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MIDDLE WHITE RIVER WATERSHED-BASED MANAGEMENT PLAN

DRAFT
March 2019

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Prepared for

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EXECUTIVE SUMMARY

The Middle White River watershed is located in north central Arkansas. It is the watershed for the White River from the confluence of the Buffalo River, in Baxter County, to the confluence of the Black River, in Independence County. This 1,476.2 square mile watershed also includes large areas of Baxter, Independence, Izard, and Stone Counties. There are two large towns in the watershed, Batesville and Mountain Home; however, the watershed is mostly rural. Forest covers 69% of the watershed, and includes the Sylamore District of the Ozark National Forest, in Stone County. Economic drivers in the watershed include tourism and outdoor recreation, livestock farming (18% of the watershed is pasture or hayland), poultry and timber production and processing, small manufacturing, and mining (sand, stone, and gravel).

Water quality in this watershed is generally considered to be good. This watershed includes important habitats for threatened and endangered species including caves, two springs designated as Ecologically Sensitive, and a portion of the White River designated as Critical Habitat for the Rabbitsfoot mussel. In addition, two streams in the watershed, North Sylamore Creek and Salado Creek, are designated as Extraordinary Resource Waters, and North Sylamore Creek is also designated as a Natural and Scenic Waterway.

This Middle White River watershed management plan has been developed as part of the Arkansas Natural Resources Commission Nonpoint Source Program goal of developing plans for all 57 8-digit hydrologic unit code watersheds within the state. This watershed was selected because there are two streams, Hicks Creek near Mountain Home, and Greenbrier Creek near Batesville, that were included on the approved 2016 and draft 2018 state lists of impaired waterbodies. Hicks Creek is impaired due to high *E. coli* levels from the Mountain Home wastewater treatment plant and runoff from the developed areas in and around Mountain Home. Greenbrier Creek is listed as impaired due to the number of low dissolved oxygen concentrations; however, this impairment is expected to be removed as a result of revised ADEQ water quality assessment methodology. Stakeholder concerns related to water quality include the effects of erosion, use of pesticides and other chemicals, mining, livestock and poultry waste, forest management, and sewage on surface and groundwater.

The focus of this watershed management plan is the **protection** and **improvement** of surface water quality in the White River and its tributaries through management of unregulated nonpoint sources of pollution. The mission of the watershed management plan is to increase awareness of water quality issues, outreach and education, and voluntary activities to implement good water quality management practices. The vision this plan is intended to create is: The uses of the Middle White River and its tributaries are attained and sustained, resulting in clean, healthy streams that enhance the socioeconomic and natural amenity benefits of the watershed, as visitors, landowners, and local communities work together to protect and improve both water quality and the quality of life throughout the watershed.

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

Table ES.1. 12-digit hydrologic unit code subwatersheds recommended for initial management of unregulated nonpoint sources.

Hydrologic Unit Code	Watershed Name	Target Pollutants	Primary activity proposed
110100040201	Hicks Creek	Nutrients, E. coli	Implement management practices
110100040504	Miller Creek	Nutrients	Water quality evaluation
110100040604	Greenbrier Creek	Nutrients	Implement management practices
110100040605	Spring Creek	Nutrients	Water quality evaluation
110100040703	Lower Salado Creek	Nutrients	Implement management practices

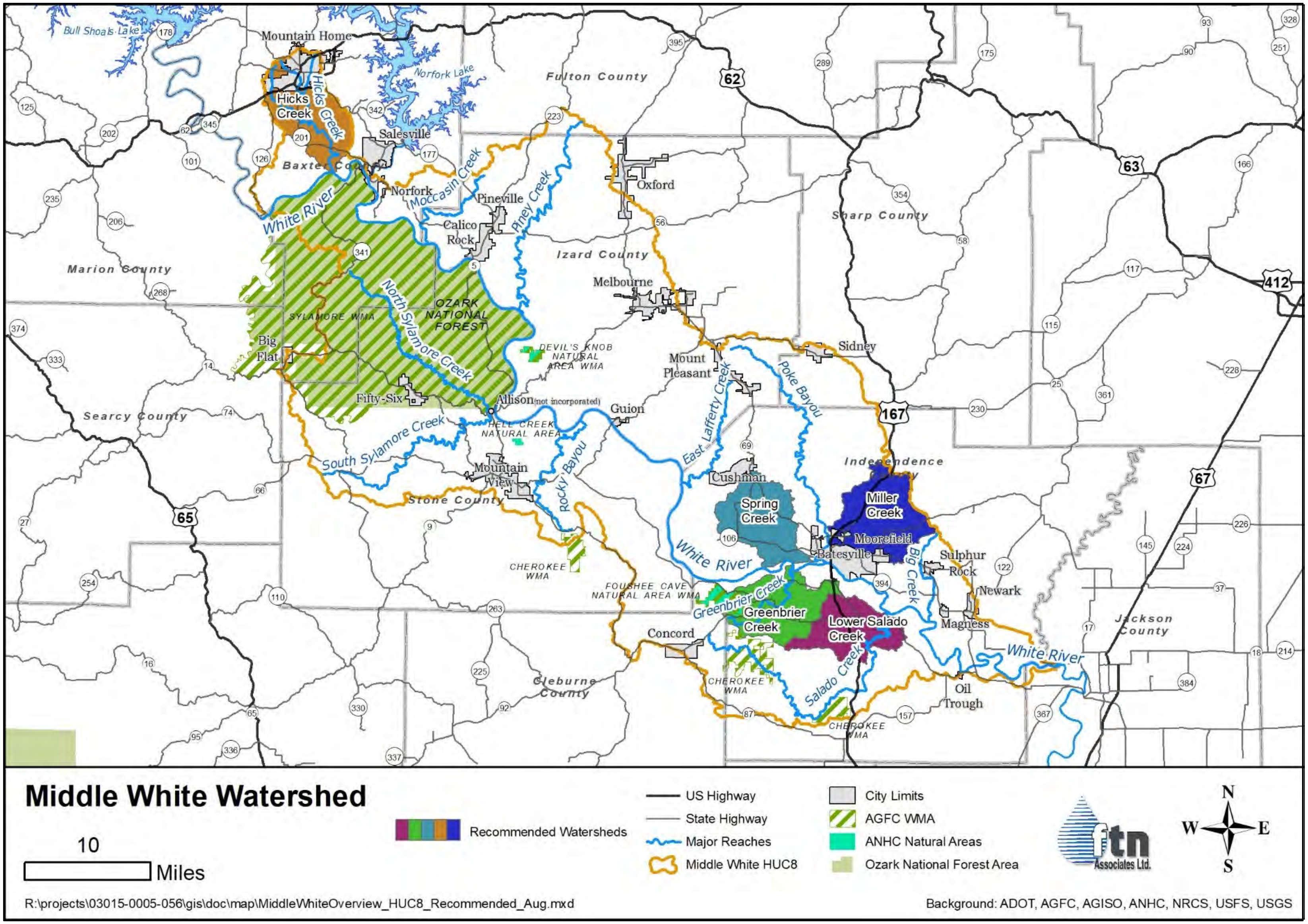

Figure ES.1 Map showing 12-digit hydrologic unit code subwatersheds recommended for initial management of unregulated nonpoint sources.

Through four watershed meetings, stakeholders identified nonpoint source pollution management practices that could be implemented in the recommended subwatersheds. 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. Watershed processes and systems are dynamic. Therefore, an adaptive management approach is proposed for the Middle White 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 Middle White River watershed can be tracked. The proposed schedule and milestones for implementing the activities outlined in this plan are shown in Table ES.2

As part of the adaptive management process, it is recommended that implementation of this plan be evaluated at 5-year intervals. It is recommended that the first evaluation be conducted in 2024. Implementation of this plan will be considered successful if the following are achieved by 2024:

- A watershed implementation team has been formed for at least one recommended subwatershed and initiated at least one project or study;
- Greenbrier Creek is removed from the state impaired waters list;
- Salado Creek at station WHI0166 has been assessed for meeting the Delta Least-altered Stream DO standard;
- Water quality data sufficient for the ADEQ biennial assessment have been collected from Spring Creek and Miller Creek recommended subwatersheds;
- The median total nitrogen values, adjusted for flow, at the routine water quality monitoring station in the Lower Salado Creek recommended subwatershed decreases;
- All dissolved oxygen measurements at the routine water quality monitoring stations in the Hicks Creek and Greenbrier Creek recommended subwatersheds meet the applicable dissolved oxygen numeric criteria; and
- No new water quality impairments resulting from unregulated nonpoint pollution sources are identified in the Middle White River watershed.

Table ES.2. Proposed implementation schedule for Middle White River watershed.

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Monitoring	Roving monitoring program (ADEQ)	2024	2026	Water quality data collection initiated	Number of sampling events	Identify and track changes in water quality Assess water quality relative to water quality standards
	Ambient monitoring program (ADEQ, USGS)	2019	Expected to continue indefinitely	Five additional years of water quality data collected	Number of sampling events Number of sampling locations	Identify and track changes in water quality Assess water quality relative to water quality standards
	ADEQ aquatic invertebrate surveys (ADEQ)	2021	Expected to continue indefinitely	At least one new survey completed at routine ambient water quality monitoring stations	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	Stream Team aquatic invertebrate surveys (Stream Teams, USGS)	2001	Expected to continue indefinitely	At least three new surveys at active stations	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	Ozark National Forest Fish surveys (USFS)	2007	Expected to continue indefinitely	At least one new survey completed at a previously surveyed location	Number of surveys Number of locations surveyed	All surface waters in Ozark National Forest achieve aquatic life support use
	ADEQ Fish Surveys (ADEQ)	1984	Expected to continue indefinitely	At least one new survey for at least one location	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	USGS North Sylamore Creek Fish Surveys (USGS)	1993	Expected to continue indefinitely	At least one new survey	Number of surveys	North Sylamore Creek achieves aquatic life support use
	Surveys of aquatic species of concern (AGFC, USFS, ANHC)	2002	Expected to continue indefinitely	At least one new survey of a population of aquatic species of concern within the Middle White River watershed	Number of surveys Number of survey locations	Stable populations of designated Threatened and Endangered aquatic species present in Middle White River watershed
Special Studies	Water quality assessment of Spring Creek and Miller Creek (Watershed Implementation Team?)	2021	2023	Spring Creek and Miller Creek water quality assessed as part of a state biennial assessment	Number of sampling events	All surface waters in Middle White River watershed meet water quality standards
	Synoptic nutrient sampling in Lower Salado Creek subwatershed (Southside or Implementation Team)	2026	2027	Decision made about whether synoptic survey is needed	Number of sampling events Number of sampling locations Sources and critical tributaries identified	Salado Creek meets water quality standards
	Nutrient and sediment load estimates (ANRC or USGS)	2021	2023	Load estimates modeled and reported	Load estimates report completed	All surface waters in Middle White River watershed meet water quality standards
	Geomorphological study	2023	2025	Geomorphological study initiated	Geomorphological study plan developed	All surface waters in Middle White River watershed achieve designated uses

Table ES.2. Proposed implementation schedule for Middle White River watershed (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Information and Education	Outreach and education to homeowners and landscape managers regarding fertilizer use to reduce nitrogen runoff	2023	2025	Outreach initiated in Southside or Mountain Home	Number of outreach events Number of flyers sent Number of radio/TV ad airings Number of people reached	All surface waters meet water quality standards
	Stormwater pollution prevention outreach in Mountain Home (Subwatershed Implementation Team)	2020	2030	Stormwater pollution prevention outreach program developed and initiated	Number of outreach events Number of flyers sent Number of radio/TV ad airings Number of people reached	Hicks Creek meets water quality standards
	Onsite wastewater system maintenance outreach (White River Waterkeeper)	2020	2025	Outreach initiated in Hicks Creek, Greenbrier Creek, and Lower Salado Creek subwatersheds	Number of people contacted/reached	All surface waters meet water quality standards
	Outreach through Hicks Creek – White River Watershed Project (Baxter County Conservation District)	2016	2020	Two field days Four presentations Radio ads Newspaper ads Newsletters mailed & emailed	Number of field days Number of presentations Number of newsletters sent Number of radio & newspaper ads Number of people reached	All surface waters meet water quality standards
Planning	Establish subwatershed implementation teams	2020	2025	At least one team formed	Number of teams	All surface waters meet water quality standards
	Develop subwatershed implementation plans	2021	2025	Preparation of at least one subwatershed implementation plan initiated	Number of plans	All surface waters meet water quality standards
Implement Management Practices	Pasture and hayland management practices in Lower Salado Creek subwatershed through NRCS programs (Independence County Extension Service)	2014	Expected to continue indefinitely	At least two new contracts signed	Number of contracts signed Amount of practices implemented	All surface waters in meet water quality standards
	Hicks Creek – White River Watershed Project (Baxter County Conservation District)	2016	2020	At least 24 contracts signed At least 55 BMPs implemented At least 60 farm plans	Number of contracts signed Amount of practices implemented Number of farm plans	All surface waters meet water quality standards
	Controlled Access for Livestock Fencing (CALF) (Arkansas Association of Conservation Districts, US Fish and Wildlife Service)	2015	2025	At least 5 new contracts signed in Middle White River watershed	Number of contracts signed Amount of practices implemented	All surface waters meet water quality standards
	Developed and residential area management practices in Hicks Creek and Lower Salado River (Mountain Home, Southside)	2020	2025	Implementation of at least one management practice planned for at least one subwatershed	Number/amount of practices implemented	All surface waters meet water quality standards
	Petition for change of ecoregion designation for monitoring stations on Greenbrier Creek (WHI0167) and Salado Creek (WHI0166) (ANRC)	2019	2020	Ecoregion designation for stations WHI0167 and WHI0166 officially changed.	Greenbrier Creek removed from impaired waters list	Greenbrier Creek meets applicable water quality standards

Table ES.2. Proposed implementation schedule for Middle White River watershed (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Evaluate	Biennial water quality assessment (ADEQ)	2020	Expected to continue indefinitely	EPA approved final impaired waters lists for 2020 and 2022	Attaining and non-attaining stream reaches in Middle White River watershed	All water quality criteria met in Greenbrier Creek All water quality criteria met in all monitored stream reaches in watershed
	Track implementation of management practices in Middle White River watershed	2019	2025	Information for period 2019 – 2024 compiled	Amount (acres, linear feet, number) of practices implemented Water quality improvement	All water quality criteria met in all monitored stream reaches
	Evaluation of watershed management plan	2025	2025	Data needed for evaluation compiled	Evaluation completed Evaluation made public	All water quality criteria met in all monitored stream reaches
Update watershed management plan for Middle White River watershed	Public meetings	2024	2025	Begin organizing public meetings	Number of attendees Number of meetings	Stakeholder input to watershed management
	Update watershed management plan	2024	2026	Entity responsible for update identified and committed Preparations for update under way	Updated watershed management plan complete and approved by ANRC and EPA Recommended subwatersheds identified Stakeholders involved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Middle White River watershed.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADEQ	Arkansas Department of Environmental Quality
AGFC	Arkansas Game and Fish Commission
ANRC	Arkansas Natural Resources Commission
Avg	average
BMP	best management practice
CCPE	Conservation Practice Physical Effects program
Cfs	cubic feet per second
cfu/100mL	colony forming units per 100 milliliters
Cr	creek
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
Deg C	degrees Celcius
DO	Dissolved oxygen
E. coli	Escherichia coli
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
HUC	Hydrologic Unit Code
HUC12	12-digit HUC
IBI	Index of Biotic Integrity
ID	identification
Kg	kilogram
kg/ha/yr	kilograms per hectare per year
lb	pounds
ln	natural logarithm

LIST OF ACRONYMS AND ABBREVIATIONS

mg/L	milligrams per liter
N	nitrogen
NAWQA	National Water Quality Assessment Program
NOAA	US National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	US Department of Agriculture Natural Resources Conservation Service
NTU	Nephelometric turbidity units
P	phosphorus
R	river
SARE	Sustainable Agriculture Research and Education
sq mi	square miles
SWAT	Soil and Water Assessment Tool
TKN	Total Kjeldahl Nitrogen
TSS	total suspended solids
UofA	University of Arkansas
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture
USFS	US Forest Service
USGS	US Geological Survey
WRAS	watershed restoration action strategy
WTP	willingness to pay
WWTP	wastewater treatment plant
Yr	year

1.0 INTRODUCTION

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

1.1 Plan Need and Mission

The Arkansas Natural Resources Commission (ANRC) Nonpoint Source Pollution Management program has set itself the goal of preparing watershed management plans for all 57 of the 8-digit Hydrologic Unit Code (HUC) watersheds located partially or completely in the state of Arkansas. The Middle White River 8-digit HUC is not one of the 11 Nonpoint Source priority watersheds designated by ANRC. However, there are two stream reaches in the Middle White River watershed that are included on the most recent (2016) approved state impaired waters list (303(d) list) due in part to pollution from nonpoint sources. Therefore, the Middle White River watershed was selected by ANRC for development of a watershed management plan to address these impairments, and meet the agency goal for development of plans.

The primary focus of this plan is the **protection** and **improvement** of surface water quality in the White River and its tributaries through management of unregulated nonpoint sources of pollution. The mission of the watershed management plan for the Middle White River watershed is to: Increase awareness of water quality issues, outreach and education, and voluntary activities to implement good water quality management practices. There are agencies and interest groups with active outreach and education programs in the Middle White River watershed that are intended to increase public awareness of water quality issues in the watershed and encourage practices that address those issues. The intention of this plan is to support the efforts of these organizations.

1.2 Watershed Vision

The vision for the Middle White River watershed is: The uses of the Middle White River and its tributaries are attained and sustained, resulting in clean, healthy streams that enhance the socioeconomic and natural amenity benefits of the watershed, as visitors, landowners, and local communities work together to protect and improve both water quality and the quality of life throughout the watershed.

1.3 Management History

Management of water quality in the upper portion of the Middle White River watershed (upstream of the Independence County line) was addressed in a Watershed Restoration Action Strategy (WRAS) developed by the Friends of the North Fork and White Rivers in 2005 (Friends of the North Fork and White Rivers, Inc. 2007). This WRAS identified perceived problems with water quality, habitat, recreation, aesthetics, and regulations in the target area, and actions to address those issues. Several of the solutions have been completed, while others are on-going.

1.4 Process

Development of the Middle White River watershed-based management plan followed the steps outlined by US Environmental Protection Agency (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 management plan, utilizing the input of watershed stakeholders. Four public meetings were held as part of the process of developing the Middle White River watershed 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 Forest Service (USFS), Natural Resources Conservation Service, Arkansas Department of Environmental Quality (ADEQ), Arkansas Department of Health, Arkansas Forestry Commission, Arkansas Game and Fish Commission (AGFC), University of Arkansas (UofA) 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.

1.5 Document Overview

This document contains elements recommended by EPA and 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 Middle White 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	4.1, 4.4
2. Subwatershed sources	4.4
3. Data Sources are accurate and verifiable	3.0
4. Data gaps	3.0
Element B: Expected Load Reductions	
1. Load reductions achieve environmental goal	4.6
2. Load reductions linked to sources	4.6
3. Model complexity appropriate	4.3
4. Basis of effectiveness estimates explained	4.5
5. Methods and data cited and verifiable	4.5, 4.6
Element C: Management Measures Identified	
1. Specific management measures are identified	4.5
2. Priority areas	3.6, 4.4, 4.5, 5.4
3. Measure selection rationale documented	4.0
4. Technically sound	4.0
Element D: Technical and Financial Assistance	
1. Estimate of technical assistance	6.3
2.Estimate of financial assistance	6.1, 6.4
Element E: Education/Outreach	
1. Public education/information	5.1
2. All relevant stakeholders are identified in outreach process	5.1
3. Stakeholder outreach	1.4, 5.1
4. Public participation in plan development	1.4
5. Emphasis on achieving water quality standards	5.1
6. Operation & maintenance of BMPs	5.1
Element F: Implementation Schedule	
1. Includes completion dates	5.9
2. Schedule is appropriate	5.9
Element G: Milestones	
1. Milestones are measureable and attainable	5.7, 5.9
2. Milestones include completion dates	5.9
3. Progress evaluation and course correction	5.7
4. Milestones linked to schedule	5.9

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 H: Load Reduction Criteria	
1. Criteria are measureable and quantifiable	4.3, 5.7
2. Criteria measure progress toward load reduction goal	5.7
3. Data and models identified	4.3
4. Target achievement dates for reduction	5.7, 5.9
5. Review of progress toward goals	5.7, 5.8
6. Criteria for revision	5.8
7. Adaptive management	5.6, 5.7, 5.9
Element I: Monitoring	
1. Description of how monitoring used to evaluate implementation	5.6, 5.7
2. Monitoring measures evaluation criteria	5.6, 5.7
3. Routine reporting of progress and methods	5.6, 5.8
4. Parameters are appropriate	5.6, 5.7
5. Number of sites is adequate	5.6
6. Frequency of sampling is adequate	5.6
7. Monitoring tied to quality assurance project plan	5.6
8. Can link implementation to improved water quality	5.6,

2.0 WATERSHED DESCRIPTION

2.1 Geography

The Middle White River watershed, identified by the U.S. Geological Survey (USGS) 8-digit HUC 11010004, covers 1,476.2 square miles (sq mi) in north central Arkansas (Center for Advanced Spatial Technologies 2006). This is the watershed for the section of the White River from the Buffalo River confluence to the Black River. This section of the White River is approximately 123 miles long, and flows southeasterly across Baxter and Independence counties, forming the boundary between Stone and Izard Counties. These four counties account for 95% of the watershed (see Table 2.1). The Middle White River watershed also includes portions of Cleburne, Fulton, Jackson, Marion, Searcy, Sharp, and White Counties at the fringes of the watershed (Figure 2.1). There are several cities located completely or partially within the watershed. The two largest are Batesville and Mountain Home (US Census Bureau 2012a). Two US Highways pass through the watershed, US Highways 62/412, and 167.

Table 2.1. County areas in the Middle White River watershed.

Counties	County area (sq mi)	Area within watershed (sq mi)	Percent of County within watershed	Percent of watershed within County
Baxter	586.28	190.56	32.50%	12.92%
Cleburne	591.78	34.99	5.91%	2.37%
Fulton	620.18	5.63	0.91%	0.38%
Independence	771.23	461.22	59.80%	31.27%
Izard	583.54	384.02	65.81%	26.04%
Jackson	641.36	1.48	0.23%	0.10%
Marion	639.77	0.12	0.02%	0.01%
Searcy	667.79	0.12	0.02%	0.01%
Sharp	606.44	28.50	4.70%	1.93%
Stone	609.19	368.35	60.47%	24.97%
Totals	6317.57	1474.98	23.30%	100%

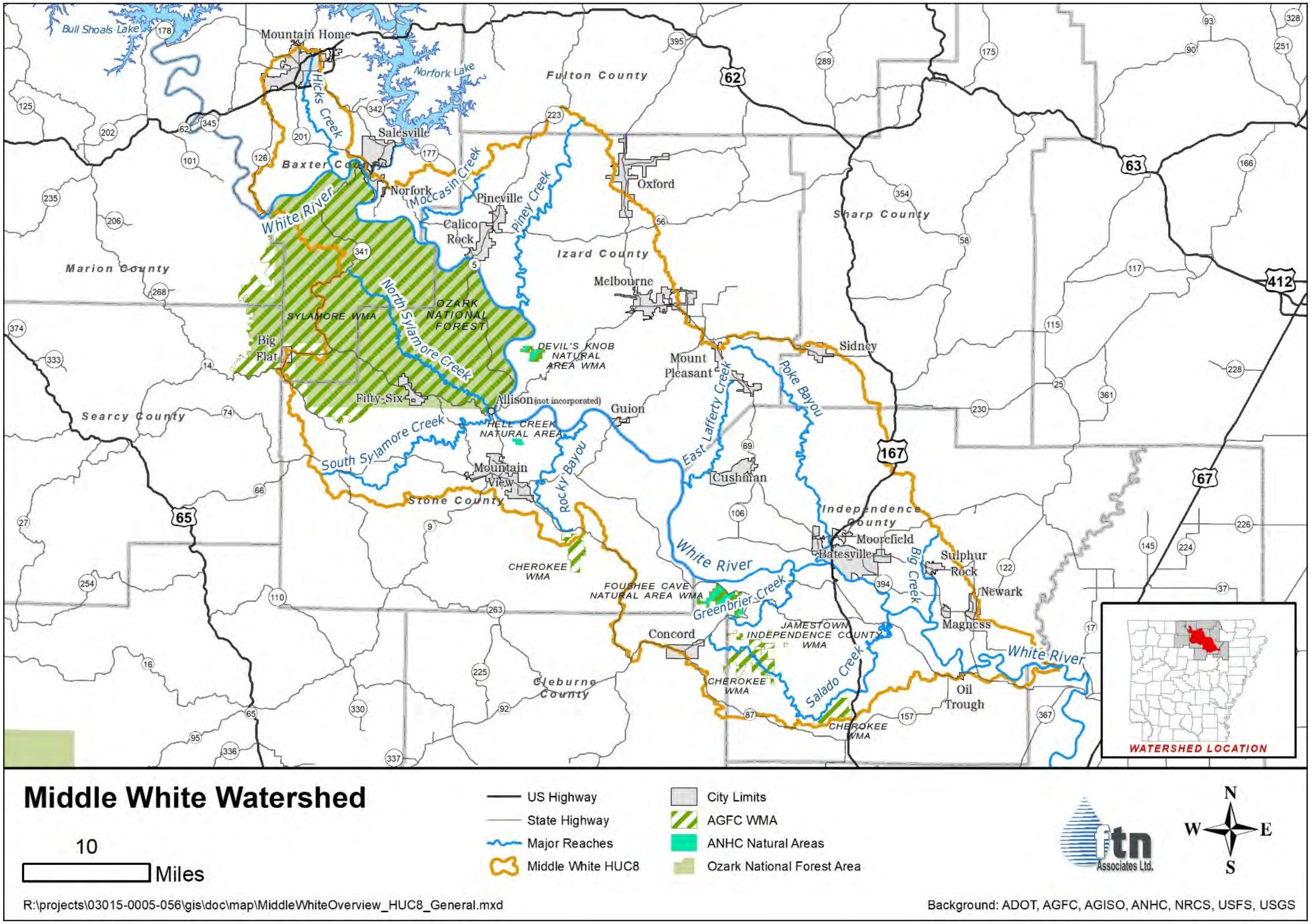


Figure 2.1. Middle White River watershed.

Around 15% of the Middle White River watershed is within one or more publicly owned areas: the Ozark-St. Francis National Forest, AGFC Wildlife Management Areas, or Arkansas Natural Heritage Commission Natural Areas. Note that several publicly owned areas are under the jurisdiction of more than one agency (Figure 2.1).

2.2 Socioeconomics

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

2.2.1 Population

Numbers of people in the counties of the Middle White River watershed are presented in Table 2.2. All of the counties associated with the Middle White River watershed experienced population increases between 2000 and 2010. Population estimates for 2017 indicate population declines since 2010 in eight of the 10 counties associated with the watershed. The population in Izard County is projected to continue to decline through 2025, while the population in Independence and Stone Counties is projected to increase by 2025. For the remaining 7 counties, it is uncertain whether population will increase or decrease.

The majority of the watershed is classified as rural. There are two urban clusters, as defined by the US Census Bureau, within the watershed, Batesville and Mountain Home (US Census Bureau 2012a). The population in Batesville and Mountain Home increased between 2000 and 2010 (Table 2.2). However, the city population estimates for 2016 (the most recent available) indicate a decline in the population of Mountain Home. The Batesville population continued to increase through 2016. Population projections for these cities were not located.

Additional demographic information for the counties associated with the Middle White River watershed is listed in Table 2.3. This includes percentages of the population for characteristics of commuting, household structure, age, gender, race, median income, poverty, fields of employment, and education level. In the counties associated with the watershed, 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 of persons in the watershed consider themselves White (non-Hispanic).

Per-capita incomes in most of the counties associated with the Middle White River watershed are below the state level, but in two counties, Baxter and Cleburne, the per-capita income is higher than for the state. The percentage of families below the poverty level in the counties of the watershed ranges from 9.2% (Baxter County) to 21.4% (Jackson County), with most counties having percentages that are higher than the state 14.2%. The same is true for the percentage of people below the poverty level. The unemployment rates in the counties of the watershed range from 4.2% (Searcy County) to 10% (Marion County), with half of the counties having unemployment rates higher than the state overall. The percentages of bachelor's, and graduate degree holders are lower than the state-wide values. However, two of the counties have higher percentages of high school graduates than the state as a whole.

Table 2.2. Numbers of people in the Middle White River watershed and associated areas.

Area	2000[a] Total population	Population Density[b] (avg/sq mi)	2010[a] Total Population	Population Density[a] (avg/sq mi)	2017 population estimate[c]	2025 projection[d]
Baxter County	38,386	69.2	41,513	74.9	41,040	35,242 - 44,981
Mountain Home City	11,012	-	12,448	-	12,312 (2016)	-
Cleburne County	24,046	43.5	25,970	46.9	25,048	21,982 - 27,174
Fulton County	11,642	18.8	12,245	19.8	12,055	11,373 - 13,808
Independence County	34,233	44.8	36,647	48.0	37,504	37,534 - 42,024
Batesville City	9,445	-	10,248	-	10,579 (2016)	-
Izard County	13,249	22.8	13,696	23.6	13,686	11,114 - 12,695
Jackson County	18,418	29.1	17,997	28.4	17,135	14,883 - 18,416
Marion County	16,140	27.0	16,653	27.9	16,428	13,003 - 17,361
Searcy County	8,261	12.4	8,195	12.3	7,938	6,829 - 8,760
Sharp County	17,119	28.3	17,264	28.6	17,393	14,415 - 18,361
Stone County	11,499	19.0	12,394	20.4	12,456	13,030 - 15,003
State of Arkansas	2,673,400	51.4	2,915,918	56.0	2,958,208	3,148,708

[a] (US Census Bureau 2012a)
[b] (US Census Bureau 2003)
[c] (US Census Bureau 2018)
[d] (UALR Institute for Economic Advancement 2015)

Table 2.3. Additional demographic information for counties associated with Middle White River watershed.

	Baxter County	Cleburne County	Fulton County	Independence County	Izard County	Jackson County	Marion County	Searcy County	Sharp County	Stone County	State of Arkansas
Commuting (percent of workers 16 and older)[a]											
Drove alone	83.8%	81.6%	84.1%	79.4%	79.9%	86.2%	80.3%	75.0%	77.2%	74.0%	82.7%
Carpooled	9.6%	10.9%	10.0%	14.6%	13.5%	8.0%	13.7%	14.8%	16.4%	12.1%	10.8%
Public Transportation	0.4%	0	0.5%	0	0	0.2%	0.2%	0.3%	0	0	0.4%
Walk or other	3.6%	2.9%	1.7%	3.1%	2.3%	2.5%	1.4%	6.0%	3.1%	7.6%	3.0%
Mean travel time (minutes)	16.9	26.2	23.6	19.0	20.9	19.5	21.4	27.7	27.3	24.3	21.6
Worked at home	2.9%	4.7%	3.5%	2.8%	4.2%	3.1%	4.3%	3.8%	3.2%	6.4%	3.2%
Household Structure (percent of all households)[b]											
Family households	66.0%	68.7%	67.9%	69.6%	66.7%	65.8%	67.3%	65.8%	67.8%	67.4%	67.6%
Two parent families	53.8%	55.6%	54.6%	53.7%	54.9%	46.1%	55.5%	53.8%	53.8%	55.9%	49.5%
Single parent families	12.2%	13.1%	13.3%	15.8%	11.8%	19.7%	11.9%	12.0%	14.0%	11.5%	18.1%
Single person household	29.5%	26.9%	28.1%	25.9%	29.7%	30.2%	28.3%	30.3%	28.2%	28.9%	27.1%
Other non-family household	4.5%	4.4%	4.0%	4.5%	3.6%	4.0%	4.4%	3.9%	4.0%	3.7%	5.3%
Age (percent of population)[a]											
Median age	51.8	47.9	48.2	39.2	48.1	40.8	51.5	47.5	47.9	49.1	37.7
Under 18	17.7%	19.7%	20.1%	24.1%	18.5%	20.2%	17.7%	19.9%	21.1%	20.1%	23.8%
18 to 24 years	5.6%	6.7%	6.7%	8.5%	7.0%	7.9%	6.1%	6.1%	6.7%	6.8%	9.7%
25 to 44 years	18.8%	20.2%	19.0%	24.4%	20.5%	27.3%	18.0%	21.1%	18.8%	18.9%	25.2%
45 to 64 years	27.8%	28.1%	29.2%	26.4%	29.2%	27.7%	31.8%	28.8%	27.9%	28.9%	25.4%
65 and older	30.1%	25.5%	25.0%	16.7%	24.8%	16.8%	26.5%	24.2%	25.5%	25.3%	15.7%
Gender (percent of population)[a]											
Female	51.6%	50.2%	50.5%	51.4%	48.1%	51.0%	50.6%	49.9%	51.0%	49.3%	50.9%
Male	48.4%	49.8%	49.5%	48.6%	51.9%	49.0%	49.4%	50.1%	49.0%	50.7%	49.1%
Race (percent of population)[a]											
White non-Hispanic	95.2%	95.0%	95.7%	89.3%	95.6%	77.4%	94.9%	93.7%	94.0%	95.2%	73.4%
Hispanic	2.0%	2.4%	1.3%	6.0%	1.9%	2.7%	2.1%	1.3%	2.1%	1.7%	7.0%
Black non-Hispanic	0.2%	0.6%	0.1%	1.9%	1.2%	17.1%	0.4%	0.4%	0.3%	0.1%	15.4%
Native American	0.5%	0.4%	0.7%	0.3%	0.2%	0.4%	0.7%	1.2%	0.6%	0.3%	0.5%
Asian	0.6%	0.6%	0.1%	0.9%	0.2%	0.1%	0.3%	1.2%	0.6%	0.2%	1.4%
Other race	0	0	0	0	0	0.1%	0	0	0	0	0.3%
>1 race, non-Hispanic	1.4%	1.1%	2.1%	1.6%	0.9%	2.3%	1.7%	2.1%	2.5%	2.5%	2.0%
Income[a]											
Per capita income	$23,068	$25,078	$19,082	$22,035	$18,964	$18,316	$18,706	$20,618	$19,404	$19,616	$22,798
Families below poverty level	9.2%	10.9%	14.6%	14.7%	16.7%	21.4%	13.5%	16.4%	16.4%	15.5%	14.2%
People below poverty level	13.8%	15.5%	23.2%	19.2%	22.0%	27.1%	19.9%	20.7%	22.2%	23.6%	19.3%

Table 2.3. Additional demographic information for counties associated with Middle White River watershed (continued).

	Baxter County	Cleburne County	Fulton County	Independence County	Izard County	Jackson County	Marion County	Searcy County	Sharp County	Stone County	State of Arkansas
Employment (percent of civilian labor force)[a]											
Unemployed	6.2%	8.5%	7.3%	6.7%	9.6%	7.7%	10.0%	4.2%	7.9%	8.1%	7.7%
Mgmt, business, science, arts	30.1%	26.4%	28.1%	29.7%	30.9%	23.8%	21.4%	26.0%	26.6%	32.8%	32.0%
Service	19.7%	18.1%	20.0%	17.8%	20.0%	16.3%	23.4%	10.7%	22.0%	19.0%	17.1%
Sales, office	21.7%	21.3%	21.4%	19.6%	21.1%	21.3%	19.6%	26.2%	18.4%	12.7%	23.9%
Natural resources, construction, maintenance	9.6%	12.7%	15.5%	13.8%	10.0%	15.6%	11.7%	19.0%	15.9%	23.3%	10.7%
Production, transportation, material moving	19.0%	21.5%	15.0%	19.1%	18.0%	22.9%	24.0%	18.1%	17.2%	12.2%	16.4%
Self-employed	7.8%	8.9%	10.4%	6.3%	11.6%	6.5%	13.0%	17.6%	10.7%	19.7%	9.4%
Education (population 25 or older)[a]											
High School graduate (or higher)	87.2%	83.3%	83.9%	84.5%	83.9%	76.6%	86.0%	84.6%	83.2%	76.5%	85.2%
Bachelor's degree (or higher)	17.7%	15.4%	11.0%	17.6%	12.4%	8.6%	15.3%	14.4%	10.1%	14.4%	21.5%
Graduate degree	5.4%	5.7%	4.2%	6.4%	4.0%	2.5%	5.3%	5.5%	3.8%	6.5%	7.6%

a U.S. Census Bureau, 2012-2016 American Community Survey 5-Year Estimates, accessed via American FactFinder (https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml?src=bkmk) August 2018
b U.S. Census Bureau, 2010 Census, accessed via American FactFinder, August 2018

2.2.2 Economics

Drivers of the economy in the Middle White River watershed include tourism and outdoor recreation (such as hiking, canoeing, hunting, and fishing), livestock farming, poultry and timber production and processing, and small manufacturing. In Izard County, sand mining is also identified as an important contributor to the economy (Association of Arkansas Counties 2018). The values of sales and receipts reported for selected economic sectors in the four counties that account for the majority of the Middle White River watershed, in the 2012 economic census, are summarized in Table 2.4. 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 (UofA Divison of Agriculture 2012). Table 2.5 lists the value of sales of agricultural products reported for the same four counties of the Middle White River watershed in the 2012 census of agriculture. Table 2.6 summarizes economic inputs to the counties of the Middle White River watershed from tourism. The US Army Corps of Engineers (USACE) has estimated the regional economic impact of the Norfork Lake and Bull Shoals Lake reservoirs. Impacts for fiscal year 2016 to areas within 30 miles of these reservoirs are listed in Table 2.7.

Table 2.4. Value of sales, shipments, receipts, revenue, or business done ($1,000) reported in 2012 Economic Census of the U.S. (US Census Bureau 2012b).

Industry category	Baxter County	Independence County	Izard County	Stone County
Manufacturing	$574,423	$1,211,422	D	$10,458
Wholesale trade	D	D	D	$34,139
Retail trade	$476,645	$441,118	$108,729	$107,472
Transportation & warehousing	D	$92,575	$21,164	$2,008
Real estate, rental	$43,717	$10,849	$5,611	$646
Professional, scientific, technical service	$30,088	$20,698	$2,732	$2,680
Administrative, support, waste management, remediation	$18,268	$29,203	$1,883	-
Education	$1,157	D	D	$211
Health care, social assistance	$337,450	$282,052	$32,691	$31,873
Arts, entertainment, recreation	$9,189+	D	$961+	D
Accommodation, food service	$61,602	$48,817	D	$14,776
Other services	$25,403	$17,828	$3,079	$1,775+

D – revenue not reported due to privacy issues

Table 2.5. Value ($1,000) of agricultural products sold in counties of the Middle White River watershed (USDA National Agricultural Statistics Service 2018).

Commodity	Baxter County	Independence County	Izard County	Stone County
All agricultural products	$20,367	$131,867	$49,402	$53,664
All crops	$601	$33,891	$63+	$841
Hay	$489	$1,714	D	$764
Grains & beans	D	$31,670	D	-
All livestock	$19,766	$97,976	$27,652+	$52,823
Cattle & calves	$12,238	$17,322	D	$21,965
Poultry & eggs	$6,381	$79,982	$27,273	$30,666
Hogs & pigs	D	$18	D	D
Horses, etc.	$218	$328	$355	$76
Sheep, goats products	$36	$92	$24	$34

D – revenue not reported due to privacy issues.

Table 2.6. Preliminary 2017 economic impacts of tourism/travel in counties of the Middle White River watershed (Arkansas Department of Parks and Tourism 2017).

Commodity	Baxter County	Independence County	Izard County	Stone County
Travel expenditures ($1,000)	$261,360	$50,611	$29,759	$95,342
Travel-generated payroll ($1,000)	$47,933	$9,942	$4,413	$18,127
Travel-generated jobs	2,349	527	213	871
Travel-generated state tax ($1,000)	$15,289	$3,011	$1,759	$5,506
Travel-generated local tax ($1,000)	$4,806	$986	$747	$2,021

Table 2.7. Fiscal year 2016 economic impacts of recreation at Bull Shoals Lake and Norfork Lake, within 30 miles of the reservoirs (USACE 2018).

Commodity	Bull Shoals Lake	Norfork Lake
Visitor spending ($1,000)	$82,041	$44,264
Sales ($1,000)	$42,707	$24,758
Jobs supported/created	706	387
Labor income ($1,000)	$17,416	$8,991
Value added ($1,000)	$22,484	$12,306

2.3 Ecoregions

Four Level III, and eight Level IV ecoregions occur in the Middle White River watershed (Figure 2.2). Table 2.8 summarizes the characteristics of these ecoregions. These characteristics are described in greater detail in the following subsections.

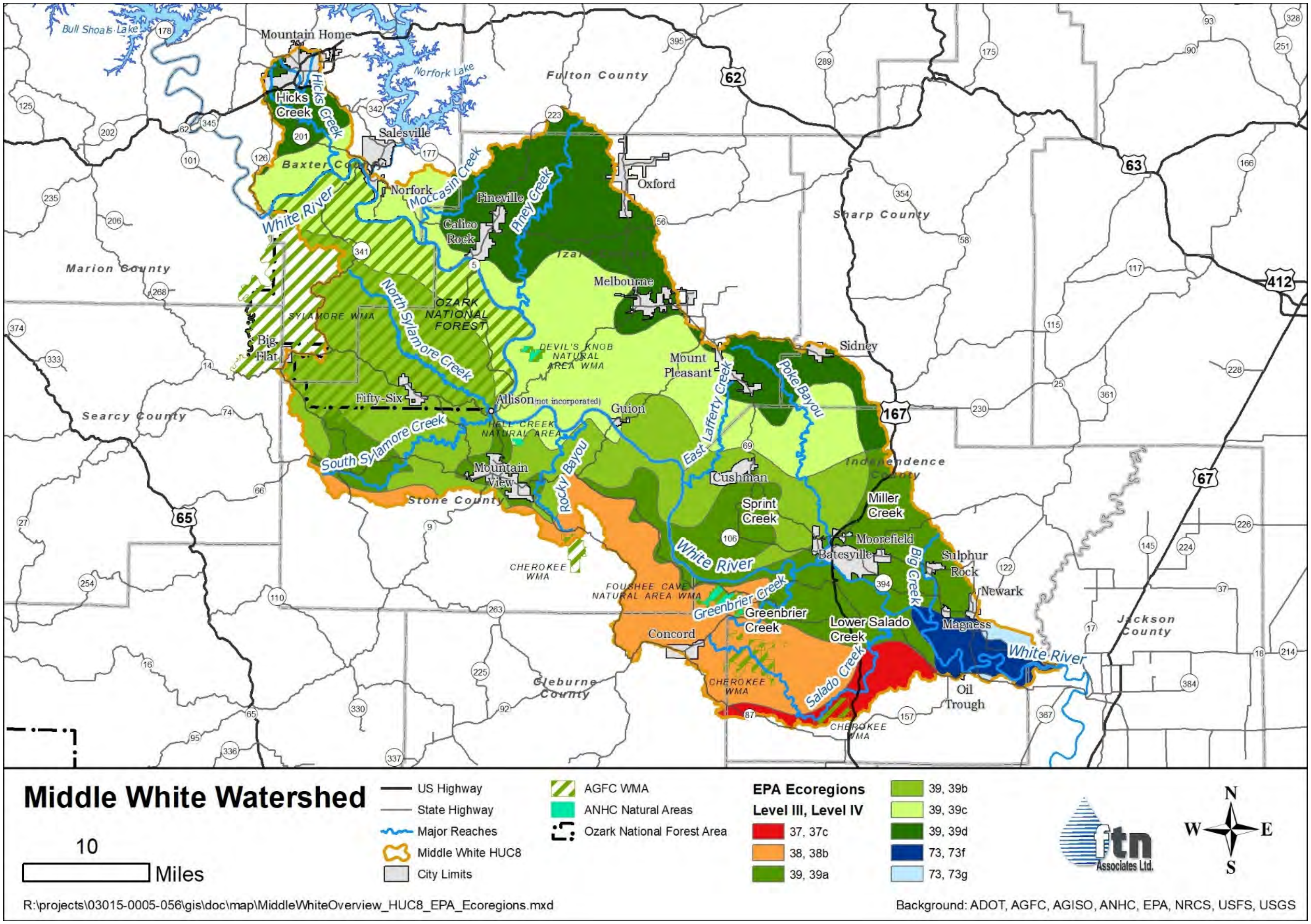


Figure 2.2. Ecoregions of the Middle White River watershed.

Table 2.8. Characteristics of Level IV ecoregions of the Middle White River watershed (from Woods et al. 2004).

Level III ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
38 – Boston Mountains	38b - Lower Boston Mountains	Low mountains, rounded high hills, and undulating plateaus.	Summer flow in many streams is zero or near zero but enduring pools fed by interstitial flow occur.	Mostly 200-1,900; up to 2,300/ 150-800	Quaternary colluvium and alluvium. Pennsylvanian sandstone, shale, limy sandstone, sandy limestone, and siltstone. Mountaintops are usually capped by resistant sandstone. Side slopes are often underlain by interbedded sandstone, siltstone, and shale.	Uplands: Enders, Nella, Mountainburg, Steprock, Nella, Linker, Sidon; in east, Steprock and Linker are more widespread than in west. On floodplains and terraces: Ceda, Cleora, Razort, Spadra. Upland soils have low natural fertility.	46-52. The east is moister than the west.	Potential natural vegetation: oak–hickory–pine forest and oak– hickory forest. Mixed oak and oak–pine forests, woodland, or savanna occur on uplands; northern red oak, white oak, post, scarlet, black, blackjack oak, pignut hickory, shagbark hickory, mockernut hickory, and shortleaf pine are native. On lower, drier south- and west-facing sites: shortleaf pine. On narrow floodplains and low terraces: sweetgum, willows, birch, American sycamore, hickories, southern red oak, and white oak
39 – Ozark Highlands	39a -Springfield Plateau	Nearly level to rolling, undissected or slightly dissected portion of the Springfield Plateau. Karst features including caves, sinkholes, and solution valleys occur.	Springs are common and contribute substantially to streamflow in the summer and fall. Many streams flow year-round, but some dry valleys occur.	260-1,600; uplands are lowest in the east/ mostly 50-200	Quaternary cherty clay solution residuum and limited amounts of alluvium. Extensive limestone and interbedded chert of the Mississippian Boone Formation. Karst	On uplands underlain by cherty limestone: Noark, Clarksville, Nixa, Captina, Tonti. On uplands underlain by sandstone: Linker, Mountainburg. On floodplains or low terraces: Secesh, Razort	44-48. Parts are in the rain shadow of the Boston Mountains.	Potential natural vegetation: oak–hickory forest and some oak– hickory–pine forest. Prior to the 19th century, savanna or tall grass prairies were common and maintained by fire. Native on uplands: mixed deciduous forest (containing black oak, white oak, blackjack oak, post oak, and hickories) with some mixed deciduous–shortleaf pine forest. Native on floodplains and low terraces: willows, maples, hickories, birch, American elm, and American sycamore.
39 – Ozark Highlands	39b - Dissected Springfield Plateau – Elk River Hills	Moderately to highly dissected, hilly part of the Springfield Plateau. Gently sloping, narrow ridge tops are separated by steep V-shaped valleys. Karst features occur.	Springs are common and contribute to streamflow in the summer and fall. Streams are usually perennial but some dry valleys occur.	300-1,850/ 50-800	Quaternary cherty clay solution residuum, colluvium, and alluvium. On uplands: limestone and interbedded chert of the Mississippian Boone Formation. Along deeply entrenched rivers: earlyMississippian or Devonian Chattanooga Shale and Ordovician Cotter Dolomite. Rock outcrops.	Clarksville, Nixa, Noark, Arkana, Moko, Portia, Estate	44-48. Parts are in the rain shadow of the Boston Mountains	Potential natural vegetation: oak–hickory–pine forest and oak– hickory forest. Native on uplands: oak–woodland, mixed deciduous forest, or mixed deciduous–pine forest containing black oak, white oak, blackjack oak, post oak, hickories, and shortleaf pine. Native on north-facing slopes and in ravines: mesic forest containing sugar maple, white oak, northern red oak, and beech.
39 – Ozark Highlands	39c - White River Hills	Moderately to highly dissected portion of the Salem Plateau containing hills, ridges, karst features, and entrenched, narrow valleys. Flat land is uncommon, but benches and bottomlands flank the White River.	Streams generally flow year-round, reflecting the influence of ground water, but dry valleys occur.	540-1,800/ 150-800	Quaternary cherty silty to sandy clay solution residuum, silty sand to sandy silt decomposition residuum, colluvium, and limited amounts of alluvium. Dolomite, chert, and limestone occur and are sometimes interbedded with sandstone and shale. Ordovician Cotter Dolomite and Jefferson City Dolomite are common but, near the southern boundary, Mississippian Boone Formation occurs.	On uplands: Arkana, Moko, Doniphan, Gassville, Nixa, Clarksville, Noark, Estate, Portia. On floodplains: Razort, Elsah.	42-47	Potential natural vegetation: oak–hickory forest, cedar glades, and, in the west, oak–hickory–pine forest. Native on uplands: mixed deciduous forest (containing black oak, white oak, blackjack oak, post oak, and hickories) and also mixed deciduous–shortleaf pine forest. Native on driest sites with shallow, rocky soils over dolomite and limestone: glades consisting of eastern redcedar, Ashe juniper, native grasses, and sparse populations of post oak and elm.
39 – Ozark Highlands	39d - Central Plateau	Undulating to hilly part of the Salem Plateau containing hollows, ridges, knobs, and karst features including caves and sinkholes; along major rivers, narrow corridors of nearly level bottomland occur. Generally, slightly to moderately dissected, but steep, highly dissected terrain is found near major rivers.	Springs are common in some areas and contribute substantially to streamflow in the summer and fall. On bottomlands, floodwaters rise and recede quickly.	Mostly 250-1,400; maximum 1,700/ 100-600	Quaternary cherty silty to sandy clay solution residuum, silty sand and sandy silt decomposition residuum, colluvium, and alluvium. Dolomite and limestone are extensive and often cherty; interbedded sandstone and shale also occur. Includes Ordovician Jefferson City Dolomite, Cotter Dolomite, Powell Dolomite, Everton Formation, and St. Peter Sandstone.	On uplands underlain by cherty carbonates: Gepp, Doniphan, Arkana, Agnos, Ventris, Gassville, Moko, Captina, Eldon. On cherty ridgetops and upper slopes: Clarksville. On sandstone uplands: Boden, Brockwell, Brocket, Lily, Portia. On floodplains or low terraces: Hontas, Sturkie, Razort. Upland soils are stony, thin, droughty, and shallower than bottomland soils.	4-49. West facing slopes receive more precipitation than valleys	Potential natural vegetation: oak–hickory forest, oak–hickory–pine forest, and scattered cedar glades. Forest, savanna, glades, barrens, and upland prairies occurred prior to the nineteenth century. Native on uplands: mixed forest containing blackjack oak, post oak, black oak, white oak, hickories. On droughty, rocky slopes: post oak, blackjack oak, and shortleaf pine. On thin soils: barrens with sparse tree cover with herbaceous ground cover. Native on north-facing slopes and in hollows: mesic forests containing sugar maple, white oak, northern red oak, and beech. On shallow, rocky, droughty soils underlain by dolomite or limestone: cedar glades. Native on floodplains and low terraces: southern red oak, white oak, American sycamore, willow, eastern cottonwood, maples, birch, and ash.

Table 2.8. Characteristics of Level IV ecoregions of the Middle White River watershed (continued).

Level III ecoregion code and name	Level IV ecoregion code and name	Topography	Hydrology	Elevation/local relief (feet)	Geology	Common soil series	Mean annual precipitation (inches)	Natural vegetation
37 – Arkansas Valley	37c - Arkansas Valley Hills	Undulating plains with occasional hills and ridges. Plains are open in the west but become increasingly interrupted by hills and ridges toward the east.		Mostly 295-600; maximum 900/ 50-200	Quaternary terrace deposits and alluvium. Pennsylvanian shale, sandstone, coal, and siltstone. Bituminous coal is found in the west and grades to semi-anthracite coal in the east.	Mostly Leadvale, Wrightsville, Taft; also Falkner, Pickwick, Ora, Cane, Guthrie. On terraces and floodplains: Barling. On scattered hills and ridges: Mountainburg, Linker.	42-49; driest in the west. In the rain shadow of the Fourche Mountains.	Potential natural vegetation: oak–hickory forest, oak–hickory–pine forest, and in the extreme western part of Arkansas, cross timbers (dominants: little bluestem–blackjack oak–post oak). Prior to the 19th century, on broad, dry, fire-prone plains in the west, extensive prairie and scattered large oaks were found on shallow, droughty soils. To the east, less extensive prairies and prairie–savanna occurred. In upland depressions and on flats with impermeable, clay-rich soils or pans, wetlands occur. Today, woodlands composed of post oak, black oak, white oak, hickories, maple, beech, elm, loblolly pine, shortleaf pine, and redcedar occur. Near Fort Smith: several thousand acres of Cherokee Prairie still remain and are maintained by regular fires. On prairie mounds: sumac and sassafras.
73 – Mississippi Alluvial Plain	73f - Western Lowlands Holocene Meander Belts	Flat to nearly flat floodplain containing the meander belts of the present and past courses of the White, Black, and Cache rivers. Point bars, natural levees, swales, and meander scars occur.	Oxbow lakes, and low gradient rivers occur.	130-300/ 5-20	Holocene sandy, silty, clayey, and gravelly alluvium.	Kobel, Commerce, Sharkey, Foley, Egam, Staser, Dundee, Forestdale, Rexor, Tichnor, Mhoon	46-52	Potential natural vegetation: southern floodplain forest. Native vegetation is bottomland hardwood forest and woodland dominated by oak communities. Eastern cottonwood, green ash, cherrybark oak, Nuttall oak, water oak, willow oak, and sweetgum are common
73 – Mississippi Alluvial Plain	73g - Western Lowlands Pleistocene Valley Trains	Wide, flat to irregular terraces with relict patterns of branching channels, irregular braided bars, dunes, interdunal depressions, and interfluves.	Includes low gradient, extensively channelized rivers, and creeks that have silty substrates. Drainage ditches occur.	150-320/ 5-20	Quaternary windblown silt (i.e., loess) veneers Quaternary sand sheets, Quaternary sand dunes, Pleistocene terrace deposits (composed of unconsolidated alluvial sand, silt, and gravel), and Pleistocene glacial outwash deposits.	Calloway, Henry, Loring, Memphis, Grenada, Calhoun, Jackport, Foley, Hillemann	46-52	Potential natural vegetation: southern floodplain forest. Native vegetation is bottomland hardwood forest with an abundance of green ash, bottomland oaks, American elm, cottonwood, sugarberry, sweetgum, water tupelo, and bald cypress; in limited areas, loblolly pine also occurred. Native on Pleistocene dunes: white oak–black oak–southern red oak forest or post oak woodland. In dune depressions or sandponds: forests dominated by overcup oak, water hickory, and pin oak with the federally-endangered shrub, pondberry, in the understory.

2.3.1 Climate

Climate normals are 30-year averages of climate data, calculated at individual recording stations for the United States by the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information. For the Middle White River watershed, the 1981-2000 climate normals are estimated using weather stations at Batesville, Calico Rock, Melbourne, Mountain Home, and Mountain View, Arkansas. 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 on Figure 2.3 (NOAA, et al. 2018).

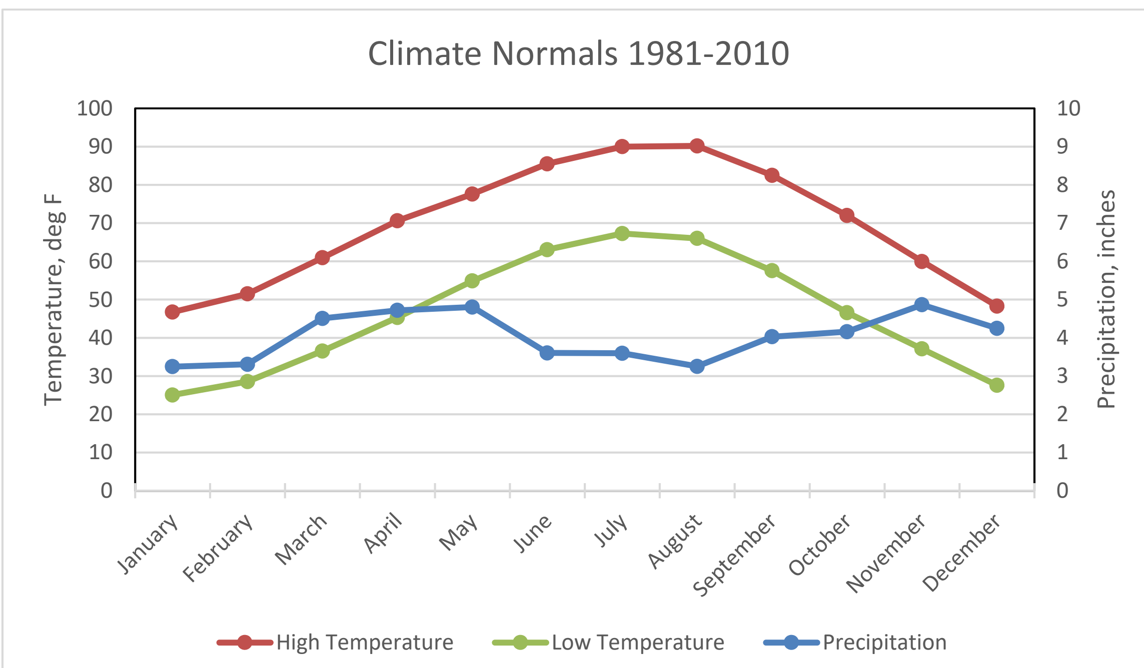


Figure 2.3. 1981-2010 Climate normals in the Middle White River watershed.

2.3.2 Geology

The majority of the Middle White River watershed is located in the Ozark Plateaus physiographic region, extending at the downstream end into the Mississippi Alluvial Plain physiographic region. The upstream end of the watershed originates in the Salem Plateau physiographic region of the Ozark Plateaus, and passes through the eastern Springfield Plateau, with small areas in the eastern watershed in the Boston Mountains physiographic region (Figure 2.4). 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 Salem Plateau is dominated by Ordovician dolostone, sandstone and limestone, while the Springfield Plateau is predominantly Mississippian limestone, and the Boston Mountains region is Pennsylvanian sandstone (McFarland 2004). Surface geology of the Mississippi Alluvial Plain within the watershed is unconsolidated river sediment deposits. A surface geology map of the Middle White River watershed is shown on Figure 2.5. Table 2.9 is a stratigraphic listing of the geologic formations present in the Middle White River watershed.

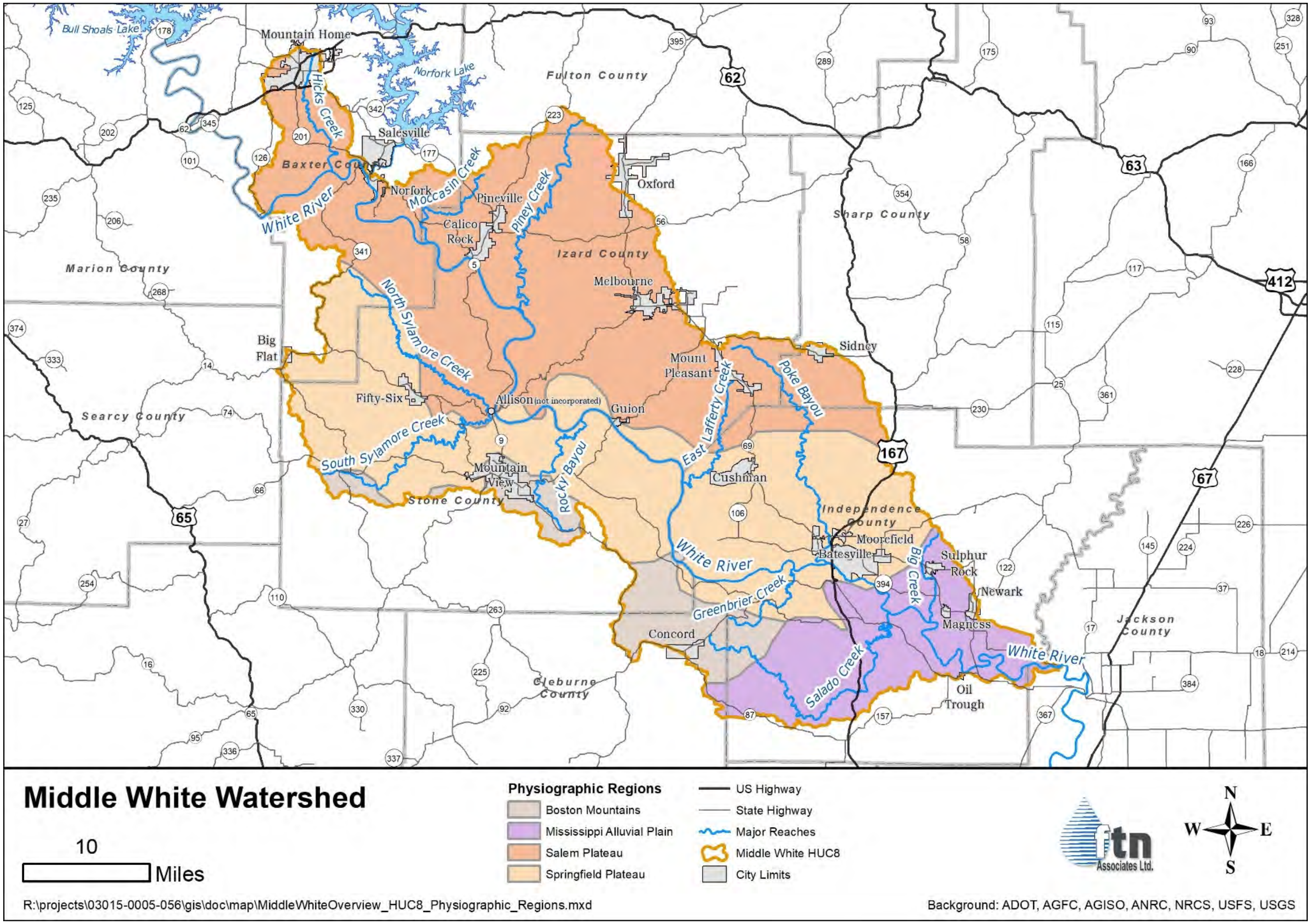


Figure 2.4. Physiographic regions within the Middle White River watershed.

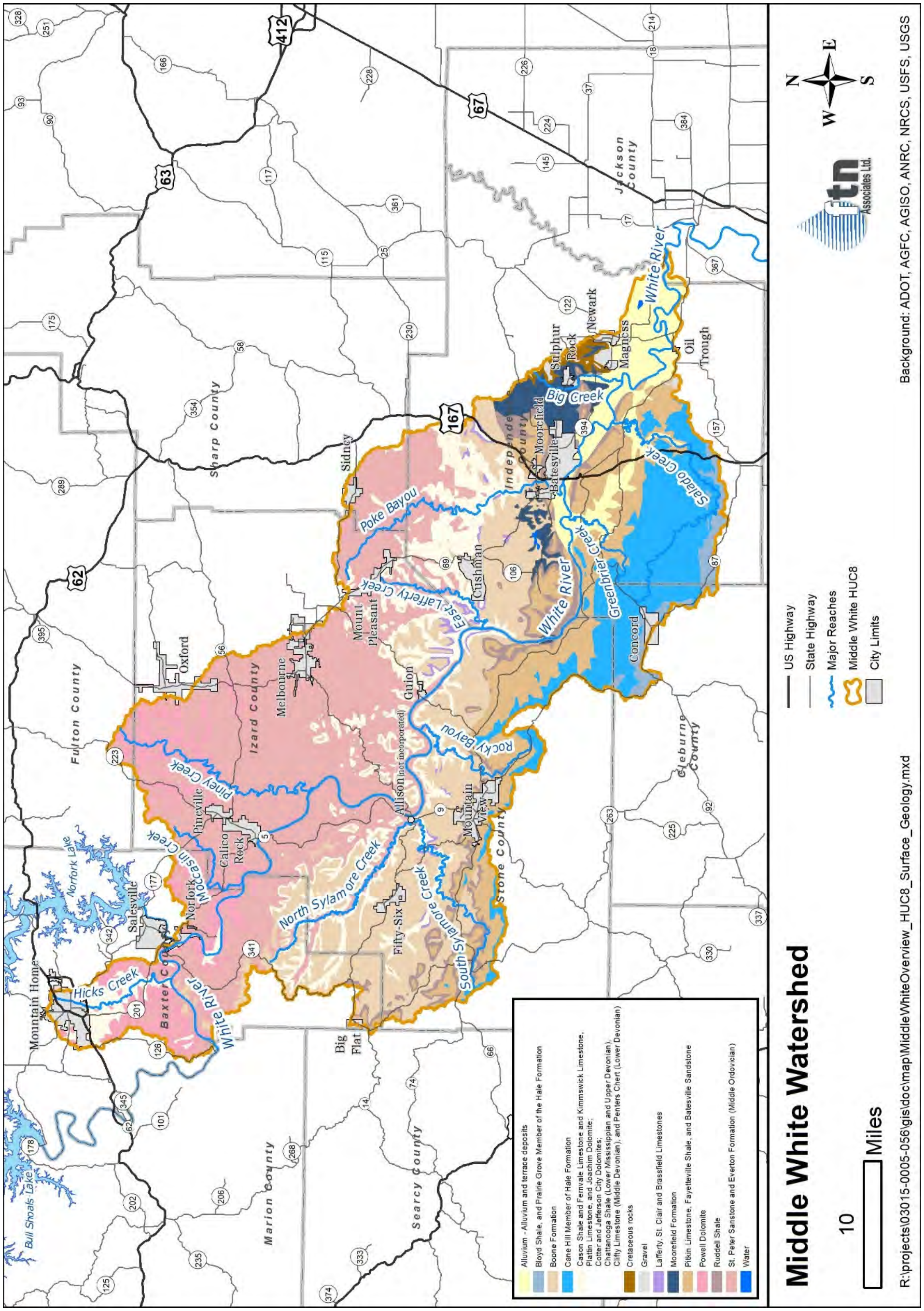


Figure 2.5. Surface geology map of the Middle White River watershed.

Table 2.9. Stratigraphic column listing with descriptions of lithology for geologic formations underlying the Middle White River watershed (Arkansas Geological Survey 2015).

Era	Period	Geologic Unit	Lithology	Thickness, feet
Quaternary	Pleistocene & Holocene	Alluvial deposits	Unconsolidated sand, gravel, silt, clay	Not reported
Tertiary	Tertiary	Alluvial deposits	Gravel	Not reported
Cretaceous	Upper Cretaceous	Cretaceous rocks	Shaley clay, gravel	Not reported
Paleozoic	Pennsylvanian	Bloyd Shale	Sandstone, shale, siltstone	175-200
		Prairie Grove	Sandstone, limestone	2-300
		Cane Hill	Shale, siltstone, sandstone	
	Mississippian	Imo Shale (member of Pitkin Limestone)	Sandstone, shale	0-140
		Pitkin Limestone	Limestone, shale	<1 - >400
		Fayetteville Shale	Shale, limestone	10-400
		Batesville Sandstone	Sandstone, shale	<1 - >200
		Ruddell Shale	Shale	0- 300
		Moorefield Formation	Shale, limestone	
		Boone Formation	Limestone, chert	300-390
		St. Joe Limestone	Limestone	0-110
	Devonian	Chatanooga Shale	Shale	0-85
		Penters Chert	Chert, limestone	0-90
	Silurian	Lafferty Limestone	Limestone	5-95
		St. Clair Limestone	Limestone	0-100
		Brassfield Limestone	Limestone	0-38
	Ordovician	Cason Shale	Shale, sandstone, limestone	0- 23
		Fernvale Limestone	Limestone	0-100
		Kimmswick Limestone	Limestone	0-55
		Plattin Limestone	Limestone (micrite)	0- 250
		Joachim Dolomite	Dolostone, limestone	0-100
		St. Peter Sandstone	Sandstone	20-300
		Everton Formation	Limestone, dolostone, sandstone	300-650
		Calico Rock Sandstone	Sandstone	
		Powell Dolomite	Shaley dolostone, sandstone	0- 215
		Cotter Dolomite	Dolostone, chert	0- 500
		Jefferson City Dolomite	Dolostone, chert	
		Roubidoux Formation	Sandstone and sandy dolomite	Not present at surface
		Gasconade Formation	Dolomite, cherty and sandy dolomite, and sandstone.	

The Middle White River watershed encompasses areas where lead, manganese, phosphate rock, and zinc deposits have been found (Arkansas Geological Survey 2001, Myers 2012). Manganese mining was important in this area from just after the Civil War to 1959 (Smith 2017). Manganese ore is associated mostly with Fernvale Limestone and Cason Shale (Suhm 1968). The only active mining in the watershed is of sand, gravel, limestone, and dolostone (Arkansas Geological Survey 2018).

Because much of the geology underlying the Middle White River watershed is comprised of carbonate formations, karst features are common. In areas north and east of the White River around Mountain Home and Batesville, there are roughly 1 to 10 sinkholes per 100 sq mi (Adamski, et al. 1995). There are a number of caves in the watershed, some of which are open to the public. The Sylamore District of the Ozark National Forest, the majority of which is located within the Middle White River watershed, contains approximately 10% of the known caves in Arkansas (Graening, Slay and Tinkle 2003). Springs are also common (see Section 2.5).

2.3.3 Topography

Elevations within the Middle White River watershed range from 197 feet above sea level where the Black River joins the White River, to 1,584 feet above sea level in the Boston Mountains region of the watershed, near Mountain View (Center for Advanced Spatial Technologies 2006). The gradient of the White River from the upstream end of the watershed (elevation 380 feet above sea level) to the downstream end (elevation 197 feet above sea level), 123.4 river miles, is approximately 1.5 feet/mile.

