 18 - 64 year old age range (See Figure 5). The watershed includes the town of Shelbyville whose population is 552 based on the 2010 census. This decline in population reflects the trend in agricultural in Northeast Missouri as farm land continues to be consolidated and controlled by absentee landowners who cash rent their cropland to large operators. The challenge becomes selling water quality BMPs to operators who have control of the land but do not own it and to absentee landowners who do not feel a connection to the land. All landowners and operators will be kept informed of the opportunities available to improve water quality within Black Creek Watershed and the progress being made by letters, newsletters and electronic means such as the SWCD or University of Missouri websites.

Total Population (2010):	821	
Persons/Sq Mile:	15.24	
Total Population (2000):	1,086	
Population Change, 2000 - 2010:	-265	
Age 0-4:	57	6.94%

Age 5-17:	142	17.30%
Age 18-64:	468	57.00%
Age 65 and up:	154	18.76%

Figure 5. Black Creek Watershed Population.
(http://ims.missouri.edu/website/watershedTool/profileComb.asp)

Physical/Natural Features: Soils

Black Creek is part of the Upper Mississippi-Salt Basin (8-digit HUC 07110005), which drains a major portion of northeast Missouri into the Mississippi River. Black Creek is in the Central Claypan Region Major Land Resource Area (MLRA 113) (USDA Natural Resources Conservation Service, 2006). Major land resource areas (MLRAs) are geographically associated land resource units (LRUs) that share a common land use, elevation and topography, climate, water, soils, and vegetation. MLRA 113 covers a large portion of North East Missouri and extends into Illinois. Nearly all this MLRA is in farms, and about 60 percent is cropland.

Soil is categorized mainly by sand, silt and clay content. Clay soils are predominant in Northeast Missouri including the Black Creek Watershed. Clay soil is defined as a soil that is at least 40 percent clay particles. Clay soils are made up of 0- to 45-percent sand and silt, 50- to 100-percent clay and a higher organic content than other soils. Clay particles are sticky and greasy and expand when wet, and have a tendency to compact and dry very hard. Clay soil does not drain well, and water can take a long time to penetrate. Once it is wet, water will runoff rather than percolate through it.

Because of the high clay content most of the soils are poorly drained. In BCW, the predominate soils are Putnam, Mexico, Leonard, Armstrong, Gara, Keswick, Lindley, and Piopolis. In addition, there are other soils present in very small percentages (i.e. Arbela, Blackoar, Fatima). See (Table 3) for a breakdown of soil types, which includes the number of acres of each soil and what percent of the watershed is made up of each soil type.

Putnam soils are deep and somewhat poorly drained. They are nearly level to gently sloping and found on the uplands. These soils were formed in silty and clayey material. The native vegetation for Putnam soils was mixed prairie grasses. Putnam soils are used mainly for row crops with wetness being the main limitation. Putnam soils are usually found in association with Mexico soils which are somewhat poorly drained and are found on the tops and gently sloping sides of convex ridges. They are down slope from and adjacent to Putnam soils.

Table 3. Soils in Black Creek Watershed.

	Map Unit Name	Acres	Percent
🟦	Arbela silt loam, 0 to 2 percent slopes, occasionally flooded	399	1.16%
🟫	Armstrong loam, 5 to 9 percent slopes	1,192	3.46%
🟧	Armstrong loam, 9 to 14 percent slopes, eroded	722	2.09%

🟩	Auxvasse silt loam, 0 to 2 percent slopes, rarely flooded	101	0.29%
🟦	Blackoar silt loam, 0 to 2 percent slopes, occasionally flooded	113	0.33%
🟩	Calwoods silt loam, 2 to 5 percent slopes	381	1.10%
🟩	Chariton silt loam, 0 to 2 percent slopes, rarely flooded	134	0.39%
🟦	Fatima silt loam, 0 to 2 percent slopes, occasionally flooded	190	0.55%
🟧	Gara loam, 14 to 20 percent slopes	3	0.01%
🟩	Gifford silt loam, 2 to 5 percent slopes, rarely flooded	239	0.69%
🟨	Gifford silt loam, 5 to 9 percent slopes, rarely flooded	155	0.45%
🟨	Gorin silt loam, 5 to 9 percent slopes, eroded	310	0.90%
🟥	Goss gravelly silt loam, 20 to 30 percent slopes	64	0.19%
🟨	Keswick loam, 5 to 9 percent slopes, eroded	2,236	6.48%
🟧	Keswick loam, 9 to 14 percent slopes, eroded	2,107	6.11%
🟦	Kickapoo fine sandy loam, 0 to 2 percent slopes, occasionally flooded	181	0.52%
🟨	Leonard silt loam, 5 to 9 percent slopes, eroded	5,722	16.58%
🟨	Leonard silt loam, 9 to 14 percent slopes, eroded	102	0.30%
🟧	Lindley loam, 14 to 20 percent slopes	1,022	2.96%
🟥	Lindley loam, 20 to 35 percent slopes	922	2.67%
🟩	Marion silt loam, 2 to 5 percent slopes	277	0.80%
🟩	Mexico silt loam, 1 to 4 percent slopes, eroded	8,886	25.75%
🟦	Moniteau silt loam, 0 to 2 percent slopes, frequently flooded	23	0.07%
🟦	Piopolis silty clay loam, 0 to 2 percent slopes, occasionally flooded	3,704	10.73%
⬛	Pits, quarry	20	0.06%
🟩	Putnam silt loam, 0 to 1 percent slopes	2,440	7.07%
🟨	Putnam silt loam, 1 to 3 percent slopes	2,700	7.83%
🟥	Ranacker-Rock outcrop complex, 20 to 40 percent slopes, very stony	27	0.08%
🟩	Vigar loam, 2 to 5 percent slopes, rarely flooded	31	0.09%
⬜	Water	81	0.23%
Total		34,484	99.94

(http://ims.missouri.edu/website/watershedTool/profileComb.asp)

Like Putnam soils, Mexico soils were formed in silty and clayed materials. Likewise the native vegetation was mixed prairie grasses. Mexico soils have a very slow permeability. These soils are used mainly for row crops with soil erosion being the main hazard.

Following the Putnam Mexico Series is the Leonard Series which consists of deep, somewhat poorly drained, moderately to strongly sloping soils on the side slopes. Likewise, these soils were formed in silty and clayey material. Their native vegetation was also mixed prairie grasses. These soils have slow permeability, with a high natural fertility. Leonard soils are used for crops and hay and have a high erosion potential.

Well drained and moderately well drained, moderately sloping to steep (Armstrong, Gara, Keswick, Lindley, and Weller series in Missouri) are on side slopes. These soils are highly erodible and if cropped will require conservation practices such as terraces, no-till and farming on the contour to help control the amount of soil erosion that will occur.

Chapter 2: Element A*: Identification of Causes and Sources of Impairment*

Water body conditions

Black Creek is listed on the state’s 2012 303(d) List of impaired waters for bacteria as indicated by excessive concentration of *E. coli* (from both the WWTF and nonpoint sources) and low dissolved oxygen (from unknown sources). See the Black Creek information sheet at (http://dnr.mo.gov/env/wpp/docs/111-black-cr-info.pdf for general information). The length of the listed segment is 19.4 miles for both *impairments*. The designated uses that are impaired are Whole Body Contact – Category B due to bacteria, and Protection of Warm Water Aquatic Life due to low dissolved oxygen concentration. Missouri DNR states that "the minimum dissolved oxygen for the protection of warm-water and cool-water fisheries shall be 5.0 mg/L. For dissolved oxygen, the Listing Methodology Document allows a water body to be judged as impaired if more than ten percent of the measurements fail to meet the water quality standard.

For Black Creek, 57 dissolved oxygen measurements were made from 2009 to 2012. Of these 57 measurements, 10 were found to be below 5 mg/L. This equates to a 17.5 percent exceedance rate (See the MDNR Water Quality Data, 2009-12, WBID 0111, in appendix C). For this reason, Black Creek was judged to be impaired due to low dissolved oxygen. The water quality standard for *E. coli* in Class B recreational waters for the protection of human health is 206 col/100 mL. This standard is for the geometric mean of all bacterial counts taken during each recreational season, April 1 through October 31. For *E. coli* bacteria, a water body is judged to be unimpaired if the geometric mean for all of the last three years for which data are available is less than the appropriate water quality standard. At least five samples must be available from a given recreational season for that season to be considered. Sufficient *E. coli* data for Black Creek are available for the 2010, 2011 and 2012 recreational seasons.

The geometric mean for *E. coli* in Black Creek has been calculated as 989.88 col/100 mL, 405.86 col/100 mL, and 572.16 col/100 mL for 2010, 2011, and 2012 respectively. Since this number is greater than the Class B *E. coli* standard of 206 col/100 mL, Black Creek is judged to be impaired by bacteria. (See the MDNR Water Quality Data, 2009-12, at website: http://www.dnr.mo.gov/mocwis_public/wqa/waterbodySearch.do search by WBID 111.0 and 112.0, in appendix C).

Bacteria has been identified as an impairments to Black Creek (see Appendix G). Bacteria can come from a variety of sources (on-site sewage systems, livestock manure mismanagement or livestock in waterways) but with no known source of bacteria determined the committee looked at research from Kansas State University that showed a direct correlation between bacteria levels in waterways and high phosphorus loading. We know that phosphorus binds with the soil and can be transported to waterways through soil erosion. Based on their knowledge of the area and an extensive windshield survey (see detailed map on driving route in Appendix E) to try and identify potential sources of E.coli. The consensus of the local Steering Committee is there is little evidence of cattle in Black Creek and a very low number of confined animal operations close to the stream. See Appendix E for general route taken for windshield survey. The windshield tour helps verify what the modeling in the watershed identified. Areas with specific land cover, land use and slope have a higher potential for contributing nutrient and sediment runoff which can affect bacteria loads. Livestock manure handling is generally not prevalent in the area since most cattle operations are pasture based. Figure 8 shows the location of two CAFO's one which is small and un-permitted and one which is permitted. The permitted CAFO is located in the lower part of the watershed. The CAFO is permitted through DNR and has a comprehensive nutrient management plan (CNMP) that outlines the amount that can be spread, the time when spreading can occur and the setback distances required when spreading so they are not considered a key source of bacteria. The location of livestock operations which are indicated on the map in Figure 8, are all pasture-based operations. Most of these livestock operations do not have direct access to Black Creek. Understanding the correlation between high phosphorus levels and bacteria levels and the way phosphorus binds with the soil, soil erosion is identified as the number one cause and source of impairment. This reduction in sediment should also show a reduction in nutrient loading which should reduce aquatic plant growth. Excessive aquatic plant growth can create low dissolved oxygen as the plants die and decay. By reducing the nutrient levels that feed these plants we should be able to reduce the low dissolved oxygen issue.

Sources of nutrient loading can include discharges from municipal and private wastewater treatment, cropland, livestock waste, and urban storm water runoff, and natural decay of vegetation. The biggest source of phosphorus and nitrogen in Black Creek Watershed is erosion and runoff from cropland. These nutrients are transported by being attached to sediment. As well as transporting nutrients sediments also cause increased suspended solids in stream water. The suspended solids decrease sun light penetration through the water column which can reduce the amount of photosynthesis needed by oxygen producing plants in the stream. When the sediments finally settle to the bottom of the stream, they suffocate life there.

In a study done by Purdue University, Indiana (Unrestricted cattle access to streams and water quality in till landscape of the Midwest doi:10.1016/j.agwat.2007.10.017) the upper 130 meters of a 1,005 meter stream was studied for the impacts from grazing cattle having access to that segment of the stream. The study showed that over a 12 month period nitrate concentration was not significantly affected, but led to a fourfold increase in TKN. Also there was a fivefold increase in total phosphorus, a fourfold increase in ammonium, an eleven fold increase in total suspended solids, a 13 fold increase in turbidity and a 36 fold increase in E.coli. However the study determined that dilution, in-stream process, and natural stream geometry downstream from the impacted section helped mitigate this pollution. Targeting the known areas where livestock are known to have access to the stream (see figure 8, page 24) with a suite of conservation practices that would limit livestock access could have a positive impact on E.Coli levels. The practices that can reduce bacteria will be promoted in the Black Creek Watershed. These practices include vegetative filter strips between small feeding operations and streams, relocation of small feeding operations away from streams, relocation of pasture feeding sites away from streams, promotion of alternative watering sites away from streams, and implementation of rotational grazing practices

In addressing soil erosion and bacteria, agricultural Best Management Practices that trap sediments, and thus reduce the amount of nitrogen and phosphorus runoff will be promoted within the watershed. Using No-till to maintain 75 percent crop residue on slopes greater than three percent, or residue management to maintain a minimum of 30 percent crop residue on a corn-soybean rotation holds soil in place and reduce overland runoff. Equivalent BMPs include combinations of terraces, alternative crops, cover crops, grass waterways, field borders, filter strips, etc. as determined by comparison of cropping factors (c) and practice factors (p) in the Revised Universal Soil Loss Equation (RUSLE).

According to the US Forest Service cropland erosion accounts for about 38% of the approximately1.5 billion tons of sediment that reach the nation's waters each year. Pasture and range erosion accounts for another 26%. (**http://www.dnr.state.md.us/forests/publications/buffers.html**)

Northern Missouri, originally prairie land, is now used primarily for crop and livestock production and is underlain by bedrock containing several relatively impermeable shale and clay layers. Surface waters are more turbid and are greatly affected by high rates of sediment deposition. These deposits, caused by soil erosion, result in poor aquatic habitat due to the fine, unstable materials of stream bottoms. Nitrogen and Phosphorus are often transported by becoming attached to sediments, and sediments are easily transported by runoff. Soil erosion is important to the movement of N into surface water. Nitrogen as ammonium (NH_4^+) is absorbed to the surfaces of clays and finer sediments or to the soil organic matter and is in organic-N forms in the soil organic matter. Nitrogen that degrades surface water is primarily transported in soil organic matter or as NO_3^-, a form that is completely water soluble. Phosphorus is primarily lost from farm fields through three processes: attached to the sediment that erodes from the field, dissolved in the surface water runoff, or dissolved in leachate and carried through the soil profile. On cultivated fields, most is lost through erosion, 85% of available phosphorus is bonded to the small soil particles comprising the sediment, whereas on non-tilled fields most phosphorus losses are dissolved in surface water runoff or in leachate. Cultivated acres with phosphorus-rich soils, however, can also lose significant amounts of phosphorus dissolved in the runoff or the leachate (**http://www.nrcs.usda.gov**). When an excessive amount of phosphorus and nitrogen is introduced, some plant species, such as algae, experience explosive growth. Overgrowth of algae clouds water and blocks sunlight from other plants and aquatic life, killing them or limiting their growth. When algae die, they sink to the bottom of the stream and begin to decompose. Bacteria feed on the decomposing algae and consume oxygen in the water. This process can deplete oxygen levels in the stream to a level that is too low to support other plant and animal life. In addition, dead algae creates more nutrient to fertilize even more algal growth, accelerating the depletion of oxygen in the stream.

Since cropland is 47.8 percent of the total land use in the watershed (See figure 4), nonpoint source pollution is potentially the greatest source of water pollution due to, soil erosion, nutrients, and pesticides. Increasing land consolidation and intensification of agricultural production practices increase nutrient runoff and sedimentation risks in the watershed. Causes of sedimentation include agricultural practices, eroding stream banks, stream access by livestock, and lack of riparian and drainage buffer strips.

A survey was prepared by the project manager and mailed to 150 landowners and operators in BCW. Although the response was limited those that did respond indicated that soil erosion from crop fields is a primary concern followed by nutrients and chemical runoff from crop fields (See Table 4). Soil erosion within the watershed is being caused by agricultural sources such as intensive farming of highly erodible soils and by stream bank erosion. Field Office Staff have completed a survey of aerial photography to identify areas along Black Creek where farming is being done close to the stream bank. These sites are a possible source of stream bank erosion. Heavy rainfall after spring planting but before crop emerges, and fall cultivation on marginal land contribute to sheet and rill erosion problems.

Table 4. Survey of Landowners in Black Creek Watershed Concerning Source of NPS Pollution.

Source of Nonpoint Source Pollution	Respondents
Sediment from soil erosion on crop fields	10
Sediment from soil erosion on pasture	3
Nutrient runoff from crop fields	7
Chemical runoff from crop fields	5
Stream bank erosion	7
Livestock having access to the stream	3

Prior water quality projects in the North Fork Salt River, such as the Mark Twain Lake/Salt River Basin watershed Conservation Effects Assessment Project (CEAP) provide valuable insights regarding land use practices, natural resource concerns, impacts of agricultural practices on water quality, and factors affecting producer adoption of conservation practices. As Black Creek is part of the greater North Fork Salt River watershed (See Figure 2) it was included in this project. Results from the Agricultural Resource Services (ARS) CEAP demonstrated that sediments, nutrients, and pesticides, are the primary water quality concerns in this watershed.

Nutrient and sediment runoff is associated with intensive fall tillage which causes rill and gully erosion. Practices such as: extending crop fields to the edge of rivers and creeks, fall application of nutrients and pesticides for spring-summer crops, minimal use of cover crops, and limited funds to install terrace practices add to this problem. On grazed pastures, natural resource concerns result from uncontrolled animal access to stream banks, heavy grazing, and limited buffering of heavy use areas from riparian areas.

Watershed Assessment

At the request of the Missouri Department of Natural Resource’s Water Protection Program (WPP), the Environmental Services Program (ESP) Water Quality Monitoring Section (WQMS) conducted a biological assessment of Black Creek. The objectives of this assessment were to assess the biological integrity and water quality of BCW and to determine stream habitat quality. Figure 6 shows the location of the biological monitoring sites in BCW. Macroinvertebrate and discrete water quality samples were collected at these sampling stations once each during the fall of 2009 and spring 2010 sampling seasons. Fall 2009 sampling was conducted on September 15 and 16 and spring 2010 sampling was conducted on April 13.

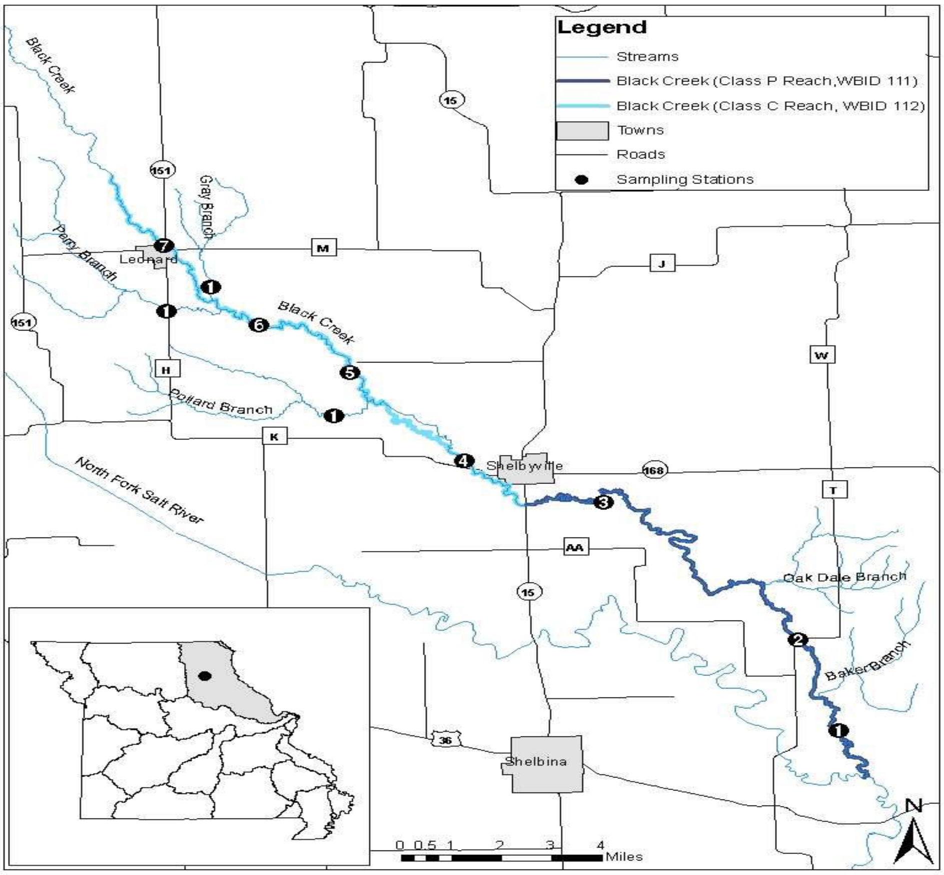


Figure 6. Map of Black Creek Sampling Stations. (Missouri Department of Natural Resources, Biological Assessment Report).

The MDNR Biological Assessment Report for Black Creek stated that Aquatic invertebrate samples were collected and analyzed following the Missouri DNR Environmental Services Program written standard operating methods contained in "Semi-Quantitative Macroinvertebrate Stream Bioassessment" by R. Sarver (2003). Invertebrate communities are judged to be impaired if the percent of sampling sites receiving a score of 16 or more is significantly less than the scores for reference streams in the same ecological drainage unit (EDU). Scores of 16 or more are considered to reflect unimpaired macroinvertebrate communities (Biological Assessment Report Black Creek – Shelby County September 2009 – April 2010).

Reference streams in this EDU received a score of 16 or higher on 73.3% of all samples. For Black Creek, 10 out of 12, (83.3%) samples scored 16 or higher (See Table 5). Because this is higher than the reference rate, the entire length of Black Creek was judged to have an unimpaired biological community.

This conclusion was based on data collected at the sampling sites identified in Figure 6. MSCI scores were in the partially supporting range at Black Creek stations #3 and #6 and in the fully supporting range at the remaining test stations during the fall 2009 sampling season. During the spring 2010 sampling season, all test stations scored in the fully supporting range.

Table 5. Missouri Department of Natural Resources Black Creek - WBID 0111, 0112 Aquatic Invertebrate Monitoring by MDNR, 2009-10.

Org	Site	Location	Date	Score
MDNR	112/13.5	Black Cr. ab. CR 127	Fall 2009	14
MDNR	112/13.5	Black Cr. ab. CR 127	Spring 2010	18
MDNR	112/8.9	Black Cr. bl. CR 226	Fall 2009	16
MDNR	112/8.9	Black Cr. bl. CR 226	Spring 2010	18
MDNR	112/3.0	Black Cr. ab. Hwy. K	Fall 2009	16
MDNR	112/3.0	Black Cr. ab. Hwy. K	Spring 2010	20
MDNR	111/16.4	Black Cr. ab. CR 349	Fall 2009	12
MDNR	111/16.4	Black Cr. ab. CR 349	Spring 2010	16
MDNR	111/6.0	Black Cr. ab. Hwy. T	Fall 2009	16
MDNR	111/6.0	Black Cr. ab. Hwy. T	Spring 2010	20
MDNR	111/2.3	Black Cr. bl. CR 478	Fall 2009	16
MDNR	111/2.3	Black Cr. bl. CR 478	Spring 2010	18

Nitrate + nitrite-N, total nitrogen, total phosphorus, and turbidity were elevated compared to U.S. EPA recommended reference condition values at all of the test stations during the spring 2010 sampling season. These results were possibly caused by surface runoff since the spring 2010 samples were collected during higher flows caused by a recent rain event. (See Figure 7 for detailed results.)

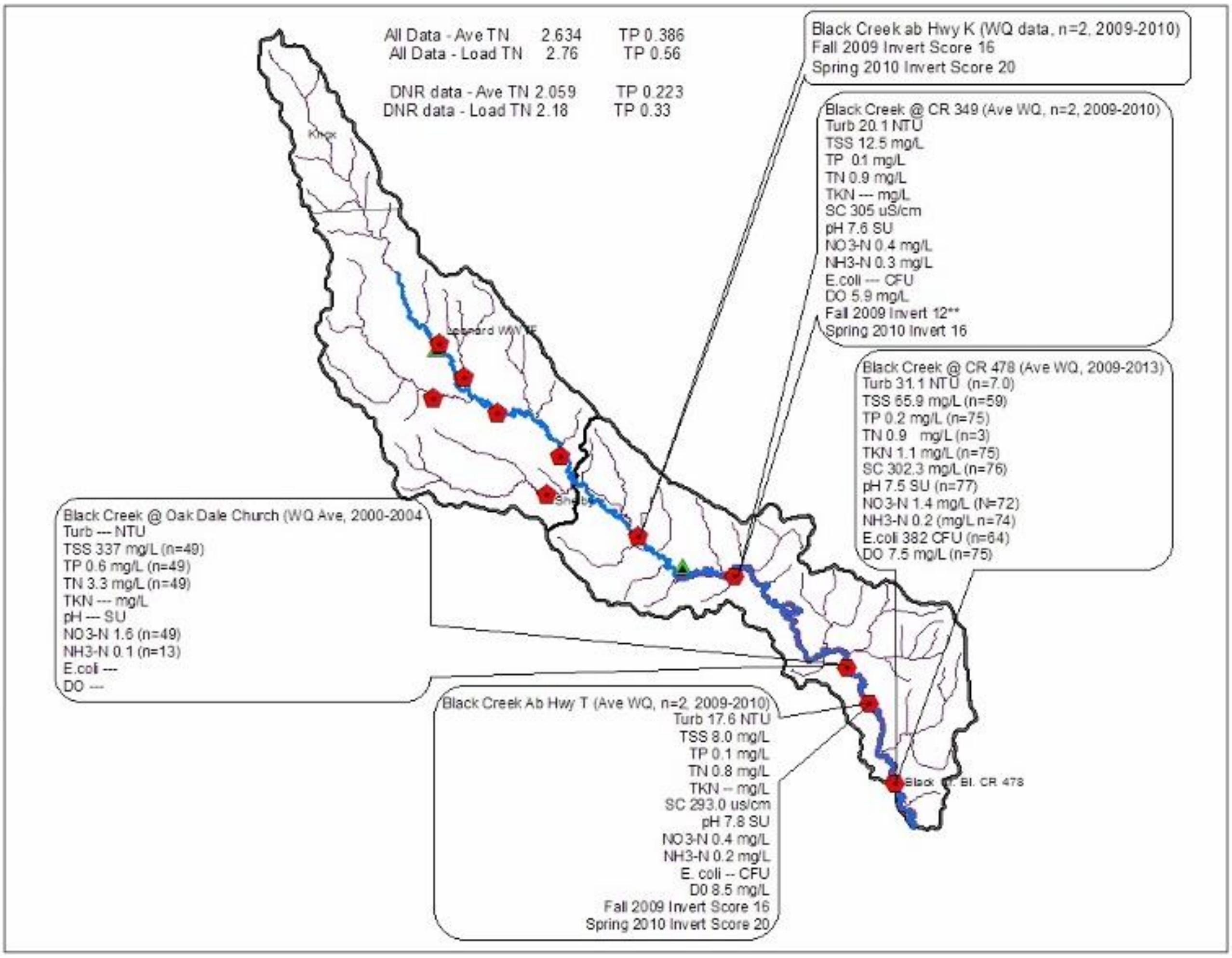


Figure 7. Map of sampling locations with sampling results.

Possible sources of impairment of Black Creek station #3 during the fall 2009 sampling season include low dissolved oxygen which may be caused by local geology, sedimentation, and poor epifaunal substrate. Epifaunals are bottom dwelling animals that live on the substrate surface. Possible sources of the low MSCI score at Black Creek station #6 during the fall 2009 sampling season include stream habitat conditions and the small stream size. The overall habitat score of 100 at station #6 was 75.2 percent of the North River biological criteria reference station score of 133. Black Creek station #6 had marginal habitat quality scores for pool variability, sediment deposition, channel flow status, and left bank stability and poor habitat quality scores for epifaunal substrate, vegetative protection of banks, and right bank riparian zone. Station #6 was also smaller, with a much narrower channel than the other Black Creek sampling stations, which could have led to less available habitat for macroinvertebrates to inhabit.

Pollutant Causes and Sources

The Black Creek TMDL identifies E.coli bacteria and low DO as major impairments. The watershed windshield survey helped verify a need for management practices to control sediment and potential nutrient loading. As recently as 2002, Shelby County ranked fourth in the state in hog production (USDA Ag Census, 2002). There has been a significant change in how and where hogs are produced in the U.S. over the past 50 years. Low consumer prices, and therefore low producer prices, have resulted in larger, more efficient operations, with many smaller farms no longer able to produce pigs profitably (http://www.epa.gov/oecaagct/ag101/printpork.html). Because of this trend swine production in this county has decreased to less than one-third the 2002 numbers. According to the 2007 Agricultural Census Shelby County has dropped to 9th in the state for hog production. As swine production moved from lots and pastures and became consolidated into large CAFOs a lot of these abandoned areas were converted to cropland. Because of this conversion, it is possible that high phosphorus levels exist in numerous crop fields, which can only be determined by proper soil testing.

Soil characteristics and land management practices strongly influence the potential for sediment and nutrient runoff from agricultural fields in BCW watershed. Almost entirely in the Central Claypan Major Land Resource Area, the landscape of this watershed is a level to gently sloping glacial till plain, mantled with loess of variable thickness.

Intensification of agricultural production contributes to nutrient runoff and sedimentation risks in this watershed. Increasingly, farms in the area are consolidating, reliance of producers on rented land and rental rates is increasing, and the size of equipment that producers are using is getting larger. These changes provide producers with additional opportunities to enhance productivity, but they also present challenges for implementing conservation practices. Larger-scale farmers typically have greater access to resources and higher management skills than the farmers they displaced. However, the variable rainfall patterns in northeast Missouri often provide producers with a very short window of opportunity for planting cover crops in the fall or the main crop in the spring. High land rental rates have discouraged some farmers from installing stream buffers through the CCRP, CREP, and other cost-share programs, and have encouraged other farmers to take land out of CRP or pastures and put it into row crops.

Forest land can significantly enhance water quality and wildlife habitat while providing landowners with alternative sources of income. Based on the experience of local NRCS and SWCD staff, this resource is under managed in BCW. Allowing livestock access to forest land can cause significant damage according to the Missouri Department of Conservation (MDC). According to MDC, livestock grazing can be highly destructive to forests. Livestock eat most vegetation they can reach, including tree regeneration, and herbaceous vegetation needed by wildlife for food and cover. The only vegetation that livestock typically avoid is thorny, undesirable plants (e.g. honey locust, multiflora rose, gooseberry, cedar) which can eventually take over grazed forests. Livestock also trample tree roots, which causes decay that eventually spreads into the main trunk of the tree. Livestock often compact forest soils, destroy creek banks, and eat exotic vegetation found in hay and pasture lands and then distribute seeds in the forest through their manure, which causes new infestations.

On row crop fields, nutrient and sediment runoff is generally associated with intensive spring and fall tillage which can cause rill and gully erosion, extending crop fields to the edge of rivers and creeks, fall application of nutrients and pesticides for spring and summer crops, minimal use of cover crops, and limited funds for installing terraces and other practices. On grazed pastures, natural resource concerns result from uncontrolled livestock access to stream banks, heavy grazing, and limited buffering of heavy use areas from riparian areas. Livestock grazing in pastures deposit manure onto land surfaces, making it possible for both bacteria and nutrients to enter surface water with runoff. In addition, livestock often have direct access to water bodies. During dry periods when stream flows are low, livestock concentrate around streams which increases streambank trampling and direct deposition of waste into the water. These wastes can cause low levels of dissolved oxygen, high levels of ammonia, and excessive algal growth. Figure 8 shows the location of recent livestock operations within BCW as determined by local soil and water conservation district staff. The two CAFOs are identified as such. The black dots represent cattle operations.

Stream data from the North Fork Salt Watershed, which includes BCW , were collected by MEC Water Resources, Inc. (MEC), U.S. G.S, and MDNR from 1971-2012. Summary data for Black Creek shows the following pollutant loadings in mean lbs/day: Ammonia Nitrogen, 4.07; Nitrate Nitrogen (NO3-), 63.43; Total Nitrogen, 127.77; Total Phosphorus, 22.18; and Total Suspended Solids, 12,962. Nonpoint source runoff from agricultural lands is believed to be responsible for these elevated nutrient and sediment levels (Mark Twain Lake - North Fork Salt Watershed Project: Integrated Conservation Practice Implementation, Monitoring, and Outreach Mississippi River Basin Healthy Watersheds Initiative, 2010).

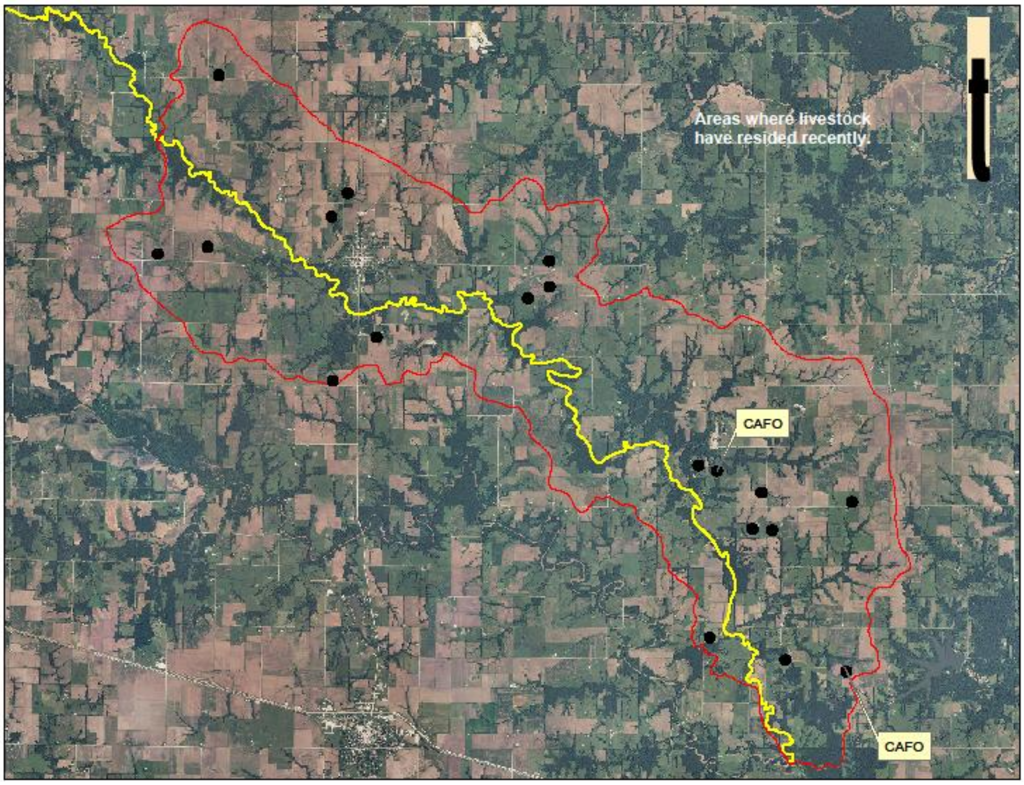


Figure 8. Location of Livestock Operations in Black Creek Watershed.

Additional data from the MDNR (2010) shows that Total Nitrogen was relatively low during the fall 2009 sampling season, ranging from 0.32 mg/L at Black Creek station #1 to 0.68 mg/L at Black Creek station #5. Values were much higher during the spring 2010 sampling season, ranging from 1.10 mg/L at Black Creek station #2 to 1.27 mg/L at Black Creek station #3. All of the spring 2010 values were above the U.S. EPA recommended value of 0.71 mg/L for the Level III Central Irregular Plains ecoregion (MDNR Biological Assessment Report).

Bacteria data collected in the Black Creek Watershed shows highest concentration in the southern part of the watershed. This area has two confined animal feeding operations and several pasture based cattle operations. Cattle have been observed in Black Creek in part of the testing locations.

Chapter 3. Element B*: Load Reductions*

Point Sources

Point source discharges are permitted through the National Pollutant Discharge Elimination System (NPDES) and can be grouped into three subcategories: municipal and industrial wastewater treatment dischargers (WWTPs), municipal and industrial storm water dischargers, and concentrated animal feeding operations (CAFOs). The only potential municipal point source discharge in BCW is the Shelbyville Wastewater Treatment Facility (WWTF), which has a design flow of 0.07 million gallons per day (MGD). Black Creek is on the 2012 303(d) list of impaired waters and the Shelbyville Wastewater Treatment Facility is cited as a point source contributor of bacteria which is affecting 19.4 miles of Black Creek. Figure 9 shows the runoff chart for E-coli bacteria developed by MDNR. Table 6 shows the percent reduction calculation formula.

The facility is required to disinfect, but until that happens the facility may be a source of bacteria. Storm water discharges from the town of Shelbyville is not considered to be a significant source of point source pollution as it is not a MS4 regulated community, any run off would be considered nonpoint source. The one permitted CAFO in BCW, if operating correctly, should not discharge any wastes. Shelbyville is currently working to pass a bond initiative to raise funds to bring their lagoon into compliance with the MDNR (Shelby County Herald, October 24th, 2012). At the Public Meeting held April 8th, 2014, the Mayor of Shelbyville indicated that they are spending 1.5 million dollars to bring their water treatment facility up to DNR specifications. The NPDES permit process regulates WWTPs and when followed will maintain the water quality standard compliance for the facility.

Nonpoint Sources

Nonpoint sources typically involve land activities that contribute bacteria, sediment, and/or nutrients to surface water as a result of runoff during or after rainfall events or periods of snow melt.

A Total Maximum Daily Load, also known as a TMDL, is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet water quality standards. According to the Missouri DNR website (http://www.dnr.mo.gov/env/wpp/tmdl/wpc-tmdl-progress.htm), a TMDL is currently in the process of being developed.

The blue curve represents the target load, in this case *E. coli* colony forming units per day (206 CFU /100 ml * flow * conversion factor = CFU / day). The red points represent the observed E. coli CFU/day within each of the five flow conditions. All points above the target (blue curve in Fig 9) are exceeding the standard. The table represents the reduction necessary, within each flow range, to bring the points above the blue curve to the target level. A 10% of the total assimilative capacity of the water body was allocated to a margin of safety (MOS).

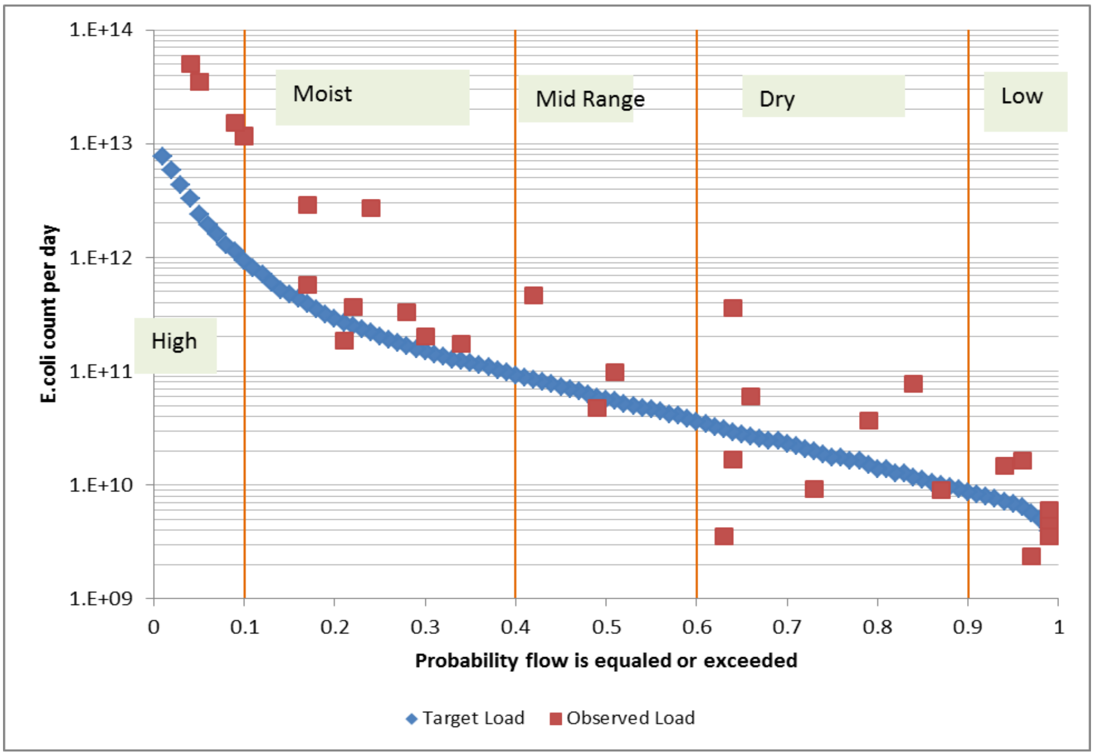


Figure 9. Black Creek E-coli Load Duration Curve.

Table 6. Calculated Percent Bacteria Reduction Within each Flow Range.

Probability Flow (%)	Condition	Target CFU/day	Observed CFU/day	Reduction
90 to 100	Low Flow	6.84E+09	1.56E+10	61%
60 to 89	Dry	1.74E+10	9.23E+10	83%
40 to 59	Mid-Range	5.68E+10	2.13E+11	76%
10 to 39	Moist	4.74E+11	3.61E+12	88%
0 to 9	High Flow	2.40E+12	3.09E+13	93%

The % reduction =
(Observed – Target – MOS)/Observed) * 100

Black Creek Watershed has a population of 821 based on the 2010 census. Of the 821, 552 live in the town of Shelbyville which leaves a total of 277 living in the rural area of Black Creek. Figure 10 shows the locations of homes within the watershed. These homes located within the rural area of the watershed will have a private septic system. According to the website, http://www.nesc.wvu.edu/septic_idb/missouri.htm#quickfacts, up to 50% of all septic systems in Missouri are presently failing. Pumping of septic tanks is a routine maintenance procedure and should take place every three years for a household of four people. Many of the existing septic systems could possibly be the original 500-gallon metal septic tanks that were installed when electrification came to the area. Many older homes may not have a septic tank and laterals (or lagoon) but a straight pipe to a cesspool. This can only be determined if there is a watershed wide survey that people will respond too. These failing septic systems that are currently in place need to be replaced. Education is needed to encourage the proper maintenance of the septic systems that are still functional. The Black Creek Steering Committee believes septic systems are a possible contributor of bacteria, along with cattle, natural degradation of organics, etc. The Steering Committee feels that at this time due to limited funds and personnel the best approach would be to use an information education campaign to alert homeowners of the concern and to make them aware of options and other programs that maybe available if they have a non functional sewer system. The Steering Committee will contact the Shelby County Health Department to explore the possibility of forming a partnership with other entities to develop a survey and to conduct an educational campaign on the proper installation and maintenance of rural septic systems.

Figure 10. Location of Homes with On-site Systems in BCW

The Shelby County SWCD has identified 17 locations in the watershed that have or recently had cattle present in Black Creek or smaller tributaries. (See Figure 8, livestock operations map on page 23). A 50 percent reduction of the cattle standing in the streams could be accomplished through a combination of stream fencing, providing shade outside the riparian corridor, locating feeding areas some distance from the stream and providing off-creek water sources, such as creek pasture ponds. Achieving 100 percent reduction of cattle standing in streams would require the installation of alternative drinking water sources and fencing for all livestock producers in the watershed. The feasibility of achieving 100 percent reductions of cattle standing in the streams is low. Work done in the Shoal Creek watershed in southwest Missouri in Barry County indicates that a reduction of the fecal coliform loadings in surface runoff could be attained with vegetated filter strips at the downstream edge of the pastures. The work done indicates that a 30 foot filter would provide a 50 percent reduction and a 40 foot filter would provide a 66 percent reduction in bacterial contamination. If the source of bacteria is determined to be cattle then the local steering committee is willing to promote BMPs to help lessen water quality impacts from cattle. Those BMPs that will be promoted are livestock exclusion, alternative watering source, woodland protection and vegetative buffers. Sampling in Black Creek for e.coli shows locations of highest concentrations and distances from potential livestock sources. (Appendix G)

According to University of Missouri Extension Assistant Professor Robert Broz, a study from Kansas State University demonstrated the correlation between phosphorus levels in water and bacteria counts. In addition to bacteria, manure contains phosphorus. Sampling for bacteria typically includes phosphorous as an additional way to determine trends of impairments. By reducing manure deposits in close proximity of the stream and soil erosion, a major contributor of phosphorus runoff, we can speculate that there will be a reduction in bacteria loads as well. Work done in a study of the Illinois River (www.illinoisriver.org/CEDocuments) showed the concentrations of total phosphorus and bacteria increase dramatically as the stream flow rate increases. Such behavior is a strong indicator that a significant part of the phosphorus loading is caused by non-point sources. The indicator bacteria increased with increased flow rate also. This is a good indication that the non-point sources of the total phosphorus and bacteria may be linked.

A review of the Lower Kansas WRAPS 9 Element Plan Overview (www.kswraps.org) shows supports for this assumption, that if you are reducing phosphorous levels, lower bacteria counts should be evident in water quality samples. The accumulated affect of the BMP load reductions directly tie to the needed load reductions of the watershed plan. The specific practices each contribute to the overall reduction of sediment loss which will directly affect nutrient and bacteria loading. As modeling was not done for bacteria, there is no bacteria load reduction calculation at this time. The Steering Committee decided to use phosphorous load reduction instead. The assumption is that if you are reducing phosphorous, lowered bacteria counts should be evident in water quality samples.

Table 12 shows the amounts of nitrogen, phosphorus and sediment that are predicted to be reduced on an annual basis compared to the baseline if the goals established for this plan are met. Also stream bank exclusion, alternative watering source and woodland protection should have a positive effect in reducing bacteria levels, by keeping livestock out of the streams, and out of the riparian woody areas.

By reducing P we should see a direct reduction in aquatic plant growth. As these plants grow, die and decay they remove available oxygen from the water and create areas of low dissolved oxygen. By reducing nutrient loading we hinder excessive aquatic plant growth and should see appropriate levels of dissolved oxygen in the water. Nutrients move in runoff water and in soil erosion.

