The Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

Mississippi River Basin Healthy Watersheds Initiative (MRBI)
Watershed Assessment for:

Coon Creek Watershed (HUC-071100080104)
Sandy Fork-West Fork Cuivre River Watershed (HUC-071100080105)
Headwaters Indian Creek Watershed (HUC-071100080201)

FINAL REPORT

Deliverable # 4 – Inventory of the Watershed
Deliverable # 5 – Resource Analysis of the Watershed
Deliverable # 6 –Identification of Conservation Needs on Susceptible Acres

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SCOPE AND OBJECTIVES

In 2009, the U.S. Department of Agriculture through the National Resources Conservation Service (NRCS) implemented the Mississippi River Basin Healthy Watersheds Initiative (MRBI) aimed at reducing nutrients and sediment in the nation's rivers and streams. The goal of the MRBI program is to develop nutrient reduction strategies that minimize the contributions of nitrogen and phosphorus to surface waters within the basin while ensuring the economic viability of agricultural lands (USDA 2017). The goal of the MRBI program is to improve water quality, restore wetlands, and enhance wildlife habitat while ensuring economic viability of agricultural lands in high-priority watersheds within the Mississippi Basin (USDA, 2017). However, watershed-scale evaluations identifying specific pollution sources and the conservation practices needed to improve water quality are needed to aid field office staff responsible for working with landowners. Therefore, a comprehensive planning effort intended to prioritize specific landscapes, crop types, and the conservation practices available is needed to help NRCS field staff implement the MRBI program where it will be the most effective considering limited available resources.

The Missouri State Office of the NRCS contracted the Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University (MSU) to perform a watershed assessment study on three 12-digit hydrologic unit code (HUC) watersheds in the Cuivre River watershed (HUC-8# 07110008). The three watersheds are Coon Creek (HUC-12# 071100080104), Sandy Fork-West Fork Cuivre River (HUC-12# 071100080105), and Headwaters Indian Creek (HUC-12# 071100080201) located in Audrain, Montgomery, Pike and Ralls Counties in northeast Missouri. Soil erosion and animal waste has been identified as major concern for water quality for streams within the Cuivre River watershed and water quality monitoring shows high levels of nutrients, bacteria, and suspended sediment (Weirich 1993; MDNR 2016). Sections of the North Fork Cuivre River downstream of these three watersheds are listed under the Missouri Department of Natural Resources (MDNR) Section 303(d) list of impaired waters for E. Coli pollution from rural nonpoint source (NPS) pollution (MDNR 2018).

The purpose of this assessment is to provide NRCS field staff with the necessary information to identify locations within the watershed where soil, slope, and land use practices have the highest pollution potential and to describe conservation practices that can be the most beneficial to improve water quality. The specific objectives of this assessment are to:

(1) Complete a comprehensive inventory of existing data in the watershed including information related to geology, soils, hydrology, climate, land use, and any existing biological or chemical monitoring data available;

(2) Perform a resource assessment of the watershed that includes analysis of the data gathered in the watershed inventory that includes identification of nonpoint source pollutants, water quality impairments, rainfall-runoff characteristics, and a field-based stream bank conditions assessment;
(3) Provide NRCS staff with information on the resource concerns within the watershed, specific field conditions that contribute that most to the water quality impairment, and what conservation practices should be implemented for the existing conditions to get the most water quality benefit.

DESCRIPTION OF THE WATERSHED

Location

The Coon Creek, Sandy Fork-West Fork Cuivre River, and Headwaters Indian Creek watersheds are located within the Cuivre River watershed of northwestern Missouri (Figure 1). The Sandy Fork-West Fork Cuivre River (33,058 acres) and Headwaters Indian Creek (36,295 acres) watersheds are primarily located in Audrain and Pike Counties, Missouri. The Coon Creek (30,516 acres) watershed is within Montgomery County and includes the towns of Wellsville (population of 1,142) and Middleton (population of 151) (Figure 2). Coon Creek and Sandy Creek flow into the West Fork Cuivre River (HUC-10# 0711000801). The Headwaters Indian Creek watershed drains a portion of Vandalia, Missouri (population of 4,320) and flows east to where Indian Creek joins the North Fork Cuivre River (HUC-10# 0711000802) (US Census Bureau, 2015). The main channel of the Cuivre River flows east and eventually enters the Mississippi River north of St. Louis.

Climate

Northeastern Missouri has a warm and temperate continental climate with hot summers and moderate winters (Peel et al., 2007). Over the 30-year period from 1990-2019, the average annual rainfall at Vandalia, Missouri ranged from 23.0-62.2 inches with an average of 40.1 inches per year (Table 1). The highest average monthly rainfall totals (>4 inches) occur from May to July, with generally less precipitation (<3 inches) during the winter months (Figure 3a). Between 1990-2019, average annual temperature ranged from 50.5-56.7 °F with an average of 53.7 °F (Figure 4b, Table 1). Over that period, average monthly temperatures range from about 28°F in January to near 76°F in July (Figure 3b). Prior to 2008, the overall annual precipitation was around 40 inches per year for the majority of that time (Figure 4a). From 2008-2010, the average annual rainfall was over 50 inches per year, followed by three years of greater than 40 inches of rainfall from 2011-2013 (Figure 4b).

Solar radiation and evaporation trends are similar to temperature trends for Vandalia, MO. From 2012-2017, average daily solar radiation by month ranged from about 5.6 MJ/m^2 in December up to around 20.6 MJ/m^2 in July with an average of 13.6 MJ/m^2 (Figure 5a). Between 2012-2017, monthly average daily estimated evaporation ranged from around 0.03 inches in December to about 0.18 inches in June with an average of 0.10 inches over the entire year (Figure 5b).

Geology, Topography, and Geomorphology

The three study watersheds are located in the Mississippi River Hills section and the Claypan Till Plains section of the Dissected Till Plain Province (Nigh and Schroeder 2002). The region is characterized by gently rolling plains where local relief is typically between 150-250 ft (Nigh and Schroeder 2002). The underlying bedrock consists of Pennsylvanian age interbedded shale and sandstones and Mississippian age limestone near the Mississippi River (Weirich 1993). These bedrock formations are exposed along some major stream courses where streams have cut through the overlying glacial till and loess flowing from north to south (Love 1997). There are several till formations identified in this region with varying amounts of clays, sands, and gravels left from the melting ice sheets (Rovey and Balco 2011). The surface of the basin is glacial till (generally less than 50 feet in depth) overlain by a 4 to 8-foot layer of loess (MDNR 2014). Typically, streams meander through broad valleys bordered by high alluvial banks (Weirich 1993). High suspended sediment load is known to be common in these streams (Young and Geller 1995). The NRCS has not published regional curves describing typical stream channel morphology in the Central Lowlands of the Interior Plains.

Landscape and Soils

The Cuivre River watershed is within the Central Mississippi Valley Wooded Slopes Major Land Resource Area (MLRA) (USDA 2006). The Central Mississippi Valley consist of nearly level to very steep upland divides. This area is dissected by both large and small tributaries to the Mississippi River, creating well defined valleys with extensive floodplains and a number of terraces along the major streams (USDA 2006). Elevations within the watershed range from 420-869 feet and are generally higher towards the western portion of the Coon Creek sub-watershed (Figure 6). LiDAR derived slope ranges from 0-56% percent with a majority of the land having slope of <4%. The slopes are generally higher (>8%) in the lower portion of Coon Creek and Indian Creek (Figure 7). Slopes <3% are generally found in the uplands and valley bottoms, while the steeper slopes, that are not road embankments, are located along the valley margin.

The majority of the upland soils are alfisols (92.0%), with inceptisols (6.0%), mollisols (1.1%) and entisols (0.2%) found along the valley bottoms (Table 2, Figure 8). Upland soils also have poor infiltration rates with over 77% of the soils in the watershed being within the Hydrological Soil Group D (very slow), 17% in Group C (slow) or C/D, with 6% in Group B (moderate) or B/D only being found along the floodplain (Table 2, Figure 9) (USDA 2009a). Soils were also classified by Land Capability Classification, which is a way to describe the suitability of a soil to grow field crops (USDA, 2018). Within the watershed, land capability classes range from Class 2-7 and limitations tending to be fairly equal among capability subclasses (e) erosion and (w) water (Table 2). Wetness tends to be the limitation along the valley bottoms and ridge tops of headwaters (Figure 10). Downslope of the ridges, erosion tends to be the major limitation in the area of the watershed with steeper slope. The majority of the soils in all three watersheds are classified in the 3e (48.8%) and 3w (30.7%) categories which have severe limitations that reduce the choice of plants or require special conservation practices (USDA 2018). Most soils within the three watersheds have a soil erosion K-factor greater than 0.4 (78.2%), with the maximum K-Factor of 0.64 located along the stream terraces in the Coon Creek watershed. (Table 2, Figure 11). A complete list of soil series found within the watershed is available in the Appendix A.

Hydrology and Drainage Network

The main channels of the Coon Creek, Sandy Fork-West Fork Cuivre River, and Headwaters Indian Creek watersheds generally flow from west to east, with the majority of tributary drainage flowing from the west into the main stem (Figure 7). There are a total of 361 miles of mapped streams within the three watersheds, with only 41 miles classified as permanent flow (Table 3). Sandy Fork-West Fork Cuivre River has the largest length of permanent streams with a total of 21 mi, while Headwaters Indian Creek has the least at 8 mi. There are a total of 672 acres of lakes and ponds within the three watersheds. Within the Central Mississippi Valley major land resource area, 3% of total water usage comes from groundwater and 97% from surface water (USDA 2006). Three major water users have been located supplying water for irrigation within Sandy Fork-West Fork Cuivre River (Figure 13). Two of the sites include surface water intakes on the West Fork Cuivre River and one on an unnamed lake that drains into an unnamed tributary in Audrain County. Between the three sites over 2.8 million gallons of water were extracted in 2017, with a decrease in water use being observed since 2013 (Table 4).

Land Use and Land Cover

The Cuivre River watershed is mainly an agricultural watershed but has significant amounts of mixed land uses. Land use for the watershed was determined using the 2014-2018 National Agricultural Statistics Service (NASS) Crop Database. Crop classes were combined to look at the general overall picture of land use in the watershed. In general, all three watersheds are predominantly row crops (24% corn and 31% soybeans). Additionally, the three watersheds have only about 10-15% of the land use classified as pastureland (Figure 12 and Table 5). The amount of land in corn and soybeans has increased in all three watersheds from 2014-2018 by 5-18%, while the amount of grass/pasture land has decreased (30-35%) suggesting a conversion of pastureland to a land cover with potentially higher pollution potential (Table 6). Another predominant land cover within these three watersheds is deciduous forest (16-20%) and has increased 1-3% from 2014 to 2018. Urban land use only makes up around 4% of the total land cover in these three watersheds. The trends of land use over the last 5 years have been relatively consistent across all three watersheds.

Previous Work and Other Available Data

<u>TMDLs and Management Plans</u>
Currently, there are no Total Maximum Daily Loads (TMDL) for streams within the three watersheds in this study. However, there was a TMDL completed for the North Fork Cuivre River in Pike and Lincoln counties in 2015 assessing fecal coliform bacteria from rural nonpoint source (NPS) pollution (MDNR 2015a). Additionally, there are two other TMDLs listed in the Cuivre River HUC 8 for dissolved oxygen and chlorophyll in Montgomery and Lincoln Counties (MDNR 2018). Further, there are several streams outside of the watersheds, but within the same counties on the 303(d) impaired streams list. These streams are listed as impaired for low dissolved oxygen, chlorophyll, total nitrogen, and total phosphorus due to rural NPS and point source pollution (MDNR 2018; MDNR 2015b).

The Missouri Nonpoint Source Management Plan (NPSMP) identified the Cuivre River watershed as a secondary priority (Group 2) for the state watershed plans (MDNR 2013). NPSMP coordinates nonpoint source pollution reduction efforts and supports state activities associated with Section 319 of the federal Clean Water Act (MDNR 2013). The Cuivre River is scheduled to begin a five-year action plan after completion of the planning effort for the initial pilot watersheds identified around the state. Surrounding watersheds like the Salt River already had a Healthy Watershed Plan created from the NRSMP statewide project and identified soil and streambank erosion, excess nutrients, and bacteria as major concerns (MDNR 2016).

<u>Surface and Ground Water Monitoring Stations</u>
There are no United States Geological Survey (USGS) gaging stations within the three study watersheds. The closet gaging station near Troy, MO is approximately 24 miles downstream from the three watersheds on the Cuivre River (USGS Gaging Station # 05514500). To be able to predict discharge within the study watershed, 28 nearby USGS gaging stations were used to complete drainage area-based regression equations to be able to estimate discharge from different size watersheds within the study area (Figure 13). A list of the USGS gaging stations can be found in Appendix B. If resources became available to install one gaging station within

each watershed, possible locations would be on Coon Creek at Post Oak School Road (UTM Zone 15N Northing: 4,331,293.15 Easting: 637,671.36), on West Fork Cuivre River at Campground Road (UTM Zone 15N Northing: 4,331,915.64 Easting: 641,636.06), and/or on Indian Creek at County Road Y (UTM Zone 15N Northing: 4,345,315.56 Easting: 644,379.04).

There is a ground water monitoring station in Vandalia, 1.2 miles north of the headwaters of Shady Creek (Site Number: 391825091285101). This station has been operating since 2007 and data shows a relatively consistent level from 2007-2015. Since 2015, water levels have consistently increased by nearly 6 feet as of 2019 (Figure 14a). There is also a ground water monitoring station in New Florence that has been operating for about 30 years located approximately 13 miles south of the Coon Creek watershed (Site Number: 393544093075601). This station, in contrast, shows a steady ground water level decline of nearly 40 feet over that time (Figure 14b). Data from these stations suggest high local variability in ground water levels in the area.

Water Quality Sampling Data

There are no water quality monitoring sites located within the three study watersheds. However, there are six stations located downstream of the three study watersheds on the North Fork-Cuivre River and the main channel of Cuivre River within the 8-Digit HUC watershed. One of these sites is located along the main stem of the Cuivre River downstream of all three study watersheds. The other five sites are located in the North Fork of the Cuivre River, with two sites downstream of the Headwaters Indian Creek Watershed. Available water quality data may be indicative of the general water quality conditions in the three study watersheds as well as conditions within the larger Cuivre River.

There are a number of permitted point sources and animal feeding operations within the three watersheds (MDNR, 2019). The Middletown wastewater treatment plant is within the Coon Creek watershed, and the only permitted point source within the study watersheds (Table 8, Figure 15). However, there are additional WWTF in several of the towns located along the boundary of the three study watersheds, but outfalls are located outside of the drainage area. Additionally, there are eight animal feeding operations within the Sandy Fork-West Fork Cuivre River and three in the southeast section Headwaters Indian Creek that are used for hog production that include land application of manure (Table 9, Figure 15). There are 80,429 hogs mostly greater than 55 pounds (MDNR, 2019).

Biological Monitoring Data

There are no biological monitoring data available within the three study watersheds. A biological assessment and sediment study was completed on Mill Creek, which is a tributary of the North Fork Cuivre River that originates in northwest Lincoln County (MDNR, 2008). For each sample, the indices value was normalized to unitless scores and combined to give an overall Missouri Stream Condition Index (MSCI) score. The samples collected had an overall MSCI score that ranged between 8-20 with an average of 14 (Table 9). The MSCI can be interpreted using three impairment categories that state that scores in the range of 16-20 indicate no impairment, 10-14 indicate impairment, and 4-8 indicate high impairment (Rabeni et al., 1997). The samples collected along Mill Creek are consistent with impairment for assessments between 2008 and 2009, however the source of impairment is unknown (MDNR 2008).

Summary

The purpose of this report is to provide the information necessary to describe the study watershed for the Mississippi River Healthy Watershed Initiative (MRBI) for three HUC-12 watersheds within the Cuivre River watershed, Coon Creek (071100080104), Sandy Fork-West Fork Cuivre River (071100080105), and Headwaters Indian Creek (071100080201). Soil erosion and animal waste have been identified as major concern for water quality for streams within the Cuivre River watershed and water quality monitoring shows high levels of nutrients, bacteria, and suspended sediment. The purpose of the full watershed assessment is to provide NRCS field staff with the necessary information to identify locations within the watershed where soil, slope, and land use practices have the highest pollution potential and to describe conservation practices that can be the most beneficial to improve water quality. Therefore, this first phase of the project provides a general description of the watershed and inventories the data that will be used in subsequent phases of the project. Information collected for the initial phase of the project provides the geographical, physical, hydrological, and water quality attributes of the watershed along with documentation of available data sources (Table 10).

RESOURCE ANALYSIS OF THE WATERSHED

The resource analysis of the watershed will include evaluation of water quality data within the watershed, observed channel conditions from both historical aerial photography and a field-based visual assessment, and water quality modeling results and load reduction analysis. Ultimately these results will help establish what combination of land use and soils have the highest pollution potential and what practices would be the most useful in reducing nutrient and sediment loads within the watershed.

Water Quality Analysis

Summary statistics for all nutrient and sediment samples were used to evaluate water quality by looking at both the range of mean concentrations and variability among sites. All water quality data was downloaded from the MDNR Water Quality Assessment System website. There was no data available within the HUC-12 watersheds, however, data was available for six sites within the Cuivre River Watershed. In the North Fork Cuivre River, average concentrations of total phosphorus (TP) ranged from 0.082-0.270 mg/L, mean total nitrogen (TN) ranged from 1.69-2.46 mg/L, and average total suspended sediment (TSS) concentrations ranged from 21-244 mg/L (Table 11). However, individual samples can exceed 1.0 mg/L TP, 6.0 mg/L TN, and 1,800 mg/L TSS suggesting nutrient and sediment concentrations can be very high at times during the year. At the furthest downstream site, average concentrations were 0.167 mg/L TP, 1.66 mg/L TN, and 105.6 mg/L TSS (Table 11). Ambient water quality criteria suggested reference conditions for streams in the Cuivre River are 0.71 mg/L TN and 0.093 mg/L TP based on the 25th percentile value for streams within the Central Irregular Plains (USEPA 2000). Therefore, average nutrient concentrations along the main stem of the Cuivre River are about 2-times higher than the ambient reference condition. These data suggest conservation practices that can reduce phosphorus and nitrogen in runoff in the Cuivre River Watershed can be an important component in improving and protecting water quality in these watersheds.

Channel Stability and Riparian Corridor Assessment

Aerial Photo Methods

Aerial photographs from 1995 and 2015 were obtained from the Missouri Spatial Data Information Service (MSDIS) online data server pre-rectified (Table 12). The error involved in the transformation process was quantified using point-to-point error analysis. A total of 10 locations on both sets of aerials were evaluated for the point-to-point errors within each of the 12-digit HUC watersheds. Overall, mean point-to-point errors ranged from 5.8-9.0 ft for the three watersheds (Table 13). Stream channels for each year were digitized to identify and measure changes over time. Both bank lines were digitized for the main stem and larger tributaries. However, since many of these channels were small and some of the channel bank was obstructed by vegetation, the channel centerline was digitized where it could clearly be seen at a scale of 1:1,500 (Martin and Pavlowsky 2011).

Channel Classification

Tributary channels and the main stem of all three watersheds were further classified by identifying historical channel changes through interpretation of the 1995 and 2015 aerial photos. Channels were first characterized as either “modified” or “natural”. Modified channels were further classified as either “channelized” or “ponded”. Finally, natural channels were classified as either “stable” or “active”. Active channels were identified by assessing planform changes since 1995 by overlay analysis of the digitized channel using the predetermined error buffer, which is based on the mean point-to-point error for each watershed to account biases attributed to rectification (Martin and Pavlowsky 2011). Active reaches were identified as areas where the buffers between the digitized channel features did not overlap for at least 100 ft to account for rectification errors. If the channel was obstructed by vegetation or not visible in both aerials, it was classified as “not visible”. A flow chart was developed to show the channel classification process during aerial photo interpretation (Figure 16).

All three watersheds have similar bank erosion results as there were limited active stream reaches identified using the aerial photo methods described above. Nearly 75% of the streams in each watershed were visible and were able to be digitized within each watershed as channels classified as “not visible” ranged from 22.1-25.4% (Table 14). Results show that between 18.3-25.1% of the channels have been modified, with the majority of those being channelized. Of the remaining, 50.7-53.8% of the analyzed streams were stable, while only 1.7-2.6% of the streams showing significant lateral migration or widening at the scale used for this evaluation. This indicates streams in these watersheds may not migrate laterally to a great extent but rather could adjust to disturbances by incision and widening. Furthermore, most of the actively eroding channels within the watershed are along the main stem of the creek (Figure 18). However, main channel erosion can be significant since banks heights can be relatively high releasing large volumes of sediment.

<u>Riparian Corridor Analysis</u>

The presence of a healthy riparian corridor can provide resistance to erosion during floods and filter runoff water moving from the uplands to the stream (Rosgen 1996, Montgomery and MacDonald 2002, USDA 2003). The riparian corridors for the three watersheds in this study were evaluated by creating a buffer around the 2015 digitized stream layer and overlaying that layer on the 2015 aerial photo. A 50 ft buffer was used on first and second order streams and a 100 ft buffer was placed around streams third order and larger (USDA 2014). The area within the buffer was classified into the following: Good, Moderate, and Poor (Figure 17). A “Good” classification represents portions of streams in which adequate riparian forest coverage extends the width of the buffer on both sides of the stream. A “Moderate” class signifies one side of the stream buffer meets the standard, but the other side does not. Alternatively, the Moderate classification can also indicate a situation where riparian coverage reaches the extent of the buffer, but the tree coverage is sparse. Finally, the Poor classification is assigned to portions of the stream where the riparian corridor does not extend to the limits of the buffer on either side of the stream.

The riparian corridor classification of the streams in the three study watersheds was fairly equal among the three categories, with poor riparian corridors typically found in the tributaries and good corridors typically identified along the larger main channels. Riparian corridors classified as good represented between 30.8-36.5% of the total stream miles in all three watersheds (Table 15). Between 34.4-36.4% were classified as having moderate riparian corridor and 28.2-33.2% were classified as having poor riparian corridor. Typically, poor and moderate riparian corridors were located along crop or pasture fields in the tributaries to the main stem along the first and second order streams (Figure 19). Good riparian forest cover is typical of the larger main channels of streams within all three watersheds.

<u>Visual Stream Survey Results</u>
A modified rapid visual stream survey was conducted on both upstream and downstream portions of all public road crossings within the watershed following an established NRCS protocol (USDA 1998). The protocol was modified by only focusing on five physical stream channel indicators, riparian corridor evaluation, and the presence of manure indicating livestock access to the stream (Appendix C). Based on the assessment, each site receives an overall score between 1 and 10, with <6.0 considered poor, 6.1 – 7.4 fair, 7.5 – 8.9 good, and >9.0 excellent.

There was a total of 407 sites evaluated within the three study watersheds using the modified visual stream assessment protocol. Of these, 93 sites were in Coon Creek, 159 is the Sandy Fork- West Fork Cuivre River, and 155 were in Headwaters Indian Creek (Table 16). Overall average scores were in the “fair” range for all watersheds, with an average score of 6.0 for Coon Creek, 6.5 for Sandy Fork-West Fork Cuivre River, and 6.7 for Headwaters Indian Creek. When stratifying site scores by classification, the Coon Creek and Sandy Fork-West Fork Cuivre River were very similar, while Headwaters Indian Creek streams scores were relatively better. While all three watersheds had 38-40% in the “fair” category, Headwaters Indian Creek had fewer sites classified as “poor” and more sites classified as “excellent” compared to the other two watersheds. Coon Creek and Sandy-Fork West Fork Cuivre River had similar totals in each category, but overall average site scores suggest streams in the Coon Creek watershed were in the poorest condition compared to all three watersheds. The spatial distribution of the four categories appears to be random across all three watersheds (Figure 20).

Overall, streams adjacent to pastures had lower scores than stream next to crop fields, with forested streams having the highest scores in the survey. In general, most “poor” ratings were due to channelization, poor riparian conditions, and presence of livestock within the stream. Occasionally there were crop fields with insufficient natural vegetation buffers between the field edge and the stream, and these would lower the evaluation score at the site. Stream conditions in pastures varied depending on livestock grazing intensity and presence or condition of the riparian corridor. Streams along pastures in the “poor” category typically exhibited poor riparian cover, over-grazing, and cattle access to the stream that greatly decreased the score of a site. Often streams in pastures also displayed evidence of moderate to severe bank erosion. The larger main stem channels consistently had incision and unstable banks, but almost all the main stem had a good riparian corridor, which agrees with the riparian corridor assessment. Since streams within pastures generally had lower scores, they could be considered a target for conservation practices to decrease nonpoint sources of nutrients and sediment in the watershed. Examples of sites evaluated for the three study watersheds can be found in Appendix D.