Land slopes in the Middle White River watershed range from < 3 degrees in valley bottoms and hill tops, to > 45 degrees on cliff faces and hill sides. Slopes of 14% or more are considered steep, while areas with slopes of 7% or less are considered flat lands. Geographic Information System (GIS) analysis indicates that approximately 44% of the watershed has slopes steeper than 14%. Table 2.10 lists the proportion of the Middle White River watershed considered flat lands, steep, and in between. Figure 2.6 shows a map of the locations of areas within the three slope ranges.

Table 2.10. Slope areas in the Middle White River watershed.

Slope ranges, degrees	Area within the watershed, Acres	Percent of watershed
<7%	302,209	32%
7-14%	229,565	24%
>14%	412,212	44%

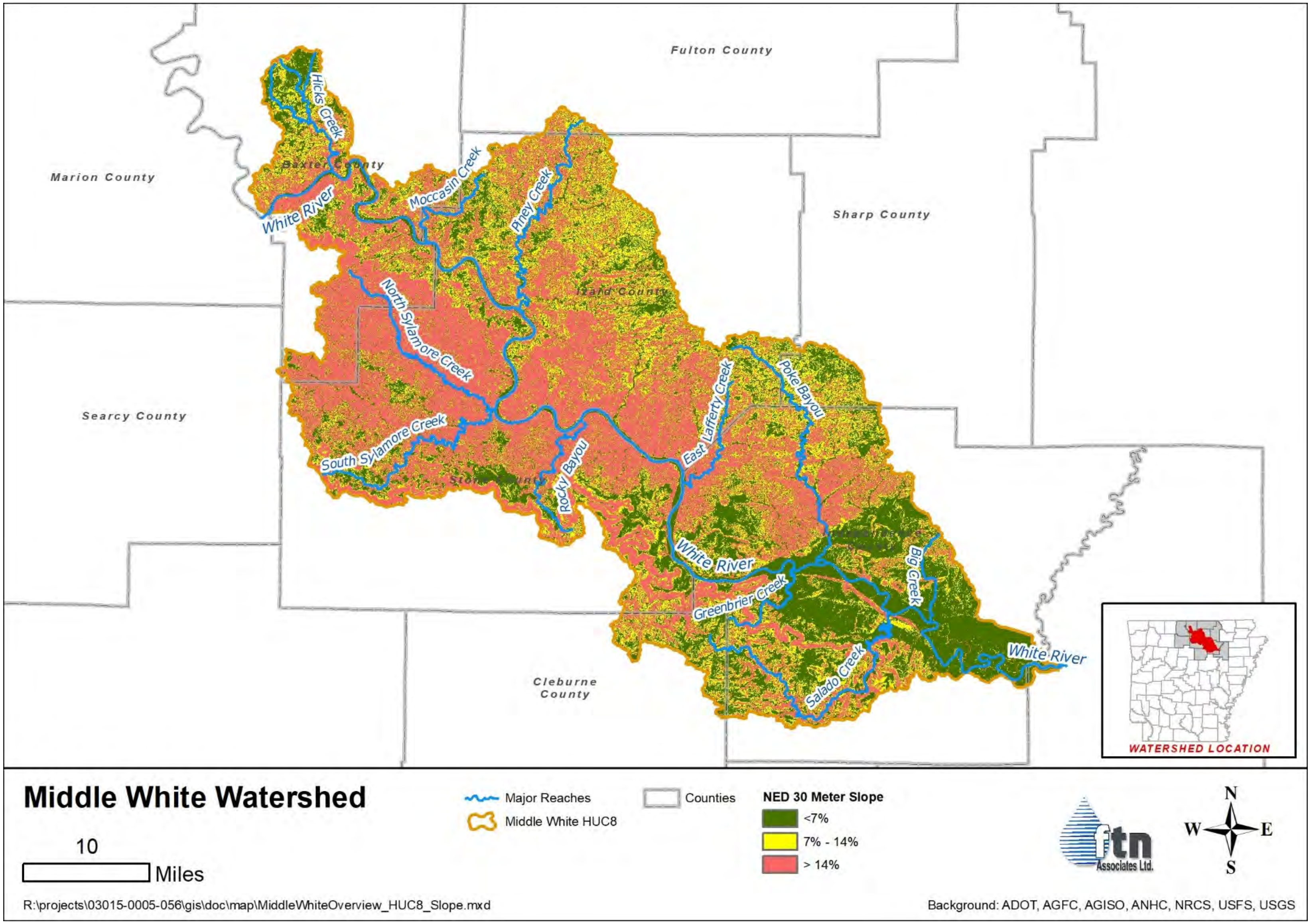


Figure 2.6. Map of slope ranges in the Middle White River watershed.

Each of the four physiographic regions in the watershed is characterized by differences in topography (Figure 2.4). Forty-four percent of the watershed is in the Salem Plateau physiographic region, where the characteristic terrain is rugged and relief can be as much as 500 feet. Thirty-six percent of the watershed is in the Springfield Plateau physiographic region. In this area of the watershed, elevations range from 1,500 to 200 feet above sea level and local relief can be as much as 300 feet. Seven percent of the watershed is in the Boston Mountains physiographic region. This area of the watershed is characterized by rugged terrain with steep-sided valleys (Adamski, et al. 1995). Thirteen percent of the watershed is in the Mississippi Alluvial Plain physiographic region. This region is characterized by flat to gently rolling plains with little relief. Elevations in this area of the watershed are around 200 feet above sea level.

2.3.4 Soils

Soils in the upland areas of the Middle White River watershed tend to be stony, and have low fertility and high erosion potential. In river valleys and the Delta lowlands, soils are deeper and more fertile, but prone to flooding (Friends of the North Fork and White Rivers, Inc. 2007). Four soil associations cover 76% of the Middle White River watershed – Brockwell-Boden-Portia, Clarksville-Noark-Nixa, Linker-Enders-Steprock, and Portia-Estate-Moko (Figure 2.7). The Clarksville-Noark-Nixa occurs on just over one-quarter of the watershed (27%). Characteristics of the major soils present in the watershed are summarized in Table 2.11.

2.3.5 Land Use/Land Cover

The majority of the land in the Middle White River watershed, 69%, is forested (Figure 2.8). Pasture and haylands is the next most common land use in the watershed. Pasture and haylands in the Middle White River watershed are primarily located on relatively flat land in river valleys and on ridge tops (Figure 2.9).

Table 2.11. Characteristics of major soil associations of the Middle White River watershed.

Name	Drainage	Character	Depth	Erosion hazard	Natural fertility	Sanitation limitation
Amagon-Dundee-Sharkey[3]	Poorly drained	Silt loam	Deep	-	Moderate	Severe
Arkana-Moko-Gassville[1,2,3]	Moderately well drained	Very cherty and stony silt loam	Moderately deep to shallow	Severe	Low - moderate	Severe
Brockwell-Boden-Portia[2,3]	Well drained	Fine sandy loam	Deep	Severe	Low	Moderate to severe
Clarksville-Nixa-Captina[2,3]	Moderately to excessively well drained	Very cherty silt loam	Deep	Severe	Low	None to severe
Clarksville-Noark-Nixa[2,3]	Somewhat excessively well drained	Very cherty silt loam	Deep	Severe	Low	Moderate to severe
Enders-Nella-Mountainburg[2,3,4]	Well drained	Fine sandy loam, gravelly, and stony	Deep to shallow	Severe	Low	Moderate to severe
Foley-Jackport-Crowley[3]	Poorly to somewhat poorly drained	Silty clay loam	Deep	Minimum	Moderate	Severe
Gepp-Doniphan-Agnos[2,3]	Well drained	Very cherty silt loam	Deep	Severe	low	Moderate
Kobel-Commerce-Dubbs[3]	Well drained	Silt loam	Deep	Moderate	Moderate	None
Linker-Enders-Steprock[3,4]	Well drained	Fine sandy loam, gravelly, and stony	Deep to shallow	Severe	Low	Severe
Loring-Oakalimeter-Tichnor[2]	Moderately well drained	Silt loam	Deep	Moderate	Moderate	Severe
Newnata-Eden-Moko[3,4]	Well drained	Silty clay loam	Deep to shallow	Severe	Moderate	Severe
Portia-Estate-Moko[2]	Well-drained	Stony and loamy	Deep to shallow	-	Low - moderate	-

[1] (US Soil Conservation Service 1984)
[2] (US Soil Conservation Service 1983a)
[3] (US Soil Conservation Service 1982)
[4] (US Soil Conservation Service 1983b)

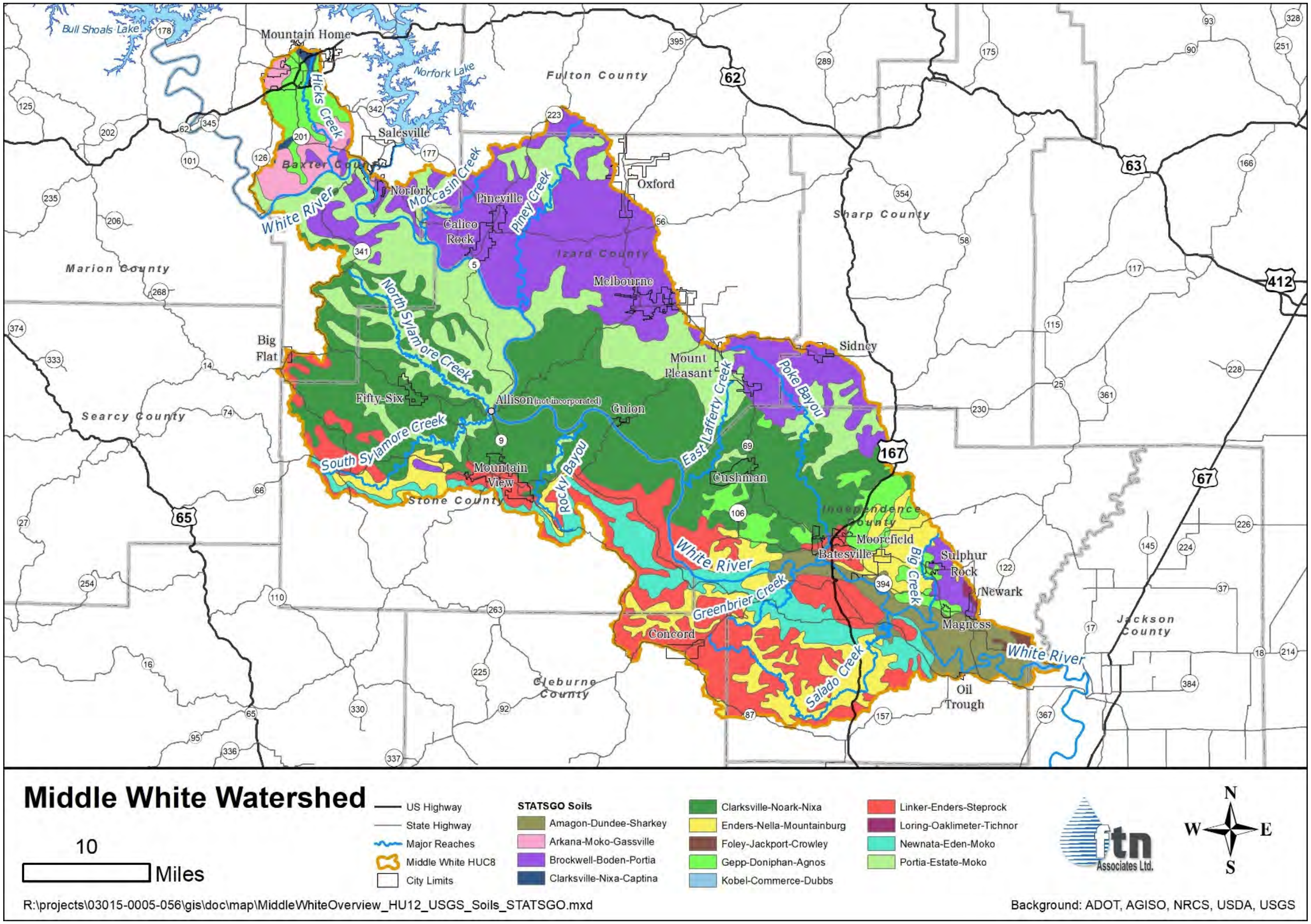


Figure 2.7. Map of soil associations in the Middle White River watershed.

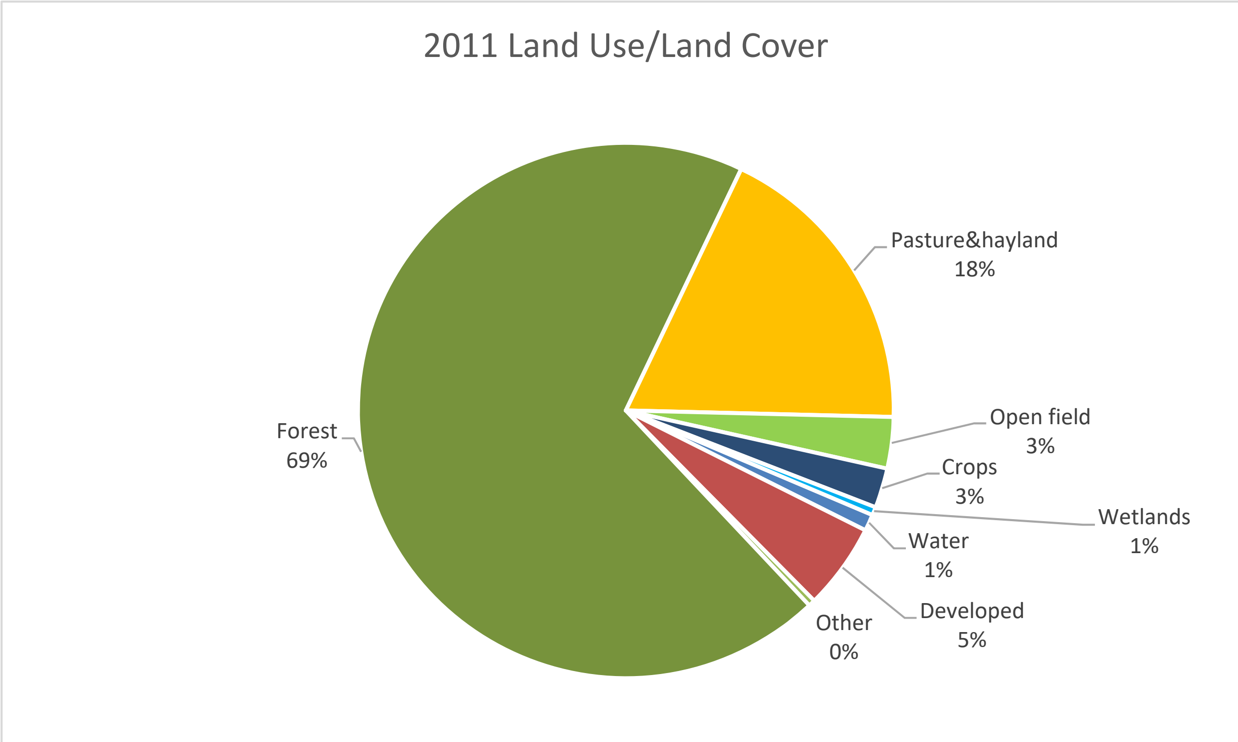


Figure 2.8. Land use/land cover percentages for the Middle White River watershed (Homer, et al. 2015).

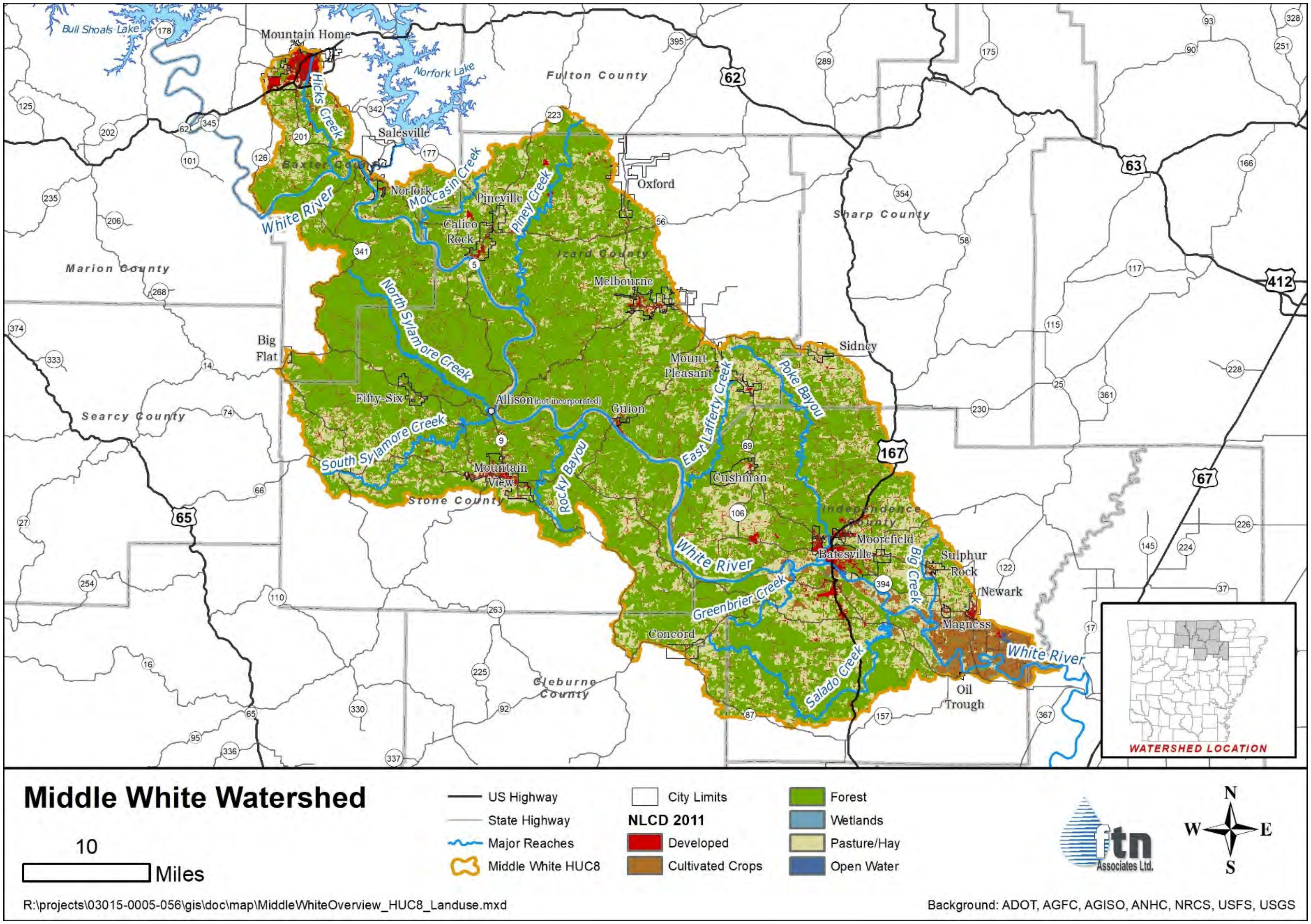


Figure 2.9. Land use map of the Middle White River watershed (Homer, et al. 2015).

2.4 Water Resources

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

2.4.1 Surface Water

There are over 2,300 miles of streams in the Middle White River watershed (Center for Advanced Spatial Technologies 2006). There were four active USGS flow gages in the Middle White River watershed in 2018 (Figure 2.10). The flow gages on the White River are also part of the USACE river stage monitoring network. Table 2.12 lists summary statistics for flow measurements from these gages. The farthest downstream USGS flow gage on the White River in this watershed is at Batesville. The largest tributary subbasin in this watershed is Sylamore Creek (North and South Sylamore Creek combined), which accounts for approximately 15% of the watershed. Subwatersheds for Piney Creek and Poke Bayou are about the same size, and each account for another 12% of the watershed.

The Middle White River watershed receives releases from the USACE reservoirs Bull Shoals Lake and Norfork Lake. These reservoirs contribute the majority of the White River flow in this watershed. Minimum flow releases have recently been set for both of these reservoirs; 800 cubic feet/second for Bull Shoals Lake and 300 cubic feet/second for Norfork Lake (USACE Little Rock District 2016).

Surface water is used as the municipal drinking water supply by several communities in the Middle White River watershed including Mountain Home, Batesville, Mountain View, Cushman, as well as the Sylamore Valley Water Association (Arkansas Department of Health 2017). Surface water sources used by communities in the Middle White River watershed for drinking water are the White River and Norfork Lake.

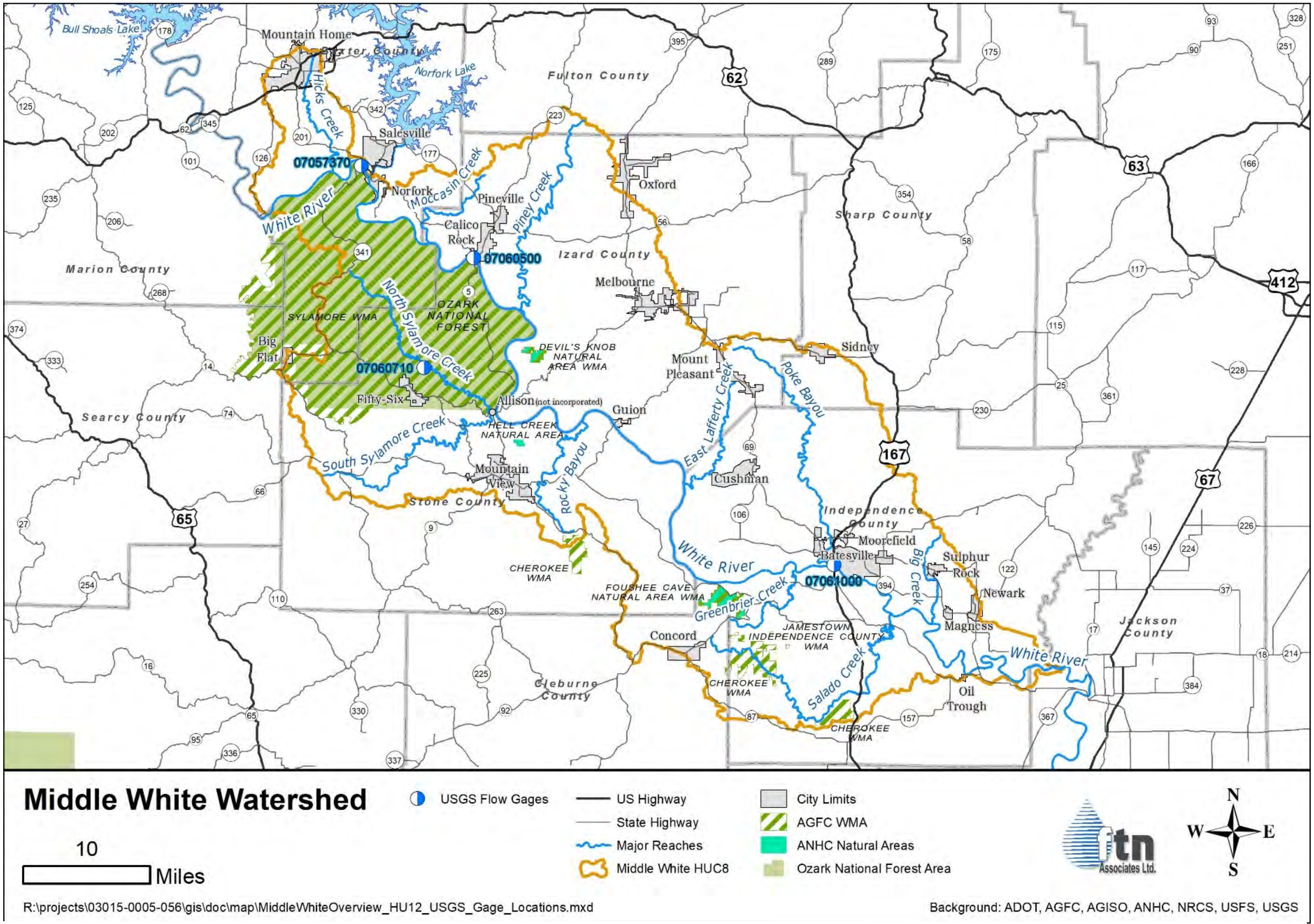


Figure 2.10. Active USGS flow gages in the Middle White River watershed, 2018.

Table 2.12. Statistics for discharge data from USGS gages active in 2018 (USGS 2018a).

Site Number	Year Established	Site Name	Annual Average Discharge (cfs*)	Lowest Mean Monthly Discharge, (cfs*)	Highest Mean Monthly Discharge (cfs*)	7Q10 Flow, (cfs*)	90% Exceeds Flow, (cfs*)	Peak Flow, (cfs*)
07057370	1996	White River near Norfork, AR	8,727	1,060	44,940	649	1,850	196,000
07060500	1939	White River at Calico Rock, AR	10,795	1,905	37,470	950	2,710	202,000
07060710	1965	North Sylamore Creek near Fifty-Six, AR	54.4	2.31	471	1.8	4.1	28,200
07061000	1937	White River at Batesville, AR	12,604	2,160	45,210	1,104	3,360	208,000

* Calculated for period 2004-2016, longest period when all stations have data. Annual average calculated for calendar year.

2.4.2 Groundwater

The Middle White River watershed is underlain by three aquifers, the Springfield Plateau aquifer and the Ozark aquifer in the uplands, and the Mississippi River Valley alluvial aquifer in the lowlands of the downstream end of the watershed. The Western Interior Plains Confining System is a series of geologic formations present at the surface in the lower and western areas of the watershed that is also a locally important water supply source (Kresse, et al. 2014).
Table 2.13 shows the geologic formations associated with each of these aquifers, and their relative position with regard to depth. Figure 2.11 shows where these aquifers are unconfined. The Ozark aquifer is present 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 2.13. Stratigraphic geology listing with aquifers underlying the Middle White River watershed (Kresse, et al. 2014).

Era	Period	Geologic Unit	Lithology	Regional Aquifer
Quaternary	Pleistocene & Holocene	Alluvial deposits	Unconsolidated sand, gravel, silt, clay	Mississippi River Valley alluvial aquifer
Tertiary	Tertiary	Alluvial deposits	Gravel	Western Interior Plains confining system
Cretaceous	Upper Cretaceous	Cretaceous rocks	Shaley clay, gravel	
Paleozoic	Pennsylvanian	Bloyd Shale	Sandstone, shale, siltstone	
		Prairie Grove	Sandstone, limestone	
		Cane Hill	Shale, siltstone, sandstone	
	Mississippian	Imo Shale (member of Pitkin Limestone)	Sandstone, shale	
		Pitkin Limestone	Limestone, shale	
		Fayetteville Shale	Shale, limestone	
		Batesville Sandstone	Sandstone, shale	
		Ruddell Shale	Shale	
		Moorefield Formation	Shale, limestone	
		Boone Formation	Limestone, chert	Springfield Plateau aquifer
		St. Joe Limestone	Limestone	
	Devonian	Chatanooga Shale	Shale	Ozark confining unit
		Penters Chert	Chert, limestone	Upper Ozark aquifer
	Silurian	Lafferty Limestone	Limestone	
		St. Clair Limestone	Limestone	
		Brassfield Limestone	Limestone	
	Ordovician	Cason Shale	Shale, sandstone, limestone	
		Fernvale Limestone	Limestone	
		Kimmswick Limestone	Limestone	
		Plattin Limestone	Limestone (micrite)	
		Joachim Dolomite	Dolostone, limestone	
		St. Peter Sandstone	Sandstone	
		Everton Formation	Limestone, dolostone, sandstone	
		Calico Rock Sandstone	Sandstone	
		Powell Dolomite	Shaley dolostone, sandstone	
		Cotter Dolomite	Dolostone, chert	
		Jefferson City Dolomite	Dolostone, chert	
		Roubidoux Formation	Sandstone and sandy dolomite	Lower Ozark aquifer
		Gasconade Formation	Dolomite, cherty and sandy dolomite, and sandstone.	

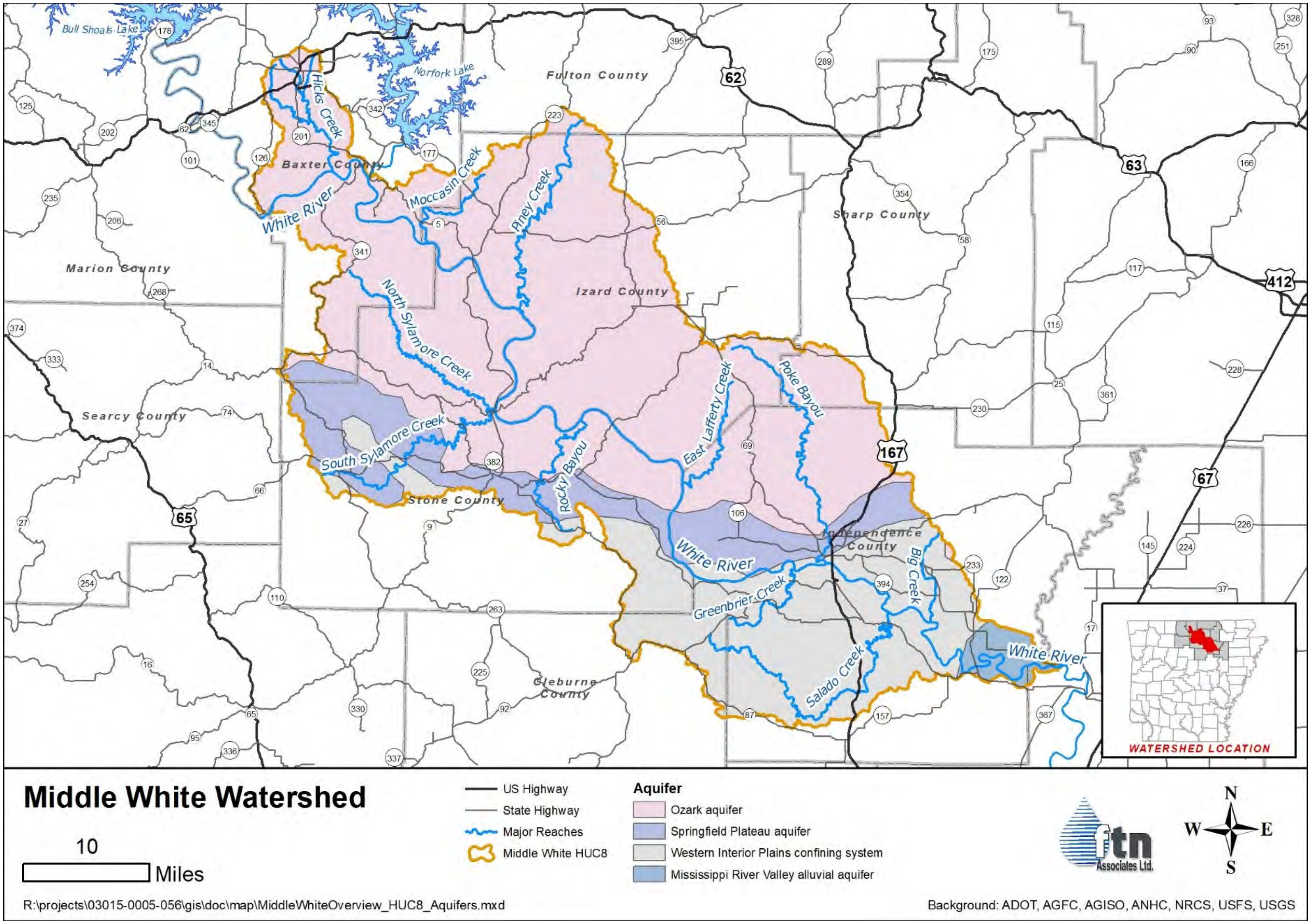


Figure 2.11. Outcrop areas of aquifers within the Middle White River watershed.

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. The Ozark aquifer is unconfined, occurring at or near the surface, over large areas of the Middle White River watershed (Figure 2.11). Where this aquifer is unconfined, it receives direct recharge from precipitation, primarily through sinkholes and rock fractures. In the southern and western Middle White River watershed, the Ozark aquifer is confined, and receives only indirect recharge from the unconfined region and the overlying Springfield Plateau aquifer. Well yields from the upper Ozark aquifer are usually 5-10 gallons/minute (gpm). The lower Ozark aquifer receives recharge primarily from the areas where it is at the surface in Missouri, with some contribution from the upper Ozark aquifer. Wells in the lower Ozark aquifer are some of the most productive in the region with yields usually ranging from 50 to 600 gpm. This is the aquifer most often used for municipal water supply (Kresse, et al. 2014).

The Springfield Plateau aquifer is associated with the Mississippian Boone Formation, which underlies the southern half of the Middle White River watershed. The Springfield Plateau aquifer is unconfined over a relatively small area of the Middle White River watershed (Figure 2.11). This aquifer is recharged primarily by rainwater via sinkholes, fractures and conduits, and losing stream reaches. Well yields from this aquifer are commonly between 10 and 100 gpm (Kresse, et al. 2014).

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 at the surface in the southern area of the watershed (Figure 2.11). Water yields from this system are adequate only for household use (Kresse, et al. 2014).

The Mississippi River Valley alluvial aquifer is a primarily unconfined aquifer in unconsolidated coarse sands and gravels of the Mississippi River Alluvial Plain. Primary recharge to this aquifer is from precipitation. In some areas, a layer of fine sand, silt, and clay occurs over the coarse sands and gravels and acts as a confining layer, blocking precipitation from the aquifer. Reported yields from this aquifer range from 500 to 5,000 gpm (Kresse, et al. 2014).

There are 18 community water systems and 17 noncommunity systems in the Middle White River watershed that use groundwater as their drinking water supply (Arkansas Department of Health 2017). Marcella Spring in Stone County has been used as a source for commercially bottled water by the Marcella Natural Springs company of Jonesboro, AR (Arkansas Geological Survey 2018).

2.4.3 Surface Water – Groundwater Connections

The karst geology present in the Middle White River watershed makes exchanges between surface water and groundwater common in the watershed. An important concern in areas of karst geology is contamination of groundwater by surface water runoff or infiltration. Surface water travels through karst geology too quickly to be cleaned of contaminants like bacteria, nutrients, or chemicals like pesticides, so contaminants from the surface of the land can easily end up in groundwater, springs, and caves. Recharge areas have been delineated for several cave/spring systems in the Middle White River watershed, including Blanchard Springs Cavern (Aley 1980), Nesbitt Spring Cave (Gilip, Galloway and Hart 2009), Hell Creek Cave (Aley and Aley 1985, Stewart 1988), and Foushee Cave (Rupar and Slay 2011). No studies were found identifying streams or stream segments in the watershed that go to groundwater, i.e., losing streams.

There are a number of springs in the Middle White River watershed, through which groundwater is discharged to surface waters. The largest of these is Blanchard Springs in the Ozark National Forest in Stone County. In the Middle White River watershed, springs have been identified that carry contaminants from outside of the watershed to streams within the watershed (Mott, Hudson and Aley 2000). While possible, no such situations have been identified in the Middle White River watershed.

2.5 Wildlife Resources

Several of the species present in the Middle White River watershed are found only within the interior highlands of Arkansas (Table 2.14). A number of native species present in the watershed 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.

Table 2.14. Arkansas endemic species present in the Middle White River watershed (McCallister 2018, Arkansas Natural Heritage Commission 2018, NatureServe 2018).

Common name	Scientific name	Category	Location in watershed
None	*Dictyostelium caveatum*	Fungi, slime mold	Blanchard Springs Cavern, Stone County
Foushee Cave Snail	*Amnicola cora*	Invertebrate	Foushee Cave, Independence County
None	*Nocomis biguttatus*	Fish gill parasite	White River at Sylamore, Izard County
White lipstooth	*Daedalochila peregrine*	Invertegrate, snail	Izard and Stone Counties
Calico Rock oval	*Patera clenchi*	Invertebrate, snail	Izard County
Arkansas Wedge	*Xolotrema occidentale*	Invertebrate, snail	Independence and Stone Counties
Boston Mountains crayfish	*Cambarus causeyi*	Invertebrate, crayfish	Stone County
Hell Creek crayfish	*Cambarus zophonastes*	Invertebrate, crayfish	Stone County
None	*Neoleptoneta arkansa*	Spider	Blanchard Springs Cavern, Stone County
None	*Apochthonius titanicus*	pseudoscorpion	Blanchard Springs Cavern, Stone County
Causey's Cave millipede	*Causeyella causeyae*	Millipede	Independence, Izard, and Stone Counties
None	*Chaetaspis attenuatus*	Millipede	Cushman Cave, Independence County; Clay Cave, Izard County
None	*Typhlogastrura fousheensis*	Springtail	Foushee Cave, Independence County
None	*Speleochus blanchardensis*	Beetle	Blanchard Springs Cavern, Stone County
None	*Anillinus alleni*	Beetle	Blanchard Springs, Stone County
Ozark Pocket Gopher	*Geomys bursarius ozarkensis*	Mammal	Izard and Stone Counites

Fish communities of the Middle White River watershed are overall more similar to fish communities of the Ouachita Mountains than to fish communities of the upper White River watershed in northwest Arkansas (Matthews and Robison 1988).

2.5.1 Protected Species

There are 21 species that have been found in the Middle White River watershed that are listed as threatened or endangered by the state and/or federal government (Table 2.15). The USFS routinely surveys populations of a number of protected species that are present in the National Forest. Populations of protected bat species are surveyed regularly in the Sylamore District of the Ozark National Forest (USFS 2016).

2.5.2 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). Around 140 Species of Greatest Conservation Need have been reported in the Middle White River watershed (Arkansas Natural Heritage Commission 2018, NatureServe 2018). Excluding those listed as threatened or endangered, this includes 60-80 plant species, two bird species, four species of mammal, nine species of mussels, 4-13 species of insects, 16 species of other types of invertebrates (e.g., snails, crayfish), and 7-10 species of reptiles and amphibians. Nine fish Species of Greatest Conservation Need have been identified in the Middle White River watershed. Only two watersheds in the state have a greater number (Adams and Adams 2015). The Nature Conservancy has identified 13 cave and karst animal Species of Greatest Conservation Need, in addition to bats, in the Middle White River watershed. Nine of these are aquatic species, and four are terrestrial (Inlander, Gallipeau, and Slay 2011).

Table 2.15. Protected species found in the Middle White River watershed (Arkansas Natural Heritage Commission 2018, NatureServe 2018).

Common name	Scientific name	Category	State Status	Federal status	Counties (ANHC)
Snuffbox	*Epioblasma triquetra*	Invertebrate	Endangered	Endangered	Baxter, Independence, Izard
Rabbitsfoot	*Quadrula cylindrica cylindrica*	Invertebrate	Endangered	Threatened	Independence, Izard, Stone
Pink Mucket	*Lampsilis abrupta*	Invertebrate	Endangered	Endangered	Baxter, Independence
Foushee Cave Snail	*Amnicola cora*	Invertebrate		Endangered	Independence
Opaque Prairie Sedge	*Carex opaca*	Plant	Endangered	None	Izard
Dwarf Bristle Fern	*Trichomanes petersii*	Plant	Threatened	None	Stone
Ovate-leaf Catchfly	*Silene ovate*	Plant	Threatened	None	Baxter, Stone
Royal Catchfly	*Silene regia*	Plant	Threatened	None	Stone
Heartleaf Plantain	*Plantago cordata*	Plant	Threatened	None	Baxter, Stone
Interrupted Fern	*Osmunda claytonia*	Plant	Threatened	None	Stone
Winterberry	*Ilex verticillate*	Plant	Threatened	None	Independence
Yellow Coneflower	*Echinacea paradoxa var. paradoxa*	Plant	Threatened	None	Baxter, Stone
Spinulose Wood Fern	*Dryopteris carthusiana*	Plant	Threatened	None	Stone
Open-ground Whitlow-grass	*Draba aprica*	Plant	Threatened	None	Stone
Showy Lady's Slipper	*Cypripedium reginae*	Plant	Endangered	None	Baxter, Stone
Gray Bat	*Myotis grisescens*	Vertebrate	Endangered	Endangered	Baxter, Independence, Izard, Stone
Indiana Bat	*Myotis sodalist*	Vertebrate	Endangered	Endangered	Independence, Izard, Stone
Northern Long-eared Bat	*Myotis septentrionalis*	Vertebrate	Endangered	Threatened	Baxter, Independence, Izard, Stone
Hell Creek Cave crayfish	*Cambarus zophonastes*	Invertebrate		Endangered	Stone
Ozark Hellbender	*Cryptobranchus alleganiensis bishop*	Vertebrate	Endangered	Endangered	Baxter, Independence

2.5.3 Nuisance Species

There are a number of non-native species of plants and animals present in the Middle White River watershed that have been classified as posing a threat to native communities and ecosystems present in the watershed. A list of non-native nuisance aquatic species that have been identified within the Middle White River watershed is included as Table 2.16.

Feral hogs are a nuisance species throughout Arkansas, including the Middle White 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 (Arkansas Agriculture Department 2018).

Table 2.16. Non-native nuisance aquatic species present in the Middle White River watershed (USGS 2018b, University of Georgia Center for Invasive Species and Ecosystem Health 2018).

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
Silver carp	Hypophthalmichthys molitrix	Fish	Exotic
Bighead carp	Hypophthalmichthys nobilis	Fish	Exotic
Yellow perch	Perca flavescens	Fish	Native transplant
Rock bass	Ambloplites rupestris	Fish	Native transplant
Goldfish	Carassius auratus	Fish	Exotic
Arkansas River shiner	Notropis girardi	Fish	Native transplant
Striped bass	Morone saxatilis	Fish	Native transplant
Western mosquitofish	Gambusia affinis	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.

2.5.4 Sensitive Areas

The Arkansas Natural Heritage Commission has identified several habitats present in Baxter, Independence, Izard, and Stone Counties as being of conservation concern. These habitats include Central Interior Highlands Calcareous and Acidic Glade and Barrens, fens, mesic hardwood forest, dry-mesic oak forest, colonial nesting sites for water birds, and caves (Arkansas Natural Heritage Commission 2018).

Caves and other karst features in the Middle White River watershed are important habitats for several protected species and Species of Greatest Conservation Need.

The White River from Batesville to the mouth of this watershed is designated as critical habitat for the threatened Rabbitsfoot mussel (US Fish and Wildlife Service 2015).

ADEQ has designated North Sylamore Creek and Salado Creek as “Extraordinary Resource Waters”. North Sylamore Creek is also designated as “Natural and Scenic Waterway”. There are two springs in the watershed designated as “Ecologically Sensitive Waterbodies”, and the White River from Bull Shoals Dam to Dam 3 is designated as trout fishery (Arkansas Pollution Control and Ecology Commission 2014).

2.6 Surface Water Quality Standards for Middle White 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 Middle White River watershed are described below.

2.6.1 Designated Uses

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 (OH) or Boston Mountain (BM) Fisheries (watersheds >10 sq. mi); or Seasonal Ozark Highlands or Boston Mountain Fisheries (watersheds <10 sq. mi.) (Arkansas Pollution Control and Ecology Commission 2014).

North Sylamore Creek and Salado Creek are designated as "Extraordinary Resource Waters". North Sylamore Creek is also designated as "Natural and Scenic Waterway". There are two springs in the watershed designated as "Ecologically Sensitive Waterbodies", and the White River from Bull Shoals Dam to Dam 3 is designated as trout fishery (Figure 2.11) (Arkansas Pollution Control and Ecology Commission 2014).

2.6.2 Numeric and Narrative Criteria

Numeric water quality criteria for selected parameters that apply in the Middle White River watershed are listed in Table 2.17. 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 Middle White River watershed (Arkansas Pollution Control and Ecology Commission 2014).

Turbidity criteria that apply in the Middle White River watershed are listed in Table 2.17. Separate turbidity criteria are specified for baseflow conditions. The baseflow criteria should not be exceeded in more than 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).

Fecal indicator bacteria (i.e., *Eschericia coli* [*E. coli*] and fecal coliform) water quality criteria that apply in the Middle White River watershed are summarized in Table 2.17. These criteria are considered to be met if less than 25% of no less than eight samples collected during the season (primary contact season or secondary contact season) are above the criteria.

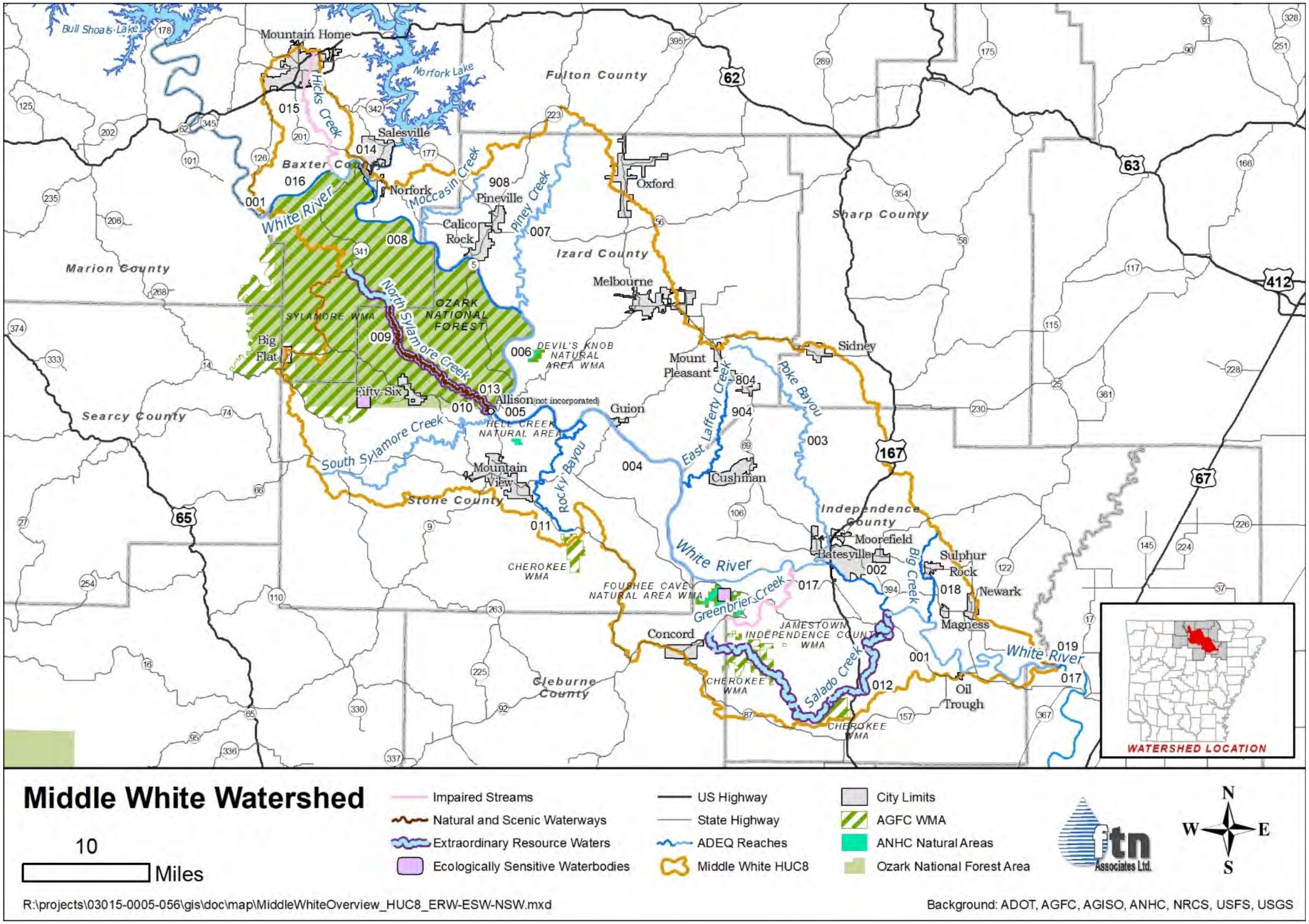


Figure 2.11. Map of Middle White River watershed showing Extraordinary Resource Waters, Natural and Scenic Waterway, and Ecologically Sensitive Waterbodies.

Table 2.17. Numeric water quality criteria for the Middle White River watershed (Arkansas Pollution Control and Ecology Commission 2014).

Parameter	Season	Location	Conditions	Criteria
Temperature	All	OH[a]	All	29 deg C
		BM[b]	All	31 deg C
		Trout waters	All	20 deg C
Turbidity	Baseflow[c]	Watershed	All	10 NTU
	All flows[d]	OH	All	17 NTU
		BM	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
		OH	Watershed 10-100 sq mi	5 mg/L
		Moccasin Creek	Below Highway 177	5 mg/L
		OH	Watershed > 100 sq mi	6 mg/L
		BM	Watershed > 10 sq mi	6 mg/L
		Trout waters	All	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

[a] Ozark Highlands ecoregion, which includes White River and all but 2 major tributaries in this watershed
[b] Boston Mountains ecoregion, which includes Greenbrier and Salado Creeks in this watershed
[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

2.6.3 Antidegradation Policy

The antidegradation policy of the Arkansas water quality standards is 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; and
- 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.

3.0 WATERSHED ASSESSMENT

3.1 Current Surface Water Quality

3.1.1 Data

Data collected by ADEQ and the USGS from 2013 through 2017 were used to characterize current water quality conditions in the watershed. The data used for this summary were downloaded in April 2018 from online databases managed by ADEQ (https://www.adeq.state.ar.us/techsvs/env_multi_lab/water_quality_station.aspx), USGS (https://waterdata.usgs.gov/nwis/qw), and EPA (https://www.waterqualitydata.us/). During the period 2013 – 2017, ADEQ collected water quality data at two locations on the White River, and 24 locations on 12 tributaries. During this period, the USGS collected data at one location on the White River and one location on a tributary. Information about these sampling locations is summarized in Table 3.1, and they are mapped on Figure 3.1.

Table 3.1. Surface water quality monitoring stations in the Middle White River watershed that were active during the period 2013 - 2017.

Entity	Program	Station Id	Stream	Location	Ecoregion*	Start Year	End Year	Number of dates
ADEQ	Special	BUFET002	N. Sylamore Cr	Barkshed Recreation Area	BM	2001	2014	11
ADEQ	Special	WHI0090	S. Sylamore Cr	CR283 near Mt. View	OH	1991	2014	38
ADEQ	Special	WHI0090A	S. Sylamore Cr	Holiday Mt. Resort crossing	OH	2013	2014	9
ADEQ	Special	WHI0144A	N. Sylamore Cr	CR76 Barkshed Recreation Area	OH	2013	2015	7
ADEQ	Special	WHI0144B	N. Sylamore Cr	CR93	OH	2015	2015	1
ADEQ	Special	WHI0144F	Roasting Ear Cr	CR86	OH	2013	2015	12
ADEQ	Special	WHI0145B	S. Sylamore Cr	1.5mi downstream of Hwy 87	OH	1997	2014	30
ADEQ	Special	WHI0159	W. Livingston Cr	SR5 near Optimus	OH	1998	2014	10

Table 3.1. Surface water quality monitoring stations in the Middle White River watershed that were active during the period 2013 – 2017 (continued).

Entity	Program	Station Id	Stream	Location	Ecoregion*	Start Year	End Year	Number of dates
ADEQ	Special	WHI0161	Piney Cr	CR263	OH	1999	2014	8
ADEQ	Special	WHI0162	Wideman Cr	CR13	OH	1999	2014	10
ADEQ	Roving	WHI0168	Piney Cr	Near Boswell	OH	2001	2014	22
ADEQ	Special	WHI0202	N. Sylamore Cr	Off SR14 near Allison	OH	2013	2014	13
ADEQ	Special	WHI0065A	Hicks Cr	Hicks Rd	OH	2015	2015	2
ADEQ	Special	WHI0139	Hicks Cr	Downstream of Mt. Home Waste Water Treatment Plant	OH	2004	2015	6
ADEQ	Special	WHI0140	Hicks Cr	Upstream of Big Cr	OH	2015	2015	3
ADEQ	Special	WHI0141	Big Cr	Upstream Hicks Cr	OH	2015	2015	4
ADEQ	Special	WHI0205	Big Cr	SR201	OH	2015	2015	2
ADEQ	Special	WHI0206	Dodd Cr	Upstream Hicks Rd	OH	2015	2015	3
ADEQ	Special	WHI0151	Salado Cr	Logging road SW of Batesville	BM	2013	2016	19
ADEQ	Roving	WHI0166	Salado Cr	Hwy 14	BM	2001	2016	29
ADEQ	Roving	WHI0167	Greenbrier Cr	Hwy 25	BM	2001	2016	26
ADEQ	Special	WHI0201	Salado Cr	Hwy 167	OH	2013	2016	20
ADEQ	Special	WHI0204	Wolf Bayou	SR14	BM	2015	2016	9
ADEQ	Ambient	WHI0011	S. Sylamore Cr	Downstream of Lick Fork Cr	OH	1993	2017	290
ADEQ	Ambient	WHI0029	White River	Oil Trough	BM	1990	2017	345
ADEQ	Ambient	WHI0046	White River	Norfork	OH	1990	2017	329
ADEQ	Ambient	WHI0065	Hicks Cr	Downstream of Mt. Home	OH	1990	2017	349
USGS	Routine	07060500	White River	Calico Rock	OH	1945	2017	585
USGS	Routine	07060710	N. Sylamore Cr	Near Fifty-Six	OH	1966	2018	659

*OH Ozark Highlands.
BM Boston Mountains.

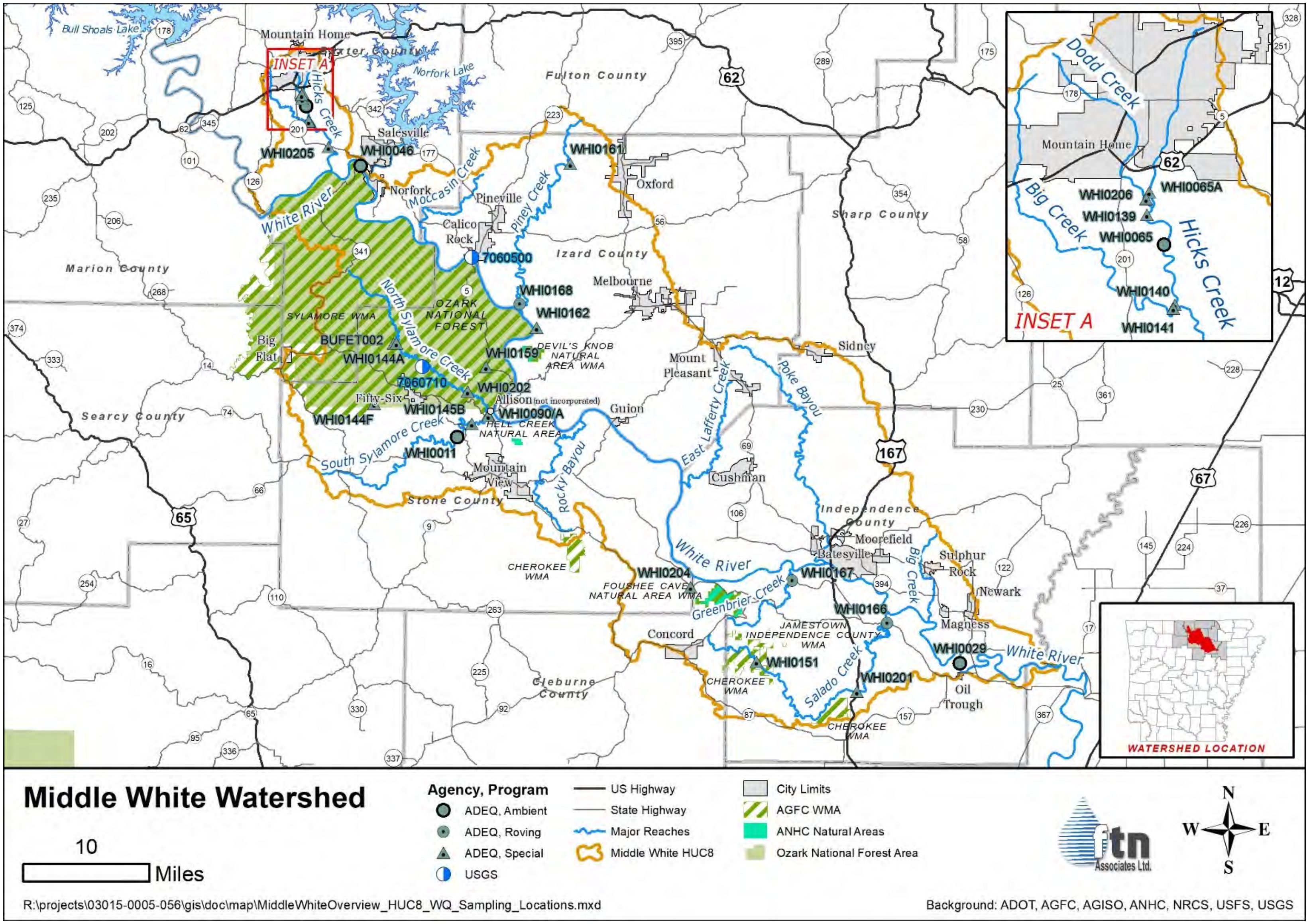


Figure 3.1. Surface water quality monitoring locations active during 2013 through 2017.

3.1.2 Assessed Water Quality Impairment

Impaired waters in the Middle White River watershed from the 2018 list are given in Table 3.2 and mapped on Figure 3.2 (water quality standards for the Middle White River watershed are included in Section 2.7). The most recent Arkansas state impaired waters list (i.e., 303(d) list) approved by EPA is from 2016 (ADEQ 2017). The impairments listed for the Middle White River watershed are the same on both the 2016 and 2018 lists. Almost 26 miles of streams in the watershed are classified as impaired. These streams have been on the state impaired waters list since 2008 (2004 for Hicks Creek) (ADEQ 2008).

Table 3.2. Impaired waters of the Middle White River watershed from the draft 2018 Arkansas 303(d) list (ADEQ 2018a).

Stream name	ADEQ Stream Segment Number	Impaired use	Pollutant	Pollutant source	Priority
Hicks Creek	015	Primary Contact	Pathogens	Municipal point source, urban runoff	Low
Greenbrier Creek	017	Fishery	Low dissolved oxygen	Unknown	Low

3.1.3 Water Quality Summary

Selected parameters of concern were examined, including parameters related to current assessed water quality impairments (dissolved oxygen, nutrients, and *E. coli*), and parameters such as turbidity and sediment, about which stakeholders have expressed concern (Friends of the North Fork and White Rivers, Inc. 2007). Only USGS collects flow measurements with water quality samples, so it is not possible to partition the majority of the data between baseflow and high flow conditions.

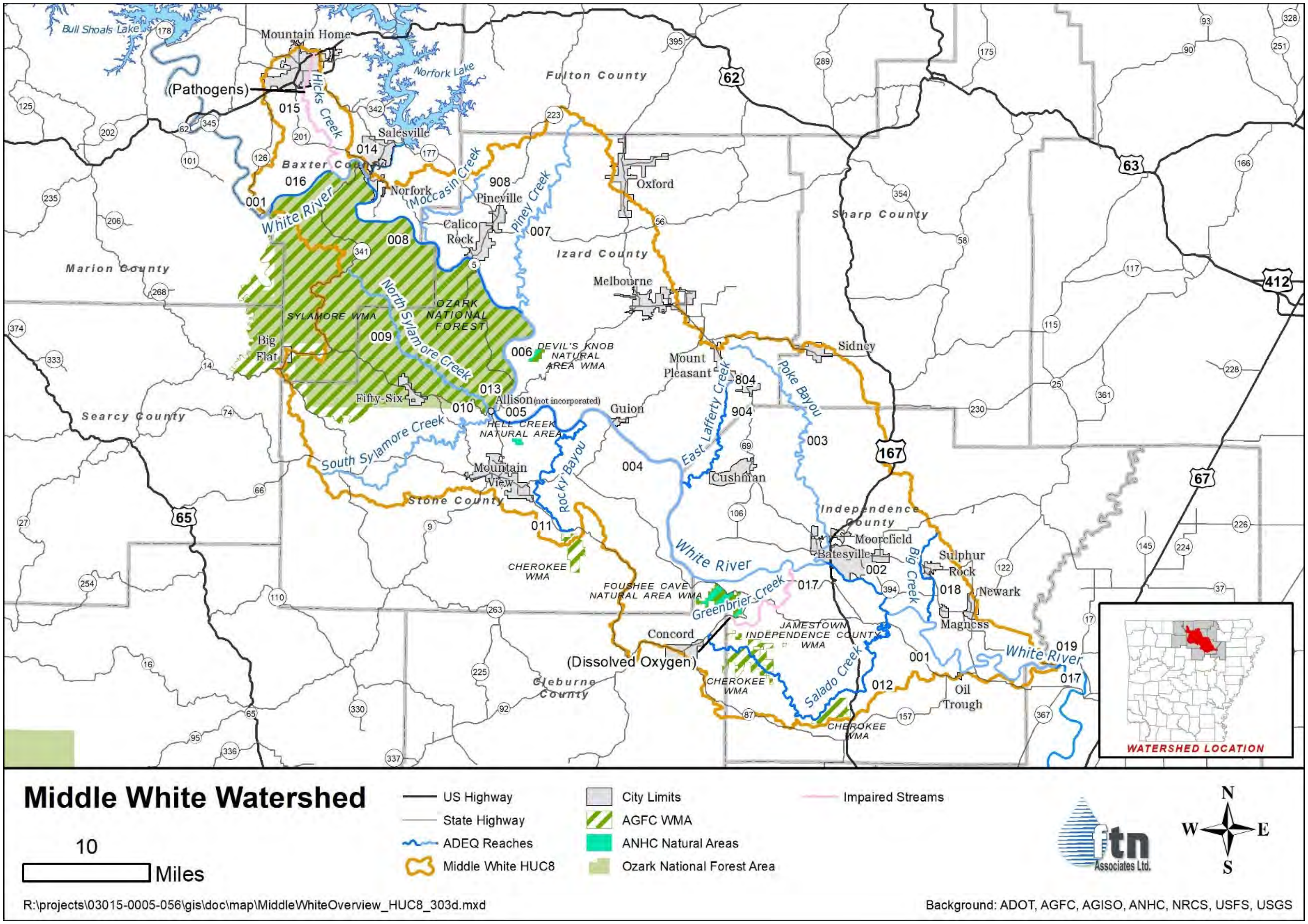


Figure 3.2. Impaired waterbodies in the Middle White River watershed identified in the final 2016 303(d) list (ADEQ 2017).

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. Also note that when a measurement is reported as not detected, a value equal to half of the detection limit has been used in calculating statistics.

On the box and whisker graphs associated with this section, water quality monitoring stations are differentiated by where they are located, on the White River, on a tributary of the White River, or on a tributary to a tributary of the White River. An example of a tributary to a tributary of the White River is Hicks Creek, which is a tributary of Big Creek, which drains to the White River (i.e., Big Creek is a White River tributary). Similarly, Roasting Ear Creek is a tributary of South Sylamore Creek, which we have classified as a White River tributary.

3.1.3.1 Sediment Parameters

ADEQ monitors turbidity and total suspended solids (TSS) as indicators of sediment water quality issues. The USGS measures suspended sediment concentrations at its water quality stations in the Middle White River watershed, rather than turbidity or TSS. Turbidity is an optical property of water related to the cloudiness of water caused by particles in the water. It is measured by how much light can pass through water. A higher turbidity value means less light can pass through the water. Turbidity in the Middle White River watershed is primarily the result of sediment or other solid materials suspended in the water. Arkansas water quality standards include numeric criteria for turbidity, but not TSS or sediment concentration. However, turbidity cannot be converted to a load, so TSS and sediment concentration measurements are needed to calculate sediment loads.

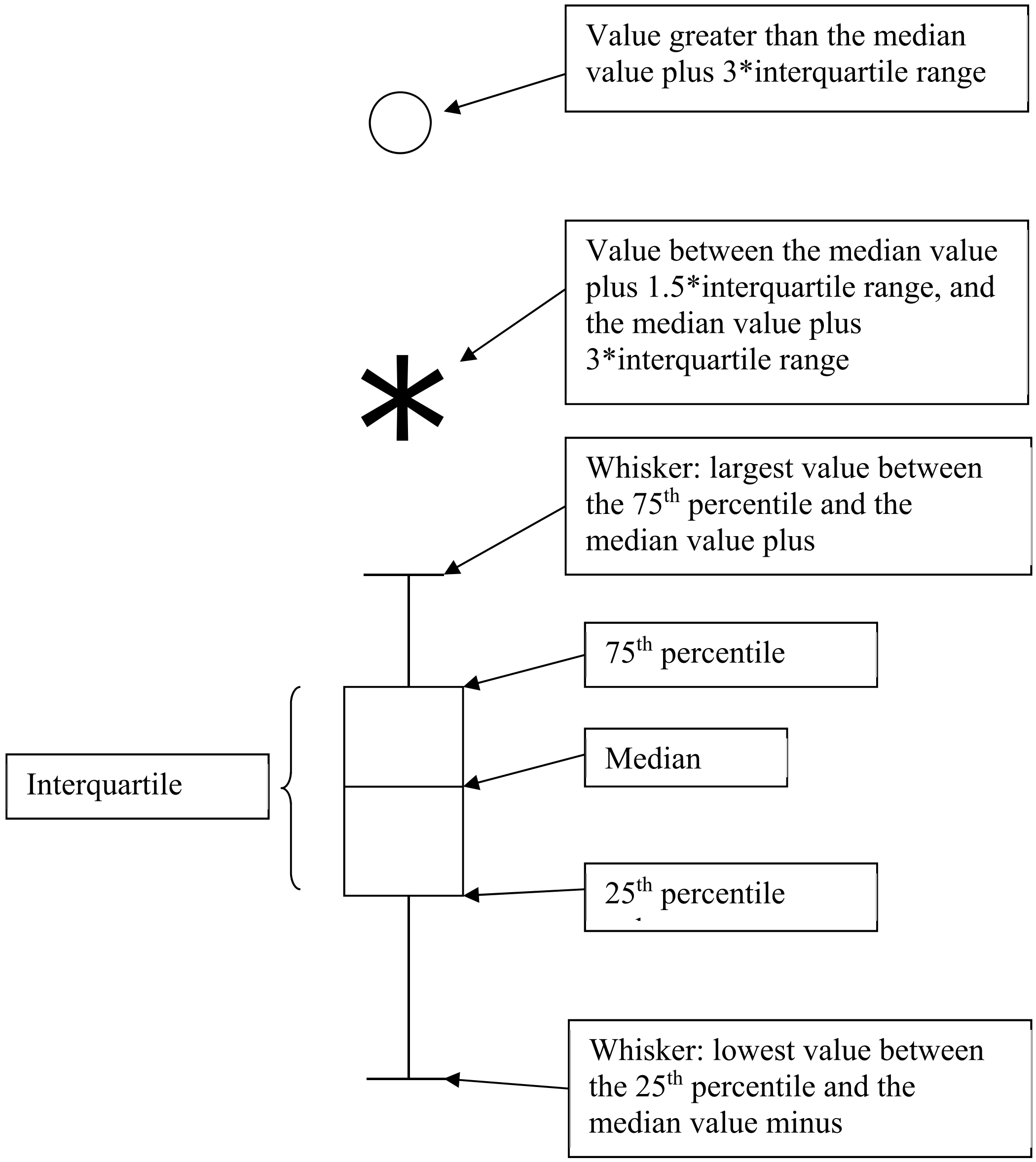


Figure 3.3. Elements of box and whisker graphs in this report.

3.1.3.1.1. Turbidity

Table 3.3 lists summary statistics for turbidity measurements from the period 2013-2017. Figure 3.4 shows a box and whisker graph of turbidity measurements from the Middle White River watershed for the period 2013-2017. The numeric turbidity water quality standard for the Ozark Highlands and Boston Mountain all flows is also shown on the plot. The Boston Mountain standard of 19 NTU applies to the monitoring locations on Greenbrier Creek (WHI0167) and Salado Creek (WHI0151, WHI0166, and WHI0201).

On Figure 3.4, median turbidity values appear to increase downstream in the White River, Big Creek, North Sylamore Creek, and Salado Creek. Mean turbidity values appear to decrease downstream in Piney Creek. No overall downstream trend is apparent in median turbidity values from stations on Hicks Creek or South Sylamore Creek.

The highest median turbidity levels for the period 2013-2017 are at stations on tributaries to the White River. The Greenbrier Creek station (WHI0167) has the highest median turbidity level, followed by Salado Creek at Highway 14 (WHI0166). The lowest median turbidity levels for this period are at tributary stations; upper North Sylamore Creek stations (8 of the 27 watershed 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 3.5 shows a box and whisker graph of base flow turbidity measurements (from June through October) for the period 2013-2017 with the base flow numeric turbidity standard, which is the same for both the Ozark Highlands and the Boston Mountain ecoregions. The base flow turbidity criterion is exceeded at least once at eight of the monitoring locations. At the Greenbrier Creek monitoring station (WHI0167), over 50% of the turbidity measurements exceed the base flow criterion, and between 50% and 25% of the turbidity measurements from Wideman Creek (WHI0162) and Salado Creek at Highway 14 (WHI0166) exceed the base flow standard.

Table 3.3. Summary statistics for turbidity measurements (in NTU) from 2013-2017 in Middle White River watershed.