Nutrients are food for algae, and water with high amounts of nutrients can produce algae in large quantities. When these algae die, bacteria decompose them, and use up oxygen. This process is called eutrophication. Dissolved oxygen concentrations can drop too low for fish to breathe, leading to fish kills. Nitrate and phosphate are nutrients. Nitrate is found in sewage discharge, fertilizer runoff, and leakage from septic systems. Phosphate is found in fertilizer and some detergents. Non-point source pollution needs to be addressed in order for needed improvements in water quality to be realized. Cropland runoff should be addressed to lower the export of nutrients and sediments.

The concern for agricultural runoff is not only excess sediment, but also the potential for the introduction of nutrients into Black Creek. However, keeping the soil on the field makes the most ecologic and financial sense. Prevention of erosion is a first step; if erosion occurs, keeping the sediment on the hillslopes is a second step.

Some things that can be done to help reduce the amount of sediment entering Black Creek and thus reducing the amount of nutrient resulting in an improvement of the low dissolved oxygen problem are:

- Increase adoption of residue and tillage management,
- cover crops, and conservation crop rotations to reduce sediments and nutrients in runoff,
- stabilize eroding gullies,
- nutrient management to match fertilizer addition to crop need,
- promote the use of precision agriculture techniques to apply nutrients,
- promote the use of prescribed grazing systems,
- develop and encourage adoption of a plan to address all resource concerns with the latest technology,
- BMPs at the tract level,
- promote the establishment of permanent vegetation, and Improve wildlife habitat.

The anticipated long-term outcomes of this WBP are: a significant decrease in sediment deposited into Black Creek, resulting in decreased turbidity, decreased levels of adsorbed nutrients, and improved dissolved oxygen content.

Soil and Water Assessment Tool

The Soil and Water Assessment Tool (SWAT) model developed by United States Department of Agriculture-Agricultural Research Service (ARS) was selected to evaluate the effectiveness of conservation practices in reducing nonpoint source pollutant loads in BCW. An ArcGIS Interface for SWAT (ArcSWAT 2009) was used for this study. The model was used to assess sediment and nutrient loads for 19 sub watersheds within BCW and to predict load reductions for selected agricultural best management practice (BMP) scenarios. Modeling was conducted by University of Missouri Extension Specialist Robert Broz and Graduate Student Nayereh Ghazanfarpour. The objectives of the modeling were to accurately and efficiently quantify sediment and nutrient (nitrogen and phosphorus) losses from the watershed, to identify and prioritize critical sub watersheds and evaluate the relative importance of managing them, and to evaluate the effectiveness of alternative BMPs in reducing pollutant loads from BCW.

Because running scenarios with SWAT is costly, modeling was not done for E. coli but for practices that have a strong correlation with E.coli. A group of researchers from the ARS have done SWAT modeling for E. coli on a stream in Pennsylvania that was fed by several smaller tributaries. Their research also included collecting streambed sediments and surface water from three sites along Beaverdam Creek in Beltsville, Maryland. Then they added some dairy manure slurry to the samples, which increased nonpathogenic *E. coli* levels in the sediments and water.

Lab studies indicated that the bacteria survived much longer in the sediments than in the water and that they lived longer when levels of organic carbon and fine sediment particles were higher. They also found that when organic carbon levels were higher, water temperatures were less likely to affect survival rates and they published the first evidence that *E. coli* can over winter in the sediment.

The ARS team also evaluated whether adding data about the deposition and release of *E. coli* in streambeds would improve computer simulations of microbial water quality. They collected 3 years of data on stream flow, weather, and *E. coli* levels in water and sediments from the steam in Pennsylvania. Then they used the information to calibrate the Soil and Water Assessment Tool (SWAT).

The resulting simulations indicated that bacterial releases from the streambed persistently degraded water quality and that pasture runoff was the main contributor to *E. coli* levels in nearby streams during temporary interludes of high water flows. The team concluded that SWAT simulations would overestimate how much pasture runoff contributes to surface water contaminated with E. coli, unless the model included data on *E. coli* levels in streambed sediments *(*This research is part of Water Availability and Watershed Management (#211) and Food Safety (#108), two ARS national programs described at (*www.nps.ars.usda.gov*).

SWAT modeling was conducted on an annual basis for the years 2000 to 2010. Average annual loads were calculated for sediment, total phosphorus and total nitrogen. Results are presented in Figures 11 to 13. These values were used as the baseline loading conditions which were compared to the simulated loads from agricultural BMP scenarios.

Bacteria and e.coli testing (Appendix G) show high levels of bacteria in sub-basins 16, 13/14, 18 and 19. Several of these sub-basins were model as being high for sediment runoff and secondary for phosphorus runoff. Sub-basins 16 and 19 will have BMP implementation that are associated with reducing bacteria counts. Sub-basins 13/14 and 18 will be part of the extended BMP implementation project for bacteria reduction.

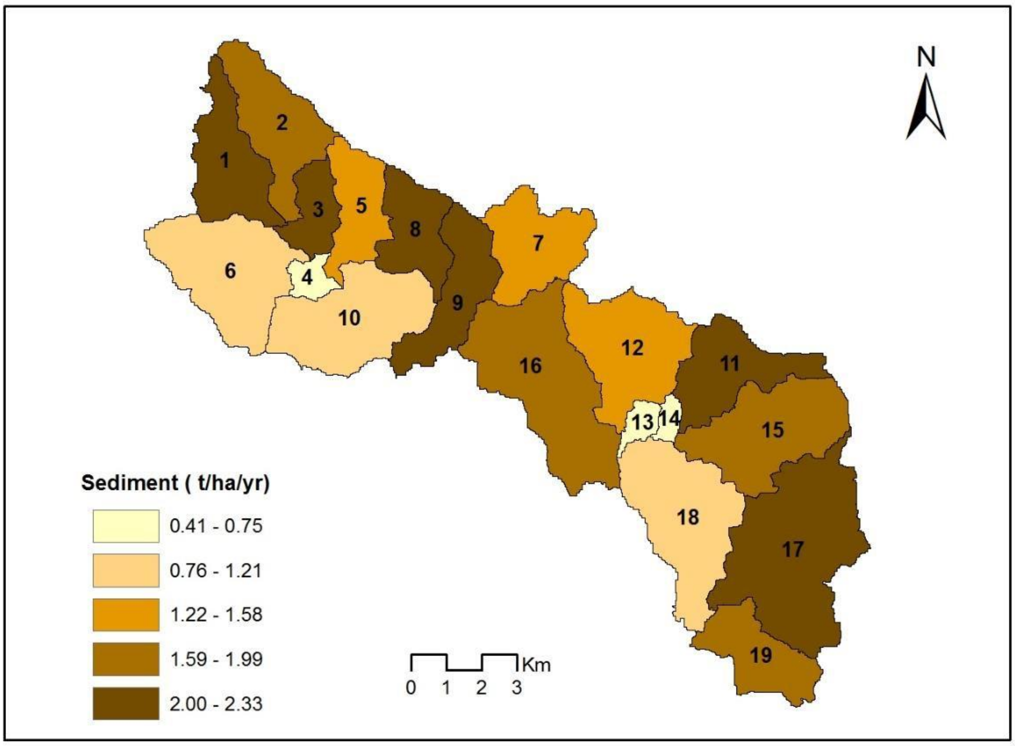


Figure 11. Sediment loading (tons/ha/yr) in each sub watershed.

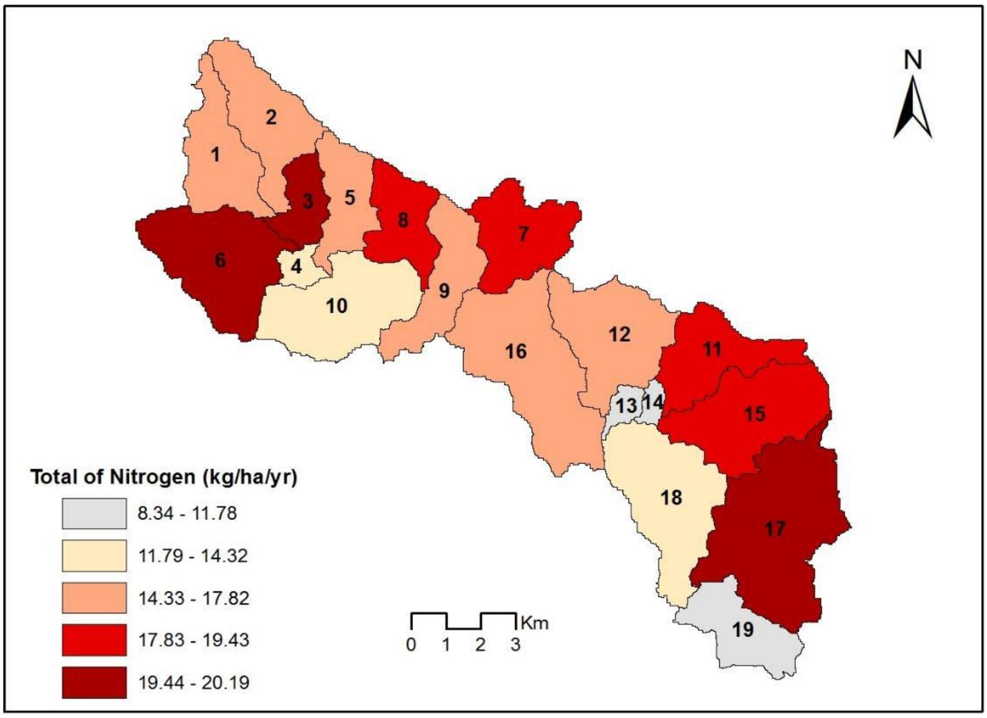


Figure 12. Total nitrogen loading (kg/ha/yr) in each sub watershed.

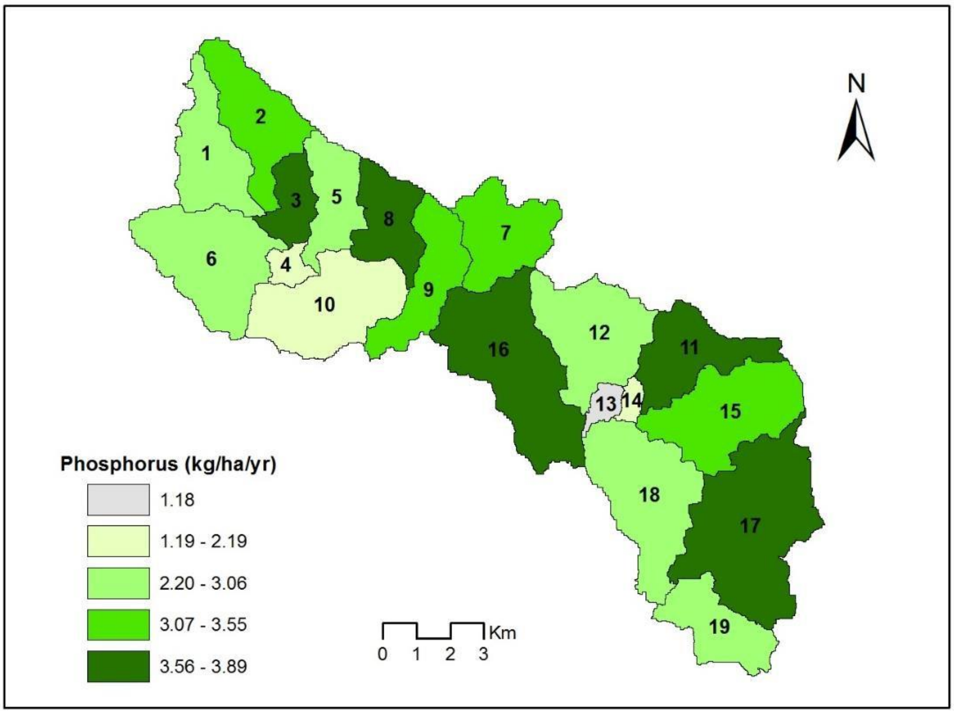


Figure 13. Total phosphorus loading (kg/ha/yr) in each sub watershed.

The size of the 19 sub watersheds vary from 186 acres to 3961 acres in size. In total, 10 sub watersheds were selected in this regard (see Figure 14). Those 10 selected are highlighted in green.

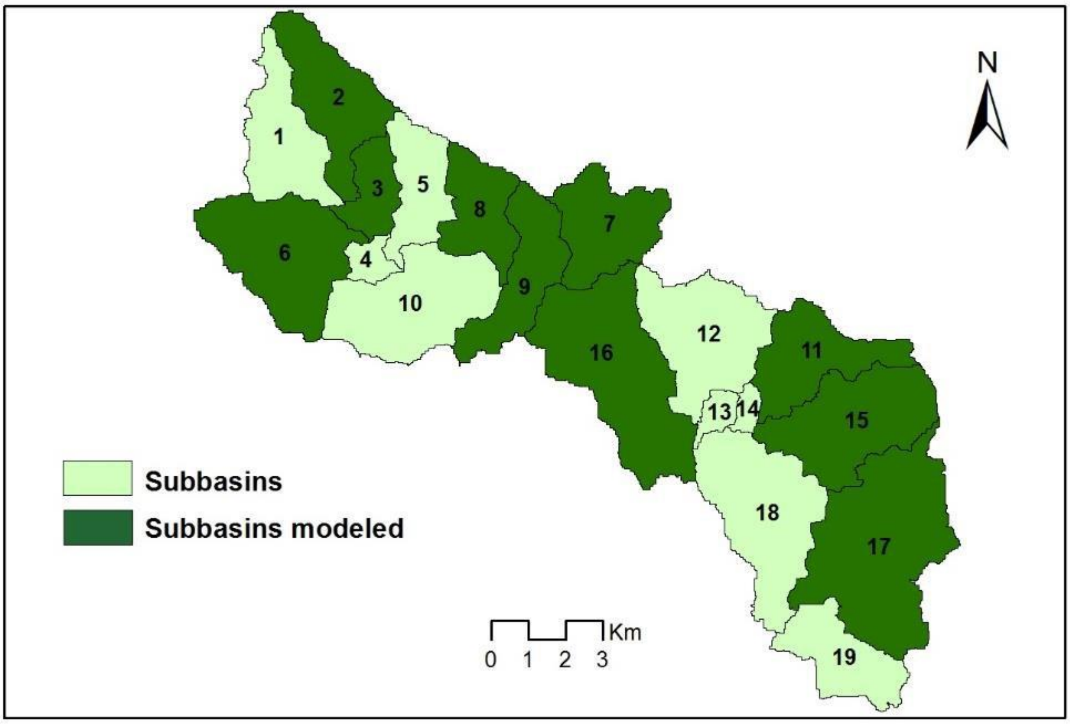


Figure 14. 10 Sub basins modeled in BMP scenarios (Dark Green).

This study examined load reductions resulting from the agricultural best management practices. The model scenarios were only performed in the sub watersheds with the highest baseline loading (Table 7).

Table 7: Sub watersheds with the highest baseline loading (Highlighted in blue).

Sub watershed number	Size in acres	TN (lbs/ac/yr)	TP (lbs/ac/yr)	Sediment (t/ac/yr)
1	1730	14.52	2.73	0.85
2	1945	15.87	2.95	0.79
3	838	17.98	3.35	0.84
4	326	12.75	1.81	0.30
5	1233	15.81	2.55	0.59
6	2937	17.49	2.57	0.49
7	1329	16.89	3.10	0.64
8	1423	17.27	3.35	0.91
9	1804	15.13	3.16	0.89
10	2521	12.43	1.95	0.37
11	1527	17.06	3.46	0.94
12	2195	14.61	2.66	0.59
13	279	7.43	1.05	0.17
14	186	9.57	1.54	0.17
15	2607	17.31	3.04	0.75
16	3463	15.66	3.27	0.81
17	3961	17.6	3.46	0.87
18	2839	12.08	2.48	0.45
19	1341	10.49	2.54	0.75

There are some current best management practice scenarios which have been implemented by MRBI from 2008 to 2012 (Figure 15). As it can be observed in the map, most the conservation practices applied in the watershed have been implemented on critical areas obtained in this study.

Color indicators were used to identify the sub-watersheds that were modeled as being the highest contributors for sediment, nitrogen and phosphorus. The darker or richer the color, the more prone an area is to contribute pollutant load. In each case certain sub-watersheds have certain characteristics that made them more vulnerable to nutrient and soil loss.

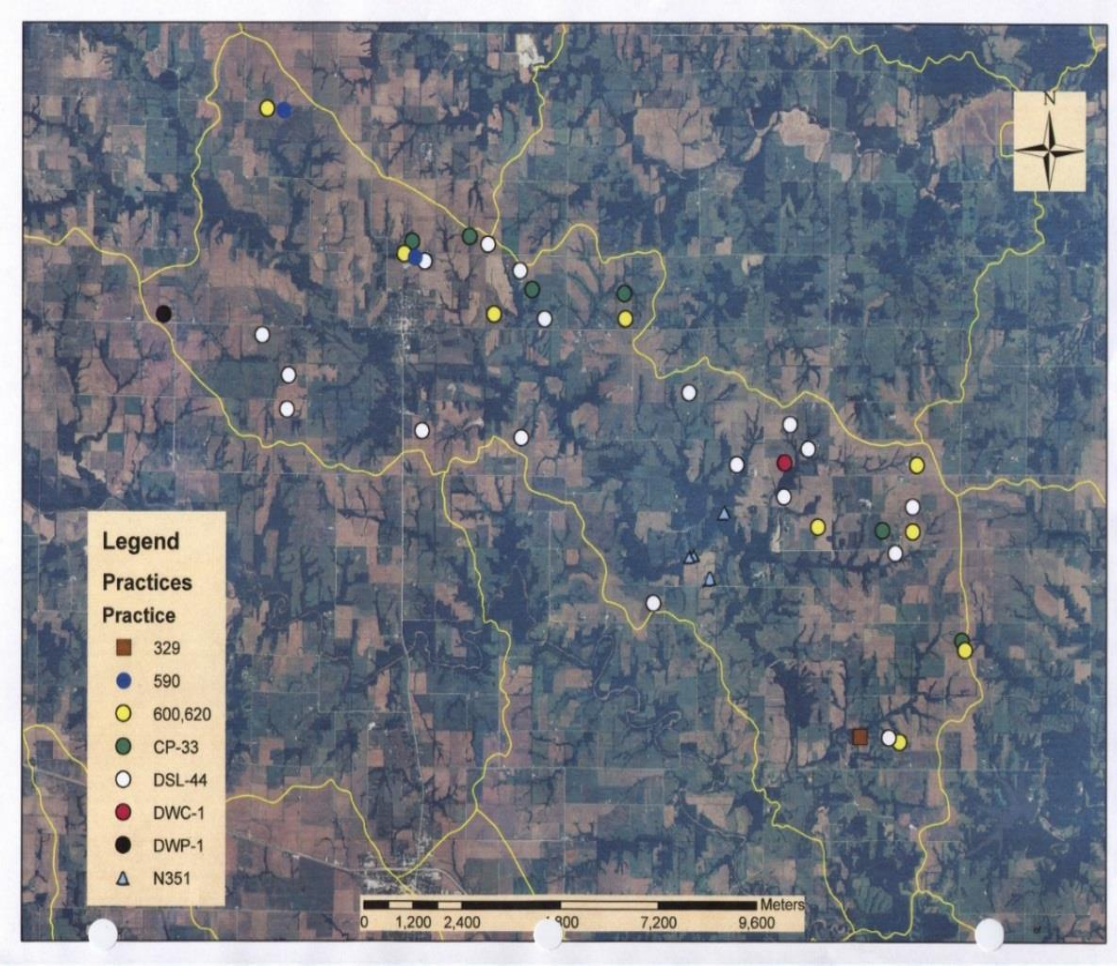


Figure 15. Map of Implemented BMPs by MRBI and State Cost Share 2008-2012

Practices that were implemented through the MRBI and the state cost share program are conservation crop rotation, nutrient management, terraces, underground outlets, grade stablization structure, Conservation Reserve Program (CRP) habitat buffer, sediment retention structures, and well decommisioning. In addition 522.1 acres of riparian acres are being protected by long term easements through the Wetland Reserve Program (WRP) (See Figure 16). Also 55,702 feet (61.39) acres of the CRP practce CP-33, Upland Wildlife Habitat Buffer have been installed. These are 30 foot to 120 foot wide buffers along the edges of crop fields.

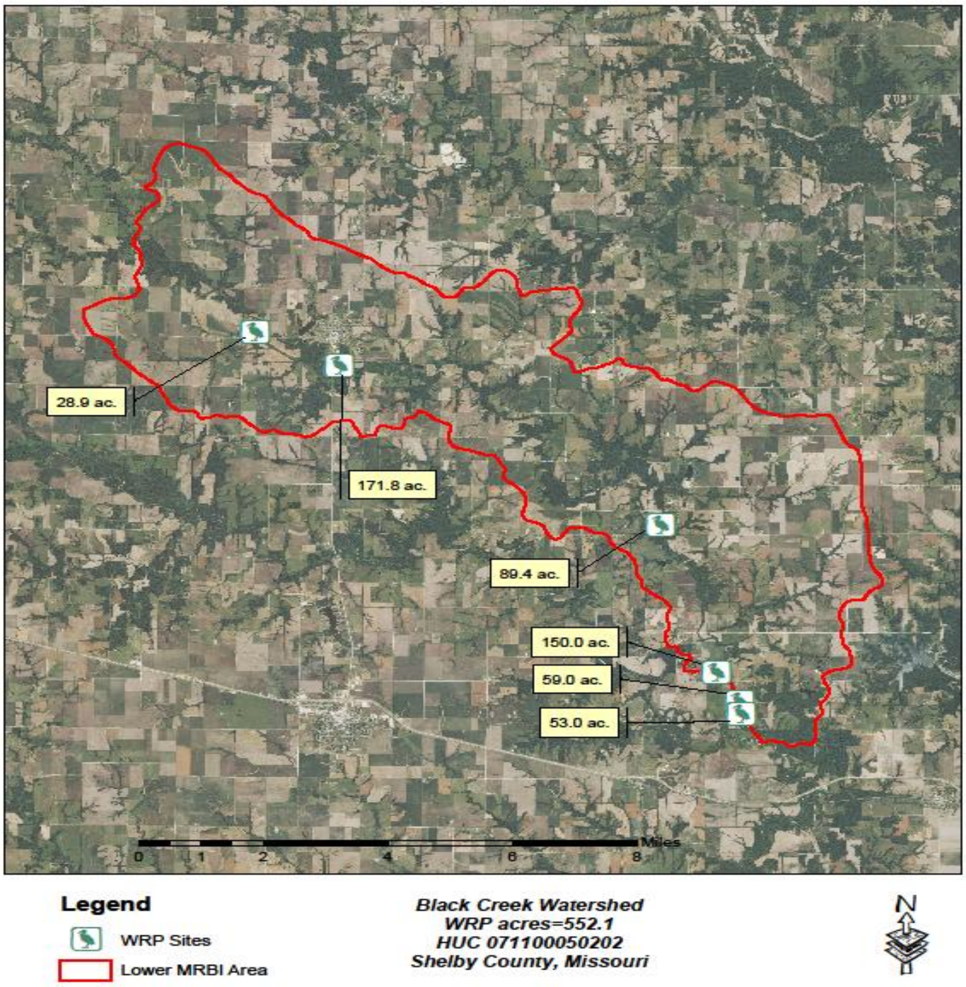


Figure 16. Black Creek Watershed Wetland Reserve Program (WRP) Easements.

Identifying Load Reduction Targets

Sediment load reduction

Results in Table 8 show that filter strips and terracing provide the highest sediment load reduction. They are expected to produce 48.5% and 44.6% sediment load reductions, respectively. Simulation results revealed that application of cover crops reduces sediment loss effectively as compared to the baseline scenario. Sediment reduction rates from radish cover crop is less than from other cover crops. The vegetative biomass of cover crops increases the amount of transpiration and decreases the impact of rain drops that can break soil aggregates. As a result of this land cover, there is an increase in water infiltration and decrease in surface runoff and runoff velocity. Planting cover crops such as cereal rye, annual rye, oats, red clover and radish after the harvest of corn and soybeans in the BCW reduced sediment loss by 37%, 38%, 41%, 42% and 5% respectively (Table 8). No-tillage and reduced tillage agriculture tend to reduce sediment loads because of increased vegetative and residue cover that protects the soil from erosion. Application of no-tillage and reduced tillage systems on selected sub watersheds decreased the sediment yield by 7.9% and 10.6%, respectively. Nutrient management (i.e., reduced nitrogen and phosphorus application) actually increased sediment yield slightly due to slower crop growth. However, the increased was small (<1%) and would not likely be significant. The sediment loads from the stream exclusion practice were not captured because information on the channels was not collected. Inter-seeding of fescue with red clover in the pastures increased sediment yield slightly. However, the increased was small, i.e., <0.1% for inter-seeding with a rotation of 2 years and < 3% for inter-seeding each year, and would likely be negligible. The least effective BMP is woodland protection which decreased sediment loss by 0.01%.

Nitrogen load reduction

The highest nitrogen load reduction in the BCW belongs to annual rye, oats and cereal rye cover crops scenarios, they reduced total of N losses by 25%, 24% and 22%, respectively. The other simulated cover crops i.e. red clover and radish decreased total N by 12% and 0.8%, respectively (Table 8). Cover crops were planted after the October corn and soybeans harvest and produced high above-ground biomass. The high biomass production resulted in increased uptake of nitrogen from the soil, which otherwise would have been lost in tile drainage. Application of filter strips showed a 12.9% reduction in total N loss. This was mainly due to a decrease in total organic nitrogen and surface runoff losses. There was a 4% reduction in the total loss nitrogen in the BCW for nutrient management, terracing and inter-seeding with rotation of 2 years practices. There is no substantial reduction in total nitrogen loss from the application of no-till and reduced tillage systems and also stream exclusion which decreased total of nitrogen by less than 1%, separately. Inter-seeding each year and also woodland protection practices increased the total nitrogen loss by less than 1%. Because of slow infiltration, due to the heavy clay pan which lies underneath the top soil layer, water drainage into groundwater is minor compared to surface water discharge (Blevins et al. 1996; Kitchen et al. 1998). When groundwater recharge occurs, it is primarily through preferential pathways such as decayed root channels or soil cracks that develop during droughts (Blevins et al. 1996). Percolation through the claypan is especially low in spring and early summer (the period of most herbicide and fertilizer applications) because the clay within the argillic horizon has swollen with fall and winter precipitation (Kitchen et al. 1998). Thus, compared to other agricultural areas of the US Midwest, groundwater is less vulnerable to contamination

Phosphorus load reduction

The highest phosphorus load reduction was provided by filter strips which was reduced by 38%. Implementation of terraces on selected fields gave a 30% reduction in P losses. Planting cover crops resulted in significant reductions in total of phosphorus losses by 32%, 28%, 27%, 27% and 3% for red clover, oats, annual rye, cereal rye and radish, respectively. The total phosphorus subbasins loads at the outlet of the entire watershed reduced by 3% for no-till and reduced tillage systems, separately. Nutrient management practice i.e., 25% reduction in nitrogen and phosphorus application rate reduced the total P loss by about 2%. Inter-seeding of fescue with red clover in the pastures of critical sub watersheds represented about 5% decrease in the total phosphorus load. The phosphorus load reduction from stream exclusion and woodland protection practices were less than 1%.

Table 8: Load reduction (%) at the outlet of the BCW under BMP scenarios

BMPs	**Total of Nitrogen**	**Total of Phosphorus**	**Sediment**
No Till	-0.39	-3.01	-7.93
Nutrient Management	-4.51	-2.00	0.26
Terracing	-4.37	-30.25	-44.64
Filter Strips	-12.94	-37.58	-48.47
Cover Crop (Cereal rye)	-21.98	-26.63	-36.74
Cover Crop (Annual rye)	-25.05	-27.14	-37.97
Cover Crop (Oats)	-24.34	-27.99	-40.99
Cover Crop (Red clover)	-12.19	-31.97	-41.69
Cover Crop (Radish)	-0.78	-1.42	-4.95
Reduced Tillage	-0.41	-3.19	-10.60
Inter-seeding (Rotation 2yr)	-3.72	-4.66	0.05
Inter-seeding (Each year)	0.69	-4.54	2.97
Stream Exclusion	-0.09	-0.13	0.00
Woodlands protection	0.05	-0.04	-0.01

Chapter 4: Element C – NPS Management Measures Best Management Practices

In every watershed, there are specific locations that contribute a greater pollutant load due to soil type, proximity to a stream and land use practices. By focusing BMPs in these areas; more significant reductions in pollutant loads can be achieved. The SWAT model identified 19 sub watersheds. Each sub watershed represents approximately three percent of the Black Creek Watershed and average in size approximately 1,000 acres. Ten of these sub watersheds were identified as critical sub watersheds. The SWAT model indicated that targeting BMPs in these ten critical sub watersheds will have the biggest impact in reducing NPS pollution and addressing the problem of low dissolved oxygen and to some extent the bacteria problem in BCW. Figure 14 shows the ten dark green colored sub watersheds that were identified as critical watersheds in BCW.

BMP scenarios were conducted for the same 11-year period (2000 to 2010) as the baseline. The average annual loads for sediment, total P and total N were calculated for each BMP scenario in the selected sub watersheds which were considered critical areas, and then compared with values obtained from the baseline conditions (See Figures 17 to 19 and Table 8). The difference in average annual load between a BMP scenario and the baseline was used to estimate the load reduction achieved by BMP implementation (Table 8).

Several landowner meetings were held to obtain local input and to verify practices that local producers are using. From these meetings of local producers a Steering Committee was selected from the participants. A group of BMPs were identified by the Steering Committee based on survey results and the local knowledge and expertise of the Steering Committee, and the NRCS and Shelby County SWCD staff (See Table 9). Best Management Practices modeled by SWAT were no-till, nutrient management, terracing, filter strips/field borders, reduced tillage, interseed 2 years, interseed each year, stream exclusion, woodland protection and various cover crops. We modeled for this selected group of practices because producers identified them as practices they felt would help reduce nutrient loss and soil erosion and that they, the producers, would be willing to implement, based on the survey which was mailed to 150 landowners and operators. The response rate on the survey was less than 10% so Soil and Water Conservation District employees used interviews, surveys and one-on-one discussions with local landowners to develop a list of feasible management practices. Respondents were allowed to choose more than one BMP.

Table 9. Best Management Practices Producers are willing to Implement.

Best Management Practice willing to Implement	**Number of Respondents**
Terraces	11
No-Till	9
Precision Agriculture	9
Grass Waterways	8
Cover Crops (Single Species)	6
Cover Crops (Multiple Species)	6
Field Borders	6
Filter Strips	7
Converting Cropland to Pasture	1
Fence Livestock out of Stream	2
Rotational Grazing	2

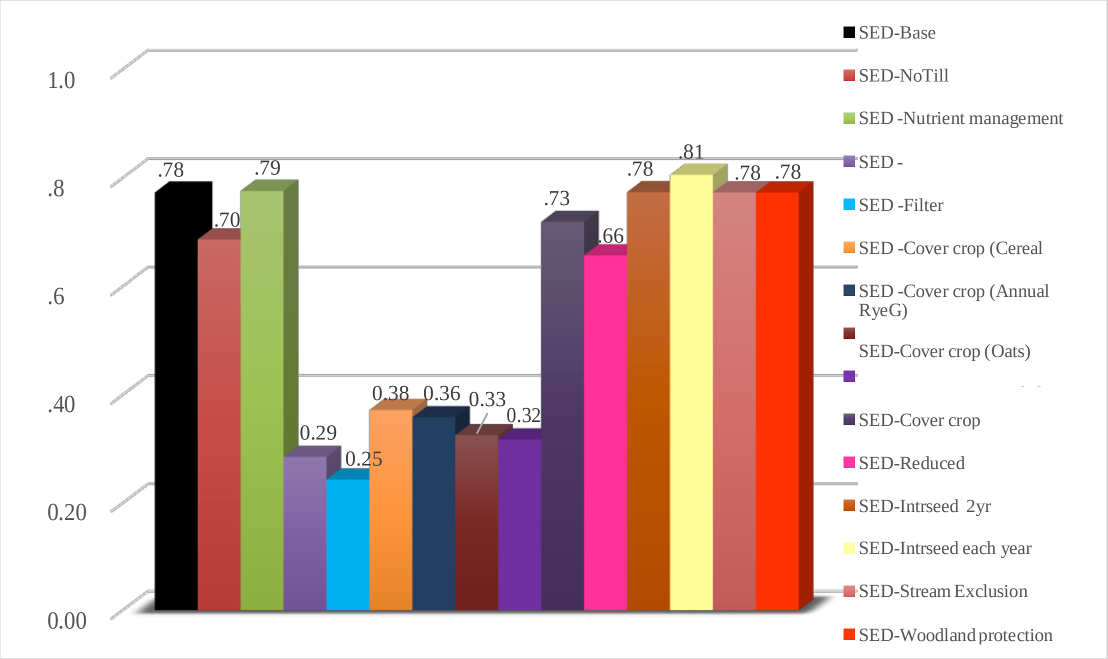


Figure 17. Sediment loading (ton/ac/yr) for each BMP scenario in selected subwatersheds of the BCW.

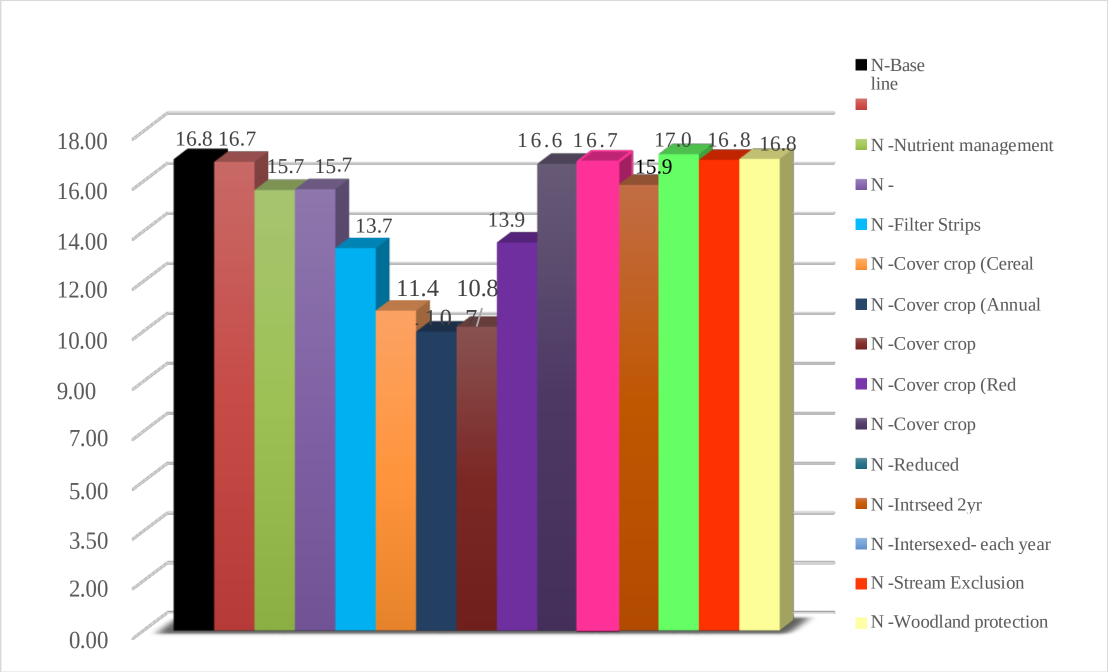


Figure 18. Nitrogen loading (lb/ac/yr) under each scenario from the selected subwatersheds of the BCW.

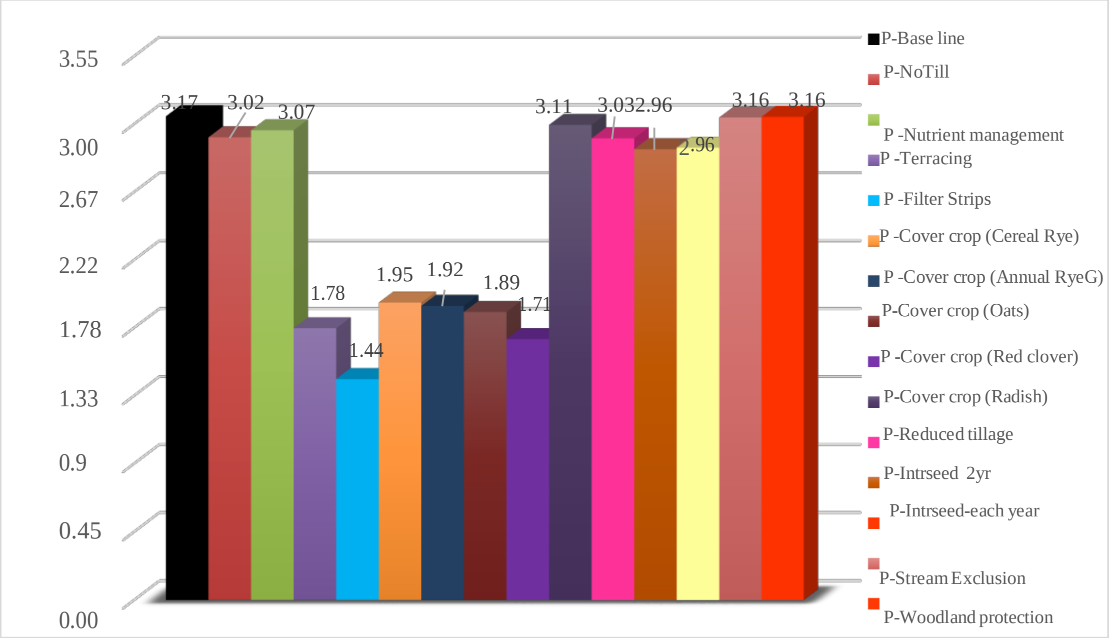


Figure 19. Phosphorus loading (lb/ac/yr) for each BMP scenario in selected subwatersheds

Cover crops were simulated by planting some winter crops following corn and soybean harvest in the agricultural management input files. The vegetative biomass of cover crops increases the amount of transpiration and decreases the impact of rain drops that can break soil aggregates. As a result of this, there is an increase in water infiltration and decrease in surface runoff and runoff velocity. All of the cover crops simulated in this study were effective in reducing both nitrogen and sediment loss. However, where they were left standing, there was an increase in phosphorus runoff. The modeled increases in phosphorus runoff, could be the result of leaching from dead plant tissue. Decomposition of cover crop residue on the soil surface may lead to an accumulation of P at the soil surface where it is susceptible to losses by runoff and erosion. The correlation normally seen between phosphorus loads and bacteria may be changed if large amounts of cover crops are used throughout the watershed.

At the beginning of the planning process all landowners and stakeholders within the watershed were mailed a survey (See Table 9) asking them to indicate which BMPs they would be willing to implement to address the water quality concerns within BCW. Based on the results of the returned surveys, the SWAT Modeling, input from local stakeholders and local knowledge of the landowners and operators within the watershed, it was the unanimous decision of the Black Creek Steering Committee to promote the following best management practices for reducing sediment, nutrient loads and bacteria in the BCW.

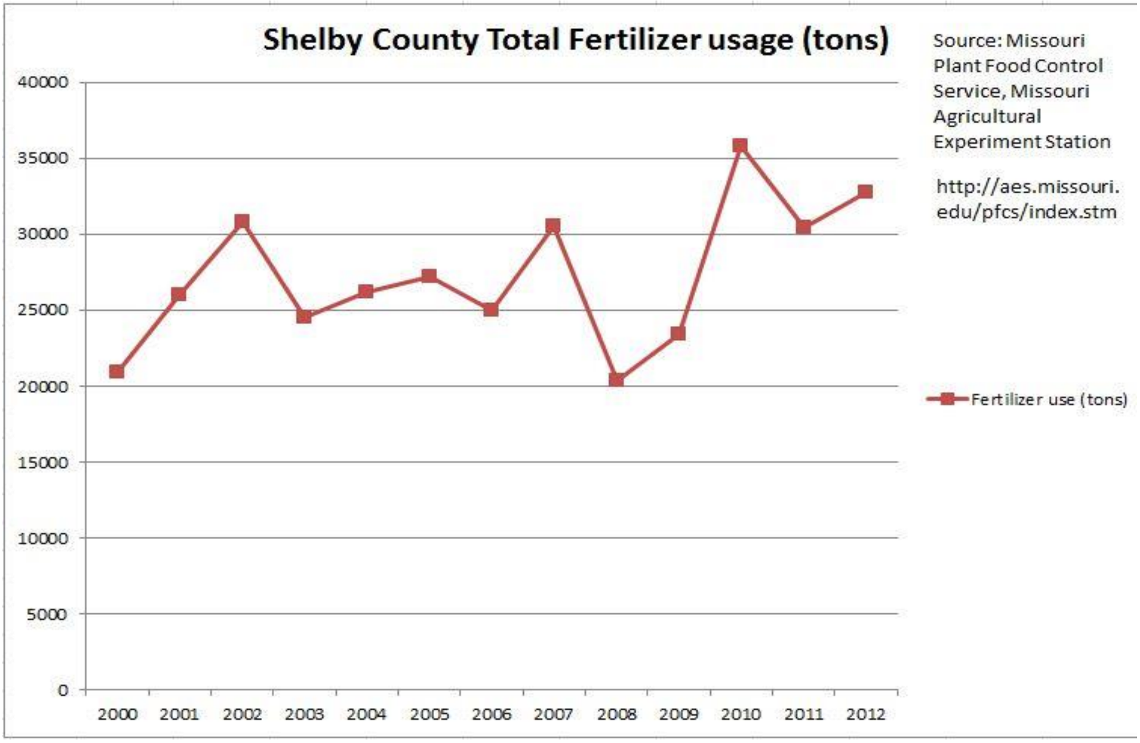
Terracing; is defined as an earth embankment, or a combination ridge and channel that is constructed across the field slope. A terrace is applied as part of a resource management system for one or more of the following purposes: to reduce erosion by reducing slope length and to retain runoff for moisture conservation. This practice is applicable where: soil erosion caused by water and excessive slope length is a problem, excess runoff is a problem, there is a need to conserve water, and soils and topography are such that terraces can be constructed and reasonably farmed and a suitable outlet can be provided. Based on the SWAT model, terraces were the most effective in reducing the loss of sediment and nutrients. Landowner acceptance of terraces within the watershed is high. This is substantiated by the high demand for cost share funds to assist in the installation of terraces through the State Cost Share Program administered by the Shelby County SWCD and by the survey results which was mailed to landowners within the watershed (See Table 9). The steering committee realizes the need for stable outlets for underground tile terraces. For terrace to be implemented in the Black Creek Watershed, a requirement will be that at the tile outlet a relief well with a 50 foot grass buffer area on the down hill side of the relief well will be used. Depending on the circumstances a field border or filter strip maybe required to help filter out sediment and nutrients depending on the closeness of the terrace outlet to the stream.

No-Till; is defined as managing the amount, orientation and distribution of crop and other plant residue on the soil surface year round and limiting soil-disturbing activities to those necessary to place nutrients, condition residue and plant crops. The purpose of No-Till is to reduce sheet/rill erosion, reduce wind erosion, improve soil organic matter content, reduce carbon dioxide ($CO2$) losses from the soil, reduce energy use, increase plant-available moisture, and provide food and escape cover for wildlife. This practice applies to all cropland and other land where crops are planted. The results from SWAT showed that an 18.6% reduction in sediment loss and a 14.3% reduction in nitrogen loss could be expected using No Till. Table 8 shows a 3% reduction of phosphorus at the outlet of Black Creek using No Till.

Nutrient Management; is defined as management of the amount (rate), source, placement, and timing of plant nutrients and other soil amendments. The purpose of nutrient management is to budget, supply, and conserve nutrients for plant production, to minimize agricultural nonpoint source pollution of surface and groundwater resources, to properly utilize manure and other organic by-products (including municipal and industrial biosolids) as a plant nutrient source, to protect air quality by reducing odors, nitrogen emissions (ammonia, oxides of nitrogen), and the formation of atmospheric particulates and to maintain or improve the physical, chemical, and biological condition of soil. This practice applies to all lands where plant nutrients and soil amendments are applied. Based on the SWAT model, Nutrient Management was effective in reducing phosphorus losses in the watershed by (2.0%) and nitrogen losses by (4.51%). The effectiveness of nutrient management in reducing sediment was insignificant.

The Steering Committee chose nutrient management as a BMP, because precision agriculture is becoming more accepted by landowners and Shelby County has agricultural suppliers who are readily available to help implement Nutrient Management. Producers' primary motivation for employing precision agriculture is to improve profitability. However, precision agriculture systems (PAS) can also provide environmental protection through reduced agrochemical use, increased nutrient-use efficiencies, and diminished off-field movement of soil and agrochemicals. From this premise, Berry et al. (2003) developed the idea of "precision conservation" and proposed that precision conservation ties efforts across scales (zones within fields to between fields to watershed and basin management) and is a key tool in achieving conservation goals. Because of the increased acceptance of Nutrient Management this practice will be promoted by info/ed only. (Table 10) shows the trend in fertilizer usage in Shelby County. Since 2008 the trend has been upward, which indicates the possible need for nutrient management.

Table 10. Shelby County Fertilizer Usage Trend.



Filter Strips; are defined as a strip or area of herbaceous vegetation that removes contaminants from overland flow. The purpose of filter strips is to reduce suspended solids and associated contaminants in runoff, reduce dissolved contaminant loadings in runoff, and reduce suspended solids and associated contaminants in irrigation tailwater. Filter strips are established where environmentally-sensitive areas need to be protected from sediment, other suspended solids, and dissolved contaminants in runoff. Using the SWAT Model filter strips where the most effective in reducing the sediment (48.47%), nitrogen (12.94%) and phosphorus (37.58%) load at the outlet of BCW.