Rainfall–Runoff Relationship

Annual and monthly runoff rates for the selected Cuivre River watersheds were estimated using equations developed from 27 USGS gaging stations in the region. Monthly runoff rates are important for understanding seasonal variability and how rainfall-runoff relationships correspond to land management. Estimated annual runoff rates from these gages will also be used to help validate the STEPL model hydrology results. A list of the equations used for this analysis of monthly mean discharge values can be found in Appendix E. Mean annual discharge for the Coon Creek watershed is 44.7 ft^3/s, 48.2 ft^3/s for Sandy Fork-West Fork Cuivre River, and 52.6 ft^3/s for Headwaters Indian Creek. Total runoff volume for the Coon Creek watershed was 32,387 ac-ft, 34,915 ac-ft for Sandy Fork-West Fork Cuivre River, and 38,104 ac-ft for the Headwaters Indian Creek watershed. Average runoff as a percentage of rainfall for the Coon Creek watershed was 31.8%, Sandy Fork-West Fork Cuivre River was 31.6% and 31.4% for Headwaters Indian Creek. These estimates are comparable with existing literature that state evapotranspiration rates for Missouri range from 60–70% (Sanford and Selnick 2013). Monthly mean runoff as a percentage of rainfall is highest in the late winter and early spring and lowest in the late summer and early fall ranging from around 13% in August to near 50% in February and March (Figure 21). The remainder of the rainfall is either lost to evapotranspiration or moved through the soil into groundwater storage through infiltration (USDA, 2009b).

Water Quality Modeling

<u>STEPL Model</u>

Existing water quality loads in the watershed and the influence of conservation practices on load reductions was estimated from a predictive model (STEPL). The Spreadsheet Tool for Estimating Pollutant Load (STEPL) uses simple algorithms to calculate nutrient and sediment loads from different land uses and load reductions from implementation of conservation practices (Tetra Tech, Inc 2017). Annual nutrient loading was calculated based on the annual runoff volume and pollutant concentrations. The annual sediment load from sheet and rill erosion was calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. Loading reductions resulting from the implementation of conservation practices was computed from known efficiencies. Accuracy is primarily limited by the wide variability in event mean concentrations (EMCs) across watersheds since EMCs are used to calculate annual pollutant loadings.

For this study, each watershed was modeled with inputs following methods outlined in the STEPL user's guide. Model inputs include drainage area, soil hydrologic group, land use, animal numbers, and estimates on septic systems within the watershed. Land use was derived from the 2018 USDA Crop database. Animal numbers were calculated per acre of pasture within the watershed using animal number ratio of one animal per 2.5 acres of pastureland based on input from local staff. Sandy Fork-West Fork Cuivre River has the majority of the CAFO operations and 35,400 swine were entered under animal numbers (MDNR 2019). The number of septic systems within each watershed was based an area ratio of the low intensity developed land use and provided by the STEPL online database. Details about the inputs for each watershed can be found in Appendix F.

Lateral stream bank erosion was accounted for by calculating length of actively eroding banks, migration rates from historical aerial photo analysis, and bank heights from a LiDAR digital elevation model (DEM) datasets identified earlier in this report. Annual migration rates were estimated by overlaying the bank lines from each aerial photo year. The areas between the 1995 and 2015 photos that do not overlap were identified as areas of bank erosion. Additionally, a buffer representing the mean point-to-point error described earlier was also used to account for the difference in photo rectification between the two years. The area of bank erosion was then divided by the length to calculate a mean width. The mean width was then divided by the number of years between photos to establish an average annual migration rate for each bank erosion polygon. This method identified a total of 38 eroding stream banks in the Coon Creek watershed, 57 in the Sandy Fork-West Fork Cuivre River, and 74 eroding stream banks in the Headwaters Indian Creek watershed (Appendix G). Total eroding bank length for these watersheds ranged from 7,142-13,369 ft, average weighted bank heights ranged from 7.6-9.7 ft, and average weighted migration rates from 1.04-2.13 ft/yr. These estimates are conservative and meant to be used as a rough estimate of the most aggressive bank erosion within each watershed to compare with other nonpoint sources. These methods also can only detect bank erosion due to lateral migration or excessive widening. More accurate bank erosion estimates, and sediment budget assessments are beyond the scope of this study.

There have already been conservation practices implemented within the three study watersheds that need to be addressed in the existing load calculations. For this, estimates of the percentage of cropland with existing conservation practices was calculated based on input from area staff. In this watershed it was estimated that 60% of the cropland already had terraces and cover crops established. These estimates were used to calculate combined efficiencies within the STEPL model's BMP calculator and applied to the watershed (Appendix H). The resulting loads then will reflect a total load that takes these existing conservation practices into account.

Modeling results were fairly similar between the three watersheds in this study, each producing similar nutrient and sediment yields. Average yields for the three Cuivre River watersheds ranged from 6.45-7.54 lb/ac/yr for nitrogen, 1.33-1.74 lb/ac/yr phosphorus, and 0.45-0.86 T/ac/yr of sediment (Table 17). Runoff rates ranged from 0.99-1.07 ac-ft/ac/yr and the percentage of rainfall as runoff was between 29.8-32.2%. Modeled percent runoff is relatively close to the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 31.6% for these watersheds. The relative agreement of these two methods adds confidence to the STEPL modelled runoff results. Additionally, model results estimate that existing conservation practices have reduced nitrogen loads 18.4-19.3%, phosphorus loads by 19.5-19.7%, and sediment loads by 17.1-21.9% for cropland sources in these three watersheds.

When assessing model results by sources for the three watersheds in this study, the vast majority of the nutrient and sediment load is from agricultural nonpoint source pollution. Model results show crop and pastureland account for 82-92% of the nutrient loads and around 58-83% of the sediment load in the three watersheds (Table 18). Despite the existing conservation practices, cropland accounts for 68-78% of the nutrient loads and 54-74% of the sediment loads in the all three watersheds. Pastureland is the second highest contributor of nutrients for in these watersheds accounting for nearly 14-24% of the nitrogen load and 6.6-11.6% of the sediment load. Bank erosion assessment results show streams can be responsible for 14.4-40.5% of the sediment load in these three watersheds, with the highest contribution in the Sandy Fork-West Fork Cuivre River watershed. This is due to the main stem of the West Fork of the Cuivre River, with relatively high banks, being located within this watershed.

<u>Load Reduction Analysis</u>

Load reduction for the three watersheds in this study were modeled with STEPL using established conservation practice efficiencies (Waidler et al. 2009, GSWCC 2013, Tetra Tech 2017). The efficiencies of combined practices were calculated with STEPL's BMP Calculator. A total of 17 cropland conservation practice scenarios and five pastureland scenarios were ultimately modeled. A description of each combined conservation practice scenario with calculated efficiencies can be found in Appendix H. Load reductions of nitrogen, phosphorus, and sediment were modeled based on the percentage of cropland and pastureland within the watershed that were treated. The result is a load reduction matrix for all three watersheds showing the load reduction for the different percentage of cropland and pastureland treated in 10% increments.

Cropland scenarios start with the use of cover crops as the first level of conservation practices with diversions, terraces, no-till, field borders, grassed waterways, and nutrient management are added or combined. Land retirement was also used as a scenario to show what would happen if the cropland was taken out of production. For pastureland, forage and biomass planting, livestock exclusion, alternative water, prescribed grazing, and winter-feeding facilities were added and combined. Since the pastureland and cropland were modeled separately within each watershed, the combined load reductions can be added together for each watershed for a combined effect.

Due to the overwhelming amount of row crops, load reduction analysis for the three study watersheds shows that conservation practices implemented on cropland can achieve significant nutrient and sediment reduction. The most intensely managed cropland scenario is one that combines cover crops, no-till, terraces, grassed waterways, and nutrient management. For example, if that scenario was applied to 50% of the 19,190 acres of cropland (9,595 acres) within the Coon Creek watershed, load reduction would be 27.1% for nitrogen, 38.2% for phosphorus, and 35% for sediment (Tables 19-21). Modeled pasture land practices showed the most intensive management can achieve up to 10% reductions in nitrogen but yield rather insignificant reductions in phosphorus and sediment compared to crops. Additionally, if all the cropland within the watershed was taken out of production, the resulting load reduction would be 67.8% for nitrogen, 70.8% phosphorus, and 69.4% sediment. These results suggest the most intensive crop practices would have similar nutrient and sediment reduction as taking land out of production. Load reduction analysis of Sandy Fork-West Fork Cuivre River and Headwaters Indian Creek showed similar results (Tables 22-27).

Summary

The purpose of this section of the report is to provide results of the resource analysis of the watershed (Deliverable #5) for the Mississippi River Basin Healthy Watersheds Initiative (MRBI) Watershed Assessment for Coon Creek Watershed (HUC-071100080104), Sandy Fork-West Fork Cuivre River Watershed (HUC-071100080105), and the Headwaters Indian Creek Watershed (HUC-071100080201). Available water quality data was limited to the areas downstream of the watershed and indicates nutrient concentrations exceed regional ambient water quality criteria suggested reference conditions for streams in the Central Irregular Plains region. As stated earlier, soil erosion and animal waste has been identified as major concern for water quality for streams within the Cuivre River watershed and water quality monitoring shows high levels of nutrients, bacteria, and suspended sediment (Weirich 1993; MDNR 2016).

Both historical aerial photos and a visual stream assessment were used to evaluate potential contributions of streambank erosion to water quality problems within the watershed. The majority of actively eroding reaches within these watersheds were located along the main stem of the streams suggesting sediment being released though bank erosion is an important component of the total sediment load in the watershed. This is especially true for the Sandy Fork-West Fork Cuivre River watershed where stream bank erosion was estimated to contribute up to 40% of the sediment load in that watershed. Due to the small size of the tributary streams within portions of these watersheds, overhead vegetation, and photo quality limitations, a complete classification of all the small tributary streams was not always possible. The riparian corridor assessment does show most poor riparian corridors are located in the headwaters and most of the good riparian areas are along the main stem of the stream. Since most of the stream bank erosion appears to be in the main stem of the stream, this suggests the stream is adjusting to some disturbance that is not being mitigated by the presence of a forested riparian corridor. Stream reaches assessed in the visual stream survey showed that much of the areas with poor riparian corridor were areas where livestock had access to the stream. Additionally, streams draining cropland generally had some sort of vegetative buffer and appeared to be relatively stable compared to those in pastureland.

Water quality modeling results indicate cropland overwhelmingly produces the majority of the nonpoint source pollution within the watershed. Model results show cropland accounts for 68-78% of the nutrient loads and 54-74% of the sediment loads in all three watersheds. Pastureland is the second highest contributor of nutrients with 6.6-24% of the total load. However, streambank erosion is a significant contributor of sediment at 15-40% of the total sediment load in these watersheds, particularly in the Sandy Fork-West Fork Cuivre River Watershed. Modelling results also indicate existing conservation practices, such as existing terraces and cover crops, are responsible for reducing the exiting loads within the watershed. Load reduction analysis suggests and that additional conservation practices can further reduce loads with the implementation of terraces, cover crops, no-till, and nutrient management.

IDENTIFICATION OF CONSERVATION NEEDS

Resource Priorities

In the three watersheds evaluated for this study, the top resource priority identified in this assessment is the reduction of sediment from nonpoint agricultural land use. Soil erosion and animal waste have been identified as major concerns for water quality for streams within the Cuivre River watershed and water quality monitoring shows high levels of nutrients, bacteria, and suspended sediment (Weirich 1993; MDNR 2016). STEPL modeling results show the majority of the sediment load is coming from cropland, particularly from the Sandy Fork-West Fork Cuivre River watershed. Load reduction estimates suggest implementation of conservation practices on cropland can have a much higher rate of reduction compared to pasture land practices. Total cropland acres for each watershed are 19,162 acres in the Coon Creek watershed, 22,221 acres in the Sandy Fork-West Fork Cuivre River watershed, and 21,592 acres in the Headwaters Indian Creek watershed. Furthermore, the trend over the last five years is for more land to be converted to cropland. Therefore, implementing cropland conservation practices will be the most effective in reducing sediment loads as this land use type generates higher pollutant loads and many of the crop practices are more efficient at reducing loads.

Conservation Planning

One of the main goals of this project is to use this assessment to help guide where conservation practices would be the most beneficial to meet water quality goals. This will be accomplished by using a management unit ranking, a susceptible acres classification, and a conservation practice rating system.

<u>Management Units</u>

To better plan for locations to implement conservation practices, the three HUC-12 watersheds were split into 27 smaller watersheds, or management units (MU) (Figure 22). MUs will allow field staff to evaluate potential projects based on a system that would rank geographic areas within the watershed. STEPL was used to estimate sediment yields for each management unit with drainage areas ranging from 1,202-7,323 acres (Table 28). Of the top ten MUs with the highest sediment yields, six are located in Sandy Fork-West Fork Cuivre River watershed, two are in Coon Creek Watershed, and one is in Headwaters Indian Creek watershed. These higher sediment yields in the Sandy Fork-West Fork Cuivre River watershed are generally related to higher LS factors for soils planted with crops. Overall, isolating specific areas within these three watersheds that are potentially generating higher sediment loads will eventually help guide conservation practice implementation strategies.

<u>Susceptible Acres Classification</u>

To identify areas with the most pollution potential within a proposed project, a susceptible acres ranking system was developed to help field staff isolate problem areas and prioritize projects within the same MU. Four risk classes were used to rank the agricultural land within the watershed based on the resource analysis of the watershed, STEPL modeling, and the VSA. <u>Highest Risk</u> land represents the most critical areas for pollution potential from the landscape and should be prioritized for planning. <u>High Risk</u> are areas that have significant risk as a pollution source, but not as high as the Highest Risk category. The Moderate Risk category could see potential gains from conservation practices but are a lower priority. Low Risk lands have adequate treatment of the landscape. Remaining areas of urban land use and water were classified as "other". A description of each class type is detailed below and summarized in Table 29.

Highest Priority – For these watersheds the highest susceptibility classification for conservation planning was based on cropland located on highly erodible soils. Highly erodible soils were identified using the Erodibility Index (EI) (USDA 2019). The EI is the ratio of potential erodibility (PE) to the soil loss tolerance (T). Soils were classified as highly erodible when EI ≥8. The EI for all of the soil series within the watershed were calculated using a series of equations detailed here.

Equation 1.
Potential Erodibility (PE) is calculated using:

$$PE = R \times K \times LS$$

Where:
R = rainfall and runoff (Wischmeier and Smith 1978)
K = susceptibility of the soil to water erosion (from soil survey)
LS = combined effect of slope length and steepness (See Equation 2 below)

Equation 2.
The LS is calculated as follows:

$$LS = (0.065 + (0.0456 \times S) + (0.006541 \times S^2)) \times (SL \div C)^{NN}$$

Where:
S = slope% (from soil survey)
SL = Slope length (from soil survey)
C = constant 22.1 metric (72.5 English units)
NN = see value below

- If S <1, then NN = 0.2
- If S ≤1 and <3, then NN = 0.3
- If S ≤3 and <5, then NN = 0.4
- If S ≥5, then NN = 0.5

Equation 3.
The EI is calculated as follows:

$$EI = PE/T$$

Where:
PE = potential erosion
T = soil loss tolerance (from soil survey)

Within these three watersheds, 35,342 acres are classified in the highest priority category, or roughly 35.4% of the watershed area (Figure 23).

High Priority - All other cropland that was not in the highest susceptibility category was placed in the high vulnerability category for conservation planning. There is a total of 27,661 acres of high priority acres in these three watersheds, or about 27.7% of the total drainage area.

Moderate Priority - Land within the moderate susceptibility category would be all pasture land within the watershed. This totals 13,408 acres, or 13.4% of the total area of the three study watersheds.

Low Priority - Low susceptibility acres was defined as all of the forested areas within the watershed or land adjacent to a stream with good riparian corridor. Within the three study watersheds there are 18,281 low priority acres, or 18.3% of the total area.

N/A – This category represents all urban land use and land classified as water or wetlands within the three study watersheds. This represents 5,177 acres, or 5.2% of the total land area.

Conservation Practice Ranking

The final part of the conservation planning portion of this project is to identify the conservation practices that are best suited to help reduce sediment loads from the Coon Creek, Sandy Fork-West Fork Cuivre River, and Headwaters Indian Creek watersheds. For this, each conservation practice, or combination of conservation practices, was ranked based on the highest benefit per acre treated for each watershed. Ranking was based on the percentage of sediment reduction achieved by each practice or combination of practices. In these three watersheds, cropland practices achieve higher load reductions than conservation practices on pasture land (Table 30). This is a result of the high number of cropland acres in the watershed, cropland having a relatively higher sediment yield per acre, and cropland conservation practices having relatively high efficiency ratings. Pastureland conservation practices rank at the bottom of all practices identified in this project because the relatively low number of pastureland acres, pastureland has a relatively lower sediment load, and conservation practices have lower efficiencies compared to conservation practices on cropland. While this analysis suggests treating cropland would ultimately be more efficient in reducing sediment loads, this analysis does not include economic or local preferences that may prohibit or encourage certain practices over others.

CONCLUSIONS

The purpose of this report is to provide the Missouri State office of the NRCS the results of a watershed assessment study of three HUC-12 watersheds within the Cuivre River watershed, Coon Creek (071100080104), Sandy Fork-West Fork Cuivre River Watershed (HUC-071100080105), and Headwaters Indian Creek (071100080201) located in Audrain, Pike, and Montgomery Counties in Missouri. These assessments support the Mississippi River Basin Healthy Watersheds Initiative (MRBI) designed to work with landowners to implement voluntary conservation practices to reduce nutrients entering the Gulf of Mexico. The goal of the MRBI program is to improve water quality, restore wetlands, and enhance wildlife habitat while ensuring economic viability of agricultural lands in high-priority watersheds within the Mississippi River Basin (USDA, 2017). Ultimately, this watershed assessment provides NRCS field staff with the necessary information to identify locations within the study watersheds where soil, slope, and land use practices have the highest pollution potential and to describe conservation practices that can be the most beneficial to improve water quality. The assessment included three phases, 1) resource inventory, 2) resource analysis, and 3) identification of resource needs. There are seven main conclusions for this assessment:

1) While there are no impaired stream segments within the three study watersheds, soil erosion and animal waste have been identified as major concerns for water quality for streams within the Cuivre River watershed and water quality monitoring shows high levels of nutrients, bacteria, and suspended sediment. Therefore, reducing the sediment loads coming from these watersheds was identified by this assessment as the top resource concern to be addressed by implementation of conservation practices aimed at reducing erosion;

2) Available water quality data was limited to the areas downstream of the watershed and indicates nutrient concentrations exceed regional ambient water quality criteria suggested, reference conditions for streams in the Central Irregular Plains region;

3) Historical aerial photo analysis was used to identify potential contributions of streambank erosion to water quality problems within the study watersheds and to evaluate riparian corridor vegetation. The majority of actively eroding reaches within these watersheds were located along the main stem of the streams suggesting sediment being released though bank erosion is an important component of the total sediment load in the watershed. This is especially true for the Sandy Fork-West Fork Cuivre River watershed where stream bank erosion was estimated to contribute up to 40% of the sediment load in that watershed;

4) The riparian corridor assessment does show most poor riparian corridors are located in the headwaters and most of the good riparian areas are along the main stem of the stream. Since most of the stream bank erosion appears to be in the main stem of the stream, this suggests the stream is adjusting to some disturbance that is not being mitigated by the presence of a forested riparian corridor. Stream reaches assessed in the visual stream survey showed that much of the areas with poor riparian corridor were areas where livestock had access to the stream. Additionally, streams draining cropland generally had some sort of vegetative buffer and appeared to be relatively stable compared to those in pastureland;

5) Water quality modeling results indicate cropland overwhelmingly produces the majority of the nonpoint source pollution within the watershed. Model results show cropland accounts for 68-78% of the nutrient loads and 54-74% of the sediment loads in all three watersheds. Pastureland is the second highest contributor of nutrients with 6.6-24% of the total load. However, streambank erosion is a significant contributor of sediment at 15-40% of the total sediment load in these watersheds, particularly in the Sandy Fork-West Fork Cuivre River Watershed;

6) Modelling results also indicate existing conservation practices, such as existing terraces and cover crops, are responsible for slightly reducing the exiting loads within the watershed. Load reduction analysis suggests and that additional conservation practices on cropland can significantly reduce loads with the implementation of terraces, cover crops, no-till, and nutrient management up to and exceeding 70%; and

7) Management units, susceptible acres, and conservation practice rankings were all created to help field staff prioritize areas and evaluate potential projects. Management units direct conservation practices to specific areas of the watershed. Susceptible acres within management units can be used to evaluate projects within management units. Finally, conservation practices are ranked in order of effectiveness for cropland and pasture land.

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TABLES

Table 1. Annual rainfall and average annual temperature for Vandalia, MO (1990-2019).

Year	Total Rainfall (in)	Average Temperature (°F)
1990	42.6	56.4
1991	40.7	54.3
1992	36.0	53.2
1993	62.2	51.9
1994	34.0	53.3
1995	37.8	52.1
1996	37.1	51.6
1997	34.3	52.5
1998	43.6	55.3
1999	34.4	55.0
2000	42.9	54.5
2001	46.1	55.6
2002	35.7	55.0
2003	41.6	53.2
2004	40.3	53.1
2005	29.9	54.7
2006	32.5	54.8
2007	28.3	54.8
2008	59.1	51.1
2009	52.7	51.8
2010	52.0	52.7
2011	31.7	53.7
2012	23.0	56.7
2013	37.6	50.9
2014	42.6	50.5
2015	51.3	54.1
2016	36.1	55.1
2017	36.8	54.7
2018	43.0	53.2
2019	38.8	55.7
n	30	30
Min	23.0	50.5
Mean	40.1	53.7
Max	62.2	56.7

data source: http://mrcc.isws.illinois.edu/CLIMATE/)

Missing data were retrieved from nearby stations: *Bowling Green 1E and *Mexico

Table 2. Watershed soil characteristics summary.

Coon Creek							
Soil Order	%	Hydrologic Soil Group	%	Soil Erosion K-Factor	%	Land Capability Classification	%
Alfisol	89.9	B	0.3	< 0.2	0.2	2e	0.5
Entisol	0	B/D	9.0	0.2 - 0.3	5.7	3e	53.8
Inceptisol	9.3	C	1.3	0.3 - 0.4	2.4	4e	8.8
Mollisol	0.5	C/D	4.7	> 0.4	91.4	6e	1.0
Other	0.4	D	84.3	Other	0.4	2s	0.3
		Other	0.4			7s	0.0
						2w	0.2
						3w	34.9
						Other	0.4

Sandy Fork-West Fork Cuivre River							
Soil Order	%	Hydrologic Soil Group	%	Soil Erosion K-Factor	%	Land Capability Classification	%
Alfisol	89.2	B	1.3	< 0.2	0.2	2e	2.4
Entisol	0.3	B/D	6.6	0.2 - 0.3	2.5	3e	46.6
Inceptisol	8.5	C	3.1	0.3 - 0.4	30.1	4e	16.2
Mollisol	1.5	C/D	20.0	> 0.4	66.7	6e	1.4
Other	0.6	D	68.5	Other	0.6	7e	0.0
		Other	0.6			2s	0.1
						7s	0.0
						2w	1.9
						3w	30.8
						Other	0.6

Headwaters Indian Creek							
Soil Order	%	Hydrologic Soil Group	%	Soil Erosion K-Factor	%	Land Capability Classification	%
Alfisol	97.0	B	0.4	< 0.2	0.0	2e	11.9
Entisol	0.4	B/D	1.2	0.2 - 0.3	0.1	3e	46.6
Inceptisol	1.1	C	8.4	0.3 - 0.4	22.0	4e	13.5
Mollisol	1.2	C/D	12.3	> 0.4	77.6	7e	0.4
Other	0.3	D	77.4	Other	0.3	2w	0.1
		Other	0.3			3w	27.1
						Other	0.3

Table 3. Drainage network summary.

Water Feature	Length/Area
Total Streams	**361 mi**
Permanent Flow	41 mi
Coon Creek	12 mi
Sandy Fork-West Fork Cuivre River	21 mi
Headwaters Indian Creek	8 mi
Intermittent Flow	320 mi
Coon Creek	100 mi
Sandy Fork-West Fork Cuivre River	99 mi
Headwaters Indian Creek	120 mi
Waterbodies	
Lakes/Ponds	672 ac
Coon Creek	202 ac
Sandy Fork-West Fork Cuivre River	249 ac
Headwaters Indian Creek	221 ac

Table 4. Major water users within the watershed.

			Usage (millions of gallons)					**%**
ID	**MWU ID**	**Prime Use**	**2013**	**2014**	**2015**	**2016**	**2017**	**Change**
1	66891939	Irrigation	12.0	6.8	0	0	-0.01	-100.1
2	66891939	Irrigation	15.3	0	6.2	3.8	-0.01	-100.1
3	70002515	Irrigation	4.3	0	3.0	1.0	2.9	-33.3
		Total	31.5	6.8	9.2	4.8	2.8	

Table 5. Percent of generalized crop data classification from 2014-2018.