Station ID	No. of measures	Minimum	25th percentile	Median	Mean	75th percentile	Maximum	No. Values Exceed All Flow Standard
07060710	15	1.0	1.0	1.0	1.2	1.0	4.5	0
BUFET002	2	0.33	--	--	--	--	0.86	0
WHI0011	59	0.34	0.89	1.09	2.33	2.19	16.50	0
WHI0029	63	0.98	3.43	4.70	9.54	8.75	61.20	10
WHI0046	59	0.56	1.06	1.54	5.20	2.56	62.0	5
WHI0065	61	0.48	1.10	1.63	4.23	3.19	47.30	4
WHI0065A	2	2.01	--	--	--	--	2.33	0
WHI0090	9	0.45	0.47	1.51	1.44	1.69	3.72	0
WHI0090A	9	0.16	0.34	0.69	0.89	0.99	2.96	0
WHI0139	3	2.38	2.43	2.59	2.57	2.70	2.74	0
WHI0140	3	1.21	1.24	1.34	1.45	1.68	1.80	0
WHI0141	3	0.90	1.04	1.46	1.32	1.56	1.60	0
WHI0144A	7	0.23	0.32	0.61	0.69	0.89	1.62	0
WHI0144B	1	1.46	--	--	--	--	--	0
WHI0144F	9	0.41	0.57	0.70	0.95	1.29	1.84	0
WHI0145B	7	0.26	0.33	1.40	1.33	2.11	3.06	0
WHI0151	16	0.55	1.24	1.80	1.68	2.09	2.55	0
WHI0159	8	0.33	0.58	0.74	0.77	1.00	1.17	0
WHI0161	7	1.28	1.70	2.48	3.39	3.37	9.92	0
WHI0162	9	0.25	0.96	1.78	5.97	5.52	35.20	1
WHI0166	16	3.85	5.88	8.81	11.19	13.50	41.60	1
WHI0167	13	3.92	8.78	11.60	14.39	14.32	37.70	2
WHI0168	9	0.81	1.29	1.72	3.44	2.84	15.4	0
WHI0201	18	0.64	1.63	2.00	6.15	2.79	75.60	1
WHI0202	10	0.55	0.58	0.82	1.37	2.02	3.63	0
WHI0204	7	1.20	1.34	1.64	6.44	6.37	29.8	1
WHI0205	3	1.24	1.31	1.51	1.54	1.79	1.88	0
WHI0206	3	2.83	3.23	4.43	6.12	9.43	11.0	0

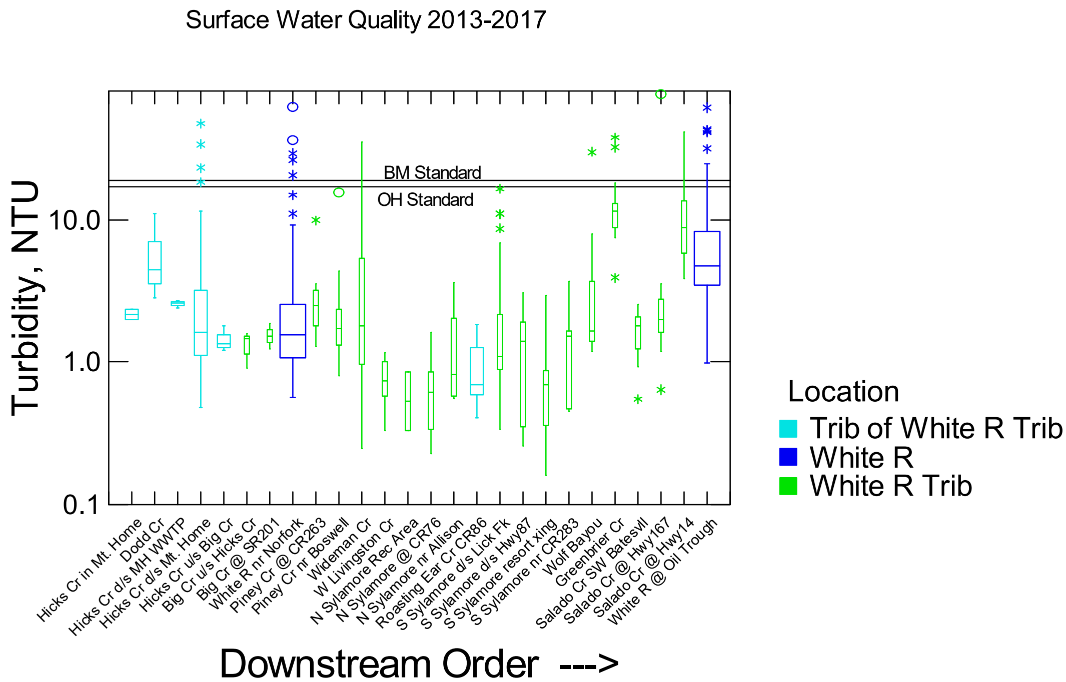


Figure 3.4. Box and whisker graph of all turbidity measurements from the Middle White River watershed for the period 2013-2017.

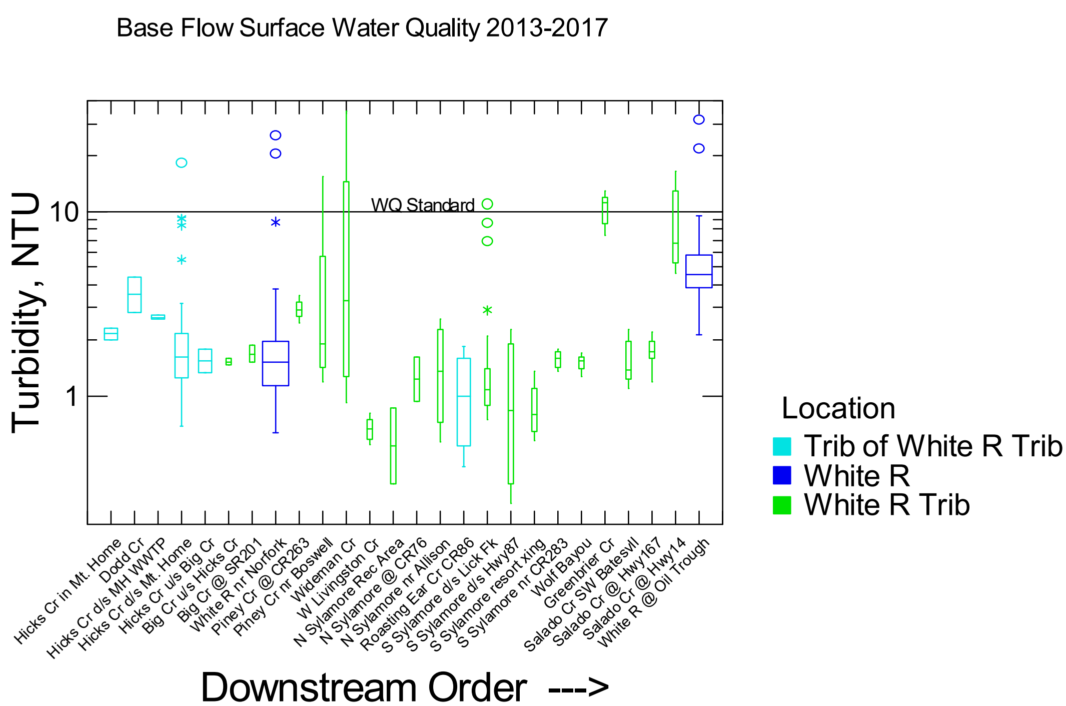


Figure 3.5. Box and whisker graph of base flow turbidity measurements (June through October) from the Middle White River watershed for the period 2013-2017.

3.1.3.1.2. TSS

Table 3.4 lists summary statistics for TSS measurements from the Middle White River watershed during the period 2013-2017. Figure 3.6 shows a box and whisker graph of these TSS measurements. Median TSS values appear to increase downstream in the White River, Piney Creek, and Salado Creek. No overall downstream trend is apparent in median TSS values from stations on other streams with multiple monitoring locations. In general, TSS concentrations throughout the watershed are relatively low.

Table 3.4. Summary statistics for TSS measurements (in mg/L) from 2013-2017 in Middle White River watershed.

Station ID	No. of measures	Minimum	25th percentile	Median	Mean	75th percentile	Maximum
BUFET002	2	0.5	--	--	--	--	4.5
WHI0011	59	0.5	0.5	1.0	1.6	1.5	15.3
WHI0029	63	0.5	3.5	6.0	9.2	13.1	37.5
WHI0046	59	0.5	1.0	2.0	5.2	3.4	67.3
WHI0065	61	0.5	1.0	1.5	2.6	2.6	22.3
WHI0065A	2	1.5	--	--	--	--	1.8
WHI0090	9	0.5	0.5	0.5	1.3	1.6	4.5
WHI0090A	9	0.5	0.5	0.5	0.7	0.6	1.5
WHI0139	3	3.2	3.3	3.5	3.4	3.5	3.5
WHI0140	3	0.5	0.8	1.5	1.3	1.9	2.0
WHI0141	3	1.0	1.1	1.5	2.1	3.2	3.8
WHI0144A	7	0.5	0.5	0.5	0.7	0.9	1.5
WHI0144B	1	1.0	--	--	--	--	--
WHI0144F	9	0.5	0.5	0.5	0.9	0.5	4.5
WHI0145B	7	0.5	0.5	0.5	0.7	0.5	2.0
WHI0151	16	0.5	0.5	0.5	0.9	1.0	2.5
WHI0159	8	0.5	0.5	0.5	0.9	1.0	3.0
WHI0161	7	0.5	1.1	1.5	1.5	2.0	2.5
WHI0162	9	0.5	0.9	1.8	3.1	5.6	7.0
WHI0166	16	3.2	5.6	8.5	9.4	10.0	29.0
WHI0167	13	2.7	6.6	11.0	11.9	17.1	27.5
WHI0168	9	0.5	0.5	2.3	3.1	3.6	11.8
WHI0201	18	0.5	0.5	1.0	6.0	1.5	91.3
WHI0202	10	0.5	0.5	0.5	0.7	0.5	2.0
WHI0204	7	0.5	0.5	1.0	4.7	4.3	23.5
WHI0205	3	1.0	1.1	1.5	1.9	2.8	3.2
WHI0206	3	4.0	4.2	5.0	9.3	15.4	18.8

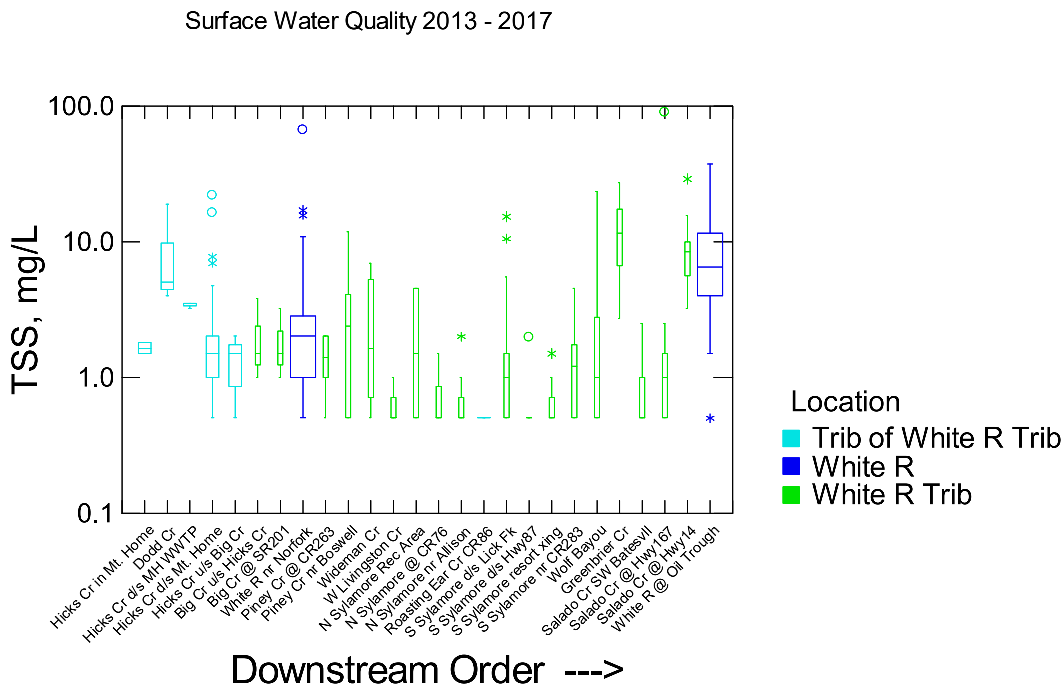


Figure 3.6. Box and whisker graph of TSS measurements from the Middle White River watershed for the period 2013-2017.

The highest median TSS concentration for the period 2013-2017 is at Greenbrier Creek (WHI0167), followed by Salado Creek at Highway 14 (WHI0166). These monitoring locations also have the highest median turbidity levels for this period. The lowest median TSS concentrations for this period are also at tributary stations. Eight tributary stations have median TSS concentrations less than the detection level (1 mg/L).

3.1.3.1.3. Suspended Sediment

Table 3.5 list summary statistics for suspended sediment measurements from 2013-2017. Figure 3.7 shows a box and whisker graph of suspended sediment measurements from the two USGS monitoring locations in the Middle White River watershed. As would be expected, suspended sediment concentrations in the White River (07060500) are higher than those in North Sylamore Creek (07060710).

Table 3.5. Summary statistics for suspended sediment measurements (in mg/L) from 2013-2017.

Station ID	No. of measures	Minimum	25th percentile	Median	Mean	75th percentile	Maximum
07060500	17	1.0	3.0	7.0	8.4	9.8	25.0
07060710	14	0.5	1.0	2.0	2.4	3.0	7.0

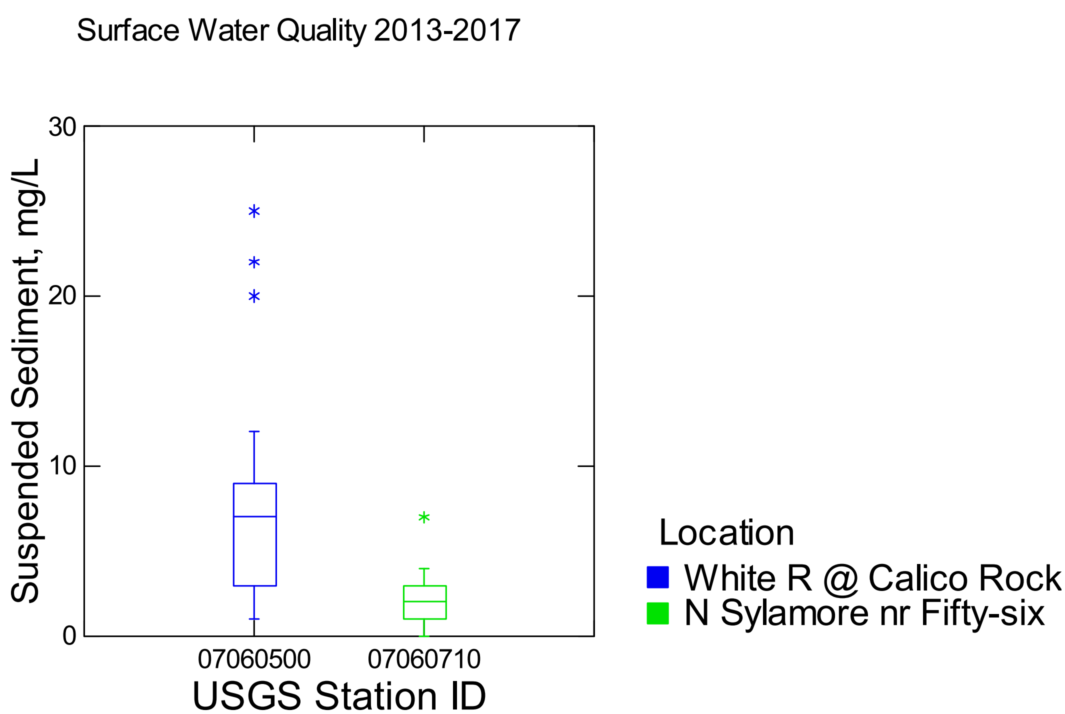


Figure 3.7. Box and whisker graph of suspended sediment measurements from the Middle White River watershed for the period 2013-2017.

3.1.3.2 *E. coli*

E. coli bacteria are monitored as an indicator of the risk to human health from contact with pathogens in the water. 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 recreation (e.g., boating).

E. coli measurements were collected during the period 2013-2017 by the USGS and ADEQ. During this period, USGS measured *E. coli* quarterly at the water quality station on the White River at Calico Rock (07060500). Table 3.6 lists summary statistics for these measurements from the primary and secondary contact seasons. All of these measurements are less than the applicable state numeric criteria.

Table 3.6 Summary statistics of USGS *E. coli* measurements (in cfu/100mL) for the period 2013-2017.

Statistic	Primary Contact (May-September)	Secondary Contact (October-April)
Number of measurements	7	11
Minimum	8.0	3.0
25th Percentile	9.2	5.0
Median	10.0	22.0
Mean	28.3	26.9
75th Percentile	49.5	46.8
Maximum	85.0	75.0

In 2015, ADEQ collected *E. coli* measurements from impaired waters in the Middle White River watershed. These data were not included in the ADEQ online water quality database at the time we did our search, but were provided to us by ADEQ personnel (J. Wise, ADEQ, personal communication, 8/7/2018). Eight measurements were collected from May through September. Measurements were collected at six stations in the Big Creek and Hicks Creek watershed, from the Mountain Home WWTP effluent, and from the station on Greenbrier Creek. A statistical summary of these measurements is given in Table 3.7. There is at least one measurement from all but one station that is greater than the primary season *E. coli* criterion. Two stations, WHI0139 and WHI0065, do not meet the *E. coli* water quality standard criteria (see Section 2.7).

Table 3.7. Summary statistics of ADEQ *E. coli* measurements (in cfu/100mL) from 2015 Primary Contact Season.

Station ID	Location Description	No. of Measures	Minimum	Mean	Median	Maximum	No. Values Exceed Standard
WHI0206	Dodd Cr	8	28	525	180	>2,000	2
WHI0065A	Hicks Cr upstream of WWTP	7	41	388	184	1,350	1
HIC02E	WWTP effluent	7	41	197	104	725	1
WHI0139	Hicks Cr downstream of WWTP	8	140	653	371	>2,000	3
WHI0065	Hicks Cr downstream	8	55	372	140	1,175	3
WHI0140	Hicks Cr downstream	4	14	174	104	475	1
WHI0205	Big Cr downstream of Hicks Cr	6	<1	62	66	96	0
WHI0167	Greenbrier Cr	8	48	150	86	625	1

3.1.3.3 Total Phosphorus

Total phosphorus is a nutrient that is not harmful to humans or animals itself. However, it can stimulate algal growth in surface waters. The algae may produce toxins that can harm humans or animals, or, so much algae may be produced that when they die off 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 any phosphorus compounds, including total phosphorus, that apply in the Middle White River watershed.

Table 3.8 lists summary statistics for total phosphorus measurements from 2013-2017. Figure 3.8 shows a box and whisker graph of total phosphorus measurements in the Middle White River watershed from the period 2013-2017. The locations with the highest median total phosphorus values for the period 2013-2017 are on Hicks Creek downstream of the Mountain Home WWTP discharge (WHI0065, WHI0140, WHI0141) and Big Creek downstream of the Hicks Creek inflow (WHI0205). The lowest median total phosphorus concentrations during this period are less than the detection level. Locations where median concentrations are less than detection level include White River near Norfork (WHI0046) and at Calico Rock (07060500), North Sylamore Creek near Fifty-Six (07060710), and Wolf Bayou (WHI0204). Median total phosphorus concentrations in Salado Creek (WHI0151, WHI0201, WHI0166) appear to increase downstream, and the median total phosphorus concentration at the downstream White River station (WHI0029 at Oil Trough) is higher than the upstream White River stations (near Norfork, WHI0046, and at Calico Rock, 07060500).

Table 3.8. Summary statistics of total phosphorus measurements (in mg/L) from 2013-2017.

Station ID	No. of measures	Minimum	25th percentile	Median	Mean	75th percentile	Maximum
07060500	19	0.010	0.010	0.010	0.018	0.020	0.070
07060710	17	0.002	0.002	0.002	0.003	0.002	0.009
BUFET002	2	0.025	--	--	0.027	--	0.029
WHI0011	58	0.005	0.042	0.055	0.062	0.070	0.239
WHI0029	63	0.005	0.005	0.031	0.094	0.042	2.700
WHI0046	58	0.005	0.005	0.005	0.053	0.050	0.340
WHI0065	60	0.128	0.599	0.885	1.313	1.975	5.430
WHI0065A	2	0.005	0.005	0.014	0.014	0.023	0.023
WHI0090	9	0.034	0.045	0.052	0.059	0.055	0.141
WHI0090A	9	0.024	0.039	0.048	0.056	0.053	0.154
WHI0139	3	0.605	0.949	1.980	2.125	3.338	3.790
WHI0140	3	0.449	0.719	1.530	1.890	3.150	3.690
WHI0141	3	0.031	0.032	0.034	0.067	0.111	0.137
WHI0144A	7	0.005	0.022	0.025	0.024	0.028	0.038
WHI0144B	1	0.175	--	--	--	--	--
WHI0144F	9	0.033	0.038	0.040	0.041	0.046	0.052
WHI0145B	7	0.036	0.047	0.052	0.049	0.053	0.055

Table 3.8. Summary statistics of total phosphorus measurements (in mg/L) from 2013-2017 (continued).

Station ID	No. of measures	Minimum	25th percentile	Median	Mean	75th percentile	Maximum
WHI0151	16	0.005	0.005	0.013	0.054	0.028	0.628
WHI0159	8	0.005	0.015	0.026	0.026	0.036	0.048
WHI0161	7	0.005	0.022	0.032	0.029	0.040	0.042
WHI0162	9	0.005	0.026	0.029	0.032	0.039	0.065
WHI0166	16	0.005	0.025	0.052	0.158	0.071	1.170
WHI0167	13	0.005	0.058	0.086	0.169	0.118	1.230
WHI0168	9	0.027	0.028	0.031	0.034	0.035	0.060
WHI0201	18	0.005	0.005	0.024	0.028	0.032	0.127
WHI0202	10	0.005	0.024	0.026	0.089	0.038	0.495
WHI0204	7	0.005	0.005	0.005	0.130	0.076	0.750
WHI0205	3	0.185	0.257	0.472	0.412	0.552	0.579
WHI0206	3	0.021	0.022	0.023	0.030	0.040	0.045

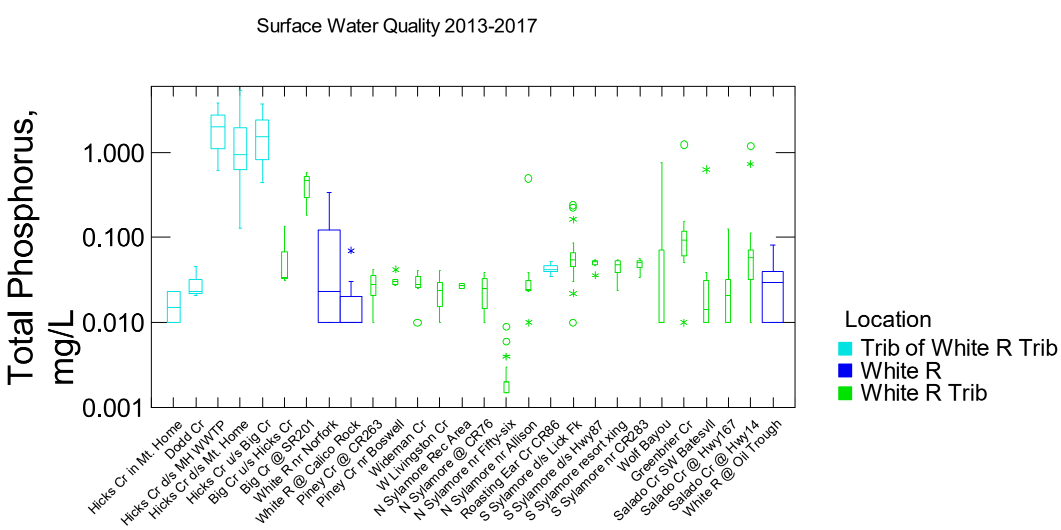


Figure 3.8. Box and whisker graph of total phosphorus measurements from Middle White River watershed for the period 2013-2017.

3.1.3.4 Dissolved Inorganic Nitrogen

Dissolved 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. Dissolved inorganic nitrogen is also a nutrient that can stimulate algal growth in surface waters. The algae may produce toxins that can harm humans or animals, or, so much algae may be produced that when they die off 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 dissolved inorganic nitrogen to protect against increased algal growth that apply in the Middle White River watershed.

Table 3.9 lists summary statistics for dissolved inorganic nitrogen measurements from 2013-2017. Figure 3.9 shows a box and whisker graph of dissolved inorganic nitrogen measurements in the Middle White River watershed from the period 2013-2017. All dissolved inorganic nitrogen measurements in the Middle White River watershed from the period 2013-2017 are less than the nitrate drinking water quality standard. The highest median dissolved inorganic nitrogen concentrations from this period are tributary monitoring locations, on Hicks Creek downstream of the Mountain Home WWTP discharge (WHI0065, WHI0140, WHI0141), and Big Creek downstream of the Hicks Creek inflow (WHI0205). The median dissolved inorganic nitrogen concentrations in Roasting Ear Creek (WHI0144F) and its receiving stream, South Sylamore Creek (WHI0011, WHI0145B, WHI0090, WHI0090A), are also higher than the rest of the monitoring locations in the watershed.

Median dissolved inorganic nitrogen concentrations are relatively similar at all of the White River monitoring locations. In Hicks Creek downstream of the Mountain Home WWTP and South Sylamore Creek downstream of Roasting Ear Creek median dissolved inorganic nitrogen concentrations appear to decline in the downstream direction, suggesting dilution.

Table 3.9. Summary statistics for dissolved inorganic nitrogen measurements (in mg/L) from 2013-2017.

Station ID	No. of measures	Minimum	25th percentile	Median	Mean	75th percentile	Maximum
07060500	19	0.118	0.182	0.295	0.281	0.366	0.443
07060710	49	0.020	0.040	0.060	0.062	0.080	0.150
BUFET002	2	0.015	--	--	--	--	0.081
WHI0011	43	0.265	0.418	0.560	0.597	0.688	1.300
WHI0029	45	0.118	0.232	0.303	0.295	0.341	0.446
WHI0046	43	0.084	0.222	0.273	0.304	0.346	0.713
WHI0065	45	0.229	1.422	1.930	1.994	2.330	4.300
WHI0065A	2	0.138	--	--	--	--	0.799
WHI0090	7	0.147	0.305	0.438	0.465	0.618	0.882
WHI0090A	7	0.157	0.320	0.443	0.479	0.663	0.885
WHI0139	3	1.940	2.155	2.800	2.733	3.295	3.460
WHI0140	3	1.210	1.350	1.770	1.787	2.228	2.380
WHI0141	3	0.434	0.435	0.439	0.460	0.491	0.508
WHI0144A	4	0.015	0.015	0.022	0.030	0.044	0.058
WHI0144F	7	0.327	0.683	0.804	0.840	1.076	1.260
WHI0145B	7	0.230	0.367	0.463	0.535	0.712	0.954
WHI0151	14	0.015	0.054	0.112	0.162	0.164	0.562
WHI0159	7	0.015	0.015	0.035	0.037	0.054	0.076
WHI0161	6	0.015	0.015	0.049	0.045	0.056	0.087
WHI0162	8	0.015	0.0465	0.066	0.068	0.094	0.115
WHI0166	15	0.015	0.136	0.173	0.200	0.242	0.517
WHI0167	12	0.092	0.179	0.360	0.358	0.471	0.770
WHI0168	8	0.073	0.101	0.118	0.148	0.204	0.260
WHI0201	17	0.015	0.015	0.051	0.069	0.088	0.261
WHI0202	8	0.033	0.119	0.168	0.154	0.196	0.231
WHI0204	7	0.015	0.045	0.054	0.060	0.063	0.137
WHI0205	3	0.671	0.734	0.925	0.842	0.928	0.929
WHI0206	3	0.033	0.057	0.129	0.206	0.375	0.457

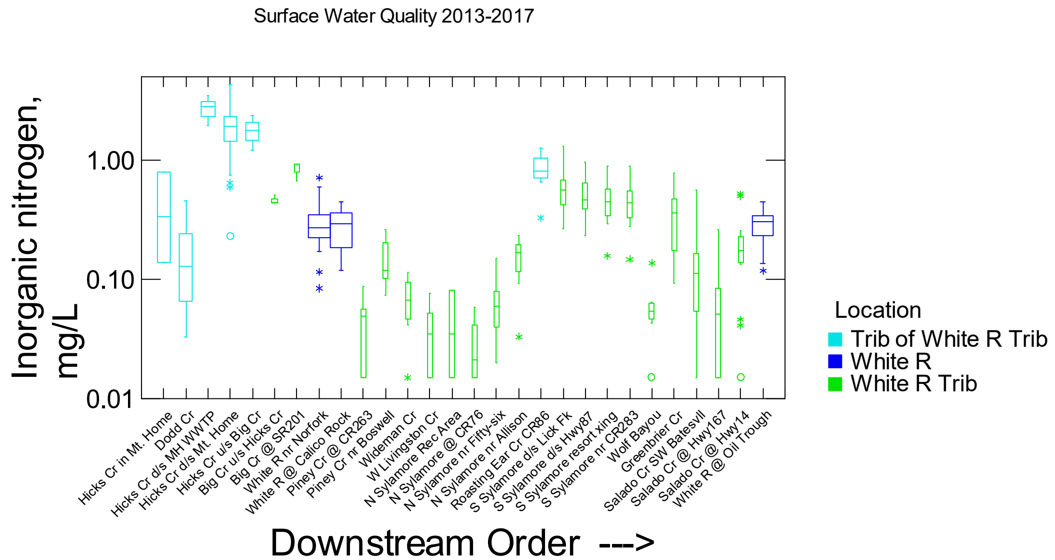


Figure 3.9. Box and whisker graph of dissolved inorganic nitrogen measurements from Middle White River watershed for the period 2013-2017.

3.1.3.5 Total Nitrogen

Total nitrogen is the sum of nitrate, nitrite, and total Kjeldahl nitrogen in water. Nitrogen is a nutrient that can stimulate algal growth in surface waters. The algae may produce toxins that can harm humans or animals, or, so much algae may be produced that when they die off 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 to protect against increased algal growth that apply in the Middle White River watershed.

Table 3.10 lists summary statistics for total nitrogen measurements from 2013-2017. Figure 3.10 shows a box and whisker graph of total nitrogen measurements in the Middle White River watershed from the period 2013-2017. The highest median total nitrogen concentrations from this period are tributary monitoring locations, on Hicks Creek downstream of the Mountain Home WWTP discharge (WHI0065, WHI0140, WHI0141), and Big Creek downstream of the Hicks Creek inflow (WHI0205). The median total nitrogen concentrations in Roasting Ear Creek (WHI0144F) and its receiving stream, South Sylamore Creek (WHI0011, WHI0145B, WHI0090, WHI0090A), are also higher than the rest of the monitoring locations in the watershed. The lowest median total nitrogen concentration for this period is in North Sylamore Creek at County Road 93 (WHI0144A).

Median total nitrogen concentrations at White River stations increase in the downstream direction (Figure 3.10). Median total nitrogen concentrations decrease in Hicks Creek downstream of the Mountain Home discharge, and in South Sylamore Creek downstream of Roasting Ear Creek. In Piney Creek, North Sylamore Creek, and Salado Creek, median total nitrogen concentrations are lower at upstream locations and highest at the farthest downstream locations.

Table 3.10. Summary statistics for total nitrogen measurements (in mg/L) from 2013-2017.

Station ID	No. of measures	Minimum	25^{th} percentile	Median	Mean	75^{th} percentile	Maximum
07060500	19	0.270	0.400	0.530	0.538	0.580	1.400
07060710	16	0.060	0.073	0.095	0.114	0.140	0.300
BUFET002	2	0.079	--	--	--	--	0.170
WHI0011	58	0.338	0.607	0.722	0.790	0.937	1.820
WHI0029	69	0.301	0.460	0.558	1.093	0.638	12.550
WHI0046	58	0.256	0.452	0.494	0.543	0.621	1.000
WHI0065	60	0.482	1.810	2.455	2.826	3.300	8.250
WHI0065A	2	0.247	--	--	--	--	0.965
WHI0090	9	0.336	0.397	0.597	0.611	0.740	1.040
WHI0090A	9	0.342	0.408	0.588	0.613	0.764	1.050
WHI0139	3	2.300	2.668	3.770	3.383	4.002	4.080
WHI0140	3	1.500	1.718	2.370	2.233	2.715	2.830
WHI0141	3	0.549	0.604	0.768	0.705	0.791	0.799
WHI0144A	7	0.030	0.071	0.120	0.141	0.188	0.303
WHI0144B	1	0.922	--	--	--	--	--
WHI0144F	9	0.378	0.733	0.926	0.919	1.125	1.400
WHI0145B	7	0.383	0.485	0.628	0.696	0.912	1.150
WHI0151	16	0.171	0.274	0.328	0.383	0.486	0.670
WHI0159	8	0.000	0.127	0.168	0.161	0.220	0.259
WHI0161	7	0.130	0.147	0.244	0.242	0.288	0.457
WHI0162	9	0.117	0.146	0.200	0.243	0.323	0.438
WHI0166	16	0.299	0.434	0.520	0.563	0.654	1.230
WHI0167	13	0.271	0.623	0.788	0.780	0.972	1.360
WHI0168	9	0.218	0.263	0.356	0.336	0.386	0.435
WHI0201	18	0.124	0.251	0.319	0.328	0.358	0.818
WHI0202	10	0.093	0.219	0.278	0.274	0.362	0.403
WHI0204	7	0.118	0.191	0.255	0.296	0.321	0.637
WHI0205	3	1.000	1.025	1.100	1.157	1.302	1.370
WHI0206	3	0.290	0.298	0.322	0.426	0.581	0.667

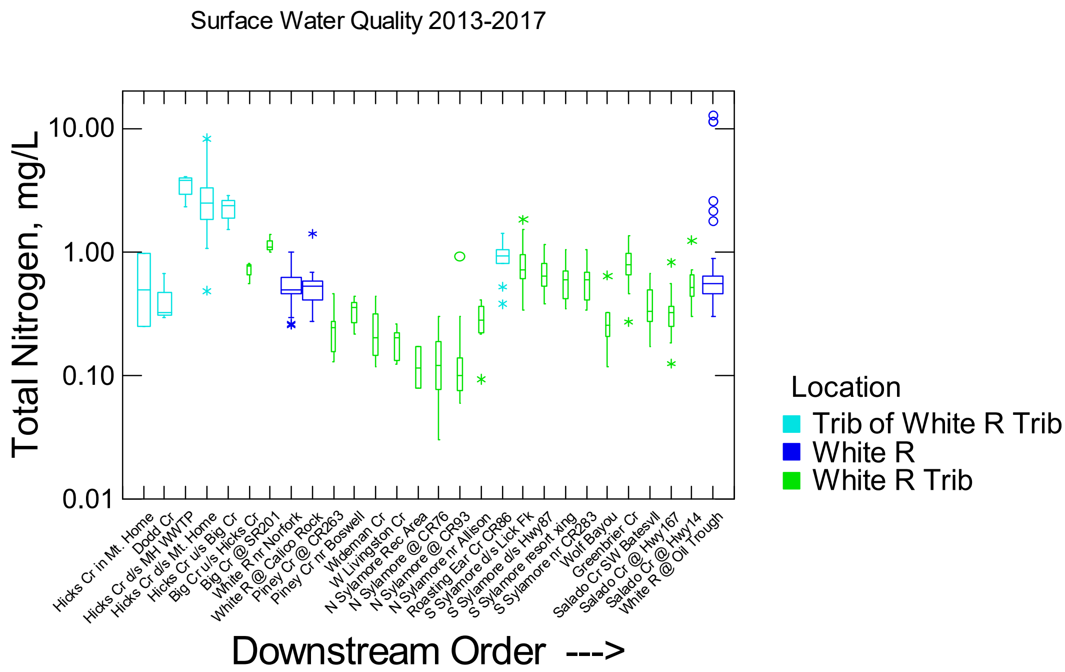


Figure 3.10. Box and whisker graph of total nitrogen measurements from Middle White River watershed for the period 2013-2017.

3.1.3.6 Dissolved Oxygen (DO)

DO in water is used by fish and other aquatic creatures living in streams. Figure 3.11 shows a box and whisker graph of DO measurements from the Middle White River watershed during the period 2013-2017. For the most part, DO concentrations at monitored locations in the White River watershed ranged from 5 mg/L to 15 mg/L during this period. The lowest median DO concentration during this period is from Greenbrier Creek. The highest median DO concentration during this period is from Big Creek at State Road 201 (WHI0205). Table 3.11 lists summary statistics for DO measurements from the period 2013-2017.

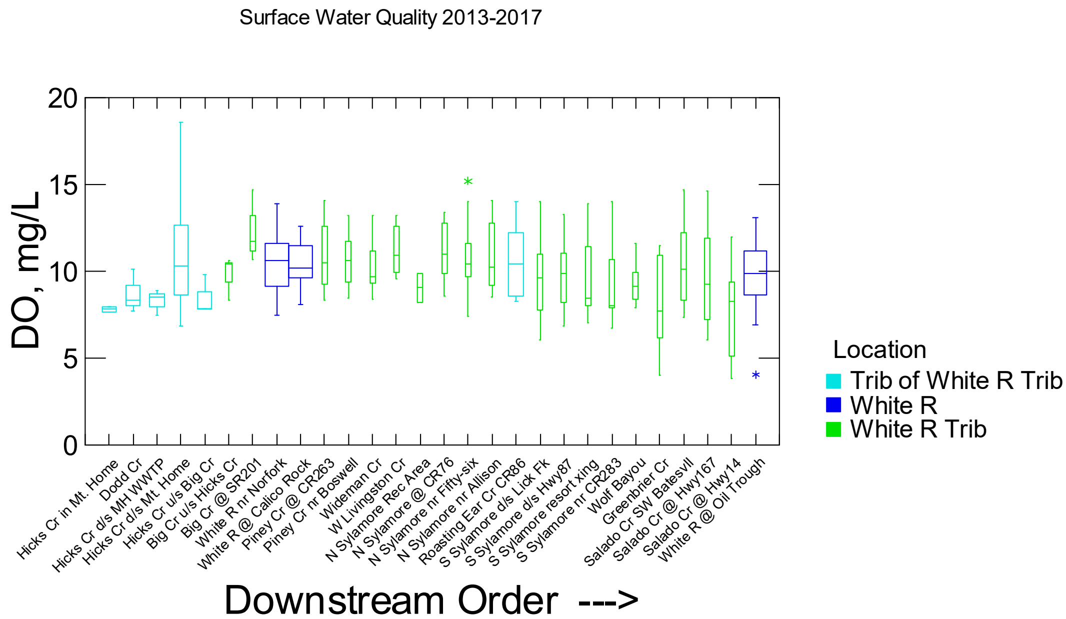


Figure 3.11. Box and whisker graph of DO measurements from Middle White River watershed for the period 2013-2017.

Table 3.11. Summary statistics for DO measurements (in mg/L) 2013-2017.

Station ID	No. of measures	Minimum	25th percentile	Median	Mean	75th percentile	Maximum	No. Values <5mg/L
WHI0144B	1	12.8	--	--	--	--	--	0
WHI0065A	2	7.66	--	--	--	--	7.98	0
WHI0206	3	7.74	7.89	8.35	8.73	9.66	10.1	0
WHI0139	3	7.48	7.74	8.50	8.29	8.78	8.88	0
WHI0065	59	6.85	8.60	10.3	11.0	12.7	18.6	0
WHI0140	3	7.84	7.84	7.85	8.50	9.31	9.80	0
WHI0141	3	8.36	8.87	10.4	9.79	10.6	10.6	0
WHI0205	3	10.7	11.0	11.7	12.4	14.0	14.7	0
WHI0046	57	7.48	9.10	10.6	10.6	11.6	13.9	0
07060500	19	8.10	9.55	10.2	10.4	11.5	12.6	0
WHI0161	7	8.35	9.10	10.5	11.0	13.0	14.1	0
WHI0168	9	8.45	9.36	10.6	10.8	12.0	13.2	0
WHI0162	9	8.40	9.09	9.68	10.4	11.6	13.2	0
WHI0159	8	9.55	9.91	11.0	11.2	12.6	13.2	0
BUFET002	2	8.20	--	--	--	--	9.89	0
WHI0144A	7	8.56	9.40	11.0	11.2	13.0	13.4	0
07060710	53	7.40	9.70	10.4	10.7	11.6	15.2	0
WHI0202	10	8.49	9.21	10.3	10.8	12.8	14.1	0
WHI0144F	9	8.24	8.56	10.4	10.5	12.4	14.0	0
WHI0144B	1	12.8	--	--	--	--	--	0
WHI0011	57	6.07	7.78	9.61	9.60	11.0	14.0	0
WHI0145B	7	6.88	8.21	9.89	9.80	11.3	13.3	0
WHI0090A	9	7.03	7.84	8.48	9.61	11.6	13.9	0
WHI0090	9	6.70	7.72	8.02	9.38	11.1	14.0	0
WHI0204	7	7.93	8.24	9.15	9.34	10.2	11.6	0
WHI0167	13	4.00	6.08	7.70	7.96	11.0	11.5	2
WHI0151	16	7.35	8.33	10.1	10.3	12.2	14.7	0
WHI0201	18	6.04	7.20	9.28	9.65	11.9	14.6	0
WHI0166	15	3.81	4.77	8.26	7.74	9.45	12.0	4
WHI0029	68	4.05	8.62	9.89	9.90	11.2	13.1	1

Figure 3.12 shows box and whisker graphs of DO measurements from the primary seasons of 2013-2017. Arkansas water quality regulations define the primary season for DO as when water temperature is 22 deg C or less, usually September to May. In addition, the numeric primary season DO water quality standard that applies in the Middle White River watershed is shown on the graph. For the most part, during the period 2013-2017, 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 two tributary stations, Greenbrier Creek (WHI0167) and Salado Creek at Highway 14 (WHI0166).

Figure 3.13 shows box and whisker graphs of DO measurements from the critical seasons of 2013-2017. Arkansas water quality regulations define the critical season for DO as when water temperature is above 22 deg C, usually May to September. Lines showing the numeric criteria for DO that apply in the Middle White River watershed are shown on Figure 3.13. For the most part, critical season DO measurements from 2013-2017 meet the numeric DO criteria. The three locations where not all DO measurements meet the applicable criterion are Greenbrier Creek (WHI0167), Salado Creek at Highway 14 (WHI0166), and White River at Oil Trough (WHI0029).

3.1.4 Current Water Quality Summary

Two monitored streams, Hicks Creek and Greenbrier Creek, have been classified as impaired by ADEQ. Several of the monitored streams have relatively high concentrations of sediment and/or nutrients. Hicks Creek and Big Creek downstream of the Hicks Creek confluence, have the highest median nutrient concentrations of the monitored locations in the watershed. Greenbrier Creek has measured DO concentrations less than 5 mg/L, and some of the highest median turbidity, TSS, total nitrogen and total phosphorus concentrations in the watershed. Water quality monitoring stations on Roasting Ear Creek, and South Sylamore Creek have relatively high median concentrations of some nutrients. The most downstream Salado Creek station, and White River at Oil Trough also have relatively high median TSS and turbidity concentrations.

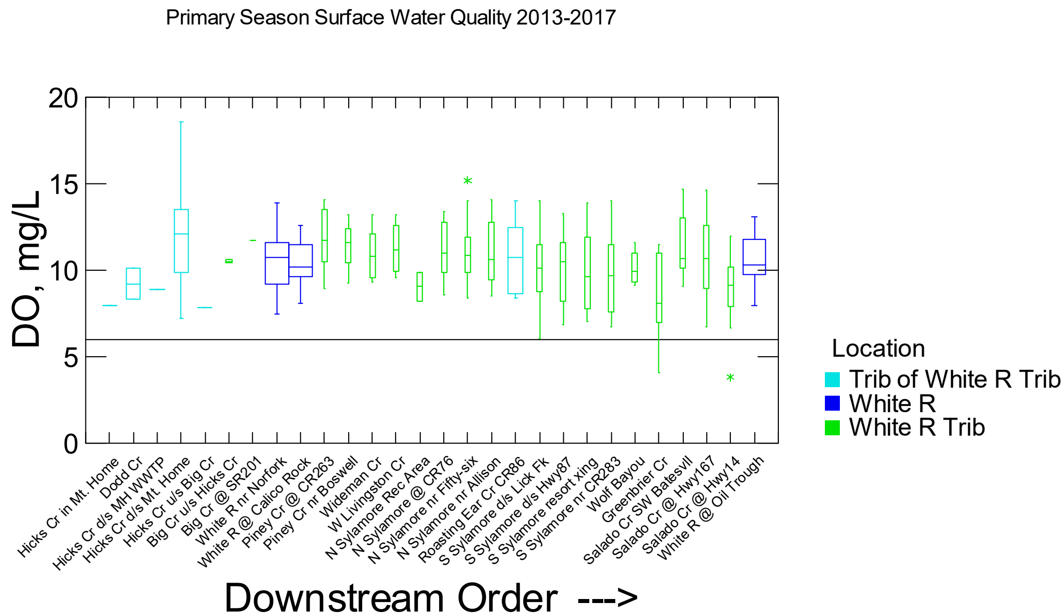


Figure 3.12. Box and whisker graph of primary season DO measurements from Middle White River watershed for the period 2013-2017.

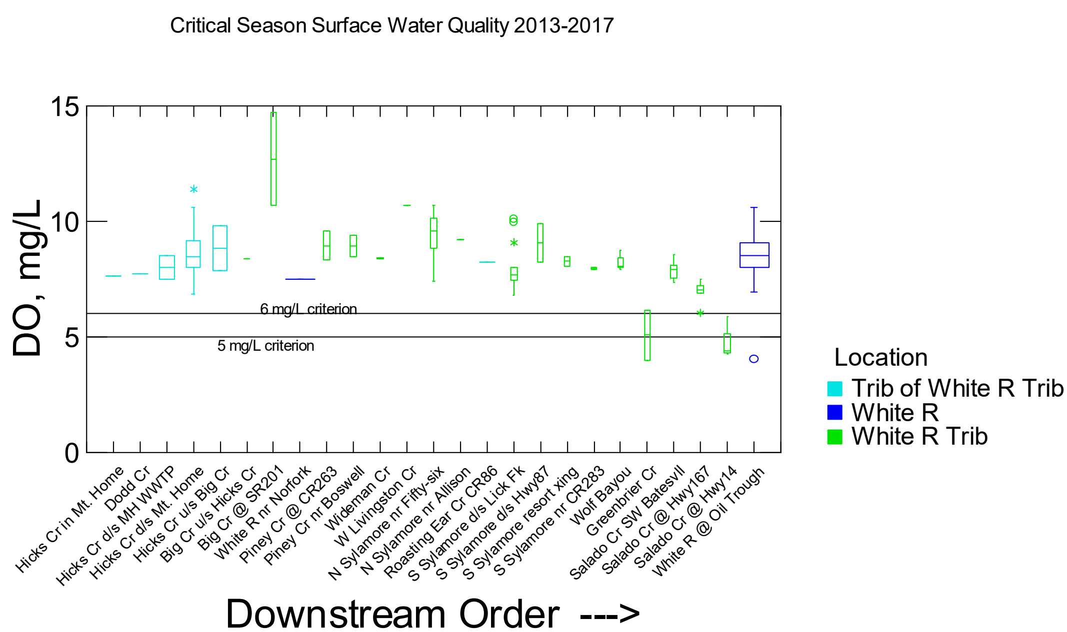


Figure 3.13. Box and whisker graph of critical season DO measurements from Middle White River watershed for the period 2013-2017.

3.2 Water Quality Over Time

While it is important to look at current water quality conditions in the watershed, it is also important to determine if water quality is changing over time. Of particular interest for nonpoint source management are locations where water quality still meets water quality standards, but pollutant concentrations are increasing over time, suggesting that water quality standards may not be met in the future if no action is taken. Locations where pollutant concentrations are decreasing over time suggest that water quality is improving and that upstream pollutant management practices are working.

3.2.1 WQ stations with long data records

There are 11 water quality monitoring stations with data records of at least 10 years that appear suitable for evaluation to determine if water quality has changed significantly over time. These stations are listed in Table 3.12. The locations of these monitoring stations are shown on Figure 3.1. There are three stations on South Sylamore Creek, one of which is a continuous record station, WHI0011. The only stations with intermittent data records evaluated for water quality changes are the ADEQ roving stations (WHI0166, WHI0167, and WHI0168). The intermittent data records from the South Sylamore Creek stations WHI0090 and WHI0145B are judged to not be consistent enough to be comparable over time (see Section 3.2.4). Therefore, the data from these stations is not analyzed.

Table 3.12. Active water quality monitoring stations with data records of at least 10 years.

Station	Agency	Stream	Location	Data Period	Type of data record
WHI0011	ADEQ	S. Sylamore Cr	d/s Lick Cr (Mountain View WWTP)	1993-2017	Continuous
WHI0029	ADEQ	White R	Oil Trough	1990-2017	Continuous
WHI0046	ADEQ	White R	Norfork	1990-2017	Continuous
WHI0065	ADEQ	Hicks Cr	D/S Mt. Home	1990-2017	Continuous
WHI0090*	ADEQ	S. Sylamore Cr	CR283	1991-2015	Intermittent
WHI0145B*	ADEQ	S. Sylamore Cr	d/s Hwy 87	1997-2014	Intermittent
WHI0168	ADEQ	Piney Cr	Near Boswell	2001-2015	Intermittent
WHI0166	ADEQ	Salado Cr	Hwy 167	2001-2016	Intermittent
WHI0167	ADEQ	Greenbrier Cr	Hwy25	2001-2016	Intermittent
07060500	USGS	White R	Calico Rock	1972-2017	Continuous
07060710	USGS	N. Sylamore Cr	Near Fifty-Six	1969-2017	Continuous

*Excluded from analysis

3.2.2 Trend Analysis of Data from Continuous Record Stations

Water quality data collected continuously, or with only short data gaps, can be evaluated mathematically to see if they exhibit trends. Therefore, data for parameters of interest from the six long term data stations with continuous data records (WHI0011, WHI0029, WHI0065, WHI0046, 07060500, and 07060710) were analyzed for trends. The analyses of these data are described in detail in Appendix B. Because of the characteristics of these data sets, non-parametric trend analysis was used. In the majority of the data sets evaluated, no trend was apparent. The stations where parameters of interest did exhibit trends identified by the analyses are listed in Table 3.13. Note that data sets for some of the parameters from some of the stations were not sufficient to be analyzed for trends (see Appendix B for full explanations).

Table 3.13. Water quality stations where parameters of interest exhibit trends.

Station	Stream	Parameter	Trend direction
WHI0011	S. Sylamore Cr	DO (2004-2017)	Decreasing
WHI0065	Hicks Cr	DO	Increasing
		Inorganic nitrogen	Decreasing
		Total nitrogen	Decreasing
07060500	White R	Total nitrogen	Increasing
07060710	N. Sylamore Cr	DO	Increasing

The decreasing trend in DO concentrations in South Sylamore Creek (WHI0011) over the period 2004-2017, may indicate declining water quality, and could be related to the relatively high nutrient concentrations reported in this stream system.

The increasing DO trend in Hicks Creek (WHI0065) could be the result of increased productivity due to relatively high nutrient levels, which could result in algae blooms. Perhaps the declining trends in nitrogen will help improve conditions. However, growth of some nuisance algae in freshwater systems is usually limited by the amount of phosphorus present, and there is no indication that phosphorus concentrations are declining in Hicks Creek. The declining trends in nitrogen concentrations in Hicks Creek at station WHI0065 could be a response to improvements in the Mountain Home WWTP.

The increasing trend in total nitrogen at the White River station at Calico Rock (07060500) may indicate a potential for water quality issues in the future. The increasing trend in DO in North Sylamore Creek may indicate improving water quality. This increasing trend appears to be the result of fewer low DO concentrations, which would seem to indicate better water quality. This is different from the increasing trend in DO concentrations in Hicks Creek, which is primarily the result of increasing high DO concentrations, indicative of increased productivity.

3.2.3 Analysis of Data from Intermittent Stations

There are five water quality stations with intermittent data records. To determine if it is a good idea to compare data from the different monitoring periods at these stations, the characteristics of the data sets from these periods were evaluated. Table 3.14 lists sampling periods and numbers of samples from each period for these stations. The number of samples collected and the length of the two sampling periods at stations WHI0090 and WHI0145B appear too different to be used to compare water quality over time. The data records from the two sampling periods at the three ADEQ roving water quality stations (WHI0166, WHI0167, WHI0168) appear similar enough to be used to compare water quality over time.

Table 3.14. Sampling periods and data sets for long term stations with intermittent records.

Station	Stream	Sampling period	Number of samples
WHI0090	S. Sylamore Cr	1991-1993	26-29
		2013-2015	9
WHI0145B	S. Sylamore Cr	1997-2000	18-20
		2013-2014	7
WHI0166	Salado Cr	2001-2003	11-12
		2013-2016	15-16
		2013-2015	13-14
WHI0167	Greenbrier Cr	2001-2003	11-12
		2013-2016	13
WHI0168	Piney Cr	2001-2003	11-12
		2013-2015	9

To evaluate whether concentrations of parameters of interest at the three ADEQ roving water quality stations are different during the two sampling periods, the median values for the data from the two periods were compared using box and whisker graphs. These box and whisker graphs include a notch that indicates the 95% confidence interval around the median value. When the notches of two box graphs overlap, the median values are not statistically significantly different. If the notches do not overlap, the median values are statistically significantly different, indicating a statistically significant difference in water quality for the two sampling periods.

Figures 3.14 through 3.17 show box and whisker graphs comparing inorganic nitrogen, total nitrogen, total phosphorus, and DO from the two roving sampling periods for the three roving stations in the Middle White River watershed. Note that fecal coliform and *E. coli* measurements were collected at these stations only in 2003, so changes cannot be evaluated for these fecal contamination indicators. For these stations, the median values from the 2013-2016 monitoring period are usually lower than the median values from the 2001-2003 monitoring period. However, only for total nitrogen at station WHI0167 (Greenbrier Creek) is the median value for the 2013-2016 data statistically significantly lower than the median value for the 2001-2003 data. A statistically significant decrease in total nitrogen suggests the possibility that water quality has improved between the two periods. The fact that the median dissolved oxygen concentration is higher for the 2013-2016 period than for the 2001-2003 period also suggests improved water quality. Another set of data will need to be collected to confirm that the different in total nitrogen concentrations represents an actual change, rather than natural variation in concentrations. The significant decrease in total nitrogen concentrations at the Greenbrier Creek station appears to be more the result of decreases in organic nitrogen (see total Kjeldahl nitrogen (TKN) graph on Figure 3.18), than decreases in inorganic nitrogen, which are not statistically significant (see inorganic nitrogen graphs on Figure 3.14).

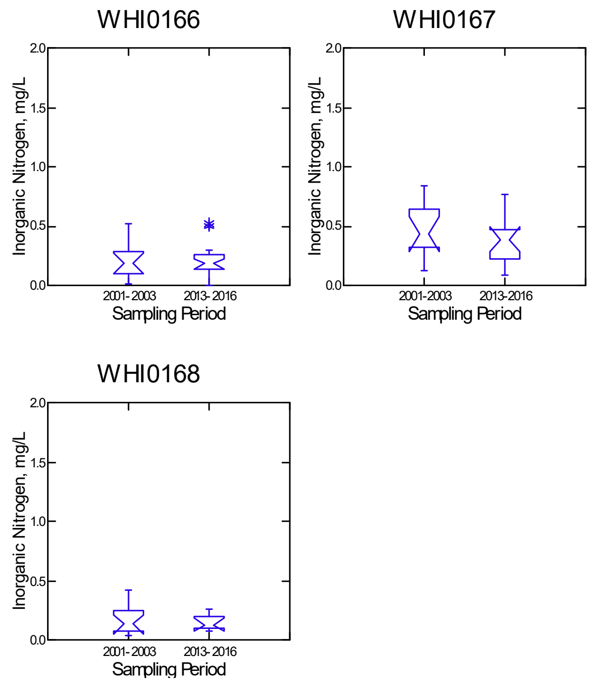


Figure 3.14. Comparison of dissolved inorganic nitrogen data from two sampling periods at ADEQ roving water quality stations.

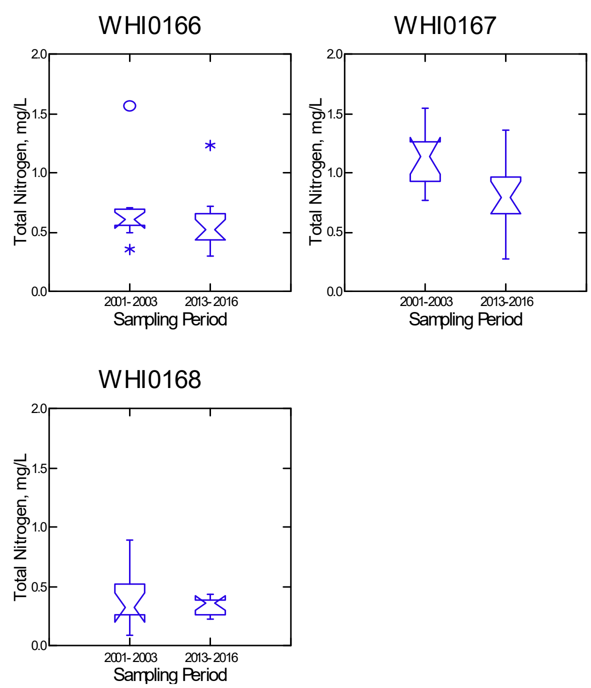


Figure 3.15. Comparison of total nitrogen data from two sampling periods at ADEQ roving water quality stations.

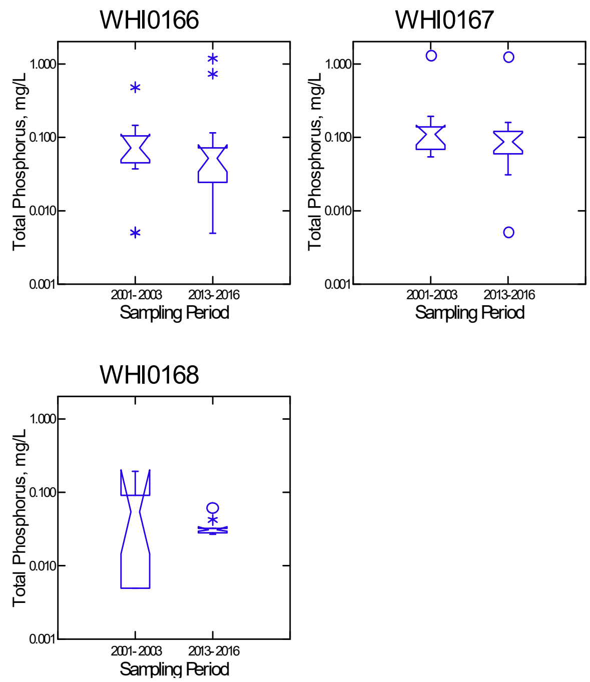


Figure 3.16 Comparison of total phosphrous data from two sampling periods at ADEQ roving water quality stations.

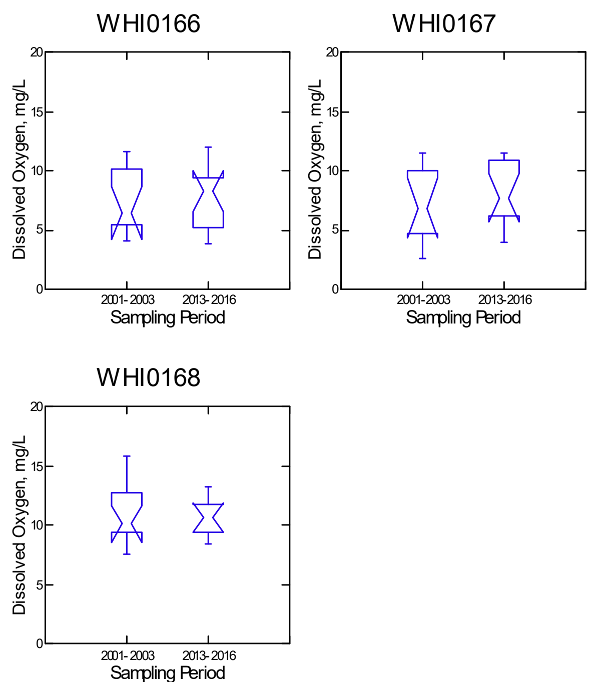


Figure 3.17 Comparison of DO data from two sampling periods at ADEQ roving water quality stations.

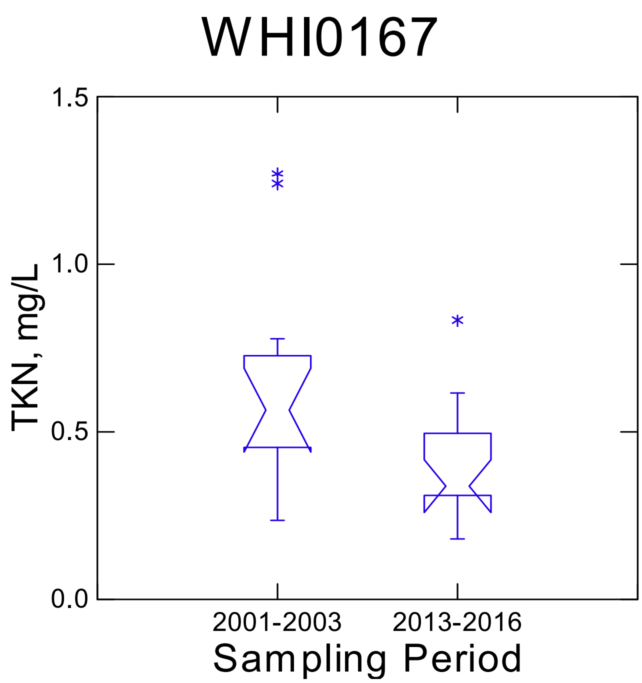


Figure 3.18 Comparison of TKN data from two sampling periods at an ADEQ roving water quality station.

3.2.4 Summary of Water Quality Over Time

There are nine water quality stations in the Middle White River watershed with long data records adequate to evaluate changes in water quality over time. Changes in dissolved inorganic nitrogen, total nitrogen, total phosphorus, and dissolved oxygen are evaluated. At stations with continuous data records, i.e., no long periods without measurements, statistical analyses are conducted to determine if there are long term trends in the levels of these parameters. At stations with intermittent data records, i.e., short periods of measurements alternating with long periods without measurements, statistical comparisons of measurements from the different monitoring periods are conducted. These analyses identify trends and possible water quality changes at several water quality stations, summarized below.

At the Hicks Creek water quality station WHI0065, there is a statistically significant increasing trend in DO that appears to indicate increasing primary productivity, and possibly, declining water quality. However, there are also statistically significant decreasing trends in dissolved inorganic nitrogen and total nitrogen, indicating that inputs of these pollutants are declining. Since primary productivity in freshwater systems is often controlled primarily by phosphorus concentrations, the decrease in nitrogen inputs may not have much effect on primary productivity in Hicks Creek.

At the White River water quality station 07060500, at Calico Rock, there is a statistically significant increasing trend in total nitrogen. It is not clear if, or how much, increasing total nitrogen affects water quality in the White River.

At the North Sylamore Creek water quality station 07060710 there is a statistically significant increasing trend in DO. At this station this appears to indicate improving water quality.

At the South Sylamore Creek water quality station WHI0011, there is a statistically significant decreasing trend in DO. There could be a water quality issue in this watershed that needs attention. Note that statistically significant trends are not evident in the nutrient parameters.

At the Greenbrier Creek water quality station WHI0167, total nitrogen and organic nitrogen (TKN) concentrations from the sampling period 2013-2016 are statistically significantly less than those from the 2001-2003 sampling period. Organic nitrogen inputs to this stream may be declining. Additional data are needed to interpret the difference in concentrations from the two available sampling periods with any confidence.

3.3 Pollutant Loads

Pollutant loads are the product of concentration and stream flow. As a result, streams with low concentrations can contribute large loads if they have very large flow. Vice versa, a stream with a high concentration but a low flow, may have a relatively small load. Yield is the load for a stream divided by the drainage area of the stream. This section discusses and compares estimates of loads and yields for several of the tributaries of the White River. The parameters for which loads are discussed are TSS (as an indicator for erosion), total phosphorus, and total nitrogen.

3.3.1 SPARROW Model

USGS has estimated total nitrogen and total phosphorus exports from subbasins of the Mississippi-Atchafalaya River Basin for 2002 using the SPARROW model (USGS 2011). Maps summarizing the SPARROW 2002 nutrient load estimates for catchments of the Middle White River watershed are shown on Figures 3.19 and 3.20 (all figures for this section are located at the end of the section). SPARROW estimates of 2002 nutrient yields for catchments of the Middle White River watershed are shown on Figures 3.21 and 3.22.

As shown on Figures 3.19 and 3.20, SPARROW estimates that, in 2002, the highest total phosphorus and total nitrogen loads were from South Sylamore Creek, Poke Bayou, and several smaller tributaries of the White River, including Lafferty Creek, Wolf Bayou, and Greenbrier Creek. However, as shown on Figures 3.21 and 3.22, catchments with highest estimated total phosphorus and total nitrogen yields for 2002 are smaller, and in somewhat different locations.

Figures 3.23 and 3.24 show charts of SPARROW estimated catchment loads for 2002 broken into loads from different source categories, including both point and nonpoint sources. In catchments with the highest nutrient loads SPARROW attributes the largest portion of the total phosphorus load to manure, and the largest portion of the total nitrogen load to atmospheric deposition.

It is possible that nutrient loads in the Middle White River watershed have changed between 2002 and the 2013-2017 time period. Therefore, additional load estimate approaches are investigated in the following sections.

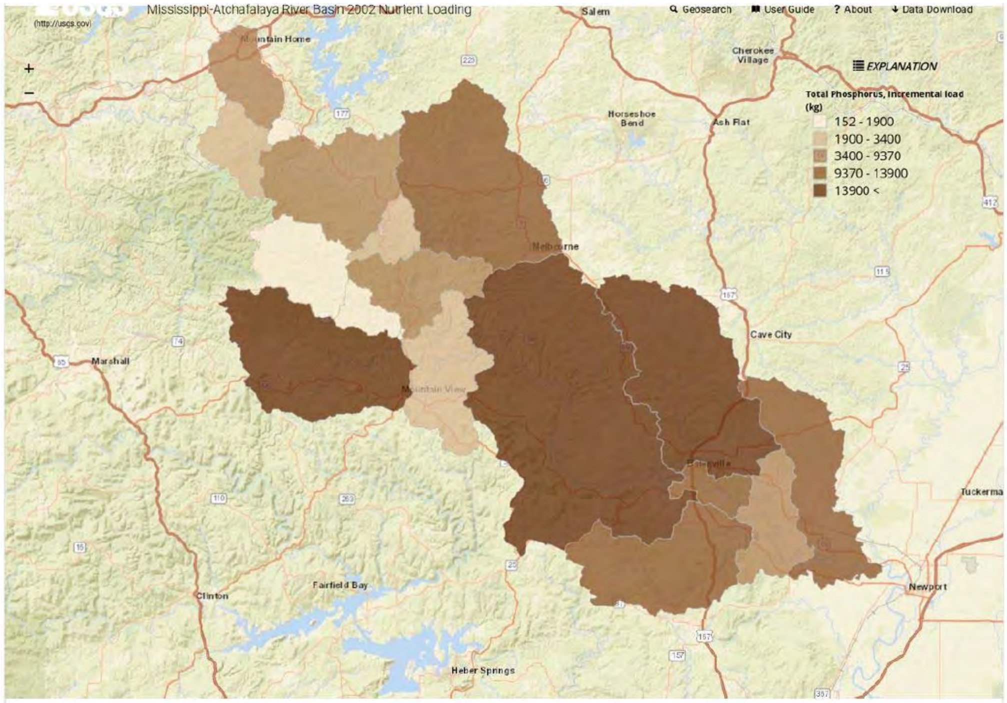


Figure 3.19. Catchment total phosphorus loads for 2002 estimated by SPARROW (USGS 2011).

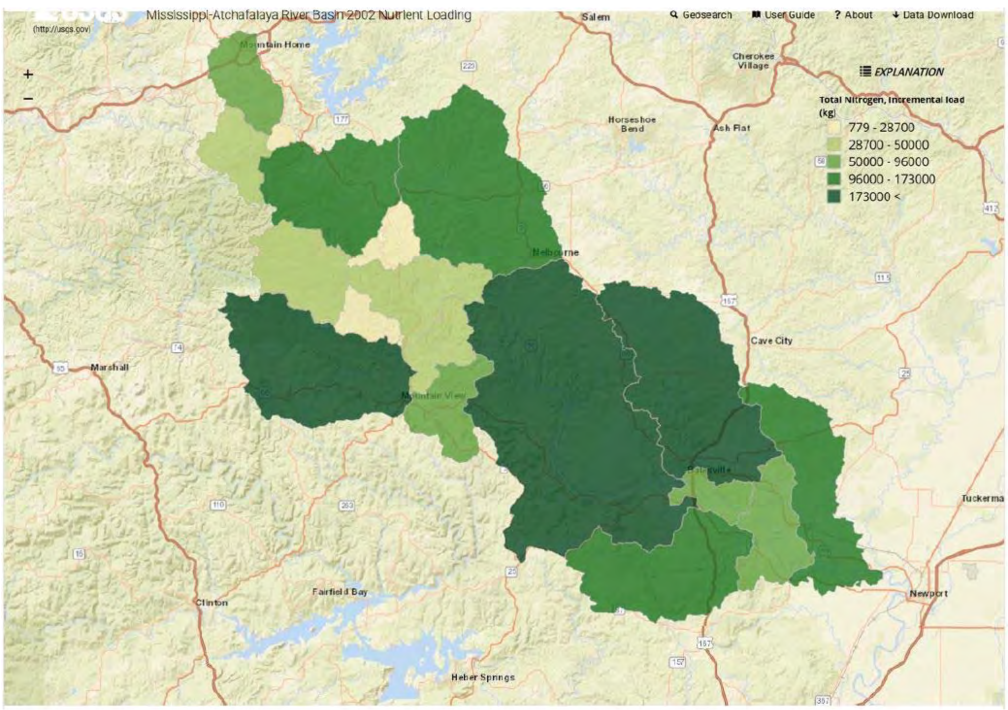


Figure 3.20. Catchment total nitrogen loads for 2002 estimated by SPARROW (USGS 2011).

