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

National Water Quality Initiative (NWQI)
Pilot Watershed Assessment for:

Lamar Lake-North Fork Spring River Watershed (HUC- 110702070206)

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

Prepared by:
Marc R. Owen, M.S., Assistant Director, OEWRI
Robert T. Pavlowsky, Ph.D., Director, OEWRI
Hannah R. Adams, Graduate Assistant, OEWRI

Completed for:
Steve G. Hefner, Water Quality Conservationist, State FTS Staff
Natural Resources Conservation Service,
United States Department of Agriculture
Parkade Center, Suite 250
601 Business Loop 70 West
Columbia, MO 65203-2546
Office: 573-876-9399

April 2, 2018

OEWRI EDR-18-003

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 identified 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 pilot watershed assessment study for the Lamar Lake - North Fork Spring River Watershed in Barton County, Missouri. The project area is a 12-digit hydrologic unit code (HUC-12# 110702070206) watershed that includes a segment of the North Fork Spring River located within the larger Spring River basin. Currently, Lamar Lake and the North Fork Spring River are listed as impaired by the Missouri Department of Natural Resources (MDNR) and Total Maximum Daily Load (TMDL) evaluations were developed for both that address nutrient and sediment load reductions (MDNR 2006, USEPA 2006). Furthermore, a comprehensive watershed management plan was developed for the Spring River basin using a water quality model that also specifically addresses best management practices (BMPs) implementation in both the North Fork Spring River and Lamar Lake watersheds pending U.S. Environmental Protection Agency (USEPA) approval (MDNR 2015).

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 Lamar Lake-North Fork Spring River watershed (HUC-12# 110702070206) is located in Barton County, Missouri and is within the Spring River basin (HUC-8# 11070207) of southwest Missouri, southeast Kansas and northeast Oklahoma (Figure 1). This watershed is one of six, 12-digit HUC watersheds of the Headwaters North Fork Spring River watershed (HUC-10# 1107020702). The North Fork Spring River begins in southwest Dade County and flows northwest into Barton County before turning south to the confluence with the Spring River in northwest Jasper County. The Lamar Lake-North Fork Spring River Watershed (13,292 acres) drains portions southeastern Barton County including the City of Lamar (population of 4,532) and its major drinking water supply reservoir (Lamar Lake) which was built in 1955 (Figure 2).

Climate

Southwest Missouri has a temperate continental climate with hot summers and moderate winters (Davis and Schumacher 1992). Over the 30 year period from 1987-2016, the average annual rainfall at Lamar, Missouri ranged from 25.6-71.0 inches with an average of 47.4 inches per year (Table 1). The highest monthly rainfall totals (>5 inches) occur in the late spring and early summer during the months of May and June, with generally less precipitation (<3 inches) during the winter months (Figure 3). Between 1987-2016, average annual temperature ranged from 53.5-60.3 °F with an average of 56.5 °F (Table 1). Over that period, average monthly temperatures range from 33.2 °F in January to 78.4 °F in July (Figure 3). Over the last 30 years, the overall precipitation and temperature trends show increasing temperatures and decreased overall rainfall since 1987 (Figure 4).

Solar radiation and evaporation trends are similar to temperature trends for Lamar. From 2000-2016, average daily solar radiation by month ranged from 6.8 MJ/m^2 in December up to 22.2 MJ/m^2 in July with an average of 14.9 MJ/m^2 (Figure 5). Between 2011-2016, monthly average daily estimated evaporation ranged from 0.04 inches in December to 0.20 inches in June with an average of 0.12 inches over the entire year (Figure 5).

Geology, Topography, and Geomorphology

The Lamar Lake-North Spring River watershed is located in the Osage Plains section of the Central Lowland Province of the Interior Plains (USDA, 2006). This region is characterized by rolling plains where local relief is typically between 50-150 ft (MDNR 1986). The underlying bedrock consists of Pennsylvanian age interbedded limestone, sandstone, shale and coal beds of the Cherokee Group that generally southeast to the northwest (Hughes 1974, Kleeschulte et al. 1985). Streams in this region are low gradient featuring low velocities, few riffles, with mixed bed sediments ranging from silt to bedrock (Davis and Schumacher 1992, Kiner et al. 1997). Published regional curves and regime equations available on the NRCS website have been developed for analysis of typical channel morphology for streams in the Osage Plains with drainage areas between 0.5-200 square miles (Figure 6, USDA 2017a).

Landscape and Soils

The Lamar Lake-North Spring River watershed is within the Cherokee Prairies Major Land Resource Area (MLRA) (USDA, 2006). The Cherokee Prairies consist of broad and flat unglaciated uplands that gently slope to the floodplains of major streams (Hughes 1974). Elevations within the watershed range from 900-1,500 feet with generally higher elevation east of the North Fork Spring River valley (Figure 7). LiDAR derived slope ranges from 0.27-67.6 percent with the majority of the land having a slope of <2% (Figure 8). Slopes <2% are generally found in the uplands and valley bottoms, while the steeper slopes, that are not road embankments, are located along the valley margin.

Upland soils within the Lamar Lake-North Fork Spring River are mostly residual soils derived from sandstones and shales formed under prairie vegetation (Hughes 1974). The majority of the upland soils are either alfisols (52.1%) or ultisols (30.1%), with mollisols (10.4%) and inceptisols (4.5%) generally being found along the valley margins and in the valley bottoms (Table 2, Figure 9). Upland soils also have poor infiltration rates with over 90% of the soils in the watershed being within the Hydrological Soil Group C (slow), Group D (very slow), or C/D, with Group B (moderate) only being found along the floodplain (Table 2, Figure 10)(USDA 2009). Soils were also classified by Land Capability Classification, which is a way of describing the suitability of a soil to grow field crops (USDA 2017b). Within the watershed, land capability classes range from Class 2-7 and limitations tending to be fairly equal among capability subclasses (e) erosion, (w) water, and (s) which is a limitation due to shallow, droughty, or stony soil (Table 2). Wetness tends to be the limitation in the developed area around Lamar and along the valley bottoms (Figure 11). Erosion tends to be the major limitation along the uplands in the rural area of the watershed with shallow, droughty, or stony soil being a limitation along the valley margins where slopes are a little steeper. Nearly 40% of the soils within the watershed have a soil erosion K-factor of >0.4 with the majority of those soils found in the urbanized areas of Lamar and in the valley bottoms (Table 2, Figure 12). A complete list of soil series found within the watershed is available in Appendix A.

Hydrology and Drainage Network

The North Fork Spring River is main stream flowing through the watershed beginning northwest of Lamar and flowing 10.8 miles to the confluence of the West Fork Spring River (Figure 7). The majority of the tributary drainage flows from east to west into the main channel, with less drainage entering from the western side of the watershed. There are a total of 52.2 miles of mapped streams within the watershed with the North Fork Spring River the only stream designated for permanent flow (Table 3). Without springs to sustain flow and the impervious nature of the underlying bedrock, streams in this area can go dry during drought periods (Davis and Schumacher 1992, Kiner et al. 1997). There are a total of 13 unnamed tributaries flowing into the North Fork Spring River within the study watershed with Lamar Lake being located in the largest tributary. There are a total of 80 reservoirs and small ponds within the watershed, with Lamar Lake being the largest at just over 148 acres.

Ground water is used for irrigation, business/industry, and to supplement the drinking water reservoir when needed. Between 2006-2016 an average of 52.7 million gallons of ground water per year were used for irrigating nearly 500 acres (Table 4). However, ground water was not used for irrigation every year and surface water was also used to irrigate a little over 200 acres when needed for an average of 12.7 million gallons per year. Business and industry also do not pump ground water every year, but they average about 3.0 million gallons per year. Finally, the Lamar Water Treatment Plant uses an average of 46.9 million gallons per year of ground water to supplement lake storage volume as needed.

Land Use and Land Cover

The Lamar Lake-North Fork Spring River watershed is mostly an agricultural watershed, but has significant amounts of mixed land uses. Land use for the watershed was determined using the 2012-2016 National Agricultural Statistics Service (NASS) Crop Database. Crop classes were combined to look at the general overall picture of land use in the watershed. Over that five year period, grass and pasture land made up nearly 40% of the land use within the watershed (Table 5, Figure 13). Developed land was the second highest category at 19.4% of the watershed area while forest land cover is 16.3%. Cropland which includes row crops, double crops, small grains, and fallow ground combined for about 13.9% of the area and alfalfa and other hay crops about 6.8% of the watershed. The remainder of the watershed area is in wetlands and open water.

Between 2012 and 2016 there has been an increase in row crops and deciduous forest within the watershed, while at the same time having a decrease in double crop systems, grass/pasture, and wetlands. From 2012-2016 land for corn production increased 57.6% and soybeans increased 43.3% while double drop winter wheat/soybeans decreased 27.1% (Table 6). Grass and pasture land, which makes up the majority of the land use in the watershed, decreased 9.7% over that time. Even though woody wetlands make up a relatively small portion of the watershed, the amount decreased 72.9%. However, deciduous forest increased over that time by 20.4%.

Previous Work and Other Available Data

TMDLs and Management Plans

A TMDL was completed on Lamar Lake in 2006 and specifically addresses reduction in total phosphorus coming from nonpoint agricultural sources and recommended a 65% reduction in nutrients to meet target concentrations of 0.040 mg/L in the lake (MDNR 2006). Additionally, in 2006 a TMDL was developed for the North Fork Spring River that addressed excess sediment in the stream from agricultural nonpoint sources (USEPA 2006). In 2015, a comprehensive watershed management plan for the larger Spring River basin was completed and is still in draft form waiting USEPA approval (MDNR 2015). In this plan both the North Fork Spring River and Lamar Lake are specifically targeted for BMPs to address each TMDL. The plan uses a combination of cropland, livestock, and urban BMPs in North Fork Spring River and cropland BMPs in Lamar Lake to meet reduction goals over a 20 year span.

Surface and Ground Water Monitoring Stations

There are no United States Geological Survey (USGS) gaging stations within the Lamar Lake-North Fork Spring River watershed. The closet gaging station on the North Fork Spring River is approximately 20 miles downstream of the study watershed at Purcell, Missouri (USGS Gaging Station #07185910). To be able to predict discharge within the study watershed, 25 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 14). A list of the USGS gaging stations can be found in Appendix B. If resources became available to install gaging stations within the watershed, two possible locations would be on the North Fork Spring River at Interstate 49 (UTM Zone 15N Northing: 4,143,144.271 Easting: 385,024.517) and/or at the dam of Lamar Lake (UTM Zone 15N Northing: 4,148,725.297 Easting: 388,475.855). Additionally, there is a ground water monitoring station in Lamar (Site Number:

372958094161001) that has been operating since 1968 and data from this station shows not only a steady decline in ground water levels in this area but ground water levels have become increasing more variable over time (Figure 15).

<u>Water Quality Sampling Data</u>
There are a total of nine historical water quality monitoring sites with data available for analysis for this project, with four being located on Lamar Lake and five on the North Fork Spring River (Figure 16). All water quality data was downloaded from the MDNR Water Quality Assessment System website. The four Lamar Lake sites had the most complete set of data with >30 nutrients samples at all four sites and 86-94 TSS samples at two sites with samples being collected from 1989-2015 (Table 7). The North Fork Spring River sites had <10 samples at all sites over a sampling period between 2003-2013. Also, there are several permitted point sources located upstream of the North Fork Spring River sites including the Lamar Waste Water Treatment Facility (WWTF) (Table 8).

<u>Biological Monitoring Data</u>
In 1991 and 1992 Missouri Department of Conservation (MDC) conducted a fish collection study that included one site within the study watershed. Results of that study showed the total number of fish collected in the survey to be relatively low compared to the other sites in the Spring River basin (Kiner et al. 1997). In 2003 and 2004, MDNR conducted a biological assessment of the upper and lower North Fork Spring River that included the section of the river located in the study watershed. The purpose of this study was to assess the macroinvertebrate community and water quality of the river. Results of these studies were that the macroinvertebrate community in the North Fork Spring River was impaired due to poor water quality from point and nonpoint sources in the watershed and poor habitat caused by fine sediment on the bed and poor riparian cover (MDNR 2004a, MDNR 2004b). One of the recommendations from these studies was for the MDC Resource Assessment and Monitoring (RAM) program to conduct a study of the watershed. In 2006, RAM data was conducted in the North Fork Spring River, but not within the study watershed.

Summary
The purpose of this report is to provide the information necessary to describe the study watershed (deliverable #1) for the National Water Quality Initiative (NWQI) Pilot Watershed Assessment for the Lamar Lake-North Fork Spring River Watershed (HUC- 110702070206). Both the North Fork Spring River and Lamar Lake are classified as impaired and previous studies indicate agricultural nonpoint source pollution and poor riparian buffers near streams are significant contributors to impairment. Ultimately, 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). All data except for the groundwater withdrawal and WWTF data are available online. Data not available online was provided by the Southwest Regional Office of the MDNR. The majority of these data came from within the watershed, however, hydrological and geomorphic data was compiled from sites near the watershed.

RESOURCE ANALYSIS OF THE WATERSHED

The resource analysis of the watershed portion of this project will focus on both the entire HUC-12 watershed and the portion of the watershed upstream of Lamar Lake. Analysis will include evaluation of water quality data within the watershed, observed channel conditions from both historical aerial photography and 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

Lamar Lake

Summary statistics for all nutrient and sediment samples were used to evaluate Lamar Lake 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. Average site concentrations of TN from Lamar Lake were between 1.10-3.08 mg/L with coefficient of variation percentage ranging between 30.2-98.8% (Table 11). Coefficient of variation percentage (cv%) is the ratio between the standard deviation and mean and describes the relative variability of the sample results. Mean site TP concentrations were between 0.063-0.099 mg/L with a cv% ranging from 34.4-112.8%. Average sediment concentration ranged from 8.5-10.2 mg/L and had a cv% between 44.6-59.9%. While these data suggests high site variability in nutrients at some sites, not all samples were collected over the same time period at each site.

Water quality data collected from selected long-term sites at Lamar Lake exhibit; (1) lower site variability, (2) slight decrease in TP from the upstream site (Site 4) to the site near the dam site

(Site 1), and (3) TP concentrations are about 2-3x higher than the TMDL target. When looking at Sites 1 and 4, which have data available over a longer period of time, concentrations of TP at Site 4 ranged from 0.011-0.223 mg/L with an average concentration of 0.096 mg/L which is about 2.5x higher than the TMDL target of 0.040 mg/L (Table 11) (MDNR 2006). Concentrations of TP at Site 1 were similar ranging from 0.034-0.208 mg/L with an average concentration of 0.082 mg/L and is around 2x higher than the TMDL target of 0.040 mg/L. Additionally, both site have similar variability for TP as Site 1 has a cv% of 34.4% and Site 4 has a cv% of 35.1%.

Nutrient concentrations in Lamar Lake tend to be higher in the summer compared to the spring, particularly for TN, while seasonal sediment concentrations are more variable. Annual average concentrations of TN, TP, and TSS in the spring and summer were compared at both Site 1 and Site 4 from Lamar Lake from 2008-2015. Again, Site 1 is near the dam and Site 4 is upstream in the east arm of the lake. At Site 1 there were higher concentrations of nutrients in the summer compared to the spring while TSS concentrations did not necessarily follow the same pattern. Overall, TN was 29.3% higher in the summer compared to the spring and increased 7 out of 8 years at Site 1. Correspondingly, TN was 20.1% higher in the summer at Site 4 and increased 6 out of 8 years (Figures 17 and 18). For TP, seasonal variability is generally 13.8% higher in the summer increasing 6 out of 8 years at Site 1. In addition, TP was only 1.0% higher in the summer at Site 4 increasing only 4 out of 8 years. Sediment had an overall decrease in the summer compared to the spring.

North Fork Spring River

North Fork Spring River samples appear to be influenced by the Lamar WWTF, but also have relatively high concentrations of nutrients likely coming from agricultural nonpoint sources upstream. Average TP concentrations at sites not directly below the plant range in values from 0.152-0.326 mg/L TP and 0.95-2.83 mg/L TN (Figure 19 and Table 11). At the site near the outfall of the WWTF, mean TP concentrations were 3.285 mg/L and 21.78 mg/L TN. Recent data provided by the MDNR from samples collected at the WWTF plant outfall from 2015-2017 show mean TP concentrations are down to 1.66 mg/L and TN is considerably lower at 3.03 mg/L (Table 9). Similarly TSS values collected below the plant averaged 21.8 mg/L for the in-stream sites compared to 7.9 mg/L at the WWTF outfall recently reported to MDNR. These data suggest the WWTF likely has reduced pollution to the North Fork Spring River since 2013. Seasonal analysis of samples collected in the North Fork Spring River is not possible due to lack of sampling.

Channel Stability and Riparian Corridor Assessment

Aerial Photo Methods

Aerial photographs from 1953, 1966, 1997, 2008, and 2014 were obtained from the Missouri State Map Library and USGS EarthExplorer. Aerials from 1953 and 1966 were unrectified, while aerials from 1997, 2008, and 2014 were downloaded pre-rectified. All aerial photographs were imported into ArcGIS where the unrectified aerials were georeferenced to the spatially referenced 2008 aerial. A minimum of 8 ground control points (GCPs) at locations clearly visible in both the unrectified and spatially referenced aerial were used to rectify each aerial using a second-order polynomial transformation (Hughes et al. 2006). The error involved in the transformation was quantified using root-mean-square error (RMSE) and point-to-point error. RMSE errors ranged from 1.0-4.9 ft for individual photos and mean point-to-point errors ranged from 4.3-8.5 ft for photo years (Table 12). After rectification, streams from each year were digitized to identify and measure changes over time. Since these channels were small and much 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). Due to photo quality and the time of year the photos were taken, it was determined the 1966 and 2008 photos were the best choice for further analysis.

Channel Classification

Tributary channels to the main stem of the North Fork Spring River were further classified by identifying historical channel changes and further interpretation of aerial photos between the 1966 and 2008 aerial photos. Channels were first characterized as modified or natural. Modified channels were further classified as channelized or impounded by dam construction. Natural channels were further classified as either stable or disturbed. Disturbed channels were identified by assessing planform changes since 1966 by overlay analysis of center lines using 2.15 ft error buffer which is based off of the 4.3 ft mean point-to-point error to account biases attributed to rectification (Martin and Pavlowsky 2011). Disturbed reaches were identified as areas where the buffers between did not overlap for at least 100 ft. If the channel was obstructed by vegetation, it was classified as undetermined. A flow chart was developed to assist in channel classification during aerial photo interpretation (Figure 20).

Channel classification results show the majority of the tributary channels could not be evaluated due to vegetation obstruction. Moreover, most channels that could be evaluated have mostly been modified by either channelization or pond construction. Of the 41.2 total tributary stream miles within the watershed, 20.9 mi, or 50.7%, were classified as undetermined mainly due to vegetation obstruction (Table 13). In the Lamar Lake watershed the total undetermined channel classification was lower at 29.1%. In the HUC-12 watershed 18.9% of the visible streams were channelized, 11.4% impounded by a dam, 13.6% stable and only 5.4% disturbed. Results from the Lamar Lake watershed were similar with 21.5% of the visible streams channelized, 13.2% impounded, 26.1% stable, and 10.1% disturbed. While there is less than 1 mi of disturbed channel in the Lamar Lake watershed, much of it is concentrated in the tributary entering the lake from the north (Figure 22).

Evaluation of the visible stream channels suggests that streams in this area do not adjust to watershed disturbance though lateral migration. Assessment of channel planform changes over time indicates relatively low rates of lateral migration within the tributaries of the HUC-12 watershed accounting for less than 10% of the classified channel. Our observations suggest that channel incision and widening may be the dominate mechanism for adjustment in these streams and this effect cannot be determined through aerial photo analysis for such small streams (Simon and Rinaldi 2000, Harden et al. 2009). Furthermore, the amount of human modified streams within the area suggests landowners may have been dealing with channel stability problems in the past. Studies have shown that channelized streams are often much larger than the original channel and slope is increased due to straightening of the channel causing incision in the channelized reach and sedimentation problems downstream (Simon and Rinaldi 2000, Davis 2007).

Riparian Corridor Analysis

Channel condition can be strongly influenced by changes in vegetation (McKenney et al. 1995, Eaton and Giles 2009). Riparian corridor mapping can be used to identify stream channels vulnerable to disturbances including vegetative buffer occurrence (Rosgen 1996, Montgomery and MacDonald 2002). To evaluate riparian corridor coverage a 50 ft buffer around the National Hydrography Dataset (NHD) was created in ArcGIS (USDA 2014). The buffer was overlain atop 2016 aerial imagery and used to classify riparian coverage. Riparian coverage consisted of three classes: Good, Moderate, and Poor (Figure 21). Good represents a portion of the stream in which there is an adequate coverage of riparian trees that extends at least 50 ft on both sides of the stream. The Moderate class signifies portions of the stream where one side of the 50 ft buffer meets the standard but the other does not. Alternatively, moderate also indicates a situation where there is coverage on both sides of the stream but tree coverage is relatively sparse. Finally, Poor classifications represent portions of the stream where neither side of the stream extends to the 50 ft buffer.

The riparian corridor within the HUC-12 watershed and the Lamar Lake watershed generally follow the channel classification results and perhaps should serve as the initial indicator of channel disturbance for this type of assessment. For the HUC-12 watershed, 50% of the channel was classified as having a good riparian corridor that approximates the amount of channel that could not be classified due to obstructions (Table 14). While this does not guarantee these areas are stable, riparian vegetation provides conditions for unstable streambanks to recover by providing roughness during floods to lower velocities and roots can help armor and hold together bank materials to reduce sediment losses via mass wasting (Rosgen 1996, Zaimes et al 2004, NRCS 2014). The amount of good riparian area in the Lamar Lake watershed is also similar to the amount of channel obstructed by vegetation. While there is approximately 17.7 miles of channel with poor riparian corridor with the HUC-12 watershed, it is a lower percentage (34%) of the total compared to the Lamar Lake watershed where 49% of the channel was classified as poor. Again, the spatial distribution of the poor riparian corridor in the Lamar Lake watershed is concentrated in the tributary flowing into the lake from the north (Figure 23).

Visual Stream Survey Results

A modified rapid visual stream survey was conducted upstream and downstream of all public road crossings with the watershed following NRCS protocols (USDA 1998). The protocol was modified by only focusing on five physical stream channel and riparian corridor variables 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 greater than 9.0 excellent. A total of 36 crossings were visited for a total of 72 possible evaluations. However, due to pond construction, road embankment, or other visual impairments a total of 63 sites were ultimately completed. Of these 63 sites, 68.3% were rated as poor, 22.2% as fair, 6.3% as good, and 3.2% as excellent (Figure 24). Most of the poor ratings were due to channelization, poor riparian conditions, and presence of livestock within the stream.

Streams in cropland areas generally appear to be stable, while streams in pasture areas are typically more unstable. While the visual survey captured information from the entire watershed including the urban areas, streams within the agricultural area are the focus of this study. The majority of the streams in areas of crops are typically channelized into grass waterways with over widened bottoms that are starting to accumulate sediment and form small rills, but do not appear to be actively incising at the sites observed (Appendix D). The range of channel conditions within the pastured areas generally follow the quality of the riparian corridor along the stream. Riparian conditions in areas where livestock have access to the stream varied from no trees and eroding banks to a thin line of mature trees where channel conditions were not as unstable. Overall, streams within the cropland areas do not score well in the Visual Survey because of ecological quality, but do not appear to be producing excessive sediment through erosion at this time. Conversely, streams in pastures show more signs of instability and may be a target for conservation practices to decrease nonpoint sources of nutrients and sediment in the watershed.

