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

National Water Quality Initiative (NWQI)
Watershed Assessment for:

FINAL

Headwaters Petite Saline Creek Watershed (HUC-103001020401)

Deliverable # 1 – Inventory of the Watershed
Deliverable # 2 – Resource Analysis of the Watershed
Deliverable # 3 – Final Report: Identification of Conservation Needs on Vulnerable Acres

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SCOPE AND OBJECTIVES

In 2012, the U.S. Department of Agriculture through the National Resources Conservation Service (NRCS) implemented the National Water Quality Initiative (NWQI) aimed at reducing nutrients and sediment in the nation's rivers and streams. The goal of the NWQI program is for the NRCS and its partners to work with landowners to implement voluntary conservation practices that improve water quality in high-priority watersheds while maintaining agricultural productivity. While high-priority watersheds have been selected around the country, typically watershed-scale evaluations identifying specific pollution sources and the conservation practices needed to improve water quality are not available to field office staff responsible for working with landowners. Therefore, a comprehensive planning effort aimed at prioritizing specific landscapes, crop types, and the conservation practices available is needed to help NRCS field staff implement the NWQI 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 for the Headwaters Petite Saline Creek watershed located in Cooper, Moniteau, and Morgan Counties in central Missouri. The project area is a 12-digit hydrologic unit code (HUC-12 #103001020401) watershed that is within the Lower Missouri-Moreau River watershed. Agricultural land use, confined animal feeding operations (CAFOs), sedimentation, stream bank erosion, and poor riparian corridors have been identified as potential water quality threats in the Lower Missouri-Moreau River watershed (MDNR 2014). Petite Saline Creek is mainly an agricultural watershed with little or no influence of industry or urban runoff and has been identified as a reference stream in developing both biological and nutrient criteria for streams in the region (Sarver et al. 2002, MDNR 2005). Furthermore, portions of Petite Saline Creek downstream of the study watershed have been listed on the 303(d) list of impaired waters in 2018 for low dissolved oxygen from an unknown source (MDNR 2018). The purpose of this assessment is to provide NRCS field staff with the necessary information to identify locations within the Headwaters Petite Saline Creek HUC-12 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

Petite Saline Creek is located in central Missouri and is a tributary of the Missouri River within the Lower Missouri-Moreau River watershed (HUC-8 #10300102) (Figure 1). The Headwaters Petite Saline Creek watershed (HUC-12 #103001020401) is one of six 12-digit HUC watersheds within the Petite Saline Creek Watershed (HUC-10 #1030010204). The headwaters of Petite Saline Creek begin in northwestern Moniteau County and flows north through Cooper County before flowing east towards the confluence with the Missouri River in northeast Moniteau County. The Headwaters Petite Saline Creek watershed (30,826 acres) is mainly in Cooper County with small areas being within Moniteau and Morgan Counties and is located north of the town of Syracuse and west of Bunceton, Missouri (Figure 2).

Climate

Missouri's climate is characterized by a large range of temperatures with hot, humid summers and cold winters due to its location in the middle of the continent (Frankson et al. 2017). Over the 30 year period from 1988–2017, the average rainfall at the closest weather station in Boonville, Missouri ranged from 26.7 to 54.1 inches with an average of 39.1 inches per year (Table 1). The highest monthly rainfall totals (>4 inches) occur in late spring to early summer with generally less precipitation during the winter months (Figure 3A). The average annual temperature ranged from 51.7-62.0°F with an average of 56.3°F between 1988-2017 (Table 1). Average monthly temperatures range from 29.6°F in January to 78.6°F in July (Figure 3B). Looking at the long-term trend, the five-year average annual rainfall has fluctuated between 35-45 inches per year over the last 30 years (Figure 4A). However, the five-year average annual temperature increased steadily from 1988 to 2010 with six of the highest annual average annual temperature records occurring between 2005 and 2012 (Figure 4B). Since 2010, average annual temperature has decreased at this weather station.

Solar radiation and evaporation trends are similar to the monthly temperature and precipitation trends in Boonville, Missouri. The average daily solar radiation by month ranged from 5.7 MJ/m^2 in December to 21.7 MJ/m^2 in June with an average of 14.1 MJ/m^2 from 2008-2017 (Figure 5). Monthly estimated average daily evaporation ranged from 0.06 inches in January to 0.10 inches in June with an average 0.08 inches from 2015-2017 (Figure 5).

Geology, Topography, and Geomorphology

The Headwaters Petite Saline Creek watershed is located along the northern edge of the Ozark Plateaus Provence of the Interior Highlands (USDA 2006). The underlying geology consists of Mississippian age limestone and Ordovician age dolomite bedrock (Starbuck 2017). The uplands along the watershed divide are gently sloping, grading to more dissected terrain moving downslope to the stream valley (Baker 1998). Elevation within the watershed range from 645.3–964.2 feet with lower elevations concentrated in the northeast portions of the watershed (Figure 6). Slopes derived from elevations range from 0–79% with lower slopes (<2%) in the uplands, slope values as high as 10% on the hillslopes, with the steepest slopes occurring along bluffs exposed along the valley margins (Figure 7). A watershed inventory published by the Missouri Department of Conservation on the Moreau River just east of Petite Saline Creek describes streams in the upper sections of the river as "Ozark like" with higher gradients and gravel/cobble beds than the slower moving, silty channels in the lower sections (Weirich 2002). Streams typically have silty banks and gravel bottoms (Nigh and Schroeder 2002). Published regional curves have been developed for typical channel morphology analysis of streams in the Ozark Plateaus and the Osage Plains physiographic regions that can be used as a reference for channel geometry of streams in the Petite Saline Creek for drainage areas <307 mi^2 (USDA 2018a) (Figure 8).

Landscape and Soils

The Headwaters Petite Saline Creek watershed is located within the Central Mississippi Valley Wooded Slopes Major Land Resource Area (MRLA) and the Ozark Highland MRLA (Figure 9). The Central Mississippi Valley are mainly deeply dissected, loess covered hills and relatively smooth loess-mantled karst plains in the uplands (USDA 2006). The Headwaters Petite Saline Creek begin in the Tipton Upland Prairie Plain of the Prairie Ozark Border subsection and eventually flow into the steeper Petite Saline Oak Savannah/Woodland Dissected Plain of the Outer Ozark Border subsection of the Ozark Highlands (Nigh and Schroeder 2002). Upland soils within the watershed are mostly alfisols (60.2%) or mollisols (36.8%), with entisols (2.9%) found along floodplains (Table 2, Figure 10). The majority (about 90%) of the soils in the watershed have moderate to high runoff potential being classified as hydrologic soil groups C, C/D, or D (Table 2, Figure 11) (USDA 2009a). Land Capability Classifications are used to determine the suitability of a soil to grow common field or pasture crops (USDA 2018b). Land capability classes within the watershed range from class 2-7 with limitations to growing crops mostly due to (e) erosion (74.8%) and (w) wetness (24.9%) with only minor limitations due to (s) shallow soil (0.1%) (Table 2, Figure 12). The dominate subclass within this watershed is 3e, which reduces the choice of plants, or requires conservation practices due to susceptibility to erosion (USDA 2018b). The majority of the soils within the watershed have a K-factor >0.3 with 67% having a K-factor >0.4 (Table 2, Figure 13). A complete list of soil series found within the watershed is available in Appendix A.

Hydrology and Drainage Network

Petite Saline Creek begins in the southern portion of the watershed and flows north toward the Missouri River (Figure 7). Major tributaries including the West Fork of Petite Saline Creek, Murphy Creek, and the Baslee Branch are located in the western portion of the watershed and flow east into Petite Saline Creek (Figure 2). There are 23 unnamed tributaries mapped within the watershed flowing into Petite Saline Creek. There are a total of 115.9 miles of mapped streams within the watershed with 40.5 miles of permanently flowing streams, 73.8 miles of intermittent streams, and 1.6 miles of concrete lined artificial streams (Table 3). There are a total of 143 mapped waterbodies within the watershed totaling of 90 acres. There are no major water users or irrigators reporting groundwater usage within the watershed.

Land Use and Land Cover

The Headwaters Petite Saline Creek watershed is mainly an agricultural watershed. Land uses for the watershed were determined using the National Agricultural Statistics Service (NASS) Crop Database from 2013-2017. Row crops made up the majority of the land use within the watersheds at 50.1%, followed by forest (17.7%) and grass/pasture (15.0%) (Table 4, Figure 14). Agricultural land use which includes row crops, double crops, small grains, alfalfa, grass/pasture, and fallow land totaled 77.9% of the land use within the watershed, with only 4% being developed land. Between 2013- 2017 corn and soybean production increase by almost 20% while there was a decrease in double crops (51.8%) and grass/pasture land (32.9%) (Table 5). This suggests that there has been at least some conversion of grassland to crop land within the watershed over the last five years.

Previous Work and Other Available Data

<u>TMDLs and Management Plans</u>

There are currently no TMDLs or watershed management plans for the Headwaters Petite Saline Creek HUC-12 watershed. However, the lower 21 miles of Petite Saline Creek downstream of the study watershed was recently listed on the 303(d) list of impaired waters for low dissolved oxygen (MDNR 2018). Downstream of the Petite Saline Creek, the Missouri

River is listed as impaired due to chlordane and PCBs and a TMDL was developed in 2006 to address these contaminants from multiple point and nonpoint sources (MDNR 2006, MDNR 2018). Currently, there are a number of impaired streams and several TMDLs have been developed for streams within the larger Lower Missouri-Moreau River HUC-8 watershed. These streams, outside of the Headwaters Petite Saline Creek HUC-12 watershed, are impaired due to E. Coli, mercury in fish, poor aquatic bioassessments, and low dissolved oxygen from a combination of point sources, industrial discharges, and agricultural nonpoint source pollution (MDNR, 2018).

Surface and Ground Water Monitoring Stations

There are no United States Geological Survey (USGS) gaging stations within the Headwaters Petite Saline Creek watershed. The closest gaging station on Petite Saline Creek is approximately 17 miles downstream at Highway U near Boonville, Missouri (USGS Gaging Station #06909950). To be able to predict discharge within the study watershed, 23 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 15). A list of the USGS gaging stations used for this analysis can be found in Appendix B. If resources became available to install gaging stations within the watershed, a possible location would be on Petite Saline Creek at Bellair Road near the confluence with Baslee Branch (E: 512,053, N: 4,298,988 UTM Zone15N). Additionally, there are no ground water monitoring stations within the study watershed. The closest ground water monitoring site is located 2.5 miles to the southeast of the watershed in Tipton (Site Number: 383929092464901) that has been in operation since 2009. Data from this station shows that the water table can fluctuate 10-15 feet annually (Figure 16). Also, it appears after a downward trend in water levels from 2009-2012 the average water level appears to be rising since 2012.

Water Quality Sampling Data

There are no water quality monitoring sites within the Headwaters Petite Saline Creek HUC-12 watershed. However, nutrient samples have been collected approximately 15 miles downstream from 2000-2014 and analyzed for nutrients. Samples collected in the early 2000s were used as a reference site to establish nutrient criteria for streams in the region (MDNR 2005). Also, there are no waste water treatment facilities within the study watershed. There are five permitted point source outfalls within the watershed. Four are for livestock waste that were delineated utilizing the Enforcement and Compliance History Online (ECHO) database on the EPA website (Figure 17). All four sites are in compliance with their respective permits which includes statutes from the Clean Water Act and the Clean Air Act (Table 6). In addition, there is a permitted storm water runoff outfall in the southwestern portion of the watershed.

Biological Monitoring Data

There are no biological monitoring sites within the Headwaters Petite Saline Creek HUC-12 watershed. However, in 1998 and in 2000 the MDNR conducted biological assessments of the Petite Saline Creek at Guyers Ford Drive, and Conner Bridge Drive approximately 20 miles downstream. Results indicate that at the time of sampling, the lower sections of the stream were fully capable of supporting aquatic life (Sarver 2012). These sites were later used to develop biological criteria for streams within the Ozark/Moreau/Loutre Ecological Drainage Unit (Sarver et al. 2002).

SUMMARY

This report was compiled to provide necessary information to describe the study watershed for the National Water Quality Initiative (NWQI) Watershed Assessment for the Headwaters Petite Saline Creek watershed (HUC-12 #103001020401). The Petite Saline Creek watershed is mostly agricultural with approximately 50% of the land area in row crops. The watershed is within a region of the state where agricultural land use, confined animal feeding operations (CAFOs), sedimentation, stream bank erosion, and poor riparian corridors have been identified as potential water quality threats. The purpose of this watershed assessment is to provide necessary information to the NRCS field staff to identify localities where slope, soil, and land use practices have the highest potential for pollution and to describe conservation practices that would benefit the watershed's water quality. This first phase of the project provides a general description of the watershed and accessible data that will be utilized in subsequent phases of the project. Information gathered for the first phase of the project provides geographical, physical, hydrological, and water quality attributes along with documentation of available data sources (Table 7).

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 an on-site visual assessment, and water quality modeling results and load reduction analysis. Ultimately these results will help establish what land uses are producing the most pollution and what practices would be the most useful in reducing nutrient and sediment loads within the watershed.

Water Quality Analysis

There were no water quality samples collected within the Headwaters Petite Saline HUC-12 watershed, however, nutrient data are available from sites downstream along the main channel. Summary statistics for all nutrient and sediment samples were used to evaluate Petite Saline Creek water quality by looking at both the range of mean concentrations and compare those numbers to an established reference concentration. All water quality data was downloaded from the MDNR Water Quality Assessment System website. Average site concentrations of TN from Petite Saline Creek were between 1.53-2.06 mg/L (Table 8). Mean site TP concentrations were between 0.140-0.230 mg/L. To put these data into perspective, ambient water quality criteria suggest reference conditions for the stream should be about 0.71 mg/L TN and 0.092 mg/L TP based on the 25^{th} percentile value for streams within the Central Irregular Plains region (Table 9, USEPA 2000). These data suggest that Petite Saline Creek has elevated nutrient concentrations when compared to the regional reference conditions. As stated earlier, agricultural land use, confined animal feeding operations (CAFOs), sedimentation, stream bank erosion, and poor riparian corridors have all been identified as potential water quality threats in the larger Lower Missouri-Moreau River watershed (MDNR 2014). Therefore, reducing agricultural nonpoint source pollution through the implementation of conservation practices in the watershed can be an important component in improving and protecting water quality in the Petite Saline Creek watershed.

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. Differences between the two photos due to transformation errors 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 the HUC-12 watershed boundary. Point-to-point errors ranged from 0-17.1 ft for a mean of 6.13 ft (Table 10). Streams 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 the tributary 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). Digitized lines representing the channel position from each year were then compared to identify areas of change and to quantify lateral migration rates.

Channel Classification

Tributary channels and the main stem of the Headwaters Petite Saline Creek were further classified by identifying historical channel changes and further interpretation of aerial photos between the years of 1995 and 2015 aerial photos from MSDIS. Channels were first characterized as modified or natural. Modified channels were further classified as either channelized or pond. Natural channels were further classified as either stable or active. Active channels were identified by assessing planform changes since 1995 by overlay analysis of the digitized channel using a 3.06 ft error buffer which is based off the 6.13 ft mean point-to-point error to account biases attributed to rectification (Martin and Pavlowsky 2011). Active reaches were identified as areas where the buffers between 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 assist in channel classification during aerial photo interpretation (Figure 18).

Channel classification results show the majority of the first order tributaries were Not Visible, either due to the presence of vegetation or not being visible in one of the aerial photographs (Figure 20). Many of the channelized segments present in the first order tributaries were either road ditches or grass waterways. Other larger tributaries were mainly classified as stable until the confluence with the main stem. Of the 135.5 mi of channel within the watershed, 40.3 mi (29.7%) was classified as not visible mainly due to vegetation obstruction (Table 11). A total of 54.6 mi (40.3%) was classified as stable followed by 37.2 mi (27.5%) as active, 3.0 mi (2.2%) was channelized, with the smallest area classified as a pond with 0.4 mi (0.3%). Evaluation of the visible stream channel suggests that a significant portion of streams in this watershed are adjusting to watershed disturbance through lateral migration. There also appears to be some channel widening along the main channel. There are some areas within the tributaries that appear to have been channelized in the past that are starting to show signs of lateral migration and bank erosion, however, these meander bends are typically less than 100 ft in length.

<u>Riparian Corridor Analysis</u>

The existence 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 corridor for the Headwaters Petite Saline Creek watershed was 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 19). A <u>Good</u> classification represents portions of streams in which adequate riparian tree coverage extends the width of the buffer on both sides of the stream. A <u>Moderate</u> class signifies one side of the stream buffer meets the good classification, 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 <u>Poor</u>

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 majority of the watershed was classified as either moderate or poor suggesting that the Headwaters Petite Saline Creek may benefit from riparian corridor enhancement along streams within the watershed (Figure 21). The moderate and poor classification makes up a combined total of 99.8 miles (74%) of the total stream miles within the watershed (Table 12). The poor classification within the HUC-12 is generally concentrated in first order streams whereas the moderate classification is concentrated within second order and higher order streams. There are 35.6 mi (26%) of streams within the watershed with the good classification mostly occurring along the main stem of the Headwaters Petite Saline Creek or larger tributaries. This method can only detect forested riparian buffers and aerial photo analysis cannot detect a healthy grassed buffer that maybe appropriate in some situations. However, for this assessment it is assumed that the lack of a forested buffer within these areas can intensify sediment loss and nutrient loading via mass wasting and limit filtration of overland flows from nearby fields (USDA 2014).

<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. A total of 87 crossings were examined for a total of 174 possible observations. However, 24 sites were already established grass waterways and not evaluated. Therefore, a total of 149 sites were ultimately completed. Of these 149 sites, 39.6% were rated as poor, 18.8% as fair, 28.2% as good, and 13.4% as excellent (Figure 22). The majority of the poor ratings were due to poor riparian corridor, presence of livestock within the stream, and lack of canopy cover.

Tributary streams in cropland areas generally appear to be moderately stable while streams in pasture areas tend to be less stable. Most of the streams in cropland areas were channelized into grass waterways with some incision and head cutting present (Appendix D). Typically streams along crop fields did not score high in the riparian corridor category, but in general had at least some kind of buffer present. In contrast, streams in areas of pasture were typically more unstable, particularly in the lower portions of the watershed. The range of channel conditions within the pastured areas generally follow the quality of the riparian corridor along the stream. In most cases the riparian corridors in areas where livestock have access to the stream had little to no vegetation present and showed evidence of eroding stream banks. Sites evaluated along the main channel of Petite Saline Creek had indicators of bank erosion and widening, even when there were adequate forested riparian corridors along both banks.

Rainfall–Runoff Relationship

Annual and monthly runoff rates for the Headwaters Petite Saline Creek watershed were estimated using equations developed from USGS gaging stations in the region. Monthly runoff rates are important for understanding seasonal variability of runoff and how rainfall-runoff relationships correspond to land management. Annual runoff rates are also be used to help validate the STEPL model hydrology results. A list of equations used for monthly mean discharge analysis can be found in (Appendix E). Mean annual discharge for the HUC-12 watershed is 48.5 ft^3/s (Figure 23a). Overall, average monthly discharge peaks in the month of April and is the lowest in August. Average runoff as percentage of rainfall was 34.6%. The remainder of the rainfall is either lost to evapotranspiration or moved through the soil into groundwater storage through infiltration (USDA, 2009b). These estimates are comparable with existing literature that state evapotranspiration rates for Missouri range from 60–70% (Sanford and Selnick 2013). Mean monthly runoff as a percentage of rainfall is highest in the late winter to early spring and lowest in the late summer to fall ranging from less than 10% in August to 50–60% in March (Figure 23b).