Field Borders; are defined as a strip of permanent vegetation established at the edge or around the perimeter of a field. The purpose of field borders is to reduce erosion from wind and water, protect soil and water quality, manage pest populations, provide wildlife food and cover, increase carbon storage, and improve air quality. This practice is applied around the perimeter of fields. The use of field borders is to support or connect other buffer practices within and between fields. This practice may also be applicable to recreation land or other land uses where agronomic crops including forages are grown. The SWAT modeling showed that a significant reduction in sediment 14.02%, phosphorus 8.77% and nitrogen 11.79% can be expected with the use of field borders along and around crop fields (See Table 8).

Cover Crops; are defined as crops including grasses, legumes and forbs that are used for seasonal cover and other conservation purposes. The purpose of cover crops is to reduce erosion from wind and water, increase soil organic matter content, capture and recycle or redistribute nutrients in the soil profile, promote biological nitrogen fixation, increase biodiversity, suppress weeds, provide supplemental forage, manage soil moisture, reduce particulate emissions into the atmosphere and minimize and reduce soil compaction. This practice is applicable on all lands requiring vegetative cover for natural resource protection and/or improvement. The use of cover crops in the SWAT Model showed that a very significant reduction in sediment and nutrient loads could be expected using various forms of cover crops. The results for various cover crops ranged from a .78% to 25.05% reduction in nitrogen, a 1.42% to 31.97% reduction in phosphorus and a 4.95% to 41.69% reduction in sediment. As a result of the effectiveness of cover crops in conjunction with the promotion of soil health by NRCS and increasing interest and promotion of cover crops in Shelby County, the Steering Committee decided to promote the implementation of cover crops (See Table 8).

Grass Waterways; are defined as a shaped or graded channel where suitable vegetation is established to carry surface water at a non-erosive velocity to a stable outlet. The purpose of grass waterways is to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding, to reduce gully erosion, and to protect/improve water quality. This practice maybe applied in areas where added water conveyance capacity and vegetative protection are needed to control erosion resulting from concentrated runoff. Although Grass Waterways were not modeled in SWAT, based on the technical expertise of the NRCS and SWCD Field Office staff, the steering committee chose it as a BMP due to it's effectiveness in controlling gully erosion and it's use with terraces. Terraces outlets into grass waterways are effective in reducing sediment and nutrients coming from the terrace discharge as the discharge water flows through a sizeable length of grass which acts as a filter.

Reduced Tillage; is full-width tillage involving one or more tillage trips which disturbs all of the soil surface and is performed prior to and/or during planting. There is 15-30 percent residue cover after planting or 500 to 1,000 pounds per acre of small grain residue equivalent throughout the critical wind erosion period. Weed control is accomplished with crop protection products and/or row cultivation.

Interseeding; is the dispersing of seed into an established vegetation cover. For the SWAT Model, the interseeding of red clover into fescue sod was used.

Stream Exclusion; which involves fencing livestock out of streams reduces nonpoint source pollution by reducing stream bank erosion and eliminating the bacteria associated with livestock waste. When the cattle have access to streams, they can deposit manure directly into the water. Using the SWAT Model, the cattle that have access were considered to spend some time in the stream. That length of time and, therefore, the amount of waste directly deposited is allowed to vary monthly to account for the seasonal changes of temperature. The results are presented in

(Table 11). The amount of manure was adjusted in the grazing systems of the pastures and woodlands in the selected subwatersheds.

Table 11. Percentage of cattle waste directly deposited in the stream in pastures with stream access.

Source: Upper Shoal Creek Watershed (FAPRI-UMC 2004 Report)

	Daily waste directly		Daily waste directly
January	3	July	10
February	3	August	10
March	3	September	7
April	4	October	4
May	4	November	3
June	7	December	3

Farmers and landowners may hesitate to participate in livestock stream exclusion best management practices because fencing and alternative watering systems are relatively expensive to install and maintain. Producers who qualify for state and federal cost-share programs can reduce installation costs, and many have found that better herd health and improved productivity help regain capital costs and offset maintenance costs.

Woodland Protection; involves fencing livestock out of the woods as livestock grazing may be the most damaging and yet most preventable of all threats to woodland health and productivity. Cattle and other livestock may cause serious immediate damage to seedlings, saplings, and ground vegetation; what is not browsed by livestock will be trampled. In just a few years, the under story may be completely gone or may be replaced by less valuable species. At the same time, livestock compact forest soils, which in turn damages mature trees? Within 10 years, continued grazing causes weakening and mortality of the trees. More sunlight then reaches the ground and, with luck, grasses grow in to cover the soil. In some cases, however, the soil is so compacted that even grasses cannot become established; severe erosion results.

Alternative water sources; are off-stream watering sources for livestock. This offers protection to riparian vegetation, improves stream water quality, and provides a permanent, clean source of water for livestock. Access to alternate water sources in upland pastures are often preferred by livestock, can improve livestock health, and can improve production. Studies show cattle will drink from a tank over a stream or pond 80% of the time, which should reduce the amount of manure being deposited in the stream. As manure is high in phosphorus, the level of phosphorus in a stream and its corresponding relationship to the levels of bacteria is being looked at.

By reducing soil erosion, a major contributor of phosphorus runoff, we can speculate that there will be a reduction in bacteria loads as well. Work done in a study of the Illinois River (www.illinoisriver.org/CEDocuments) showed the concentrations of total phosphorus and bacteria increase dramatically as the stream flow rate increases. Such behavior is a strong indicator that a significant part of the phosphorus loading is caused by non-point sources. The indicator bacteria increased with increased flow rate also. This is a good indication that the non-point sources of the total phosphorus and bacteria may be linked in their transport mechanism.

A review of the Lower Kansas WRAPS 9 Element Plan Overview (www.kswraps.org*)* shows supports for this assumption, that if you are reducing phosphorous levels, lower bacteria counts should be evident in water quality samples. The accumulated affect of the BMP load reductions directly tie to the needed load reductions of the watershed plan. The specific practices each contribute to the overall reduction of sediment loss which will directly affect nutrient and bacteria loading. As modeling was not done for bacteria, there is no bacteria load reduction calculation at this time. The Steering Committee decided to use phosphorus load reduction instead. The assumption is that if you are reducing phosphorus, lowered bacteria counts should be evident in water quality samples.

(Table 12) shows the amounts of nitrogen, phosphorus and sediment that are predicted to be reduced on an annual basis compared to the baseline if the goals established for this plan are met. Also stream bank exclusion and woodland protection should have a positive effect in reducing bacteria levels, by keeping livestock out of the streams, and out of the riparian woody areas.

Stream bank Stabilization

This practice is complicated because the eroding streambank is often a symptom of a larger problem occurring elsewhere within the watershed. Consequently, finding an effective erosion control method can be difficult for a landowner unless they receive appropriate professional assistance. The limitations of currently available methods in terms of high cost, difficult installation, or inapplicability to larger stream systems have caused landowners to try techniques that are ineffective and may lead to increased instability. The Steering Committee will seek assistance from the Missouri Department of Conservation to identify a suitable site for a streambank stabilization demo project.

Table 12. Annual sediment, nitrogen and phosphorus loadings under each scenario in the BCW.

BMPs	Total of Nitrogen (lbs/yr)	Total of Phosphorus (lbs/yr)	Sediment (ton/yr)
Base line	515,315	96,325	23,219
No Till	513,330	93,421	21,377
Nutrient Management	492,056	94,398	23,280
Terracing	492,815	67,188	12,854
Filter Strips	448,608	60,124	11,965
Cover Crop (Cereal rye)	402,072	70,668	14,689
Cover Crop (Annual rye)	386,352	70,180	14,402
Cover Crop (Oats)	389,899	69,366	13,701
Cover Crop (Red clover)	452,516	65,527	13,538
Cover Crop (Radish)	511,302	94,961	22,068
Reduced Tillage	513,196	93,254	20,756
Inter-seeding (Rotation 2yr)	496,146	91,830	23,229
Inter-seeding (Each year)	518,872	91,949	23,908
Stream Exclusion	514,868	96,202	23,218
Woodlands protection	515,574	96,285	23,217

Chapter 5. Element D: Technical and Financial Assistance

Funding needs are difficult to anticipate and will likely change over time. Currently with the uncertainties associated with federal agency budgets and reauthorization of the Farm Bill, NRCS is restricted to operating only the programs that were authorized under the existing continuing budget resolution. Therefore the best way to be prepared for changes in availability of funds is to build partnerships and identify the funding needs for implementing BMPs in the watershed. Black Creek will work directly with the local SWCD and NRCS offices to secure appropriate funding for general practices. As a possible funding source Black Creek Steering committee will also look at opportunities through the Missouri Department of Conservation, Fish and Wildlife Service, Regional Conservation Partnership Program (RCPP), 319 program and other potential partners. When funds become available in the future, local stakeholders will be better prepared to develop a funding proposal. Until additional funding opportunities are available, current programs such as CRP, CCRP, General EQIP, and the State Cost-Share Program will be used to address the WBP goals.

The SWAT modeling divided Black Creek Watershed into 19 subbasins and identified ten of those subbasins as priority subbasins to be targeted for BMPs that will have the greatest affect in reducing sediment, nitrogen and phosphorus which should result in an improvement of Low Dissolved Oxygen in the watershed. Each of these ten subbasins are approximately 1800 acres in size. In looking at the modeling results, the Steering Committee will recommend to the Shelby County Soil and Water Conservation District that these ten subbasins should be prioritized for treatment. Subbasins 3,8,11 and 17 have the highest sediment, nitrogen and phosphorus loading and will have the biggest impact on improving Low Dissolved Oxygen if treated. This group should receive the highest priority for assistance for implementing BMPs. Subbasins 2, 9,15 and 16 have the second highest sediment, nitrogen and phosphorus loading, with subbasins 6 and 7 having the lowest among the 10 subbasins. Priority group 2 and 3 should be targeted for assistance for BMP installation in that order.

This watershed management plan will get the watershed into a position to apply for any initiatives that may come in the future depending on the new Farm Bill, etc. The key to possible Federal Funding is having the watershed plan in place so that the watershed will be ready when the funding becomes available.

The estimated costs associated with the various implementation strategies are highly conservative and will likely change as targeting of the watershed is finalized and further information becomes available. In addition, funding for some of these efforts has already been identified and implementation is already underway; therefore these figures do not entirely represent additional funds needed. See Table 14 in Chapter 7 for a schedule of BMP Implementation and Responsible Organizations.

Current funding sources within the Black Creek Watershed are State Cost Share, and additional MDC Cost Share for CRP Mid Contract Management. In 2013, $189,821.00 was obligated through the MRBI program in Black Creek. From 2008 through 2013 there was $196,627 obligated through the State Cost Share program.

Possible sources for future funding within the Black Creek are: State Cost Share, CRP, 319 Grant, RCPP, and Missouri DNR. Funding is a major issue when it comes to the successful implementation of the WBP. MRBI funds will no longer be available. Even though the Steering Committee plans to apply for a 319 Grant, there is no guarantee that this grant will be available or that it will awarded to the project. A new source of possible funding is the RCPP program, this will be explored by the Steering Committee. If additional funding can not be secured, the Steering Committee will continue to move forward using available funding such as EQIP and State Cost Share. Local producers are committed to improving water quality in Black Creek and are actively implementing practices that are affective at reducing soil erosion and nutrient loading. These practices should help reduce bacteria and low dissolved oxygen impairments. Local funding through NRCS and SWCD will be utilized as much as possible while the advisory committee reviews opportunities for other funding sources to implement more practices.

Future funds from the State Cost Share Program will be allocated as available. Other sources of funds to explore are agencies and organizations such as the Missouri Department of Conservation, US Fish and Wildlife Service, Ducks Unlimited, Quail Unlimited and other environmental organizations.

Technical Assistance; Presently the Shelby County district has one full time district technician, a fulltime temporary SWAT technician that may be rehired each year, the SWCD has one full tech and one full time clerical. The intent of the Black Creek Steering Committee and the Shelby County SWCD is to hire a half time project manager and a full time technician to assist with the implementation of the approved BMPs within the Black Creek Watershed if adequate funding can be secured. Other technical assistance would come from NRCS and SWCD staff. The Shelby County SWCD also has on staff a wildlife biologist, funded through Quail Forever, who can assist with wildlife issues. The Missouri DNR and University of Missouri would also be possible sources of technical assistance.

Chapter 6. Element E: Public Information and Education

Personnel from the Shelby County SWCD will initiate contact with farmers in BCW to encourage installation of agricultural BMPs. This one-on-one contact will facilitate communication of the water quality problems and the corrective actions needed. The technical staff from the Shelby County SWCD office will conduct a number of education and outreach activities in the watershed to raise local awareness and encourage community support and participation in reaching the implementation plan milestones. Such activities will include information exchange through newsletters, postcard mailings, field days, presentations at local events, and a display at the Shelby County Fair. The technical staff will work with organizations such as the University of Missouri Cooperative Extension, Missouri Department of Conservation, Pheasant and Quail Forever to sponsor farm tours and field days and Shelby County Health Department.

Public meetings will be held to increase awareness of local watershed management issues. Three field days will be held to highlight the benefits of implementing BMPs; semi-annual radio programs will be utilized to provide updated information on BMP's and watershed issues; and a semi-annual newsletter will be published in the SWCD and University of Missouri Extension newsletters and distributed in the Shelby County area. Five educational workshops will be held and public service announcements will be published in local newspapers. Annual meetings of local SWCD's and other community based groups will also be utilized to obtain public input. In conjunction with the Shelby County Health Department a survey will be developed for use within the watershed concerning use of septic systems. A workshop will be offered on the proper maintenance of septic systems.

A general information campaign will be used to increase awareness of nutrient management issues in Black Creek. Three basic activities will be conducted:

- Development of a brochure about Black Creek showing some of the watershed areas that are most at-risk for nutrient runoff.
- Articles in the Soil and Water Conservation District newsletter or special newsletters from the SWCD to county residents.
- A poster to be displayed at meetings and in the district office of the watershed area, displaying nutrient loading information and a list of potential best management practices that can be used to avoid, control, and trap nutrient runoff.

Along with these three information awareness practices the district will work in cooperation with the local University of Extension specialists and the Natural Resource Conservation Service personnel to offer the following educational events:

- Cover crop program on proper use and selection to secure nutrients in the soil. This will include information on management, economics and proper planting procedures.
- Field day on cover crop use within the watershed
- Testing for Plant Nutrient Program that would contain information on the different ways of testing to determine nutrient levels. Including information on soil testing, plant leaf testing, stalk nitrate testing and what each one means to plant growth and to economic return.
- Field day on “lab” session to demonstrate testing procedures for nutrient loads
- Marginal Soils for Crop Production Program – this would cover the economic and environmental concerns associated with returning marginal soils to production, how to determine a marginal soil, ways of improving marginal soils for certain forms of production.
- Potential field day that could be tied in with nutrient testing
- Indicators of Water Quality Program – connection between soil, nutrients and water quality – focusing on management practices that are designed to protect water quality and help long-term soil health and development. Recognizing who determines the water quality issues and the role the land owners and producers play in protecting water quality.
- Managed grazing management practices for nutrient management which include feeding habits, grazing along the stream, watering of livestock, and economic benefits of improving pasture management.
- Potential field day or training for managed intensive grazing.
- Variable Rate Application – increasing technology to provide variable rate application of nutrients to reduce potential nutrient loss, maintain yields and increase productivity.
- Potential field day on Geographic Information System (GIS) equipment needs and interfacing with computers
- Phone Applications for Farmer Decision Making and Management – learn the latest “apps” that are designed to assist producers with farm management decisions.

The local SWCD will explore opportunities to work with the Shelby Co. Health Department on providing awareness and information regarding proper maintenance and operation of on-site sewage systems for reduced e.coli/bacteria contamination. For those landowners who do not want to use stream exclusion, limited stream access practices may be offered to reduce bacteria loading.

Table 13. Public Information and Education Schedule.

Venue	Schedule	Contact	Completion Date	Cost
Radio	Two per year	Univ. of Mo. Extension	On Going	No Cost
Shelby County SWCD Newsletters	Semi-Annually	Shelby Co. SWCD Board	On Going	No Cost
Educational Workshop	Annually	Shelby County SWCD/ Univ. of Mo. Extension	2015 - 2019	$500.00 each
Field Demonstrations	One per year	Shelby County SWCD/ Univ. of Mo. Extension	2015 - 2017	$1000.00 each
Local Newspaper	Two articles per year	SWCD Board/ Univ. of Mo. Extension	On Going	$100.00 per year
Individual Contacts	Weekly	NRCS, SWCD & Extension Staff	On Going	No Cost

Chapter 7. Element F: Schedule for BMP Implementation and Responsible Organizations

The watershed management process should help local stakeholders better understand their impact on water quality. A successful watershed management plan requires participation from people who live in the watershed. While the primary land use is row cropping and pasture/hay land, the watershed also has abundant wildlife such as deer and turkey. The problems that exist in the watershed are primarily ones that can be significantly improved or eliminated through implementation of BMPs. Emphasis should also be placed on preventing future problems through information and educational activities. The timeframe of ten years for implementation is estimated and listed completion dates may be modified as determined by stakeholder commitments and available funding. Ten years for a tentative completion date was chosen based on the size of the watershed, previous and up coming retirements of staff, work load within the Soil District, anticipated funding, unknown weather conditions and potential unforeseen situations. As progress is made and it is seen that more time is needed for complete implementation of the plan, the plan maybe extended. Funding needs are difficult to anticipate and will likely change over time. Funding is estimated based on Shelby County SWCD and MRBI cost share data. The cost for terraces in 2014 is based on money obligated from MRBI. The remaining estimated cost of BMPs for this plan are based on a review of State and Soil District average cost for practices.

Table 14 shows the schedule for BMP implementation. The goal for each BMP to be implemented over the life of the plan is listed under the Number per Life of Plan column. The practices listed each have an estimated load reduction associated with them. The focus of the plan for reducing E.coli are associated with resolving these issues that are acceptable and doable by most land owners. This includes looking at sediment and soil erosion where we can determine load reductions and success in reducing sediment. By determining the sediment load reduction through practice implementation we can determine if we have reached our goal of a 50% sediment load reduction at the end of the 10 year period. The goal for reducing nutrient loading over the life of the plan is 60%. The goal for E-coli bacteria is to have bacteria levels reduced to Class B recreational water quality standards. That goal is no more than 206 Colonies/100ml between April 1 and October 31. Because the selected practices have a benefit at reducing nutrient load and sediment, in it anticipated that the bacterial load will be reduced in all three areas.

Table 14 includes a schedule for BMP implementation. The Steering Committee plans to begin implementing the WBP as soon as approval is received. The Committee realizes that it will take at least a year to get up full speed. For this reason the percent completed goal for the first two years reflect this. The percent completed by year is cumulative with the goal of having 100 percent of the plan complete by the last year.

Table 14. Schedule for BMP Implementation and Responsible Organizations.

Priority	Crop Management	Number	Estimate	Funding	Partners &	Estimated %

area	Strategies	Per Life of Plan	Of Cost	Source	Activities	Load Reduction		
						N	**P**	**Sediment**
	Nutrient Management							
6, 7, 8, 9, 11, 15, 17	Nutrient Management/Precision Agriculture	5000 ac	$1000.00	Info/Ed funds	NRCS/SWCD UME Councils/ Info Ed/ Workshops, Field Demonstrations, BMP Implementation			
	Implementation of Nutrient Management Percentage of Goal	*Year 1 10%*	*Year 2 20%*	*Year 3 30%*	*Year 4-6 Year 7-10 70% 100%*	*4.5%*	*2%*	*0%*
	Sediment Control Structures							
2, 3, 6, 7, 8, 9, 11, 15, 16, 17	Grade Stabilization Structures	10 Structure Total	$100,000	State Cost Share Funds/ EQIP	NRCS/SWCD UME Councils/ Info Ed/ Workshops, Field Demonstrations, Design, BMP Implementation			
	Terracing	100,000 ft.	$300,000					
	Implementation of Sediment Structures	*Year 1 10%*	*Year 2 20%*	*Year 3 30%*	*Year 4-6 Year 7-10 70% 100%*	*4%*	*30.%*	*44%*
	Run-off Filtration Practices							
2, 3, 6, 7, 8, 9, 11, 15, 16, 17	Grass Waterways	5 ac	$10,800	State Cost Share /EQIP/ CRP	NRCS/SWCD UME Councils/ Info Ed/ Workshops, Field Demonstrations, Write and Implement plans & practices			
	WQ-10 (Stream Protection)	12ac	$16,500					
		10 ac	$3000					
2, 3, 6, 7, 8, 9, 11, 15, 16, 17	Field Borders/Filter Strips/Riparian Forest Buffers	2000 ac	$60,000					
	Cover Crops	10 Ac	$10,000					
	Wetlands							
	Implementation of Run-off Filtration Practices	*Year 1 5%*	*Year 2 10%*	*Year 3 25%*	*Year 4-6 Year 7-10 55% 100%*	*16%*	*25%*	*35%*
	Livestock Management Strategies	**Number**	**Estimate Of Cost**	**Funding Source**	**Partners & Activities**			
	Grazing Systems							
6, 7, 9, 15, 17	Alternative Watering System	5 Systems	$17,500	State Cost Share/ EQIP	NRCS/SWCD/UME Councils/ Info Ed/ Workshops, Field Demonstrations, Write and Implement Plans & Practices			
6, 7, 9, 15, 17	Use Exclusion/	500 ac	$25,000					
6, 7, 9, 15, 17	Planned Grazing Systems	1,000 ac	$30,000					
6, 7, 9, 15, 17	Pasture Improvement	2000 ac	$30,000					
	Implementation of Livestock	Year 1 2%	Year 2 5%	Year 3 15%	40%			

	Management Strategies				100% Year 4-6 Year 7-10	2% 2% 3%
	Conservation Tillage					
	No Till					
2, 3, 6, 7, 8, 9, 11, 15, 16, 17	*No Till/Reduced Tillage*	2000 ac	$30,000	EQIP	NRCS/SWCD/ UME Councils/ Info Ed Workshops, Field Demonstrations, Write and Implement plans & practices	
2, 3, 6, 7, 8, 9, 11, 15, 16, 17	*Implementation of Conservation Tillage practices*	Year 1 10%	Year 2 10%	Year 3 40%	Year 4-6 Year 7-10 70% 10%	*1% 3% 10%*
6, 7, 8, 9, 11, 15, 16, 17	Stream Bank Stabilization	1 Demo Project	$10,000	MDC	NRCS/SWCD/MDC	
TBD	*Implementation of Stream Bank Stabilization Demo Project*				Year 5 100%	
TBD	**Water Quality** Monitoring for E-coli	Yearly		DNR	DNR/Stream Team	
TBD	Monitoring for Low Dissolved Oxygen	Yearly		DNR	DNR/Stream Team	
	1/2 time Technician	Yearly	$15,000/ yr	SWCD	Work on all aspects of implementing the plan	
	Manager	Yearly	$50,000	SWCD	Manage and provide technical assistance of implementing the plan	

Chapter 8. Element G: Milestones

The long-term goals of implementation are restored water quality of BCW and removal of BCW streams from Missouri's Section 303(d) list. Progress toward long-term goals will be assessed during implementation through tracking of BMP installations and continued water quality monitoring. Those attending workshops and field days will be asked to sign in so that participation maybe tracked. An evaluation tool will be developed and used at workshops and field days to determine increase awareness and knowledge of specific practices and concerns, including pre and post knowledge of water quality issues. A producer survey will also be developed to ascertain the willingness to change behaviors or adopt specific practices. These will either be given out at the workshop/field days or three to six months after the event to see if producers have followed through on changing behavior and adopting practices. Public request for information concerning water quality and BMPs will be tracked. The number of BMPs implemented versus the amount planned will be monitored. The amount of cost share dollars spent within the watershed will be tracked.

Annual status reports of progress on the implementation of milestones detailed in Tables 15 and 16 will be shared with the Steering Committee and Shelby County SWCD, and a comprehensive review and evaluation of progress will occur every two years. If it becomes apparent that these milestones are not being met, the goals set forth in the plan will be re-evaluated and appropriate remedial action determined at that time. Modeling helped identify 10 critical areas which are approximately 1800 acres in size. The Steering Committee is committed to ensuring that funding will target these critical areas.

Milestones: See Table 15 and 16

- Yearly track water quality: monitor for E.coli bacteria and dissolved oxygen to achieve target of 206 or less CFU/100ML for E-coli and 5 or more milligrams/liter D.O. is being achieved.

- Land use/Land cover; Implementation of this WBP will result in an increase in the number of cropland acres being no tilled by 2000 acres. An increase in number of acres of cover crop by 2000 acres, nutrient management/precision agriculture by 5000 acres, field borders by 10 acres, planed grazing systems by 1000 acres, pasture land improvement by 2000 acres.

- Riparian Condition: increase use exclusion by 200 acres, increase number of wetlands by 10 acres, and filter strips / riparian buffer by 10 acres. Plan and implement one stream bank stabilization project.

- Aquatic Biological Communities: assessment of the condition of fish and benthic macro invertebrate communities related to reference streams and Bio criteria. Aquatic invertebrate monitoring by MDNR was completed in 2009 and 2012 and was judged to have an unimpaired biological community at that time. MDNR plans to do follow up Aquatic Invertebrate monitoring to see if any changes have occurred.

- BMP and other implementation efforts: Track and map BMP implementations, indicate location of BMPs installed, are they in one of the 10 priority areas determined by SWAT. Track load reduction achieved by BMPs based on SWAT predictions.

- Education/Information. Track Info/Ed activities to determine, if land owner are accepting proposed BMP installation, to determine increase in land owner knowledge of the water quality problem, to determine if land owner and operators are adapting to new technology such as increase use of cover crops.

Table 15. Milestones for Conservation Practices.

Category	BMP	Units	Implementation Goal	By Year
Crop Management strategies	Nutrient Management	Acres	5000	Year 1 10% Year 2 20% Year 3 30% Year 4-6 70% Year 7-10 100%
Sediment Control Structures	Grade Stabilization Structures	Practices	10	Year 1 10% Year 2 20% Year 3 30% Year 4-6 70% Year 7-10 100%
	Terraces	Feet	100,000	
Stream bank Stabilization	Demo Project	1	1	
Run Off Filtration Practices	Grass Waterways	Acres	5	Year 1 5% Year 2 10% Year 3 20% Year 4-6 55% Year 7-10 100%
	WQ-10	Acres	12	
	Field Borders Filter Strips Riparian Forest Buffers	Acres	10	
	Cover Crop	Acres	2000	
	Wetlands	Acres	10,000	

Livestock Management Strategies	Alternative Watering Systems	Practices	6	Year 1 Year 2 Year 3 Year 4-6 Year 7-8	2% 5% 15% 40% 100%
	Use Exclusion	Acres	200		
	Planned Grazing Systems	Acres	1000		
	Pasture Improvement	Acres	2000		
Conservation Tillage	No Till/Reduced Tillage	Acres	2000	Year 1 Year 2 Year 3 Year 4-6 Year 7-10	10% 10% 40% 70% 100%
Streambank Stabilization	Demo	Project	1	Year 5	100%
Water Quality	Monitoring for E-coli			Yearly	
	Monitoring for Low Dissolved Oxygen				

Table 16. Milestones for Information/Education.

Venue	Schedule	Completion Date
Radio	Two per year	On Going
Shelby County SWCD Newsletter	Semi-Annually	On Going
Educational Workshop	Annually	2015-2019
Field Demonstrations	One per year	2015-2017
Local Newspaper	2 articles per year	On Going
Individual Contacts	Weekly	On Going

Additional monitoring of E-coli bacteria will be conducted in Black Creek by the Missouri Department of Natural Resources in 2015. If concentrations are still high at that time, the plan will be reviewed and any new funding sources that may be available will be considered. A determination will be made at that time whether a plan revision is needed to address this concern.

Chapter 9. Element H: Performance

Dissolved oxygen is perhaps the most well-established indicator of water quality in the absence of toxins. http://www.lenntech.com/why_the_oxygen_dissolved_is_important.htm#ixzz3AspfVly6 . Biologically speaking, the level of oxygen is a much more important measure of aquatic life use attainment than bacteria as indicated by E. coli. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. The lower the DO concentration gets, the greater the stress become. Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kill.

Excessive sedimentation can overwhelm aquatic ecosystems, smothering freshwater breeding substrates. Sediments can transport attached pollutants such as nutrients, bacteria, and toxic chemicals from agriculture into our streams. Nutrient impaired waters can cause problems ranging from recreational annoyances, to serious public health concerns, to adverse effects on the ecology of the aquatic ecosystem. Nitrogen and phosphorus are the primary nutrients that contribute to agricultural nonpoint source pollution. Excessive nitrogen and phosphorus in waterways can cause algal blooms which can lead to the development of hypoxic conditions, or low dissolved oxygen concentrations, unable to sustain aquatic life.

Modeling has been done to show the hydrologic response areas (HRA) that are most likely to contribute to soil erosion and nutrient loading. These areas will be selected as priority areas, (as discussed in Chapter 5), for implementing practices and offering cost-share for practices that should reduce bacteria impairments.

An example of what the Black Creek Steering Committee hopes to achieve is the success of the Little Elk Creek Watershed Plan in Oklahoma. The installed cropland and grazing land BMPs decreased the amount of erosion, which in turn reduced nutrient loading to streams because phosphorus and nitrogen typically binds to soil particles. Reductions in nutrients reduced algal growth and resulted in increased levels of dissolved oxygen observed in Little Elk Creek. No samples fell below state dissolved oxygen criteria in the 2008 assessment. (www.epa.gov/nps/success/)

Black Creek has bacteria as an identified impairment. No direct source has been identified for the bacteria and a survey of present livestock practices does not indicate poor manure management or heavy loading by livestock being in the waterways. Knowing that there appears to be a direct correlation between bacteria and phosphorus levels and low dissolved oxygen can be a result of decaying aquatic plants, the reduction of sediment associated with soil erosion is a high priority. It is determined that by controlling soil erosion and sedimentation we will see a decrease in bacteria and nutrient loading. This should improve water quality by reducing bacteria loading in the waterways.

The Steering Committee feels that the best and quickest way to achieve their goals of reducing bacteria levels is to work with landowners to install BMPs that reduce sediment and nutrient loading in the watershed. As discussed previously in this plan, sediment and nutrients have an impact on bacteria.

NRCS recognizes the direct correlation between sediment reduction and the load reduction of nutrients. Other less popular practices such as riparian re-establishment and stream bank protection will also be considered in these areas. Short- and long-term goals for watershed management will be contingent on available funding and personnel resources.

Effects of implementation programs in the watershed on sediment loading to Black Creek from known sources (pasture, row crop, stream bank erosion), and any new sources will be evaluated every three years to determine if changes may be needed to the plan. Following that evaluation, the Watershed-Based Plan will be revised to reflect new information and address any short comings identified.

The SWAT modeling indicates that a load reduction as high as 56% for sediment at the outlet of Black Creek Watershed may be possible using selected BMPs. The short-term goal is for at least a 25 percent sediment load reduction to be measured during the first five years, with a long-term goal of a 50 percent sediment load reduction during the 10-year life of the plan.

Because studies have shown the direct correlation between high nutrient and sediment loading and high bacteria counts, it is expected that this SWAT modeled reduction of 50% sediment will reduce the impairment of high bacteria enough to remove it from the 303d list in this 10 year period.

The plan is a rolling plan and will be reviewed every 3 years by the Steering Committee and adjusted if it is seen that established goals will not be achieved over the 10 year period of the plan. If necessary, the Steering Committee will revise the plan in order to extend its completion date.

Attainment of these load reduction goals will be measured using water quality monitoring data, RUSLE II calculations for sediment load reductions; visual assessments using before and after pictures; tracking of the total number of practices implemented, especially in critical areas along streams and if funding is available additional SWAT modeling.

The Shelby County SWCD will provide outreach, technical and financial assistance to farmers and homeowners in BCW through the Missouri Soil and Water Conservation Cost Share Program. Their responsibilities will include promoting implementation goals; available funding and the benefits of BMPs; and providing assistance with the survey, design, layout, and approval of agricultural BMPs and education and outreach activities. Specific education and outreach methods recommended by the steering committee are described in element E. Tracking of Information/Education activities will be conducted by the Shelby County SWCD, which will be eligible for technical assistance funding to support their duties.

Successful implementation depends on stakeholders taking responsibility for their role in the process. While the primary role falls on the landowners, local, state and federal agencies also have a stake in seeing that Missouri waters are clean and provide a healthy environment for its citizens. While it is unreasonable to expect that the natural environment (*e.g.* streams and rivers) can be made 100% free of risk to human health, it is desirable to minimize NPS problems and meet water quality standards. Missouri's approach to correcting NPS pollution problems has been, and will continue to be, encouragement of local participation through education and financial incentives.

Chapter 10. Element I: Monitoring

Every WBP requires monitoring to evaluate the overall success of restoration and remediation efforts. The goal of monitoring for this WBP will be to develop a long-range monitoring program with clearly defined milestones that will measure beneficial use support in the watershed.

A review committee will be formed from members of the Shelby County Soil and Water Conservation District Board and NRCS District personnel. This committee will conduct a full review of the plan's progress every three years. Baseline stream water quality data will be compared to future collected data, numbers of implemented practices in critical areas will be tracked, and visual observations, including before and after pictures, will be used in determining progress and success in the project area.

Effects of implementation programs in the watershed on sediment loading to Black Creek from various sources (e.g. pasture, row crop, forest land, stream bank erosion, and any new sources) will be evaluated every three years by monitoring data from agencies, tracking practices implemented and evaluation of Info/Ed activities to determine the future strategy to be followed. Following that evaluation, this WBP will be revised to reflect new information and address short-comings identified with earlier plans. According to DNR, as of July 2014, the WQ monitoring will be scaled back from 12 times per year to 8 times per year. Since the water body is impaired for bacteria, DNR will maintain 5 samples to be collected for bacteria (E-coli) (see map on page 16 Figure 8 for sample sites), which will be collected during the recreational season (along with nutrients). This will allow the department to continue to assess Black Creek for bacteria. The remaining 3 samples will be collected between Oct -March. The frequency monitoring may be increased in future years after practices have been implemented that address the impairment.

A cadre of individuals who have received stream team training has been identified by the Steering Committee and will be called upon and used in the advent that the DNR sampling becomes insufficient or additional water quality monitoring is needed. If additional water quality monitoring is needed than what can be provided by DNR or Stream Team members, then funding will be sought to use Truman State University personnel.

As the WBP evolves and expands to be more inclusive of the entire watershed and all parameters of concern, it is anticipated that this list will change accordingly. At this time, the following parameters will continue to be monitored in BCW by DNR, Field Office Staff, and a yet to be formed Stream Team:

- Water quality: nutrients, sediments, suspended solids, Fecal Coliform and E.coli bacteria, dissolved oxygen, turbidity, biochemical oxygen demand (BOD).

- Land use/Land cover: acreage in different land uses, quality and type of land cover, timing and other variables of associated management practices

- Riparian Condition: extent and quality of riparian zones in the watershed. To include quality and type of vegetation, degree of impact or stability, condition of stream banks, and primary source of threat or impact.

- Aquatic Biological Communities: assessment of the condition of fish and benthic macro invertebrate communities related to reference streams and Bio criteria. Aquatic Invertebrate Monitoring by MDNR was completed in 2009 and 2012 and was judged to have an unimpaired biological community at that time. MDNR plans to do follow up Aquatic Invertebrate monitoring in 2014 to see if any changes have occurred.

- BMP and other implementation efforts: type, extent, and when possible, specific location of practices to include an estimate of the potential load reduction affected by implementation

Appendix A List of Acronyms

ARS	Agricultural Resource Services
BMP	Best Management Practice
CARES	Center for Applied Research & Environmental Systems
CAFOs	Confined Animal Feeding Operations
CCRP	Continuous Conservation Reserve Program
CCWWC	Clarence Cannon Wholesale Water Commission
CEAP	Conservation Effects Assessment Program
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
EDU	Ecological drainage unit
EPA	Environmental Protection Agency
ESP	Environmental Services Program
GIS	Geological Information System
HUC	Hydrologic Unit Codes
kg/ha/yr	Kilogram/hectacre/year
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
MGD	Million Gallons per Day
MLRA	Major Land Resource Area
MSCI	Missouri Stream Condition Index
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NPDES	National Pollutant Discharge Elimination System
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
USDA	United States Department of Agriculture
RBI	Mississippi River Basin Initiative
RCPP	Regional Conservation Partnership Program
SWAT	Soil and Water Assessment Tool
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
WBP	Watershed Based Plan
WQMS	Water Quality Monitoring Section
WRP	Wetland Reserve Program
WWTF	Waste Water Treatment Facility
WWTPs	Waste Water Treatment Plants

Appendix B Glossary: Terms and Definitions

BMPs: Best Management Practices (BMPs) are those practices determined to be the most efficient, practical, and cost-effective measures identified to guide a particular activity or to address a particular problem.

MLRA: Major Land Resource Area are geographically associated land resource units delineated by the Natural Resources Conservation Service and characterized by a particular pattern that combines soils, water, climate, vegetation, land use, and type of farming.

NPS: Nonpoint Source Pollutionunlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water.

PSP: Point Source Pollution on the most basic level, is water pollution that comes from a single, discrete place, typically a pipe. The Clean Water Act specifically defines a "point source" in section 502(14) of the Act. That definition states:

The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

SWAT: Soil and Water Assessment Tool is a sophisticated basin-scale computer model that predicts impacts of weather, soils, land use and land management on water supplies and pollution as well as soil erosion, fertility and crop production.

TMDL: Total Maximum Daily Load is the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards.

WBP: Watershed-based Plan. The primary purpose of a watershed-based plan is to guide watershed coordinators, resource managers, policy makers, and community organizations to restore and protect the quality of lakes, rivers, streams, and wetlands in a given watershed. The plan is intended to be a practical tool with specific recommendations on practices to improve and sustain water quality. These are also “living documents”, meaning that as conditions change over time in a watershed, the plan must be reexamined and revised to reflect goals that have been achieved or not met.

MRBI: Mississippi River Basin Healthy Watersheds Initiative

Appendix C Reference List

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Evaluation of Water Quality and Best Management Practices (BMPs) in the Black Creek Watershed Using the SWAT Model

GENERAL HISTORY OF SHELBY COUNTY, MISSOURI 1911
Written by Shelby Contains and graciously donated to this website (https://archive.org/details/generalhistoryof00bing) by the Shelby County Historical Society, Kathleen Wilham, President - ©Copyright 1911

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Watershed Evaluation and Comparison Tool
(http://www.cares.missouri.edu/)

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Appendix D. Fact Sheets and Reference Materials

Total Maximum Daily Load Report

Bacteria TMDL Transmittal

1. Name: Black Creek

WBID: 111
Class: C
Designated Uses: AQL, LWW, WBC B, GEN
Impaired Use: WBC B

Listed Impairment Sources: there are excess bacteria E. coli from Shelbyville WWTF and from Nonpoint Sources indicating the potential existence of disease causing pathogens in the water.

Extent of impairment: 19.4 miles.

2. Location of the impaired segment: Shelby County, HUC 12=071100050202.
3. Applicable Water Quality Standard: A geometric mean E. coli of no more than 206 CFU/100 ml in the ambient water.
4. Data: sixty samples were collected during the recreation season of 2010 through 2014. All data were gathered from the same site at county road (CR) 478 (site number 111/2.3). This site is about 14.4 miles downstream from Shelbyville WWTP and 2.3 miles upstream of the watershed outlet. The data ranged from 23 to over 2420 CFU/100 ml with an overall geometric mean of 429. Additional statistics are depicted in appendix C.

2. CALCULATION OF LOAD CAPACITY

Establishing the relationship between the in-stream water quality target and the contribution from each of the polluting sources (source loading) is a critical component of TMDL development. This relationship provides a method to choose the most appropriate land management that will achieve the desired load reduction. Computer models are used to evaluate the efficacy of different best management practices for each contributing source. Relevant monitoring data should support the linkage between flow and loading conditions to waterbody responses.

Model:

A Load Duration Curve (LDC) analysis was used to calculate the TMDL target. A load duration curve represents the TMDL at every stream flow associated with its probability of occurrence. The curve is the product of the endpoint concentration (CFU/100 ml), the flow in cubic meter per second (m^3/s), and a conversion factor (calculated in Appendix C). The formula looks like this:

Load (CFU/day) = [**Concentration** (col/100 ml)] x [**Flow** (m^3/s)] x [(Conversion Factor)] (1)

Since there are no long-term daily discharge records at the mouth of Black Creek, a flow duration curve was synthesized from the USG gauge number 05502500 based on relative drainage area. The flow duration curve was transformed into a bacteria load duration curve using formula (1) and appropriate bacteria standard (Appendix C).

Load Capacity:

Load capacity (LC) is defined as the greatest amount of a pollutant a waterbody can receive without being in violation of Missouri's Water Quality Standards. This total load is then divided among a Waste Load Allocation (WLA) for point sources, a Load Allocation (LA) for nonpoint sources, and a margin of safety (MOS). An allowance load for a MOS will be provided explicitly and/or through conservative assumptions. This is necessary because of the high variability of bacteria concentration in the stream system.

The 50% flow probability corresponds to 28,223,648,824 CFU/day. In this calculation, the load is very large and takes a wide space (11 digits). This number may be formatted to scientific notation: 2.82E+10 (7 digits wide). This load calculation is based on the long-term average flow and is here for illustration purposes only. The actual load will be a continuum over the range of all possible stream flows.

3. WASTE LOAD ALLOCATION (POINT SOURCE LOADS)

The Waste Load Allocation (WLA) is that portion of a receiving stream's load capacity that is allocated to existing or future point source discharges. It is assumed that all point sources are authorized to land-apply their waste or discharge it to state waters. The critical conditions for point source dominated systems are generally associated with periods of low flow and, consequently, low dilution potential. There is one domestic wastewater treatment facility in Black Creek watershed. Shelbyville WWTF – MO0054704 – a lagoon system that is permitted to discharge no more than 0.074 MGD[1] [0.00324 m^3/s] to WBID 111.

The WLA for Shelbyville WWTF is calculated as follows:

WLA = (Flow) (Average Number of Col/100 ml) x (Conversion Factor).

WLA = (0.00324 m^3/s) x (206 CFU /100ml) x (864,000,000) = 576,668,816 CFU per day (or about 5.8 E+8).

One sample collected on 9/26/2013, showed an E. coli count of 3.80 E+9 when stream flow was 0.0028 m^3/s. Because this flow was less than the design flow of Shelbyville, it is safe to assume that all the bacteria originated from domestic discharge. The corresponding reduction for this particular sample will be (3.80E+09 – 5.8E+8)/ 3.80E+09 = 84.7%.

This WLA is presumed constant throughout the recreation season.

4. LOAD ALLOCATION (NON-POINT SOURCE LOAD)

The load allocation (LA) is that portion of a pollutant load which excludes permitted point sources and is, algebraically, the difference between the TMDL and the waste load allocation, plus any explicit MOS and any allocation for MS4s[2]. The Margin of Safety (MOS) maybe explicitly set to a percent of the Load Capacity at all flow probabilities, usually 10% or implicitly with the adoption of conservative modeling assumptions.

The following equation expresses the TMDL calculation:

TMDL or LC (Load Capacity) = WLA + LA + MS4 + MOS

---

[1] MGD=Million Gallons per Day.

[2] MS4 = Municipal Separate Storm Sewer System. http://water.epa.gov/polwaste/npdes/stormwater/Municipal-Separate-Storm-Sewer-System-MS4-Main-Page.cfm

Solving the equation for LA:
Load Allocation (LA) = LC – (WLA + MOS + MS4)
For a 10% MOS, LA = 0.9 LC – (WLA + MS4).

5. MARGIN OF SAFETY (MOS)

A margin of safety (MOS) is allowed to account for any uncertainties in scientific and technical understanding and modeling of water quality in natural systems. The MOS is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the MOS can be achieved through one of two approaches:

> *(1)* Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
> *(2)* Implicit - Incorporate the MOS as part of the design conditions for the waste load allocation and the load allocation calculations (or conservative assumptions in the analysis).

6. SEASONAL VARIATION

Black Creek is designated for whole body contact recreation category B during the period from April 1 to October 31. During this recreation season, human activities in and around the stream intensify. The TMDL addresses seasonal variation by associating a daily load to every flow. The critical season extends from June to October when the flow is at its lowest and the stream use is at its peak.

7. MONITORING PLANS FOR TMDL UNDER THE PHASED APPROACH

Monitoring the waterbody is an important part of any water quality improvement project. Monitoring reveals the problem and defines its scope and extent. After various management practices are in place, monitoring shows whether water quality has improved and is meeting state standards. Stream monitoring should satisfy the frequency and duration conditions of the endpoint, as described in the current water quality standard.

8. IMPLEMENTATION

To stay below the TMDL curve, any existing loads above the curve must be reduced. The percent reduction is determined through comparison of E. coli in both observed (existing load) and predicted (TMDL) counts. This difference [existing – standard] must be positive.

$$\text{Percent reduction} = \frac{(\text{Existing count/day} - \text{Target count/day})}{\textbf{Existing count/day}} \times 100$$

Using this equation, it is apparent that each excedance corresponds to a percent reduction. This reduction may be realized through various management methods. It should be noted that there are samples greater than the target load at extreme low flows, suggesting a point source sole contribution.

Improved watershed management will control runoff and consequently reduce bacteria contamination. These same management practices will improve water quality by reducing sediment and nutrient entrainment. Efforts should try to address all sources of bacteria. Possibilities include limiting livestock access to water ways, maintaining on-site wastewater treatment system (OWTS) a.k.a septic system.

9. REASONABLE ASSURANCES

An educated and functional stakeholder group has the knowledge and ability to affect change in a watershed. Black Creek partnership, if it exists, will formulate plans to reduce the bacteria load in the river. Part of the function of such a group is securing the funds to enable solutions to be implemented. Possible sources of funds include:

- 319 Nonpoint Source Grants and mini-grants
- Soil and Water Grants
- Farm Bill Equip Funds
- Federal Agency funding
- Private Contributions
- State Revolving Funds for Nonpoint Sources (specifically for on-site septic financial assistance)
- Community Development Block Grants
- EPA Environmental Justice Grants
- Department of Economic Development Funds
- Missouri Department of Transportation Funds

There is currently a Mississippi River Basin Initiative (MRBI) project in upper Black River watershed (WBID 112. The goal of the project is to reduce sediment and nutrients delivery to Black Cree and ultimately to the Mississippi River.