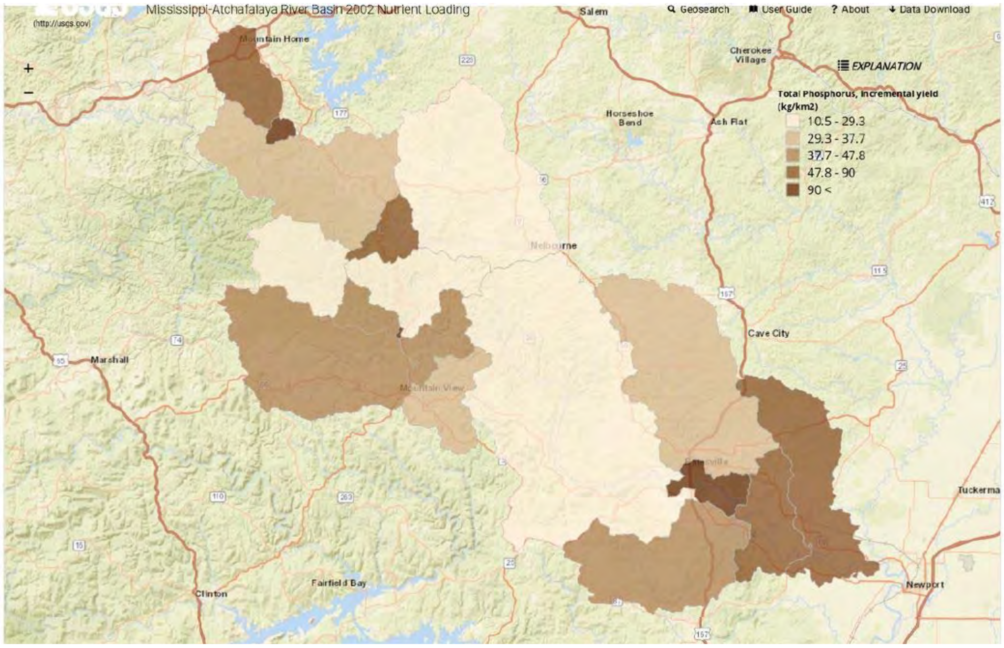


Figure 3.21. Catchment total phosphorus yields for 2002 estimated by SPARROW (USGS 2011).

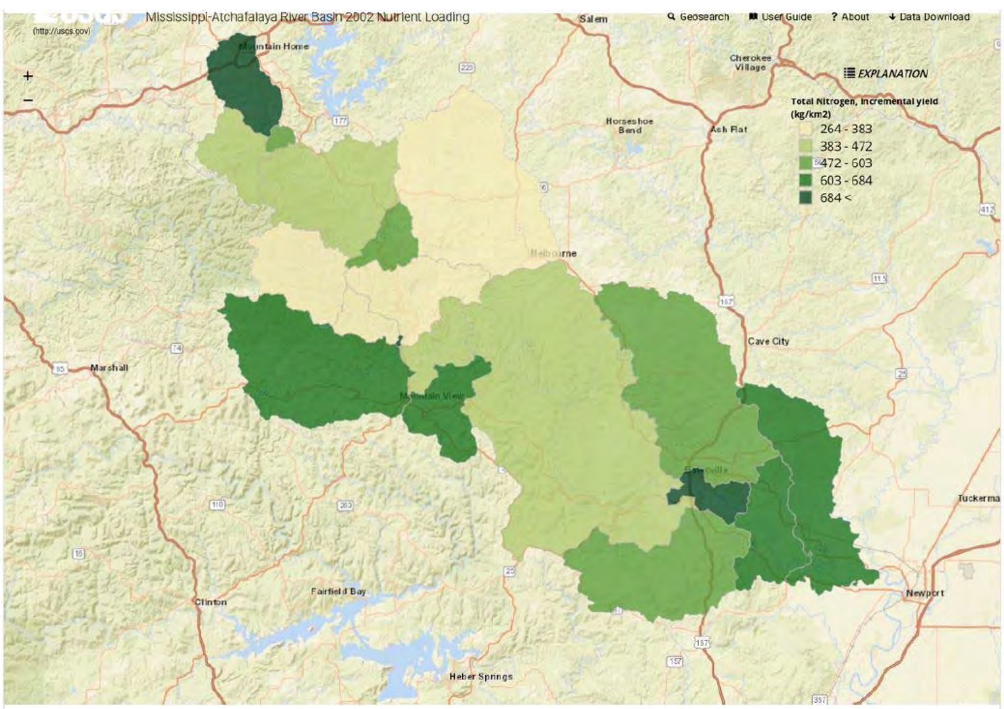


Figure 3.22. Catchment total nitrogen yields for 2002 estimated by SPARROW (USGS 2011).

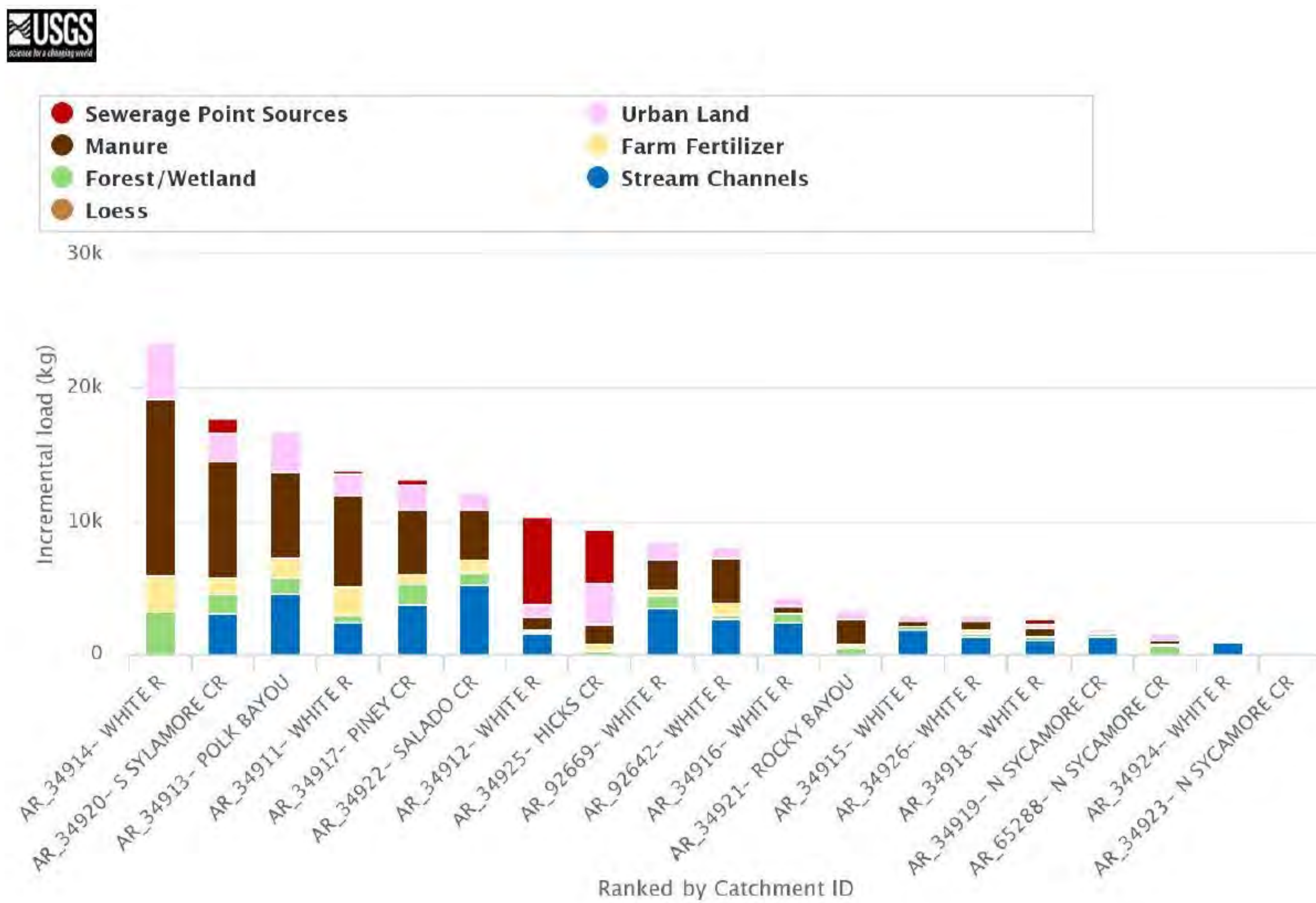


Figure 3.23. Graph of catchment total phosphorus loads for 2002 by source estimated by SPARROW (USGS 2011).

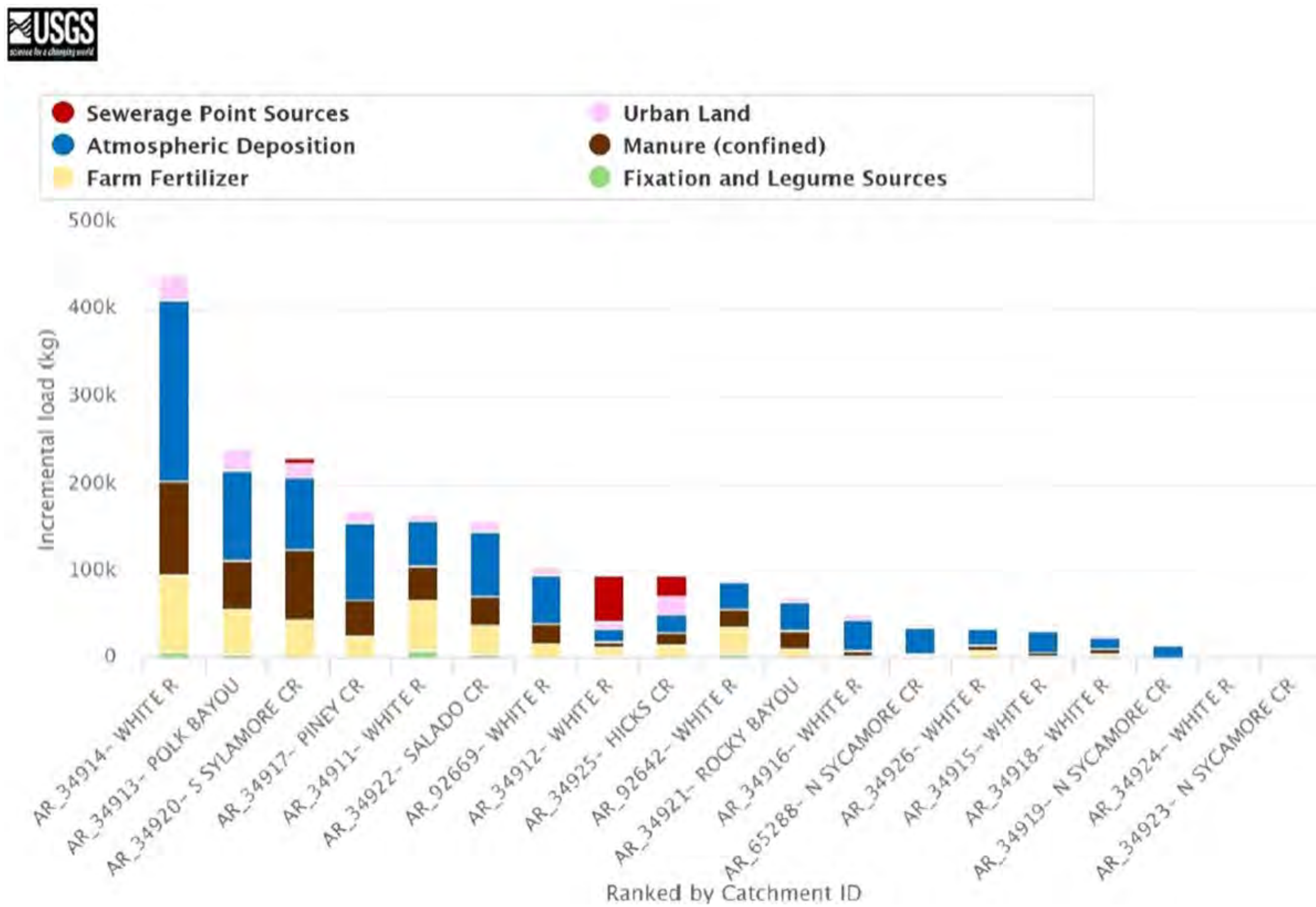


Figure 3.24. Graph of catchment total nitrogen loads for 2002 by source estimated by SPARROW (USGS 2011).

3.3.2 Load Estimates using Export Coefficients

A simple, widely used method of estimating loads is the use of export coefficients. An export coefficient is the mass of a pollutant leaving a unit of area over a unit of time. The load from a watershed is estimated by multiplying the export coefficient by the area of the watershed. White et al. (2015) developed export coefficients for sediment, total nitrogen, and total phosphorus (kg/ha/yr) for selected land uses (cultivated cropland, undisturbed forest, grassland, urban) for all of the ecoregions in the US. The Ozark Highlands ecoregion export coefficients (listed in Table 3.15) were used to estimate sediment, total nitrogen, and total phosphorus loads for major tributaries of the Middle White River watershed, based on 2011 land use data (Homer, et al. 2015). For each tributary watershed, the load from each land use was calculated by multiplying the land use area by the appropriate export coefficient, and then summed to get the total load for the subwatershed. These estimated loads and associated yields are summarized by White River tributary in Table 3.16, and Figures 3.25 and 3.26. The calculations are included as Appendix C.

In general, loads estimated for White River tributaries using this method increase as the tributary watershed size increases. However, with regard to yield, smaller tributary watersheds tend to have larger yields. The largest estimated yields are from Big Creek (of which Hicks Creek is a tributary) and Greenbrier Creek, both of which are among the smaller watersheds.

Table 3.15. Ozark Highlands export coefficients from White et al. (2015) used to estimate loads.

Land Use	Sediment export (kg/ha/yr)	Total nitrogen export (kg/ha/yr)	Total phosphorus export (kg/ha/yr)
Developed	1.04	10.5	1.8
Cultivated crops	4.83	23.2	2.21
Forest	0	1.27	0.059
Grassland (pasture/hayland)	0.03	1.36	0.437

Table 3.16. Annual loads and yields estimated for White River tributaries using export coefficients from White et al. 2015.

Tributary	Drainage Area (sq km)	Sediment Load (kg)	Sediment Yield (kg/sq km)	Total nitrogen Load (kg)	Total nitrogen Yield (kg/sq km)	Total phosphorus Load (kg)	Total phosphorus Yield (kg/sq km)
Piney Cr	451.1	2,304	5.1	75,636	167.7	9,757	21.6
Poke Bayou	444.4	3,772	8.5	86,497	194.6	13,094	29.5
S Sylamore Cr	369.4	2,232	6.0	64,976	175.9	8,587	23.2
Salado Cr	291.5	2,493	8.6	53,685	184.2	7,348	25.2
N Sylamore Cr	198.6	653.8	3.3	30,894	155.6	2,384	12.0
Lafferty Cr	156.6	680.7	4.3	25,187	160.8	3,219	20.6
Rocky Bayou	110.6	619.0	5.6	19,212	173.6	2,270	20.5
Big Cr-Hicks Cr	105.3	2,580	24.5	35,642	338.5	5,886	55.9
W Rocky Bayou	91.5	450.6	4.9	15,179	165.8	1,877	20.5
Sprint Cr	88.4	1,081	12.2	18,890	213.8	3,269	37.0
Greenbrier Cr	87.6	2,141	24.4	23,556	268.9	3,416	39.0
Wolf Bayou	86.5	287.4	3.3	13,152	152.1	1,652	19.1
Moccasin Cr	62.9	376.2	6.0	10,895	173.2	1,496	23.8
Livingston Cr	55.2	186.5	3.4	8,643	156.7	652.3	11.8
Wideman Cr	34.2	92.3	2.7	1,040	30.4	199.0	5.8

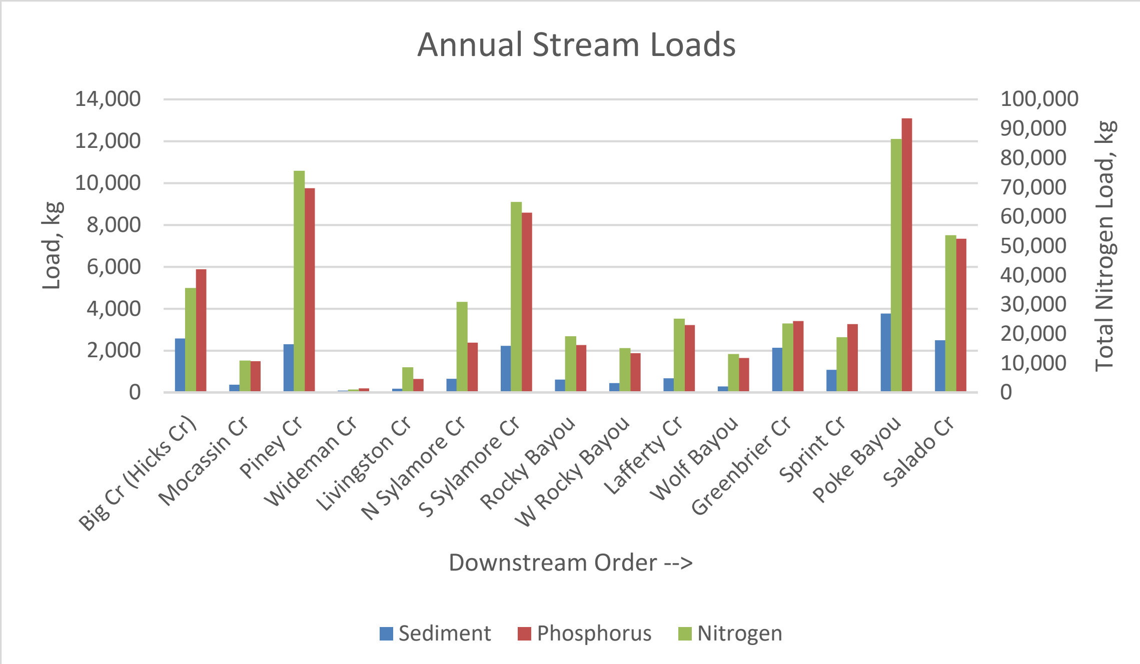


Figure 3.25. Annual loads for White River tributaries estimated using export coefficients from White et al. 2015.

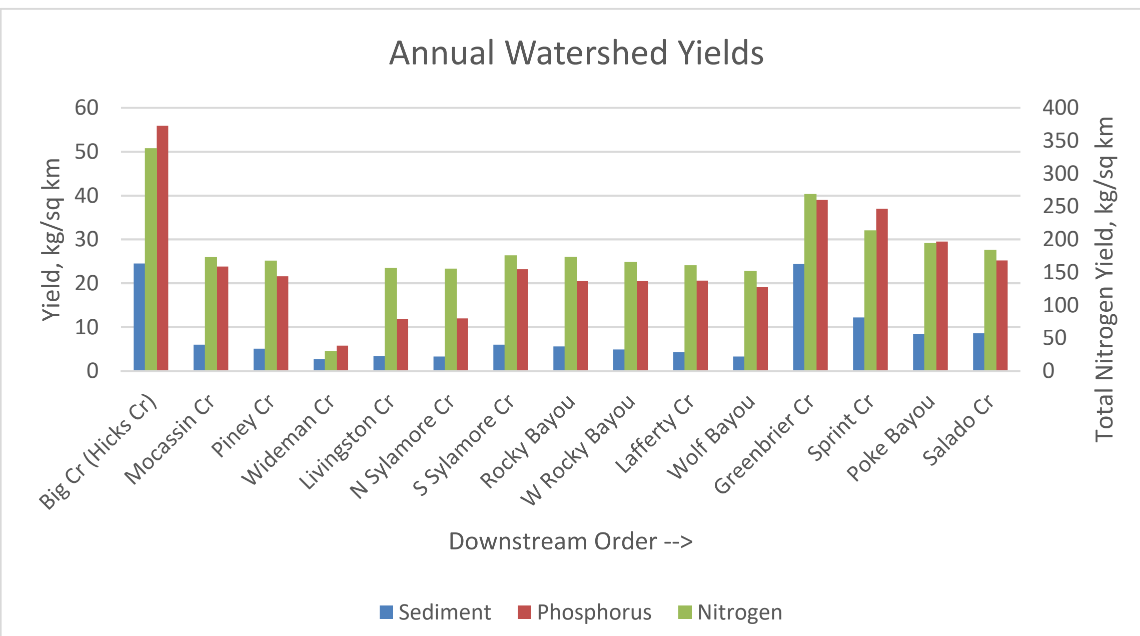


Figure 3.26. Yields for White River tributary watersheds based on loads estimated using export coefficients from White et al. 2015.

3.3.3 Current Load Estimates

Estimates of current load for TSS, total nitrogen, and total phosphorus were calculated using data collected during the period 2013-2017. Loads were estimated by multiplying the harmonic mean flow by the harmonic mean concentration for this period[4]. Where water quality is monitored at multiple locations on a stream, or in a subbasin (e.g., Hicks Creek-Big Creek, North Sylamore Creek), a load was estimated only for one monitoring location, usually the farthest downstream. As can be seen in the statistics tables in Section 3.1, for a number of the monitoring stations where data were collected during the period 2013-2017, only three or less data points were collected. These stations were excluded due to the small number of data points. Given these criteria, loads were estimated for seven locations with data from the period 2013-2017; WHI0065 on Hicks Creek, WHI0168 on Piney Creek, WHI0162 on Wideman Creek, WHI0202 on North Sylamore Creek, WHI0090 on South Sylamore Creek, WHI0167 on Greenbrier Creek, and WHI0166 on Salado Creek.

Flow is not measured at the ADEQ water quality monitoring locations where loads are estimated. For those locations, the harmonic mean flow estimated by USGS StreamStats is used to estimate the load (https://water.usgs.gov/osw/streamstats/). StreamStats output is included in Appendix D.

There was an approximately two-year period, 2013-2015, when samples were collected at all seven target monitoring locations on the same, or close to the same, dates. At some locations, samples were collected on additional dates. However, to keep the load estimates for all of the sampling locations as comparable as possible, only data from dates sampled at multiple stations were used to calculated the harmonic mean concentration. The data used to calculate the harmonic mean concentrations are listed in Appendix D. The estimated loads are summarized on Figure 3.27. Estimated yields (load/drainage area) are summarized on Figure 3.28.

[4] Harmonic mean is the reciprocal of arithmetic mean. It is considered the most appropriate mean for rates, such as flow. It also is less influenced by occasional large values, which occur in some of the water quality records.

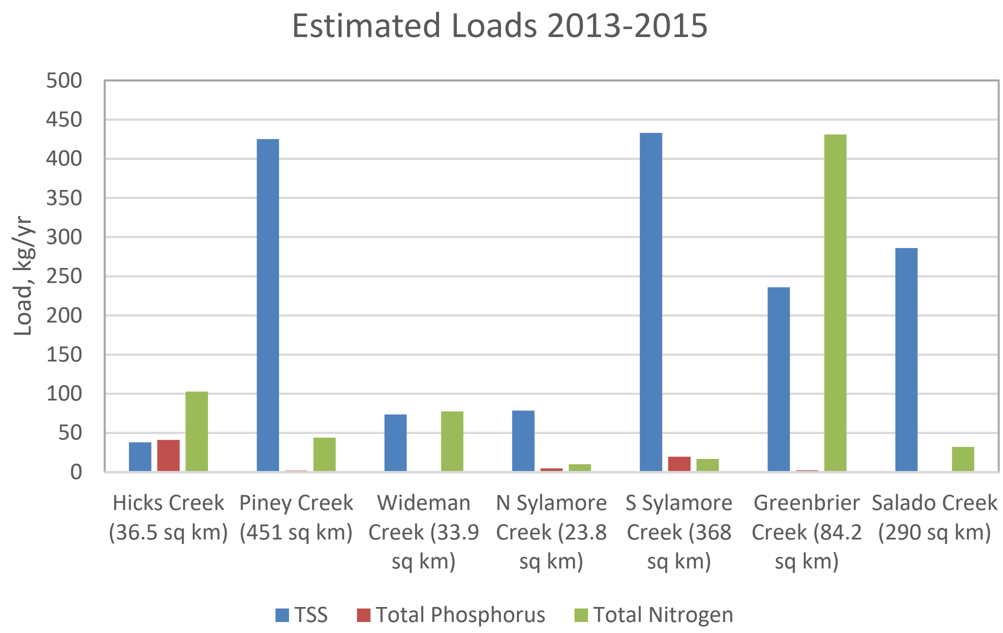


Figure 3.27. Estimated loads based on measurements from 2013-2015.

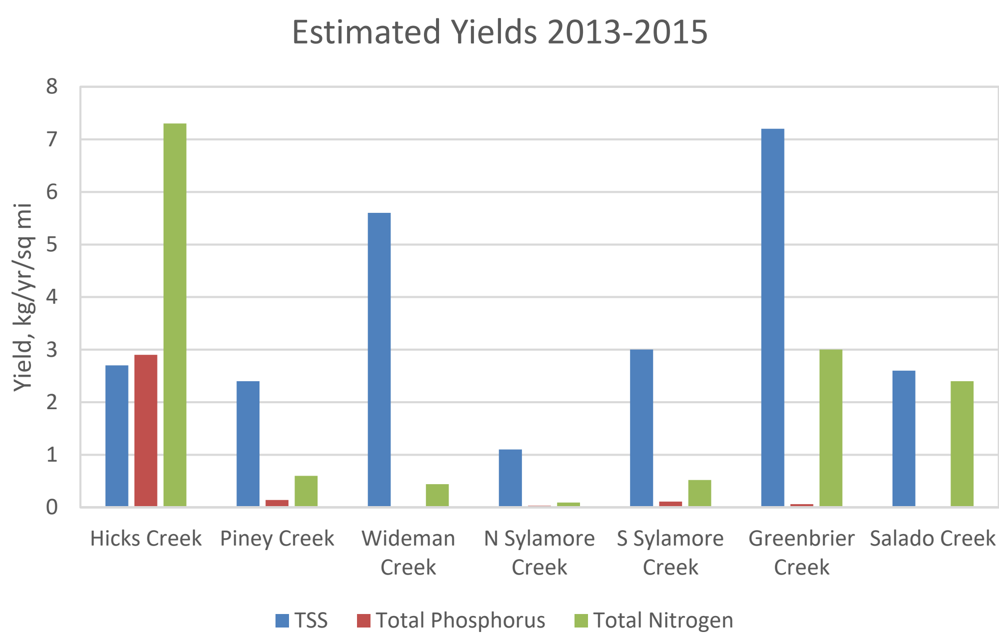


Figure 3.28. Estimated yields based on measurements from 2013-2015.

The ADEQ monitoring program is not designed to collect the type of data needed to calculate realistic estimates of loads. As a result, the loads shown on Figure 3.27 are not expected to accurately represent actual pollutant loads at these locations. These estimates of current load cannot be compared to the 2002 SPARROW estimates to see if loads have changed over time. However, they can be compared to each other, to get a relative idea of how the monitored streams compare in terms of the load they are contributing to the White River.

Relative size of TSS loads shown on Figure 3.27 appear to be strongly related to watershed size. The two monitoring locations with the largest contributing drainage areas (shown in parentheses with the stream name) have the largest TSS loads. This is not the case with the nutrients. The Hicks Creek monitoring location has the largest total phosphorus load, but a relatively small drainage area. The South Sylamore Creek monitoring station has the second largest total phosphorus load, and a drainage area approximately ten times larger than the Hicks Creek station. The Greenbrier Creek station has the largest total nitrogen load, while the drainage area is in the middle range.

Examining pollutant yields provides another perspective on water quality in the monitored streams. TSS yields are greatest for the Greenbrier Creek and Wideman Creek monitoring stations (Figure 3.28). No cause for these high TSS yields is readily apparent. Nutrient yields are greatest for the Hicks Creek monitoring station. This is not surprising since this monitoring station is located just downstream of the outfall of the Mountain Home WWTP. Relatively high total nitrogen yields at the Greenbrier and Salado Creek stations are not as easily explained. As expected, yields for the North Sylamore Creek monitoring station are the lowest of the monitored locations.

3.3.4 Data gaps

The monitoring programs active in the Middle White River watershed are not designed to collect the data needed to calculate realistic estimates of loads for the White River tributaries. The most recent model of loads in the watershed estimates total nitrogen and total phosphorus loads for 2002. To get more current realistic estimates of pollutant loads to the White River, a new or updated model would need to be developed, or a study specifically designed to collect data for load estimates would need to be implemented.

3.3.5 Load Summary

USGS has modeled total phosphorus and total nitrogen loads for catchments of the Middle White River watershed for the year 2002. Loads were estimated for subwatersheds for the Middle White River watershed using export coefficients recently developed using a regional SWAT model (White, et al. 2015). Recent (i.e., from the period 2013-2017) available water quality data were also used to calculate estimates of load. While the available recent data are not from a monitoring program designed to facilitate accurate load estimates, the estimates calculated using these data can provide insight into the relationships among loads in tributaries of the White River in this watershed.

There are differences in loads and yields of TSS, sediment, total phosphorus, and total nitrogen estimated for monitored locations on White River tributaries in the Middle White River watershed. The size of TSS loads appears to be most strongly influenced by the size of the drainage area, although TSS yields for the monitored locations range from 1 kg/yr/sq mi to just over 7 kg/yr/sq mi. Relatively high nutrient loads and yields for the Hicks Creek monitoring station may be at least partly the result of the influence of the Mountain Home WWTP, which discharges upstream of the monitoring station. The high total nitrogen load and yield for the Greenbrier Creek station can only be the result of nonpoint sources.

3.4 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.

Measurements of geomorphologic characteristics have been collected by USGS from North Sylamore Creek as part of the National Water Quality Assessment (NAWQA) program and associated studies (e.g., Panfil and Jacobson 2001). However, no geomorphological studies were found for areas within the Middle White River watershed.

In general, streams in the Ozark Highlands, such as White River tributaries located within the Middle White River watershed, are considered to be somewhat unstable. These streams are responding to the changes in land use and land cover that have occurred in this region since settlement. Specific land use/land cover changes believed to affect stream stability in the Ozark Highlands include large-scale commercial timber harvest that occurred in the region between the 1880s and 1920s, and removal of riparian forest. Symptoms of stream instability in Ozark Highlands streams include large gravel bars and bank erosion (Jacobson and Primm 1997). Researchers have noted morphologic changes in Ozark streams in northern Arkansas that include decreased pool depths, increased stream widths, and increase in gravel in the substrate (Adams, Adams and Connolly 2017).

3.5 Hydrology

There were four active USGS flow gages in the Middle White River watershed in 2018 (Figure 3.29). Table 3.17 lists summary statistics for flow measurements from these gages. The farthest downstream USGS flow gage on the White River in this watershed is at Batesville. Only one of the White River tributaries in the Middle White River watershed has a USGS flow gage. Only USGS measures flow when collecting water quality samples or conducting biological surveys.

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 White River at Calico Rock (07060500). No statistically significant long-term trends were identified in annual, seasonal, or peak White River flows at this location. A statistically significant decreasing trend in minimum flows was identified (Wagner, Krieger, and Merriman 2014).

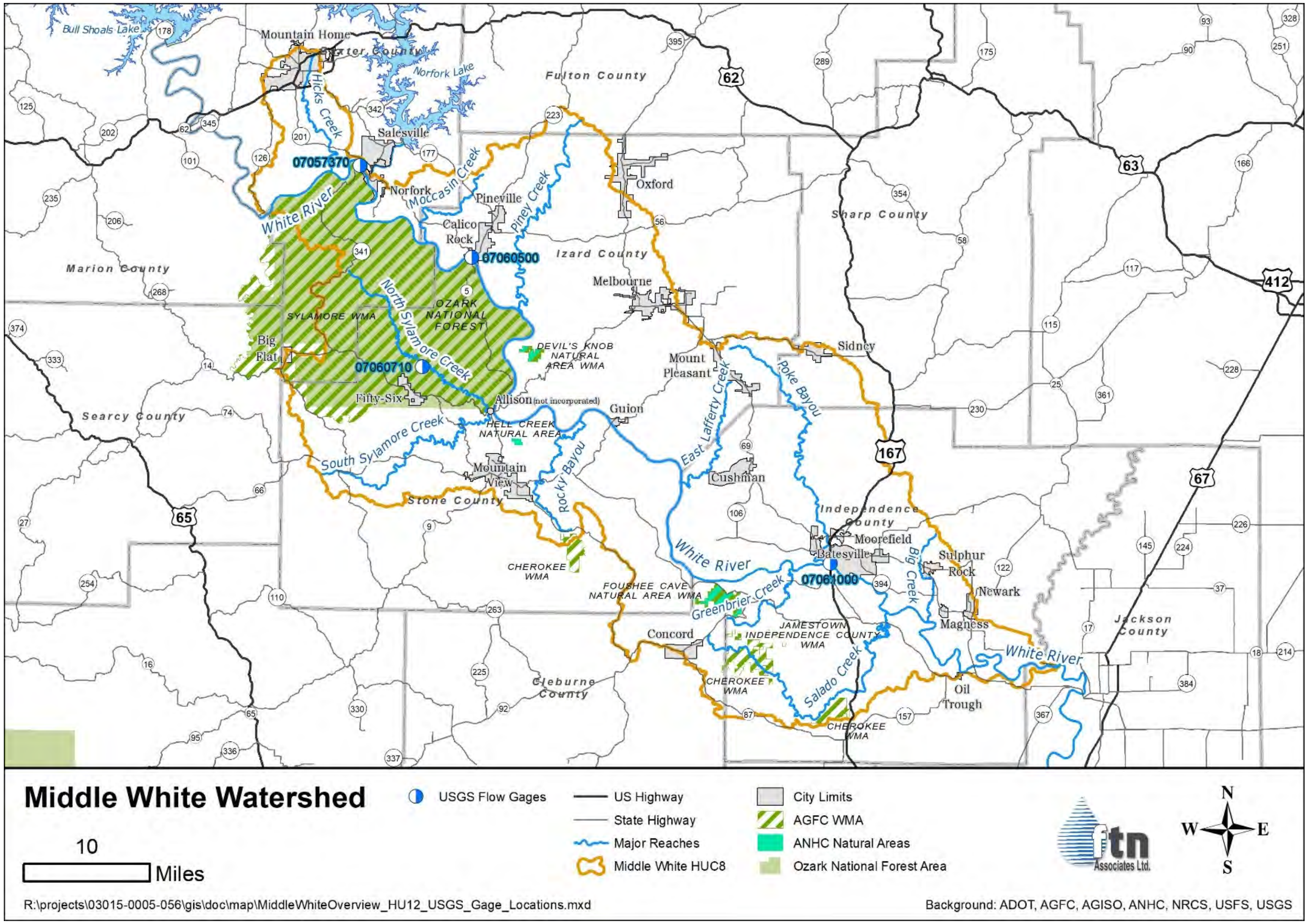


Figure 3.29. Active USGS flow gages in the Middle White River watershed, 2017.

As part of this same study, pool elevations and releases from selected USACE reservoirs were also evaluated for long term trends. The Middle White River watershed receives releases from the USACE reservoirs Bull Shoals Lake and Norfork Lake. Statistically significant increasing trends were identified in pool elevations for both Bull Shoals Lake and Norfork Lake. Additionally, statistically significant increasing trends were identified in annual mean and maximum daily releases from Bull Shoals Lake, and in the number of low flow days in releases from Bull Shoals Lake. No trend was apparent in releases from Norfork Lake (Wagner, Krieger and Merriman 2014). Minimum flow releases have recently been set for both of these reservoirs; 800 cfs for Bull Shoals Lake and 300 cfs for Norfork Lake (USACE Little Rock District 2016).

Table 3.17. Statistics for discharge data from USGS gages active in 2018 (USGS 2018a).

Site Number	Year Established	Site Name	Annual Average Discharge (cfs*)	Lowest Mean Monthly Discharge, (cfs*)	Highest Mean Monthly Discharge (cfs*)	7Q10 Flow, (cfs*)	90% Exceeds Flow, (cfs*)	Peak Flow, (cfs*)
07057370	1996	White River near Norfork, AR	8,727	1,060	44,940	649	1,850	196,000
07060500	1939	White River at Calico Rock, AR	10,795	1,905	37,470	950	2,710	202,000
07060710	1965	North Sylamore Creek near Fifty-Six, AR	54.4	2.31	471	1.8	4.1	28,200
07061000	1937	White River at Batesville, AR	12,604	2,160	45,210	1,104	3,360	208,000

* calculated for period 2004-2016, longest period when all stations have data. Annual average calculated for calendar year.

Flows in the White River are largely controlled by releases from Bull Shoals and Norfork reservoirs. Some elements of White River flows appear to be changing over time. Minimum releases have been set for Bull Shoals and Norfork reservoirs. No information was found on evaluation of flows in White River tributaries within this watershed.

3.6 Aquatic Habitat

Physical habitat in streams is a combination of factors that support aquatic organisms, including water depth, water velocity, water temperature, 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.

ADEQ collects habitat information during fish surveys and uses this information to develop an index of fish habitat integrity score. Fish Habitat integrity scores for fish survey locations in the Middle White River watershed are summarized in Table 3.18. Higher scores indicate better fish habitat. Locations surveyed are shown on Figure 3.30.

Table 3.18. ADEQ fish habitat integrity scores from fish survey locations in Middle White River watershed (ADEQ 2018b).

ADEQ Station ID	ADEQ Sample ID	Stream Name	Date	Habitat integrity scores		
				Pool	Riffle	Run
WHI0147	4F007	South Sylamore Cr	7/30/1997	153.1	21.7	152.4
WHI0146	4F008	South Sylamore Cr	7/30/1997	67.8	47.4	90.4
WHI0145	4F009	South Sylamore Cr	7/30/1997	96.3	27.1	143.8
WHI0151	4F010	Salado Cr	6/16/1998	211.5	8.2	4.4
WHI0161	4F011	Piney Cr	9/16/1999	95.2	4.9	NA*
WHI0162	4F012	Wideman Cr	6/14/1999	71.2	55.7	25.6
WHI0159	4F013	West Livingston Cr	6/14/1999	166.3	19.2	27.2
WHI0147	4F014	South Sylamore Cr	9/14/1999	233.6	53.8	98.5
WHI0146	4F015	South Sylamore Cr	9/14/1999	31.7	24.2	50.6
WHI0145	4F016	South Sylamore Cr	9/14/1999	202.9	34.8	62.3
WHI0144A	4F017	North Sylamore Cr	9/19/2013	61.2	19.4	13.2
WHI0147	4F018	South Sylamore Cr	9/20/2013	83	11.2	41.9
WHI0202	4F019	North Sylamore Cr	9/19/2013	92.7	17.2	21.1
WHI0168	4F020	Piney Cr	9/16/2011	95.2	4.9	NA*

*This habitat is not present at this location.

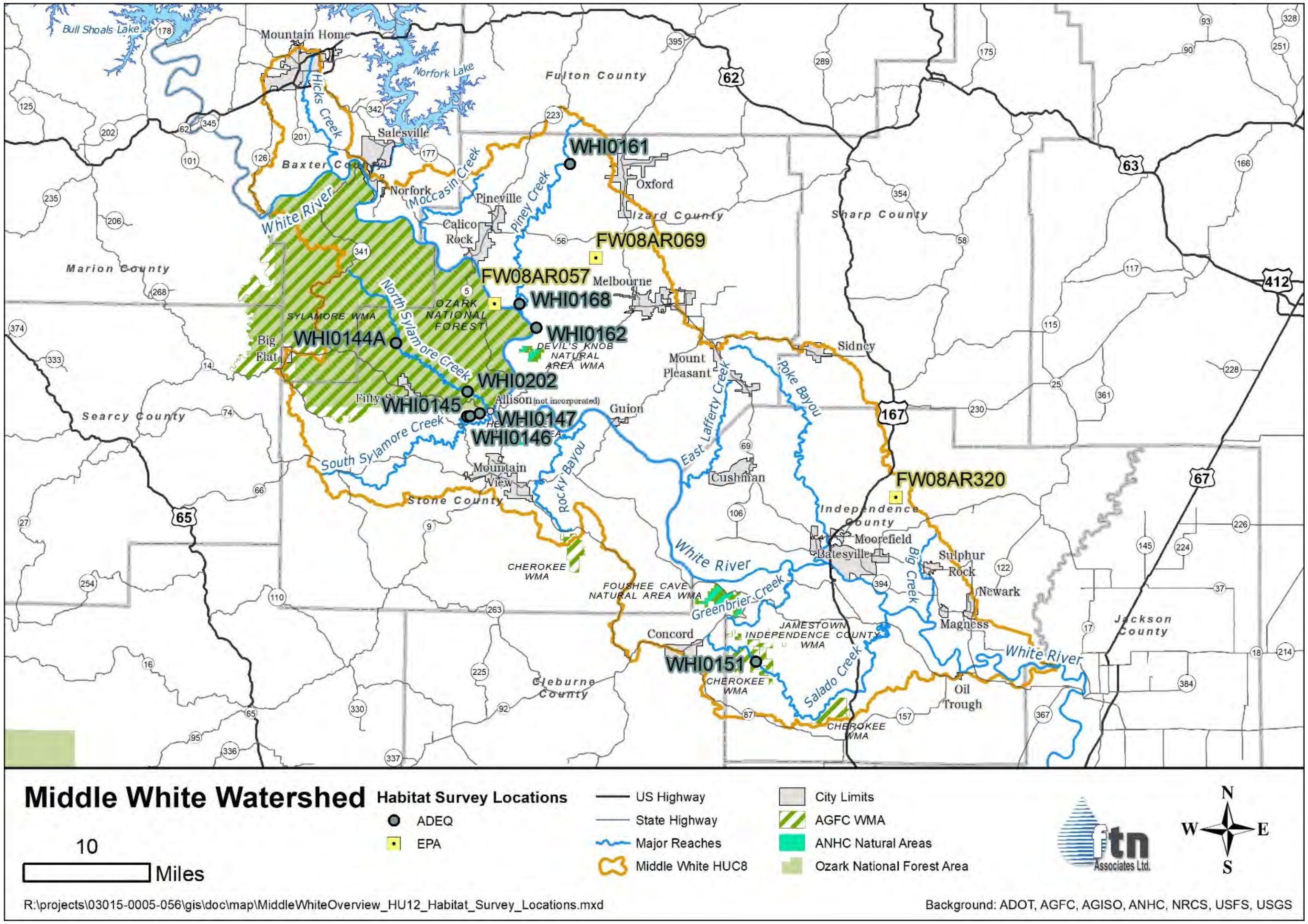


Figure 3.30. Locations of habitat surveys in Middle White River watershed.

There are three sites on South Sylamore Creek that were surveyed more than once, WHI0145, WHI0146, and WHI0147. These sites are associated with an instream gravel mining operation. The 1997 surveys (Sample IDs 4F007, 4F008, and 4F009) were conducted prior to initiation of mining. The 1999 surveys (Sample IDs 4F014, 4F015, and 4F016) were conducted after mining was initiated. In the mined area (WHI0146), habitat scores for all three habitats (pool, riffle, and run) were lower after mining started. At the upstream (WHI0145) and downstream locations (WHI0147) pool and riffle habitat scores were higher after mining started, and run habitat scores were lower. The downstream location (WHI0147) was surveyed again in 2013 (sample 4F018). In 2013, integrity scores for all three habitats were lower than in 1997 (sample 4F007), and 1999 (sample 4F014).

EPA also collected habitat information from the watershed during the 2004 National Aquatic Resources Survey and the 2009 National Rivers and Streams Assessment (EPA 2013). Table 3.19 summarizes the habitat condition results from the EPA work in the Middle White River watershed. In the 2009 National Rivers and Streams Assessment, habitat condition is classified as good, fair, or poor.

Table 3.19. EPA habitat condition results for locations in Middle White River watershed.

EPA Station ID	Stream Name	Year	Substrate	In-stream cover	Riparian vegetation
FW08AR057	White River	2008	Good	Good	Fair
FW08AR069	Band Mill Cr	2008	Good	Good	Poor
FW08AR320	Gravel Cr	2008	Good	Good	Poor

There are a few locations in the watershed where aquatic habitat has been evaluated. Condition categories were not found for the locations evaluated by ADEQ. EPA evaluations categorized instream habitat as good, but riparian areas as being in poor condition.

3.7 Surveys of Aquatic Communities

Aquatic communities respond to 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 for aquatic invertebrates. Much of the biological monitoring in the watershed is being used to characterize best possible ecoregion reference conditions. Figure 5.3 shows locations in the Middle White River watershed where biological surveys have been conducted since 2000.

3.7.1 Fish Communities

During the period 2013-2017 ADEQ, and USGS conducted fish community surveys in the Middle White River watershed (ADEQ 2018b, National Water Quality Monitoring Council 2018). The locations of these surveys are shown on Figure 3.31. Researchers from the University of Central Arkansas are currently surveying fish communities in the Middle White River watershed for a project to assess distribution and status of fish species (University of Central Arkansas 2018). EPA conducted fish surveys in the watershed during the 2009 National Rivers and Streams Assessment (EPA 2013). In addition, the USFS conducted fish surveys in the watershed during 2007 (USFS 2016).

In 2014 ADEQ conducted fish surveys on Salado Creek as part of data collection for development of nutrient criteria for Extraordinary Resource Waters in the Boston Mountains ecoregion. In 2011 and 2013, ADEQ conducted fish surveys on Ecoregion Reference Streams, including North and South Sylamore Creeks, West Livingston Creek, and Piney Creek in the Middle White River watershed. Fish surveys were also conducted on most of these streams in the late 1990s (ADEQ 2018b). ADEQ has developed a series of fish IBIs for each of the ecoregions in the State. IBIs are used to classify the health of streams based on selected characteristics of the fish community. IBI values for ADEQ fish surveys conducted since 2005 are listed in Table 3.20.

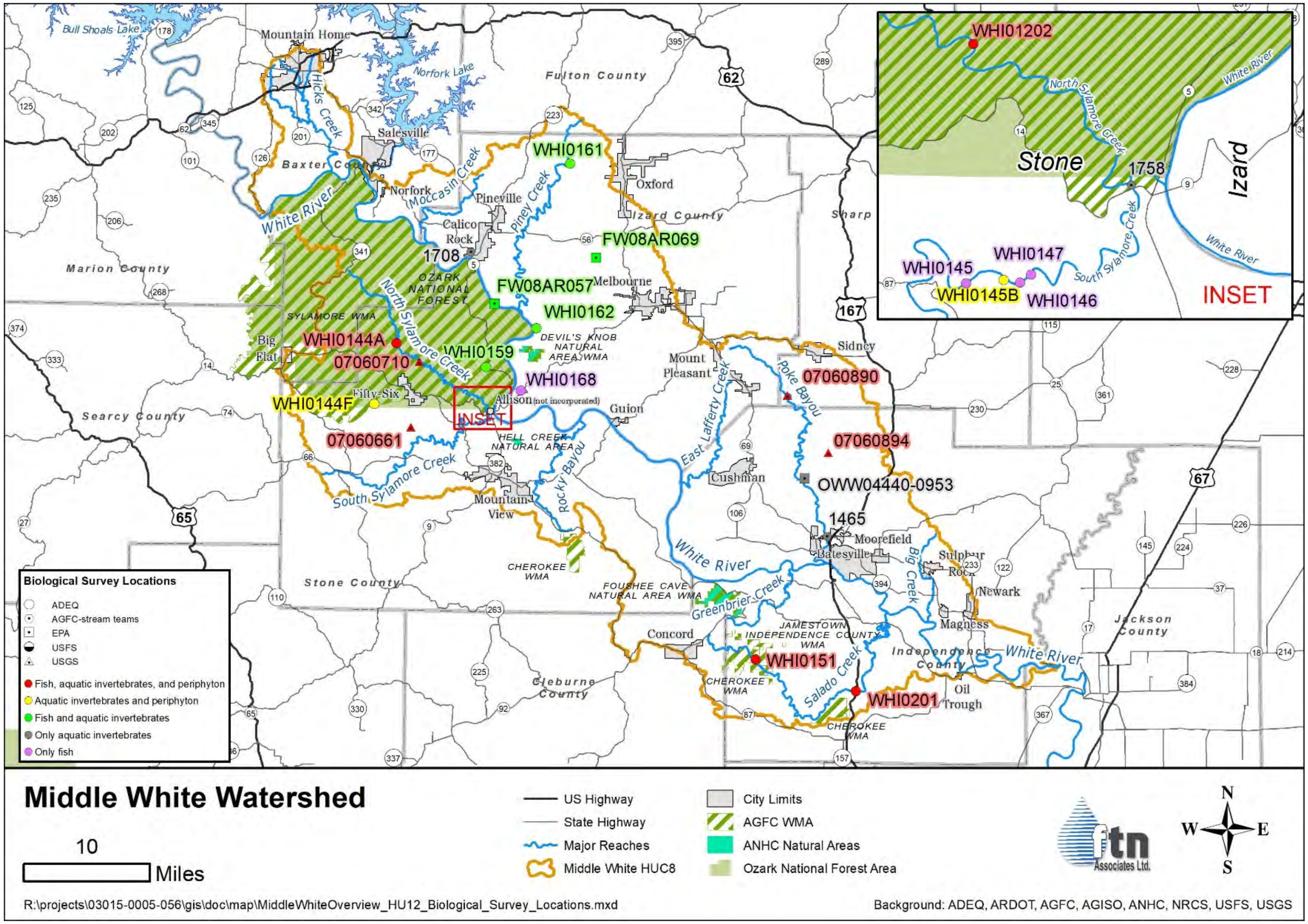


Figure 3.31. Locations of aquatic community surveys in the Middle White River watershed.

Table 3.20. IBI scores and associated stream health ratings based on recent fish surveys.

Stream (Station ID)	Agency	Year	Index Score	Rating
Tributary of W. Livingston Cr	USFS	2007	18	Fair
Tributary of E. Livingston Cr	USFS	2007	24	Fair
Spring Tributary of W. Livingston Cr	USFS	2007	13	Fair
E. Livingston Cr	USFS	2007	37	Excellent
Livingston Cr	USFS	2007	33	Good
Bearhead Br	USFS	2007	16	Fair
Coldwater Cr	USFS	2007	28	Good
Farris Cr	USFS	2007	22	Fair
Goose Cr	USFS	2007	13	Fair
Sycamore Cr	USFS	2007	27	Good
Twin Cr	USFS	2007	16	Fair
Walker Cr	USFS	2007	25	Good
Sneeds Cr	USFS	2007	23	Fair
Sugarloaf Cr	USFS	2007	11	Poor
Perry Cr	USFS	2007	39	Excellent
White R. (FW08AR057)	EPA	2009	73.81	Good
Band Mill Cr (FW08AR069)	EPA	2009	60.42	Fair
Gravel Cr (FW08AR320)	EPA	2009	60.11	Fair
Salado Cr (WHI0201)	ADEQ	2014	19	Good
Salado Cr (WHI0151)	ADEQ	2014	24	Good
South Sylamore Cr (WHI0147)	ADEQ	2013	39	Excellent
North Sylamore Cr (WHI0202)	ADEQ	2013	41	Excellent
North Sylamore Cr (WHI0144A)	ADEQ	2013	39	Excellent
West Livingston Cr (WHI0159)	ADEQ	2011	25	Good
Piney Cr (WHI0168)	ADEQ	2011	33	Good

In 2006, USGS conducted fish surveys at four locations in the Middle White River watershed; North Sylamore Creek near Fifty-Six (07060710), Sullivan Creek near Sandtown (07060894), Poke Bayou near Sidney (07060890), and Roasting Ear Creek near Newnata (07060661) as part of a study to evaluate relationships between biological metrics, land use, and water quality in small Ozark streams (Justus, et al. 2010). USGS used fish survey data from the North Sylamore Creek in 2001 and 2002 to calculate an IBI developed by Dauwalter et al. (2003). The resulting IBI value placed North Sylamore Creek in the Reference category, indicating a healthy fish community (Petersen 2004).

The USFS has conducted fish surveys on streams in the Middle White River watershed as part of implementing the 2005 Revised Land and Resource Management Plan for the Ozark-St. Francis National Forests. In 2007, fish surveys were conducted at 14 stream sites and one spring located within the watershed in the Sylamore District of the Ozark National Forest (USFS 2008). No new fish survey results have been reported by USFS as of the most recent monitoring and evaluation report, from 2015 (USFS 2016). The USFS used the ADEQ fish IBI to classify the condition of the fisheries based on their surveys (USFS 2008). This information is listed in Table 3.20. Only one fish community surveyed by USFS was classified as poor, in Sugarloaf Creek.

The USGS conducts fish surveys at the North Sylamore Creek gaging station (07060710), as part of the NAWQA program (National Water Quality Monitoring Council 2018). USGS has conducted fish surveys at this location routinely since 1993. Fish counts from this series of surveys are graphed on Figure 3.32. The number of fish collected has ranged from 23 to 543, but most years between 200 and 400 fish were collected. With the exception of 2004, the number of species identified is fairly consistent among years, with between 15 and 18 species identified most years. The graph on Figure 3.32 shows variation in the make-up of the fish community over time.

Matthews et al. (2016) analyzed fish surveys conducted at 12 locations in the Piney Creek subwatershed over a 40-year period. Matthews et al. (2016) concluded that the fish community in Piney Creek is relatively stable. Variability evident in the surveys apparently is the result of natural events, with the limited human activities in the watershed not significantly affecting the fish community over the long term.

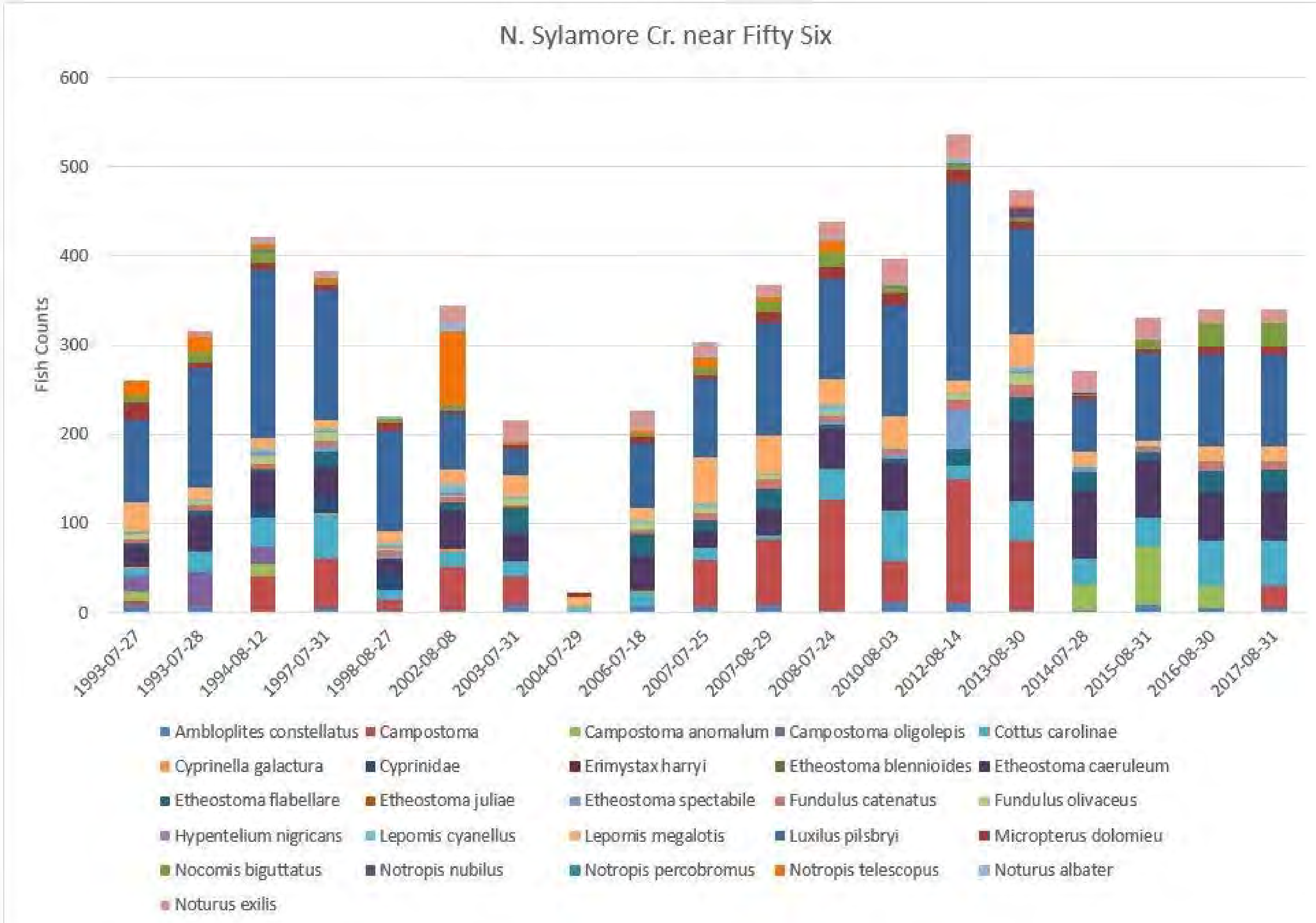


Figure 3.32. USGS fish counts over time at North Sylamore Creek near Fifty-Six (Station 07060710).

3.7.2 Aquatic Invertebrates

During the period 2013-2017 ADEQ and local Stream Teams have conducted aquatic invertebrate surveys in the Middle White River watershed (ADEQ 2018c)(W. Posey, AGFC, personal communication 6/13/18). The locations of these surveys are shown on Figure 3.31. EPA conducted aquatic invertebrate surveys in the watershed as part of the 2004 National Aquatic Resource Survey and the 2009 National Rivers and Streams Assessment (EPA 2013).

In 2013, ADEQ conducted aquatic invertebrate surveys on North and South Sylamore Creeks, and Roasting Ear Creek as part of data collection for development of nutrient criteria for Extraordinary Resource Waterbodies in the Ozark Highlands ecoregion. During the period 2014-2015, ADEQ conducted aquatic invertebrate surveys on Salado Creek as part of data collection for development of nutrient criteria for Extraordinary Resource Waterbodies in the Boston Mountain ecoregion (ADEQ 2016). Results from these surveys were not found in the ADEQ online aquatic invertebrate database (ADEQ 2018c). ADEQ also conducted aquatic invertebrate surveys in Salado Creek during 1998, and in Piney Creek, West Livingston Creek, and Wideman Creek during 1999.

As part of the National Rivers and Streams Assessment, EPA conducted aquatic invertebrate surveys at two sites in the Middle White River watershed (Figure 3.31). As part of this assessment, aquatic invertebrate community condition was characterized using a multimetric index (EPA 2013). The reported aquatic invertebrate community condition at these sites are listed in Table 3.21.

Stream Teams conduct aquatic invertebrate surveys at three locations in the Middle White River watershed (Figure 3.31).

Table 3.21. Condition of aquatic invertebrate communities surveyed by EPA in the National Rivers and Streams Assessment, 2009 (EPA 2013).

Station	Stream	Year	Condition
FW08AR057	White R	2009	Poor
FW08AR069	Band Mill Cr	2009	Poor

In 2006, USGS conducted aquatic invertebrate surveys at three locations in the Middle White River watershed; Sullivan Creek near Sandtown (07060894), Poke Bayou near Sidney (07060890), and Roasting Ear Creek near Newnata (07060661) as part of a study to evaluate relationships between biological metrics, land use, and water quality in small Ozark streams (Justus, et al. 2010).

3.7.3 Periphyton

Periphyton communities have been surveyed in the Middle White River watershed by ADEQ and USGS. The locations where periphyton surveys have been conducted are shown on Figure 3.31.

ADEQ has collected periphyton from several streams in the Middle White River watershed as part of data collection for development of nutrient criteria for Extraordinary Resource Waterbodies in the Ozark Highlands and Boston Mountain ecoregions (ADEQ 2016).

The USGS has studied periphyton within the Middle White River watershed as part of the NAWQA Program. The USGS collected data on the amount of periphyton present at one reach of North Sylamore Creek as part of this program. These data were collected in 1993-1995 (Petersen and Femmer 2003). In 2006, USGS conducted periphyton surveys at three locations in the Middle White River watershed; Sullivan Creek near Sandtown (07060894), Poke Bayou near Sidney (07060890), and Roasting Ear Creek near Newnata (07060661) as part of a study to evaluate relationships between biological metrics, land use, and water quality in small Ozark streams (Justus, et al. 2010).

Justus et al. (2010) found that periphyton metrics were most sensitive to changes in nutrient concentrations in small Ozark streams. Petersen and Femmer (2003), evaluating periphyton data from the USGS NAWQA 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.

3.7.4 Aquatic Communities Data Gaps

Most biological surveys in the Middle White River watershed appear to have been targeted at streams expected to have healthy aquatic communities. The only two locations in the watershed with long-term fish community monitoring are mostly undeveloped, North Sylamore Creek and Piney Creek. No records were found to indicate that biological communities of the impaired Greenbrier Creek have been surveyed. The most recent ADEQ biological survey on the impaired Hicks Creek indicated on the ADEQ website is a 2001 aquatic invertebrate survey on Hicks Creek. There is an active Stream Team that regularly surveys aquatic invertebrates in Hicks Creek.

3.7.5 Aquatic Communities Summary

Information on surveys of fish, aquatic invertebrates, and periphyton communities was found for the Middle White River watershed. The majority of surveys have been conducted on streams with little or no human development in their watersheds. Condition categories were not found for the locations surveyed by ADEQ. USGS, USFS, and EPA categorized the fish communities at the locations they surveyed mostly as fair to excellent. Sugarloaf Creek was the only stream where the fish community was categorized as poor. EPA categorized the aquatic invertebrate communities at the two locations they surveyed (White River and Band Mill Creek) as poor. Periphyton community surveys were not used to categorize the health of the streams, so community condition categories were not found.

3.8 Cave Aquatic Habitat and Species of Greatest Conservation Need

The Nature Conservancy has 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 and Slay 2011). In addition, Inlander, Gallipeau and Slay (2011) evaluated threats to these species. This study included 30 cave habitat sites within the

Middle White 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 overall threat scores for aquatic Species of Greatest Conservation Need (Figure 3.33). Three sites in the watershed are classified as having medium-high vulnerability to groundwater contamination, which could impact the species. Thirteen 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, and Slay 2011).

There are at least 30 cave or karst sites in the Middle White River watershed where aquatic Species of Greatest Conservation Need for Arkansas are present. Of these, eight have been classified as experiencing a medium-high threat to community health due to a combination of potential for water contamination and human access. All other sites have lower risk of being negatively impacted by water contamination and/or human access (Inlander, Gallipeau and Slay 2011).

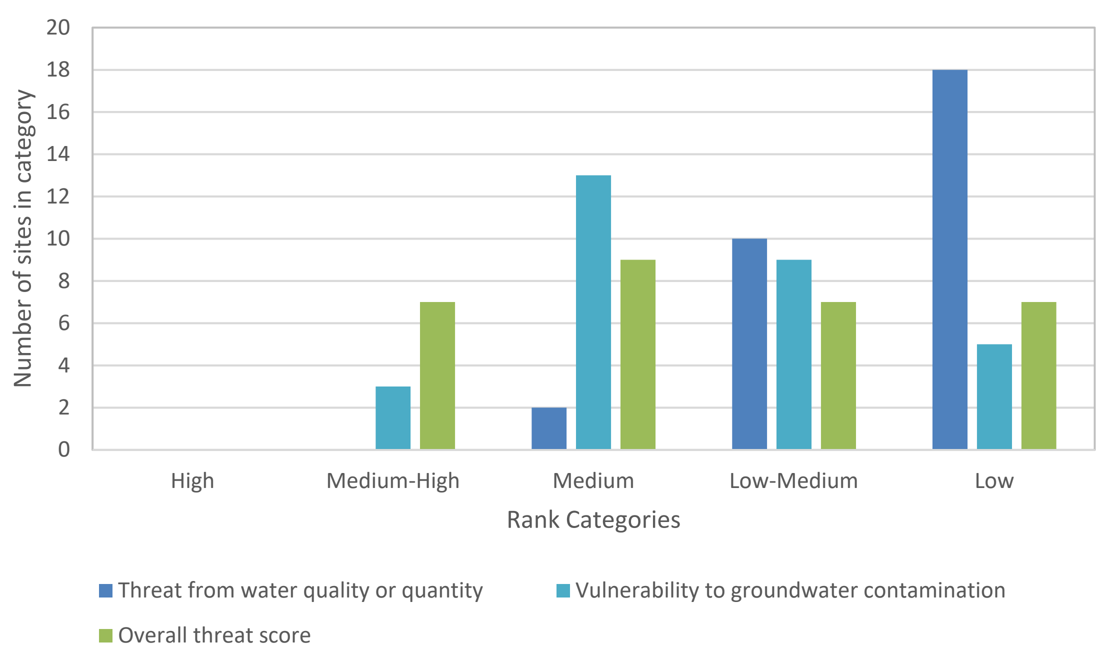


Figure 3.33. Inlander, Gallipeau, and Slay 2011 ranking of threats to Species of Greatest Conservation Need in selected cave habitat sites in the Middle White River.

3.9 Subwatersheds Recommended for Initial Management

The Middle White River watershed is large, covering 1,476.2 sq mi. This section describes the approach used to identify areas in the watershed where nonpoint source pollution management appears to be most needed at this time.

For this watershed management plan, 12-digit hydrologic cataloging unit (HUC12) subwatersheds delineated by the USGS are utilized as focus areas for nonpoint source management. There are 44 HUC12 subwatersheds within the Middle White River watershed. Figure 3.34 shows the HUC12 subwatersheds with the numeric codes used to identify them. Three to five HUC12 subwatersheds is a reasonable number to recommend for initiating management of nonpoint source pollution sources under this watershed management plan.

3.9.1 Approach for Identifying Recommended HUC12 Subwatersheds

To identify HUC12 subwatersheds to recommend for management under this plan, available information was used to rank all of the HUC12 subwatersheds of the Middle White River in terms of water quality concerns. HUC12 subwatersheds with the most information suggesting water quality concerns were ranked the highest. The following information was used to rank the HUC12 subwatersheds:

1. Condition of aquatic communities, including fish, aquatic invertebrates, and periphyton;
2. Water quality data, including concentrations, loads, trends, and natural resource concerns;
3. Condition of aquatic habitat, including substrate, streambanks, and riparian areas;
4. The presence of aquatic habitats designated for protection; and
5. Groundwater quality vulnerability.

To rank the HUC12 subwatersheds, each subwatershed was assigned a score of 1 or 0 for each type of information. A score of 1 was assigned if the information indicated water quality concerns. A score of 0 was assigned if the information did not indicate water quality concerns. Where a type of data was not available, no score was assigned. These scores were then summed.

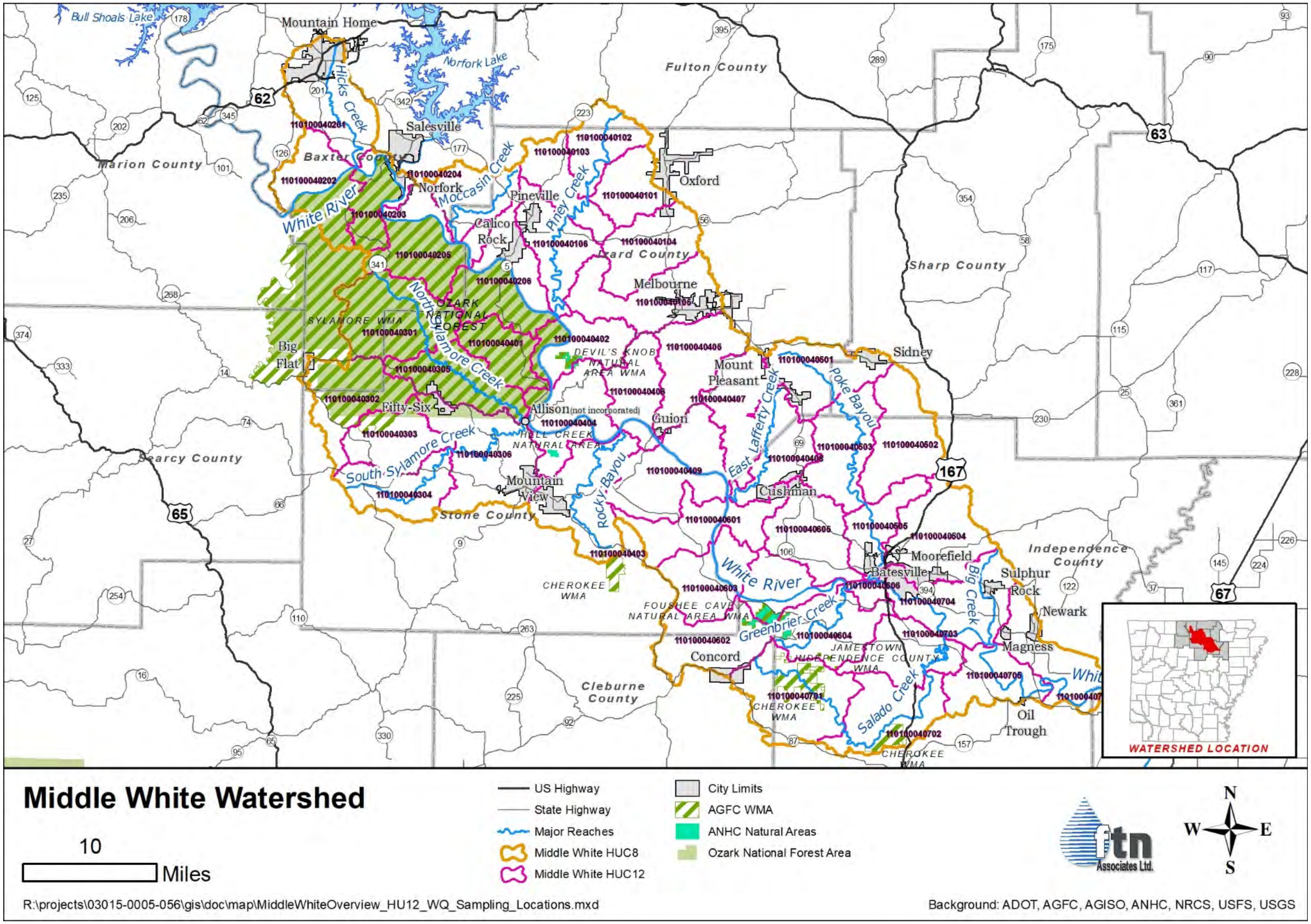


Figure 3.34. HUC12 subwatersheds of the Middle White River watershed.