Water Quality Modeling

<u>STEPL Model</u>

Existing water quality loads in the watershed and the influence of best management practices (BMPs) 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 BMPs (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 BMPs was computed from known BMP 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, the entire 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 2017 USDA Crop database. Animal numbers were calculated per acre of pasture within the watershed using an animal number ratio of one animal per 2.5 acres of pastureland based on input from local staff. Animal numbers for CAFO operations within the watershed were entered at 148,000 chickens and 66,000 swine (MDNR 2019). Local staff felt that a considerable amount of poultry litter was being trucked into the watershed and spread on about 25% of the cropland in the watershed at 2.5 T/ac annually. While the manure generated by an individual bird is well known, the amount of bedding can vary between operations. As a conservative estimate, we added an additional 100,000 turkeys to the watershed to simulate the importing of litter into this watershed. This was then applied over five months on 25% of the cropland within the watershed. The number of septic systems within each watershed was based on a ratio of one septic system for every 1.45 acres of low intensity developed land use according to 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 lengths of active reaches, 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 from polygons representing areas of bank erosion identified by overlaying the bank lines from each aerial photo year with the error buffer. 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. If there were multiple polygons in a reach, an area weighted average was used for both the migration rate and the bank height. This method identified a total of 65 eroding stream reaches within the watershed with an average length of 1,126 ft, average area weighted bank height of 3.9 ft, and average area weighted annual migration rate was 0.76 ft/yr (Appendix G).

There has already been a considerable amount of conservation practices implemented within the Headwaters Petite Saline Creek watershed 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 80% of the cropland already was terraced, 20% had cover crops, and 30% were no-till. These estimates were used to calculate combined efficiencies within the STEPL model's BMP calculator and applied to the watershed (Table 13). The resulting loads reflect a total load that takes these existing conservation practices into account.

Average yields for the Headwaters Petite Saline Creek watershed were 6.5 lb/ac/yr for nitrogen, 1.3 lb/ac/yr phosphorus, and 0.65 T/ac/yr of sediment (Table 14). Runoff rates were 1.0 ac-ft/ac/yr and the percentage of rainfall as runoff was 30.3% for the watershed. Modeled percent runoff is relatively close to the estimated percentage of rainfall as runoff from the USGS gaging station equation estimate, which was 34.6% for the watershed. The relative agreement of these two methods (about 13% difference) adds confidence to the STEPL modelled runoff results. Additionally, results also show that existing conservation practices have reduced nitrogen loads by about 28%, phosphorus loads by 37%, and sediment loads by 34% for cropland sources in the watershed.

When assessing model results by sources for the Headwaters Petite Saline Creek watershed, the majority of the nutrient and sediment load is from agricultural nonpoint source pollution, but streambank erosion is a major contributor to the total sediment load in the watershed. Model results show crop and pastureland account for over 80% of the nutrient load within the watershed and around 63% of the sediment load (Table 15). Cropland accounts for around 70% of the nutrient load in the watershed. Pastureland is the second highest contributor for nitrogen in the watershed at nearly 19% of the load. Pastureland and streambank erosion have very similar contributions to the phosphorus load, which is around 10%. However, streambank erosion accounts for nearly 35% of the total sediment load in the watershed.

Load Reduction Analysis

Load reductions for the watershed were modeled in STEPL using established conservation practice efficiencies. The efficiencies of combined conservation practices were calculated with STEPL's BMP Calculator. A total of nine cropland conservation practices scenarios and three pastureland conservation practices scenarios were modeled. A description of each combined conservation practices scenarios with calculated efficiencies can be found in Appendix H. Load reductions of nitrogen, phosphorus, and sediment for watershed were modeled based on the percentage of cropland and pastureland within the watershed that were treated. The result is a load reduction matrix for both 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 and from there terraces, no-till, and nutrient management are added and/or combined. Land retirement was also used as a scenario to show what would happen if the land was taken out of production. For pastureland, the first level conservation practice was prescribed grazing. From there, alternative water and heavy use area protection 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.

Load reduction analysis indicate substantial nutrient and sediment reduction can be achieved in the Headwaters Petite Saline Creek watershed through implementation of cropland conservation practices since the relative amount of cropland within the watershed is so high. For instance, the most intensely managed scenario is one that combines cover crops, no till, terraces, and nutrient management. If that scenario was applied to 50% of the 20,251 acres of cropland (10,126 acres) within the watershed, load reduction would be 28.4% for nitrogen, 36.8% for phosphorus, and 30.9% for sediment (Tables 16-18). In contrast, applying the most intensely managed scenario to 50% of the 3,694 acres of pastureland (1,847 acres), which is prescribed grazing, alternative water, and heavy use area protection, the reduction would be only 4% for nitrogen, 1.8% for phosphorus, and 1.6% for sediment. An important part of the load reduction modeling is the benefit of multiple practices applied to cropland within the watershed. Since an estimated 80% of the cropland has existing terraces, adding cover crops, no-till, and nutrient management to that same land can more than double the reduction of nutrients and sediment. Additionally, if all the cropland within the watershed was taken out of production and the land retired, the resulting load reduction would be 71% for nitrogen, 72.4% phosphorus, and 67.0% for sediment. Again, this is mainly a function of the high relative percentage of cropland acres in the watershed.

SUMMARY

The purpose of this section of the report is to provide results of the resource analysis of the watershed (Deliverable #2) for the National Water Quality Initiative (NWQI) Watershed Assessment for the Headwaters Petite Saline Creek Watershed (HUC-103001020401). Water quality data from the lower Petite Saline Creek exceed regional ambient water quality criteria suggested reference conditions for streams in the Central Irregular Plains region. Agricultural land use, confined animal feeding operations (CAFOs), sedimentation, stream bank erosion, and poor riparian corridors have all been identified as potential water quality threats in the larger Lower Missouri-Moreau River watershed (MDNR 2014). Therefore, reducing agricultural nonpoint source pollution through the implementation of conservation practices in the watershed can be an important component in improving and protecting water quality in Petite Saline Creek.

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 the watershed were located along the main stem of the stream suggesting sediment being released though bank erosion is an important component of the total sediment load in the watershed. Due to the small size of the tributary streams within the watershed, overhead vegetation, and photo quality limitations, a complete classification of all the small tributary streams was not possible. The riparian corridor assessment shows 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 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 that cropland produces around 70% of the nutrients and 56% of the sediment load from the Headwaters Petite Saline Creek watershed. Streambank erosion is the second highest source of sediment in the watershed producing around 35% of the total sediment load and a phosphorus load that is similar to pastureland sources. Modelling results also show existing conservation practices, such as existing terraces, are responsible for significantly reducing the exiting loads within the watershed. However, load reduction analysis suggests and that additional conservation practices can further reduce loads with the implementation of cover crops, no-till, and nutrient management on cropland that previously only had terraces.

IDENTIFICATION OF CONSERVATION NEEDS

Resource Priorities

The top resource priority identified in this study is reduction of sediment from cropland within the Headwaters Petite Saline Creek. The Petite Saline Creek watershed is mostly agricultural with approximately 50% of the land area in row crops and model results indicate cropland accounts for approximately 70% of the nutrient load and 55% of the sediment load. The watershed is within a region of the state where agricultural land use, confined animal feeding operations (CAFOs), sedimentation, stream bank erosion, and poor riparian corridors have been identified as potential water quality threats. There has already been a significant amount of conservation practice implementation within the watershed. Through conversations with local staff and field observations it was estimated 80% of the cropland in the watershed was already terraced. However, model results indicate further implementation of conservation practices on cropland would be the most effective method of reducing sediment loads in the watershed. This would be accomplished through incorporating more intensive management practice such as cover crops, no-till, and nutrient management on already terraced fields. Load reduction analysis indicates there would be further, substantial gains in reducing pollution by implementation of these combined practices in the Headwaters Petite Saline Creek watershed.

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 priority acres classification, and a conservation practice rating system.

Management Units

To better plan for locations to implement conservation practices, the Headwaters Petite Saline Creek watershed was split into 12 smaller watersheds, or management units (MUs) (Figure 24). MUs will allow field staff to evaluate potential projects based on a system that would rank geographic areas within the watershed. STEPL was then used to estimate sediment yields for each management unit with drainage areas ranging from 1,600-3,500 acres (Table 19). In the Headwaters Petite Saline Creek watershed, the four MUs with the highest sediment yields are all located in the central part of the watershed (MUs 3, 5, 7, and 8). The landscape in this area is are more susceptible to runoff as the land is on relatively steeper slopes and the soil types can generate more runoff.

Vulnerable Acres Classification

To identify areas with the most pollution potential within a proposed project, a vulnerable acres classification system was developed to help field staff isolate problem areas and rank 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. Highest Risk land represents the most critical areas for pollution potential from the landscape and should be prioritized for planning. High Risk 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 vulnerability. Low Risk lands have adequate treatment of the landscape. Remaining areas of urban land use and water were classified as “other” (Figure 25). A description of each class type is described below and summarized in Table 20.

Highest Vulnerability – in the Headwaters Petite Saline Creek watershed the highest vulnerability 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)

In the entire Headwaters Petite Saline Creek watershed, 13,562 acres (44.0%) are classified in the highest vulnerability category.

High Vulnerability – All other cropland that was not in the highest vulnerability category was placed in the high vulnerability category for conservation planning. There is a total of 6,699 acres (21.7%) of high priority acres in the Headwaters Petite Saline Creek watershed.

Moderate Vulnerability - Land within the moderate vulnerability category would be all of the pastureland within the watershed. The Headwaters Petite Saline Creek watershed has 3,689 acres (12.0%) of moderate vulnerable acres.

Low Vulnerability - Low priority acres are all of the forested areas within the watershed. Within the Headwaters Petite Saline Creek watershed there are 5,592 low priority acres (18.1%).

N/A – This category represents all urban land use and land classified as water or wetlands within the watershed. This represents 1,284 acres, or 4.2% 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 for the Headwaters Petite Saline Creek watersheds. For this, each conservation practice, or combination of conservation practices, was ranked based on the highest sediment load reduction by percentage of land treated for both pasture and cropland. A total of 12 practices were evaluated, nine being cropland practices and three were pastureland practices. All of the cropland conservation practices ranked higher than the pastureland conservation practices for reducing sediment loads (Table 21). The top practice for reducing the sediment load on cropland was land retirement. The next two practices in the rankings were combinations of cover crop, no-till, and terraces on cropland. Load reduction analysis shows no-till is much more effective at reducing sediment loads than cover crops. The top pasture conservation practice at reducing sediment loads was a prescribed grazing/alternative water/heavy use protection system. There is a total of 20,261 acres of cropland and only 3,689 acres of pastureland within the Headwaters Petite Saline Creek watershed.

CONCLUSIONS

The purpose of this report is to provide the Missouri State office of the NRCS a watershed assessment for the Headwaters Petite Saline Creek watershed, which is part of the National Water Quality Initiative (NWQI). Agricultural land use, confined animal feeding operations

(CAFOs), sedimentation, stream bank erosion, and poor riparian corridors have been identified as potential water quality threats in the larger Lower Missouri-Moreau River watershed (MDNR 2014). Petite Saline Creek is mainly an agricultural watershed with little or no influence of industry or urban runoff and has been identified as a reference stream in developing both biological and nutrient criteria for streams in the region (Sarver et al. 2002, MDNR 2005). Furthermore, portions of Petite Saline Creek downstream of the study watershed have been recently listed on the 303(d) list of impaired waters in 2018 for low dissolved oxygen from an unknown source (MDNR 2018). Therefore, reducing agricultural nonpoint source pollution through the implementation of conservation practices in the watershed can be an important component in improving and protecting water quality in Petite Saline Creek

The purpose of this 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. 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) There are currently no TMDLs or watershed management plans for the Headwaters Petite Saline Creek HUC-12 watershed. However, the lower 21 miles of Petite Saline Creek downstream of the study watershed was recently listed on the 303(d) list of impaired waters for low dissolved oxygen (MDNR 2018). Agricultural land use, confined animal feeding operations (CAFOs), sedimentation, stream bank erosion, and poor riparian corridors have been identified as potential water quality threats in the larger Lower Missouri-Moreau River watershed (MDNR 2014). Therefore, reducing agricultural nonpoint source pollution through the implementation of conservation practices in the watershed can be an important component in improving and protecting water quality in the Petite Saline Creek watershed;

2) While there are no water quality data available in the Headwaters Petite Saline Creek watershed, water quality data available from the lower Petite Saline Creek are 2-3x higher than regional ambient water quality criteria suggested reference conditions for streams in the Central Irregular Plains region;

3) 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 the watershed were located

along the main stem of the stream suggesting sediment being released though bank erosion is an important component of the total sediment load in the watershed;

4) The riparian corridor assessment shows 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 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 that cropland produces around 70% of the nutrients and 56% of the sediment load from the Headwaters Petite Saline Creek watershed. Streambank erosion is the second highest source of sediment in the watershed producing around 35% of the total sediment load;

6) There has already been a significant amount of conservation practice implementation within the watershed. Through conversations with local staff and field observations it was estimated 80% of the cropland in the watershed is already terraced. Load reduction analysis suggests and that additional conservation practices can further reduce loads with the implementation of cover crops, no-till, and nutrient management on cropland that previously only had terraces; and

7) Management units, vulnerable acres classification, and conservation practice rankings were created to help staff prioritize areas and evaluate potential projects. Management units direct conservation practices to specific areas of the watershed based on sediment loads. Vulnerable acres can then be used to evaluate projects within management units. For the Headwaters Petite Saline Creek watershed, 45.9% of the watershed was classified in the Highest Vulnerability classification. This is based on amount of cropland on highly erodible soils. The top practice for reducing the sediment loads is implementation of a system that includes cover crop, no-till, and terraces on cropland.

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TABLES

Table 1. Annual rainfall and average annual temperature for Boonville, Missouri (1988-2017).

Year	Total Rainfall (in)	Average Temperature (˚F)
1988	30.1	53.8
1989	26.7	51.7
1990	44.3	55.6
1991	31.0	55.7
1992	35.3	53.9
1993	54.1	53.0
1994	32.8	55.1
1995	49.4	54.6
1996	39.0	53.8
1997	37.5	54.8
1998	48.0	58.4
1999	31.8	57.7
2000	38.5	56.3
2001	46.9	57.4
2002	44.9	56.6
2003	39.3	55.2
2004	42.3	55.3
2005	34.8	61.6
2006	29.0	60.8
2007	30.7	60.9
2008	37.6	62.0
2009	53.3	54.8
2010	53.0	61.9
2011	42.0	54.5
2012	29.0	59.9
2013	42.4	52.7
2014	43.7	52.4
2015	45.5	55.3
2016	34.5	55.9
2017	32.1	59.2
n	30	30
Min	26.7	51.7
Mean	39.1	56.3
Max	54.1	62.0

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

Table 2. Watershed soil characteristics summary

Soil Order	%	Hydrologic Soil Group	%	Soil Erosion K-Factor	%	Land Capability Classification	%
Alfisol	60.2	B	0.9	<0.2	0.1	2e	7.3
Entisol	2.9	B/D	5.6	0.2-0.3	3.0	2w	17.0
Mollisol	36.8	C	24.9	0.3-0.4	29.8	3e	60.0
Other	0.1	C/D	33.4	>0.4	67.0	3w	7.9
		D	35.1	other	0.1	4e	4.6
		Other	0.1			6e	2.9
						7s/8	0.1
						Other	0.2

Table 3. Drainage network summary (based on National Hydrology Dataset)

Water Feature	Length/Area
Streams	115.9 miles
Permanent Flow	40.5 miles
Intermittent Flow	73.8 miles
Concrete/Artificial	1.6 miles
Waterbodies, Lakes, Ponds	90 acres

Table 4. Generalized crop data classification from 2013-2017

General Land Use/Land Cover	Year					2013 - 2017 Average
	2013	2014	2015	2016	2017	
Row crops	46.7	49.4	46.7	52.3	55.6	50.1
DblCrop	8.5	6.7	3.2	7.5	4.1	6.0
Small Grains	1.7	1.5	4.0	0.6	0.1	1.6
Alfalfa and other Hay	3.8	3.0	3.2	5.6	5.9	4.3
Fallow/Idle Cropland and Barren	0.0	0.0	4.5	0.1	0.1	0.9
Developed Land	4.1	4.0	4.0	3.9	3.9	4.0
Forest	17.0	17.1	18.4	18.1	18.2	17.8
Grass/Pasture	17.9	17.9	15.6	11.7	12.0	15.0
Wetlands	0.2	0.1	0.2	0.1	0.1	0.1
Open Water	0.3	0.2	0.2	0.2	0.2	0.2

Table 5. Selected specific crop data from 2013-2017 with percent change.

Class Name	Year					% Change 2013-2017
	2013	2014	2015	2016	2017	
Corn	23.2	21.7	21.9	23.1	27.8	19.8
Soybeans	23.4	27.7	24.5	28.7	27.8	18.6
Dbl Crop WinWht/Soybeans	8.5	6.7	3.2	7.5	4.1	-51.8
Developed/Low Intensity	0.6	0.5	0.6	3.4	0.5	-11.1
Deciduous Forest	16.9	16.9	17.7	17.5	17.6	4.3
Grass/Pasture	17.9	17.9	15.5	11.7	12.0	-32.9
Woody Wetlands	0.2	0.1	0.1	0.1	0.01	-93.3

Table 6. Permitted point sources within the watershed.

Site Number	Facility Name	Type	Stream	Waste	Status
1	B K Farms, LLC K2 site	Animal Feeding Operation	Petite Saline Creek	Livestock waste control/ storm water construction	Compliant
2	Kliethernms Farms	Animal Feeding Operation	Petite Saline Creek	Livestock waste control	Compliant
3	B K Farms, Home Site	Animal Feeding Operation	Petite Saline Creek	Livestock waste control/storm water construction	Compliant
4	Lakeview Farms	Animal Feeding Operation	Tributary to Petite Saline Creek	Livestock waste control/storm water construction	Compliant
5	MFA Agri Service B/P - Tipton	Storm water- industrial	Petite Saline Creek	Storm Water	Compliant

Table 7. Data and source summary with web site address

Data Needed	Source	Agency	Within HUC-12 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
Water Quality	MDNR Water Quality Assessment System	MDNR		X	http://www.dnr.mo.gov/mocwis_public/wqa/waterbodySearch.do
Biological Monitoring	MDNR Water Quality Assessment System	MDNR		X	http://www.dnr.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 8. Summary of water quality data for the Headwaters Petite Saline Creek watershed

Site	River		TN (mg/L					TP (mg/L)				
ID	Mile	n	min	mean	max	stdev	cv%	min	mean	max	stdev	cv%
PSC_O	8.0	4	0.92	1.53	2.70	0.80	52.4	0.080	0.140	0.240	0.070	49.8
PSC_GF	15.2	18	0.52	2.06	6.88	1.47	71.4	0.030	0.159	0.540	0.143	89.4
PSC_87	17.4	9	0.89	1.57	3.01	0.63	39.8	0.110	0.230	0.530	0.167	72.5

Table 9. Ambient water quality criteria recommendations for total nitrogen (TN) and total phosphorus (TP), Ecoregion IX (USEPA 2000)

Parameter	25^{th} Percentile	Range
TN (mg/L)	0.71	0.28 – 6.23
TP (mg/L)	0.093	0.010-2.090

Table 10. List of aerial photos used for analysis

Photo Year	Source	Type	Resolution (ft)	Point-To-Point Error Range (ft)	Mean Point-To-Point Error (ft)
1995	USGS	Black and White DOQQ	3.3	0-17.1	6.13
2015	USGS	Color DOQQ	0.5		

Table 11. Channel classification results for the Headwaters Petite Saline Creek watershed

Stream Length (miles)					
Pond	Channelized	Active	Not Visible	Stable	Total
0.4	3.0	37.2	40.3	54.6	135.5
(0.3%)	(2.2%)	(27.5%)	(29.7%)	(40.3%)	(100%)

Table 12. Riparian corridor classification results for the Headwaters Petite Saline Creek watershed

Total Length (mi)	Good	Moderate	Poor
135.5	35.6	54.9	44.9
	(26%)	(41%)	(33%)

Table 13. Existing conservation practice estimates for cropland in the watershed

Conservation Practices	% of Cropland
No Practices	11.2
Cover Crop	2.8
Terraces	44.8
Terrace and Cover Crop	11.2
No-till	4.8
No-till and Terraces	19.2
No-till and Cover Crop	1.2
No-till, Terraces, and Cover Crops	4.8
Cropland with Conservation	88.8%
Cropland without Conservation	11.2%
Combined Efficiencies	N = 0.328 P = 0.462 Sed = 0.549

Table 14. 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
103001020401	30,826	30,811	1.0	30.3	201,125	40,893	20,101	6.5	1.3	0.65	2.40	0.488	480