Rainfall–Runoff Relationship

Annual and monthly runoff rates for the HUC-12 watershed and the Lamar Lake watershed were estimated using equations developed from USGS gaging stations in the region. Monthly runoff rates are important for understanding the seasonal variability and how rainfall-runoff relationships correspond to land management and annual runoff rates will 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 HUC-12 watershed is 21.9 ft^3/s and 5.3 ft^3/s for the Lamar Lake watershed (Figure 25). Total runoff volume for the HUC-12 watershed was 15,778 ac-ft and 3,884 ac-ft for the Lamar Lake watershed. For both watersheds, average discharge peaks in the month May and is the lowest in August. Average runoff as a percentage of rainfall for the HUC-12 watershed was 30.1% and 32.4% for Lamar Lake. The remainder of the rainfall is either lost to evapotranspiration or moves through the soil into groundwater storage through infiltration (USDA 2009). These estimates compare well with the literature where evapotranspiration rates for Missouri range from 60-70% and infiltration rates average around 3.8% of rainfall totals in the area (Czarnecki et al. 2009, 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 less than 10% in August to 50-60% in March.

Water Quality Modeling

STEPL Model

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, both the entire HUC-12 and Lamar Lake watershed were each 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 2016 USDA Crop database. Animal numbers were calculated per acre of pasture within the watershed using data within the STEPL online databases which have total animal number ratio of one animal per 6.2 acres of pastureland with 95% being beef cattle and 5% being horses (USDA 2012). During the visual stream assessment no dairy cattle, sheep, hogs were observed within the watershed. The number of septic systems within each watershed was based on a ratio of one septic system for every 1.3 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. Additionally, lateral stream bank erosion was accounted for by calculating stream channel length and migration rates from historical aerial photo analysis and bank heights from LiDAR datasets at disturbed stream reaches identified earlier in this report. There was a total of 33 eroding stream reaches within the watershed with an average length of 352 ft, average height of 1.8 ft, and average annual migration rate was 0.53 ft/yr (Appendix G).

Model results show the Lamar Lake watershed produces slightly higher nutrient and sediment yields than the entire HUC-12 watershed while having slightly lower runoff rates. Average yields for Lamar Lake were 11.2 lb/ac/yr for nitrogen, 1.65 lb/ac/yr phosphorus, and 0.32 T/ac/yr of sediment (Table 15). Average yields for the entire HUC-12 were 10.7 lb/ac/yr for nitrogen, 1.82 lb/ac/yr phosphorus, and 0.32 T/ac/yr sediment. Nutrient yields reported in this study are 5-86% higher than reported yields from USGS modeling in 2002 for the Spring River Basin (Preston et al. 2011). Runoff rates for Lamar Lake were slightly lower at 1.01 ac-ft/ac/yr compared to 1.11 ac-ft/ac/yr for the entire HUC-12 watershed. Runoff results from the model are fairly close to the estimates from the nearby gages. These rates do not include the 150 acre lake, so when that volume is added the % rainfall as runoff for Lamar Lake is 30.4% and 29.1% for the HUC-12 watershed. These are very close to the estimated % of rainfall as runoff from the USGS gaging stations, which was 32.4% for Lamar Lake and 30.1% for the HUC-12. The agreement of these two methods (within 10%) increases the confidence in the STEPL modelled runoff results.

When assessing model results by sources for both the HUC-12 and Lamar Lake watersheds, the majority of the nonpoint source pollution is originating from cropland with pasture land the second highest contributor. For the HUC-12 watershed, model results show agricultural nonpoint sources account for over 69% of the nutrient and sediment load (Table 16). Cropland accounts for 36.4-55.1% of the load and pastureland 22.8-43% of the load. The remaining is mostly from urban sources in and around the City of Lamar. Agricultural nonpoint sources make up greater than 80% of the nutrient and sediment load of the Lamar Lake watershed. Here, nutrients and sediment derived from cropland account for similar percentages of the total load as the HUC-12 watershed at 25.3-44.7%. However, pastureland is producing comparatively more of the total load, accounting for 41.5-64.2% of nutrients and sediment and urban has a much smaller contribution as well. Additionally, streambank erosion is accounting for less than 10% of the sediment load in both watersheds.

Load Reduction Analysis

Load reduction for both the HUC-12 watershed and the Lamar Lake watershed were modeled STEPL using established BMP efficiencies. The efficiencies of combined BMPs were calculated with STEPL's BMP Calculator. A total of seven cropland BMP scenarios and three pastureland BMPs scenarios were ultimately modeled. A description of each combined BMP scenario with calculated efficiencies can be found in Appendix H. Load reductions of nitrogen, phosphorus, and sediment for both the HUC-12 watershed and the Lamar Lake 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 BMP and from there terraces, grass waterways, reduced till, no till and nutrient management are added 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 BMP was livestock exclusion and alternative water sources. From there, prescribed grazing and forest buffers 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 HUC-12 watershed through implementation of cropland conservation practices and augmented by pastureland conservation practices. For instance, the most intensely managed scenario is one that combines cover crops, no till, and nutrient management. If that scenario was applied to 50% of the 2,071 acres of cropland (1,036 acres) within the HUC-12 watershed, load reduction would be 10.4% for nitrogen, 23.7% for phosphorus, and 17.6% for sediment (Tables 17, 19, and 21). In contrast, applying the most intensely managed scenario to 50% of the 5,833 acres of pastureland, which is livestock exclusion, alternative water, prescribed grazing, and forest buffer, the reduction would be 16.8% for nitrogen, 8.6% for phosphorus, and 11.3% for sediment. Additionally, if all the cropland within the watershed was taken out of production, the resulting load reduction would be 32.9% for nitrogen, 45.7% phosphorus, and 42.1% sediment.

Results of the load reduction scenarios from the Lamar Lake watershed show that with a combination of intensely managed conservation practices on both cropland and pastureland, it is possible to meet the 65% phosphorus reduction goal in the watershed. Model results show that by applying the most intensely managed crop BMP scenario to 100% of the cropland within the watershed would yield approximately a 38% reduction in phosphorus (Table 20). Alternatively, by taking 90-100% of the cropland out of production, a similar phosphorus load reduction can be achieved. Combining that with implementing the most intensely managed pasture BMP to 90-100% of the pastureland would achieve an additional 28-32% reduction in phosphorus that would be close to the 65% goal. There would be an additional benefit by reducing nitrogen and sediment by more than 50% (Tables 18 and 22). Total cropland within the Lamar Lake watershed is 315 acres and 1,946 acres for pastureland, so targeting resources on the agriculture land uses within this smaller footprint is realistic.

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) Pilot Watershed Assessment for the Lamar Lake-North Fork Spring River Watershed (HUC- 110702070206). The resource analysis of the watershed portion of this project focuses on both the entire HUC-12 watershed and the watershed upstream of Lamar Lake. Analysis of the existing water quality data available from Lamar Lake show the average phosphorus concentration at the dam is two-times higher than the recommended target concentration from the TMDL. Nutrient concentrations in the North Fork Spring River were heavily influenced by the City of Lamar's WWTP, but recent samples from the outfall show a reduction of nutrients since the time the original stream samples were collected. Nevertheless, agricultural nonpoint source sediment is still considered the main pollution problem within the North Fork Spring River.

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. Historical aerial photo analysis provided mixed results. Due to the small size of the streams within the watershed, overhead vegetation, and photo quality limitations, a complete classification of all the streams was not possible. However, areas with poor riparian corridor were classified and results indicate many streams have been modified either by channelization or by pond construction. Of the non-modified reaches, only a small portion showed evidence of significant lateral migration suggesting perhaps stream in the area may adjust to watershed disturbance by incision and widening that is difficult to assess on aerials. A riparian corridor assessment was probably the most effective method to highlight areas of disturbance. The visual stream survey helped confirm the channel instability within areas of poor riparian corridor and the extent of channelization within the watershed.

Water quality modeling results show cropland and pastureland overwhelmingly produce the majority of the nonpoint source pollution within the watershed and other sources such as urban and streambank erosion are negligible.   Model results show that agricultural land produces over 75% of the nutrients and sediment within the HUC-12 watershed and over 87% of the nutrients and sediment in the Lamar Lake watershed. Other sources, such as streambank erosion, produce less than 10% of the total sediment load for both watersheds. However, load reduction analysis suggests that the TP reduction goal within the Lamar Lake watershed is attainable using combinations of high intense management BMPs on the majority of crop and pastureland within the watershed.

IDENTIFICATION OF CONSERVATION NEEDS

Resource Priorities

<u>Lamar Lake Watershed</u>

The top resource priority identified in this study is Lamar Lake due to the importance of the public drinking water supply.   Lamar Lake is considered impaired for not meeting Missouri water quality standards due to excess nutrients. A TMDL analysis identified excess phosphorus from nonpoint source agriculture as the main source of pollution within the watershed and that concentrations coming to the lake must be reduced by 65% to meet water quality goals. STEPL modeling estimates phosphorus is coming from crops (45%) and pasture land (42%) in relatively equal proportions. This suggests implementation of conservation practices on both cropland and pasture is necessary to meet the 65% reduction goals. However, there is approximately 1,946 acres of pastureland in the Lamar Lake watershed compared to just 315 acres of cropland.   Therefore, addressing cropland first may be easier and more effective in the short-term while implementing pastureland conservation practices will likely take longer and have less of an effect on load reduction per acres of land treated.

<u>HUC-12 Watershed</u>

For the HUC-12 watershed, sediment has been identified as the top resource concern from agriculture nonpoint source pollution. TMDL analysis shows nonpoint source agriculture in the North Fork Spring River is the main pollution source and that sediment must be reduced by 20-90% to meet water quality goals depending on flow. STEPL modeling results indicate the majority of sediment is coming from cropland (44%) and the second highest source is pastureland (25%). Other significant sources of sediment within the HUC-12 watershed include urban land use (16%) and streambank erosion (8.3%). There is nearly three times more pastureland (5,833 acres) in the watershed than cropland (2,071 acres), but load reduction analysis suggests implementing conservation practices on cropland would be more effective in terms of load reduction per acre of land treated. However, the main focus of conservation efforts in the watershed should be directed to the Lamar Lake watershed, if all possible, due to the significance of the drinking water reservoir. Additionally, implantation of conservation practices in the Lamar Lake watershed aimed at reducing phosphorus loads will also reduce sediment transport into the larger HUC-12 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 HUC-12 watershed was split into 16 smaller watersheds, or management units (MU) (Figure 26). 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 phosphorus and sediment yields for each management unit with drainage areas ranging from 500-2,000 acres (Table 23). However, MU-1 represents the valley bottoms and internally drained areas of the main stem of the North Fork Spring River that is mostly forested and very different compared to the upland watersheds. So not including MU-1, drainage areas of the other MUs ranges from 500-1,000 acres.

Since the Lamar Lake watershed was identified as the top resource concern, the three management units that represent the drainage area were designated as Zone 1 and the remaining 13 MUs are within Zone 2 (Figure 26). Therefore, MU-10, MU-11, and MU-12 will be the top three management units in the ranking (Table 23). Since phosphorus was identified as the top pollution concern in the Lamar Lake watershed, MUs 10, 11, and 12 were then classified by phosphorus yield from high to low. MU-12 was ranked #1 with a P-yield of 2.03 lb/ac/yr, #2 is MU-10 at 1.89 lb/ac/yr, and finally MU-11 is #3 at 1.40 lb/ac/yr.

The HUC-12 watershed was identified as the secondary resource concern within the study area, therefore the 13 MUs outside of the Lamar Lake watershed were designated as Zone 2. Within the North Fork Spring River, sediment was identified as the major pollutant and the annual sediment yield was used to rank these 13 MUs within the HUC-12 watershed. Sediment yields ranged from 1.12 T/ac/yr for MU-6 to 0.21 T/ac/yr in MU-16. Additionally, MU-13 was placed on the bottom of the list since it is mostly urban with very little agricultural land use with in the MU.

Priority Acres Classification

To identify areas with the most pollution potential within a proposed project, a priority 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 resources 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 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 described below and summarized in Table 25.

Highest Priority - There are three situations that will classify the land for the highest priority for conservation planning. First, cropland that is also on highly erodible soils. Erodible soils were identified using a K-factor >0.35 which would be considered moderately-high. Second, cropland that was adjacent to poor riparian buffer identified in the aerial photo analysis portion of this project. The final situation that would cause the land to be in the highest priority acres would be pasture land adjacent to poor riparian buffer. In the entire HUC-12 watershed, 1,281 acres are classified in the highest priority category and 165 acres within the Lamar Lake watershed.

High Priority - Again, there are three situations that will classify the land for the high priority for conservation planning. First, all other cropland that was not in the highest priority category is in the high priority category. The second condition would be pastureland on highly erodible soils with a K-factor >0.35. Finally, pasture land adjacent to moderate riparian buffer from the aerial photo analysis would also be in the high priority classification. There is a total of 2,381 acres of high priority acres in the HUC-12 watershed, with 515 acres within the Lamar Lake watershed.

Moderate Priority - Land within the moderate priority category would be pasture land that is not in the highest or high priority classification. The HUC-12 watershed has 4,242 acres of moderate priority acres with 1,581 acres in the Lamar Lake watershed.

Low Priority - Low priority acres would be defined as all of the forested areas within the watershed or land adjacent to a stream with good riparian corridor. Within the HUC-12 watershed there are 2,364 low priority acres with 363 acres in the Lamar Lake watershed.

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 the Lamar Lake and HUC-12 watershed attain water quality goals. For this, each conservation practice, or combination of conservation practices, was ranked based on the highest benefit per acre treated for each watershed. Ranking for the HUC-12 watershed was based on sediment reduction and the ranking for the Lamar Lake watershed was based on phosphorus reduction. Cropland practices make up the top eight rankings for both watersheds (Table 25). This is a result of cropland having a relatively higher load per acre and cropland conservation practices having relatively high efficiency ratings. Pastureland conservation practices rank in the bottom four of the 12 practices identified in this project because pastureland has a relatively lower load and lower efficiencies than cropland. Overall there is a lot more pastureland to treat versus cropland in both watersheds. While this analysis suggests treating cropland would ultimately be more efficient in reducing pollution in both watersheds per treated acre, this analysis does not include economic or social aspects 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 for the National Water Quality Initiative (NWQI) Pilot Watershed Assessment for the Lamar Lake-North Fork Spring River Watershed. Both the North Fork Spring River and Lamar Lake are classified as impaired and previous studies indicate agricultural nonpoint source pollution and poor riparian buffers near streams are significant contributors to impairment. Ultimately, 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. 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) Existing TMDLs developed for both Lamar Lake and North Fork of the Spring River suggest nutrient and sediment load reductions from nonpoint agriculture is necessary to meet water quality goals. The phosphorus reduction goal in Lamar Lake is set at 65% to meet target water quality concentrations. Lamar Lake is the primary drinking water supply for the City of Lamar so reducing nutrient contributions from lands draining to the lake are necessary to meet target concentrations;

2) Recent water quality data from Lamar Lake shows phosphorus levels have not changed much in the last decade and remain 2-3 times higher than the TMDL target concentration. There are relatively few water quality samples from the North Fork Spring River and they were collected during low flow conditions. There are no other water quality samples available within the study watershed;

3) Both historical aerial photos and a visual stream assessment were used to identify potential contributions of streambank erosion to water quality problems within the watershed and evaluate riparian corridor vegetation. Due to the small size of the streams within the watershed, overhead vegetation, and photo quality limitations, a complete classification of all the streams was not possible. However, areas with poor riparian corridor were classified and results indicate many streams have been modified either by channelization or by pond construction. Of the non-modified reaches, only a small portion showed evidence of significant lateral migration suggesting perhaps stream in the area may adjust to watershed disturbance by incision and widening that is difficult to assess on aerials. A riparian corridor assessment was probably the most effective method to highlight areas of disturbance. The visual stream survey helped confirm the channel instability within areas of poor riparian corridor and the extent of channelization within the watershed;

4) Water quality modeling results show cropland and pastureland overwhelmingly produce the majority of the nonpoint source pollution within the watershed and other sources such as urban and streambank erosion are less important. Results show that agricultural land produces over 80% of the nutrients and sediment within the HUC-12 and Lamar Lake watershed. Other sources, such as streambank erosion, produce less than 10% of the total sediment load for both watersheds;

5) Load reduction analysis suggests that the phosphorus reduction goal within the Lamar Lake watershed is attainable using up to four combinations of conservation practices on the majority of crop and pastureland within the watershed. Model results show that by applying the most intensely managed crop conservation practices scenario to 100% of the cropland within the watershed would yield approximately a 38% reduction in phosphorus. Combining that with implementing the most intensely managed pasture BMP to 90-100% of the pastureland would achieve an additional 28-32% reduction in phosphorus that would be close to the 65% reduction goal for phosphorus;

6) Reduction of sediment in the HUC-12 watershed from conservation practices implemented on crop and pasture land can also yield significant benefits to the North Fork Spring River watershed. Model results show that by applying the most intensely managed crop

conservation practices scenario to 100% of the cropland within the watershed would yield approximately a 35% reduction in sediment. Combining that with implementing the most intensely managed pasture conservation practice to 100% of the pastureland would achieve an additional 22% reduction in sediment; and

7) Management units, priority 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. Priority 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.

REFERENCES

Czarnecki, J.B., J.A. Gillip, P.M. Jones, amd D.S. Yeatts (2009) Groundwater Flow Model of the Ozark Plateaus Aquifer System, Northwestern Arkansas, Southeastern Kansasm Southwestern Missouri, and Northwestern Oklahoma. United States Geological Survey, U.S. Department of the Interior Scientific Investigations Report 2009-5148 (Revised March 2010).

Davis, J.V. and J.G. Schumacher (1992) Water-Quality Characterization of the Spring River Basin, Southwestern Missouri and Southeastern Kansas. U.S. Geological Survey Water-Resources Investigations Report 90-4176.

Davis, L. (2007) Spatial Patterns of Geomorphic Processes in Channelized Tributary Streams. Physical Geography Vol. 28 (4), 301-310.

Eaton B.C. and T.R. Giles (2009) Assessing the effect of vegetation-related bank strength on channel morphology and stability in gravel-bed streams using numerical models. Earth Surface Processes and Landforms Vol. 34 (5), 712-724.

Harden, C.P., W. Foster, and C. Morris (2009). Rates and Processes of Streambank Erosion in Tributaries of the Little River, Tennessee. Physical Geography Vol. 30 (1), 1-16.

Hughes, H.E. (1974) Soil Survey of Barton County, Missouri. U.S. Department of Agriculture, Soil Conservation Service.

Hughes, M.L., P.F. McDowell, and W. A. Marcus (2006). Accuracy Assessment of Georectified Aerial Photographs: Implications for Measuring Lateral Channel Movement in a GIS. Geomorphology Vol. 74, 1-16.

Kiner L.K., C. Vitello, and K. Hash (1997) Spring River Basin Inventory and Management Plan. Missouri Department of Conservation.

Kleeschulte, M.J., T.O. Mesko, and J.E. Vandike (1985) Appraisal of the Groundwater Resources of Barton, Vernon, and Bates Counties, Missouri. Missouri Department of Natural Resources Division of Geology and Land Survey in cooperation with the U.S. Geological Survey. Water Resources Report No. 36.

LMVP (2015) 2015 Lakes of Missouri Volunteer Program data Lamar City Lake. http://www.lmvp.org/Lakes/lamar/lamar.htm

Martin, D.J. and R.T. Pavlowsky (2011). Spatial Patterns of Channel Instability along an Ozark River, Southwest Missouri. Physical Geography Vol. 32, 445-468.

McKenney, R., R.B. Jacobson, and R. C. Wertheimer (1995). Woody Vegetation and Channel Morphogenesis in Low-Gradient, Gravel-Bed Streams in the Ozark Palteaus, Missouri and Arkansas. Geomorphology Vol. 13, 175-198.

MDNR (1986) Missouri Water Atlas. Missouri Department of Natural Resources Division of Geology and Land Survey.

MDNR (2004a) Biological Assessment Study Upper North Fork of the Spring River Barton and Dade Counties. Missouri Department of Natural Resources, Air and Land Protection Division Environmental Services Program, Water Quality Monitoring Section. 2003-2004.

MDNR (2004b) Biological Assessment Study Lower North Fork of the Spring River Barton and Jasper Counties. Missouri Department of Natural Resources, Field Services Division Environmental Services Program, Water Quality Monitoring Section. 2004.

MDNR (2006) Total Maximum Daily Load (TMDL) for Lamar Lake Barton County, Missouri. Missouri Department of Natural Resources Water Protection Program. Completed: June 29, 2006 and Approved: July 20, 2006.

MDNR (2015) Spring River Nonpoint Source Watershed Plan (Draft Plan), September 22, 2015.

Montgomery D.R. and L.H. MacDonald (2002) Diagnostic approach to stream channel assessment and monitoring. Journal of the American Water Resources Association, Vol. 38, 1-16.

Preston, S.D., R. B. Alexander, G. E. Schwarz, and C. G. Crawford (2011) Factors Affecting Stream Nutrient Loads: A Synthesis of Regional SPARROW Model Results for the Continental United States. Journal of the American Water Resources Association (JAWRA) Vol. 47(5), 891-915.

Rosgen, D.L. (1996) Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Sanford W.E. and D. L. Selnick (2013) Estimation of Evapotranspiration Across the Conterminous United States Using Regression with Climate and Land-Cover Data. Journal of the American Water Resources Association Vol. 49 (1), 217-230.

Simon, A. and M. Rinaldi (2000). Channel Instability in the Loess Area of the Midwestern United States. Journal of the American Water Resources Association Vol. 36 (1), 133-150.

Tetra Tech, Inc. (2017) User's Guide Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) Version 4.4. Developed for U.S. Environmental Protection Agency by Tetra Tech Inc., Fairfax, Virginia, September 2017.

USDA (1998) Stream Visual Assessment Protocol. National Resources Conservation Service, U. S. Department of Agriculture National Water and Climate Center Technical Note 99-1.

USDA (2006) Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. National Resources Conservation Service, United States Department of Agriculture Handbook 296.

USDA (2009a) Chapter 7, Hydrologic Soil Groups. National Resources Conservation Service, United States Department of Agriculture. Part 630 Hydrology National Engineering Handbook.

USDA (2009b) Chapter 20, Watershed Yield. National Resources Conservation Service, United States Department of Agriculture. Part 630 Hydrology National Engineering Handbook.

USDA (2012) USDA Census of Agriculture. United States Department of Agriculture.

USDA (2014) Riparian Forest Buffer. Natural Resource Conservation Service, United States Department of Agriculture Conservation Practice Standard. Code 391.

USDA (2017b) Natural Resources Conservation Service. Regional Hydraulic Geometry Curves. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/manage/hydrology/?cid=nrcs143_015052 (July 20, 2017).

USDA (2017b) Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054242 (July 20, 2017).

USEPA (2006) North Fork Spring River Jasper County, Missouri Total Maximum Daily Load, October 2006. U.S. Environmental Protection Agency Region 7.

