BUFFALO RIVER WATERSHED-BASED MANAGEMENT PLAN

MAY 22, 2018

Buffalo River
Watershed-Based
Management Plan

Prepared for

Arkansas Natural Resources Commission
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FTN No. R03015-005-031

May 22, 2018

EXECUTIVE SUMMARY

The Buffalo River in north central Arkansas is a tributary of the White River. The Buffalo River originates in Newton County and flows into the White River in Baxter County. The watershed is primarily rural. Approximately 80% of the watershed is forested. Animal agriculture is widespread in the watershed, including beef and dairy cattle, and poultry and swine feeding operations. Pasture and hayland associated with animal agriculture accounts for 14% of the land cover in the watershed, often along streams.

The majority of the Buffalo River is a National River. The Buffalo River and its tributaries are considered high quality water resources. The Buffalo River and its tributary Richland Creek are designated as Extraordinary Resource Waters and Natural and Scenic Waterways. The Buffalo River and its tributaries support over 50 species of fish and over 20 species of mussels. Portions of the Buffalo River have been designated critical habitat for the threatened Rabbitsfoot mussel. The watershed also includes important habitat for endangered bat species.

One tributary of the Buffalo River has been identified as not achieving state water quality standards for TDS due to the influence of a regulated point source. Stakeholders are concerned that there may be water quality issues that are not being identified in the state biennial water quality assessment. Pollutants of concern identified by stakeholders include nutrients, bacteria, sediment, trash, and water temperature. Stakeholders have expressed concerns about both regulated and unregulated pollutant sources in the watershed, including confined animal feeding operations, municipal wastewater treatment facilities, onsite wastewater treatment systems, recreationists, feral hogs, livestock in streams, introduced invasive species, use of fertilizers and manure on pasture, streambank erosion, unpaved roads, gravel mining, and timber management and harvest.

At the direction of Governor Asa Hutchinson, the Beautiful Buffalo River Action Committee (BBRAC) was organized in September 2016 to establish an Arkansas-led approach to identify and address potential issues of concern in the Buffalo River watershed, including the development of a non-regulatory watershed management plan for the Buffalo River watershed.

BBRAC members originally included: Arkansas Department of Environmental Quality, Arkansas Department of Health, Arkansas Agriculture Department, Arkansas Department of Parks and Tourism, and Arkansas Natural Resources Commission (ANRC). Additional state agencies have also become participants in the organization. The Buffalo River Watershed Management Plan (WMP) was prepared through the direction of the Arkansas Natural Resources Commission.

This plan is intended to address the entire Buffalo River watershed. It provides a framework for landowners, communities, and organizations to voluntarily undertake water quality projects in the watershed and improve their ability to solicit and secure funding and assistance for these projects from various government and private sources. It includes discussion of current and historical water quality and quantity data from the watershed, as well as recent research within the watershed.

Land use, water quality, and geological information was compiled and analyzed to identify tributary subwatersheds on which to focus initial management practices and activities. Based on these analyses, six subwatersheds are recommended for initial nonpoint source pollution management (Table ES.1 and Figure ES.1).

Table ES.1. Subwatersheds recommended for initial nonpoint source pollution management.

Name of Monitored Stream	**12-digit HUC Number**	**12-digit HUC Name**	**Land Use Summary**		
			Pasture and hayland	**Developed land**	**Forest**
Mill Creek (upper)	110100050206	Flatrock Creek	14%	4%	77%
Calf Creek	110100050401	Calf Creek	30%	4%	64%
Bear Creek	110100050403	Headwaters Bear Creek	--	--	--
	110100050404	Outlet Bear Creek	--	--	--
Brush Creek	110100050405	Brush Creek-Buffalo River	24%	5%	67%
Tomahawk Creek	110100050407	Tomahawk Creek-Buffalo River	31%	3%	63%
Big Creek (lower)	110100050505	Long Creek	--	--	--
	110100050506	Davis Creek-Big Creek Lower	--	--	--
	110100050507	Bratton Creek-Big River	--	--	--

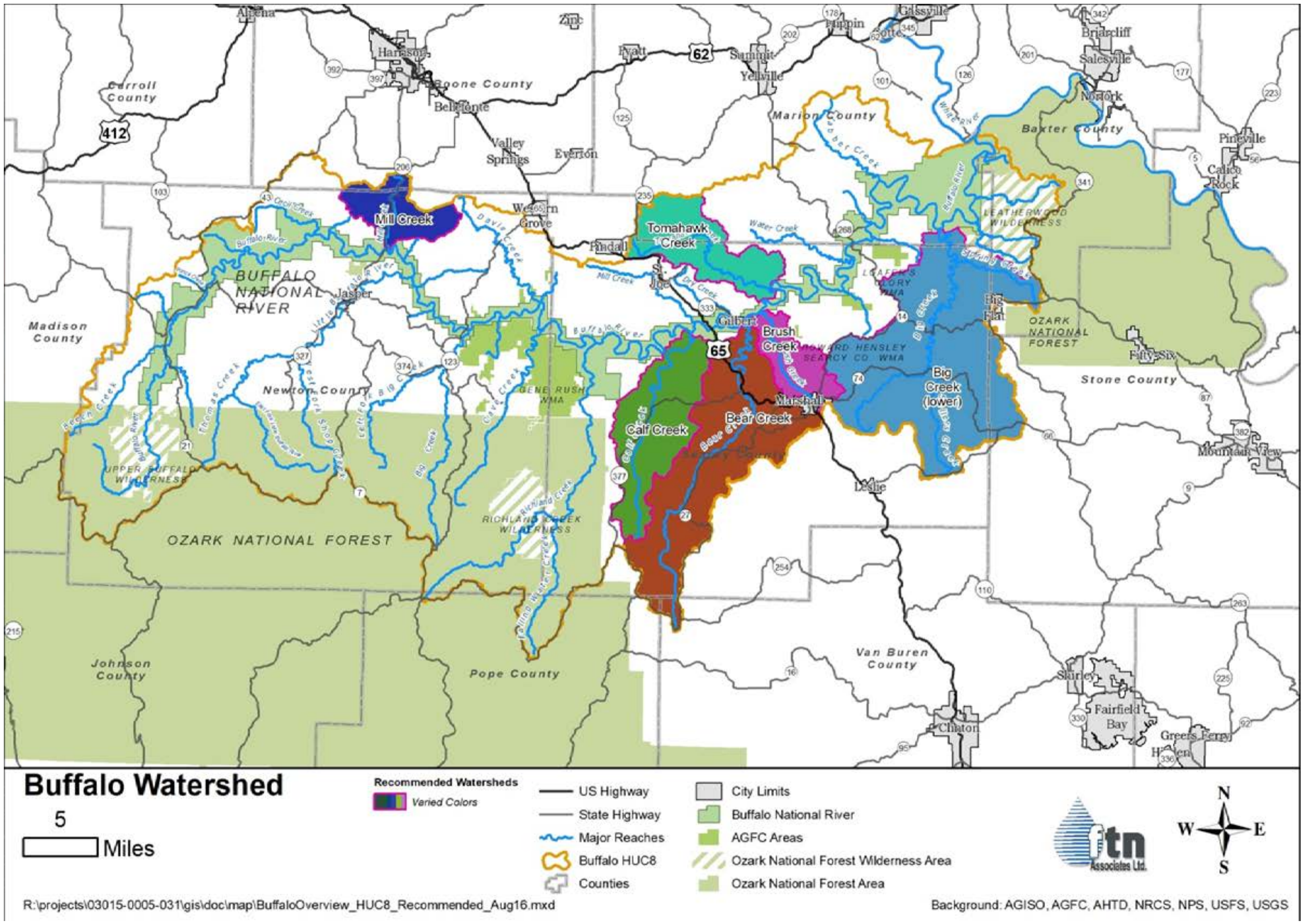

Figure ES.1. Buffalo River subwatersheds recommended for initial nonpoint source pollution management.

SWAT modeling of the Buffalo River watershed was completed in February 2018. The SWAT model was used to estimate loads of sediment, total nitrogen, and total phosphorus produced by each of the 12-digit HUCs of the Buffalo River watershed. Five 12-digit HUCs were identified where modeled loads of all three parameters were in the top 25% for the watershed:

- 110100050401 – Calf Creek,
- 110100050403 - Headwaters Bear Creek,
- 110100050404 - Outlet Bear Creek,
- 110100050503 – Clabber Creek, and
- 110100050505 – Long Creek.

Four of these 12-digit HUCs are included in the subwatersheds recommended for initial nonpoint source management in this plan (see Table ES.1).

The following are five categories in which management recommendations are made for these subwatersheds:

1. Management Practices;
2. Monitoring;
3. Studies;
4. Awareness, Outreach and Education; and
5. Teams.

Through several watershed meetings, stakeholders identified suites of nonpoint source pollution management practices that could be implemented in the recommended subwatersheds (Table ES.2). These practices, along with estimates of associated pollutant load reductions and relative costs for their implementation, are included in the plan. Examples of available sources of technical and funding assistance for implementation of management practices are also identified.

The following recommendations are made for monitoring in the Buffalo River watershed:

- Support existing monitoring and enhance those programs.
- Add total suspended solids as a constituent for analysis in the water quality samples already being collected.
- Add a routine water quality monitoring station at the county road downstream of Dogpatch Springs so that loading from Dogpatch Springs can be assessed.
- Support the Buffalo National River and ADEQ in developing an algae monitoring program to assess algal species and densities in the Buffalo River and its tributaries.
- Develop a trash index and implement a trash monitoring program for tributaries.

The following studies are proposed, primarily for the six recommended subwatersheds:

- Initiate microbial source tracking for *E. coli* using quantitative polymerase chain reaction and host-specific markers.
- Support the Buffalo National River program in its continuous monitoring of dissolved oxygen and evaluation of relationships with nutrient loading in the Buffalo River and its tributaries.
- Conduct analysis of LiDAR data for recommended subwatersheds, starting with Calf Creek, to assess streambank erosion.

Table ES.2. Management strategies proposed for recommended subwatersheds of the Buffalo River.

Strategy	Inorganic nitrogen	Bacteria	Phosphorus	Turbidity/ Sediment
Pasture and Hayland Management Practices				
Nutrient management plans	X	X	X	
Riparian buffers	X	X	X	X
Farm pond/sediment basin construction	X	X	X	X
Livestock stream access control	X	X	X	X
Prescribed/rotational grazing	X	X	X	X
Silvopasture establishment	X	X	X	X
Pasture planting and management	X	X	X	X
Forest Management Practices				
Prescribed forest burns				
Forestry best management practices			X	X
Trail management practices			X	X
Ecotone Management Practices				
Streambank restoration and stabilization	X	X	X	X
Gamebird habitat restoration	X	X	X	X
Filter strips of native plants	X	X	X	X
Management Practices for Multiple Land Uses				
Unpaved road environmentally sensitive maintenance			X	X
On-site wastewater system management/repair/replace	X	X	X	
Control of invasive and destructive species (e.g., feral hogs)	X	X	X	X
Karst protection practices	X	X	X	X

The following are recommendations for Awareness, Outreach, and Education Programs in the Buffalo River watershed:

- Support existing Buffalo National River awareness, outreach and education programs;
- Support existing education programs of the Buffalo National River and its partners;
- Support existing education and outreach programs of other organizations active in the Buffalo River watershed;

- Initiate outreach program focused on proper maintenance of onsite wastewater treatment systems;
- Quantify ecosystem services in recommended subwatersheds using both market and non-market valuation approaches for better understanding and appreciation of the value of these services and quality of life in the Buffalo River watershed; and
- Regular reporting of trash index results.

Two sets of teams are proposed to help implement the recommended practices and activities:

- Watershed Implementation Team(s) for each recommended subwatershed to champion implementing recommended practices & activities, monitor progress, and adapt to changing conditions.
- Stream Team(s) to help monitor water quality and promote streambank restoration/stabilization, as well as encourage wildlife habitat initiatives and alternative sources of revenue.

Watershed processes and systems are dynamic. Therefore, an adaptive management approach is proposed for the Buffalo River watershed and outlined in this plan. As part of this approach, continued water quality and biological monitoring is recommended so that progress toward the vision and goals for the Buffalo River watershed can be tracked. The proposed schedule and milestones for implementing the activities outlined in this plan is shown in Table ES.3.

Table ES.3. Proposed schedule for implementation of the Buffalo River watershed-based management plan.

Activity	Action (lead)	Start	Anticipated Completion	2023 Milestones	Indicator	Long Term Goal
Routine Monitoring	Quarterly ambient water quality monitoring (USNPS BNR, ADEQ)	1985	Expected to continue indefinitely	Four additional years of water quality data collected TSS added to monitoring program	Number of long term water quality stations Number of sampling events	Identify and track changes in water quality over time Identify stressors Characterize sediment loads
	Routine ambient water quality monitoring (ADEQ, USGS)	1990	Expected to continue indefinitely	Four years of water quality data collected	Number of long term water quality stations Number of sampling events	Identify and track changes in water quality over time Assess water quality with regard to state standards
	Annual fish community, aquatic invertebrate, and aquatic habitat monitoring (USNPS Heartland Network)	2005	Expected to continue indefinitely	Four additional years of biological data collected	Number of long term biological stations Number of surveys	Identify and track changes in biological communities over time Identify factors influencing biological communities
	Tributary continuous dissolved oxygen monitoring program (USNPS BNR)	2015	Expected to continue indefinitely	Four additional years of dissolved oxygen monitoring completed	Number of sampling stations Number of monitoring events	Assess tributary water quality with regard to state DO criteria Assess tributary nutrient condition Identify factors influencing tributary DO levels Track changes in tributary DO over time
	Trash Index (Stream Team)	2018	Continue at least through 2028	Trash monitoring program established At least two years of monitoring completed	Number of trash monitoring stations Number of trash surveys	Identify and track sources of trash in the Buffalo River tributaries
	Dogpatch Springs routine water quality monitoring location (Subwatershed Implementation Team, Stream Team)	2018	Expected to continue indefinitely	Monitoring station established At least two years of routine monitoring completed	Number of sampling events	Quantify pollutant contributions from Dogpatch Springs to Mill Creek Track changes in water quality over time
	Routine algae monitoring (USNPS BNR, ADEQ)	2018	Expected to continue indefinitely	Monitoring program established At least two years of monitoring completed	Number of sampling stations Number of sampling events	Identify algal species present and track changes in community composition Track frequency of blooms Determine causes of algal blooms
	Summer swimming guide *E. coli* monitoring (White River Waterkeeper)	2018	Expected to continue indefinitely?	Monitoring locations established At least five years of monitoring completed	Number of sampling locations Number of sampling events	Inform public about safety of swimming areas Track E. coli levels at swimming areas
Special Studies	Study of *E. coli* in Mill Creek (upper) subwatershed (ADEQ)	2016	2017	Study completed and report published	Report published	Reduce fecal coliform, *E. coli* , and inorganic nitrogen levels in recommended subwatersheds to targets
	Microbial source tracking of *E. coli* in recommended subwatersheds with *E. coli* reduction targets (Subwatershed Implementation Teams, ADEQ)	2018	2025	MST study in Mill Creek (upper) subwatershed completed Usefulness of MST determined If deemed useful, MST studies for Brush and Tomahawk Creeks will also be completed	Number of sampling events Number of sampling stations Number of subwatersheds studied	Reduce inorganic nitrogen, fecal coliform, and *E. coli* levels in recommended subwatersheds to target levels
	LiDAR Analysis in recommended subwatersheds to identify streambank erosion (Subwatershed Implementation Teams)	2019	2022	Analysis of LiDAR data for Calf Creek subwatershed Usefulness of LiDAR for identifying bank erosion sites determined If deemed useful, LiDAR analysis will be completed for remaining five recommended subwatersheds	Number of subwatersheds analyzed	Reduce streambank erosion in Buffalo River watershed Improve channel stability in Buffalo River watershed
	Big Creek (lower) and Bear Creek subwatershed water quality characterization studies (Subwatershed Implementation Teams)	2019	2023	Studies completed for both Big Creek (lower) and Bear Creek subwatersheds	Number of sampling locations Number of sampling events	Reduce inorganic nitrogen, fecal coliform, and *E. coli* levels in Big Creek (lower); and inorganic nitrogen concentrations in Bear Creek, to targets

Table ES.3. Proposed schedule for implementation of the Buffalo River watershed-based management plan (continued).

Activity	Action (lead)	Start	Anticipated Completion	2023 Milestones	Indicator	Long Term Goal
Information and Education	Quantify ecosystem services in recommended subwatersheds (Subwatershed implementation teams)	2019	2026	Studies completed for Bear Creek and two other recommended subwatersheds.	Number of subwatersheds analyzed Number of reports prepared Number of reports distributed Number of presentations of results	Increased awareness of the importance of quality natural lands to local and regional quality of life
	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	2012	Expected to continue indefinitely	5 conferences held	Number of conference attendees from Buffalo River watershed	Increased awareness and adoption of pasture best management practices in Buffalo River Watershed
	Field Days (Conservation Districts)	Unknown	Expected to continue indefinitely	1 to 3 field days held in recommended subwatersheds	Number of field days in recommended subwatersheds Number of attendees	Increase acceptance and use of practices that protect and improve water quality
	Buffalo National River programs (USNPS)	1975	Expected to continue indefinitely	No net loss in the number of programs offered Printed materials, including signs, updated	Number of programs Number of attendees	Increased awareness of water quality issues Improved visitor stewardship and engagement
	Trash Index reporting (Stream Teams, USNPS, Interest Groups)	2020	At least through 2028	Trash index reports added to USNPS park displays and website Results of at least six trash index surveys distributed	Number of places trash index survey results reported Number of surveys reported	Increase awareness of trash issue in Buffalo River Assess effectiveness of outreach programs Track USNPS Leave No Trace Behind program Reduce trash in Buffalo River
	Ozark Highlands Karst Program (TNC)	2007	Expected to continue	Report of sensitive areas in at least one recommended subwatershed requested or provided	Number of requests for information on sensitive areas Amount of materials on sensitive areas distributed	Increase awareness of how land surface activities impact groundwater and cave/karst species Increase use of practices that protect and improve groundwater and cave/karst habitats
	Training in environmentally sensitive maintenance of unpaved road (Arkansas Rural Services)	2017	Expected to continue indefinitely	Representatives from each of the counties in the watershed attend free training session	Number of attendees from Buffalo River watershed	Increase use of practices that protect and improve water quality in the Buffalo River watershed
	Onsite wastewater system maintenance outreach (interest groups, subwatershed implementation teams, White River Waterkeeper)	2018	2028	Outreach program organized At least one outreach effort in a recommended subwatershed	Number of homeowners contacted Amount of materials distributed Number of events hosted or attended	Increase the number of well maintained systems Reduce pollutant releases from onsite systems. Improve groundwater quality in watershed *E. coli* land inorganic nitrogen levels reduced to targets in recommended subwatersheds
Planning	Establish Subwatershed Implementation Teams	2018	2028	Subwatershed implementation teams established in at least 3 recommended subwatersheds	Number of teams established	Improve water quality, aquatic habitat, stream stability, and economic returns in recommended subwatersheds
Implement Management Strategies	Pasture and hayland management practices (landowners, farmers, ranchers)	2018	2028	New management practices planned/contracted or implemented in at least two recommended subwatersheds	Number of contracts Number of practices planned Number of practices implemented Area treated Years practices maintained	Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds Increased channel stability Reduced erosion
	Forestry best management practices (landowners, foresters)	2018	2028	Increased implementation of forestry best management practices in Buffalo River watershed	Amount of best management practices added since 2017 Years practices maintained	Reduce erosion Reduce sediment and nutrient inputs to streams from forestry activities

Table ES.3. Proposed schedule for implementation of the Buffalo River watershed-based management plan (continued).

Activity	Action (lead)	Start	Anticipated Completion	2023 Milestones	Indicator	Long Term Goal
Implement Management Strategies (continued)	Ecotone restoration and management practices in recommended subwatersheds (County Conservation Districts, landowners, farmers, ranchers)	2018	2028	New restoration projects planned/contracted or implemented in at least two recommended subwatersheds	Number of practices planned/ contracted Number of practices implemented Area treated Years practices maintained	Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds Increased channel stability Reduced erosion Increase populations of species of greatest conservation need
	Environmentally sensitive maintenance for unpaved roads (Counties)	2018	Expected to continue indefinitely	County personnel participating in training as required by state program Use of Environmentally Sensitive Maintenance practices increased in at least one Buffalo River watershed county At least one improvement project funded in Buffalo River watershed	Miles of county roads in watershed properly graded, Number of crossings improved Number of training attendees	Reduce road erosion Reduce road maintenance Reduce sediment inputs to streams from unpaved roads
	Karst protection practices (The Nature Conservancy, NRCS)	2018	2028	Karst protection practices planned or implemented by at least one landowner or community in a recommended subwatershed (including areas outside of subwatershed that contribute groundwater to the subwatershed)	Number of practices planned/contracted Number of practices implemented Area treated Years practices maintained	Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds Cave/karst species of greatest conservation need protected
	Forestry best management practices (Arkansas Forestry Commission)	2008	Expected to continue indefinitely	Increased implementation of forestry best management practices in Buffalo River watershed	Amount of best management practices added since 2017	Reduce erosion Reduce sediment and nutrient inputs to streams from forestry activities
	Control of invasive and destructive species (AGFC, US Fish and Wildlife, landowners, Conservation Districts)	2018	2028	Feral hog problem areas identified in at least one recommended subwatershed	Number of feral hogs eliminated Size of feral hog population affecting Buffalo River watershed	Reduce erosion Reduce inputs of sediment, nutrients, and *E. coli* to surface waters Reduce property damage
Evaluate	Biennial water quality assessment (ADEQ)	2018	Expected to continue indefinitely	EPA approved final 303(d) lists for 2018 and 2020	Attaining and nonattaining stream reaches in Buffalo River watershed	All water quality criteria met in Bear Creek All water quality criteria met in all monitored stream reaches in the watershed
	Annual voluntary forestry best management practices assessment (Arkansas Forestry Commission)	2016	Expected to continue indefinitely	Two biennial surveys completed (2017 and 2020)	Published assessment reports	Estimate and document extent of forestry best management practices implementation, and identify areas to focus best management practices education efforts
	Track implementation of best management practices in Buffalo River watershed	2018	2028	Information for period 2018 through 2022 compiled	Linear feet/acres of best management practices implemented Water quality improvement	All water quality criteria met in all monitored stream reaches in the watershed Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds
	Plan evaluation	2024	2024	Data needed for evaluation compiled	Evaluation completed Evaluation report made public	All water quality criteria met in all monitored stream reaches in the watershed Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds

Table ES.3. Proposed schedule for implementation of the Buffalo River watershed-based management plan (continued).

Activity	Action (lead)	Start	Anticipated Completion	2023 Milestones	Indicator	Long Term Goal
Update Buffalo River Watershed-based Management Plan	Public Meetings	2023	2024	Begin organizing public meetings	Number of attendees Number of meetings	Stakeholder input to watershed management planning
	Update Watershed Management Plan	2024	2025	Entity responsible for update identified and committed Preparations for update under way	Updated watershed management plan completed Recommended subwatersheds identified Stakeholder relationships continued/ improved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Buffalo River watershed

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF APPENDICES

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF ACRONYMS

ADEQ = Arkansas Department of Environmental Quality

ADH = Arkansas Department of Health

AGFC = Arkansas Game and Fish Commission

ANRC = Arkansas Natural Resources Commission

BBRAC = Beautiful Buffalo River Action Committee

BCRET = Big Creek Research Extension Team

BOD = biochemical oxygen demand

CAFO = Confined Animal Feedlot Operation

CALF = Controlled Access for Livestock

cfs = cubic feet per second

cfu = colony forming units

CRP = Conservation Reserve Program

Deg C = degrees Celcius

DO = Dissolved oxygen

EPA = US Environmental Protection Agency

ERW = Extraordinary Resource Waters

EQIP = Environmental Quality Incentives Program of the US Natural Resources Conservation Service

FSA = Farm Services Agency

GIS = Geographic Information System

gpm = gallons per minute

HUC = Hydrologic Unit Code

IBI = Index of Biotic Integrity

Kg = kilogram

lb = pounds

mg/L = milligrams per liter

mL = milliliter

MST = microbial source tracking

N = nitrogen

LIST OF ACRONYMS (CONTINUED)

NOAA = US National Oceanographic and Atmospheric Administration

NPDES = National Pollutant Discharge Elimination System

NRCS = US Natural Resources Conservation Service

NTU = Nephelometric turbidity units

P = phosphorus

QPCR = quantitative polymerase chain reaction

SARE = Sustainable Agriculture Research and Education

SCI = Stream Condition Index

SID = Sewage Improvement District

Sq km = square kilometer

Sq mi = square miles

su = standard units

SWAT = Soil and Water Assessment Tool

TDS = Total dissolved solids

TKN = Total Kjeldahl Nitrogen

TMDL = total maximum daily load

TNC = The Nature Conservancy

TSS = total suspended solids

UofA = University of Arkansas

USDA = US Department of Agriculture

USFWS = US Fish and Wildlife Service

USGS = US Geological Survey

USNPS = US National Park Service

WTP = willingness to pay

WWTP - wastewater treatment plant

1.0 INTRODUCTION

This watershed-based management plan addresses the Buffalo River watershed located in north-central Arkansas. The primary focus of this plan is protection and improvement of surface water quality in the Buffalo River and its tributaries through management of unregulated nonpoint sources of pollution.

1.1 Management History

The Flood Control Act of 1938 included plans to dam the Buffalo River as part of the White River flood control project. In the 1960s, the Ozark Society was formed to prevent the damming of the Buffalo River. After a decade of political maneuvering and public outreach by those for and against damming the river, federal legislation was passed in 1972 designating the Buffalo River as the first National River in the US, and a National Park was established along the river corridor.

The following list shows that there continues to be strong interest in protecting the Buffalo River:

- There are a number of interest groups actively working in the watershed, in addition to the Ozark Society.
- In 1992, 15.8 miles of the Buffalo River were designated part of the National Wild and Scenic River system.
- In the state water quality regulations, the Buffalo River and its tributary Richland Creek are designated as Natural and Scenic Waterways, and as Extraordinary Resource Waters.
- A recent state law prohibits the application of poultry litter transported from state nutrient surplus areas using the ANRC cost-share, in the Buffalo River watershed (A.CA. s 15-20-1203).
- In 2015, after public concerns were raised about the permitting of a swine confined animal operation in the Buffalo River watershed, the Arkansas Pollution Control and Ecology Commission modified state regulations for liquid animal waste management systems to limit the size of swine confined animal operations that can be permitted in the Buffalo River watershed (Arkansas Pollution Control and Ecology Commission 2015).

- In September 2016, the Governor of Arkansas established the Beautiful Buffalo River Action Committee (BBRAC).

1.2 Plan Need and Purpose

One of the charges of the BBRAC is to develop a watershed management plan for the Buffalo River and its watershed. This charge is being implemented through the Arkansas Natural Resources Commission (ANRC) nonpoint source pollution control priority watershed program. The goal of the priority watershed program is to reduce nonpoint source pollutants so that all streams achieve their designated uses through implementation of a watershed-based management plan that includes the nine elements recommended by the US Environmental Protection Agency (EPA) (EPA 2008).

The purpose of this plan is to provide a framework for landowners, communities, and organizations to voluntarily undertake water quality projects in the watershed and improve their ability to solicit and secure funding and assistance for these projects from various government and private sources.

1.3 Process

Development of the Buffalo River watershed-based management plan followed the steps outlined by EPA in the Handbook for Developing Watershed Plans (EPA 2008):

1. Building partnerships,
2. Characterizing the watershed,
3. Finalizing management goals and identifying solutions, and
4. Designing an implementation program.

ANRC worked with consultants to develop this watershed-based management plan, utilizing the input of watershed stakeholders. Four public meetings were held as part of the process of developing the Buffalo River watershed-based management plan. The purposes of these public meetings were to inform stakeholders of the plan and the process for developing it, and to request and obtain stakeholder input for the plan. In particular, stakeholder input was sought in identifying priority issues in the watershed, and selecting management strategies for addressing nonpoint source pollution in the watershed. Stakeholders who participated in development of this plan include US National Park Service, US Army Corps of Engineers, US Fish and Wildlife Service, US Forest Service, Natural Resources Conservation Service, Arkansas Department of Environmental Quality, Arkansas Department of Health, Arkansas Forestry Commission, Arkansas Game and Fish Commission, University of Arkansas Cooperative Extension Service, County Conservation Districts, recreation and environmental interest groups, farmers, and ranchers. Sign-in sheets for the public meetings are included as Appendix A.

1.4 Document Overview

This document contains elements recommended by EPA and the Arkansas Department of Environmental Quality (ADEQ) for watershed management plans. Section 2 describes many of the features of the watershed. Sections 3 and 4 summarize conditions in the watershed, including water quality, hydrology, and ecology. Section 5 provides information on pollutant sources in the Buffalo River watershed. Section 6 identifies watershed goals and objectives, subwatersheds recommended for initial management of nonpoint pollutant sources, pollutant load reduction targets, and management strategies for controlling nonpoint source pollution in the recommended subwatersheds. Section 7 outlines the overall implementation plan, with schedule, list of management and outreach activities, and identification of indicators and monitoring to track progress and effects. Section 8 discusses costs and benefits of proposed management, and assistance that is available for implementation of nonpoint source pollution management practices.

Watershed-based management plans developed to meet the requirements for Clean Water Act Section 319 funding must address nine planning elements required by EPA to manage and protect against nonpoint source pollution. Table 1.1 provides a roadmap for where the required planning elements are addressed in this plan.

Table 1.1. The required nine planning elements to manage and protect against nonpoint source pollution, and the location of the elements within this plan.

Element	Report Section(s)
Element A: Identification of Causes and Sources	
1. Sources identified, described, and mapped	5.0, 6.5, 6.6, Appendix E
2. Subwatershed sources	6.5
3. Data Sources are accurate and verifiable	5.0, 6.5. 6.6
4. Data gaps	3.2.8, 3.3.6, 4.4
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	6.4
2. Load reductions linked to sources	6.6, 6.7
3. Model complexity appropriate	6.4, 6.8
4. Basis of effectiveness estimates explained	6.8, Appendix H
5. Methods and data cited and verifiable	6.8
Element C: Management Measures Identified	
1. Specific management measures are identified	6.7
2. Priority areas	6.2, 6.5, 6.6
3. Measure selection rationale documented	6.7
4. Technically sound	6.7
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	8.3
2.Estimate of financial assistance	8.1, 8.2
Element E: Education/outreach	
2. Public education/information	7.1
1. All relevant stakeholders are identified in outreach process	1.3, 7.1, Appendix A
3. Stakeholder outreach	7.1
4. Public participation in plan development	1.3, 6.7, Appendix A, B
5. Emphasis on achieving water quality standards	7.1
6. Operation & maintenance of BMPs	7.1
Element F: Implementation Schedule	
1. Includes completion dates	7.10
2. Schedule is appropriate	7.10
Element G: Milestones	
1. Milestones are measureable and attainable	7.8, 7.10
2. Milestones include completion dates	7.8, 7.10
3. Progress evaluation and course correction	7.8, 7.9
4. Milestones linked to schedule	7.10
Element H: Load Reduction Criteria	
1. Criteria are measureable and quantifiable	6.4, 7.8
2. Criteria measure progress toward load reduction goal	7.8
3. Data and models identified	7.6
4. Target achievement dates for reduction	7.8
5. Review of progress toward goals	7.8
6. Criteria for revision	7.8, 7.9
7. Adaptive management	7.8, 7.9

Table 1.1. The required nine planning elements to manage and protect against nonpoint source pollution, and the location of the elements within this plan (continued).

Element	Report Section(s)
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	7.8.3
2. Monitoring measures evaluation criteria	7.8.3
3. Routine reporting of progress and methods	7.8
4. Parameters are appropriate	7.8.3
5. Number of sites is adequate	7.6
6. Frequency of sampling is adequate	7.6
7. Monitoring tied to QAPP	7.6
8. Can link implementation to improved water quality	7.6

2.0 WATERSHED DESCRIPTION

2.1 Geography

The Buffalo River is a tributary of the White River in north central Arkansas. Approximately 150 miles long (Moix and Galloway 2005), the river flows easterly across Newton and Searcy counties before crossing the southeastern corner of Marion County to meet the White River. The majority of the Buffalo River watershed is located in Newton (46%) and Searcy (37%) counties, followed by Marion County (11%) and Baxter County (2.5%) (Mott and Laurans 2004). The remainder of the watershed (less than 3%) includes portions of Boone, Madison, Pope, Stone, and Van Buren counties at the fringes of the watershed (Figure 2.1). There are just five incorporated areas within the watershed: Gilbert, Marshall, and Saint Joe in Searcy County, Jasper in Newton County, and Big Flat in Baxter County (US Census Bureau 2012).

The Buffalo River watershed covers 1,342.7 square miles, drained by over 2,000 miles of streams (Center for Advanced Spatial Technologies 2006). It is a sub-basin of the Upper White River basin and is identified by the U.S. Geological Survey (USGS) 8-digit Hydrologic Unit Code (HUC) 11010005. There are 37 12-digit HUC subwatersheds within the Buffalo River watershed.

Major tributaries to the Buffalo River include Bear Creek, two Big Creeks (one in Newton County and another in Searcy and Marion counties), Calf Creek, Cave Creek, Cecil Creek, Clabber Creek, Davis Creek, Little Buffalo River, two Mill Creeks (one in Newton County and one in Searcy County), Richland Creek, Tomahawk Creek, and Water Creek. Other major streams in the watershed include Thomas Creek, a tributary of the Little Buffalo River, and Spring and Sellers Creeks, tributaries of the eastern Big Creek (ANRC 2014).

Approximately 40% of the Buffalo River watershed is within one or more publicly owned areas: the Ozark-St. Francis National Forest, eight Arkansas Game and Fish Commission Wildlife Management Areas, and the Buffalo National River (a unit of the US National Park Service [USNPS]) (Figure 2.1).

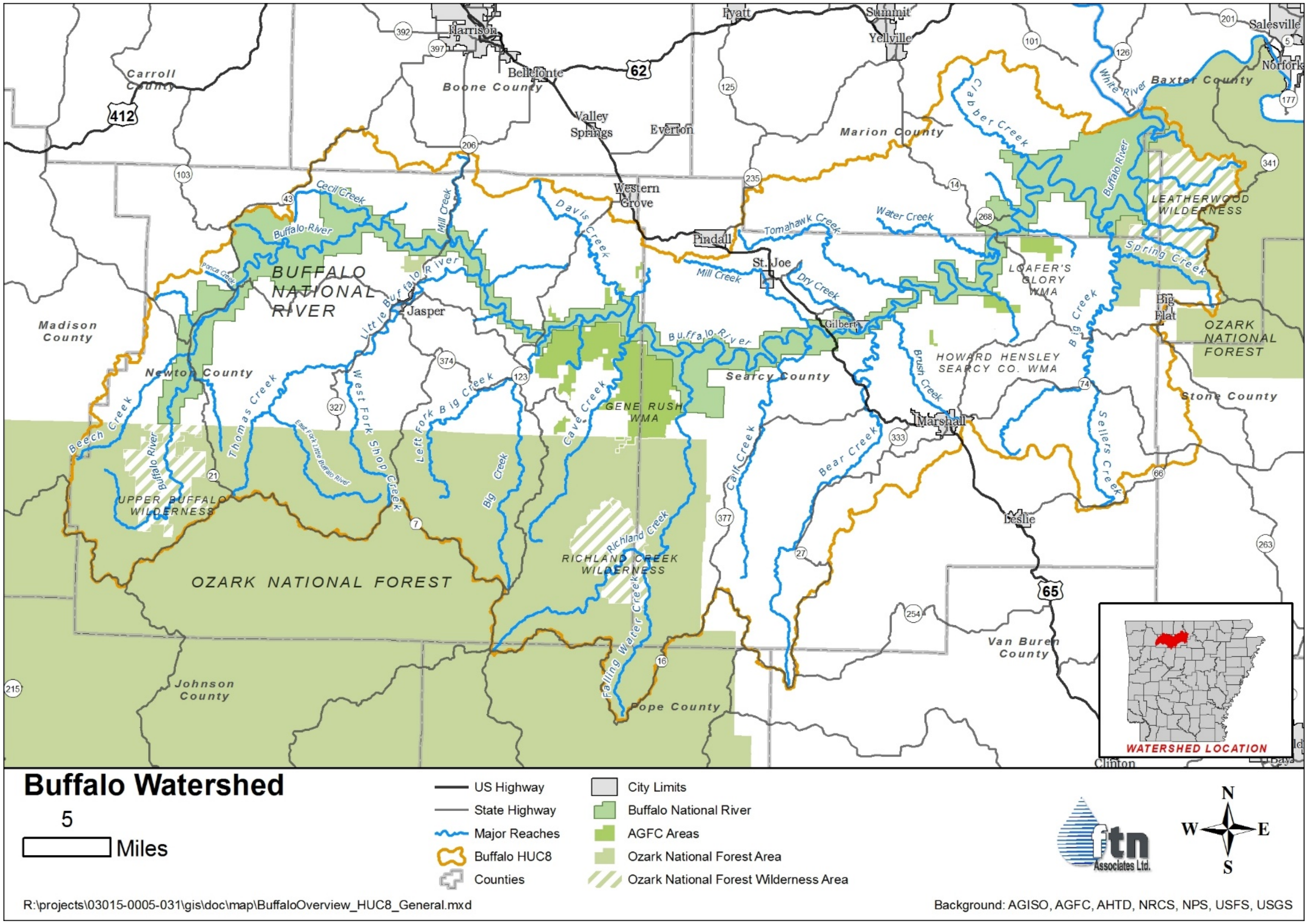

Figure 2.1. Buffalo River watershed.

2.2 Socioeconomics

This section summarizes demographic and economic information for the Buffalo River watershed. Demographic information from the US Census Bureau for the counties of the Buffalo River watershed is presented.

2.2.1 Population

Numbers of people in the counties of the Buffalo River watershed are presented in Table 2.1. The watershed is rural, with no urbanized areas and no urban clusters as defined by the US Census Bureau (US Census Bureau 2012). The population change in the counties of the watershed has been small, with 0.2% decrease from 2000 to 2010 followed by a 1.8% decrease to 2015. Between 2000 and 2010, population increased in most of the surrounding counties (by an average of 8.3%, ±5.1%) but decreased slightly in Newton and Searcy counties (by 3.2% and 0.8% respectively). Since then, from 2010 to 2015, the populations in the surrounding counties have had slight changes – decreases of 3.0% or less in Baxter, Marion, and Van Buren counties; and increases of 2.6% or less in Boone, Madison, Pope, and Stone counties. In the same period, the populations in Newton and Searcy counties decreased by 5.0% and 4.0% respectively. The populations in Baxter, Marion, Searcy, and Van Buren counties are projected to continue to decline (by 0.2% to 4.2%) through 2020 while the Boone, Madison, and Newton County populations are projected to increase slightly (1.3% or 1.9%) and the Pope and Stone County populations are projected to increase by 4.2% and 7.5%.

Additional demographic information for the Buffalo River watershed and surrounding counties is listed in Table 2.2. This includes percentages of the population for characteristics of commuting, household structure, age, gender, race, median income, poverty, fields of employment, and education level. Within the watershed, the majority of commuters drive alone, though a higher percentage carpool than across the state as a whole. About two-thirds of households are families, and most of these include two parents. The population of the watershed is older than the state-wide profile. There are lower percentages of persons under age 18, 18 to 34 years, and 35 to 49 years; while there are higher percentages of persons aged 50 to 64 years and 65 and older. The majority (>94%) of persons in the watershed consider themselves White (non-Hispanic).

Table 2.1. Numbers of people in the Buffalo River watershed and surrounding counties.

County	2000[a] Total population	Population Density[b] (avg/sq mi)	2010[a] Total Population	Population Density[a] (avg/sq mi)	2015 population estimate[c]	2020 projection[d]
Buffalo River Watershed[†]	15,874	11.8	15,837	11.8	15,545	n/a
Baxter	38,386	69.2	41,513	74.9	41,040	36,791 – 44,135
Boone	33,948	57.4	36,903	62.5	37,222	35,277 – 40,782
Madison	14,243	17.0	15,717	18.8	15,767	14,328 – 17,819
Marion	16,140	27.0	16,653	27.9	16,458	14,003 – 17,396
Newton	8,608	10.5	8,330	10.1	8,052	7,533 – 8,630
Pope	54,469	67.1	61,754	76.0	63,390	62,693 – 69,564
Searcy	8,261	12.4	8,195	12.3	7,965	7,151 – 8,621
Stone	11,499	19.0	12,394	20.4	12,456	12,683 – 14,115
Van Buren	16,192	22.8	17,295	24.4	16,771	15,154 – 17,069
State of Arkansas	2,673,400	51.4	2,915,918	56.0	2,958,208	3,034,437 – 3,110,424

[†] Values for the watershed aggregated from US Census Bureau data for block groups intersecting the watershed. The counts for block groups partially within the watershed were proportioned by area.

[a] (US Census Bureau 2012)

[b] (US Census Bureau 2003)

[c] (US Census Bureau 2015)

[d] (UALR Institute for Economic Advancement 2015)

Household and per-capita incomes in the counties of the Buffalo River watershed are below those state-wide. However, there is a slightly lower percentage of families below the poverty level, and a slightly higher percentage of people below the poverty level than for the state as a whole. The unemployment rate is two percentage points lower than the state-wide rate. The percentages of high school graduates, bachelor's, and graduate degree holders are all lower than the state-wide values.

Table 2.2. Additional demographic information for the Buffalo River watershed and surrounding area (US Census Bureau 2015).

	Buffalo River Watershed[1]	Baxter County	Boone County	Madison County	Marion County	Newton County	Pope County	Searcy County	Stone County	Van Buren County	State of Arkansas
Commuting (number of persons)											
Drove alone	77.4%	84.6%	85.2%	77.8%	76.1%	75.2%	84.0%	77.9%	76.9%	83.4%	82.6%
Carpooled	14.2%	8.9%	9.2%	13.3%	17.8%	13.7%	9.9%	14.2%	12.8%	10.3%	10.8%
Public Transportation	0.5%	0.4%	0.0%	0.7%	0.3%	0.7%	0.1%	0.4%	0.0%	0.2%	0.4%
Walk or other	4.1%	2.1%	3.1%	2.3%	2.3%	4.6%	3.7%	4.3%	4.1%	2.9%	3.1%
Mean travel time (minutes)	32.42	17.1	20.3	31.7	23.1	36.2	18.8	31.3	25.2	27.4	21.6
Worked at home	3.8%	4.0%	2.5%	6.0%	3.5%	5.8%	2.3%	3.4%	6.2%	3.3%	3.2%
Household structure											
Family households	66.5%	65.8%	69.3%	73.4%	68.5%	67.3%	68.2%	64.4%	62.7%	66.1%	66.8%
Two parent families	57.2%	52.9%	55.0%	60.9%	57.4%	56.6%	53.1%	56.9%	53.0%	50.7%	49.1%
Single parent families	9.3%	12.9%	14.3%	12.6%	11.1%	10.7%	15.1%	7.6%	9.7%	15.4%	17.7%
Single person household	29.8%	30.0%	26.7%	23.9%	26.8%	30.1%	26.9%	31.2%	34.2%	29.6%	28.2%
Other non-family household	3.8%	4.2%	4.0%	2.7%	4.6%	2.7%	5.0%	4.4%	3.1%	4.3%	5.0%
Age (number of persons)											
Median age	NA	51.5	41.4	41.8	51.3	47.7	35.2	47.0	48.5	47.1	37.7
Under 18	20.0%	17.6%	22.7%	23.7%	17.4%	20.0%	22.8%	20.6%	21.0%	20.0%	23.9%
18 to 34 years	16.4%	15.1%	19.2%	18.4%	14.8%	15.8%	27.1%	17.1%	15.8%	16.9%	22.7%
35 to 49 years	17.5%	15.3%	18.5%	19.2%	15.5%	17.2%	17.7%	16.3%	15.7%	17.1%	18.8%
50 to 64 years	23.3%	22.4%	20.2%	21.7%	26.3%	24.3%	18.4%	22.8%	23.1%	21.9%	19.2%
65 and older	22.8%	29.6%	19.4%	17.0%	26.0%	22.7%	14.0%	23.2%	24.5%	24.2%	15.3%
Gender (number of persons)											
Female	50.2%	51.7%	51.3%	49.9%	50.3%	49.9%	50.5%	50.0%	49.3%	50.6%	50.9%
Male	49.8%	48.3%	48.7%	50.1%	49.7%	50.1%	49.5%	50.0%	50.7%	49.4%	49.1%
Race (number of persons)											
White non-Hispanic	94.2%	95.3%	94.5%	90.9%	94.8%	94.4%	85.5%	94.1%	95.3%	93.6%	73.6%
Hispanic	1.7%	1.9%	2.2%	5.2%	2.2%	1.1%	7.8%	1.9%	1.7%	2.9%	6.9%
Black non-Hispanic	0.1%	0.3%	0.4%	0.0%	0.3%	0.0%	2.9%	0.3%	0.0%	0.5%	15.4%
Native American	1.2%	0.6%	0.7%	0.5%	0.7%	1.4%	0.6%	1.1%	0.2%	0.4%	0.8%
Asian	0.8%	0.5%	0.5%	0.6%	0.7%	0.5%	0.7%	1.1%	0.2%	0.2%	1.4%
Other race	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
>1 race, non-Hispanic	1.9%	1.3%	1.7%	2.7%	1.3%	2.7%	2.5%	1.6%	2.6%	2.3%	1.9%
Income											
Per capita income	$18,285	$22,475	$21,946	$20,693	$17,779	$18,038	$20,047	$18,533	$18,944	$19,047	$22,798
Families below poverty level	13.8%	10.7%	13.9%	16.6%	12.7%	13.7%	14.8%	17.1%	16.5%	15.8%	14.2%
People below poverty level	20.0%	15.9%	17.7%	20.5%	18.8%	20.5%	20.0%	23.6%	24.6%	21.4%	19.3%

Table 2.2. Additional demographic information for the Buffalo River watershed and surrounding area (continued).

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	Buffalo River Watershed[1]	Baxter County	Boone County	Madison County	Marion County	Newton County	Pope County	Searcy County	Stone County	Van Buren County	State of Arkansas
Employment											
Unemployed	5.7%	7.6%	8.4%	7.3%	10.9%	4.4%	7.6%	5.9%	7.0%	11.2%	7.7%
Mgmt, business, science, arts	25.1%	29.2%	30.7%	27.1%	19.4%	23.5%	28.8%	27.7%	31.4%	25.3%	32.0%
Service	18.0%	19.7%	18.9%	14.7%	25.8%	20.0%	17.6%	11.9%	21.6%	16.7%	17.1%
Sales, office	22.0%	23.3%	25.4%	19.3%	20.1%	18.8%	23.4%	26.0%	14.1%	22.1%	23.9%
Natural resources, construction, maintenance	13.8%	8.5%	10.9%	15.6%	11.7%	14.1%	11.1%	16.0%	21.0%	19.6%	10.7%
Production, transportation, material moving	21.1%	19.3%	14.1%	23.2%	23.0%	23.5%	19.1%	18.4%	11.9%	16.3%	16.4%
Self-employed	18.8%	12.1%	12.4%	16.8%	12.4%	20.2%	9.4%	21.7%	21.9%	15.2%	9.4%
Education (population 25 or older)											
High School graduate (or higher)	82.1%	87.4%	85.8%	78.4%	85.4%	81.9%	82.7%	81.9%	79.1%	81.9%	84.8%
Bachelor's degree (or higher)	13.5%	17.9%	14.7%	10.7%	13.2%	14.6%	20.9%	13.9%	15.9%	12.3%	21.1%
Graduate degree	4.7%	4.8%	5.4%	3.6%	4.1%	4.9%	7.4%	5.1%	6.3%	4.0%	7.5%

[1] Values for the watershed aggregated from US Census Bureau data for Block Groups intersecting the watershed. The counts for Block Groups partially within the watershed were proportioned by area.

[2] Calculated from US Census Bureau statistics. Result may not be as accurate as original census statistics.

2.2.1 Economics

The largest drivers of the economy in the Buffalo River watershed are tourism and outdoor recreation (such as hiking, canoeing, hunting, and fishing). Livestock farming and timber production also contribute to the economy in the area (Association of Arkansas Counties 2017). The value of sales and receipts reported for selected economic sectors in the counties within the Buffalo River watershed in the 2012 economic census is summarized in Table 2.3. Agriculture and timber are not economic sectors reported in the economic census. However, they contribute value to manufacturing, real estate, wholesale trade, and transportation and warehousing economic sectors (U of A Divison of Agriculture 2012). Table 2.4 lists the value of sales of agricultural products reported for the counties within the Buffalo River watershed in the 2012 census of agriculture. Tables 2.5 and 2.6 summarize economic inputs to the counties within the Buffalo River watershed from tourism.

Table 2.3. Sales and receipts for 2012 in $1,000 for counties in the Buffalo River watershed (US Census Bureau 2016).

Economic Sector	Baxter County	Boone County	Madison County	Marion County	Newton County	Pope County	Searcy County	Stone County	Van Buren County	Total
Portion of county within watershed	5.8%	1.7%	0.3%	23.3%	75.3%	1.4%	74.7%	1.7%	0.3%	–
Manufacturing	$574,423	$493,651	D*	$244,842	$5,301	$1,506,729	D*	$10,458	D*	$2,835,404
Wholesale Trade	D*	D*	D*	$16,497	D*	$322,369	D*	$34,139	$35,553	$408,558
Retail Trade	$476,645	$493,268	$130,207	$94,779	$17,001	$869,392	$49,780	$107,472	$168,365	$2,406,909
Transportation† & Warehousing	D*	$102,697	D*	D*	$2,352	$113,198	n/a	$2,008	$45,416	$265,671
Accommodation & Food Service	$61,602	D*	$7,445	$8,462	D*	D*	D*	$14,776	$15,795	$108,080
Total	$1,112,670	$1,089,616	$137,652	$364,580	$24,654	$2,811,688	$49,780	$168,853	$265,129	$6,024,622

* data withheld by US Census Bureau to avoid disclosure of data for individual businesses
†Does not include railroad transportation or U.S. Postal Service as these are out of scope for the census.

Table 2.4. Value of 2012 sales in $1,000 of agricultural commodities for counties in the Buffalo River watershed (US Department of Agriculture 2014).

Commodity	Baxter	Boone	Madison	Marion	Newton	Pope	Searcy	Stone	Van Buren	Total
Portion of county within watershed	5.8%	1.7%	0.3%	23.3%	75.3%	1.4%	74.7%	1.7%	0.3%	–
All agricultural products	$20,367	$124,065	$208,163	$39,667	$28,655	$150,102	$13,038	$53,664	$19,947	$657,668
Crops (incl. nursery & greenhouse)	$601	$1,329	$3,145	$560	$1,004	$10,396	$1,012	$841	$1,067	$19,955
Hay	$489	$1,075	$2,134	D*	$797	$1,615	$976	$764	$976	$8,826
Livestock	$19,766	$122,736	$205,018	$39,107	$27,651	$139,706	$12,026	$52,823	$18,880	$637,713
Cattle & calves	$12,238	$33,941	$21,995	$11,873	$6,284	$15,680	$9,438	$21,965	$9,248	$142,662
Milk from cows	–	$971	$1,547	–	–	–	$684	D*	$568	$3,770
Hogs & Pigs	D*	D*	$15	D*	$821	$4,456	D*	D*	D*	$5,292
Poultry & eggs	$6,381	$87,438	$180,788	$26,680	$20,360	$119,028	D*	$30,666	$6,862	$478,203

* data withheld by USDA NASS to avoid disclosure of data for individual farms

Table 2.5. Preliminary 2015 tourism economic impacts for counties in the Buffalo River watershed (Arkansas Department of Parks and Tourism 2016).

	Baxter	Boone	Madison	Marion	Newton	Pope	Searcy	Stone	Van Buren
Portion of county within watershed	5.8%	1.7%	0.3%	23.3%	75.3%	1.4%	74.7%	1.7%	0.3%
Total travel expenditures	$248,024,325	$78,129,815	$11,099,282	$52,831,277	$14,559,881	$168,950,409	$10,958,306	$85,942,510	$61,279,737
Travel-generated payroll	$45,523,290	$14,377,943	$1,602,500	$10,323,012	$2,687,943	$25,754,794	$1,731,754	$16,353,240	$9,983,222
Travel-generated employment	2,328 jobs	819 jobs	68 jobs	543 jobs	154 jobs	1,371 jobs	85 jobs	841 jobs	537 jobs
Travel-generated state tax	$14,526,524	$4,642,607	$673,248	$3,124,452	$864,269	$7,211,447	$661,242	$4,969,321	$3,782,691
Travel-generated local tax	$4,562,107	$1,503,591	$290,724	$1,194,722	$339,283	$2,375,141	$256,001	$1,822,192	$1,767,119
Visitors (person-trips)	1,041,452	331,808	43,502	214,450	57,822	677,208	53,781	352,509	229,343

Table 2.6. Contributions and Impacts of Buffalo National River visitor spending to local economy in 2015 ($ in 1,000s) (Thomas and Koontz 2016).

	Recreation Visits	Visitor Spending	Contributions[a] & Impacts[b] due to Buffalo NR			
			Jobs	Labor Income	Value Added	Economic Output
Total visitors (importance to regional economy)	1,463,304	$62,243.2	969	$24,528.1	$40,151.7	$72,009.0
Non-local visitors (inflow to regional economy)	1,014,290	$55,289.2	878	$22,367.5	$36,715.4	$65,876.4

[a] Defined by NPS as gross economic activity in region that is associated with National Park visits. Indicator of relative magnitude and importance to regional economies.
[b] Defined by NPS as net changes to the regional economy due to non-local visitors to National Parks. Spending by local visitors excluded because would still likely be spent in local economy. Indicator of economic activity that would be lost if park was not there.

2.3 Climate

Climate normals are 30-year averages of climate data, calculated at individual recording stations for the U.S. by the National Oceangraphic Atmospheric Administration’s (NOAA) National Centers for Environmental Information. For the Buffalo River watershed, the 1981-2000 climate normals are estimated using weather stations at Deer, Gilbert, and Marshall, AR. The average annual precipitation is approximately 49 inches. The lowest average monthly precipitation occurs in August, with the highest occurring in May and November. The warmest average monthly temperatures occur in August, while the coldest occur in January. The average monthly precipitation and the average monthly minimum and maximum temperatures are shown in Figure 2.2 (NOAA, et al. 2015).

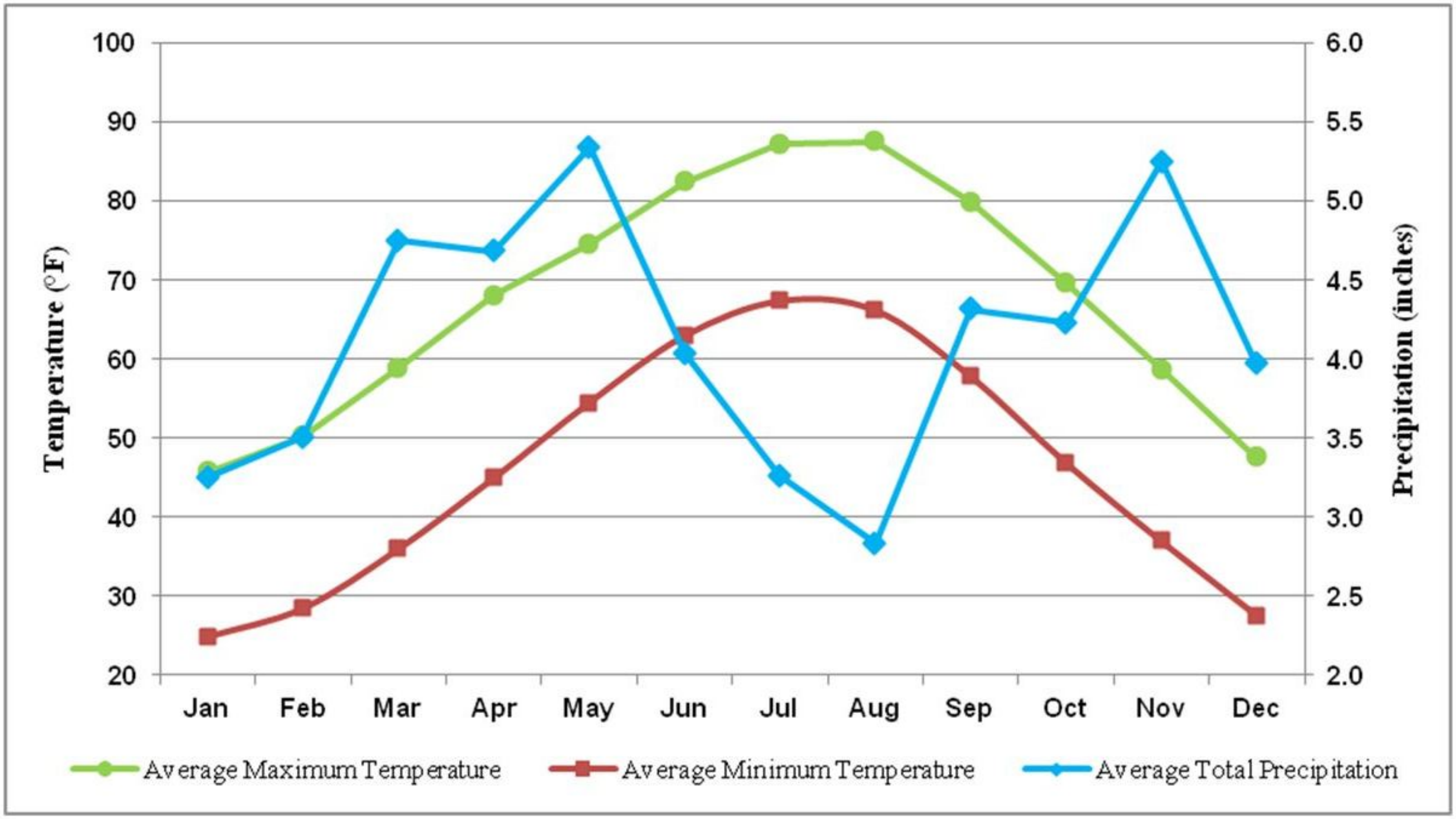

Figure 2.2. 1981-2010 climate normals in the Buffalo River watershed.

2.4 Geology

The Buffalo River watershed is situated in the northern Boston Mountains and the southern Springfield Plateau and Salem Plateau physiographic regions of the Ozark Plateaus (Figure 2.3). The geology of the Ozark Plateaus consists of sedimentary rock that was deposited in shallow marine seas during the Ordovician through Pennsylvanian periods. The geology of the Boston Mountains is dominated by sandstones, while the Springfield Plateau is predominantly limestone (Arkansas Geological Survey 2015a). A surface geology map of the Buffalo River watershed is shown in Figure 2.4. Approximately 64% of the surface geology is limestone and dolomite formations, including most of the Buffalo River bed (Scott and Smith 1994).

The Buffalo River watershed is underlain by a series of gently folded sandstone, shale, cherty dolomite, and limestone formations (Table 2.7). The rocks underlying the watershed have been affected by tectonic forces and erosion, resulting in widespread presence of faults and solution/karst features. Karst features in the Buffalo River watershed are associated primarily with the Boone Formation (USNPS 2017a). Within the boundaries of the National River parklands, there are over 300 cave systems (USNPS 2017a).

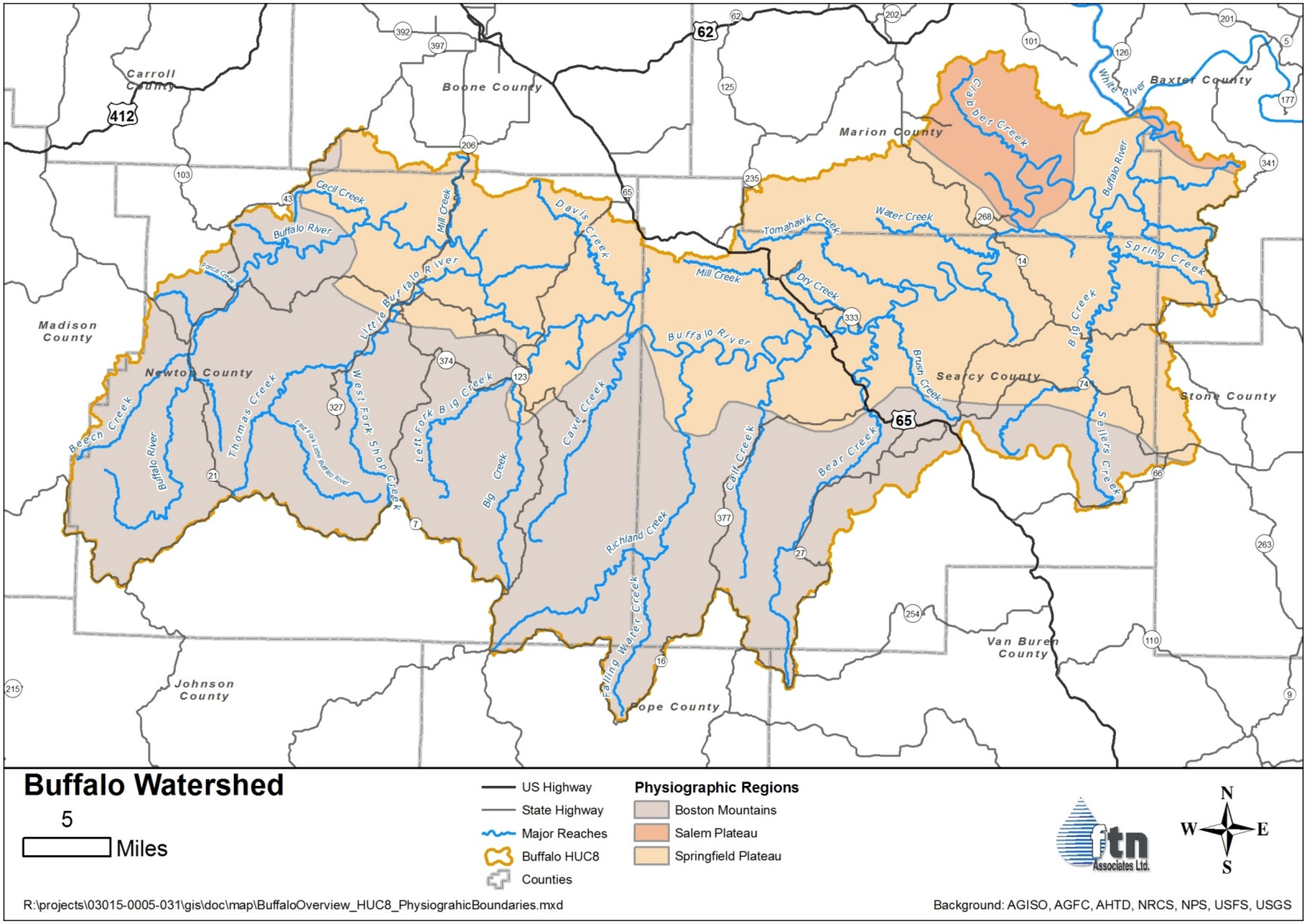

Figure 2.3. Physiographic regions within the Buffalo River watershed.

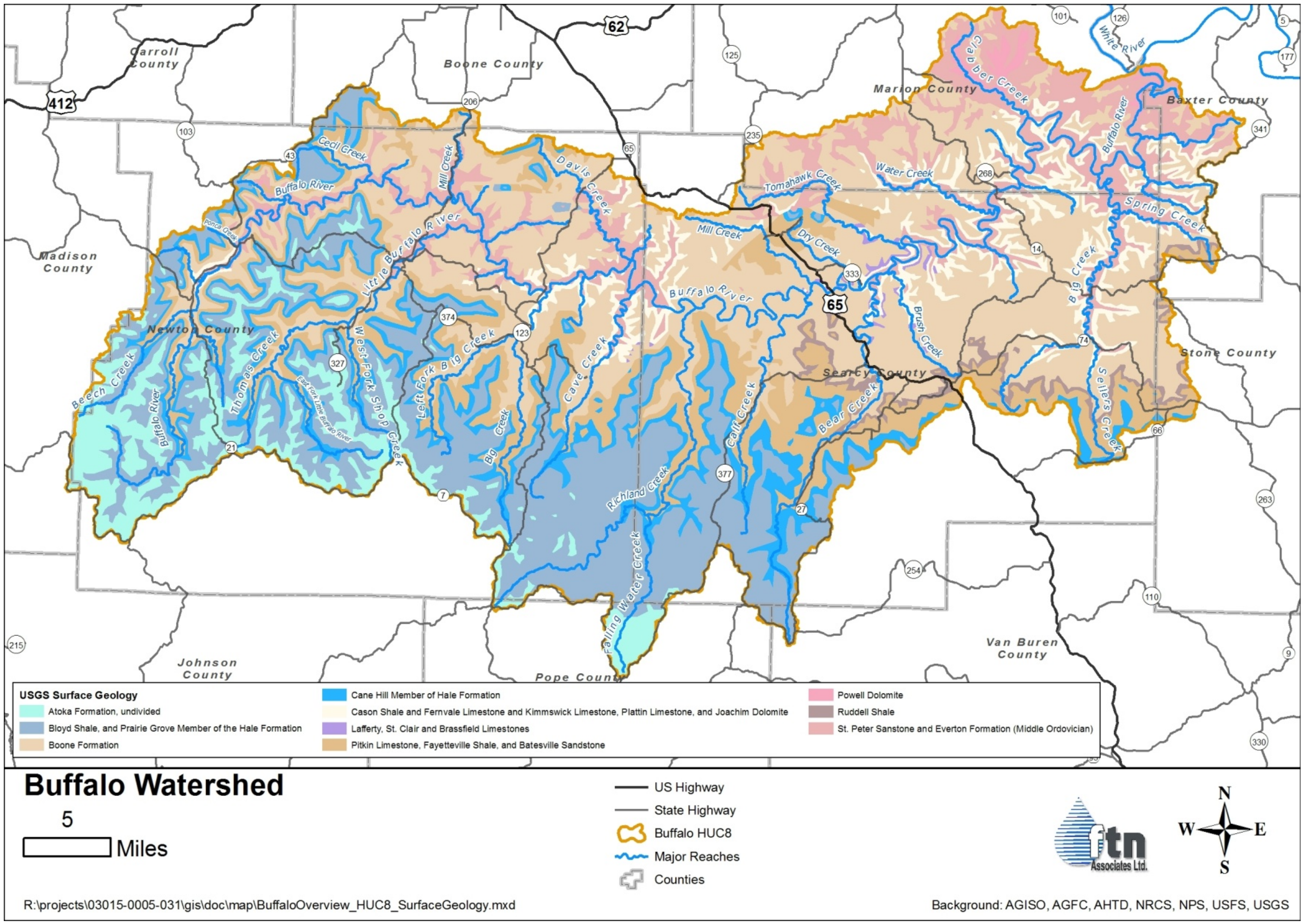

Figure 2.4. Surface geology map of the Buffalo River watershed.

Table 2.7. Stratigraphic column listing with descriptions of lithology for geologic formations underlying the Buffalo River watershed (Arkansas Geological Survey 2015b).

Era	Period	Geologic Unit	Lithology	Percent of watershed surface[a]	Thickness, feet
Paleozoic	Pennsylvanian	Atoka Formation	Sandstone, shale, limestone	6.1%	100-500
		Bloyd Formation	Limestone, Sandstone, shale	28.1%	175-200
		Hale Formation	Silty shale		100-180
	Mississippian	Pitkin Limestone	Limestone	13.4%	50-100
		Fayetteville Shale	Shale	Not exposed at surface	10-400
		Batesville Sandstone	Sandstone		0-200
		Moorefield Formation and Ruddell Shale	Shale and limestone	1.9%	0-300
		Boone Formation	Cherty limestone	31.8%	300-350
		St. Joe Limestone	Limestone	Not exposed at surface	0-100
	Silurian	Laferty Limestone	limestone	0.2%	5-20
		St. Clair Limestone	Limestone		0-100
		Brassfield Limestone	Limestone		0-38
	Ordovician	Cason Shale	Shale	5.9%	<23
		Fernvale Limestone	Limestone		0-100
		Kimmswick Limestone	Limestone		0-55
		Plattin Limestone	Limestone		0-160
		Joachim Dolomite	Dolostone		0-50
		St. Peter Sandstone	Sandstone	12.3%	0-175
		Everton Formation	Limestone, sandy dolostone		250-460
		Powell Dolomite	Shaly dolostone	0.7%	<200
		Cotter Dolomite	Cherty limestone	Not exposed at surface	250-500
		Roubidoux Formation	Sandstone and sandy dolomite		100 – 250
		Gasconade Formation	Dolomite, cherty and sandy dolomite, and sandstone.		350 – 360

[a] (Mott & Laurans 2004)

The Buffalo River watershed is located in the lead and zinc fields of northern Arkansas. The Buffalo River watershed had the largest zinc deposits in northern Arkansas (Pitcaithley 1989). Zinc and lead ores occurred in the Cotter, Powell, Smithville, and Everton formations of the Ordovician period, and the Boone Formation and Batesville Sandstone of the Mississippian period. The most productive zinc and lead ore deposits occurred in the Boone and Everton formations. Copper ore was also present in mineable quantities in at least one location in the Buffalo River watershed (McKnight 1935). The Arkansas Geological Survey indicates the presence of at least one historical coal mine in the watershed (Arkansas Geological Survey 2017).

2.5 Topography

Elevations within the Buffalo River watershed range from 384 feet above sea level where the Buffalo River joins the White River, to 2,562 feet above sea level in the Boston Mountains of the upper watershed (Center for Advanced Spatial Technologies 2006). The Buffalo River has cut deeply into the bedrock, resulting in tall vertical bluffs at river bends. From Ponca to Pruitt, the river gradient is an average of 13 feet per mile. Between Pruitt and Highway 65, the river gradient averages 5 foot per mile, and downstream of Highway 65, the average river gradient is 3 feet per mile (USNPS 1977).

Land slopes in the Buffalo River watershed range from less than 1% in valley bottoms and on upland flats, to 60% on hill sides. Slopes of 14% or more are considered steep, while areas with slopes of 7% or less are considered flat lands. GIS analysis indicates that approximately 40% of the watershed has slopes steeper than 14%. Table 2.8 lists the proportion of the Buffalo River watershed considered flat lands, steep, and in between. Figure 2.5 shows a map of the locations of areas within the three slope ranges.

Table 2.8. Slope areas in the Buffalo River watershed.

Slope ranges, degrees	Area within the watershed, Acres	Percent of watershed
<7%	220,509	25.7%
7-14%	289,259	33.8%
>14%	347,209	40.5%

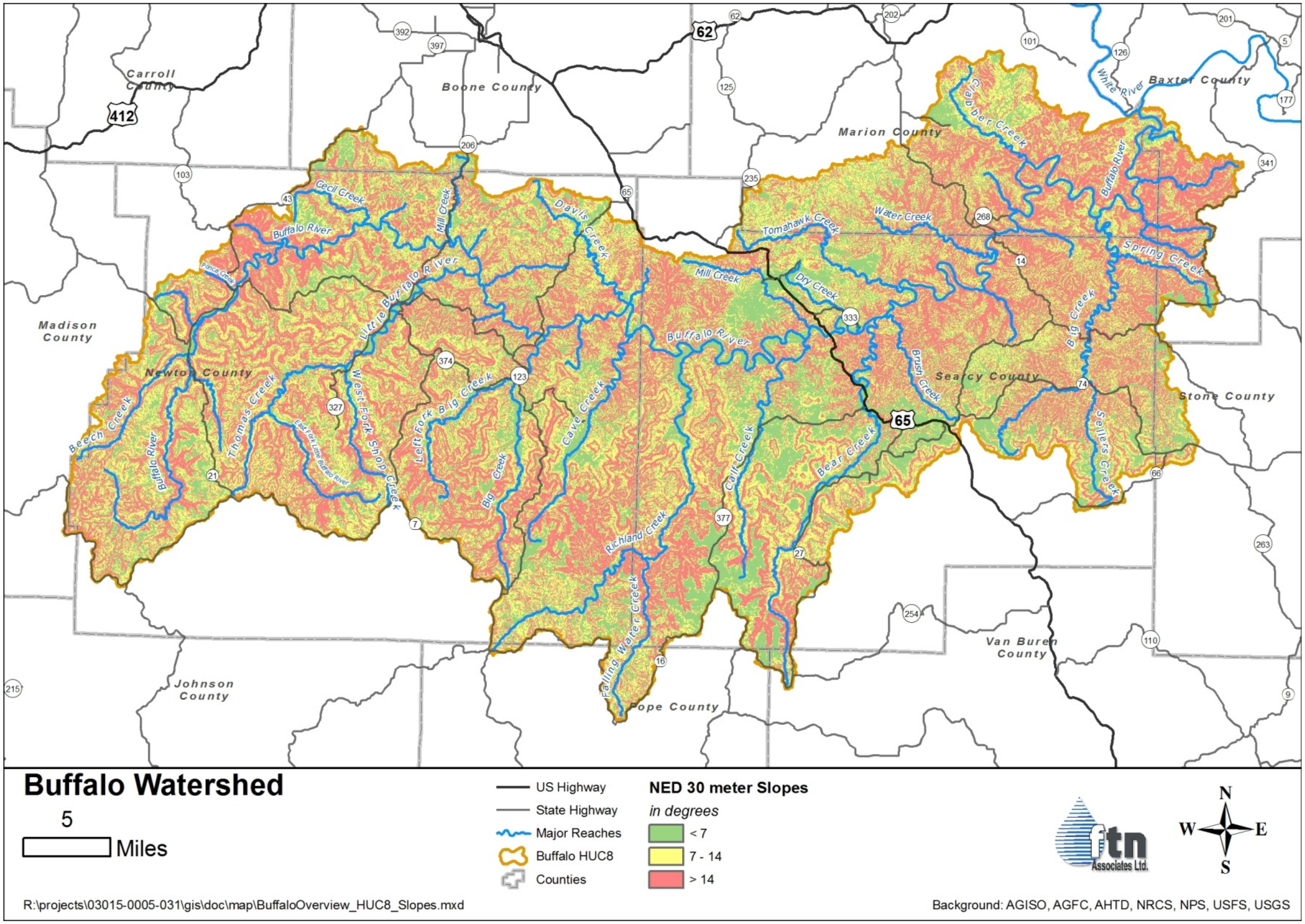

Figure 2.5. Map of slope ranges in the Buffalo River watershed.

Each of the three physiographic regions in the watershed is characterized by differences in topography (Figure 2.3). Nineteen percent of the watershed is in the Salem Plateau physiographic region, where the characteristic terrain is gently rolling hills with local relief ranging from 50 to 100 feet. Forty-seven percent of the watershed is in the Springfield Plateau physiographic region. In this area of the watershed, elevations range from 1,000 to 1,700 feet above sea level and local relief is less than 200 to 300 feet. Thirty-four percent of the watershed is in the Boston Mountains physiographic region. This area of the watershed is characterized by rugged terrain with local relief of up to 1,000 feet (Adamski, et al. 1995). Elevations in this region of the watershed range from 1,200 to 2,576 feet above sea level.

2.6 Soils

Two soil associations account for 76% of the watershed soils; Enders-Nella-Mountainburg-Steprock in the Boston Mountains, and Clarksville-Nixa-Noark in the Springfield Plateau (Figure 2.6). However, the soil characteristics in the watershed are complex and diverse. Sixty-four dominant soil taxonomic units are present in the Buffalo River watershed, that include a total of 167 soil mapping units (Scott and Smith 1994). Most soils in the watershed include significant amounts of coarse fragments, primarily of chert (Mott and Laurans 2004).

2.7 Land Use/Land Cover

The majority of the land in the Buffalo River watershed, 80%, is forested (Figure 2.7). Pasture and haylands is the next most common land use in the watershed. The majority of the pasture and haylands in the watershed are located in the portion of the watershed downstream of the Searcy County line. Approximately 60% of the pasture and haylands in the Buffalo River watershed is located on relatively flat land in river valleys and ridge tops (Figure 2.8). Approximately one-third of the Buffalo River watershed is public land, i.e., National Park, Wildlife Management Areas, or National Forest (Table 2.9). The majority of the public land in the watershed is forested; however, the National Park also includes pasture and haylands. There are also pasture and haylands on privately held lands within the boundaries of the Ozark National Forest (Figure 2.8).

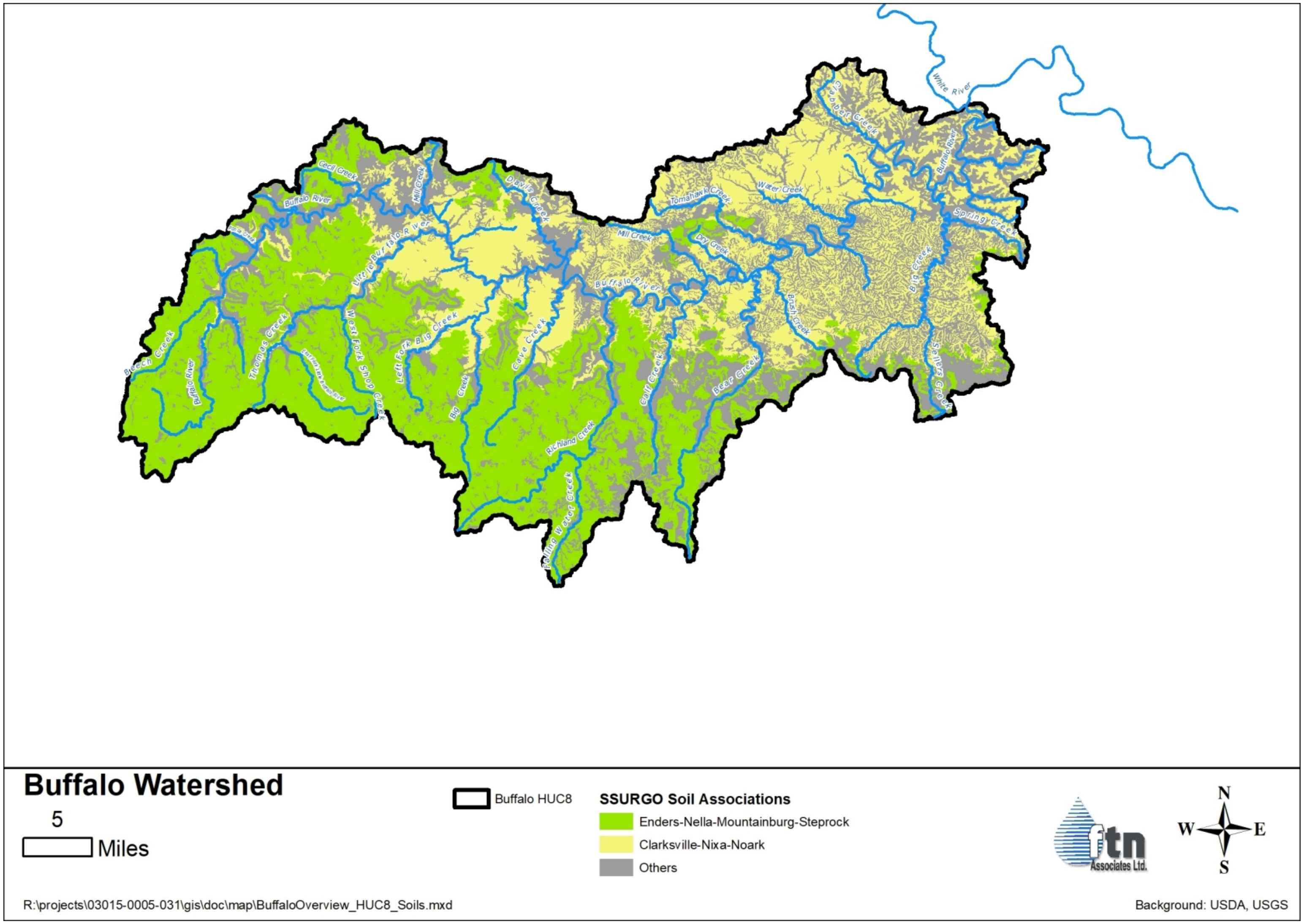

Figure 2.6. Over three-quarters of the soils in the Buffalo River watershed are in two soil associations.

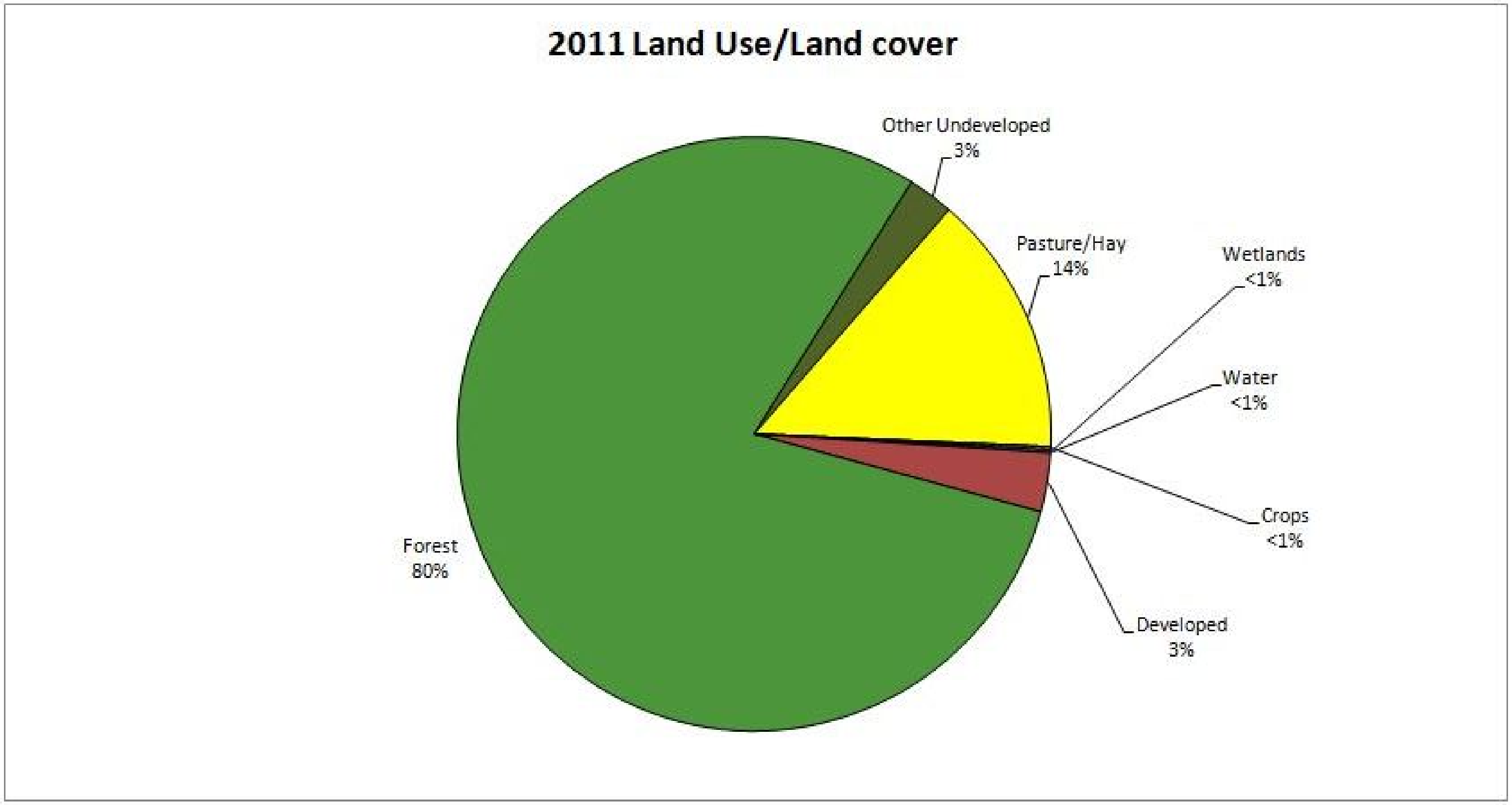

Figure 2.7. Land use/land cover percentages for the Buffalo River watershed (Homer, et al. 2015).

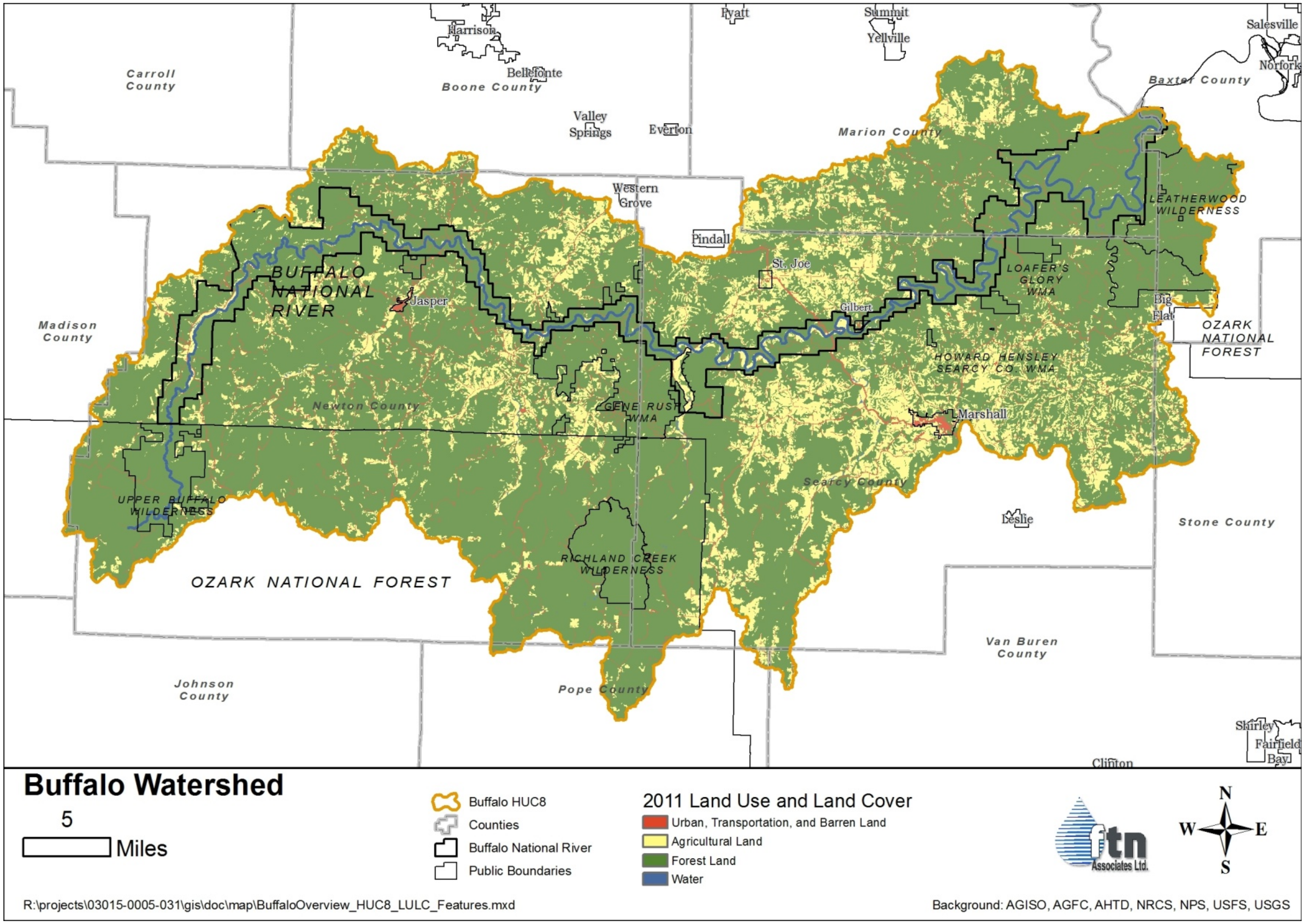

Figure 2.8. Land use map of the Buffalo River watershed (Homer, et al. 2015).

Table 2.9. Public lands in the Buffalo River watershed.

Land Holder	Percent of Watershed Held	Percent of Held Land Forested	Percent of Held Land in Pasture/Hay	Percent of Held Land in Other Undeveloped
National Park Service	11%	88%	5%	3%
National Forest Service	26%	92%	4%	1%
Arkansas Game and Fish Commission	3%	96%	<1%	1%

2.8 Water Resources

Surface water and groundwater resources of the Buffalo River watershed are described in this section.

2.8.1 Surface Water

There are over 2,000 miles of streams in the Buffalo River watershed (Center for Advanced Spatial Technologies 2006). There were nine active USGS flow gages in the Buffalo River watershed in 2016 (Figure 2.9). Table 2.10 lists summary statistics for flow measurements from these gages during the period January 2006 through December 2015. The farthest downstream USGS flow gage on the Buffalo River is at Harriet. Average annual flow at that gage over the period 2003-2015 (the period of record for which complete calendar years of approved data are available as of January 2016) ranges from 753.6 cubic feet per second (cfs) to 2,678 cfs (USGS 2017a). The largest tributary subbasin is the Little Buffalo River, which accounts for over 10% of the watershed. The downstream, or lower, Big Creek, and Richland Creek tributary subbasins each also account for approximately 10% of the Buffalo River watershed.

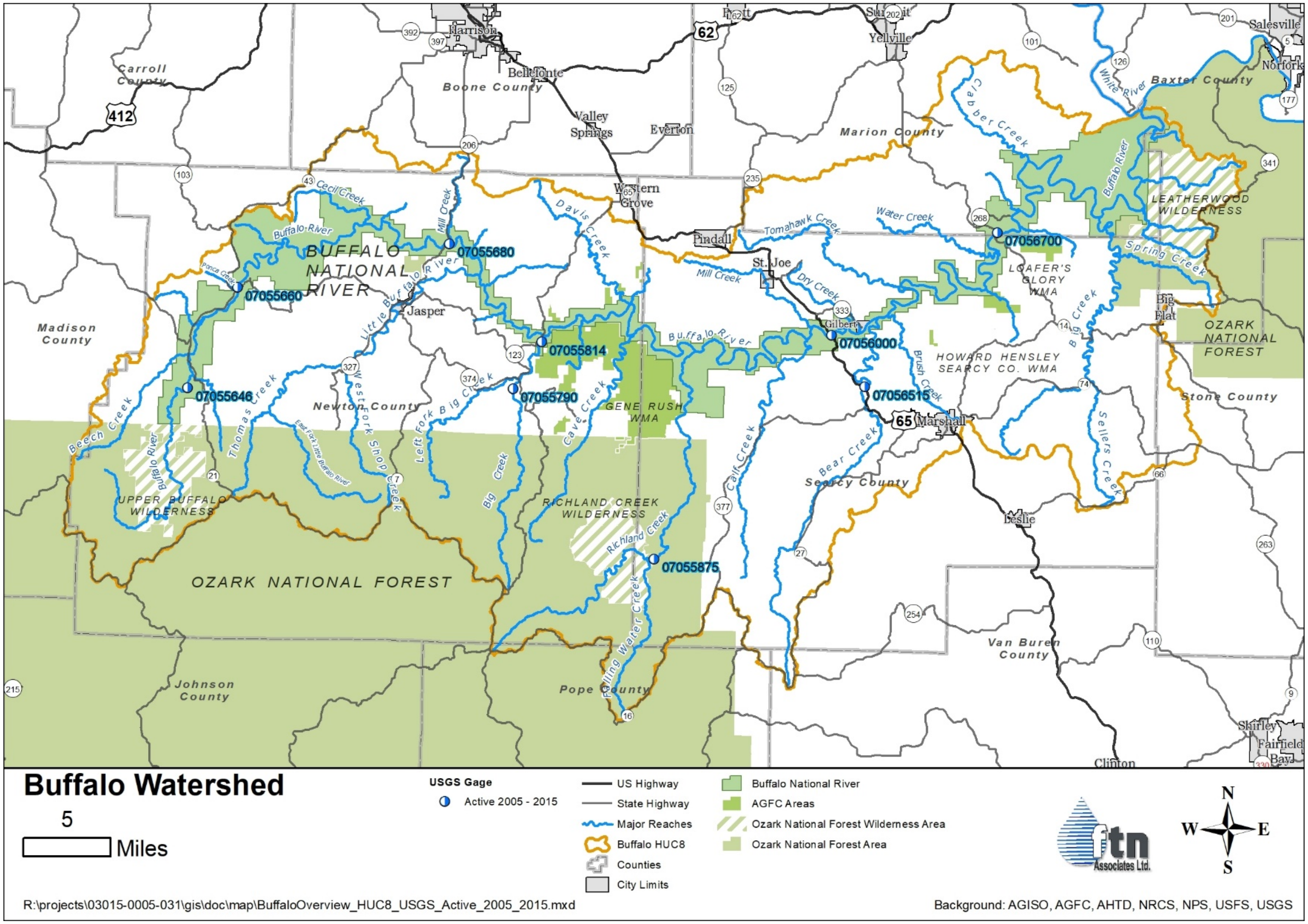

Figure 2.9. Active USGS flow gages in the Buffalo River watershed, 2016.

Table 2.10. Statistics for discharge data from USGS gages from 2006-2015 (USGS 2017a).

Site Number	Year Established	Site Name	Annual Average Discharge, cfs	Lowest Monthly Discharge, cfs	Highest Monthly Discharge, cfs	7Q10 Flow, cfs+	90% Exceeds Flow+	Peak Flow, cfs
07055646*	1993	Buffalo R near Boxley	108.1	0.116	1,166	0.0	0.879	27,700
07055660	2008	Buffalo R at Ponca	193.5	0.198	1,196	0.011	2.50	39,000
07055680	2008	Buffalo R at Pruitt	284.2	0.797	1,856	0.613	6.60	26,900
07055790	2014	Big Cr near Mt. Judea	Period of record too short	1.51	365.1	1.83	3.00	14,600
07055814	2015	Big Cr at Carver	Data prior to March 2016 not approved by USGS for statistics					
07055875*	1995	Richland Cr near Witts Spring	135.3	0.03	1,102	0.0	0.790	32,900
07056000*	1939	Buffalo R near St. Joe	1,217	16.4	9,115	7.43	43.0	134,000
07056515*	1999	Bear Cr near Silver Hill	124.6	0.887	1,037	0.479	5.50	33,700
07056700*	2002	Buffalo R near Harriet	1,512	44.7	12,010	28.3	66.0	161,000

*Daily flows available for entire period of 1/1/2006 – 12/31/2015
+These statistics are based on data from the entire period of record for each gage.

2.8.2 Groundwater

The Buffalo River watershed is underlain by two aquifers, the Springfield Plateau aquifer and the Ozark aquifer. The Western Interior Plains Confining System is a series of geologic formations present at the surface in the Boston Mountains that is also a locally important water supply source (Kresse, et al. 2014). Table 2.11 shows the geologic formations associated with each of these aquifers, and their relative position with regard to depth. Figure 2.10 shows where these aquifers are unconfined. The Ozark aquifer is present under the entire watershed, beneath the Springfield Plateau aquifer. The Springfield Plateau aquifer is present beneath the Western Interior Plains confining system as well as where it is unconfined (Westerman, et al. 2016).

Table 2.11. Stratigraphic geology listing with aquifers underlying the Buffalo River watershed.

Era	**Period**	**Geologic Unit**	**Lithology**	**Regional Aquifer** (Kresse, et al. 2014)
Paleozoic	Pennsylvanian	Atoka Formation	Sandstone, shale, limestone	Western Interior Plains confining system
		Bloyd Formation	Limestone, sandstone, shale	
		Hale Formation	Silty shale	
	Mississippian	Pitkin Limestone	Limestone	
		Fayetteville Shale	Shale	
		Batesville Sandstone	Sandstone	
		Moorefield Formation and Ruddell Shale	Shale and limestone	
		Boone Formation	Cherty limestone	Springfield Plateau aquifer
		St. Joe Limestone	Limestone	
	Silurian	Laferty Limestone	limestone	Ozark aquifer
		St. Clair Limestone	Limestone	
		Brassfield Limestone	Limestone	
	Ordovician	Cason Shale	Shale	
		Fernvale Limestone	Limestone	
		Kimmswick Limestone	Limestone	
		Plattin Limestone	Limestone	
		Joachim Dolomite	Dolostone	
		St. Peter Sandstone	Sandstone	
		Everton Formation	Limestone, sandy dolostone	
		Powell Dolomite	Shaly dolostone	
		Cotter Dolomite	Cherty limestone	
		Roubidoux Formation	Sandstone and sandy dolomite	
		Gasconade Formation	Dolomite, cherty and sandy dolomite, and sandstone.	

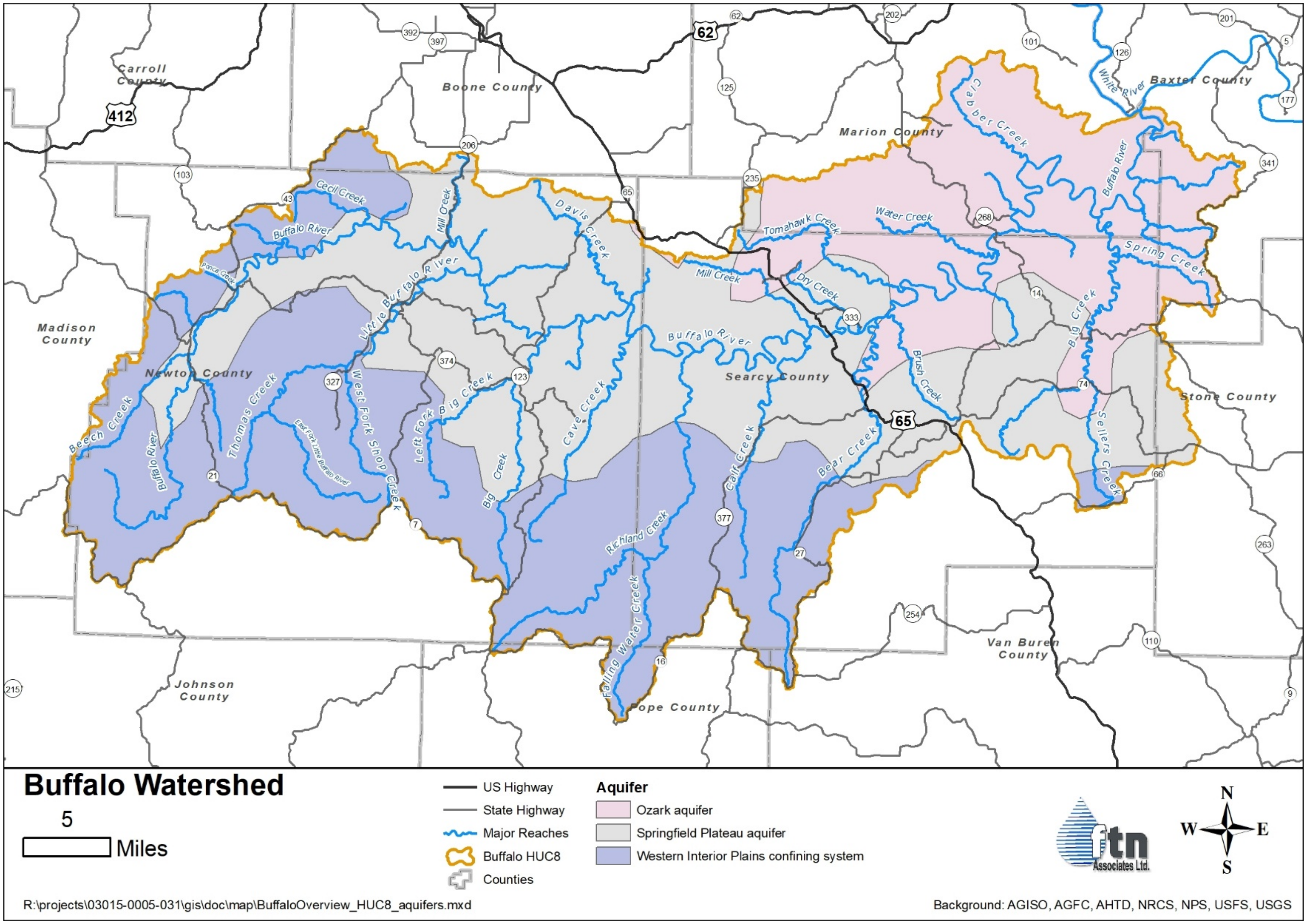

Figure 2.10. Outcrop areas of aquifers within the Buffalo River watershed.

The Ozark aquifer is the largest aquifer and most important source of fresh groundwater in the Ozark region of northern Arkansas and southern Missouri. This aquifer is a thick sequence of water-bearing rock ranging in age from the Late Cambrian to Middle Devonian. In the Buffalo River watershed, the Everton Formation is the primary water bearing formation of the Ozark aquifer that is present. In most of the Buffalo River watershed, this aquifer is confined and receives only indirect recharge. In the far eastern Buffalo River watershed, the Ozark aquifer is unconfined, occurring at or near the surface (Figure 2.10). The Everton Formation is present at the surface in approximately 12% of the watershed (Mott and Laurans 2004). The largest spring within the Buffalo National River boundary, discharges from the Ozark aquifer (Kuniansky 2011).

The Springfield Plateau aquifer is associated with the Mississippian Boone Formation, which underlies most of the Buffalo River watershed. The Springfield Plateau aquifer is unconfined over large areas of the Buffalo River watershed (Figure 2.10), with the Boone Formation present at the surface in approximately 1/3 watershed (Mott and Laurans 2004). An inventory of springs in the Mill Creek subwatershed found the majority of the springs discharge from the Springfield Plateau aquifer (Kuniansky 2011).

The Western Interior Plains Confining System is composed of low to moderately permeable formations of Mississippian and Pennsylvanian age. This system is unconfined and present in approximately half of the watershed (Mott and Laurans 2004, Kresse, et al. 2014). Water yields from this system are adequate only for household use (Kresse, et al. 2014).

Recharge areas for several springs in the Buffalo River watershed extend beyond the boundaries of surface watersheds (Soto 2014). For example, the recharge area for the Dogpatch Springs and Mitch Hill Spring in the Buffalo River watershed have been found to include areas outside of the watershed, in the watershed of Crooked Creek (Mott, Hudson, & Aley 2000, Soto 2014). Recharge areas for other springs that have been investigated are entirely within the Buffalo River watershed, but include areas in more than one subwatershed of the Buffalo River (Soto 2014).

2.8.3 Surface Water – Groundwater Connections

The karst geology present in the Buffalo River watershed makes exchanges between surface water and groundwater common in the watershed. There are hundreds of springs in the Buffalo River watershed, through which groundwater is discharged to surface waters (USNPS 2015a). The USGS has identified seven sections of the Buffalo River that appear to receive significant inputs of flow from groundwater (Moix and Galloway 2005). Dye tracer studies have shown that there are areas in the watershed where infiltration of rainfall from the surface to groundwater occurs rapidly through sinkholes, faults, and existing solution channels (Kuniansky 2011). The USGS has identified five sections of the Buffalo River where much or all of the river flow goes to groundwater (Moix and Galloway 2005).

2.9 Wildlife Resources

Within the boundaries of the Buffalo National River, 15 species of mammals, 209 species of birds, 60 species of reptiles and amphibians, 76 species of fish, and 514 vascular plant species have been confirmed present by the USNPS (USNPS 2016a). Fish surveys conducted by USGS during 2001-2003 identified 56 to 66 fish species in the Buffalo River and its tributaries (Petersen 2004, Petersen and Justus 2005). Mussel surveys of just the Buffalo River have identified 21 to 27 species present in the river (Harris 1996, Matthews et al 2009). In 1981 elk, originally native to the area, were reintroduced to the watershed by the Arkansas Game and Fish Commission (USNPS 2015b).

Several of the species present in the Buffalo River watershed are found only within the Ozark Highlands ecoregion (Petersen and Justus 2005, Matthews et al. 2009). No species have been identified that occur only in the Buffalo River watershed. There are a number of native species present in the watershed that are listed as threatened or endangered by the state or federal government. There are also a number of native species present that the state has identified as species of greatest conservation need. In addition, there are plants and animals present in the watershed that are not native and that are believed to pose a threat to native species.

2.9.1 Protected Species

There are 11 species that have been found in the Buffalo River watershed that are listed as threatened or endangered by the state and federal government (Table 2.12). Four of these species are bats, two are mussels, and five are plants.

Table 2.12. Protected species found in the Buffalo River watershed (Arkansas Natural Heritage Commission 2015; NatureServe 2015; Williams 2009; Williams, Usrey, Hodges, Harris, & Christian 2009).

Common name	Scientific name	Category	State Status	Federal status
Snuffbox	*Epioblasma triquetra*	Invertebrate	Endangered	Endangered
Rabbitsfoot	*Quadrula cylindrica cylindrica*	Invertebrate	Endangered	Threatened
Alabama Snow-wreath	*Neviusia alabamensis*	Plant	Threatened	None
Dwarf Bristle Fern	*Trichomanes petersii*	Plant	Threatened	None
French's Shooting Star	*Primula frenchii*	Plant	Threatened	None
Ovate-leaf Catchfly	*Silene ovate*	Plant	Threatened	None
Royal Catchfly	*Silene regia*	Plant	Threatened	None
Gray Bat	*Myotis grisescens*	Vertebrate	Endangered	Endangered
Indiana Bat	*Myotis sodalist*	Vertebrate	Endangered	Endangered
Ozark Big-eared Bat	*Corynorhinus townsendii ingens*	Vertebrate	Endangered	Endangered
Northern Long-eared Bat	*Myotis septentrionalis*	Vertebrate	Endangered	Threatened

2.9.2 Species of Greatest Conservation Need

There are 377 species of native amphibians, birds, crayfish, fish, insects, invertebrates, mammals, mussels, and reptiles present in Arkansas that are identified as Species of Greatest Conservation Need in the Arkansas Wildlife Action Plan (Fowler 2015). Forty-two of these Species of Greatest Conservation Need have been documented by the USNPS within the boundaries of the Buffalo National River; 11 mammals, 21 birds, two reptiles, three amphibians, and five fish species (USNPS 2016b). The Arkansas Natural Heritage Commission has identified 144 species of conservation interest in Newton and Searcy Counties, which account for the majority of the Buffalo River watershed; 53 invertebrate species, 23 species of vertebrates (fish, birds, and mammals), and 68 plant species (Arkansas Natural Heritage Commission 2015). The

Nature Conservancy has identified 10 cave and karst animal Species of Greatest Conservation Need, in addition to bats, in the Buffalo River watershed. Six of these are aquatic species, and four are terrestrial (Inlander, Gallipeau, & Slay 2011).

2.9.3 Nuisance Species

There are a number of non-native species of plants and animals present in the Buffalo River watershed that have been classified as posing a threat to native communities and ecosystems present in the watershed. At least 21 non-native invasive plant species are known to be present at the Buffalo National River. Recent control efforts within the Buffalo National River have focused on Tree of Heaven (*Ailanthus altissima)*, Chinese Privet *(Ligustrum sinense)* and European Privet *(Ligustrum vulgare)*, and Mimosa *(Albizia julibrissin)* (USNPS 2015c). A list of non-native nuisance aquatic species that have been identified within the Buffalo River watershed is included as Table 2.13.

Table 2.13. Non-native nuisance aquatic species present in the Buffalo River watershed (USGS 2017b, University of Georgia Center for Invasive Species and Ecosystem Health 2017).

Common name	Scientific name	Category	Source*
Freshwater jellyfish	Craspedacusta sowerbyi	Invertebrate	Exotic
Redbreast sunfish	Lepomis auritus	Fish	Native transplant
Common carp	Cyprinus carpio	Fish	Exotic
Yellow perch	Perca flavescens	Fish	Native transplant
Asian clam	Corbicula fluminea	Mollusk	Exotic
Brittle waternymph	Najas minor	Aquatic plant	Exotic
Watercress	Nasturtium officinale	Aquatic plant	Exotic
Water purslane	Ludwigia palustris	Aquatic plant	Exotic

* Exotic indicates the species is from outside of the US; Native transplant indicates the species is native to the US, but is not native to this watershed.

Feral hogs are a nuisance species throughout Arkansas, including the Buffalo River watershed. They compete directly with many native animals for food. The rooting and wallowing of feral hogs damages pasture; destroys sensitive natural areas and habitats, including glades, marshes, and springs; and can cause erosion that affects water quality (USNPS 2015d).

2.9.4 Sensitive Areas

The Arkansas Natural Heritage Commission has identified several habitats present in Newton and Searcy Counties as being of conservation concern. These habitats include sinkhole ponds, Ozark Mountain headwater streams, Ozark Mountain upland streams, Ozark Mountain upland rivers, mesic hardwood forest, dry-mesic oak forest, colonial nesting sites for water birds, and caves (Arkansas Natural Heritage Commission 2015). The USNPS reports that the oak-pine forest present within the Buffalo National River boundaries is globally ranked as imperiled to vulnerable (USNPS 2015e).

Caves and other karst features in the Buffalo River watershed are important habitats for all of the protected bat species. The largest colony of Indiana bats known in the state hibernates in Sherfield Cave in the watershed (The Nature Conservancy 2017a).

In 2016, Audubon Arkansas designated the Buffalo National River as an Important Bird Area. The National Park provides important habitat for a number of bird species of conservation concern, including the Bald Eagle, Northern Bobwhite, Cerulean Warbler, Swainson’s Warbler, and Louisiana Waterthrush (Audubon Arkansas 2016)

In 2015, the US Fish and Wildlife Service designated two segments of the Buffalo River as critical habitat for the endangered Rabbitsfoot mussel. The designated critical habitat areas on the Buffalo River are from the confluence of Cecil Creek to Highway 65, and from Highway 14 to the confluence with the White River (Federal Register, Vol 80 No. 83, Thursday April 30, 2015, 50 CFR part 17, p24692-24774).

3.0 WATER QUALITY

HIGHLIGHTS

- Stakeholders are concerned about nutrients, bacteria (i.e., *E. coli*), sediment, trash, pesticides, and water temperatures in the Buffalo River and its tributaries.
- There is one stream in the watershed classified as impaired by ADEQ, Bear Creek. Discharge from a municipal wastewater treatment plant is causing total dissolved solids (TDS) in Bear Creek to exceed state water quality standards.
- Monitored springs do not meet drinking water criteria due to the presence of *E. coli*.
- The surface water quality monitoring network in the Buffalo River watershed is one of the most extensive in the state, including over 30 routine monitoring stations.
- While water quality in the Buffalo River watershed is generally considered some of the best in the state, measurements of DO, *E. coli*, and turbidity at some surface water and spring quality monitoring stations occasionally exceed water quality standards.
- Routine measurements of inorganic nitrogen, fecal coliforms, and/or turbidity from several surface water and spring monitoring stations exhibit increasing trends over time.

Water quality is the primary focus of this watershed-based plan. This plan section describes surface water and groundwater quality in the Buffalo River watershed. Included in this section are state water quality standards that apply to surface waters and groundwater in the watershed, surface waters that have been classified as having impaired water quality by ADEQ, descriptions of active surface water and groundwater quality monitoring programs and studies in the Buffalo River watershed, and available water quality data from the period 2012-2016. In addition, surface water and groundwater quality data are evaluated for trends, and tributary loads for selected pollutants are estimated. Finally, water quality data gaps are discussed.

3.1 Stakeholder Identified Water Quality Issues

At the first public meeting held for development of this watershed-based management plan, stakeholders were asked what they see as issues in the Buffalo River watershed. The issues put forth by the stakeholders included a range of subjects, not just water quality concerns. A summary of the water quality issues identified by stakeholder is given in Table 3.1. A summary of this meeting, with a list of all the issues identified by stakeholders, is included in Appendix B.

Table 3.1. Water quality-related issues in the Buffalo River watershed identified by stakeholders.

Pollutants	Polluted resources	Pollutant impacts	Pollutant sources	Uses threatened
Nutrients Bacteria *E. coli* Sediment Trash Fertilizer Pesticides Human waste Animal waste Temperature	Streams Springs Groundwater	Health Ecological Aesthetic Safety Habitat	Concentrated Animal Feeding Operations (CAFOs) Feral hogs Recreationists Cattle in streams ATVers Restrooms/porta-potties in floodplain Failing/abandoned septic systems Wastewater treatment systems Utility & road easement management Fertilizer Manure Gravel roads Timber management and harvest Fracking Erosion In-stream gravel mining Streambank erosion	Recreation Aesthetics Fishing/fish community Drinking water

3.2 Surface Water Quality

This section includes discussion of surface water quality standards, impaired surface waters in the watershed, surface water quality monitoring programs and studies in the watershed, a review of available recent water quality data, and evaluation of water quality trends and pollutant loads.

3.2.1 Surface Water Quality Standards for Buffalo River Watershed

Arkansas state water quality standards consist of Designated Uses for waterbodies, numeric standards for selected water pollutants or water quality indicators, narrative criteria for pollutants or indicators without numeric standards, and an antidegradation statement. State water quality standards that apply to surface waters in the Buffalo River watershed are described below.

3.2.1.1 Designated Uses

All of the Buffalo River, Richland Creek, and Falling Water Creek are designated as “Extraordinary Resource Waters”. The Buffalo River and Richland Creek upstream of Falling Water Creek are also designated as “Natural and Scenic Waterway” (Arkansas Pollution Control and Ecology Commission 2014).

Designated uses of all the streams in the watershed are primary contact recreation (watersheds >10 sq. mi); secondary contact recreation; Domestic, Industrial and Agricultural Water Supply; Perennial Ozark Highlands and Boston Mountain Fisheries (watersheds >10 sq. mi); and Seasonal Ozark Highlands and Boston Mountain Fisheries (watersheds <10 sq. mi.). There are no designated use variations granted in the watershed (Arkansas Pollution Control and Ecology Commission 2014).

3.2.1.2 Numeric and Narrative Criteria

Numeric water quality criteria for selected parameters that apply in the Buffalo River watershed are listed in Table 3.2. Numeric water quality criteria for toxic substances and metals can be found in Regulation 2 of the Arkansas Pollution Control and Ecology Commission (Arkansas Pollution Control and Ecology Commission 2014). In addition to numeric water quality criteria, state narrative criteria have been developed for the following: nuisance species; color; taste and odor; solids, floating material, and deposits; toxic substances; oil and grease; temperature; turbidity; and nutrients. Site specific numeric water quality criteria for nutrients have not yet been developed for the Buffalo River watershed (Arkansas Pollution Control and Ecology Commission 2014).

Table 3.2. Numeric water quality criteria for the Buffalo River watershed (Arkansas Pollution Control and Ecology Commission 2014).

Parameter	Season	Location	Conditions	Criteria
Temperature	All	Ozark Highlands[a]	All	29 deg C
		Boston Mountains[b]	All	31 deg C
Turbidity	Baseflow[c]	Watershed	All	10 NTU
	All flows[d]	Ozark Highlands	All	17 NTU
		Boston Mountains	All	19 NTU
pH	All	Watershed	All	6 – 9 su
Dissolved oxygen	Primary season[e]	Watershed	All	6 mg/L
	Critical season[f]	Watershed	Watershed < 10 sq mi	2 mg/L
		Ozark Highlands	Watershed 10-100 sq mi	5 mg/L
		Ozark Highlands	Watershed > 100 sq mi	6 mg/L
		Boston Mountains	Watershed > 10 sq mi	6 mg/L
E. coli	Primary contact[g]	Extraordinary resource waters, natural and scenic waterways, reservoirs	Individual sample	298 colonies/100 mL
			Geometric mean	126 colonies/100 mL
		Other waters	Individual sample	410 colonies/100 mL
	Secondary contact[h]	Extraordinary resource waters, natural and scenic waterways, reservoirs	Individual sample	1,490 colonies/100 mL
			Geometric mean	630 colonies/100 mL
		Other waters	Individual sample	2,050 colonies/100 mL
Fecal coliform	Primary contact[g]	Watershed	Individual sample	400 colonies/100 mL
			Geometric mean	200 colonies/100 mL
	Secondary contact[h]	Watershed	Individual sample	2,000 colonies/100 mL
			Geometric mean	1,000 colonies/100 mL
TDS	All	Buffalo River	All	200 mg/L
	All	Other streams in Ozark Mountains	Ecoregion reference	240 mg/L
	All	Other streams in Boston Mountains	Ecoregion reference	85 mg/L
	All	Other streams	Drinking water	500 mg/L

[a] Buffalo River and its tributaries downstream of Bear Creek
[b] Buffalo River and its tributaries upstream of, and including, Bear Creek
[c] Baseflow = June- October
[d] All flows = entire year
[e] Primary season = when water temperature is 22 deg C or less, usually September – May
[f] Critical season = when water temperature is > 22 deg C, usually May – September
[g] Primary contact = May 1 to September 30
[h] Secondary contact = October 1 to April 30

Turbidity criteria that apply in the Buffalo River watershed are listed in Table 3.2. Separate turbidity criteria are specified for baseflow conditions. The baseflow criteria should not be exceeded in more that 20% of samples collected June to October. The “all flow” criteria should not be exceeded in more than 25% of all samples collected over an entire year (Arkansas Pollution Control and Ecology Commission 2014).

Bacteria (i.e., *E. coli* and fecal coliform) water quality criteria that apply in the Buffalo River watershed are summarized in Table 3.2. These criteria are considered to be met if less than 25% of no less than 8 samples collected during the season (primary contact season or secondary contact season) are below the criteria.

3.2.1.3 Antidegradation Policy

The antidegradation policy of the Arkansas water quality standards are summarized below:

- Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
- Water quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important economic or social development, although water quality must still be adequate to fully protect existing uses.
- For outstanding state or national resource waters, those uses and water quality for which the outstanding waterbody was designated shall be protected.
- For potential water quality impairments associated with a thermal discharge, the antidegradation policy and implementing method shall be consistent with Section 316 of the Clean Water Act.

3.2.2 Assessed Surface Water Quality Impairment in Buffalo River Watershed

The most recent EPA-approved state impaired waters list (i.e., 303(d) list) for Arkansas is from 2016. Only one waterbody in the Buffalo River watershed is included on the final 2016 impaired waters list; Bear Creek (stream segment 026). This stream segment is shown on Figure 3.1. This 23.9-mile-long stream segment is listed as not supporting its designated uses of

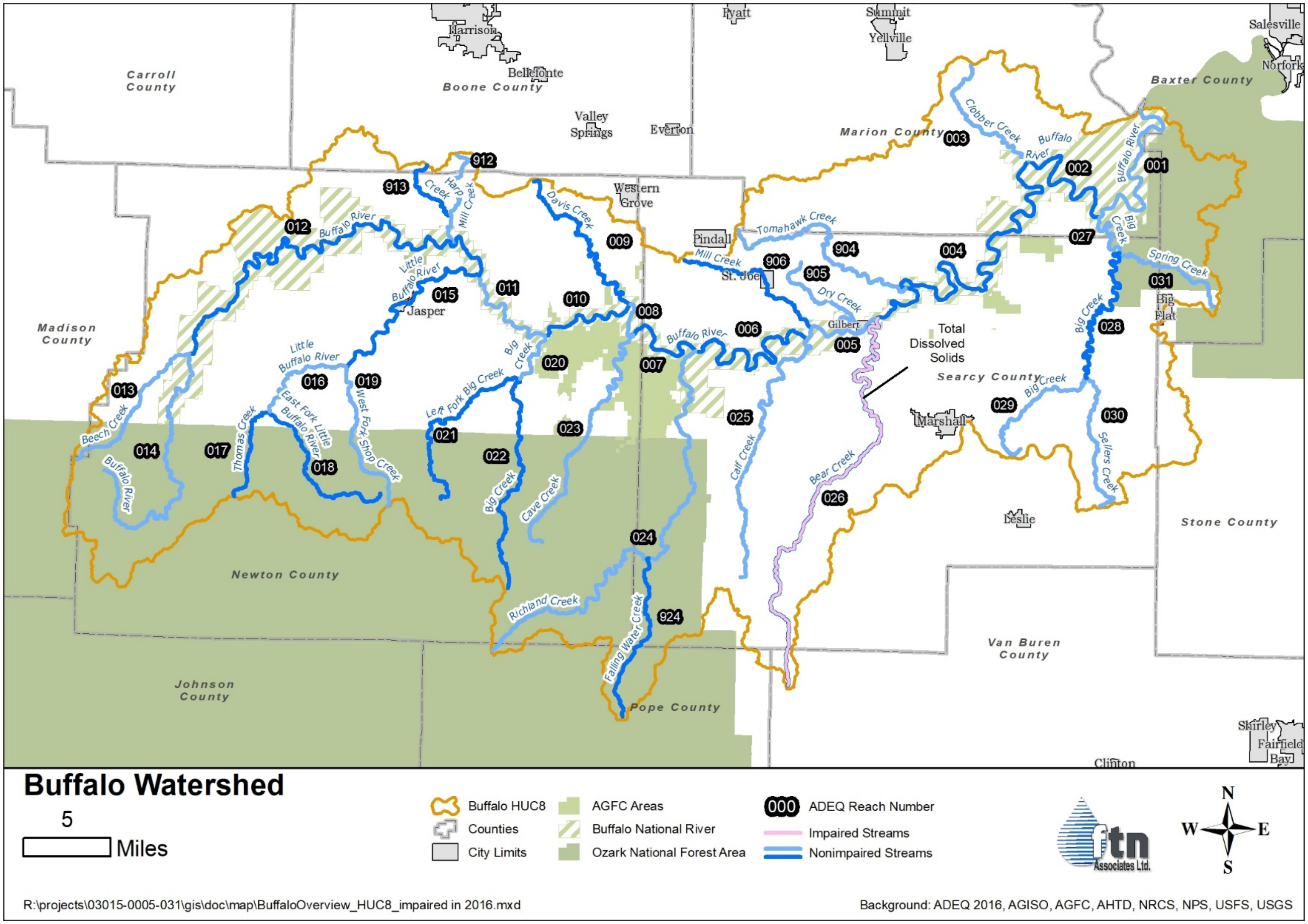

Figure 3.1. Impaired waters of the Buffalo River watershed from the 2016 303(d) list.

Fisheries Support, Domestic Water Supply, and Agricultural and Industrial Water Supply due to high total dissolved solids (TDS) levels. The source of the TDS causing this impairment is a municipal point source (ADEQ 2016). Several stream segments in the Buffalo River watershed previously listed as impaired have been removed from the impaired waters list because data collected recently show that those stream segments are meeting all numeric water quality standards. Big Creek in Newton County (i.e., Big Creek [middle]) was identified in the 2016 state biennial assessment of water quality as having insufficient available data to complete a nutrient assessment (ADEQ 2016).

3.2.3 Surface Water Quality Monitoring in the Buffalo River Watershed

The Buffalo River watershed has one of the most extensive routine surface water quality monitoring networks in the state. Water quality data are collected from the Buffalo River and a number of its tributaries through active monitoring programs of the ADEQ, USNPS, and USGS. During the period from 2012 through 2016, ADEQ collected water quality data at eight locations in the watershed, the USNPS collected data at 36 locations, and the USGS collected data at six locations. Information about these sampling locations is summarized in Table 3.3. Figure 3.2 maps these locations in the Buffalo River watershed. An inventory of historical surface water quality sampling locations is included in Appendix C. Table 3.4 summarizes the water quality parameters monitored as part of the various monitoring programs and studies on-going in the Buffalo River watershed.

3.2.3.1 ADEQ Water Quality Monitoring

ADEQ monitors surface water quality in the Buffalo River watershed through several programs. There is one ADEQ ambient water quality monitoring network site in the watershed that is sampled monthly (WHI0049A). This site is located on the Buffalo River. There is also one active roving water quality monitoring network site in the watershed, located on Bear Creek (UWBRK01). Roving sites throughout the state are divided into four regional groups. Each group of roving sites is sampled for chemical and bacterial analysis on a rotating basis, bimonthly over a 2-year period, every 6 years. Historically, there were two more roving sites in the watershed (see Appendix C).

Table 3.3. Surface water quality monitoring stations in the Buffalo River watershed that were active during the period 2012 - 2016.

Entity	Program[a]	Station Id	Stream	Location	Start Year	End Year[c]	Number of dates[c]
USGS	Routine	07055646[b]	Buffalo R	Near Boxley	1993	2016	131
USGS	Study	07055790	Big Cr (middle)	Mt Judea	2014	2015	21
USGS	Study	07055794	Big Cr (middle)	Vendor	2014	2014	1
USGS	Study	07055807	L Fork Big Cr	Vendor	2014	2014	1
USGS	Study	07055814	Big Cr	Carver	2014	2016	44
USGS	Routine	07056515[b]	Bear Cr	Silver Hill	1999	2016	123
ADEQ, USNPS	Routine	BUFR01[b]	Buffalo R	Wilderness Area boundary	1985	2016	191
ADEQ, USNPS	Routine	BUFR02[b]	Buffalo R	Ponca access	1985	2016	197
ADEQ, USNPS	Project	BUFR03[b]	Buffalo R	Pruitt access	1985	2016	267
ADEQ, USNPS	Project	BUFR0304	Buffalo R	Crow Hole	2010	2016	88
ADEQ, USNPS	Routine	BUFR04[b]	Buffalo R	Hasty Bridge	1985	2016	190
ADEQ, USNPS	Routine	BUFR05[b]	Buffalo R	Wollum access upstream of Richland Cr	1985	2016	174
ADEQ, USNPS	Routine	BUFR06[b]	Buffalo R	Gilbert access	1985	2016	179
ADEQ, USNPS	Routine	BUFR07[b]	Buffalo R	Hwy 14	1985	2016	179
ADEQ, USNPS	Routine	BUFR08[b]	Buffalo R	Rush access above Rush Cr	1985	2016	174
ADEQ, USNPS	Routine	BUFR09[b]	Buffalo R	Mouth	1985	2016	148
USNPS	Project	BUFR414	Buffalo R	Carver access	2007	2015	162
USNPS	Project	BUFR415	Buffalo R	Below Big Cr (middle)	2013	2015	151
ADEQ, USNPS	Routine	BUFT01[b]	Beech Cr	Hwy 21	1985	2016	90
ADEQ, USNPS	Routine	BUFT02[b]	Ponca Cr	Hwy 74	1985	2016	150
ADEQ, USNPS	Routine	BUFT03[b]	Cecil Cr	Mouth	1985	2016	160
ADEQ, USNPS	Routine	BUFT04[b]	Mill Cr (upper)	Mouth	1985	2016	279
ADEQ, USNPS	Project	BUFT0401	Mill Cr (upper)	Below old campground	2009	2016	63
ADEQ, USNPS	Project	BUFT0402	Mill Cr (upper)	Spring Valley Rd	2009	2016	64

Table 3.3. Surface water quality monitoring stations in the Buffalo River watershed that were active during the period 2012 – 2016 (continued).

Entity	Program[a]	Station Id	Stream	Location	Start Year	End Year[c]	Number of dates[c]
ADEQ, USNPS	Project	BUFT0405	Harp Cr	Hwy 7 crossing	2009	2016	53
ADEQ, USNPS	Project	BUFT0406	Flatrock Cr	Mouth	2009	2016	18
ADEQ, USNPS	Routine	BUFT05[b]	Little Buffalo R	Mouth	1985	2016	197
ADEQ, USNPS	Routine	BUFT06[b]	Big Cr (middle)	Carver	1985	2016	324
ADEQ, USNPS	Routine	BUFT07[b]	Davis Cr	Mouth	1985	2016	162
ADEQ, USNPS	Routine	BUFT08[b]	Cave Cr	Gene Rush WMU	1985	2016	158
ADEQ, USNPS	Routine	BUFT09[b]	Richland Cr	Mouth	1985	2016	149
ADEQ, USNPS	Routine	BUFT10[b]	Calf Cr	Mouth	1985	2016	155
ADEQ, USNPS	Routine	BUFT11[b]	Mill Cr (lower)	Tyler Bend campground	1985	2016	154
ADEQ, USNPS	Routine	BUFT12[b]	Bear Cr	Mouth	1985	2016	157
ADEQ, USNPS	Routine	BUFT13[b]	Brush Cr	Mouth	1985	2016	120
ADEQ, USNPS	Routine	BUFT14[b]	Tomahawk Cr	County Rd 82	1985	2016	159
ADEQ, USNPS	Routine	BUFT15[b]	Water Cr	1.5 miles upstream of Buffalo R	1985	2016	152
ADEQ, USNPS	Routine	BUFT16[b]	Rush Cr	Mouth	1985	2016	157
ADEQ, USNPS	Routine	BUFT17[b]	Clabber Cr	Mouth	1985	2016	158
ADEQ, USNPS	Routine	BUFT18[b]	Big Cr (lower)	Mouth	1985	2016	134
ADEQ, USNPS	Routine	BUFT23[b]	Middle Cr	Mouth	1985	2016	128
ADEQ, USNPS	Routine	BUFT24[b]	Leatherwood Cr	Mouth	1985	2016	131
ADEQ	Study	BUFT903	Falling Water Cr	Below falls	2001	2016	23
ADEQ	Roving	UWBRK01[b]	Bear Cr	Hwy 65	1994	2016	37
ADEQ	Ambient	WHI0049A[b]	Buffalo R	Hwy 65	1990	2016	344
ADEQ	Study	WHI0155	Cave Cr	on CR67 S of Bass	1999	2016	10
ADEQ	Study	WHI0210	Harp Cr	on CR21 near Marble Falls	2016	2016	5
ADEQ	Study	WHI0211	Mill Cr (upper)	off SR7 DS of Dogpatch	2016	2016	5

Table 3.3. Surface water quality monitoring stations in the Buffalo River watershed that were active during the period 2012 – 2016 (continued).

Entity	Program[a]	Station Id	Stream	Location	Start Year	End Year[c]	Number of dates[c]
ADEQ	Study	WHI0212	Unnamed Trib of Mill Cr (upper)	US of Dogpatch	2016	2016	5
ADEQ	Study	WHI0213	Mill Cr (upper)	off SR7 US of Dogpatch	2016	2016	5
USNPS	Biology	HTLN_BUFF_PRUT1	Buffalo R	Pruitt	2006	2015	15
USNPS	Biology	HTLN_BUFF_RUSH	Buffalo R	Rush	2006	2015	14
USNPS	Biology	HTLN_BUFF_TYLE1	Buffalo R	Tyler Bend	2007	2015	14
USNPS	Project	BUFF_3P_BUFT04	Mill Cr (upper)	Pruitt Yardell Rd bridge	2015	2015	2
BCRET	Study	Ephemeral stream	Ephemeral stream	On C&H farm, down slope of holding ponds	2014	2016	47
BCRET	Study	Site 2	Big Cr (middle)	upstream of C&H farm	2013	2016	155
BCRET	Study	Site 5	Big Cr (middle)	downstream of C&H farm	2013	2016	163
BCRET	Study	Site 3	Big Cr (middle)	upstream of C&H barn	2013	2014	53
BCRET	Study	Site 4	Big Cr (middle)	downstream of C&H barn	2013	2014	18
BCRET	Study	Left fork	Left Fork Big Cr (middle)	Near confluence with Big Cr (middle)	2015	2016	68
BCRET	Study	Field 1	Big Cr (middle)	Edge of field	2014	2016	21
BCRET	Study	Field 5a	Big Cr (middle)	Edge of field	2014	2016	8
BCRET	Study	Field 12	Big Cr (middle)	Edge of field	2014	2016	5

Routine = routine water quality monitoring program, Project = water quality sampling as part of USNPS special project, Study = short term water quality sampling as part of a study, Biology = water quality sampling associated with USNPS routine fish and aquatic invertebrate monitoring program

[b] long term station for trend analysis

[c] As of January 2017

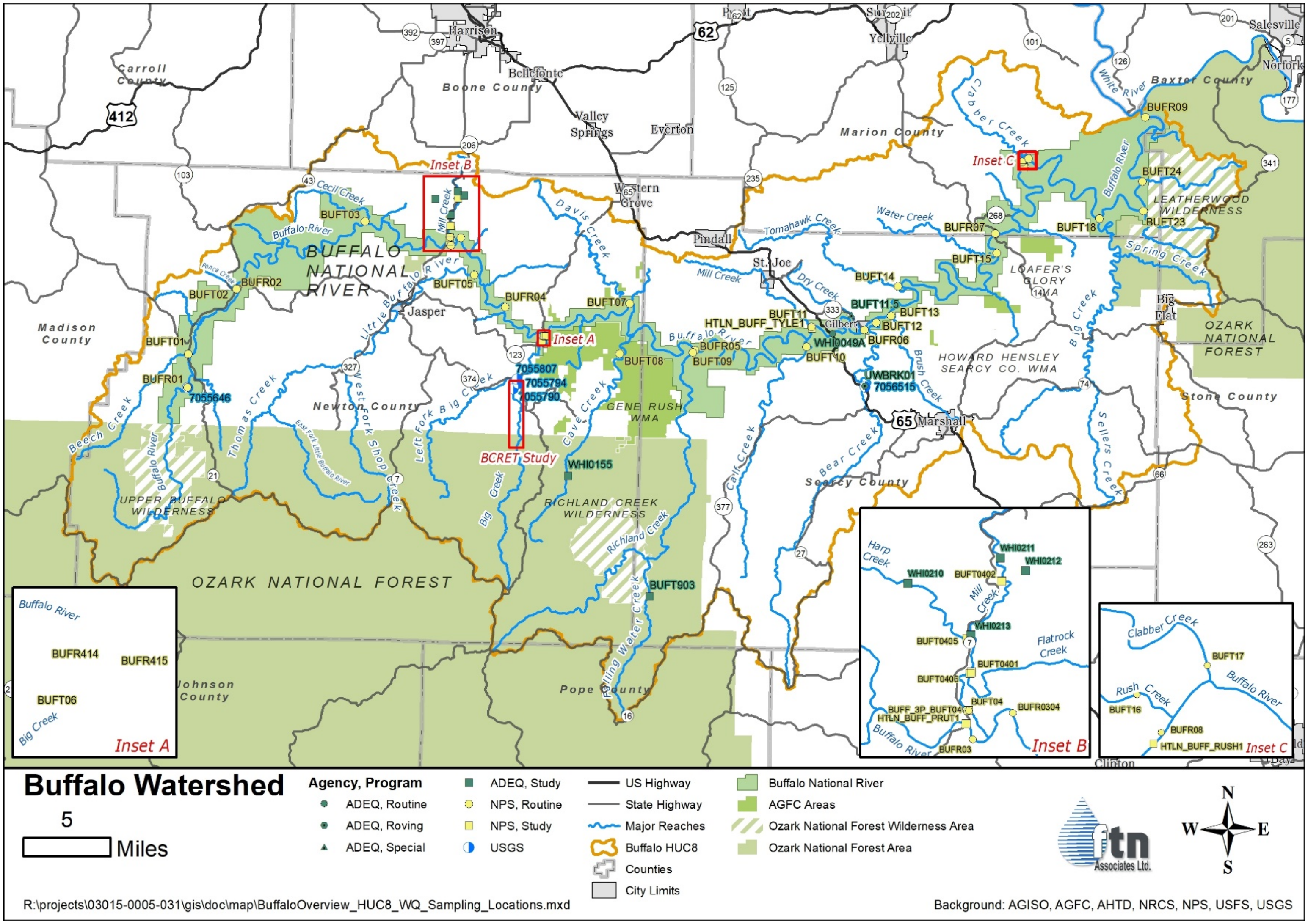

Figure 3.2. Surface water quality monitoring locations active during 2012 through 2016.

Table 3.4. Water quality parameters currently monitored in active monitoring programs and studies in the Buffalo River watershed.

Parameters	USNPS with ADEQ	ADEQ ambient	ADEQ roving	ADEQ special study	USGS	BCRET study
Metals	X	X	X	S	S	
Dissolved Oxygen	X	X	X	S	X	
Turbidity	X	X	X	S		
Nutrients	X	X	X	S	X	X
TSS		X	X	S		X
E. coli	X			S	S	X
Alkalinity	X	X	X	S	X	
Minerals	X	X	X	S	S	
Temperature	X	X	X	S	X	
Conductivity	X	X	X	S	X	
pH	X	X	X	S	X	
Hardness	X	X	X	S	S	
Total organic carbon	X	X	X	S	S	
Suspended sediment					X	

X = parameter monitored at all locations, S = parameter monitored at only some of the locations

In addition, there are sites in the watershed where ADEQ is collecting water quality data as part of a special project, the nutrient Extraordinary Resource Waters Boston Mountains Project, and as part of a special study in one of the Buffalo River tributary subwatersheds (ADEQ 2016). ADEQ began a two-year study of Mill Creek (upper) and its tributaries in 2016. For this study, water quality data on *E. coli* concentrations are being collected at eight locations. The purpose of this study is to identify stream reaches with high *E. coli* levels. A report of the study results is expected in late 2017 (personal communication, T. Wentz, ADEQ, 8/25/2017).

3.2.3.1 USGS Surface Water Quality Monitoring

The USGS collects surface water quality data, usually at flow gage stations. Historically, the USGS has collected water quality at 21 sites within the Buffalo River watershed (see Appendix C). Water quality data are no longer collected at the majority of these sites. USGS has collected water quality data within the last five years from six of the sites (USGS 2016).

3.2.3.2 USNPS Surface Water Quality Monitoring

The USNPS started routine water quality monitoring in the watershed in 1985. This program is a partnership between USNPS and ADEQ. USNPS personnel collect water quality samples using ADEQ sampling methods. The samples are then analyzed by ADEQ for all parameters except turbidity and bacteria. The USNPS analyzes for turbidity and bacteria. The USNPS currently monitors water quality in the Buffalo River watershed through several programs. Twenty-nine surface water sites are sampled for the USNPS routine monitoring program. Twenty of these sites are located on tributaries, and nine are located on the Buffalo River. These sites are sampled quarterly.

Recently, the USNPS began collecting continuous dissolved oxygen measurements at tributary routine water quality monitoring stations. The tributary sites are split into three groups of four to six stations. Each group of stations is monitored every three years. Continuous dissolved oxygen measurements are collected from May 1 through September 30.

USNPS also collects water quality samples for special studies. They are currently collecting water quality data at 13 sites as part of special studies. These sites are sampled "15 times more often" than the routine monitoring locations (Personal communication, L. Miller, USNPS, 1/26/18). Water quality measurements are also collected as part of USNPS fish and aquatic invertebrate monitoring programs.

3.2.3.3 Big Creek (middle) Water Quality Monitoring

The University of Arkansas (UofA) Division of Agriculture Big Creek Research Extension Team (BCRET) is currently conducting a study in the Big Creek (middle) subwatershed to evaluate "the potential impact and sustainable management of the C&H swine farm operation on water quality" of Big Creek (middle) and springs and ephemeral streams down gradient of the farm. This study was initiated in 2013. Water quality monitoring is one of the tasks of this study. For this study, baseflow water quality samples are collected weekly, and storm samples are collected periodically. Surface water quality sampling locations for this study include sites on Big Creek (middle) upstream and downstream of a CAFO farm operation, a site on an ephemeral stream, and surface runoff sites for three fields. It is anticipated that water quality monitoring for this study will continue at least until 2019 (a total of five years) (UofA Division of Agriculture 2017).

3.2.4 Summary of Water Quality Data 2012 - 2016

Below, recent water quality data for selected parameters is summarized. Summaries of water quality data collected in the Buffalo River watershed have been prepared in the past (Table 3.5). These summaries covered USNPS data collected from 1985 through 1994 (Mott 1997), 1991 through 1998 (Mott and Laurans 2004), and 1995 through 2011 (Watershed Conservation Resource Center 2017). This section of the report summarizes water quality data collected by USNPS, USGS, and ADEQ during the period from 2012 through 2016, which has not been previously summarized. Selected parameters of concern are examined in this section, including parameters related to past and current assessed water quality impairments (dissolved oxygen), and parameters such as bacteria, nutrients, and turbidity, about which stakeholders have expressed concern. Although Bear Creek is listed as impaired due to TDS criterion exceedances, TDS is not usually measured at USNPS routine monitoring sites. Therefore, TDS data will not be discussed in this section.

This plan section includes several box and whisker graphs. Box and whisker graphs show the range and distribution of values, they show the minimum and maximum values as well as the 25th percentile, median or 50th percentile, and 75th percentile. Figure 3.3 illustrates the elements of the box and whisker graphs in this plan. Note that the interquartile range is equal to the 75th percentile value minus the 25th percentile value.

Please note that the data reviewed below is not the same data used by ADEQ for the 2016 state water quality assessment to determine whether waterbodies are supporting designated uses or are impaired. Comparisons of measurements to water quality standards in this section are purely for informational purposes, and are not intended to identify impaired waterbodies.

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Table 3.5. Previous evaluations comparing water quality among monitoring locations.

Author & year of report	Data period evaluated	Parameters evaluated												Monitoring locations
		Fecal colifrom	E. coli	Conductivity	Temperature	Dissolved oxygen	Turbidity	Nitrate/nitrite	Total Kjeldahl N	Ammonia	Total phosphorus	Orthophosphate	pH	
Chaney 1986	1985	X		X	X	X	X							R1-R9, T1-T27, 11 public use sites, 11 spring sites
Apel 1990	1989	X		X	X	X	X	X	X	X	X			R1-R9, T1-T19, T23, T-24, 3 spring sites
Mott 1997	1985 - 1995	X		X	X	X	X	X	X	X	X	X	X	R1-R9,T1-T18, T23, T24, 3 spring sites
Mott and Laurans 2004	1991 - 1998	X		X		X	X	X		X		X		R1-R9, T1-T18, T23, T24, 3 spring sites
Usrey 2013	2009 - 2012		X											R1-R9, T1-T19, T23-T26, 3 spring sites
Watershed Conservation Resource Center 2017	1995-2011	X		X	X	X	X	X				X	X	R1-R9, T1-T19, T23-T26, 3 spring sites

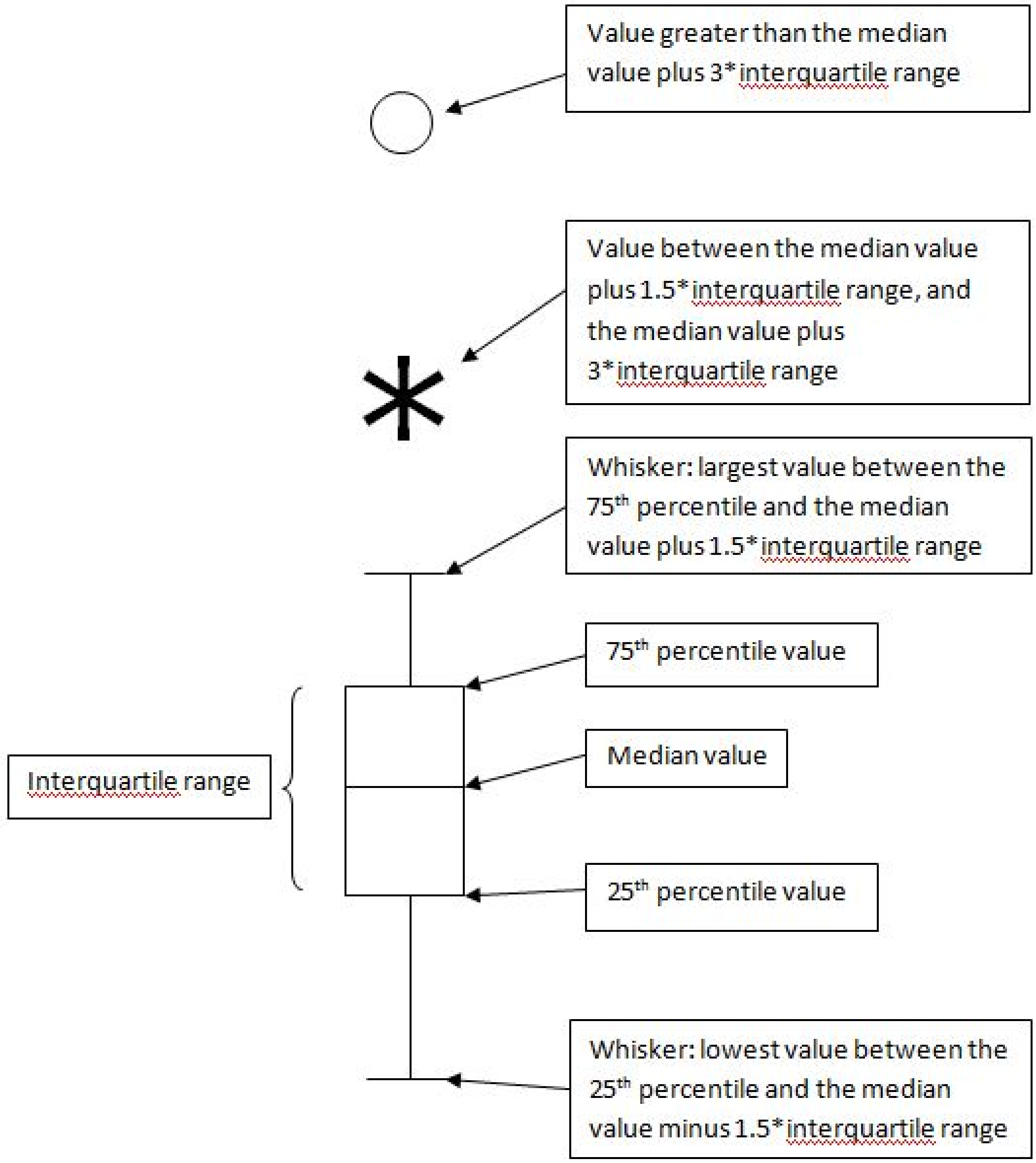

Figure 3.3. Box and whisker graph elements.

3.2.4.1 Dissolved Oxygen

Dissolved oxygen (DO) in water is used by fish and other aquatic organisms living in streams. Figure 3.4 shows a box and whisker graph of DO measurements from the Buffalo River watershed during the period 2012-2016. For the most part, DO concentrations at monitored locations in the Buffalo River watershed ranged from 5 mg/L to 15 mg/L during this period. The lowest median DO concentrations during this period were at Harp Creek, and the Buffalo River at Crow Hole (downstream of Mill Creek (upper) confluence) and the Pruitt access. The highest median DO concentration during this period is greater than 11 mg/L. There are several tributaries with median DO concentrations for the period 2012-2016 that are greater than 11 mg/L.

Figure 3.5 shows box and whisker graphs of DO measurements from the primary seasons of 2012-2016. Arkansas water quality regulations define the primary season for DO as when water temperature is 22 deg C or less, usually September to May. The numeric primary season DO water quality standard that applies in the Buffalo River watershed is shown on the graph. For the most part, during the period 2012-2016, DO concentrations measured during the primary season met the primary season DO water quality standard. DO concentrations below the water quality standard were measured during the primary season at four tributary stations, Big Creek (middle) at Carver, Cave Creek mouth, Calf Creek, and Bear Creek at Highway 65; and at one Buffalo River station, at Highway 65.

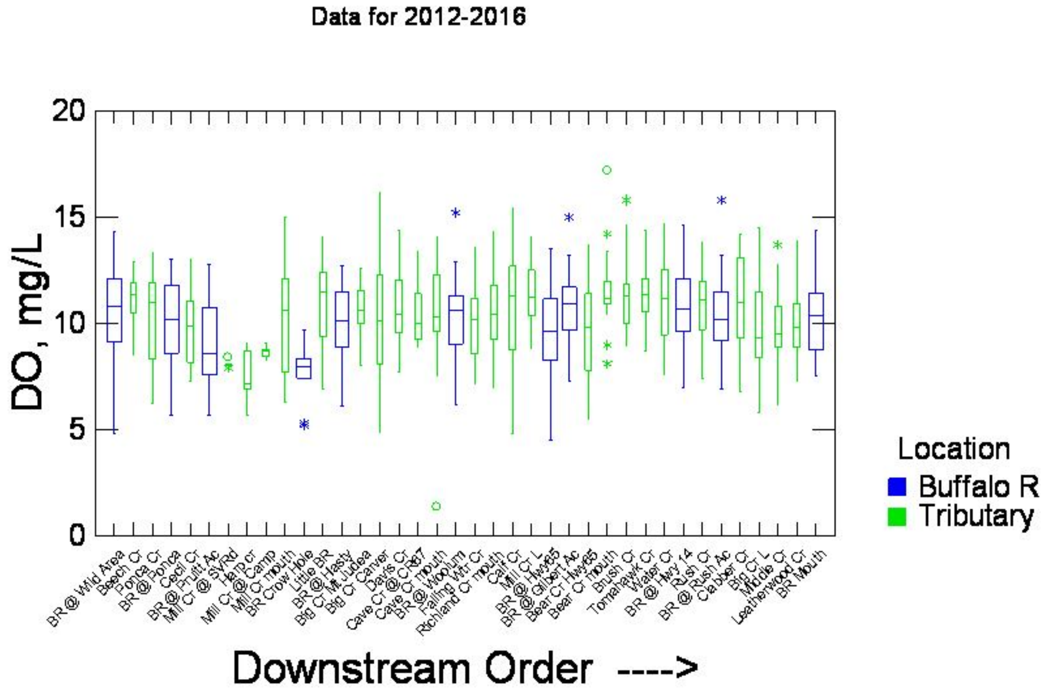

Figure 3.4. Dissolved oxygen measurements from the Buffalo River watershed 2012-2016.

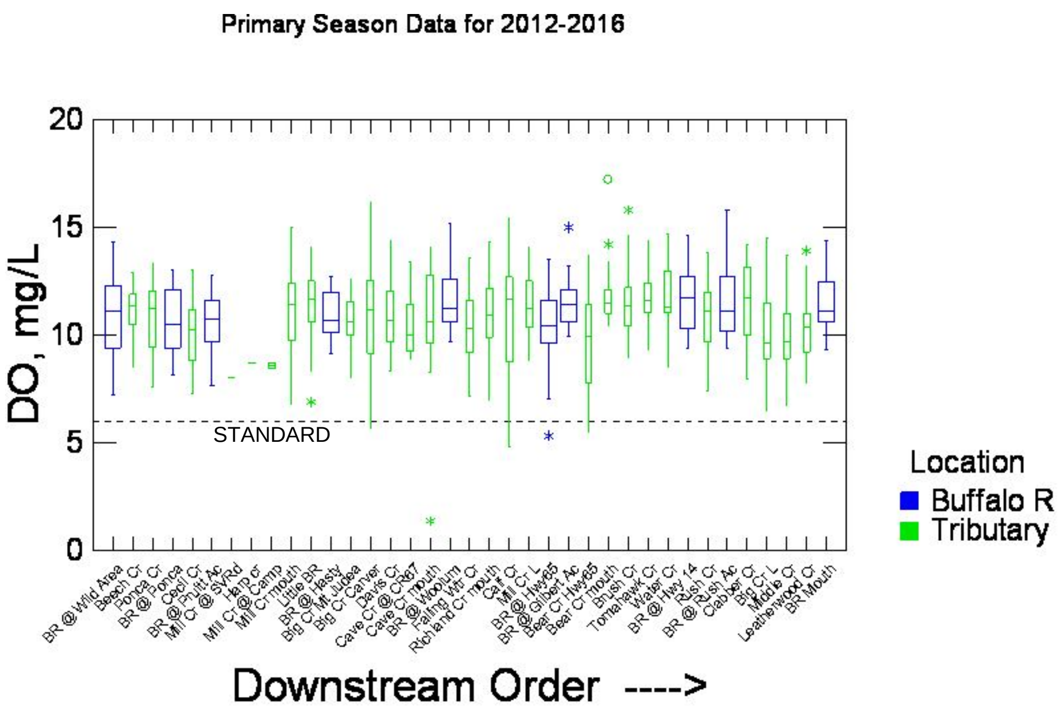

Figure 3.5 Primary season dissolved oxygen measurement from the Buffalo River watershed, 2012-2016 with water quality standard.

Figure 3.6 shows box and whisker graphs of DO measurements from the critical seasons of 2012-2016. Arkansas water quality regulations define the critical season for DO as when water temperature is above 22 deg C, usually May to September. The numeric critical season DO water quality standards for the Ozark Highlands watersheds 10 to 100 sq miles, and Boston Mountains watersheds larger than 10 sq miles (see Table 3.2) are also shown on Figure 3.6. All measured critical season DO concentrations for Ozark Highlands stations (downstream, and including, Bear Creek mouth) meet the Ozark Highlands critical season water quality criteria for watersheds larger than 10 sq miles. The majority of measured critical season DO concentrations for the Boston Mountain monitoring stations meet the Boston Mountain critical season DO water quality criterion for watersheds larger than 10 sq miles. However, there are two Boston Mountain stations where a quarter of the critical season DO measurements for the period 2012-2016 were below the water quality criterion, Big Creek (middle) at Carver, and Buffalo River at Highway 65. Note that the ADEQ 2016 biennial assessment of water quality (which evaluated data from 2010-2015) did not identify any of the streams in the Buffalo River watershed as impaired due to low DO (ADEQ 2016, 2017g).

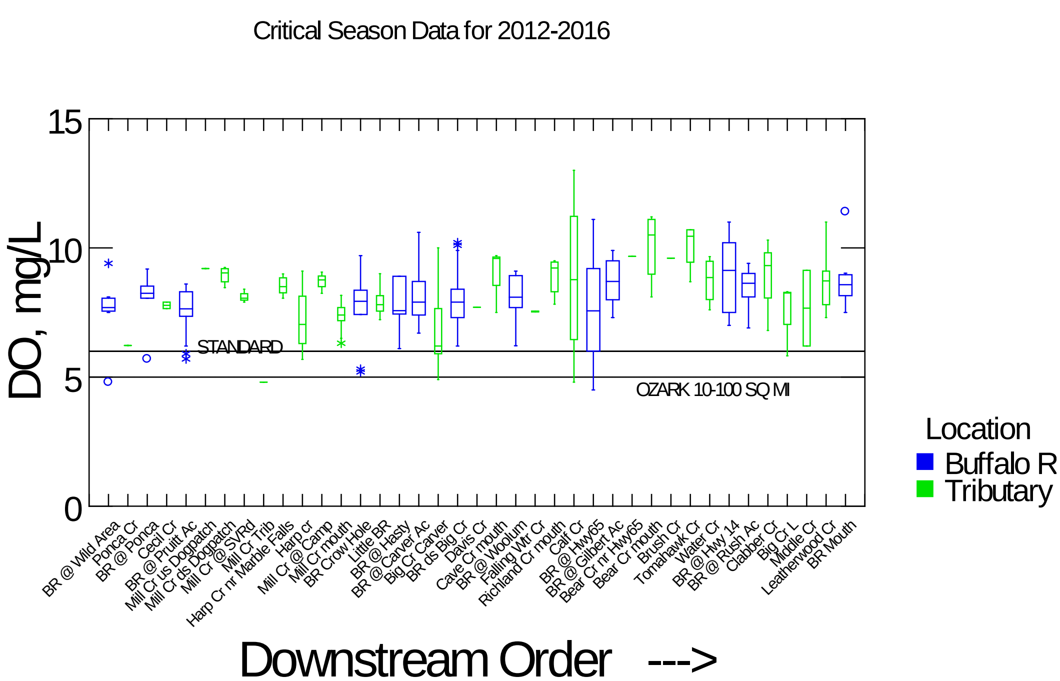

Figure 3.6. Critical season dissolved oxygen measurements from the Buffalo River watershed, 2012-2016 with water quality standards.

High DO values during the critical season may be caused by oxygen production by algal blooms. Under normal circumstances, the highest possible amount of dissolved oxygen in water is controlled by water temperature. During the day, when photosynthesis occurs, algal blooms can produce large amounts of oxygen, which can result in higher DO concentrations in water than are normally possible. This is called supersaturation, i.e., DO saturation greater than 100% of what is normally possible based on the water temperature. Evaluation of DO saturation during the critical period would provide insight into whether the high DO concentrations are due to good water quality conditions, or high rates of photosynthesis from algal blooms.

3.2.4.2 E. coli

E. coli bacteria are monitored as an indicator of the risk to human health from use of water contaminated with human or animal waste. The *E. coli* water quality standards are intended to protect the health of people involved in recreational activities that involve both primary contact with the water (e.g., swimming) and secondary contact (e.g., boating).

Figure 3.7 shows a box and whisker graph of *E. coli* measurements from the Buffalo River watershed during the period 2012-2016 for the primary contact season (May – September). The individual sample *E. coli* water quality standards for primary contact in Extraordinary Resource Waters (ERW, applies to all Buffalo River stations and Richland Creek, see Table 3.2), and all other waters are shown on the graph in Figure 3.7. *E. coli* results reported as not detected are shown on the graph as 0.01 cfu/100mL, rather than zero, so they are visible on the log scale. Seventy-five percent or more of the *E. coli* measurements from all but one of the monitoring locations are below the ERW individual sample standard. *E. coli* levels that exceed the ERW primary contact water quality standards were measured at seven of the 12 Buffalo River stations during the period 2012-2016. *E. coli* levels that exceed the “all other waters” primary contact water quality standards were measured at six of the 26 monitored locations in non-ERW waters in the watershed during the period 2012-2016.

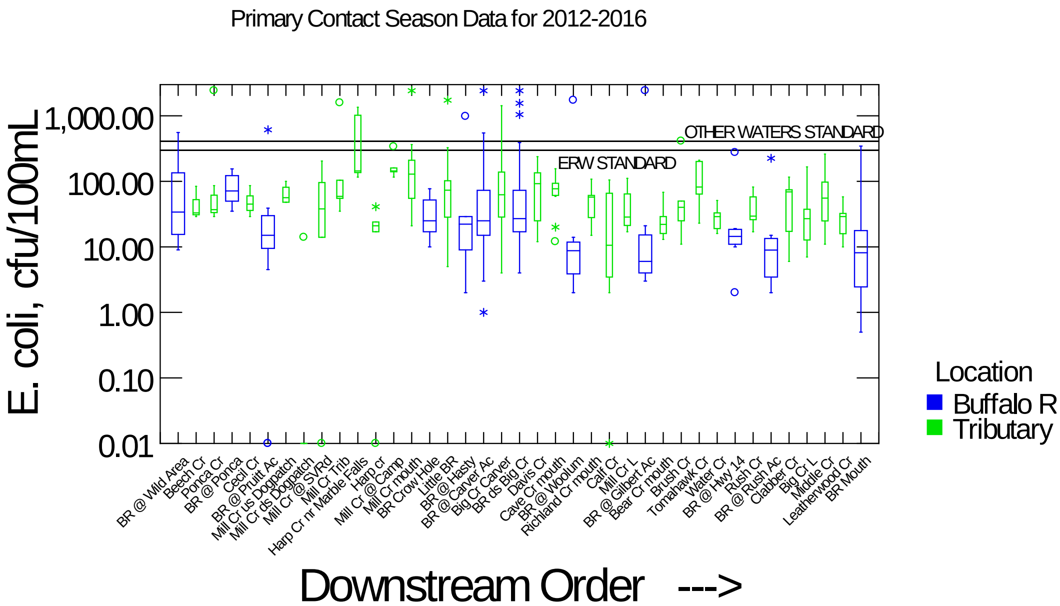

Figure 3.7. Primary contact season *E. coli* measurements from the Buffalo River watershed 2012-2016 with water quality standard.

Figure 3.8 shows a box and whisker graph of *E. coli* measurements from the Buffalo River watershed during the period 2012-2016 for the secondary contact season (October – April). *E. coli* results reported as not detected are shown on the graph as 0.01 cfu/100mL, rather than zero, so they are visible on the log scale. The individual sample water quality standards for secondary contact in ERW, and all other waters are shown on the graph in Figure 3.8. *E. coli* levels that exceed the ERW secondary contact water quality standard were measured only at the Buffalo River station below Big Creek (middle) during the period 2012-2016. *E. coli* levels that exceed the secondary contact water quality standard for non-ERW waters were measured at seven of the 19 monitored locations in non-ERW waters in the watershed during the period 2012-2016.

There are a few monitored locations where *E. coli* levels have been measured during the period 2012-2016 that exceed both primary and secondary contact water quality standards. These locations are the Buffalo River below Big Creek (middle), Big Creek (middle) at Carver, and Little Buffalo River.

Figure 3.9 shows a box and whisker plot of the *E. coli* data for both primary and secondary contact seasons combined. *E. coli* results reported as not detected are shown on the graph as 0.01 cfu/100mL, rather than zero, so they are visible on the log scale. In general, median *E. coli* levels in the Buffalo River for the period 2012-2016 are lower at monitored locations downstream of Davis Creek than those upstream.

Usery (2013) found that during baseflow conditions, *E. coli* concentrations were higher at Buffalo River locations with lower flows. He concluded that, during base-flow conditions, *E. coli* sources in the upper watershed have a greater impact on *E. coli* levels in the Buffalo River than those in the lower watershed (Usery 2013).

The highest median *E. coli* levels for the period 2012-2016 are at tributary stations in the Mill Creek (upper) watershed, and at Big Creek (middle) at Carver. The Buffalo River station with the highest median *E. coli* level is at Ponca.

The lowest median *E. coli* levels in the Buffalo River for this period are at the mouth, Gilbert, and Woolum. The tributary stations with the lowest median *E. coli* levels for this period are Calf Creek and Beech Creek.

The *E. coli* data from the USNPS routine water quality monitoring program do not meet the ADEQ criteria for use in determining whether state numeric bacteria water quality standards are being met, because sampling is not frequent enough (see Section 3.2.1.2). *E. coli* data from the BCRET study do meet these criteria. The USNPS compared 2013 and 2014 *E. coli* data from the BCRET study to state numeric bacteria water quality standards and found that the data from some of the study sampling locations indicated impairment during 2014 (Cheri 2016).

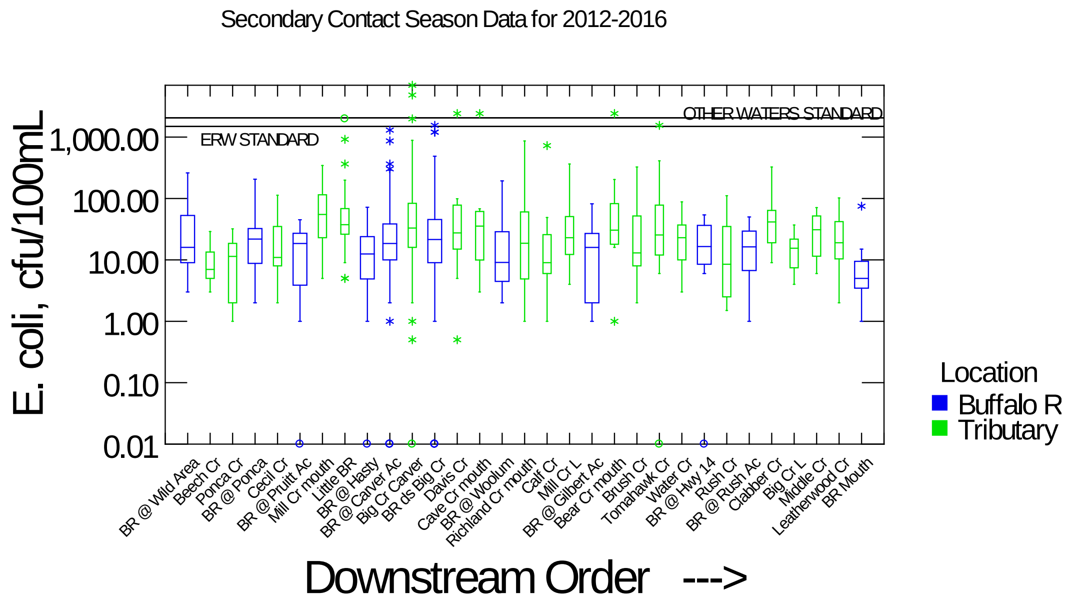

Figure 3.8. Secondary contact season *E. coli* measurements from the Buffalo River watershed 2012-2016 with water quality standard.

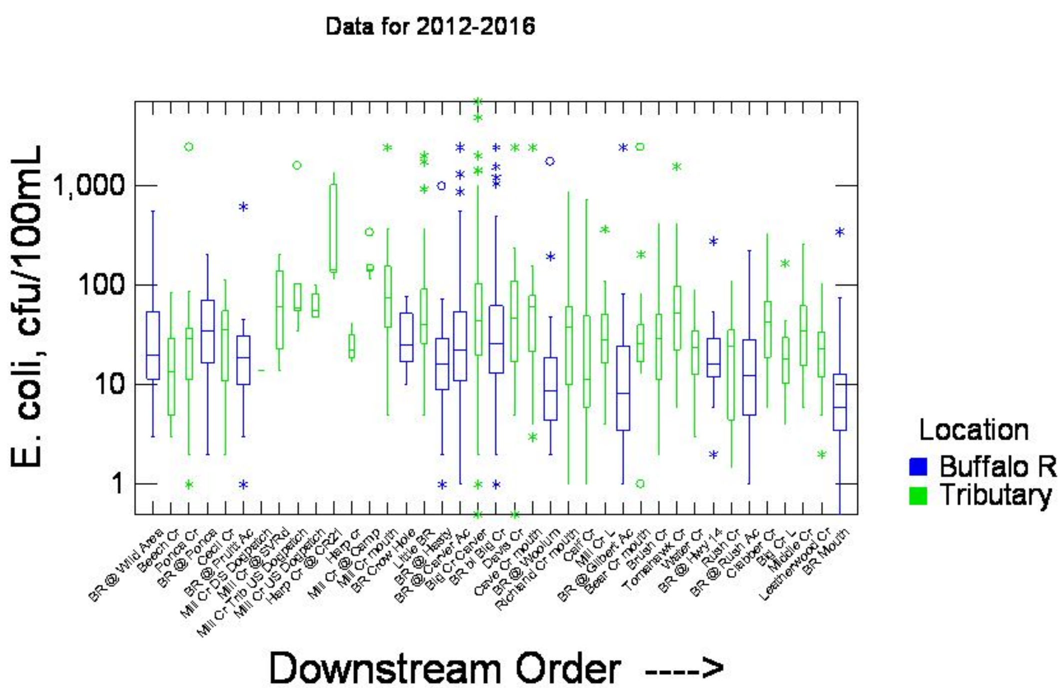

Figure 3.9. *E. coli* measurements from 2012 through 2016.

3.2.4.3 Total Nitrogen

Nitrogen is an essential nutrient for plants and occurs naturally in water. However, unnaturally high levels of nitrogen in water can stimulate nuisance algal and plant growth. The algae may produce toxins that can harm humans or animals, or, so much algae may be produced that when they die and decompose oxygen in the water is depleted to levels that can be harmful to fish and other aquatic organisms. There are no numeric water quality standards for total nitrogen that apply to the Buffalo River watershed.

Total nitrogen itself is not analyzed for at most of the routine water quality monitoring sites in the watershed. However, if nitrate, nitrite, ammonia, and total Kjeldahl nitrogen are measured, total nitrogen can be calculated from those measurements. Prior to 2014, all of these nitrogen parameters were not usually measured at the USNPS routine monitoring sites. In late 2014, ADEQ began analyzing the samples from the USNPS routine monitoring sites for all of the nitrogen parameters needed to calculate total nitrogen. In these calculations, when reported results for nitrogen parameters were “less than detection,” a value of zero was used.

Figure 3.10 shows a box and whisker plot of total nitrogen calculated from nitrogen parameters data from 2014-2016 for the Buffalo River and tributary monitoring locations. The highest median total nitrogen concentration for this period is from the Mill Creek (upper) monitoring location. Median total nitrogen concentrations for three other tributary monitoring locations are also markedly higher than median concentrations from the rest of the monitoring locations. In the Buffalo River, median total nitrogen concentrations appear to increase from the headwaters to the highest value at Woolum, and then generally decrease downstream to the mouth.

3.2.4.4 Inorganic Nitrogen

Inorganic nitrogen is the sum of nitrate and nitrite nitrogen in water. Nitrate can be harmful to babies. The Federal drinking water quality standard for nitrate nitrogen is 10 mg/L. Inorganic nitrogen is also a nutrient that can stimulate algal growth in streams (see Section 3.2.4.3). There are no numeric water quality standards for inorganic nitrogen to protect against increased algal growth that apply in the Buffalo River watershed.

Figure 3.11 shows a box and whisker plot of inorganic nitrogen measurements in the Buffalo River watershed from the period 2012-2016. When reported results for inorganic nitrogen were “less than detection,” a value of zero is shown. All inorganic nitrogen measurements in the Buffalo River watershed from the period 2012-2016 are less than the nitrate drinking water quality standard. The highest median inorganic nitrogen concentrations from the period 2012-2016 are tributary monitoring locations, including Brush Creek, Bear Creek at Highway 65, Davis Creek, and Mill Creek (upper).

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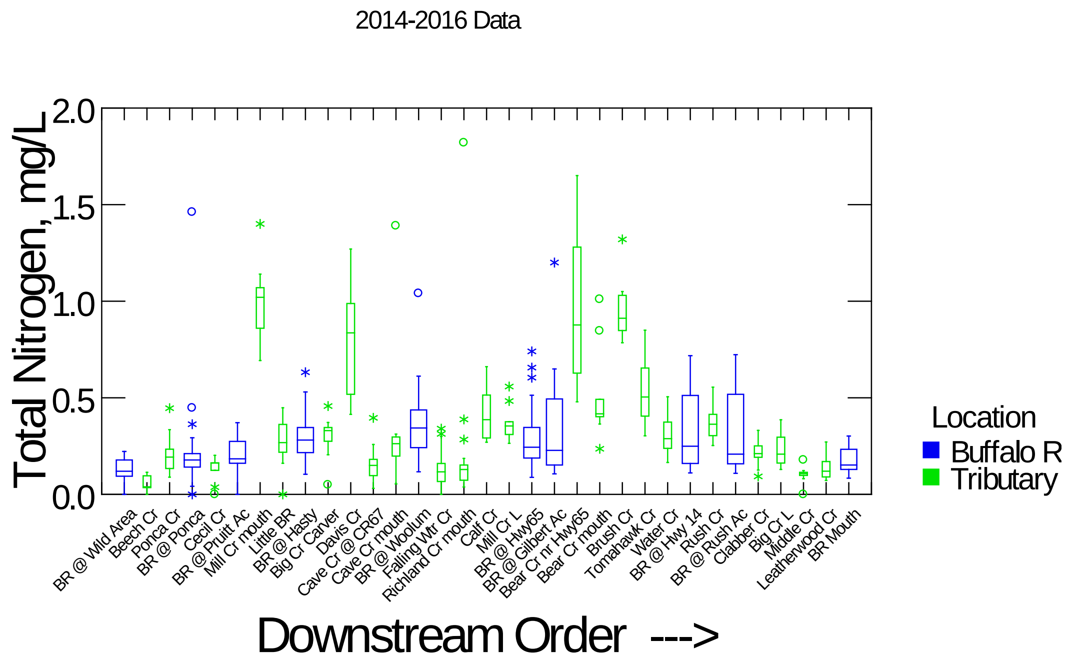


Figure 3.10. Total nitrogen measurements from the Buffalo River watershed from 2014-2016.

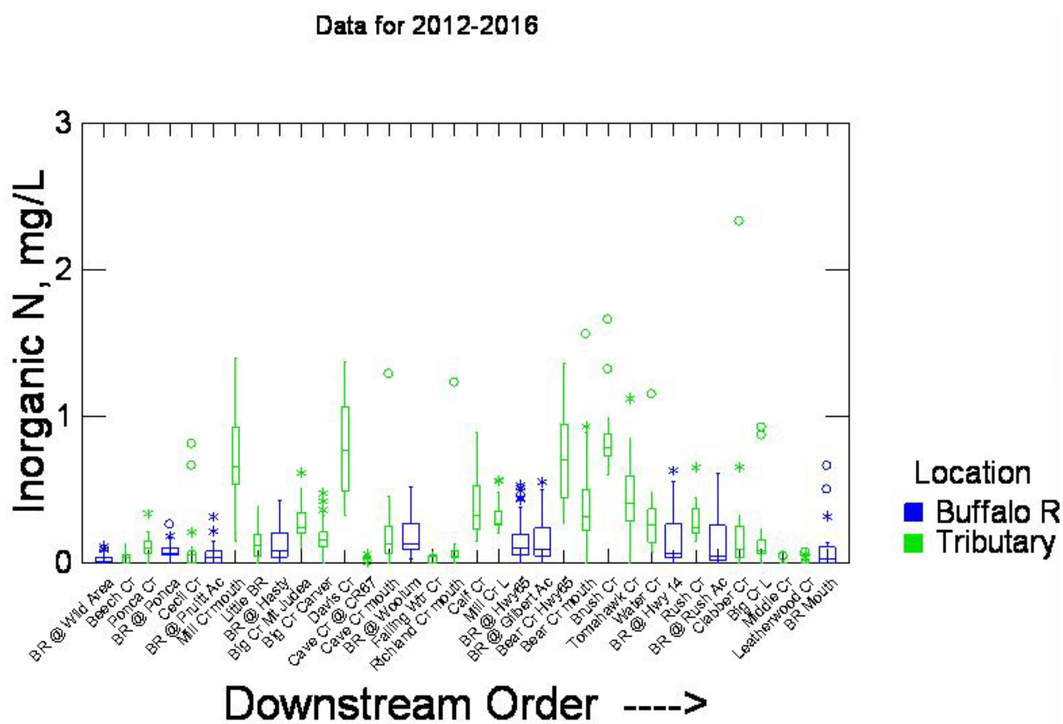


Figure 3.11. Inorganic nitrogen measurements from the Buffalo River watershed from 2012-2016.

Figure 3.12 shows a box and whisker plot of inorganic nitrogen measurements from 2012-2016 for just the Buffalo River monitoring locations. The median inorganic nitrogen concentration at the Ponca station is greater than the Buffalo River stations both upstream and immediately downstream. Downstream of Woolum, median inorganic nitrogen concentrations in the Buffalo River decline, despite the fact that some tributaries to this portion of the river do have relatively high inorganic nitrogen concentrations. Maximum inorganic nitrogen concentrations gradually increase in the downstream direction.

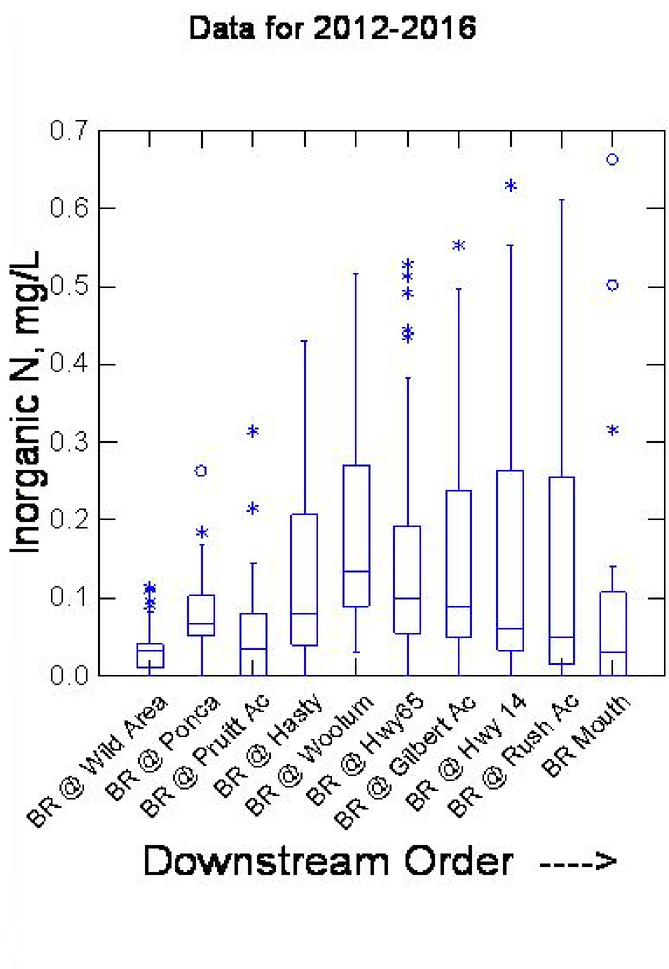


Figure 3.12. Inorganic nitrogen measurements from the Buffalo River stations from 2012-2016.

3.2.4.5 Total Phosphorus

Phosphorus is essential to plant growth and occurs naturally in water. It is not harmful to humans or animals itself. However, unnaturally high levels of this nutrient can stimulate algal and plant growth in streams the same as nitrogen (see Section 3.2.4.3). There are no numeric water quality standards for total phosphorus that apply in the Buffalo River watershed.

Prior to 2014, total phosphorus was not usually measured at the USNPS routine water quality monitoring sites. In late 2014, ADEQ began analyzing the samples from the USNPS routine water quality monitoring sites for total phosphorus.

Figure 3.13 shows a box and whisker plot of total phosphorus measurements from the Buffalo River watershed for the period 2014-2016. For most of the monitoring locations, in at least a quarter of the samples, total phosphorus could not be detected (non-detect results have been set to 0.001 for graphing on a log scale). At many of the monitoring locations, total phosphorus was not detected in at least half of the samples. The highest median total phosphorus concentration for the 2014-2016 period is at a Bear Creek monitoring location. This monitoring location, and those on three other tributaries, have very few non-detect measurements of total phosphorus.

There is no apparent pattern in total phosphorus concentrations in the Buffalo River. The highest median total phosphorus concentration in the river during this period was measured at Highway 65.

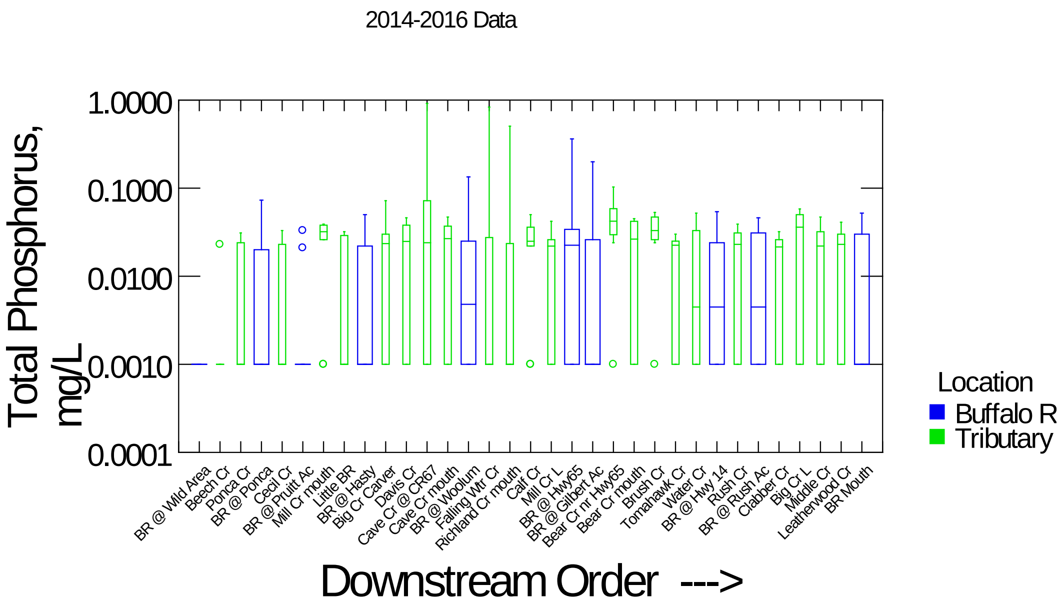


Figure 3.13. Total phosphorus measurements from the Buffalo River watershed from 2014-2016.

3.2.4.6 Orthophosphate

Orthophosphate is a nutrient that is not harmful to humans or animals itself. However, it can stimulate algal growth in streams (see Section 3.2.4.3). There are no numeric water quality standards for any phosphorus compounds, including orthophosphate, that apply in the Buffalo River watershed.

Figure 3.14 shows a box and whisker plot of orthophosphate measurements in the Buffalo River watershed from the period 2012-2016. There are a large number of the orthophosphate measurements that are reported as less than detection (non-detect results have been set to 0.0001 for graphing on a log scale). The median orthophosphate value for the period 2012-2016 is less than detection at 30 of the 38 monitoring locations. The locations with the highest median orthophosphate values for the period 2012-2016 are Bear Creek at Highway 65 and Calf Creek.

3.2.4.7 Turbidity

Turbidity is a measure of how much light can pass through water. A higher turbidity value means less light can pass through the water. Turbidity in the Buffalo River watershed is primarily the result of sediment or other solid materials suspended in the water.

Figure 3.15 shows a box and whisker plot of turbidity measurements from the Buffalo River watershed for the period 2012-2016. The numeric turbidity water quality standards for the Ozark Highlands and Boston Mountain regions “all flows” are also shown on the plot (water quality standards are listed in Table 3.2). The Ozark Highlands standard applies to the Buffalo River and its tributaries downstream of Bear Creek, as well as the Bear Creek mouth station. The Boston Mountains standard applies to the Buffalo River and its tributaries upstream of Bear Creek mouth, including Bear Creek at Highway 65.

There is no apparent downstream trend in median turbidity levels in the Buffalo River. All tributaries downstream of Bear Creek have relatively low median turbidity values for this period. This is related to the differences in the geology in the upper and lower Buffalo River watershed (Mott 1997, Mott and Laurans 2004).

The highest median turbidity levels for the period 2012-2016 are at tributary stations. The Beech Creek station has the highest median turbidity level, followed by Falling Water Creek and Cave Creek at County Road 67. The lowest median turbidity levels are also at tributary stations. Water Creek, Rush Creek, Middle Creek and Leatherwood Creek all have the lowest median turbidity values for the period 2012-2016. Of the water quality stations on the Buffalo River, the farthest upstream station has the highest median turbidity level, and the Pruitt station has the lowest median turbidity value. Twenty-one of the 36 stations have at least one turbidity measurement that exceeds the all flows numeric turbidity standard. The 75th percentile turbidity values for all of the stations are below the standard.

Figure 3.16 shows a box and whisker plot of baseflow turbidity measurements (from June through October) for the period 2012-2016 with the baseflow numeric turbidity standard, which is the same for both the Ozark Highlands and the Boston Mountain ecoregions. There are 14 stations where at least one turbidity measurement during this period exceeded the water quality standard, including all but two of the Buffalo River stations. The water quality standard was exceeded in only two tributaries during this period, even though the highest median baseflow turbidity measurement was at a tributary station (Beech Creek).

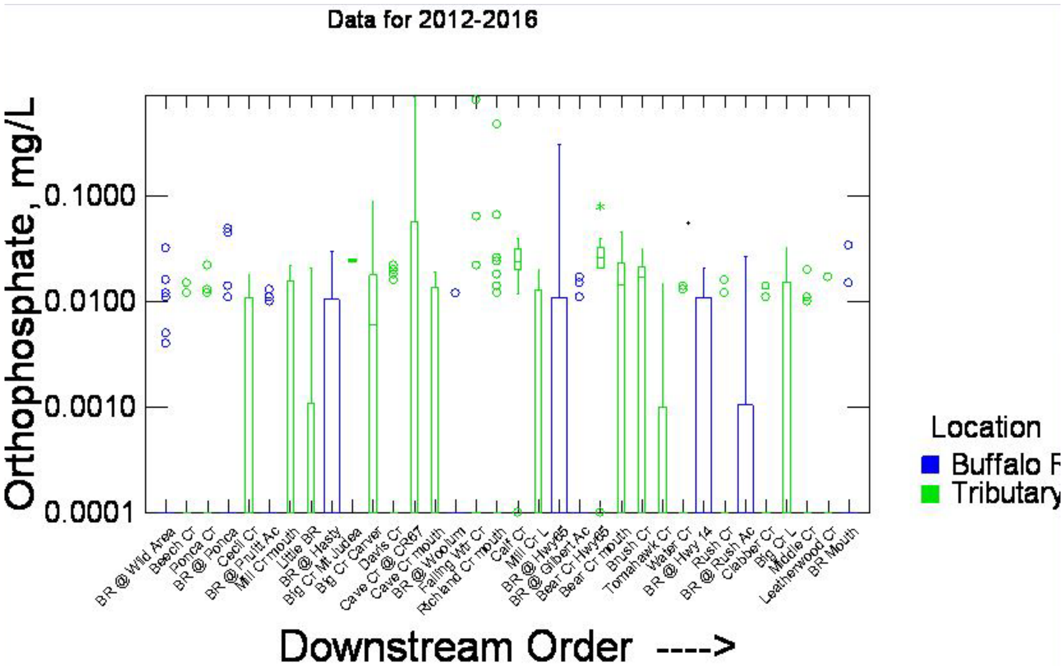


Figure 3.14. Orthophosphate measurements from the Buffalo River watershed from 2012-2016

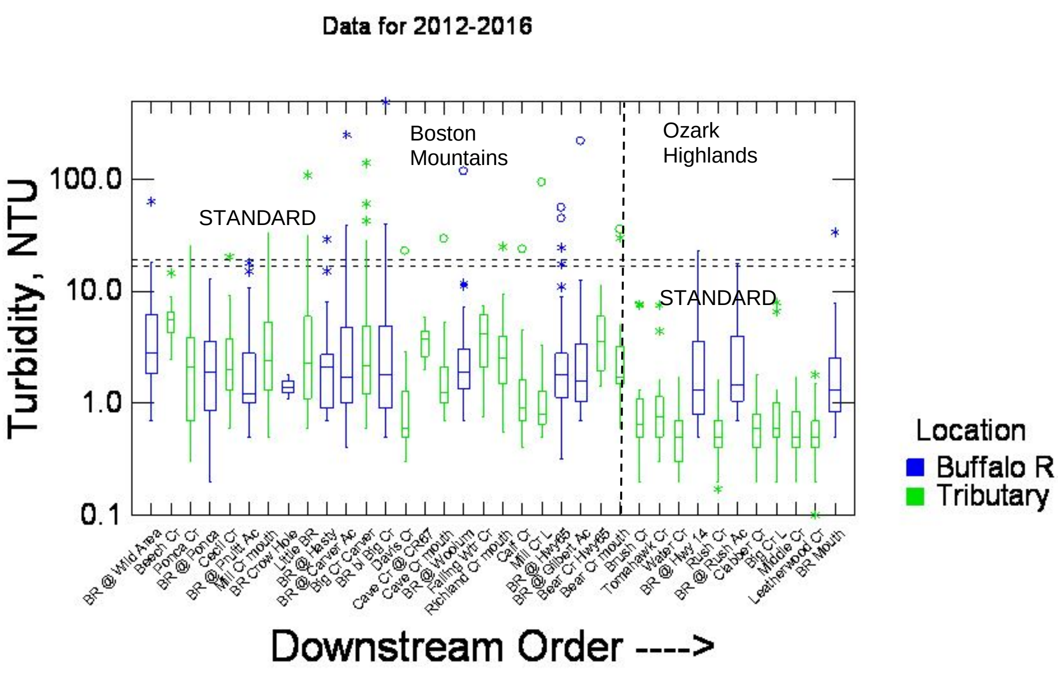


Figure 3.15. Turbidity measurements from the Buffalo River watershed 2012-2016 with water quality standards for all flows.

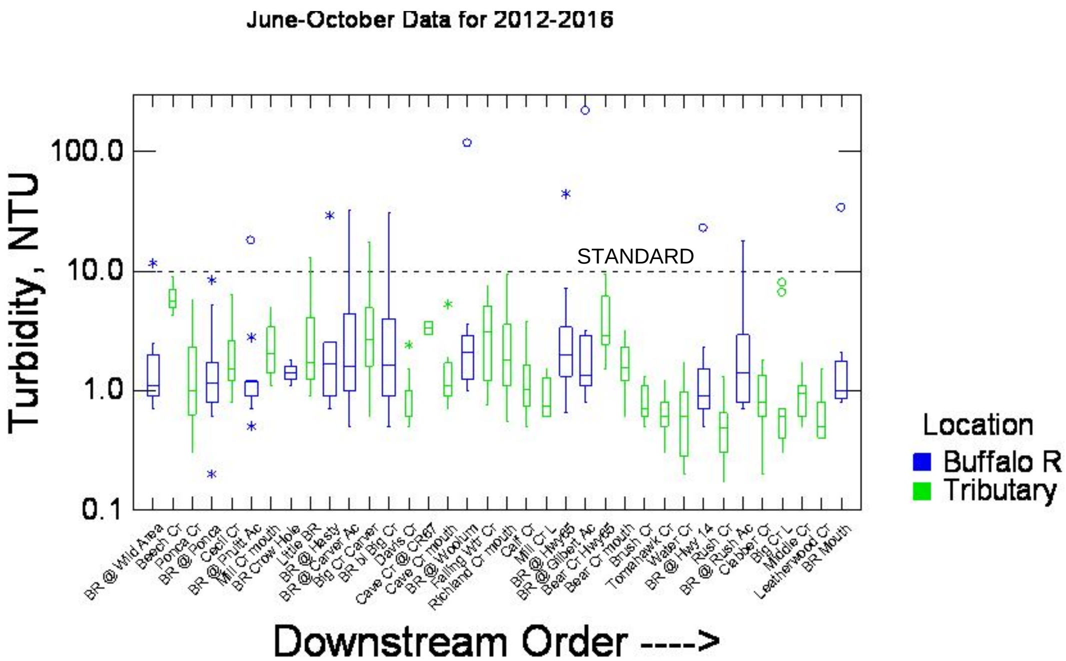


Figure 3.16. Baseflow turbidity measurements from the Buffalo River watershed 2012-2016 with water quality standard.

3.2.5 Surface water Quality Trends Analysis

Trends in water quality indicate that conditions at a location are either improving or getting worse over time. For most parameters, increasing trends suggest worsening water quality, while decreasing trends suggest water quality is improving. For DO, decreasing trends usually suggest that water quality is getting worse.

White et al. (2004) evaluated water quality trends using USGS water quality data collected from the Buffalo River near St. Joe (07056000) during the period 1991 through 2001. During the period 1999 through 2001, six high-flow samples were collected each year, in addition to the routine monthly samples. White et al. (2004) evaluated water quality trends for baseflow and high flow data separately, as well as for all of the data combined. The results of this evaluation are summarized in Table 3.6.

Table 3.6. Results of trend analyses of water quality for Buffalo River near St. Joe 1991 through 2001 (White, Haggard and Chaubey 2004).

Parameter	Data Set	Trend	Amount of change due to time (R2)
Conductivity	All data	Decreasing trend	9%
	Base-flow data	Decreasing trend	9%
	High-flow data	Decreasing trend	12%
Dissolved oxygen	All data	Decreasing trend	6%
	Base-flow data	Decreasing trend	7%
	High-flow data	No trend	-
pH	All data	Decreasing trend	5%
	Base-flow data	No trend	-
	High-flow data	No trend	-
Fecal coliform	All data	No trend	-
	Base-flow data	No trend	-
	High-flow data	No trend	-
E. coli	All data	Increasing trend	6%
	Base-flow data	No trend	-
	High-flow data	Increasing trend	17%
Fecal streptococci	All data	No trend	-
	Base-flow data	No trend	-
	High-flow data	No trend	-
Percent suspended sediment <0.062 mm	All data	Increasing trend	38%
	Base-flow data	Increasing trend	50%
	High-flow data	Increasing trend	31%
Suspended sediment concentration	All data	Increasing trend	12%
	Base-flow data	No trend	-
	High-flow data	Increasing trend	16%
Ammonia	All data	No trend	-
	Base-flow data	Insufficient data	-
	High-flow data	No trend	-
Nitrite	All data	Insufficient data	-
	Base-flow data	Insufficient data	-
	High-flow data	Insufficient data	-
Nh3+organic N	All data	Increasing trend	8%
	Base-flow data	Insufficient data	-
	High-flow data	Increasing trend	14%
Nitrate + nitrite	All data	No trend	-
	Base-flow data	Increasing trend	<1%
	High-flow data	Increasing trend	7%
Total nitrogen	All data	No trend	-
	Base-flow data	Increasing trend	2%
	High-flow data	Increasing trend	22%
Total phosphorus	All data	No trend	-
	Base-flow data	No trend	-
	High-flow data	No trend	-
Dissolved phosphorus	All data	No trend	-
	Base-flow data	Insufficient data	-
	High-flow data	No trend	-
Orthophosphate	All data	Insufficient data	-
	Base-flow data	Insufficient data	-
	High-flow data	Insufficient data	-

For this plan, we evaluated trends at 33 surface water quality monitoring locations in the watershed with a period of record of at least 20 years, ending no later than 2015. These stations are identified in Table 3.3 and shown on Figure 3.2. Fecal coliforms, inorganic nitrogen, DO, and turbidity were analyzed for trends at these stations. *E. coli* data have been collected only since 2009, eight years. That is too short of a period to evaluate for trends, therefore fecal coliform data, which have a longer data record, were evaluated for trends instead. Data records for total phosphorus and total nitrogen are also too short for trend analysis. Orthophosphate data were not analyzed for trends because in 2003 and 2012 ADEQ changed the method they use to analyze for orthophosphate in water samples. As a result, orthophosphate measurements from before and after these method changes are not comparable and cannot be used to evaluate long term changes.

The data analyzed for trends do not meet the criteria for linear regression analysis, so an alternative method of identifying and evaluating trends was used. In this method, the data from long term sampling locations from 1985 through 2015 were examined. These data were divided into three groups that correspond to the following 10-year periods, 1985 through 1994, 1995 through 2004, and 2005 through 2015. Median values from these three periods were compared, using their 95% confidence intervals. When the 95% confidence intervals around two medians do not overlap, the medians are statistically significantly different. This indicates, with 95% confidence, that the water quality during one period is different from the other. The details of these analyses are included in Appendix D, along with tables summarizing the changes over time at each of the water quality monitoring stations evaluated.

Table 3.7 lists the statistically significant changes in water quality identified using this method. Statistically significant changes in fecal coliform levels and inorganic nitrogen and DO concentrations have occurred at a number of stations, while statistically significant changes in turbidity levels have occurred at few locations.

Table 3.7. Surface water quality monitoring locations with statistically significant changes between 10-year periods.

Station Location	Parameter	Change between 1985-1994 and 1995-2004*	Change between 1995-2004 and 2005-2015*	Change between 1985-1994 and 2005-2015*
Buffalo at Wilderness Area	Inorganic N	Decrease	**INCREASE**	**INCREASE**
	DO	Increase	**INCREASE**	**INCREASE**
Buffalo at Ponca	Fecal coliform	**INCREASE**	Decrease	Increase
	Inorganic N	Increase	Increase	**INCREASE**
Buffalo at Pruitt	Fecal coliform	**INCREASE**	Decrease	**INCREASE**
Buffalo at Woolum	Inorganic N	Increase	Increase	**INCREASE**
Buffalo at Hwy 65	Inorganic N	Increase	Increase	**INCREASE**
	DO	**DECREASE**	Increase	Decrease
Buffalo at Gilbert	DO	Increase	Increase	**INCREASE**
Buffalo at mouth	Fecal coliform	No change	Increase	**INCREASE**
Beech Creek	DO	**INCREASE**	Decrease	Increase
Ponca Creek	Inorganic N	**INCREASE**	Decrease	**INCREASE**
Cecil Creek	Fecal coliform	Increase	Increase	**INCREASE**
Mill Creek (upper)	Fecal coliform	Increase	**INCREASE**	**INCREASE**
	Inorganic N	Increase	Increase	**INCREASE**
Big Creek (middle)	Fecal coliform	No change	Increase	**INCREASE**
Little Buffalo R	Fecal coliform	Increase	Increase	**INCREASE**
Davis Creek	Inorganic N	**INCREASE**	**INCREASE**	**INCREASE**
Cave Creek	Fecal coliform	Increase	Increase	**INCREASE**
Calf Creek	Turbidity	**DECREASE**	Decrease	**DECREASE**
Bear Creek at mouth	Inorganic N	**INCREASE**	Increase	**INCREASE**
	DO	Increase	Increase	**INCREASE**
Brush Creek	Inorganic N	Increase	**INCREASE**	**INCREASE**
Tomahawk Creek	Inorganic N	Increase	Increase	**INCREASE**
	DO	Increase	Increase	**INCREASE**
Water Creek	Fecal coliform	Increase	Increase	**INCREASE**
	Inorganic N	Increase	Increase	**INCREASE**
	Turbidity	**DECREASE**	Increase	No change
	DO	Increase	Increase	**INCREASE**
Rush Creek	Inorganic N	**INCREASE**	Increase	**INCREASE**
Big Creek (lower)	Fecal coliform	**INCREASE**	Increase	**INCREASE**
	Inorganic N	Increase	Increase	**INCREASE**
	Turbidity	Increase	Increase	**INCREASE**
Middle Creek	Inorganic N	Increase	**DECREASE**	Decrease
Leatherwood Creek	Inorganic N	Increase	**DECREASE**	**DECREASE**

*ALL CAPS indicate statistically significant change

Statistically significant increases in water quality constituent levels over time are more common than statistically significant decreases. Statistically significant changes in two parameters have occurred at several of the stations. Statistically significant increases in three parameters (fecal coliform, inorganic nitrogen, and turbidity) are evident in the data from the Big Creek (lower) station. Statistically significant changes in all four parameters are evident in the data from the Water Creek station.

There are also some stations where the median constituent levels consistently increased or decreased between the three 10-year periods, but the changes were not statistically significant (see tables in Appendix D). Conditions at these locations may warrant additional scrutiny and continued tracking.

3.2.6 Pollutant Loads

Loads of selected pollutants have been reported for some tributaries and Buffalo River locations by researchers. A SWAT model for the Buffalo River watershed, to estimate loads of sediment and nutrients from each of the 37 12-digit HUC subwatersheds, was completed February 2018, and is included as Appendix E. Because the USNPS collects instantaneous flow measurements with water quality samples, daily loads can be calculated for the USNPS sample dates and locations.

However, since the majority of the USNPS sampling has occurred during baseflow or low flow conditions, while large portions of the annual load are usually transported during high flow conditions, a different approach was used to estimate the annual loads used in this plan. Loads of inorganic nitrogen, orthophosphate, and *E. coli* were estimated. It is not possible to calculate a load using turbidity measurements.

3.2.6.1 From Previous Studies

Loads for selected pollutants have been calculated at selected locations in the Buffalo River watershed by several researchers. Table 3.8 summarizes this previous work. Although some of these studies identified sources of the pollutants evaluated, no quantitative estimates of loads from sources were included in the research reports.

In 1991, Mill Creek (upper) was estimated to be contributing 5.5 lb/day of inorganic nitrogen to the Buffalo River, over 96% of the inorganic nitrogen load in the Buffalo River downstream of the confluence with Mill Creek (upper) (Maner and Mott 1991).

Annual loads of total nitrogen, total phosphorus, and inorganic nitrogen have been estimated by several researchers for the Buffalo River near St. Joe. The estimated loads are summarized in Table 3.9. Since these loads were not estimated using the same methods, they are not necessarily comparable (White, Haggard and Chaubey 2004). However, all show that total phosphorus loads are lowest, and total nitrogen loads are greatest.

Table 3.8. Previous estimates of pollutant loads in the Buffalo River watershed.

Locations	Time period	Parameters	Load	Reference
Calf Creek and Buffalo River	2001-2002	TKN, inorganic N, Total N, dissolved P, orthophosphorus, TP, DOC, suspended sediment	lb/yr	Galloway and Green 2004a
Bear Creek and Buffalo River	1999-2004	TKN, inorganic N, Total N, dissolved P, orthophosphorus, TP, DOC, suspended sediment	lb/yr	Galloway and Green 2004b
Bear Creek and Buffalo River	1999-2000	TKN, inorganic N, Total N, dissolved P, orthophosphorus, TP, DOC, suspended sediment	lb/yr	Petersen, Haggard and Green 2002
Buffalo River near St. Joe	1991-2001	TP, inorganic N, total N	kg/sq km	White et al. 2004
Buffalo River near St. Joe	1990-1995	TP, inorganic N, total N	kg/sq km	Clark et al. 2000
Mill Cr (upper) and Buffalo River	8/19/1991	BOD, TSS, NH3-N, NO3-N, PO4, TP	lb/day	Maner and Mott 1991

Table 3.9. Estimated annual nutrient loads for the Buffalo River near St. Joe, as reported in (White, Haggard and Chaubey 2004) .

Reference	Time period	Total phosphorus, kg/sq km	Inorganic nitrogen, kg/sq km	Total nitrogen, kg/sq km
Clark et al. 2000	1990-1995	<17	<28	<110
Petersen et al. 2002	1999-2000	91	164	478
White et al. 2004	1991-2001	29	86	195

3.2.6.2 Estimated Annual Loads

Annual pollutant loads from monitored tributaries were estimated using tributary median constituent concentrations for the period 2005-2015, and estimated average annual runoff volumes. Due to the characteristics of the data, the annual loads estimated using this method are not expected to be a realistic representation of the actual loads contributed by the tributaries. However, these estimates are believed to be adequate to make relative comparisons among tributaries.

The USGS estimated the average annual runoff for four long-term flow gages in the Buffalo River watershed. The estimated average annual runoff for these gages ranged from 18.61 inches/year for the Buffalo River headwaters, to 9.77 inches/year for the Buffalo River near Rush (Pugh and Westerman 2014). The estimated average annual runoff volume for each of the subwatersheds was estimated by multiplying the drainage area of the monitored tributary by 17 inches. This value is similar to the average annual runoff for Richland Creek near Witt's Spring (17.33 inches). The resulting estimated annual loads for *E. coli*, inorganic nitrogen, and orthophosphate are listed in Table 3.10, and graphed in Figures 3.17 through 3.19.

It is interesting to note that the tributaries with the largest watersheds and runoff volumes (i.e., Little Buffalo River, Big Creek (lower), and Richland Creek) do not always have the largest estimated annual loads. For example, estimated annual nutrient loads are highest for Bear Creek, even though it has a smaller watershed and estimated runoff volume.

3.2.7 Surface Water Quality Summary

There are over 50 surface water quality monitoring stations in the Buffalo River watershed that were active during the period 2012-2016. The majority of these stations are sampled quarterly. Overall, water quality at the routine monitoring locations in the Buffalo River watershed appears good. Measurements of turbidity, *E. coli*, and DO at these locations sometimes don't meet water quality standards, but there are no water quality impairments related to these parameters identified in the 2016 state water quality assessment (ADEQ 2016). There is one impaired waterbody in the watershed identified in the 2016 state water quality assessment; Bear Creek is classified as impaired due to high levels of TDS. A municipal wastewater treatment plan is identified as the source of the TDS causing the impairment.

Table 3.10. Estimated annual loads of selected parameters from monitored Buffalo River tributaries.

Tributary Monitoring Station ID	Monitored Tributary Name	Tributary Drainage Area, Ac	Estimated Runoff Volume, L	Median 2009-2015 E. coli, cfu/100mL	Estimated E. coli load, cfu/year	Median 2005-2015 inorganic nitrogen, mg/L	Estimated inorganic nitrogen load, kg/year	Median 2005-2015 ortho-phosphate, mg/L	Estimated ortho-phosphate load, kg/year
BUFT05	Little Buffalo R	91,825	160,456,082,550	37.5	6,017,103	0.075	12,034	0.01	1,605
BUFT01	Beech Cr	12,444	21,744,791,628	17	369,661	0.044	957	0.011	239
BUFR01	Upper Buffalo R	37,907[a]	66,239,486,114	19	1,258,550	0.025	1,656	0	0
BUFT03	Cecil Cr	14,784[b]	25,833,735,088	46	1,188,352	0.032	827	0.008	207
BUFT02	Ponca Cr	2,886[b]	5,043,729,231	18.5	93,309	0.113	570	0.0095	48
BUFT04	Mill Cr U	13,607	23,777,031,476	64	1,521,730	0.727	17,286	0.012	285
BUFT06 & 7055814	Big Cr Mid	57,536[b]	100,539,081,575	41.25	4,147,237	0.1315	13,221	0.012	1,206
BUFT08	Cave Cr	33,618	58,744,487,701	49	2,878,480	0.089	5,228	0.012	705
BUFT09	Richland Cr	83,536	145,971,786,680	34.5	5,036,027	0.045	6,569	0.005	730
BUFT07	Davis Cr	17,920[b]	31,313,618,288	26.5	829,811	0.637	19,947	0.0095	297
BUFT10	Calf Cr	31,755	55,489,059,639	15	832,336	0.337	18,700	0.028	1,554
BUFT12	Bear Cr	58,990	103,079,818,237	21.5	2,216,216	0.313	32,264	0.018	1,855
BUFT13	Brush Cr	12,874	22,496,178,674	20	449,924	0.77	17,322	0.02	450
BUFT11	Mill Cr L	9,088[b]	15,880,477,846	22.5	357,311	0.273	4,335	0.0125	199
BUFT14	Tomahawk Cr	23,589	41,219,695,413	64	2,638,061	0.382	15,746	0.0085	350
BUFT15	Water Cr	24,516	42,839,546,091	23	985,310	0.245	10,496	0	0
BUFT16	Rush Cr	9,656	16,873,007,711	12	202,476	0.233	3,931	0	0
BUFT17	Clabber Cr	16,992	29,692,020,198	40	1,187,681	0.052	1,544	0	0
BUFT18	Big Cr L	85,888	150,081,699,081	25.25	3,789,563	0.132	19,811	0.012	1,801
BUFT23	Middle Cr	7,168[b]	12,525,447,315	20.5	498,222	0	0	0	0
BUFT24	Leatherwood Cr	8,128[b]	14,202,962,581	17		0		0	

[a] drainage area from USGS gage
[b] drainage area calculated using USGS StreamStats online utility

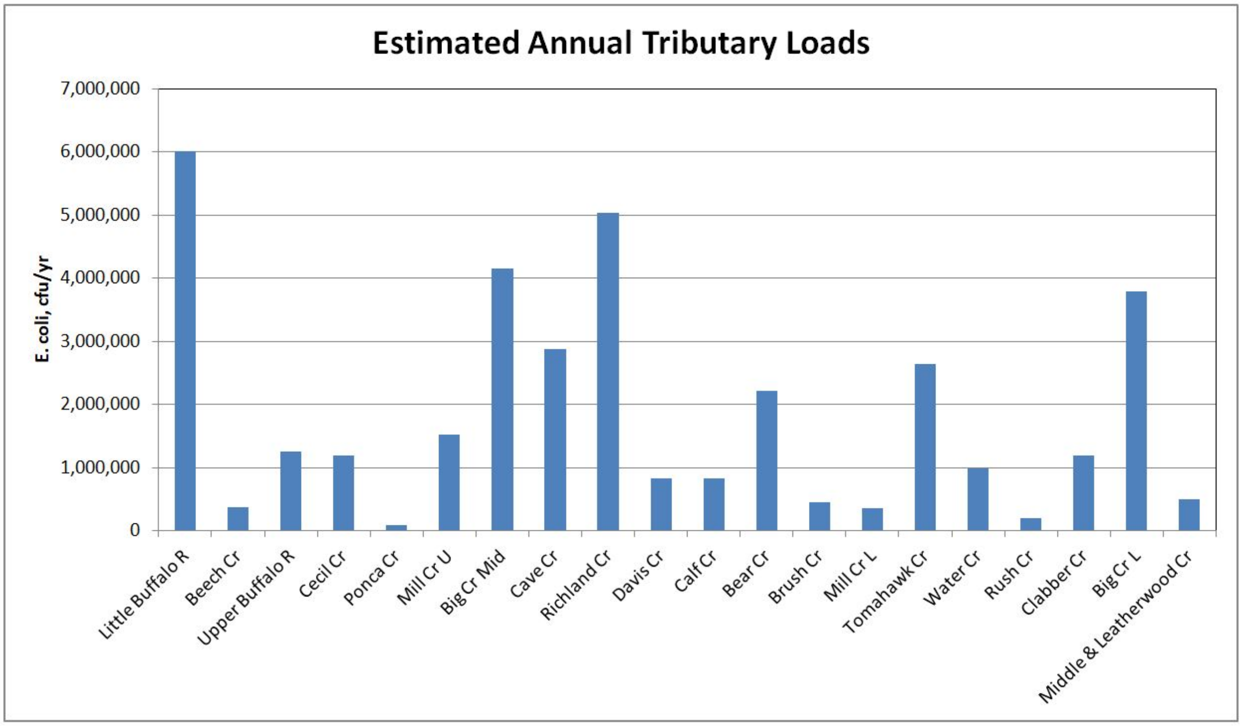


Figure 3.17. Estimated annual *E. coli* loads for monitored tributaries in the Buffalo River watershed.

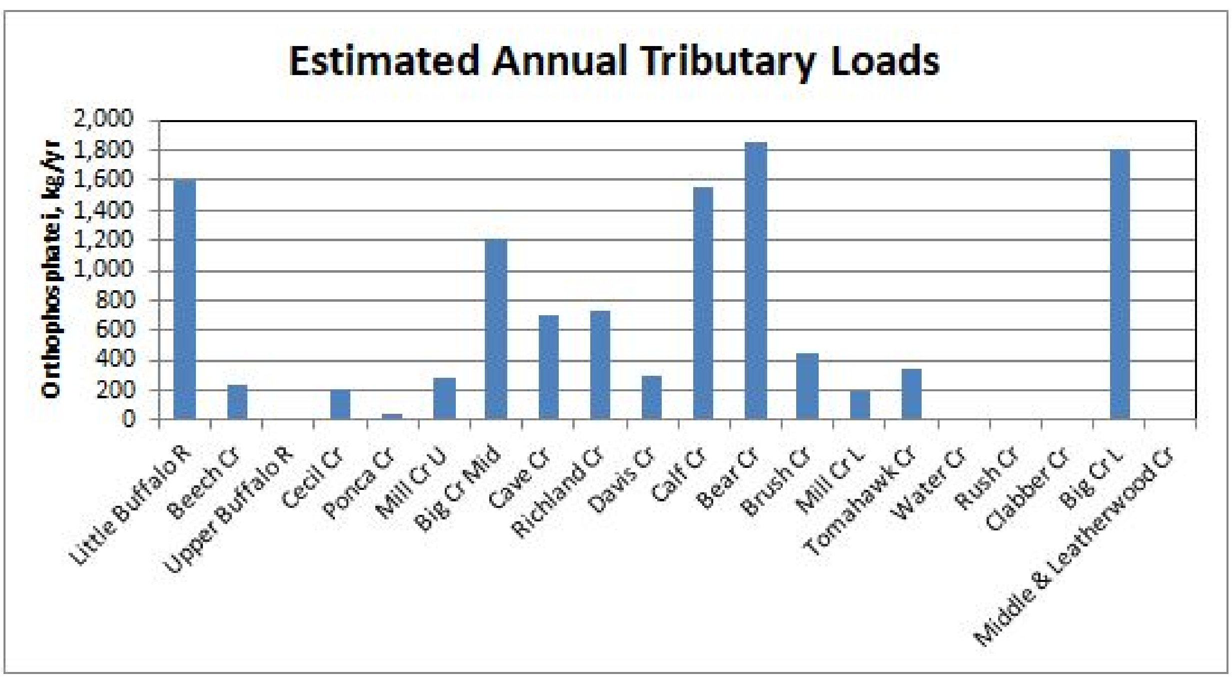


Figure 3.18. Estimated annual inorganic nitrogen loads for monitored tributaries in the Buffalo River watershed.

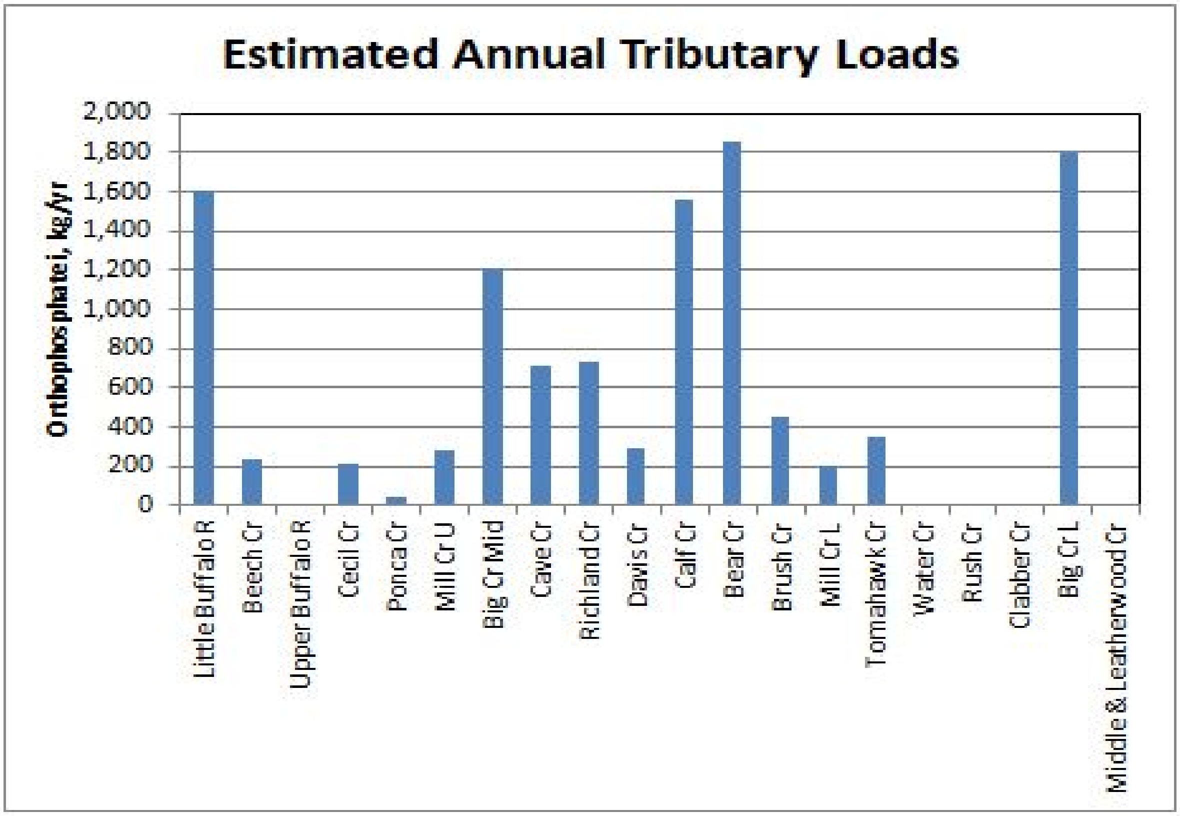


Figure 3.19. Estimated annual orthophosphate loads for monitored tributaries in the Buffalo River watershed.