10. PUBLIC PARTICIPATION

The Missouri Department of Natural Resources, Water Pollution Control Program, developed this TMDL and will public notice it, so the public will have an opportunity to review the document. Any public comments will be addressed in a timely manner.
Public meeting may be schedule to present the findings to the inhabitants of Black Creek watershed.

11. APPENDICES AND LIST OF DOCUMENTS ON FILE WITH DNR

Appendix A – Map of the watershed

Appendix B – Map of Sample Locations and Impaired Stream Segment

Appendix C --Statistics and Load Duration Curve.

Appendix D – Conversion Factor and Geometric Mean Calculation

Appendix E – Maps of the land uses in the watershed

Appendix F – Tables

Appendix G: -- Water Quality Data.

Documents on File

NPDES Permit for Shelbyville in Shelby County, MO.

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MRBI-B Watershed Modeling Report

Background:

MRBI-B project extends over eight 12-digit hydrologic unit codes (HUC) and covers a total area of about 198,697 acres (table below).

WATERSHED	HUC_12	HU_12_NAME	Area (acre)
BEAR	071100050105	Muddy Fork-North Fork Salt River	23,645
	071100050106	Saling Branch-North Fork Salt River	20,505
	071100050108	Upper Bear Creek	28,890
	071100050109	Middle Bear Creek	20,358
	071100050110	Lower Bear Creek	20,066
	071100050111	Old Channel-North Fork Salt River	13,415
		Sub-Total	126,878
BLACK	071100050201	Pollard Branch-Black Creek	37,336
	071100050202	Black Creek	34,484
		Sub-Total	71,819
		Total	198,697

The land use is mostly row crops and grassland (table below and graph).

Class	Land Use Type	Bear Watershed		Black Watershed	
		Acres	Percent	Acres	Percent
1	Urban	1,223	1.7%	3,178	2.5%
2	Row and Close-growing Crops	43,260	60.2%	45,424	35.8%
3	Grassland	16,889	23.5%	54,230	42.7%
4	Forest and Woodland	7,174	10.0%	17,612	13.9%
5	Open water	3,236	4.5%	6,394	5.0%
6	Barren	49	0.1%	30	0.0%
	Total	71,830	100.0%	126,869	100.0%

The two acres difference between the two tables probably accounts for the lack of data regarding land use.

Modeling:

The Spreadsheet Tool for the Estimation of Pollutant Loads (STEPL) model was used to predict pollutants load reduction resulting from the implementation of selected best management practices (BMP). The watershed is mostly cropland and grassland. The simulated BMPs are reduced tillage systems and contour farming on 50% of the cropland area, road grass and legume seeding on 1/2 of forest land. Combined BMPs were applied on 30% of the pastureland and on 20% of the user defined areas. Runoff Management System was applied to feedlots. The user defined areas are barren land and open water. The resulting reductions are summarized below.

Percent reductions with BMP

	Nitrogen	Phosphorus	BOD	Sediment
BLACK	19.1	37.3	7.0	33.4
BEAR	17.6	27.4	3.5	18.1

Total load by land uses (with BMP)

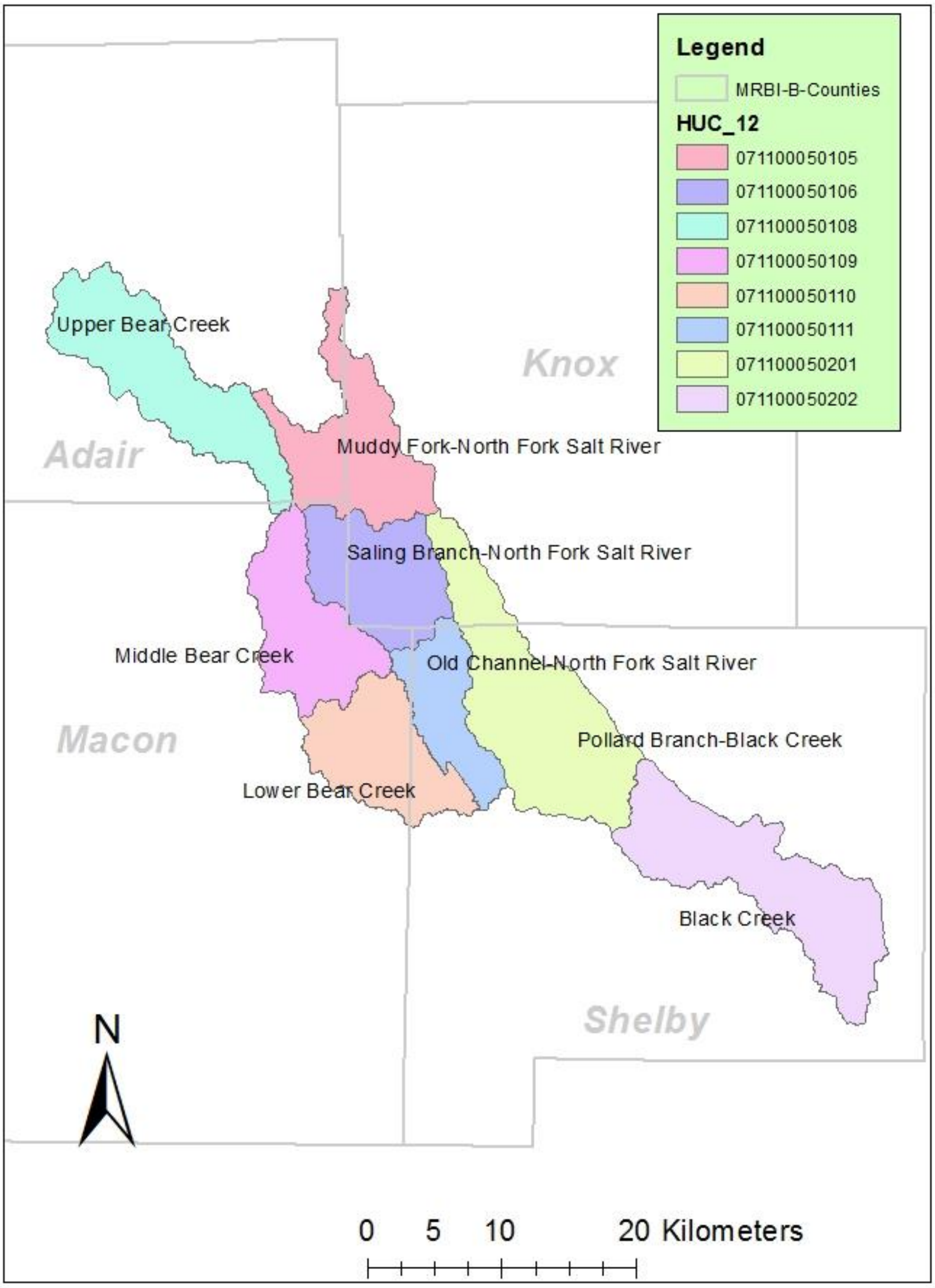
Sources	N Load (lb/yr)	P Load (lb/yr)	BOD Load (lb/yr)	Sediment Load (t/yr)
Urban	24,712.45	3,803.66	95,242.69	567.22
Cropland	731,142.79	155,248.95	1,622,982.20	32,671.67
Pastureland	320,841.55	31,792.68	1,052,964.05	7,423.36
Forest	4,529.12	2,208.42	11,078.72	152.54
Feedlots	206,116.01	7,214.06	274,821.35	0.00
User Defined	18,266.45	7,032.58	36,532.90	5,708.27
Septic	1,865.29	730.57	7,616.61	0.00
Total	1,307,473.66	208,030.93	3,101,238.52	46,523.06

Monitoring:

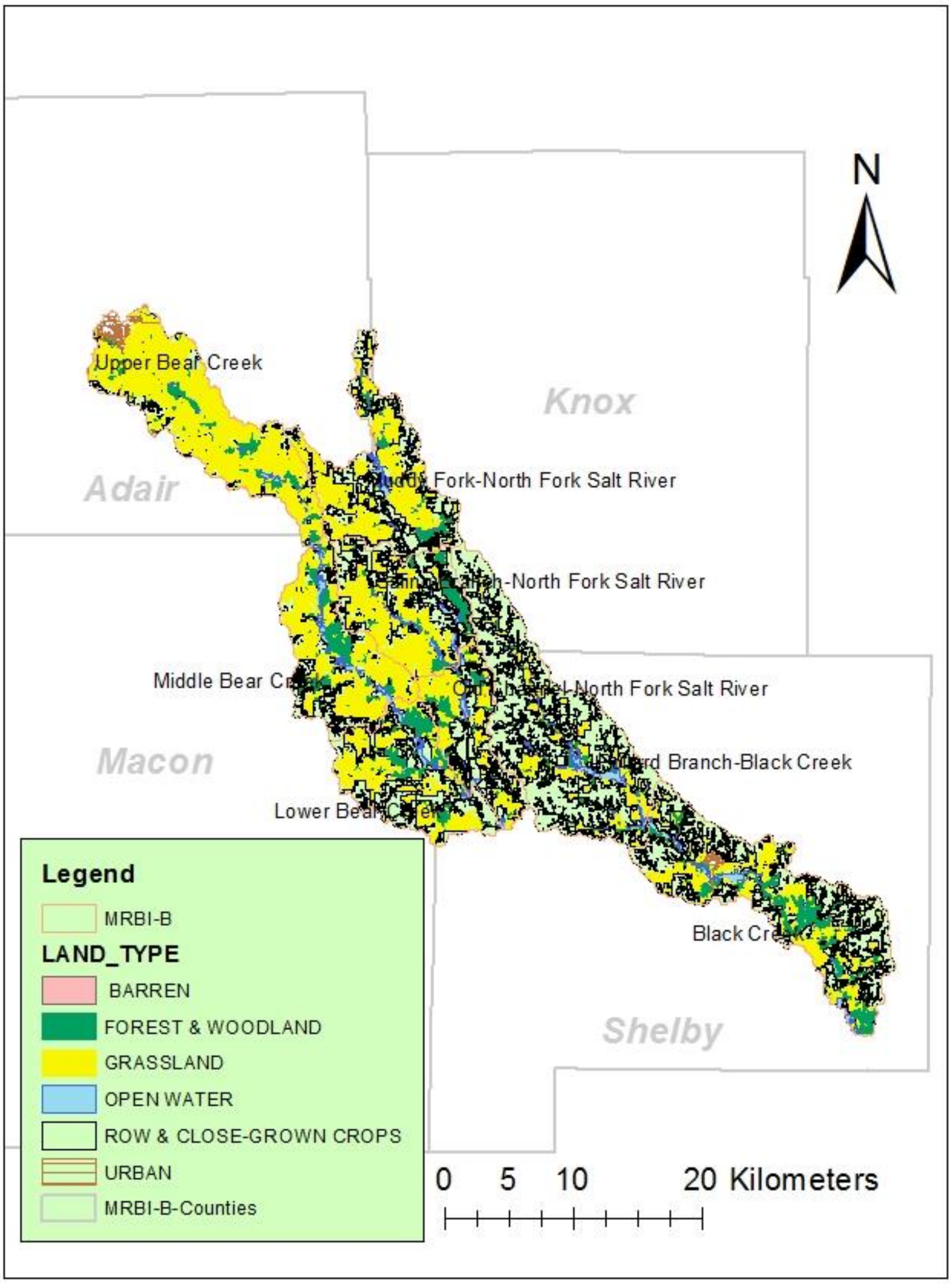
There are twenty seven water quality sampling sites, seven volunteer water-quality monitoring sites, and four USGS flow gauges in this watershed. The water quality sampling sites are listed in the table below:

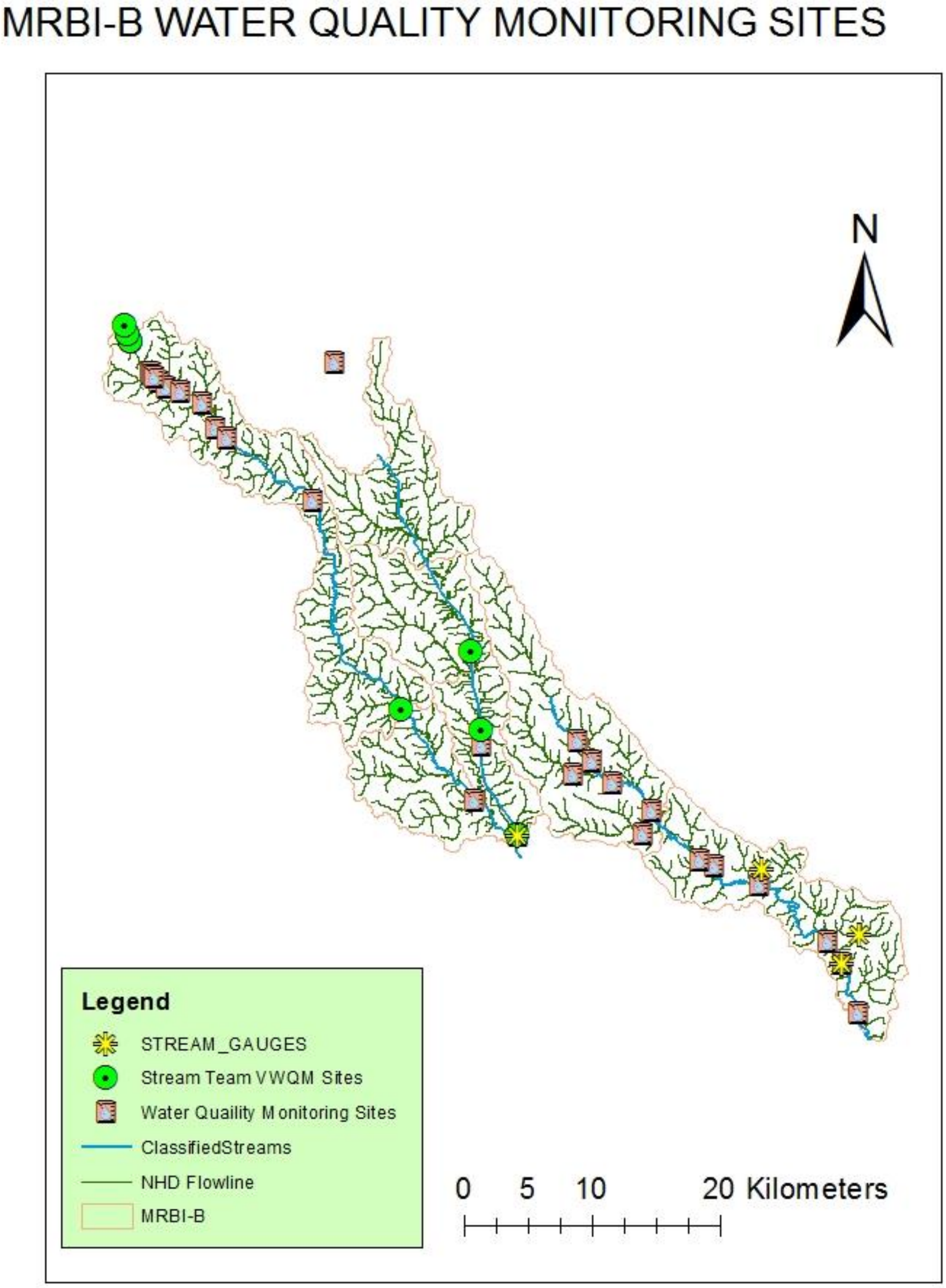
SITE_CODE	SITE_NAME	WBID	LOC_TYPE	COUNTY
110/46.7	N. Fk. Salt R. at Hwy. 151	110.00	River/Stream	Shelby
110/51.6	N. Fk. Salt R. bl. CR 105	110.00	River/Stream	Shelby
110/81.4	N. Fk. Salt R. 0.6 mi. ab. Tiger Way	110.00	River/Stream	Adair
111/16.4	Black Cr. Ab. CR 349	111.00	River/Stream	Shelby
111/2.3	Black Cr. Bl. CR 478	111.00	River/Stream	Shelby
111/6.0	Black Cr. Ab. Hwy T	111.00	River/Stream	Shelby
111/7.1	Black Cr. nr Oak Dale Church	111.00	River/Stream	Shelby
112/13.5	Black Cr. Ab.CR 127	112.00	River/Stream	Shelby
112/15.5/0.5	Gray Br. @CR 134	112.00	River/Stream	Shelby
112/15/1.8	Perry Br. @Hwy H	112.00	River/Stream	Shelby
112/18.0	Black Cr. Bl. Hwy M	112.00	River/Stream	Shelby
112/3.0	Black Cr. Ab. Hwy K	112.00	River/Stream	Shelby
112/7.4/1.3	Pollard Br. @CR 227	112.00	River/Stream	Shelby
112/8.9	Black Cr. Bl. CR 226	112.00	River/Stream	Shelby
115/26.3	Bear Cr. 13.9 mi.bl. Kirksville WWTP	115.00	River/Stream	Adair
115/3.9	Bear Cr. 4 mi. NW of Hagers Grove	115.00	River/Stream	Shelby
115/33/0.2	Bear Cr. at Hwy. KK	115.00	River/Stream	Adair
115/33/1.1	Bear Cr. 6 mi.bl. Kirksville WWTP	115.00	River/Stream	Adair
115/33/3.5	Bear Cr. at Desoto Ln.	115.00	River/Stream	Adair
115/33/5.1	Bear Cr. 2.1 mi.bl. Kirksville WWTP	115.00	River/Stream	Adair
115/33/6.1	Bear Cr. 1.1 mi.bl. Kirksville WWTP	115.00	River/Stream	Adair
115/33/6.5	Bear Cr. 0.7 mi.bl. Kirksville WWTP	115.00	River/Stream	Adair
115/33/7.0	Bear Cr. 0.2 mi. bl. Kirksville WWTP	115.00	River/Stream	Adair
115/33/7.1	Bear Cr. 0.1 mi.bl. Kirksville WWTP	115.00	River/Stream	Adair
115/33/7.2	Kirksville WWTP Effluent Outfall 001	115.00	Facility Municipal Sewage (POTW)	Adair
115/33/7.3	Bear Cr. 0.1 mi.ab. Kirksville WWTP	115.00	River/Stream	Adair
7036/0.1	Shelbyville Lake nr dam	7036.00	Reservoir	Shelby

MRBI-B Watershed



MRBI-B LANDUSE





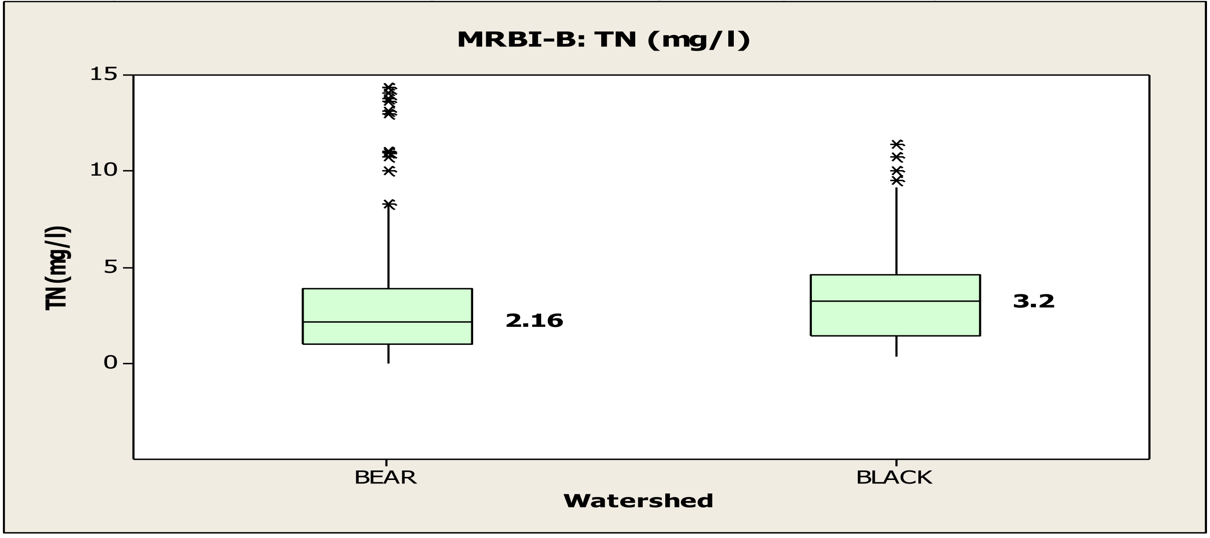
Black Creek - water body ID 111 (class P) – is listed impaired on the 2012 303(d) list. This 19.4-mile segment does not meet whole body contact recreation criterion due to excessive E. coli indicator bacteria. It is also listed for low dissolved oxygen, which impairs aquatic life use. Shelbyville WWTF and nonpoint source are named as sources of bacteria. Low dissolved oxygen is from an unknown source. Shelby County Soil & Water Conservation District (SWCD) was awarded a 319-grant to address Black Creek impairment. The University of Missouri's department of biological engineering is helping modeling the watershed with SWAT (Soil & Water Assessment Tool).

A second modeling approach was used to link long term average stream flow with nutrients and total suspended solid (TSS) loading. Long-term average daily flow data from USGS gauging station on North Fork Salt River at Hagers Grove, Missouri – station number 05502300 were used to create a flow duration curve at the outlet of Bear Creek watershed. USGS gauging station on Black Creek below Shelbyville, Missouri was used to develop the flow duration at the outlet of Black Creek watershed. Nutrient thresholds were determined from the pooled data of both watersheds. The threshold concentrations along with other statistics are presented in the table below:

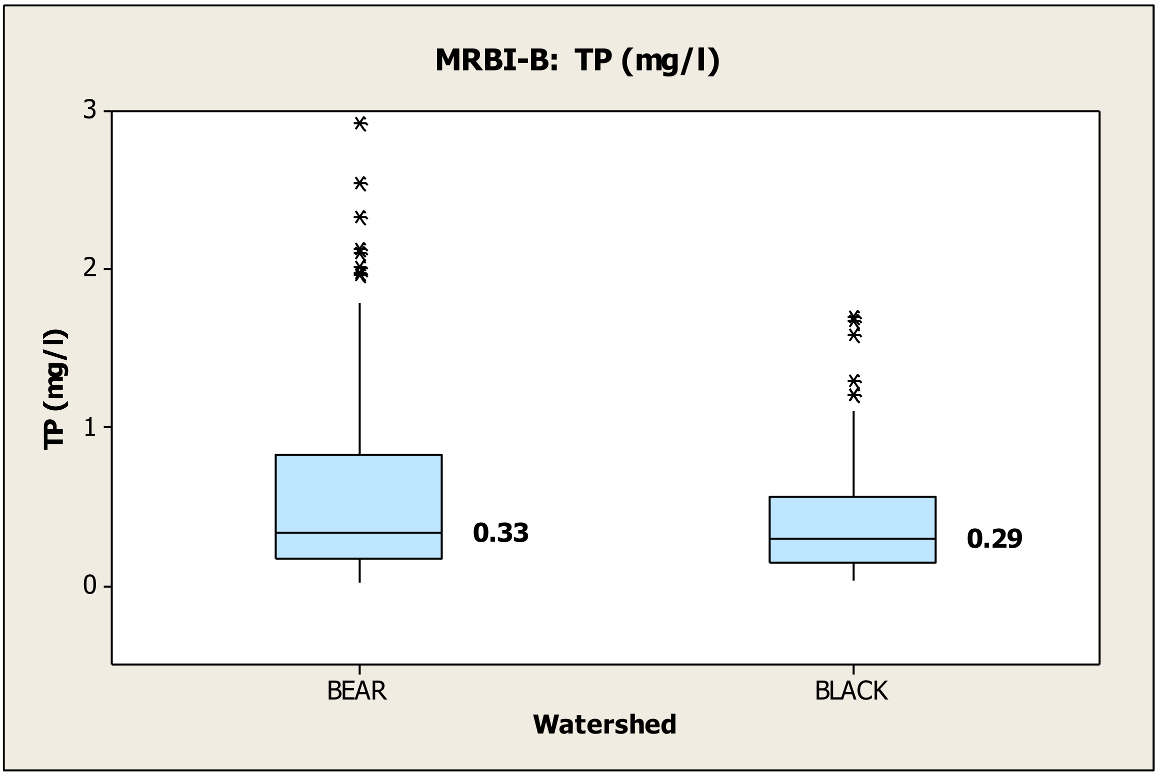
	Flow ft^3/s	**TN mg/L**	**TP mg/L**	**TSS mg/L**
Count	**1123**	**248**	**418**	**1378**
Average	**469.3**	**2.6**	**0.7**	**234.8**
Min	**0.002**	**0.013**	**0.02**	**1**
Max	**14300**	**10.76**	**9.72**	**4460**
Geometric Mean	**43.1**	**1.2**	**0.5**	**89.3**
25th percentile		**0.67**	**0.20325**	**37**

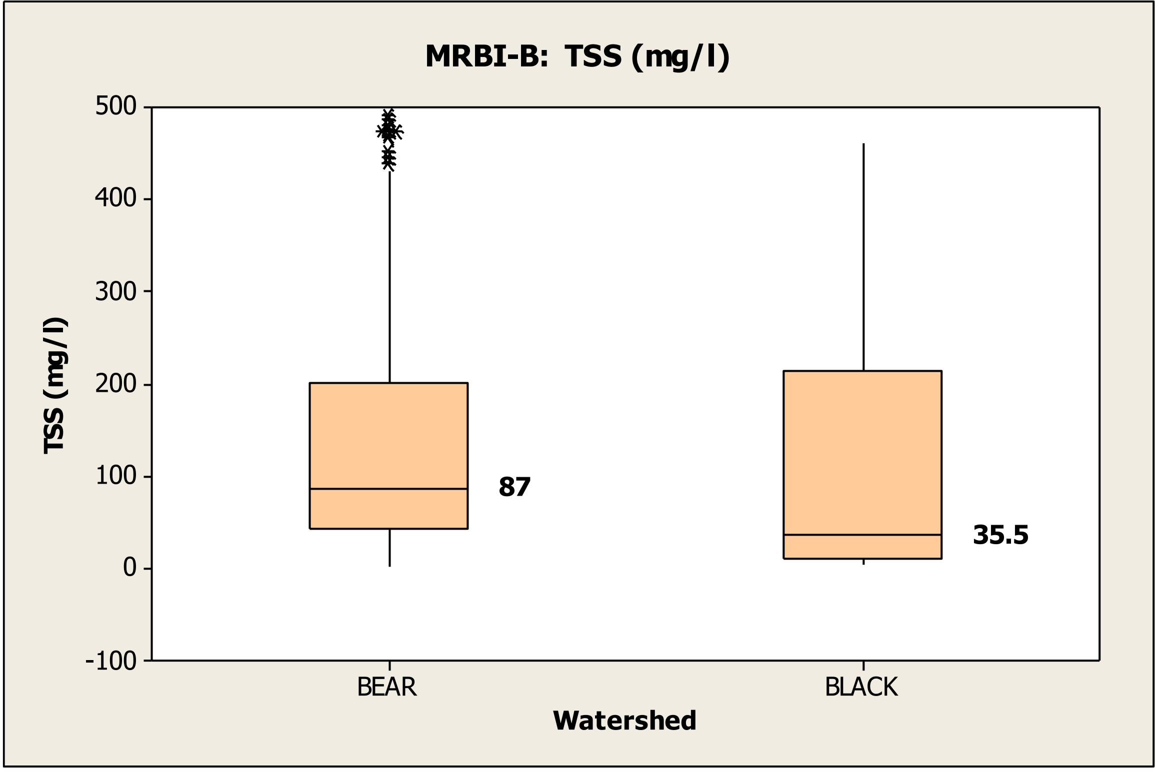
Note: 15 mg/L of TSS was used as threshold.

Summary statistics shown in the graphs below are grouped by water body ID.

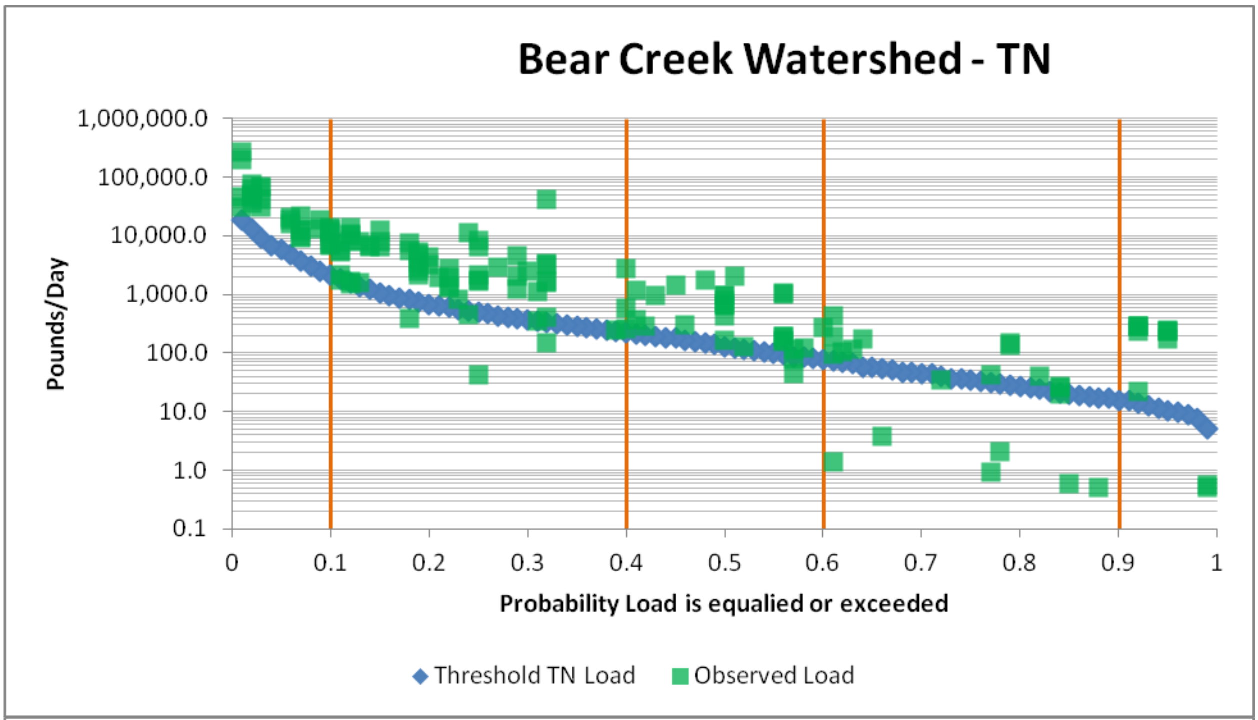


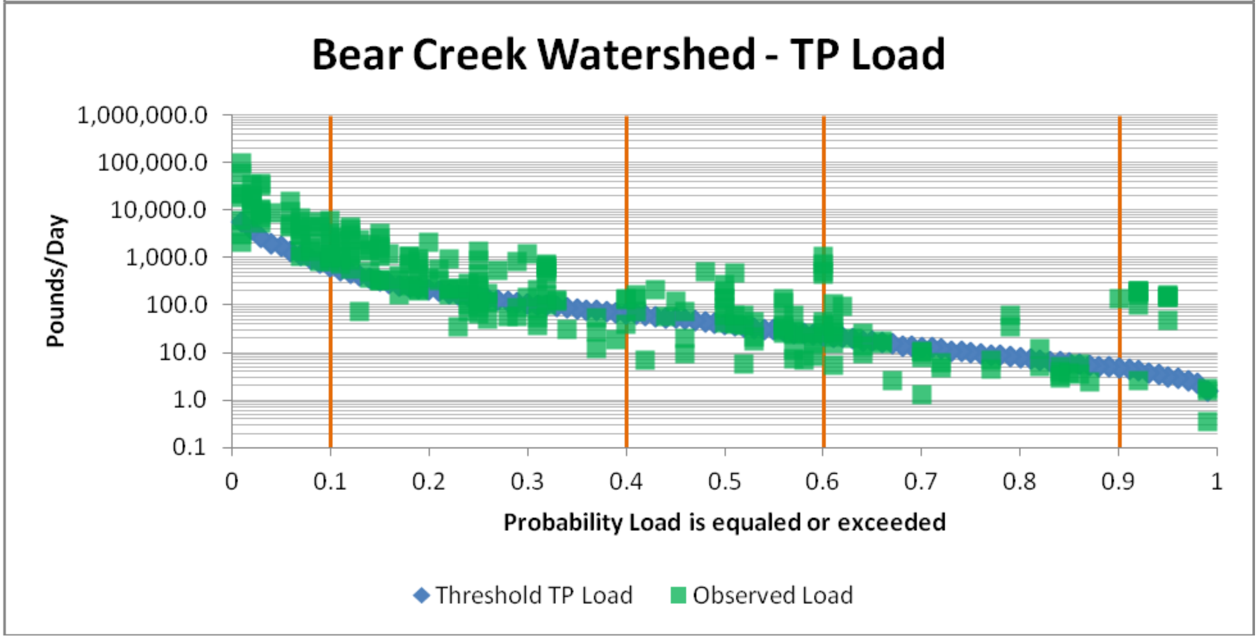
Black Creek Watershed contains WBID 111 and 112, while Bear Creek Watershed contains WBID 110 and 115.

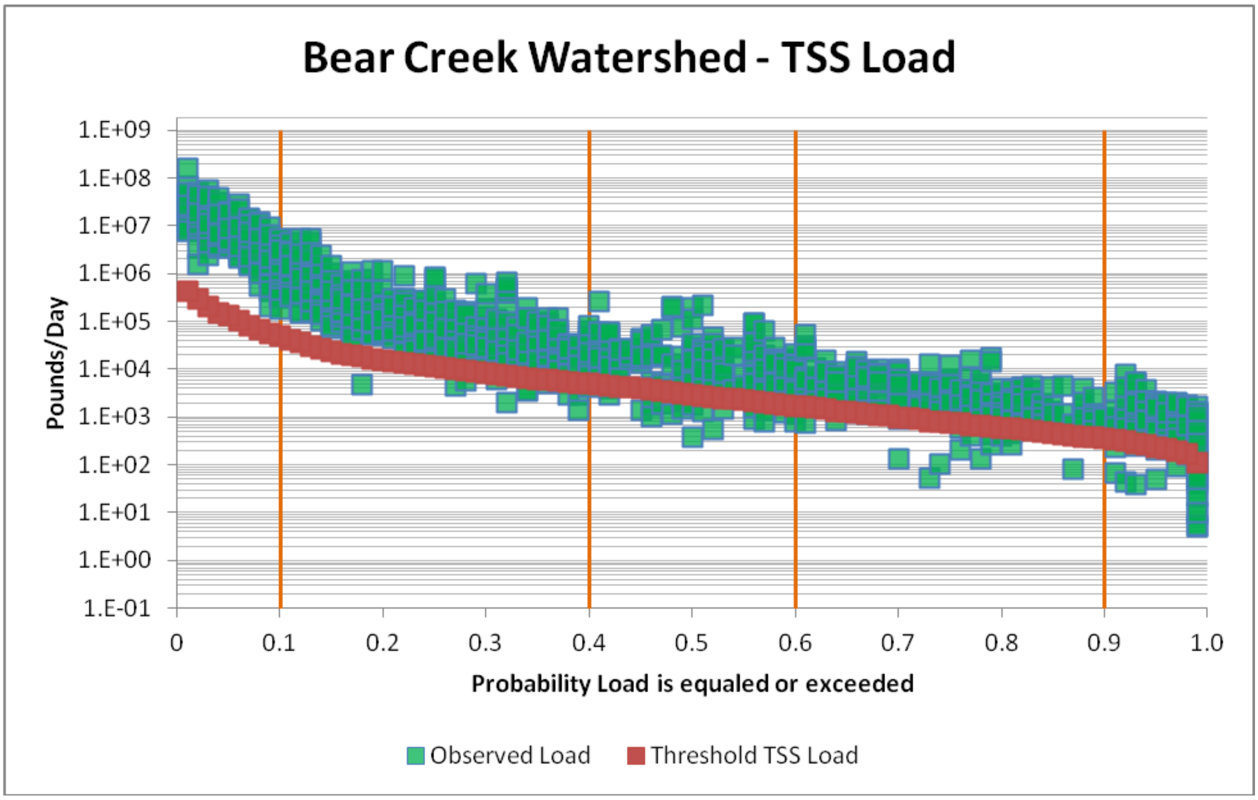




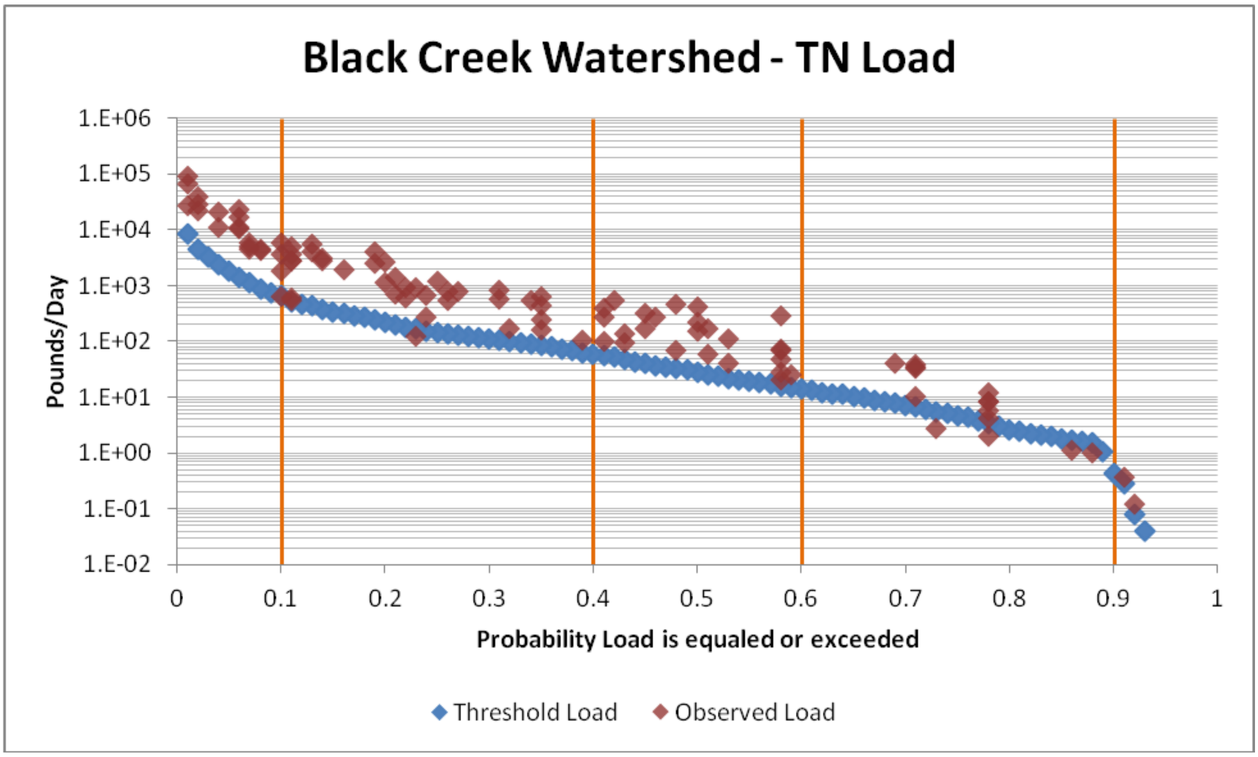
The horizontal lines in the graphs show the first quartile, the median, and the third quartile of the data values. The symbol * represents outliers. To improve picture clarity, only concentration values close to the median are viewed – the maximum on the Y-axis is reduced.

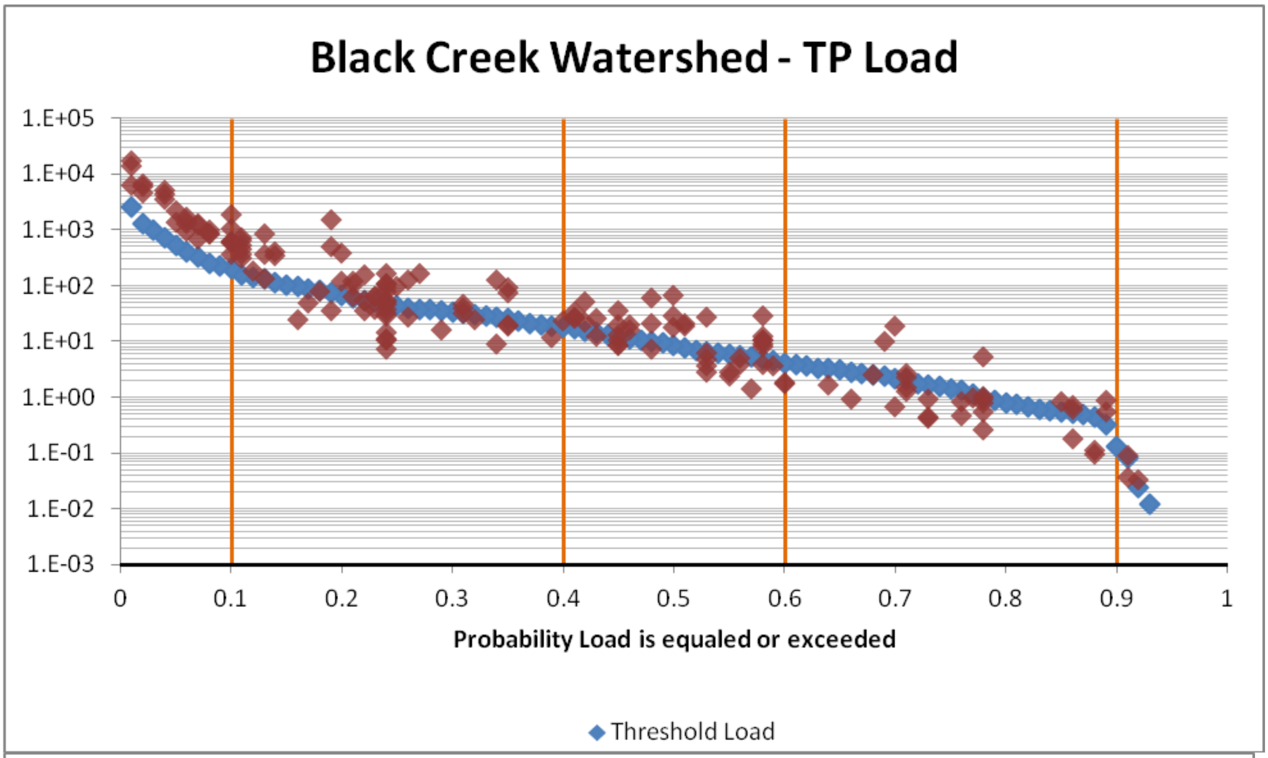

Bear Creek Watershed - TN
Pounds/Day
1,000,000.0
100,000.0
10,000.0
1,000.0
100.0
10.0
1.0
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Probability Load is equalied or exceeded
◆ Threshold TN Load
🟩 Observed Load

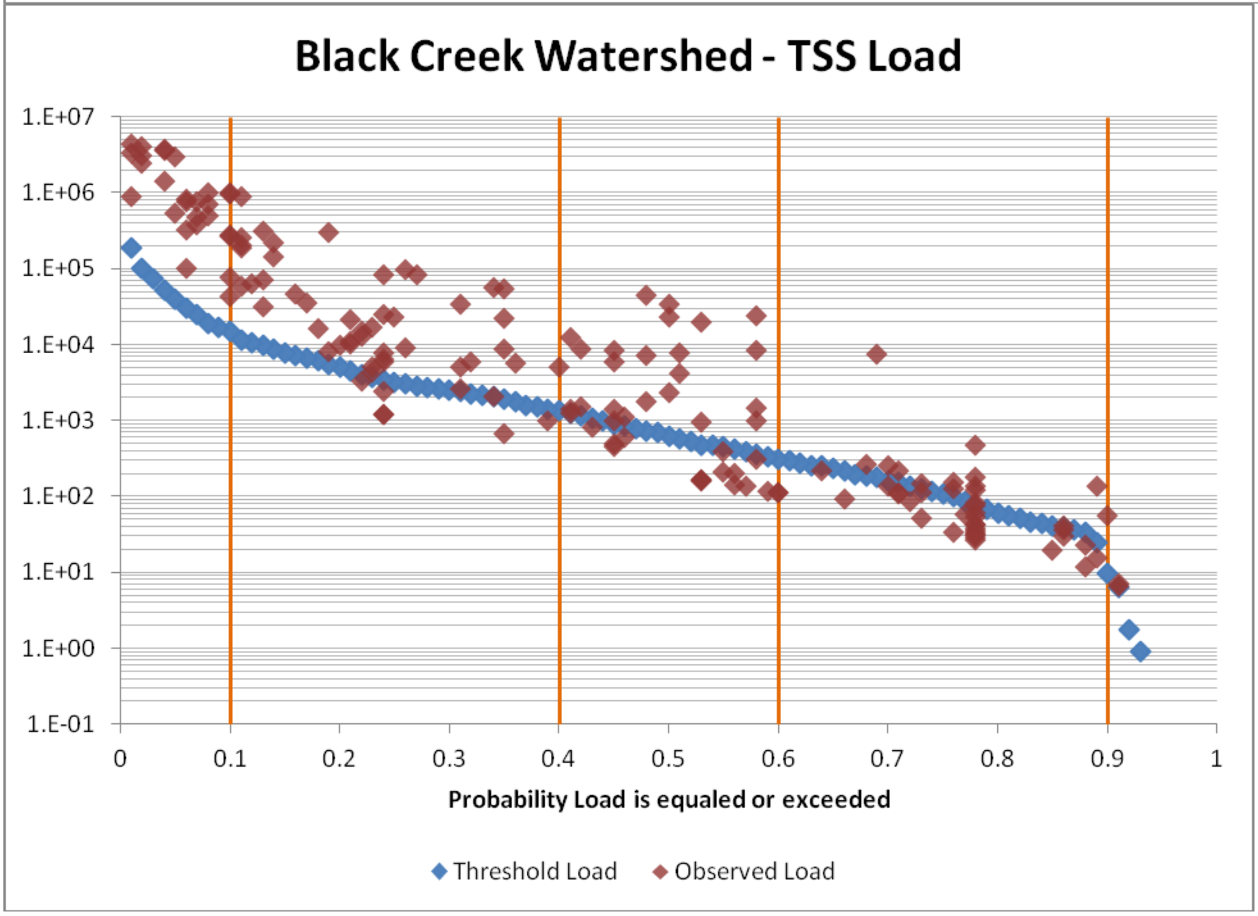

Bear Creek Watershed - TP Load
Pounds/Day
1,000,000.0
100,000.0
10,000.0
1,000.0
100.0
10.0
1.0
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Probability Load is equaled or exceeded
◆ Threshold TP Load
🟩 Observed Load



It is apparent, from the graph above, that almost all observed loads are greater than the threshold load.