Zaimes G.N., R.C. Schultz, and T.M. Isenhart (2004) Stream Bank Erosion Adjacent to Riparian Forest Buffers, Row-Crop Fields, and Continuously-Grazed Pastures along Bear Creek in Central Iowa. Journal of Soil and Water Conservation Vol. 59 (1), 19-27.

TABLES

Table 1. Annual rainfall and average annual temperature for Lamar, Missouri (1987-2016).

Year	Total Rainfall (in)	Average Temperature (°F)
1987	53.5	55.8
1988	45.7	53.9
1989	39.4	53.5
1990	59.4	57.8
1991	29.4	58.2
1992	71.0	56.0
1993	56.3	54.3
1994	59.0	56.1
1995	51.6	55.7
1996	43.0	54.7
1997	46.2	54.9
1998	52.8	58.2
1999	52.0	57.7
2000	39.6	56.8
2001	50.9	57.5
2002	39.2	56.4
2003	46.4	56.0
2004	56.4	56.3
2005	38.2	57.5
2006	38.4	58.7
2007	63.2	57.7
2008	67.7	55.5
2009	55.6	55.5
2010	43.8	57.1
2011	27.6	57.6
2012	25.6	60.3
2013	46.5	55.4
2014	26.9	55.2
2015	54.1	57.2
2016	41.6	58.5
n	30	30
Min	25.6	53.5
Mean	47.4	56.5
Max	71.0	60.3

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	52.1	B	4.6	<0.2	31.9	2e	25.3
Inceptisol	4.5	C	46.3	0.2-0.3	11.7	2s	12.2
Mollisol	10.4	C/D	2.8	0.3-0.4	15.0	2w	17.5
Ultisol	30.1	D	43.5	>0.4	38.5	3e	6.3
Other	2.9	Other	2.9	other	2.9	3s	6.3
						3w	16.3
						4e	2.5
						6s	7.7
						7s	3.1
						Other	2.9

Table 3. Drainage network summary

Water Feature	Length/Area
Streams	52.2 miles
Permanent Flow	10.8 miles
Intermittent Flow	41.4 miles
Waterbodies	246.7 acres
Lamar Lake	148.5 acres
Other Ponds/Lakes	98.2 acres

Table 4. Major water users within the watershed.

Type	Average Annual Usage 2006-2016 (Gallons)
Irrigation	
Well (498 acres)	52,748,273
Surface Water (207 Acres)	12,717,000
Business/Industry	
Well	2,997,931
Lamar WTP	
Well	46,911,597

Table 5. Generalized crop data classification from 2012-2016

General Land Use/Land Cover	Year					2012-2016
	2012	2013	2014	2015	2016	Average
Row Crops	8.0	7.8	9.6	7.9	11.8	9.0
Dbl Crop	5.2	4.4	3.7	2.7	3.8	4.0
Small Grains	0.0	0.2	0.0	2.4	0.1	0.6
Alfalfa and other Hay	6.5	7.3	7.0	6.7	6.5	6.8
Fallow/Idle Cropland and Barren	0.0	0.1	0.0	1.6	0.1	0.4
Developed Land	19.3	19.3	19.6	19.6	19.5	19.4
Forest	14.5	15.3	15.8	18.3	17.7	16.3
Grass/Pasture	41.4	41.2	40.3	37.9	37.4	39.7
Wetlands	2.8	2.1	1.6	0.5	0.8	1.6
Open Water	2.2	2.3	2.3	2.3	2.4	2.3

Table 6. Specific crop data from 2012-2016 with percent change.

Class Name	Year					% Change
	2012	2013	2014	2015	2016	2012-2016
Corn	3.1	2.6	4.3	4.2	4.8	57.6
Soybeans	4.8	5.2	5.1	3.7	6.9	43.3
Dbl Crop WinWht/Soybeans	5.2	4.4	3.7	2.7	3.8	-27.1
Developed/Med Intensity	1.9	1.9	2.2	2.1	2.0	8.8
Developed/High Intensity	1.2	1.2	1.3	1.4	1.3	12.2
Deciduous Forest	14.5	15.3	15.8	18.2	17.5	20.4
Grass/Pasture	41.4	41.2	40.3	37.9	37.4	-9.7
Woody Wetlands	2.8	2.1	1.6	0.5	0.8	-72.9
Open Water	2.2	2.3	2.3	2.3	2.4	8.4

Table 7. Water quality monitoring sites with nutrient and sediment data summary.

Site ID	TP (n)	TP start	TP end	TN (n)	TN start	TN end	TSS (n)	TSS start	TSS end
LL_1	183	6/13/1989	9/17/2015	183	6/13/1989	9/17/2015	86	5/19/2003	9/17/2015
LL_2	51	2/1/1992	12/29/1992	47	2/1/1992	12/29/1992	0	NA	NA
LL_3	35	5/15/1992	12/29/1992	30	5/15/1992	12/29/1992	0	NA	NA
LL_4	110	5/19/2003	9/17/2015	110	5/19/2003	9/17/2015	94	5/19/2003	9/17/2015
NFSR_16.8	3	9/27/2006	9/27/2012	3	9/27/2006	9/27/2012	1	9/27/2012	9/27/2012
NFSR_20.5	9	8/30/2004	5/2/2013	5	8/30/2004	5/2/2013	2	9/27/2012	5/2/2013
NFSR_24.6	6	7/27/2005	7/21/2010	4	7/27/2005	9/1/2005	5	7/27/2005	9/15/2010
NFSR_24.9	6	8/30/2004	7/21/2010	1	8/30/2004	8/30/2004	0	NA	NA
NFSR_26.5	6	9/23/2003	4/16/2013	6	9/23/2003	4/16/2013	2	10/10/2012	4/16/2013

n = sample number

TP = total phosphorus

TN = total nitrogen

TSS = total suspended sediment

NA = not available

Table 8. Permitted point sources within the watershed.

Site Number	Facility Name	Type	Stream	Waste	Status
1	Blue Top Motel and Cafe	Outfall	TRIB N FK SPRING R	Domestic (Sanitary) Wastewater	Expired
2	Super 8 Motel	Outfall	TRIB N FK SPRING R	Domestic (Sanitary) Wastewater	Expired
3	Feltenberger Enterprises Courtesy Court	Outfall	N. Fk. Spring R.	Domestic (Sanitary) Wastewater	Effective
4	Lamar WWTF	Outfall	Tributary to North Fork Spring River	Domestic (Sanitary) Wastewater	Effective
5	Lamar Municipal WTP	Outfall	TRIB N FORK SPRING R	Non-Domestic Process Water	Effective
6	Lamar Municipal WTP	Outfall	TRIB N FORK SPRING R	Non-Domestic Process Water	Effective
7	Jerry Marti	Land Application Site	Unnamed Tributary to North Fork Spring River	Domestic (Sanitary) Wastewater	Effective

Table 9. Lamar WWTF Data (2015-2017).

Parameter	n	Concentration (mg/L)
TP	6	1.66
TN	6	3.03
TSS	27	7.94

Data source: Missouri Department of Natural Resources

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		http://www.dnr.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		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 11. Summary statistics for Lamar Lake and North Fork Spring River samples.

Site ID	TN (mg/L)					TP (mg/L)					TSS (mg/L)				
	min	mean	max	stdv	cv%	min	mean	max	stdv	cv%	min	mean	max	stdv	cv%
LL_1	0.40	1.10	2.65	0.37	33.3	0.034	0.082	0.208	0.028	34.4	3.3	8.5	29.7	3.8	44.6
LL_2	0.90	2.31	5.00	1.12	48.3	0.010	0.063	0.230	0.051	80.8	NA	NA	NA	NA	NA
LL_3	0.80	3.08	15.70	3.04	98.8	0.020	0.099	0.450	0.111	112.8	NA	NA	NA	NA	NA
LL_4	0.46	1.24	2.11	0.37	30.2	0.011	0.096	0.223	0.034	35.1	2.9	10.2	51.9	6.1	59.9
NFSR_16.8	1.28	1.73	2.18	0.45	26.0	0.140	0.157	0.190	0.029	18.4	NA	8.0	NA	NA	NA
NFSR_20.5	1.64	2.83	6.00	2.12	1.64	0.130	0.326	0.880	0.219	67.3	13.0	15.0	17.0	2.8	18.9
NFSR_24.6	15.80	21.78	28.50	6.82	31.3	2.520	3.285	4.710	0.948	28.9	5.0	8.4	18.0	5.5	65.0
NFSR_24.9	NA	0.95	NA	NA	NA	0.130	0.168	0.200	0.031	18.5	NA	NA	NA	NA	NA
NFSR_26.5	0.60	1.65	2.92	0.94	57.0	0.040	0.152	0.290	0.099	65.3	5.0	25.5	46.0	29.0	113.7

Table 12. List of Aerial Photographs used in stream channel change analysis

Photo Year/Date	Number of Photos	Source	Type	Resolution (ft)	RMSE Range (ft)	Max P2P Error (ft)	Mean P2P Error (ft)
Sept. 1953	7	MSU Library	Black and White	3.0	1.0-4.9	8.2	4.6
Sept. 1966	7	MSU Library	Black and White	3.0	2.3-4.9	6.6	4.3
March 1997	23	USGS	Black and White DOQ Geotiff	3.3	Pre-rectified	13.4	8.5
April 2008	23	USGS	Color High Resolution Orthoimagery Geotiff	2.0	Pre-rectified	n/a	n/a
July 2014	23	USGS	Color NAIP Geotiff	3.3	Pre-rectified	8.2	5.2

Table 13. Tributary channel classification results from historical aerial photo analysis

Watershed	Total length (mi)	Channelized	Impoundment	Stable	Disturbed	Undetermined
HUC-12	41.2	7.8 (18.9%)	4.7 (11.4%)	5.6 (13.6%)	2.2 (5.4%)	20.9 (50.7%)
Lamar Lake	7.4	1.6 (21.5%)	1.0 (13.2%)	1.9 (26.1%)	0.7 (10.1%)	2.2 (29.1%)

Table 14. Summary of riparian corridor analysis results of tributary streams.

Watershed	Total length (mi)	Good	Moderate	Poor
HUC-12	41.2	20.6 (50%)	6.6 (16%)	14.0 (34%)
Lamar Lake	7.4	2.2 (30%)	1.6 (21%)	3.6 (49%)

Table 15. STEPL Model Results

Watershed ID	Total Ad (ac)	Runoff (ac-ft)	Runoff Yield (ac-ft/ac)	% Rainfall as Runoff	Annual Load N- lb/yr	Annual Load P- lb/yr	Annual Load Sed- t/yr	Annual Yield N- lb/ac/yr	Annual Yield P- lb/ac/yr	Annual Yield Sed- t/ac/yr	Mean Concentration N- mg/L	Mean Concentration P- mg/L	Mean Concentration Sed- mg/L
HUC-12	13,278	14,704	1.11	29.1	142,561	24,115	3,616	10.7	1.82	0.27	3.57	0.603	180.9
Lamar Lake	2,901*	2,918	1.01	29.2	32,449	4,787	934	11.2	1.65	0.32	4.09	0.603	235.4

* only includes land draining to the lake

Table 16. STEPL results breakdown by sources.

Sources	HUC-12 N Load (lb/yr)	%	HUC-12 P Load (lb/yr)	%	HUC-12 Sediment Load (t/yr)	%	Lamar Lake N Load (lb/yr)	%	Lamar Lake P Load (lb/yr)	%	Lamar Lake Sediment Load (t/yr)	%
Urban	24,930	17.5	3,854	16.0	572	15.8	2,432	7.5	376	7.9	56	6.0
Cropland	51,934	36.4	13,289	55.1	1,603	44.3	8,201	25.3	2,141	44.7	345	36.9
Pastureland	61,248	43.0	5,492	22.8	906	25.1	20,830	64.2	1,988	41.5	429	45.9
Forest	1,007	0.7	493	2.0	28	0.8	161	0.5	78	1.6	6	0.6
Feedlots	1,851	1.3	370	1.5	0	0.0	617	1.9	123	2.6	0	0.0
User Defined	660	0.5	254	1.1	206	5.7	55	0.2	21	0.4	17	1.8
Septic	448	0.3	175	0.7	0	0.0	24	0.1	9	0.2	0	0.0
Streambank	482	0.3	186	0.8	302	8.3	129	0.4	50	1.0	81	8.6
Total	142,560	100	24,115	100	3,616	100	32,449	100	4,787	100	934	100

Table 17. Nitrogen load reduction results for the HUC-12 watershed.

List of Practices	Nitrogen 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
Terrace	1.0	1.9	2.9	3.9	4.9	5.8	6.8	7.8	8.8	9.7
Cover Crop and Grass Waterways	1.2	2.3	3.5	4.6	5.8	6.9	8.1	9.2	10.9	11.5
Cover Crop and Reduced Till	1.2	2.4	3.6	4.8	6.0	7.2	8.5	9.7	10.9	12.1
Terrace and Grass Waterways	1.4	2.7	4.1	5.4	6.8	8.2	9.5	10.9	12.2	13.6
Cover Crop and No Till	1.6	3.2	4.8	6.4	7.9	9.5	11.1	12.7	14.3	15.9
Cover Crop, Reduced Till, Nutrient Management	1.8	3.5	5.3	7.0	8.8	10.6	12.3	14.1	15.8	17.6
Cover Crop, No Till, Nutrient Management	2.1	4.2	6.2	8.3	10.4	12.5	14.5	16.6	18.7	20.8
Land Retirement	3.3	6.6	9.9	13.2	16.5	19.7	23.0	26.3	29.6	32.9
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	1.4	2.8	4.2	5.6	7.0	8.4	9.8	11.2	12.6	14.1
Livestock Exclusion, Alternative Water, Prescribed Grazing	2.6	5.2	7.7	10.3	12.9	15.5	18.1	20.6	23.2	25.8
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	3.4	6.7	10.1	13.4	16.8	20.2	23.5	26.9	30.2	33.6

Table 18. Nitrogen load reduction results for the Lamar Lake watershed.

List of Practices	Nitrogen load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.5	0.9	1.4	1.9	2.3	2.8	3.2	3.7	4.2	4.6
Terrace	0.7	1.4	2.0	2.7	3.4	4.1	4.8	5.5	6.1	6.8
Cover Crop and Grass Waterways	0.8	1.7	2.5	3.3	4.2	5.0	5.9	6.7	7.5	8.5
Cover Crop and Reduced Till	0.9	1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.5
Terrace and Grass Waterways	1.0	1.9	2.9	3.9	4.9	5.8	6.8	7.8	8.8	9.7
Cover Crop and No Till	1.1	2.3	3.4	4.6	5.7	6.8	8.0	9.1	10.2	11.4
Cover Crop, Reduced Till, Nutrient Management	1.2	2.4	3.7	4.9	6.1	7.3	8.5	9.7	11.0	12.2
Cover Crop, No Till, Nutrient Management	1.5	2.9	4.4	5.9	7.4	8.8	10.2	11.7	13.2	14.6
Land Retirement	2.3	4.6	6.9	9.1	11.4	13.8	16.0	18.3	20.6	22.9
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	2.1	4.3	6.4	8.6	10.7	12.9	15.0	17.2	19.3	21.5
Livestock Exclusion, Alternative Water, Prescribed Grazing	3.9	7.8	11.6	15.5	19.4	23.3	27.2	31.0	34.9	38.8
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	5.0	10.1	15.1	20.1	25.2	30.2	35.2	40.3	45.3	50.4

Table 19. Phosphorus load reduction results for the HUC-12 watershed.

List of Practices	Phosphorus load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.4	0.8	1.2	1.6	2.1	2.5	2.9	3.3	3.7	4.1
Terrace	1.8	3.5	5.3	7.1	8.9	10.6	12.4	14.2	16.0	17.7
Cover Crop and Grass Waterways	2.0	4.0	5.9	7.9	9.9	11.9	13.9	15.9	17.8	19.8
Cover Crop and Reduced Till	2.3	4.5	6.8	9.0	11.3	13.6	15.8	18.1	20.3	22.6
Terrace and Grass Waterways	2.9	5.8	8.7	11.6	14.5	17.4	20.5	23.2	26.1	29.0
Cover Crop and No Till	4.0	8.0	11.9	15.9	19.9	23.9	27.8	31.8	35.8	39.8
Cover Crop, Reduced Till, Nutrient Management	3.8	7.7	11.5	15.3	19.1	23.0	26.8	30.7	34.5	38.3
Cover Crop, No Till, Nutrient Management	4.7	9.5	14.2	19.0	23.7	28.4	33.2	37.9	42.7	47.4
Land Retirement	4.6	9.1	13.7	18.3	22.8	27.4	32.0	36.6	41.1	45.7
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	1.0	2.0	3.1	4.1	5.1	6.1	7.1	8.1	9.2	10.2
Livestock Exclusion, Alternative Water, Prescribed Grazing	1.3	2.6	4.0	5.3	6.6	7.9	9.2	11.5	11.9	13.2
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	1.7	3.4	5.1	6.9	8.6	10.3	12.0	13.7	15.4	17.1

Table 20. Phosphorus load reduction results for the Lamar Lake watershed.

List of Practices	Phosphorus load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.3	0.7	1.0	1.4	1.7	2.0	2.4	2.7	3.1	3.4
Terrace	1.4	2.8	4.3	5.7	7.1	8.5	9.9	11.4	12.8	14.2
Cover Crop and Grass Waterways	1.7	3.4	5.1	6.8	8.5	10.2	11.9	13.6	15.3	16.9
Cover Crop and Reduced Till	1.8	3.7	5.5	7.4	9.2	11.1	12.9	14.8	16.6	18.5
Terrace and Grass Waterways	2.4	4.7	7.1	9.4	11.8	14.2	16.5	18.9	21.2	23.6
Cover Crop and No Till	3.2	6.5	9.7	13.0	16.2	19.5	22.7	26.0	29.2	32.5
Cover Crop, Reduced Till, Nutrient Management	3.0	6.1	9.1	12.2	15.2	18.3	21.3	24.4	27.4	30.5
Cover Crop, No Till, Nutrient Management	3.8	7.7	11.5	15.3	19.1	23.0	26.8	30.6	34.5	38.3
Land Retirement	3.7	7.5	11.2	15.0	18.7	22.5	26.2	29.9	33.7	37.4
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	1.9	3.9	5.8	7.7	9.7	11.6	13.5	15.5	17.4	19.3
Livestock Exclusion, Alternative Water, Prescribed Grazing	2.5	4.9	7.4	9.9	12.4	14.8	17.3	19.8	22.3	24.7
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	3.2	6.4	9.5	12.7	15.9	19.1	22.2	25.4	28.6	31.8

Table 21. Sediment load reduction results for the HUC-12 watershed.

List of Practices	Sediment load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.4	0.8	1.3	1.8	2.2	2.7	3.1	3.5	4.0	4.4
Terrace	1.8	3.5	5.3	7.1	8.9	10.6	12.4	14.2	16.0	17.7
Cover Crop and Grass Waterways	3.0	6.1	9.1	12.1	15.2	18.2	21.2	24.3	27.3	30.4
Cover Crop and Reduced Till	2.1	4.1	6.2	8.2	10.3	12.3	14.4	16.4	18.5	20.5
Terrace and Grass Waterways	3.5	7.0	10.5	14.0	17.5	21.0	24.5	28.0	31.5	35.0
Cover Crop and No Till	3.5	7.0	10.5	14.1	17.6	21.1	24.6	28.1	31.6	35.1
Cover Crop, Reduced Till, Nutrient Management	2.1	4.1	6.2	8.2	10.3	12.3	14.4	16.4	18.5	20.5
Cover Crop, No Till, Nutrient Management	3.5	7.0	10.5	14.1	17.6	21.1	24.6	28.1	31.6	35.1
Land Retirement	4.2	8.5	12.6	16.8	21.1	25.3	29.5	33.7	37.9	42.1
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	1.7	3.5	5.2	6.9	8.7	10.4	12.1	13.9	15.6	17.3
Livestock Exclusion, Alternative Water, Prescribed Grazing	2.0	4.0	6.0	8.0	9.9	11.9	13.9	15.9	17.9	19.9
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	2.3	4.5	6.8	9.1	11.3	13.6	15.9	18.1	20.4	22.6

Table 22. Sediment load reduction results for the Lamar Lake watershed.

List of Practices	Sediment load reduction by % of land treated									
Cropland	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cover Crop	0.4	0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.3	3.7
Terrace	1.3	2.7	4.0	5.3	6.6	8.0	9.3	10.6	11.9	13.3
Cover Crop and Grass Waterways	2.5	5.1	7.6	10.1	12.7	15.2	17.7	20.2	22.8	25.3
Cover Crop and Reduced Till	1.7	3.4	5.1	6.8	8.6	10.3	12.0	13.7	15.4	17.1
Terrace and Grass Waterways	2.6	5.2	7.9	10.5	13.1	15.7	18.3	21.0	23.6	26.2
Cover Crop and No Till	2.9	5.9	8.8	11.7	14.7	17.6	20.5	23.4	26.4	29.3
Cover Crop, Reduced Till, Nutrient Management	1.7	3.4	5.1	6.8	8.6	10.3	12.0	13.7	15.4	17.1
Cover Crop, No Till, Nutrient Management	2.9	5.9	8.8	11.7	14.7	17.6	20.5	23.4	26.4	29.3
Land Retirement	3.5	7.0	10.5	14.0	17.6	21.1	24.6	28.1	31.6	35.1
Pasture Land	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Livestock Exclusion and Alternative Water	3.2	6.3	9.5	12.7	15.9	19.0	22.2	25.4	28.6	31.7
Livestock Exclusion, Alternative Water, Prescribed Grazing	3.6	7.3	10.9	14.6	18.2	21.9	25.5	29.2	32.8	36.5
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	4.2	8.3	12.5	16.6	20.8	24.9	29.1	33.2	37.4	41.5

Table 23. Management unit priority ranking

Zone ID	Watershed ID	Total Ad (ac)	Crop acres	Pasture acres	Annual Yield P-lb/ac/yr	Annual Yield Sed t/ac/yr	Priority Rank
1	12	741	96	533	2.03	0.48	1
1	10	928	125	432	1.89	0.49	2
1	11	1,382	93	980	1.40	0.33	3
2	6	568	371	129	5.17	1.12	4
2	3	583	186	115	3.23	0.71	5
2	7	1,089	356	555	3.03	0.61	6
2	8	972	169	717	2.25	0.59	7
2	14	717	147	118	3.10	0.54	8
2	4	846	182	448	2.37	0.49	9
2	2	517	77	166	2.18	0.44	10
2	9	472	12	344	1.45	0.32	11
2	15	727	0	197	1.50	0.26	12
2	5	581	20	294	1.24	0.25	13
2	1	2,136	171	606	1.15	0.22	14
2	16	581	2	261	1.03	0.21	15
2	13	439	0	17	1.60	0.30	16

Table 24. Summary of priority acres by watershed

Priority Rank	Land Use and Conditions	HUC-12 Acres (%)	Lamar Lake Acres (%)
Highest	Cropland and K-factor >0.35 Cropland and poor riparian buffer Pasture and poor riparian buffer	1,281 (9.7%)	165 (5.4%)
High	Cropland and K-factor <0.35 Pasture and K-factor >0.35 Pasture and moderate riparian buffer	2,381 (17.9%)	515 (16.9%)
Moderate	All other pasture	4,242 (32.0%)	1,581 (51.8%)
Low	Forest and scrubland	2,364 (17.8%)	363 (11.9%)
Urban	Urban and barren	2,593 (19.5%)	253 (8.3%)
Water	Water and wetlands	417 (3.1%)	174 (5.7%)
Total		13,278 (100%)	3,051 (100%)

Table 25. Ranked conservation practices by most benefit per acres treated.