Table 15. STEPL load results by sources

Sources	N Load (lb/yr)	%	P Load (lb/yr)	%	Sediment Load (t/yr)	%
Urban	10,027	5.0	1,554	3.8	230	1.1
Cropland	139,535	69.4	29,482	72.1	11,086	55.2
Pastureland	37,860	18.8	4,357	10.7	1,529	7.6
Forest	2,228	1.1	1,081	2.6	90	0.4
Septic	10.4	0.0	4.1	0.0	0.0	0.0
Streambank	11,465	5.7	4,414	10.8	7,165	35.6
Total	201,125	100	40,893	100	20,101	100

Table 16. Nitrogen load reduction results for the Headwaters Petite Saline Creek watershed by conservation practice. Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	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	5.1	6.4	7.7	9.0	10.3	11.6	12.9
Terrace	2.3	4.7	7.0	9.3	11.7	14.0	16.3	18.7	21.0	23.3
No-Till	3.2	6.5	9.7	13.0	16.2	19.4	22.7	25.9	29.2	32.4
Cover Crop and terrace	3.3	6.5	9.8	13.0	16.3	19.5	22.8	26.0	29.3	32.6
Cover Crop and No-Till	4.1	8.2	12.0	16.3	20.4	24.5	28.5	32.6	36.7	40.8
No-Till and Terrace	4.5	8.9	13.0	17.9	22.4	26.8	31.3	35.8	40.3	44.7
Cover Crop, No-Till- and Terrace	5.1	10.2	15.0	20.4	25.5	30.5	35.6	40.7	45.8	50.9
Cover Crop, No-Till, Terrace, Nutrient Management	5.7	11.4	17.0	22.7	28.4	34.1	39.7	45.4	51.1	56.8
Land Retirement	7.1	14.2	21.0	28.5	35.6	42.7	49.8	56.9	64.0	71.1
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Prescribed Grazing	0.5	1.1	1.6	2.2	2.7	3.2	3.8	4.3	4.9	5.4
Prescribed Grazing and Alternative Water	0.7	1.3	2.0	2.6	3.3	4.0	4.6	5.3	5.9	6.6
Prescribed Grazing, Alternative Water, Heavy Use Protection	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0

Table 17. Phosphorus load reduction results for the Headwaters Petite Saline Creek watershed by conservation practice. Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	**Phosphorous load reduction by % of land treated**									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0
Terrace	2.9	5.8	8.7	11.7	14.6	17.5	20.4	23.3	26.2	29.2
No-Till	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0
Cover Crop and terrace	3.4	6.7	10.0	13.4	16.8	20.2	23.5	26.9	30.2	33.6
Cover Crop and No-Till	6.2	12.4	19.0	24.7	30.9	37.1	43.3	49.5	55.7	61.9
No-Till and Terrace	6.8	13.6	20.0	27.1	33.9	40.7	47.4	54.2	61.0	67.8
Cover Crop, No-Till- and Terrace	6.9	13.8	21.0	27.6	34.5	41.4	48.3	55.2	62.1	69.0
Cover Crop, No-Till, Terrace, Nutrient Management	7.4	14.7	22.0	29.4	36.8	44.2	51.5	58.9	66.3	73.6
Land Retirement	7.2	14.5	22.0	29.0	36.2	43.4	50.7	57.9	65.2	72.4
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Prescribed Grazing	0.2	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.8
Prescribed Grazing and Alternative Water	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.5
Prescribed Grazing, Alternative Water, Heavy Use Protection	0.4	0.7	1.1	1.4	1.8	2.1	2.5	2.9	3.2	3.6

Table 18. Sediment load reduction results for the Headwaters Petite Saline Creek watershed by conservation practice. Areas highlighted in gray indicate percentage of land with existing conservation practices.

List of Practices	**Sediment load reduction by % of land treated**									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.4	7.1
Terrace	2.8	5.6	8.5	11.3	14.1	16.9	19.8	22.6	25.4	28.2
No-Till	5.4	10.9	16.0	21.7	27.2	32.6	38.0	43.5	48.9	54.3
Cover Crop and Terrace	3.2	6.5	9.7	13.0	16.2	19.5	22.7	26.0	29.2	32.5
Cover Crop and No-Till	5.6	11.2	17.0	22.4	28.0	33.6	39.2	44.8	50.4	56.0
No-Till and Terrace	6.1	12.2	18.0	24.3	30.4	36.5	42.6	48.7	54.8	60.8
Cover Crop, No-Till- and Terrace	6.2	12.4	19.0	24.7	30.9	37.1	43.3	49.5	55.6	61.8
Cover Crop, No-Till, Terrace, Nutrient Management	6.2	12.4	19.0	24.7	30.9	37.1	43.3	49.5	55.6	61.8
Land Retirement	6.7	13.4	20.0	26.8	33.5	40.2	46.9	53.6	60.3	67.0
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Prescribed Grazing	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.7
Prescribed Grazing and Alternative Water	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.1	0.7
Prescribed Grazing, Alternative Water, Heavy Use Protection	0.3	0.6	1.0	1.3	1.6	1.9	2.2	2.6	2.9	3.2

Table 19. Management unit priority ranking for Headwaters Petite Saline Creek watershed

Watershed ID	Total Ad (acres)	Crop (acres)	Pasture (acres)	Annual Yield Sed (T/ac/yr)	Priority Rank
5	2,378	2,088	65	1.06	1
3	1,951	1,611	84	0.95	2
8	1,791	795	364	0.86	3
7	3,063	1,776	565	0.86	4
9	2,451	1,757	202	0.80	5
4	3,515	2,284	498	0.76	6
6	1,664	740	200	0.76	7
11	2,958	1,314	460	0.76	8
2	2,898	2,245	341	0.75	9
12	2,035	1,021	439	0.74	10
10	2,837	1,708	302	0.73	11
1	3,306	2,910	190	0.52	12

Table 20. Summary of vulnerable acres for Headwaters Petite Saline Creek watershed

Vulnerability Rank	Land Use and Conditions	HPSC Acres (%)
Highest	Cropland with Erodibility Index ≥ 8	13,562 44.0%
High	Cropland with Erodibility Index < 8	6,699 21.7%
Moderate	Pasture	3,689 12.0%
Low	Forest	5,592 18.1%
N/A	Urban Water and wetlands	1,284 4.2%
	Total	30,826 100.0%

Table 21. Conservation practice ranking for Headwaters Petite Saline Creek watershed.

Rank	**Conservation Practices Ranking for sediment reduction**
1	CROPLAND - Land Retirement
2	CROPLAND - Cover Crop, No-Till, Terrace, and Nutrient Management
3	CROPLAND - Cover Crop, No-Till, and Terrace
4	CROPLAND - No-Till and Terrace
5	CROPLAND - Cover Crop and No-Till
6	CROPLAND - Cover Crop and Terrace
7	CROPLAND - No-Till
8	CROPLAND - Terrace
9	CROPLAND - Cover Crop
10	PASTURELAND - Prescribed Grazing, Alternative Water, and Heavy Use Protection
11	PASTURELAND - Prescribed Grazing and Alternative Water
12	PASTURELAND - Prescribed Grazing

FIGURES

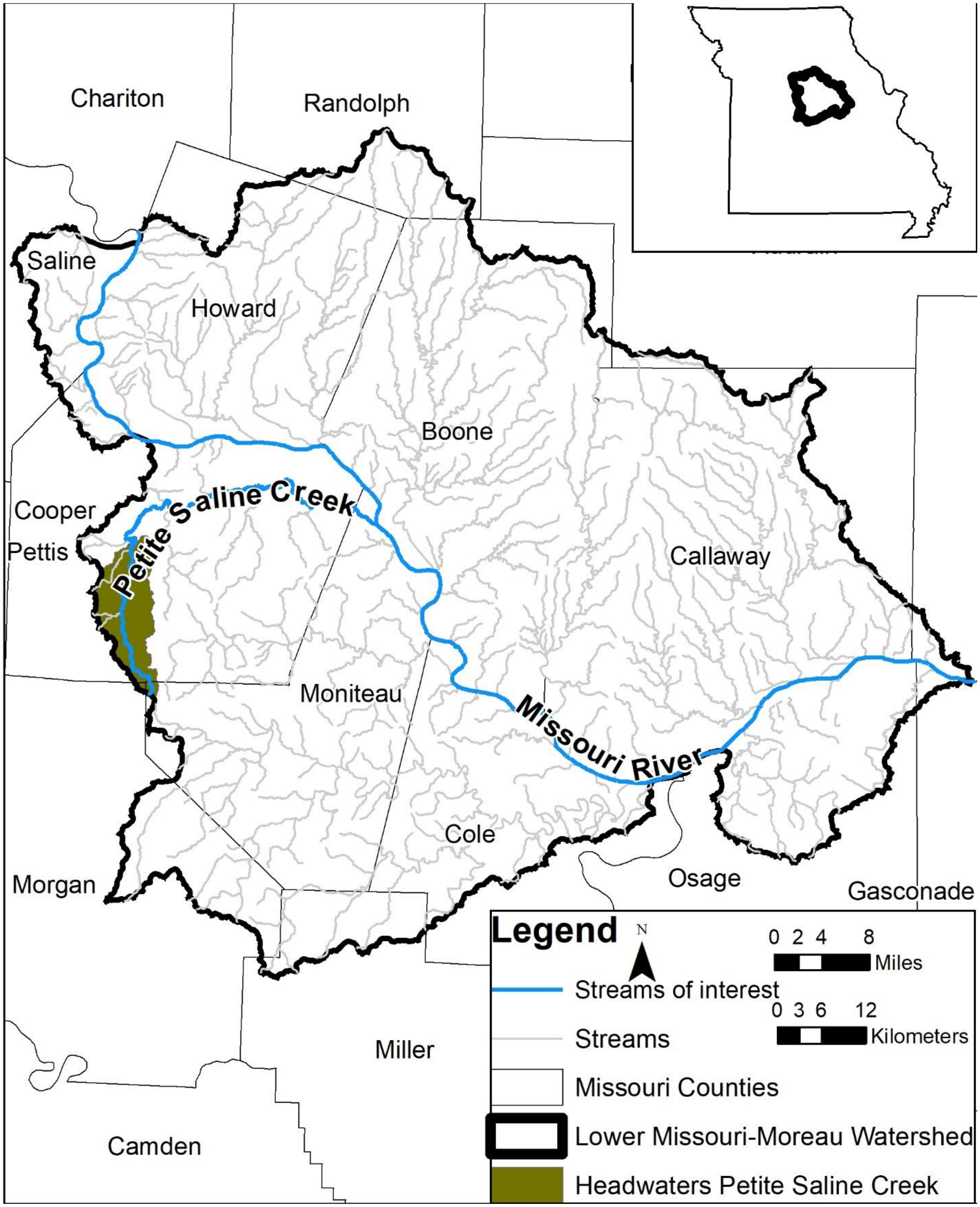


Figure 1. Location of Headwaters Petite Saline Creek in the Lower Missouri-Moreau Watershed.

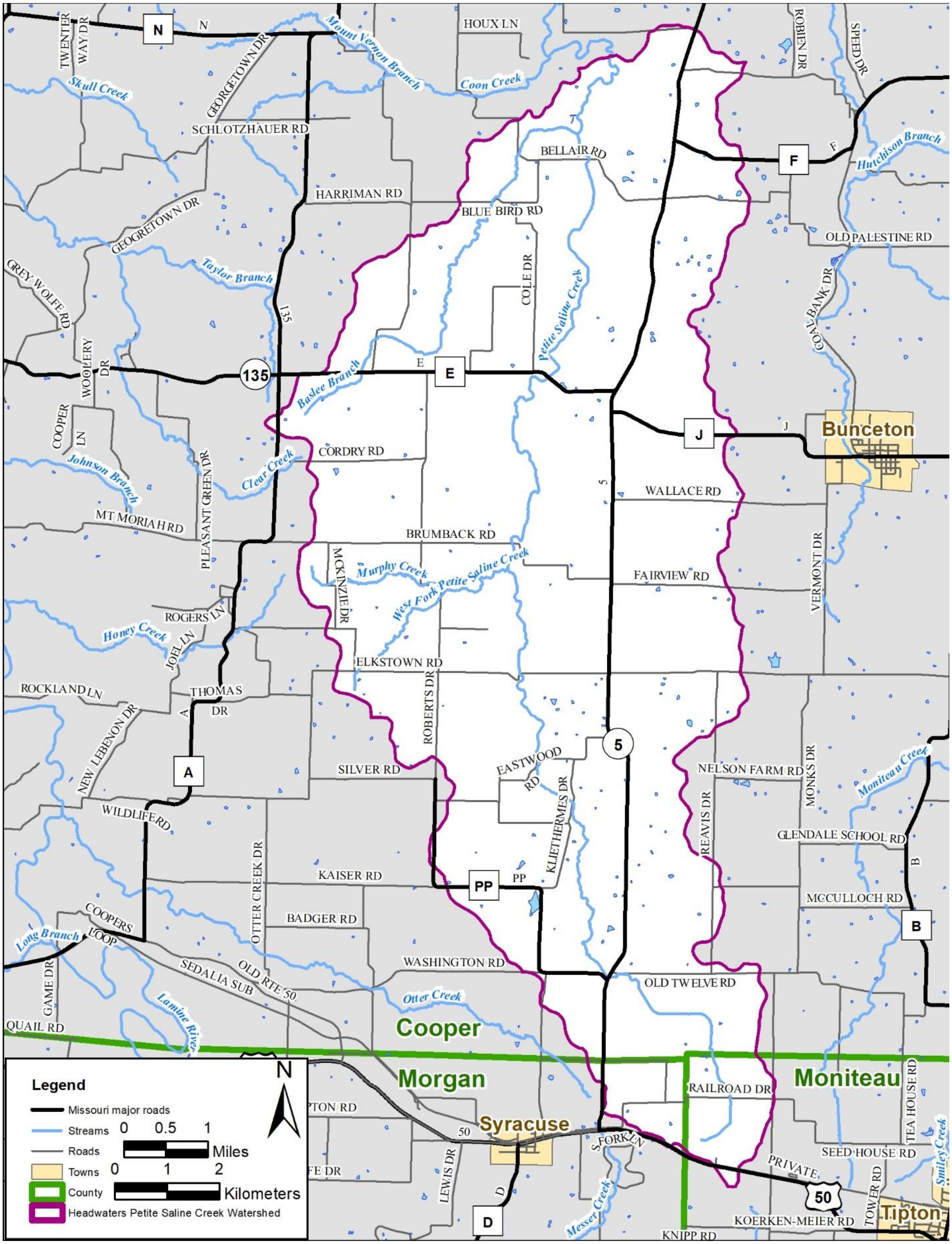


Figure 2. The Headwaters Petite Saline Creek watershed.

A)

B)

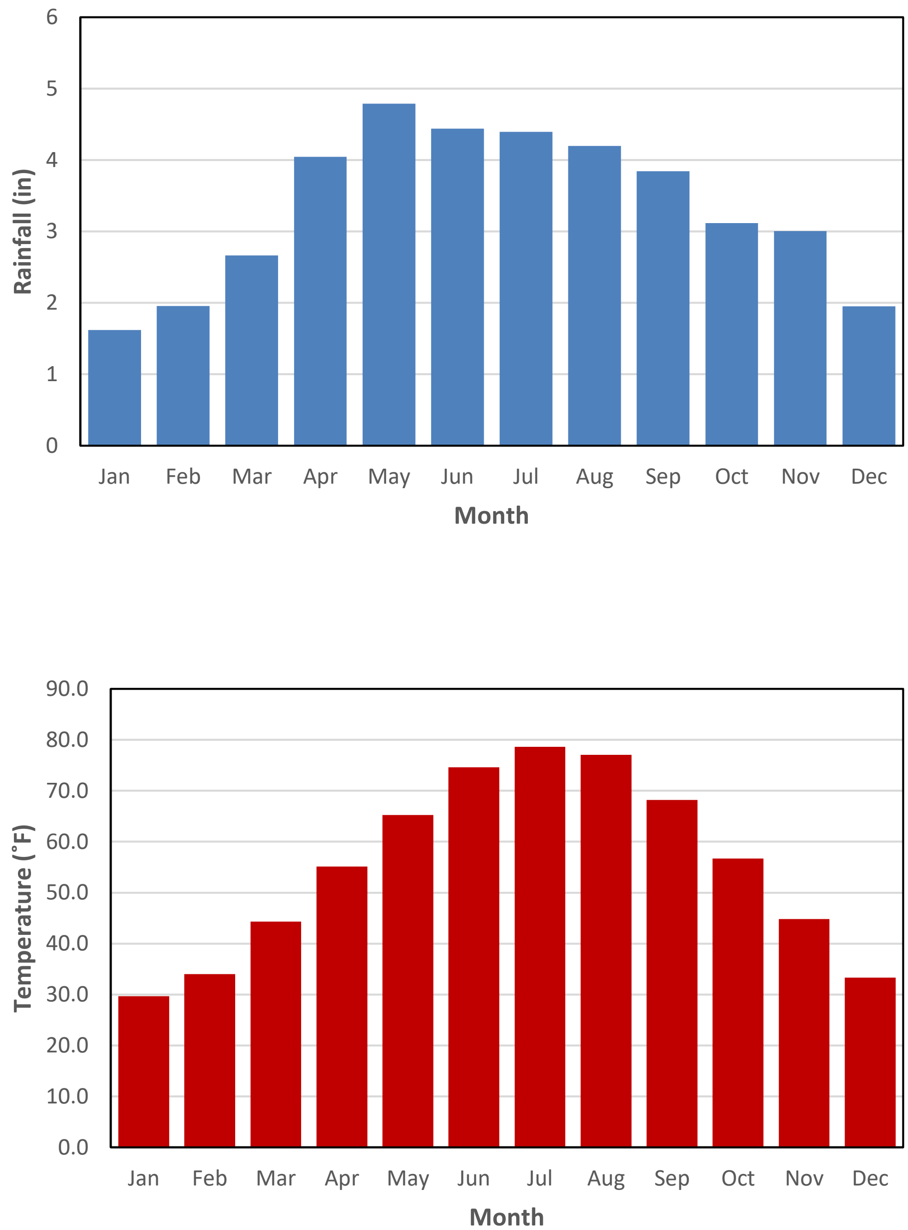
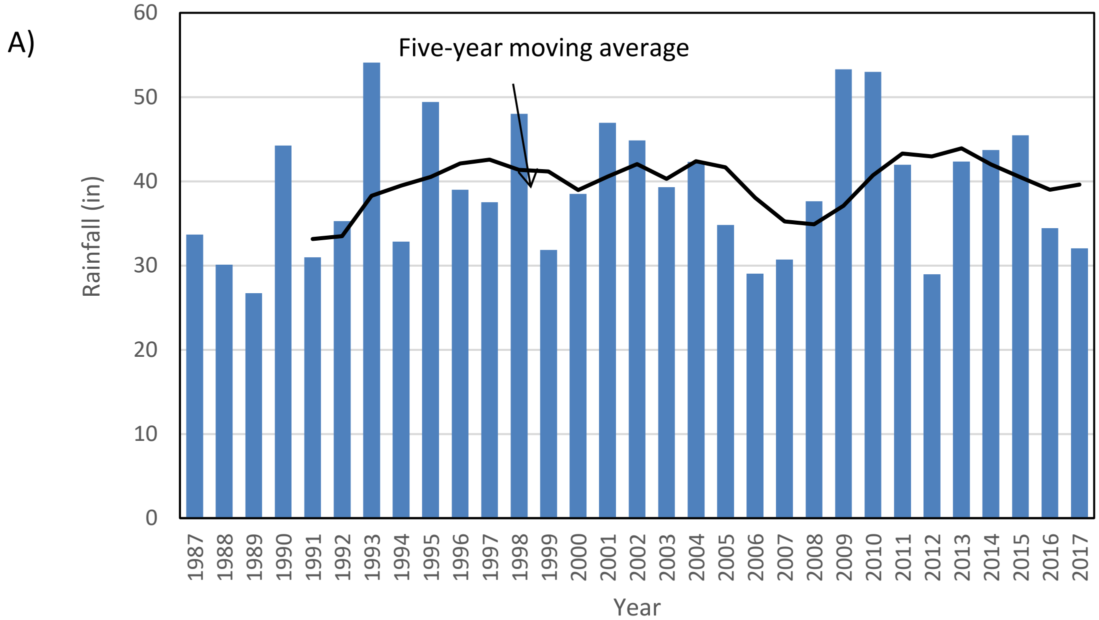


Figure 3. Mean monthly A) rainfall and B) temperature from 1988-2017 for Boonville, Missouri.