Coon Creek			Year			% Change
General Land Use/Land Cover	2014	2015	2016	2017	2018	2014-2017
Row Crops	50.4	38.1	56.8	55.3	55.3	9.7
Dbl Crop	3.5	0.1	1.3	2.6	2.6	-26.9
Small Grains	0.1	0.0	0.0	0.2	0.2	143.6
Alfalfa & Other Hay	3.2	3.3	4.4	4.8	4.8	51.3
Fallow/Idle Cropland & Barren	0.0	17.6	0.1	0.1	0.1	21.1
Developled Land	4.5	4.6	4.5	4.5	4.5	-1.8
Forest	16.9	18.5	17.9	17.4	17.4	3.0
Grass/Pasture	20.8	17.3	14.6	14.4	14.4	-30.6
Wetlands	0.2	0.1	0.1	0.4	0.4	134.6
Open Water	0.4	0.4	0.4	0.4	0.4	8.6
Sandy Fork-West Fork Cuivre River			Year			% Change
General Land Use/Land Cover	2014	2015	2016	2017	2018	2014-2017
Row Crops	57.5	46.3	61.2	61.1	62.6	8.9
Dbl Crop	2.9	0.1	2.3	2.7	0.9	-69.7
Small Grains	0.1	0.0	0.0	0.0	0.0	-97.7
Alfalfa & Other Hay	1.6	1.6	2.8	2.7	3.8	133.9
Fallow/Idle Cropland & Barren	0.1	16.1	0.3	0.1	0.1	28.6
Developled Land	4.3	4.4	4.2	4.2	4.2	-2.1
Forest	16.4	17.8	17.7	16.9	16.7	2.3
Grass/Pasture	16.3	12.8	10.8	11.5	10.6	-35.3
Wetlands	0.2	0.2	0.2	0.1	0.4	158.5
Open Water	0.6	0.7	0.7	0.7	0.7	8.5
Headwaters Indian Creek			Year			% Change
General Land Use/Land Cover	2014	2015	2016	2017	2018	2014-2017
Row Crops	48.4	37.8	44.9	51.6	52.5	8.5
Dbl Crop	1.4	0.0	1.6	1.2	0.8	-42.2
Small Grains	0.0	0.1	0.0	0.1	0.0	0.0
Alfalfa & Other Hay	3.1	4.2	4.9	4.8	6.2	98.5
Fallow/Idle Cropland & Barren	0.0	13.8	12.1	0.1	0.1	144.9
Developled Land	4.5	4.5	4.0	4.4	4.3	-3.3
Forest	19.2	20.8	18.2	20.1	20.4	6.4
Grass/Pasture	22.9	18.4	13.9	17.6	15.1	-34.0
Wetlands	0.2	0.2	0.2	0.1	0.2	21.6
Open Water	0.3	0.3	0.2	0.3	0.3	12.4

Table 6. Specific crop data from 2014-2018 with percent change.

Coon Creek Class Name	2014	2015	Year 2016	2017	2018	% Change 2014-2017
Corn	19.9	19.6	20.9	19.7	19.7	-0.9
Soybeans	28.5	16.3	32.3	33.7	33.7	18.2
Other Hay/Non Alfalfa	3.1	3.2	4.3	4.8	4.8	55.1
Deciduous Forest	16.8	18.3	17.8	17.2	17.2	2.3
Grassland/Pasture	20.8	17.3	14.6	14.4	14.4	-30.6
Sandy Fork-West Fork Cuivre River Class Name	2014	2015	Year 2016	2017	2018	% Change 2014-2017
Corn	27.1	22.2	26.3	24.9	28.5	5.2
Soybeans	28.8	23.1	33.3	35.5	32.5	12.8
Other Hay/Non Alfalfa	1.4	1.6	2.8	2.6	3.6	157.1
Deciduous Forest	16.4	17.5	17.3	16.8	16.5	0.6
Grassland/Pasture	16.3	12.8	10.9	11.5	10.6	-35.0
Headwaters Indian Creek Class Name	2014	2015	Year 2016	2017	2018	% Change 2014-2017
Corn	20.7	24.4	19.5	24.3	23.6	14.0
Soybeans	26.3	12.8	30.0	26.8	28.3	7.5
Other Hay/Non Alfalfa	2.9	4.2	5.4	4.7	6.1	107.2
Deciduous Forest	19.2	20.5	20.4	20.0	19.8	3.0
Grassland/Pasture	22.9	18.4	15.9	17.6	15.1	-34.0

Table 7. Water quality monitoring sites with nutrient and sediment data summary within the HUC 8.

Site ID	TP (n)	TP start date	TP end date	TP Mean (mg/L)	TN (n)	TN start date	TN end date	TN Mean (mg/L)	TSS (n)	TSS start date	TSS end date	TSS Mean (mg/L)
170/3.5	17	3/27/2002	3/23/2009	0.128	15	3/27/2002	3/23/2009	1.69	15	3/27/2002	3/23/2009	21
170/5.2	5	9/29/2016	6/7/2017	0.270	5	9/29/2016	6/7/2017	2.46	5	9/29/2016	6/7/2017	244
170/9.2	15	3/27/2002	9/18/2002	0.144	13	3/27/2002	9/18/2002	1.89	16	3/27/2002	9/4/2002	123
158/4.5*	45	7/2/2012	6/28/2016	0.183	N/A	N/A	N/A	N/A	45	7/2/2012	6/28/2016	154
158/7.2*	7	10/10/2013	6/9/2014	0.082	N/A	N/A	N/A	N/A	7	10/10/2013	6/9/2014	31
152/29.8*	267	9/19/1967	10/2/2018	0.167	224	9/19/1967	10/2/2018	1.66	201	10/21/1982	10/2/2018	106

n = sample number

TP = total phosphorus

TN = total nitrogen

TSS = total suspended sediment

* = Downstream from watersheds

170/158 = North Fork and Cuivre River

152 = Cuivre River

Table 8. Permitted point sources within the watershed.

Site Number	Facility Name	Type	Stream	Waste	Status
1	Middletown City WWTF	Outfall	Coon Creek	Domestic (Sanitary) Wastewater	Effective
2	Wellsville East WWTF	Outfall	Trib. to White Oak Creek	Domestic (Sanitary) Wastewater	Effective
3	Vandalia WWTF	Outfall	Trib. to Spencer Creek	Domestic (Sanitary) Wastewater	Effective
4	Martinsburg WWTF	Outfall	Trib. to Little Loutre Creek	Domestic (Sanitary) Wastewater	Effective
5	Martinsburg WWTF	Outfall	Trib. to Little Loutre Creek	Domestic (Sanitary) Wastewater	Effective
6	Curryville WWTF	Outfall	Tributary to South Spencer Creek	Domestic (Sanitary) Wastewater	Effective

Table 9. Animal Feeding Operations.

Site	Permit ID	Disposal Type	Animal	AFO Class	Swine >55lb	Swine <55lb	Est. Liquid Discharge (gallons)	Treatment Type	Waste Type	Rec Stream
1	MOGS10361	Outfall Pipe	Hogs	Class IC	7,340	0	3,390,911	Land Application Site	Manure	Trib. to Bear Slough
2	MOGS10343	Outfall Pipe	Hogs	Class IC	4,960	0	2,287,910	Land Application Site	Manure	Trib. to W. Fk. Cuivre R.
3	MOGS10278	Outfall Pipe	Hogs	Class IC	4,800	0	2,308,462	Land Application Site	Manure	Trib. to W. Fk. Cuivre R.
4	MOGS10075	Outfall Pipe	Hogs	Class IC	2,800	0	2,071,328	Land Application Site	Manure	Trib. to W. Fk. Cuivre R.
5	MOG010549	Outfall Pipe	Hogs	Class IC	4,000	0	3,158,916	Land Application Site	Manure	Trib. to W. Fk. Cuivre R.
6	MOG010581	Outfall Pipe	Hogs	Class IC	4,000	0	2,357,269	Land Application Site	Manure	Trib. to Lost Creek
7	MOGS10547	Outfall Pipe	Hogs	Class IC	4,800	0	1,446,932	Land Application Site	Manure	Trib. to Sandy Creek
8	MOGS10050	Outfall Pipe	Hogs	Class IC	4,000	0	2,346,402	Land Application Site	Manure	Trib. to Sandy Creek
9	MOGS10013	Outfall Pipe	Hogs	Class IB	2,400	0	406,705	Land Application Site	Manure	Trib. to Sandy Creek
10	MOGS10013	Outfall Pipe	Hogs	Class IB	7,200	0	4,864,557	Land Application Site	Manure	Trib. to Sandy Creek
11	MOGS10001	Outfall Pipe	Hogs	Class IB	4,000	0	2,104,057	Land Application Site	Manure	Trib. to W. Fk. Cuivre R.
12	MOGS10001	Outfall Pipe	Hogs	Class IB	5,000	0	2,474,923	Land Application Site	Manure	Trib. to W. Fk. Cuivre R.
13	MOGS10001	Outfall Pipe	Hogs	Class IB	4,000	0	2,123,781	Land Application Site	Manure	Trib. to W. Fk. Cuivre R.
14	MOGS10585	Outfall Pipe	Hogs	Class IC	4,960	0	1,495,162	Land Application Site	Manure	Trib. to Lick Creek
15	MOGS10296	Outfall Pipe	Hogs	Class IC	4,690	0	2,293,368	Land Application Site	Manure	Trib. to Henderson Branch
16	MOGS10044	Outfall Pipe	Hogs	Class IC	1,799	0	2,202,778	Land Application Site	Manure	Trib. to Shady Cr.
17	MOGS10044	Outfall Pipe	Hogs	Class IC	396	0	2,241,556	Land Application Site	Manure	Trib. to Shady Cr.
18	MOGS10044	Outfall Pipe	Hogs	Class IC	995	240	434,286	Land Application Site	Manure	Trib. to Prairie Branch
19	MOG010444	Outfall Pipe	Hogs	Class IC	750	0	0	Land Application Site	Manure	Trib. to North Fork Cuivre R.
20	MOG010444	Outfall Pipe	Hogs	Class IC	2,016	320	2,300,000	Land Application Site	Manure	Trib. to North Fork Cuivre R.
21	MOGS10569	Outfall Pipe	Hogs	Class IC	4,960	0	1,495,162	Land Application Site	Manure	Trib. to Elkhorn Creek

Table 10. Data and source summary with web site address.

Data Needed	Source	Agency	Within Watershed	Nearby Watershed	Website
HUC 8 Watershed	National Hydrography Dataset	USGS	x		https://nhd.usgs.gov
HUC 10 Watershed	National Hydrography Dataset	USGS	x		https://nhd.usgs.gov
HUC 12 Watershed	National Hydrography Dataset	USGS	x		https://nhd.usgs.gov
Stream Network	National Hydrography Dataset	USGS	x		https://nhd.usgs.gov
Soils (polygons)	NRCS Geospatial Data Gateway	USDA	x		https://datagateway.nrcs.usda.gov
Soils (attributes)	NRCS Web Soil Survey	USDA	x		https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
Precipitation	Cli-mate	MRCC	x		http://mrcc.isws.illinois.edu/CLIMATE/
Temperature	Cli-mate	MRCC	x		http://mrcc.isws.illinois.edu/CLIMATE/
Solar Radiation	Missouri Climate Center	UMC	x		www.climate.missouri.edu
Evapotranspiration	Missouri Climate Center	UMC	x		www.climate.missouri.edu
Elevation (LiDAR)	MSDIS	UMC	x		http://msdis.missouri.edu/
Geology	MSDIS	UMC	x		http://msdis.missouri.edu/
Stream Geomorphology	NRCS-National Water Management Center	USDA		x	www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/manage/hydrology/?cid=nrcs143_015052
Land Use/Land Cover	National Agricultural Statistics Service	USDA	x		www.nass.usda.gov
Hydrology	National Water Information System	USGS		x	https://waterdata.usgs.gov/nwis/rt
Groundwater Levels	Groundwater Watch	MDNR	x		https://groundwaterwatch.usgs.gov
Groundwater Withdrawal	Southwest Regional Office	MDNR	x		https://dnr.mo.gov/
Water Quality	MDNR Water Quality Assessment System	MDNR	x		https://apps5.mo.gov/mocwis_public/wqa/waterbodySearch.do
WWTF Water Quality	Southwest Regional Office	MDNR	x		https://dnr.mo.gov/
Biological Data	MDNR Water Quality Assessment System	MDNR	x		https://apps5.mo.gov/mocwis_public/wqa/waterbodySearch.do

HUC = Hydrologic Unit Code
WWTF = Waste Water Treatment Facility
NRCS = National Resource Conservation Service
MSDIS = Missouri Spatial Data Information Service
USGS = United States Geological Survey
USDA = United States Department of Agriculture
MRCC = Midwest Regional Climate Center
UMC = University of Missouri-Columbia
MDNR = Missouri Department of Natural Resources

Table 11. Water quality data summary

Site ID	TP (mg/L) n	min	mean	max	SD	CV%	TN (mg/L) n	min	mean	max	SD	CV%	TSS (mg/L) n	min	mean	max	SD	CV%
170/3.5	17	0.010	0.128	0.520	0.111	87.2	15	0.62	1.69	4.21	1.18	69.7	15	5.0	21.0	69.0	17.6	83.7
170/5.2	5	0.030	0.270	1.120	0.475	175.8	5	0.24	2.46	6.10	2.38	96.9	5	5.0	244.0	1,200	534.4	219.0
170/9.2	15	0.050	0.144	0.520	0.151	104.9	13	0.53	1.89	4.46	1.21	64.3	16	5.0	122.6	1,540	381.9	311.6
158/4.5	45	0.010	0.183	1.000	0.215	117.2	N/A	N/A	N/A	N/A	N/A	N/A	45	5.0	153.8	1,810	341.3	221.9
158/7.2	7	0.035	0.082	0.160	0.048	58.3	N/A	N/A	N/A	N/A	N/A	N/A	7	5.0	31.0	88.0	28.9	93.3
152/29.8	267	0.000	0.167	1.030	0.176	105.2	224	0.34	1.66	5.90	1.09	65.3	201	5.0	105.6	2,350	227.9	215.8

n = sample number

TP = total phosphorus

TN = total nitrogen

TSS = total suspended sediment

NA = not available

Table 12. Aerial photography used for channel change analysis

Photo Year	Source	Type	Resolution (ft)
1995	USGS	Black and White Photo	3.3
2015	USGS	Color High Resolution	0.5

Table 13. Point-to-point (PTP) errors by watershed.

Watershed	Range PTP Error (ft)	Mean PTP Error (ft)
Coon Creek	1.82 - 11.75	7.00
Sandy Fork-West Fork Cuivre River	1.47 - 10.60	5.84
Headwaters Indian Creek	3.44 - 12.67	8.97

Table 14. Stream classification analysis summary.

Watershed	Total Length (mi)	Channelized	Dam/Pond	Stable	Active	Not Visible
Coon Creek	147.1	20.5 13.9%	6.3 4.3%	79.1 53.8%	3.8 2.6%	37.4 25.4%
Sandy Fork-West Fork Cuivre River	169.2	30.8 18.2%	11.6 6.9%	85.8 50.7%	3.6 2.1%	37.4 22.1%
Headwaters Indian Creek	208.6	32.9 15.8%	13.0 6.2%	106.3 51.0%	3.5 1.7%	52.9 25.3%

Table 15. Riparian corridor analysis summary

Watershed	Total Length (mi)	Good	Moderate	Poor
Coon Creek	147.1	47.7 32.4%	50.6 34.4%	48.8 33.2%
Sandy Fork-West Fork Cuivre River	169.2	52.1 30.8%	61.6 36.4%	55.5 32.8%
Headwaters Indian Creek	208.6	76.1 36.5%	73.6 35.3%	58.9 28.2%

Table 16. Overall visual stream assessment results by watershed.

Watershed	Total	<6.0 Poor	6.0-7.4 Fair	7.5-8.9 Good	>8.9 Excellent	Overall Score
Coon Creek	93	33 (35.5%)	37 (39.8%)	22 (23.6%)	1 (1.1%)	6.0
Sandy Fork-West Fork Cuivre River	159	56 (35.2%)	61 (38.4%)	39 (24.5%)	3 (1.9%)	6.5
Headwaters Indian Creek	155	38 (24.5%)	60 (38.7%)	37 (23.9%)	20 (12.9%)	6.7

Table 17. STEPL model results

Watershed ID	Total Ad (ac)	Runoff (ac-ft)	Runoff Yield (ac-ft/ac)	% Rainfall as runoff	Annual Load			Annual Yield			Mean Concentration		
					N- lb/yr	P- lb/yr	Sed- t/yr	N- lb/ac/yr	P- lb/ac/yr	Sed- t/ac/yr	N- mg/L	P- mg/L	Sed- mg/L
Coon Creek	30,515	32,787	1.07	32.2	213,696	44,193	15,701	7.00	1.45	0.51	2.77	0.572	406
Sandy Fork-West Fork Cuivre River	33,058	35,391	1.07	32.0	249,296	57,635	28,552	7.54	1.74	0.86	2.99	0.690	684
Headwaters Indian Creek	36,295	36,087	0.99	29.8	234,130	48,333	16,490	6.45	1.33	0.45	2.59	0.535	365

Table 18. STEPL results by sources

Sources	N Load (lb/yr)	%	P Load (lb/yr)	%	Sediment Load (t/yr)	%
Coon Creek						
Urban	11,841	5.5	1,837	4.2	272	1.7
Cropland	146,903	68.7	34,288	77.6	10,408	66.3
Pastureland	46,290	21.7	4,499	10.2	1,036	6.6
Forest	2,543	1.2	1,213	2.7	160	1.0
Streambank	6,119	2.9	2,356	5.3	3,825	24.4
Total	213,696	100.0	44,193	100.0	15,701	100.0
Sandy Fork-West Fork Cuivre River						
Urban	12,042	4.8	1,869	3.2	277	1.0
Cropland	179,253	71.9	43,592	75.6	15,496	54.3
Pastureland	36,896	14.8	3,808	6.6	1,050	3.7
Forest	2,587	1.1	1,236	2.2	156	0.5
Streambank	18,518	7.4	7,130	12.4	11,574	40.5
Total	249,296	100.0	57,635	100.0	28,552	100.0
Headwaters Indian Creek						
Urban	12,927	5.5	2,006	4.2	297	1.8
Cropland	159,255	68.0	37,714	78.0	12,149	73.7
Pastureland	54,909	23.5	5,597	11.6	1,491	9.0
Forest	3,247	1.4	1,556	3.2	184	1.1
Streambank	3,791	1.6	1,459	3.0	2,369	14.4
Total	234,130	100.0	48,333	100.0	16,490	100.0

Table 19. Nitrogen load reduction results for Coon Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Nitrogen load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	1.3	2.6	3.9	5.2	6.5	7.8	9.0	10.3	11.6	12.9
Diversion	1.2	2.4	3.6	4.7	5.9	7.1	8.3	9.5	10.7	11.8
Terrace to Underground Outlet	2.1	4.3	6.4	8.6	10.7	12.9	15.0	17.1	19.3	21.4
Cover Crop and Terraces to Underground Outlet	3.1	6.2	9.2	12.3	15.4	18.5	21.6	24.6	27.7	30.8
Field Borders	5.1	10.3	15.4	20.5	25.6	30.8	35.9	41.0	46.2	51.3
Cover Crop to Grassed Waterway	2.8	5.5	8.3	11.1	13.9	16.6	19.4	22.2	25.0	27.7
Terrace to Grassed Waterway	3.3	6.5	9.8	13.0	16.3	19.5	22.8	26.0	29.3	32.5
Cover Crop and No-Till	3.7	7.3	11.0	14.6	18.3	21.9	25.6	29.2	32.9	36.5
Cover Crop, No-Till, and Nutrient Management	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5	45.0
Cover Crop and Terrace to Grassed Waterway	4.0	8.1	12.1	16.2	20.2	24.2	28.3	32.3	36.3	40.4
No-Till and Terrace to to Underground Outlet	4.0	8.0	12.1	16.1	20.1	24.1	28.1	32.2	36.2	40.2
Cover Crop, No-Till, and Terrace to Underground Outlet	4.7	9.3	14.0	18.7	23.4	28.0	32.7	37.4	42.0	46.7
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	5.3	10.6	15.9	21.2	26.5	31.8	37.1	42.4	47.7	53.0
No-Till and Terrace to Grassed Waterway	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5	45.0
Cover Crop, No-Till, and Terrace to Grassed Waterway	5.1	10.1	15.2	20.3	25.3	30.4	35.5	40.6	45.6	50.7
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	5.4	10.8	16.3	21.7	27.1	32.5	38.0	43.4	48.8	54.2
Land Retirement	6.8	13.6	20.3	27.1	33.9	40.7	47.5	54.3	61.0	67.8
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
Livestock Exclusion and Alternative Water	0.5	1.1	1.6	2.1	2.7	3.2	3.7	4.2	4.8	5.3
Prescribed Grazing	0.7	1.4	2.1	2.8	3.6	4.3	5.0	5.7	6.4	7.1
Winter Feeding Facilities	0.6	1.2	1.9	2.5	3.1	3.7	4.4	5.0	5.6	6.2
Livestock Exclusion, Alternative Water, and Prescribed Grazing	1.1	2.1	3.2	4.3	5.3	6.4	7.5	8.6	9.6	10.7

Table 20. Phosphorus load reduction results for Coon Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Phosphorus load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.7	1.3	2.0	2.7	3.4	4.0	4.7	5.4	6.0	6.7
Diversion	2.6	5.2	7.9	10.5	13.1	15.7	18.3	21.0	23.6	26.2
Terrace to Underground Outlet	2.8	5.6	8.5	11.3	14.1	16.9	19.7	22.6	25.4	28.2
Cover Crop and Terraces to Underground Outlet	3.3	6.5	9.8	13.0	16.3	19.5	22.8	26.0	29.3	32.5
Field Borders	5.6	11.2	16.7	22.3	27.9	33.5	39.0	44.6	50.2	55.8
Cover Crop to Grassed Waterway	3.7	7.4	11.1	14.9	18.6	22.3	26.0	29.7	33.4	37.2
Terrace to Grassed Waterway	4.9	9.9	14.8	19.8	24.7	29.6	34.6	39.5	44.4	49.4
Cover Crop and No-Till	6.1	12.2	18.2	24.3	30.4	36.5	42.6	48.7	54.7	60.8
Cover Crop, No-Till, and Nutrient Management	6.9	13.8	20.7	27.6	34.5	41.3	48.2	55.1	62.0	68.9
Cover Crop and Terrace to Grassed Waterway	5.2	10.4	15.6	20.7	25.9	31.1	36.3	41.5	46.7	51.9
No-Till and Terrace to to Underground Outlet	6.7	13.3	20.0	26.7	33.4	40.0	46.7	53.4	60.0	66.7
Cover Crop, No-Till, and Terrace to Underground Outlet	6.8	13.6	20.4	27.2	34.0	40.8	47.6	54.4	61.2	68.0
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	7.4	14.7	22.1	29.4	36.8	44.1	51.5	58.8	66.2	73.5
No-Till and Terrace to Grassed Waterway	7.2	14.5	21.7	28.9	36.2	43.4	50.6	57.9	65.1	72.4
Cover Crop, No-Till, and Terrace to Grassed Waterway	7.3	14.6	21.9	29.2	36.5	43.8	51.1	58.4	65.8	73.1
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	7.6	15.3	22.9	30.6	38.2	45.9	53.5	61.2	68.8	76.4
Land Retirement	7.1	14.2	21.2	28.3	35.4	42.5	49.6	56.6	63.7	70.8
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	0.1	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9
Livestock Exclusion and Alternative Water	0.3	0.5	0.8	1.1	1.3	1.6	1.9	2.2	2.4	2.7
Prescribed Grazing	0.2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.1
Winter Feeding Facilities	0.3	0.7	1.0	1.3	1.6	2.0	2.3	2.6	2.9	3.3
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.5	1.0	1.5	2.0	2.5	3.0	3.4	3.9	4.4	4.9

Table 21. Sediment load reduction results for Coon Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Sediment load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.7	1.5	2.2	2.9	3.7	4.4	5.1	5.8	6.6	7.3
Diversion	2.6	5.1	7.7	10.2	12.8	15.3	17.9	20.5	23.0	25.6
Terrace to Underground Outlet	2.9	5.8	8.8	11.7	14.6	17.5	20.5	23.4	26.3	29.2
Cover Crop and Terraces to Underground Outlet	3.4	6.7	10.1	13.4	16.8	20.2	23.5	26.9	30.3	33.6
Field Borders	4.8	9.5	14.3	19.0	23.8	28.5	33.3	38.0	42.8	47.5
Cover Crop to Grassed Waterway	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.1	45.1	50.1
Terrace to Grassed Waterway	5.8	11.5	17.3	23.1	28.9	34.6	40.4	46.2	52.0	57.7
Cover Crop and No-Till	5.8	11.6	17.4	23.2	29.0	34.8	40.6	46.4	52.2	58.0
Cover Crop, No-Till, and Nutrient Management	5.8	11.6	17.4	23.2	29.0	34.8	40.6	46.4	52.2	58.0
Cover Crop and Terrace to Grassed Waterway	5.9	11.9	17.8	23.7	39.6	35.6	41.5	47.4	53.3	59.3
No-Till and Terrace to Underground Outlet	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7	63.0
Cover Crop, No-Till, and Terrace to Underground Outlet	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6	64.0
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	6.4	12.8	19.2	25.6	32.0	38.4	44.8	51.2	57.6	64.0
No-Till and Terrace to Grassed Waterway	7.0	13.9	20.9	27.8	34.8	41.7	48.7	55.7	62.6	69.6
Cover Crop, No-Till, and Terrace to Grassed Waterway	7.0	14.0	21.0	28.0	35.0	42.0	49.0	56.0	63.0	69.6
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	7.0	14.0	21.0	28.0	35.0	42.0	49.0	56.0	63.0	69.6
Land Retirement	6.9	13.9	20.8	27.8	34.7	41.7	48.6	55.5	62.5	69.4
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Livestock Exclusion and Alternative Water	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Prescribed Grazing	0.2	0.4	0.5	0.7	0.9	1.1	1.2	1.4	1.6	1.8
Winter Feeding Facilities	0.2	0.4	0.6	0.8	1.1	1.3	1.5	1.7	1.9	2.1
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.4	0.8	1.3	1.7	2.1	2.5	2.9	3.3	3.8	4.2