Rank	BMPs in the HUC-12 watershed for sediment reduction	BMPs in the Lamar Lake watershed for phosphorus reduction
1	CROPLAND - Land Retirement	CROPLAND - Cover Crop, No Till, Nutrient Management
2	CROPLAND - Cover Crop, No Till, Nutrient Management	CROPLAND - Land Retirement
3	CROPLAND - Cover Crop and No Till	CROPLAND - Cover Crop and No Till
4	CROPLAND – Terraces and Grass Waterways	CROPLAND - Cover Crop, Reduced Till, Nutrient Management
5	CROPLAND - Cover Crop and Grass Waterways	CROPLAND – Terraces and Grass Waterways
6	CROPLAND - Cover Crop, Reduced Till, Nutrient Management	CROPLAND - Cover Crop and Reduced Till
7	CROPLAND - Cover Crop and Reduced Till	CROPLAND - Cover Crop and Grass Waterways
8	CROPLAND - Terraces	CROPLAND - Terraces
9	PASTURELAND - Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	PASTURELAND - Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer
10	PASTURELAND - Livestock Exclusion, Alternative Water, Prescribed Grazing	PASTURELAND -Livestock Exclusion, Alternative Water, Prescribed Grazing
11	PASTURELAND - Livestock Exclusion and Alternative Water	CROPLAND -Cover Crop
12	CROPLAND -Cover Crop	PASTURELAND -Livestock Exclusion and Alternative Water

FIGURES

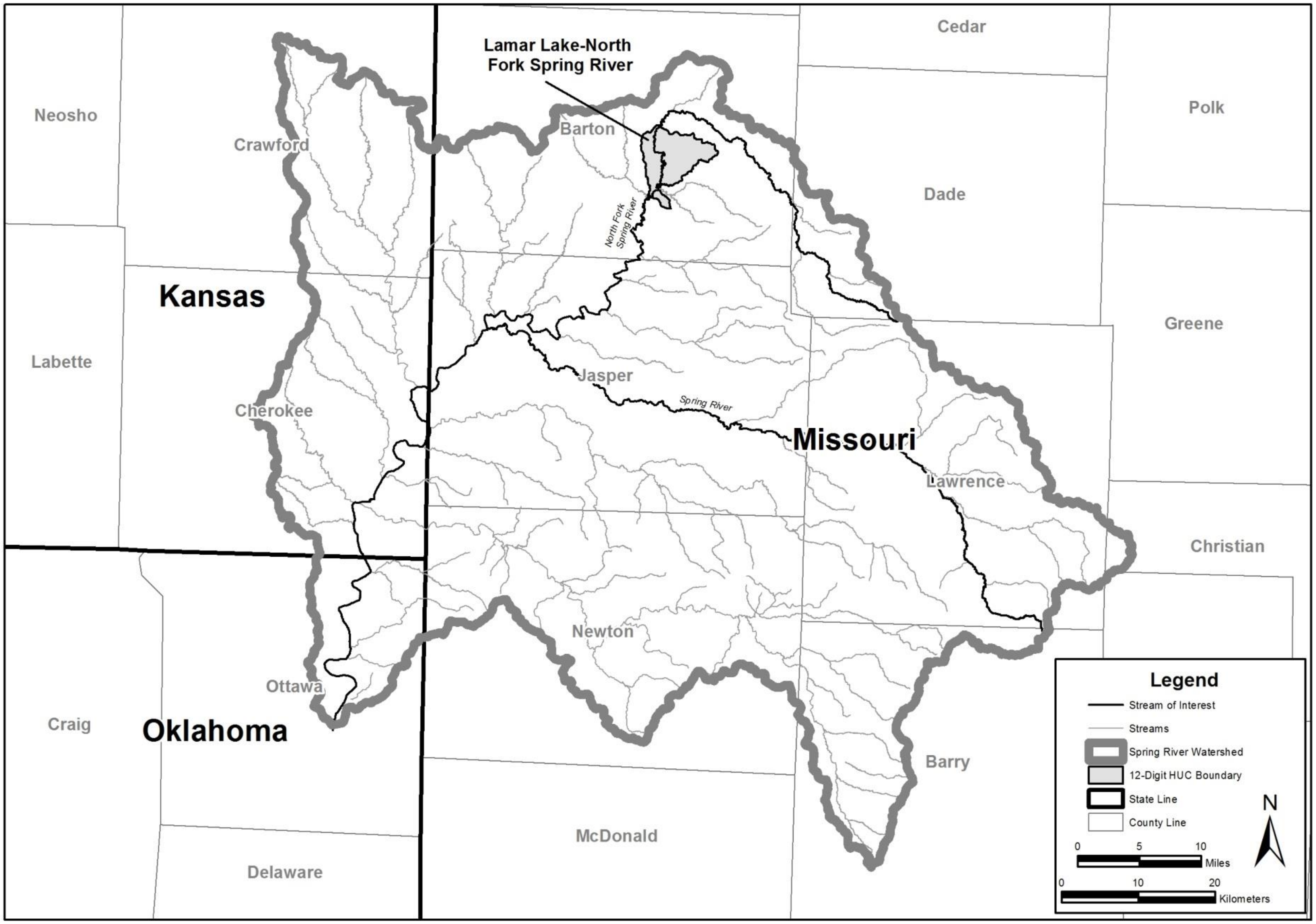


Figure 1. Spring River basin in southwest Missouri, southeast Kansas, and northwest Oklahoma.

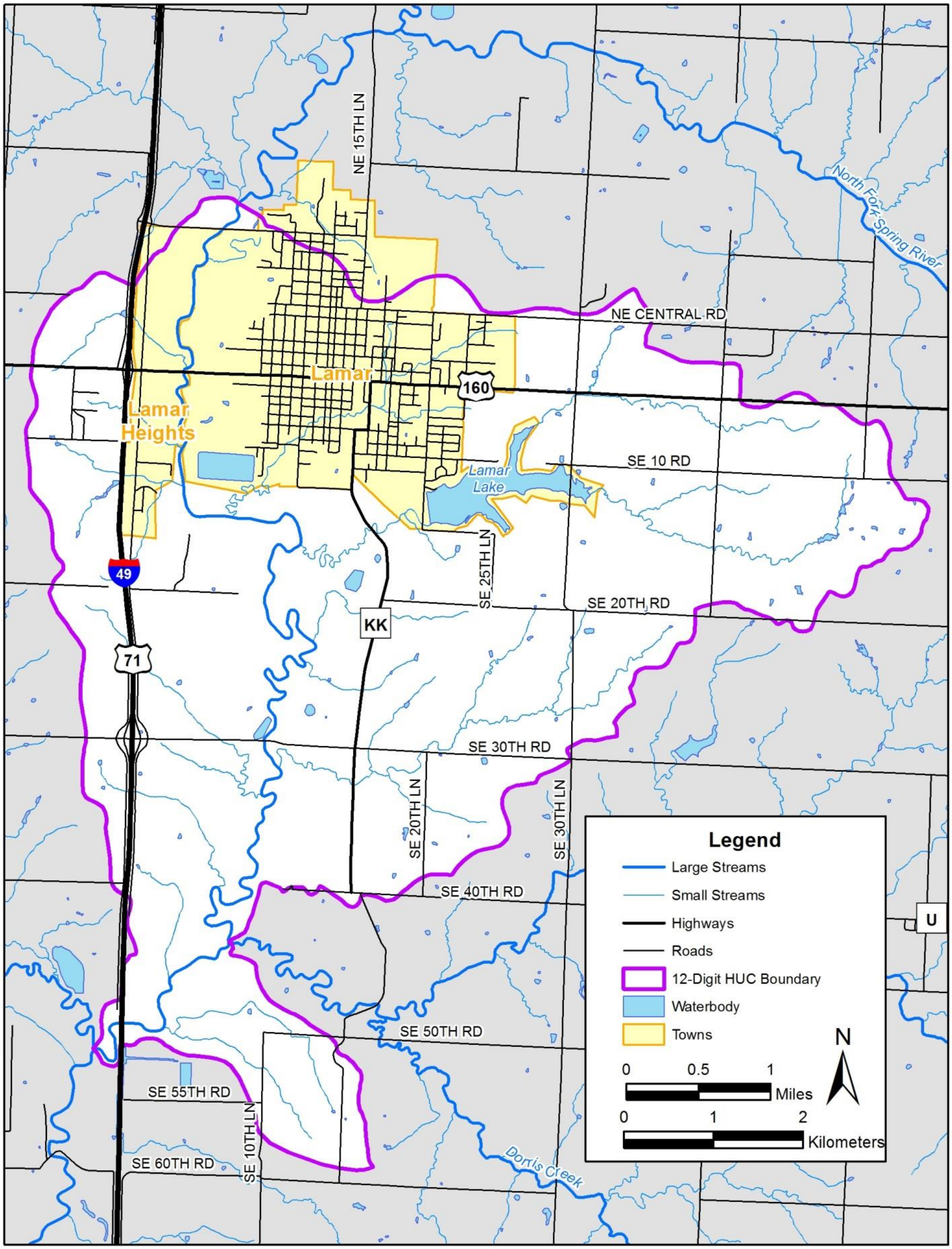


Figure 2. The Lamar Lake-North Fork Spring River watershed.

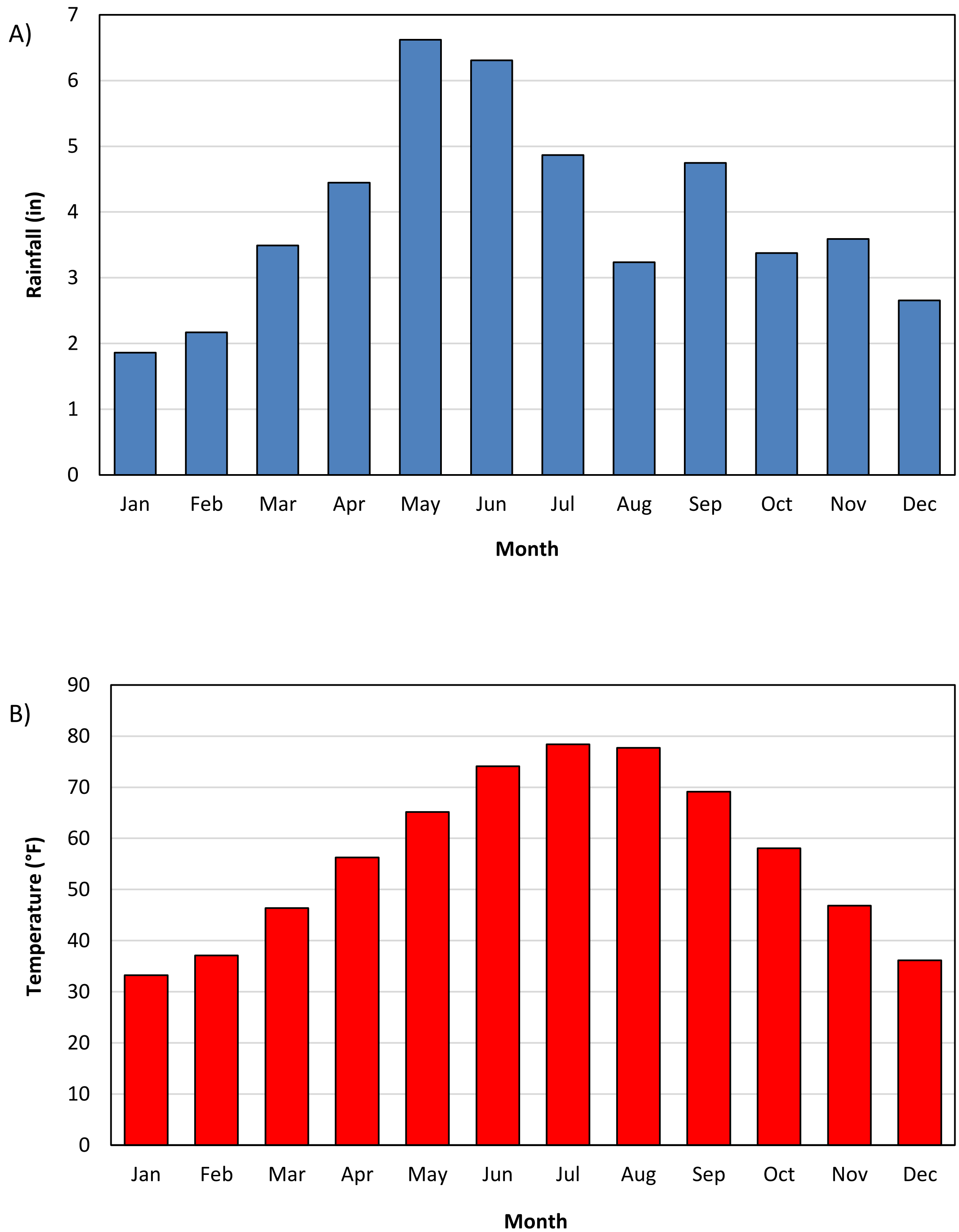


Figure 3. Mean monthly A) rainfall and B) temperature from 1987-2016 for Lamar, Missouri.

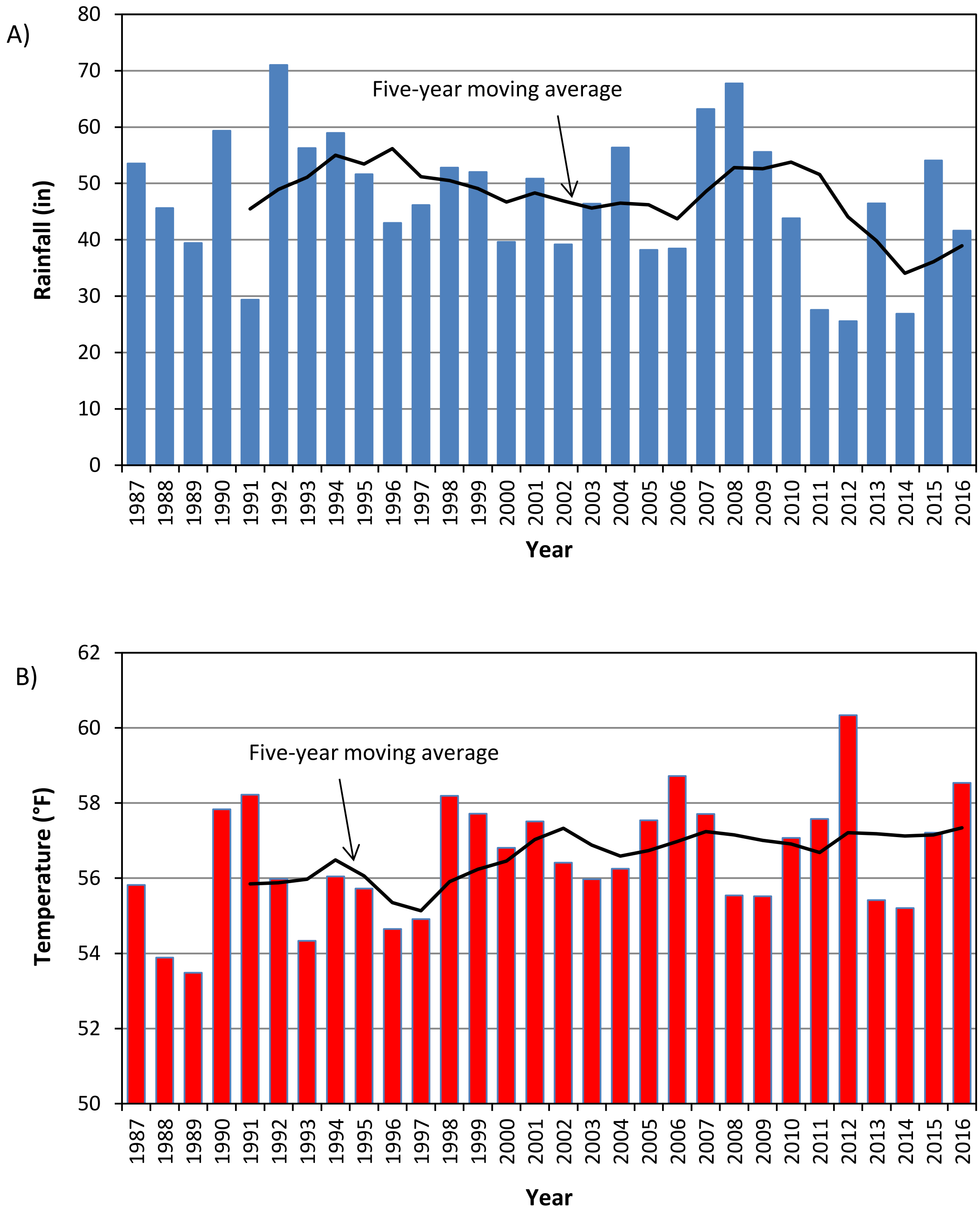


Figure 4. A) Annual total rainfall and B) average annual temperature from 1987-2016 for Lamar, Missouri.

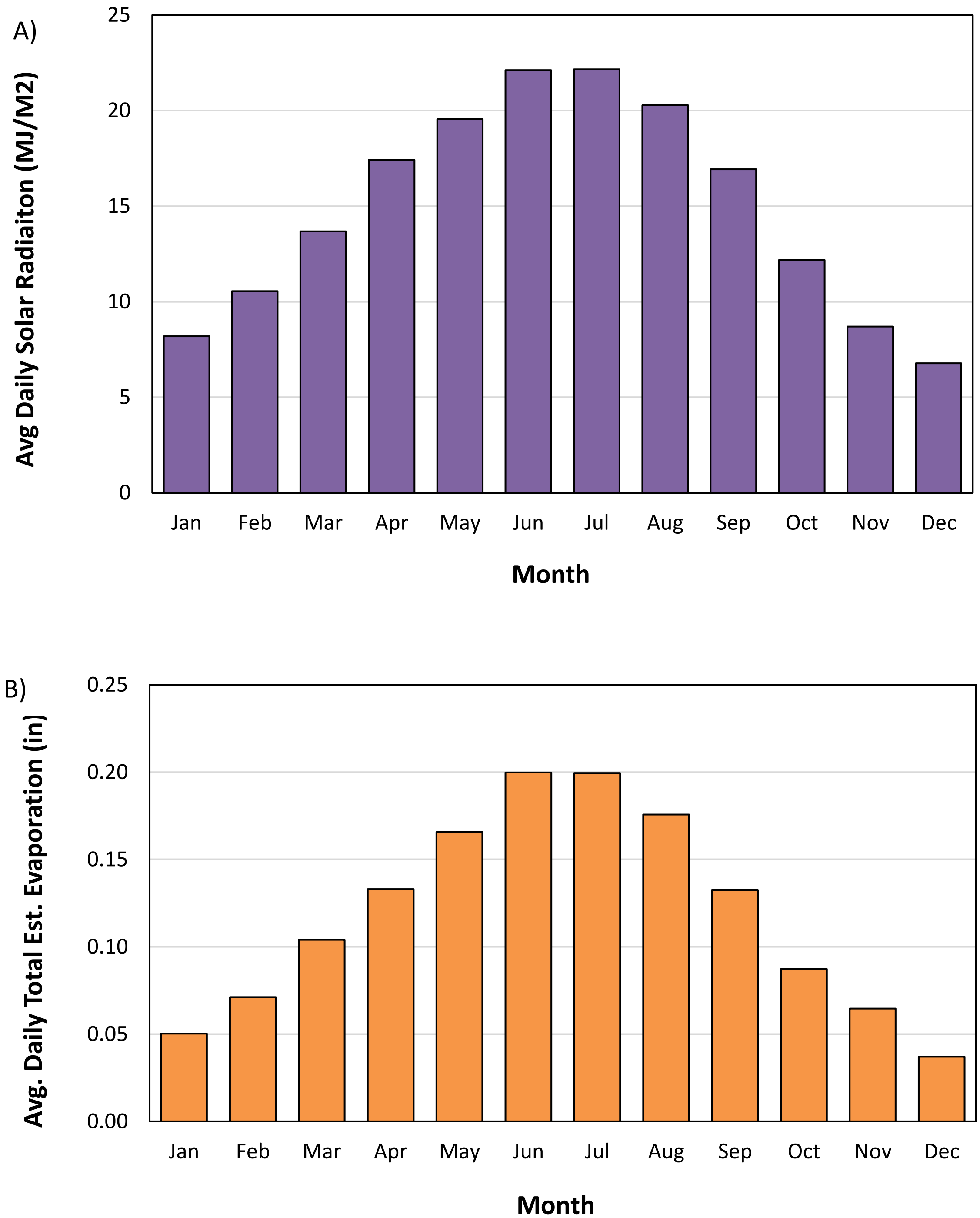
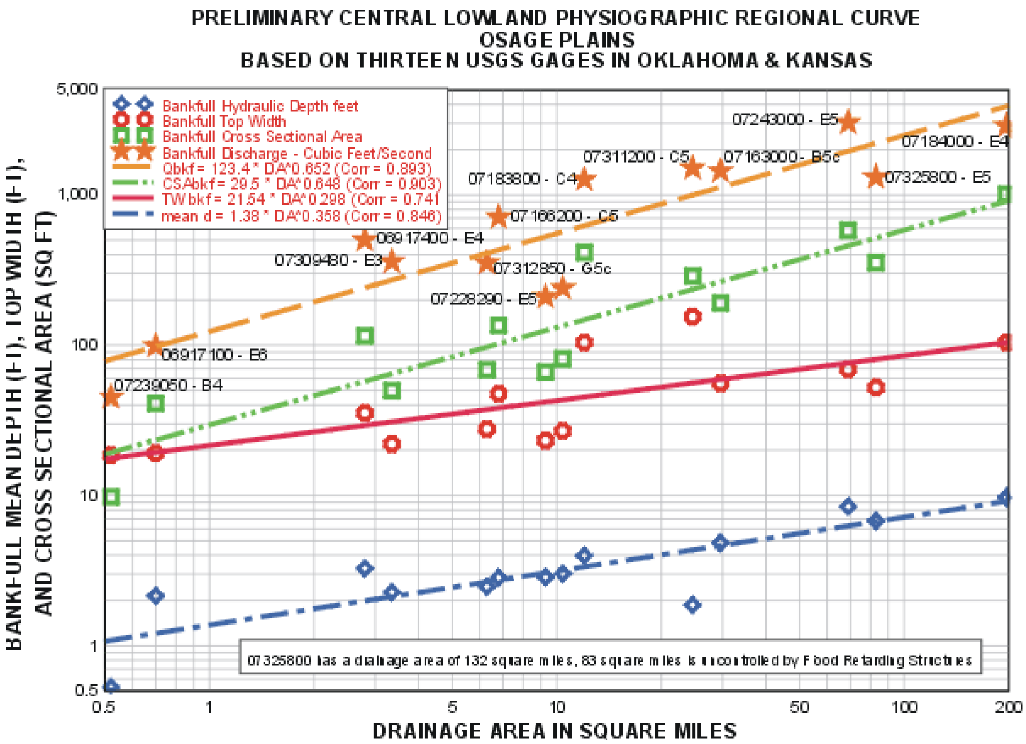


Figure 5. Average daily A) solar radiation (2000-2016) and B) estimated evaporation (2011-2016) for Lamar, Missouri.