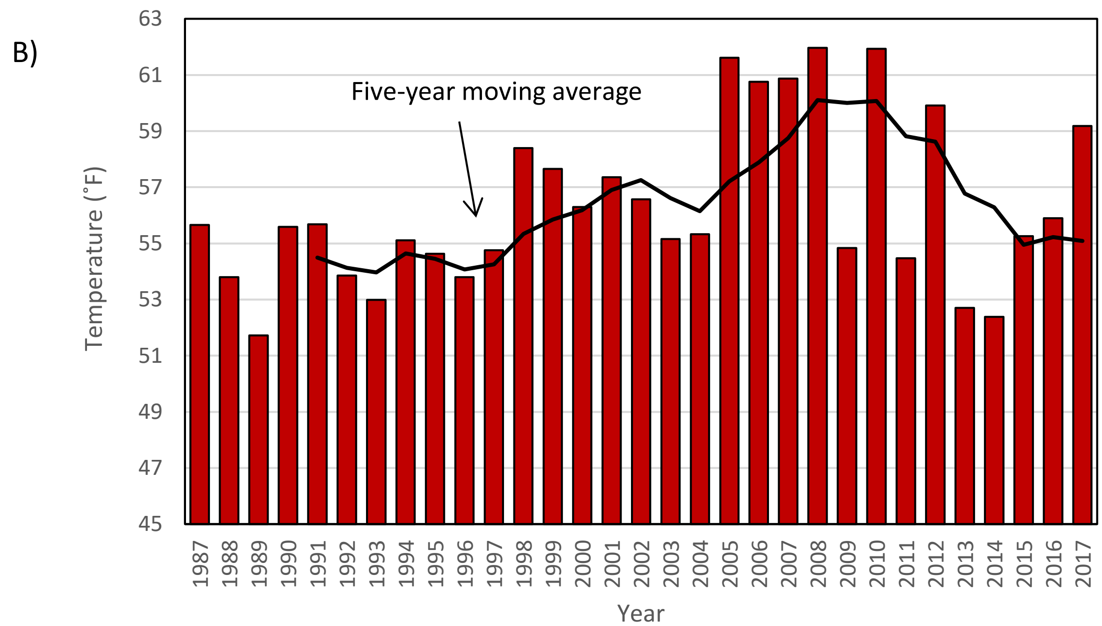


Figure 4. A) Annual total and B) average annual temperature from 1987-2017 for Boonville, Missouri.

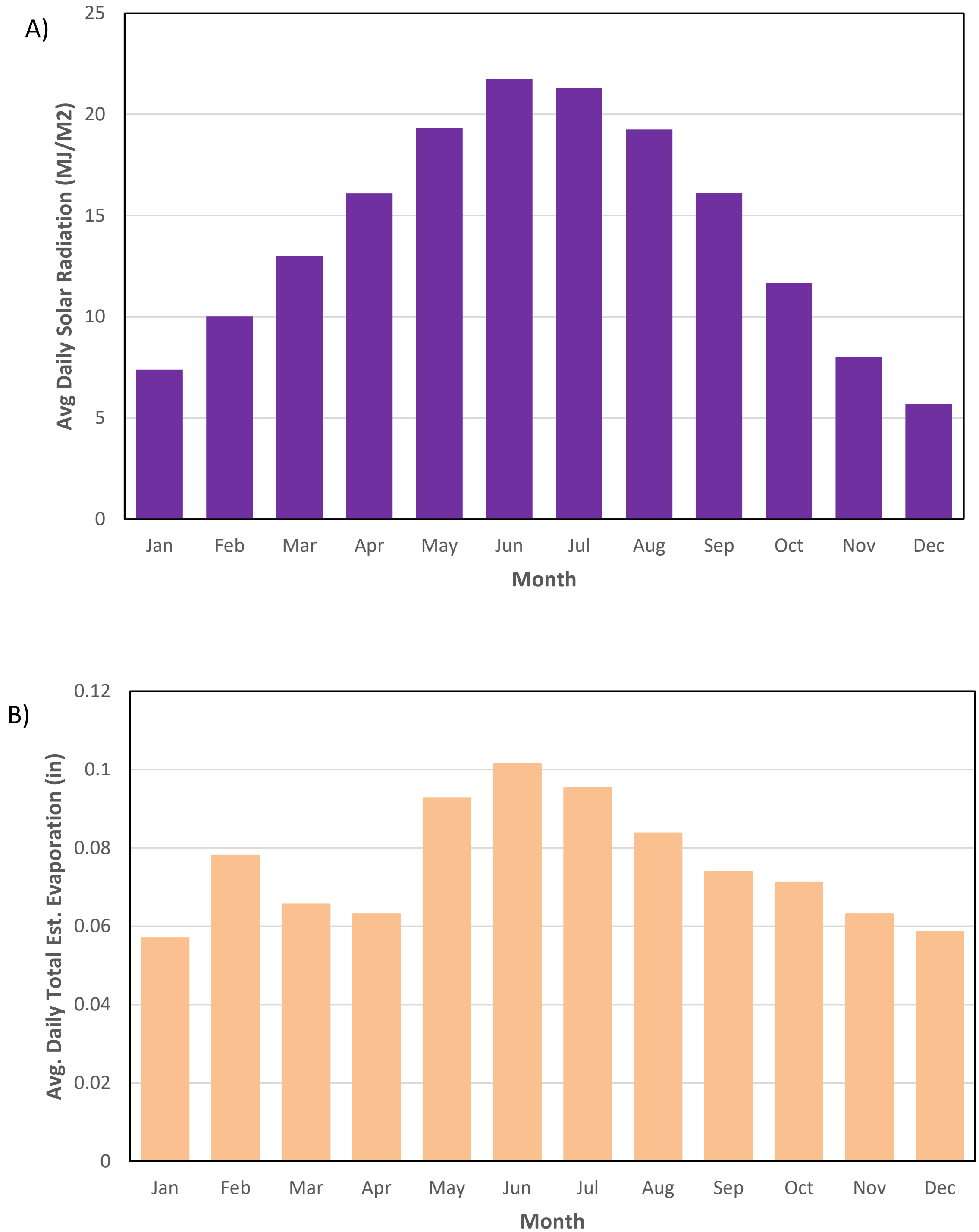


Figure 5. Average daily A) solar radiation (2008-2017) and B) estimated evaporation (2015-2017) for Boonville, Missouri.

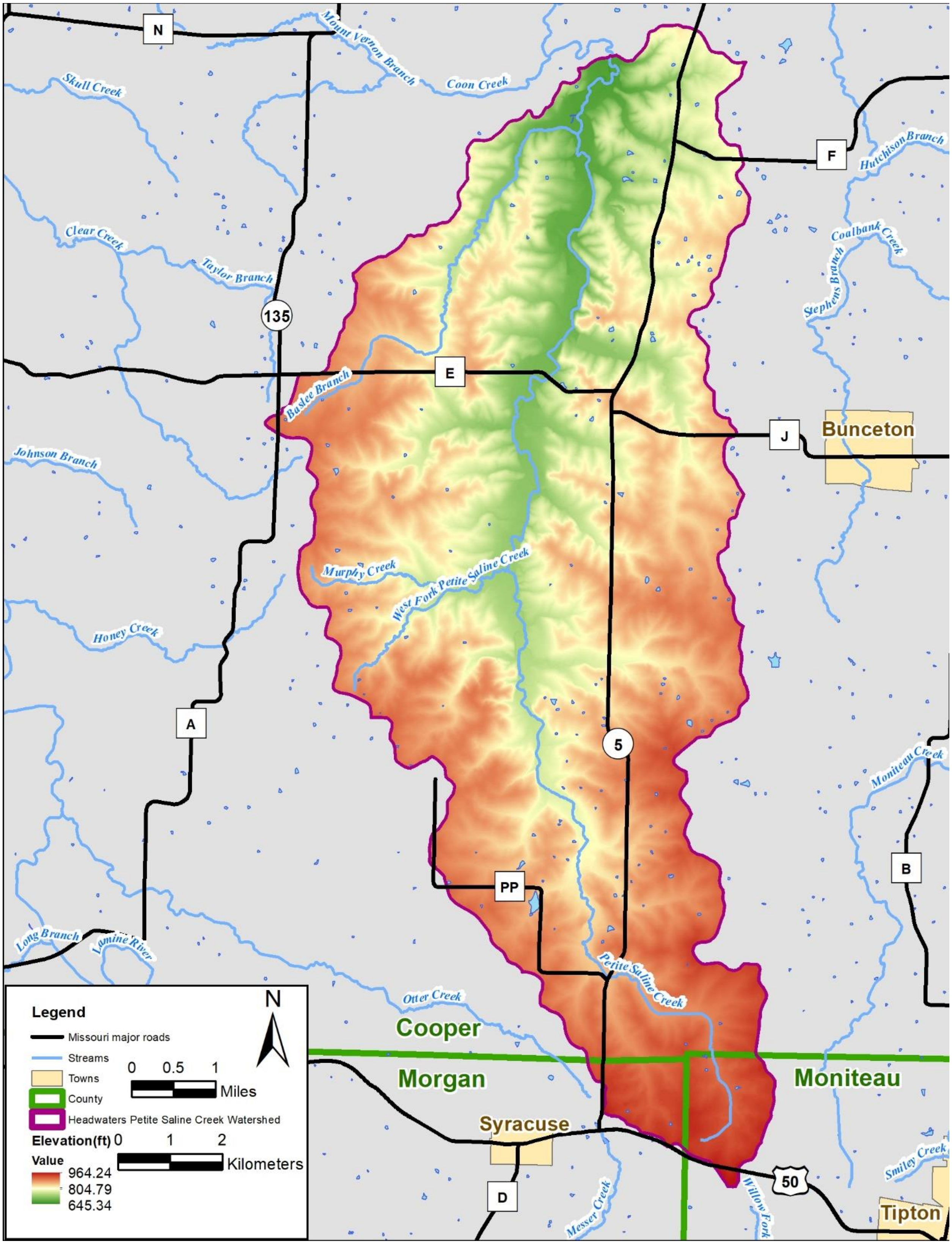


Figure 6. Elevations within the watershed.

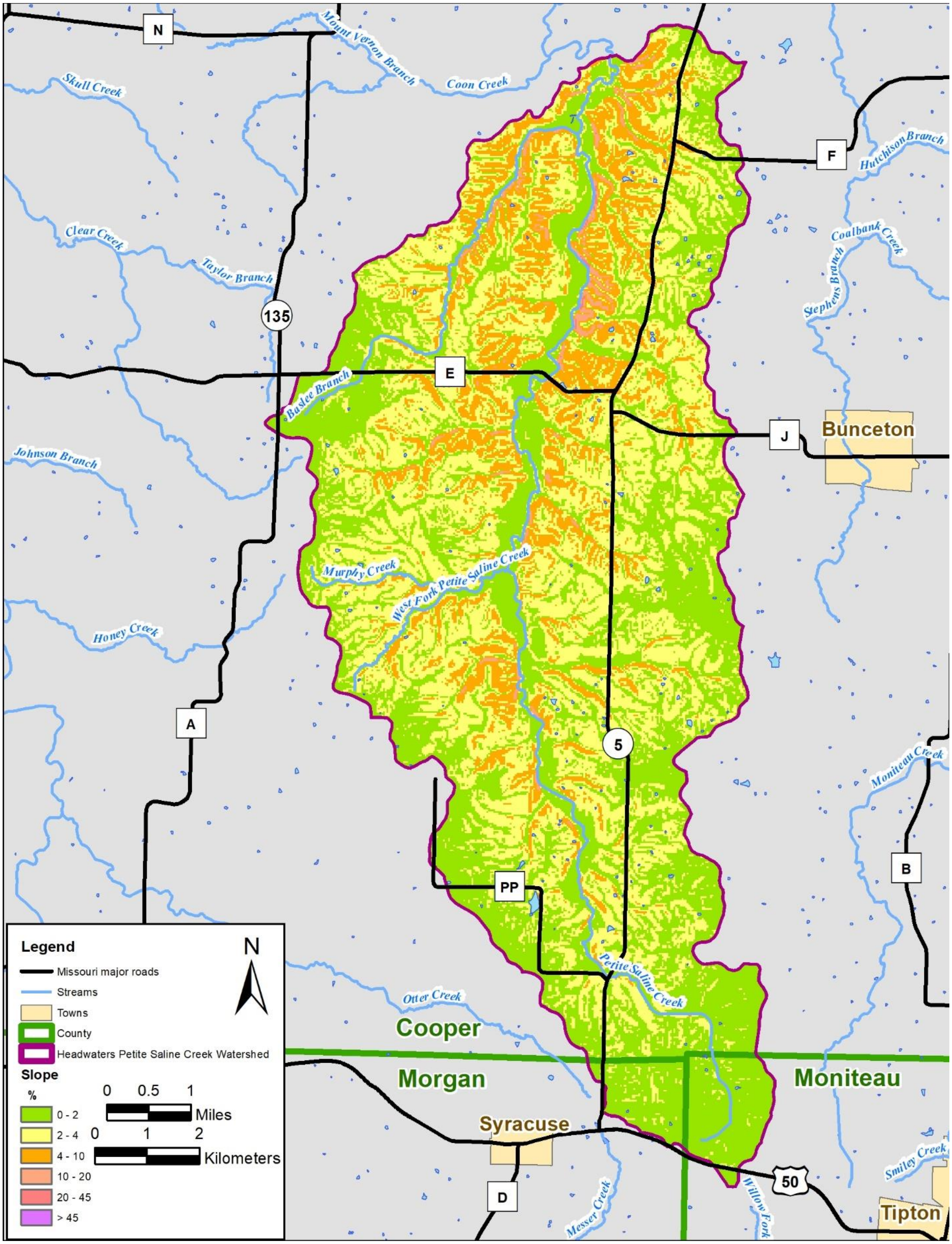
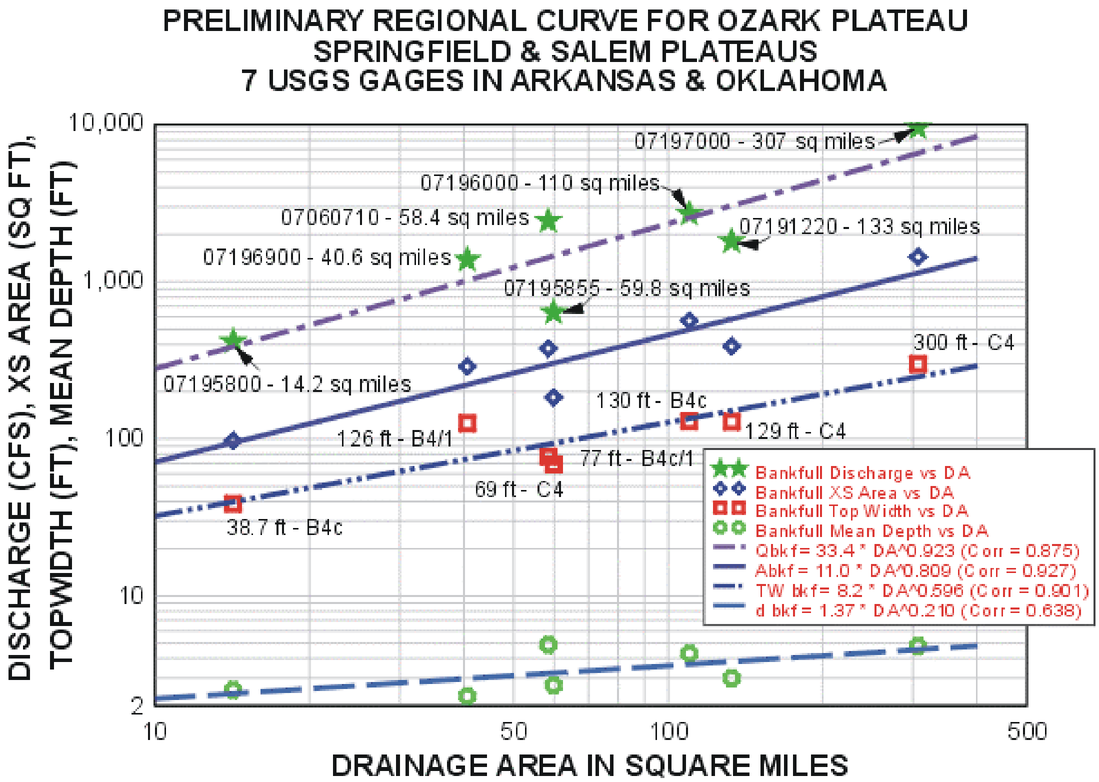


Figure 7. Slope classification across the watershed.

A)



B)

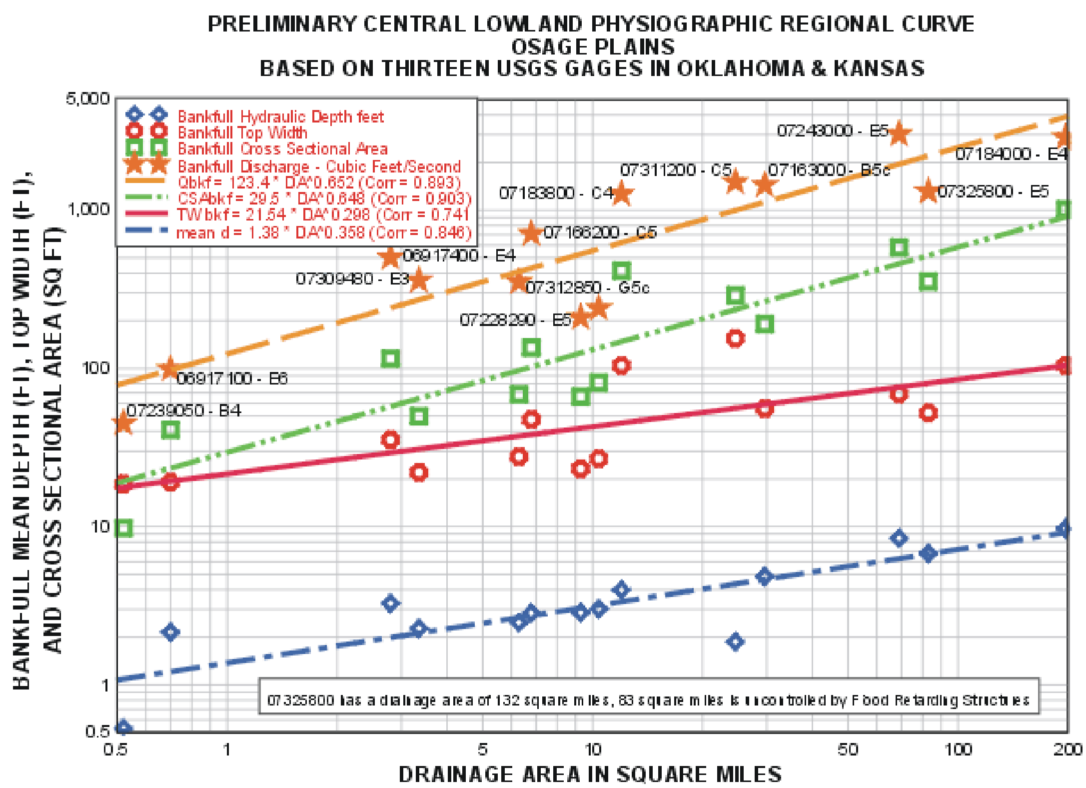


Figure 8. Regional channel geometry curves for A) Springfield and Salem Plateaus and B) Osage Plains. Source: NRCS-National Water Management Center