Table 22. Nitrogen load reduction results for Sandy Fork-West Fork Cuivre River watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Nitrogen load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	1.3	2.6	3.9	5.2	6.5	7.8	9.1	10.4	11.7	13.0
Diversion	1.3	2.7	4.0	5.3	6.6	8.0	9.3	10.6	11.9	13.3
Terrace to Underground Outlet	2.3	4.6	6.8	9.1	11.4	13.7	16.0	18.3	20.5	22.8
Cover Crop and Terraces to Underground Outlet	3.2	6.4	9.7	12.9	16.1	19.3	22.5	25.8	29.0	32.2
Field Borders	5.3	10.6	15.9	21.2	26.5	31.8	37.1	42.4	47.7	53.0
Cover Crop to Grassed Waterway	3.0	6.1	9.1	12.2	15.2	18.2	21.3	24.3	27.4	30.4
Terrace to Grassed Waterway	3.6	7.1	10.7	14.2	17.8	21.4	24.9	28.5	32.0	35.6
Cover Crop and No-Till	3.9	7.9	11.8	15.8	19.7	23.7	27.6	31.6	35.5	39.5
Cover Crop, No-Till, and Nutrient Management	4.8	9.5	14.3	19.1	23.8	28.6	33.4	38.2	42.9	47.1
Cover Crop and Terrace to Grassed Waterway	4.3	8.7	13.0	17.3	21.6	26.0	30.3	34.6	39.0	43.3
No-Till and Terrace to to Underground Outlet	4.3	8.7	13.0	17.4	21.7	26.0	30.4	34.7	39.0	43.4
Cover Crop, No-Till, and Terrace to Underground Outlet	5.0	10.0	14.9	19.9	24.9	29.9	34.8	39.8	44.8	49.8
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	5.6	11.2	16.8	22.4	27.9	33.5	39.1	44.7	50.3	55.9
No-Till and Terrace to Grassed Waterway	4.8	9.7	14.5	19.4	24.2	29.1	33.9	38.8	43.6	48.5
Cover Crop, No-Till, and Terrace to Grassed Waterway	5.4	10.8	16.2	21.6	27.0	32.4	37.8	43.2	48.6	54.0
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	5.7	11.5	17.2	23.0	28.7	24.5	40.2	46.0	51.7	57.5
Land Retirement	7.1	14.1	21.2	28.2	35.3	42.4	49.4	56.5	63.5	70.6
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
Livestock Exclusion and Alternative Water	0.4	0.7	1.1	1.4	1.8	1.8	2.5	2.8	3.2	3.6
Prescribed Grazing	0.5	1.0	1.4	1.9	2.4	2.4	3.4	3.8	4.3	4.8
Winter Feeding Facilities	0.4	0.8	1.3	1.7	2.1	2.1	3.0	3.4	3.8	4.2
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.7	1.5	2.2	2.9	3.6	3.6	5.1	5.8	6.5	7.3

Table 23. Phosphorus load reduction results for Sandy Fork-West Fork Cuivre River watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	**Phosphorus load reduction by % of land treated**									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.7	1.3	2.0	2.7	3.4	4.0	4.7	5.4	6.1	6.7
Diversion	2.6	5.2	7.8	10.4	13.0	15.6	18.2	20.8	23.4	26.0
Terrace to Underground Outlet	2.8	5.6	8.4	11.3	14.1	16.9	19.7	22.5	25.3	28.1
Cover Crop and Terraces to Underground Outlet	3.2	6.5	9.7	13.0	16.2	19.5	22.7	26.0	29.2	32.4
Field Borders	5.4	10.9	16.3	21.8	28.2	32.7	38.1	43.5	49.0	54.4
Cover Crop to Grassed Waterway	3.8	7.7	11.5	15.4	19.2	23.1	26.9	30.7	34.6	38.4
Terrace to Grassed Waterway	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
Cover Crop and No-Till	6.0	12.0	18.0	24.0	30.0	36.0	42.1	48.1	54.1	60.1
Cover Crop, No-Till, and Nutrient Management	6.7	13.4	20.2	26.9	33.6	40.3	47.6	53.7	60.5	67.2
Cover Crop and Terrace to Grassed Waterway	5.2	10.5	15.7	21.6	26.2	31.4	36.7	41.9	47.0	52.4
No-Till and Terrace to Underground Outlet	6.6	13.2	19.8	26.3	32.9	39.5	46.1	52.7	59.3	65.8
Cover Crop, No-Till, and Terrace to Underground Outlet	6.7	13.4	20.1	26.8	33.5	40.2	46.9	53.6	60.3	67.1
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	7.2	14.4	21.6	28.8	36.0	43.2	50.4	57.5	64.7	71.9
No-Till and Terrace to Grassed Waterway	7.2	14.3	21.5	28.6	35.8	42.9	50.1	57.2	64.4	71.6
Cover Crop, No-Till, and Terrace to Grassed Waterway	7.2	14.4	21.7	28.9	36.1	43.3	50.6	57.8	65.0	72.2
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	7.5	15.0	22.6	30.1	37.6	45.1	52.6	60.1	67.7	75.2
Land Retirement	7.0	14.0	21.1	28.1	35.1	42.1	49.1	56.1	63.2	70.2
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5
Livestock Exclusion and Alternative Water	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.7
Prescribed Grazing	0.1	0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4
Winter Feeding Facilities	0.2	0.4	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.1
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.3	0.7	1.0	1.3	1.6	2.0	2.3	2.6	2.9	3.3

Table 24. Sediment load reduction results for Sandy Fork-West Fork Cuivre River watershed. Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Sediment load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.6	1.2	1.9	2.5	3.1	3.7	4.3	5.0	5.6	6.2
Diversion	2.2	4.3	6.5	8.7	10.9	13.0	15.2	17.4	19.6	21.7
Terrace to Underground Outlet	2.5	5.0	7.5	9.9	12.4	14.9	17.4	19.9	22.4	24.8
Cover Crop and Terraces to Underground Outlet	2.9	5.7	8.6	11.4	14.3	17.1	20.0	22.9	25.7	28.6
Field Borders	4.0	8.1	12.1	16.1	20.2	24.2	28.3	32.3	36.3	40.4
Cover Crop to Grassed Waterway	4.3	8.5	12.8	17.0	21.3	25.5	29.8	34.0	38.3	42.5
Terrace to Grassed Waterway	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.3	44.2	49.1
Cover Crop and No-Till	4.9	9.9	14.8	19.7	24.6	29.6	34.5	39.4	44.3	49.3
Cover Crop, No-Till, and Nutrient Management	4.9	9.9	14.8	19.7	24.6	29.6	34.5	39.4	44.3	49.3
Cover Crop and Terrace to Grassed Waterway	5.0	10.1	15.1	20.1	25.2	30.2	35.3	40.3	45.3	50.4
No-Till and Terrace to Underground Outlet	5.4	10.7	16.1	21.4	26.8	32.1	37.5	42.8	48.2	53.5
Cover Crop, No-Till, and Terrace to Underground Outlet	5.4	10.9	16.3	21.8	27.2	32.6	38.1	43.5	49.0	54.4
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	5.4	10.9	16.3	21.8	27.2	32.6	38.1	43.5	49.0	54.4
No-Till and Terrace to Grassed Waterway	5.9	11.8	17.7	23.7	29.6	35.5	41.4	47.3	53.2	59.1
Cover Crop, No-Till, and Terrace to Grassed Waterway	5.9	11.9	17.8	23.8	29.7	35.7	41.6	47.6	53.5	59.4
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	5.9	11.9	17.8	23.8	29.7	35.7	41.6	47.6	53.5	59.4
Land Retirement	5.9	11.8	17.7	23.6	29.5	35.4	41.3	47.2	53.1	59.0
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Livestock Exclusion and Alternative Water	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
Prescribed Grazing	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Winter Feeding Facilities	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.2	0.3	0.7	1.0	1.2	1.5	1.7	1.9	2.2	2.4

Table 25. Nitrogen load reduction results for Headwaters Indian Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Nitrogen load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	1.3	2.5	3.8	5.1	6.3	7.6	8.9	10.1	11.4	12.7
Diversion	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.7	10.9	12.1
Terrace to Underground Outlet	2.1	4.3	6.4	8.6	10.7	12.9	15.0	17.2	19.3	21.4
Cover Crop and Terraces to Underground Outlet	3.1	6.1	9.2	12.3	15.3	18.4	21.4	24.5	27.6	30.6
Field Borders	5.1	10.2	15.2	20.3	25.4	30.5	35.6	40.6	45.7	50.8
Cover Crop to Grassed Waterway	2.8	5.6	8.4	11.2	14.0	16.8	19.6	22.4	25.2	28.1
Terrace to Grassed Waterway	3.3	6.6	9.9	13.2	16.4	19.7	23.0	26.3	29.6	32.9
Cover Crop and No-Till	3.7	7.3	11.0	14.7	18.4	22.0	25.7	29.4	33.1	36.7
Cover Crop, No-Till, and Nutrient Management	4.5	9.0	16.5	18.0	22.5	27.0	31.5	36.0	40.5	45.0
Cover Crop and Terrace to Grassed Waterway	4.1	8.1	12.2	16.2	20.3	24.3	28.4	32.4	36.5	40.5
No-Till and Terrace to to Underground Outlet	4.0	8.1	12.1	16.2	20.3	24.2	28.3	32.3	36.4	40.4
Cover Crop, No-Till, and Terrace to Underground Outlet	4.7	9.3	14.0	18.7	23.4	28.0	32.7	37.4	42.1	46.7
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	5.3	10.6	15.9	21.1	26.4	31.7	37.0	42.3	47.6	52.9
No-Till and Terrace to Grassed Waterway	4.5	9.0	13.6	18.1	22.6	27.1	31.6	36.1	40.7	45.2
Cover Crop, No-Till, and Terrace to Grassed Waterway	5.1	10.1	15.2	20.3	25.4	30.4	35.5	40.6	45.7	50.7
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	5.4	10.8	16.2	21.7	27.1	32.5	37.9	43.3	48.7	54.2
Land Retirement	6.7	13.5	20.2	26.9	33.7	40.4	47.1	53.9	60.6	67.3
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	0.3	0.6	0.9	1.3	1.6	1.9	2.2	2.5	2.8	3.2
Livestock Exclusion and Alternative Water	0.6	1.1	1.7	2.3	2.9	3.4	4.0	4.6	5.1	5.7
Prescribed Grazing	0.8	1.5	2.3	3.1	3.8	4.6	5.4	6.1	6.9	7.7
Winter Feeding Facilities	0.7	1.4	2.0	2.7	3.4	4.1	4.7	5.4	6.1	6.8
Livestock Exclusion, Alternative Water, and Prescribed Grazing	1.2	2.3	3.5	4.7	5.8	7.0	8.2	9.3	10.5	11.7

Table 26. Phosphorus load reduction results for Headwaters Indian Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Phosphorus load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.7	1.4	2.0	2.7	3.4	4.1	4.8	5.4	6.1	6.8
Diversion	2.6	5.3	7.9	10.6	13.2	15.9	18.5	21.1	23.8	26.4
Terrace to Underground Outlet	2.9	5.7	8.6	11.4	14.3	17.1	20.0	22.8	25.7	28.5
Cover Crop and Terraces to Underground Outlet	3.3	6.6	9.9	13.2	16.4	19.7	23.0	26.3	29.6	32.9
Field Borders	5.6	11.2	16.8	22.4	28.0	33.6	39.2	44.7	50.3	55.9
Cover Crop to Grassed Waterway	3.8	7.6	11.4	15.2	19.0	22.8	26.6	30.5	34.3	38.1
Terrace to Grassed Waterway	5.0	10.0	15.1	20.1	25.1	30.1	35.2	40.2	45.2	50.2
Cover Crop and No-Till	6.1	12.3	18.4	24.5	30.6	36.8	42.9	49.0	55.1	61.3
Cover Crop, No-Till, and Nutrient Management	6.9	13.8	20.7	27.6	34.6	41.5	48.4	55.3	62.2	69.1
Cover Crop and Terrace to Grassed Waterway	5.3	10.5	15.8	21.1	26.3	31.6	36.9	42.1	47.4	52.7
No-Till and Terrace to to Underground Outlet	6.7	13.4	20.2	26.9	33.6	40.3	47.0	53.8	60.5	67.2
Cover Crop, No-Till, and Terrace to Underground Outlet	6.8	13.7	20.5	27.4	34.2	41.1	47.9	54.8	61.6	68.4
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	7.4	14.8	22.1	29.5	36.9	44.3	51.7	59.1	66.4	73.8
No-Till and Terrace to Grassed Waterway	7.3	14.6	21.9	29.2	36.5	43.8	51.1	58.3	65.6	72.9
Cover Crop, No-Till, and Terrace to Grassed Waterway	7.4	14.7	22.1	29.5	36.8	44.2	51.5	58.9	66.3	73.6
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	7.7	15.4	23.1	30.8	38.4	46.1	53.8	61.5	69.2	76.9
Land Retirement	7.1	14.3	21.4	28.6	35.7	42.9	50.0	57.1	64.3	71.4
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.9
Livestock Exclusion and Alternative Water	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0
Prescribed Grazing	0.2	0.5	0.7	1.0	1.2	1.5	1.7	1.9	2.2	2.4
Winter Feeding Facilities	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.3	3.7
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.6	1.1	1.7	2.3	2.8	3.4	4.0	4.6	5.1	5.7

Table 27. Sediment load reduction results for Headwaters Indian Creek watershed.
Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices in Deliverable	Sediment load reduction by % of land treated									
Cropland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Cover Crop	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	7.9
Diversion	2.8	5.6	8.3	11.1	13.9	16.7	19.5	22.2	25.0	27.8
Terrace to Underground Outlet	3.2	6.4	9.5	12.7	15.9	19.1	22.2	25.4	28.6	31.8
Cover Crop and Terraces to Underground Outlet	3.7	7.3	11.0	14.6	18.3	21.9	25.6	29.2	32.9	36.5
Field Borders	5.2	10.3	15.5	20.7	25.8	31.0	36.1	41.3	46.5	51.6
Cover Crop to Grassed Waterway	5.4	10.9	16.3	21.8	27.2	32.7	38.1	43.5	49.0	54.4
Terrace to Grassed Waterway	6.3	12.6	18.8	25.1	31.4	37.7	43.9	50.2	56.5	62.8
Cover Crop and No-Till	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7	63.0
Cover Crop, No-Till, and Nutrient Management	6.3	12.6	18.9	25.2	31.5	37.8	44.1	50.4	56.7	63.0
Cover Crop and Terrace to Grassed Waterway	6.4	12.9	19.3	25.8	32.2	38.7	45.1	51.5	58.0	64.4
No-Till and Terrace to to Underground Outlet	6.8	13.7	20.5	27.4	34.2	41.1	47.9	54.8	61.6	68.5
Cover Crop, No-Till, and Terrace to Underground Outlet	7.0	13.9	20.9	27.8	34.8	41.8	48.7	55.7	62.6	69.6
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	7.0	13.9	20.9	27.8	34.8	41.8	48.7	55.7	62.6	69.6
No-Till and Terrace to Grassed Waterway	7.6	15.1	22.7	30.3	37.8	45.4	52.9	60.5	68.1	75.6
Cover Crop, No-Till, and Terrace to Grassed Waterway	7.6	15.2	22.8	30.4	38.0	45.6	53.2	60.8	68.4	76.0
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	7.6	15.2	22.8	30.4	38.0	45.6	53.2	60.8	68.4	76.0
Land Retirement	7.5	15.1	22.6	30.2	37.7	45.3	52.8	60.4	67.9	75.5
Pastureland	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**
Forage and Biomass Planting	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Livestock Exclusion and Alternative Water	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3
Prescribed Grazing	0.2	0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	2.4
Winter Feeding Facilities	0.3	0.6	0.8	1.1	1.4	1.7	2.0	2.3	2.5	2.8
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.6	1.1	1.7	2.2	2.8	3.4	3.9	4.5	5.0	5.6

Table 28. Annual sediment yield ranked by Management Unit.

MU ID	Ad (acres)	Crop (acres)	Pasture (acres)	Sediment Yield (T/ac/yr)	Priority Rank
1	1,202	373	336	1.00	1
14	5,226	4,109	312	1.00	2
13	3,980	2,309	543	0.99	3
22	3,505	1,755	531	0.87	4
11	2,338	1,291	279	0.85	5
15	4,601	3,559	452	0.84	6
16	3,426	1,352	789	0.82	7
18	4,863	3,592	397	0.79	8
5	2,641	1,826	316	0.77	9
4	2,324	1,115	402	0.77	10
12	3,146	1,468	279	0.76	11
21	2,948	1,117	749	0.74	12
19	3,660	2,151	490	0.73	13
3	2,726	1,287	585	0.71	14
8	1,953	1,432	237	0.69	15
24	2,647	963	509	0.68	16
7	4,838	3,818	359	0.67	17
25	3,390	1,688	569	0.66	18
20	3,485	2,545	478	0.66	19
2	4,937	1,498	1,239	0.65	20
6	2,611	1,521	421	0.64	21
17	5,465	4,540	446	0.64	22
9	2,340	2,026	153	0.61	23
26	3,199	1,885	600	0.59	24
23	7,323	5,405	885	0.57	25
10	4,932	4,267	364	0.56	26
27	6,126	4,084	684	0.49	27

Table 29. Summary of susceptibility classification for the three study watersheds.

Vulnerability Class	Land Use and Conditions	CC Acres (%)	SFWFCR Acres (%)	HIC Acres (%)
Highest	Cropland with Erodibility Index ≥8	11,611 (38.0%)	10,738 (32.5%)	12,933 (35.8%)
High	Cropland with Erodibility Index <8	7,569 (24.8%)	11,489 (34.7%)	8,603 (23.7%)
Moderate	Pasture	4,412 (14.5%)	3,498 (10.6%)	5,498 (15.1%)
Low	Forest	5,309 (17.4%)	5,544 (16.8%)	7,429 (20.5%)
N/A	Urban Water and wetlands	1,616 (5.3%)	1,789 (5.4%)	1,773 (4.9%)
	Total	30,516 (100%)	33,058 (100%)	36,295 (100%)

Table 30. Ranked conservation practices by largest sediment load reduction.

Rank	Practice	Land Use
1	Cover Crop, No-Till, and Terrace to Grassed Waterway	Crop
2	No-Till and Terrace to Grassed Waterway	Crop
3	Land Retirement	Crop
4	Cover Crop, No-Till, and Terrace to Underground Outlet	Crop
5	No-Till and Terrace to Underground Outlet	Crop
6	Cover Crop and Terrace to Grassed Waterway	Crop
7	Cover Crop and No-Till	Crop
8	Terrace to Grassed Waterway	Crop
9	Cover Crop to Grassed Waterway	Crop
10	Field Borders	Crop
11	Cover Crop and Terraces to Underground Outlet	Crop
12	Terrace to Underground Outlet	Crop
13	Diversion	Crop
14	Cover Crop	Crop
15	Livestock Exclusion, Alternative Water, and Prescribed Grazing	Pasture
16	Winter Feeding Facilities	Pasture
17	Prescribed Grazing	Pasture
18	Livestock Exclusion and Alternative Water	Pasture
19	Forage and Biomass Planting	Pasture

FIGURES

Figure 1. Cuivre River basin in northeastern Missouri.

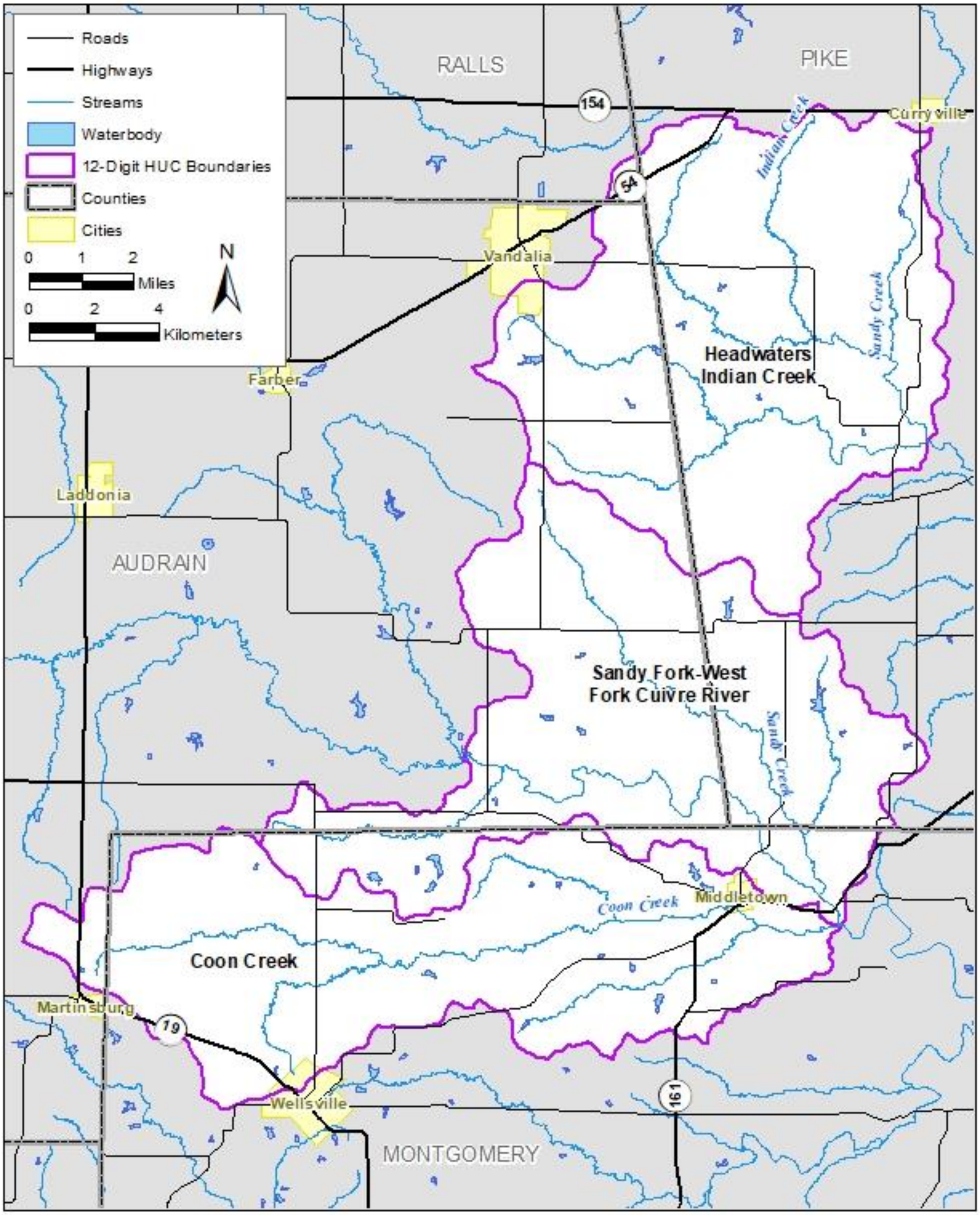


Figure 2. The Coon Creek, Sandy Fork-West Fork Cuivre River and Headwaters Indian Creek watersheds.