Trend analysis was conducted on DO, inorganic nitrogen, fecal coliform, and turbidity data from routine water quality monitoring locations with data records for the entire period from 1985 through 2015. The results of this analysis indicate that inorganic nitrogen, fecal coliform, and/or turbidity levels have increased over time at several of the monitoring locations. These results suggest that water quality at some places in the watershed is being negatively impacted.

Annual loads of *E. coli*, inorganic nitrogen, and orthophosphate were estimated for each of the monitored Buffalo River tributaries. Bear Creek has the greatest estimated inorganic nitrogen and orthophosphate loads, even though it does not have the greatest runoff volume. The highest estimated *E. coli* load was from the Little Buffalo River, which does have the greatest runoff volume.

3.2.8 Surface Water Quality Data Gaps

In general, existing surface water quality monitoring stations provide good spatial coverage of the Buffalo River and its major tributaries. In addition, the majority of the active surface water quality monitoring stations have data records of 20 years or more for most parameters of interest. The parameters monitored appear to be appropriate. Adding total suspended solids (TSS) to the USNPS routine water quality monitoring program would be useful for characterizing sediment loads. TSS analyses are commonly run on ADEQ routine water quality monitoring samples, and they have agreed to do the analyses on the USNPS samples beginning in 2018.

As with most routine water quality monitoring programs, the majority of water quality sampling occurs during baseflow conditions. In most surface water systems, the majority of nonpoint source loading of pollutants of concern occurs during high flow conditions. Therefore, there may not be enough samples collected during high loading conditions to give a realistic picture of pollutant loads. Intensive water quality studies have been conducted on some streams to characterize pollutant loads during a range of flow conditions. Such studies can be conducted on any of the streams in the watershed.

The USNPS operates the most extensive routine water quality monitoring program in the Buffalo River watershed. ADEQ uses much of the data from the USNPS program to assess water quality in the watershed. The exception is the fecal coliform and *E. coli* data collected from routine monitoring locations. The quarterly sampling frequency means these data don’t meet the ADEQ data requirements for assessing whether bacteria water quality standards are being met. Fecal coliform and *E. coli* data from USNPS special studies do meet ADEQ data requirements. Special studies can be used to assess whether bacteria water quality standards are being met.

3.3 Groundwater Quality

This plan section describes groundwater quality in the Buffalo River watershed. Included in this section are descriptions of state and federal water quality standards that apply to groundwater in the watershed, active spring and groundwater quality monitoring programs in the Buffalo River watershed, and available groundwater quality data from the period 2012-2016. In addition, spring water quality data are evaluated for trends. Finally, groundwater quality data gaps are discussed.

3.3.1 Groundwater Quality Standards for Buffalo River Watershed

Arkansas has no water quality standards for groundwater. However, groundwater used for drinking water should meet federal drinking water standards. Drinking water standards for selected parameters are listed in Table 3.11.

Table 3.11. Selected drinking water quality standards.

Contaminant	Maximum contaminant level
Total coliforms	< 5% of samples testing positive for coliforms, or, if less than 40 samples/month, less than 2 sample/month test positive for coliforms
Nitrate as nitrogen	10 mg/L
Fluoride	4 mg/L

3.3.2 Groundwater Quality Monitoring in the Buffalo River Watershed

Water quality data are collected from groundwater wells and several springs in the Buffalo River watershed through active monitoring programs of the USNPS and USGS. During the period from 2012 through 2016, the USNPS collected water quality samples from three springs as part of its routine water quality monitoring program; Luallen, Gilbert, and Mitch Hill Springs. During the same period, the USGS collected water quality samples from two wells and three seeps in the watershed. The USGS has sampled only one well more than once. The other well and the seeps were sampled only once. As part of the Big Creek Research and Extension Team study of the C&H farm in the Big Creek (middle) subwatershed, a spring and a well on the farm were sampled during the 2012-2016 period, as well as two interceptor trenches located down gradient of the farm waste storage ponds. Figure 3.20 shows spring and groundwater well sampling locations. Table 3.12 lists the locations monitored during the period 2012-2016, and the aquifer from which the sampled water comes.

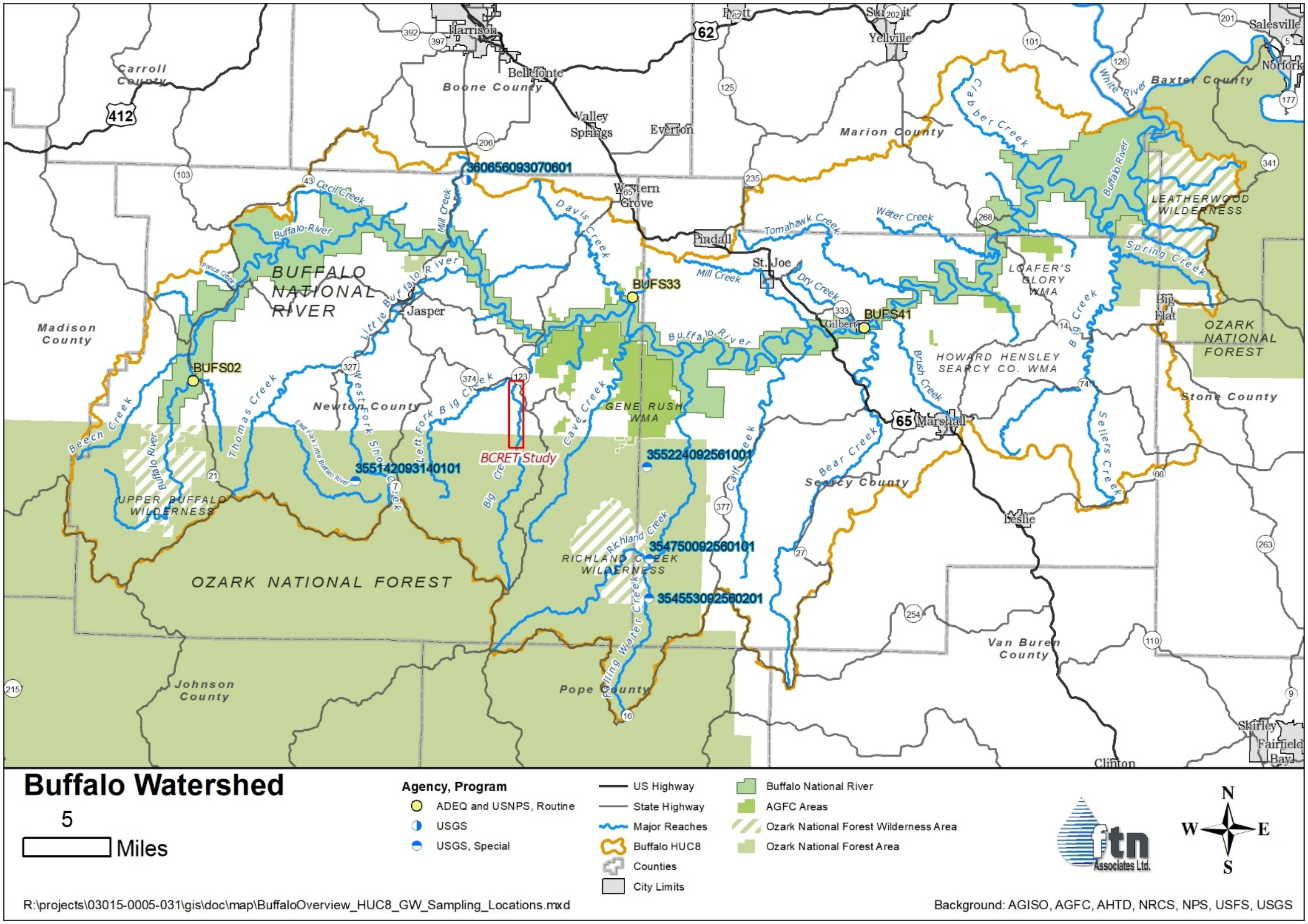


Figure 3.20. Groundwater quality sampling locations in the Buffalo River watershed 2012-2016.

Table 3.12. Groundwater sampling locations in the Buffalo River watershed 2012-2016.

Entity	Program	Station Id	Name	Aquifer	Formation	Start Year	End Year	Number of dates
ADEQ, USNPS	Routine	BUFS02	Luallen Sp	Springfield	Boone	1985	2016	168
ADEQ, USNPS	Routine	BUFS33	Mitch Hill Sp	Ozark	Everton[a]	1985	2016	158
ADEQ, USNPS	Routine	BUFS41	Gilbert Sp	Springfield	Boone	1987	2016	159
USGS	Special	360656093070601	Well	Ozark	Gunter Sandstone[b]	1972	2016	5
USGS	Special	355224092561001	Seep near Dry Cr	Unknown	Unknown	2013	2013	1
USGS	Special	355142093140101	Seep at Natural Bridge	Unknown	Unknown	2013	2013	1
USGS	Special	354750092560101	Well	Unknown	Unknown	2013	2013	1
USGS	Special	354553092560201	Seep near Falling Water Cr	Springfield	Boone	2013	2013	1
UofA	Study	Site 1 – spring	Spring on C&H farm	Springfield	Boone	2013	2016	150
UofA	Study	House well	House well on C&H farm	Unknown	Unknown	2015	2016	76
UofA	Study	Interceptor trench 1	Interceptor trench 1	Springfield	Boone	2014	2016	40
UofA	Study	Interceptor trench 2	Interceptor trench 2	Springfield	Boone	2014	2016	22

3.3.3 Groundwater Quality in the Buffalo River Watershed

In the Ozarks, nutrients and bacteria in groundwater are a concern. The karst geology of the area makes groundwater more susceptible to contamination resulting from activities on the land surface. For the most part, groundwater in the Western Interior Plains confining system is less susceptible to contamination. Historic studies of the Springfield Plateau and Ozark aquifers in Northwest Arkansas, west of the Buffalo River watershed, found that nitrate and fecal coliform concentrations in groundwater tend to be significantly higher in these aquifers where they are overlain by large areas of pasture used for cattle production and land application of poultry litter. Higher levels of coliforms are particularly apparent following rain storms (Steele, McCalister and Adamski 1990, Daniel and Steele 1991, Steele and McCalister 1991). However, these, and other more recent studies, have found few instances of nitrate levels that exceed the drinking water standard in any of the aquifers underlying the Buffalo River watershed (Kresse, et al. 2014).

3.3.3.1 E. coli

E. coli concentrations were measured in springs included in the USNPS routine water quality monitoring program during the period 2012-2016. The USGS analyzed for coliphages in a sample from well 360656093070601 in 2016, but none were detected. Figure 3.21 shows a box and whisker plot of the *E. coli* measurements from the three USNPS monitored springs. The highest median *E. coli* concentration for these springs for this period is from Mitch Hill Spring. The median *E. coli* concentration from Luallen Spring is the lowest of the monitored surface waters or springs in the Buffalo River watershed during the 2012-2016 period.

Figure 3.21 also shows the numeric *E. coli* water quality standard for primary contact recreation. All of the *E. coli* measurements from these springs during this period were below state water quality standards for secondary contact recreation (2,050 cfu/100mL). However, there were a few *E. coli* measurements from Mitch Hill Spring and Gilbert Spring that exceeded the primary contact recreation standard. Since *E. coli* were present in all of the samples, none of these springs meet drinking water quality standards. There is anecdotal evidence that local residents may be using these springs for drinking water (Usery 2013), so this is a concern.

3.3.3.2 Total Nitrogen

Beginning in 2014, all of the nitrogen parameters needed to calculated total nitrogen have been measured in the springs included in the USNPS routine water quality monitoring program. Figure 3.22 shows a box and whisker plot of the total nitrogen results from the USNPS monitored springs during the period 2014-2016. The median total nitrogen concentration for Mitch Hill Spring is the highest of all of the monitored locations in the Buffalo River watershed. The median total nitrogen concentration for Gilbert Spring is among the highest of the median values for all of the monitored locations in the watershed. The median total nitrogen concentration for Luallen Spring is similar to the median values for the majority of the surface water quality monitoring locations in the watershed.

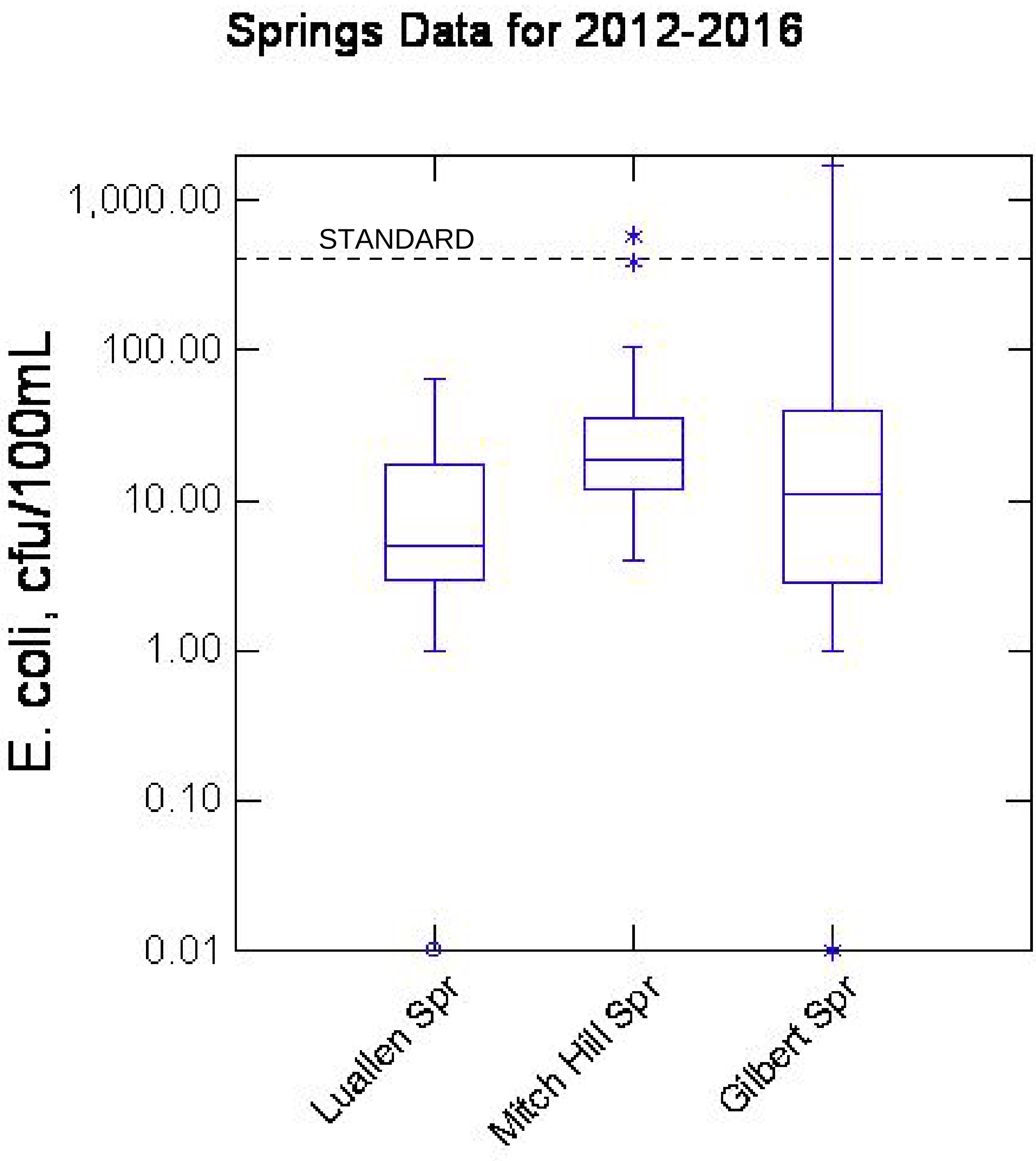


Figure 3.21. *E. coli* measurements from springs in the Buffalo River watershed, 2012-2016 with water quality standard.

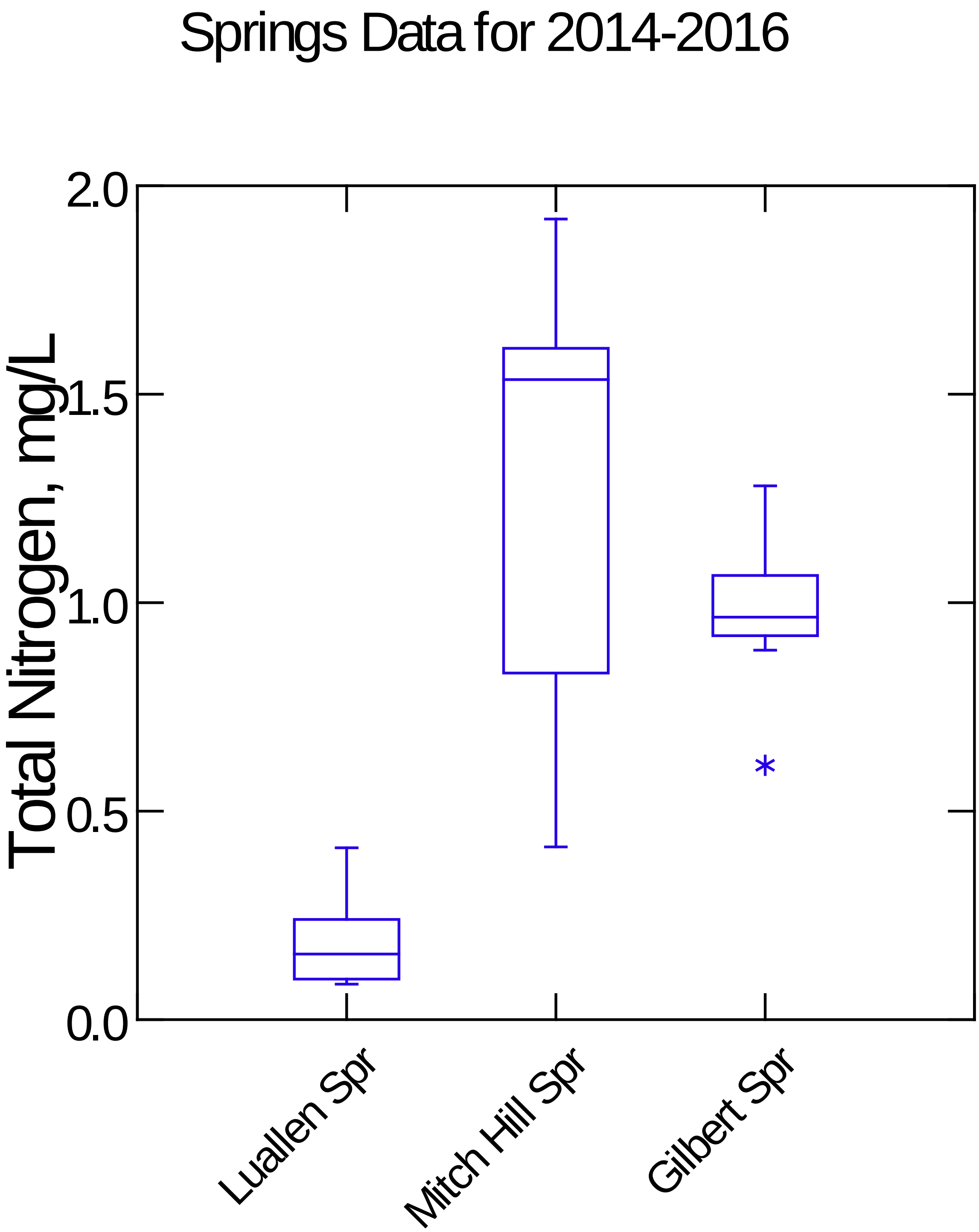


Figure 3.22 Total nitrogen measurements from springs in the Buffalo River watershed 2014-2016.

3.3.3.3 Inorganic Nitrogen

Inorganic nitrogen concentrations were measured in the springs included in the USNPS routine water quality monitoring program during the period 2012-2016. The USGS also measured inorganic nitrogen in one sample from well 360656093070601 in 2016. Figure 3.23 shows a box and whisker plot of the inorganic nitrogen measurements from USNPS monitored springs during the period 2012-2016. The single USGS inorganic nitrogen measurement from well 360656093070601 during this period was less than 0.04 mg/L. The median inorganic nitrogen concentrations for Mitch Hill Spring and Gilbert Spring are the highest of the monitored locations in the Buffalo River watershed during the period 2012-2016. Even the Luallen Spring median inorganic nitrogen concentration for this period was greater than all of the median concentrations for the Buffalo River monitoring locations, and 14 of the tributary monitoring locations. The maximum inorganic nitrogen concentrations at these springs during the period 2012-2016 are below the drinking water standards.

Based on the results of several water quality studies of primarily forested areas in the Ozarks, researchers identified 0.4 mg/L as an estimate of the maximum background, or natural, nitrate concentration for the Ozark Plateaus aquifers, such as those that feed Luallen, Mitch Hill, and Gilbert Springs (T. Kresse, et al. 2014). Figure 3.23 shows a line at the concentration 0.4 mg/L. The majority of the inorganic nitrogen measurements from Mitch Hill and Gilbert Springs during 2012-2016 were greater than 0.4 mg/L. These results suggest that these springs are being affected by non-natural sources of inorganic nitrogen. In contrast, even the maximum inorganic nitrogen measurement from Luallen Spring during 2012-2016 was less than 0.4 mg/L.

3.3.3.4 Total Phosphorus

Beginning in 2014, total phosphorus has been measured in the springs included in the USNPS routine water quality monitoring program. Figure 3.24 shows a box and whisker plot of the total phosphorus results from the USNPS monitored springs during the period 2014-2016. The median total phosphorus concentrations for the springs are similar to those for many of the tributary stations (Figure 3.13). Gilbert Spring is one of only a few monitoring locations in the Buffalo River watershed where all total phosphorus measurements are above the detection limit (non-detect results are shown as zero on the Figure 3.24 plot).

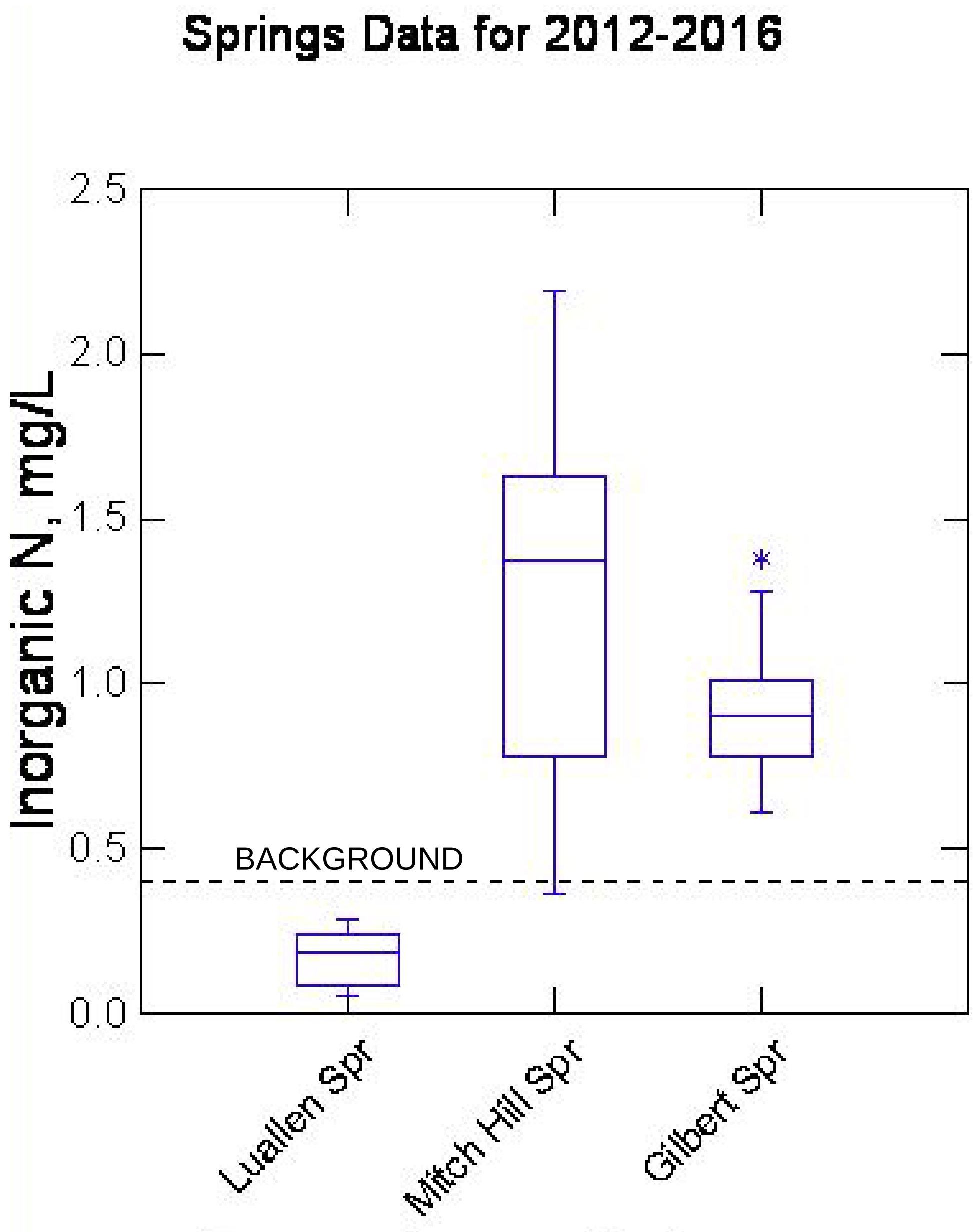


Figure 3.23. Inorganic nitrogen measurements from springs in the Buffalo River watershed, 2012-2016 showing maximum natural background.

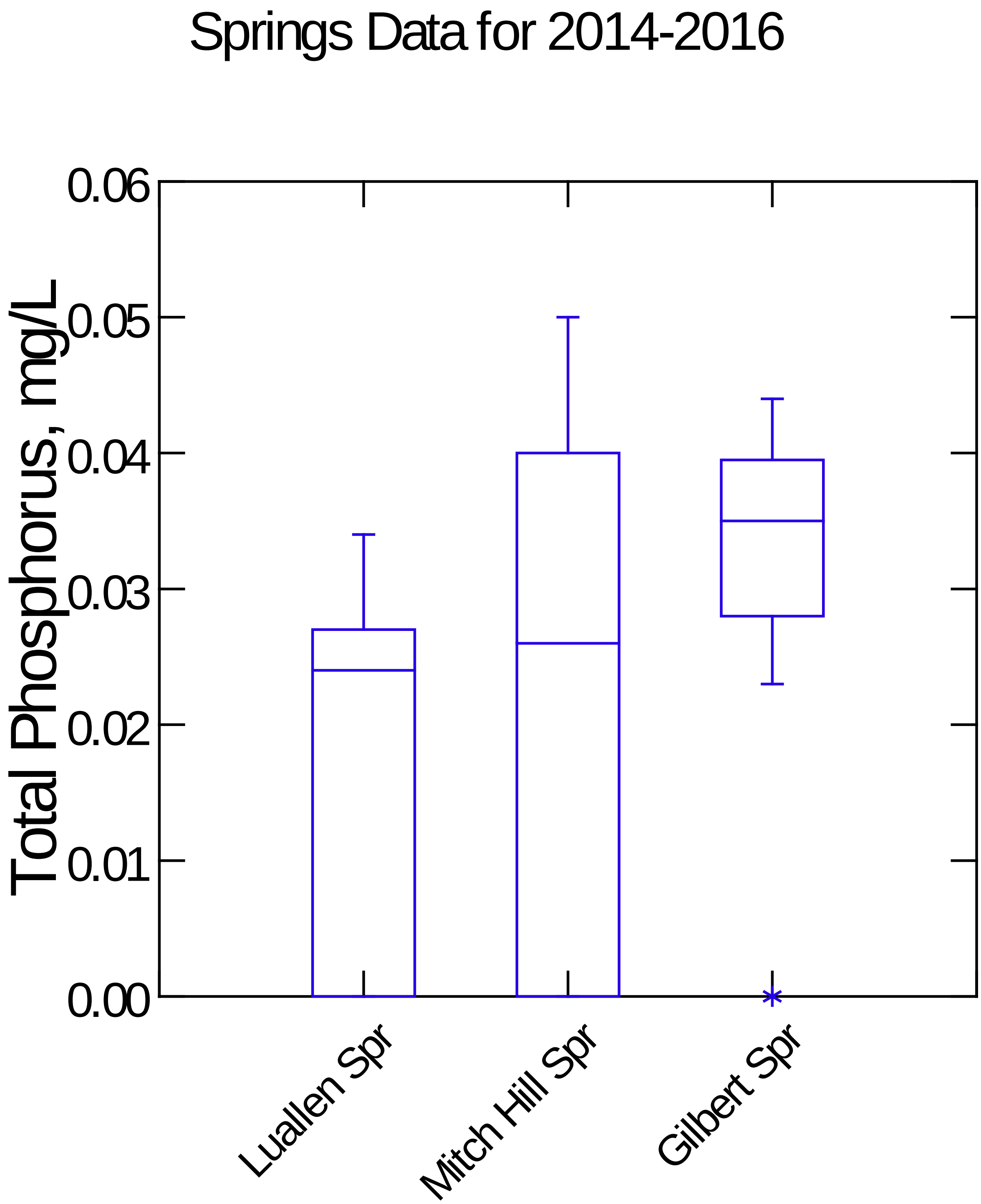


Figure 3.24 Total phosphorus measurements from springs in the Buffalo River watershed 2014-2016.

3.3.3.5 Orthophosphate

Orthophosphate concentrations are measured in the springs included in the USNPS routine water quality monitoring program during the period 2012-2016. The USGS also measured orthophosphate in one sample from well 360656093070601 during 2016. Figure 3.25 shows a box and whisker plot of the orthophosphate measurements from USNPS monitored springs during the period 2012-2016. The single USGS orthophosphate measurement from well 360656093070601 during this period was less than 0.004 mg/L. The median orthophosphate concentrations for Gilbert Spring and Luallen Spring are some of the highest of the monitored locations in the Buffalo River watershed during the period 2012-2016.

Adamski (1997) identified 0.01 mg/L as the maximum natural background concentration of orthophosphate in groundwater in the Ozark Plateaus aquifers, such as those that feed Luallen, Mitch Hill, and Gilbert Springs. Figure 3.25 shows a line at the concentration 0.01 mg/L. Orthophosphate concentrations greater than 0.01 mg/L were measured at all three springs during the period 2012-2016. All of the orthophosphate measurements from Gilbert Spring during this period were higher than the natural background concentration.

3.3.4 Spring Water Quality Trends Analysis

There are three springs in the watershed that have been monitored for water quality over a period of over 30 years. Using the same method as for the surface water quality data (see Section 3.2.5), the data from these long record locations was evaluated to determine if statistically significant changes in water quality were evident for fecal coliforms, inorganic nitrogen, and turbidity. Results of this analysis are summarized in Table 3.13. The notched box and whisker plots of these data are included in Appendix D.

Table 3.13. Spring water quality monitoring locations with statistically significant changes between 10-year periods.

Station Location	Parameter	Change between 1985-1994 and 1995-2004*	Change between 1995-2004 and 2005-2015*	Change between 1985-1994 and 2005-2015*
Mitch Hill Spring	Fecal coliform	Increase	Increase	**INCREASE**
	Inorganic N	**INCREASE**	**INCREASE**	**INCREASE**
Gilbert Spring	Inorganic N	**INCREASE**	Decrease	Increase

*ALL CAPS indicate statistically significant increase

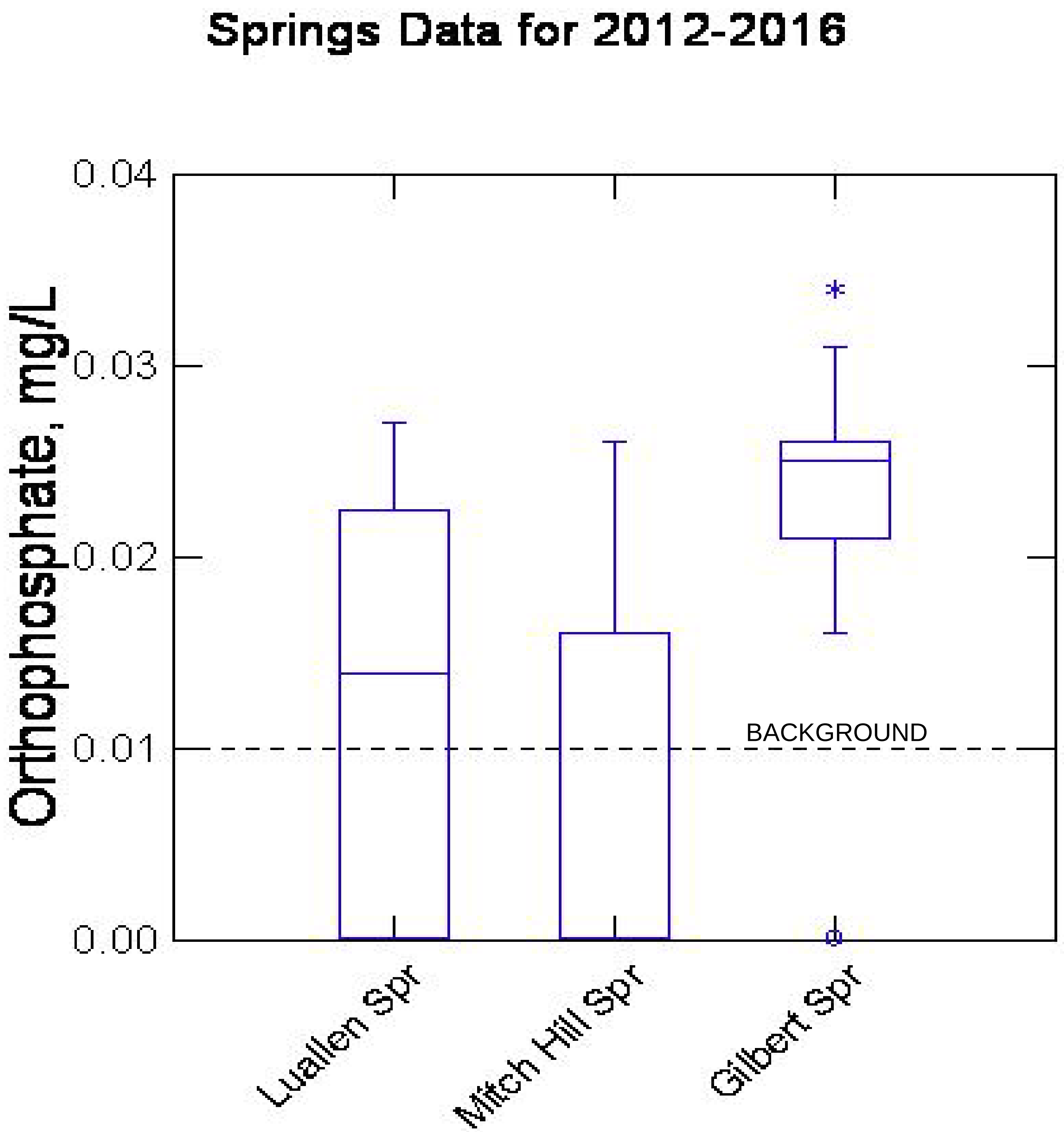


Figure 3.25. Orthophosphate measurements from springs in the Buffalo River watershed, 2012-2016 showing maximum natural background.

3.3.5 Groundwater Quality Summary

The three monitored springs exhibit differences in water quality that reflect differences in geology and land use in their recharge areas. The median inorganic nitrogen concentration for Mitch Hill Spring is the highest of the monitored locations in the Buffalo River watershed during the period 2012-2016. Over 75% of the inorganic nitrogen concentrations measured at this spring are above the reported natural background levels, but all are below the drinking water standard. Inorganic nitrogen concentrations, and fecal coliform levels, in Mitch Hill Spring appear to be increasing over time.

Phosphorus levels in Gilbert Spring are highest of the monitored springs.

Median concentrations of inorganic nitrogen and *E. coli* in Luallen Spring during the period 2012-2016 are lower than for the other springs, and among the lowest of the monitored locations in the Buffalo River watershed. The median orthophosphate concentration for Luallen Spring during this period is between the median values for Gilbert Spring and Mitch Hill Spring.

There is anecdotal evidence that springs in the Buffalo River watershed, including the three monitored springs, are occasionally used by locals for drinking water. Because *E. coli* are present in all three of the monitored springs, they do not meet drinking water standards.

3.3.6 Groundwater Quality Data Gaps

Previous studies of springs in the Buffalo River watershed, and bacteria and nutrient levels in the monitored springs, suggest that groundwater has the potential to impact surface water quality in the watershed. There are over 200 springs in the Buffalo River watershed, but water quality data are routinely collected from only three (USNPS n.d.). It would be useful to have routine water quality monitoring at other springs in the watershed. Adding water quality monitoring at springs that are known or suspected of contributing to surface water quality issues in the watershed, e.g., Dogpatch Springs, should be the priority.

4.0 WATERSHED CONDITION

This plan section describes the condition of the Buffalo River watershed in terms of elements other than water quality. These elements include aquatic communities, hydrology, and channel stability.

HIGHLIGHTS

- The Buffalo River and its tributaries have diverse populations of fish, mussels, and other aquatic invertebrates.
- The condition of fish communities in the Buffalo River is generally classified as good or excellent, although fish in some tributaries might be impacted.
- The condition of aquatic invertebrate communities at monitored locations in the Buffalo River and its tributaries are classified as fair to very good.
- The invasive species Asian Clam is present in the Buffalo River.
- Filamentous algae appear to be more prevalent at monitored locations in the lower Buffalo River.
- There is one cave site in the watershed assessed as having a high threat level with regard to water quality and aquatic species.
- Many streams in the watershed have unstable geomorphology, and streambank erosion is a concern in many areas.
- There has been no significant change in flows over time.

4.1 Aquatic Communities

Aquatic communities respond to, and integrate, changes in habitat, including water quality, and are useful indicators of stream health. The condition of aquatic communities is characterized based on information such as the abundance of animals, the number of different species present, the water quality and habitat requirements of the species that are present, and how sensitive the species that are present are to changes in water quality or physical habitat. In many cases, selected information about the aquatic communities present are used to develop a score or grade that reflects the health of streams, such as an Index of Biotic Integrity (IBI) for fishes or Stream Condition Index (SCI) for macroinvertebrates.

4.1.1 Fish Communities

USGS and ADEQ have conducted fish community surveys in the Buffalo River watershed. USGS has conducted fish surveys at over 40 locations in the watershed. Two locations on the Buffalo River and two on tributaries, were surveyed as part of the National Water Quality Assessment Program. These surveys were conducted in 1995 and 2006 (Petersen 1998, Justus et al. 2010). The USGS also surveyed 42 locations in the watershed in 2001 and 2002. This included 10 locations on the Buffalo River, and 32 locations on tributaries, with 12 survey locations in the upper reaches or headwaters of selected tributaries (Petersen 2004a). ADEQ conducted fish surveys in two Buffalo River tributaries in 1999, and at locations on the Buffalo River in 2009, 2011, and 2014. Locations where USGS and ADEQ conducted fish surveys are shown on Figure 4.1. Historical surveys of fish communities in the Buffalo River watershed, and evaluation of information from the survey results, do not appear to indicate that fish communities are being negatively affected by water pollution or habitat alteration (Petersen 2004a).

In 2006, the USNPS Heartland Network Inventory and Monitoring Program initiated a fish community monitoring program to characterize and track the condition of the Buffalo River and its tributaries. Through this program, six locations on the Buffalo River were sampled annually from 2006 to 2010 and 30 tributaries sampled every five years (six tributaries sampled each year) (Petersen, Justus, et al. 2008). The USNPS fishsurvey locations are shown on Figure 4.1. Following revision of the protocols of the fish community monitoring program in 2012, the USNPS continued fish sampling in 2013 (DeBacker, et al. 2012, Schwoerer and Dodd 2016). Through 2013, a total of 54 fish species have been collected through the USNPS monitoring program. The greatest number of species (46) has been collected at the Buffalo River sampling location near Tyler Bend (BM04). The farthest upstream sampling location on the Buffalo River (BM01) has the fewest species; 29.

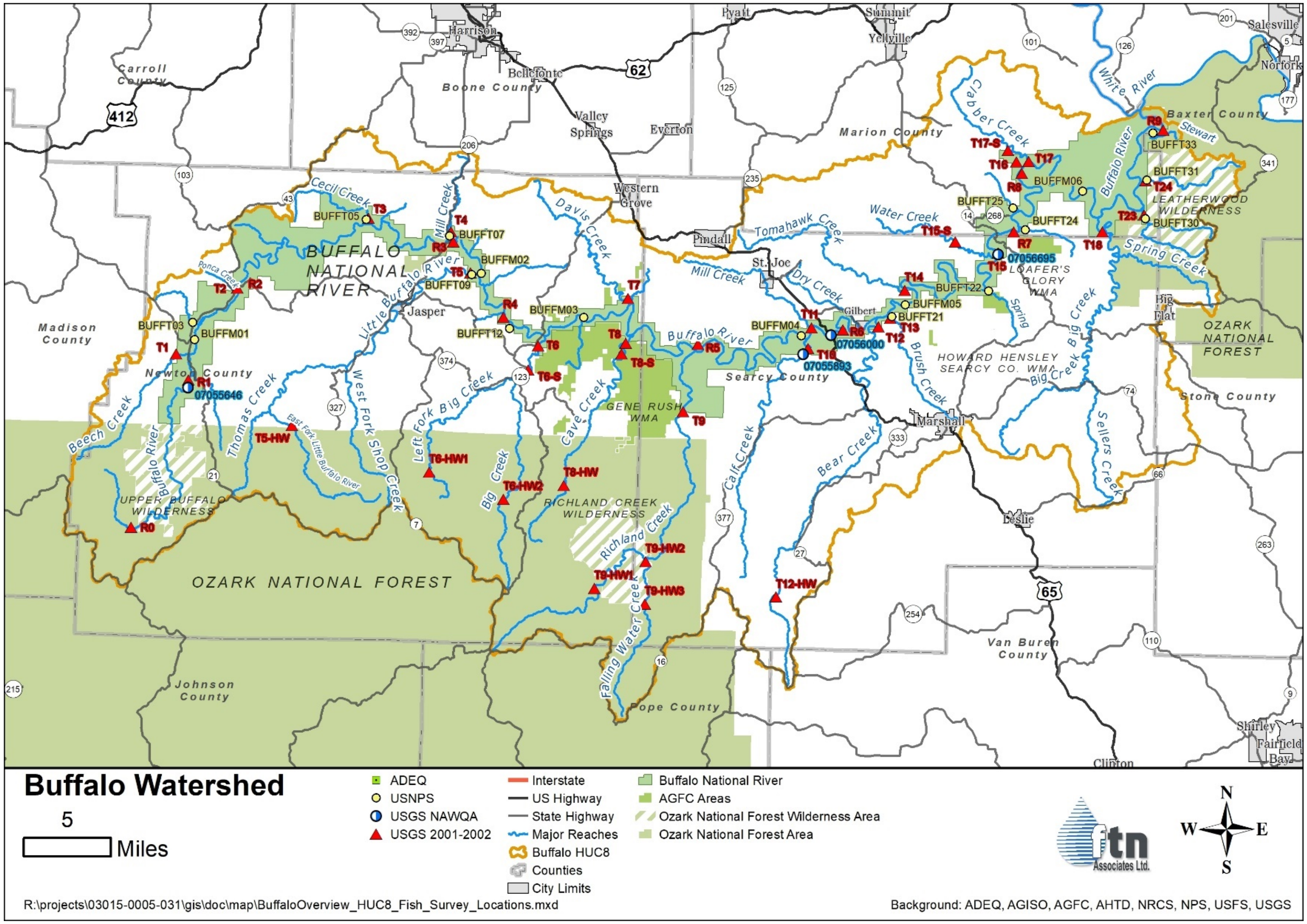


Figure 4.1. Fish survey locations in the Buffalo River watershed.

An Index of Biotic Integrity (IBI) has been used by researchers to classify the condition of the fish communities at biological monitoring locations in the Buffalo River watershed (Petersen 2004a, Dodd 2009). IBI values greater than or equal to 60 indicate the fish community is not adversely impacted (i.e., classified as good or excellent/reference condition) (Schwoerer and Dodd 2016). Figure 4.2 shows Buffalo River and tributary fish IBI values reported by Petersen (2004a) and Dodd (2009). Several of the tributaries have IBI values below 60. IBI values based on the USNPS fisheries data collected from just the Buffalo River stations for the period 2006 through 2013 were within the ranges for streams with “Good” to “Reference” levels of fish community condition (Figure 4.3). There are a number of sensitive fish species present in the Buffalo River that would be vulnerable to changes in habitat, temperatures, and/or flow regimes (Schwoerer and Dodd 2016).

4.1.2 Aquatic Invertebrates

Studies in the Buffalo River watershed have determined that there were localized impacts to aquatic invertebrate communities. A macroinvertebrate survey of Mill Creek (upper) in 1990 found aquatic insect assemblages to be impacted (Maner and Mott 1991, Apel 1990, Matthis 1990). Matthis (1990) also characterized the aquatic invertebrate community of the Buffalo River at Ponca as impacted. Mott and Laurans (2004) report that Bryant (1997) and Usrey (2001) classified the aquatic invertebrate communities in the middle reaches of the Buffalo River as impacted by water quality. The impact manifested as shifts in the invertebrate communities, along with increased prevalence of the invasive exotic Asian Clam. Asian Clam can only displace native invertebrates when the native populations are stressed or impaired. Bryant (1997) and Usrey (2001) found that invertebrate species richness and diversity were negatively correlated with nitrate concentration, i.e., where species richness and diversity were lower, nitrate concentrations were higher. A study of four Buffalo River tributaries by Bradley (2001) found that tributaries with disturbed watersheds had lower percentages of pollution sensitive species, higher percentages of pollution tolerant species, and lower species diversity than a tributary with a largely forested watershed.

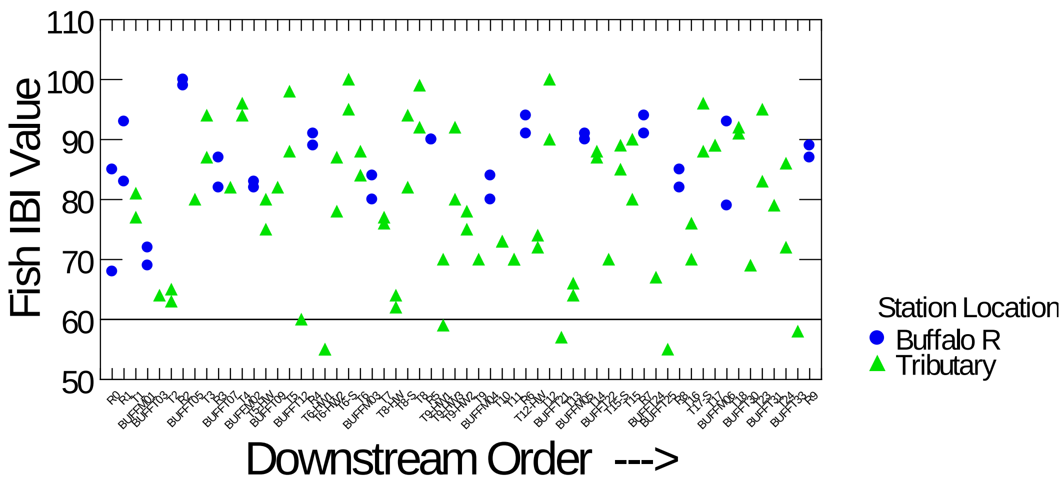


Figure 4.2. Reported Fish IBI score values from 2001-2007.

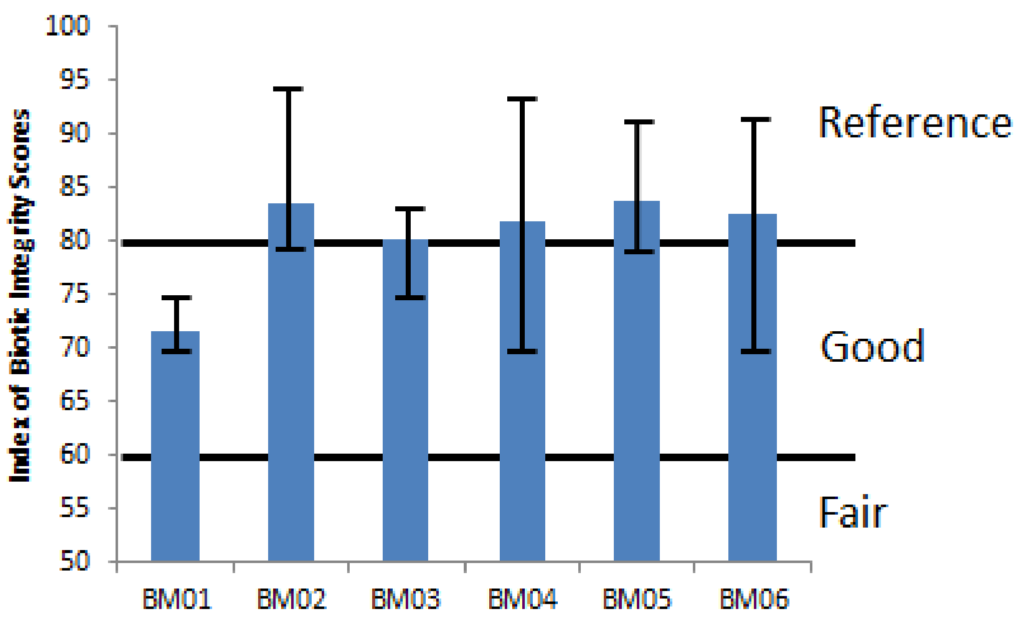


Figure 4.3. Fish Index of Biotic Integrity scores base on 2006-2013 samples (from Schwoerer and Dodd 2016).

Mott and Laurans (2004) also summarized aquatic invertebrate surveys that have been conducted for several springs in the Buffalo River watershed. Mathis (1994) surveyed aquatic invertebrates in Fitton, Chestnut, and Hutchinson Springs. He found the aquatic invertebrate communities of these springs to be richer and more diverse than springs in the Ozarks that have poorer water quality. Jackson (2001) also studied aquatic invertebrate communities in springs within the Buffalo River watershed. In this study, seven springs were sampled; Luallen, Lost Valley, Leatherwood, Fitton, Hutchinson, Mitch Hill, and Gilbert Springs. The water quality of these seven springs was similar. Differences in the aquatic invertebrate communities associated with these springs was found to be the result primarily of differences in how consistently the springs flowed through the year, as well as the substrate, and whether there were plants growing in the spring.

In 2005, the USNPS Heartland Network Inventory and Monitoring Program initiated an aquatic invertebrate sampling program to characterize and track the condition of the Buffalo River and its tributaries (Bowles, et al. 2007). Through this program, six locations on the Buffalo River were sampled annually through 2009 and then biannually. This program also sampled 24 locations on tributaries. The tributary locations were split into five groups, and a different group was sampled each year (Bowles, Luraas, et al. 2007, Bowles 2015). Sampling locations for the USNPS aquatic invertebrate monitoring program are shown on Figure 4.4.

ADEQ also evaluates aquatic invertebrate communities throughout the State. ADEQ sampled aquatic invertebrate communities in several Buffalo River tributaries in 1999 and 2001, and at two locations on the Buffalo River in 2010 (ADEQ 2017a). The 2010 sampling locations are shown on Figure 4.4.

The EPA conducted a population census of aquatic invertebrates at a location on the Buffalo River as part of the 2001 National Aquatic Resource Survey Wadeable Streams Assessment. The USGS has surveyed aquatic invertebrates at locations on the Buffalo River and two of its tributaries as part of the National Water Quality Assessment Program (Justus, et al. 2010).

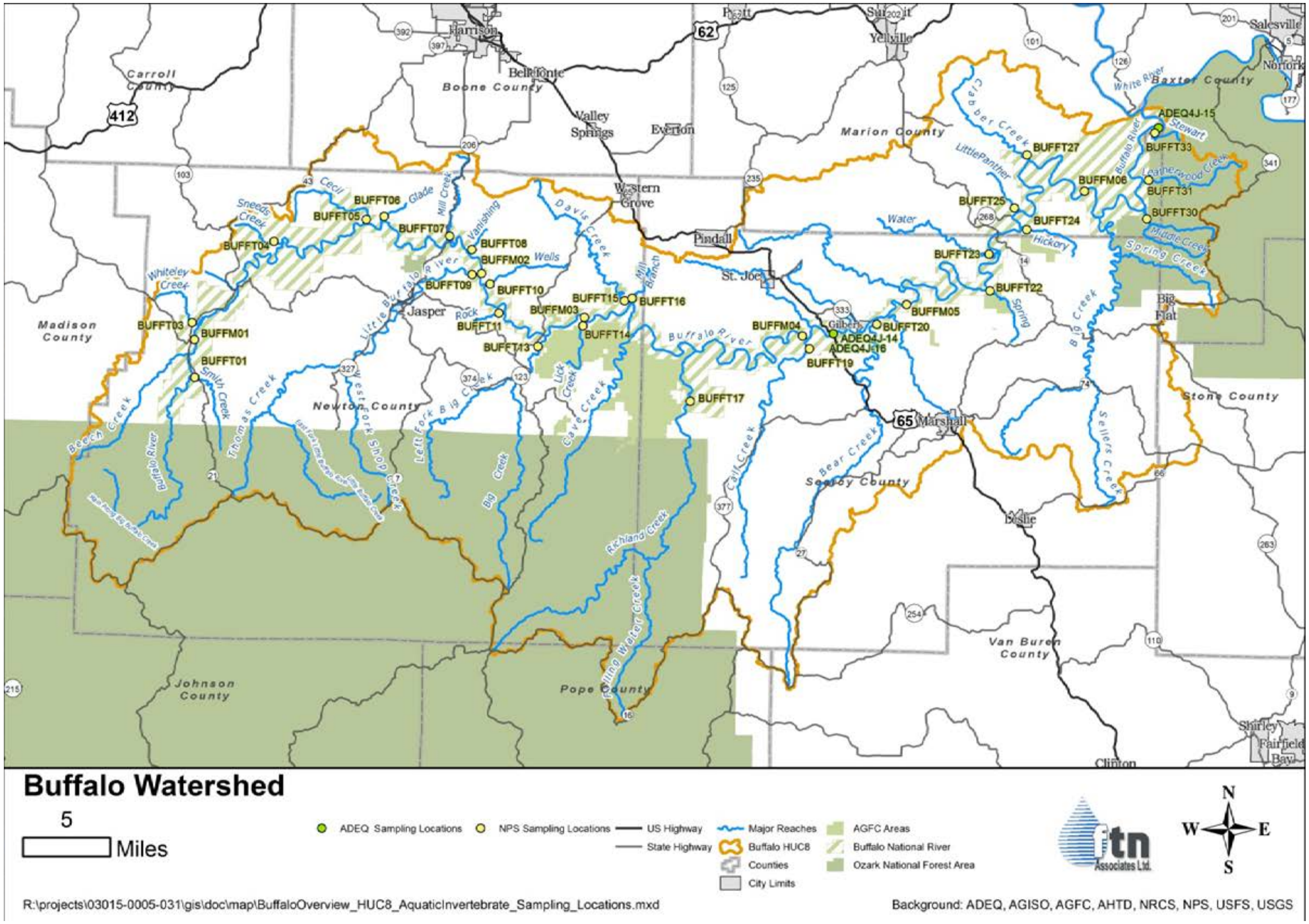


Figure 4.4. Aquatic invertebrate survey locations in the Buffalo River watershed.

Based on the results of the USNPS monitoring program, the aquatic invertebrate communities within the Buffalo River are diverse and include species sensitive to disturbance and water quality pollution. A Stream Condition Index (SCI) based on the data from the USNPS monitoring program has been used by researchers to classify the condition of the aquatic invertebrate communities at USNPS monitoring locations in the Buffalo River watershed. SCI values greater than or equal to 16 indicate the invertebrate community is not adversely impacted (Bowles 2015). SCI values reported in Bowles et al. (2013), and Bowles (2015) are shown on Figure 4.5. Although SCI values below 16 are found in the watershed, the researchers conclude that these low SCI values are more reflective of natural variability in the aquatic invertebrate communities than indicative of water quality impacts. Overall, they conclude the aquatic invertebrate communities in the streams in the Buffalo National River are in good condition (Bowles, Hinsey, et al. 2013, Bowles 2015). Based on one index of biotic integrity for aquatic invertebrates, the condition of aquatic invertebrate communities in the Buffalo River ranges from “Fair” to “Very Good” (Figure 4.6) (Schwoerer and Dodd 2016).

Surveys of mussels in the Buffalo River have not found evidence of declines in native mussels. The native mussel population in the river is characterized as “moderately diverse and abundant” (Matthews, et al. 2009). The majority of the native mussel species found in the Buffalo River are species of conservation concern. The presence of stable populations of these mussel species of conservation concern make the Buffalo River an important refuge for mussel species that are declining state-wide and nationally (Harris 1996, Matthews, et al. 2009).

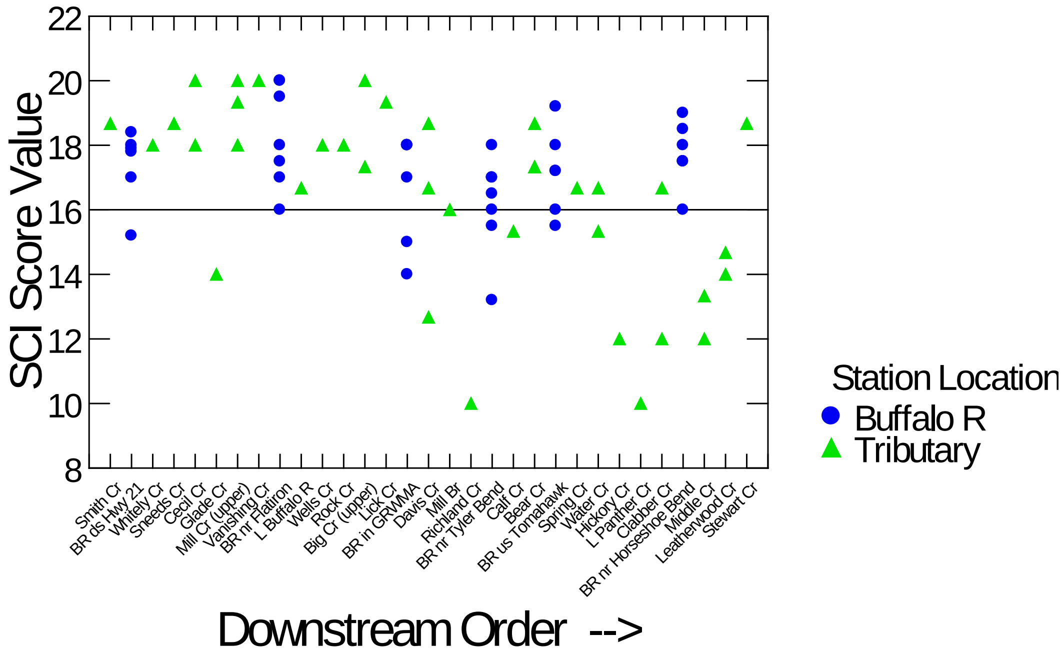


Figure 4.5. Reported aquatic invertebrate SCI score values for 2005-2011.

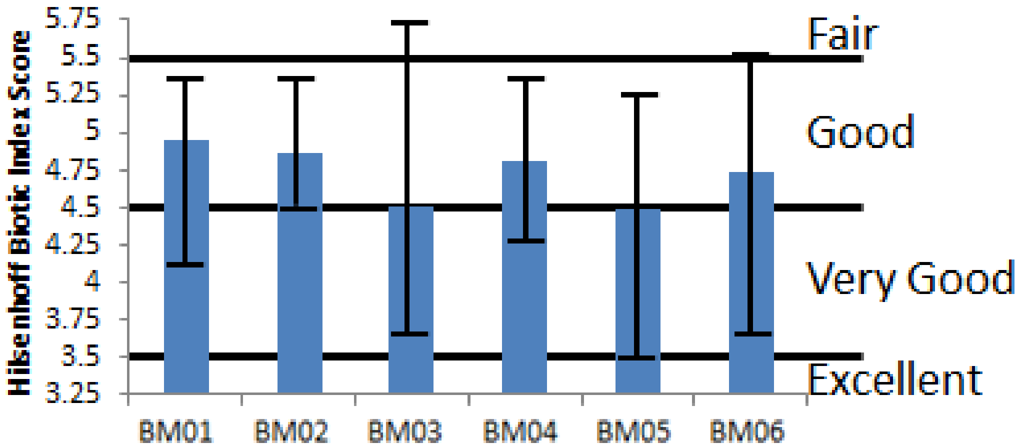


Figure 4.6. Aquatic invertebrate Index of Biotic Integrity Scores based on USNPS samples from 2005-2013 (from Schwoerer and Dodd 2016).

4.1.3 Periphyton

Periphyton are algae that are attached to the bottoms of streams, rivers, and lakes. Periphyton is the most common type of algae present in the Buffalo River (Mott and Laurans 2004). Meyer and Rippey (1976) conducted an extensive survey of algae, including periphyton, in the Buffalo River in the 1970s. They found that periphyton occur in both disturbed and undisturbed streams in the watershed. Natural distribution and species present in periphyton communities of the Buffalo River depends on how consistent flow is, and diversity of available habitat. In general, periphyton species diversity increases downstream in the Buffalo River (Meyer and Rippey 1976).

More recently, the USGS has studied periphyton in the Buffalo River watershed as part of the National Water Quality Assessment Program. The USGS collected data on the amount of periphyton present at six locations in the watershed as part of this program. These data were collected in 1993-1995 and 2003-2006 (Petersen and Femmer 2003). The locations sampled for this program are shown on Figure 4.7.

As part of the USNPS aquatic invertebrate sampling program (see Section 4.1.2), the percentage of the sampling grid with filamentous algae and periphyton is recorded. Figure 4.8 shows the range of percentages recorded at each of the USNPS aquatic invertebrate sampling locations during the period 2005 through 2011. The graphs show that, of the locations monitored, the downstream locations tend to have more filamentous algae, and greater areas of periphyton tend to occur at Gilbert and Maumee. The greater occurrence of filamentous algae at the downstream locations may be a response to higher nutrient levels (Bowles, Hinsey, et al. 2013).

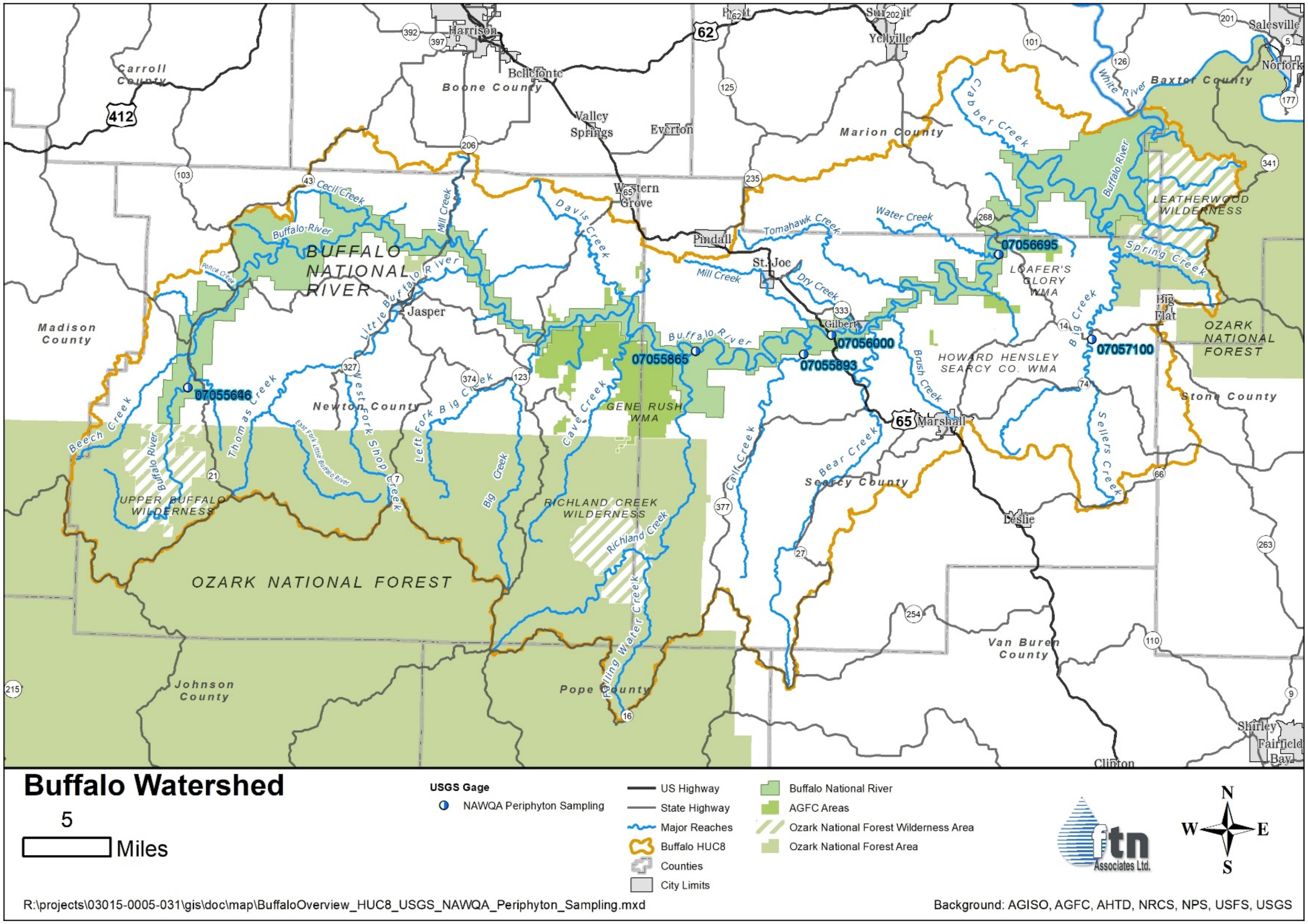
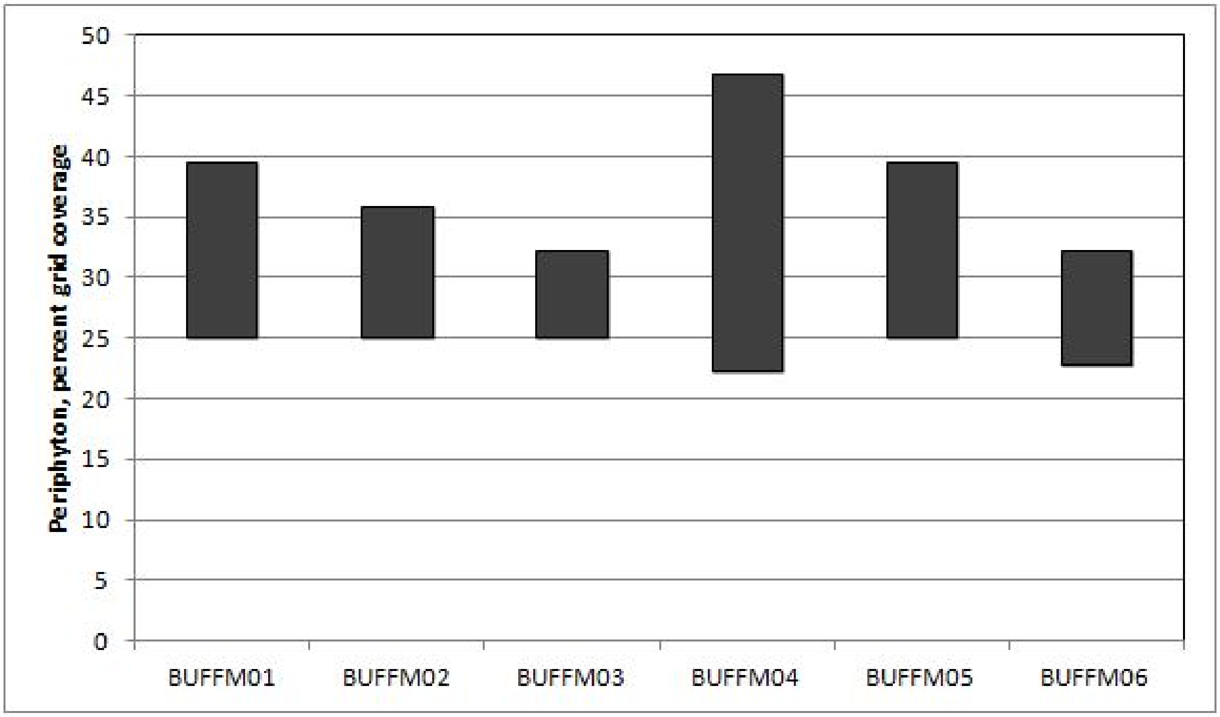


Figure 4.7. USGS NAWQA Buffalo River periphyton sampling locations.



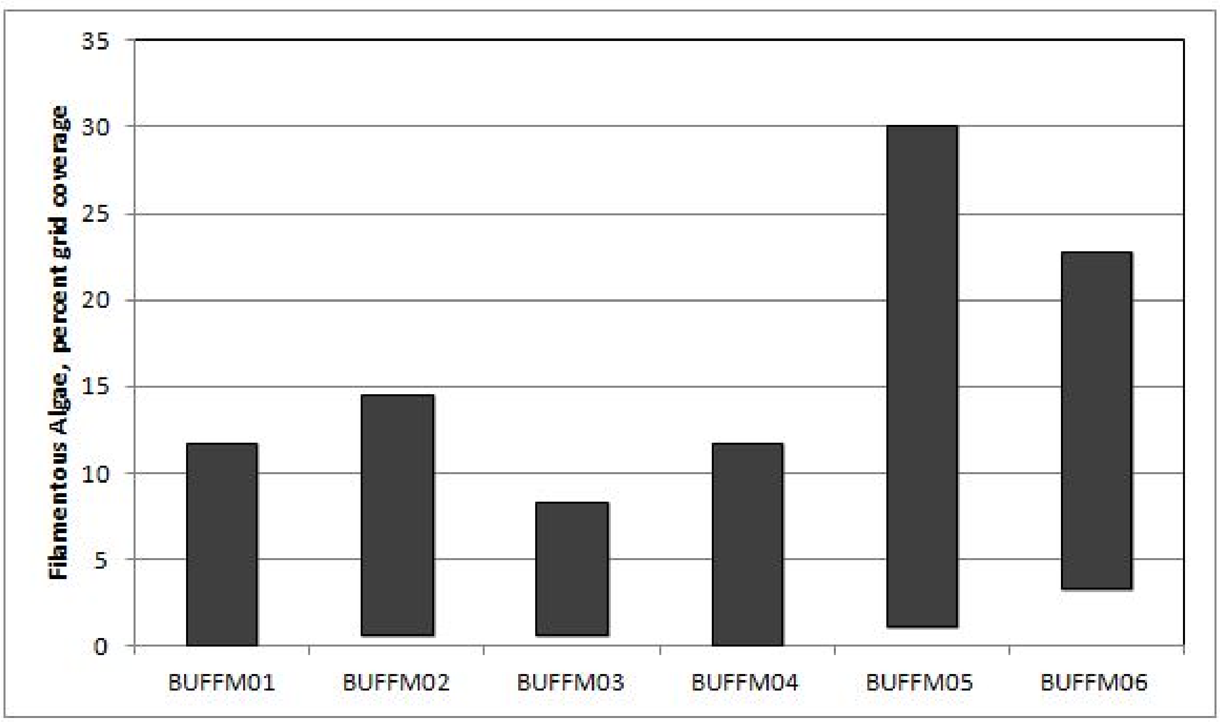


Figure 4.8. Periphyton coverage measurements at USNPS biological sampling locations.

Petersen and Femmer (2003), evaluating periphyton data from the USGS National Water Quality Assessment Program, found that, in Ozark streams, the amount of blue-green species of periphyton tended to increase as the percentage of the stream watershed in agricultural land use increased. They also found that the amount of diatom algae increased as stream alkalinity increased, and stream orthophosphate, total phosphorus, and dissolved organic carbon decreased. Therefore, the presence of large amounts of blue-green species is considered indicative of poorer water quality, while the presence of large amounts of diatom algae is considered indicative of better water quality. When Meyer and Rippey (1976) surveyed algae in the Buffalo River, diatoms were the most abundant and diverse algal species. In samples collected from the Buffalo River and selected tributaries during 1993 through 1995, blue-green algae were the most abundant (Petersen and Femmer 2003). This could be the result of changes in water quality, or differences in sampling methods.

Algal blooms have, and continue to, cause concern on the Buffalo River. "Large clumps of algae" were noted in the Buffalo River downstream of the Mill Creek (upper) confluence during a 1991 water quality survey. The algae growth was believed to be supported by high nutrient water from Mill Creek (upper) (Maner and Mott 1991). Algal blooms in late summer are often extensive enough that visitors voice concern (Petersen and Femmer 2003, Schwoerer and Dodd 2016). Algae were reported by tourists in the Buffalo River between Highway 65 and Spring Creek during September 2016. The algae were identified as green algae species from samples collected by USGS and USNPS (Walkenhorst 2016).

The USNPS is currently working with ADEQ to develop an algae monitoring program that will improve the ability to characterize the algal communities of the Buffalo River and its tributaries, track changes in algal communities, identify drivers behind algal blooms, and track the incidence of algal blooms (S. Hodges, personal communication, 9/5/17).

4.1.4 Aquatic Habitat

Physical habitat in streams is a combination of factors that support aquatic organisms, including water depth, water velocity, channel substrate (i.e., what kind of material makes up the stream bottom), and cover. Physical habitat in streams, and the condition of that habitat, varies naturally, but can also be affected by human activities.

Physical habitat information was collected from 42 locations on the Buffalo River and its tributaries during 2001-2002 as part of a USGS study (Petersen 2004b). Information on aquatic habitat is collected as part of the USNPS aquatic invertebrate and fish survey programs. Table 4.1 lists aquatic habitat variables that are monitored by USNPS. No reports were found characterizing the condition of aquatic habitat in the Buffalo River or its tributaries.

Table 4.1. Aquatic habitat variables monitored by USNPS (Petersen, Justus, et al. 2008, Bowles, Luraas, et al. 2007, DeBacker, et al. 2012).

Habitat Variable	Invertebrate Habitat	Fish Habitat
Riffle length	X	--
Stream width	X	X
Percent embeddedness of substrate	X	X
Percent periphyton	X	--
Percent filamentous algae	X	--
Percent sedimentation	X	--
Percent organic material	X	--
Substrate size	X	X
Velocity	X	X
Depth	X	X
Channel unit type	--	X
Pool form	--	X
Canopy cover	--	X
Presence of man-made structures	--	X
Fish cover	--	X
Stream bank stability	--	X
Stream bank angle	--	X
Stream bank material	--	X
Percent of stream bank with vegetation	--	X
Stream bank height	--	X
Type of cover on bank (e.g., plants, rip-rap)	--	X

4.1.5 Cave Aquatic Habitat and Species

A survey of reptiles and amphibians in the Buffalo National River environs found abundant and healthy populations of amphibians associated with caves and springs. As a result, the authors characterized the cave ecosystems in the National Park as “secure and healthy” (Wiggs and Angelo 2003).

The Nature Conservancy recently conducted a literature-based survey of the occurrence of state Species of Greatest Conservation Need associated with cave habitats in the Ozarks region of Arkansas (Inlander, Gallipeau, & Slay 2011). In addition, Inlander et al. (2011) evaluated threats to these species. This study included 35 cave habitat sites within the Buffalo River watershed where aquatic Species of Greatest Conservation Need have been identified. The majority of these sites were classified as having medium-low or low threat scores for aquatic Species of Greatest Conservation Need. Four sites had threat scores in the medium range, and one site had a threat score in the medium-high range. The site in the Buffalo River watershed with the highest threat score for aquatic species was classified as being highly susceptible to groundwater contamination, which could impact the species. Three other sites in the watershed were classified as having a medium risk of groundwater contamination. All of the remaining sites with aquatic Species of Greatest Conservation Need had medium-low to low risk of groundwater contamination (Inlander, Gallipeau, & Slay 2011).

4.2 Geomorphology and Channel Stability

Stream geomorphology addresses the relationships between characteristics of a stream watershed (i.e., topography, geology, and land use) and the shape of the stream channel (i.e., width, depth, and slope). A “stable” stream channel experiences only small changes in shape or location over time. Panfil and Jacobson (2001) conducted geomorphological analysis of several Buffalo River tributaries in 1999. Table 4.2 is a summary of stream channel characteristics reported by Panfil and Jacobson.

Table 4.2. Summary statistics for 19 stream reaches of Buffalo River tributaries (from Panfil and Jacobson 2001).

Characteristic	Mean	Standard deviation	Median	Minimum (tributary)	Maximum (tributary)
Slope	0.00423	0.00282	0.0041	0.0009 (Richland Cr)	0.0106 (Middle Cr)
Bankfull width (m)	22.1	7.9	19.4	13.9 (Brush Cr)	36.4 (Big Cr middle)
Bankfull depth (m)	0.89	0.24	0.85	0.5 (Brush Cr)	1.50 (Richland Cr)
Pool depth (m)	0.36	0.17	0.32	0.15 (Middle Cr)	0.80 (Richland Cr)
Pool length (m)	87.6	65.9	65.2	21.4 (Middle Cr)	258.1 (Cave Cr)
Percent pools	29	14	22	10 (Brush Cr)	50 (Little Buffalo)
Percent of pools that are persistent	70	16	75	43 (Rush Cr)	95 (Richland Cr)

Mott and Laurans (2004) concluded that the geomorphology and channel stability of the Buffalo River and its tributaries have been affected by historic and recent land clearing in the watershed. Removing forest from watersheds, and particularly streambanks, tends to increase erosion, which changes the sediment load in streams. Changes in sediment load result in changes in stream characteristics such as channel width and depth, and/or stream slope. Panfil and Jacobson (2001) found that Buffalo River tributaries with larger areas of carbonate bedrock and cleared land in their watersheds have shallower channels, fewer persistent pools, more gravel in the streambed, and more eroding banks than tributaries with sandstone bedrock and little cleared land. In addition, the size of gravel bars in the Buffalo River downstream of where tributaries join the river are larger when the tributary watershed has larger areas of carbonate bedrock and cleared land.

Other researchers postulate that climate change is contributing to instability in the Buffalo River stream system. The stream channels in the Buffalo River watershed originally formed in a climate different from the current climate. The high-intensity rainstorms that are more prevalent now than in the past, exceed the capacity of the stream channels, contributing to instability (S. Hodges, USNPS, personal communication 9/5/17).

The presence of moderate to severe bank erosion is an indicator of stream channel instability. Mott and Laurans (2004) report that in 1994 the USNPS identified 14 sites along the Buffalo River in need of streambank restoration, encompassing a total of 5,736 feet of streambank. In 1999, Panfil and Jacobson (2001) evaluated channel stability for 19 stream reaches on Buffalo River tributaries. They found that, on average, 16% of streambanks were severely eroding, and 46% were moderately to severely eroding. Stream reaches of Middle Creek had the lowest percentages of severe, and moderate to severe, bank erosion. Stream reaches of Calf Creek had the highest percentages of severe, and moderate to severe, bank erosion (Panfil and Jacobson 2001). The USNPS is currently actively managing several sites on the Buffalo River with severe bank erosion (USNPS 2009).

Debacker et al. (2012) have proposed that geomorphological information be collected for the Buffalo River (not tributaries) as part of the USNPS fish sampling program (see Section 4.1.1). Morphological information that is proposed to be monitored at Buffalo River fish sampling locations includes: longitudinal stream profiles; proportion of glides, riffles, runs, and pools; proportion of stream bank that is eroded; stream channel bottom profile; substrate size; and presence and size of point bars and islands.

4.3 Hydrology

Information on flow monitoring in the Buffalo River watershed is included in Section 2.8.1. The USGS analyzed flow data from their stream gage on the Buffalo River near St. Joe (0705600) for water year 1940 through 1998, and found no change in the discharge pattern nor annual peak instantaneous discharges over time. Trends in baseflow and runoff were also examined, but no unusual changes were identified (Mott and Laurans 2004). More recently, the USGS analyzed flow data from 1951-2011 for 38 stream gages across the state to identify long term trends. One of the stream gages analyzed was on the Buffalo River near St. Joe (0705600). No statistically significant long-term trends were identified in annual, seasonal, peak, or minimum Buffalo River flows (Wagner, Krieger, and Merriman 2014).

4.4 Data Gaps

The USNPS aquatic invertebrate and fish community monitoring programs, and associated collection of periphyton and aquatic habitat characteristics data, will become more useful as they continue and more data is collected. Consideration should be given to monitoring populations of endangered/threatened aquatic species, or aquatic species of greatest conservation need in the watershed.

Stakeholder concerns about algal blooms in the Buffalo National River will be better addressed through the algae monitoring program currently being developed.

An index of habitat quality either needs to be developed for, or applied to, the data being collected, for that information to be useful for characterizing condition.

Consideration should also be given to periodic repetition of surveys of cave habitats and species in the watershed, as well as surveys of mussel populations.

A geomorphologic survey of the Buffalo River and its tributaries would be useful to identify areas where stream banks and beds are stable, eroding, or agrading. There is some evidence the Buffalo River is becoming shallower, wider, and warmer because of changing geomorphology. Collection of geomorphological data during routine fish surveys would be beneficial for identifying and tracking changes over time.

The hydrology of the Buffalo River watershed is complicated, with water moving frequently between the surface and underground. Additional research will continue to improve understanding of the flow sources and sinks in the watershed, including quantification of these sources and sinks. This, in turn, will contribute to improved understanding of water quality conditions and potential threats. More frequent flow measurements on tributaries and springs where water quality data are collected would be helpful for improving estimates of pollutant loads.

5.0 WATERSHED POLLUTION SOURCES ASSESSMENT

This section provides an overview of pollution sources in the Buffalo River watershed. Pollution sources in the watershed include regulated and unregulated sources. Activities at regulated sources are subject to state and/or federal laws that are intended to protect the quality of water resources, both surface and groundwater. Activities at unregulated sources are not subject to federal or state laws for protection of water quality. Regulated sources include point sources, such as wastewater treatment plants that discharge wastewater through a pipe into a stream; and some nonpoint sources, for example stormwater runoff from industrial sites, or littering in the Buffalo National River. An example of unregulated pollution sources is runoff from forest land or pasture.

HIGHLIGHTS

- There are pollution sources in the watershed regulated through state and federal programs.
- The primary unregulated pollution sources in the watershed include pastures and hayland, some onsite wastewater treatment systems, and forested land.

5.1 Regulated Point Sources

There are five facilities permitted to discharge wastewater in the Buffalo River watershed under the federal National Pollution Discharge Elimination Program (NPDES) (Table 5.1). In Arkansas, this program is administered by ADEQ. These permits are for municipal wastewater treatment plants. The City of Marshall municipal wastewater treatment plant has been identified by ADEQ as contributing to exceedance of TDS water quality standards in Bear Creek.

Table 5.1. NPDES permitted point sources discharging in the Buffalo River watershed (ADEQ 2017b).

Permit No.	Type	Facility Name	Receiving Reach	Receiving Stream/ Subbasin	Reported Permit Violations?
AR0034941	Domestic	Buffalo Point Lower Plant	004	Buffalo River	No
AR0034959	Domestic	Buffalo Point Upper Plant	004	Panther Creek	No
AR0034088	Domestic	Marble Falls SID No. 1 – WWTP	012	Mill Creek (upper)	Yes
AR0034584(c)	Municipal	City of Jasper	015	Little Buffalo River	No
AR0034011(c)	Municipal	City of Marshall	026	Forest Creek	No
ARG640167	Filter Backwash	Deer Community Water Association	--	Little Buffalo R	No

The Marble Falls Sewage Improvement District (SID) wastewater treatment plant (WWTP) has a history of problems affecting both surface and groundwater quality. Studies of the Mill Creek (upper) subwatershed of the Buffalo River watershed have identified the Marble Falls WWTP as a source of nutrients and coliforms in Dogpatch Springs and Mill Creek (upper) (Maner and Mott 1991, Aley 2010, Usery 2013). In 2009, ADEQ alerted USNPS staff at the Buffalo National River of raw sewage leaking from the Marble Falls WWTP near the headwaters of Mill Creek (Usrey 2011). In 2015, discharge from the Marble Falls WWTP exceeded the discharge permit standards for BOD, fecal coliforms, and TSS. In the last quarter of 2016, the WWTP was reported to be in compliance with all discharge permit requirements (EPA 2017a). This discharge permit is currently being reviewed for renewal. Documents associated with this renewal indicate that the Marble Falls SID is seeking funding to construct a new treatment system (ADEQ 2017). Repair or replacement of the sewage collection network will also be necessary to stop all leaks (Aley 2010, ADEQ 2010, Engineering Services, Inc. 2010).

Point sources not covered under the NPDES program can be regulated under state law. There is one facility discharging in the Buffalo River watershed with a state discharge permit, listed in Table 5.2.

Table 5.2. State permitted point sources discharging in the Buffalo River watershed (ADEQ 2017b).

Permit No.	Type	Facility Name	Receiving Stream/ Subbasin
3650-WR-1	Car Wash	Marshall Car Wash	Bear Creek

5.2 Regulated Nonpoint Sources

Regulated nonpoint sources in the Buffalo River watershed include locations with Phase I or Phase II stormwater permits, Concentrated Animal Feedlot Operation (CAFO) permits, land application permits, solid waste facilities, mining sites, and liquid storage tanks. No active Brownfield sites, RCRA sites, current state priority hazardous waste contaminated sites, nor CERCLA superfund sites were identified within the Buffalo River watershed.

5.2.1 Animal Agriculture Operations

The regulated animal agriculture operation in the Buffalo River watershed that is most well-known is the CAFO, C&H Farms, in the Big Creek (middle) subwatershed. This facility was permitted by ADEQ through the NPDES program. This NPDES permit expired in October 2016, but has been extended while ADEQ decides whether or not to issue the state permit C&H Farms applied for in April 2016.

Spreading manure from confined animal operations on pasture is a common method of disposal in the Ozarks. According to ADEQ Regulation 5, “No confined animal operation using a liquid waste disposal system shall be constructed or operated unless the owner has first obtained a permit from the Department [ADEQ].” Table 5.3 lists confined animal operations in the Buffalo River watershed with active state permits for liquid waste disposal.

Table 5.3. Agricultural discharge permits in the Buffalo River watershed (ADEQ 2017b).

Permit No.	Type	Facility Name	Subwatershed
3132-WR-4	Swine	Lorne Campbell Hog Farm	Big Creek (middle)
3523-WR-4	Swine	Lionel Humphrey	Richland Creek
3540-WR-7	Swine	Ellis Campbell / EC Farms	Little Buffalo R
3823-WR-5	Swine	David & Sherry Dotson	Richland Creek
4065-W	Dairy	Larry West	Bear Creek
4067-W	Dairy	Ron Hogue	Calf Creek
4468-WR-1	Swine	Junior Yancy / Yancy's Farm	Richland Creek

It is noteworthy that the number of swine and dairy operations, and the number of dairy cows and swine, in the Buffalo River watershed has declined over time. Table 5.4 lists the number of swine and dairy operations, along with the number of swine and cows, reported for Newton and Searcy Counties in the USDA Census of Agriculture since 1982. Note that the most recent Census of Agriculture available at this time is for 2012. These data are graphed in Figures 5.1 and 5.2. The declines over time are most readily apparent in these graphs. This points out that, while they can still be locally important sources of nutrients and/or fecal bacteria, these sources are not as widespread in the Buffalo River watershed as they have been in the past.

Table 5.4. Dairy and swine numbers for Newton and Searcy Counties since 1982 (USDA 2017b).

	Newton County				Searcy County			
Year	Dairy Farms	Dairy Cows	Swine Farms	Swine	Dairy Farms	Dairy Cows	Swine Farms	Swine
1982	124	739	105	8,250	120	2,172	54	5,709
1987	58	361	62	8,662	67	1,994	32	3,425
1992	42	509	41	10,835	53	2,722	26	6,454
1997	16	199	27	8,515	41	1,896	24	3,456
2002	3	D	14	2,863	20	1,330	17	974
2007	0	0	23	1,318	12	528	16	D
2012	1	D	11	2,013	4	180	18	788

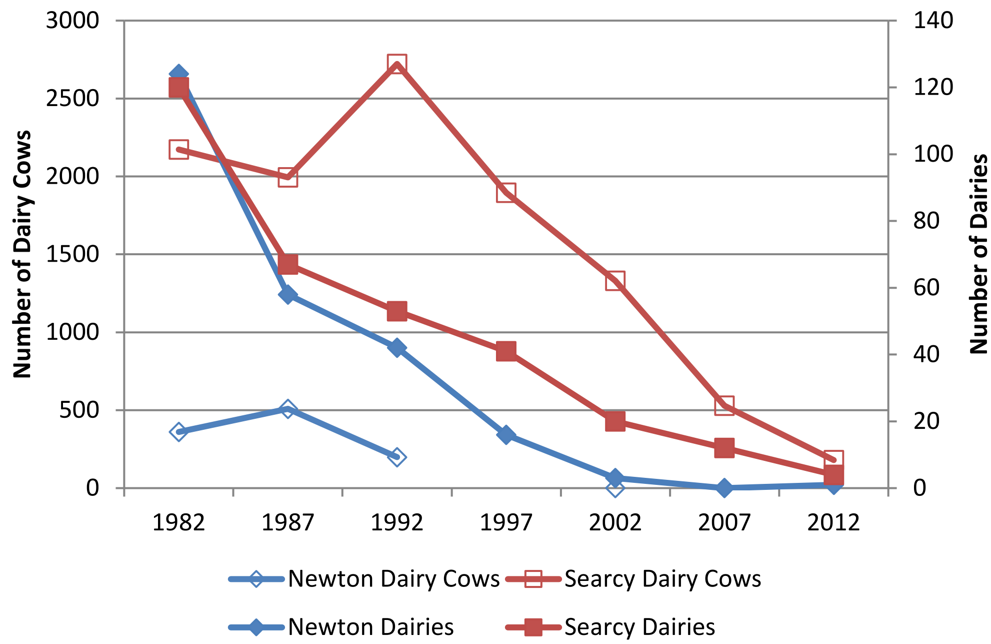


Figure 5.1. Number of dairy cows and dairies reported in Newton and Searcy Counties over time.

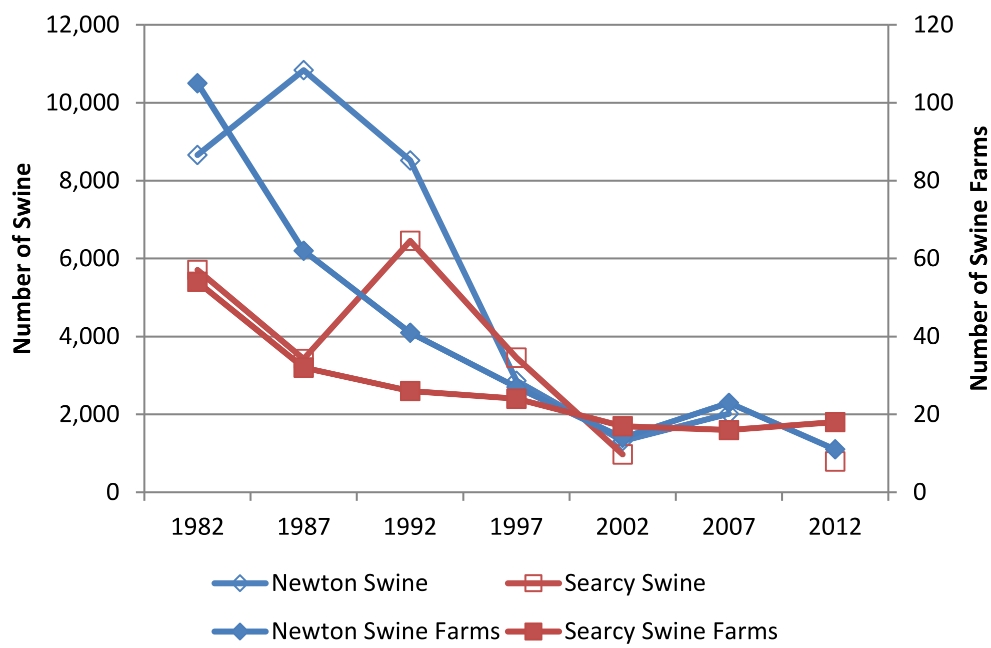


Figure 5.2. Number of swine and swine farms reported in Newton and Searcy Counties over time.

5.2.2 Onsite Wastewater Treatment Systems

The Arkansas Department of Health (ADH) issues permits for construction of onsite wastewater treatment systems, e.g., septic systems. Under specific circumstances, the ADH requires that discharges from onsite wastewater treatment systems be monitored by a third party (Arkansas State Board of Health 2014). In some cases, ADEQ issues a discharge permit for onsite wastewater treatment systems (see Table 5.5).

Table 5.5. ADEQ permitted onsite wastewater treatment system in the Buffalo River watershed (ADEQ 2017b).

Permit No.	Type	Facility Name	Subwatershed
3816-W	Domestic Septic System	Tyler Bend Campground	Buffalo River

5.2.3 Phase I and II Stormwater Permits

Stormwater runoff from developed areas is a potential source of a variety of pollutants that can impact water quality. There are no communities in the Buffalo River watershed with active MS4 stormwater permits. However, there are a number of active NPDES construction and industrial stormwater permits for locations within the watershed (Tables 5.6 and 5.7).

Table 5.6. Active NPDES construction stormwater permit within the Buffalo River watershed (ADEQ 2017b).

Permit No.	Facility Name	Subwatershed
ARR153893	C & H Hog Farms	Big Creek (middle)

Table 5.7. Active NPDES industrial stormwater permits for locations within the Buffalo River watershed (ADEQ 2017b).

Permit No.	Facility Name	Subwatershed
ARR000816	Newton County Recycling & Transfer Station	Little Buffalo River
ARR000914	Universal Pultrusions, LLC	Brush Creek
ARR001378	Universal Pultrusions East Plant	Brush Creek
ARR00A083	Ozark Timber Treating, Inc.	Mill Creek (lower)
ARR00A974	Hudson Lumber Company	Buffalo R (Cane Branch)
ARR00A984	Fowler Lumber Company	Little Buffalo River
ARR00B555	Branscum & Harness Lumber	Bear Creek
ARR00B556	Phillips Sawmill	Little Buffalo River
ARR00B606	B & E Sawmill, Inc.	Buffalo R (Sheldon Branch)

5.2.4 Hazardous Waste

ADEQ has identified one hazardous waste generator in the Buffalo River watershed, Universal Pultrusions, LLC, in Marshall (ADEQ 2017c). The facility is classified as a small quantity generator, meaning that it generates 100 kilograms or less per month of hazardous waste, or 1 kilogram or less per month of acutely hazardous waste.

5.2.5 Storage Tanks

ADEQ has identified 55 facilities within the Buffalo River watershed with underground storage tanks (Table 5.8). Seven of these facilities have reported underground tanks with leaks. All of the leaking tanks are located at gas stations. Leaking underground storage tanks have the potential to contaminate groundwater. There are also two registered storage tanks located in the watershed (Table 5.9).

Table 5.8. Summary of facilities located within the Buffalo River watershed identified by ADEQ has having storage tanks (ADEQ 2017d).

County	Facilities with only Underground Tanks	Facilities with only above ground tanks	Facilities with both above and underground tanks	Facilities with Temporarily out of service tanks	Leak reported for underground tank
Newton	25	6	4	3	4
Searcy	30	11	9	7	3

Table 5.9. ADEQ registered storage tanks located in the Buffalo River watershed (ADEQ 2017c).

Permit No.	Type	Facility Name	Subwatershed
51000006	RST	Buffalo Outdoor Center	Ponca Creek
51001609	RST	Lost Valley Canoe	Ponca Creek

5.2.6 Mining Sites

There are several active permitted mines in the Buffalo River watershed (see Table 5.10).

Table 5.10. ADEQ permitted mines in the Buffalo River watershed (ADEQ 2017c).

Permit No.	Type	Facility Name	Subwatershed
0002-MN-AG2-010	Mining	Marion County Paving	Water Creek
0483-MN-A1	Mining	Martin Sand and Gravel	Davis Creek
ARG500074	Sand and Gravel (NPDES)	Silver Hills Farm	Bear Creek

5.2.7 Solid Waste and Litter

The only permitted solid waste facility in the Buffalo River watershed is a solid waste transfer station located in Jasper.

Stakeholders have expressed concern about litter, primarily along the Buffalo River. Various organizations regularly host clean-up events along the Buffalo River to remove trash. Sources of this trash are believed to include recreationists using the Buffalo River, and illegal dumping in the watershed. During the period 2012-2016, several illegal dumps in the Buffalo River watershed were reported to, and investigated by, ADEQ (Table 5.11).

Table 5.11. Illegal dumps identified in the Buffalo River watershed 2012-2016 (ADEQ 2017e).

County	Number of complaints about locations within Buffalo River watershed	Confirmed illegal dumps
Newton	5	4
Searcy	6	4
Marion	0	0

5.3 Unregulated Nonpoint Pollution Sources in the Buffalo River Watershed

Stakeholders identified a number of unregulated nonpoint pollution sources in the Buffalo River watershed as pollution sources of concern (Table 3.1). Previous studies and evaluations of the Buffalo River watershed have identified unregulated nonpoint sources believed to be impacting biological communities and water quality in the Buffalo River and its tributaries. This information is summarized below.

5.3.1 Land Use

Several studies have found that levels of some pollutants in streams, stream habitat, and condition of stream biological communities are correlated with the amount of agricultural land use (e.g., pasture) in stream watersheds in the Ozarks (Watershed Conservation Resource Center 2017, Usrey 2013, Petersen 2004a, Mott and Laurans 2004, Petersen and Femmer 2003, Panfil & Jacobson 2001, Mott 1997, Smart, et al. 1983).

NRCS recommends that slopes over 15% in the Buffalo River watershed should not be cleared and used for pasture (NRCS 1995). In 2011 there were approximately 18,700 acres of pasture (2.2%) in the watershed on slopes steeper than 15% (Homer et al. 2015).

Evaluating geomorphologic and land use information from the 1990s, Panfil and Jacobson (2001) found that aquatic habitat characteristics of the Buffalo River and its tributaries can be influenced by bedrock geology, watershed slope, and land use, particularly forest removal. In particular, tributaries with greater areas of carbonate bedrock and non-forested land have shallower channels, gravel rich substrate, fewer persistent pools, and more eroding banks than tributaries with more sandstone bedrock and more forested land. In the Buffalo River, larger gravel bars form just downstream of tributaries whose watersheds are less steep and have greater areas of carbonate bedrock and non-forested land.

5.3.2 Riparian Buffers

Lack of riparian buffers is also correlated with levels of some pollutants and stream habitat condition. Riparian buffers stabilize streambanks, protecting them from erosion, and filter pollutants from runoff. Land clearing in riparian areas results in destabilization and erosion of streambanks of the Buffalo River and its tributaries (Mott and Laurans 2004).

5.3.3 Animal Waste

Waste from animal agriculture operations is a potential source of nutrients and bacteria, e.g., *E. coli*. Animal wastes deposited in or beside streams can also provide nutrients and coliforms, e.g., as happens when cows loiter in streams. A number of studies have identified waste from domestic animals and wildlife as sources of fecal coliforms and *E. coli* in the Buffalo River near Ponca, and Gilbert Spring (Usery 2013, Mott and Laurans 2004, Mott et al. 2002, Mott 1997, NRCS 1995). Justus et al. (2010) found that indices of algal, macroinvertebrate, and fish community integrity declined as estimated cattle production in Ozark stream basins increased. Justus et al. (2010) also found that, in the Ozark region, nutrient concentrations were highest in streams draining watersheds that had the highest estimated cattle and poultry production.

Table 5.12 lists numbers of beef and poultry farms, along with numbers of cattle and birds (chickens and turkeys), reported for Newton and Searcy Counties in the USDA Census of Agriculture since 1982. These data are graphed on Figures 5.3 and 5.4. Numbers of dairy cows and swine are listed in Table 5.4 and graphed in Figures 5.1 and 5.2. Overall, it appears that the number of animal agriculture operations in Newton and Searcy Counties, has declined since 1982. In addition, in Searcy County, the number of cattle, swine, and poultry have declined fairly consistently over the years, suggesting less animal waste. In Newton County, numbers of cattle and swine have declined over time, while poultry numbers have recently increased. Overall, there have been declines in some types of animal agriculture in the Buffalo River watershed, but waste from animal agriculture operations is still a concern.

Table 5.12. Beef cattle and poultry reported in Newton and Searcy Counties since 1982 (USDA 2017a).

	Newton County				Searcy County			
Year	**Beef Farms**	**Beef Cows**	**Poultry Farms**	**Poultry**	**Beef Farms**	**Beef Cows**	**Poultry Farms**	**Poultry**
1982	449	8,679	110	10,884	553	16,422	94	1,793
1987	437	8,810	54	258	571	18,528	68	13,803
1992	397	3,239	37	47,101	492	16,623	24	353
1997	441	11,272	39	40,460	514	18,601	32	742
2002	440	D	43	43,588	463	18,625	16	397
2007	430	D	69	220,240	419	17,518	44	742
2012	431	11,072	88	317,215	408	13,361	49	1,242

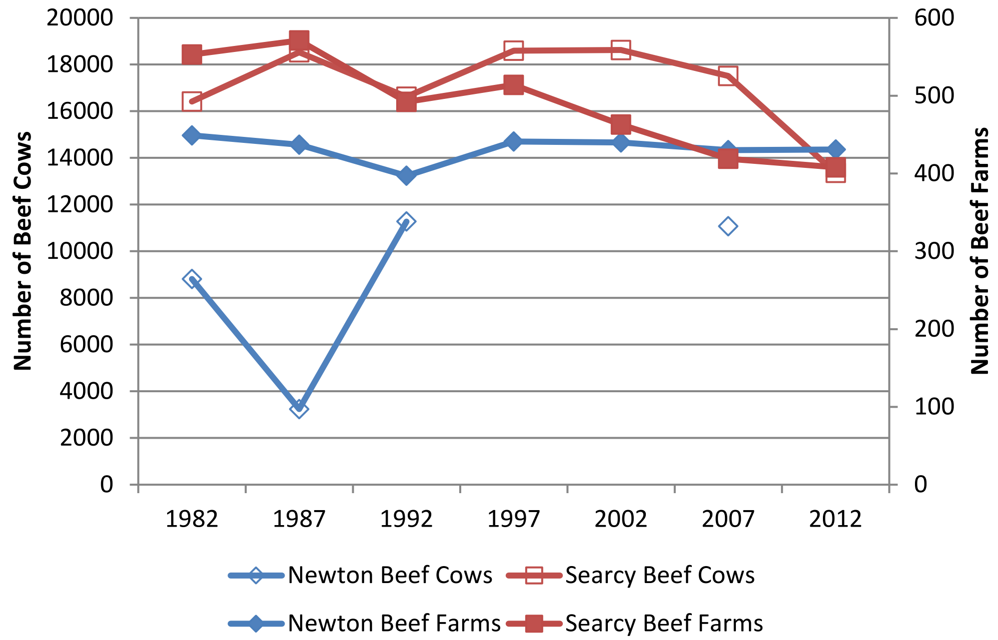


Figure 5.3. Number of beef cows and farms reported in Newton and Searcy Counties over time.

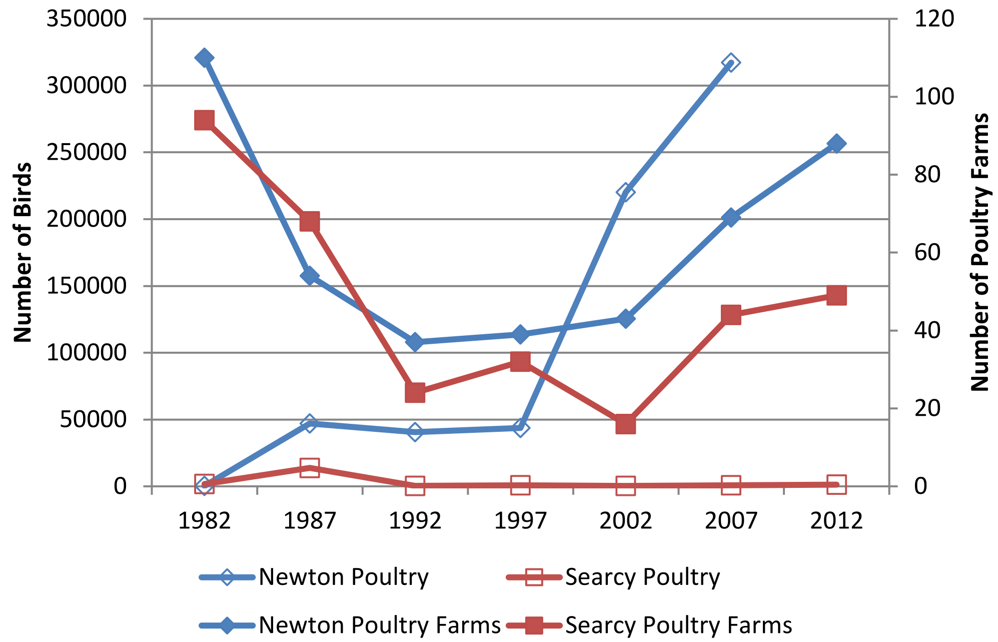


Figure 5.4. Number of poultry and farms reported in Newton and Searcy Counties over time.

5.3.4 Animals in Streams

Cows using streams can make streambanks more susceptible to erosion, or change the shape of the stream channel, which can trigger channel erosion upstream or downstream. Livestock in streams contribute to destabilization and erosion of streambanks along the Buffalo River and its tributaries (Mott and Laurans 2004).

5.3.5 Pasture Management

Concentrated over-grazing and grazing on streambanks contributes to destabilization and erosion of streambanks along the Buffalo River and its tributaries (Mott and Laurans 2004).

5.3.6 Streambank Erosion

Areas of severe streambank erosion have been identified along the Buffalo River (Mott and Laurans 2004; personal communication, USNPS, 3/16/2017).

5.3.7 Unpaved Roads

Unpaved roads have been identified as significant sources of sediment in rivers and streams in other areas of the Ozark Highlands. There are 1,683 miles of unpaved roads in the Buffalo River watershed (Center for Advanced Spatial Technologies 2006). Mott and Laurans (2004) identified unpaved roads within the Buffalo National River boundaries as a source of "large volumes of sediment to [the] river during storm runoff."

5.3.8 Springs and Groundwater

Several studies have identified the Dogpatch Springs as sources of nutrients in Mill Creek (upper) (Aley 2010, Maner and Mott 1991, Mott, Hudson and Aley 2000). Dye studies have determined that the recharge area for the Dogpatch Springs includes land outside of the Buffalo River watershed, in the Crooked Creek watershed (Soto 2014). Based on these studies, groundwater originating in an adjoining river basin is suspected of contributing to negative water quality in the Buffalo River watershed (Mott and Laurans 2004, Soto 2014).

Gilbert Spring has also been identified as potentially affecting water quality in the Buffalo River (Mott et al. 2002a). Research suggests that significant amounts of Gilbert Spring flow come from the adjacent Buffalo River tributary, Dry Creek (Soto 2014). Water from Dry Creek has been determined to be the primary contributor to water quality issues in Gilbert Spring (Mott et al. 2002a).

Mitch Hill Spring has been identified by some researchers as having the potential to affect water quality in the Buffalo River. Davis Creek contributes significantly to the flow of Mitch Hill Spring (Mott et al 2002b, personal communication, D. Mott, Buffalo National River, retired, 1/15/18). Dye studies indicate that the recharge area for Mitch Hill Spring extends outside the Buffalo River watershed, to include part of the Crooked Creek watershed (Soto 2014).

5.3.9 Onsite Wastewater Treatment Systems

Not all onsite wastewater treatment systems are covered by state regulations. Therefore, it is possible that unregulated onsite wastewater treatment systems are present in the Buffalo River watershed. Studies in the watershed have identified onsite wastewater treatment systems as pollution sources. An in-depth study of septic systems in Gilbert found that several systems were contributing untreated sewage to Gilbert Spring. These systems were repaired in 2001 (Mott et al. 2002a). Studies of the Mill Creek (upper) subwatershed of the Buffalo River watershed have identified septic systems as sources of nutrients and coliforms in Mill Creek (upper) and its tributaries (Maner and Mott 1991, Aley 2010, Usery 2013).

5.3.10 Recreation

Mott and Laurans (2004) identified the following impacts of recreation; bank and trail erosion, trash, and channel alteration and bank destabilization resulting from construction and use of boat launch areas.

5.3.11 Timber Harvest

Timber harvest activities in the Buffalo River watershed have the potential to impact water quality in Buffalo River tributaries, and eventually the Buffalo River. Harvest activities that do not follow the Arkansas Forestry Commission recommended best management practices have the potential to negatively affect stream water quality at stream crossings, unpaved roads, riparian buffers, log landings, and skid trails.

6.0 MANAGEMENT OF UNREGULATED NONPOINT POLLUTION SOURCES

This section identifies the plan management objectives and goals, subwatersheds recommended for initial management of unregulated nonpoint pollution sources, pollutant load reduction targets, and management practices that can be used to achieve the pollutant load reduction targets.

HIGHLIGHTS

- The objective of this plan is to sustain and improve water quality in the Buffalo River watershed, ensuring water quality standards are met.
- Six subwatersheds are recommended for initial nonpoint source pollution management – Mill Creek (upper), Calf Creek, Bear Creek, Brush Creek, Tomahawk Creek, and Big Creek (lower).
- Target percent load reductions for inorganic nitrogen are set for all six recommended subwatersheds, and range from 32% for Calf Creek, to 70% for Big Creek (lower).
- Fecal coliform levels for Calf Creek and Bear Creek have declined over time, so no *E. coli* reduction targets are set for these subwatersheds.
- Target percent reductions for *E. coli* for the remaining four recommended subwatersheds range from 44% for Tomahawk Creek to 82% for Big Creek (lower).
- Management practices that reduce nitrogen and bacteria in runoff from pasture and haylands can be used to achieve the target percent load reductions.
- Management practices that reduce nitrogen and bacteria loads from pasture and haylands can also reduce phosphorus and sediment loads.

6.1 Management Objective and Goals for Buffalo River Watershed

The overall objective of this watershed-based management plan is to sustain and improve the water resources of the Buffalo River watershed so that the vision for this watershed can be achieved. The vision for the Buffalo River watershed is: The uses of the Buffalo River and its tributaries are sustained by meeting water quality standards as they flow through the rolling hills, fields, forests, pastures, wetlands, and local communities of the Buffalo River watershed, as its residents and other stakeholders work together to improve the socioeconomic and extraordinary natural amenities of the Buffalo River watershed.

There are three management goals to achieve the vision for the Buffalo River watershed:

1. Keep pollutants out of both surface water and groundwater,
2. Minimize streambank and stream bed disturbance, and
3. Minimize activities that result in long-term or irrevocable degradation of water quality.

Surface water and groundwater are strongly interconnected in this watershed, and water moves easily between the surface and underground. As a result, pollutants on the land surface and in surface waters can end up in groundwater, and pollutants in groundwater can find their way into surface waters far from the original pollutant source.

Land clearing that occurred in the Buffalo River watershed in the early 20th Century is believed to have significantly changed the character of the river and its tributaries, making the channels less stable and the streams more erosive. Maintaining and restoring woodlands along the streambanks stabilizes the channels and slows bank erosion, filters pollutants from runoff flowing through the buffer, provides shading and cooling of streams, and contributes to in-stream habitat. Clearing wooded streambanks and disturbing the stream channels contributes to bank erosion both upstream and downstream of the disturbed area.

The Buffalo National River has been set aside for the enjoyment and appreciation of the public. The USNPS works with the public to keep the public areas as undisturbed as possible so that all may have the same experience of the natural beauty that characterizes the river. This is done through minimizing those activities that can cause long-term or irrevocable degradation of water quality, within the National River boundaries, and throughout the watershed.

6.2 Identification of Recommended Subwatersheds

The Buffalo River watershed is large, almost 900,000 acres. It is important to the many stakeholders that management activities make a real difference in improving and protecting the quality of both the surface water and groundwater, and other natural resources, in the watershed.

The 12-digit HUC subwatersheds delineated by the USGS are the typical management units for watershed-based plans. There are 37 12-digit HUC subwatersheds within the Buffalo River watershed.

For most watershed-based management plans, critical areas for nonpoint source pollution management are subwatersheds with impaired waterbodies. There is only one waterbody in the Buffalo River watershed classified as impaired by ADEQ, and that impairment is caused by a regulated point source rather than unregulated nonpoint sources (see Section 3.2.2). For this watershed management plan, therefore, areas recommended for initial nonpoint source pollution management are areas where there are indications that the surface water resources may be more susceptible to nonpoint source pollution, or that ecological condition may be declining. Several types of data were evaluated to identify these areas, including biological surveys, water quality constituent concentrations, water quality constituent loads, natural resources concerns based on watershed characteristics, and presence of carbonate bedrock. The evaluation of these data is described in Appendix F.

The six subwatersheds recommended for initial nonpoint source pollution management are Mill Creek (upper) (consisting of 12-digit HUC 110100050206 - Flatrock Creek), Calf Creek (consisting of 12-digit HUC 110100050401 - Calf Creek), Bear Creek (consisting of 12-digit HUC 110100050403 - Headwaters Bear Creek and 12-digit HUC 110100050404 - Outlet Bear Creek), Brush Creek (consisting of 12-digit HUC 110100050405 - Brush Creek-Buffalo River), Tomahawk Creek (consisting of 12-digit HUC 110100050407 - Tomahawk Creek-Buffalo River), and Big Creek (lower) (consisting of 12-digit HUC 110100050505 - Long Creek, 12-digit HUC 110100050506 - Davis Creek-Big Creek Lower, and 12-digit HUC 110100050507 - Bratton Creek-Big River). The locations of the recommended subwatersheds for this plan are shown on Figure 6.1.

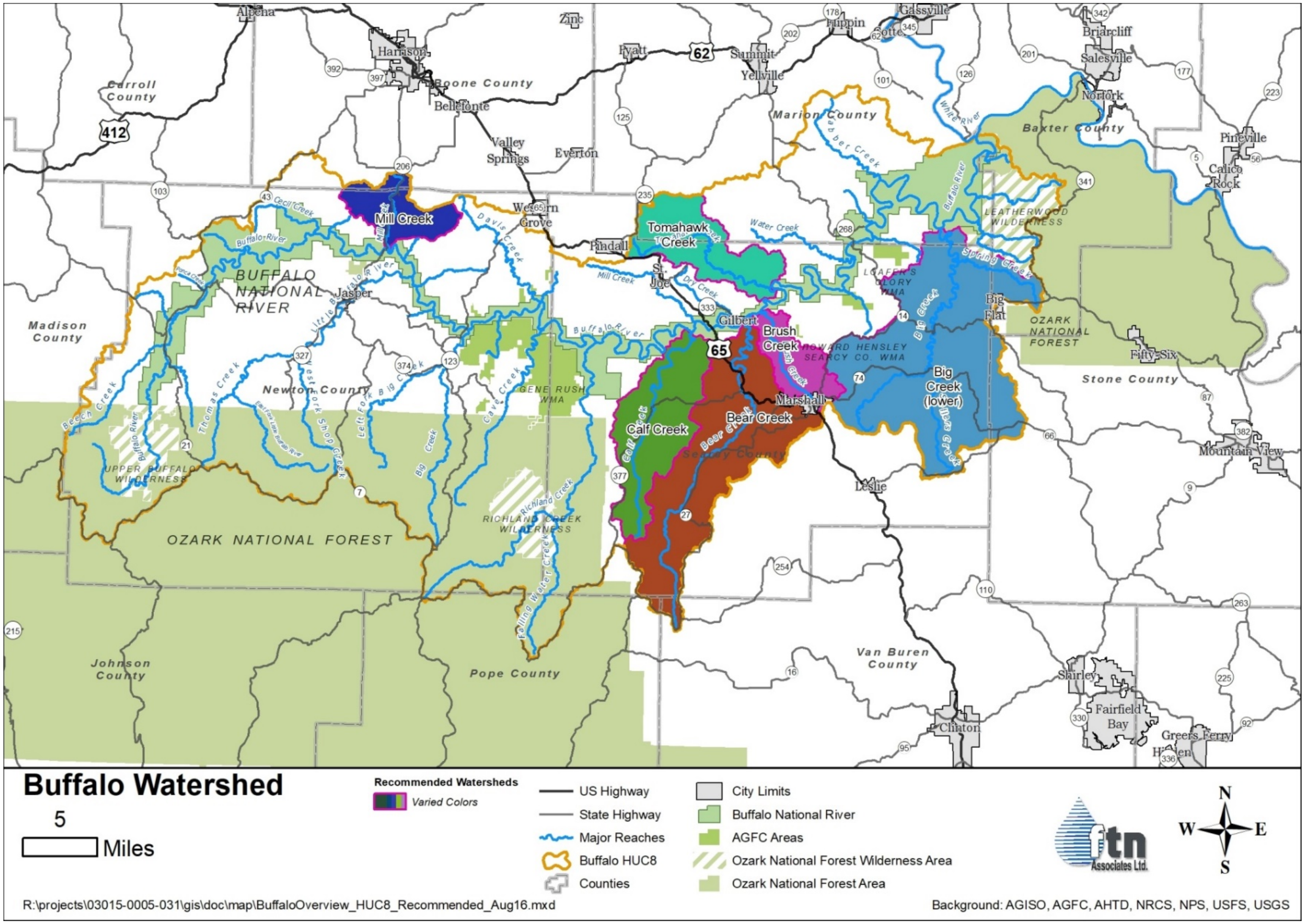


Figure 6.1. Map of recommended subwatersheds.

The ranking of 12-digit HUC subwatersheds based on sediment, total nitrogen, and total phosphorus loads estimated using the SWAT model, was evaluated when the results became available in February 2018 (included as Appendix E). The results from the SWAT model support the ranking of the 12-digit HUC subwatersheds outlined in Appendix F. All of the recommended subwatersheds identified through the WMP analyses have modeled loads in the top 25% for at least one of the parameters modeled with SWAT. Figure 6.2 shows the recommended subwatersheds for the WMP, and the 12-digit HUC subwatersheds where SWAT-estimated loads of all three parameters are in the top 25%. Three of the WMP recommended subwatersheds, Calf Creek, Bear Creek, and Big Creek (lower), include 12-digit HUC subwatersheds where SWAT-estimated loads of all three parameters are in the top 25%.

6.3 Management of Other Subwatersheds

There are six subwatersheds specifically recommended for nonpoint source pollution management through this watershed-based management plan. However, these are not the only subwatersheds with potentially significant water quality or biological issues (see Appendix F). There are other Buffalo River subwatersheds where some stakeholder groups believe there are urgent water quality issues that should be addressed, e.g., Big Creek (middle). This plan is not intended to restrict management activities in areas outside of the recommended subwatersheds. There is value in management of water quality issues outside of the recommended subwatersheds for protection of the Buffalo National River.

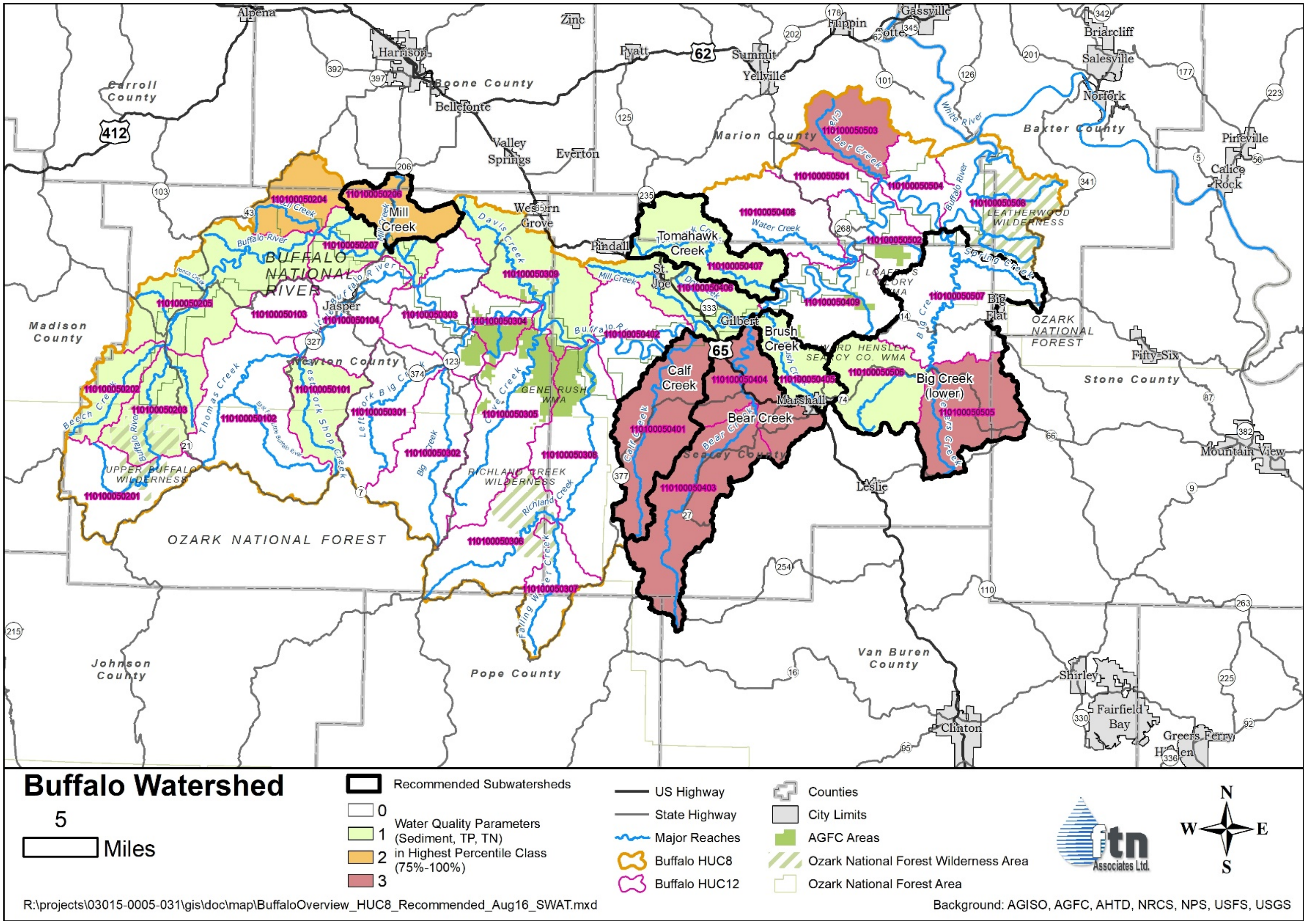


Figure 6.2. Comparison of recommended subwatersheds to SWAT priority 12-digit HUCs.

6.4 Management Targets for Recommended Subwatersheds

There have been no formal water quality standard impairments attributable to nonpoint sources identified in the recommended subwatersheds. There have been no studies identifying target water quality conditions in these subwatersheds. Therefore, the information used to identify the recommended subwatersheds is also used to identify priority water quality parameters for management. Based on the data analyses in Appendix F, and considering the availability of data for setting management targets, inorganic nitrogen and bacteria (fecal coliforms and *E. coli*) are suggested as the target water quality parameters for management in the recommended subwatersheds. Practices that reduce inorganic nitrogen and bacteria in surface waters can also reduce other parameters that are of concern to stakeholders in surface waters, including sediment and phosphorus.

6.4.1 Inorganic Nitrogen Load Reduction Targets

The water quality monitoring stations within the recommended subwatersheds have some of the highest median measured inorganic nitrogen concentrations and estimated loads in the Buffalo River watershed (Section 3.2, Appendix F). Statistically significant increasing trends in inorganic nitrogen concentrations were identified at water quality monitoring stations in all of the recommended subwatersheds except Calf Creek (Section 3.2.5, Appendix F). Although not statistically significant, there was an increase in median inorganic nitrogen concentrations between the 1985-1994 and 2005-2015 periods at the Calf Creek water quality station. Therefore, inorganic nitrogen water quality targets for the recommended subwatersheds are the median inorganic nitrogen concentrations for the earliest period, 1985-1994. Target inorganic nitrogen load reductions for the subwatersheds were calculated using the difference between the median concentrations for the periods 1985-1994, and 2005-2015. These concentrations and reductions are listed in Table 6.1.

Table 6.1. Target inorganic nitrogen load reductions for recommended subwatersheds.

Subwatershed	Target Inorganic Nitrogen concentration (1985-1994), mg/L	2005-2015 median Inorganic Nitrogen concentration, mg/L	Target Load Reduction
Mill Creek (upper)	0.438	0.727	40%
Calf Creek	0.230	0.337	32%
Bear Creek	0.100	0.313	68%
Brush Creek	0.515	0.770	33%
Tomahawk Creek	0.225	0.382	41%
Big Creek (lower)	0.04	0.132	70%

The causes behind such large changes in median concentrations between the 1985-1994 and 2005-2015 periods at the Bear Creek and Big Creek (lower) water quality stations are unknown. Investigation of inorganic nitrogen sources in these subwatersheds will be vital to successfully achieving the large target reductions.

6.4.2 Coliform Load Reduction Targets

Statistically significant increasing trends in fecal coliform concentrations were identified at water quality monitoring stations in the Mill Creek (upper) and Big Creek (lower) recommended subwatersheds (Section 3.2.5). Although a statistically significant trend was not identified at the water quality station in the Brush Creek subwatershed, the median fecal coliform concentration for the period 1985-1994 is less than the median concentration for the period 2005-2015. Target fecal coliform load reductions for the subwatersheds were calculated using the median concentration for the period 1985-1994. These concentrations and reductions are listed in Table 6.2.

Table 6.2. Fecal coliform reduction targets for recommended subwatersheds.

Subwatershed	Fecal Coliform concentration 1985-1994, cfu/100mL	Fecal Coliform concentration 2005-2015, cfu/100mL	Percent difference between periods	Target load reduction
Mill Creek (upper)	18	72.5	75%	75%
Calf Creek	16	12	-25%	0
Bear Creek	20	13.5	-48%	0
Brush Creek	8.5	20	53%	53%
Tomahawk Creek	54	31	-74%	41%*
Big Creek (lower)	5.5	19	71%	71%

* Calculated using 75th percentile, see text for explanation.

For Mill Creek (upper), the target is a 75% reduction in fecal coliform load. For Brush Creek, the target is a 53% reduction in fecal coliform load. For Big Creek (lower), the target is a 71% reduction of fecal coliform load. For Calf Creek and Bear Creek, since the median fecal coliform concentrations declined between the two periods, and the 2005-2015 median fecal coliform concentration is less than the 75th percentile for the Buffalo River watershed, the target is to have no increase in fecal coliform load. Although the median fecal coliform levels for Tomahawk Creek declined between the 1985-1994 and 2005-2015 periods, the 2005-2015 median fecal coliform level is still in the upper quartile for the Buffalo River watershed. Therefore, the target fecal coliform load reduction for Tomahawk Creek was calculated using the difference between the 2005-2015 median fecal coliform level, and the 75th percentile median fecal coliform level for the period 2005-2015, 18.25 cfu/100 mL. This results in a 41% fecal coliform load reduction target for Tomahawk Creek.

Although there is not long-term data for *E. coli*, this is the monitored water quality parameter that is the current standard for protection of human health from fecal contamination. Graphs of fecal coliform data against *E. coli* data at the water quality monitoring stations in the recommended subwatersheds appear to show strong linear relationships between these two coliform measurements (Appendix G). Therefore, linear regression analysis was used to estimate *E. coli* target levels for Mill Creek (upper), Brush Creek, and Big Creek (lower) from the fecal coliform median concentrations for the period 1985-1994 (Appendix G). The estimated targets and reduction to meet these targets are shown in Table 6.3. For Tomahawk Creek, the target

E. coli concentration is the 75th percentile median concentration for the period 2009-2015. It was assumed that *E. coli* concentrations at the Calf Creek, Bear Creek, and Tomahawk Creek water quality monitoring stations have decreased since the 1985-1994 period, the same as fecal coliform levels. The median *E. coli* concentrations for the 2009-2015 period from the Calf Creek and Bear Creek water quality monitoring stations are below the 75th percentile, so the target for *E. coli* management in these subwatersheds is no increase in *E. coli* concentrations.

Table 6.3. *E. coli* reduction targets for selected recommended subwatersheds (see Appendix G for calculations).

Subwatershed	**Target *E. coli* concentration, cfu/100mL**	**Median *E. coli* concentration 2009-2015, cfu/100mL**	**Target load reduction**
Mill Creek (upper)	15	64	76%
Brush Creek	7.3	20	64%
Tomahawk Creek	36	64	44%
Big Creek (lower)	4.5	25.25	82%

Median fecal coliform levels in both Mill Creek and Big Creek (lower) have increased by three to four times. The fecal coliform increase in Mill Creek appears to be related, at least partially, to releases of raw sewage from the Marble Falls WWTP (see Section 5.1). The cause(s) of the increase in Big Creek (lower), however, is unknown. Investigation of *E. coli* and fecal coliform sources in both of these subwatersheds will be vital to achieving the target coliform load reductions.

6.5 Pollution Source Assessment for Recommended Subwatersheds

The water quality issues and pollutant sources identified for each of the recommended subwatersheds, in analyses for this plan and other studies, are discussed below. The SWAT model identified areas within each of the recommended subwatersheds with higher nonpoint source loads (see Appendix E).

6.5.1 Mill Creek (upper) Subwatershed

Natural resource concerns whose scores for this subwatershed are in the upper quartile include concentrated flow erosion, sheet/rill/wind erosion, streambank erosion, sediment, nutrients, and pesticides. Water quality data from the Mill Creek (upper) routine water quality monitoring station in this subwatershed also suggest nutrients as a concern. This station has median inorganic nitrogen, orthophosphate, and turbidity levels in the top quartile, and median DO concentration in the lowest quartile for the Buffalo River watershed. SWAT model ediment and total nitrogen loads from this subwatershed are also in the top quartile for the Buffalo River watershed. SWAT model total phosphorus load from this watershed is in the third quartile (Appendix E). Indices based on recent aquatic invertebrate and fish surveys at the USNPS routine Mill Creek (upper) water quality monitoring station, however, indicate that aquatic communities are not impaired (see Appendix F).

Although the subwatershed score for the NRCS pathogen natural resources concern assessment is not in the upper quartile, the Mill Creek (upper) water quality monitoring station has the highest median *E. coli* and fecal coliform levels in the Buffalo River watershed for the period 2005-2015 (Appendix F). In addition, increasing trends were identified for inorganic nitrogen and fecal coliform levels (see Section 3.2.5). Because of the relatively small subwatershed size, estimated inorganic nitrogen and *E. coli* loads are not in the top quartile for the Buffalo River (Appendix F). However, a study in 1991 concluded that over 90% of the nitrate nitrogen (i.e., inorganic nitrogen) load in the Buffalo River just downstream of the Mill Creek (upper) confluence, was from Mill Creek. At that time, Mill Creek (upper) had the highest measured nitrate nitrogen concentrations in the Buffalo River watershed (Maner and Mott 1991). So, although loads from Mill Creek (upper) are not in the upper quartile, they may be having a significant effect on Buffalo River water quality.

6.5.1.1 Unregulated Nonpoint Sources of Pollution

The results of studies conducted to identify sources of high levels of *E. coli* and nutrients in Mill Creek (upper) and its tributaries have led researchers to suspect that onsite wastewater treatment systems associated with development along Harp Creek, and campgrounds along Mill

Creek (upper), contribute inorganic nitrogen and *E. coli* to Mill Creek (Maner and Mott 1991, Usrey 2011). Three of the five *E. coli* measurements from Harp Creek at County Road 21 during the period 2012-2016 exceeded the primary contact water quality standard for all other waters (see Section 3.2.4).

Table 6.4. Summary of unregulated nonpoint pollution sources for management in Mill Creek (upper) subwatershed.

Land use	% Area	Priority Pollutants	Priority Nonpoint Sources	Land Use Map*
Developed	4.0%	*E. coli*, Inorganic nitrogen	Onsite wastewater treatment systems	
Hayland and pasture	14.0%	*E. coli*, Inorganic nitrogen	Livestock (cattle in streams, animal feeding operations, manure storage), hayland and pasture fertilizing and runoff	
Forest	77.3%	*E. coli*, Inorganic nitrogen	Animals in streams (feral hogs)	

* Green = forest, yellow = hay/pasture, red = developed, blue = stream

The 1991 study of Mill Creek (upper) identified Upper and Lower Dogpatch Springs as significant sources of inorganic nitrogen loads to Mill Creek (Maner and Mott 1991). Dye studies have determined that the recharge area for these springs includes a 10 sq mi area (i.e., 70% of the recharge area) within the Crooked Creek watershed (Mott, et al. 2000, Soto 2014). This area of the Crooked Creek watershed is primarily pasture and hayland, while the Dogpatch Springs recharge area within the Buffalo River watershed is mostly forested (Figure 6.3). Therefore, surface water infiltration on pastures and hayland in the Crooked Creek watershed is suspected as a source of the nutrients in the groundwater feeding the Dogpatch Springs, impacting Mill Creek (upper), and, ultimately, the Buffalo River (Maner and Mott 1991; Mott, et al. 2000). Modeling of groundwater vulnerability in northern Arkansas by The Nature Conservancy has identified areas along Crooked Creek and Harp Creek as areas of concern where land use practices could impact groundwater quality (Inlander, Gallipeau and Slay 2011). The SWAT model results do not suggest that land management in the Mill Creek subwatershed is a significant source of nutrient loading (Appendix E).

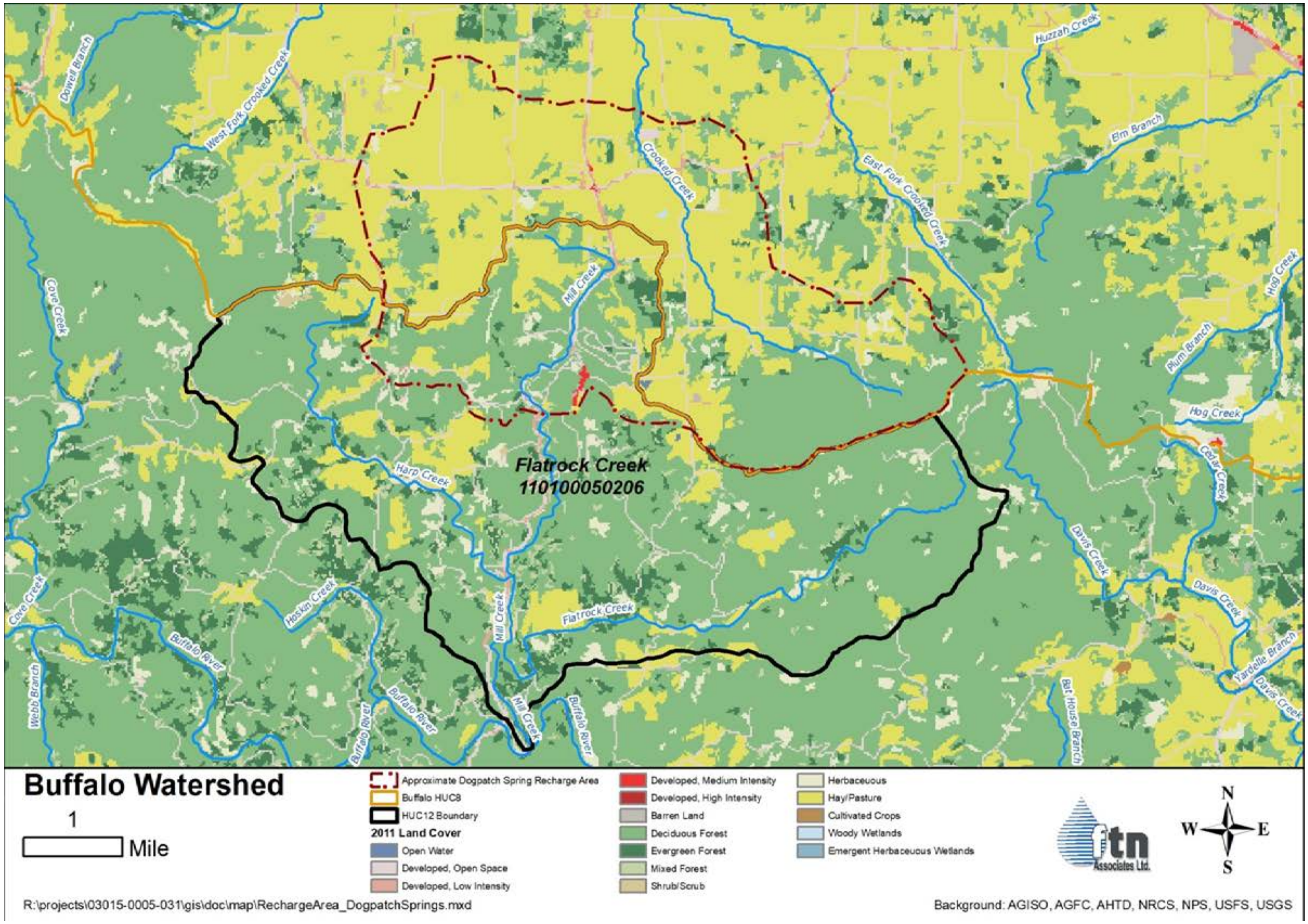


Figure 6.3. Land use in Dogpatch Springs recharge area.

6.5.1.1 Regulated Pollution Sources

Regulated pollution sources that have been identified in the Mill Creek (upper) subwatershed include the Marble Falls SID wastewater treatment system, stormwater runoff from Ozark Timber Treating, Inc., and a couple facilities with registered storage tanks (ADEQ 2017c)

The Marble Falls SID facility has a history of problems affecting both surface and groundwater quality. In 2009, ADEQ alerted USNPS staff at the Buffalo National River of raw sewage leaking from the Marble Falls SID near the headwaters of Mill Creek (upper) (Usrey 2011). A 2009 dye study found that raw sewage was leaking from a lift station into the groundwater, and being discharged to Mill Creek (upper) via the Dogpatch Springs (Aley 2009). Investigations of the Marble Falls sewage collection and treatment systems by ADEQ and two independent researchers determined that there are leaks throughout the system that are likely releasing untreated and/or partially treated sewage to the underlying karst groundwater system (Aley 2010, ADEQ 2010, Engineering Services, Inc. 2010). Also in 2009, water quality samples from the USNPS routine monitoring location on Mill Creek (upper) exhibited higher than normal levels of *E. coli* and fecal coliforms (Usrey 2011). It is likely that the statistically significant increase in median fecal coliform levels between the 1995-2004 and 2005-2015 periods is due, at least in part, to raw sewage releases from the Marble Falls SID.

Researchers conducting dye studies in 1998 and 1999 to determine the recharge area for Dogpatch Springs, also noted that prior to their study, “raw sewage was observed spilling from a lift station into the ephemeral portion of Mill Creek just above the Dogpatch Springs.”, which could affect water quality and flow in the springs (Mott, et al. 2000). So, 2009 was not the first time a raw sewage leak from the Marble Falls SID to Mill Creek (upper) and the Dogpatch Springs had occurred.

In 2015, discharge from the Marble Falls SID WWTP exceeded the discharge permit standards for BOD, fecal coliforms, and TSS. In the last quarter of 2016, the WWTP was reported to be in compliance with all discharge permit requirements (EPA 2017a). This discharge permit is currently being reviewed for renewal. Documents associated with this renewal indicate that the Marble Falls SID is seeking funding to construct a new treatment system (ADEQ 2017c). Repair or replacement of the sewage collection network will also be necessary to stop all leaks.

6.5.1.2 Plan Management Focus for Mill Creek (upper)

The suggested focus for this subwatershed includes improved understanding of the sources of inorganic nitrogen, *E. coli*, and fecal coliform inputs to surface water and the Dogpatch Springs; and reduction of *E. coli*, fecal coliform, inorganic nitrogen, and other pollutant inputs from nonpoint sources. Most likely nonpoint sources of concern in this subwatershed include onsite wastewater treatment systems (i.e., septic systems). Livestock operations and associated pasture, particularly in the areas outside the Buffalo River watershed that supply recharge to the Dogpatch Springs and are in areas of high groundwater vulnerability, should also be a focus for voluntary management to improve and protect water quality in Mill Creek and the Buffalo River.

6.5.2 Calf Creek Subwatershed

Natural resource concerns whose scores for this subwatershed are in the upper quartile for the Buffalo River watershed include nutrients, pathogens, pesticides, sediment, concentrated flow erosion, sheet/rill/wind erosion, and streambank erosion. Water quality data from the Calf Creek routine water quality monitoring station in this subwatershed also indicate nutrients as a concern. This station has the highest median orthophosphate concentration in the Buffalo River watershed for the period 2005-2015. In addition, this station has a median inorganic nitrogen concentration in the top quartile for the Buffalo River watershed. SWAT model sediment, total nitrogen, and total phosphorus loads from this subwatershed are all in the upper quartile for the Buffalo River watershed. The results of a single reported aquatic invertebrate survey suggest the community is impaired (see Appendix F). Fish IBIs from Petersen (2004) indicate fish communities are not impaired.

6.5.2.1 Unregulated Nonpoint Sources of Pollution

Pasture and hayland in the Calf Creek subwatershed is a potentially significant unregulated nonpoint source of pollutants.GIS analysis identified 41 miles of streams in the subwatershed within 50 feet of pasture or hayland. This is equivalent to over half of the mapped stream length in the subwatershed. In addition, infiltration of nutrients and bacteria from pastures on ridge tops can impact groundwater. The SWAT model identified areas within the subwatershed that generate sediment and nutrient loads in the upper 25th percentile. Streamside and ridge top pastures shown on the map in Table 6.5. A full page subwatershed map that also shows SWAT model units with high sediment and nutrient loads is included in Appendix I.

The rural nature of this subwatershed suggests that unregulated onsite wastewater treatment systems may be present, and have the potential to be sources of pollution.

Table 6.5. Summary of nonpoint pollution sources for management in Calf Creek subwatershed.

Land use	% Area	Priority Pollutants	Priority Nonpoint Sources	Land Use Map*
Developed	3.5%	Inorganic nitrogen	Onsite wastewater treatment systems	
Hay/pasture	29.7%	Inorganic nitrogen	Livestock (cattle in streams, animal feeding operations, manure storage), hay/pasture fertilizing and runoff	
Forest	63.9%	Inorganic nitrogen	Animals in streams (feral hogs)	

* green = forest, yellow = hay/pasture, red = developed, blue = stream

6.5.2.2 Regulated Pollution Sources

One regulated pollution source has been identified in this subwatershed, a dairy farm permitted for liquid animal waste disposal.

6.5.2.3 Plan Management Focus for Calf Creek

The suggested focus for this subwatershed is reduction of nonpoint source nutrient inputs to surface water from pasture along streams and on ridges, and in areas where SWAT modeling indicated high loads, and improved habitat for aquatic invertebrates.

6.5.3 Bear Creek Subwatershed

The Bear Creek subwatershed includes two 12-digit HUC subwatersheds. Scores for nutrient and pathogen natural resource concerns, for both of the 12-digit HUC subwatersheds that make up the Bear Creek subwatershed, are in the upper quartile for the Buffalo River watershed. Scores for the following other natural resource concerns for the Bear Creek Outlet 12-digit HUC subwatershed are also in the upper quartile; concentrated flow erosion, sheet/rill/wind erosion, sediment, and pesticides.

Water quality data from the Bear Creek routine water quality monitoring station in this subwatershed also indicate nutrients as a concern. The median inorganic nitrogen and orthophosphate concentrations at this station for the period 2005-2015 are in the upper quartile for the Buffalo River watershed, as are the estimated inorganic nitrogen and orthophosphate loads. In addition, inorganic nitrogen concentrations at this station exhibit an increasing trend over time; the median inorganic nitrogen concentration at the Bear Creek routine water quality station for the period 2005-2015 is more than three times higher than the median concentration for the 1985-1994 period. SWAT model loads of sediment, total nitrogen, and total phosphorus for both of the Bear Creek 12-digit HUC subwatersheds are in the upper quartile. Results of aquatic invertebrate surveys at this station, however, indicate no impacts to these communities (Bowles 2015).

Fish IBIs from community surveys in 2001 and 2002 indicate no impacts to these communities either (Petersen 2004a). Bear Creek is listed in the EPA-approved 2016 state impaired waters list (i.e., 303(d) list) as having impaired drinking water, agricultural and industrial source water, and aquatic life support uses due to high TDS concentrations (ADEQ 2017g).

6.5.3.1 Unregulated Pollution Sources

Pasture and hayland in the Bear Creek subwatershed is a potentially significant unregulated nonpoint source of pollutants. GIS analysis identified over 65 miles of streams in the subwatershed within 50 feet of pasture or hayland. This is equivalent to almost half (48%) of the mapped stream length in this subwatershed. In addition, infiltration of nutrients and bacteria from pastures on ridge tops can impact groundwater. Both streamside and ridge top pasture areas are shown on the map in Table 6.6. The SWAT model identified other areas within the subwatershed that contribute sediment and nutrient loads in the upper 25th percentile. A full page subwatershed map showing streamside and ridge top pasture, along with areas identified by SWAT as generating high sediment and nutrient loads, is included in Appendix I.

The rural nature of this subwatershed suggests that unregulated onsite wastewater treatment systems may be present, and have the potential to be sources of pollution.

Table 6.6. Summary of nonpoint pollution sources for management in Bear Creek subwatershed.

Land use	% Area	Priority Pollutants	Priority Nonpoint Sources	Land Use Map*
Developed	4.5%	Inorganic nitrogen	Individual wastewater treatment	
Hayland and pasture	29.6%	Inorganic nitrogen	Livestock (cattle in streams, animal feeding operations, manure storage), hayland and pasture fertilizing and runoff	
Forest	63.2%	Inorganic nitrogen	Animals in streams (feral hogs)	

* green = forest, yellow = hayland and pasture, red = developed, blue = stream, magenta = water quality impaired stream reach

6.5.3.1 Regulated Pollution Sources

There are several regulated pollution sources located in the Bear Creek subwatershed (Table 6.7). ADEQ attributes the high TDS concentrations to discharges from a municipal point source (ADEQ 2016). The only permitted municipal wastewater discharge to Bear Creek is the City of Marshall wastewater treatment plant.

The Marshall WWTP has reported nitrate levels in its discharge that exceed the permit limit of 10 mg/L once in 2015 and in 2016 (EPA 2017a). The WWTP upgraded in 2014, adding nitrate removal to meet new nitrate discharge standards (ADEQ 2017c). As a result, it is expected that nitrate inputs from the WWTP are lower since 2014 than previously.

Table 6.7. Regulated pollution sources in Bear Creek subwatershed.

Permit No.	Type	Facility Name	Receiving Stream
3650-WR-1	Car Wash	Marshall Car Wash	Bear Creek
AR0034011	Municipal wastewater treatment plant (NPDES)	City of Marshall	Forest Creek
4065-W	land application of liquid waste from dairy	Larry West	Unknown
ARR00B555	industrial stormwater runoff (NPDES)	Branscum & Harness Lumber	Unknown
ARG500074	Sand and Gravel (NPDES)	Silver Hills Farm	Bear Creek

6.5.3.2 Plan Management Focus for Bear Creek

The suggested focus for the Bear Creek subwatershed includes improved understanding of the sources of inorganic nitrogen inputs to surface water, and reduction of nonpoint source nutrient inputs to surface water, primarily from streamside pasture and other focus areas shown on the watershed map in Table 6.6 and Appendix I.

6.5.4 Brush Creek Subwatershed

Scores for this 12-digit HUC subwatershed for all of the natural resource concerns evaluated, except one, are in the upper quartile for the Buffalo River watershed; concentrated flow erosion, sheet/rill/wind erosion, streambank erosion, sediment, nutrients, pathogens, and pesticides. Data from the water quality monitoring station in this subwatershed also indicate nutrients as a concern. The median inorganic nitrogen and orthophosphate concentrations at this station for the period 2005-2015 are in the upper quartile for the Buffalo River watershed, as is the estimated inorganic nitrogen load. In addition, inorganic nitrogen concentrations at this station exhibit an increasing trend over time. SWAT model total phosphorus load from this subwatershed is in the upper quartile, while loads for the other modeled parameters are only in the first and second quartile. The published results of the most recent fish survey indicate the fish community is impacted. No published results of the aquatic invertebrate stream condition index for this location were found (see Appendix F).

6.5.4.1 Unregulated Pollution Sources

Pasture and hayland in the Brush Creek subwatershed is an unregulated nonpoint source of pollutants. GIS analysis identified over 9 miles of streams in the subwatershed within 50 feet of pasture or hayland. This is equivalent to almost 30% of the mapped stream length in this subwatershed. In addition, infiltration of nutrients and bacteria from pastures on ridge tops can impact groundwater. Both streamside and ridge top pasture areas are shown on the map in Table 6.8. The SWAT model identified other areas within the subwatershed that contribute sediment and nutrient loads in the upper 25th percentile. A full page subwatershed map showing streamside and ridge top pasture, along with areas identified by SWAT as generating high sediment and nutrient loads, is included in Appendix I.

The rural nature of this subwatershed suggests that unregulated onsite wastewater treatment systems may be present, and have the potential to be sources of pollution.

6.5.4.2 Regulated Pollution Sources

Regulated source of pollution that have been identified in this subwatershed include stormwater runoff from two industrial facilities in Marshall, and 29 facilities with regulated storage tanks in Marshall. Fifteen of these tanks are currently in use, and one of these, at a gas station, has leaked in the past (ADEQ 2017d).

Table 6.8. Summary of nonpoint pollution sources for management in Brush Creek subwatershed.

Land use	% Area	Priority Pollutants	Priority Nonpoint Sources	Land Use Map*
Developed	5.3%	*E. coli*, Inorganic nitrogen	Onsite wastewater treatment	
Hayland and pasture	24.4%	*E. coli*, Inorganic nitrogen	Livestock (cattle in streams), hayland and pasture fertilizing and runoff	
Forest	66.8%	*E. coli*, Inorganic nitrogen	Animals in streams (feral hogs)	

* green = forest, yellow = hayland and pasture, red = developed, blue = stream

6.5.4.3 Plan Management Focus for Brush Creek

The suggested focus for the Brush Creek subwatershed is reduction of nonpoint source nutrients, particularly inorganic nitrogen, along with *E. coli*, and fecal coliform inputs to surface waters, and improvement of fish habitat. Focus areas for reducing nonpoint source nutrients and bacteria are streamside and ridge top pastures, and other areas highlighted on the maps in Table 6.8 and Appendix I.

6.5.5 Tomahawk Creek Subwatershed

Scores for this 12-digit HUC subwatershed for all of the natural resource concerns evaluated, except one, are in the upper quartile for the Buffalo River watershed; concentrated flow erosion, sheet/rill/wind erosion, streambank erosion, sediment, nutrients, pathogens, and pesticides. Data from the water quality monitoring station in this subwatershed also indicate nutrients and pathogens (i.e., fecal coliforms and *E. coli*) as concerns. The median inorganic nitrogen, *E. coli*, and fecal coliform concentrations at this station for the period 2005-2015 are in the upper quartile for the Buffalo River watershed. In addition, inorganic nitrogen concentrations at this station exhibit an increasing trend over time. SWAT model total phosphorus load from this subwatershed is in the upper quartile, while loads for the other modeled parameters are only in the second quartile. Published results for aquatic invertebrate indices at this location were not found (see Appendix F). Fish surveys in 2001 and 2002 indicate the fish community is not impacted (Petersen 2004a).

6.5.5.1 Unregulated Pollution Sources

Pasture and hayland in the Tomahawk Creek subwatershed is an unregulated nonpoint source of pollutants.GIS analysis identified over 20 miles of streams in the subwatershed within 50 feet of pasture or hayland. This is equivalent to approximately one-third (34%) of the mapped stream length in this subwatershed. In addition, infiltration of nutrients and bacteria from pastures on ridge tops can impact groundwater. Both streamside and ridge top pasture areas are shown on the map in Table 6.9. The SWAT model identified other areas within the subwatershed that contribute sediment and nutrient loads in the upper 25th percentile. A full page subwatershed map showing streamside and ridge top pasture, along with areas identified by SWAT as generating high sediment and nutrient loads, is included in Appendix I.

The rural nature of this subwatershed suggests that unregulated onsite wastewater treatment systems may be present, and have the potential to be sources of pollution.

Table 6.9. Summary of nonpoint pollution sources for management in Tomahawk Creek subwatershed.

Land use	% Area	Priority Pollutants	Priority Nonpoint Sources	Land Use Map*
Developed	2.8%	*E. coli*, Inorganic nitrogen	Onsite wastewater treatment	
Hay/pasture	30.8%	*E. coli*, Inorganic nitrogen	Livestock (cattle in streams), hay/pasture fertilizing and runoff	
Forest	63.0%	*E. coli*, Inorganic nitrogen	Animals in streams (feral hogs)	

* green = forest, yellow = hay/pasture, red = developed, blue = stream

6.5.5.2 Regulated Pollution Sources

No regulated pollution sources were identified in this subwatershed.

6.5.5.3 Plan Management Focus for Tomahawk Creek

The suggested focus for the Tomahawk Creek subwatershed is reduction of nonpoint source nutrient, *E. coli*, and fecal coliform inputs to surface waters, initially concentrating on streamside and ridge top pastures, and areas of high loading identified by the SWAT model.

6.5.6 Big Creek (lower) Subwatershed

The Big Creek (lower) subwatershed includes three 12-digit HUC subwatersheds. There is only one natural resource concern whose scores for all three 12-digit HUC subwatersheds were in the upper quartile for the Buffalo River watershed; metals. For the remaining natural resource concerns, scores for only the two upstream 12-digit HUC subwatersheds (Long Creek and Davis Creek) are in the upper quartile. These natural resource concerns are concentrated flow erosion, sheet/rill/wind erosion, streambank erosion, sediment, nutrients, pathogens, and pesticides (see Appendix F).

Data from the Big Creek (lower) water quality monitoring station in this subwatershed also indicate water quality concerns. The median DO concentration for this station, for the period 2005-2015, is in the lower quartile for the Buffalo River watershed, while the median orthophosphate and fecal coliform concentrations are in the upper quartile. Inorganic nitrogen, fecal coliform, and turbidity levels at this station all exhibit increasing trends over time. The Big Creek (lower) subwatershed is the second largest subwatershed of the Buffalo River. Therefore, it is not surprising that the estimated loads of inorganic nitrogen, orthophosphate, and *E. coli* are in the top quartile for the Buffalo River watershed. Published results for aquatic invertebrate indices at this location were not found (see Appendix F). Fish IBIs based on surveys in 2001 and 2002 indicate fish communities are not impaired (Petersen 2004a).

The median inorganic nitrogen and fecal coliform levels at the Big Creek (lower) water quality station for the period 2005-2015 are more than three times higher than the median values for the 1985-1994 period. No information was found that suggested a reason for the marked increase in inorganic nitrogen and fecal coliform levels in Big Creek (lower).

SWAT model loads from the Long Creek 12-digit HUC for all three modeled parameters were in the upper quartile for the Buffalo River watershed. SWAT load from the Davis Creek 12-digit HUC for total phosphorus is in the upper quartile, while model sediment and total nitrogen loads are in the third quartile. SWAT loads from the Bratton Creek-Big Creek 12-digit HUC are in the lowest and second quartile (Appendix E).

6.5.6.1 Unregulated Pollution Sources

Pasture and hayland in the Big Creek (lower) subwatershed is an unregulated nonpoint source of pollutants. GIS analysis identified 69 miles of streams in the subwatershed within 50 feet of pasture or hayland. This is equivalent to one-third of the mapped stream length in this subwatershed. In addition, infiltration of nutrients and bacteria from pastures on ridge tops can impact groundwater. The majority of pasture and hayland occurs in the upper part of this subwatershed (see Table 6.10). Both streamside and ridge top pasture areas are highlighted on the map in Table 6.10. The SWAT model identified other areas within the subwatershed that contribute sediment and nutrient loads in the upper 25th percentile. A full page subwatershed map showing streamside and ridge top pasture, along with areas identified by SWAT as generating high sediment and nutrient loads, is included in Appendix I.

The rural nature of this subwatershed suggests that unregulated onsite wastewater treatment systems may be present, and have the potential to be sources of pollution.

6.5.6.2 Regulated Pollution Sources

The only regulated potential pollution sources in this subwatershed are registered storage tanks in Big Flat and Harriet (ADEQ 2017d).

6.5.6.3 Plan Management Focus

The suggested focus for the Big Creek (lower) subwatershed includes improved understanding of the sources of inorganic nitrogen, *E. coli,* and fecal coliform inputs to surface water, and reduction of nonpoint source nutrient, *E. coli*, and fecal coliform inputs to surface waters. Focus areas for management include pasture and haylands along streams and on ridge tops, and areas identified by SWAT as generating high sediment and nutrient loads (Appendix I).

Table 6.10. Summary of nonpoint pollution sources for management in Big Creek (lower) subwatershed.

Land use	% Area	Priority Pollutants	Priority Nonpoint Sources	Land Use Map*
Developed	1.8%	*E. coli*, Nitrogen	Individual wastewater treatment	
Hayland and pasture	22.8%	*E. coli*, Nitrogen	Livestock (cattle in streams), hayland and pasture fertilizing and runoff	
Forest	56.3%	*E. coli*, Nitrogen	Animals in streams (feral hogs)	

* green = forest, yellow = hayland and pasture, red = developed, blue = stream

6.6 Pollutant Sources to be Managed

The primary nonpoint sources of inorganic nitrogen and *E. coli* present in the recommended subwatersheds are onsite wastewater treatment systems, pasture, and haylands. In pasture and haylands, areas recommended for initial management are those areas identified by the SWAT model as contributing high nutrient and sediment loads, then areas within 50 feet of streams, and, finally, areas on ridge tops, particularly where karst features are present.

6.6.1 Onsite Wastewater Treatment Systems

Even though several communities are located within each of the recommended subwatersheds, only Marble Falls (Mill Creek (upper) subwatershed) and Marshall (Brush Creek subwatershed) are served by centralized, permitted wastewater treatment systems. The other communities, as well as the individual residences and locations such as gas stations and campgrounds, scattered throughout the subwatersheds, are typically served by onsite wastewater treatment systems (e.g., septic systems, small package treatment plants). The majority of the land within each of the recommended subwatersheds is classified as being of "very limited suitability" for septic systems (Table 6.11).

Table 6.11. Septic system suitability of soils within recommended subwatersheds (Center for Advanced Spatial Technologies 2006).

Soils Septic System Suitability	Mill Creek (upper)	Calf Creek	Bear Creek	Brush Creek	Tomahawk Creek	Big Creek (lower)
Slightly limited	2%	7%	7%	13%	9%	2%
Limited	14%	22%	24%	27%	20%	34%
Very limited	84%	70%	67%	60%	71%	63%
Not rated	0	0	<1%	0	0	1%

Some onsite wastewater treatment systems are subject to discharge permitting by the state (ADEQ or Arkansas Department of Health), while others are not. Information on the number of systems permitted by Arkansas Department of Health, and unpermitted systems present in the recommended subwatersheds is not readily available.

6.6.2 Pasture and Hayland

The two most common agricultural operations in the Buffalo River watershed are raising cattle and hay production. County Conservation District personnel in Newton and Searcy County were asked about agricultural operations in the Buffalo River watershed. They indicated that pastures are primarily located in river valley bottoms along streams, and on ridge tops. Fields in the river valleys are most often used for hay production. Many cattle ranchers get two hay cuttings from river valley fields, then graze cattle on the last cutting and through the winter (personal communication). In many river valley pastures and haylands, the land has been cleared all the way to the water's edge to maximize acreage. The lack of riparian buffer maximizes the conveyance of nutrients and *E. coli* from pastures to streams, and destabilizes the streambank, increasing streambank erosion. GIS analysis was used to identify mapped stream reaches within

50 feet of pasture or hayland land cover. Table 6.12 lists the percentage of mapped streams in each of the recommended subwatersheds that run through or adjacent to pasture or hayland.

Table 6.12. Pasture-related statistics for recommended subwatersheds.

Subwatershed	Percent pasture & hayland	Relative rank	Percent of streams in pasture & hayland	Percent of pasture & hayland on slope > 14%
Tomahawk Creek	30.8%	1	34%	11%
Calf Creek	29.7%	2	51%	5.8%
Bear Creek	29.6%	3	48%	9.6%
Brush Creek	24.4%	5	30%	22%
Big Creek (lower)	20.0%	6	33%	16%
Mill Creek (upper)	14.0% (24.5% including Crooked Creek area)	12	19%	4.5%

Nutrients and *E. coli* from pasture and hayland can come from cattle grazing on the land, cattle loitering in streams, and from chemical fertilizers and manure applied to the land as fertilizer.

Several studies have reported that water quality is poorer in streams with larger areas of pasture and hayland in their watersheds, within the Ozarks region, and within the Buffalo River watershed itself (Watershed Conservation Resource Center 2017, Usrey 2013, Petersen 2004a, Mott and Laurans 2004, Petersen and Femmer 2003, Panfil & Jacobson 2001, Mott 1997, Smart, et al. 1983). SWAT model results indicate pasture and hayland as important sources of sediment and nutrients in the Buffalo River watershed (see Appendix E). Studies in the Ozarks region have also found that groundwater in aquifers under pastures has higher levels of inorganic nitrogen and fecal coliforms than groundwater in aquifers under forest (Steele, et al. 1990, Daniel & Steele 1991, Steele & McCalister 1991). Table 6.12 lists the percentage of the recommended subwatersheds in pasture and hayland during 2011, along with the rank relative to the other subwatersheds (a rank of 1 is assigned to the subwatershed with the greatest percentage of pasture and hayland, and 27 to the subwatershed with the lowest percentage). Pasture over karst in all of the recommended subwatersheds has the potential to contribute nutrients to groundwater, and, eventually, the Buffalo River.

Spreading manure from confined animal production operations (e.g, poultry, swine, dairy) on pasture and hayland is a common method of disposal in the Ozarks. While poultry production is not as widespread in the Buffalo River watershed as in other areas of northern Arkansas, poultry litter is available in some areas and is used to fertilize pastures in those areas. County Conservation District personnel indicate that soil nutrient tests are used to determine poultry litter application rates to pasture and hayland in the watershed. There is one active Liquid Animal Waste System permit in the Calf Creek subwatershed, and an active agricultural discharge permit in the Bear Creek (lower) subwatershed (Section 5.2). A cursory search of satellite imagery on the ADEQ EnviroView interactive map identified possible confined animal houses within the Mill Creek (upper) subwatershed, but not in any of the other recommended subwatersheds (ADEQ 2017f).

6.7 Management Practices

The primary focus for nonpoint source management in the Buffalo River watershed is nitrogen, *E. coli*, and fecal coliforms from pasture, hayland, and onsite wastewater treatment systems. At the second public meeting for this watershed-based management plan, stakeholders were asked to identify management practices to address issues in the Buffalo River watershed. Table 6.13 lists the practices identified at the public meeting (see Appendix B for full meeting summary). Those practices identified by stakeholders that are appropriate for managing nitrogen and fecal bacteria from pasture, hayland, and onsite wastewater treatment systems are highlighted in yellow in Table 6.13.

Table 6.13. Management practices for the Buffalo River watershed identified by stakeholders.

Litter management	Streambank restoration
Unpaved road BMPs	Soil/nutrient mgt
Greenbelt buffers – pasture/stream	Erosion control BMPs
Prescribed forest burns	Quail habitat mgt, restoration
Feral hog capture	Farm pond/sediment basin construction
Steep slope erosion BMPs	Trail management practices
Septic system repair/replace	Forest mgt. practices

Note: practices highlighted in yellow are appropriate for managing nitrogen and fecal bacteria.

Through its CPPE program, the NRCS determined that the following management practices not already identified by stakeholders, are also effective for reducing nitrogen and fecal bacteria inputs to both surface and groundwater from pasture: stream access control, prescribed/rotational grazing, silvopasture establishment, and karst sinkhole treatment. Pasture planting can also reduce nitrogen and fecal bacteria inputs to surface water from pasture.

The USNPS and area farmers have implemented some of these practices in the past to manage nonpoint sources in the Buffalo River watershed. In 1995, the NRCS Middle Tributaries Project provided cost-share to encourage use of nonpoint management practices in the Tomahawk Creek, Calf Creek, Bear Creek, and Brush Creek subwatersheds (personal communication, D. Mott, Buffalo National River, retired, 1/15/18). Several projects to improve manure management at dairies located in the watershed were initiated in the 1990s (Formica 1990, Arkansas Watershed Coalition 2017). Changes in milk pricing in the 1990s and 2000s resulted in closure of many dairies in Arkansas, including many of those in the Buffalo River watershed, making this less of an issue for current water quality (Anon. 2017). Table 6.14 summarizes selected management activities in the watershed since 2000. In addition to the programs listed in Table 6.14, Arkansas NRCS annual reports show that farmers in the counties of the Buffalo River watershed have been implementing management practices through the NRCS Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (NRCS 2017). Information on the specific practices and amounts implemented in these counties is not provided in the annual reports.

Table 6.14. Examples of management activities in the Buffalo River watershed since 2000.

<table>
<tr><th>Project/program
(lead agency/organization)</th><th colspan="2">Practices</th><th>Location</th><th>Status</th></tr>
<tr><td rowspan="5">01-1800 Newton County Buffalo River Watershed Cost Share (Conservation District)</td><td>Fencing
(for prescribed grazing)</td><td>65,410 ft
(1,740.5 ac)</td><td rowspan="5">Newton County</td><td rowspan="5">Complete
2005</td></tr>
<tr><td>Watering facilities</td><td>11</td></tr>
<tr><td>Pasture planting</td><td>888 ac</td></tr>
<tr><td>Swine irrigation system</td><td>2 systems</td></tr>
<tr><td>Waste storage structure</td><td>1</td></tr>
<tr><td>02-700 Local Watershed Dairy Assistance Program (Buffalo Conservation District)</td><td colspan="2">Clean-out service for dairy milking parlors and dry stacks, with nutrient management planning and land application of waste</td><td>Searcy County</td><td>Complete
2005</td></tr>
<tr><td>03-160 Newton County Mini-grant (Newton County Conservation District)</td><td colspan="2">Equipment purchased for rental:
No-til drill for pasture planting
Rotowiper for herbicide application</td><td>Newton County</td><td>Complete
2004</td></tr>
<tr><td>04-108 Newtown County Mini-grant (Newton County Conservation District)</td><td colspan="2">Stabilization of 900 ft of eroding streambank with two rock vanes and 400 ft of peak stone toe protection</td><td>Little Buffalo River</td><td>Complete</td></tr>
<tr><td>05-102 Newton County Spreader (Newton County Conservation District)</td><td colspan="2">Purchase lime spreader for rental</td><td>Newton County</td><td>Complete</td></tr>
<tr><td>Smith Creek Preserve (The Nature Conservancy)</td><td colspan="2">Management of forest and Sherfield Cave as habitat for Indiana Bat</td><td>Newton County</td><td>On-going</td></tr>
<tr><td>Council Rock Forest (The Nature Conservancy)</td><td colspan="2"></td><td>Newton County</td><td>On-going</td></tr>
</table>

6.8 Meeting Reduction Goals

This section explores whether it is possible to achieve the nitrogen and *E. coli* reduction targets (Section 6.4) using the management practices identified (Section 6.7). Information on the effectiveness in reducing selected pollutants in surface waters have been published for a number of the pasture and hayland management strategies identified in the previous section. This information is summarized in Table 6.15. Table 6.15 shows reported reduction percentages for nitrate, fecal coliforms/*E. coli*, sediment, and phosphorus. This information shows that, while the focus of management in this plan is inorganic nitrogen and *E. coli*, practices that reduce these pollutants also reduce other pollutants of concern in the Buffalo River watershed.

In addition, suites of management practices are typically implemented, not individual management practices, so the actual reduction efficiencies for both inorganic nitrogen and *E. coli* reduction are likely to be greater than indicated in the table. For example, stream exclusion, alternative water supplies, prescribed/rotational grazing, and pasture management could be implemented as a suite of practices. With stream exclusion, riparian habitat and streambank restoration could also be implemented. Unfortunately, there are an almost infinite number of possible combinations of practices, so the reduction efficiencies for individual management practices only are shown in Table 6.15.

Studies in the Buffalo River watershed suggest that pasture and hayland management also affects groundwater quality in this watershed, which ultimately can impact the quality of surface waters. NRCS states that several of the management practices recommended in this plan can also protect groundwater quality. However, information on effectiveness of these management practices in reducing target pollutants in groundwater was not found.

6.8.1 Inorganic Nitrogen Reduction

Estimates of the extent of pasture and hayland practices that would be required to achieve the target inorganic nitrogen load reductions for the recommended subwatersheds are listed in Table 6.16. Included in Table 6.16 are estimates of the area of pasture and length of streams within or adjacent to pasture for each subwatershed (estimated using GIS analysis). The values shown in Table 6.16 were calculated using the following assumptions; that 70% of the inorganic nitrogen load to the streams is from pasture and haylands, that 100% of the pasture and haylands in the subwatersheds is contributing to the inorganic nitrogen load, and that 100% of the inorganic nitrogen load is from surface runoff. Based on the results shown in Table 6.16, it may be possible to achieve the plan target inorganic nitrogen load reductions by managing pasture and haylands in all of the recommended subwatersheds except Big Creek (lower).

Table 6.15. Reported pollutant reduction percentages for selected management practices for the recommended subwatersheds of the Buffalo River.

Practice	TSS reduction	Bacteria reduction	Nitrogen reduction	Phosphorus reduction
Stream exclusion (Fencing + alternative water supply)/Access control	83%[a], 75%[j]	30% - 95%[h]	32%[a], 60%[j]	76%[a], 60%[j]
Alternative water supply	38%[a], 89%[b], 38-96%[e], 30%[j]	57%[b]	41%[a], 13-77%[e], 30%[j]	74-97%[e], 30%[j]
Heavy use area treatment	No information	No information	No information	No information
Prescribed/rotational grazing	60%[b], 20%[j]	60% - 72%[g]	20%[j]	20%[j]
Forested riparian buffer	76%[a], 94%[b], 55-95%[e], 45-70%[j]	30%[b]	47-59%[a], 37-57%[e], 44-70%[j]	53-63%[a], 45-70%[j]
Streambank stabilization/ restoration	Up to 100%[c]	No information	No information	No information
Erosion control practices for unpaved roads	48% - 95%[d]	No information	No information	No information
Forestry BMPs (SMZ, stream crossing, road BMPs)	See Forested riparian buffer, and erosion control for unpaved roads, 50%[j]	Not applicable	See Forested riparian buffer, and erosion control for unpaved roads, 50%[j]	See Forested riparian buffer, and erosion control for unpaved roads, 50%[j]
Pasture planting	59%[a]	No information	66%[a]	67%[a]
Filter strips	53% - 91%[a], 31% - 98%[b], 18-99%[e]	30% - 100%[b]	1-93%[e]	2-93%[e]
Grassed waterway	17%[a], 74%[i]	No information	No information	No information
Waste storage facility	Not applicable	No information	52%[a], 29-75%[e]	58%[a], 26-90%[e]
Nutrient management plans	72-92%[e]	No information	0-84%[e]	8-91%[e]
Herbaceous riparian buffer	23%[f], 50-70%[j]	41%[b]	68%[f], 31-48%[j]	67%[f], 50-70%[j]
Pond	77%[a]	No information	82%[a]	72-80%[a]
Feral hog management	No information	No information	No information	No information
Silvopasture establishment	No information	No information	No information	No information
Economic development plan				

[a] (Merriman, Gitau and Chaubey 2009)
[b] VT database
[c] www.watershedconservation.org/proj_brentwood.html
[d] (TNC n.d.)
[e] BMP Tool II
[f] (Garrett 2011)
[g] (Peterson, Redmon and McFarland a)
[h] (Peterson, Redmon and McFarland b)
[I] (Hjelmfelt and Wang 1999)
[j] PDEP 2013

Repairing or replacing failing onsite wastewater treatment systems could result in 100% removal of inorganic nitrogen from that source.

Table 6.16. Pasture and hayland treatment to achieve inorganic nitrogen load reductions.

	Mill Creek (upper)	Calf Creek	Bear Creek	Brush Creek	Tomahawk Creek	Big Creek (lower)
Target percent load reduction for pasture (70% of total load)	57%	46%	97%	47%	59%	100%
Estimated feet of streambank in pasture and hayland[a]	47,385	326,304	520,740	78,213	165,069	549,909
Acres pasture in subwatershed	3,810[b]	9,428	17,686	3,138	7,275	19,544
Feet forest riparian buffer (70% reduction)	39,000	213,000	NA[c]	53,000	138,000	NA[c]
Feet herbaceous riparian buffer (48% reduction)	NA[c]	311,000	NA[c]	77,000	NA[c]	NA[c]
Feet pasture stream exclusion (60% reduction)	45,000	249,000	NA[c]	61,000	161,000	NA[c]
Acres pasture planting (66% reduction)	3,300	6,500	NA[c]	2,200	6,400	NA[c]
Acres prescribed grazing (20% reduction)	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]

[a] estimated as 1.5 x feet of streams within 50 ft of 2011 pasture/hayland land cover
[b] includes land in Crooked Creek watershed within Dogpatch Springs recharge area
[c] not able to achieve target reduction with this practice alone, however, it may be possible to achieve the target reduction by implementing several practices together.

6.8.2 Reduction of *E. coli* Load

Estimates of the extent of pasture and hayland practices that would be required to achieve the target *E. coli* load reductions for the recommended subwatersheds are listed in Table 6.17. Included in Table 6.17 are estimates of the area of pasture and length of streams within or adjacent to pasture for each subwatershed. The values shown in Table 6.17 were calculated using the following assumptions; that 90% of the *E. coli* load to the streams is from pasture and haylands, that 100% of the pasture and haylands in the subwatersheds is contributing to the *E. coli* load, and that 100% of the *E. coli* load is from surface runoff.

Table 6.17. Treatment to reduce *E. coli* load to target levels.

Treatment	Mill Creek (upper)	Brush Creek	Tomahawk Creek	Big Creek (lower)
Target percent load reduction for pasture (assuming 90% of total load)	83%	59%	46%	79%
Estimated feet of streambank in pasture and hayland[a]	47,385	78,213	165,069	549,909
Acres pasture in subwatershed	3,810[b]	3,138	17,686	19,544
Feet forest riparian buffer (50% reduction)	NA[c]	NA[c]	150,397	NA[c]
Feet herbaceous riparian buffer (40% reduction)	NA[c]	NA[c]	NA[c]	NA[c]
Feet pasture stream exclusion (60% reduction)	NA[c]	76,000	125,330	NA[c]
Acres prescribed grazing (60% reduction)	NA[c]	NA[c]	5,523	NA[c]

[a] estimated as 1.5 x feet of streams within 50 ft of 2011 pasture/hayland land cover
[b] includes pasture in Crooked Creek watershed within Dogpatch Springs recharge area
[c] not able to achieve target reduction with this practice alone, however, it may be possible to achieve the target reduction by implementing several practices together.

Repairing or replacing failing individual wastewater treatment systems could result in 100% removal of *E. coli* from that source.

As shown in Table 6.15, practices that reduce inorganic nitrogen and *E. coli* inputs to surface water from pasture and haylands also reduce phosphorus and sediment inputs. Table 6.18 shows expected load reductions for *E. coli*, phosphorus, and sediment that result from implementation of management practices to the extent needed to achieve the target reductions for inorganic nitrogen (from Table 6.16) in each of the recommended subwatersheds. The calculations for these reduction estimates are included in Appendix H. The load reductions shown in Table 6.18 are estimates based on currently available information. Due to our incomplete understanding of the processes at work in the Buffalo River watershed, and the vagaries of weather and stakeholder participation, actual results may differ from those identified here.

Table 6.18. Expected reductions in total surface runoff load for multiple pollutants associated with management of nitrogen from pasture and hayland.

Practice	Extent of practice	Nitrogen reduction[b]	Coliform Reduction[c]	Phosphorus reduction[d]	Sediment reduction[e]
Mill Creek (upper) target nitrogen reduction = 40%, target coliform reduction = 75%					
Forest riparian buffer	39,000 ft	40%	37%	46%	6%
Herbaceous riparian buffer	47,000 ft[a]	34%	36%	56%	8%
Pasture stream exclusion	45,000 ft	40%	51%	46%	8%
Pasture planting	3,300 ac	40%	Unknown	46%	8%
prescribed grazing	3,800 ac[a]	14%	54%	16%	3%
Calf Creek Target nitrogen reduction = 32%, no target for coliform reduction					
Forest riparian buffer	213,000 ft	32%	29%	37%	7%
Herbaceous riparian buffer	311,000 ft	32%	34%	53%	11%
Pasture stream exclusion	249,000 ft	32%	41%	37%	9%
Pasture planting	6,500 ac	32%	Unknown	37%	8%
prescribed grazing	9,400 ac[a]	14%	54%	16%	4%
Bear Creek Target nitrogen reduction = 68%, no target for coliform reduction					
Forest riparian buffer	521,000 ft[a]	49%	45%	56%	11%
Herbaceous riparian buffer	521,000 ft[a]	34%	36%	56%	11%
Pasture stream exclusion	521,000 ft[a]	42%	54%	48%	12%
Pasture planting	18,000 ac[a]	46%	Unknown	54%	10%
prescribed grazing	18,000 ac[a]	14%	54%	16%	3%
Brush Creek Target nitrogen reduction = 33%, target coliform reduction = 53%					
Forest riparian buffer	53,000 ft	33%	30%	38%	7%
Herbaceous riparian buffer	77,000 ft	33%	35%	55%	10%
Pasture stream exclusion	61,000 ft	33%	42%	38%	9%
Pasture planting	2,200 ac	33%	Unknown	38%	10%
prescribed grazing	3,100 ac[a]	14%	54%	16%	5%

Table 6.18. Expected reductions in total surface runoff load for multiple pollutants associated with management of nitrogen from pasture and hayland (continued).

Practice	Extent of practice	Nitrogen reduction[b]	Coliform Reduction[c]	Phosphorus reduction[d]	Sediment reduction[e]
Tomahawk Creek Target nitrogen reduction = 41%, target coliform reduction = 41%					
Forest riparian buffer	138,000 ft	41%	38%	47%	10%
Herbaceous riparian buffer	165,000 ft[a]	34%	36%	56%	12%
Pasture stream exclusion	161,000 ft	41%	53%	47%	12%
Pasture planting	6,400 ac	41%	Unknown	48%	9%
prescribed grazing	7,300 ac[a]	14%	54%	16%	3%
Big Creek (lower) Target nitrogen reduction = 70%, target coliform reduction = 71%					
Forest riparian buffer	549,000 ft[a]	49%	45%	56%	15%
Herbaceous riparian buffer	549,000 ft[a]	34%	36%	56%	15%
Pasture stream exclusion	549,000 ft[a]	42%	54%	48%	16%
Pasture planting	19,000 ac[a]	46%	Unknown	54%	11%
prescribed grazing	19,000 ac[a]	14%	54%	16%	4%

[a] this extent represents treatment of 100% of streambanks or pasture and hayland area
[b] Assuming 70% of total inorganic nitrogen load to surface waters come from pasture and hayland.
[c] Assuming 90% of total fecal coliform load to surface waters comes from pasture and hayland,
[d] Assuming 80% of phosphorus load to surface waters comes from pasture and hayland.
[e] Assuming 23% of sediment load to surface waters comes from pasture and hayland.

7.0 IMPLEMENTATION PROGRAM

The implementation program for the Buffalo River watershed-based management plan includes several elements. In addition to implementing practices to manage unregulated nonpoint pollution sources, the program includes:

- Information and education activities aimed at watershed stakeholders,
- Teams to guide and coordinate voluntary activities in recommended subwatersheds,
- Water quality and biological monitoring to document any changes resulting from voluntary nonpoint source pollution management activities,
- Regular evaluation of progress toward plan goals, and
- Updating the plan to accommodate changes in the watershed, and/or in understanding of the watershed.

These elements are described in this section. This section also includes a schedule and milestones for the implementation program.

There are a number of organizations and agencies involved in management of the Buffalo River watershed. Implementation of this plan will be undertaken by a coalition of interest groups and local stakeholders with the cooperation and assistance of federal and state agencies.

HIGHLIGHTS

- This plan will be implemented by stakeholders with the assistance of federal and state agencies.
- There are a number of agencies and organizations with active information and education programs in the Buffalo River watershed that address watershed issues.
- Two additional information activities are proposed – documentation of ecosystem services, and reporting of trash monitoring.
- Formation of Watershed Implementation Teams for the recommended subwatersheds is proposed.
- Research on how to influence change can be applied in the watershed.
- Monitoring of water quality, fisheries, aquatic invertebrates, algae, and the presence of trash is described.
- Studies are proposed to improve understanding of pollution sources and selection of appropriate nonpoint source management practices in the recommended subwatersheds.
- Approaches for evaluation of, and updating, the plan are outlined.

7.1 Information and Education

Watershed-based management is fundamentally a social activity (Thornton & Laurin 2005). While technical solutions to problems are necessary for effective watershed management, they are not sufficient. Decisions on how to protect and improve water quality, and implement management practices, are ultimately based on the socioeconomic perceptions, beliefs, and values of landowners and stakeholders on how these technical solutions will affect them. The Information and Education objectives of this watershed-based plan, therefore, are to:

- Increase local landowner and public awareness of the need for, and the benefits of, watershed restoration and protection practices;
- Increase stakeholder support and participation in watershed management activities; and
- Improve the understanding of how water quality and environmental improvements contribute to increased economic and social capital in the community.

Since the effort to protect the Buffalo River in the 1960's, the Buffalo River watershed has been the focus of a variety of information and education outreach programs. The majority of these efforts have focused on the aesthetic, ecological, and recreational features of the Buffalo National River and the need for protection and preservation of these features. Examples of the active information and education programs related to water quality protection and improvement that are aimed at, or applicable to, Buffalo River stakeholders are described below. Table 7.1 summarizes stakeholder groups for the Buffalo River watershed, and the organizations that have active information and education programs that target them.

Table 7.1. Buffalo River watershed stakeholder groups and outreach programs.

Stakeholder Groups	Organizations with Information and Education Programs for the Stakeholders
Agriculture producers	Natural Resources Conservation Service, University of Arkansas Division of Agriculture, County Conservation Districts, Arkansas Grazing Lands Coalition, The Nature Conservancy, Arkansas Cattlemen's Association, Arkansas Farm Bureau, Arkansas Pork Producers Association
Recreationists	US National Park Service Buffalo National River, Arkansas Game and Fish Commission, Arkansas Canoe Club, Audubon Arkansas, Backcountry Horsemen of America, Buffalo National River Partners, Buffalo River Coalition, Buffalo River Watershed Alliance, Friends of the Norfork and White Rivers, Ozark Off-road Cyclists, Ozark Society, The Nature Conservancy, White River Waterkeeper
Landowners and residents	US National Park Service Buffalo National River, Rural Water Associations, NRCS, University of Arkansas Division of Agriculture, County Conservation Districts, Arkansas Forestry Commission, Arkansas Game and Fish Commission, Arkansas Natural Heritage Commission, The Nature Conservancy, Arkansas Master Naturalists, White River Waterkeeper
Local and county governments	Arkansas Economic Development Commission, The Nature Conservancy, Arkansas Natural Resources Commission
Concessioners, vendors, hostelers, restaurants	US National Park Service Buffalo National River, Buffalo River Regional Chamber of Commerce

7.1.1 Buffalo National River

Interpretation and education is an important element of the USNPS. The interpretation and education programs of the Buffalo National River (BNR) include information about the natural resources present in the park, the threats to these resources, and how visitors and others can protect and preserve these natural features and communities. Interpretation and education facilities at Buffalo National River include the Tyler Bend Visitor Center, and ranger stations at Buffalo Point and Steel Creek river access areas. There are also numerous wayside exhibits throughout the park that provide information about natural and cultural resources in the park. A variety of interpretive activities are offered for park visitors, which include guided hikes, floats, and cave tours; interpretive programs on a variety of subjects; and the Junior Ranger program.

The Buffalo National River also has school curriculum-based educational programs. These programs include presentations at schools, citizen science events at the park, summer camps focusing on stream and cave ecology, and educational field trips at the park.

USNPS staff from the Buffalo National River utilize a variety of methods for conducting interpretation and education outside of the park. These include presentations in local communities, presentations and displays at county fairs and area festivals, a biennial newspaper (Currents), and the park website, Facebook page, and Twitter feed. USNPS staff also work with the concessioners, such as canoe liveries, who provide services in the park so they can educate their customers about how to safely use the park, including Leave No Trace Behind (USNPS 2015f).

7.1.2 Natural Resources Conservation Service

Information and education activities of the Natural Resources Conservation Service (NRCS) include participation in field days and farm demonstrations, soil and water stewardship materials, and informational and training programs at county offices. Through these activities, NRCS provides information and education on a wide range of topics related to agriculture in the state, including benefits of, implementation, and maintenance of agricultural practices to protect water quality so water quality standards are met.

7.1.3 University of Arkansas Division of Agriculture

The UofA Division of Agriculture is the primary research and information support agency for the agricultural sector in Arkansas. The Division of Agriculture conducts information and education through the Cooperative Extension Service. Information and education activities of the Cooperative Extension Service include displays and presentations at fairs and festivals, participation in field days and farm demonstrations, informational and training programs at county offices, newsletters, publications on a variety of topics including short and long-term agricultural methods that protect water quality so water quality standards are met, and a website that provides access to information about programs and resources, and copies of informational publications.

7.1.4 County Conservation Districts

Information and education activities of the County Conservation Districts include displays and presentations at fairs and festivals, participation in field days and farm demonstrations, soil and water stewardship materials, and informational and training programs at county offices. Through these activities, County Conservation Districts provide information and education on a wide range of topics related to agriculture and rural life, including benefits, implementation, and maintenance of agricultural practices to protect water quality so water quality standards are met.

7.1.5 Arkansas Unpaved Roads Program

The Arkansas Unpaved Roads program is a partnership between the Arkansas Economic Development Commission, Division of Rural Services, the AGFC and The Nature Conservancy, with the purpose of creating “a better unpaved county road system with a reduced negative environmental impact.” This program focuses on road maintenance practices that help streams meet sediment and turbidity water quality standards. Training of a county representative and road crew personnel in Environmentally Sensitive Maintenance for unpaved roads is required for a county to be eligible to receive grant money from the program (Arkansas Department of Rural Services 2017). Several training workshops in Environmentally Sensitive Maintenance are offered each year. The training is a partnership effort by UofA Center for Training Transportation Professionals, the Arkansas Economic Development Commission, Division of Rural Services, and The Nature Conservancy. In the area of the Buffalo River watershed, county personnel have been trained in Environmentally Sensitive Maintenance in Searcy, Stone, and Van Buren Counties (The Nature Conservancy 5-12-17 presentation to BBRAC).

7.1.6 Arkansas Natural Resource Agencies

Arkansas natural resource agencies, including Arkansas Forestry Commission, AGFC, Arkansas Natural Heritage Commission, and ANRC, all have information and education programs aimed at increasing public interest, understanding, and stewardship of the natural resources of our state. These agencies use a variety of methods to reach Arkansans, including websites; newsletters; presentations and displays at meetings, fairs, and festivals; news media stories; and hosting volunteer and training events.

7.1.7 Arkansas Grazing Lands Coalition

One of the goals of the Arkansas Grazing Lands Coalition is education of landowners and operators on implementation and maintenance of “grazing practices that promote environmental, financial, and social stability.” This goal is accomplished in part through sponsorship of field days, and an annual conference (Arkansas Grazing Lands Coalition 2017).

7.1.8 The Nature Conservancy

The Nature Conservancy uses their Strawberry River Preserve and Demonstration Ranch in Sharp County as an outreach and education project. This preserve showcases economically feasible specialized grazing techniques that protect streambanks and stream ecology. Training workshops in these techniques have been offered for local ranchers by The Nature Conservancy (The Nature Conservancy 2015).

Through its Ozark Highlands Karst program, The Nature Conservancy educates local governments, developers, and farmers about the sensitivity of karst areas to groundwater pollution from surface activities. They also provide information about how to reduce impacts of surface activities on groundwater and cave biota in karst areas (The Nature Conservancy 2017b).

7.1.9 Other Nonprofit Interest Groups

There are a number of nonprofit groups with interests in the Buffalo River watershed. These include the Arkansas Canoe Club, Arkansas Cattlemen's Association, Arkansas Farm Bureau, Arkansas Master Naturalists, Arkansas Pork Producers Association, Audubon Arkansas, Backcountry Horsemen of America, Buffalo National River Partners, Buffalo River Coalition, Buffalo River Watershed Alliance, Friends of the Norfork and White Rivers, Ozark Off-road Cyclists, Ozark Society, and White River Waterkeeper. These organizations provide information and education to their members and the public through a variety of methods including, websites; newsletters; presentations and displays at meetings, fairs, and festivals; news media stories; and hosting events.

7.2 Proposed Information and Education Programs for Buffalo River Watershed

To further assist in improvement of water quality in the recommended subwatersheds, some additional information and education programs are proposed. These programs are described below.

7.2.1 Onsite Wastewater System Maintenance Outreach

For recommended subwatersheds where human sources are identified as contributing to *E. coli* loads (see studies described in Section 7.7), information and education about proper maintenance of onsite wastewater systems could improve water quality and ensure water quality standards are achieved. The Arkansas Department of Health offers training for operators of regulated onsite wastewater systems that serve camps, trailer parks, or multiple households. The EPA SepticSmart information and education program has a variety of materials that can be used to inform and educate homeowners with individual onsite wastewater systems, e.g., septic systems. SepticSmart is endorsed by the Arkansas Rural Water Association. White River Waterkeeper has expressed interest in education outreach to homeowners with individual onsite wastewater systems in the region (J. Green, personal communication, October 12, 2017, White River Waterkeeper).

7.2.2 Quantify Ecosystem Services

Ecosystem services are the benefits people obtain from ecosystems (MEA 2005) and the direct and indirect contributions of ecosystems to human well-being (TEEB 2010). Some of these services are protected by state water quality regulations as designated uses specified in state water quality standards. As categorized by the Millennium Ecosystem Assessment (MEA), these include *provisioning* services such as food, water, timber and fiber; *regulating* services that affect climate, floods, disease, wastes, and water quality; *cultural* services that provide recreational, aesthetic, and spiritual benefits; and *supporting* services such as soil formation, nutrient cycling, and photosynthesis (MEA 2005). Typically, only provisioning services have market value, with the monetary benefits determined within the market place where goods and services are bought and sold. However, there are significantly more benefits or values that are provided by ecosystem services other than provisioning services.

A taxonomy of economic values for ecosystem services has been developed based on whether there is a physical relationship between the ecosystem and human use (NRC 2004). Use values can be consumptive, non-consumptive, or indirect. Consumptive uses, for example, include commercial fishing and water withdrawals for drinking (i.e., market-based provisioning services). Non-consumptive uses include boating, swimming, or health impacts. Indirect uses includes habitat for birds and bird-watching, or spawning habitat for fish. There are also non-use values, which are not tied directly or indirectly to human use. For example, there are option values, where there currently is no desire to use the ecosystem, but there may be in the future and people value having that future option. Bequest and altruistic values relate to wanting the resource or service available for future generations (bequest) or available for others now (altruistic).

Economists have developed methods for quantifying the value of many of the non-consumptive, indirect, and non-use ecosystem services (Table 7.2). Many of these methods are applicable for estimating the value of ecosystem services that contribute to sustaining and improving water quality within the Buffalo River watershed and its tributaries.

Table 7.2. Monetary valuation methods for ecosystem goods and services.

Market Place Method – value based on ecosystem goods and services bought and sold in commercial markets	**Productivity Method** – value based on products or services that contribute to the production of commercially marketed goods
Hedonic Pricing Method – value based on services that directly affect market price of another good (e.g., streamside vs non-streamside property)	**Travel Cost Method** – value associated with ecosystem used for recreation and willingness of people to pay to travel to the site
Damage Cost Avoided/Replacement Cost Method – value based on cost of avoiding damages from lost services or cost of replacing services (e.g., drinking water treatment costs)	**Contingent Valuation Method** – value based on asking people their willingness to pay for specific ecosystem services based on scenario (most widely used method for estimating non-use values)
Contingent Choice Method – value based on asking people to make trade-offs among choices of services or characteristics. Does not ask for willingness to pay, but infers value from trade-offs	**Benefit Transfer Method** – value based on transferring existing benefit estimates to similar location, issue or use.

The value of ecosystem services is generally unknown and rarely considered by society because the services are "free". Because most people are risk averse and fear loss significantly more than gain (Kahneman and Tversky 1979, Thaler et al. 1997), Buffalo River watershed ecosystem services can be quantified so the differential loss of valued services (e.g., monetary value) can be estimated. For example, manure decomposition (supporting service) makes nutrients available for grass/hay production that offsets the cost of fertilizer application. Soil health, in addition to water quality, represents a category of ecosystem services with significant value to cattle ranchers and hay producers that can also contribute to improved water quality.

The initial quantification of ecosystem services is proposed for Bear Creek. Bear Creek receives inputs that can affect water quality from both point and nonpoint sources, including wastewater effluent, septic tank leakage, sediment loading from erosion, and fecal bacteria loading from pastures. Another potential impact to Bear Creek is altered fish and benthic habitat from streambank and stream bed erosion or disturbance. Flooding can be exacerbated by removal or modification of riparian vegetation. These, and similar drivers and pressures can all impact aquatic ecosystems and their services. A DPSIR model framework (Bradley and Yee 2015) is proposed to illustrate the linkages among drivers (D), pressures (P), status (S), impacts (I), and responses (R) and their relationship with ecosystem service changes and well-being in Bear

Creek. The voluntary set of practices and activities proposed in this watershed management plan represent one set of responses to the impacts on these ecosystem services.

The suggested method for quantifying Bear Creek ecosystem services follows the frameworks proposed by Grizzetti et al. (2016), and Ready (2017, in preparation), using the tools assessed by Bagstad et al., (2013) and InVEST (www.naturalcapitalproject.org/invest/). InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a suite of open source ecosystem service models developed by the Natural Capital Project. The Natural Capital Project is a joint initiative of the University of Minnesota, The Nature Conservancy, Stanford University and World Wildlife Fund (www.naturalcapitalproject.org). A set of ecosystem services for initial valuation, along with the proposed valuation method, is shown in Table 7.3.

There are a number of options for implementing a study quantifying ecosystems services in a Buffalo River subwatershed. The study could be sponsored by an interest group, local stakeholders, or watershed implementation team, and be conducted by a university, or contractor. For information and education purposes, the results of the study will need to be published and made available to local stakeholders, for example, through interest groups and/or local newspapers.

7.2.3 Trash Index Reporting

The organization(s) conducting trash monitoring (see section 7.6) will compile the trash index scores and distribute the information to each of the Buffalo River concessions and Buffalo National River visitor contact centers. Other possible outlets for this information include local newspapers, radio and TV stations, public schools within the watershed, and local community colleges and universities within the watershed. This will help raise awareness of the extent and impacts of improper trash disposal in the watershed.

Table 7.3. Freshwater Ecosystem services, type of value and applied valuation methods. The classification of ecosystem services has been developed for fresh and transitional water (Reynaud and Lanzanova, 2015).

Ecosystem services	Category[a]	Value type	Valuation method[b]	Examples of economic good provided
1-Water for Drinking	Provisioning	Direct	MP, CV	Water for domestic uses
2-Raw (biotic) materials	Provisioning	Direct	MP, RC	Algae as fertilizers
3-Water for no-drinking purposes	Provisioning	Direct	MP, PF	Water for industrial or agricultural uses
4-Raw materials for energy	Provisioning	Direct	RC	Wood from riparian zones
5-Water purification	Regulation	Indirect	RC, CV	Excess nitrogen removal by microorganisms
6-Erosion prevention	Regulation	Indirect	RC	Vegetation controlling soil erosion
7-Flood protection	Regulation	Indirect	RC, CV	Vegetation acting as barrier for the water flow
8-Maintaining populations and habitats	Regulation	Indirect	RC	Habitats use as a nursery
9-Pest and disease control	Regulation	Indirect	RC, CV	Natural predation of diseases and parasites
10-Soil formation	Regulation	Indirect	RC	Rich soil formation in flood plains
11-Carbon sequestration	Regulation	Indirect	RC, MP	Carbon accumulation in sediments
12-Location climate regulation	Regulation	Indirect	RC, MP	Maintenance of temperature patterns
13-Recreation	Cultural	Direct	CV,TC, DC, HP	Swimming, recreational fishing, sightseeing
14-Recreational fishing	Cultural	Direct	TC, CV	Sportfishing for smallmouth bass
15-Recreational canoeing/swimming	Cultural	Direct	MP, TC, CV	Canoing/kayaking, swimming
16-Intellectual and aesthetic appreciation	Cultural	Non-use	CV, DC	Matter for research, artistic representation
17-Spiritual and symbolic appreciation	Cultural	Non-use	CV, TC, DC	Sense of being
18-Raw abiotic materials	Extra abiotic	Direct	PF, MP	Extraction of sand and gravel
19-Abiotic energy sources	Extra abiotic	Direct	PF, MP	Hydropower generation

[a] Provisioning, Regulation and maintenance, Cultural, Extra abiotic services.
[b] Contingent valuation (CV), Hedonic price (HP), Market price (MP), production function (PF), Replacement cost (RC), travel cost (TC).

7.3 Subwatershed Implementation Teams

The greatest efficacy in implementing watershed management plans is typically achieved through individual subwatershed implementation teams. These subwatershed implementation teams serve to coordinate and track voluntary implementation of nonpoint source management practices and studies within their subwatersheds. While there is general interest in activities occurring within other subwatersheds within an 8-digit HUC watershed, the greatest interest, and benefits, are typically associated with stakeholders who live, work, or recreate within subwatersheds of the 8-digit HUC (e.g., local landowners, business operators, county judges or mayors of local towns, and similar individuals who are interested in working together). Therefore, it is recommended that local stakeholders form a watershed implementation team for each of the six recommended subwatersheds. Individuals will need to be contacted to determine their interest in that subwatershed as well as their willingness to work with individuals and organizations interested in implementing the watershed management plan within the subwatershed. Teams could include one to five members, who would be asked to commit to a three-year term. Team responsibilities could include planning implementation projects or studies, obtaining funding for projects or studies, and serving as a clearing house for information on the amount and types of nonpoint source pollution management practices and water quality studies occurring in the subwatershed. Some individuals may serve on multiple teams because their interests are county-wide, spanning multiple subwatersheds (e.g., Conservation District personnel).

7.4 Implement Nonpoint Source Pollution Management Strategies

Nonpoint source pollution management strategies recommended for voluntary implementation in this plan are listed in Table 7.4, along with an indication of the target nonpoint source pollutants within the recommended subwatersheds that they address. The practices are organized by the land use where they apply. Maintenance of practices once they are implemented is important element of nonpoint source pollution management strategies.

Table 7.4. Management strategies proposed for recommended subwatersheds of the Buffalo River.

Strategy	Inorganic nitrogen	Fecal bacteria	Phosphorus	Turbidity/ Sediment
Pasture and Hayland Management Practices				
Nutrient management plans	X	X	X	
Riparian buffers	X	X	X	X
Farm pond/sediment basin construction	X	X	X	X
Livestock stream access control	X	X	X	X
Prescribed/rotational grazing	X	X	X	X
Silvopasture establishment	X	X	X	X
Pasture planting and management	X	X	X	X
Forest Management Practices				
Prescribed forest burns				
Forestry best management practices			X	X
Trail management practices			X	X
Ecotone Management Practices				
Streambank restoration and stabilization	X	X	X	X
Gamebird habitat restoration	X	X	X	X
Filter strips of native plants	X	X	X	X
Management Practices for Multiple Land Uses				
Unpaved road environmentally sensitive maintenance			X	X
On-site wastewater system management/repair/replace	X	X	X	
Control of invasive and destructive species (e.g., feral hogs)	X	X	X	X
Karst protection practices	X	X	X	X

There is no legal requirement that anyone implement any of the practices listed in Table 7.4. These are practices that are suggested for landowners, operators, and other stakeholders interested in protecting or improving water quality in the Buffalo River watershed. In addition to protecting water quality and ensuring water quality standards are met, implementing and maintaining these practices can increase the value and returns on the property where they are implemented. This is not an exclusive list of practices, but rather those that are generally accepted within the watershed and suggested by stakeholders. There are other practices not listed that could also improve or protect water quality and habitat. Programs that can provide technical and financial assistance to landowners, operators, and other stakeholders for implementing these practices are listed in Section 8.

7.5 Influencing Implementation of Management Practices and Activities

Over the past decade, there has been considerable work conducted on ways of leading and implementing change within organizations and communities (Grenny et al. 2013). In general, there are three important domains, each with two important subdomains, that are critical in influencing change. The domains are personal, social, and structural and the sub-domains are motivation and ability. These three domains and two sub-domains form a six-celled matrix (Table 7.5).

Table 7.5. Domain, sub-domain, and elements that can influence behavioral change in implementing management practices and activities.

Domain	Motivation	Ability
Personal	Links to values and personal benefits	Training, skill building
Social	Peer pressure	Social support
Structural	Rewards, accountability	Change the environment

In many instances, the emphasis has only been on personal motivation and ability, ensuring that individuals have the motivation to change and are provided with the training and ability to make the change. However, the importance of social elements of peer pressure and support groups (e.g., Grazing Land Coalition) is also critical in supporting the personal domain. In addition, making changes in the economic environment (i.e., structural domain) through cost-share and rewards (i.e., motivation), and changing the physical environment in which individuals interact (e.g., electric fence vs barbed wire fence), are also critical in bringing about changes in how land and water are viewed and managed. The ability to promote change is strongest when all six cells are addressed simultaneously, not just one or two of the cells. In some cases, it might not be possible to address all six, but the emphasis should be on addressing as many of the six cells as possible to encourage and promote change.

Pasture management, and streambank restoration and stabilization represent two recommended approaches for sustaining and improving water quality within the Buffalo River watershed. Examples of factors that might influence change for each of the elements in the matrix for these two management efforts (i.e., pasture management, streambank restoration/stabilization) are shown in Tables 7.6 and 7.7, respectively.

Wildflowers are included in Table 7.6 as a structural influencing factor. A landowner in Mississippi who had restored riparian buffers next to his cropland remarked during a field day demonstration of streambank restoration, how much he enjoyed seeing wildflowers growing next to his fields. He said that if anyone had attempted to encourage him to restore the riparian area so he could grow wildflowers he would have thrown them off his property. Now, he would frequently just drive around the field edges to look at the wildflowers. He had even brought neighbors to see the displays of wildflowers in the spring. Some ecosystem services won't be appreciated until they become part of the landowner's landscape, but then they become valued features.

The recommendation is that all six elements of the influence matrix be considered during implementation of management practices and activities in the Buffalo River watershed.

Table 7.6. Elements that might help influence implementation of pasture management practices.

Domain	Motivation	Ability
Personal	• Better pasture/forage quality • Increased rate of gain • Reduced hay feeding • Sustain water supply • Cost-share programs	• Grazing land conf. • Field days • YouTube/other videos • Grazing stick • NRCS tech assistance • AR Cooperative Ext.
Social	• Leaders implementing practices • Cattleman of the Year Award	• Grazing land coalition • Field days • Rancher to rancher exchanges • Conferences
Structural	• NRCS EQIP funding • NRCS RCPP funding • 319 funding • US Fish and Wildlife Service Controlled Access for Livestock Fencing funding	• Grow grass, not algae campaign • Grazing stick • Promote 2 strand electric fence • 4-5 forage paddocks • Stockpile paddock • Alternative water supply

Table 7.7. Elements that might help influence implementation of streambank restoration and stabilization practices.

Domain	Motivation	Ability
Personal	• Reduced land loss • Gamebird hunting leases • Aesthetics • Reduced flood damage • Cost-share programs	• NRCS tech assistance • AR Cooperative Ext. • AGFC tech assistance • The Nature Conservancy tech assistance
Social	• Leaders implementing practices • Conservationist of the Year Award	• Rancher to rancher exchanges • Conferences • Field Days
Structural	• NRCS EQIP funding • NRCS RCPP funding • 319 funding • AGFC – Stream Teams	• Timber • Buffer strips/zones • Wildflowers

7.6 Monitoring

Monitoring is an essential element of adaptive watershed management. The objectives of the ongoing and proposed monitoring programs and special studies in the Buffalo River watershed include:

- Determine compliance with state water quality standards,
- Characterize current water quality conditions, including patterns,
- Characterize water quality trends and impacts, and
- Identify sources of pollutants (Mott 1997, Mott, Hudson, & Aley 2000).

7.6.1 Routine Surface Water Quality Monitoring

There are over 30 active surface water quality monitoring stations in the Buffalo River watershed. These stations are monitored through USNPS, ADEQ and USGS surface water quality monitoring programs in the Buffalo River watershed, as described in Section 3.2.3. Table 7.8 lists water quality parameters monitored through these programs, which include the indicator pollutants, inorganic nitrogen and *E. coli*, and other parameters of concern (phosphorus, TSS, total dissolved solids, temperature). Note that recently added parameters and programs should make it possible for ADEQ to evaluate nutrient impacts at the routine monitoring stations, i.e., diel dissolved oxygen monitoring program, and addition of analysis for total phosphorus and all elements of total nitrogen. In addition, TSS analysis is being added to USNPS stations in 2018. All routine water quality monitoring programs are expected to continue. Note that these monitoring programs are operated according to agency data quality control programs.

Table 7.8. Water quality parameters monitored in routine monitoring programs in the Buffalo River watershed.

Parameters	USNPS with ADEQ	ADEQ ambient	ADEQ roving	ADEQ special study	USGS
Metals	X	X	X	X	S
Dissolved Oxygen	X	X	X	X	X
Turbidity	X	X	X	X	
Nutrients	X	X	X	X	X
TSS	X	X	X	X	--
E. coli	X			X	S
Alkalinity	X	X	X	X	X
Minerals	X	X	X	X	S
Temperature	X	X	X	X	X
Conductivity	X	X	X	X	X
pH	X	X	X	X	X
Hardness	X	X	X	X	S
Total organic carbon	X	X	X	X	S
Suspended sediment	--	--	--	--	X

X = monitored at all stations, S = monitored at some stations, but not all

Overall, the existing surface water quality monitoring programs, which are expected to continue for the next five to ten years, are adequate in terms of the number of monitored sites, and their locations.

The majority of the active surface water quality monitoring stations are routinely sampled only quarterly. This frequency of sampling appears adequate for tracking long term trends in water quality. It is not adequate for use in evaluating whether water quality meets *E. coli* standards.

In addition to the existing routine water quality monitoring programs, the White River Waterkeeper is planning to initiate a summer *E. coli* monitoring program in the White River basin, including monitoring locations in the Buffalo River watershed. The purpose of this program is to provide weekly information to the public on *E. coli* levels at selected public swimming areas. This program is scheduled to begin May of 2018 (personal communication, J. Green, White River Waterkeeper, 1/15/18).

7.6.2 Groundwater Quality Monitoring

The USNPS routinely monitors water quality of three springs within the Buffalo National River boundaries. Routine sampling of these springs is expected to continue. No other routine monitoring of springs or groundwater in the Buffalo River watershed was identified. The same water quality parameters are measured in the springs as at the surface water sites (see Table 7.8).

Dogpatch Springs have been identified by researchers as contributing significant inorganic nitrogen and coliform loads to Mill Creek (upper) in Newton County, and to the Buffalo River. However, it appears that these springs are not currently routinely monitored. Monitoring these springs would assist with allocating pollutant loads and recommending management practices to reduce inorganic nitrogen and *E. coli* in Mill Creek and the Buffalo River, as well as to document any changes in spring water quality that result from implementation of nonpoint and/or point source pollution management practices within the springs recharge area within and outside the Buffalo River watershed. ADEQ is currently considering monitoring these springs (ADEQ, personal communication,7/12/17). A local stream team could also be responsible for monitoring the springs. A county road crosses the springs downstream of the privately-owned lands of the Dogpatch park (S. Hodges, USNPS, private communication, 9/5/17).

7.6.3 Biological Monitoring

The USNPS has an active fish community and aquatic invertebrate monitoring programs in the Buffalo National River through the Heartland Network Inventory and Monitoring Program. Revisions were recently made to the monitoring program, and it is expected to continue (DeBacker, Bowles, Dodd, & Morrison 2012). The current USNPS program is well designed, and is expected to be adequate for identifying impacts on the aquatic invertebrate and fish communities. This information can be used by ADEQ to evaluate nutrient impacts in the watershed. The algae monitoring program being developed by the USNPS and ADEQ will assist with answering questions about nuisance algal blooms in the Buffalo River.

7.6.4 Trash Index

Litter and trash are an eyesore and contribute to decreased water quality, decreased property values, pest and rodent problems, and potential impacts on wildlife and fisheries. Developing an approach for monitoring litter and trash will help inform the public, establish the magnitude of the problem, apportion the trash from the Buffalo River and tributary sources, and provide a tool for evaluating litter reduction efforts.

A trash index score will be computed for three occasions: the week following Spring Break for Arkansas schools and universities, after Memorial Day, and after the Fourth of July. These are typically high use periods for the Buffalo River and its tributaries. While Spring Break does not occur at the same time each year, it does represent a time when the water is typically high and conducive to floating. The trash monitoring sites will be co-located with the USNPS Heartland biological monitoring sites sampled each year on a rotating panel basis (see Figures 4.1 and 4.2).

The assessment methodology is described in *Rapid Trash Assessment Methodology, Version 8* (California State Water Boards 2007). The assessment is conducted on a 100-ft area of shoreline at a sampling site. A team of two people document characteristics of the site such as public access to the site, a description of the shoreline, and a “high-water” line. Trash located below the high-water line can be expected to move into the river or be swept downstream during the next high-flow event. In conducting the assessment, the team members systematically walk from downstream to upstream and pick up trash items as they come to them. A tally of the number and types of items found is kept as the items are picked up. Items found above and below the high-water line are tallied separately. A trash score is calculated for the site based on the six parameters listed below. Instructions on a worksheet developed specifically for the rapid trash assessment (Figure 7.1) allow monitoring personnel to assign scores for each parameter.

Rapid Trash Assessment Worksheet

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

WATERSHED/STREAM: ______________________________ DATE/TIME: _______________
MONITORING GROUP, STAFF: ________________________ SAMPLE ID: _______________
SITE DESCRIPTION (Station Name, Number, etc.): ______________________________________

	CONDITION CATEGORY			
Trash Assessment Parameter	**Optimal**	**Sub optimal**	**Marginal**	**Poor**
1. Level of Trash	On first glance, no trash visible. Little or no trash (<10 pieces) evident when streambed and stream banks are closely examined for litter and debris, for instance by looking under leaves.	On first glance, little or no trash visible. After close inspection small levels of trash (10-50 pieces) evident in stream bank and streambed.	Trash is evident in low to medium levels (51-100 pieces) on first glance. Stream, bank surfaces, and riparian zone contain litter and debris. Evidence of site being used by people: scattered cans, bottles, food wrappers, blankets, clothing.	Trash distracts the eye on first glance. Stream, bank surfaces, and immediate riparian zone contain substantial levels of litter and debris (>100 pieces). Evidence of site being used frequently by people: many cans, bottles, and food wrappers, blankets, clothing.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Actual Number of Trash Items Found	0 to 10 trash items found based on a trash assessment of a 100-foot stream reach.	11 to 50 trash items found based on a trash assessment of a 100-foot stream reach.	51 to 100 trash items found based on a trash assessment of a 100-foot stream reach.	Over 100 trash items found based on a trash assessment of a 100-foot stream reach.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Threat to Aquatic Life	Trash, if any, is mostly paper or wood products or other biodegradable materials. Note: A large amount of rapidly biodegradable material like food waste creates high oxygen demand, and should not be scored as optimal.	Little or no (<10 pieces) transportable, persistent, buoyant litter such as: hard or soft plastics, Styrofoam, balloons, cigarette butts. Presence of settleable, degradable, and non-toxic debris such as glass or metal.	Medium prevalence (10-50 pieces) of transportable, persistent, buoyant litter such as: hard or soft plastics, Styrofoam, balloons, cigarette butts Larger deposits (< 50 pieces) of settleable debris such as glass or metal. Any evidence of clumps of deposited yard waste or leaf litter.	Large amount (>50 pieces) of transportable, persistent, buoyant litter such as: hard or soft plastics, balloons, Styrofoam, cigarette butts; toxic items such as batteries, lighters, or spray cans; large clumps of yard waste or dumped leaf litter; or large amount (>50 pieces) of settleable glass or metal.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Threat to Human Health	Trash contains no evidence of bacteria or virus hazards such as medical waste, diapers, pet or human waste. No evidence of toxic substances such as chemical containers or batteries. No ponded water for mosquito production. No evidence of puncture and laceration hazards such as broken glass or metal debris.	No bacteria or virus hazards or sources of toxic substances, but small presence (<10 pieces) of puncture and laceration hazards such as broken glass and metal debris. No presence of ponded water in trash items such as tires or containers that could facilitate mosquito production.	Presence of **any one** of the following: hypodermic needles or other medical waste; used diaper, pet waste, or human feces; any toxic substance such as chemical containers, batteries, or fluorescent light bulbs (mercury). Medium prevalence (10-50 pieces) of puncture hazards.	Presence of **more than one** of the items described in the marginal condition category, or high prevalence of any one item (e.g. greater than 50 puncture or laceration hazards).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Figure 7.1(a). Rapid trash assessment worksheet, page 1.