A)



B)

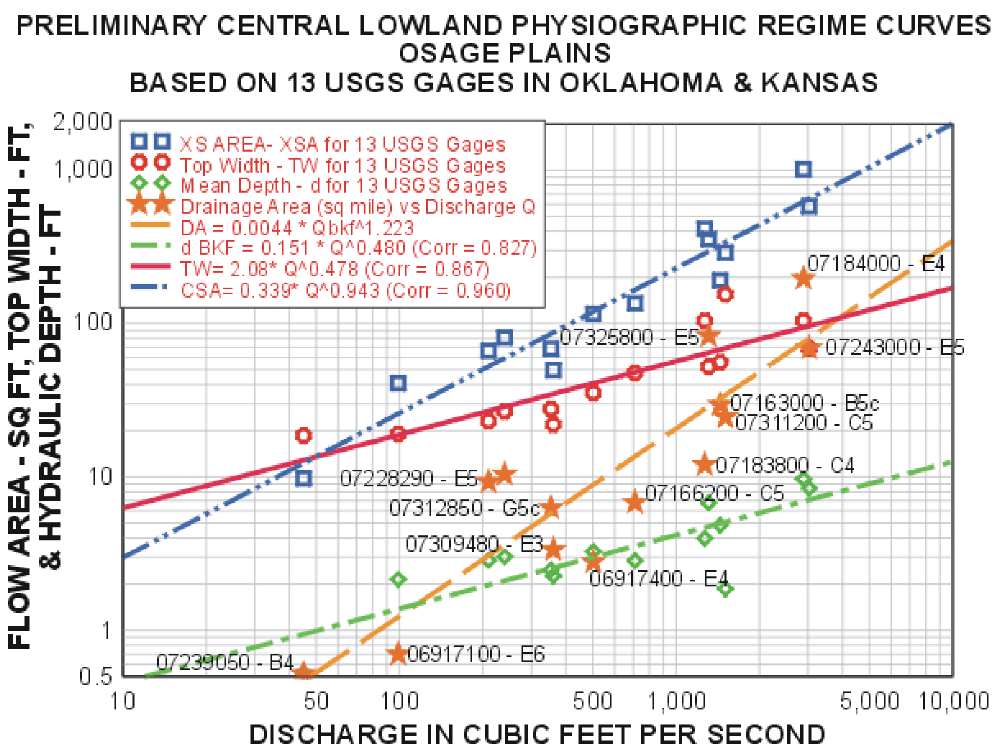


Figure 6. Preliminary A) regional and B) regime curves for the Osage Plain physiographic region. Source: NRCS-National Water Management Center
www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/manage/hydrology/?cid=nrcs143_015052

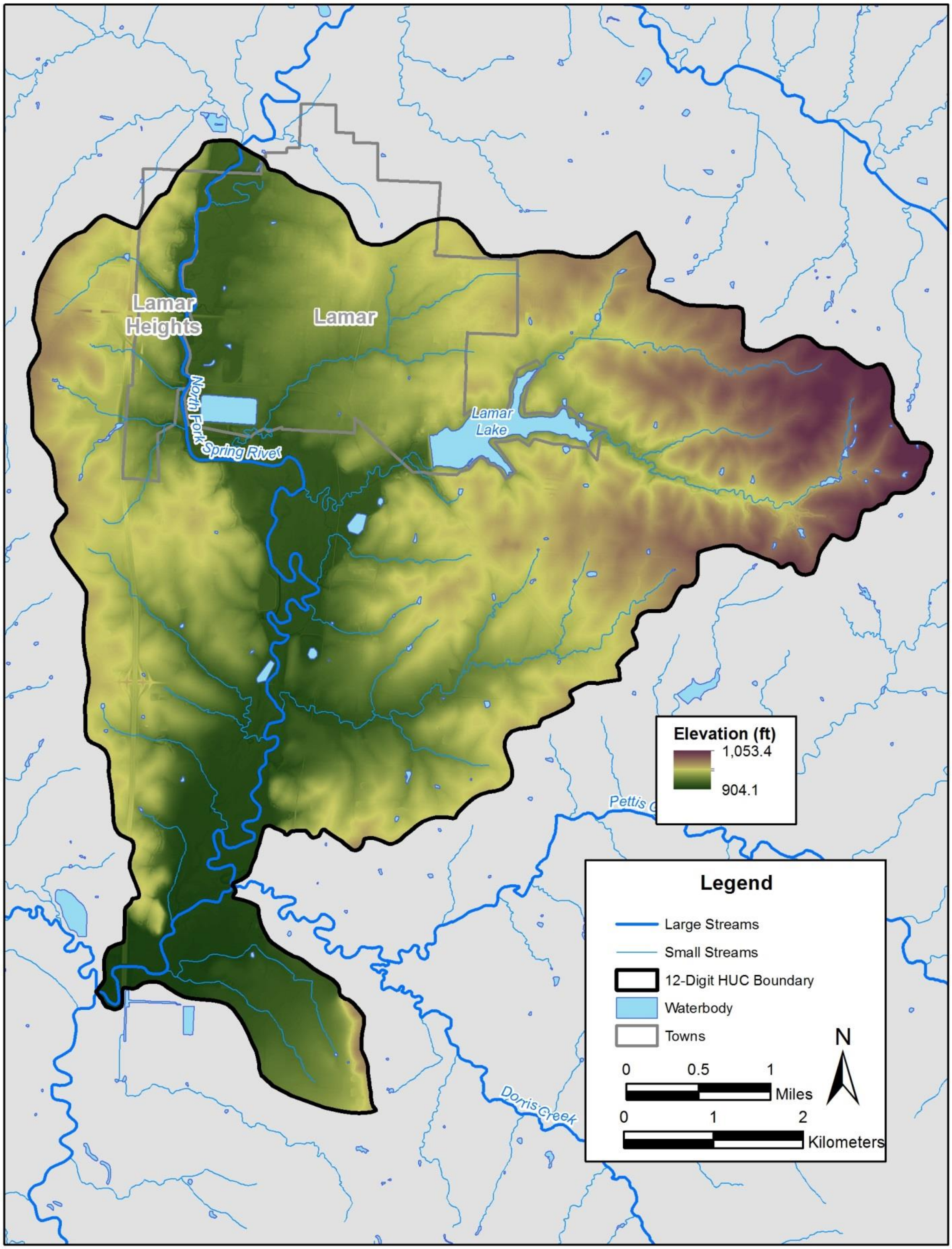


Figure 7. LiDAR elevations within the watershed.

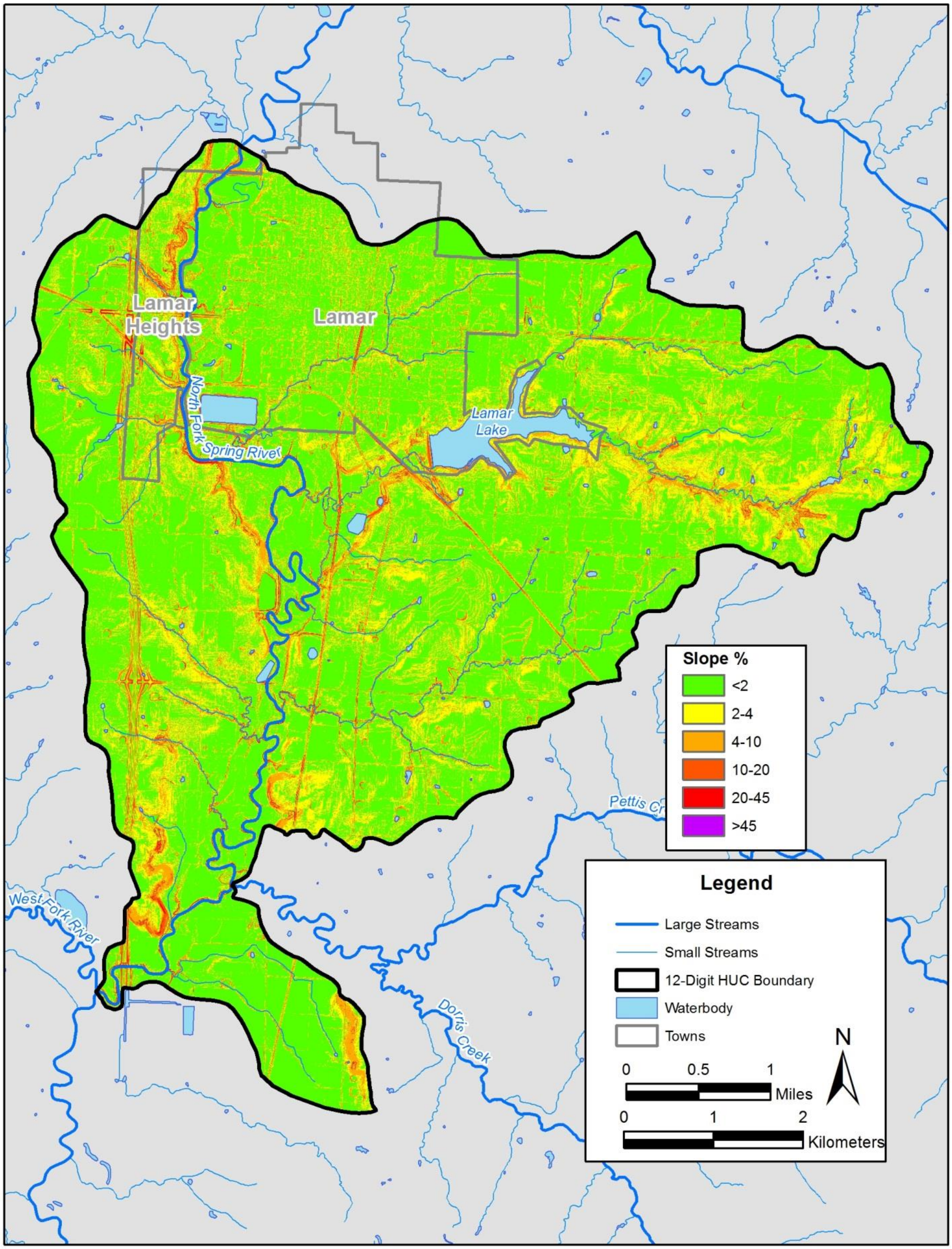


Figure 8. LiDAR based slope classification across the watershed.

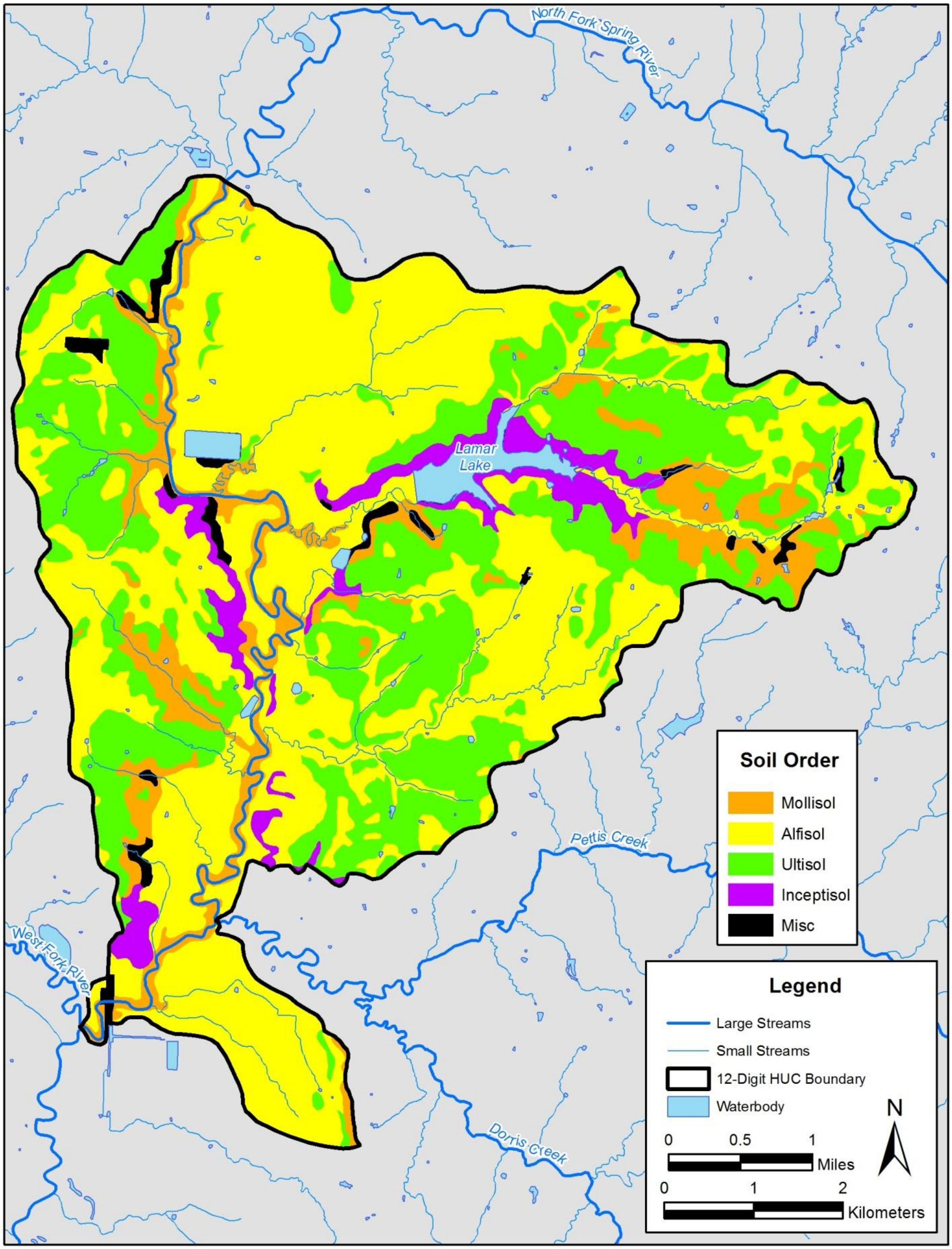


Figure 9. Soil series classified by order.

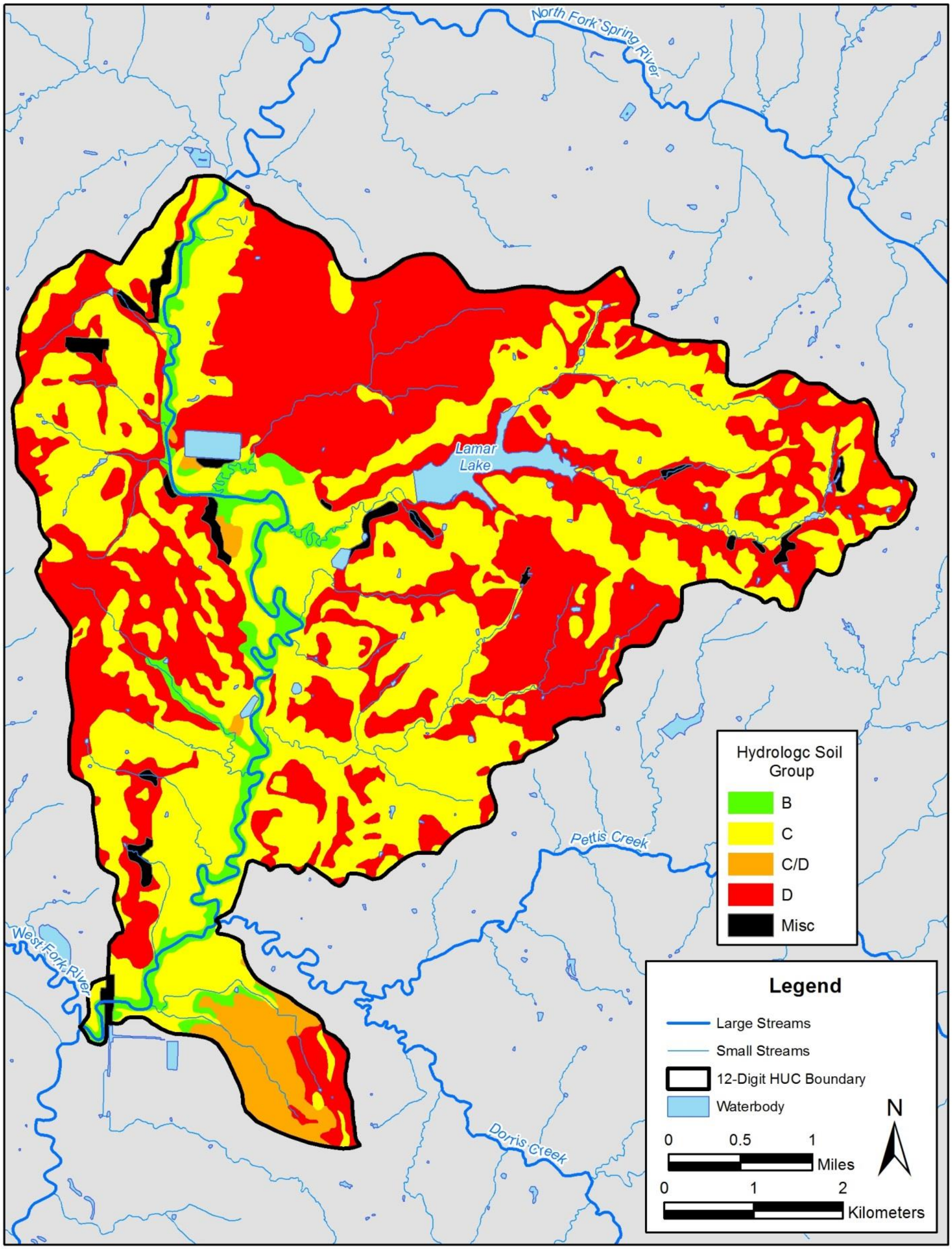


Figure 10. Soil series classified by hydrologic soil group.

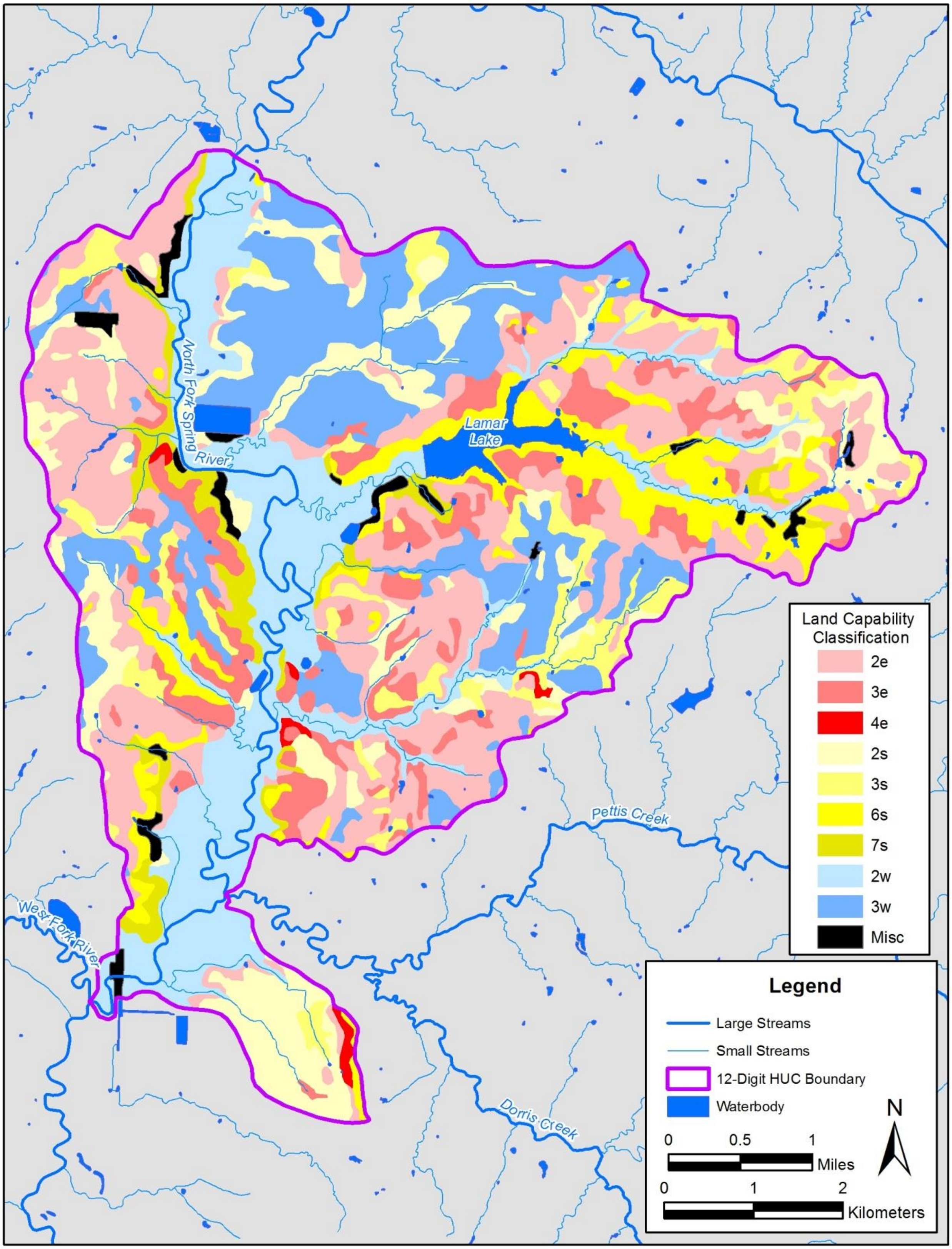


Figure 11. Soil series classified by land capability classification.