Black Creek Watershed - TP Load
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
1.E-02
1.E-03
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Probability Load is equaled or exceeded
◆ Threshold Load


Black Creek Watershed - TSS Load
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
1.E-01
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Probability Load is equaled or exceeded
◆ Threshold Load
◆ Observed Load

The percent daily load reduction of all loads exceeding the threshold load within each of the flow ranges was estimated using the following formula:

$$Percent\ reduction = \frac{(Observed\ Load - 0.9 * Threshold\ Load)}{Observed\ Load} * 100$$

Where: 1) The observed load is the geometric mean of loads within a flow range.

2) The threshold load corresponds to the medial load within the same flow range.

3) A 10 % margin of safety (MOS) was applied to account for any uncertainty.

Estimated TN Load Reduction in Bear Creek Watershed			
Flow Probability	Threshold Load	Existing Load	Percent Reduction
[0 to 0.1)	5,790	33,026	84%
[0.1 to 0.4)	1,071	4,179	77%
[0.4 to 0.6)	130	569	79%
[0.6 to 0.9)	34	127	76%
[0.9 to 1.0]	11	185	95%

Estimated TP Load Reduction in Bear Creek Watershed			
Flow Probability	Threshold Load	Existing Load	Percent Reduction
[0 to 0.1)	1,728	9,398	83%
[0.1 to 0.4)	320	1,011	72%
[0.4 to 0.6)	39	108	68%
[0.6 to 0.9)	10	43	79%
[0.9 to 1.0]	3	143	98%

Estimated TSS Load Reduction in Bear Creek Watershed			
Flow Probability	Threshold Load	Existing Load	Percent Reduction
[0 to 0.1)	129,600	9,690,491	99%
[0.1 to 0.4)	23,985	179,018	88%
[0.4 to 0.6)	2,916	14,424	82%
[0.6 to 0.9)	761	3,325	79%
[0.9 to 1.0]	235	890	76%

Estimated TN Load Reduction in Black Creek Watershed			
Flow Probability	Threshold Load	Existing Load	Percent Reduction
[0 to 0.1)	1,798.00	14,983.29	89%
[0.1 to 0.4)	342.26	1,412.02	78%
[0.4 to 0.6)	27.86	154.06	84%
[0.6 to 0.9)	4.78	16.47	74%
[0.9 to 1.0]	0.44	ND	

Estimated TP Load Reduction in Black Creek Watershed			
Flow Probability	Threshold Load	Existing Load	Percent Reduction
[0 to 0.1)	536.74	2,436.88	80%
[0.1 to 0.4)	102.17	325.48	72%

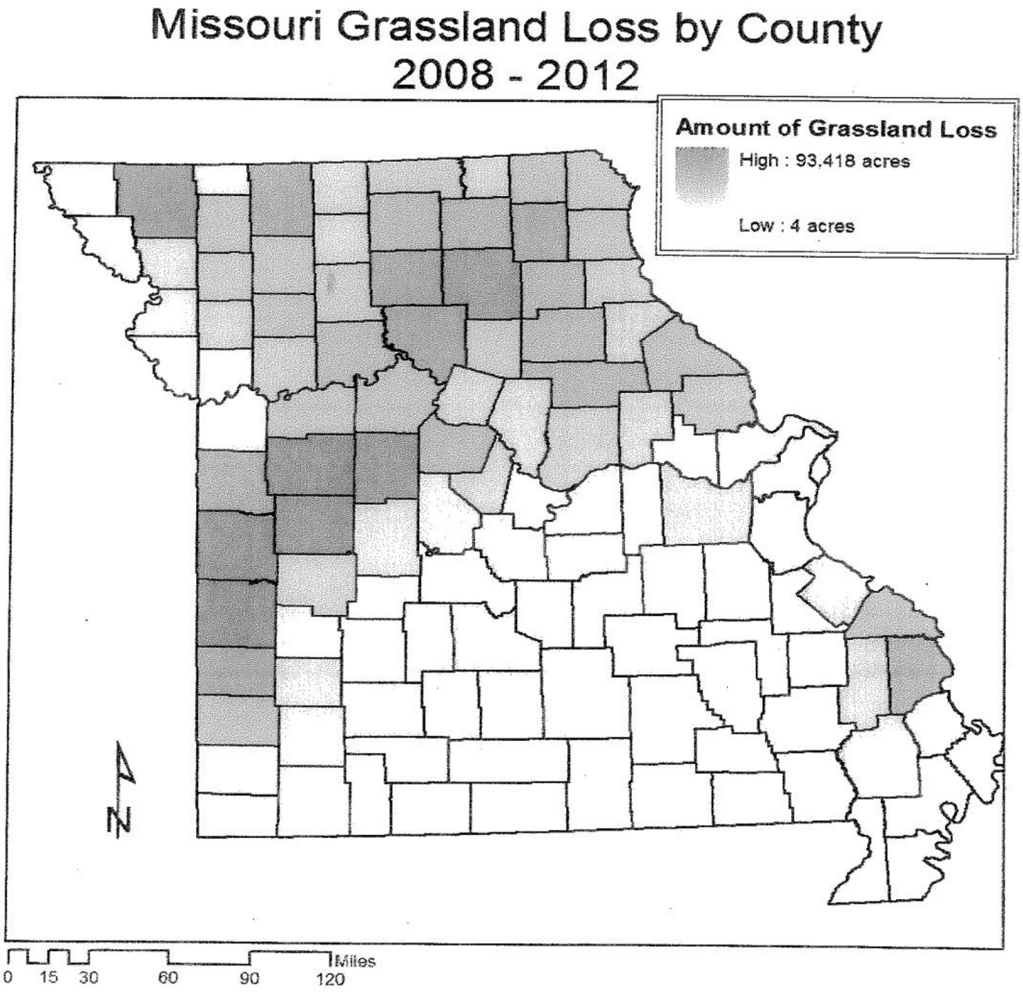
[0.4 to 0.6)	8.32	20.16	63%
[0.6 to 0.9)	1.43	3.54	64%
[0.9 to 1.0]	0.13	ND	

Estimated TSS Load Reduction in Black Creek Watershed			
Flow Probability	Threshold Load	Existing Load	Percent Reduction
[0 to 0.1)	40,255.38	1,120,308.60	97%
[0.1 to 0.4)	7,662.60	65,901.78	90%
[0.4 to 0.6)	623.70	3,851.58	85%
[0.6 to 0.9)	106.90	229.11	58%
[0.9 to 1.0]	9.80	54.81	84%

ND= no data

Where there are no observed data or when all observed loads are lower than the threshold load within a flow range, the corresponding reduction

Appendix E. Maps and Photos



Missouri Grassland Loss by County
2008 - 2012

NAME	Acres
Adair	51,792
Andrew	28,440
Atchison	21,697
Audrain	51,111
Barry	11,336
Barton	64,212
Bates	93,419
Benton	27,610
Bollinger	33,328
Boone	27,906
Buchanan	23,362
Butler	8,613
Caldwell	44,619
Callaway	36,448
Camden	1,695
Cape Girardeau	53,502
Carroll	47,973
Carter	1,005
Cass	59,268
Cedar	18,642
Chariton	59,459
Christian	4,113
Clark	41,108
Clay	18,352
Clinton	36,230
Cole	16,771
Cooper	51,782
Crawford	3,409
Dade	30,967
Dallas	6,239
Daviess	43,027
DeKalb	40,332
Dent	1,874
Douglas	1,319
Dunklin	3,398
Franklin	29,244
Gasconade	18,147
Gentry	44,760
Greene	10,292
Grundy	33,708
Harrison	58,851
Henry	73,309
Hickory	11,386
Holt	13,518
Howard	31,605
Howell	1,597
Iron	904
Jackson	16,024
Jasper	49,839
Jefferson	6,262
Johnson	80,578
Knox	52,677
Laclede	7,243
Lafayette	42,652
Lawrence	27,916
Lewis	42,343
Lincoln	40,914
Linn	59,747
Livingston	38,381
Macon	66,613
Madison	4,068
Maries	10,763
Marion	35,340
McDonald	2,618
Mercer	33,968
Miller	10,482
Mississippi	1,741
Moniteau	32,840
Monroe	48,083
Montgomery	32,443
Morgan	21,762
New Madrid	1,095
Newton	15,045
Nodaway	70,846
Oregon	1,701
Osage	19,499
Ozark	563
Pemiscot	246
Perry	44,065
Pettis	69,766
Phelps	3,554
Pike	46,459
Platte	21,067
Polk	17,292
Pulaski	2,430
Putnam	39,147
Ralls	32,345
Randolph	38,504
Ray	38,615
Reynolds	1,180
Ripley	3,457
Saline	43,333
Schuyler	32,179
Scotland	42,591
Scott	11,980
Shannon	1,057
Shelby	47,996
St Charles	18,593
St Clair	36,149
St Francois	7,820
St Louis	3,397
St Louis City	4
Ste Genevieve	25,445
Stoddard	26,792
Stone	927
Sullivan	48,838
Taney	411
Texas	5,397
Vernon	76,037
Warren	14,775
Washington	1,376
Wayne	5,525
Webster	5,340
Worth	18,359
Wright	4,889

1,332,670

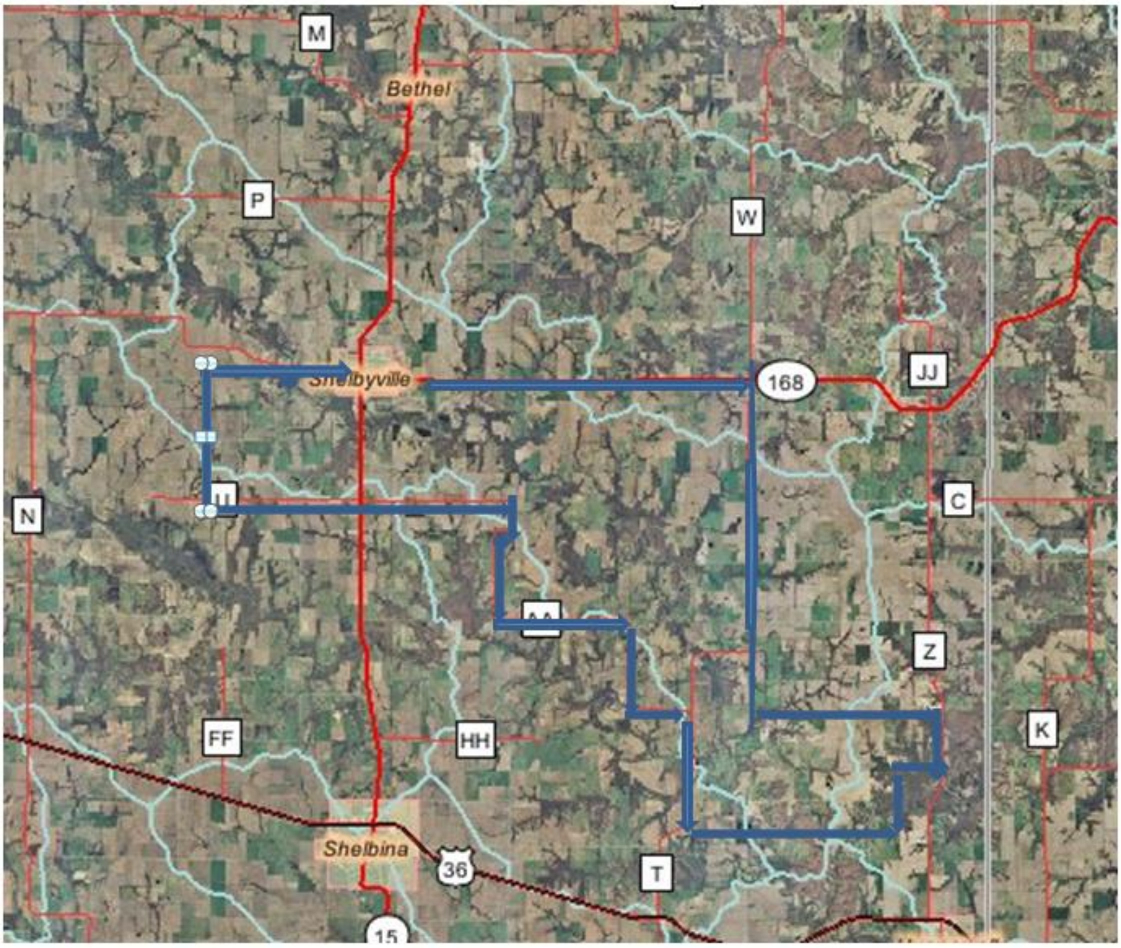
1,137,935

632,458

27,219/co across state.

3,163,063

Map of approximate driving route for watershed windshield survey



Evaluation of Water Quality and Best Management Practices (BMPs) in the Black Creek Watershed Using the SWAT Model

Prepared for:
Watershed Planning Committee

Prepared by:

Nayereh Ghazanfarpour

Robert Broz

Claire Baffaut

Mitch Krueger

Department of Natural Resources (DNR)

December 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

Black Creek Watershed is currently on the state's 2012 303(d) List for low dissolved oxygen caused by unknown sources and bacteria, with nonpoint sources (NPS) and the Shelbyville wastewater treatment facility cited as a potential source. The Nonpoint Source Program and Grants Guidelines for States and Territories for fiscal year 2004 and beyond require a Watershed–Based Plan (WBP) to be completed prior to implementation using incremental funds.

The guidance defines the nine key elements to be addressed in a watershed-based plan. These components include: 1) identification of causes and sources that will need to be controlled to achieve load reductions, 2) estimate of load reductions expected from the management measures described, 3) a description of the management measures that will need to be implemented to achieve load reductions, 4) an estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources or authorities who will bear responsibility, 5) an information/education component that will be used to enhance public understanding of the project and encourage early participation in the overall program, 6) a schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious,

7) a description of interim, measurable milestones for determining whether control actions are being implemented, 8) a set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made or whether the Watershed Plan or Total Maximum Daily Load (TMDL) needs to be revised, and 9) a monitoring component to evaluate the effectiveness of the implementation efforts over time.

In order for a watershed management plan to become an effective tool, it must be amenable to revision and update. The Black Creek Watershed Management Plan (WMP) has been developed as a dynamic document that will be revised to incorporate the latest information, address new strategies, and define new partnerships between watershed stakeholders.

Stream data from the North Fork Salt watershed, of which the Black Creek Watershed is a part, were collected by MEC Water Resources, Inc. (MEC), U.S. Army Corps of Engineers, and Missouri Department of Natural Resources (MDNR) from 1971-2010. Summary data for Black Creek shows the following in mean lbs/day; Ammonia Nitrogen = 4.07, Nitrate Nitrogen= 63.43, Total Nitrogen = 127.77, Total Phosphorus = 22.18, Total Suspended Solids = 12,962. Runoff from agricultural lands is believed to be responsible for these elevated nutrient and sediment levels (Mark Twain Lake- North Fork Salt Watershed Project: Integrated Conservation Practice Implementation, Monitoring and Outreach; Mississippi River Basin Healthy Watersheds Initiative (MRBI)).

The only discharging point source in watershed is the Shelbyville Wastewater Treatment Facility which has a design flow of 0.07 million gallons per day (MGD).

Thus, it is imperative to conduct research that can contribute towards mitigating the contaminant loads from this watershed. For this purpose, the Soil and Water Assessment Tool (SWAT) model developed by USDA-ARS was selected to study the watershed with the following basic objectives:

- To accurately and efficiently quantify sediment and nutrient (Nitrogen and phosphorus) losses from the watershed
- To identify and prioritize critical sub-watersheds and to evaluate the relative importance of managing them
- To evaluate the effectiveness of alternative best management practices (BMPs) at reducing pollutant loads from the Black Creek Watershed

2. The Study Area

The study was conducted in the Black Creek Watershed (BCW) which is located in the Northeast Missouri covering a total area of about 34,484 acres (53.9 sq. miles) in the Shelby County (Figure 1). Black Creek is a tributary of the North Fork of the Salt River which is part of the Mark Twain Lake watershed (Figure 2). Mark Twain Lake is the drinking water source for the Clarence Cannon Consolidated Water District which provides three million gallons of drinking water daily, through 325 miles of water transmission lines, to approximately 42,000 people living in 14 counties in northeast Missouri.

Black Creek Watershed is designated by a 12-Digit Hydrologic Unit Code (HUC) 071100050202 (Figure 3).

Based on data from the Center for Applied Research and Environmental Systems (CARES) website of University of Missouri, the total population for the Black Creek watershed was 1,086 as of 2001. There were 429 households in the watershed with over half of the population in the 18- 64 year old age range (See Table 1). The watershed includes the town of Shelbyville whose population is 544 based on the 2010 census.

Forty percent of livestock in the watershed have access to streams. Much of the riparian area along Black Creek is degraded by overgrazing or row-crop agriculture. Only 5 percent of the riparian area is protected through the Conservation Reserve Program (CRP) or Wetland Reserve Program (WRP) long-term easements. Most of the protected area is at the southern end of the watershed where it merges with the North Fork Salt River. This region periodically backs up during high water levels in Mark Twain Lake. The major water bodies within the Black Creek watershed are listed in Table 2 with stream length.

Figure 1: Location Map of Black Creek Watershed

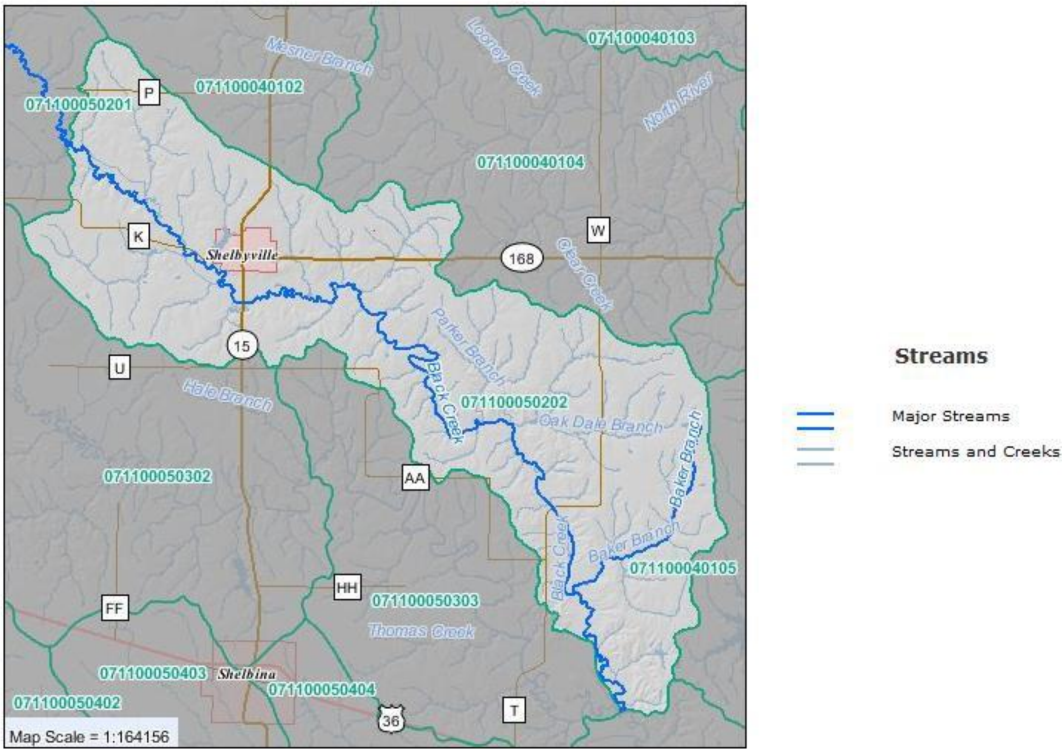


Figure 2: Hydrologic Unit Code (HUC) and Streams of Black Creek Watershed

Source: **www.***cares***.***missouri***.edu**

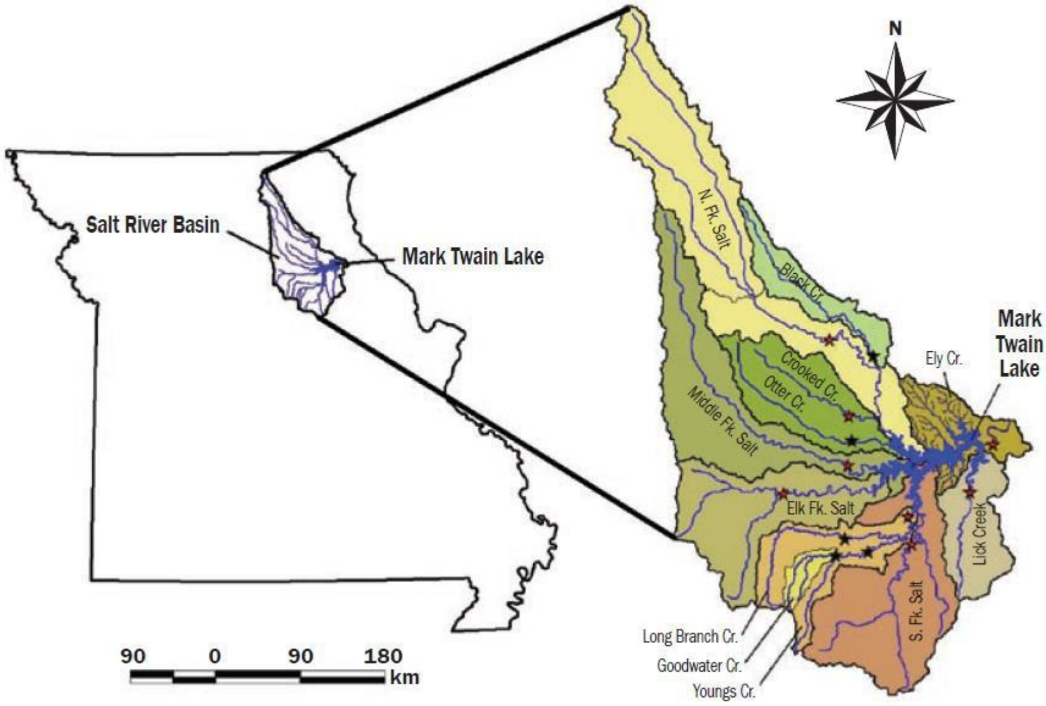


Figure 3: Position of Black Creek Watershed within Salt River Basin
Source: Overview of the Mark Twain Lake/Salt River Basin Conservation Effects Assessment Project, 2008

Table 1: Black Creek Watershed Population (*source:* www.*cares.missouri*.edu)

	Population	Percent
Age 0-4	62	5.71%
Age 5-17	239	22.01%
Age 18-64	594	54.70%
Age 65 and up	191	17.59%
Total Population	1,086	100%
Persons/Sq Mile	20.16	-

Table 2: Major Water Bodies within the Black Creek Watershed

Stream Name	Stream Length (Miles)
Baker Branch	4.82
Black Creek	26.74
Oak Dale Branch	4.46
Parker Branch	3.37
Total	39.39

According to the Center for Applied Research and Environmental Systems (CARES) website of University of Missouri, land use in 2001 within the Black Creek watershed can be described as the below:

Cropland is the primary land use of the watershed, accounting for approximately 47.64% of the available acres. Grassland, 30.92%, Forest, 13.57%, Wetland, 2.57%, Developed, 4.81% and Water, 0.49% make up the rest.

The Black Creek watershed lies within the clay pan soil region. These soils are characterized by a subsoil horizon with an abrupt and large increase in clay content within a short vertical distance in the soil profile (Soil Science Society of America 2001). Smectite clay minerals with high shrink-swell potential dominate the argillic zone. During the winter and spring periods, the clays are swollen, and their low saturated hydraulic conductivity impedes infiltration and perches water above the clay pan, causing a high probability of runoff (Blanco-Canqui et al. 2002). There is also a high probability of annual shrinkage cracks forming during the late summer and early fall periods. Preferential flow through these cracks is significant (Baer and Anderson, 1997). According to the State Soil Geographic (STATSGO) database, the clay pan soils in the watershed include the Mexico series which cover 92% of the land area. Other soil series include the Lindley series, which covers 6.7% of the watershed, is well drained and moderately permeable, and forms in dissected glacial till that may have a thin loess cap; and the Fatima series, which is 1.5% of the watershed, is moderately well drained with moderate permeability, and forms in alluvium.

Most soils in the basin are classified in hydrologic groups C and D (USDA NRCS 2005). Group C soils are primarily hillslope soils in dissected till. They have a slow infiltration rate and moderate runoff potential due to argillic horizons or paleosols that impede downward movement of water. Group D soils occurring at summits have a very slow infiltration rate and high runoff potential due to claypans, as described above. Group D soils formed in alluvium have a seasonally high water table and/or high flooding potential.

Annual rainfall of 38- 40 inches per year with spring and summer showers enhance runoff potential.

Topography within the watershed ranges from 0 percent slope to greater than 10 percent slope. Most of the lands are in the 0 - 6 percent range (Figure 4).

Elevation in the watershed varies from 192 m (629 ft) above mean sea level to 244 m (800 ft) above mean sea level. The mean elevation in the BCW is 224 m (734 ft) (Figure 5).

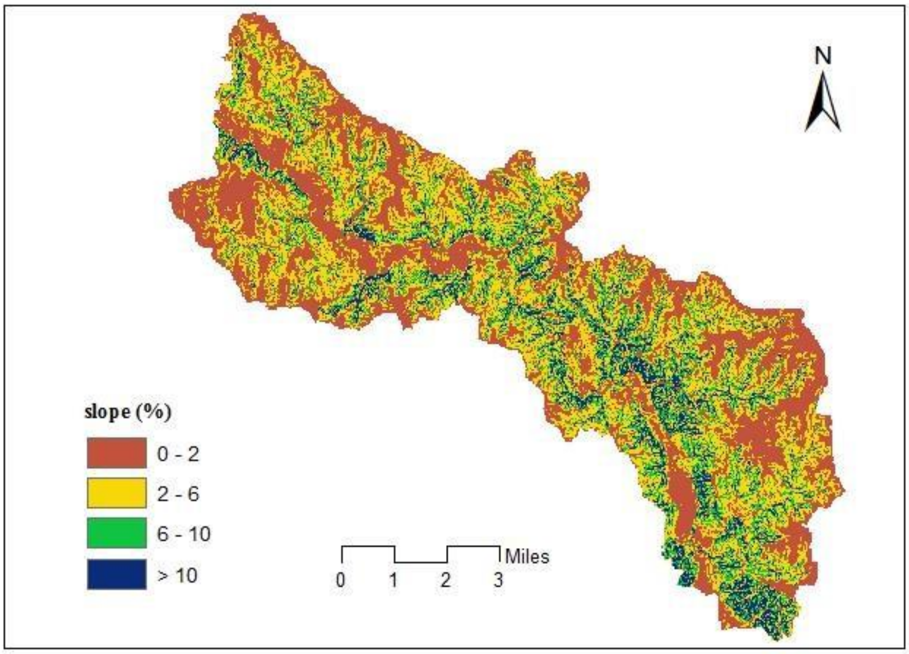


Figure 4: Slope map of BCW (*calculated from DEM*)

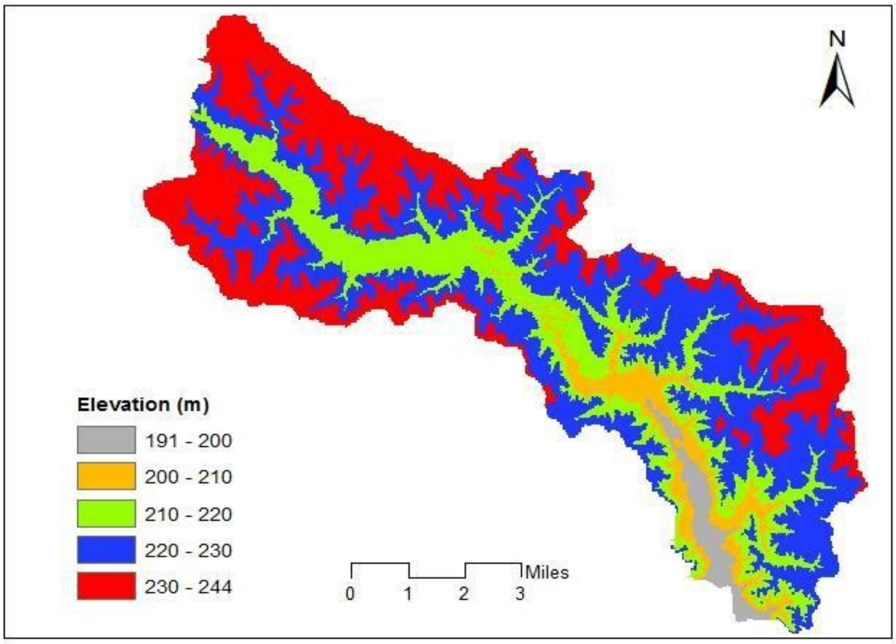


Figure 5: Elevation map of BCW (*calculated from DEM*)

3. SWAT Model

The Soil and Water Assessment Tool (SWAT) was selected for this study due to its ability to simulate agricultural best management practices. An ArcGIS Interface for SWAT was used as ArcSWAT 2009 for this study.

The model was used to assess sediment and nutrient loads for 19 sub watersheds within the Black Creek Watershed, and to predict load reductions under selected agricultural best management practices (BMPs) scenarios.

SWAT is a continuous time, watershed-scale model developed by the USDA Agricultural Research Service. SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time (Neitsch et al., 2002a). In the last ten years, SWAT has been used extensively in the United States for TMDL development and watershed management planning. It is also widely accepted as an effective water quality modeling tool.

4. Model Input Data Organization

The SWAT model simulates a number of climate, hydrological, erosion, plant and pollutant processes and requires, at a minimum, topography, land use and soils data. However, additional data, such as local management practices and point source loadings, will increase the accuracy of modeling predictions. The best available local and national data were input into the model for use in the Black Creek Watershed. These inputs are described as follows.

4.1. Data Inputs

a) <u>Base GIS layers</u>

Digital Elevation Model – Stream network and slope data were determined from a 30-meter (1/3 arc second) Digital Elevation Model (DEM; Figure 6) obtained from the National Map Seamless Server (http://seamless.usgs.gov/index.php). More information about the National Elevation Dataset is available at: http://ned.usgs.gov/.

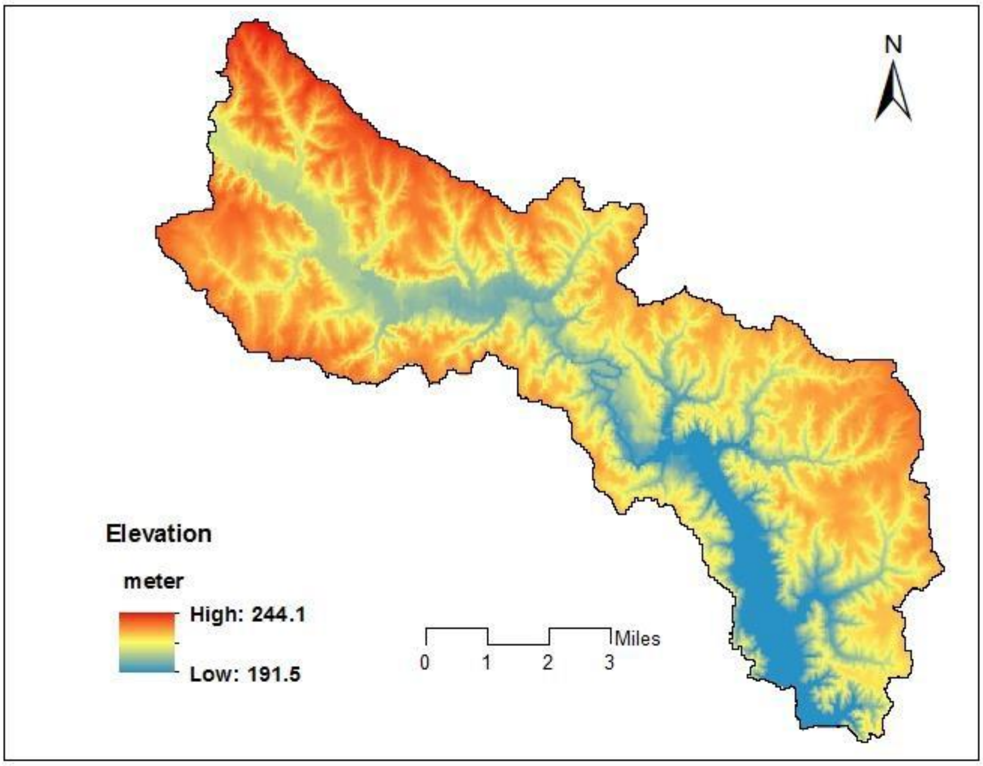


Figure 6: Digital Elevation Model (DEM) of the BCW
Source: http://seamless.usgs.gov/index.php

Sub watersheds- Within the SWAT model environment, the watershed can be further divided into smaller watersheds called sub watersheds. This permits some flexibility for model calibration as well as making modifications to management scheduling and targeting alternative management practices. Sub watersheds are the main units used in SWAT to summarize load results and determine target BMP areas. Jha et al. (2004) have demonstrated that, to adequately predict nutrient and sediment loads, threshold sub watershed areas should be on average about 2 to 5% of the total watershed area. Using 3% of the total watershed area as threshold, in total, 19 sub watersheds were therefore delineated (Figure 9) for the Black Creek Watershed application.

Land Cover and Land Use information were determined from the 2006 National Land Cover Database (NLCD: http://www.mrlc.gov/index.php); also available via the National Map Seamless Server. Pixel size for the 2006 NLCD is 30-meters.

In order to reduce the number of functional units handled by the SWAT model, some of the smallest land cover classes were aggregated into similar classes. The resulting land cover map was used as input for the SWAT model (Figure 7). The aggregation step was taken as a way to maintain model computation efficiency while simplifying some of the least prevalent land cover classes. This layer was re-classified according to SWAT's broader land use categories.

To classify the cropland into corn, soybean, sorghum, and wheat, crop data from the National Agricultural Statistics Service (NASS) (http://www.nass.usda.gov) was used. The average (2004-2008) cropland consisted of 28.3% corn, 61.5% soybean, 2.2% sorghum, and 8.0% wheat (Figure 8).

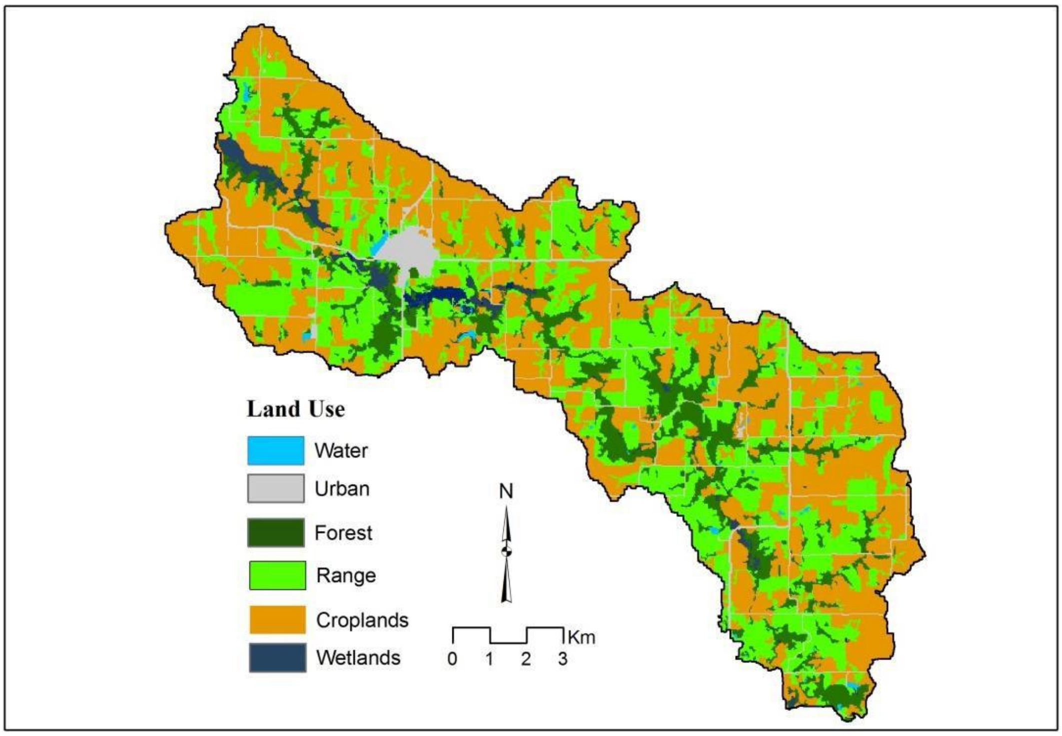


Figure 7: Land use classification for BCW watershed
Source: (2006 national land cover dataset)

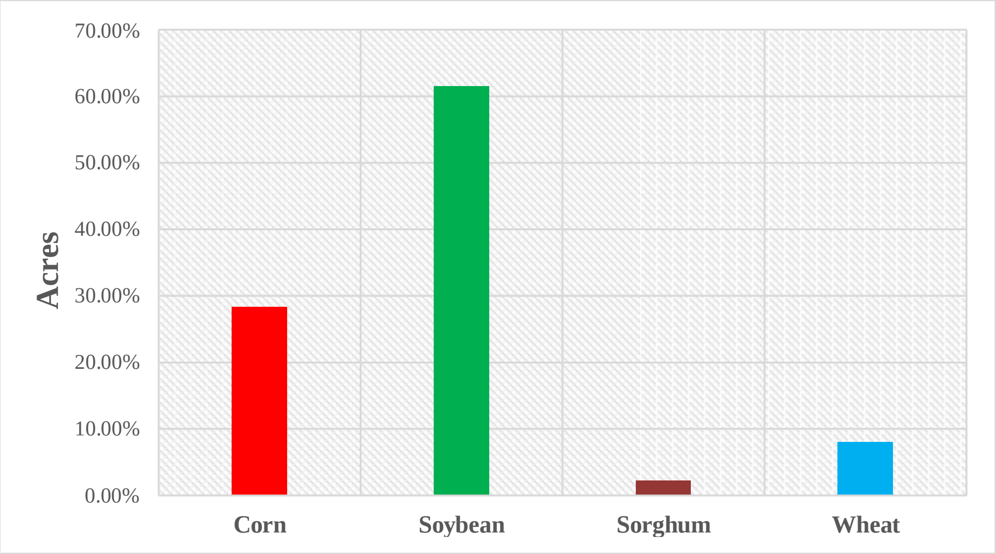


Figure 8: Crop data – source: (*http://www.nass.usda.gov*)

Soils Data were derived from the State Soil Geographic (STATSGO) database then the soil layer was overlaid with the land use and slope layers to create Hydrologic Response Units (HRUs). HRUs, the smallest modeling unit used in SWAT, correspond to a unique combination of soil, land use and slope. Modeling accuracy increases when sub watersheds are modeled with multiple HRUs. A threshold value set at 13% (i.e., any land use or soil area representing less than 13% of a sub watershed surface area is not modeled) resulted in at least two HRUs per sub watershed. In total, 839 HRUs were created in the watershed.

Spatial Data – All data used for this project were projected in UTM coordinates (NAD 83, Zone 15N).

b) Additional Data Input

Weather data- The SWAT model requires daily values of Precipitation, Temperature, Relative, humidity, Wind speed, and solar radiation. Daily precipitation and minimum and maximum temperature data measured from the Shelbina National Weather Service cooperative weather station was used in the analysis. Solar radiation, wind speed, and relative humidity data were estimated by the model. The weather monitoring station is located at latitude of 39.68° and longitude of -92.05° at elevation of 747 ft (Figure 9).

Cropping and management information- The cropping and management information for conventional and no-till tillage systems obtained from Ghidey et al. (2007) revised by Dr. Newell Kitchen (University of Missouri, Division of Plant Science). Appendix A lists the crop and tillage management for conventional tillage system used for the Black Creek Watershed as rotations of corn-soybeans-soybeans and corn-soybeans- wheat assumed representative of the croplands in the BCW. The distribution of grasses in the pastures is considered as 50% in fescue and 50% hay. Planned grazing was applied to facilitate the movement of cattle in the model (fescue 1 and fescue 2 in Appendix B). We assumed that each fescue pasture would be fertilized with commercial nitrogen and phosphorus once every two years. The different operations that take place in the pastures are described in detail in Appendix B.

Forests of the Black Creek Watershed typically are composed of deciduous species. Some producers allow their livestock to graze freely in woodlots, so cows were left in the woodland for protection during the winter.

Stream flow and water quality- Measurements of stream flow and water quality recorded by USGS were used for model simulation, calibration and validation (Figure 9).

We did not model water impoundment and control structures, given that we had no information on numbers of existing impoundments and structures or how much acreage an average impoundment or structure would protect.

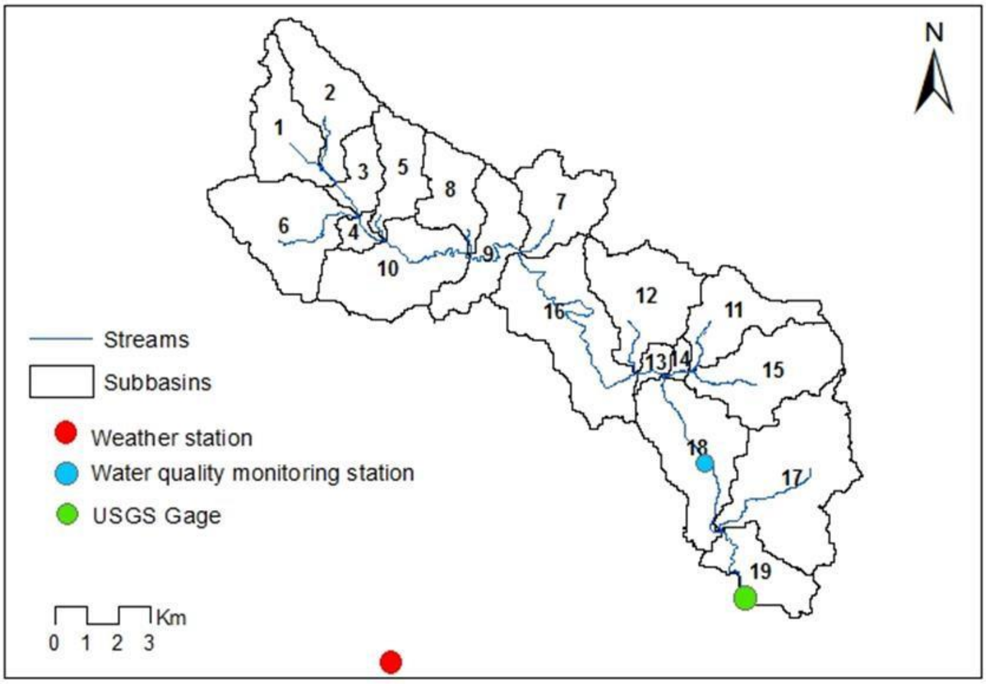


Figure 9: Streams, sub basins and monitoring stations in the BCW

4.2. SWAT Model Calibration and Validation

Flow, sediment, and water quality parameters are estimated with SWAT model. When data are available, it is always best to compare the simulated values obtained during a given numbers of years to measured data during that time and adjust model parameters. The process is called calibration. Simulated values and measured data are then compared for a different period of time not used for the model calibration; this is called model validation. Ideally, one would have flow, sediment, and water quality data over several years to calibrate and validate the model. In reality, the data are rarely available and the model is calibrated, validated, or simply verified with what is available.

a) Flow calibration and validation

Standard calibration procedures were followed as detailed in the SWAT 2000 manual (Neitsch et al., 2002b). First, simulated flow at the outlet of sub watershed #19 was calibrated using recorded flow data from USGS gage station, the only gage station in the watershed with flow data available for the simulation period.

Surface runoff was modeled using the daily curve number (CN) method while potential evapotranspiration was modeled using the Hargreaves method. These methods were used in the SWAT modeling of the Goodwater Creek Watershed (Ghidey et al. 2005) and Long Branch Lake Watershed (FAPRI, 2006) and are considered appropriate for the Black Creek Watershed.

The model calibration for flow data was performed over a four-year period (2005-2008). Table 3 lists the model parameters that were adjusted during calibration. These parameters were manually adjusted to further refine the model. The model's simulated flow data are shown in comparison to USGS flow records in Figures 10 for calibration period. Model validation was conducted using flow data from the same USGS gage used in the calibration phase. Validation was performed for 2009-2010 years (Figure 11). The Nash–Sutcliffe efficiency (NSE) statistic was used for model evaluation. The NSE indicates how well the plot of observed versus simulated data fits the 1:1 line (Nash and Sutcliffe, 1970). An ENS value of 1 indicates a perfect 1: 1 relationship between measured and estimated values. Model performance was considered acceptable for $0.4 < NS < 0.75$, and good for $NS > 0.75$, based on Popov (1979) as cited by Van Liew and Garbrecht (2003), Ramanarayanan et al. (1997), and Moriasi et al. (2007).