Rapid Trash Assessment Worksheet

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

	CONDITION CATEGORY			
Trash Assessment Parameter	**Optimal**	**Sub optimal**	**Marginal**	**Poor**
5. Illegal Dumping	D: No evidence of illegal dumping. No bags of trash, no yard waste, no household items placed at site to avoid proper disposal, no shopping carts.	D: Some evidence of illegal dumping. Limited vehicular access limits the amount of potential dumping, or material dumped is diffuse paper-based debris.	D: Presence of **one** of the following: furniture, appliances, shopping carts, bags of garbage or yard waste, coupled with vehicular access that facilitates in-and-out dumping of materials to avoid landfill costs.	D: Evidence of chronic dumping, with **more than one** of the following items: furniture, appliances, shopping carts, bags of garbage, or yard waste. Easy vehicular access for in-and-out dumping of materials to avoid landfill costs.
Illegal Littering	L: Any trash is incidental litter (< 5 pieces) or carried downstream from another location.	L: Some evidence of litter within creek and banks originating from adjacent land uses (<10 pieces).	L: Prevalent (10-50 pieces) in-stream or shoreline littering that appears to originate from adjacent land uses.	L: Large amount (>50 pieces) of litter within creek and on banks that appears to originate from adjacent land uses.
D-SCORE	10 9	8 7 6	5 4 3	2 1 0
L-SCORE	10 9	8 7 6	5 4 3	2 1 0
6. Accumulation of Trash	There does not appear to be a problem with trash accumulation from downstream transport. Trash, if any, appears to have been directly deposited at the stream location.	Some evidence (<10 pieces) that litter and debris have been transported from upstream areas to the location, based on evidence such as silt marks, faded colors or location near high water line.	Evidence that (10 to 50 pieces) trash is carried to the location from upstream, as evidenced by its location near high water line, siltation marks on the debris, or faded colors.	Trash appears to have accumulated in substantial quantities at the location based on delivery from upstream areas, and is in various states of degradation based on its persistence in the waterbody. Over 50 items of trash have been carried to the location from upstream.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Total Score _______________

SITE DEFINITION:

UPPER/LOWER BOUNDARIES OF REACH: ____

HIGH WATER LINE: ____

UPPER EXTENT OF BANKS OR SHORE: ____

____

NOTES:

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Figure 7.1(b). Rapid trash assessment worksheet, page 2.

Rapid Trash Assessment Worksheet

Surface Water Ambient Monitoring Program, San Francisco Bay Regional Water Quality Control Board

TRASH ITEM TALLY (Tally with (•) if found above high water line, and (|) if below)

PLASTIC # Above___ # Below____	**METAL** # Above___ # Below____
Plastic Bags	Aluminum Foil
Plastic Bottles	Aluminum or Steel Cans
Plastic Bottle Caps	Bottle Caps
Plastic Cup Lid/Straw	Metal Pipe Segments
Plastic Pipe Segments	Auto Parts (specify below)
Plastic Six-Pack Rings	Wire (barb, chicken wire etc.)
Plastic Wrapper	Metal Object
Soft Plastic Pieces	**LARGE (specify below)** # Above___ # Below____
Hard Plastic Pieces	Appliances
Styrofoam cups pieces	Furniture
Styrofoam Pellets	Garbage Bags of Trash
Fishing Line	Tires
Tarp	Shopping Carts
Other (write-in)	Other (write-in)
BIOHAZARD # Above___ # Below____	**TOXIC** # Above___ # Below____
Human Waste/Diapers	Chemical Containers
Pet Waste	Oil/Surfactant on Water
Syringes or Pipettes	Spray Paint Cans
Dead Animals	Lighters
Other (write-in)	Small Batteries
CONSTRUCTION DEBRIS#Above___#Below__	Vehicle Batteries
Concrete (not placed)	Other (write-in)
Rebar	**BIODEGRADABLE** # Above___ # Below____
Bricks	Paper
Wood Debris	Cardboard
Other (write-in)	Food Waste
MISCELLANEOUS # Above___ # Below____	Yard Waste (incl. trees)
Synthetic Rubber	Leaf Litter Piles
Foam Rubber	Other (write-in)
Balloons	**GLASS** # Above___ # Below____
Ceramic pots/shards	Glass bottles
Hose Pieces	Glass pieces
Cigarette Butts	**FABRIC AND CLOTH** # Above___ # Below____
Golf Balls	Synthetic Fabric
Tennis Balls	Natural Fabric (cotton, wool)
Other (write-in)	Other (write-in)
Total pieces Above: **Below:**	**Grand total:**
Tally all trash in above rows; make notes below as needed to facilitate scoring.	
Littered:	
Dumped:	
Downstream Accumulation:	

SPECIFIC DESCRIPTION OF ITEMS FOUND:_______________________________________

Figure 7.1(c). Rapid trash assessment worksheet, page 3.

The parameters are as follows:

1. Level of trash,
2. Actual number of items found,
3. Threat to aquatic life,
4. Threat to human health,
5. Illegal dumping and littering, and
6. Accumulation of trash.

The trash index scores will be compiled and distributed to each of the Buffalo River concessions, and Buffalo National River visitor contact centers. The index scores will be tracked over time and used, in part, to assess the effectiveness of outreach and education programs related to the Leave No Trace Behind goal.

7.7 Special Studies Related to Nonpoint Source Pollution

Special studies are on-going in at least two subwatersheds of the Buffalo River. Additional special studies are proposed to identify management practices that are most appropriate for the recommended subwatersheds, and critical areas for implementation within the subwatersheds. Potential vehicles for these studies include ADEQ, USNPS, universities, watershed implementation teams, and interest groups. The USNPS has cooperative agreements with both the University of Central Arkansas, and North Arkansas College at the Buffalo National River. The Buffalo River Watershed Alliance has sponsored studies in the Buffalo River watershed.

7.7.1 Proposed Study - Microbial Source Tracking in Recommended Subwatersheds

Microbial source tracking (MST) will be used to determine the origins of *E. coli* and fecal coliforms in the Mill Creek (upper). Big Creek (lower), Tomahawk Creek, and Brush Creek recommended subwatersheds might be assessed if the Mill Creek (upper) study is productive. Specific genetic markers can be identified for human, bovine, swine, and poultry bacteria sources. Thus, MST can be used to confirm the presence or absence of these sources in the subwatersheds.

Gibson et al. (2017) used quantitative polymerase chain reaction (QPCR) methods to characterize these gene markers for microbial source attribution in the Beaver Lake watershed in Northwest Arkansas. EPA has patented approaches for MST that are available free for nonprofit research projects, if certain criteria are satisfied.

The EPA or similar methods will be used to partition microbial sources in the Mill Creek (upper) subwatershed as a proof of concept for the Buffalo River watershed. Sampling sites will include the Dogpatch Springs, and stream reaches with high *E. coli* levels identified by the recent ADEQ study (described in Section 3.2.3.1). Genetic markers for human, bovine, swine, and poultry sources will be identified and used to determine which of these sources are present. Once it is confirmed what sources are contributing to the *E. coli* load, the nonpoint source management practices that address those sources can be targeted for implementation. ADEQ is considering conducting an MST study in the Mill Creek (upper) subwatershed (personal communication, T. Ramick, ANRC, 10/2/2017).

If the results of the Mill Creek (upper) MST study are found to be helpful, MST studies will also be completed in the three remaining recommended subwatersheds with *E. coli* reduction targets (Big Creek (lower), Brush Creek, and Tomahawk Creek). For Brush Creek and Tomahawk Creek, samples from the stream routine monitoring station will be used for the MST analyses. For the Big Creek (lower) subwatershed, sampling sites will be in stream reaches with high *E. coli* levels identified by the subwatershed water quality characterization study (Section 7.7.2).

7.7.2 Proposed Study – Subwatershed Water Quality Characterization

The Big Creek (lower) subwatershed is one of the largest subwatersheds of the Buffalo River. The Bear Creek subwatershed is also one of the larger subwatersheds. Intensive synoptic water quality studies are proposed for these subwatersheds, similar to the one being conducted by ADEQ in the Mill Creek (upper) subwatershed (see Section 3.2.3.1). The purpose of these studies will be to identify critical areas for implementation of nonpoint source management practices within the subwatersheds. Of particular interest in such studies would be the influence of springs and groundwater on water quality in the subwatershed. More than one study of "problem" areas in the Buffalo River watershed have found that pollutants of concern are being transported via groundwater from outside of the subwatershed being studied (Mott et al. 2000, 2002).

The proposed design for these studies is two intensive synoptic sampling events. One sampling event would be during the spring to characterize water quality under high flow conditions, when runoff influences dominate. The second sampling event would be during the summer to characterize water quality under base flow conditions, when groundwater and point source influences tend to dominate. Four sampling sites are proposed on Bear Creek, located at county road bridges. Six sampling sites are proposed in the Big Creek (lower) subwatershed-three on Big Creek, and single sites near the mouths of Long Creek, Davis Creek, and Sellers Creek. Proposed water quality parameters for the study are in situ measurements of temperature, dissolved oxygen, and conductivity; and lab analysis for turbidity, total nitrogen, total phosphorus, TSS, and *E. coli*.

7.7.3 Proposed Study – LiDAR Analysis of Streambank Erosion

LiDAR data for the state, including the Buffalo River watershed, was recently flown and will be available from NRCS in March 2018. It is proposed that LiDAR data for the Calf Creek subwatershed be analyzed to see if it can be used to identify areas where streambank erosion or instability appears to be occurring. Site visits will be used to ground-truth, or confirm, these possible areas as candidates for streambank stabilization and riparian area restoration. County Conservation District personnel will be contacted for information on landowners of the bank/riparian areas who might be interested in voluntarily participating in riparian area restoration and bank stabilization. The conservation district personnel will provide information on cost-share programs that provide financial assistance for interested landowners, technical support available, and contacts for additional information. All landowner information will remain confidential.

It is proposed that LiDAR analysis of streambank erosion be conducted first in the Calf Creek subwatershed, as a proof of concept. If the analysis proves reliable and useful, it can be completed for other recommended subwatersheds.

7.8 Evaluation

This watershed-based plan for the Buffalo River watershed was developed within an adaptive management framework. Adaptive management is an iterative process of optimal decision-making through evaluating results and adjusting actions based on what has been learned. The evaluation framework outlined below considers three major elements of the implementation of a watershed-based plan: program inputs, outputs, and outcomes. These elements will be evaluated for information/education, monitoring, and implementation of management practices. State and federal agencies, nonprofit organizations, and watershed implementation teams will provide information they have collected about implementation activities to the organization conducting the evaluation.

It is recommended that an evaluation of plan implementation occur approximately every five years. Therefore, the first evaluation of this plan would occur in 2024.

7.8.1 Inputs

The inputs for implementation of this plan are the assistance programs available, and stakeholder participation. Indicators that measure this component of the plan implementation are listed in Table 7.9. The stakeholders and organizations that participate in implementation of this plan should provide the subwatershed implementation teams and/or the evaluating organization with annual totals for these inputs indicators for the period 2018 through 2023 by February 2024.

Table 7.9. Indicators of inputs for implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Monitoring programs	Resources spent on monitoring in Buffalo River watershed Hours and number of personnel involved
	Stream Teams	Number of inquiries Number of teams formed Number of participants on teams Hours and number of AGFC personnel involved
	Special studies	Resources spent on special studies Hours and number of personnel involved
Information/Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	Number of conference attendees from Buffalo River watershed
	Events – field days, festivals, river clean up	Number of attendees Hours and number of people involved Cost
	Community presentations	Number of attendees Hours and number of people involved Cost
	K-12 education programs	Number of attendees Hours and number of people involved Cost
	Interest groups meetings, websites, newsletters	Number of meeting attendees Hours and number of people involved Cost
	Training in Environmentally Sensitive Maintenance for unpaved roads	Number of attendees Hours and number of people involved Cost
Implement management practices	Assistance programs in the Buffalo River watershed	Resources distributed to Buffalo River watershed Hours and number of people assisting stakeholders in Buffalo River watershed Number of Buffalo River watershed stakeholders requesting assistance
	Subwatershed implementation teams	Number of teams active in watershed Number of non-agency people on teams

7.8.2 Outputs

The outputs for implementation of this plan are formation of teams, and implementation of nonpoint source management practices, information and education, monitoring and special studies. Indicators that measure this component of the plan implementation are listed in Table 7.10. The stakeholders and organizations that participate in implementation of this plan should provide subwatershed implementation teams and/or the evaluating organization with annual totals for these indicators for the period 2018 through 2023 by February 2024.

7.8.3 Outcomes

The intended outcomes for this watershed-based management plan include improvement in water quality and aquatic habitat in recommended subwatersheds, prevention of declines in water quality and aquatic habitat elsewhere, and increased awareness of, and interest in, water quality and aquatic habitat concerns of the Buffalo River watershed. The long term objective of this watershed-based plan is that waterbodies in the Buffalo River watershed will continue to meet water quality criteria and attain their designated uses. The primary indicators suggested for this goal are inorganic nitrogen and *E. coli* levels. Fecal coliform levels; water temperatures; DO, total phosphorus and TSS concentrations; and indicators of biological integrity are suggested as secondary indicators. These parameters, most of which are currently being monitored, are recommended for use in evaluation of the overall effectiveness of nonpoint source pollution management within the Buffalo River watershed. Within the next four to six years, the goal of this plan is to see incremental progress toward the target inorganic nitrogen and *E. coli* levels, and document stakeholder activities contributing to good water quality and quality of life in the Buffalo River watershed.

The monitored waterbodies in the Buffalo River watershed are assessed by ADEQ every two years to develop the Arkansas integrated water quality assessment report, which includes the 303(d) list of impaired waterbodies. This assessment will be used to evaluate achievement of the goal of no new impaired waterbodies in the watershed.

Table 7.10. Indicators of outputs of implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Monitoring programs	Number of active water quality monitoring stations Number of stations sampled Number of water quality parameter measurements collected Number of sampling events Number of biological surveys Number of algal surveys
	Stream Teams	Number of teams Number of streams monitored Number of active water quality monitoring stations Number of stations sampled Number of water quality parameter measurements collected Number of sampling events Number of trash surveys conducted
	Special studies	Number of studies completed Number of subwatersheds studied Study results reported
Information/Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	Number of conferences
	Events	Number of events in watershed Number of events outside watershed where watershed information presented
	Community presentation	Number of presentations
	K-12 education programs	Number of programs
	Interest group meetings, websites, newsletters	Number of meetings Number of website visits Number of newsletters distributed
	Training in environmentally sensitive maintenance for unpaved roads	Number of workshops in Buffalo River counties
	Trash Surveys	Number of times survey results published Number of places survey results published
Implement management practices	Assistance programs in the Buffalo River watershed	Number/amount of management practices implemented Number of contracts/projects started and finished
	Implementation teams	Number of teams formed Number of subwatersheds with teams Number of projects and studies organized by teams

Implementation of this plan will be considered successful if the following are achieved by 2023:

- A watershed implementation team has been formed for at least one recommended subwatershed and initiated at least one project or study,
- At least one stream team is active in the Buffalo River watershed,
- The median inorganic nitrogen values, adjusted for flow, at the routine water quality monitoring stations in the recommended subwatersheds decrease,
- The median *E. coli* values, adjusted for flow, at the routine water quality monitoring stations in the Mill Creek (upper), Brush Creek, Tomahawk Creek, and Big Creek (lower) recommended subwatersheds decrease,
- The median *E. coli* values, adjusted for flow, at the routine water quality monitoring stations in the Calf Creek and Bear Creek recommended subwatersheds do not significantly increase,
- No new water quality impairments resulting from unregulated nonpoint pollution sources are identified in the Buffalo River watershed,
- Baseline algal species and densities have been established for the USNPS Heartland program fish and aquatic invertebrate monitoring locations,
- Aquatic invertebrate and fish index scores remain stable or improve, and
- Trash index scores have been established for the Buffalo River and its tributaries, and the results are routinely published.

If these criteria are not satisfied, the management approaches, scientific knowledge, and stakeholder knowledge and opinions in the recommended subwatersheds will be re-evaluated by the stakeholders involved in managing water quality and nonpoint sources in the subwatershed(s) (e.g., watershed implementation team), and management elements adjusted accordingly. This evaluation will need to take into account the fact that it can take more than five years, or even decades, before water quality improvements resulting from implementation of management measures become apparent (Meals et al. 2010). The time period required to see significant changes in water quality is, in part, a function of how close water quality measurement locations are to where management activities are implemented.

7.9 Update Watershed Management Plan

A comprehensive update of this watershed management plan will be prepared in 2024 by the organization with responsibility for the plan evaluation. This update will consider and address the following information:

- Results of the evaluation of the implementation of this plan, described in Section 7.8,
- Relevant information about the Buffalo River system and how it works, nonpoint source management practices, and pollutant sources in the watershed that has been developed since 2017,
- Changes in water quality related issues in the watershed,
- Changes in water quality management assistance programs, and
- Changes in land use, industry, population, and/or the economy in the watershed.

As part of the update process, a summary of changes in the watershed over the period since completion of the previous watershed management plan, will be prepared. This summary will be presented at one or more public stakeholder meetings held by the organization updating the plan. At this meeting(s), stakeholders will provide input on adjustments to management of and/or goals for the Buffalo River watershed. This may include a focus on management in other subwatersheds for water quality improvement or protection.

An update of this watershed management plan will be prepared by the organization, utilizing the information from the implementation evaluation and the public meeting(s), and any other information that the organization preparing the update deems appropriate. The organization preparing the update will hold one or more public stakeholder meetings to present the updated plan and elicit stakeholder feedback. They will then prepare the final update of the watershed management plan, incorporating stakeholder comments.

7.10 Implementation Schedule

This section describes the schedule for implementation of this watershed-based plan for the Buffalo River watershed. Table 7.11 summarizes the schedule. For the most part, implementation of nonpoint source pollution management practices can start any time. However, it may be more effective, and allow for more efficient use of resources, to wait to implement management practices and information and education programs to reduce *E. coli* loads until after MST studies have been completed to identify the types of *E. coli* sources contributing to the load.

This schedule includes the elements of the adaptive management approach, where practices are implemented, monitoring is conducted to document results, the results are evaluated relative to the goals and criteria specified in the plan, and the plan is modified based on the results of the evaluation, accommodating any changes in regulations, available assistance programs, understanding of the watershed, or management priorities.

Table 7.11. Proposed schedule for implementation of the Buffalo River watershed-based management plan.

Activity	Action (lead)	Start	Anticipated Completion	2023 Milestones	Indicator	Long Term Goal
Routine Monitoring	Quarterly ambient water quality monitoring (USNPS BNR, ADEQ)	1985	Expected to continue indefinitely	Four additional years of water quality data collected TSS added to monitoring program	Number of long term water quality stations Number of sampling events	Identify and track changes in water quality over time Identify stressors Characterize sediment loads
	Routine ambient water quality monitoring (ADEQ, USGS)	1990	Expected to continue indefinitely	Four years of water quality data collected	Number of long term water quality stations Number of sampling events	Identify and track changes in water quality over time Assess water quality with regard to state standards
	Annual fish community, aquatic invertebrate, and aquatic habitat monitoring (USNPS Heartland Network)	2005	Expected to continue indefinitely	Four additional years of biological data collected	Number of long term biological stations Number of surveys	Identify and track changes in biological communities over time Identify factors influencing biological communities
	Tributary continuous dissolved oxygen monitoring program (USNPS BNR)	2015	Expected to continue indefinitely	Four additional years of dissolved oxygen monitoring completed	Number of sampling stations Number of monitoring events	Assess tributary water quality with regard to state DO criteria Assess tributary nutrient condition Identify factors influencing tributary DO levels Track changes in tributary DO over time
	Trash Index (Stream Team)	2018	Continue at least through 2028	Trash monitoring program established At least two years of monitoring completed	Number of trash monitoring stations Number of trash surveys	Identify and track sources of trash in the Buffalo River tributaries
	Dogpatch Springs routine water quality monitoring location (Subwatershed Implementation Team, Stream Team)	2018	Expected to continue indefinitely	Monitoring station established At least two years of routine monitoring completed	Number of sampling events	Quantify pollutant contributions from Dogpatch Springs to Mill Creek Track changes in water quality over time
	Routine algae monitoring (USNPS BNR, ADEQ)	2018	Expected to continue indefinitely	Monitoring program established At least two years of monitoring completed	Number of sampling stations Number of sampling events	Identify algal species present and track changes in community composition Track frequency of blooms Determine causes of algal blooms
	Summer swimming guide *E. coli* monitoring (White River Waterkeeper)	2018	Expected to continue indefinitely?	Monitoring locations established At least five years of monitoring completed	Number of sampling locations Number of sampling events	Inform public about safety of swimming areas Track E. coli levels at swimming areas
Special Studies	Study of *E. coli* in Mill Creek (upper) subwatershed (ADEQ)	2016	2017	Study completed and report published	Report published	Reduce fecal coliform, *E. coli*, and inorganic nitrogen levels in recommended subwatersheds to targets
	Microbial source tracking of *E. coli* in recommended subwatersheds with *E. coli* reduction targets (Subwatershed Implementation Teams, ADEQ)	2018	2025	MST study in Mill Creek (upper) subwatershed completed Usefulness of MST determined If deemed useful, MST studies for Brush and Tomahawk Creeks will also be completed	Number of sampling events Number of sampling stations Number of subwatersheds studied	Reduce inorganic nitrogen, fecal coliform, and *E. coli* levels in recommended subwatersheds to target levels
Special Studies (continued)	LiDAR Analysis in recommended subwatersheds to identify streambank erosion (Subwatershed Implementation Teams)	2019	2022	Analysis of LiDAR data for Calf Creek subwatershed Usefulness of LiDAR for identifying bank erosion sites determined If deemed useful, LiDAR analysis will be completed for remaining five recommended subwatersheds	Number of subwatersheds analyzed	Reduce streambank erosion in Buffalo River watershed Improve channel stability in Buffalo River watershed

Table 7.11. Proposed schedule for implementation of the Buffalo River watershed-based management plan (continued).

Activity	Action (lead)	Start	Anticipated Completion	2023 Milestones	Indicator	Long Term Goal
	Big Creek (lower) and Bear Creek subwatershed water quality characterization studies (Subwatershed Implementation Teams)	2019	2023	Studies completed for both Big Creek (lower) and Bear Creek subwatersheds	Number of sampling locations Number of sampling events	Reduce inorganic nitrogen, fecal coliform, and *E. coli* levels in Big Creek (lower); and inorganic nitrogen concentrations in Bear Creek, to targets
Information and Education	Quantify ecosystem services in recommended subwatersheds (Subwatershed implementation teams)	2019	2026	Studies completed for Bear Creek and two other recommended subwatersheds.	Number of subwatersheds analyzed Number of reports prepared Number of reports distributed Number of presentations of results	Increased awareness of the importance of quality natural lands to local and regional quality of life
	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	2012	Expected to continue indefinitely	5 conferences held	Number of conference attendees from Buffalo River watershed	Increased awareness and adoption of pasture best management practices in Buffalo River Watershed
	Field Days (Conservation Districts)	Unknown	Expected to continue indefinitely	1 to 3 field days held in recommended subwatersheds	Number of field days in recommended subwatersheds Number of attendees	Increase acceptance and use of practices that protect and improve water quality
	Buffalo National River programs (USNPS)	1975	Expected to continue indefinitely	No net loss in the number of programs offered Printed materials, including signs, updated	Number of programs Number of attendees	Increased awareness of water quality issues Improved visitor stewardship and engagement
	Trash Index reporting (Stream Teams, USNPS, Interest Groups)	2020	At least through 2028	Trash index reports added to USNPS park displays and website Results of at least six trash index surveys distributed	Number of places trash index survey results reported Number of surveys reported	Increase awareness of trash issue in Buffalo River Assess effectiveness of outreach programs Track USNPS Leave No Trace Behind program Reduce trash in Buffalo River
	Ozark Highlands Karst Program (TNC)	2007	Expected to continue	Report of sensitive areas in at least one recommended subwatershed requested or provided	Number of requests for information on sensitive areas Amount of materials on sensitive areas distributed	Increase awareness of how land surface activities impact groundwater and cave/karst species Increase use of practices that protect and improve groundwater and cave/karst habitats
	Training in environmentally sensitive maintenance of unpaved road (Arkansas Rural Services)	2017	Expected to continue indefinitely	Representatives from each of the counties in the watershed attend free training session	Number of attendees from Buffalo River watershed	Increase use of practices that protect and improve water quality in the Buffalo River watershed
	Onsite wastewater system maintenance outreach (interest groups, subwatershed implementation teams, White River Waterkeeper)	2018	2028	Outreach program organized At least one outreach effort in a recommended subwatershed	Number of homeowners contacted Amount of materials distributed Number of events hosted or attended	Increase the number of well maintained systems Reduce pollutant releases from onsite systems. Improve groundwater quality in watershed *E. coli* land inorganic nitrogen levels reduced to targets in recommended subwatersheds
Planning	Establish Subwatershed Implementation Teams	2018	2028	Subwatershed implementation teams established in at least 3 recommended subwatersheds	Number of teams established	Improve water quality, aquatic habitat, stream stability, and economic returns in recommended subwatersheds
Implement Managemen t Strategies	Pasture and hayland management practices (landowners, farmers, ranchers)	2018	2028	New management practices planned/contracted or implemented in at least two recommended subwatersheds	Number of contracts Number of practices planned Number of practices implemented Area treated Years practices maintained	Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds Increased channel stability Reduced erosion

Table 7.11. Proposed schedule for implementation of the Buffalo River watershed-based management plan (continued).

Activity	Action (lead)	Start	Anticipated Completion	2023 Milestones	Indicator	Long Term Goal
	Forestry best management practices (landowners, foresters)	2018	2028	Increased implementation of forestry best management practices in Buffalo River watershed	Amount of best management practices added since 2017 Years practices maintained	Reduce erosion Reduce sediment and nutrient inputs to streams from forestry activities
	Ecotone restoration and management practices in recommended subwatersheds (County Conservation Districts, landowners, farmers, ranchers)	2018	2028	New restoration projects planned/contracted or implemented in at least two recommended subwatersheds	Number of practices planned/ contracted Number of practices implemented Area treated Years practices maintained	Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds Increased channel stability Reduced erosion Increase populations of species of greatest conservation need
	Environmentally sensitive maintenance for unpaved roads (Counties)	2018	Expected to continue indefinitely	County personnel participating in training as required by state program Use of Environmentally Sensitive Maintenance practices increased in at least one Buffalo River watershed county At least one improvement project funded in Buffalo River watershed	Miles of county roads in watershed properly graded, Number of crossings improved Number of training attendees	Reduce road erosion Reduce road maintenance Reduce sediment inputs to streams from unpaved roads
	Karst protection practices (The Nature Conservancy, NRCS)	2018	2028	Karst protection practices planned or implemented by at least one landowner or community in a recommended subwatershed (including areas outside of subwatershed that contribute groundwater to the subwatershed)	Number of practices planned/contracted Number of practices implemented Area treated Years practices maintained	Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds Cave/karst species of greatest conservation need protected
	Forestry best management practices (Arkansas Forestry Commission)	2008	Expected to continue indefinitely	Increased implementation of forestry best management practices in Buffalo River watershed	Amount of best management practices added since 2017	Reduce erosion Reduce sediment and nutrient inputs to streams from forestry activities
	Control of invasive and destructive species (AGFC, US Fish and Wildlife, landowners, Conservation Districts)	2018	2028	Feral hog problem areas identified in at least one recommended subwatershed	Number of feral hogs eliminated Size of feral hog population affecting Buffalo River watershed	Reduce erosion Reduce inputs of sediment, nutrients, and *E. coli* to surface waters Reduce property damage
Evaluate	Biennial water quality assessment (ADEQ)	2018	Expected to continue indefinitely	EPA approved final 303(d) lists for 2018 and 2020	Attaining and nonattaining stream reaches in Buffalo River watershed	All water quality criteria met in Bear Creek All water quality criteria met in all monitored stream reaches in the watershed
	Annual voluntary forestry best management practices assessment (Arkansas Forestry Commission)	2016	Expected to continue indefinitely	Two biennial surveys completed (2017 and 2020)	Published assessment reports	Estimate and document extent of forestry best management practices implementation, and identify areas to focus best management practices education efforts

Table 7.11. Proposed schedule for implementation of the Buffalo River watershed-based management plan (continued).

Activity	Action (lead)	Start	Anticipated Completion	2023 Milestones	Indicator	Long Term Goal
Evaluate (Continued)	Track implementation of best management practices in Buffalo River watershed	2018	2028	Information for period 2018 through 2022 compiled	Linear feet/acres of best management practices implemented Water quality improvement	All water quality criteria met in all monitored stream reaches in the watershed Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds
	Plan evaluation	2024	2024	Data needed for evaluation compiled	Evaluation completed Evaluation report made public	All water quality criteria met in all monitored stream reaches in the watershed Inorganic nitrogen and *E. coli* concentrations reduced in recommended subwatersheds
Update Buffalo River Watershed-based Management Plan	Public Meetings	2023	2024	Begin organizing public meetings	Number of attendees Number of meetings	Stakeholder input to watershed management planning
	Update Watershed Management Plan	2024	2025	Entity responsible for update identified and committed Preparations for update under way	Updated watershed management plan completed Recommended subwatersheds identified Stakeholder relationships continued/ improved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Buffalo River watershed

8.0 IMPLEMENTATION COST, BENEFITS, AND ASSISTANCE

This section of the plan includes estimates of costs expected for implementation of the recommended practices, benefits associated with implementing management practices, and technical and funding assistance available to stakeholders who elect to implement recommended practices.

HIGHLIGHTS

- Implementing the practices recommended in this plan can provide monetary and non-monetary benefits to landowners, communities, and society at large through improved environmental services.
- There are a variety of government and non-government programs that can provide technical and financial assistance to stakeholders interested in implementing practices recommended in this plan.
- Additional funding will increase the likelihood that the recommendations in this plan will be implemented.

8.1 Implementation Costs

The cost information provided below is estimated. Actual costs may differ from those given below.

8.1.1 Planning

Support for watershed implementation teams is expected to cost approximately $5,000 per year, for three years. These moneys will provide for team members' travel and expenses associated with meetings.

8.1.2 Monitoring

Cost estimates of existing state and federal monitoring programs are not provided here. They may be available from the agency(ies) involved.

The cost of sampling a new water quality monitoring station for Dogpatch Springs can vary from the cost of in situ instrumentation with volunteer monitoring through the AGFC

Stream Team or similar volunteer arrangement (approximately $5,000 for an in situ instrument with four parameters plus a backup instrument) to $40-50,000 per year for the USGS to monitor the site. Cost of sample analysis for total nitrogen, total phosphorus, and *E. coli* by a commercial laboratory, is estimated to cost around $200 per sample.

Estimated of cost implementing the trash index score in Buffalo River tributaries is $6,000, which includes compensation for volunteers for travel and meals during the three assessment periods.

8.1.3 Proposed Special Studies

Table 8.1 lists estimated costs for each of the proposed special studies. See Section 7.7 for descriptions of the activities included in these cost estimates.

Table 8.1 Estimated costs for proposed special studies.

Study	Costs
LiDAR	$5,000/subwatershed
Ecosystem services	$60,000-$75,000/subwatershed
Synoptic survey for water quality characterization in Big Creek (lower) and Bear Creek subwatersheds	$18,000-$20,000 for both
Microbial source tracking	$30,000-$35,000/subwatershed

8.1.4 Estimated Cost of Nonpoint Source Pollution Management

The cost of implementing management practices to reduce pollution from unregulated nonpoint sources can be variable, depending on materials markets and site conditions (e.g., slope, soil type). Table 8.2 summarizes cost information found for management practices identified in Sections 6.7 and 6.8. One column of Table 8.2 lists the reimbursement values that have been set by NRCS for EQIP. While EQIP reimbursement allocations do not necessarily reflect the actual cost of implementing the practice (past 319 projects have offered funding assistance at 40% cost-share), they provide an idea of relative costs of the shown management practices.

Table 8.2. EQIP reimbursements and reported implementation costs for selected nonpoint source pollution management practices applicable in the Buffalo River watershed.

Practice	Unit	2017 EQIP (non-HU) reimbursement per unit	Unit Cost
Fence	Feet	$1.08-$1.74	$2.15-$2.60[a]
Watering facility	Gallons	$0.89-$2.73	--
Watering facility	Each	--	$2,000-$10,000[a]
Pipeline	Feet	$0.85-$2.71	--
Riparian forest buffer plants	Each	$0.39-$0.68	--
Riparian forest buffer forgone pasture income	Acres	$206.23	--
Riparian forest buffer establishment & maintenance	Acres	--	$218- $7,112[a-d]
Riparian herbaceous buffer	Acres	$167.40-$272.35	$168- $400[a]
Prescribed grazing	Acres	$20.26-$68.18	--
Streambank protection	Feet	$7.58-$157.08	$72.59[e]
Forage planting	Acres	$203.05-$293.18	--
Nutrient management plan written	Each	$1,706.40-$2,844	--
Nutrient management	Acres	$1.62-$12.75	--

[a] (Lynch & Tjaden 2000)
[b] (Butler & Long 2005)
[c] (Whitescarver 2013)
[d] (Washington State University 2006)
[e] (Brasel & Lonadie 2004)

Table 8.3 provides examples of potential relative costs for implementation of selected management practices for pasture and hayland that achieve target inorganic nitrogen loads in the recommended subwatersheds. Table 8.4 lists examples of potential costs for implementation of selected management practices for pasture and hayland that achieve target *E. coli* loads in the recommended subwatersheds. Note that the estimated costs shown in Table 8.3 and 8.4 have been rounded to two significant digits.

8.2 Estimated Economic and Environmental Benefits

While there are costs associated with implementing best management practices, as noted in Section 8.1 above, there are also benefits. Some of these are environmental benefits associated with these management practices that are enjoyed by both to the landowner and downstream users. Environmental benefits that humans receive from nature are called ecosystem services, and include goods or products (provisioning services) that typically have market value, such as timber production, commercial fisheries, agricultural production, and biochemical extracts. In addition, there are other services and benefits provided by ecosystems that are not as easy to value economically, but are critical to our quality of life, including regulating services such as erosion control, improved air and water quality through contaminant removal, and pollination; supporting services such as soil moisture retention, nutrient cycling, and soil formation; and cultural services such as fishing, bird watching, and wildflowers that provide aesthetic pleasure. Additional examples of environmental benefits associated with ecosystem services are listed in Table 8.5.

Best management practices proposed for the Buffalo River subwatersheds recommended for initial management are listed in Table 8.6 along with the environmental benefits that accrue from the implementation of these practices. While not all of these benefits have directly marketable economic value, there have been economic assessments of several of them. For example, excluding cattle from streams, providing alternative water supplies, and rotational grazing have resulted in increased cattle production, which has a direct economic value. Alternative water supply alone was documented to improve production in steers and heifers from 0.6 to 1.8 lb/day through reduction in foot rot, bovine virus diarrhea, fever, tuberculosis, and environmental mastitis (Faulkner 2000, Zeckoski et al. 2007). In Missouri, beef cattle raised and finished on high quality pasture through prescribed grazing had an average daily gain of two or more pounds and reached marketable weight within 20 months (NRCS 2006). One of the hazards for stream exclusion is flooding, which can destroy fences, requiring repeated replacement. GPS-enabled ear tags, currently being researched at the US Department of Agriculture (USDA) Jornada Experimental Rangeland, will, in the near future, eliminate the need for actual fences, reduce the effects of flooding on stream exclusion, and reduce the time required to move cattle from one area to another (http://www.ediblegeography.com/invisible-fences-an-interview-with-dean-anderson-2/).

Table 8.3. Estimated costs for achieving inorganic nitrogen reductions by treating pasture and haylands.

Practice	Assumed unit cost	Mill Creek (upper)		Calf Creek		Bear Creek	
		Amount	Total cost	Amount	Total cost	Amount	Total cost
50 ft forested riparian buffer	$2,000/ac	44.8 ac	$90,000	244 ac	$490,000	598 ac	$1,200,000
50 ft non-forest riparian buffer	$400/ac	53.9 ac	$22,000	357 ac	$140,000	598 ac	$240,000
Livestock exclusion from pasture streams	$1.75/ft for fence, $1,500/ watering facility	45,000 ft of fence, 45 1,000 gal tanks	$150,000	249,000 ft of fence, 249 1,000 gal tanks	$810,000	520,000 ft of fence, 520 1,000 gal tanks	$1,700,000
Pasture planting	$250/ac	3,300 ac	$820,000	6,500 ac	$1,600,000	8,100 ac	$2,000,000
Prescribed grazing	$68/ac	3,800 ac	$260,000	9,400 ac	$640,000	8,100 ac	$550,000

Practice	Assumed unit cost	Brush Creek		Tomahawk Creek		Big Creek (lower)	
		Amount	Total cost	Amount	Total cost	Amount	Total cost
50 ft forested riparian buffer	$2,000/ac	61 ac	$120,000	158 ac	$320,000	631 ac	$1,300,000
50 ft non-forest riparian buffer	$400/ac	88 ac	$35,000	189 ac	$75,000	631 ac	$250,000
Livestock exclusion from pasture streams	$1.75/ft for fence, $1,500/ watering facility	61,000 ft of fence, 61 1,000 gal tanks	$200,000	161,000 ft of fence, 161 1,000 gal tanks	$520,000	550,000 ft of fence, 550 1,000 gal tanks	$1,800,000
Pasture planting	$250/ac	2,200 ac	$550,000	6,400 ac	$1,600,000	20,000 ac	$5,000,000
Prescribed grazing	$68/ac	3,100 ac	$210,000	7,300 ac	$500,000	20,000 ac	$1,400,000

Table 8.4. Estimated costs for achieving *E. coli* reductions by treating pasture and haylands.

Practice	Assumed unit cost	Mill Creek (upper)		Brush Creek		Tomahawk Creek		Big Creek (lower)	
		Amount	Total cost	Amount	Amount	Total cost	Total cost	Amount	Total cost
50 ft forested riparian buffer	$2,000/ac	53.9 ac*	$110,000	89.5 ac*	$180,000	172 ac	$340,000	631 ac*	$1,300,000
50 ft non-forest riparian buffer	$400/ac	53.9 ac*	$22,000	89.5 ac*	$36,000	190 ac*	$75,000	631 ac*	$250,000
Pasture stream exclusion	$1.75/ft for fence, $1,500/ watering facility	47,000 ft* of fence, 47 1,000 gal tanks	$150,000	76,000 ft of fence, 76 1,000 gal tanks	$250,000	120,000 ft of fence, 120 1,000 gal tanks	$390,000	550,000 ft* of fence, 550 1,000 gal tanks	$1,800,000
Prescribed grazing	$68/ac	3,800 ac*	$260,000	3,100 ac*	$210,000	5,500 ac	$370,000	20,000 ac*	$1,400,000

*This amount is 100% of the pasture and halyands area assumed to be contributing to the *E. coli* load. For this subwatershed, treatment of 100% of contributing pasture and hayland by this practice alone is not expected to achieve the target reduction.

Table 8.5. Environmental benefits and ecosystem services associated with increased soil health and best management practices.

Ecosystem service or environmental benefit	Description
Contaminant removal	Contaminants (sediment, nutrients, heavy metals, pesticides) absorbed onto soils, chelated by organic matter, or filtered from runoff, or taken up by vegetation, reducing contaminant loading/concentrations in receiving waterbodies.
Erosion control	Vegetation, soil cover, or impounded water reduces impacts of rainfall in disrupting soil particles and/or reducing soil transport in runoff, including settling in impounded water, to receiving waterbodies.
Fish habitat	Riparian vegetation, organic debris reduce soil and bank erosion and provide structure in streams for fish and other aquatic organisms.
Flood mitigation	Soil organic matter, vegetation, retain water, slow water flow, and attenuate peak flow to reduce flooding.
Forage quality	Improved vegetative cover, soil organic matter, and nutrient cycling increase forage quality for grazing and increase animal production.
Nutrient retention - cycling	Nutrient retention and slow release to crops reduces fertilizer requirements and associated costs, improves yields and reduces nutrient loading to receiving waterbodies.
Soil formation	Vegetation, no/reduced tillage, and mulch add organic matter to soils, increase infiltration, reduce compaction, and improve soil structure and soil health, for potential increased crop yields or animal production.
Soil moisture retention	Increased soil organic matter from vegetative cover or residue retains water and increases soil moisture. Each 1 percent increase in soil organic matter helps soils hold about 20,000 gallons more water per acre, reducing irrigation costs.
Timber production	Forested riparian buffers reduce soil/bank erosion, reduce nutrient and other contaminant loading, improve fish habitat , and provide harvestable timber for additional revenue.
Water purification	Contaminate sorption, filtering through soils and vegetative/organic debris, and uptake improves water quality by purifying the water.
Waterfowl habitat	Winter water retention, forested riparian buffers increase habitat for waterfowl and potential hunting leases.
Wildflower/wildlife habitat	Filter strips, buffers, riparian corridors, conservation reserves provide additional habitat for wildflowers, birds, and wildlife and can be leased for hunting.

Table 8.6. Environmental benefits associated with implementing best management practices in the Buffalo River subwatersheds.

Best Management Practice	Contaminant removal	Erosion control	Fish habitat	Flood mitigation	Forage quality	Nutrient retention	Soil formation	Soil moisture	Timber production	Water purification	Wildlife-flower habitat
Bank stabilization/ stream restoration	•	•	•	•		•				•	•
Riparian buffer	•	•	•	•		•			•	•	•
Livestock stream access control	•	•	•	•	•	•	•	•		•	•
Pasture planting	•	•		•	•	•	•	•		•	•
Prescribed grazing	•	•		•	•	•	•	•		•	•
Filter strips	•	•		•	•	•	•	•		•	•
Farm pond/ sediment basin	•	•	•	•		•		•		•	
Silvopasture	•	•		•	•	•	•	•	•	•	•
Nutrient management plans						•					
Forestry best management practices	•	•	•			•			•	•	
Game bird habitat restoration	•	•		•		•	•	•		•	•
Control of invasive and destructive species		•	•		•	•					
Karst protection practices	•	•	•			•				•	•

8.3 Technical Assistance

8.3.1 Monitoring

Agencies and universities conducting water quality monitoring generally have their own technical resources. Technical assistance for volunteer water quality monitoring programs is available through the AGFC Stream Team Program.

8.3.2 Information and Education

Information and assistance with education and outreach activities is available through the ADEQ Public Outreach and Assistance Division, Watershed Conservation Resource Center, Cooperative Extension Service, and others. A number of resources are also available from EPA through the Nonpoint Source Outreach Toolbox (http://cfpub.epa.gov/npstbx/index.html).

The ADEQ Public Outreach and Assistance Division offers technical assistance and resources to interested citizens and groups. The Watershed Outreach and Education program of this division provides “a variety of tools and services to facilitate and promote awareness, appreciation, knowledge, and stewardship of water resources.” This includes the Water Education for Teachers program, and presentations at schools, interest groups, and events (ADEQ 2015).

8.3.3 Watershed Implementation Teams

The ADEQ Public Outreach and Assistance Division offers technical assistance to volunteer watershed groups, including facilitating meetings, identifying partnerships, and grant writing (ADEQ 2015).

8.3.4 Technical Assistance for Nonpoint Source Pollution Management

There are a number of sources for technical assistance for nonpoint source pollution management in recommended subwatersheds. These are summarized in Table 8.7 and discussed below.

Table 8.7. Examples of sources for technical assistance with implementing nonpoint source pollution management.

Practice/ Strategy	County Conservation Districts	U of A Division of Agriculture	AGFC	Arkansas Forestry Commission	NRCS, FSA	EPA	US Fish and Wildlife Service	US Forest Service	TNC	Other non-profit Interest Groups	Arkansas Unpaved Roads Program
Unpaved road BMPs	X			X				X	X		X
Riparian buffers	X	X	X		X	X	X		X	X	
Filter strip of native plants	X	X	X		X	X	X		X	X	
Prescribed forest burns		X	X	X	X		X	X			
Control of invasive & destructive species	X	X	X		X		X				
Septic system repair/replace						X					
Forest mgt. practices		X		X	X			X			
Streambank restoration/ stabilization	X	X	X		X	X	X		X	X	
Nutrient management	X	X			X						
Game bird habitat management/restoration	X	X	X		X		X			X	
Farm pond/sediment basin construction	X	X			X						
Trail management practices				X				X		X	
Livestock stream access control	X	X			X				X	X	
Prescribed/rotational grazing	X	X			X				X	X	
Silvopasture establishment	X	X		X	X				X	X	
Pasture planting	X	X	X		X					X	
Karst protection practices		X	X		X		X		X		

8.3.4.1 County Conservation Districts

Conservation Districts for the counties in the Buffalo River watershed are active in nonpoint source management within the watershed. They work closely with NRCS to provide technical support to landowners, including information and guidance about management practices for protecting soil and water resources, including benefits, costs, implementation, and maintenance. Conservation Districts within the Buffalo River watershed can provide technical support through a number of special projects including the Feral Swine Initiative, Acres for Wildlife, Controlled Access for Livestock Fencing (CALF), Quail Special Project, and Unpaved Roads (Arkansas Association of Conservation Districts 2017).

8.3.4.2 UofA Division of Agriculture

The UofA Cooperative Extension Service provides technical assistance through a range of programs and services including testing of manure, hay, soil, and water; assistance with rotational (prescribed) grazing, nutrition and feeding of livestock, sprayer calibration, and grassland management; and field days and on-farm demonstrations. Cooperative Extension Service also maintains an extensive library of up-to-date, research-based fact sheets, applied research publications, and best management practice manuals and guidelines.

The experiment station program of the UofA Division of Agriculture generates, interprets, and distributes information and technology useful to farmers in Arkansas.

8.3.4.3 Arkansas Game and Fish Commission

The AGFC Stream Team program assists individuals with planning and implementing stream related projects, including streambank restoration and stabilization. The Stream Team staff deals routinely with streambank issues, providing assistance with planning, design, permitting, and finding funding.

Through the AGFC Private Lands Program and Acres for Wildlife Program, Private Lands Biologists provide technical assistance to volunteer landowners and tenants with managing their lands to improve both upland and aquatic wildlife habitat, including controlling invasive and destructive species, such as feral hogs. Management actions that improve wildlife habitat usually also improve water quality and reduce nonpoint source pollution.

8.3.4.4 Arkansas Unpaved Roads Program

Arkansas Rural Services manages the state Unpaved Roads Program. Arkansas Rural Services provides free one-day training sessions on maintenance techniques for unpaved roads that reduce the impact of sediment and road runoff on water quality, as well as reducing road maintenance costs. The location of these training sessions alternates among all of the counties in the state. To maintain eligibility for grants for unpaved roads maintenance or improvement, at least one representative from each county must attend this training every 5 years (Arkansas Department of Rural Services 2017).

8.3.4.5 Arkansas Forestry Commission

The Arkansas Forestry Commission can provide a variety of technical assistance to landowners. This includes assistance with siting and developing practices to protect and improve wildlife habitat and water quality, and preparation of forest management plans (Arkansas Forestry Commission 2017a). The Arkansas Forestry Commission has also prepared guidance on best forest management practices, and provides training in those practices (Arkansas Forestry Commission 2017b).

8.3.4.6 Natural Resources Conservation Service

The NRCS offers several programs to help landowners address natural resources concerns related to pasture management, including the Grazing Lands Conservation Initiative. NRCS grassland specialists can work with farmers on resource assessments of pastures to design effective grazing systems. These specialists also provide guidance on implementation and maintenance of these grazing systems. All owners and managers of private grazing lands are eligible for NRCS technical assistance (NRCS 2015).

Technical assistance is available for a variety of practices through EQIP. Assistance is available for planning and implementing pasture management, erosion control, forest restoration, nutrient management, prescribed burning, streambank stabilization, and feral hog capture.

8.3.4.7 Southern Sustainable Agriculture Research and Education

The Sustainable Agriculture Research and Education program (SARE) of the USDA supports farmers, researchers, and educators exploring practices that improve farm stewardship and profitability, and the vigor of farm communities. The program emphasizes outreach and distribution of the results of program research. This information is available from the program website and includes a variety of print and electronic materials appropriate for producers (http://www.southernsare.org/About-Us).

8.3.4.8 The Nature Conservancy

The Nature Conservancy manages the Strawberry River Preserve and Demonstration Ranch to showcase economically feasible and sustainable specialized grazing techniques that protect streambanks and stream ecology. Training workshops and technical assistance for these techniques are available from The Nature Conservancy (The Nature Conservancy 2015).

Through their Ozark Highlands Karst program, The Nature Conservancy has worked with communities, developers, and farmers to develop management plans to protect water quality and biota in caves in the karst area of Arkansas, including the Buffalo River watershed (https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/ozark-karst-program.xml).

The Nature Conservancy has been involved with training programs for county road crews on maintenance practices to reduce erosion associated with unpaved roads, and was involved in development of the state unpaved roads program.

The Nature Conservancy is also involved in the Fire Learning Network, assisting with prescribed burns in the National Forest and private lands, and with annual classes that train land managers in use of prescribed burns (https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/interior-highlandsfire-restoration-program.xml).

8.3.4.9 US Environmental Protection Agency

The EPA website provides access to information on a variety of water quality subjects, including nonpoint source pollution management.

8.3.4.10 US Fish and Wildlife Service

Through its Partners for Fish and Wildlife program, the USFWS provides technical assistance to private landowners on projects to protect, improve, or restore native habitat. Habitat for endangered species, such as the Rabbitsfoot mussel, is a priority for this program. Assistance is available for designing, installing, and maintaining habitat-enhancing projects, including streambank stabilization, restoration of riparian habitats, stream habitat, forest and native grasslands restoration, and prescribed burning (https://www.fws.gov/arkansas-es/PFW_Habitat.html).

8.3.4.11 US Forest Service

Through the Forest Stewardship program, the US Forest Service provides professional planning and technical assistance to landowners for managing private forest lands. Forest stewardship plans increase the likelihood that private forests will remain intact, productive, and healthy, and that the water quality and other environmental benefits of these forests will be maintained (US Forest Service 2016).

8.4 Funding Assistance

8.4.1 Monitoring

ADEQ, ANRC, USNPS, and USGS have funded water quality monitoring projects in the Buffalo River watershed, as have nonprofit interest groups. ADEQ and USNPS monitoring is self-funded. Much of the funding for the USGS monitoring program is provided by state and local cooperators. USGS flow and/or water quality monitoring sites could be added in the watershed if a local entity would provide funds.

State Wildlife Grant funding from the AGFC can be used for wildlife monitoring projects. The AGFC Stream Team program can also provide funding for volunteer monitoring programs through mini-grants.

In 2015, approximately $2.3 million in federal funds were spent on nonpoint source pollution projects in Arkansas through the ANRC 319 grant program. Thirty-one percent of these funds were spent on water quality monitoring projects (ANRC 2016).

8.4.2 Information and Education

All projects funded through the ANRC Nonpoint Source Pollution Management Program (Section 319(h) funds) are required to include an education and outreach component. In 2015, approximately $2.3 million in federal funds were spent on nonpoint source pollution projects in Arkansas through the ANRC 319 grant program. Eighteen percent of these funds were spent on outreach projects (ANRC 2016).

Projects funded through NRCS and Farm Services Agency cost-share and easement programs are often used as demonstrations in NRCS and Conservation District outreach and education programs.

The Arkansas Grazing Lands Coalition sponsors field days.

There are several private foundations that fund education, and which may fund environmental education. The EPA also provides grants for environmental education (http://www2.epa.gov/education/environmental-education-ee-grants).

8.4.3 Funding Assistance for Nonpoint Source Pollution Management

There are a number of agencies and programs that offer financial assistance for implementation of nonpoint source pollution management practices in the Buffalo River watershed. The majority of these are grant programs, some of which require matching funds from the grant recipient. In addition, at least one tax incentive program is active that addresses practices that reduce nonpoint source pollution. Table 8.8 lists management practices for the recommended subwatersheds along with selected funding sources.

Several of the management practices listed in Table 8.8 cannot be funded by the programs shown. However, there are programs that can fund several of those practices. The Arkansas Unpaved Roads Grant Program provides funds to counties and other entities that maintain public unpaved roads in the state, to implement best management practices to reduce erosion from unpaved public roads (http://ruralservices.arkansas.gov/grants/unpaved-roads-grant/). There are several sources that can provide funding for development and maintenance of trails, including the Arkansas Recreational Trails Program, the American Hiking Society's National Trails Fund, the North Face Explore Fund, and The Conservation Alliance Grants.

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Table 8.8. Potential sources of funding for multiple suggested management practices for the Buffalo River watershed.

	Conservation Stewardship Program	Healthy Forest Reserve Program	Environmental Quality Incentives Program	Conservation Reserve Program	Partners for Fish and Wildlife	Arkansas Water and Wastewater Funding	State Wildlife Grants	Aquatic Habitat Restoration Program
Lead/Contact Organization	NRCS	NRCS	NRCS	Farm Services Agency (FSA)	USFWS	ANRC	AGFC	Southeast Aquatic Resources Partnership
Who can receive funds	Individuals	Individuals	Individuals	Individuals	Individuals, counties, organizations	Cities, counties, organizations	State agencies, organizations	Agencies, organizations
Practices that can be funded:								
Unpaved road BMPs								
Riparian buffers	X		X	X	X	X		X
Filter strips of native plants	X		X	X	X	X	X	
Prescribed forest burns		X			X		X	
Control of invasive and destructive species								
Septic system repair/replace								
Forest mgt. practices	X	X	X				X	
Streambank restoration/ stabilization	X		X		X	X		X
Nutrient management	X		X					
Game bird habitat mgt, restoration	X		X	X	X		X	
Farm pond/sediment basin construction			X					
Trail management								
Livestock stream access control	X		X		X	X		
Prescribed/rotational grazing	X		X					
Silvopasture establishment	X	X	X					
Pasture planting/mgt	X		X			X		
Karst protection practices			X		X		X	

8.4.3.1 NRCS

There are NRCS programs active in Arkansas that provide funding assistance for development and installation of nonpoint source pollution management practices that are applicable to the recommended subwatersheds of the Buffalo River. These programs provide funding to individuals rather than groups or organizations. This includes the Conservation Stewardship Program, the Healthy Forest Reserve Program, and EQIP. In these programs, a cost-share is usually required. Information about these programs, including application deadlines, cost-share requirements, and funding caps, is available online (http://www.ar.nrcs.usda.gov/programs/) or from a local USDA service center, local conservation district, or local cooperative extension agents. Table 8.9 shows funding provided to individuals in the counties of the Buffalo River watershed during the 2016 fiscal year (Arkansas Natural Resources Conservation Service 2017). The 2017 fiscal year national budget for the EQIP program is $1,650 million. For the Conservation Stewardship Program, the 2017 fiscal year national budget is $1,561 million (USDA 2017b).

Table 8.9. Financial assistance provided by NRCS programs to Buffalo River counties in 2016 (Arkansas Natural Resources Conservation Service 2017).

County	EQIP	Conservation Stewardship Program
Baxter	$216,259	$101,766
Marion	$218,915	$166,454
Newton	$283,241	-0-
Searcy	$725,861	$177,369

8.4.3.2 Farm Services Agency

The Farm Services Agency administers the Conservation Reserve Program (CRP). Through this land conservation program, landowners receive yearly rental payments for land enrolled in the program. CRP land contracts typically are for 10 to 15 years. Marginal pasture land along streams that can be used for establishment of riparian buffers can be eligible for CRP enrollment. In addition to rental payments, the Farm Services Agency may pay up to 50% of eligible costs for establishing riparian buffers (https://www.fsa.usda.gov/programs-and-services/conservation-programs/prospective-participants/index).

8.4.3.3 US Fish and Wildlife Service

There are two USFWS programs active in the Buffalo River watershed that provide funding assistance for development and installation of nonpoint source pollution management practices. Funding is available for individuals through the USFWS Partners for Fish and Wildlife program, and the CALF program (in cooperation with the Arkansas Association of Conservation Districts). Funding from these programs may require cost-share. The 2017 fiscal year national budget for the Partners for Fish and Wildlife program was $54 million (US Fish and Wildlife Service 2017). It is unknown how much of these funds will be available for projects in Arkansas, or in the Buffalo River watershed.

8.4.3.4 ANRC

ANRC manages the state Section 319 grant program. This program provides grants to non-profit groups, organizations and academic institutions for projects related to reduction, control or abatement of nonpoint source pollution. Organizations seeking grants must be capable of implementing projects, and are typically required to provide a minimum of 43% non-federal matching contributions. In 2015, approximately $2.3 million in federal funds were spent on nonpoint source pollution projects in Arkansas through the ANRC 319 grant program. Thirty-nine percent of these funds were spent on implementation of management practices (ANRC 2016). The 2017 fiscal year national budget for the Section 319 grant program is $164,915,000 (EPA 2017b). It is unknown how much of these funds will be available for Arkansas projects.

8.4.3.5 Other State Agency Grant Programs

There are at least two other state agencies that provide funding for activities included in the management measures of this plan. The AGFC Stream Team Mini-Grants can be used to fund stream clean-up and stream bank stabilization projects. State Wildlife Grants can be used to address habitat issues, such as erosion and sedimentation, that impact species of greatest conservation need. The Rural Services Division of the Arkansas Economic Development Commission provides grants to counties to help fund unpaved road projects through the Arkansas Unpaved Roads Program. In 2016, a project in Searcy County was funded through the Arkansas Unpaved Roads program. For fiscal year 2018, approximately $325,000 is expected to be available statewide for grants through the Arkansas Unpaved Roads program (Johnston 2017).

8.4.3.6 Non-monetary Implementation Support

Agencies, organizations, and individuals can support implementation of nonpoint source management practices in ways other than providing funds. One way is through the loan of equipment. The AGFC has specialized equipment that can be loaned to landowners for establishment of native warm season grasses and forbs. Over ten years ago, the Newton County Conservation District purchased equipment to be rented to landowners, including a no-till drill, roto-wiper for herbicide application, and a lime spreader. AGFC, USDA-APHIS Wildlife Services, and some Conservation Districts, have feral hog trapping equipment available for short-term loan through the Feral Hog Initiative (Sanders 2016).

Another method of non-monetary support is offering free or low-cost materials. An example is the AGFC competitive program under their Acres for Wildlife initiative, which provides warm season grass seed and herbicide to landowners who want to establish native habitat for bob-white quail (Arkansas Game and Fish Commission 2016). Another example is the Arkansas Forestry Commission sale of bulk tree seedlings for forest restoration at low prices.

8.4.3.7 Tax Incentives

Tax incentives are a slightly different financial mechanism for encouraging the use of management practices. The Arkansas Private Wetland and Riparian Zone Creation, Restoration, and Conservation Tax Credits Act of 1995 allows the application of a tax credit against Arkansas state taxes by taxpayers involved in conservation or restoration of riparian zones. Detailed information on this program is available from ANRC, who manages the program (http://anrc.ark.org/divisions/water-resources-management/wetlands- riparian-zone-tax-credit/).

9.0 REFERENCES

Adamski, J. 1997. *Nutrients and Pesticides in Ground Water of the Ozark Plateaus in Arkansas, Kansas, Missouri, and Oklahoma.* USGS.

Adamski, J. Petersen, J., Friewald, D., & Davis, J. 1995. *Environmental and Hydrologic Setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma.* USGS.

ADEQ. 2010. *Summary Report Marble Falls Dye Trace Investigation.* ADEQ.

ADEQ. 2015. *Watershed Outreach and Education Program*. Retrieved February 25, 2015, from https://www.adeq.state.ar.us/poa/watershed/

ADEQ. 2016. *Integrated Water Quality Monitoring Assessment Report.* Little Rock: ADEQ.

ADEQ. 2017a. *Biological Monitoring - Macroinvertebrate Data*. Retrieved February 6, 2014, from https://www.adeq.state.ar.us/water/planning/surface/macroinvertebrates.aspx

ADEQ. 2017b. *ADEQ Facility and Permit Summary Data System*. Retrieved May 2017, from https://www.adeq.state.ar.us/home/pdssql/pds.aspx

ADEQ. 2017c. *Arkansas Hazardous Waste Generators Facility Summary*. Retrieved November 2017, from Arkansas Department of Environmental Quality: http://www2.adeq.state.ar.us/hazwaste/rcra2/facil_sum.aspx

ADEQ. 2017d. *Storage Tank Facility data*. Retrieved November 16, 2017, from ADEQ: https://www.adeq.state.ar.us/rst/programs/fees/facility_data.aspx

ADEQ. 2017e. *Solid Waste Illegal Dumps Complaints and Inspections Data*. Retrieved November 7, 2017, from Arkansas Department of Environmental Quality: https://www.adeq.state.ar.us/complaints/searches/sw_illegal_dumps.aspx#Display

ADEQ. 2017f. *EnviroView*. Retrieved May 2017, from http://arkansasdeq.maps.arcgis.com/apps/webappviewer/index.html?id=96a9f37d695e4c48a047f11f5b541139

ADEQ. 2017g. Final 2016 303(d) List. Retrieved October 2017 from Arkansas Department of Environmental Quality: https://www.adeq.state.ar.us/water/planning/integrated/303d/list.aspx.

Aley, T. 2009. *Dye Trace from Raw Sewage Discharge at Dogpatch Sewage Lift Station to Lower Mill Creek and Buffalo National River, Arkansas.* Ozark Underground Laboratory.

Aley, T. 2010. *Assessment of the Impacts of Leaks in the Marble Falls Sewage System on Water Quality in Mill Creek and the Buffalo River.* USNPS.

ANRC. 2014. *Buffalo Watershed - 11010005*. Retrieved December 2016, from ArkansasWater: http://arkansaswater.org//index.php?option=com_content&task=view&id=125&Item

ANRC. 2016. *The Arkansas Annual Report FY2016.* Arkansas Natural Resources Commission.

Apel, J. 1990. *1989 Water Quality Report.* NPS.

Arkansas Association of Conservation Districts. 2017. Special Projects. Retrieved October 2017 from https://aracd.org/special_projects/default.htm.Bagstad, K.J., D.J. Semmens, S. Waage, and R. Winthrop. 2013. A comparative assessment of decision-support tools for ecosystem services quantification and valuation. Ecosyst. Serv. 5: e27-e39

Arkansas Dairy - History and Future. 2017. Retrieved July 2017, from Arkansas State Legislature: http://www.arkleg.state.ar.us/assembly/2017/Meeting%20Attachments/470/I14786/EXHIBIT%20G%20-%2012-15-16%20TENCLEVE%20-%20AR%20Dairy%20History%20and%20Future.pdf

Arkansas Department of Rural Services. 2017. *Unpaved Roads Grant*. Arkansas Department of Rural Services Retrieved August 2017, from Arkansas Rural Services: http://ruralservices.arkansas.gov/grants/unpaved-roads-grant/

Arkansas Department of Parks and Tourism. 2016. *Arkansas Department of Parks and Tourism 2015-2016 Annual Travel and Tourism Report.* Arkansas Department of Parks and Tourism. Retrieved January 30, 2017, from http://www.arkansas.com/!userfiles/annual_report_2016/2016_Annual_Report_Combined.pdf

Arkansas Forestry Commission. 2017a. *Landowner Assistance*. Retrieved October 2017, from Arkasnas Agriculture Department: http://www.aad.arkansas.gov/arkansas-famous-and-historic-trees

Arkansas Forestry Commission. 2017b. *Best Management Practices*. Retrieved October 2017b, from Arkansas Agriculture Department: http://www.aad.arkansas.gov/best-management-practices-water-quality

Arkansas Game and Fish Commission. 2016. *Acres for Wildlife Program*. Retrieved September 2017, from Arkansas Game and Fish Commission: https://www.agfc.com/en/get-involved/in-the-field/acres-for-wildlife/

Arkansas Geological Survey. 2015a. *Ozark Plateaus Geology*. Retrieved April 6, 2017, from http://www.geology.ar.gov/education/geo_ozark_plateaus.htm

Arkansas Geological Survey. 2015b. *Stratigraphy, Ozark Plateaus*. Retrieved October 2017, from Arkansas Geological Survey: http://www.geology.ar.gov/geology/strat_ozark_plateaus.htm

Arkansas Geological Survey. 2017. *Mineral Commodity Search/Map*. Retrieved April 2017, from http://www.geology.arkansas.gov/minerals/amc_map.htm

Arkansas Grazing Lands Coalition. 2017. *Programs and Projects*. Retrieved August 17, 2017, from Arkansas Grazing Lands Coalition: http://www.argrazinglandscoalition.org/programs_projects.html

Arkansas Natural Heritage Commission. 2015. *Rare Species Search Engine*. Retrieved August 9, 2017, from http://www.naturalheritage.com/Research-and-Data/rare-species-search

Arkansas Natural Resources Conservation Service. 2017. *2016 Annual Report.* NRCS.

Arkansas Pollution Control and Ecology Commission. 2014. *Regulation No. 2, Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas.* Little Rock: Arkansas Pollution Control and Ecology Commission.

Arkansas Pollution Control and Ecology Commission. 2015. *Regulation 5 Liquid Animal Waste Management Systems.* Arkansas Pollution Control and Ecology Commission.

Arkansas State Board of Health. 2014. *Rules and Regulations Pertaining to Onsite Wastewater Systems.* Little Rock: Arkansas Department of Health.

Arkansas Watershed Coalition. 2007. 319 Document Database. Retrieved July 2017, from http://www.arkansaswater.org/319/Document%20Database/Public_view.php.

Association of Arkansas Counties. 2017. *Association of Arkansas Counties*. Retrieved February 2017, from http://www.arcounties.org

Audubon Arkansas. 2016. *Audubon Arkansas, Buffalo National River Designated Improtant Bird Area*. Retrieved August 2017, from http://ar.audubon.org/press-release/buffalo-national-river-designated-important-bird-area

Bowles, D. 2015. *Aquatic Invertebrate Monitoring at Buffalo National River, 2005-2013.* USNPS.

Bowles, D., Hinsey, J., Cribbs, J., & Morrison, L. 2013. *Aquatic Invertebrate Monitoring at Buffalo National River 2005-2011 Status Report.* USNPS.

Bowles, D., Luraas, J., Morrison, L., Dodd, H., Williams, M., Rowell, G. Haack, J. 2007. *Protocol for Monitoring Aquatic Invertebrates at Ozark National Scenic Riverways, Missouri, and Buffalo National River, Arkansas.* Fort Collins, CO: USNPS.

Bradley, Christina. 2001. *A Two-year Seasonal Comparison of the Macroinvertebrate Community Structure of Four Ozark Streams Experiencing Differing Degrees of Anthropogenic Disturbance*. M.S. Thesis, University of Central Arkansas, Conway, Arkansas.

Bradley, P. and S. Yee. 2015. *Using the DPSIR Framework to Develop a Conceptual Model: Technical Support Document.* US Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, Narragansett, RI. EPA/600/R-15/154.

Brasel, K., & Lonadier, M. 2004. *Little Buffalo River Streambank Stabilization Project.* Arkansas Natural Resources Commission.

Bryant, C.T. 1997. *An Assessment of the Macroinvertebrate Community of the Buffalo National River*. M.S. Thesis, University of Central Arkansas, Conway, Arkansas.

Butler, S., & Long, J. 2005. *Economics and Survival of Hand-planted Riparian Forest Buffers in West Central Maine.* Bangor: US Natural Resources Conservation Service.

California Water Boards. 2007. *A Rapid Trash Assessment Method Applied to Waters of the San Francisco Bay Region: Trash Measurement in Streams*. California Water Boards. Online at www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/water_quality.html.’

Center for Advanced Spatial Technologies. 2006. *Buffalo*. Retrieved December 8, 2016, from Arkansas Watershed Information System: http://watersheds.cast.uark.edu/viewhuc.php?hucid=11010005

Chaney, S.W. 1985. *Water Quality Monitoring Report: Buffalo National River*. US National Park Service.

Cheri, K. 2016. *Documents related to the Mount Judea C&H Hog CAFO and research articles on the CAFO industry.* Retrieved November 2017, from Buffalo River Watershed Alliance: http://buffaloriveralliance.org/page-1558368

Clark, G.M., D.K. Mueller, M.A. Mast. 2000. *Nutrient concentrations and yields in undeveloped stream basins of the United States*. Journal of American Water Resources Association. 364: 849-860

Daniel, T., & Steele, K. 1991. *Interaction of Poultry Waste and Limestone Terrain on Water Quality.* Fayetteville: University of Arkansas.

DeBacker, M., Bowles, D., Dodd, H., & Morrison, L. 2012. *Five-Year Review and Recommendations for Revision of Aquatic Sampling Protocols at Buffalo National River and Ozark National Scenic Waterways.* USNPS.

Dodd, H. 2009. *Fish Community Monitoring at Buffalo National River: 2006-2007 Status Report.* US National Park Service.

Engineering Services, Inc. 2010. *Wastewater Treatment System Rehabilitation to Serve the Community of Marble Falls, Arkansas.* Marble Falls Sewage Improvement District.

EPA. 2008. *Handbook for Developing Watershed Plans to Restore and Protect Our Waters.* Washington DC: EPA.

EPA. 2016. *STORET*. Retrieved January 2017

EPA. 2017a. *Enforcement and Compliance History Online, Detailed Facility Report*. Retrieved November 16, 2017, from https://echo.epa.gov/detailed-facility-report?fid=110010066579

EPA. 2017b. *FY 2017 EPA Budget in Brief.* US Environmental Protection Agency.

Faulkner, D. 2000. Economics Section. Pp 1-54, in Virginia Forage and Grassland Council Grazing Handbook.

Fowler, A. 2015. *Arkansas Wildlife Action Plan.* Little Rock, AR: Arkansas Game and Fish Commission.

Galloway, J., & Green, R. 2004a. *Hydrologic and Water-Quality Characteristics for Calf Creek near Silver Hill, Arkansas and Selected Buffalo River Sites, 2001-2002.* USGS.

Galloway, J., & Green, R. 2004b. *Hydrologic and Water-Quality Characteristics for Bear Creek near Silver Hill, Arkansas and Selected Buffalo River Sites, 1999-2004.* USGS.

Garrett, H. 2011. *Silvopasture Ecosystem Services.* [Online] Available at: http://www2.dnr.cornell.edu/ext/info/pubs/ [Accessed May 2017].

Gibson, K.E., J.A. Lee, J.M. Jackson, L.N. Smith, G. Almeida. 2017. *Identification of factors affecting fecal pollution in Beaver Lake reservoir.* Journal of Environmental Quality. 465, pp 1048-1056.

Grenny, J., K. Patterson, D. Maxfield, R. McMillan, A. Switzler. 2013. *Influencer: The Science of Leading Change, Second Edition*. McGraw Hill.

Grizzerti, B. D. Lanzanova, D. Liquete, A. Reynaud, and A.C. Cardoso. 2016. *Assessing water ecosystem services for water resources management*. Env. Sci. & Policy 61: 194-203.

Harris, J. 1996. *The Freshwater Mussel Resources of the Buffalo National River, Arkansas, Phase I Qualitative Survey: Location Species Composition, and Status of Mussel Beds.* USNPS.

Hjelmfelt, A. & Wang, M. 1999. *Modeling hydrologic and water quality responses to grass waterways.* Journal of Hydrologic Engineering 43, pp. 251-256.

Homer, C., Dewitz, J., Yang, L., Jin, S., Danielson, P., Xian, G. Megown, K. 2015. *Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information*. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, 345-354.

Inlander, E., Gallipeau, C., & Slay, M. 2011. *Mapping the Distribution, Habitat, and Threats for Arkansas' Species of Greatest Conservation Need.* The Nature Conservancy.

InVEST. 2015. http://www.naturalcapitalproject.org/invest/

Jackson, Michaelann Leah. 2001. *A Survey of the Macroinvertebrate Fauna of Seven Springs in the Buffalo National River Watershed.* M.S. Thesis, University of Central Arkansas, Conway, Arkansas.Kahneman, D. and A. Tversky. 1979. Prospect theory: An analysis of decision under risk. Econometica. 47: 263-292

Johnston, A. 2017, May 16. *BBRAC Planning and Progress.* Retrieved November 2017, from ADEQ: https://www.adeq.state.ar.us/water/bbri/bbrac/meeting-materials.aspx

Justus, B., Petersen, J., Femmer, S., Davis, J., & Wallace, J. 2010. *A Comparison of Algal, Macroinvertebrate, and Fish Assemblage indicies for assessing low-level nutrient enrichment in wadeable Ozark streams.* Ecological Indicators 103, 627-638.

Kresse, T., Hays, P., Merriman, K., Gillip, J., Fugitt, D., Spellman, J., Battreal, J. 2014. *Aquifers of Arkansas - Protection, Managment, and Hydraulic and Geochemical Characteristics of Groundwater Resources in Arkansas.* USGS.

Kuniansky, E. 2011. *U.S. Geological Survey Karst Interest Group Proceedings, Fayetteville, Arkansas, April 26-29, 2011.* US Geological Survey.

Lynch, L., & Tjaden, R. 2000. *When a Landowner Adopts a Riparian Buffer - Costs and Benefits.* College Park: Maryland Cooperative Extension Service.

Meals, DW, SA Dressing, TE Davenport. 2010. *Lag time in water quality response to best management practices: A review.* Journal of Environmental Quality. 39:85-96.

Maner, M., & Mott, D. 1991. *Mill Creek Survey.* NPS.

Mathis, Michael. 1994. *A Survey of the Macroinvertebrate Fauna of Three Springs in the Buffalo National River.* University of Central Arkansas. Conway, Arkansas.

Matthews, M., Usrey, F., Hodges, S., Harris, J., & Christian, A. 2009. *Species richness, distribution, and relative abundance of freshwater mussels Bivalva:Unionidae of the Buffalo National River, Arkansas*. Journal of the Arkansas Academy of Science, Vol. 63, 113-130.

Matthis, M. 1990. *Macroinvertebrate Community Structure at Selected Sites on the Upper Buffalo River.* Fayetteville, AR: University of Arkansas.

McKnight, E. 1935. *Zinc and Lead Deposits of Northern Arkansas.* US Geological Survey.

MEA Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being. Synthesis.* Island Press. Washington, D.C.

Merriman, K., Gitau, M., & Chaubey, I. 2009. *A tool for estimating best management practice effectiveness in Arkansas*. Applied Engineering in Agriculture, vol. 252, 199-213.

Meyer, R., & Rippey, L. 1976. *Spatial and temporal distributions of algae and selected water quality parameters in the Buffalo River, Arkansas*. In R. Babcock, & H. MacDonald, Final Report Buffalo River Ecosystems 1 April 1974 - 31 March 1975 pp. 103-115. Santa Fe: USNPS.

Moix, M. W., & Galloway, J. M. 2005. *Base Flow, Water Quality, and Streamflow Gain and Loss of the Buffalo River, Arkansas, and Selected Tributaries, July and August 2003.* Reston, Virginia: U.S. Geological Survey. Retrieved from https://pubs.usgs.gov/sir/2004/5274/SIR2004-5274.pdf

Mott, D. 1997. *Buffalo National River, Arkansas, Ten Years of Water Quality Monitoring.* NPS.

Mott, D., Hudson, M., & Aley, T. 2000. *Nutrient loads traced to interbasin groundwater transport at Buffalo National River, Arkansas.* Inside Eart*h*, 6-10.

Mott, D., Mays, N., Usrey, F., Maner, M., Aley, T., & Cassat, D. 2002a. *The Impacts of On-site Septic Systems to the Water Quality of the Buffalo River Near Gilbert, Arkansas.* USNPS.

Mott, D., Aley, T., Hudson, H., Bitting, C., Luraas, J., Mays, N., Henthorne, J., and, Henthorne, B. 2002b. Delineation and characterization of karst groundwater recharge in the vicinity of Davis Creek and John Eddings Cave, Buffalo National River, Arkansas. U. S. Department of Interior, National Park Service, Buffalo National River.

Mott, D. N., & Laurans, J. 2004. *Water Resources Management Plan: Buffalo National River, Arkansas.* National Park Service, U.S. Department of the Interior. Retrieved from https://www.nature.nps.gov/water/planning/management_plans/buff_final_screen.pdf

NatureServe. 2015. *NatureServe explorer*. Retrieved August 25, 2017, from http://explorer.natureserve.org/

NOAA, Arguez, A., Durre, I., Applequist, S., Squires, M., Vose, R. Bilotta, R. 2015, August 17. *NOAA's U.S. Climate Normals 1981-2010.* doi:10.7289/V5PN93JP

NRC(National Research Council). 2004. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. National Academies Press. Washington, D.C.

NRCS. 1995. *Buffalo River Tributaries, Watershed Plan Environmental Assessment*. Natural Resources Conservation Service. Little Rock, Arkansas.

NRCS. 2006. *Conservation Practices that Save: Prescribed Grazing Systems*. USDA NRCS. Available online at http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/energy/conservation/?cid=nrcs143_023633

NRCS. 2015. *Grazing Lands*. Retrieved October 20, 2015, from http://www.nrcs.usda.gov/wps/portal/nrcs/detail/ar/technical/landuse/pasture/?cid=nrcs142p2_034578

NRCS. 2017. *Publications and Fact Sheets*. Retrieved July 2017, from https://www.nrcs.usda.gov/wps/portal/nrcs/main/ar/newsroom/factsheets/

NRCS. 1995. *Buffalo River Tributaries, Watershed Plan - Environmental Assessment.* USDA Natural Resources Conservation Service.

Panfil, M., & Jacobson, R. 2001. *Relations Among Geology, Physiography, Land Use, and Stream Habitat Conditions in the Buffalo and Current River Systems, Missouri and Arkansas.* USGS.

PDEP (Pennsylvania Department of Environmental Protection). 2013. *Chesapeake Bay Program Best Management Practices*. Available online at http://files.dep.state.pa.us/Water/BPNPSM/NutrientTrading/BMPDescriptions.pdf. Retrieved October 2017.

Petersen, J. 1998. *Water Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma - Fish communities in Streams and Their Relations to Selected Environmental Factors.* USGS.

Petersen, J. 2004a. *Fish Communities of the Buffalo River Basin and Nearby Basins of Arkansas and their Relation to Selected Environmental Factors, 2001-2002.* USGS.

Petersen, J. 2004b. *Stream Habitat and Water-Quality Information for Sites in the Buffalo River Basin and Nearby Basins of Arkansas, 2001-2002.* USGS.

Petersen, J. & Femmer, S. 2003. *Periphyton Communities in Streams of the Ozark Plateaus and Their Relations to Selected Environmental Factors.* USGS.

Petersen, J., Haggard, B., & Green, R. 2002. *Hydrologic Characteristics of Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999-2000.* USGS.

Petersen, J., Justus, B., Dodd, H., Bowles, D., Morrison, L., Williams, M., & Rowell, G. 2008. *Methods for Monitoring Fish Communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri: Version 1.0.* USGS.

Peterson, J., Redmon, L. & McFarland, M. n.d.a. *Reducing Bacteria with Best Management Practices for Livestock, Prescribed Grazing,* s.l.: Texas AgriLife Extension Service.

Peterson, J., Redmon, L. & McFarland, M. n.d.b. *Reducing Bacteria With Best Management Practices for Livestock, Fence,* s.l.: Texas AgriLife Extension Service.

Pitcaithley, D. 1989. *Let the River Be, A History of Ozark's Buffalo River.* US National Park Service.

Pugh, A. L., & Westerman, D. A. 2014. *Mean Annual, Seasonal, and Monthly Precipitation and Runoff in Arkansas, 1951-2011.* USGS.

Ready, R. 2018. *Valuing Ecosystem Services Generated by Nutrient Reductions: A Spatial Approach*. In preparation. Montana State University.

Reynaud, A., D. Lanzanova. 2015. *A global meta-analysis of ecosystem services values provided by lakes.* Presented at the 2nd Annual Conference of the French Association of Environmental and Resource Economists, 10-11 September in Toulouse.

Sanders, C. 2016. *Feral Hog Initiative Underway to Aid Landowners in Trapping Swine*. Retrieved October 11, 2017, from UAPB News: https://uapbnews.wordpress.com/2016/08/25/feral-hog-initiative-underway-to-aid-landowners-in-trapping-swine/

Schwoerer, J., & Dodd, H. 2016. *Vulnerability of Stream Communities to Climate and Land Use Change at the Buffalo National River BUFF.* USNPS.

Scott, H., & Smith, P. 1994. *The Prediction of Sediment and Nutrient Transport in the Buffalo River Watershed Using a Geographic Information System.* University of Arkansas Water Resources Research Center.

Smart, M., Jones, J., & Sebaugh, J. 1983. *Stream-watershed relations in the Missouri Ozark Plateau Province.* Journal of Environmental Quality. 141., 77-82.

Soto, L. 2014. *Summary of Previous Dye Tracing Reports in the Area of the Buffalo National River, Arkansas.* USNPS.

Steele, K., & McCalister, W. 1991. *Potential nitrate pollution of ground water in limestone terraine by poultry litter, Ozark Region, USA*. In I. Bogardi, R. Kuzelka, & W. Ennega, Nitrate Contamination, NATO ASI Series Series G: Ecological Sciences Vol. 30. Berlin: Springer.

Steele, K., McCalister, W., & Adamski, J. 1990. *Nitrate and bacteria contamination of limestone aquifers in poultry/cattle producing areas of Northwestern Arkansas, USA*. Fourth International Conference on Environmental Contamination, pp. 238-249. Barcelona, Spain.

TEEB. 2010. *The Economics of Ecosystems and Biodiversity. Ecological and Economic Foundation*. Earthscan. London and Washington.

The Nature Conservancy. 2015. *Strawberry River Preserve and Demonstration Ranch*. Retrieved January 16, 2015, from http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/strawberry-river-preserve-and-demonstration-ranch.xml

The Nature Conservancy. 2017a. *Arkansas Smith Creek Preserve*. Retrieved October 2017, from The Nature Conservancy: https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/smith-creek-preserve.xml

The Nature Conservancy. 2017b. *Ozark Highlands Karst Program*. Retrieved October 2017, from The Nature Conservancy Arkansas: https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/ozark-karst-program.xml

The Nature Conservancy. n.d. *Better Unpaved Roads for Nature and People.* The Nature Conservancy.

Thaler, R.H., A. Tversky, D. Kahneman, and A. Schwartz. 1997. T*he effect of myopia and loss aversion on risk taking: An experimental test.* Quarterly Jour. Econ. 112: 647-661

Thomas, C. C., & Koontz, L. 2016. *2015 National Park Visitor Spending Effects: Economic Contributions to Local Communities, States, and the Nation.* Natural Resource Stewardship and Science, US Department of the Interior. Fort Collins, Colorado: National Park Service. Retrieved February 16, 2017, from https://www.nps.gov/nature/customcf/NPS_Data_Visualization/NPS_VSE_2015_FINAL.pdf

Thornton, KW and Laurin, CR. 2005.*Soft sciences and the hard reality of lake management*. Lake and Reservoir Management 21: 203-208.

UofA Divison of Agriculture. 2012. *Economic Contribution of Arkansas Agriculture.* Little Rock: University of Arkansas Division of Agriculture.

UALR Institute for Economic Advancement. 2015. *County Level Population Projections.* Retrieved January 25, 2017, from Population Estimates and Projections: http://iea.ualr.edu/population-estimates-a-projections.html

University of Georgia Center for Invasive Species and Ecosystem Health. 2017. *EDDMapS, Early Detection and Distribution Mapping System*. Retrieved August 2017, from http://www.eddmaps.org/

UofA Division of Agriculture. 2017. *Big Creek Research and Extension Team*. University of Arkansas Retrieved August 2017, from UofA Division of Agriculture Research and Extension: https://bigcreekresearch.org/

US Census Bureau. 2003. *2000 Census of Population and Housing, Population and Housing Unit Counts, Arkansas.* PHC-3-5, Washington DC.

US Census Bureau. 2012. *2010 Census of Population and Housing, Population and Housing Unit Counts, Arkansas.* Washington DC: US Government Printing Office.

US Census Bureau. 2015. *2011-2015 American Community Survey 5-Year Estimates.* Retrieved January 27, 2017, from American FactFinder: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

US Census Bureau. 2016. *2012 Economic Census of the United States.* Retrieved January 27, 2017, from American FactFinder: http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

US Department of Agriculture. 2014. *2012 Census Volume 1, Chapter 2: County Level Data, Arkansas.* Retrieved January 30, 2017, from USDA Census of Agriculture: https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Arkansas/st05_2_002_002.pdf

US Department of Agriculture. 2017a. USDA Census of Agriculture. Online at https://www.agcensus.usda.gov/. Retrieved January 2018.

US Department of Agriculture. 2017b. *FY 2017 Budget Summary.* Washington D.C.: US Office of Budget and Program Analysis.

US Fish and Wildlife Service. 2017. *The United States Department of the Interior Budget Justifications and Performance Information Fiscal Year 2017, Fish and Wildlife.* US Department of the Interior.

US Forest Service. 2016. *Forest Stewardship Program*. Retrieved October 2017, from US Forest Service: https://www.fs.fed.us/spf/coop/programs/loa/fsp.shtml

Usrey, Faron. 2001. *Macroinvertebrate Community Assessment of the Mid-reaches of the Buffalo National River.* M.S. Thesis, University of Central Arkansas, Conway, Arkansas.

Usery, F. 2013. *Assessment of Escherichia coli Concentrations in the Surface Waters of Buffalo National River.* NPS.

USGS. 2016. *USGS Water Quality Data for Arkansas*. Retrieved December 2016, from http://waterdata.usgs.gov/ar/nwis/qw

USGS. 2017a. *Surface Water Data for Arkansas*. Retrieved January 20, 2017, from https://waterdata.usgs.gov/ar/nwis/sw

USGS. 2017b. *NAS-Nonindigenous Aquatic Species*. Retrieved April 2017, from https://nas.er.usgs.gov

USNPS. 1977. *Final Master Plan, Buffalo National River*. US National Park Servied.

USNPS. 2009. *Buffalo National River Core Operations Analysis Final Report.* USNPS.

USNPS. 2015a. *Buffalo Nationa River, Springs and Seeps*. Retrieved August 2017, from https://www.nps.gov/buff/learn/nature/springs.htm

USNPS. 2015b. *Buffalo Nationla River, Elk*. Retrieved August 2017, from https://www.nps.gov/buff/learn/nature/elk.htm

USNPS. 2015c. *Buffalo National River, Invasive Plants*. Retrieved August 2017, from https://www.nps.gov/buff/learn/nature/invasive-plants.htm

USNPS. 2015d. *Feral Hogs*. Retrieved October 2017, from Buffalo National River: https://www.nps.gov/buff/learn/nature/feral-hogs.htm

USNPS. 2015e. *Buffalo National River, Forests*. Retrieved August 2017, from https://www.nps.gov/buff/learn/nature/forests.htm

USNPS. 2015f. *Buffalo National River Long-range Interpretive Plan.* USNPS.

USNPS. 2016a. *NPSpecies*. Retrieved August 9, 2017, from https://irma.nps.gov/NPSpecies/Search/SpeciesList

USNPS. 2016b. *Buffalo National River - Research*. Retrieved December 2016, from https://www.nps.gov/buff/learn/nature/research.htm

USNPS. 2017. *Cave/Karst Systems*. Retrieved April 2017, from https://www.nps.gov/buff/learn/nature/cave.htm

USNPS. n.d. *Climate and Geology*. Retrieved March 30, 2017, from https://www.nps.gov/buff/learn/nature/climate-and-geology.htm

Usrey, F. 2011. *Bacteria Monitoring for Mill Creek and Associated Reaches of Buffalo River Status and Trends for 2010.* NPS.

Wagner, D., Krieger, J., & Merriman, K. 2014. *Trends in Precipitation, Streamflow, Reservoir Pool Elevations, and Reservoir Releases in Arkansas and Selected Sites in Louisiana, Missouri, and Oklahoma, 1951 - 2011.* Reston, VA: US Geological Survey.

Walkenhorst, E. 2016. More algae seen on Buffalo River. *Metro*.

Washington State University. 2006. *WSU Experimental Riparian Buffer Site Installation and Maintenance Costs 2003-2005.* Retrieved August 2017, from Riparian Buffers: https://puyallup.wsu.edu/agbuffers/data/

Watershed Conservation Resource Center. 2017. *Surface-Water Quality in the Buffalo National River.* USNPS.

Westerman, D., Gillip, J., Richards, J., Hays, P., & Clark, B. 2016. *Altitudes and Thicknesses of Hydrogeologic Units of the Ozark Plateaus Aquifer System in Arkansas, Kansas, Missouri, and Oklahoma.* Reston, VA: US Geological Survey.

White, K., Haggard, B., & Chaubey, I. 2004. *Water quality at the Buffalo National River, Arkansas, 1991-2001*. Transactions of the ASAE. *472*, 407-417.

Whitescarver, B. 2013. *Planting and Growing a Successful Riparian Forest Buffer.* Retrieved August 2017, from Whitescarver Natural Resources Management LLC: http://www.gettingmoreontheground.com/2013/07/13/planting-and-growing-a-successful-riparian-forest-buffer/

Wiggs, R., & Angelo, D. 2003. *A Herpetofaunal Inventory of Buffalo National River.* USNPS.

Williams, M. 2009. *An Evaluation of Biological Inventory Data Collected at Buffalo National River.* US National Park Service.

Williams, M., Usrey, F., Hodges, S., Harris, J., & Christian, A. 2009. *Species richness, distribution, and relative abundance of freshwater mussels Bivalva:Unionidae of the Buffalo River, Arkansas*. Journal of the Arkansas Academy of Science, Vol. 63, 113-130.

Zeckoski, R., B. Benham, and C. Lunsford. 2007. *Streamside livestock exclusion: A tool for increasing farm income and improving water quality*. Virginia Cooperative Extension Publication No. 442-766. Available online at https://pubs.ext.vt.edu/442/442-766/442-766_pdf.pdf

APPENDIX A

Sign In Sheets for Watershed Management Plan Public Meetings

MEETING SIGN-IN SHEET Buffalo River Watershed Management Plan

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	12/8/16
Facilitator:	Kent Thornton	**Place/Room:**	Searcy Co Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Mitch Rouse	ADEQ	501-514-0575	rouse@adeq.state.ar.us →	
David Holsted	Harrison Daily News	870-743-0607		
Stetson C. Painter	Senator John Boozman	870-424-0129		stetson_painter@boozman.senate.gov
Jason Smedley	Farm Bureau			jason.smedley@arfb.com
Larry Kelley	Retired	479-601-2296	Fayetteville	
Brian Thompson	BRWA	479 879 0688	FAY	
Mitchell McCutcheon	Former	870-434-5260	H.C. 32 Box 60 Mt. Judea Ark 72655	
Pam Stewart				jampack1@mac.com
Jack Stewart	BRWA Alliance	870-715-0260		" " "
Jo Smith	Artist			js6pottery@gmail.com
Caven Clark	NPS	870/365-2790		
Gerald Weber	Friends of the North Fork & White	870-269-2704		jerryweber@yelcot.net
Alan Estes				ESTES55@WINDSTREAM.NET

13

MEETING SIGN-IN SHEET Buffalo River Watershed Management Plan

Project:	ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:**	12/8/16
Facilitator:	Kent Thornton	**Place/Room:**	Searcy Co Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Sarah Clem	ADEQ	681-0812		clem@adeq.state.ar.us
Donnally Davis	ADEQ	501-514-8001		davis@adeq.state.ar.us
MATT McNAIR	ADPT	501-682-1227	1 CAPitol mall LR, AR 72201	MATT.MCNAIR@ARKANSAS.GOV
Allen Brown	ANRC	501-682-3902		
McBlair	Farmer	870 448-2702	14587 Hwy ... Rd Marshall 72650	
Joe Golden	SELF	870 741-1165		joeatgo@gmail.com
John Bailey	Ar FB	501-791-7937		john.bailey@arfb.com
Ginny Masullo				masullo.ginny1@gmail.com
[illegible]				[illegible]
Kristina Hale				haltroad@yahoo.com
Barry Lilley	Retired		1978 Hwy 64 Morrilton Ark	
Bob Allen	retired			bob@ozarker.org
Mart. Olesen	BRWA			molesen12@gmail.com

MEETING SIGN-IN SHEET Buffalo River Watershed Management Plan

Project:	ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:**	12/8/16
Facilitator:	Kent Thornton	**Place/Room:**	Searcy Co Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Carolyn Davis	Retired	870-448-3761	722 Quaker Lane Marshall AR 72650	—
Jerry Master	APPA	479-970-0031	579 Rock Mt. Rd Dover, AR 72837	arkpork@yahoo.com
Sharon Daniel		870-448-2698	301 Dogwood Blvd. Marshall	
Jacque Alexander	BRBCH	501-951-9915	575 Getaway St Joe Ar	theloosecayuse@gmail.com
[illegible]	[illegible]	479-388-5764	1791 Sunbridge Lane Rogers AR 72758	
Cecile Knight	Retired	501-951-8704	PO Box 74 Gilbert AR 72636	knightcecile@yahoo.com
Richard Connell	Fence Buider	448-2064	Marshall, Ark 72650 873 Ivory Trail	
Dean Lawrence	Retired	448-2423	198 Lawrence Marshall, Ark	
Michael Parsons	Director	870-504-3640	P.O.Box 74, [illegible]	—
J[illegible] Miller		" "	PO Box " "	
Carol Bitting	Land owner	870 446 5508	HC 73 Box 182A Marble Falls, AR	lcbitting@gmail.com
Zella Holden	citizen	501 593-9850	5531 Country Club Searcy AR	
David Peterson	Ozark Society	501-679-2935	56 Ridge Drive Greenbrier AR 72058	drpdrp@windstream.net

MEETING SIGN-IN SHEET Buffalo River Watershed Management Plan

Project: ARKANSAS WATERSHED PLAN Public Meeting | **Meeting Date:** 12/8/16

Facilitator: Kent Thornton | **Place/Room:** Searcy Co Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Chris Harris			P.O. Box 1121	Scootes@windstream.net
Tom Harris				Walter.Thomas.Harris@windstrea
Billy D. Ragland	Farmer	870-448-3700	1813 S. Maume Rd Marshall AR 72650	
Rick Monk				rgmonk@fs.fed.us
Alice Andrews	Ozark Society	501-219-4295	63 Robinwood D.	alice2090k@yahoo.com
Emily Walkenhorst	Ark D-G	501-399-3601		ewalkenhorst@arkansasonline.com
Donald Ragland	Retired Ark WO	870-504-0032	Marshall 124 Golden Acres	[illegible]

MEETING SIGN-IN SHEET	Marshall - Buffalo River WMP meeting		
Project:	ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:**	12-8-16
Facilitator:	K. Thornton	**Place/Room:**	Searcy County Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Gordon Watkins	BRWA	870-577-1211	HCR 72 Box 34 Parthenon AR	gwatkins@ritternet.com
Marvin Smith				ms6wood@gmail.com
Ellen Corley				foothold farm @ yahoo.com
William Mendez	USFS	479 964-7207	Ozark NF 605 W C St Russellville	wmendez@fs.us
LAURA Timby	TOWN COUNCIL GILBERT	870 504 2688	PO Box 25 Gilbert 72636	laurab2053@gmail.com

MEETING SIGN-IN SHEET Buffalo River Watershed Management Plan	
Project: ARKANSAS WATERSHED PLAN Public Meeting	Meeting Date: 12/8/16
Facilitator: Kent Thornton	Place/Room: Searcy Co Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Rex Robbins		501-772-8503		rex.robbins@gmail.com
Shawn Hodges		870-365-2778		Shawn_Hodges@nps.gov
Jane Dale				↑
Sara Toonk				emptycreek@yahoo.com
Robert Lee Hensley		870-4486772		
Greg Hedland		501-940-6082		
Stan Hayes		870-448-6792		stanhayes@windstream.net
Sarah Younger		870-439-2798		
Charles Younger		870-439-2798		
Darryl Treat		870-448-2557		treatd@windstream.net
Misti Collier		870.504.3622		mdcolli1970@yahoo.com
Harold Hensley		870 496 2225		
Arch Smith		870 448 2432		

13

7

MEETING SIGN-IN SHEET	Buffalo River Watershed Management Plan		
Project:	ARKANSAS WATERSHED PLAN Public Meeting	Meeting Date:	12/8/2016
Facilitator:	Kent Thornton	Place/Room:	Searcy Co Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Ryan Benefield	ANRC			
Keith Stokes		(479)229-1814	tuskfarm@Centurylink.NET →	
Jim Krieger	BNRP/AR master naturalist	952-831-3194	Jimkrieger@	Yahoo.com
Jessie Green	ADEQ	501-915-2746		greenj@adeq.state.AR.US
John Chamberlin	APCEC	501 590 6636	johngchamberlin@ chamberlinresear	ch.com
Edward (Gene) Eller		318-512-2356	thereb[illegible]ingwoman@ gmail.com	677 Brush Creek Rd Marshall, AR 72650
Don Rainbolt	Agriculture	870-504-1353		donrainbolt@yahoo.com
John Naill	Agriculture/Outdoors	501-681-9407	PO Box 23471 Little Rock, AR 72221	jdnaill@sbcglobal.net
EDD FRENCH	BNRP	870 688 0153	PO. BOX 549 JASPER AR 72641	BUFFREE@RITTER NET. COM
Patti Kent	Self			patikent85@hotmail.com
TERESA TURK	OZARK River Stewards			teresa_turk@hotmail.com
Randy Clark			pclark5@windstream.net	
Mark Smith		479-264-1527	Masmith35@gmail.com	~~263~~

13

MEETING SIGN-IN SHEET Marshall - Buffalo River WMP

Project: ARKANSAS WATERSHED PLAN Public Meeting		**Meeting Date:** Dec 8 2016	
Facilitator: K. Thornton		**Place/Room:** Searcy County Civic Center	

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Margaret Konert				Pegkonert@gmail.com
Laura Miller	NPS			laura_a_miller@nps.gov
Kyle Weaver	Congressman			kyle.weaver@mail.house.gov
Teri Garrett	Womack			teri.garrett@mail.house.gov
Ed Alexander	Friends of River			edalex3079@gmail.com
Joseph Terry				TerryJK@att.net
Matt Anderson	USFS			manderson08@fs.fed.us
Woodie Methvin				Woodie.Methvin@AFBIC
HARLEY THOMPSON	OZARK OPPORTUNITIES			HTHOMPSON@OZARKOPP.ORG
Emily Jones	NPCA	865-335-4666		ejones@npca.org
Jerry Shell	Growing Searcy Co Healthy Com	870-405-2795		jerryshell8@gmail.com
Melissa Lombardi	USFWS	501-733-2056		melissa_lombardi@fws.gov
Harlie Treat	Farm Bureau			hrtreat@yahoo.com

13

MEETING SIGN-IN SHEET Marshall	Buffalo River WMP meeting
Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 12-8-16
Facilitator: K. Thornton	**Place/Room:** Searcy County Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Kay Marmaduke			PO Box 37 Witts Springs AR 72686	sorry, I don't have one
Niagle Ratchford			144 Outlook Dr Marshall, AR	niagle@yahoo.com
Cody Wyatt			Western Grove, AR	ccwyatt@yahoo.com
Mike Mulford	USFS			mmulford@fs.fed.us
Jim Dixon	USFS			jldixon01@fs.fed.us
LinWellford				LinWellford@gmail.com
Don Richardson	ANRC			dsrenviro@gmail.com
MICHAEL FARAR			3102 FLAG RD FOX, AR 72051	hbitsko@gmail.com
Ruth Weinstein				ruthgardens76@gmail.com
BOB EVANS			3224 COZAHOME RD HARRIET, AR 72639	NA
CHARLES DANIEL				cddaniel@windstream.net
Dillon Carr				dillon.carr@ar.usda.gov
*Duplicate David Holsted	Harrison Daily Times	870-743-0607		davidh@harrisondaily.com

12

MEETING SIGN-IN SHEET Marshall Buffalo River WMP meeting	
Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 12-8-16
Facilitator: K. Thornton	**Place/Room:** Searcy County Civic Center

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Paul Port	AGFC			paul.port@agfc.ar.gov
Chuck Orvis	Friends of the White & North	870-430-5777		corvis@centurytel.net
Jim Mille				Jim@sotocamp.com
Brian Thompson	BRWA			thompsonadd@gmail.com
Garry Lilley			805 Ceder Morrilton 72110	

5

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MEETING SIGN-IN SHEET			
Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	3/30/17
Facilitator:		**Place/Room:**	Jasper AR

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
EDD FRENCH	INN Keeper			BUFFRE@ RITTERNET. COM
Dave Mott	Farmer			mott2640@gmail.com
Chuck Bitting	NPS	870-577-4445		chuck_bitting@nps.gov
Rex Robbins	Land Owner			
John Chamberlin	APCEC			
LARRY DAVIS			HCGL BOX560 DEER	
Adam Willis	Extension Agent			
Gordon Watkins	BRWA			
Rick Adams.	NRCS			rick.adams@ar.usda.gov
PAUL VILLINES	NCCD	870 861 5692	2805 Ar 43 Hwy Ponca	
Marti Olesen	BRWA			

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MEETING SIGN-IN SHEET

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	3/30/17
Facilitator:		**Place/Room:**	Jasper AR

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Carolyn Davis	—	870-448-3761	722 Quaker LN Marshall AR 72650	—
Jeanmarie "Rain" Mako	Mountain Bike Patrol	870-861-5884	HC 33 box 46 Pettigrew AR 72752	mako-blaisus@gmail.com
Michael McLelland	Retired-farm	870-446-6028	HC 31-Box 103 Jasper Ar 72641	
Tim McSweeney	Retired		Parthenon, AR	timcsweeney3@yahoo.com
Kay Marmaduke	Retired	870-496-2333	PO Box 37 Witts Springs AR 72686	none
Perry Haynes	Retired	479 981 0237		phfarmer@gmail
Mike Daniels	UA-CES	501 944-0995	2301 S. University Little Rock AR	mdaniels@uaex.edu
HEATHER SACO	ADEQ	501 944-5789		sacoh@adeq.state.ar.us
David Peterson	Ozark Society	501-679-2935	56 Ridge Drive Greenbrier, AR 72058	drpdrp@windstream.net
Alice Andrews	Ozark Society	501-219-4295	63 Robinwood Dr Little Rock	alice2090K@yahoo.com
Emily Jones	NPCA	865 335-4666	706 Walnut St. Ste 200 Knoxville TN 37902	ejones@npca.org
Ginny Masullo	Nurse-RN	479-530-0180	1837 Ripple Rd Fay AR	masullo.ginny1@gmail.com
Carol Bitting		870 446 5528	HC 73 Box 182A Marble Falls	lcbitting@gmail.com

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MEETING SIGN-IN SHEET

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	3/30/17
Facilitator:		**Place/Room:**	Jasper AR

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Shawn Hodges				
Ashley Rodman	NPS			ashley_rodman@nps.gov
Don House	Photographer			dhouse@NWARK.com
Kevin Cheri	NPS			
Caven Clark	NPS			caven_clark@nps.gov
Allie Rouse	ADEQ			rouse1@adeq.state.ar.us
Mitch Rouse	ADEQ			rouse@adeq.state.ar.us
Jeff Dezort	NCTIMES			jeffd@newtoncountytimes.com
Mitchell McCutchen				ARRadioman at Gmail.com
CAROLYN SHEARMAN	SIERRA CLUB			tucshea@gmail.com
Rob Mendez	USFS			wmendez@fs.fed.us
Beverly Knight	—			
Ellen Corley				

(4)

MEETING SIGN-IN SHEET

Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 3/30/17
Facilitator:	**Place/Room:** Jasper AR

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
STEVE BLUMREICH	FRIENDS OF RIVERS	417-839-0193	P.O. BOX 2244 M.H. AR 72654	sblum1326@gmail.com
John Bailey	ArFB			john.bailey@arfb.com
CHRIS WYATT	AFC	870-429-6281	RTE 1 BOX 275 WESTERN GROVE	CHRISTOPHER.WYATT@ARKANSAS.GOV
Bob Allen	ACC			bob@ozarker.org
Kevin Elliott	City of Marshall	870-448-2543	PO Box 1420 Marshall	
Bob Shofner	FARMER			Shofner50@gmail.com
JOHN MEYER	BIOLOGIST	870 446 5949	HC 31 BOX 96 JASPER	—
Adam Clark				
MATT McNAIR				
Joe Golden				
Kay Moore		817-688-7816	417 Rio Rd Millsap TX	kay.kay1214@yahoo.com
Laura Lynn	Writer	(760) 966-6000		
[illegible]	Mayor Jasper	870-446-2633		

MEETING SIGN-IN SHEET

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	3/30/17
Facilitator:		**Place/Room:**	Jasper AR

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Steve Miller			PO Box 526 Jasper	
Darryl Treat		870-448-2557		
Jessie Green				jessiejean7@gmail.com
Brian Thompson	BRWA			THOMPSONADD@GMAIL.com
Jason Smedley	ARFB			jason.smedley@arfb.com
Jack Stewart	BRWA			jack.stewart_us@yahoo.com
Pam Stewart			Box 632 Jasper AR 72641	"
SUSANNE Long		870-446-2414	P.O. Box 786 Jasper AR	longsusanne@yahoo.com

(6)

MEETING SIGN-IN SHEET

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	3/30/17
Facilitator:		**Place/Room:**	Jasper AR

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Kyle Weaver	Rep. Womack	479-464-0446		
Teri Garrett	"	870-741-6900		
~~Keith Stokes~~	~~Senator Cotton~~			
Keith Stokes	Senator Cotton		Keith_Stokes@Cotton.Senate.Gov	

MEETING SIGN-IN SHEET

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	June 8th, 2017
Facilitator:		**Place/Room:**	Marshall

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Shawn Hodges	NPS			
Kevin Cheri	"			
Ashley Rodman	"			
Alice Andrews				
Rick Monk	USFS			
Kay Marmaduke				
Cecile Knight				
Billy D. Ragland				
Jack Stewart	B			
Pam Stewart				
Bob Shofner	FARMER			
Mitch Rowe				
Travis Eddings	FB / Landowner			[illegible] teddings71@gmail.com

MEETING SIGN-IN SHEET

Project:	ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:**	Jun 8, 2017
Facilitator:		**Place/Room:**	Marshall

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Heather Saco	ADEQ	501 944 5789		
Travis Flower	Sen. John Boozman	870 866 0199		Travis_Flower@Boozman.Senate.gov
Allie Rouse	ADEQ			
Marti Olesen	BRWA			
Carolyn Davis				
Adam Redman	AFC	870-448-5014		
James Burnett		949-636-5034	PO Box 11 Harriet	James.burnett.sr@gmail.com

MEETING SIGN-IN SHEET

Project: ARKANSAS WATERSHED PLAN Public Meeting	Meeting Date: June 8, 2017
Facilitator:	Place/Room: Marshall

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Lewis Still		479-595-2130		LWStill@Earthlink.net
Steve Higniight	ArFarmBureau	501-517187?		steven.higniight earth.com
Paula D Smith	Cattle Farmer	8707049448	120 Hollow Rd St Joe AR	davelinesmith@yahoo.com
Brent Clark	NRCS			
Stephanie Daniel	NRCS			
Kaitlyn Maloch	NRCS		Marshall, AR	kaitlyn.maloch@ar.usda.gov
Halee Moore	NRCS		Marshall, AR	Halee.Moore@arnacd.net
Charles Daniel	MD		Marshall AR	
Sharon Daniel	✓		" "	
Carolyn Shearman	Sierra Club			
John Chamberlain				
Bronwyn King	Chamber of Commerce		Marshall	bronwyn56@hotmail.com

MEETING SIGN-IN SHEET

Project:	ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:**	June 8th, 2017
Facilitator:		**Place/Room:**	Marshall

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
STEVE BLUMRECH				
Reta Ruff	Cattle farmer	870-448-6447	338 Calf Creek Rd marshall, Ar. 72650	Richland1953@live.com
JERRY WEBER	Friend of NF&WR			
Darryl Treat				
SHARON DANIEL				
Keith Stokes	SENATOR COTTON			
Darrell Ragland	Arkansas Forestry Commission			

MEETING SIGN-IN SHEET Buffalo WMP	
Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 10-12-17
Facilitator:	**Place/Room:** Jasper

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
STEVE BLUMREICH	FRIENDS OF RIVERS			
Jessie Green	White River Waterkeeper			
Keith Stokes	SENATOR COTTON			
CHRIS WYATT	AFC			
Emily Jones	N.P.C.A.			
[illegible]	BRWA			
Cindy DeWitt				camill027@aol.com
HEATHER SACO	ADEQ			
JEFF DEROIT	NC TIMES			
David Mott	Farmer			
Mitchell McCutcheon	Farmer			
Jim Wise	ADEQ			
Monty Williams.				

P2of2

MEETING SIGN-IN SHEET Buffalo WMP	
Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 10-12-17
Facilitator:	**Place/Room:** Jasper

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Jerry Masters	APPA			
Clare Whitlock				
Pam Stewart				
Jack Stewart				
Gina Booth				gmabe ritternet.com
Chris Keaton	RC			
Emily Walkenhorst	Ark D-G			
Matt McNair	ADPT	501-682-1227	1 Capitol Mall LR, AR 72201	matt.mcnair@arkansas.gov
Paul Villines		870 861 5692	2805 AR 43 Hwy Ponca, Ar 72670	
Shawn Hodges	NPS			
Ashley Rodman	NPS			
Cameron Cheri	NPS			

APPENDIX B

Summary of Watershed Management Plan Public Meetings

Arkansas Natural Resources Commission

Bruce Holland
Executive Director

101 East Capitol, Suite 350
Little Rock, Arkansas 72201
http://www.anrc.arkansas.gov/

Phone: (501) 682-1611
Fax: (501) 682-3991
E-mail: anrc@arkansas.gov

Asa Hutchinson
Governor

Arkansas Natural Resources Commission's Development of the Buffalo River Watershed Management Plan
First Stakeholder Meeting
December 8, 2016: Marshall, AR
Meeting Summary

The Arkansas Natural Resources Commission (ANRC) recently sponsored a stakeholder meeting as part of the development of the watershed management plan for the Buffalo River. The meeting was held in Marshall on December 8, 2016. The meeting agenda is included as Attachment 1. Approximately 130 individuals attended the meeting, including farmers, landowners, and political representatives, as well as individuals from agricultural, conservation, recreational, and other interests groups, and employees from state and federal agencies.

At the direction of Governor Asa Hutchinson, the Beautiful Buffalo River Action Committee was organized to establish an Arkansas led approach to identify and address potential issues of concern in the Buffalo River watershed, including the development of a non-regulatory watershed management plan for the Buffalo River watershed.

The meeting was facilitated by FTN Associates, Ltd. (FTN), an engineering and environmental consulting firm headquartered in Little Rock, with a branch office in Fayetteville. The Arkansas Natural Resources Commission contracted FTN to assist the agency with the development of the Buffalo River Watershed Management Plan. The process will be completed by June of 2018.

Basic information on the watershed-based management plan for the Buffalo River Watershed was presented at the Marshall meeting. A copy of the presentation can be found in Attachment 2 below. Significant points about the plan that were stressed repeatedly were:

- The plan will provide a framework for landowners, communities, and organizations to voluntarily undertake water quality projects in the watershed and improve the ability to solicit and secure funding and assistance for these projects from various government and private sources.
- This plan will not recommend or directly lead to additional regulations in the watershed.
- This plan will not result in recommendations regarding land ownership rights.
- The plan will not address facilities that are already permitted by the Arkansas Department of Environmental Quality because those entities are required to meet certain regulations. The watershed plan is nonregulatory.

Following the introductory presentation, attendees broke into two large groups to allow meeting participants to identify issues and/or express their concerns about activities occurring within the

Buffalo River watershed. The emphasis was on water quality concerns or issues, but participants were free to also identify other issues. The two groups consisted of agriculture/commerce/governance and tourism/recreation/environment interests. Individuals could stay in one group or participate in both groups. In some instances, potential management practices, measures, or actions were raised. These topics were also noted.

After about one hour of the group sessions, attendees came back together and FTN personnel reported on the issues identified by each group. Concerns and/or issues identified by participants in the two groups are listed in Attachments 3 and 4.

Attendees were also encouraged to provide information on issues in the watershed to FTN or ANRC any time after the meeting or at a later date. Contact information for FTN and ANRC project personnel was provided (See contact information below).

There were two question and answer sessions: one after the introductory presentation of the watershed management plan process during the first portion of the meeting; and a second after the issues identified by the attendees were reported.

A summary of the questions and responses is included in Attachment 5. Not all questions raised are listed because several questions addressed the same subject. In addition, responses are included for questions whose answers were unknown when asked at the meeting.

The information gathered at the Marshall meeting will be integrated with additional information obtained through analysis and research and used to develop a draft watershed management plan for the Buffalo River watershed. This process will occur over the next 12 to 18 months.

The next watershed meeting will be held in about 3 months and is currently scheduled to be in Jasper, AR. Its purposes will be to:

1. Reiterate the issues raised during the first stakeholder meeting;
2. Present the current status and trends in water quality within the Buffalo River watershed;
3. Elicit information from stakeholders on potential management practices, measures and actions to address the water quality issues raised in the first meeting; and
4. Describe the next steps in the planning process.

For additional information or to provide additional questions, contact:

- ANRC, Allen Brown (allen.brown@arkansas.gov) or (501) 682-1611)
- FTN Associates, Terry Horton (twh@ftn-assoc.com) or (501) 225-7779)

ATTACHMENT 1
Arkansas Natural Resources Commission
Buffalo River Watershed Management Plan:
A Voluntary, Non-Regulatory Project
Civic Center, Marshall AR
8 December 2016
Agenda

Time	Topic	Individual
9:30 am	Welcome, Meeting Purposes: • Provide background on the Beautiful Buffalo River Action Committee & watershed plan • Describe the watershed management planning process • Elicit stakeholder input on issues within the Buffalo River watershed • Discuss next steps	K. Thornton, FTN
9:35	Background and WMP Planning Process • Beautiful Buffalo River Action Committee's function • Watershed Management Plan and planning process	K. Thornton
10:00	Breakout Groups • Dialogue on watershed issues • Two Groups - Agriculture/Commerce/Governance - Tourism/Recreation/Environment	ALL
11:00	Report Out • Agriculture/Commerce/Governance (10 min) • Tourism/Recreation/Environment (10 min)	ALL
11:20	General Discussion	All
11:50	Next Steps	K. Thornton
11:55	Remaining Questions	All
12:00	**Adjourn**	

Contacts:
Allen Brown, ANRC – Allen.Brown@arkansas.gov
Terry Horton, FTN – twh@ftn-assoc.com

Buffalo River Watershed Management Plan: A Voluntary, Non-Regulatory Project

1st Stakeholder Meeting
Marshall, AR
8 December 2016

Meeting Purposes

- Provide Background on the Beautiful Buffalo River Action Committee & Watershed Plan
- Describe the Watershed Management Planning Process
- Elicit Your Input On Issues Within The Buffalo River Watershed
- Discuss Next Steps

Beautiful Buffalo River Action Committee (BBRAC)

- Established by Exec. Memo
  - 30 September 2016
- Mission – Identify and address potential issues of common concern in the Buffalo River Watershed

BBRAC

- Five Agencies
  - DEQ (Co-Chair)
  - ANRC (Co-Chair) - WMP
  - Agriculture
  - Health
  - Parks and Tourism
  - AG&FC, AGISO - Partners

BBRAC

- **First Year Priorities**
  - Stakeholder engagement
  - Develop Buffalo River Watershed Management Plan
  - Identify and implement early actions
  - Identify research needs and opportunities

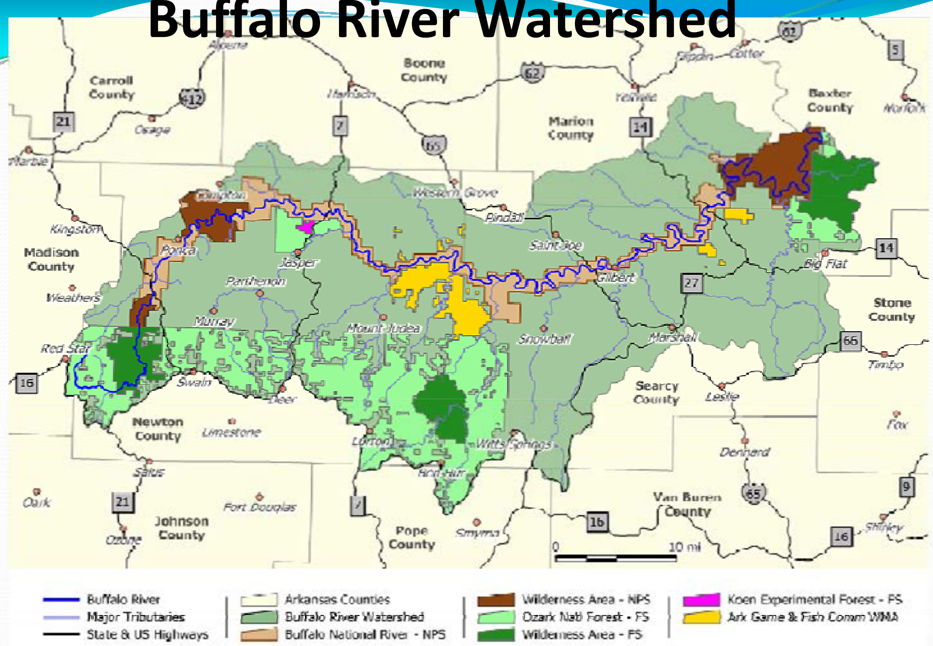
Watershed Management Plan

- **Three Key Features:**
  1. Water Quality Emphasis
     - Extraordinary Resource Water
  2. Nonpoint Sources – non-regulatory
  3. Voluntary participation

Watershed Management Plan

- **Implications:**
  - ➢ **Focus on sustaining, not restoring, water quality**
  - ➢ **Acknowledges, but does not address, hog farm => permitted, regulated facility (BBRAC Issue)**
  - ➢ **No requirement to participate**
    - ❖ **Are benefits of participating**

Buffalo River Watershed



Watershed Planning Process

- **Six Steps**
  1. Building partnerships
  2. Characterizing the watershed
  3. Mgt goals, practices, measures, actions
  4. Design implementation program
  5. Implement the WMP
  6. Measure progress – adaptive mgt.

EPA 9 Planning Elements

1. Sources and causes of known impairment
2. Mgt measures, expected benefits
3. NPS mgt practice descriptions, potential areas
4. Technical and financial assistance needs, cost est., possible funding sources & partners
5. Education and outreach
6. Implementation schedule
7. Interim, measureable milestones
8. Evaluation criteria
9. Monitoring program and review process

Stakeholder Input

- **Meetings:**
  - **Watershed Issues (Today's Topic)**
  - **Management practices, measures, actions, awareness, outreach suggestions**
  - **Costs, financial/technical assistance, benefits,**
  - **Draft plan recommendations, comments**
  - **Final plan and implementation**
- **Correspondence, BBRAC, reports, studies, etc.**

Schedule

- **12-18 months – WMP**
- **Series of Stakeholder meetings ~ quarterly**
  - **Meet in watershed**
- **BBRAC meetings ~ quarterly**
  - **First meeting – January 2017**
  - **Meet in Little Rock**

Meeting Ground Rules

- 1. One speaker at a time
- 2. Request acknowledgement
- 3. Listen first to understand, then to be understood
- 4. Please don't interrupt
- 5. Respect others ideas, thoughts
- 6. Ok to disagree – respectfully, openly
- 7. No side conversations

Cell Phones off/on vibrate

Questions on the WMP Planning Process?

Today's Activity

- **Watershed Issues**
  - **Emphasis on Water Quality, but**
  - **Raise other issues of concern**
  - **BBRAC multiple agencies**
- **Breakout Groups**
  - **Facilitated dialogue**

Breakout Groups

- **Two Breakout Groups for Dialogue**
  - **Agriculture/Commerce/Governance**
  - **Tourism/Recreation/Environment**
- **Dialogue for 1 hr**
- **Report out and discuss issues**

Breakout Groups

- Agriculture/Commerce/Governance

  Northeast Corner of Civic Center

- Tourism/Recreation/Environment

  Southwest Corner of Civic Center

Report Out

Next Steps

- Meeting Summary – distributed to everyone attending and on email list
- Continue to elicit your input
- Characterize the watershed
- Schedule next meeting; likely in March
- Next meetings topic
  - Practices, measures, actions, awareness, outreach ideas, suggestions to address issues

Questions?

Final Comments?


Thank You
Happy Holidays

ATTACHMENT 3

Agriculture/Commerce/Governance Break-Out Group
Issues Mentioned by Participants

Water Quality Issues

1. Hog farm
2. Feral hogs - -no information on population numbers or locations
3. Manure & fertilizer application
4. Groundwater study – where the water comes from & goes – Karst recharge zones
5. Wellhead protection for drinking water
6. Utility companies and Department of Transportation right of way management – use of pesticides and fertilizers
7. Sanitary waste into the Buffalo River
8. Privies in floodplain
9. Erosion inputs – sedimentation and streambanks.
10. Gravel road management and sediments
11. Timberland management
12. Livestock in streams
13. Algal bloom in Buffalo River; both human & animals, fish, etc health issue
14. Failing septic systems
15. Manure import to Buffalo watershed from Nutrient Surplus Area
16. In-stream gravel mining
17. Fracking for natural gas when prices increase

Other Issues

1. Sustain the family farm & use
2. Diversification of economic opportunities without impairing water quality
3. Governments working together or against each other, i.e. inter-governmental cooperation, communication
4. Drug resistant bacteria
5. Over-use of Buffalo River; exceeds capacity
6. Technology Best Management Practices for waste management
7. Increased cooperation between National Park Service & local government
8. Education & cooperation among stakeholders
9. Economic development funding

Management Practices/Actions for Issues

1. Zero discharge to watershed
2. Source tracking – natural or man-made
3. Nutrient management zone – plans, voluntary
4. Agri-tourism

ATTACHMENT 4

Tourism/Recreation/Environment Break-Out Group
Issues Mentioned by Participants

Water Quality Issues

1. Permitted hog farm
2. Feral hogs
3. Trash in the river and on the banks
4. Excess nutrients, which lead to algae blooms
5. Human waste in the river
6. Failing septic tanks
7. Bacteria, E coli, etc. in the water
8. Developed areas, with greater impervious surfaces that increase runoff
9. Sedimentation in the streams
10. Road maintenance contributing to sedimentation
11. Erosion and sedimentation
12. Spraying/cutting of easements by utility companies
13. Livestock in streams
14. Failing/abandoned septic systems
15. Need wastewater treatment facilities upgrades
16. Groundwater transfer among watersheds because of karst geology
17. Gravel in the river and tributaries
18. Convert forest -> pasture and other land use conversion
19. Fertilization in the watershed and runoff
20. Pollutants in caves & springs
21. Facilities in floodplain flooded
22. ATV use in & around the stream contributing to erosion
23. Sawdust disposal in gullies

Other Issues

1. Credibility of agencies, organizations and individuals
2. Poverty/lack of jobs in the watershed
3. Prescribed burns in Wilderness Areas
4. Invasive Species (Hay w/weeds)
5. Limited industrial opportunities in the watershed
6. Need for education and better communication reflecting generational differences
7. Investment in tourism infrastructure for hotels and restaurants
8. Respect for local culture and lifestyle
9. Recognition of private land -private property rights
10. Interagency communication & collaboration
11. Need economic development plan

Management Practices/Actions for Issues

1. Additional trash/restroom facilities along the river
2. Construct farm ponds in natural drainage (sediment traps)
3. River use permits for the Buffalo River (National Park Service)
4. Increase monitoring in River & tributaries
5. Create a porta-potty fund for facilities along the river

Arkansas Natural Resources Commission

Bruce Holland
Executive Director

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Asa Hutchinson
Governor

ATTACHMENT 5

Questions Raised at the Marshall Meeting and Responses

Question: Will it be possible to get 319 money even though there aren't impaired streams?

Response: Section 319 funds, which are administered by EPA and provided to the States for implementing nonpoint source management practices, are available for implementing management practices that can improve water quality. The funds are not restricted only to impaired stream segments.

Question: In some cases the Arkansas Department of Environmental Quality (ADEQ) apparently doesn't have the power to address a point source that is impacting water quality. How then can that source be addressed?

Response: ADEQ does have the authority to address permitted facilities if the discharge from that facility is impairing uses of the stream into which the point source discharges. Because it is a regulatory action, there are review procedures in place to ensure that appropriate actions are being taken. It might appear that no action is being taken because of the time required for review, but only ADEQ has the authority to address permitted facilities and point sources.

Question: How does the watershed management plan get updated? What part do/can citizens play?

Response: The WMPs are reviewed by ANRC every 5 years as part of the Nonpoint Source Management Section's update of priority watersheds throughout the State. Supplements are added to the WMPs each time financial or technical assistance is provided for the implementation of management practices in the watershed or its subwatersheds. In addition, success stories are prepared for those watershed management practices that have documented improvements in water quality following implementation of these practices. Individual landowners are critical in this process because implementation is voluntary. Little happens unless individual landowners voluntarily participate. Other citizens and organizations can play major roles in creating awareness of water quality issues, and supporting outreach and education efforts encouraging participation in watershed management practices, measures, actions, or programs. Landowner and citizen participation is essential and critical.

Question: If a landowner wants to apply nutrients (manure products or other fertilizer) to his or her permitted land, can they get assistance (including funds) to reduce the impact of the fertilizing on water quality?

Response: Yes, if they satisfy the requirements of the program for receiving technical or financial assistance.

Question: Are levels of bacteria (E. coli, fecal coliforms, Cryptosporidia, Giardia) increasing in the river?

Response: This question will be answered over the next several months as water quality data for the Buffalo River and its tributaries are analyzed. Both the current status, and trends, in water quality constituents, including these indicators of pathogens, will be assessed.

Question: Do the poultry companies hold their growers accountable for land applying chicken litter in the watershed?

Response: Some poultry companies require their growers to prepare nutrient management plans for the land application of poultry litter. During discussions with ADEQ, Peco indicated it will require its growers to prepare nutrient management plans for their land application of poultry litter.

Question: After a WMP has been in place, does some entity do testing to determine if the practices improved the stream or not?

Response: Several ANRC watershed management projects have monitored water quality following implementation of management practices to document improvements in water quality. These success stories can be found at www.**arkansaswater.org** . In addition, ADEQ conducts a biennial review of water quality throughout the State. Improvements in water quality following implementation can sometimes be detected in this review. Water quality stations are generally not located at sites where management practices are implemented so improvements might not be detected. Improvements in water quality can also take from several years to decades to detect because of a lag in watershed response to the practices. Not detecting an improvement does not necessarily mean improvements have not or are not occurring, but simply that they cannot yet be detected.

Question: Do some WMPs fail to make a difference in water quality?

Response: Because implementing management practices is voluntary, if no landowners are interested in implementing management practices following the development of a WMP, then no improvements in water quality are likely to occur. However, a major part of the process of developing a WMP is building partnerships and relationships among landowners and communities within the watershed, making people aware of financial and technical assistance that is available for management practices, and the benefits that can accrue from implementing these management practices.

Question: Why is this program directed at my cattle farm, when the hog farm puts out a lot more pollution than my cows do?

Response: The WMP is not directed at any single entity, farm or land use practice, in the watershed. Management practices are recommended for selected subwatersheds, which represent areas of 30-40 square miles. A suite of criteria are used to screen subwatersheds to identify those in which water quality might be more sensitive to changes in land use activities or practices, but this does not result in recommending practices for individuals, nor will it in the future. Part of the analysis of water quality data is to assess pollutant loadings from each of the subwatersheds, but these loadings are not apportioned to individual sources. Differences in loadings are part of the screening criteria.

Question: Why aren't the meetings at night?

Response: We have found participation in meetings to be greater during the day than at night. During the first two rounds of meetings held throughout the state as part of the Arkansas Water Plan Update process, we typically had from 50 to 100 people or more attending the meetings during the day, but from 0 to 10 people (maximum) attending evening meetings. People currently have such full lives that attending an additional meeting at night is no longer attractive.

Question: What can be done to attract more young people to these meetings?

Response: We don't have an answer to this question, but plan to pursue this as we proceed through both the Beautiful Buffalo River Action Committee and WMP planning process. This is an important question to address, because our younger people are our future leaders.

Question: Can there be meetings in Jasper also, since people from there and other parts of the watershed may have a hard time coming to Marshall?

Response: We currently are planning to hold the next meeting in Jasper with one option being alternate meetings in Marshall and Jasper to permit more individuals within the watershed to participate.

Question: After FTN is done with the WMP **–** where and how do we go from there?

Response: Developing the plan is not the goal; implementing the plan is the goal. Successful implementation of watershed management plans typically occurs when champions (leaders) emerge from stakeholders who take ownership of the plan and its recommendations and work with others for implementation. Some of these individuals have already indicated their interest. Identifying additional champions to work with these interested individuals is a critical part of the planning process.

Question: Is there a Twitter account or other social media account set up for this project?

Response: There is no Twitter or other social media account set up for this project. Currently, there are also no plans for establishing a Twitter account because of the need for at least daily review and response.

Question: You say this plan is voluntary and non-regulatory, but is that really true if an agency or political subdivision subsequently takes the completed plan and implements new rules and regulations? What keeps this "voluntary" WMP from becoming mandatory?

Response**:** The recommendations in ANRC WMPs are only for voluntary practices, actions or measures.

Question: How can this be a comprehensive watershed management plan if it doesn't consider permitted facilities (i.e., the hog farm)?

Response: The WMP will identify all permitted facilities in the watershed, but it will not recommend practices, measures or actions related to the facilities. In many instances, the individual permits include required practices that must be implemented for issuance of the permit. The WMP addresses only those activities for which voluntary management practices could help improve water quality and identifies agencies or organizations that may provide financial and/or technical assistance for landowners who are interested in voluntarily implementing management practices.

Request: Please provide contact information other than just email – I don't have email.

Response: We will mail the meeting summaries, meeting announcements, and other pertinent information to anyone who does not have email if they will provide their name and address to either Allen Brown, ANRC, or Terry Horton, FTN Associates:

- Allen Brown, Arkansas Natural Resources Commission,
  101 E Capitol Ave # 350, Little Rock, AR 72201
  allen.brown@arkansas.gov, (501) 682-1611

- Terry Horton, FTN Associates,
  3 Innwood Circle, Little Rock, AR 72211.
  twh@ftn-assoc.com, (501) 225-7779.

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Asa Hutchinson
Governor

Arkansas Natural Resources Commission's Development of the Buffalo River Watershed Management Plan
Second Stakeholder Meeting
March 30, 2017: Jasper, AR
Meeting Summary

The Arkansas Natural Resources Commission (ANRC) sponsored a second stakeholder meeting as part of the development of a voluntary, non-regulatory watershed management plan for the Buffalo River. The meeting was held in Jasper on March 30, 2017. The meeting agenda is included as Attachment 1. Approximately 65 individuals attended the meeting, including farmers, landowners, and political representatives, as well as individuals from agricultural, conservation, recreational, and other interests groups, and employees from state and federal agencies.

At the direction of Governor Asa Hutchinson, the Beautiful Buffalo River Action Committee was organized to establish an Arkansas led approach to identify and address potential issues of concern in the Buffalo River watershed, including the development of a voluntary, non-regulatory watershed management plan for the Buffalo River watershed.

The meeting was facilitated by FTN Associates, Ltd. (FTN), an engineering and environmental consulting firm headquartered in Little Rock. The Arkansas Natural Resources Commission contracted FTN to assist the agency with the development of the Buffalo River Watershed Management Plan. The process will be completed by June of 2018.

The meeting was initiated by summarizing the results of the December 2016 meeting in Marshall. A copy of the presentation can be found in Attachment 2 below. One of the primary outcomes of the Marshall meeting was stakeholder identification of water quality and other issues within the Buffalo River watershed. These issues served as a focus for stakeholder discussion of management practices that might be implemented to ameliorate these issues.

Following the summary presentation, attendees broke into two large groups to allow meeting participants to identify management practices that might be implemented within the Buffalo River watershed to address the issues identified in Marshall. The emphasis was on management practices to address water quality concerns or issues, but participants were free to also identify other management activities or actions to address other watershed issues. The two groups consisted of: Agriculture/Commerce/Local Communities, and Tourism/Recreation/Environment interests. Individuals could stay in one group or participate in both groups.

After about one hour of the group sessions, attendees came back together and FTN personnel reported on the management practices identified by each group. Management practices identified by participants in the two groups are listed in Attachments 3 and 4. Attendees were also encouraged to provide information on other management practices, activities or actions in the watershed to FTN or ANRC any time after the meeting or at a later date. Contact information for FTN and ANRC project personnel was provided (See contact information below).

Following the stakeholder discussions of management practices, FTN discussed preliminary analyses that were conducted to help identify a set of subwatersheds within the Buffalo River watershed that currently appear to be susceptible to change or where changes have been occurring over the past 30 years and where the initiation of additional implementation of management practices could reduce this susceptibility and/or ameliorate these changes (See Attachment 2).

These analyses considered:

1. An Index of Biotic Integrity (IBI) for fish, and a Stream Condition Index (SCI) for macroinvertebrates (bugs) monitored by the National Park Service at 6 sites in the Buffalo National River and at 26 sites in its tributaries;
2. Water quality measurements over 30 years at 9 sites within the Buffalo National River and 20 of its tributaries (turbiditynitrate+nitrite-N, ortho-phosphate-P, and fecal coliforms were the four constituents analyzed);
3. Nitrate, ortho-phosphate, and fecal coliform loadings for these same water quality sites;
4. Trend analyses considering three 10-year periods (1985-1994, 1995-2004, 2005-2015) for the water quality constituents:
5. 2016 USDA Natural Resource Conservation Service (NRCS) Resource Concern Assessment of the 37 subwatersheds within the Buffalo River watershed for 8 potential concerns (sheet/rill erosion, gully formation, streambank erosion, sedimentation, nutrients, pathogens, petroleum/heavy metals, and pesticides and herbicides); and
6. Percentage of the subbasin or subwatershed with underlying carbonate bedrock.

Subwatersheds were considered of higher interest for initiating additional management practices if:

1. IBI or SCI scores were less than a threshold score;
2. Median water quality constituent concentrations were in the upper quartile of the range over 30 years;
3. Water quality constituent loads were in the upper quartile over the last 10 years;
4. Statistically significant trends in water quality constituent concentrations were observed;
5. NRCS Resource Concern scores were in the upper quartile; and
6. Underlying carbonate bedrock constituted greater than 60% of the subwatershed.

Cumulative scores for each of the above mentioned criteria for each subwatershed were computed. The subwatersheds that received the highest cumulative ranking, listed in upstream to downstream order, were:

- Ponca & Whiteley Creek
- Mill Creek*

- Davis Creek
- Calf Creek*
- Bear Creek*
- Brush Creek*
- Tomahawk Creek
- Water Creek

* Highest ranked subwatersheds.

The middle Big Creek subwatershed was analized using the same process, but it did not achieve the highest rankings, therefore it wasn't listed. Stakeholders attending the meeting expressed a strong interest in this subwatershed and requested it be included in the list of highly ranked subwatersheds. If there is stakeholder consensus, this subwatershed will be added to the list as a stakeholder-interest subwatershed. Several stakeholders also requested that dissolved oxygen and E. coli water quality parameters be included in the rankings of streams. These two constituents will be analyzed and used in screening subwatersheds.

There were two question and answer sessions: one during/after the summary presentation of the watershed management plan process during the first portion of the meeting; and a second after the preliminary screening analyses were presented.

A summary of the questions and responses is included in Attachment 5. Not all questions raised are listed because several questions addressed the same subject.

The information gathered at the Jasper meeting will be integrated with additional information obtained through analysis and research and used in developing a draft watershed management plan for the Buffalo River watershed. This process will occur over the next 8-12 months.

The next watershed meeting will be held in mid to late June and is currently scheduled to be in Marshall, AR. Its purposes will be to:

1. Summarize the results of the Jasper meeting;
2. Provide results from the additional analyses suggested by stakeholders at the Jasper meeting;
3. Present suggested management goals, costs and benefits of implementing the suggested, and additional, management practices in the highest ranked watersheds;
4. Provide information on agencies, organizations, and educational institutions that offer technical and financial assistance to stakeholders interested in voluntarily implementing management practices; and
5. Describe the next steps in the planning process.

For additional information or to provide additional questions, contact:

- ANRC, Tony Ramick (tony.ramick@arkansas.gov) or (501) 682-1611); or
- FTN Associates, Terry Horton (twh@ftn-assoc.com) or (501) 225-7779).

Attachment 1
Buffalo River Watershed Management Plan:
A Voluntary, Non-Regulatory Project
Carroll Electric Community Room
Jasper, AR
30 March 2017
Agenda

Time	Topic	Individual
1:00 pm	Welcome, Meeting Purposes: • Summarize the Marshall Meeting and Watershed Issues • Elicit stakeholder input on management practices to address issues within the Buffalo River watershed • Describe a process to identify where to start implementation of management practices • Discuss next steps	K. Thornton, FTN
1:05	Summarize the 8 December Marshall Meeting • Watershed Management Plan and planning process • Issues raised by stakeholders • Questions	K. Thornton
1:40	Breakout Groups • Dialogue on watershed management practices to address issues • Two Groups - Agriculture/Commerce/Local Communities - Tourism/Recreation/Environment	ALL
2:25	Report Out • Agriculture/Commerce/Local Communities (10 min) • Tourism/Recreation/Environment (10 min)	ALL
2:45	Process for Identifying Where to Initiate Management Practices, Considering: • Biology • Water quality • Land use • Karst geology • Cumulative scores	K. Thornton
3:25	Next Steps	K. Thornton
3:30	**Adjourn**	

Contacts:

Tony Ramick, ANRC – Tony.Ramick@arkansas.gov; Terry Horton, FTN – twh@ftn-assoc.com

Buffalo River Watershed Management Plan: A Voluntary, Non-Regulatory Project

2nd Stakeholder Meeting
Jasper, AR
30 March 2017

Meeting Purposes

- Summarize the Marshall Meeting
- Elicit Your Input On Management Practices to Address Issues Within The Buffalo River Watershed
- Describe the Screening Process for Identifying Places to Start
- Discuss Next Steps

8 December Marshall Meeting

- Beautiful Buffalo River Action Committee (BBRAC)
  - Mission – Identify and address potential issues of common concern in the Buffalo River Watershed
  - 5 Agencies (ADEQ, ANRC – Co-Chairs)
  - 1st Year – Develop Watershed Management Plan
  - Identify/implement early actions

8 December Marshall Meeting

- Watershed Management Plan
  1. Water Quality Emphasis
     - Extraordinary Resource Water
  2. Nonpoint Sources – non-regulatory
  3. Voluntary participation

8 December Marshall Meeting

- **Watershed Management Plan**
  - **Focus on sustaining and improving water quality**
  - **Does not address regulated/permitted facilities or operations (BBRAC Issue)**
  - **No requirement to participate**
    - **Are benefits of participating**

Watershed Planning Process

1. **Building partnerships**
2. **Characterizing the watershed**
3. **Mgt goals, practices, measures, actions**
4. **Design implementation program**
5. **Implement the WMP**
6. **Measure progress – adaptive mgt.**

Stakeholder Input

- 5 Meetings:
  1. Watershed Issues (Marshall)
  2. Management practices, measures, actions, awareness, outreach suggestions (Today)
  3. Costs, financial/technical assistance, benefits,
  4. Draft plan recommendations, comments
  5. Final plan and implementation
- Correspondence, BBRAC, reports, studies, etc.

Marshall – WQ Issues

In-Stream

- Excess nutrients (N, P)
- Algae
- Streambank erosion
- Sedimentation
- Gravel-mining
- Livestock in stream
- Bacteria
- Trash
- Invasive species
- Human waste (users)

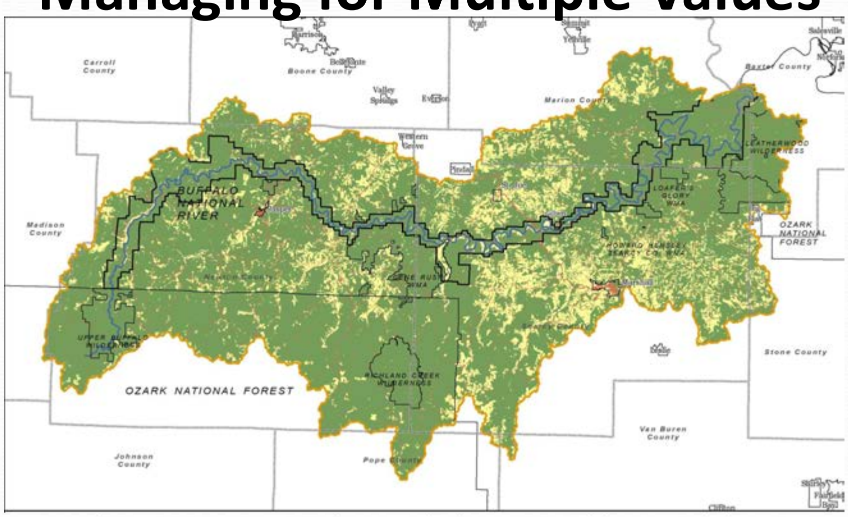
Watershed Contributions

- Septic systems
- Manure/litter
- Fertilizer application
- Dirt/gravel roads
- Easement maintenance
- Timberland mgt
- Feral hogs
- ATV use
- Sawdust disposal
- Development

Marshall – Other Issues

- Permitted CAFO
- Groundwater transfers
- Limited job opportunities, economic development
- Prescribed burns
- Respect for local culture, lifestyle
- Property rights
- Tourism infrastructure
- Education & communication - all
- Agency credibility
- Drug resistant bacteria
- Over-use
- Increased coop of fed. agencies & local gov't.
- New technology for waste mgt.

Managing for Multiple Values



Today's Activity

- Watershed Management Practices
  - Emphasis on Water Quality Issues, But Other Thoughts Welcome
- Breakout Groups
  - Facilitated dialogue

Breakout Groups

- Two Breakout Groups for Dialogue
  - Agriculture/Commerce/Local Communities
  - Tourism/Recreation/Environment
- Dialogue for 45 minutes
- Report out and discuss management practices

Meeting Ground Rules

1. One stakeholder at a time
2. Request acknowledgement
3. Listen first to understand, then to be understood
4. Please don't interrupt
5. Respect others ideas, thoughts
6. Ok to disagree – respectfully, openly
7. No side conversations

Cell Phones off/on vibrate

Breakout Groups

- Agriculture/Commerce/Local Comm.

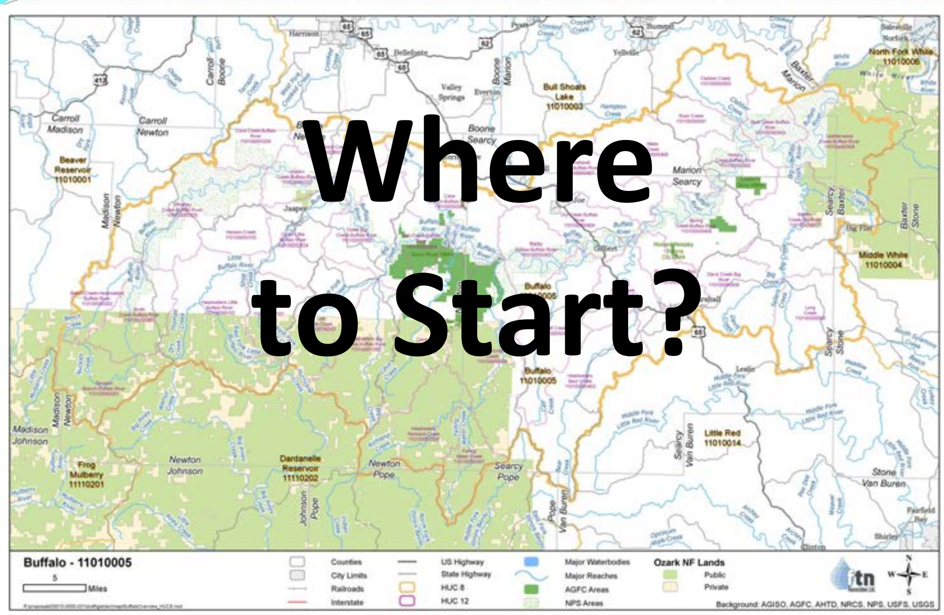
  One Corner of Center

- Tourism/Recreation/Environment

  Opposite Corner of Center

Report Out

Where to Start?



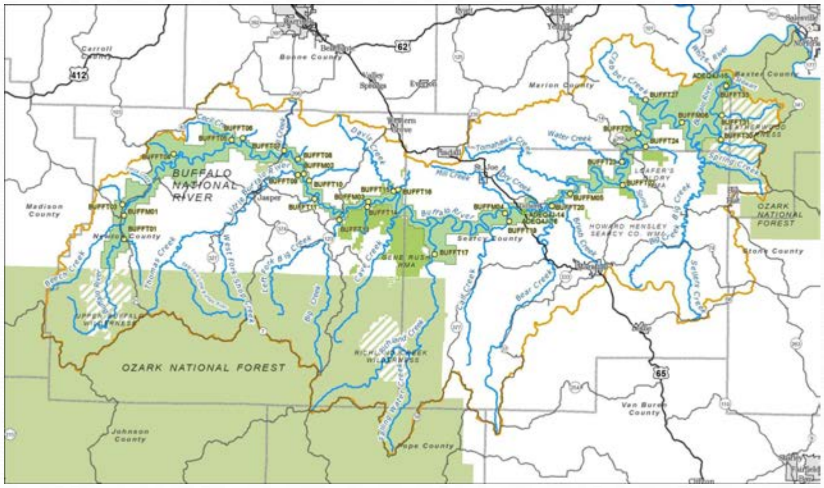
Where To Start?

- 1st Principles:
  - If everything's a priority; nothing's a priority
  - Water runs down hill
  - Streams reflect their watersheds
- 37 HUC12 subwatersheds => Smaller number
  - Screening process and criteria

Where To Start?

- Screening Criteria – In Progression
  - Stream biology – Integrators
  - Water quality – Affects biology
  - Land use – Affects water quality
  - Karst geology – Affects water quality
- Intersection of multiple criteria – Both/And

Biological Monitoring Sites



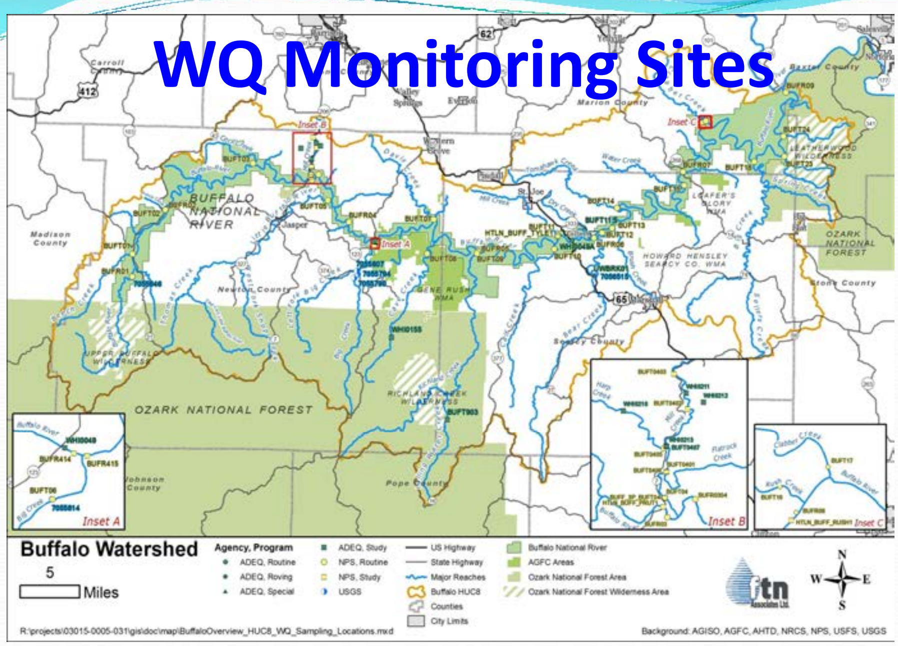
Fish and Bugs

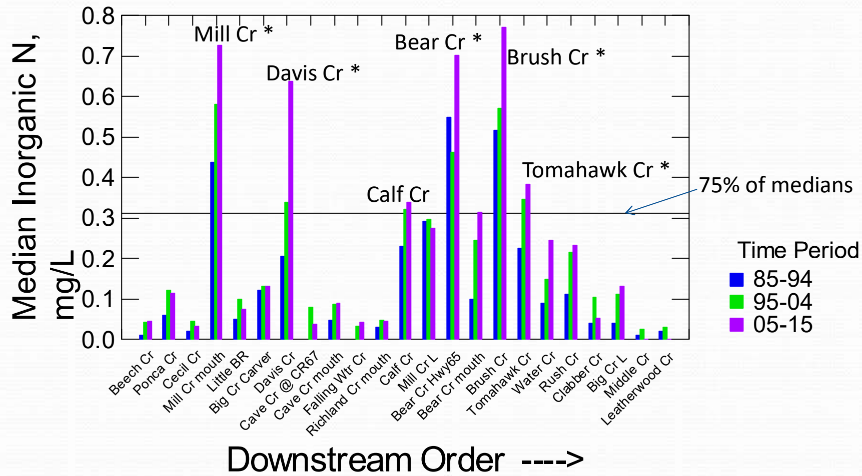
- **SCI < 16 (Benthic Bugs)**
  - **Mainstem – None (2013)**
  - **Hoskin (Glade) Cr**
  - **Richland Cr**
  - **Davis Cr**
  - **Calf Cr**
  - **Water Cr**
  - **Hickory Cr**
  - **Clabber Cr**
  - **Middle Cr**
  - **Leatherwood Cr**
- **IBI < 70 (Fish)**
  - **Mainstem – Ponca**
  - **Whiteley (Ponca) Cr**
  - **Brush Cr**
  - **Hickory Cr**
  - **Middle Cr**
  - **Leatherwood Cr**

Water Quality

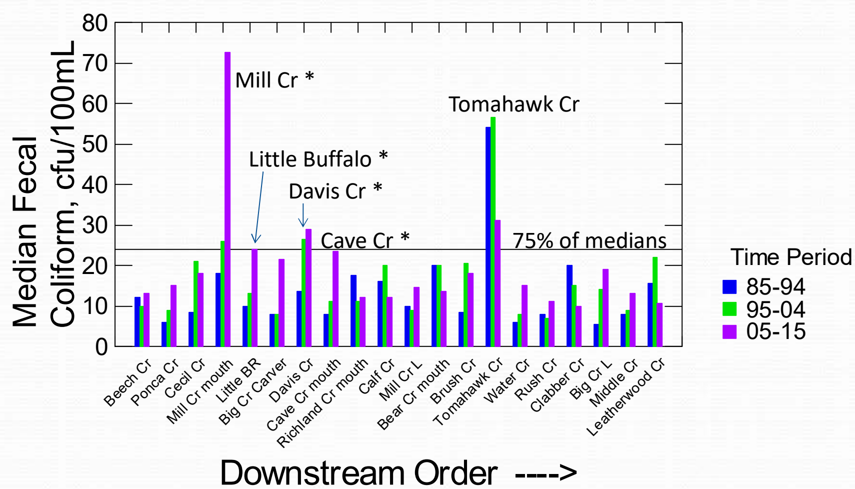
- Four Constituents
  - Turbidity (sediment)
  - Nutrients (Nitrate, σ-P)
  - Bacteria (Fecal coliforms)
- Concentration (upper 25%)
- Load (upper 25%)
- Trends – 3-10 Year Periods

WQ Monitoring Sites



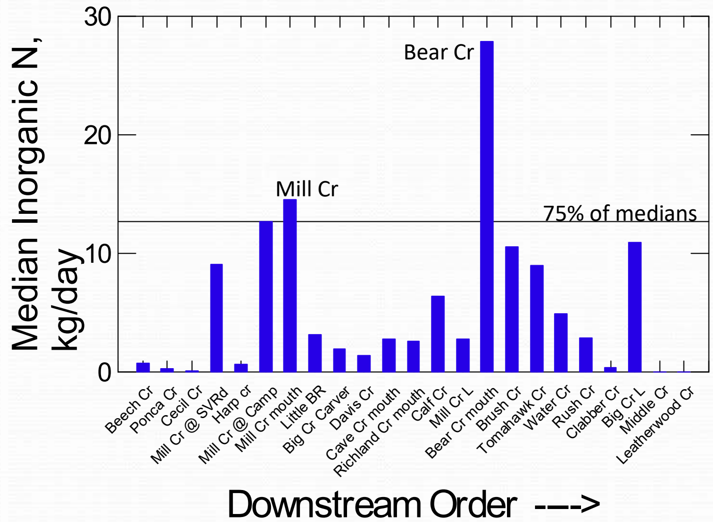


* Statistically significant increase over time



* Statistically significant increase over time

Load – 2005-2015



Sum WQ Scores

- WQ (Upper 25%) + Load (Upper 25%)
  - Mill Creek
  - Cave Creek
  - Davis Creek
  - Calf Creek
  - Bear Creek
  - Dry Creek

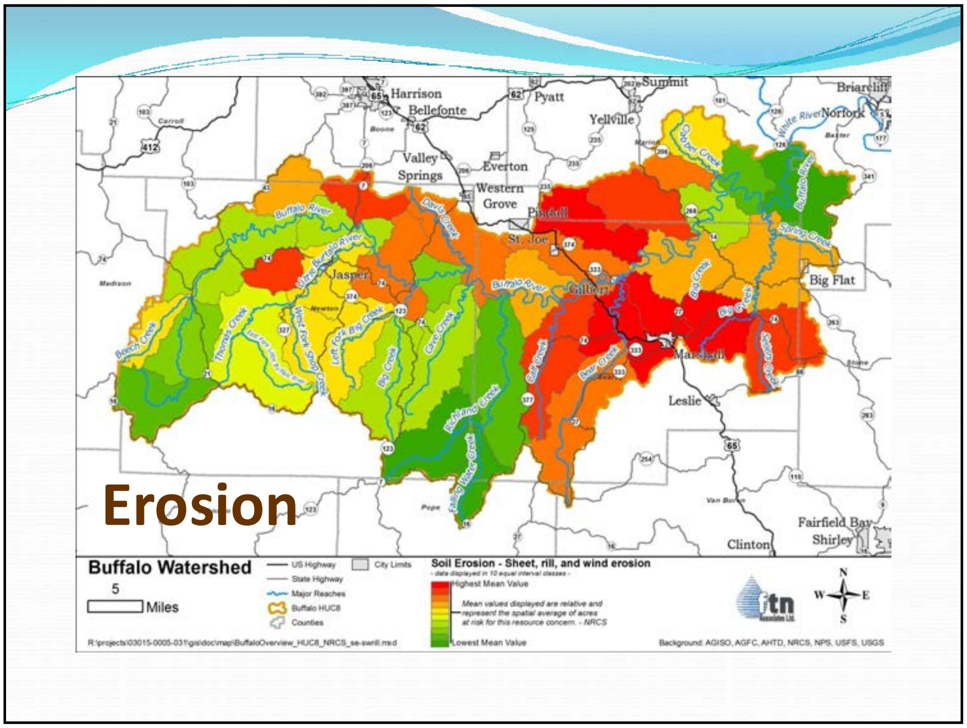
Increasing Trends

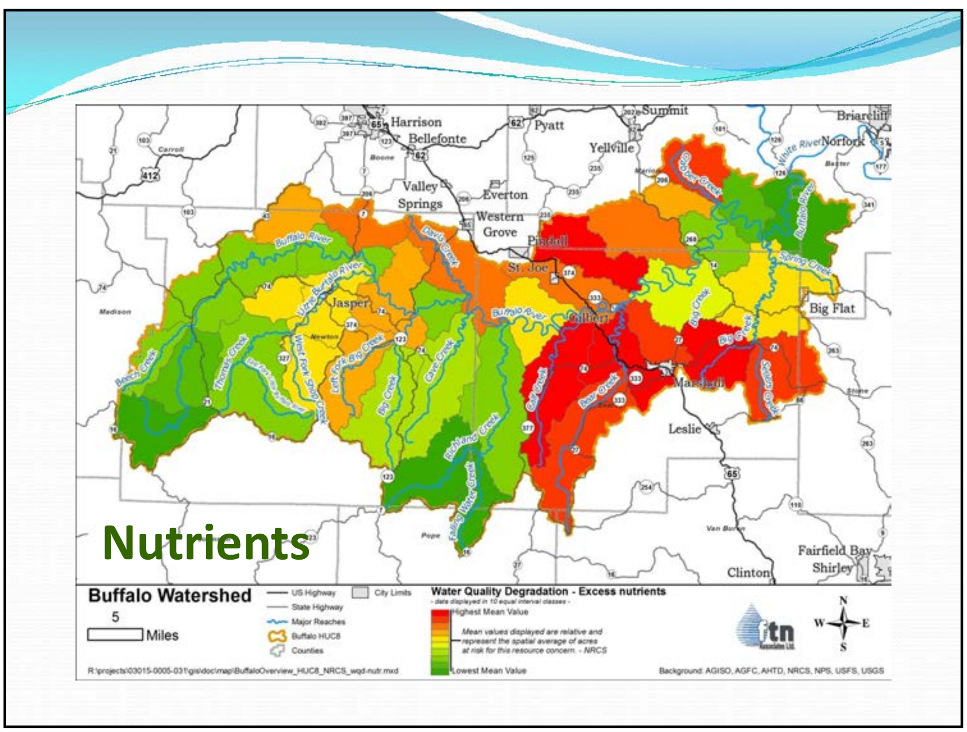
- Little Buffalo River
- Smith Creek
- Whiteley Creek
- Mill Creek
- Cave Creek
- Davis Creek*
- Bear Creek
- Brush Creek
- Tomahawk Creek
- Water Creek

* 3 Constituents

NRCS Resource Concerns Assessment

- Sheet and Rill Erosion
- Gully Formation
- Bank Erosion
- Sedimentation
- Nutrients
- Pathogens
- Pesticides
- Heavy Metals


Erosion
Buffalo Watershed
5
Miles
US Highway
State Highway
Major Reaches
Buffalo HUC8
Counties
City Limits
Soil Erosion - Sheet, rill, and wind erosion
Highest Mean Value
Mean values displayed are relative and represent the spatial average of acres at risk for this resource concern. - NRCS
Lowest Mean Value
Background: AGISO, AGFC, AHTD, NRCS, NPS, USFS, USGS
Harrison
Bellefonte
Pyatt
Summit
Yellville
Briarcliff
Norfork
Valley Springs
Everton
Western Grove
Pindall
St. Joe
Jasper
Gilbert
Marshall
Leslie
Big Flat
Fairfield Bay
Shirley
Clinton
Buffalo River
Little Buffalo River
Davis Creek
Big Creek
Spring Creek
Beech Creek
Thomas Creek
West Fork Smith Creek
Left Fork Big Creek
Cave Creek
Richland Creek
Bear Creek
Calf Creek
Water Creek
Falling Water Creek
White River
ftn


Nutrients
Buffalo Watershed
5
Miles
US Highway
State Highway
Major Reaches
Buffalo HUC8
Counties
City Limits
Water Quality Degradation - Excess nutrients
Highest Mean Value
Mean values displayed are relative and represent the spatial average of acres at risk for this resource concern. - NRCS
Lowest Mean Value
Background: AGISO, AGFC, AHTD, NRCS, NPS, USFS, USGS
Harrison
Bellefonte
Pyatt
Summit
Yellville
Briarcliff
Norfork
Valley Springs
Everton
Western Grove
Pindall
St. Joe
Jasper
Gilbert
Marshall
Leslie
Big Flat
Fairfield Bay
Shirley
Clinton
Buffalo River
Little Buffalo River
Davis Creek
Big Creek
Spring Creek
Beech Creek
Thomas Creek
West Fork Smith Creek
Left Fork Big Creek
Cave Creek
Richland Creek
Bear Creek
Calf Creek
Falling Water Creek
White River
ftn

Sum Resource Concerns

Upper 25% for ≥ 5 concerns

- Mill Creek
- Calf Creek
- Bear Creek
- Brush Creek
- Tomahawk Creek
- Water Creek
- Clabber Creek
- Long Creek
- Big Creek (Lower)

Carbonate Bedrock - USGS

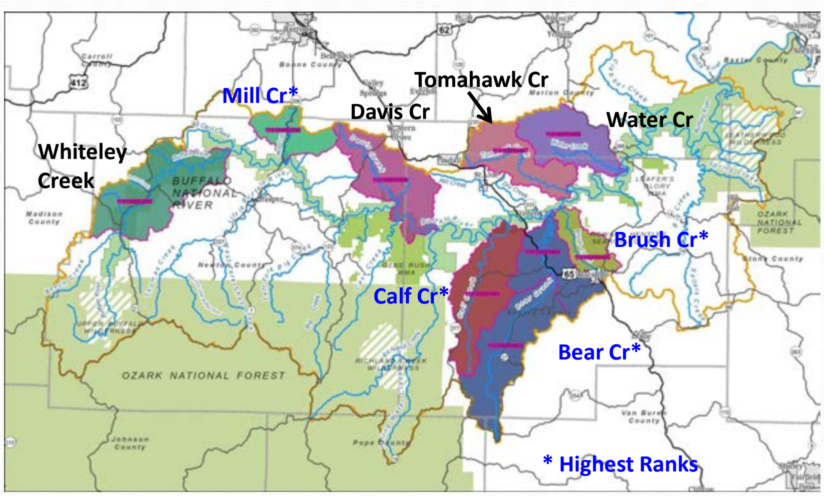
- Greater Than 60% of Subbasin
  - Mill Creek
  - Davis Creek
  - Brush Creek
  - Tomahawk Creek
  - Water Creek
  - Rush Creek

Total Cumulative Scores – Initial Start

- Subwatersheds – HUC12 Pour Point
  - Ponca & Whiteley Creek
  - Mill Creek*
  - Davis Creek
  - Calf Creek*
  - Bear Creek*
  - Brush Creek*
  - Tomahawk Creek
  - Water Creek

*Highest ranks

Potential Starting Locations, Based on Screening



Screening Process Caveats

- Not Exclusionary
  - Place to start ONLY.
  - Additional management practices positive, and encouraged, in any subwatershed
- Continue to Evaluate
  - Add new information as becomes available (e.g. SCI in April)
  - Sites could change with additional information

Questions on the Screening Process?

Next Steps

- Meeting Summary – distributed to everyone attending *and* on email list (or address)
- Continue to elicit your input
- Cost/benefits – management practices
- Schedule next meeting; likely in June
- Next meetings topic
  - Integrated practices, estimated costs, financial and technical assistance available

Points of Contact

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Thank You

ATTACHMENT 3

Agriculture/Commerce/Local Communities Break-Out Group Management Practices Mentioned by Participants

1. Consider soil depth in nutrient application
2. Investigate mass balance of nutrients, including:
   - Import or export of litter for use in the watershed
   - Consider 7 counties
3. Implement State Dirt Roads practices
4. Create greenbelt buffers between pasture/stream
5. Pave dirt roads, particularly Tomahawk Church Road
6. Determine how much litter is imported to Buffalo from Nutrient Surplus areas
7. Don't allow nutrients in excess of agronomic need
8. Encourage corporations to regulate their growers
9. Consider quotas on River use
10. Promote better timber management – prescribed burns
11. Create a State/Federal Task Force to control feral hogs
12. Conduct source tracking for E coli, etc.
13. Promote awareness and outreach for pasture management
14. Conduct an economic analysis of Park – cost vs benefits
15. Develop environmental stewardship programs for visitors
16. Donate to Project to help the Watershed
17. Prepare an economic development d plan for basin
18. Practice erosion control on forested hillsides
19. Promote these forest management practices to smaller owners
20. Educate/cost share in replacing old septic systems
21. Promote a suite of BMP practices for land owners.
22. Create a mentorship program to promote small business
23. Create a Watershed COOP
24. Consider nutrient trading when regulations finalized.
25. Develop a tradeoff/offset or mitigation bank for development (e.g., parking lot ↔ natural area)
26. Develop Arkansas Eco-tours
27. Promote streambank restoration - /stabilization for small landowners; model after IRWP – mapped areas
28. Implement soil BMPs

ATTACHMENT 4

Tourism/Recreation/Environment Break-Out Group Management Practices Mentioned by Participants

1. Form a destination management organization for marketing the region.
2. Work with AGFC to control feral hogs
3. Don’t publicize the Buffalo; promoting over-use
4. Develop more visitor contact centers,
5. Investigate ways of generating additional financial resources
6. Promote public – private business partnerships
7. Promote quail habitat management – benefits water quality and land owner
8. Capture real time data on campgrounds, rentals, etc. so can eliminate over-crowding
9. Market and manage visitor expectations and experiences
10. Construct farm ponds to control sedimentation and loading
11. Consider nutrient trading when regulations finalized.
12. Create mitigation bank for development
13. Create Economic “Zone” – fees, tags for counties, as source of revenue
14. Consider redistribution of funds (e.g., sales taxes) for infrastructure, wastewater, roads maintenance
15. Manage horse-use in watershed
16. Implement better road management, including paving, and maintain roads
17. Create a “Friends” group for the Buffalo National River
18. Approach legislature on license plate revenue – “Buffalo National Park” plate
19. Promote environmentally friendly businesses
20. Create an agri-tourism program
21. Respect all business interests, (Ag-tourism, etc.)
22. Promote Eco-tourism
23. Help local communities get grants/funds for decentralized waste treatment systems.
24. Promote carrying your own “portable potties” for larger groups on the river
25. Create incentives to remove abandoned septic systems
26. Map & prioritize needs in watershed by subwatersheds

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Asa Hutchinson
Governor

ATTACHMENT 5

Questions Raised at the Jasper Meeting and Responses

Question: Please explain point source vs non-point source

Response: We have used point vs non-point sources in the past, because most people relate to point sources being a discharge from a pipe (i.e., a specific point). It is more accurate to refer to permitted vs non-permitted sources. Some non-point sources can be permitted for only certain activities, which means they are regulated activities. The watershed management plan addresses only non-permitted activities, because it focuses on voluntary, non-regulatory participation.

Question: Who are the Stakeholders?

Response: We consider stakeholders to be people who live in, work in, or visit the area, and those who avail themselves of the amenities in the watershed.

Question: Why is the list of issues in the summary of the last meeting different from what is on the slide?

Response: The summary list was consolidated from each of the groups list to eliminate duplication.

Question: Will the results of this plan be used to avoid making the hard regulatory decisions?

Response: This plan is not intended to be regulatory in nature – it is a voluntary, non-regulatory plan to assist stakeholders with obtaining assistance (financial and/or technical) to improve things in the watershed.

Question: In the next meeting you will talk about funding sources – where would most of the funds come from?

Response: Funds for watershed management practices have typically been available from the USDA NRCS Environmental Quality Improvement Program (EQIP) and Farm Services Agency Conservation Reserve Program (CRP), EPA Section 319 program administered through ANRC, USFWS Confined Livestock Access Fencing (CALF), The Nature Conservancy through the unpaved roads program, and similar agencies and organizations. In addition to funds, there are also technical assistance and educational opportunities available.

Question: You mentioned that there was only 1 stream segment listed on the 303d list, but there are three stream segments listed on the 2008 303d list – the latest official list?

Response: In the latest (2016) draft 303d list two of the streams segments are no longer listed because data collected from these stream segments since 2007 meet all numeric water quality criteria.

Question: What water quality data are you referring to for these analyses?

Response: We are using water quality data collected by US Geological Service (USGS), Arkansas Department of Environmental Quality (ADEQ), and National Park Service.

Question: What is the period of data that you are looking at?

Response: Three 10-year periods – 1985 – 1994, 1995-2004, and 2005-2015.

Question: It would be useful if you included a map of the density of humans and animals in each sub-watershed.

Response: These data are only available at the county level and not available at the sub-watershed level. There is population density available at the township level, but it is still difficult to apportion by subwatershed. In general, the population density throughout the Buffalo River watershed is relatively low. Livestock data are not available at the subwatershed level, only at the county level.

Question: Why did you not include E. coli and dissolved oxygen (DO) in the water quality parameters?

Response: DO concentrations vary throughout the day, so sampling time affects results. We initially did review the DO data, and did not see major changes in concentrations. We will conduct the DO analyses as we have with the other water quality constituents and include these results in our screening analyses. We did not include E. coli data because we had 30 years of fecal coliform, a similar indicator of bacteria. E. coli data have only been collected since about 2005 or 2006. We will include E. coli medians for the period of record and include these as part or our screening analyses.

Question: What nutrients were looked at? What was the last year included?

Response: The two nutrient species were nitrate+nitrite-N and ortho-phosphate-P. These data were considered from 1985 through 2015.

Question: Why did you use carbonate bedrock as an indication of karst topography, why not look at the Boone formation?

Response: We did not want to restrict the area to the Boone formation – there are other karst formations in the watershed. Most of the fractures of concern occur in carbonate bedrock, regardless of the formation.

Question: What biological data sets were used?

Response: We used the benthic (bug) and fish data collected through the NPS Heartland Inventory and Monitoring Network. This network includes not only the Buffalo River watershed, but also other watersheds in the MO and AR Ozarks

Question: Were most of the measurements taken during base flow? Most of the nutrient loading occurs during storm flow – that has been missed.

Response: Agreed. Most of the loading does occur during storm events. However, storm event data, except for very short periods, was not available. One of the recommendations might be to monitor some storms. Monitoring storm events in a watershed the size of the Buffalo River watershed, however, is labor and resource intensive.

Question: Were you aware of the problems and the lower detection limits for the ortho-phosphate data? In 2012 ADEQ raised the detection limits for some parameters. Can we ask the agency to change the detection limits for sampling on the Buffalo?

Response: We were aware of the lower ortho-phosphate detection limits prior to 2004, when ADEQ changed to another method. This is why we considered only ortho-phosphate data during the last 10 year period (2005-2015). We were not aware the detection limit was changed in 2012 and will investigate that change. We can certainly ask for a lower detection limit.

Question: Where is Big Creek on your list of watersheds to start with? The reason many people are here is because of the concern over Big Creek.

Response: Big Creek subwatershed did not rank as high as other watersheds based on the screening criteria we used. This is a stakeholder-driven watershed management plan. If Big Creek is a subwatershed that should receive higher consideration, we will add it for further consideration. We will list the subwatersheds of interest from upstream to downstream.

Question: Big Creek just became an issue recently. Therefore, it may not have the impacts showing up yet in the data.

Response: The watershed management plan is a living document. If issues with Big Creek or the Little Buffalo arise, these subwatersheds can be added. We indicated we would add Big Creek to the list for further consideration because of stakeholder interest

Question: Why did you not look at the data on a finer grid?

Response: The watershed management plans developed through ANRC have all focused on the 12-digit hydrologic unit code. The HUC12 subwatershed is consistent with implementing management practices at a scale that can make a difference in improving water quality, but also at a scale at which these results can be observed within a reasonable time frame. This is a voluntary program for land owners who are interested in implementing management practices, and does not highlight or target specific land parcels.

Questions: You said this is a starting point. Starting point for what?

Response: A starting point for where to consider the initial implementation of other management practices. This is not intended to be a restrictive or exclusionary list. Any management practices implemented can produce positive results. This is a voluntary program. The screening analyses were an approach for initially identifying subwatersheds that appear to be susceptible to future change or in which increasing trends in constituents are occurring. Voluntary implementation of management practices in these subwatersheds might help reduce these trends and/or susceptibility of change.

Question: Will any of the recommendations include source tracking? We would like to recommend source tracking including DNA tracking and source isotopes.

Response: If stakeholders are interested in source tracking, this study can be recommended. Source tracking, however, is fairly expensive and does require sophisticated analyses.

Question: Would source tracking testing be covered under 319 funding?

Response: Unfortunately, no.

Question: Can more sophisticated instruments be used?

Response: Yes, but more sophisticated instrumentation is also results in more expensive analyses.

Question: Where will the next meeting be?

Response: In Marshall near the end of June.

Question: Do you have experience with other WMPs? How did they work? Do you have any success stories?

Response: ANRC documents those management practices and watershed managment activities that have made a difference and improved water quality. Check out www.arkansaswater.org to find success stories from other watersheds that have management plans.

Question: Are questions here limited to the WMP or can we ask questions be passed along to the BBRAC?

Response: We have representatives from ANRC here. They are part of the BBRAC and questions can be provided to them for the BBRAC. Any comments we (FTN) receive concerning the BBRAC, we provide to ANRC.

Arkansas Natural Resources Commission

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Asa Hutchinson
Governor

Arkansas Natural Resources Commission's Development of the Buffalo River Watershed Management Plan
Third Stakeholder Meeting
June 8, 2017: Marshall, AR
Meeting Summary

The Arkansas Natural Resources Commission (ANRC) sponsored a third stakeholder meeting as part of the development of a voluntary, non-regulatory watershed management plan (WMP) for the Buffalo River watershed. The meeting was held in Marshall on June 8, 2017. The meeting agenda is included as Attachment 1. Approximately 40 individuals attended the meeting, including farmers, landowners, and political representatives, as well as individuals from agricultural, conservation, recreational, and other interests groups, and employees from state and federal agencies.

At the direction of Governor Asa Hutchinson, the Beautiful Buffalo River Action Committee was organized to establish an Arkansas led approach to identify and address potential issues of concern in the Buffalo River watershed, including the development of a voluntary, non-regulatory WMP for the Buffalo River watershed.

The meeting was facilitated by FTN Associates, Ltd. (FTN), an engineering and environmental consulting firm headquartered in Little Rock. The Arkansas Natural Resources Commission contracted FTN to assist the agency with the development of the Buffalo River WMP. The process will be completed by June of 2018.

The meeting was initiated by summarizing the results of the March 2017 meeting in Jasper. A copy of the presentation is included as Attachment 2.

At the March meeting in Jasper, dissolved oxygen (DO) and E. coli analyses were requested as additional screening criteria for tributary subwatersheds. These analyses were conducted and presented. Subwatersheds with median DO concentrations in the lower quartile and E. coli concentrations in the upper quartile were noted and added to the cumulative scores for each subwatershed (See Attachment 2). The lowest DO medians were associated with Falling Water Creek, a tributary to Richland Creek, and Bear Creek. The highest median E. coli concentrations were associated with Mill Creek and Tomahawk Creek. The highest cumulative scores based on the screening criteria were associated with Mill Creek, Calf Creek, Brush Creek, Tomahawk Creek, and Lower Big Creek. These 5 subwatersheds are recommended for consideration of additional management practices as the watershed management plan is implemented (See Attachment 2). The screening process is not meant to be exclusionary. These subwatersheds represent the initial places to start in implementing the watershed management plan. Additional, voluntary management practices are encouraged anywhere in the Buffalo River watershed.

The desired outcome for the Buffalo River WMP is to sustain and improve water quality in the Buffalo River and its tributaries. To achieve this desired outcome, three goals are proposed:

1. Keep pollutants out of the water (both surface and groundwater)
2. Minimize stream bank and bed disturbance, and
3. Leave no trace behind.

For nonpoint sources, the Buffalo River and its tributaries are currently attaining the designated uses and water quality criteria. To establish targets for water quality improvements in the recommended subwatersheds, changes in four water quality constituents over a 30-year period were considered – sediment, nitrate, ortho-phosphorus, and E. coli. There is limited sediment data available for the Buffalo River and its tributaries. Most of the monitoring data are for turbidity, not sediment. There are 30 years of nitrate record for the Buffalo River and its major tributaries. Ortho-phosphorus data are limited to the most recent 10 year period because of methodological issues. E. coli data have been collected only during the most recent 10 year period; however, there are 30 years of record for fecal coliform measurements. Nitrate and E. coli were selected as management indicators; to guide selection of management practices and track resulting improvements in water quality. Nitrate is soluble and can enter surface water through runoff and shallow subsurface flow or infiltrate through the soils and enter the groundwater. Nitrate is a useful management indicator because it can provide information on the effectiveness of management practices in reducing the movement of soluble constituents (including ortho-phosphorus and pesticides) through surface and groundwater. E. coli is transported as a particulate, in many instances, sorbed to sediment particles. It is a useful management indicator because it can be used to evaluate the effectiveness of management practices in reducing bacteria, and other constituents, such as total phosphorus, sorbed to sediment particles.

The initial target load reductions proposed for nitrate and fecal coliforms in the five subwatersheds were median concentrations measured during the 1985-1994 period. Median concentrations during the period 2005-2015 were compared to the 1985-1994 medians to determine target reductions. For Calf and Brush Creek, about a 30% nitrate reduction would be needed to achieve their nitrate targets. For Mill and Tomahawk Creek, about a 40% nitrate reduction would be needed, and for Lower Big Creek, about a 70% nitrate reduction would be needed to achieve their nitrate targets. For Calf and Tomahawk Creeks, median fecal coliform concentrations for the 2005-2016 period were lower than during the 1985-1994 period, so existing management practices should be continued. For Brush Creek, about a 50% reduction would be required to achieve the 1985-1994 median fecal coliform target loads. For Mill and Lower Big Creeks, about a 70-75% reduction would be needed to achieve the 1985-1994 median fecal coliform targets (See Attachment 2).

The overall emphasis for management practices to achieve the water quality targets and WMP goals is on vegetation enhancement, soil health, streambank stabilization, and individual wastewater disposal systems. Management practices considered, in addition to the management practices suggested by stakeholders at the March Jasper meeting, include fencing (stream exclusion), prescribed/rotational grazing, alternative water sources, fertilizer/nutrient management, and soil health management.

Management practice efficiencies in reducing nitrogen and bacterial concentrations were obtained from multiple sources, including NRCS Conservation Practice Standards, the Arkansas BMP Tool II, National Pollutant Removal Performance Database, International Stormwater BMP Database and the Chesapeake Bay Program BMP Efficiencies. Attachment 2 lists the management efficiencies for not only nitrogen and coliforms, but also for sediment and total phosphorus for various BMPs. Although the emphasis is on achieving target reductions for nitrate and E. coli, the same BMPs also reduce sediment and phosphorus inputs to surface waters.

For four of the five subwatersheds (Mill, Calf, Brush, and Tomahawk Creek), the extent of BMPs, and relative cost (based on 2016 EQIP cost share) to achieve nitrate or E. coli reduction targets were presented. Expected reductions in sediment and total phosphorus were also included, even though these constituents were not explicitly targeted for reduction (See Attachment 2). These are considered to be conservative estimates of load reductions because each of the BMPs is assumed to be implemented independently. In general, BMPs are implemented as suites of management practices, not independently, with the exception of stream exclusion. The stream exclusion BMP was combined with alternative water sources because an alternative water source would likely be needed if cattle were excluded from drinking from the stream. Stream exclusion, however, provides opportunities for implementing riparian buffers, either forested or non-forested, pasture planting, and rotational grazing as a suite of management practices, which would likely increase load reductions for all constituents. The precise set of BMPs, location, and management effectiveness can be determined during watershed management plan implementation. Lower Big Creek is a larger subwatershed (~ 85,000 acres) and we were still working on management estimates it at the time of the meeting, but the approach will be the same as for the other subwatersheds.

Individual management practices, in general, were estimated to achieve the target load reductions for nitrate and coliforms in these four subwatersheds. Steamside buffers, forested or non-forested riparian buffers, were not estimated to be sufficient in attaining bacteria load reductions in Brush and Mill Creek. However, other management practices (e.g., stream exclusion, prescribed grazing) were estimated to achieve target load reductions. Implementing suites of BMPs would permit these targets to be attained. The importance of wastewater disposal systems is illustrated in Mill Creek. Point source discharges of both nitrate and E. coli have been documented in Mill Creek (Mott and Maner 1991). These nitrate load estimates, however, are over 25 years old. The extent of nitrate and coliform loadings from wastewater disposal systems is unknown in Mill Creek, but these systems are likely to be contributing to the total load from the subwatershed. The number of individual wastewater disposal systems in Mill Creek, and whether they are permitted or unpermitted systems, is unknown. Whether management practices for nonpoint sources would be able to achieve the estimated target reductions, however, depends on the relative contribution of these wastewater discharges. Obtaining this information will be one of the action items included in the WMP.

There are sources of funding to assist landowners in implementing management practices on their property. The USDA Environmental Quality Incentive Program (EQIP) cost share values were used in estimating the relative cost for various management practices. There are other cost-sharing sources as well, including EPA Section 319 funds (administered through ANRC), USDA Farm Services Agency Conservation Reserve Program and Regional Conservation Partnership Program, and the USFWS Confined Access and Livestock Fencing (CALF) program. The USFWS CALF program can, if program requirements are satisfied, pay up to 100% of the cost of fencing and alternative water supplies. Stakeholders in the watershed have participated in some of these programs in the past (See Attachment 2).

The next meeting will be scheduled for Jasper, probably in October. At the next meeting, draft WMP recommendations for implementation will be provided, including not only management practices, but also awareness, outreach and education activities that will contribute to attaining the three WMP goals and the desired outcome of sustaining and improving water quality in the Buffalo River watershed.

Attachment 1

Buffalo River Watershed Management Plan: A Voluntary, Non-Regulatory Project
Marshall Civic Center
Marshall, AR
8 June 2017
Agenda

Time	Topic	Individual
1:00 pm	Welcome, Meeting Purposes: • Summarize the Jasper Meeting and suggested management practices • Describe the additional analyses performed and suggested subwatersheds for initial implementation of additional management practices • Describe the process for establishing target loads and management practices to achieve load reductions • Discuss next steps	K. Thornton, FTN
1:05	Summarize the 30 March Jasper Meeting • Watershed Management Plan and planning process • Management practices suggested by stakeholders	K. Thornton
1:15	Additional Analyses and Suggested Recommendations • Discuss DO and E. coli analyses • Provide suggested subwatersheds for initiation of management practices, based on additional analyses • Questions	K. Thornton
1:45	Approach for Target Loads and Management Practices • Desired Outcome and Goals • Target loads • Management practices and efficiencies • Projected load reductions and estimated costs • Questions	K. Thornton
2:50	Next Steps	K. Thornton
3:00	**Adjourn**	
3:00 – 3:30	Informal Discussions, If Desired	All

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Terry Horton, FTN – twh@ftn-assoc.com (501) 225-7779

Buffalo River Watershed Management Plan: A Voluntary, Non-Regulatory Project

3rd Stakeholder Meeting
Marshall, AR
8 June 2017

Meeting Purposes

- Summarize Jasper March meeting
- Discuss additional analyses and recommended watersheds
- Discuss target loads and management practices
- Receive your feedback
- Discuss next steps

30 March Jasper Meeting

- Watershed Management Plan
  - Water Quality Emphasis
    - Extraordinary Resource Water
  - Nonpoint Sources – non-regulatory
  - Voluntary participation

30 March Jasper Meeting

- Watershed Management Plan
  - Focus on sustaining and improving water quality
  - Does not address regulated/permitted facilities or operations (BBRAC Issue)
  - No requirement to participate
    - Are benefits of participating

30 March Jasper Meeting

- Elicited management practices to address issues identified in December Marshall meeting
- Discussed criteria used to screen subwatersheds for initiation of management practices
- Request to consider DO and E. coli

Management Practices Suggested

- Litter management
- Unpaved road BMPs
- Greenbelt buffers – pasture/stream
- Prescribed forest burns
- Feral hog capture
- Steep slope erosion BMPs
- Septic system repair/replace
- Forest mgt. practices
- Streambank restoration
- Soil/nutrient mgt
- Erosion control BMPs
- Quail habitat mgt, restoration
- Farm pond/sediment basin construction
- Trail management practices

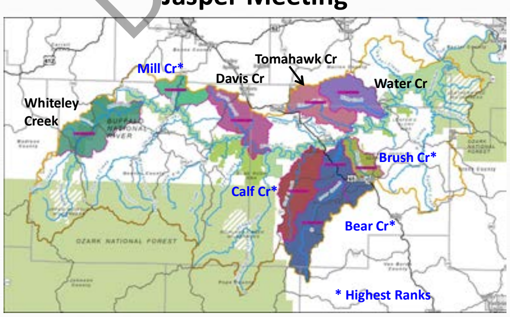
Other Recommendations

- Destination mgt. org.
- River use quotas
- Feral Hog Task Force
- Source tracking – E. coli
- Pasture mgt education
- B/C analysis of BNR
- Visitor environmental stewardship program
- Forest managment
- Promote econ. opportun.
- Develop agro/eco-tourism
- Watershed Coop
- Nutrient trading
- Mitigation bank for development
- Promote indiv. porta potties
- More visitor contact centers
- Form "Friends of the River"

Watershed Assessment

- Screening Criteria
  - Biology – Fish, Benthic organisms
  - Water quality – Turbidity, Nitrate, SRP, fecal coliforms
  - Trends – Turbidity, Nitrate, fecal coliforms
  - Loads – Nitrate, SRP, fecal coliforms
  - 8 NRCS Resource Concerns
  - Carbonate bedrock

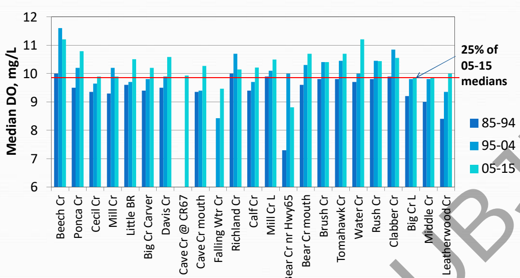
Suggested Recommendations – Jasper Meeting



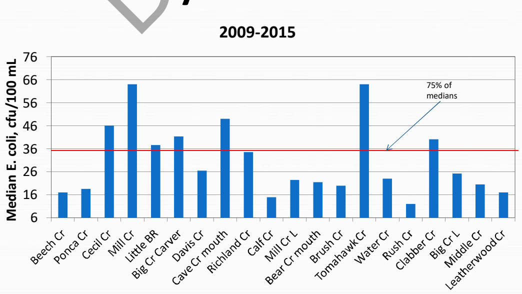
Additional Analyses

- Dissolved Oxygen
  - 3 10-year periods
- E. coli
  - Period of record – 2009-2015

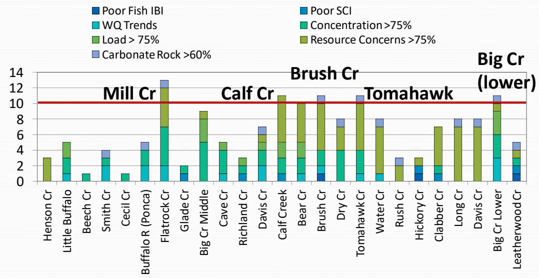
Dissolved Oxygen Analysis



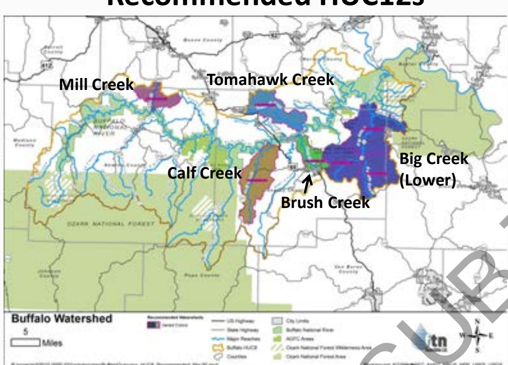
E. coli Analysis



Updated Screening Scores



Recommended HUC12s



Screening Process Caveats

- **Not Exclusionary**
  - **Place to start ONLY.**
  - **Additional management practices positive, and encouraged, in any subwatershed**

Approach

Desired Outcome:
Sustain, improve water quality

- Three Goals:
  - Keep pollutants out of the water (surface and groundwater)
  - Minimize stream bank and bed disturbance
  - Leave no trace behind

Target Load Process

- 3 10-year periods
  - Look at trends over 30 years
  - Consider % reduction to 1985-1994 levels
- Constituents
  - Sediment – Very limited data, turbidity values only
  - Nitrate – 30 years of record*
  - Phosphorus – Last 10 years only (orthophosphate)
  - E. coli - Only one period – use F. coli trends*

  * Management focus

Nitrate Trends

HUC12	1985-1994 median (Target) (mg/L)	1995-2004 median (mg/L)	2005-2015 median (mg/L)	Reduction Needed To Achieve Target
Mill Cr	0.438	0.581	0.727	40%
Calf Cr	0.230	0.321	0.337	32%
Brush Cr	0.515	0.570	0.770	33%
Tomahawk Cr	0.225	0.346	0.382	41%
Lower Big Cr	0.04	0.111	0.132	70%

Bacteria Trends (F. coli)

HUC12	1985-1994 median (Target) (cfu/100 mL)	1995-2004 median (cfu/100 mL)	2005-2016 median (cfu/100 mL)	Reduction Needed To Achieve Target
Mill Cr	18	26	72.5	75%
Calf Cr	16	20	12	0%
Brush Cr	8.5	20.5	20	53%
Tomahawk Cr	54	56.5	31	0%
Lower Big Cr	5.5	14	19	71%

Constituent Focus for Mgt

- Nitrate
  - Soluble – surface & groundwater considerations
  - Corresponding Ortho-P, other soluble constituent reductions
- E. coli
  - Particulate transport
  - Corresponding sediment, TP reductions

Emphasis

- Vegetative enhancement
- Soil health
- Streambank stablization
- Individual wastewater disposal systems

Suggested Practices

- Recommended at Jasper Meeting, and
- Additional considerations
  - Fencing
  - Prescribed/rotation grazing
  - Alternative water sources
  - Fertilizer application/nutrient management
  - Soil health management

Management Practice Efficiency

- Estimated Practice Efficiency
  - Arkansas BMP Tool II
  - NRCS Conservation Practice Standards
  - National Pollutant Removal Performance Database
  - International Stormwater BMP Database
  - Chesapeake Bay Program BMPs

Practices – Expected Reductions

Practice	Nitrogen Reduction	Coliform Reduction	Sediment Reduction	Phosphorus Reduction
Stream Exclusion/ Controlled Access	32%	30% - 95%	83%	76%
Off-stream Water Source	13% - 77%	57%	38% - 96%	74% - 97%
Forested stream buffer	37% - 70%	30%	45% - 94%	45% - 70%
Non-forest stream buffer	31% - 68%	41%	23% - 70%	50% - 70%

Practices – Expected Reductions

Practice	Nitrogen Reduction	Coliform Reduction	Sediment Reduction	Phosphorus Reduction
Prescribed Grazing	20%	60% - 72%	20% - 60%	20%
Streambank Stabilization			Up to 100%	X
Filter Strips	1% - 93%	30% - 100%	18% - 99%	2% - 93%
Pasture Planting/Mgt	66%	X	59%	67%
Pond	82%	X	77%	72% - 80%
Nutrient Management Plan	0 – 84%	X	72% - 92%	8% - 91%

Practices – Expected Reductions

Practice	Nitrogen Reduction	Coliform Reduction	Sediment Reduction	Phosphorus Reduction
Forestry BMPs	50%		34% - 95%	50%
Maintenance Unpaved Roads			48% - 95%	X
Indiv. WW Disposal Sys	100%	100%		100%
Feral hog capture	X	X	X	X

Nitrate Reduction Estimates

HUC12	1985-1994 median - Target (mg/L)	2005-2015 median (mg/L)	Nitrate Reduction Needed to Achieve Target	Sources
Mill Cr	0.438	0.727	40%	Indiv. WWT , pasture
Calf Cr	0.230	0.337	32%	Indiv. WWT , pasture
Brush Cr	0.515	0.770	33%	Indiv. WWT , pasture
Tomahawk Cr	0.225	0.382	41%	Indiv. WWT , pasture
Lower Big Cr	0.04	0.132	70%	Indiv. WWT , pasture

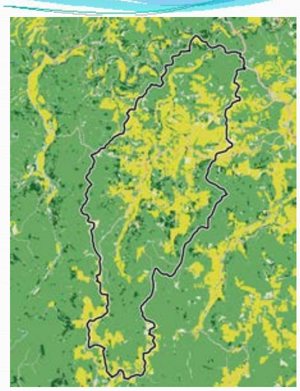
Bacteria Reduction Estimates

HUC12	1985-1994 median - Target (cfu/100 mL)	2005-2016 median (cfu/100 mL)	Bacteria Reduction Needed to Achieve Target	Sources
Mill Cr	18	72.5	75%	Indiv. WWT , pasture
Calf Cr	16	12	0%	
Brush Cr	8.5	20	53%	Indiv. WWT , pasture
Tomahawk Cr	54	31	0%	
Lower Big Cr	5.5	19	71%	Indiv. WWT , pasture

Calf Creek

31,755 acres

- **64% Forest**
- **3.5% Developed**
- **33% Pasture**



Estimated Reduction/Cost*

Calf Creek Watershed = 31,755 ac (9,428 ac pasture)

Practice	Amount	Cost ($ 1,000) **	Pasture N Redctn (46%)	Coliform Redctn	Sediment Redctn	Phos Redctn
Stream exclusion	165,000 ft 165 tanks	536	46%	41%	40%	36%
Forested buffer	162 ac	326	46%	29%	32%	36%
Non-forest buffer	238 ac	95	46%	34%	47%	53%
Pasture planting/ Mgt	1,100 ac	275	46%	Unknown	29%	37%

*Independent BMP implementation
**EQIP 2016 non-HUC allocation (approximately 75% of total cost)

Brush Creek

12,865 acres

67% Forest
5.3% Developed
28% Pasture

Estimated Reduction/Cost*

Brush Creek Watershed = 12,865 ac (3,138 ac pasture)

Practice	Amount	Cost ($ 1,000) **	Pasture N Redctn (47%)	Coliform Redctn (59%)	Sediment Redctn	Phos Redctn
Stream exclusion	40,000 ft 40 tanks	130	47%	47%	35%	38%
Forested buffer	40 ac	80	47%	34%	28%	38%
Non-forest buffer	58 ac	23	47%	39%	41%	55%
Pasture planting/ mgt	2,200 ac	550	47%	Unknown	25%	38%

*Independent BMP implementation
**EQIP 2016 non-HUC allocation (approximately 75% of total cost)

Estimated Reduction/Cost*

Brush Creek Watershed = 12,865 ac (3,138 ac pasture)

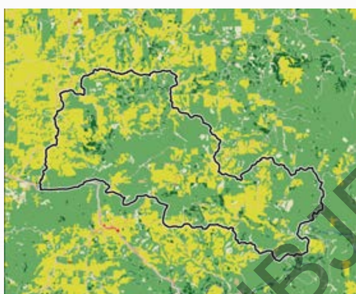
Practice	Amount	Cost ($ 1,000) **	Pasture N Redctn (47%)	Coliform Redctn (59%)	Sediment Redctn	Phos Redctn
Stream exclusion	51,000 ft 51 tanks	166	59%	59%	44%	47%
Forested buffer	60 ac	119	70%	50%	42%	56%
Non-forest buffer	60 ac	24	48%	40%	42%	56%
Prescribed grazing	3,000 ac	204	20%	59%	12%	16%

*Independent BMP implementation
**EQIP 2016 non-HUC allocation (approximately 75% of total cost)

Tomahawk Creek

23,589 acres

63% Forested
2.9% Developed
34% Pasture



Estimated Reduction/Cost*

Tomahawk Creek Watershed = 23,589 ac (7,275 ac pasture)

Practice	Amount	Cost ($ 1,000) **	Pasture N Redctn (59%)	Coliform Redctn	Sediment Redctn	Phos Redctn
Stream exclusion	161,000 ft 161 tanks	523	59%	52%	44%	47%
Forested buffer	158 ac	335	59%	42%	35%	47%
Pasture planting/Mgt	6,400 ac	1,600	59%	Unknown	31%	48%
Prescribed grazing	7,200 ac	490	20%	60%	12%	16%

*Independent BMP implementation
**EQIP 2016 non-HUC allocation (approximately 75% of total cost)

Mill Creek

13,607 acres

- 77% Forested
- 4.6% Developed
- 18% Pasture

Estimated Reduction/Cost*

Mill Creek Watershed = 13,607 ac (3,810 ac pasture)

Practice	Amount	Cost ($ 1,000) **	Pasture N Redctn (57%)	Coliform Redctn (83%)	Sediment Redctn	Phos Redctn
Stream exclusion	45,000 ft 45 tanks	146	57%	51%	43%	45%
Forested buffer	44 ac	87	57%	37%	34%	46%
Pasture planting/mgt	1,600 ac	400	57%	unknown	31%	46%
Indiv. WW disposal	unknown					

*Independent BMP implementation
**EQIP 2016 non-HUC allocation (approximately 75% of total cost)

Potential Funding Sources

- ANRC 319 Program – e.g., Conservation Districts
- NRCS EQIP – Individual Landowner
- FSA CRP – Individual Landowner
- NRCS MRBI – Individual Landowner
- NRCS RCPP – e.g., Conservation Districts
- USFWS Controlled Access Livestock Fencing (CALF) Program – Individual Landowner
- TNC – Individual Landowner

Not Starting From Scratch

- County Conservation Districts
  - Streambank restoration
  - Bank stabilization
  - Pasture planting
  - Stream exclusion with alternate water
  - Manure management
  - Equipment
- NRCS
  - Pasture planting
  - Manure management
  - Bank stabilization
- US NPS
  - Bank stabilization
  - Tree planting
  - Stream fencing

Next Steps

- Meeting Summary – distributed to everyone attending and on email list (or address)
- Continue to elicit your input
- Refine management practice analyses; add outreach and education
- Schedule next meeting; likely in September
- Next meetings topic
  - Draft Recommendations

Points of Contact

Tony Ramick, ANRC
Tony.Ramick@arkansas.gov
(501) 682-3914

Terry Horton, FTN
twh@ftn-assoc.com
(501) 225-7779

ATTACHMENT 3

Questions Raised at the June 8 2017 Meeting and Responses

Question: Could the increase in DO over time be due to changes in the method for measuring DO?

Response: It is unlikely. Different probes or meters might have been used, but all are calibrated before use, so the results would be expected to be consistent.

Question: What is the difference between day and night DO?

Response: Daytime DO measurements include oxygen added to the water through plant photosynthesis. At night, this source of oxygen is not available to the stream and DO concentrations typically will be at their lowest concentration around sunrise. Most DO measurements are taken during the day, and may not capture these lower values.

Question: What time of year are the DO measurements from? DO is usually lowest in July and August.

Response: The data consist of quarterly samples, so they include measurements from winter, spring, summer, and fall.

Question: What is the source of the DO data?

Response: The DO data are primarily from the US National Park Service water quality monitoring program.

Question: Why have coliform levels declined in Calf Creek and Tomahawk Creek?

Response: We don't know.

Question: What is stream exclusion?

Response: These are practices that keep cattle out of streams. Usually it includes fencing along the stream and some kind of alternative water supply, since the cattle won't be able to drink from the stream.

Question: ADEQ is currently taking public comments on the permit renewal for the Marble Falls wastewater treatment facility. How will that affect the management?

Response: The WMP focuses only on non-regulatory management. The permit renewal is a permitted action that will not be included in the WMP.

Question: Why are you not recommending middle Big Creek because it has a permitted facility, but you are recommending Mill Creek, which has permitted sources?

Response: The inclusion of Mill Creek is not because it has permitted sources. Mill Creek was included because it ranked the highest considering all the screening criteria, and median concentrations and loads have increased over the 30 year period. Most of the subwatersheds have some permitted sources (some individual septic systems require a permit).

Question: If the point source permit for Marble Falls is not renewed, does it become a nonpoint source?

Response: No. If the permit is not renewed, the facility has to be shut down. This is an ADEQ action.

Question: Is litter application management included in the watershed management plan?

Response: Not specifically. Management of litter applications would be addressed in nutrient management plans and conservation management plans, which will be recommended in the plan.

Question: You are recommending planting (e.g. pasture planting). Do your recommendations include specific species?

Response: No. Appropriate species will depend upon the specific location or pasture. Since we don't know who will volunteer, we don't know where the planting will be done, and won't be able to include species recommendations in the plan. However, technical and possible financial assistance might be available to help individual landowners answer this question.

Question: You list federal sources for funding assistance. Will these sources be available in the future?

Response: Our assumption is that these sources will be available in the future. However, we have no idea of the level of funding that might be available.

Question: Does whether or not a stream is recommended in the plan affect the availability of funding assistance? Will projects not located in recommended watersheds be eligible for funding?

Response: Based on past WMP implementation, the first priority is typically for those subwatersheds recommended in the Plan. This, however, does not exclude other subwatersheds from being eligible for funding.

Question: Is the plan updated? How often? How do we go about changing or updating the plan?

Response: Once the WMP is accepted by EPA, it is provided to stakeholders for implementation. Stakeholder groups or organizations in other watersheds have taken responsibility for championing the implementation of the WMP and updating the plan. The frequency is typically based on when significant actions or activities occur within the watersheds.

Question: What do you mean by leave no trace behind?

Response: "Leave no trace behind" is a program of the Buffalo National River that encourages park visitors to minimize impact on the Buffalo River. This includes minimizing streambank disturbance, properly disposing of human waste and litter, and similar activities. All users of Buffalo River watershed resources can minimize their impact on watershed resources and the Buffalo River by following the principles of "leave no trace behind".

Question: If I don't want to do any of the practices recommended in the plan am I going to be penalized in any way?

Response: No. This is a voluntary program.

Question: In your data analysis, do you differentiate whether the pollutants are from the watershed or the river?

Response: There are water quality monitoring stations on the river and on the major tributaries. This allows us characterize loads from the tributaries.

Question: Is there funding assistance for upgrading or fixing septic systems?

Response: No, not to our knowledge.

Questions: Will the BBRAC continue after the plan is done?

Response: It is our understanding the BBRAC will continue after the plan.

Question: Will the other agencies in the BBRAC have input into what happens in the watershed?

Response: The BBRAC agencies currently do have input into what happens in the watershed through their respective programs.

Question: What is the role of the BBRAC?

Response: The BBRAC is a non-regulatory organization that provides a forum for agencies to communicate and work together.

Question: Do we (stakeholders) have access to the data and analyses?

Response: Yes. You may make a request from ANRC.

Question: How can we implement a project, such as streambank erosion control?

Response: The WMP will have contacts for agencies and organizations that can provide technical and financial assistance for implementing various management practices, such as streambank erosion control.

Question: How do we submit an action item?

Response: The best approach is to raise the action item at the stakeholder meetings so it can be discussed by participants. Action items can be submitted to:

Tony Ramick, ANRC – Tony.Ramick@arkansas.gov; (501) 682-3914
Terry Horton, FTN – twh@ftn-assoc.com (501) 225-7779

All action items will be considered, but will not necessarily be included in the WMP. For example, a number of suggestions were made to increase economic opportunities in the watershed. This is an important issue, but doesn't necessarily relate to water quality. This action item will be forwarded to the Arkansas Economic Development Commission.

Arkansas Natural Resources Commission

Bruce Holland
Executive Director

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Little Rock, Arkansas 72201
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Asa Hutchinson
Governor

Arkansas Natural Resources Commission's Development of the Buffalo River Watershed Management Plan
Fourth Stakeholder Meeting
October 12, 2017: Jasper, AR
Meeting Summary

The Arkansas Natural Resources Commission (ANRC) sponsored the fourth and final stakeholder meeting as part of the development of a voluntary, non-regulatory watershed management plan (WMP) for the Buffalo River watershed. The meeting was held in Jasper on October 12, 2017. The meeting agenda is included as Attachment 1. Approximately 30 individuals attended the meeting, including farmers and landowners, as well as individuals from agricultural, conservation, recreational and other interest groups, and employees from state and federal agencies.

At the direction of Governor Asa Hutchinson, the Beautiful Buffalo River Action Committee was organized to establish an Arkansas led approach to identify and address potential issues of concern in the Buffalo River watershed, including the development of a voluntary, non-regulatory WMP for the Buffalo River watershed.

The meeting was facilitated by FTN Associates, Ltd. (FTN), an engineering and environmental consulting firm headquartered in Little Rock. The Arkansas Natural Resources Commission contracted with FTN to assist the agency with the development of the Buffalo River WMP. The process will be completed by June of 2018.

The meeting was initiated by summarizing the results of the June 2017 meeting in Marshall. A copy of the presentation is included as Attachment 2.

The focus of this meeting in Jasper was to discuss the recommended management practices and activities to be included in the watershed management plan. Recommended management activities and practices were proposed within 5 categories:

- Management practices
- Monitoring
- Additional Studies
- Awareness, Outreach and Education
- Teams

These recommendations were provided for stakeholder review prior to the meeting via the web and are listed in Attachment 3. The management emphasis is on vegetative establishment, soil health, and streambank restoration and stabilization.

Management practice recommendations were included for three types of land use – pasture, forest, and ecotones or edges between different land uses. Nitrate and E. coli reduction estimates, and relative cost, were provided by different pasture management practices for the six subwatersheds recommended for initial management focus. These estimates were for independent application of a particular management practice. Nearly all management practices are implemented as suites of practices, rather than independently. However, without knowledge of the specific field or acreage characteristics, it is not feasible to estimate which combination or suites of management practices might be implemented. In some subwatersheds, independent applications of a practice were estimated to achieve the target load reduction. For other subwatersheds, a combination of practices would be required to achieve target load reductions. In addition to recommended management practices by land use, karst sinkhole treatment, invasive/destructive species control, and unpaved road erosion control practices were also recommended. Identification of failing septic systems was also recommended within these subwatersheds.

There is an excellent on-going water quality monitoring program within the Buffalo River watershed, so the first recommendation in this category is to continue this monitoring program. Additional recommendations included adding total suspended solids (TSS) to the constituents being analyzed. Turbidity is currently being monitored, but it is not as useful as TSS in assessing erosion and sedimentation. ADEQ has indicated they can add this constituent to their list of water quality analytes. Adding a water quality monitoring site at the county road bridge downstream of Dogpatch Springs would help assess the relative contributions of nitrate, E. coli, and other constituents that might be entering the Buffalo River watershed from the contiguous Crooked Creek watershed through groundwater. The NPS Buffalo National River (BNR) and ADEQ are in the process of designing an algal monitoring program for the Buffalo River and its tributaries. Supporting the design and implementation of an algal monitoring program is a management plan recommendation. The EPA National Aquatic Resource Survey Program has developed and implemented a trash index as part of their monitoring efforts. Incorporating this trash index as part of tributary monitoring efforts could help determine the relative contribution of trash from the tributaries to the Buffalo River. The trash index monitoring could be conducted by a Stream Team or by watershed implementation teams, discussed below.

Four additional studies are recommended. The first is to conduct a microbial source tracking study in the Mill Creek subwatershed. As mentioned above, there is an indication that E. coli, as well as nitrate and other constituents, might be entering the Buffalo River subwatershed through Dogpatch Springs. Failing septic systems and the Marble Falls wastewater treatment facility might also be contributing bacteria to Mill Creek. While recommended treatment practices for permitted sources are not considered as part of the watershed management plan, having a better understanding of the relative contribution of human vs. non-human sources can help determine the relative contribution, and location, of non-human sources of E. coli.

The NPS has initiated continuous diel (24-hour period) DO monitoring at selected sites in the BNR. It is recommended that this diel DO monitoring be expanded to include all the tributary sites currently being sampled for water quality. Six tributary sites might be sampled each year so that over a 3-year period, all the sites would be monitored. The NPS Heartland Inventory program has a rotating panel design that could be followed in selecting tributary sites for monitoring. LiDAR data from the NRCS will be available state-wide in March 2018. This

LiDAR data could be used to prototype an assessment of streambank erosion and instability within the Calf Creek subwatershed. Stream teams or subwatershed teams could ground truth selected sites to assess the accuracy of the LiDAR analyses and identify candidate sites for streambank restoration and stabilization. If the LiDAR assessment was accurate, the analyses could be conducted for all 37 HUC12 subwatersheds within the Buffalo River watershed.

Finally, it is recommended the Bear Creek subwatershed serve as a prototype for quantifying ecosystem services provided in the watershed. Ecosystem services, by definition, are the benefits people obtain from ecosystems and the direct and indirect contributions of ecosystems to human well-being. As categorized by the Ecosystem Millennium Assessment, these include: *provisioning* services such as food, water, timber and fiber; *regulating* services that affect climate, floods, disease, wastes, and water quality; *cultural* services that provide recreational, aesthetic, and spiritual benefits; and *supporting* services such as soil formation, nutrient cycling, and photosynthesis (MEA 2005). Typically, only provisioning services have market value, with the monetary benefits determined within the market place where goods and services are bought and sold. However, there are significantly more benefits or values that are provided by ecosystem services other than provisioning services. Because these are provided "free", the loss of these benefits is not considered. For example, if microbial communities did not decompose manure and cycle nutrients, ranchers would have to pay for commercial fertilizer to provide the nutrients needed for forage, which would be a significant additional cost. Having a better understanding of these lost benefits might promote additional pasture management practices.

There are currently many excellent awareness, outreach and educational programs within the Buffalo River watershed offered not only by the NPS BNR and their partners, but also other agencies and organizations such as the NRCS, University of Arkansas Cooperative Extension Program, County Conservation Districts, Arkansas Grazing Land Coalition, rural water utilities, and others. It is recommended that these programs and activities by supported and encouraged to continue.

Two sets of teams are proposed to help implement the recommended practices and activities. Watershed implementation teams are recommended for each subwatershed. Those individuals who live, work, recreate within any subwatershed usually have the greatest desire to see improved water quality for themselves, their children and grandchildren. One to three individuals could be identified in each subwatershed as the points of contract to which the remaining landowners in the watershed could voluntarily report what implementation measures they have accomplished. Stream teams are also recommended for the Buffalo River watershed. The AGFC administers a program to offer training and support for individuals interested in learning more about streams and their management. Stream teams can be as small as 2-3 individuals.

Over the past decade, there has been considerable work conducted on ways of leading and implementing change within organizations and communities. What has emerged is that there are three important domains to consider and two important elements within each domain. The domains are personal, social, and structural and the elements are motivation and ability. These three domains and two elements form a six-celled matrix (See slide 36 Attachment 2). In many instances, the emphasis is only on personal motivation and ability, ensuring that individuals have the motivation to change and are provided with the training and ability to make the change. However, the importance of social elements of peer pressure and support groups (e.g. Grazing Land Coalition) is also critical in supporting the personal domain. In addition, making changes in the physical environment (i.e., structural domain) through cost-share and rewards (i.e., motivation), and by changing the physical environment in which individuals interact (e.g., electric fence vs. barbed wire fence) are also critical in bringing about changes in how land and water are viewed and managed. The key is to simultaneously address all six cells, not just one or two of the cells. In some cases, it might be possible to address all six, but the emphasis should be on implementing as many of the six cells as possible to encourage and promote change. This is the recommended approach for implementing the Buffalo River watershed management plan.

Questions raised during the meeting were captured, and responses to these questions are included in Attachment 4.

Next Steps

Comments from this meeting will be considered and, where applicable, will be incorporated into a final draft watershed management plan. The final draft Buffalo River Watershed Management Plan will be uploaded to the website previously used for the watershed management recommendations and available for stakeholder review for 30 days. Stakeholders will be notified when the final draft may be viewed on the website. Any comments received will be assessed and incorporated, where applicable, into the final Buffalo River Watershed Management Plan draft. The Draft Buffalo River Watershed Management Plan will be submitted to EPA for acceptance. EPA “accepts” the plan as opposed to “approving” it because there are no proposed mandatory regulations in this program. Following EPA acceptance, the watershed management plan will be available to guide implementation of management practices and activities within the Buffalo River watershed.