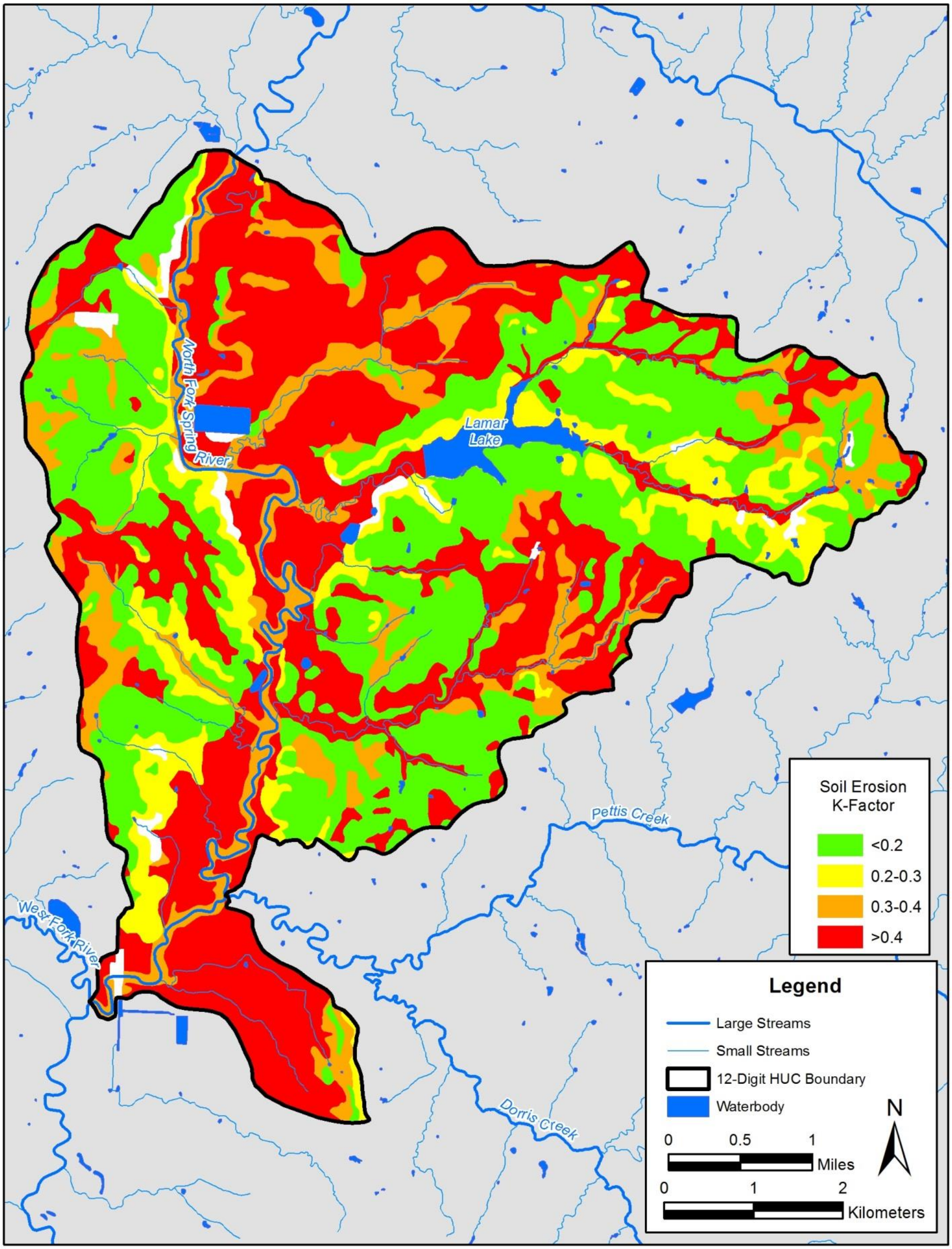


Figure 12. Soil series classified by soil erosion K-factor.

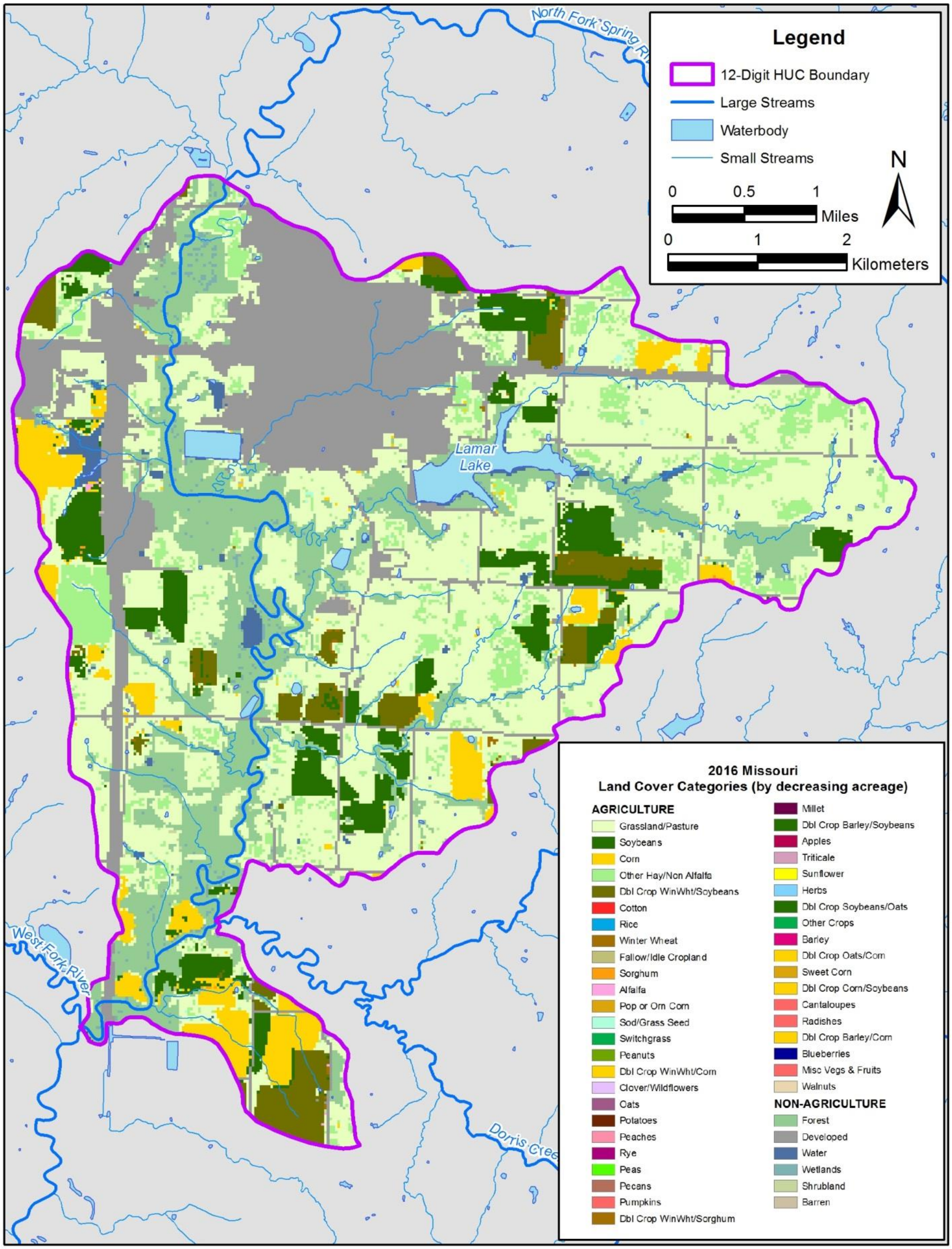


Figure 13. 2016 crop data from the NASS.

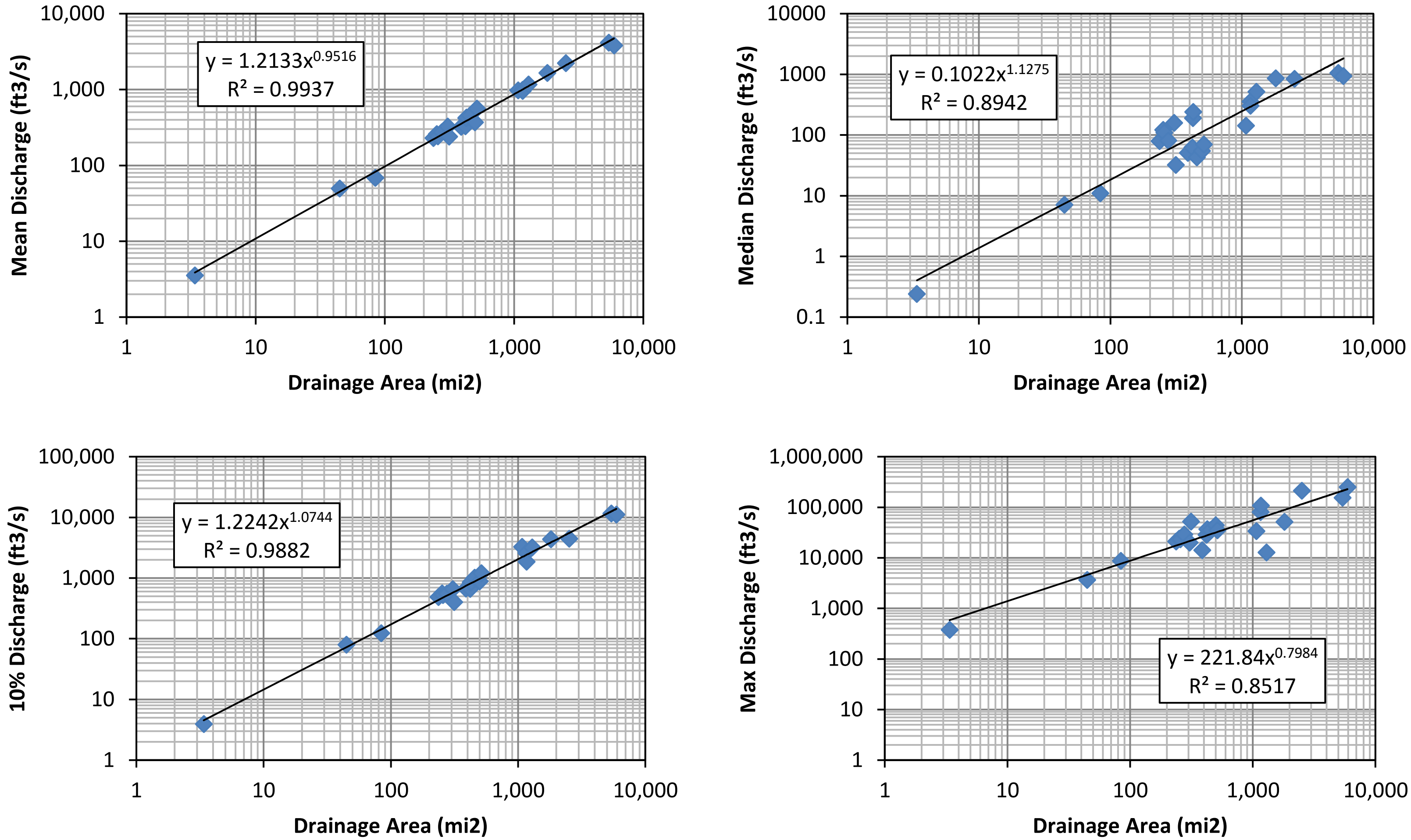


Figure 14. Drainage area and discharge relationships for 25 USGS gaging stations near the study watershed.

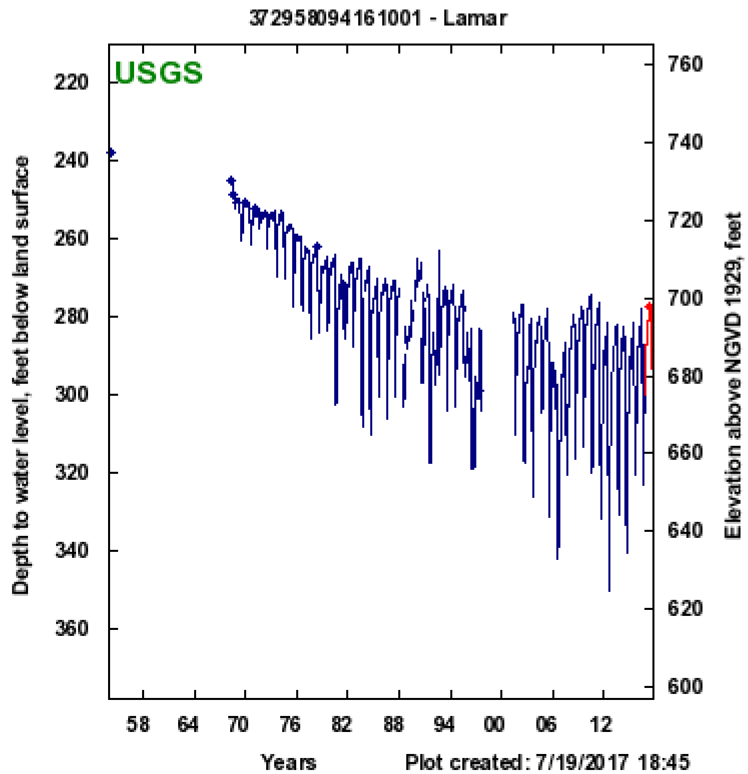


Figure 15. Ground water level change for Lamar (1968-2017).

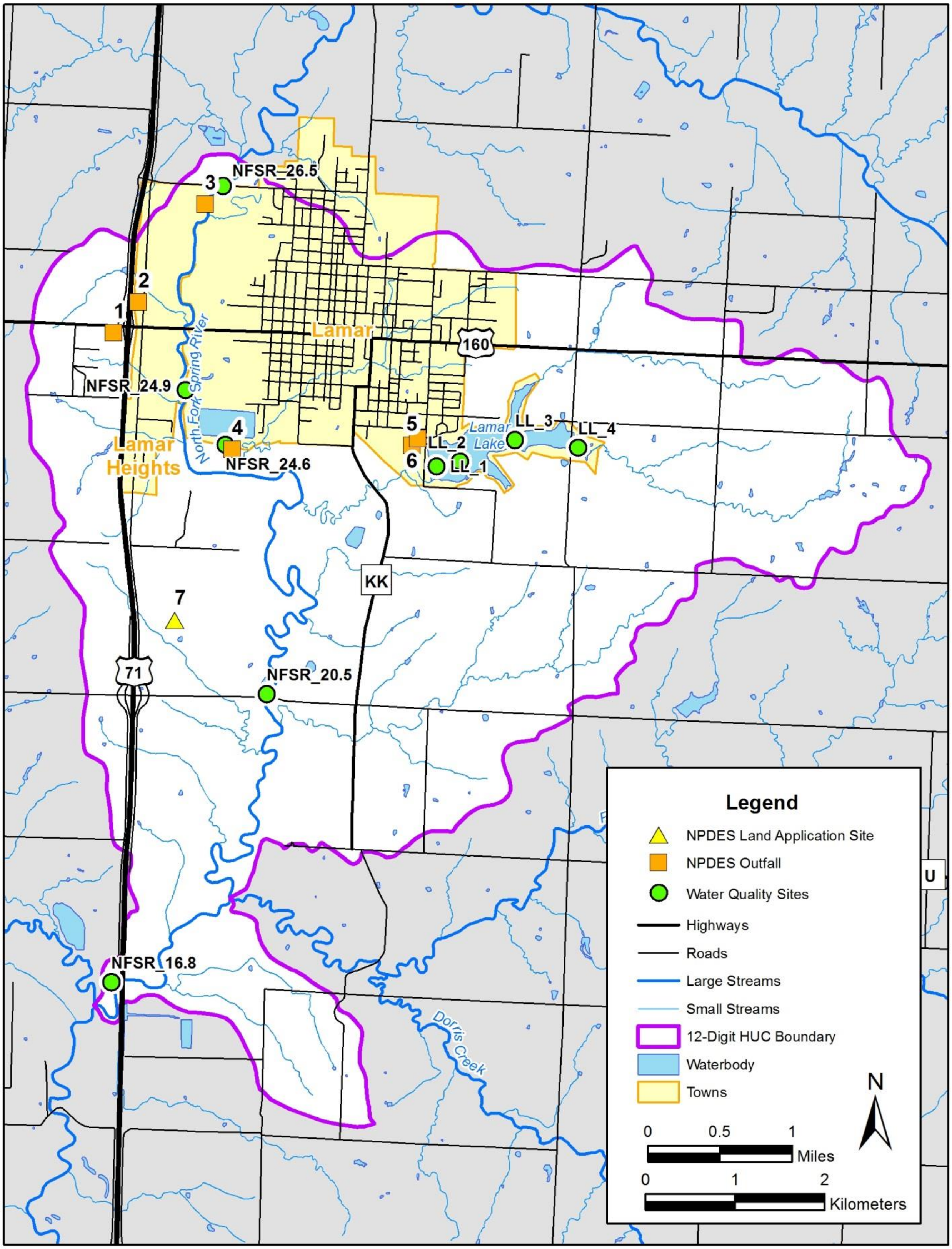


Figure 16. Permitted point sources and water quality monitoring station locations.

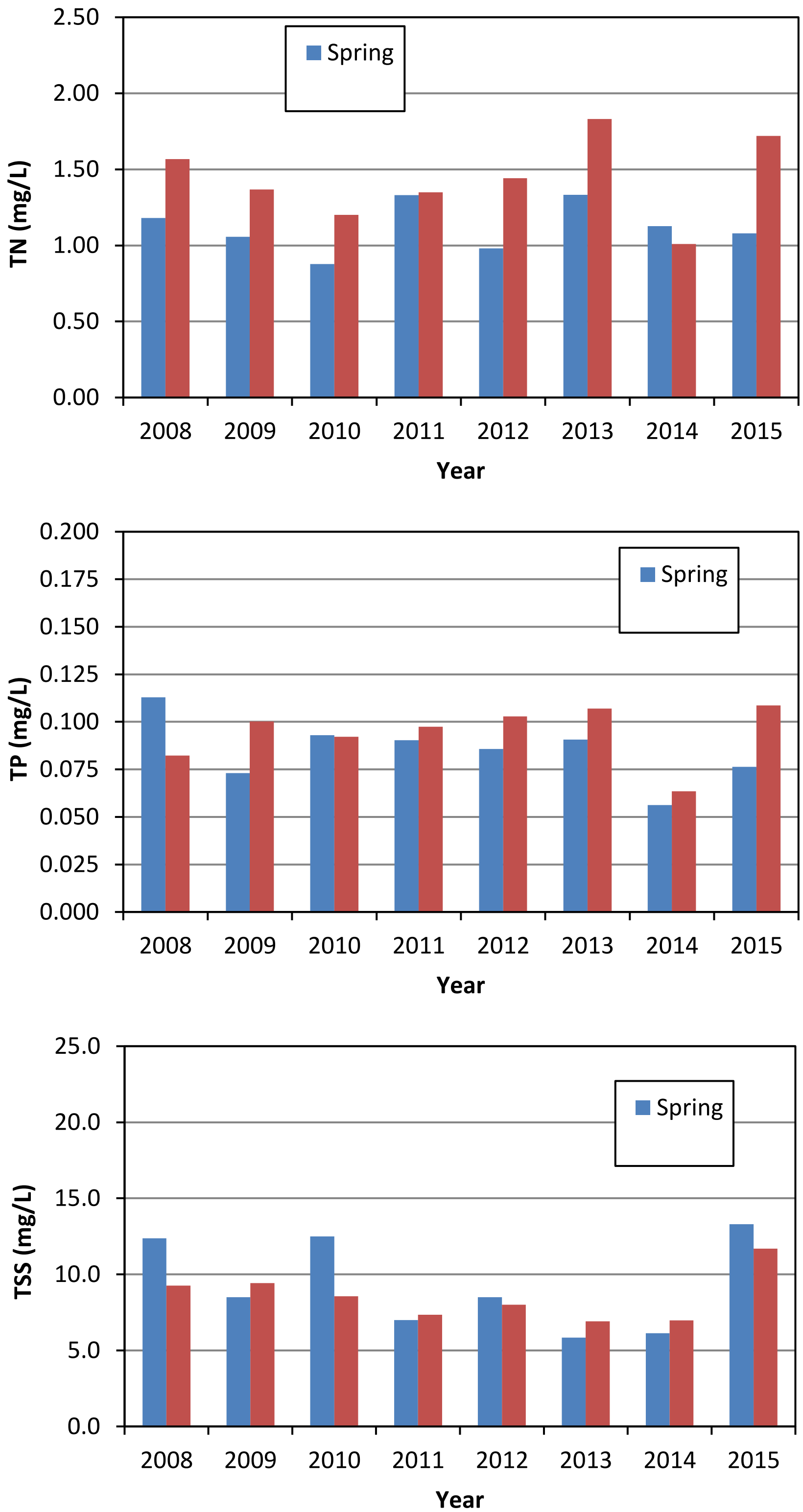


Figure 17. Average spring and summer A) TN, B) TP, and C) TSS concentrations from Site 1 (2008-2015).

Source - MDNR Water Quality Assessment System

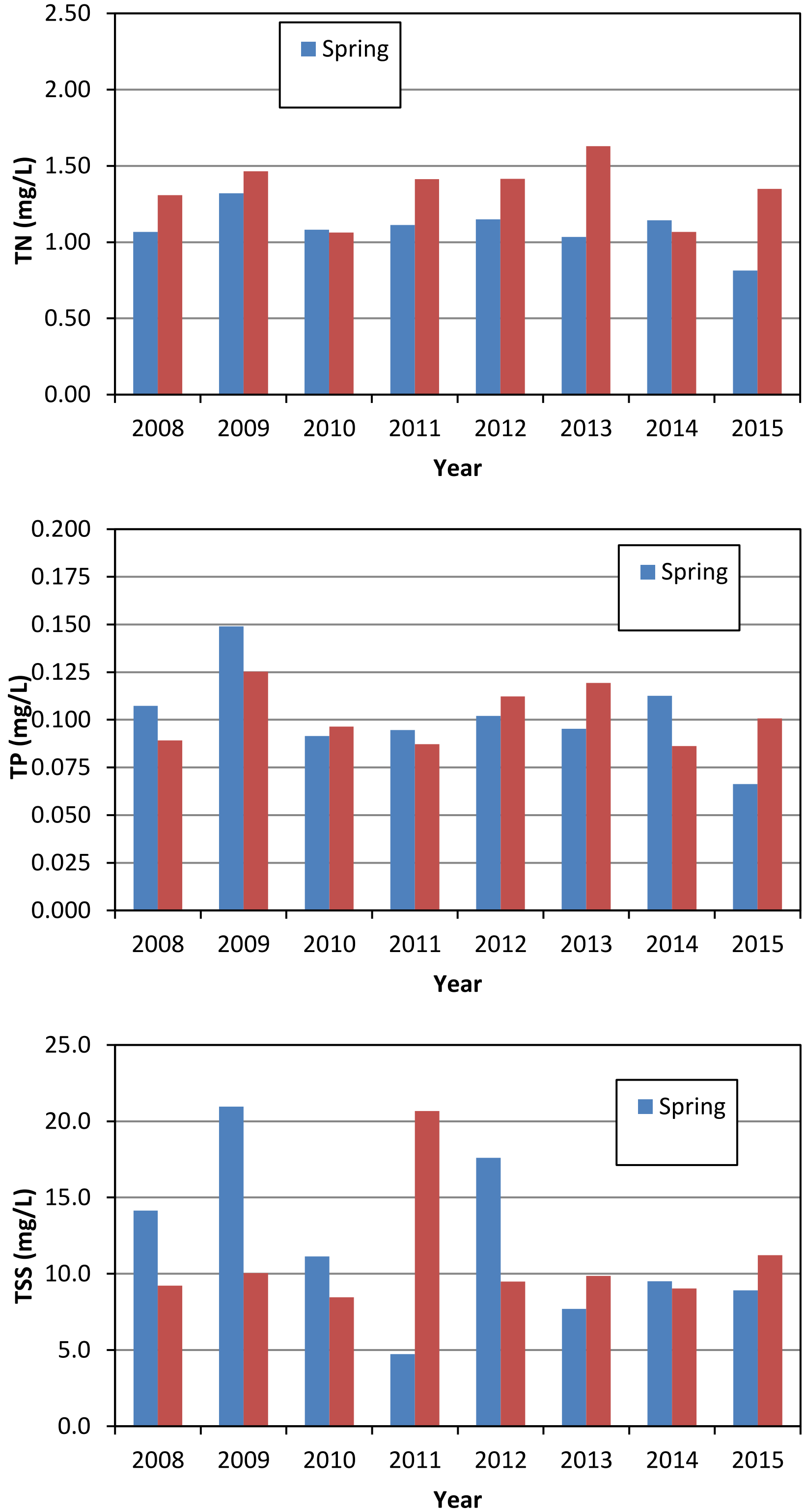


Figure 18. Average spring and summer A) TN, B) TP, and C) TSS concentrations from Site 1 (2008-2015).