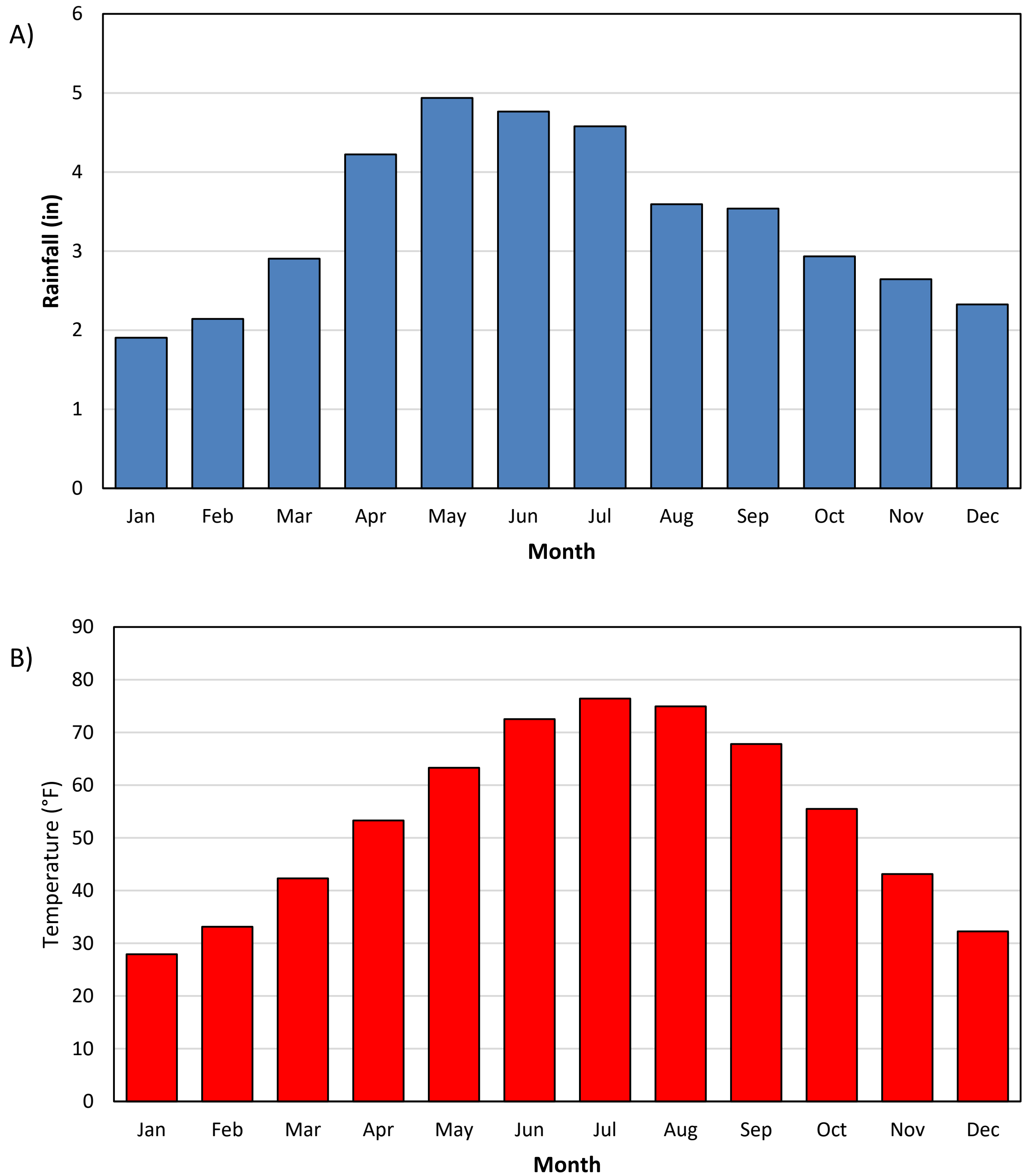


Figure 3. Mean monthly A) rainfall and B) temperature from 1990-2019 for Vandalia, MO.

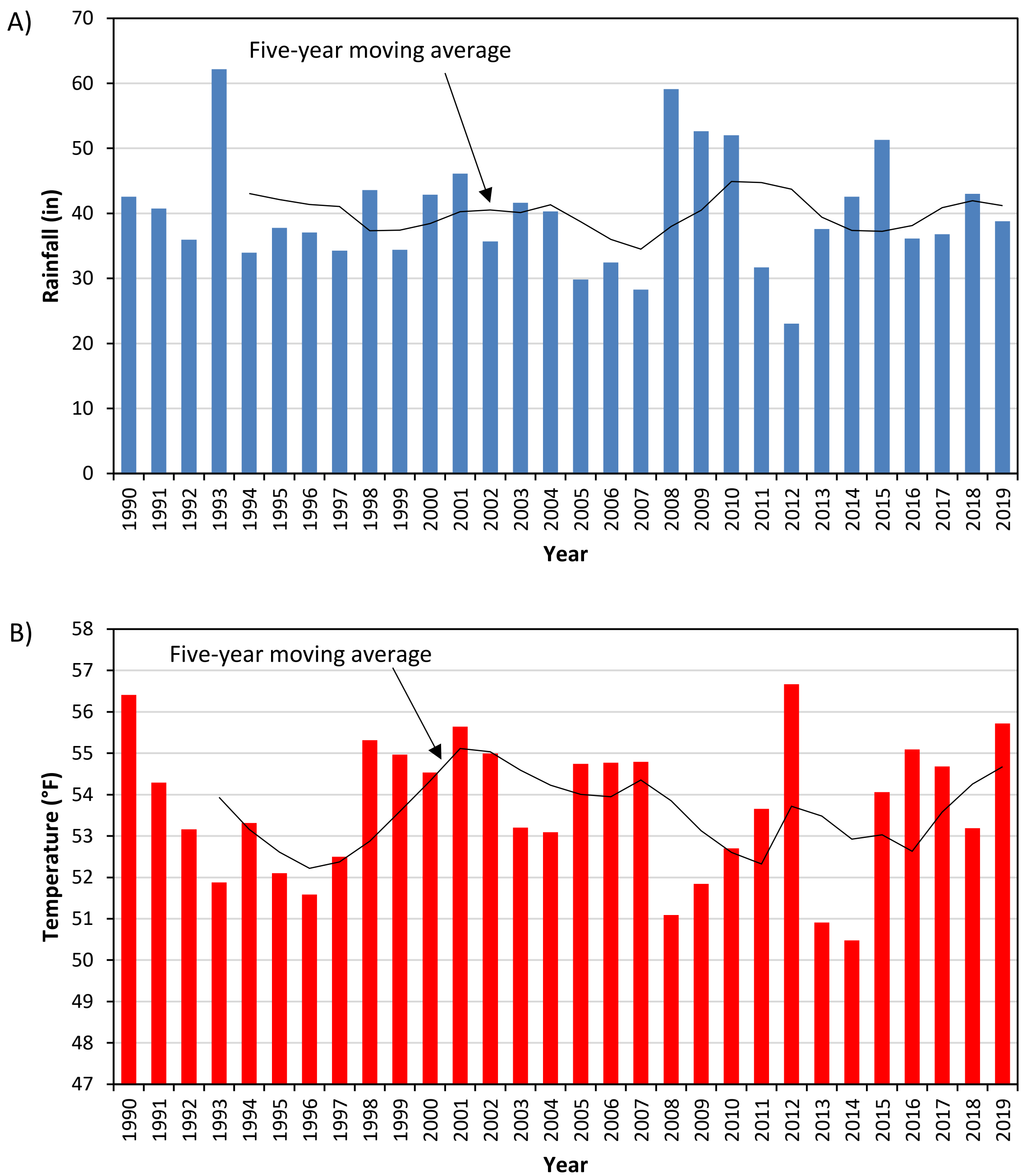


Figure 4. A) Annual total rainfall and B) average annual temperature from 1990-2019 for Vandalia, MO.

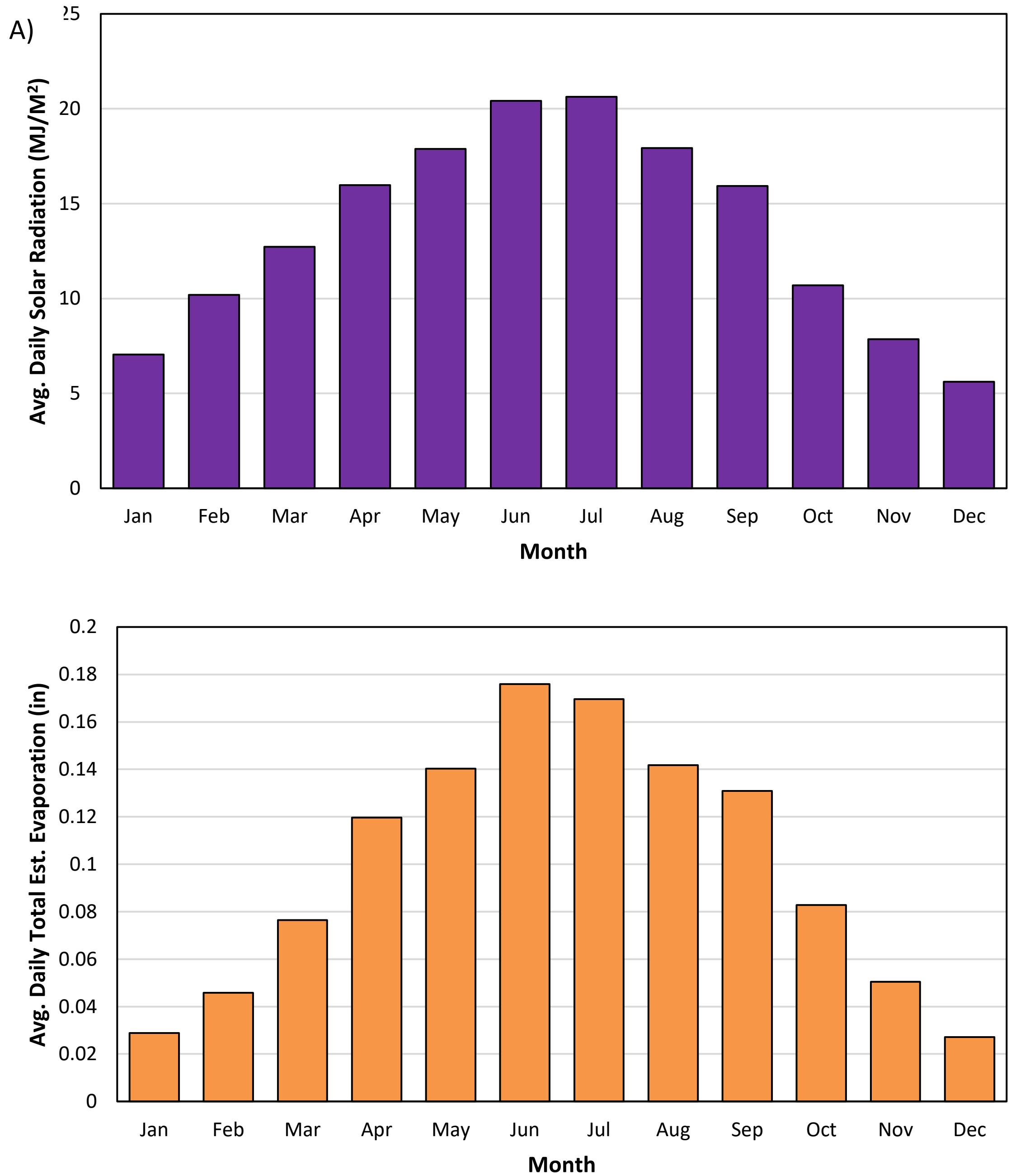


Figure 5. Average daily A) solar radiation (2013-2018) and B) estimated evaporation (2013-2018) for Vandalia, Audrain County MO.

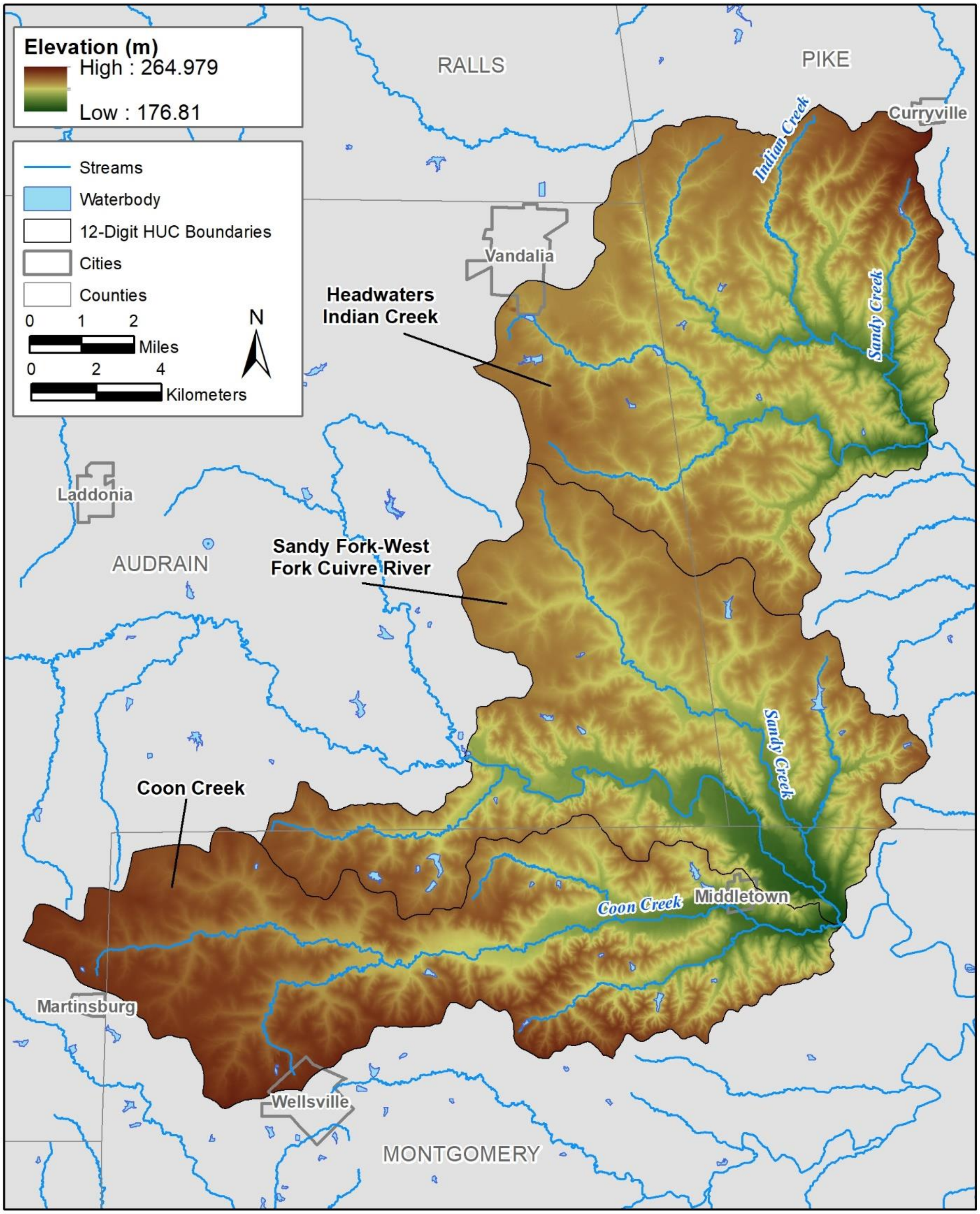


Figure 6. LiDAR elevations within the watershed.

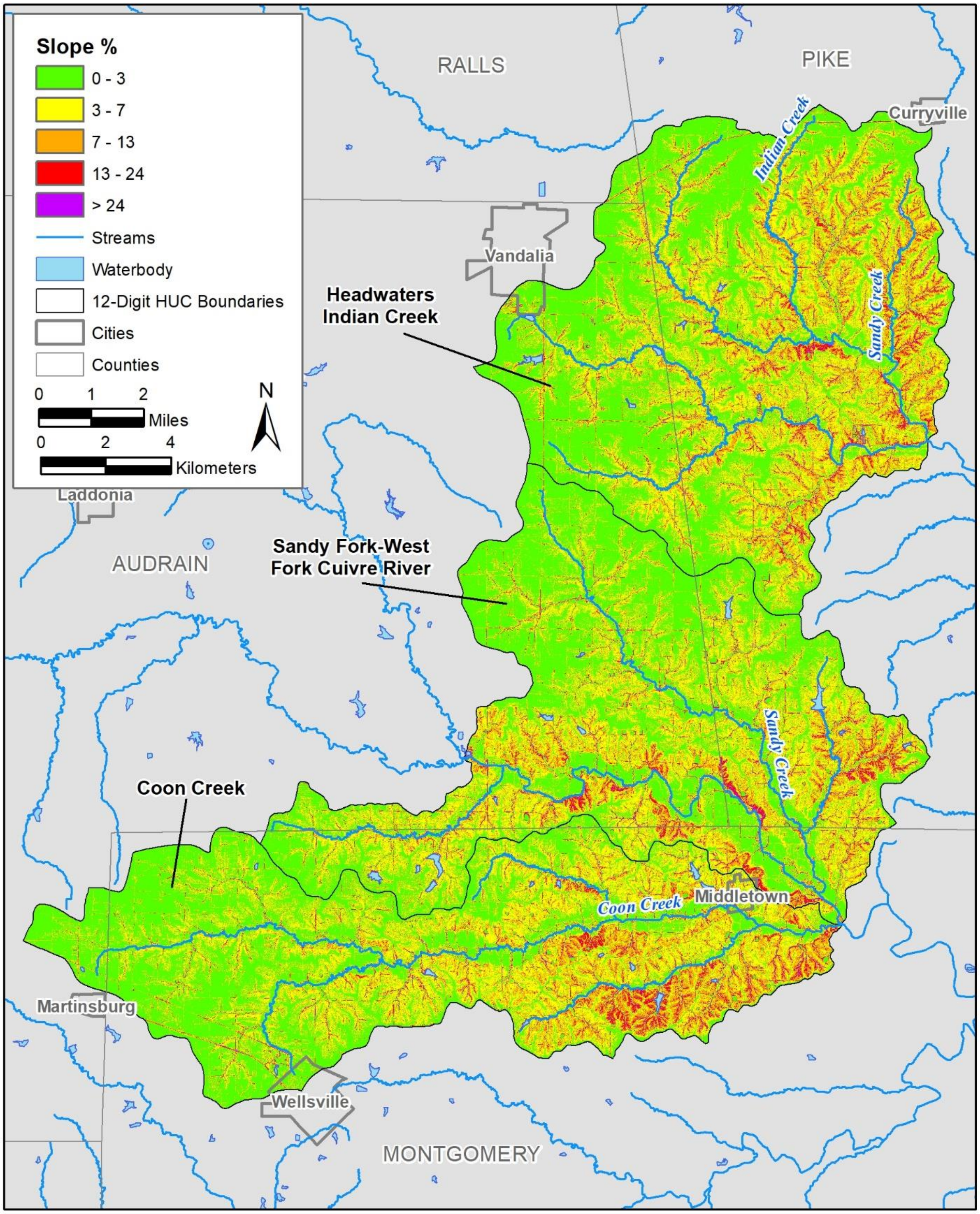


Figure 7. LiDAR based slope classification across the watershed.

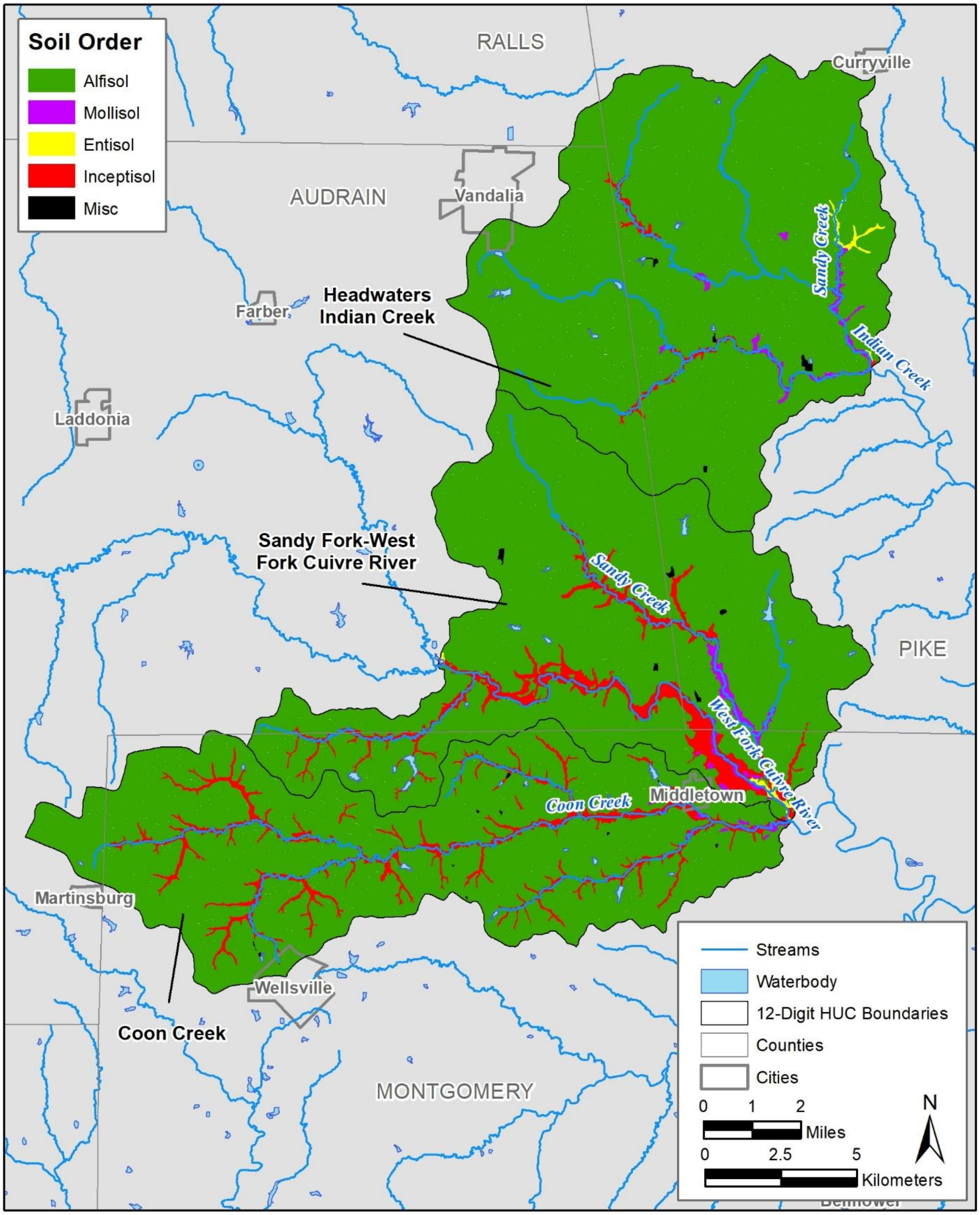


Figure 8. Soil series classified by order.

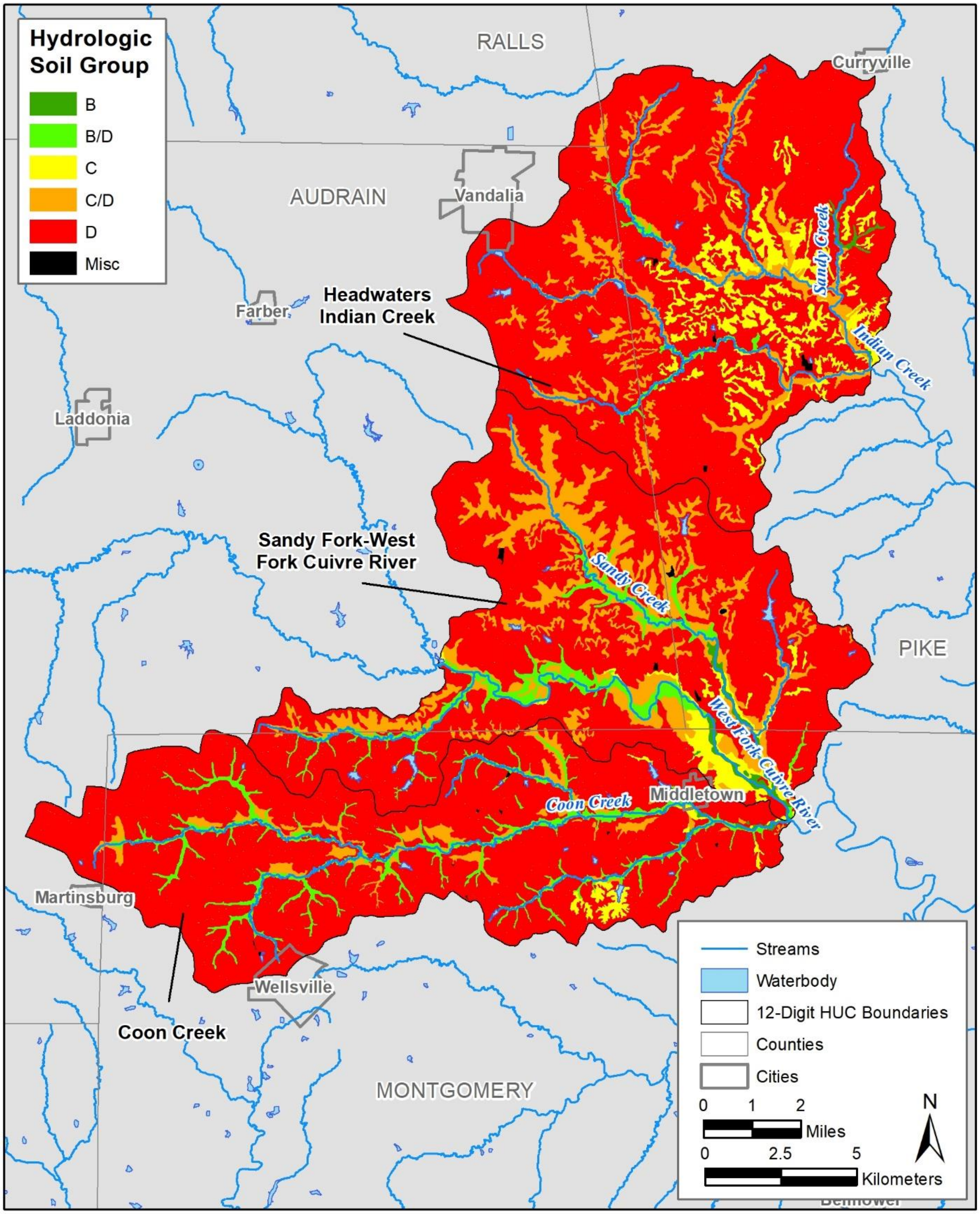


Figure 9. Soil series classified by hydrologic soil group.