ATTACHMENT 1
Buffalo River Watershed Management Plan:
A Voluntary, Non-Regulatory Project
Carroll Electric Community Room
Jasper, AR
12 October 2017
Agenda

Time	**Topic**	**Individual**
1:00 pm	Welcome, Meeting Purposes: • Summarize the Marshall Meeting discussions • Discuss the recommendations for the Buffalo River Watershed Management Plan • Elicit stakeholder input on the recommended practices and activities • Discuss next steps	K. Thornton, FTN
1:05	Summarize the 8 June Marshall Meeting • Watershed Management Plan and planning process • WQ goals, target loads, and estimated load reductions and costs associated with various management practices	K. Thornton
1:25	Recommended Watershed Management Practices & Activities • Recommended Management Practices • Recommended Monitoring • Recommended Studies • Recommended Awareness, Outreach and Education Activities • Recommended Teams • Questions • Other Recommendations	K. Thornton
2:35	Influencing Implementation • Personal Domain • Social Domain • Structural Domain	K. Thornton
3:00	Next Steps	K. Thornton
3:15	**Adjourn**	

Contacts:

Allen Brown, ANRC – Allen.Brown@arkansas.gov; (501) 682-3902

Terry Horton, FTN – twh@ftn-assoc.com (501) 225-7779

Buffalo River Watershed Management Plan: A Voluntary, Non-Regulatory Project

4th Stakeholder Meeting
Jasper, AR
12 October 2017

Meeting Purposes

- Summarize Marshall June meeting
- Discuss recommended practices and activities for watershed management
- Receive your feedback
- Discuss next steps

8 June Marshall Meeting

- Watershed Management Plan
  - Water Quality Emphasis
    - Extraordinary Resource Water
  - Nonpoint Sources – non-regulatory
  - Voluntary participation

8 June Marshall Meeting

- Watershed Management Plan
  - Focus on sustaining and improving water quality
  - Does not address regulated/permitted facilities or operations (BBRAC Issue)
  - No requirement to participate
    - Are benefits of participating

8 June Marshall Meeting

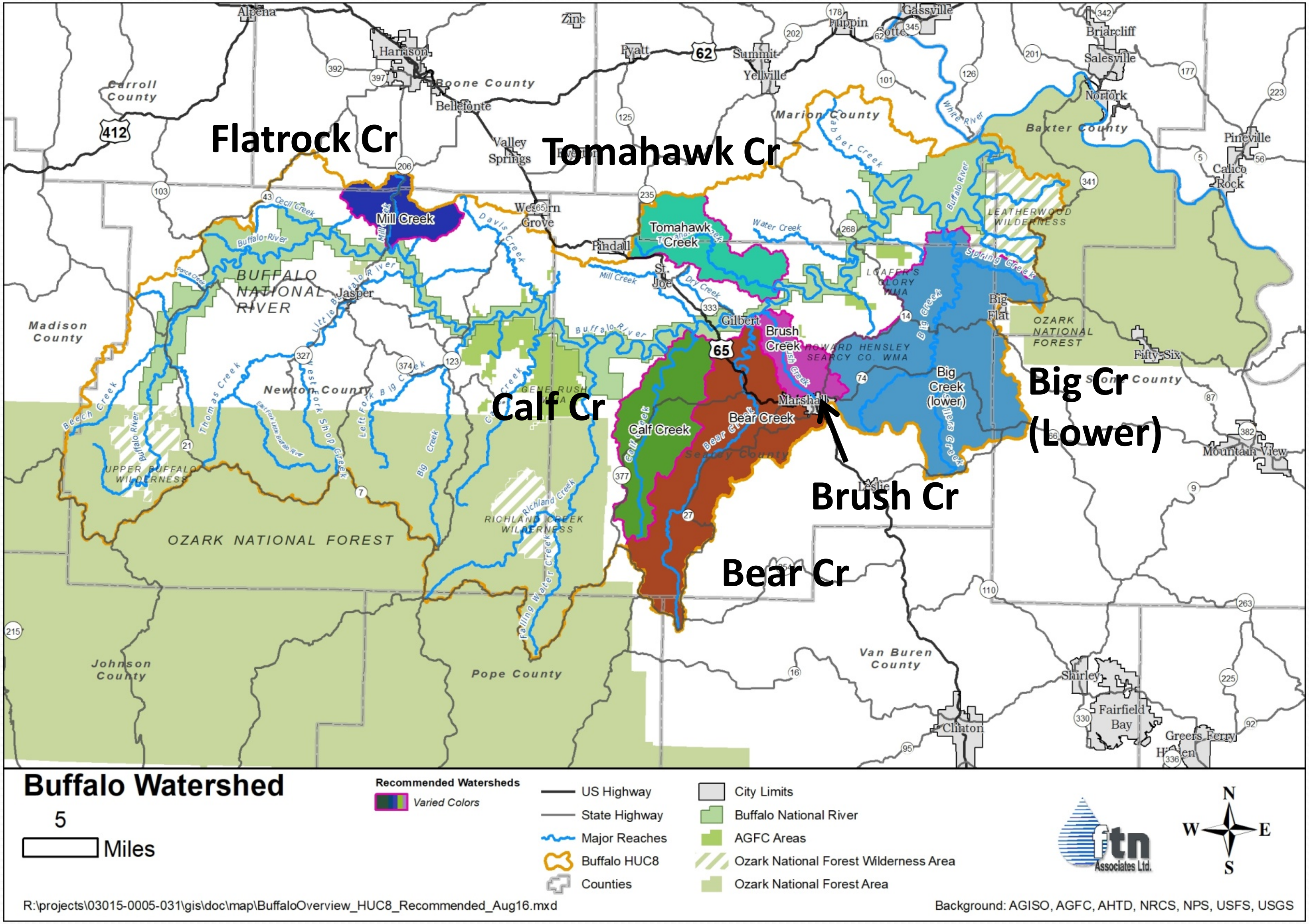
- **Water quality desired outcome & goals**
- **Initial focus subwatersheds/tributaries**
- **Water quality target loads**
- **Management practices and estimated load reductions and relative cost**

Desired Outcome:

Sustain, improve water quality

- Three Goals:
  - Keep pollutants out of the water (surface and groundwater)
  - Minimize stream bank and bed disturbance
  - Leave no trace behind

Initial Focus Tributaries



Constituent Focus for Mgt

- Nitrate
  - Soluble – surface & groundwater considerations
  - Corresponding Ortho-P, other soluble constituent reductions
- E. coli
  - Particulate transport
  - Corresponding sediment, TP reductions

Nitrate Reduction Estimates

Tributary	1985-1994 median - Target (mg/L)	2005-2015 median (mg/L)	Nitrate Reduction Needed to Achieve Target	Sources
Flatrock Cr	0.438	0.727	40%	On-site WWT , pasture
Calf Cr	0.230	0.337	32%	On-site WWT , pasture
Bear Cr	0.100	0.313	68%	On-site WWT , pasture
Brush Cr	0.515	0.770	33%	On-site WWT , pasture
Tomahawk Cr	0.225	0.382	41%	On-site WWT , pasture
Lower Big Cr	0.04	0.132	70%	On-site WWT , pasture

Bacteria Reduction Estimates

Tributary	Target E. coli concentration (cfu/100mL)	Median E. coli concentration 2009-2015 (cfu/100mL)	Reduction Needed to Achieve Target	Sources
Flatrock Cr	15	64	76%	On-site WWT , pasture
Calf Cr	15	15	0	
Bear Cr	21.5	21.5	0	
Brush Cr	7.3	20	64%	On-site WWT , pasture
Tomahawk Cr	36*	64	44%	On-site WWT , pasture
Lower Big Cr	4.5	25.3	82%	On-site WWT , pasture

* 75th percentile of 2009-2015 medians

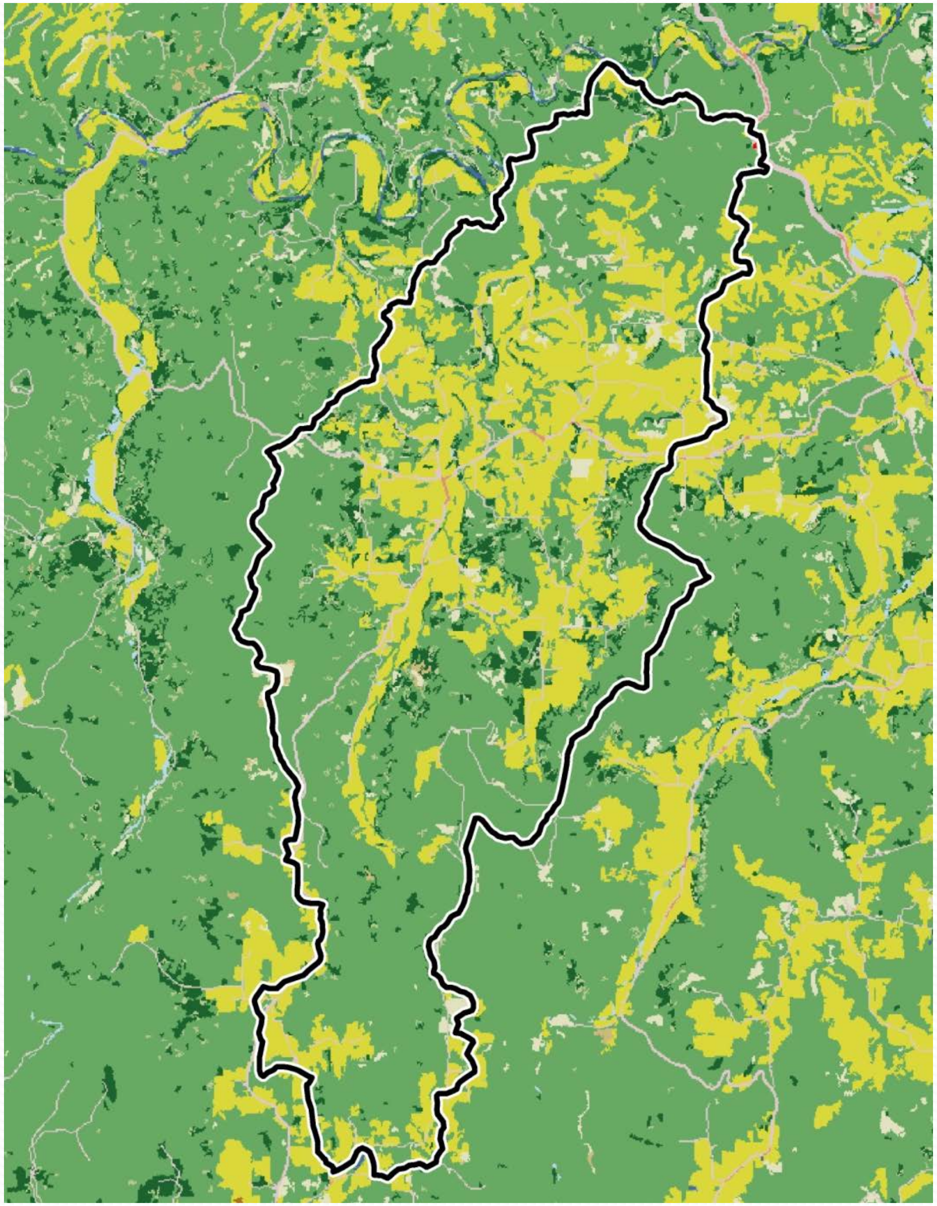
Practices – Expected Reductions

Practice	Nitrogen Reduction	Coliform Reduction	Sediment Reduction	Phosphorus Reduction
Prescribed grazing	20%	60% - 72%	20% - 60%	20%
Non-forest stream buffer	31% - 68%	41%	23% - 70%	50% - 70%
Forested stream buffer	37% - 70%	30%	45% - 95%	45% - 70%
Pasture planting/Mgt	66%	X	59%	67%
Stream exclusion	32% - 60%	30% - 95%	75% - 83%	60% - 76%

Calf Creek

31,755 acres

64% Forest
3.5% Developed
33% Pasture



Estimated Reduction/Cost*

Calf Creek Watershed = 31,755 ac (9,428 ac pasture)

Practice	Amount	Cost ($ 1,000) **	Nitrogen Reduction (46%)	Coliform Reduction	Sediment Reduction	Phosphorus Reduction
Stream exclusion	249,000 ft 249 tanks	809	46%	41%	9%	37%
Forested buffer	244 ac	489	46%	29%	7%	37%
Non-forest buffer	357 ac	143	46%	34%	11%	53%
Pasture planting/ Mgt	6,500 ac	1,625	46%	Unknown	8%	37%

*Independent BMP implementation

**EQIP 2016 non-HUC allocation (approximately 75% of total cost)

Additional Analyses

- Distributed Marshall meeting summary
- Included gully formation concerns (NRCS)
  - Addition of Bear Creek subwatershed
- Developed relationship between E. coli and fecal coliforms
  - Target reduction estimates based on E. coli
- Refined cost estimates for management practices

Recommended Management Practices & Activities

Recommended Watershed Management Practices/Activities

- Recommended Management Practices
- Recommended Monitoring
- Recommended Studies
- Recommended Awareness, Outreach and Education Activities
- Recommended Teams

Management Emphasis

- **Vegetative enhancement**
- **Soil health**
- **Streambank restoration/stablization**

Recommended Practices/Activities

- Management Practices
  - Pasture (NRCS, Coop Extension, Conservation Districts, Grazing Land Coalition)
    - Nutrient management plans
    - Livestock stream exclusion/controlled access
    - Forest/non-forest riparian buffers
    - Pasture planting/management
    - Prescribed/rotational grazing
    - Silvopasture establishment
    - Ponds/sediment basins

NO_3 Estimated Reduction/Cost ($K)*

Practice	Flatrock (40%)	Calf Cr (32%)	Bear Cr (68%)	Tomahawk (41%)	Brush Cr (33%)	Big Cr (L) (70%)
Stream exclusion	40%/ $150**	32%/ $810	42%/ $1,700	41%/ $520	33%/ $200	53%/ $1,800
Forested buffer	40%/ $90	32%/ $490	49%/ $1200	41%/ $320	33%/ $120	49%/ $1,300
Non-forest buffer	34%/ $22	32%/ $140	34%/ $240	36%/ $75	33%/ $35	49%/ $250
Pasture planting/Mgt	40%/ $820	32%/ $1,600	46%/ $2,000	41%/ $1,600	33%/ $550	41%/ $5,000
Prescribed grazing	14%/ $260	14%/ $640	14%/ $550	14%/ $500	14%/ $210	14%/ $1,400

**EQIP 2016 non-HUC allocation (approximately 75% of total cost)

E. coli Estimated Reduction/Cost ($K)*

Practice	Flatrock (75%)	Calf Cr (0%)	Bear Cr (0%)	Tomahawk (41%)	Brush Cr (53%)	Big Cr (L) (71%)
Stream exclusion	51%/ $150**	41%	54%	53%/ $390	42%/ $250	54%/ $1,800
Forested buffer	37%/ $110	29%	45%	38%/ $340	30%/ $180	45%/ $1,300
Non-forest buffer	36%/ $22	43%	36%	36%/ $75	35%/ $36	36%/ $250
Pasture planting/Mgt	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Prescribed grazing	54%/ $260	54%	54%	54%/ $370	54%/ $210	54%/ $1,400

*Independent BMP implementation

**EQIP 2016 non-HUC allocation (approximately 75% of total cost)

Recommended Practices/Activities

- Management Practices
  - Forest (NRCS, AFC, USFS, USNPS, Coop Ext.)
    - Pre-harvest planning – skid trails, landings
    - Streamside management zones
    - Roads – water bars, diversion ditches, grade control
    - Revegetation following harvest
    - Prescribed burns
    - Trail management

Recommended Practices/Activities

- Management Practices
  - Ecotones/edges (NRCS, AGFC)
    - Gamebird habitat restoration
    - Streambank restoration/stabilization
    - Filter strips/native plants
  - Karst Sinkhole Treatment
  - Invasive or destructive species control
  - Unpaved roads erosion management
  - Identify failing on-site WWT

Recommended Monitoring

- Continue existing monitoring
- Additional monitoring
  - Additional constituent - TSS
  - Additional station – County road access downstream of Dogpatch Springs
  - Algal species and densities
    - Support USNPS & ADEQ in developing / enhancing a monitoring program in the Buffalo/tributaries

Recommended Monitoring

- Additional Monitoring
  - Trash Index
    - Three times/yr –
      - Earth Day (week of April 22)
      - Week following Memorial Day
      - Week following July 4th
    - Heartland stations and panel frequency
    - Heartland & Stream Team(s)

Recommended Studies

- Microbial Source Tracking
  - Flatrock Creek & Dogpatch Springs
  - Partition human/non-human sources
  - Quantitative PCR with host-specific markers
  - Establish Flatrock Creek PCR stations based on ADEQ 2015-2017 study results
  - Bi-weekly January – December

Recommended Studies

- Dissolved Oxygen (DO)
  - Support USNPS Tributary Sites Program
    - Diel DO study
    - 6 tributaries/year, 3 year rotation
    - Continuous monitoring May 1 – Sept 30
    - Conforms to ADEQ water quality assessment requirements

Recommended Studies

- Streambank Erosion
  - LiDAR Analysis
    - NRCS LiDAR data available March 2018
    - Calf Creek prototype
    - Ground truth suspect areas
    - Design/implement streambank restoration/stabilization plan

Recommended Studies

- **Ecosystem Services**
  - **Quantify (value) ecosystem services in Bear Creek**
    - **Identify potential ecosystem services**
    - **Quantify market value services**
    - **Use non-market valuation procedures to estimate non-market benefits**

Recommended Awareness, Outreach and Education Activities

- Support existing BNR awareness, outreach and education programs, e.g.,
  - Leave No Trace media
  - Day-By-The Buffalo
  - Stream and cave ecology camps
  - Bioblitz Citizen Science
  - At The Waters Edge

Recommended Awareness, Outreach and Education Activities

- Support existing BNR partners and programs
  - Buffalo National River Partners
  - Ozark Unlimited Resources
  - Park Neighbors and Partners
  - NorthArk/UCA Learning Center, ASU Learning Center

Recommended Awareness, Outreach and Education Activities

- Support and use existing programs of
  - Cooperative Extension Service
  - County Conservation Districts
  - Arkansas Unpaved Roads Program
  - Arkansas Grazing Lands Coalition
  - Rural water utilities
  - Nonprofit interest groups

Recommended Teams

- **Subwatershed Implementation Team(s)**
  - **Champion implementing recommended practices & activities**
  - **Monitor progress, adapt to changing conditions**
  - **5-7 residents of a subwatershed**

Recommended Teams

- Stream Team(s) (AGFC)
  - Monitor water quality and promote streambank restoration/stabilization
  - Encourage wildlife habitat initiatives and alternative sources of revenue
  - 2-5 individuals within subwatershed

Comments – Additional Recommendations

Influencing Implementation

Influencing Implementation*

Domain	Motivation	Ability
Personal	Links to Values and Personal Benefits	Training, Skill Building
Social	Peer Pressure	Social Support
Structural	Rewards, Accountability	Change The Environment

* Grenny et al. 2013. Influencer: The New Science of Leading Change

Pasture Management Practices*

Domain	Motivation	Ability
Personal	•Better pasture/forage quality •Increased rate of gain •Reduced hay feeding •Sustain water supply •Cost-share programs	• Grazing land conf. •Field days •YouTube/other videos •Grazing stick • NRCS tech assistance • AR Coop Ext.
Social	•Leaders implementing practices •Cattleman of the Year Award	• Grazing land coalition •Field days •Rancher to rancher exchanges •Conferences

Pasture Management (Con't)*

Domain	Motivation	Ability
Structural	•EQIP funding •RCPP funding •319 funding •USFWS CALF funding	•Grow grass, not algae campaign •Grazing stick •Promote 2 strand electric fence •4-5 forage paddocks •Stockpile paddock •Alternative water supply

*Simultaneous actions, not either-or.

Streambank Restoration/ Stabilization*

Domain	Motivation	Ability
Personal	•Reduced land loss •Gamebird hunting leases •Aesthetics •Reduced flood damage •Cost-share programs	•NRCS tech assistance • AR Coop Ext. •AGFC tech assistance •TNC tech assistance
Social	•Leaders implementing practices •Conservationist of the Year Award	•Rancher to rancher exchanges •Conferences •Field Days

Streambank Restoration – Stabilization (Con’t)*

Domain	Motivation	Ability
Structural	•EQIP funding •RCPP funding •319 funding •AGFC – Stream Teams	•Timber •Buffer strips/zones •Wildflowers

*Simultaneous actions, not either-or.

Potential Funding Sources

- ANRC 319 Program – e.g., Conservation Districts
- NRCS
  - Env. Quality Incentives Prog (EQIP) – Indiv. Landowner
  - Conserv. Stewardship Prog (CSP) – Indiv. Landowner
  - Healthy Forest Reserve Prog (HFRP) – Indiv. Landowner
  - State Ac for Wildlife Enhance (SAFE) – Indiv. Landowner
  - Regional Conservation Partnership Prog (RCPP) – Conserv. Districts
- FSA CRP (Continuous) – Indiv. Landowner

Potential Funding Sources (Con't)

- USFWS
  - Controlled Access Livestock Fencing (CALF) Program – Indiv. Landowner
  - Partners for Wildlife – Indiv. Landowner
- TNC – Indiv. Landowner
- Arkansas Unpaved Roads Program (AEDC, AFGC, TNC) – Counties

Not Starting From Scratch

- County Conservation Districts
  - Pasture planting
  - Manure management
  - Bank stabilization
  - Streambank restoration
  - Stream exclusion with alternate water sources
  - Equipment
- NRCS
  - Pasture planting
  - Manure management
  - Bank stabilization
- US NPS
  - Bank stabilization
  - Tree planting
  - Stream fencing
- AR Grazing Land Coalition
  - Conferences
  - Field Days

Next Steps

Next Steps

- Meeting Summary – distributed to everyone attending and on email list (or address)
- Continue to elicit your input
- Prepare final draft watershed management plan
- Post web-site copy for review
- Assess comments and submit final plan to EPA for acceptance
- Stakeholders Implement the Plan

Snap Shot Reports

- Water Quality Improvement or Nonpoint Source Reduction, Control or Abatement
  - ANRC documenting water quality improvement projects, agency programs, or stakeholder activities
  - Numerous categories
    - BMPs
    - Education and Outreach
    - Monitoring
    - Others
- http://www.arkansaswater.org/ - Reporting Form

Points of Contact

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Thank You

ATTACHMENT 3:

Recommended Watershed Management Practices and Activities

There are five categories in which recommendations are being made:

1. Recommended Management Practices;
2. Recommended Monitoring;
3. Recommended Studies;
4. Recommended Awareness, Outreach and Education; and
5. Recommended Teams.

These recommendations are intended to address concerns about nutrient and E. coli levels in surface waters and groundwater, as well as concerns about erosion in the watershed, channel instability, excess sediment in streams, and stream water temperatures. Most of the recommendations below were suggested by participants in the stakeholder meetings.

Recommended Management Practices

Recommended land use management practices are provided for three land uses – pasture, forest, and ecotone (transition area from one land use type to another, such as pasture to streambank or pasture to forest) management.

Recommended pasture management practices:

- Nutrient management plans,
- Livestock stream exclusion/controlled access,
- Forest/non-forest riparian buffers,
- Pasture planting/management,
- Prescribed/rotational grazing,
- Silvopasture establishment, and
- Ponds/sediment basins.

Recommended forest management practices:

- Pre-harvest planning – skid trails, landings;
- Streamside management zones;
- Roads – water bars, diversion ditches, grade control;
- Revegetation following harvest;
- Prescribed burns; and
- Trail management.

Recommended management practices for ecotones:

- Gamebird habitat restoration,
- Streambank restoration/stabilization, and
- Filter strips/native plants.

In addition to land use management practices, karst sinkhole identification and treatments, unpaved roads erosion management, invasive or destructive species control, and identification of failing on-site wastewater treatment systems (e.g., septic systems) are also recommended. Karst sinkhole treatments include cleaning trash from sinkholes and minimizing pollutant sources around the sinkholes.

Recommended Monitoring

- Support existing monitoring and enhance those programs.
- Add total suspended solids as a constituent for analysis in the water quality samples already being collected.
- Consider adding a station at the county road downstream of Dogpatch Springs so that loading from Dogpatch Springs can be assessed.
- Support the Buffalo National River and ADEQ in developing an algae monitoring program to assess algal species and densities in the Buffalo River and its tributaries.
- Develop a trash index and implement a trash monitoring program for tributaries.

Recommended Studies

- Initiate microbial source tracking for E. coli in Flatrock Creek subwatershed, including Dogpatch Springs contributions, using quantitative polymerase chain reaction and host-specific markers.
- Support the Buffalo National River program in its diel (24 hour) monitoring of dissolved oxygen and evaluation of relationships with nutrient loading in the Buffalo River and its tributaries.
- Conduct LiDAR analysis in recommended subwatersheds, starting with Calf Creek, to assess streambank erosion using the NRCS LiDAR data that will be available in March 2018. Ground truth the LiDAR data at selected locations through Watershed Implementation or Stream Teams.
- Quantify ecosystem services in recommended subwatersheds, starting with Bear Creek subwatershed, using both market and non-market valuation approaches for better understanding and appreciation of the value of these services and quality of life in the Buffalo River watershed.

Recommended Awareness, Outreach, and Education Programs

- Support existing Buffalo National River awareness, outreach and education programs, such as
  - Leave No Trace,
  - Day-By-The Buffalo,
  - Stream and cave ecology camps,
  - Bioblitz Citizen Science, and
  - At The Waters Edge.
- Support existing Buffalo National River partners and programs, such as
  - Buffalo National River Partners,
  - Ozark Unlimited Resources,
  - Park Neighbors and Partners,
  - NorthArk/UCA Learning Center, and
  - ASU Learning Center.
- Support existing education and outreach programs by
  - Cooperative Extension Service,
  - County Conservation Districts,
  - Arkansas Unpaved Roads Program,
  - Arkansas Grazing Lands Coalition
  - Rural water utilities, and
  - Nonprofit interest groups.

Recommended Teams

- Watershed Implementation Team(s) for each recommended subwatershed to champion implementing recommended practices & activities, monitor progress, and adapt to changing conditions.
- Stream Team(s) to help monitor water quality and promote streambank restoration / stabilization, as well as encourage wildlife habitat initiatives and alternative sources of revenue.

ATTACHMENT 4

Questions Raised at the October 12 2017 Meeting and Responses

Question: Does Flatrock Creek refer to the Mill Creek subwatershed?

Response: Yes. The official USGS name for that HUC12 is Flatrock Creek. It is typically referenced as Mill Creek.

Question: Please explain the difference between forest and non-forest buffer.

Response: Forest buffers are developed by planting native tree species, which grow into forested areas with corresponding understory species. Forested riparian buffers are very effective in stabilizing and restoring streambanks as well as reducing pollutant transport and loading to streams. Non-forested buffers consist of planting native grasses which can also serve to stabilize and restore streambanks and reduce pollutant transport and loading to streams. Non-forest buffers are generally preferred next to cropland because agricultural equipment use is not impeded by trees.

Question: There have been issues with the phosphorus detection limit. Are you recommending lower detection limits?

Response: It may be feasible that a for lower phosphorus detection limit could be set as well as the addition of total nitrogen and total phosphorus analysis, but this is at the discretion of ADEQ.

Question: Is the algal monitoring by ADEQ and BNR separate efforts, or a joint effort?

Response: The proposed algal monitoring is a joint effort between the BNR and ADEQ. Both agencies are interested in implementing an algal monitoring program.

Question: On the DO study, would the six subwatersheds monitored on the three-year rotation include other subwatersheds than the recommended six?

Response: Yes. All of the currently monitored tributaries would be monitored. It is recommended this occur by partitioning the tributaries into three groups of six, with a different group of six monitored each year. This would result in each group of tributaries being monitored every three years.

Question: Once the plan is final, who benefits? Do landowners in the recommended subwatersheds have a greater likelihood of receiving funding?

Response: The desired outcome is that all stakeholders will benefit. For EPA Section 319 funds, those recommended subwatersheds would receive greater consideration for funding. Other funding programs have different priorities, but having an EPA accepted watershed management plan has influenced other agencies to fund projects within the recommended subwatersheds in the past. However, there is no assurance of funding.

Question: How does funding from EPA 319 work? Does ANRC lose the money if it doesn't get used within a certain time period?

Response: EPA provides funding to ANRC to be used within five years. Most 319 project contracts are for three to five years.

Question: What is the most efficient and likely way to get money?

Response: NRCS programs, such as EQIP, generally have more money to distribute than the 319 program. NRCS funding typically goes directly to landowners. Funding from 319 is declining. Funds are awarded to organizations, such as County Conservation Districts, who then can contract with individual landowners to implement practices.

Question: In your tables you show that it would take $1.8 million to implement practices to meet the reduction targets. How many $1.8 million projects could 319 fund?

Response: The $1.8 million estimate was for an independent application of a single management practice within the subwatershed. These cost estimates are for relative comparison among management practices. Typically, management practices are implemented as suites of practices, so the total cost to achieve the target load reduction might be less, but it could also be more, depending on the specific characteristics of the subwatershed. 319 funds do not exceed more than $75 thousand for a single cost share project. Cost share projects are subject to ANRC's Title X Agricultural cost share rules. However, 319 projects can include partnerships with other funding agencies or organizations, leveraging funds from multiple sources.

Question: It appears the primary purpose for prioritizing streams is to apportion funds. Looking at page three of the recommendations. What statutory requirements prevent the prioritization of Big Creek middle? Can you tell me what statutory requirements those are?

Response: The primary purpose of the watershed characterization was to determine in which subwatersheds there were indications that water quality has been declining over time, currently water quality is poorer than other tributaries, have natural resource concerns within the subwatershed, and have a significant portion of the subwatershed with karst geology. These subwatersheds were recommended for initial management focus. No subwatershed, with a water quality monitoring station at its mouth, was excluded, including Big Creek (middle). We looked at the same 20 criteria for all of the tributaries, regardless of the disposition of regulated/permitted facilities within the subwatershed. In fact, two of our recommended subwatersheds have permitted point sources, Marshall wastewater system discharges to Bear Creek, and the Marble Falls wastewater system discharges to Mill Creek. The statutory requirements for the program refer to which sources can be addressed through voluntary management practices. ANRC does not address regulated or permitted facilities or activities through its watershed management programs. Regulated/permitted facilities are addressed by another agency. Though issues with regulated sources can't be addressed in the plan, the plan includes tables listing all permitted and regulated facilities in the Buffalo River watershed.

Question: If the City of Marshall wants to make changes to their treatment, are there sources of funding available for that?

Response: Yes, there are loans and grants available to municipalities for upgrading treatment facilities. ANRC offers some of these loans, but not through the nonpoint source management program or 319 program.

Question: There has been a lot of talk about lack of funds to implement the practices. I think it would be good to include a recommendation to go to the governor and request special funding to jump-start implementation.

Response: Funding is generally always an issue, regardless of the program. Estimates of funds that might be required to implement management practices to achieve target loads, increase monitoring efforts, conduct additional studies, or improve outreach and education programs are included as part of the 9-elements that EPA requires in a watershed management plan. In addition, these recommendations will go to the BBRAC. Agency funding is established through the legislative process.

Question: Who is going to implement this plan?

Response: Hopefully you will - local groups, conservation districts, etc. Agencies can support implementation of projects and practices, but these are voluntary projects, implemented by stakeholders and land owners. ANRC looks for partners to implement the completed plans. For example, the Illinois River Watershed Partnership is implementing the Illinois River watershed management plan. The Beaver Watershed Alliance is implementing the Beaver watershed management plan. These partners help leverage funds for implementation. The Buffalo River watershed management plan will be one of 13 plans being implemented, so it is competing with other groups in the state for funds.

Question: How long before the draft plan will be available?

Response: We expect the final draft plan will be ready by the middle of November. We will notify people when it is uploaded to the web as we did for the recommendations.

Question: Will there be any more meetings?

Response: This is the final meeting for the Buffalo River Watershed Management Plan, but BBRAC will continue to have meetings. The public is invited to attend those meetings.

Question: Once the plan is finalized, who needs to take responsibility?

Response: As mentioned above, hopefully, stakeholders within the Buffalo River watershed will assume responsibility for implementation. The plan will be available as a guide for implementing practices. Groups in other watersheds have taken responsibility for watershed management plans.

Question: Is CRP available in Arkansas? I understand it is only available for land along streams.

Response: CRP is available in Arkansas. There are programs for both cropland and “marginal pasture”. Marginal pasture means pasture along streams. For cropland, land away from streams can be entered in CRP.

Question: Can a project that includes practices not listed in the watershed management plan get funding?

Response: Yes. The plan isn’t intended to exclude any practices. It includes those practices that stakeholders have identified and those that have been accepted by stakeholders and implemented in other watersheds. There are many additional practices that can also improve water quality.

Question: Is there a reason why not all stakeholder recommendations have been included?

Response: We are documenting all recommendations provided by stakeholders. Some of these are not directly related to water quality, so we haven't included them in the list of recommendations. However, we are providing all stakeholder recommendations to the BBRAC for consideration as well to other respective agencies that are not part of the BBRAC, such as the Arkansas Economic Development Commission. There were several stakeholder recommendations for economic activities that are not part of water quality management.

Question: When the watershed management plan is final, what organizations will be notified that it is ready, and how does that happen?

Response: In the past, word of mouth has been the most effective in announcing the EPA accepted watershed management plan is available. The plan will be uploaded to the arkansaswater.org website. ANRC usually sends out emails to some agencies. The fact that the plan is final will also be reported at the annual nonpoint source program meeting, which most of the relevant agencies attend, and in the program annual report.

Question: You have included streambank stabilization as a recommendation. I had rock vanes installed along an eroding streambank and it really helped. Would that be an option that could be included under the streambank stabilization recommendation?

Response: Yes. There are a number of streambank restoration and stabilization practices that are applicable and available for cost-share from different agencies.

Question: It would be helpful to include specific information describing how to use the LiDAR data, and quantify ecosystem services, including references.

Response: The plan includes more information and details about how these proposed studies could be conducted.

Question: It seems like water quality in the lower part of the Buffalo River watershed would be better because there is more water to diffuse pollutants. Is that the case?

Response: Discharge increases downstream in the watershed, which could increase dilution. However, it depends on where in the watershed the contaminant source is located to be able to answer this question.

Question: You have discussed E. coli, but I am concerned about poisons in the water from pesticides and herbicides. Are those a threat to swimmers? Also, I am interested in participating in a stream team.

Response: Pesticides can be harmful to swimmers depending on the particular pesticide and concentration. There has been some monitoring of pesticides and herbicides in the past.

Comment: You have recommended diurnal DO studies. It would be very helpful if all parameters needed for ADEQ to assess nutrients were monitored.

Response: Our understanding is that the parameters needed for ADEQ to assess nutrients include monitoring data for diurnal DO, total phosphorus and total nitrogen, and aquatic communities status. ADEQ is currently analyzing BNR samples for total phosphorus and total nitrogen. The National Park Service Heartland program does routine monitoring of aquatic invertebrates and fisheries, and BNR personnel are working with ADEQ to develop an algae monitoring program.

Comment: Seems like it would be helpful/useful for the agencies to work together to locate sanitary sewer lines, and locations with septic tanks. This could be used to target education efforts, or repair programs.

Response: This comment will be provided to the Arkansas Department of Health (ADH).

Comment: It would also be helpful to know where private wells are. Private well owners could need outreach and education regarding how to protect their wells from contamination, and how to get the water tested if they are concerned.

Response: This comment will be provided to ADEQ and ADH

Comment: I suggest you not rely on money so much as an incentive. Government funding of those programs in the future is likely to decrease. Other incentives, such as getting influential local people interested and involved, can also be effective.

Response: Agreed

Comment: Every county should have a copy of the plan someplace where it is easy to access, e.g., the conservation district, or courthouse.

Response: The plan will be available on the www.arkansaswater.org website and the Conservation Districts will be notified.

APPENDIX C

Historical Water Quality Data Inventory

Table C.1. Inventory of surface water quality monitoring in Buffalo River watershed.

Organization name	Station Id	Stream	Start Year	End Year*
USGS	07055646	Buffalo R	1993	2016
USGS	07055680	Buffalo R	1964	1988
USGS	07055688	Little Buffalo R	1994	1995
USGS	07055696	Shop Cr	1994	1995
USGS	07055700	Little Buffalo R	1963	1988
USGS	07055790	Big Cr	2014	2015
USGS	07055794	Big Cr	2014	2014
USGS	07055807	Left Fork Big Cr	2014	2014
USGS	07055814	Big Cr	2014	2016
USGS	07055866	Unnamed trib of Richland Cr	2002	2002
USGS	07055875	Richland Cr	1992	1999
USGS	07055885	Richland Cr	1999	1999
USGS	07055893	Calf Creek	2001	2006
USGS	07056000	Buffalo R	1945	2004
USGS	07056507	Bear Cr	1983	1986
USGS	07056510	Bear Cr	1964	1999
USGS	07056515	Bear Cr	1999	2016
USGS	07056545	Bear Cr	2001	2002
USGS	07056695	Water Cr	1994	2006
USGS	07056700	Buffalo R	1979	1982
USGS	07057000	Buffalo R	1945	1988
USGS	07057100	Big Cr	1963	2006
USNPS	BUFF_CARV1	Buffalo R	2013	2015
USNPS	BUFF_GILB1	Buffalo R	2006	2006
USNPS	BUFF_LWBC1	Buffalo R	2005	2005
USNPS	BUFF_PRUT1	Buffalo R	2005	2015
USNPS	BUFF_RUSH1	Buffalo R	2006	2015
USNPS	BUFF_TYLE1	Buffalo R	2006	2015
USNPS	BUFFR01	Buffalo R	1989	1989
USNPS	BUFFR02	Buffalo R	1989	1989
USNPS	BUFROZARK	Buffalo R	2009	2009
USNPS	BUFERBIE	Buffalo R	2009	2009
USNPS	BUFR0150	Buffalo R	2007	2007
USNPS	BUFR0220	Buffalo R	2007	2007
USNPS	BUFR0258	Buffalo R	2007	2007
USNPS	BUFR0262	Buffalo R	2007	2007
USNPS	BUFR0269	Buffalo R	2007	2007
USNPS	BUFR0280	Buffalo R	2007	2007
ADEQ, USNPS	BUFR01	Buffalo R	1985	2016
ADEQ, USNPS	BUFR02	Buffalo R	1985	2016
ADEQ, USNPS	BUFR03	Buffalo R	1985	2016
ADEQ, USNPS	BUFR0304	Buffalo R	2010	2016
ADEQ, USNPS	BUFR04	Buffalo R	1985	2016
USNPS	BUFR0414	Buffalo R	2007	2015
USNPS	BUFR0415	Buffalo R	2013	2015
ADEQ, USNPS	BUFR05	Buffalo R	1985	2016
ADEQ, USNPS	BUFR05.9	Buffalo R	2000	2001

Table C.1. Inventory of surface water quality monitoring in Buffalo River watershed (continued).

Organization name	Station Id	Stream	Start Year	End Year*
USNPS	BUFR0586	Buffalo R	2007	2007
USNPS	BUFR0587	Buffalo R	2007	2007
USNPS	BUFR0589	Buffalo R	2007	2007
ADEQ, USNPS	BUFR06	Buffalo R	1985	2016
ADEQ, USNPS	BUFR06.1	Buffalo R	2000	2001
USNPS	BUFR0677	Buffalo R	2007	2007
ADEQ, USNPS	BUFR07	Buffalo R	1985	2016
USNPS	BUFR0720	Buffalo R	2007	2007
ADEQ, USNPS	BUFR08	Buffalo R	1985	2016
ADEQ, USNPS	BUFR09	Buffalo R	1985	2016
ADEQ, USNPS	BUFR100	Buffalo R	2001	2002
ADEQ, USNPS	BUFT01	Beech Cr	1985	2016
ADEQ, USNPS	BUFT02	Ponca Cr	1985	2016
ADEQ, USNPS	BUFT03	Cecil Cr	1985	2016
ADEQ, USNPS	BUFT04	Mill Cr	1985	2016
ADEQ, USNPS	BUFT401	Mill Cr	2009	2011
ADEQ, USNPS	BUFT402	Mill Cr	2009	2011
USNPS	BUFT403	Mill Cr	2009	2011
ADEQ, USNPS	BUFT405	Harp Cr	2009	2011
USNPS, USNPS	BUFT406	Flatrock Cr	2009	2011
USNPS, USNPS	BUFT407	Mill Cr	2011	2011
ADEQ, USNPS	BUFT05	Little Buffalo R	1985	2016
ADEQ, USNPS	BUFT06	Big Cr	1985	2016
ADEQ, USNPS	BUFT07	Davis Cr	1985	2016
ADEQ, USNPS	BUFT08	Cave Cr	1985	2016
ADEQ, USNPS	BUFT09	Richland Cr	1985	2016
ADEQ, USNPS	BUFT10	Calf Cr	1985	2016
ADEQ, USNPS	BUFT11	Mill Cr	1985	2016
ADEQ, USNPS	BUFT11.5	Dry Cr	2000	2015
ADEQ, USNPS	BUFT12	Bear Cr	1985	2016
ADEQ	BUFT1201	Bear Cr	2001	2005
ADEQ, USNPS	BUFT13	Brush Cr	1985	2016
ADEQ, USNPS	BUFT14	Tomahawk Cr	1985	2016
ADEQ, USNPS	BUFT15	Water Cr	1985	2016
ADEQ, USNPS	BUFT16	Rush Cr	1985	2016
ADEQ, USNPS	BUFT17	Clabber Cr	1985	2016
ADEQ, USNPS	BUFT18	Big Cr	1985	2016
ADEQ, USNPS	BUFT19	Cedar Cr	1995	1995
ADEQ, USNPS	BUFT23	Middle Cr	1985	2016
ADEQ, USNPS	BUFT24	Leatherwood Cr	1985	2016
ADEQ, USNPS	BUFT25	Little Buffalo R	1993	1993
ADEQ, USNPS	BUFT26	Little Buffalo R	1993	1993
ADEQ, USNPS	BUFT501	East Fork Little Buffalo R	2001	2002
ADEQ, USNPS	BUFT601	East Fork Big Cr	2001	2002
ADEQ, USNPS	BUFT602	West Fork Big Cr	2001	2002
ADEQ, USNPS	BUFT801	Cave Cr	2001	2002
ADEQ, USNPS	BUFT901	Richland Cr	2001	2002
ADEQ, USNPS	BUFT902	Richland Cr	2001	2002

Table C.1. Inventory of surface water quality monitoring in Buffalo River watershed (continued).

Organization name	Station Id	Stream	Start Year	End Year*
ADEQ, USNPS	BUFT903	Falling Water Cr	2001	2002
EPA NARS	OWW04440-0325		2004	2004
ADEQ	UWBRK01	Bear Cr	1994	2016
ADEQ	WHI0049	Buffalo R	2002	2011
ADEQ	WHI0049A	Buffalo R	1990	2016
ADEQ	WHI0152	Big Cr	1998	2003
ADEQ	WHI0154	Bear Cr	1999	1999
ADEQ	WHI0155	Cave Cr	1999	2016
ADEQ	WHI0210	Harp Cr	2016	2016
ADEQ	WHI0211	Mill Cr	2016	2016
ADEQ	WHI0212	Unnamed Trib of Mill Cr	2016	2016
ADEQ	WHI0213	Mill Cr	2016	2016
UofA	Field 1	Big Cr (upper)	2014	2016
UofA	Field 5a	Big Cr (upper)	2014	2016
UofA	Field 12	Big Cr (upper)	2014	2016
UofA	Ephemeral stream on C&H farm	Big Cr (upper)	2014	2016
UofA	Site 2 - upstream of C&H farm	Big Cr (upper)	2013	2016
UofA	Site 5 - downstream of C&H farm	Big Cr (upper)	2013	2016
UofA	Site 3 - upstream of C&H barn	Big Cr (upper)	2013	2014
UofA	Site 4 - downstream of C&H barn	Big Cr (upper)	2013	2014
UofA	Left fork	Left fork Big Creek	2015	2016
ADEQ	LRC0001	Richland Creek	1994	1997
ADEQ	URC001	Richland Creek	1994	1994
Nix	BC1	Big Creek	2014	2016
Nix	BC2	Big Creek	2014	2016
Nix	BC3	Big Creek	2015	2016
Nix	BC4	Big Creek	2014	2016
Nix	BC5	Big Creek	2014	2016
Nix	BC6	Big Creek	2014	2016
Nix	BC7	Big Creek	2014	2016
Nix	BC7A	Big Creek	2014	2016
Nix	BC8	Big Creek	2015	2016
Nix	LFBC1	Left Fork Big Creek	2014	2016
Nix	LFBC3	Left Fork Big Creek	2014	2016
Nix	B1	Buffalo River	2014	2016
Nix	B2	Buffalo River	2014	2016

*As of January 2017

Table C.2. Inventory of groundwater and spring water quality sampling locations in the Buffalo River watershed.

Organization name	Station Id	Spring/Aquifer	Start Year	End Year*
USNPS	BUF03S01	Fitton Cave Spring/ Springfield aquifer	2010	2010
USNPS	BUF03S02	VanDyke Spring	2010	2010
ADEQ, USNPS	BUF04S02	Boiling Spring	2009	2009
USNPS	BUF06S01	Limekin Hollow Spring	2010	2010
ADEQ	BUF14S02	Pyramid Spring	2005	2006
ADEQ	BUF14S03	Blue Heron Spring	2005	2006
ADEQ	BUF14S04	Lucky Dog Mine Spring	2005	2006
ADEQ	BUFCS500	John Eddings Cave Spring	2001	2004
ADEQ, USNPS	BUFCS501	Elm Spring	2001	2010
USNPS	BUFCS701	Maumee Spring	2010	2010
ADEQ	BUFES003	Glencoe Spring	2005	2006
ADEQ	BUFS02	Luallen Spring	1985	2016
ADEQ	BUFS33	Mitch Hill Spring/ Ozark aquifer	1985	2016
ADEQ	BUFS41	Gilbert Spring	1985	2016
ADEQ	BUFS700	Yardell Spring	2001	2004
ADEQ	BUFS701	Yardell Branch Spring	2002	2002
ADEQ	BUFS703	Shaddox Spring/Brook Spring	2001	2002
USGS	354455093033801	Atoka Formation	2002	2002
USGS	354553092560201	Unnamed seep	2013	2013
USGS	354750092560101	Well, unknown aquifer	2013	2013
USGS	355142093140101	Unnamed seep	2013	2013
USGS	355202092425201	Ozark Plateaus aquifer	1993	1993
USGS	355224092561001	Unnamed seep	2013	2013
USGS	355434092375601	Roubidoux Formation	1956	1958
USGS	355722093093401	Roubidoux Formation	1977	1980
USGS	360014093112901	Everton Formation	1970	1995
USGS	360400092310001	Ordovician aquifer	1993	1993
USGS	360527092442001	Everton Formation	1995	1995
USGS	360549092363001	Everton Formation	1995	1995
USGS	360656093070601	Gunter Sandstone	1972	2016
USGS	360837092415801	Everton Formation/ Ozark aquifer	1995	1995
UofA	Site 1 - spring	Spring on C&H farm/ Springfield aquifer	2013	2016
UofA	House well at C&H farm	Springfield aquifer	2015	2016
UofA	Interceptor trench 1 at C&H farm	Springfield aquifer	2014	2016
UofA	Interceptor trench 2 at C&H farm	Springfield aquifer	2014	2016

* As of January 2017

APPENDIX D

Water Quality Data Trend Analysis

WATER QUALITY TREND ANALYSIS

For this plan, we evaluated trends at 33 surface water quality monitoring locations and three spring monitoring locations in the watershed with a period of record of at least 10 years, ending no later than 2010. Fecal coliforms, inorganic nitrogen, and turbidity were analyzed for trends at these stations. These data do not meet the criteria for linear regression analysis, so an alternative method of identifying and evaluating trends was used. In this method, the data from long term sampling locations from 1985 through 2015 were divided into three groups that corresponded to the following 10-year periods, 1985 through 19941995 through 2004, and 2005 through 2015. The combined data for the ten year periods1985-1994, 1995-2004, and 2005-2015, were then compared.

Median values from these three periods were compared, using their 95% confidence intervals. Notched box and whisker plots show the 95% confidence interval for the median values. When the box notches representing the 95% confidence interval around the median do not overlap, the medians are statistically significantly different. This indicates, with 95% confidence, that the water quality during one period is different from the other. The notched box and whisker plots for each of the long term water quality monitoring stations, for fecal coliforms, inorganic nitrogen, and turbidity are included at the end of this appendix. Tables D-1 through D-4 summarize the results of the trend evaluations.

Table D.1. Dissolved Oxygen trends evaluation.

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
Little BR	BUFT05	110100050104	50	9.60	39	9.70	76	10.50	Increase	Increase	Increase
Beech Cr	BUFT01	110100050202	31	10.00	22	11.60	23	11.20	**Increase**	Decrease	Increase
BR @ Wild Area	BUFR01, 07055646	110100050203	90	9.05	114	9.50	100	10.60	Increase	**Increase**	**Increase**
Luallen Spr	BUFS02	110100050203	43	9.00	38	9.80	46	9.94	Increase	Increase	Increase
Cecil Cr	BUFT03	110100050204	48	9.35	38	9.65	51	9.90	Increase	Increase	Increase
BR @ Ponca	BUFR02	110100050205	73	9.40	43	9.80	53	10.01	Increase	Increase	Increase
Ponca Cr	BUFT02	110100050205	50	9.50	37	10.20	38	10.79	Increase	Increase	Increase
Mill Cr mouth	BUFT04	110100050206	57	9.30	39	10.20	149	9.90	Increase	Decrease	Increase
BR @ Pruitt Ac	BUFR03	110100050207	74	9.10	42	10.30	116	9.20	Increase	Decrease	Increase
Big Cr Carver	BUFT06, 07055814	110100050303	52	9.40	43	9.80	177	10.20	Increase	Increase	Increase
BR @ Hasty	BUFR04	110100050303	70	9.40	42	10.40	56	9.41	Increase	Decrease	NC
Cave Cr mouth	BUFT08	110100050305	48	9.35	42	9.40	46	10.27	Increase	Increase	Increase
Richland Cr mouth	BUFT09	110100050308	43	10.00	35	10.70	52	10.14	Increase	Decrease	Increase
BR @ Woolum	BUFR05	110100050309	71	9.90	42	10.50	41	10.30	Increase	Decrease	Increase
Davis Cr	BUFT07	110100050309	52	9.50	43	9.90	47	10.58	Increase	Increase	Increase
Mitch Hill Spr	BUFS33	110100050309	49	8.10	46	8.50	48	8.27	Increase	Decrease	Increase
Calf Cr	BUFT10	110100050401	51	9.40	43	9.70	45	10.21	Increase	Increase	Increase
Bear Cr @ Hwy65	UWBRK01	110100050404	ND	ND	82	9.10	11	8.80	ND	Decrease	ND
Bear Cr mouth	BUFT12	110100050404	53	9.60	45	10.30	44	10.70	Increase	Increase	**Increase**
Brush Cr	BUFT13	110100050405	41	9.80	36	10.40	33	10.40	Increase	NC	Increase
BR @ Gilbert Ac	BUFR06	110100050406	71	9.70	44	10.46	43	10.80	Increase	Increase	**Increase**
BR @ Hwy65	WHI0049A	110100050406	43	10.00	93	8.80	130	9.54	**Decrease**	Increase	Decrease

Table D.1. Dissolved Oxygen trends evaluation (continued).

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
Gilbert Spr	BUFS41	110100050406	47	8.80	58	8.80	53	9.20	NC	Increase	Increase
Mill Cr L	BUFT11	110100050406	49	9.90	38	10.10	44	10.50	Increase	Increase	Increase
Tomahawk Cr	BUFT14	110100050407	54	9.80	42	10.45	45	10.70	Increase	Increase	**Increase**
Water Cr	BUFT15	110100050408	48	9.70	39	10.00	43	11.20	Increase	Increase	**Increase**
Rush Cr	BUFT16	110100050501	51	9.80	42	10.45	45	10.44	Increase	NC	Increase
BR @ Hwy 14	BUFR07	110100050502	72	9.65	41	10.60	44	10.65	Increase	Increase	Increase
BR @ Rush Ac	BUFT08	110100050502	72	9.10	41	9.80	43	10.00	Increase	Increase	Increase
Clabber Cr	BUFT17	110100050503	50	9.90	43	10.84	46	10.55	Increase	Decrease	Increase
Big Cr L	BUFT18	110100050507	37	9.20	34	9.80	41	9.85	Increase	Increase	Increase
BR Mouth	BUFR09	110100050508	54	9.95	33	10.40	47	9.84	Increase	Decrease	Decrease
Leatherwood Cr	BUFT23	110100050508	37	8.40	34	9.35	41	10.00	Increase	Increase	Increase
Middle Cr	BUFT23	110100050508	37	9.00	34	9.80	41	9.87	Increase	Increase	Increase

ND= no data for this period
NC= no change, i.e., medians are within 0.05 mg/L

Table D-2. Fecal Coliform trends evaluation.

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	**Median**	**N**	**Median**	**N**	**Median**	**1985-1994 to 1995-2004**	**1995-2004 to 2005-2015**	**1985-1994 to 2005-2015**
Little BR	BUFT05	110100050104	69	10.0	41	13.0	44	24.0	Increase	Increase	**Increase**
Beech Cr	BUFT01	110100050202	41	12.0	23	10.0	23	13.0	Decrease	Increase	NC
BR @ Wild Area	BUFR01, 07055646	110100050203	107	6.0	115	10.0	47	13.0	Increase	Increase	Increase
Luallen Spr	BUFS02	110100050203	77	4.0	40	3.0	47	6.0	Decrease	Increase	Increase
Cecil Cr	BUFT03	110100050204	62	8.5	39	21.0	58	24.0	Increase	Increase	**Increase**
Ponca Cr	BUFT02	110100050205	65	6.0	39	9.0	40	15.0	Increase	Increase	Increase
BR @ Ponca	BUFR02	110100050205	89	16.0	43	38.0	50	24.5	**Increase**	Decrease	Increase
Mill Cr mouth	BUFT04	110100050206	74	18.0	41	26.0	60	72.5	Increase	**Increase**	**Increase**
BR @ Pruitt Ac	BUFR03	110100050207	88	6.0	42	18.0	55	12.0	**Increase**	Decrease	**Increase**
BR @ Hasty	BUFR04	110100050303	85	6.0	41	12.0	47	11.0	Increase	NC	Increase
Big Cr Carver	BUFT06, 07055814	110100050303	68	8.0	45	8.0	52	21.5	NC	Increase	**Increase**
Cave Cr mouth	BUFT08	110100050305	62	8.0	43	11.0	48	23.5	increase	increase	**Increase**

Table D-2. Fecal Coliform trends evaluation (continued).

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
Richland Cr mouth	BUFT09	110100050308	60	17.5	34	11.0	40	12.0	Decrease	NC	Decrease
Mitch Hill Spr	BUFS33	110100050309	64	2.0	45	7.0	46	11.5	Increase	Increase	**Increase**
Davis Cr	BUFT07	110100050309	68	13.5	44	26.5	47	29.0	Increase	Increase	Increase
BR @ Woolum	BUFR05	110100050309	83	2.0	42	3.5	41	5.0	Increase	Increase	Increase
Calf Cr	BUFT10	110100050401	67	16.0	42	20.0	43	12.0	Increase	Decrease	Decrease
Bear Cr mouth	BUFT12	110100050404	65	20.0	42	20.0	46	13.5	NC	Decrease	Decrease
Brush Cr	BUFT13	110100050405	46	8.5	36	20.5	35	18.0	Increase	Decrease	Increase
Mill Cr L	BUFT11	110100050406	65	10.0	42	9.0	44	14.5	NC	Increase	Increase
BR @ Gilbert Ac	BUFR06	110100050406	85	4.0	43	9.0	45	4.0	Increase	Decrease	NC
Gilbert Spr	BUFS41	110100050406	50	10.0	61	11.0	45	5.0	NC	Decrease	Decrease
Tomahawk Cr	BUFT14	110100050407	70	54.0	42	56.5	43	31.0	Increase	Decrease	Decrease
Water Cr	BUFT15	110100050408	66	6.0	39	8.0	44	15.0	Increase	Increase	**Increase**
Rush Cr	BUFT16	110100050501	67	8.0	43	7.0	44	11.0	NC	Increase	Increase

Table D-2. Fecal Coliform trends evaluation (continued).

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
BR @ Hwy 14	BUFR07	110100050502	85	2.0	43	9.0	46	6.0	Increase	Decrease	Increase
BR @ Rush Ac	BUFT08	110100050502	84	4.0	42	5.5	43	7.0	Increase	Increase	Increase
Clabber Cr	BUFT17	110100050503	67	20.0	43	15.0	45	10.0	Decrease	Decrease	Decrease
Big Cr L	BUFT18	110100050507	46	5.5	35	14.0	45	19.0	**Increase**	Increase	**Increase**
Middle Cr	BUFT23	110100050508	47	8.0	35	9.0	43	13.0	NC	Increase	Increase
Leatherwood Cr	BUFT23	110100050508	48	15.5	35	22.0	44	10.5	Increase	Decrease	Decrease
BR Mouth	BUFR09	110100050508	65	2.0	34	2.0	44	6.0	NC	Increase	**Increase**

ND= no data for this period
NC= no change, i.e., medians are within 1 cfu/100mL

Table D-3. Inorganic nitrogen trends evaluation.

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
Little BR	BUFT05	110100050104	37	0.050	41	0.099	44	0.075	Increase	Decrease	Increase
Beech Cr	BUFT01	110100050202	25	0.010	23	0.041	25	0.044	Increase	increase	Increase
BR @ Wild Area	BUFR01, 07055646	110100050203	80	0.008	114	0.000	67	0.025	Decrease	**Increase**	**Increase**
Luallen Spr	BUFS02	110100050203	38	0.220	40	0.190	45	0.193	Decrease	Increase	Decrease
Cecil Cr	BUFT03	110100050204	24	0.020	40	0.045	43	0.032	Increase	Decrease	Increase
BR @ Ponca	BUFR02	110100050205	59	0.045	41	0.071	55	0.072	Increase	NC	**Increase**
Ponca Cr	BUFT02	110100050205	37	0.060	39	0.121	41	0.113	**Increase**	Decrease	**Increase**
Mill Cr mouth	BUFT04	110100050206	43	0.438	41	0.581	50	0.727	Increase	Increase	**Increase**
BR @ Pruitt Ac	BUFR03	110100050207	55	0.024	41	0.049	48	0.032	Increase	Decrease	increase
Big Cr Carver	BUFT06, 07055814	110100050303	37	0.121	43	0.130	66	0.132	Increase	Increase	Increase
BR @ Hasty	BUFR04	110100050303	55	0.060	40	0.080	47	0.079	Increase	NC	increase
Cave Cr mouth	BUFT08	110100050305	23	0.046	41	0.086	47	0.089	Increase	Increase	Increase
Richland Cr mouth	BUFT09	110100050308	24	0.030	36	0.046	53	0.045	Increase	NC	Increase
BR @ Woolum	BUFR05	110100050309	51	0.060	41	0.105	45	0.132	Increase	Increase	Increase
Davis Cr	BUFT07	110100050309	36	0.205	43	0.337	47	0.637	**Increase**	**Increase**	**Increase**
Mitch Hill Spr	BUFS33	110100050309	34	0.510	45	0.828	45	1.160	**Increase**	**Increase**	**Increase**

Table D-3. Inorganic nitrogen trends evaluation (continued).

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
Calf Cr	BUFT10	110100050401	25	0.230	44	0.321	45	0.337	Increase	Increase	Increase
Bear Cr mouth	BUFT12	110100050404	27	0.100	45	0.245	47	0.313	**Increase**	Increase	**Increase**
Brush Cr	BUFT13	110100050405	18	0.515	35	0.570	36	0.770	Increase	**Increase**	**Increase**
BR @ Gilbert Ac	BUFR06	110100050406	50	0.065	41	0.100	46	0.094	Increase	Decrease	Increase
BR @ Hwy65	UWBRK01	110100050406	48	0.065	116	0.090	133	0.100	Increase	Increase	**Increase**
Gilbert Spr	BUFS41	110100050406	33	0.780	57	0.920	44	0.873	**Increase**	Decrease	Increase
Mill Cr L	BUFT11	110100050406	23	0.292	42	0.296	44	0.273	Increase	Decrease	Decrease
Tomahawk Cr	BUFT14	110100050407	40	0.225	42	0.346	44	0.382	Increase	Increase	**Increase**
Water Cr	BUFT15	110100050408	21	0.090	37	0.147	43	0.245	Increase	Increase	**Increase**
Rush Cr	BUFT16	110100050501	41	0.110	42	0.215	45	0.233	**Increase**	Increase	**Increase**
BR @ Hwy 14	BUFR07	110100050502	54	0.055	41	0.090	44	0.101	Increase	Increase	Increase
BR @ Rush Ac	BUFT08	110100050502	53	0.060	40	0.073	42	0.071	Increase	Increase	Increase
Clabber Cr	BUFT17	110100050503	40	0.040	41	0.103	46	0.052	Increase	Decrease	Increase
Big Cr L	BUFT18	110100050507	18	0.040	35	0.111	43	0.132	Increase	Increase	**Increase**
BR Mouth	BUFR09	110100050508	27	0.040	34	0.045	45	0.066	Increase	Increase	Increase
Leatherwood Cr	BUFT23	110100050508	19	0.020	35	0.029	43	0.000	Increase	**Decrease**	**Decrease**
Middle Cr	BUFT23	110100050508	19	0.010	35	0.025	42	0.000	Increase	**Decrease**	Decrease

ND= no data for this period
NC= no change, i.e., medians are within 0.002 mg/L

Table D-4. Turbidity trends evaluation.

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
Little BR	BUFT05	110100050104	54	1.4	41	1.4	86	1.9	NC	Increase	Increase
Beech Cr	BUFT01	110100050202	29	5.5	23	5.6	24	5.2	NC	Decrease	Decrease
BR @ Wild Area	BUFR01, 07055646	110100050203	60	2.5	43	2.1	83	2.8	Decrease	Increase	Increase
Luallen Spr	BUFS02	110100050203	50	1.4	40	2.0	47	2.0	Increase	NC	Increase
Cecil Cr	BUFT03	110100050204	47	1.8	39	1.8	52	1.8	NC	NC	NC
Ponca Cr	BUFT02	110100050205	50	1.7	39	1.7	41	1.7	NC	NC	NC
BR @ Ponca	BUFR02	110100050205	65	1.3	43	1.5	58	1.9	Increase	Increase	Increase
Mill Cr mouth	BUFT04	110100050206	59	2.2	41	1.7	155	2.1	Decrease	Increase	NC
BR @ Pruitt Ac	BUFR03	110100050207	66	1.3	42	1.4	122	1.4	NC	NC	NC
BR @ Hasty	BUFR04	110100050303	62	1.5	42	1.6	58	1.7	NC	NC	Increase
Big Cr Carver	BUFT06, 07055814	110100050303	54	1.8	45	1.7	220	2.1	NC	Increase	increase
Cave Cr mouth	BUFT08	110100050305	50	1.3	44	1.0	55	1.5	Decrease	Increase	Increase
Richland Cr mouth	BUFT09	110100050308	44	3.2	34	2.4	53	2.8	Decrease	Increase	Decrease
Mitch Hill Spr	BUFS33	110100050309	52	0.7	47	0.7	51	0.9	NC	Increase	Increase

Table D-4. Turbidity trends evaluation (continued).

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
Davis Cr	BUFT07	110100050309	53	0.5	45	0.5	52	0.6	NC	NC	NC
BR @ Woolum	BUFR05	110100050309	60	1.3	42	1.4	50	1.8	NC	Increase	Increase
Calf Cr	BUFT10	110100050401	56	2.1	45	1.2	45	1.1	**Decrease**	NC	**Decrease**
Bear Cr mouth	BUFT12	110100050404	57	1.4	44	1.4	51	1.8	NC	Increase	Increase
Brush Cr	BUFT13	110100050405	40	0.5	36	0.4	35	0.6	NC	Increase	NC
Mill Cr L	BUFT11	110100050406	51	0.7	43	0.5	44	0.7	Decrease	Increase	NC
BR @ Hwy65	UWBRK01	110100050406	195	2.2	114	2.2	134	2.1	NC	NC	NC
BR @ Gilbert Ac	BUFR06	110100050406	60	1.8	43	1.8	47	1.6	NC	Decrease	Decrease
Gilbert Spr	BUFS41	110100050406	50	0.9	62	1.0	56	1.1	NC	NC	Increase
Tomahawk Cr	BUFT14	110100050407	58	0.9	43	0.8	51	0.8	NC	NC	NC
Water Cr	BUFT15	110100050408	51	0.6	39	0.4	46	0.6	**Decrease**	Increase	NC
Rush Cr	BUFT16	110100050501	52	0.6	44	0.6	48	0.6	NC	NC	NC
BR @ Hwy 14	BUFR07	110100050502	61	1.3	43	1.3	49	1.5	NC	Increase	Increase
BR @ Rush Ac	BUFT08	110100050502	59	1.2	42	1.4	48	1.5	Increase	NC	Increase

Table D-4. Turbidity trends evaluation (continued).

Location Name	Station ID(s)	HUC12	1985-1994		1995-2004		2005-2015		Change between periods		
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015
Clabber Cr	BUFT17	110100050503	52	0.6	44	0.5	50	0.7	NC	Increase	NC
Big Cr L	BUFT18	110100050507	40	0.6	34	0.8	56	0.8	Increase	Increase	**Increase**
Middle Cr	BUFT23	110100050508	39	0.4	35	0.4	45	0.4	NC	NC	NC
Leatherwood Cr	BUFT23	110100050508	40	0.5	35	0.6	47	0.5	NC	NC	NC
BR Mouth	BUFR09	110100050508	46	1.5	34	1.0	52	1.5	Decrease	Increase	NC

ND= no data for this period
NC= no change, i.e., medians are within 0.1 mg/L

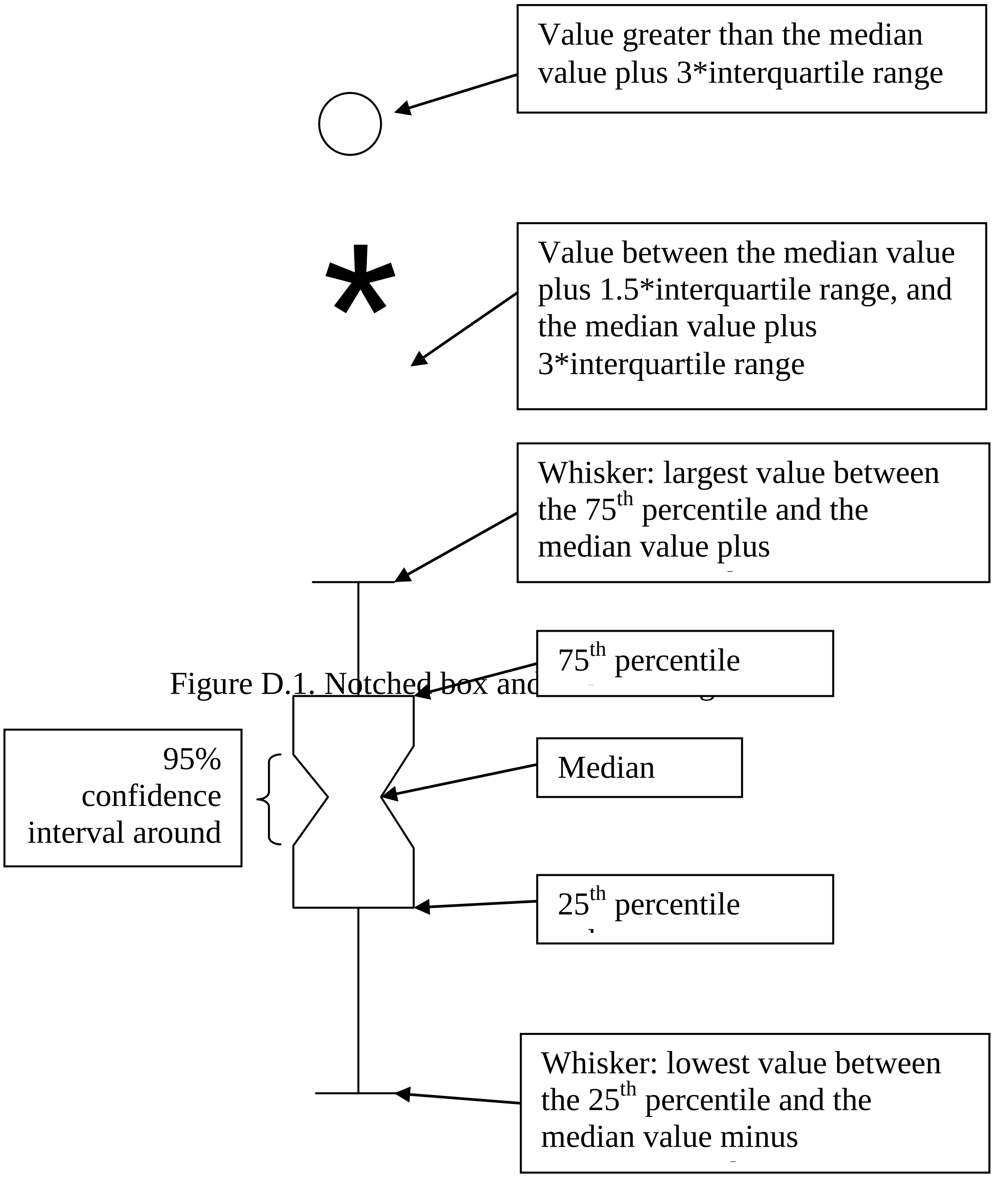


Figure D.1. Notched box and

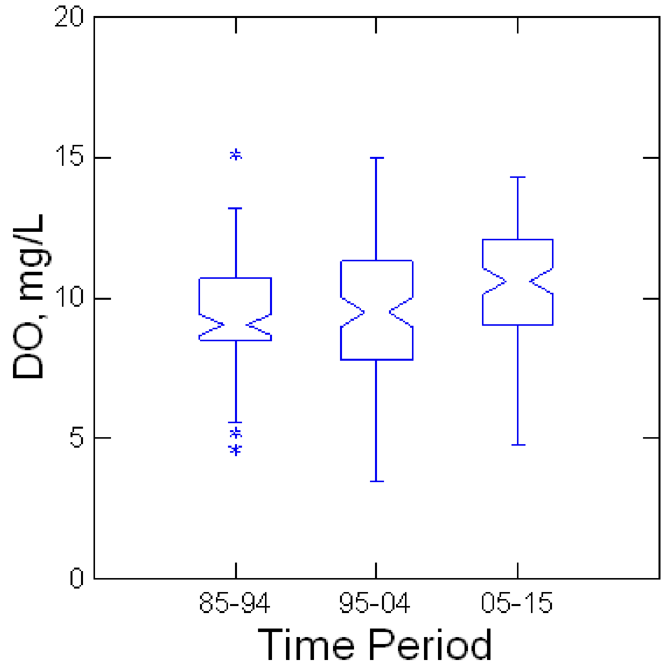
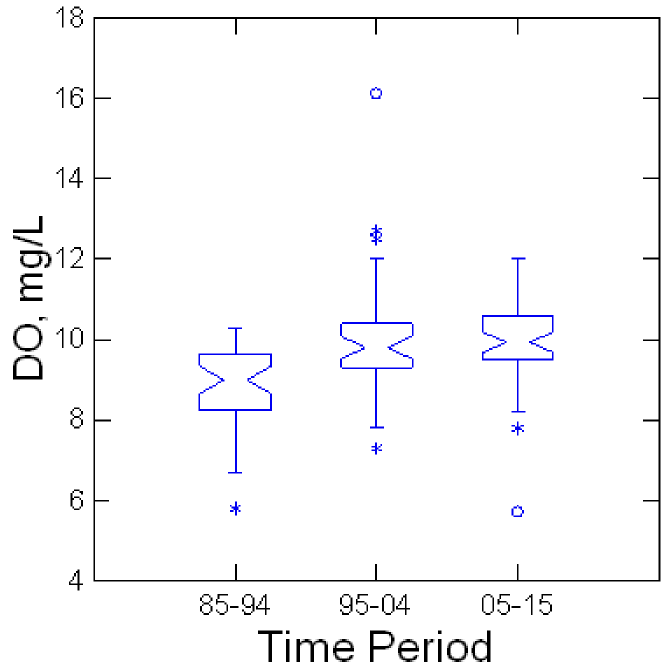


Figure D.2 Box plot of DO data from Buffalo River at the Wilderness Area Boundary.

Figure D.3 Box plot of DO data from Luallen Spring by period.



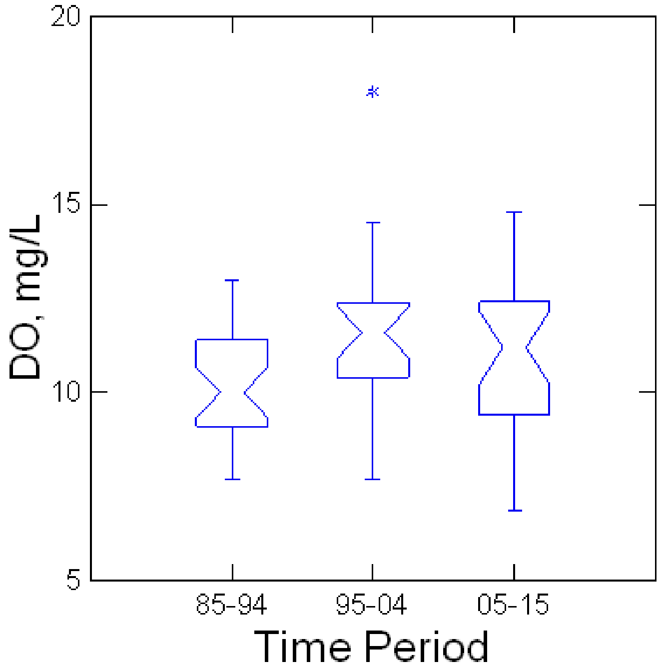


Figure D.4 Box plot of DO data from Beech Creek by period.

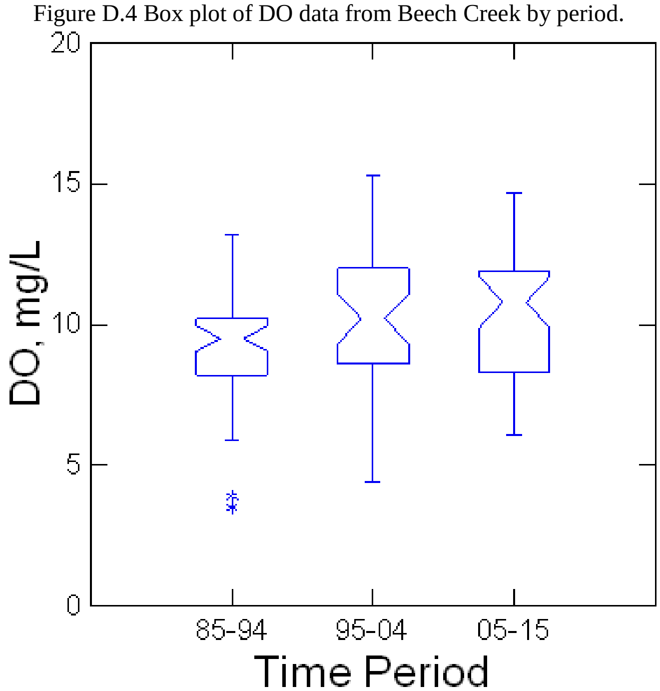


Figure D.5 Box plot of DO data from Ponca Creek by period.

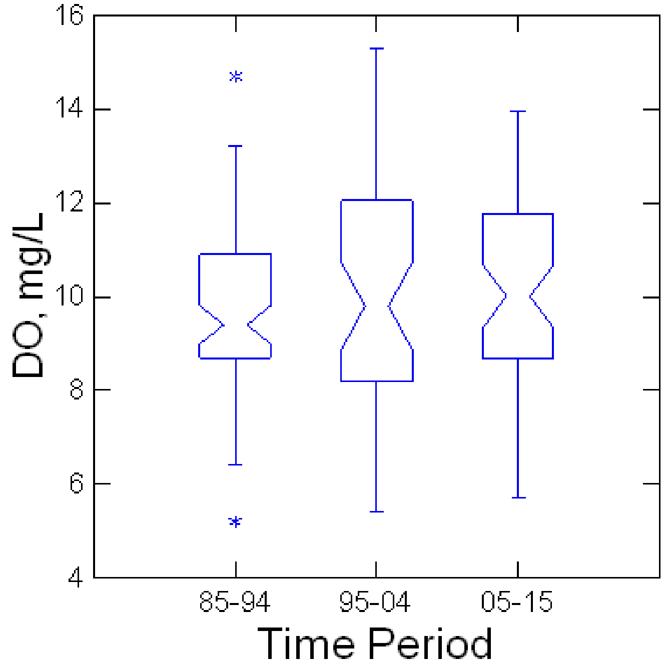


Figure D.6 Box plot of DO data from Buffalo River at Ponca access by period.

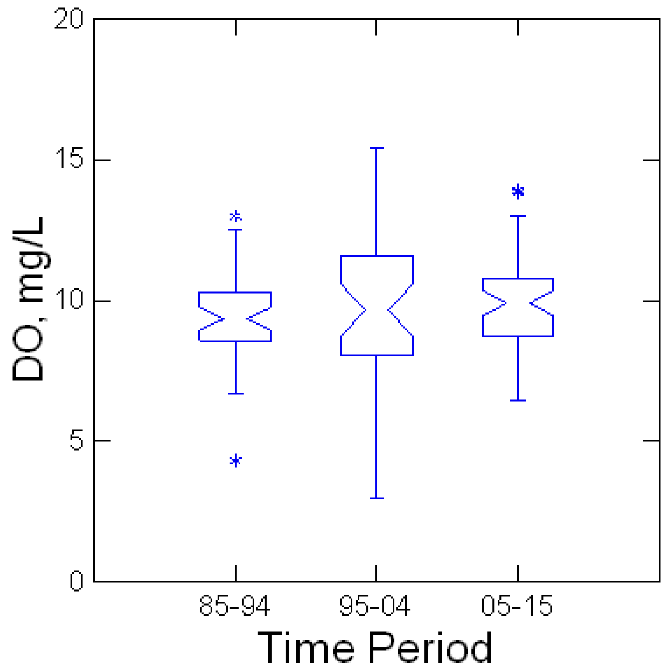


Figure D.7 Box plot of DO data from Cecil Creek by period.

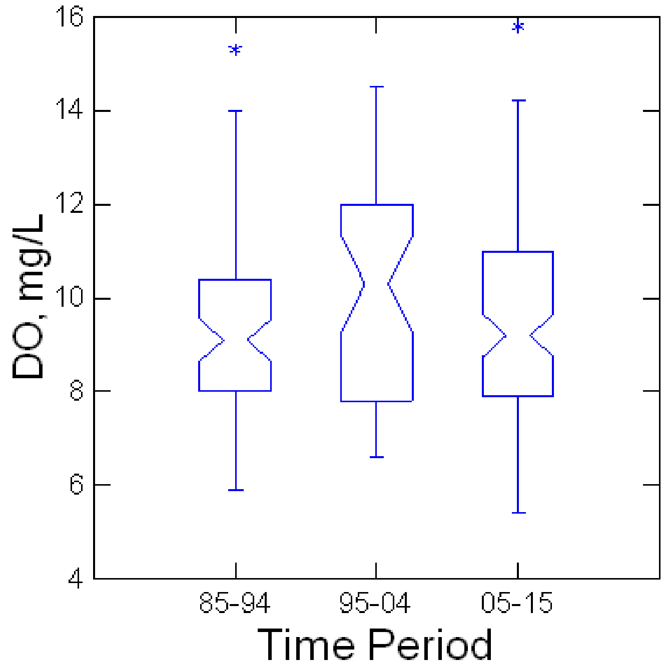


Figure D.8 Box plot of DO data from Buffalo River at Pruitt access by period.

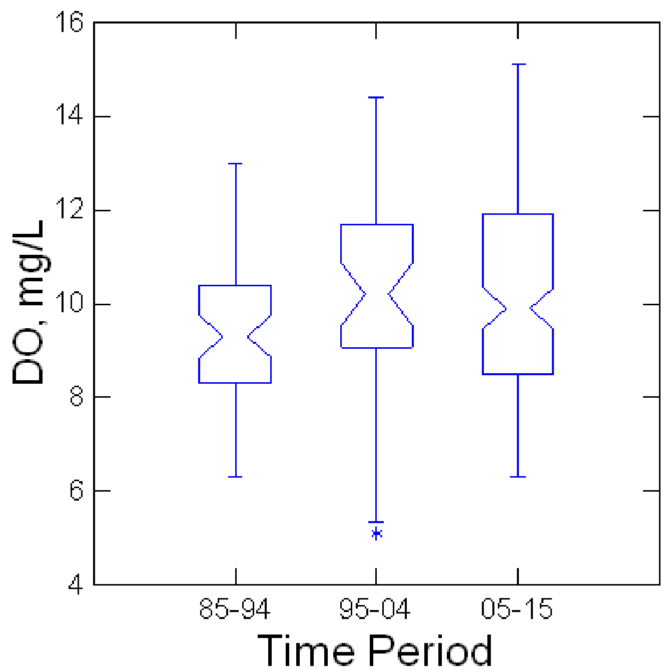


Figure D.9 Box plot of DO data from Mill Creek (upper) by period.

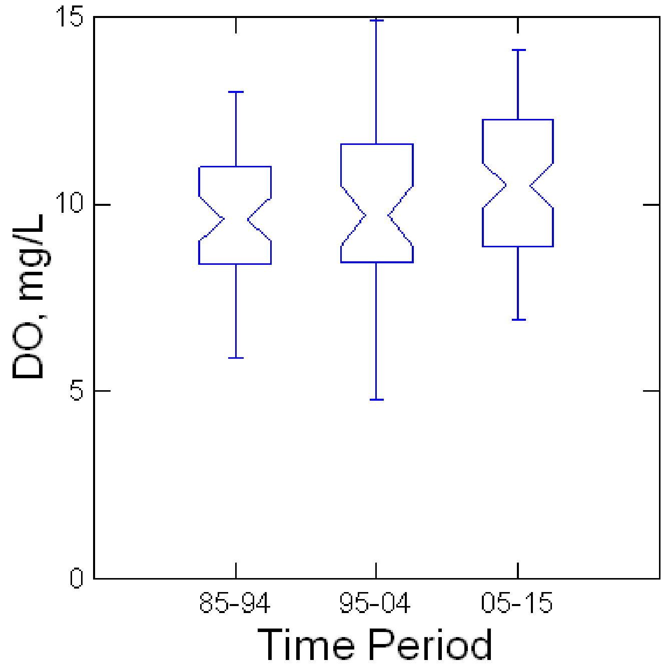


Figure D.10 Box plot of DO data from Little Buffalo River by period.

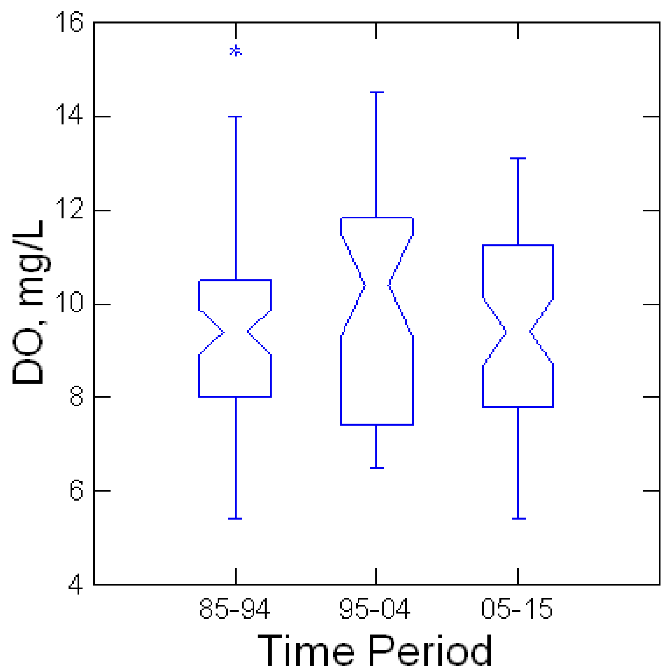


Figure D.11 Box plot of DO data from Buffalo River at Hasty by period.

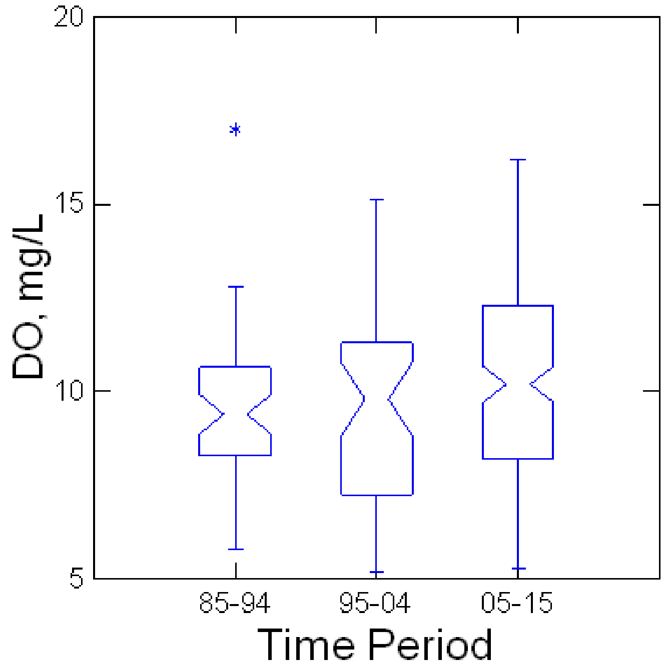


Figure D.12 Box plot of DO data from Big Creek near Carver by period.

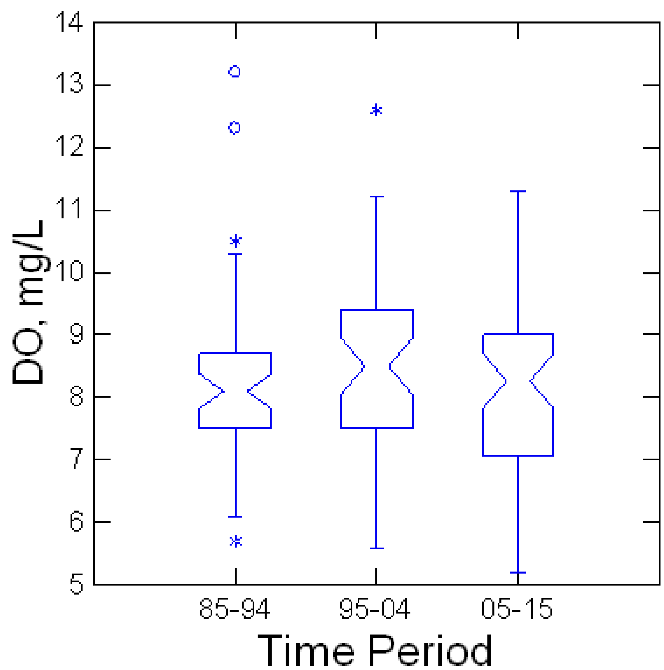


Figure D.13 Box plot of DO data from Mitch Hill Spring by period.

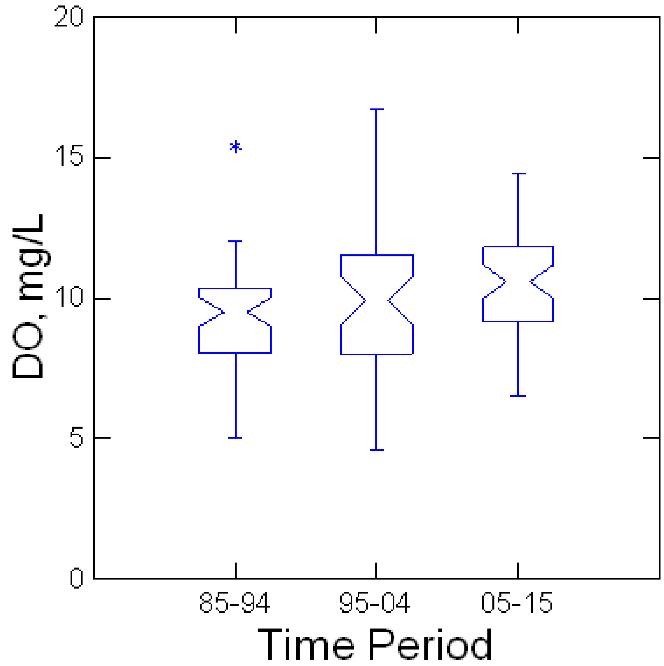


Figure D.14 Box plot of DO data from Davis Creek by period.

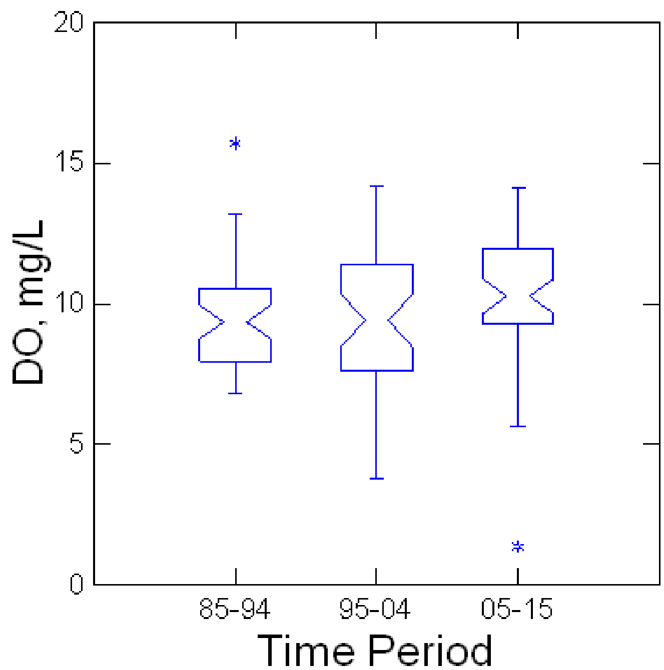


Figure D.15 Box plot of DO data from Cave Creek by period.

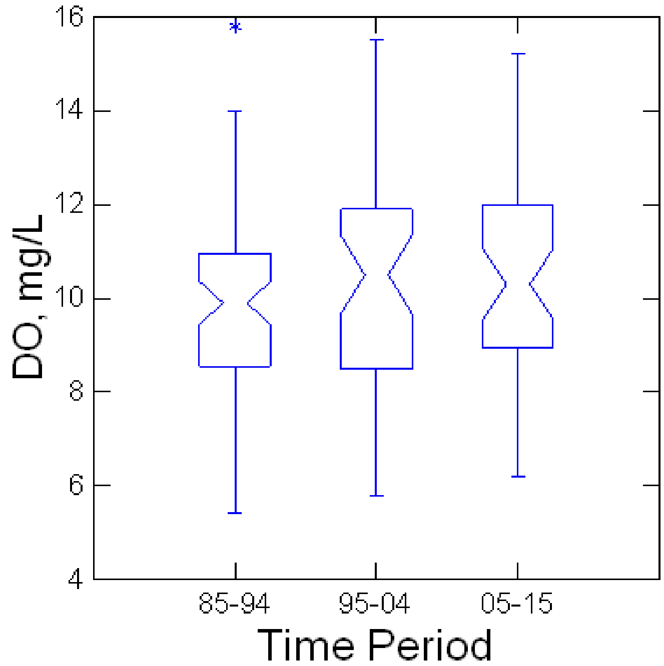


Figure D.16 Box plot of DO data from Buffalo River at Wollum by period.

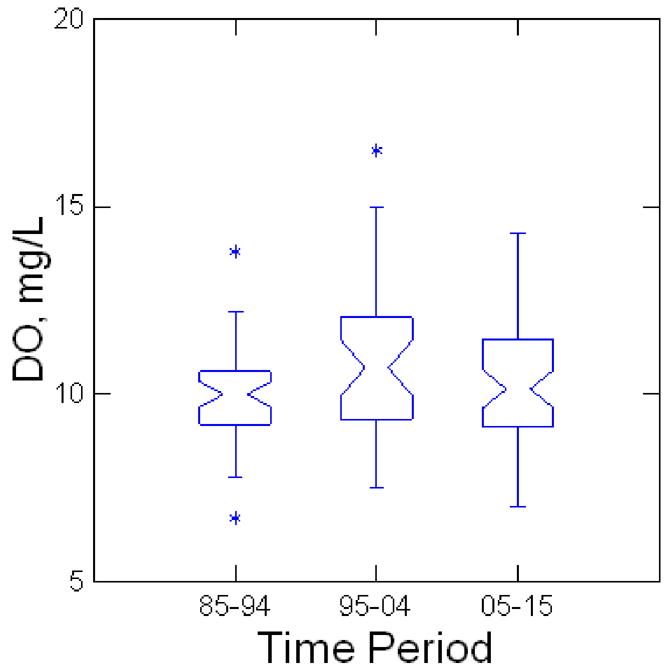


Figure D.17 Box plot of DO data from Richland Creek by period.

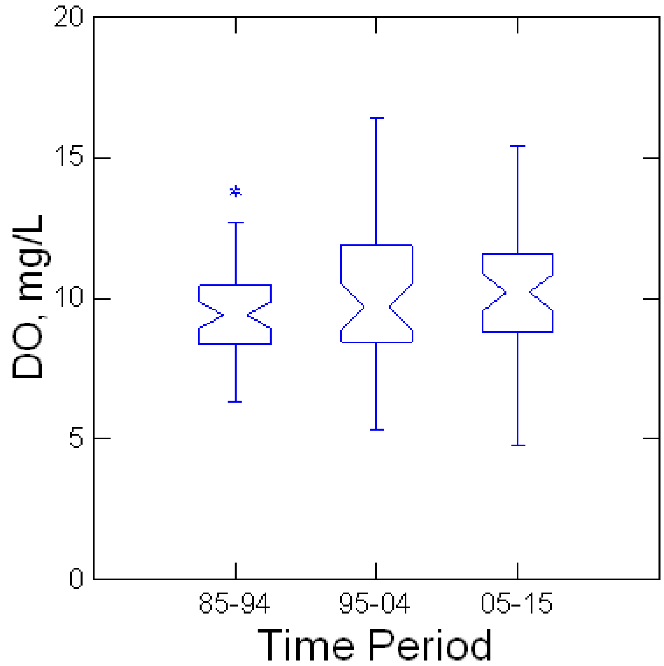


Figure D.18 Box plot of DO data from Calf Creek by period.

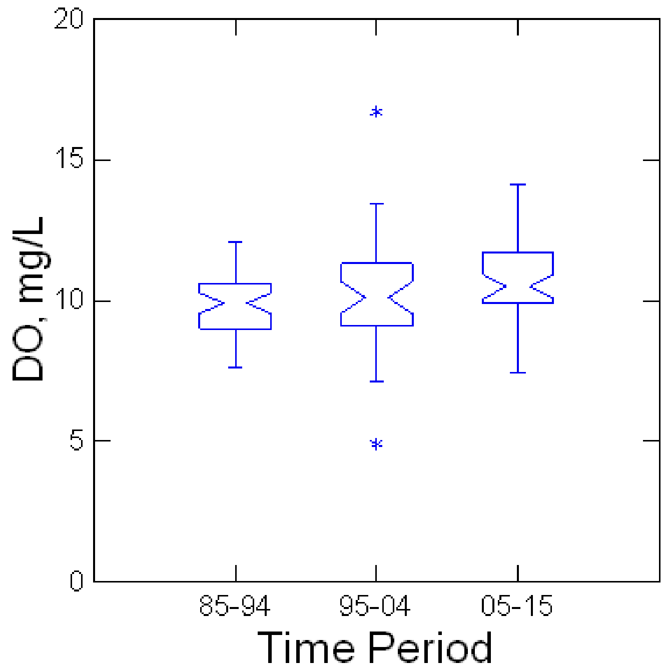


Figure D.19 Box plot of DO data from Mill Creek (lower) by period.

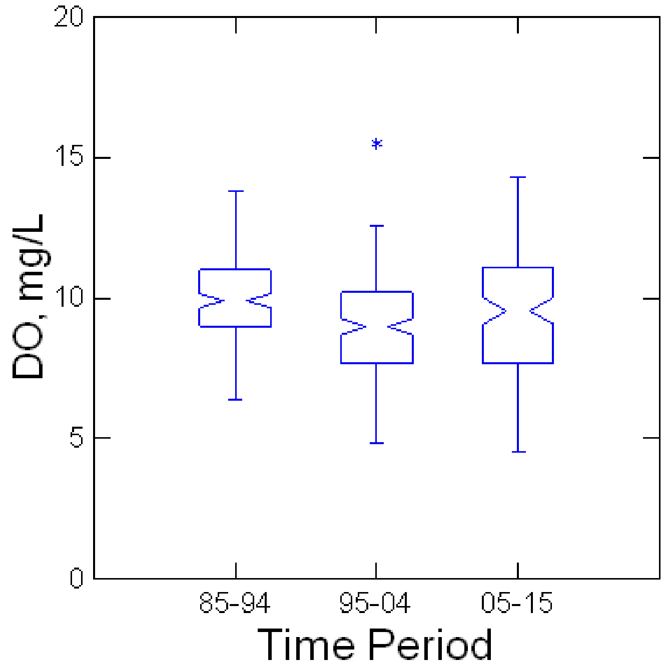


Figure D.20 Box plot of DO data from Buffalo River at Highway 65 by period.

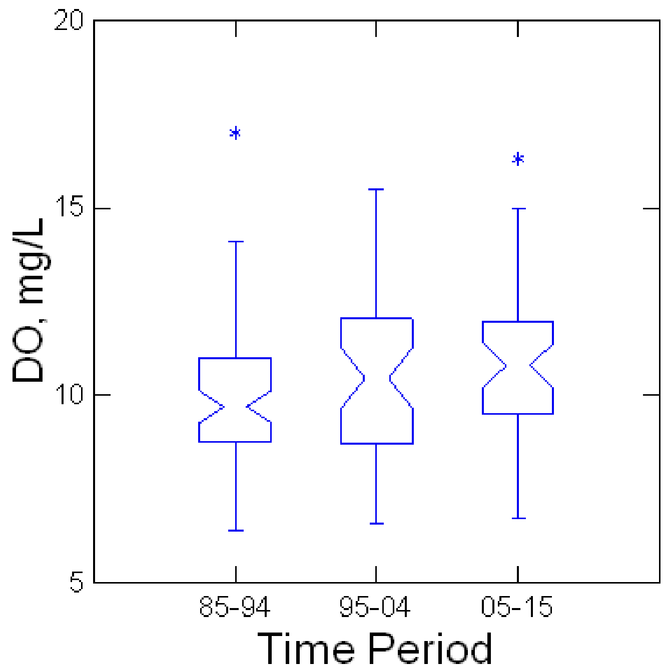


Figure D.21 Box plot of DO data from Buffalo River at Gilbert access by period.

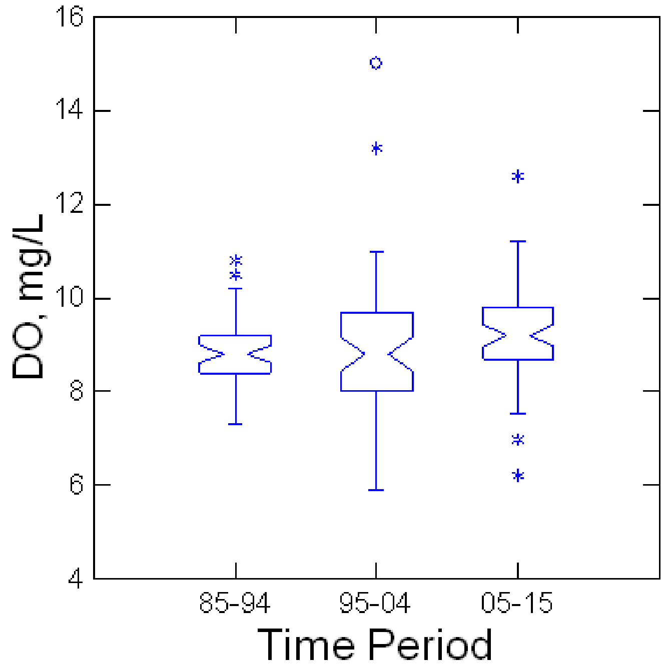


Figure D.22 Box plot of DO data from Gilbert Spring by period.

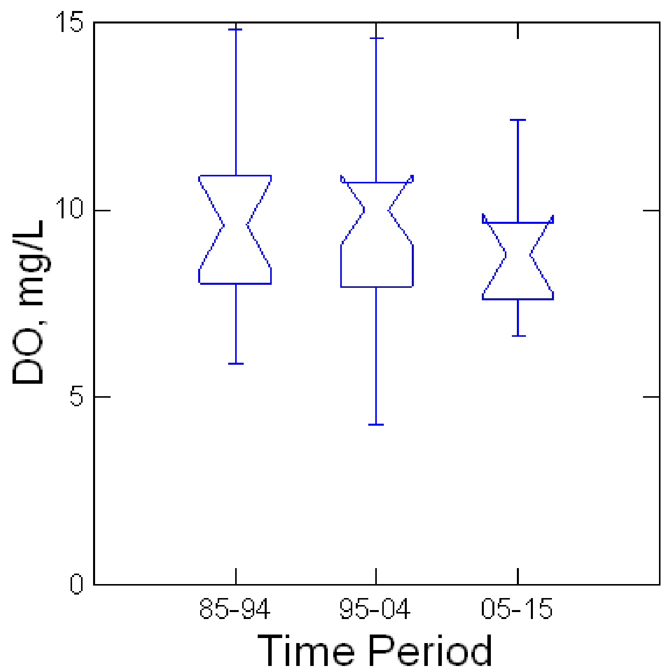


Figure D.23 Box plot of DO data from Bear Creek near Highway 65 by period.

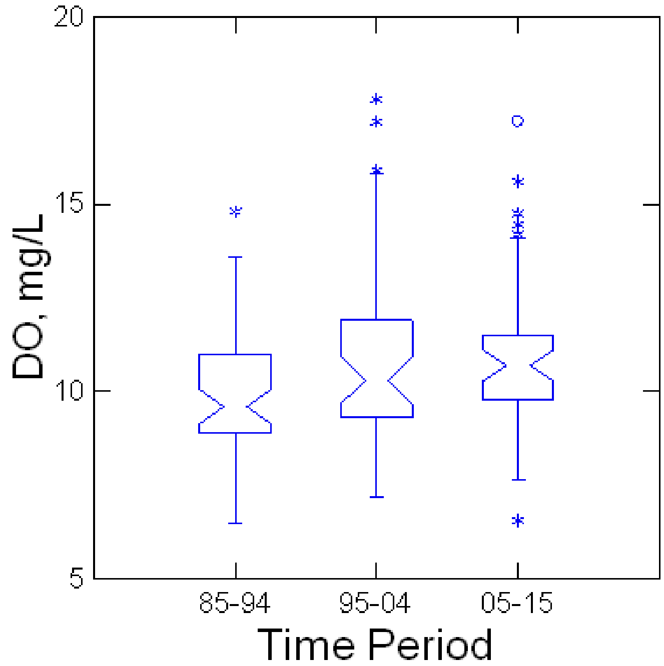


Figure D.24 Box plot of DO data from Bear Creek at mouth by period.

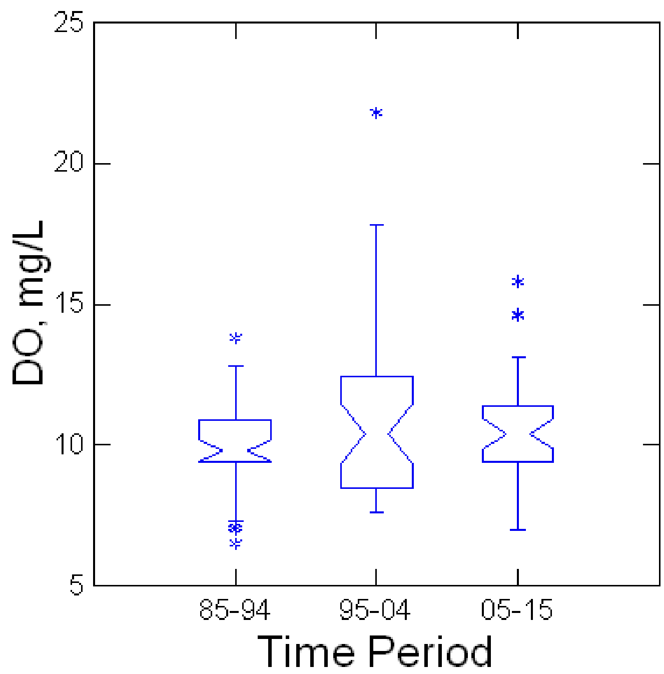


Figure D.25 Box plot of DO data from Brush Creek by period.

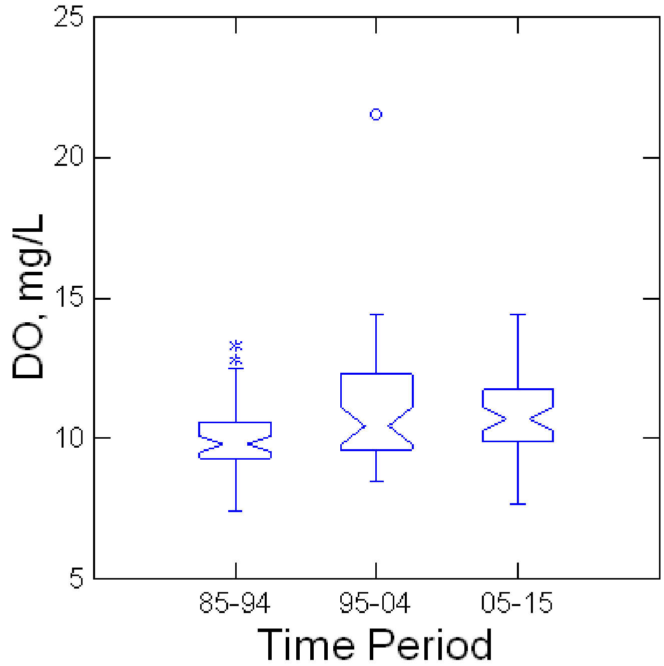


Figure D.26 Box plot of DO data from Tomahawk Creek by period.

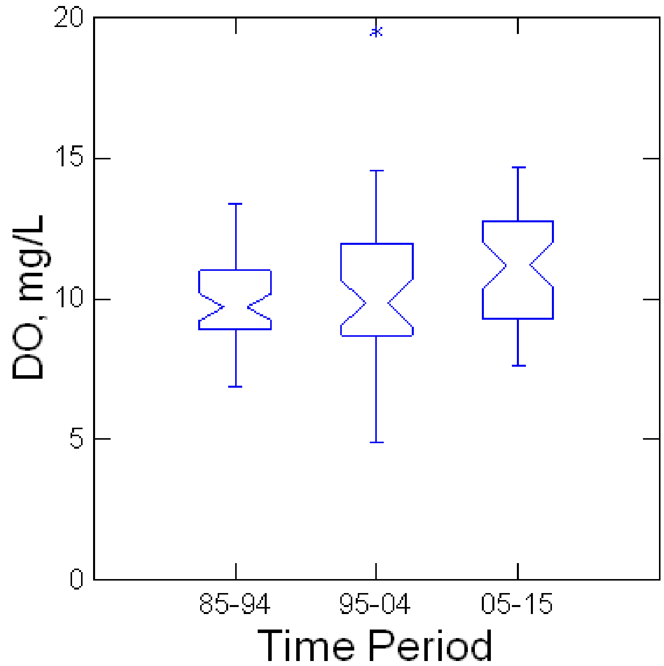


Figure D.27 Box plot of DO data from Water Creek by period.

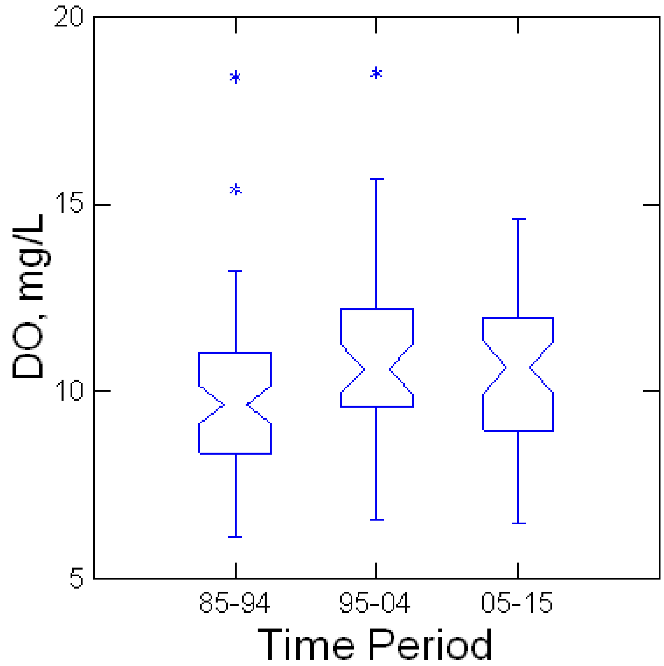


Figure D.28 Box plot of DO data from Buffalo River at Highway 14 by period.

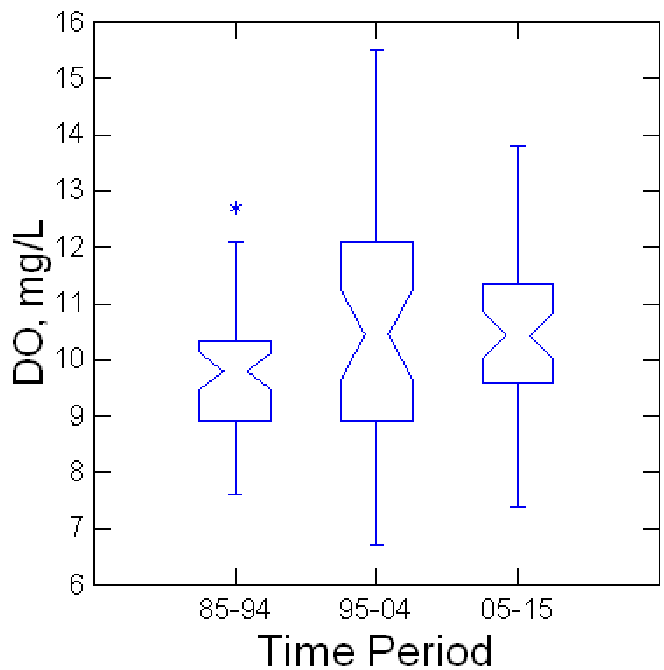


Figure D.29 Box plot of DO data from Rush Creek by period.

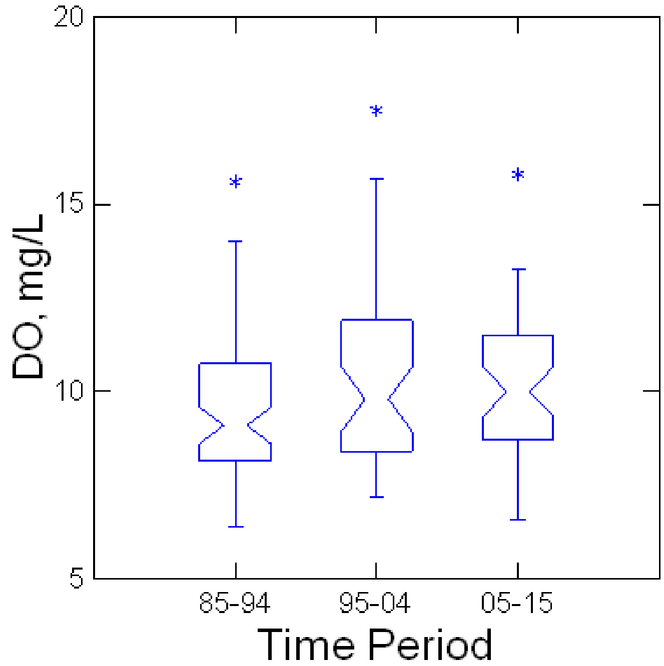


Figure D.30 Box plot of DO data from Buffalo River at Rush access by period.

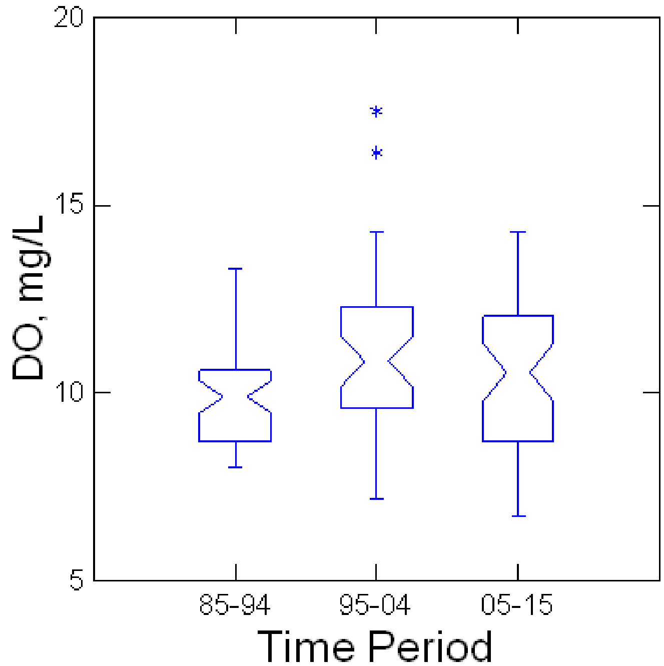


Figure D.31 Box plot of DO data from Clabber Creek by period.

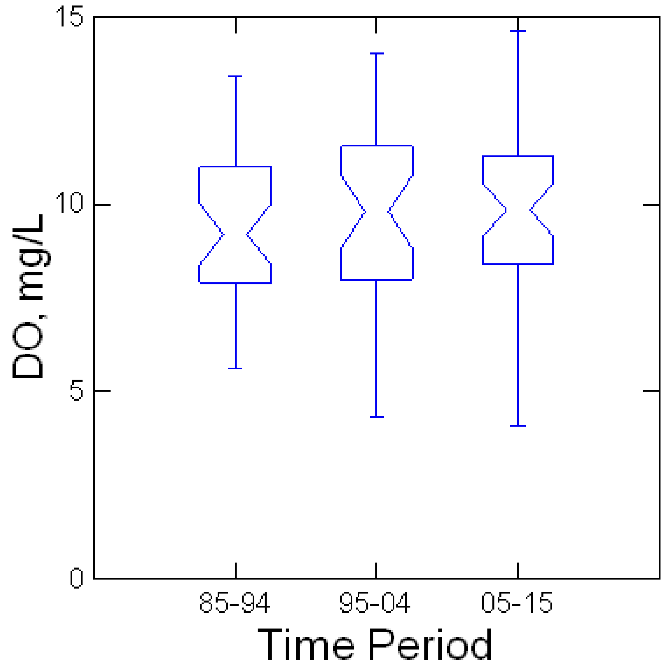


Figure D.32 Box plot of DO data from Big Creek (lower) by period.

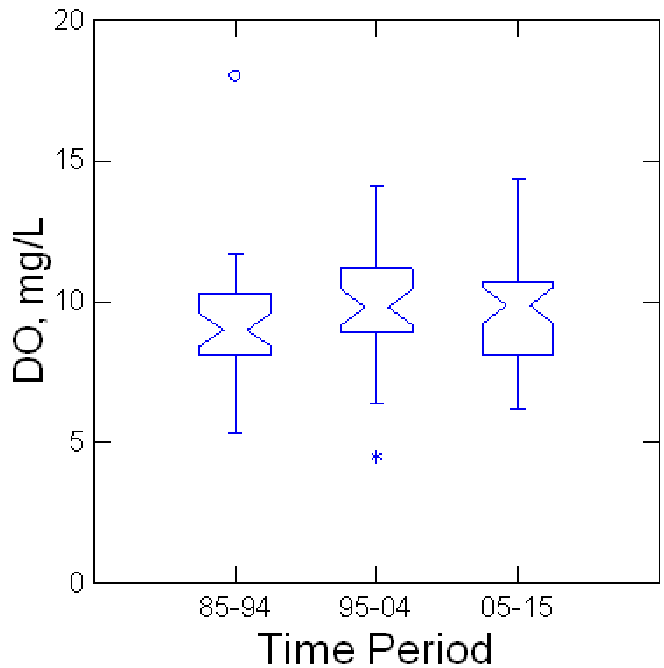


Figure D.33 Box plot of DO data from Middle Creek by period.

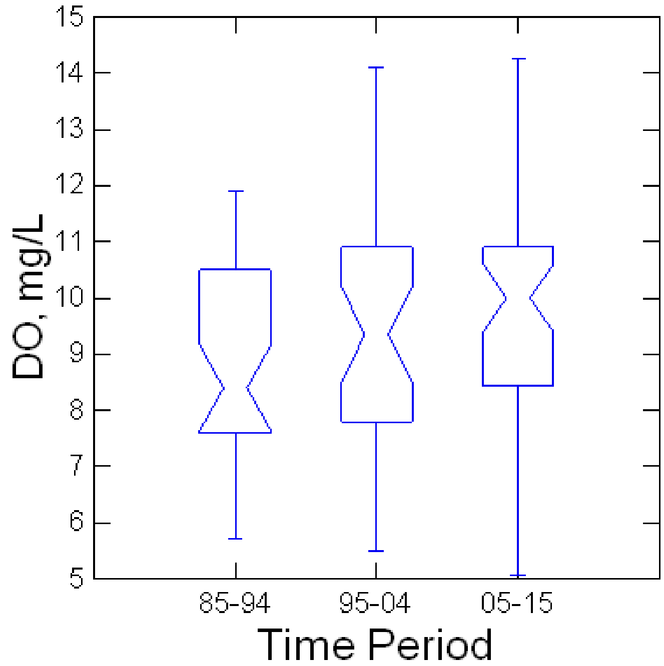


Figure D.34 Box plot of DO data from Leatherwood Creek by period.

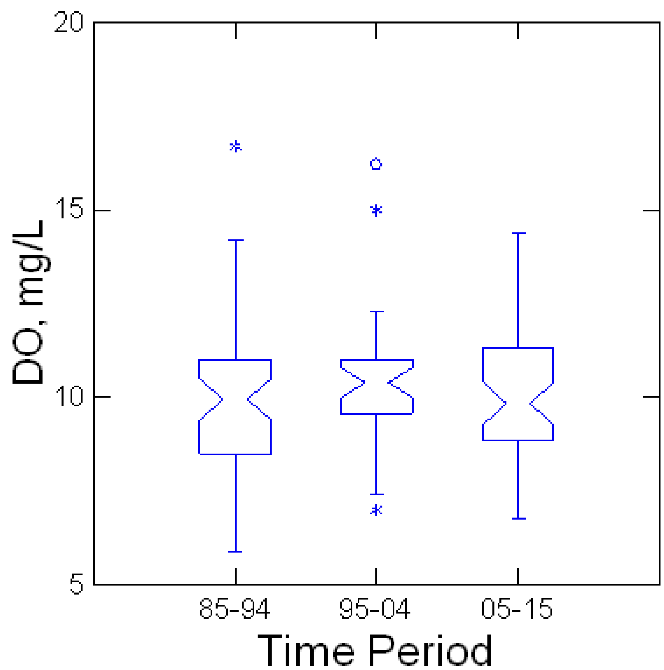


Figure D.35 Box plot of DO data from Buffalo River mouth by period.

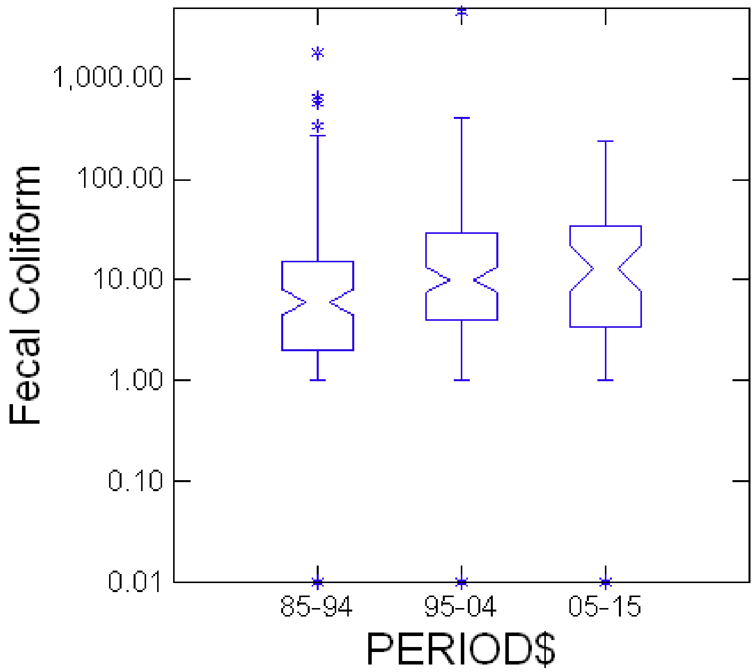


Figure D.36 Box plot of fecal coliform data from Buffalo River at the Wilderness Area boundary by period.

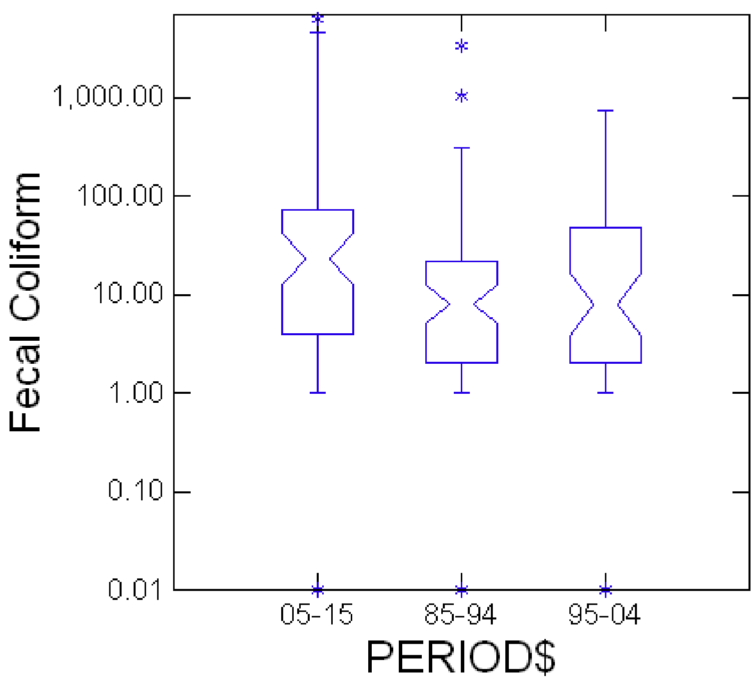


Figure D.37 Box plot of fecal coliform data from Big Creek (upper) near Carber by period.

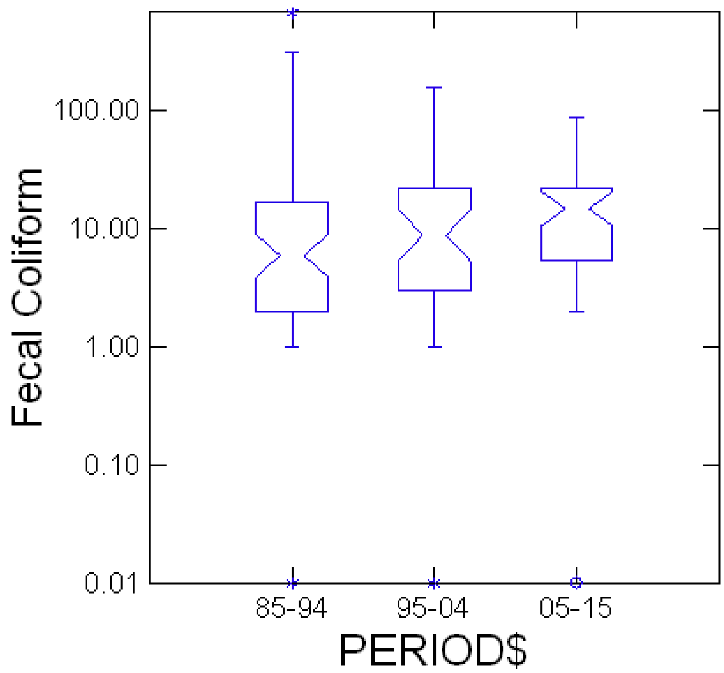


Figure D.38 Box plot of fecal coliform data from Water Creek by period.

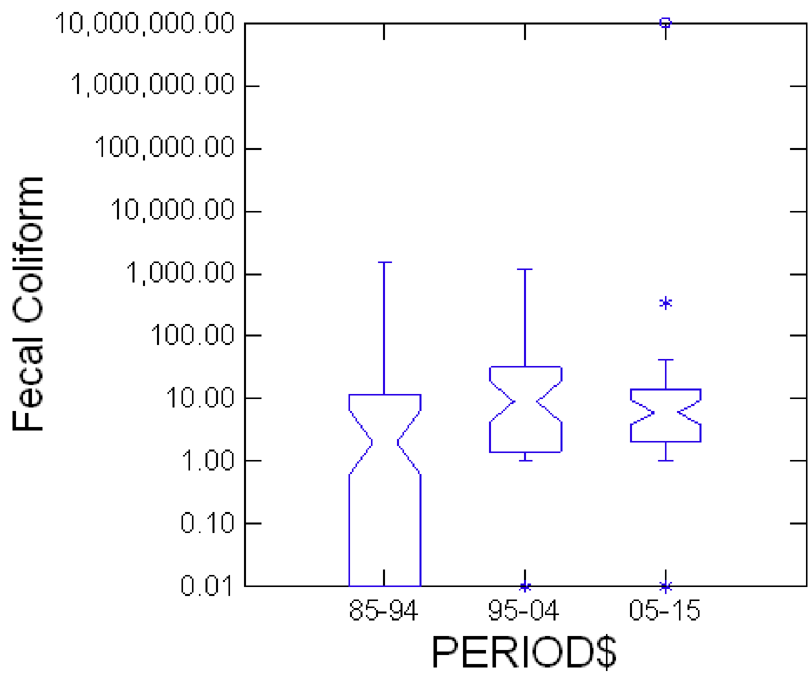


Figure D.39 Box plot of fecal coliform data from Buffalo River at Highway 14 by period

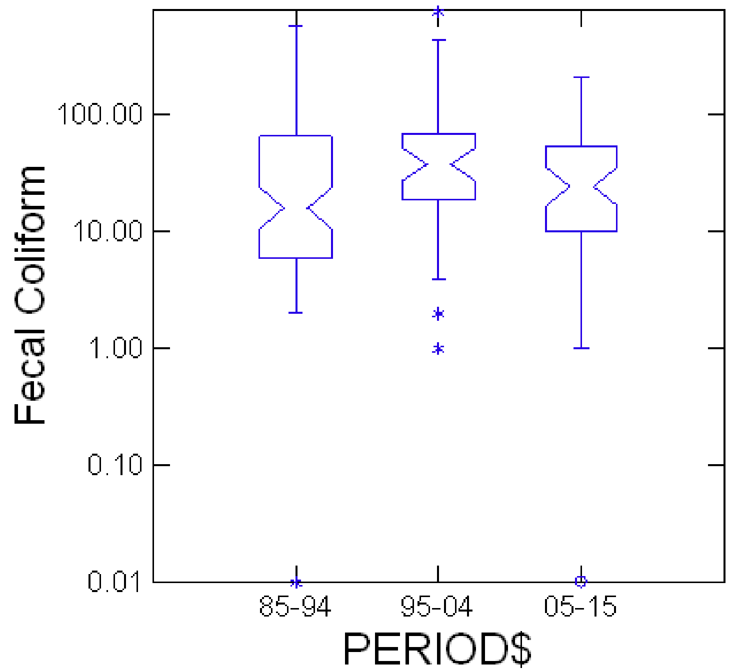


Figure D.40 Box plot of fecal coliform data from Buffalo River at Ponca access by period

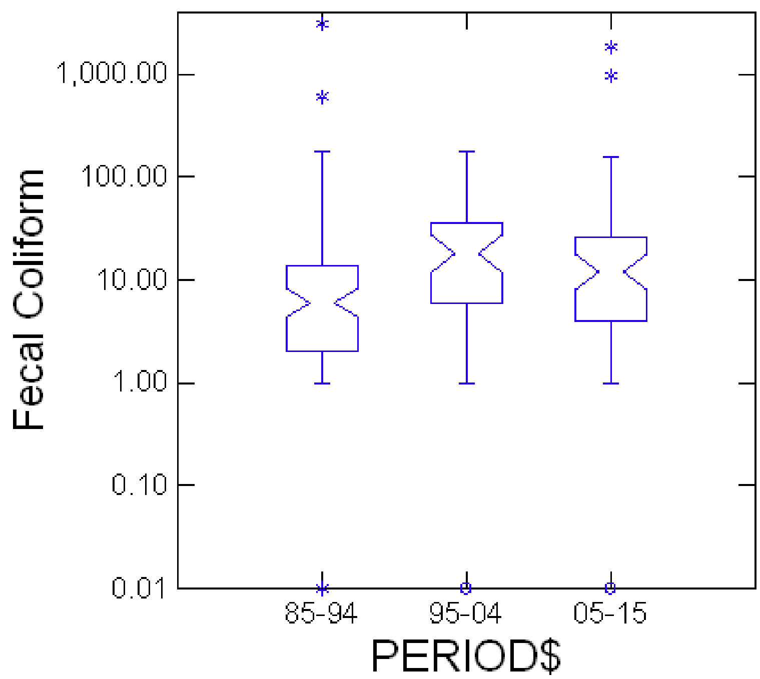


Figure D.41 Box plot of fecal coliform data from Buffalo River at Pruitt access by period

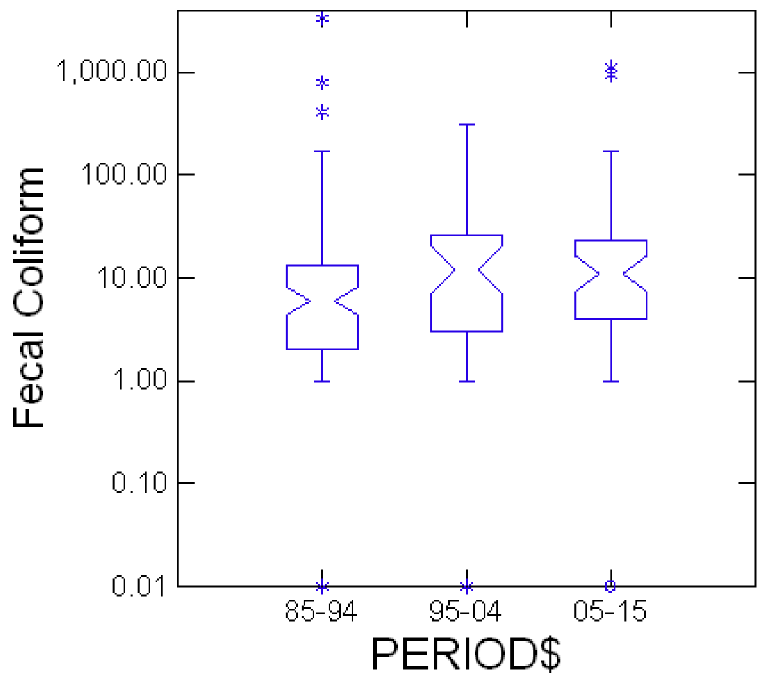


Figure D.42 Box plot of fecal coliform data from Buffalo River at Hasty by period

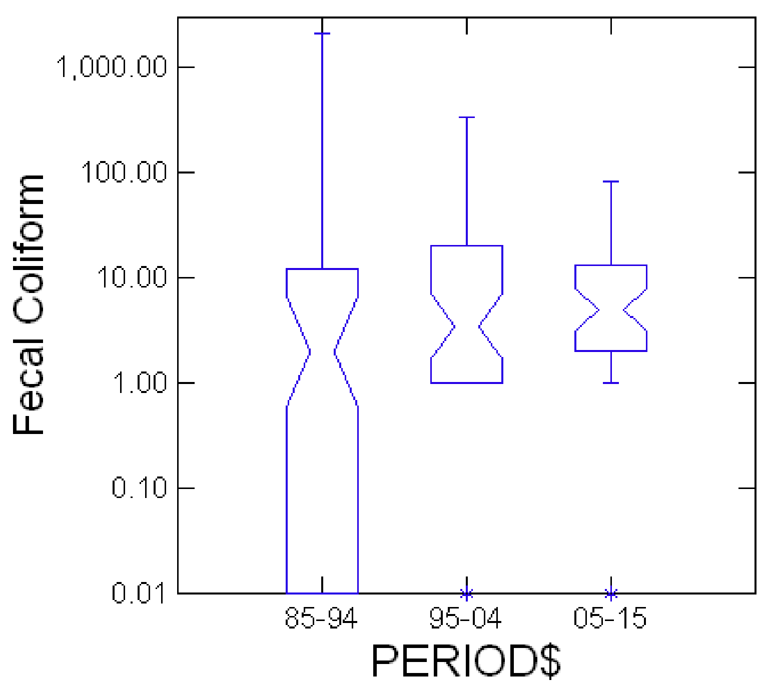


Figure D.43 Box plot of fecal coliform data from Buffalo River at Wollum by period

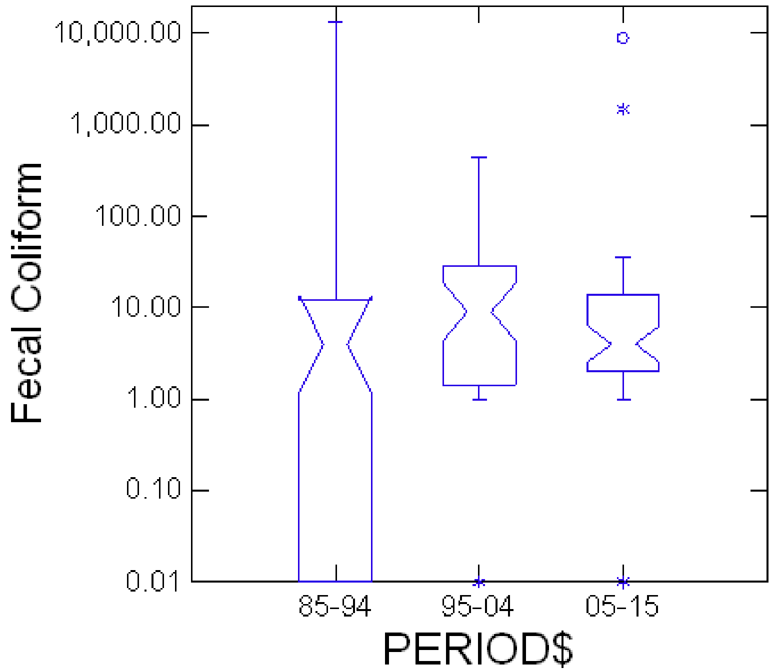


Figure D.44 Box plot of fecal coliform data from Buffalo River at Gilbert access by period

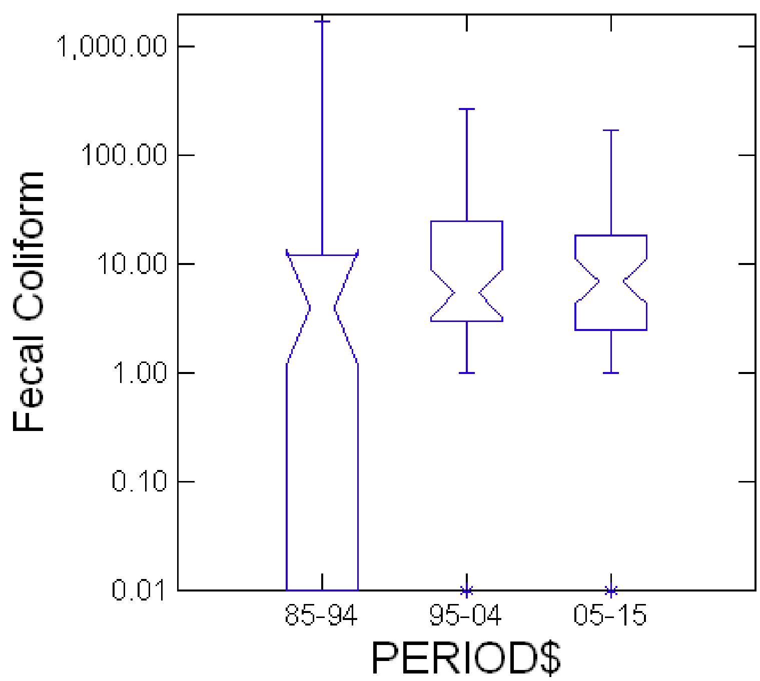


Figure D.45 Box plot of fecal coliform data from Buffalo River at Rush access by period

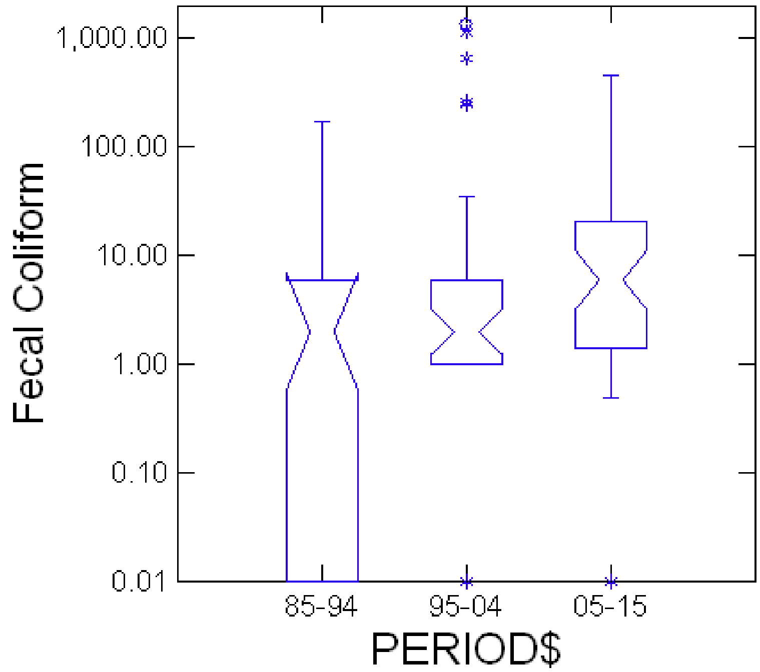


Figure D.46 Box plot of fecal coliform data from Buffalo River mouth by period

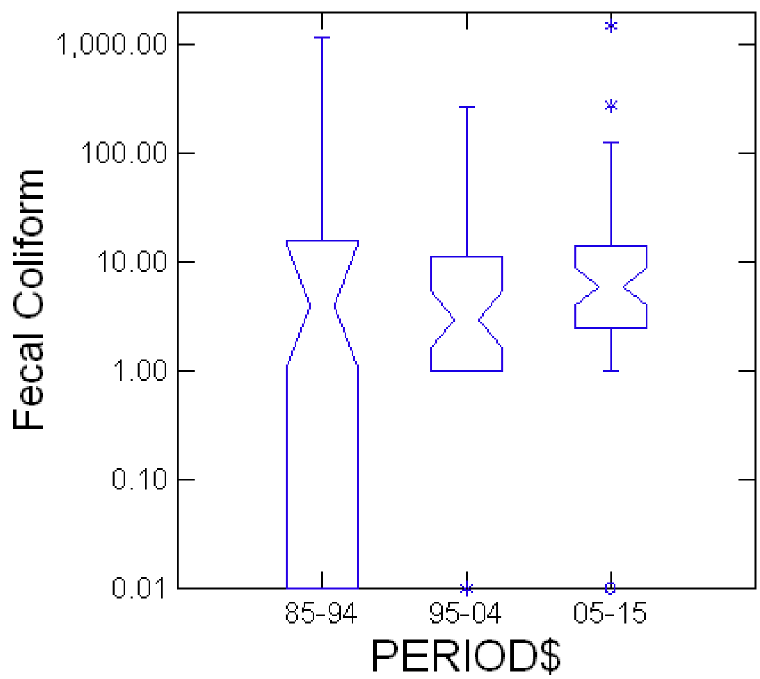


Figure D.46 Box plot of fecal coliform data from Luallen Spring by period

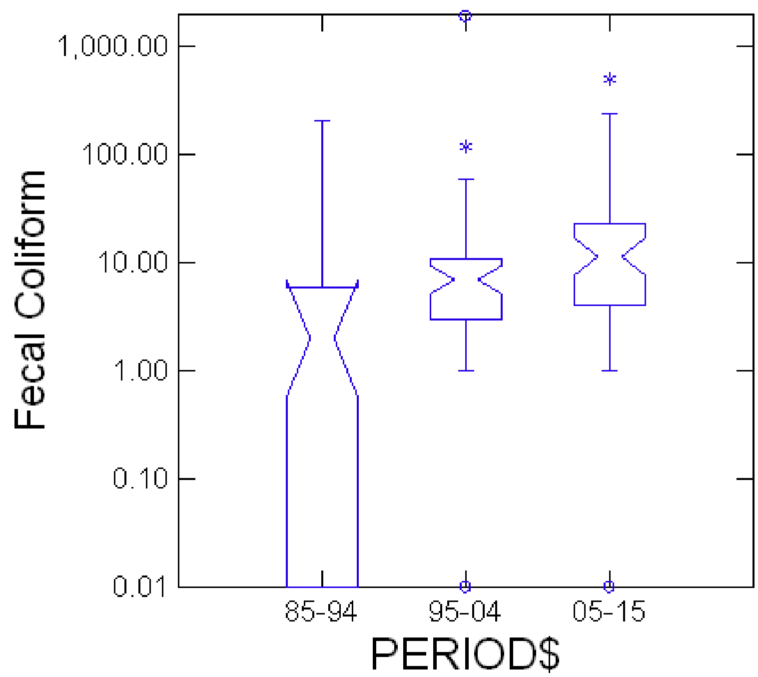


Figure D.47 Box plot of fecal coliform data from Mitch Hill Spring by period

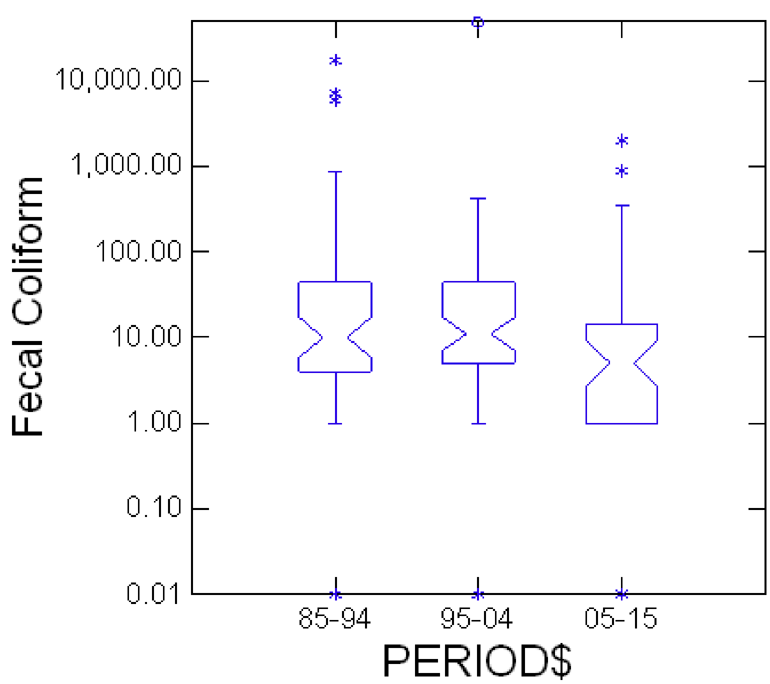


Figure D.48 Box plot of fecal coliform data from Gilbert Spring by period

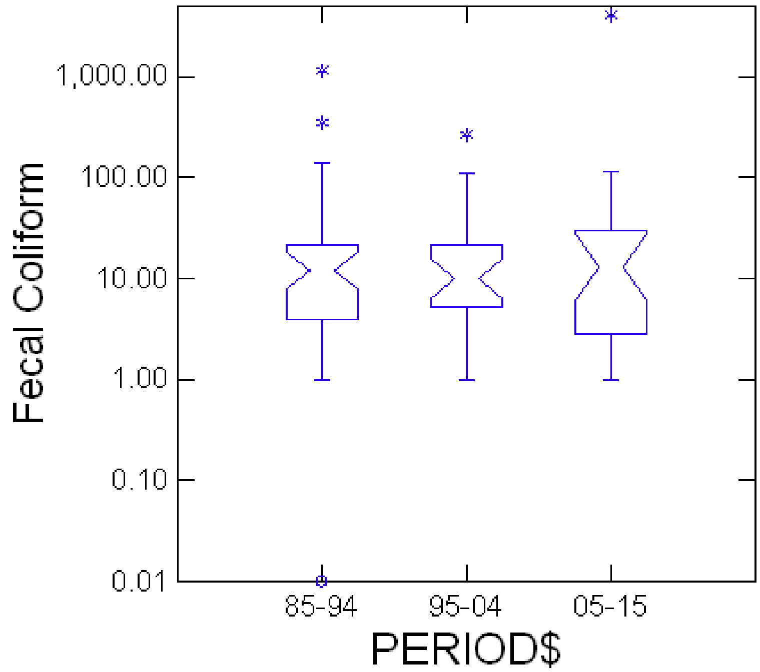


Figure D.49 Box plot of fecal coliform data from Beech Creek by period

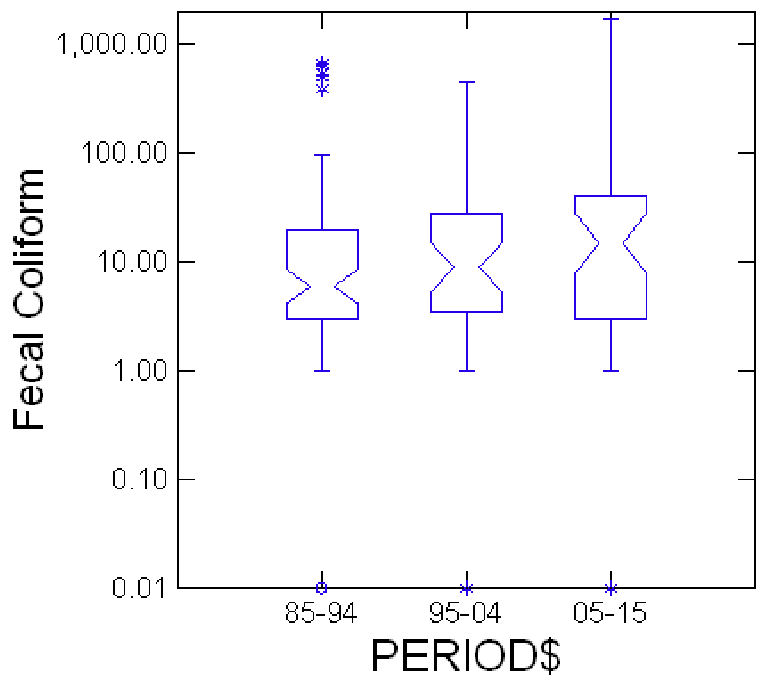


Figure D.50 Box plot of fecal coliform data from Ponca Creek by period

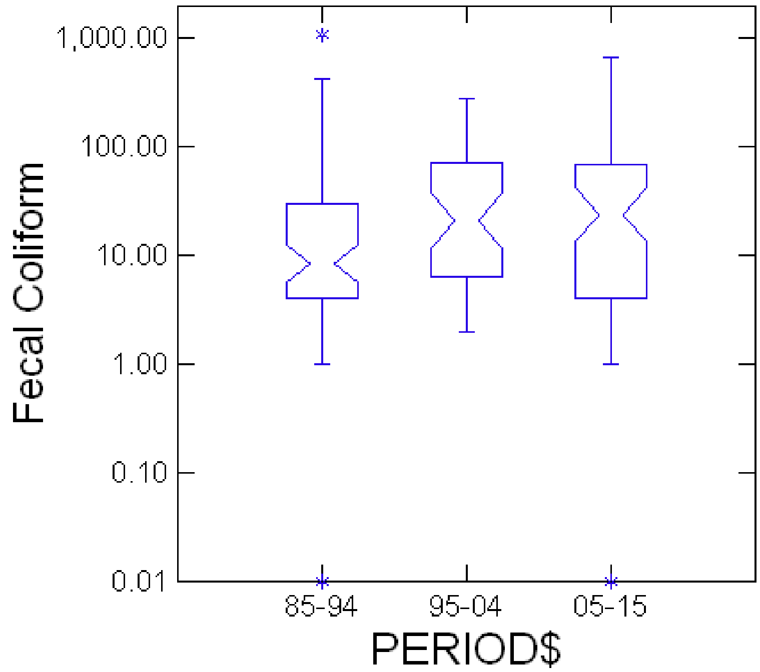


Figure D.51 Box plot of fecal coliform data from Cecil Creek by period

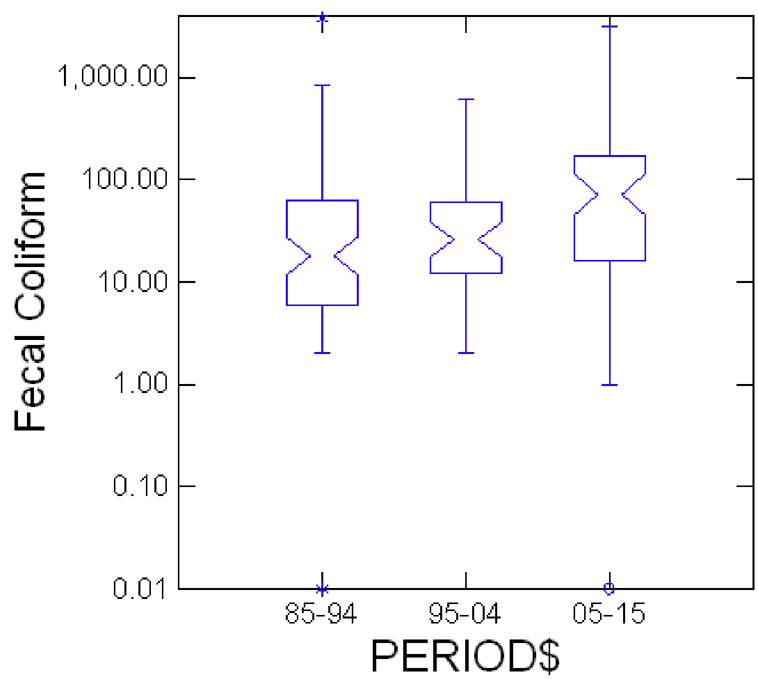


Figure D.52 Box plot of fecal coliform data from Mill Creek (upper) by period

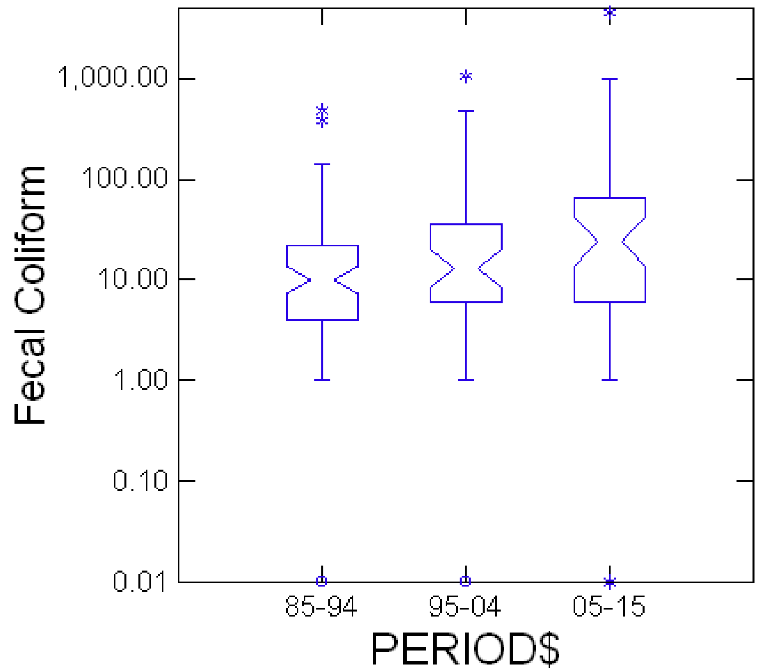


Figure D.53 Box plot of fecal coliform data from Little Buffalo River by period

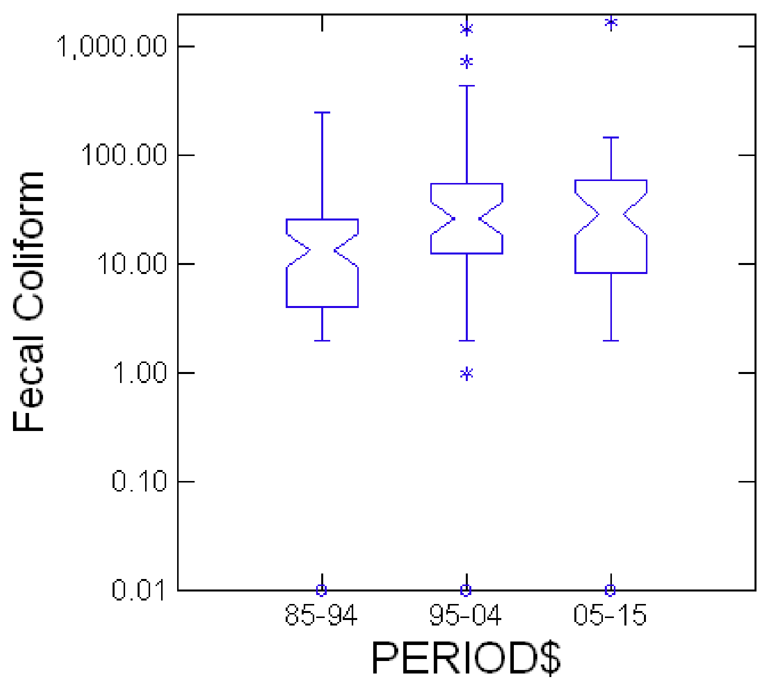


Figure D.54 Box plot of fecal coliform data from Davis Creek by period

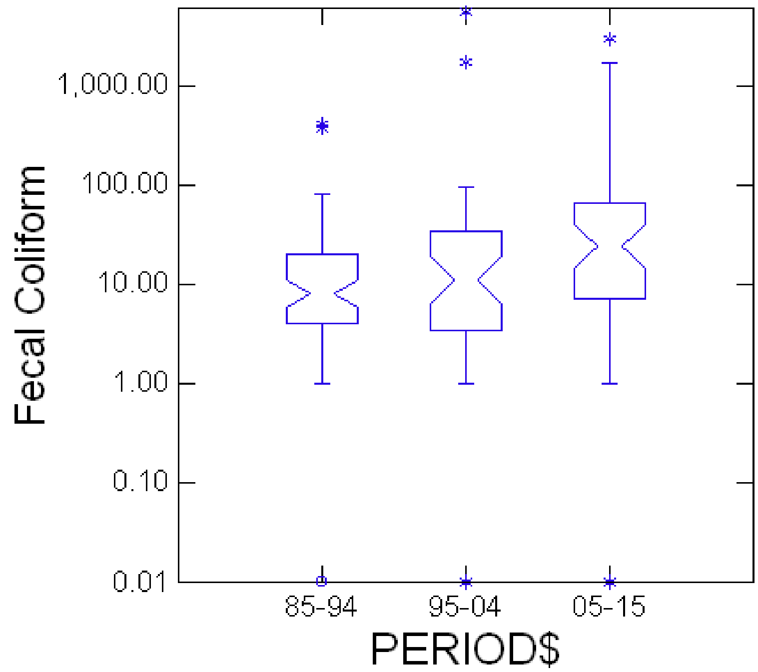


Figure D.55 Box plot of fecal coliform data from Cave Creek by period

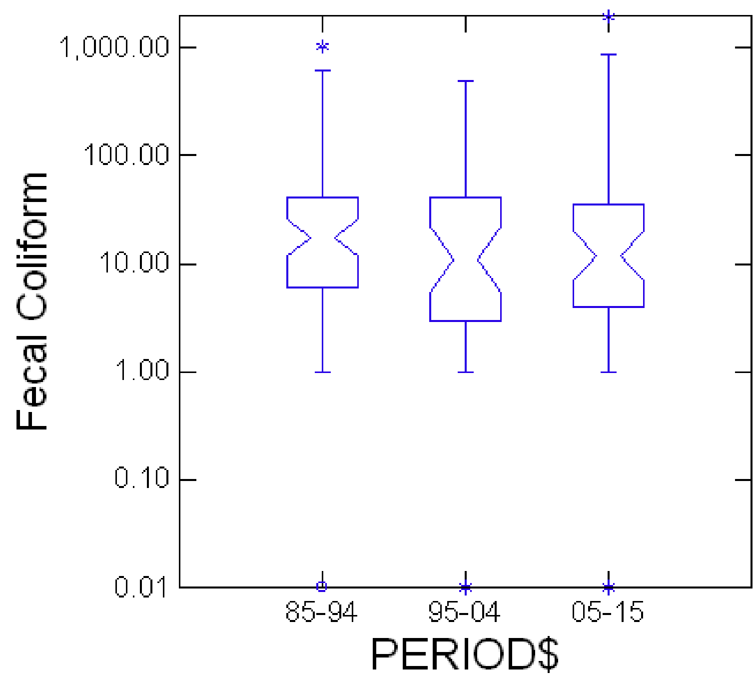


Figure D.56 Box plot of fecal coliform data from Richland Creek by period

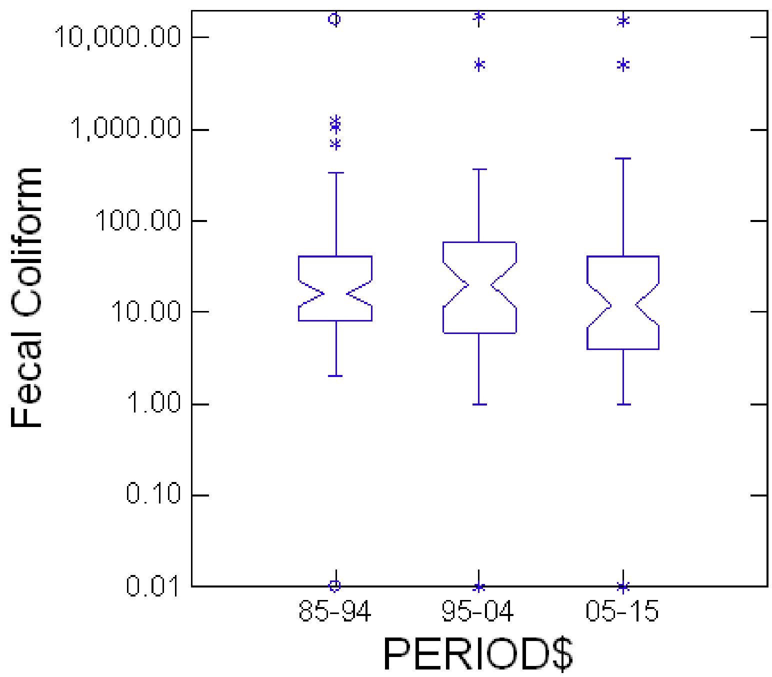


Figure D.57 Box plot of fecal coliform data from Calf Creek by period

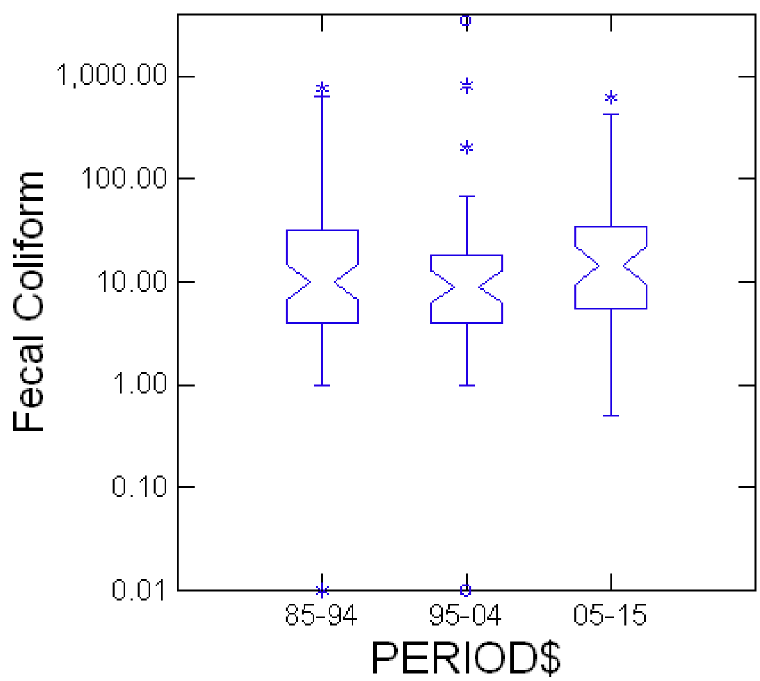


Figure D.58 Box plot of fecal coliform data from Mill Creek (lower) by period

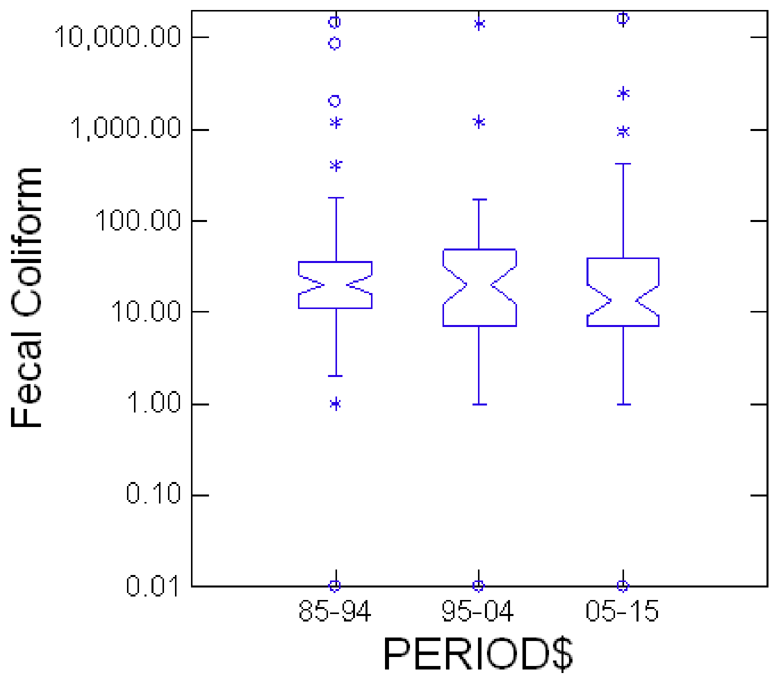


Figure D.59 Box plot of fecal coliform data from Bear Creek mouth by period

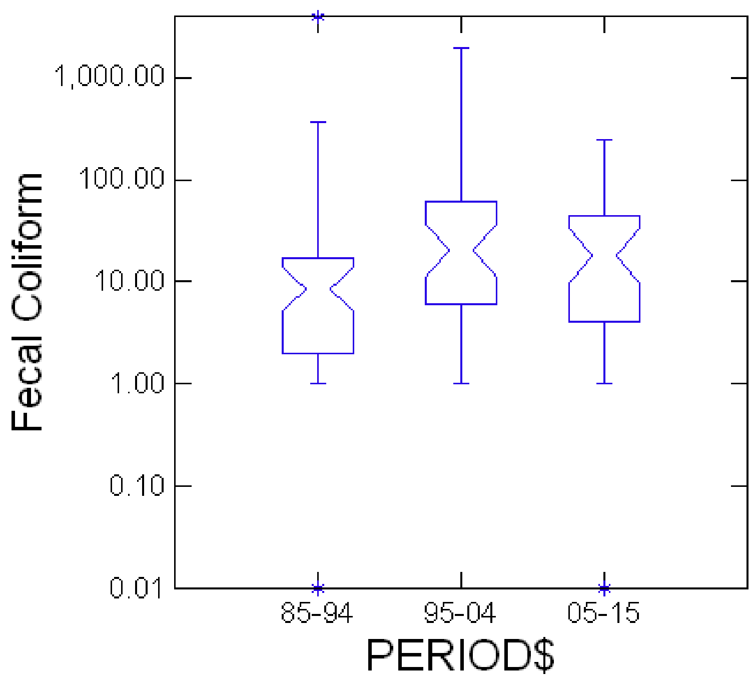


Figure D.60 Box plot of fecal coliform data from Brush Creek by period

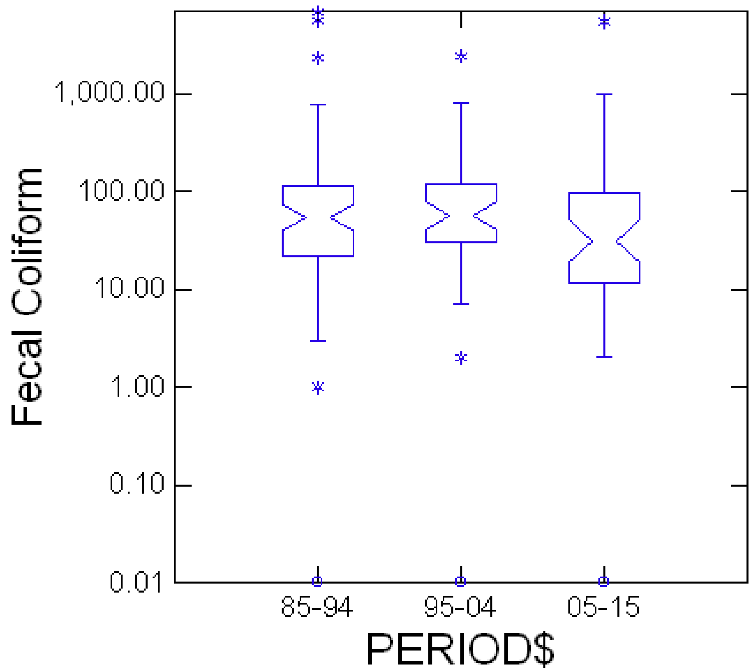


Figure D.61 Box plot of fecal coliform data from Tomahawk Creek by period

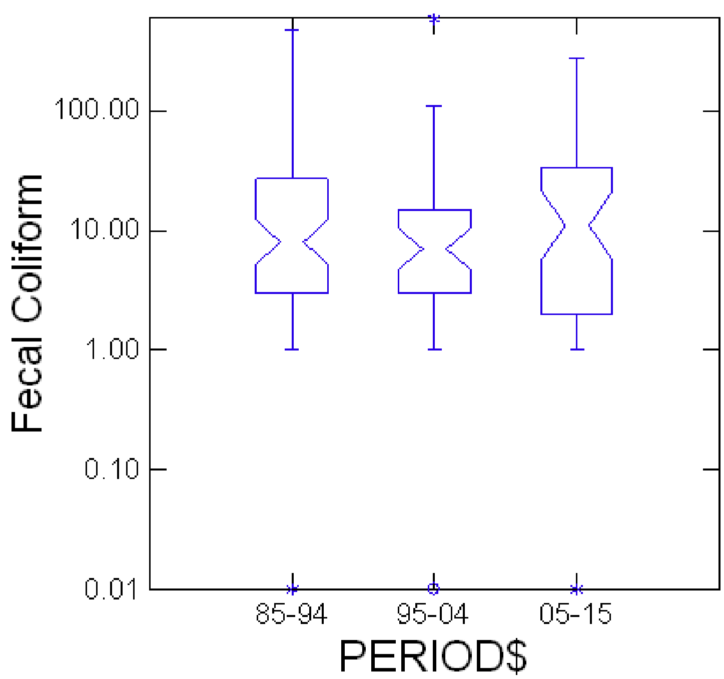


Figure D.62 Box plot of fecal coliform data from Rush Creek by period

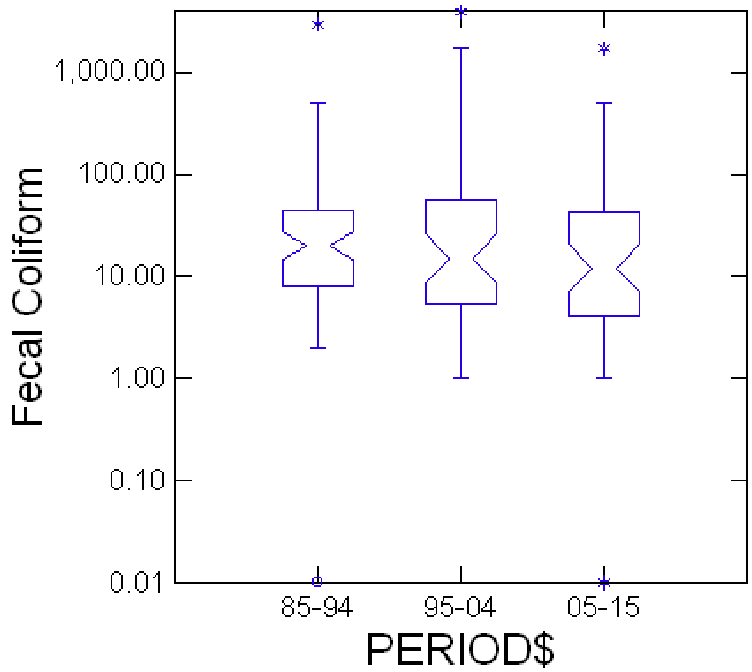


Figure D.63 Box plot of fecal coliform data from Clabber Creek by period

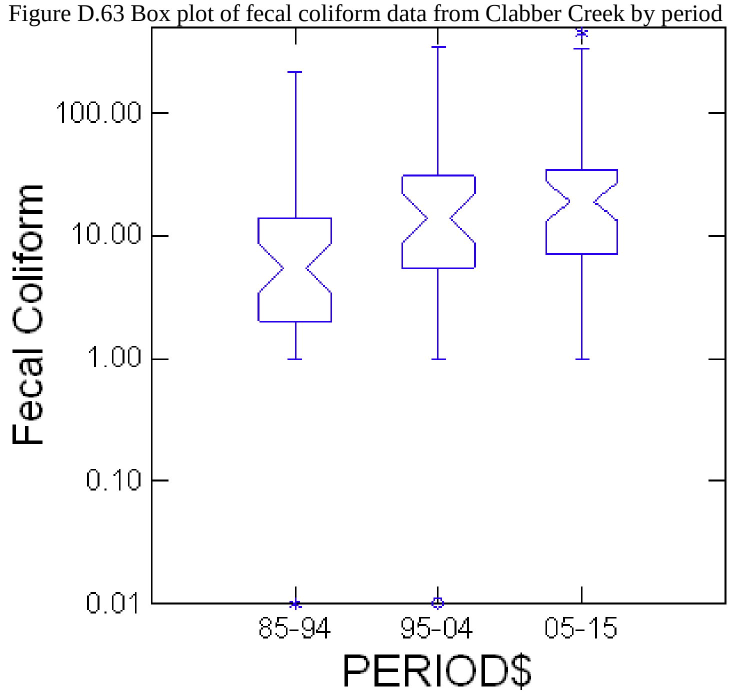


Figure D.64 Box plot of fecal coliform data from Big Creek (lower) by period

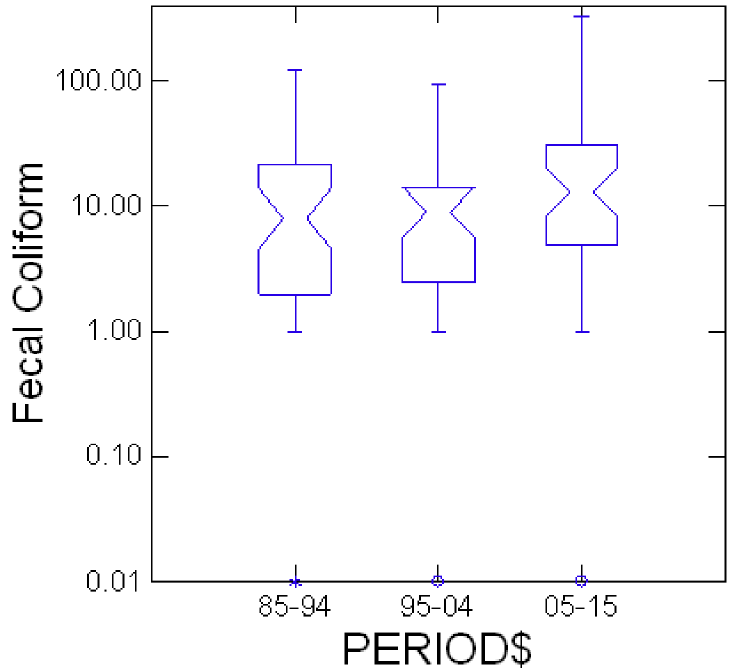


Figure D.65 Box plot of fecal coliform data from Middle Creek by period

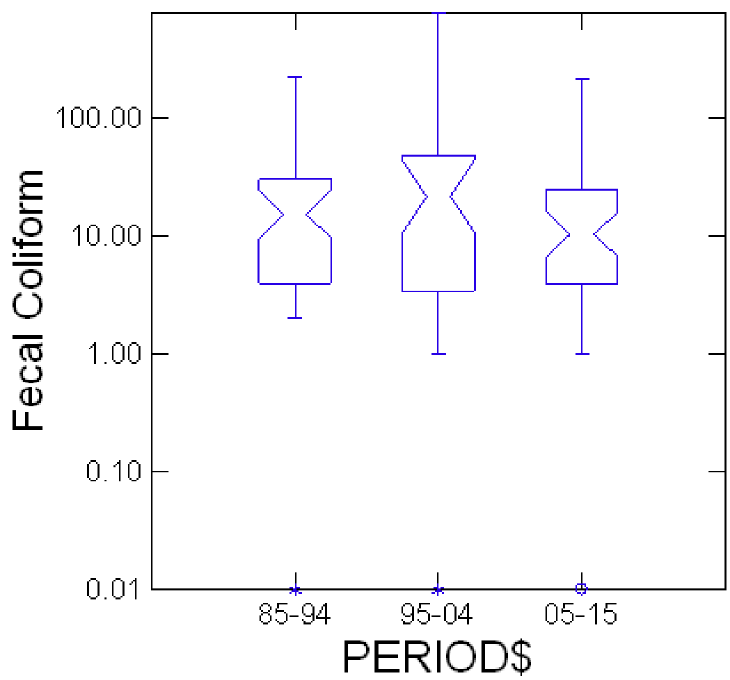


Figure D.66 Box plot of fecal coliform data from Leatherwood Creek by period

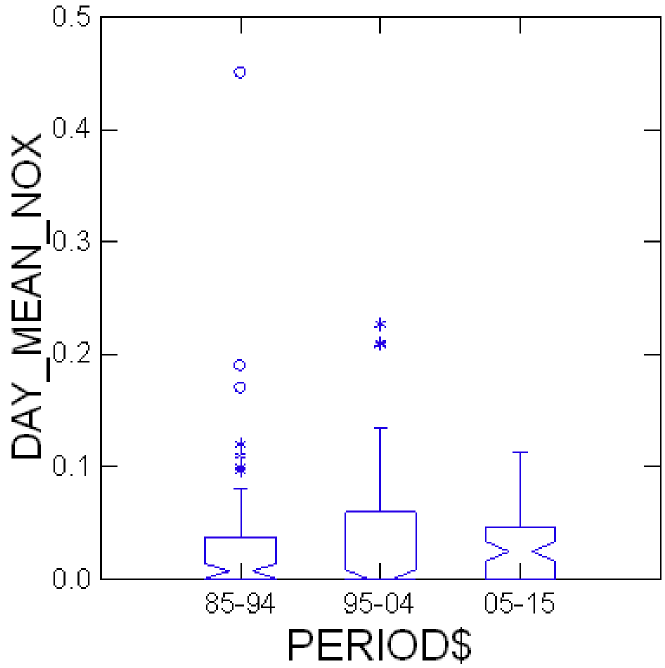


Figure D.67 Box plot of inorganic nitrogen data from Buffalo River at the Wilderness Area boundary by period

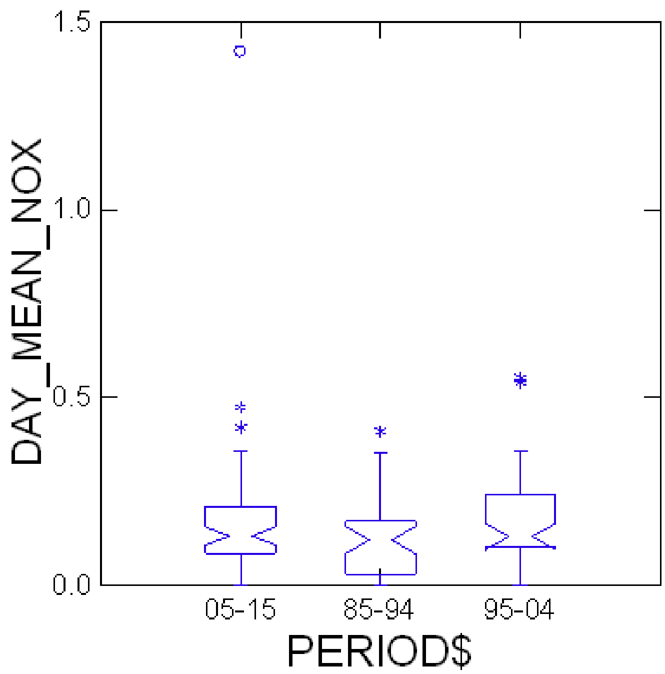


Figure D.68 Box plot of inorganic nitrogen data from Big Creek (lower) near Carver by period

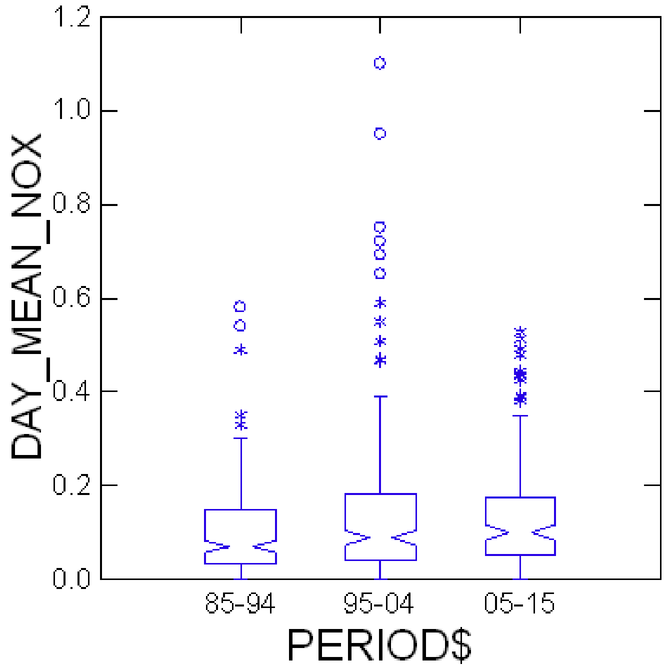


Figure D.69 Box plot of inorganic nitrogen data from Buffalo River at Highway 65 by period

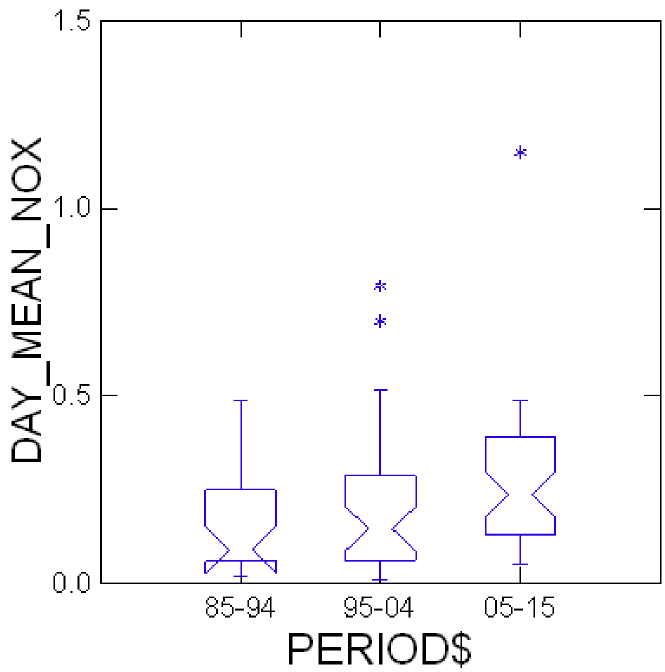


Figure D.70 Box plot of inorganic nitrogen data from Water Creek by period

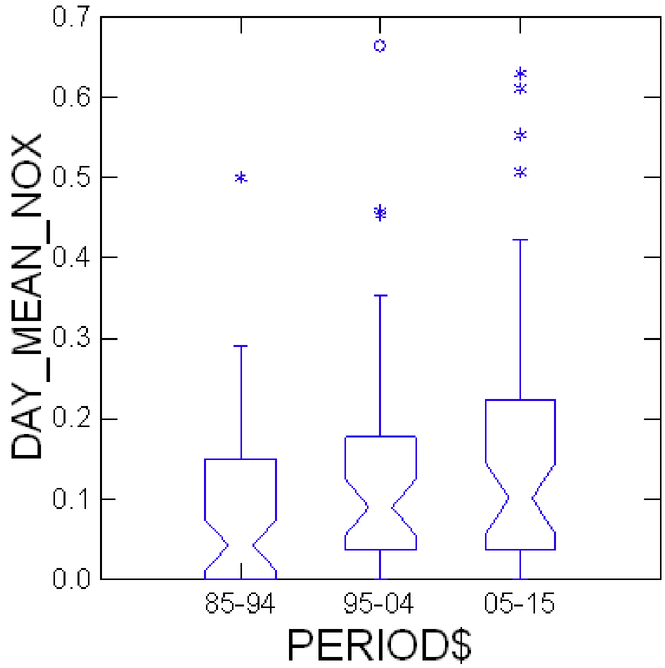


Figure D.71 Box plot of inorganic nitrogen data from Buffalo River at Highway 14 by period

Results for NPS_NAME_CORR041717$ = BR @ Ponca

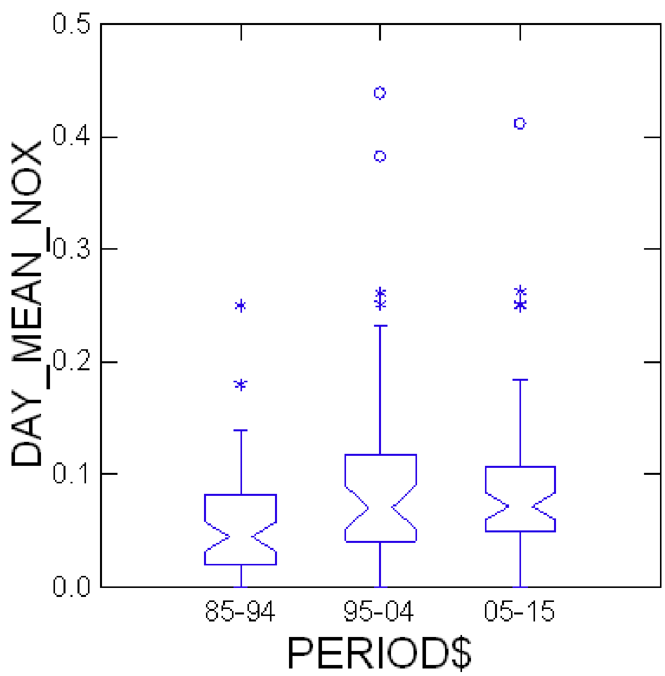


Figure D.72 Box plot of inorganic nitrogen data from Buffalo River at Ponca access by period

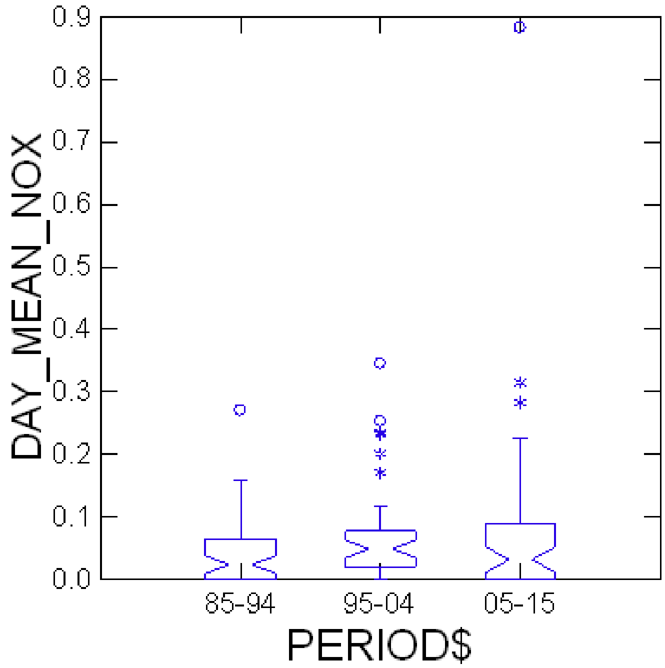


Figure D.73 Box plot of inorganic nitrogen data from Buffalo River at Pruitt access by period

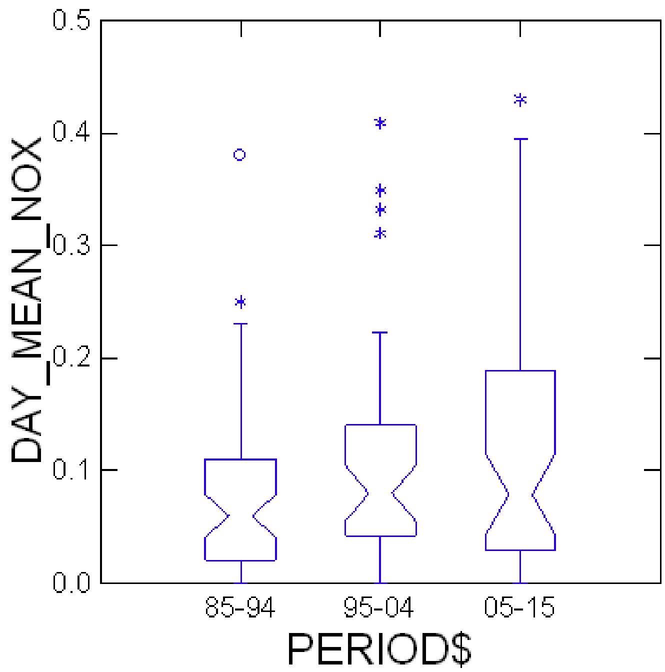


Figure D.74 Box plot of inorganic nitrogen data from Buffalo River at Hasty by period

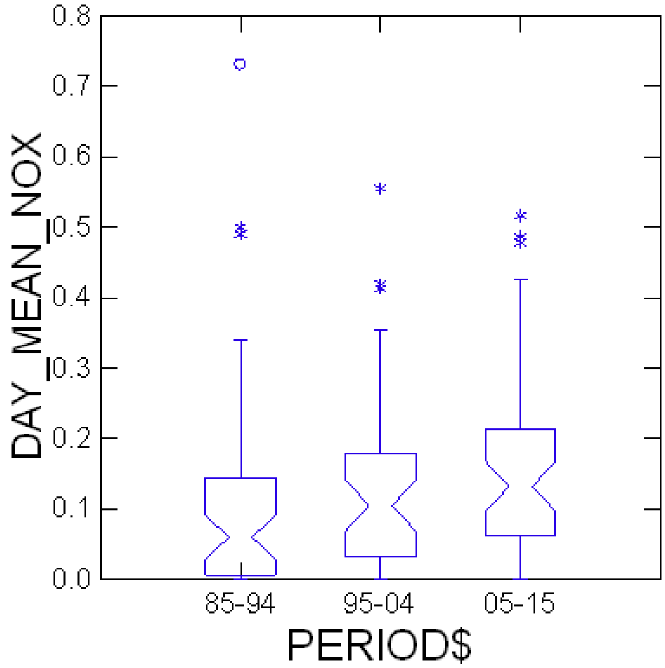


Figure D.75 Box plot of inorganic nitrogen data from Buffalo River at Woolum by period

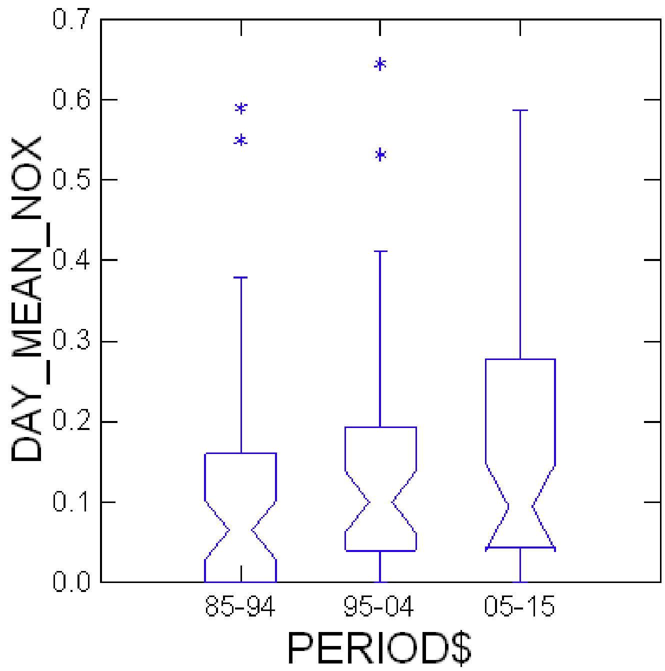


Figure D.76 Box plot of inorganic nitrogen data from Buffalo River at Gilbert access by period

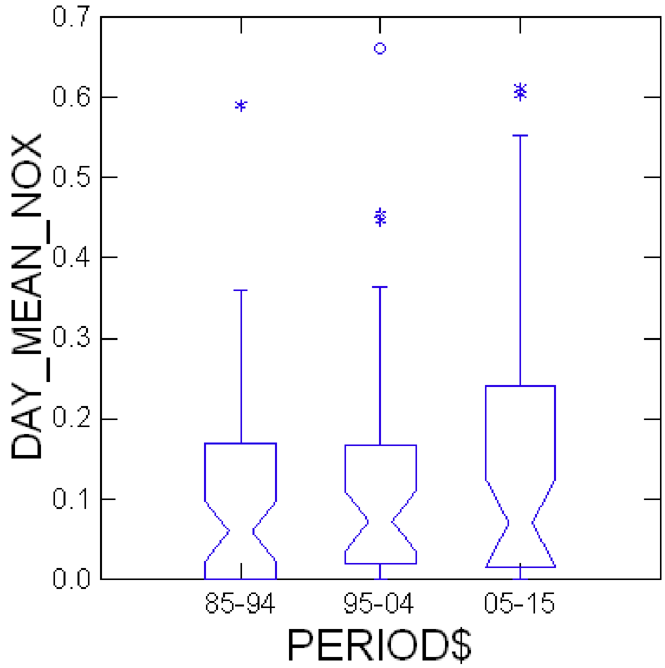


Figure D.77 Box plot of inorganic nitrogen data from Buffalo River at Rush access by period

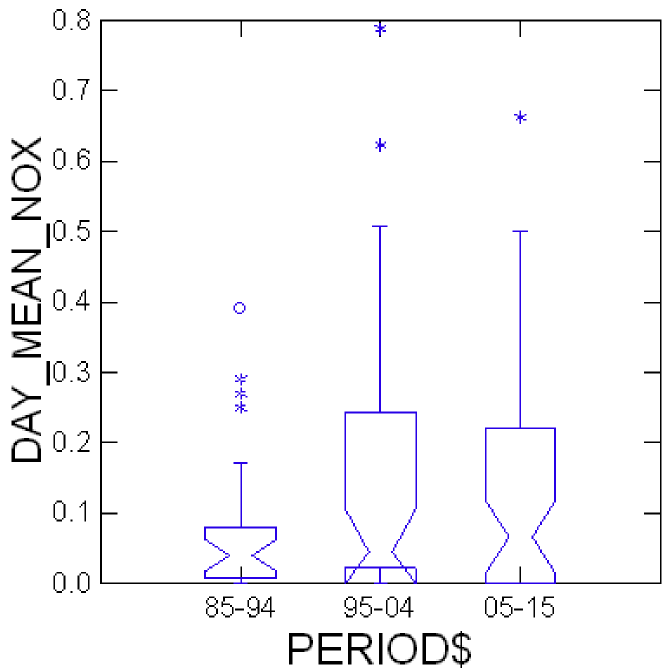


Figure D.78 Box plot of inorganic nitrogen data from Buffalo River mouth by period

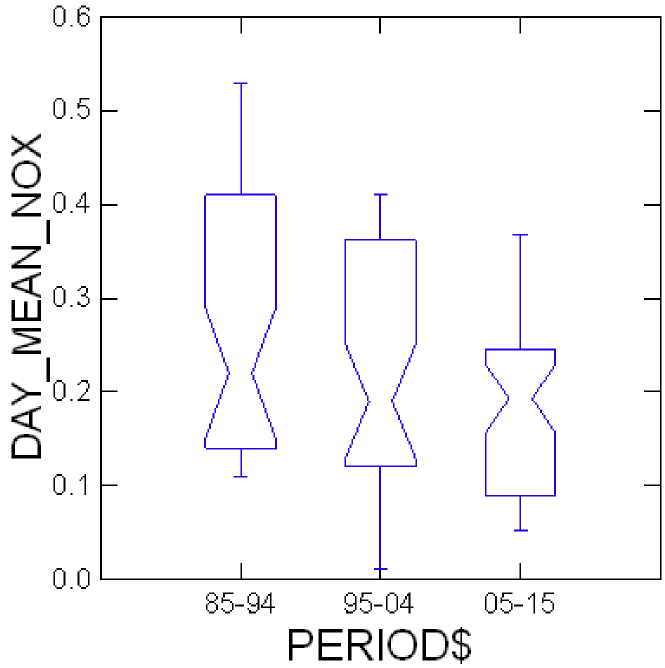


Figure D.79 Box plot of inorganic nitrogen data from Luallen Spring by period

Results for NPS_NAME_CORR041717$ = Mitch Hill Spr

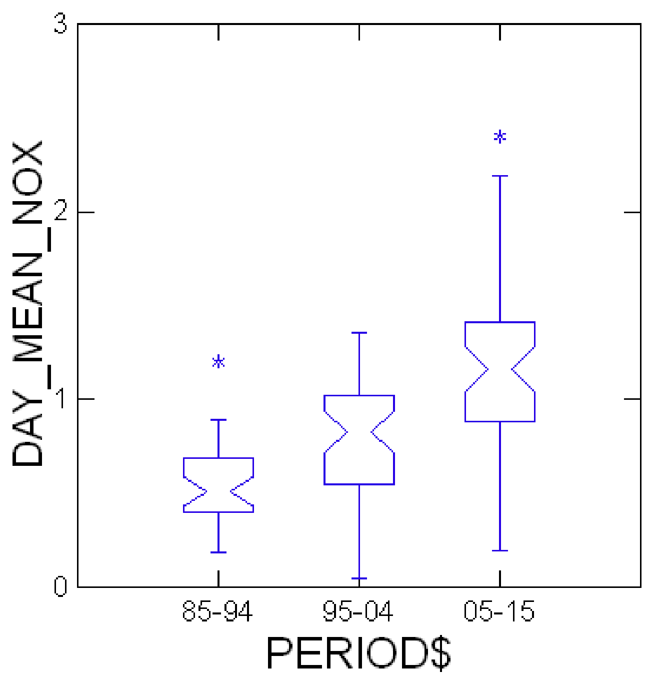


Figure D.80 Box plot of inorganic nitrogen data from Mitch Hill Spring by period

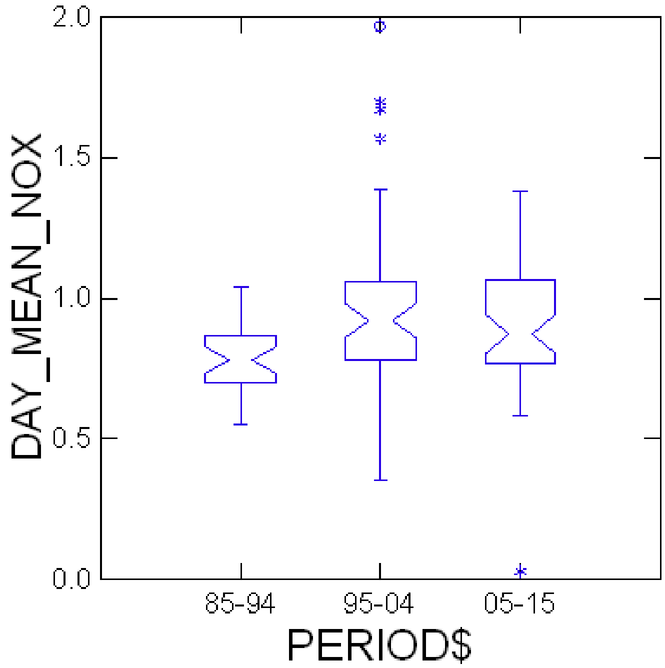


Figure D.81 Box plot of inorganic nitrogen data from Gilbert Spring by period

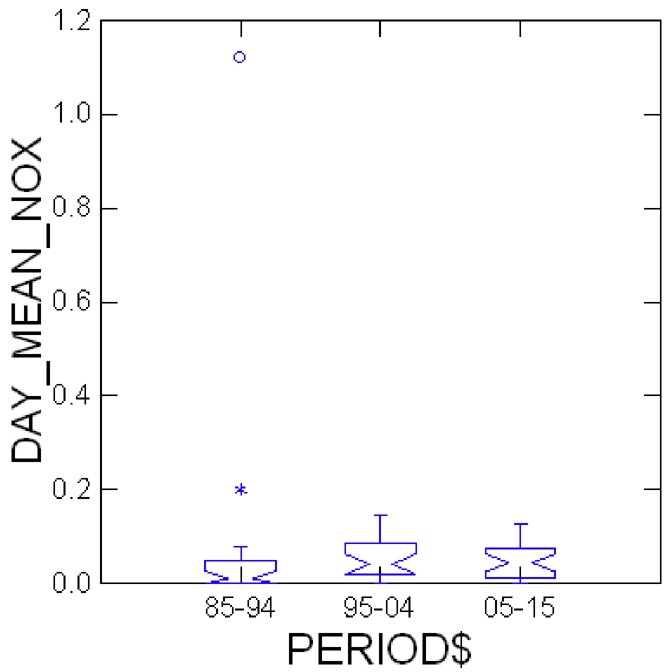


Figure D.82 Box plot of inorganic nitrogen data from Beech Creek by period

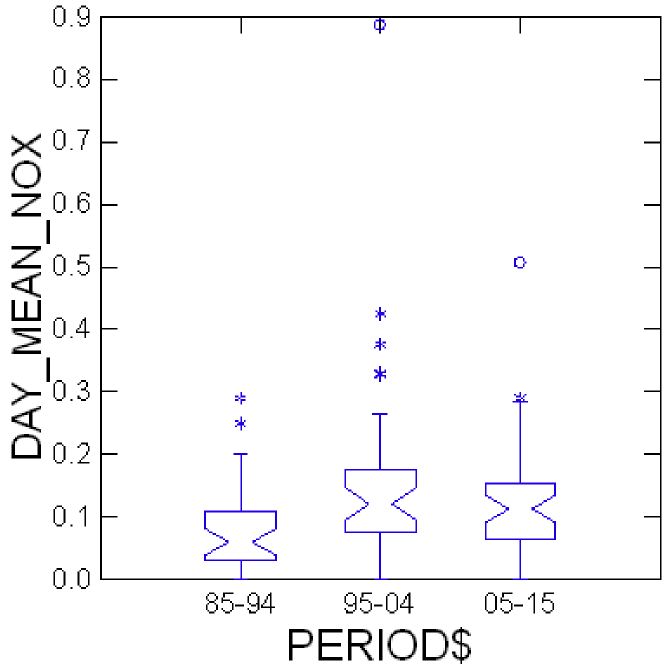


Figure D.83 Box plot of inorganic nitrogen data from Ponca Creek by period

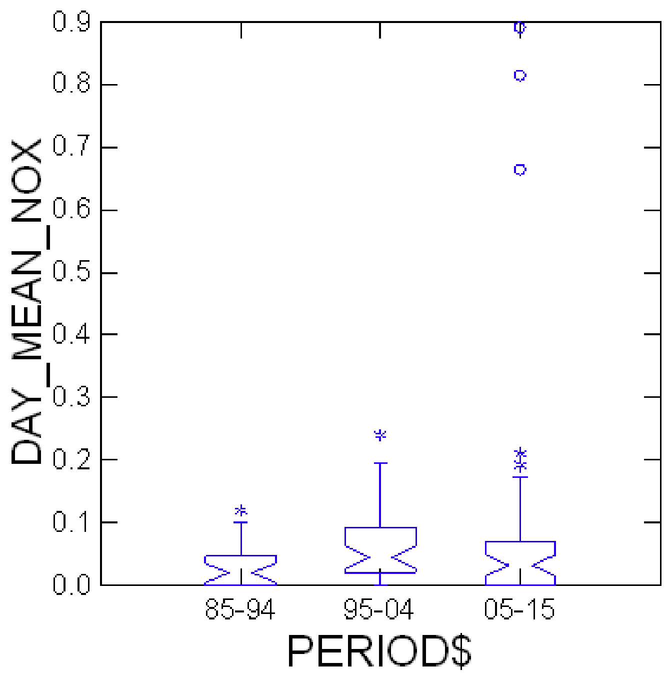


Figure D.84 Box plot of inorganic nitrogen data from Cecil Creek by period

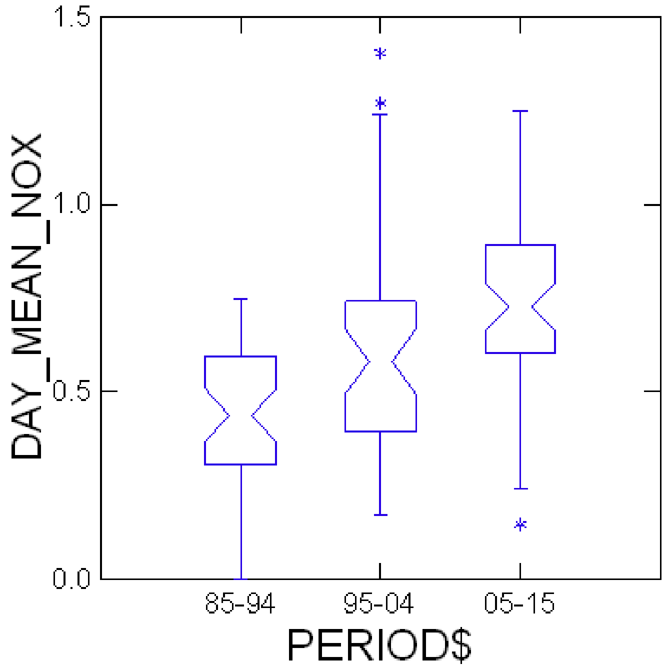


Figure D.85 Box plot of inorganic nitrogen data from Mill Creek (upper) by period

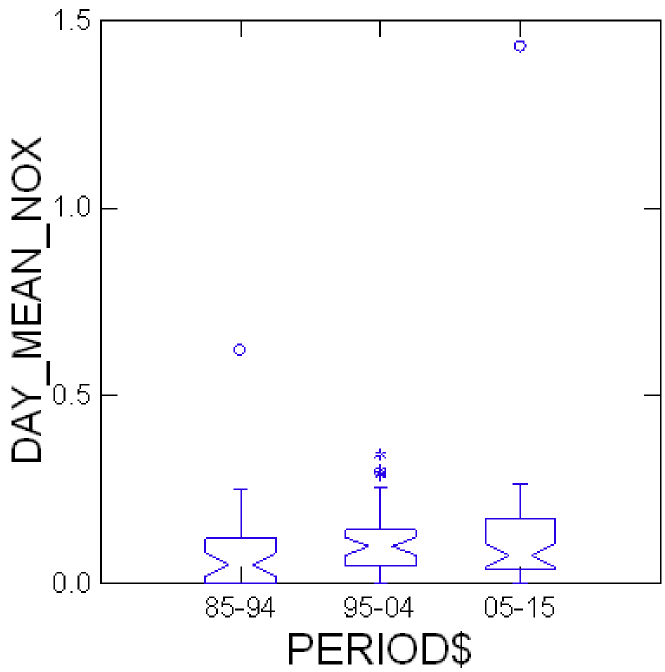


Figure D.86 Box plot of inorganic nitrogen data from Little Buffalo River by period

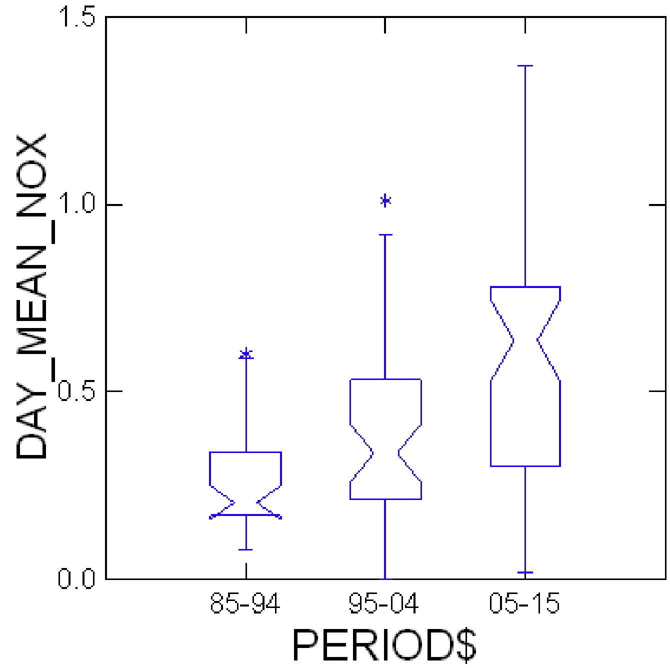


Figure D.87 Box plot of inorganic nitrogen data from Davis Creek by period

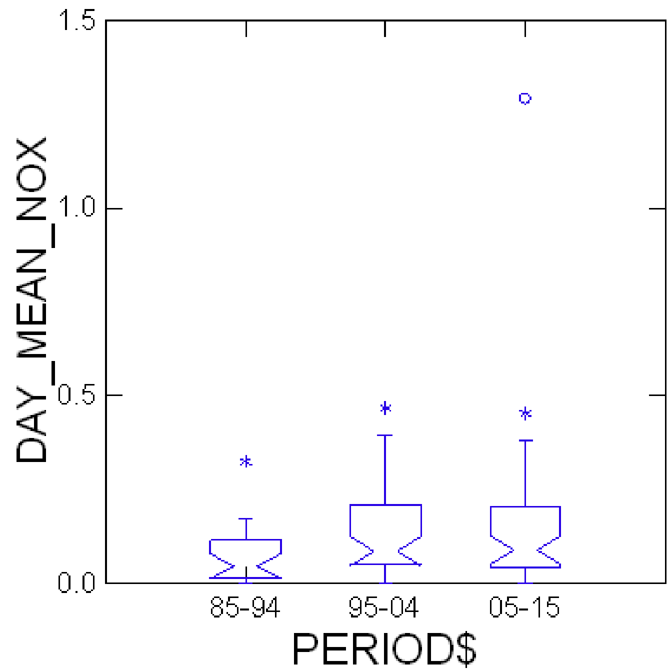


Figure D.88 Box plot of inorganic nitrogen data from Cave Creek by period

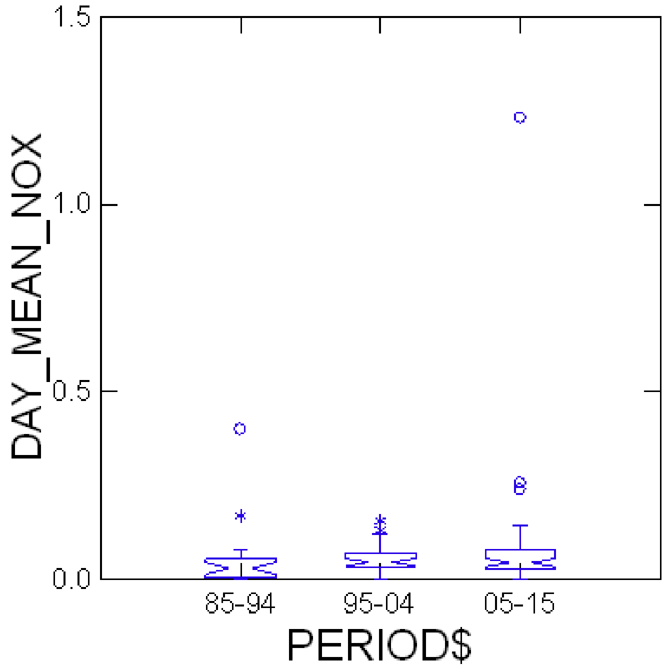


Figure D.89 Box plot of inorganic nitrogen data from Richland Creek by period

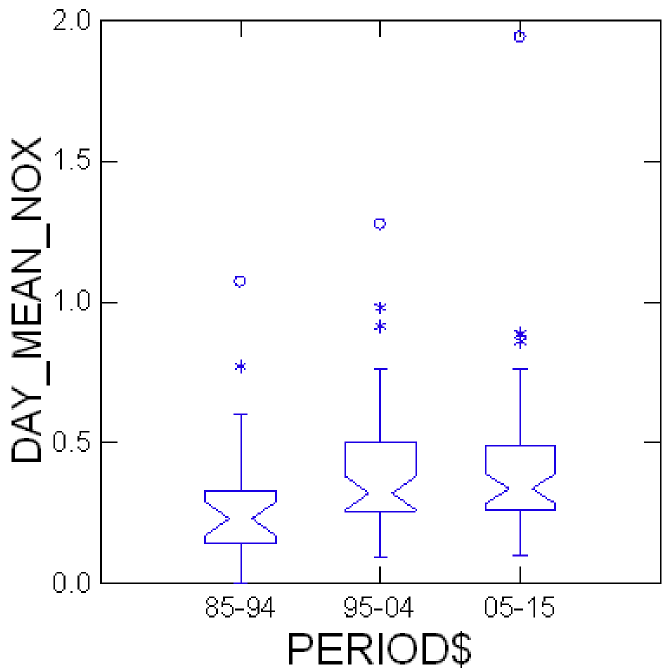


Figure D.90 Box plot of inorganic nitrogen data from Calf Creek by period

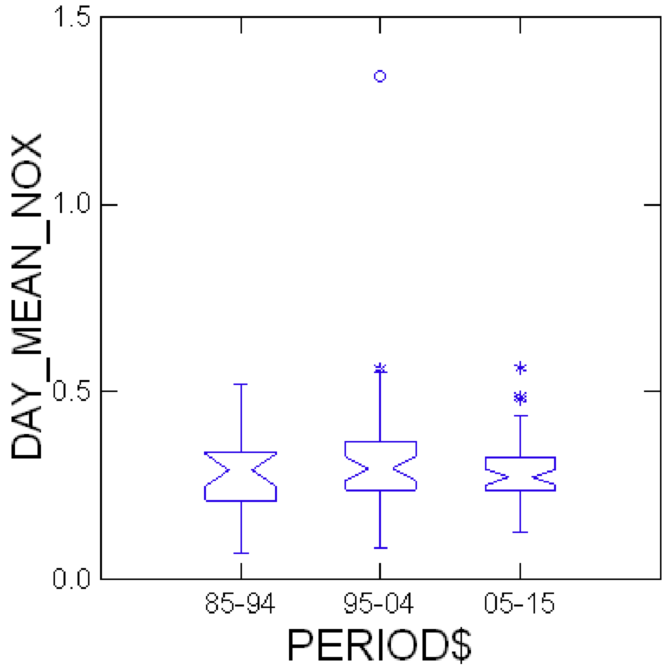


Figure D.91 Box plot of inorganic nitrogen data from Mill Creek (lower) by period