The calibration of flow data did not meet these suggested minimum values (NS= 0.36 for calibration and NS=0.25 for validation period). Due to the limited observed flow data collected, it was not possible to improve upon these values during the calibration without making unreasonable adjustments to model input parameters. The absence of flow data during October through March of each year hindered the ability to understand the necessary adjustments needed to conduct a rigorous calibration of the model. Also, the actual rainfall in BCW may not be accurately reflected by the only gauge used for this study which is outside of the watershed, and the distance between the gauge and the station is great enough to create error in the calibration process. If this is the case, then the problem is not necessarily with model performance, but rather, with quality of input data. This challenge for watershed-scale modeling is not uncommon, potential solutions are developing a more dense rain gauge network or switching to more spatially-explicit rainfall datasets such as those collected by radar (i.e., NEXRAD). Despite these limitations, model calibration generally provided results approximate to values and trends seen in the monitoring data that were available.

b) Sediment calibration and validation

The model calibration for sediment data was performed over a four-year period (2005-2008) which these data were collected at a gage station located in the outlet of BCW and collected by USGS.

Table 3 lists the model parameters that were adjusted during calibration. The model's simulated sediment data are shown in comparison to sediment records in Figures 12 for calibration period. The calibrated model then was validated for years 2009 and 2010 using sediment data from the same gage used in the calibration phase (Figure 13). The calibration was considered acceptable with the Nash-Sutcliffe efficiency coefficient close to 0.4.

Table 3: Summary of SWAT model calibration parameters for the BCW

Parameters	Parameter Values		
Stream flow	Default	Calibrated	Units
PET method	Penman/Monteith	Hargreaves	-
CN	varied	- 5	-
Sol_Awc	0.14	0.21	(mm H2O/mm soil)
Sol_K	0.19	0.21	(mm/hr)
SURLAG	4	2	-
Sediment	Default	Calibrated	Units
USLE_P	1	0.34	-
SLSUBBSN	varied	30 -	(m)
USLE_K	0.28	20	-
Nitrogen	Default	Calibrated	Units
CDN	0	0.5	-
ERORGN	0	0.5	-
Phosphorous	Default	Calibrated	Units
PHOSKD	175	200	(m3/Mg)
PSP	0.4	0.2	-

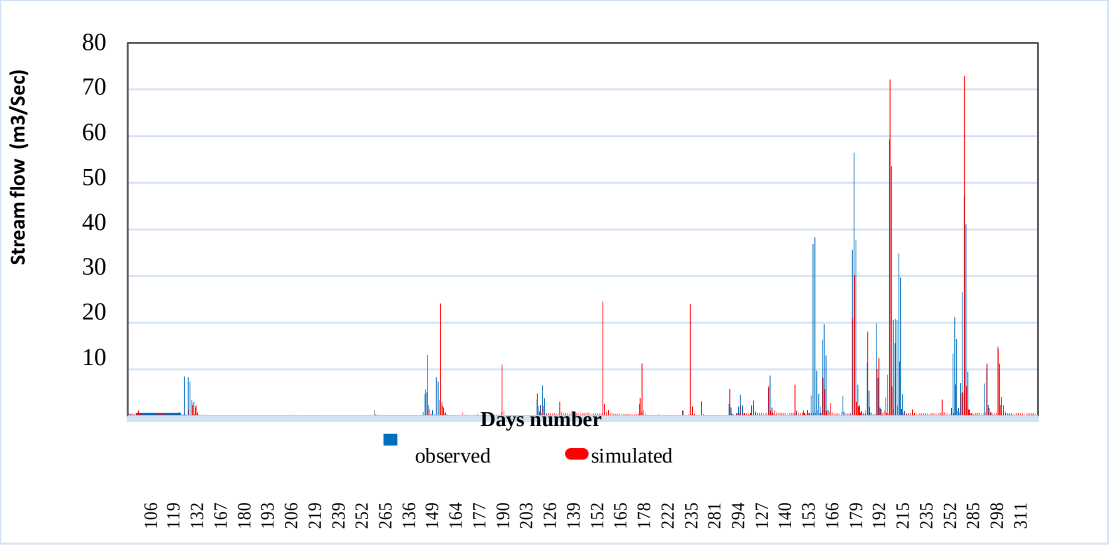


Figure 10: Comparison of SWAT simulated daily flow and observed flow data for the calibration period

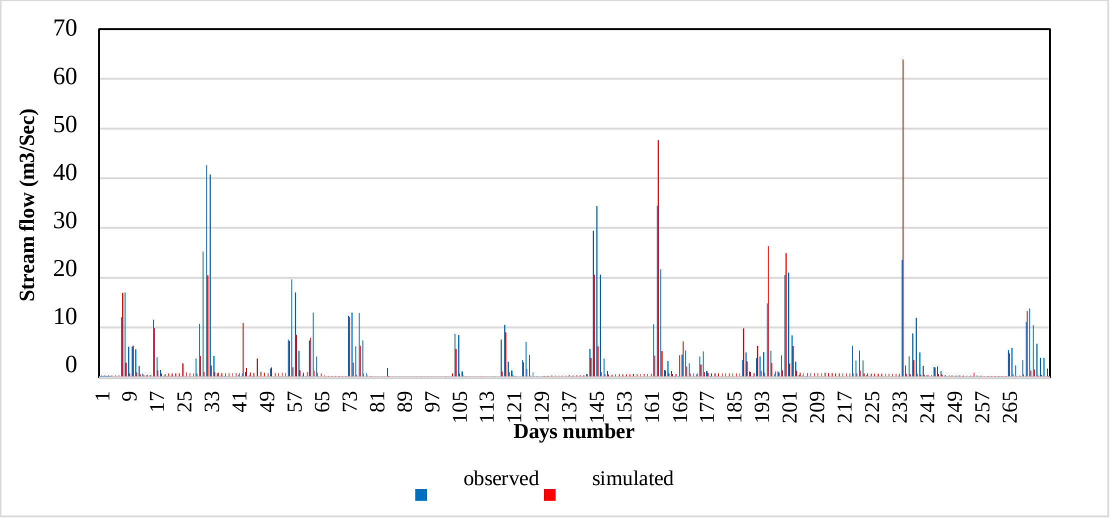


Figure 11: Comparison of SWAT simulated daily flow and observed flow data for the validation period

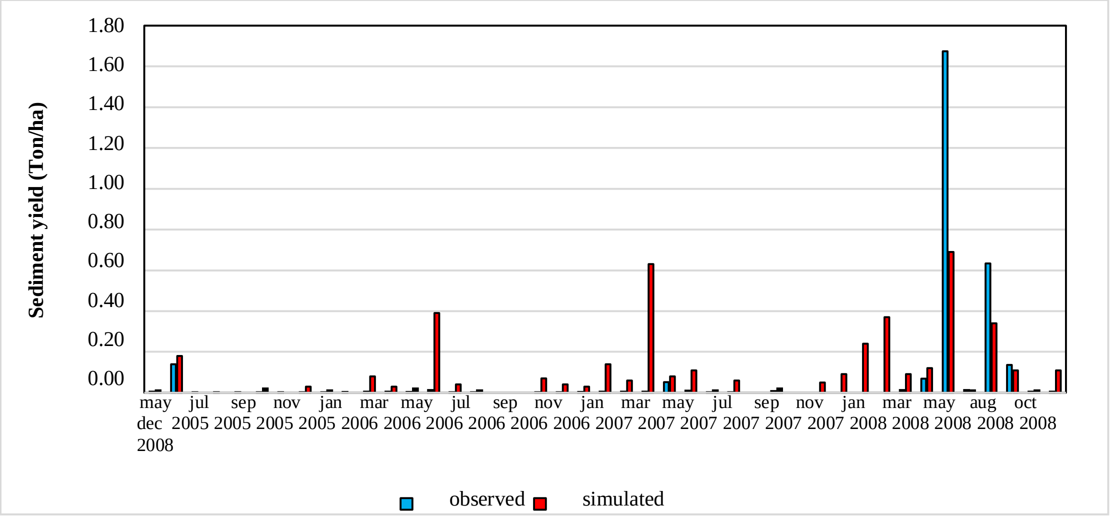


Figure 12: Comparison of SWAT simulated monthly sediment and observed sediment data for the calibration period

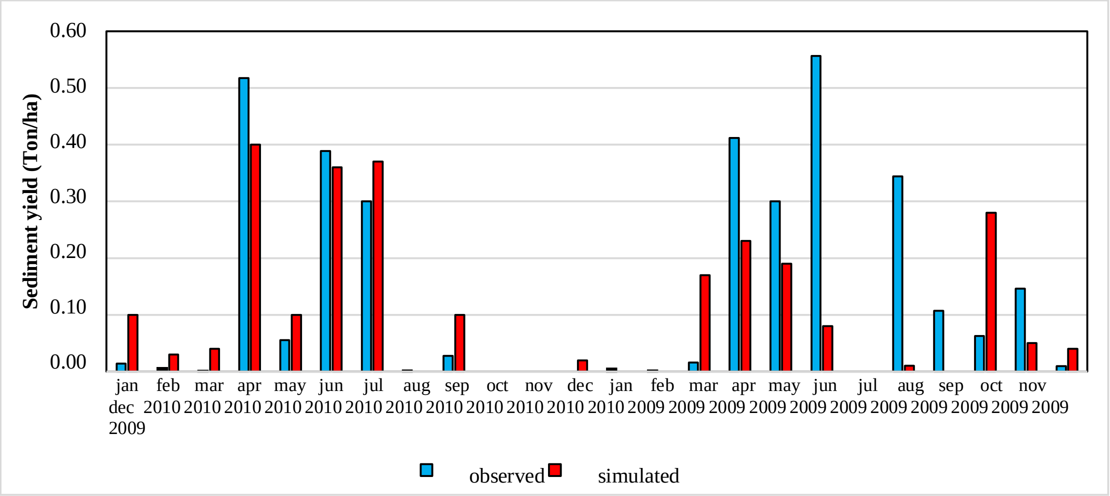


Figure 13: Comparison of SWAT simulated monthly sediment and observed sediment data for the validation period

c) Nitrogen calibration and validation

Calibration and validation of the BCW SWAT model was based on monthly model predictions for total nitrogen loads compared against measured monthly data. The model calibration for nitrogen data was performed over a four-year period (2005-2008). Table 3 lists the model parameters changed for nitrogen calibration. The predicted and observed monthly average loss of nitrogen (Figure 14) has NSE value of 0.19.

Validation of nitrogen was accomplished for years 2009 and 2010 in the Black Creek Watershed. The model failed the validation period for total of nitrogen with NSE value of -0.01 (Figure 15). As such, it is recommended that nitrogen results from alternative management scenarios be interpreted with caution; it would be more appropriate to view nitrogen results in light of relative differences between scenarios, rather than placing confidence in actual values. However the annual average of total of nitrogen for the observed and simulated periods were close to each other.

d) Phosphorus calibration and validation

Calibration of monthly total phosphorus loads over the years 2005 to 2008 showed an NSE of 0.35 (Figure 16). Table 3 lists the model parameters changed for phosphorus calibration.

The validation was performed over years 2009-2010 with the Nash-Sutcliffe efficiency coefficient close to 0.24 (Figure 17).

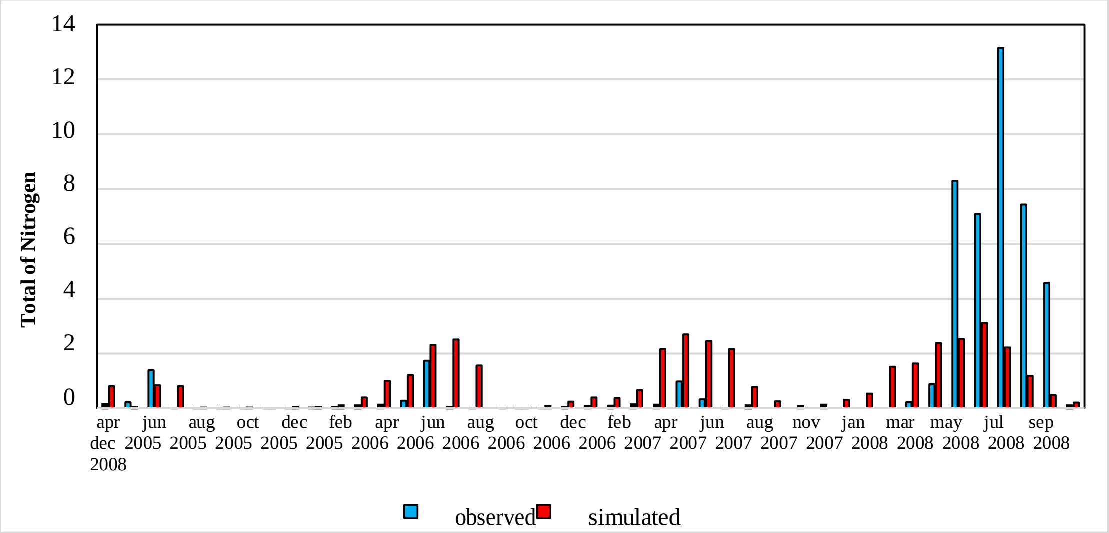


Figure 14: Comparison of SWAT simulated monthly nitrogen and observed nitrogen data for the calibration period

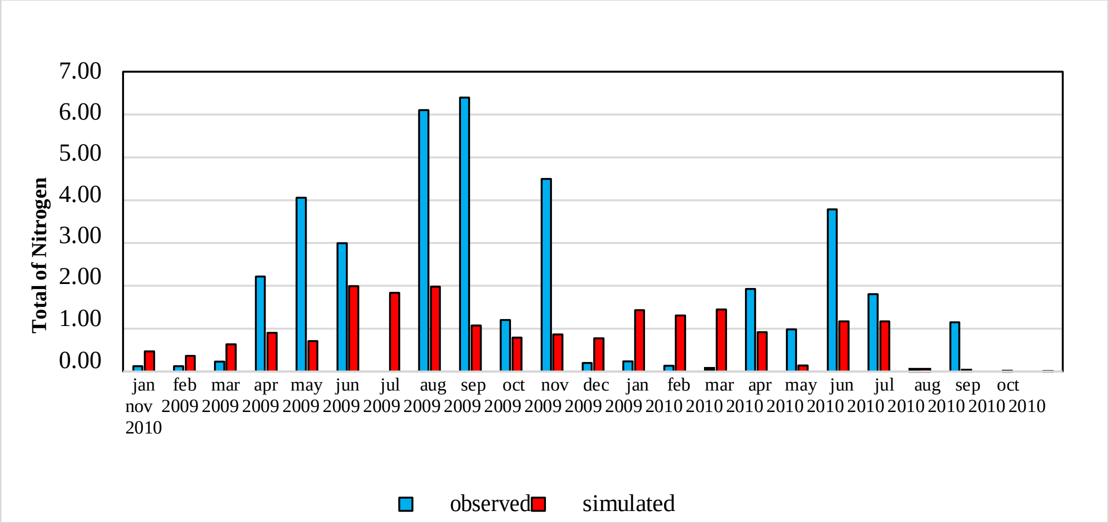


Figure 15: Comparison of SWAT simulated monthly nitrogen and observed nitrogen data for the validation period

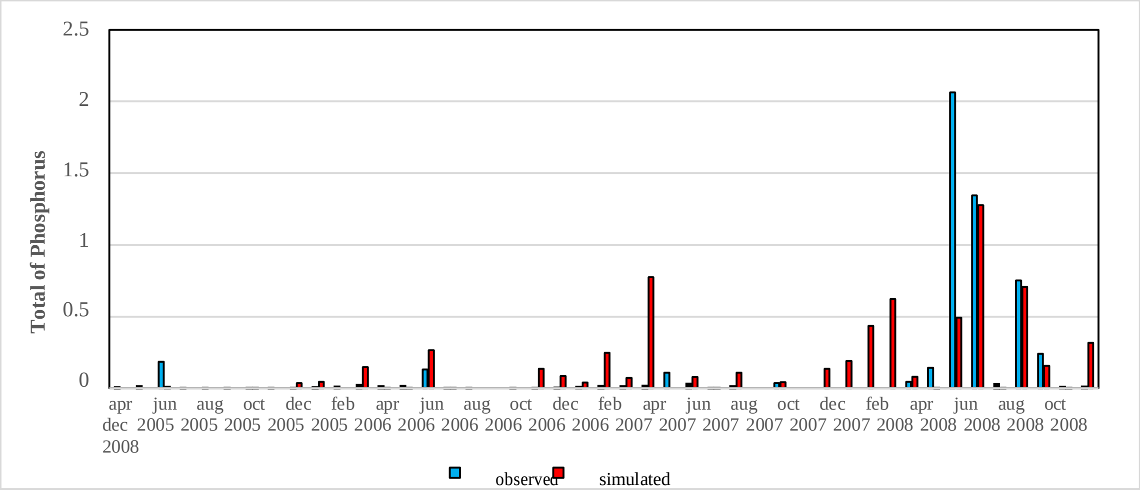


Figure 16: Comparison of observed and simulated total phosphorus concentrations for calibration period

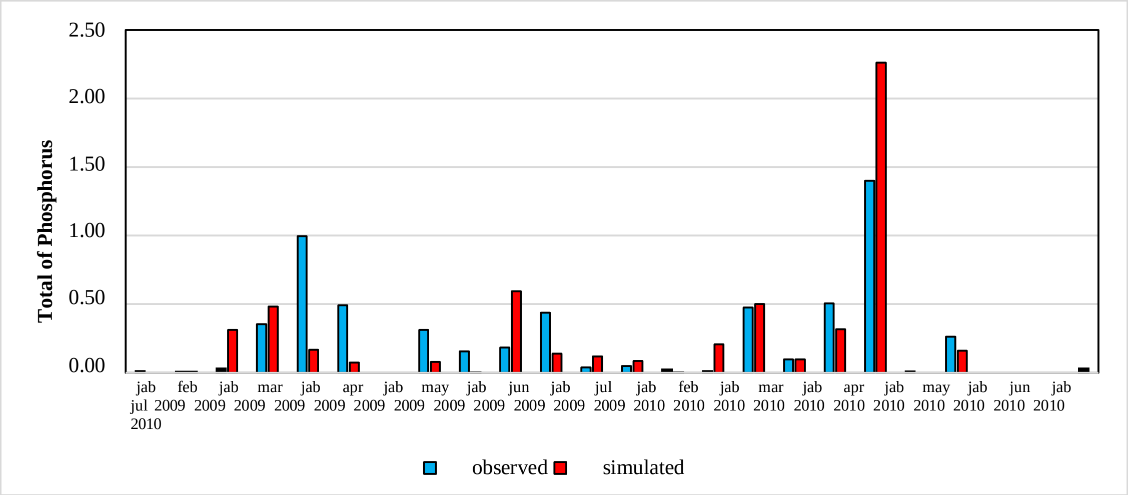


Figure 17: Comparison of observed and simulated total phosphorus concentrations for validation period

5. Baseline Results

SWAT was run on an annual basis from 2000 to 2010. Average annual loadings were calculated for sediment, total phosphorus and total nitrogen. Due to temporal variability, these results are unlikely to be observed on a year-to-year basis. The time variability is caused by climatic changes from year to year. Results are presented in Figures 18 to 20. These values were used as the baseline loading conditions to which the simulated loads from the BMP scenarios were compared (see Section 8.).

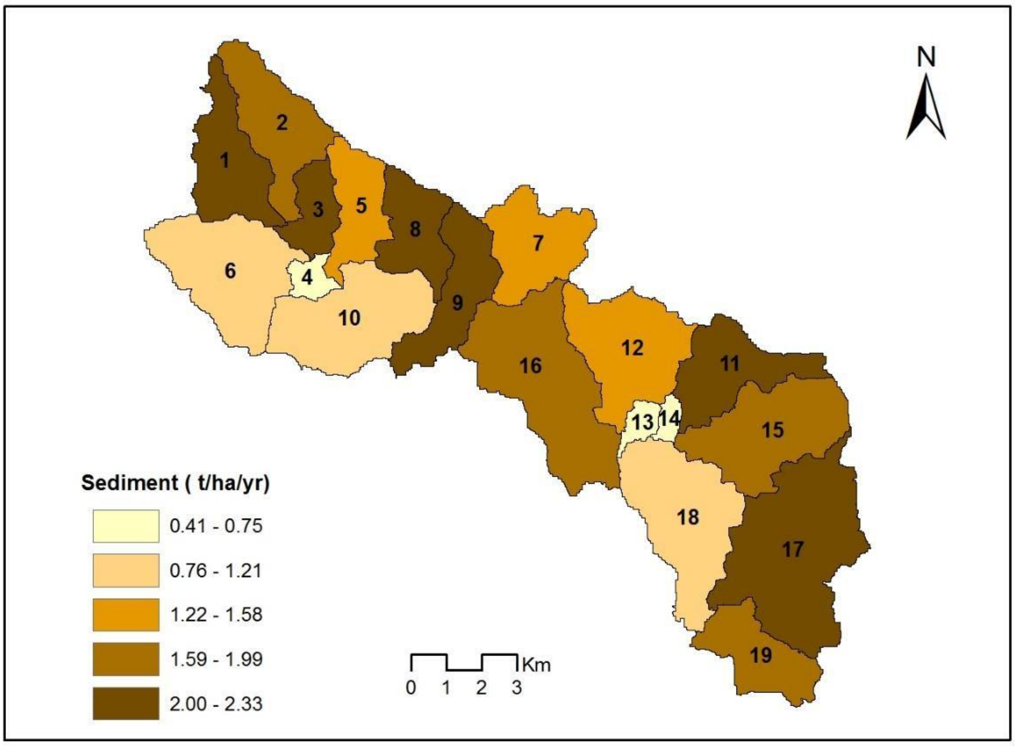


Figure 18: Sediment loading (ton/ha/yr) per sub watershed

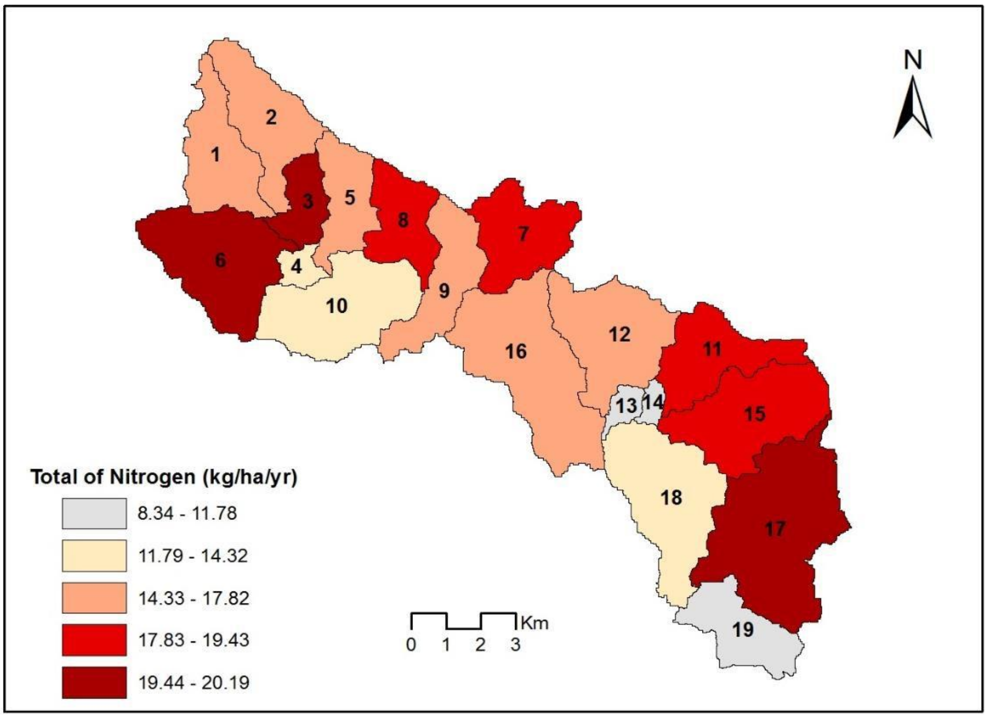


Figure 19: Total nitrogen loading (kg/ha/yr) per sub watershed

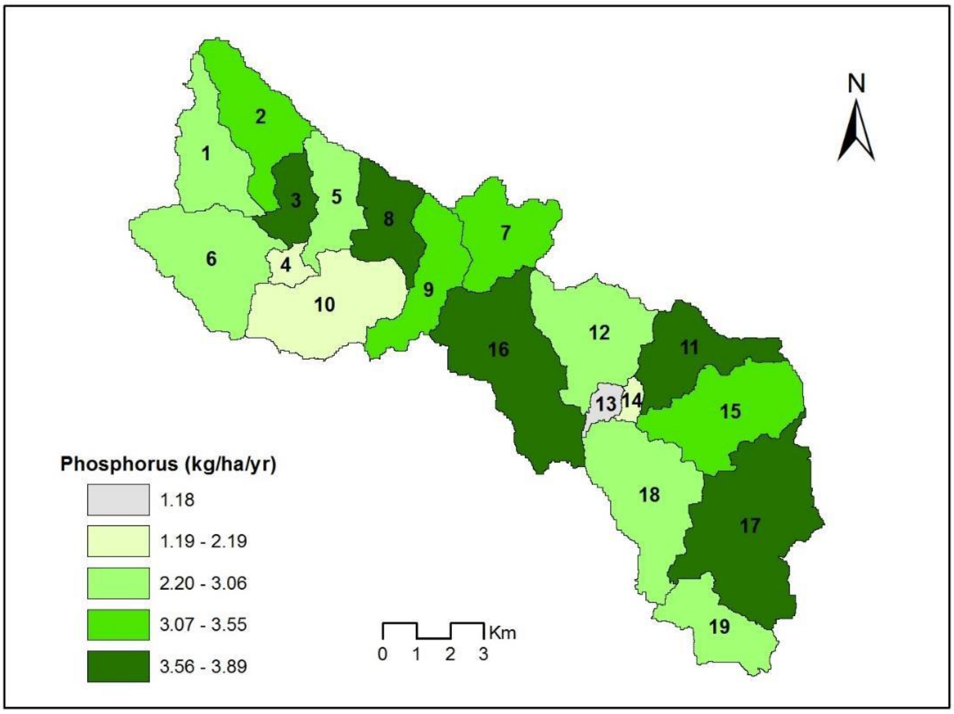


Figure 20: Total phosphorus loading (kg/ha/yr) per sub watershed

6. Critical areas

This study examined load reductions resulting from the BMPs. The model scenarios were only performed in the sub watersheds with the highest baseline loading (Table 4). In total, 10 sub watersheds were selected in this regard (see Figure 21).

There are some current BMPs scenarios which have been implemented by MRBI from 2008 to 2012 (Figure 22). As it can be observed in the map, most the conservation practices applied in the watershed have been implemented on critical areas obtained in this study.

Table 4: Determination of sub watersheds with the highest baseline loading (Highlighted cells)

Sub watershed	TN (kg/ha/yr)	TP (kg/ha/yr)	Sediment
1	16.30	3.06	2.09
2	17.82	3.31	1.96
3	20.19	3.76	2.08
4	14.32	2.03	0.75
5	17.75	2.86	1.46
6	19.64	2.89	1.21
7	18.96	3.48	1.58
8	19.39	3.76	2.26
9	16.99	3.55	2.21
10	13.95	2.19	0.92
11	19.15	3.89	2.33
12	16.40	2.99	1.46
13	8.34	1.18	0.42
14	10.75	1.73	0.41
15	19.43	3.41	1.85
16	17.58	3.67	1.99
17	19.76	3.88	2.14
18	13.56	2.78	1.10
19	11.78	2.85	1.85

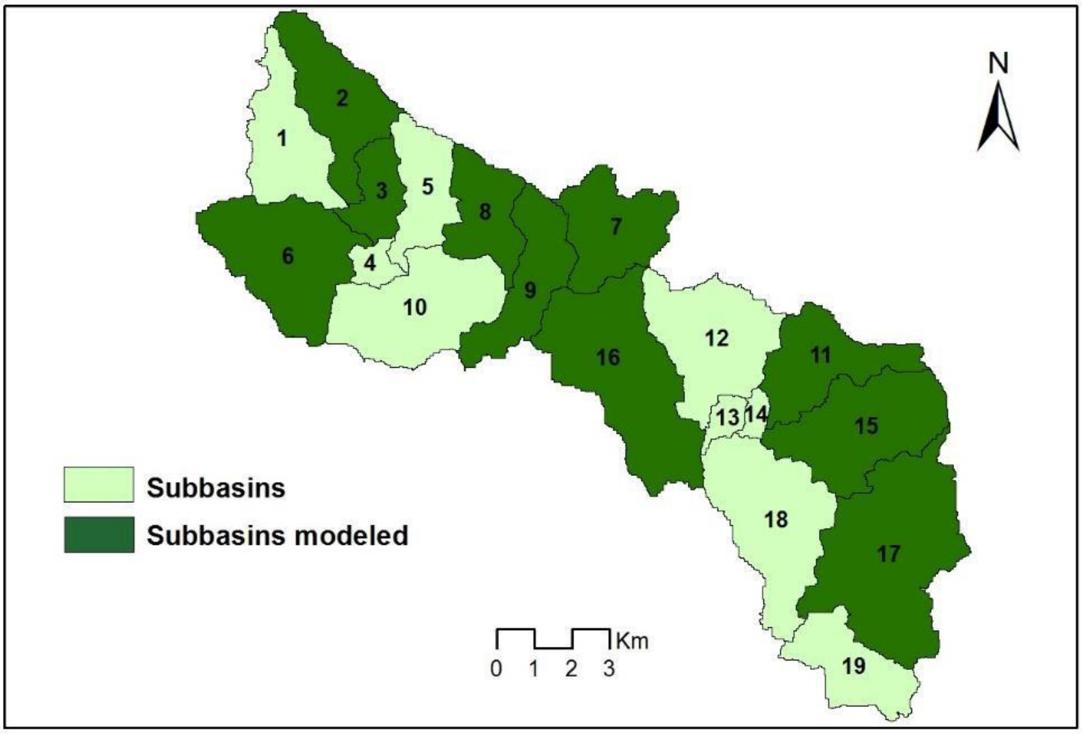


Figure 21: Sub basins modeled in BMP scenarios

7. Best Management Practices Scenarios

BMP scenarios were modeled in SWAT using the following methods:

No-till - The cropping and management information for no-till tillage systems are presented in Appendix A. No-till agriculture was modeled by removing tillage operations, and increasing bio-mixing efficiency from 0.2 to 0.5 in the agricultural management input files.

Nutrient management (fertilizer application rate reduction) was simulated with a 25% reduction of fertilizer application rates.

Filter strips- Installation of filter strips was simulated by adding 10 m edge-of-field filter strips in the crop rotations input file of selected sub watersheds.

Terracing- USLE practice factor was adjusted for the agricultural area in the selected sub watersheds, SLSUBBSN (Average slope length) was set to the distance between terraces. USLE_P was adjusted from 0.10 to 0.12 for different slopes.

Cover crop- Cover crop was simulated by planting winter crops like cereal rye, annual rye, oats, red clover and radish following corn and soybeans harvest in the agricultural management input files (Appendix A).

Reduced tillage- The cropping and management information for this kind of tillage are described in Appendix A for the rotation of corn-soybeans-soybeans and rotation of corn-soybeans-wheat.

Stream Exclusion- When the cattle have access to streams, they can deposit manure directly into the water. The cattle that have access were considered to spend some time in the stream. That length of time and, therefore, the amount of waste directly deposited is allowed to vary monthly to account for the seasonal changes of temperature. The results are presented in Table of 5. The amount of manure was adjusted in the grazing systems of the pastures and woodlands in the selected sub watersheds.

Woodland protection- To protect the woodland acres that are located in the critical sub watersheds, cattle which are usually left in the forest during the winter would be permanently removed from the woodland.

Inter-seeding- We assumed that 50 % of the pastures are in hay and 50 % are in fescue, and considered two scenarios for fescue in the critical sub watersheds: a) All of the fescue are over-seed with red clover each year, b) All of the fescue are over-seed with red clover once every two years (Rotation of 2 years). Because the SWAT model does not allow two different plants growing at the same time filed, we chose to build an imaginary plant that is an average between fescue and red clover, a legume that fixes nitrogen at half the rate that clover would normally do. Since a legume fixes the nitrogen it needs, we have suppressed the commercial nitrogen application in the management scenario. The resulting parameters of this fabricated plant are given in Appendix C.

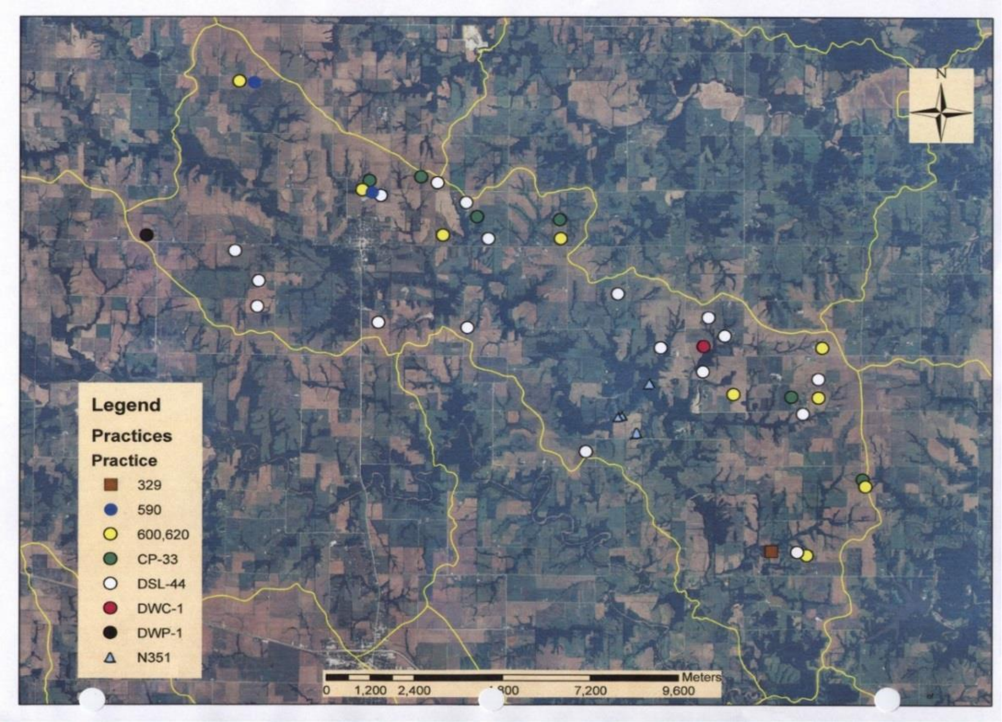


Figure 22: Map of Implemented BMPs by MRBI (2008-2012)

Table 5: Percentage of cattle waste directly deposited in the stream in pastures with stream access

Source: Upper Shoal Creek Watershed (FAPRI-UMC Report)

	Daily waste directly		Daily waste directly
January	3	July	10
February	3	August	10
March	3	September	7
April	4	October	4
May	4	November	3
June	7	December	3

8.BMP Scenario Results

BMP scenarios were run for the same 11-year period (2000 to 2010) as the baseline. The average annual loads for sediment, total of P and total of N were calculated under each scenario per selected sub watersheds which supposed as critical areas, and then compared with values obtained from the baseline conditions (See Figures 23 to 31 and Table 6). The difference in average annual load between a BMP scenario and the baseline was used to indicate the load reduction achieved by BMP implementation (Table 7).

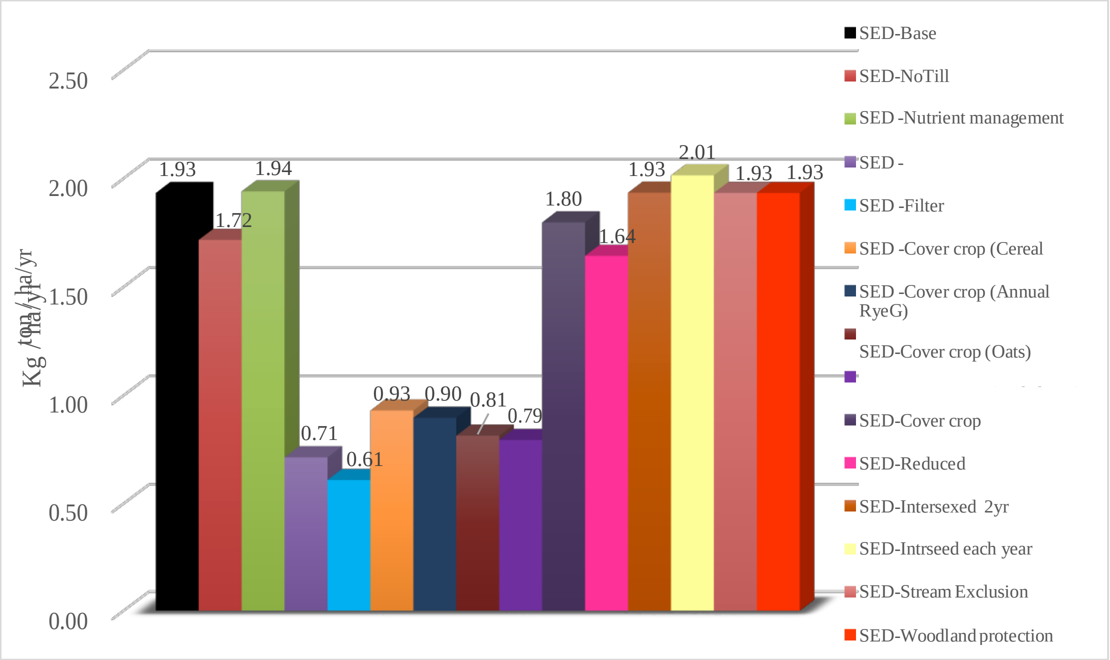


Figure 23: Sediment loading (ton/ha/yr) under each scenario from the selected sub watersheds of the BCW

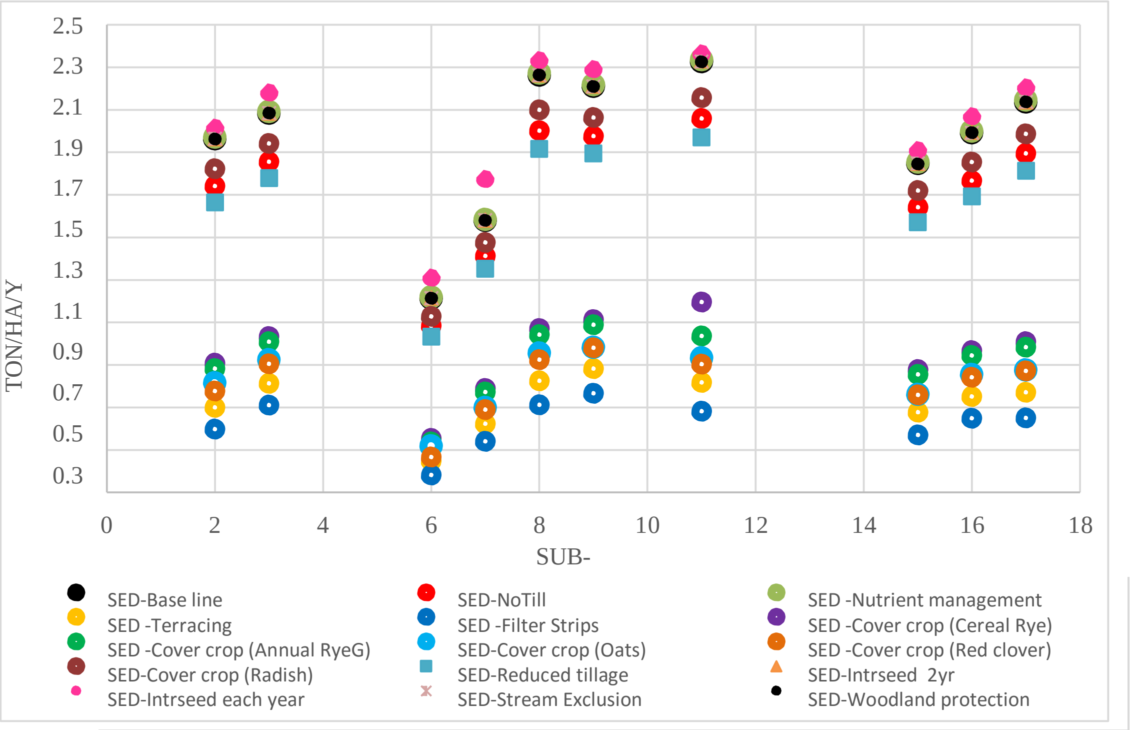


Figure 24: Sediment losses (ton/ha/yr) under each scenario per selected sub watersheds

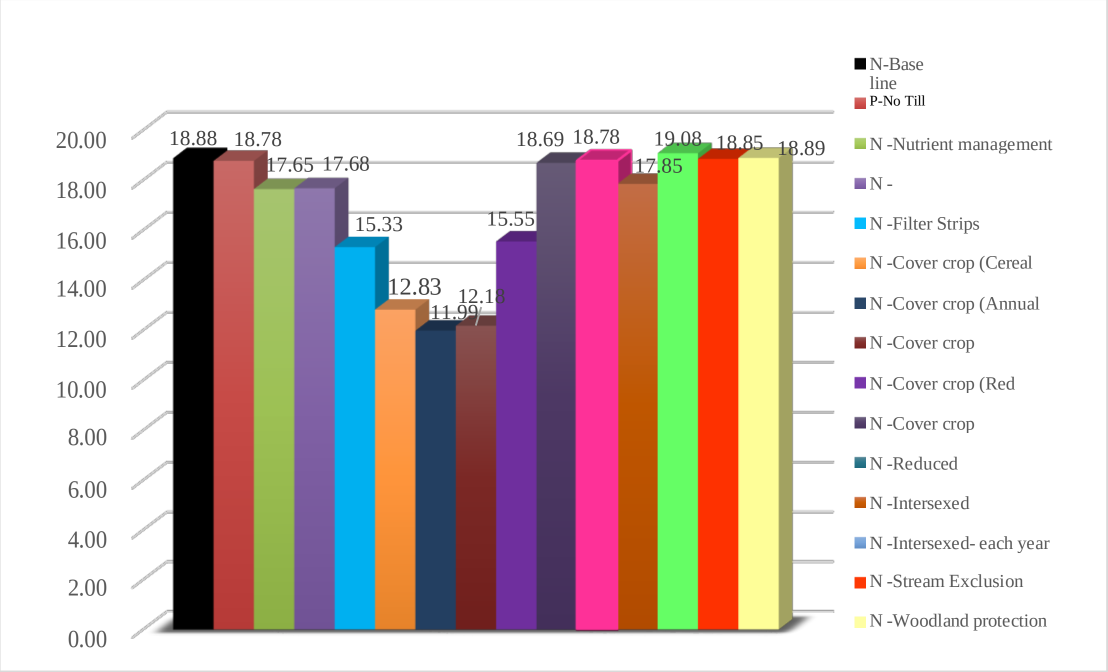


Figure 25: Nitrogen loading (kg/ha/yr) under each scenario from the selected sub watersheds of the BCW

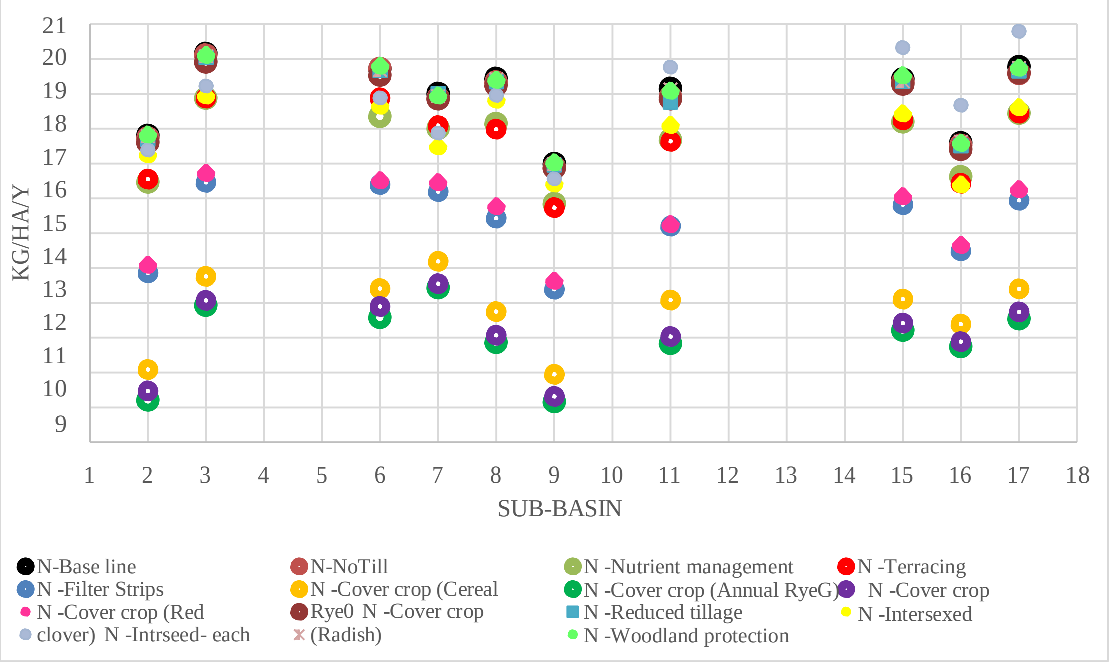


Figure 26: Nitrogen losses (kg/ha/yr) under each scenario per selected sub watersheds