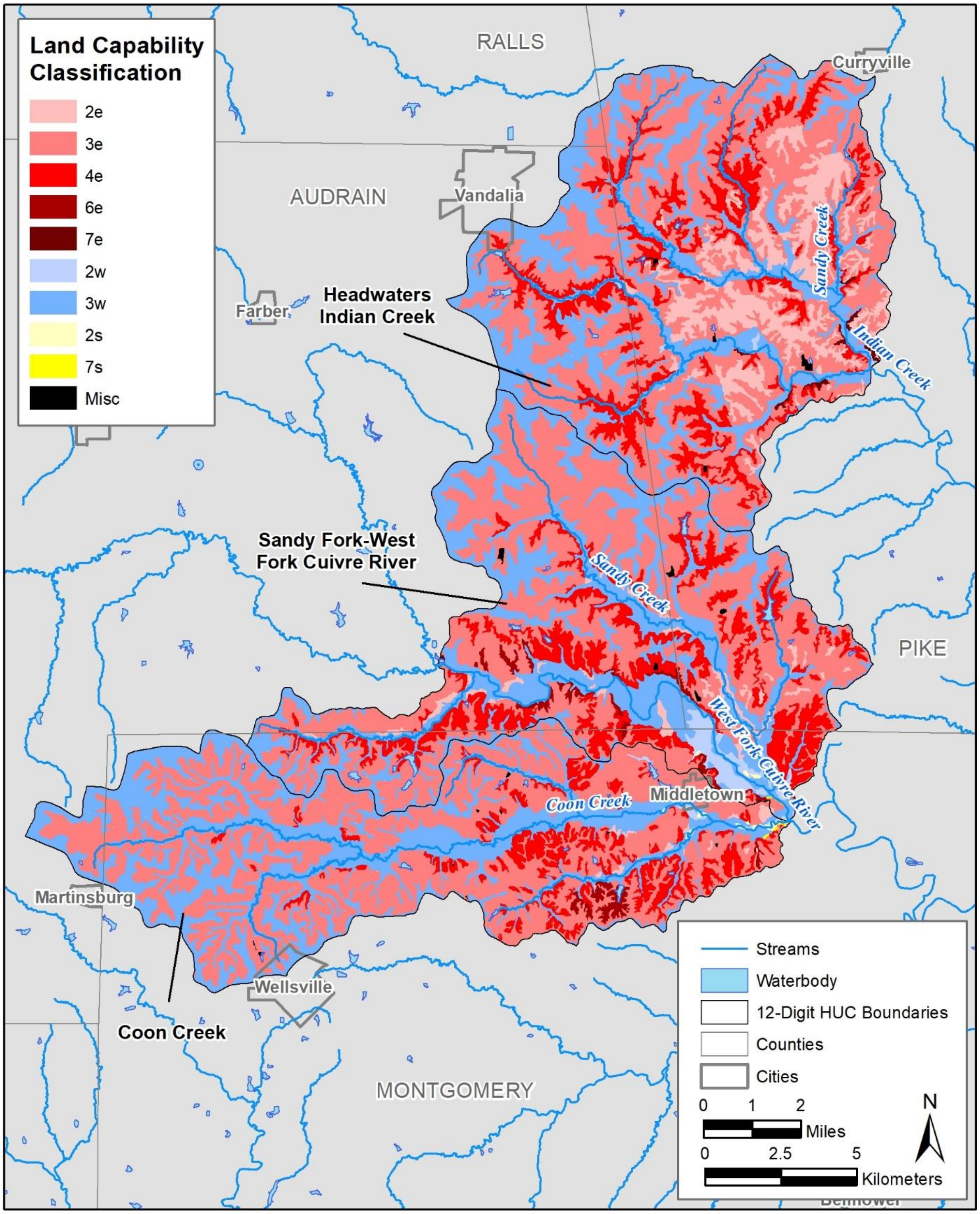


Figure 10. Soil series classified by land capability classification.

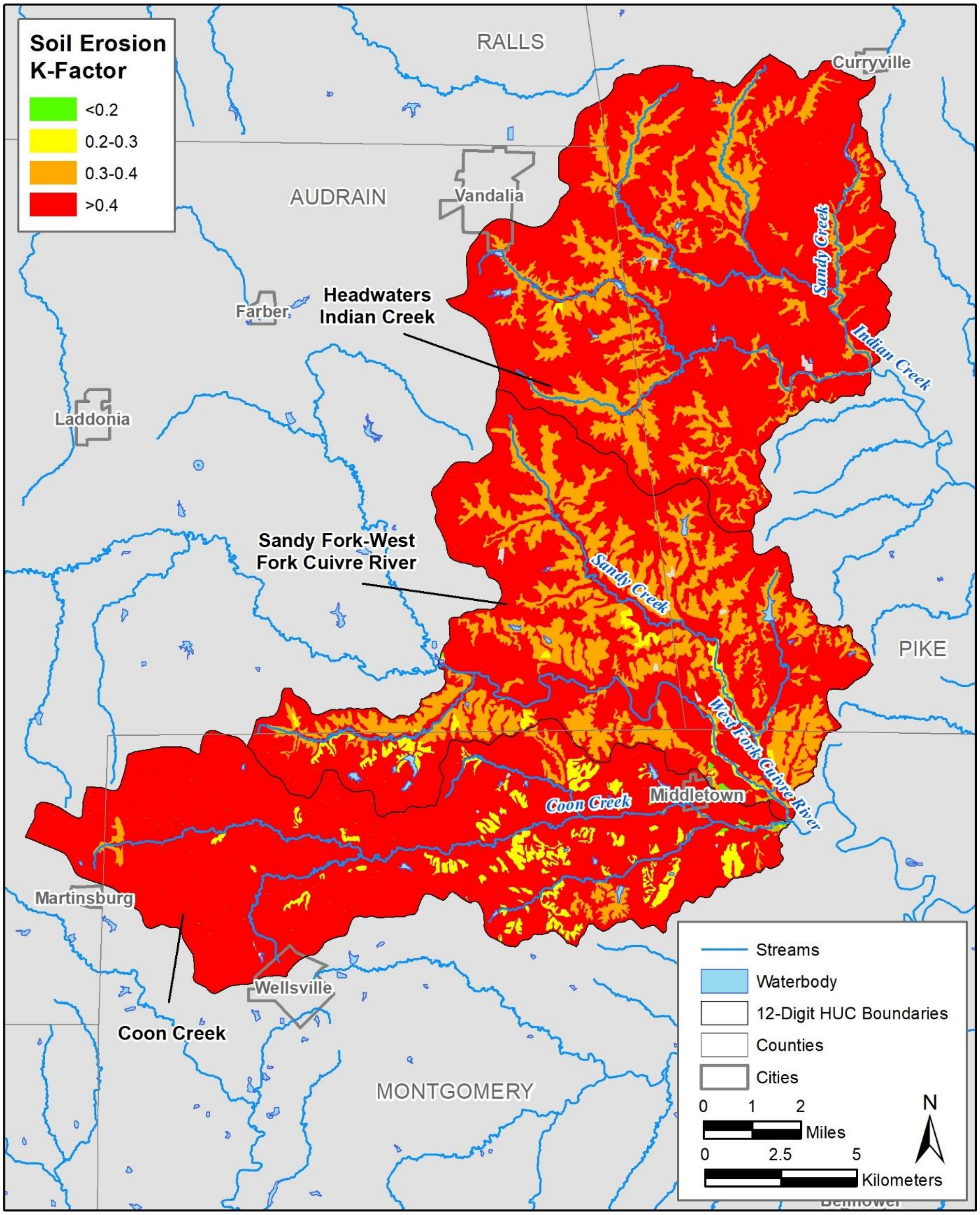


Figure 11. Soil series classified by soil erosion K-factor.

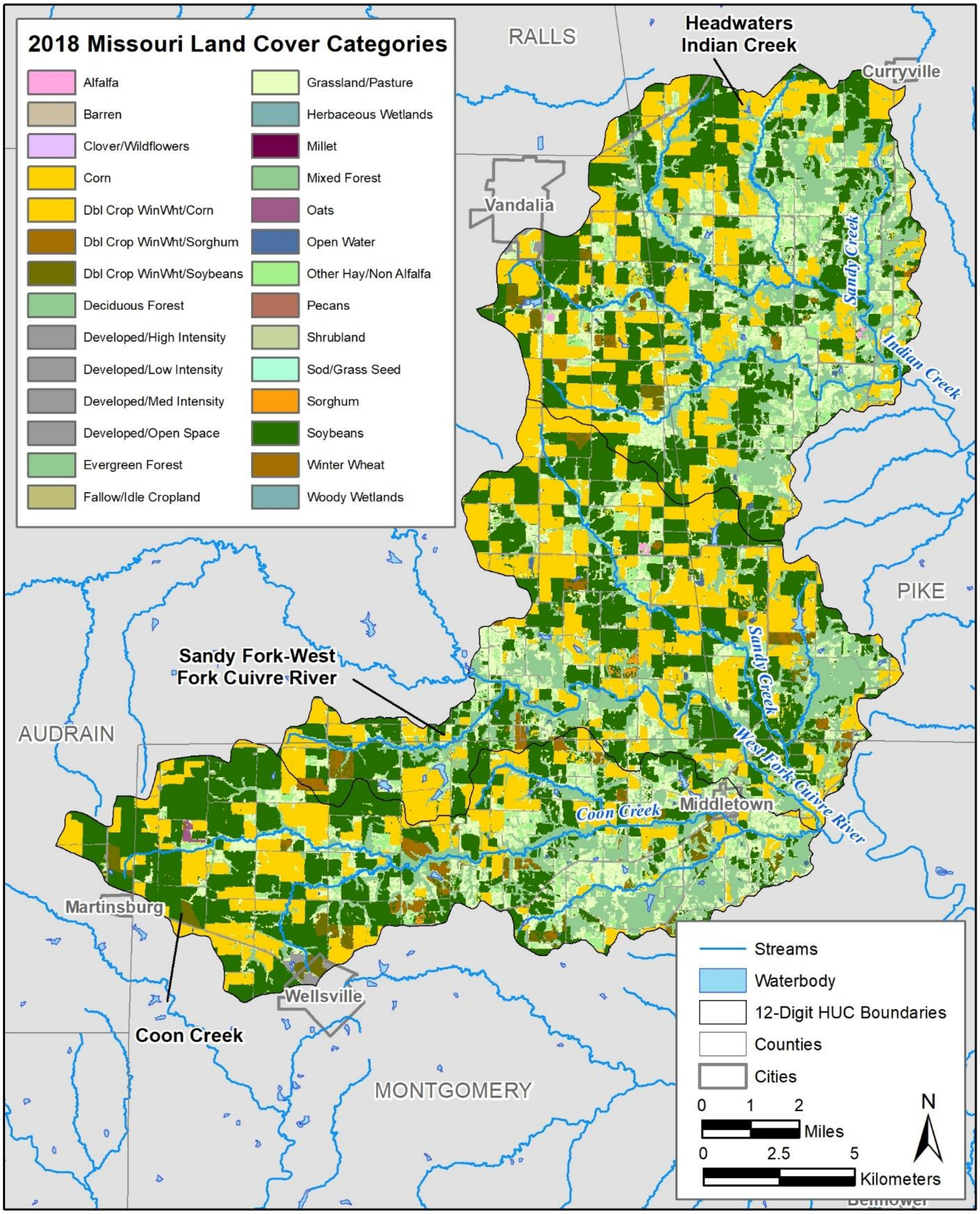


Figure 12. 2018 crop data from the NASS.

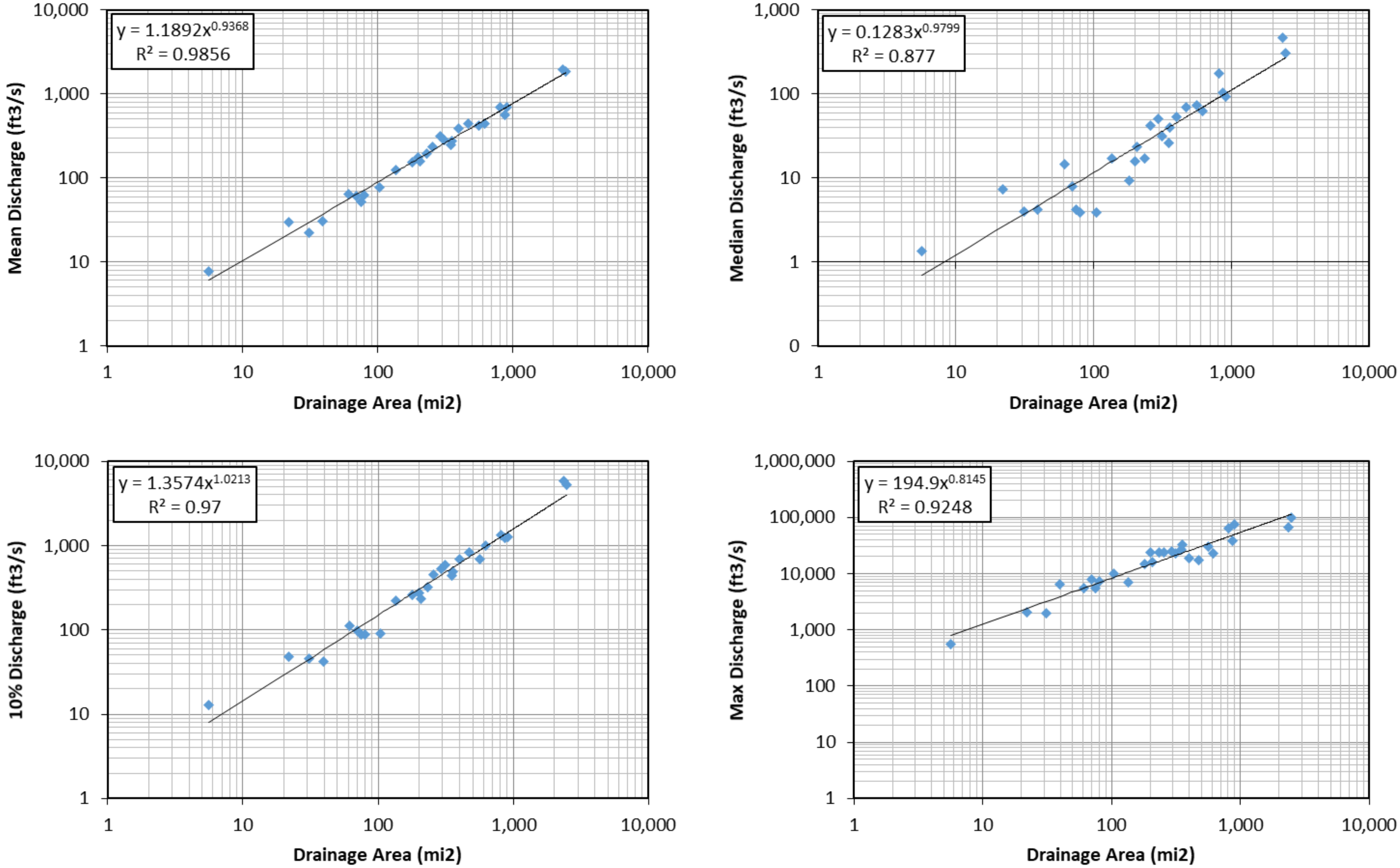


Figure 13. Drainage area and discharge relationships for 27 USGS gaging stations near the study watershed.

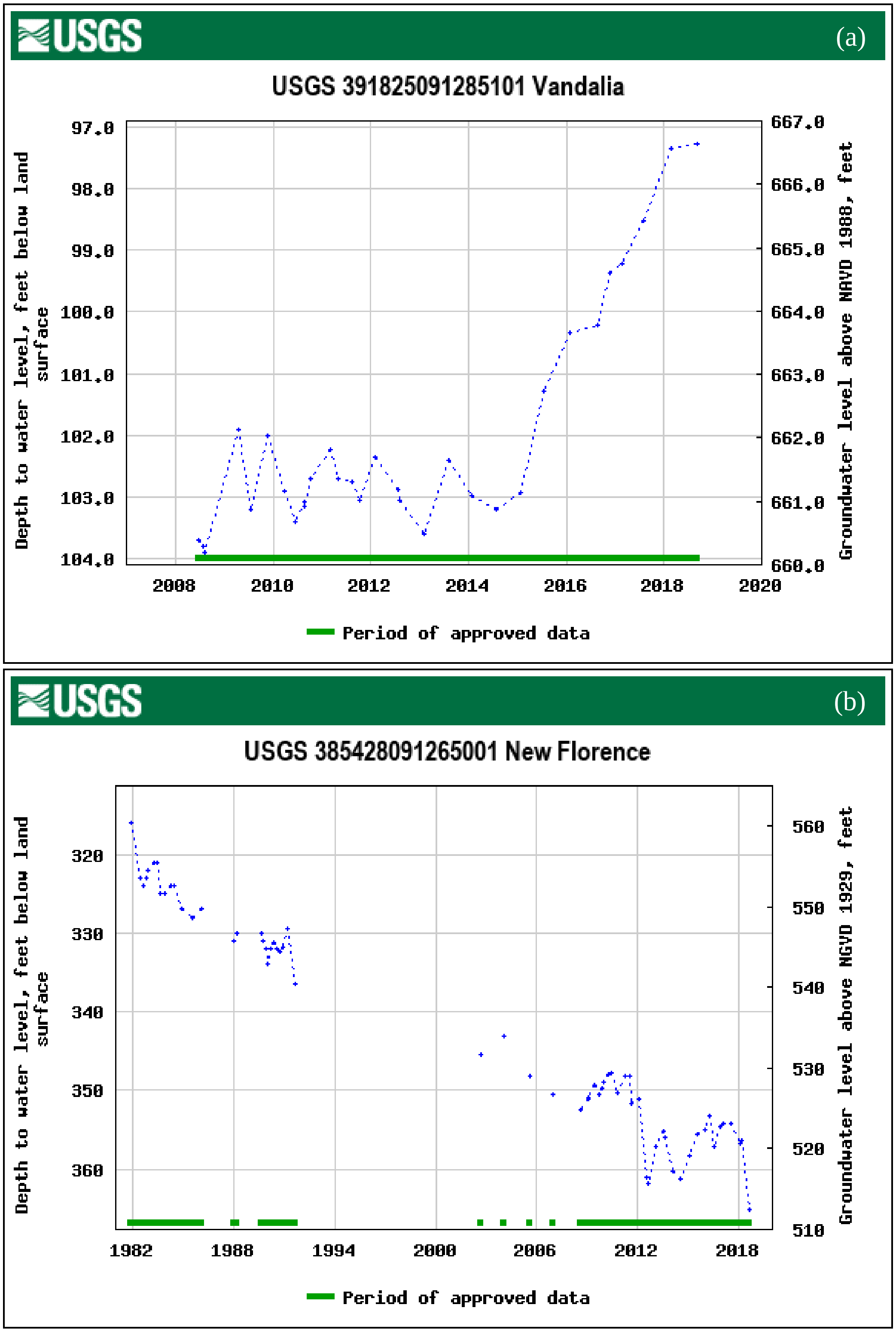


Figure 14. Ground water level change for (a) Vandalia (2007-2019) and (b) New Florence (1981-2019).

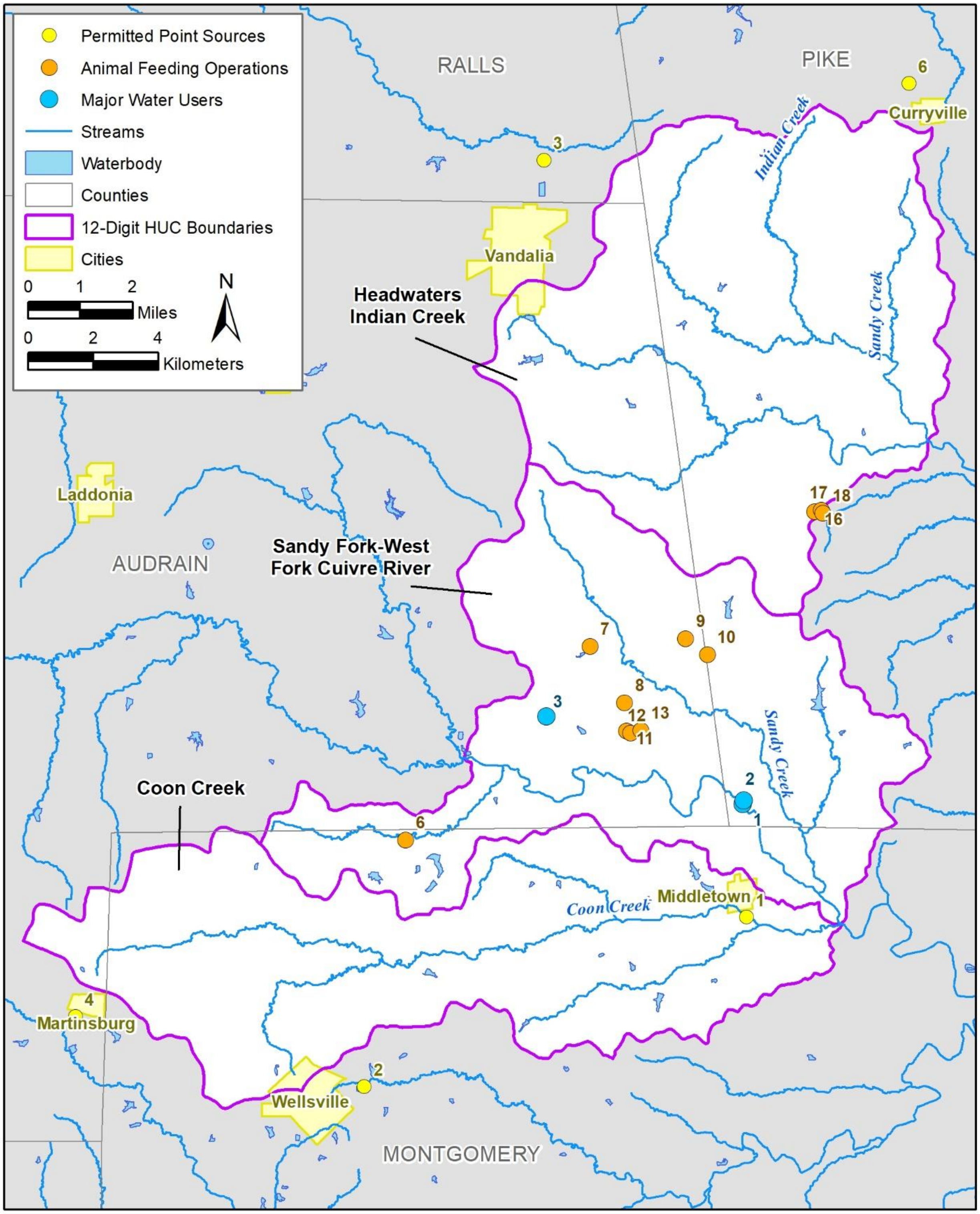


Figure 15. Permitted point sources, animal feeding operations and major water users.

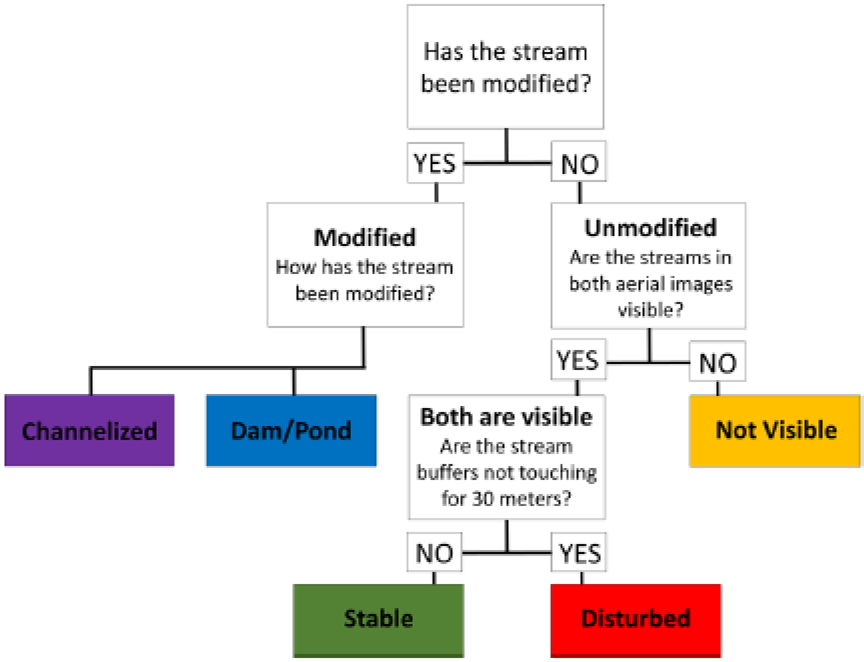


Figure 16. Flow chart showing decision tree for classifying stream channels from aerial photo analysis.