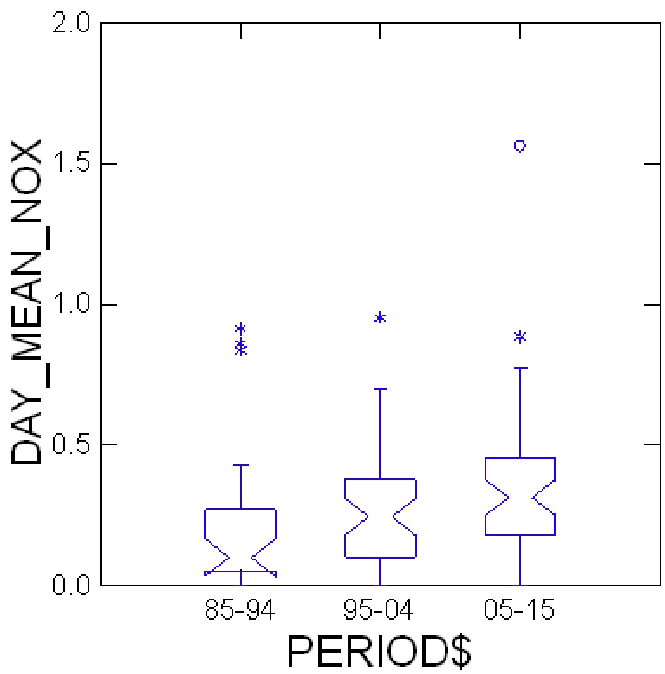


Figure D.92 Box plot of inorganic nitrogen data from Bear Creek by period

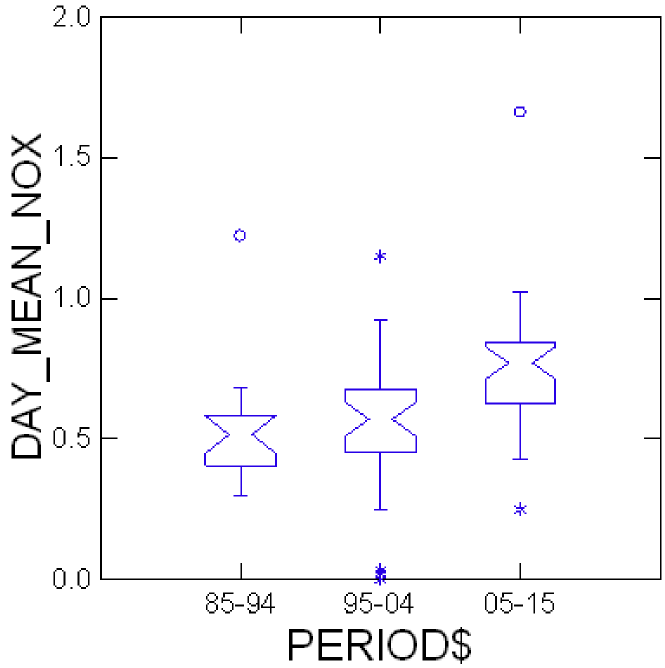


Figure D.93 Box plot of inorganic nitrogen data from Brush Creek by period

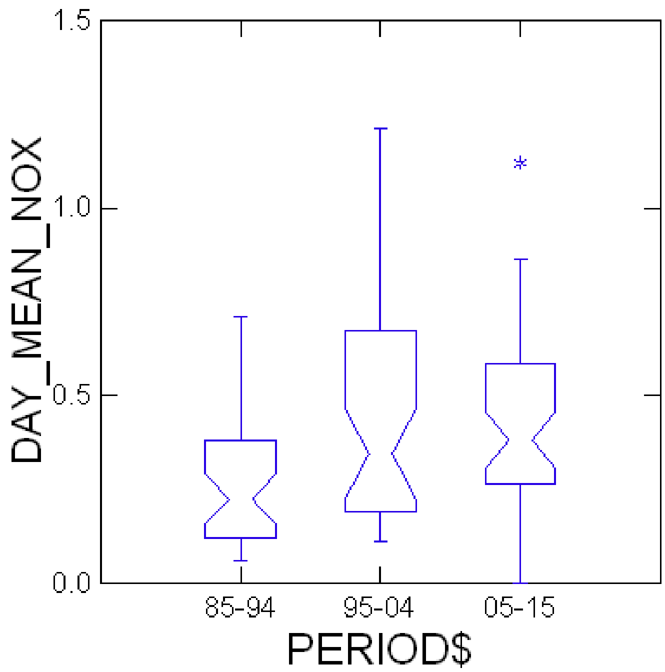


Figure D.94 Box plot of inorganic nitrogen data from Tomahawk Creek by period

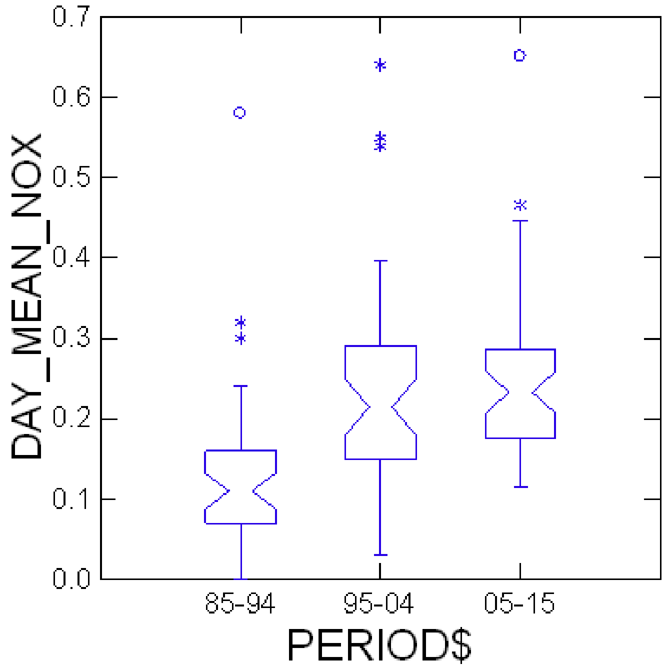


Figure D.95 Box plot of inorganic nitrogen data from Rush Creek by period

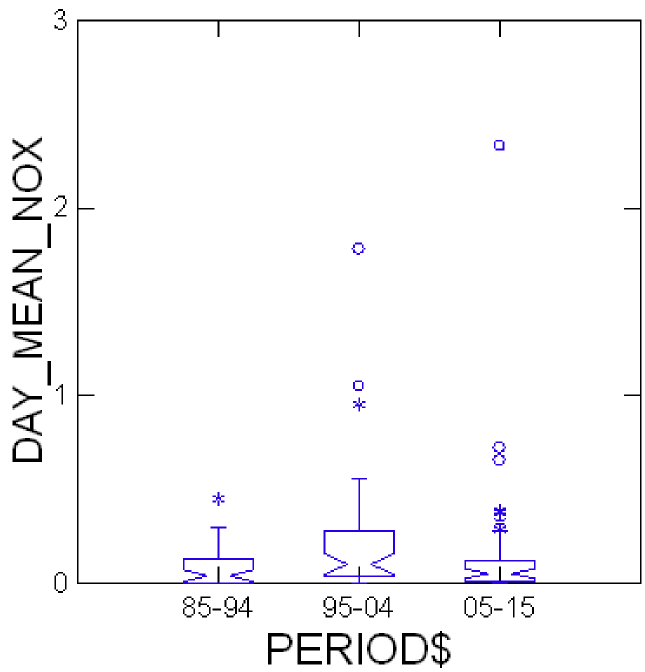


Figure D.96 Box plot of inorganic nitrogen data from Clabber Creek by period

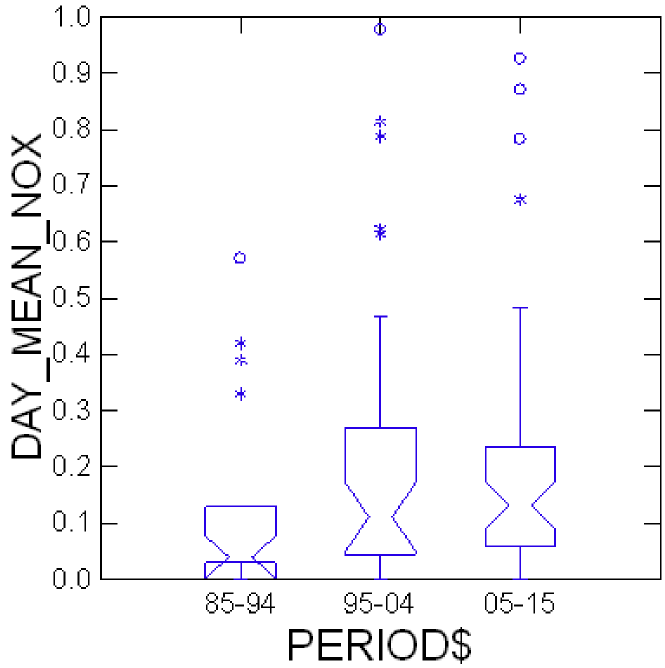


Figure D.97 Box plot of inorganic nitrogen data from Big Creek (lower) by period

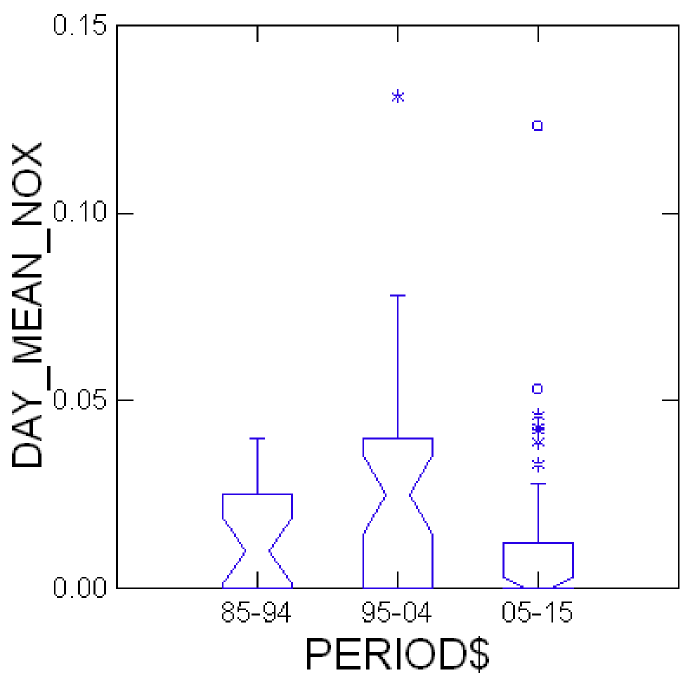


Figure D.98 Box plot of inorganic nitrogen data from Middle Creek by period

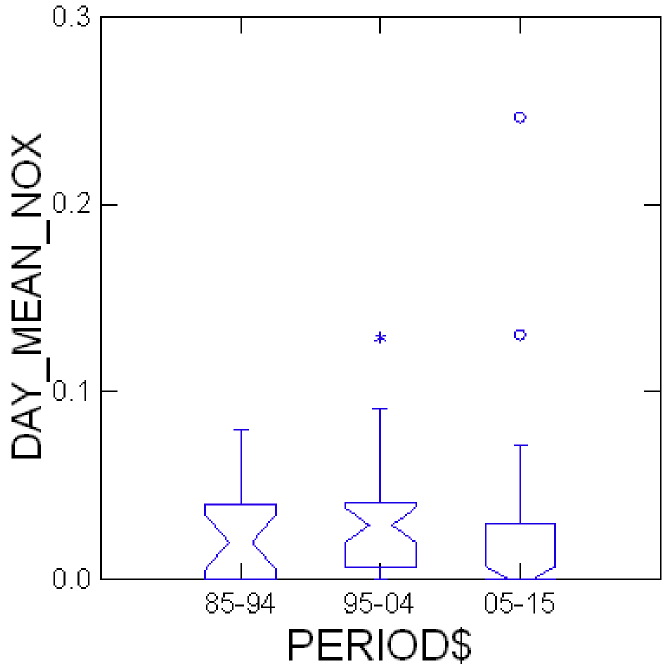


Figure D.99 Box plot of inorganic nitrogen data from Leatherwood Creek by period

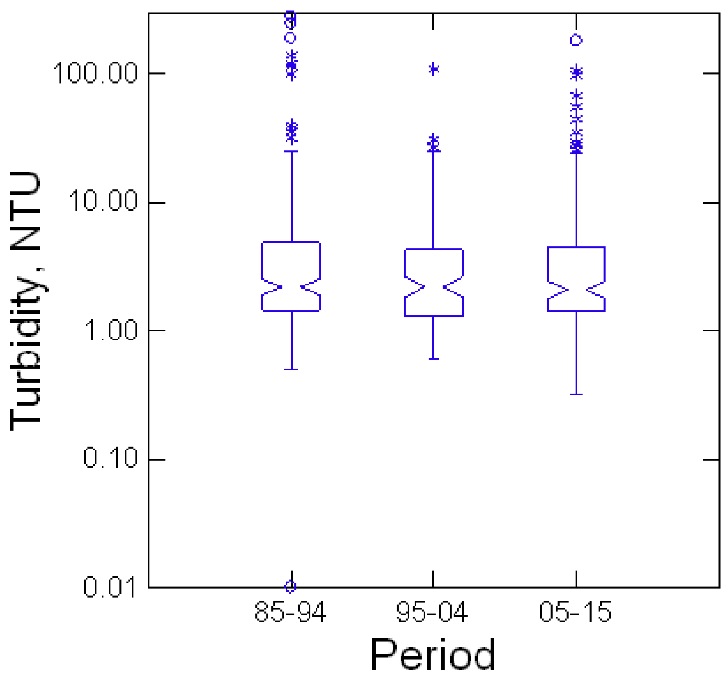


Figure D.100 Box plot of turbidity data from Buffalo River at Highway 65 by period

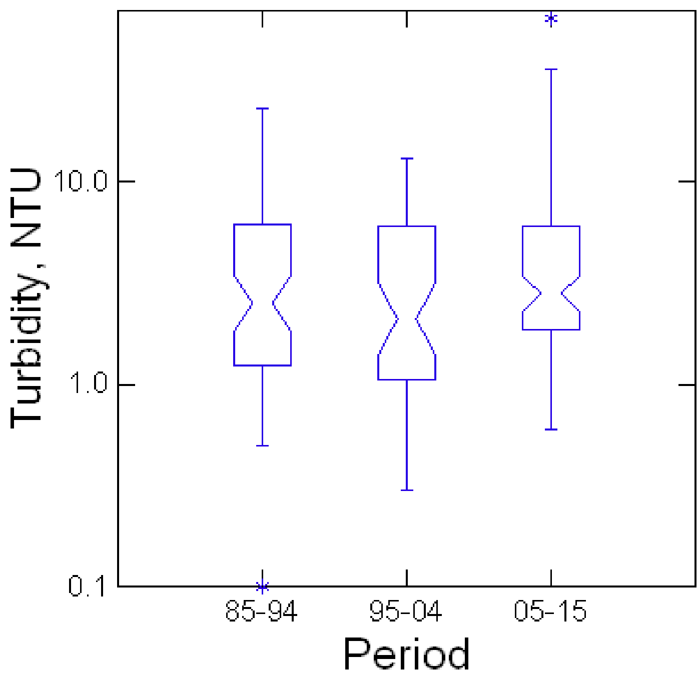


Figure D.101 Box plot of turbidity data from Buffalo River at Wilderness Area boundary by period

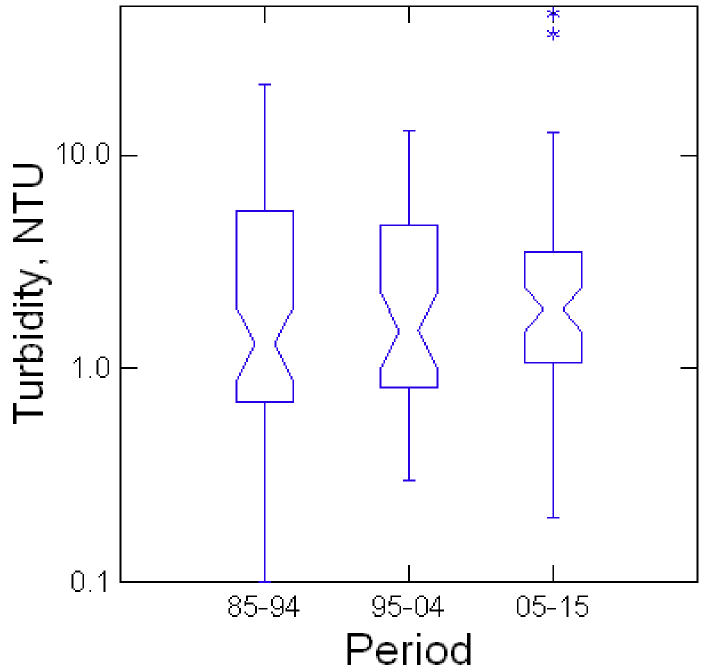


Figure D.102 Box plot of turbidity data from Buffalo River at Ponca access by period

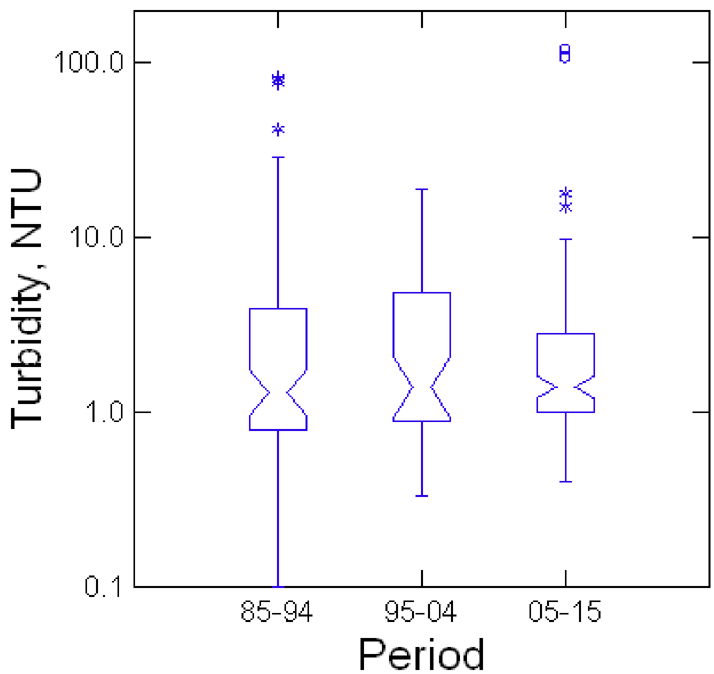


Figure D.103 Box plot of turbidity data from Buffalo River at Pruitt access by period

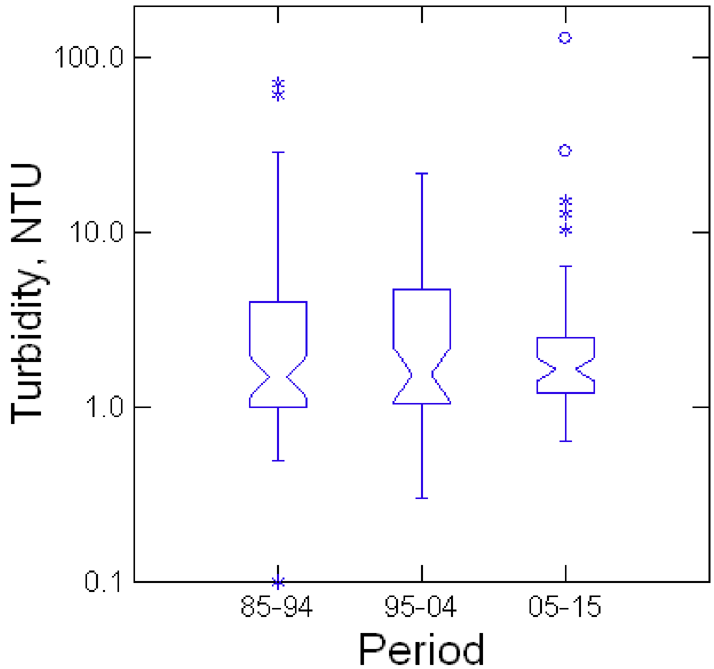


Figure D.104 Box plot of turbidity data from Buffalo River at Hasty by period

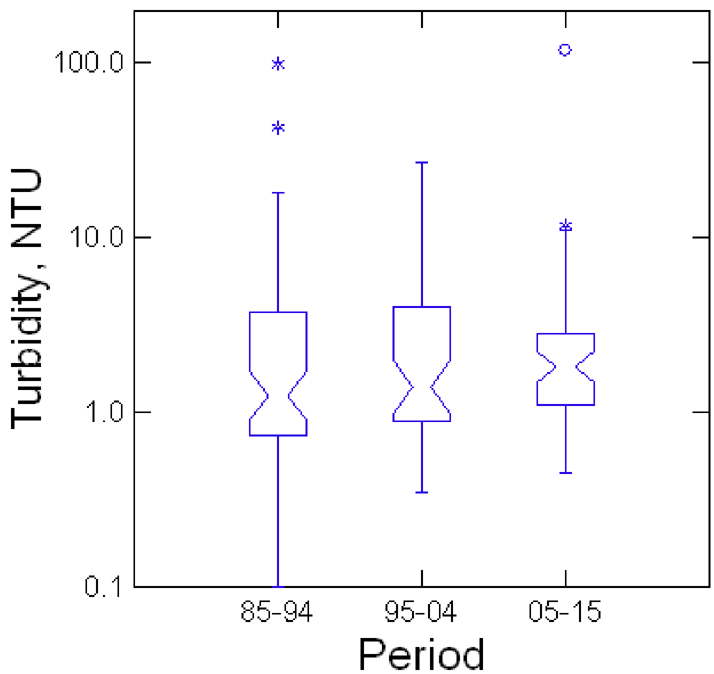


Figure D.105 Box plot of turbidity data from Buffalo River at Woolum by period

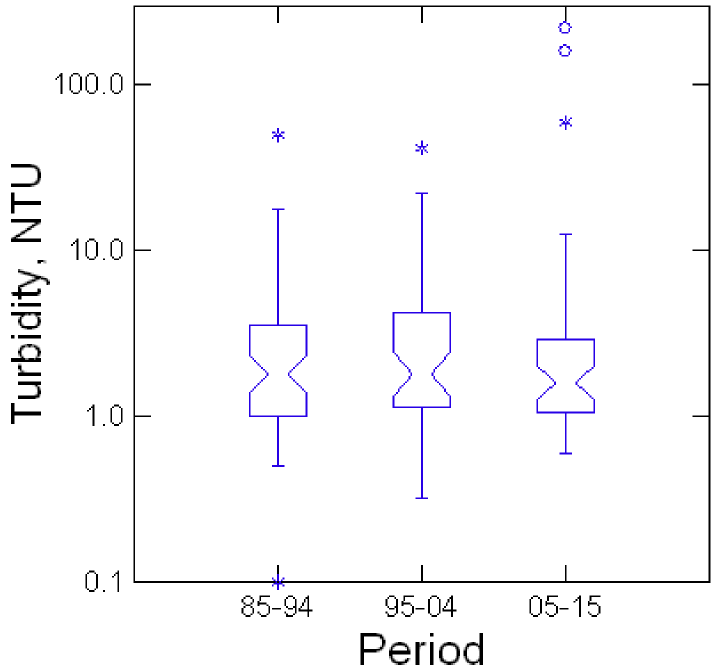


Figure D.106 Box plot of turbidity data from Buffalo River at Gilbert access by period

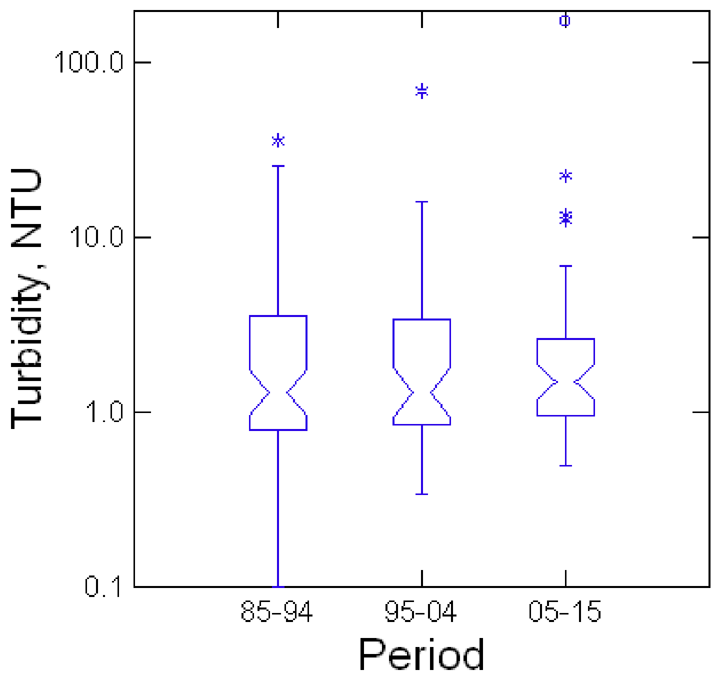


Figure D.107 Box plot of turbidity data from Buffalo River at Highway 14 by period

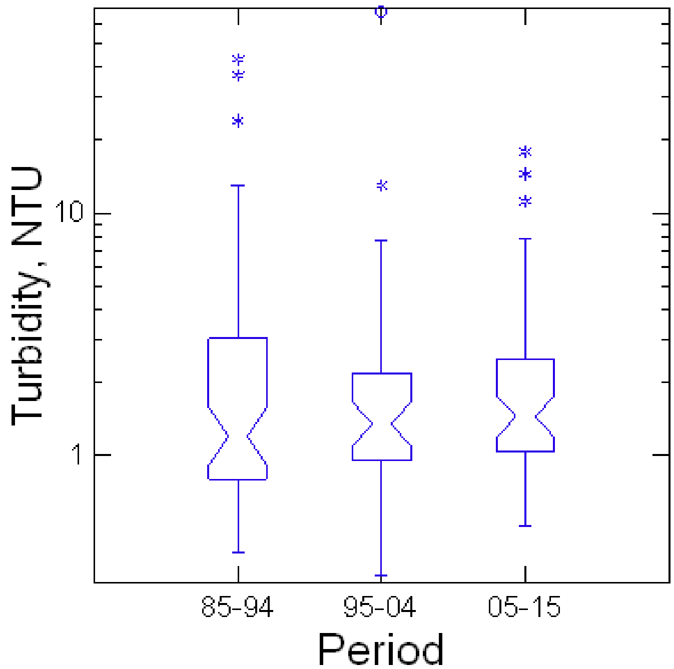


Figure D.108 Box plot of turbidity data from Buffalo River at Rush access by period

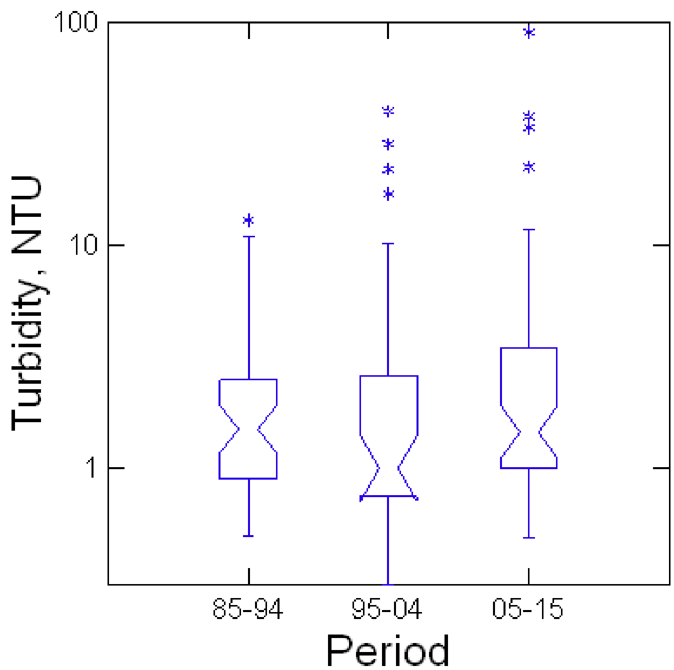


Figure D.109 Box plot of turbidity data from Buffalo River mouth by period

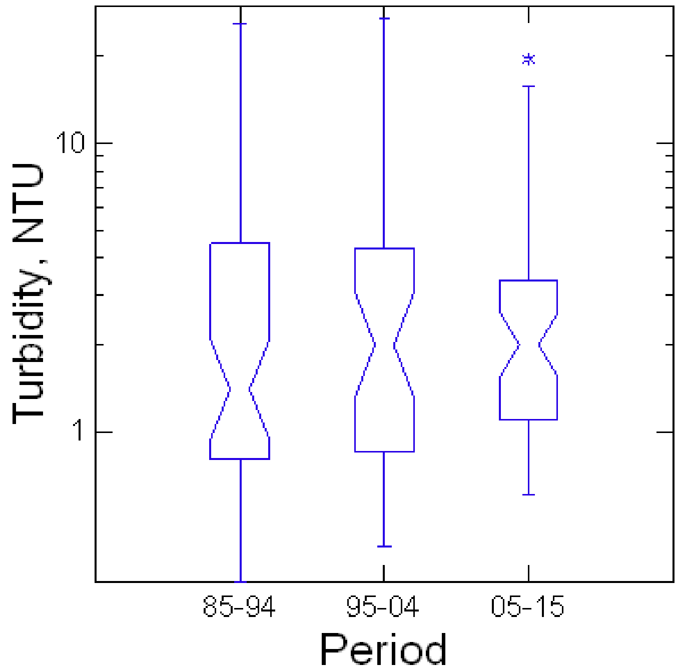


Figure D.110 Box plot of turbidity data from Luallen Spring by period

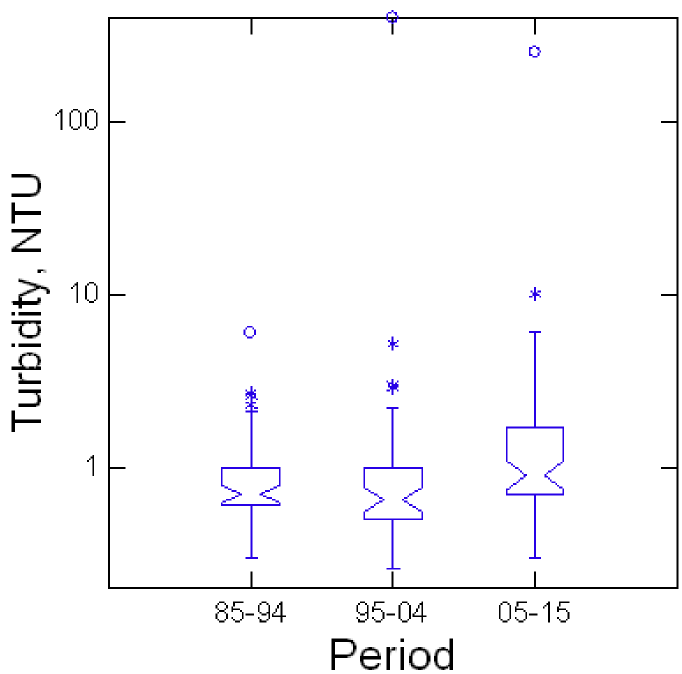


Figure D.111 Box plot of turbidity data from Mitch Hill Spring by period

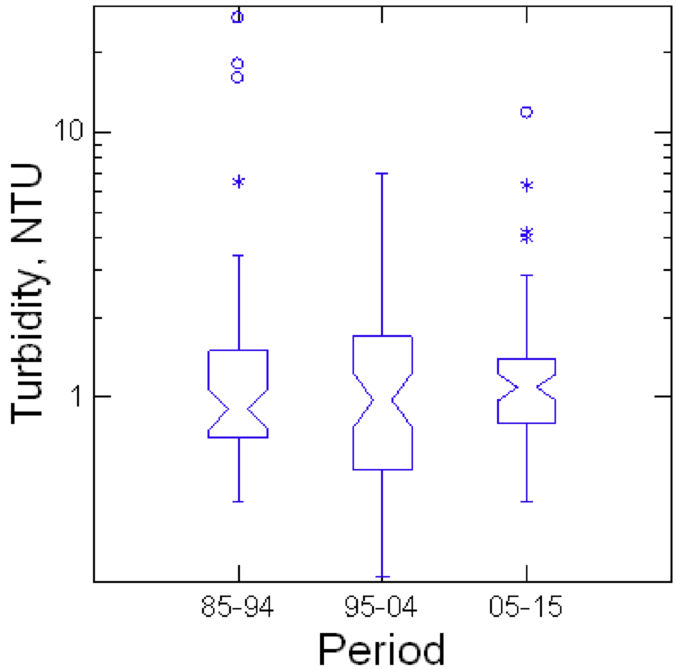


Figure D.112 Box plot of turbidity data from Gilbert Spring by period

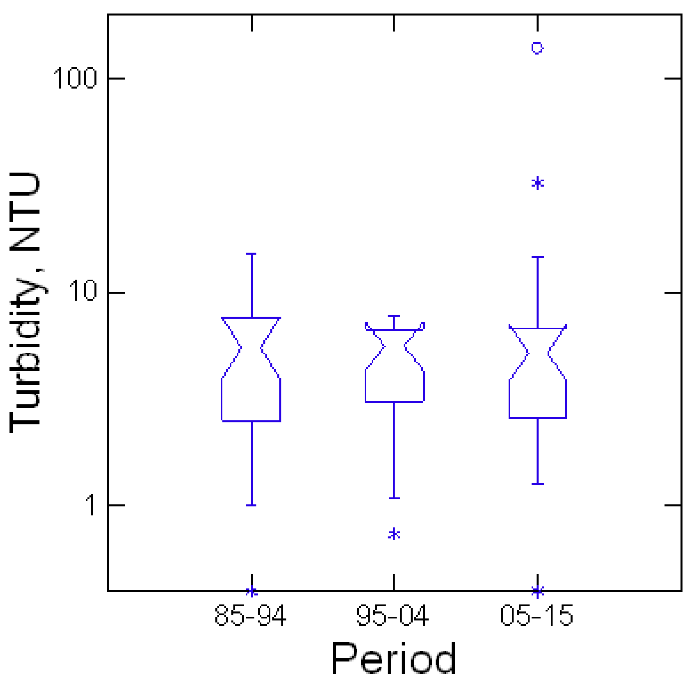


Figure D.113 Box plot of turbidity data from Beech Creek by period

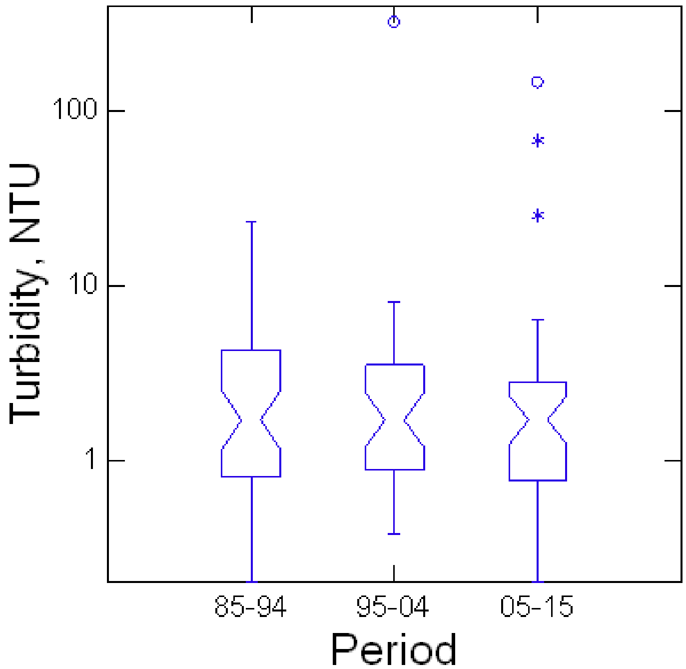


Figure D.114 Box plot of turbidity data from Ponca Creek by period

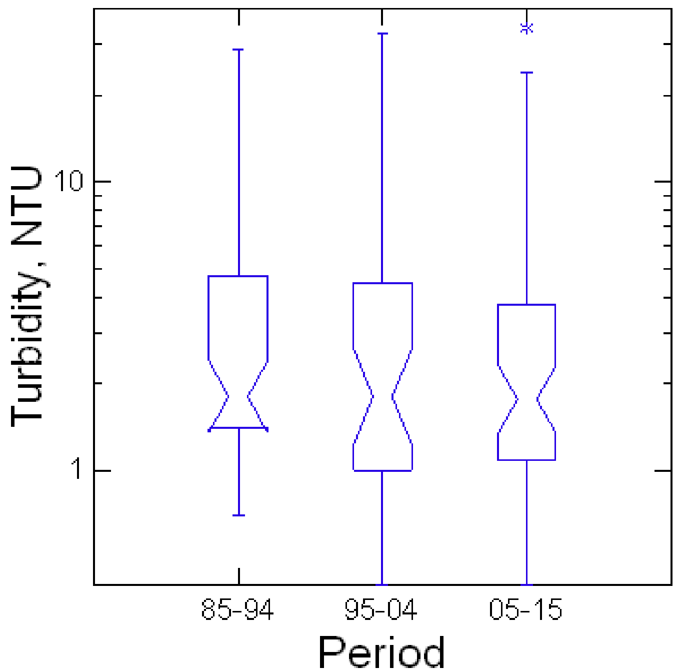


Figure D.115 Box plot of turbidity data from Cecil Creek by period

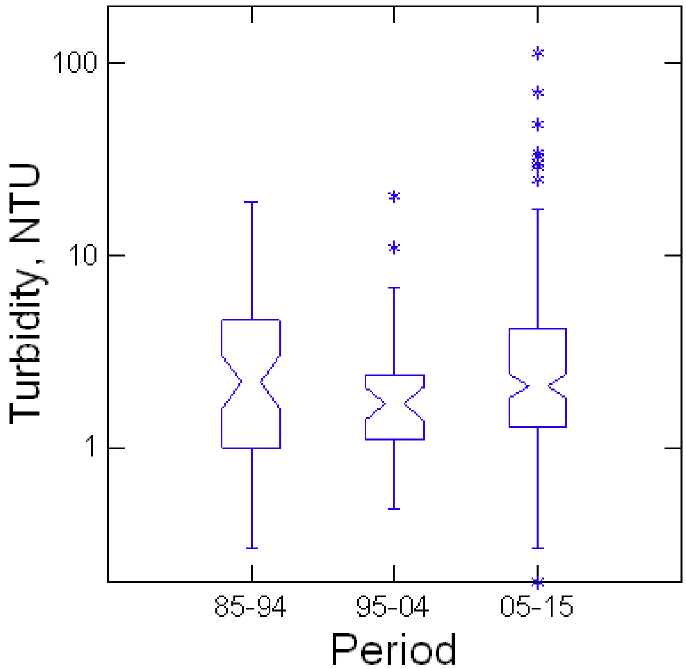


Figure D.116 Box plot of turbidity data from Mill Creek (upper) by period

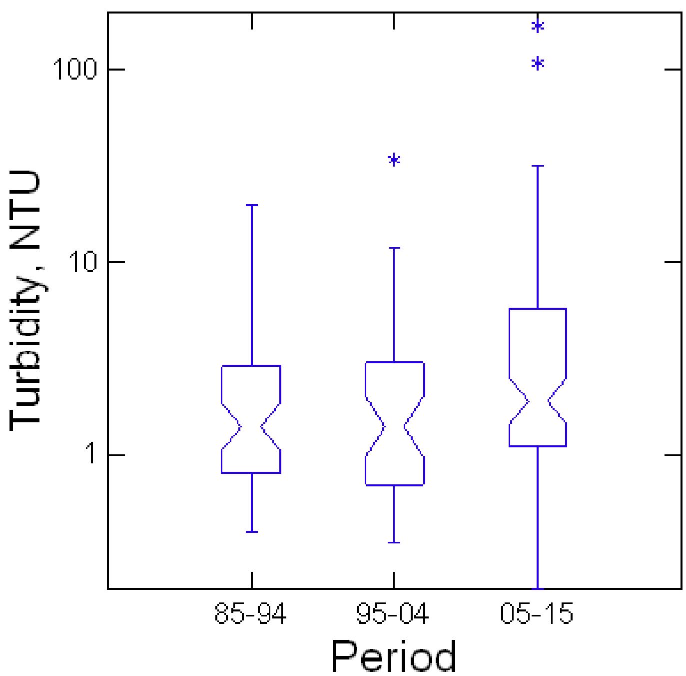


Figure D.117 Box plot of turbidity data from Little Buffalo River by period

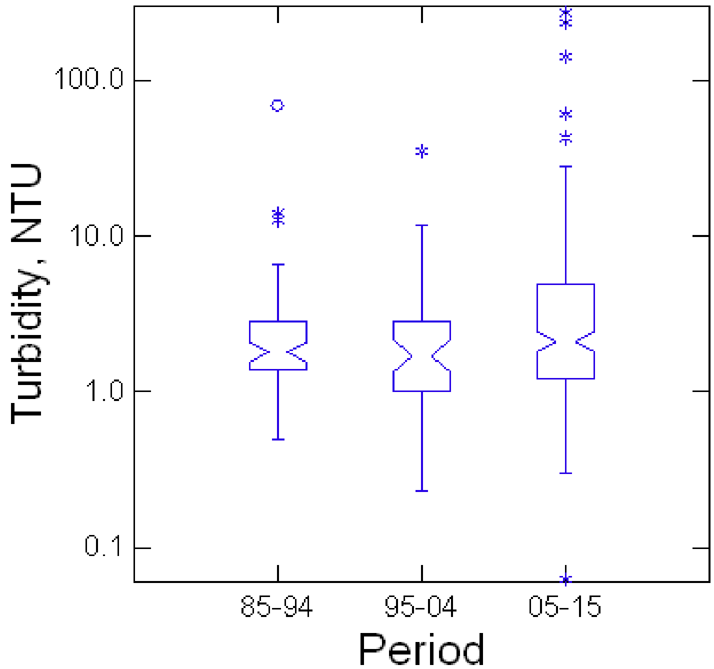


Figure D.118 Box plot of turbidity data from Big Creek (upper) by Carver by period

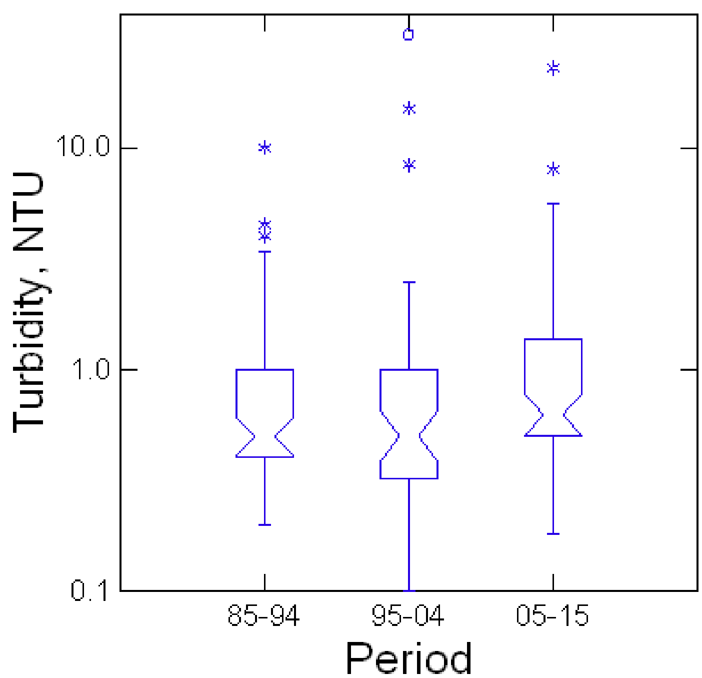


Figure D.119 Box plot of turbidity data from Davis Creek by period

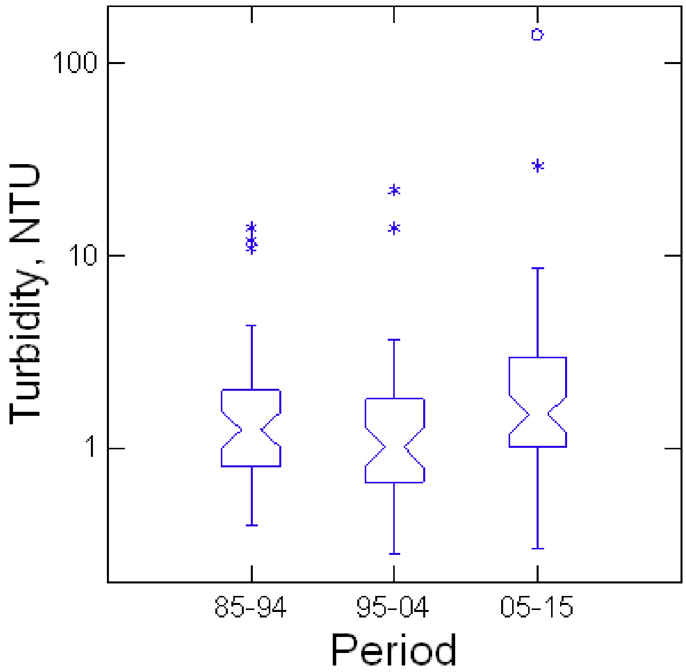


Figure D.120 Box plot of turbidity data from Cave Creek by period

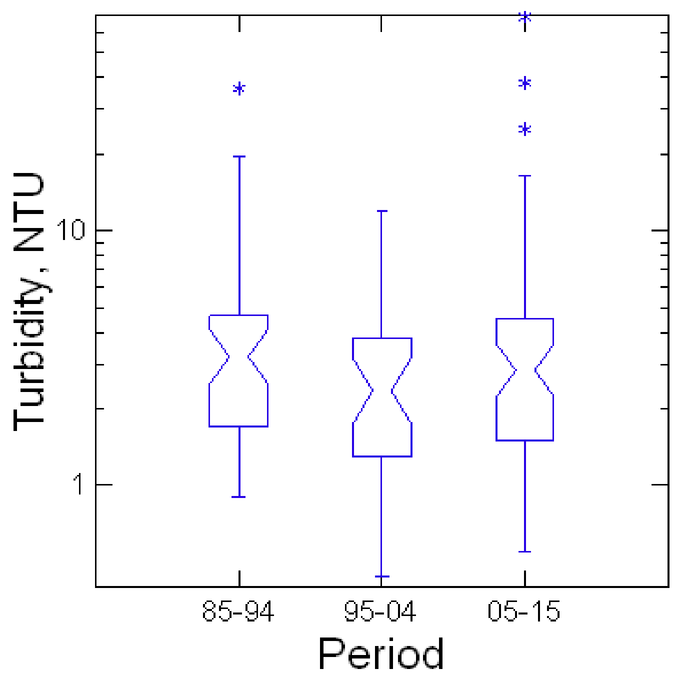


Figure D.121 Box plot of turbidity data from Richland Creek by period

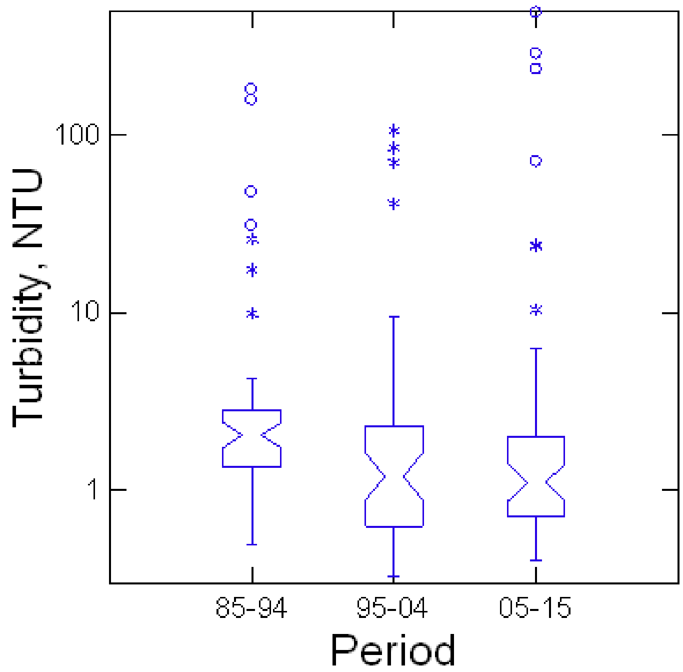


Figure D.122 Box plot of turbidity data from Calf Creek by period

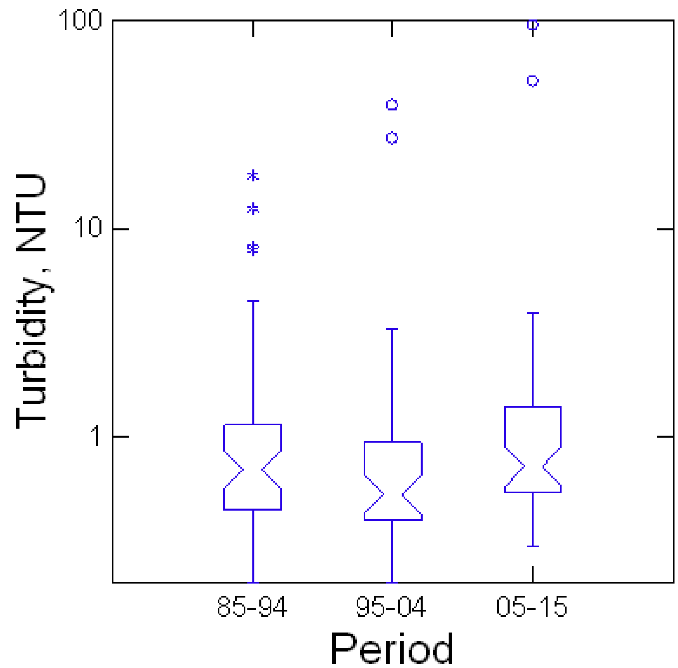


Figure D.123 Box plot of turbidity data from Mill Creek (lower) by period

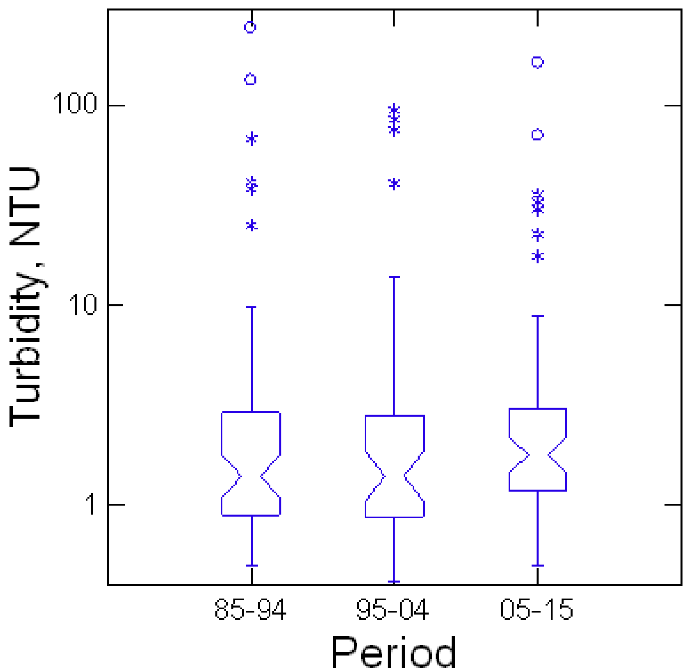


Figure D.124 Box plot of turbidity data from Bear Creek by period

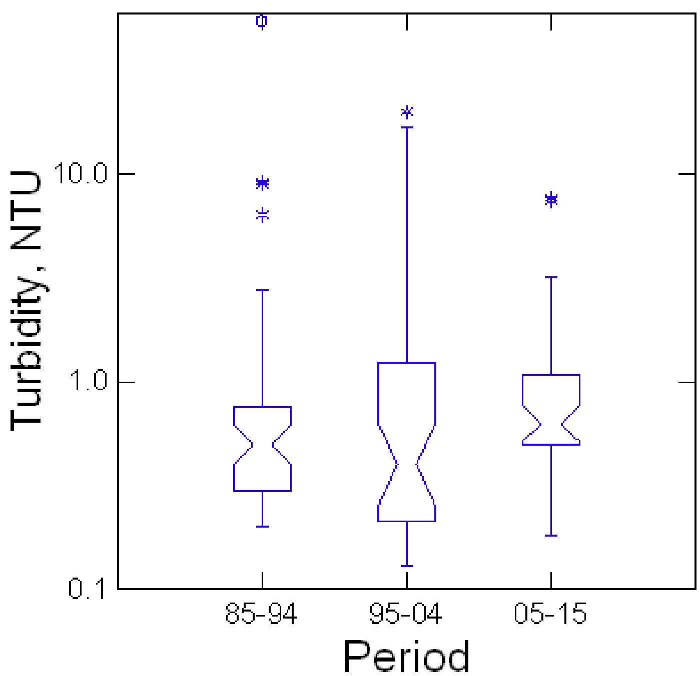


Figure D.125 Box plot of turbidity data from Brush Creek by period

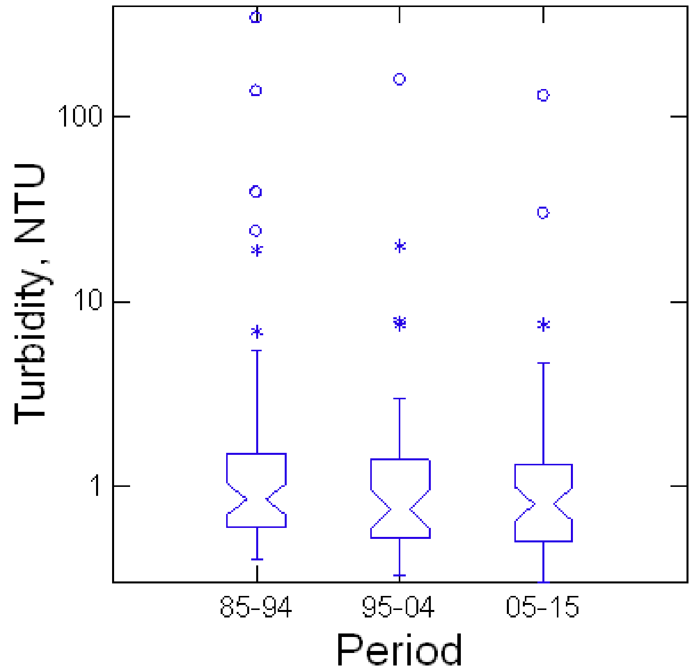


Figure D.126 Box plot of turbidity data from Tomahawk Creek by period

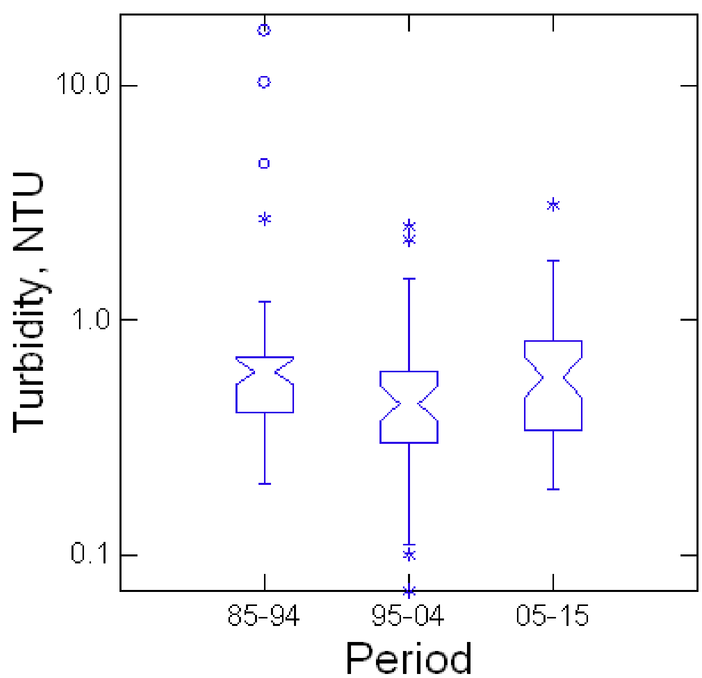


Figure D.127 Box plot of turbidity data from Water Creek by period

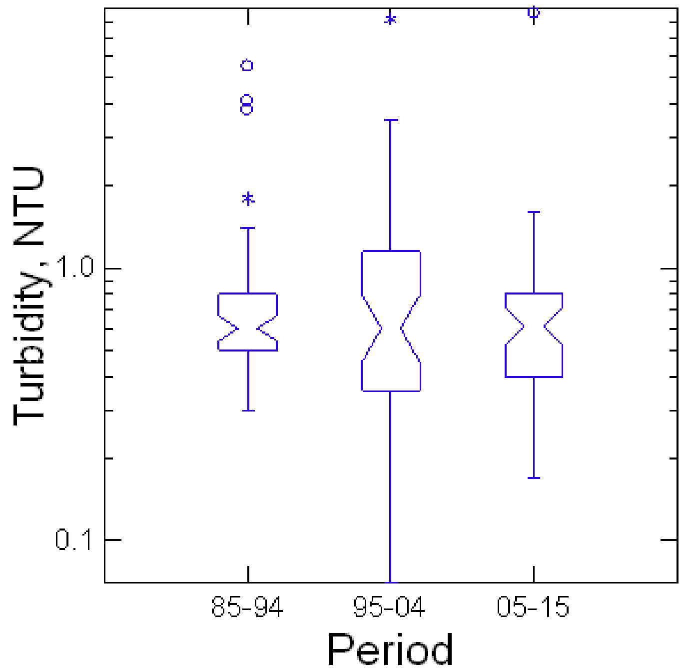


Figure D.128 Box plot of turbidity data from Rush Creek by period

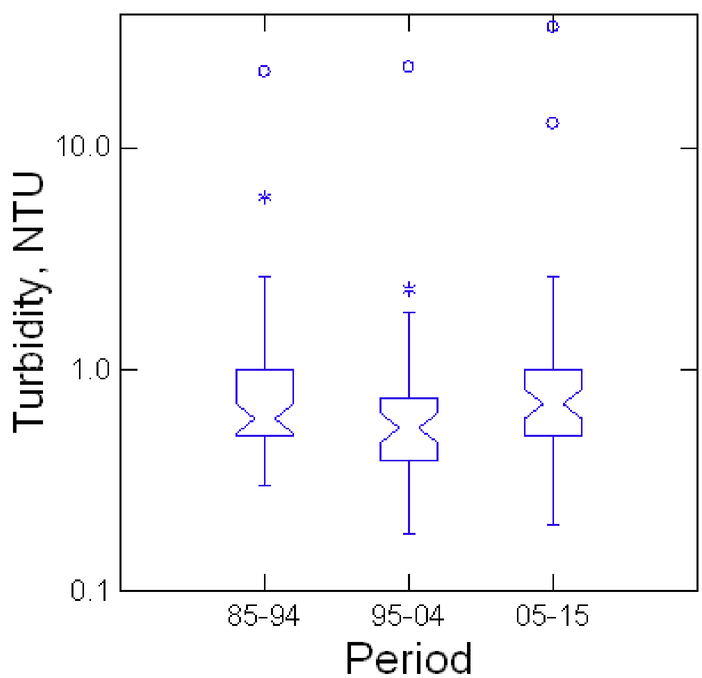


Figure D.129 Box plot of turbidity data from Clabber Creek by period

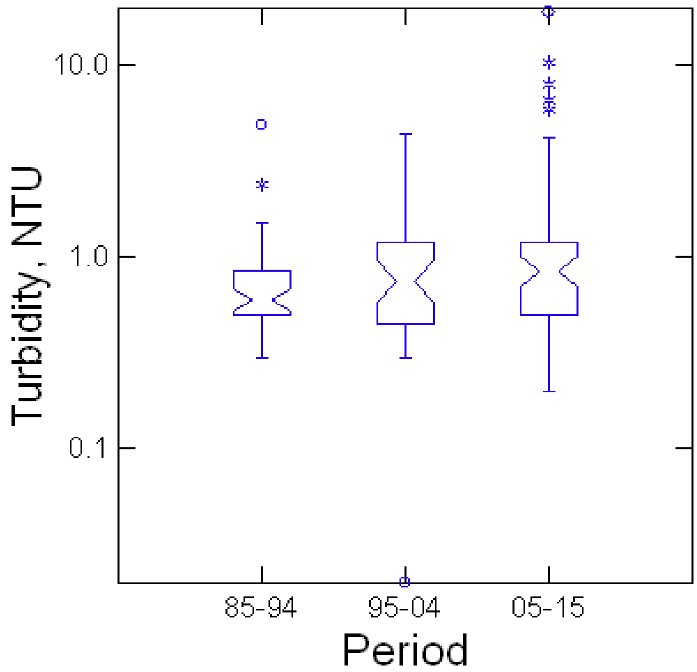


Figure D.130 Box plot of turbidity data from Big Creek (lower) by period

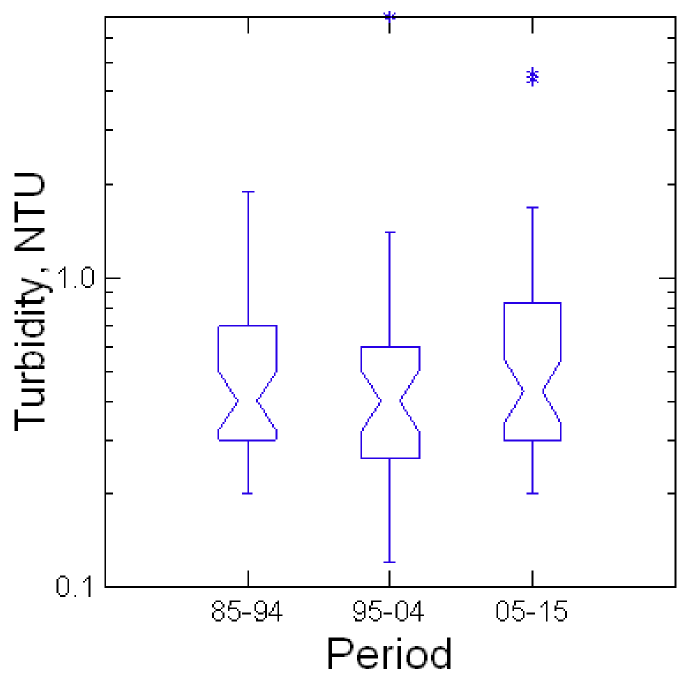


Figure D.131 Box plot of turbidity data from Middle Creek by period

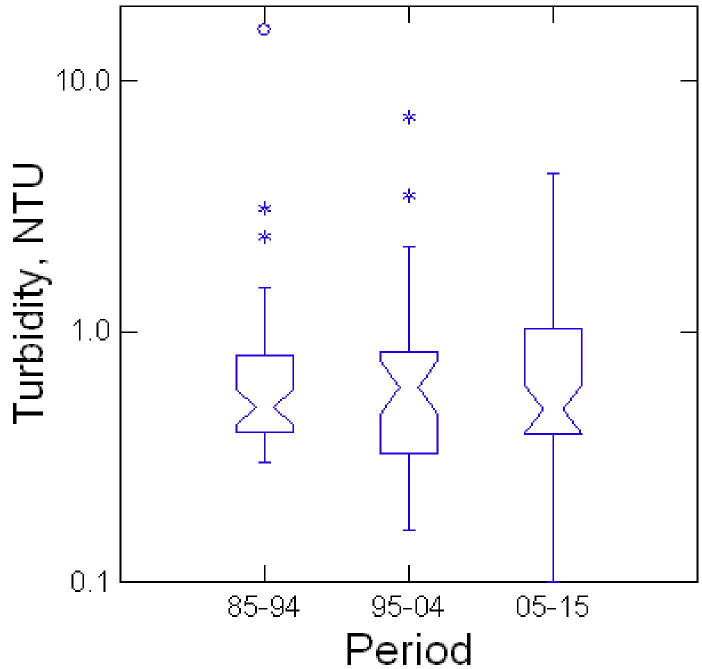


Figure D.132 Box plot of turbidity data from Leatherwood Creek by period

APPENDIX E

Buffalo River Watershed SWAT Model Report

FTN Associates Ltd.
water resources / environmental consultants

BUFFALO RIVER WATERSHED

SWAT MODEL

February 27, 2018

BUFFALO RIVER WATERSHED
SWAT MODEL

Prepared for:

Arkansas Natural Resources Commission
101 E Capitol Ave # 350
Little Rock, AR 72201

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Project 14-900
FY 2014, CWA Section 319 (h)
FTN No. 03015-0005-046

February 27, 2018

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 Study Area

The Buffalo River Watershed is home to approximately 16,000 Arkansans, lies within the White River Basin in Northwest Arkansas, and has a drainage area of 1,340 square miles. The Buffalo River originates in southwest Newton County, and then flows north and then east. The watershed includes parts of Baxter, Boone, Madison, Marion, Newton, Pope, Searcy, Stone and Van Buren counties. However, almost 95% of the watershed is found in three counties: Newton, Searcy and Marion counties (Scott & Hofer, 1995). A number of towns are located within the watershed. Marshall is the largest, located in the southeastern part of the watershed. Jasper is the second largest and is located in the western portion.

1.1.1 Geology

The watershed is located within the Ozark Plateaus Physiographic Province with mountain ridges and intervening valleys and is characterized by typical dendritic drainage patterns. In the watershed, there are abundant caves, sinkholes, losing streams, and springs that are linked in karst hydrologic systems, with carbonate lithologies determining the potential for karst development (Hudson, Turner & Bitting, 2011). The strata in the watershed is composed of an aggregate sequence of sedimentary rocks that is nearly 500m thick and includes carbonate, sandstone, and shale formations of Pennsylvanian, Mississippian, and Ordovician age (Hudson, 1998).

The Boston Mountains Section of the Ozark Plateau covers about 35% of the watershed, located in the southern and western portions (Figure 1-1), and is capped by Pennsylvanian aged rocks that are generally composed of sandstones and shales, although limestone may be present (Arkansas Geological Survey, 2017). This area is also very rugged with steep slopes and elevations greater than 2,500 ft. The naming of this area is believed to have originated during a time when a difficult undertaking was called a “Boston” – because crossing the mountains with wagons was a very difficult task (U.S. Geological Survey, 1980). Small springs can be found in the Boston Mountains; however, most springs and caves in the western part of the watershed are concentrated within the Boone Formation (see Figure 1-2) of the Springfield Plateau and discharge at or near the basal contact of the St. Joe Limestone Member (Hudson et al., 2011).

The majority of the watershed is located in the Springfield Plateau (approximately 55%). This section is overlaid by the Mississippian aged limestones of the Boone Formation (Arkansas Geological Survey, 2017). The Boone Formation is the main karst aquifer in the watershed, however, the Ordovician aged Everton Formation, which is present at lower elevation, forms a second karst aquifer and is responsible for the largest spring (Mitch Hill Spring) in the Buffalo River National Park (Hudson et al., 2011). The Everton Formation is part of the Salem Plateau, which contains dolostones, sandstones and limestones (McFarland, 2004), and covers the remaining 10% of the watershed.

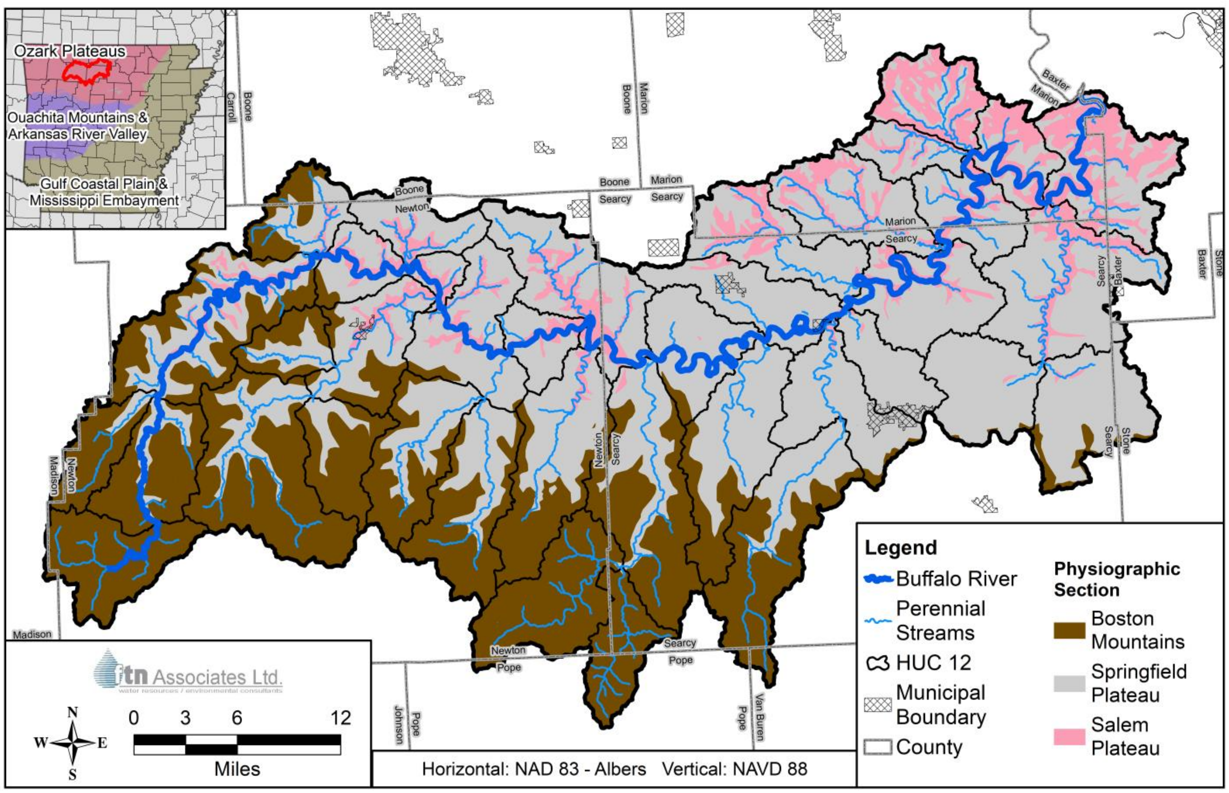

Figure 1-1 Buffalo River Physiographic Sections.

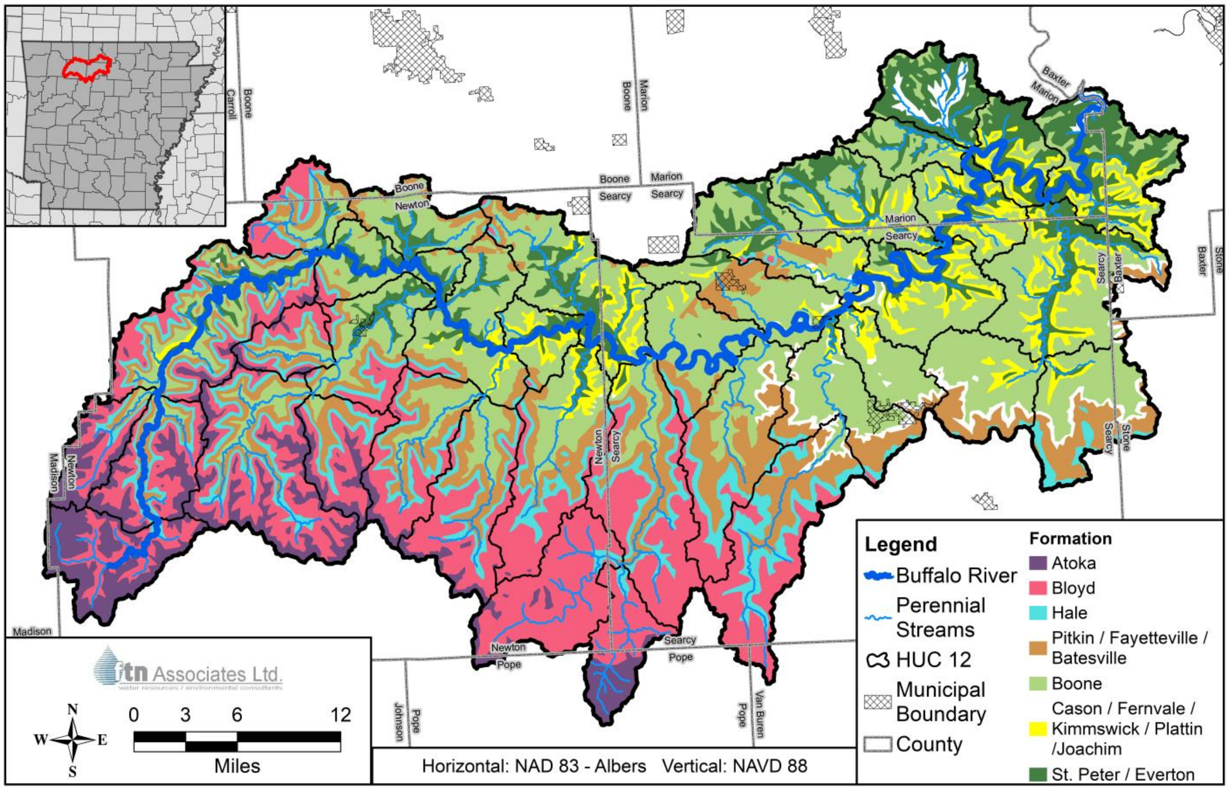

Figure 1-2 Buffalo River Geology.

1.1.2 Land Use

Nearly 80% of the watershed is forested, 17% of the land is either pasture or hay, and the remaining 3% is mostly low density urban. Widespread forest cover coincides with the rugged terrain and poor soils in the watershed (Fowlkes, McCright, & Lowrance, 1988); however, the large amount of public land managed by the National Park Service (NPS), U.S. Forest Service, and the Arkansas Game and Fish Commission also contributes to the high percentage of forest cover (Figure 1-3). These three government entities manage approximately 91,000 acres (11%), 195,000 acres (23%), and 23,000 acres (3%) of the watershed respectively. Included in this public land, are some unique natural resources, including the Buffalo River National Park, Gene Rush and Loafer's Glory Wildlife Management Areas, and the Ozark National Forest.

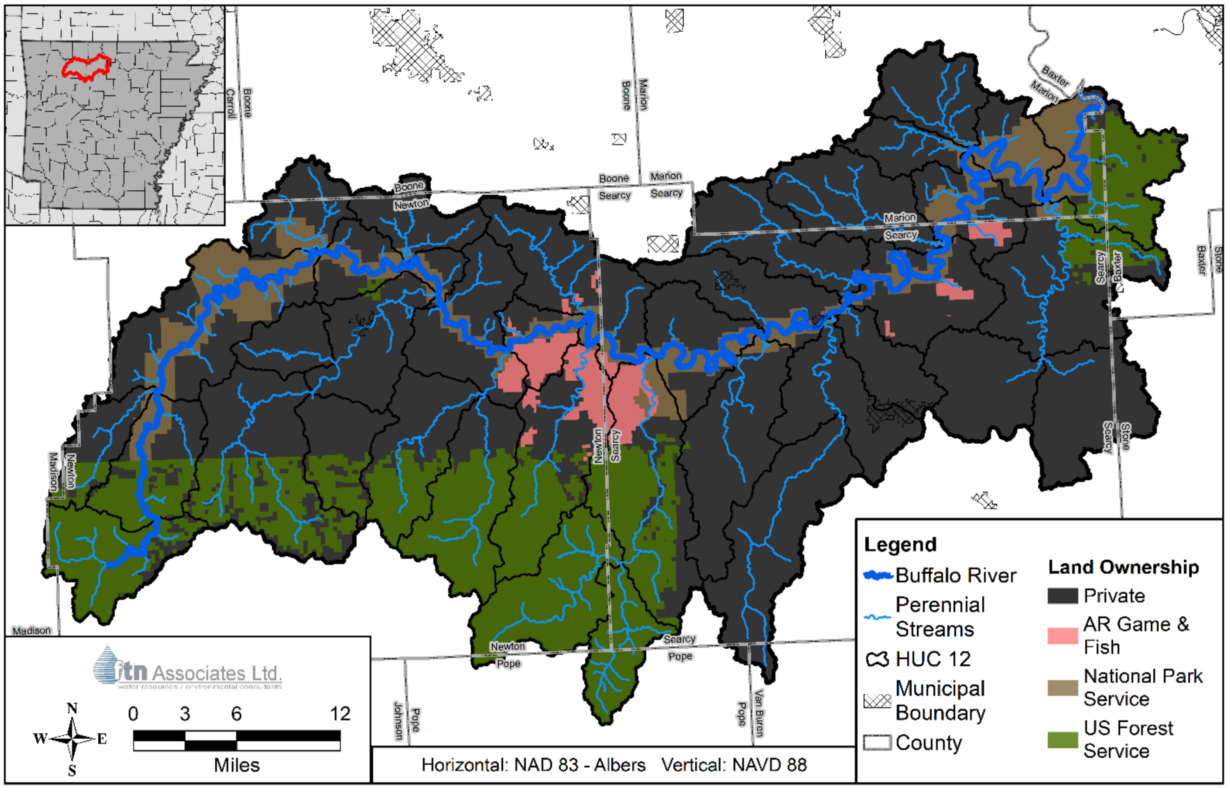

Figure 1-3 Land Ownership in the Buffalo River Watershed.

1.2 Objective

There are several activities that are potential threats to water quality in the Buffalo River and its tributaries. These activities include: agricultural practices (e.g., livestock in streams, poor or non-existent riparian buffers, poor quality pastures, clearing land with a slope greater than 15% for pasture, timber harvest, and manure application and storage), recreation, unpaved roads, stream bank erosion, and groundwater contributions from outside the watershed. This project will focus on non-point source threats that are generally associated with land use/management and physical properties such as slope and soil classification.

An initial step in protecting water quality in the watershed is to prepare a U.S. Environmental Protection Agency (U.S. EPA) accepted nine element watershed-based management plan, prioritize sub-watersheds (12 Digit Hydrologic Unit Code Watersheds [HUC12s]) so investment strategies can be developed, and target projects that will have the greatest impact on water quality objectives. Implementing projects that have a positive and quantifiable impact on water quality and that are supplemented with grants should encourage local support for their implementation.

The objective of this project is to prepare an application of the Soil and Water Assessment Tool (SWAT) model (Arnold, Srinivasan, Muttiah, & Williams, 1998) for the Buffalo River Watershed. Sub-watersheds (HUC12s) will be prioritized based on modeled average annual sediment, total phosphorus, and total nitrogen loading rates. This will assist planners and regulatory personnel in developing investment strategies that will have the greatest impact on water quality objectives.

1.3 Materials and Methods

When compared to most watersheds in the State of Arkansas, the Buffalo River Watershed contains a large amount of measured streamflow and water quality data. This data is invaluable to researchers and regulators that are monitoring water quality in the watershed and making recommendations for improvements. It is also very useful for calibrating a watershed model that can be used to better understand the processes that lead to water quality issues and fill in any data gaps that exist. For this project, the Soil and Water Assessment Tool (SWAT) model was used to assess sediment, total phosphorus, and total nitrogen loading rates in the Buffalo River Watershed. The SWAT model is a continuous simulation, physically based watershed model that was developed to assist water resource managers in assessing impacts of land management practices on water supplies and nonpoint source pollution in a watershed or large river basin (Arnold et al., 1998). The SWAT model can partition a watershed into sub-watersheds or sub-basins that can be used to spatially segregate areas of interest. For this project, sub-basins were developed at the outlets of HUC12s and at monitoring sites that were used for model calibration and validation. The sub-basins were then further split into hydrologic response units (HRUs). HRUs are areas inside a sub-basin that share unique soil, land cover, and physical properties.

Development of the SWAT model required: 1) gathering and processing a significant amount of data, 2) model development using ArcSWAT, and 3) model calibration/validation using existing monitoring data. Crucial data sources such as elevation, land use, and soil properties are readily available at national scales and were easily downloaded from federally managed websites. The SWAT development team also supplies several databases that were used to estimate model parameters and set up the model efficiently. This work is also heavily dependent on monitoring data from several agencies, e.g., U.S. Geological Survey, Arkansas Department of Environmental Quality (ADEQ), NPS, and the University of Arkansas - Division of Agriculture Research & Extension. After all the data was collected, the SWAT model was created in ArcSWAT and calibrated manually using the most current version of the model - SWAT2012 rev. 664 (released December 23, 2016). Auto-calibration using SWAT-CUP (Abbaspour, Vejdani, & Haghighat, 2007) was attempted, but failed to yield acceptable results after several iterations. Similarly, Govender and Everson (2005) and Wang and Melesse (2005) found that manual calibration resulted in better predictions than using the auto-calibration Parameter Estimation program (PEST). Van Liew et al. (2005) also describes how a modeler is able to perform both quantitative and qualitative comparisons during manual calibration, while it's only possible to perform a qualitative analysis using auto-calibration techniques. SWAT-CUP, however, was utilized to assess the sensitivity of various parameters prior to model calibration.

The SWAT model was developed with a warm-up period of 10 years (1987-1996), so that water and nutrient cycles could reach equilibrium before model output was compared to measured values. Model calibration was performed during a ten-year period from 2007-2016, and model validation was performed from 1997-2006. Climate and streamflow data during these periods appear relatively similar, except for a large flood event that occurred in March 2008. An event like this did not occur during the validation period, and could explain some of the difference in model performance. Model calibration was performed on the latter period, because four additional USGS stream gages became operational during this period. This data was much more valuable during calibration, in order to ensure that model parameters were adjusted to the best possible values and to give added confidence in the model results throughout the watershed.

2.0 DATA SOURCES

2.1 Hydrography

The main objective of this project is the prioritization of HUC12s sub-basins to improve water quality in the Buffalo River Watershed. While hydrography data (e.g., HUC12 boundaries and a stream drainage network) is not expressly needed for the SWAT model, it was used to define areas of interest, model output locations, and for general mapping purposes. National Hydrography Dataset (NHD) – High Resolution data was downloaded from the USGS's TNM (The National Map) Download website (U.S. Geological Survey, 2017a) for this project. The NHD dataset lists 37 HUC 12s in the Buffalo River Watershed (Figure 2-1). These sub-basins range in size from 15.1 (Rush Creek) to 67.8 (Headwaters of Little Buffalo) square miles, with an average of 36.2 square miles per sub-basin.

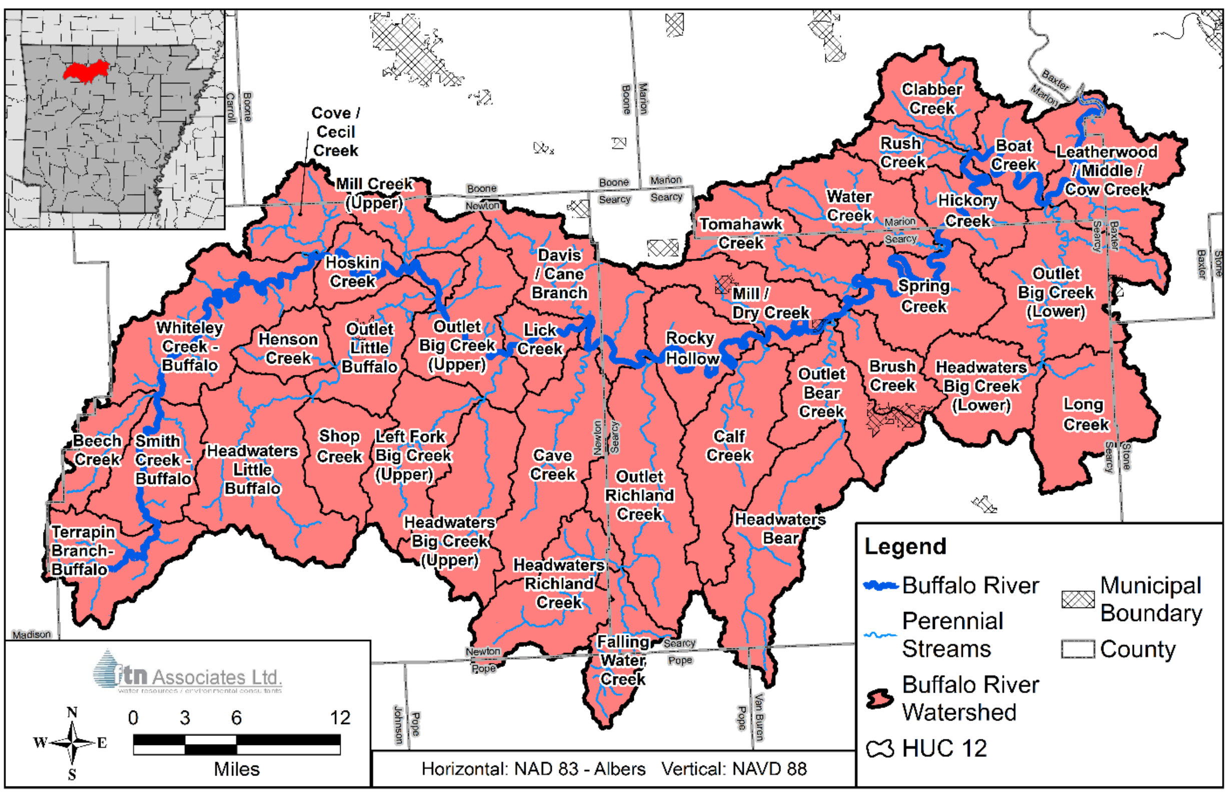

Figure 2-1 Twelve Digit Hydrologic Unit Code (HUC12) Watersheds.

2.2 Topography

National Elevation Dataset (NED) data was obtained using the USGS's TNM (The National Map) Download website (U.S. Geological Survey, 2017b). One-Third arc-second (approximately 10 meters horizontally) resolution data was used for this project (Figure 2-2); this was the finest resolution data available that completely covered the entire watershed. Finer resolution (3 meter) LiDAR data was available in some areas, mainly around the Buffalo National River Park corridor, but was not used in order to maintain consistency in the model.

A slope grid (Figure 2-3) was calculated from the 1/3 arc-second NED data using ArcSWAT, and three slope categories: 1) less than 12.5%, 2) 12.5% - 25%, and 3) greater than 25% slope were defined for the model, based on the results. The total area in each of these three slope classes is relatively similar and covers approximately 25%, 35%, and 40% of the watershed respectively (Figure 2-4). The large amount of land in the largest slope class (>25%) reveals the ruggedness of the watershed. Scott & Hofer (1995) previously reported that approximately 28% of the watershed had a slope greater than 24%. The increase in area in the largest slope class is most likely due to finer (10 meter) resolution data that was used for this project as compared to the 30-meter resolution data used by Scott and Hofer.

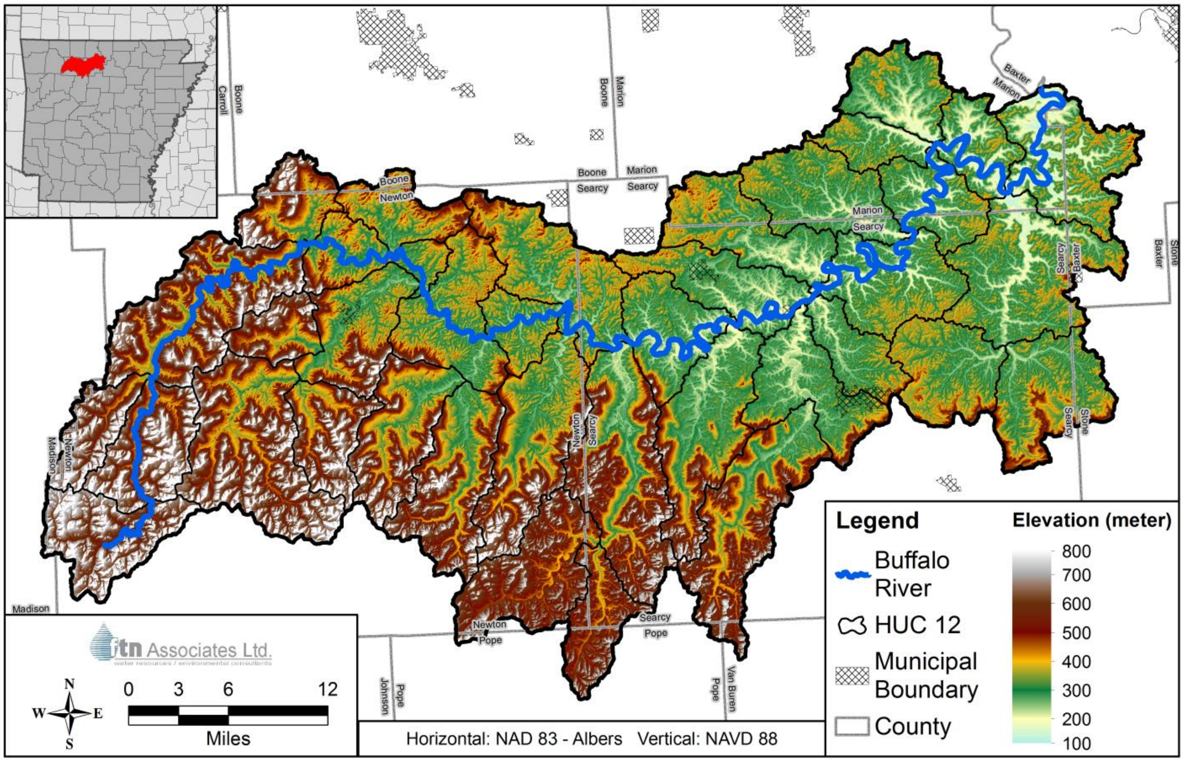

Figure 2-2 National Elevation Dataset (NED) - Elevation Values.

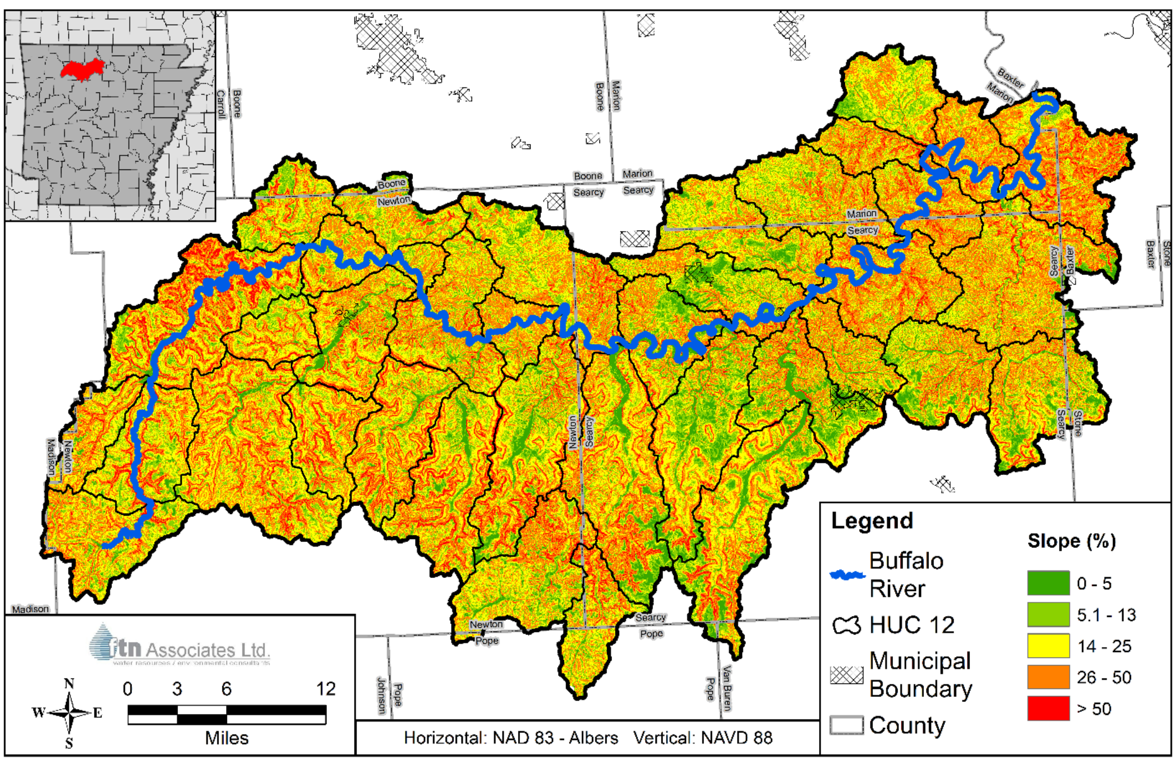

Figure 2-3 National Elevation Dataset (NED) - Calculated Slope to Downstream Grid Cell.

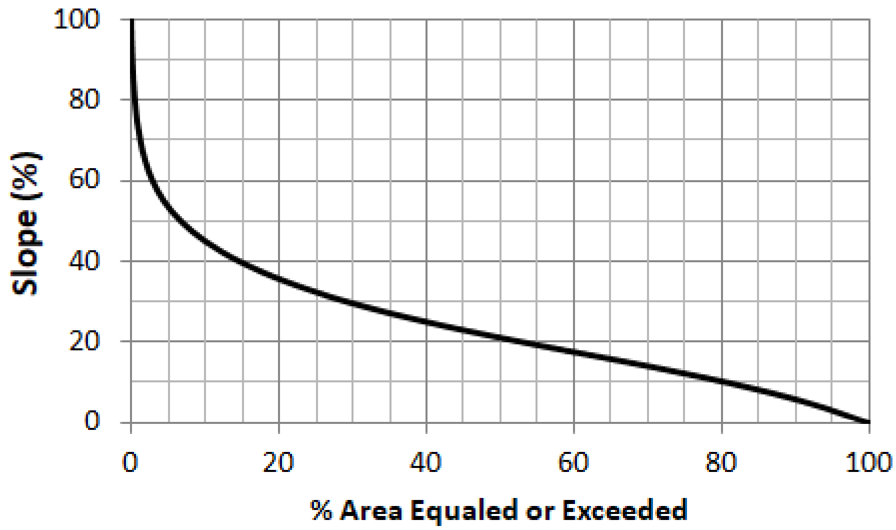

Figure 2-4 Buffalo River Watershed Slope Exceedence Curve.

2.3 Soil Properties

The U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) has compiled two geographic soil databases for the Unites States: 1) the Soil Survey Geographic Data Base (SSURGO), and 2) the State Soil Geographic Data Base (STATSGO). SSURGO is more detailed, and according to the USDA is primarily used for farm and ranch conservation planning all the way to watershed resource planning and management, while the STATSGO dataset is primarily used for river basin, state and multi-county planning (USDA, 2017). Both sources of soil data were downloaded (Texas A&M AgriLife Research, 2017a) and considered for use in the SWAT model.

A review of previous studies that discussed the effect of soil data on SWAT model performance was mixed. Gowda et al. (2013) used the ADAPT model to simulate agricultural land in south-central Minnesota and quantify the effect of soil data scale by using both STATSGO and SSURGO data. This study showed that STATSGO predicted higher annual nitrate losses and lower annual phosphorus losses. Singh, Kalin, and Srivastava (2011) studied the effect of soil data resolution in order to identify critical source areas of sediment in Alabama using SWAT. Their conclusion was that total sediment yield was much higher using the

STATSGO dataset vs. the SSURGO dataset. However, Mukundan, Radcliffe, and Risse (2010) showed that model predictions using the two datasets were similar and had statistically insignificant differences using a SWAT model of the North Fork Broad River in Georgia.

An independent comparison of modeled hydrology, using both the SSURGO and STATSGO datasets, was completed for the Buffalo River Watershed. Without calibration, both models tended to be biased - with modeled streamflow values being higher than observed. Each model's overall performance was assessed with four statistics (Nash-Sutcliffe Efficiency-NSE, Kling-Gupta Efficiency-KGE, Coefficient of Determination –R^2, and Percent Bias-PBIAS) that were calculated using model output and monitoring data at four USGS gaging stations (07055646, 07055680, 07056000, and 07056700) along the main stem of the Buffalo River. There was an improvement in model performance when using SSURGO data and evaluating daily output; however, STATSGO performed better based on monthly output. The reason for better daily statistics using SSURGO was evident after reviewing the hydrographs and daily flow duration curves. Using the SSURGO dataset resulted in better predictions of baseflow and the falling limb of the hydrograph. This is most likely due to the large area of the watershed that STATSGO represents as one soil type in the southern and western part of the watershed (Figure 2-5), whereas in the SSURGO dataset, this region is represented by multiple soils types (Figure 2-6).

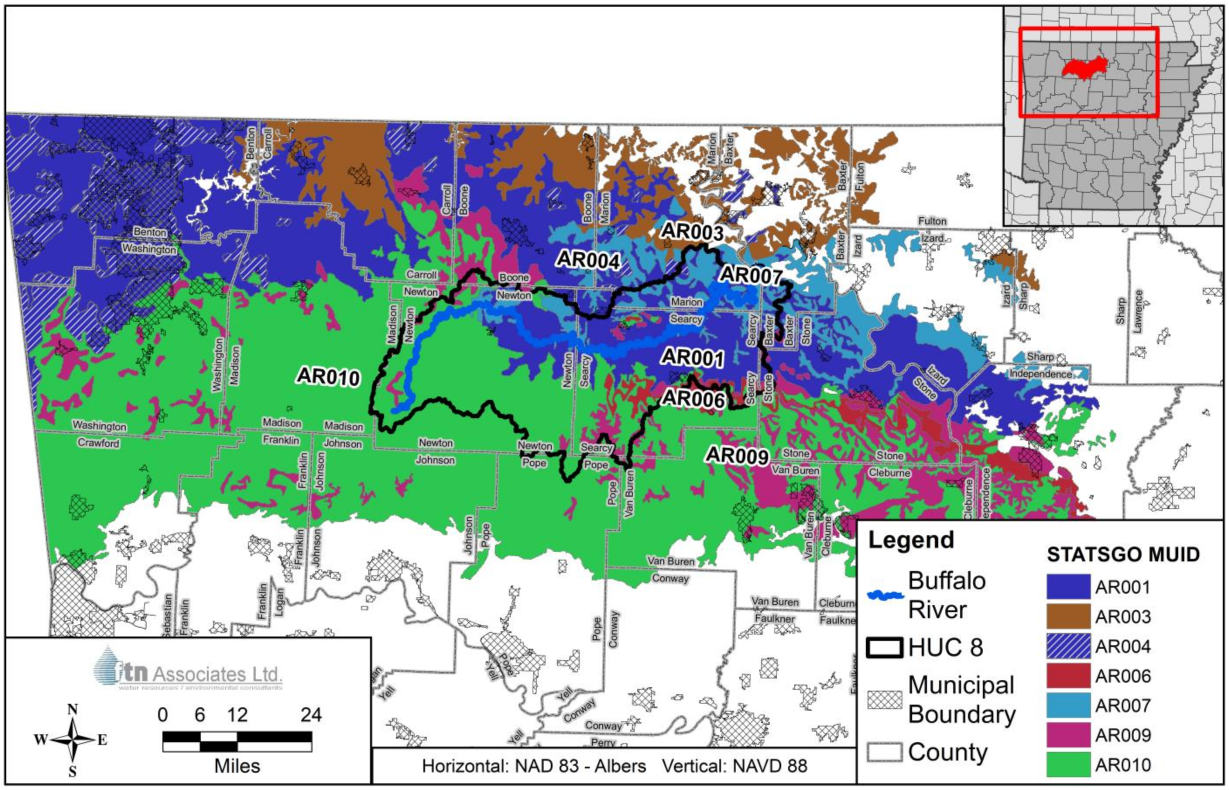

Figure 2-5 STATSGO Map Units (MUID) in the Buffalo River Watershed.

In the STATSGO dataset this area is represented by map unit (MUID) "AR010". This soil unit extends westward to the Arkansas State Line and to the south along Interstate 40. The Enders Series is the largest soil component, and is described as having a very slow permeability (Fowlkes, McCright, & Lowrance, 1988). This is also evident by its saturated hydraulic conductivity (18 mm/hr) and "C" Hydrologic Soil Group Classification. ArcSWAT automatically assigns the properties of the largest soil group to the map unit area. Soils with slow permeability (i.e., a small saturated hydraulic conductivity value) will produce more runoff in a shorter time period and less water as interflow and baseflow. Whereas, in the same part of the watershed, the SSURGO dataset contains mostly Nella Series soils. These soils have a higher saturated hydraulic conductivity (101 mm/hr) and a "B" Hydrologic Soil Group Classification. Even though the soil properties were very different in each dataset, both the STATSGO and SSURGO SWAT models predicted sediment loads that were biased, i.e., the predicted loads were higher than estimated. However, when compared to the measured data, daily sediment loads (like runoff) were better when using the model with SSURGO data. Increased accuracy at the daily scale means that hydrologic and water quality processes in the watershed are being modeled more accurately and a more thorough understanding of sources of flow, sediment and nutrients can be developed, because several processes can be averaged out using monthly output. Averaging over a large time step can result in good calibration statistics, but flow and nutrients could be coming from sources that might not reflect what is actually happening in the watershed. For example, when using monthly output, most of the flow volume could come from surface runoff on 1 or 2 days or it could come from a mix of surface flows, interflow, and significant groundwater flows during different parts of the month. Both of these scenarios could result in the same monthly mean flow, but the one that matches the finest resolution output interval would be more accurate. Therefore, since the SSURGO dataset performed better based on daily output, it was selected as the data source for establishing soil properties in the watershed.

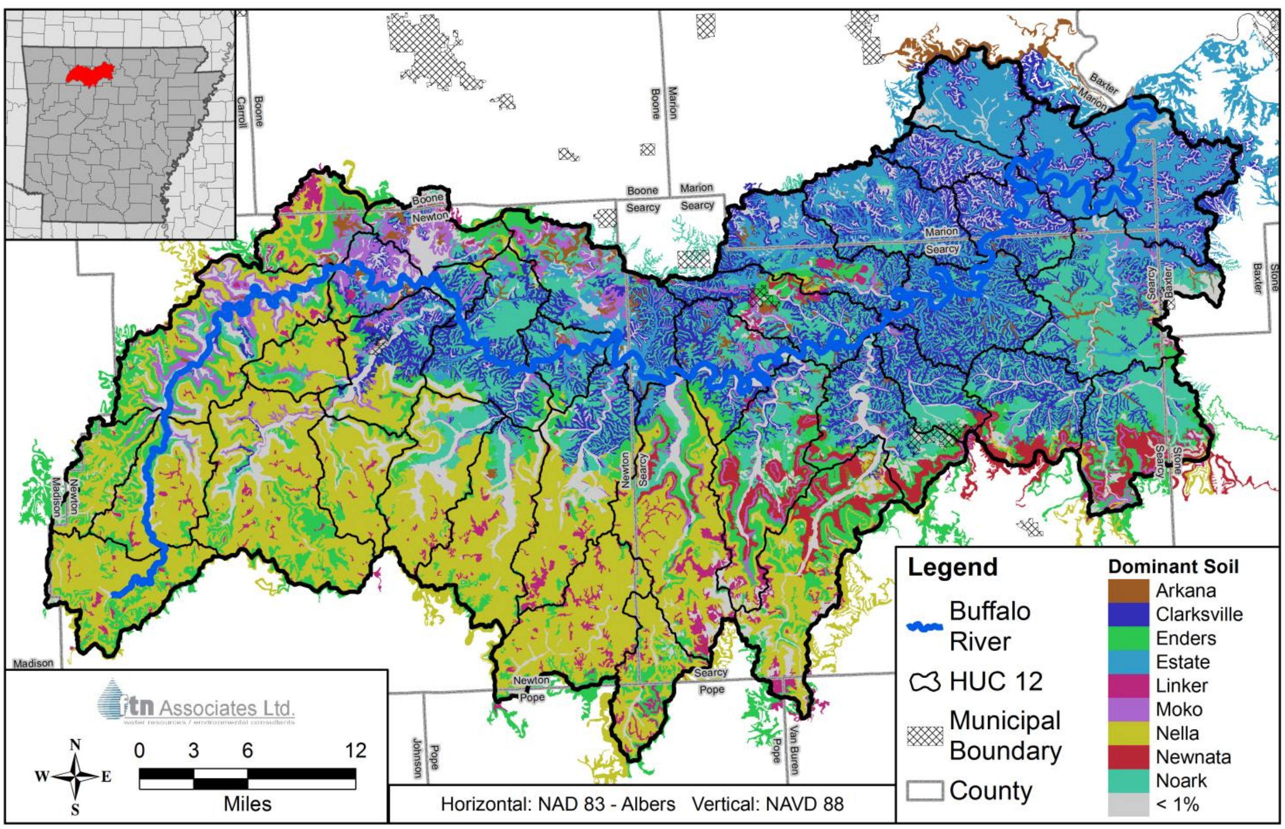

Figure 2-6 SSURGO Soil Map – Map Unit Names.

According to the SSURGO soils database, five soil types cover approximately 75 percent of the Buffalo River Watershed: Clarksville, Enders, Estate, Nella, and Noark (Figure 2-7). In the Boston Mountains Physiographic Section, Nella and Enders soils dominate, but Linker soils are also present to a lesser extent on mountain tops and ridges. Clarksville, Estate, and Noark soils command the most area in the Springfield and Salem Plateaus, however Moko and Newnata soils also make up significant portion of several sub-watersheds.

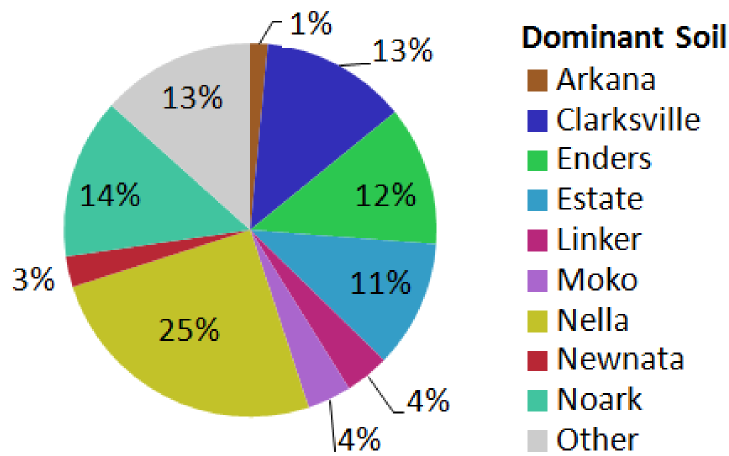

Figure 2-7 SSURGO Map Unit Percentages for the Buffalo River Watershed.

As discussed earlier, soil saturated hydraulic conductivity and Hydrologic Soil Group classification can have a large impact on modeled hydrology and sediment transport. The Buffalo River Watershed mainly contains soils with slow to moderate infiltration rates and “C” or “B” Hydrologic Soil Group classifications, respectively (Figure 2-8 and Figure 2-9). However, Moko soils, in the “D” (slow infiltration) Hydrologic Soil Group, make up a significant portion of several sub-watersheds, and “A” Hydrologic Soil Group soils with high infiltration rates can be found around the Buffalo River and major tributaries.

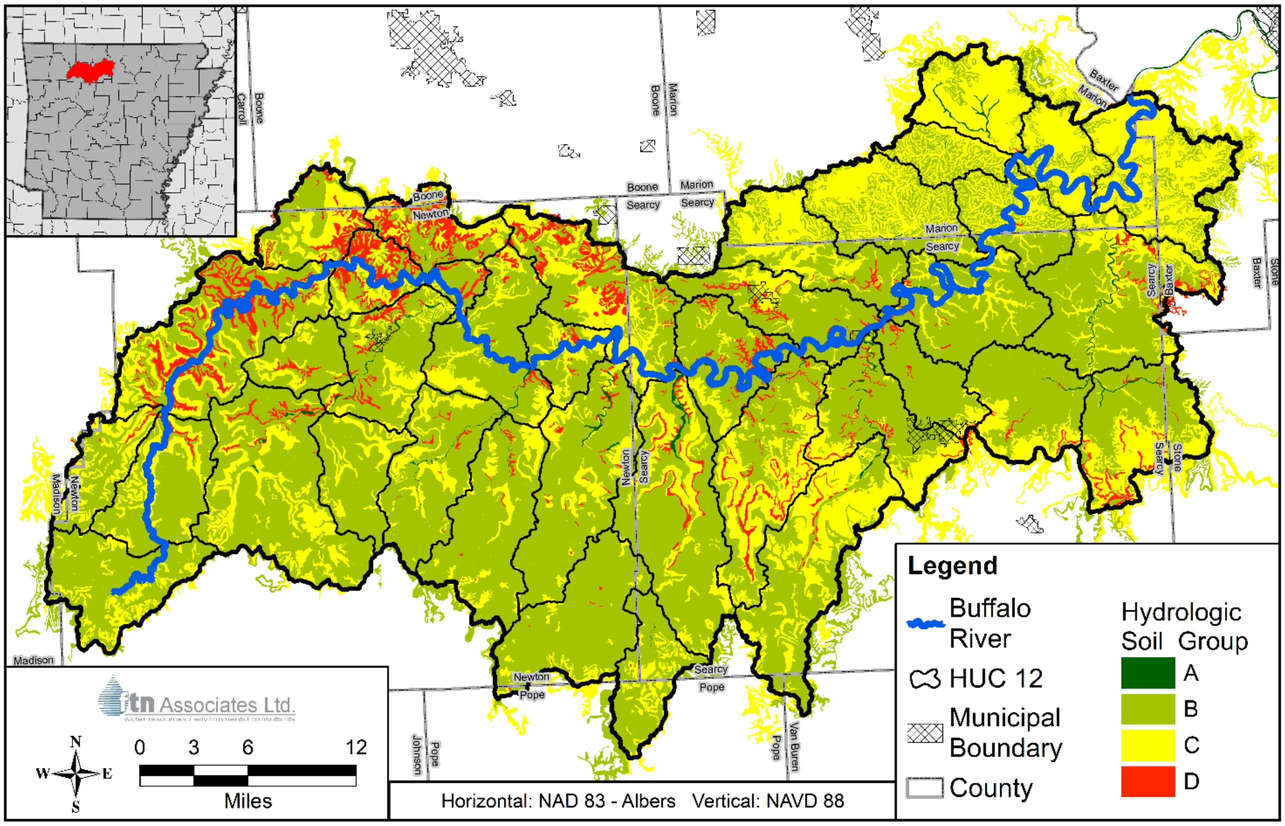

Figure 2-8 SSURGO Soil Map - Hydrologic Soil Group Classifications.

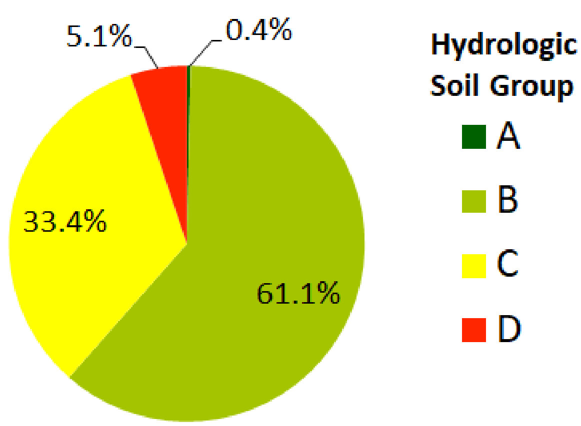

Figure 2-9 SSURGO Hydrologic Soil Group Percentages for the Buffalo River Watershed.

2.4 Land Use

Management practices and land use can have a large effect on water, sediment, and nutrient yields in a watershed. The SWAT model has been used by numerous researchers to evaluate the effect of land use change and the implementation of Best Management Practices (BMPs) on water quality and quantity (Krysanova & Srinivasan, 2015). High quality spatially distributed land use data is essential for assigning several SWAT model parameters. National Land Cover Database (NLCD) -2011 data produced by the Multi-Resolution Land Characteristics Consortium was used to define land use in the Buffalo River Watershed (Figure 2-10). The NLCD-2011 was produced using Landsat images and is a representation of land use for nominal year 2011 (Homer et al., 2015). NLCD data was downloaded from the USGS's TNM (The National Map) Download website (U.S. Geological Survey, 2017c) and is at a spatial resolution of approximately 10 meters. The NLCD-2011 land use dataset was used for the entire model calibration and validation periods. NLCD data is also available for nominal years 2001 and 2006, but after analyzing all three datasets there appeared to be very little change in land use during this period, with the only appreciable change being a conversion of forest to grassland. However, this change occurred in less than 0.5% of the watershed, so using 2011 land use data and not varying land use through the model simulation was deemed acceptable for this project. The percentage of the watershed covered by each land use classification in the NLCD-2011 dataset is shown in Figure 2-11. Nearly 80% of the watershed is forested, approximately 17% of the land is either pasture or hay, and the remaining 3% is mostly low density urban.

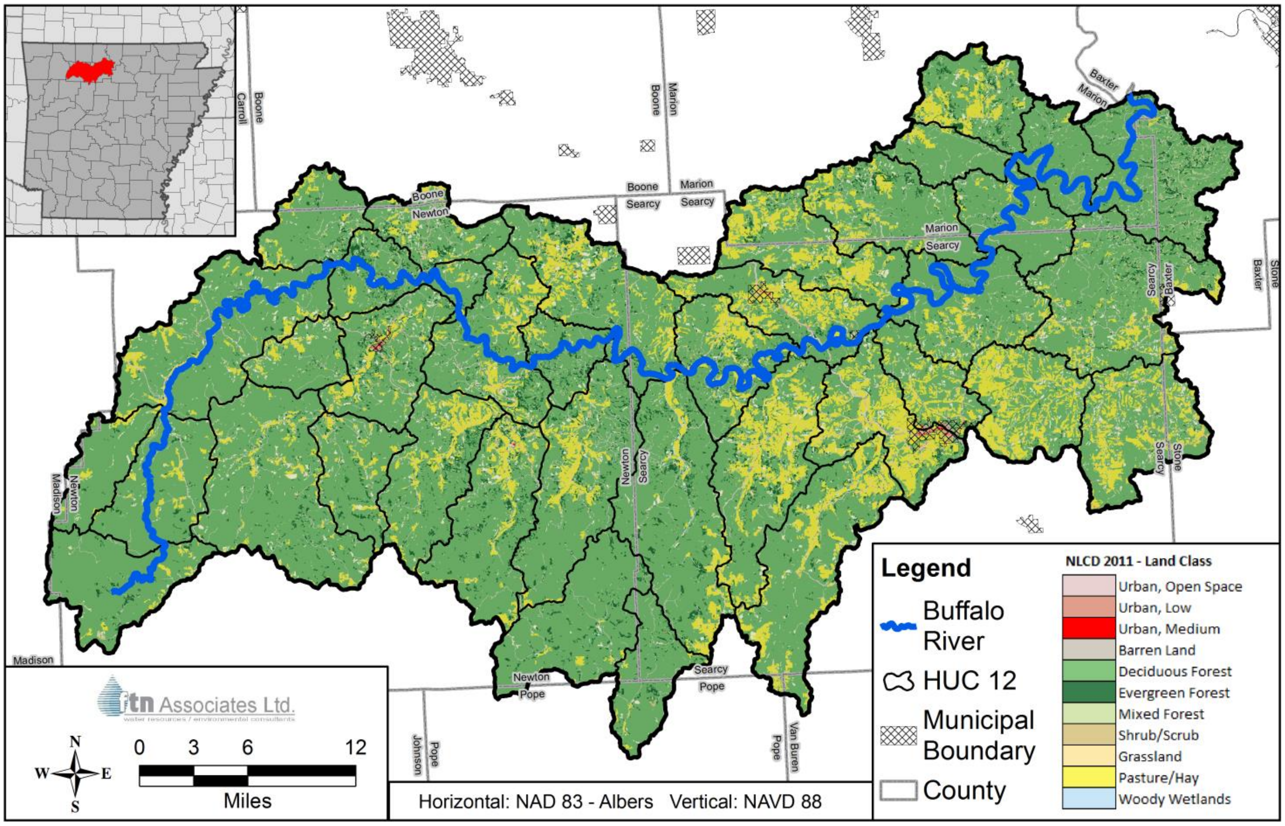

Figure 2-10 USGS NLCD-2011 Data.

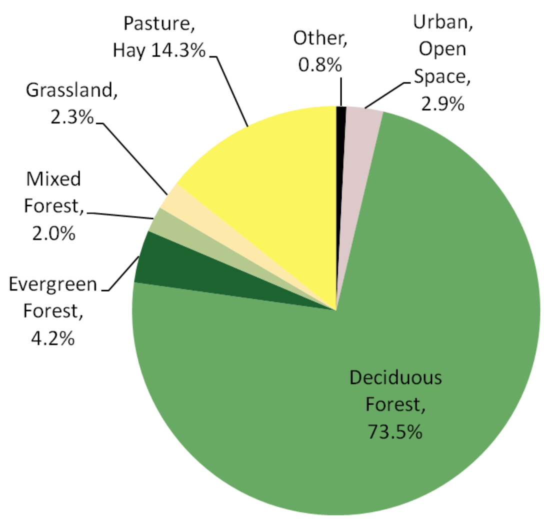

Figure 2-11 USGS NLCD-2011 Land Class Percentages for the Buffalo River Watershed.

2.5 Climate

Spatial variability of precipitation has a significant effect on daily flows in most streams. Prior to the development of the climate input for the SWAT model, a literature review was conducted regarding model results using different sources of precipitation data. This review revealed that PRISM rainfall estimates (Daly et al., 2008) produced better SWAT model results than either Climate Forecast System Reanalysis (CFSR) estimates (Saha et al., 2010) or rainfall data from discrete gauges (Radcliffe & Mukundan, 2017). PRISM is a data set that provides meteorological values on a uniform grid across the US by spatially interpolating between measurements using various local watershed characteristics and other available data. PRISM data is also being used as input to a new program being developed by Texas A&M, the USDA and the U.S. EPA, called the Hydrologic and Water Quality (HAWQS) assessment tool, which runs SWAT from an online platform (Texas A&M AgriLife Research, 2017b). Given these findings, PRISM was selected for this project and used to create daily precipitation, min/max temperature, and relative humidity time series datasets for each sub-basin in the model.

Daily time series of precipitation, min/max/mean temperature and mean dew point temperature were generated for 370 PRISM grid cells that intersected or were within approximately 5 kilometers of the Buffalo River Watershed. Individual daily PRISM rasters (4 km resolution) that cover the contiguous United States of America were downloaded from Oregon State University's PRISM Climate Group website (PRISM Climate Group, 2017). Only the precipitation and min/max temperature time series were directly used by the model, while mean temperature and dew point temperature data were used to calculate relative humidity time series for each grid cell.

Precipitation data from the Jasper rainfall gauge (National Oceanic and Atmospheric Administration, 2017) and the PRISM grid that it intersects (Figure 2-12) were compared to confirm that the data was reliable for the study area (Figure 2-13). The PRISM and gauge data were highly correlated, with the PRISM data only slightly over predicting the measured values (approximately 2.2% bias). According to the PRISM Climate Group, the algorithms used to produce PRISM started incorporating NEXRAD data after January 1, 2002. This may explain additional differences in model performance at daily and monthly output intervals during the calibration and validation periods. However, during both periods, the total rainfall from PRISM was slightly higher than the measured values at the Jasper gauge.

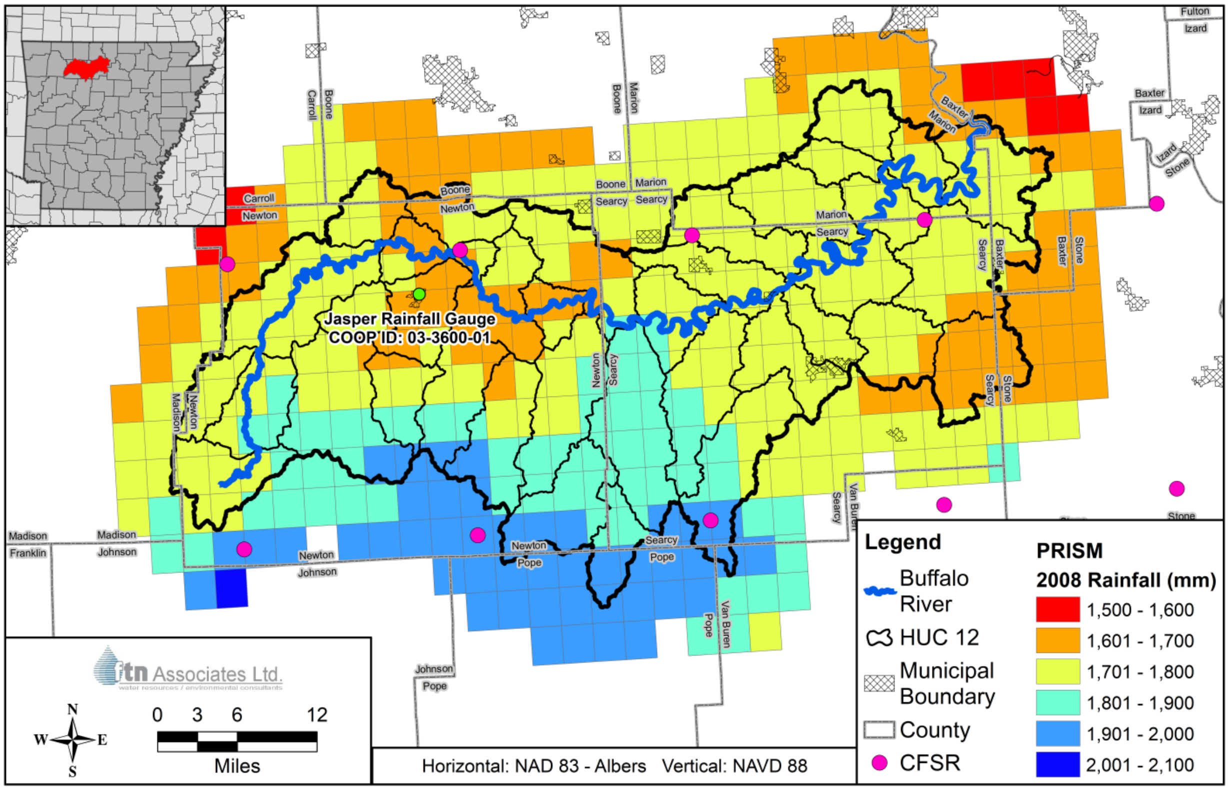

Figure 2-12 PRISM Rainfall Totals for ’08, the Jasper COOP rain gauge and CFSR Grid Centroids.

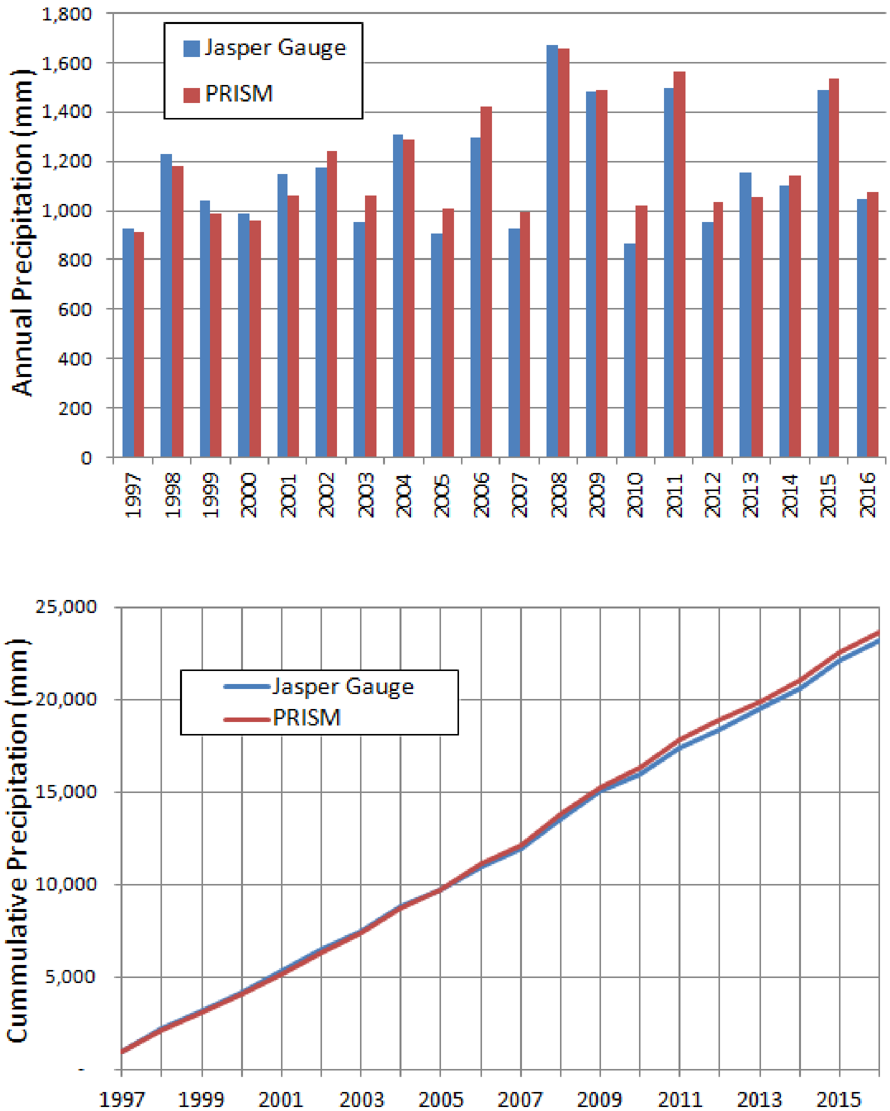

Figure 2-13 PRISM Rainfall vs. Measured Rainfall at the Jasper COOP Gauge.

Wind speed and solar radiation values aren't available from the PRISM Climate Group, so the Climate Forecast System Reanalysis (CFSR) dataset was used to develop model input for these parameters. Both wind speed and solar radiation inputs are necessary because the Pennman-Monteith method was used to calculate potential evaporation for the Buffalo River Watershed SWAT model. This CFSR data was downloaded from Texas A&M's Global Weather Data for SWAT website (Texas A&M AgriLife Research, 2017c). This data was only available through July 31, 2014, and SWAT's weather generator filled the remaining period through

December 2016. The spatial resolution of the CFSR dataset is approximately an order of magnitude greater than the PRISM dataset (approximately 38 kilometers) and only ten grid cells intersected the Buffalo River Watershed (see Figure 2-12).

2.6 Point Sources

Assessing the impacts of point sources isn’t a goal of this study; however, making sure they are accounted for during model creation and calibration is necessary to ensure that modeled output accurately partitions nutrient and sediment loads to point and non-point sources. The Buffalo River Watershed is mostly rural and regulated point source discharges are small compared to more densely populated areas in the country. According to data obtained from the ADEQ’s website, there are only four National Pollutant Discharge Elimination System (NPDES) permitted wastewater facilities in the watershed (Figure 2-14) and all are categorized as Minor Municipal Discharge facilities (design flows of less than 1 million gallons per day -MGD). The Marshall Waste Water Treatment Plant (WWTP) is the largest, with a design treatment capacity of 0.5 million gallons per day (MGD) and an average discharge of 0.22 MGD - according to monitoring data from 2012-2016 that was obtained from the U.S. EPA’s ECHO website (U.S. EPA, 2017). Mean daily flowrate and nutrient loads calculated for the four facilities are presented below in Table 2.1. Monitoring data for ammonia (NH_3) is available at all four sites; however, only the Marshall WWTP reported values for nitrate and nitrites ($NO_3 + NO_2$), and the only site that has recorded phosphorus measurements is the NPS Buffalo Point site. However, the total phosphorus load is relatively small; the largest reported load at the NPS site is less than 1 kg/day and the calculated mean is 0.1 kg/d.

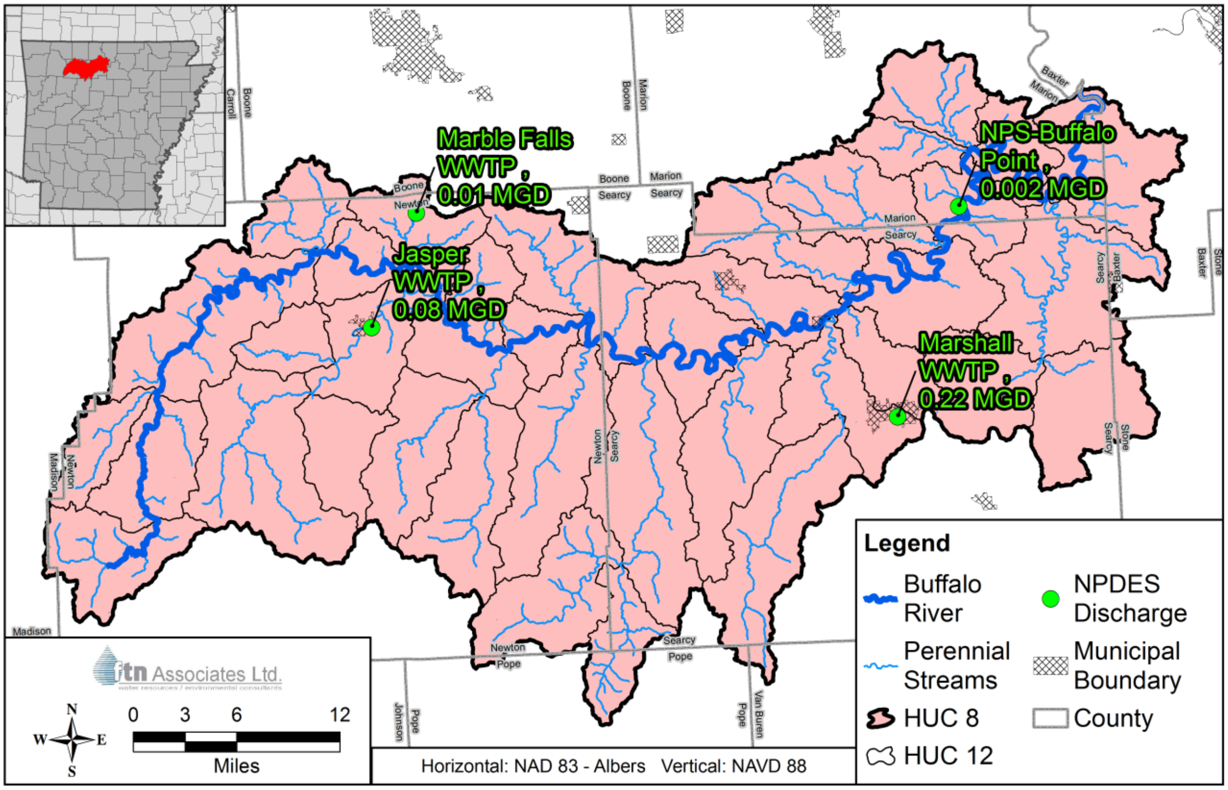

Figure 2-14 NPDES Permitted Wastewater Discharges with average discharge values.

Table 2.1 NPDES Permitted Wastewater Discharge Point Sources.

NPDES Permit #s	ADEQ Facility ID	Facility Name	County	Latitude	Longitude	Design Flow (MGD)	[1]Flow (MGD)	[1]NO_3+NO_2 (kg/d)	[1]NH_3 (kg/d)	[1]TP (kg/d)
AR0034941 AR0034959	45-00017	Buffalo Point National Park	Marion	36.07898	-92.56284	0.022	0.002	[2]NR	0.0	[2]NR
AR0034088	51-00011	Marble Falls	Newton	36.10313	-93.12407	0.01	0.01	[2]NR	0.1	[2]NR
AR0034584	51-00012	City of Jasper	Newton	36.00926	-93.17797	0.1	0.08	[2]NR	0.2	[2]NR
AR0034011	65-00016	City of Marshall	Searcy	35.90509	-92.63986	0.5	0.22	5.8	0.4	0.1

1. Mean values calculated from monitoring data collected from 2012-2017.
2. Not Reported.

2.7 Soil Nutrients

In landscapes altered by human activity, soil fertility is largely influenced by land use and management practices and less dependent on soil type and geography (Cope, Evans, and Williams, 1981). However, when comparing native unmanaged areas, soil type and the environment will have a large influence on soil fertility. Initial concentrations of phosphorus and nitrogen in the soil horizon are required to execute the SWAT model. Specifically, four nutrient levels: 1) Labile P, 2) Organic P, 3) Nitrate, and 4) Organic N are needed for each soil layer.

Labile P and Nitrate levels for forested land uses (Deciduous, Evergreen, and Mixed) were estimated from data presented in two studies on nutrient availability in forested lands. The first study (Singh, Goyne, and Kabrick, 2015) focused on key environmental and soil properties that influenced total and available soil P in a Missouri Ozark Highlands forest ecosystem, and was based on soil phosphorus test (i.e., Mehlich-3 and Bray-1) results for fifty pedons and three soil horizons. From this data, Singh et al. (2015) reported the following mean and ±95% confidence intervals for the 1st mineral horizon: 1) Mehlich-3 available P equal to 10.3±0.79 mg/kg, 2) Bray-1 available P equal to 9.0±0.95 mg/kg, and 3) a Total P of 150±14 mg/kg. For forested land uses in the Buffalo River SWAT model, soil Labile P (solution P or available P) was estimated at approximately half of the Mehlich-3 value (10 x ½ = 5 mg/kg), according to procedures presented in Vadas and White (2010). It is important to note that this value (5 mg/kg) is equal to the SWAT default and is described in the 2009 SWAT Theoretical Documentation as being “representative of unmanaged land under native conditions”, which is a good description of forested land in the Buffalo River Watershed. Soil nitrate values for forested areas in the model were estimated using a second study that was conducted in a mixed-wood forest in northern Alberta Canada (Jerabkova, Prescott, and Kishchuk, 2006). To understand whether deciduous stands have higher N availability and faster N turnover than coniferous stands, six soil samples were taken from nine forest stands (three deciduous, three mixed, and three coniferous forest stands), or 54 samples in total. Average mineral soil (top 7 cm) nitrate concentrations for the three forest types (deciduous, mixed, and coniferous) were reported as 0.11, 0.19, 0.44 mg/kg respectively. These values were used to initialize soil nitrate levels for the three forest types in the model.

The initial Labile P (solution P) concentration for hay/pasture land uses in the Buffalo River Watershed was estimated from soil test data listed by county and crop type from the University of Arkansas Soil Testing Research Laboratory. In 2016, there were 181 soil samples taken from hay/pasture sites in Newton and Searcy counties. The 2016 average Mehlich-3 available P values for these counties are 56 and 60 mg/kg respectively. For hay/pasture land uses in the Buffalo River SWAT model, soil Labile P (solution P) was estimated as half of the two-county average Mehlich-3 value (58 x 1/2 = 29 mg/kg).

Soil nitrate concentrations for hay/pasture land uses were initialized using SWAT defaults. Soil nitrate can vary substantially in time and space, due to differences in management practices and because nitrogen is highly mobile in the environment, when compared to phosphorus. The SWAT default method sets initial soil nitrate levels by depth using Equation 2.1, where soil depth (z, in millimeters) is the only required input. According to this equation, the nitrate concentration at the soil surface is 7 mg/kg: background nitrate levels in the upper 1 foot of mineral soils typically range from 5-10 mg/kg (Camberato and Nielsen, 2017). The SWAT model was developed with a 10-year warm-up period and the initial nitrate level has less of an impact on the model than initial phosphorus levels, because nitrogen is highly mobile compared to phosphorus and soil nitrate levels should reach equilibrium during the warm-up period.

Equation 2.1 $$\boldsymbol{NO3_z = 7 * e^{\frac{-z}{1000}}}$$

Organic N and P concentrations for all soils were initialized using Organic Carbon Content (%) data reported in the SSURGO soils database, a C:N ratio of 14:1, and an N:P ratio of 8:1 (SWAT default nutrient ratios reported in User's Manual). Average Organic Carbon Content for soils in the Buffalo River Watershed is approximately 1.1% (11,000 mg/kg). For the Buffalo River Watershed, using the default method resulted in average initial Organic N and P values (top soil layer) of approximately 800 and 100 mg/kg respectively.

2.8 Monitoring Data

In the Buffalo River Watershed there is a considerable amount of monitoring data with widespread spatial coverage. Stream monitoring sites that are the most useful for SWAT model calibration contain data for water quality (e.g., Total Nitrogen -TN, Total Phosphorus-TP, and

Suspended Sediment Concentration-SSC) and streamflow measurements. The best locations also include a significant number of measurements throughout the entire flow regime at the site and were taken during the model calibration and validation periods (calendar years 1997-2016). The NPS and ADEQ collaboratively monitor water quality at multiple locations along the Buffalo River, several major tributaries, and springs in the Buffalo National River Park corridor. The U.S. Geological Survey (USGS) operates several stream flow gages in the watershed, and these sites were crucial for model calibration. The USGS also monitors water quality at a few of these sites, as does the ADEQ and NPS. Recently the University of Arkansas Big Creek Research and Extension Team (BCRET) began monitoring water quality in the Big Creek watershed, and the USGS also started reporting flow values at a newly installed (April 2014) stream gage (07055790) on Big Creek.

2.8.1 Streamflow

Measured stream flow data were not used as direct inputs to the SWAT model, but they are needed as calibration targets (i.e., measured data that are compared with model predictions). There are eleven USGS stream flow gages in the Buffalo River Watershed, eight of which are currently active (Figure 2-15). Data from all eight currently active stations were used in the hydrology calibration. Only four of these gages, however, have been active for more than 15 years and were used for both model calibration and validation. Lately, there has been an increase in the number of stream gages in the watershed. In 2014, two sites (07055790 and 07055814) were added along Big Creek as part of a research and monitoring program that focused on understanding and quantifying the effect of a newly permitted concentrated animal feeding operation (CAFO). The USGS recently stopped reporting streamflow values for Big Creek near Carver (07055814); flow data from this gage was not used for model calibration because of the limited amount of approved data (March – October 2016) at the site. The USGS also began reporting streamflow at two new sites (07055660 and 07055680) on the upper Buffalo River in 2008, and both were used in model calibration. USGS 07056700, Buffalo River near Harriet, became operational in 2002. This gage was used for model calibration only, because daily streamflow data for years reported during the validation period (1997-2007) were rated as “poor” according to USGS Water-Year Summary Reports.

Mean daily streamflow (discharge) data was downloaded from the USGS's National Water Information System (NWIS): Web Interface for all gages in the Buffalo River Watershed (U.S. Geological Survey, 2017d). Mean monthly and annual streamflow was then calculated from the daily data at each gage. Data at all three time-scales were used in the model calibration and validation process.

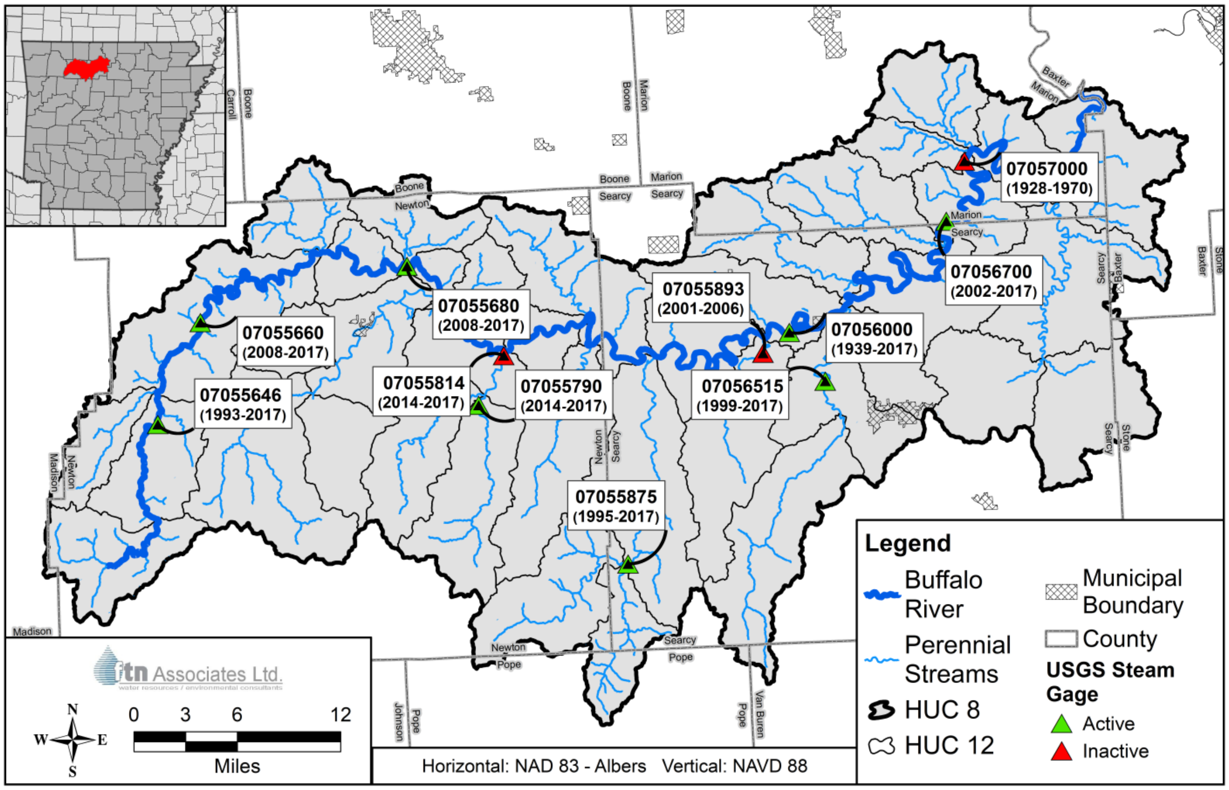

Figure 2-15 USGS Streamflow Gage Locations and Monitoring Period.

Table 2.2 USGS Stream Gages in the Buffalo River Watershed.

Gage ID	Station Name	Drainage Area (mi^2)	Start Date	End Date	Daily Values Count	% Approved Data	Calibration Station	Validation Station
07055646	Buffalo River near Boxley, AR	57	4/17/93	-	8,239	86%	YES	YES
07055660	Buffalo River at Ponca, AR	116	5/3/08	-	3,511	92%	YES	NO
07055680	Buffalo River at Pruitt, AR	190	6/14/08	-	3,484	93%	YES	NO
07055790	Big Creek near Mt. Judea, AR	41	4/23/14	-	1,349	83%	YES	NO
07055814	Big Creek at Carver, AR	90	2/10/15	4/27/17	800	25%	NO	NO
07055875	Richland Creek near Witts Spring, AR	67	6/1/95	-	8,247	92%	YES	YES
07055893	Calf Creek near Silver Hill, AR	45	1/17/01	8/11/06	1,118	54%	NO	NO
07056000	Buffalo River near St. Joe, AR	829	10/1/39	-	28,562	98%	YES	YES
07056515	Bear Creek near Silver Hill, AR	83	1/22/99	-	6,908	91%	YES	YES
07056700	Buffalo River near Harriet, AR	1,070	10/1/02	-	5,564	90%	YES	NO
07057000	Buffalo River near Rush, AR	1,096	10/1/28	9/29/70	15,339	100%	NO	NO

2.8.2 Water Quality

Unlike streamflow measurements that are recorded frequently (e.g., 15 minutes), water quality monitoring in the Buffalo River Watershed is generally performed on a seasonal or monthly basis. However, three U.S. Geological Survey (USGS) sites have reported daily values of several constituents (e.g., turbidity, nitrate+nitrite, pH, DO, temperature, and specific conductance). The Bear Creek near Silver Hill (07056515) site lists daily water quality results from March 2013 through April 2016. The USGS also reports daily values for the Big Creek at Carver (07055814) and the Big Creek at Mt. Judea (07055790) sites. This data, however, was not used to calibrate the SWAT model, because the focus of this project is on sediment, total phosphorus, and total nitrogen loads, the parameters measured at these sites could not directly be used to make these assessments. Instead, Suspended-Sediment Concentration (SSC), Total Phosphorus (TP), and Total Nitrogen (TN) monitoring data collected at five sites in the watershed were used for model calibration.

Turbidity is easily measured, a potential indicator of stream pollution, and is used to assess stream impairment by regulators. The NPS and ADEQ report turbidity values at several sites in the watershed. Measurements of turbidity, however, are not directly useful for SWAT calibration purposes, because turbidity is a measure of relative clarity and not a direct measurement of solid-phase material. Suspended-Sediment Concentration (SSC) and Total Suspended Solids (TSS) are common direct measurements of total solids in a water body, and can be used in assessing sediment loading rates (Gray, Glysson, Turcios, & Schwarz, 2000). The main difference between the two measurements is that when a TSS analysis is performed, only an aliquot of the original sample is used, whereas the whole sample is used when performing a SSC analysis (Glysson, Gray, & Conge, 2000). According to Gray et al. 2000 and Glysson et al. 2000, this difference can have a substantial impact on sediment transport calculations, and on October 25th, 2006 the Federal Interagency Sedimentation Project (FISP) (2006) Technical Committee released a memorandum stating:

> *The SSC analytical method, ASTM D 3977, Standard Test Method for Determining Sediment Concentration in Water Samples (ASTM, 2006), is the accepted standard for determining concentrations of suspended material in surface water samples. It is recommended that this method be used by all U.S. Federal agencies' sediment*

laboratories, and by cooperating laboratories providing suspended-sediment data to the Federal government.

According to Gray et al. (2000), SSC values tend to exceed TSS values – especially when sand in the sample exceeds about a quarter of the dry mass. This research also suggests that this difference "has important ramifications for computations of suspended solid-phase discharges" and that the TSS method "is shown to be fundamentally unreliable for the analysis of natural-water samples". SSC monitoring data is available at four USGS monitoring stations in the Buffalo River Watershed (07055646, 07056507, 07056000, and 07056515). This data was exclusively used to calibrate sediment loads. If TSS and SSC values were mixed, bias could have been introduced to certain geographic areas in the model. Instead, only one parameter (SSC) was used, in order to reduce any uncertainty that might arise from using two different measurements.

Both Orthophosphate (PO_4) and Total Phosphorus (TP) measurements are available throughout the Buffalo River Watershed. These measurements are useful for assessing stream impairment, and locating sources contributing excess nutrients to a stream or water body. The majority of phosphorus measurements in the Buffalo River Watershed are reported as filtered samples of orthophosphate as phosphorus (PO_4 as P). However, at calibration sites with streamflow data, there is a significant amount of Total Phosphorus data. When the water sample is filtered prior to the orthophosphate measurement, it is commonly called Soluble Reactive Phosphorus (SRP). Soluble is used in this description, because the sample is filtered and represents the portion of phosphorus that is in solution, as opposed to being attached to sediment. The SWAT model divides phosphorus transported in a reach into two different forms called Organic P (ORGP) and Mineral P (MINP). Conventionally, SRP is assumed to equal MINP and Total Phosphorus (TP) is equal to the sum of ORGP and MINP. Given the scope of this study, only Total Phosphorus measurements were used for model calibration. However, in the future, stream flow measurements paired with SRP data could be used with the Buffalo River Watershed SWAT model to study soluble phosphorus transport.

Monitoring data for several species of nitrogen is available in the watershed, including: 1) Nitrate+Nitrite [NO_3+NO_2], 2) Ammonia [NH_4+NH_3], 3) Organic Nitrogen [Organic N], 4) Total Kjeldahl Nitrogen [TKN=NH_4+NH_3+Organic N] and 5) Total Nitrogen [TN=TKN+NO_3+NO_2]. The two species that have been measured the most are Nitrate+Nitrite and Ammonia. However, the goal of this project is to quantify total nitrogen loads at HUC12s in the watershed, and only Total Nitrogen was used for model calibration. The ADEQ Water Quality Monitoring Database doesn't explicitly contain Total Nitrogen measurements for sites in the Buffalo River Watershed, but Total Nitrogen was calculated by summing site and date paired measurements of Nitrate+Nitrite and Total Kjeldahl Nitrogen. The USGS, however, directly reports Total Nitrogen measurements and no processing was necessary.

TN, TP, and SSC water quality measurements that could be paired with streamflow data were used to create load estimates for use in model calibration. There are four sites in the Buffalo River Watershed that have a significant number of paired data. The location and number of water quality measurements performed by the USGS and ADEQ from January 1, 1997 through December 31, 2016 are presented below in Figure 2-16 and Figure 2-17, respectively. Data from both organizations (U.S. Geological Survey, 2017d; Arkansas Department of Environmental Quality, 2017) included data flags to alert the user if there was a problem during sampling or if the value was below the detection limit of the test method being used. Streams in the Buffalo River Watershed generally contain low levels of Total Phosphorus and Total Nitrogen, and water quality results are routinely reported as below the reporting limit ("censored" values). In order to produce load estimates with this data, values below the reported limit were estimated according to the 15% and 50% non-detect rules in the Environmental Protection Agency's Practical Methods for Data Analysis and Unified Guidance for RCRA Facilities (U.S. EPA, 2000; U.S. EPA, 2009). The U.S. EPA's 15% rule recommends that imputing arbitrary values (e.g., one half the reporting limit) should be limited to data sets with less than 15% censored values, and the 50% rule suggests that a more detailed procedure be used when there are more than 15% but less than 50% censored values. For this project, if the monitoring data for a particular constituent and site had less than 15% censored values, a value of one half the reporting limit was used. If the censored values were between 15% and 50% of the total number of measurements, a procedure called Robust Regression on Order Statistics (Robust ROS) was used to impute values (Helsel, 2005; Dressing et al., 2016). Robust ROS uses a fitted model to arbitrarily assign values for censored values, with a common reporting limit, so that each one accounts for an equal share of the estimated cumulative probability for each reporting limit (U.S. EPA, 2009). Once the imputed values for all the censored values were calculated, the mean of the values for each reporting limit was assigned to all the values in that group. This last step was needed because load estimates are calculated from water quality and streamflow measurements. Robust ROS is commonly used to calculate statistics (e.g., mean, standard deviation) from water quality measurements alone, when there are a high number of censored values. However, when pairing this data with streamflow measurement on the same day to calculate a load, the imputed value, estimated based on a fitted model using water quality data alone, could result in load values that have considerable more spread, simply because the assigned cumulative probability for one value might result in a large imputed value on a day that coincidently reported higher streamflow. The goal of using Robust ROS in this study was to assign values to censored values that weren't arbitrarily assigned (e.g., one half of the reporting limit or equal to the reporting limit). It's for this reason that the mean of the imputed values for each group of censored values, with the same reporting limit, was used instead of the original Robust ROS values. In general, the mean values are similar to one half the reporting limit, but in some cases this procedure results in values that are much closer to the actual reporting limit (see Appendix A for the originally reported values and calculated mean imputed values).

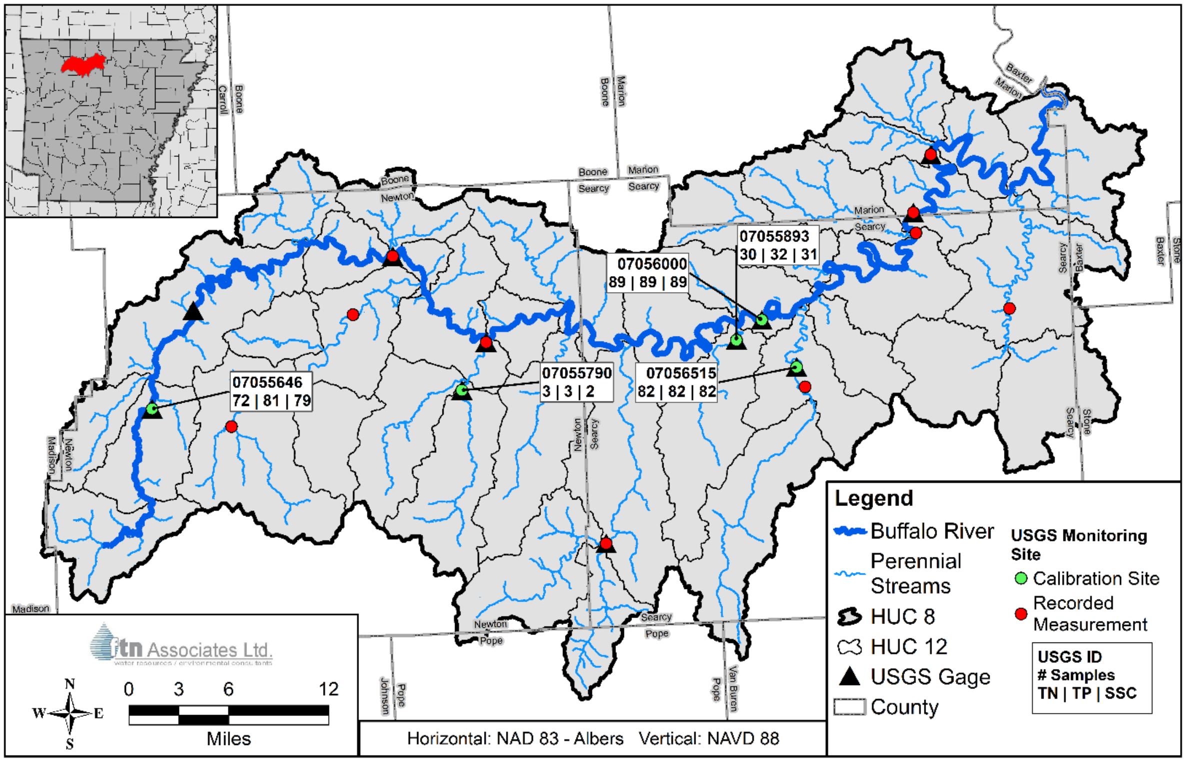

Figure 2-16 USGS Water Quality Monitoring Sites (Total Nitrogen-TN, Total Phosphorus-TP, and Suspended Sediment Concentration-SSC).

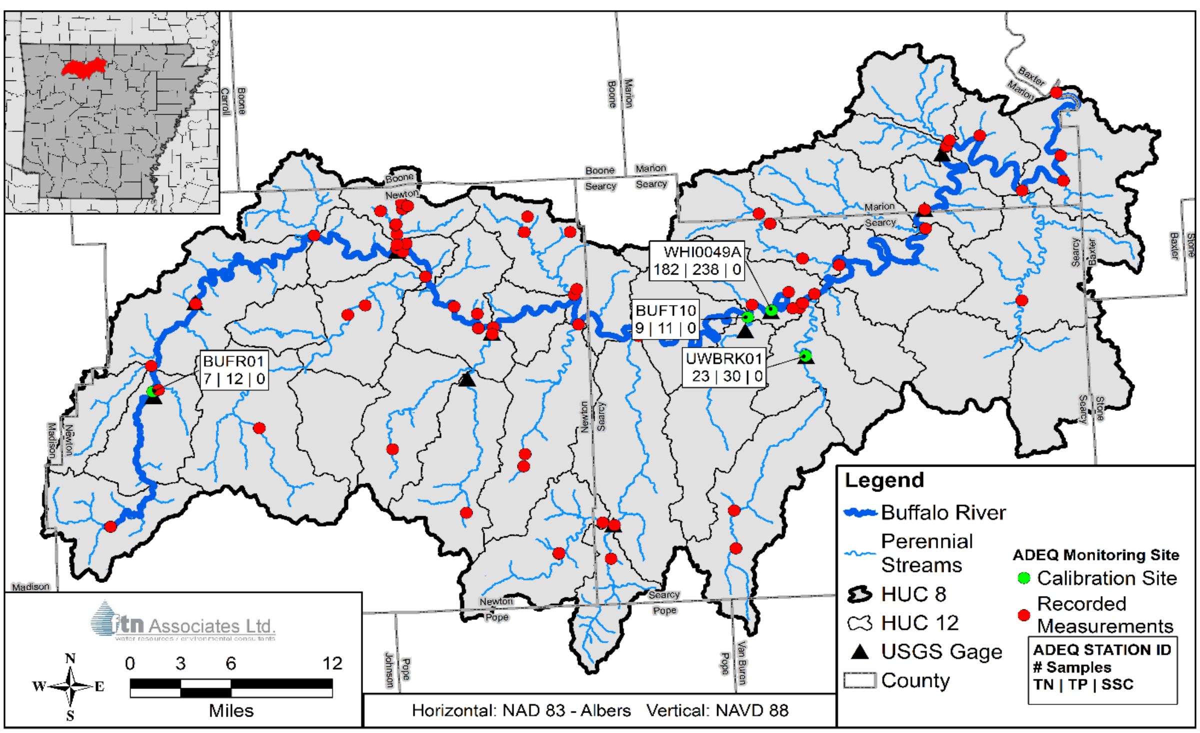

Figure 2-17 ADEQ Water Quality Monitoring Sites (Total Nitrogen-TN, Total Phosphorus-TP, and Suspended Sediment Concentration-SSC).

3.0 MODEL DEVELOPMENT

ArcSWAT 2012 (http://swat.tamu.edu/software/arcswat/) was used to develop the SWAT model and estimate spatially derived model inputs for the sub-basins and HRUs in the watershed. All input spatial data was first projected to an "Albers" Equal-Area Conic projection coordinate system for use in the program. This projection was selected because it has little distortion in shape or scale and area is preserved (Snyder, 1987). Examples of model variables calculated using ArcSWAT include: 1) the slope for each HRU and sub-basin river reach, which was derived from the Digital Elevation Model (DEM), and 2) the SCS curve number for each modeled HRU, which was calculated using soil and land use data. HRUs were defined in ArcSWAT using one third arc-second (approximately 10 meters) resolution DEM gridded data, SSURGO soil polygons, and 10-meter resolution National Land Cover gridded data. Due to the fine resolution of the data used for this project, ArcSWAT created 24,160 individual HRUs for the Buffalo River Watershed. Over 90% of these were less than approximately 50 acres in size (Figure 3-1). In ArcSWAT, the user has the option of removing HRUs that are less than a defined area or percentage threshold. HRUs with small areas were removed using a sub-basin percentage threshold of 5% for land cover, soil class, and slope class. Using these thresholds, ArcSWAT automatically reapportioned the area of the removed HRUs to the remaining ones so that 100% of the area in each sub-basin was conserved. This process resulted in a final HRU count of 1,821 HRUs for the Buffalo River Watershed. Small HRUs contribute very little to overall model performance and were removed because the scale and objective of this project did not require that level of detail.

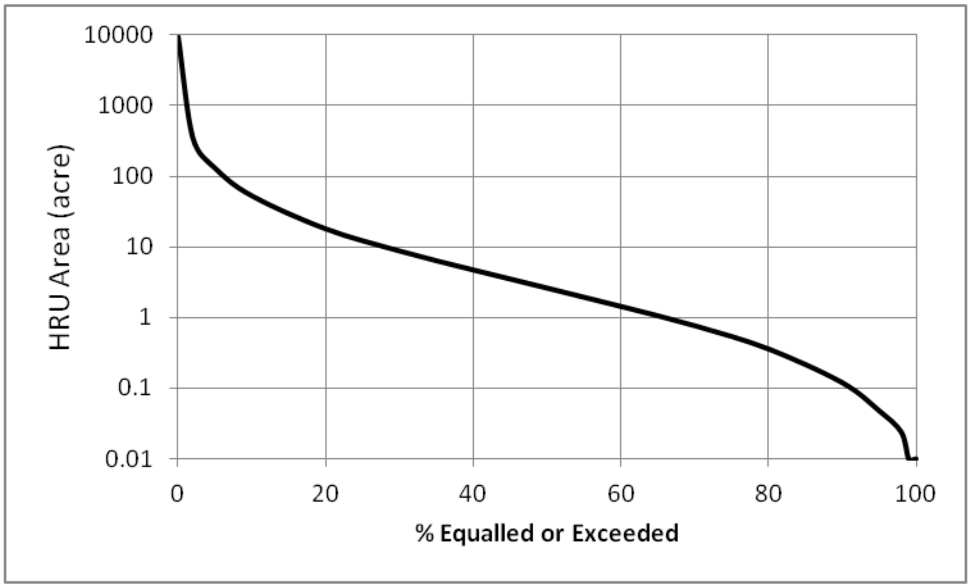

Figure 3-1 HRU Area Exceedence Curve.

Additional inputs or modifications to the model were prepared outside of ArcSWAT, and included in the model prior to calibration. The following subsections will discuss the data and processes used to generate this input.

3.1 Climate Data

Daily time series of precipitation, min/max temperature, and relative humidity were developed for the SWAT model using the PRISM dataset. Precipitation and min/max temperature values are directly reported in the PRISM dataset but relative humidity (RH) input had to be estimated using mean daily temperature (T, in Celsius) and dew point (Td, in Celsius) temperature values by first calculating saturated (e_s) and actual (e) vapor pressures according to Equation 3.1 and Equation 3.2, and then dividing the former by the latter as shown in Equation 3.3 (Chow, Maidment, & Mays, 1988).

Equation 3.1 $$e_s = 611 * e^{\frac{17.27*T}{237.3+T}}$$

Equation 3.2 $$e = 611 * e^{\frac{17.27*Td}{237.3+Td}}$$

Equation 3.3 $$R_H = \frac{e}{e_s}$$

Daily solar radiation and wind speed input data, in SWAT model format, were downloaded from Texas A&M's Global Weather Data for SWAT website (Texas A&M AgriLife Research, 2017c), and no processing was necessary. However, this data was only available through July 31^{st}, 2014, and SWAT's weather generator was used to automatically fill in the remaining period. The weather generator uses the nearest station with data to estimate values for model input. Three stations in northern Arkansas were used by the weather generator. These stations reported solar radiation and wind speed data and were located near the cities of Eureka Springs, Mountain Home, and Clarksville.

3.2 Curve Number Adjustment

The Buffalo River Watershed SWAT model uses a modification of the USDA-Soil Conservation Service (SCS) curve number method to predict surface runoff. This method uses a unitless "curve number" to estimate the amount of runoff generated from a particular land use and soil type. Conceptually, land slope should also be a factor in the generation and peak timing of surface runoff, and surface runoff should increase with slope (Dodds, 1997). However, the original SCS runoff curve number methodology does not include slope as one of the factors. Several researchers have studied the effect of slope on runoff (Huang, 2006; Haggard et al. 2005; Evett and Dutt, 1985). One of the first attempts to include slope in a model using the SCS methodology was by Sharpley and Williams (1990). This method was implemented in the Erosion/Productivity Impact Calculator (EPIC) model. In the EPIC model documentation, an equation is presented that adjusts the SCS Curve Number based on land slope and the calculated curve numbers for three antecedent runoff conditions. These equations are presented below (Equation 3.4, 3.5, and 3.6), where α is slope, CN_2 is the curve number for "normal" conditions, CN_1 is the curve number under "dry" conditions, and CN_3 is the curve number for "wet" conditions.

Equation 3.4 $$CN_{2\alpha} = \frac{1}{3}(CN_3 - CN_2)\left(1 - 2 * exp(-13.86 * \alpha)\right) + CN_2$$

Equation 3.5 $$CN_3 = CN_2 * exp(0.00673(100 - CN_2))$$

Equation 3.6 $$CN_1 = CN_2 - \frac{20(100 - CN_2)}{100 - CN_2 + exp\left(2.533 - 0.0636(100 - CN_2)\right)}$$

By default, the SWAT model calculates the "normal" conditions curve number (CN2) for each hydrologic response unit (HRU) based on a lookup table with various land uses, hydrologic soil groups, and an assumed 5% land slope - the equation presented by Sharpley and Williams (1990) was developed with this assumption as well. The SWAT model theoretical documentation also provides the Sharpley and Williams (1990) curve number adjustment equations, but the slope adjustment must be done manually and is not included as an option in ArcSWAT. Prior to model calibration, curve numbers (CN2) generated by ArcSWAT were adjusted using these equations, the original ArcSWAT calculated curve number, and slope for each HRU.

3.3 Phosphorus Availability Index

Accurate partitioning of soil phosphorus into the pools modeled by SWAT is critical for simulating phosphorus transport. In SWAT, the phosphorus availability index (PAI; also known as "PSP" in SWAT) parameter is used to establish equilibrium between the mineral (inorganic) active and solution pools, and is especially important because inorganic phosphorus fertilizer is applied to the solution pool, and can easily be transported in runoff. The value used for this parameter was calculated using Equation 3.7, which was first presented in Vadas and White (2010). This equation is similar to one that was first presented in Sharpley et al. (1984), and was developed to estimate the phosphorus availability index in highly weathered soils. Sharpley et al. (1984) also provides two other equations to estimate the phosphorus availability index in calcareous and slightly weathered soils. However, the equation for highly weathered soils is most applicable for this project because the watershed mostly contains highly weathered Ultisols and moderately weathered Alfisols (Figure 3-2). These soil orders are common in humid, temperate, and stable landscapes such as the Ozark Plateaus. Soil clay (Clay%) and organic carbon content (OrgC%) inputs to Equation 3.7 were estimated by calculating the average of the values reported in the first layer of the SSURGO dataset. Solution P (SolP) was taken as one half of the average Mehlich-3 value from hay/pasture land uses in the watershed (see Soil Nutrients Section 2.7 for more information). Using these values and Equation 3.7 the value of PSP was calculated to be 0.27 (SWAT default is 0.4).

Equation 3.7 $PSP = -0.053 * ln(Clay\%) + 0.001 * (SolP) - 0.029 * (OrgC\%) + 0.42$

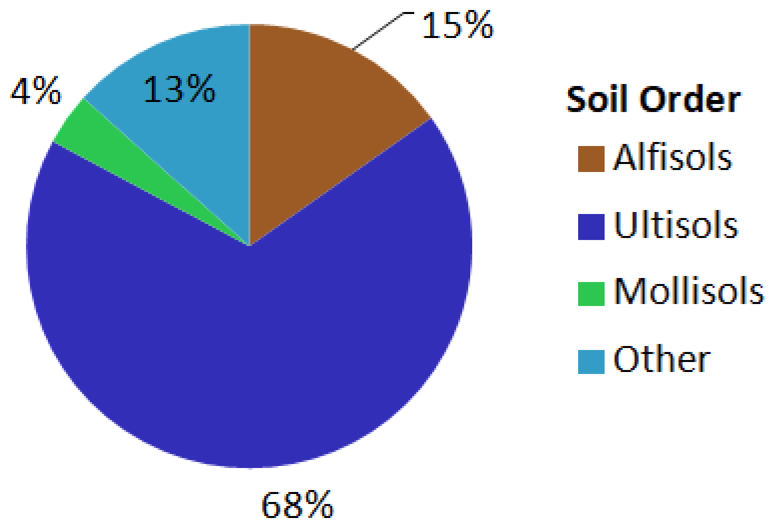

Figure 3-2 Soil Order Percentages in the Buffalo River Watershed.

3.4 Management Practices

In the Buffalo River Watershed, agricultural land is almost exclusively used for beef cattle grazing and hay production. In the SWAT model, management practices were scheduled by date. The fertilizer application rate used in the model is based on recommendations for hay and pasture developed by University of Arkansas Cooperative Extension Service and verified by talking with local extension agents and farmers. It is common practice in this area to apply triple seventeen (17-17-17) fertilizer in the early spring (March) at the start of the growing season. Occasionally fertilizer is also applied in the fall, but this is not consistently done nor is it as widespread, so this practice was not included in the model. Urea and manure fertilizers are also used in the watershed, but they aren't as widely used as triple seventeen and no data exists in the watershed to develop specific fertilizer application rates for each of the individual hay/pasture HRUs in the model. Instead, the most common practices were used in the model for all hay/pasture HRUs (Table 3.1).

Table 3.1 SWAT Model Hay/Pasture Management Operations and Scheduling.

Management Operation	Date
Fertilize with 17-17-17 at 200 lb/ac	March 1
Harvest only operation #1	June 1
Harvest only operation #2	July 15

4.0 CALIBRATION/VALIDATION

The hydrology in the watershed was calibrated first, followed by the suspended sediment, total phosphorus, and total nitrogen loads. During model calibration, parameters were adjusted according to land use type and primary physiographic section. Using this systematic approach ensured that parameters developed for portions of the watershed with calibration data would also be applicable in areas without data. If land use was the primary factor affecting the calibration parameter, values were developed for each group and applied to all those land uses in the model. Physiographic sections are general areas with similar geologic structures and geomorphic history. In the Buffalo River Watershed, the Boston Mountains Section is geologically different than the Springfield and Salem Plateaus. The Springfield and Salem Plateaus contain numerous springs that provide baseflow to streams during the dry season (July – November). In contrast, streams in the Boston Mountains dry up more frequently and less baseflow is provided from the mostly sandstones and shale formation in this section.

Model calibration and validation was successfully completed in large part due to lessons learned from previous research described by Amin et al. (2017). This research focused on using a version of SWAT (SWAT-Topo) to model nonpoint source pollution in a karst watershed in northeastern Pennsylvania. Many of the values used in the calibration process were first estimated from this research and performance was greatly improved compared to using the model defaults. Even though SWAT-Topo was not used for this study, calibration parameter values used in the Buffalo River SWAT model appear to be similar in magnitude to values reported by Amin et al. (2016).

4.1 Methods for Evaluating Model Performance

Model calibration and validation was performed manually by comparing measured streamflow and calculated sediment and nutrient loads to model output. Hydrograph plots and exceedance probability curves were first visually inspected for correctness, then model output was assessed quantitatively using two statistics: 1) Percent Bias (PBIAS), and 2) the Nash-Sutcliffe coefficient of efficiency (NSE). PBIAS is useful for assessing the total mass balance and is a measure of the average tendency of the simulated data to be larger or smaller than the measured values, while NSE is used to assess model residual variance (Gupta et al., 1999). These statistics have been used in numerous SWAT modeling projects and appropriate values for evaluating the accuracy of the model have been established. For this project, model statistics were appraised based on recommendations according to Moriasi et al. (2007), which are presented below in Table 4.1 for reference. The values in this table are for comparing monthly averages of measured and modeled data. Moriasi et al. (2007) does not provide guidance for assessing model performance for daily or annual averages, but in general, the criteria should be stricter when assessing larger time steps and looser at shorter time steps. NSE values were calculated for daily, monthly, and annual averages, but only the monthly values were used in the final assessment of model performance and for concluding that the model was sufficiently calibrated. PBIAS values are identical for daily, monthly, and annual averages and relaxing or tightening of the criteria is not necessary when evaluating model performance at different time scales. The formulas (Equation 4.1 and 4.2) used to calculate PBIAS and NSE are provided below, where "Obs" is the observed (measured) and "Sim" is the simulated (modeled) value.

Table 4.1 Monthly model performance criteria (Moriasi et al., 2007).

Performance Rating	NSE	PBIAS		
		Flow	Sediment	TN and TP
Very Good	0.75 < NSE ≤ 1.00	PBIAS < ±10	PBIAS < ±15	PBIAS < ±25
Good	0.65 < NSE ≤ 0.75	±10 ≤ PBIAS < ±15	±15 ≤ PBIAS < ±30	±25 ≤ PBIAS < ±40
Satisfactory	0.50 < NSE ≤ 0.65	±15 ≤ PBIAS < ±25	±30 ≤ PBIAS < ±55	±40 ≤ PBIAS < ±70
Unsatisfactory	NSE ≤ 0.50	PBIAS ≥ ±25	PBIAS ≥ ±55	PBIAS ≥ ±70

Equation 4.1 $$\boldsymbol{PBIAS = \frac{\sum_{i=1}^{n}\left(Obs_i - Sim_i\right)*100}{\sum_{i=1}^{n}\left(Obs_i\right)}}$$

Equation 4.2 $$\boldsymbol{NSE = 1 - \frac{\sum_{i=1}^{n}(Obs_i - Sim_i)^2}{\sum_{i=1}^{n}\left(Obs_i - \overline{Obs}\right)^2}}$$

4.2 Estimated Sediment and Nutrient Loads

Total Nitrogen (TN), Total Phosphorus (TP), and Suspended Sediment Concentration (SSC) water quality measurements that could be paired with streamflow data for the same day were used to estimate daily loads for model calibration. In the Buffalo River Watershed, there are four monitoring locations that report a significant number of measurements of at least one of these constituents and also have reported daily streamflow data. Daily load values were first calculated from the paired data, assuming that the average daily streamflow and concentration measurement was applicable for the entire day. This assumption may not be accurate during a large storm event and at a sub-daily time scale, when streamflow and water quality can change rapidly, but modeling short term dynamics such as these are beyond the scope of this project and the ability of the model. Next, a “rating curve” was developed that represented an empirical relationship between daily load and streamflow values at the monitoring location. For this project, Locally Weighted Scatterplot Smoothing (LOWESS) regression was used to ascertain the overall pattern in the data and develop the rating curve. Using the rating curve, daily load estimates were then generated for every day that streamflow was recorded. Generating load estimates from a rating curve is helpful for model calibration because it smooths out the effect of individual water quality measurements, which are subject to sampling error, while making an estimate that is based on the entire data set (Cohn et al., 1992). LOWESS regression was used in this analysis because log-linear regression methods, which are commonly used for load estimation, are only applicable when the flow and load data exhibit a bivariate lognormal distribution; however, when plotting log transformed load and flow data in the Buffalo River Watershed, a majority of the data appeared to have a concave shape. This indicated that the data did not follow a lognormal distribution and that traditional log-linear regression methods would not be applicable. SSC and TP load versus streamflow plots appear to have the greatest curvature, while TN load appears to be more log-linear with streamflow.

4.2.1 LOWESS

Nonparametric regression techniques are useful for modelling data that are intrinsically nonlinear. Cleveland (1979) first introduced LOWESS as a robust nonparametric technique that essentially joins several local polynomial regressions together to create a smooth function. The LOWESS rating curve developed to estimate Total Phosphorus (TP) loads from daily streamflow data at USGS 0705600 is presented below in Figure 4-1. There appears to be a change in the slope of the data around 500-600 cubic feet per second, which the LOWESS rating curve is able to reproduce.

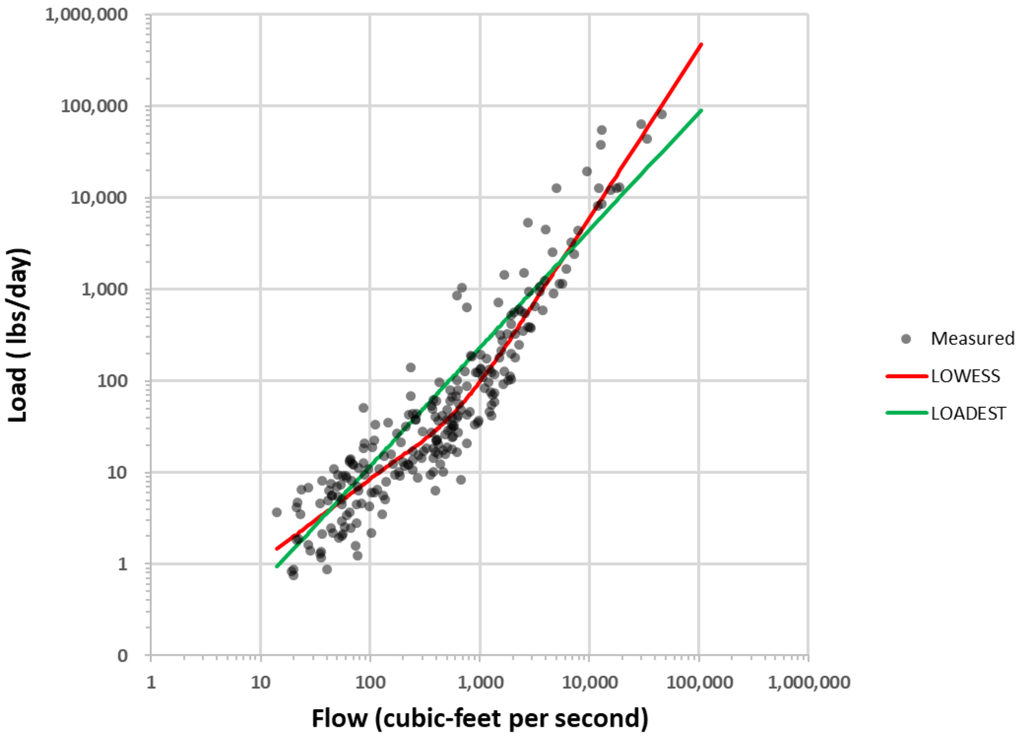

Figure 4-1 Rating Curves developed to estimate daily TP loads at USGS 07056000.

A second rating curve, developed by the LOADEST program, is also provided in Figure 4-1. LOADEST is an executable FORTRAN program that's been used by previous researchers to estimate sediment and nutrient loads in the Buffalo River Watershed (e.g., Petersen, Haggard and Green, 2002; Galloway and Green, 2004a; Galloway and Green, 2004b). LOADEST develops a model to estimate loads from paired water quality and streamflow data, and options have been built into the program to account for problems arising from using censored data (Adjusted Maximum Likelihood Estimation; AMLE) and for datasets with non-normally distributed residuals (Least Absolute Deviation; LAD). In 2013, the USGS released a new version of program that added several features to facilitate residual analysis and bias identification (Runkel, 2013). This new release followed research by Stenback et al. (2010), which showed that LOADEST rating curves over-estimated nitrate loads in Iowa and was found to poorly characterize nitrate and phosphorus variation with streamflow. Of course, this is not a problem with LOADEST, but is due to the fact that the input data could not be represented by the explanatory variables (flow and time) and the equations used in the program.

Goodness of fit statistics for the two rating curve methods are provided below in Table 4.2. Using the LOWESS method resulted in a better fit, as indicated by a larger NSE and reduced PBIAS. Monthly Total Phosphorus (TP) loads were estimated for the calibration and validation periods (1997-2016) using both rating curves and a plot of this data is presented below in Figure 4-2. The rating curves are plotted on a logarithmic scale in Figure 4-1, which may obscure large difference between the two methods when streamflow is highest. For example, a large flood event occurred on March 19, 2008. During this event, the mean daily flow at USGS 07056000 was 105,000 cubic-feet per second, and on this day alone, the LOWESS estimated TP load was 190 tons greater than the estimated load from LOADEST.

Table 4.2 LOWESS and LOADEST model statistics for estimating daily TP loads at USGS 07056000.

Statistic	**LOWESS**	**LOADEST**
NSE	0.76	0.49
PBIAS (%)	20	56
R Squared	0.89	0.84

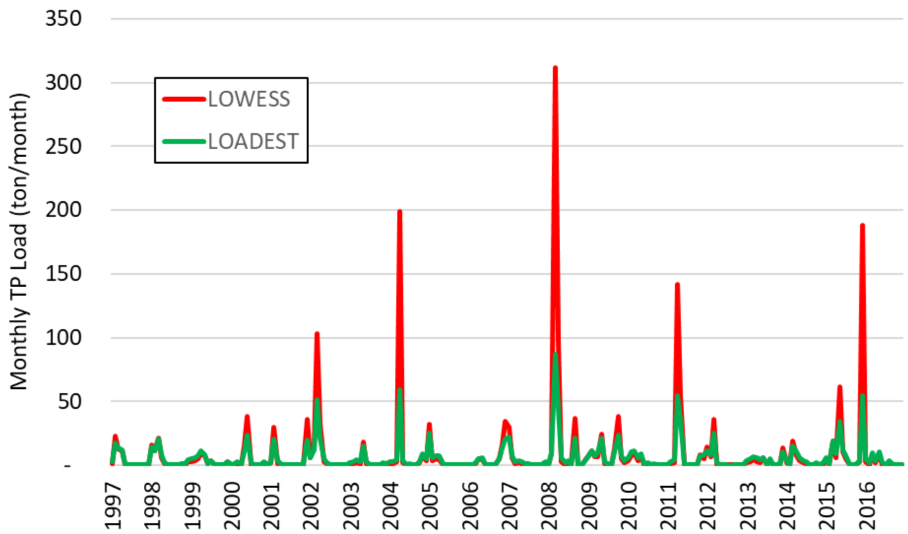

Figure 4-2 LOWESS and LOADEST estimated TP loads at USGS 07056000.

As stated earlier, most of the load vs. streamflow plots that were created for the Buffalo River Watershed exhibit a concave shape and log-linear regression isn't suitable to estimate loads from this data (see Appendix B). This may not be a problem if only one monitoring location at the outlet of a watershed is used in model calibration and only relative loads from different areas in the model are being compared. However, when performing multi-site calibration using rating curves with varying degree of curvature to calibrate a model, the bias should be reduced to a minimum so as to not favor certain areas, which could result in calibrating the model to artificially high and low load estimates in different areas. Load estimates using LOWESS were found to have lower bias compared to LOADEST, which is why it was used to estimate loads for this project.

4.3 Calibration Parameters

The parameters used in model calibration are presented in Table 4.3. Most of the parameters used for model calibration are unitless coefficients, which could only be estimated prior to calibration. Other parameters were selected for model calibration due to the lack of available data in the watershed. Since values for these parameters could not be obtained, model calibration was used to optimize the unknown values. As discussed earlier, values in the model were adjusted either for the entire watershed, or on the basis of land use or physiographic section. See the footnotes to Table 4.3 for a description of the variables that were modified according to the latter two criteria.

Table 4.3 Parameters used to calibrate the Buffalo River Watershed SWAT model.

Parameter	Description	Unit	Range	Default Value	Calibrated Value
Surface Water Parameters					
CN2	SCS runoff curve number	none	35-98	Varies	+10%
ESCO	Soil evaporation compensation factor	none	0-1	0.95	0.3 [a] | 0.6 [b]
EPCO	Plant uptake compensation factor	none	0-1	1	1
CANMX	Canopy storage capacity	mm	0-100	0	6 [a] | 3 [b]
SURLAG	Surface runoff lag coefficient	none	0-100	4	0.7
Groundwater Parameters					
ALPHA_BF	Baseflow recession constant	1/day	0-1	0.048	0.09 [c] | 0.05 [d]
RCHRG_DP	Deep aquifer percolation fraction	none	0-1	0.05	0.05 [c] | 0.35 [d]
REVAPMN	Water depth in shallow aquifer for percolation	mm	0-1000	750	0
GWQMN	Water depth in shallow aquifer for return flow	mm	0-5000	1000	10
GW_DELAY	Ground water delay time	days	0-500	31	1
GW_REVAP	Ground water revap coefficient	none	0.02-0.2	0.02	0.08 [a] | 0.02 [b]
Routing Parameters					
CH_N1	Manning's "n" for the tributary channels	none	0.011 - 0.2	0.014	0.06 [c] | 0.05 [d]
CH_N2	Manning's "n" for the main channel	none	0.011 - 0.2	0.014	0.05 [c] | 0.03 [d]
Sediment Parameters					
ADJ_PKR	Peak rate adjustment factor – sub-basin	none	0-10	1	4
PRF_BSN	Peak rate adjustment factor – main channel	none	0-10	1	1
SPCON	Sediment transport coefficient	none	0.0001-0.01	0.0001	0.0004
SPEXP	Sediment transport exponent	none	1-2	1.5	1.5
CH_COV1	Channel erodibility factor	none	0-20	0	19 [e] | 12 [f]
CH_COV2	Channel cover factor	none	0-20	0	14 [e] | 3 [f]
USLE_C	USLE land cover and management factor	none		Varies	0.003[a] | 0.004[b]
Phosphorus Parameters					
P_UPDIS	Phosphorus uptake distribution parameter	none	0-30	20	5
PPERCO	Phosphorus percolation coefficient	m3/mg	10-17.5	10	17.5
PHOSKD	Phosphorus soil partitioning coefficient	m3/mg	100-200	175	100
Nitrogen Parameters					
N_UPDIS	Nitrogen uptake distribution parameter	none	0-30	20	5
NPERCO	Nitrate percolation coefficient	none	0.01-1	0.2	0.8
SHALLST_N	Initial NO3 concentration in shallow aquifer	mg/L	0-1000	0	0.1

a. Value assigned to all forest land uses.
b. Value assigned to hay/pasture and urban land uses.
c. Value assigned to HRUs or Sub-basins in the Boston Mountains.
d. Value assigned to HRUs or Sub-basins in the Springfield and Salem Plateaus.
e. Value assigned to tributary channels.
f. Value assigned to Buffalo River channels.

4.4 Hydrology

Streamflow monitoring data from eight USGS locations in the watershed were used to calibrate the hydrology parameters in the model. Only four of the stream gage locations reported measurements during the validation period and could be used for model validation. NSE and PBIAS statics calculated using the monitoring data and model output are shown in Table 4.4. The performance rating assigned to each value is also included in the table. The ratings were assigned according to criteria established in Moriasi et al. (2007), which was discussed previously in the Methods for Evaluating Model Performance section (4.1). Only the PBIAS statistic for USGS 07056700 received a rating other than the highest level of “Very Good” during model calibration. However, PBIAS at this site is less than one percent from having the highest rating. Overall, the statistics for the validation simulation are not quite as good, but most are rated in the top two categories as “Very Good” or “Good”. Further information on model calibration and validation can be found in Appendix C and D, including: 1) Monthly time series plots of measured and modeled streamflow, 2) scatter plots with statistics calculated from measured vs. modeled monthly values, and 3) duration curves for measured and modeled daily flows.

Table 4.4 Monthly streamflow calibration and validation statistics and performance ratings.

	Calibration				Validation			
Station	**NSE**		**PBIAS**		**NSE**		**PBIAS**	
07055646	0.79	Very Good	7.26	Very Good	0.64	Satisfactory	15.02	Good
07055660	0.79	Very Good	3.11	Very Good	-	-	-	-
07055680	0.81	Very Good	-9.61	Very Good	-	-	-	-
07055790	0.86	Very Good	-5.19	Very Good	-	-	-	-
07055875	0.81	Very Good	1.85	Very Good	0.72	Good	-5.17	Very Good
07056000	0.86	Very Good	-7.65	Very Good	0.77	Very Good	-13.38	Good
07056515	0.86	Very Good	-5.26	Very Good	0.76	Very Good	-9.31	Very Good
07056700	0.86	Very Good	-10.63	Good	-	-	-	-

4.5 Sediment

Sediment loads estimated at three USGS gage locations in the watershed were used to calibrate the sediment parameters in the model, and for model validation. NSE and PBIAS statistics calculated from the estimated loads and model output are shown in Table 4.5. All statistics calculated during the calibration period received the highest ranking of “Very Good”, and the statistics for the validation period all received a ranking of “Satisfactory” or better. Additional information on model calibration and validation can be found in Appendix C and D.

Table 4.5 Monthly sediment load statistics and performance ratings.

	Calibration				Validation			
Station	NSE		PBIAS		NSE		PBIAS	
07055646	0.92	Very Good	3.20	Very Good	0.6	Satisfactory	23.60	Good
07056000	0.86	Very Good	-0.97	Very Good	0.59	Satisfactory	12.60	Very Good
07056515	0.85	Very Good	-5.34	Very Good	0.73	Good	19.05	Good

4.6 Phosphorus

Total Phosphorus loads estimated at four USGS locations in the watershed were used to calibrate the phosphorus parameters in the model; however only three locations were available for model validation due to the lack of flow data during the validation period for USGS 07055790. NSE and PBIAS statistics calculated using the estimated total phosphorus loads and model output are present below in Table 4.6. All statistics calculated during the calibration period received the highest ranking of “Very Good”. Only the NSE statistic during the validation period at USGS 07055646 received a ranking other than “Very Good”, but still received the next best rating of “Good”. Additional information on model calibration and validation can be found in Appendix C and D.

Table 4.6 Monthly phosphorus load statistics and performance ratings.

	Calibration				Validation			
Station	NSE		PBIAS		NSE		PBIAS	
07055646	0.81	Very Good	-23.97	Very Good	0.66	Good	-15.48	Very Good
07055790	0.78	Very Good	20.64	Very Good	-	-	-	-
07056000	0.76	Very Good	11.76	Very Good	0.75	Very Good	3.34	Very Good
07056515	0.75	Very Good	-12.46	Very Good	0.75	Very Good	-13.80	Very Good

4.7 Nitrogen

Total Nitrogen loads estimated at three USGS locations in the watershed were used to calibrate the nitrogen parameters in the model, but only two locations were available for model validation due to the lack of streamflow data at USGS 07055790. Over 70 measurements of total nitrogen were available at USGS 07055646 since January 1997; however almost 65% of these measurements have been reported as below the reporting limit. Loads estimated from this data could be considerably biased due to the lack of measurements reported above the reporting limit and any method that imputes new values might not be accurate given the large number of censored values. The NSE and PBIAS statistics calculated using the estimated total nitrogen loads and model output are presented below in Table 4.7. All statistics calculated during the calibration period received the highest ranking of "Very Good". Only the NSE statistic during the validation period at USGS 07056000 received a ranking other than "Very Good", but still received the next best rating of "Good". Additional information on model calibration and validation can be found in Appendix B and C.

Table 4.7 Monthly nitrogen load statistics and performance ratings.

	Calibration				Validation			
Station	NSE		PBIAS		NSE		PBIAS	
07055790	0.78	Very Good	-21.55	Very Good	-	-	-	-
07056000	0.78	Very Good	13.51	Very Good	0.7	Good	4.93	Very Good
07056515	0.85	Very Good	8.13	Very Good	0.79	Very Good	5.13	Very Good

5.0 USING MODEL RESULTS TO PRIORITIZE AREAS

The SWAT model generates simulated values for all reach, sub-basin, and HRU modeling objects. Average annual yields of sediment, total phosphorus, and total nitrogen were calculated for all HRUs and sub-basins in the model using output from calibration and validation periods (1/1/1997 through 12/31/2016). This data was then used to accomplish the main objective of this study, which is the prioritization of HUC12 sub-watersheds, so that investment strategies can be developed that will have the greatest impact on water quality objectives. Prioritization was accomplished by grouping each HUC12 into four percentile classes (0-25%, 25-50%, 50-75%, and 75-100%) based on its respective average annual load per unit area (yield). HUC12 sub-watersheds in the highest class (75-100%) produced sediment or nutrient yields that were greater than at least 75% of the HUC12s in the Buffalo River Watershed, and water quality improvement projects in these areas are likely to provide substantial benefits. In addition to the HUC12 prioritization, a more detailed analysis of critical source areas was also conducted and revealed specific areas where projects are likely to have the most impact on water quality.

5.1 Sediment Yield

SWAT simulated average annual sediment yield, from modeled HRUs, is shown in Figure 5-1. One thing that stands out from this figure is the cluster of HRUs with elevated sediment yields in the Bear, Calf, and Long Creek Watersheds. After reviewing the soil, land use, and slope data, it is clear that this area has a distinct combination of factors that result in sediment yields that are the largest in the watershed. According to the SSURGO Soils dataset, Newnata and Moko soils with low saturated hydraulic conductivity and high erodibility dominate these areas. The USDA soil survey of Searcy County by Laurent, Lowrance, and McCright (1988), reports the following regarding Newnata series soils in the area: 1) they can be severely eroded if a pasture is overgrazed, 2) several inches of topsoil have already been lost in areas with this soil, 3) the soil is subject to landslides, and 4) most areas show evidence of gullies. Land use and slope are also factors effecting sediment yields in this area, with the highest yields coming from pasture land uses where slopes are greater than 25%.

A radar plot showing the average annual sediment yield from different combinations of soil, slope, and land use is also provided in Figure 5-2. The values along the concentric circles are in pounds per acre per year (lb/ac/yr), and the labels along the perimeter are for different soil/slope groups. For example, the data point at the end of the radial line extending to "Newnata >25" is the average sediment yield for all HRUs with Newnata soils and slope greater than 25%. Moko and Newnata soils along with some of the highest percentages of pasture are present in the Calf, Headwaters Bear, Outlet Bear, and Long Creek HUC12 sub-watersheds, which explains why these areas have the highest modeled sediment yields in the Buffalo River Watershed (Figure 5-3). Data in this figure could also be used in prioritizing projects, after reviewing the project location and taking an inventory of the soil, slope, and land use of the area.

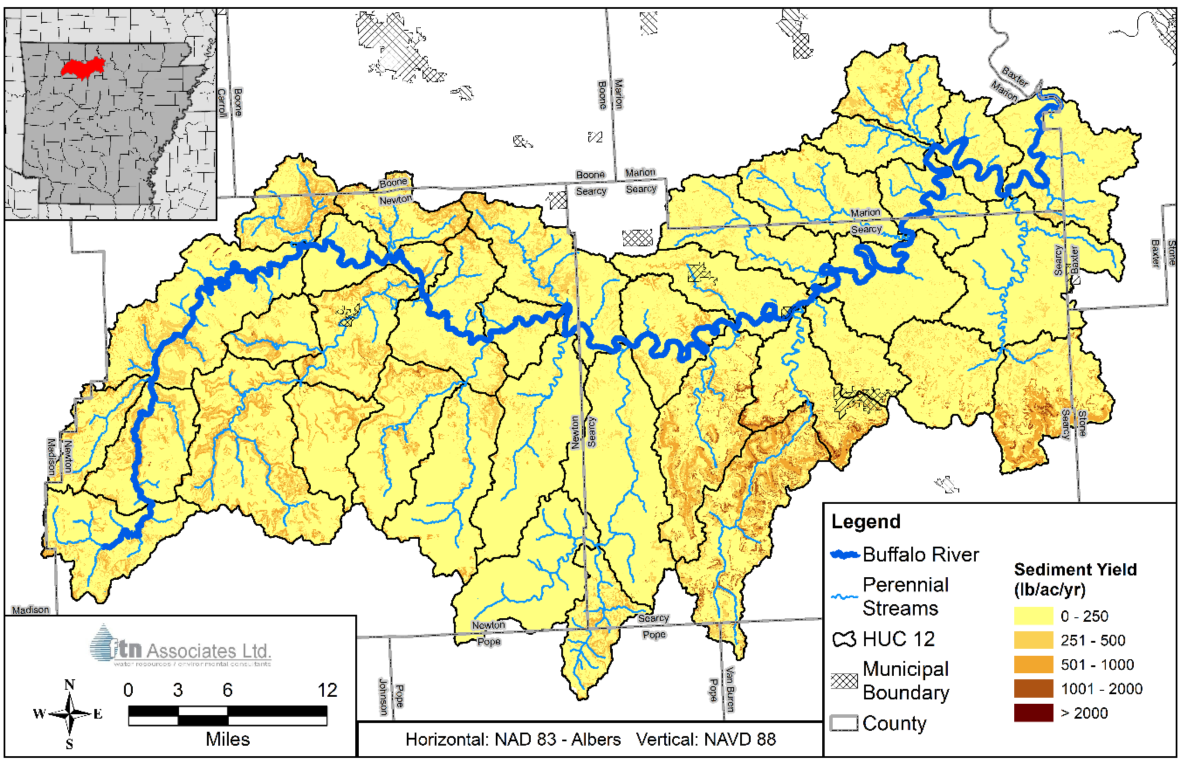

Figure 5-1 HRU Average Annual Sediment Yield.

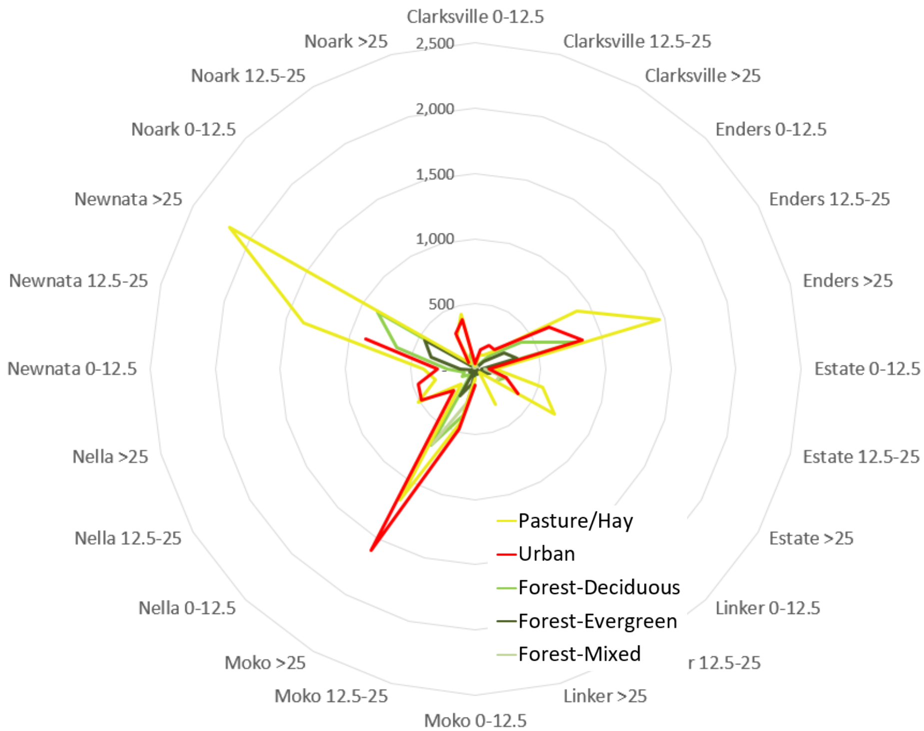

Figure 5-2 Critical Source Areas for Sediment Loss.

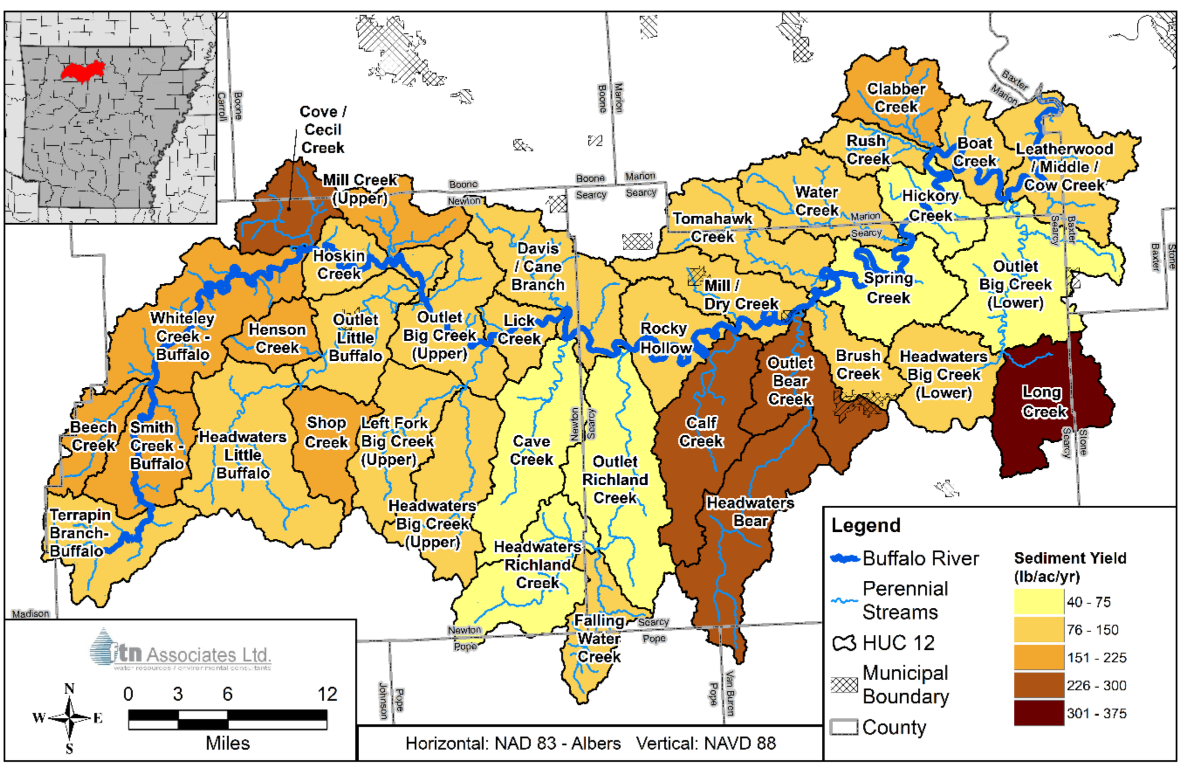

Figure 5-3 HUC12 Sub-Watershed Average Annual Sediment Yield.

5.2 Total Phosphorus Yield

Total Phosphorus (TP) yield in the Buffalo River Watershed is highly correlated to transport factors (such as sediment and surface runoff yield) and source factors (such as land use and soil nutrient level). Despite the karst geology, TP leaching and groundwater transport is limited in many areas in Northwest Arkansas, where the primary mechanism for phosphorus loading is via surface runoff, due to the presence of high clay content soils with increased buffering capacity (Haggard, Moore, Chaubey, & Stanley, 2003). Thus, areas with large sediment and surface runoff yields and high levels of soil phosphorus are also responsible for large TP yields. TP yields and soil phosphorus content are also highly correlated with land use in the watershed, due to the addition of phosphorus fertilizers for hay production and grazing, and low natural phosphorus levels in unmanaged forest areas. Some of the largest TP yields (Figure 5-4 and Figure 5-5) in the Buffalo River Watershed are in the Calf, Headwaters Bear, Outlet Bear and Long Creek HUC12 sub-watersheds, where sediment yield and the percentage of hay/pasture land use is relatively high compared to other sub-watersheds. Modeled average annual TP yield for these sub-watersheds is approximately double the average TP yield at the watershed outlet (0.44 lb/ac/yr). Sub-watersheds with the lowest TP yield have the highest percentage of forested land and/or are generally flat with a small percentage of area in the largest slope class (>25% slopes).

A radar plot showing the average annual TP yield from different combinations of soil, slope, and land use is provided in Figure 5-6. The values along the concentric circles are in pounds per acre per year, and the labels along the perimeter are for different soil/slope groups, similar to the radar plot shown previously in the Sediment Yield section. Data in this figure could also be very useful in prioritizing projects, after reviewing the project location and taking an inventory of the soil, slope and land use of the area. Like in the radar plot for sediment yield, Newnata, Moko, and Enders soils on large slopes produce the largest TP yields. However, the difference between forest and managed lands (urban, hay/pasture) is even more prominent in the TP radar plot.

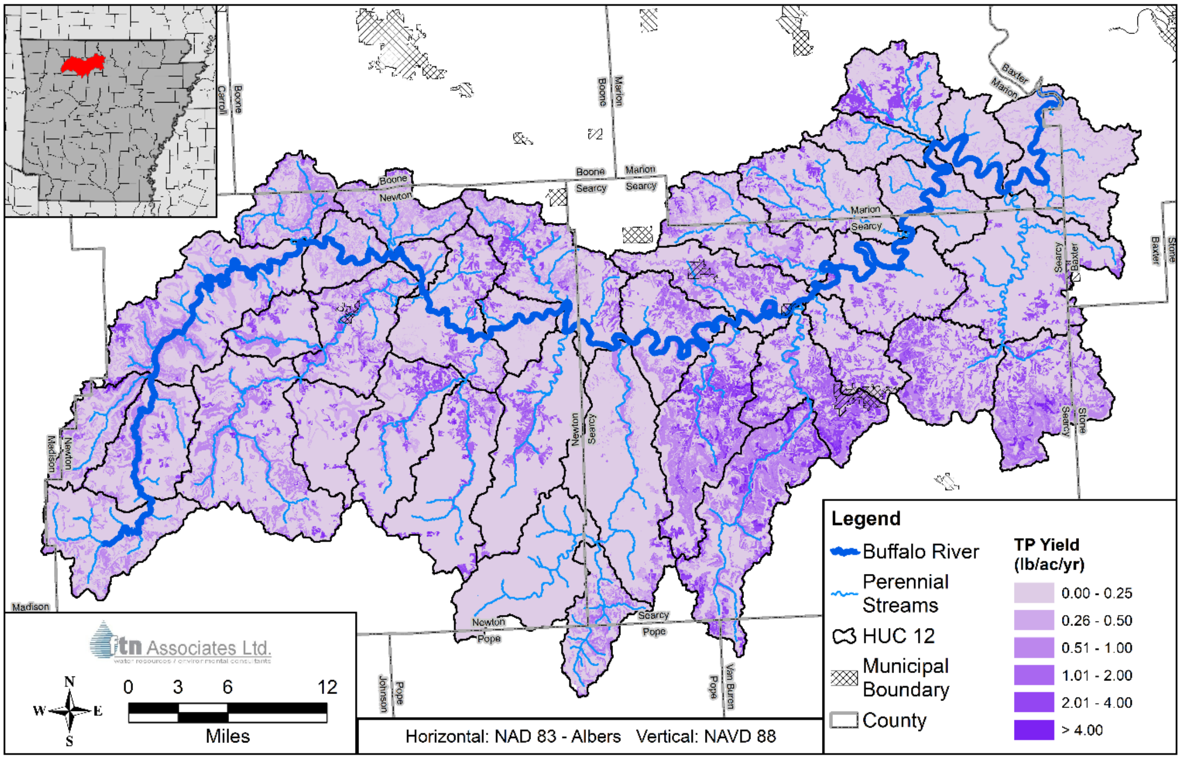

Figure 5-4 HRU Average Annual Total Phosphorus Yield to Streams.

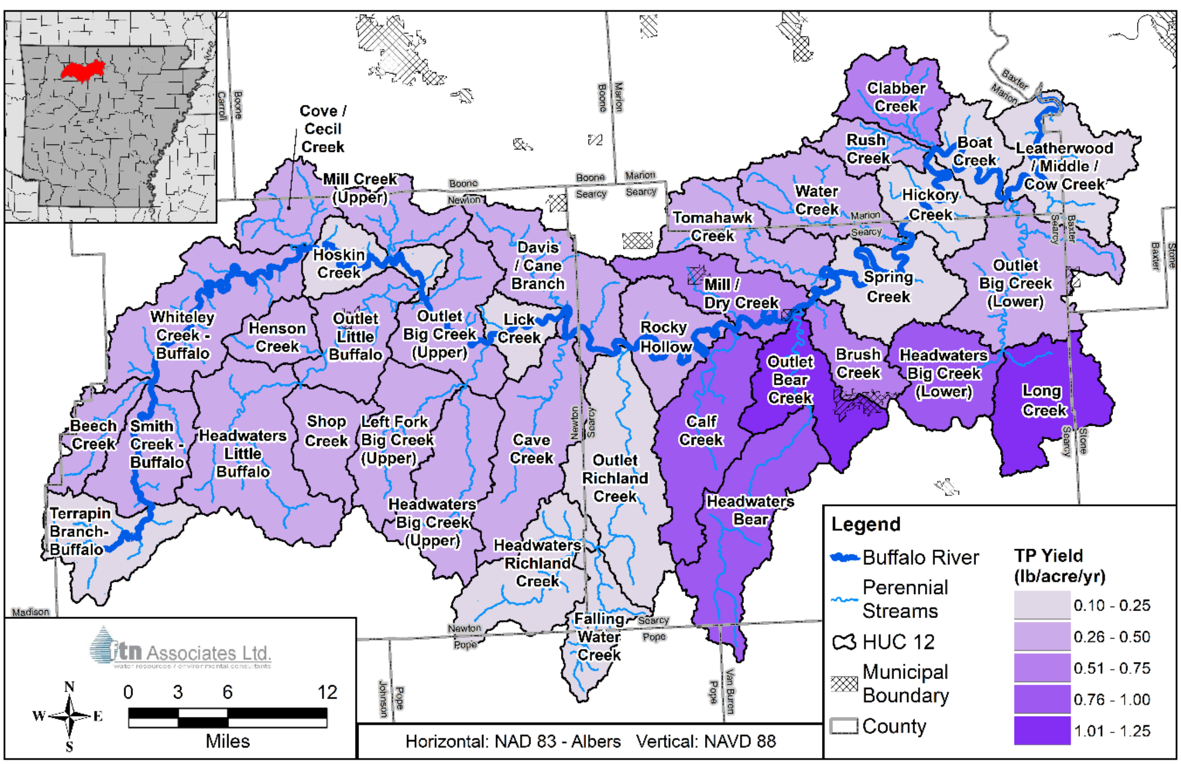

Figure 5-5 HUC12 Average Annual Total Phosphorus Yield to Streams.

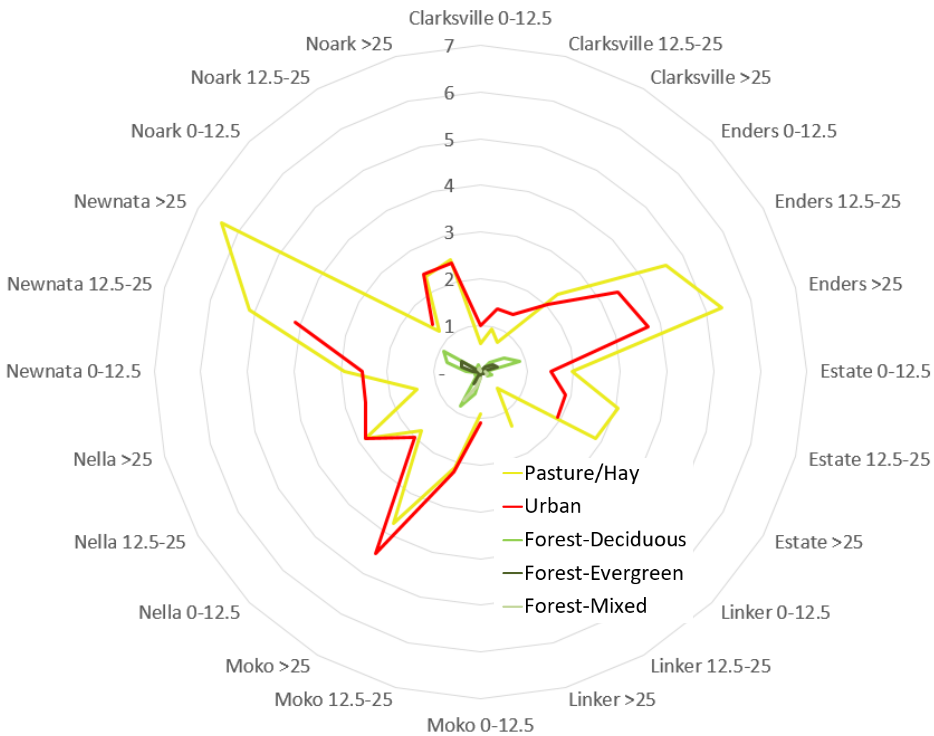

Figure 5-6 Critical Source Areas for Total Phosphorus Loss.

5.3 Total Nitrogen Yield

Whereas phosphorus transport (yield) in the watershed is primarily associated with surface runoff, nitrogen is transported through surface runoff, lateral subsurface flow, and groundwater. Nitrogen in the nitrate (NO_3) form is especially mobile and can leach below the root zone and eventually enter a stream through lateral flows or groundwater sources. The transport of nitrogen in a karst watershed is difficult to accurately simulate using SWAT or any other modeling platform, given the complexities involved and a lack of understanding of groundwater flow pathways throughout the entire watershed. However, in general, Total Nitrogen (TN) yields, like Total Phosphorus (TP) yields, increase with an increase in managed land (urban and hay/pasture), and model calibration results show that at larger sub-watershed scales the model is able to accurately reproduce measured TN loads.

Geology and topography are important factors effecting the transport of nitrogen in the watershed. Modeled lateral subsurface flows are larger in sub-watersheds with steeper slopes and nitrogen yield from this source also increases as a result. Modeled groundwater contributions are also more significant in sub-watersheds that have a majority of their area in the Springfield/Salem Plateaus, which contain a larger proportion of springs and other karst features. Similar to sediment and TP yields, TN yields are highest in the Calf, Headwaters Bear, Outlet Bear and Long Creek HUC12 sub-watersheds (Figure 5-7 and Figure 5-8). However, relatively large TN yields are also found in the Mill Creek (Upper), Davis/Cane Branch, Cove/Cecil Creek and Hoskin Creek sub-watersheds, which have relatively low TP yields, but a high percentage of area with steep slopes and an abundant karst features.

Modeled average annual TN yield at the watershed outlet is 2.3 lb/ac/yr. In general, sub-watersheds with the lowest TN yields have the highest percentage of forested land and area in the Boston Mountains; these sub-watersheds include the Terrapin Branch -Buffalo River, Headwaters Little Buffalo, Shop Creek, and Headwaters Richland Creek.

A radar plot showing the modeled average annual TN yield from different combinations of soil, slope, and land use is provided in Figure 5-9. The values along the concentric circles are in pounds per acre per year, and the labels along the perimeter are for different soil/slope groups, similar to the radar plot shown previously in the Sediment and TP Yield sections. TN yield from forested land is more pronounced than TP yield, but in general, TN yields from managed lands (urban and hay/pasture) are still 2-3 times greater than forested areas.

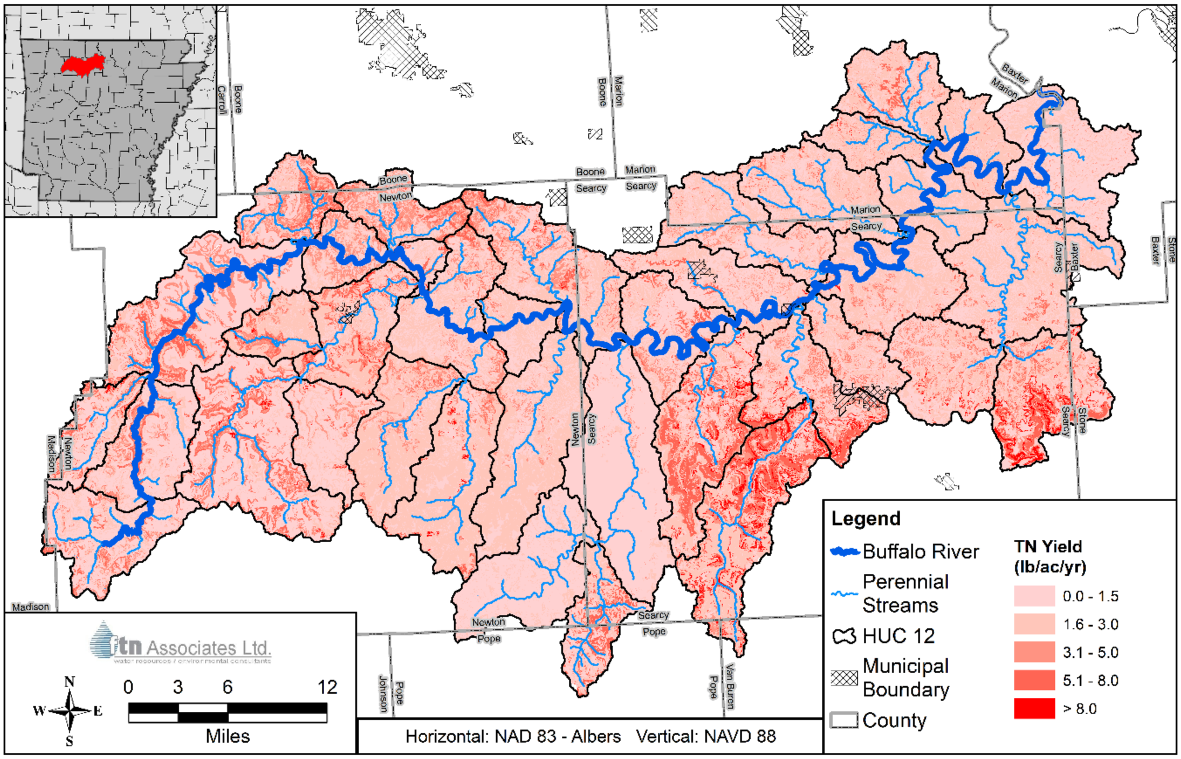

Figure 5-7 HRU Average Annual Total Nitrogen Yield to Streams.

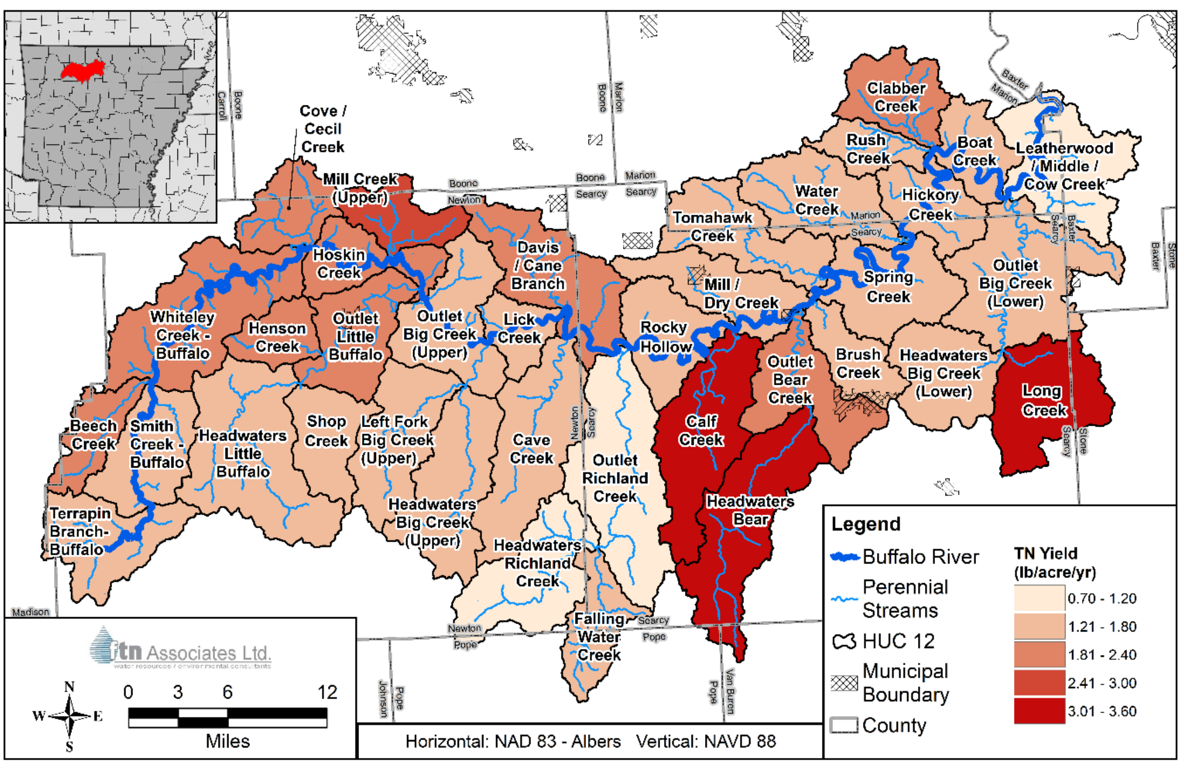

Figure 5-8 HUC 12 Average Annual Total Nitrogen Yield to Streams.