Source - MDNR Water Quality Assessment System

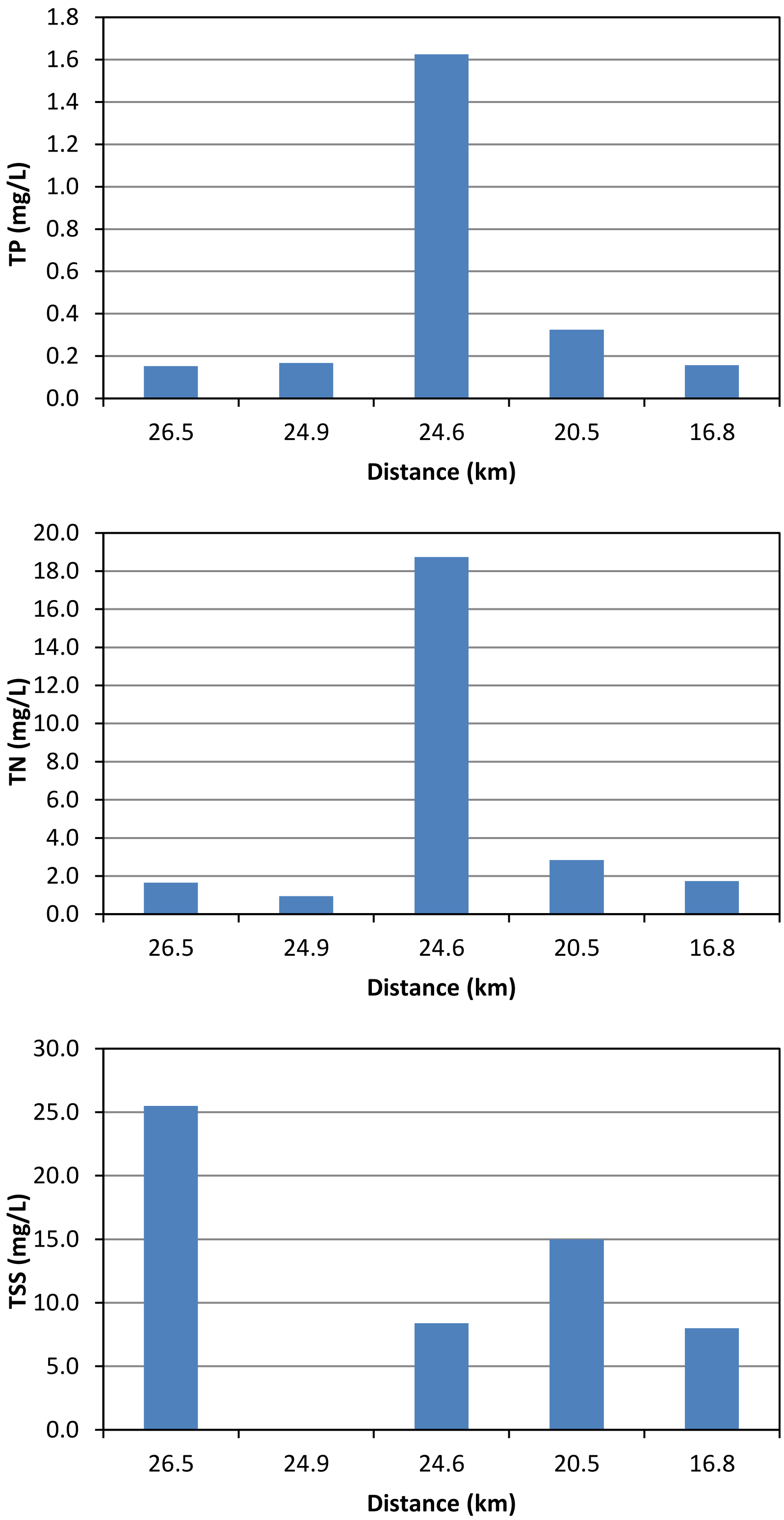


Figure 19.Average A) TN, B) TP, and C) TSS concentrations from sites along the North Fork Spring River.

Source - MDNR Water Quality Assessment System

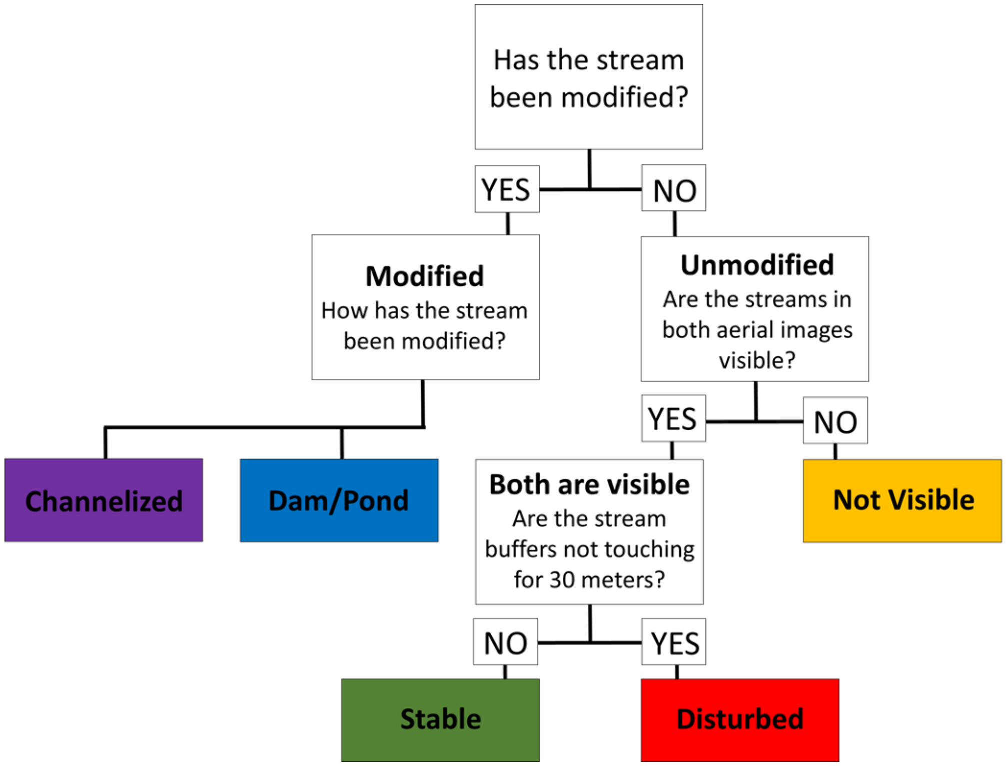


Figure 20. Flow chart showing decision tree for classifying stream channels from aerial photo analysis.

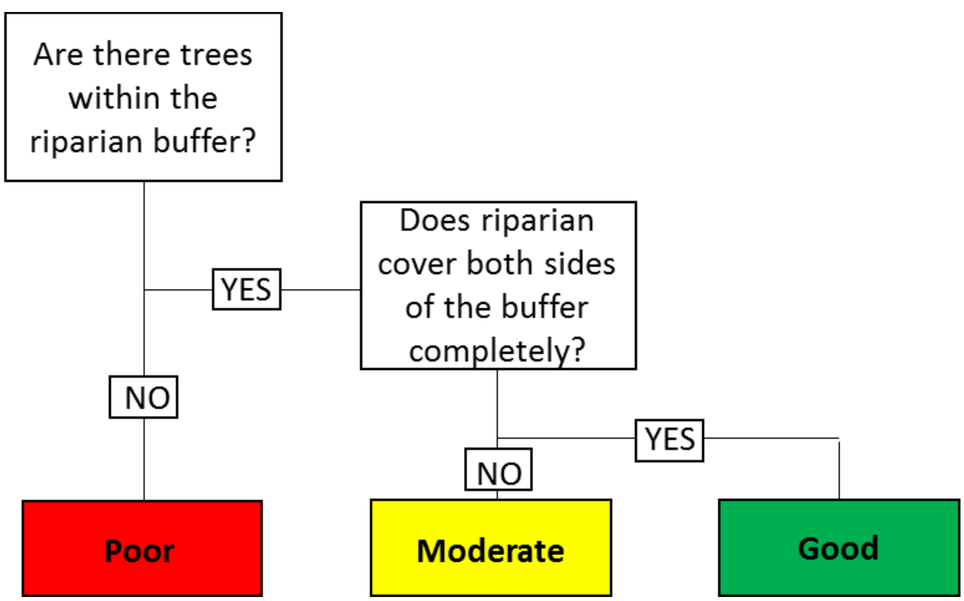


Figure 21. Flow chart showing decision tree for riparian corridor assessment from aerial photo analysis.

Channel Planform Classification

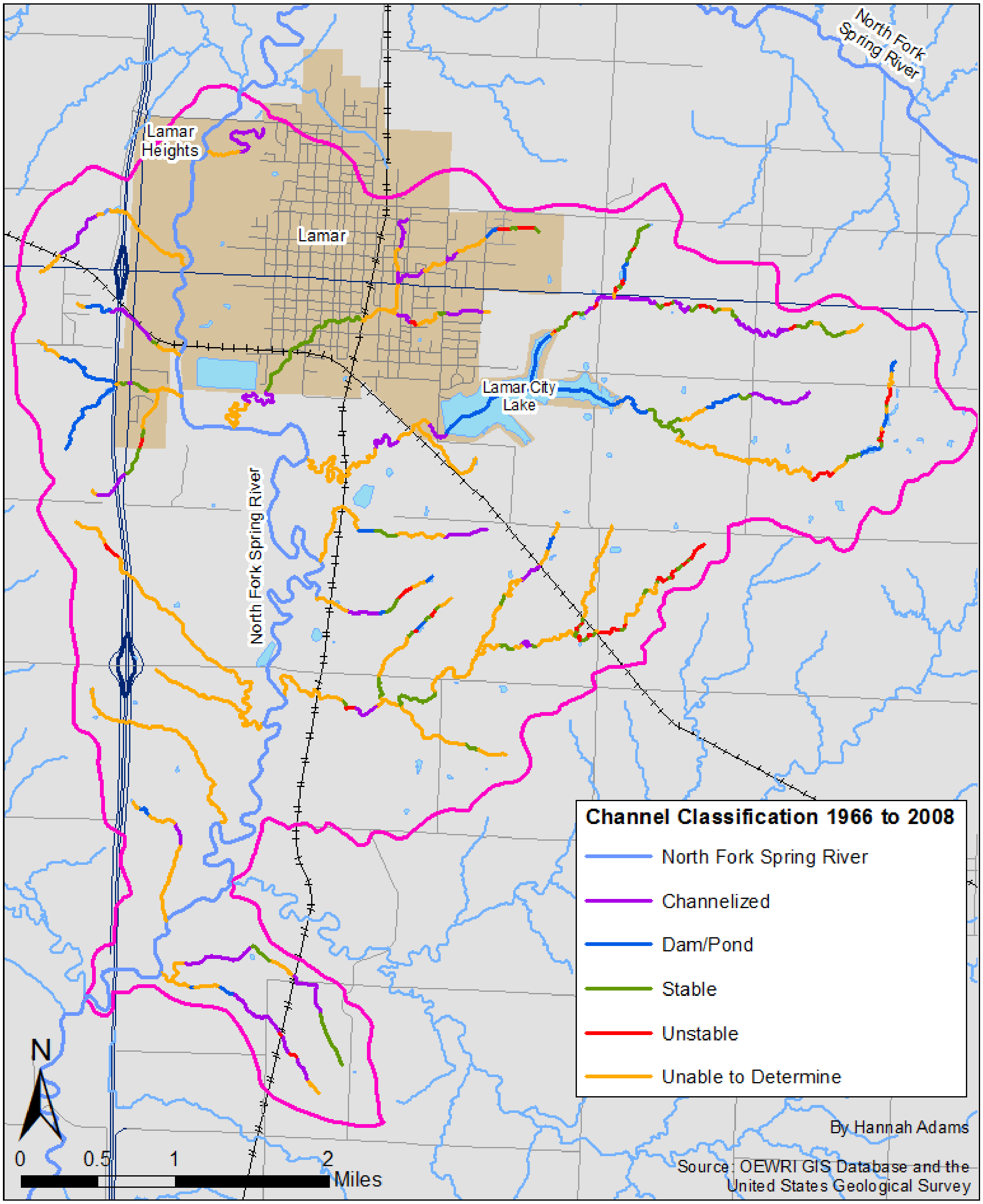


Figure 22. Channel classification results from historical aerial photo analysis.

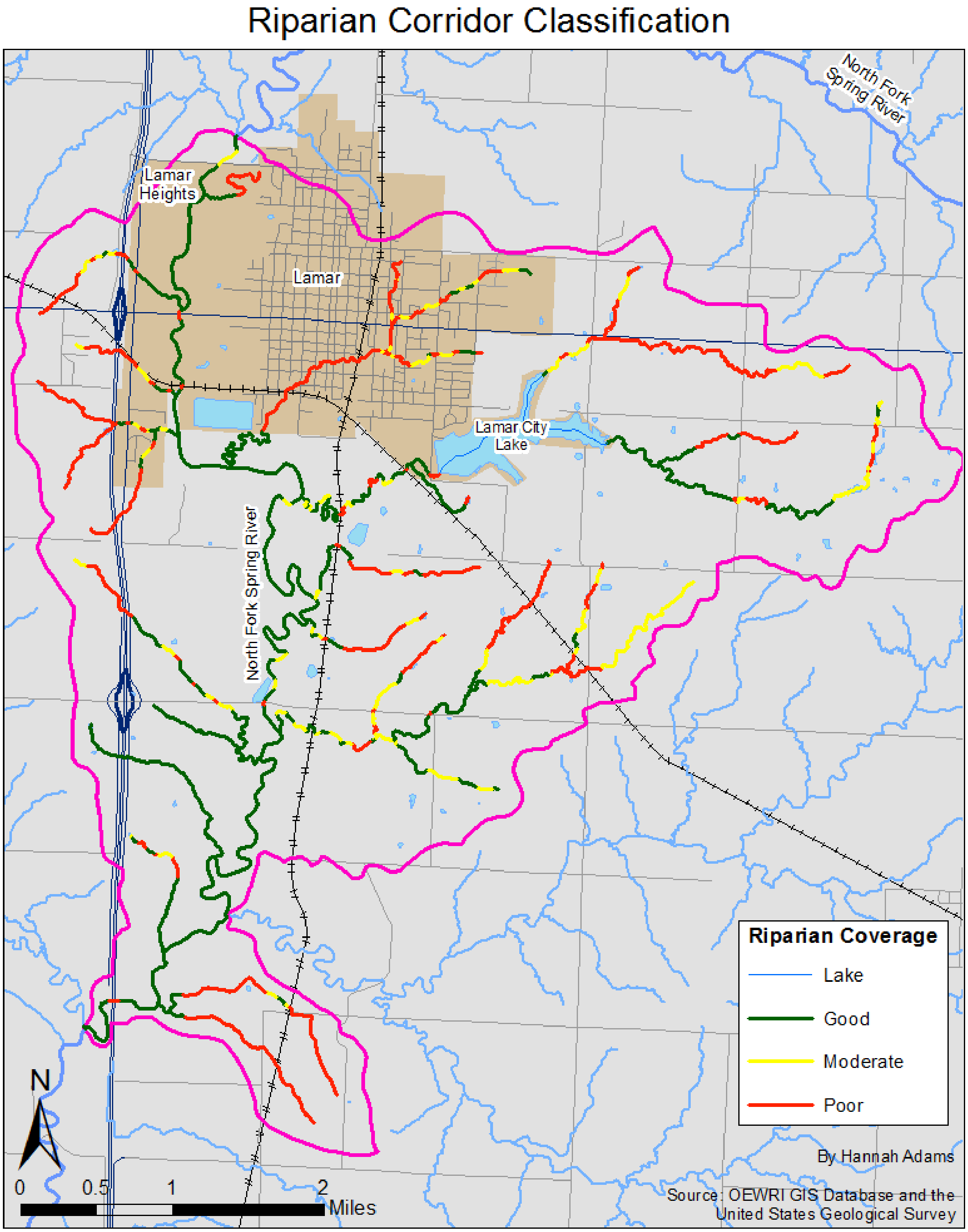


Figure 23. Riparian corridor assessment results from aerial photo analysis.

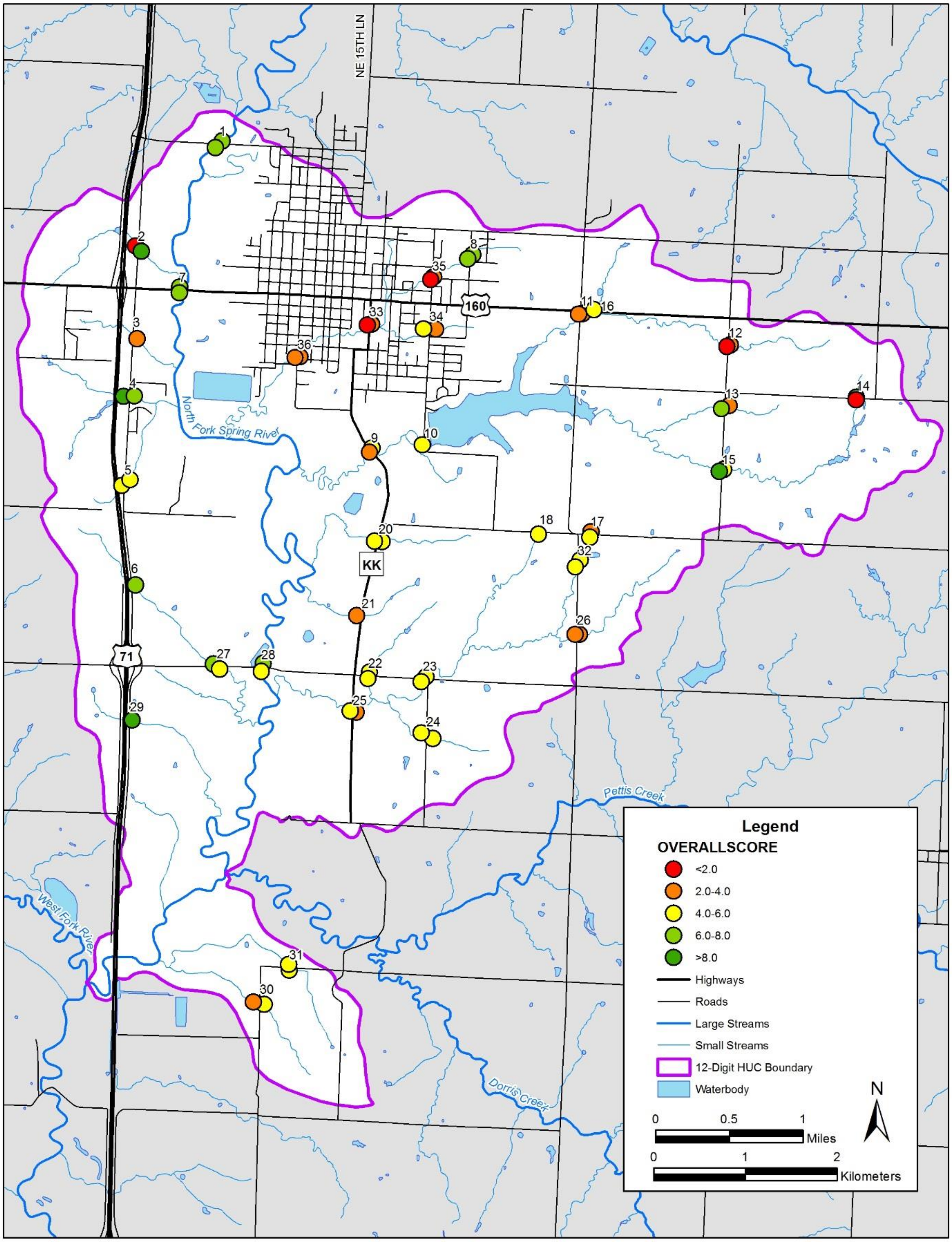


Figure 24. Visual stream survey results.

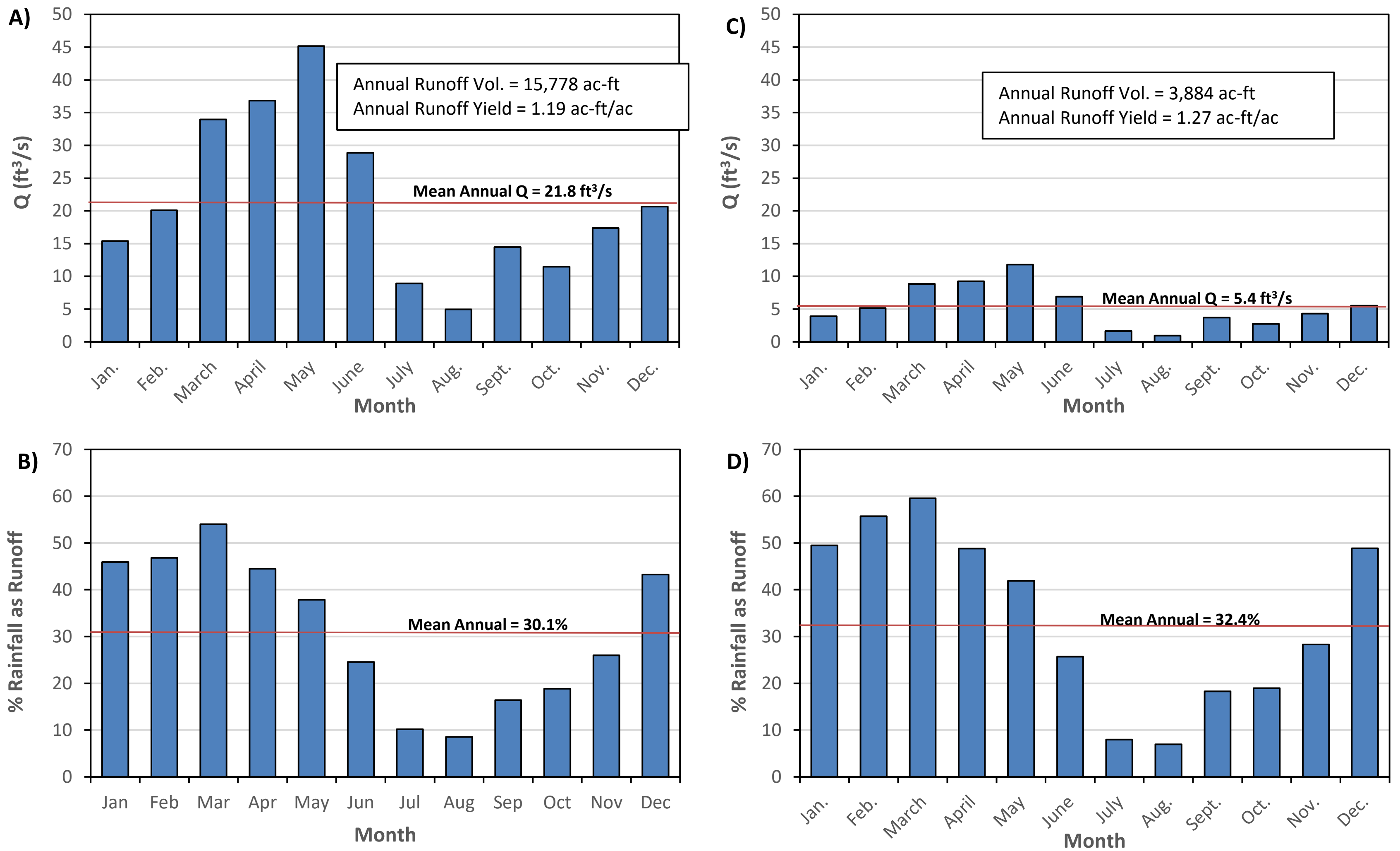


Figure 25. Mean monthly discharge and runoff percentage for the A), B) HUC-12 watershed and the C), D) Lamar Lake watershed.