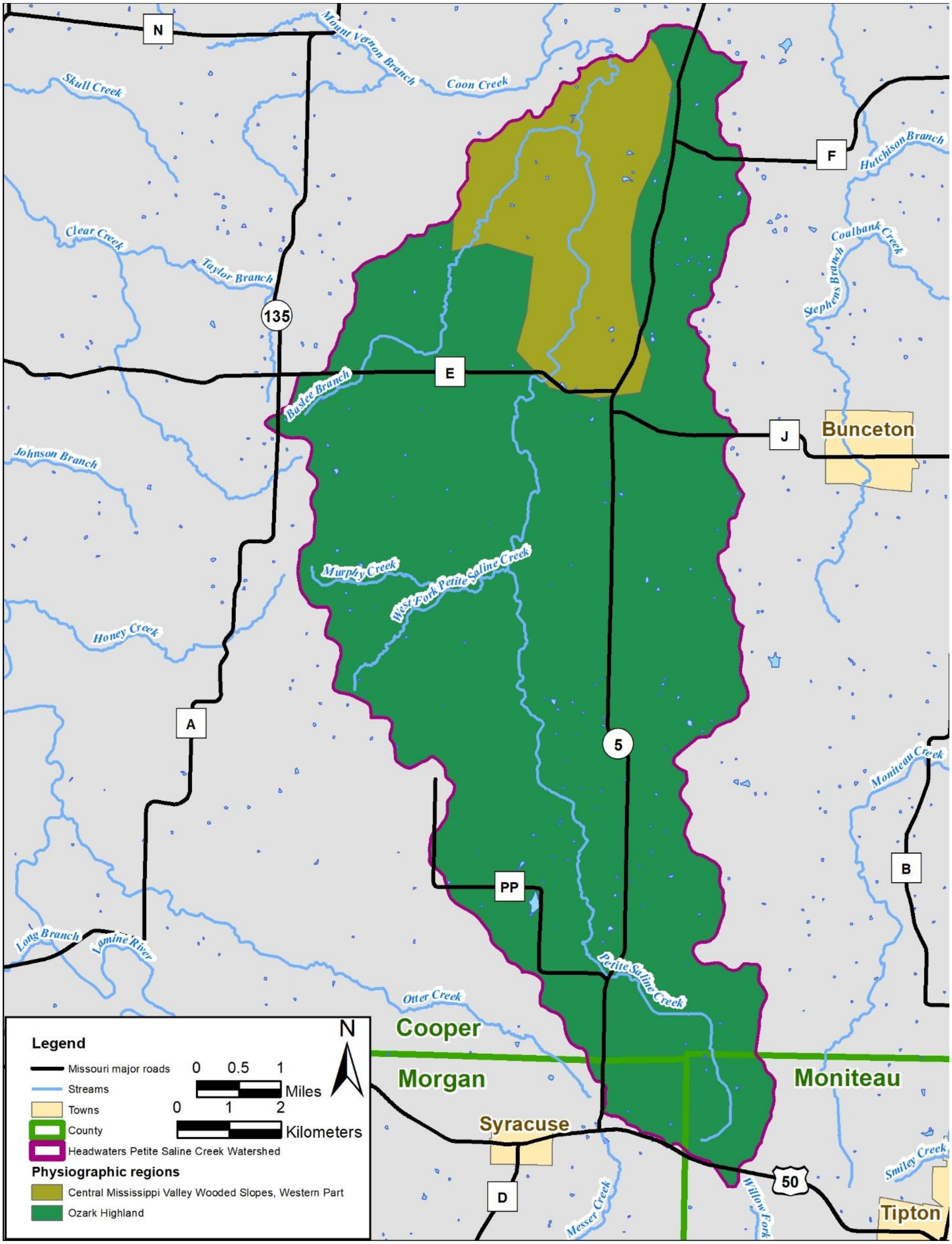


Figure 9. Major Land Resource Area

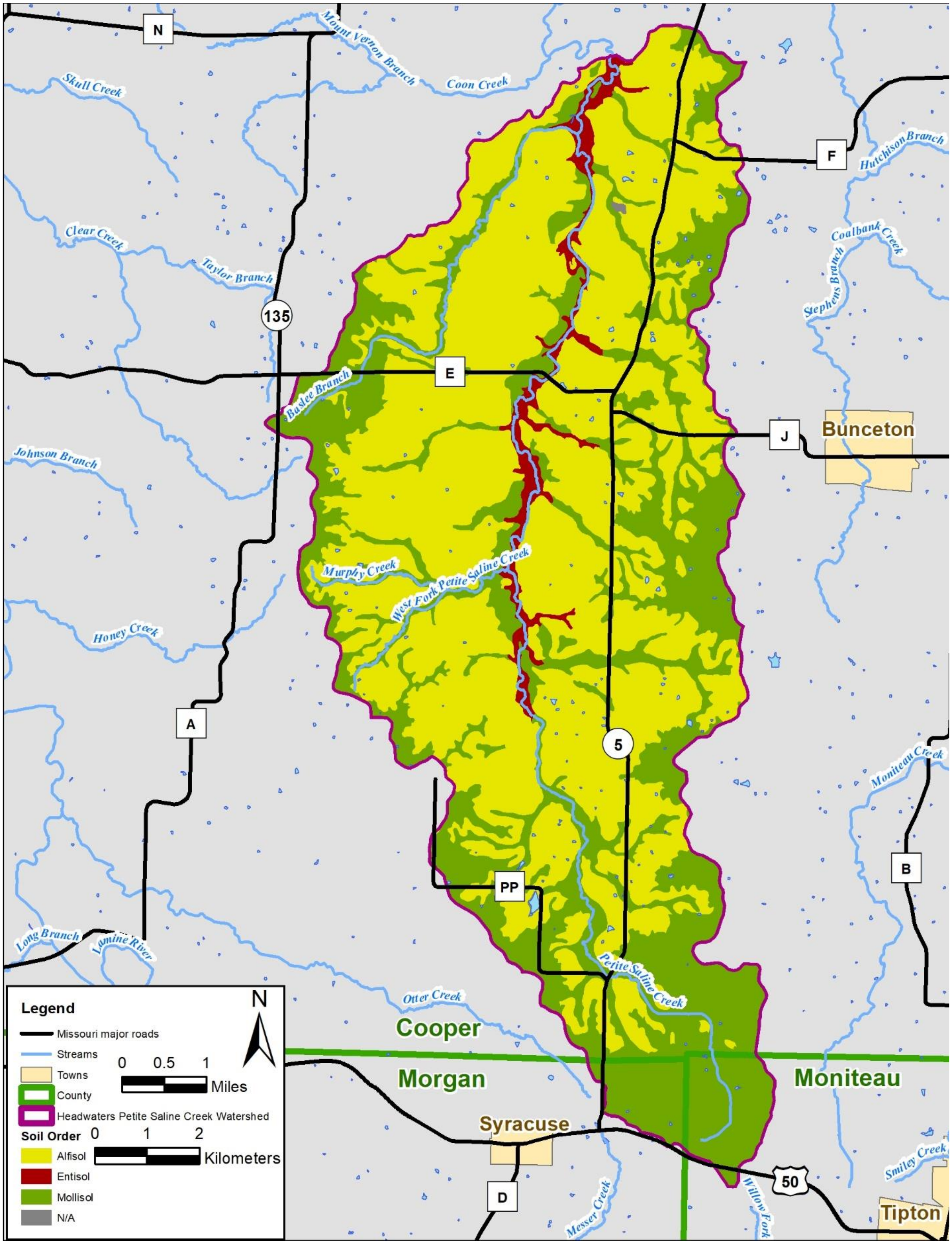


Figure 10. Soil series classified by order.

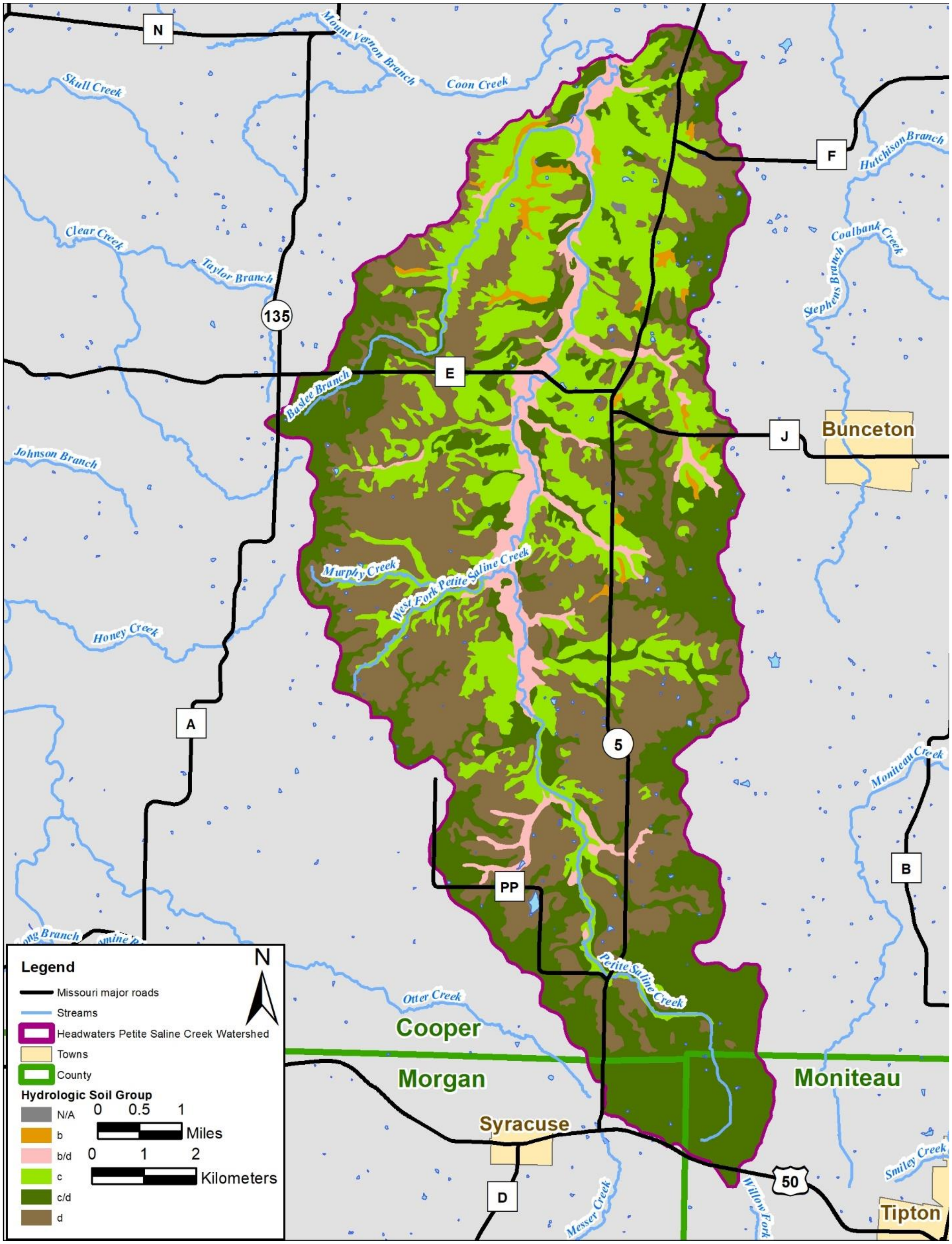


Figure 11. Soil series classified by hydrologic soil group.

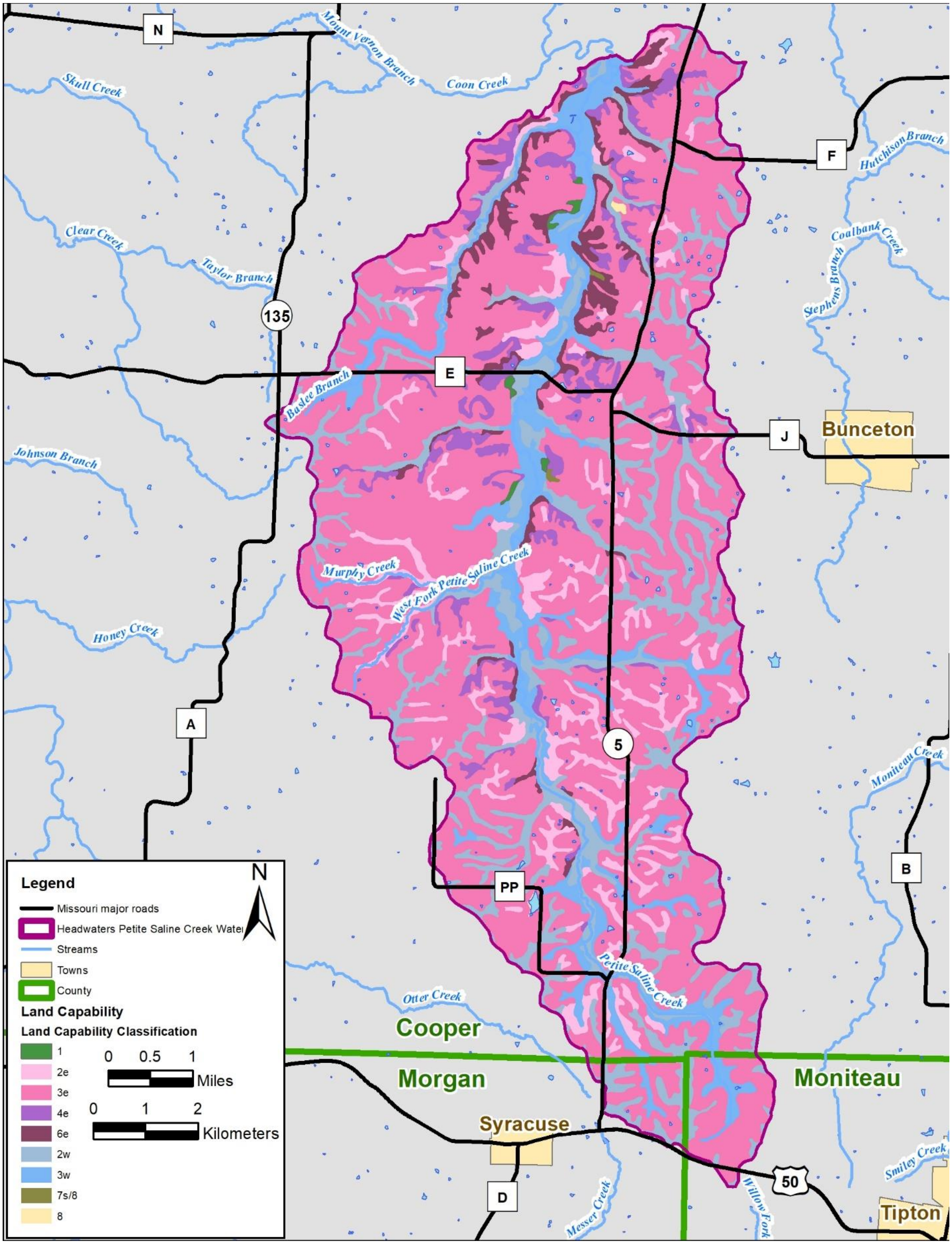


Figure 12. Soil series classified by land capability classification.

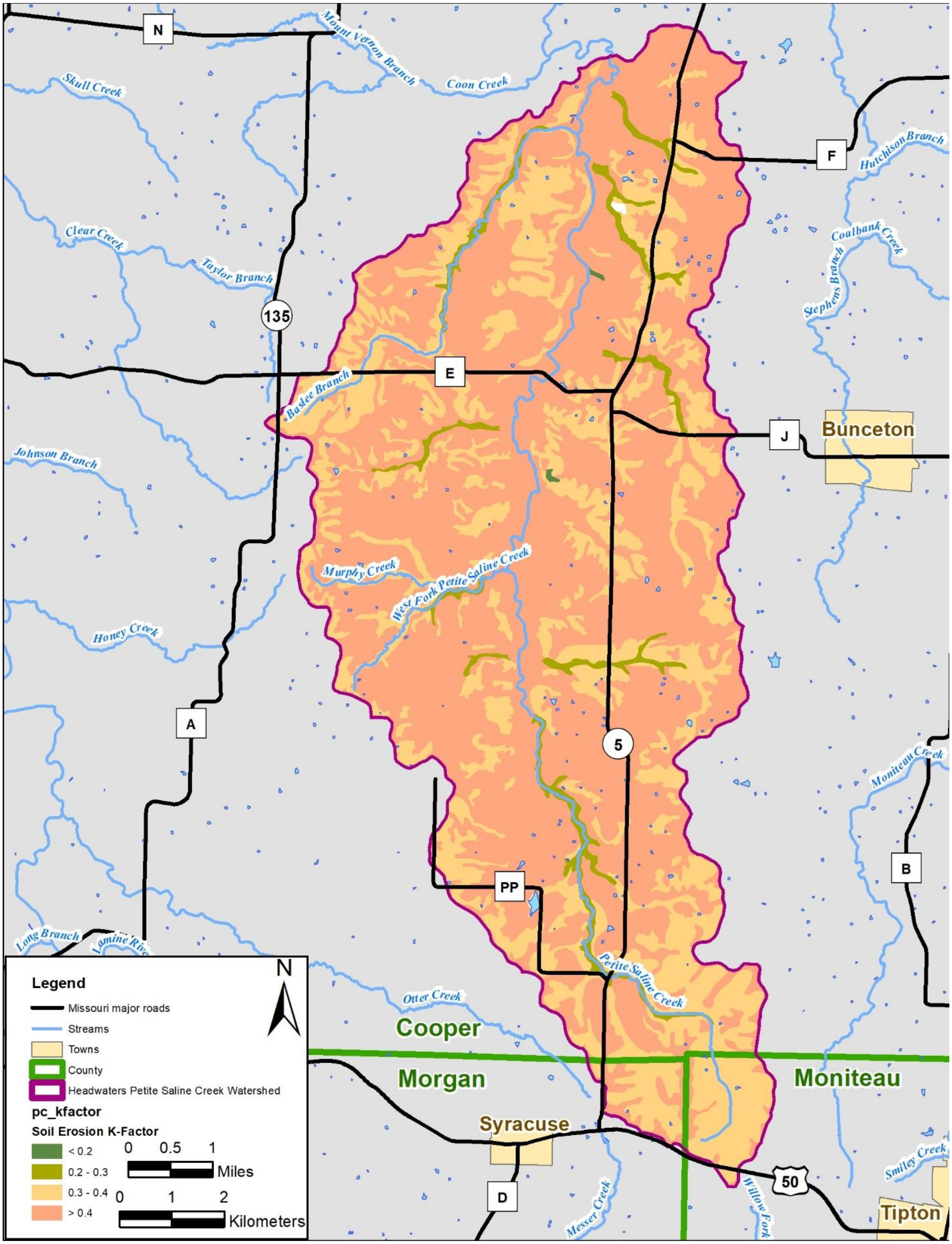


Figure 13. Soil series classified by soil erosion K-factor.

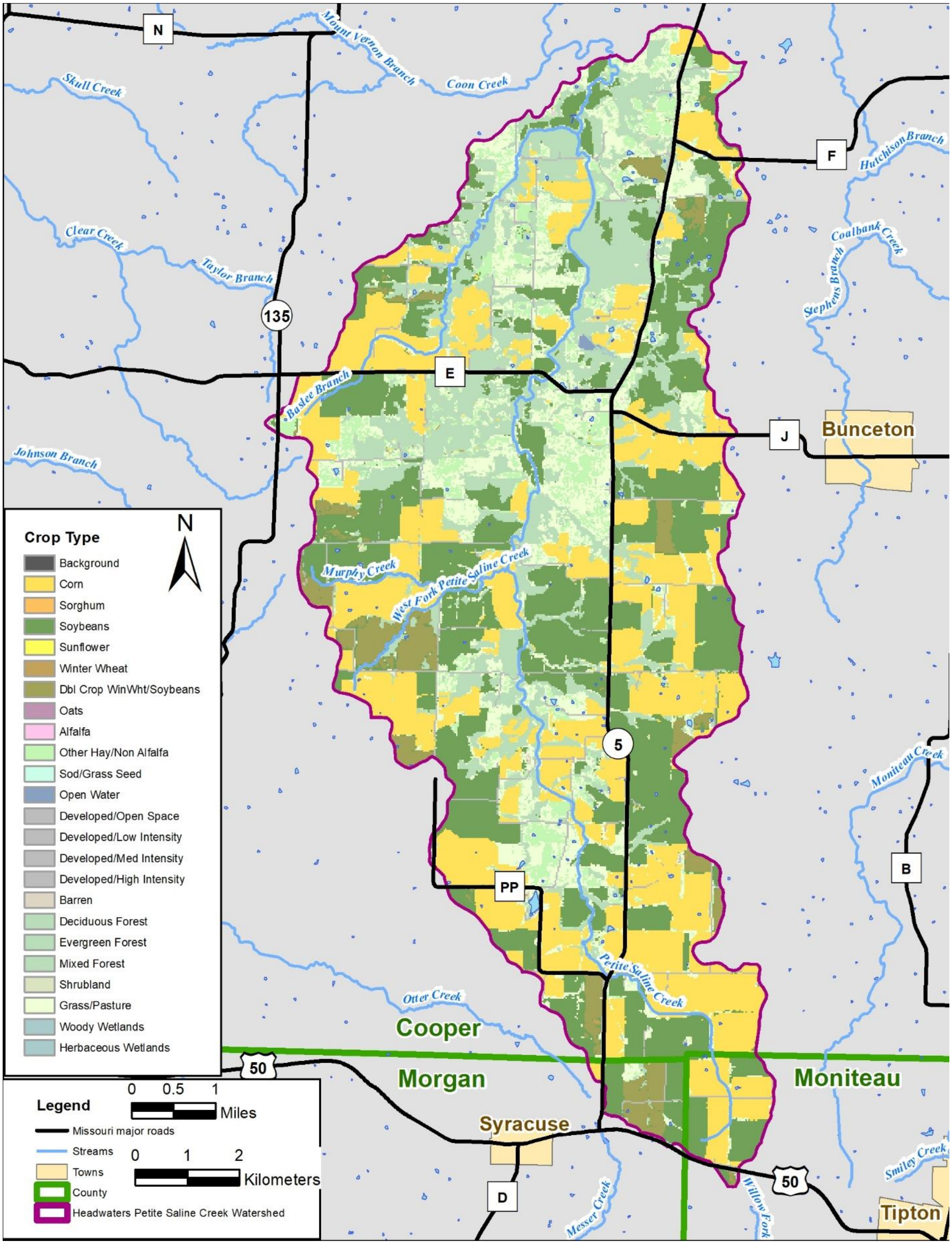


Figure 14. 2017 crop data from the NASS.