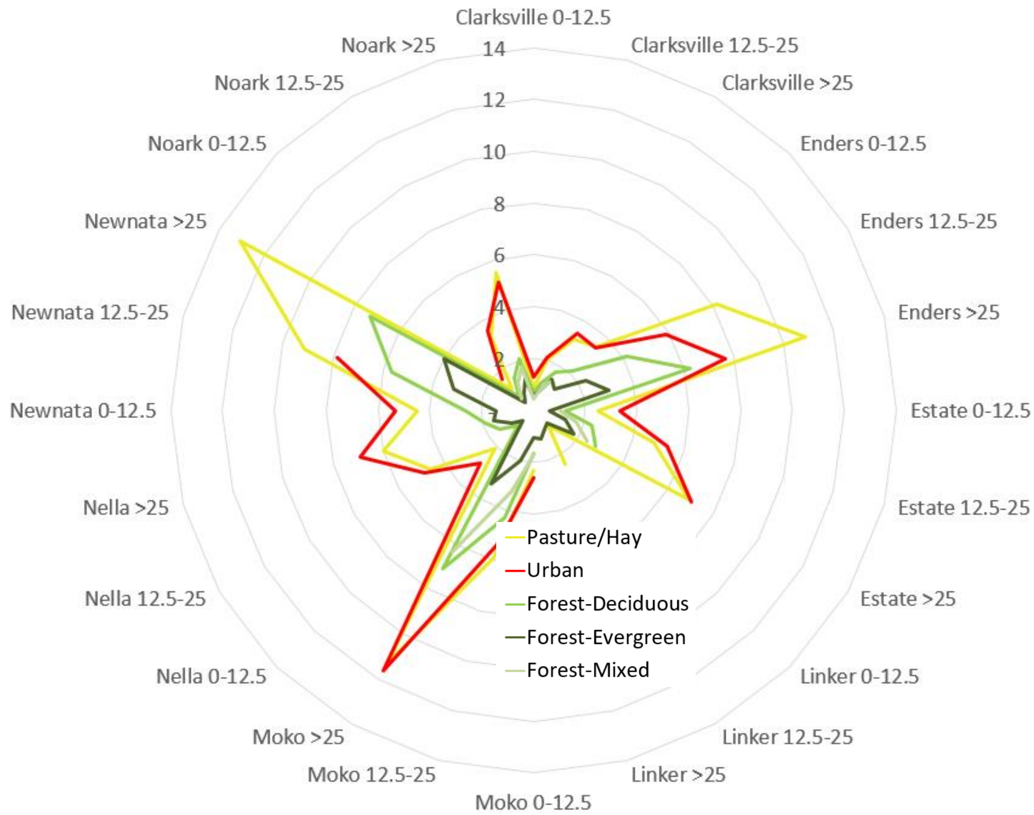

Figure 5-9 Critical Source Areas for Total Nitrogen Loss.

5.4 Priority Sub-basins

Prioritization was accomplished by grouping each HUC12 into four percentile classes (0-25%, 25-50%, 50-75%, and 75-100%) based on its respective average annual yield. HUC12 sub-watersheds in the highest class (75-100%) produced sediment or nutrient yields that were greater than at least 75% of the HUC12s in the Buffalo River Watershed. Calf, Headwaters Bear, Outlet Bear, Clabber, and Long Creek are the only HUC12 sub-watersheds listed in the highest percentile class for sediment, total phosphorus (TP), and total nitrogen (TN) yield (see Figure 5-10, Figure 5-11, and Figure 5-12, respectively). The Cove/Cecil Creek and Mill Creek (Upper) sub-watersheds rank in the highest class for sediment and TN, as well as the second highest class for TP.

The HUC12 sub-watershed percentile classes help to identify and group general areas of concern; however further review of yields at the smaller HRU scale may be warranted; yields from critical source areas may be masked due to averaging at the sub-watershed scale. HRUs that have sediment, TP, and TN yields in the 75-100 percentile class are shown in Figure 5-13. A large number of HRUs in the highest percentile class are present in the Calf, Headwaters Bear, Outlet Bear, Clabber, and Long Creek sub-watersheds, which also rank highest in the sub-watershed percentile classes. However, clusters of high sediment and nutrient yielding HRUs are also present in the Davis/Cane Branch, Left Fork Big Creek (Upper), and Headwaters Big Creek (Upper) HUC12s, which aren't included in the any of the highest priority (75-100 percentile class) sub-watersheds.

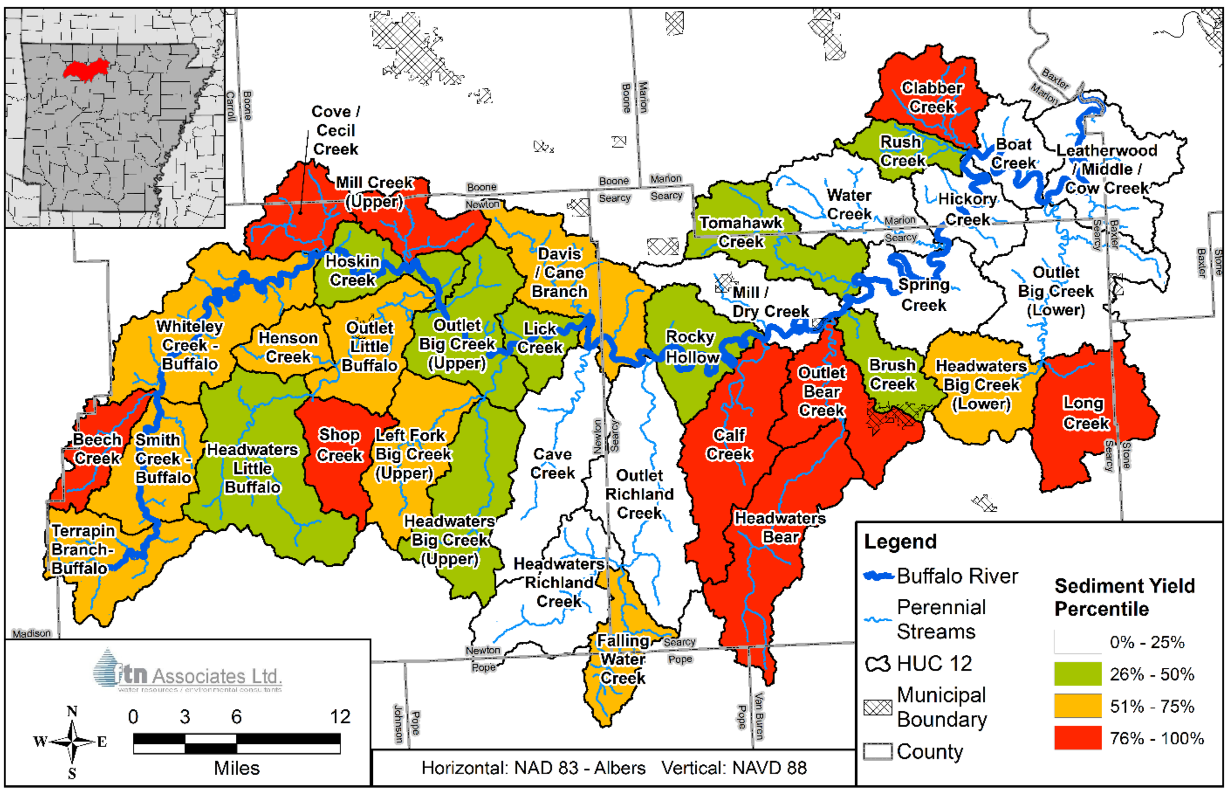

Figure 5-10 Sediment Priority Sub-watersheds.

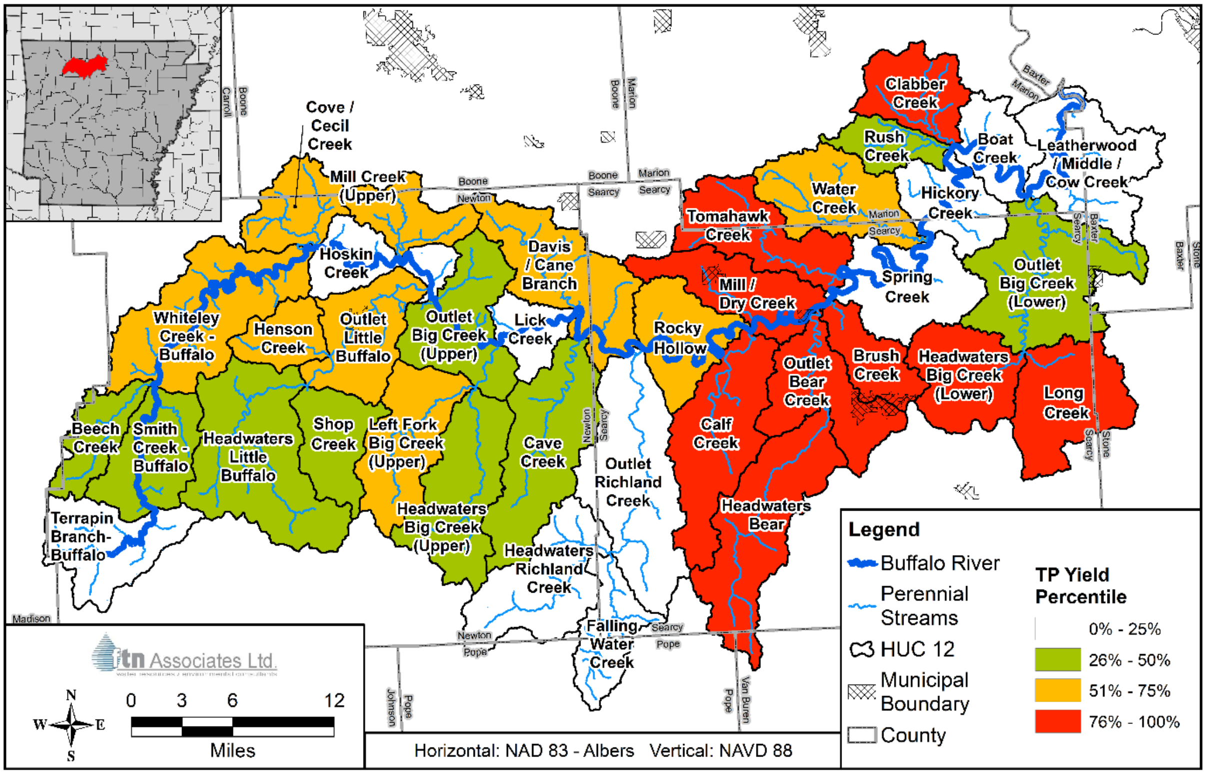

Figure 5-11 Total Phosphorus (TP) Priority Sub-watersheds.

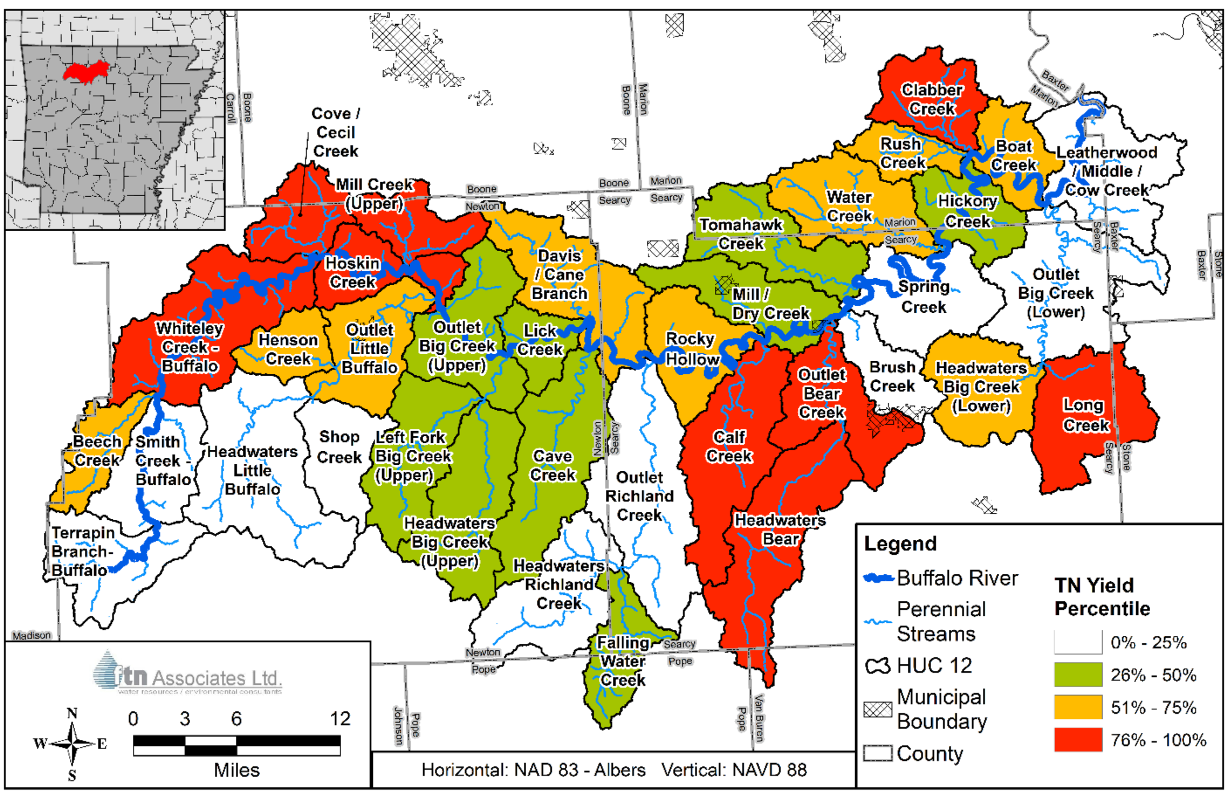

Figure 5-12 Total Nitrogen (TN) Priority Sub-watersheds.

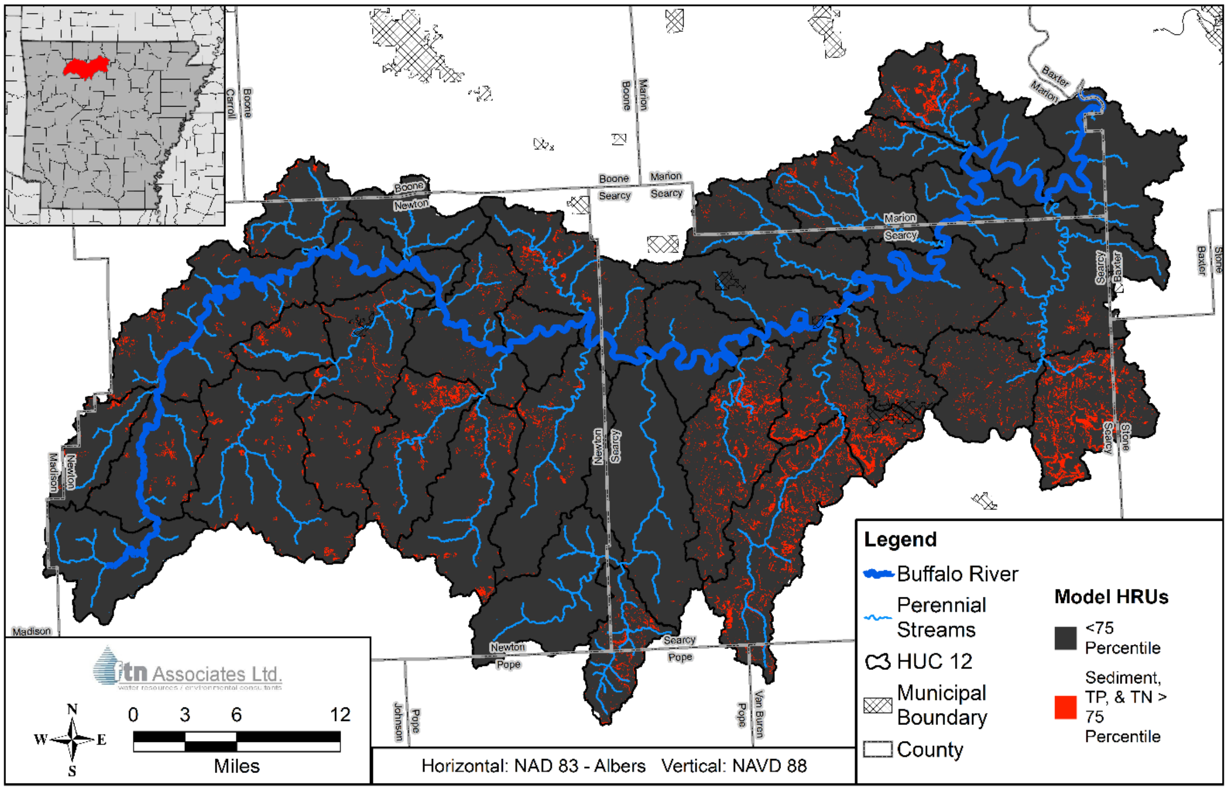

Figure 5-13 HRUs with Sediment, TP, and TN yields in the 75-100 Percentile Range.

6.0 CONCLUSIONS

The purpose of this project is to prioritize areas so investment strategies can be developed, that will have the greatest impact on water quality objectives in the Buffalo River Watershed. SWAT is well suited for this task, given that major factors affecting water quality (e.g., land use, management practices, soil properties, and topography) are thoroughly represented in the model. Developing the Buffalo River Watershed SWAT model was also necessary to gain a better understanding of factors effecting water quality throughout the watershed and in areas with little or no water quality data. Calibration and validation results suggest that the model is able to reproduce measured flows and sediment and nutrient loads at multiple locations in the watershed, and can be used to prioritize areas that have the greatest impact on water quality.

Modeled sediment, total phosphorus (TP), and total nitrogen (TN) yields for all HUC12 and modeled HRUs were used to prioritize areas in the Buffalo River Watershed. Prioritization was accomplished by grouping each HUC12 into four percentile classes (0-25%, 25-50%, 50-75%, and 75-100%) based on its respective average annual yield. HUC12 sub-watersheds in the highest class (75-100%) produced sediment or nutrient yields that were greater than at least 75% of the HUC12s in the Buffalo River Watershed. At the larger HUC12 sub-watershed scale, Calf, Headwaters Bear, Outlet Bear, Clabber, and Long Creek are the only areas listed in the highest percentile class for sediment, TP, and TN yield (Figure **6-1**). The Cove/Cecil Creek and Mill Creek (Upper) sub-watersheds rank in the highest class for sediment and TN, as well as the second highest class for TP and are also shown in Figure 6-1. At the HRU scale, there are areas throughout the watershed that rank in the highest percentile class for all three measures and would likely benefit from water quality improvement projects and funding. After reviewing model output at the HRU scale for the Calf, Headwaters Bear, Outlet Bear and Long Creek HUC12 sub-watersheds, critical sources of sediment and nutrients were also identified. Particularly, the combination of hay/pasture land use on slopes greater than 12.5% and Newnata, Moko, or Enders series soils can result in some of the largest sediment and nutrient yields in the watershed.

The results from the SWAT model also support the selection of 4 of the 6 sub-watersheds recommended for initiation of additional management practices in the Buffalo River Watershed Management Plan (BRWMP) – Mill Creek (Upper), Calf Creek, Bear Creek, and Big Creek (Lower). The Long Creek sub-watershed is within the Big Creek (Lower) drainage. These sub-watersheds all rank in the highest percentile class for at least two of the water quality parameters modeled in SWAT; the two remaining sub-watersheds listed in the BRWMP (Tomahawk and Brush Creek) are also listed in the highest percentile class for one water quality parameter (Figure 6-1). One notable difference between the two studies is the omission of the Clabber Creek sub-watershed in the BRWMP, even though sediment, TP, and TN yields from the SWAT model are all in the highest percentile class. However, the SWAT analyses considered only average annual sediment, TN, and TP loads as the sub-watershed evaluation criteria, while the BRWMP considered other criteria, including fish and benthic invertebrate index scores, bacterial concentration, increased trends in water quality constituents, and the NRCS Resource Assessment concerns when developing a list of recommended sub-watersheds for initial non-point source pollution management.

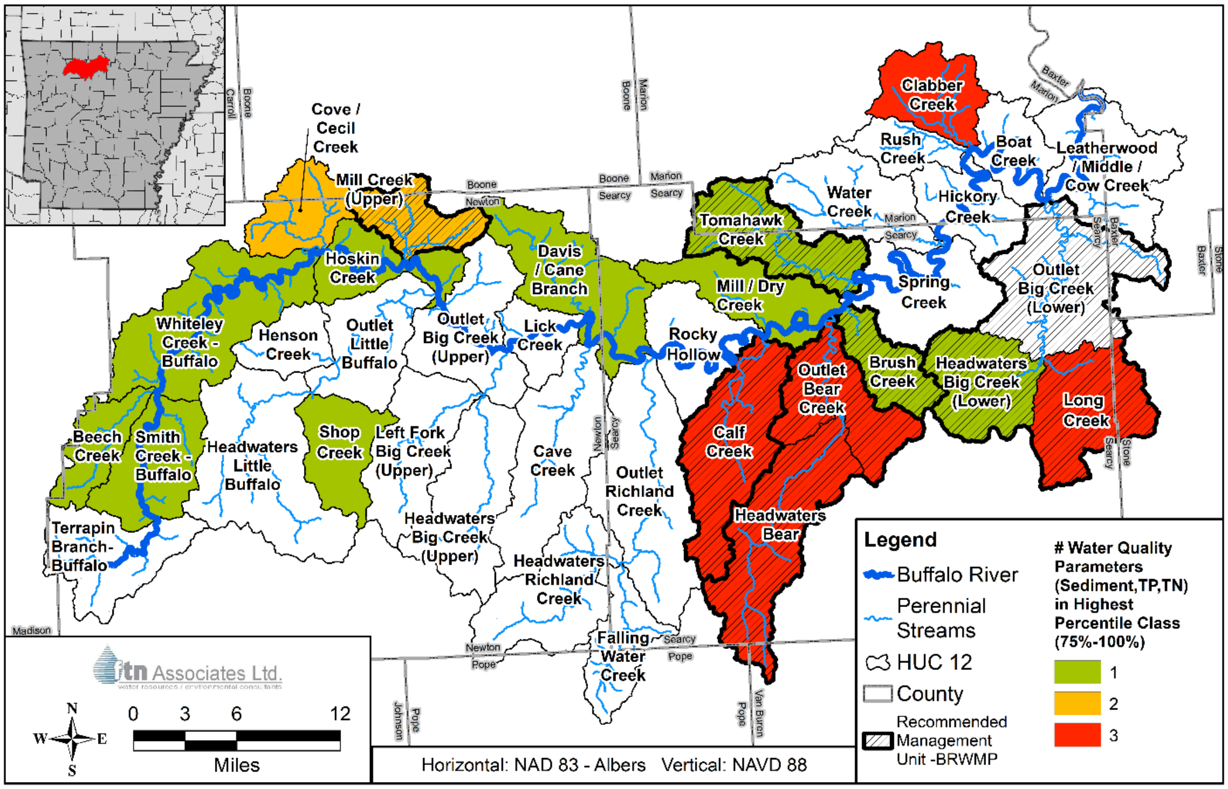

Figure 6-1 HUC12 Sub-watershed Highest Percentile Class (75-100%) Count. The dark lines outline the drainage areas recommended for initial management in the BRWMP. Some drainage areas (e.g., Big Creek Lower) include more than one HUC12.

7.0 REFERENCES

Abbaspour, K. C., Vejdani, M., & Haghighat, S. (2007). SWAT-CUP calibration and uncertainty programs for SWAT. In *MODSIM* 2007 International Congress on Modelling and Simulation, Modelling and Simulation Society of Australia and New Zealand.

Amin, M. M., Veith, T. L., Collick, A. S., Karsten, H. D., & Buda, A. R. (2017). Simulating hydrological and nonpoint source pollution processes in a karst watershed: A variable source area hydrology model evaluation. Agricultural Water Management, 180, 212-223.

Arkansas Department of Environmental Quality. (2017). Water Quality Monitoring Data. Retrieved April 27, 2017 from, https://www.adeq.state.ar.us/techsvs/env_multi_lab/water_quality_station.aspx.

Arkansas Geological Survey (2017). Ozark Plateaus Physiographic Region. Retrieved November 14, 2017 from, http://www.geology.ar.gov/education/ozark_plateaus.htm.

Arnold, J.G., Srinivasan, R., Muttiah, R.S., & Williams, J.R. (1998). Large area hydrologic modeling and assessment—Part 1: Model development. Journal of the American Water Resources Association, 34(1), 73-89.

Camberato J. & Nielsen, R.L. (2017). Soil Sampling to Assess Current Soil N Availability. Purdue University. June 2017. Retrieved December 07, 2017, from https://www.agry.purdue.edu/ext/corn/news/timeless/AssessAvailableN.html.

Chow, V. T., Maidment, D. R., & Mays, L.W. (1988). Applied Hydrology. International edition, MacGraw-Hill, Inc, 59.

Cleveland, W. S. (1979). Robust locally weighted regression and smoothing scatterplots. Journal of the American statistical association, 74(368), 829-836.

Cohn, T. A., Caulder, D. L., Gilroy, E. J., Zynjuk, L. D., & Summers, R. M. (1992). The validity of a simple statistical model for estimating fluvial constituent loads: An empirical study involving nutrient loads entering Chesapeake Bay. Water Resources Research, 28(9), 2353-2363.

Cope, J.T., Evans, C.E., and Williams H.C. (1981). Soil test fertility recommendations for Alabama crops. Alabama Agric. Station Circular No. 251.

Daly, C., Halbleib, M., Smith, J. I., Gibson, W. P., Doggett, M. K., Taylor, G. H., Curtis, J. & Pasteris, P. P. (2008). Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. International Journal of Climatology, 28(15), 2031-2064.

Dodds, WK. (1997). Distribution of runoff and rivers related to vegetative characteristics, latitude, and slope: a global perspective. Journal of the North American Benthological Society 16: 162–168.

Dressing, S. A., Meals, D. W., Harcum, J. B., Spooner, J., Stribling, J. B., Richards, R. P., Millard, C.J., Lanberg, S.A. & O'Donnell, J. G. (2016). Monitoring and Evaluating Nonpoint Source Watershed Projects. EPA 841-R-16-010. US Environmental Protection Agency, Washington, DC. Accessed December 20, 2016. https://www. epa. gov/nps/monitoring-and-evaluating-nonpoint-source-watershed-projects.

Evett, S.R., & Dutt, G.R. (1985). Length and slope effects on runoff from sodium dispersed, compacted earth microcatchments. Soil Science Society of America Journal 49: 734–738.

Federal Interagency Sedimentation Project. (2006). Technical Committee Memorandum 2007.01. Collection and Use of Total Suspended Solids (TSS) Data. October 25, 2006.

Fowlkes, D.H., McCright, R.T., & Lowrance, J.S. (1988). Soil Survey of Newton County Arkansas. U.S. Department of Agriculture Soil Conservation Service.

FTN Associates. (2018). Buffalo River Watershed-Based Management Plan. Prepared for the Arkansas Natural Resources Commission.

Galloway, J. M., & Green, W. R. (2004a). Hydrologic and Water-quality Characteristics for Bear Creek Near Silver Hill, Arkansas and Selected Buffalo River Sites, 1999-2004. US Department of the Interior, US Geological Survey.

Galloway, J. M., & Green, W. R. (2004b). Hydrologic and Water-quality Characteristics for Calf Creek Near Silver Hill, Arkansas and Selected Buffalo River Sites, 2001-2002. US Department of the Interior, US Geological Survey.

Glysson, G. D., Gray, J. R., & Conge, L. M. (2000). Adjustment of total suspended solids data for use in sediment studies. American Society of Civil Engineers Joint Conference on Water Resource Engineering and Water Resources Planning and Management. Minneapolis, MN.

Gowda, P. H., Mulla, D. J., Nangia, V., & Ale, S. (2013). Scale effects of STATSGO and SSURGO on flow and water quality predictions. Journal of Water Resource and Protection, 5(03), 266.

Govender, M. & C. S. Everson. (2005). Modelling streamflow from two small South African experimental catchments using the SWAT model. Hydrol. Proc. 19(3): 683-692.

Gray, J. R., Glysson, G. D., Turcios, L. M., & Schwarz, G. E. (2000). Comparability of suspended-sediment concentration and total suspended solids data. US Geological Survey Water-Resources Investigations Report 00-4191, 20.

Gupta, H. V., Sorooshian, S., & Yapo, P. O. (1999). Status of automatic calibration for hydrologic models: Comparison with multilevel expert calibration. Journal of Hydrologic Engineering, 4(2), 135-143.

Haggard, B., Moore, P., & Brye, K. (2005). Effect of Slope on Runoff from a Small Variable-Slope Box. Journal of Environmental hydrology, 13.

Haggard, B. E., Moore Jr, P. A., Chaubey, I., & Stanley, E. H. (2003). Nitrogen and phosphorus concentrations and export from an Ozark Plateau catchment in the United States. Biosystems Engineering, 86(1), 75-85.

Helsel, D.R. (2005). Nondetects and Data Analysis. New York: John Wiley & Sons.

Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., & Megown, K. (2015). Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354.

Huang, M., Gallichand, J., Wang, Z., & Goulet, M. (2006). A modification to the Soil Conservation Service curve number method for steep slopes in the Loess Plateau of China. Hydrological processes, 20(3), 579-589.

Hudson, M.R. (1998). Geologic map of parts of the Jasper, Hasty, Ponca, Gaither, and Harrison quadrangles in and adjacent to Buffalo National River, northwestern Arkansas: U.S. Geological Survey Open-File Report 98-116, 1:24,000 scale.

Hudson, M.R., Turner, K.J., & Bitting C. (2011). Geologic Framework of Karst Features in Western Buffalo National River, Northern Arkansas. U.S. Geological Survey Karst Interest Group Proceedings, Fayetteville, Arkansas, April 26–29, 2011.

Jerabkova, L., Prescott, C. E., & Kishchuk, B. E. (2006). Nitrogen availability in soil and forest floor of contrasting types of boreal mixedwood forests. Canadian Journal of Forest Research, 36(1), 112-122.

Krysanova, V., & Srinivasan, R. (2015). Assessment of climate and land use change impacts with SWAT. Regional Environmental Change. Reg Environ Change 15: 431. DOI: 10.1007/s10113-014-0742-5.

Laurent, G.D., Lowrance, S., & McCright, R.T. (1988). Soil Survey of Searcy County, Arkansas. U.S. Department of Agriculture Soil Conservation Service.

McFarland, J.D. (2004). Stratigraphic Summary of Arkansas. Arkansas Geological Survey. IC-36.

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE, 50(3), 885-900.

Mott, D.N. & Laurans, J. (2004). Water Resources Management Plan – Buffalo National River Arkansas. U.S. Dept. of the Interior, National Park Service.

Mukundan, R., Radcliffe, D. E., & Risse, L. M. (2010). Spatial resolution of soil data and channel erosion effects on SWAT model predictions of flow and sediment. Journal of Soil and Water Conservation, 65(2), 92-104.

National Oceanic and Atmospheric Administration. (2017). Climate Data Online. Retrieved April 24, 2017 from, https://www.ncdc.noaa.gov/cdo-web/.

Petersen, J.C., Haggard, B.E., and Green, W.R. (2002) Hydrologic characteristics of Bear Creek near Silver Hill and Buffalo River near St. Joe, Arkansas, 1999- 2000. U.S. Geological Survey Water-Resources Investigations Report 02-4024.

PRISM Climate Group. (2017). Oregon State University - PRISM Gridded Climate Data. Retrieved April 21, 2017 from, http://www.prism.oregonstate.edu/.

Radcliffe, D. E. & Mukundan, R. (2017). PRISM vs. CFSR precipitation data effects on calibration and validation of SWAT models. JAWRA Journal of the American Water Resources Association, 53(1), 89-100. DOI: 10.1111/1752-1688.12484.

Runkel, R. L. (2013). Revisions to LOADEST, April 2013. Retrieved January 2018, from https://water.usgs.gov/software/loadest/.

Saha, S., Moorthi, S., Pan, H. L., Wu, X., Wang, J., Nadiga, S., ... & Liu, H. (2010). The NCEP Climate Forecast System Reanalysis. Bulletin of the American Meteorological Society, 91(8), 1015-1057.

Scott, H.D., & Hofer, K.R. (1995). Spatial and Temporal Analysis of the Morphological and Land Use Characteristics of the Buffalo River Watershed. Arkansas Water Resources Center. Publication No. 170.

Sharpley, A. N., Jones, C. A., Gray, C., & Cole, C. V. (1984). A simplified soil and plant phosphorus model: II. Prediction of labile, organic, and sorbed phosphorus. Soil Science Society of America Journal, 48(4), 805-809.

Sharpley A.N. and Williams J.R. (1990). EPIC—Erosion/Productivity Impact Calculator: 1. Model Documentation. US Department of Agriculture Technical Bulletin No. 1768.

Singh, H. V., Kalin, L., & Srivastava, P. (2011). Effect of soil data resolution on identification of critical source areas of sediment. Journal of Hydrologic Engineering, 16(3), 253-262.

Singh, G., Goyne, K. W., & Kabrick, J. M. (2015). Determinants of total and available phosphorus in forested Alfisols and Ultisols of the Ozark Highlands, USA. Geoderma Regional, 5, 117-126.

Snyder, J. P. (1987). Map projections--A working manual. US Geological Survey Professional Paper 1395.

Soto, L. (2014). Summary of previous dye tracing reports in the area of the Buffalo National River, Arkansas: U. S. National Park Service.

Stenback, G. A., Crumpton, W. G., Schilling, K. E., & Helmers, M. J. (2011). Rating curve estimation of nutrient loads in Iowa rivers. Journal of Hydrology, 396(1), 158-169.

Texas A&M AgriLife Research. (2017a). Soil and Water Assessment Tool - SSURGO and STATSGO Soil Databases. Retrieved April 10, 2017 from, http://swat.tamu.edu/software/arcswat/.

Texas A&M AgriLife Research. (2017b). Hydrologic and Water Quality System (HAWQS). https://epahawqs.tamu.edu/.

Texas A&M AgriLife Research. (2017c). Global Weather Data for SWAT. https://globalweather.tamu.edu/.

U.S. Department of Agriculture. (2017). Digital Soils Data Fact Sheet – NRCS Illinois. www.nrcs.usda.gov/wps/portal/nrcs/detail/il/soils/surveys/?cid=nrcs141p2_030690.

U.S. EPA. (2000). Guidance for Data Quality Assessment. Practical Methods for Data Analysis. EPA QA/G-9.

U.S. EPA. (2009). Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance. EPA 530/R-09-007.

U.S. EPA. (2017). United States Environmental Protection Agency – Enforcement and Compliance History Online (ECHO) Facility Search. Retrieved April 13, 2017 from, https://echo.epa.gov/facilities/facility-search?mediaSelected=cwa.

U.S. Geological Survey. (1980). Geographic Names Information System (GNIS). Retrieved November 10, 2017 from, https://geonames.usgs.gov.

U.S. Geological Survey. (2017a). National Hydrography Dataset (NHD) Best Resolution. Retrieved April 7, 2017 from, ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Hydrography/NHD/HU8/HighResolution/GDB/NHD_H_11010005_GDB.zip.

U.S. Geological Survey. (2017b). National Elevation Dataset (NED) 1/3 arc-second. Retrieved April 7, 2017 from, https://viewer.nationalmap.gov/basic/.

U.S. Geological Survey. (2017c). National Land Cover Database (NLCD) – 2011, 2006, and 2001. Retrieved April 7, 2017 from, https://viewer.nationalmap.gov/basic/.

U.S. Geological Survey. (2017d). National Water Information System. Retrieved April 21, 2017 from, https://waterdata.usgs.gov/ar/nwis/nwis.

Vadas, P. A., & White, M. J. (2010). Validating soil phosphorus routines in the SWAT model. Transactions of the ASABE, 53(5), 1469-1476.

Van Liew, M. W., J. G. Arnold, & D. D. Bosch. (2005). Problems and Potential of Autocalibrating a Hydrologic Model. Trans. ASAE 48(3): 1025-1040.

Wang, X. & A. M. Melesse. (2005.) Evaluation of the SWAT Model’s Snowmelt Hydrology in a Northwestern Minnesota Watershed. Trans. ASAE 48(4): 1359-1376.

APPENDIX A

Water Quality Data

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07055646	10/21/1998	10:45	SSC		8		78.0
USGS	07055646	12/8/1998	9:00	SSC		8		142.0
USGS	07055646	1/26/1999	10:30	SSC		12		118.0
USGS	07055646	3/23/1999	16:10	SSC		9		132.0
USGS	07055646	6/8/1999	12:10	SSC		12		10.0
USGS	07055646	9/7/1999	11:00	SSC		18		0.1
USGS	07055646	10/21/1999	12:40	SSC		15		0.1
USGS	07055646	12/21/1999	14:35	SSC		8		27.0
USGS	07055646	2/22/2000	12:55	SSC		7		66.0
USGS	07055646	4/11/2000	10:45	SSC		11		77.0
USGS	07055646	6/6/2000	12:10	SSC		9		38.0
USGS	07055646	8/4/2000	8:30	SSC		11		2.4
USGS	07055646	10/12/2000	10:20	SSC		24		0.1
USGS	07055646	12/12/2000	11:15	SSC		6		21.0
USGS	07055646	1/10/2001	10:00	SSC		6		63.0
USGS	07055646	2/7/2001	13:15	SSC		6		67.0
USGS	07055646	3/7/2001	10:45	SSC		6		69.0
USGS	07055646	4/17/2001	11:35	SSC		6		86.0
USGS	07055646	5/23/2001	15:15	SSC		9		45.0
USGS	07055646	6/26/2001	10:00	SSC		11		12.0
USGS	07055646	7/17/2001	10:00	SSC		9		8.7
USGS	07055646	8/16/2001	13:20	SSC		14		9.1
USGS	07055646	9/11/2001	11:45	SSC		10		14.0
USGS	07055646	11/20/2001	11:30	SSC		11		7.4
USGS	07055646	12/12/2001	12:15	SSC		6		92.6
USGS	07055646	1/9/2002	11:25	SSC		6		14.0
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USGS	07055646	3/12/2002	12:45	SSC		11		575.0
USGS	07055646	5/8/2002	10:50	SSC		10		38.1
USGS	07055646	7/9/2002	10:50	SSC		12		8.1
USGS	07055646	9/11/2002	7:55	SSC		3		2.8
USGS	07055646	11/26/2002	12:15	SSC		1		1.6
USGS	07055646	12/10/2002	11:50	SSC		1		1.9
USGS	07055646	1/14/2003	15:00	SSC		1		5.5
USGS	07055646	2/19/2003	12:15	SSC		4		55.5
USGS	07055646	3/11/2003	11:30	SSC		1		31.8
USGS	07055646	5/20/2003	13:00	SSC		141		1,430.0
USGS	07055646	7/8/2003	13:00	SSC		9		9.1
USGS	07055646	9/3/2003	12:30	SSC		9		1.0
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USGS	07055646	1/14/2004	12:30	SSC		7		29.3
USGS	07055646	2/19/2004	10:30	SSC		6		106.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07055646	3/30/2004	12:15	SSC		13		328.0
USGS	07055646	5/12/2004	13:15	SSC		8		41.8
USGS	07055646	7/7/2004	12:00	SSC		10		44.0
USGS	07055646	8/25/2004	15:15	SSC		10		3.0
USGS	07055646	11/4/2009	13:00	SSC		3		147.0
USGS	07055646	12/21/2009	11:30	SSC		2		30.6
USGS	07055646	2/18/2010	11:15	SSC		1		93.5
USGS	07055646	4/13/2010	11:00	SSC		2		67.8
USGS	07055646	6/14/2010	14:00	SSC		5		26.6
USGS	07055646	8/19/2010	10:15	SSC		2		1.5
USGS	07055646	10/31/2012	12:00	SSC		4		2.3
USGS	07055646	12/12/2012	13:40	SSC		1		5.0
USGS	07055646	2/8/2013	11:00	SSC		1		44.2
USGS	07055646	4/9/2013	12:45	SSC		4		101.0
USGS	07055646	6/11/2013	12:25	SSC		13		46.1
USGS	07055646	8/15/2013	13:45	SSC		1		169.0
USGS	07055646	2/19/2014	11:00	SSC		2		51.7
USGS	07055646	4/9/2014	10:30	SSC		6		303.0
USGS	07055646	6/16/2014	10:15	SSC		6		39.3
USGS	07055646	8/18/2014	12:15	SSC		9		22.7
USGS	07055646	10/15/2014	13:30	SSC		10		129.0
USGS	07055646	12/19/2014	12:30	SSC		7		180.0
USGS	07055646	4/6/2015	10:45	SSC		3		108.0
USGS	07055646	6/26/2015	12:20	SSC	<	0.5	0.250	77.5
USGS	07055646	8/19/2015	13:40	SSC		1		2.3
USGS	07055646	4/1/2016	9:00	SSC		5		157.0
USGS	07055646	10/21/1998	10:45	TN	<	0.15	0.095	78.0
USGS	07055646	12/8/1998	9:00	TN	<	0.18	0.097	142.0
USGS	07055646	1/26/1999	10:30	TN	E	0.12		118.0
USGS	07055646	3/23/1999	16:10	TN	<	0.16	0.095	132.0
USGS	07055646	6/8/1999	12:10	TN	<	0.13	0.091	10.0
USGS	07055646	9/7/1999	11:00	TN	<	0.15	0.095	0.1
USGS	07055646	10/21/1999	12:40	TN	<	0.1	0.076	0.1
USGS	07055646	12/21/1999	14:35	TN	E	0.17		27.0
USGS	07055646	2/22/2000	12:55	TN	<	0.1	0.076	66.0
USGS	07055646	4/11/2000	10:45	TN	<	0.15	0.095	77.0
USGS	07055646	6/6/2000	12:10	TN	<	0.14	0.092	38.0
USGS	07055646	8/4/2000	8:30	TN	<	0.11	0.083	2.4
USGS	07055646	10/12/2000	10:20	TN	E	0.12		0.1
USGS	07055646	12/12/2000	11:15	TN	<	0.13	0.091	21.0
USGS	07055646	1/10/2001	10:00	TN	<	0.18	0.097	63.0
USGS	07055646	2/7/2001	13:15	TN	E	0.18		67.0
USGS	07055646	3/7/2001	10:45	TN	E	0.11		69.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07055646	4/17/2001	11:35	TN	<	0.13	0.091	86.0
USGS	07055646	5/23/2001	15:15	TN	<	0.11	0.083	45.0
USGS	07055646	6/26/2001	10:00	TN	<	0.1	0.076	12.0
USGS	07055646	7/17/2001	10:00	TN	E	0.14		8.7
USGS	07055646	8/16/2001	13:20	TN	E	0.1		9.1
USGS	07055646	9/11/2001	11:45	TN		0.3		14.0
USGS	07055646	11/20/2001	11:30	TN	<	0.19	0.099	7.4
USGS	07055646	12/12/2001	12:15	TN	<	0.15	0.095	92.6
USGS	07055646	1/9/2002	11:25	TN	<	0.13	0.091	14.0
USGS	07055646	2/14/2002	9:30	TN	<	0.13	0.091	55.2
USGS	07055646	3/12/2002	12:45	TN	E	0.14		575.0
USGS	07055646	5/8/2002	10:50	TN	<	0.14	0.092	38.1
USGS	07055646	7/9/2002	10:50	TN	E	0.1		8.1
USGS	07055646	9/11/2002	7:55	TN	E	0.12		2.8
USGS	07055646	11/26/2002	12:15	TN	<	0.15	0.095	1.6
USGS	07055646	12/10/2002	11:50	TN	E	0.14		1.9
USGS	07055646	1/14/2003	15:00	TN	<	0.16	0.095	5.5
USGS	07055646	2/19/2003	12:15	TN	E	0.1		55.5
USGS	07055646	3/11/2003	11:30	TN	<	0.16	0.095	31.8
USGS	07055646	5/20/2003	13:00	TN	E	0.71		1,430.0
USGS	07055646	7/8/2003	13:00	TN	<	0.14	0.092	9.1
USGS	07055646	9/3/2003	12:30	TN	<	0.13	0.091	1.0
USGS	07055646	11/4/2009	13:00	TN	<	0.53	0.099	147.0
USGS	07055646	12/21/2009	11:30	TN	<	0.13	0.091	30.6
USGS	07055646	2/18/2010	11:15	TN	<	0.2	0.098	93.5
USGS	07055646	4/13/2010	11:00	TN	<	0.33	0.099	67.8
USGS	07055646	6/14/2010	14:00	TN	<	0.13	0.091	26.6
USGS	07055646	10/31/2012	12:00	TN	<	0.14	0.092	2.3
USGS	07055646	12/12/2012	13:40	TN	<	0.15	0.095	5.0
USGS	07055646	2/8/2013	11:00	TN	<	0.19	0.099	44.2
USGS	07055646	4/9/2013	12:45	TN	<	0.11	0.083	101.0
USGS	07055646	6/11/2013	12:25	TN	<	0.07	0.075	46.1
USGS	07055646	8/15/2013	13:45	TN		0.18		169.0
USGS	07055646	10/29/2013	11:00	TN	<	0.08	0.074	3.2
USGS	07055646	1/13/2014	9:30	TN	<	0.22	0.098	222.0
USGS	07055646	2/19/2014	11:00	TN	<	0.08	0.074	51.7
USGS	07055646	4/9/2014	10:30	TN	<	0.09	0.074	303.0
USGS	07055646	8/18/2014	12:15	TN	<	0.15	0.095	22.7
USGS	07055646	10/15/2014	13:30	TN		0.18		129.0
USGS	07055646	12/19/2014	12:30	TN		0.11		180.0
USGS	07055646	2/2/2015	11:50	TN	<	0.1	0.076	34.3
USGS	07055646	4/6/2015	10:45	TN	<	0.12	0.087	108.0
USGS	07055646	6/26/2015	12:20	TN	<	0.09	0.074	77.5

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07055646	8/19/2015	13:40	TN		0.12		2.3
USGS	07055646	4/1/2016	9:00	TN	<	0.11	0.083	157.0
USGS	07055646	10/21/1998	10:45	TP	<	0.05	0.006	78.0
USGS	07055646	12/8/1998	9:00	TP	<	0.05	0.006	142.0
USGS	07055646	1/26/1999	10:30	TP		0.008		118.0
USGS	07055646	3/23/1999	16:10	TP		0.004		132.0
USGS	07055646	6/8/1999	12:10	TP		0.005		10.0
USGS	07055646	9/7/1999	11:00	TP		0.004		0.1
USGS	07055646	10/21/1999	12:40	TP	E	0.004		0.1
USGS	07055646	12/21/1999	14:35	TP		0.035	0.035	27.0
USGS	07055646	2/22/2000	12:55	TP	<	0.008	0.004	66.0
USGS	07055646	4/11/2000	10:45	TP	E	0.004		77.0
USGS	07055646	6/6/2000	12:10	TP	<	0.008	0.004	38.0
USGS	07055646	8/4/2000	8:30	TP	E	0.004		2.4
USGS	07055646	10/12/2000	10:20	TP	E	0.003		0.1
USGS	07055646	12/12/2000	11:15	TP	<	0.004	0.002	21.0
USGS	07055646	1/10/2001	10:00	TP	<	0.004	0.002	63.0
USGS	07055646	2/7/2001	13:15	TP	E	0.003		67.0
USGS	07055646	3/7/2001	10:45	TP	E	0.003		69.0
USGS	07055646	4/17/2001	11:35	TP		0.005		86.0
USGS	07055646	5/23/2001	15:15	TP	E	0.002		45.0
USGS	07055646	6/26/2001	10:00	TP	E	0.003		12.0
USGS	07055646	7/17/2001	10:00	TP	<	0.004	0.002	8.7
USGS	07055646	8/16/2001	13:20	TP		0.004		9.1
USGS	07055646	9/11/2001	11:45	TP		0.006		14.0
USGS	07055646	11/20/2001	11:30	TP	E	0.002		7.4
USGS	07055646	12/12/2001	12:15	TP	E	0.004		92.6
USGS	07055646	1/9/2002	11:25	TP	E	0.003		14.0
USGS	07055646	2/14/2002	9:30	TP		0.004		55.2
USGS	07055646	3/12/2002	12:45	TP		0.011		575.0
USGS	07055646	5/8/2002	10:50	TP		0.006		38.1
USGS	07055646	7/9/2002	10:50	TP		0.004		8.1
USGS	07055646	9/11/2002	7:55	TP		0.005		2.8
USGS	07055646	11/26/2002	12:15	TP		0.005		1.6
USGS	07055646	12/10/2002	11:50	TP		0.005		1.9
USGS	07055646	1/14/2003	15:00	TP		0.005		5.5
USGS	07055646	2/19/2003	12:15	TP		0.012		55.5
USGS	07055646	3/11/2003	11:30	TP	E	0.004		31.8
USGS	07055646	5/20/2003	13:00	TP		0.164		1,430.0
USGS	07055646	7/8/2003	13:00	TP		0.005		9.1
USGS	07055646	9/3/2003	12:30	TP		0.007		1.0
USGS	07055646	11/12/2003	13:00	TP	E	0.003		19.6
USGS	07055646	12/15/2003	13:15	TP	E	0.004		53.1

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07055646	1/14/2004	12:30	TP	E	0.004		29.3
USGS	07055646	2/19/2004	10:30	TP	E	0.004		106.0
USGS	07055646	3/30/2004	12:15	TP		0.013		328.0
USGS	07055646	5/12/2004	13:15	TP		0.005		41.8
USGS	07055646	7/7/2004	12:00	TP	<	0.004	0.002	44.0
USGS	07055646	8/25/2004	15:15	TP		0.004		3.0
USGS	07055646	11/4/2009	13:00	TP		0.008		147.0
USGS	07055646	12/21/2009	11:30	TP	E	0.005		30.6
USGS	07055646	2/18/2010	11:15	TP	<	0.008	0.004	93.5
USGS	07055646	4/13/2010	11:00	TP	E	0.006		67.8
USGS	07055646	6/14/2010	14:00	TP		0.015		26.6
USGS	07055646	8/19/2010	10:15	TP	<	0.008	0.004	1.5
USGS	07055646	10/31/2012	12:00	TP		0.012		2.3
USGS	07055646	12/12/2012	13:40	TP	<	0.004	0.002	5.0
USGS	07055646	2/8/2013	11:00	TP	<	0.004	0.002	44.2
USGS	07055646	4/9/2013	12:45	TP		0.004		101.0
USGS	07055646	6/11/2013	12:25	TP	<	0.004	0.002	46.1
USGS	07055646	8/15/2013	13:45	TP		0.01		169.0
USGS	07055646	10/29/2013	11:00	TP		0.008		3.2
USGS	07055646	1/13/2014	9:30	TP		0.013		222.0
USGS	07055646	2/19/2014	11:00	TP		0.005		51.7
USGS	07055646	4/9/2014	10:30	TP		0.009		303.0
USGS	07055646	8/18/2014	12:15	TP		0.006		22.7
USGS	07055646	10/15/2014	13:30	TP		0.02		129.0
USGS	07055646	12/19/2014	12:30	TP		0.018		180.0
USGS	07055646	2/2/2015	11:50	TP		0.005		34.3
USGS	07055646	4/6/2015	10:45	TP		0.007		108.0
USGS	07055646	6/26/2015	12:20	TP		0.006		77.5
USGS	07055646	8/19/2015	13:40	TP		0.009		2.3
USGS	07055646	4/1/2016	9:00	TP	<	0.02	0.006	157.0
BCRET	07055790	5/1/2014	9:58	TN		0.11		53.6
BCRET	07055790	5/8/2014	1:13	TN		0.55		22.2
BCRET	07055790	5/9/2014	9:52	TN		0.17		43.6
BCRET	07055790	5/13/2014	9:22	TN		0.38		396.0
BCRET	07055790	5/19/2014	1:30	TN		0.14		77.3
BCRET	07055790	5/28/2014	9:16	TN		0.21		23.3
BCRET	07055790	6/5/2014	1:16	TN		0.28		15.2
BCRET	07055790	6/9/2014	8:51	TN		0.26		39.9
BCRET	07055790	6/19/2014	8:55	TN		0.32		9.7
BCRET	07055790	6/24/2014	9:27	TN		0.35		66.1
BCRET	07055790	6/27/2014	12:17	TN		0.42		36.8
BCRET	07055790	7/1/2014	9:30	TN		0.4		15.8
BCRET	07055790	7/7/2014	9:12	TN		0.4		8.7

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
BCRET	07055790	7/15/2014	11:32	TN		0.4		113.0
BCRET	07055790	7/18/2014	10:45	TN		0.3		35.9
BCRET	07055790	7/23/2014	10:09	TN		0.31		105.0
BCRET	07055790	7/25/2014	9:55	TN		0.29		95.3
BCRET	07055790	7/31/2014	9:32	TN		0.3		29.9
BCRET	07055790	8/12/2014	9:54	TN		0.23		15.6
BCRET	07055790	8/20/2014	10:14	TN		0.37		7.8
BCRET	07055790	8/26/2014	11:14	TN		0.46		4.5
BCRET	07055790	9/3/2014	9:39	TN		0.6		3.3
BCRET	07055790	9/11/2014	11:30	TN		0.52		3.5
BCRET	07055790	9/18/2014	9:54	TN		0.61		3.8
BCRET	07055790	9/23/2014	10:59	TN		0.53		3.0
BCRET	07055790	9/30/2014	9:57	TN		0.57		3.0
BCRET	07055790	10/8/2014	9:31	TN		0.57		2.6
BCRET	07055790	10/14/2014	9:21	TN		1.03		120.0
BCRET	07055790	10/14/2014	9:31	TN		0.51		120.0
BCRET	07055790	10/22/2014	10:09	TN		0.47		9.7
BCRET	07055790	10/30/2014	11:47	TN		0.42		4.4
BCRET	07055790	11/5/2014	9:10	TN		0.48		7.3
BCRET	07055790	11/12/2014	9:27	TN		0.31		6.7
BCRET	07055790	11/24/2014	9:23	TN		0.38		3.8
BCRET	07055790	12/4/2014	10:35	TN		0.33		4.9
BCRET	07055790	12/9/2014	9:38	TN		0.23		13.4
BCRET	07055790	12/15/2014	12:09	TN		0.33		30.0
BCRET	07055790	12/22/2014	11:00	TN		0.24		34.0
BCRET	07055790	1/8/2015	10:53	TN		0.39		55.2
BCRET	07055790	1/14/2015	11:15	TN		0.34		27.5
BCRET	07055790	1/21/2015	11:05	TN		0.3		16.7
BCRET	07055790	1/29/2015	1:20	TN		0.27		10.6
BCRET	07055790	2/3/2015	10:50	TN		0.09		12.8
BCRET	07055790	2/10/2015	10:25	TN		0.23		10.4
BCRET	07055790	2/26/2015	10:34	TN		0.25		44.4
BCRET	07055790	3/3/2015	10:55	TN		0.23		45.3
BCRET	07055790	3/11/2015	11:20	TN		0.27		183.0
BCRET	07055790	3/19/2015	10:47	TN		0.35		140.0
BCRET	07055790	3/25/2015	11:30	TN		0.29		88.0
BCRET	07055790	3/26/2015	1:35	TN		0.41		531.0
BCRET	07055790	4/2/2015	12:30	TN		0.22		90.2
BCRET	07055790	4/9/2015	12:50	TN		0.25		45.6
BCRET	07055790	4/15/2015	12:40	TN		0.26		224.0
BCRET	07055790	4/23/2015	12:15	TN		0.25		89.0
BCRET	07055790	4/29/2015	12:13	TN		0.982		37.8
BCRET	07055790	5/4/2015		TN		0.23		22.2

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
BCRET	07055790	5/7/2015	12:05	TN		0.36		74.7
BCRET	07055790	5/8/2015	1:25	TN		1.2		183.0
BCRET	07055790	5/11/2015	12:47	TN		1.12		4,010.0
BCRET	07055790	5/14/2015	12:47	TN		0.39		168.0
BCRET	07055790	5/18/2015	12:17	TN		0.25		291.0
BCRET	07055790	5/26/2015	1:32	TN		0.56		486.0
BCRET	07055790	6/1/2015	1:15	TN		0.25		139.0
BCRET	07055790	6/4/2015	1:05	TN		0.23		68.4
BCRET	07055790	6/8/2015	1:12	TN		0.27		33.5
BCRET	07055790	6/17/2015	12:49	TN		0.23		54.9
BCRET	07055790	6/22/2015	12:55	TN		0.16		82.0
BCRET	07055790	6/29/2015	1:22	TN		1.88		51.7
BCRET	07055790	7/7/2015	19:45	TN		1.03		138.0
BCRET	07055790	7/9/2015	12:55	TN		0.24		466.0
BCRET	07055790	7/16/2015	12:54	TN		0.33		38.5
BCRET	07055790	7/23/2015	12:40	TN		0.31		17.9
BCRET	07055790	7/30/2015	12:50	TN		0.38		7.9
BCRET	07055790	8/6/2015	12:22	TN		0.52		4.3
BCRET	07055790	8/13/2015	1:01	TN		0.5		3.7
BCRET	07055790	8/20/2015	11:49	TN		0.53		1.8
BCRET	07055790	8/27/2015	1:20	TN		0.54		2.7
BCRET	07055790	9/2/2015	12:19	TN		0.55		2.6
BCRET	07055790	9/10/2015	12:59	TN		0.58		2.9
BCRET	07055790	9/16/2015	12:24	TN		0.62		2.8
BCRET	07055790	9/24/2015	12:07	TN		0.56		2.6
BCRET	07055790	9/30/2015	11:50	TN		0.66		2.4
BCRET	07055790	10/8/2015	11:20	TN		0.6		1.9
BCRET	07055790	10/14/2015	11:28	TN		0.76		1.8
BCRET	07055790	10/22/2015	12:15	TN		0.69		1.0
BCRET	07055790	10/28/2015	11:56	TN		0.78		0.8
BCRET	07055790	11/4/2015	12:03	TN		0.76		0.9
BCRET	07055790	11/12/2015	12:03	TN		0.64		3.7
BCRET	07055790	11/18/2015	11:25	TN		0.56		220.0
BCRET	07055790	12/2/2015	11:57	TN		0.39		80.9
BCRET	07055790	12/14/2015	12:30	TN		0.38		525.0
BCRET	07055790	12/22/2015	11:02	TN		0.32		33.1
BCRET	07055790	1/5/2016	11:40	TN		0.46		66.6
BCRET	07055790	1/25/2016	11:00	TN		0.24		25.6
BCRET	07055790	2/10/2016	11:04	TN		0.24		13.6
BCRET	07055790	2/24/2016	10:52	TN		0.37		134.0
BCRET	07055790	3/10/2016	10:51	TN		0.25		550.0
BCRET	07055790	3/16/2016	11:23	TN		0.24		180.0
BCRET	07055790	3/24/2016	11:35	TN		0.2		60.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
BCRET	07055790	3/31/2016	10:45	TN		0.33		517.0
BCRET	07055790	4/4/2016	11:48	TN		0.2		98.8
BCRET	07055790	4/20/2016	11:42	TN		0.2		21.9
BCRET	07055790	4/28/2016	11:30	TN		0.27		14.8
BCRET	07055790	5/2/2016	11:43	TN		0.16		78.2
BCRET	07055790	5/10/2016	10:58	TN		0.31		536.0
BCRET	07055790	5/18/2016	11:10	TN		0.25		53.1
BCRET	07055790	5/26/2016	11:30	TN		0.2		303.0
BCRET	07055790	6/2/2016	11:04	TN		0.2		52.8
BCRET	07055790	6/7/2016	11:10	TN		0.19		38.4
BCRET	07055790	6/15/2016	11:25	TN		0.42		13.5
BCRET	07055790	6/22/2016	10:23	TN		0.44		6.4
BCRET	07055790	6/29/2016	10:41	TN		0.47		3.4
BCRET	07055790	7/6/2016	6:26	TN		0.43		3.0
BCRET	07055790	7/13/2016	7:33	TN		0.43		5.7
BCRET	07055790	7/20/2016	7:39	TN		0.44		3.4
BCRET	07055790	7/27/2016	7:21	TN		0.47		6.4
BCRET	07055790	8/3/2016	7:43	TN		0.29		14.2
BCRET	07055790	8/16/2016	10:41	TN		0.33		299.0
BCRET	07055790	8/24/2016	10:53	TN		0.22		42.0
BCRET	07055790	8/30/2016	11:10	TN		0.21		32.5
BCRET	07055790	9/7/2016	7:38	TN		0.46		9.6
BCRET	07055790	9/15/2016	10:45	TN		0.42		5.4
BCRET	07055790	9/28/2016	11:12	TN		0.42		6.1
BCRET	07055790	10/5/2016	10:07	TN		0.58		4.3
BCRET	07055790	10/13/2016	10:29	TN		0.88		10.9
BCRET	07055790	10/20/2016	10:48	TN		0.39		6.1
BCRET	07055790	10/27/2016	10:42	TN		0.36		4.2
BCRET	07055790	11/3/2016	9:36	TN		0.47		3.6
BCRET	07055790	11/10/2016	10:38	TN		0.48		3.1
BCRET	07055790	11/17/2016	10:43	TN		0.49		3.0
BCRET	07055790	11/21/2016	10:05	TN		0.52		3.4
BCRET	07055790	11/29/2016	11:30	TN		0.23		27.6
BCRET	07055790	12/14/2016	11:03	TN		0.27		10.6
BCRET	07055790	1/5/2017	12:00	TN		0.31		5.1
BCRET	07055790	1/19/2017	10:30	TN		0.21		26.9
BCRET	07055790	2/2/2017	10:30	TN		0.21		15.0
BCRET	07055790	2/15/2017	11:24	TN		0.42		105.0
BCRET	07055790	3/1/2017	11:18	TN		0.27		49.8
BCRET	07055790	3/16/2017	7:13	TN		0.3		88.2
BCRET	07055790	3/27/2017	10:51	TN		1.49		1,100.0
BCRET	07055790	4/6/2017	11:55	TN		0.26		189.0
BCRET	07055790	4/13/2017	11:56	TN		0.17		86.6

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
BCRET	07055790	4/17/2017	10:51	TN		0.24		92.0
BCRET	07055790	4/27/2017	10:35	TN		0.24		555.0
BCRET	07055790	5/1/2017	11:01	TN		0.39		446.0
BCRET	07055790	5/11/2017	7:24	TN		0.38		57.8
BCRET	07055790	5/18/2017	10:45	TN		0.3		54.4
BCRET	07055790	5/1/2014	9:58	TP		0.008		53.6
BCRET	07055790	5/8/2014	1:13	TP		0.028		22.2
BCRET	07055790	5/9/2014	9:52	TP		0.018		43.6
BCRET	07055790	5/13/2014	9:22	TP		0.086		396.0
BCRET	07055790	5/19/2014	1:30	TP		0.018		77.3
BCRET	07055790	5/28/2014	9:16	TP		0.02		23.3
BCRET	07055790	6/5/2014	1:16	TP		0.026		15.2
BCRET	07055790	6/9/2014	8:51	TP		0.026		39.9
BCRET	07055790	6/19/2014	8:55	TP		0.02		9.7
BCRET	07055790	6/24/2014	9:27	TP		0.068		66.1
BCRET	07055790	6/27/2014	12:17	TP		0.022		36.8
BCRET	07055790	7/1/2014	9:30	TP		0.012		15.8
BCRET	07055790	7/7/2014	9:12	TP		0.034		8.7
BCRET	07055790	7/15/2014	11:32	TP		0.05		113.0
BCRET	07055790	7/18/2014	10:45	TP		0.03		35.9
BCRET	07055790	7/23/2014	10:09	TP		0.032		105.0
BCRET	07055790	7/25/2014	9:55	TP		0.04		95.3
BCRET	07055790	7/31/2014	9:32	TP		0.03		29.9
BCRET	07055790	8/12/2014	9:54	TP		0.036		15.6
BCRET	07055790	8/20/2014	10:14	TP		0.032		7.8
BCRET	07055790	8/26/2014	11:14	TP		0.018		4.5
BCRET	07055790	9/3/2014	9:39	TP		0.018		3.3
BCRET	07055790	9/11/2014	11:30	TP		0.024		3.5
BCRET	07055790	9/18/2014	9:54	TP		0.028		3.8
BCRET	07055790	9/23/2014	10:59	TP		0.026		3.0
BCRET	07055790	9/30/2014	9:57	TP		0.032		3.0
BCRET	07055790	10/8/2014	9:31	TP		0.028		2.6
BCRET	07055790	10/14/2014	9:21	TP		0.45		120.0
BCRET	07055790	10/14/2014	9:31	TP		0.058		120.0
BCRET	07055790	10/22/2014	10:09	TP		0.028		9.7
BCRET	07055790	10/30/2014	11:47	TP		0.016		4.4
BCRET	07055790	11/5/2014	9:10	TP		0.023		7.3
BCRET	07055790	11/12/2014	9:27	TP		0.026		6.7
BCRET	07055790	11/24/2014	9:23	TP		0.016		3.8
BCRET	07055790	12/4/2014	10:35	TP		0.024		4.9
BCRET	07055790	12/9/2014	9:38	TP		0.022		13.4
BCRET	07055790	12/15/2014	12:09	TP		0.044		30.0
BCRET	07055790	12/22/2014	11:00	TP		0.052		34.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
BCRET	07055790	1/8/2015	10:53	TP		0.024		55.2
BCRET	07055790	1/14/2015	11:15	TP		0.02		27.5
BCRET	07055790	1/21/2015	11:05	TP		0.026		16.7
BCRET	07055790	1/29/2015	1:20	TP		0.02		10.6
BCRET	07055790	2/3/2015	10:50	TP		0.018		12.8
BCRET	07055790	2/10/2015	10:25	TP		0.012		10.4
BCRET	07055790	2/26/2015	10:34	TP		0.026		44.4
BCRET	07055790	3/3/2015	10:55	TP		0.028		45.3
BCRET	07055790	3/11/2015	11:20	TP		0.03		183.0
BCRET	07055790	3/19/2015	10:47	TP		0.028		140.0
BCRET	07055790	3/25/2015	11:30	TP		0.036		88.0
BCRET	07055790	3/26/2015	1:35	TP		0.076		531.0
BCRET	07055790	4/2/2015	12:30	TP		0.042		90.2
BCRET	07055790	4/9/2015	12:50	TP		0.048		45.6
BCRET	07055790	4/15/2015	12:40	TP		0.048		224.0
BCRET	07055790	4/23/2015	12:15	TP		0.032		89.0
BCRET	07055790	4/29/2015	12:13	TP		0.018		37.8
BCRET	07055790	5/4/2015		TP		0.034		22.2
BCRET	07055790	5/7/2015	12:05	TP		0.034		74.7
BCRET	07055790	5/8/2015	1:25	TP		0.544		183.0
BCRET	07055790	5/11/2015	12:47	TP		0.53		4,010.0
BCRET	07055790	5/14/2015	12:47	TP		0.05		168.0
BCRET	07055790	5/18/2015	12:17	TP		0.04		291.0
BCRET	07055790	5/26/2015	1:32	TP		0.2		486.0
BCRET	07055790	6/1/2015	1:15	TP		0.05		139.0
BCRET	07055790	6/4/2015	1:05	TP		0.034		68.4
BCRET	07055790	6/8/2015	1:12	TP		0.022		33.5
BCRET	07055790	6/17/2015	12:49	TP		0.034		54.9
BCRET	07055790	6/22/2015	12:55	TP		0.032		82.0
BCRET	07055790	6/29/2015	1:22	TP		0.748		51.7
BCRET	07055790	7/7/2015	19:45	TP		0.38		138.0
BCRET	07055790	7/9/2015	12:55	TP		0.05		466.0
BCRET	07055790	7/16/2015	12:54	TP		0.03		38.5
BCRET	07055790	7/23/2015	12:40	TP		0.028		17.9
BCRET	07055790	7/30/2015	12:50	TP		0.022		7.9
BCRET	07055790	8/6/2015	12:22	TP		0.028		4.3
BCRET	07055790	8/13/2015	1:01	TP		0.024		3.7
BCRET	07055790	8/20/2015	11:49	TP		0.022		1.8
BCRET	07055790	8/27/2015	1:20	TP		0.024		2.7
BCRET	07055790	9/2/2015	12:19	TP		0.02		2.6
BCRET	07055790	9/10/2015	12:59	TP		0.028		2.9
BCRET	07055790	9/16/2015	12:24	TP		0.03		2.8
BCRET	07055790	9/24/2015	12:07	TP		0.018		2.6

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
BCRET	07055790	9/30/2015	11:50	TP		0.022		2.4
BCRET	07055790	10/8/2015	11:20	TP		0.02		1.9
BCRET	07055790	10/14/2015	11:28	TP		0.056		1.8
BCRET	07055790	10/22/2015	12:15	TP		0.018		1.0
BCRET	07055790	10/28/2015	11:56	TP		0.032		0.8
BCRET	07055790	11/4/2015	12:03	TP		0.038		0.9
BCRET	07055790	11/12/2015	12:03	TP		0.044		3.7
BCRET	07055790	11/18/2015	11:25	TP		0.05		220.0
BCRET	07055790	12/2/2015	11:57	TP		0.022		80.9
BCRET	07055790	12/14/2015	12:30	TP		0.048		525.0
BCRET	07055790	12/22/2015	11:02	TP		0.02		33.1
BCRET	07055790	1/5/2016	11:40	TP		0.026		66.6
BCRET	07055790	1/25/2016	11:00	TP		0.022		25.6
BCRET	07055790	2/10/2016	11:04	TP		0.016		13.6
BCRET	07055790	2/24/2016	10:52	TP		0.058		134.0
BCRET	07055790	3/10/2016	10:51	TP		0.044		550.0
BCRET	07055790	3/16/2016	11:23	TP		0.028		180.0
BCRET	07055790	3/24/2016	11:35	TP		0.024		60.0
BCRET	07055790	3/31/2016	10:45	TP		0.056		517.0
BCRET	07055790	4/4/2016	11:48	TP		0.026		98.8
BCRET	07055790	4/20/2016	11:42	TP		0.018		21.9
BCRET	07055790	4/28/2016	11:30	TP		0.012		14.8
BCRET	07055790	5/2/2016	11:43	TP		0.016		78.2
BCRET	07055790	5/10/2016	10:58	TP		0.06		536.0
BCRET	07055790	5/18/2016	11:10	TP		0.02		53.1
BCRET	07055790	5/26/2016	11:30	TP		0.036		303.0
BCRET	07055790	6/2/2016	11:04	TP		0.018		52.8
BCRET	07055790	6/7/2016	11:10	TP		0.018		38.4
BCRET	07055790	6/15/2016	11:25	TP		0.05		13.5
BCRET	07055790	6/22/2016	10:23	TP		0.028		6.4
BCRET	07055790	6/29/2016	10:41	TP		0.021		3.4
BCRET	07055790	7/6/2016	6:26	TP		0.023		3.0
BCRET	07055790	7/13/2016	7:33	TP		0.017		5.7
BCRET	07055790	7/20/2016	7:39	TP		0.024		3.4
BCRET	07055790	7/27/2016	7:21	TP		0.027		6.4
BCRET	07055790	8/3/2016	7:43	TP		0.014		14.2
BCRET	07055790	8/16/2016	10:41	TP		0.039		299.0
BCRET	07055790	8/24/2016	10:53	TP		0.016		42.0
BCRET	07055790	8/30/2016	11:10	TP		0.02		32.5
BCRET	07055790	9/7/2016	7:38	TP		0.059		9.6
BCRET	07055790	9/15/2016	10:45	TP		0.016		5.4
BCRET	07055790	9/28/2016	11:12	TP		0.017		6.1
BCRET	07055790	10/5/2016	10:07	TP		0.043		4.3

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
BCRET	07055790	10/13/2016	10:29	TP		0.066		10.9
BCRET	07055790	10/20/2016	10:48	TP		0.03		6.1
BCRET	07055790	10/27/2016	10:42	TP		0.021		4.2
BCRET	07055790	11/3/2016	9:36	TP		0.022		3.6
BCRET	07055790	11/10/2016	10:38	TP		0.021		3.1
BCRET	07055790	11/17/2016	10:43	TP		0.02		3.0
BCRET	07055790	11/21/2016	10:05	TP		0.021		3.4
BCRET	07055790	11/29/2016	11:30	TP		0.027		27.6
BCRET	07055790	12/14/2016	11:03	TP		0.024		10.6
BCRET	07055790	1/5/2017	12:00	TP		0.019		5.1
BCRET	07055790	1/19/2017	10:30	TP		0.024		26.9
BCRET	07055790	2/2/2017	10:30	TP		0.026		15.0
BCRET	07055790	2/15/2017	11:24	TP		0.082		105.0
BCRET	07055790	3/1/2017	11:18	TP		0.016		49.8
BCRET	07055790	3/16/2017	7:13	TP		0.031		88.2
BCRET	07055790	3/27/2017	10:51	TP		0.096		1,100.0
BCRET	07055790	4/6/2017	11:55	TP		0.034		189.0
BCRET	07055790	4/13/2017	11:56	TP		0.028		86.6
BCRET	07055790	4/17/2017	10:51	TP		0.046		92.0
BCRET	07055790	4/27/2017	10:35	TP		0.042		555.0
BCRET	07055790	5/1/2017	11:01	TP		0.032		446.0
BCRET	07055790	5/11/2017	7:24	TP		0.026		57.8
BCRET	07055790	5/18/2017	10:45	TP		0.024		54.4
USGS	07056000	2/19/1997	12:30	SSC		20		1,220.0
USGS	07056000	4/22/1997	7:15	SSC		18		898.0
USGS	07056000	8/18/1997	15:10	SSC		21		52.0
USGS	07056000	11/18/1997	14:25	SSC		37		226.0
USGS	07056000	2/9/1998	14:30	SSC		10		623.0
USGS	07056000	5/12/1998	13:50	SSC		22		948.0
USGS	07056000	8/5/1998	7:55	SSC		22		35.0
USGS	07056000	1/20/1999	10:45	SSC		15		674.0
USGS	07056000	2/9/1999	10:30	SSC		27		2,880.0
USGS	07056000	3/9/1999	12:05	SSC		52		2,280.0
USGS	07056000	3/25/1999	8:45	SSC		16		1,270.0
USGS	07056000	4/12/1999	13:50	SSC		15		1,920.0
USGS	07056000	4/15/1999	8:30	SSC		28		2,900.0
USGS	07056000	5/5/1999	10:45	SSC		565		12,800.0
USGS	07056000	6/3/1999	9:40	SSC		21		419.0
USGS	07056000	6/24/1999	12:15	SSC		23		209.0
USGS	07056000	7/1/1999	8:30	SSC		463		9,520.0
USGS	07056000	7/22/1999	9:00	SSC		17		131.0
USGS	07056000	8/11/1999	8:35	SSC		16		59.0
USGS	07056000	9/7/1999	12:00	SSC		22		36.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056000	10/6/1999	8:30	SSC		41		19.2
USGS	07056000	11/23/1999	8:30	SSC		18		35.7
USGS	07056000	12/8/1999	12:15	SSC		34		102.0
USGS	07056000	12/13/1999	11:30	SSC		49		6,770.0
USGS	07056000	1/20/2000	8:10	SSC		16		134.0
USGS	07056000	2/1/2000	9:45	SSC		16		74.1
USGS	07056000	2/27/2000	9:45	SSC		39		2,060.0
USGS	07056000	3/13/2000	12:25	SSC		12		622.0
USGS	07056000	4/19/2000	11:45	SSC		21		438.0
USGS	07056000	5/6/2000	17:15	SSC		51		851.0
USGS	07056000	5/17/2000	11:25	SSC		14		270.0
USGS	07056000	6/13/2000	9:00	SSC		19		351.0
USGS	07056000	6/15/2000	8:30	SSC		102		2,550.0
USGS	07056000	6/17/2000	18:30	SSC		852		12,900.0
USGS	07056000	6/22/2000	9:00	SSC		104		13,000.0
USGS	07056000	7/26/2000	10:10	SSC		57		292.0
USGS	07056000	8/16/2000	9:05	SSC		45		74.4
USGS	07056000	9/7/2000	10:20	SSC		28		20.0
USGS	07056000	10/3/2000	7:40	SSC		45		40.0
USGS	07056000	11/15/2000	12:20	SSC		26		488.0
USGS	07056000	12/19/2000	9:40	SSC		22		392.0
USGS	07056000	1/16/2001	14:00	SSC		21		1,270.0
USGS	07056000	1/29/2001	18:15	SSC		172		691.0
USGS	07056000	2/14/2001	6:45	SSC		28		1,940.0
USGS	07056000	2/21/2001	8:15	SSC		33		2,290.0
USGS	07056000	3/20/2001	13:00	SSC		20		768.0
USGS	07056000	4/25/2001	8:15	SSC		16		468.0
USGS	07056000	5/9/2001	11:00	SSC		19		246.0
USGS	07056000	6/7/2001	7:40	SSC		22		187.0
USGS	07056000	7/10/2001	11:45	SSC		23		99.0
USGS	07056000	8/17/2001	7:10	SSC		29		66.0
USGS	07056000	9/6/2001	9:45	SSC		23		20.0
USGS	07056000	10/17/2001	11:40	SSC		24		390.0
USGS	07056000	11/13/2001	15:15	SSC		24		77.0
USGS	07056000	12/6/2001	8:45	SSC		23		636.0
USGS	07056000	12/17/2001	17:30	SSC		231		33,700.0
USGS	07056000	1/23/2002	11:30	SSC		25		466.0
USGS	07056000	1/25/2002	9:00	SSC		54		3,930.0
USGS	07056000	2/1/2002	13:25	SSC		136		19,000.0
USGS	07056000	2/22/2002	8:45	SSC		19		1,350.0
USGS	07056000	3/20/2002	8:10	SSC		430		45,800.0
USGS	07056000	4/8/2002	15:00	SSC		478		29,500.0
USGS	07056000	4/23/2002	14:45	SSC		25		1,350.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056000	6/12/2002	10:00	SSC		10		1,190.0
USGS	07056000	6/19/2002	11:45	SSC		20		417.0
USGS	07056000	7/10/2002	7:15	SSC		5		162.0
USGS	07056000	8/13/2002	10:15	SSC		3		76.1
USGS	07056000	9/11/2002	10:40	SSC		3		36.2
USGS	07056000	10/24/2002	8:05	SSC		4		27.0
USGS	07056000	11/5/2002	12:15	SSC		2		45.4
USGS	07056000	12/17/2002	12:10	SSC		3		129.0
USGS	07056000	1/14/2003	10:15	SSC		3		379.0
USGS	07056000	3/12/2003	14:10	SSC		3		570.0
USGS	07056000	3/25/2003	12:00	SSC		5		1,310.0
USGS	07056000	4/21/2003	13:15	SSC		84		1,490.0
USGS	07056000	5/15/2003	11:15	SSC		27		1,110.0
USGS	07056000	5/17/2003	18:45	SSC		132		15,800.0
USGS	07056000	6/10/2003	14:30	SSC		24		634.0
USGS	07056000	7/23/2003	7:20	SSC		29		75.7
USGS	07056000	8/19/2003	11:30	SSC		18		55.5
USGS	07056000	9/1/2003	14:00	SSC		26		54.9
USGS	07056000	10/1/2003	9:00	SSC		19		28.5
USGS	07056000	11/18/2003	13:50	SSC		145		3,970.0
USGS	07056000	11/19/2003	13:25	SSC		29		2,790.0
USGS	07056000	12/23/2003	8:30	SSC		23		558.0
USGS	07056000	1/6/2004	17:15	SSC		40		380.0
USGS	07056000	2/3/2004	11:10	SSC		21		554.0
USGS	07056000	3/5/2004	11:15	SSC		435		5,050.0
USGS	07056000	3/23/2004	11:00	SSC		19		380.0
USGS	07056000	2/19/1997	12:30	TN	<	0.3	0.150	1,220.0
USGS	07056000	4/22/1997	7:15	TN	<	0.25	0.125	898.0
USGS	07056000	8/18/1997	15:10	TN	<	0.27	0.135	52.0
USGS	07056000	11/18/1997	14:25	TN	<	0.18	0.090	226.0
USGS	07056000	2/9/1998	14:30	TN	<	0.15	0.075	623.0
USGS	07056000	5/12/1998	13:50	TN	<	0.15	0.075	948.0
USGS	07056000	8/5/1998	7:55	TN	<	0.15	0.075	35.0
USGS	07056000	1/20/1999	10:45	TN	E	0.27		674.0
USGS	07056000	2/9/1999	10:30	TN		0.48		2,880.0
USGS	07056000	3/9/1999	12:05	TN		0.49		2,280.0
USGS	07056000	3/25/1999	8:45	TN	<	0.25	0.125	1,270.0
USGS	07056000	4/12/1999	13:50	TN	E	0.23		1,920.0
USGS	07056000	4/15/1999	8:30	TN		0.32		2,900.0
USGS	07056000	5/5/1999	10:45	TN		2.2		12,800.0
USGS	07056000	6/3/1999	9:40	TN		0.23		419.0
USGS	07056000	6/24/1999	12:15	TN	<	0.28	0.140	209.0
USGS	07056000	7/1/1999	8:30	TN		1.5		9,520.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056000	7/22/1999	9:00	TN	<	0.18	0.090	131.0
USGS	07056000	8/11/1999	8:35	TN	<	0.17	0.085	59.0
USGS	07056000	9/7/1999	12:00	TN	<	0.11	0.055	36.0
USGS	07056000	10/6/1999	8:30	TN	<	0.15	0.075	19.2
USGS	07056000	11/23/1999	8:30	TN	<	0.15	0.075	35.7
USGS	07056000	12/8/1999	12:15	TN		0.82		102.0
USGS	07056000	12/13/1999	11:30	TN		0.9		6,770.0
USGS	07056000	1/20/2000	8:10	TN	E	0.19		134.0
USGS	07056000	2/1/2000	9:45	TN	<	0.18	0.090	74.1
USGS	07056000	2/27/2000	9:45	TN		0.39		2,060.0
USGS	07056000	3/13/2000	12:25	TN	<	0.18	0.090	622.0
USGS	07056000	4/19/2000	11:45	TN	<	0.15	0.075	438.0
USGS	07056000	5/6/2000	17:15	TN	<	0.29	0.145	851.0
USGS	07056000	5/17/2000	11:25	TN	<	0.21	0.105	270.0
USGS	07056000	6/13/2000	9:00	TN	E	0.18		351.0
USGS	07056000	6/15/2000	8:30	TN		0.55		2,550.0
USGS	07056000	6/17/2000	18:30	TN		2.6		12,900.0
USGS	07056000	6/22/2000	9:00	TN		0.6		13,000.0
USGS	07056000	7/26/2000	10:10	TN		0.23		292.0
USGS	07056000	8/16/2000	9:05	TN	<	0.16	0.080	74.4
USGS	07056000	9/7/2000	10:20	TN	<	0.17	0.085	20.0
USGS	07056000	10/3/2000	7:40	TN		0.7		40.0
USGS	07056000	11/15/2000	12:20	TN	<	0.45	0.225	488.0
USGS	07056000	12/19/2000	9:40	TN	<	0.41	0.205	392.0
USGS	07056000	1/16/2001	14:00	TN	<	0.37	0.185	1,270.0
USGS	07056000	1/29/2001	18:15	TN		1.2		691.0
USGS	07056000	2/14/2001	6:45	TN		0.43		1,940.0
USGS	07056000	2/21/2001	8:15	TN		0.87		2,290.0
USGS	07056000	3/20/2001	13:00	TN		0.25		768.0
USGS	07056000	4/25/2001	8:15	TN	E	0.17		468.0
USGS	07056000	5/9/2001	11:00	TN		0.22		246.0
USGS	07056000	6/7/2001	7:40	TN	E	0.12		187.0
USGS	07056000	7/10/2001	11:45	TN	E	0.18		99.0
USGS	07056000	8/17/2001	7:10	TN	<	0.14	0.070	66.0
USGS	07056000	9/6/2001	9:45	TN	E	0.14		20.0
USGS	07056000	10/17/2001	11:40	TN		0.2		390.0
USGS	07056000	11/13/2001	15:15	TN	E	0.08		77.0
USGS	07056000	12/6/2001	8:45	TN	E	0.29		636.0
USGS	07056000	12/17/2001	17:30	TN		1.2		33,700.0
USGS	07056000	1/23/2002	11:30	TN	<	0.31	0.155	466.0
USGS	07056000	1/25/2002	9:00	TN		0.56		3,930.0
USGS	07056000	2/1/2002	13:25	TN		0.73		19,000.0
USGS	07056000	2/22/2002	8:45	TN	E	0.19		1,350.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056000	3/20/2002	8:10	TN		1.1		45,800.0
USGS	07056000	4/8/2002	15:00	TN		1.3		29,500.0
USGS	07056000	4/23/2002	14:45	TN	E	0.1		1,350.0
USGS	07056000	6/12/2002	10:00	TN		0.23		1,190.0
USGS	07056000	6/19/2002	11:45	TN	E	0.12		417.0
USGS	07056000	7/10/2002	7:15	TN	E	0.16		162.0
USGS	07056000	8/13/2002	10:15	TN	E	0.12		76.1
USGS	07056000	9/11/2002	10:40	TN	<	0.17	0.085	36.2
USGS	07056000	10/24/2002	8:05	TN	E	0.11		27.0
USGS	07056000	11/5/2002	12:15	TN	E	0.14		45.4
USGS	07056000	12/17/2002	12:10	TN	E	0.2		129.0
USGS	07056000	1/14/2003	10:15	TN	E	0.27		379.0
USGS	07056000	3/12/2003	14:10	TN	E	0.12		570.0
USGS	07056000	3/25/2003	12:00	TN	E	0.14		1,310.0
USGS	07056000	4/21/2003	13:15	TN		0.8		1,490.0
USGS	07056000	5/15/2003	11:15	TN		0.21		1,110.0
USGS	07056000	5/17/2003	18:45	TN		0.77		15,800.0
USGS	07056000	6/10/2003	14:30	TN		0.17		634.0
USGS	07056000	7/23/2003	7:20	TN	E	0.17		75.7
USGS	07056000	8/19/2003	11:30	TN	E	0.15		55.5
USGS	07056000	9/1/2003	14:00	TN	E	0.37		54.9
USGS	07056000	10/1/2003	9:00	TN	<	0.15	0.075	28.5
USGS	07056000	11/18/2003	13:50	TN		1.1		3,970.0
USGS	07056000	11/19/2003	13:25	TN		0.6		2,790.0
USGS	07056000	12/23/2003	8:30	TN	E	0.15		558.0
USGS	07056000	1/6/2004	17:15	TN	E	0.13		380.0
USGS	07056000	2/3/2004	11:10	TN	E	0.16		554.0
USGS	07056000	3/5/2004	11:15	TN		2.4		5,050.0
USGS	07056000	3/23/2004	11:00	TN	E	0.16		380.0
USGS	07056000	2/19/1997	12:30	TP	<	0.01	0.007	1,220.0
USGS	07056000	4/22/1997	7:15	TP	<	0.01	0.007	898.0
USGS	07056000	8/18/1997	15:10	TP	<	0.01	0.007	52.0
USGS	07056000	11/18/1997	14:25	TP		0.01		226.0
USGS	07056000	2/9/1998	14:30	TP		0.03		623.0
USGS	07056000	5/12/1998	13:50	TP	<	0.01	0.007	948.0
USGS	07056000	8/5/1998	7:55	TP	<	0.01	0.007	35.0
USGS	07056000	1/20/1999	10:45	TP	<	0.004	0.002	674.0
USGS	07056000	2/9/1999	10:30	TP		0.025		2,880.0
USGS	07056000	3/9/1999	12:05	TP		0.049		2,280.0
USGS	07056000	3/25/1999	8:45	TP		0.006		1,270.0
USGS	07056000	4/12/1999	13:50	TP		0.01		1,920.0
USGS	07056000	4/15/1999	8:30	TP		0.024		2,900.0
USGS	07056000	5/5/1999	10:45	TP		0.54		12,800.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056000	6/3/1999	9:40	TP		0.007		419.0
USGS	07056000	6/24/1999	12:15	TP	<	0.02	0.010	209.0
USGS	07056000	7/1/1999	8:30	TP		0.38		9,520.0
USGS	07056000	7/22/1999	9:00	TP		0.008		131.0
USGS	07056000	8/11/1999	8:35	TP		0.008		59.0
USGS	07056000	9/7/1999	12:00	TP		0.006		36.0
USGS	07056000	10/6/1999	8:30	TP		0.008		19.2
USGS	07056000	11/23/1999	8:30	TP	E	0.007		35.7
USGS	07056000	12/8/1999	12:15	TP	E	0.004		102.0
USGS	07056000	12/13/1999	11:30	TP		0.088		6,770.0
USGS	07056000	1/20/2000	8:10	TP		0.021		134.0
USGS	07056000	2/1/2000	9:45	TP	E	0.004		74.1
USGS	07056000	2/27/2000	9:45	TP		0.051		2,060.0
USGS	07056000	3/13/2000	12:25	TP	E	0.005		622.0
USGS	07056000	4/19/2000	11:45	TP	<	0.008	0.005	438.0
USGS	07056000	5/6/2000	17:15	TP		0.04		851.0
USGS	07056000	5/17/2000	11:25	TP	E	0.006		270.0
USGS	07056000	6/13/2000	9:00	TP	E	0.005		351.0
USGS	07056000	6/15/2000	8:30	TP		0.109		2,550.0
USGS	07056000	6/17/2000	18:30	TP		0.79		12,900.0
USGS	07056000	6/22/2000	9:00	TP		0.121		13,000.0
USGS	07056000	7/26/2000	10:10	TP		0.009		292.0
USGS	07056000	8/16/2000	9:05	TP	E	0.007		74.4
USGS	07056000	9/7/2000	10:20	TP		0.008		20.0
USGS	07056000	10/3/2000	7:40	TP	E	0.004		40.0
USGS	07056000	11/15/2000	12:20	TP		0.006		488.0
USGS	07056000	12/19/2000	9:40	TP	E	0.003		392.0
USGS	07056000	1/16/2001	14:00	TP		0.008		1,270.0
USGS	07056000	1/29/2001	18:15	TP		0.28		691.0
USGS	07056000	2/14/2001	6:45	TP		0.019		1,940.0
USGS	07056000	2/21/2001	8:15	TP		0.02		2,290.0
USGS	07056000	3/20/2001	13:00	TP		0.005		768.0
USGS	07056000	4/25/2001	8:15	TP		0.007		468.0
USGS	07056000	5/9/2001	11:00	TP		0.008		246.0
USGS	07056000	6/7/2001	7:40	TP		0.009		187.0
USGS	07056000	7/10/2001	11:45	TP		0.008		99.0
USGS	07056000	8/17/2001	7:10	TP		0.007		66.0
USGS	07056000	9/6/2001	9:45	TP		0.007		20.0
USGS	07056000	10/17/2001	11:40	TP		0.008		390.0
USGS	07056000	11/13/2001	15:15	TP	E	0.003		77.0
USGS	07056000	12/6/2001	8:45	TP		0.012		636.0
USGS	07056000	12/17/2001	17:30	TP		0.24		33,700.0
USGS	07056000	1/23/2002	11:30	TP		0.004		466.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056000	1/25/2002	9:00	TP		0.058		3,930.0
USGS	07056000	2/1/2002	13:25	TP		0.128		19,000.0
USGS	07056000	2/22/2002	8:45	TP		0.01		1,350.0
USGS	07056000	3/20/2002	8:10	TP		0.33		45,800.0
USGS	07056000	4/8/2002	15:00	TP		0.4		29,500.0
USGS	07056000	4/23/2002	14:45	TP		0.008		1,350.0
USGS	07056000	6/12/2002	10:00	TP		0.015		1,190.0
USGS	07056000	6/19/2002	11:45	TP		0.009		417.0
USGS	07056000	7/10/2002	7:15	TP		0.014		162.0
USGS	07056000	8/13/2002	10:15	TP		0.017		76.1
USGS	07056000	9/11/2002	10:40	TP		0.011		36.2
USGS	07056000	10/24/2002	8:05	TP		0.011		27.0
USGS	07056000	11/5/2002	12:15	TP		0.009		45.4
USGS	07056000	12/17/2002	12:10	TP		0.005		129.0
USGS	07056000	1/14/2003	10:15	TP		0.007		379.0
USGS	07056000	3/12/2003	14:10	TP		0.008		570.0
USGS	07056000	3/25/2003	12:00	TP		0.01		1,310.0
USGS	07056000	4/21/2003	13:15	TP		0.09		1,490.0
USGS	07056000	5/15/2003	11:15	TP		0.014		1,110.0
USGS	07056000	5/17/2003	18:45	TP		0.14		15,800.0
USGS	07056000	6/10/2003	14:30	TP		0.008		634.0
USGS	07056000	7/23/2003	7:20	TP		0.011		75.7
USGS	07056000	8/19/2003	11:30	TP		0.015		55.5
USGS	07056000	9/1/2003	14:00	TP		0.01		54.9
USGS	07056000	10/1/2003	9:00	TP		0.009		28.5
USGS	07056000	11/18/2003	13:50	TP		0.21		3,970.0
USGS	07056000	11/19/2003	13:25	TP		0.062		2,790.0
USGS	07056000	12/23/2003	8:30	TP		0.008		558.0
USGS	07056000	1/6/2004	17:15	TP		0.005		380.0
USGS	07056000	2/3/2004	11:10	TP		0.006		554.0
USGS	07056000	3/5/2004	11:15	TP		0.47		5,050.0
USGS	07056000	3/23/2004	11:00	TP		0.009		380.0
USGS	07056515	2/9/1999	13:18	SSC		19		159.0
USGS	07056515	3/9/1999	10:45	SSC		26		279.0
USGS	07056515	3/25/1999	9:35	SSC		18		80.0
USGS	07056515	4/12/1999	12:45	SSC		17		105.0
USGS	07056515	4/15/1999	7:30	SSC		28		358.0
USGS	07056515	5/4/1999	23:45	SSC		123		68.0
USGS	07056515	6/3/1999	10:35	SSC		51		12.0
USGS	07056515	6/24/1999	11:30	SSC		46		9.7
USGS	07056515	6/30/1999	17:00	SSC		156		923.0
USGS	07056515	7/22/1999	9:45	SSC		52		12.0
USGS	07056515	8/10/1999	14:00	SSC		54		6.4

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056515	9/7/1999	10:45	SSC		84		3.6
USGS	07056515	10/5/1999	11:30	SSC		90		2.7
USGS	07056515	11/22/1999	13:50	SSC		55		4.5
USGS	07056515	12/8/1999	11:20	SSC		89		9.9
USGS	07056515	12/12/1999	17:00	SSC		198		1,110.0
USGS	07056515	1/20/2000	8:40	SSC		20		15.0
USGS	07056515	2/1/2000	10:30	SSC		25		11.0
USGS	07056515	2/27/2000	8:45	SSC		28		461.0
USGS	07056515	3/13/2000	11:35	SSC		17		49.0
USGS	07056515	4/19/2000	10:30	SSC		27		26.0
USGS	07056515	5/6/2000	16:15	SSC		54		409.0
USGS	07056515	5/17/2000	10:00	SSC		19		29.0
USGS	07056515	6/13/2000	8:15	SSC		27		27.0
USGS	07056515	6/14/2000	22:30	SSC		99		259.0
USGS	07056515	6/17/2000	17:30	SSC		95		366.0
USGS	07056515	6/21/2000	14:30	SSC		134		1,150.0
USGS	07056515	7/26/2000	9:20	SSC		95		11.0
USGS	07056515	8/16/2000	10:30	SSC		85		7.9
USGS	07056515	9/7/2000	9:40	SSC		79		6.4
USGS	07056515	10/3/2000	10:00	SSC		51		4.4
USGS	07056515	11/15/2000	11:15	SSC		31		85.0
USGS	07056515	12/19/2000	8:30	SSC		35		28.0
USGS	07056515	1/16/2001	13:15	SSC		17		110.0
USGS	07056515	1/29/2001	15:20	SSC		196		335.0
USGS	07056515	2/14/2001	8:45	SSC		48		765.0
USGS	07056515	2/21/2001	10:30	SSC		21		191.0
USGS	07056515	3/20/2001	10:00	SSC		24		55.0
USGS	07056515	4/25/2001	10:35	SSC		18		49.0
USGS	07056515	5/9/2001	9:00	SSC		19		29.0
USGS	07056515	6/7/2001	8:45	SSC		39		17.0
USGS	07056515	7/10/2001	8:55	SSC		76		8.5
USGS	07056515	8/17/2001	8:30	SSC		78		9.2
USGS	07056515	9/6/2001	10:45	SSC		84		5.1
USGS	07056515	10/17/2001	9:45	SSC		27		6.2
USGS	07056515	11/13/2001	14:05	SSC		81		8.2
USGS	07056515	12/6/2001	11:00	SSC		26		13.1
USGS	07056515	12/16/2001	22:30	SSC		818		2,910.0
USGS	07056515	1/23/2002	10:00	SSC		29		940.0
USGS	07056515	1/24/2002	19:00	SSC		43		1,840.0
USGS	07056515	1/31/2002	13:50	SSC		3010		4,200.0
USGS	07056515	2/21/2002	9:45	SSC		24		233.0
USGS	07056515	3/19/2002	15:00	SSC		266		4,130.0
USGS	07056515	4/8/2002	13:20	SSC		69		2,710.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056515	4/24/2002	9:15	SSC		27		166.0
USGS	07056515	6/11/2002	15:00	SSC		9		78.8
USGS	07056515	6/19/2002	9:35	SSC		14		21.4
USGS	07056515	7/9/2002	11:00	SSC		11		10.0
USGS	07056515	8/13/2002	13:15	SSC		29		10.0
USGS	07056515	9/11/2002	13:30	SSC		10		6.0
USGS	07056515	10/24/2002	10:00	SSC		8		4.9
USGS	07056515	11/5/2002	13:15	SSC		58		5.4
USGS	07056515	12/17/2002	10:35	SSC		4		23.0
USGS	07056515	1/14/2003	8:30	SSC		2		33.9
USGS	07056515	3/12/2003	10:50	SSC		2		44.8
USGS	07056515	3/25/2003	9:30	SSC		4		138.0
USGS	07056515	4/21/2003	14:30	SSC		39		33.6
USGS	07056515	5/15/2003	12:45	SSC		23		108.0
USGS	07056515	5/16/2003	16:45	SSC		178		572.0
USGS	07056515	6/10/2003	13:20	SSC		26		43.2
USGS	07056515	7/23/2003	8:30	SSC		29		20.8
USGS	07056515	8/19/2003	10:45	SSC		17		9.3
USGS	07056515	9/1/2003	14:30	SSC		21		7.7
USGS	07056515	10/1/2003	9:40	SSC		27		5.1
USGS	07056515	11/18/2003	12:45	SSC		41		410.0
USGS	07056515	11/19/2003	12:00	SSC		21		218.0
USGS	07056515	12/23/2003	9:15	SSC		60		376.0
USGS	07056515	1/6/2004	16:30	SSC		33		70.0
USGS	07056515	2/3/2004	10:15	SSC		24		65.0
USGS	07056515	3/5/2004	9:45	SSC		59		394.0
USGS	07056515	3/23/2004	9:45	SSC		25		43.2
USGS	07056515	2/9/1999	13:18	TN		0.58		159.0
USGS	07056515	3/9/1999	10:45	TN		0.6		279.0
USGS	07056515	3/25/1999	9:35	TN	E	0.43		80.0
USGS	07056515	4/12/1999	12:45	TN		0.48		105.0
USGS	07056515	4/15/1999	7:30	TN		0.58		358.0
USGS	07056515	5/4/1999	23:45	TN		1.3		68.0
USGS	07056515	6/3/1999	10:35	TN		0.69		12.0
USGS	07056515	6/24/1999	11:30	TN	<	0.72	0.360	9.7
USGS	07056515	6/30/1999	17:00	TN		1.3		923.0
USGS	07056515	7/22/1999	9:45	TN		0.64		12.0
USGS	07056515	8/10/1999	14:00	TN		0.61		6.4
USGS	07056515	9/7/1999	10:45	TN		0.6		3.6
USGS	07056515	10/5/1999	11:30	TN		0.52		2.7
USGS	07056515	11/22/1999	13:50	TN		0.7		4.5
USGS	07056515	12/8/1999	11:20	TN	<	0.17	0.085	9.9
USGS	07056515	12/12/1999	17:00	TN		1.7		1,110.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056515	1/20/2000	8:40	TN	E	0.6		15.0
USGS	07056515	2/1/2000	10:30	TN	E	0.53		11.0
USGS	07056515	2/27/2000	8:45	TN		0.82		461.0
USGS	07056515	3/13/2000	11:35	TN		0.35		49.0
USGS	07056515	4/19/2000	10:30	TN		0.3		26.0
USGS	07056515	5/6/2000	16:15	TN		0.6		409.0
USGS	07056515	5/17/2000	10:00	TN		0.3		29.0
USGS	07056515	6/13/2000	8:15	TN		0.5		27.0
USGS	07056515	6/14/2000	22:30	TN		1.2		259.0
USGS	07056515	6/17/2000	17:30	TN		0.8		366.0
USGS	07056515	6/21/2000	14:30	TN		0.87		1,150.0
USGS	07056515	7/26/2000	9:20	TN		0.7		11.0
USGS	07056515	8/16/2000	10:30	TN		0.63		7.9
USGS	07056515	9/7/2000	9:40	TN		0.58		6.4
USGS	07056515	10/3/2000	10:00	TN		0.72		4.4
USGS	07056515	11/15/2000	11:15	TN	<	0.83	0.415	85.0
USGS	07056515	12/19/2000	8:30	TN	E	1		28.0
USGS	07056515	1/16/2001	13:15	TN	<	0.92	0.460	110.0
USGS	07056515	1/29/2001	15:20	TN		1.9		335.0
USGS	07056515	2/14/2001	8:45	TN		1.3		765.0
USGS	07056515	2/21/2001	10:30	TN		1.6		191.0
USGS	07056515	3/20/2001	10:00	TN		0.61		55.0
USGS	07056515	4/25/2001	10:35	TN		0.39		49.0
USGS	07056515	5/9/2001	9:00	TN		0.48		29.0
USGS	07056515	6/7/2001	8:45	TN		0.5		17.0
USGS	07056515	7/10/2001	8:55	TN		0.65		8.5
USGS	07056515	8/17/2001	8:30	TN		0.67		9.2
USGS	07056515	9/6/2001	10:45	TN	E	0.66		5.1
USGS	07056515	10/17/2001	9:45	TN		1		6.2
USGS	07056515	11/13/2001	14:05	TN	E	0.85		8.2
USGS	07056515	12/6/2001	11:00	TN	E	0.77		13.1
USGS	07056515	12/16/2001	22:30	TN		3		2,910.0
USGS	07056515	1/23/2002	10:00	TN	E	0.59		940.0
USGS	07056515	1/24/2002	19:00	TN		0.77		1,840.0
USGS	07056515	1/31/2002	13:50	TN		6.3		4,200.0
USGS	07056515	2/21/2002	9:45	TN		0.52		233.0
USGS	07056515	3/19/2002	15:00	TN		1		4,130.0
USGS	07056515	4/8/2002	13:20	TN		0.56		2,710.0
USGS	07056515	4/24/2002	9:15	TN		0.38		166.0
USGS	07056515	6/11/2002	15:00	TN		0.51		78.8
USGS	07056515	6/19/2002	9:35	TN	<	0.65	0.325	21.4
USGS	07056515	7/9/2002	11:00	TN	<	0.91	0.455	10.0
USGS	07056515	8/13/2002	13:15	TN	E	0.97		10.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056515	9/11/2002	13:30	TN	E	1.1		6.0
USGS	07056515	10/24/2002	10:00	TN	<	1.2	0.600	4.9
USGS	07056515	11/5/2002	13:15	TN	E	1.2		5.4
USGS	07056515	12/17/2002	10:35	TN	E	0.9		23.0
USGS	07056515	1/14/2003	8:30	TN	E	0.92		33.9
USGS	07056515	3/12/2003	10:50	TN	<	0.5	0.250	44.8
USGS	07056515	3/25/2003	9:30	TN		0.36		138.0
USGS	07056515	4/21/2003	14:30	TN		0.52		33.6
USGS	07056515	5/15/2003	12:45	TN		0.39		108.0
USGS	07056515	5/16/2003	16:45	TN		1.2		572.0
USGS	07056515	6/10/2003	13:20	TN	E	0.54		43.2
USGS	07056515	7/23/2003	8:30	TN	E	0.94		20.8
USGS	07056515	8/19/2003	10:45	TN	<	0.93	0.465	9.3
USGS	07056515	9/1/2003	14:30	TN	E	1		7.7
USGS	07056515	10/1/2003	9:40	TN	E	1.2		5.1
USGS	07056515	11/18/2003	12:45	TN		1		410.0
USGS	07056515	11/19/2003	12:00	TN		0.69		218.0
USGS	07056515	12/23/2003	9:15	TN		0.91		376.0
USGS	07056515	1/6/2004	16:30	TN	E	0.62		70.0
USGS	07056515	2/3/2004	10:15	TN	E	0.5		65.0
USGS	07056515	3/5/2004	9:45	TN		0.85		394.0
USGS	07056515	3/23/2004	9:45	TN		0.58		43.2
USGS	07056515	2/9/1999	13:18	TP		0.031		159.0
USGS	07056515	3/9/1999	10:45	TP		0.055		279.0
USGS	07056515	3/25/1999	9:35	TP		0.02		80.0
USGS	07056515	4/12/1999	12:45	TP		0.027		105.0
USGS	07056515	4/15/1999	7:30	TP		0.082		358.0
USGS	07056515	5/4/1999	23:45	TP		0.28		68.0
USGS	07056515	6/3/1999	10:35	TP		0.031		12.0
USGS	07056515	6/24/1999	11:30	TP	<	0.02	0.017	9.7
USGS	07056515	6/30/1999	17:00	TP		0.29		923.0
USGS	07056515	7/22/1999	9:45	TP		0.027		12.0
USGS	07056515	8/10/1999	14:00	TP		0.027		6.4
USGS	07056515	9/7/1999	10:45	TP		0.019		3.6
USGS	07056515	10/5/1999	11:30	TP		0.022		2.7
USGS	07056515	11/22/1999	13:50	TP		0.018		4.5
USGS	07056515	12/8/1999	11:20	TP		0.019		9.9
USGS	07056515	12/12/1999	17:00	TP		0.36		1,110.0
USGS	07056515	1/20/2000	8:40	TP		0.049		15.0
USGS	07056515	2/1/2000	10:30	TP		0.019		11.0
USGS	07056515	2/27/2000	8:45	TP		0.067		461.0
USGS	07056515	3/13/2000	11:35	TP		0.016		49.0
USGS	07056515	4/19/2000	10:30	TP		0.023		26.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056515	5/6/2000	16:15	TP		0.105		409.0
USGS	07056515	5/17/2000	10:00	TP		0.03		29.0
USGS	07056515	6/13/2000	8:15	TP		0.025		27.0
USGS	07056515	6/14/2000	22:30	TP		0.23		259.0
USGS	07056515	6/17/2000	17:30	TP		0.173		366.0
USGS	07056515	6/21/2000	14:30	TP		0.22		1,150.0
USGS	07056515	7/26/2000	9:20	TP		0.023		11.0
USGS	07056515	8/16/2000	10:30	TP		0.017		7.9
USGS	07056515	9/7/2000	9:40	TP		0.02		6.4
USGS	07056515	10/3/2000	10:00	TP		0.018		4.4
USGS	07056515	11/15/2000	11:15	TP		0.031		85.0
USGS	07056515	12/19/2000	8:30	TP		0.022		28.0
USGS	07056515	1/16/2001	13:15	TP		0.024		110.0
USGS	07056515	1/29/2001	15:20	TP		0.35		335.0
USGS	07056515	2/14/2001	8:45	TP		0.155		765.0
USGS	07056515	2/21/2001	10:30	TP		0.035		191.0
USGS	07056515	3/20/2001	10:00	TP		0.016		55.0
USGS	07056515	4/25/2001	10:35	TP		0.021		49.0
USGS	07056515	5/9/2001	9:00	TP		0.017		29.0
USGS	07056515	6/7/2001	8:45	TP		0.03		17.0
USGS	07056515	7/10/2001	8:55	TP		0.022		8.5
USGS	07056515	8/17/2001	8:30	TP		0.033		9.2
USGS	07056515	9/6/2001	10:45	TP		0.024		5.1
USGS	07056515	10/17/2001	9:45	TP		0.047		6.2
USGS	07056515	11/13/2001	14:05	TP		0.04		8.2
USGS	07056515	12/6/2001	11:00	TP		0.043		13.1
USGS	07056515	12/16/2001	22:30	TP		0.98		2,910.0
USGS	07056515	1/23/2002	10:00	TP		0.026		940.0
USGS	07056515	1/24/2002	19:00	TP		0.081		1,840.0
USGS	07056515	1/31/2002	13:50	TP		2.98		4,200.0
USGS	07056515	2/21/2002	9:45	TP		0.041		233.0
USGS	07056515	3/19/2002	15:00	TP		0.32		4,130.0
USGS	07056515	4/8/2002	13:20	TP		0.13		2,710.0
USGS	07056515	4/24/2002	9:15	TP		0.035		166.0
USGS	07056515	6/11/2002	15:00	TP		0.046		78.8
USGS	07056515	6/19/2002	9:35	TP		0.038		21.4
USGS	07056515	7/9/2002	11:00	TP		0.038		10.0
USGS	07056515	8/13/2002	13:15	TP		0.041		10.0
USGS	07056515	9/11/2002	13:30	TP		0.041		6.0
USGS	07056515	10/24/2002	10:00	TP		0.043		4.9
USGS	07056515	11/5/2002	13:15	TP		0.044		5.4
USGS	07056515	12/17/2002	10:35	TP		0.043		23.0
USGS	07056515	1/14/2003	8:30	TP		0.033		33.9

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
USGS	07056515	3/12/2003	10:50	TP		0.023		44.8
USGS	07056515	3/25/2003	9:30	TP		0.024		138.0
USGS	07056515	4/21/2003	14:30	TP		0.034		33.6
USGS	07056515	5/15/2003	12:45	TP		0.041		108.0
USGS	07056515	5/16/2003	16:45	TP		0.26		572.0
USGS	07056515	6/10/2003	13:20	TP		0.029		43.2
USGS	07056515	7/23/2003	8:30	TP		0.04		20.8
USGS	07056515	8/19/2003	10:45	TP		0.042		9.3
USGS	07056515	9/1/2003	14:30	TP		0.038		7.7
USGS	07056515	10/1/2003	9:40	TP		0.044		5.1
USGS	07056515	11/18/2003	12:45	TP		0.141		410.0
USGS	07056515	11/19/2003	12:00	TP		0.078		218.0
USGS	07056515	12/23/2003	9:15	TP		0.135		376.0
USGS	07056515	1/6/2004	16:30	TP		0.031		70.0
USGS	07056515	2/3/2004	10:15	TP		0.023		65.0
USGS	07056515	3/5/2004	9:45	TP		0.111		394.0
USGS	07056515	3/23/2004	9:45	TP		0.035		43.2
ADEQ	BUFR01	8/4/2014	9:45	TN		0.094		19.4
ADEQ	BUFR01	1/5/2015	9:51	TN		0.178		282.0
ADEQ	BUFR01	3/30/2015	9:34	TN		0.102		195.0
ADEQ	BUFR01	1/11/2016	8:25	TN		0.113		137.0
ADEQ	BUFR01	4/4/2016	14:21	TN	<	0.08	0.074	106.0
ADEQ	BUFR01	6/27/2016	9:35	TN		0.134		4.0
ADEQ	BUFR01	9/26/2016	9:45	TN		0.222		9.2
ADEQ	BUFR01	1/9/2017	9:35	TN	<	0.08	0.074	5.3
ADEQ	BUFR01	3/13/2017	10:05	TN		0.175		260.0
ADEQ	BUFR01	5/15/2000	12:22	TP	<	0.02	0.006	36.0
ADEQ	BUFR01	8/4/2014	9:45	TP	<	0.02	0.006	19.4
ADEQ	BUFR01	11/3/2014	9:38	TP	<	0.02	0.006	4.7
ADEQ	BUFR01	1/5/2015	9:51	TP	<	0.02	0.006	282.0
ADEQ	BUFR01	3/30/2015	9:34	TP	<	0.02	0.006	195.0
ADEQ	BUFR01	7/6/2015	8:45	TP	<	0.02	0.006	26.6
ADEQ	BUFR01	10/26/2015	9:45	TP	<	0.02	0.006	0.3
ADEQ	BUFR01	1/11/2016	8:25	TP	<	0.02	0.006	137.0
ADEQ	BUFR01	4/4/2016	14:21	TP	<	0.02	0.006	106.0
ADEQ	BUFR01	6/27/2016	9:35	TP	<	0.02	0.006	4.0
ADEQ	BUFR01	9/26/2016	9:45	TP	<	0.02	0.006	9.2
ADEQ	BUFR01	1/9/2017	9:35	TP	<	0.02	0.006	5.3
ADEQ	BUFR01	3/13/2017	10:05	TP	<	0.02	0.006	260.0
ADEQ	UWBRK01	4/20/1999	12:50	TN		0.48		99.0
ADEQ	UWBRK01	6/8/1999	9:10	TN		0.836		11.0
ADEQ	UWBRK01	10/22/2001	16:00	TN		1.036		6.9
ADEQ	UWBRK01	1/28/2002	15:45	TN		0.916		253.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	UWBRK01	3/25/2002	15:20	TN		3.369		2,290.0
ADEQ	UWBRK01	5/21/2002	14:55	TN		0.588		82.8
ADEQ	UWBRK01	9/23/2002	15:20	TN		2.004		4.8
ADEQ	UWBRK01	6/24/2003	10:50	TN		0.664		32.4
ADEQ	UWBRK01	8/26/2003	10:50	TN		1.071		9.4
ADEQ	UWBRK01	4/29/2014	10:42	TN		0.479		326.0
ADEQ	UWBRK01	6/9/2014	8:32	TN		0.647		133.0
ADEQ	UWBRK01	10/7/2014	11:45	TN		1.65		8.7
ADEQ	UWBRK01	11/4/2014	10:54	TN		1.28		10.4
ADEQ	UWBRK01	1/13/2015	12:49	TN		1		60.7
ADEQ	UWBRK01	4/13/2015	9:30	TN		0.639		461.0
ADEQ	UWBRK01	6/23/2015	13:00	TN		0.852		81.8
ADEQ	UWBRK01	8/3/2015	9:15	TN		1.28		10.4
ADEQ	UWBRK01	10/6/2015	12:05	TN		1.63		9.0
ADEQ	UWBRK01	1/12/2016	13:17	TN		0.902		128.0
ADEQ	UWBRK01	3/29/2016	12:18	TN		0.572		80.1
ADEQ	UWBRK01	5/9/2016	9:27	TN		0.616		306.0
ADEQ	UWBRK01	2/16/1999	9:15	TP		0.023		66.0
ADEQ	UWBRK01	4/20/1999	12:50	TP		0.028		99.0
ADEQ	UWBRK01	6/8/1999	9:10	TP		0.049		11.0
ADEQ	UWBRK01	8/16/1999	17:50	TP		0.036		5.1
ADEQ	UWBRK01	10/22/2001	16:00	TP	<	0.02	0.017	6.9
ADEQ	UWBRK01	1/28/2002	15:45	TP	<	0.02	0.017	253.0
ADEQ	UWBRK01	3/25/2002	15:20	TP		1.03		2,290.0
ADEQ	UWBRK01	5/21/2002	14:55	TP		0.062		82.8
ADEQ	UWBRK01	7/29/2002	14:35	TP		0.185		13.6
ADEQ	UWBRK01	9/23/2002	15:20	TP		0.046		4.8
ADEQ	UWBRK01	11/4/2002	15:05	TP		0.094		4.4
ADEQ	UWBRK01	1/7/2003	15:00	TP		0.083		74.9
ADEQ	UWBRK01	3/10/2003	15:15	TP		0.064		49.2
ADEQ	UWBRK01	4/29/2003	10:45	TP	<	0.03	0.023	44.4
ADEQ	UWBRK01	6/24/2003	10:50	TP	<	0.03	0.023	32.4
ADEQ	UWBRK01	8/26/2003	10:50	TP	<	0.03	0.023	9.4
ADEQ	UWBRK01	4/29/2014	10:42	TP		0.103		326.0
ADEQ	UWBRK01	6/9/2014	8:32	TP		0.06		133.0
ADEQ	UWBRK01	10/7/2014	11:45	TP		0.056		8.7
ADEQ	UWBRK01	11/4/2014	10:54	TP		0.057		10.4
ADEQ	UWBRK01	1/13/2015	12:49	TP		0.037		60.7
ADEQ	UWBRK01	4/13/2015	9:30	TP	<	0.02	0.017	461.0
ADEQ	UWBRK01	6/23/2015	13:00	TP		0.048		81.8
ADEQ	UWBRK01	8/3/2015	9:15	TP		0.035		10.4
ADEQ	UWBRK01	10/6/2015	12:05	TP		0.07		9.0
ADEQ	UWBRK01	1/12/2016	13:17	TP		0.036		128.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	UWBRK01	3/29/2016	12:18	TP		0.025		80.1
ADEQ	UWBRK01	5/9/2016	9:27	TP		0.024		306.0
ADEQ	WHI0049A	12/30/1997	11:20	TN		0.389		538.0
ADEQ	WHI0049A	1/27/1998	11:25	TN		0.279		2,340.0
ADEQ	WHI0049A	2/17/1998	12:15	TN		0.47		3,160.0
ADEQ	WHI0049A	3/10/1998	13:45	TN		0.301		3,750.0
ADEQ	WHI0049A	4/7/1998	14:20	TN		0.202		1,860.0
ADEQ	WHI0049A	8/18/1998	12:30	TN		0.221		70.0
ADEQ	WHI0049A	9/22/1998	12:35	TN		0.223		168.0
ADEQ	WHI0049A	11/9/1998	11:00	TN		0.158		181.0
ADEQ	WHI0049A	12/15/1998	11:15	TN		0.646		2,070.0
ADEQ	WHI0049A	3/23/1999	10:50	TN		0.279		1,520.0
ADEQ	WHI0049A	4/6/1999	12:55	TN		0.442		6,190.0
ADEQ	WHI0049A	5/11/1999	13:30	TN		0.4		1,160.0
ADEQ	WHI0049A	6/15/1999	12:45	TN		0.294		365.0
ADEQ	WHI0049A	7/20/1999	13:30	TN		0.254		159.0
ADEQ	WHI0049A	8/24/1999	12:35	TN		0.251		42.0
ADEQ	WHI0049A	9/21/1999	12:35	TN		0.224		28.0
ADEQ	WHI0049A	11/16/1999	12:10	TN		0.136		32.6
ADEQ	WHI0049A	12/14/1999	9:55	TN		0.858		1,930.0
ADEQ	WHI0049A	1/25/2000	11:00	TN		0.203		102.0
ADEQ	WHI0049A	2/29/2000	11:00	TN		0.21		1,130.0
ADEQ	WHI0049A	5/30/2000	12:45	TN		0.66		2,530.0
ADEQ	WHI0049A	6/27/2000	10:30	TN		0.767		1,450.0
ADEQ	WHI0049A	8/1/2000	10:45	TN		0.207		318.0
ADEQ	WHI0049A	8/22/2000	12:10	TN		0.132		43.3
ADEQ	WHI0049A	9/19/2000	9:25	TN	<	0.06	0.030	21.7
ADEQ	WHI0049A	1/16/2001	11:15	TN		0.39		1,270.0
ADEQ	WHI0049A	3/20/2001	11:40	TN		0.381		768.0
ADEQ	WHI0049A	4/17/2001	9:40	TN		0.291		704.0
ADEQ	WHI0049A	5/22/2001	11:10	TN		0.23		173.0
ADEQ	WHI0049A	6/26/2001	11:00	TN		0.25		116.0
ADEQ	WHI0049A	7/24/2001	12:45	TN		0.148		49.0
ADEQ	WHI0049A	8/28/2001	10:50	TN		0.195		28.0
ADEQ	WHI0049A	9/25/2001	11:05	TN		0.218		182.0
ADEQ	WHI0049A	10/30/2001	12:00	TN		0.164		90.0
ADEQ	WHI0049A	11/13/2001	9:25	TN		0.163		77.0
ADEQ	WHI0049A	12/11/2001	11:55	TN		0.247		635.0
ADEQ	WHI0049A	2/12/2002	10:10	TN		0.526		1,400.0
ADEQ	WHI0049A	3/19/2002	11:15	TN		1.556		26,200.0
ADEQ	WHI0049A	4/16/2002	13:00	TN		0.33		1,890.0
ADEQ	WHI0049A	5/21/2002	11:50	TN		0.24		1,200.0
ADEQ	WHI0049A	7/9/2002	11:45	TN		0.55		174.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	WHI0049A	8/13/2002	10:05	TN		0.142		76.1
ADEQ	WHI0049A	9/10/2002	11:30	TN		0.187		36.9
ADEQ	WHI0049A	12/17/2002	12:00	TN		0.736		129.0
ADEQ	WHI0049A	3/4/2003	11:30	TN		0.4		1,030.0
ADEQ	WHI0049A	4/1/2003	10:45	TN		0.166		867.0
ADEQ	WHI0049A	4/22/2003	13:15	TN		0.387		1,110.0
ADEQ	WHI0049A	6/30/2003	11:30	TN		0.315		179.0
ADEQ	WHI0049A	8/5/2003	13:05	TN		0.292		87.3
ADEQ	WHI0049A	9/9/2003	12:20	TN		0.189		47.3
ADEQ	WHI0049A	10/7/2003	8:31	TN		0.306		33.0
ADEQ	WHI0049A	11/4/2003	15:30	TN		0.267		51.0
ADEQ	WHI0049A	12/9/2003	11:00	TN		0.246		227.0
ADEQ	WHI0049A	1/20/2004	11:15	TN		0.415		1,980.0
ADEQ	WHI0049A	6/29/2004	10:00	TN		0.163		243.0
ADEQ	WHI0049A	7/27/2004	10:25	TN		0.208		392.0
ADEQ	WHI0049A	8/16/2004	10:30	TN		0.168		78.6
ADEQ	WHI0049A	9/27/2004	15:25	TN		0.206		21.1
ADEQ	WHI0049A	11/29/2004	14:30	TN		0.336		2,100.0
ADEQ	WHI0049A	12/13/2004	13:30	TN		0.366		984.0
ADEQ	WHI0049A	1/24/2005	17:05	TN		0.508		1,360.0
ADEQ	WHI0049A	2/14/2005	12:05	TN		0.217		1,880.0
ADEQ	WHI0049A	3/8/2005	9:40	TN		0.161		1,160.0
ADEQ	WHI0049A	4/12/2005	12:15	TN		0.352		3,720.0
ADEQ	WHI0049A	5/3/2005	12:45	TN		0.204		505.0
ADEQ	WHI0049A	5/31/2005	11:30	TN		0.224		176.0
ADEQ	WHI0049A	7/12/2005	13:30	TN		0.13		41.2
ADEQ	WHI0049A	8/9/2005	12:15	TN		0.139		21.5
ADEQ	WHI0049A	9/27/2005	9:41	TN		0.138		23.3
ADEQ	WHI0049A	1/24/2006	8:49	TN		0.194		54.6
ADEQ	WHI0049A	2/21/2006	9:24	TN		0.1		120.0
ADEQ	WHI0049A	3/28/2006	11:05	TN		0.076		486.0
ADEQ	WHI0049A	4/25/2006	11:20	TN		0.34		726.0
ADEQ	WHI0049A	5/30/2006	10:50	TN		0.243		154.0
ADEQ	WHI0049A	6/27/2006	10:45	TN		0.191		64.6
ADEQ	WHI0049A	10/17/2006	12:00	TN		0.876		11,900.0
ADEQ	WHI0049A	11/14/2006	11:30	TN		0.369		680.0
ADEQ	WHI0049A	1/30/2007	11:10	TN		0.396		1,220.0
ADEQ	WHI0049A	2/13/2007	11:15	TN		0.673		7,870.0
ADEQ	WHI0049A	3/20/2007	10:55	TN		0.212		563.0
ADEQ	WHI0049A	4/17/2007	11:10	TN		0.158		1,020.0
ADEQ	WHI0049A	6/5/2007	10:45	TN		0.122		227.0
ADEQ	WHI0049A	7/10/2007	10:50	TN		0.143		822.0
ADEQ	WHI0049A	8/7/2007	10:50	TN		0.149		66.4

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	WHI0049A	9/11/2007	10:55	TN		0.164		43.8
ADEQ	WHI0049A	10/23/2007	10:45	TN		0.191		87.7
ADEQ	WHI0049A	11/6/2007	11:10	TN		0.123		65.2
ADEQ	WHI0049A	12/4/2007	11:10	TN		0.205		50.3
ADEQ	WHI0049A	1/29/2008	11:17	TN		0.153		136.0
ADEQ	WHI0049A	2/12/2008	10:55	TN		0.841		1,690.0
ADEQ	WHI0049A	4/8/2008	10:50	TN		0.331		2,770.0
ADEQ	WHI0049A	5/6/2008	10:10	TN		0.111		1,260.0
ADEQ	WHI0049A	6/3/2008	9:50	TN		0.247		1,020.0
ADEQ	WHI0049A	7/1/2008	10:25	TN		0.21		427.0
ADEQ	WHI0049A	8/12/2008	9:50	TN		0.239		381.0
ADEQ	WHI0049A	9/9/2008	11:10	TN		0.62		1,770.0
ADEQ	WHI0049A	10/14/2008	11:14	TN		0.201		190.0
ADEQ	WHI0049A	11/18/2008	11:07	TN		0.279		245.0
ADEQ	WHI0049A	2/17/2009	10:18	TN		0.328		1,570.0
ADEQ	WHI0049A	3/24/2009	11:25	TN		0.177		1,270.0
ADEQ	WHI0049A	4/7/2009	10:43	TN		0.335		1,670.0
ADEQ	WHI0049A	5/5/2009	10:49	TN		0.242		5,660.0
ADEQ	WHI0049A	6/9/2009	10:37	TN		0.179		456.0
ADEQ	WHI0049A	7/28/2009	10:55	TN		0.317		233.0
ADEQ	WHI0049A	8/18/2009	10:55	TN		0.238		68.6
ADEQ	WHI0049A	8/31/2009	9:00	TN		0.198		49.7
ADEQ	WHI0049A	9/29/2009	10:55	TN		0.602		967.0
ADEQ	WHI0049A	10/20/2009	11:20	TN		0.417		1,530.0
ADEQ	WHI0049A	11/17/2009	11:30	TN		0.497		3,520.0
ADEQ	WHI0049A	1/12/2010	11:45	TN		0.248		538.0
ADEQ	WHI0049A	2/23/2010	11:20	TN		0.467		3,170.0
ADEQ	WHI0049A	3/23/2010	10:55	TN		0.567		6,190.0
ADEQ	WHI0049A	4/27/2010	11:15	TN		0.314		763.0
ADEQ	WHI0049A	5/11/2010	10:45	TN		0.318		503.0
ADEQ	WHI0049A	6/8/2010	10:50	TN		0.288		260.0
ADEQ	WHI0049A	6/8/2010	14:35	TN		0.351		260.0
ADEQ	WHI0049A	7/6/2010	11:00	TN		0.179		60.4
ADEQ	WHI0049A	8/3/2010	10:55	TN		0.228		105.0
ADEQ	WHI0049A	9/7/2010	11:05	TN		0.188		41.7
ADEQ	WHI0049A	10/19/2010	8:39	TN		0.216		44.9
ADEQ	WHI0049A	12/7/2010	7:10	TN		0.126		112.0
ADEQ	WHI0049A	2/7/2011	11:13	TN		0.165		361.0
ADEQ	WHI0049A	3/1/2011	9:32	TN		0.481		1,950.0
ADEQ	WHI0049A	4/5/2011	11:05	TN		0.544		2,390.0
ADEQ	WHI0049A	5/3/2011	14:04	TN		0.694		17,600.0
ADEQ	WHI0049A	6/6/2011	14:48	TN		0.247		601.0
ADEQ	WHI0049A	6/14/2011	8:00	TN		0.325		368.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	WHI0049A	7/5/2011	11:02	TN		0.356		87.6
ADEQ	WHI0049A	9/6/2011	10:38	TN		0.153		55.3
ADEQ	WHI0049A	10/4/2011	9:56	TN		0.273		54.4
ADEQ	WHI0049A	12/5/2011	16:24	TN		0.495		5,290.0
ADEQ	WHI0049A	1/10/2012	9:30	TN		0.45		422.0
ADEQ	WHI0049A	3/13/2012	10:05	TN		0.452		4,730.0
ADEQ	WHI0049A	4/10/2012	9:39	TN		0.174		502.0
ADEQ	WHI0049A	5/22/2012	9:50	TN		0.291		87.8
ADEQ	WHI0049A	6/12/2012	9:05	TN		0.598		86.9
ADEQ	WHI0049A	11/6/2012	12:10	TN		0.168		50.2
ADEQ	WHI0049A	1/8/2013	9:01	TN		0.336		307.0
ADEQ	WHI0049A	2/19/2013	9:43	TN		0.463		761.0
ADEQ	WHI0049A	3/5/2013	9:30	TN		0.567		1,020.0
ADEQ	WHI0049A	4/2/2013	11:00	TN		0.263		1,510.0
ADEQ	WHI0049A	5/7/2013	9:20	TN		0.131		1,620.0
ADEQ	WHI0049A	6/4/2013	9:10	TN		0.504		2,600.0
ADEQ	WHI0049A	7/9/2013	10:43	TN		0.261		70.0
ADEQ	WHI0049A	8/13/2013	8:47	TN		0.64		3,530.0
ADEQ	WHI0049A	9/17/2013	8:51	TN		0.246		56.4
ADEQ	WHI0049A	2/18/2014	9:12	TN		0.279		399.0
ADEQ	WHI0049A	3/18/2014	9:45	TN		0.74		7,230.0
ADEQ	WHI0049A	4/29/2014	9:06	TN		0.329		1,920.0
ADEQ	WHI0049A	5/6/2014	9:30	TN		0.277		618.0
ADEQ	WHI0049A	6/23/2014	9:25	TN		0.456		763.0
ADEQ	WHI0049A	7/8/2014	8:25	TN		0.287		219.0
ADEQ	WHI0049A	8/4/2014	11:13	TN		0.211		400.0
ADEQ	WHI0049A	8/4/2014	14:40	TN		0.188		400.0
ADEQ	WHI0049A	9/8/2014	14:10	TN		0.215		68.4
ADEQ	WHI0049A	9/16/2014	7:21	TN		0.227		86.7
ADEQ	WHI0049A	10/28/2014	7:38	TN		0.261		145.0
ADEQ	WHI0049A	11/3/2014	8:29	TN		0.172		96.8
ADEQ	WHI0049A	12/1/2014	12:26	TN		0.141		184.0
ADEQ	WHI0049A	1/6/2015	9:11	TN		0.604		2,470.0
ADEQ	WHI0049A	2/10/2015	9:21	TN		0.341		233.0
ADEQ	WHI0049A	3/31/2015	9:49	TN		0.432		2,100.0
ADEQ	WHI0049A	4/14/2015	8:18	TN		0.656		4,600.0
ADEQ	WHI0049A	5/4/2015	10:33	TN		0.235		568.0
ADEQ	WHI0049A	5/5/2015	9:05	TN		0.253		518.0
ADEQ	WHI0049A	6/2/2015	9:44	TN		0.306		2,750.0
ADEQ	WHI0049A	7/13/2015	16:58	TN		0.308		1,640.0
ADEQ	WHI0049A	8/11/2015	9:20	TN		0.432		141.0
ADEQ	WHI0049A	9/15/2015	8:40	TN		0.183		109.0
ADEQ	WHI0049A	10/13/2015	8:11	TN		0.162		43.9

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	WHI0049A	11/16/2015	11:18	TN		0.302		116.0
ADEQ	WHI0049A	12/7/2015	14:24	TN		0.359		637.0
ADEQ	WHI0049A	2/2/2016	14:15	TN		0.209		414.0
ADEQ	WHI0049A	3/29/2016	14:50	TN		0.139		818.0
ADEQ	WHI0049A	4/26/2016	14:40	TN		0.393		327.0
ADEQ	WHI0049A	6/21/2016	14:50	TN		0.206		212.0
ADEQ	WHI0049A	7/19/2016	15:15	TN		0.232		109.0
ADEQ	WHI0049A	8/30/2016	14:25	TN		0.136		364.0
ADEQ	WHI0049A	9/27/2016	15:00	TN		0.352		246.0
ADEQ	WHI0049A	10/18/2016	15:00	TN		0.301		263.0
ADEQ	WHI0049A	12/6/2016	13:25	TN		0.154		277.0
ADEQ	WHI0049A	1/23/2017	14:52	TN		0.213		559.0
ADEQ	WHI0049A	2/27/2017	14:56	TN		0.15		586.0
ADEQ	WHI0049A	3/27/2017	15:06	TN		0.951		12,300.0
ADEQ	WHI0049A	5/18/2004	11:15	TP		0.012		614.0
ADEQ	WHI0049A	6/29/2004	10:00	TP	<	0.03	0.013	243.0
ADEQ	WHI0049A	7/27/2004	10:25	TP		0.019		392.0
ADEQ	WHI0049A	8/16/2004	10:30	TP		0.015		78.6
ADEQ	WHI0049A	9/27/2004	15:25	TP		0.016		21.1
ADEQ	WHI0049A	10/18/2004	13:45	TP		0.017		302.0
ADEQ	WHI0049A	11/29/2004	14:30	TP		0.016		2,100.0
ADEQ	WHI0049A	12/13/2004	13:30	TP	<	0.01	0.007	984.0
ADEQ	WHI0049A	1/24/2005	17:05	TP		0.016		1,360.0
ADEQ	WHI0049A	2/14/2005	12:05	TP		0.011		1,880.0
ADEQ	WHI0049A	3/8/2005	9:40	TP		0.028		1,160.0
ADEQ	WHI0049A	4/12/2005	12:15	TP		0.029		3,720.0
ADEQ	WHI0049A	5/3/2005	12:45	TP	<	0.01	0.007	505.0
ADEQ	WHI0049A	5/31/2005	11:30	TP		0.028		176.0
ADEQ	WHI0049A	7/12/2005	13:30	TP		0.022		41.2
ADEQ	WHI0049A	8/9/2005	12:15	TP		0.041		21.5
ADEQ	WHI0049A	9/27/2005	9:41	TP		0.028		23.3
ADEQ	WHI0049A	10/24/2005	9:43	TP		0.016		22.0
ADEQ	WHI0049A	11/29/2005	9:44	TP	<	0.01	0.007	56.7
ADEQ	WHI0049A	1/24/2006	8:49	TP	<	0.01	0.007	54.6
ADEQ	WHI0049A	2/21/2006	9:24	TP		0.017		120.0
ADEQ	WHI0049A	3/28/2006	11:05	TP		0.01		486.0
ADEQ	WHI0049A	4/25/2006	11:20	TP		0.032		726.0
ADEQ	WHI0049A	5/30/2006	10:50	TP		0.019		154.0
ADEQ	WHI0049A	6/27/2006	10:45	TP		0.037		64.6
ADEQ	WHI0049A	7/25/2006	10:50	TP		0.046		27.4
ADEQ	WHI0049A	8/22/2006	10:46	TP		0.041		36.7
ADEQ	WHI0049A	9/19/2006	10:50	TP		0.052		23.4
ADEQ	WHI0049A	10/17/2006	12:00	TP		0.127		11,900.0

AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	WHI0049A	11/14/2006	11:30	TP		0.013		680.0
ADEQ	WHI0049A	12/19/2006	11:00	TP		0.025		923.0
ADEQ	WHI0049A	1/30/2007	11:10	TP		0.02		1,220.0
ADEQ	WHI0049A	2/13/2007	11:15	TP		0.104		7,870.0
ADEQ	WHI0049A	3/20/2007	10:55	TP		0.011		563.0
ADEQ	WHI0049A	4/17/2007	11:10	TP		0.035		1,020.0
ADEQ	WHI0049A	5/8/2007	11:05	TP		0.016		646.0
ADEQ	WHI0049A	6/5/2007	10:45	TP		0.035		227.0
ADEQ	WHI0049A	7/10/2007	10:50	TP		0.042		822.0
ADEQ	WHI0049A	8/7/2007	10:50	TP		0.039		66.4
ADEQ	WHI0049A	9/11/2007	10:55	TP		0.032		43.8
ADEQ	WHI0049A	10/23/2007	10:45	TP		0.02		87.7
ADEQ	WHI0049A	11/6/2007	11:10	TP		0.039		65.2
ADEQ	WHI0049A	12/4/2007	11:10	TP		0.02		50.3
ADEQ	WHI0049A	1/29/2008	11:17	TP	<	0.01	0.007	136.0
ADEQ	WHI0049A	2/12/2008	10:55	TP		0.156		1,690.0
ADEQ	WHI0049A	4/8/2008	10:50	TP		0.026		2,770.0
ADEQ	WHI0049A	5/6/2008	10:10	TP		0.011		1,260.0
ADEQ	WHI0049A	6/3/2008	9:50	TP		0.025		1,020.0
ADEQ	WHI0049A	7/1/2008	10:25	TP		0.042		427.0
ADEQ	WHI0049A	8/12/2008	9:50	TP		0.03		381.0
ADEQ	WHI0049A	9/9/2008	11:10	TP		0.034		1,770.0
ADEQ	WHI0049A	10/14/2008	11:14	TP		0.021		190.0
ADEQ	WHI0049A	11/18/2008	11:07	TP		0.033		245.0
ADEQ	WHI0049A	1/13/2009	10:50	TP		0.012		199.0
ADEQ	WHI0049A	2/17/2009	10:18	TP		0.025		1,570.0
ADEQ	WHI0049A	3/24/2009	11:25	TP		0.018		1,270.0
ADEQ	WHI0049A	4/7/2009	10:43	TP		0.014		1,670.0
ADEQ	WHI0049A	5/5/2009	10:49	TP		0.038		5,660.0
ADEQ	WHI0049A	6/9/2009	10:37	TP		0.017		456.0
ADEQ	WHI0049A	7/28/2009	10:55	TP		0.054		233.0
ADEQ	WHI0049A	8/18/2009	10:55	TP		0.033		68.6
ADEQ	WHI0049A	8/31/2009	9:00	TP		0.026		49.7
ADEQ	WHI0049A	9/29/2009	10:55	TP		0.024		967.0
ADEQ	WHI0049A	10/20/2009	11:20	TP		0.038		1,530.0
ADEQ	WHI0049A	11/17/2009	11:30	TP		0.05		3,520.0
ADEQ	WHI0049A	12/8/2009	11:12	TP		0.013		562.0
ADEQ	WHI0049A	1/12/2010	11:45	TP		0.021		538.0
ADEQ	WHI0049A	2/23/2010	11:20	TP		0.038		3,170.0
ADEQ	WHI0049A	3/23/2010	10:55	TP		0.05		6,190.0
ADEQ	WHI0049A	4/27/2010	11:15	TP		0.021		763.0
ADEQ	WHI0049A	5/11/2010	10:45	TP		0.014		503.0
ADEQ	WHI0049A	6/8/2010	10:50	TP		0.027		260.0

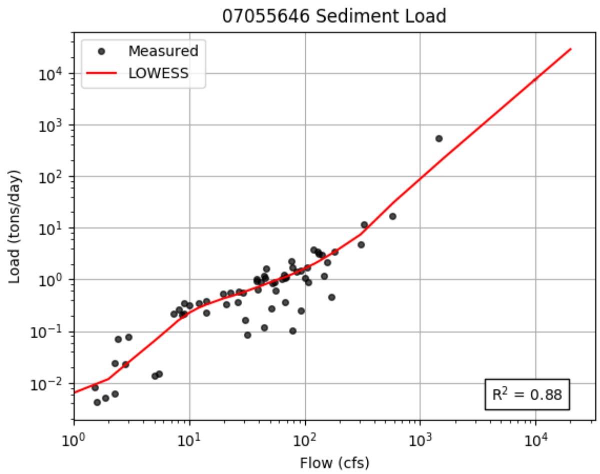
AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	WHI0049A	6/8/2010	14:35	TP		0.027		260.0
ADEQ	WHI0049A	7/6/2010	11:00	TP		0.028		60.4
ADEQ	WHI0049A	8/3/2010	10:55	TP		0.033		105.0
ADEQ	WHI0049A	9/7/2010	11:05	TP		0.028		41.7
ADEQ	WHI0049A	10/19/2010	8:39	TP		0.023		44.9
ADEQ	WHI0049A	11/16/2010	7:27	TP		0.023		45.0
ADEQ	WHI0049A	12/7/2010	7:10	TP		0.055		112.0
ADEQ	WHI0049A	1/18/2011	11:09	TP		0.011		102.0
ADEQ	WHI0049A	2/7/2011	11:13	TP		0.014		361.0
ADEQ	WHI0049A	3/1/2011	9:32	TP		0.05		1,950.0
ADEQ	WHI0049A	4/5/2011	11:05	TP		0.044		2,390.0
ADEQ	WHI0049A	5/3/2011	14:04	TP		0.135		17,600.0
ADEQ	WHI0049A	6/6/2011	14:48	TP		0.021		601.0
ADEQ	WHI0049A	6/14/2011	8:00	TP		0.025		368.0
ADEQ	WHI0049A	7/5/2011	11:02	TP		0.108		87.6
ADEQ	WHI0049A	8/30/2011	9:47	TP		0.027		77.7
ADEQ	WHI0049A	9/6/2011	10:38	TP		0.017		55.3
ADEQ	WHI0049A	10/4/2011	9:56	TP		0.025		54.4
ADEQ	WHI0049A	11/1/2011	11:01	TP		0.027		60.5
ADEQ	WHI0049A	12/5/2011	16:24	TP		0.04		5,290.0
ADEQ	WHI0049A	1/10/2012	9:30	TP		0.016		422.0
ADEQ	WHI0049A	2/14/2012	11:00	TP		0.019		1,070.0
ADEQ	WHI0049A	3/13/2012	10:05	TP		0.035		4,730.0
ADEQ	WHI0049A	4/10/2012	9:39	TP		0.018		502.0
ADEQ	WHI0049A	5/22/2012	9:50	TP		0.044		87.8
ADEQ	WHI0049A	6/12/2012	9:05	TP		0.039		86.9
ADEQ	WHI0049A	7/10/2012	9:05	TP		0.036		21.2
ADEQ	WHI0049A	8/7/2012	9:34	TP		0.048		14.1
ADEQ	WHI0049A	9/11/2012	8:55	TP		0.043		46.5
ADEQ	WHI0049A	10/9/2012	10:46	TP		0.024		35.1
ADEQ	WHI0049A	11/6/2012	12:10	TP		0.035		50.2
ADEQ	WHI0049A	12/4/2012	9:41	TP	<	0.02	0.010	65.5
ADEQ	WHI0049A	1/8/2013	9:01	TP	<	0.02	0.010	307.0
ADEQ	WHI0049A	2/19/2013	9:43	TP	<	0.02	0.010	761.0
ADEQ	WHI0049A	3/5/2013	9:30	TP		0.024		1,020.0
ADEQ	WHI0049A	4/2/2013	11:00	TP		0.022		1,510.0
ADEQ	WHI0049A	5/7/2013	9:20	TP		0.031		1,620.0
ADEQ	WHI0049A	6/4/2013	9:10	TP		0.039		2,600.0
ADEQ	WHI0049A	7/9/2013	10:43	TP		0.032		70.0
ADEQ	WHI0049A	8/13/2013	8:47	TP		0.056		3,530.0
ADEQ	WHI0049A	9/17/2013	8:51	TP		0.03		56.4
ADEQ	WHI0049A	10/15/2013	8:11	TP	<	0.02	0.010	61.6
ADEQ	WHI0049A	11/5/2013	8:13	TP	<	0.02	0.010	82.6

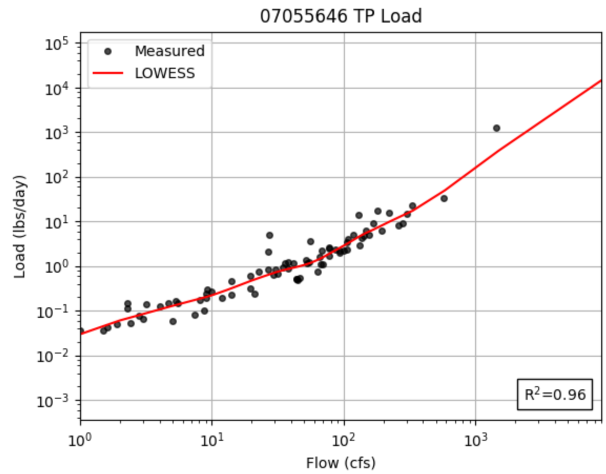
AGENCY	SITE ID	DATE	TIME	PARAMETER CODE	REMARK "E" -estimatd "<" -censored	REPORTED VALUE (mg/L)	IMPUTED VALUE (mg/L)	DAILY MEAN FLOW (CFS)
ADEQ	WHI0049A	12/2/2013	9:35	TP	<	0.02	0.010	168.0
ADEQ	WHI0049A	1/7/2014	13:14	TP		0.027		539.0
ADEQ	WHI0049A	2/18/2014	9:12	TP		0.028		399.0
ADEQ	WHI0049A	3/18/2014	9:45	TP		0.062		7,230.0
ADEQ	WHI0049A	4/29/2014	9:06	TP		0.04		1,920.0
ADEQ	WHI0049A	5/6/2014	9:30	TP		0.259		618.0
ADEQ	WHI0049A	6/23/2014	9:25	TP		0.154		763.0
ADEQ	WHI0049A	7/8/2014	8:25	TP	<	0.02	0.010	219.0
ADEQ	WHI0049A	8/4/2014	11:13	TP	<	0.02	0.010	400.0
ADEQ	WHI0049A	8/4/2014	14:40	TP	<	0.02	0.010	400.0
ADEQ	WHI0049A	9/8/2014	14:10	TP		0.022		68.4
ADEQ	WHI0049A	9/16/2014	7:21	TP		0.027		86.7
ADEQ	WHI0049A	10/28/2014	7:38	TP		0.045		145.0
ADEQ	WHI0049A	11/3/2014	8:29	TP		0.021		96.8
ADEQ	WHI0049A	12/1/2014	12:26	TP	<	0.02	0.010	184.0
ADEQ	WHI0049A	1/6/2015	9:11	TP		0.026		2,470.0
ADEQ	WHI0049A	2/10/2015	9:21	TP		0.111		233.0
ADEQ	WHI0049A	3/31/2015	9:49	TP		0.029		2,100.0
ADEQ	WHI0049A	4/14/2015	8:18	TP		0.103		4,600.0
ADEQ	WHI0049A	5/4/2015	10:33	TP	<	0.02	0.010	568.0
ADEQ	WHI0049A	5/5/2015	9:05	TP	<	0.02	0.010	518.0
ADEQ	WHI0049A	6/2/2015	9:44	TP		0.362		2,750.0
ADEQ	WHI0049A	7/13/2015	16:58	TP	<	0.02	0.010	1,640.0
ADEQ	WHI0049A	8/11/2015	9:20	TP	<	0.02	0.010	141.0
ADEQ	WHI0049A	9/15/2015	8:40	TP	<	0.02	0.010	109.0
ADEQ	WHI0049A	10/13/2015	8:11	TP	<	0.02	0.010	43.9
ADEQ	WHI0049A	11/16/2015	11:18	TP	<	0.02	0.010	116.0
ADEQ	WHI0049A	12/7/2015	14:24	TP		0.023		637.0
ADEQ	WHI0049A	1/11/2016	9:52	TP	<	0.02	0.010	1,810.0
ADEQ	WHI0049A	2/2/2016	14:15	TP	<	0.02	0.010	414.0
ADEQ	WHI0049A	3/29/2016	14:50	TP	<	0.02	0.010	818.0
ADEQ	WHI0049A	4/26/2016	14:40	TP	<	0.02	0.010	327.0
ADEQ	WHI0049A	5/24/2016	14:45	TP	<	0.02	0.010	547.0
ADEQ	WHI0049A	6/21/2016	14:50	TP		0.028		212.0
ADEQ	WHI0049A	7/19/2016	15:15	TP		0.038		109.0
ADEQ	WHI0049A	8/30/2016	14:25	TP		0.027		364.0
ADEQ	WHI0049A	9/27/2016	15:00	TP	<	0.02	0.010	246.0
ADEQ	WHI0049A	10/18/2016	15:00	TP		0.031		263.0
ADEQ	WHI0049A	12/6/2016	13:25	TP	<	0.02	0.010	277.0
ADEQ	WHI0049A	1/23/2017	14:52	TP		0.022		559.0
ADEQ	WHI0049A	2/27/2017	14:56	TP	<	0.02	0.010	586.0
ADEQ	WHI0049A	3/27/2017	15:06	TP		0.195	0.195	12,300.0

APPENDIX B

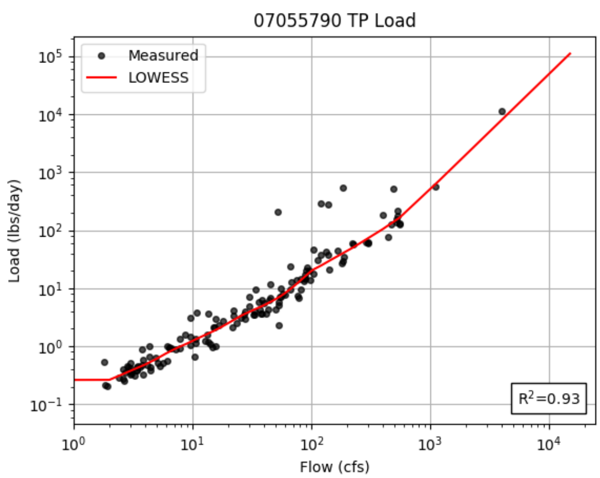
LOWESS Rating Curves

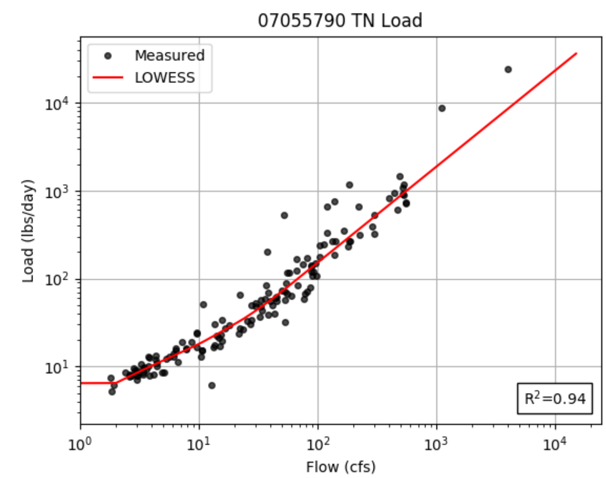
USGS 07055646 - Buffalo River near Boxley, AR



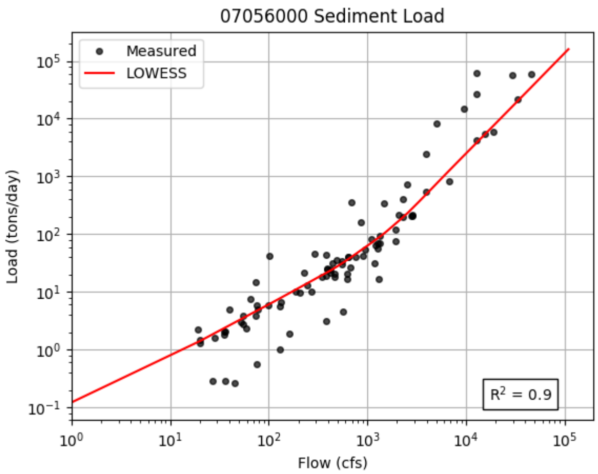


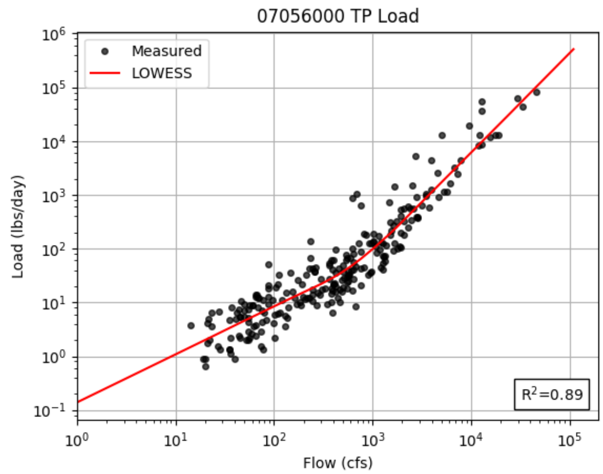
USGS 0705790 – Big Creek near Mt. Judea, AR

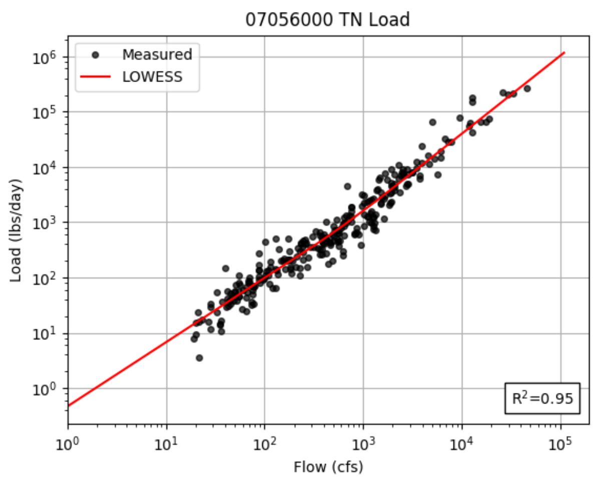




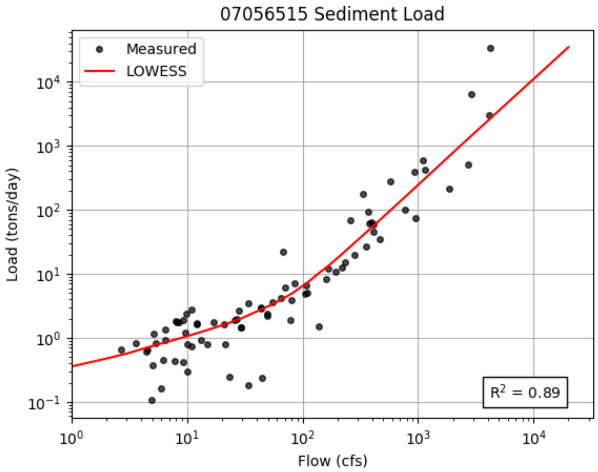
USGS 07056000 - Buffalo River near St. Joe, AR

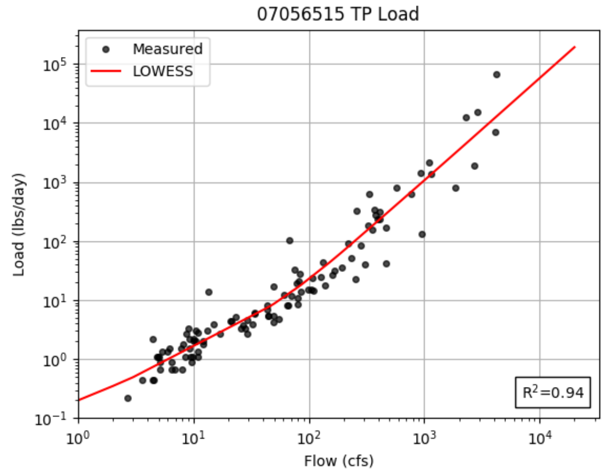


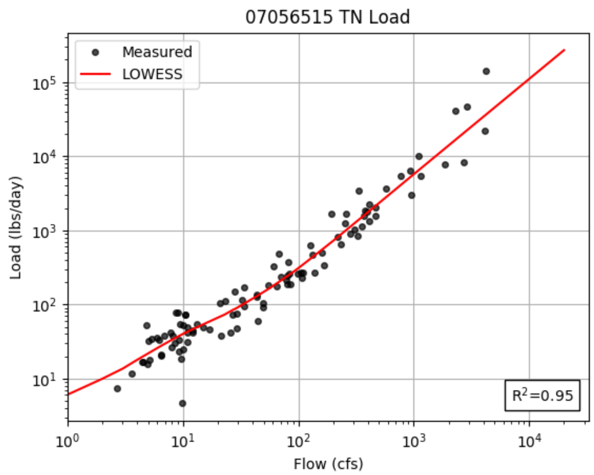




USGS 07056515 - Bear Creek near Silver Hill, AR

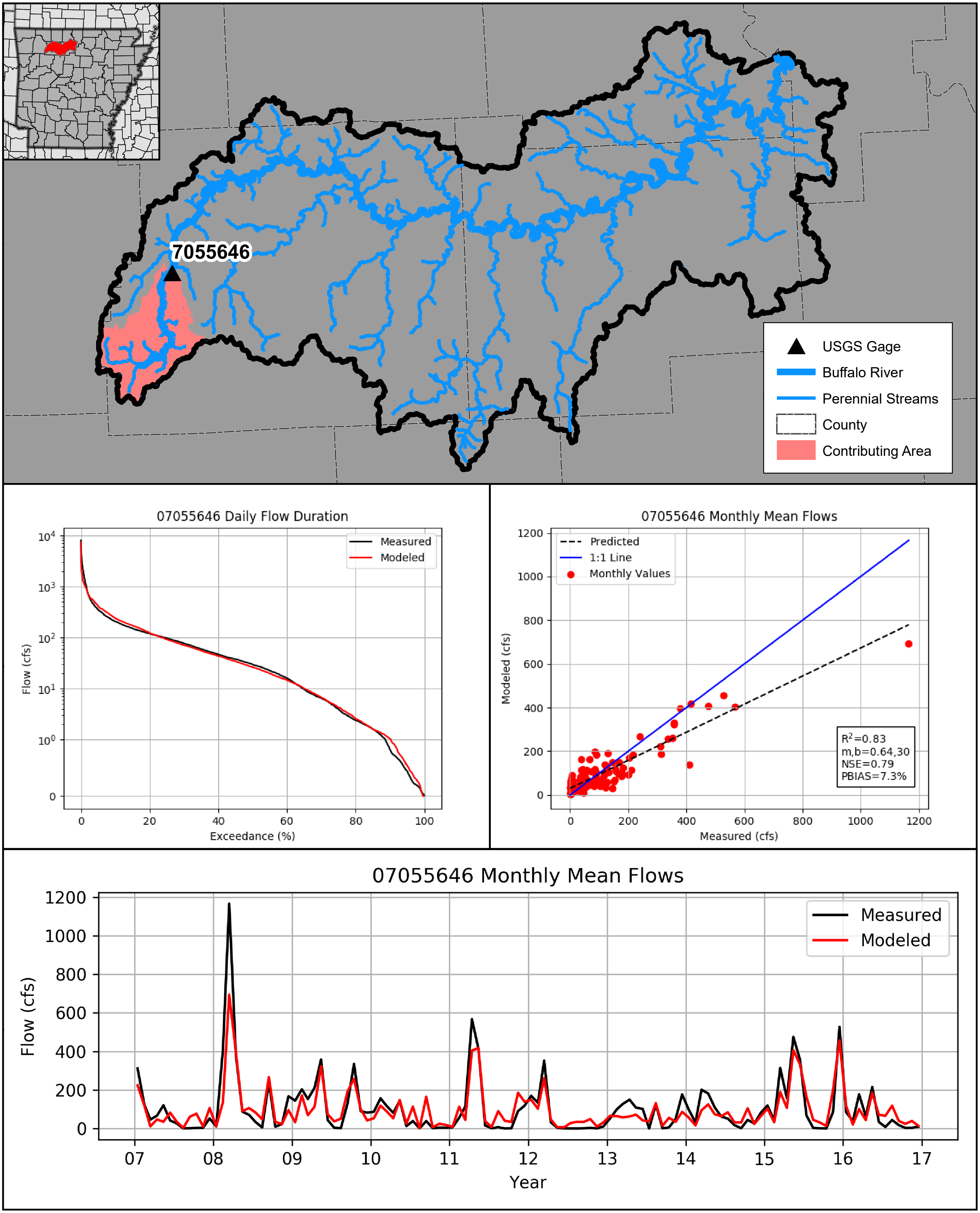




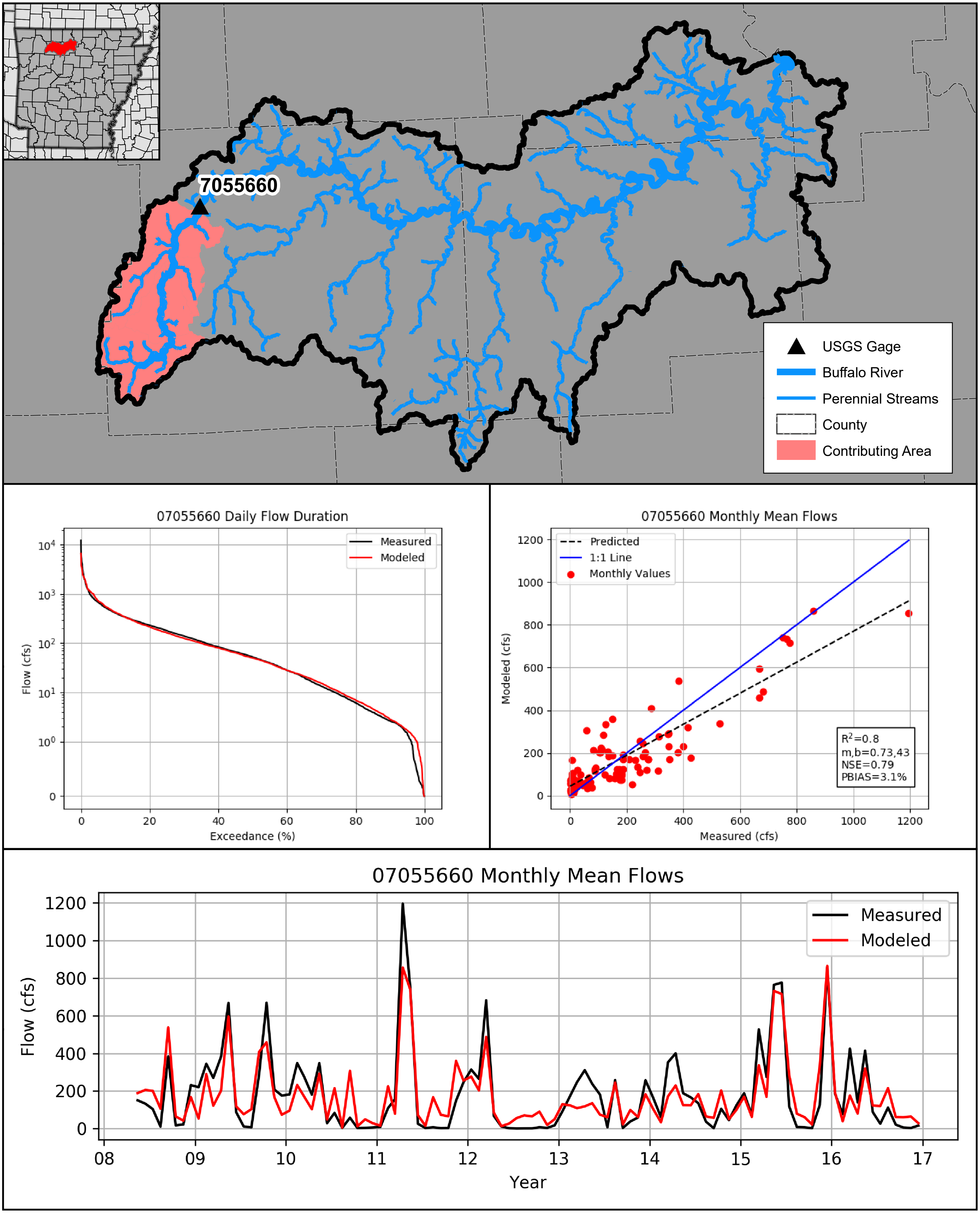


APPENDIX C

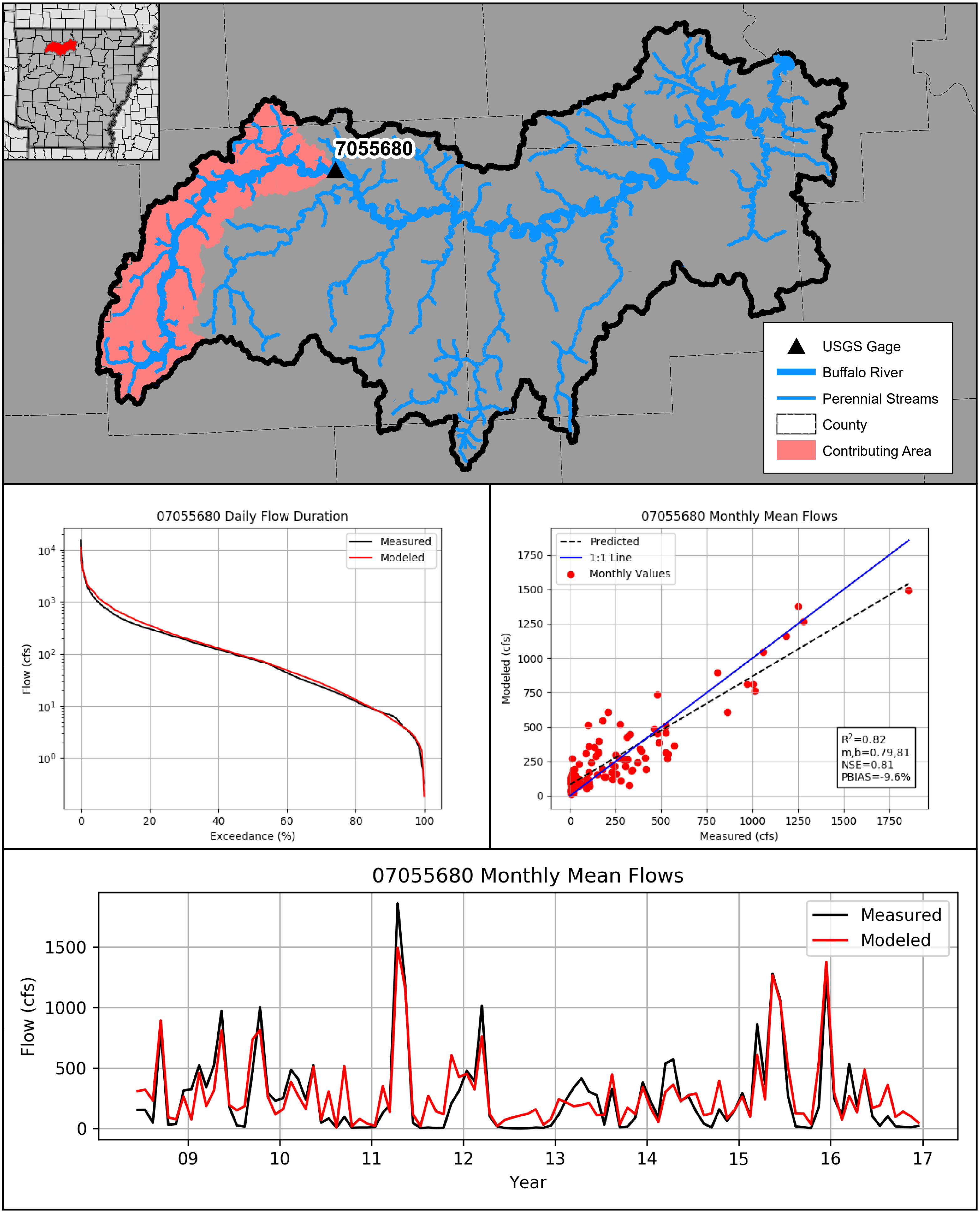
Calibration Plots



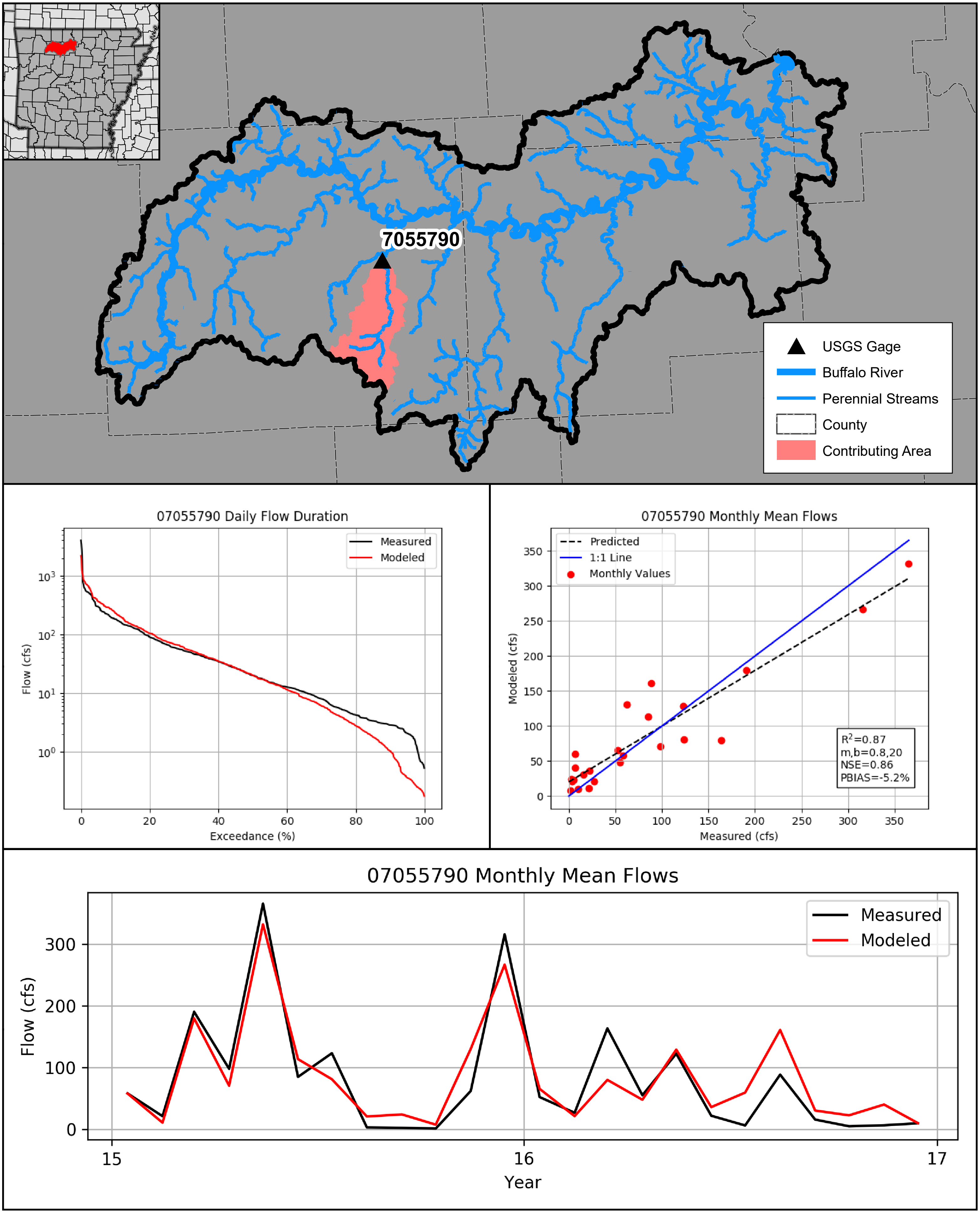
USGS 07055646 - Buffalo River near Boxley, AR
Hydrology Calibration Station 1 of 8



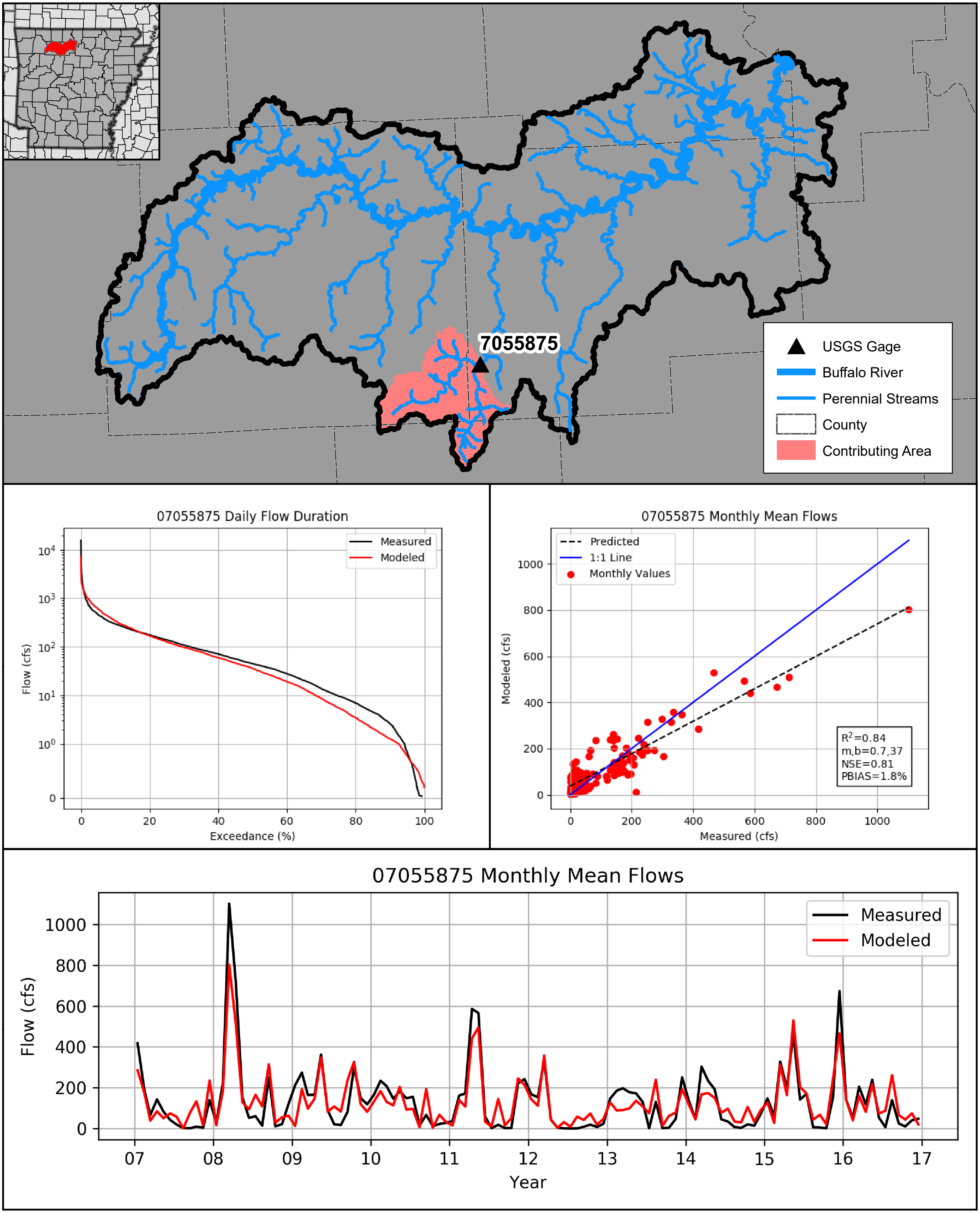
USGS 07055660 - Buffalo River at Ponca, AR
Hydrology Calibration Station 2 of 8



USGS 07055680 - Buffalo River at Pruitt, AR
Hydrology Calibration Station 3 of 8

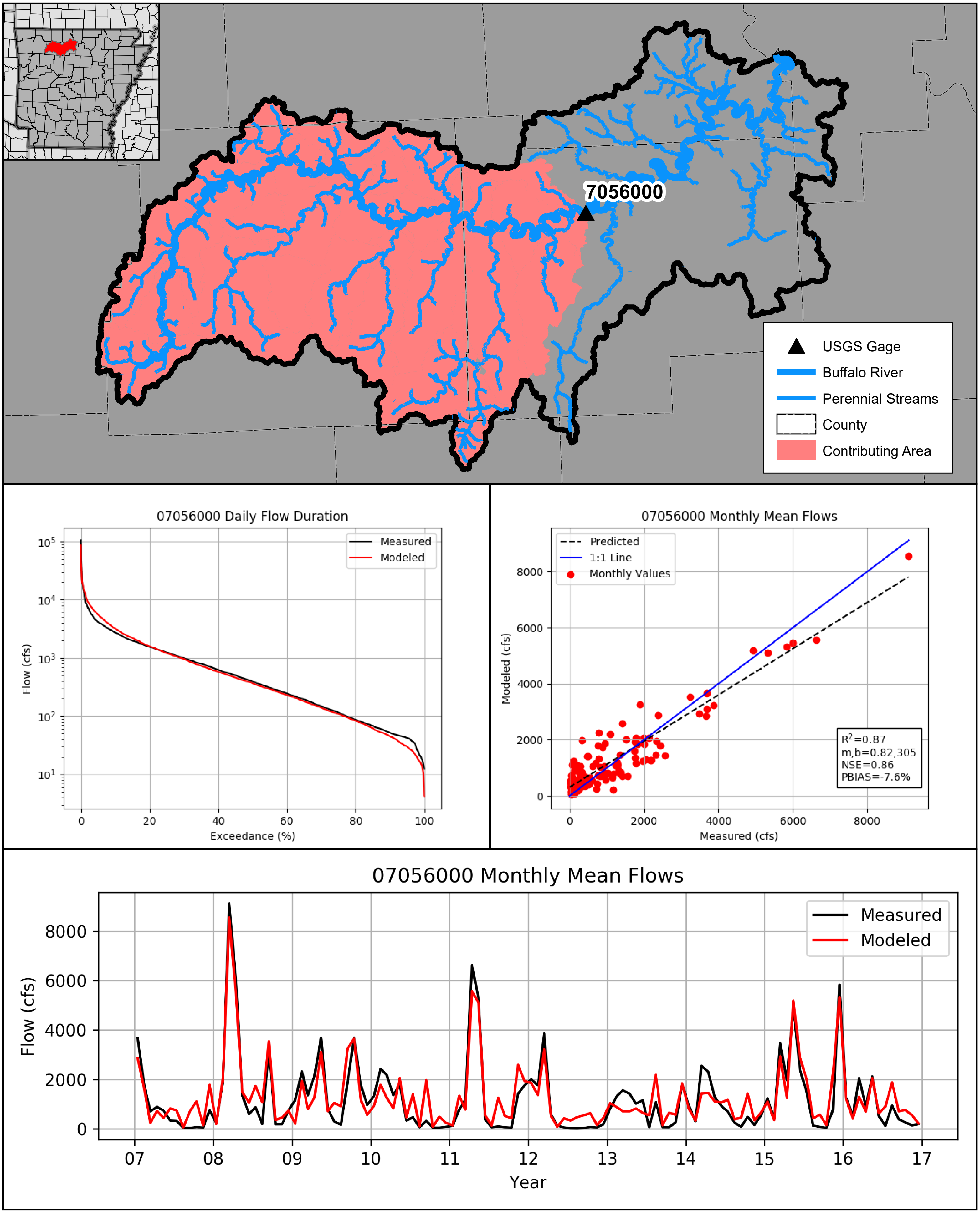


USGS 07055790 - Big Creek near Mt. Judea, AR
Hydrology Calibration Station 4 of 8

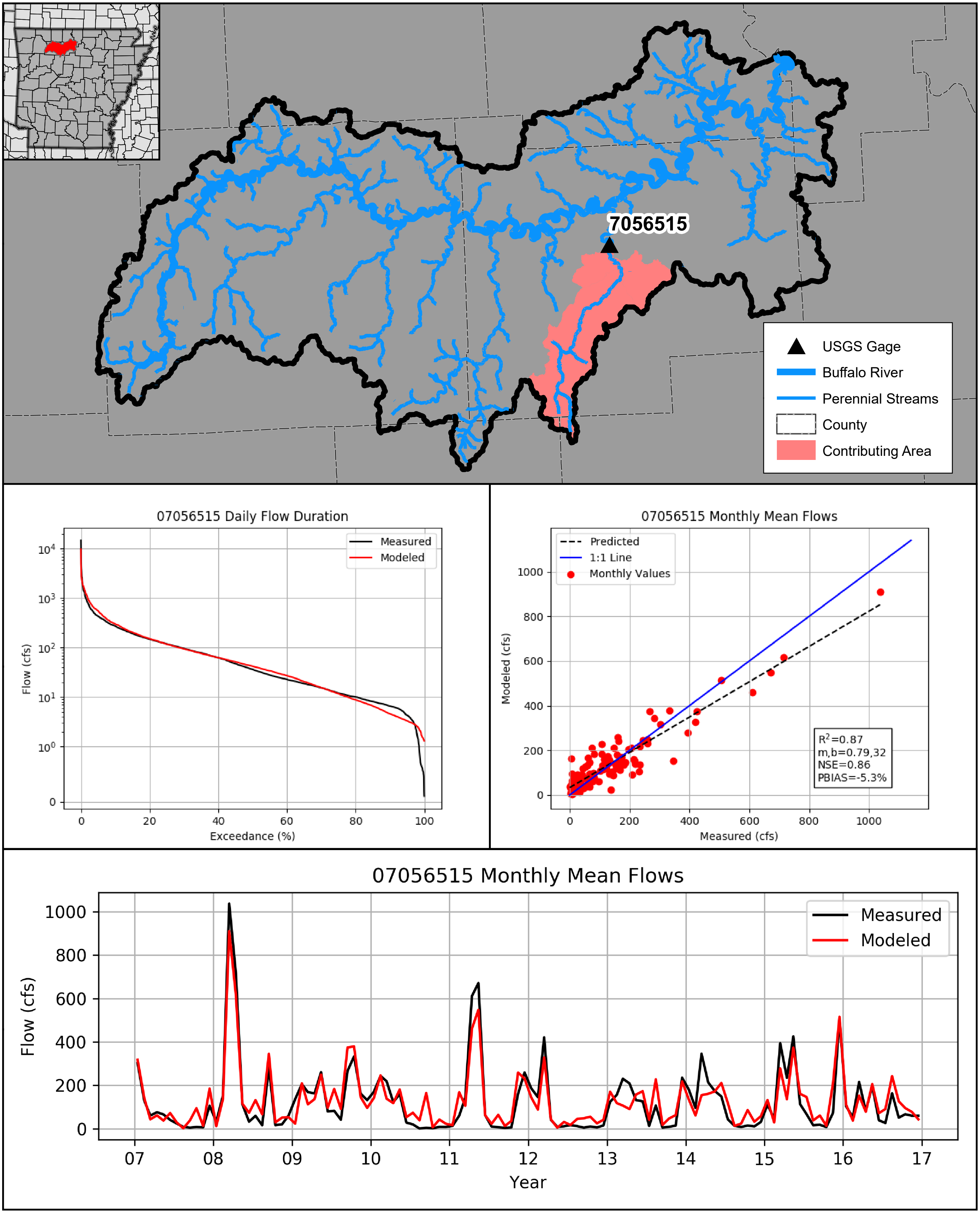


USGS 07055875 - Richland Creek near Witts Spring, AR

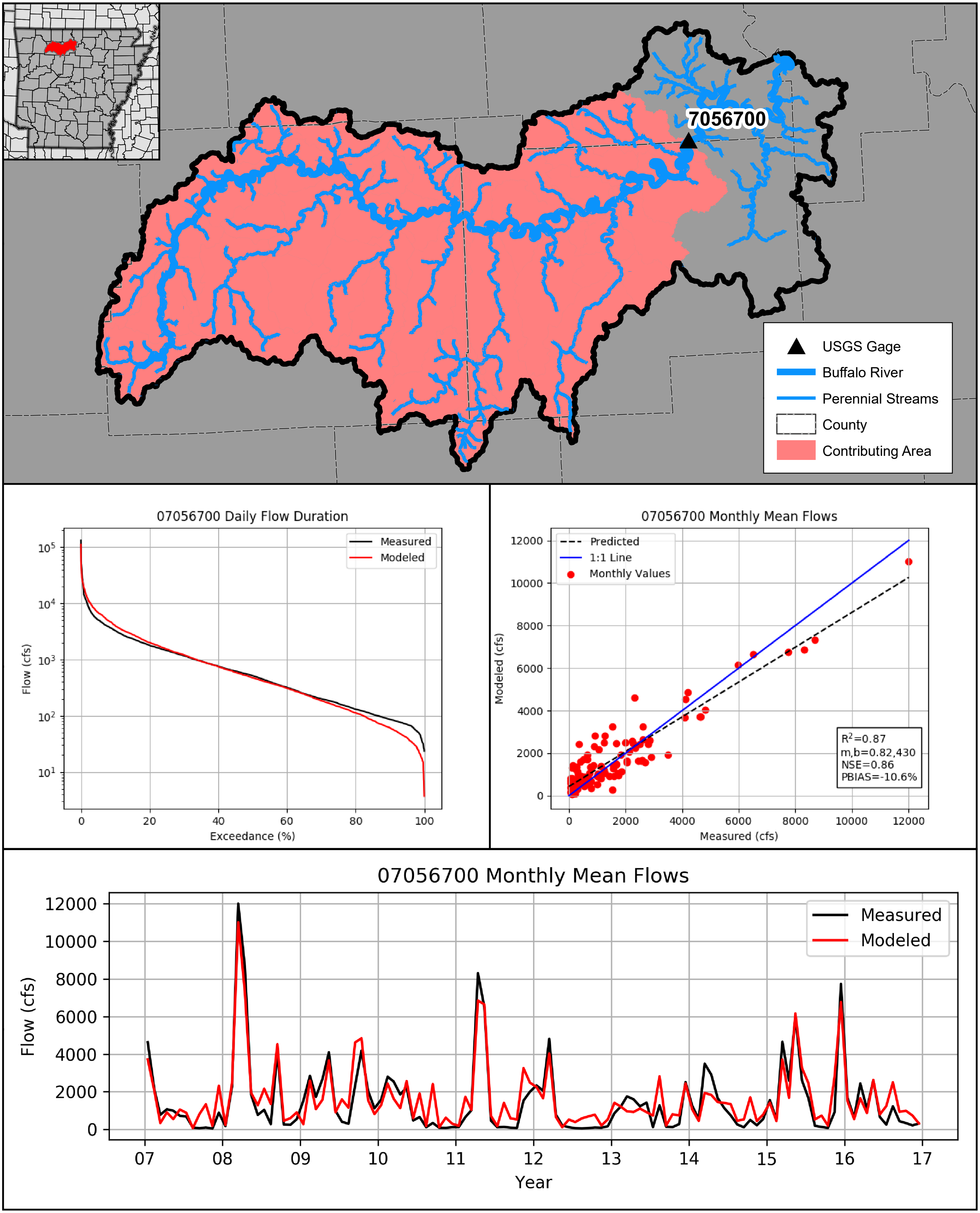
Hydrology Calibration Station 5 of 8



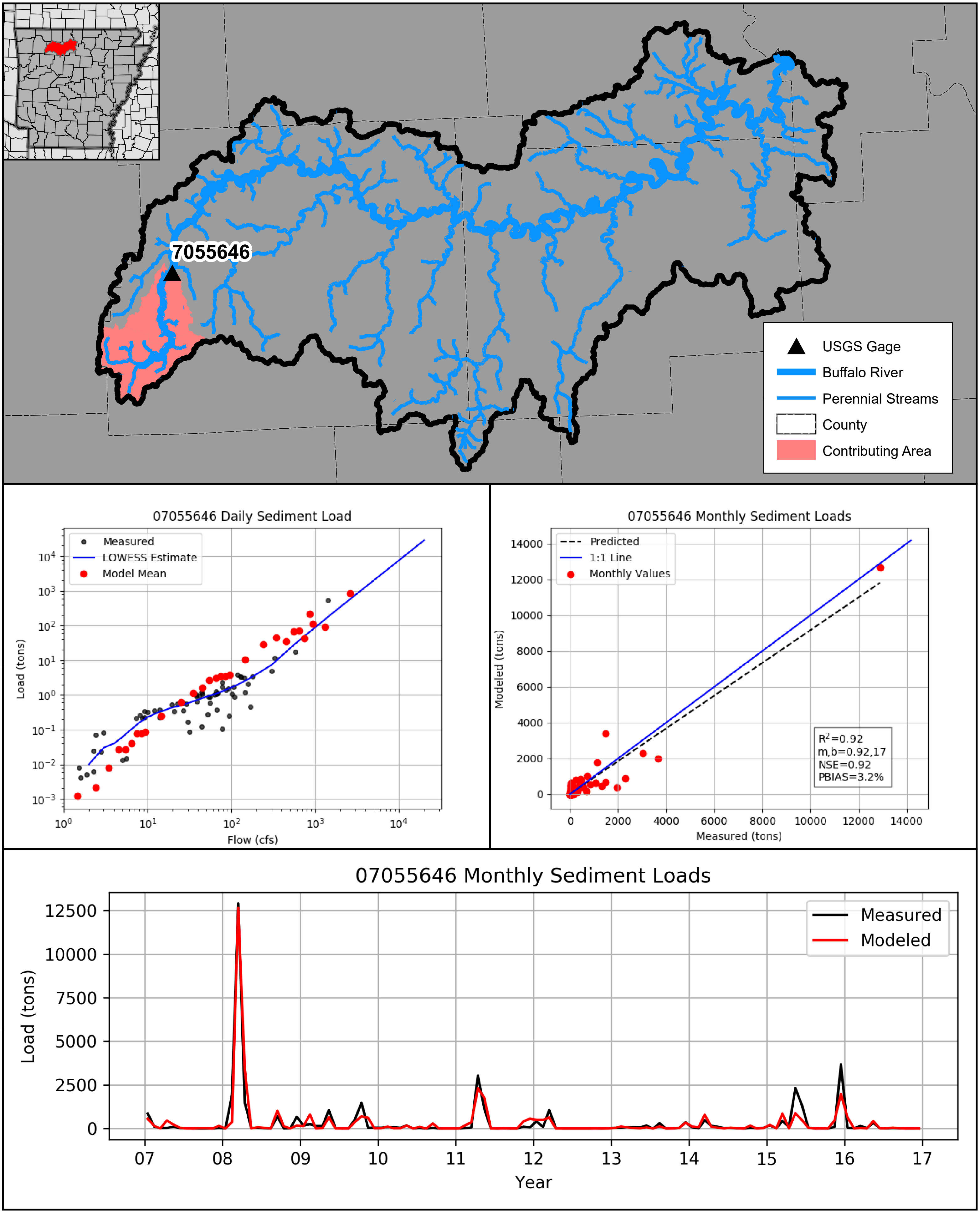
USGS 07056000 - Buffalo River near St. Joe, AR
Hydrology Calibration Station 6 of 8



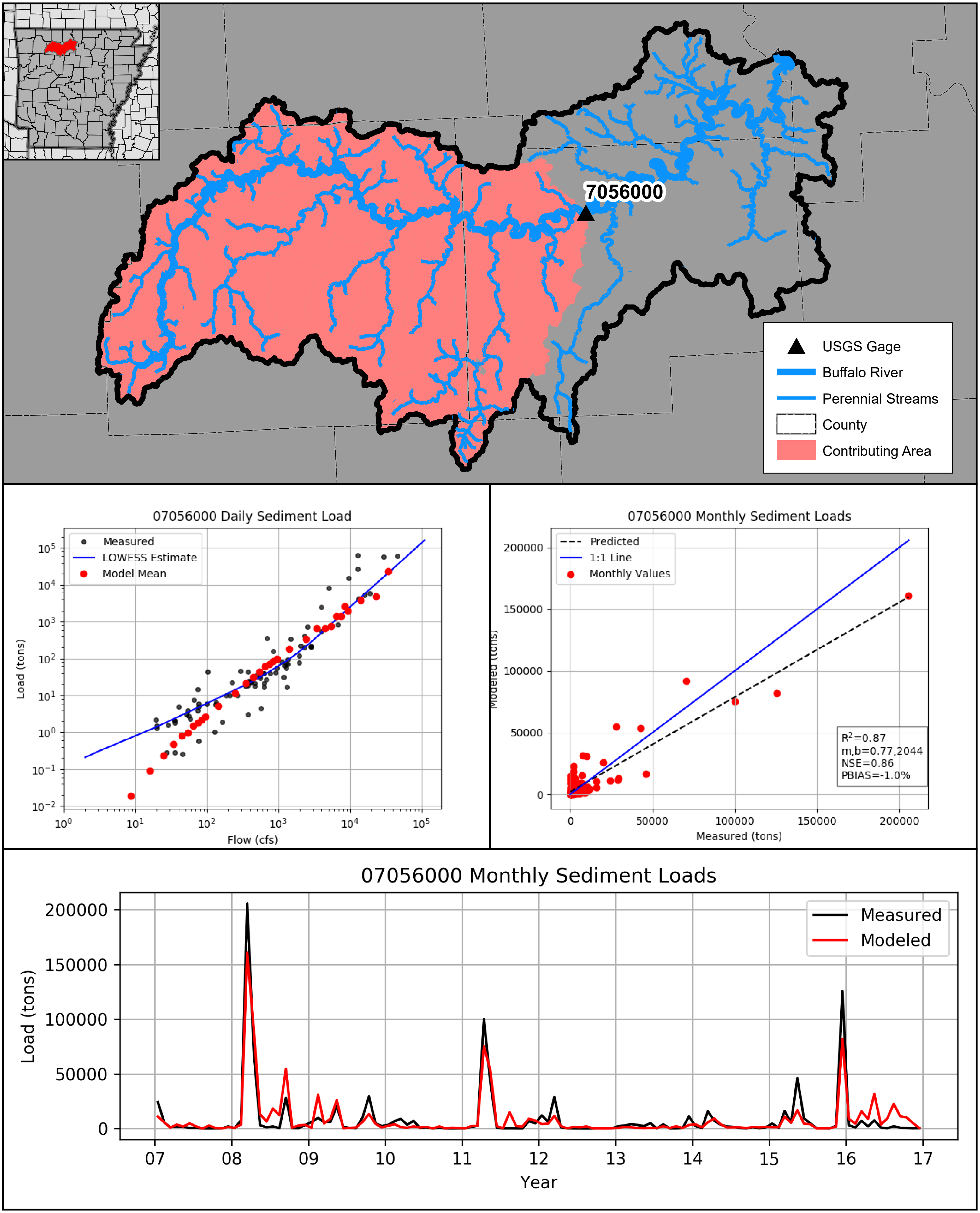
USGS 07056515 - Bear Creek near Silver Hill, AR
Hydrology Calibration Station 7 of 8



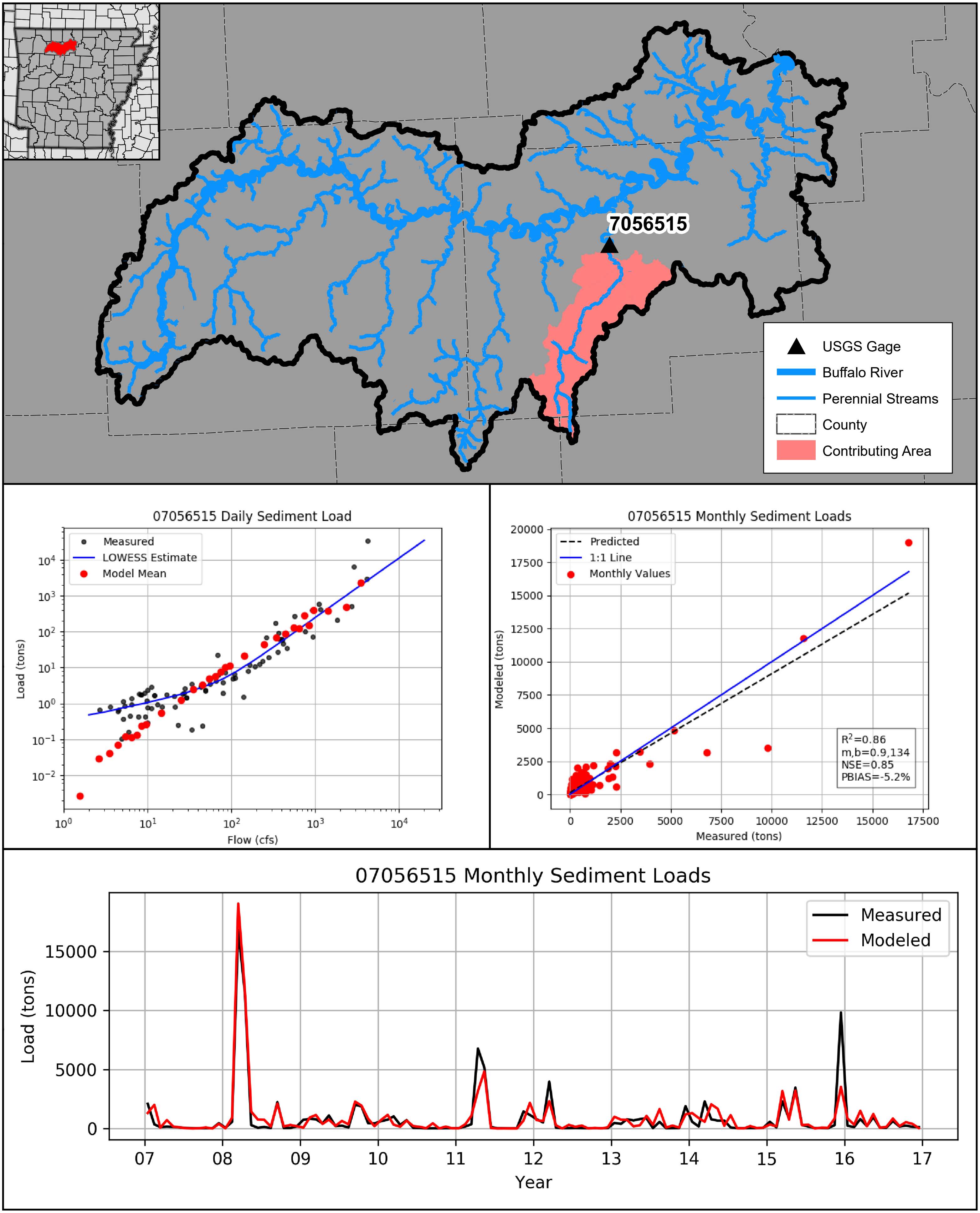
USGS 07056700 - Buffalo River near Harriet, AR
Hydrology Calibration Station 8 of 8



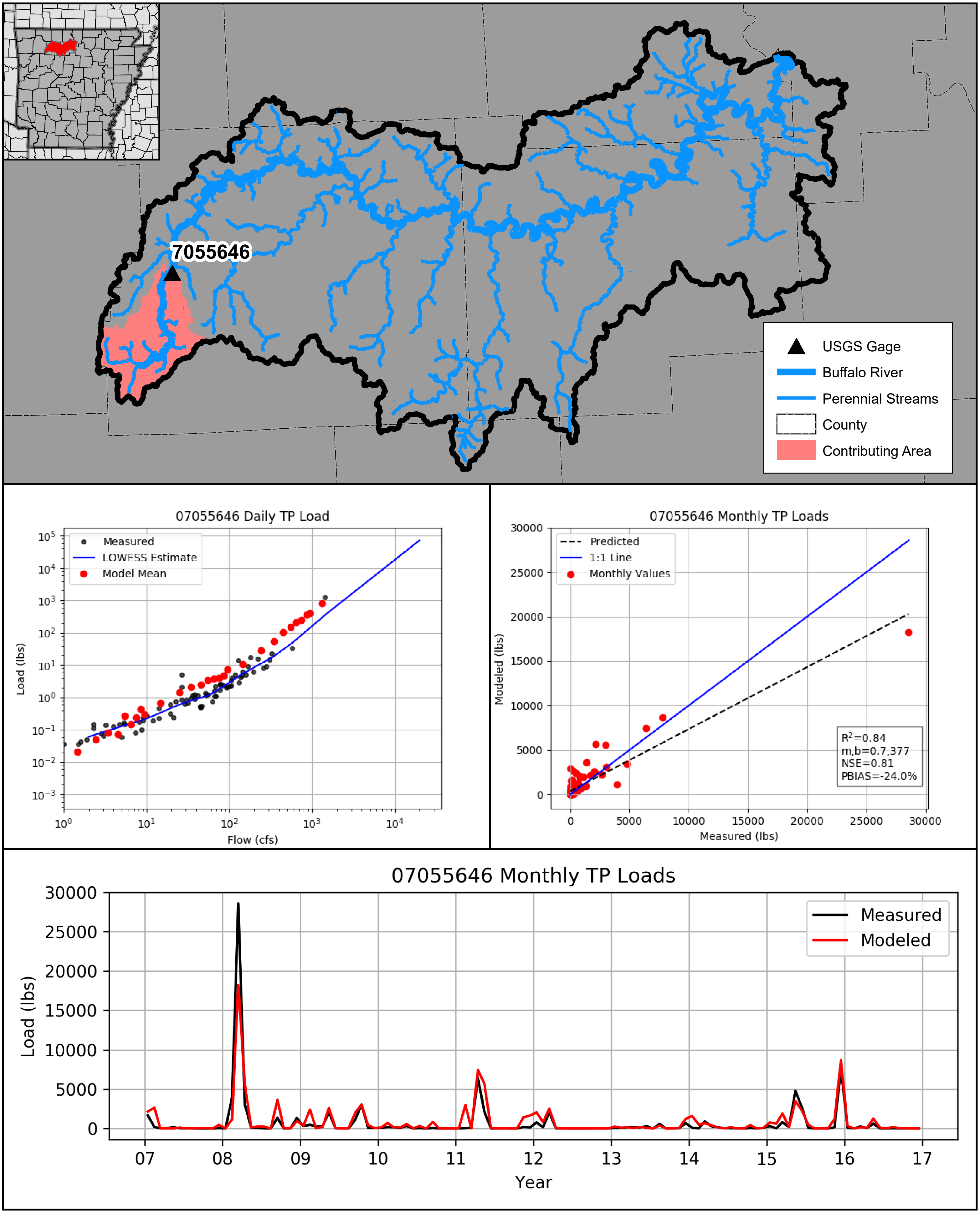
USGS 07055646 - Buffalo River near Boxley, AR
Sediment Calibration Station 1 of 3



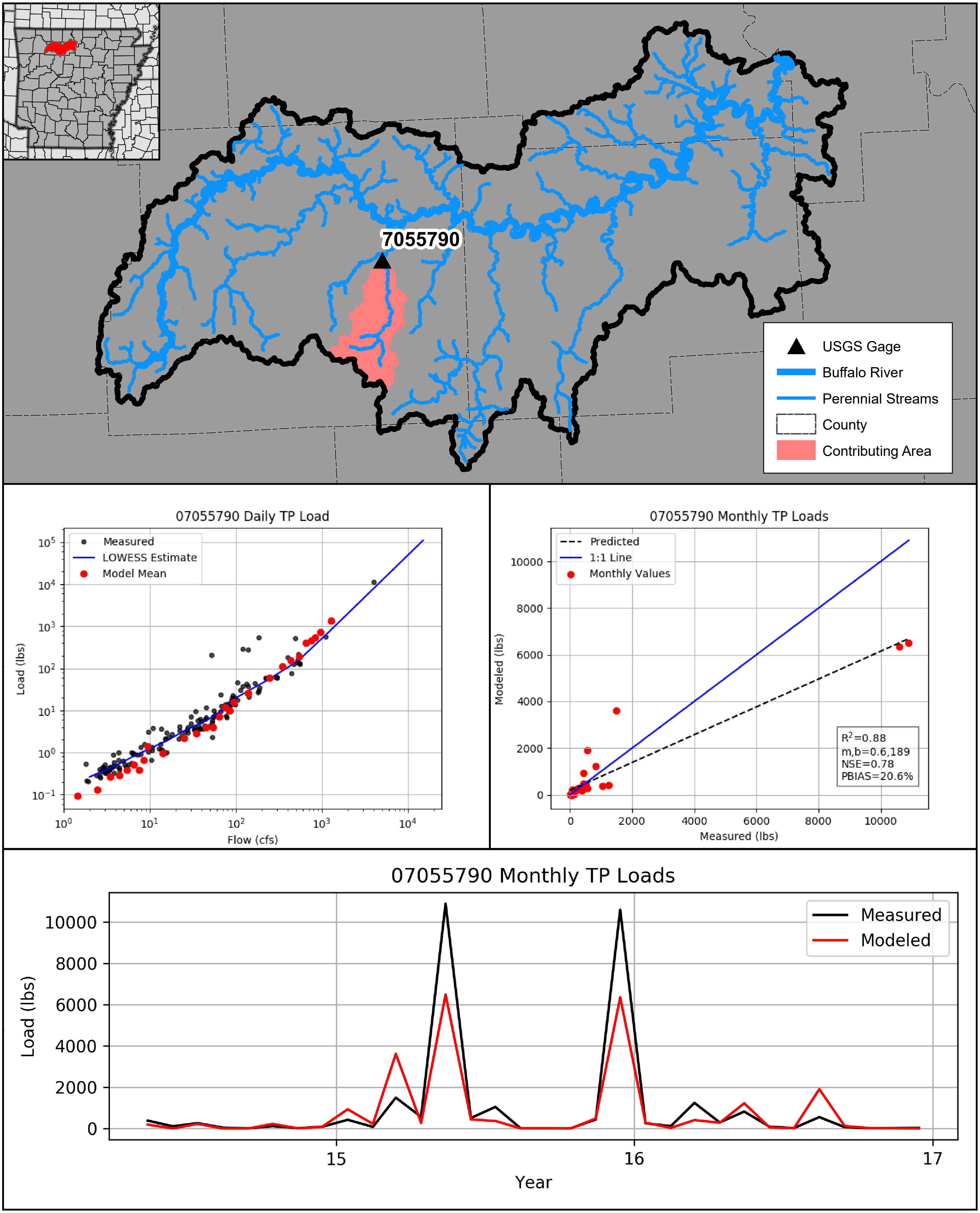
USGS 07056000 - Buffalo River near St. Joe, AR
Sediment Calibration Station 2 of 3



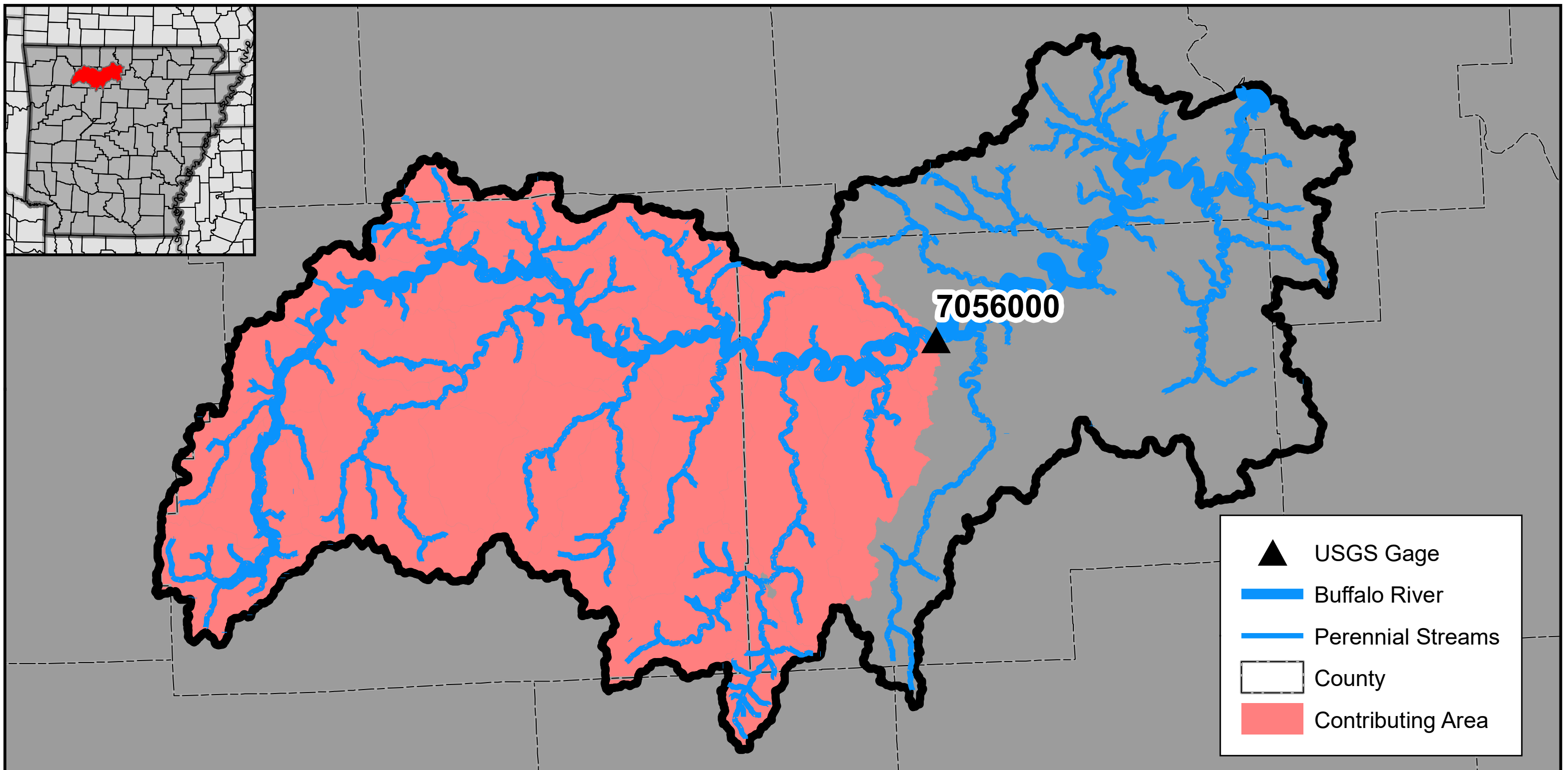
USGS 07056515 - Bear Creek near Silver Hill, AR
Sediment Calibration Station 3 of 3

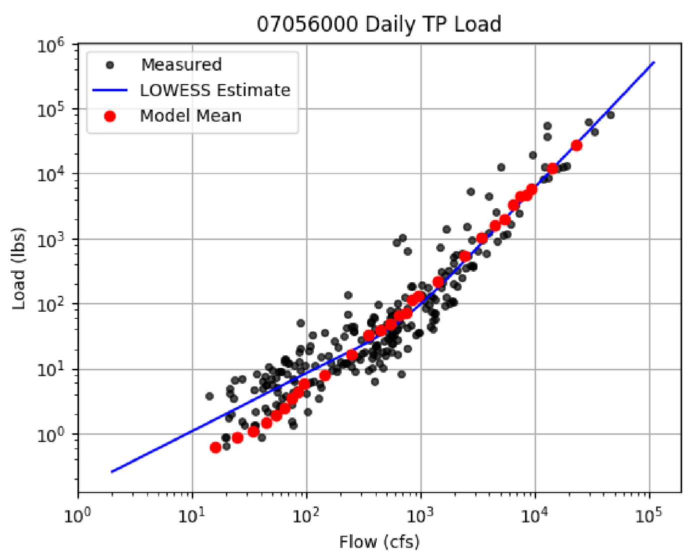


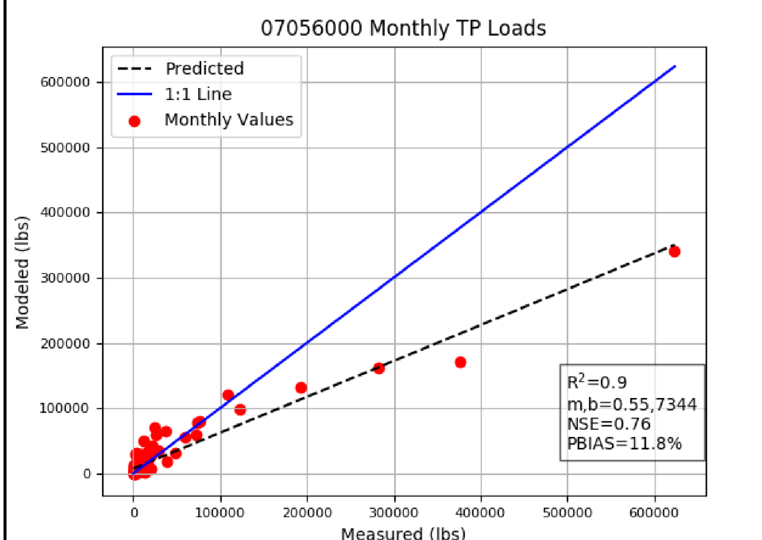
USGS 07055646 - Buffalo River near Boxley, AR
TP Calibration Station 1 of 4