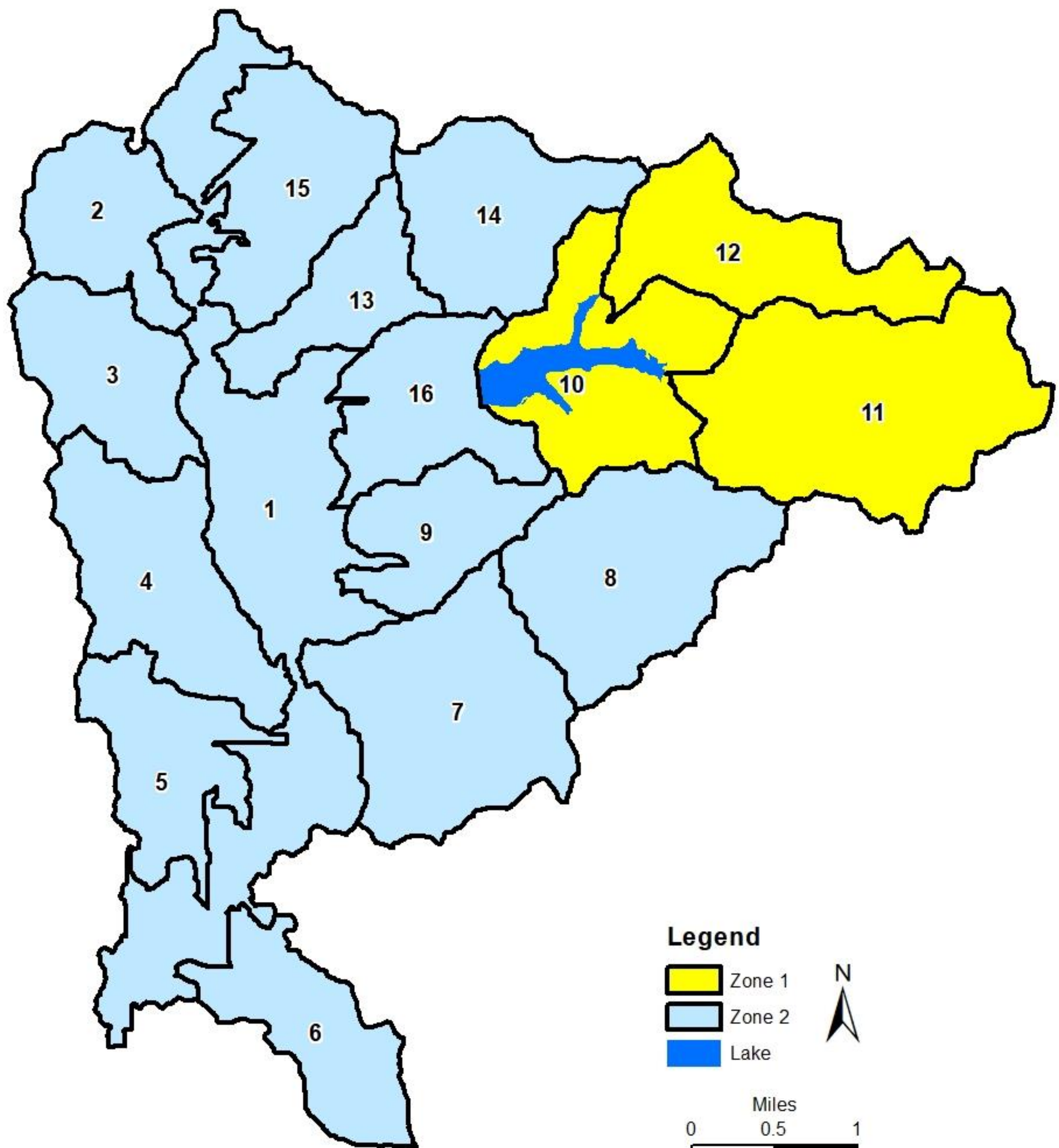


Figure 26. Management unit zones.

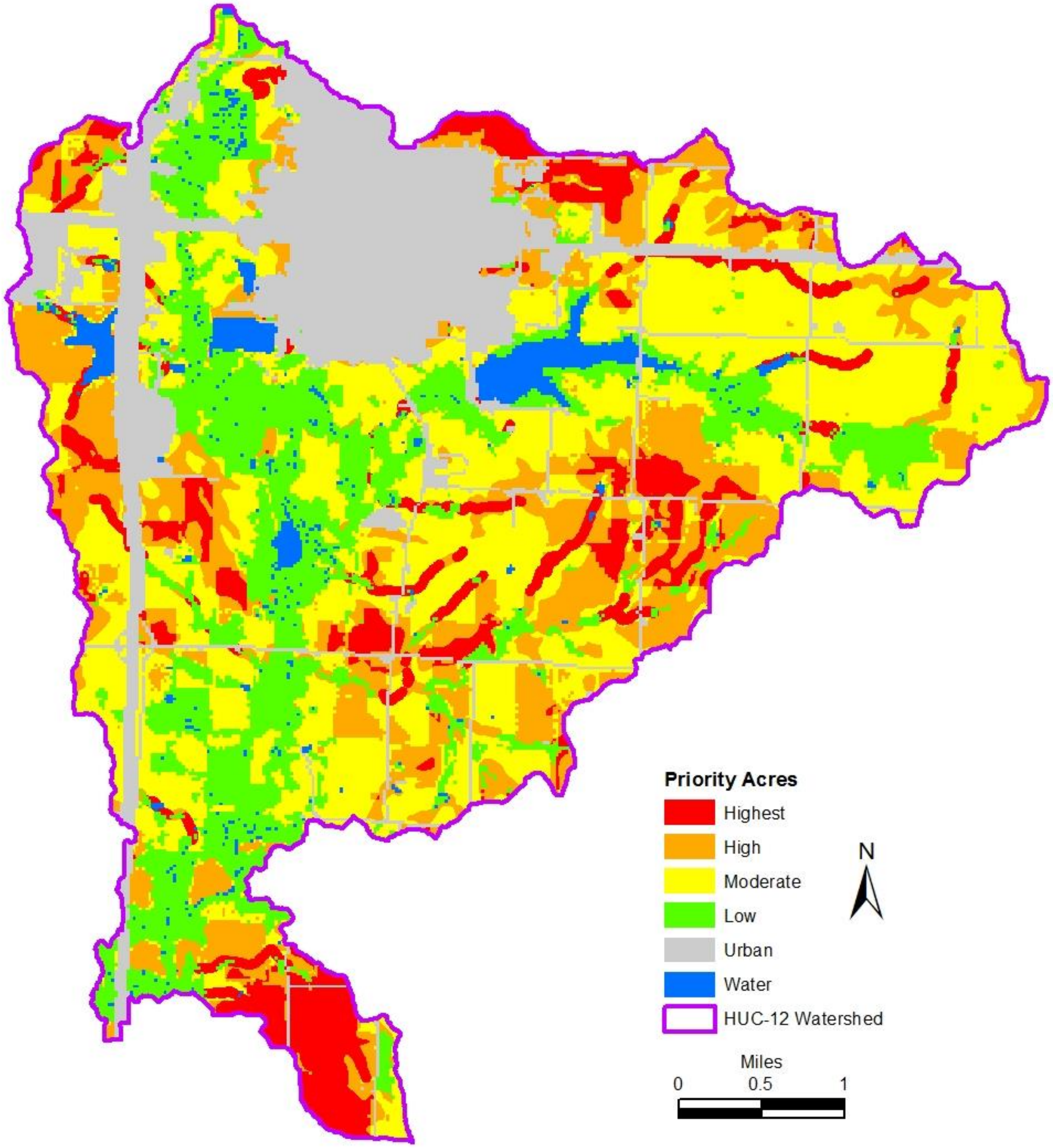


Figure 27. Priority acres within the watershed.

APPENDICES

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

MU#	Acres	% Area	Description	Hydrologic Soil Group	Landform	K-Factor	Soil Order	Land Capability Classification
40008	2,172	16.3	Parsons silt loam, 0 to 1 percent slopes	D	Uplands	0.43	Alfisol	3w
40031	406	3.1	Barco fine sandy loam, 2 to 5 percent slopes	C	Uplands	0.17	Ultisol	2e
40032	66	0.5	Barco fine sandy loam, 2 to 5 percent slopes, eroded	C	Uplands	0.20	Ultisol	3e
40034	2,843	21.4	Barco loam, 2 to 5 percent slopes	C	Uplands	0.17	Ultisol	2e
40035	689	5.2	Barco loam, 2 to 5 percent slopes, eroded	C	Uplands	0.17	Ultisol	3e
40038	1,252	9.4	Barden silt loam, 1 to 5 percent slopes	D	Uplands	0.32	Alfisol	2s
40039	167	1.3	Barden silt loam, 1 to 5 percent slopes, eroded	D	Uplands	0.32	Alfisol	3s
40046	580	4.4	Collinsville fine sandy loam, 2 to 5 percent slopes	D	Uplands	0.24	Mollisol	6s
40047	64	0.5	Collinsville fine sandy loam, 5 to 14 percent slopes	D	Uplands	0.24	Mollisol	6s
40048	191	1.4	Collinsville fine sandy loam, 2 to 14 percent slopes, stony	D	Uplands	0.24	Mollisol	7s
40074	8.8	0.1	Liberal silty clay loam, 3 to 8 percent slopes, eroded	D	Uplands	0.28	Alfisol	4e
40075	23	0.2	Liberal-Coweta-Barco complex, 2 to 14 percent slopes	D	Uplands	0.37	Alfisol	4e
40085	668	5.0	Parsons silt loam, 1 to 3 percent slopes	D	Uplands	0.49	Alfisol	3s
40086	64	0.5	Parsons silt loam, 1 to 3 percent slopes, eroded	D	Uplands	0.49	Alfisol	3e
40099	264	2.0	Hector fine sandy loam, 2 to 5 percent slopes	D	Uplands	0.24	Inceptisol	6s
40100	113	0.8	Hector fine sandy loam, 5 to 14 percent slopes	D	Uplands	0.20	Inceptisol	6s
40102	216	1.6	Hector fine sandy loam, 5 to 14 percent slopes, stony	D	Uplands	0.28	Inceptisol	7s
44000	368	2.8	Cherokee silt loam, 0 to 1 percent slopes	C/D	Terrace	0.49	Alfisol	2s
46002	1,160	8.7	Hepler silt loam, 0 to 1 percent slopes, occasionally flooded	C	Floodplains	0.43	Alfisol	2w
46010	257	1.9	Hepler silt loam, overwash, 0 to 1 percent slopes, occasionally flooded	C	Floodplains	0.43	Alfisol	2w
46012	364	2.7	Hepler-Radley complex, 0 to 1 percent slopes, occasionally flooded	C	Floodplains	0.43	Alfisol	2w
46020	549	4.1	Radley-Verdigris complex, 0 to 2 percent slopes, occasionally flooded	B	Floodplains	0.37	Mollisol	2w
70052	53	0.4	Arnica loam, 2 to 5 percent slopes	C	Uplands	0.28	Alfisol	2e
70099	296	2.2	Bolivar fine sandy loam, 2 to 5 percent slopes, eroded	C	Uplands	0.17	Alfisol	4e
71260	56	0.4	Arnica silt loam, 2 to 5 percent slopes	B	Terrace	0.43	Alfisol	2e
71261	12	0.1	Arnica silt loam, 2 to 5 percent slopes, eroded	C	Terrace	0.43	Alfisol	3e
99000	46	0.3	Pits, quarry	NA	NA	NA	NA	NA
99001	145	1.1	Water	NA	NA	NA	NA	NA
99003	47	0.4	Miscellaneous water	NA	NA	NA	NA	NA
99010	144	1.1	Pits-Dumps complex	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
6917630	East Drywood Creek at Prarie State Park	East Drywood Creek	2001	15	3.4	890.0	0.00	0.24	3.90	376.00	3.55
7185095	Tar Creek at 22nd Street Bridge at Miami, OK	Tar Creek	2004	12	44.7	762.2	1.42	7.09	79.55	3,630.00	49.47
6917240	Marmaton R nr Uniontown, KS	Marmaton River	2001	15	84.0	858.9	0.00	11.00	123.20	8,710.00	68.75
6918740	Little Sac River near Morrisville, MO	Little Sac River	1985	31	237.0	880.3	14.00	79.00	483.10	20,900.00	230.00
6918460	Turnback Creek above Greenfield, MO	Turnback Creek	1965	51	252.0	870.5	29.00	122.00	560.00	23,700.00	258.55
6918440	Sac River near Dadeville, MO	Sac River	1966	50	257.0	869.8	23.00	109.00	524.90	23,300.00	241.67
6921070	Pomme de Terre River near Polk, MO	Pomme de Terre River	1968	48	276.0	872.6	10.00	81.00	554.00	28,900.00	275.34
7185700	Spring River at La Russel, MO	Spring River	2007	9	306.0	1,014.6	55.00	159.00	655.80	19,900.00	326.42
6917000	L Osage R at Fulton, KS	L Osage River	1948	68	314.0	772.0	0.20	32.00	400.00	51,800.00	238.37
6917500	Marmaton R nr Fort Scott, KS	Marmaton River	2008	8	388.0	750.5	2.50	51.00	670.80	14,100.00	322.20
6919500	Cedar Creek near Pleasant View, MO	Cedar Creek	1948	68	420.0	739.5	0.92	62.00	662.00	28,300.00	329.12
7185765	Spring River at Carthage, MO	Spring River	2001	15	425.0	923.7	50.00	190.00	845.00	28,700.00	419.34
7187000	Shoal Creek above Joplin, MO	Shoal Creek	1941	75	427.0	884.3	88.00	241.00	865.00	36,700.00	428.48
6917560	Marmaton River near Richards, MO	Marmaton River	2005	13	455.0	745.0	3.00	43.00	1,016.00	35,300.00	454.29
6917060	Little Osage River at Horton, MO	Little Osage River	2000	16	498.0	700.0	0.88	55.00	880.20	43,700.00	369.66
7185910	North Fork Spring River near Purcell, MO	Spring River	2007	10	515.0	850.0	7.12	69.60	1,200.00	35,000.00	558.86
6918060	Marmaton River near Nevada, MO	Marmaton River	2003	13	1,074.0	729.2	11.00	142.00	3,250.00	33,800.00	972.58
6919000	Sac River near Stockton, MO	Sac River	1921	68	1,160.0	758.1	50.00	356.00	2,570.00	79,800.00	991.86
7186000	Spring River near Waco, MO	Spring River	1924	92	1,164.0	833.6	65.00	303.00	1,860.00	108,000.00	961.39
6919020	Sac River at Hwy J below Stockton, MO	Sac River	1973	43	1,292.0	750.2	66.00	515.50	3,200.00	12,800.00	1,162.22
6919900	Sac River near Caplinger Mills, MO	Sac River	1974	42	1,810.0	721.1	85.00	860.00	4,350.00	51,200.00	1,650.40
7188000	Spring River near Quapaw, OK	Spring River	1939	77	2,516.0	746.3	214.00	845.00	4,460.00	210,000.00	2,220.18
6918070	Osage River above Schell City, MO	Osage River	2001	10	5,410.0	700.0	126.00	1,050.00	11,600.00	153,000.00	4,156.42
7185000	Neosho River near Commerce, OK	Neosho River	1939	77	5,926.0	749.0	59.56	934.00	11,100.00	251,000.00	3,800.96

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. Score sheets and photos of selected visual stream assessment sites.

Site # 6: Downstream

Channel condition	8
Hydrologic alteration	9
Riparian zone	4
Bank stability	7
Canopy cover	7
Manure presence	4

Overall Score 6.5

Site # 12: Upstream

Channel condition	2
Hydrologic alteration	2
Riparian zone	2
Bank stability	4
Canopy cover	1
Manure presence	1

Overall Score 2.0

Site # 12: Downstream

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

Overall Score 1.7

Site # 14: Downstream

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

Overall Score
1.0

Site # 22: Downstream

Channel condition	5
Hydrologic alteration	6
Riparian zone	3
Bank stability	2
Canopy cover	9
Manure presence	3

Overall Score
4.7

Site # 24: Downstream

Channel condition	5
Hydrologic alteration	5
Riparian zone	5
Bank stability	4
Canopy cover	9
Manure presence	3

Overall Score
5.2

Site # 25: Downstream

Channel condition	6
Hydrologic alteration	4
Riparian zone	1
Bank stability	3
Canopy cover	1
Manure presence	5

Overall Score
3.3

Site # 26: Upstream

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

Overall Score
3.6

Site # 26: Downstream

Channel condition	8
Hydrologic alteration	6
Riparian zone	3
Bank stability	1
Canopy cover	1
Manure presence	1

Overall Score
3.3

Site # 27: Downstream

Channel condition	7
Hydrologic alteration	6
Riparian zone	4
Bank stability	5
Canopy cover	8
Manure presence	3

Overall Score
5.5

Site # 32: Downstream

Channel condition	1
Hydrologic alteration	2
Riparian zone	5
Bank stability	7
Canopy cover	9
Manure presence	3

Overall Score
4.5

Site # 35: Downstream

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

Overall Score
1.0

Site # 31: Upstream

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

Overall Score
3.6

Site # 30: Upstream

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

Overall Score
3.6

Site # 30: Downstream

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

Overall Score
3.6

Site # 17: Upstream

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

Overall Score
2.6

Site # 17: Downstream

Channel condition	1
Hydrologic alteration	5
Riparian zone	5
Bank stability	8
Canopy cover	7
Manure presence	3

Overall Score
4.8

Site # 13: Upstream

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

Overall Score
3.8

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

Month	R^2	b_0	b_1	Lamar Lake (m^3/s)	HUC-12 (m^3/s)	Lamar Lake (ft^3/s)	HUC-12 (ft^3/s)
Jan.	0.94	0.0108	0.9268	0.11	0.44	3.92	15.38
Feb.	0.96	0.0144	0.9226	0.15	0.57	5.15	20.10
March	0.97	0.0254	0.9117	0.25	0.96	8.84	33.96
April	0.99	0.0248	0.9378	0.26	1.04	9.23	36.83
May	0.97	0.0341	0.9091	0.33	1.28	11.80	45.15
June	0.97	0.0171	0.9699	0.20	0.82	6.89	28.84
July	0.98	0.0026	1.1437	0.05	0.25	1.65	8.91
Aug.	0.96	0.0017	1.1147	0.03	0.14	0.96	4.96
Sept.	0.97	0.0102	0.9259	0.10	0.41	3.69	14.48
Oct.	0.97	0.0067	0.9732	0.08	0.32	2.72	11.45
Nov.	0.94	0.0115	0.9429	0.12	0.49	4.32	17.38
Dec.	0.93	0.0165	0.8950	0.16	0.59	5.52	20.67

* Power function equation $y = b_0 (x)^{b1}$
Where: y = mean monthly discharge in m^3/s
X = drainage area in km^2

Appendix F. STEPL model inputs for the HUC-12 and Lamar Lake watersheds.

Watershed ID	Total Ad (ac)	HSG	Land Use (ac)						# of Animals		Low Density Residential (ac)	# Septic Systems
			Urban	Cropland	Pastureland	Forest	Feedlots	User Defined	Beef Cattle	Horse		
12Digit	13,278	C	2,593.3	2,070.8	5,832.7	2,364.2	0.5	416.9	761	42	946	720
Lamar Lake	2,901	C	252.5	314.8	1,945.5	363.9	0.2	23.9	246	14	50	38

Appendix G. Eroding stream channel inputs into STEPL.

Reach ID	Length (ft)	Height (ft)	Area (ft^2)	Mean Width (ft)	Avg. Migration Rate (ft/yr)
1	350	1.5	14,882	42.5	1.01
2	572	0.5	7,465	13.1	0.31
3	104	2.9	1,800	17.4	0.41
4	370	3.1	3,643	9.8	0.23
5	110	0.7	4,126	37.7	0.90
6	514	0.9	9,977	19.4	0.46
7	886	1.1	7,728	8.7	0.21
8	116	3.4	1,199	10.3	0.25
9	139	0.9	4,834	34.7	0.83
10	141	2.1	2,502	17.7	0.42
11	150	1.7	6,208	41.5	0.99
12	168	2.9	1,907	11.4	0.27
13	222	2.5	4,791	21.6	0.51
14	410	1.3	15,424	37.7	0.90
15	924	2.2	32,485	35.2	0.84
16	496	0.8	12,262	24.7	0.59
17	765	2.2	19,807	25.9	0.62
18	568	0.4	12,067	21.2	0.51
19	616	2.4	12,805	20.8	0.49
20	346	2.4	22,530	65.1	1.55
21	549	2.8	1,498	2.7	0.06
22	152	1.0	3,724	24.4	0.58
23	200	2.5	3,915	19.5	0.47
24	302	1.6	7,435	24.6	0.59
25	168	2.8	1,853	11.0	0.26
26	266	3.5	2,791	10.5	0.25
27	160	2.9	2,224	13.9	0.33
28	261	0.5	2,813	10.8	0.26
29	166	0.6	1,714	10.4	0.25
30	100	1.0	3,121	31.3	0.75
31	239	3.3	2,817	11.8	0.28
32	642	0.9	21,940	34.2	0.81
33	441	0.8	8,598	19.5	0.46
Average	**352**	**1.8**	**7,966**	**22.5**	**0.53**

Appendix H. Combined BMPs efficiencies for selected practices.

List of Practices	Combined BMP Efficiencies		
<u>Cropland</u>	Nitrogen	Phosphorus	Sediment
Cover Crop	0.196	0.070	0.100
Terrace	0.253	0.308	0.400
Cover Crop and Grass Waterways	0.276	0.303	0.685
Cover Crop and Reduced Till	0.317	0.401	0.463
Terrace and Grass Waterways	0.328	0.481	0.790
Cover Crop and No Till	0.397	0.709	0.793
Cover Crop, Reduced Till, Nutrient Management	0.485	0.736	0.463
Cover Crop, No Till, Nutrient Management	0.546	0.872	0.793
Land Retirement	0.898	0.808	0.950
<u>Pasture Land</u>			
Livestock Exclusion and Alternative Water	0.309	0.384	0.691
Livestock Exclusion, Alternative Water, Prescribed Grazing	0.591	0.524	0.794
Livestock Exclusion, Alternative Water, Prescribed Grazing, Forest Buffer	0.776	0.714	0.904