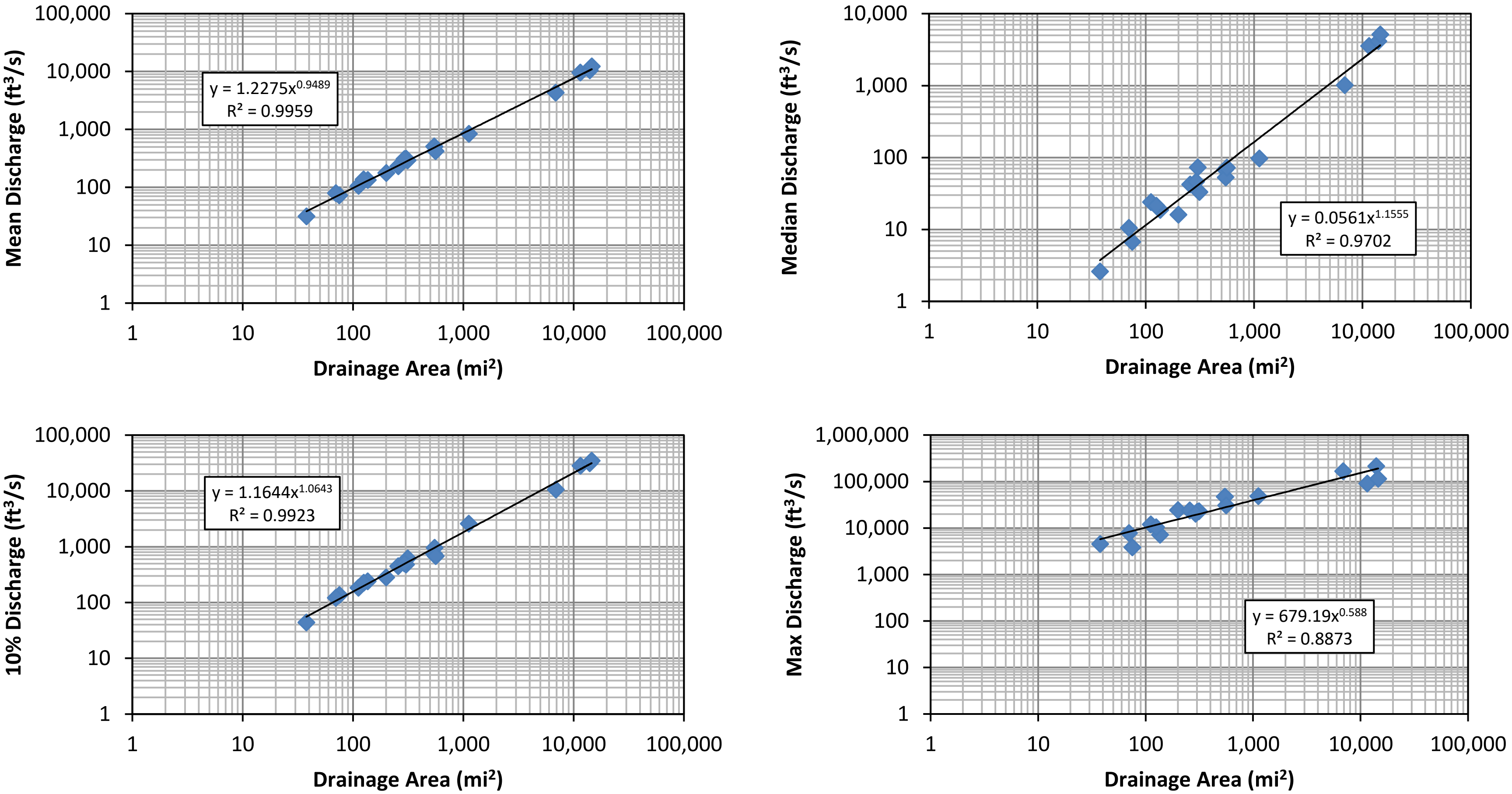


Figure 15. Drainage area and discharge relationships for 24 USGS gaging stations near the study watershed.

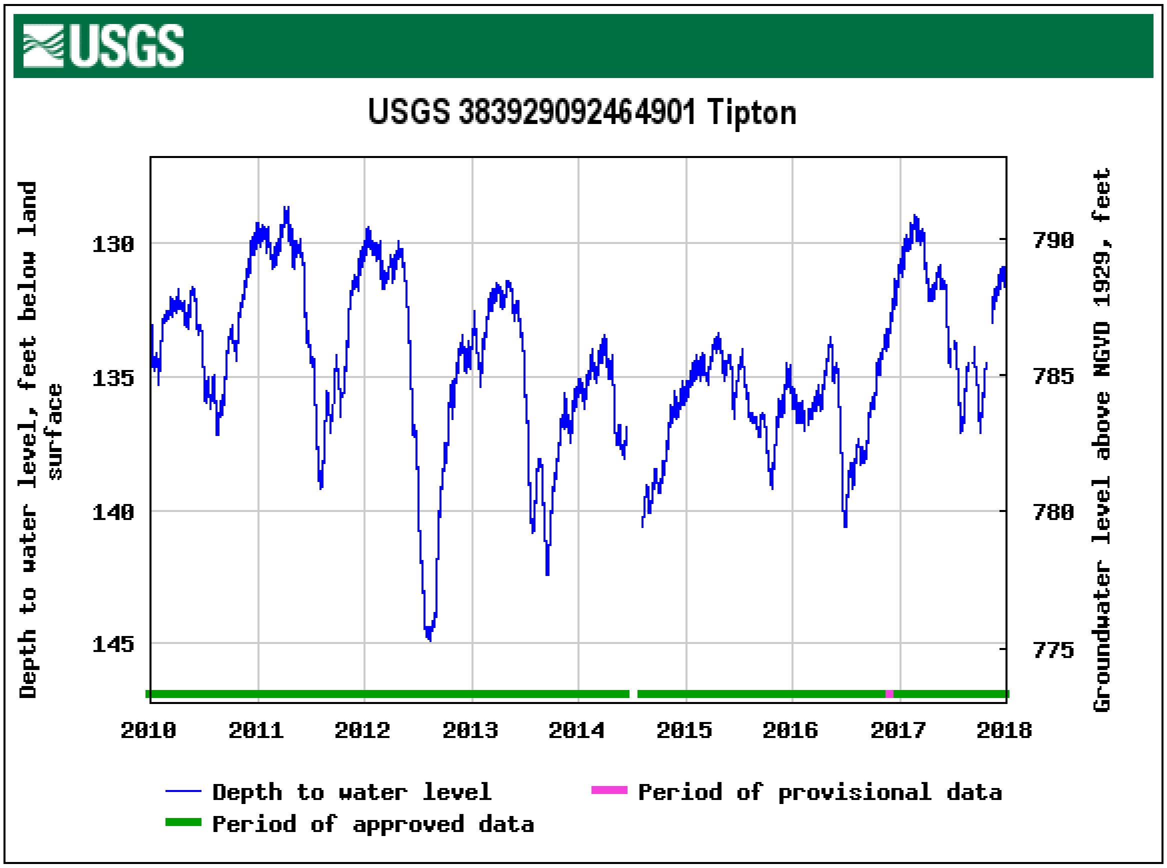


Figure 16. Ground water level change for Tipton (2010-2017).

https://nwis.waterdata.usgs.gov/nwis/gwlevels?site_no=383929092464901&begin_date=01/01/2010&end_date=12/31/2017&format=img&submitted_form=brief_list&pres_qual=y

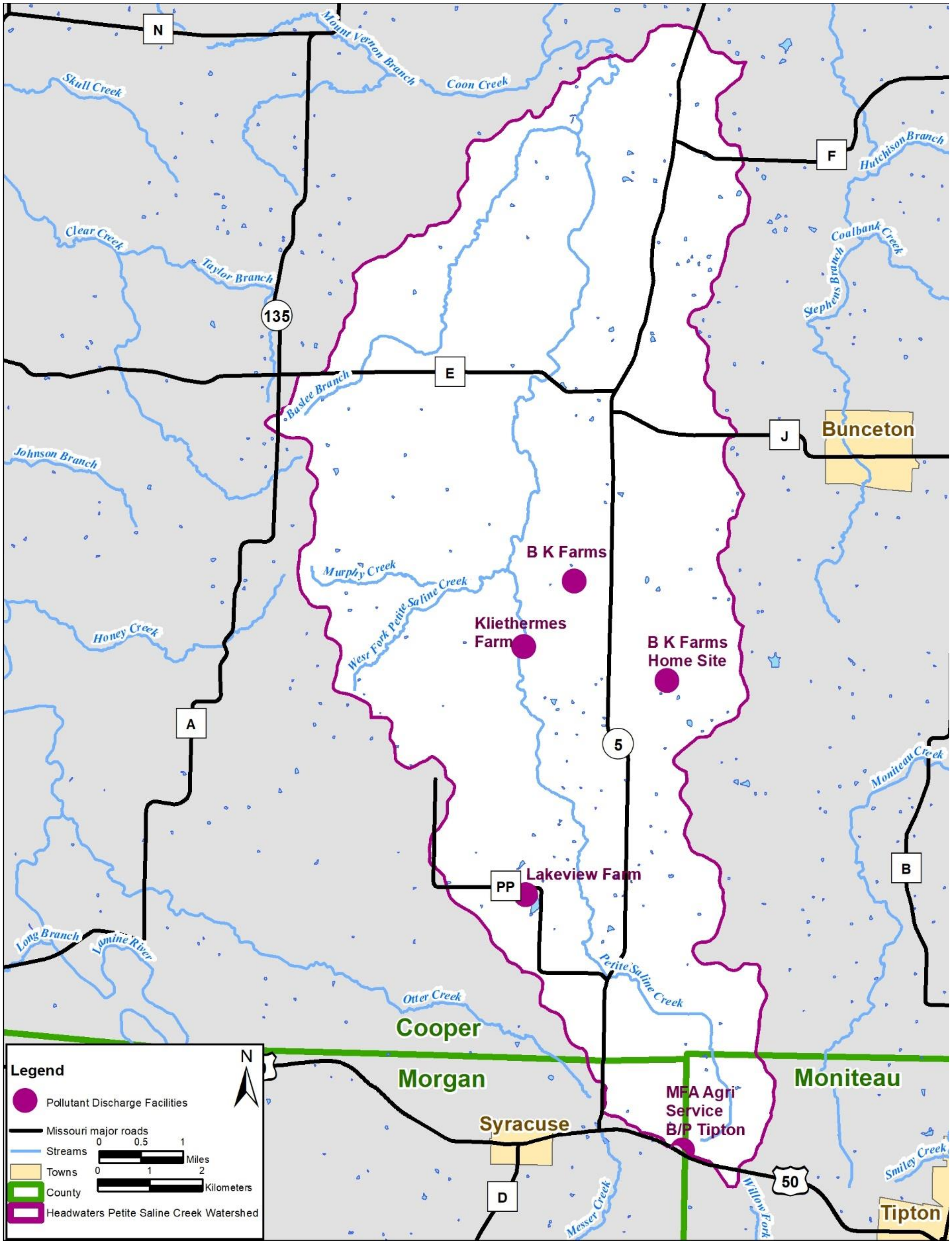


Figure 17. Permitted Point Sources and Confined Animal Feeding Operation Locations.

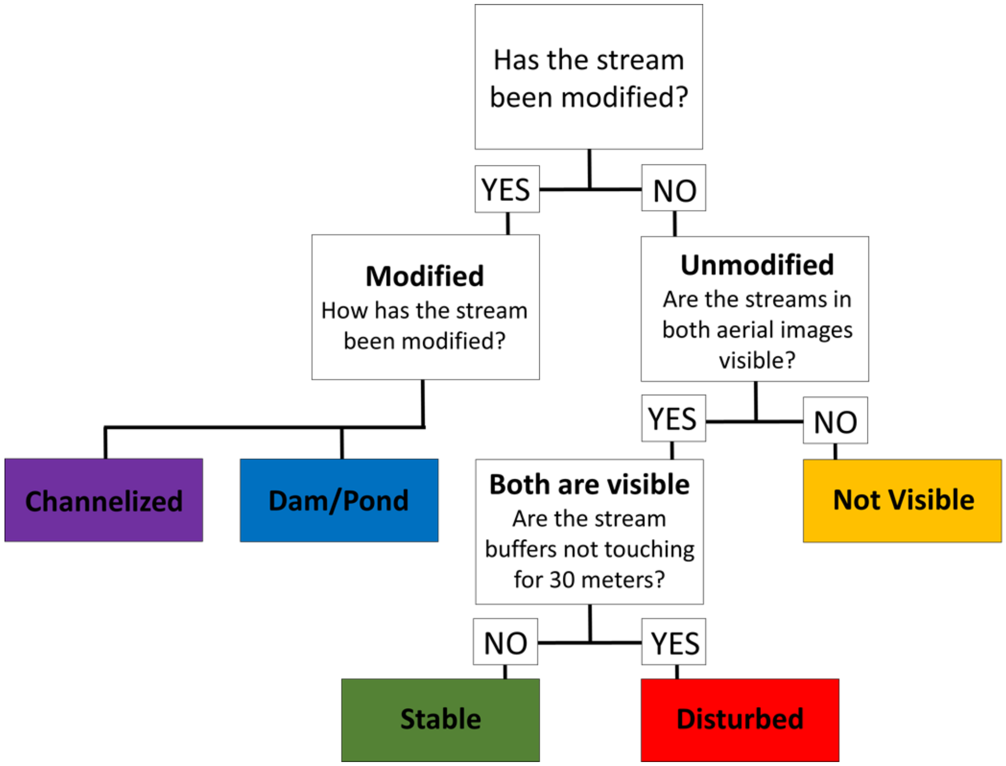


Figure 18. Flow chart showing decision tree for classifying stream channels from aerial photo analysis.

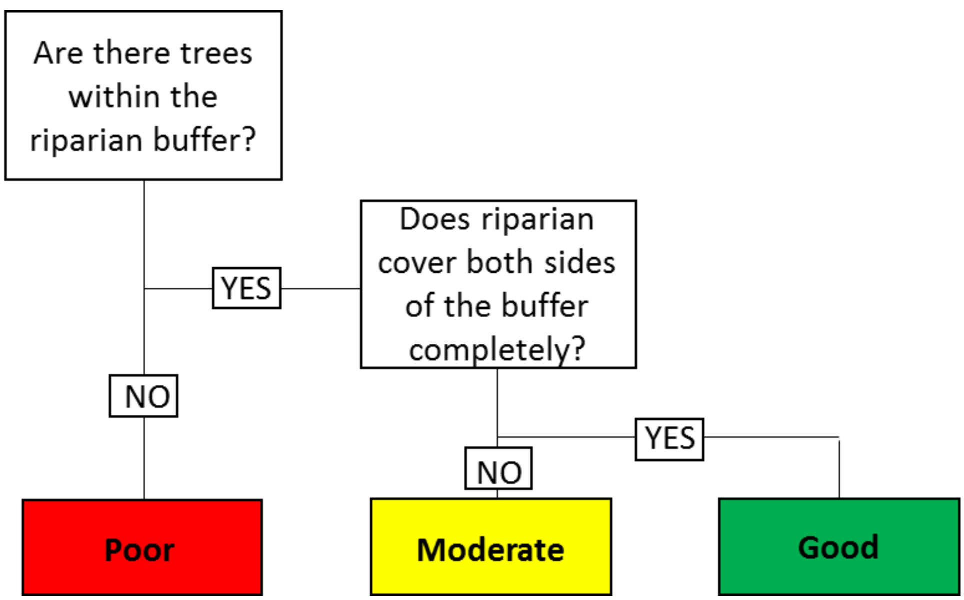


Figure 19. Flow chart showing decision tree for riparian corridor assessment from aerial photo analysis.