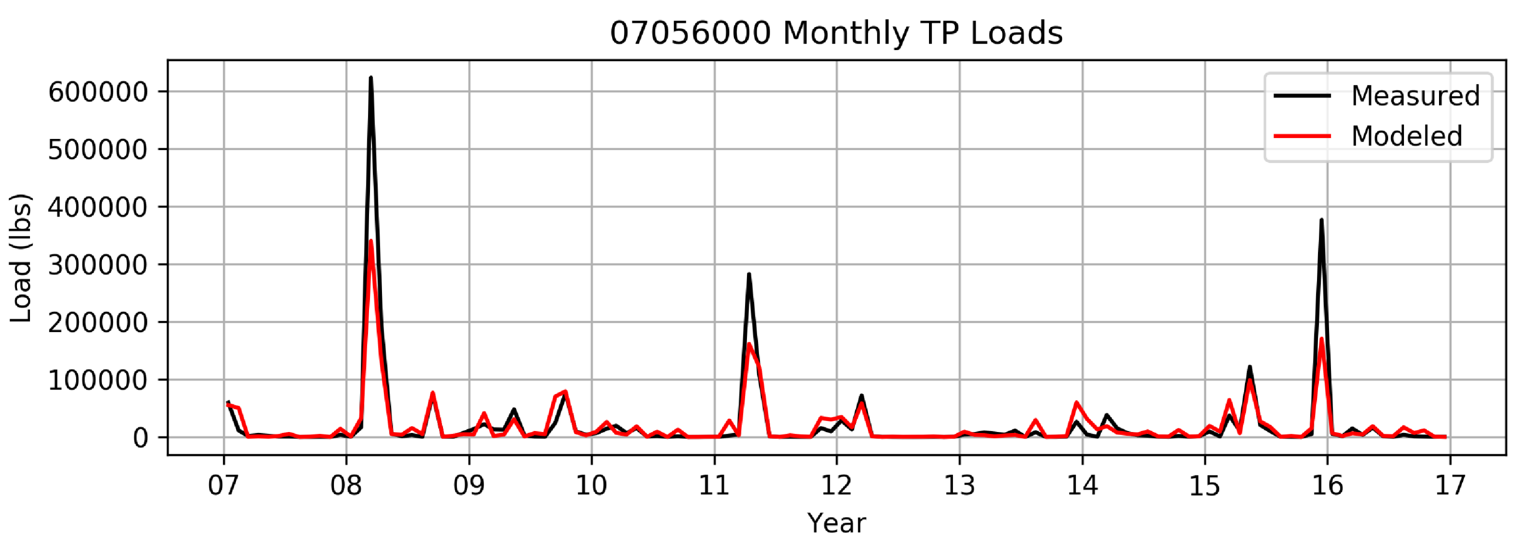


USGS 07055790 - Big Creek near Mt. Judea, AR
TP Calibration Station 2 of 4

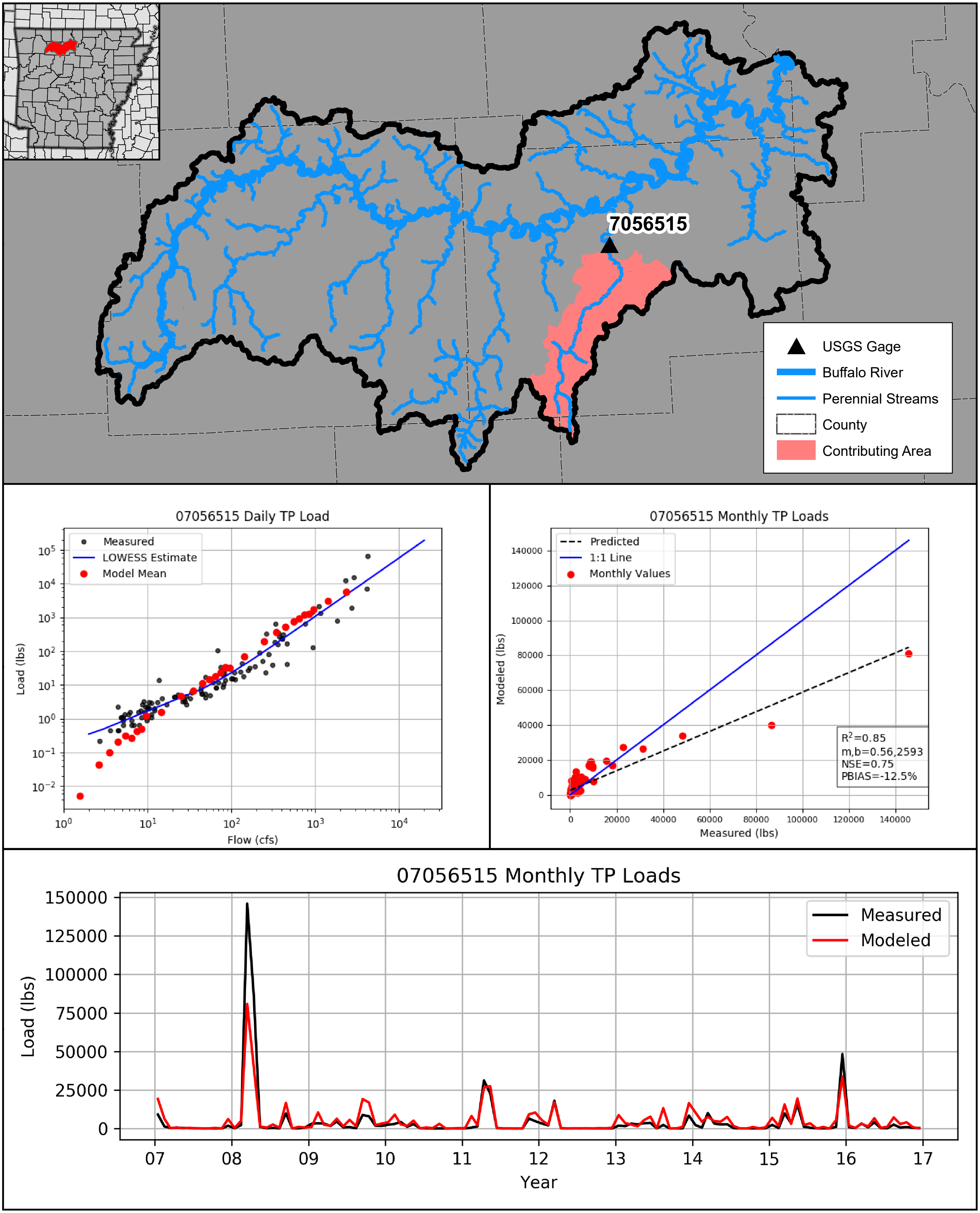




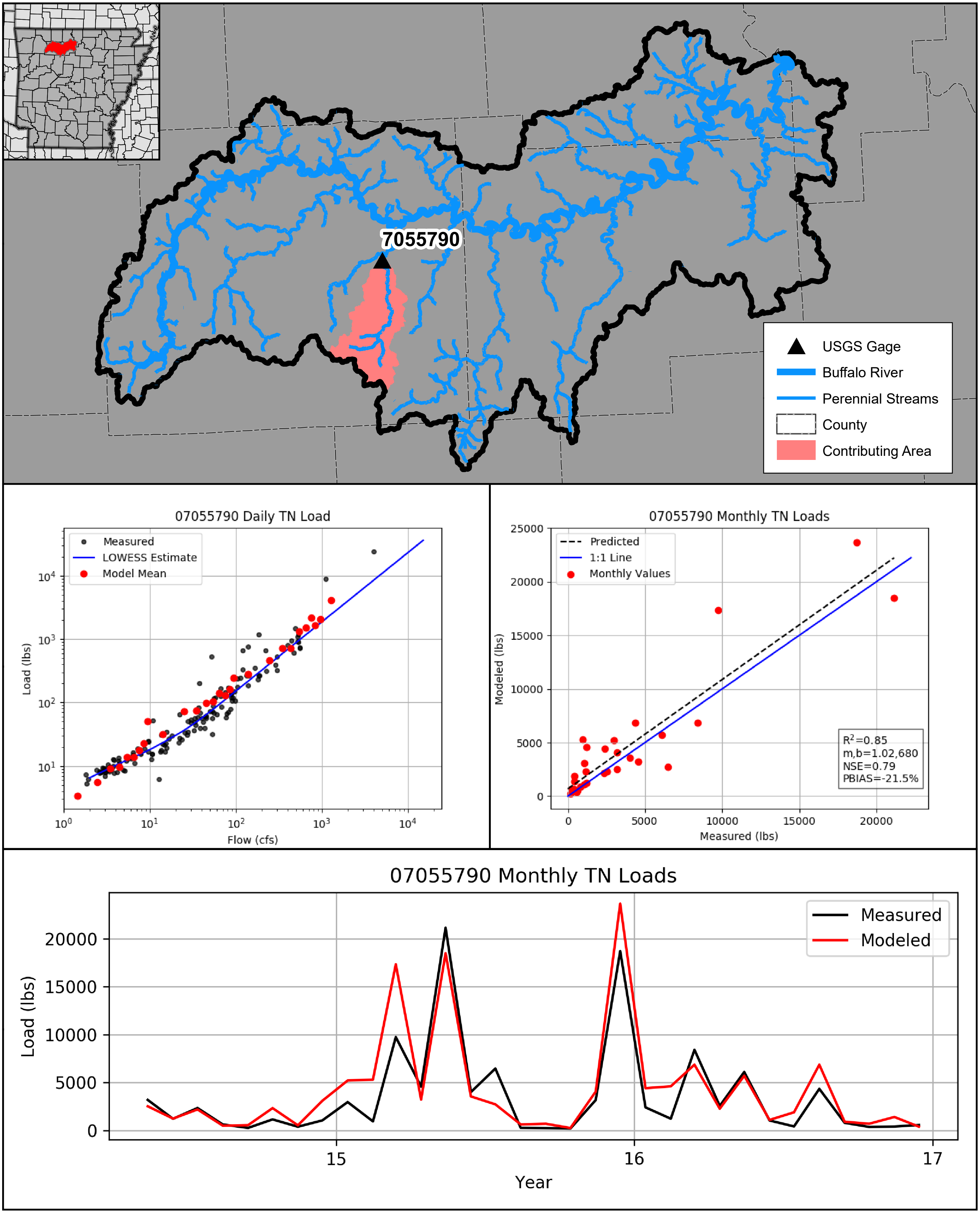




USGS 07056000 - Buffalo River near St. Joe, AR
TP Calibration Station 3 of 4



USGS 07056515 - Bear Creek near Silver Hill, AR
TP Calibration Station 4 of 4



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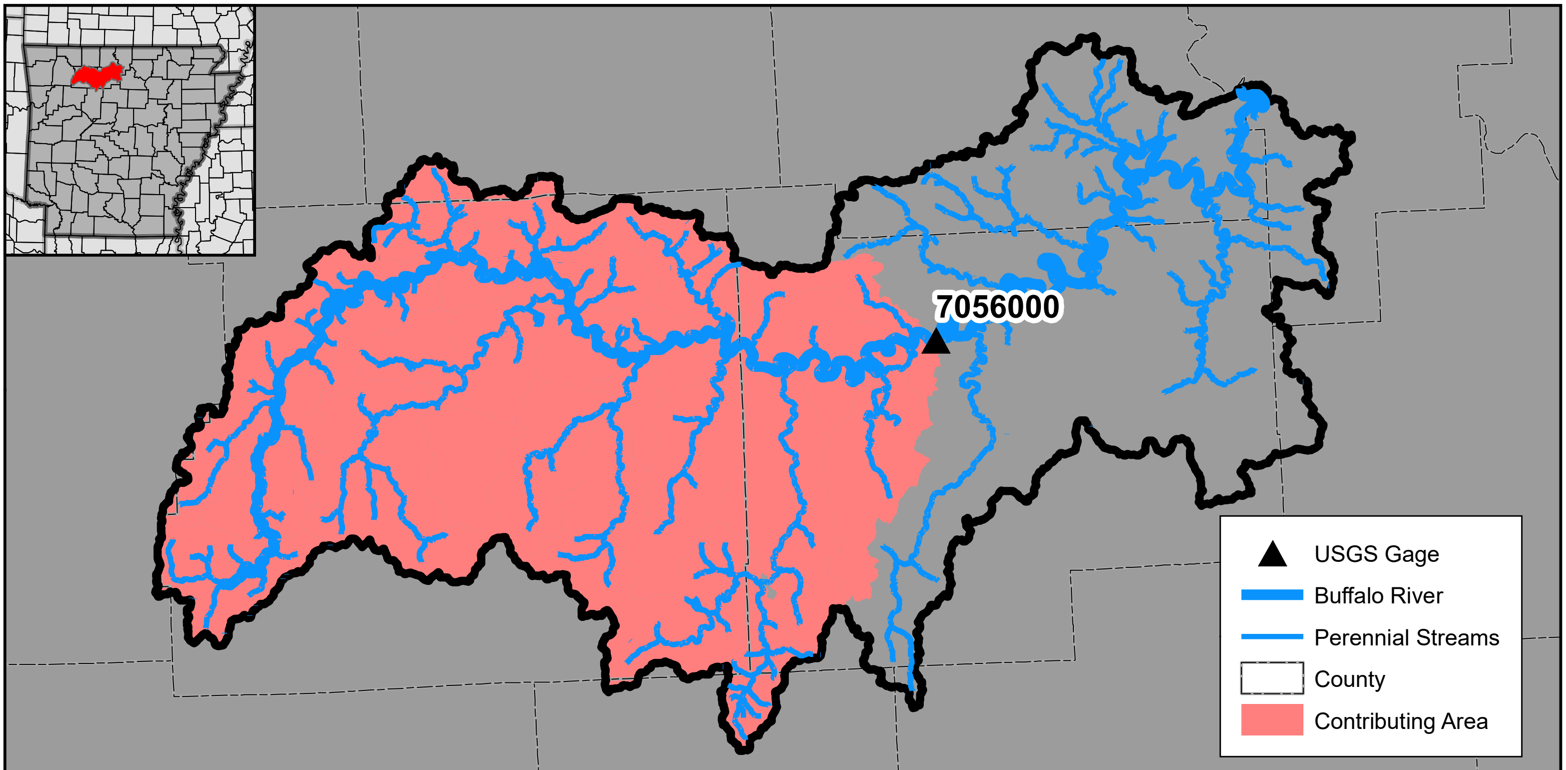
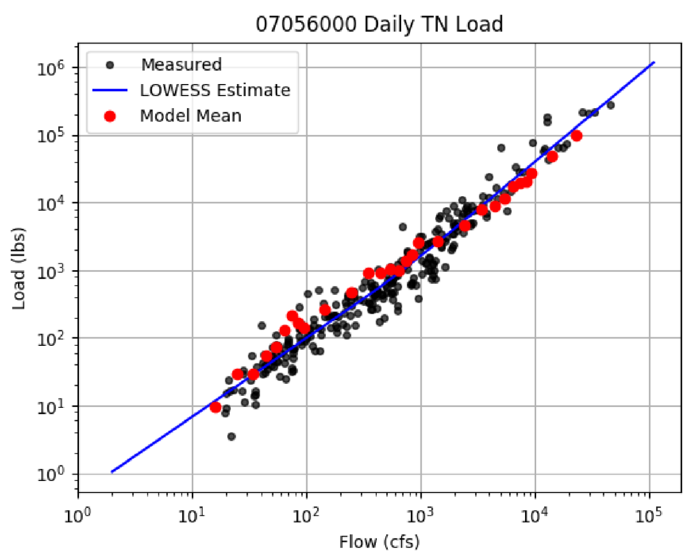
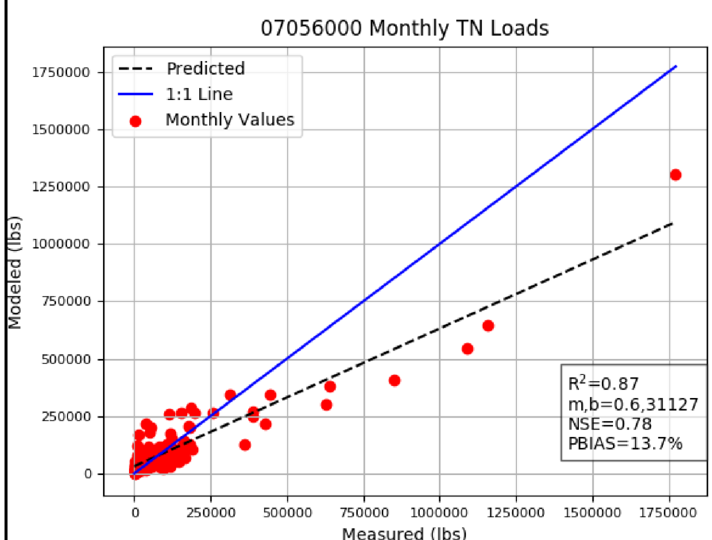
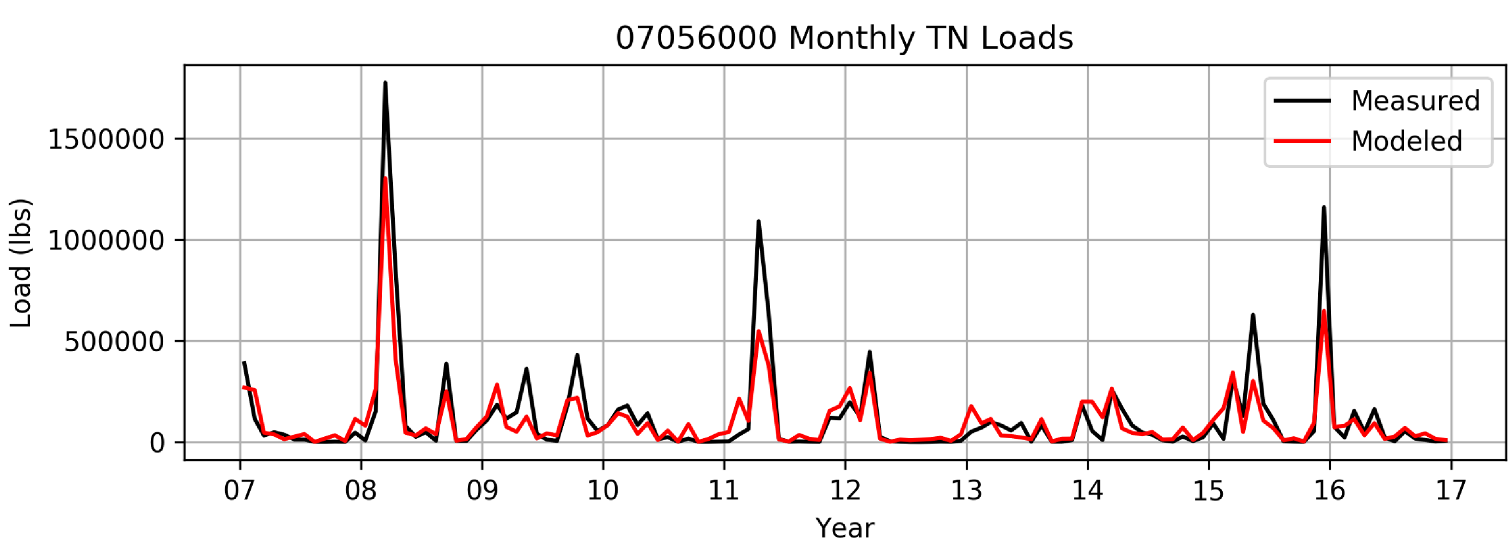
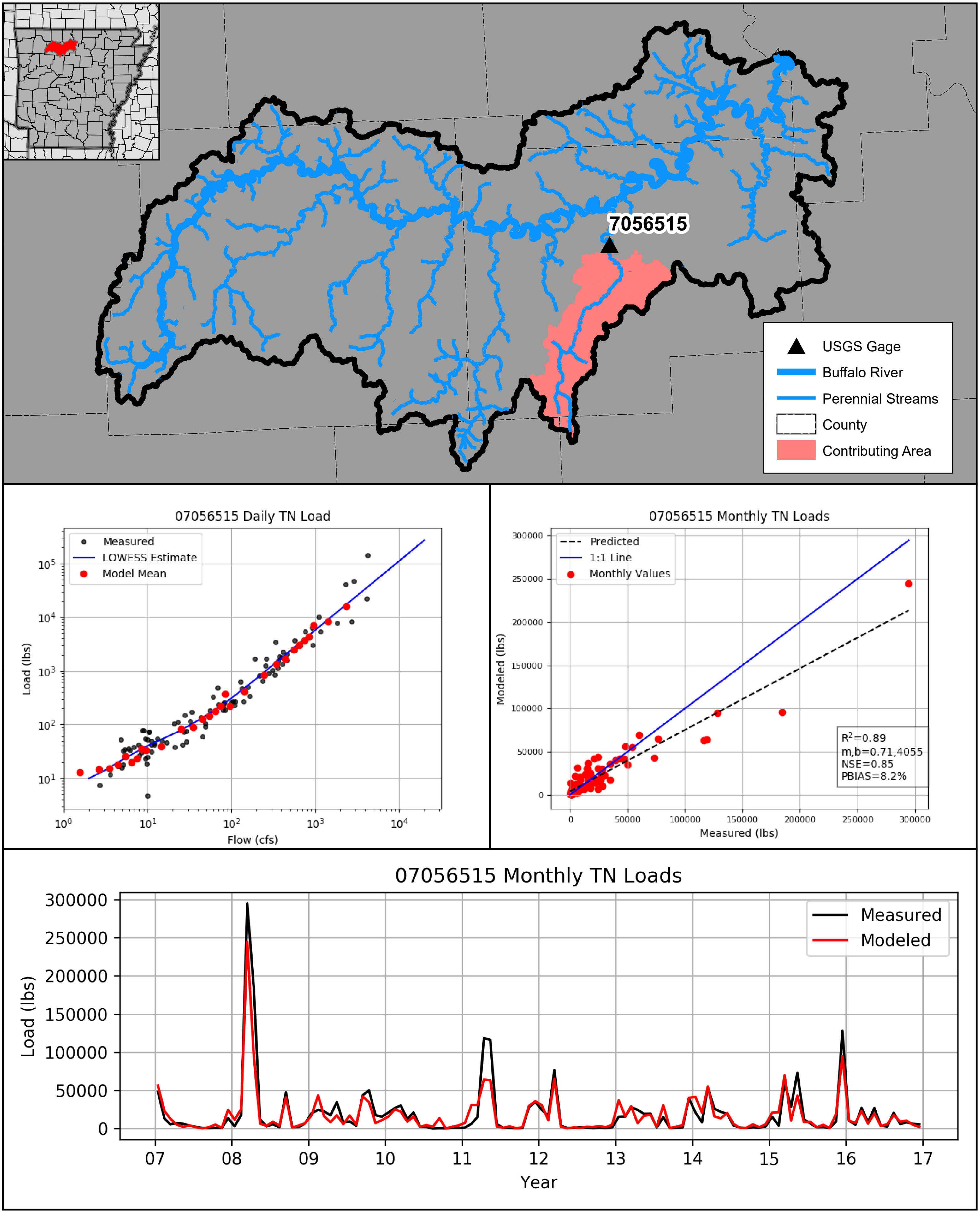








USGS 07056000 - Buffalo River near St. Joe, AR
TN Calibration Station 2 of 3

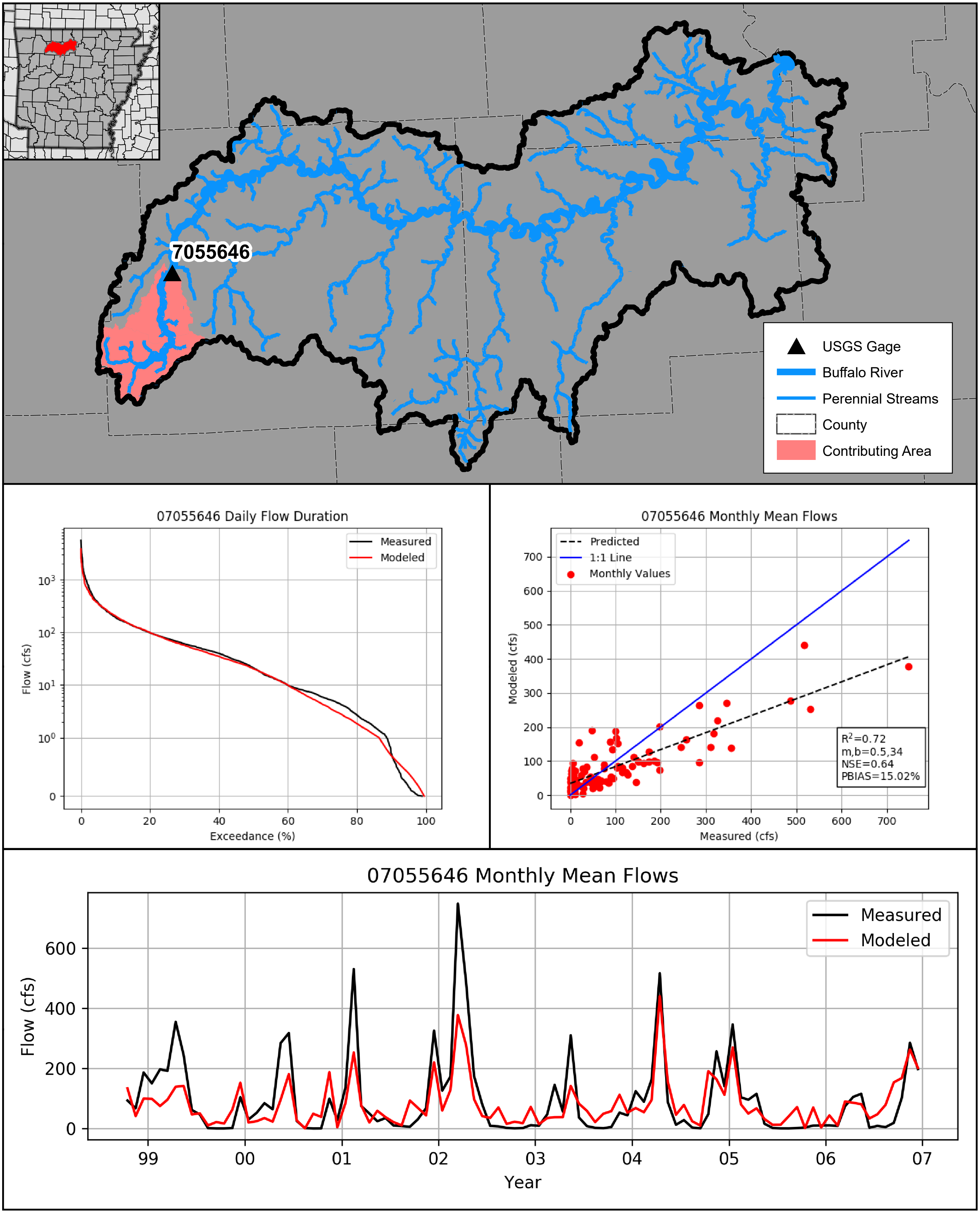


USGS 07056515 - Bear Creek near Silver Hill, AR

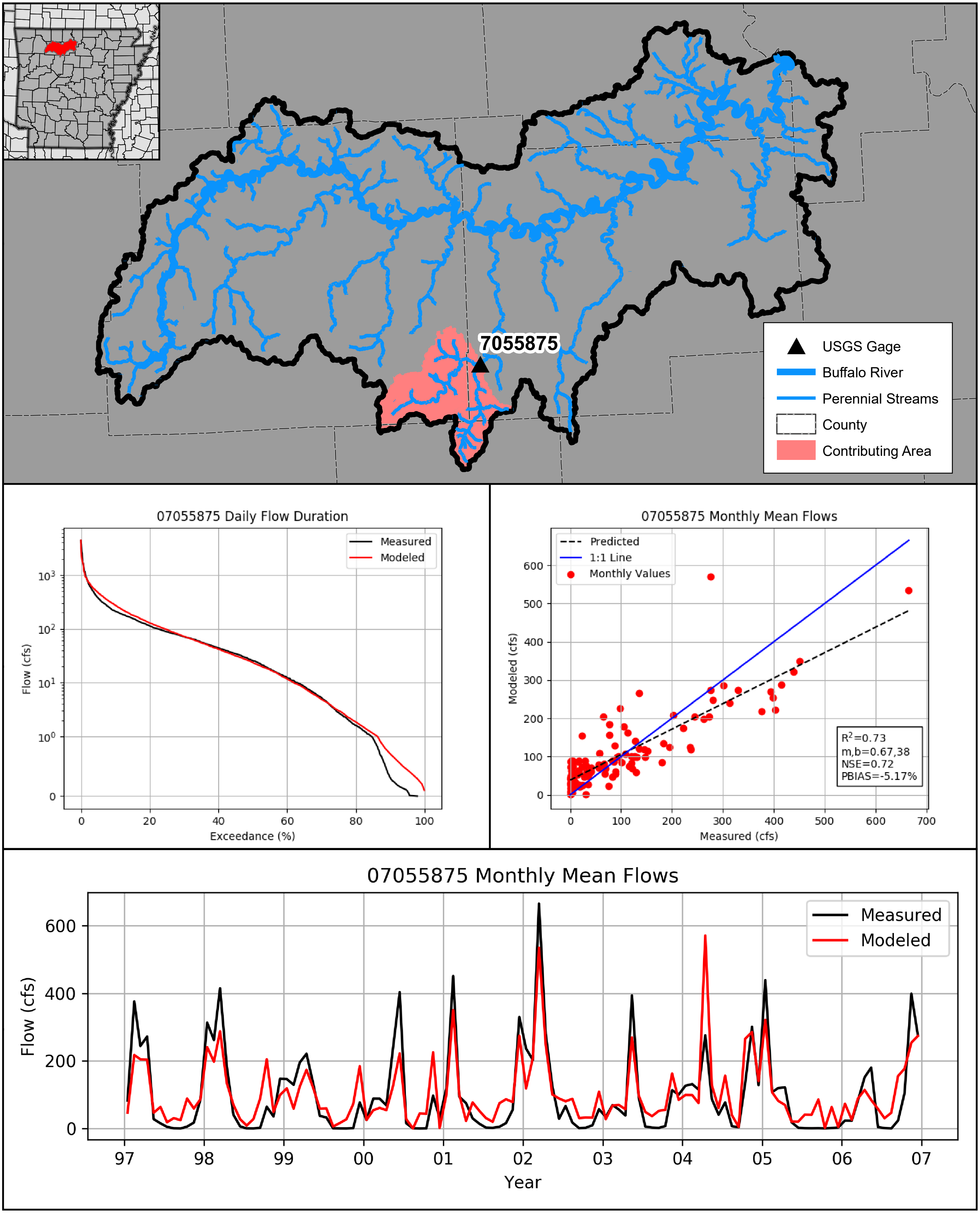
TN Calibration Station 3 of 3

APPENDIX D

Validation Plots

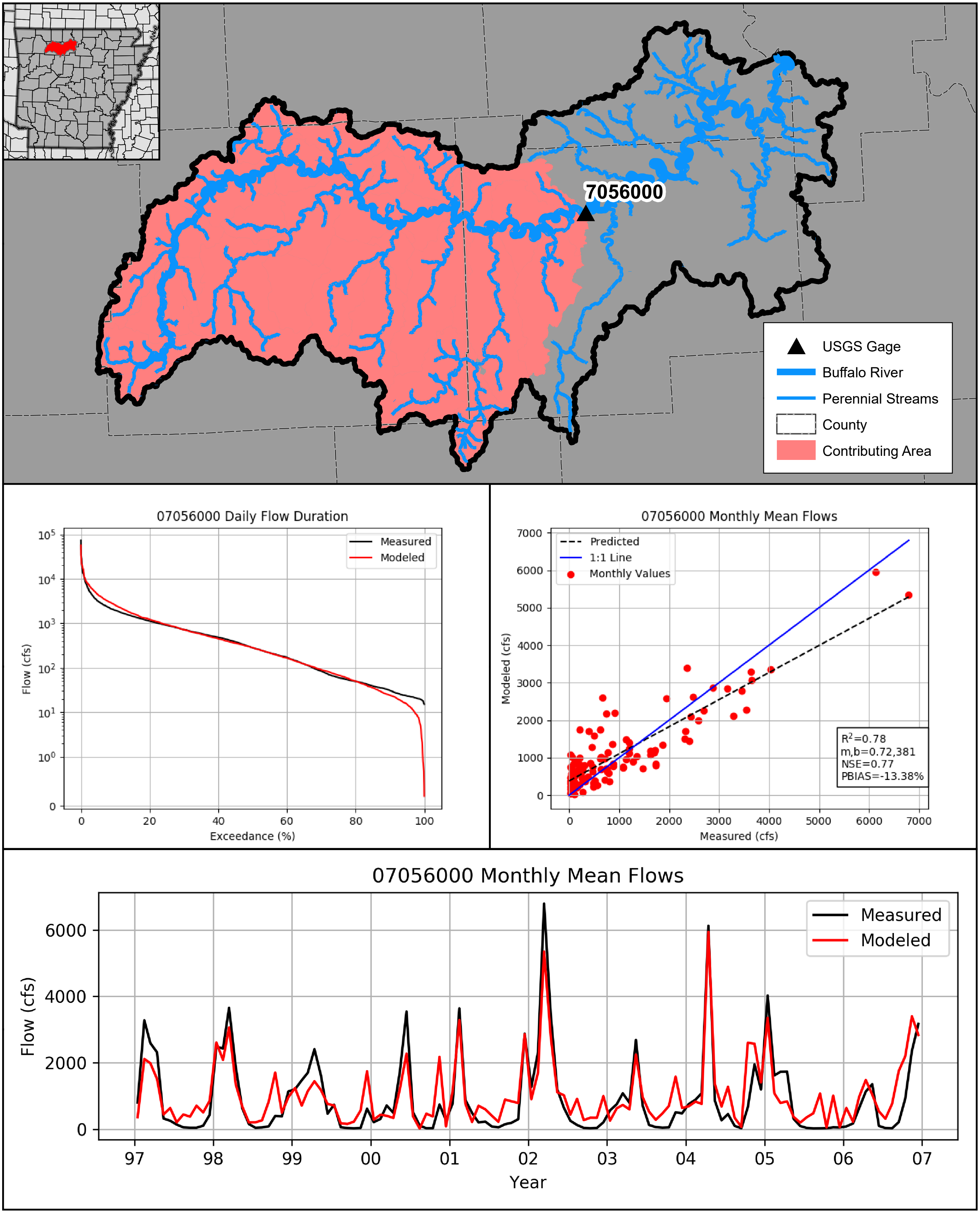


USGS 07055646 - Buffalo River near Boxley, AR
Hydrology Validation Station 1 of 4

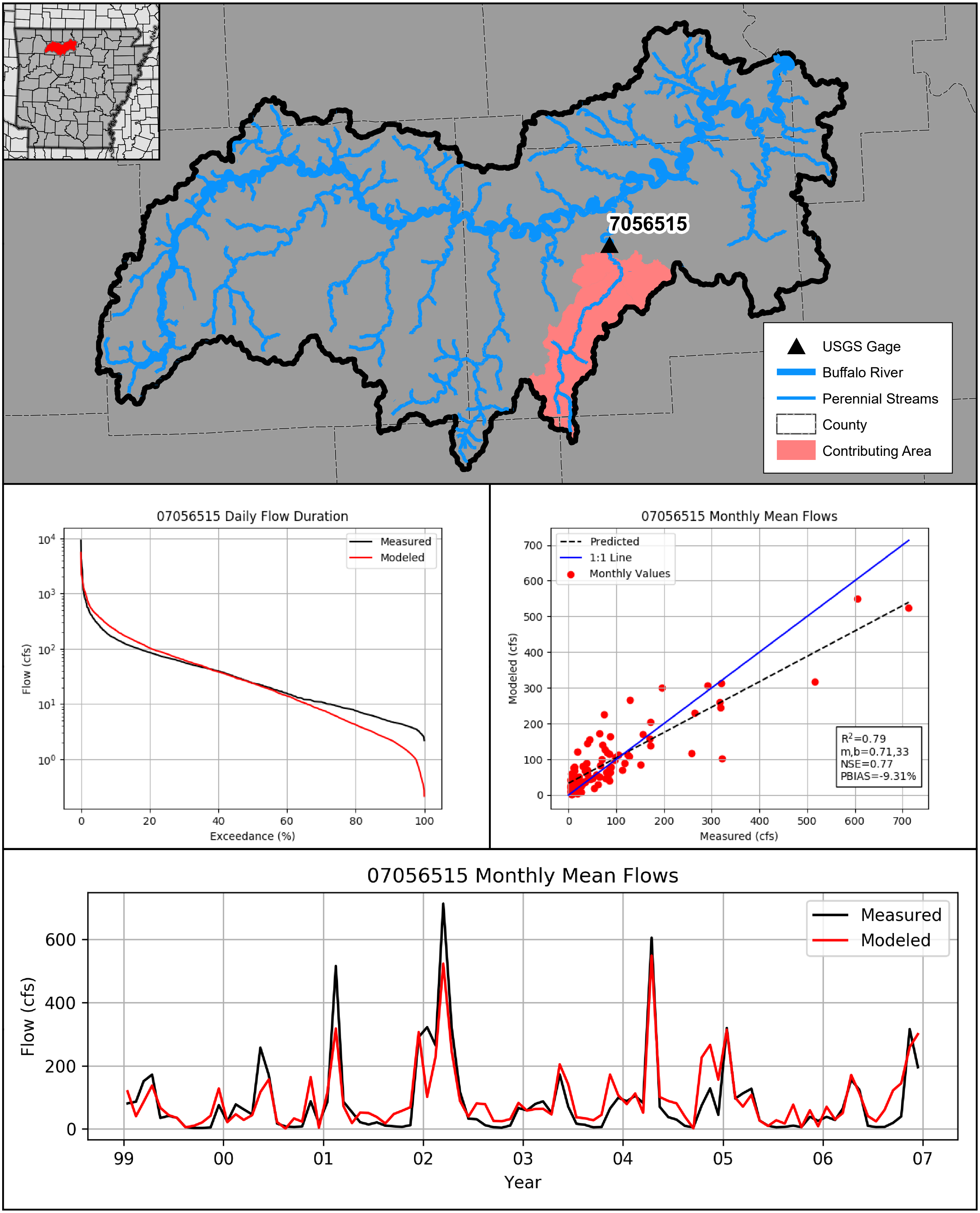


USGS 07055875 - Richland Creek near Witts Spring, AR

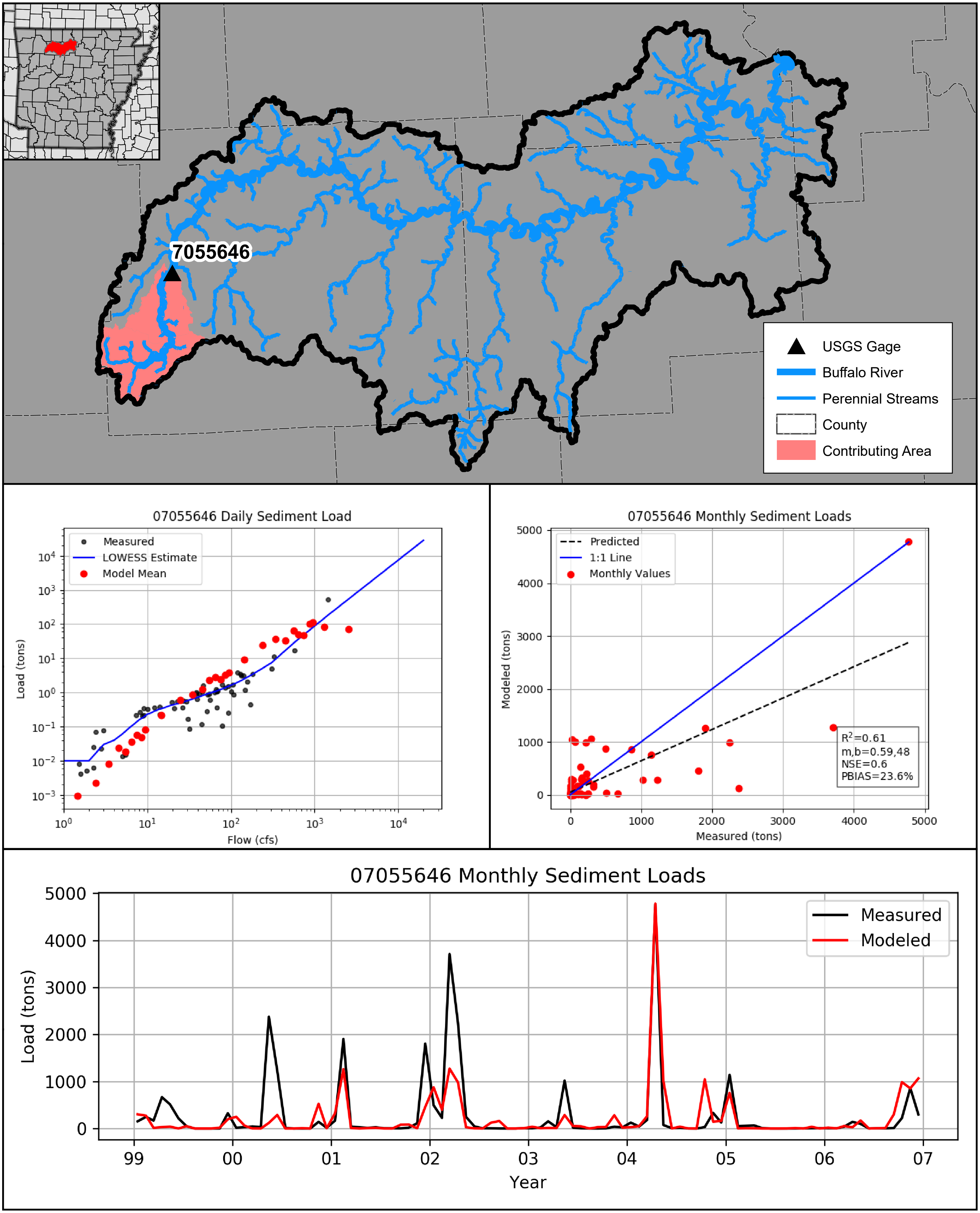
Hydrology Validation Station 2 of 4



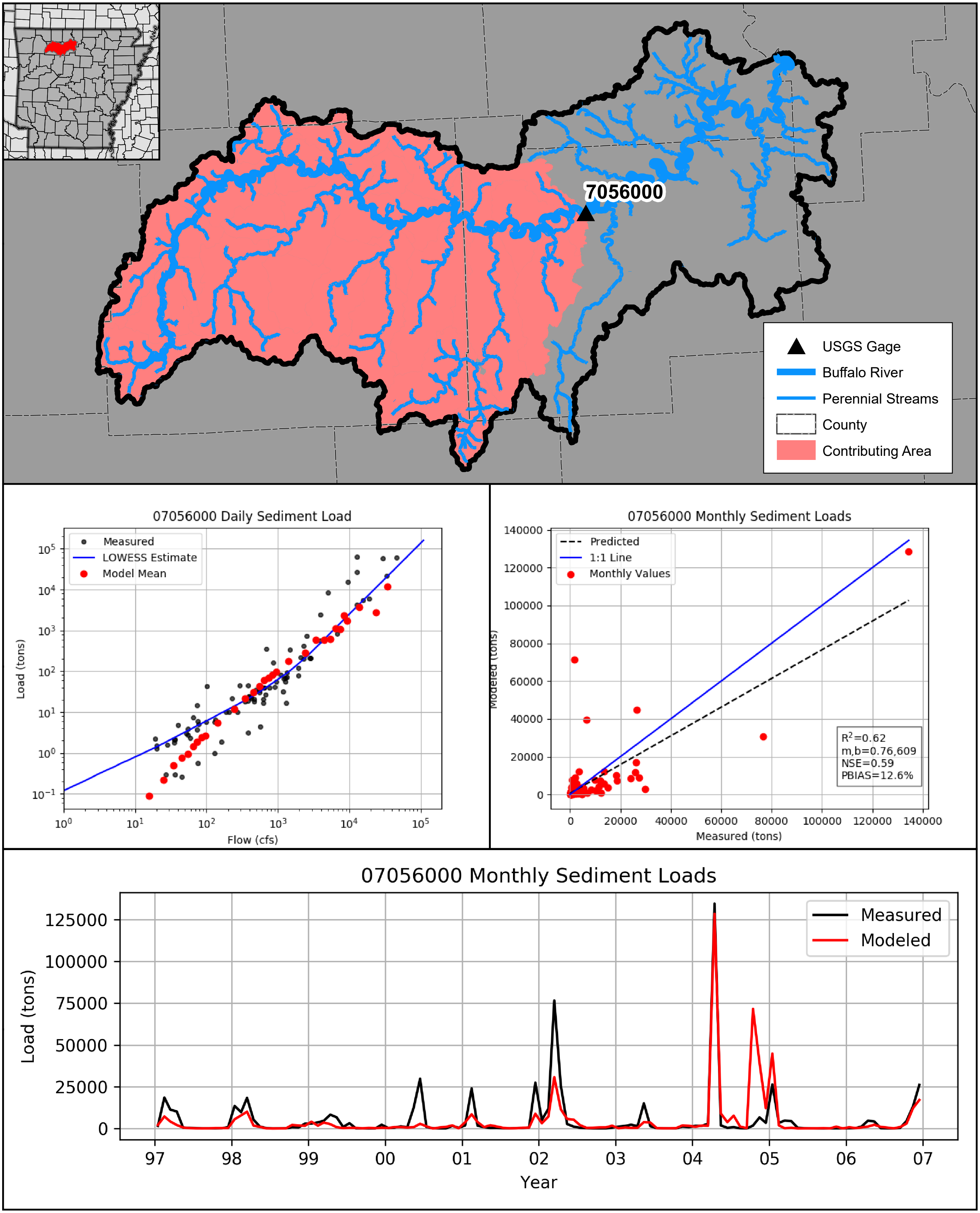
USGS 07056000 - Buffalo River near St. Joe, AR
Hydrology Validation Station 3 of 4



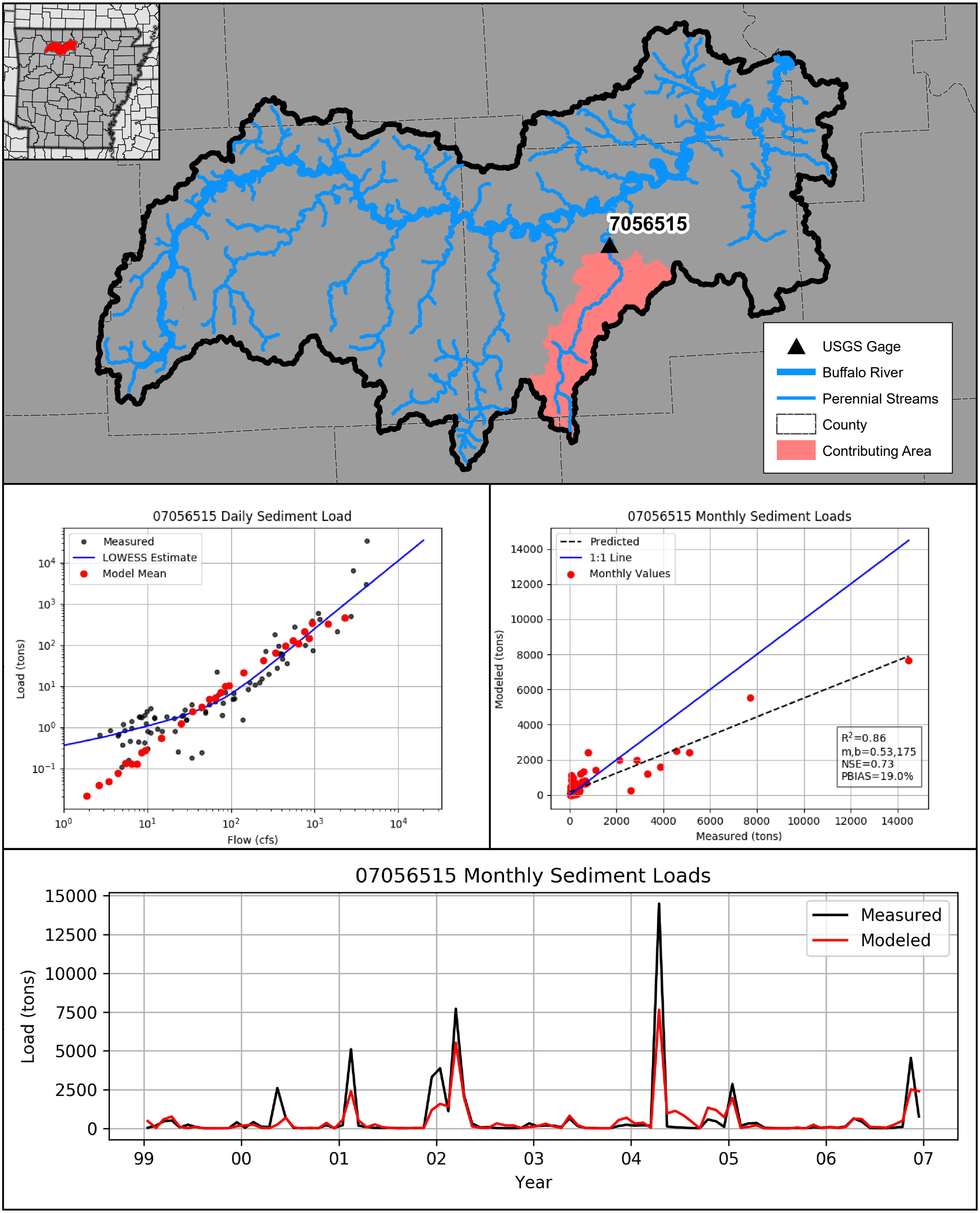
USGS 07056515 - Bear Creek near Silver Hill, AR
Hydrology Validation Station 4 of 4



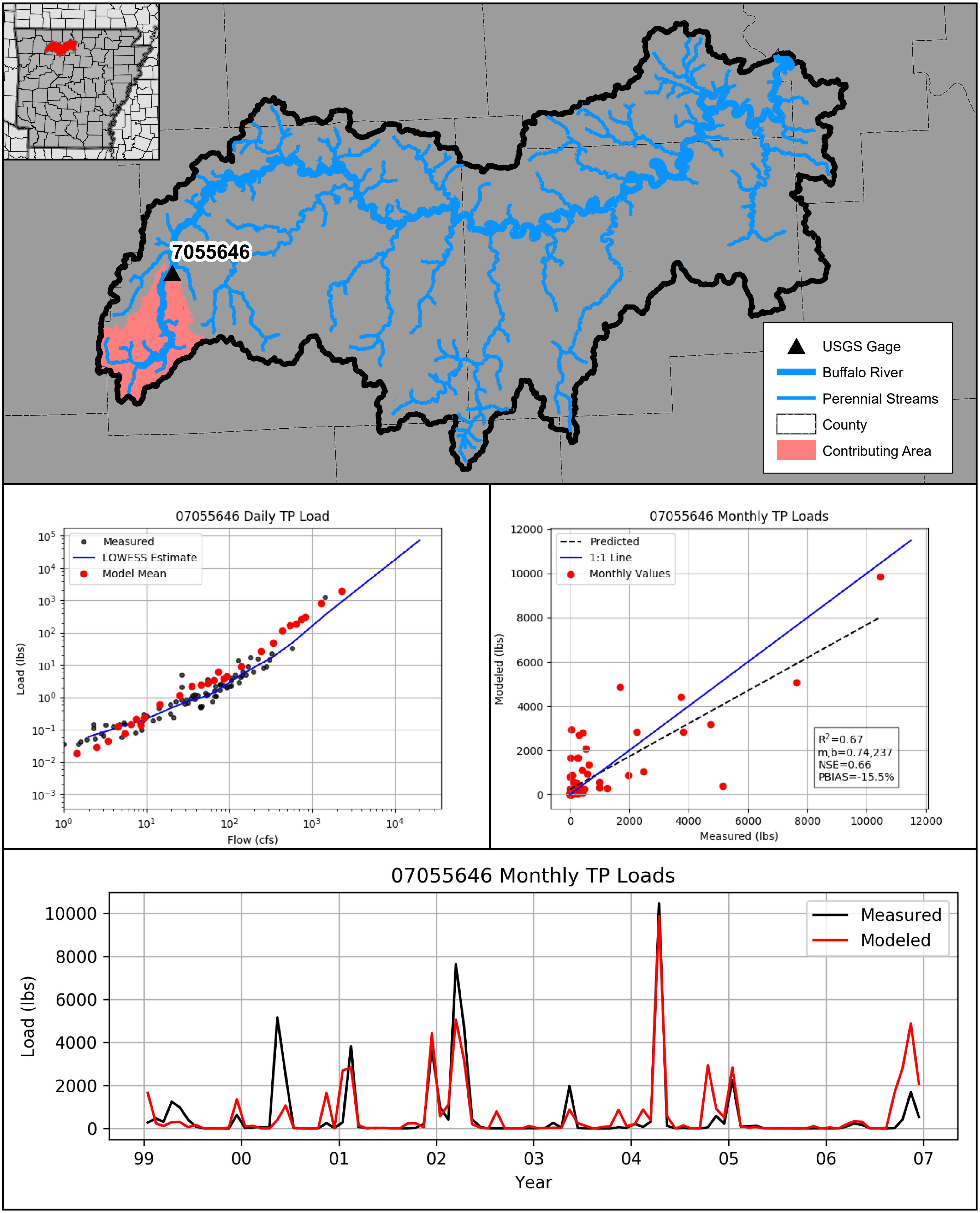
USGS 07055646 - Buffalo River near Boxley, AR
Sediment Validation Station 1 of 3



USGS 07056000 - Buffalo River near St. Joe, AR
Sediment Validation Station 2 of 3



USGS 07056515 - Bear Creek near Silver Hill, AR
Sediment Validation Station 3 of 3



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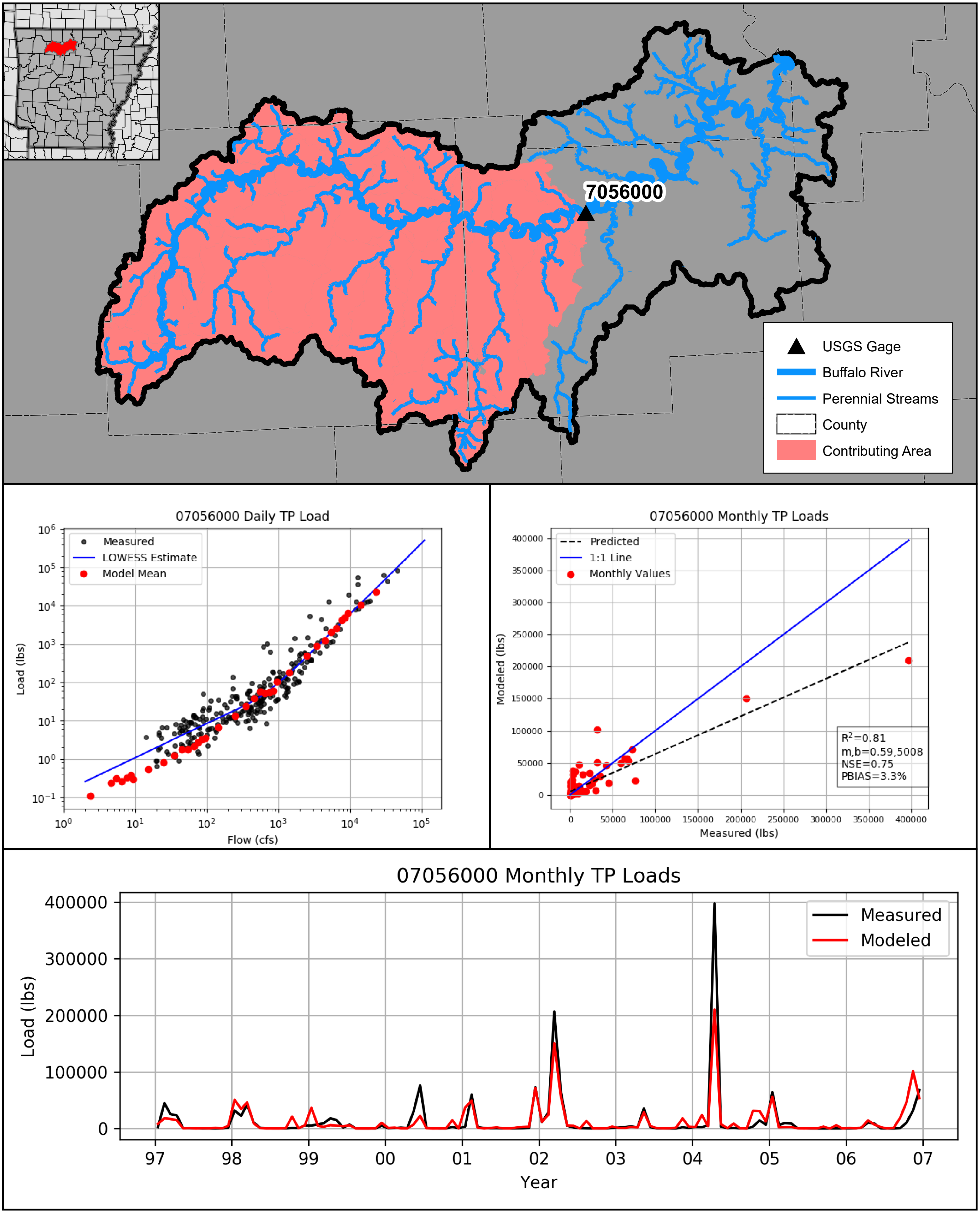
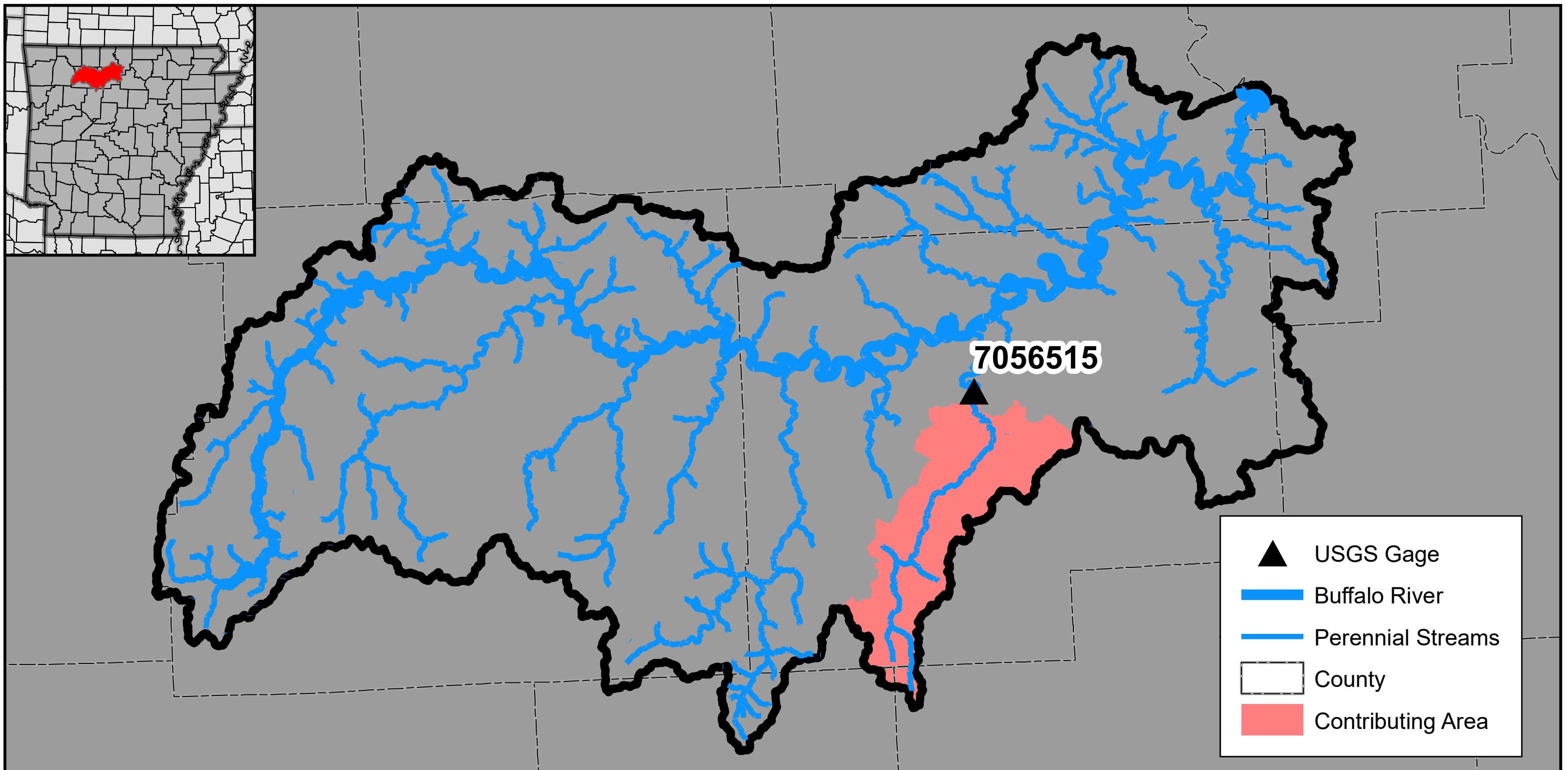
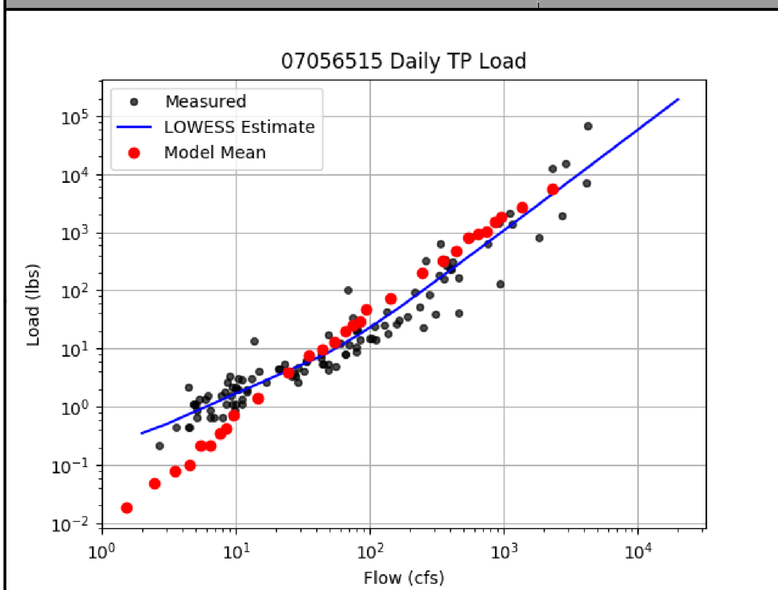
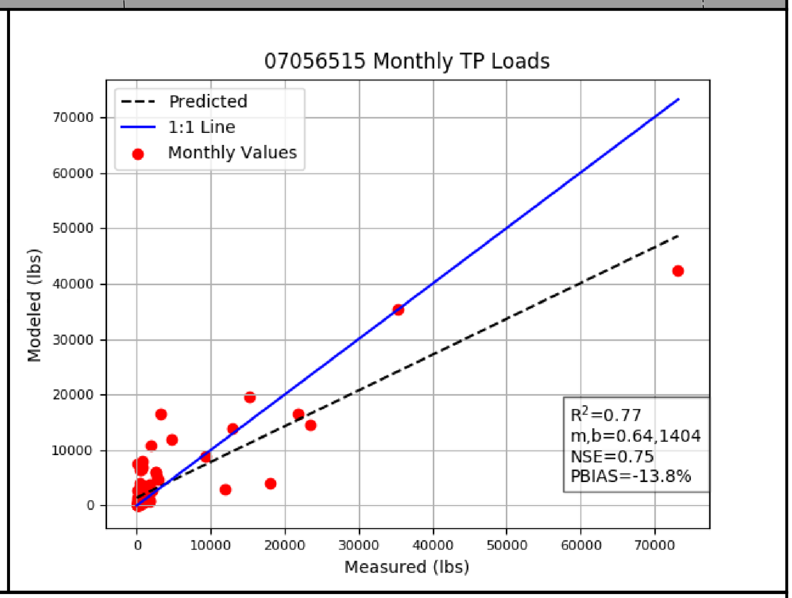
TP Validation Station 1 of 3

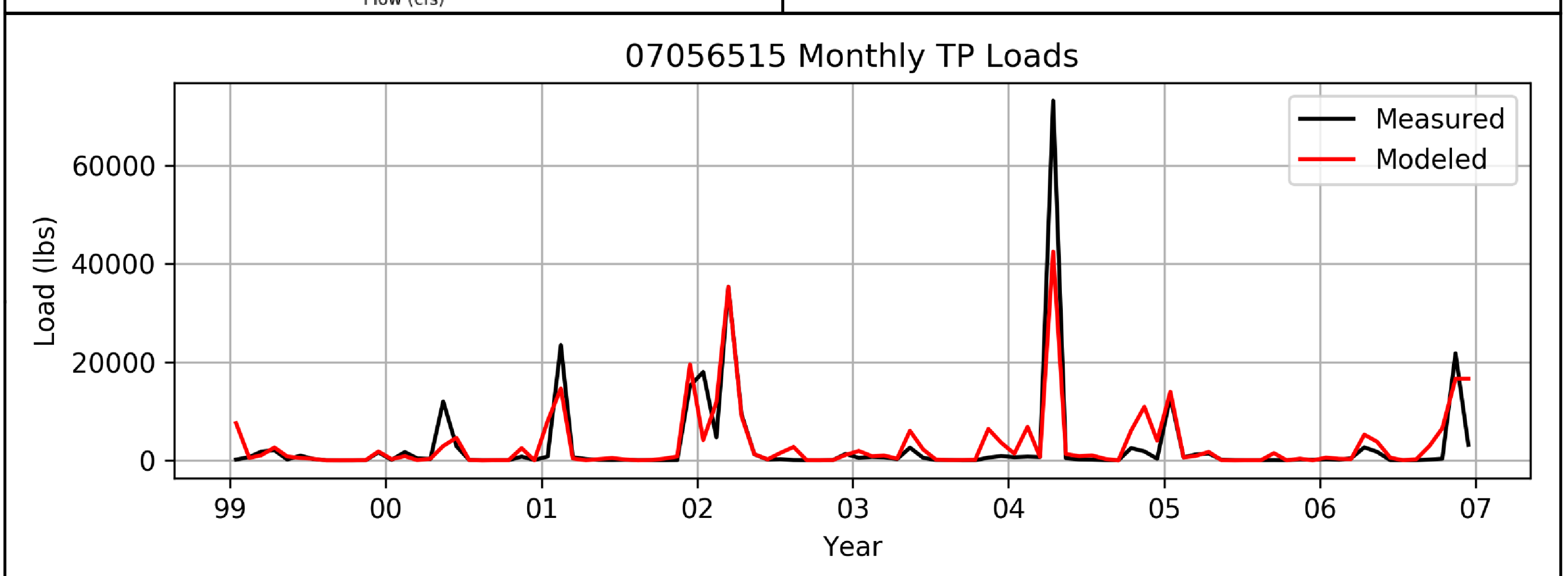


USGS 07056000 - Buffalo River near St. Joe, AR
TP Validation Station 2 of 3

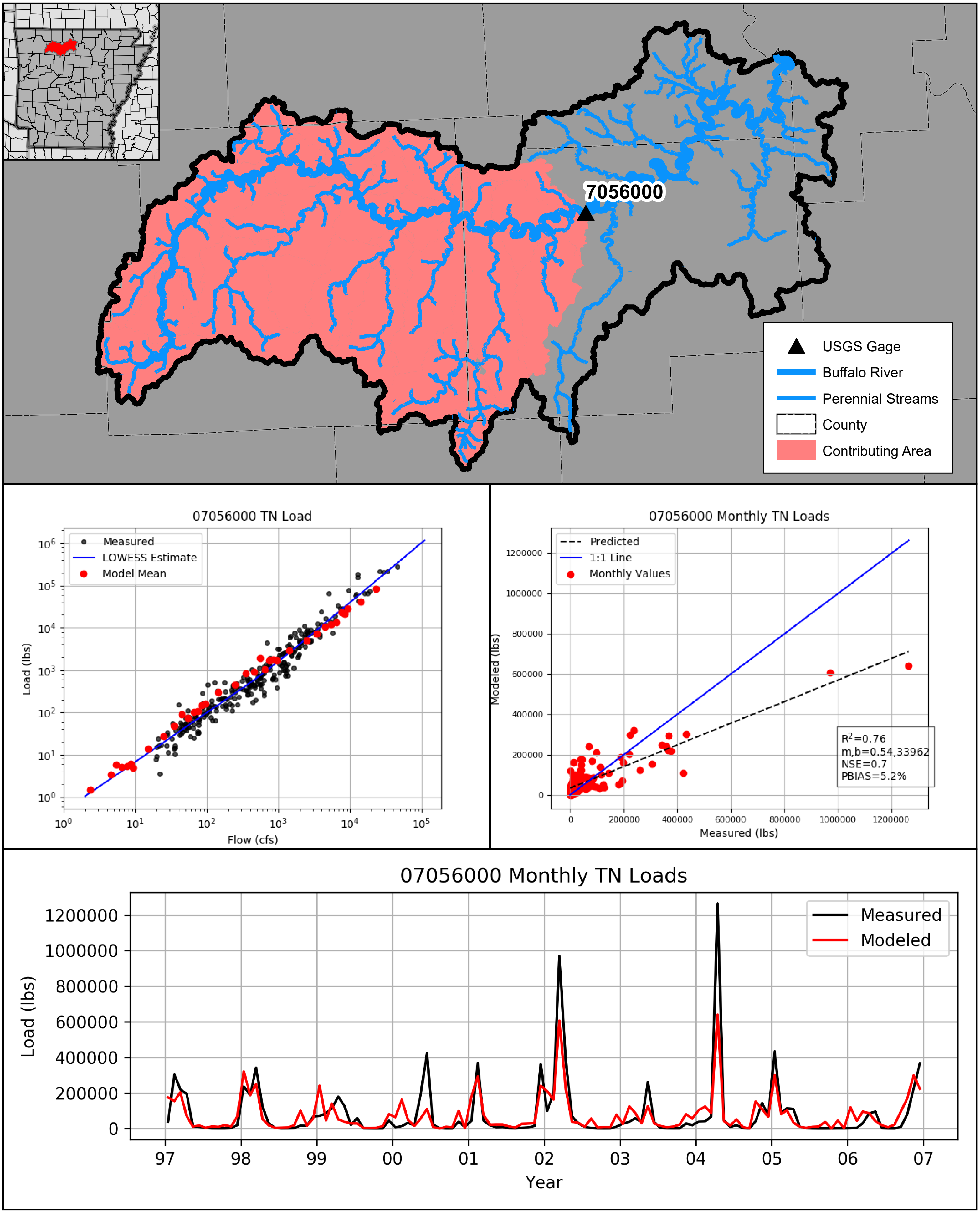




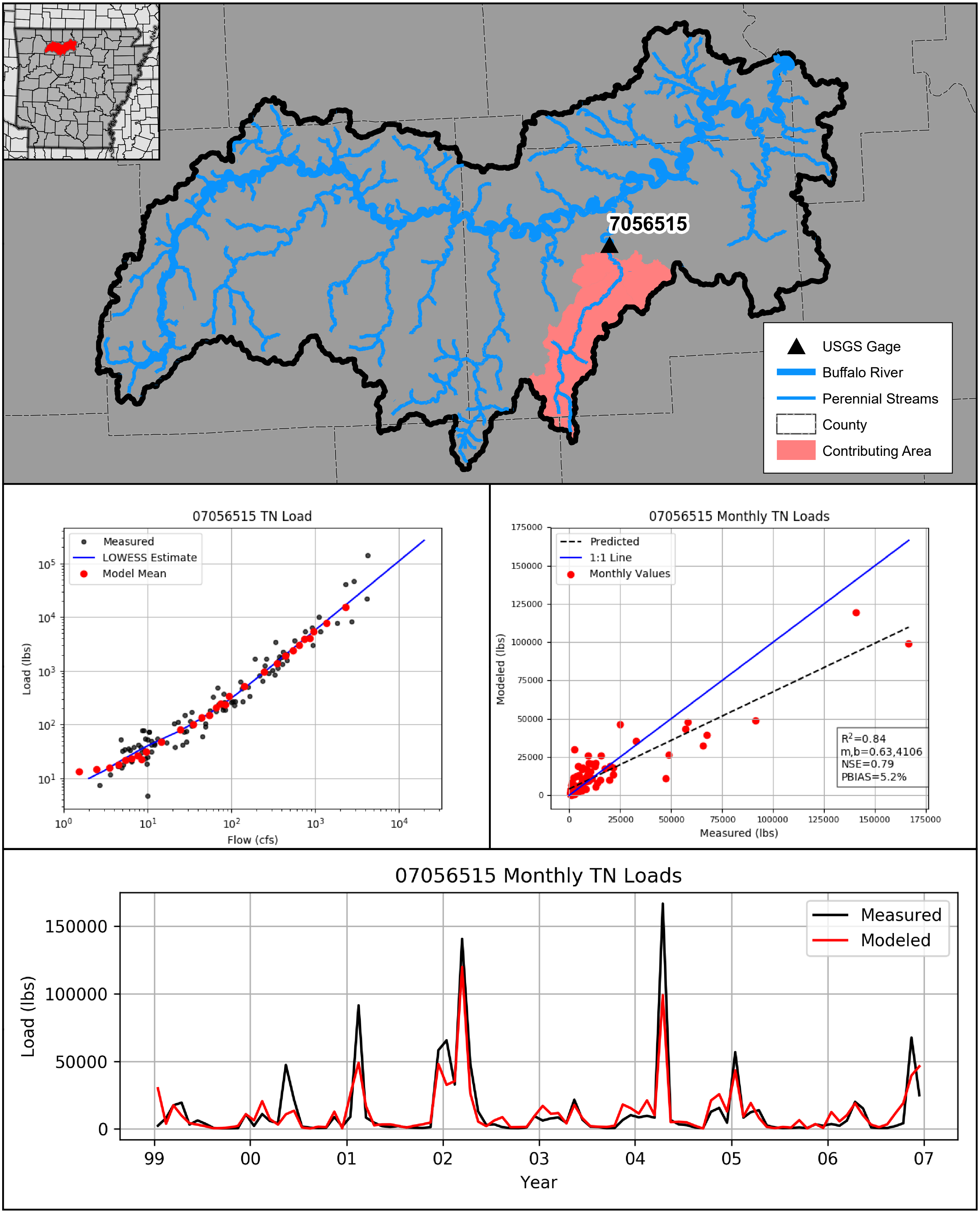




USGS 07056515 - Bear Creek near Silver Hill, AR
TP Validation Station 3 of 3



USGS 07056000 - Buffalo River near St. Joe, AR
TN Validation Station 1 of 2



USGS 07056515 - Bear Creek near Silver Hill, AR
TN Validation Station 2 of 2

APPENDIX F

Identification of Recommended Watersheds

IDENTIFICATION OF RECOMMENDED SUBWATERSHEDS

The Buffalo River watershed is large, almost 900,000 acres. It is important to the many stakeholders that management activities make a real difference in improving and protecting the quality of both the surface water and groundwater, and other natural resources, in the watershed. This section describes the approach used to identify areas in the Buffalo River watershed where nonpoint source pollution management appears to be most needed, and is expected to be most beneficial.

There are currently no waterbodies in the Buffalo River watershed classified as impaired by Arkansas Department of Environmental Quality (ADEQ), where the impairment is attributed to nonpoint sources. For this watershed management plan, therefore, areas recommended for initial management are areas where there are indications that the surface water resources may be more susceptible to ecological impacts, or that ecological condition may be declining. Several types of data were evaluated to identify these areas, including biological surveys, water quality constituent concentrations, water quality constituent loads, natural resources concerns based on watershed characteristics, and presence of carbonate bedrock.

The evaluation unit for these analyses is the 12-digit HUC (HUC12) subwatersheds delineated by the USGS. There are 37 HUC12 subwatersheds within the Buffalo River watershed. Figure 1 shows the Buffalo River HUC12 subwatersheds, and identifies where routine biological and/or water quality monitoring data are available. There are nine HUC12 subwatersheds where neither routine biological nor water quality data is collected. However, most of these unmonitored HUC12 subwatersheds are upstream of HUC12 subwatersheds where monitoring stations are located.

Table 1 lists the HUC12 subwatersheds along with their composite ranking scores for biological impact, water quality concentration, pollutant load, and natural resources concerns, as well as for the presence of carbonate bedrock. Scores greater than zero mean that the data reviewed indicates the location is either susceptible to or experiencing ecological impacts. Higher scores mean that more data sources indicate impacts, while lower scores mean that fewer data sources indicate impacts. Thus, the higher the score, the greater the indication that the

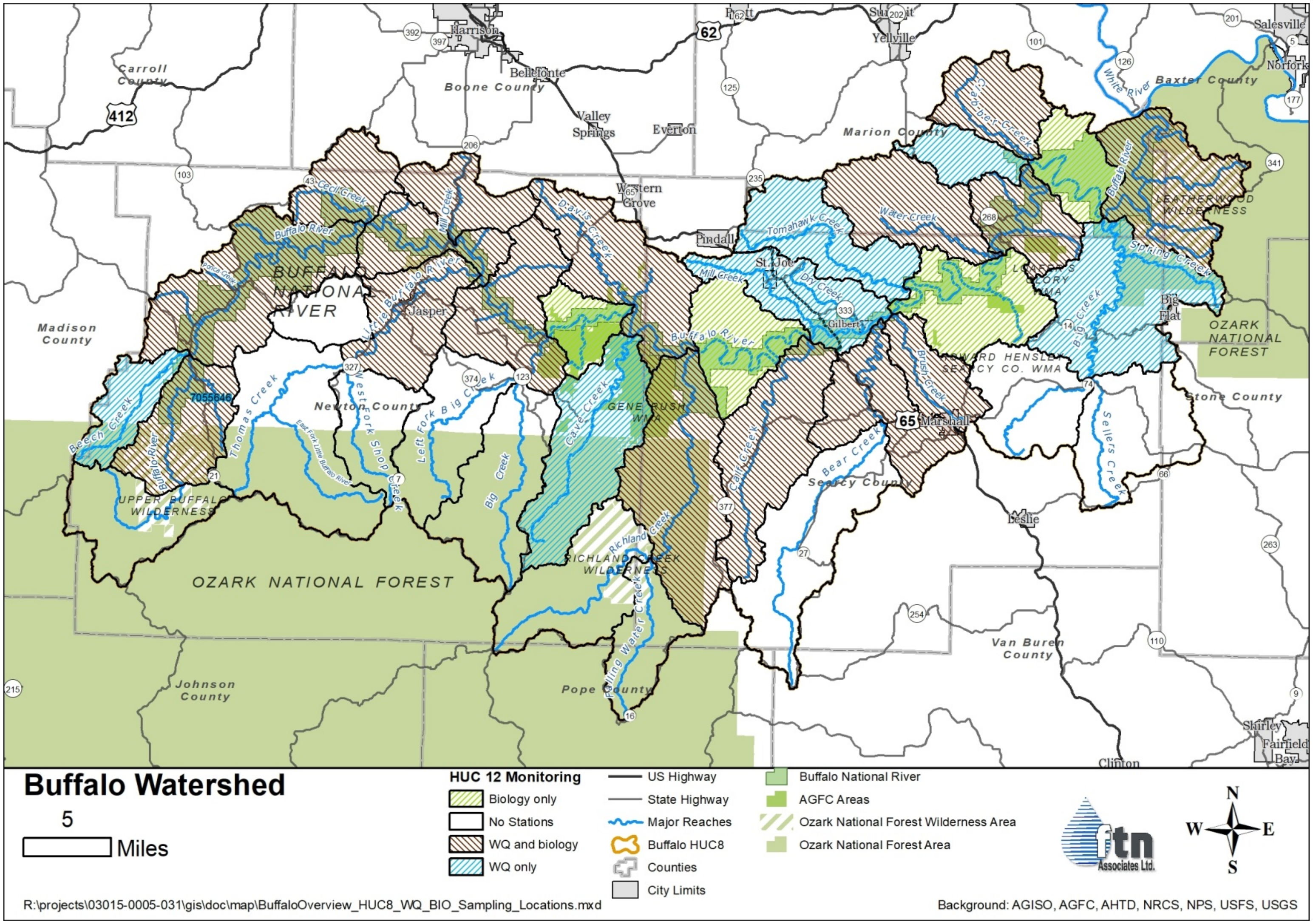


Figure 1. Biological and water quality monitoring stations in the Buffalo River HUC12 subwatersheds.

Table 1. Rankings for Buffalo River HUC12 Subwatersheds.

HUC12 ID	HUC12 Name	Total Scores							Private Lands, %
		Biological	Increasing Trends	Median Concentrations > 75%	Annual Loads > 75%	Resource Concerns > 75%	Carbonate Bedrock >60%	Sum	
110100050101	Shop Creek	ND	ND	ND	ND	0	0	0	70%
110100050102	Headwaters Little Buffalo River	ND	ND	ND	ND	0	0	0	57%
110100050103	Henson Creek	ND	ND	ND	ND	4	0	4	100%
110100050104	Outlet Little Buffalo River	0	1	3	2	0	0	6	97%
110100050201	Terrapin Branch-Buffalo River	ND	ND	ND	ND	0	0	0	20%
110100050202	Beech Creek-Headwaters Buffalo River	ND	0	1	0	0	0	1	70%
110100050203	Smith Creek-Buffalo River	0	2	1	0	0	1	4	34%
110100050204	Cove Creek-Buffalo River (Cecil Cr)	0	1	2	0	0	0	3	79%
110100050205	Whiteley Creek-Buffalo River (Ponca)	0	0	2	0	0	1	3	47%
110100050206	Flatrock Creek (Mill Cr upper)	0	2	6	0	6	1	15	97%
110100050207	Hoskin Creek-Buffalo River (Glade Cr)	1	0	1	ND	0	ND	2	58%

Table 1. Rankings for Buffalo River HUC12 Subwatersheds (continued).

HUC12 ID	HUC12 Name	Total Scores: Biological	Increasing Trends	Median Concentrations > 75%	Annual Loads > 75%	Resource Concerns > 75%	Carbonate Bedrock >60%	Sum	Private Lands, %
110100050301	Left Fork Creek	ND	ND	ND	ND	0	0	0	66%
110100050302	Headwaters Big Creek-Buffalo River	ND	ND	ND	ND	0	0	0	46%
110100050303	Outlet Big Creek-Buffalo River Middle	0	0	5	2	1	0	8	82%
110100050304	Lick Creek-Buffalo River	0	ND	ND	ND	0	ND	0	31%
110100050305	Cave Creek	ND	1	3	1	0	0	5	36%
110100050306	Headwaters Richland Creek	ND	ND	ND	ND	0	0	0	11%
110100050307	Falling Water Creek	ND	ND	ND	ND	0	0	0	12%
110100050308	Outlet Richland Creek	1	0	1	1	0	0	3	28%
110100050309	Cane Branch-Buffalo River (Davis Cr)	0	2	4	1	1	1	9	85%
110100050401	Calf Creek	1	0	2	2	7	0	12	97%
110100050402	Rocky Hollow-Buffalo River	0	ND	ND	ND	0	ND	0	66%
110100050403	Headwaters Bear Creek	ND	ND	ND	ND	2	0	2	100%
110100050404	Outlet Bear Creek	0	1	2	2	6	0	11	99%
110100050405	Brush Creek-Buffalo River	1	1	2	1	7	1	13	99%

Table1. Rankings for Buffalo River HUC12 Subwatersheds (continued).

		Total Scores							
HUC12 ID	HUC12 Name	Biological	Increasing Trends	Median Concentrations > 75%	Annual Loads > 75%	Resource Concerns > 75%	Carbonate Bedrock >60%	Sum	Private Lands, %
110100050406	Dry Creek-Buffalo River	ND	1	4	0	3	1	9	84%
110100050407	Tomahawk Creek-Buffalo River	ND	1	3	0	7	1	12	100%
110100050408	Water Creek	0	2	0	0	7	1	10	99%
110100050409	Spring Creek-Buffalo River	0	ND	ND	ND	1	ND	1	70%
110100050501	Rush Creek	ND	0	0	0	3	1	4	94%
110100050502	Hickory Creek-Buffalo River	2	0	0	ND	1	ND	3	53%
110100050503	Clabber Creek	1	0	1	0	5	0	7	99%
110100050504	Boat Creek-Buffalo River	0	ND	ND	ND	1	ND	1	35%
110100050505	Long Creek	ND	ND	ND	ND	8	1	9	100%
110100050506	Davis Creek-Big Creek Lower	ND	ND	ND	ND	8	1	9	100%
110100050507	Bratton Creek-Big River (Big Cr Lower)	ND	3	3	3	1	1	11	79%
110100050508	Leatherwood Creek-Buffalo River	2	0	1	0	1	1	5	3%

ND = no data is available from the sources used.

ecological integrity at a location is susceptible to adverse affects. The methods used to evaluate and assign scores to the Buffalo River HUC12 subwatersheds are described in the following subsections.

1.1 Biological Data

The condition of biological communities is widely used to evaluate the condition of aquatic ecosystems. Active biological monitoring programs and their data are described in Section _. Both fishery and aquatic invertebrate monitoring data collected by the US NPS were used to rank the HUC12 subwatersheds.

A Stream Condition Index (SCI) has been used by researchers to classify the condition of the aquatic invertebrate communities at monitoring locations in the Buffalo River watershed. SCI values reported in Bowles et al. (2013), and Bowles (2015) were used to score HUC12 subwatersheds. Where SCI values for more than one year were available for a monitoring location, the average SCI value was calculated and used to determine a score for invertebrate condition. SCI values greater than or equal to 16 indicate the invertebrate community is not adversely impacted (Bowles, 2015). Any HUC12 subwatershed with a monitoring location with an SCI value less than 16 was assigned a score of 1. Any HUC12 subwatershed where all monitoring locations had SCI values greater than or equal to 16 was assigned a score of zero.

An Index of Biotic Integrity (IBI) has been used by researchers to classify the condition of the fish communities at biological monitoring locations in the Buffalo River watershed (Dodd, 2009). IBI values reported in Dodd (2009) were used to score the HUC12 subwatersheds. In Schwoerer and Dodd (2016), IBI values greater than or equal to 60 indicate the fish community is not adversely impacted (i.e., classified as good or excellent/reference condition). Any HUC12 with a monitoring location with an IBI value less than 60 was assigned a score of 1. Any HUC12 where IBI values at all monitoring locations were greater than or equal to 60 was assigned a score of zero. If IBI values for more than one year were available for a monitoring location, the average of the IBI values was calculated and used for the ranking.

A total biological score was calculated for each HUC12 subwatershed by summing the SCI (aquatic invertebrate) and IBI (fishery) scores. This total biological score is shown in Table

1. The SCI and IBI values for each of the monitoring locations and the rankings for the associated HUC12 subwatersheds are included in Attachment A.

1.2 Water Quality Data

Measurements of 6 water quality constituents of concern were also used to rank the HUC12 subwatersheds. Turbidity measurements were used as an indicator to evaluate sediment issues. Inorganic nitrogen, orthophosphate phosphorus, and dissolved oxygen measurements were used as indicators to evaluate nutrient issues. Fecal coliform and *E. coli* measurements were used as indicators to evaluate bacteria issues and potential human health threats.

Water quality data were analyzed in two ways to rank the HUC12 subwatersheds. First, HUC12 subwatersheds were assigned scores based on the presence of trends in constituent values. The presence of trends in constituent values was evaluated by comparing median values for three 10-year periods; 1985-1994, 1995-2004, and 2005-2015 (see plan Section 3.2.5). The HUC 12 subwatersheds were assigned separate scores for each of the constituents of interest. Note that the *E. coli* data record was too short to be evaluated for trends, so fecal coliform data only were used. In addition, orthophosphate phosphorus trends were not evaluated because changes in analytical methods throughout the period of record, which changed detection limits, made it difficult to determine if differences in measurements from different periods are the result of changes in water quality, or the changes in method.

Any HUC12 subwatershed with one or more stations where a statistically significant increase occurred between the periods of 1995-2004 and 2005-2015 was assigned a score of 1. A score of 1 was also assigned when there was a statistically significant increase only between the 1985-1994 and 2005-2015 periods, as long as the median values always increased from one period to the next. A score of 2 was assigned to HUC12 subwatersheds with at least one monitoring location where there was a statistically significant increase between all three periods. HUC12 subwatersheds where no sampling locations exhibited statistically significant trends were assigned a score of zero. For dissolved oxygen, the ranking was based on the presence of statistically significant decreases, rather than increases. The trend scores for all of the constituents were summed for each HUC12 to calculate a total trend score. These total scores are shown in Table 1. The scores for each of the constituents are included in Attachment B.

In addition, the HUC12 subwatersheds were assigned scores based on the median concentration for the period 2005-2015. The subwatersheds were assigned separate scores for each of the constituents of interest. For dissolved oxygen, HUC12 subwatersheds with at least one sampling location where the median dissolved oxygen concentration for the period 2005-2015 was within the lowest quartile of values, i.e., less than or equal to the 25th percentile value, were assigned a score of 1, unless the only sampling location meeting this criterion was a spring sampling location. HUC12 subwatersheds where the median dissolved oxygen concentrations for all sampling locations (except those in springs) were greater than the 25th percentile value were assigned a score of zero. For the rest of the constituents of interest, HUC12 subwatersheds where the median concentration for at least one sampling location (other than a spring sampling location) was within the top quartile, i.e., greater than or equal to the 75th percentile, were assigned a score of 1. HUC12 subwatersheds where the median concentrations for all sampling locations (except those in springs) were less than the 75th percentile were assigned a score of zero. For this evaluation, *E. coli* data were also used to characterize bacteria issues, at the request of the stakeholders. *E. coli* measurements began in 2009 at the majority of the monitoring locations. Therefore, the median *E. coli* levels for the period 2009-2015 were used to score the HUC12 subwatersheds. In an effort to compare data as similar as possible, only routine monitoring locations that were active during the entire 2005-2015 period (or 2009-2015 for *E. coli*) were evaluated for the ranking. Locations with shorter monitoring periods were excluded. The median concentration scores for all of the constituents were summed for each HUC12 to calculate a total score. These total scores are shown in Table 1. The scores for each of the constituents are included in Attachment C.

1.3 Loads

HUC12 subwatersheds were ranked based on estimated tributary loads for three constituents of interest; inorganic nitrogen, orthophosphate phosphorus, and *E. coli*. Turbidity units cannot be converted to load units, so turbidity was not included. Because loads naturally increase downstream in the Buffalo River, only the farthest upstream Buffalo River monitoring location (at the Upper Buffalo Wilderness Area boundary) was evaluated in the ranking. Only tributary water quality monitoring locations and the one Buffalo River location were ranked.

The subwatersheds were assigned separate scores for each of the three constituent loads of interest. Subwatersheds where the estimated load for at least one monitoring location was within the upper quartile, i.e., greater than or equal to the 75th percentile, were assigned a score of 1. HUC12 subwatersheds where the estimated loads for all monitoring locations were less than the 75th percentile were assigned a score of zero. The load scores for the three constituents were summed for each HUC12 to determine a total load score. These total load scores are shown in Table 1. The loads, description of how they were calculated, and scores for each of the constituents are included in Attachment D.

Use of SWAT model loads to rank HUC12 subwatersheds was evaluated after they became available February 2018. The same subwatersheds had the highest total rank scores when SWAT model loads were used, as when Attachment D load estimates were used.

1.4 NRCS Natural Resource Concerns

Every 5 years the NRCS conducts state and national resource assessments to assess major concerns of land use practices on the environment. There are nine major resource concerns, ranging from soil erosion and soil quality degradation to water quality degradation and inadequate habitat for fish and wildlife to air quality degradation. The latest resource assessment for Arkansas was conducted in 2016. The state resource assessments are conducted at the HUC 12 watershed scale, which is consistent with the scale used by the ANRC for watershed management. Most of the major resource concerns are partitioned to account for specific factors contributing to the resource concern. For example, the soil erosion major resource concern is partitioned into sheet, rill, and wind erosion; concentrated flow erosion, or gully formation; and streambank erosion. Eight resource concern categories were ranked for each HUC12 subwatershed, including: sheet, rill, and wind erosion; concentrated flow erosion; streambank erosion; excess sediment; excess nutrients; heavy metals and petroleum; pathogens; and pesticides and herbicides. If the resource concern score was in the upper quartile of scores for the

37 HUC12 subwatersheds, i.e., greater than or equal to the 75th percentile, the subwatershed received a score of 1. The total of the natural resources concerns ranks for each HUC12 subwatershed are shown in Table 1. The scores for each of the resource concerns for each HUC12 are included in Attachment E.

1.5 Presence of Carbonate Bedrock

Interactions between surface and groundwater quality have been shown to occur through the karst features present in the Buffalo River watershed. These interactions can bring pollutants to surface waters from sources in neighboring watersheds (Mott et al. 2000, Soto 2014). Therefore, the presence of karst features was included in the ranking of Buffalo River subwatersheds for nonpoint source management.

The karst features in the Buffalo River watershed are strongly linked to carbonate rock formations, therefore, the percentage of carbonate bedrock was used as an indicator of the presence of karst features that could readily transport nonpoint source pollution to streams. HUC12 subwatersheds where greater than 60% of the subbasin was underlain with carbonate bedrock were assigned a score of 1. HUC12 subwatersheds where less than 60% of the subbasin had underlying carbonate bedrock were assigned a score of zero. These scores are shown in Table 1.

1.6 Private Lands

For the most part, public lands such as those owned and managed by the US Forest Service, the US National Park Service, Arkansas Game and Fish Commission, etc., are not eligible for assistance with managing nonpoint source pollution through the Arkansas Nonpoint Source Pollution Program. Therefore, HUC12 subwatersheds with little or no privately held land would provide few opportunities for the Arkansas Nonpoint Source Pollution Program. All of the higher ranked HUC12 subwatersheds had a significant proportion of the subwatershed in private ownership (see Table 1).

1.7 Recommended HUC12 Subwatersheds

Cumulative scores were compiled for each of the subwatersheds of the Buffalo National River. The individual and cumulative criteria scores for the Buffalo River HUC12 subwatersheds are shown on Figure 2. There were nine HUC12 subwatersheds with total scores of zero. These were all subwatersheds without water quality monitoring stations within their boundaries.

The six HUC12 subwatersheds with total scores greater than 10 are Flatrock Creek (110100050206), Calf Creek (110100050401), Outlet Bear Creek (110100050404), Brush Creek-Buffalo River (110100050405), Tomahawk Creek-Buffalo River (110100050407), and Bratton Creek-Big River (110100050507). The two HUC12 subwatersheds upstream of Bratton Creek-Big River are also included, so the entire Big Creek (lower) subwatershed is recommended for initial management. The HUC12 subwatershed upstream of Outlet Bear Creek is also included, so the entire Bear Creek subwatershed is recommended for initial management. The locations of the HUC12 subwatersheds that make up the recommended subwatersheds for this plan are shown on Figure 3. The water quality issues identified for each of the recommended subwatersheds, in this analysis and other studies, are summarized below.

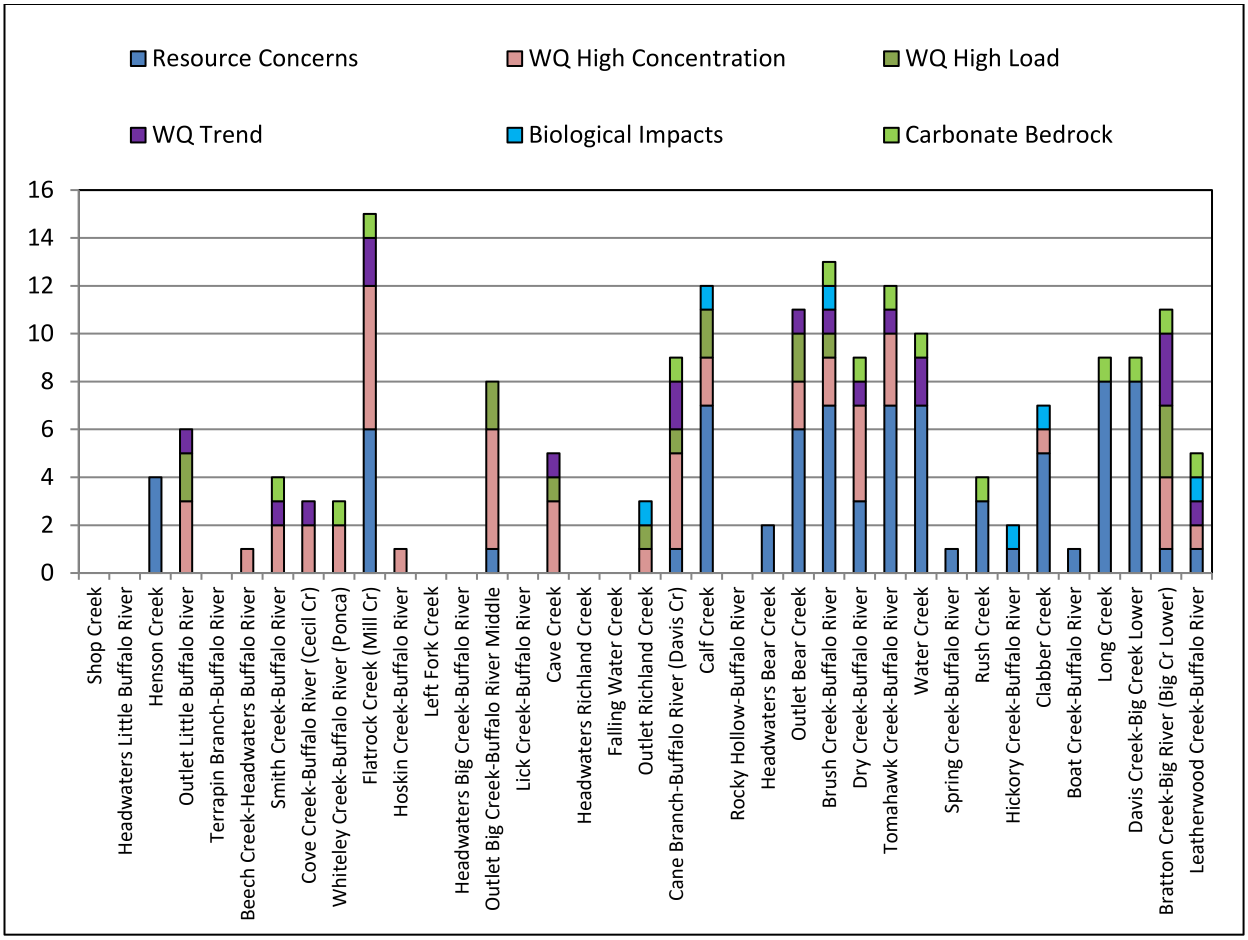


Figure 2. Graph of ranking scores for Buffalo River HUC12 subwatersheds (from Table 1).

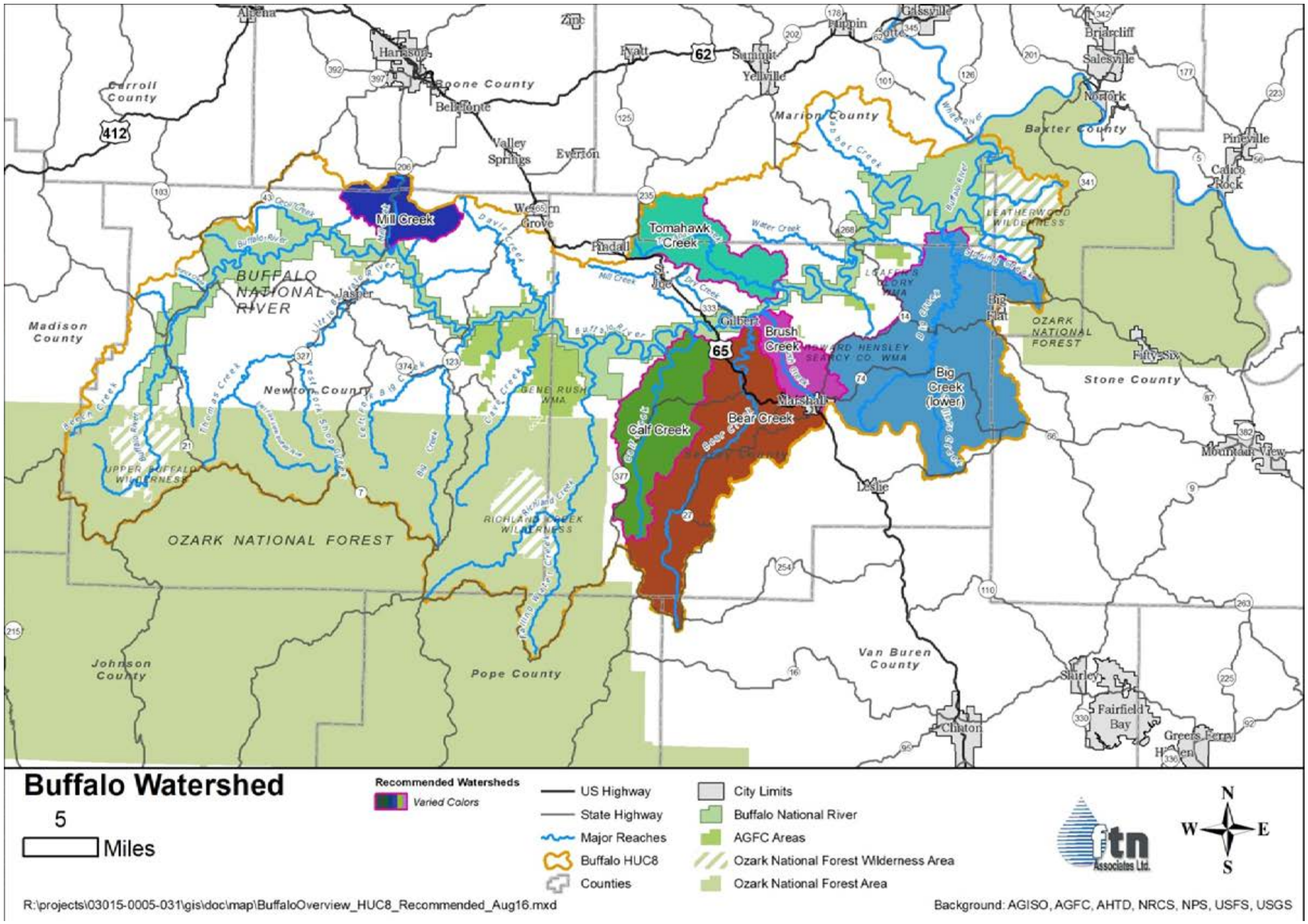


Figure 3. Map of recommended subwatersheds.

ATTACHMENT A

Biological Monitoring Data with HUC12 Ranking Scores

Table A.1 lists aquatic invertebrate Stream Condition Index (SCI) values reported for stations on the Buffalo River and its tributaries in Bowles et al. 2013 and Bowles 2015. SCI values greater than or equal to 16 indicate the invertebrate community is not adversely impacted (Bowles 2015). Therefore, stations with average SCI values less than 16 are assigned a ranking score of 1, and stations with average SCI values equal to or greater than 16 are assigned a ranking score of zero.

Table A.2 lists fish IBI values reported in Dodd (2009). The IBI scores are assigned to condition classes as follows: IBI values <40 = poor condition, IBI values 40-60 = fair condition, IBI values 60-80 = good condition, and IBI values >80 = excellent condition. IBI values for the Buffalo River and selected tributaries range from 55 to 91.5, i.e., fair to excellent condition. For ranking the HUC12 subwatersheds, average IBI values < 60 (i.e., fair condition) were assigned a ranking score of 1. IBI values equal to or greater than 60 (i.e., good to excellent condition) were assigned a ranking score of zero.

In both Tables A.1 and A.2, there are HUC12 subwatersheds with more than one biological monitoring station, e.g., 110100050508. Any HUC12 subwatershed with at least one monitoring location with a ranking score of 1 is assigned a ranking score of 1. Any HUC12 subwatershed where all monitoring locations have ranking scores of zero are assigned a ranking score of zero. Table A.3 shows the ranking scores for each of the HUC12 subwatersheds based on aquatic invertebrate SCI values, and fish IBI values. The total biological ranking scores for each HUC12 subwatershed are also included in Table A.3. These values are shown in Table3.1 of the text.

Table A.1. Reported Stream Condition Index (SCI) Values for Buffalo River Watershed Stations.

Stream Name	Station ID	HUC12	2005 SCI[a]	2006 SCI[a]	2007 SCI[a]	2008 SCI[a]	2009 SCI[a]	2010 SCI[a]	2011 SCI[a]	2013 SCI[b]	Average SCI	Ranking Score
Little Buffalo R	BUFFT09	110100050104		16.67							16.67	0
Smith Cr	BUFFT01	110100050203					18.67				18.67	0
Cecil Cr	BUFFT05	110100050204			18.00					20.00	19.00	0
Buffalo R	BUFFM01	110100050205		>16	<16	>16	>16		>16	>16	>16	0
Whitely Cr	BUFFT03	110100050205		18.00							18.00	0
Sneeds Cr	BUFFT04	110100050205				18.67					18.67	0
Mill Cr	BUFFT07	110100050206			18.00				20.00	19.33	19.11	0
Buffalo R	BUFFM02	110100050207	>16	>16	>16	>16	16.00		>16	>16	>16	0
Glade Cr	BUFFT06	110100050207					14.00				14.00	1
Vanishing Cr	BUFFT08	110100050207						20.00			20.00	0
Wells Cr	BUFFT10	110100050303					18.00				18.00	0
Rock Cr	BUFFT11	110100050303					18.00				18.00	0
Big Cr	BUFFT13	110100050303				17.33				20.00	18.66	0
Buffalo R	BUFFM03	110100050304	>16	>16	>16	>16	<16		<16	>16	>16	0
Lick Cr	BUFFT14	110100050304						19.33			19.33	0
Richland Cr	BUFFT17	110100050308						10.00			10.00	1
Davis Cr	BUFFT15	110100050309				16.67			12.67	18.67	16.00	0
Mill Branch	BUFFT16	110100050309				16.00					16.00	0
Calf Cr	BUFFT19	110100050401							15.33		15.33	1
Buffalo R	BUFFM04	110100050402	<16	>16	16.00	>16	>16		<16	>16	>16	0
Bear Cr	BUFFT20	110100050404					17.33		17.33	18.67	17.78	0
Water Cr	BUFFT23	110100050408					15.33			16.67	16.00	0
Buffalo R	BUFFM05	110100050409	16.00	<16	>16	>16	>16		>16	>16	>16	0
Spring Cr	BUFFT22	110100050409		16.67							16.67	0
Hickory Cr	BUFFT24	110100050502		12.00							12.00	1
Little Panther Cr	BUFFT25	110100050502			10.00						10.00	1
Clabber Cr	BUFFT27	110100050503						16.67	12.00		14.34	1
Buffalo R	BUFFM06	110100050504	>16		>16	>16	16.00		>16	>16	>16	0
Middle Cr	BUFFT30	110100050508		12.00					13.33		12.66	1
Leatherwood Cr	BUFFT31	110100050508		14.00					14.67		14.34	1
Stewart Cr	BUFFT33	110100050508			18.67						18.67	0

[a] (Bowles, Hinsey, et al. 2013)
[b] (Bowles 2015)

Table A.2. Reported fish IBI values (Dodd, 2009).

Stream Name	Station ID	HUC12	2006 IBI	2007 IBI	Average IBI	Ranking Score
Little Buffalo R	BUFFT09	110100050104	82		82	0
Cecil Cr	BUFFT05	110100050204		80	80	0
Buffalo R	BUFFM01	110100050205	72	69	70.5	0
Whitely Cr	BUFFT03	110100050205	64		64	0
Mill Cr	BUFFT07	110100050206		82	82	0
Buffalo R	BUFFM02	110100050207	83	82	82.5	0
Sheldon Branch	BUFFT12	110100050303		60	60	0
Buffalo R	BUFFM03	110100050304	80	84	82	0
Buffalo R	BUFFM04	110100050402	80	84	82	0
Brush Cr	BUFFT21	110100050405		57	57	1
Buffalo R	BUFFM05	110100050409	91	90	91.5	0
Hickory Cr	BUFFT24	110100050502	67		67	0
Little Panther Cr	BUFFT25	110100050502		55	55	1
Buffalo R	BUFFM06	110100050504	93	79	86	0
Middle Cr	BUFFT30	110100050508	69		69	0
Leatherwood Cr	BUFFT31	110100050508	79		79	0
Stewart Cr	BUFFT33	110100050508		58	58	1

Table A.3. HUC12 subwatershed ranking scores based on aquatic invertebrate and fish indices.

HUC12 Name	HUC ID	Aquatic Invertebrate Ranking Score	Fish Ranking Score	Total Biological Ranking Score
Shop Creek	110100050101	No Data	No Data	-
Headwaters Little Buffalo River	110100050102	No Data	No Data	-
Henson Creek	110100050103	No Data	No Data	-
Outlet Little Buffalo River	110100050104	0	0	0
Terrapin Branch-Buffalo River	110100050201	No Data	No Data	-
Beech Creek-Headwaters Buffalo River	110100050202	No Data	No Data	-
Smith Creek-Buffalo River	110100050203	0	No Data	0
Cove Creek-Buffalo River	110100050204	0	0	0
Whiteley Creek-Buffalo River	110100050205	0	0	0
Flatrock Creek	110100050206	0	0	0
Hoskin Creek-Buffalo River	110100050207	1	0	1
Left Fork Creek	110100050301	No Data	No Data	-
Headwaters Big Creek-Buffalo River	110100050302	No Data	No Data	-

Table A.3. HUC12 subwatershed ranking scores based on aquatic invertebrate and fish indices (continued).

HUC12 Name	HUC ID	Aquatic Invertebrate Ranking Score	Fish Ranking Score	Total Biological Ranking Score
Outlet Big Creek-Buffalo River Middle	110100050303	0	0	0
Lick Creek-Buffalo River	110100050304	0	0	0
Cave Creek	110100050305	No Data	No Data	-
Headwaters Richland Creek	110100050306	No Data	No Data	-
Falling Water Creek	110100050307	No Data	No Data	-
Outlet Richland Creek	110100050308	1	No Data	1
Cane Branch-Buffalo River	110100050309	0	No Data	0
Calf Creek	110100050401	1	No Data	1
Rocky Hollow-Buffalo River	110100050402	0	0	0
Headwaters Bear Creek	110100050403	No Data	No Data	-
Outlet Bear Creek	110100050404	0	No Data	0
Brush Creek-Buffalo River	110100050405	No Data	1	1
Dry Creek-Buffalo River	110100050406	No Data	No Data	-
Tomahawk Creek-Buffalo River	110100050407	No Data	No Data	-
Water Creek	110100050408	0	No Data	0
Spring Creek-Buffalo River	110100050409	0	0	0
Rush Creek	110100050501	No Data	No Data	-
Hickory Creek-Buffalo River	110100050502	1	1	2
Clabber Creek	110100050503	1	No Data	1
Boat Creek-Buffalo River	110100050504	0	0	0
Long Creek	110100050505	No Data	No Data	-
Davis Creek-Big Creek Lower	110100050506	No Data	No Data	-
Bratton Creek-Big River	110100050507	No Data	No Data	-
Leatherwood Creek-Buffalo River	110100050508	1	1	2

References

Bowles, David, et al. 2013. *Aquatic Invertebrate Monitoring at Buffalo National River 2005-2011 Status Report.* s.l. : US National Park Service.

Bowles, David. 2015. *Aquatic Invertebrate Monitoring at Buffalo National River, 2005-2013.* s.l. : USNPS.

Dodd, Hope. 2009. *Fish Community Monitoring at Buffalo National River: 2006-2007 Status Report.* s.l. : US National Park Service.

ATTACHMENT B

Trend Analysis for Selected Water Quality Parameters with HUC12 Ranking Scores

Table B.1 summarizes the scoring results for the HUC12 subwatersheds for each of the parameters evaluated for trends. Tables B.2 through B.5 show the median values for each of the periods at each of the evaluated locations and the changes between periods, i.e., increase or decrease, or no change. Bold text in the "Change between periods" columns indicated a statistically significant difference between the medians from the two periods. The ranking scores assigned to each location based on the trend analysis is shown in the last column of Tables B.2 through B.5. To be included in the evaluation, a monitored location had to have data for at least the period 1995-2015, and have at least 10 measurements in each of the 10-year periods.

Box and whisker graphs showing the 95% confidence interval for the median value, were used to determine if changes between periods were statistically significant. Figure B.1 is a diagram explaining the elements of the box and whisker graphs. Figures B.2 through B.132 show the box and whisker graphs used to evaluate the changes in median values between the 10-year periods for each of the constituents and monitoring locations evaluated.

Table B.1. HUC12 trend ranking scores summary.

HUC12 ID	HUC12 NDme	Ranking Scores for Trends				Sum of Scores
		DO	Fecal coliform	Inorganic nitrogen	Turbidity	
110100050101	Shop Creek	ND	ND	ND	ND	ND
110100050102	Headwaters Little Buffalo River	ND	ND	ND	ND	ND
110100050103	Henson Creek	ND	ND	ND	ND	ND
110100050104	Outlet Little Buffalo River	0	1	0	0	1
110100050201	Terrapin Branch-Buffalo River	ND	ND	ND	ND	ND
110100050202	Beech Creek-Headwaters Buffalo River	0	0	0	0	0
110100050203	Smith Creek-Buffalo River	0	0	0	0	0
110100050204	Cove Creek-Buffalo River (Cecil Cr)	0	1	0	0	1
110100050205	Whiteley Creek-Buffalo River (Ponca)	0	0	0	0	0
110100050206	Flatrock Creek (Mill Cr)	0	1	1	0	2
110100050207	Hoskin Creek-Buffalo River (Glade Cr?)	0	0	0	0	0
110100050301	Left Fork Creek	ND	ND	ND	ND	ND
110100050302	Headwaters Big Creek-Buffalo River	ND	ND	ND	ND	ND

Table B.1. HUC12 trend ranking scores summary (continued).

HUC12 ID	HUC12 NDme	Ranking Scores for Trends				Sum of Scores
		DO	Fecal coliform	Inorganic nitrogen	Turbidity	
110100050303	Outlet Big Creek-Buffalo River Middle	0	1	0	0	1
110100050304	Lick Creek-Buffalo River	ND	ND	ND	ND	ND
110100050305	Cave Creek	0	1	0	0	1
110100050306	Headwaters Richland Creek	ND	ND	ND	ND	ND
110100050307	Falling Water Creek	ND	ND	ND	ND	ND
110100050308	Outlet Richland Creek	0	0	0	0	0
110100050309	Cane Branch-Buffalo River (Davis Cr)	0	1	2	0	3
110100050401	Calf Creek	0	0	0	0	0
110100050402	Rocky Hollow-Buffalo River	ND	ND	ND	ND	ND
110100050403	Headwaters Bear Creek	ND	ND	ND	ND	ND
110100050404	Outlet Bear Creek	0	0	1	0	1
110100050405	Brush Creek-Buffalo River	0	0	1	0	1
110100050406	Dry Creek-Buffalo River	0	0	1	0	1
110100050407	Tomahawk Creek-Buffalo River	0	0	1	0	1
110100050408	Water Creek	0	1	1	0	2
110100050409	Spring Creek-Buffalo River	ND	ND	ND	ND	ND
110100050501	Rush Creek	0	0	0	0	0
110100050502	Hickory Creek-Buffalo River	0	0	0	0	0
110100050503	Clabber Creek	0	0	0	0	0
110100050504	Boat Creek-Buffalo River	ND	ND	ND	ND	ND
110100050505	Long Creek	ND	ND	ND	ND	ND
110100050506	Davis Creek-Big Creek Lower	ND	ND	ND	ND	ND
110100050507	Bratton Creek-Big River (Big Cr Lower)	0	1	1	1	3
110100050508	Leatherwood Creek-Buffalo River	0	1	0	0	1

Table B.2. Dissolved Oxygen trends evaluation.

Location Name	Station ID	HUC12	1985-1994		1995-2004		2005-2015		Change between periods			DO Trend Ranking Score
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015	
Little BR		110100050104	50	9.60	39	9.70	76	10.50	Increase	Increase	Increase	0
Beech Cr		110100050202	31	10.00	22	11.60	23	11.20	Increase	Decrease	Increase	0
BR @ Wild Area		110100050203	90	9.05	114	9.50	100	10.60	Increase	Increase	Increase	0
Luallen Spr		110100050203	43	9.00	38	9.80	46	9.94	Increase	Increase	Increase	0
Cecil Cr		110100050204	48	9.35	38	9.65	51	9.90	Increase	Increase	Increase	0
BR @ Ponca		110100050205	73	9.40	43	9.80	53	10.01	Increase	Increase	Increase	0
Ponca Cr		110100050205	50	9.50	37	10.20	38	10.79	Increase	Increase	Increase	0
Mill Cr mouth		110100050206	57	9.30	39	10.20	149	9.90	Increase	Decrease	Increase	0
BR @ Pruitt Ac		110100050207	74	9.10	42	10.30	116	9.20	Increase	Decrease	Increase	0
Big Cr Carver		110100050303	52	9.40	43	9.80	177	10.20	Increase	Increase	Increase	0
BR @ Hasty		110100050303	70	9.40	42	10.40	56	9.41	Increase	Decrease	NC	0
Cave Cr mouth		110100050305	48	9.35	42	9.40	46	10.27	Increase	Increase	Increase	0
Richland Cr mouth		110100050308	43	10.00	35	10.70	52	10.14	Increase	Decrease	Increase	0
BR @ Woolum		110100050309	71	9.90	42	10.50	41	10.30	Increase	Decrease	Increase	0
Davis Cr		110100050309	52	9.50	43	9.90	47	10.58	Increase	Increase	Increase	0
Mitch Hill Spr		110100050309	49	8.10	46	8.50	48	8.27	Increase	Decrease	Increase	0
Calf Cr		110100050401	51	9.40	43	9.70	45	10.21	Increase	Increase	Increase	0
Bear Cr @ Hwy65		110100050404	ND	ND	82	9.10	11	8.80	ND	Decrease	ND	0
Bear Cr mouth		110100050404	53	9.60	45	10.30	44	10.70	Increase	Increase	Increase	0
Brush Cr		110100050405	41	9.80	36	10.40	33	10.40	Increase	NC	Increase	0
BR @ Gilbert Ac		110100050406	71	9.70	44	10.46	43	10.80	Increase	Increase	Increase	0
BR @ Hwy65		110100050406	43	10.00	93	8.80	130	9.54	Decrease	Increase	Decrease	0
Gilbert Spr		110100050406	47	8.80	58	8.80	53	9.20	NC	Increase	Increase	0
Mill Cr L		110100050406	49	9.90	38	10.10	44	10.50	Increase	Increase	Increase	0
Tomahawk Cr		110100050407	54	9.80	42	10.45	45	10.70	Increase	Increase	Increase	0

Table B.2. Dissolved Oxygen trends evaluation (continued).

Location Name	Station ID	HUC12	1985-1994		1995-2004		2005-2015		Change between periods			DO Trend Ranking Score
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015	
Water Cr		110100050408	48	9.70	39	10.00	43	11.20	Increase	Increase	Increase	0
Rush Cr		110100050501	51	9.80	42	10.45	45	10.44	Increase	NC	Increase	0
BR @ Hwy 14		110100050502	72	9.65	41	10.60	44	10.65	Increase	Increase	Increase	0
BR @ Rush Ac		110100050502	72	9.10	41	9.80	43	10.00	Increase	Increase	Increase	0
Clabber Cr		110100050503	50	9.90	43	10.84	46	10.55	Increase	Decrease	Increase	0
Big Cr L		110100050507	37	9.20	34	9.80	41	9.85	Increase	Increase	Increase	0
BR Mouth		110100050508	54	9.95	33	10.40	47	9.84	Increase	Decrease	Decrease	0
Leatherwood Cr		110100050508	37	8.40	34	9.35	41	10.00	Increase	Increase	Increase	0
Middle Cr		110100050508	37	9.00	34	9.80	41	9.87	Increase	Increase	Increase	0

ND= no data for this period
NC= no change, i.e., medians are within 0.05 mg/L

Table B.3. Fecal Coliform trends evaluation.

Location Name	Station ID	HUC12	1985-1994		1995-2004		2005-2015		Change between periods			Coliform Trend Ranking Score
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015	
Little BR		110100050104	69	10.0	41	13.0	44	24.0	Increase	Increase	**Increase**	1
Beech Cr		110100050202	41	12.0	23	10.0	23	13.0	Decrease	Increase	NC	0
BR @ Wild Area		110100050203	107	6.0	115	10.0	47	13.0	Increase	Increase	Increase	0
Luallen Spr		110100050203	77	4.0	40	3.0	47	6.0	Decrease	Increase	Increase	0
Cecil Cr		110100050204	62	8.5	39	21.0	58	24.0	Increase	Increase	**Increase**	1
Ponca Cr		110100050205	65	6.0	39	9.0	40	15.0	Increase	Increase	Increase	0
BR @ Ponca		110100050205	89	16.0	43	38.0	50	24.5	**Increase**	Decrease	Increase	0
Mill Cr mouth		110100050206	74	18.0	41	26.0	60	72.5	Increase	**Increase**	**Increase**	1
BR @ Pruitt Ac		110100050207	88	6.0	42	18.0	55	12.0	**Increase**	Decrease	**Increase**	0
BR @ Hasty		110100050303	85	6.0	41	12.0	47	11.0	Increase	NC	Increase	0
Big Cr Carver		110100050303	68	8.0	45	8.0	52	21.5	NC	Increase	**Increase**	0
Cave Cr mouth		110100050305	62	8.0	43	11.0	48	23.5	increase	increase	**Increase**	1
Richland Cr mouth		110100050308	60	17.5	34	11.0	40	12.0	Decrease	NC	Decrease	0
Mitch Hill Spr		110100050309	64	2.0	45	7.0	46	11.5	Increase	Increase	**Increase**	1
Davis Cr		110100050309	68	13.5	44	26.5	47	29.0	Increase	Increase	Increase	0
BR @ Woolum		110100050309	83	2.0	42	3.5	41	5.0	Increase	Increase	Increase	0
Calf Cr		110100050401	67	16.0	42	20.0	43	12.0	Increase	Decrease	Decrease	0
Bear Cr mouth		110100050404	65	20.0	42	20.0	46	13.5	NC	Decrease	Decrease	0
Brush Cr		110100050405	46	8.5	36	20.5	35	18.0	Increase	Decrease	Increase	0
Mill Cr L		110100050406	65	10.0	42	9.0	44	14.5	NC	Increase	Increase	0
BR @ Gilbert Ac		110100050406	85	4.0	43	9.0	45	4.0	Increase	Decrease	NC	0
Gilbert Spr		110100050406	50	10.0	61	11.0	45	5.0	NC	Decrease	Decrease	0
Tomahawk Cr		110100050407	70	54.0	42	56.5	43	31.0	Increase	Decrease	Decrease	0
Water Cr		110100050408	66	6.0	39	8.0	44	15.0	Increase	Increase	**Increase**	1
Rush Cr		110100050501	67	8.0	43	7.0	44	11.0	NC	Increase	Increase	0
BR @ Hwy 14		110100050502	85	2.0	43	9.0	46	6.0	Increase	Decrease	Increase	0

Table B.3. Fecal Coliform trends evaluation (continued).

Location Name	Station ID	HUC12	1985-1994		1995-2004		2005-2015		Change between periods			Coliform Trend Ranking Score
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015	
BR @ Rush Ac		110100050502	84	4.0	42	5.5	43	7.0	Increase	Increase	Increase	0
Clabber Cr		110100050503	67	20.0	43	15.0	45	10.0	Decrease	Decrease	Decrease	0
Big Cr L		110100050507	46	5.5	35	14.0	45	19.0	**Increase**	Increase	**Increase**	1
Middle Cr		110100050508	47	8.0	35	9.0	43	13.0	NC	Increase	Increase	0
Leatherwood Cr		110100050508	48	15.5	35	22.0	44	10.5	Increase	Decrease	Decrease	0
BR Mouth		110100050508	65	2.0	34	2.0	44	6.0	NC	Increase	**Increase**	1

ND= no data for this period
NC= no change, i.e., medians are within 1 cfu/100mL

Table B.4. Inorganic nitrogen trends evaluation.

Location Name	Station ID	HUC12	1985-1994		1995-2004		2005-2015		Change between periods			Inorganic N Trend Ranking Score
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015	
Little BR		110100050104	37	0.050	41	0.099	44	0.075	Increase	Decrease	Increase	0
Beech Cr		110100050202	25	0.010	23	0.041	25	0.044	Increase	increase	Increase	0
BR @ Wild Area		110100050203	80	0.008	114	0.000	67	0.025	**Decrease**	**Increase**	Increase	1
Luallen Spr		110100050203	38	0.220	40	0.190	45	0.193	Decrease	Increase	Decrease	0
Cecil Cr		110100050204	24	0.020	40	0.045	43	0.032	Increase	Decrease	Increase	0
BR @ Ponca		110100050205	59	0.045	41	0.071	55	0.072	Increase	NC	**Increase**	0
Ponca Cr		110100050205	37	0.060	39	0.121	41	0.113	**increase**	Decrease	**Increase**	0
Mill Cr mouth		110100050206	43	0.438	41	0.581	50	0.727	Increase	Increase	**Increase**	1
BR @ Pruitt Ac		110100050207	55	0.024	41	0.049	48	0.032	Increase	Decrease	increase	0
Big Cr Carver		110100050303	37	0.121	43	0.130	66	0.132	Increase	Increase	Increase	0
BR @ Hasty		110100050303	55	0.060	40	0.080	47	0.079	Increase	NC	increase	0
Cave Cr mouth		110100050305	23	0.046	41	0.086	47	0.089	Increase	Increase	Increase	0
Richland Cr mouth		110100050308	24	0.030	36	0.046	53	0.045	Increase	NC	Increase	0
BR @ Woolum		110100050309	51	0.060	41	0.105	45	0.132	increase	Increase	Increase	0
Davis Cr		110100050309	36	0.205	43	0.337	47	0.637	**Increase**	**Increase**	**Increase**	2
Mitch Hill Spr		110100050309	34	0.510	45	0.828	45	1.160	**Increase**	**Increase**	**Increase**	2
Calf Cr		110100050401	25	0.230	44	0.321	45	0.337	Increase	Increase	Increase	0
Bear Cr mouth		110100050404	27	0.100	45	0.245	47	0.313	**Increase**	Increase	**Increase**	1
Brush Cr		110100050405	18	0.515	35	0.570	36	0.770	Increase	**Increase**	**Increase**	1
BR @ Gilbert Ac		110100050406	50	0.065	41	0.100	46	0.094	Increase	Decrease	Increase	0
BR @ Hwy65		110100050406	48	0.065	116	0.090	133	0.100	Increase	Increase	**Increase**	1
Gilbert Spr		110100050406	33	0.780	57	0.920	44	0.873	**Increase**	Decrease	Increase	0
Mill Cr L		110100050406	23	0.292	42	0.296	44	0.273	Increase	Decrease	Decrease	0
Tomahawk Cr		110100050407	40	0.225	42	0.346	44	0.382	Increase	Increase	**Increase**	1

Table B.4. Inorganic nitrogen trends evaluation (continued).

			1985-1994		1995-2004		2005-2015		Change between periods			Inorganic N Trend Ranking Score
Location Name	**Station ID**	**HUC12**	**N**	**Median**	**N**	**Median**	**N**	**Median**	**1985-1994 to 1995-2004**	**1995-2004 to 2005-2015**	**1985-1994 to 2005-2015**	
Water Cr		110100050408	21	0.090	37	0.147	43	0.245	Increase	Increase	**Increase**	1
Rush Cr		110100050501	41	0.110	42	0.215	45	0.233	**Increase**	Increase	**Increase**	0
BR @ Hwy 14		110100050502	54	0.055	41	0.090	44	0.101	Increase	Increase	Increase	0
BR @ Rush Ac		110100050502	53	0.060	40	0.073	42	0.071	Increase	Increase	Increase	0
Clabber Cr		110100050503	40	0.040	41	0.103	46	0.052	Increase	Decrease	Increase	0
Big Cr L		110100050507	18	0.040	35	0.111	43	0.132	**Increase**	Increase	**Increase**	1
BR Mouth		110100050508	27	0.040	34	0.045	45	0.066	Increase	Increase	Increase	0
Leatherwood Cr		110100050508	19	0.020	35	0.029	43	0.000	Increase	**Decrease**	**Decrease**	0
Middle Cr		110100050508	19	0.010	35	0.025	42	0.000	Increase	**Decrease**	**Decrease**	0

ND= no data for this period
NC= no change, i.e., medians are within 0.002 mg/L

Table B.5. Turbidity trends evaluation.

Location Name	Station ID	HUC12	1985-1994		1995-2004		2005-2015		Change between periods			Turbidity Trend Ranking Score
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015	
Little BR		110100050104	54	1.4	41	1.4	86	1.9	NC	Increase	Increase	0
Beech Cr		110100050202	29	5.5	23	5.6	24	5.2	NC	Decrease	Decrease	0
BR @ Wild Area		110100050203	60	2.5	43	2.1	83	2.8	Decrease	Increase	Increase	0
Luallen Spr		110100050203	50	1.4	40	2.0	47	2.0	Increase	NC	Increase	0
Cecil Cr		110100050204	47	1.8	39	1.8	52	1.8	NC	NC	NC	0
Ponca Cr		110100050205	50	1.7	39	1.7	41	1.7	NC	NC	NC	0
BR @ Ponca		110100050205	65	1.3	43	1.5	58	1.9	Increase	Increase	Increase	0
Mill Cr mouth		110100050206	59	2.2	41	1.7	155	2.1	Decrease	Increase	NC	0
BR @ Pruitt Ac		110100050207	66	1.3	42	1.4	122	1.4	NC	NC	NC	0
BR @ Hasty		110100050303	62	1.5	42	1.6	58	1.7	NC	NC	Increase	0
Big Cr Carver		110100050303	54	1.8	45	1.7	220	2.1	NC	Increase	increase	0
Cave Cr mouth		110100050305	50	1.3	44	1.0	55	1.5	Decrease	Increase	Increase	0
Richland Cr mouth		110100050308	44	3.2	34	2.4	53	2.8	Decrease	Increase	Decrease	0
Mitch Hill Spr		110100050309	52	0.7	47	0.7	51	0.9	NC	Increase	Increase	0
Davis Cr		110100050309	53	0.5	45	0.5	52	0.6	NC	NC	NC	0
BR @ Woolum		110100050309	60	1.3	42	1.4	50	1.8	NC	Increase	Increase	0
Calf Cr		110100050401	56	2.1	45	1.2	45	1.1	**Decrease**	NC	**Decrease**	0
Bear Cr mouth		110100050404	57	1.4	44	1.4	51	1.8	NC	Increase	Increase	0
Brush Cr		110100050405	40	0.5	36	0.4	35	0.6	NC	Increase	NC	0
Mill Cr L		110100050406	51	0.7	43	0.5	44	0.7	Decrease	Increase	NC	0
BR @ Hwy65		110100050406	195	2.2	114	2.2	134	2.1	NC	NC	NC	0
BR @ Gilbert Ac		110100050406	60	1.8	43	1.8	47	1.6	NC	Decrease	Decrease	0
Gilbert Spr		110100050406	50	0.9	62	1.0	56	1.1	NC	NC	Increase	0
Tomahawk Cr		110100050407	58	0.9	43	0.8	51	0.8	NC	NC	NC	0
Water Cr		110100050408	51	0.6	39	0.4	46	0.6	**Decrease**	Increase	NC	0
Rush Cr		110100050501	52	0.6	44	0.6	48	0.6	NC	NC	NC	0
BR @ Hwy 14		110100050502	61	1.3	43	1.3	49	1.5	NC	Increase	Increase	0

Table B.5. Turbidity trends evaluation (continued).

Location Name	Station ID	HUC12	1985-1994		1995-2004		2005-2015		Change between periods			Turbidity Trend Ranking Score
			N	Median	N	Median	N	Median	1985-1994 to 1995-2004	1995-2004 to 2005-2015	1985-1994 to 2005-2015	
BR @ Rush Ac		110100050502	59	1.2	42	1.4	48	1.5	Increase	NC	Increase	0
Clabber Cr		110100050503	52	0.6	44	0.5	50	0.7	NC	Increase	NC	0
Big Cr L		110100050507	40	0.6	34	0.8	56	0.8	Increase	Increase	**Increase**	1
Middle Cr		110100050508	39	0.4	35	0.4	45	0.4	NC	NC	NC	0
Leatherwood Cr		110100050508	40	0.5	35	0.6	47	0.5	NC	NC	NC	0
BR Mouth		110100050508	46	1.5	34	1.0	52	1.5	Decrease	Increase	NC	0

ND= no data for this period
NC= no change, i.e., medians are within 0.1 mg/L

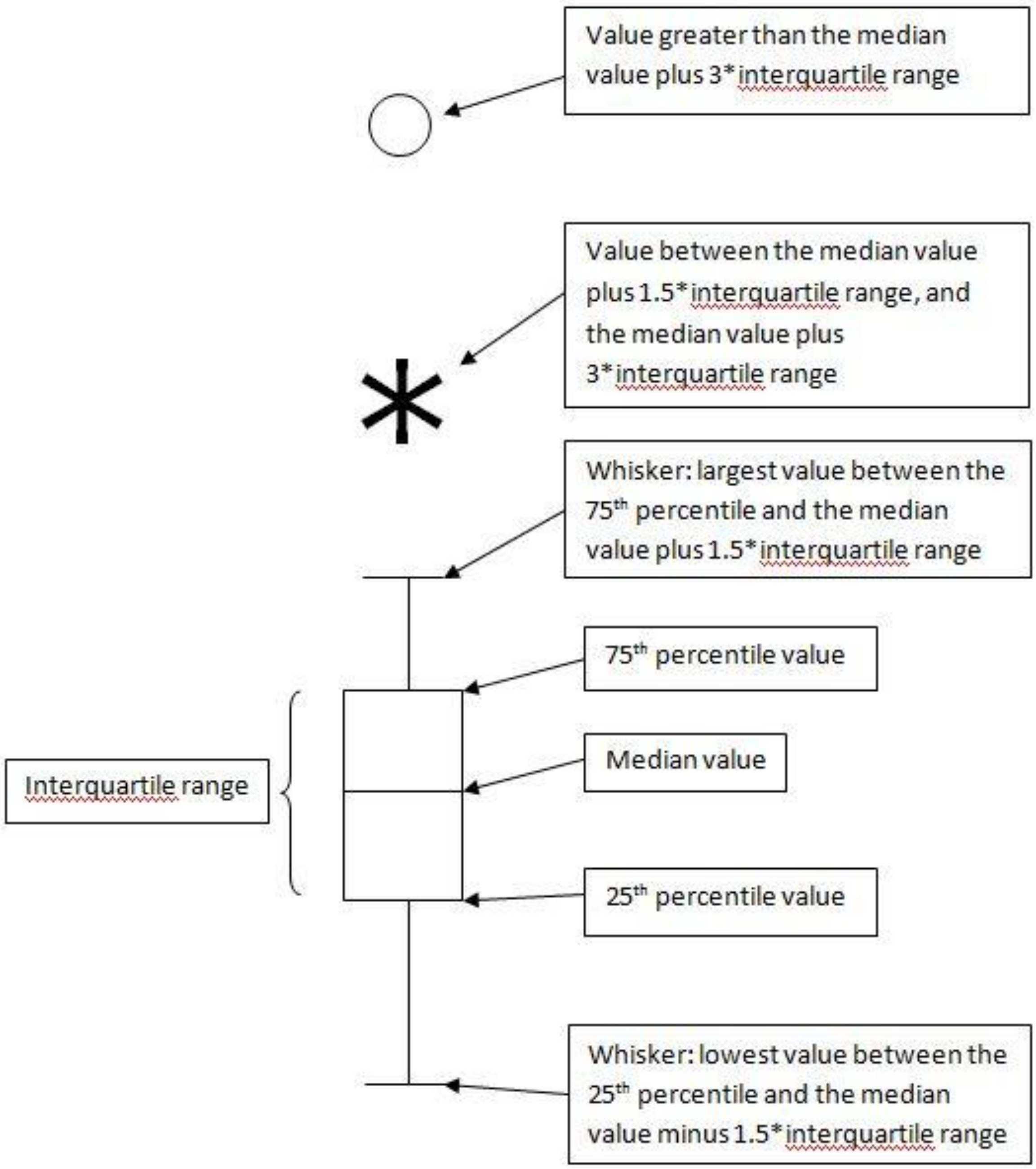


Figure B.1. Box and whisker graph elements.

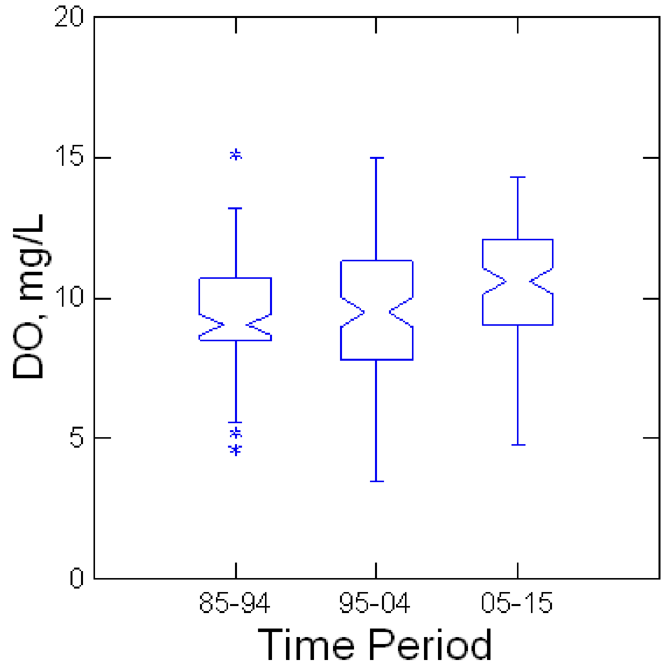


Figure B.2. Box plot of DO data from Buffalo River at the Wilderness Area Boundary.

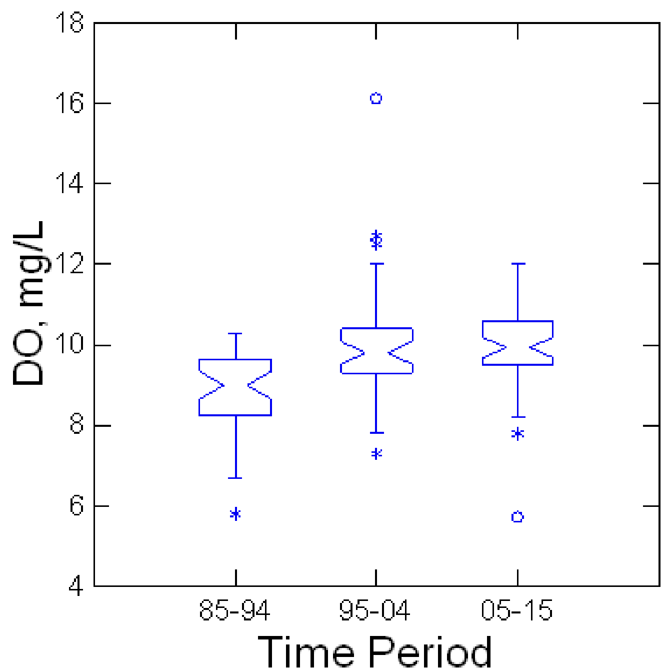


Figure B.3. Box plot of DO data from Luallen Spring by period.

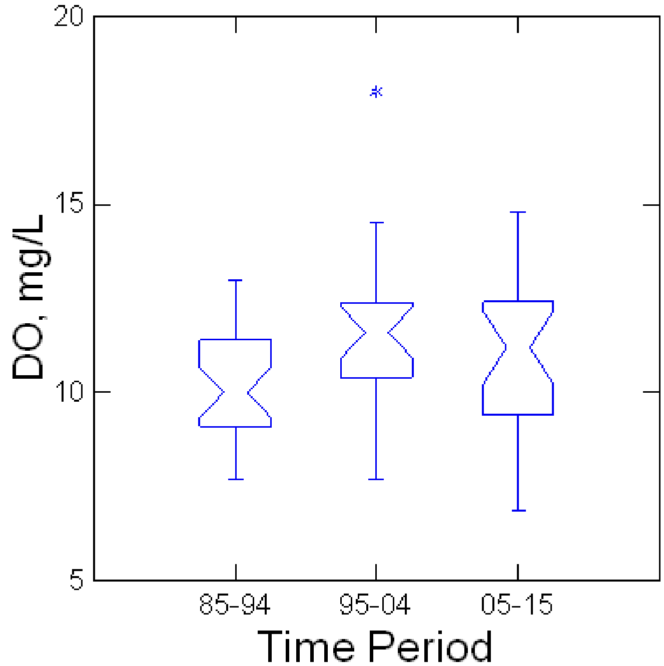


Figure B.4. Box plot of DO data from Beech Creek by period.

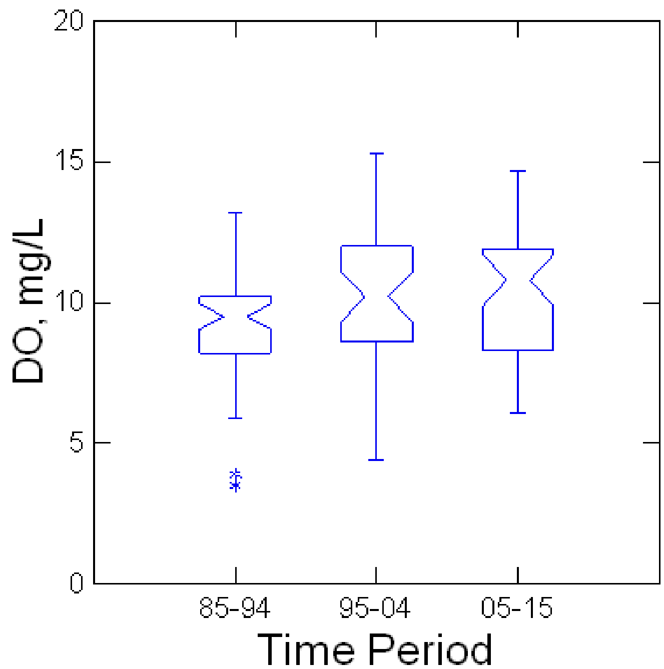


Figure B.5. Box plot of DO data from Ponca Creek by period.

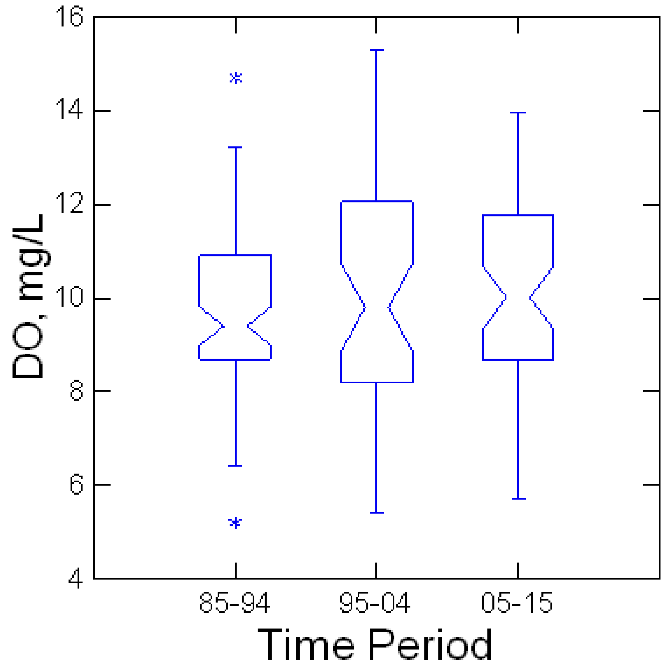


Figure B.6. Box plot of DO data from Buffalo River at Ponca access by period.

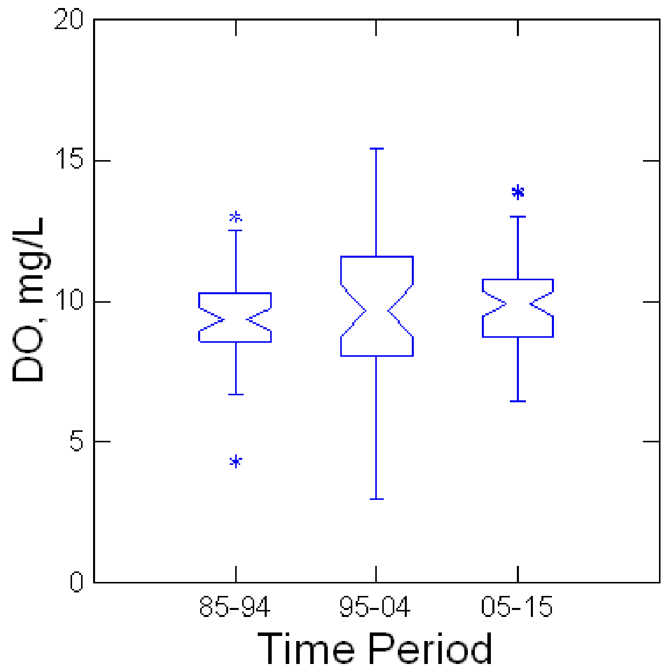


Figure B.7. Box plot of DO data from Cecil Creek by period.

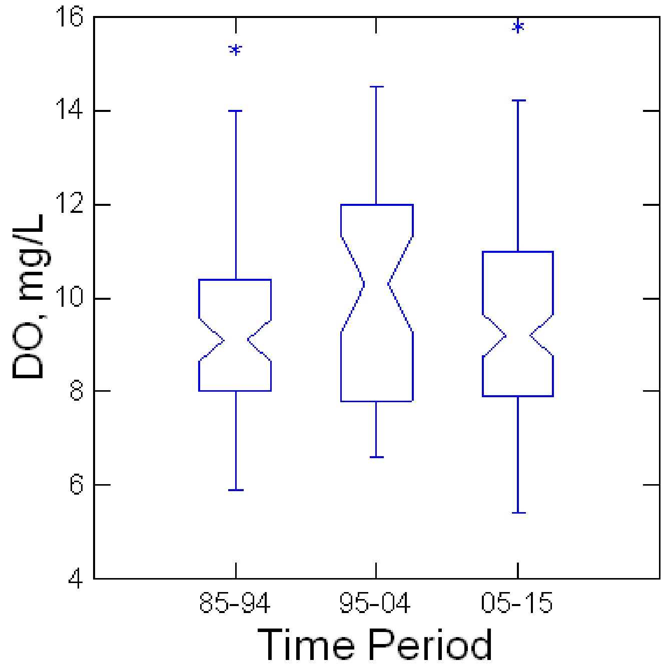


Figure B.8. Box plot of DO data from Buffalo River at Pruitt access by period.

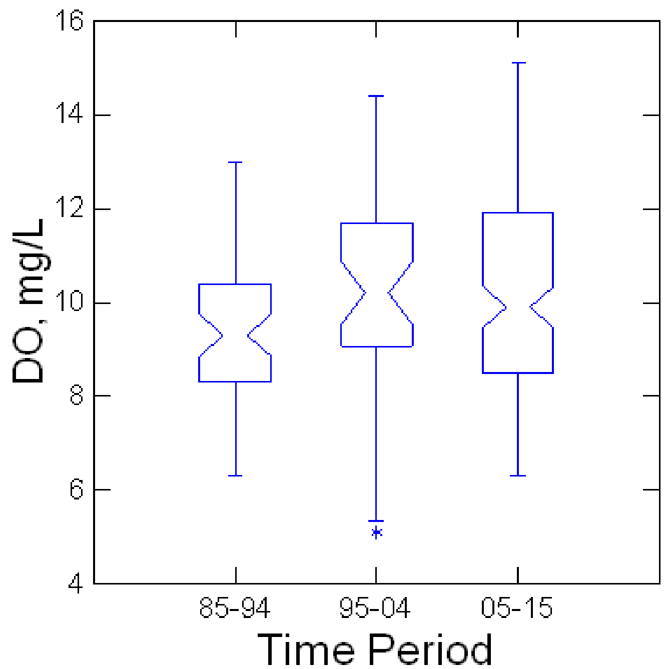


Figure B.9. Box plot of DO data from Mill Creek (upper) by period.

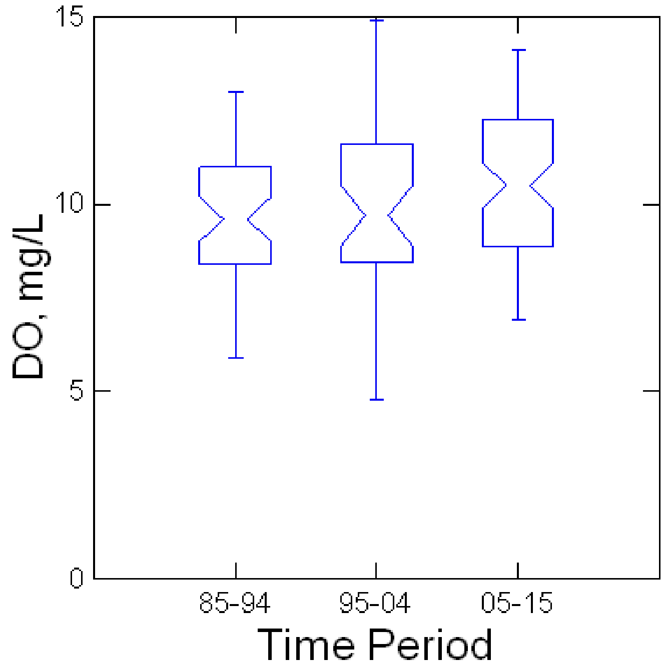


Figure B.10. Box plot of DO data from Little Buffalo River by period.

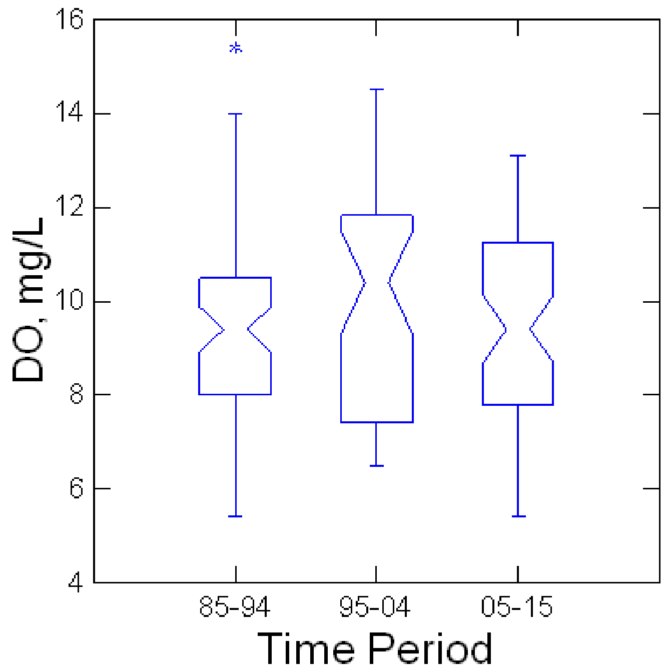


Figure B.11. Box plot of DO data from Buffalo River at Hasty by period.

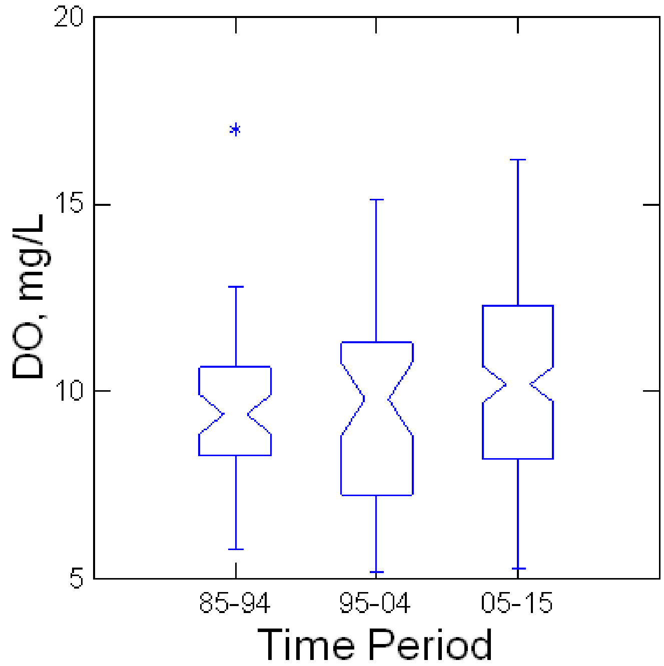


Figure B.12. Box plot of DO data from Big Creek near Carver by period.

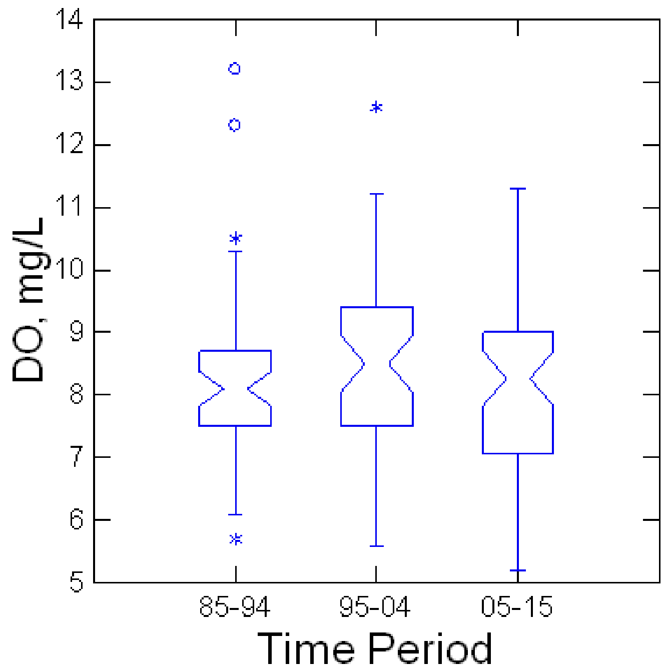


Figure B.13. Box plot of DO data from Mitch Hill Spring by period.

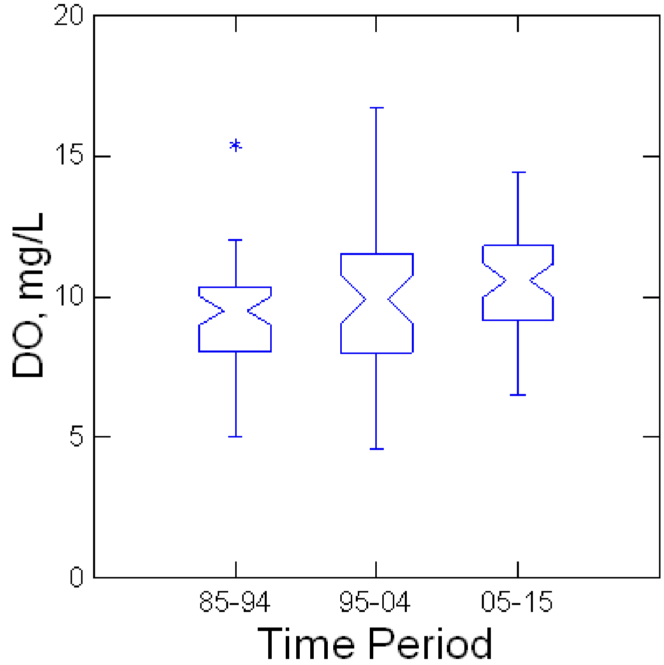


Figure B.14. Box plot of DO data from Davis Creek by period.

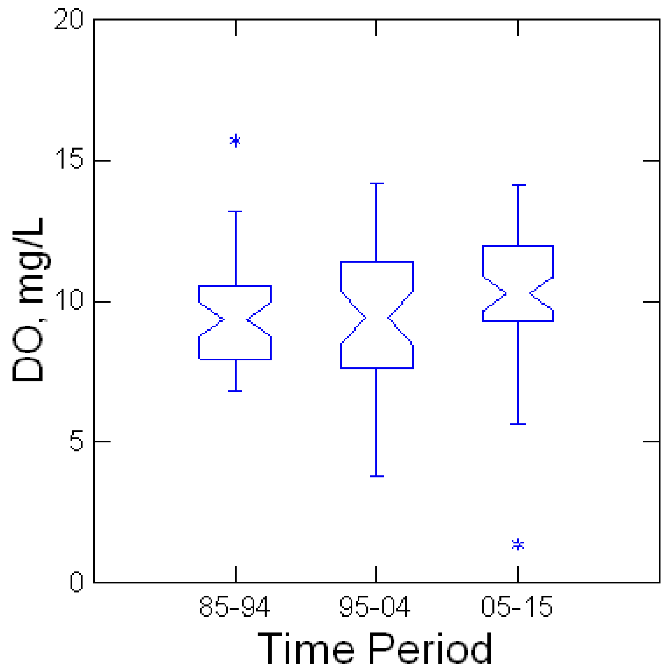


Figure B.15. Box plot of DO data from Cave Creek by period.

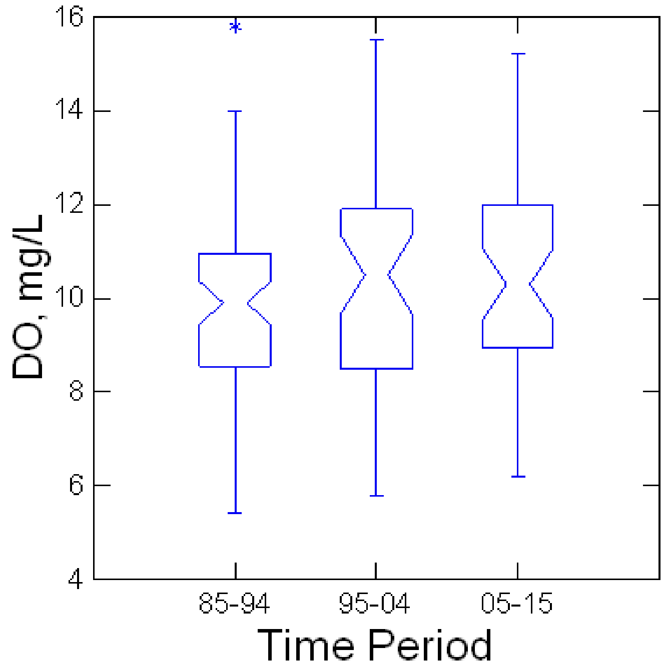


Figure B.16. Box plot of DO data from Buffalo River at Wollum by period.

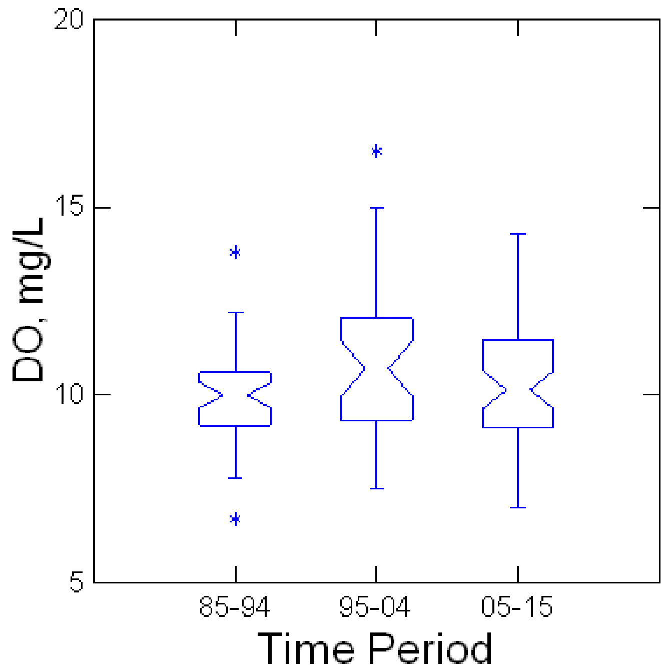


Figure B.17. Box plot of DO data from Richland Creek by period.

3.5

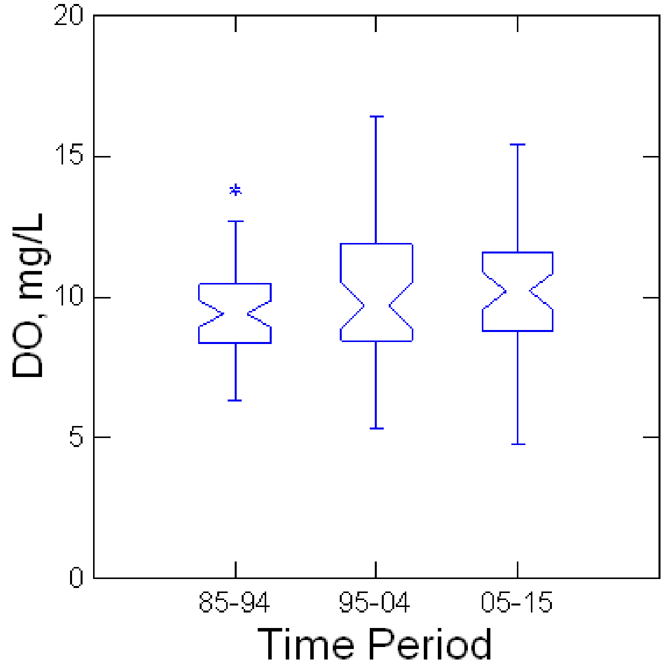


Figure B.18. Box plot of DO data from Calf Creek by period.

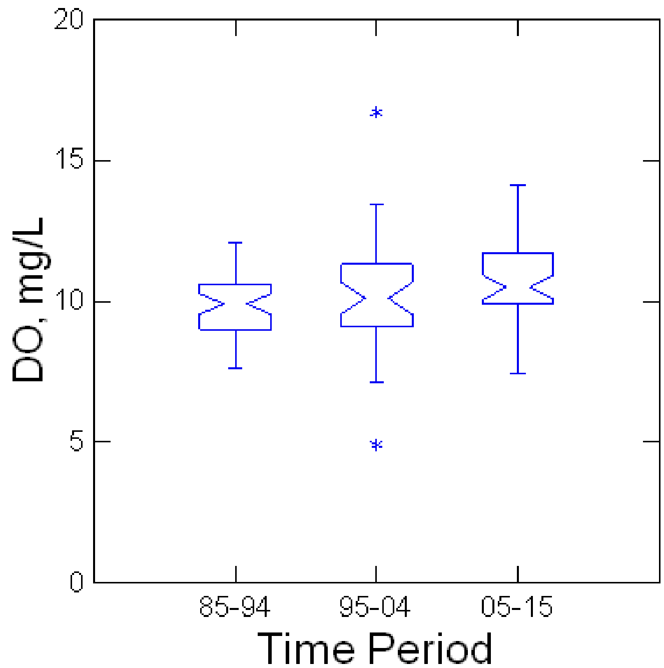


Figure B.19. Box plot of DO data from Mill Creek (lower) by period.

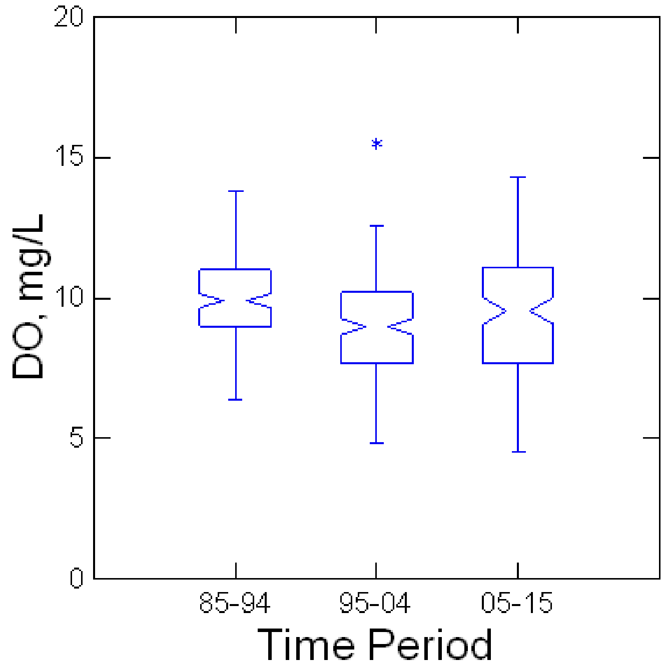


Figure B.20. Box plot of DO data from Buffalo River at Highway 65 by period.

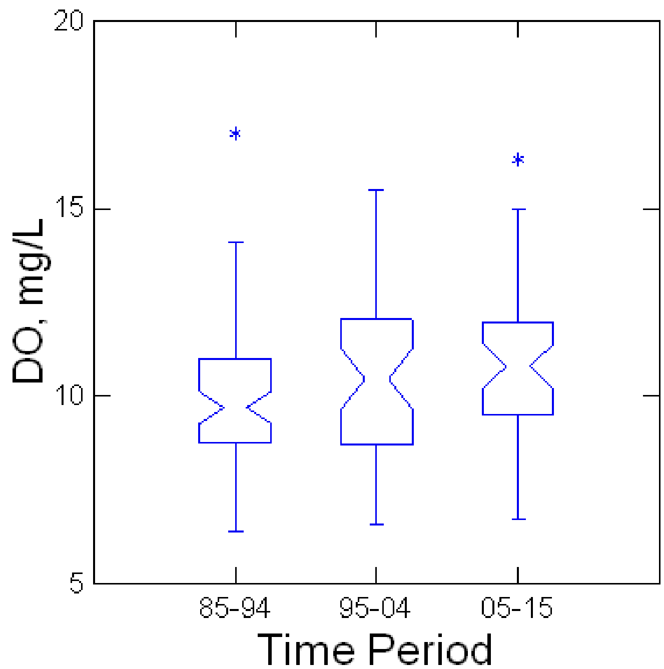


Figure B.21. Box plot of DO data from Buffalo River at Gilbert access by period.

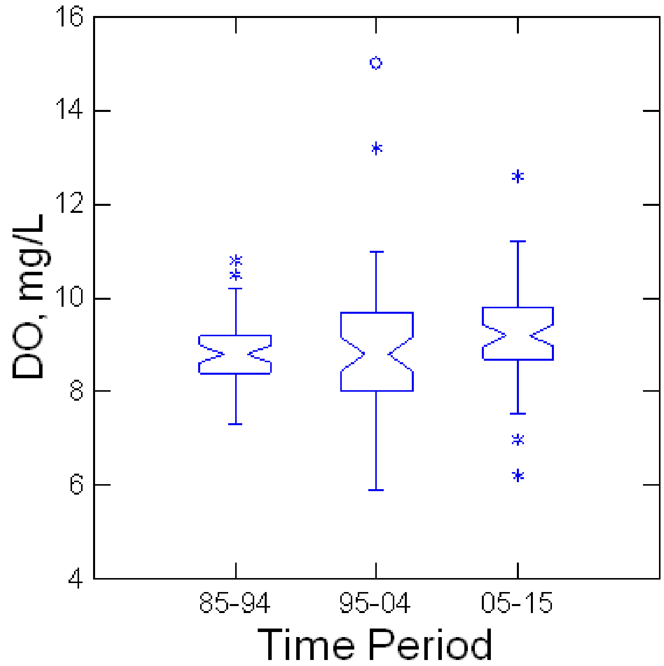


Figure B.22. Box plot of DO data from Gilbert Spring by period.

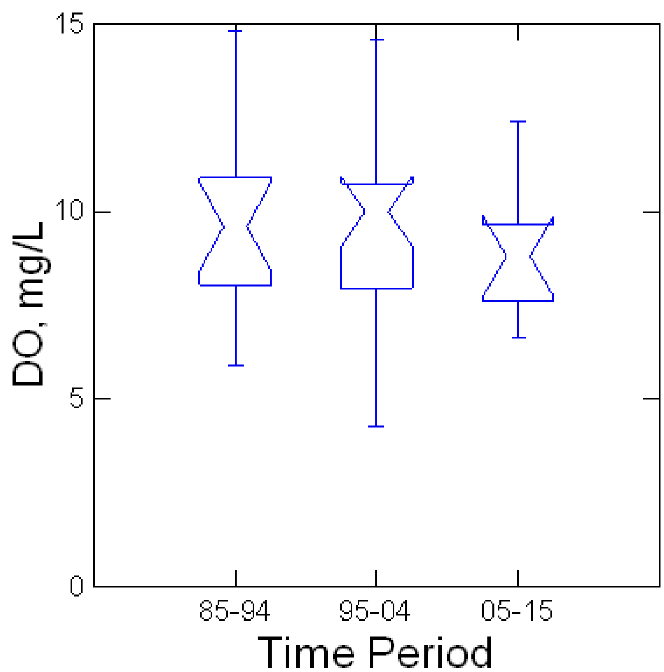


Figure B.23. Box plot of DO data from Bear Creek near Highway 65 by period.

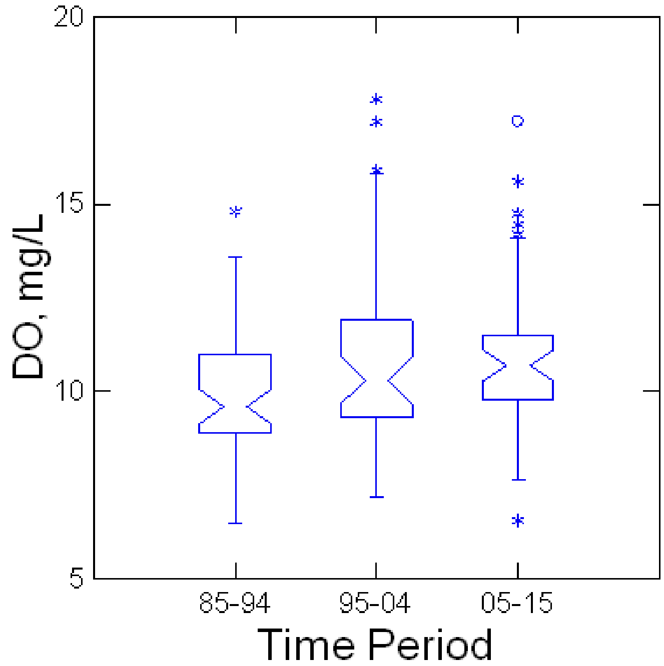


Figure B.24. Box plot of DO data from Bear Creek at mouth by period.

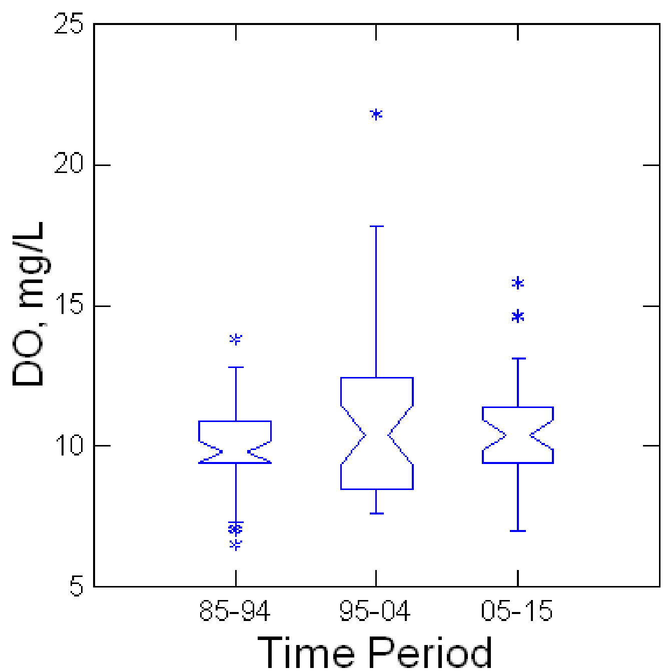


Figure B.25. Box plot of DO data from Brush Creek by period.

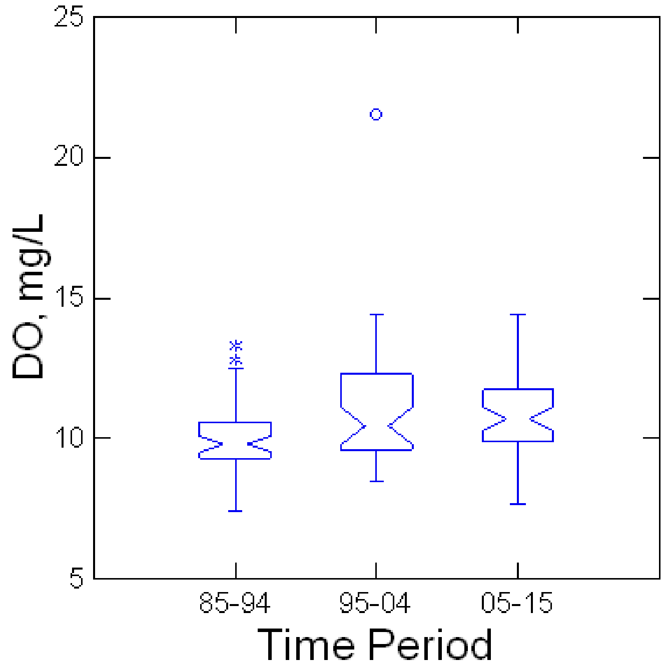


Figure B.26. Box plot of DO data from Tomahawk Creek by period.

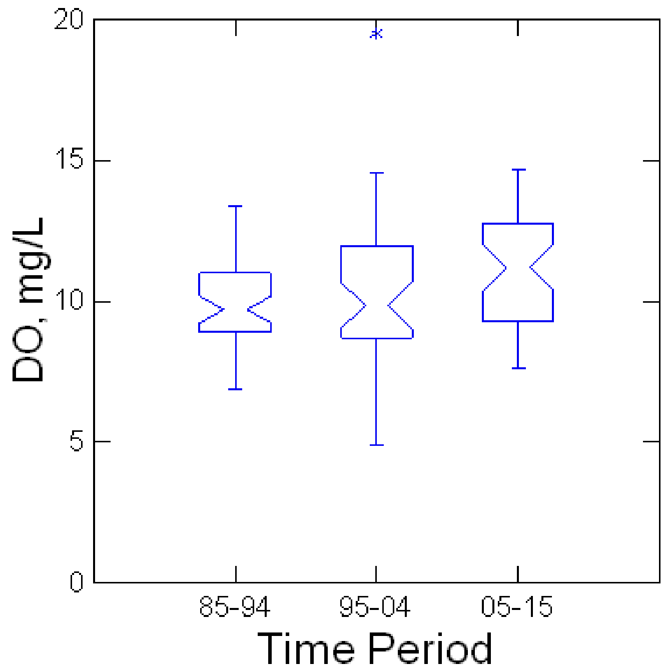


Figure B.27. Box plot of DO data from Water Creek by period.

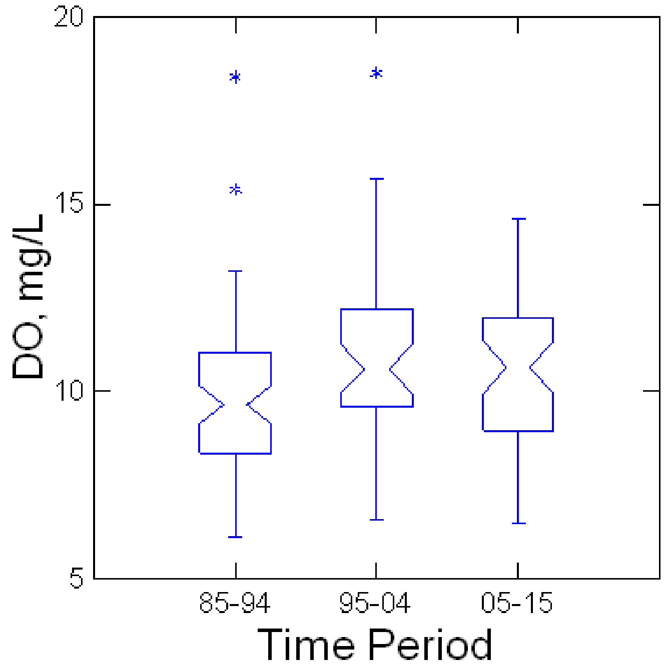


Figure B.28. Box plot of DO data from Buffalo River at Highway 14 by period.

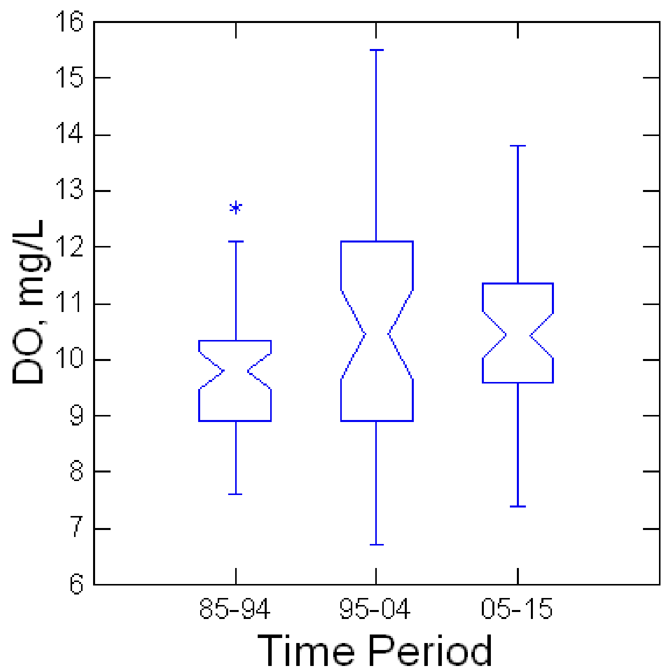


Figure B.29. Box plot of DO data from Rush Creek by period.

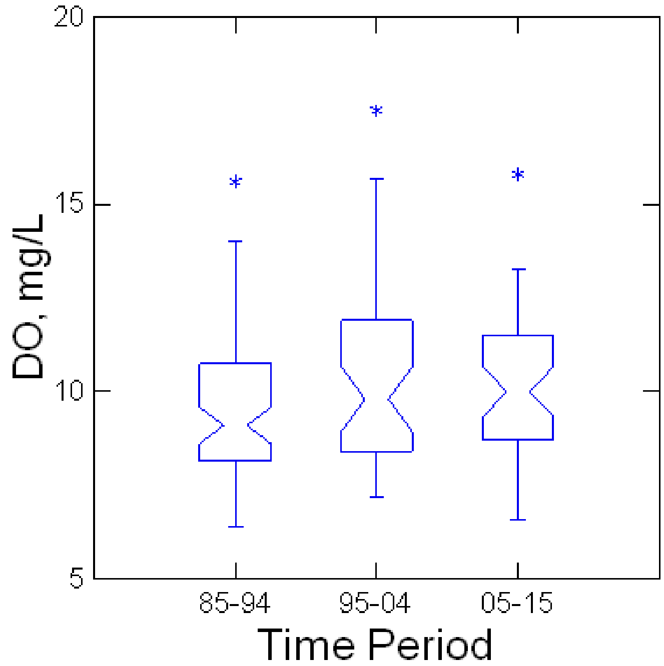


Figure B.30. Box plot of DO data from Buffalo River at Rush access by period.

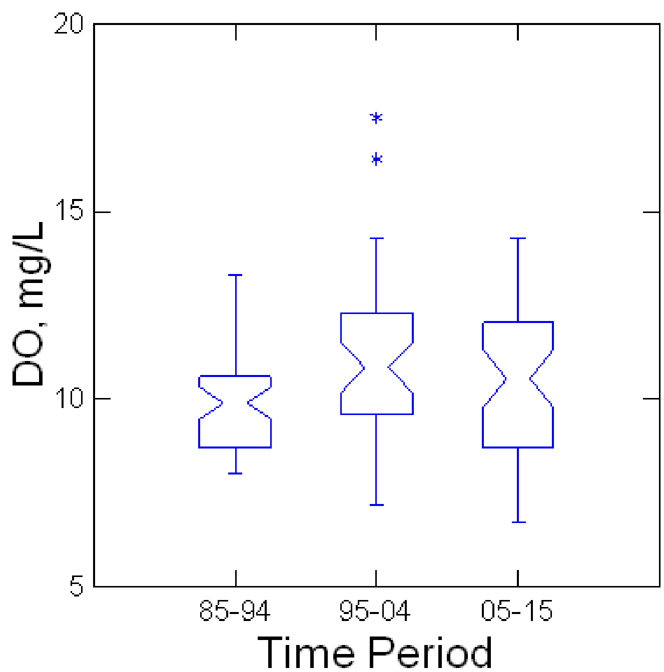


Figure B.31. Box plot of DO data from Clabber Creek by period.

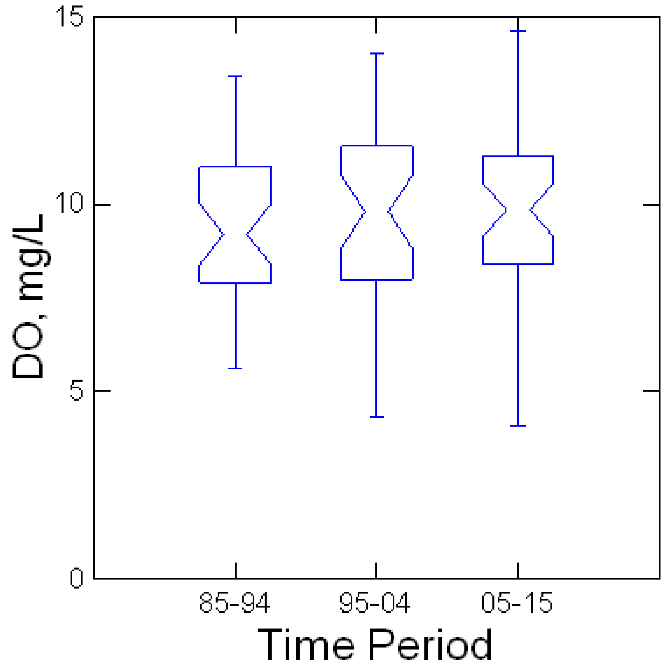


Figure B.32. Box plot of DO data from Big Creek (lower) by period.

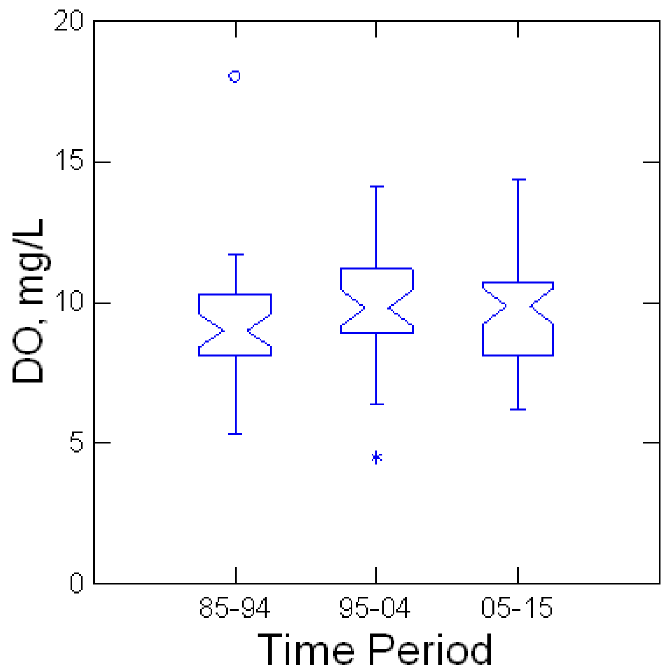


Figure B.33. Box plot of DO data from Middle Creek by period.

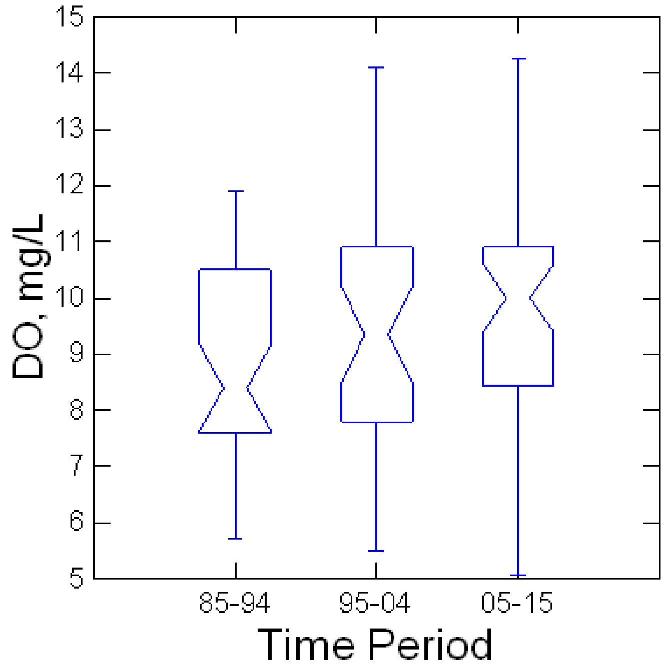


Figure B.34. Box plot of DO data from Leatherwood Creek by period.

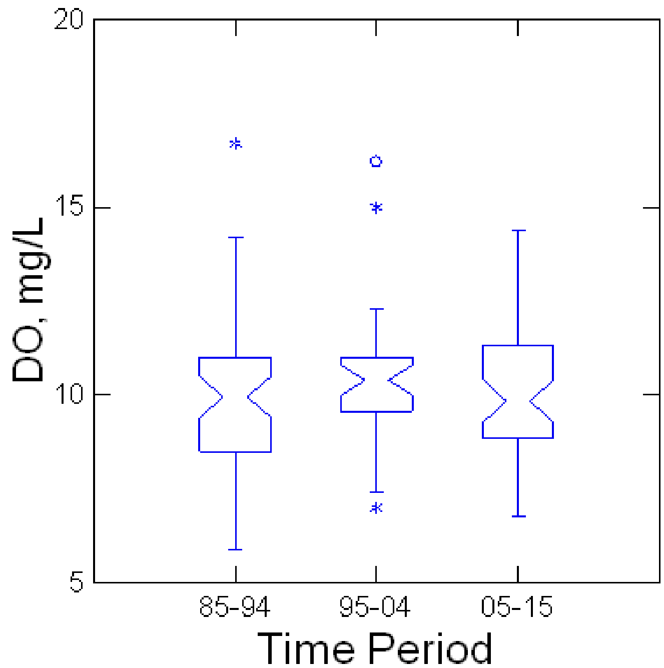


Figure B.35. Box plot of DO data from Buffalo River mouth by period.

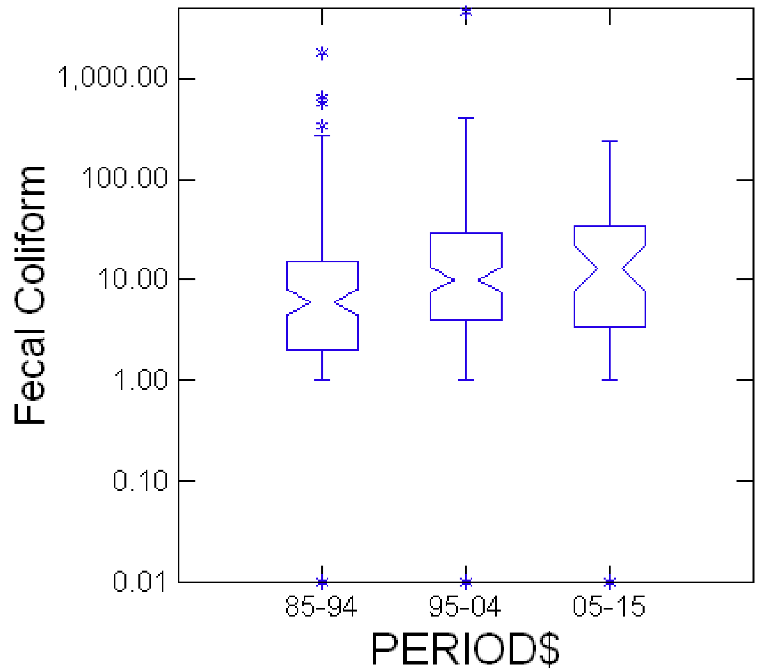


Figure B.36. Box plot of fecal coliform data from Buffalo River at the Wilderness Area boundary by period.

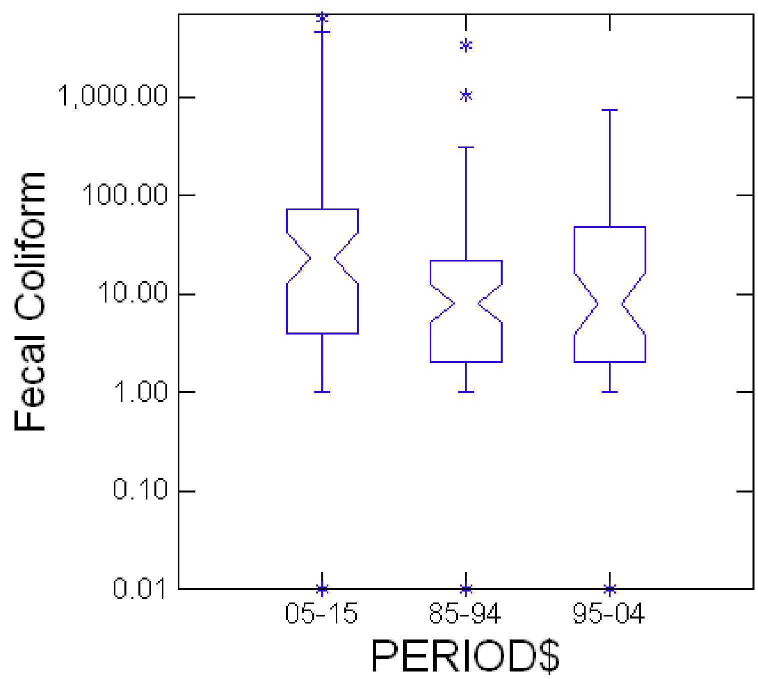


Figure B.37. Box plot of fecal coliform data from Big Creek (upper) near Carber by period.

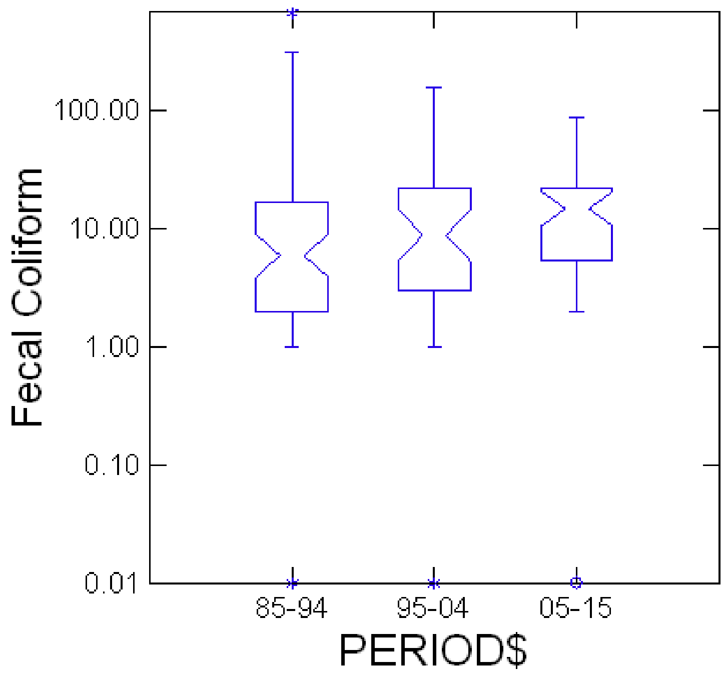


Figure B.38. Box plot of fecal coliform data from Water Creek by period.

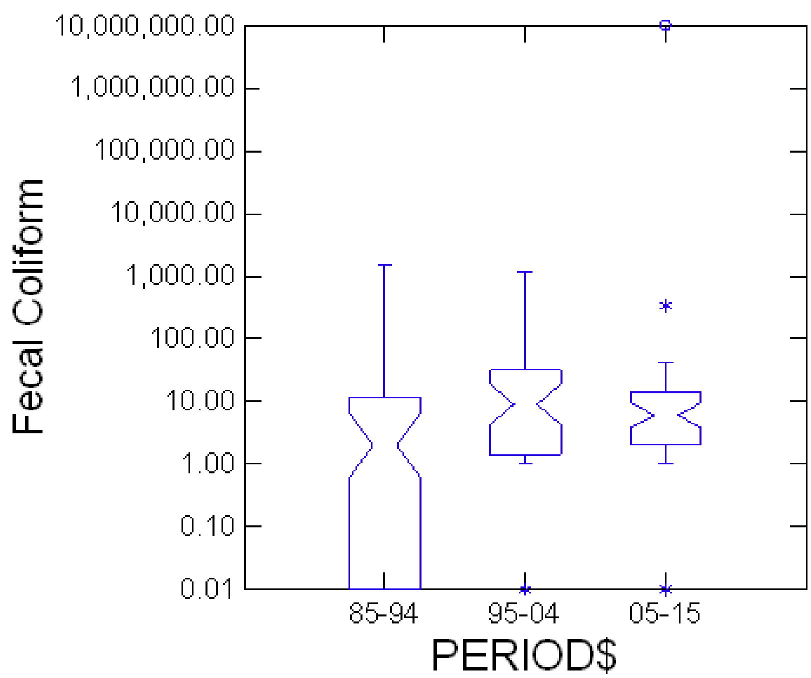


Figure B.39. Box plot of fecal coliform data from Buffalo River at Highway 14 by period.

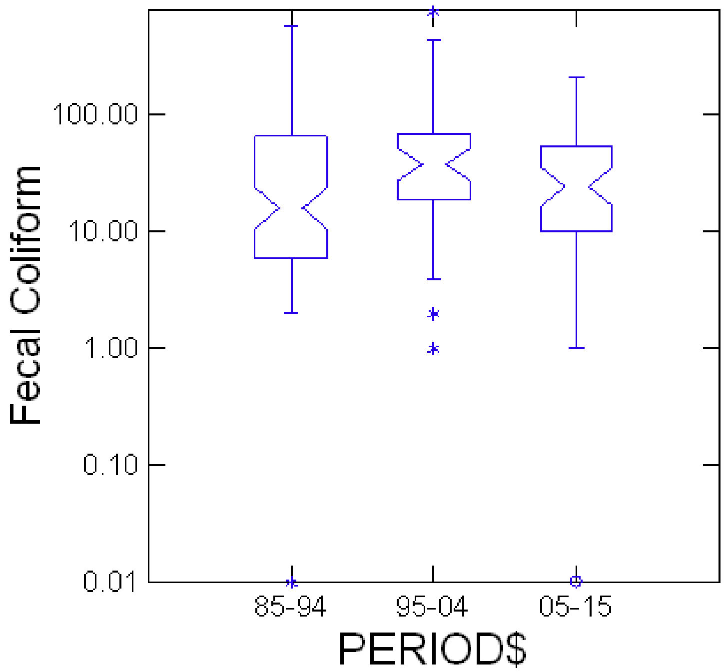


Figure B.40. Box plot of fecal coliform data from Buffalo River at Ponca access by period.

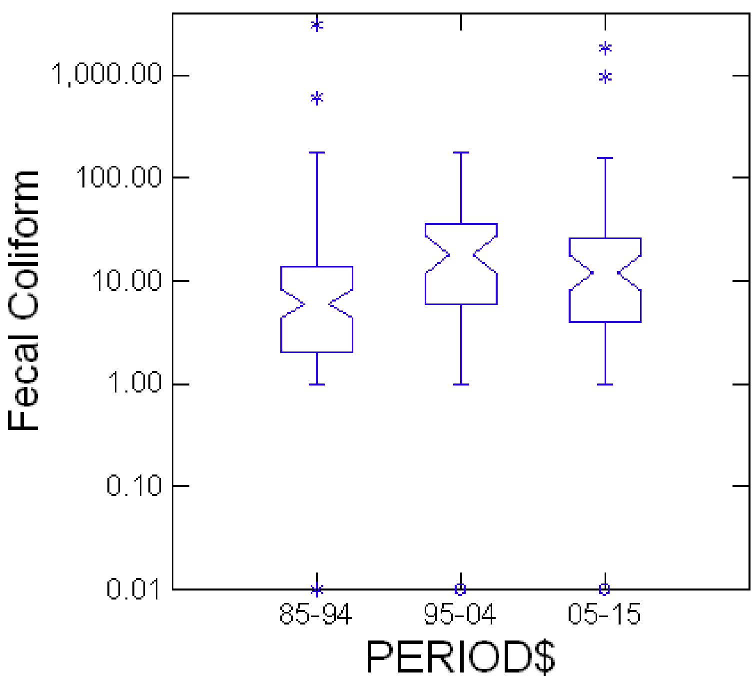


Figure B.41. Box plot of fecal coliform data from Buffalo River at Pruitt access by period.

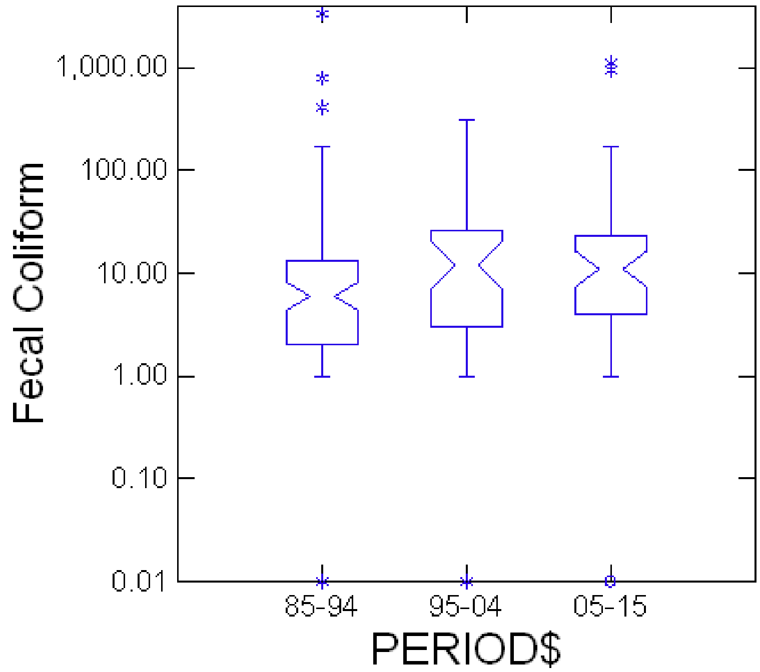


Figure B.42. Box plot of fecal coliform data from Buffalo River at Hasty by period.

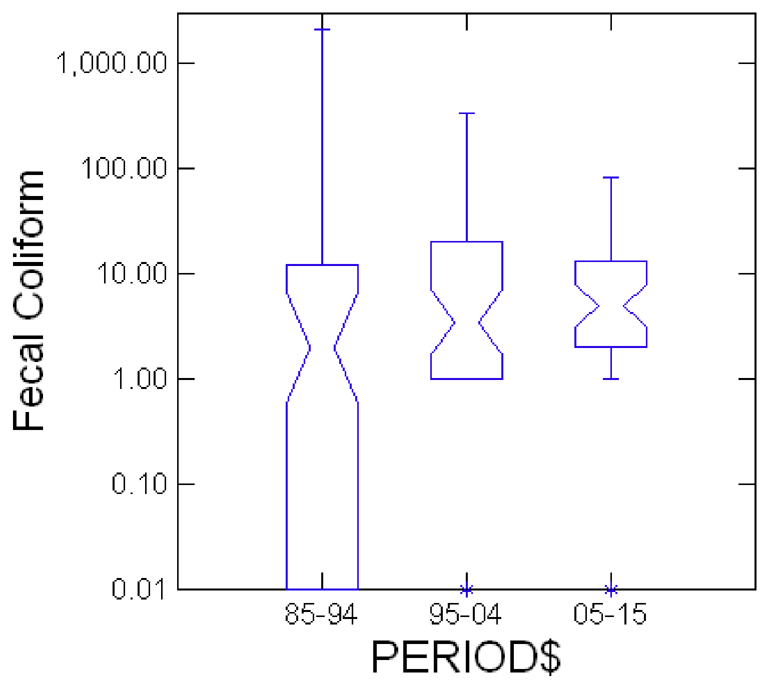


Figure B.43. Box plot of fecal coliform data from Buffalo River at Wollum by period.

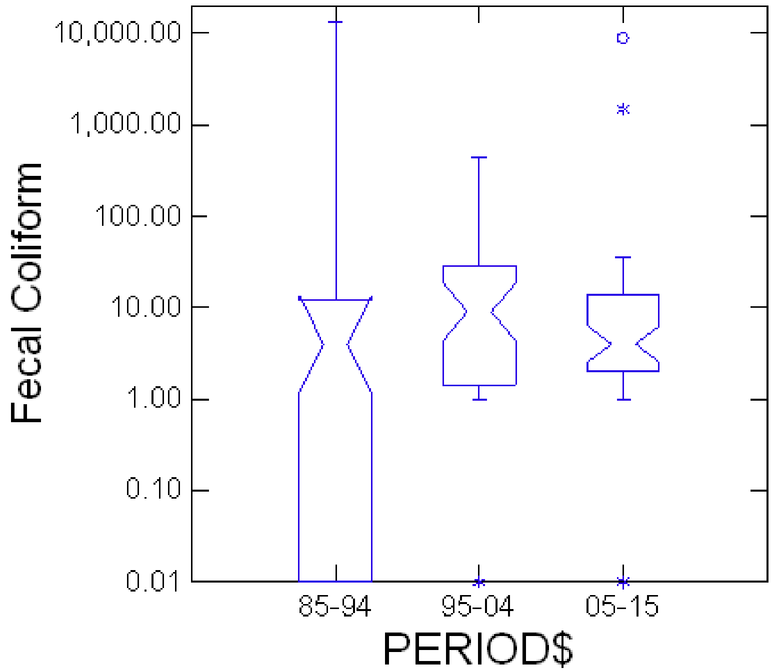


Figure B.44. Box plot of fecal coliform data from Buffalo River at Gilbert access by period.

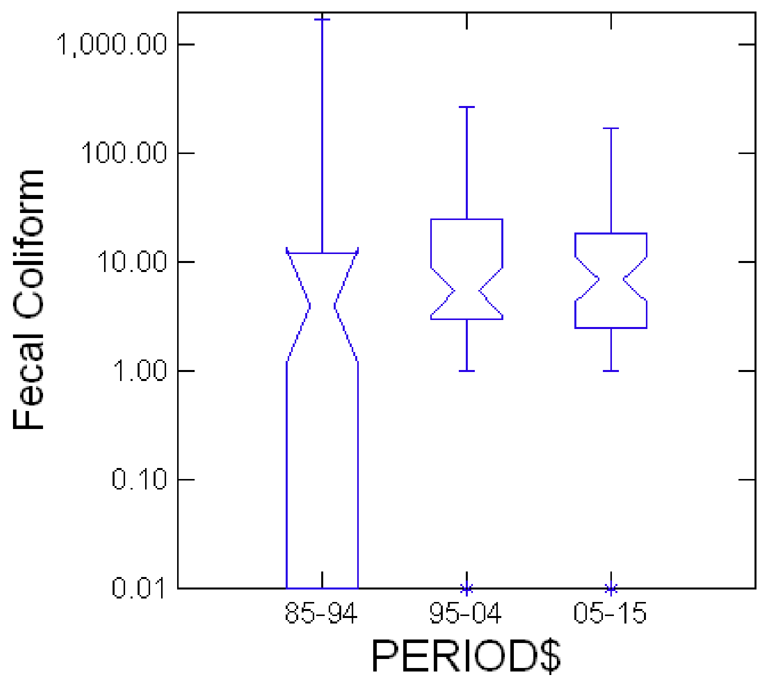


Figure B.45. Box plot of fecal coliform data from Buffalo River at Rush access by period.

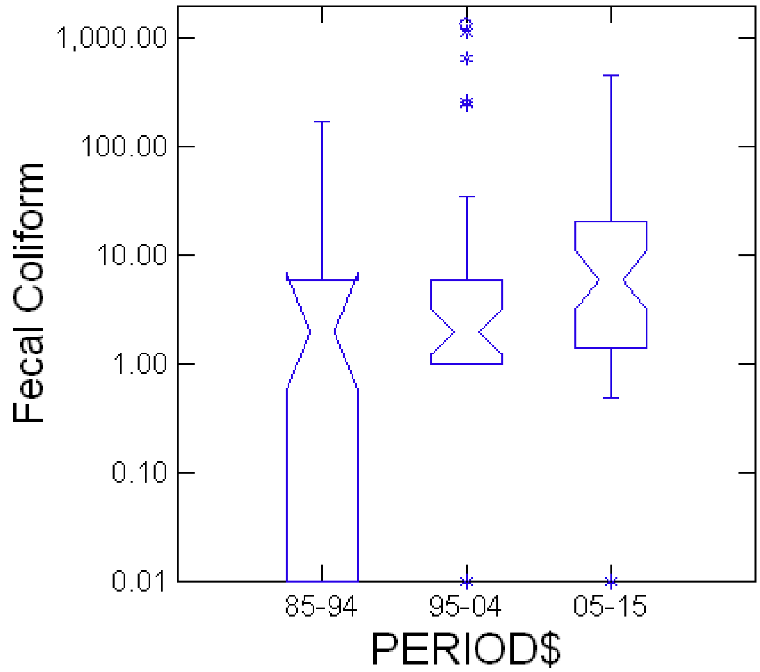


Figure B.46. Box plot of fecal coliform data from Buffalo River mouth by period.

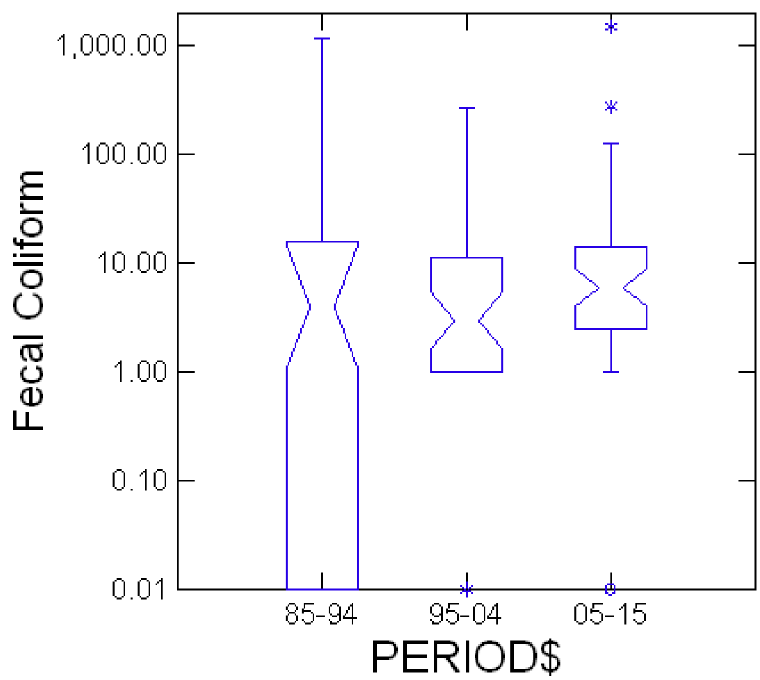


Figure B.46. Box plot of fecal coliform data from Luallen Spring by period.

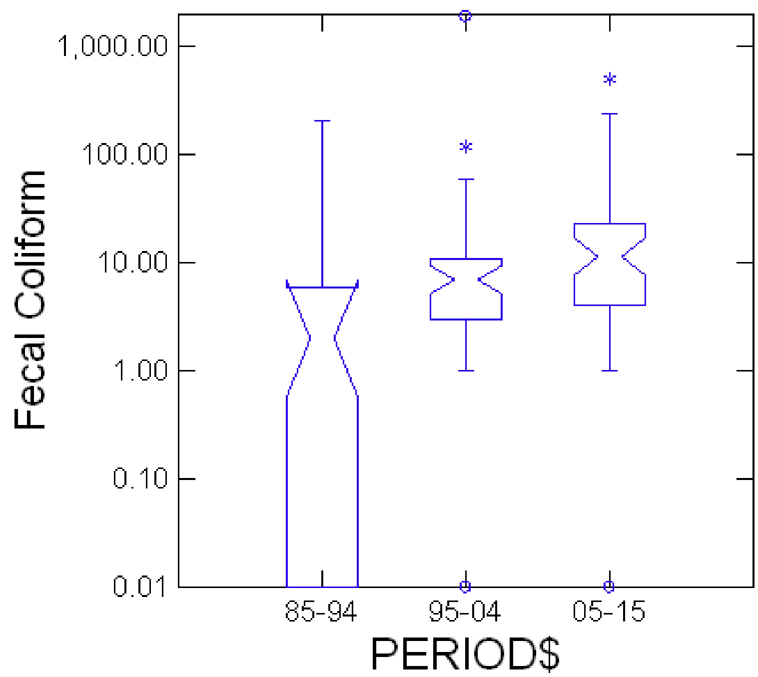


Figure B.47. Box plot of fecal coliform data from Mitch Hill Spring by period.

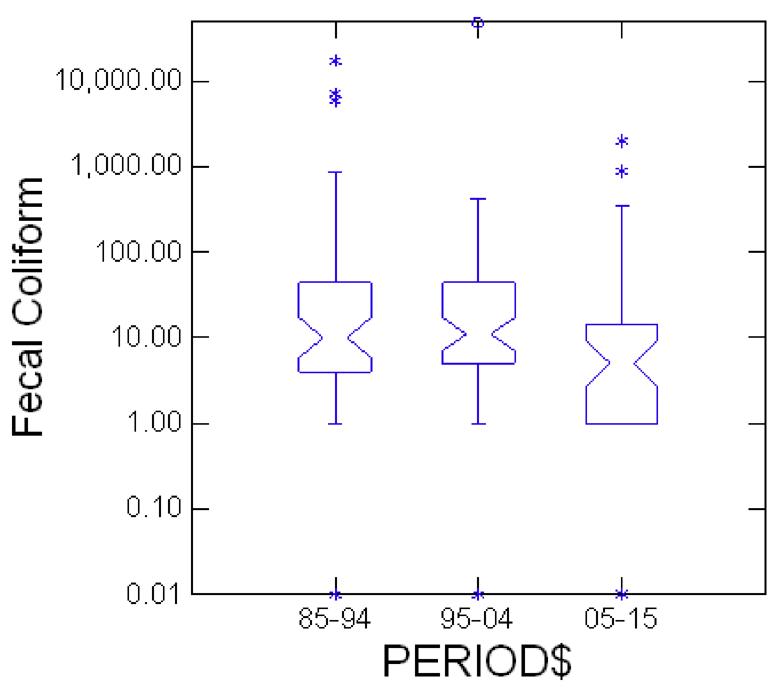


Figure B.48. Box plot of fecal coliform data from Gilbert Spring by period.

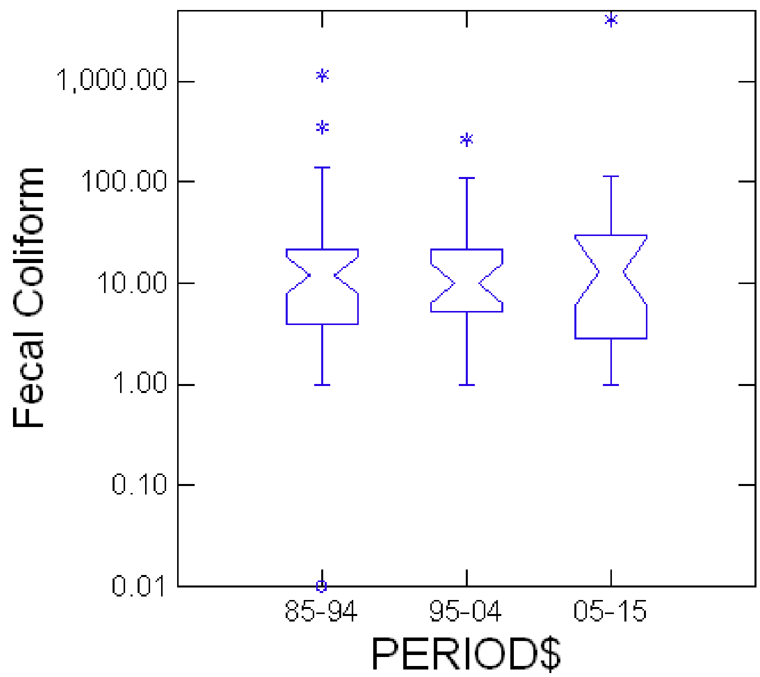


Figure B.49. Box plot of fecal coliform data from Beech Creek by period.

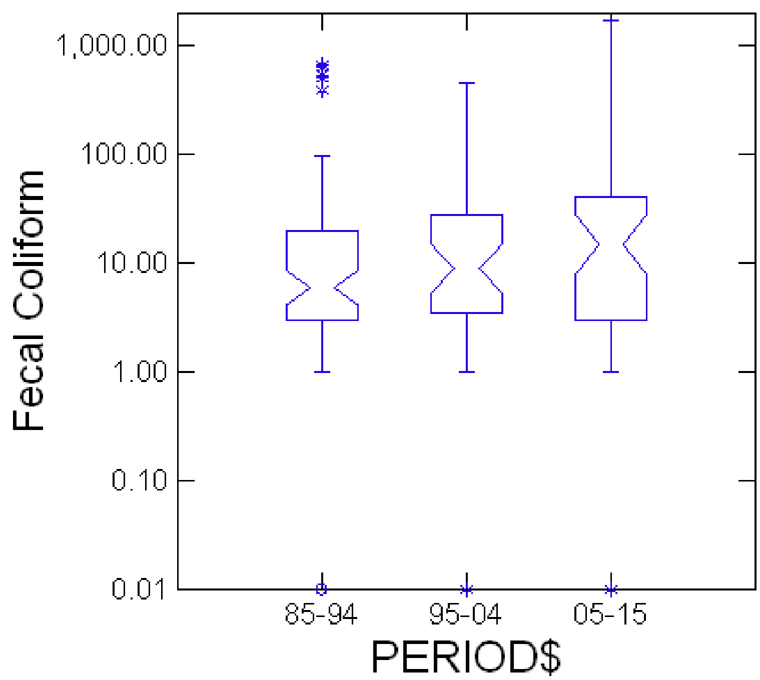


Figure B.50. Box plot of fecal coliform data from Ponca Creek by period.

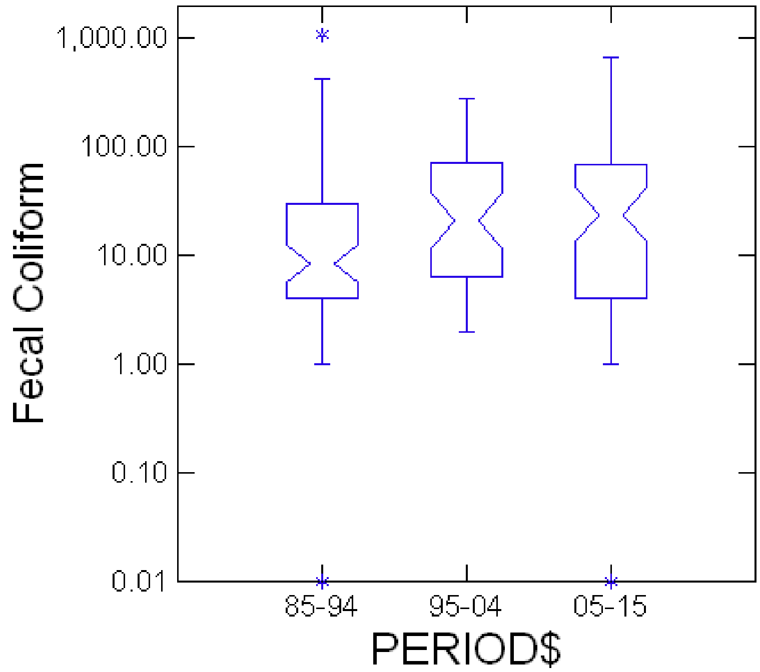


Figure B.51. Box plot of fecal coliform data from Cecil Creek by period.