Scores were assigned as follows. For information on condition of aquatic communities and habitat, HUC12 subwatersheds where condition was classified as poor based on surveys were assigned a score of 1, all others where condition was classified based on surveys received a score of 0. Biological and/or habitat surveys have been conducted in only 19 of the 44 HUC12 subwatersheds (see Section 3.7).

Scores were assigned to HUC12 subwatersheds based on the median concentrations of turbidity, TSS, total phosphorus, inorganic nitrogen, total nitrogen, and dissolved oxygen from the period 2013-2017. For each water quality parameter, all of the water quality stations in the Middle White River watershed were ranked from highest to lowest median concentration. For dissolved oxygen concentrations, HUC12 subwatersheds with at least one water quality station with a median concentration in the lowest 25th percentile were assigned a score of 1. Low dissolved oxygen typically indicates water quality issues. All other HUC12 subwatersheds where data were available, were assigned a score of 0 for dissolved oxygen. For all other water quality parameters, HUC12 subwatersheds with at least one station where the median concentration was in the highest 25th percentile were assigned a score of 1, and all others were assigned a score of 0. Note that there are active water quality monitoring stations in only 17 of the 44 HUC12 subwatersheds (see Section 3.1).

There was data available from three HUC12 subwatersheds sufficient to evaluate water quality trends. Measurements of dissolved oxygen, inorganic nitrogen, total nitrogen, total phosphorus, and fecal coliforms were evaluated for trends (see Section 3.2). A score of 1 was assigned if a trend indicative of declining water quality was found. At least one trend indicative of declining water quality was identified in all three HUC12 subwatersheds with water quality data evaluated for trends.

Scores were assigned to the HUC12 subwatersheds based on sediment, total phosphorus, and total nitrogen yields calculated using export coefficients (see Section 3.3.2). The HUC12 subwatersheds of the Middle White River watershed were ranked from highest to lowest yields (i.e., load/area). The HUC12 subwatersheds with estimated yields in the upper 25^{th} percentile were assigned a score of 1, and the rest were assigned a score of 0.

US Department of Agriculture Natural Resource Conservation Service (NRCS) Natural Resource Concern Assessment Scores were also used to rank the HUC12 subwatersheds. Every 5 years the NRCS conducts state and national resource assessments to assess major concerns related to impacts of land use practices on the environment. There are nine major resource concerns, addressing such issues as soil erosion and soil quality degradation, water quality degradation, inadequate habitat for fish and wildlife, and air quality degradation. 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. The latest resource assessment for Arkansas was conducted in 2016. The state resource assessments are conducted at the HUC12 subwatershed scale, with a mean score for each resource concern assigned to the HUC12 subwatersheds. For our scoring, the HUC12 subwatersheds of the Middle White River watershed were ranked from highest to lowest mean natural resource concern score. Eight resource concern categories were ranked for each HUC12 subwatershed: sheet, rill, and wind erosion; concentrated flow erosion; streambank erosion; excess sediment; excess nutrients; heavy metals and petroleum; pathogens; and pesticides and herbicides. Those subwatersheds with mean natural resource concern scores in the upper 25th percentile for the Middle White River watershed were assigned a ranking score of 1, while all others were assigned a ranking score of 0.

There are a number of stream reaches and some springs in the Middle White River watershed that have been designated by state or federal agencies as having habitats that should be specifically protected. HUC12 subwatersheds with designated trout fishery, Extraordinary Resource Water, Ecologically Sensitive Water, or critical habitat for a threatened or endangered species, were assigned a score of 1. All other HUC12 subwatersheds were assigned a score of 0 for this ranking information.

The Nature Conservancy has prepared a map of groundwater quality vulnerability in northern Arkansas based on the results of the model DRASTIK. A copy of this map was presented in Inlander, Gallipeau and Slay (2011). Ranking scores were assigned to the HUC12 subwatersheds based on the groundwater vulnerability map in Inlander, Gallipeau and Slay

(2011). GIS mapping was used to overlay the HUC12 subwatershed boundaries on the groundwater vulnerability map. Those HUC12 subwatersheds where DRASTIK model results indicated medium-high or greater vulnerability in 50% or more of the subwatershed (based on professional judgement) were assigned a score of 1, and all others were assigned a score of 0.

As noted above, not all of the data types used in ranking the HUC12 subwatersheds of the Middle White River watershed, are available for all of the HUC12 subwatersheds. The data types used for ranking that covered the entire Middle White River watershed were: 1) the NRCS Natural Resource Concerns assessment; 2) estimated yields of sediment, total nitrogen, and total phosphorus (based on land use); and 3) modeling of groundwater quality vulnerability. Ranking scores for just these data are shown on Figure 3.35. The HUC12 subwatersheds with the six highest total scores from just these data include Hicks Creek and Greenbrier Creek, as well as Miller Creek, Lower Salado Creek, Spring Creek, and Big Creek-White River. These HUC12 subwatersheds had the most Natural Resource Concern scores and estimated yields in the upper 25^{th} percentile. In addition, for all of these HUC12 subwatersheds except Spring Creek, 50% or more of the subwatershed area was classified with medium-high or greater vulnerability to groundwater contamination.

Among the HUC12 subwatersheds with water quality monitoring locations, and aquatic community and aquatic habitat survey locations, the ones with the highest total ranking scores, based on just these data, are Hicks Creek and Greenbrier Creek. The Outlet of South Sylamore Creek subwatershed has the third highest total score (Figure 3.36).

3.9.2 Recommended HUC12 Subwatersheds

Table 3.21 shows a summary of the scores for each type of information used to rank the HUC12 subwatersheds of the Middle White River watershed, and the totals of the scores for each HUC12 subwatershed. When all of the ranking scores for each HUC12 subwatershed are added together, Hicks Creek has the highest total score, followed by Greenbrier Creek, Lower Salado Creek and Miller Creek, and Spring Creek. There are also nine HUC12 subwatersheds where the total score is zero. Because not all HUC12 subwatersheds have scores (i.e., data) for all of the information categories, the percentage of scores equal to 1 is also shown in Table 3.22.

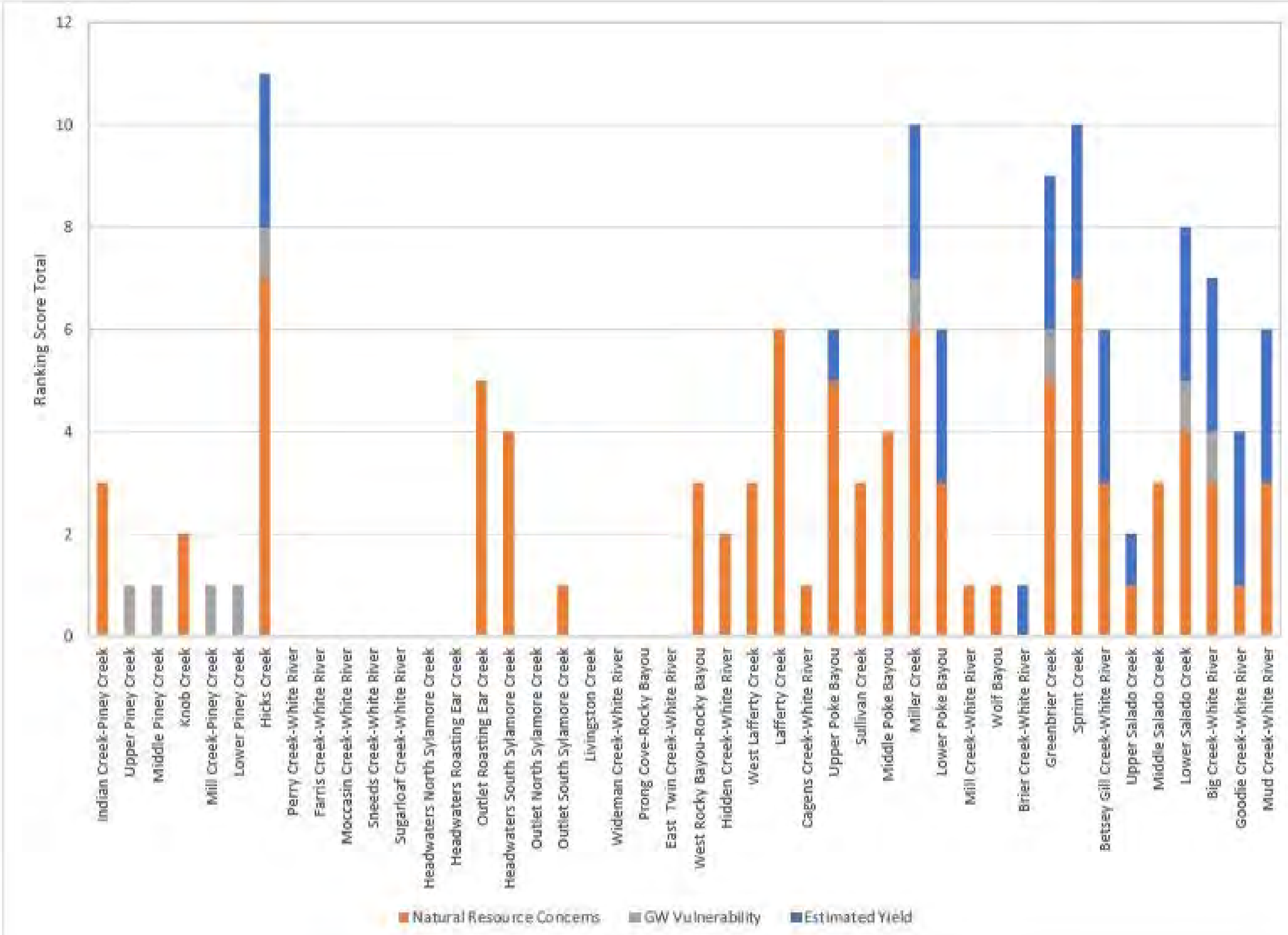


Figure 3.35. Graph of HUC12 subwatershed ranking scores for data types available for entire Middle White River watershed.

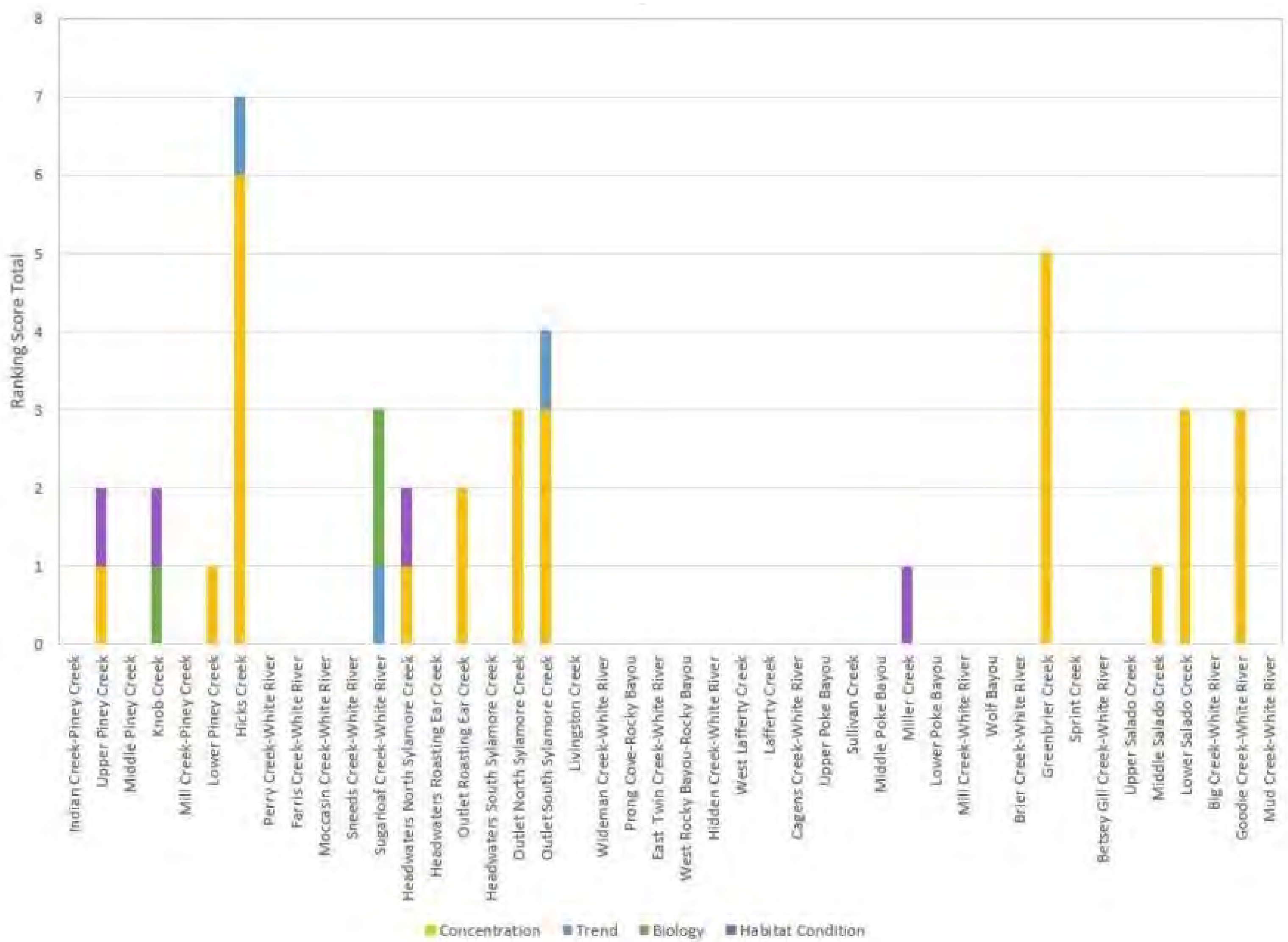


Figure 3.36 Graph of HUC12 subwatershed ranking scores for data types not available for entire Middle White River watershed.

Table 3.22. Summary ranking scores for HUC12 subwatersheds of Middle White River watershed.

USGS HUC12 Subwatershed ID Number	USGS HUC12 Subwatershed Name	Natural Resource Concerns	Median 2013-2017 Concentration	Water Quality Trends	Estimated Load Yields	Habitat Condition	Biological Condition	Groundwater Quality Vulnerability	Designated Sensitive Habitat	Total of Scores	Percent of 1 Scores
110100040101	Indian Creek-Piney Creek	3	ND	ND	0	ND	ND	0	0	3	21%
110100040102	Upper Piney Creek	0	1	ND	0	1	0	1	0	3	14%
110100040103	Middle Piney Creek	0	ND	ND	0	ND	ND	1	0	1	7%
110100040104	Knob Creek	2	ND	ND	0	1	1	0	0	4	24%
110100040105	Mill Creek-Piney Creek	0	ND	ND	0	ND	ND	1	0	1	7%
110100040106	Lower Piney Creek	0	1	ND	0	0	0	1	0	2	10%
110100040201	Hicks Creek	7	6	1	3	ND	ND	1	0	18	86%
110100040202	Perry Creek-White River	0	ND	ND	0	ND	0	0	1	1	7%
110100040203	Farris Creek-White River	0	0	ND	0	ND	0	0	1	1	5%
110100040204	Moccasin Creek-White River	0	ND	ND	0	ND	ND	0	0	0	0%
110100040205	Sneeds Creek-White River	0	ND	ND	0	ND	0	0	1	1	7%
110100040206	Sugarloaf Creek-White River	0	0	1	0	0	2	0	1	4	18%
110100040301	Headwaters North Sylamore Creek	0	1	ND	0	1	0	0	1	3	14%
110100040302	Headwaters Roasting Ear Creek	0	ND	ND	0	ND	ND	0	1	1	7%

Table 3.22. Summary ranking scores for HUC12 subwatersheds of Middle White River watershed (continued).

USGS HUC12 Subwatershed ID Number	USGS HUC12 Subwatershed Name	Natural Resource Concerns	Median 2013-2017 Concentration	Water Quality Trends	Estimated Load Yields	Habitat Condition	Biological Condition	Groundwater Quality Vulnerability	Designated Sensitive Habitat	Total of Scores	Percent of 1 Scores
110100040303	Outlet Roasting Ear Creek	5	2	ND	0	ND	0	0	1	8	38%
110100040304	Headwaters South Sylamore Creek	4	ND	ND	0	ND	ND	0	0	4	29%
110100040305	Outlet North Sylamore Creek	0	3	ND	0	0	0	0	1	4	18%
110100040306	Outlet South Sylamore Creek	1	3	1	0	0	0	0	0	5	22%
110100040401	Livingston Creek	0	0	ND	0	ND	ND	0	0	0	0%
110100040402	Wideman Creek-White River	0	0	ND	0	0	ND	0	1	1	5%
110100040403	Prong Cove-Rocky Bayou	0	ND	ND	0	ND	ND	0	0	0	0%
110100040404	East Twin Creek-White River	0	ND	ND	0	ND	ND	0	1	1	7%
110100040405	West Rocky Bayou-Rocky Bayou	3	ND	ND	0	ND	ND	0	0	3	21%
110100040406	Hidden Creek-White River	2	ND	ND	0	ND	0	0	1	3	20%
110100040407	West Lafferty Creek	3	ND	ND	0	ND	0	0	0	3	20%
110100040408	Lafferty Creek	6	ND	ND	0	ND	ND	0	0	6	43%

Table 3.22. Summary ranking scores for HUC12 subwatersheds of Middle White River watershed (continued).

USGS HUC12 Subwatershed ID Number	USGS HUC12 Subwatershed Name	Natural Resource Concerns	Median 2013-2017 Concentration	Water Quality Trends	Estimated Load Yields	Habitat Condition	Biological Condition	Groundwater Quality Vulnerability	Designated Sensitive Habitat	Total of Scores	Percent of 1 Scores
110100040409	Cagens Creek-White River	1	ND	ND	0	ND	ND	0	1	2	14%
110100040501	Upper Poke Bayou	5	ND	ND	1	ND	ND	0	0	6	43%
110100040502	Sullivan Creek	3	ND	ND	0	ND	0	0	0	3	21%
110100040503	Middle Poke Bayou	4	ND	ND	0	ND	0	0	0	4	27%
110100040504	Miller Creek	6	ND	ND	3	1	0	1	0	11	69%
110100040505	Lower Poke Bayou	3	ND	ND	3	ND	0	0	0	6	43%
110100040601	Mill Creek-White River	1	ND	ND	0	ND	0	0	0	1	7%
110100040602	Wolf Bayou	1	0	ND	0	ND	0	0	0	1	5%
110100040603	Brier Creek-White River	0	ND	ND	2	ND	0	0	0	1	7%
110100040604	Greenbrier Creek	5	5	ND	3	ND	ND	1	0	14	70%
110100040605	Spring Creek	7	ND	ND	3	ND	ND	0	0	10	71%
110100040606	Betsey Gill Creek-White River	3	ND	ND	3	ND	ND	0	1	7	50%
110100040701	Upper Salado Creek	1	0	ND	0	0	0	0	1	3	14%
110100040702	Middle Salado Creek	3	1	ND	0	ND	ND	0	1	5	25%
110100040703	Lower Salado Creek	4	3	ND	3	ND	0	1	1	12	57%
110100040704	Big Creek-White River	3	ND	ND	3	ND	ND	1	1	8	57%

Table 3.22. Summary ranking scores for HUC12 subwatersheds of Middle White River watershed (continued).

USGS HUC12 Subwatershed ID Number	USGS HUC12 Subwatershed Name	Natural Resource Concerns	Median 2013-2017 Concentration	Water Quality Trends	Estimated Load Yields	Habitat Condition	Biological Condition	Groundwater Quality Vulnerability	Designated Sensitive Habitat	Total of Scores	Percent of 1 Scores
110100040705	Goodie Creek-White River	1	3	ND	3	ND	ND	0	1	8	40%
110100040706	Mud Creek-White River	3	ND	ND	3	ND	ND	0	1	7	50%

ND = no data available for this HUC12 subwatershed

The Hicks Creek HUC12 subwatershed also has the highest percentage of scores that are 1, followed by Spring Creek, Greenbrier Creek, Miller Creek, and then Lower Salado Creek. The same HUC12 subwatersheds are the top five in both total scores and percentage of scores equal to 1, although there is some variation in the order of the top five spots. The fact that the HUC12 subwatersheds with streams on the state list of impaired waterbodies have the highest-ranking scores, indicates that the ranking approach used is appropriate for identifying subwatersheds with water quality issues.

The five HUC12 subwatersheds recommended for nonpoint source pollution management through this current watershed are listed below and mapped on Figure 3.37:

- Hicks Creek (HUC ID number 110100040201);
- Greenbrier Creek (HUC ID number 110100040604);
- Miller Creek (HUC ID number 110100040504);
- Spring Creek (HUC ID number 110100040605); and
- Lower Salado Creek (HUC ID number 110100040703).

3.9.3 Management of Other HUC12 Subwatersheds

There are five HUC12 subwatersheds specifically recommended for management through this watershed management plan. As can be seen in Table 3.22, these are not the only subwatersheds with potential water quality or biological issues. 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 anywhere in the Middle White River watershed.

3.10 Stakeholder Concerns

On May 31, 2018, ANRC sponsored a stakeholder meeting as part of development of this watershed management plan. At this meeting, stakeholders were asked to identify issues and concerns about activities occurring in the Middle White River watershed. The emphasis was on water quality issues, but stakeholders were free to identify other issues. Table 3.23 is a list of the water quality issues identified by stakeholders for this watershed management plan.

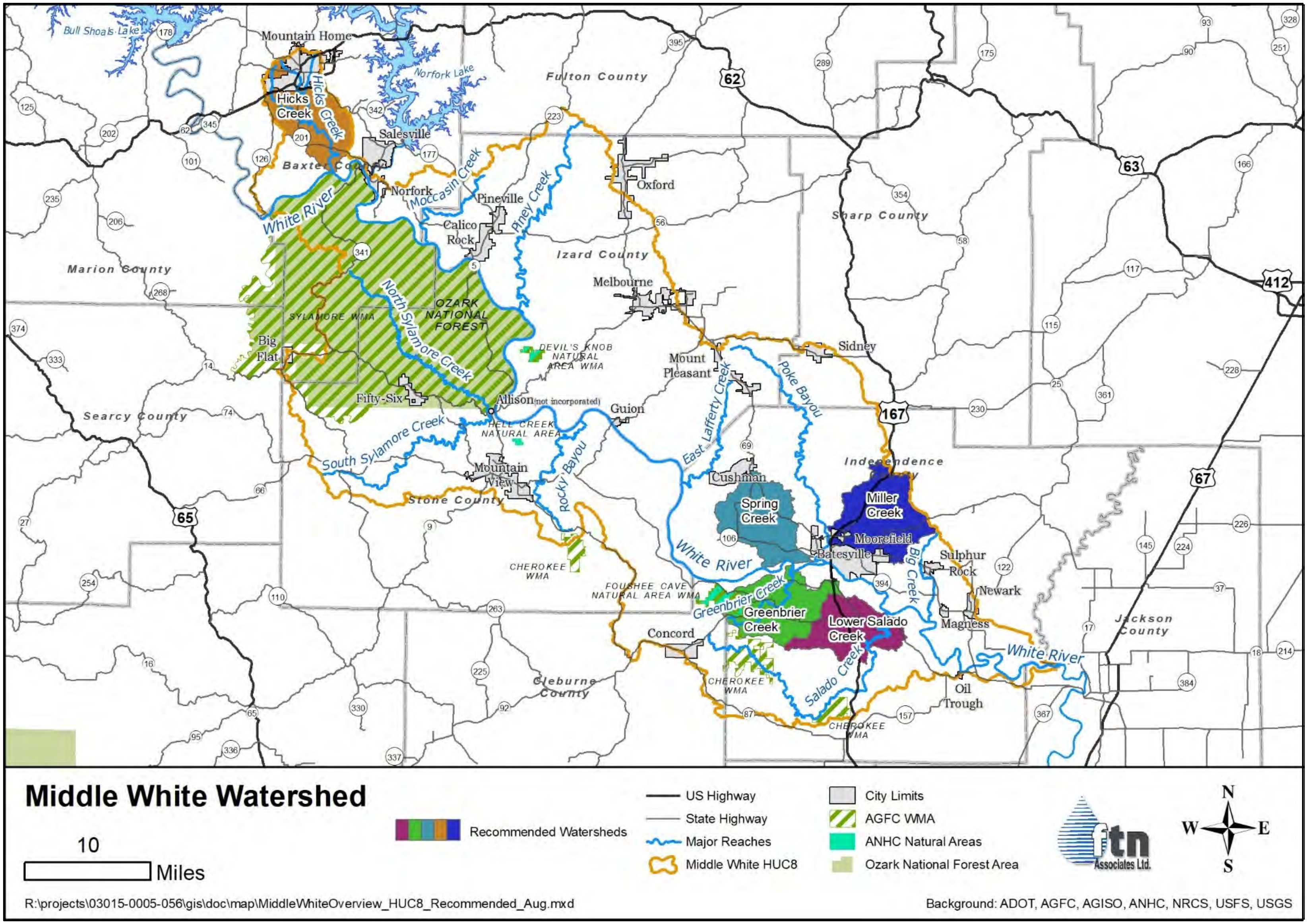


Figure 3.37. Middle White River HUC12 subwatersheds recommended for initial nonpoint source pollution management.

Table 3.23. Water quality issues in the Middle White River watershed identified at stakeholder meeting.

Legal/illegal gravel mining	Cattle in streams
Protecting public water supply and source water areas	Need to upgrade wastewater facilities throughout the watershed
Destruction of riparian areas	Pesticide spraying in ditches by county
Protecting karst areas from nutrients, bacteria leaching from soils above	Tourism and recreation major part of the economy and dependent on good water quality
Failed septic systems	Erosion from croplands
Overgrazing of pastures and erosion	Erosion from dirt and gravel roads
Clear cutting and other forest management practices affect stream water quality	

In 2005, a Watershed Restoration Action Strategy was prepared for the watershed of the White River from Bull Shoals Dam to the Independence County line (Friends of the North Fork and White Rivers, Inc. 2007). Issues and concerns identified during public meetings associated with the Watershed Restoration Action Strategy are listed in Table 3.24.

Table 3.24. Issues identified in Watershed Restoration Action Strategy (Friends of the North Fork and White Rivers, Inc. 2007).

Water Quality	Habitat Quality	Recreation, aesthetics, general	Regulatory Issues
• Elevated nutrients in rivers • Septic systems • Livestock and poultry waste • Poor water well placement • Contamination of fish, wildlife, and humans • Toxic spills • Wastewater discharges • Overuse of fertilizers, pesticides, and other chemicals • Instream flow, stream minimum flow • Sediment and erosion • Unregulated development with substandard road and drainage • Instream gravel mining • Mining of sod, dirt or stone near rivers	• Destruction of riparian buffers • Loss of undeveloped area • Reduction of habitat due to development • Forest health and maintenance	• Need for walk-in fishing access • Lack of watercraft horsepower limits • Lack of watercraft speed limits • Public apathy • Loss of aesthetics, need to preserve natural beauty • Trash dumping	• Perceived lack of enforcement of existing regulations

4.0 MANAGEMENT PLAN

4.1 Management Concerns for Recommended Subwatersheds

4.1.1 Hicks Creek HUC12 Subwatershed

Natural Resource Concern scores for this subwatershed in the upper 25th percentile for the Middle White River watershed are excess nutrients, pathogens, excess sediment, streambank erosion, concentrated flow erosion, and sheet, rill, and wind erosion. Hicks Creek is on the state list of impaired waterbodies due to high measurements of *E. coli* (ADEQ 2017, 2018a), which is expected to be addressed through management of regulated point and nonpoint sources. Median concentrations of turbidity, TSS, and nutrients for 2013-2017 at Hicks Creek water quality stations are in the upper 25th percentile, and the median concentration of DO for 2013-2017 at one Hicks Creek water quality station is in the lowest 25th percentile. Median nutrient concentrations for 2013-2017 at the water quality station closest to the subwatershed outlet on Big Creek are also in the upper 25th percentile. Estimated yields of sediment, total phosphorus, and total nitrogen are all in the upper 25th percentile for the watershed. In addition, water quality trends that suggest declining water quality were identified at a monitoring station on Hicks Creek. Groundwater quality is also considered to be vulnerable in areas of this subwatershed.

Based on available water quality data, and ADEQ water quality assessments, the high *E. coli* levels that have resulted in Hicks Creek being on the state list of impaired waters, are from the Mountain Home WWTP and runoff from developed areas in and around Mountain Home. It is expected that this impairment will be addressed by regulation of the point and nonpoint sources through the state National Pollutant Discharge Elimination System (NPDES) program. It is possible that storm runoff from Mountain Home will be regulated under the NPDES stormwater program starting in 2019. Because Mountain Home is classified by the US Census Bureau as an “urbanized cluster”, and stormwater runoff from Mountain Home enters an impaired waterbody (Hicks Creek), Mountain Home may be required by ADEQ to obtain an NPDES municipal stormwater discharge permit. If this occurs, nonpoint sources in the Hicks Creek subwatershed within the delineated permit area will become regulated nonpoint sources. Therefore, nonpoint sources of *E. coli* in the Hicks Creek subwatershed will not be addressed in this plan. High nutrient and sediment concentrations in Hicks Creek can be reduced along with *E. coli* levels through management of regulated point and nonpoint sources.

The relatively high nutrient concentrations in lower Big Creek are likely at least partly the result of the influence of the Mountain Home WWTP, a regulated point source. However, there are unregulated nonpoint sources of nutrients in the areas of the Hicks Creek subwatershed that do not drain to Hicks Creek. Therefore, the suggested focus for nonpoint source pollution management in this subwatershed includes maintaining, improving, or increasing practices that reduce nonpoint source inputs of nutrients, pathogens, and sediment to streams and groundwater.

4.1.2 Greenbrier Creek HUC12 Subwatershed

Natural Resource Concern scores for the Greenbrier Creek subwatershed in the upper 25th percentile for the Middle White River watershed are excess nutrients, pathogens, heavy metals, and pesticides. Median concentrations of turbidity, TSS, total phosphorus, and total nitrogen for the period 2013-2017 are in the upper 25th percentile for the watershed, and the median concentration of DO for 2013-2017 is in the lowest 25th percentile. Estimated yields of sediment, total phosphorus, and total nitrogen are all in the upper 25th percentile for the watershed.

Greenbrier Creek is on the state list of impaired waterbodies because it was assessed in 2004 using the DO criteria for Boston Mountain perennial streams with watersheds larger than 10 sq mi, 6 mg/L. Since then, ADEQ has determined that DO criteria for Delta least-altered streams with watersheds 10 to 100 sq mi (5 mg/L for primary season and 3 mg/L for critical season) are more appropriate for Greenbrier Creek at the ADEQ water quality monitoring location (station WHI0167). The DO measurements that have been collected appear to indicate Greenbrier Creek is meeting the Delta least-altered stream DO criteria. However, ADEQ has not been able to collect enough critical season DO measurements to officially assess it since the change in evaluation method (J Wise, ADEQ, personal communication 12/10/18).

A comparison of nutrient concentrations collected since 2001 at station WHI0167 indicated that nitrogen inputs to Greenbrier Creek have declined. In addition, DO concentrations may have increased (see Section 3.2). This suggests that there may be a relationship between nitrogen concentrations and DO. Linear regression analysis of DO to nutrient concentrations found a statistically significant negative correlation between TKN and DO concentrations (Appendix E).

The recommended focus for the Greenbrier Creek subwatershed is delisting Greenbrier Creek as an impaired waterbody, while maintaining, improving, or increasing practices that reduce nonpoint source inputs of nutrients, pathogens, and sediment to the stream and groundwater.

4.1.3 Miller Creek HUC12 Subwatershed

Natural Resource Concern scores for the Miller Creek subwatershed in the upper 25th percentile for the Middle White River watershed were excess nutrients, excess sediment, pathogens, pesticides, streambank erosion, and rill, sheet, and wind erosion. Estimated yields of sediment, total phosphorus, and total nitrogen were all in the upper 25th percentile for the watershed. A 2008 EPA habitat survey of Gravel Creek in this subwatershed classified riparian vegetation as poor. Groundwater quality is also vulnerable in this subwatershed. No water quality data were found from the Miller Creek subwatershed.

The recommended focus in the Miller Creek subwatershed is water quality monitoring to determine if water quality is meeting standards, and maintaining, improving, or increasing practices that reduce nonpoint source inputs of nutrients, pathogens, and sediment to streams and groundwater.

4.1.4 Spring Creek HUC12 Subwatershed

Natural Resource Concern scores for the Spring Creek subwatershed in the upper 25th percentile for the Middle White River watershed were excess nutrients, excess sediment, pathogens, pesticides, concentrated flow erosion, streambank erosion, and rill, sheet, and wind erosion. Estimated yields of sediment, total phosphorus, and total nitrogen were all in the upper 25th percentile for the watershed. No water quality data were found from the Spring Creek subwatershed.

The recommended focus in the Spring Creek subwatershed is water quality monitoring to determine if water quality is meeting standards, and maintaining, improving, or increasing practices that reduce nonpoint source inputs of nutrients, pathogens, and sediment to streams.

4.1.5 Lower Salado Creek HUC12 Subwatershed

Natural Resource Concern scores for the Lower Salado Creek subwatershed in the upper 25th percentile for the Middle White River watershed are excess nutrients, pathogens, petroleum and heavy metals, and pesticides. Median concentrations of turbidity and TSS for the period 2013-2017 are in the upper 25th percentile for the watershed, and the median concentration of DO for 2013-2017 is in the lowest 25th percentile. Estimated yields of sediment, total phosphorus, and total nitrogen are all in the upper 25th percentile for the watershed. Salado Creek is designated an Extraordinary Resource Water[body] of the Boston Mountains ecoregion (Arkansas Pollution Control and Ecology Commission 2014). The Salado Creek fish community in this subwatershed has been characterized as being good, i.e., generally similar to communities in Boston Mountain ecoregion reference streams.

The majority of the Lower Salado Creek subwatershed is relatively flat, and much of the stream has a low gradient, more like streams of the Delta region than the reaches of Salado Creek in the Upper and Middle Salado Creek HUC12 subwatersheds. Therefore, ADEQ has changed the DO evaluation criteria for Salado Creek station WHI0166 to those for Least-altered Delta streams with watersheds greater than 100 sq mi (5 mg/L for both primary and critical season). A number of DO measurements from station WHI0166 on Salado Creek are below the applicable Least-altered Delta Stream DO water quality criterion of 5 mg/L. However, there are not enough measurements for ADEQ to assess whether this reach of Salado Creek meets the DO criterion.

DO saturation percentages were calculated for the samples from station WHI0166. If the DO levels were not influenced by decomposing organic matter, DO percent saturation values for the sample would be close to 100%. DO percent saturation values ranged from 101% to 41%. When DO concentrations were less than 5 mg/L, DO percent saturation values ranged from 72% to 41%. This suggests that the low DO levels are not solely the result of natural conditions, and that decomposing organic matter, which could include die-off from algal blooms, is affecting DO levels in Salado Creek at station WHI0166.

A comparison of nutrient concentrations collected since 2001 at station WHI0166 indicated that total phosphorus inputs to lower Salado Creek may have declined, and DO concentrations may have increased (see Section 3.2). This suggests that there may be a relationship between phosphorus concentrations and DO. However, linear regression analysis of DO to nutrient concentrations did not find a statistically significant relationship with total phosphorus. This analysis did find a statistically significant negative correlation between total nitrogen and DO (Appendix E).

The recommended focus for nonpoint source pollution management in the Lower Salado Creek subwatershed is maintaining, improving, or increasing practices that reduce nonpoint source inputs of nitrogen, pathogens, and sediment to the stream and groundwater.

4.2 Management Targets for Recommended Subwatersheds

Water quality pollutants and parameters targeted for management in this watershed management plan were selected based on water quality impairments in the watershed. The water quality pollutants and parameters targeted for management in this watershed management plan are DO and Nutrients.

DO was selected because the DO concentrations at station WHI0166 on Salado Creek appear to be low relative to other water quality monitoring station in the Middle White River watershed. Nutrients were selected because they were identified as a concern by stakeholders (see Section 3.10), and they may be contributing to the low DO levels in Salado Creek at station WHI0166. Reducing *E. coli* levels in the Hicks Creek subwatershed will be addressed through management of regulated sources, and thus is not being addressed in this watershed management plan.

For this watershed management plan, management targets are developed for only three of the five recommended subwatersheds, Hicks Creek (110100040201), Greenbrier Creek (110100040604), and Lower Salado Creek (110100040703). Because there are no water quality measurements available from the Spring Creek (110100040605) or Miller Creek

(110100040504) subwatersheds, it is not possible to develop reduction targets, or determine if reduction targets are needed. If water quality measurements are collected from these subwatersheds, it will be possible, in the future, to determine if reductions in nonpoint source pollution loads are needed, and develop reduction targets.

4.2.1 Dissolved Oxygen Management Targets

The DO numeric criterion for lower Salado Creek is 5 mg/L during both primary and critical seasons (J. Wise, ADEQ, personal communication, 12/10/18). DO concentrations below this criterion have been measured at the lower Salado Creek water quality monitoring station (WHI0166) during both the critical and the primary season. To be assessed as achieving the DO criterion, ADEQ requires that 90% or more of the DO measurements from primary and critical seasons of the assessment period must be equal to or greater than the criterion. The watershed management plan DO target for lower Salado Creek is that 90% or more of DO measurements at station WHI0166, over a five-year period, data from both seasons combined, are 5 mg/L or greater.

All DO measurements from water quality monitoring stations in the Hicks Creek and Greenbrier Creek subwatersheds during the period 2013-2017 meet the applicable numeric criteria (listed in Table 4.1). The focus for the Hicks Creek and Greenbrier Creek subwatersheds, therefore, is to prevent worsening of water quality. Thus, the management target for DO for Hicks Creek and Greenbrier Creek is that there be zero DO measurements less than the criteria.

Table 4.1. Numeric criteria for DO in recommended subwatersheds (J. Wise, ADEQ, personal communication, 12/10/18; Arkansas Pollution Control and Ecology Commission 2014).

Subwatershed	DO criteria, mg/L	
	Primary season	Critical season
Hicks Creek	6	6
Greenbrier Creek	5	3
Lower Salado Creek	5	5

4.2.2 Nutrient Management Targets

There are no numeric criteria for nutrients that apply to the Middle White River watershed. Therefore, no management targets are set for nutrients in the recommended subwatersheds for this plan.

For informational purposes, total nitrogen and total phosphorus measurements collected in the Middle White River watershed during the period 2013-2017 were examined. Data from water quality monitoring stations in those subwatersheds not recommended for initial management, but with percentages of pasture and forest land use similar to that in the recommended subwatersheds (i.e., pasture > 20% and/or forest < 75%), were combined and compared to data from water quality stations in the recommended subwatersheds. Box and whisker graphs comparing these data sets are shown on Figures 4.1 and 4.2.

4.3 Load Reduction Targets

Given the existing levels of pollutants in the recommended HUC12 subwatersheds, and the target levels or loads, we can determine the reduction needed to achieve the target levels. For Hicks Creek and Greenbrier Creek subwatersheds, management targets are already being met, so no reductions are needed.

In the Lower Salado Creek subwatershed, however, it appears that the DO management target is not being met in Salado Creek at station WHI0166. As noted in Section 4.1.5, linear regression analysis identified a statistically significant relationship between DO levels and nitrogen concentrations at Salado Creek water quality station WHI0166. Therefore, it may be possible to improve DO levels in this stream reach by reducing nitrogen inputs. The linear regression relationship is used below to set a nitrogen reduction target associated with DO concentrations that meet water quality standards.

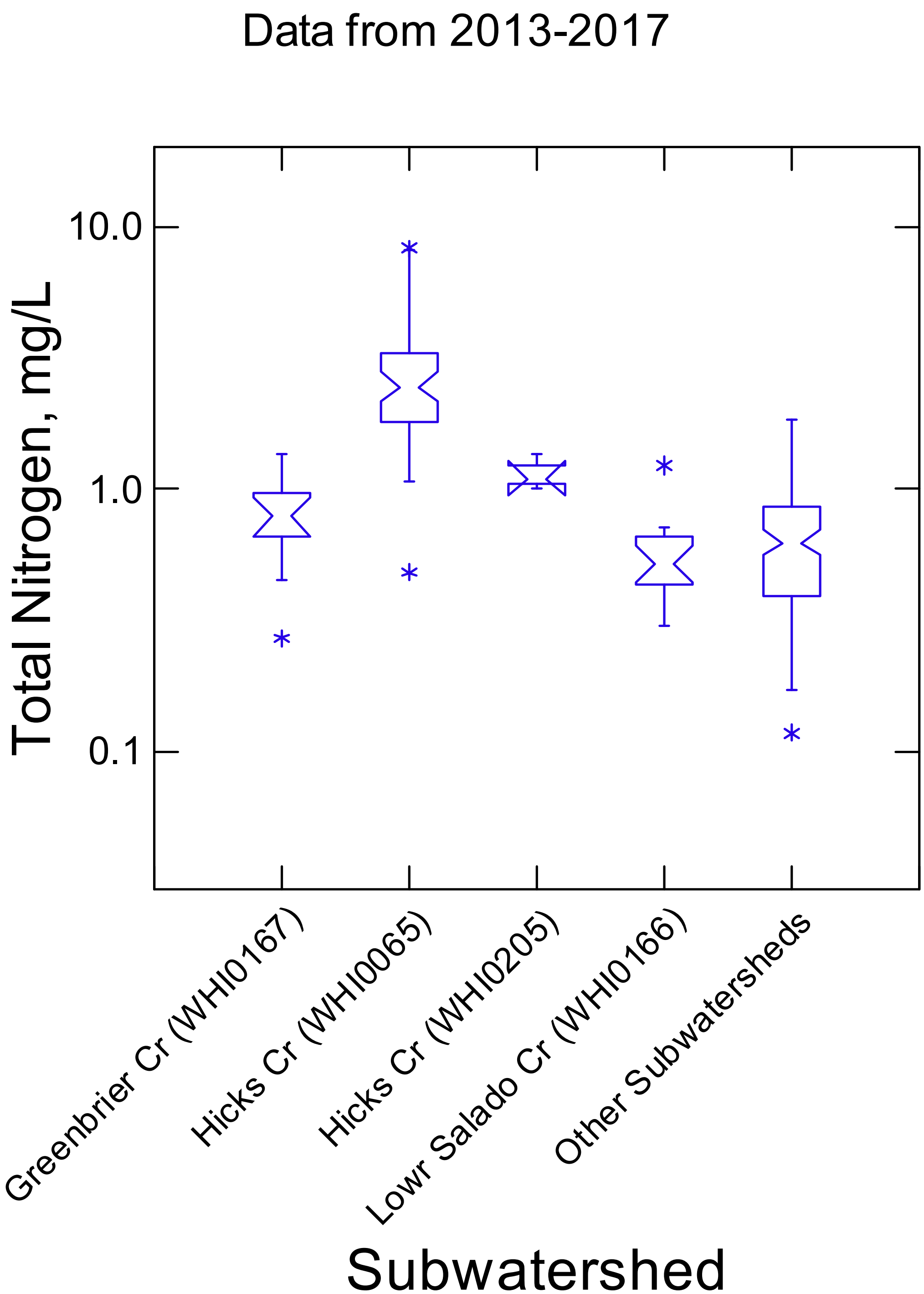


Figure 4.1. Box and whisker graph comparing total nitrogen measurements from recommended subwatersheds to other Middle White River subwatersheds with similar land use.

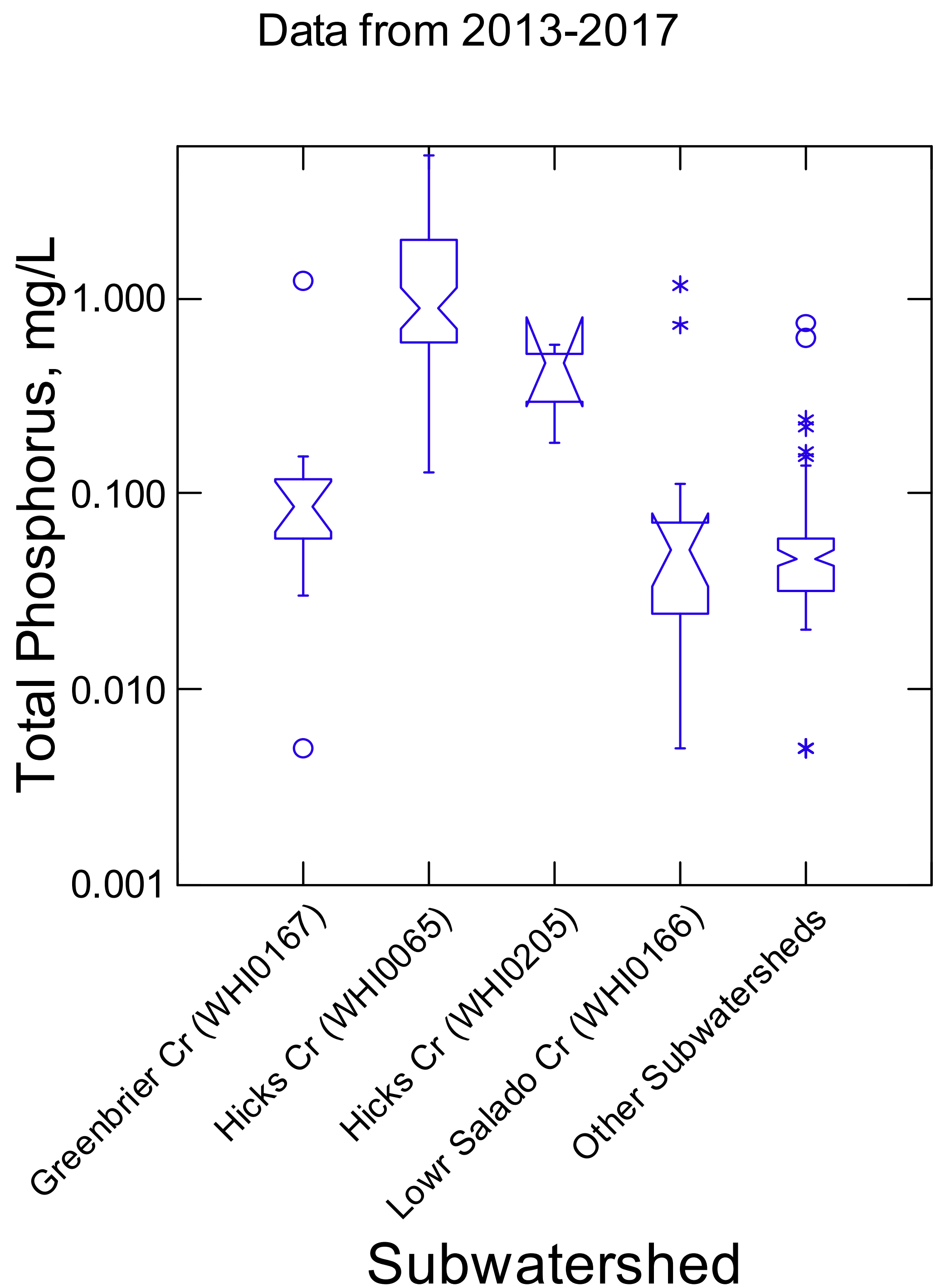


Figure 4.2. Box and whisker graph comparing total phosphorus measurements from recommended subwatersheds to other Middle White River subwatersheds with similar land use.

At the Lower Salado Creek water quality station, WHI0166, there are 15 DO measurements collected during the period 2013-2017 (Table 4.2). Five of these measurements, i.e., 33%, were less than 5 mg/L. For no more than 10% of the DO measurements from this five-year period to be less than 5 mg/L, only one of the measurements can be less than 5 mg/L, i.e., 6%.

Linear regression analysis identified a statistically significant linear relationship between DO and TKN concentrations at station WHI0166. The equation for this relationship is: DO = 4.22 – 3.23 * ln (TKN). The R^2 value associated with this relationship indicates that variations in TKN concentration account for around 36% of the variation in DO. Note that the linear regression analysis indicates that variation in water temperature accounts for around 62% of the variation in DO.

Table 4.2. DO measurements from station WHI0166 2013-2017.

Date	**DO, mg/L**
5/14/2013	8.27
8/20/2013	4.40
1/27/2014	12.0
4/8/2014	9.23
6/24/2014	4.26
10/14/2014	3.81
11/18/2014	9.16
2/9/2015	11.9
4/27/2015	7.51
6/29/2015	4.38
8/17/2015	5.89
9/21/2015	8.26
12/28/2015	10.8
3/7/2016	9.53
4/25/2016	6.66

The target reduction for nitrogen is the change in TKN needed to make less than 10% of the 2013-2017 seasonal DO measurements meet the 5 mg/L criterion. Thus, the DO concentration of 4.26 mg/L from 2013-2017 needs to increase to 5.0 mg/L. The linear regression equation for DO and TKN given above was used to calculate TKN concentrations associated with DO concentrations of 4.26 mg/L and 5.0 mg/L. The target reduction for nitrogen was calculated by taking the percent difference of these two calculated TKN values. These calculations are summarized in Table 4.3.

Table 4.3. Calculation of reduction target for nitrogen in lower Salado Creek.

DO mg/L	Estimated TKN mg/L	Percent Difference TKN
4.26	0.99	21%
5.00	0.78	

Note that the data used in the analysis above do not meet ADEQ requirements for evaluation of water quality standards (ADEQ 2018d). As a result, the lower Salado Creek stream reach is not currently included on the Arkansas list of impaired waterbodies (ADEQ 2017, 2018a).

4.4 Nonpoint Pollution Sources to be Targeted for Management

The focus of nonpoint source pollution management in the recommended subwatersheds of the Middle White River watershed is nutrients (total nitrogen and total phosphorus) from developed areas, pasture, and hayland. Table 4.4 lists the recommended subwatersheds and nonpoint pollution sources of the target pollutants known or expected to be present. Focus areas for management include developed areas, and pasture and haylands along streams and on ridge tops. Of particular interest are areas within 50 feet of streams, and areas where karst features are present. Note that this watershed management plan is intended to address only unregulated nonpoint sources. Some nonpoint sources, such as stormwater runoff from urban areas or industrial sites, may be regulated and/or permitted by ADEQ.

Table 4.4. Nonpoint nutrient sources in recommended subwatersheds.

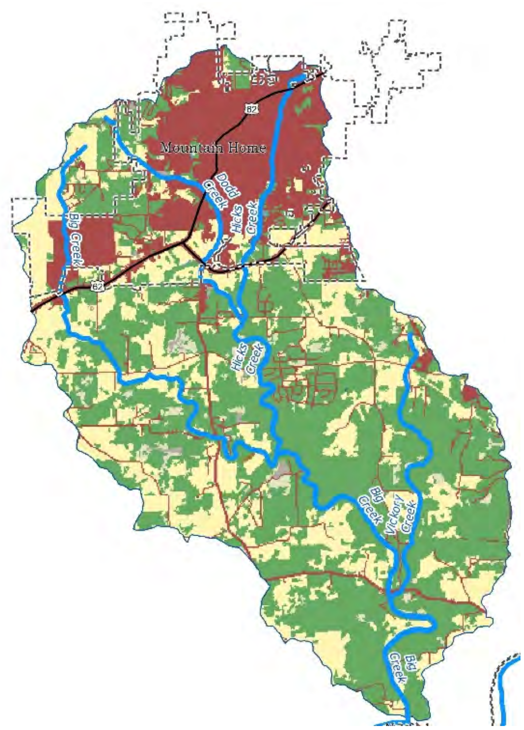
Hicks Creek (110100040201)			
Target Land Use	**% of Area**	**Nonpoint Pollutant Sources**	**Land Use Map**
Developed	23%	Onsite wastewater treatment systems, leaking sewer lines, illicit discharges, pets and wildlife	
Pasture and hayland	28%	Livestock, feral hogs, other wildlife	
Forest	49%	Feral hogs, other wildlife	

Table 4.4. Nonpoint nutrient sources in recommended subwatersheds (continued).

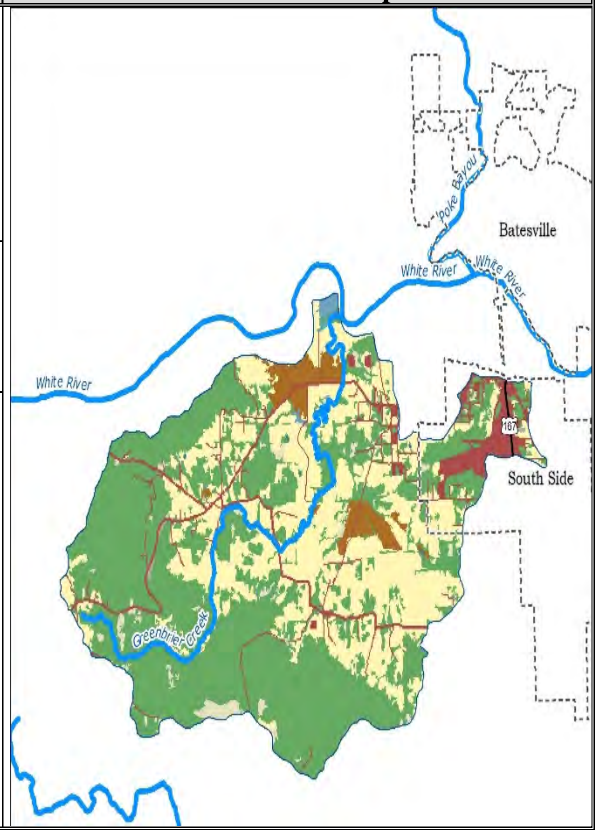
Greenbrier Creek (110100040604)			
Target Land Use	**% of Area**	**Nonpoint Pollutant Sources**	**Land Use Map**
Developed	7%	Fertilizer runoff or seepage, illicit discharges, onsite wastewater treatment systems, pets, wildlife	
Pasture and Hayland	35%	Livestock, feral hogs and other wildlife, manure and fertilizer runoff	
Forest	54%	Feral hogs and other wildlife	

Table 4.4. Nonpoint nutrient sources in recommended subwatersheds (continued).

Lower Salado Creek (110100040703)			
Target Land Use	**% of Area**	**Nonpoint Pollutant Sources**	**Land Use Map**
Developed	8%	Fertilizer runoff or seepage, illicit discharges, onsite wastewater treatment systems, pets, wildlife	
Hay and pasture	38%	Livestock, feral hogs and other wildlife, manure and fertilizer runoff	
Forest	51%	Feral hogs and other wildlife	

4.4.1 On-site Wastewater Treatment Systems

Areas within the three HUC12 subwatersheds recommended for initial management are located within incorporated areas of Mountain Home or Southside, which are served by centralized sewer collection and treatment systems. However, there are residences, subdivisions, campgrounds, and businesses within these subwatersheds that are known or suspected of treating sewage using on-site wastewater treatment systems (e.g., septic systems, small package treatment plants). Some on-site wastewater treatment systems are subject to discharge permitting and monitoring by ADEQ. Most on-site wastewater treatment systems are regulated by the Arkansas Department of Health. In some situations, monitoring of these systems is required (Arkansas State Board of Health 2014). Information on the number of systems permitted by the Arkansas Department of Health present in the recommended subwatersheds is not readily available.

The majority of the land within the recommended HUC12 subwatersheds is classified as being of "very limited suitability" for septic systems (see Table 4.5). Given the karst geology underlying these subwatersheds, it is possible that pollutants discharged to the subsurface, as with septic systems, could find their way into groundwater and surface water.

Table 4.5. Suitability of soils in recommended subwatersheds for septic systems (Center for Advanced Spatial Technologies 2006).

Soils Septic System Suitability	Hicks Creek Subwatershed	Greenbrier Creek Subwatershed	Lower Salado Creek Subwatershed
Slightly limited	22.8%	<1%	2.0%
Moderately limited	<1%	0	0
Limited	23.0%	26.6%	13.4%
Very limited	52.2%	72.5%	83.7%
Not rated	1.5%	<1%	<1%

4.4.2 Illicit Wastewater or Sewage Discharges

Discharge of untreated wastewater to stormwater collection systems can occur as the result of leaks in wastewater collection pipes, or accidental or purposeful connection of wastewater pipe to storm drains, ditches, or streams. If untreated sewage is entering the storm drains and/or streams within Mountain Home, Southside, or other developments in the Hicks Creek, Greenbrier Creek and Lower Salado Creek subwatersheds, it could be a source of nutrients.

Identification and elimination of illicit discharges is a required part of stormwater pollution prevention plans associated with NPDES municipal storm runoff permits. No active storm runoff NPDES permits were found for municipalities or developments in the recommended subwatersheds (ADEQ 2018e). However, it is possible that runoff from Mountain Home that goes into Hicks Creek, which is listed as impaired, could be regulated under the state municipal storm runoff NPDES general permit in the future.

4.4.3 Pets and Wildlife

In cities, the waste from pets, if not properly disposed of, can be a significant source of nutrients and pathogens (e.g., *E. coli*) to surface waters (Hobbie, et al. 2017, Northern Virginia Regional Commission 2004). Wildlife associated with developed areas, such as racoons and Canada geese, also contribute nutrients and pathogens to surface waters (Northern Virginia Regional Commission 2004, Pieper 2013). In less developed areas of the recommended subwatersheds, feral hogs may contribute to erosion, nutrient, or pathogen issues. Feral hogs have been reported in Baxter and Independence Counties (Rushing 2012). It was not confirmed if feral hogs have been reported in the recommended subwatersheds.

4.4.4 Fertilizer

Commercial fertilizer applied to lawns in developed areas can be a significant source of nutrients to surface waters (Hobbie, et al. 2017). The same is true for commercial fertilizers applied to pastures and croplands. Focus areas for management are primarily areas within 50 feet of streams and where karst features are present.

Records from the US Department of Agriculture (USDA) National Agricultural Statistical Service online CropScape application were reviewed to determine the types of crops planted in the two subwatersheds recommended for initial nonpoint source management where crops are grown, Greenbrier Creek and Lower Salado Creek (https://nassgeodata.gmu.edu/CropScape/). These records indicate that, in the Greenbrier Creek subwatershed, cropland upstream of the water quality monitoring station (WHI0167) has primarily been planted with soybeans. Since soybeans are not usually fertilized with nitrogen, cropland in the Greenbrier Creek subwatershed is assumed to not be contributing to the nitrogen load. These records indicate that the majority of the cropland in the Lower Salado Creek subwatershed is also planted in soybeans each year. Other crops planted in this subwatershed appear to be planted in rotation with soybeans, so we assume that fertilizer use on these crops is low, and not a significant contribution to nitrogen load.

4.4.5 Livestock and Manure

Livestock using pastures are sources of nutrients that can enter surface water and groundwater in the recommended subwatersheds (Justus, et al. 2010). Focus areas for management include pasture and haylands along streams and on ridge tops, particularly areas within 50 feet of streams and where karst features are present.

Cattle production has been increasing in Independence County (including Greenbrier Creek and Lower Salado Creek subwatersheds) since 1982, while remaining fairly steady in Baxter County (Hicks Creek subwatershed) (see Figure 4.3). Cattle wastes deposited in or beside streams can provide nutrients and pathogens to streams (e.g., cows loitering in streams). James et al. (2007) found that pastured cattle deposited significantly more manure in and near streams than in other areas of the pasture. Studies have shown that, unless access to streams is restricted, cattle generally spend much of the day in the riparian area, no matter the season, or the availability of other water sources (Zuo and Miller-Goodman 2004, Bagshaw, et al. 2008).

Manure from animal production facilities is a potential source of nutrients in the recommended subwatersheds. Based on 2017 aerial imagery, it appears there may be active confined animal production facilities operating in the recommended subwatersheds (ADEQ

2018f). Poultry production has been increasing in Independence County since 1982, while declining and remaining steady since 2002 in Baxter County (see Figure 4.4). The most common method of disposing of manure from confined animal operations in northern Arkansas is spreading it on pastures. Stockpiles of manure from poultry houses and other confined animal operations are another potential source of nutrients to surface water and groundwater.

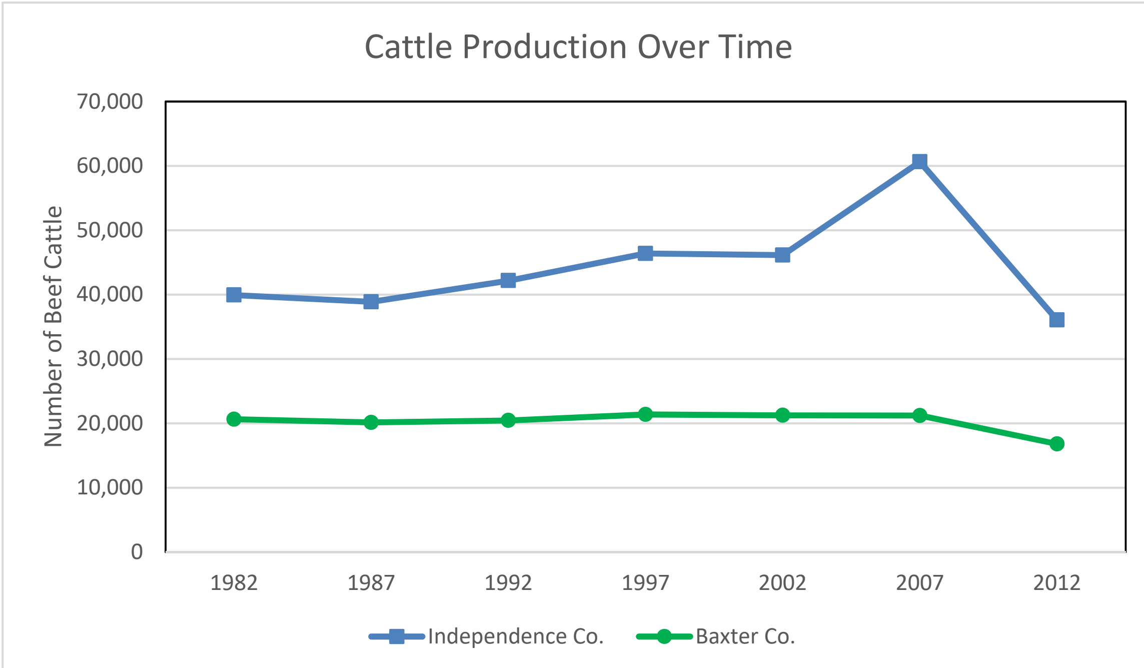


Figure 4.3. Beef cattle reported in Baxter and Independence Counties since 1982 (USDA National Agricultural Statistics Service 2018). The lower cattle production numbers reported for 2012 are likely a result of severe drought conditions in Arkansas that year (Kemper, et al. 2012).

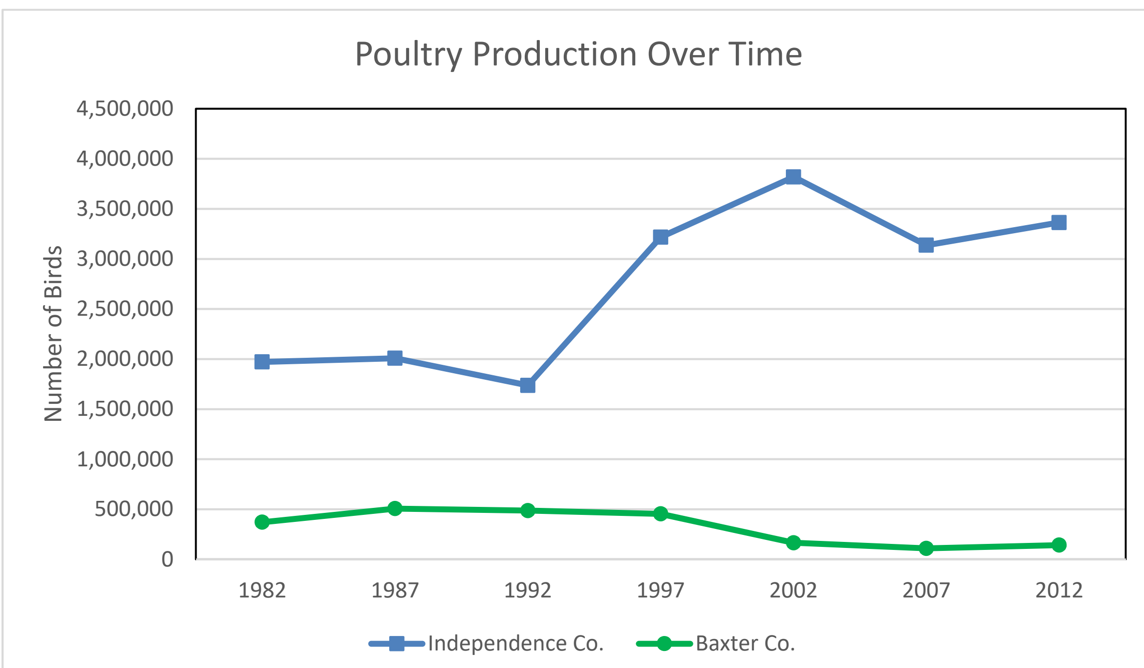


Figure 4.4. Poultry numbers reported for Baxter and Independence Counties since 1982 (USDA National Agricultural Statistics Service 2018).

4.5 Management Practices

At the second public meeting for this watershed management plan, stakeholders were asked to identify management practices to address issues in the Middle White River watershed. Table 4.6 lists the practices identified at the meeting. Those practices identified by stakeholders that are applicable to the target pollutant and nonpoint sources in the recommended subwatersheds are highlighted in yellow.

Table 4.6. Management practices for the Middle White River watershed recommended by stakeholders (yellow highlighted practices are applicable to plan target pollutant and sources).

Nutrient Management Plans	Integrated Pest Management plans
Restrict development along White River	Rotational grazing, flash grazing, pasture management
Stream fencing	Voluntary septic system inspections & repair
Arkansas Unpaved Roads Program	Streambank restoration
Livestock exclusion/restricted access to streams	Arkansas Forestry Commission Forestry recommended practices
Rosgen channel training and low water crossings recommendations	Pasture improvement
Erosion control practices	Woodland restoration with prescribed burning
Greenbelt buffers	Unpaved road management practices & training

ANRC and its partners have implemented nonpoint source pollution management projects in the past that included the recommended subwatersheds. Table 4.7 summarizes the projects in the Middle White River watershed since 2000. Project 16-200 is on-going. In addition to the projects listed in Table 4.7, the Arkansas NRCS annual reports show that farmers in all of the counties of the Middle White River watershed have been implementing management practices through the NRCS Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP), e.g., (NRCS 2017a).

There are two approaches for managing nonpoint source pollution inputs. One is to reduce the sources of the pollutant that end up in runoff. The second is to treat runoff to reduce pollutant load.

Table 4.7. Examples of nonpoint source management practices implemented in the recommended Middle White River watershed since 2000.

Project ID & Name (Lead)	Location	Practice	Extent	Status	Pollutant Reduction
02-162	Stone County	Pasture Aerator	NA	Completed 2003	No information
04-106 Marion County 2004 Mini Grant Project (Crooked Creek Conservation District)	Marion County	No-till Drill	NA	Completed 2005	1,339 lb/yr N 699 lb/yr P 873 lb/yr sediment[1]
05-500 Middle White River – South Izard County (Izard County Conservation District)	MWR watershed south Izard County	Farm Plans	100	Completed 2008	13,072 lb/yr N 6,531 lb/yr P 7,876 lb/yr sediment[1] 32,084 tons soil[2]
		Brush Management	5,100 ac		
		Fence	42,892 ft		
		Pasture & Hay Planting	250 ac		
		Pest Management	7,042 ac		
		Prescribed Grazing	7,065 ac		
		Nutrient Management	7,065 ac		
06-800 Middle White River Watershed (Stone County Conservation District)	MWR watershed Stone County	Cross Fence	129,007 ft	Completed 2008	449 lb/yr N 224 lb/yr P 236 lb/yr sediment[3]
		Pasture & Hay Planting	762 ac		
		Water Facilities	10		
		Pipeline	12,665 ft		
		Brush Management	552 ac		
		Spring Development	5		
		Critical Area Planting	6 ac		
16-200 Hicks Creek – White River Watershed Project (Baxter County Conservation District)	Hicks Cr, Perry Cr-White R, Farris Cr-White R, Moccasin Cr-White R, Sneeds Cr-White R, and Sugarloaf Cr-White R in Baxter County	Brush Management		In progress, expect completion 2020	19,225 lb/yr N 9,609 lb/yr P 7,440 ton/yr sediment[4]
		Fence			
		Pasture Establishment			
		Livestock Pipeline			
		Heavy Use Areas			
		Watering Facilities			
		Spring Development			
		Pond			
		Equipment to Rent	NA		
		Farm Plans	60		

[1] (ANRC, 2007)
[2] (Izard County Conservation District, 2008)
[3] (ANRC, 2010)
[4] (ANRC, 2017)

Developed, residential, and agricultural land uses are present in the recommended subwatersheds and have potential nonpoint sources of nutrients associated with them. Below, management practices appropriate to the unregulated nonpoint sources of nitrogen associated with these land uses in the recommended subwatersheds are discussed separately

4.5.1 Developed and Residential Areas

In this watershed management plan, nonpoint sources of nutrients associated with developed and residential areas in within the incorporated areas of Mountain Home in the Hicks Creek subwatershed are assumed to regulated, as it is likely that Mountain Home stormwater runoff will be regulated under an NPDES permit in the near future.

Possible nutrient sources associated with developed and residential areas in the Greenbrier Creek and Lower Salado Creek subwatersheds that could be reduced include commercial fertilizer, leaking septic systems or sewage collection systems, and pet waste. Homeowners and lawn care companies can reduce the amount of fertilizer that gets into runoff from lawns by applying fertilizers only during the growing season, not over-applying fertilizer, and not applying fertilizer immediately before or after heavy rainfall (Patton 2008). Pet waste can be picked up and disposed of so that it does not get into runoff.