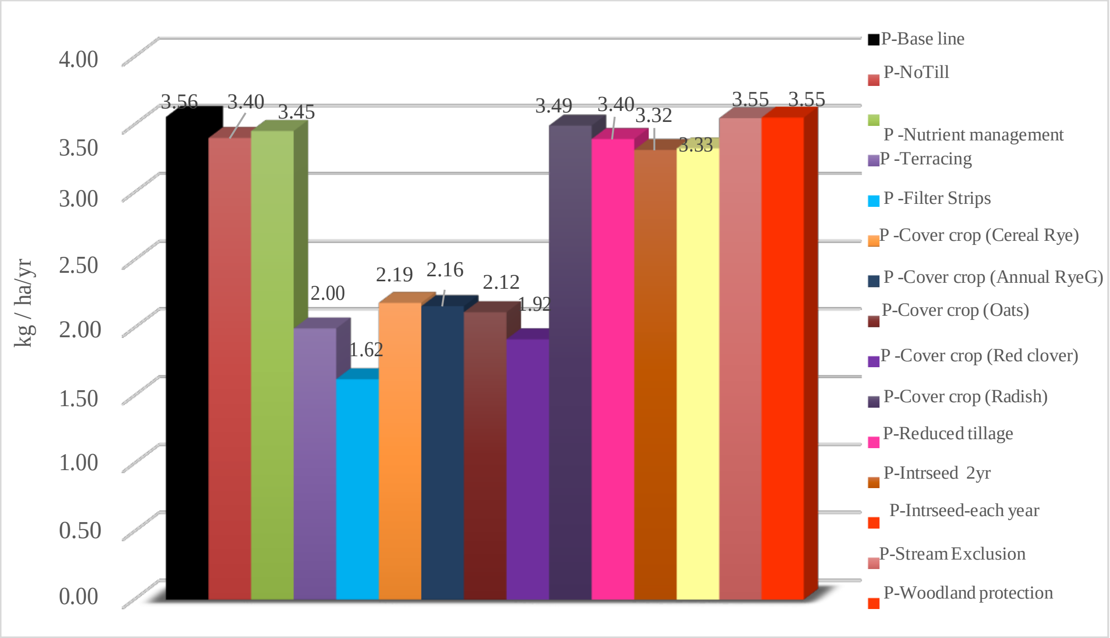


Figure 27: Phosphorus loading (kg/ha/yr) under each scenario from the selected sub watersheds of the BCW

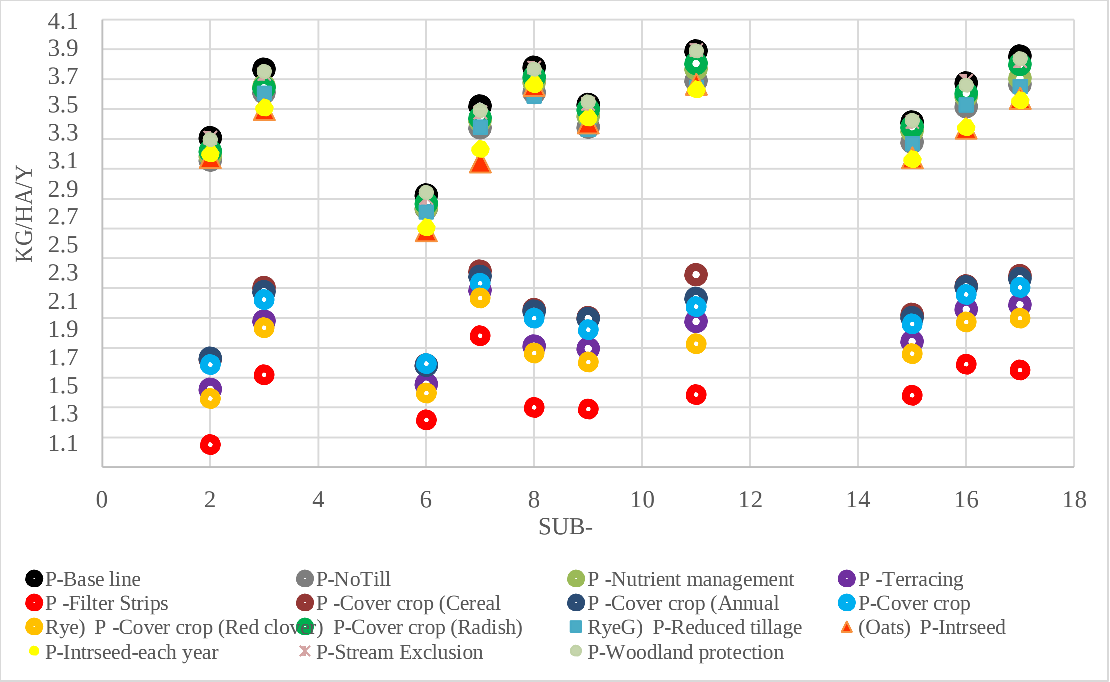


Figure 28: Phosphorus losses (kg/ha/yr) under each scenario per selected sub watersheds

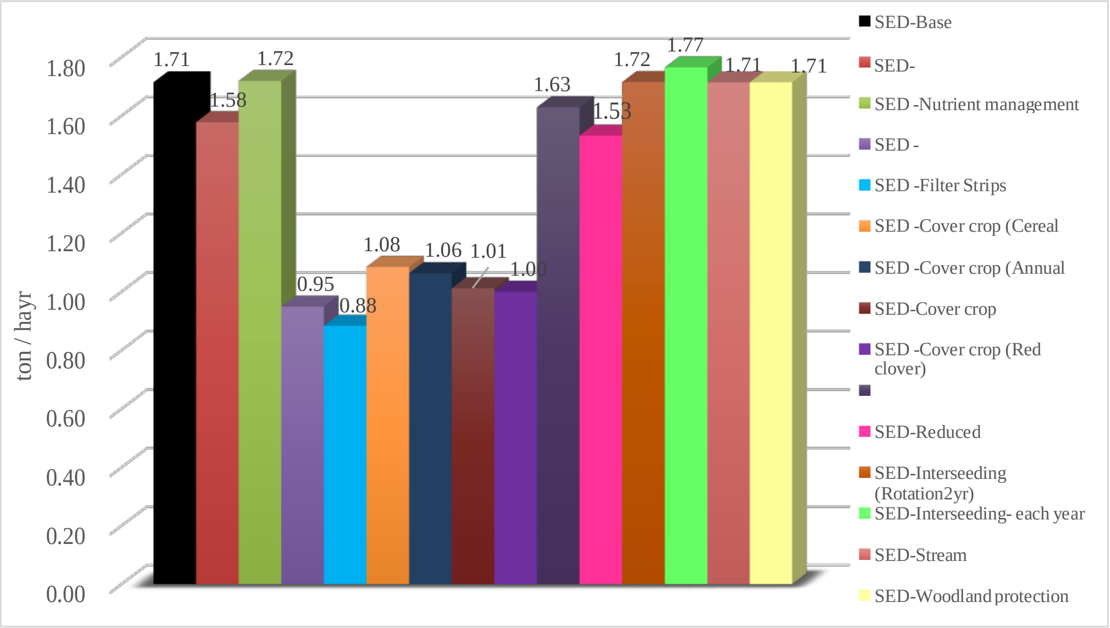


Figure 29: Annual sediment loss (ton/ha/yr) under each scenario in the BCW

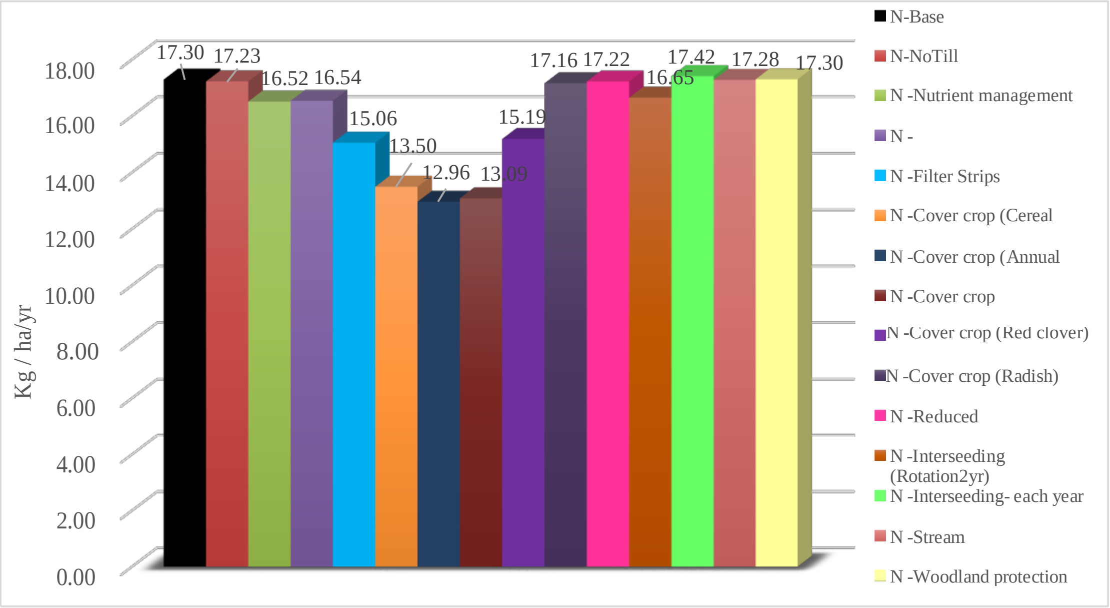


Figure 30: Annual nitrogen loss (kg/ha/yr) under each scenario in the BCW

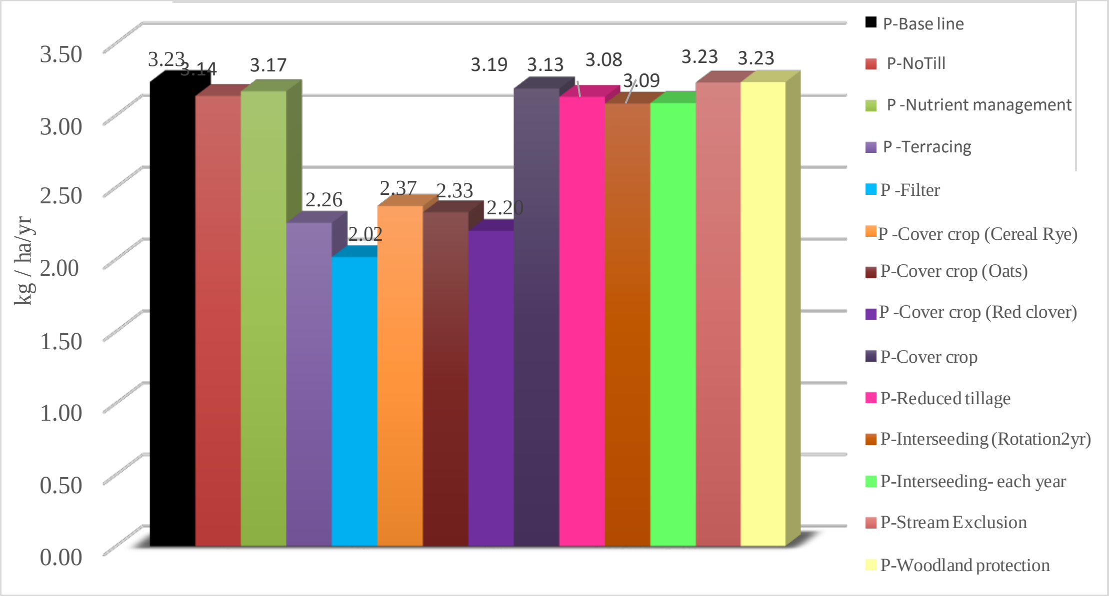


Figure 31: Annual phosphorus loss (kg/ha/yr) under each scenario in the BCW

Table 6: Annual sediment, nitrogen and phosphorus loadings under each scenario in the BCW

BMPs	Total of Nitrogen (kg/yr)	Total of Phosphorus (kg/yr)	Sediment (ton/yr)
Base line	234,234	43,784	23,219
No Till	233,332	42,464	21,377
Nutrient Management	223,662	42,908	23,280
Terracing	224,007	30,540	12,854
Filter Strips	203,913	27,329	11,965
Cover Crop (Cereal rye)	182,760	32,122	14,689
Cover Crop (Annual rye)	175,569	31,900	14,402
Cover Crop (Oats)	177,227	31,530	13,701
Cover Crop (Red clover)	205,689	29,785	13,538
Cover Crop (Radish)	232,410	43,164	22,068
Reduced Tillage	233,271	42,388	20,756
Inter-seeding (Rotation 2yr)	225,521	41,741	23,229
Inter-seeding (Each year)	235,851	41,795	23,908
Stream Exclusion	234,031	43,728	23,218
Woodlands protection	234,352	43,766	23,217

Table 7: Load reduction (%) at the outlet of the BCW under BMP scenarios

BMPs	Total of Nitrogen	Total of Phosphorus	Sediment
No Till	-0.39	-3.01	-7.93
Nutrient Management	-4.51	-2.00	0.26
Terracing	-4.37	-30.25	-44.64
Filter Strips	-12.94	-37.58	-48.47
Cover Crop (Cereal rye)	-21.98	-26.63	-36.74
Cover Crop (Annual rye)	-25.05	-27.14	-37.97
Cover Crop (Oats)	-24.34	-27.99	-40.99
Cover Crop (Red clover)	-12.19	-31.97	-41.69
Cover Crop (Radish)	-0.78	-1.42	-4.95
Reduced Tillage	-0.41	-3.19	-10.60
Inter-seeding (Rotation 2yr)	-3.72	-4.66	0.05
Inter-seeding (Each year)	0.69	-4.54	2.97
Stream Exclusion	-0.09	-0.13	0.00
Woodlands protection	0.05	-0.04	-0.01

9. Load Reductions from BMP Scenarios

9.1 Sediment load reduction

Results in the table 7 show that filter stripes and terracing provide the highest sediment load reduction. They are expected to produce 48.5% and 44.6% sediment load reductions, respectively.

Simulation results revealed that application of cover crops reduces sediment loss effectively as compared to the baseline scenario. The sediment reduction rates from the radish is less than other cover crops. The vegetative biomass of cover crops increases the amount of transpiration and decreases the impact of rain drops that can break soil aggregates. As a result of this, there is an increase in water infiltration and decrease in surface runoff and runoff velocity. Planting cover crops such as cereal rye, annual rye, oats, red clover and radish after the harvest of corn and soybeans in the BCW reduced the sediment loss by 37%, 38%, 41%, 42% and 5% respectively (Table 7).

No-tillage and reduced tillage agriculture tend to reduce sediment loads because of increased vegetative and residue cover that protects the soil from erosion. Application of no-tillage and reduced tillage systems on selected sub watersheds decreased the sediment yield by 7.9% and 10.6%, respectively.

Nutrient management (i.e., reduced nitrogen and phosphorus application) actually increased sediment yield slightly due to slower crop growth. However, the increased was small (<1%) and would not likely be observed.

The sediment loads from the stream exclusion practice were not captured because information on the channels was not collected.

Inter-seeding of fescue with red clover in the pastures increased sediment yield slightly. However, the increased was small, i.e., <0.1% for inter-seeding with a rotation of 2 years and < 3% for inter-seeding to each year, and would likely be negligible.

The least effective BMP is woodland protection which decreased sediment loss by 0.01%.

9.2 Nitrogen load reduction

The highest nitrogen load reduction in the BCW belongs to annual rye, oats and cereal rye cover crops scenarios, they reduced total of N losses by 25%, 24% and 22%, respectively. The other simulated cover crops i.e. red clover and radish decreased total N by 12% and 0.8%, respectively (Table 7).

Cover crops were planted after the October corn and soybeans harvest and produced high above-ground biomass. The high biomass production resulted in increased uptake of nitrogen from the soil, which otherwise would have been lost in tile drainage.

Application of filter strips showed a 12.9% reduction in total N loss. This was mainly due to a decrease in total organic nitrogen and surface runoff losses.

There was a 4% reduction in the total loss nitrogen in the BCW for nutrient management, terracing and inter-seeding with rotation of 2 years practices.

There is no substantial reduction in total nitrogen loss from the application of no-till and reduced tillage systems and also stream exclusion which decreased total of nitrogen by less than 1%, separately.

Inter-seeding at each year and also woodland protection practices increased the total nitrogen loss by less than 1%.

9.3 Phosphorus load reduction

The highest phosphorus load reduction was provided by filter strips which reduced by 38%.

Implementation of terraces on selected fields gave a 30% reduction in P losses.

Planting cover crops resulted in significant reductions in total of phosphorus losses by 32%, 28%, 27%, 27% and 3% for red clover, oats, annual rye, cereal rye and radish, respectively.

The total phosphorus sub basins loads at the outlet of the entire watershed reduced by 3% for no-till and reduced tillage systems, separately.

Nutrient management practice i.e., 25% reduction in nitrogen and phosphorus application rate reduced the total P loss by about 2%.

Inter-seeding of fescue with red clover in the pastures of critical sub watersheds represented about 5% decrease in the total of phosphorus load.

The phosphorus load reduction from stream exclusion and woodland protection practices were less than 1%.

10. Conclusions

This study developed a calibrated SWAT model for the Black Creek Watershed. The model was used to simulate baseline loading conditions for total of P, total of N, and sediments and analyzed the impact of some best management practices on the water quality.

The average loss of nitrogen was 17.3 kg/ha/yr, the average loss of sediment was 1.71 ton/ha/yr and the average phosphorus loss was 3.23 kg/ha/yr.

Among the individual BMPs simulated, cover crop emerged as the most effective BMP. Cover crops showed good reductions in sediment and nutrient yields due to increased cover on cold season. Cover crop was simulated by planting some winter crops following corn and soybeans harvest in the agricultural management input files. The vegetative biomass of cover crops increases the amount of transpiration and decreases the impact of rain drops that can break soil aggregates. As a result of this, there is an increase in water infiltration and decrease in surface runoff and runoff velocity. All of the cover crops, except radish, simulated in this study were effective in reducing nitrogen, phosphorus and sediment losses.

The filter strips modeled in the erosion control practice were a close second. Filter strips may represent a large sediment and nutrient load reductions in the BCW. Terraces would result in significant reductions in sediment and phosphorus while they would cause a small reduction in nitrogen.

No-till and reduced tillage practices seem more effective at reducing losses of sediment than phosphorus and nitrogen.

Nutrient management and inter-seeding practices showed the smaller reductions in nitrogen and phosphorus losses relatively to other conservation practices, while increased sediment yield slightly due to slower crop growth. However, the increased were small and would not likely be observed.

The least effective BMPs are woodland protection and stream exclusion.

In summary, this SWAT modeling study yielded valuable quantitative information on the relative effectiveness of BMPs in reducing pollutant loads and improving water quality. Comparisons of pollutant yields and loads in the watershed with and without the practices installed were based on relatively long- term (11 years). The expected reductions may not be observed on a year-to-year basis due to weather variability. Therefore, short term water quality measurements might not show any improvement. However, results indicated reductions in sediment and nutrient loads when the conservation practices were implemented.

Limitations on funding, personnel, and producer interest likely impede our ability to fully implement conservation practices. However, we can use models to show how close to ideal current efforts might achieve.

Each practice must be carefully evaluated and prioritized according to its cost and effectiveness to obtain the ultimate environmental outcome.

ACKNOWLEDGEMENTS:

The authors would like to thank the following people who have contributed to this project at various stages: Dr. Raghavan Srinivasan from Texas A&M University, Dr. Newell Kitchen and Daniel Downing from Missouri University.

Appendix A: Crop and Tillage Management

Corn-Soybeans-Soybeans Rotation

Conventional tillage system (Baseline)

Crop type	Management	Date
Corn	Disk Plow Ge23ft	Nov 11
	Anhydrous Ammonia @ 145.6 kg ha-1 (injected)	March 25
	Elemental Nitrogen @ 56 kg ha-1	April 11
	Elemental Phosphorous @ 59.4 kg ha-1	April 11
	Field Cultivator Ge15ft	April 11
	Planting	May 5
	Atrazine @ 2.25 kg ha-1	May 18
	Harvest and kill	Oct 11
Soybean	Field Cultivator Ge15ft	May 11
	Planting	May 12
	Harvest and kill	Oct 1
Soybean	Field Cultivator Ge15ft	May 11
	Planting	May 12
	Harvest and kill	Oct 1

Corn-Soybeans-Soybeans Rotation No-

till tillage system (BMP)

Crop type	Management	Date
Corn	Anhydrous Ammonia @ 145.6 kg ha-1 (knifed)	March 23
	Elemental Nitrogen @ 56 kg ha-1	April 8
	Elemental Phosphorous @ 59.4 kg ha-1	April 8
	Atrazine @ 1.25 kg ha-1	April 8
	Generic No-till Mixing	April 8
	Planting	May 5
	Atrazine @ 1.25 kg ha-1	May 16
	Harvest and kill	Oct 18
Soybean	Roundup @ 1 quart/acre	May 10
	Planting	May 12
	Roundup @ 1 quart/acre	June 12
	Harvest and kill	Oct 1
Soybean	Roundup @ 1 quart/acre	May 10
	Planting	May 12
	Roundup @ 1 quart/acre	June 12
	Harvest and kill	Oct 1

Corn-Soybeans-Soybeans Rotation Reduced

tillage system (BMP)

Crop type	Management	Date
Corn	Anhydrous Ammonia @ 145.6 kg ha-1 (injected)	March 25
	Elemental Nitrogen @ 56 kg ha-1	April 11
	Elemental Phosphorous @ 59.4 kg ha-1	April 11
	Field Cultivator Ge15ft	April 11
	Field Cultivator Ge15ft	May 1
	Planting	May 5
	Atrazine @ 2.25 kg ha-1	May 18
	Harvest and kill	Oct 11
Soybean	Planting	May 12
	Harvest and kill	Oct 1
Soybean	Planting	May 12
	Harvest and kill	Oct 1

Corn-Soybeans-Wheat Rotation

Conventional tillage system (Baseline)

Crop type	Management	Date
Corn	Disk Plow Ge23ft	Nov 11
	Anhydrous Ammonia @ 145.6 kg ha-1 (injected)	March 25
	Elemental Nitrogen @ 56 kg ha-1	April 11
	Elemental Phosphorous @ 59.4 kg ha-1	April 11
	Field Cultivator Ge15ft	April 11
	Planting	May 5
	Atrazine @ 2.25 kg ha-1	May 18
	Harvest and kill	Oct 11
Soybean	Field Cultivator Ge15ft	May 11
	Planting	May 12
	Harvest and kill	Oct 1
Wheat	Planting	Oct 5
	Elemental Nitrogen @ 67.2 kg ha-1	March 15
	Harvest and kill	June 25

Corn-Soybeans-Wheat Rotation No-till tillage system (BMP)

Crop type	**Management**	**Date**
Corn	Anhydrous Ammonia @ 145.6 kg ha-1 (knifed)	March 23
	Elemental Nitrogen @ 56 kg ha-1	April 8
	Elemental Phosphorous @ 59.4 kg ha-1	April 8
	Atrazine @ 1.25 kg ha-1	April 8
	Generic No-till Mixing	April 8
	Planting	May 5
	Atrazine @ 1.25 kg ha-1	May 16
	Harvest and kill	Oct 18
Soybean	Roundup @ 1 quart/acre	May 10
	Planting	May 12
	Roundup @ 1 quart/acre	June 12
	Harvest and kill	Oct 1
Wheat	Planting	Oct 5
	Elemental Nitrogen @ 67.2 kg ha-1	March 15
	Harvest and kill	June 25

Corn-Soybeans-Wheat Rotation Reduced tillage system (BMP)

Crop type	**Management**	**Date**
Corn	Anhydrous Ammonia @ 145.6 kg ha-1 (injected)	March 25
	Elemental Nitrogen @ 56 kg ha-1	April 11
	Elemental Phosphorous @ 59.4 kg ha-1	April 11
	Field Cultivator Ge15ft	April 11
	Field Cultivator Ge15ft	May 1
	Planting	May 5
	Atrazine @ 2.25 kg ha-1	May 18
	Harvest and kill	Oct 11
Soybean	Planting	May 12
	Harvest and kill	Oct 1
Wheat	Planting	Oct 5
	Elemental Nitrogen @ 67.2 kg ha-1	March 15
	Harvest and kill	June 25

Corn-Soybeans-Soybeans Rotation

Cover crops: Cereal Rye / Annual Rye / Oats / Red clover / Radish, (BMP)

Crop type	**Management**	**Date**
Corn	Disk Plow Ge23ft	March 21
	Anhydrous Ammonia @ 145.6 kg ha-1 (injected)	March 28
	Elemental Nitrogen @ 56 kg ha-1	April 11
	Elemental Phosphorous @ 59.4 kg ha-1	April 11
	Field Cultivator Ge15ft	April 11
	Planting	May 5
	Atrazine @ 2.25 kg ha-1	May 18
	Harvest and kill	Oct 9
	Cover crop	Oct 10
	Kill	March 5
Soybean	Field Cultivator Ge15ft	May 11
	Planting	May 12
	Harvest and kill	Oct 1
	Cover crop	Oct 2
	Kill	April 1
Soybean	Field Cultivator Ge15ft	May 11
	Planting	May 12
	Harvest and kill	Oct 1
	Cover crop	Oct 2
	Kill	March 20

Appendix B: Pasture Management (Baseline)

Under the baseline scenario cattle were rotated across two pastures every two months in spring and fall, and one month in summer. Cows were left in the woodland for protection during the winter.

Year	Pasture	Management	Date
	Hay	Elemental Nitrogen @ 67.5 kg ha-1	March 1
		Elemental Phosphorous @ 39 kg ha-1	March 1
		Harvest and kill	May 1
		Harvest	Sep 15
1	Fescue 1	Elemental Nitrogen @ 67.5 kg ha-1	March 11
1		Elemental Phosphorous @ 39 kg ha-1	March 11
1		Grazing	March 26- May 15
1		Grazing	July 16- Aug 15
1		Grazing	Oct 16- Dec 15
1		Harvest and kill	May 1
2		Grazing	March 26- May 15
2		Grazing	July 16- Aug 15
2		Grazing	Oct 16- Dec 15
2		Harvest and kill	May 1
1	Fescue 2	Elemental Nitrogen @ 67.5 kg ha-1	March 12
1		Elemental Phosphorous @ 39 kg ha-1	March 12
1		Grazing	May 16- July 15
1		Grazing	Aug 16- Oct 15
1		Harvest and kill	May 1
2		Grazing	May 16- July 15
2		Grazing	Aug 16- Oct 15
2		Harvest and kill	May 1
Fescue 1: for the sub basins 1,2,3,4,5,6,7,8,9,10 Fescue 2: for the sub basins 11,12,13,14,15,16,17,18,19			

Appendix C: Crop Parameters

Crop parameters used by the SWAT model for an imaginary plant that combines fescue and red clover characteristics (BMP)

Source: Upper Shoal Creek Watershed (FAPRI-UMC Report)

Radiation use efficiency: 25 (kg/ha) / (MJ/m2)

Harvest Index: 0.90

Maximum potential leaf area index: 4.0

Fraction of the plant growing season at 1st point on the leaf area development curve: 0.15

Fraction of the maximum leaf area index at 1st point on the leaf area development curve: 0.01 Fraction of the plant growing season at 2nd point on the leaf area development curve: 0.50 Fraction of the maximum leaf area index at 2nd point on the leaf area development curve: 0.95 Fraction of the growing season when the leaf are declines: 0.78

Maximum canopy height: 1.20 m (47 inches)

Maximum root depth: 1.75 m (70 inches)

Optimal temperature for plant growth: 18 deg C (64 deg F)

Minimum temperature for plant growth: 2.5 deg C (36.5 deg F)

Normal fraction of nitrogen in seeds: 0.0442 kg N / kg seeds

Normal fraction of phosphorus in seeds: 0.0036 kg P / kg seeds

N fraction in the plant at emergence: 0.0525

N fraction in the plant at 50 % maturity: 0.0245

N fraction in the plant at maturity: 0.0196

P fraction in the plant at emergence: 0.0079

P fraction in the plant at 50 % maturity: 0.0031

P fraction in the plant at maturity: 0.0023

Lower limit of harvest index: 0.5

Minimum value of the USLE crop and management factor (C factor): 0.003

Maximum stomatal conductance: 0.006 m/s

Threshold vapor pressure deficit: 4 kPa

Rate of decline in radiation used efficiency per unit increase in vapor pressure deficit: 0.75

Rate of decline in leaf conductance per unit increase in vapor pressure deficit: 9.00

Elevated CO2 atmospheric concentration at the 2nd point on the radiation use efficiency curve: 660 ppm

Biomass / energy ration corresponding to the previous CO2 level: 34

Plant residue decomposition coefficient: 0.05

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Appendix G. Monitoring Reports

MISSOURI
DEPARTMENT OF
NATURAL RESOURCES

Black Creek *E.coli* Sampling Project Report

Black Creek
Shelby County

June 2016 – October 2016

Prepared for:

Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch

Prepared by:

Missouri Department of Natural Resources
Division of Environmental Quality
Northeast Regional Office and
Soil and Water Conservation Program

Table of Contents

1.0 Introduction

A nine element watershed based plan has been completed and approved for Black Creek Watershed (12 digit HUC 071100050202) in Shelby County. The main stem of Black Creek has two Class P reaches within this HUC 12 watershed (Water Body Identification [**WBID**] 111 and 112) and 17 unnamed tributaries and their respective sub-watersheds that currently have the WBID 3960 (Missouri Use Designation Dataset [**MUDD**] Version 1.0).

The Class P reach of Black Creek (WBID 111), which is 19.4 miles in length, is included on the United States Environmental Protection Agency (**USEPA**) approved Missouri 2016 303(d) list of impaired waters. *E. coli* bacteria are the pollutant of concern for the impaired segment; with the source of the impairment listed as the Shelbyville Wastewater Treatment Facility (WWTF) and non-point sources. The impaired use is whole body contact B, and other uses for the stream reach are aquatic life and livestock watering. Total Maximum Daily Loads (TMDL) for Black Creek will be developed by the Missouri Department of Natural Resources (MDNR) in accordance with Section 303(d) of the federal Clean Water Act (CWA). Prior to this sampling effort in 2016, there was past *E. coli* data for WBID 111, but no *E.coli* data for WBID 112.

The purpose of this monitoring plan is to establish baseline *E.coli* data for the main stem of Black Creek (WBID 111 and 112) for sampling sites at the upstream portion to the downstream portion of this watershed, examine variability of *E.coli* results at each site, and provide additional monitoring data that could be used to track progress on reducing *E.coli* levels in Black Creek. Funding for implementation of best management practices in the watershed is expected to be available for the project area during FY17.

2.0 Study Area

The Black Creek HUC 12 watershed (HUC 071100050202) is located in northeast Missouri (see Appendix A for a map of the Black Creek watershed). Black Creek is a tributary of the North Fork of the Salt River which is part of the Mark Twain Lake watershed. The Black Creek HUC 12 watershed consists of 34,484 acres. Naturally formed clay pans are the predominant soils, which contribute to high runoff potential in the watershed.

The Black Creek HUC 12 watershed is located completely within the borders of Shelby County, Missouri.

2.1 Site Descriptions

Sampling was conducted at 10 sites on the main stem of Black Creek. All sites were accessed at road crossings/bridges in the watershed and the samples were collected upstream of the road crossing/bridge. Of the 10 sites, 9 sites are found within the project HUC 12 (HUC

071100050202) and include all known public road crossings on Black Creek within that HUC 12. One site, the most upstream site, is located upstream of the project HUC 12, and is in HUC 12 071100050201. See Appendix A for a map of the sampling locations and Appendix B for site photos.

Site BC227: Main stem of Black Creek, immediately upstream from the County Road 227 bridge. Sampling was done from the road right-of-way. The watershed is approximately 45.4 square miles. GPS derived UTM Coordinates are 576304E and 4411140N (3 meter accuracy).

Site BCK: Main stem of Black Creek, immediately upstream from Route K. Sampling was done from the highway right-of-way. The watershed is approximately 65.3 square miles. GPS derived UTM Coordinates are 580348E and 4406885N (3 meter accuracy).

Site BC15: Main stem of Black Creek, immediately upstream from Hwy 15, and upstream of the Shelbyville WWTF. Construction of the Hwy 15 bridge was occurring during the sampling months, so sampling was done upstream of the construction zone. Sampling was done from the highway right-of-way. The watershed is approximately 73.8 square miles. GPS derived UTM Coordinates are 582034E and 4405284N (4 meter accuracy).

Site BC349: Main stem of Black Creek, immediately upstream from County Road 349. The site is approximately 2.5 miles downstream of the Shelbyville WWTF. Sampling was done from the road right-of-way. The watershed is approximately 78.3 square miles. GPS derived UTM Coordinates are 584715E and 4405344N (5 meter accuracy).

Site BC342: Main stem of Black Creek, immediately upstream from County Road 342. Sampling was done from the road right-of-way. The watershed is approximately 86.1 square miles. GPS derived UTM Coordinates are 587682E and 4402573N (4 meter accuracy).

Site BC345: Main stem of Black Creek, immediately upstream from County Road 345. Sampling was done from the road right-of-way. The watershed is approximately 87.6 square miles. GPS derived UTM Coordinates are 588928E and 4401618N (3 meter accuracy).

Site BC352: Main stem of Black Creek, immediately upstream from County Road 352. Sampling was done from the road right-of-way. The watershed is approximately 99.3 square miles. GPS derived UTM Coordinates are 590112E and 4400944N (3 meter accuracy).

Site BCT: Main stem of Black Creek, immediately upstream from Route T. Sampling was done from the highway right-of-way. The watershed is approximately 100.6 square miles. GPS derived UTM Coordinates are 591158E and 4399251N (3 meter accuracy).

Site BC474: Main stem of Black Creek, immediately upstream from County Road 474. Sampling was done from the road right-of-way. The watershed is approximately 102.1 square miles. GPS derived UTM Coordinates are 591479E and 4396932N (3 meter accuracy).

Site BC478: Main stem of Black Creek, immediately upstream from County Road 478. Sampling was done from the road right-of-way. The watershed is approximately 110.1 square miles. GPS derived UTM Coordinates are 592417E and 4395342N (3 meter accuracy).

3.0 Methods

3.1 Sample Collection

Bacterial sampling took place monthly from June 2016 through October 2016. At each sampling site, one grab sample was collected for *E.coli* analysis. For QC purposes, one *E. coli* field duplicate sample was collected at one of the sample sites, randomly chosen, during each sampling month. During the first month's sampling event (June 2016), a grab sample was collected from the Shelbina Wastewater Treatment Plant, and was used as a positive control. During each month's sampling event, a sterile water sample was placed in the sampling cooler and was used as a negative control.

Bacterial sample collection adhered to the following MDNR Standard Operating Procedures: 1) MDNR-ESP-001 Required/Recommended Containers, Volume, Preservatives, Holding Times, and Special Sampling Considerations and; 2) MDNR-ESP-005, General Sampling Considerations Including the Collection of Grab, Composite, and Modified Composite Samples from Stream and Wastewater Flows. Water samples for *E. coli* analysis were placed in a cooler with ice and delivered for analysis within six hours of sample collection to the Northeast Regional Office at 1709 Prospect Drive, Macon, MO 63552.

At each sampling site, field parameters (pH, temperature, conductivity, and dissolved oxygen) were measured immediately after the collection of the grab sample. Field analysis for pH, temperature, conductivity and DO were performed in a manner consistent with MDNR-ESP-100 "Field Analysis of Water Samples for pH", MDNR-ESP-101 Field Measurement of Water Temperature", MDNR-ESP-102 "Field Analysis of Specific Conductance", MDNR-ESP-103 "Sample Collection and Field Analysis for Dissolved Oxygen Using a YSI Membrane Electrode Meter, Hach HQ40d LDO probe or YSI Pro ODO probe.

3.2 Chain of Custody

Sample collection details were recorded on an MDNR chain-of-custody form following the Standard Operating Procedure MDNR-ESP-002, Field Sheet and Chain-of- Custody Record. The MDNR chain-of-custody accompanied the sample to the Northeast Regional Office. Original chain-of-custodies were mailed to the ESP\CAS\Data Entry Unit for establishment of sample records in the ESP, LIMS and for filing. Scanned *E. coli* bench sheets were e-mailed to ESP at randy.niemeyer@dnr.mo.gov and lynn.milberg@dnr.mo.gov for data entry into LIMS.

3.3 Discharge Measurements

USGS stream gage 05503100 is located on Black Creek at Route T, which is site BCT for this project. After each sampling date, stream discharge measured by this gage at the time of sample collection at BCT was recorded for the sampling date. Stream discharge for this gage was found at http://waterdata.usgs.gov/mo/nwis/uv?site_no=05503100 .

3.4 Sample Analyses

Samples were analyzed at the Department of Natural Resources Northeast Regional Office. Water samples were analyzed for Most Probable Number (MPN) per 100 milliliter *E. coli* bacteria counts using IDEXX Colilert equipment and supplies. Bacterial analysis will followed the MDNR Standard Operating Procedure MDNR-ESP-109, Analysis of *E. coli* and Total Coliforms Using IDEXX Colilert and Quanti-Tray Test Method, based on USEPA methods.

3.5 Quality Insurance/Quality Control (QA/QC)

According to applicable Standard Operating Procedures, specific QA/QC procedures were followed during the project. One negative control was included in each monthly analysis and one positive control was analyzed in June.

3.5.1 QA/QC Methods

Sample collections, field measurements, and analyses were conducted in accordance with the applicable SOPs and Fiscal Year 2017 Quality Assurance Project Plan for 319 Project – Black Creek.

3.5.2 QA/QC Samples

A negative control was analyzed with each set of *E. coli* samples (see Appendix C). All negative controls were reported as <1.0/100 ml MPN. On June 28, 2016 a positive control was collected at the Shelbina Wastewater Treatment Facility and provided for analysis, and the result was >2419.6/100 mL MPN.

Field duplicate samples were collected during all ten *E. coli* sampling events (see Appendix C). A precision criterion for duplicates was calculated based on the formula in Standard Method for Examination of Water and Wastewater (22nd Edition); Microbial Examination; QA/QC; Section 9.0 (e). After each set of samples was analyzed, a |R| value was calculated for each pair of duplicate sample results for comparison to the criterion. The value |R| is an absolute value calculated by subtracting the *log* of each duplicate sample from the *log* of the original sample.

The precision criterion (0.38) was calculated using the five duplicate samples from the June 2016 to October 2016 sample collection. All duplicate sample |R| values were below the criterion.

4.0 Data Results

Please refer to Appendix C for *E.coli* results

5.0 Data Analysis

Standard analysis for *E. coli* data is the calculation of a geometric mean (geomean) of the samples taken from a WBID in the recreational season (see below and Appendix C). For the purposes of this report, the higher of the two values from duplicate samples were used in the calculation of geomeans at a site. When a sample result was >2419.6, the value of 4839.2 was used in the calculation of the geomean. Additional data analysis of minimum and maximum *E. coli* values help to visually represent variability of *E. coli* loading to a stream (see Appendix E).

The *E. coli* geomean of samples collected during this project were as follows:

Site BC227 = 262.3/100 ml MPN
Site BCK = 179.8/100 ml MPN
Site BC15 = 286.6/100 l MPN
Site BC349 = 285.1/100 ml MPN
Site BC342 = 140.7/100 ml MPN
Site BC345 = 746.6/100 ml MPN
Site BC352 = 375.4/100 ml MPN
Site BCT = 893.3/100 ml MPN
Site BC474 = 623.8/100 ml MPN
Site BC478 = 371.3/100 ml MPN

6.0 Discussion

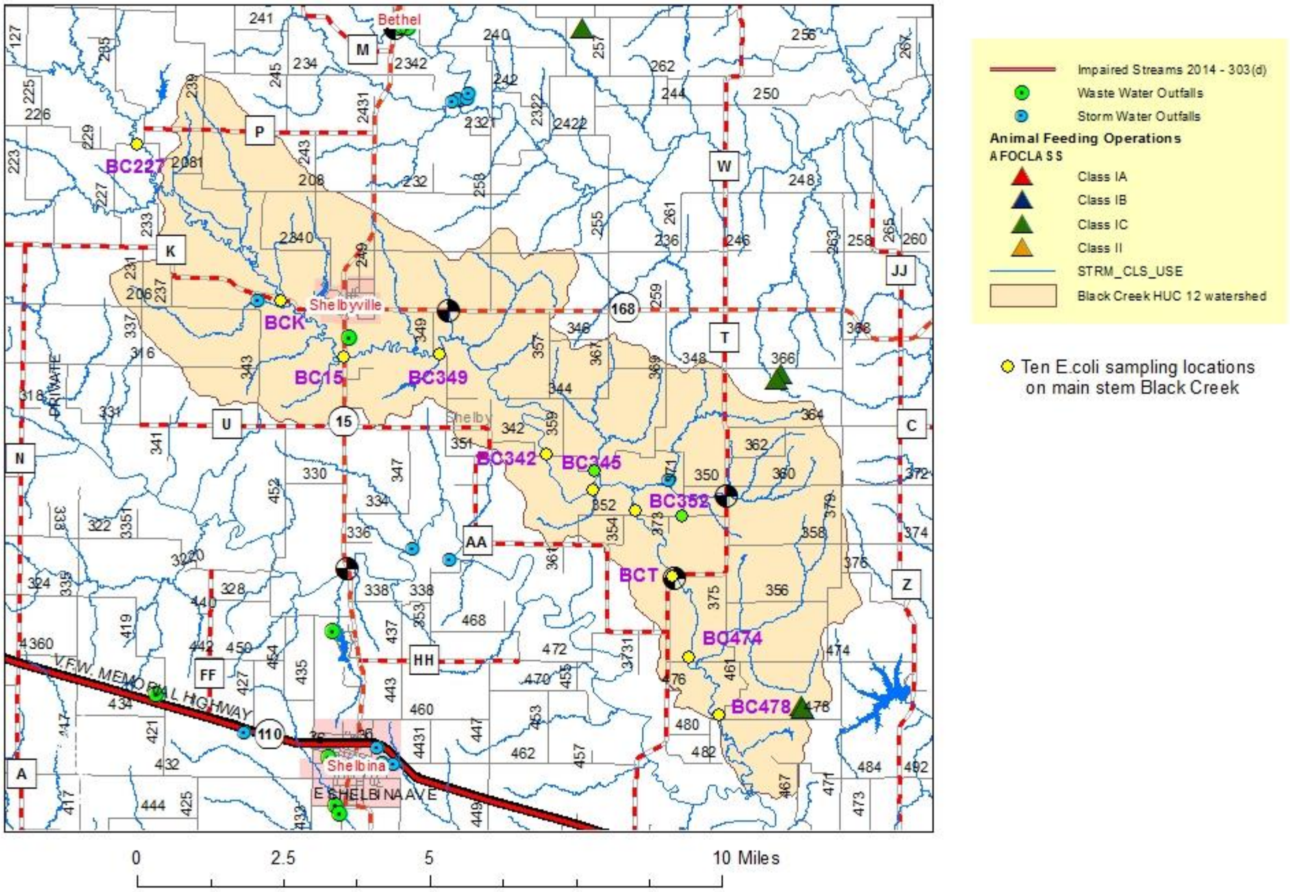
Discharge Monitoring Reports from the Shelbyville WWTF report the facility discharged during each month of this study. Their reported *E.coli* values are less than 100 MPN/100 mL in June and July, but then increase to above their permitted limits in August, September, and October. Site BC349, is the site located in the nearest downstream proximity to the Shelbyville WWTF outfall, and is located approximately 2.5 miles downstream of the WWTF outfall. In July, August, and September, *E.coli* values at Site BC349 were greater than values at site BC15, which is located approximately 0.5 miles upstream from the Shelbyville WWTF outfall, indicating that the WWTF may have affected downstream *E.coli* values at site BC349. However, during two sampling events when flow was lower (June and October; 2.1 and 3.7 cfs respectively), values at BC349 were about equal to or lower than values at BC15.

The site with the lowest geomean in the study area was BC342, which is approximately 7.3 miles downstream of the Shelbyville WWTF. This site appeared to have the greatest stream flow velocity, when compared to the other sites in the study area; however, this is observational data only because flow velocity was not measured at the sampling sites. The site with the greatest geomean in the study area was site BCT, which is approximately 4.3 miles downstream from site BC342. BC345, which is approximately 1.5 miles downstream of BC342 also had a relatively higher geomean when compared to the other sites. Both sites BC345 and BCT had much slower water velocity at the sites, and water was essentially impounded several hundred feet upstream at site BC345 due to the road crossing at the site.

During two sampling events when flows were greater (11 cfs), *E.coli* values were also greater, indicating that nonpoint sources are contributing to *E.coli* loading in Black Creek. Geomeans of *E.coli* values were greater at the 5 downstream sites (BC 345 to BC478) when compared to the 5 upstream sties. Observation of land use in the area suggest that cattle access to streams may be contributing to *E.coli* loading in the lower half of the watershed.