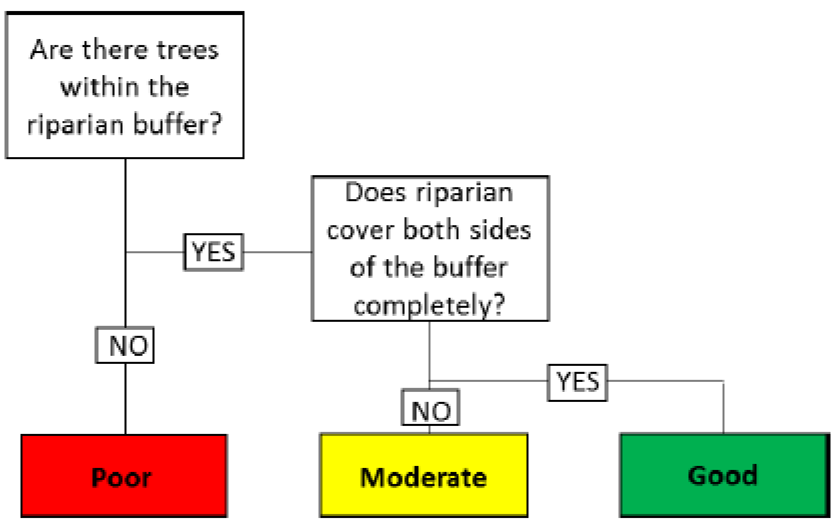


Figure 17. Flow chart showing decision tree for riparian corridor assessment from aerial photo analysis.

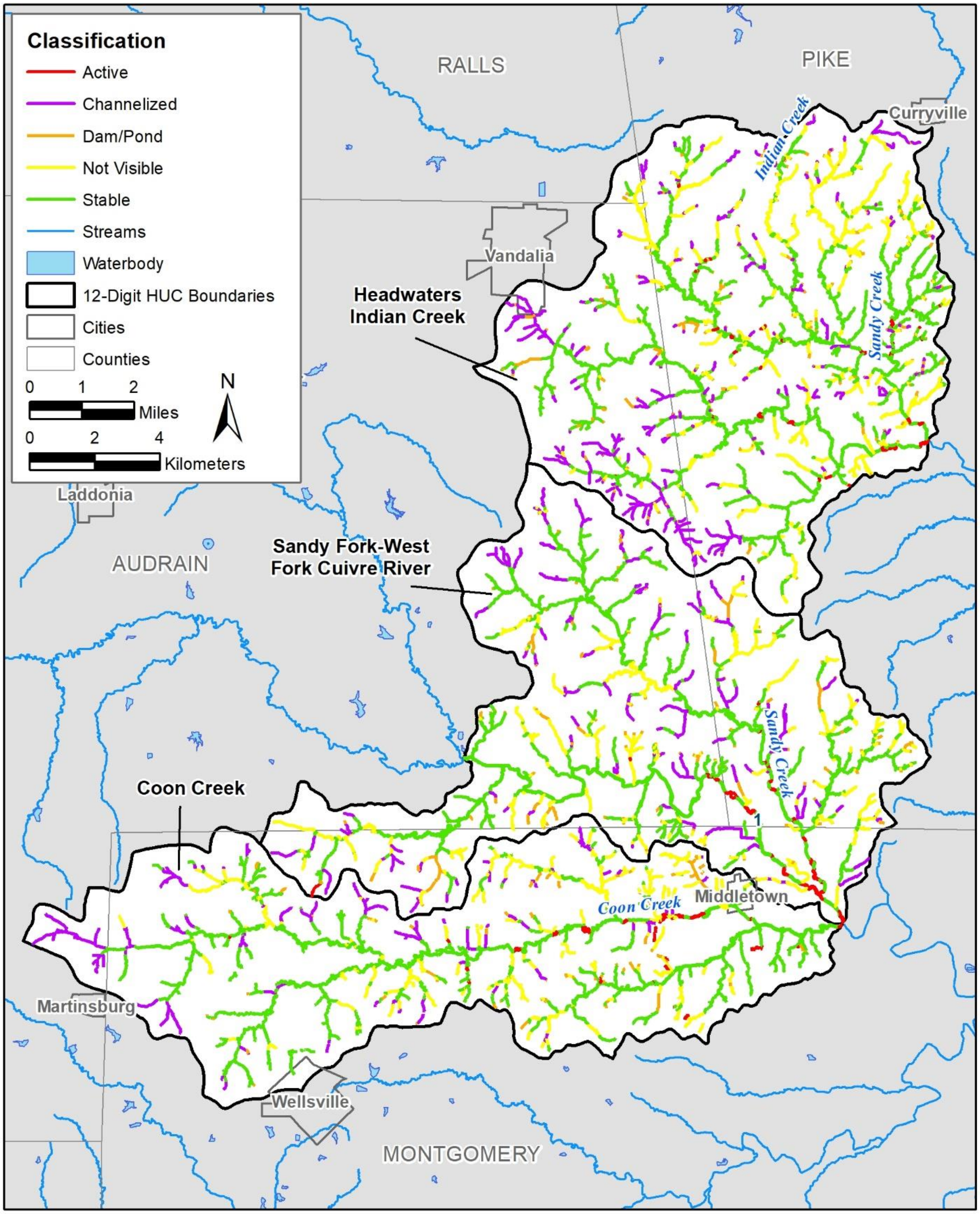


Figure 18. Channel stability classification

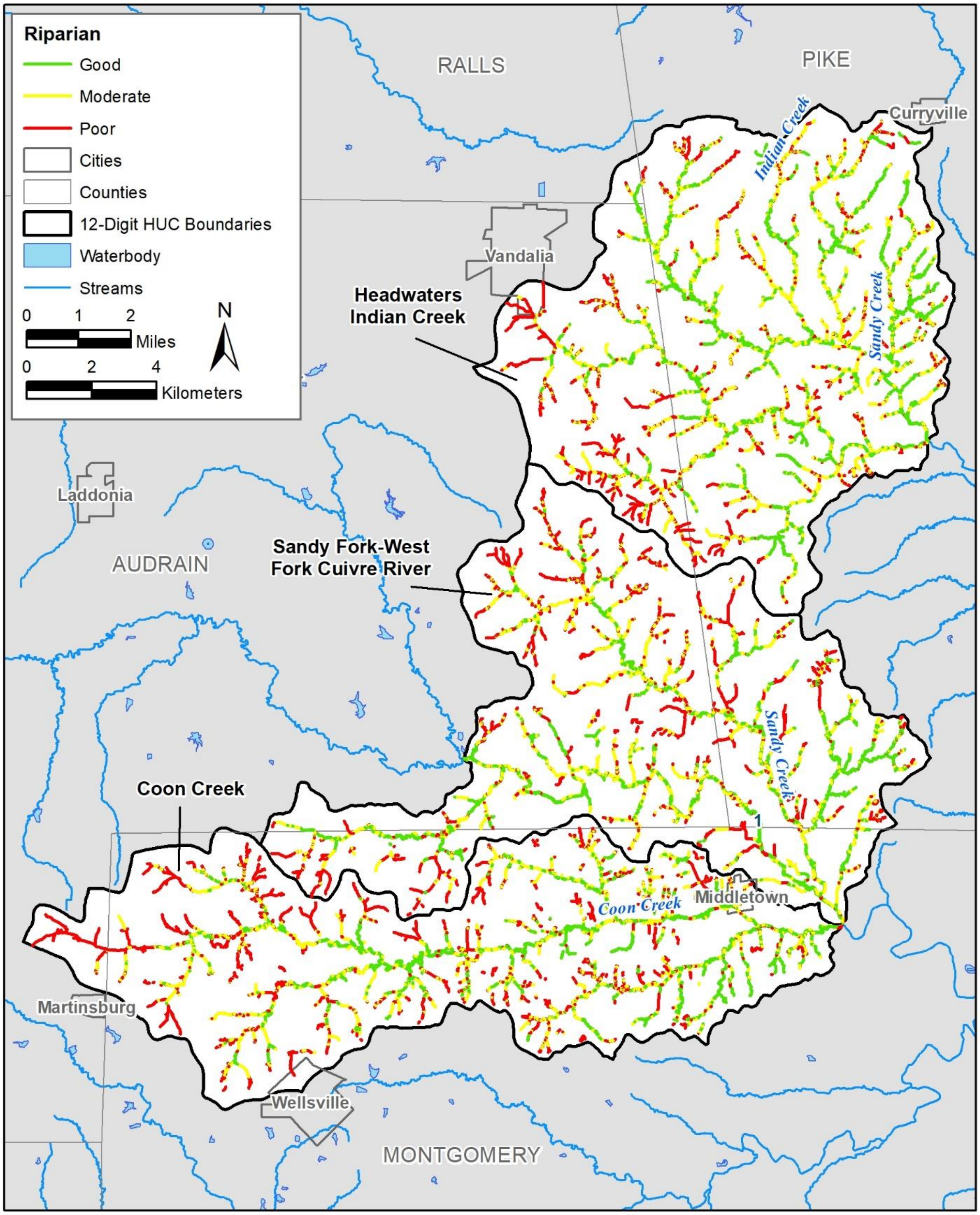


Figure 19. Riparian corridor classification

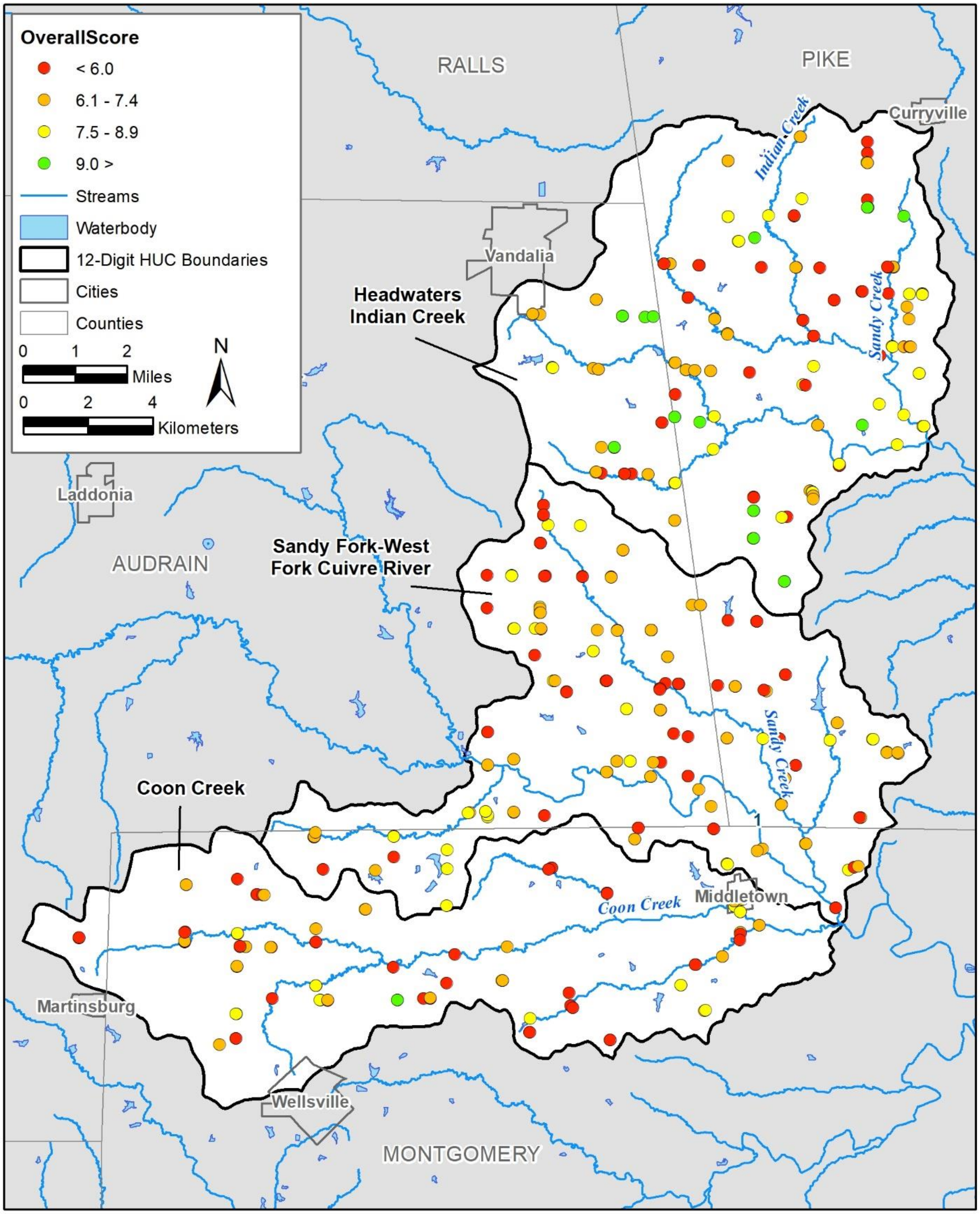
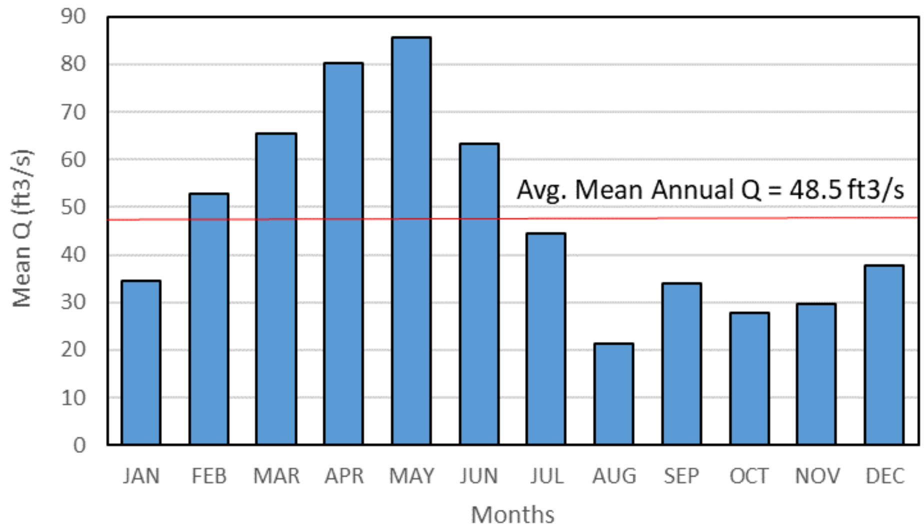


Figure 20. Visual stream assessment results.



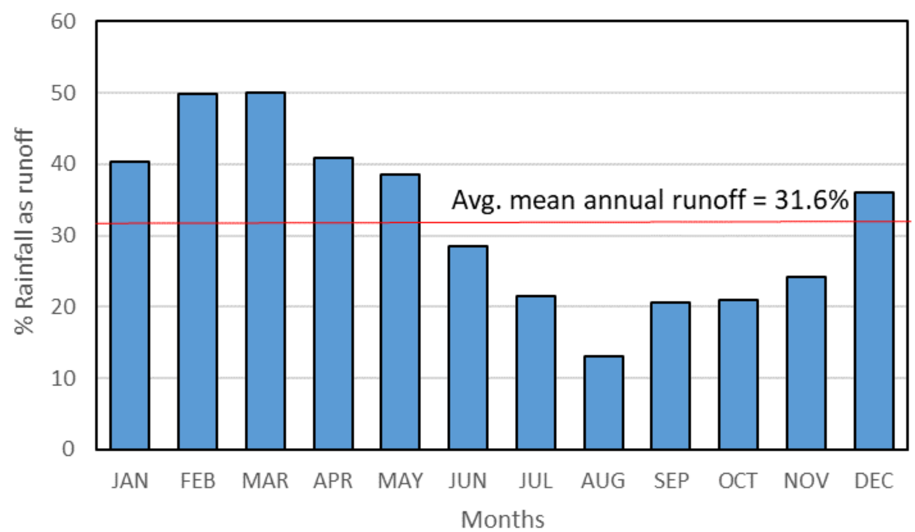


Figure 21. Mean monthly discharge and runoff percentage for the three study watersheds.

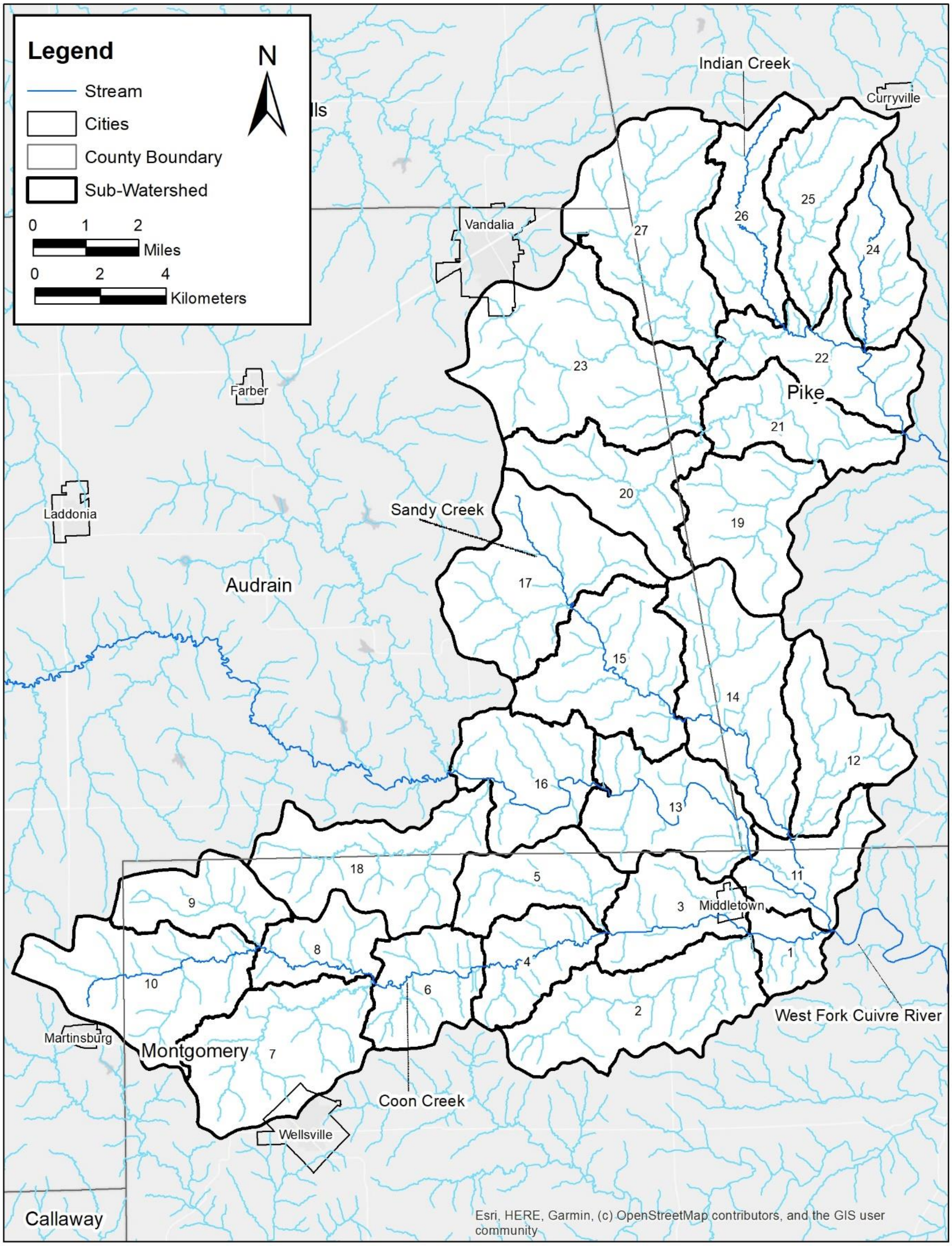


Figure 22. Management units within the three study watersheds in the Cuivre River.

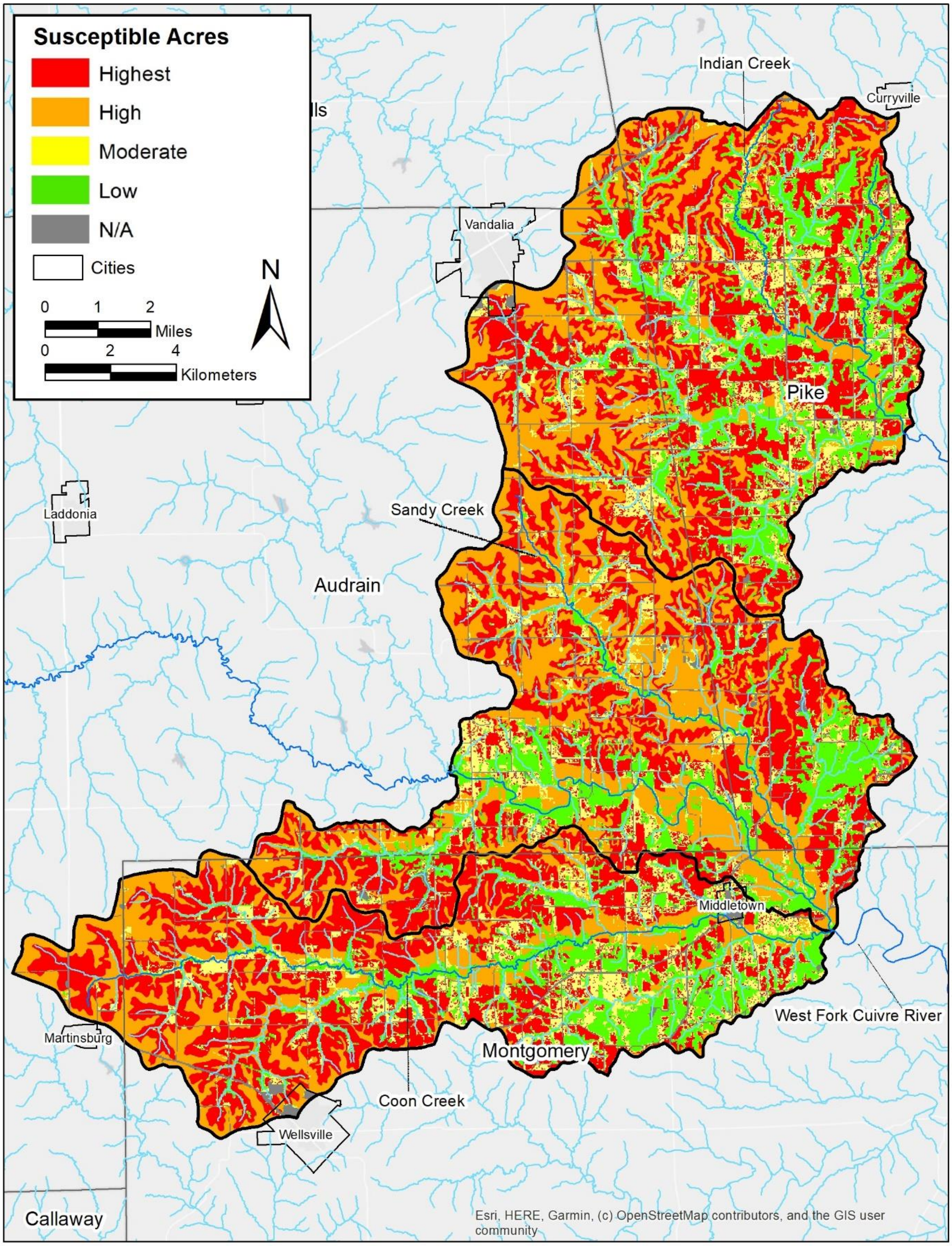


Figure 23. Distribution of susceptible acres classification within the three study watersheds.

APPENDICES

Appendix A. Soil series data and information for within the watershed.