Much of the developed area in the Greenbrier Creek and Lower Salado Creek subwatersheds is served by a “low pressure” sewage collection system installed around 2008 (Southside Public Water Authority 2018, ADEQ 2018e). New construction within the service area for this system is required to connect to the system (Southside Public Water Authority 2018). Being relatively new, leakage from this system is less likely to be a source of nutrients in these subwatersheds. Conversion from on-site wastewater treatment to the centralized wastewater treatment system may be at least part of the reason behind the declines in median TKN and total nitrogen concentrations at the Greenbrier Creek and lower Salado Creek water quality monitoring stations between the periods 2001-2003 and 2013-2016 (see Section 3.2).

There are stormwater management practices for residential and urban areas that can passively treat storm runoff to reduce nutrients. A recent review of stormwater best management practices (BMPs) commonly used and studied in urban areas found that the following practices often resulted in statistically significant reductions in nitrogen concentrations in runoff; grass strip, media filter, porous pavement, retention pond, and wetland basin or channel (Clary, et al. 2017). Riparian buffers (i.e., greenbelt buffers suggested by stakeholders) are also a recommended practice to improve water quality in residential areas (Barry n.d.). Riparian buffers have been shown to reduce total nitrogen inputs to streams (Klapproth and Johnson 2009, Merriman, Gitau and Chaubey 2009).

4.5.2 Pasture and Hayland

Through its Conservation Practice Physical Effects program (CPPE), the NRCS determined that the following management practices not already identified by stakeholders (Table 4.6) are also effective for reducing nutrient inputs to both surface water and groundwater from pasture: silvopasture establishment, karst sinkhole treatment, conservation cover, vegetated treatment area, agrichemical handling facility, manure storage, feral hog management, filter strip, and livestock shelter structure (NRCS 2017b).

Possible agricultural nutrient sources associated with pasture and haylands in the recommended subwatersheds that could be reduced include commercial fertilizer, use of manure from confined animal operations as fertilizer, feral hogs, and livestock in streams. Agricultural users of commercial fertilizers often have a nutrient management plan, and usually have a monetary incentive to apply commercial fertilizer when it is least likely to runoff, because of the cost of the fertilizer. Nutrient management plans (recommended by stakeholders) and associated practices can help farmers apply commercial fertilizer so the amount in runoff and groundwater is minimized. Agrichemical handling facilities reduce the exposure of stored fertilizers to rain and keep it out of runoff and groundwater.

There are practices that can reduce animal manure sources of nutrients in runoff. Feral hogs are present in forest and on agricultural lands throughout Arkansas, and are the focus of active efforts to control their population, including large-scale eradication efforts (Arkansas Cooperative Extension Service 2018, Arkansas Agriculture Department 2018). Reducing feral hogs reduces their manure as a nutrient source.

Eliminating or reducing livestock access to streams associated with pastures (recommended by stakeholders) can reduce inputs of livestock waste directly into the streams. Practices such as alternative water sources, livestock shelter structures, and flash grazing of riparian areas (recommended by stakeholders) can reduce the time livestock spend in pasture streams and reduce inputs of livestock waste into the streams. Rotational and prescribed grazing (recommended by stakeholders) reduces runoff of nutrients from livestock waste on pastures. Waste storage facilities reduce exposure of waste from confined animal production operations to rainfall to keep it out of runoff. Nutrient management plans (recommended by stakeholders) and associated practices can help farmers apply manure from confined animal operations to pastures so the amount that gets into runoff and groundwater is minimized.

Management practices that can reduce nutrients in runoff from pasture and haylands include riparian buffer – forested or herbaceous (suggested by stakeholders), pasture improvement or establishment (recommended by stakeholders), silvopasture establishment, conservation cover, and vegetated treatment area. When these practices are used around sinkholes, they can reduce nutrient inputs to groundwater. In state aerial imagery from 2017 (available on ADEQ EnviroView and AquaView), it appears that trees are present along many of the bigger streams through pastures in the Greenbrier Creek and Lower Salado Creek subwatersheds (ADEQ 2018f). Where forested riparian buffers are not present, they can be added.

4.6 Meeting Reduction Goals

This section explores whether it is possible to achieve the 21% nitrogen reduction goal for the Lower Salado Creek subwatershed, using the management practices identified in Section 4.5. Information on the effectiveness in reducing selected pollutants in surface waters has been published for a number of the management practices identified in the previous section. This information is summarized in Table 4.8. Table 4.8 shows reported reduction percentages for TKN, total nitrogen, total phosphorus, sediment, fecal coliforms, and *E. coli*. This shows that, while the focus of management in this plan is nitrogen, practices that reduce this pollutant also reduce other pollutants that are a concern in the recommended subwatersheds.

Table 4.8. Summary of available information on reduction efficiencies of management practices for plan target pollutants. Note negative values indicate pollutant increase from practice.

Practice	TKN reduction	Total nitrogen reduction	Total phosphorus reduction	Sediment reduction	Fecal Coliform reduction	*E. coli* reduction
Repair of failing on-site wastewater treatment systems and/or leaking wastewater collection systems, and removal of illicit discharges to stormwater systems	100% from this source	100% from this source	100% from this source	Not applicable	100% from this source	100% from this source
Pick up and properly dispose of pet waste	100% from this source	100% from this source	100% from this source	Not applicable	100% from this source	100% from this source
Media filters for stormwater	-4,900% to 95%, median 39%[n]	17-71%, median 32%[m] -312% to 94%, median 19%[n]	-79% to 88%, median 59%[m] -621% to 99%, median 47%[n]	8-98% TSS, median 86%[m] -2,300% to 100% TSS, median 81%[n]	-85% to 83%, median 37%[m] -43,233% to 100%, median 45%[n]	No information
Constructed wetland	-800% to 92%, median 11%[n] -416% to 79%, median 9%[n]	-49% to 76%, median 24%[m] -10,570% to 98%, median 2%[n] -5,929% to 78%, median 21%[n]	71%[a] -55% to 100%, median 48%[m] -1,679% to 99%, median 27%[n] -5,500% to 93%, median 12%[n]	-100% to 100%, median 72%[m] -3,294% to 100% TSS, median 58%[n] -17,900% to 100%, median 34%[n]	55-97%, median 78%[m] -1,150% to 100%, median 55%[n] -6,900% to 94%, median 0%[n]	-17,005% to 100%, median 69%[n]
Stormwater detention pond	-619% to 92%, median 11%[n]	-19% to 43%, median 24%[m] -418% to 86%, median 8%[n]	0-48%, median 20%[m] -1,072% to 92%, median 19%[n]	-1% to 90% TSS, median 49%[m] -5,378% to 100% TSS, median 57%[n]	78-97%, median 88%[m] -574,900% to 100%, median 31%[n]	-3,053% to 100%, median 52%[n]
Stormwater retention pond	-1,383% to 97%, median 24%[n]	-12% to 76%, median 31%[m] -662% to 91%, median 27%[n]	12% to 91%, median 52%[m] -10,300% to 99%, median 49%[n]	-33% to 99% TSS, median 80%[m] -8,600% to 100% TSS, median 75%[n]	-6% to 99%, median 70%[m] -7,900% to 100%, median 67%[n]	-7,900% to 100%, median 68%[n]
Porous pavement	-182% to 99%, median 42%[n]	0-85%, median 42%[m]	0-100%, median 65%[m] -733% to 95%, median 26%[n]	0-97% TSS, median 89%[m] -1,500% to 99% TSS, median 53%[n]	No information	No information

Table 4.8. Summary of available information on reduction efficiencies of management practices for plan target pollutants. Note negative values indicate pollutant increase from practice (continued).

Practice	TKN reduction	Total nitrogen reduction	Total phosphorus reduction	Sediment reduction	Fecal Coliform reduction	*E. coli* reduction
Correct application of commercial fertilizer	No information	No information	No information	No information	Not applicable	Not applicable
Stream exclusion (Fencing + alternative water supply)/Access control	No information	32%[a], 60%[e], 18-25%[h]	76%[a], 60%[e], 18-25%[h]	83%[a], 75%[e] 18-25% TSS[h]	30% - 95%[f] 44-52%[k]	46%[h]
Alternative water supply	No information	41%[a], 13-77%[c], 30%[e]	74-97%[c], 30%[e]	38%[a], 38-96%[c], 30%[e]	57%[b], 51-94%[l]	85%[l]
Livestock shelter structure	No information	No information	No information	No information	No Information	85%[h]
Heavy use area treatment	No information	86%[i]	50%[i]	98%[i]	92-99%[i]	No information
Prescribed/rotational grazing	No information	20%[g]	20%[g]	60%[b], 20%[g]	90-96%[e]	60% - 72%[e]
Forested riparian buffer	No information	47-59%[a], 37-57%[c], 44-70%[g], 68-89%[o]	53-63%[a], 45-70%[g], 30-80%[o]	76%[a], 55-95%[c], 45-70%[g], 60-90%[o]	30%[b]	No information
Pasture planting	No information	66%[a]	67%[a]	59%[a]	No information	No information
Filter strips	-1,536% to 80%, median 4%[k]	1-93%[c] -586% to 70%, median 17%[k]	2-93%[c] 27-96%[j] -25,400% to 99%, median -46%[k]	53% - 91%[a], 18-99%[c] 41-100%[j] -34,881% to 99% TSS, median 50%[k]	30-100%[j] -5,970% to 100%, median -5%[k]	58-99%[j]
Conservation cover	No information	No information	No information	70-76%[a]	No information	No information
Vegetated treatment area	>85%[q]	>85%, average 70%[q]	12-97%, average 70%[q]	70-90% of solids[q]	64-87%[q]	No information

Table 4.8. Summary of available information on reduction efficiencies of management practices for plan target pollutants. Note negative values indicate pollutant increase from practice (continued).

Practice	TKN reduction	Total nitrogen reduction	Total phosphorus reduction	Sediment reduction	Fecal Coliform reduction	*E. coli* reduction
Waste storage facility	No information	52%[a], 29-75%[c], 35%[k]	58%[a], 26-90%[c], 54%[k]	Not applicable	44-99%[k]	97-99%[k]
Agrichemical storage facility	No information	No information	No information	No information	Not applicable	Not applicable
Nutrient management plans	No information	0-84%[c]	8-91%[c]	72-92%[c]	No information	No information
Herbaceous riparian buffer	No information	68%[d], 31-48%[g], 50-76%[p]	67%[d], 50-70%[g], 50-89%[p]	23%[d], 50-70%[g], 66-84%[p]	21-100%[o], 70-95%[q]	No information
Pond	See stormwater retention pond	82%[a]	72-80%[a]	77%[a]	See stormwater retention pond	See stormwater retention pond
Feral hog management	No information	No information	No information	No information	No information	No information
Silvopasture establishment	No information	No information	No information	No information	No information	No information

[a] (Merriman, et al., 2009)
[b] VT database
[c] BMP Tool II
[d] (Garrett, 2011)
[e] (Peterson, et al., 2011a)
[f] (Peterson, et al., 2011b)
[g] https://www.hrpdcva.gov/Documents/Phys%20Planning/2011/ChesBayTMDL/AdditMaterials/CB_Model_BMP_Doc.pdf
[h] (Peterson, et al., 2011c)
[i] with use of mulch, straw, and seed on high use areas from (Peterson, et al., 2011d)
[j] (Peterson, et al., 2011e)
[k] Stream crossing combined with other practices from (Peterson, et al., 2011f)
[l] (Peterson, et al., 2011g)
[m] (Center for Watershed Protection, 2007)
[n] (Geosyntec Consultants, 2018)
[o] (North Carolina Department of Environment and Natural Resources, n.d.)
[p] (Klapproth & Johnson, 2009)
[q] (Koelsch, et al., 2006)

It is useful to consider that, typically, suites of management practices are implemented together. Pollutant reductions from implementing suites of practices are likely to be greater than those indicated for individual practices in Table 4.8. For example, stream access control, alternative water supply, and rotational grazing can be implemented together as a suite of practices. Given the large number of potential combinations of practices, it is only practical at this point to consider the impacts of practices individually.

In addition, it is good to keep in mind that studies in the Ozarks suggest that land management on karst terrain can affect groundwater quality, which can in turn affect surface water quality (Mott, Hudson and Aley 2000). NRCS states that several of the management practices recommended in this plan can also protect groundwater quality (NRCS 2017b). However, information on effectiveness of these practices in reducing target pollutants in groundwater was not found. In addition, no data was found that would indicate if there are problems with groundwater quality in the Middle White River watershed.

The target reductions for nitrogen loads from hayland and pasture, and residential and developed areas in the Lower Salado Creek subwatershed, are 21%. With no data available to indicate otherwise, we assume that the loads from developed areas and pastures are equal, so the reduction target is the same for both sources.

4.6.1 Developed and Residential Areas

Practices that appear appropriate for reducing nitrogen inputs from developed and residential nonpoint sources in the Lower Salado Creek subwatershed are listed in Table 4.9. Based on state imagery from 2017, it appears that forested riparian buffers of some kind are already present along the majority of the stream reaches in developed areas within this subwatershed. Therefore, riparian buffers are excluded from Table 4.9. Although those stormwater management practices that have been studied have been shown to reduce nitrogen concentrations by over 90% in some cases, the median removal efficiencies reported for several of these practices are less than 21%. However, since multiple practices are usually implemented together, it should be possible to achieve the target 21% nitrogen load reduction. A water quality survey could be useful in characterizing nitrogen loads from different locations within the subwatershed. This knowledge would help with siting practices to effectively reduce nitrogen load.

Table 4.9. Management practices for reducing nitrogen from developed and residential areas.

Practices	Range of reported TKN reductions[a]	Median of reported change in TKN[b]	Range of reported total nitrogen reductions[a]	Reported medians of total nitrogen reductions[b]	Reduction assumed for estimates[c]
Pet waste management program	-	-	-	-	-
Inspect and repair on-site wastewater systems	-	-	-	-	-
Fertilizer management program	-	-	-	-	-
Media filter	0- 95%	39%	0-94%	19%, 32%	25%
Constructed wetland	0-92%	10%	0-98%	2%, 21%, 24%	20%
Detention pond	0-92%	11%	0-86%	8%, 24%	15%
Retention pond	0-97%	24%	0-91%	27%, 31%	30%
Porous pavement	0-99%	42%	0-85%	42%	40%
Filter strips	0-80%	4%	0-93%	17%	20%

[a] Note that all of these practices also increased nitrogen in some cases.
[b] These median values are based on including cases where nitrogen increased as well as those where nitrogen was reduced.
[c] Based on reported median values.

4.6.2 Pasture and Hayland

Practices that appear appropriate for reducing nitrogen inputs from pasture and hayland in the Lower Salado Creek subwatershed are listed in Table 4.10. Based on state imagery from 2017, it appears that trees, which may be forested riparian buffers, are present along many of the stream reaches adjacent to pasture and hayland in this subwatershed. A water quality survey could help with siting practices where they would do the most good.

Table 4.10. Management practices for reducing total nitrogen from pasture and hayland.

Practices	Range of reported reductions	Reduction assumed for estimates
Nutrient Management Plan	8-84%	40%
Waste storage facility	29-75%	30%
Agrichemical storage facility	-	30%
Stream access control	18-60%	40%
Alternative water supply	13-77%	40%
Livestock shelter structure	-	-
Prescribed grazing	20%	20%
Pasture improvement	66%	50%
Silvopasture establishment	-	-
Forested riparian buffer	37-89%	50%
Herbaceous riparian buffer	31-76%	40%
Filter strip	0-93%	10%
Heavy use area treatment	86%	70%
Vegetated treatment area	>85%	50%
Feral hog management	-	-

5.0 IMPLEMENTATION STRATEGY

The implementation strategy for the Middle White River watershed management plan includes several elements. These elements are described in this section. 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,
- Milestones for implementation,
- Criteria for evaluation of progress,
- Regular evaluation of progress toward plan goals,
- Updating the plan to accommodate changes in the watershed, and/or in understanding of the watershed, and
- Proposed implementation schedule.

5.1 Information and Education

Watershed management is fundamentally a social activity (Thornton and 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 plan, therefore, include the following:

- 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 for water quality protection and improvement; and

- Improve the understanding of how water quality and environmental improvements contribute to increased economic and social capital in the community.

5.1.1 Existing Outreach and Education in the Middle White River Watershed

There are a number of organizations active in the Middle White River watershed that have outreach and education programs in place that could be used as vehicles to accomplish the Information and Education objectives of this watershed management plan. Examples are listed in Table 5.1. Outreach and education activities of some of these organizations are described below. Most, but not all, of these organizations are active throughout the Middle White River watershed.

Table 5.1. Middle White 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, Poultry Federation
Recreationists	USFS, US Fish and Wildlife Service, USACE, AGFC, Arkansas Canoe Club, Audubon Arkansas, Friends of the North Fork and White Rivers, Ozark Off-road Cyclists, Ozark Society, Ozark Highlands Trail Association, The Nature Conservancy, Federation of Fly Fishers, Trout Unlimited, Lyon College Education and Adventure Program
Landowners and residents	USFS, US Army Corps of Engineers, Rural Water Associations, NRCS, University of Arkansas Division of Agriculture, County Conservation Districts, Arkansas Forestry Commission, AGFC, Arkansas Natural Heritage Commission, The Nature Conservancy, Arkansas Master Naturalists, Trout Unlimited, Friends of the North Fork and White Rivers
Local and county governments	Arkansas Economic Development Commission, The Nature Conservancy, Arkansas Natural Resources Commission, Friends of the North Fork and White Rivers, Arkansas Department of Parks and Tourism
Concessioners, vendors, hostelers, restaurants	USACE, Friends of the North Fork and White Rivers, Arkansas Economic Development Commission

5.1.1.1 US Forest Service

Information and education activities of the USFS include interpretive programs at Blanchard Springs Caverns; Ozark-St. Francis National Forest website (https://www.fs.usda.gov/osfnf) and Facebook page (https://www.facebook.com/ozarkstfrancis); publications; presentations and displays at meetings, fairs, and festivals; news media stories; and hosting volunteer and training events. Given the location of the Sylamore District of the Ozark National Forest, information and education activities are focused primarily in Stone County, however, visitors from all over the Middle White River watershed can be exposed to USFS interpretive programs in person and online.

5.1.1.2 Natural Resources Conservation Service

Information and education activities of the NRCS include participation in field days and farm demonstrations, soil and water stewardship materials, and informational and training programs at county offices, in addition to information posted on their website (https://www.nrcs.usda.gov/wps/portal/nrcs/ar/home/), Twitter (https://twitter.com/arkansasnrcs), and YouTube (https://www.youtube.com/channel/UCWPRIlokkCy1DTROlEoW5OA/featured). 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 or improve water quality so water quality standards are met.

5.1.1.3 University of Arkansas Division of Agriculture

The UofA Division of Agriculture is a research and information support agency for the agricultural sector in Arkansas. The Division of Agriculture provides 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 feral hog management, and short and long-term agricultural methods that protect water quality so water quality standards are met. A website (https://www.uaex.edu/), and Facebook (https://www.facebook.com/uaex.edu/), Twitter (https://twitter.com/UAEX_edu), Instagram (https://www.instagram.com/uaex_edu/), and YouTube (https://www.youtube.com/user/ARextension) accounts provide access to information about programs and resources, and copies of informational publications and videos.

The Arkansas Cooperative Extension Service also provides information on protecting water quality for non-agricultural landowners and residents in developed areas, through their website and social media. In addition, they work with communities in Northwest and Southeast Arkansas to provide public urban stormwater education and participation programs to fulfill requirements of NPDES municipal stormwater permits. These programs include printed materials; videos; commercials; storm drain markers; demonstrations and presentations to children, adults, and local companies; stream and lake clean-up events; and social media that include slogans or catch phrases like “slow it down, spread it out and soak it in”, “Know the Flow – storms on streets drain to creeks”, “If it rains, it drains”, and an animated spokesperson Wayne the raindrop. This information could be useful to the Middle White River watershed municipalities even if they don’t come under NPDES municipal stormwater permits. Information on this topic is available to the public on the Cooperative Extension Service website, https://www.uaex.edu/environment-nature/water/stormwater/default.aspx.

5.1.1.4 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, in addition to websites (e.g., http://www.stonecountyconservationdistrict.com/, http://www.baxtercountycd.com/, http://www.independenceccd.com/) and social media like Facebook (e.g., https://www.facebook.com/izardcountyconservationdistrict/, https://www.facebook.com/stonecountyconservationdistrict/, https://www.facebook.com/independececcd/). 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. The Baxter County Conservation District is also conducting education and outreach activities as part of the active 319 Project in the Hicks Creek subwatershed.

5.1.1.5 Arkansas Natural Resource Agencies

Arkansas natural resource agencies, including Arkansas Forestry Commission, AGFC, Arkansas Natural Heritage Commission, and the ANRC all have information and education programs aimed at increasing public interest, understanding, and stewardship of the natural resources of our state, including protecting water quality to achieve water quality standards. These agencies use a variety of methods to reach Arkansans, including websites (https://www.agfc.com/en/, http://www.naturalheritage.com/, https://www.anrc.arkansas.gov/); social media (e.g., https://www.youtube.com/user/ArkansasGameandFish, https://www.facebook.com/arnaturalheritage/, https://www.facebook.com/Arkansas-Natural-Resources-Commission-127788010626999/); newsletters; presentations and displays at meetings, fairs, and festivals; news media stories; and hosting volunteer and training events.

5.1.1.6 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." Protecting and improving water quality to meet standards is part of this goal. This goal is accomplished in part through sponsorship of field days, and an annual conference (Arkansas Grazing Lands Coalition 2017).

5.1.1.7 Friends of the North Fork and White Rivers

The Friends of the North Fork and White River conducts and is active in a number of activities to educate local stakeholders about water quality in Bull Shoals Lake, Norfork Lake, White River (from Bull Shoals Lake to Independence County line), North Fork of the White River, and their tributaries, and what can be done to protect and improve that water quality. These activities include resources and a program to educate students about aquatic food webs, an

Enviroscape physical model to demonstrate nonpoint source pollution, video on nonpoint source pollution, presentations at meetings of their own and other local groups, trash clean up events at local streams and rivers, newspaper stories, website (http://friendsoftherivers.org/), and social media posts (https://www.facebook.com/Friends-of-the-North-Fork-of-the-White-River-and-Bryant-Creek-242047022547296/). They also offer scholarships, lead stream teams in Mountain Home and surrounding area (including Dodd Creek and Hicks Creek) with children and adults, are supporting a Paint the Drain project by Mountain Home High School, and collaborate with Trout Unlimited White River Chapter on a youth mentoring program based on trout fishing on Dry Run Creek (a tributary of North Fork of the White River) (Friends of the North Fork and White Rivers 2018).

5.1.1.8 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, including water quality that meets state standards. 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 2017). Because groundwater influences many of the surface waters in this area of the state, including the Middle White River watershed, this program helps surface waters meet state water quality standards.

5.1.1.9 Other Nonprofit Interest Groups

There are a number of nonprofit groups with interests in the Middle White River watershed. These include the Arkansas Backcountry Horsemen of America, Arkansas Cattlemen’s Association, Arkansas Farm Bureau, Arkansas Master Naturalists, Arkansas Pork

Producers Association, Audubon Arkansas, Federation of Fly Fishers, Ozark Off-road Cyclists, Ozark Society, The Poultry Federation, Trout Unlimited, and White River Waterkeeper. These organizations provide information and education to their members and the public through a variety of methods including, websites; social media; newsletters; presentations and displays at schools, meetings, conferences, fairs, and festivals; news media stories; and hosting events like day camps, contests, and river clean ups. Many of these organizations already provide information and education about how to protect and improve water quality so that state water quality standards are met. Several of these organizations, e.g., Friends of the North Fork and White Rivers, Trout Unlimited, Ozark Off-road Cyclists, Arkansas Backcountry Horsemen of America, primarily focus their efforts only in select areas of the Middle White River watershed.

5.1.2 Proposed Information and Education Programs for Middle White River Watershed

There are a number of information and education programs active in the Middle White River watershed that target agricultural producers. However, all of the subwatersheds recommended for initial management in this plan have significant residential and developed areas that can contribute nutrients and other pollutants to surface waters. Therefore, to further assist in protection and improvement of water quality in the recommended subwatersheds to meet water quality standards, some additional information and education programs that target stakeholders in developed and residential areas are proposed. These programs are described below.

5.1.2.1 Hicks Creek Impairment

Hicks Creek is included on the state list of impaired waterbodies due to high levels of *E. coli* in the creek just downstream of Mountain Home and its wastewater treatment plant. The Mountain Home WWTP has not reported fecal coliform levels exceeding its permit limits in at least 12 years (EPA 2018a). ADEQ conducted water quality sampling in Hicks Creek and its tributary Dodd Creek during the summer of 2015. The results of this water quality sampling indicate that, occasionally, discharge from the WWTP may exceed water quality standards. However, high *E. coli* levels are coming from other sources in addition to the WWTP. Whether or not Mountain Home stormwater runoff ends up being regulated under an NPDES permit, it is important to continue to make Mountain Home residents aware that the stream running through their city is not meeting water quality standards for primary body contact use, and encourage officials and residents to take actions to improve water quality in Hicks Creek. The Friends of the North Fork and White Rivers have several projects going that help bring attention to this issue, including sponsoring painting storm drains and Stream Teams monitoring Dodd Creek and Hicks Creek. These activities need to continue.

5.1.2.2 Onsite Wastewater System Maintenance Outreach

Information and education about proper maintenance of onsite wastewater systems could improve water quality in the recommended subwatersheds 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 (https://www.epa.gov/septic). 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, September 11, 2018, White River Waterkeeper).

5.1.2.3 Social Media Platform for the Middle White River

Social media platforms are one of the primary sources of information on almost any topic within any age demographic. Within the Middle White River watershed, the average age of landowners is in the 50+ category (see Section 2.2.1). The two social media platforms used most extensively by this age group are Facebook and YouTube (Figure 5.1). Using these two social media platforms in the Middle White River watershed, then, can be one of the more effective approaches for outreach and education. Most of the organizations active in the Middle White River watershed already utilize social media platforms to interact with their constituents. For example, ANRC and the UofA Cooperative Extension currently have Facebook pages (https://www.facebook.com/Arkansas-Natural-Resources-Commission-127788010626999/, https://www.facebook.com/uaex.edu/). NRCS Arkansas uses Twitter extensively (https://twitter.com/arkansasnrcs), and all three agencies host and refer users to YouTube (https://www.youtube.com/channel/UCWPRIlokkCy1DTROlEoW5OA/featured, https://www.youtube.com/user/ARextension). These three agencies also interact regularly with landowners in the watershed as well as nonprofit organizations such as Friends of the North Fork and White Rivers, the White River Waterkeeper, municipalities, conservation districts, county agencies, and other entities. As importantly, these three agencies also have individuals who routinely monitor traffic and post information on their platforms.

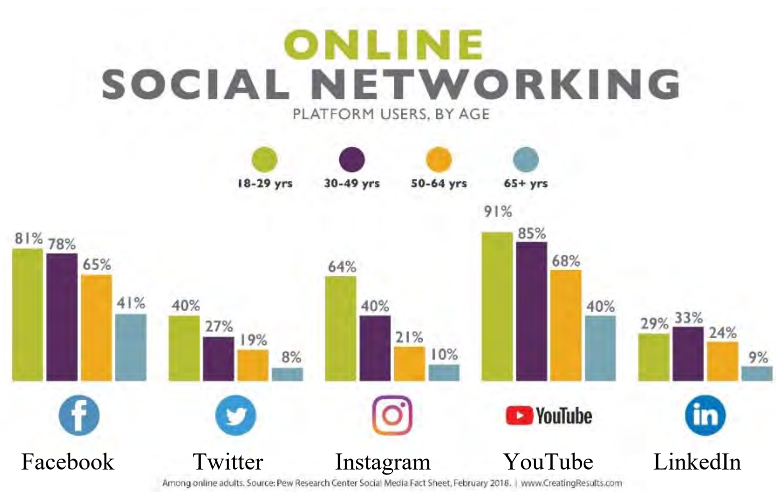


Figure 5.1. Social media platforms use by age group (Mickey 2018).

To enhance the effectiveness of social media in attaining the Middle White River watershed management plan goals, several questions, including the following, need to be addressed:

- What are the social media goals?
- What social media platforms are proposed?
- Who is the target audience?
- What are the core demographics?

- What are the core metrics for tracking effectiveness?
- How often will these metrics be assessed?
- What type of content will be hosted?
- What are the best times to post on the platforms?
- Who will monitor and maintain the social media platforms?

A social media marketing checklist is included in Appendix F (York 2018).

The social media goals for the Middle White River watershed include the following:

- Provide landowners with technical information, opportunities for cost-share programs, and testimonials of landowners who have cost-effectively implemented management practices;
- Increase community engagement, volunteerism, and educational activities in furthering the WMP goals;
- Encourage behavioral actions that protect and sustain existing water quality throughout the Middle White River watershed; and
- Highlight the economic benefits to landowners from protecting, sustaining, and improving water quality within the watershed.

Facebook and Twitter platforms already exist within ANRC, NRCS, and UofA Cooperative Extension as well as county conservation districts (see information above and in Section 5.1.1). The platforms not only currently have followers, but followers who are landowners within the watershed and represent the target audience for information (i.e., 50+ age demographic).

The following core metrics are suggested for these social media platforms:

- Number of clicks or hits;
- Number of likes;
- Retweets; and
- Reach (e.g., how broadly information is being discussed among residents and visitors in the watershed).

Both Facebook and Twitter have free analytics tools (e.g., Facebook Insights) that track the metrics listed above, including analytics on days and times of day with the greatest traffic on the site. This information can be used to decide when it is most effective to post new information on these social media platforms.

Weekly assessment (e.g., Monday morning) of the platform metrics can be used to determine the effectiveness and reach of the platform in supporting the watershed management goals.

There currently is extensive content on watershed management practices, outreach and education efforts and information, meeting, workshop, and field day announcements, and YouTube and other videos on technical assistance on the ANRC, NRCS, and UofA Cooperative Extension platforms, but these sites are not always linked to each other or linked to the Middle White River watershed activities, university and nonprofit organizations social media platforms and websites. ANRC initially will develop these links and ensure that its platform is linked to any institutions or organizations interested in implementing this watershed management plan.

5.1.2.4 Quantify Ecosystem Services

Ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005) and the direct and indirect contributions of ecosystems to human well-being (Kumar 2010). 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 (Millennium Ecosystem Assessment 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 (National Research Council 2004). Use values can be consumptive, non-consumptive, or indirect use. 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 use 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 5.2). Many of these methods are applicable for estimating the value of ecosystem services that contribute to sustaining and improving water quality within the Middle White River watershed and its tributaries.

Table 5.2. 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 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 (WTP) for specific ecosystem services based on scenario (most widely used method for estimating nonuse values)
Contingent Choice Method – value based on asking people to make trade-offs among choices of services or characteristics. Does not ask for WTP, 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), the ecosystem services will 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 Hicks Creek. Hicks Creek receives both point and nonpoint source pollutant contributions, which diminish water quality, including wastewater effluent, septic tank leakage, sediment loading from erosion, and runoff from developed areas and pastures. 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 – DPSIR) and their relationship with ecosystem service changes and well-being in Hicks 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.

Ecosystem services will be quantified following the frameworks proposed by Grizzetti et al. (2016), Ready (in preparation), and 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). The set of ecosystem services considered for initial valuation, along with the proposed valuation method, is shown in Table 5.3.

Table 5.3. 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).

5.2 Subwatershed Implementation Teams

The greatest efficacy in implementing watershed management plans, and protecting and improving water quality, 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 watershed implementation teams. Two teams may be adequate for the recommended subwatersheds, one for the Hicks Creek subwatershed, and one for the four recommended subwatersheds in the Batesville area, Greenbrier Creek, Lower Salado Creek, Spring Creek, and Miller Creek.

A recent article provided empirical evidence that nonprofit watershed groups or teams can provide public goods (Grant and Langpap 2018) . In economics, a public good is a commodity or service available to all individuals and where one individual cannot reduce the availability to others. Grant and Langpap reviewed information from 2,150 watersheds across the lower U.S. from 1996 to 2008. Watershed groups in these watersheds increased from 500 to 1,500 over this same period. They found the activity of these watershed groups resulted in improved water quality, specifically a decrease in dissolved oxygen deficiency (i.e., increase in dissolved oxygen concentrations in waterbodies), compared to watersheds in which there were no groups. Donations to watershed groups were associated with reduced dissolved oxygen deficiency. Watershed groups can make a significant difference in improved water quality within a watershed through their activities.

Individuals will need to be contacted to determine their interest in each 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. An example of the team approach for implementation is the work the Friends of the North Fork and White Rivers did preparing a Watershed Restoration Action Strategy for the White River from Bull Shoals Dam to the Independence County Line, and the North Fork River from Norfork Dam to the White River (Friends of the North Fork and White Rivers, Inc. 2007).

5.3 Subwatershed Implementation Plans

The process of developing a local subwatershed implementation plan can increase the implementation of voluntary management practices by encouraging stakeholder buy-in and leveraging technical and financial resources. An example is the Watershed Restoration Action Strategy developed by the Friends of the North Fork and White Rivers. Subwatershed implementation plans developed by the watershed implementation teams can be a mechanism for implementing management practices in the Middle White River recommended subwatersheds. These plans will include more specific information about pollutant sources that exist and how these sources will be addressed by management practices. The purpose of these plans is to provide a roadmap for how the water quality will be protected and/or improved so that it meets state water quality standards. Subwatershed implementation plans can be prepared for each HUC12 recommend subwatershed, as supplements to this watershed management plan.

5.4 Implement Nonpoint Source Pollution Management Strategies

Nonpoint source pollution management practices that are being and will be implemented in the Middle White River watershed are listed in Table 5.4, 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. Focus areas for management include pasture and haylands along streams and on ridge tops, areas within 50 feet of streams, and, finally, areas on ridge tops, particularly where karst features are present.

There is no legal requirement that anyone implement any of the practices listed in Table 5.4. These are practices that are suggested for landowners, operators, and other stakeholders interested in protecting water quality in the Middle White River watershed. In addition to protecting water quality, 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 6.

Table 5.4. Management practices proposed for recommended subwatersheds of the Middle White River.

Practice	Nitrogen	Phosphorus	Coliforms	Turbidity/ Sediment
Developed and Residential Area Management Practices				
Fertilizer use management	X	X		
Media filter	X	X	X	X
Porous pavement	X	X	X	X
Pasture and Hayland Management Practices				
Nutrient management plans	X	X	X	
Livestock stream access control	X	X	X	X
Alternative water supply	X	X	X	X
Heavy use area treatment	X	X	X	X
Prescribed/rotational grazing	X	X	X	X
Pasture planting and improvement	X	X	X	X
Vegetated treatment area	X	X	X	X
Silvopasture establishment	X	X	X	X
Livestock shelter structure	X	X	X	X
Manure/litter or agrichemical storage	X	X	X	
Control of invasive and destructive species (e.g., feral hogs)	X	X	X	X
Management Practices for Multiple Land Uses				
On-site wastewater system management/repair/replace	X	X	X	
Riparian buffers	X	X	X	X
Karst protection practices	X	X	X	X
Ponds	X	X	X	X
Wetlands	X	X	X	X
Filter strips	X	X	X	X

5.5 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, and two important subdomains within each domain, 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 5.5).

Table 5.5. Domain, sub-domain, and elements that can influence behavioral change in implementing management practices and activities.

Domain	Sub-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., Neighborhood Associations, 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., native grass pasture vs. fescue or bermudagrass) 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 not 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.

Pasture management and stormwater management represent two recommended approaches for improving water quality within the Middle White 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, stormwater management) are shown in Tables 5.6 and 5.7, respectively.

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

Table 5.6. 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 conference • Field days • YouTube/other videos • Grazing stick • NRCS tech assistance • UofA 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 • AGFC Acres for Wildlife • 4-5 forage paddocks • Stockpile paddock • Alternative water supply

Table 5.7. Elements that might help influence implementation of stormwater management practices in developed and residential areas.

Domain	Motivation	Ability
Personal	• Aesthetics • Reduced flood damage • Cost-share programs	• UofA Cooperative Ext. • The Nature Conservancy technical assistance
Social	• Leaders implementing practices • Conservationist of the Year Award • NPDES permit	• Rain garden demonstrations • Good neighbor YouTube • Master Gardener programs
Structural	• 319 funding • Tax breaks for riparian buffers	• Grow grass not algae campaign • Trash cans for dog waste

5.6 Monitoring

Monitoring is an essential element of adaptive watershed management. The objectives of the ongoing and proposed monitoring programs and special studies in the Middle White 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.

For all water quality monitoring, existing and proposed, it is recommended that the frequency and timing of sampling result in data that meet ADEQ data requirements for evaluation of water quality standards, e.g., assessment methodology, 2018 Integrated Assessment (ADEQ 2018d). For example, at least 8 *E. coli* samples collected per season (primary contact and secondary contact seasons) in a year, and at least 10 dissolved oxygen measurements collected per season (primary and critical seasons) over a two- to five-year period.

5.6.1 Routine Surface Water Quality Monitoring

Water quality data are collected from the White River and several of its tributaries at 13 locations through active routine monitoring programs of ADEQ, USGS, and local Stream Teams (supported by AGFC). Sampling locations are mapped on Figure 3.1, and information about these sampling locations is summarized in Table 3.1. Table 5.8 lists water quality parameters monitored through these programs, which include the indicator pollutants, dissolved oxygen and *E. coli*, and other parameters of concern (nitrogen, phosphorus, TSS, temperature). 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 5.8. Water quality parameters monitored 2013-2017 in active monitoring programs and studies in the Middle White River watershed.

Parameters	ADEQ ambient	ADEQ roving	ADEQ special study	USGS	Stream Teams
Metals	X	X	X	X	--
Dissolved Oxygen	X	X	X	X	X
Turbidity	X	X	X	--	X
Nutrients	X	X	X	X	X
TSS	X	X	X	--	--
Pathogens			X	X	--
Alkalinity	X	X	X	--	--
Minerals	X	X	X	X	--
Temperature	X	X	X	X	X
Conductivity	X	X	X	X	--
pH	X	X	X	X	X
Hardness	X	X	X	X	--
Total organic carbon	X	X	X	X	--
Suspended sediment	--	--	--	X	--
Organics	--	--	--	X	--

ADEQ routinely monitors surface water quality at seven locations in the Middle White River watershed through different programs. There are four ADEQ ambient water quality monitoring network sites in the watershed that are sampled monthly (Figure 3.1). There are also three ADEQ roving water quality monitoring network sites in the watershed, currently scheduled for sampling in 2024. 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. In addition, there are sites in the watershed where ADEQ is collecting water quality data as part of special studies (ADEQ 2016).

The USGS collects surface water quality data at two flow gage stations in the Middle White River watershed. Historically, the USGS has collected water quality at 35 surface water sites within the Middle White River watershed. Water quality data are no longer collected at the majority of these sites. USGS has collected water quality data within the last 5 years from two of the sites (USGS 2018c). The North Sylamore Creek (07060710) location is sampled as part of the USGS NAWQA program.

In addition to agency water quality monitoring programs, there are three interest groups that are currently monitoring water quality at locations in the Middle White River watershed as part of the AGFC Stream Team program (listed in Table 5.9). Water quality data collected by stream teams is used for water quality screening and planning voluntary water quality or habitat improvement projects, but not for determining if water quality standards are being met (W. Posey, AGFC, personal communication 6/13/18).

Table 5.9. Active Stream Team water quality monitoring locations in the Middle White River watershed (W. Posey, AGFC, personal communication 6/13/18).

Entity	Station Id	Stream	Location	Start Year	End Year
Stream Team 794	1750	Calico Cr	--	2018	2018
Stream Team 794	1708	Calico Cr	--	2016	2018
Stream Team 794	1758	South Sylamore Cr	--	2018	2018
Stream Team 821	1365	Dodd Cr	ASU-Mt. Home campus	2001	2018
Stream Team	1465	Poke Bayou	--	2006	2018

For the ADEQ and USGS water quality monitoring programs, it is recommended that data adequate to assess water quality with regard to state numeric water quality standards, be collected at least once every five years. In particular, it is important to be able to check the status of stream reaches currently included on the state list of impaired waterbodies, Hicks Creek and Greenbrier Creek.

5.6.2 Biological Monitoring

ADEQ is in the process of incorporating more biological surveys into its routine water quality monitoring and assessment programs (T. Wentz, ADEQ, personal communication, 12/11/18). We recommend the continuation of the fish survey programs of the USFS (USFS 2016), University of Oklahoma (Matthews and Marsh-Matthews 2016), and Adams Fish Ecology Lab (University of Central Arkansas 2018) already active in the Middle White River watershed, and invertebrate surveys by Stream Teams. In addition, we suggest regular surveys of populations of aquatic Threatened and Endangered species, and Species of Greatest Conservation Need located within the Middle White River watershed. Regular surveys of populations associated with designated Critical Habitat (White River from Batesville to Black River) and Ecologically Sensitive Waters (Foushee Cave Spring and unidentified spring) are of particular interest. Other than the work done by the USFS, much of the work surveying aquatic species in the Middle White River watershed has been at least partially sponsored and funded by the AGFC through the State Wildlife Grant program. Fish surveys on Piney Creek were funded by EPA (Matthews and Marsh-Matthews 2016).

5.6.3 Special Studies

Special studies are proposed in recommended subwatersheds to evaluate existing water quality, and characterize sources of target nonpoint source pollutants to assist with implementation of management practices. These studies will include data quality assurance planning.

5.6.3.1 Proposed Study – Subwatershed Water Quality Assessments

Two of the recommended subwatersheds, Spring Creek and Miller Creek, have no water quality monitoring data associated with them. However, based primarily on land use, these subwatersheds were ranked high with regard to the potential for water quality issues. Therefore, it is recommended that a set of water quality data be collected from each of these subwatersheds, that can be used to assess whether applicable water quality standards are being met in the primary streams – Spring Creek and Miller Creek. A single water quality monitoring location is proposed near the downstream end of each of the subwatersheds. Sampling frequency and analytical methods will be determined by ADEQ data requirements for the biannual statewide assessment of water quality. It may be possible for ADEQ to sample these streams as part of the agency roving monitoring program. The studies could also be conducted by a university, or, with outside funding, by the USGS or a contractor.

5.6.3.2 Proposed Study – Dissolved Oxygen Assessment

ADEQ is having difficulty collecting sufficient dissolved oxygen measurements from Greenbrier Creek and Salado Creek during the critical season to assess attainment of the dissolved oxygen critical season numeric criteria. There are too few incidences of water temperatures above 22°C (i.e., critical condition for dissolved oxygen) during the summer at the water quality stations. This may be because of shading, or inputs of cooler groundwater from springs during the low flow critical period. In order to collect sufficient data points to assess dissolved oxygen, continuous or remote monitoring of dissolved oxygen is recommended for the next roving station monitoring event in the Middle White River watershed, tentatively scheduled for 2024.

5.6.3.3 Proposed Studies – Synoptic Nutrient Sampling Lower Salado Creek

A synoptic water quality survey is proposed to be undertaken in the Lower Salado Creek subwatershed to identify areas with high loads of nitrogen that may be causing the low dissolved oxygen conditions. This will provide insight into the nonpoint source pollution management practices and implementation locations that will reduce the inputs of nitrogen that may be causing low dissolved oxygen conditions. Proposed sampling locations would be: 1) Upper Salado Creek below the confluence with Bear Branch; 2) Middle Salado Creek below the confluence with McCoy Branch, but above the bifurcation of Salado Creek; 3) Lower Salado Creek below the confluence with Caney Creek; and 4) Lower Salado Creek at the current water quality monitoring station before the confluence with the White River. Two sampling periods are proposed – Spring elevated flow (March/April) and summer low flow (July/August). Duplicate samples would be collected at each site during each sampling period. These surveys could be completed by a local university, or contractor hired by the watershed implementation team or another interest group.

5.6.3.4 Nutrient and Sediment Loads

The majority of the current water quality monitoring programs active in the Middle White River watershed are not designed to collect the data needed to calculate realistic estimates of nutrient or sediment loads for the White River tributaries. It would therefore be beneficial to develop a new, or updated, model of the watershed to estimate sediment and nutrient loads. An intensive, synoptic study collecting appropriate water quality and flow measurements is recommended to collect data for model input and calibration. ANRC has sponsored load modeling studies for several 8-digit HUC watersheds in the state. The USGS has also conducted water quality modeling studies for several water bodies in the state. If at all possible, the nutrient and sediment loads from this study should be such that they can be compared to previous model results (e.g., SPARROW in USGS 2011), so that it may be possible to track changes in loads over time.

5.6.3.5 Geomorphological Study

As noted in Section 3.4, no geomorphological studies of areas within the Middle White River watershed were found. If there have not been any such studies, it may be useful to conduct one. Stakeholders attending public meetings during the development of this plan expressed concern about eroding streambanks, particularly along the White River. Available LiDAR, satellite, and aerial imagery may be useful for evaluating the extent of streambank erosion. In addition to sediment, streambank erosion can contribute nutrient loads to surface waters (Watershed Conservation Resource Center 2018).

5.7 Evaluation

This watershed management plan for the Middle White 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.

5.7.1 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 5.10. 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 input indicators for the period 2018 through 2023 by February 2024.

Table 5.10. Indicators of inputs for implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Agency monitoring programs	Resources spent on monitoring in Middle White 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 Middle White River watershed
	Events – field days, festivals, river clean ups	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 Number of website posts/updates Hours and number of people involved Cost
	Middle White River social media	Number of posts, Tweets, etc. Cost
Implement management practices	Assistance programs in the Middle White River watershed	Resources distributed to Middle White River watershed Hours and number of people assisting stakeholders in Middle White River watershed Number of Middle White River watershed stakeholders requesting assistance
	Subwatershed implementation teams	Number of teams active in watershed Number of non-agency people on teams

5.7.2 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 5.11. 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.

5.7.3 Outcomes

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

The monitored waterbodies in the Middle White 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 goals of delisting impaired waterbodies, and no new impaired waterbodies in the watershed.

Table 5.11. Indicators of outputs of implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Agency 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
	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 invertebrate surveys
	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
	Middle White River social media	Number of likes, re-Tweets, etc. Reach
Implement management practices	Assistance programs in the Middle White River watershed	Number/amount of management practices implemented Number of contracts/projects started and finished
	Subwatershed 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 2024:

- A watershed implementation team has been formed for at least one recommended subwatershed and initiated at least one project or study;
- Greenbrier Creek is removed from the state impaired waters list;
- Salado Creek at station WHI0166 has been assessed for meeting the Delta Least-altered Stream DO standard;
- Water quality data sufficient for the ADEQ biennial assessment have been collected from Spring Creek and Miller Creek recommended subwatersheds;
- The median total nitrogen values, adjusted for flow, at the routine water quality monitoring station in the Lower Salado Creek recommended subwatershed decreases;
- All dissolved oxygen measurements at the routine water quality monitoring stations in the Hicks Creek and Greenbrier Creek recommended subwatersheds meet the applicable dissolved oxygen numeric criteria; and
- No new water quality impairments resulting from unregulated nonpoint pollution sources are identified in the Middle White River watershed.

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 recommended 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, Dressing and Davenport 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.

5.8 Update Watershed Management Plan

Development of the subwatershed implementation plans for the recommended subwatersheds will be part of the update of this watershed management plan. The responsibility for updates to the subwatershed implementation plans will be established in those plans. A comprehensive update of this watershed management plan will be prepared in 2024 by the agency/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 5.7;
- Relevant information about the Middle White River system and how it works, nonpoint source management practices, and pollutant sources in the watershed that has been developed since 2019;
- 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 economy in the watershed.

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. At the meeting(s), stakeholders will provide input on adjustments to management of, and/or goals for, the Middle White 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, utilizing the information from the implementation evaluation and the public meeting(s), and any other information deemed appropriate, will be prepared. This update will be presented at one or more public stakeholder meetings to elicit feedback. The final update of the watershed management plan will then be prepared, incorporating stakeholder comments.

5.9 Implementation Schedule

This section describes the schedule for implementation of this watershed plan for the Middle White River watershed. Table 5.12 summarizes the schedule. 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 nitrogen loads in the Lower Salado Creek subwatershed until after studies have been completed to identify whether the dissolved oxygen water quality standard is being achieved at station WHI0166, and the areas or tributaries contributing to the nutrient load affecting dissolved oxygen. The schedule reflects this approach.

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 5.12. Proposed implementation schedule for Middle White River watershed.

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Monitoring	Roving monitoring program (ADEQ)	2024	2026	Water quality data collection initiated	Number of sampling events	Identify and track changes in water quality Assess water quality relative to water quality standards
	Ambient monitoring program (ADEQ, USGS)	2019	Expected to continue indefinitely	Five additional years of water quality data collected	Number of sampling events Number of sampling locations	Identify and track changes in water quality Assess water quality relative to water quality standards
	ADEQ aquatic invertebrate surveys (ADEQ)	2021	Expected to continue indefinitely	At least one new survey completed at routine ambient water quality monitoring stations	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	Stream Team aquatic invertebrate surveys (Stream Teams, USGS)	2001	Expected to continue indefinitely	At least three new surveys at active stations	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	Ozark National Forest Fish surveys (USFS)	2007	Expected to continue indefinitely	At least one new survey completed at a previously surveyed location	Number of surveys Number of locations surveyed	All surface waters in Ozark National Forest achieve aquatic life support use
	ADEQ Fish Surveys (ADEQ)	1984	Expected to continue indefinitely	At least one new survey for at least one location	Number of surveys Number of locations surveyed	All surface waters in Middle White River watershed achieve aquatic life support use
	USGS North Sylamore Creek Fish Surveys (USGS)	1993	Expected to continue indefinitely	At least one new survey	Number of surveys	North Sylamore Creek achieves aquatic life support use
	Surveys of aquatic species of concern (AGFC, USFS, ANHC)	2002	Expected to continue indefinitely	At least one new survey of a population of aquatic species of concern within the Middle White River watershed	Number of surveys Number of survey locations	Stable populations of designated Threatened and Endangered aquatic species present in Middle White River watershed
Special Studies	Water quality assessment of Spring Creek and Miller Creek (Watershed Implementation Team?)	2021	2023	Spring Creek and Miller Creek water quality assessed as part of a state biennial assessment	Number of sampling events	All surface waters in Middle White River watershed meet water quality standards
	Synoptic nutrient sampling in Lower Salado Creek subwatershed (Southside or Implementation Team)	2026	2027	Decision made about whether synoptic survey is needed	Number of sampling events Number of sampling locations Sources and critical tributaries identified	Salado Creek meets water quality standards
	Nutrient and sediment load estimates (ANRC or USGS)	2021	2023	Load estimates modeled and reported	Load estimates report completed	All surface waters in Middle White River watershed meet water quality standards
	Geomorphological study	2023	2025	Geomorphological study initiated	Geomorphological study plan developed	All surface waters in Middle White River watershed achieve designated uses

Table 5.12. Proposed implementation schedule for Middle White River watershed (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Information and Education	Outreach and education to homeowners and landscape managers regarding fertilizer use to reduce nitrogen runoff	2023	2025	Outreach initiated in Southside or Mountain Home	Number of outreach events Number of flyers sent Number of radio/TV ad airings Number of people reached	All surface waters meet water quality standards
	Stormwater pollution prevention outreach in Mountain Home (Subwatershed Implementation Team)	2020	2030	Stormwater pollution prevention outreach program developed and initiated	Number of outreach events Number of flyers sent Number of radio/TV ad airings Number of people reached	Hicks Creek meets water quality standards
	Onsite wastewater system maintenance outreach (White River Waterkeeper)	2020	2025	Outreach initiated in Hicks Creek, Greenbrier Creek, and Lower Salado Creek subwatersheds	Number of people contacted/reached	All surface waters meet water quality standards
	Outreach through Hicks Creek – White River Watershed Project (Baxter County Conservation District)	2016	2020	Two field days Four presentations Radio ads Newspaper ads Newsletters mailed & emailed	Number of field days Number of presentations Number of newsletters sent Number of radio & newspaper ads Number of people reached	All surface waters meet water quality standards
Planning	Establish subwatershed implementation teams	2020	2025	At least one team formed	Number of teams	All surface waters meet water quality standards
	Develop subwatershed implementation plans	2021	2025	Preparation of at least one subwatershed implementation plan initiated	Number of plans	All surface waters meet water quality standards
Implement Management Practices	Pasture and hayland management practices in Lower Salado Creek subwatershed through NRCS programs (Independence County Extension Service)	2014	Expected to continue indefinitely	At least two new contracts signed	Number of contracts signed Amount of practices implemented	All surface waters in meet water quality standards
	Hicks Creek – White River Watershed Project (Baxter County Conservation District)	2016	2020	At least 24 contracts signed At least 55 BMPs implemented At least 60 farm plans	Number of contracts signed Amount of practices implemented Number of farm plans	All surface waters meet water quality standards
	Controlled Access for Livestock Fencing (CALF) (Arkansas Association of Conservation Districts, US Fish and Wildlife Service)	2015	2025	At least 5 new contracts signed in Middle White River watershed	Number of contracts signed Amount of practices implemented	All surface waters meet water quality standards
	Developed and residential area management practices in Hicks Creek and Lower Salado River (Mountain Home, Southside)	2020	2025	Implementation of at least one management practice planned for at least one subwatershed	Number/amount of practices implemented	All surface waters meet water quality standards
	Petition for change of ecoregion designation for monitoring stations on Greenbrier Creek (WHI0167) and Salado Creek (WHI0166) (ANRC)	2019	2020	Ecoregion designation for stations WHI0167 and WHI0166 officially changed.	Greenbrier Creek removed from impaired waters list	Greenbrier Creek meets applicable water quality standards

Table 5.12. Proposed implementation schedule for Middle White River watershed (continued).

Activity	Action (Lead)	Start	Anticipated Completion	2024 Milestones	Indicator	Long Term Goal
Evaluate	Biennial water quality assessment (ADEQ)	2020	Expected to continue indefinitely	EPA approved final impaired waters lists for 2020 and 2022	Attaining and non-attaining stream reaches in Middle White River watershed	All water quality criteria met in Greenbrier Creek All water quality criteria met in all monitored stream reaches in watershed
	Track implementation of management practices in Middle White River watershed	2019	2025	Information for period 2019 – 2024 compiled	Amount (acres, linear feet, number) of practices implemented Water quality improvement	All water quality criteria met in all monitored stream reaches
	Evaluation of watershed management plan	2025	2025	Data needed for evaluation compiled	Evaluation completed Evaluation made public	All water quality criteria met in all monitored stream reaches
Update watershed management plan for Middle White River watershed	Public meetings	2024	2025	Begin organizing public meetings	Number of attendees Number of meetings	Stakeholder input to watershed management
	Update watershed management plan	2024	2026	Entity responsible for update identified and committed Preparations for update under way	Updated watershed management plan complete and approved by ANRC and EPA Recommended subwatersheds identified Stakeholders involved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to protecting and improving water quality in the Middle White River watershed.

6.0 IMPLEMENTATION COSTS, 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.

6.1 Implementation Cost Estimates

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

6.1.1 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.

6.1.2 Monitoring

The costs of existing routine water quality and biological monitoring in the Middle White River watershed are included in agency budgets.

6.1.3 Proposed Special Studies

Table 6.1 lists estimated costs for each of the proposed special studies. See Section 5.6.3 for descriptions of the activities included in these cost estimates. In addition, it is expected that ADEQ will conduct water quality monitoring of Spring Creek and Miller Creek as part of an upcoming roving water quality monitoring program. The cost of sampling new water quality monitoring stations for Spring Creek and Miller Creek could range up to $40,000-$50,000 per year for the USGS to monitor one site. The cost of sample analysis for, by a commercial laboratory, is estimated to be around $800 per sample.

Table 6.1. Estimated costs for proposed special studies.

Study	Component Costs	Total Cost
Two-year DO assessment for Greenbrier Creek and Salado Creek (station WHI0166 only)	~$2,000 per site for equipment $10,000/year for personnel to manage two sites (install equipment, data retrieval, travel)	$24,000
One-year Synoptic survey of nutrients in Lower Salado Creek subwatershed	Analysis of 16 samples @$800/sample ($14,400) 2 people at $1,000/trip ($2,000) $500 for statistical analysis	$16,900
Nutrient and sediment load estimates – SWAT model	-	$130,000

6.1.4 Estimated Cost of Nonpoint Source Pollution Management

Over the years, funding has been provided for implementation of management practices in the Middle White River watershed. There are a number of agencies and programs that offer financial assistance for implementation of nonpoint source pollution management practices in the Middle White River watershed.

The cost of implementing management practices to reduce nonpoint source pollution can be variable, depending on materials markets and site conditions (e.g., slope, soil type). Table 6.2 lists available cost information for management practices identified in Section 4.5. While NRCS EQIP reimbursement allocations do not necessarily reflect the actual cost of implementing the practice, they provide an idea of relative costs of the shown management practices.

Table 6.2. EQIP reimbursements (NRCS 2019) and reported implementation costs for selected nonpoint source pollution management practices applicable in the Middle White River watershed.

Practice	Unit	2019 EQIP (non-HU*) reimbursement per unit	Unit Cost
Fence	Feet	$0.90-$1.67	$2.15-$2.60[a]
Watering facility	Gallons	$0.40-$2.82	--
Watering facility	Each	$701.34	$2,000-$10,000[a]
Livestock pipeline	Feet	$1.10-$3.58	--
Riparian forest buffer plants	Each	$0.44-$0.77	--
Riparian forest buffer forgone pasture income	Acres	$211.70	--
Riparian forest buffer establishment & maintenance	Acres	--	$218- $7,112[a-d]
Riparian herbaceous buffer	Acres	$188.32-$307.50	$168- $400[a]
Prescribed grazing	Acres	$21.30-$66.59	--
Forage planting	Acres	$132.65-$239.18	--
Nutrient management plan written	Each	$ 1,796-$ 5,089	--
Nutrient management	Acres	$4.46-$29.46	--
Heavy use area protection	Square feet	$0.57 - $2.71	--
Vegetated treatment area	Acres	$ 1,438.67 - $ 8,619.76	--
Silvopasture establishment	Acres	$188.15 - $242.23	--
Livestock shelter structure	Square feet	$2.47	--
Manure/litter storage structure	Square feet	$1.80 - $4.40	--
Agrichemical handling facility	Square feet	$5.24	--
Feral hog control	Each	$676.11 - $751.58	
Media filter	Cubic meters treated water	--	$5 - $10,000[e]
Porous pavement	Square feet	--	$1.81 - $74.42[f]
Ponds	Cubic yard	$2.61 - $4.51	--
	Cubic meters of treated water	--	$3 - $400[e]
Constructed wetlands	Square feet	--	$2.10 - $12.90[f]
	Cubic meters of treated water	--	$5 - $70[e]

* HU = historically underserved producers
[a] (Lynch & Tjaden 2000)
[b] (Butler & Long 2005)
[c] (Whitescarver 2013)
[d] (Washington State University 2006)
[e] (Narayanan and Pitt 2006)
[f] (Herrera Environmental Consultants 2012)

Table 6.3 provides examples of potential relative costs for implementation of selected management practices for pasture and hayland that achieve the target inorganic nitrogen load reduction for the Lower Salado Creek subwatershed. Table 6.4 lists examples of potential costs for implementation of selected management practices for developed areas that achieve the target nitrogen load reduction in the Lower Salado Creek subwatershed. Note that the estimated costs shown in Table 6.3 and 6.4 have been rounded to two significant digits. Calculations for these cost estimates are included as Appendix G.

Part of the difference in the estimated costs for reducing nitrogen inputs from pasture and from developed areas are a result of differences in the cost estimation. However, the fact that nonpoint pollution sources in developed areas tend to be more concentrated, means that removing pollutants from runoff in developed areas can be expensive. In addition, it is usually more expensive to install pollution removal practices in already developed areas, than it is to incorporate them during development, i.e., low impact development.

Table 6.3. Estimated costs for achieving nitrogen reduction target for Lower Salado Creek using selected practices for pasture and hayland.

Practice	Assumed unit cost	Amount of practice	Estimated cost ($1,000)
50 foot forested riparian buffer	$2,000 per acre	49 acres	$98
50 foot non-forest riparian buffer	$400 per acre	68 acres	$27
Restrict livestock stream access	$1.75 per foot fence, $1,500 per 1,000-gallon tank	99,000 foot fence 99 tanks	$320
Prescribed grazing	$68 per acre	7,000 acres	$490

Table 6.4. Estimated costs for achieving nitrogen reduction target for Lower Salado Creek using selected practices for developed areas.

Practice	Assumed cost per cubic meter of runoff treated	Assumed volume of runoff treated (cubic meters)	Estimated cost ($1,000)
Sand stormwater filter	$18	37,000	$660
Stormwater pond	$7	42,000	$290
Constructed wetland	$15	44,000	$660
Porous pavement	$5	23,000	$120

6.2 Estimated Economic and Environmental Benefits

While there are costs associated with implementing best management practices, as noted in Section 6.1 above, there are also benefits. Some of these are environmental benefits 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. These include 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 6.5.

Table 6.5. Environmental benefits and ecosystem services associated with increased soil health and best management practices.

Ecosystem service or environmental benefit	Description
Contaminant removal	Contaminants (sediment, pathogens, nutrients, heavy metals, pesticides) are absorbed onto soils, chelated by organic matter, 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 constructed ponds or wetlands, to receiving waterbodies.
Fish habitat	Riparian vegetation and organic debris reduce soil and bank erosion and provide structure in streams for fish and other aquatic organisms.
Flood mitigation	Soil organic matter, vegetation covering soil, and constructed ponds and wetlands 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. Carbon sequestration?
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.

Table 6.5. Environmental benefits and ecosystem services associated with increased soil health and best management practices. (continued).

Ecosystem service or environmental benefit	Description
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 and silvopasture can provide harvestable timber for additional revenue.
Water purification	Contaminant sorption, filtering through soils and vegetative/organic debris, and uptake improves water quality by purifying the water.
Waterfowl habitat	Constructed ponds and wetlands increase habitat for waterfowl.
Wildlife habitat	Filter strips, riparian buffers, pastures of native grasses and forbs, and conservation reserve lands, some of which many be leased for hunting, provide additional habitat for pollinators, sport birds, sportfish, and other wildlife.

Best management practices proposed for the Middle White River subwatersheds recommended for initial management are listed in Table 6.6 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, Benham and Lunsford 2012). 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 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 6.6. Environmental benefits associated with implementing best management practices in the Middle White 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 habitat
Riparian buffer	•	•	•	•		•			•	•	•
Livestock stream access control	•	•	•	•	•	•	•	•		•	•
Pasture planting	•	•		•	•	•	•	•		•	•
Prescribed grazing	•	•		•	•	•	•	•		•	•
Filter strips	•	•		•	•	•	•	•		•	•
Farm pond, stormwater detention or retention pond	•	•	•	•		•		•		•	•
Silvopasture	•	•		•	•	•	•	•	•	•	•
Nutrient management	•				•	•	•				
Control of invasive and destructive species		•	•		•	•					•
Karst protection practices	•	•	•			•				•	•
Constructed wetland	•	•	•	•		•				•	•
Porous pavement	•	•		•		•		•		•	

6.3 Technical Assistance

6.3.1 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.

6.3.2 Information and Education

Information for and assistance with education and outreach activities is available through the ADEQ Public Outreach and Assistance Division, Watershed Conservation Resource Center, Clear Choices Clean Water, Arkansas 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” (ADEQ 2019).

Arkansas Cooperative Extension Service implements stormwater education programs required by municipal storm runoff NPDES permits in Northwest and Southeast Arkansas (UofA Division of Agriculture Cooperative Extension Service 2018). Information and education sources related to public education about urban stormwater (see Section 5.5.1) are available on the Arkansas Cooperative Extension Service website, https://www.uaex.edu/environment-nature/water/stormwater/default.aspx.

6.3.3 Technical Assistance for Nonpoint Source Pollution Management

There are a number of sources for technical assistance for management practices in recommended subwatersheds. These are summarized in Table 6.7 and discussed below.

Table 6.7. Examples of sources of technical assistance for nonpoint source management practices for the Middle White River watershed.

Practice	UofA Division of Agriculture Cooperative Extension Service	County Conservation Districts	NRCS, Farm Services Agency	AGFC	Arkansas Department of Parks and Tourism	ANRC	US Fish and Wildlife Service	USFS	The Nature Conservancy
Fertilizer use management	X					X			
Media filter						X			
Porous pavement						X			
Nutrient management plans	X	X	X			X			
Livestock stream access control	X	X	X			X			X
Alternative water supply		X	X			X			
Heavy use area treatment	X	X	X			X			
Prescribed/rotational grazing	X	X	X			X			X
Pasture planting and improvement	X	X	X	X		X	X		
Vegetated treatment area		X	X			X			
Silvopasture establishment		X	X			X			
Livestock shelter structure		X	X			X			
Manure/litter or agrichemical storage		X	X			X			
Riparian buffers	X	X	X	X	X	X	X	X	X
On-site wastewater system management/repair/replace									
Control of invasive and destructive species (e.g., feral hogs)	X	X	X	X			X		
Karst protection practices		X	X			X	X		X
Ponds	X	X	X	X		X			
Constructed wetlands		X	X			X			
Filter strips	X	X	X	X		X	X		X

6.3.3.1 County Conservation Districts

Conservation Districts for the counties in the Middle White 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 Middle White 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, and Quail Special Project. The Middle White River watershed is within one of the target areas for the Controlled Access for Livestock Fencing program (Arkansas Association of Conservation Districts 2015). Baxter County, Izard County, and Stone County are part of the North Focal Landscape for the Arkansas Quail Special Project (AGFC n.d.).

6.3.3.2 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 Arkansas Cooperative Extension Service includes practices to keep fertilizer out of runoff in its factsheet “Fertilizing Your Lawn” available on their website (Patton 2008).

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

6.3.3.3 Arkansas Game and Fish Commission

Through the AGFC Private Lands Program and Acres for Wildlife Program, Private Lands Biologists can provide technical assistance to volunteer landowners and tenants with managing their lands to improve both upland and aquatic wildlife habitat, in working pastures and haylands, farm ponds, and in set-aside areas like fenced-off riparian areas. AGFC is working with the National Bobwhite Conservation Initiative to help restore quail habitat in Arkansas. The majority of the Middle White River watershed is classified as having a medium quail restoration potential (Jackson, et al. 2015). Through the relatively new Native Warm Season Grass/Forb component of the Acres for Wildlife Program, free technical assistance is available on managing pastures to improve habitat for bobwhite quail and other wildlife. AGFC biologists can also assist landowners and tenants with 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.

6.3.3.4 ANRC

The ANRC provides technical assistance with management practices, implementation, and funding to stakeholders through the Nonpoint Source Pollution Management program, primarily through direct contact with stakeholders. In many cases, ANRC acts as a clearinghouse for stakeholders, directing them to personnel and programs in other agencies where stakeholders can get the assistance they need.

6.3.3.5 NRCS and Farm Services Agency

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 2018).

Technical assistance is available for a variety of practices through EQIP. Assistance is available for planning and implementing pasture management, restricted livestock stream access, nutrient management, upland and aquatic wildlife habitat improvement, farm ponds, constructed wetlands, and feral hog capture. Farm Services Agency (FSA) also provides technical assistance planning and implementing habitat improvement on Conservation Reserve Program lands through their programs, such as State Acres for Wildlife Enhancement Initiative and Pollinator Habitat Initiative (FSA 2018).

6.3.3.6 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).

6.3.3.7 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 (https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/ozark-karst-program.xml).

6.3.3.8 US Environmental Protection Agency

The EPA website provides access to information on a variety of water quality subjects, including management measures. In particular, information on stormwater management practices for developed and residential areas, including Low Impact Development, is available.

6.3.3.9 US Fish and Wildlife Service

Through its Partners for Fish and Wildlife program the US Fish and Wildlife Service 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 restoration of riparian habitats, stream habitat, forest, and native grasslands, and protecting karst habitats (https://www.fws.gov/arkansas-es/PFW_Habitat.html, https://www.fws.gov/arkansas-es/proj_pfw.html).

6.3.3.10 US Forest Service

The USFS develops and makes available technical resources on a range of subjects related to forest management that can be useful to individual landowners, and to communities. Programs are available to assist with stewardship of privately-owned forest land, agroforestry (including silvopasture), and management of trees and forested areas within urban areas and communities (https://www.fs.fed.us/managing-land/private-land, https://www.urbanforestrysouth.org/). Forested riparian buffers can be used as agroforestry elements in pastures, and as a way to restore lost canopy cover in developed areas.

6.4 Financial Assistance

This section describes programs that can provide financial assistance for implementation of the activities recommended in this plan. The programs described here are examples. This is not intended to be a complete listing of all available programs that can provide funding assistance.

6.4.1 Monitoring

ADEQ, USFS, and USGS have funded water quality monitoring projects in the Middle White River watershed. The monitoring programs in the Middle White River watershed are self-funded. USGS flow and/or water quality monitoring sites could be added in the watershed if a local entity would provide funds.

The AGFC Stream Team program can also provide funding for volunteer monitoring programs through mini-grants. ANRC can assist with funding water quality monitoring projects. In 2017, ANRC contributed to water quality monitoring projects in the state that totaled around $500,000 (ANRC 2017).

State Wildlife Grant funding from the AGFC has been used for biological surveys and monitoring projects in the Middle White River watershed. In 2016, $577,051 of federal funds were distributed as State Wildlife Grants in Arkansas (https://www.wildlifearkansas.com/grants.html).

6.4.2 Information and Education

Projects funded through the ANRC Nonpoint Source Pollution Management Program (Section 319[h] funds) usually include an education and outreach component. In 2017, approximately $300,000 were spent on outreach projects in Arkansas through the ANRC 319 grant program. Eighteen percent of these funds were spent on outreach projects (ANRC 2017).

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).

In addition, organizations can often find local businesses or organizations to sponsor information and education activities, such as painting storm drains, festivals, and clean-up days.

6.4.3 Nonpoint Source Pollution Management

There are a number of agencies and programs that offer financial assistance for implementation of nonpoint source pollution management practices recommended for the Middle White River watershed. The majority of these are grant programs, many 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 6.8 lists management practices for the recommended subwatersheds along with selected funding sources. It is notable that many federal assistance programs are seeing reductions in available funds. However, it is also notable that use of many of these practices can improve the bottom line for producers or communities (see Section 6.2).