Black Creek, Shelby County
June 2016 – October 2016
Appendix A – Site Map
Page 6

Black Creek Watershed (HUC 12 071100050202)
2016 Sampling Sites



Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BC227 – facing upstream) (Photo taken 5/17/2016)
Page 7

Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BCK – facing upstream) (Photo taken 5/17/2016)
Page 8

Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BC15 – facing upstream) (Photo taken 5/17/2016)
Page 9

Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BC349– facing upstream) (Photo taken 5/17/2016)
Page 10

Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BC342– facing upstream) (Photo taken 5/17/2016)
Page 11

Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BC345– facing upstream) (Photo taken 5/17/2016)
Page 12

Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BC352– facing upstream) (Photo taken 5/17/2016)
Page 13

Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BCT– facing upstream) (Photo taken 5/17/2016)
Page 14

Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BC474– facing upstream) (Photo taken 5/17/2016)
Page 15

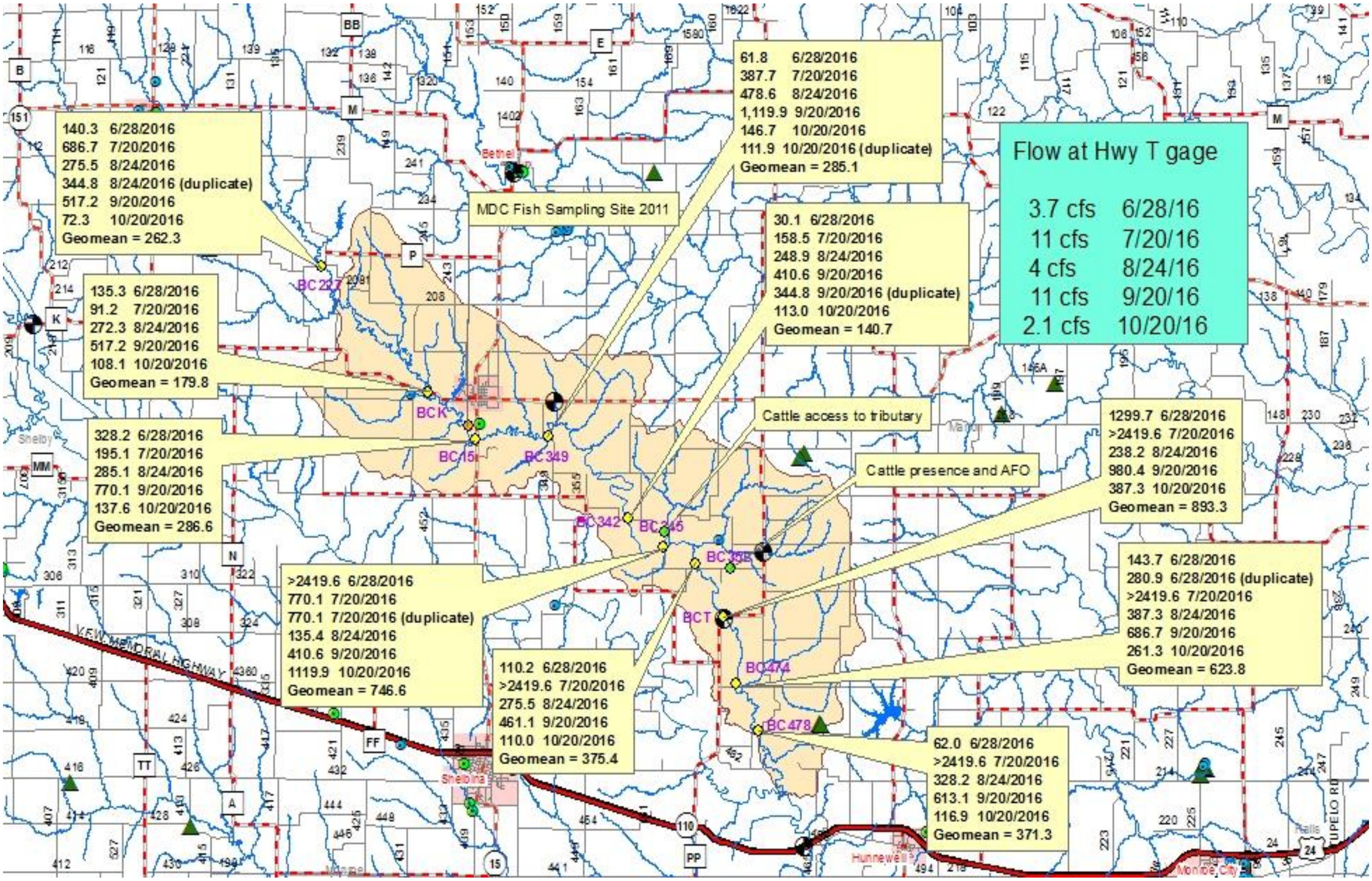
Black Creek, Shelby County
June 2016 – October 2016
Appendix B – Black Creek Site Photos (Site BC478– facing upstream) (Photo taken 5/17/2016)
Page 16

Black Creek, Shelby County
June 2016 – October 2016
Appendix C. E.coli Sampling Results - Table
Page 17

Sampling Date	Stream Discharge (cfs) at BCT USGS gage 05503100	BC227 *E.coli* Results (MPN/ 100 mL)	BCK *E.coli* Results (MPN/100 mL)	BC15 *E.coli* Results (MPN/100 mL)	BC349 *E.coli* Results (MPN/100 mL)	BC342 *E.coli* Results (MPN/100 mL)	BC345 *E.coli* Results (MPN/100 mL)	BC352 *E.coli* Results (MPN/100 mL)	BCT *E.coli* Results (MPN/100 mL)	BC474 *E.coli* Results (MPN/100 mL)
6/28/16	3.7	140.3	135.3	328.2	61.8	30.1	>2419.6	110.2	1299.7	**143.7**
7/20/16	11	686.7	91.2	195.1	387.7	158.5	**770.1***	>2419.6	>2419.6	>2419.6
8/24/16	**4**	**275.5**	272.3	285.1	478.6	248.9	135.4	275.5	238.2	387.3
9/20/16	11	517.2	517.2	770.1	1119.9	**410.6***	410.6	461.1	980.4	686.7
10/20/16	2.1	72.3	108.1	137.6	**146.7***	113.0	1119.9	110.0	387.3	261.3
Maximum		686.7	517.2	770.1	1119.9	410.6	>2419.6	>2419.6	>2419.6	>2419.6
Minimum		72.3	91.2	137.6	61.8	30.1	135.4	110.2	238.2	143.7
Geomean		262.3	179.8	286.6	285.1	140.7	746.6	375.4	893.3	623.8
n		5	5	5	5	5	5	5	5	5

Bold = duplicate sample values
*Value used to calculate geomean
Samples with results >2419.6 use 4839.2 for the geomean calculation

Black Creek, Shelby County
June 2016 – October 2016
Appendix C. E.coli Sampling Results - Map
Page 18



140.3 6/28/2016
686.7 7/20/2016
275.5 8/24/2016
344.8 8/24/2016 (duplicate)
517.2 9/20/2016
72.3 10/20/2016
Geomean = 262.3

135.3 6/28/2016
91.2 7/20/2016
272.3 8/24/2016
517.2 9/20/2016
108.1 10/20/2016
Geomean = 179.8

328.2 6/28/2016
195.1 7/20/2016
285.1 8/24/2016
770.1 9/20/2016
137.6 10/20/2016
Geomean = 286.6

MDC Fish Sampling Site 2011

61.8 6/28/2016
387.7 7/20/2016
478.6 8/24/2016
1,119.9 9/20/2016
146.7 10/20/2016
111.9 10/20/2016 (duplicate)
Geomean = 285.1

30.1 6/28/2016
158.5 7/20/2016
248.9 8/24/2016
410.6 9/20/2016
344.8 9/20/2016 (duplicate)
113.0 10/20/2016
Geomean = 140.7

Flow at Hwy T gage

3.7 cfs 6/28/16
11 cfs 7/20/16
4 cfs 8/24/16
11 cfs 9/20/16
2.1 cfs 10/20/16

Cattle access to tributary

Cattle presence and AFO

1299.7 6/28/2016
>2419.6 7/20/2016
238.2 8/24/2016
980.4 9/20/2016
387.3 10/20/2016
Geomean = 893.3

>2419.6 6/28/2016
770.1 7/20/2016
770.1 7/20/2016 (duplicate)
135.4 8/24/2016
410.6 9/20/2016
1119.9 10/20/2016
Geomean = 746.6

110.2 6/28/2016
>2419.6 7/20/2016
275.5 8/24/2016
461.1 9/20/2016
110.0 10/20/2016
Geomean = 375.4

143.7 6/28/2016
280.9 6/28/2016 (duplicate)
>2419.6 7/20/2016
387.3 8/24/2016
686.7 9/20/2016
261.3 10/20/2016
Geomean = 623.8

62.0 6/28/2016
>2419.6 7/20/2016
328.2 8/24/2016
613.1 9/20/2016
116.9 10/20/2016
Geomean = 371.3

Black Creek, Shelby County
June 2016 – October 2016
Appendix D. Field Parameters – Dissolved Oxygen (mg/L)
Page 19

Sampling Date	BC227 Dissolved Oxygen (mg/L)	BCK Dissolved Oxygen (mg/L)	BC15 Dissolved Oxygen (mg/L)	BC349 Dissolved Oxygen (mg/L)	BC342 Dissolved Oxygen (mg/L)	BC345 Dissolved Oxygen (mg/L)	BC352 Dissolved Oxygen (mg/L)	BCT Dissolved Oxygen (mg/L)	BC474 Dissolved Oxygen (mg/L)	BC478 Dissolved Oxygen (mg/L)	Average
6/28/16	3.85	3.44	4.78	3.13	5.06	3.1	6.06	6.58	3.71	5.42	4.51
7/20/16	3.94	3.69	6.38	2.62	5.59	2.27	6.3	5.08	4.34	4.59	4.48
8/24/16	4.63	5.14	5.94	4.35	6.5	7.94	6.92	7.04	5.55	6.86	6.09
9/20/16	3.19	4.13	4.94	4.76	5.61	5.33	6.05	5.08	4.89	5.77	4.98
10/20/16	1.63	1.17	2.96	1.17	4.22	1.38	5.07	2.27	1.79	4.51	2.62
Maximum	4.63	5.14	6.38	4.76	6.5	7.94	6.92	7.04	5.55	6.86	
Minimum	1.63	1.17	2.96	1.17	4.22	1.38	5.07	2.27	1.79	4.51	
Average	3.45	3.51	5.0	3.21	5.40	4.00	6.08	5.21	4.06	5.43	

Black Creek, Shelby County
June 2016 – October 2016
Appendix D. Field Parameters – Conductivity (µS/cm)
Page 20

Sampling Date	BC227 Conductivity (µS/cm)	BCK Conductivity (µS/cm)	BC15 Conductivity (µS/cm)	BC349 Conductivity (µS/cm)	BC342 Conductivity (µS/cm)	BC345 Conductivity (µS/cm)	BC352 Conductivity (µS/cm)	BCT Conductivity (µS/cm)	BC474 Conductivity (µS/cm)
6/28/16	237	231	234	232	206	202	244	231	221
7/20/16	259	244	244	229	194	189	172	146	153
8/24/16	262	258	293	291	274	273	322	315	317
9/20/16	223	249	257	257	246	255	284	283	273
10/20/16	347	351	362	365	348	356	513	393	391
Maximum	347	351	362	365	348	356	513	393	391
Minimum	223	231	234	229	194	189	172	146	153
Average	267	267	278	275	254	255	307	274	271

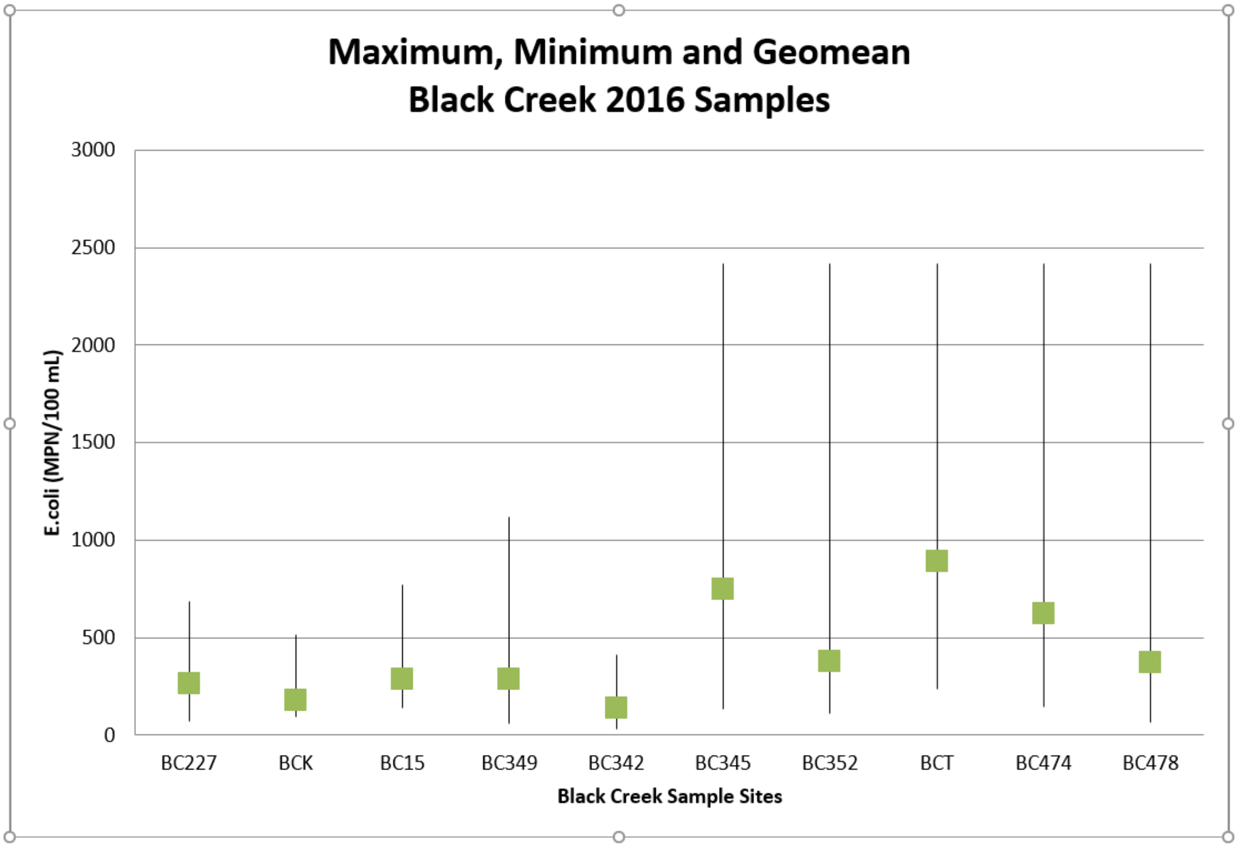
Black Creek, Shelby County
June 2016 – October 2016
Appendix D. Field Parameters – pH (standard units)
Page 21

Sampling Date	BC227 pH	BCK pH	BC15 pH	BC349 pH	BC342 pH	BC345 pH	BC352 pH	BCT pH	BC474 pH	BC478 pH	Average
6/28/16	7.37	7.63	7.83	7.69	7.71	7.69	7.66	7.71	7.65	7.71	7.67
7/20/16	7.46	7.34	7.73	7.48	7.82	8.1	7.79	7.57	8.06	7.49	7.68
8/24/16	7.03	7.14	7.32	7.00	7.26	7.85	7.3	7.44	7.56	7.35	7.33
9/20/16	6.89	6.94	7.11	6.99	7.00	7.25	7.23	7.24	7.11	7.22	7.10
10/20/16	7.08	7.15	7.47	7.32	7.72	7.41	7.75	7.48	7.51	7.41	7.43
Maximum	7.46	7.63	7.83	7.69	7.82	8.1	7.79	7.71	8.06	7.71	
Minimum	6.89	6.94	7.11	6.99	7.00	7.25	7.23	7.24	7.11	7.22	
Average	7.17	7.24	7.49	7.30	7.50	7.66	7.55	7.49	7.58	7.44	

Black Creek, Shelby County
June 2016 – October 2016
Appendix D. Field Parameters – Temperature (°C)
Page 22

Sampling Date	BC227 Temperature (C)	BCK Temperature (C)	BC15 Temperature (C)	BC349 Temperature (C)	BC342 Temperature (C)	BC345 Temperature (C)	BC352 Temperature (C)	BCT Temperature (C)	BC474 Temperatu (C)
6/28/16	25.3	25.3	25.9	25.5	24.2	27	26.8	27.1	25.7
7/20/16	25.1	25.6	26.1	25.2	25.5	25.6	25.5	24.8	24.8
8/24/16	22.6	23	23.1	22.9	23.2	24	24.5	24.5	23.7
9/20/16	21.6	22	21.9	22	22.1	22.1	22.6	23	22.6
10/20/16	15.9	16	16.4	16.2	14.9	16.4	15.9	16.5	16.4
Maximum	25.3	25.6	26.1	25.5	25.5	27	26.8	27.1	25.7
Minimum	15.9	16	16.4	16.2	14.9	16.4	15.9	16.5	16.4
Average	22.1	22.4	22.7	22.4	22.0	23.0	23.1	23.2	22.6

Black Creek, Shelby County
June 2016 – October 2016
Appendix E. Maximum, Minimum, and Geomean
Page 23



Monitoring Data

Missouri Department of Natural Resources Black Creek - WBID 0111

MDNR Water Quality Data, 2009-12

Org	Site Code	Site Name	Mo	Dy	Yr	Time	C (C)	DO (mg/l)	NO3N (mg/l)	TKN (mg/l)	TN (mg/l)	TP (mg/l)	TSS (mg/l)
MDNR	**111/16.4**	**Black Cr. Ab. CR 349**	**9**	**15**	**2009**	**1540**	20	4.2	<0.05		0.44	0.07	14
MDNR	**111/16.4**	**Black Cr. Ab. CR 349**	**4**	**13**	**2010**	**0955**	16.6	7.6	0.37		1.27	0.17	11
MDNR	**111/6.0**	**Black Cr. Ab. Hwy T**	**9**	**15**	**2009**	**1255**	21.3	6.6	<0.05		0.4	0.05	6
MDNR	**111/6.0**	**Black Cr. Ab. Hwy T**	**4**	**13**	**2010**	**1305**	18.8	10.4	0.41		1.1	0.12	10
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**9**	**15**	**2009**	**1020**	19.5	5.2	<0.05		0.32	0.05	17
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**3**	**17**	**2010**	**0855**	7.3	10.4	0.57	0.58	1.15	0.16	40
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**4**	**13**	**2010**	**1035**	17.2	8.6	0.41		1.19	0.14	5
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**5**	**5**	**2010**	**1300**	17.28	7.87	1.73	0.68	**2.41**	0.18	38
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**5**	**26**	**2010**	**0915**	22.22	4.65	3.11	0.99	**4.1**	0.13	26
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**6**	**8**	**2010**	**0915**	20.31	6.8	2.32	3.37	**5.69**	0.62	711
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**6**	**22**	**2010**	**1418**	25.53	6.14	1.01	0.82	**1.83**	0.11	78
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**7**	**7**	**2010**	**0845**	24.18	7.95	1.64	1.84	**3.48**	0.34	247
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**7**	**26**	**2010**	**1225**	25.25	6.04	0.33	1.52	**1.85**	0.42	170
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**8**	**5**	**2010**	**1121**	26.98	5.95	0.24	0.62	**0.86**	0.12	11
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**8**	**25**	**2010**	**0834**	22.36	3.77	0.28	1.01	**1.29**	0.15	29
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**9**	**8**	**2010**	**0823**	19.24	3.81	0.11	0.54	**0.65**	0.12	18
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**9**	**29**	**2010**	**0820**	15.98	7.88	0.22	0.45	**0.67**	0.28	31
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**10**	**6**	**2010**	**0856**	11.84	7.62	0.43	0.38	**0.81**	0.18	<5.0
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**10**	**20**	**2010**	**0809**	11.32	6.05	.00499	0.63	**0.64**	0.08	<5.0
												2010 Geomean	
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**11**	**4**	**2010**	**0238**		3.97	.00499	0.62	**0.63**	0.13	7
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**11**	**18**	**2010**	**1105**	6.66	6.03	0.01	0.4	**0.4**	0.06	6
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**12**	**9**	**2010**	**0831**	0.38	8.85	0.02	0.37	**0.39**	0.05	6
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**12**	**21**	**2010**	**1150**	0.49	9.13	0.0296	0.45	**0.48**	0.06	12
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**1**	**18**	**2011**	**1046**	0.03	11.06	2.21	1.61	**3.82**	0.11	5
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**1**	**26**	**2011**	**1057**	0.06	10.23	2.09	1.29	**3.38**	0.08	7
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**2**	**8**	**2011**	**1121**	0.03	2.48	1.315	0.925	**2.24**	0.04	5
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**2**	**23**	**2011**	**1128**	7.17	9.02	3.57	0.9	**4.5**	0.2	35
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**3**	**9**	**2011**	**1212**	5.22	8.1	2.37	1.15	**3.52**	0.26	88
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**3**	**22**	**2011**	**1139**	15.23	6.22	1.06	1	**2**	0.065	15
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**4**	**5**	**2011**	**1035**	9.6	10.74	0.09	1	**1**	0.093	21
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**4**	**19**	**2011**	**1202**	11.49	9.49	0.74	1.42	**2.16**	0.2	47
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**5**	**5**	**2011**	**0815**	12.46	8.29	2.74	0.47	**3.21**	0.088	
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**5**	**25**	**2011**	**0935**	18.51	7.31	2.21	4.25	**6.46**	0.69	926
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**6**	**8**	**2011**	**1130**	25.8	5.22	1.47	1.37	**2.84**	0.22	28
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**6**	**22**	**2011**	**1110**	22.22	6.23	1.45	1.39	**2.84**	0.26	56
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**7**	**6**	**2011**	**1100**	24.47	6.49	0.53	1.07	**1.6**	0.16	15
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**7**	**26**	**2011**	**1002**	27.27	3.8	0.09	0.73	**0.82**	0.1	13
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**9**	**8**	**2011**	**0940**	16.4	6.17	0.09	0.48	**0.57**	0.049	8
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**9**	**27**	**2011**	**1005**	14.5	6.16	0.045	0.615	**0.66**	0.0435	<5.0
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**10**	**4**	**2011**	**1030**	12.9	4.31	0.02	0.59	**0.61**	0.06	25
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**10**	**19**	**2011**	**1035**	10	0.75	.00499	1.09	**1.1**	0.32	8
												2011 Geomean	
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**11**	**2**	**2011**	**1130**	11.9	2.44	.00499	1.21	**1.22**	0.45	E15.0
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**11**	**15**	**2011**	**1010**	9	8.18	.00499	0.52	**0.53**	0.085	<5.0
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**11**	**29**	**2011**	**1115**	4.1	11.44	0.07	0.7	**0.8**	0.14	8
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**12**	**13**	**2011**	**1210**	3.3	11.27	0.11	0.8	**0.9**	0.15	9
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**12**	**27**	**2011**	**1200**	2	12.6	3.1	1.03	**4.1**	0.34	19
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**1**	**9**	**2012**	**1230**	2.4	11.5	2.13	0.22	**2.35**	1.67	22
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**1**	**25**	**2012**	**0958**	0.7	12.83	1.17	0.61	**1.78**	0.11	13
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**2**	**7**	**2012**	**1105**	3	12.08	3.42				46
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**2**	**22**	**2012**	**1200**	5.5	12.6	3.27	0.7	**4**	0.095	13
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**3**	**8**	**2012**	**1108**	9	9.92	2.36	1.21	**3.57**	0.43	36
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**3**	**22**	**2012**	**1100**	17.6	7.53	0.22	0.93	**1.15**	0.13	7
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**4**	**2**	**2012**	**1030**	18.7	6.91	1.85	1.09	**2.94**	0.24	19
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**4**	**17**	**2012**	**1050**	14.8	8.01	3.72	2.23	**5.95**	0.57	256
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**5**	**2**	**2012**	**1130**	16.3	7.38	4.29	3.44	**7.73**	1.1	310
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**5**	**15**	**2012**	**1100**	18.3	7.88	1.01	1	**2**	0.086	<5.0
MDNR	**111/2.3**	**Black Cr. Bl. CR 478**	**5**	**29**	**2012**	**1110**	23.8	5.52	0.1	0.77	**0.9**	0.07	<5.0
												2012 Geomean	

* Blue values were calculated from NO3N and TKN

Aquatic Invertebrate Monitoring by MDNR, 2009-10

Org	Site	Location	Date	Score
MDNR	112/13.5	Black Cr. ab. CR 127	Fall 2009	14
MDNR	112/13.5	Black Cr. ab. CR 127	Spring 2010	18
MDNR	112/8.9	Black Cr. bl. CR 226	Fall 2009	16
MDNR	112/8.9	Black Cr. bl. CR 226	Spring 2010	18
MDNR	112/3.0	Black Cr. ab. Hwy. K	Fall 2009	16
MDNR	112/3.0	Black Cr. ab. Hwy. K	Spring 2010	20
MDNR	111/16.4	Black Cr. ab. CR 349	Fall 2009	12
MDNR	111/16.4	Black Cr. ab. CR 349	Spring 2010	16
MDNR	111/6.0	Black Cr. ab. Hwy. T	Fall 2009	16
MDNR	111/6.0	Black Cr. ab. Hwy. T	Spring 2010	20
MDNR	111/2.3	Black Cr. bl. CR 478	Fall 2009	16
MDNR	111/2.3	Black Cr. bl. CR 478	Spring 2010	18

Aquatic invertebrate samples were collected and analyzed following the Missouri DNR Environmental Services Program written standard operating methods contained in "Semi-Quantitative Macroinvertebrate Stream Bioassessment" by R. Sarver, 2003. Invertebrate communities are judged to be impaired if the percent of sampling sites receiving a score of 16 or more is significantly less than for reference streams in the same ecological drainage unit (EDU). Scores of 16 or more are considered to reflect unimpaired macro invertebrate communities.

Reference streams in this EDU score 16 or higher on 73.3% of all samples. For Black Creek, 10 of 12, or 83.3% of all samples scored 16 or higher. Because this is higher than the reference rate, all of Black Creek is judged to have an **unimpaired** biological community.

Missouri Department of Natural Resources Water Protection Program

(573)751-1300

www.dnr.mo.gov

The water quality standard for *E. coli* in Class B recreational waters for protection of human health is 206 col/100 mL. This standard is for the geometric mean of all bacterial counts taken during each recreational season, April 1 through October 31. For *E. coli* bacteria, a water body is judged to be unimpaired if the geometric means for all of the last three years for which data is available are less than the appropriate water quality standard. At least five samples must be available from a given recreational season for that season to be considered. The geometric mean for *E. coli* in Black Creek has been calculated as 989.88 col/100 mL, 405.86 col/100 mL, and 572.16 col/100 mL for 2010, 2011, and 2012 respectively. Since this number is greater than the Class B E. coli standard of 206 col/100 mL, Black Creek is judged to be **impaired** by bacteria.

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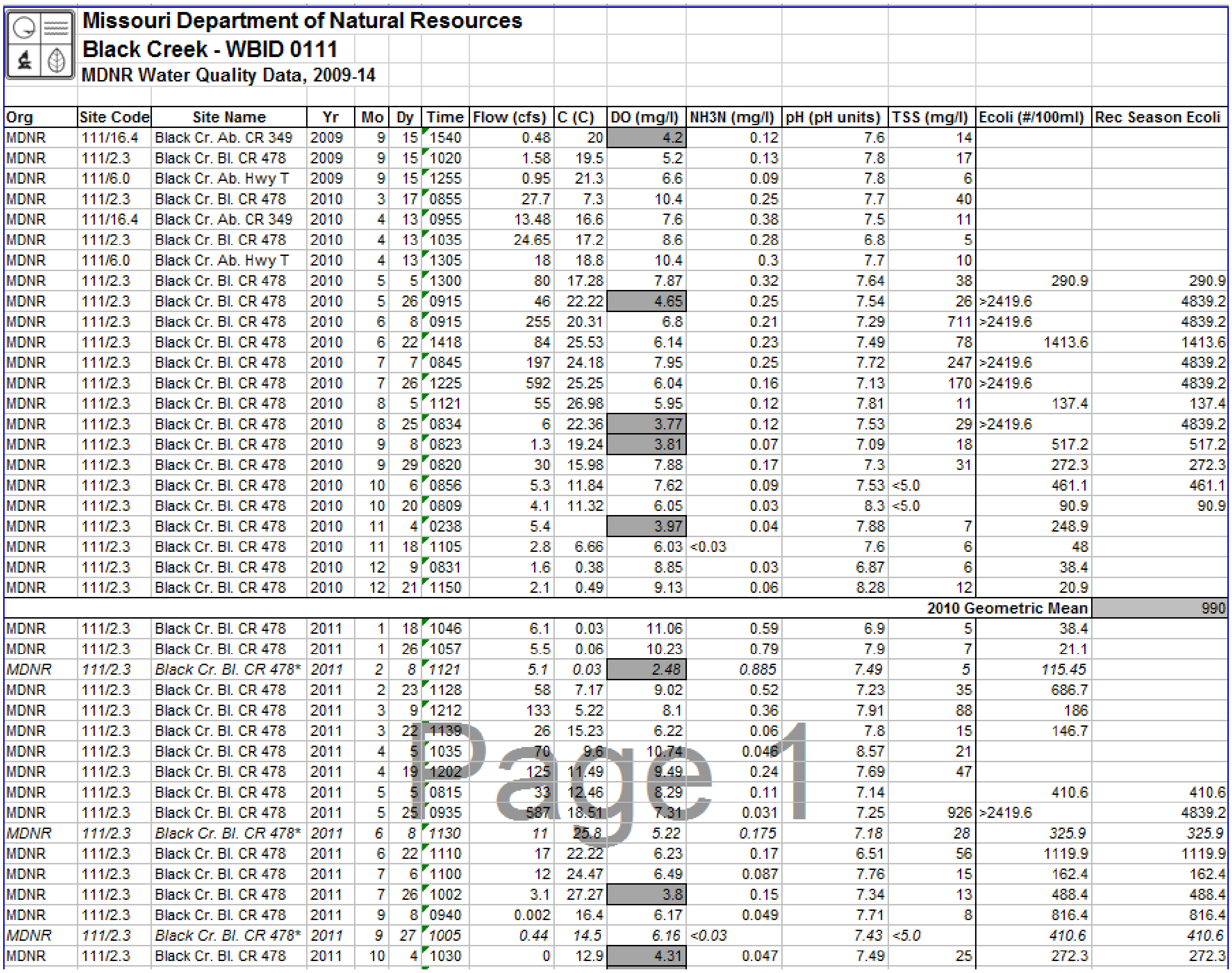
Black Creek Nutrients

Org	Site Code	Site Name	Mo	Dy	Yr	Time	TN (mg/l)	TP (mg/l)
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	26	2000	2200	1.51	0.98
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	30	2000	2000	0.97	0.12
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	4	2001	2000	10.76	3.95
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	7	2001	2300	7.46	1.1
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	24	2001	1200	0.81	0.35
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	24	2001	1201	2.72	0.31
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	1	2001	1900	3.3	1.7
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	5	2001		2.38	0.74
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	6	2001	2200	1.71	0.4
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	10	2001	2100	2.55	0.61
MEC	111/7.1	Black Cr. nr Oak Dale Church	7	3	2001	0800	3.38	0.82
MEC	111/7.1	Black Cr. nr Oak Dale Church	7	9	2001	1341	1.85	0.47
MEC	111/7.1	Black Cr. nr Oak Dale Church	7	24	2001	1200	3.38	0.82
MEC	111/7.1	Black Cr. nr Oak Dale Church	4	5	2002	0600	4.85	0.4
MEC	111/7.1	Black Cr. nr Oak Dale Church	4	21	2002	1300	7.2	0.61
MEC	111/7.1	Black Cr. nr Oak Dale Church	4	26	2002	1000	4.83	0.71
MEC	111/7.1	Black Cr. nr Oak Dale Church	4	29	2002	1500	4.81	0.41
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	3	2002	0700	3.9	0.94
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	8	2002	1500	3.16	0.74
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	10	2002	1200	2.63	0.68
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	13	2002	1200	2.12	0.41
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	19	2002	1400	2.68	0.66
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	25	2002	0340	3.24	0.9

MEC	111/7.1	Black Cr. nr Oak Dale Church	6	12	2002	2100	4.46	0.91
MEC	111/7.1	Black Cr. nr Oak Dale Church	8	8	2002		0.78	0.1
MEC	111/7.1	Black Cr. nr Oak Dale Church	4	25	2003	0150	3.9	0.05
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	1	2003	1640	3.18	0.36
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	4	2003	1720	3.21	0.35
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	9	2003	0950	2.2	0.38
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	18	2003	0110	4.74	0.28
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	22	2003	0711	4.58	0.3
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	10	2003	1230	0.46	0.14
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	19	2003	1627	3.34	0.14
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	25	2003	1930	2.21	0.17
MEC	111/7.1	Black Cr. nr Oak Dale Church	7	1	2003	1550	1.07	0.19
MEC	111/7.1	Black Cr. nr Oak Dale Church	7	11	2003	1600	2.22	0.19
MEC	111/7.1	Black Cr. nr Oak Dale Church	4	20	2004	0008	4.25	0.52
MEC	111/7.1	Black Cr. nr Oak Dale Church	4	29	2004		2.79	0.33
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	11	2004		1.32	0.14
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	24	2004		5.07	0.54
MEC	111/7.1	Black Cr. nr Oak Dale Church	5	30	2004		3.33	0.34
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	1	2004		5.56	0.51
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	2	2004		4.38	0.33
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	9	2004		3.32	0.64
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	14	2004		3.3	0.72
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	15	2004	0010	4.94	0.19
MEC	111/7.1	Black Cr. nr Oak Dale Church	6	24	2004	0010	1.17	0.4
MEC	111/7.1	Black Cr. nr Oak Dale Church	7	2	2004	1210	1.48	0.47
MEC	111/7.1	Black Cr. nr Oak Dale Church	7	11	2004	1430	1.79	0.54
MDNR	111/6.0	Black Cr. Ab. Hwy T	9	15	2009	1255	0.4	0.05
MDNR	111/6.0	Black Cr. Ab. Hwy T	4	13	2010	1305	1.1	0.12
MDNR	111/2.3	Black Cr. Bl. CR 478	9	15	2009	1020	0.32	0.05
MDNR	111/2.3	Black Cr. Bl. CR 478	3	17	2010	0855	1.15	0.16



Missouri Department of Natural Resources

Black Creek - WBID 0111

MDNR Water Quality Data, 2009-14

Org	Site Code	Site Name	Yr	Mo	Dy	Time	Flow (cfs)	C (C)	DO (mg/l)	NH3N (mg/l)	pH (pH units)	TSS (mg/l)	Ecoli (#/100ml)	Rec Season Ecoli
MDNR	111/16.4	Black Cr. Ab. CR 349	2009	9	15	1540	0.48	20	4.2	0.12	7.6	14		
MDNR	111/2.3	Black Cr. Bl. CR 478	2009	9	15	1020	1.58	19.5	5.2	0.13	7.8	17		
MDNR	111/6.0	Black Cr. Ab. Hwy T	2009	9	15	1255	0.95	21.3	6.6	0.09	7.8	6		
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	3	17	0855	27.7	7.3	10.4	0.25	7.7	40		
MDNR	111/16.4	Black Cr. Ab. CR 349	2010	4	13	0955	13.48	16.6	7.6	0.38	7.5	11		
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	4	13	1035	24.65	17.2	8.6	0.28	6.8	5		
MDNR	111/6.0	Black Cr. Ab. Hwy T	2010	4	13	1305	18	18.8	10.4	0.3	7.7	10		
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	5	5	1300	80	17.28	7.87	0.32	7.64	38	290.9	290.9
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	5	26	0915	46	22.22	4.65	0.25	7.54	26	>2419.6	4839.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	6	8	0915	255	20.31	6.8	0.21	7.29	711	>2419.6	4839.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	6	22	1418	84	25.53	6.14	0.23	7.49	78	1413.6	1413.6
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	7	7	0845	197	24.18	7.95	0.25	7.72	247	>2419.6	4839.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	7	26	1225	592	25.25	6.04	0.16	7.13	170	>2419.6	4839.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	8	5	1121	55	26.98	5.95	0.12	7.81	11	137.4	137.4
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	8	25	0834	6	22.36	3.77	0.12	7.53	29	>2419.6	4839.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	9	8	0823	1.3	19.24	3.81	0.07	7.09	18	517.2	517.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	9	29	0820	30	15.98	7.88	0.17	7.3	31	272.3	272.3
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	10	6	0856	5.3	11.84	7.62	0.09	7.53	<5.0	461.1	461.1
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	10	20	0809	4.1	11.32	6.05	0.03	8.3	<5.0	90.9	90.9
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	11	4	0238	5.4		3.97	0.04	7.88	7	248.9	
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	11	18	1105	2.8	6.66	6.03	<0.03	7.6	6	48	
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	12	9	0831	1.6	0.38	8.85	0.03	6.87	6	38.4	
MDNR	111/2.3	Black Cr. Bl. CR 478	2010	12	21	1150	2.1	0.49	9.13	0.06	8.28	12	20.9	
													2010 Geometric Mean	990
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	1	18	1046	6.1	0.03	11.06	0.59	6.9	5	38.4	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	1	26	1057	5.5	0.06	10.23	0.79	7.9	7	21.1	
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2011*	*2*	*8*	*1121*	*5.1*	*0.03*	*2.48*	*0.885*	*7.49*	*5*	*115.45*	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	2	23	1128	58	7.17	9.02	0.52	7.23	35	686.7	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	3	9	1212	133	5.22	8.1	0.36	7.91	88	186	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	3	22	1139	26	15.23	6.22	0.06	7.8	15	146.7	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	4	5	1035	70	9.6	10.74	0.046	8.57	21		
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	4	19	1202	125	11.49	9.49	0.24	7.69	47		
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	5	5	0815	33	12.46	8.29	0.11	7.14		410.6	410.6
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	5	25	0935	587	18.51	7.31	0.031	7.25	926	>2419.6	4839.2
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2011*	*6*	*8*	*1130*	*11*	*25.8*	*5.22*	*0.175*	*7.18*	*28*	*325.9*	*325.9*
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	6	22	1110	17	22.22	6.23	0.17	6.51	56	1119.9	1119.9
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	7	6	1100	12	24.47	6.49	0.087	7.76	15	162.4	162.4
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	7	26	1002	3.1	27.27	3.8	0.15	7.34	13	488.4	488.4
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	9	8	0940	0.002	16.4	6.17	0.049	7.71	8	816.4	816.4
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2011*	*9*	*27*	*1005*	*0.44*	*14.5*	*6.16*	*<0.03*	*7.43*	*<5.0*	*410.6*	*410.6*
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	10	4	1030	0	12.9	4.31	0.047	7.49	25	272.3	272.3

MDNR	111/2.3	Black Cr. Bl. CR 478	2011	10	19	1035	0	10	0.75	0.095	7.4	8	23.1	23.1
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	11	2	1130	0	11.9	2.44	0.095	7.53	E15.0	130.1	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	11	15	1010	4.102	9	8.18	0.047	7.55	<5.0	148.3	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	11	29	1115	11.329	4.1	11.44	0.047	8.08	8	387.3	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	12	13	1210	1.202	3.3	11.27	0.039	7.64	9	69.5	
MDNR	111/2.3	Black Cr. Bl. CR 478	2011	12	27	1200	10.7	2	12.6	0.42	7.9	19	365.4	
													2011 Geometric Mean	406
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	1	9	1230	2.14	2.4	11.5	0.34	8	22	56.9	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	1	25	0958	1.6	0.7	12.83	0.1	7.76	13	2419.6	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	2	7	1105	22.922	3	12.08		7.2	46	613.1	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	2	22	1200	5.6	5.5	12.6	0.098	8.3	13	90.6	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	3	8	1108	9.196	9	9.92	0.36	7.6	36	80.1	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	3	22	1100	12.031	17.6	7.53	0.16	7.66	7	613.1	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	4	2	1030	E50.0	18.7	6.91	0.23	7.52	19	298.7	298.7
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	4	17	1050	198	14.8	8.01	0.41	7.37	256	>2419.6	4839.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	5	2	1130	840	16.3	7.38	0.52	7.24	310	>2419.6	4839.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	5	15	1100	E6.0	18.3	7.88	0.13	7.6	<5.0	113.7	113.7
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	5	29	1110	1.25	23.8	5.52	0.18	7.4	<5.0	77.1	77.1
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	7	2	1045	0.11	25.5	5.54	0.14	7.41	11	1299.7	1299.7
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	7	16	1115	2.42	26.4	4.72	0.22	7.37	20	1299.7	1299.7
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	8	15	1240	0	19.8	7.09	0.13	7.9	14	186	186
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	10	11	1000	0.036	9.8	7.01	0.049	7.24	<5.0	816.4	816.4
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	10	25	0905		18.9	5	0.15	7.11	25	344.8	344.8
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	11	6	1205	0.523	7.6	6.34	0.1	7.42	7	547.5	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	11	26	1150	0.374	5.3	8.91	0.14	6.98	67	123.6	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	12	6	1120	0.357	7.1	6.79	0.12	7.41	8	75.9	
MDNR	111/2.3	Black Cr. Bl. CR 478	2012	12	27	1115	4.6	0.5	12.29	0.43	7.47	39	1553.1	
													2012 Geometric Mean	594
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	1	8	1125	0.5	0.7	10.8	0.48	8.2	15	28.8	
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	1	22	1120	0.5	0.3	12.24	1.02	7.32	11	45.7	
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	2	7	0952	14.6	2.9	12.07	0.65	7.5	19	58.1	
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	2	20	0904		0		0.51	7.3	105	579.4	
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	3	5	0953		1.3		0.35	7.68		48	
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	3	19	0930		4.3	11.7	0.38	7.25			
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	4	2	1000		7.8	10.75	0.077	7.65	17	88.4	88.4
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	4	23	1230		12.1	9.04	0.27	7.71	57	410.6	410.6
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	5	8	0920		15.8	8.14	0.3	7.36	100	579.4	579.4
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	5	21	1030	12.145	20.7	5.84	0.095	7.47	20	325.5	325.5
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	6	10	1055	17	19.4	7.1	0.091	7.2	12	186	186
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	6	24	1030	4.4	24.2	4.5	0.17	7.4	15	191.8	191.8
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	7	1	1200	5.84	21.7	5.7	0.24	7.22	31	579.4	579.4
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	7	15	1215	0.6	23.9	5.58	0.1	7.29	10	95.9	95.9
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	8	7	1000	0.222	23.7	5.04	0.086	7.42	18	387.3	387.3
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	8	19	1215	0.07	21	6.54	0.084	7.45	14	727	727
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2013*	*9*	*5*	*1139*	*<0.1*	*21.65*	*6.47*	*0.0945*	*7.835*	*19.5*	*230.25*	*230.25*
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	9	26	0905	<0.1	17.8	4.73	0.082	7.53	31	1553.1	1553.1

MDNR	111/2.3	Black Cr. Bl. CR 478	2013	10	10	0850	<0.1	13.3	6.14	0.2	7.66	19	78.9	78.9
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	10	30	1058	<0.1	11.7	5.45	0.11	7.67	50	1119.9	1119.9
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2013*	*11*	*5*	*0930*	*3.587*	*10.4*	*5.85*	*0.089*	*7.33*	*16*	*187.65*	
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	11	26	0915		2	5.86	0.15	6.94	9	209.8	
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2013*	*12*	*5*	*0945*	*0.178*	*2.35*	*6.515*	*0.135*	*7.275*	*4.25*	*205.25*	
MDNR	111/2.3	Black Cr. Bl. CR 478	2013	12	30	1020		1.1	10.67	<0.03	7.16	<5.0		
													2013 Geometric Mean	321
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	1	16	1100	23	0.1	10.9	0.56	7.1	14	574.8	
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	1	28	1120	0.7	0.4	7.1	0.46	7.1	<5.0	1	
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	2	13	0815		0.1	7.01	0.68	7.14	6	3.1	
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2014*	*2*	*25*	*0815*	*46*	*1.65*		*0.34*	*7.06*	*39.5*	*210.05*	
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	3	4	1015		0.2	10.06	0.3	7.25	12	9.8	
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	3	4	1020		0.2	10.06	0.14	7.25	12	7.5	
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	3	27	0955	0.68	6.9	12.08	0.097	7.56	17	68.9	
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2014*	*4*	*8*	*0915*		*10.85*	*9.59*	*0.215*	*6.925*	*36.5*	*59.9*	*89.9*
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	4	22	0930	7.654	14.9	9.13	E0.032	7.2	9	150	150
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	5	6	0910	6.5	16.1	6.73	0.22	7.61	13	209.8	209.8
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	5	22	0900	5.44	20.5	5.27	0.21	6.94	21	488.4	488.4
MDNR	*111/2.3*	*Black Cr. Bl. CR 478**	*2014*	*6*	*9*	*1120*	*376*	*20.65*	*7.15*	*0.32*	*7.2*	*519.5*	*>2419.6*	*4839.2*
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	6	24	1110	77	23.6	6.9	0.16	7.8	47	1046.2	1046.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	7	2	0900	11	23	5.89	0.22	6.95	66	579.4	579.4
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	8	14	0858	3.1	20.6	5.76	0.1	7.01	14	435.2	435.2
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	10	24	0850	11.784	12.1	7.01	0.096	7.1	7	63.8	63.8
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	11	5	1100	9.8	9.9	6.8	0.1	7.5	<5.0	46.4	
MDNR	111/2.3	Black Cr. Bl. CR 478	2014	11	5	1115	9.8	9.8	6.8	0.095	7.5	<5.0	56.3	
													2014 Geometric Mean	364

** Sample is average of two field duplicates*

Black Creek WB 111 is a Class B Whole Body Contact Recreational water with an E coli standard of 206 counts/100 ml. This standard is interpreted as the geometric mean of at least five samples taken during the recreational season (April 1 to Oct. 31) of an given year. A water is judged to be impaired by bacteria if the standard is exceeded in any of the last three years for which adequate data is available. There was adequate data in 2012, 2013 and 2014 and the standard was exceeded in all three years. Thus, this waterbody is judged to be **impaired** by bacteria.

13 of 105 dissolved oxygen measurements failed to meet the 5 mg/L standard. For a stream with a ten percent exceedence frequency of a standard, 13 exceedences in 105 measurements has a binomial probabilitiy Type One error rate of 0.2495. Since this is gerater than the minimum allowed error rate of 0.1, this stream is judged to be **unimpaired** by low DO and is recommended for delisting in 2016.

Water Quality Data - Public Search

Biological Assessments Database

Missouri Department of Natural Resources, Water Protection Program, (573) 751-1300, www.dnr.mo.gov

4/27/2015 rav