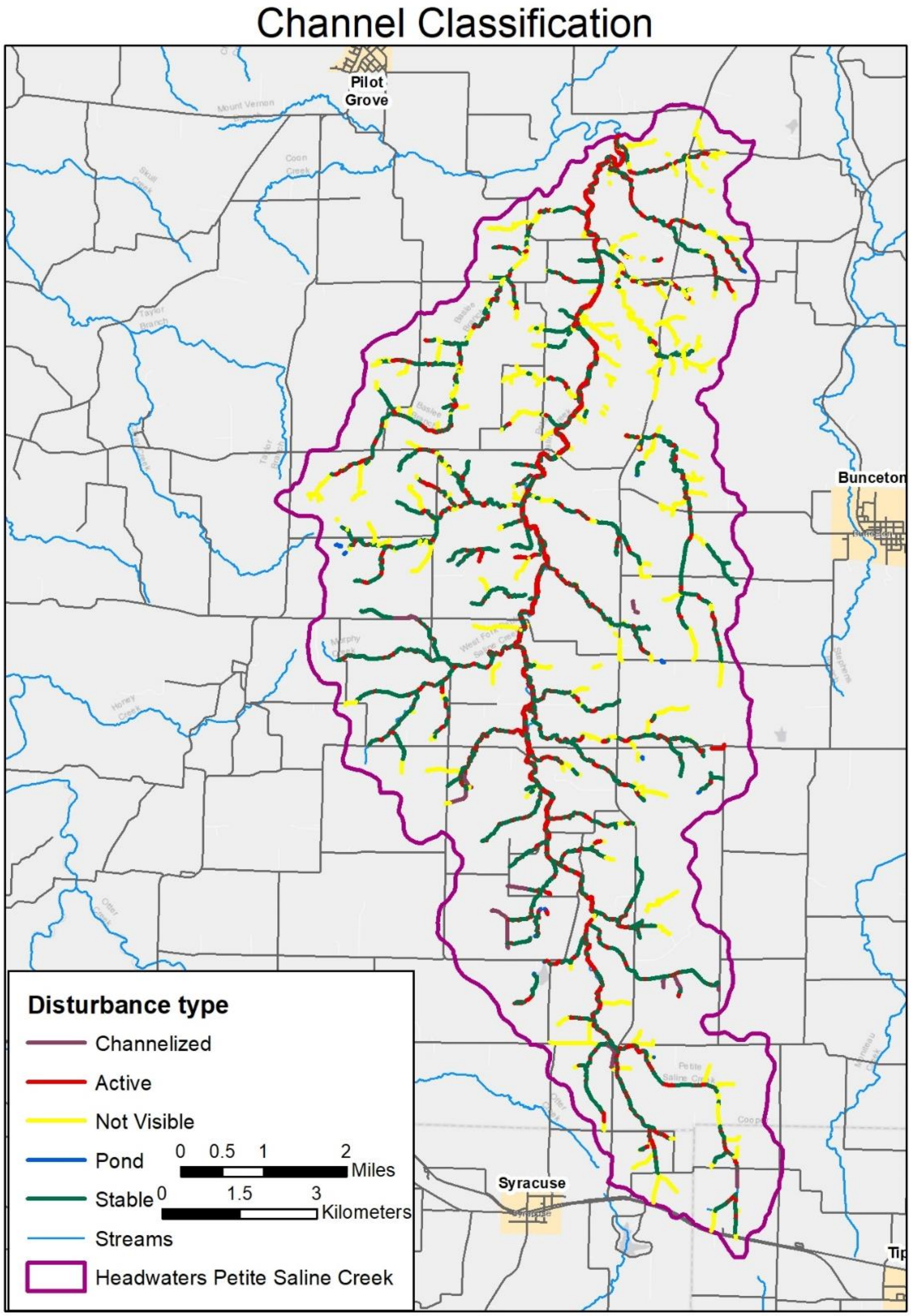


Figure 20. Channel stability classification

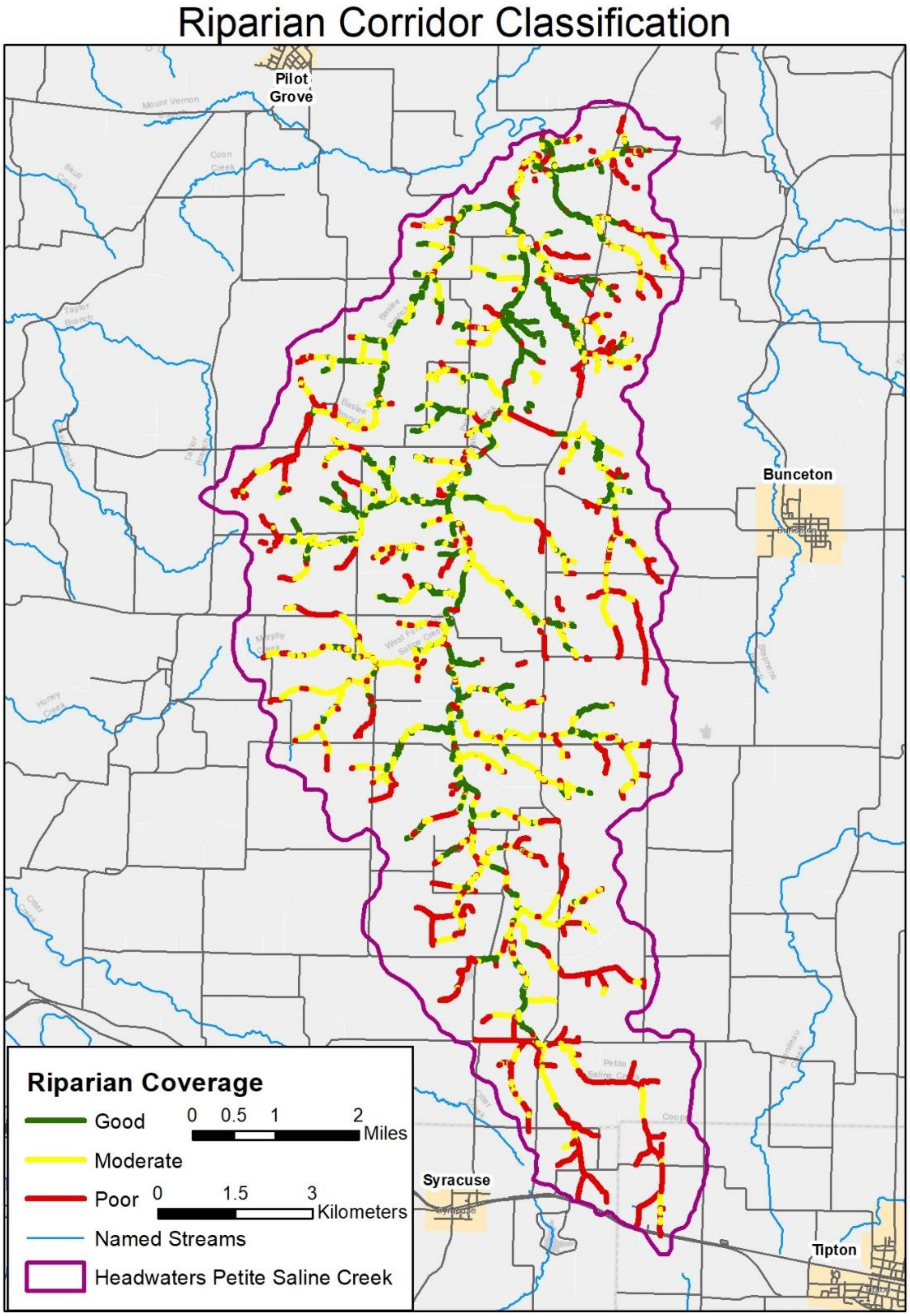


Figure 21. Riparian corridor classification

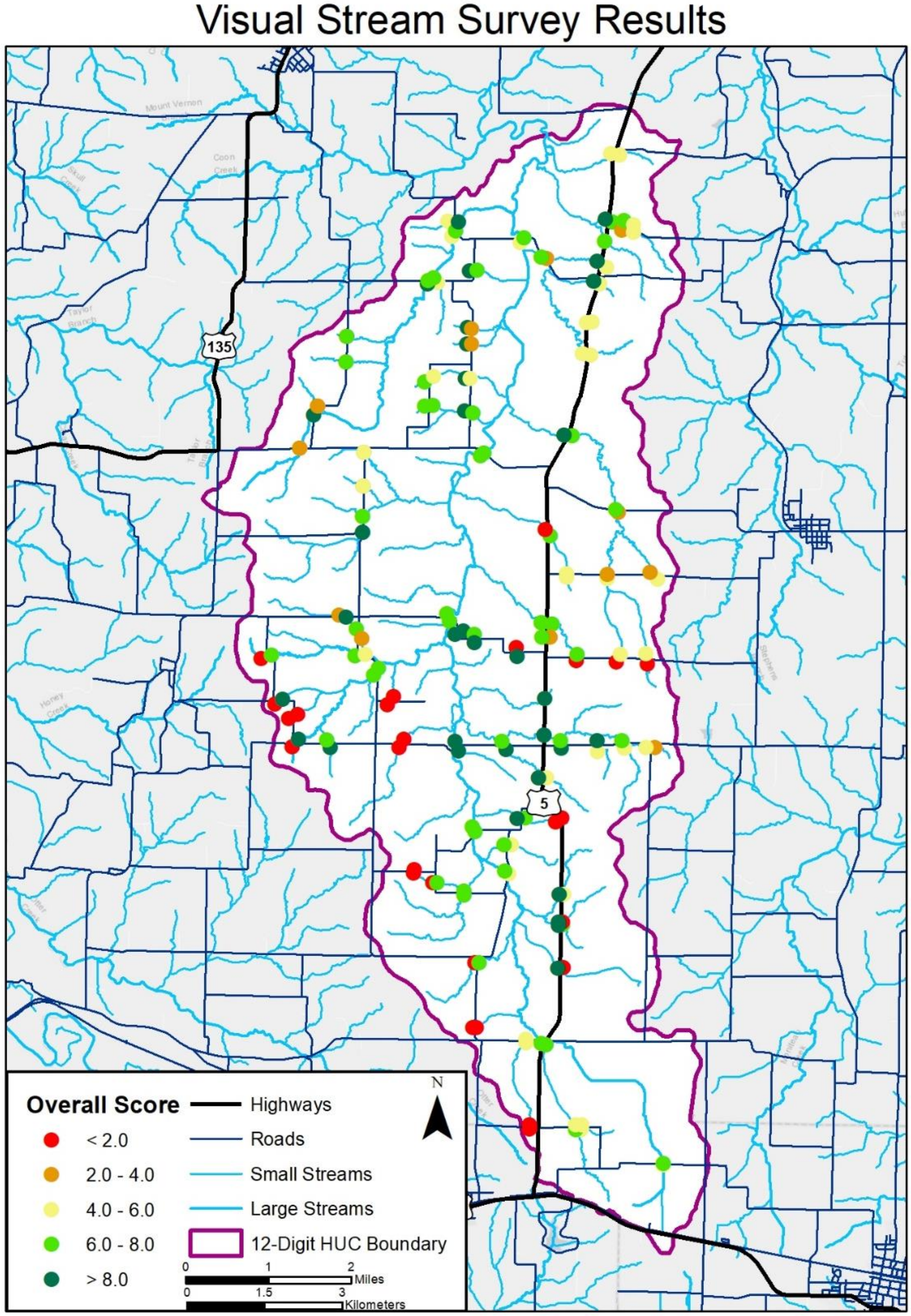
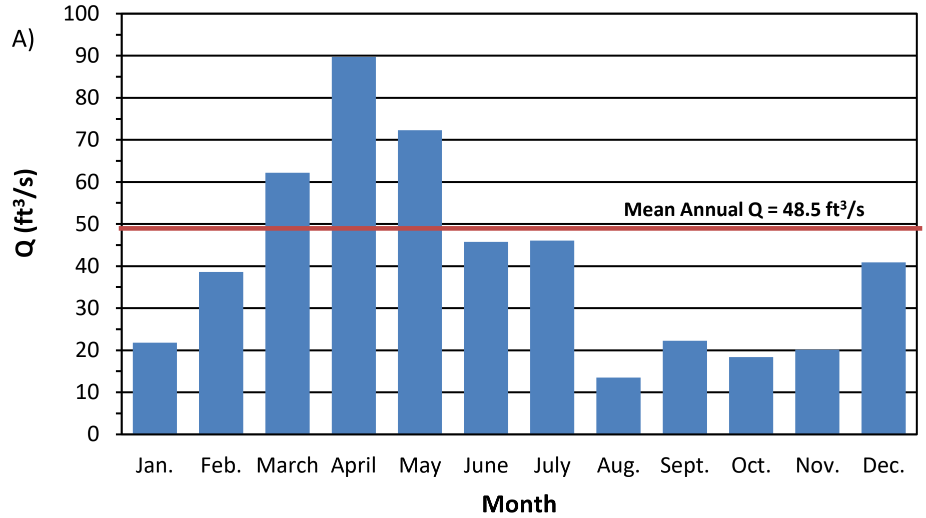


Figure 22. Visual stream assessment results



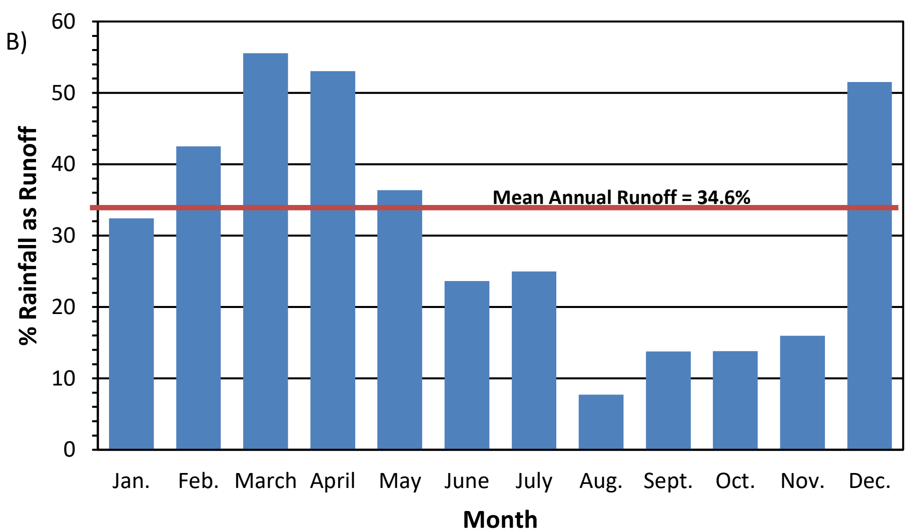


Figure 23. Mean monthly discharge and runoff percentage for the Headwaters Petite Saline watershed.

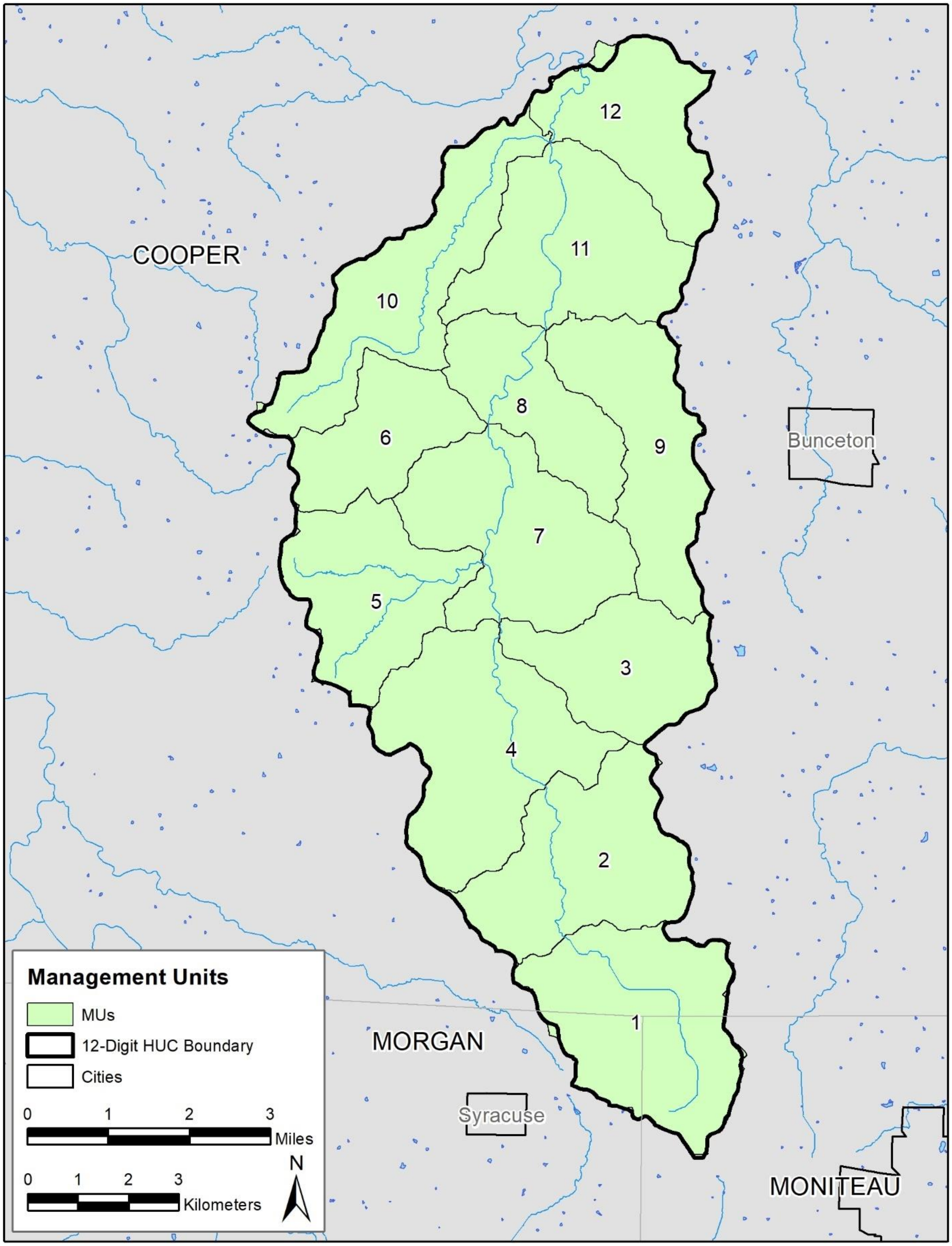


Figure 24. Management units with the watershed.

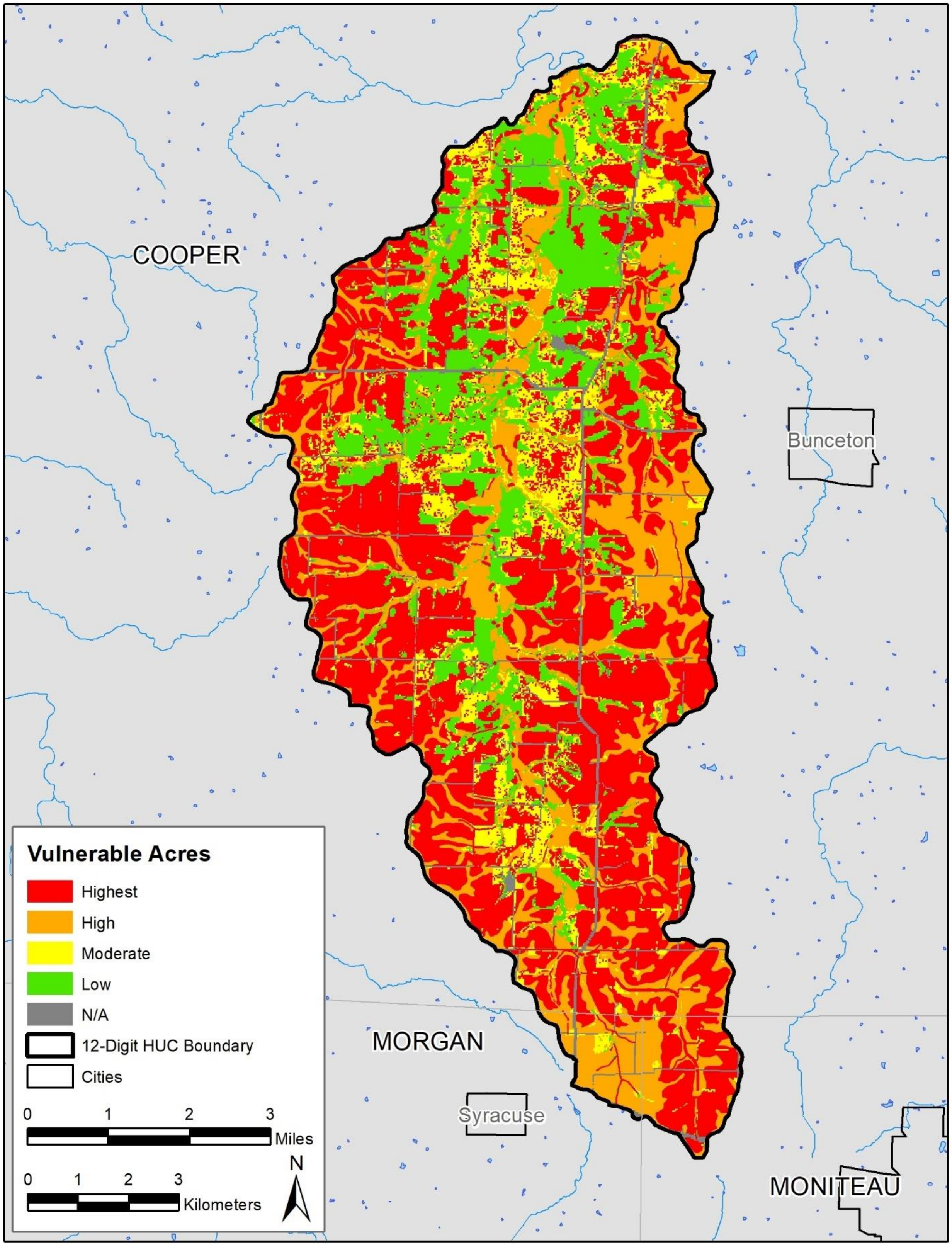


Figure 25. Spatial distribution of vulnerable acres within the watershed.