MU#	Acres	% Area	Series Name	Hydrologic Soil Group	Landform	K Factor	Soil Order	Land Capability Classification	Slope % Range
10118	9	0.0	Sampsel silty clay loam	C/D	Upland	0.32	Alfisol	3e	7
30013	1,294	1.3	Armster clay loam	D	Upland	0.24	Alfisol	4e	7
30028	326	0.3	Armstrong clay loam	D	Upland	0.24	Alfisol	4e	7
30066	2,695	2.7	Gorin silt loam	C	Upland	0.43	Alfisol	2e	4
30068	225	0.2	Gorin silt loam	C	Upland	0.43	Alfisol	3e	7
30205	44	0.0	Snead silty clay loam	D	Upland	0.28	Alfisol	4e	12
36031	82	0.1	Nodaway silt loam	B	Floodplain	0.37	Entisol	3w	1
50001	4,917	4.9	Armstrong loam	D	Upland	0.37	Alfisol	4e	7
50008	10,832	10.9	Keswick silt loam	D	Upland	0.43	Alfisol	3e	7
50009	991	1.0	Keswick silt loam	D	Upland	0.43	Alfisol	4e	12
50012	8,241	8.3	Putnam silt loam	D	Upland	0.49	Alfisol	3w	0
50018	3,586	3.6	Armstrong loam	D	Upland	0.37	Alfisol	4e	5
50020	1,807	1.8	Calwoods silt loam	D	Upland	0.55	Alfisol	2e	4
50022	341	0.3	Calwoods silty clay loam	D	Upland	0.49	Alfisol	3e	4
50027	72	0.1	Goss cobbly silt loam	C	Upland	0.49	Alfisol	6e	22
50031	5	0.0	Lenzburg clay loam	C	Upland	0.24	Entisol	7e	30
50032	3	0.0	Lenzburg silty clay loam	C	Upland	0.2	Entisol	3e	3
50041	391	0.4	Lindley loam	C	Upland	0.37	Alfisol	6e	25
50052	301	0.3	Winnegan silt loam	D	Upland	0.43	Alfisol	6e	22
50054	4,107	4.1	Armster silt loam	D	Upland	0.49	Alfisol	3e	4
50058	9,324	9.3	Mexico silt loam	D	Upland	0.55	Alfisol	3w	1
50059	24,713	24.8	Mexico silt loam	D	Upland	0.55	Alfisol	3e	2
50060	734	0.7	Mexico silty clay loam	D	Upland	0.49	Alfisol	3e	2
54000	945	0.9	Chariton silt loam	C/D	Stream Terrace	0.43	Alfisol	3w	1
54001	390	0.4	Gifford silt loam	D	Stream Terrace	0.37	Alfisol	2e	3
54005	1,414	1.4	Twomile silt loam	D	Stream Terrace	0.64	Alfisol	3w	1
56003	2,434	2.4	Twomile silt loam	C/D	Floodplain	0.49	Alfisol	3w	1
56010	3,755	3.8	Belknap silt loam	B/D	Floodplain	0.43	Inceptisol	3w	1

MU#	Acres	% Area	Series Name	Hydrologic Soil Group	Landform	K Factor	Soil Order	Land Capability Classification	Slope % Range
60006	202	0.2	Marion silt loam	D	Upland	0.55	Alfisol	3e	3
60022	7,280	7.3	Leonard silt loam	C/D	Upland	0.37	Alfisol	3e	3
60055	14	0.0	Winfield silt loam	C	Upland	0.55	Alfisol	2e	4
60084	20	0.0	Crider silt loam	C	Upland	0.49	Alfisol	3e	7
60086	25	0.0	Crider silt loam	C	Upland	0.49	Alfisol	4e	12
60101	20	0.0	Gasconade-Rock outcrop complex	D	Upland	0.2	Mollisol	7s	33
60112	153	0.2	Goss very gravelly silt loam	C	Upland	0.49	Alfisol	7e	32
60127	265	0.3	Hatton silt loam	D	Upland	0.49	Alfisol	3e	6
60139	615	0.6	Keswick clay loam	D	Upland	0.24	Alfisol	4e	7
60142	217	0.2	Keswick loam	D	Upland	0.32	Alfisol	4e	12
60234	20	0.0	Weller silt loam	D	Upland	0.49	Alfisol	2e	2
60271	924	0.9	Keswick loam	D	Upland	0.32	Alfisol	4e	12
64004	260	0.3	Auxvasse silt loam	C/D	Stream Terrace	0.55	Alfisol	3w	1
64026	671	0.7	Okaw silt loam	D	Stream Terrace	0.43	Alfisol	3w	1
64040	154	0.2	Weller silt loam	D	Stream Terrace	0.49	Alfisol	2e	2
66000	338	0.3	Moniteau silt loam	C/D	Floodplain	0.49	Alfisol	3w	1
66041	6	0.0	Klum loam, sandy substratum	B	Floodplain	0.32	Entisol	2w	1
66058	681	0.7	Belknap silt loam	C	Floodplain	0.43	Inceptisol	2w	1
66072	23	0.0	Cedargap silt loam	B	Floodplain	0.37	Mollisol	2s	1
66076	90	0.1	Coland clay loam	C/D	Floodplain	0.2	Mollisol	3w	1
66107	39	0.0	Tice silt loam	B/D	Floodplain	0.37	Mollisol	2w	1
66116	21	0.0	Haymond silt loam	B	Floodplain	0.43	Inceptisol	2w	0
67015	1,567	1.6	Belknap silt loam	B/D	Floodplain	0.43	Inceptisol	3w	2
67055	122	0.1	Klum loam, sandy substratum	B	Floodplain	0.32	Entisol	3w	2
67085	693	0.7	Twomile silt loam	C/D	Floodplain	0.49	Alfisol	3w	2
67521	300	0.3	Cedargap silt loam	B	Floodplain	0.28	Mollisol	3w	1
67522	98	0.1	Cedargap silt loam	B	Floodplain	0.37	Mollisol	2s	1
67545	357	0.4	Klum loam, sandy substratum	C/D	Floodplain	0.32	Mollisol	3w	1
67565	78	0.1	Twomile silt loam	C/D	Floodplain	0.49	Alfisol	3w	1
75442	186	0.2	Healing silt loam	C	Floodplain	0.37	Mollisol	2e	2
99001	383	0.4	Water	NA	NA	NA	NA	NA	NA
99003	28	0.0	Miscellaneous water	NA	NA	NA	NA	NA	NA

Appendix B. USGS gaging stations near the watershed.

USGS Gage ID	Station Name	Stream	Start Year	Years of Record	Ad (mi2)	Elevation (ft)	90%	50%	10%	Max	Mean
05495500	Bear Creek near Marcelline, IL	Bear Creek	1944	75	349	505	1.20	25.80	435	27,000	246
05497150	North Fabius River near Ewing, MO	North Fabius River	2005	14	471	506	8.80	69.20	830	17,500	441
05498150	Middle Fabius River near Ewing, MO	Middle Fabius River	2005	14	400	522	4.32	53.10	696	19,000	385
05500000	South Fabius River near Taylor, MO	South Fabius River	1935	84	620	483	4.50	63.00	1,000	22,800	438
05501000	North River at Palmyra, MO	North River	1934	85	354	474	3.48	40.00	487	32,600	272
05502000	Bear Creek at Hannibal, MO	Bear Creek	1938	76	31	509	0.43	4.00	46.00	2,010	22.41
05503800	Crooked Creek near Paris, MO	Crooked Creek	1979	40	80	650	0.00	3.90	87.90	7,150	62.92
05504800	South Fork Salt River above Santa Fe, MO	South Fork Salt River	1940	79	233	644	1.70	17.00	318	24,000	194
05506100	Long Branch near Santa Fe, MO	Long Branch	1994	24	180	625	0.03	9.31	257	14,900	154
05506350	Middle Fork Salt River near Holliday, MO	Middle Fork Salt River	1998	21	313	649	2.70	31.20	582	22,900	280
05506800	Elk Fork Salt River near Madison, MO	Elk Fork Salt River	1968	51	200	690	1.60	16.00	275	24,100	175
05507600	Lick Creek at Perry, MO	Lick Creek	1979	40	104	624	0.01	3.90	90.63	9,830	77.63
05507800	Salt River near Center, MO	Salt River	1979	40	2,350	500	52.00	469	5,900	65,600	1,968
05508805	Spencer Creek below Plum Creek near Frankford, MO	Spencer Creek	1976	43	206	485	0.91	23.40	232	16,100	160
05512500	Bay Creek at Pittsfield, IL	Bay Creek	1939	80	39	638	0.34	4.20	42.00	6,510	30.25
05514500	Cuivre River near Troy, MO	Cuivre River	1922	90	903	450	6.10	94.15	1280	76,400	695
05514840	Dardenne Creek at O'Fallon, MO	Dardenne Creek	1999	20	61	462	2.79	14.50	113	5,460	63.54
05587000	Macoupin Creek near Kane, IL	Macoupin Creek	1921	91	868	427	8.50	104	1220	38,100	570
06909500	Moniteau Creek near Fayette, MO	Moniteau Creek	1948	38	75	608	0.00	4.20	87.00	5,430	51.97
06909950	Petite Saline Creek at Hwy U nr Boonville, MO	Petite Saline Creek	2007	12	136	600	1.13	16.90	223	7,100	125
06910230	Hinkson Creek at Columbia, MO	Hinkson Creek	1966	33	70	584	0.42	8.00	99.00	7,810	61.43
06910750	Moreau River near Jefferson City, MO	Moreau River	1947	46	561	544	7.80	73.50	684	30,700	419
06927000	Maries River at Westphalia, MO	Maries River	1947	41	257	543	4.27	42.00	451	23,800	232
06927240	Auxvasse Creek near Reform, MO	Auxvasse Creek	2008	11	292	522	4.62	50.60	528	25,300	318
06935850	Creve Coeur Creek at Chesterfield, MO	Creve Coeur Creek	1997	22	6	495	0.34	1.33	13.00	566	7.69
06935890	Creve Coeur Creek near Creve Coeur, MO	Creve Coeur Creek	1997	22	22	449	2.41	7.26	48.09	2,050	29.41
07016500	Bourbeuse River at Union, MO	Bourbeuse River	1921	98	808	489	42.00	177	1,350	63,000	693

Appendix C. Score sheet for visual stream survey

Channel Condition:

Natural; no structures, dikes. No evidence of down-cutting or excessive lateral cutting	Evidence of past channel alteration, but with significant recovery of channel and banks. Any dikes or levies are set back to provide access to an adequate flood plain.	Altered channel; <50% of the reach with riprap and/or channelization. Excess aggradation; braided channel. Dikes or levees restrict flood plain width.	Channel is actively downcutting or widening. >50% of the reach with riprap or channelization. Dikes or levees prevent access to the flood plain.
10	7	3	1

Hydrologic Alteration:

Flooding every 1.5 to 2 years. No Dams, No dikes or other structures limiting streams access to the flood plain. Channel is not incised.	Flooding occurs only once every 3 to 5 years; limited channel incision.	Flooding occurs only once every 6 to 10 years: channel deeply incised.	No flooding; channel deeply incised or structures prevent access to flood plain or dam operations prevent flood flows. Flooding occurs on a 1-year rain event or less.
10	7	3	1

Riparian Zone:

Natural Vegetation extends at least two active channel widths on each side.	Natural vegetation extends one active width both sides. Or If less than one width covers entire flood plain.	Natural vegetation extends half of the active channel width on each side.	Natural vegetation extends a third of the active channel width on each side. OR, filtering function moderately compromised.	Natural Vegetation less than 1/3 of active channel width on each side. OR, Lack of regeneration OR, Filtering severely function compromised.
10	8	5	3	1

Bank Stability:

Banks are stable; banks are low (at elevation of flood plain); 33% or more of eroding surface area of banks in outside bends id protected by roots that extend to the base-flow elevation.	Moderately stable; banks are low, less than 33% of eroding surface	Moderately unstable; banks may be low but typically high; outside bends are actively eroding (overhanging vegetation at top of bank, some mature trees falling into stream annually, some slope failures apparent.	Unstable; banks may be low, but typically are high; some straight reaches and inside edges of bends are actively eroding as well as outside bends (overhanging vegetation at top of bare bank, numerous mature trees falling into stream annually, numerous slope failures apparent).
10	7	3	1

Canopy Cover:

> 75% of water surface shaded and upstream 2 to 3 miles generally well shaded.	>50% shaded in reach Or >75% in reach, but upstream 2 to 3 miles poorly shaded.	20 to 50% shaded.	< 20% of water surface in reach shaded.
10	7	3	1

Manure Presence:

	Evidence of livestock access to riparian zone	Occasional manure in stream or waste storage structure located on the flood plain	Extensive amount of manure on banks or in stream. or Untreated human waste discharge pipes present.
	5	3	1

Appendix D. Examples of VSA survey sites.

Channel condition	10
Hydrologic alteration	6
Riparian zone	1
Bank stability	3
Canopy cover	1
Manure presence	3

Overall Score 4.0

Channel condition	10
Hydrologic alteration	9
Riparian zone	2
Bank stability	8
Canopy cover	6
Manure presence	

Overall Score 6.7

Channel condition	10
Hydrologic alteration	7
Riparian zone	8
Bank stability	8
Canopy cover	9
Manure presence	

Overall Score 8.4

Channel condition	3
Hydrologic alteration	3
Riparian zone	5
Bank stability	4
Canopy cover	4
Manure presence	

Overall Score 4.0

Channel condition	10
Hydrologic alteration	8
Riparian zone	7
Bank stability	8
Canopy cover	7
Manure presence	

Overall Score 8.0

Channel condition	10
Hydrologic alteration	7
Riparian zone	10
Bank stability	7
Canopy cover	8
Manure presence	

Overall Score 8.4

Channel condition	10
Hydrologic alteration	10
Riparian zone	1
Bank stability	1
Canopy cover	1
Manure presence	1

Overall Score 4.0

Channel condition	10
Hydrologic alteration	8
Riparian zone	7
Bank stability	7
Canopy cover	3
Manure presence	2

Overall Score 6.2

Channel condition	1
Hydrologic alteration	3
Riparian zone	3
Bank stability	2
Canopy cover	1
Manure presence	

Overall Score 2.0

Appendix E. Monthly mean discharge equations developed from regional USGS gaging stations.

Month	R^2	b_0	b_1	Coon Creek Ad = 47.7 mi^2 Q (ft^3/s)	Sandy Fork-West Fork Ad = 51.7 mi^2 Q (ft^3/s)	Headwaters Indian Ad = 56.7 mi^2 Q (ft^3/s)
Jan.	0.95	0.9179	0.9181	31.9	34.3	37.4
Feb.	0.99	1.3394	0.9298	48.7	52.5	57.2
March	0.99	1.487	0.9579	60.3	65.1	71.1
April	0.98	2.1029	0.9218	74.1	79.8	87.0
May	0.98	2.1342	0.9345	79.0	85.1	92.9
June	0.95	1.4682	0.9523	58.2	62.8	68.7
July	0.94	0.9855	0.9642	40.9	44.2	48.4
Aug.	0.92	0.4621	0.969	19.5	21.1	23.1
Sept.	0.94	1.0088	0.889	31.3	33.6	36.5
Oct.	0.95	0.7275	0.9215	25.6	27.6	30.0
Nov.	0.95	0.8447	0.9014	27.5	29.6	32.2
Dec.	0.96	1.0145	0.9149	34.8	37.5	40.8

Equation: $y=b_0x^{\wedge}b_1$
Where: y = mean monthly discharge (ft^3/s)
x = drainage area (mi^2)

Appendix F. STEPL model inputs for the three Cuivre River watersheds.

Watershed	Total		Land Use (ac)					# of Animals		# Septic
	Ad (ac)	HSG	Urban	Cropland	Pastureland	Forest	Water	Beef Cattle	Swine (Hog)	Systems
Coon Creek	30,516	D	1,375	19,190	4,406	5,302	243	1,762	1,781	161
Sandy Fork-West Fork	33,058	D	1,420	22,245	3,491	5,536	366	1,396	35,400	117
Headwaters Indian	36,295	D	1,590	21,623	5,481	7,417	184	2,192	3,430	143

Appendix G. Eroding streambank inputs into STEPL for the Cuivre River watershed

Coon Creek Watershed

Length (ft)	Height (ft)	Area (ft2)	Mean Width (ft)	Avg. Erosion Rate (ft/yr)
658	12.3	23,172	35.2	1.8
270	11.8	3,349	12.4	0.6
38	11.5	128	3.3	0.2
67	11.5	473	7.0	0.4
44	11.5	181	4.1	0.2
159	11.5	798	5.0	0.3
9	11.5	9	1.0	0.1
35	11.5	67	1.9	0.1
61	10.7	475	7.8	0.4
298	10.7	10,540	35.3	1.8
63	10.2	408	6.4	0.3
44	9.8	132	3.0	0.2
137	9.0	3,709	27.0	1.3
115	9.0	493	4.3	0.2
155	9.0	1,669	10.7	0.5
300	9.0	10,497	35.0	1.8
223	8.7	6,280	28.1	1.4
203	8.5	2,732	13.5	0.7
212	8.2	1,866	8.8	0.4
115	8.2	727	6.3	0.3
248	8.2	4,816	19.4	1.0
333	8.2	12,319	37.0	1.8
26	8.2	17	0.6	0.0
181	8.2	3,920	21.6	1.1
172	8.2	2,525	14.7	0.7
248	8.2	4,175	16.8	0.8
278	7.4	7,462	26.8	1.3
361	7.2	9,845	27.3	1.4
210	6.9	4,049	19.2	1.0
104	6.9	1,487	14.3	0.7
360	6.6	12,291	34.1	1.7
126	6.2	1,695	13.5	0.7
473	5.7	8,014	16.9	0.8
27	5.2	44	1.6	0.1
412	4.3	7,425	18.0	0.9
79	3.9	911	11.5	0.6
10	3.9	16	1.7	0.1
285	1.6	16,562	58.2	2.9

Total Length = 7,142 ft
Weighted mean height = 9.0 ft
Weighted mean rate = 1.4 ft/yr

Sandy Fork-West Fork Cuivre River

Length (ft)	Height (ft)	Area (ft2)	Mean Width (ft)	Avg. Erosion Rate (ft/yr)
421	13.1	17,787	42.3	2.1
365	12.3	17,443	47.8	2.4
621	11.5	16,053	25.8	1.3
248	11.5	9,701	39.1	2.0
466	11.5	13,879	29.8	1.5
306	11.5	4,871	15.9	0.8
322	11.5	11,168	34.7	1.7
483	10.7	37,355	77.4	3.9
4	10.7	1.4	0.3	0.0
127	10.7	2,249	17.7	0.9
131	9.8	1,606	12.2	0.6
95	9.8	146	1.5	0.1
323	9.8	3,049	9.4	0.5
569	9.5	34,310	60.3	3.0
50	9.5	179	3.5	0.2
434	9.5	20,396	47.0	2.4
281	9.5	6,958	24.8	1.2
132	9.2	2,512	19.0	0.9
124	9.0	672	5.4	0.3
410	9.0	17,511	42.7	2.1
868	9.0	43,225	49.8	2.5
162	9.0	2,033	12.5	0.6
178	9.0	1,552	8.7	0.4
300	9.0	11,315	37.7	1.9
250	8.2	5,959	23.8	1.2
297	8.2	9,950	33.5	1.7
180	8.2	3,715	20.6	1.0
181	7.4	2,738	15.1	0.8
231	7.4	4,144	18.0	0.9
157	7.4	4,339	27.7	1.4
99	7.4	1,391	14.1	0.7
54	7.4	581	10.7	0.5
353	7.4	1,545	4.4	0.2
87	7.1	831	9.6	0.5
201	6.9	4,366	21.7	1.1
49	6.9	329	6.7	0.3
3	6.9	1	0.2	0.0
117	6.9	1,634	14.0	0.7
376	6.9	9,107	24.2	1.2

566	6.6	5,790	10.2	0.5
194	6.6	5,922	30.6	1.5
5	6.6	3	0.5	0.0
319	6.6	8,719	27.3	1.4
76	6.6	1,116	14.6	0.7
125	6.2	474	3.8	0.2
42	6.2	50	1.2	0.1
59	6.1	686	11.7	0.6
502	5.9	27,836	55.4	2.8
26	5.7	90	3.5	0.2
49	5.7	347	7.1	0.4
43	5.7	76	1.8	0.1
347	5.7	4,031	11.6	0.6
191	5.2	2,664	13.9	0.7
100	5.2	1,978	19.7	1.0
460	4.9	6,510	14.1	0.7
115	4.1	2,259	19.6	1.0
93	3.3	2,137	22.9	1.1

Total Length = 13,369 ft
Weighted mean height = 9.7 ft
Weighted mean rate = 2.1 ft/yr

Headwaters Indian Creek

Length (ft)	Height (ft)	Area (ft2)	Mean Width (ft)	Avg. Erosion Rate (ft/yr)
119.0	10.5	2,388	20.1	1.0
334.3	10.2	7,543	22.6	1.1
208.0	10.2	4,764	22.9	1.1
59.0	9.8	160	2.7	0.1
85.4	9.4	326	3.8	0.2
137.6	9.0	1,649	12.0	0.6
153.9	8.9	567	3.7	0.2
87.4	8.9	369	4.2	0.2
45.5	8.5	46	1.0	0.1
196.4	8.5	1,090	5.5	0.3
145.4	8.4	1,115	7.7	0.4
256.3	8.2	3,963	15.5	0.8
281.4	8.2	8,807	31.3	1.6
305.7	8.2	4,222	13.8	0.7
94.0	8.2	1,185	12.6	0.6
14.3	8.2	4	0.3	0.0
122.0	8.2	539	4.4	0.2
42.6	8.2	239	5.6	0.3
50.2	8.2	293	5.8	0.3
63.6	8.2	361	5.7	0.3
68.0	8.2	492	7.2	0.4
42.0	8.2	311	7.4	0.4
179.4	7.9	2,351	13.1	0.7
26.4	7.9	93	3.5	0.2
174.4	7.5	1,589	9.1	0.5
107.0	7.5	818	7.6	0.4
20.1	7.5	40	2.0	0.1
37.5	7.4	109	2.9	0.1
135.2	7.4	984	7.3	0.4
190.6	7.4	959	5.0	0.3
9.8	7.4	8	0.9	0.0
257.1	7.2	10,169	39.5	2.0
130.3	7.2	1,305	10.0	0.5
106.5	7.2	1,199	11.3	0.6
126.3	6.9	1,298	10.3	0.5
27.9	6.6	93	3.3	0.2
17.7	6.6	74	4.2	0.2
128.1	6.2	299	2.3	0.1
31.4	6.2	30	1.0	0.0

227.8	6.2	1,688	7.4	0.4
100.8	5.9	1,056	10.5	0.5
61.9	5.9	271	4.4	0.2
24.4	5.9	53	2.2	0.1
52.1	5.7	453	8.7	0.4
67.4	5.7	446	6.6	0.3
11.9	5.7	17	1.4	0.1
36.2	5.6	199	5.5	0.3
191.3	5.2	5,001	26.1	1.3
150.6	5.2	2,923	19.4	1.0
6.0	5.2	6	0.9	0.0
104.5	4.9	1,131	10.8	0.5
54.1	4.9	559	10.3	0.5
78.1	4.9	667	8.5	0.4
100.4	4.9	2,515	25.1	1.3
93.3	4.9	1,834	19.7	1.0
38.2	4.9	205	5.4	0.3
52.4	4.9	413	7.9	0.4
19.3	4.6	63	3.3	0.2
48.9	4.6	144	2.9	0.1
252.8	4.6	7,001	27.7	1.4
106.2	4.3	2,170	20.4	1.0
2.9	4.1	1	0.3	0.0
41.4	3.9	347	8.4	0.4
66.8	3.9	537	8.0	0.4
31.7	3.9	102	3.2	0.2
207.8	3.8	6,118	29.4	1.5
39.4	3.6	14	0.4	0.0
24.4	3.6	9	0.4	0.0
17.2	3.6	45	2.6	0.1
77.1	3.0	194	2.5	0.1
35.5	2.0	192	5.4	0.3
95.5	1.5	1,197	12.5	0.6
88.9	1.5	770	8.7	0.4
110.1	1.1	1,358	12.3	0.6

Total Length = 7,335 ft
Weighted mean height = 7.6 ft
Weighted mean rate = 1.0 ft/yr

Appendix H. Combined conservation practice efficiencies for selected practices

List of Practices	Combined BMP Efficiencies		
Cropland	Nitrogen	Phosphorus	Sediment
Cover Crop	0.196	0.070	0.100
Diversion	0.100	0.300	0.350
Terrace to Underground Outlet	0.253	0.308	0.400
Cover Crop and Terrace to Underground Outlet	0.399	0.356	0.460
Field Borders	0.700	0.700	0.650
Cover Crop to Grassed Waterway	0.276	0.303	0.685
Terrace to Grassed Waterway	0.328	0.481	0.790
Cover Crop and No-Till	0.397	0.709	0.793
Cover Crop, No-Till, and Nutrient Management	0.546	0.872	0.793
Cover Crop and Terrace to Grassed Waterway	0.459	0.517	0.811
No-Till and Terrace to Underground Outlet	0.440	0.783	0.862
Cover Crop, No-Till, and Terrace to Underground Outlet	0.550	0.799	0.876
Cover Crop, No-Till, Terrace to Underground Outlet, and Nutrient Management	0.661	0.911	0.876
No-Till and Terrace to Grassed Waterway	0.496	0.838	0.952
Cover Crop, No-Till, and Terrace to Grassed Waterway	0.595	0.849	0.957
Cover Crop, No-Till, Terrace to Grassed Waterway, and Nutrient Management	0.657	0.917	0.957
Land Retirement	0.898	0.808	0.950
Pasture Land			
Forage and Biomass Planting	0.181	0.150	0.000
Livestock Exclusion and Alternative Water	0.309	0.384	0.187
Prescribed Grazing	0.408	0.227	0.333
Winter Feeding Facilities	0.350	0.400	0.400
Livestock Exclusion, Alternative Water, and Prescribed Grazing	0.591	0.524	0.794