6.4.3.1 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 Middle White River. These programs provide funding to individuals rather than groups or organizations. This includes the Conservation Stewardship 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 6.9 shows funding provided to individuals in the counties of the Middle White River watershed during the 2017 fiscal year (NRCS 2017a). The 2018 Farm Bill has increased available funding for a number of conservation programs, including EQIP and Conservation Stewardship Program (National Sustainable Agriculture Coalition 2018). The 2019 fiscal year national budget for the EQIP program is $1,614 million. For the Conservation Stewardship Program, the 2019 fiscal year national budget is $1,645 million (USDA 2018).

Table 6.8. Examples of programs that can provide funding assistance for recommended nonpoint source management practices.

	Conservation Stewardship Program	**Environmental Quality Incentives Program**	**Conservation Reserve Program**	**Partners for Fish and Wildlife**	**Nonpoint Source Program**	**State Wildlife Grants**	**Outdoor Recreation Grants**	**Aquatic Habitat Restoration Program**	**Controlled Access for Livestock Fencing**
Lead/Contact Organization	NRCS	NRCS	FSA	US Fish and Wildlife Service	ANRC	AGFC	Arkansas Department of Parks and Tourism	Southeast Aquatic Resources Partnership	County Conservation Districts, US Fish and Wildlife Service
Who can receive funds	Individuals	Individuals	Individuals	Individuals, counties, organizations	Cities, counties, organizations	State agencies, organizations	Communities, county government	Agencies, organizations	Individuals
Practices that may be funded:									
Fertilizer use management									
Media filter					X				
Porous pavement					X				
Stormwater pond									
Riparian buffers	X	X	X	X	X		X	X	
Filter strips of native plants	X	X	X	X	X	X			
Control of invasive and destructive species		X							
Septic system repair/replace									
Nutrient management	X	X							
Pasture planting and improvement	X	X	X	X					
Farm pond/sediment basin construction		X							
Livestock stream access control	X	X		X	X				X
Prescribed/rotational grazing	X	X							X
Silvopasture establishment	X	X							
Control of invasive and destructive species (e.g., feral hogs)		X							
Karst protection practices		X		X		X			

Table 6.9. Financial assistance provided by NRCS programs to Middle White River counties in 2017 (NRCS 2017a).

County	EQIP	Conservation Stewardship Program
Baxter	$216,066	$165,185
Independence	$312,411	$531,421
Izard	$929,844	$81,435
Stone	$496,269	$136,181

6.4.3.2 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 or filter strips (https://www.fsa.usda.gov/programs-and-services/conservation-programs/prospective-participants/index).

6.4.3.3 US Fish and Wildlife Service

There are two US Fish and Wildlife Service programs active in the Middle White River watershed that provide funding assistance for development and installation of nonpoint source pollution management practices. Funding is available for individuals through the US Fish and Wildlife Service Partners for Fish and Wildlife program, and the Controlled Access for Livestock Fencing program (in cooperation with the Arkansas Association of Conservation Districts). Funding from these programs may require cost-share. The 2019 fiscal year national budget for the Partners for Fish and Wildlife program is $36 million (US Department of the Interior 2018). It is unknown how much of these funds will be available for projects in Arkansas, or in the Middle White River watershed.

6.4.3.4 ANRC

ANRC manages the state Section 319 grant program. This program provides grants to non-profit groups, organizations, communities, and academic institutions for projects related to reduction, control or abatement of nonpoint source pollution. Eligible projects can include implementation of best management practices on pastures, as well as stormwater management and low impact development practices in developed areas. Organizations seeking grants must be capable of implementing projects, and are typically required to provide a minimum of 43% non-federal matching contributions. In 2017, approximately $1.99 million in federal funds were spent on nonpoint source pollution projects in Arkansas through the ANRC 319 grant program. Thirty-three percent of these funds were spent on implementation of management practices (ANRC 2017). The Section 319 grant program is not funded in 2019 proposed presidential budget (EPA 2018b).

6.4.3.5 Arkansas Department of Parks and Tourism

The Arkansas Department of Parks and Tourism manages grant programs to assist communities with developing or improving outdoor recreation areas. Riparian buffers can be incorporated in community parks and recreation areas.

6.4.3.6 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 (AGFC 2016). Another example is the provision of low-cost or free tree seedlings by the Arkansas Forestry Commission, Arkansas Urban Forestry Council, and National Arbor Day Foundation.

6.4.3.7 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/).

7.0 REFERENCES

Adams, Ginny, and Reid Adams. 2015. "Use of Historical and Current Collections to Assess the Distribution and Status of Fishes in the Ouachita, Strawberry, and White River Drainages." *Arkansas Wildlife Action Plan.* March. Accessed August 2018. https://www.wildlifearkansas.com/proposals/2015Preproposals/Use%20of%20Historical%20and%20Current%20Collections%20to%20Assess%20the%20Distribution%20and%20Status%20of%20Fishes%20in%20the%20Ouachita,%20Strawberry%20and%20White%20River%20Drainages.pdf.

Adams, Ginny, Reid Adams, and Matthew Connolly. 2017. "Using Historical and Current Collections to Assess Stream Geomorphology, and Fish Assembleges in the Spring, Myatt, Eleven Point, and Current River Drainages." *Arkansas Wildlife Action Plan - State Wildlife Action Plan Preproposals for 2017.* March 21. Accessed August 2018. https://www.wildlifearkansas.com/proposals/2017Preproposals/Preproposals2017.html.

Adamski, J.C., J.C. Petersen, D.A. Friewald, and J.V. Davis. 1995. *Environmental and Hydrologic Setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma.* Water Resources Investigation Report 94-4022, USGS.

ADEQ. 2008. "Final Impaired Waterbodies List 2008." *Arkansas's Draft Water Quality Limited Waterbodies - 303(d) List.* Accessed January 2015. http://www2.adeq.state.ar.us/water/branch_planning/303d/pdfs/2008_impaired_waterbodies_list_303%28d%29.pdf.

ADEQ. 2016. *Integrated Water Quality Monitoring Assessment Report.* 305(b) 303(d), Little Rock: ADEQ.

ADEQ. 2017. "Final 2016 303(d) List." *Arkansas' Final/Draft Impaired Waterbodies - 303(d) List by Year.* Accessed June 2018. https://www.adeq.state.ar.us/water/planning/integrated/303d/pdfs/2016/final-2016-303d-list.pdf.

ADEQ. 2018a. "Draft 2018 303(d) list." *Arkansas' Final/Draft Impaired Waterbodies - 303(d) List by Year.* July. Accessed October 2018. https://www.adeq.state.ar.us/water/planning/integrated/303d/list.aspx.

ADEQ. 2018b. *Biological Monitoring - Fish Data.* Accessed May 2018.

ADEQ. 2018c. *Biological Monitoring - Macroinvertebrate Data.* Accessed June 2018. https://www.adeq.state.ar.us/water/planning/surface/macroinvertebrates.aspx.

ADEQ. 2018d. "2018 Assesment Methodology." *Arkansas Final/Draft Impaired Waterbodies - 303(d) List by Year.* July. Accessed October 2018. https://www.adeq.state.ar.us/water/planning/integrated/303d/list.aspx.

ADEQ. 2018e. *ADEQ Facility and Permit Summary.* May. Accessed May 22, 2018. https://www.adeq.state.ar.us/home/pdssql/pds.aspx.

ADEQ. 2018f. *ADEQ AquaView.* Accessed January 2019. http://arkansasdeq.maps.arcgis.com/apps/webappviewer/index.html?id=6df7f199aa3e45f99c0a970cb6acf3a2.

ADEQ. 2019. *Watershed Outreach and Education Program.* Accessed January 2019. https://www.adeq.state.ar.us/poa/watershed/.

AGFC. 2016. *Acres for Wildlife Program.* Accessed September 2017. https://www.agfc.com/en/get-involved/in-the-field/acres-for-wildlife/.

AGFC. n.d. "Bringing Back the Bobwhite." *Arkansas Bobwhite Quail Resources.* Accessed December 2018. https://www.agfc.com/en/hunting/small-game/quail/arkansas-bobwhite-quail-resources/.

Aley, Thomas, and Cathy Aley. 1985. "Water Quality Protection Studies Hell Creek Cave, Arkansas."

Aley, Thomas. 1980. "Delineation of the Recharge Area for Blanchard Springs and the Identification, Location, and Evaluation of Water Quality Hazard Area."

ANRC. 2007. *Nonpoint Source Pollution Management Program Arkansas 2006 Annual Report.* ANRC.

ANRC. 2010. *Arkansas 2009 Annual Report.* ANRC.

ANRC. 2017. *The Arkansas Annual Report, FY 2017.* ANRC.

Arkansas Agriculture Department. 2018. *Arkansas Feral Hog Eradication Task Force.* Accessed October 2018. https://www.agriculture.arkansas.gov/feral-hog-eradication-task-force.

Arkansas Association of Conservation Districts. 2015. *Special Projects.* Accessed October 2018. https://aracd.org/special_projects/default.htm.

Arkansas Cooperative Extension Service. 2018. *Controlling Feral Hogs in Arkansas.* Accessed October 2018. https://www.uaex.edu/environment-nature/wildlife/feral-hogs.aspx.

Arkansas Department of Health. 2017. *Drinking Water Information for Arkansans.* Accessed September 2018. https://www.healthy.arkansas.gov/programs-services/topics/drinking-water-information-for-arkansans.

Arkansas Department of Parks and Tourism. 2017. *2017 Arkansas Tourism Economic Impact.* Little Rock, AR: Arkansas Department of Parks and Tourism.

Arkansas Geological Survey. 2001. "Arkansas Mineral Resources." *Arkansas Geological Survey.* July. Accessed August 2018. https://www.geology.arkansas.gov/pdf/Arkansas%20Mineral%20Resources%20.pdf.

Arkansas Geological Survey. 2015. *Stratigraphy, Ozark Plateaus.* Accessed September 2018. http://www.geology.ar.gov/geology/strat_ozark_plateaus.htm.

Arkansas Geological Survey. 2018. *Mineral Commodity Search/Map.* Accessed May 2018. http://www.geology.ar.gov/minerals/amc_map.htm.

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

Arkansas Natural Heritage Commission. 2018. *Rare Species Search Engine.* Accessed April 2018. http://www.naturalheritage.com/Research-and-Data/rare-species-search.

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 State Board of Health. 2014. *Rules and Regulations Pertaining to Onsite Wastewater Systems.* Regulation, Arkansas Department of Health. https://www.healthy.arkansas.gov/programs-services/topics/onsite-wastewater.

Association of Arkansas Counties. 2018. *Association of Arkansas Counties.* Accessed February 2017. http://www.arcounties.org.

Bagshaw, CS, B Thorrold, M Davison, LJH Duncan, and LR Matthews. 2008. "The influence of season and providing a water trough on stream use by beef cattle grazing hill-country in New Zealand." *Applied Animal Behaviour Science* 155-166.

Bagstad, Kenneth, Darius Semmens, Sissel Waage, and Robert Winthrop. 2013. "A comparative assessment of decision-support tools for ecosystem services quantification and valuation." *Ecosystem Services* 5: 27-39.

Barry, Jon. n.d. *Forests and Urban Stormwater.* FSA5029, University of Arkansas Division of Agriculture.

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

Brasel, Karen, and Margaret Lonadier. 2004. *Little Buffalo River Streambank Stabilization Project.* Arkansas Natural Resources Commission.

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

Center for Advanced Spatial Technologies. 2006. *Arkansas Watershed Information System.* Accessed July 2018. http://watersheds.cast.uark.edu/viewhuc.php?hucid=11010004.

Center for Advanced Spatial Technologies. 2006. *Middle White.* Accessed July 2018. http://watersheds.cast.uark.edu/viewhuc.php?hucid=11010004.

Center for Watershed Protection. 2007. *National Pollutant Removal Performance Database, version 3.* Center for Watershed Protection.

Clary, Jane, Johnathan Jones, Marc Leisenring, Paul Hobson, and Eric Strecker. 2017. *International Stormwater BMP Database 2016 Summary Statistics.* Water Environment & Reuse Foundation.

Dauwalter, Daniel, Edmund Pert, and William Keith. 2003. "An index of biotic integrity for fish assemblages in Ozark Higland streams of Arkansas." *Southeastern Naturalist* 447-468.

EPA. 2008. *Handbook for Developing Watershed Plans to Restore and Protect Our Waters.* 841-B-08-002, Washington DC: EPA.

EPA. 2013. *National Aquatic Resource Surveys.* September 12. Accessed July 2018. http://water.epa.gov/type/watersheds/monitoring/aquaticsurvey_index.cfm.

EPA. 2018a. *Enforcement Compliance History Online, Effluent Limit Exceedences Report.* December. Accessed January 15, 2019. https://echo.epa.gov/trends/loading-tool/reports/effluent-exceedances/?permit_id=ARR000063.

EPA. 2018b. *FY 2019 Budget in Brief.* EPA-190-R-18-002, Washington, DC: US Environmental Protection Agency. https://www.epa.gov/planandbudget/fy-2019-epa-budget-brief.

Faulkner, David. 2000. "Economics Section." In *Virginia Forage and Grassland Council Grazing Handbook*, by Natural Resources Conservation Service. unpublished.

Fowler, Allison (Ed). 2015. *Arkansas Wildlife Action Plan.* Little Rock, AR: Arkansas Game and Fish Commission.

Friends of the North Fork and White Rivers, Inc. 2007. *Watershed Restoration Action Strategy (WRAS) for the North Fork and White Rivers (Middle White River Watershed).* Friends of the North Fork and White Rivers, Inc.

Friends of the North Fork and White Rivers. 2018. *Friends of the North Fork and White Rivers.* Accessed January 15, 2019. http://friendsoftherivers.org/education-action/home/.

FSA. 2018. *Conservation Reserve Program.* June. Accessed January 2019. https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index.

Garrett, H.E. 2011. "Silvopasture Ecosystem Services." *Publications.* November. Accessed May 2017. http://www2.dnr.cornell.edu/ext/info/pubs/.

Geosyntec Consultants. 2018. *International Stormwater Database - Query Builder.* Accessed October 2018. http://www.bmpdatabase.org/bmpstat.html.

Gilip, Johnathan, Joel Galloway, and Rheannon Hart. 2009. *Assessment of Local Recharge Area Characteristics for Four Caves in Northern Arkansas and Northeastern Oklahoma, 2004-07.* Scientific Investigations Report 2009-5118, Reston, VA: US Geological Survey.

Graening, G.O., Michael Slay, and Karen Tinkle. 2003. "Subteranean biodiversity of Arkansas, Part 1: Bioinventory and bioassessment of caves in the Sylamore Ranger District, Ozark National Forest, Arkansas." *Journal of the Arkansas Academy of Science, Vol. 57* 44-58.

Grant, Laura, and Christian Langpap. 2018. "Private provision of public goods by environmental groups." *Proceedings of the National Academy of Sciences of the United States of America.* https://www.pnas.org/content/early/2018/10/02/1805336115.

Grenny, Joseph, Kerry Patterson, David Maxfield, Ron McMillan, and Al Switzler. 2013. *Influencer: The Science of Leading Change, Second Edition.* McGraw Hill.

Grizzetti, Bruna, Denis Lanzanova, Camino Liquiete, Arnaud Reynaud, and Anna C Cardoso. 2016. "Assessing water ecosystem services for water resources management." *Environmental Science and Policy* 61: 194-203.

Herrera Environmental Consultants. 2012. "Technical Memorandum for Puget Sound Stormwater BMP Cost Database." January. Accessed January 2019. https://fortress.wa.gov/ecy/publications/othersupplements/1303009other.pdf.

Hobbie, Sarah, Jacques Finlay, Benjamin Janke, Daniel Nidzgorski, Dylan Millet, and Lawrence Baker. 2017. "Contrasting nitrogen and phosphorus budgets in urban watersheds and implications for managing urban water pollution." *PNAS* 4177-4182.

Homer, CG, JA Dewitz, L Yang, S Jin, P Danielson, G Xian, J Coulston, ND Herold, JD Wickham, and K Megown. 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, Ethan, Cory Gallipeau, and Michael Slay. 2011. *Mapping the Distribution, Habitat, and Threats for Arkansas' Species of Greatest Conservation Need.* The Nature Conservancy.

Izard County Conservation District. 2008. *05-500 Final Report.* ANRC.

Jackson, Clifton, Allison Fowler, Steven Fowler, Jason Honey, Brian Infield, Trevor Mills, Eley Talley, and Ted Zawislak. 2015. *Strategic Quail Management Plan.* Arkansas Game and Fish Commission.

Jacobson, Robert B, and Alexander T Primm. 1997. *Historical Land-use Changes and Potential Effects on Stream Disturbance in the Ozark Plateaus, Missouri.* Water Supply Paper 2484, USGS.

James, E, P Kleinman, T Veith, R Stedman, and A Sharpley. 2007. "Phosphorus contributions from pastured dairy cattle to streams of the Cannonsville Watershed." *Journal of Soil and Water Conservation* 40-47.

Justus, B, James Petersen, Suzanne Femmer, Jeri Davis, and J Wallace. 2010. "A Comparison of Algal, Macroinvertebrate, and Fish Assemblage indicies for assessing low-level nutrient enrichment in wadeable Ozark streams." *Ecological Indicators 10(3)* 627-638.

Kahneman, Daniel, and Amos Tversky. 1979. "Prospect theory: An analysis of decision under risk." *Econometrica* 47 (2): 263-291.

Kemper, Nathan, Archie Flanders, Brad Watkins, and Michael Popp. 2012. *Impact of the 2012 Drought on Field Crops and Cattle Production in Arkansas.* UofA Division of Agriculture.

Klapproth, Julia, and James Johnson. 2009. *Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality.* Publication 420-151, Petersburg: Virginia Cooperative Extension. pubs.ext.vt.edu/420/420-151/420-151_pdf.pdf.

Koelsch, Richard, Jeffrey Lorimer, and Kyle Mankin. 2006. "Vegetative treatment systems for open lot runoff: Review of literature." *Conference Presentations and White Papers: Biological Systems Engineering* 5: 575-607. digitalcommons.unl.edu/biosysengpres/5.

Kresse, TM, PD Hays, KR Merriman, JA Gillip, DT Fugitt, JT Spellman, AM Nottmeier, DA Westerman, JM Blackstock, and JL Battreal. 2014. *Aquifers of Arkansas - Protection, Managment, and Hydraulic and Geochemical Characteristics of Groundwater Resources in Arkansas.* Scientific Investigations Report 2014-5149, USGS.

Kumar, Pushpam (Editor). 2010. *The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations.* London and Washington DC: Earthscan.

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

Matthews, William J, and Edie Marsh-Matthews. 2016. "Dynamics of an upland stream fish community over 40 years: trajectories and support for the loose equilibrium concept." *Ecology 97(3)* 706-719.

Matthews, William, and Henry Robison. 1988. "A distribution of the fishes of Arkansas: A mulitvariate analysis." *COPEIA* 358-374.

McCallister, Chris T. 2018. *Endemic Biota.* February 16. http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=6598.

McFarland, John David. 2004. *Stratigraphic Summary of Arkansas.* Little Rock: Arkansas Geological Survey.

Meals, Donald W, Steven A Dressing, and Thomas E Davenport. 2010. "Lag time in water quality response to best management practices: A review." *Journal of Environmental Quality 39(1)* 85-96.

Merriman, KR, MW Gitau, and I Chaubey. 2009. "A tool for estimating best management practice effectiveness in Arkansas." *Applied Engineering in Agriculture 25(2)* 199-213.

Mickey, Beth. 2018. "*2018 Stats: Social Media Network Usage by Age Group*", February 23, 2018, https://knowledge.creatingresults.com/2018/02/23/2018-stats-social-media-network-usage-by-age-group/. This is an online article at www.CreatingResults.com. Accessed January 2019.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being.* Washington DC: Island Press.

Mott, David, Mark Hudson, and Thomas Aley. 2000. "Nutrient loads traced to interbasin groundwater transport at Buffalo National River, Arkansas." *Inside Earth* 6-10.

Myers, Robert A. 2012. "Lead and Zinc Mining." *The Encyclopedia of Arkansas History & Culture.* February 29. Accessed August 2018. http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=5405.

Narayanan, Arvind, and Robert Pitt. 2006. "Costs of Urban Stormwater Control Practices (Preliminary Report)." *Costs of Urban Stormwater Control Practices.* February. Accessed January 2019. http://rpitt.eng.ua.edu/class/International%20urban%20water%20systems/Arvind%20Costs%20of%20Urban%20Stormwater%20Control%20Feb%2005%202006%20clean%20copy.htm#_Toc126933204.

National Research Council. 2004. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making.* Washington DC: National Academies Press.

National Sustainable Agriculture Coalition. 2018. *2018 Farm Bill by the Numbers.* December 18. Accessed February 15, 2019. http://sustainableagriculture.net/blog/2018-farm-bill-by-the-numbers/.

National Water Quality Monitoring Council. 2018. *Water Quality Portal.* April. Accessed April 2018. https://www.waterqualitydata.us/portal/.

NatureServe. 2018. *NatureServe explorer.* Accessed September 25, 2015. http://explorer.natureserve.org/.

NOAA, Anthony Arguez, Imke Durre, Scott Applequist, Mike Squires, Russell Vose, Xungang Yin, and Rocky Bilotta. 2018. "NOAA's U.S. Climate Normals (1981-2010)." *NOAA National Centers for Environmental Information.* August. Accessed March 2, 2017. doi:10.7289/V5PN93JP.

North Carolina Department of Environment and Natural Resources. n.d. "A Review of the Scientific Literature on Fecal Coliform Attenuation by Riparian Buffers." Accessed Month 2018. https://ncdenr.s3.amazonaws.com/.../Fecal%20Coliform%20Attenuation%20by%20Ri...

Northern Virginia Regional Commission. 2004. "Implementation Plan for the Fecal Coliform TMDL (Total Maximum Daily Load) for Four Mile Run, Virginia."

NRCS. 2006. "Conservation Practices that Save: Prescribed Grazing Systems." *USDA Natural Resources Conservation Service.* April. Accessed 2017. http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/energy/conservation/?cid=nrcs143_023633.

NRCS. 2017a. *2017 Arkansas NRCS Annual Report.* December. Accessed October 2018. https://www.nrcs.usda.gov/wps/portal/nrcs/ar/newsroom/factsheets/NRCSEPRD1380442/.

NRCS. 2017b. "RMS Planning Tool, Identify resource problems and recommended practices." *Conservation Practice Physical Effects CPPE; NRCS Economics.* August. Accessed October 2018. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/tools/?cid=nrcs143_009740.

NRCS. 2018. *Grazing Lands Conservation Initiative.* Accessed March 2019. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/people/partners/glci/.

NRCS. 2019. *Arkansas Payment Schedules.* January. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/?cid=nrcseprd1328226.

Panfil, Maria, and Robert Jacobson. 2001. *Relations Among Geology, Physiography, Land Use, and Stream Habitat Conditions in the Buffalo and Current River Systems, Missouri and Arkansas.* USGS.

Patton, Aaron. 2008. *Fertilizing Your Lawn.* FSA2114, Arkansas Cooperative Extension Service.

Petersen, James, and Suzanne Femmer. 2003. *Periphyton Communities in Streams of the Ozark Plateaus and Their Relations to Selected Environmental Factors.* USGS.

Petersen, James. 2004. *Fish Communities of the Buffalo River Basin and Nearby Basins of Arkansas and their Relation to Selected Environmental Factors, 2001-2002.* USGS.

Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011a. *Reducing Bacteria with Best Management Practices for Livestock, Prescribed Grazing.* Texas AgriLife Extension Service.

Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011b. *Reducing Bacteria With Best Management Practices for Livestock, Fence.* Texas AgriLife Extension Service.

Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011c. *Reducing Bacteria with Livestock Best Management Practices - Livestock Shade Structure.* ESP-408, Texas A&M Agrilife Extension Service.

Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011d. *Reducing Bacteria with Best Management Practices for Livestock - Heavy Use Area Protection.* ESP-406, Texas A&M Agrilife Extension Service.

Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011e. *Reducing Bacteria with Best Management Practices for Livestock - Filter Strips.* ESP-405, Texas A&M Agrilife Extension Service.

Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011f. *Reducing Bacteria with Best Management Practices for Livestock - Stream Crossing.* ESP-416, Texas A&M Agrilife Extension Service.

Peterson, Jennifer, Larry Redmon, and Mark McFarland. 2011g. *Reducing Bacteria with Best Management Practices for Livestock - Watering Facility.* ESP-412, Texas A&M Agrilife Extension Service.

Pieper, Kevin. 2013. "Geese foul up favorite swimming holes." *USA Today*, August 8. https://www.usatoday.com/story/news/nation/2013/08/02/geese-foul-up-favorite-swimming-holes/2611491/.

Ready, Richard. in preparation. *Valuing Ecosystem Services Generated by Nutrient Reductions: A Spatial Approach.* Montana State University.

Reynaud, Arnaud, Denis 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.

Rupar, Bryan, and Mike Slay. 2011. "Foushee Cave Land Acquisition = Protection for Karst-dependent Animal Species." *State Wildlife Action Plan Preproposals for 2011.* Accessed September 2018. https://www.wildlifearkansas.com/proposals/2011PreProposals/Preproposals2011.html.

Rushing, Jaret. 2012. "Feral Hogs and the Effect They Have on Timberland." May 8. Accessed October 2018. www.arkansas.gov/abof/pdfs/ABRF_hogs_jrushing.pdf.

Sanders, Carol. 2016. *Feral Hog Initiative Underway to Aid Landowners in Trapping Swine.* August 25. Accessed October 11, 2017. https://uapbnews.wordpress.com/2016/08/25/feral-hog-initiative-underway-to-aid-landowners-in-trapping-swine/.

Smith, James. 2017. "Manganese Mining." *The Encyclopedia of Arkansas History & Culture.* June 6. Accessed August 2018. http://www.encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=4315.

Southside Public Water Authority. 2018. *Wastewater Information.* Accessed October 2018. https://www.spwa.org/wastewater-information-1.

Stewart, James H. 1988. *A Recovery Plan for the Cave Crayfish Cambarus zophonastes.* US Fish and Wildlife Service.

Suhm, R.W. 1968. "Manganese in North Arkansas." *Rocks & Minerals* 34.

Thaler, Richard, Amos Tversky, Daniel Kahneman, and Alan Schwartz. 1997. "The effect of myopia and loss averaion on risk taking: An experimental test." *Quarterly Journal of Economics* 112: 647-661.

The Nature Conservancy. 2015. *Strawberry River Preserve and Demonstration Ranch.* Accessed January 16, 2015. http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/strawberry-river-preserve-and-demonstration-ranch.xml.

The Nature Conservancy. 2017. *Ozark Highlands Karst Program.* Accessed October 2017. https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arkansas/placesweprotect/ozark-karst-program.xml.

Thornton, KW, and CR Laurin. 2005. "Soft sciences and the hard reality of lake management." *Lake and Reservoir Management 21(2)* 203-208.

UALR Institute for Economic Advancement. 2015. "County Level Population Projections." *Population Estimates and Projections.* Accessed January 25, 2017. http://iea.ualr.edu/population-estimates-a-projections.html.

Univeristy of Central Arkansas. 2018. *Adams Fish Ecology Lab Current Projects.* Accessed August 2018. https://sites.google.com/a/uca.edu/adams-fish-ecology-lab/teaching.

University of Georgia Center for Invasive Species and Ecosystem Health. 2018. *EDDMapS, Early Detection and Distribution Mapping System.* August. Accessed August 2018. http://www.eddmaps.org/.

UofA Division of Agriculture Cooperative Extension Service. 2018. *Arkansas Stormwater Education Program.* Accessed December 2018. https://www.uaex.edu/environment-nature/water/stormwater/.

UofA Divison of Agriculture. 2012. *Economic Contribution of Arkansas Agriculture.* Little Rock: University of Arkansas Division of Agriculture.

US Census Bureau. 2003. "2000 Census of Population and Housing, Population and Housing Unit Counts, Arkansas." PHC-3-5, Washington DC.

US Census Bureau. 2012a. *2010 Census of Population and Housing, Population and Housing Unit Counts, Arkansas.* CPH-2-5, Washington DC: US Government Printing Office.

US Census Bureau. 2012b. "2012 Economic Census of the United States." *American FactFinder.* Accessed April 19, 2018. http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml.

US Census Bureau. 2018. "2013-2017 American Community Survey 5-year Estimates." *American FactFinder.* Accessed April 2018.

http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF.

US Department of the Interior. 2018. *The United States Department of the Interior Budget Justifications and Performance Information Fiscal Year 2019 Fish and Wildlife Service.* Washington, DC: US Department of the Interior. https://www.fws.gov/budget/.

US Fish and Wildlife Service. 2015. *Rabbitsfoot (Quadrula cylindrica cylindrica).* Accessed August 2018. https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=F03X.

US Soil Conservation Service. 1982. *Soil Survey of Independence County.* US Department of Agriculture.

US Soil Conservation Service. 1983a. *Soil Survey of Baxter and Marion Counties Arkansas.* US Soild Conservation Service.

US Soil Conservation Service. 1983b. *Soil Survey of Stone County Arkansas.* US Soil Conservation Service.

US Soil Conservation Service. 1984. *Soil Survey of Fulton and Izard Counties Arkansas.* US Department of Agriculture.

USACE Little Rock District. 2016. *White River Watershed Arkansas and Missouri White River Bull Shoals Lake Master Plan for Development and Management of Bull Shoals Lake.* USACE.

USACE. 2018. *Fast Facts.* August. http://www.corpsresults.us/fastfacts/fastfacts.cfm.

USDA National Agricultural Statistics Service. 2018. *Census of Agriculture.* August. Accessed August 2018. https://www.nass.usda.gov/AgCensus/index.php.

USDA. 2018. *FY 2019 Budget Summary.* Washington, DC: US Department of Agriculture.

USFS. 2008. *Fiscal Years 2006 and 2007 Ozark-St. Francis National Forests Fisheries and Wildlife Monitoring Report.* USFS.

USFS. 2016. *Fiscal Year 2015 Monitoring and Evaluation Report for the Land and Resource Management Plan Ozark - St. Francis National Forests.* US Forest Service.

USGS. 2011. *Mississippi-Atchafalaya River Basin 2002 Nutrient Loading.* Accessed June 2018. https://sparrow.wim.usgs.gov/marb/.

USGS. 2018a. *USGS Surface-Water Data for Arkansas.* April. Accessed April 2018. http://waterdata.usgs.gov/ar/nwis/sw.

USGS. 2018b. *NAS-Nonindigenous Aquatic Species.* January. Accessed April 2018. https://nas.er.usgs.gov.

USGS. 2018c. *USGS Water Quality Data for Arkansas.* Accessed April 2018. http://waterdata.usgs.gov/ar/nwis/qw.

Wagner, Daniel, Joshua Krieger, and Katherine Merriman. 2014. *Trends in Precipitation, Streamflow, Reservoir Pool Elevations, and Reservoir Releases in Arkansas and Selected Sites in Louisiana, Missouri, and Oklahoma, 1951 - 2011.* Scientific Investigations Report 2013-5240, Reston, VA: US Geological Survey.

Washington State University. 2006. "WSU Experimental Riparian Buffer Site Installation and Maintenance Costs 2003-2005." *Riparian Buffers.* Washington State University. Accessed August 2017. https://puyallup.wsu.edu/agbuffers/data/.

Watershed Conservation Resource Center. 2018. *Project 13-1100 White River Bank Restoration and Monitoring Project Project Summary Report.* Arkansas Natural Resources Commission.

Westerman, Drew, Johnathan Gillip, Joseph Richards, Phillip Hays, and Brian Clark. 2016. *Altitudes and Thicknesses of Hydrogeologic Units of the Ozark Plateaus Aquifer System in Arkansas, Kansas, Missouri, and Oklahoma.* Scientific Investigations Report 2016-5130, Reston, VA: US Geological Survey.

White, Michael, Daren Harmel, Haw Yen, Jeff Arnold, Marilyn Gambone, and Richard Haney. 2015. "Development of sediment and nutrient export coefficients for U.S. ecoregions." *Journal of the American Water Resources Association* 758-775.

Whitescarver, Bobby. 2013. "Planting and Growing a Successful Riparian Forest Buffer." *Whitescarver Natural Resources Management LLC.* Whitescarver Natural Resources Management LLC. July 13. Accessed August 2017. http://www.gettingmoreontheground.com/2013/07/13/planting-and-growing-a-successful-riparian-forest-buffer/.

Woods, AJ, TL Foti, SS Chapman, JM Omernik, JA Wise, EO Murray, WL Prior, JB Jr. Paga, JA Comstock, and M Radford. 2004. *Ecoregions of Arkansas.* color poster with map, descriptive text, summary tables, and photographs, Reston, VA: US Geological Survey.

York, Alex. 2018. *7 Steps in Creating a Winning Social Media Marketing Strategy in 2018.* April 20. https://one18media.com/7-steps-creating-winning-social-media-marketing-strategy-2018/.

Zeckoski, R, B Benham, and C Lunsford. 2012. *Streamside Livestock Exclusion: A tool for increasing farm income and improving water quality.* Publication number 442-766, Virginia Cooperative Extension.

Zuo, MH, and MS Miller-Goodman. 2004. "Landscape use by cattle affected by pasture developments." *Journal of Range Management* 426-434.

APPENDIX A

Sign In Sheets from Public Meetings Held for Development of the Middle White River Watershed Management Plan

MEETING SIGN-IN SHEET

Project:	ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:**	May 31, 2018
Facilitator:	Kent Thornton	**Place/Room:**	UACCB

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
BARRY FERRELL			119 PINE TREE LANE BATESVILLE, AR 72501	BARRYFERRELL@SUDDENLINKMAIL.COM
DAN + PATRICIA STEWART	farmer	870-269-2684	445 Star Gap Rd Mtn View, AR 72560 ~~stargapfarm@gmail~~	stargapfarm@gmail.com
Philip Antici		870-307-2158	2558 Goff Dr, Batesville	philipantici@ffcmail.com
Matt McNair	Ark. Dept. of Parks & Tourism	501-682-1227	Matt.Mcnair@arkansas.gov	1 Capitol Mall, LR, 72201
Marc Phillips	AFC	870-994-2187	P.O. Box 26 Ash Flat AR 72513	Marc.phillips@agriculture.arkansas.gov
Julia McNeil	ICCD	8703071224	2950 White Dr Batesville AR 72501	juliamnail@gmail.com

Meeting Sign-In Sheet

Project:	ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:**	May 31, 2018
Facilitator:	Kent Thornton	**Place/Room:**	UACCB

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Ricki Gilbert	In. CO. Conservation	870-793-4164 x 3	490 E College St RM 242 Batesville, AR 72501	rickigilbert@ar.nacdnet.net
Alyssa Bangs	USFWS	501-513-4472	110 S. Amity Rd, Ste 300 Conway, AR 72032	alyssa_bangs@fws.gov
Gerald Weber	Friends of the NF & Wlz	870-269-2704	17221 Hwy 9 Mountain View AR 72560	jerryweber@yelcot.net
Suzanne Teel	NRCS	870-523-8986	2115 Malcolm Newport, AR 72112	suzanne.teel@ar.usda.gov
Carl Lindstrom	Citizen	870-585-2144		CEL1281@AOL.COM
Darcia Routh	ADH	501-661-2856	4815 W. Markham St Slot 37, LK AR 72205	darcia.routh@arkansas.gov
John Bailey	ArFB	501)251-7737		john.bailey@arfb.com
Roger Cousins	NRCS	870-793-4164	490 E College St Rm 242 Batesville, AR 72501	roger.cousins@ar.usda.gov
Scott Roulier	Lyon	870 613-4313	34 Big Pine 72501	scott.roulier@lyon.edu
Dean Gammill	Stone Co Farm Bureau	870-213-6675	19749 Hwy 263	ddgammill@hotmail.com
Judge G. Ahrens	Indep Cnty	Judge		
Don Hubbell	UA-LFST	870-793-7432	70 Exp. Sta Dr Batesville, AR	dhubbell@uark.edu
Jody Urquhart	ARFB	501 224 4400		

MEETING SIGN-IN SHEET

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	May 31, 2018
Facilitator:	Kent Thornton	**Place/Room:**	UACCB

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Tom Hess	Landowner - Farm Bureau	870-805-9046	3090 Oneal Rd. Batesville	thess@uark.edu
Sonia Blankenship	IC OEM	870-291-3940	PO Box 327 Melbourne, AR 72556	oemdirector@izardcountyar.org
Lynn Cornelius	FutureFuel	8706985631	2800 Gap Rd Batesville, AR	lynncornelius@ffcmail.com
Sam Cooke	Friends North Fork & White River	870 307 8922	22 Southridge CT Batesville Ar	sdcooke22@gmail.com

MEETING SIGN-IN SHEET

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	May 31, 2018
Facilitator:	Kent Thornton	**Place/Room:**	UACCB

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Jim Cunningham	City of Newark	870-799-2663	Newark Ar. 72562	newarkcityhall@yahoo.com
Carissa Ennis	NRCS	(870)		Carissa.ennis@ar.usda.gov
Zach Avey	NRCS	870-615-9851	~~[illegible]~~	Zachary.Avey@ar.usda.gov
Richard Norwood	ADH	501-269-5401		richardj.norwood@arkansas.gov
Tim Burnley	AGFC	870-404-6369	201 E 5th St Mtn Home 72653	tim.burnley@agfc.ar.gov

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MEETING SIGN-IN SHEET Middle White River

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	9-11-18
Facilitator:	Dr. Kent Thornton-FTN	**Place/Room:**	Calico Rock

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Joseph Krystofik	USFWS	501-513-4479	110 S. Amity Rd. Ste 300 Conway, AR 72032	joe_krystofik@fws.gov
Tom Hess				
Lynn Cornelius	FutureFuel Chemical			
Tim Burnley	AGFC			
Marcia Seay		870-373-5032	PO Box 296 Pineville AR 72566	mseay72566@yahoo.com
Marc Phillips	AFC	870-994-2187		
Terrie Green				
Carl Lindstrom		870-585-2144	—	—
Kristi Williams	ADEQ	—	—	williams@adeq.state.ar.us
Dan Stewart				
Jerry Weber				
John Bailey				
Matt McNair	ADPT	501-682-1227	MM	

MEETING SIGN-IN SHEET Middle White River	
Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 9-11-18
Facilitator: Dr. Kent Thornton - FTN	**Place/Room:** Calico Rock

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Elijah Snow	Senator John Boozman	870-866-0199	1001 Hwy 62 E. Suite 11, Mountain Home, AR	Elijah_Snow@boozman.senate.gov
Wendy Hendrix	NRCS	8		
Zeke Marler	FSA			zeke.marler@ar.usda.gov
[illegible]	Izard Co			
Sonia Blankenship	Izard Co OEM			

MEETING SIGN-IN SHEET Middle White River

Project:	**ARKANSAS WATERSHED PLAN Public Meeting**	**Meeting Date:**	11/28/18
Facilitator:		**Place/Room:**	UACC Batesville

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Tommy Crenshaw	Ind Co Conservation Dis	870 793-4164		
Kenny Crawford	Fulton Co. CON	870-404-6121	323 Ridge RD CAMP AR 72520	
Shannon Davis	Cache River Drainage Dist	8709265050	PO Box 483 Bono AR72416	Shannondavisfarms@gmail.com
Rheannon Hart	USGS	501 228 3664	LR	rmhart@usgs.gov
Bill Baldwin	USGS	5012283602	LR	bbaldwin@usgs.gov
Sean Saunders	AGFC	501-765-9208		
Alyssa Baugs	USFWS			
JERRY WEBER	FRIENDS OF NF & WRS	870-269-2704	17221 HWY 9 MOUNTAIN VIEW, 72560	jerryweber@yelcot.net
Chelsea Varner	Farmer, Realtor	870-307-4343	P.O. Box 145 Salado, AR 72575	chelseamweaver@yahoo.com
Tom Hess				thess@uark.edu

MEETING SIGN-IN SHEET Middle White River

Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 11/28/18
Facilitator:	**Place/Room:** UACC Batesville

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Carol Prewett	Farmer	501-688-7682	114 Sage Circle Salem AR	CRPrewett@att.net
Logan Stone	Financial Planner farmer	870 404 0989	892 Elizabeth Rd Gepp AR	loganrstone@gmail.com
Michael McDaniel	City of Batesville	870-698-2442	500 Riverbank Rd. Batesville, AR 72501	wwinspector@cityofbatesville.com
Scott Williams	SPWA	870 251 2508	1401 Batesville Blvd Batesville, AR	southsidewater@sbcglobal.net
Jim Ulmer	City of Batesville	479-790-6428	302 E Millsap Rd Fayetteville, AR 72703	julmer@olsson.com
Sam Cooke	Friends North Fork White			
Kenny CLARK	JACKSON COUNTY Cons Board member	870-217-3971	170 VH 221 Newport AR 72112	KCCLARK49@yahoo.
Stan Haywood	Mud Creek	870-512-8647	2770 Hwy 14 W[illegible]	Stan Haywood@yahoo.com

Middle White

MEETING SIGN-IN SHEET

Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 11/28/18
Facilitator:	**Place/Room:** UACC Batesville

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Glen Willis	Independence Emerg Mgt	870-793-8816	1730 Myers ST Batesville	glen.willis@independencecounty.com
Ron Byars	Independence Road Dept	870 834 7327	192 East Main Batesville	Ronbyars50c@Gmail
Lynn Cornelius	FutureFuel	870 698 5634		lynncornelius@ffcmail.com
Susan Jeffery	FutureFuel	870 698 5304		susanjeffery@ffcmail.com
Marc Phillips	AAD - AFC	870-994-2187	P.O. Box 26 Ash Flat AR 72513	
Kenny Smothers	AAD - AFC	870 - 613-1939	#1 Forestry Rd, Batesville, AR	
Julia Neil				
Gary Lynch		870-834-6805	P.O. Box 326 Sulphur Rock	gobslynch@hotmail.com

MEETING SIGN-IN SHEET Middle White River

Project: ARKANSAS WATERSHED PLAN Public Meeting	**Meeting Date:** 11/20/15
Facilitator:	**Place/Room:** UACC Batesville

Name	Organization or Occupation	Phone	Mailing Address	E-Mail
Dennis Haigwood	DHM Farms	870-217-2421	2805 Stewart, Newport	haigwoodfamily@yahoo.com
Darcia Routh	ADH - Engineering	501-661-2623	4815 W Markham, Slot 37	darcia.routh@arkansas.gov
Richard Morad	"	"	"	richard.morad@arkansas.gov
ZACH FOSTER	ADPT	501-682-6947	One Capitol Mall, Little Rock, 72201	zach.foster@arkansas.gov
Matt McNair	"	"	"	matt.mcnair@arkansas.gov

APPENDIX B

Water Quality Trend Analyses

APPENDIX B. WATER QUALITY TREND ANALYSIS

Water quality stations chosen for analysis of long-term trends in water quality are listed in Table B.1 (in downstream order). These are the only stations in the watershed have continuous, or nearly continuous, water quality records of over 15 years that continue through 2017. The parameters analyzed for trends are dissolved oxygen, TSS (ADEQ only), suspended sediment (USGS only), turbidity (ADEQ only), dissolved inorganic nitrogen, total nitrogen, and total phosphorus. Only data from the period 1993 through 2017 is used in the trend analyses so comparable periods are evaluated for all of the stations.

Table B.1. Active water quality monitoring stations with data records of at least 10 years.

Station	Agency	Stream	Location	Data Period
WHI0065	ADEQ	Hicks Cr	D/S Mt. Home	1990-2017
WHI0046	ADEQ	White R	Norfork	1990-2017
07060500	USGS	White R	Calico Rock	1972-2017
07060710	USGS	N. Sylamore Cr	Near fifty-six	1972-2017
WHI0011	ADEQ	S. Sylamore Cr	d/s Lick Cr (Mountain View WWTP)	1993-2017
WHI0029	ADEQ	White R	Oil Trough	1990-2017

Characteristics of the data determine what type of trend analysis is most appropriate. Data characteristics of concern include the presence of seasonal patterns, whether the data are normally distributed, and whether concentrations appear to be related to flow rate. These characteristics are discussed in the following sections.

B.1. Dissolved Oxygen

Figure B.1 shows graphs of the dissolved oxygen data for the selected water quality stations for the period 1993 through 2017 (all figures referenced in this subsection are located at end of this subsection). There is an apparent dip in dissolved oxygen concentrations at the South Sylamore station (WHI0011), and the White River at Oil Trough (WHI0029) during the period 2000-2005. This pattern is not apparent in the data from any of the upstream White River stations, nor in the data from any of the other White River tributaries. The dissolved oxygen data from the Hicks Creek station (WHI0065) appear to show an increase in concentrations over time, at least until sometime between 2010 and 2015. Since then, concentrations may be declining.

Dissolved oxygen concentrations may also be increasing at the North Sylamore Creek station (07060710).

Dissolved oxygen data typically exhibits a seasonal pattern, because it is affected by temperature (Figure B.2). Therefore, a trend analysis method that accounts for this effect is used.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics (using SYSTAT version 12.02.00). These statistics are given in Table B.2. For most stations, but not all, the dissolved oxygen data are normally distributed. Because not all of the data sets are normally distributed, a non-parametric statistical trend test is used.

Table B.2. Normality test results for 1993-2017 dissolved oxygen data from long term stations.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.990	0.07	0.866	0.03	Not normal
WHI0029	0.994	0.26	0.577	0.14	Normal
WHI0046	0.994	0.21	0.426	>0.15	Normal
WHI0065	0.980	0.00	1.609	<0.01	Not normal
07060500	0.986	0.00	1.476	<0.01	Not normal
07060710	0.996	0.30	0.589	0.13	Normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in dissolved oxygen concentrations. The USGS program for the Kendall family of tests was used to run the statistical test (Helsel, Mueller and Slack 2006). The program was set up to use 12 seasons, i.e., each month is considered a separate season. The program input and output are included as Attachment 1. The test results are summarized in Table B.3.

Table B.3. Results of Seasonal Mann-Kendall test of 1993-2017 dissolved oxygen data, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	129	1.09	0.59	No
WHI0011 (2004-2017)	S. Sylamore Cr	-243	-4.14	0.02	Yes, decreasing
WHI0029	White R	354	2.87	0.16	No
WHI0029 (2004-2017)	White R	-55	-0.93	0.55	No
WHI0046	White R	215	1.54	0.34	No
WHI0065	Hicks Cr	346	2.48	0.09	Yes, increasing
07060500	White R	28	0.49	0.65	No
07060710	N. Sylamore Cr	426	4.79	0.00	Yes, increasing

Dissolved oxygen concentrations at two of the stations exhibit statistically significant increasing trends, Hicks Creek (WHI0065) and North Sylamore Creek (07060710). The p-values indicate that there is a 91% confidence that there is a statistically significant increasing trend in dissolved oxygen at the Hicks Creek station, while the confidence for the statistically significant increasing trend at the North Sylamore Creek station is over 99%. Usually, increasing dissolved oxygen concentrations would be considered an indicator of improving water quality. However, given that the Hicks Creek station is located downstream of the Mountain Home WWTP, the increasing dissolved oxygen concentrations may result from increased productivity from nutrient inputs.

We wondered if the dip in dissolved oxygen concentrations during the period 2000-2005 at the South Sylamore Creek station (WHI0011) and the White River at Oil Trough (WHI0029) is influencing the trend results. Therefore, the Seasonal Mann-Kendall analysis was also run on a subset of the dissolved oxygen data from these stations for the period 2004-2017 (14 years). These analyses indicate a statistically significant declining trend in dissolved oxygen at the South Sylamore Creek station (WHI0011).

Dissolved oxygen can be affected flow, particularly in smaller streams, as there can be more aeration of the water at faster flows. Flows are measured routinely at the USGS stations, but not the ADEQ stations. However, there are USGS flow gages close to the two ADEQ stations on the White River that can be used to evaluate the relationship between flow and dissolved oxygen concentrations. Flow data from USGS gage 07057370 will be associated with water quality data from ADEQ station WHI0046, both are located on the White River near Norfork. Flow data from USGS gage 07061000, White River at Batesville, will be associated with water quality data from ADEQ station WHI0029, White River at Oil Trough. Graphs of dissolved oxygen concentration versus flow at the four stations with associated flow measurements are shown in Figure B.3. The graphs in Figure B.3 do not show readily apparent relationships between dissolved oxygen concentrations and flow at the White River stations, but there may be a relationship at the North Sylamore Creek station.

For stations associated with daily flow data, another trend analysis, weighted regression on time, discharge, and season (WRTDS), can be applied (Hirsch, Moyer and Archfield 2010). This analysis was applied using an R software package prepared by the USGS (Hirsch and De Cicco 2015). Figure B.4 shows WRTDS estimates of annual average dissolved oxygen concentrations.[1] The graphs in Figure B.4 show estimated mean annual dissolved oxygen concentrations increasing over time at all four the stations. Note that there are gaps in the flow records for the White River gages at Norfork and Batesville, so the WRTDS analysis periods for those stations are shorter. The fact that the mean annual concentration dots on the graphs are close to the line showing the flow normalized concentrations indicates that flow does not have much effect on the dissolved oxygen concentrations at these stations.

[1] Flux, i.e., concentration times flow, is the preferred output of the WRTDS analysis for evaluation of trends. However, it is not reasonable to evaluate some parameters in terms of flux, e.g., dissolved oxygen. In addition, the EGRET program does not calculate flux for parameters where concentrations are reported in units other than mg/L, e.g., fecal coliforms, which are reported as cfu/100 mL

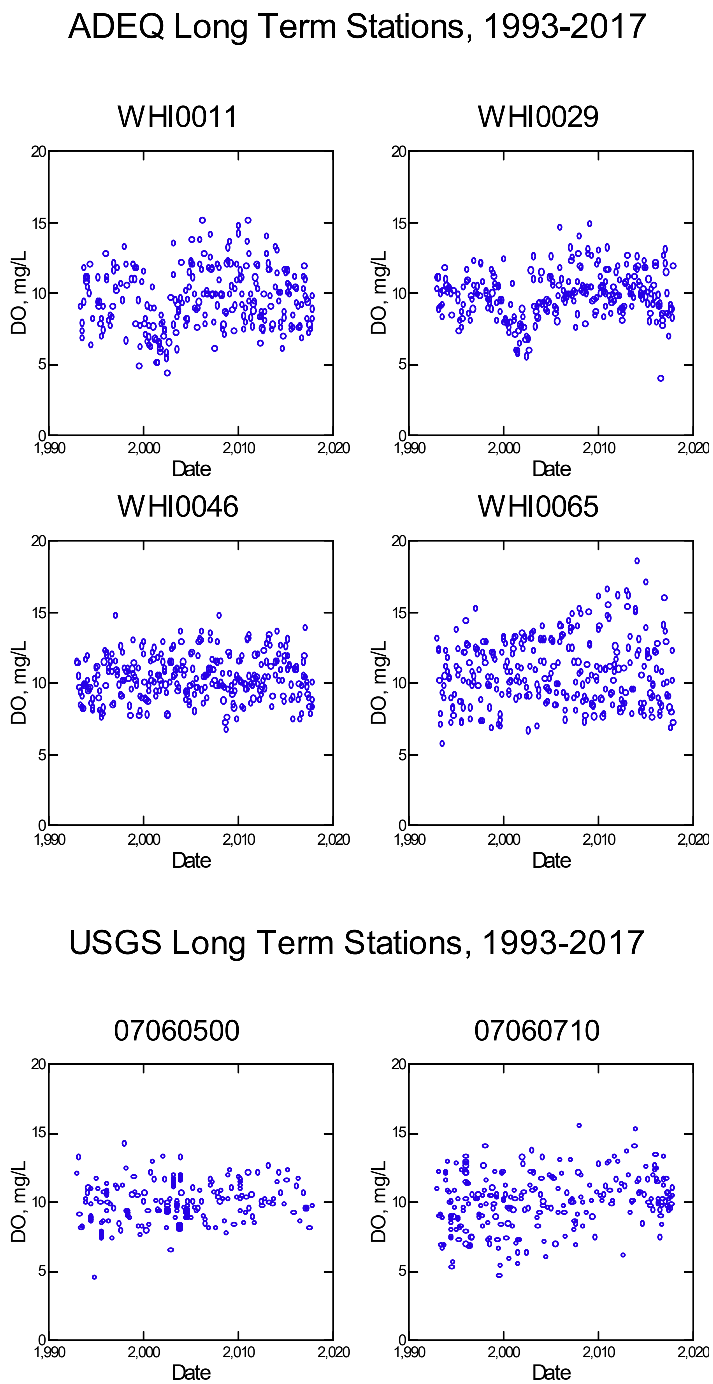


Figure B.1. Dissolved oxygen concentrations from 1993-2017 at long term water quality stations.

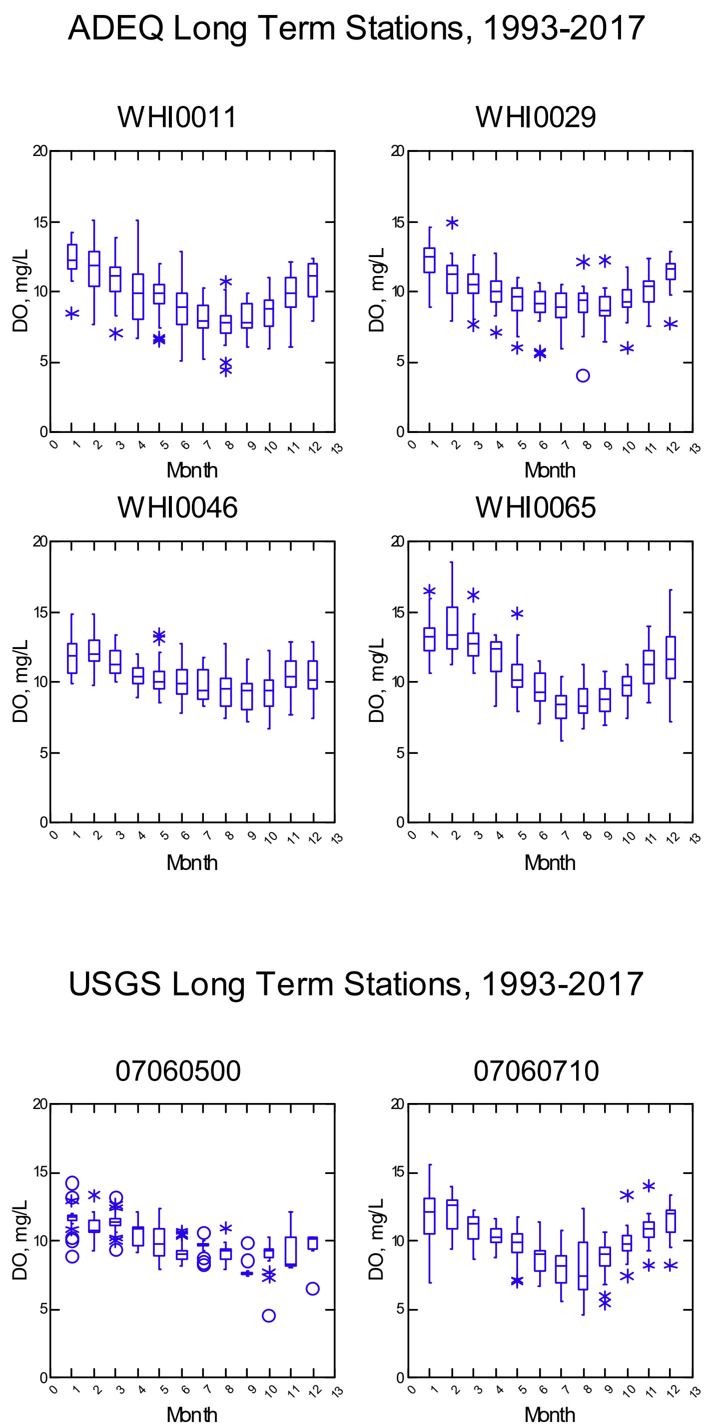


Figure B.2. Dissolved oxygen concentrations from long term stations showing seasonal patterns in data from 1993-2017.

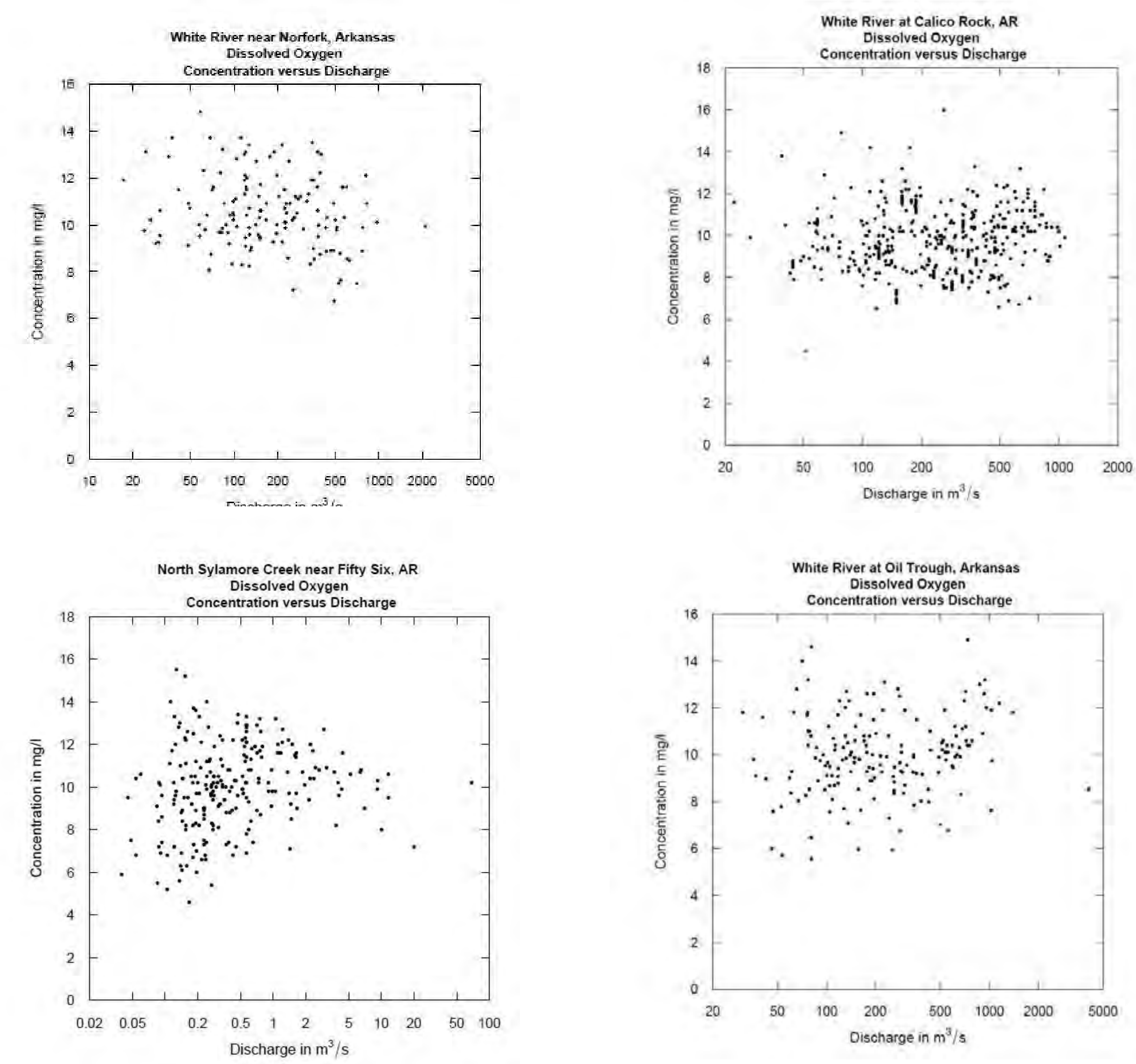
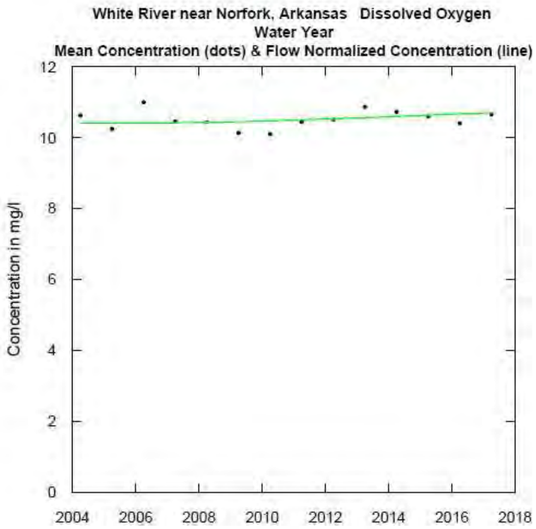
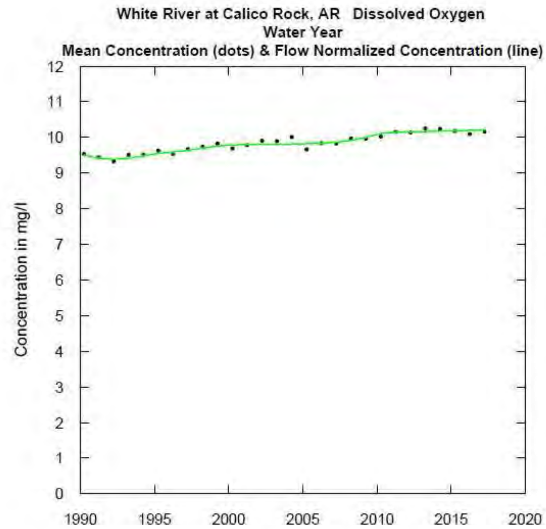
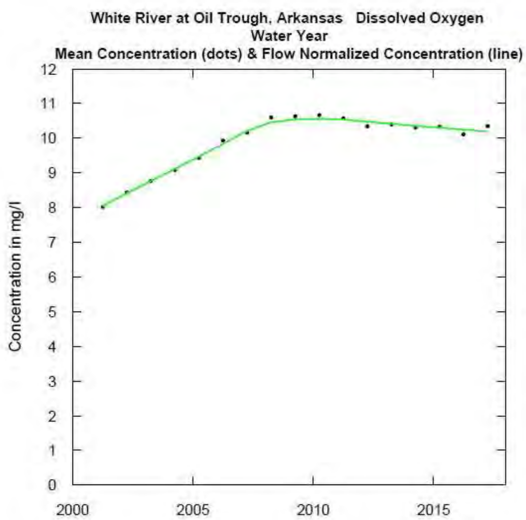


Figure B.3. Dissolved oxygen concentrations versus flow at long term stations associated with flow gages.







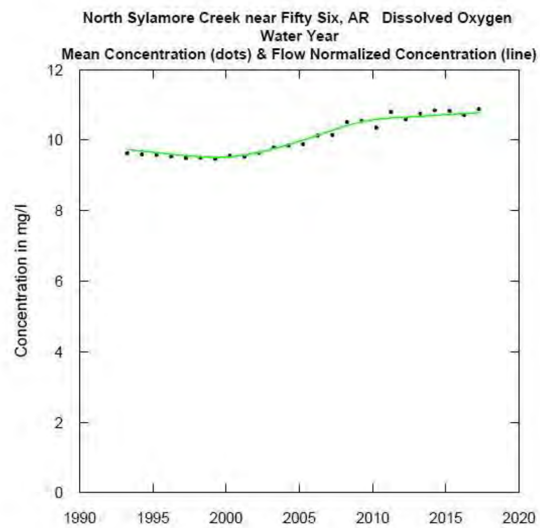


Figure B.4. WRTDS estimates of annual average dissolved oxygen concentrations at long term stations associated with flow gages.

B.2. Dissolved Oxygen Saturation

To provide insight into the trends observed in dissolved oxygen concentrations, dissolved oxygen saturation values were also evaluated for trends. Algae blooms resulting from nutrient contamination often cause supersaturation of dissolved oxygen in water, i.e., dissolved oxygen saturation greater than 100%. Figure B.5 shows graphs of dissolved oxygen saturation over time for the long-term water quality stations (all figures referenced in this subsection are located at end of this subsection).

DO saturation is reported by USGS, but had to be calculated for the ADEQ stations. For ADEQ station, saturation DO was estimated from water temperature and elevation of the station using the following equation: [exp(7.7117-1.31403*ln(temperature deg C +45.93))]*[(1-(elevation km/44.3))^5.25]. Elevations for the ADEQ water quality stations are estimated from USGS topographic maps as shown on the ADEQ online AquaView map, and listed in Table B.4. Given these elevations (ranging from 230 ft to 615 ft), the elevation factor of the equation, i.e., [(1-(elevation km/44.3))^5.25], is close to 1 (0.98 to 0.99). Therefore, for these estimates, it was assumed to be 1. The DO saturation values were then calculated as the measured DO divided by the saturation DO.

Table B.4. Elevation of ADEQ water quality stations.

Station ID	Elevation, ft	Elevation, km	Elevation factor
WHI0011	355	0.108	0.987
WHI0029	230	0.070	0.992
WHI0046	355	0.108	0.987
WHI0065	615	0.187	0.978

As with dissolved oxygen concentration, dissolved oxygen saturation exhibits seasonal patterns (see Figure B.6).

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.5. Only one set of data appears to have a normal distribution. Because most of the data sets are not normally distributed, a non-parametric statistical trend test is used.

Table B.5. Normality test results for 1993-2017 dissolved oxygen saturation data from long term stations.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.981	0.002	0.705	0.065	Not normal
WHI0029	0.974	0.00	2.388	<0.01	Not normal
WHI0046	0.996	0.606	0.247	>0.15	Normal
WHI0065	0.988	0.013	1.132	<0.01	Not normal
07060500	0.970	0.00	1.065	<0.01	Not normal
07060710	0.988	0.040	1.023	0.010	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in dissolved oxygen saturation. The USGS program for the Kendall family of tests was used to run the statistical test. The program was set up to use 12 seasons, i.e., each month is considered a separate season. The program input and output are included as Attachment 2. The test results are summarized in Table B.6. Because the stations with increasing DO trends (Table B.3) also have statistically significant increasing trends in DO saturation, it is possible that the increase in DO is the result of increased presence of algal blooms. This would indicate worsening water quality, rather than improving.

Table B.6. Results of Seasonal Mann-Kendall test of 1993-2017 dissolved oxygen saturation data, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	121	1.049	0.61	No
WHI0029	White R	386	3.257	0.10	No
WHI0046	White R	248	1.781	0.30	No
WHI0065	Hicks Cr	413	2.970	0.04	Yes, increasing
07060500	White R	97	1.742	0.13	No
07060710	N. Sylamore Cr	440	4.948	0.00	Yes, increasing

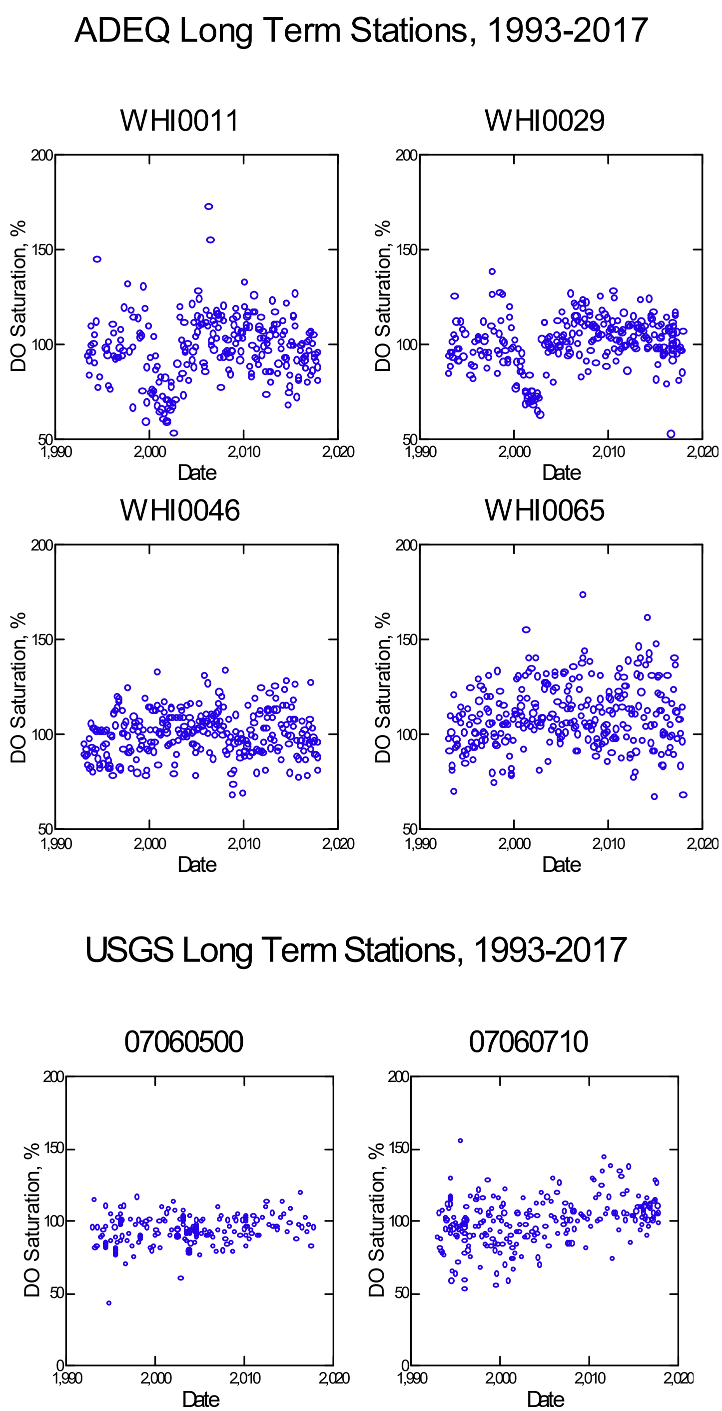


Figure B.5. Dissolved oxygen saturation from 1993-2017 at long term water quality stations.