APPENDICES

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

MUSYM	Area (ac)	% Area	Description	Hydrologic Soil Group	Landform	K-Factor	Soil Order	Land Class
10000	299.7	0.97	Arisburg silt loam, 1 to 5 percent slopes	c	Uplands	0.37	Mollisol	2e
10001	9.9	0.03	Arisburg silt loam, 2 to 5 percent slopes, eroded	c	Uplands	0.37	Mollisol	2e
10055	87.3	0.28	Knox silt loam, 5 to 9 percent slopes, eroded	b	Uplands	0.37	Alfisol	3e
10103	135.8	0.44	McGirk silt loam, 2 to 5 percent slopes	c/d	Uplands	0.49	Alfisol	2e
10151	115.5	0.37	Wakenda silt loam, 2 to 5 percent slopes	b	Uplands	0.32	Mollisol	2e
10153	29.4	0.10	Wakenda silt loam, 5 to 9 percent slopes, eroded	c	Uplands	0.43	Mollisol	3e
30167	601.8	1.95	Pershing silt loam, 2 to 5 percent slopes	d	Uplands	0.43	Alfisol	3e
30168	428.4	1.39	Pershing silt loam, 2 to 5 percent slopes, eroded	d	Uplands	0.49	Alfisol	3e
30170	27.5	0.09	Pershing silt loam, 5 to 9 percent slopes, eroded	c/d	Uplands	0.49	Alfisol	3e
36050	16.7	0.05	Zook silty clay loam, 0 to 2 percent slopes, occasionally flooded	d	Floodplains	0.32	Mollisol	2w
60027	106.9	0.35	Weller silt loam, 2 to 5 percent slopes, eroded	d	Uplands	0.49	Alfisol	2e
60030	70.3	0.23	Winfield silt loam, 5 to 9 percent slopes	c	Uplands	0.43	Alfisol	3e
60063	35.9	0.12	Bluelick silt loam, 15 to 25 percent slopes, eroded	c	Uplands	0.37	Alfisol	6e
60064	28.8	0.09	Bluelick silt loam, 3 to 8 percent slopes, eroded	c	Uplands	0.37	Alfisol	3e
60065	265.9	0.86	Bluelick silt loam, 8 to 15 percent slopes, eroded	c	Uplands	0.37	Alfisol	4e
60080	3,070	9.96	Crestmeade silt loam, 1 to 4 percent slopes, eroded	c/d	Uplands	0.37	Mollisol	3e
60149	936.1	3.04	Leslie silt loam, 1 to 3 percent slopes	c/d	Uplands	0.43	Mollisol	2w
60150	857.2	2.78	Leslie silt loam, 2 to 5 percent slopes, eroded	c/d	Uplands	0.43	Mollisol	3e
60167	9.2	0.03	Menfro silt loam, 3 to 9 percent slopes	c	Uplands	0.43	Alfisol	3e
60196	9.8	0.03	Newcomer loam, 9 to 14 percent slopes, eroded	c	Uplands	0.24	Alfisol	6e
60234	32.6	0.11	Weller silt loam, 2 to 5 percent slopes	d	Uplands	0.49	Alfisol	2e
60244	37.5	0.12	Winfield silt loam, 5 to 10 percent slopes, eroded	c	Uplands	0.55	Alfisol	3e
60258	139.5	0.45	Glensted silt loam, 2 to 5 percent slopes, eroded	c/d	Uplands	0.43	Alfisol	2e
64001	72.9	0.24	Freeburg silt loam, 0 to 3 percent slopes, rarely flooded	c/d	Stream Terraces	0.43	Alfisol	2w
64007	63.4	0.21	Freeburg silt loam, 0 to 2 percent slopes, occasionally flooded	c/d	Stream Terraces	0.55	Alfisol	2w
64023	219.3	0.71	Leslie silt loam, terrace, 0 to 2 percent slopes	c/d	Stream Terraces	0.37	Mollisol	2w
64028	58.4	0.19	Shannondale silt loam, 0 to 2 percent slopes, rarely flooded	c	Stream Terraces	0.43	Mollisol	1
64044	48.4	0.16	Jemerson silt loam, 2 to 5 percent slopes, rarely flooded	b	Stream Terraces	0.43	Alfisol	2e
66000	89.9	0.29	Moniteau silt loam, 0 to 2 percent slopes, occasionally flooded	c/d	Floodplains	0.49	Alfisol	3w
66004	849.1	2.75	Dockery silt loam, 0 to 2 percent slopes, frequently flooded	b/d	Floodplains	0.49	Entisol	3w
66077	542	1.76	Dameron silt loam, 0 to 3 percent slopes, occasionally flooded	c	Floodplains	0.24	Mollisol	2w
66106	391.7	1.27	Speed silt loam, 0 to 2 percent slopes, occasionally flooded	b/d	Floodplains	0.43	Mollisol	2w
66132	42	0.14	Dockery silt loam, 1 to 3 percent slopes, frequently flooded	b/d	Floodplains	0.49	Entisol	3w
66135	380.3	1.23	Dameron silt loam, 1 to 4 percent slopes, occasionally flooded	c	Floodplains	0.24	Mollisol	2w
67040	36.2	0.12	Jemerson silt loam, 1 to 3 percent slopes, rarely flooded	b	Floodplains	0.55	Alfisol	2w
67086	9.7	0.03	Freeburg silt loam, 1 to 3 percent slopes, rarely flooded	c/d	Floodplains	0.43	Alfisol	2w
70024	739.7	2.40	Goss very gravelly silt loam, 15 to 35 percent slopes, very stony	c	Uplands	0.49	Alfisol	6e
70029	16	0.05	Moko-Rock outcrop complex, 15 to 50 percent slopes, very stony	d	Uplands	0.17	Mollisol	7s/8
70085	282.3	0.92	Eldon gravelly silt loam, 8 to 15 percent slopes	c	Uplands	0.37	Alfisol	4e
73036	1,212	3.93	Willowfork silt loam, 0 to 3 percent slopes	c/d	Uplands	0.37	Mollisol	3w

MUSYM	Area (ac)	% Area	Description	Hydrologic Soil Group	Landform	K-Factor	Soil Order	Land Class
73044	2,132	6.92	Crestmeade silt loam, 0 to 2 percent slopes	c/d	Uplands	0.43	Mollisol	2w
73045	382.8	1.24	Crestmeade silty clay loam, 1 to 3 percent slopes, eroded	c/d	Uplands	0.37	Mollisol	3e
73046	906.5	2.94	Wrengart silt loam, 3 to 8 percent slopes, eroded	c	Uplands	0.49	Alfisol	3e
73137	5,887	19.10	Clafork silt loam, 2 to 5 percent slopes, eroded	d	Uplands	0.49	Alfisol	3e
73138	1,163	3.77	Clafork silt loam, 2 to 5 percent slopes	d	Uplands	0.49	Alfisol	2e
73527	759.7	2.46	Bunceton silt loam, 3 to 8 percent slopes	c	Uplands	0.43	Alfisol	3e
73528	2,655	8.61	Bunceton silt loam, 3 to 8 percent slopes, eroded	c	Uplands	0.37	Alfisol	3e
73529	67.7	0.22	Bunceton silt loam, 8 to 15 percent slopes, eroded	c	Uplands	0.37	Alfisol	4e
73531	2,141	6.95	Clafork silt loam, 5 to 8 percent slopes, eroded	d	Uplands	0.49	Alfisol	3e
73536	51.5	0.17	Cotton silt loam, 2 to 5 percent slopes	d	Uplands	0.55	Alfisol	2e
73537	34.5	0.11	Cotton silt loam, 8 to 15 percent slopes, eroded	d	Uplands	0.55	Alfisol	4e
73581	121.4	0.39	Wrengart silt loam, 15 to 25 percent slopes	c	Uplands	0.43	Alfisol	6e
73592	152.5	0.49	Wrengart silt loam, 3 to 8 percent slopes	c	Uplands	0.43	Alfisol	3e
73594	13.1	0.04	Goss silt loam, 3 to 8 percent slopes	c	Uplands	0.37	Alfisol	3e
73595	203.7	0.66	Goss silt loam, 8 to 15 percent slopes	c	Uplands	0.37	Alfisol	4e
73597	347.6	1.13	Cotton silt loam, 5 to 8 percent slopes, eroded	d	Uplands	0.55	Alfisol	3e
73977	554.1	1.80	Wrengart silt loam, 8 to 15 percent slopes, eroded	c/d	Uplands	0.43	Alfisol	4e
73978	151.6	0.49	Cotton silt loam, 2 to 5 percent slopes, eroded	c/d	Uplands	0.55	Alfisol	2e
75378	7.5	0.02	Sturkie silt loam, 0 to 2 percent slopes, frequently flooded	b/d	Floodplains	0.43	Mollisol	3w
75386	193.1	0.63	Speed silt loam, 1 to 3 percent slopes, rarely flooded	b/d	Floodplains	0.43	Mollisol	2w
75497	232.7	0.75	Tanglenook silt loam, 0 to 2 percent slopes, occasionally flooded	c/d	Floodplains	0.37	Mollisol	3w
76386	236.8	0.77	Speed silt loam, 0 to 2 percent slopes, rarely flooded	b/d	Floodplains	0.43	Mollisol	2w
99000	11.1	0.04	Pits, quarry	N/A	N/A	N/A	N/A	8
99001	14.9	0.05	Water	N/A	N/A	N/A	N/A	8

Appendix B. USGS gaging stations near the watershed.

Station Name	Stream	Start Year	Record	Ad (mi^2)	Elevation (ft)	90%	50%	10%	Max	Mean
Middle Fork Salt River near Holliday, MO	Middle Fork Salt River	1998	19	313	648.7	2.7	33.1	618	22,900	291
Lindley Creek near Polk, MO	Lindley Creek	1957	60	112	884.1	0.6	24.0	184	12,000	106
Elk Fork Salt River near Madison, MO	Elk Fork Salt River	1968	49	200	690.2	1.6	16.0	282	24,100	177
Lamine River near Otterville, MO	Lamine River	1987	30	543	652.9	8.3	68.0	747	47,000	507
Blackwater River at Valley City, MO	Blackwater River	1958	59	547	650.2	3.7	52.7	960	47,200	505
Blackwater River at Blue Lick, MO	Blackwater River	1922	95	1,120	593.8	5.5	97.0	2,580	48,400	842
Grand River near Sumner, MO	Grand River	1924	93	6,880	631.2	136	1,010	10,600	166,000	4,320
Moniteau Creek near Fayette, MO	Moniteau Creek	2002	15	75.1	607.9	0.1	6.7	136	3,820	72.3
Petite Saline Creek at Hwy U near Boonville, MO	Petite Saline Creek	2007	10	136	600.0	1.2	18.7	242	7,100	133
Hinkson Creek at Columbia, MO	Hinkson Creek	1990	27	69.8	583.5	0.9	10.5	122	7,810	78.9
Weaubleau Creek near Weaubleau, MO	Weaubleau Creek	2012	5	37.8	668.0	0.03	2.6	43.9	4,500	31.6
Moreau River near Jefferson City, MO	Moreau River	1947	70	561	543.7	7.7	71.9	682	30,700	420
Osage River at Warsaw, MO	Osage River	1925	6	11,500	631.8	400	3,540	28,260	89,700	9,599
Little Niangua River near Macks Creek, MO	Little Niangua river	2007	10	125	830.0	1.6	21.4	227	10,400	137
Osage river near Bagnell, MO	Osage river	1925	92	14,000	549.1	526	4,150	31,400	212,000	10,541
Tavern Creek below St. Elizabeth	Tavern Creek	2014	3	303	570.0	19.2	72.9	483	22,200	312
Osage River below St. Thomas, MO	Osage River	1996	21	14,584	525.7	960	5,150	34,800	114,000	12,238
Maries River at Westphalia, MO	Maries River	1947	70	257	542.8	4.2	42.0	450	23,800	232
Auxvasse Creek near Reform, MO	Auxvasse Creek	2008	9	292	522.0	4.7	46.2	502	20,200	307
Gasconade River near Rich Fountain, MO	Gasconade River	1921	96	3,180	553.7	574	1,470	6,400	178,000	3,086
Niangua River at Tunnel Dam near Macks Creek, MO	Niangua River	1995	22	598	692	82.0	225	897	45,600	498
Niangua River ab Lake Niangua nr Macks Creek, MO	Niangua River	2008	9	522	743	187	315	1,334	49,500	700
Bourbeuse River at Union, MO	Bourbeuse River	1921	96	808	489	42.0	176	1,350	63,000	692
Roubidoux Creek at Polla Rd bl Ft. Leonard Wood	Roubidoux Creek	2008	9	273	785	0.0	0.6	241	24,700	159

Appendix C. Score sheet for visual stream survey with examples

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 visual stream survey results

Site # 51: Downstream

Channel condition	1
Hydrologic alteration	1
Riparian zone	8
Bank stability	1
Canopy cover	10
Manure presence	

Overall Score 4.2

Site # 47: Downstream

Channel condition	8
Hydrologic alteration	8
Riparian zone	5
Bank stability	8
Canopy cover	10
Manure presence	

Overall Score 7.8

Site # 1: Upstream

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

Overall Score 5.4

Site # 24: Downstream

Channel condition	10
Hydrologic alteration	9
Riparian zone	5
Bank stability	8
Canopy cover	3
Manure presence	5

Overall Score 6.7

Site # 61: Downstream

Channel condition	3
Hydrologic alteration	9
Riparian zone	10
Bank stability	9
Canopy cover	2
Manure presence	3

Overall Score 6.0

Site # 22: Upstream

Channel condition	7
Hydrologic alteration	8
Riparian zone	5
Bank stability	5
Canopy cover	2
Manure presence	

Overall Score 5.4

Site # 27: Upstream

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

Overall Score
8.2

Site # 68: Upstream

Channel condition	5
Hydrologic alteration	10
Riparian zone	5
Bank stability	3
Canopy cover	3
Manure presence	

Overall Score
5.2

Site # 79: Downstream

Channel condition	10
Hydrologic alteration	5
Riparian zone	10
Bank stability	3
Canopy cover	7
Manure presence	1

Overall Score
6.0

Site # 46: Downstream

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

Overall Score
2.8

Site # 34: Downstream

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

Overall Score
9.6

Site # 57: Upstream

Channel condition	1
Hydrologic alteration	1
Riparian zone	0
Bank stability	3
Canopy cover	1
Manure presence	1

Overall Score
1.2

Site # 36: Upstream

Channel condition	10
Hydrologic alteration	3
Riparian zone	5
Bank stability	7
Canopy cover	7
Manure presence	

Overall Score
6.4

Site # 38: Upstream

Channel condition	3
Hydrologic alteration	5
Riparian zone	4
Bank stability	5
Canopy cover	2
Manure presence	

Overall Score
3.8

Site # 30: Downstream

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

Overall Score
9.0

Site # 2: Upstream

Channel condition	9
Hydrologic alteration	8
Riparian zone	2
Bank stability	7
Canopy cover	1
Manure presence	

Overall Score
5.4

Site # 2: Downstream

Channel condition	10
Hydrologic alteration	7
Riparian zone	1
Bank stability	10
Canopy cover	1
Manure presence	

Overall Score
5.8

Site # 13: Upstream

Channel condition	10
Hydrologic alteration	3
Riparian zone	1
Bank stability	3
Canopy cover	7
Manure presence	5

Overall Score
4.8

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

Month	R^2	b_0	b_1	m^3/s	ft^3/s
Jan.	0.97	0.00395	1.04671	0.62	21.79
Feb.	0.98	0.00904	0.99352	1.09	38.57
March	0.98	0.01850	0.94397	1.76	62.15
April	0.99	0.02858	0.92995	2.54	89.75
May	0.99	0.01768	0.98462	2.05	72.28
June	0.99	0.00780	1.05946	1.30	45.77
July	0.97	0.01468	0.92968	1.30	46.03
Aug.	0.98	0.00183	1.10622	0.38	13.47
Sept.	0.94	0.00465	1.01721	0.63	22.26
Oct.	0.92	0.00289	1.07595	0.52	18.35
Nov.	0.98	0.00344	1.05903	0.57	20.12
Dec.	0.96	0.01536	0.89574	1.16	40.88

Appendix F. STEPL model inputs for the Headwaters Petite Saline Creek watershed.

Watershed	Total		Land Use (ac)					# of Animals				# Septic
	Ad (ac)	HSG	Urban	Cropland	Pastureland	Forest	Other	Beef Cattle	Swine (Hog)	Chicken	Turkey	Systems
Headwaters Petite Saline Creek	30,826	D	1,220	20,261	3,689	5,592	64	1,480	66,000	148,000	100,000	104

Appendix G. Eroding streambank inputs into STEPL

Reach ID	Length (ft)	Area (ft)	Avg. Area Weighted Height (ft)	Avg. Area Weighted Mean Width (ft)	Avg. Migration Rate (ft/yr)
1	784	24,297	5.32	33.9	1.70
2	4,158	127,538	9.35	34.5	1.72
3	1,630	18,996	2.83	14.8	0.74
4	2,147	852	1.31	8.1	0.41
5	3,247	95,227	1.31	42.1	2.10
6	635	9,814	6.56	15.5	0.78
7	1,928	25,754	6.85	20.5	1.02
8	189	2,365	2.95	12.5	0.62
9	1,146	11,357	3.66	11.5	0.57
10	101	5,624	2.46	55.9	2.80
11	1,826	14,064	3.27	10.4	0.52
12	3,069	75,338	8.05	28.0	1.40
13	1,365	17,956	9.18	15.9	0.79
14	3,287	49,689	7.72	20.9	1.05
15	804	6,138	3.16	8.6	0.43
16	184	1,452	0.98	7.9	0.40
17	4,183	138,654	8.12	37.2	1.86
18	844	9,213	2.32	14.8	0.74
19	442	4,446	0.98	15.0	0.75
20	124	1,931	3.28	15.6	0.78
21	1,078	13,673	2.91	18.5	0.92
22	150	877	4.27	5.8	0.29
23	467	9,318	1.99	23.0	1.15
24	448	5,156	1.29	11.7	0.59
25	2,012	20,327	4.12	11.7	0.59
26	273	1,781	1.04	7.5	0.37
27	377	3,362	1.62	9.1	0.45
28	1,537	17,849	2.13	13.3	0.67
29	834	4,670	2.53	5.8	0.29
30	3,830	73,227	7.37	32.1	1.61
31	2,666	38,919	2.78	18.1	0.91
32	3,654	53,648	1.52	21.6	1.08
33	1,298	13,529	4.34	12.3	0.61
34	546	5,494	6.56	11.2	0.56
35	145	3,430	3.94	23.6	1.18
36	168	1,305	6.56	7.8	0.39
37	877	14,538	5.55	20.0	1.00
38	969	5,623	6.43	9.5	0.47
39	1,537	17,849	2.13	13.3	0.67
40	1,268	18,983	5.87	15.5	0.78
41	726	11,148	3.10	17.5	0.87
42	595	3,370	3.57	5.9	0.30
43	653	6,701	1.56	10.5	0.53
44	468	4,810	2.20	11.1	0.55
45	325	2,331	0.82	7.2	0.36
46	483	3,298	1.66	8.3	0.42
47	354	2,062	5.28	9.1	0.46
48	550	5,331	2.38	10.8	0.54
49	1,004	12,569	1.66	19.7	0.99
50	108	813	0.98	7.5	0.37
51	1,744	15,654	3.00	11.9	0.60
52	1,629	20,688	4.92	15.0	0.75

Reach ID	Length (ft)	Area (ft)	Avg. Area Weighted Height (ft)	Avg. Area Weighted Mean Width (ft)	Avg. Migration Rate (ft/yr)
53	291	1,511	3.63	6.8	0.34
54	955	11,546	5.25	15.2	0.76
55	361	1,828	8.20	5.1	0.25
56	555	2,160	3.92	3.9	0.20
57	402	2,881	1.50	8.7	0.43
58	981	23,645	1.88	46.6	2.33
59	1,051	5,669	3.48	5.6	0.28
60	1,519	13,092	3.53	11.9	0.60
61	428	1,348	1.90	3.2	0.16
62	264	655	7.38	2.5	0.12
63	1,180	6,335	3.30	6.0	0.30
64	185	3,572	7.38	19.3	0.97
65	164	609	4.92	3.7	0.19
Average	**1,126**	**17,352**	**3.88**	**15.2**	**0.76**

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
Terrace	0.253	0.308	0.400
No-Till	0.250	0.687	0.770
Cover Crop and Terrace	0.399	0.356	0.460
Cover Crop and No-Till	0.397	0.709	0.793
No-Till and Terrace	0.440	0.783	0.862
Cover Crop, No-Till, and Terrace	0.550	0.799	0.876
Cover Crop, No-Till, Terrace, Nutrient Management	0.661	0.911	0.876
Land Retirement	0.898	0.808	0.950
Pasture Land			
Prescribed Grazing	0.406	0.227	0.333
Prescribed Grazing and Alternative Water	0.487	0.316	0.458
Prescribed Grazing, Alternative Water, Heavy Use Protection	0.581	0.448	0.638