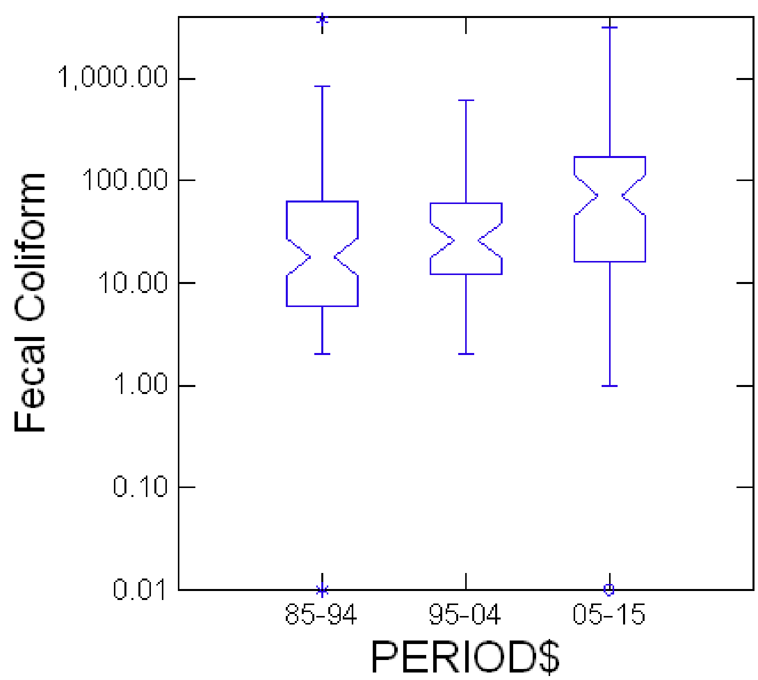


Figure B.52. Box plot of fecal coliform data from Mill Creek (upper) by period.

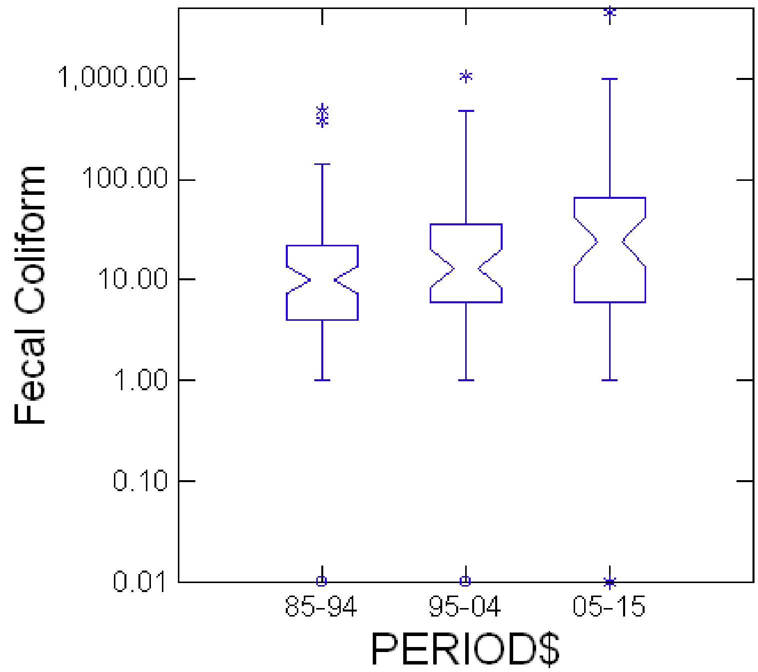


Figure B.53. Box plot of fecal coliform data from Little Buffalo River by period.

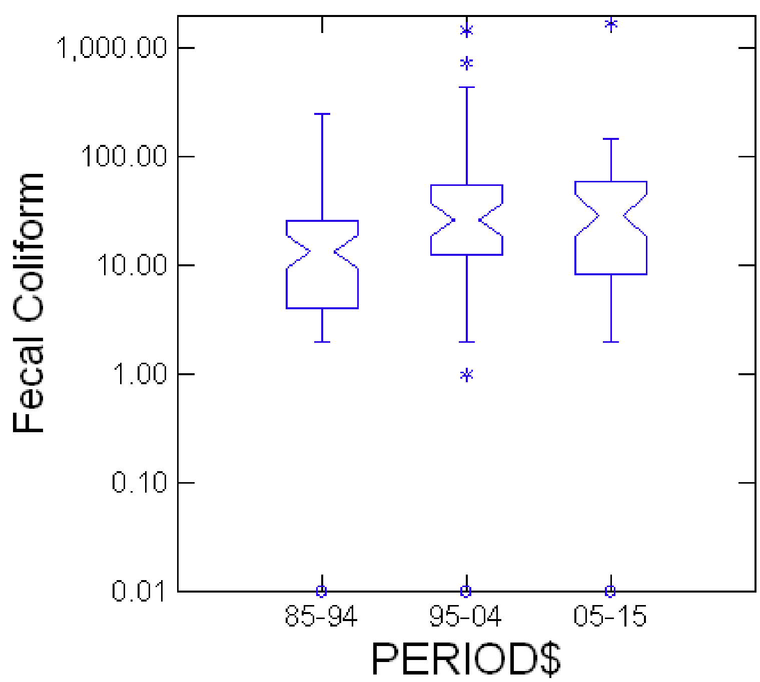


Figure B.54. Box plot of fecal coliform data from Davis Creek by period.

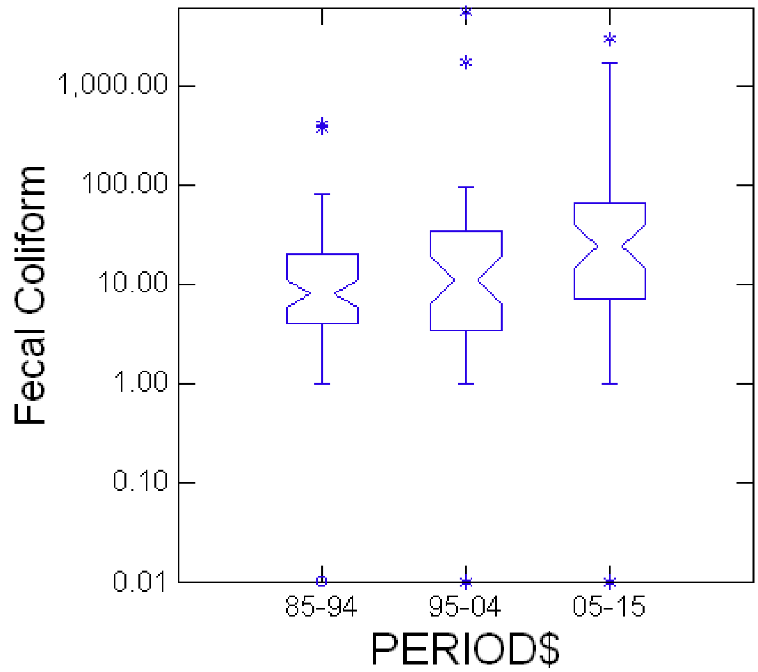


Figure B.55. Box plot of fecal coliform data from Cave Creek by period.

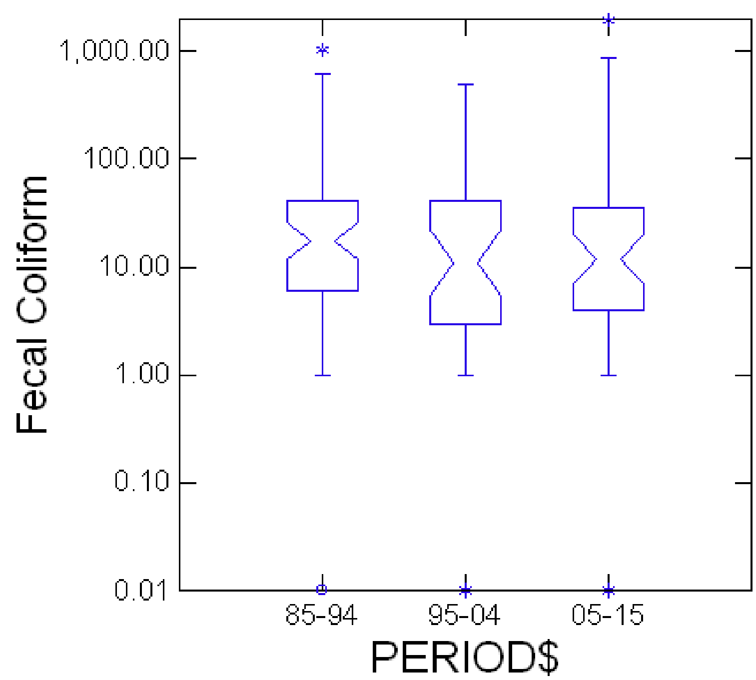


Figure B.56. Box plot of fecal coliform data from Richland Creek by period.

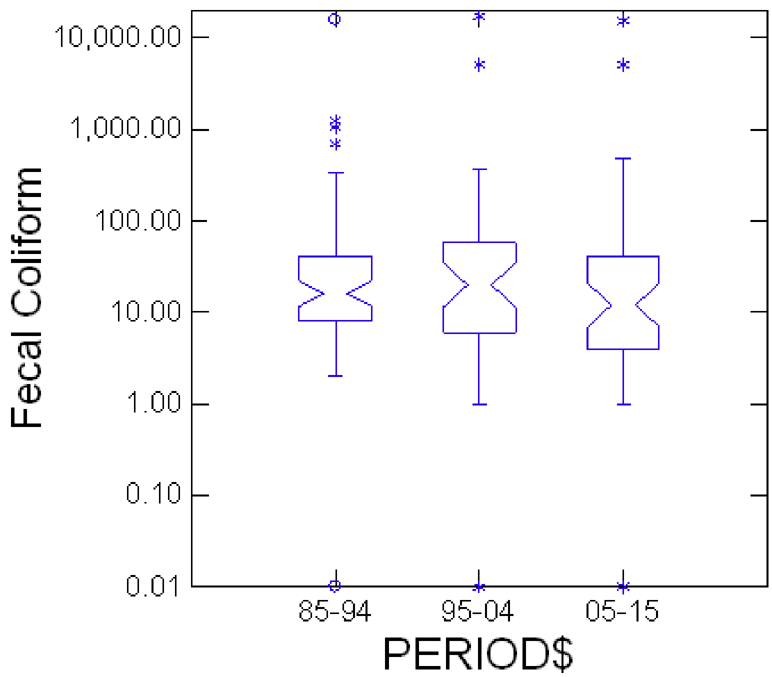


Figure B.57. Box plot of fecal coliform data from Calf Creek by period.

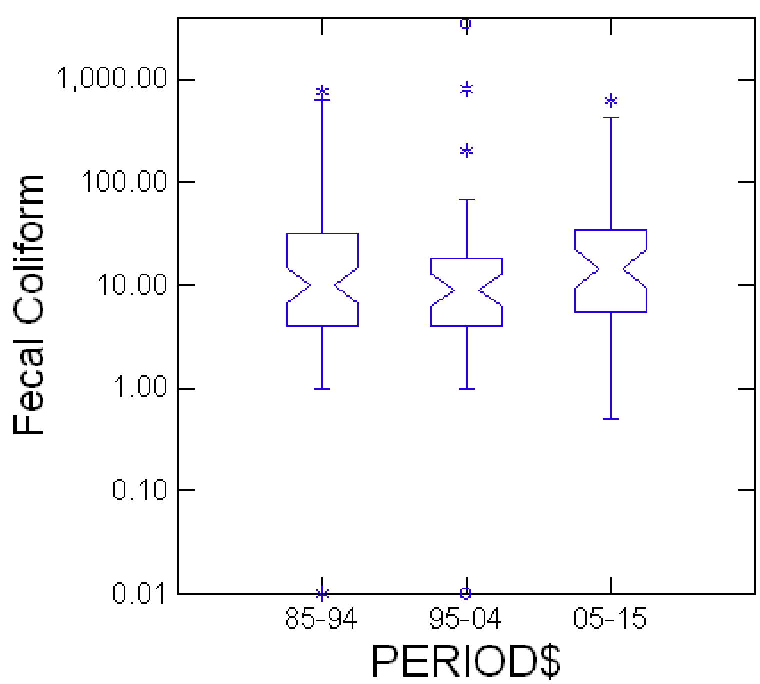


Figure B.58. Box plot of fecal coliform data from Mill Creek (lower) by period.

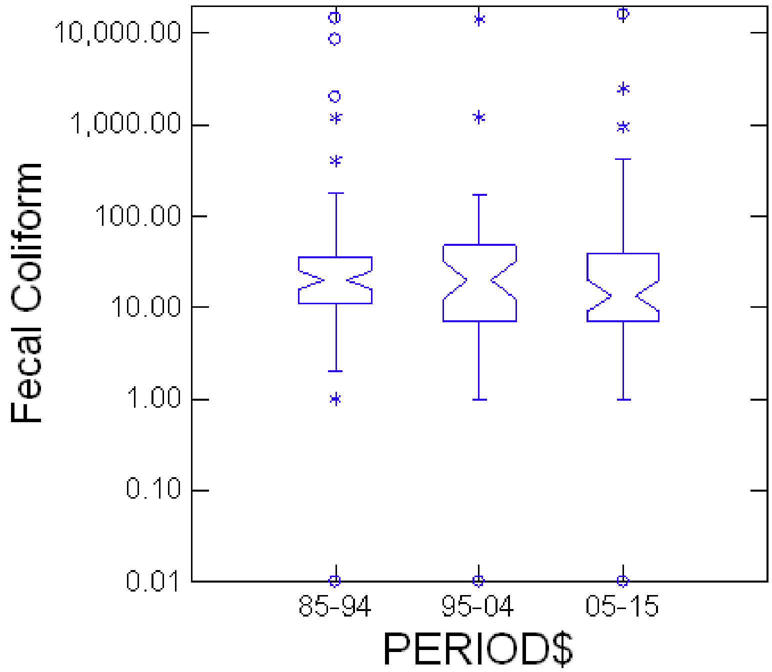


Figure B.59. Box plot of fecal coliform data from Bear Creek mouth by period.

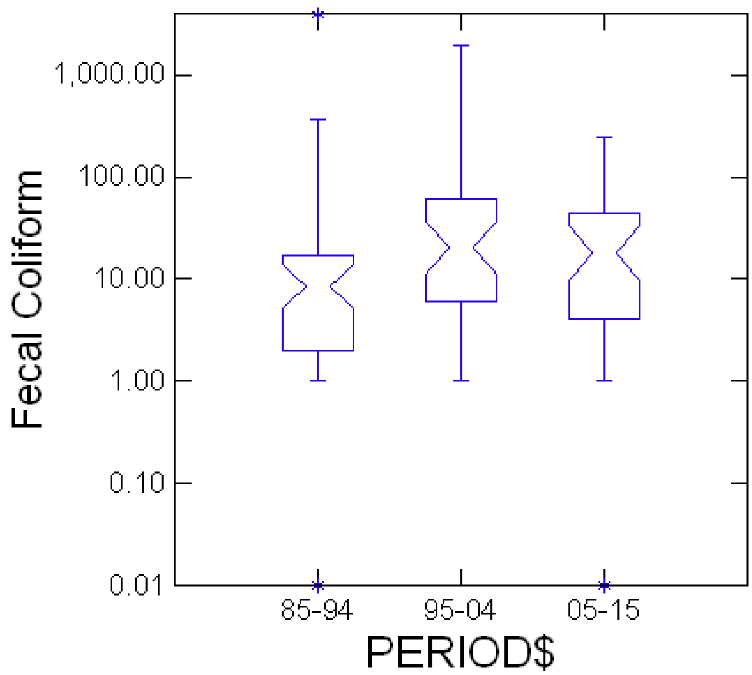


Figure B.60. Box plot of fecal coliform data from Brush Creek by period.

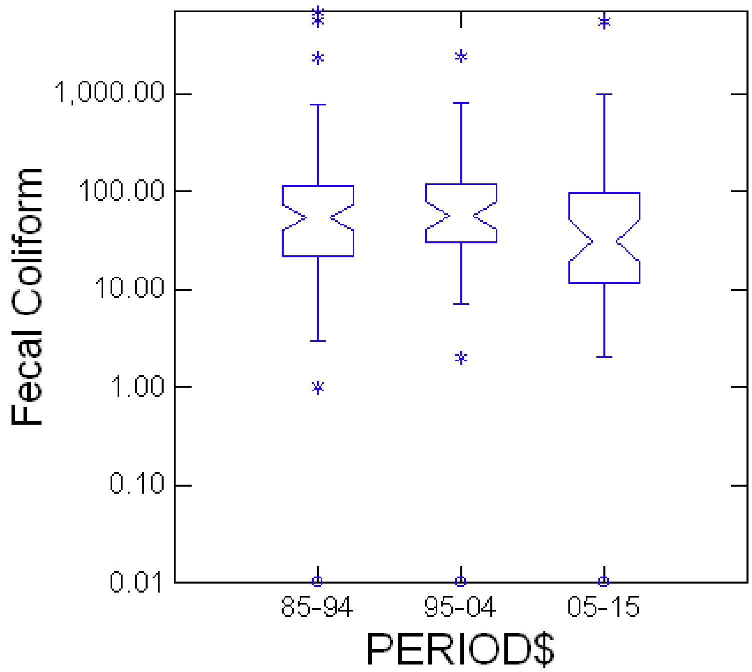


Figure B.61. Box plot of fecal coliform data from Tomahawk Creek by period.

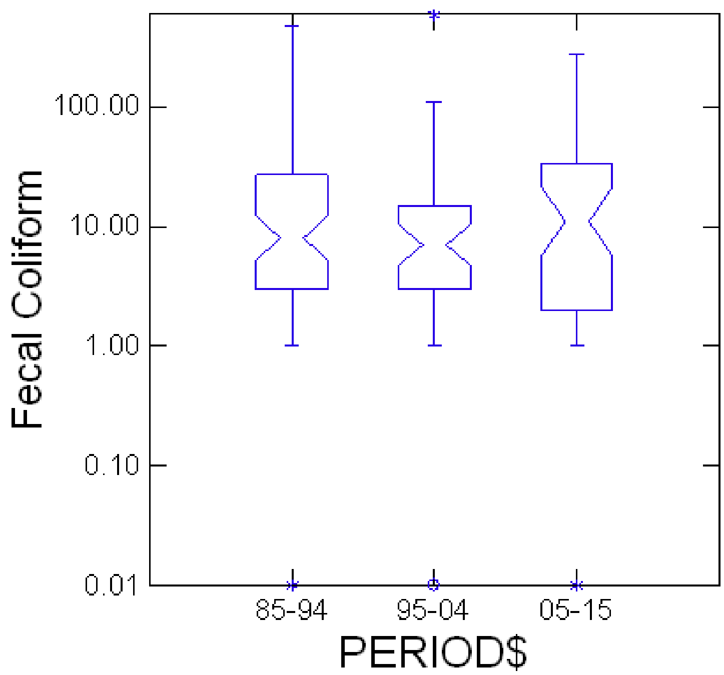


Figure B.62. Box plot of fecal coliform data from Rush Creek by period.

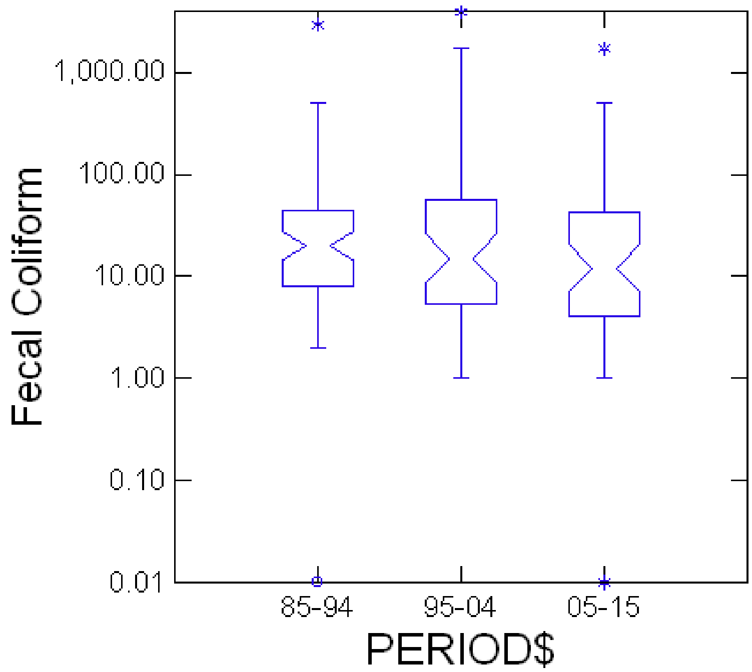


Figure B.63. Box plot of fecal coliform data from Clabber Creek by period.

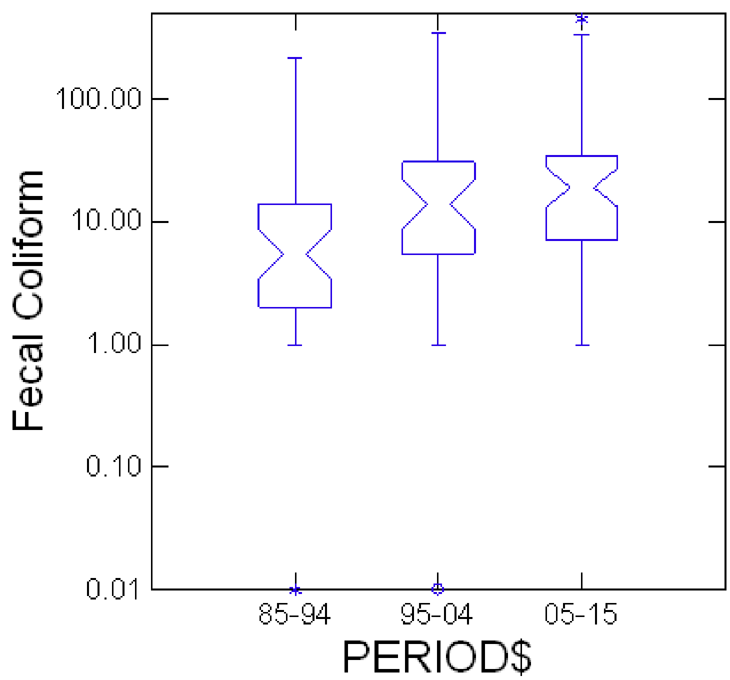


Figure B.64. Box plot of fecal coliform data from Big Creek (lower) by period.

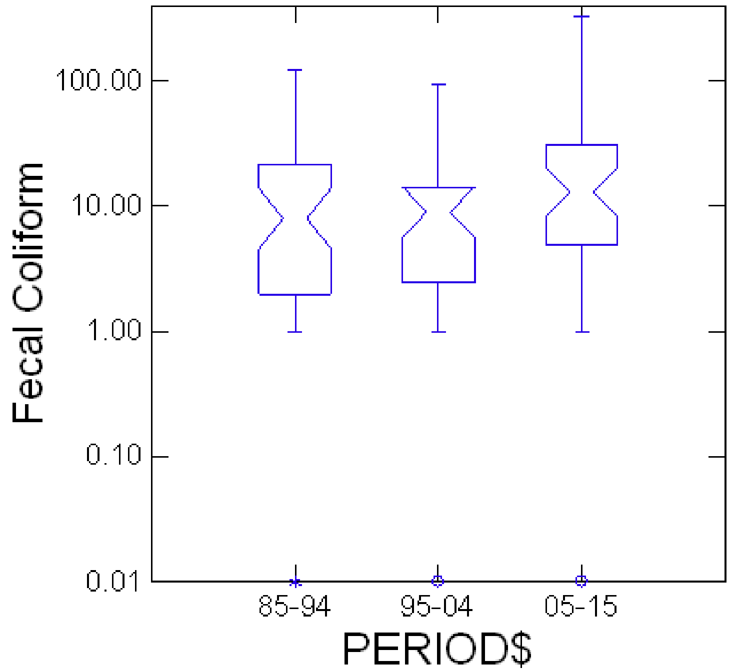


Figure B.65. Box plot of fecal coliform data from Middle Creek by period.

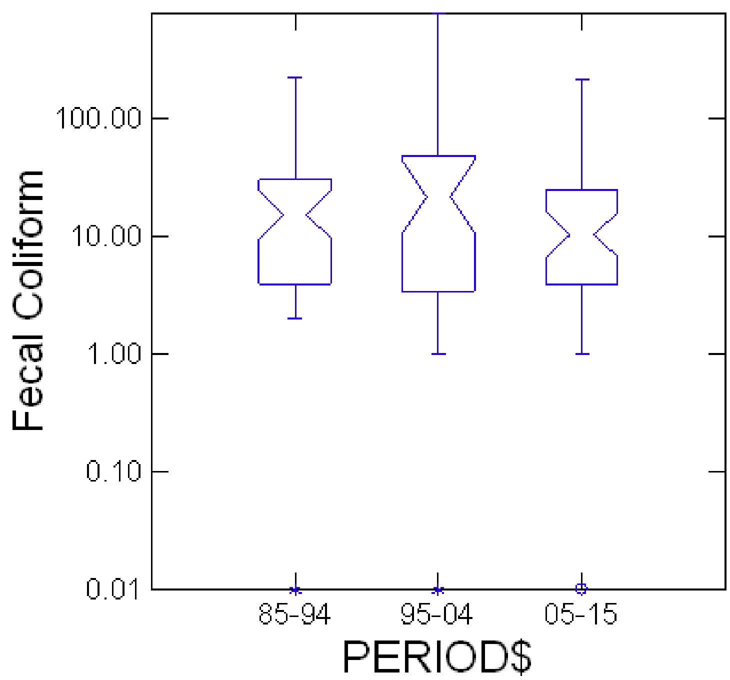


Figure B.66. Box plot of fecal coliform data from Leatherwood Creek by period.

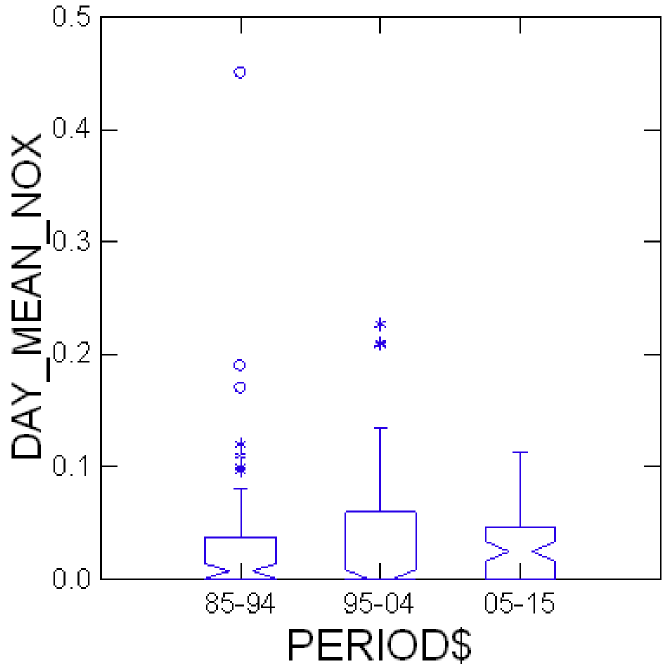


Figure B.67. Box plot of inorganic nitrogen data from Buffalo River at the Wilderness Area boundary by period.

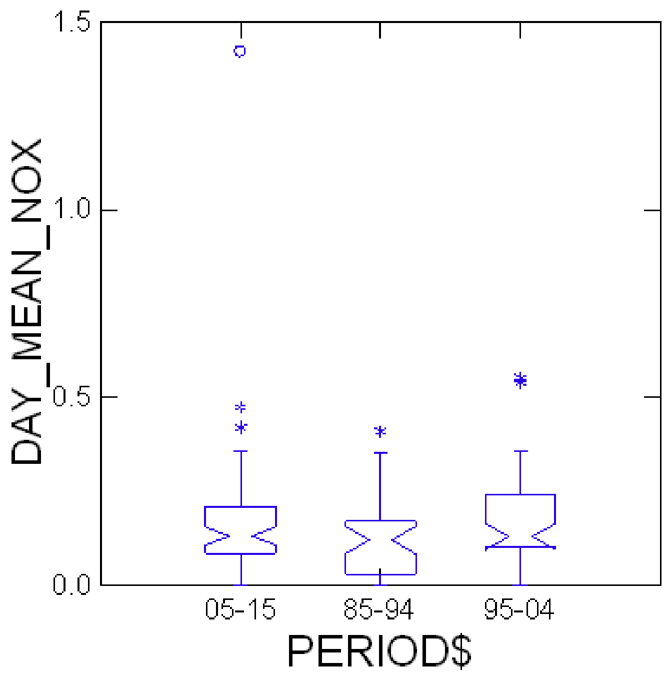


Figure B.68. Box plot of inorganic nitrogen data from Big Creek (lower) near Carver by period.

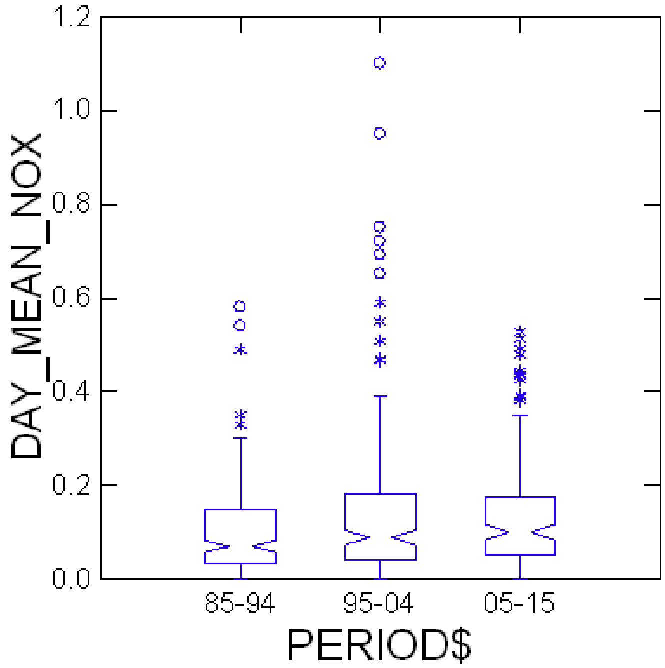


Figure B.69. Box plot of inorganic nitrogen data from Buffalo River at Highway 65 by period.

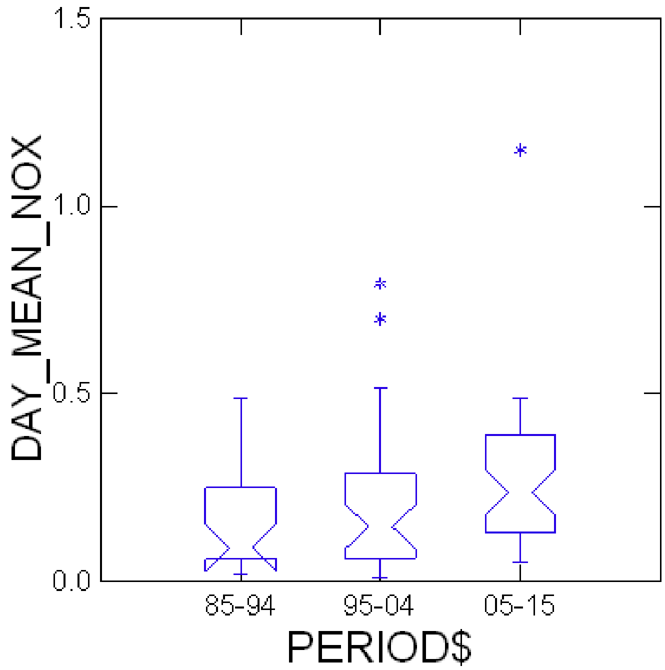


Figure B.70. Box plot of inorganic nitrogen data from Water Creek by period.

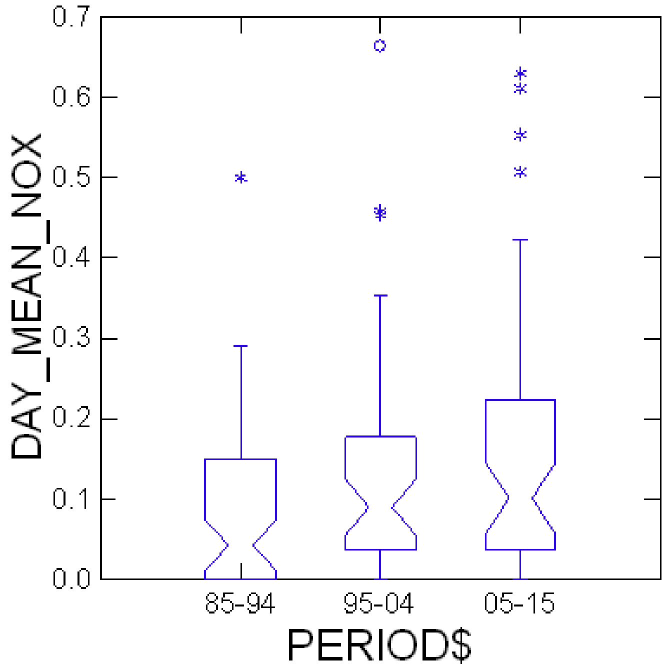


Figure B.71. Box plot of inorganic nitrogen data from Buffalo River at Highway 14 by period.

Results for NPS_NAME_CORR041717$ = BR @ Ponca

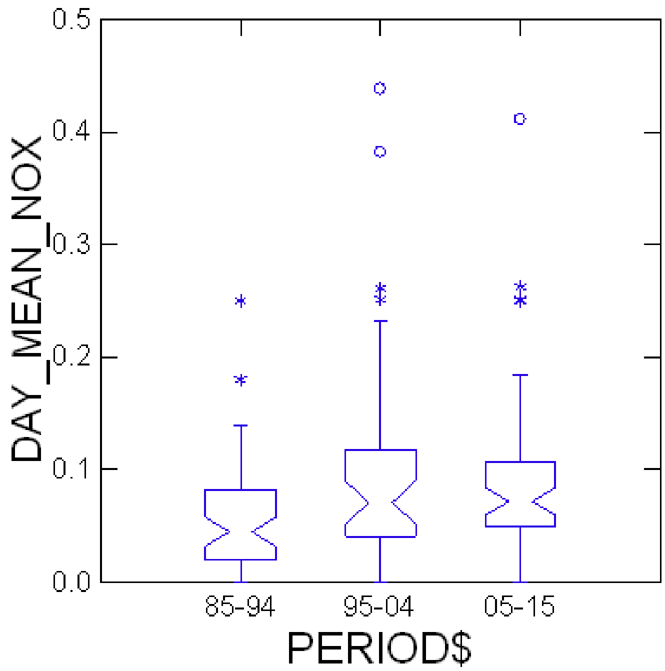


Figure B.72. Box plot of inorganic nitrogen data from Buffalo River at Ponca access by period.

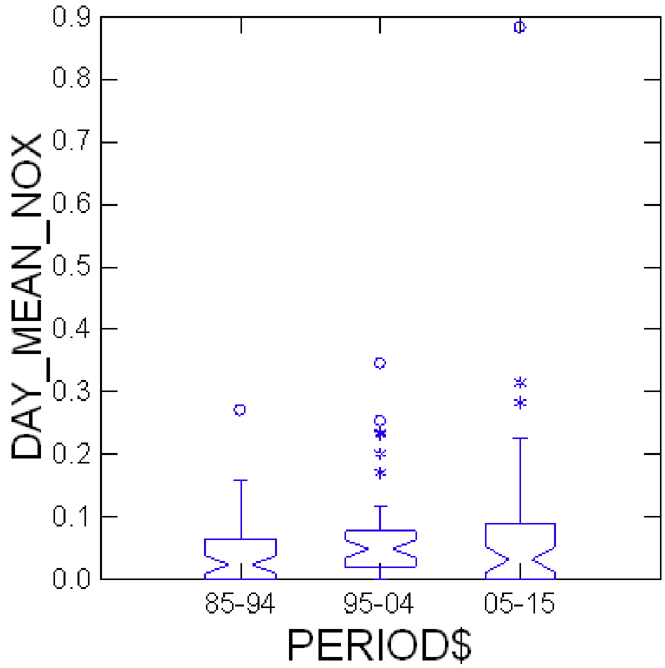


Figure B.73. Box plot of inorganic nitrogen data from Buffalo River at Pruitt access by period.

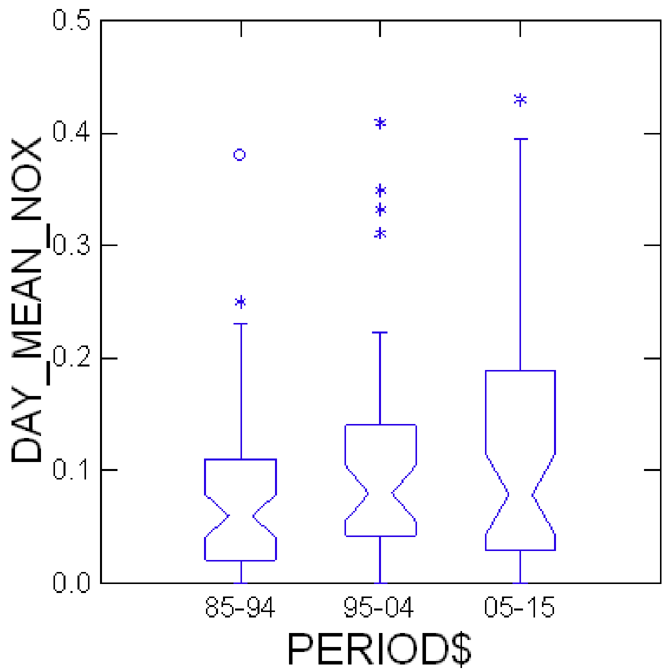


Figure B.74. Box plot of inorganic nitrogen data from Buffalo River at Hasty by period.

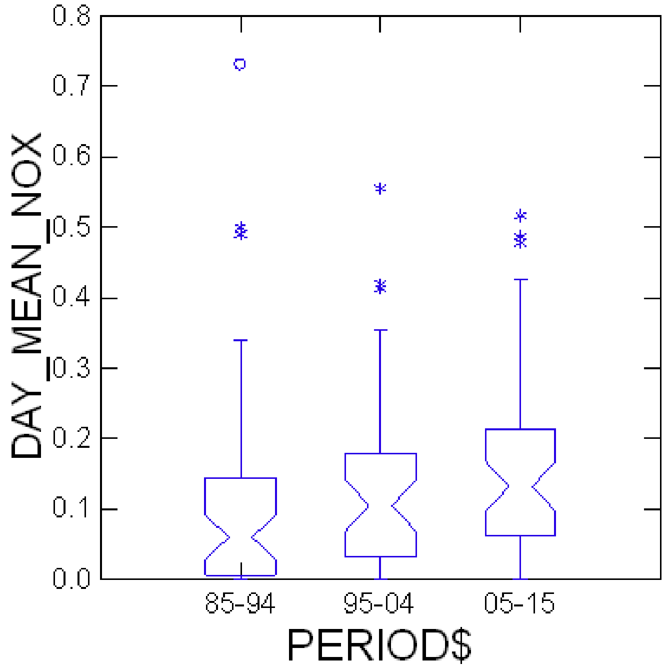


Figure B.75. Box plot of inorganic nitrogen data from Buffalo River at Woolum by period.

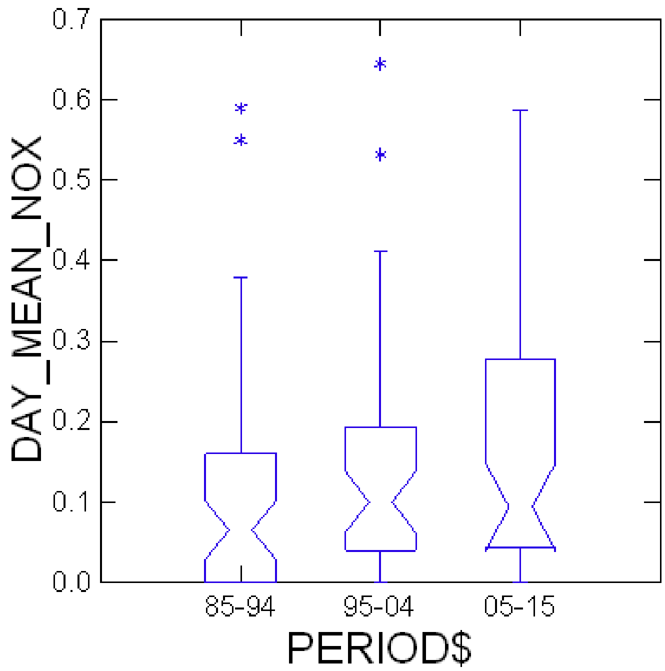


Figure B.76. Box plot of inorganic nitrogen data from Buffalo River at Gilbert access by period.

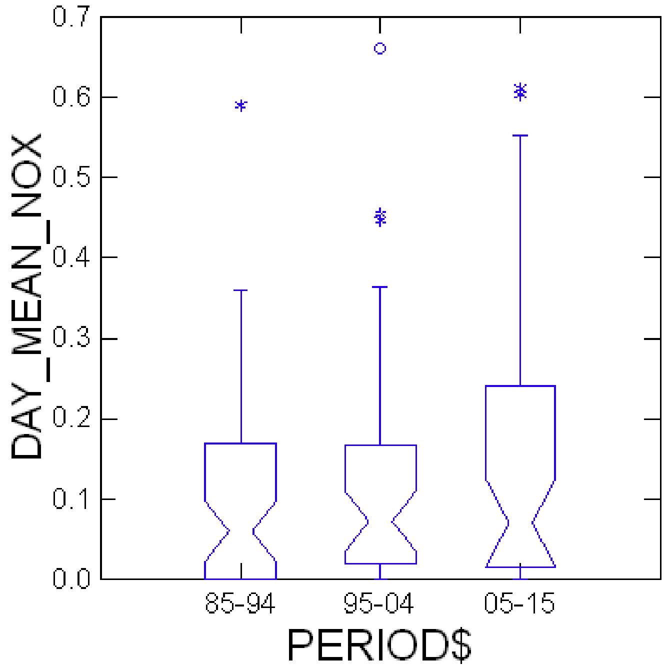


Figure B.77. Box plot of inorganic nitrogen data from Buffalo River at Rush access by period.

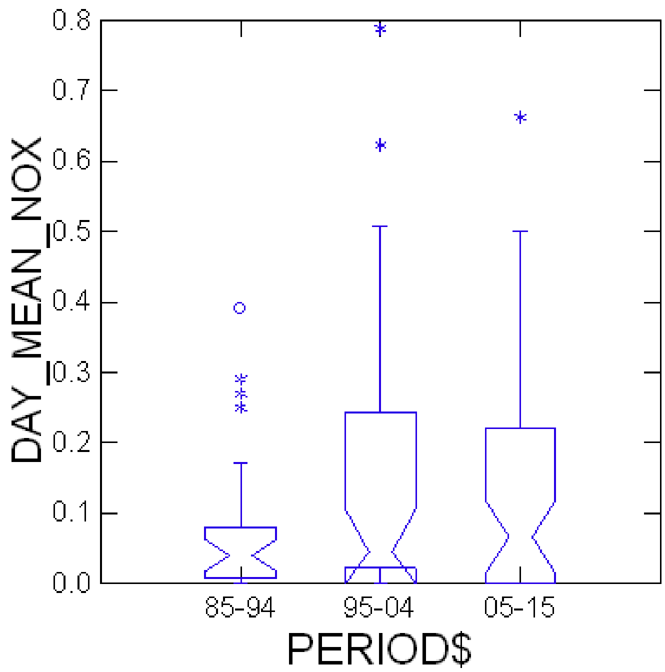


Figure B.78. Box plot of inorganic nitrogen data from Buffalo River mouth by period.

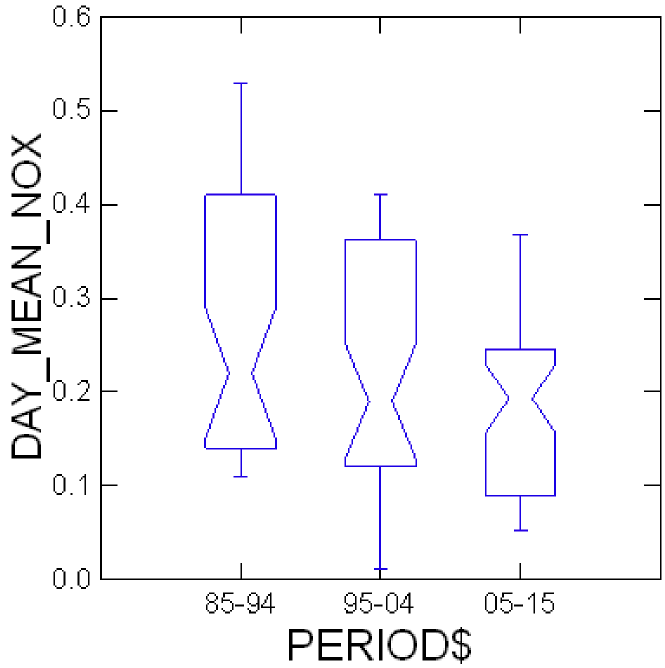


Figure B.79. Box plot of inorganic nitrogen data from Luallen Spring by period.

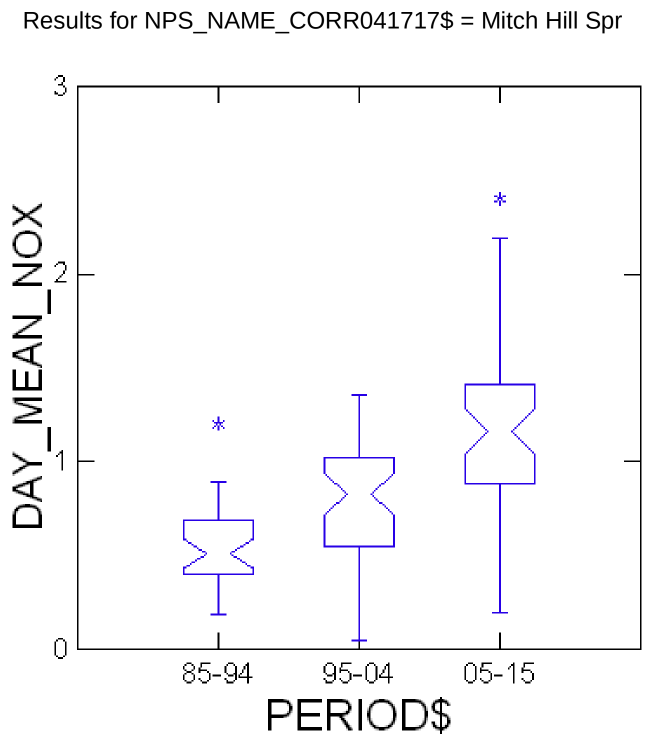


Figure B.80. Box plot of inorganic nitrogen data from Mitch Hill Spring by period.

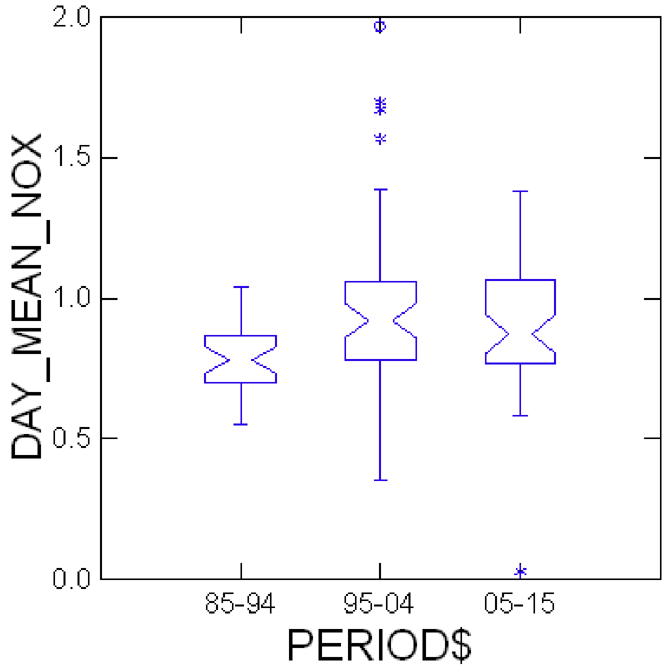


Figure B.81. Box plot of inorganic nitrogen data from Gilbert Spring by period.

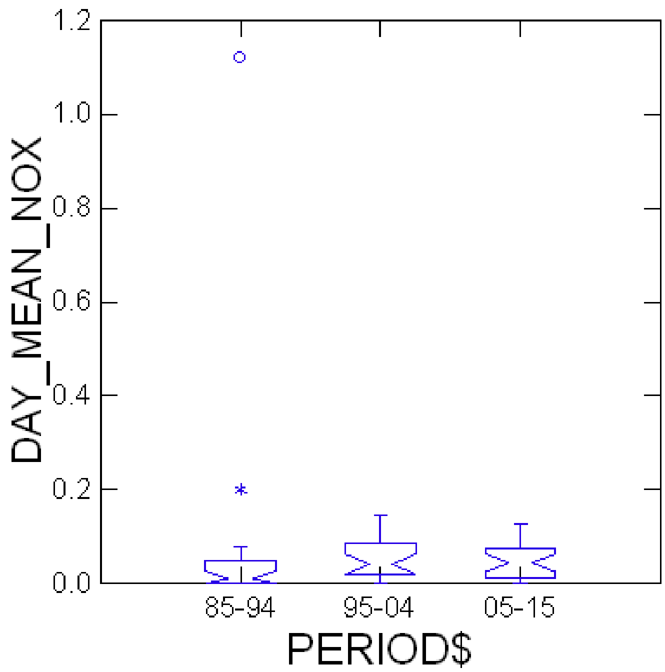


Figure B.82. Box plot of inorganic nitrogen data from Beech Creek by period.

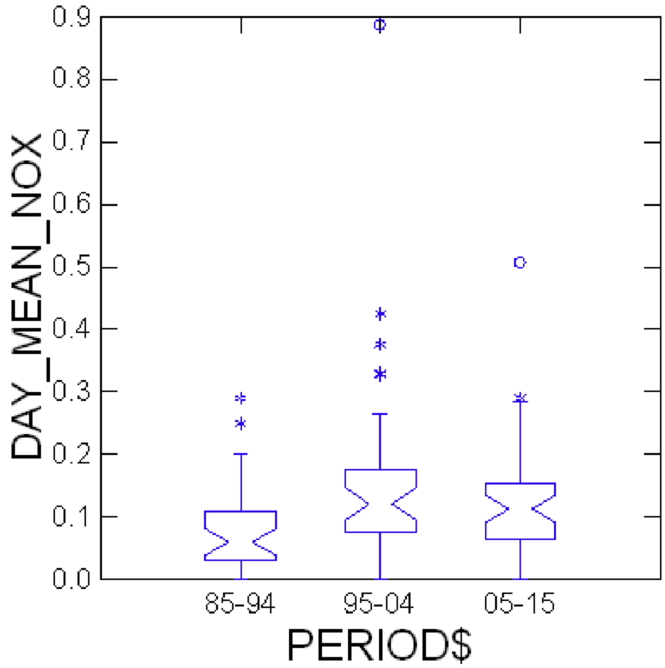


Figure B.83. Box plot of inorganic nitrogen data from Ponca Creek by period.

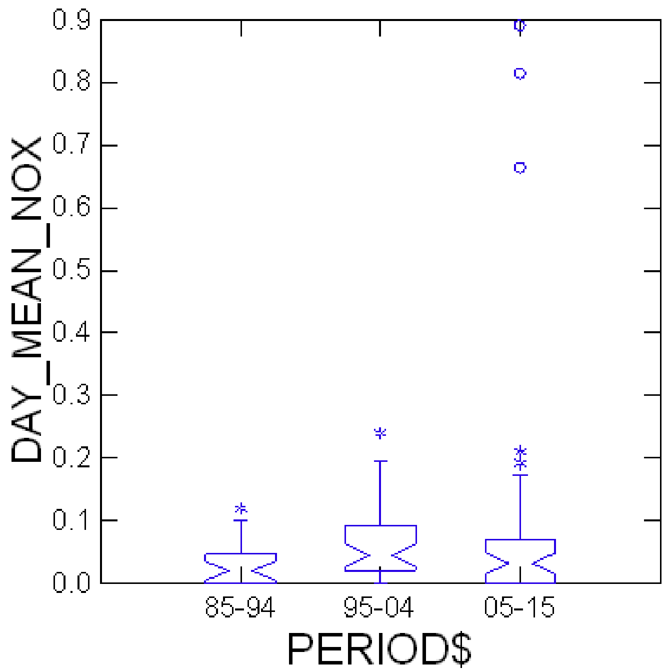


Figure B.84. Box plot of inorganic nitrogen data from Cecil Creek by period.

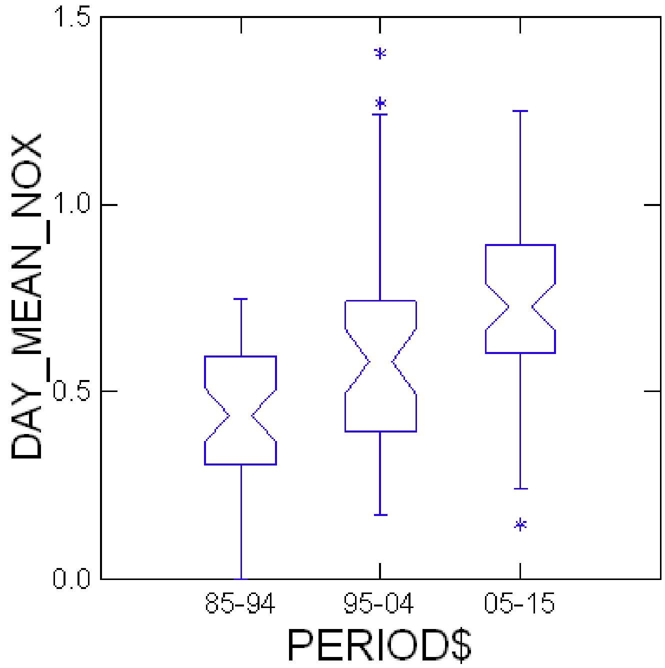


Figure B.85. Box plot of inorganic nitrogen data from Mill Creek (upper) by period.

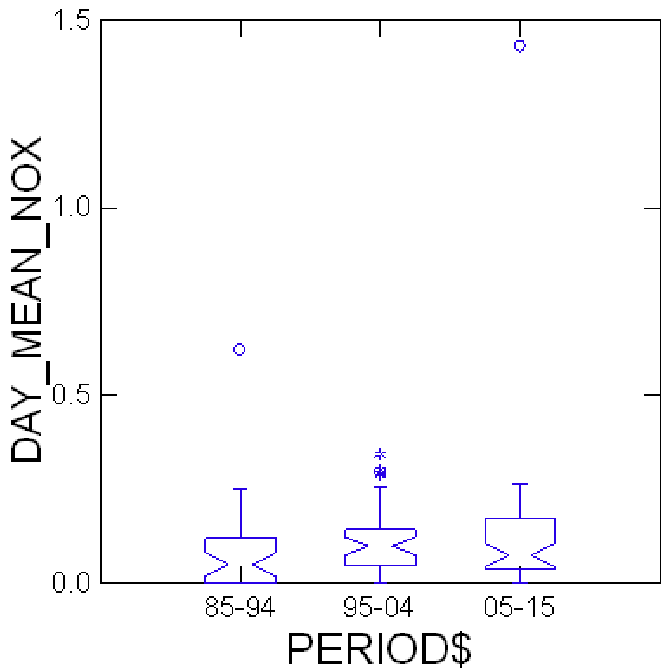


Figure B.86. Box plot of inorganic nitrogen data from Little Buffalo River by period.

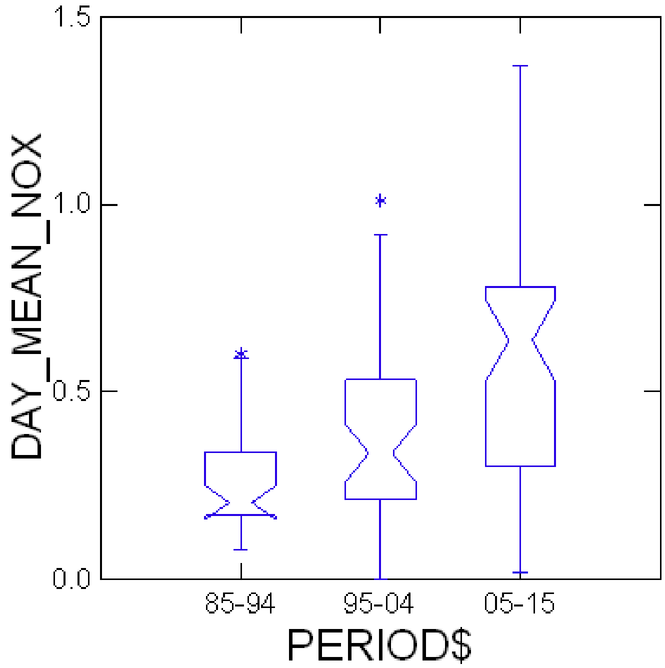


Figure B.87. Box plot of inorganic nitrogen data from Davis Creek by period.

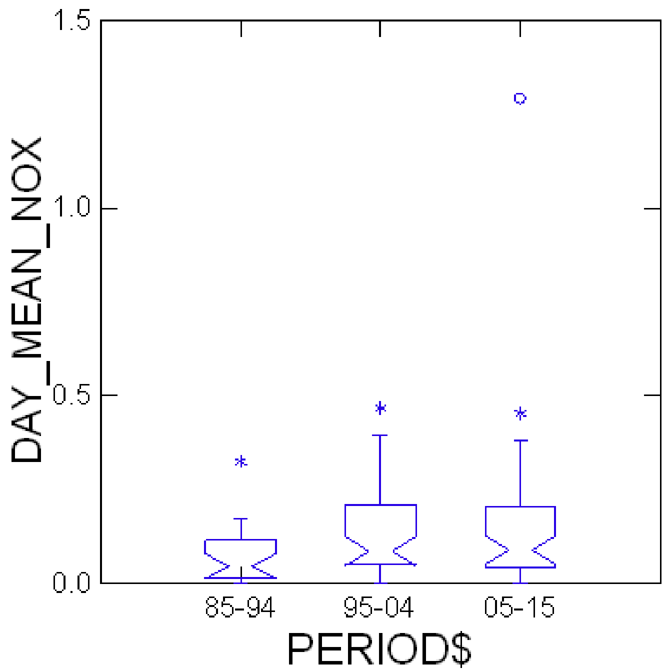


Figure B.88. Box plot of inorganic nitrogen data from Cave Creek by period.

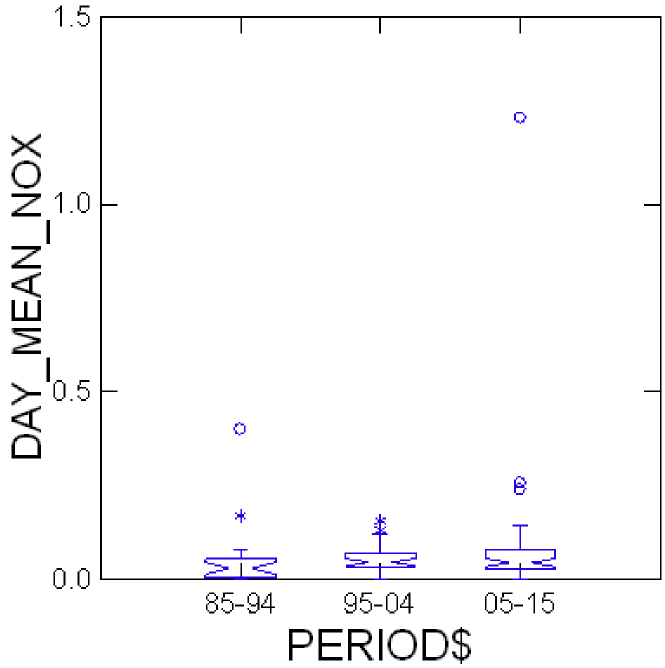


Figure B.89. Box plot of inorganic nitrogen data from Richland Creek by period.

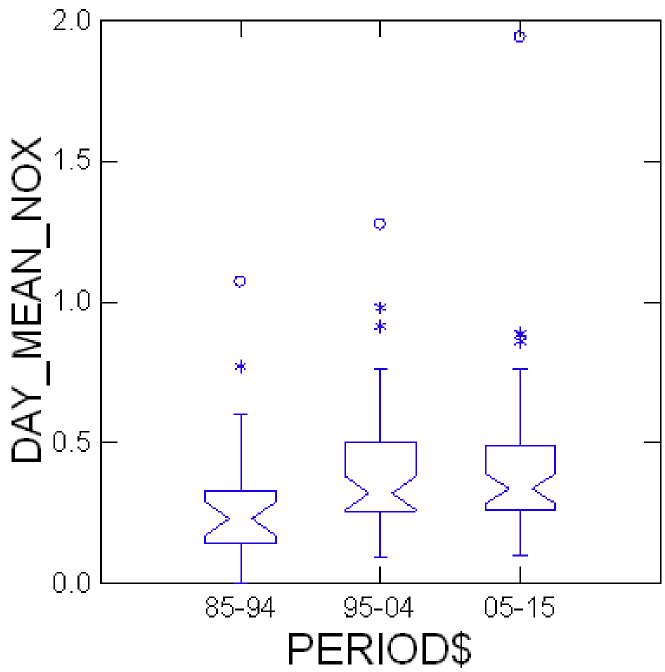


Figure B.90. Box plot of inorganic nitrogen data from Calf Creek by period.

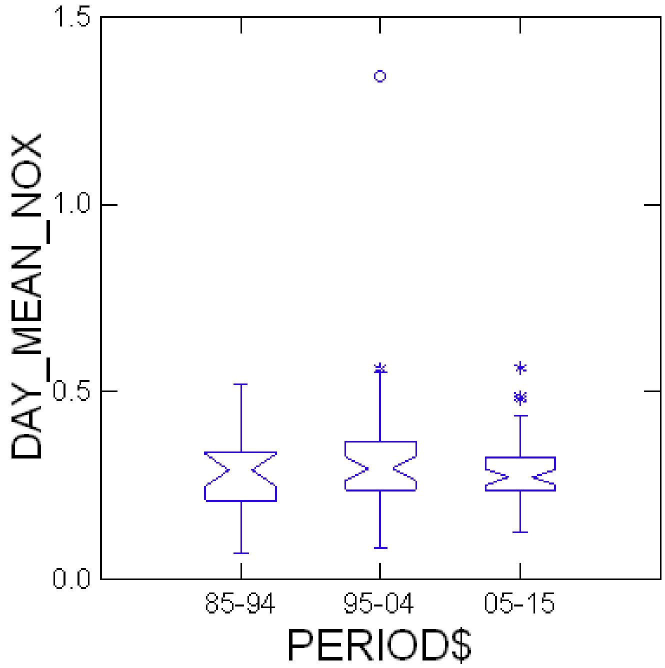


Figure B.91. Box plot of inorganic nitrogen data from Mill Creek (lower) by period.

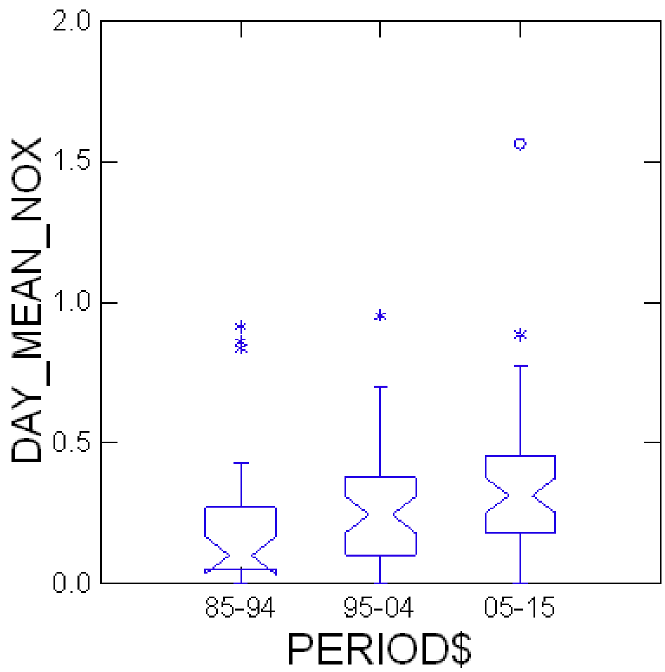


Figure B.92. Box plot of inorganic nitrogen data from Bear Creek by period.

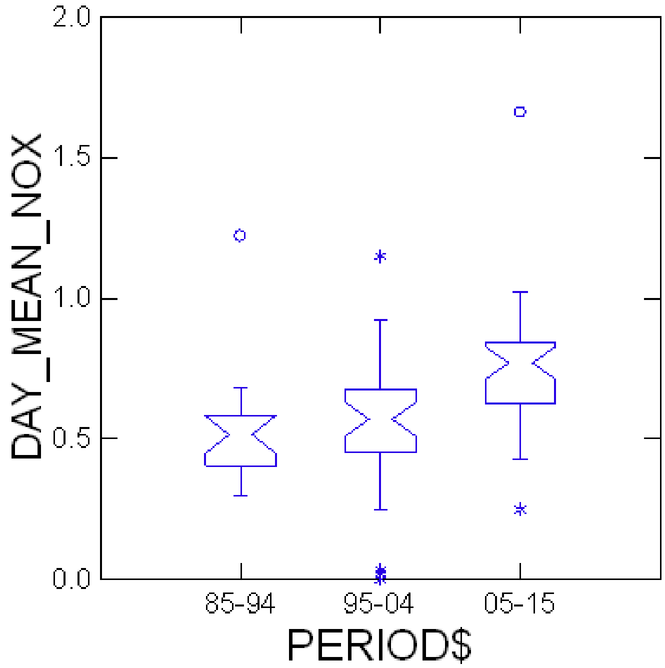


Figure B.93. Box plot of inorganic nitrogen data from Brush Creek by period.

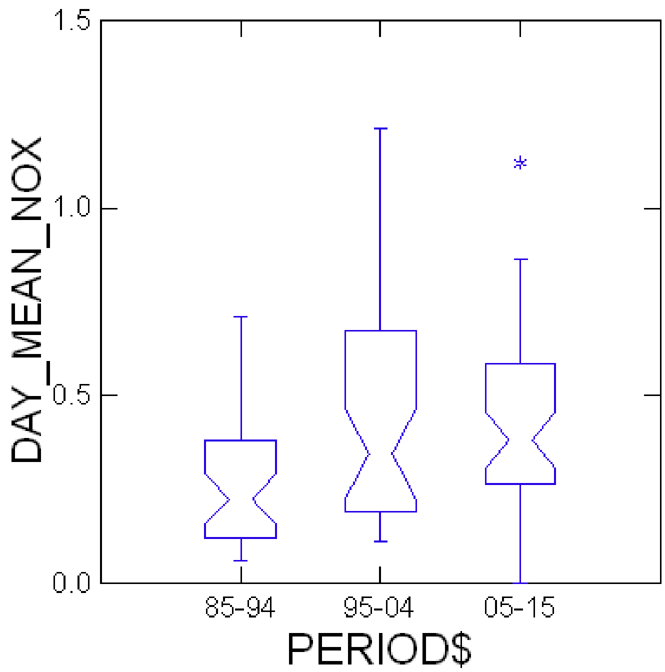


Figure B.94. Box plot of inorganic nitrogen data from Tomahawk Creek by period.

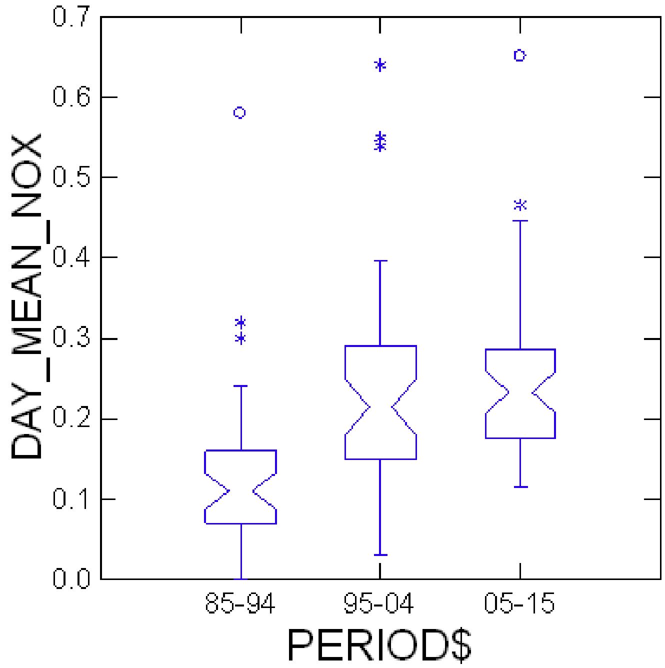


Figure B.95. Box plot of inorganic nitrogen data from Rush Creek by period.

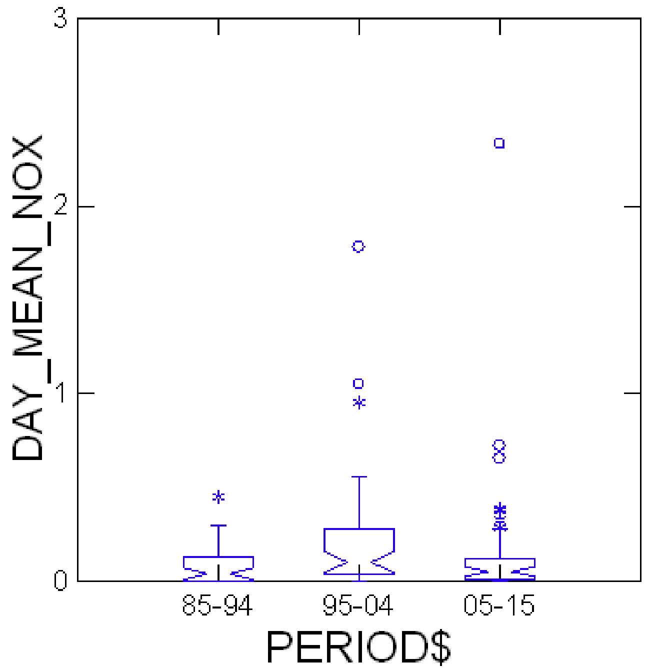


Figure B.96. Box plot of inorganic nitrogen data from Clabber Creek by period.

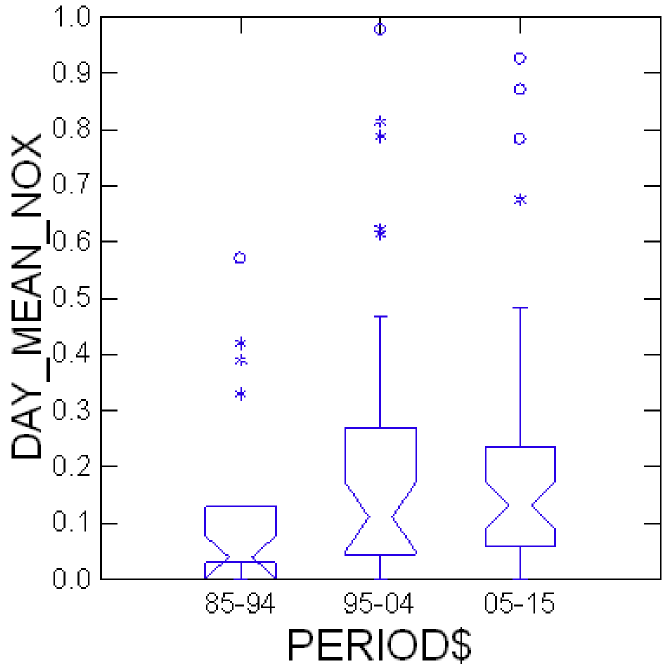


Figure B.97. Box plot of inorganic nitrogen data from Big Creek (lower) by period.

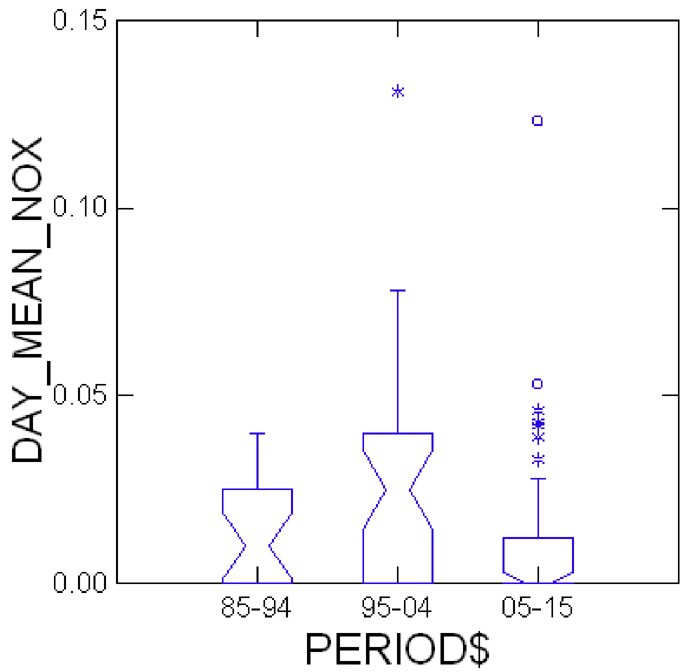


Figure B.98. Box plot of inorganic nitrogen data from Middle Creek by period.

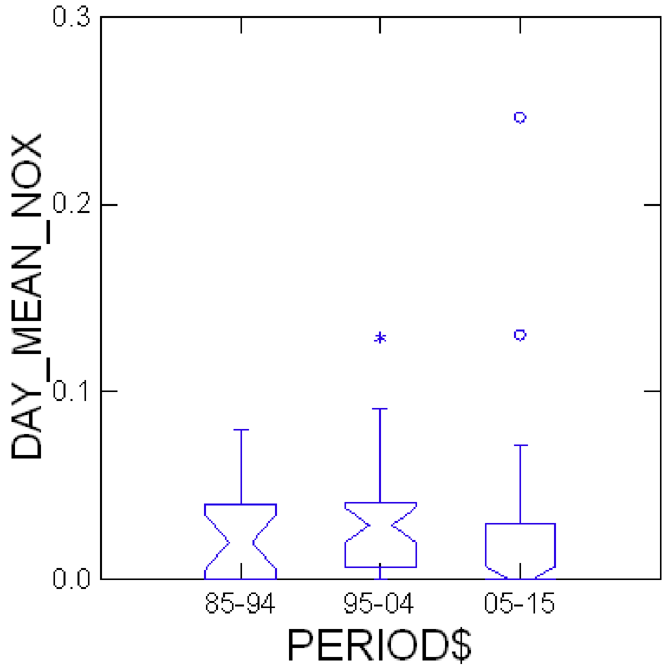


Figure B.99. Box plot of inorganic nitrogen data from Leatherwood Creek by period.

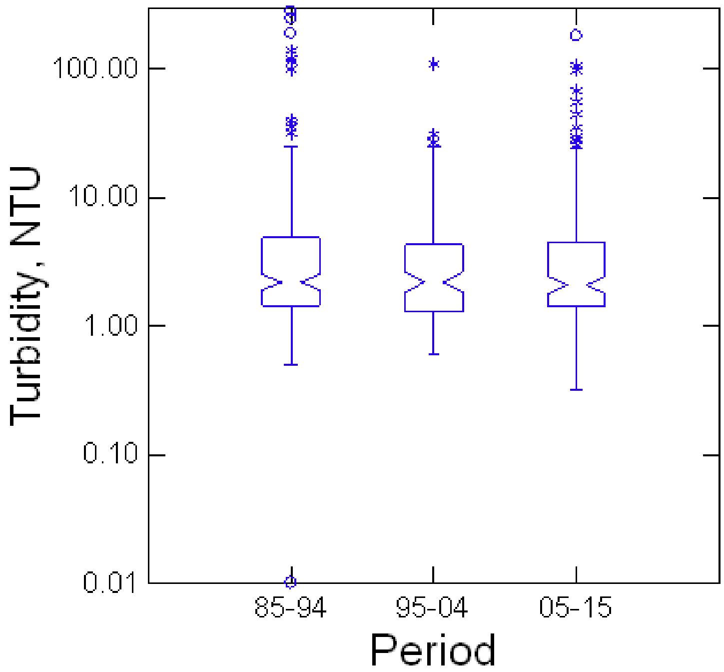


Figure B.100. Box plot of turbidity data from Buffalo River at Highway 65 by period.

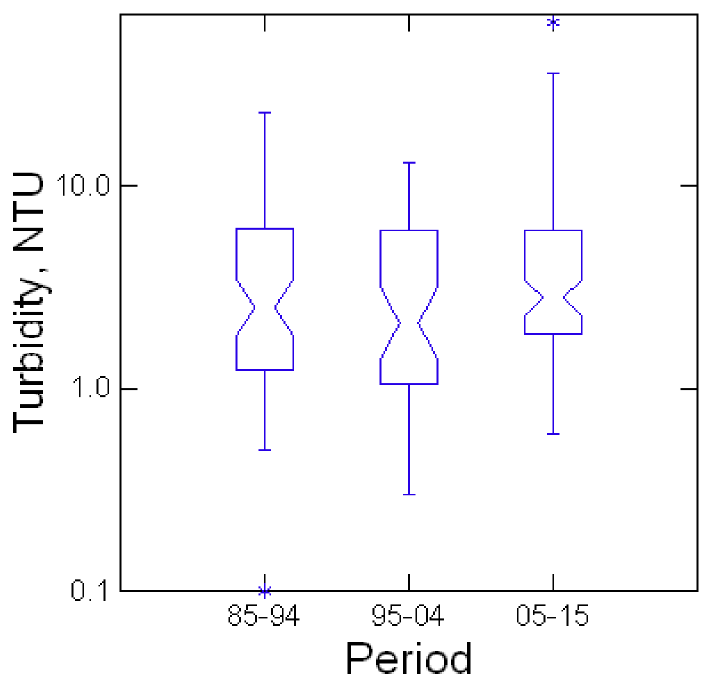


Figure B.101. Box plot of turbidity data from Buffalo River at Wilderness Area boundary by period.

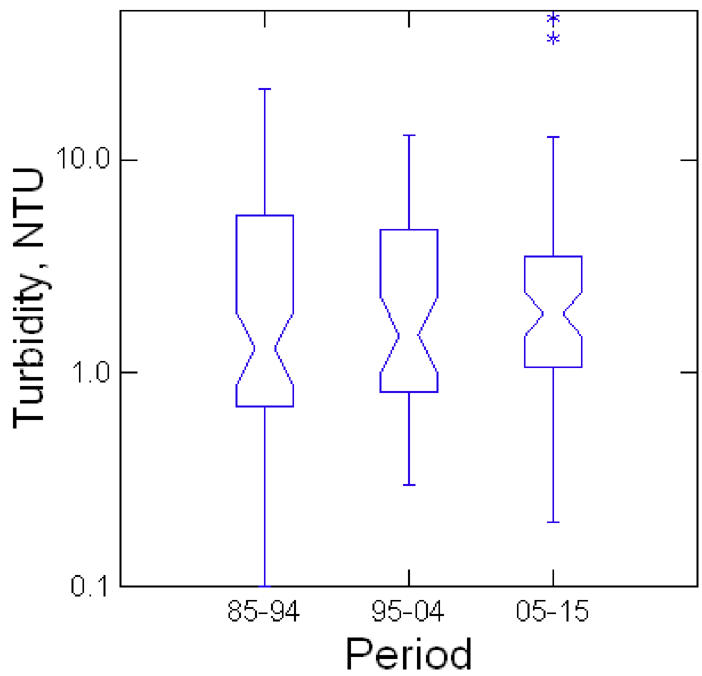


Figure B.102. Box plot of turbidity data from Buffalo River at Ponca access by period.

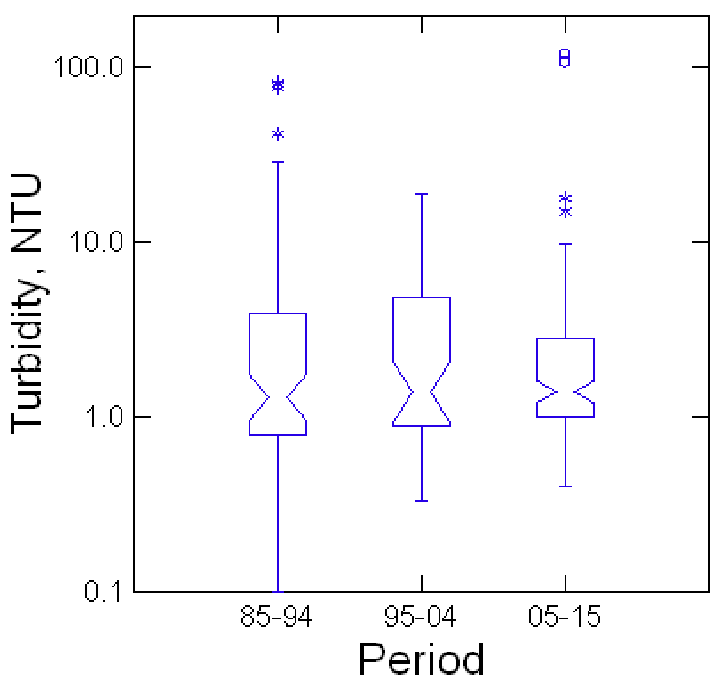


Figure B.103. Box plot of turbidity data from Buffalo River at Pruitt access by period.

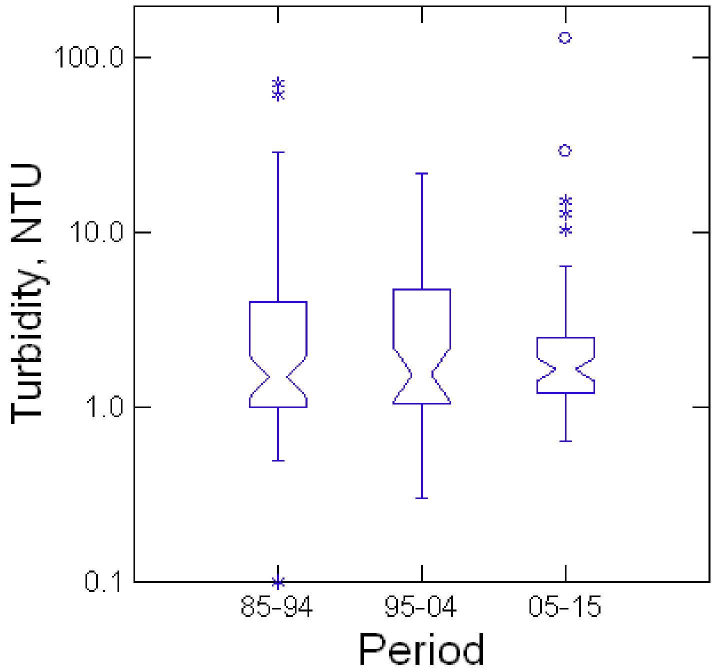


Figure B.104. Box plot of turbidity data from Buffalo River at Hasty by period.

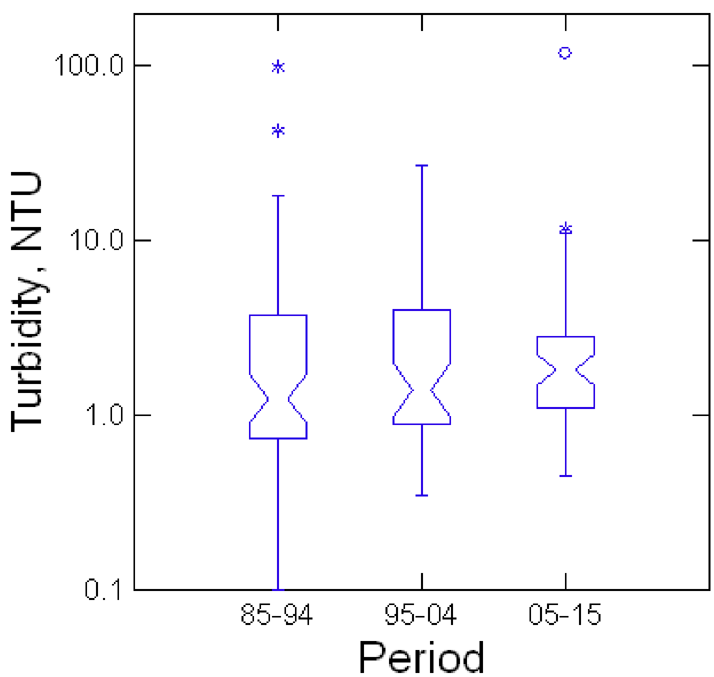


Figure B.105. Box plot of turbidity data from Buffalo River at Woolum by period.

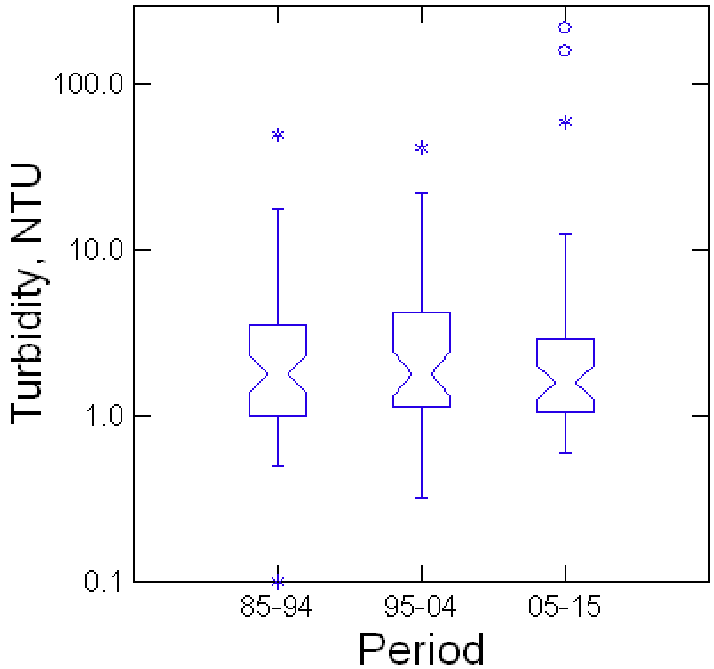


Figure B.106 Box plot of turbidity data from Buffalo River at Gilbert access by period

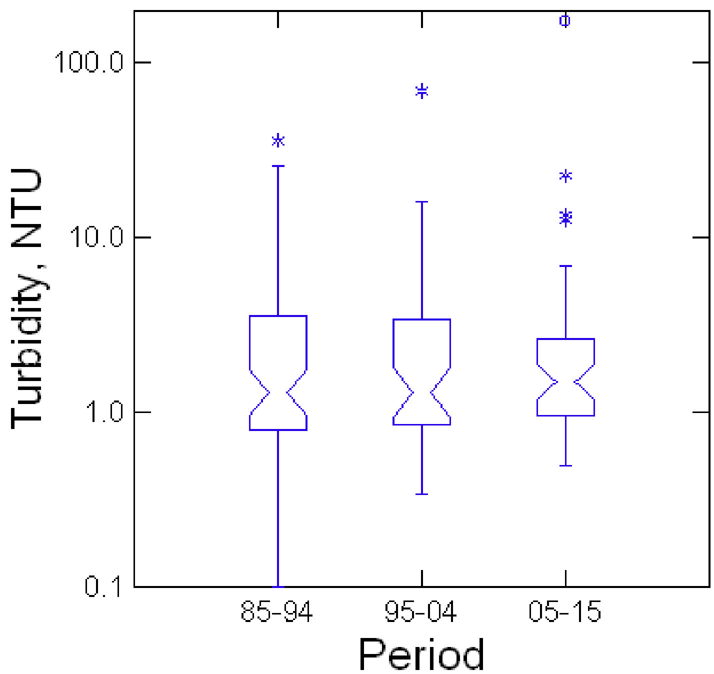


Figure B.107. Box plot of turbidity data from Buffalo River at Highway 14 by period.

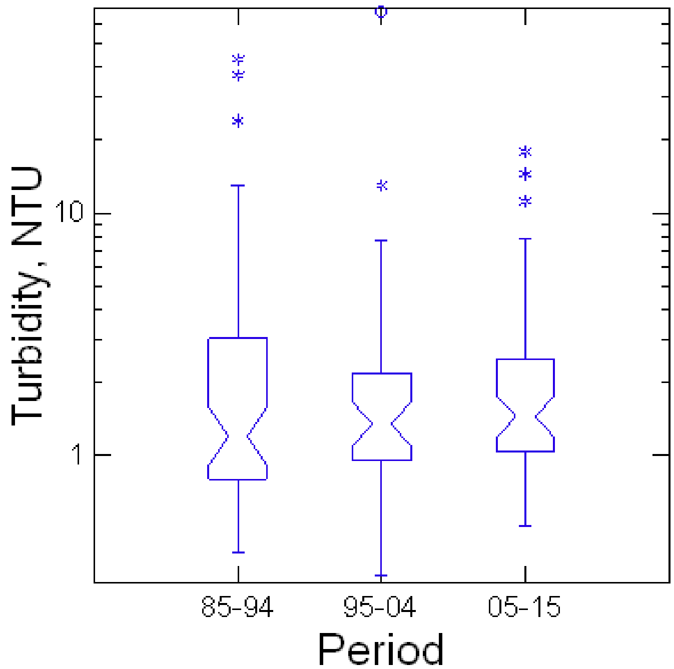


Figure B.108. Box plot of turbidity data from Buffalo River at Rush access by period.

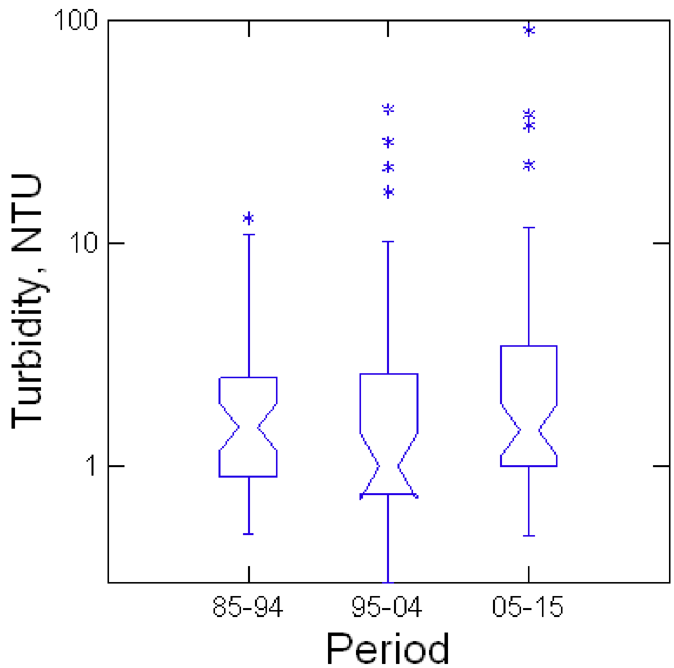


Figure B.109. Box plot of turbidity data from Buffalo River mouth by period.

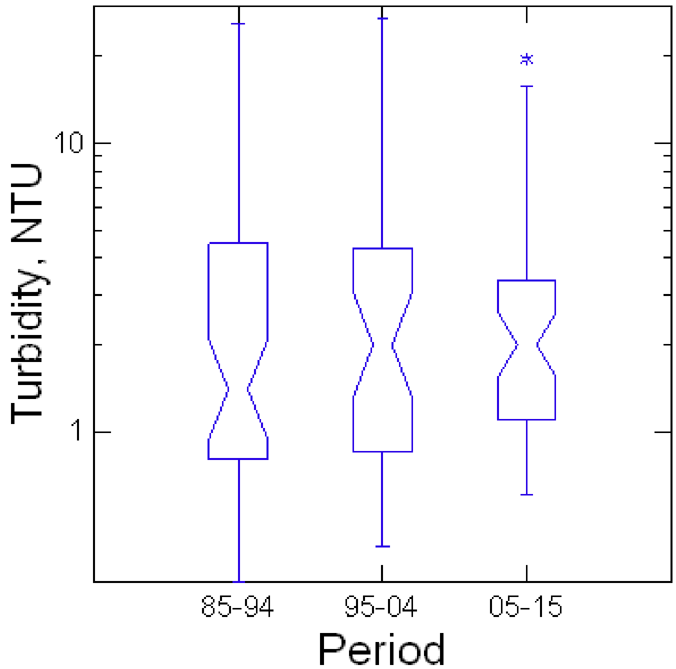


Figure B.110. Box plot of turbidity data from Luallen Spring by period.

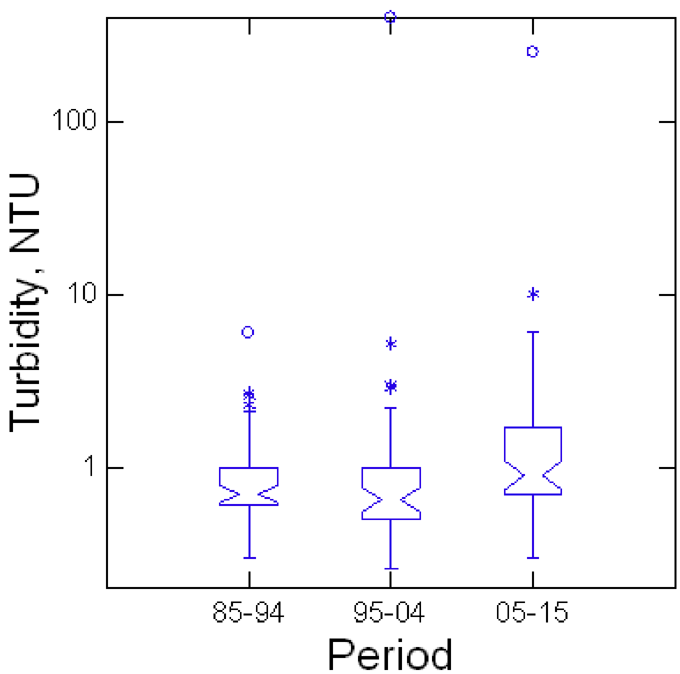


Figure B.111. Box plot of turbidity data from Mitch Hill Spring by period.

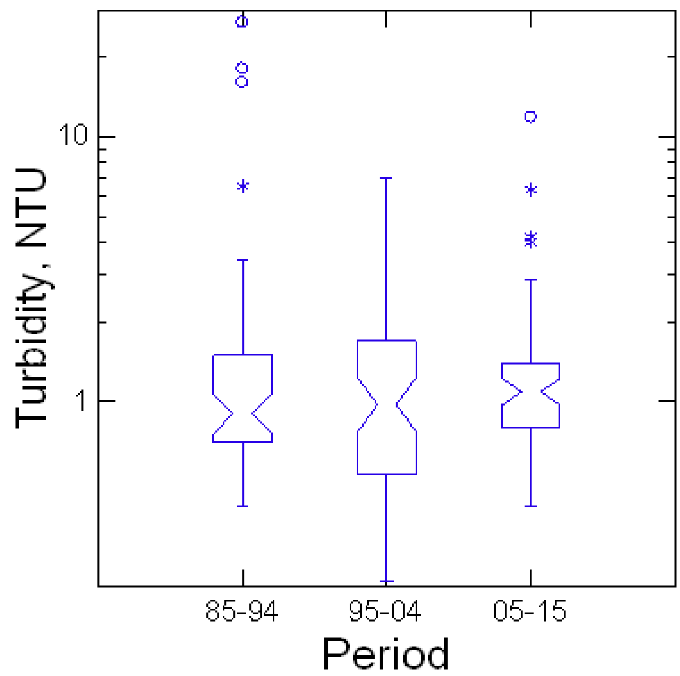


Figure B.112. Box plot of turbidity data from Gilbert Spring by period.

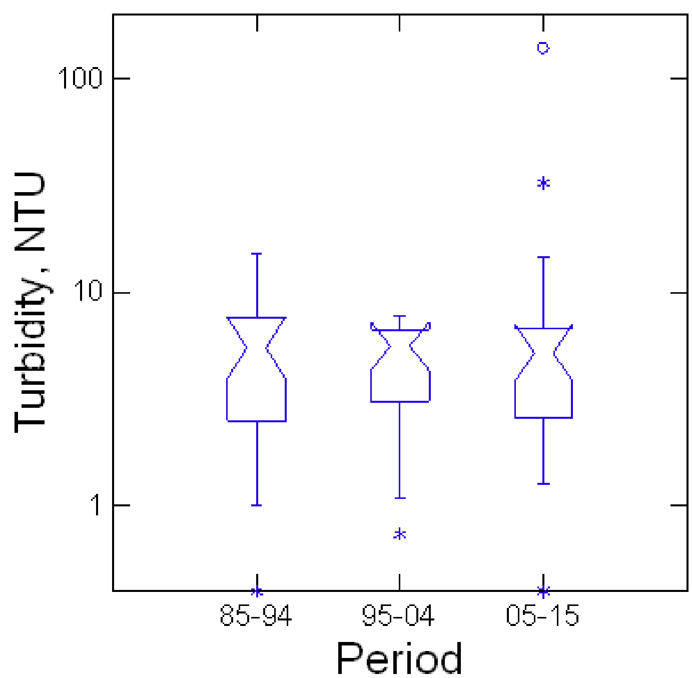


Figure B.113. Box plot of turbidity data from Beech Creek by period.

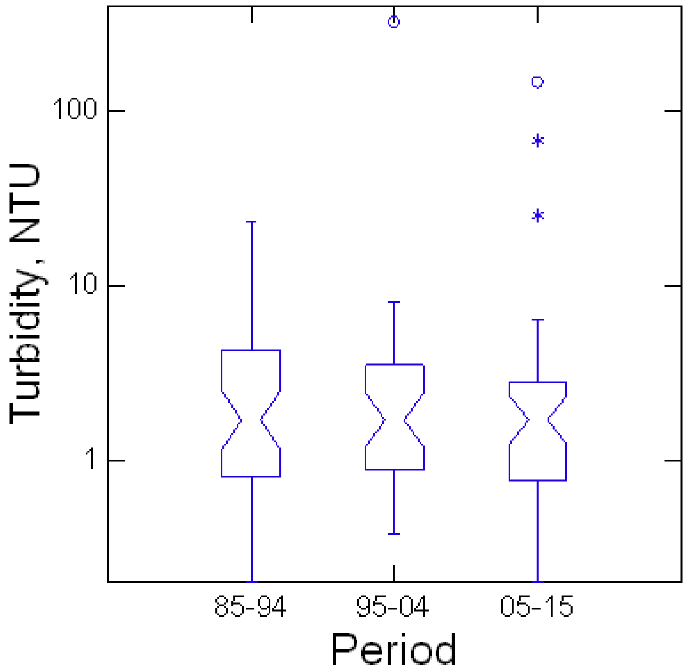


Figure B.114. Box plot of turbidity data from Ponca Creek by period.

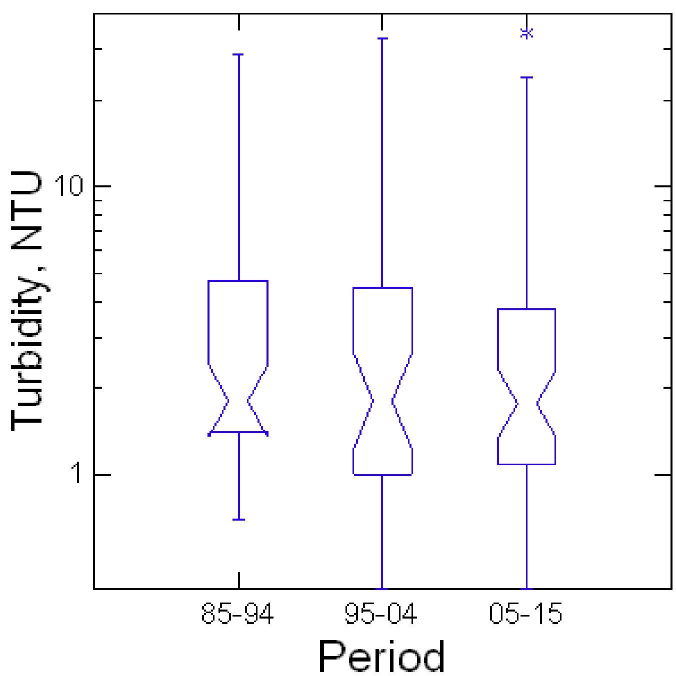


Figure B.115. Box plot of turbidity data from Cecil Creek by period.

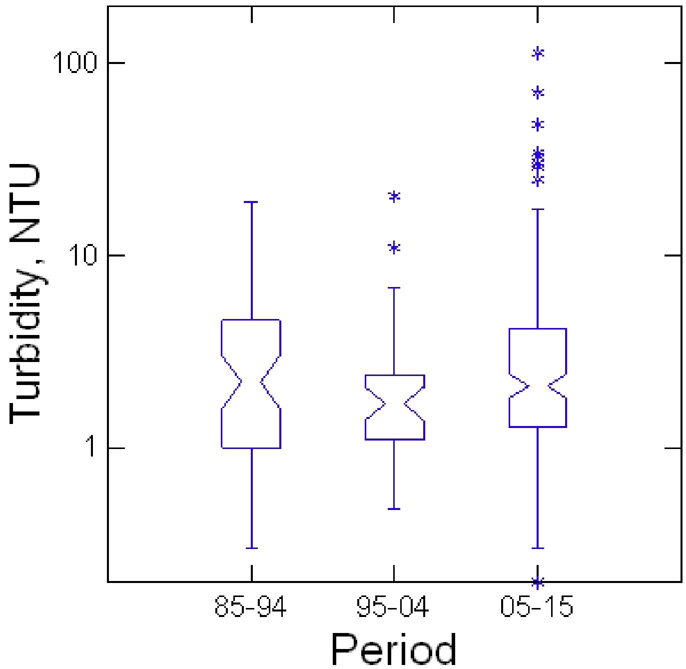


Figure B.116. Box plot of turbidity data from Mill Creek (upper) by period.

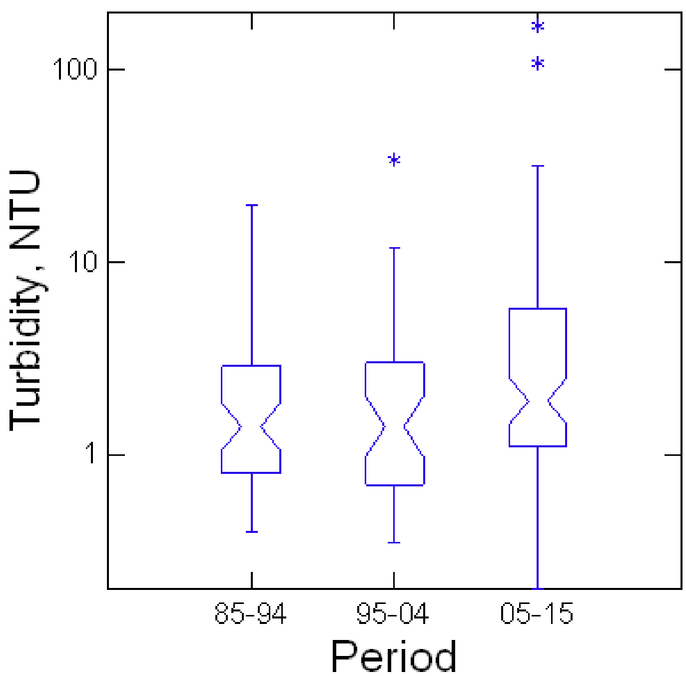


Figure B.117. Box plot of turbidity data from Little Buffalo River by period.

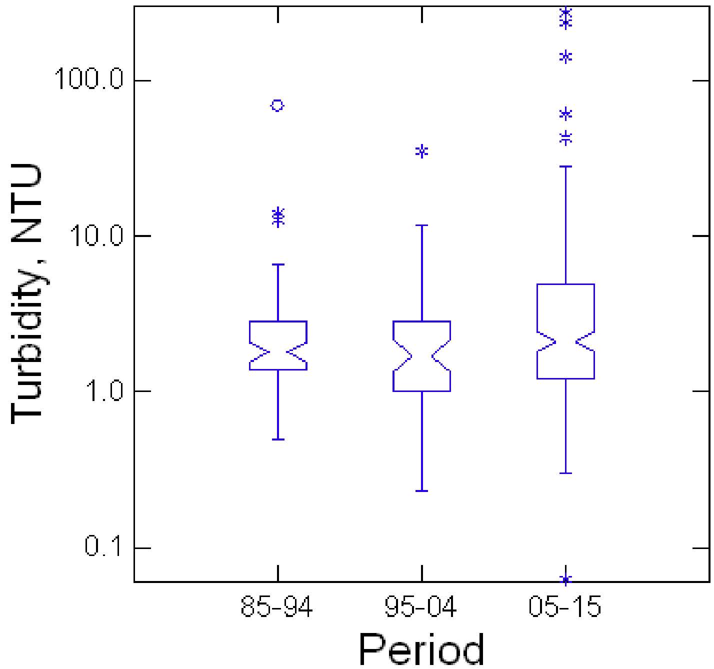


Figure B.118. Box plot of turbidity data from Big Creek (upper) by Carver by period.

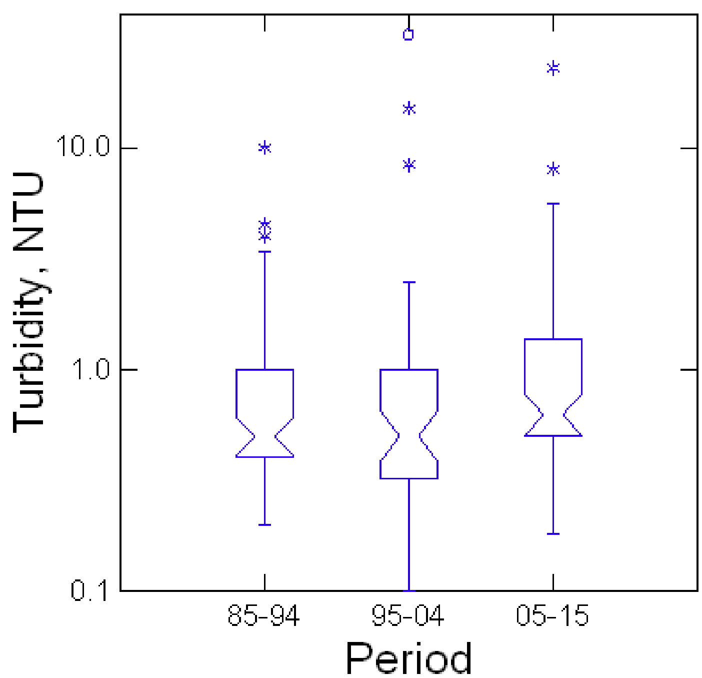


Figure B.119. Box plot of turbidity data from Davis Creek by period.

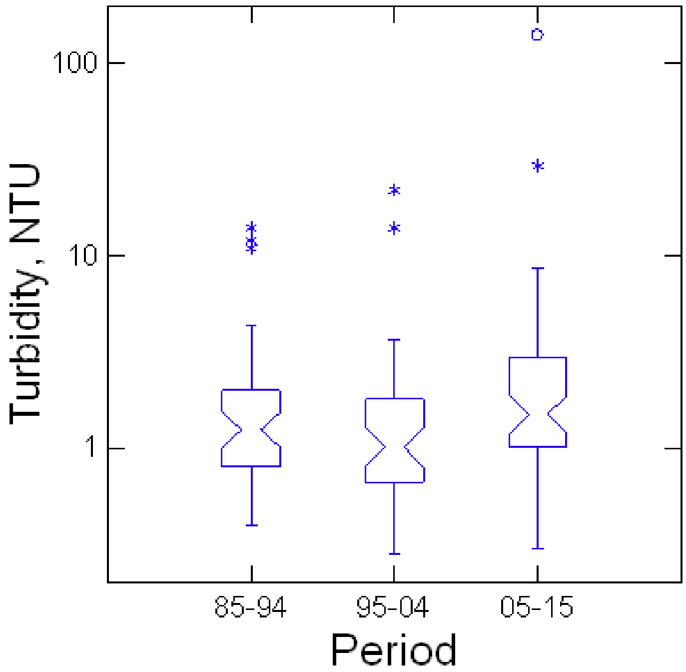


Figure B.120. Box plot of turbidity data from Cave Creek by period.

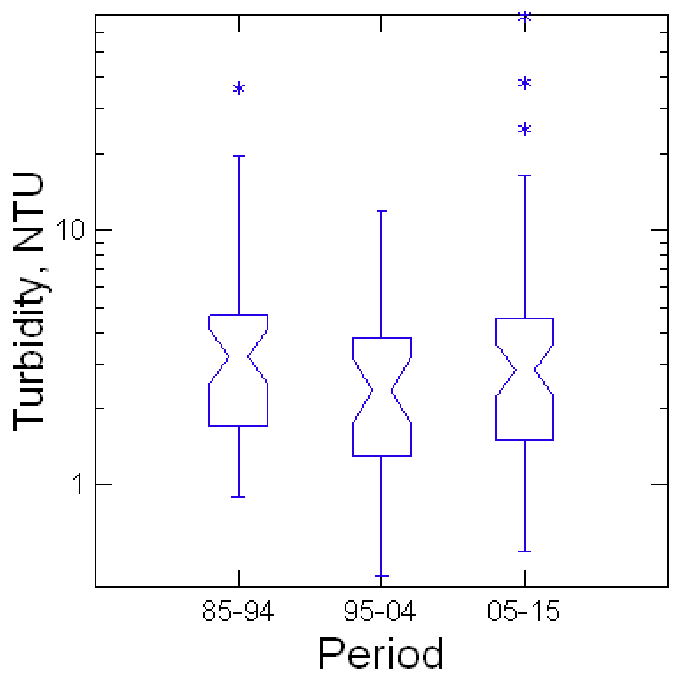


Figure B.121. Box plot of turbidity data from Richland Creek by period.

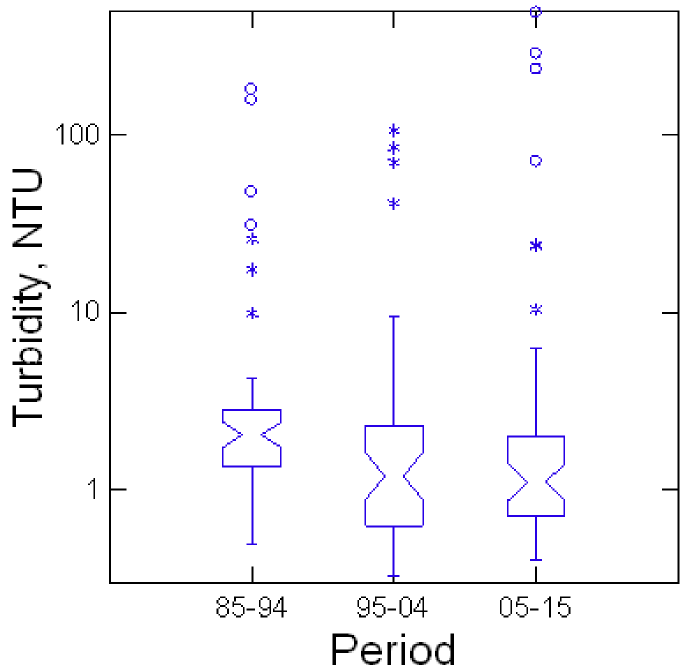


Figure B.122. Box plot of turbidity data from Calf Creek by period.

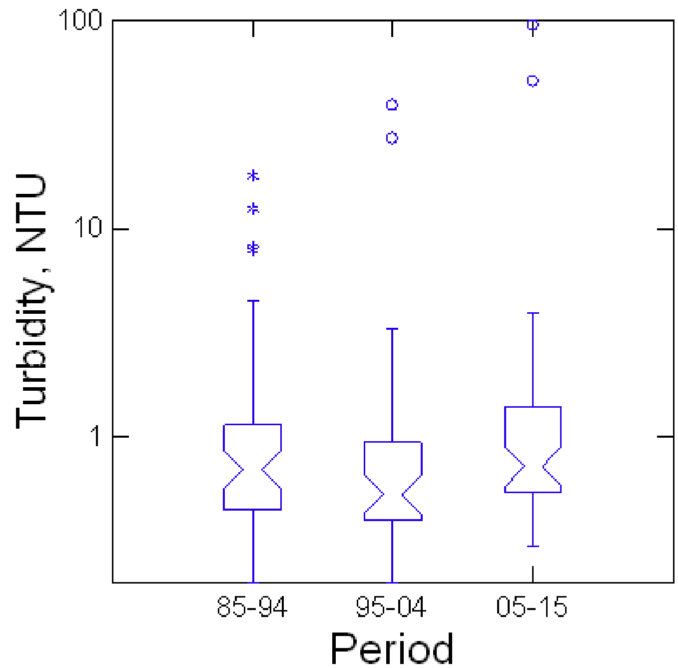


Figure B.123. Box plot of turbidity data from Mill Creek (lower) by period.

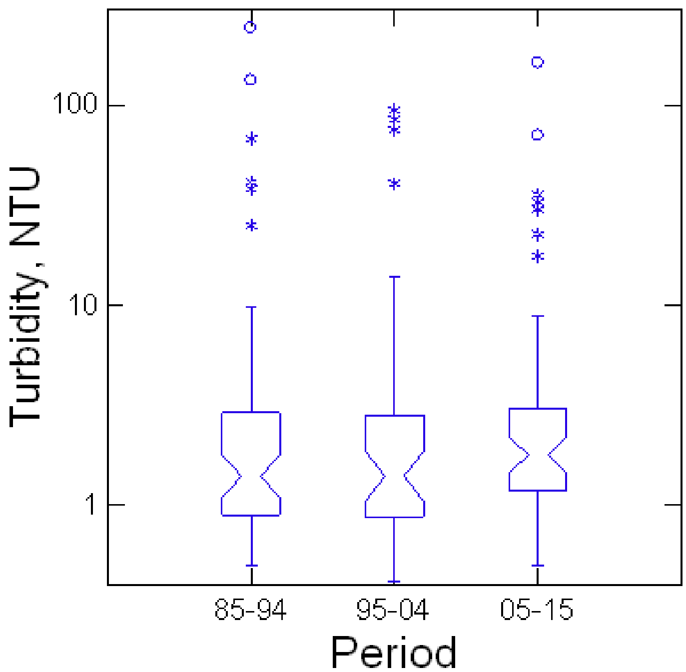


Figure B.124. Box plot of turbidity data from Bear Creek by period.

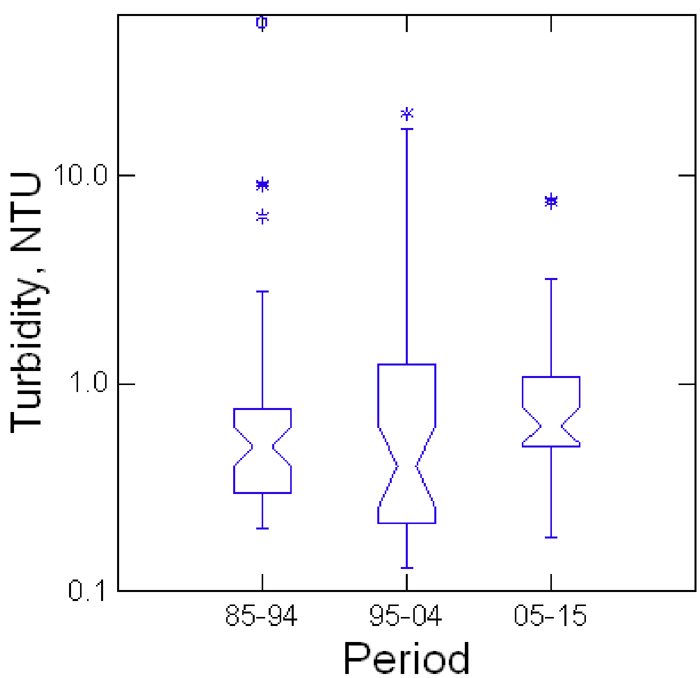


Figure B.125. Box plot of turbidity data from Brush Creek by period.

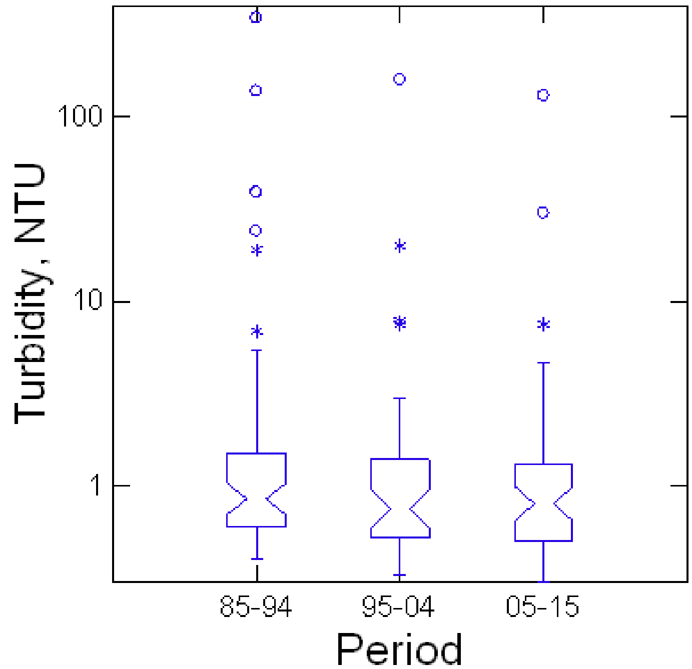


Figure B.126. Box plot of turbidity data from Tomahawk Creek by period.

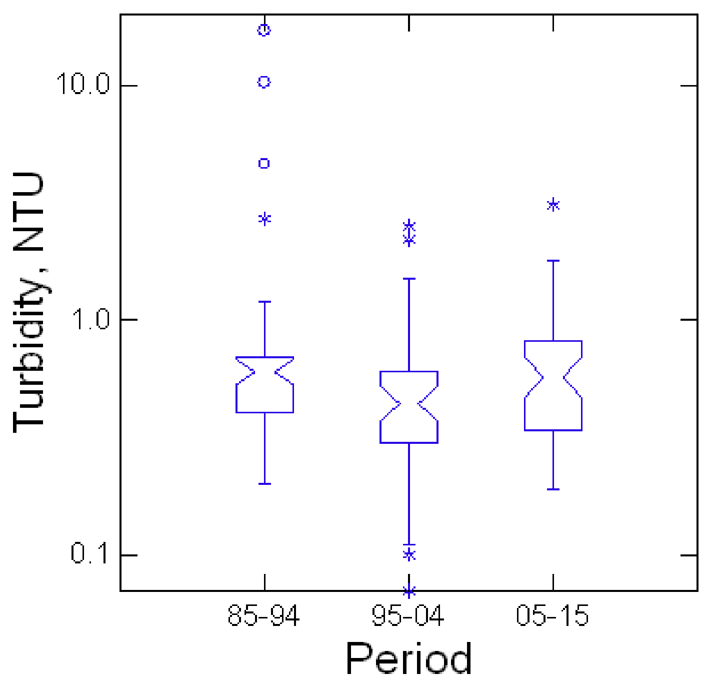


Figure B.127. Box plot of turbidity data from Water Creek by period.

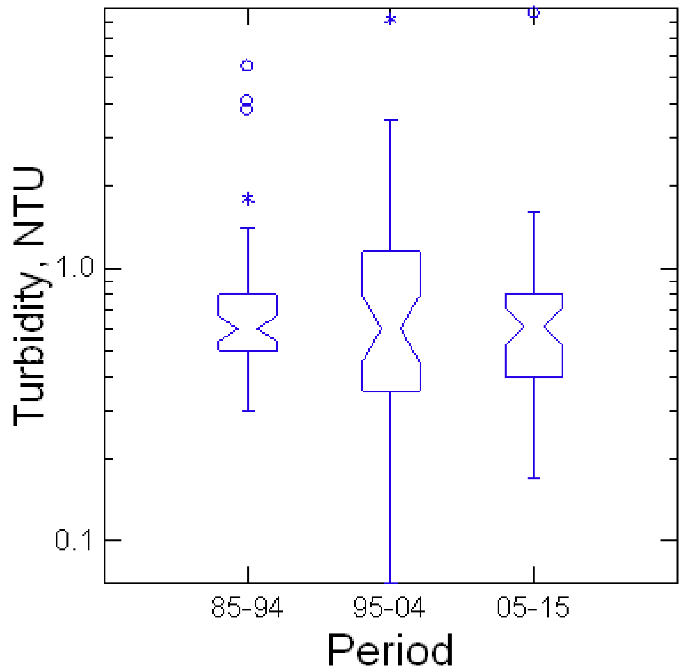


Figure B.128. Box plot of turbidity data from Rush Creek by period.

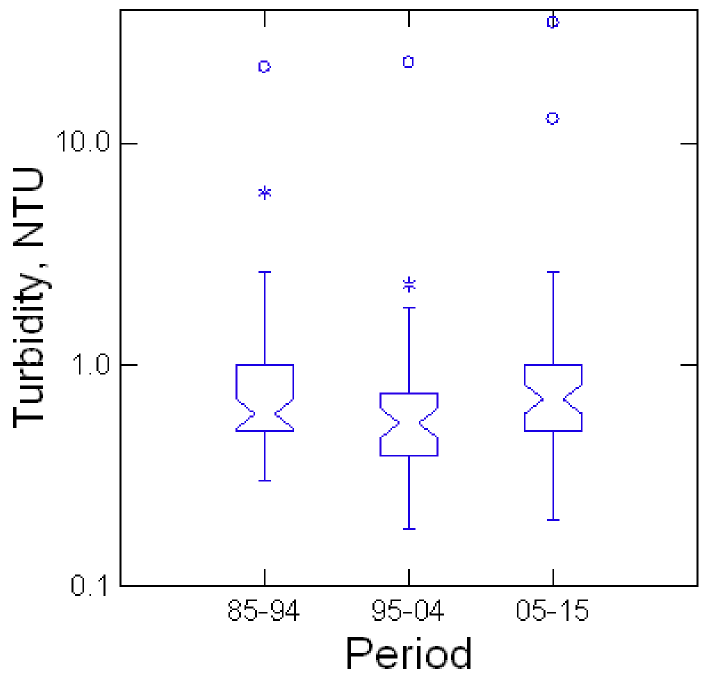


Figure B.129. Box plot of turbidity data from Clabber Creek by period.

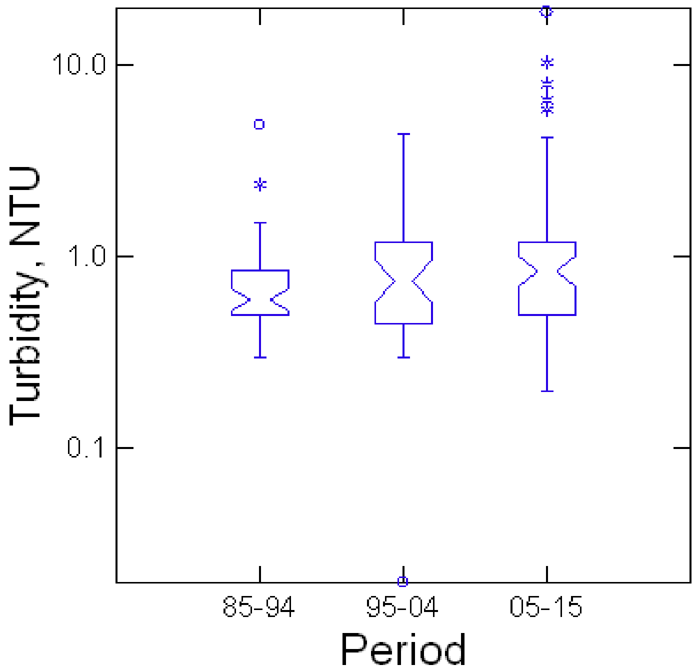


Figure B.130. Box plot of turbidity data from Big Creek (lower) by period.

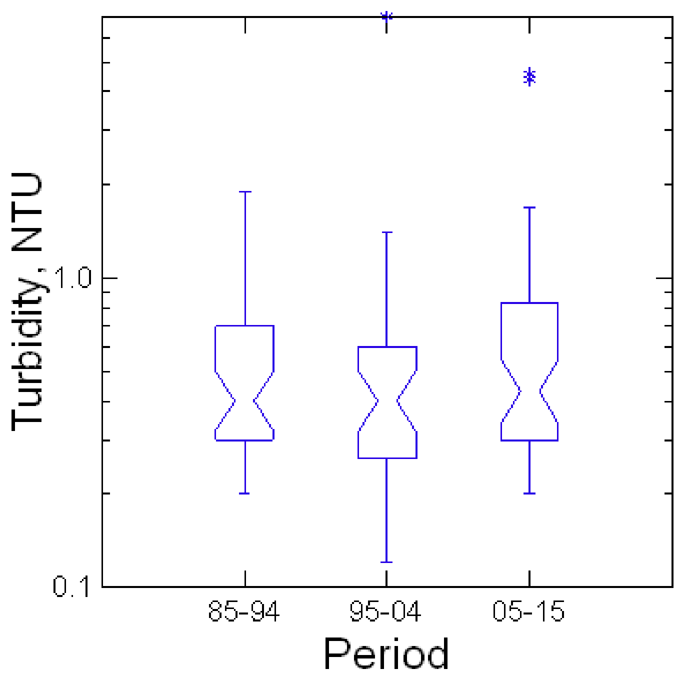


Figure B.131. Box plot of turbidity data from Middle Creek by period.

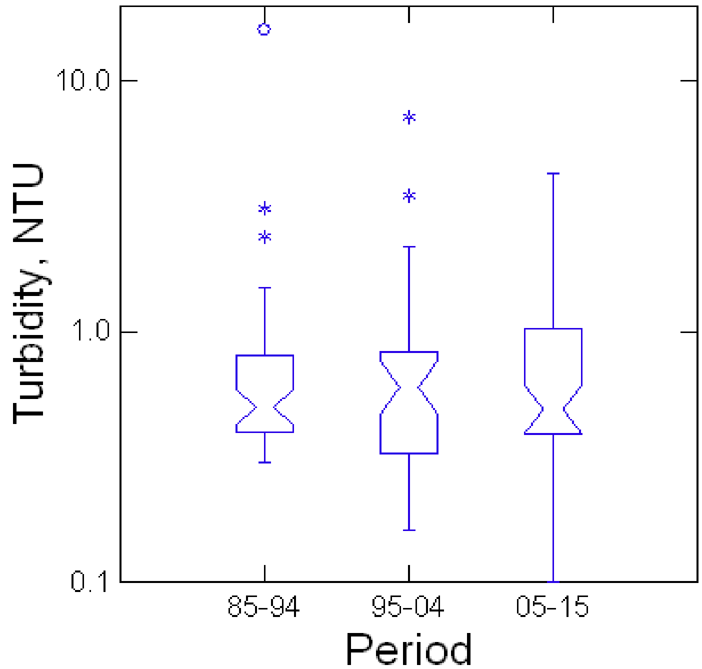


Figure B.132. Box plot of turbidity data from Leatherwood Creek by period.

ATTACHMENT C

HUC12 Ranking Scores for Selected Water Quality Parameters

Attachment C – Evaluation of 2005-2015 median concentrations for HUC12 ranking

Table C.1 summarizes the scoring results for the HUC12 subwatersheds for each of the parameters evaluated. Tables C.2 through C.6 show the 2005-2015 median values for each of the evaluated locations, and the percentile value used to evaluate them. The ranking score assigned to each location based on the comparison to the percentile value is shown in the last column of Tables C.2 through C.6. To be included in the evaluation, a monitored location had to have at least 20 measurements from the 2005-2015 period.

Table C.1. HUC12 concentration ranking scores summary.

HUC12 ID	HUC12 NDme	Ranking Scores for Median Concentration 2005-2015					Sum of Scores
		DO	E. coli	Inorganic nitrogen	Orthophos phate	Turbidity	
110100050101	Shop Creek	ND	ND	ND	ND	ND	ND
110100050102	Headwaters Little Buffalo River	ND	ND	ND	ND	ND	ND
110100050103	Henson Creek	ND	ND	ND	ND	ND	ND
110100050104	Outlet Little Buffalo River	0	1	0	0	1	
110100050201	Terrapin Branch-Buffalo River	ND	ND	ND	ND	ND	ND
110100050202	Beech Creek-Headwaters Buffalo River	0	ND	0	0	1	
110100050203	Smith Creek-Buffalo River	0	0	0	1	1	
110100050204	Cove Creek-Buffalo River (Cecil Cr)	0	1	0	0	0	
110100050205	Whiteley Creek-Buffalo River (Ponca)	0	1	0	0	0	
110100050206	Flatrock Creek (Mill Cr)	0	1	1	0	1	
110100050207	Hoskin Creek-Buffalo River (Glade Cr?)	1	0	0	0	0	
110100050301	Left Fork Creek	ND	ND	ND	ND	ND	ND
110100050302	Headwaters Big Creek-Buffalo River	ND	ND	ND	ND	ND	ND

Table C.1. HUC12 concentration ranking scores summary (continued).

HUC12 ID	HUC12 NDme	Ranking Scores for Median Concentration 2005-2015					Sum of Scores
		DO	E. coli	Inorganic nitrogen	Orthophos phate	Turbidity	
110100050303	Outlet Big Creek-Buffalo River Middle	1	1	0	0	1	3
110100050304	Lick Creek-Buffalo River	ND	0	ND	ND	0	0
110100050305	Cave Creek	0	1	0	0	ND	1
110100050306	Headwaters Richland Creek	ND	ND	ND	ND	ND	ND
110100050307	Falling Water Creek	ND	ND	ND	ND	ND	ND
110100050308	Outlet Richland Creek	0	0	0	0	1	1
110100050309	Cane Branch-Buffalo River (Davis Cr)	1	0	1	1	0	3
110100050401	Calf Creek	0	0	1	1	0	2
110100050402	Rocky Hollow-Buffalo River	ND	ND	ND	ND	ND	ND
110100050403	Headwaters Bear Creek	ND	ND	ND	ND	ND	ND
110100050404	Outlet Bear Creek	0	0	1	1	0	3
110100050405	Brush Creek-Buffalo River	0	0	1	1	0	2
110100050406	Dry Creek-Buffalo River	1	0	1	1	1	4
110100050407	Tomahawk Creek-Buffalo River	0	1	1	0	0	2
110100050408	Water Creek	0	0	0	0	0	0
110100050409	Spring Creek-Buffalo River	ND	ND	ND	ND	ND	ND
110100050501	Rush Creek	0	0	0	0	0	0
110100050502	Hickory Creek-Buffalo River	0	0	0	0	0	0
110100050503	Clabber Creek	0	1	0	0	0	1
110100050504	Boat Creek-Buffalo River	ND	ND	ND	ND	ND	ND
110100050505	Long Creek	ND	ND	ND	ND	ND	ND
110100050506	Davis Creek-Big Creek Lower	ND	ND	ND	ND	ND	ND
110100050507	Bratton Creek-Big River (Big Cr Lower)	1	0	0	0	0	1
110100050508	Leatherwood Creek-Buffalo River	1	0	0	0	0	1

Table C.2. Evaluation of median DO concentrations for 2005-2015.

Location Name	HUC12 ID	2005-2015 Number of values	2005-2015 Median mg/L	Ranking Score
Little BR	110100050104	76	10.50	0
Beech Cr	110100050202	23	11.20	0
BR @ Wild Area	110100050203	100	10.60	0
Luallen Spr	110100050203	46	9.94	0
Cecil Cr	110100050204	51	9.90	0
BR @ Ponca	110100050205	53	10.01	0
Ponca Cr	110100050205	38	10.79	0
Mill Cr mouth	110100050206	149	9.90	0
BR @ Pruitt Ac	110100050207	116	9.20	1
Big Cr Carver	110100050303	177	10.20	0
BR @ Hasty	110100050303	56	9.41	1
Cave Cr mouth	110100050305	46	10.27	0
Richland Cr mouth	110100050308	52	10.14	0
BR @ Woolum	110100050309	41	10.30	0
Mitch Hill Spr	110100050309	48	8.27	1
Davis Cr	110100050309	47	10.58	0
Calf Cr	110100050401	45	10.21	0
Bear Cr mouth	110100050404	44	10.70	0
Brush Cr	110100050405	33	10.40	0
BR @ Gilbert Ac	110100050406	43	10.80	0
Gilbert Spr	110100050406	53	9.20	1
Mill Cr L	110100050406	44	10.50	0
BR @ Hwy65	110100050406	130	9.54	1
Tomahawk Cr	110100050407	45	10.70	0
Water Cr	110100050408	45	11.20	0
Rush Cr	110100050501	45	10.44	0
BR @ Hwy 14	110100050502	44	10.65	0
BR @ Rush Ac	110100050502	43	10.00	0
Clabber Cr	110100050503	46	10.55	0
Big Cr L	110100050507	41	9.85	1
BR Mouth	110100050508	47	9.84	1
Middle Cr	110100050508	41	9.87	1
Leatherwood Cr	110100050508	41	10.00	0
		25^{th} percentile	9.90	

Table C.3. Evaluation of median E. coli concentrations for 2009-2015.

Location Name	HUC12 ID	2009-2015 Number of values	2009-2015 Median cfu/100mL	Ranking Score
Little BR	110100050104	72	37.5	1
BR @ Wild Area	110100050203	71	19	0
Luallen Spr	110100050203	30	5	0
Cecil Cr	110100050204	41	46	1
BR @ Ponca	110100050205	28	40.5	1
Ponca Cr	110100050205	24	18.5	0
Mill Cr mouth	110100050206	139	64	1
BR @ Pruitt Ac	110100050207	104	11	0
Big Cr Carver	110100050303	160	41.25	1
BR @ Hasty	110100050303	45	19	0
Cave Cr mouth	110100050305	32	49	1
Richland Cr mouth	110100050308	26	34.5	0
BR @ Woolum	110100050309	27	5.5	0
Mitch Hill Spr	110100050309	32	21	0
Davis Cr	110100050309	28	26.5	0
Calf Cr	110100050401	28	15	0
Bear Cr mouth	110100050404	28	21.5	0
Brush Cr	110100050405	22	20	0
BR @ Gilbert Ac	110100050406	28	6	0
Gilbert Spr	110100050406	36	12.5	0
Mill Cr L	110100050406	28	22.5	0
Tomahawk Cr	110100050407	29	64	1
Water Cr	110100050408	28	23	0
Rush Cr	110100050501	29	12	0
BR @ Hwy 14	110100050502	27	12	0
BR @ Rush Ac	110100050502	26	8.5	0
Clabber Cr	110100050503	31	40	1
Big Cr L	110100050507	28	25.25	0
BR Mouth	110100050508	28	10	0
Middle Cr	110100050508	28	20.5	0
Leatherwood Cr	110100050508	28	17	0
		75th percentile	36.0	

Table C.4. Evaluation of median fecal coliform concentrations for 2009-2015.

Location Name	HUC12 ID	2005-2015		Ranking Score
		Number of values	Median, cfu/100mL	
Little BR	110100050104	44	24	1
Beech Cr	110100050202	23	13	0
BR @ Wild Area	110100050203	47	13	0
Luallen Spr	110100050203	47	6	0
Cecil Cr	110100050204	55	18	0
BR @ Ponca	110100050205	50	24.5	1
Ponca Cr	110100050205	40	15	0
Mill Cr mouth	110100050206	60	72.5	1
BR @ Pruitt Ac	110100050207	54	12	0
Big Cr Carver	110100050303	51	21	1
BR @ Hasty	110100050303	47	11	0
Cave Cr mouth	110100050305	48	23.5	1
Richland Cr mouth	110100050308	40	12	0
BR @ Woolum	110100050309	41	5	0
Mitch Hill Spr	110100050309	46	11.5	0
Davis Cr	110100050309	47	29	1
Calf Cr	110100050401	43	12	0
Bear Cr mouth	110100050404	46	13.5	0
Brush Cr	110100050405	35	18	0
BR @ Gilbert Ac	110100050406	45	4	0
Gilbert Spr	110100050406	45	5	0
Mill Cr L	110100050406	44	14.5	0
Tomahawk Cr	110100050407	43	31	1
Water Cr	110100050408	44	15	0
Rush Cr	110100050501	44	11	0
BR @ Hwy 14	110100050502	46	6	0
BR @ Rush Ac	110100050502	43	7	0
Clabber Cr	110100050503	45	10	0
Big Cr L	110100050507	45	19	1
BR Mouth	110100050508	44	6	0
Middle Cr	110100050508	43	13	0
Leatherwood Cr	110100050508	44	10.5	0
		75^{th} percentile	18.25	

Table C.5. Evaluation of median inorganic nitrogen concentrations for 2005-2015.

Location Name	HUC12 ID	2005-2015		Ranking Score
		Number of values	Median, mg/L	
Little BR	110100050104	44	0.075	0
Beech Cr	110100050202	25	0.044	0
BR @ Wild Area	110100050203	67	0.025	0
Luallen Spr	110100050203	45	0.193	0
Cecil Cr	110100050204	43	0.032	0
BR @ Ponca	110100050205	55	0.072	0
Ponca Cr	110100050205	41	0.113	0
Mill Cr mouth	110100050206	50	0.727	1
BR @ Pruitt Ac	110100050207	48	0.032	0
Big Cr Carver	110100050303	66	0.132	0
BR @ Hasty	110100050303	47	0.079	0
Cave Cr mouth	110100050305	47	0.089	0
Richland Cr mouth	110100050308	53	0.045	0
BR @ Woolum	110100050309	45	0.132	0
Mitch Hill Spr	110100050309	45	1.160	1
Davis Cr	110100050309	47	0.637	1
Calf Cr	110100050401	45	0.337	1
Bear Cr mouth	110100050404	47	0.313	1
Brush Cr	110100050405	36	0.770	1
BR @ Gilbert Ac	110100050406	46	0.094	0
Gilbert Spr	110100050406	44	0.873	1
Mill Cr L	110100050406	44	0.273	0
BR @ Hwy65	110100050406	133	0.100	0
Tomahawk Cr	110100050407	44	0.382	1
Water Cr	110100050408	45	0.237	0
Rush Cr	110100050501	45	0.233	0
BR @ Hwy 14	110100050502	44	0.101	0
BR @ Rush Ac	110100050502	42	0.071	0
Clabber Cr	110100050503	46	0.052	0
Big Cr L	110100050507	43	0.132	0
BR Mouth	110100050508	45	0.066	0
Middle Cr	110100050508	42	0.000	0
Leatherwood Cr	110100050508	43	0.000	0
		75th percentile	0.273	

Table C.6. Evaluation of median orthophosphate concentrations for 2005-2015.

Location Name	HUC12 ID	2005-2015 Number of values	2005-2015 Median, mg/L	Ranking Score
Little BR	110100050104	44	0.010	0
Beech Cr	110100050202	25	0.011	0
BR @ Wild Area	110100050203	67	0.000	0
Luallen Spr	110100050203	45	0.019	1
Cecil Cr	110100050204	44	0.008	0
BR @ Ponca	110100050205	55	0.006	0
Ponca Cr	110100050205	42	0.010	0
Mill Cr mouth	110100050206	50	0.012	0
BR @ Pruitt Ac	110100050207	48	0.007	0
BR @ Hasty	110100050303	47	0.009	0
Big Cr Carver	110100050303	53	0.012	0
Cave Cr mouth	110100050305	47	0.012	0
Richland Cr mouth	110100050308	53	0.005	0
BR @ Woolum	110100050309	42	0.000	0
Davis Cr	110100050309	48	0.010	0
Mitch Hill Spr	110100050309	45	0.014	1
Calf Cr	110100050401	45	0.028	1
Bear Cr mouth	110100050404	47	0.018	1
Brush Cr	110100050405	35	0.020	1
BR @ Gilbert Ac	110100050406	46	0.010	0
BR @ Hwy65	110100050406	133	0.010	0
Gilbert Spr	110100050406	44	0.027	1
Mill Cr L	110100050406	44	0.013	1
Tomahawk Cr	110100050407	44	0.009	0
Water Cr	110100050408	45	0.000	0
Rush Cr	110100050501	45	0.000	0
BR @ Hwy 14	110100050502	44	0.010	0
BR @ Rush Ac	110100050502	43	0.009	0
Clabber Cr	110100050503	46	0.000	0
Big Cr L	110100050507	43	0.012	0
BR Mouth	110100050508	45	0.008	0
Leatherwood Cr	110100050508	43	0.000	0
Middle Cr	110100050508	42	0.000	0
		75th percentile	0.012	

Table C.7. Evaluation of median turbidity concentrations for 2005-2015.

Location Name	HUC12 ID	2005-2015		Ranking Score
		Number of values	Median, NTUL	
Little BR	110100050104	86	1.91	1
Beech Cr	110100050202	24	5.21	1
BR @ Wild Area	110100050203	83	2.80	1
Luallen Spr	110100050203	47	2.00	1
Cecil Cr	110100050204	52	1.77	0
BR @ Ponca	110100050205	58	1.90	0
Ponca Cr	110100050205	41	1.70	0
Mill Cr mouth	110100050206	155	2.10	1
Mill Cr @ Camp	110100050206	55	2.20	1
BR @ Pruitt Ac	110100050207	122	1.40	0
BR @ Hasty	110100050303	58	1.66	0
Big Cr Carver	110100050303	220	2.10	1
Cave Cr mouth	110100050305	55	1.50	0
Richland Cr mouth	110100050308	53	2.83	1
BR @ Woolum	110100050309	50	1.83	0
Mitch Hill Spr	110100050309	51	0.90	0
Davis Cr	110100050309	52	0.63	0
Calf Cr	110100050401	45	1.11	0
Bear Cr mouth	110100050404	51	1.79	0
Brush Cr	110100050405	35	0.63	0
BR @ Gilbert Ac	110100050406	47	1.60	0
Gilbert Spr	110100050406	56	1.09	0
Mill Cr L	110100050406	44	0.73	0
BR @ Hwy65	110100050406	134	2.09	1
Tomahawk Cr	110100050407	51	0.80	0
Water Cr	110100050408	46	0.57	0
Rush Cr	110100050501	48	0.61	0
BR @ Hwy 14	110100050502	49	1.50	0
BR @ Rush Ac	110100050502	48	1.45	0
Clabber Cr	110100050503	50	0.70	0
Big Cr L	110100050507	56	0.85	0
BR Mouth	110100050508	52	1.46	0
Middle Cr	110100050508	45	0.43	0
Leatherwood Cr	110100050508	47	0.49	0
		75^{th} percentile	1.90	

ATTACHMENT D

Estimated Annual Loads of Selected Water Quality Parameters with HUC12 Ranking Scores

Attachment D

HUC12 subwatersheds were ranked based on estimated tributary loads for three constituents of interest; inorganic nitrogen, orthophosphorus, and E. coli. Turbidity units cannot be converted to load units, so turbidity was not included. Because loads naturally increase downstream in the Buffalo River, only the farthest upstream Buffalo River monitoring location (at the Upper Buffalo Wilderness Area boundary) was evaluated in the ranking. Only tributary monitoring locations and the one Buffalo River location were ranked.

The annual loads used for ranking were calculated using tributary median constituent concentrations for the period 2005-2015, and estimated average annual runoff volumes. The USGS estimated the average annual runoff for four long-term flow gages in the Buffalo River watershed. The estimated average annual runoff for these gages ranged from 18.61 inches for the Buffalo River headwaters to 9.77 inches for the Buffalo River near Rush (Pugh and Westerman 2014). The estimated average annual runoff volume for each of the subwatersheds was estimated by multiplying the drainage area of the monitored tributary by 17 inches. This value is similar to the average annual runoff for Richland Creek near Witt's Spring (17.33 inches).

Table D.1. Evaluation of estimated HUC12 E. coli loads.

HUC12 ID	Tributary Monitoring station ID	Monitored Tributary Name	Tributary Drainage Area, Ac	Estimated Runoff Volume, L	Median 2009-2015 E. coli, cfu/100mL	Estimated E. coli load, cfu/year	Ranking score
110100050101	ND	Little Buffalo R					ND
110100050102	ND	Little Buffalo R					ND
110100050103	ND	Little Buffalo R					ND
110100050104	BUFT05	Little Buffalo R	91,825	160,456,082,550	37.5	6,017,103	1
110100050201	ND	Upper Buffalo R					ND
110100050202	BUFT01	Beech Cr	12,444	21,744,791,628	17	369,661	0
110100050203	BUFR01	Upper Buffalo R	37,907[a]	66,239,486,114	19	1,258,550	0
110100050204	BUFT03	Cecil Cr	14,784[b]	25,833,735,088	46	1,188,352	0
110100050205	BUFT02	Ponca Cr	2,886[b]	5,043,729,231	18.5	93,309	0
110100050206	BUFT04	Mill Cr U	13,607	23,777,031,476	64	1,521,730	0
110100050207	NE	None					NA
110100050301	ND	Big Cr U					ND
110100050302	ND	Big Cr U					ND
110100050303	BUFT06 & 7055814	Big Cr U	57,536[b]	100,539,081,575	41.25	4,147,237	1
110100050304	NE	None					NA
110100050305	BUFT08	Cave Cr	33,618	58,744,487,701	49	2,878,480	1
110100050306	ND	Richland Cr					ND
110100050307	ND	Richland Cr					ND
110100050308	BUFT09	Richland Cr	83,536	145,971,786,680	34.5	5,036,027	1
110100050309	BUFT07	Davis Cr	17,920[b]	31,313,618,288	26.5	829,811	0
110100050401	BUFT10	Calf Cr	31,755	55,489,059,639	15	832,336	0
110100050402	NE	None					NA
110100050403	ND	Bear Cr					ND
110100050404	BUFT12	Bear Cr	58,990	103,079,818,237	21.5	2,216,216	0
110100050405	BUFT13	Brush Cr	12,874	22,496,178,674	20	449,924	0
110100050406	BUFT11	Mill Cr L	9,088[b]	15,880,477,846	22.5	357,311	0
110100050407	BUFT14	Tomahawk Cr	23,589	41,219,695,413	64	2,638,061	0
110100050408	BUFT15	Water Cr	24,516	42,839,546,091	23	985,310	0

Table D.1. Evaluation of estimated HUC12 E. coli loads (continued).

HUC12 ID	Tributary Monitoring station ID	Monitored Tributary Name	Tributary Drainage Area, Ac	Estimated Runoff Volume, L	Median 2009-2015 E. coli, cfu/100mL	Estimated E. coli load, cfu/year	Ranking score
110100050409	ND	None					NA
110100050501	BUFT16	Rush Cr	9,656	16,873,007,711	12	202,476	0
110100050502	NE	None			NA		NA
110100050503	BUFT17	Clabber Cr	16,992	29,692,020,198	40	1,187,681	0
110100050504	ND	None					NA
110100050505	ND	Big Cr L					ND
110100050506	ND	Big Cr L					ND
110100050507	BUFT18	Big Cr L	85,888	150,081,699,081	25.25	3,789,563	1
110100050508	BUFT23	Middle Cr	7,168[b]	12,525,447,315	20.5	498,222	0
110100050508	BUFT24	Leatherwood Cr	8,128[b]	14,202,962,581	17		
					75th percentile	2,698,165	

[a] drainage area from USGS gage
[b] drainage area calculated using USGS StreamStats online utility
NE = only Buffalo River water quality monitoring stations are present (no tributary monitoring stations), so not evaluated; ND = no water quality monitoring stations

Table D.2 Evaluation of estimated HUC12 inorganic nitrogen loads.

HUC12 ID	Tributary Monitoring station ID	Monitored Tributary Name	Tributary Drainage Area, Ac	Estimated Runoff Volume, L	Median 2005-2015 inorganic nitrogen, mg/L	Estimated inorganic nitrogen load, kg/year	Ranking score
110100050101	ND	Little Buffalo R					ND
110100050102	ND	Little Buffalo R					ND
110100050103	ND	Little Buffalo R					ND
110100050104	BUFT05	Little Buffalo R	91,825	160,456,082,550	0.075	12,034	0
110100050201	ND	Upper Buffalo R					ND
110100050202	BUFT01	Beech Cr	12,444	21,744,791,628	0.044	957	0
110100050203	BUFR01	Upper Buffalo R	37,907[a]	66,239,486,114	0.025	1,656	0
110100050204	BUFT03	Cecil Cr	14,784[b]	25,833,735,088	0.032	827	0
110100050205	BUFT02	Ponca Cr	2,886[b]	5,043,729,231	0.113	570	0
110100050206	BUFT04	Mill Cr U	13,607	23,777,031,476	0.727	17,286	0
110100050207	NE	None					NA
110100050301	ND	Big Cr U					ND
110100050302	ND	Big Cr U					ND
110100050303	BUFT06 & 7055814	Big Cr U	57,536[b]	100,539,081,575	0.1315	13,221	0
110100050304	NE	None					NA
110100050305	BUFT08	Cave Cr	33,618	58,744,487,701	0.089	5,228	0
110100050306	ND	Richland Cr					ND
110100050307	ND	Richland Cr					ND
110100050308	BUFT09	Richland Cr	83,536	145,971,786,680	0.045	6,569	0
110100050309	BUFT07	Davis Cr	17,920[b]	31,313,618,288	0.637	19,947	1
110100050401	BUFT10	Calf Cr	31,755	55,489,059,639	0.337	18,700	1
110100050402	NE	None					NA
110100050403	ND	Bear Cr					ND
110100050404	BUFT12	Bear Cr	58,990	103,079,818,237	0.313	32,264	1
110100050405	BUFT13	Brush Cr	12,874	22,496,178,674	0.77	17,322	1
110100050406	BUFT11	Mill Cr L	9,088[b]	15,880,477,846	0.273	4,335	0
110100050407	BUFT14	Tomahawk Cr	23,589	41,219,695,413	0.382	15,746	0

Table D.2 Evaluation of estimated HUC12 inorganic nitrogen loads (continued).

HUC12 ID	Tributary Monitoring station ID	Monitored Tributary Name	Tributary Drainage Area, Ac	Estimated Runoff Volume, L	Median 2005-2015 inorganic nitrogen, mg/L	Estimated inorganic nitrogen load, kg/year	Ranking score
110100050408	BUFT15	Water Cr	24,516	42,839,546,091	0.245	10,496	0
110100050409	ND	None					ND
110100050501	BUFT16	Rush Cr	9,656	16,873,007,711	0.233	3,931	0
110100050502	NE	None					NA
110100050503	BUFT17	Clabber Cr	16,992	29,692,020,198	0.052	1,544	0
110100050504	ND	None					ND
110100050505	ND	Big Cr L					ND
110100050506	ND	Big Cr L					ND
110100050507	BUFT18	Big Cr L	85,888	150,081,699,081	0.132	19,811	1
110100050508	BUFT23	Middle Cr	7,168[b]	12,525,447,315	0	0	0
110100050508	BUFT24	Leatherwood Cr	8,128[b]	14,202,962,581	0		
					75th percentile	17,295	

Table D.3 Evaluation of estimated HUC12 orthophosphate loads.

HUC12 ID	Tributary Monitoring station ID	Monitored Tributary Name	Tributary Drainage Area, Ac	Estimated Runoff Volume, L	Median 2005-2015 orthophosphate, mg/L	Estimated orthosphosphate load, kg/year	Ranking score
110100050101	ND	Little Buffalo R			NA	included	NA
110100050102	ND	Little Buffalo R			NA	included	NA
110100050103	ND	Little Buffalo R			NA	included	NA
110100050104	BUFT05	Little Buffalo R	91,825	160,456,082,550	0.01	1,605	1
110100050201	ND	Upper Buffalo R			NA	included	NA
110100050202	BUFT01	Beech Cr	12,444	21,744,791,628	0.011	239	0
110100050203	BUFR01	Upper Buffalo R	37,907[a]	66,239,486,114	0	0	0
110100050204	BUFT03	Cecil Cr	14,784[b]	25,833,735,088	0.008	207	0
110100050205	BUFT02	Ponca Cr	2,886[b]	5,043,729,231	0.0095	48	0
110100050206	BUFT04	Mill Cr U	13,607	23,777,031,476	0.012	285	0
110100050207	NE	None					
110100050301	ND	Big Cr U			NA	included	NA
110100050302	ND	Big Cr U			NA	included	NA
110100050303	BUFT06 & 7055814	Big Cr U	57,536[b]	100,539,081,575	0.012	1,206	1
110100050304	NE	None			NA		NA
110100050305	BUFT08	Cave Cr	33,618	58,744,487,701	0.012	705	0
110100050306	ND	Richland Cr			NA	included	NA
110100050307	ND	Richland Cr			NA	included	NA
110100050308	BUFT09	Richland Cr	83,536	145,971,786,680	0.005	730	0
110100050309	BUFT07	Davis Cr	17,920[b]	31,313,618,288	0.0095	297	0
110100050401	BUFT10	Calf Cr	31,755	55,489,059,639	0.028	1,554	1
110100050402	NE	None			NA		NA
110100050403	ND	Bear Cr			NA	included	NA
110100050404	BUFT12	Bear Cr	58,990	103,079,818,237	0.018	1,855	1
110100050405	BUFT13	Brush Cr	12,874	22,496,178,674	0.02	450	0
110100050406	BUFT11	Mill Cr L	9,088[b]	15,880,477,846	0.0125	199	0

Table D.3 Evaluation of estimated HUC12 orthophosphate loads (continued).

HUC12 ID	Tributary Monitoring station ID	Monitored Tributary Name	Tributary Drainage Area, Ac	Estimated Runoff Volume, L	Median 2005-2015 orthophosphate, mg/L	Estimated orthosphosphate load, kg/year	Ranking score
110100050407	BUFT14	Tomahawk Cr	23,589	41,219,695,413	0.0085	350	0
110100050408	BUFT15	Water Cr	24,516	42,839,546,091	0	0	0
110100050409	ND	None			NA		NA
110100050501	BUFT16	Rush Cr	9,656	16,873,007,711	0	0	0
110100050502	NE	None			0.009		
110100050503	BUFT17	Clabber Cr	16,992	29,692,020,198	0	0	0
110100050504	ND	None			NA		NA
110100050505	ND	Big Cr L			NA	included	NA
110100050506	ND	Big Cr L			NA	included	NA
110100050507	BUFT18	Big Cr L	85,888	150,081,699,081	0.012	1,801	1
110100050508	BUFT23	Middle Cr	7,168[b]	12,525,447,315	0	0	0
110100050508	BUFT24	Leatherwood Cr	8,128[b]	14,202,962,581	0		
					75^{th} percentile	849	

ATTACHMENT E

HUC12 Ranking Scores based on Natural Resources Concerns

Attachment E Ranking scores for Natural Resource Concerns

Table E.1. Natural Resource Concern index values and ranking scores.

HUC12 ID	Concentrated flow erosion		Sheet, rill, wind erosion		Streambank erosion		Water quality – excess sediment	
	Mean index value	**Ranking score**	**Mean index value**	**Ranking score**	**Mean index value**	**Ranking score**	**Mean index value**	**Ranking score**
110100050101	1.33	0	1.52	0	0.48	0	1.48	0
110100050102	1.09	0	1.22	0	0.38	0	1.25	0
110100050103	1.94	1	2.20	1	0.87	1	2.26	1
110100050104	1.36	0	1.52	0	0.64	0	1.89	0
110100050201	0.37	0	0.45	0	0.17	0	0.46	0
110100050202	1.35	0	1.50	0	0.49	0	1.50	0
110100050203	0.65	0	0.75	0	0.24	0	0.73	0
110100050204	1.46	0	1.70	0	0.66	0	1.74	0
110100050205	0.88	0	1.02	0	0.32	0	1.00	0
110100050206	1.81	1	2.13	1	0.82	1	2.39	1
110100050207	0.87	0	0.94	0	0.37	0	1.13	0
110100050301	1.27	0	1.55	0	0.57	0	1.65	0
110100050302	0.80	0	1.00	0	0.36	0	1.09	0
110100050303	1.54	0	1.84	0	0.83	1	2.02	0
110100050304	0.54	0	0.65	0	0.25	0	0.64	0
110100050305	0.75	0	0.95	0	0.37	0	1.09	0
110100050306	0.19	0	0.22	0	0.07	0	0.21	0
110100050307	0.17	0	0.20	0	0.07	0	0.26	0
110100050308	0.48	0	0.55	0	0.21	0	0.59	0
110100050309	1.63	0	2.02	0	0.75	0	2.02	0
110100050401	1.66	1	2.13	1	0.81	1	2.30	1
110100050402	1.28	0	1.61	0	0.60	0	1.50	0
110100050403	1.66	0	1.95	0	0.75	0	2.02	0
110100050404	1.68	1	2.36	1	0.76	0	2.35	1
110100050405	1.84	1	2.33	1	0.82	1	2.29	1

Table E.1. Natural Resource Concern index values and ranking scores (continued).

HUC12 ID	Concentrated flow erosion		Sheet, rill, wind erosion		Streambank erosion		Water quality – excess sediment	
	Mean index value	**Ranking score**	**Mean index value**	**Ranking score**	**Mean index value**	**Ranking score**	**Mean index value**	**Ranking score**
110100050406	1.53	0	2.04	1	0.64	0	1.85	0
110100050407	1.76	1	2.37	1	0.81	1	2.22	1
110100050408	1.76	1	2.10	1	0.94	1	2.28	1
110100050409	1.41	0	1.63	0	0.60	0	1.37	0
110100050501	1.67	1	1.83	0	0.76	1	2.02	0
110100050502	0.99	0	1.06	0	0.41	0	1.09	0
110100050503	1.15	0	1.38	0	0.52	0	2.17	1
110100050504	0.45	0	0.47	0	0.18	0	0.78	0
110100050505	1.79	1	2.28	1	0.83	1	2.33	1
110100050506	1.81	1	2.54	1	0.82	1	2.23	1
110100050507	1.51	0	1.75	0	0.60	0	1.76	0
110100050508	0.11	0	0.12	0	0.04	0	0.16	0
75^{th} percentile value	1.66		2.04		0.76		2.17	

Table E.1. Natural Resource Concern index values and ranking scores (continued).

HUC12 ID	Water quality – excess nutrients		Water quality – pathogens etc. from manure		Water quality - pesticides		Water quality - metals	
	Mean index value	Ranking score	Mean index value	Ranking score	Mean index value	Ranking score	Mean index value	Ranking score
110100050101	5.27	0	2.40	0	3.73	0	0.00	0
110100050102	2.86	0	1.30	0	2.31	0	0.00	0
110100050103	5.64	0	2.75	0	4.60	0	0.00	0
110100050104	5.14	0	2.46	0	4.28	0	0.00	0
110100050201	1.00	0	0.65	0	0.69	0	0.00	0
110100050202	3.06	0	1.40	0	2.29	0	0.00	0
110100050203	1.50	0	0.79	0	1.13	0	0.00	0
110100050204	6.11	0	3.29	0	4.34	0	0.00	0
110100050205	2.56	0	1.42	0	2.00	0	0.00	0
110100050206	7.43	1	4.32	0	5.55	1	0.00	0
110100050207	2.77	0	0.87	0	2.49	0	0.00	0
110100050301	6.27	0	4.31	0	4.05	0	0.00	0
110100050302	3.75	0	2.74	0	2.76	0	0.00	0
110100050303	6.08	0	3.67	0	4.86	0	0.00	0
110100050304	2.21	0	1.34	0	1.77	0	0.00	0
110100050305	3.72	0	2.83	0	2.73	0	0.00	0
110100050306	0.83	0	0.51	0	0.38	0	0.00	0
110100050307	0.75	0	0.48	0	0.49	0	0.00	0
110100050308	2.51	0	1.45	0	1.67	0	0.00	0
110100050309	6.70	0	4.44	1	5.28	0	1.30E-06	0
110100050401	9.16	1	6.95	1	6.10	1	2.10E-06	0
110100050402	4.99	0	3.28	0	4.05	0	1.15E-05	0
110100050403	7.96	1	4.85	1	5.33	0	2.21E-05	0
110100050404	9.28	1	8.28	1	6.83	1	2.78E-05	0

Table E.1. Natural Resource Concern index values and ranking scores (continued).

HUC12 ID	Water quality – excess nutrients		Water quality – pathogens etc. from manure		Water quality - pesticides		Water quality - metals	
	Mean index value	Ranking score	Mean index value	Ranking score	Mean index value	Ranking score	Mean index value	Ranking score
110100050405	7.76	1	5.26	1	6.24	1	4.75E-05	0
110100050406	7.08	0	5.57	1	5.46	1	5.04E-05	0
110100050407	8.66	1	6.91	1	6.54	1	5.49E-05	0
110100050408	7.16	1	4.01	0	5.85	1	5.52E-05	1
110100050409	4.70	0	2.15	0	4.10	0	6.19E-05	1
110100050501	5.81	0	1.99	0	5.14	0	6.33E-05	1
110100050502	3.09	0	0.82	0	2.82	0	7.26E-05	1
110100050503	7.76	1	5.19	1	5.96	1	1.37E-04	1
110100050504	1.82	0	0.22	0	1.74	0	2.05E-04	1
110100050505	8.06	1	5.85	1	6.57	1	2.76E-04	1
110100050506	9.36	1	8.18	1	6.96	1	0.315287	1
110100050507	5.29	0	2.57	0	4.56	0	0.526051	1
110100050508	0.41	0	0.05	0	0.40	0	0.996287	1
75^{th} percentile value	7.16		4.44		5.46		5.52E-05	

APPENDIX G

Linear Regression Analysis of Relationship Between Fecal Coliform and *E. Coli* Concentrations at Routine Monitoring Stations in Recommended Subwatersheds

Appendix G

Mill Cr

SELECT (NPS_NAME_CORR041717$ = 'Mill Cr mouth') AND (LN_DAYMEAN_EC <> .)

Dependent Variable	LN_DAYMEAN_EC
N	45
Multiple R	0.895
Squared Multiple R	0.801
Adjusted Squared Multiple R	0.796
Standard Error of Estimate	0.607

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	1.533	0.257	0.000	.	5.963	0.000
LN_DAYMEAN_FC	0.750	0.057	0.895	1.000	13.153	0.000

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	63.829	1	63.829	173.011	0.000
Residual	15.864	43	0.369		

WARNING

Case 3,281 is an Outlier (Studentized Residual : 3.075)

Test for Normality

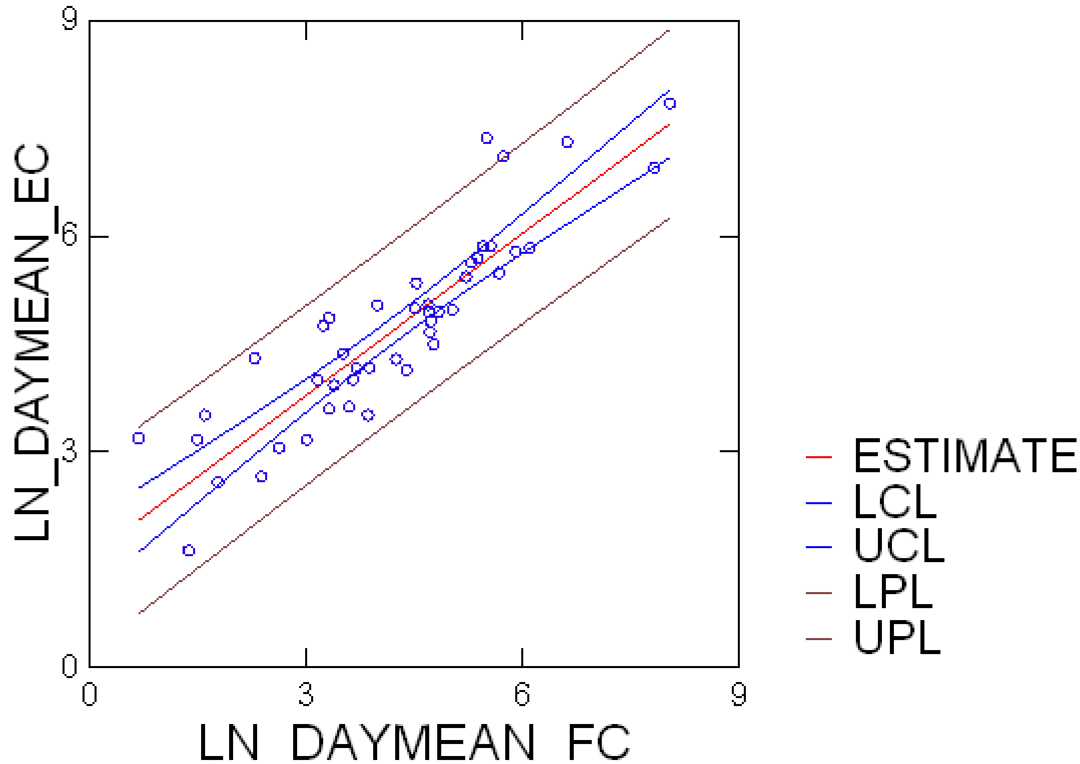
	Test Statistic	p-value
K-S Test (Lilliefors)	0.128	0.064
Anderson-Darling Test	0.897	0.020

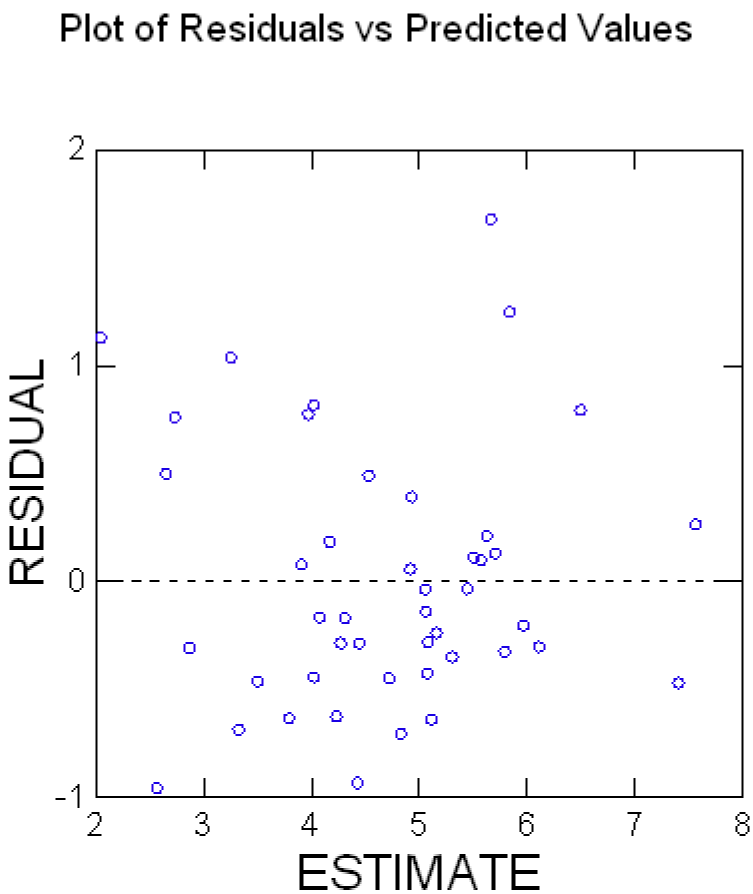
Durbin-Watson D Statistic	2.173
First Order Autocorrelation	-0.121

Information Criteria

AIC	86.787
AIC (Corrected)	87.373
Schwarz's BIC	92.207

Confidence Interval and Prediction Interval





	Median concentration 1985-1994, cfu/100mL	Median concentration 2005-2015, cfu/100mL	Percent difference between periods	Median concentration 2009-2015, cfu/100mL	Target load reduction
Fecal coliform	18	72.5	75%		75%
E. coli (estimated)	15	55.9	73%	64	76%

Brush Creek

SELECT (NPS_NAME_CORR041717$ = 'Brush Cr') AND (LN_DAYMEAN_EC <> .)

Dependent Variable	LN_DAYMEAN_EC
N	25
Multiple R	0.881
Squared Multiple R	0.776
Adjusted Squared Multiple R	0.766

Dependent Variable	LN_DAYMEAN_EC
Standard Error of Estimate	0.816

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	1.424	0.263	0.000	.	5.415	0.000
LN_DAYMEAN_FC	0.687	0.077	0.881	1.000	8.922	0.000

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	53.020	1	53.020	79.599	0.000
Residual	15.320	23	0.666		

WARNING

Case 4,671 has large Leverage (Leverage : 0.512)
Case 4,671 is an Outlier (Studentized Residual : 3.862)

Test for Normality

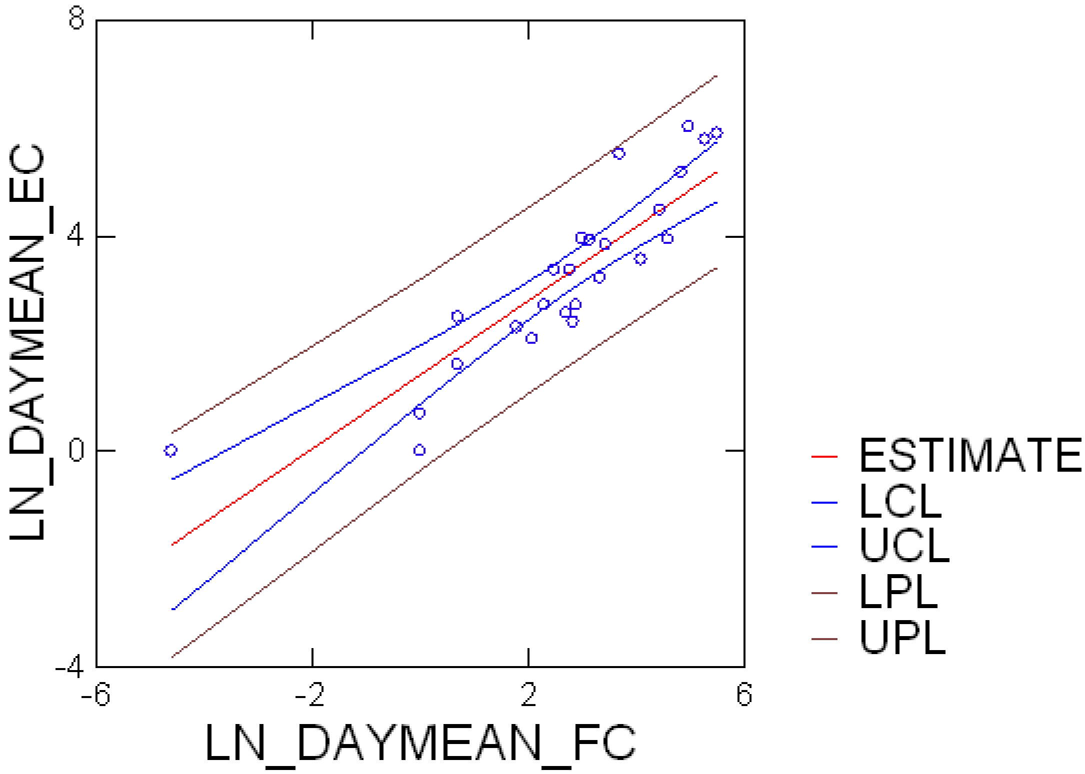
	Test Statistic	p-value
K-S Test (Lilliefors)	0.122	0.438
Anderson-Darling Test	0.374	>0.15

Durbin-Watson D Statistic	2.197
First Order Autocorrelation	-0.130

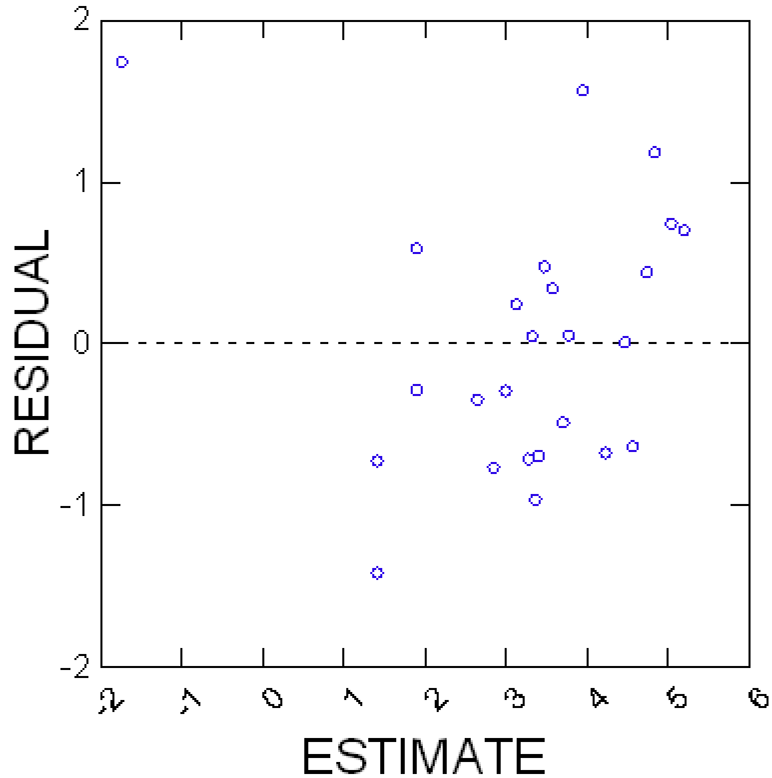
Information Criteria

AIC	64.704
AIC (Corrected)	65.847
Schwarz's BIC	68.361

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



	Median concentration 1985-1994, cfu/100mL	Median concentration 2005-2015, cfu/100mL	Percent difference between periods	Median concentration 2009-2015, cfu/100mL	Target load reduction
Fecal coliform	8.5	20	53%		53%
E. coli (estimated)	7.3	15.2	52%	20	64%

Big Creek (lower)

SELECT (NPS_NAME_CORR041717$ = 'Big Cr L') AND (LN_DAYMEAN_EC <> .)

Dependent Variable	LN_DAYMEAN_EC
N	32
Multiple R	0.745
Squared Multiple R	0.555
Adjusted Squared Multiple R	0.540
Standard Error of Estimate	0.824

Regression Coefficients $B = (X'X)^{-1}X'Y$						
Effect	**Coefficient**	**Standard Error**	**Std. Coefficient**	**Tolerance**	**t**	**p-value**
CONSTANT	1.952	0.253	0.000	.	7.712	0.000
LN_DAYMEAN_FC	0.466	0.076	0.745	1.000	6.120	0.000

Analysis of Variance					
Source	**SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
Regression	25.430	1	25.430	37.450	0.000
Residual	20.371	30	0.679		

WARNING

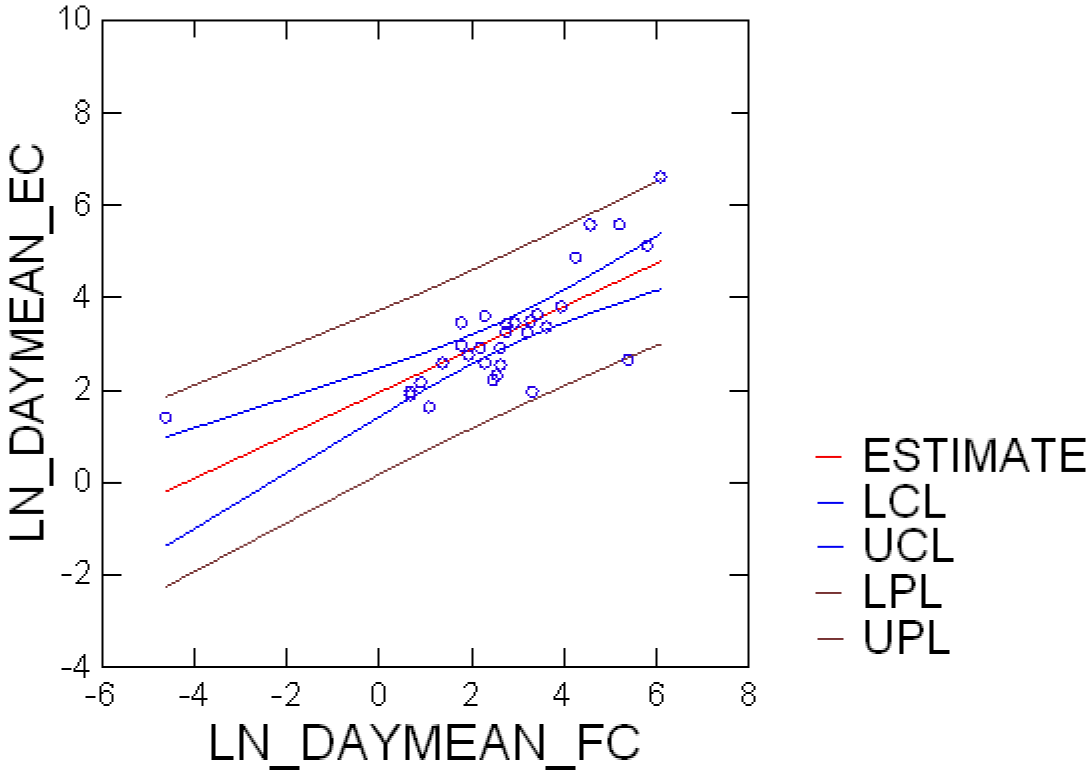
Case 5,446 has large Leverage (Leverage : 0.489)
Case 5,446 is an Outlier (Studentized Residual : 3.020)

Test for Normality		
	Test Statistic	**p-value**
K-S Test (Lilliefors)	0.172	0.017
Anderson-Darling Test	0.664	0.075

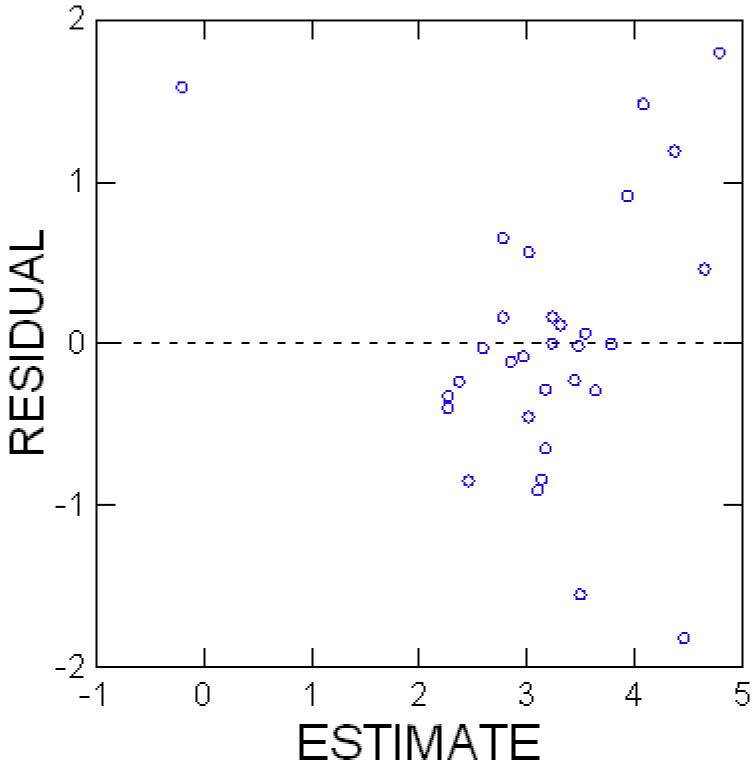
Durbin-Watson D Statistic	2.165
First Order Autocorrelation	-0.098

Information Criteria	
AIC	82.360
AIC (Corrected)	83.218
Schwarz's BIC	86.758

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



	Median concentration 1985-1994, cfu/100mL	Median concentration 2005-2015, cfu/100mL	Percent difference between periods	Median concentration 2009-2015, cfu/100mL	Target load reduction
Fecal coliform	5.5	19	71%		71%
E. coli (estimated)	4.5	10.8	58%	25.25	82%

Tomahawk Cr

	Median concentration 2009-2015, cfu/100mL	75th percentile of 2009-2015 median concentrations, cfu/100mL	Percent difference	Target load reduction
E. coli	64	36	44%	44%

APPENDIX H

Calculation of Pollutant Load Reductions from Implementation of Nonpoint Source Pollution Management Practices for Pasture and Hayland

APPENDIX H

The following equations and associated assumptions were used to calculate the values shown in Tables H.1 through H.4, and Tables5.7-5.9 in Section 5.

Given a target subwatershed load reduction of X%, and assuming that pasture and hayland contributes Y% of the total load, the load from pasture and hayland would need to be reduced Z% = X/Y to achieve the target subwatershed load reduction.

Given a management practice results in R% reduction of the pollutant load, and the reduction target for pasture and hayland is Z%; and assuming 100% of a source (e.g., pasture and hayland, streambanks) contributes equally to the pollutant load; then, the management practice would need to be implemented on P% = Z/R of the source to achieve the target pasture and hayland reduction.

Similarly, given a management practice results in R% reduction of the pollutant load, and P% of a source (e.g., pasture and hayland, streambanks) is treated; and assuming that the source contributes Y% of the total load, and 100% of a source contributes equally to the pollutant load; then the treatment would result in D% = R*P*Y total load reduction..

Table H.1. Estimated nitrogen load reductions from implementation of selected single practices on pasture and haylands in recommended subwatershed.

		Flatrock Creek	Calf Creek	Bear Creek	Brush Creek	Tomahawk Creek	Big Creek (lower)
Subwatershed target inorganic nitrogen load reduction		40%	32%	68%	33%	41%	70%
Assumed proportion of load from pasture and hayland		70%					
Reduction of load from pasture and hayland to achieve subwatershed target load reduction		57%	46%	97%	47%	59%	100%
Forested riparian buffer	Assumed nitrogen reduction efficiency	70%					
	Proportion of source treated	82%	65%	100%	67%	84%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	40%	32%	49%	33%	41%	49%
Herbaceous riparian buffer	Assumed nitrogen reduction efficiency	48%					
	Proportion of source treated	100%	95%	100%	98%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	34%	32%	34%	33%	34%	34%
Controlled livestock access to streams	Assumed nitrogen reduction efficiency	60%					
	Proportion of source treated	95%	76%	100%	78%	98%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	40%	32%	42%	33%	41%	42%
Prescribed grazing	Assumed nitrogen reduction efficiency	20%					
	Proportion of source treated	100%	100%	100%	100%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	14%	14%	14%	14%	14%	14%
Pasture and hayland planting	Assumed nitrogen reduction efficiency	66%					
	Proportion of source treated	87%	69%	100%	71%	89%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	40%	32%	46%	33%	41%	46%

Table H.2. Estimated coliform load reductions from implementation of selected single practices on pasture and haylands in recommended subwatershed to achieve nitrogen reduction targets.

		Flatrock Creek	Calf Creek	Bear Creek	Brush Creek	Tomahawk Creek	Big Creek (lower)
Subwatershed target coliform load reduction		75%	0	0	53%	41%	71%
Assumed proportion of load from pasture and hayland		90%					
Reduction of load from pasture and hayland to achieve subwatershed target load reduction		83%	0	0	59%	46%	79%
Forested riparian buffer	Assumed coliform reduction efficiency	50%					
	Proportion of source treated for N reduction*	82%	65%	100%	67%	84%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	37%	29%	45%	30%	38%	45%
Herbaceous riparian buffer	Assumed coliform reduction efficiency	40%					
	Proportion of source treated for N reduction*	100%	95%	100%	98%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	36%	34%	36%	35%	36%	36%
Controlled livestock access to streams	Assumed coliform reduction efficiency	60%					
	Proportion of source treated for N reduction*	95%	76%	100%	78%	98%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	51%	41%	54%	42%	53%	54%
Prescribed grazing	Assumed coliform reduction efficiency	60%					
	Proportion of source treated for N reduction*	100%	100%	100%	100%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	54%	54%	54%	54%	54%	54%
Pasture and hayland planting	Assumed coliform reduction efficiency	unknown					
	Proportion of source treated for N reduction*	87%	69%	100%	71%	89%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	unknown	unknown	unknown	unknown	unknown	unknown

* from Table G.1

Table H.3. Estimated total phosphorus load reductions from implementation of selected single practices on pasture and haylands in recommended subwatershed to achieve nitrogen reduction targets.

		Flatrock Creek	Calf Creek	Bear Creek	Brush Creek	Tomahawk Creek	Big Creek (lower)
Assumed proportion of load from pasture and hayland		80%					
Forested riparian buffer	Assumed coliform reduction efficiency	70%					
	Proportion of source treated for N reduction*	82%	65%	100%	67%	84%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	46%	37%	56%	38%	47%	56%
Herbaceous riparian buffer	Assumed coliform reduction efficiency	70%					
	Proportion of source treated for N reduction*	100%	95%	100%	98%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	56%	53%	56%	55%	56%	56%
Controlled livestock access to streams	Assumed coliform reduction efficiency	60%					
	Proportion of source treated for N reduction*	95%	76%	100%	78%	98%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	46%	37%	48%	38%	47%	48%
Prescribed grazing	Assumed coliform reduction efficiency	20%					
	Proportion of source treated for N reduction*	100%	100%	100%	100%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	16%	16%	16%	16%	16%	16%
Pasture and hayland planting	Assumed coliform reduction efficiency	67%					
	Proportion of source treated for N reduction*	87%	69%	100%	71%	89%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	46%	37%	54%	38%	48%	54%

* from Table G.1

Table H.4. Estimated sediment load reductions from implementation of selected single practices on pasture and haylands in recommended subwatershed to achieve nitrogen reduction targets.

		Flatrock Creek	Calf Creek	Bear Creek	Brush Creek	Tomahawk Creek	Big Creek (lower)
Assumed proportion of load from pasture and hayland[+]		16%	20%	16%	24%	19%	18%
Assumed proportion of load from streambanks[+]		36%	24%	50%	32%	34%	43%
Proportion of stream miles associated with pasture and haylands		18%	51%	48%	30%	34%	33%
Assumed proportion of load from pasture streambanks^		11%	16%	32%	15%	17%	22%
Forested riparian buffer	Assumed sediment reduction efficiency	70%					
	Proportion of source treated for N reduction*	82%	65%	100%	67%	84%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	6%	7%	11%	7%	10%	15%
Herbaceous riparian buffer	Assumed coliform reduction efficiency	70%					
	Proportion of source treated for N reduction*	100%	95%	100%	98%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	8%	11%	11%	10%	12%	15%
Controlled livestock access to streams	Assumed coliform reduction efficiency	75%					
	Proportion of source treated for N reduction*	95%	76%	100%	78%	98%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	8%	9%	12%	9%	12%	16%
Prescribed grazing	Assumed coliform reduction efficiency	20%					
	Proportion of source treated for N reduction*	100%	100%	100%	100%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	3%	4%	3%	5%	3%	4%
Pasture and hayland planting	Assumed coliform reduction efficiency	59%					
	Proportion of source treated for N reduction*	87%	69%	100%	71%	89%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	8%	8%	10%	10%	9%	11%

[+] Based on results from HAWQS model of subwatershed

^ Assumes sediment load from pasture streambanks is two times that from non-pasture streambanks, i.e., 2*pasture stream miles + 1*non-pasture stream miles = total sediment load from streambanks

* from Table G.1

Table H.5. Estimated coliform load reductions from implementation of selected single practices on pasture and haylands in recommended subwatershed.

		Flatrock Creek	Calf Creek	Bear Creek	Brush Creek	Tomahawk Creek	Big Creek (lower)
Subwatershed target coliform load reduction		75%	0	0	53%	41%	71%
Assumed proportion of load from pasture and hayland		90%					
Reduction of load from pasture and hayland to achieve subwatershed target load reduction		83%	0	0	59%	46%	79%
Forested riparian buffer	Assumed coliform reduction efficiency	50%					
	Proportion of source treated	100%	0	0	100%	92%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	45%	0	0	45%	41%	45%
Herbaceous riparian buffer	Assumed coliform reduction efficiency	40%					
	Proportion of source treated	100%	0	0	100%	100%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	36%	0	0	36%	36%	36%
Controlled livestock access to streams	Assumed coliform reduction efficiency	60%					
	Proportion of source treated	100%	0	0	98%	77%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	54%	0	0	53%	42%	54%
Prescribed grazing	Assumed coliform reduction efficiency	60%					
	Proportion of source treated	100%	0	0	98%	77%	100%
	Reduction in subwatershed load from treatment of pasture and haylands	54%	0	0	53%	42%	54%
Pasture and hayland planting	Assumed coliform reduction efficiency	unknown					
	Proportion of source treated	unknown	unknown	unknown	unknown	unknown	unknown
	Reduction in subwatershed load from treatment of pasture and haylands	unknown	unknown	unknown	unknown	unknown	unknown

Table H.6. Summary of results from HAWQS sediment models for HUC12s of recommended subwatersheds.

		Modeled mean annual loads						
			Streambanks & channel		Pasture & hayland		Forest	
Subwatershed	**HUC12 ID**	**Total, tons**	**Tons**	**Percent of total**	**Tons**	**Percent of total**	**Tons**	**Percent of total**
Flatrock Creek	110100050206	256	96	36%	36	14%	104	41%
Calf Creek	110100050401	2,125	524	24%	415	20%	1,142	54%
Bear Creek	110100050403	5,627	2,158	39%	995	18%	2,424	43%
	110100050404	4,347	2,842	66%	620	14%	850	20%
	Total	9,974	5,000	50%	1,615	16%	3,274	33%
Brush Creek	110100050405	297	97	33%	64	22%	114	38%
Tomahawk Creek	110100050407	572	199	34%	94.5	16%	240	42%
Big Creek (lower)	110100050505	2,015	23.7	16%	37.6	27%	1,107	55%
	110100050506	1,254	550	44%	278	22%	400	32%
	110100050507	1,718	1,284	75%	94.9	6%	264	15%
	Total	4,987	2,158	43%	910	18%	1,771	36%

APPENDIX I

Maps of Recommended Subwatersheds Showing Focus Areas for Management

APPENDIX I

The following land use maps of the recommended subwatersheds can be used to identify focus areas for implementing pasture and hayland practices to reduce nutrient and coliform bacteria in runoff. SWAT modeling identified model units generating loads in the top 25% of sediment, nitrogen, and phosphorus (see report in Appendix E). These model units are shown on the following maps. Pasture and haylands within these model units are recommended as the highest priority for management.

Any pasture and haylands within 50 feet of streams, are recommended as an area to focus management. Because of the mapping scale, 50 foot buffers along the streams are roughly equivalent to the width of the stream lines on the maps. Therefore, any pasture/hayland area with a stream line through it is an area where management practices could be focused.

Pasture and haylands on ridge tops, i.e., between stream lines on the following maps, are the third recommended focus area for management of nutrients and coliform bacteria. The underlying karst geology of this region means nutrients and coliform bacteria from upland pastures have the potential to infiltrate into groundwater.

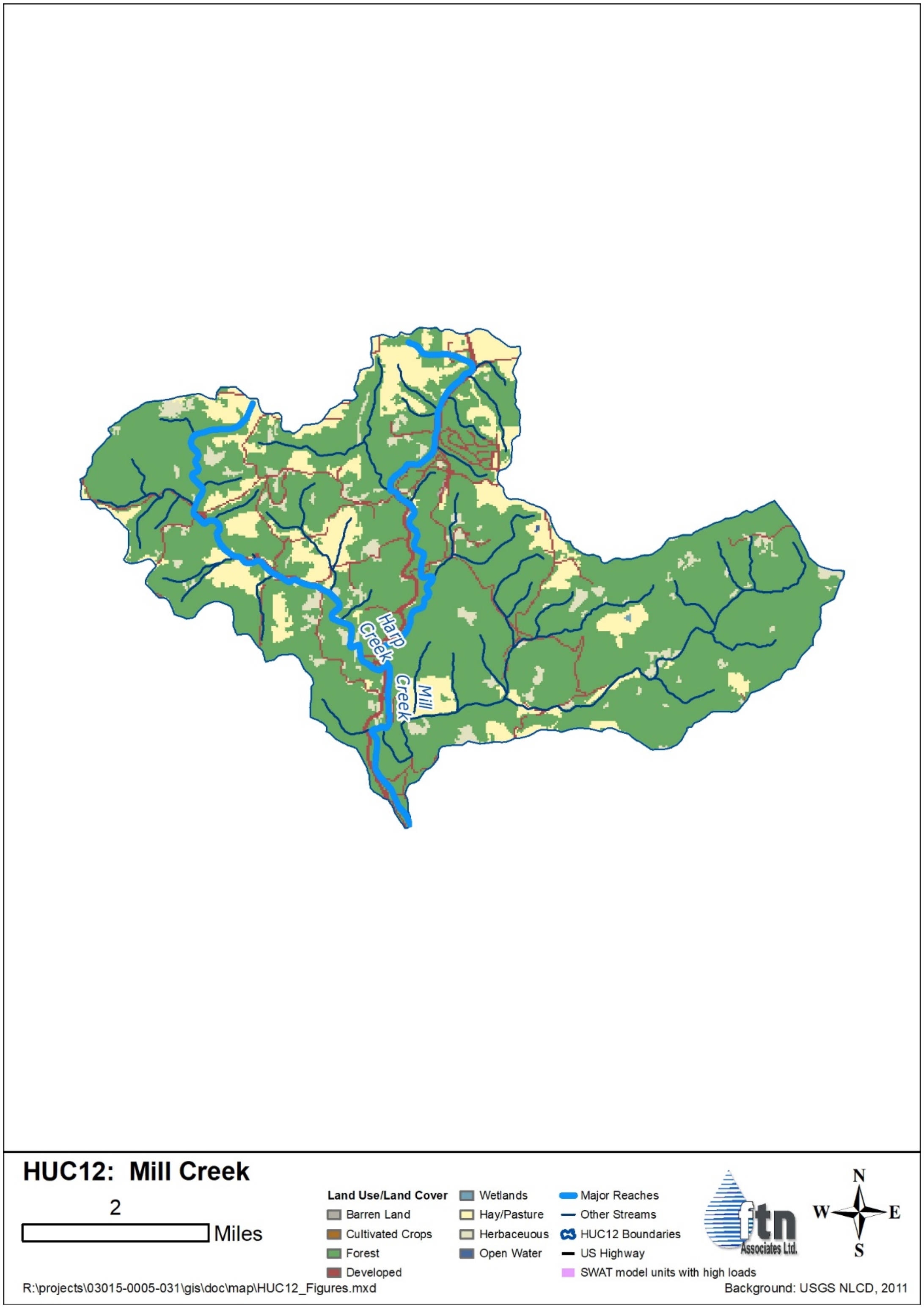


Figure I.1. Land use map of Mill Creek (upper) subwatershed showing focus areas for management.

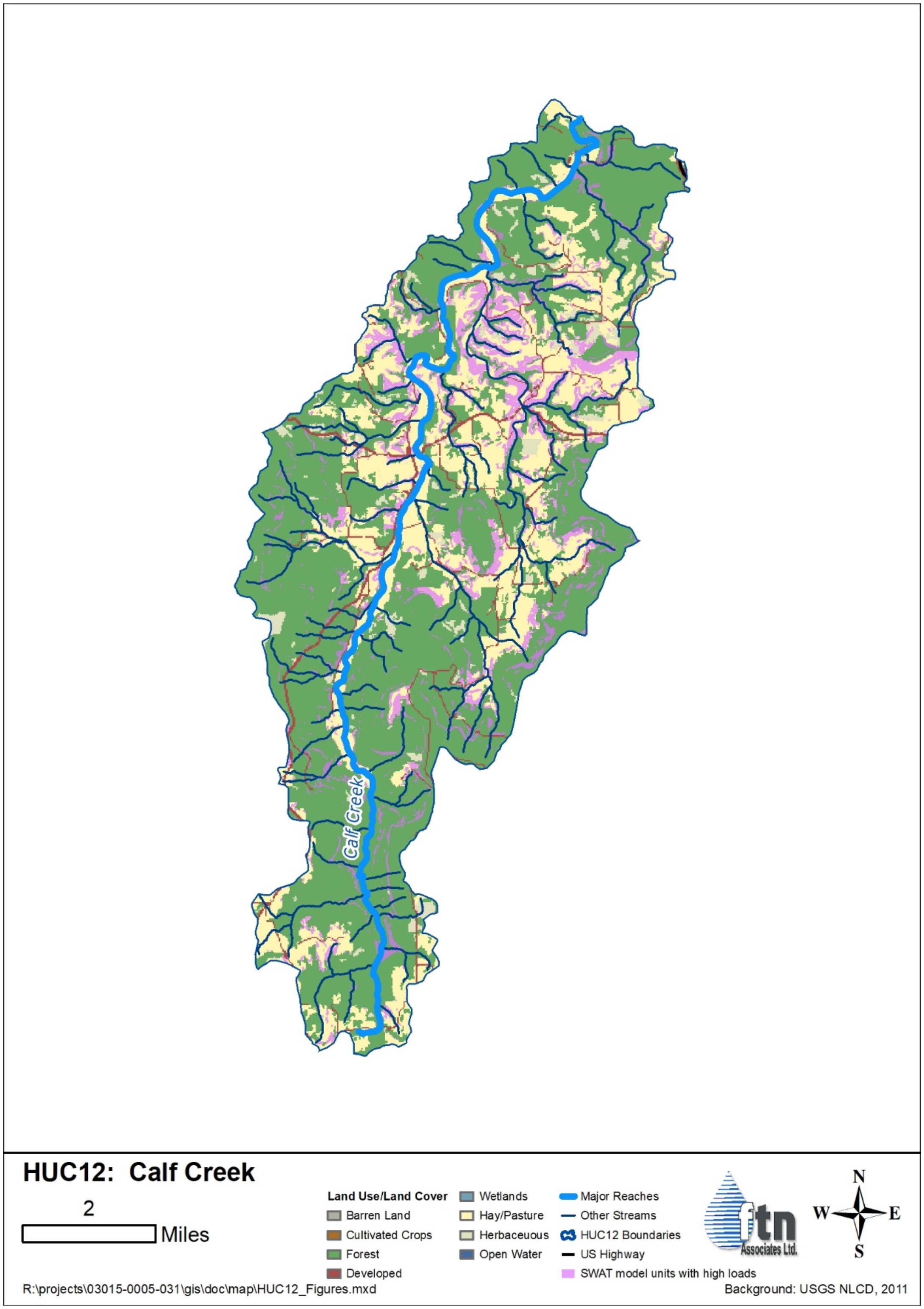


Figure I.2. Land use map of Calf Creek subwatershed showing focus areas for management.

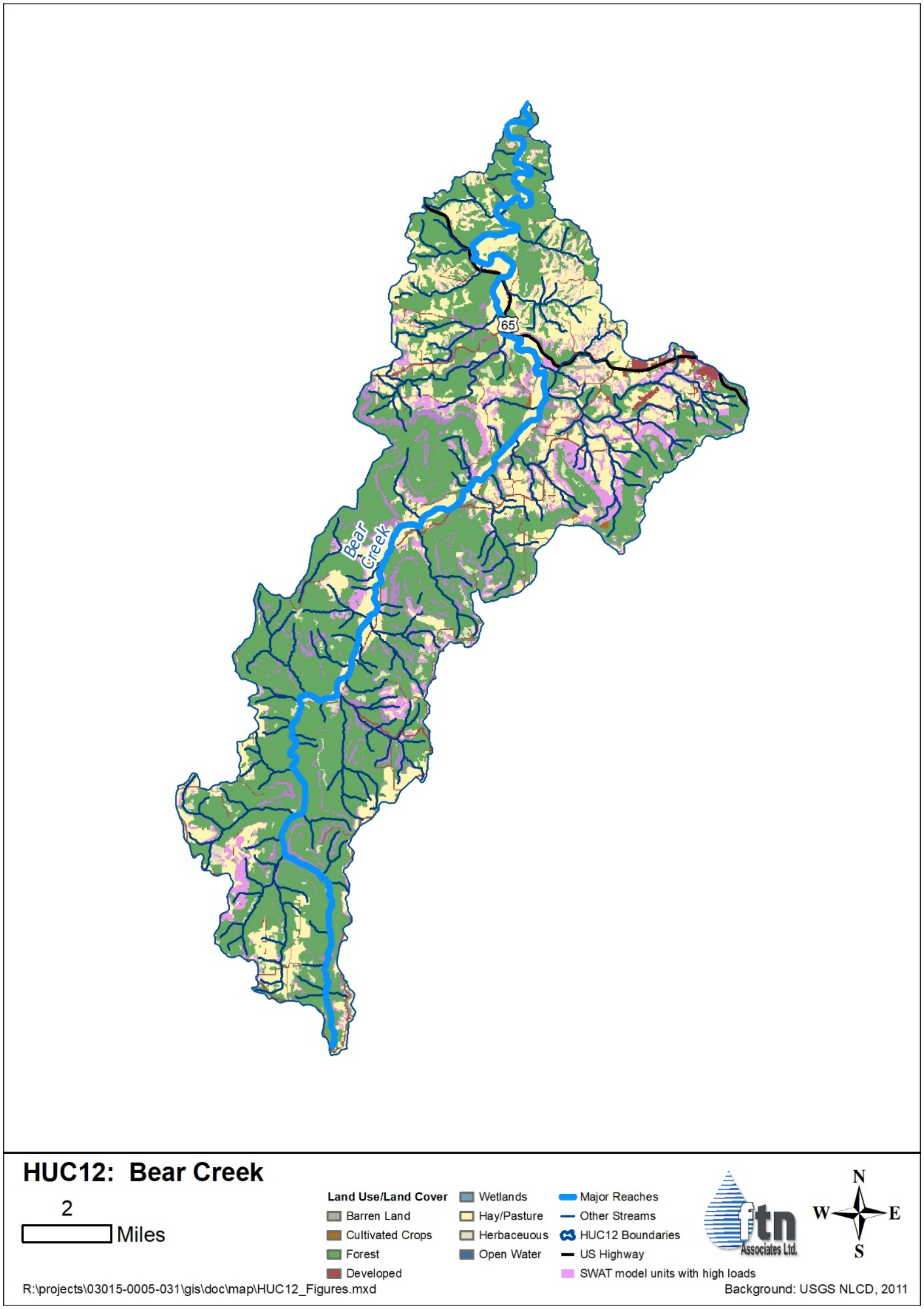


Figure I.3. Land use map of Bear Creek subwatershed showing focus areas for management.

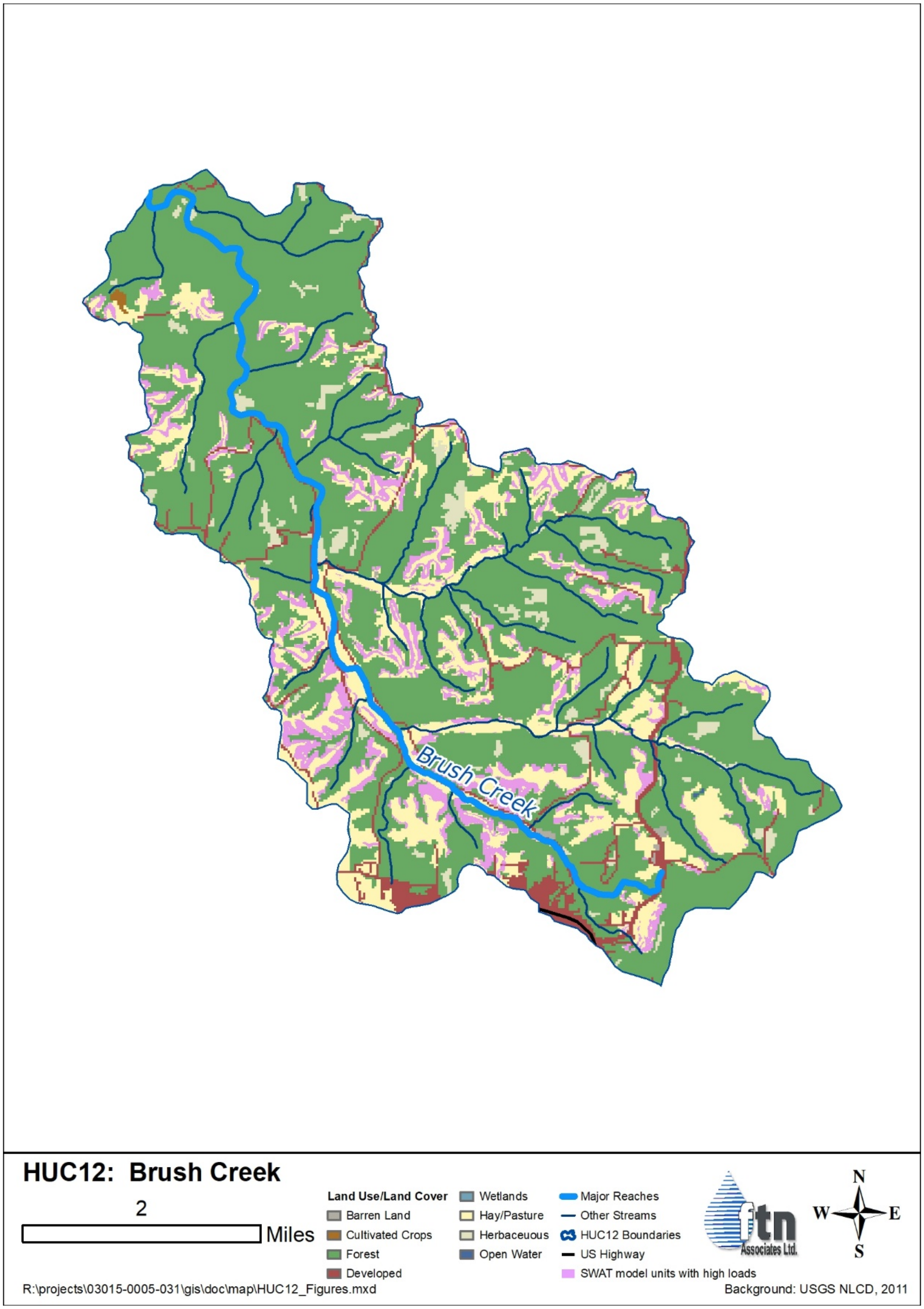


Figure I.4. Land use map of Brush Creek subwatershed showing focus areas for management.

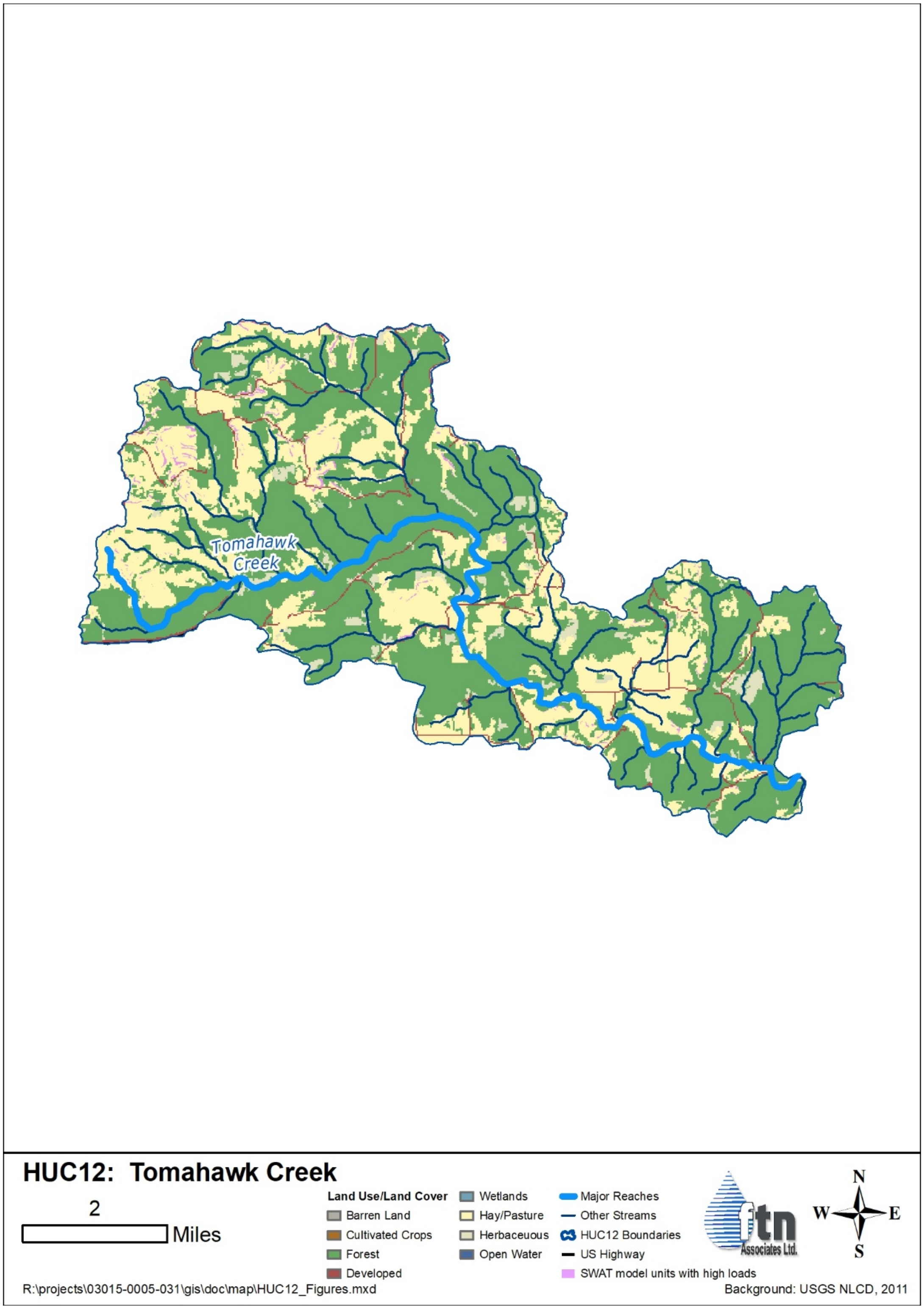


Figure I.5. Land use map of Tomahawk Creek subwatershed showing focus areas for management.

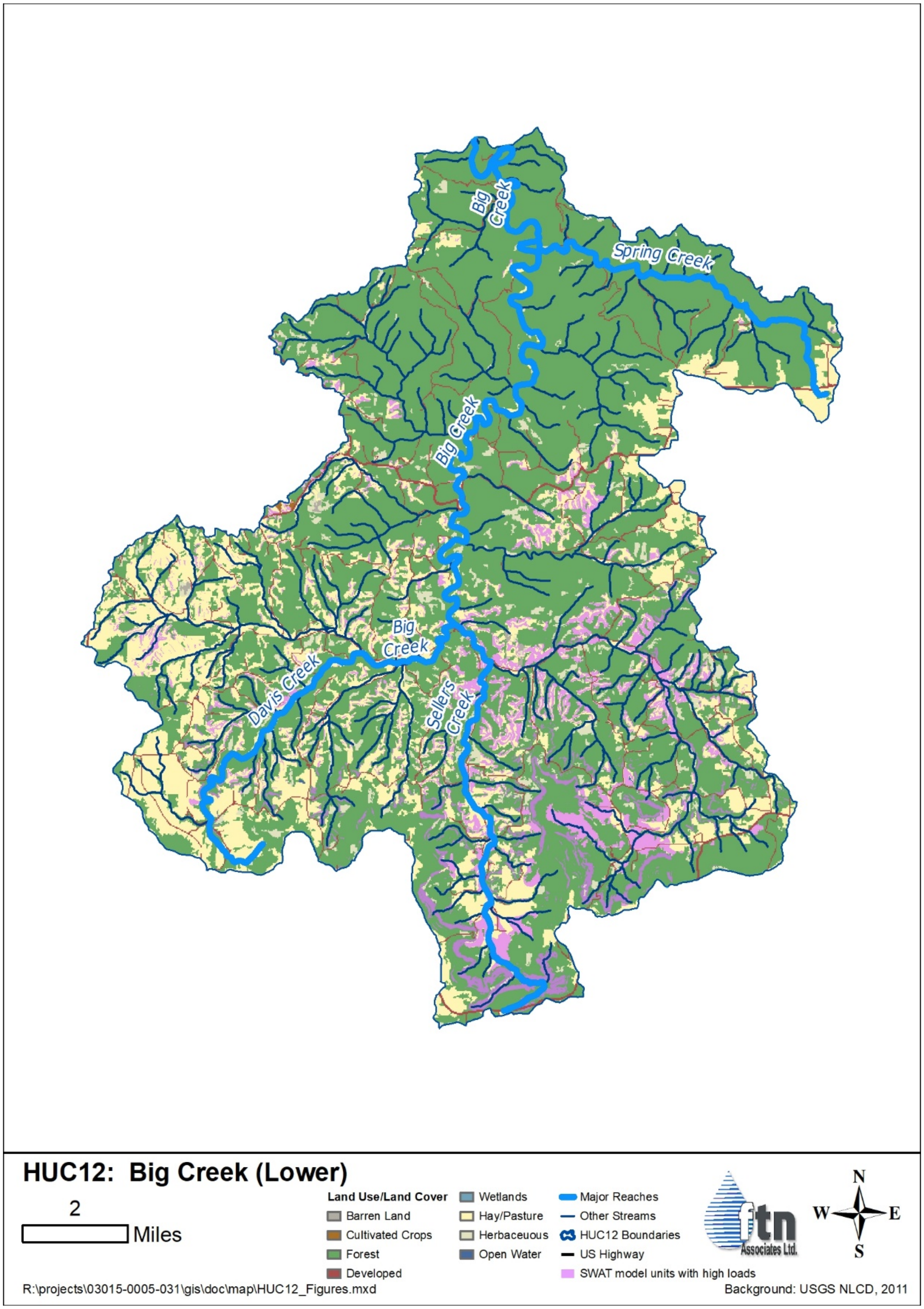


Figure I.6. Land use map of Big Creek (lower) subwatershed showing focus areas for management.