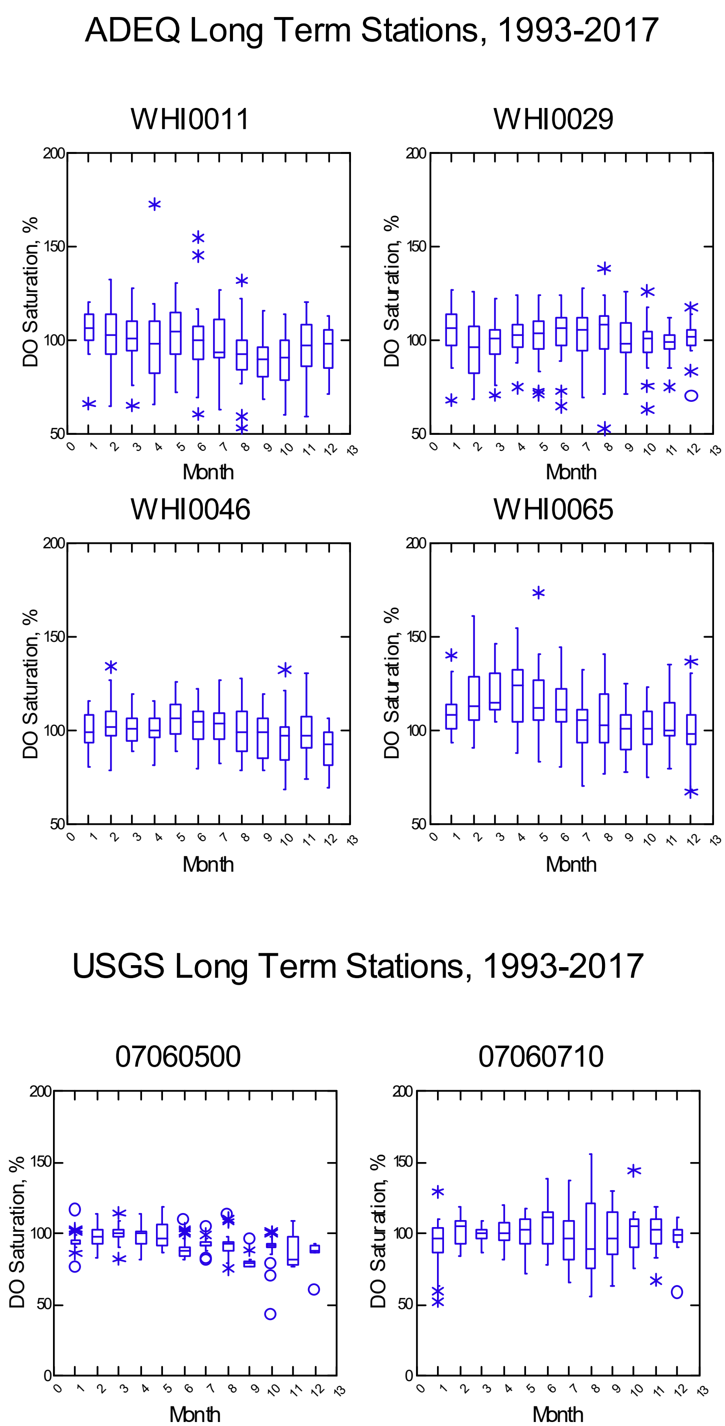


Figure B.6. Dissolved oxygen saturation from long term stations showing seasonal patterns in data from 1993-2017.

B.3. Dissolved Inorganic Nitrogen

Figure B.7 shows graphs of the available dissolved inorganic nitrogen data for the selected water quality stations for the period 1993-2017 (all figures referenced in this subsection are located at end of this subsection). Note that this is USGS parameter code 00631. There are no readily apparent trends in dissolved inorganic nitrogen concentrations at the stations. However, it is apparent that there was a drop in the dissolved inorganic nitrogen concentrations at the Hicks Creek station (WHI0065) sometime between 1995 and 2000, most likely as the result of a change in the Mountain Home sewerage treatment plant.

Inorganic nitrogen may exhibit seasonal patterns, depending on the sources. Figure B.8 shows box plots of dissolved inorganic nitrogen by month. These plots suggest that inorganic nitrogen exhibits seasonal patterns at some stations. For example, at station WHI0011 (South Sylamore Cr) dissolved inorganic nitrogen appears to usually be lower during the period July through September, than during other parts of the year.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.7. Note that only USGS data after 1970 are used, because prior to that, data was not routinely collected. Dissolved inorganic nitrogen measurements from all of the stations are not normally distributed. Because the data sets are not normally distributed, a non-parametric statistical trend test is used.

Table B.7. Normality test results for dissolved inorganic nitrogen data from long term stations.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.957	0.00	2.84	<0.01	Not normal
WHI0029	0.136	0.00	76.2	<0.01	Not normal
WHI0046	0.980	0.00	1.23	<0.01	Not normal
WHI0065	0.715	0.00	28.9	<0.01	Not normal
07060500	0.980	0.00	1.04	<0.01	Not normal
07060710	0.826	0.00	10.5	<0.01	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in dissolved inorganic nitrogen concentrations. The USGS program for the Kendall family of tests was used to run the statistical test. The program was set up to use 12 seasons, i.e., each month is considered a separate season. The program input and output are included as Attachment 3. The test results are summarized in Table B.8.

Table B.8. Results of Seasonal Mann-Kendall test of dissolved inorganic nitrogen data, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	-12	-0.081	0.94	No
WHI0029	White R	10	0.064	0.97	No
WHI0046	White R	75	0.526	0.77	No
WHI0065	Hicks Cr	-1181	-8.38	0.00	Yes, decreasing
WHI0065 (1999-2017)	Hicks Cr	-416	-4.38	0.01	Yes, decreasing
07060500	White R	111	2.01	0.22	No
07060710	N. Sylamore Cr	-121	-1.41	0.32	No

A trend in dissolved inorganic nitrogen concentrations is evident only in the data from the Hicks Creek station (WHI0065). Two periods were evaluated for the Hicks Creek Station (WHI0065). As noted previously and shown in Figure B.7, there was noticeable drop in the dissolved inorganic nitrogen concentrations at the Hicks Creek station (WHI0065) sometime between 1995 and 2000. To determine if the decreasing trend identified was solely the result of that drop in concentrations, the data just from the period since the drop was evaluated for trend. These data also show a decreasing trend.

Dissolved inorganic nitrogen can be affected flow. Graphs of dissolved inorganic nitrogen concentration versus flow at the four stations with associated flow measurements are shown in Figure B.9. The graphs in Figure B.9 appear to show relationships between dissolved inorganic nitrogen concentrations and flow at the stations.

For stations associated with daily flow data, WRTDS trend analysis can be applied. This analysis was applied using an R software package prepared by the USGS (EGRET). Figure B.10 shows WRTDS estimates of annual average dissolved inorganic nitrogen flux (or export). The graphs in Figure B.10 show estimated mean annual dissolved inorganic nitrogen flux has increased over time at all four the stations. However, at three of the stations, White River at Norfork (WHI0046) and Oil Trough (WHI0029) and North Sylamore Creek (07060710), flux appears to show a declining trend since about 2010. At the White River at Calico Rock

(078060500), there appears to have been little change in dissolved inorganic nitrogen flux over the last several years.

The EGRET R software package calculates a flux bias statistic that characterizes bias in the WRTDS estimates of flux. Table B.9 lists the flux bias statistics associated with the WRTDS analyses of inorganic nitrogen data. Flux bias statistic value between -0.1 and 0.1 indicate that the bias associated with WRTDS estimates of annual mean flux is likely less than 10% (Hirsch and De Cicco 2015). The flux bias statistic for WRTDS results from USGS Station 07060710 suggest that WRTDS estimates for that station are negatively biased, i.e., are lower than true values. Therefore, the apparent declining trend may be false.

Table B.9. Flux bias statistics associated with WRTDS estimates of mean annual inorganic nitrogen flux.

Station ID	Stream	Flux Bias Statistic
07060500	White R	0.013
07060710	N. Sylamore Cr	-0.234
WHI0029	White R	0.00794
WHI0046	White R	-0.00658

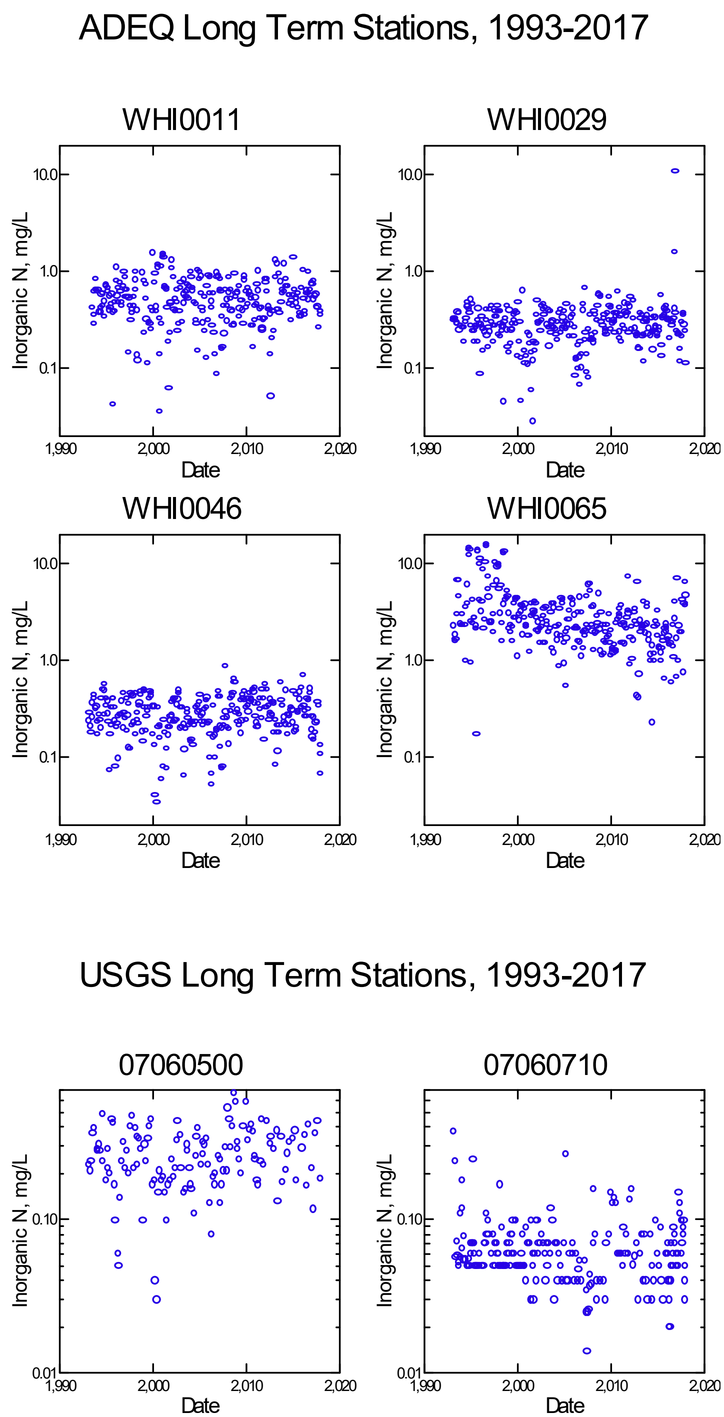


Figure B.7. Dissolved inorganic nitrogen concentrations for1993-2017 at long term water quality stations.

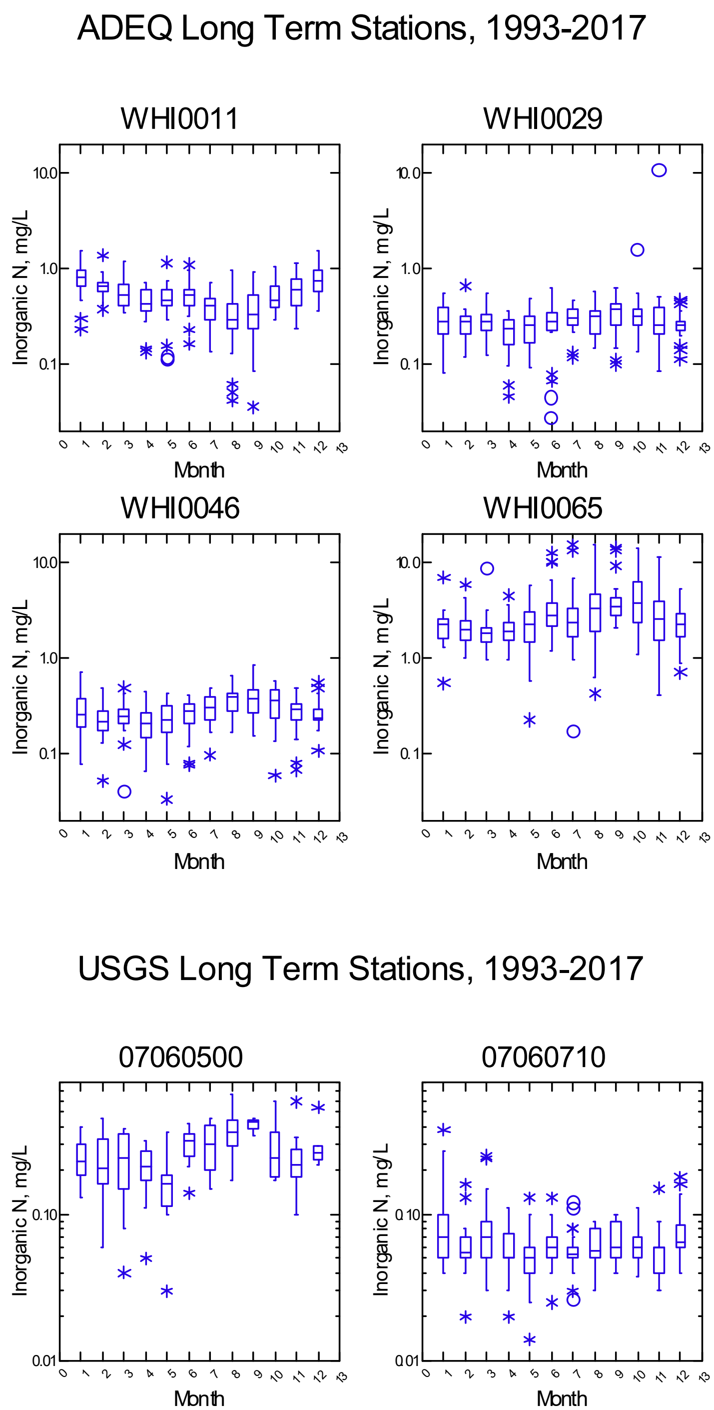
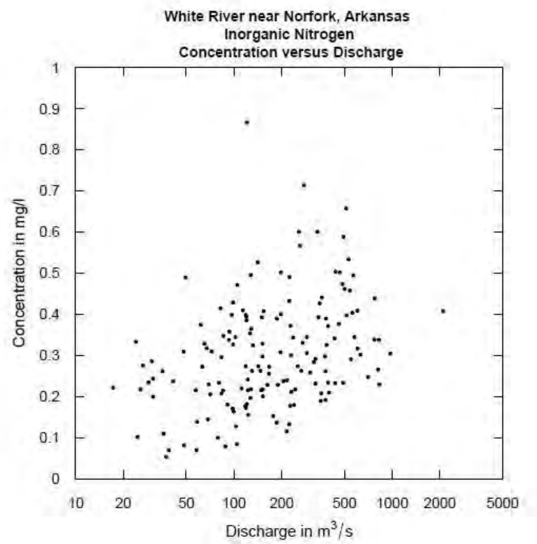
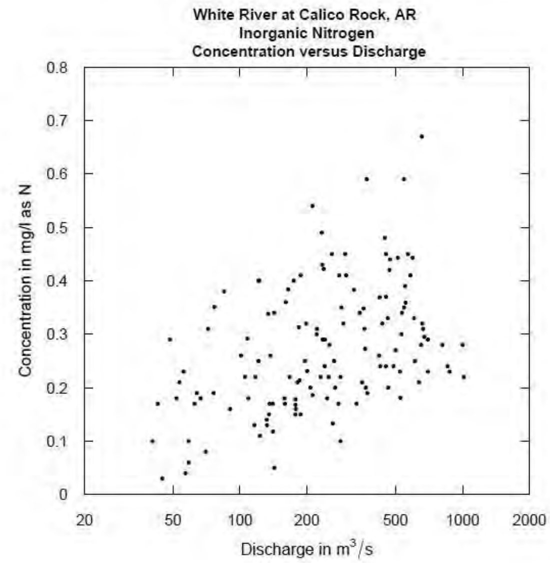
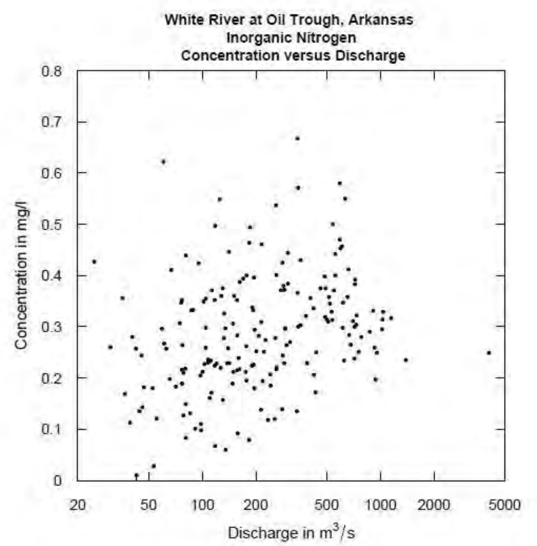


Figure B.8. Dissolved inorganic nitrogen from some long-term stations show seasonal patterns in data from 1993-2017.







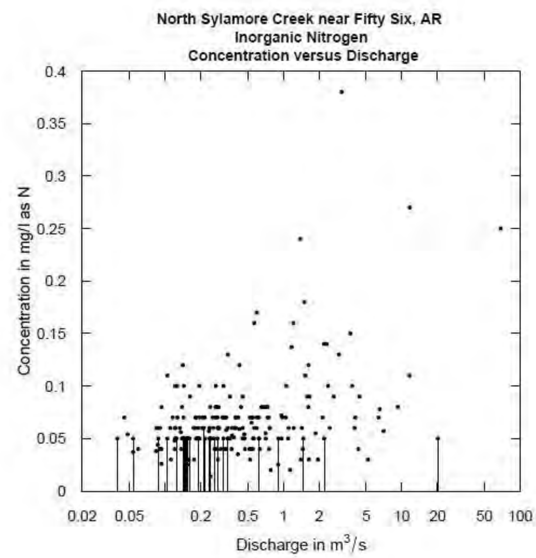


Figure B.9. Dissolved inorganic nitrogen concentrations versus flow at long term stations associated with flow gages.

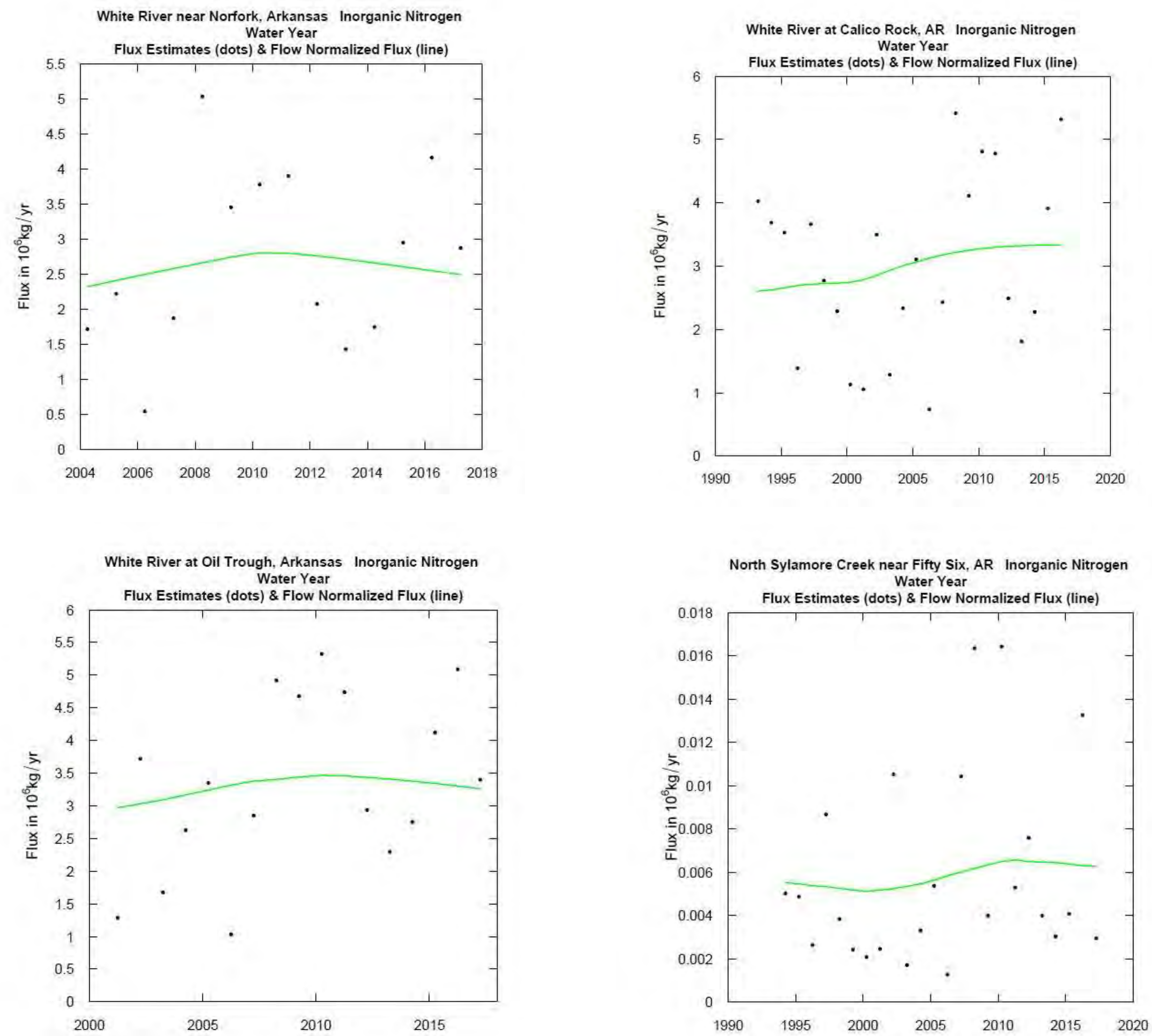


Figure D.10. WRTDS estimates of annual average dissolved inorganic nitrogen flux at long term stations associated with flow gages.

B.4. Total Nitrogen

Figure B.11 shows graphs of the available total nitrogen data for the long-term water quality stations for the period 1993-2017 (all figures referenced in this subsection are located at end of this subsection). Note that this is USGS parameter code 00600. For station 07060710, 89 of the 128 total nitrogen values reported are censored, i.e., less than detection. In addition, the reported detection level has declined over time. This fact, and the long gap in the total nitrogen data record, mean that these data are not suitable for evaluation of water quality trends. The total nitrogen data records at all of the stations start after 1993. Therefore, the period of record used for total nitrogen trend analysis is 2000-2017. The data graphs appear to show potential trends in total nitrogen concentrations at some of the stations.

Total nitrogen data may exhibit seasonal patterns, depending on the sources. Figure B.12 shows box plots of total nitrogen by month. These plots suggest that total nitrogen exhibits seasonal patterns at some stations. For example, at station WHI0011 (South Sylamore Cr) dissolved total nitrogen appears to usually be lower during the period July through September, than during other parts of the year.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.10. Total nitrogen measurements from all of the stations are not normally distributed. Because the data sets are not normally distributed, a non-parametric statistical trend test is used.

Table B.10. Normality test results for total nitrogen data from long term stations for the period 2000-2017.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.968	0.00	1.59	<0.01	Not normal
WHI0029	0.192	0.00	59.9	<0.01	Not normal
WHI0046	0.924	0.00	2.72	<0.01	Not normal
WHI0065	0.909	0.00	4.65	<0.01	Not normal
07060500	0.869	0.00	1.44	<0.01	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in total nitrogen concentrations for the period 2000-2017. The USGS program for the Kendall family of tests was used to run the statistical test. The program was set up to use 12 seasons, i.e., each month is considered a separate season. The program input and output are included as Attachment 4. The test results are summarized in Table B.11.

Table B.11. Results of Seasonal Mann-Kendall test of total nitrogen data for 2000-2017, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	1.0	0.0	1.0	No
WHI0029	White R	86	1.01	0.58	No
WHI0046	White R	38	0.43	0.76	No
WHI0065	Hicks Cr	-257	-3.12	0.03	Yes, decreasing
07060500	White R	87	2.59	0.05	Yes, increasing

A statistically significant trend is evident in the total nitrogen data from the USGS White River station at Calico Rock (07060500), and at the ADEQ station on Hicks Creek (WHI0065). The data from the Calico Rock White River station (07060500) exhibit an increasing trend over time, with a 95% confidence. The data from the Hicks Creek station (WHI0065) exhibit a decreasing trend over time, with a 97% confidence.

As with dissolved inorganic nitrogen, total nitrogen can be affected flow. Graphs of total nitrogen concentration versus flow at the three stations being analyzed with daily flow measurements are shown in Figure B.13. The graphs in Figure B.13 appear to show relationships between total nitrogen concentrations and flow at the upstream White River stations, Norfork and Calico Rock. There doesn't appear to be much relationship at the White River station at Oil Trough.

For stations associated with daily flow data, WRTDS trend analysis can be applied. This analysis was applied using an R software package prepared by the USGS. Figure B.14 shows WRTDS estimates of annual average total nitrogen flux (or export). The graphs in Figure B.14 show that flow-normalized estimated mean annual total nitrogen flux has not changed much during the period 2000-2017. This increasing trend identified at the White River at Calico Rock (07060500) by the Mann-Kendall analysis is confirmed by the WRTDS results, but the WRTDS results suggest that total nitrogen concentrations are increasing slowly.

The EGRET R software package calculates a flux bias statistic that characterizes bias in the WRTDS estimates of flux. Table B.12 lists the flux bias statistics associated with the

WRTDS analyses of total nitrogen data. Flux bias statistic value between -0.1 and 0.1 indicate that the bias associated with WRTDS estimates of annual mean flux is likely less than 10% (Hirsch and De Cicco 2015).

Table B.12. Flux bias statistics associated with WRTDS estimates of mean annual inorganic nitrogen flux.

Station ID	Stream	Flux Bias Statistic
WHI0029	White R	0.0223
WHI0046	White R	-0.00592
07060500	White R	0.0103

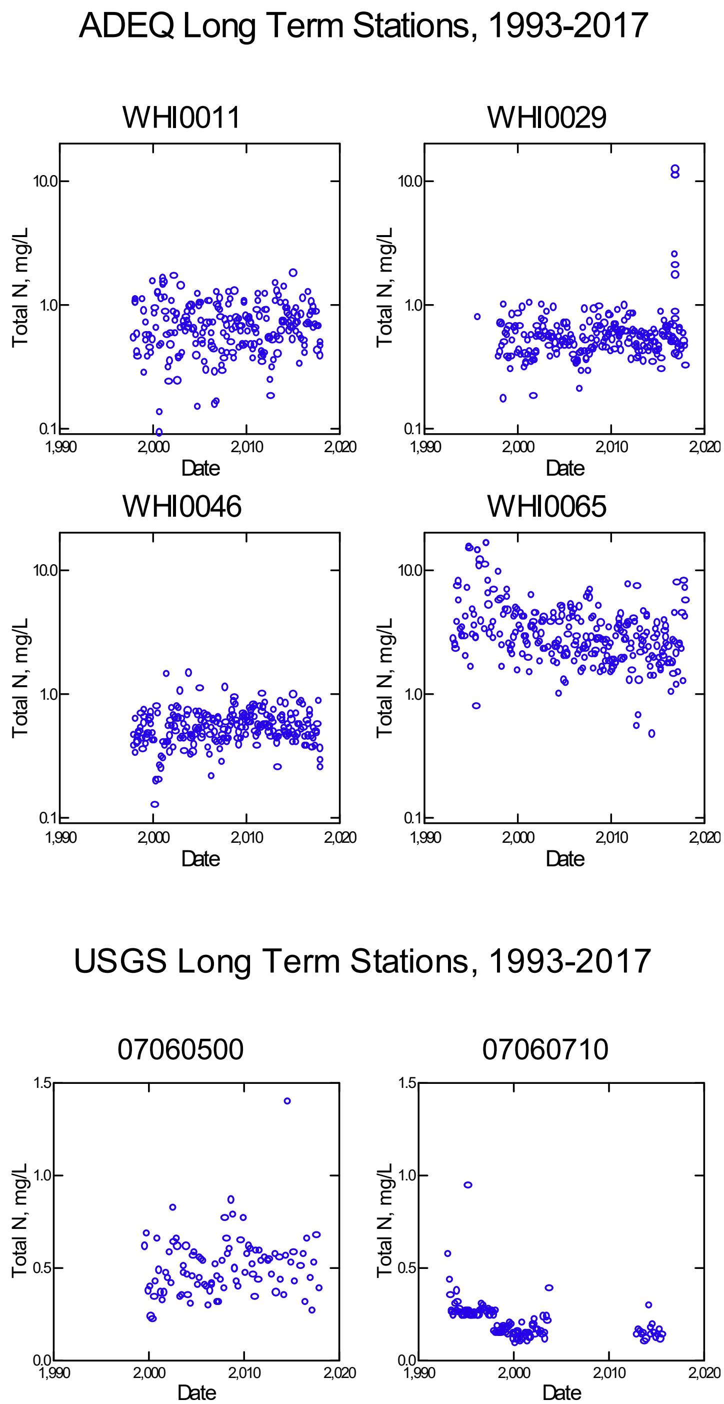


Figure B.11. Total nitrogen concentrations from 1993-2017 at long term water quality stations.

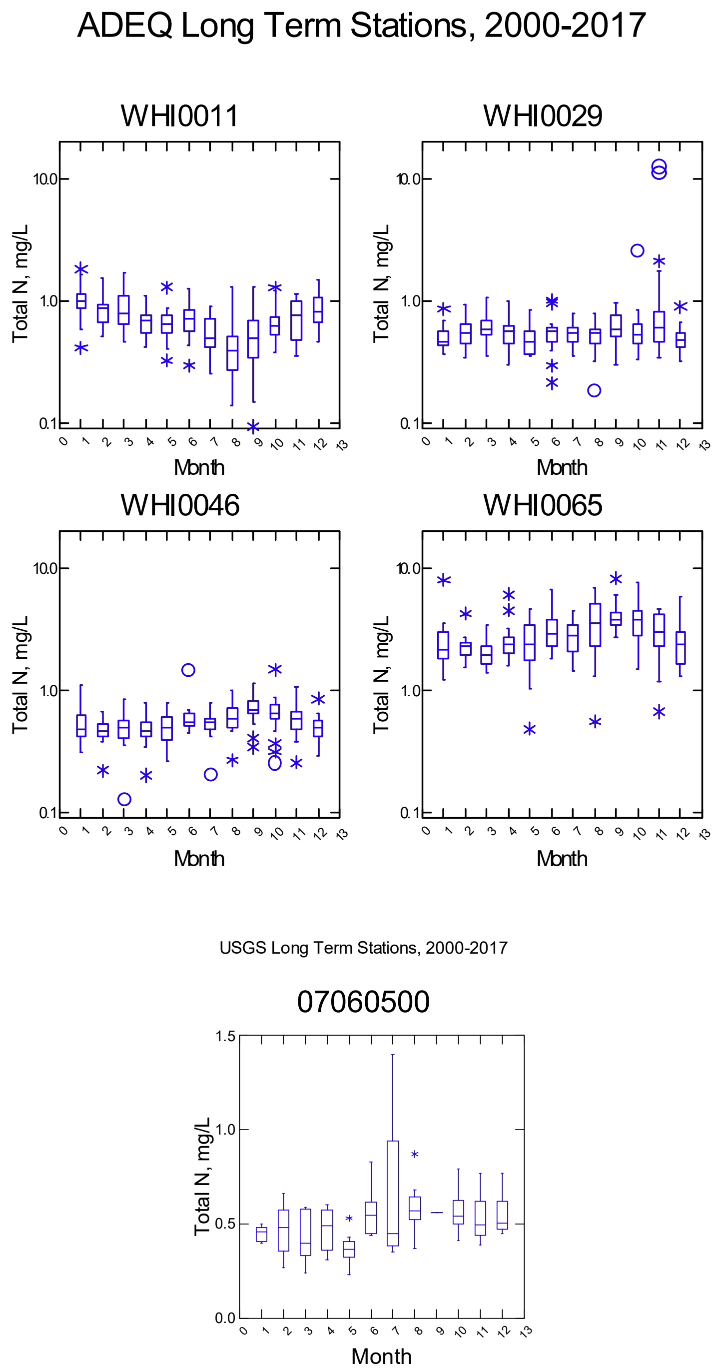


Figure B.12. Total nitrogen from some long-term stations show seasonal patterns in data from 2000-2017.

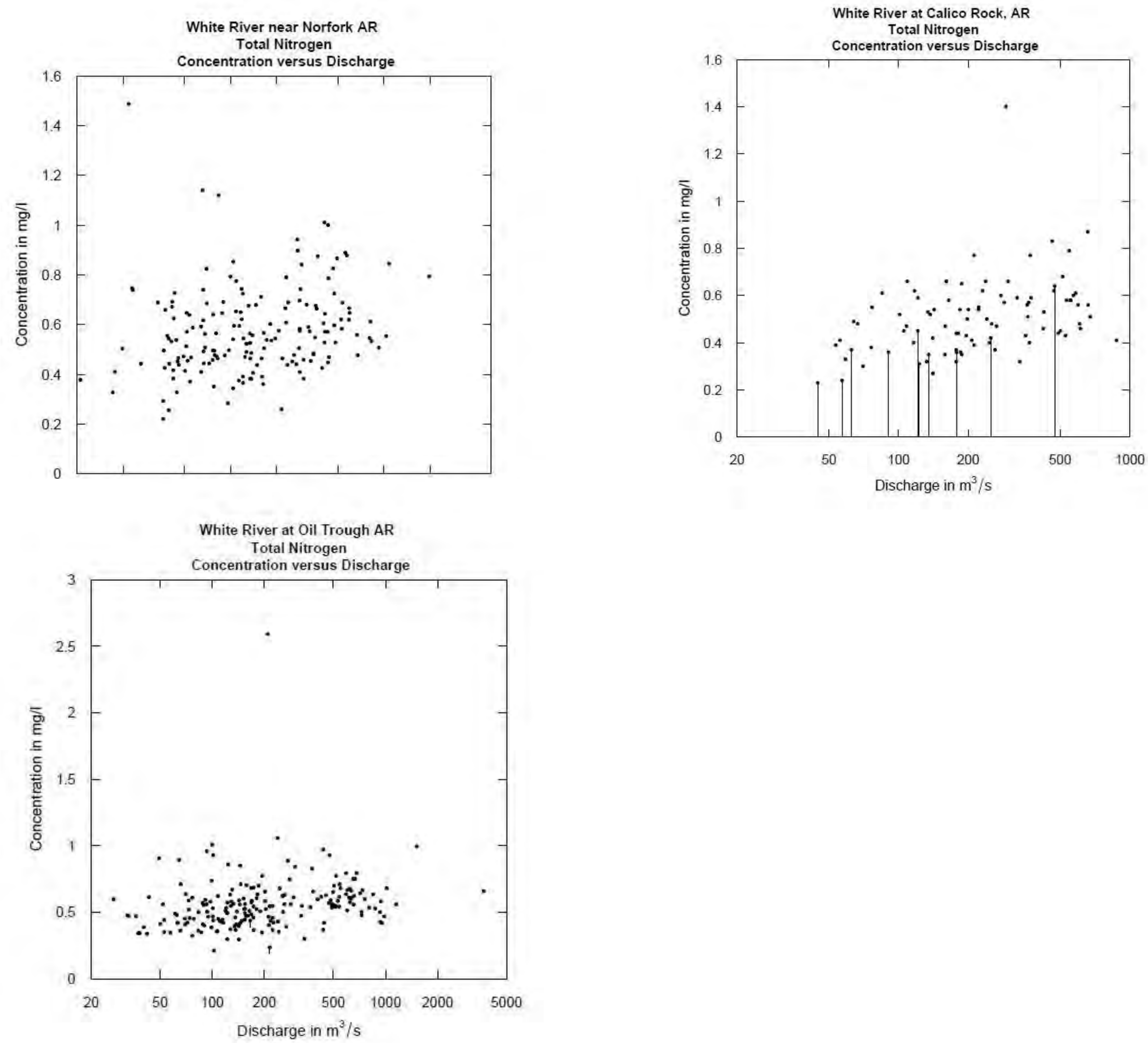
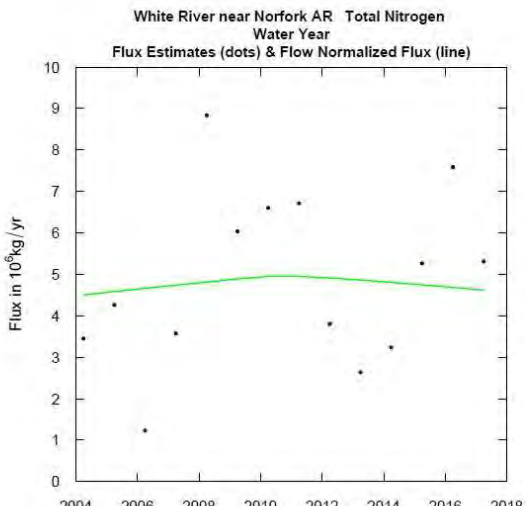
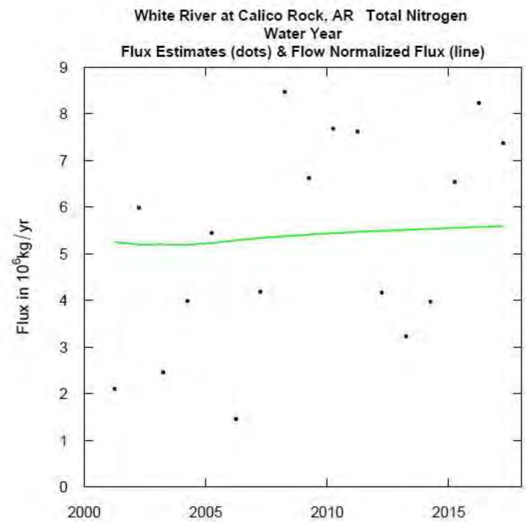


Figure B.13. Total nitrogen concentrations versus flow at long term stations associated with flow gages.





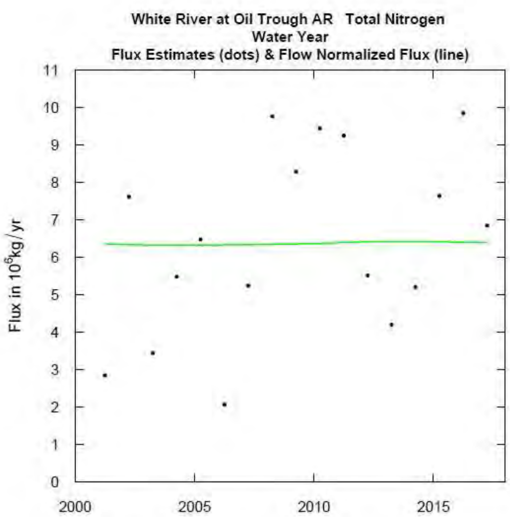


Figure B.14. WRTBS estimates of annual average total nitrogen flux at long term stations associated with flow gages.

B.5. Total Phosphorus

Figure B.15 shows graphs of the available total phosphorus data for the period 1993-2017 for the selected water quality stations (all figures referenced in this subsection are located at end of this subsection). The total phosphorus data from the USGS stations is heavily censored, with around two-thirds of the data reported as less than detection; 65 of the 96 measurements at station 07060500, and 118 of the 186 measurements at station 07060710. In addition, the detection limits for total phosphorus have varied over time. Similarly, at ADEQ station WHI0046, 96 of the 291 measurements are reported as less than detection, and it appears that there was a change in the detection limit during the period 2004-2012. This makes the total phosphorus data from these stations unsuitable for trend analysis. Therefore, only total phosphorus data from three of the ADEQ monitoring stations, WHI0011, WHI0029, and WHI0065, are evaluated for trends. Total phosphorus data from these stations appear to exhibit changes over time.

Total phosphorus data may exhibit seasonal patterns, depending on the sources. Figure 16 shows box plots of total phosphorus by month. These plots suggest that total phosphorus exhibits seasonal patterns at some stations. For example, at station WHI0065 (Hicks Creek) total phosphorus appears to usually be higher during the period August through October, than during other parts of the year.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.13. Total phosphorus measurements from all of the stations are not normally distributed. Because the data sets are not normally distributed, a non-parametric statistical trend test is used.

Table B.13. Normality test results for total phosphorus data from long term stations for the period 1993-2017.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
WHI0011	0.663	0.00	21.18	<0.01	Not normal
WHI0029	0.167	0.00	71.07	<0.01	Not normal
WHI0065	0.894	0.00	9.67	<0.01	Not normal

The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in total phosphorus concentrations for the period 1993-2017. The USGS program for the Kendall family of tests was used to run the statistical test. The program was set up to use 12 seasons, i.e., each month is considered a separate season. The program input and output are included as Attachment 5. The test results are summarized in Table B.14. No trends are indicated by this test.

Table B.14. Results of Seasonal Mann-Kendall test of total phosphorus data for 1993-2017, assuming 12 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
WHI0011	S. Sylamore Cr	-92	-0.69	0.65	No
WHI0029	White R	-196	-1.42	0.32	No
WHI0065	Hicks Cr	-1	0.00	1.0	No

Total phosphorus can also be affected flow. Only one of the stations being analyzed for trends has daily flow measurements available nearby, WHI0029, White River at Oil Trough. Figure 17 shows a graph of total phosphorus data from this station versus flow. There is no readily apparent relationship between total phosphorus and flow at this station.

The WRTDS trend analysis (Hirsch, Moyer and Archfield 2010) was applied to the total phosphorus data from station WHI0029. Figure 18 shows WRTDS estimates of annual average total phosphorus flux (or export) for this station. The WRTDS results suggest that total phosphorus flux at this station has been declining since sometime between 2005 and 2010. However, the current total phosphorus flux appears greater than at the beginning of the analysis period.

The EGRET R software package calculates a flux bias statistic that characterizes bias in the WRTDS estimates of flux. Table B.15 lists the flux bias statistics associated with the WRTDS analyses of total nitrogen data. Flux bias statistic value between -0.1 and 0.1 indicate that the bias associated with WRTDS estimates of annual mean flux is likely less than 10% (Hirsch and De Cicco 2015).

Table B.15. Flux bias statistics associated with WRTDS estimates of mean annual inorganic nitrogen flux.

Station ID	Stream	Flux Bias Statistic
WHI0046	White R	0.0232

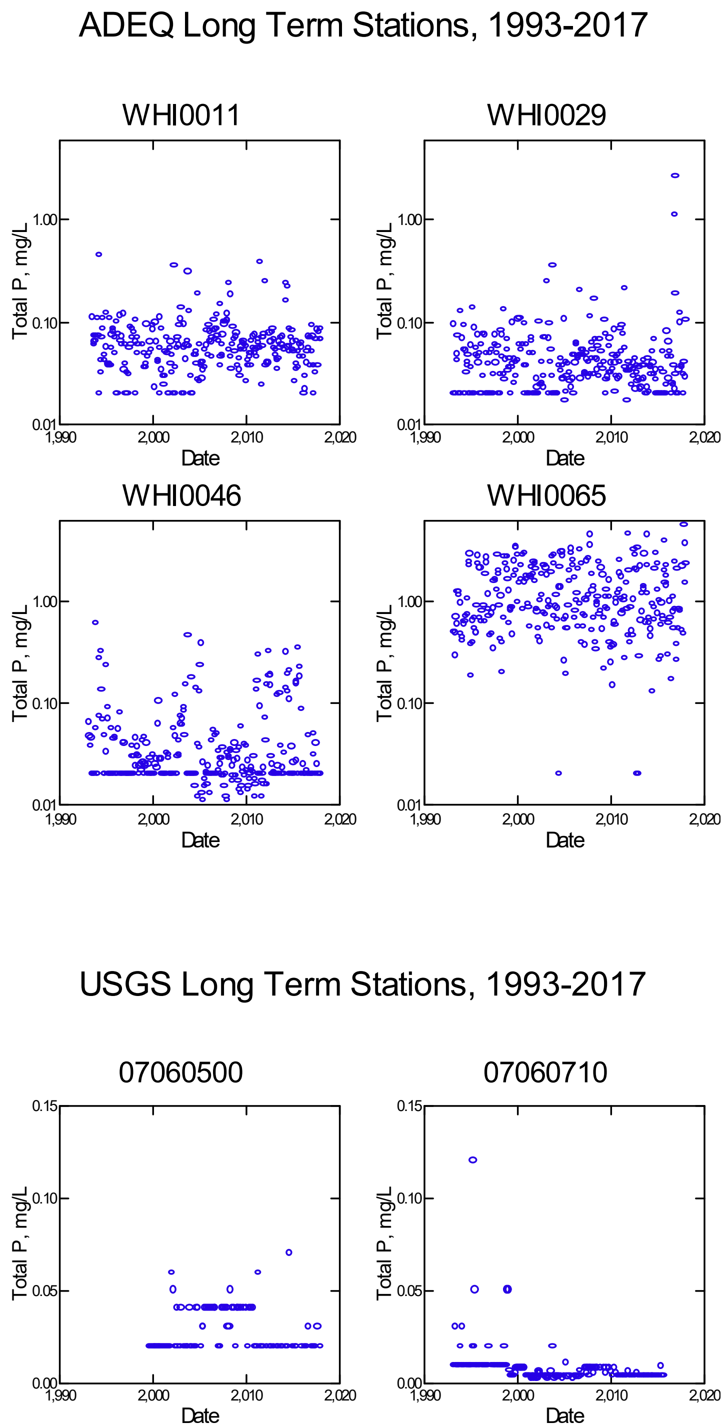


Figure B.15. Total phosphorus concentrations from 1993-2017 at long term water quality stations.

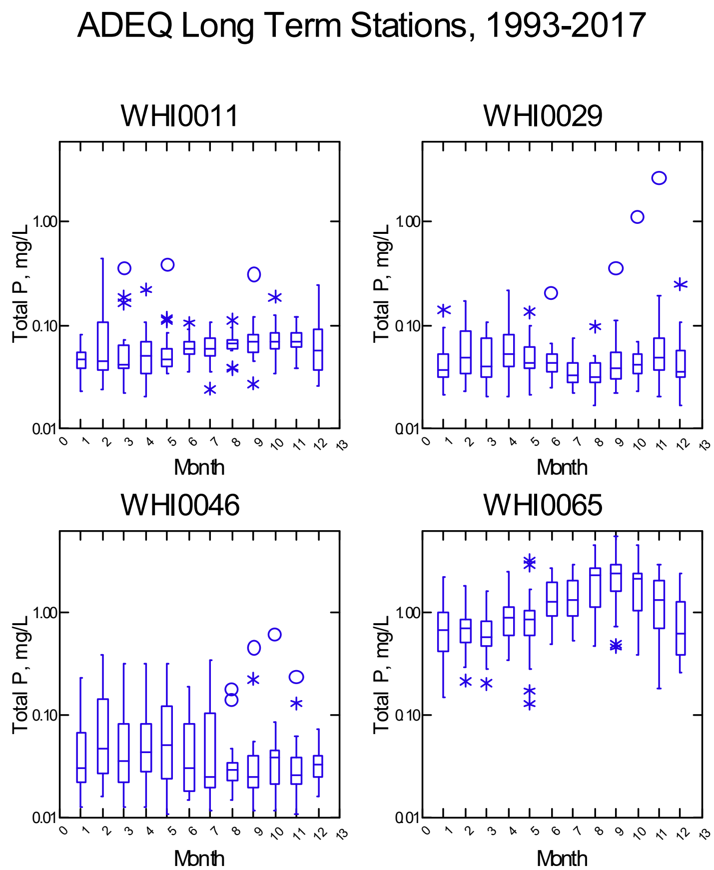


Figure B.16. Total phosphorus from some long-term stations show seasonal patterns in data from 1993-2017.

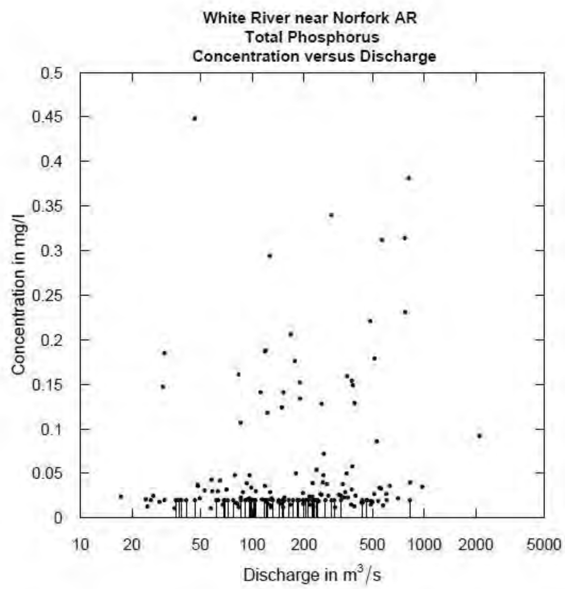


Figure B.17. Total phosphorus concentrations versus flow at White River near Norfork (WHI0046).

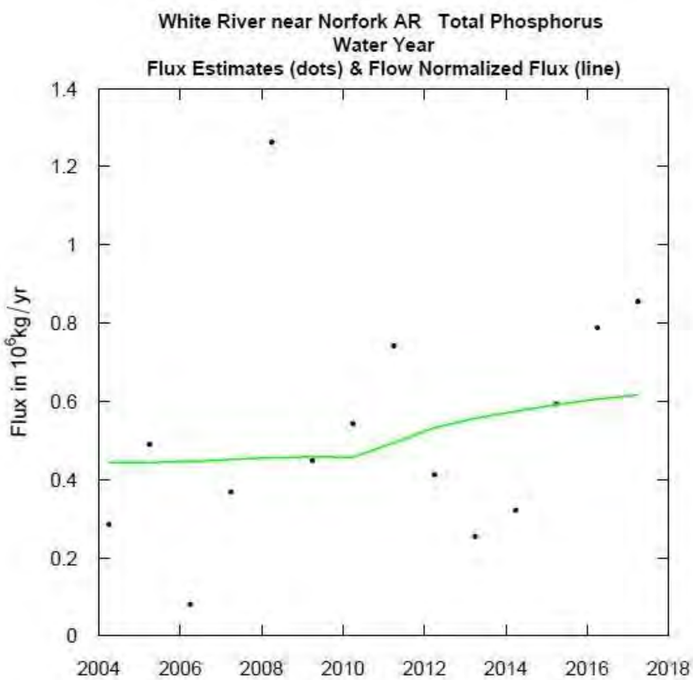


Figure B.18. WRTDS estimates of annual average total phosphorus flux at White River near Norfork long term station (WHI0046).

B.6. Fecal Coliforms

Figure B.19 shows graphs of the available fecal coliform data for the long-term water quality stations for the period 1993-2017. Note that this is USGS parameter code 31625. The only water quality station with fecal coliform measurements from the entire period 1993-2017 is the USGS station on the White River at Calico Rock (07060500). The fecal coliform data record for the USGS station on the North Sylamore Creek (07060710) ends in 2012. The fecal coliform data records for the ADEQ stations end in 1999. Only the fecal coliform data from USGS station 07060500 (White River at Calico Rock) is suitable for trend analysis.

Fecal coliform data may exhibit seasonal patterns. Figure B.20 shows a box plot of fecal coliform measurements from USGS station 07060500 by month. This plot appears to show a seasonal pattern in the data that may need to be accounted for in trend analysis.

The data were tested for normal distribution using the Shapiro-Wilk and Anderson-Darling statistics. These statistics are given in Table B.16. The fecal coliform measurements from station 07060500 are not normally distributed, so non-parametric trend analysis is used.

Table B.16. Normality test results for fecal coliform data from White River at Calico Rock (07060500) for the period 1993-2017.

Station	Shapiro-Wilk Statistic	Shapiro-Wilk p-value	Anderson-Darling Statistic	Anderson-Darling p-value	Data distribution
07060500	0.631	0.00	13.17	<0.01	Not normal

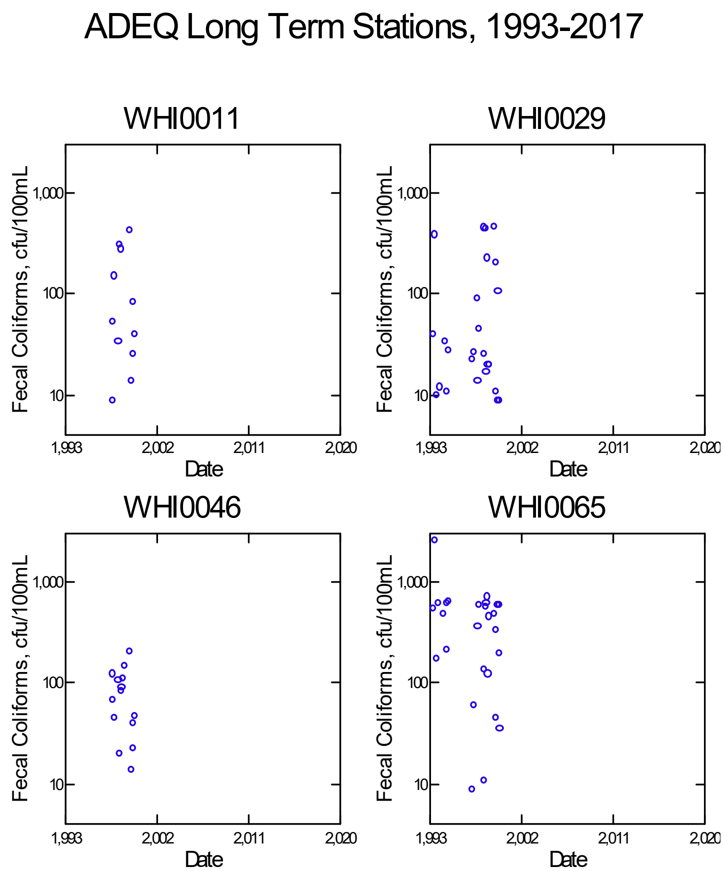
The Seasonal Mann-Kendall non-parametric statistical test is used to evaluate trends in fecal coliform measurements for the period 1993-2017. The USGS program for the Kendall family of tests was used to run the statistical test. In the data record, fecal coliform measurements were collected 7 to 4 times a year. Therefore, the program was set up with four seasons. Each season included data from three months. Based on the box plot in Figure B.20, data from different months were grouped into seasons as follows; June-August, September-November, December-February, and March-May. The program input and output are included as Attachment 6. The test results are summarized in Table B.17. No trends are indicated by this test.

Table B.17. Results of Seasonal Mann-Kendall test of fecal coliform data for 1993-2017, assuming 4 seasons.

Station	Stream	S statistic	Z statistic	P value	Statistical trend?
07060500	White River	48	0.627	0.55	No
07060500 (2000-2017)	White River	-41	-0.895	0.35	No

Fecal coliforms can be related to flow. Figure B.21 shows a graph of fecal coliform data from this station versus flow. It appears that there may be a relationship between flow and fecal coliform levels.

The WRTDS trend analysis was also applied to these data. Figure B.22 shows WRTDS estimates of annual fecal coliform levels for this station. The WRTDS results indicate that fecal coliform levels in the White River at Calico Rock have been declining since sometime after 2000. We re-evaluated the fecal coliform data from 2000-2017 using the Seasonal Mann-Kendal test (see Table B.17). The declining trend shown during this period in the WRTDS results did not give a statistically significant result to the Mann-Kendall test.



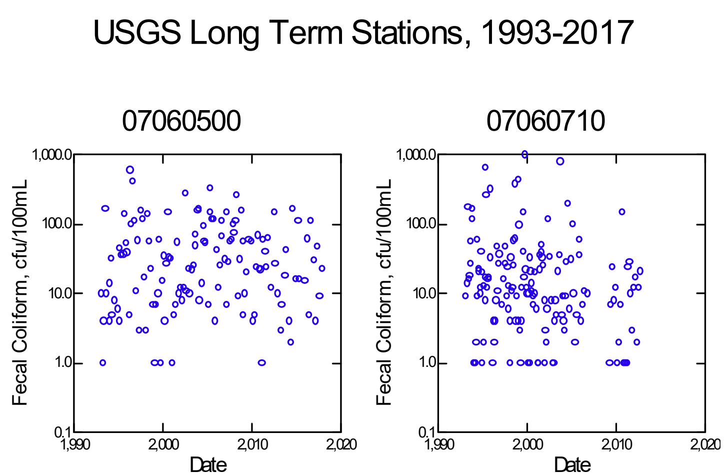


Figure B.19. Fecal coliform concentrations from 1993-2017 at long term water quality stations.

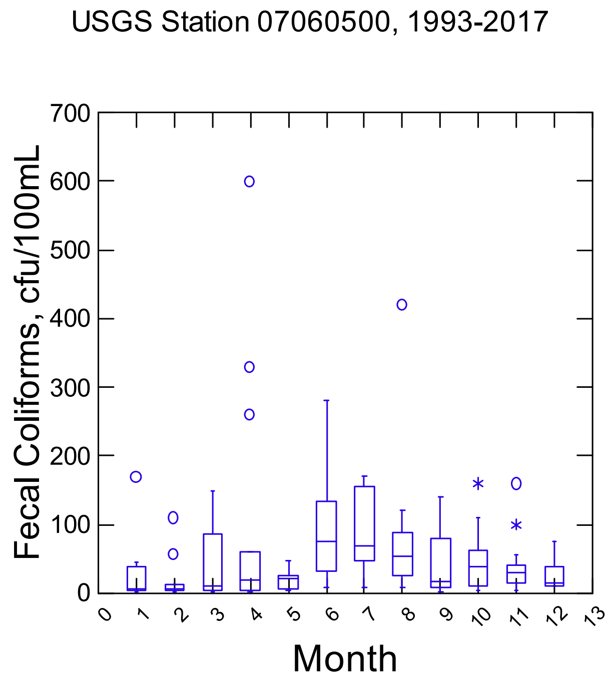


Figure B.20. Fecal coliform data from USGS station 07060500, White River at Calico Rock, 1993-2017, show seasonal pattern.

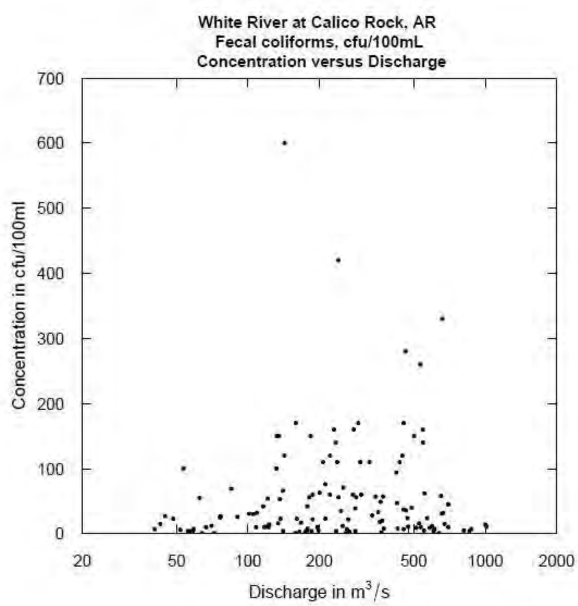


Figure B.21. 1993-3017 fecal coliform concentrations versus flow at White River at Calico Rock (07060500).

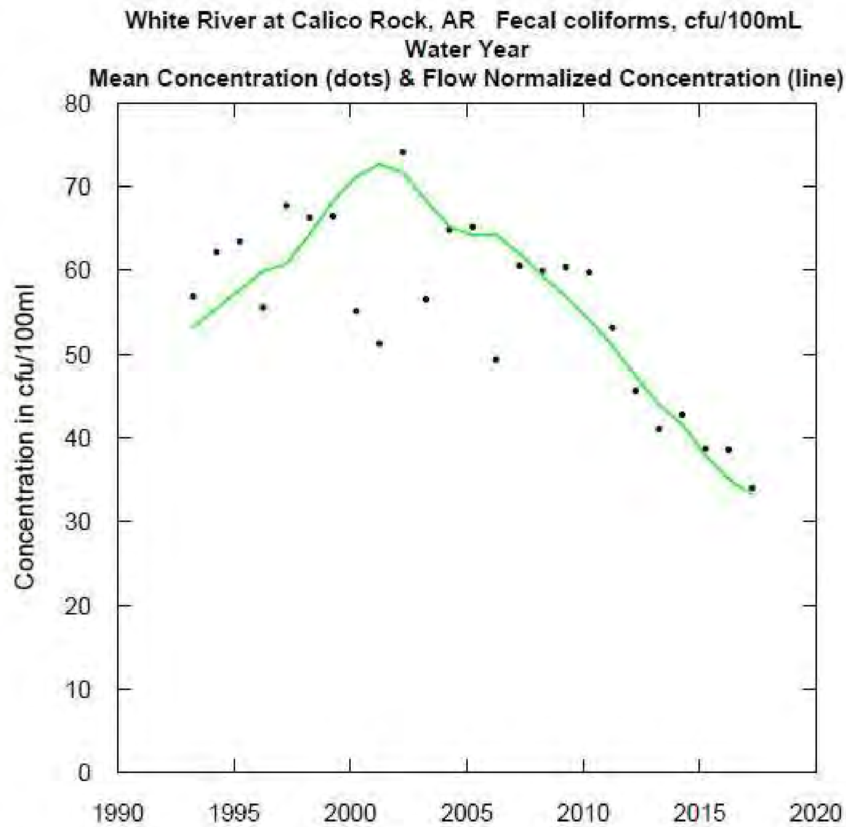


Figure B.22. WRTDS estimates of annual average fecal coliform concentration at White River at Calico Rock (07060500).

B.7. REFERENCES

Helsel, Dennis R, David K Mueller, and James R Slack. 2006. Computer Program for the Kendall Family of Trend Tests. Scientific Investigations Report 2005-5275, US Geological Survey. Accessed 2018. https://pubs.usgs.gov/sir/2005/5275/.

Hirsch, Robert M, and Laura A De Cicco. 2015. User Guide to Exploration and Graphics for RivEr Trends (EGRET) and dataRetrieval: R Packages for Hydrologic Data. Techniques and Methods 4-A10, USGS.

Hirsch, Robert, Douglas Moyer, and Stacey Archfield. 2010. "Weighted regressions on time, discharge, and season (WRTDS), with an application to Chesapeake Bay River inputs." Journal of the Americal Water Resources Association 46 (5): 857-880.

ATTACHMENT 1

Dissolved Oxygen Seasonal Mann-Kendall Input and Output

2 0 DO WHI0011 1993-2017
1993 5 9.1
1993 7 6.8
1993 8 7.3
1993 9 7.9
1993 10 9.4
1993 11 11.8
1993 12 11.1
1994 1 10.8
1994 2 10.4
1994 3 11.1
1994 5 10
1994 6 12
1994 8 6.4
1994 10 8.2
1995 3 11.1
1995 4 9.4
1995 5 9.1
1995 6 9.4
1995 7 7.8
1995 8 8.2
1995 9 7
1995 10 7.4
1995 11 9.1
1996 2 12.8
1996 3 10.9
1996 4 11.2
1996 5 8.1
1996 7 7.7
1996 8 8.5
1996 9 8.3
1996 10 9.1
1996 11 11.6
1996 12 12.1
1997 2 10.4
1997 3 10.2
1997 4 11.8
1997 8 10.7
1997 10 9.5
1998 1 13.3
1998 3 12.03
1998 4 6.65
1998 5 10.6
1998 10 11
1998 12 12
1999 1 12
1999 2 11.8
1999 3 11
1999 4 7.88
1999 5 11.8
1999 7 9.5
1999 8 4.9
1999 9 7.7

1999 10 6.2
1999 11 10.8
2000 1 11.56
2000 2 7.88
2000 3 8.21
2000 4 7.1
2000 5 6.6
2000 6 9.12
2000 8 7.75
2000 8 6.91
2000 9 6.38
2000 10 6.27
2000 11 8.91
2000 12 10.48
2001 2 7.65
2001 3 8.94
2001 4 6.79
2001 5 6.72
2001 6 5.09
2001 7 5.13
2001 8 6.57
2001 9 6.42
2001 10 5.91
2001 11 6.07
2001 12 7.84
2002 1 8.45
2002 2 7.99
2002 3 7.02
2002 4 7.46
2002 5 7.37
2002 6 5.81
2002 7 5.42
2002 8 4.39
2002 10 6.56
2002 12 9.68
2003 3 13.5
2003 4 11.3
2003 4 7.78
2003 5 9.49
2003 6 7.24
2003 7 6.04
2003 8 8.33
2003 9 9.21
2003 10 8.74
2003 11 8.84
2003 12 9.62
2004 1 12.2
2004 2 9.35
2004 6 7.72
2004 7 10.2
2004 8 8.25
2004 9 9.58
2004 10 8.16
2004 11 10.4

2004 12 11.5
2005 1 12.3
2005 2 12.1
2005 3 13.8
2005 4 11.1
2005 5 12
2005 5 9.96
2005 7 8.98
2005 8 8.81
2005 9 7.63
2005 10 8.92
2005 11 9.4
2005 12 12
2006 1 13.8
2006 3 11.7
2006 4 15.1
2006 5 9.91
2006 6 12.8
2006 7 8.41
2006 8 7.86
2006 9 9.93
2006 10 10.2
2006 11 9.91
2006 12 11.8
2007 1 14.1
2007 2 12.5
2007 3 11.7
2007 4 11.8
2007 5 9.89
2007 6 9.91
2007 7 7.96
2007 8 6.15
2007 9 9.91
2007 10 9.14
2007 11 12
2007 12 12
2008 1 10.9
2008 2 11.8
2008 3 9.98
2008 4 9.89
2008 5 9.89
2008 6 7.44
2008 7 7.76
2008 8 7.09
2008 9 8.66
2008 10 8.61
2008 11 12.1
2008 12 12.3
2009 1 13.2
2009 2 13.6
2009 3 9.95
2009 4 12.1
2009 5 10.5
2009 6 8.83

2009 8 7.36
2009 9 9.12
2009 10 10.3
2009 11 10.9
2009 12 12
2010 1 14.2
2010 2 14.8
2010 3 11.6
2010 4 11
2010 5 11.1
2010 6 9.94
2010 7 9.17
2010 8 8.4
2010 9 7.46
2010 10 8
2010 11 8.92
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2011 1 13.6
2011 2 15.1
2011 3 12.8
2011 4 9.46
2011 5 9.92
2011 6 8.28
2011 7 7.65
2011 8 8.77
2011 9 9.26
2011 10 9.47
2011 11 11.1
2011 12 10.7
2012 1 12
2012 2 11.9
2012 3 10.3
2012 4 8.33
2012 5 6.52
2012 6 8.73
2012 7 8.38
2012 8 7.53
2012 9 7.41
2012 10 9.96
2012 11 8.72
2012 12 8.05
2013 1 12.8
2013 2 14
2013 3 12.1
2013 4 11.7
2013 5 11.7
2013 6 9.85
2013 7 9.08
2013 8 7.47
2013 9 7.78
2013 12 10.4
2014 1 13.3
2014 2 13
2014 3 11.4

2014 4 9.48
2014 5 10.1
2014 6 7.6
2014 7 7.99
2014 8 10.1
2014 9 6.07
2014 10 6.94
2014 11 8.67
2014 12 8.27
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2015 3 11.6
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2015 8 7.42
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2015 10 7.59
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2016 3 9.3
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2016 5 9.04
2016 6 7.62
2016 7 7.67
2016 8 7.73
2016 9 6.8
2016 10 9.22
2016 11 10.3
2016 12 11.2
2017 1 11.9
2017 2 11
2017 3 9.8
2017 4 8.19
2017 5 9.61
2017 6 9.37
2017 7 7.24
2017 8 7.78
2017 9 7.43
2017 10 8.88
2017 11 9.83
2017 12 8.22

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: O WHI0011 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.050
S = 129.
z = 1.086
p = 0.2774
p = 0.5946 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 9.259 + 0.1625E-01 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0	DO WHI0011 2004-2017
2004 1 12.2
2004 2 9.35
2004 6 7.72
2004 7 10.2
2004 8 8.25
2004 9 9.58
2004 10 8.16
2004 11 10.4
2004 12 11.5
2005 1 12.3
2005 2 12.1
2005 3 13.8
2005 4 11.1
2005 5 12
2005 5 9.96
2005 7 8.98
2005 8 8.81
2005 9 7.63
2005 10 8.92
2005 11 9.4
2005 12 12
2006 1 13.8
2006 3 11.7
2006 4 15.1
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2006 6 12.8
2006 7 8.41
2006 8 7.86
2006 9 9.93
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2006 11 9.91
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2007 2 12.5
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2007 5 9.89
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2007 7 7.96
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2007 9 9.91
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2008 1 10.9
2008 2 11.8
2008 3 9.98
2008 4 9.89
2008 5 9.89
2008 6 7.44
2008 7 7.76
2008 8 7.09

2008 9 8.66
2008 10 8.61
2008 11 12.1
2008 12 12.3
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2009 5 10.5
2009 6 8.83
2009 8 7.36
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2012 7 8.38
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2017 2 11
2017 3 9.8
2017 4 8.19
2017 5 9.61
2017 6 9.37
2017 7 7.24
2017 8 7.78
2017 9 7.43
2017 10 8.88
2017 11 9.83
2017 12 8.22

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO WHI0011 2004-2017

The record is 15 complete water years with 12 seasons per year
beginning in water year 2004.

The tau correlation coefficient is -0.249
S = -243.
z = -4.143
p = 0.0000
p = 0.0196 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 10.64 + -0.9778E-01 * Time

where Time = Year (as a decimal) - 2003.75
(beginning of first water year)

2 0 DO WHI0029 1993-2017
1993 1 10.3
1993 2 11.1
1993 3 11.1
1993 4 8.9
1993 5 10
1993 6 9.1
1993 7 8.3
1993 8 9.2
1993 9 10.2
1993 10 10.2
1993 11 11.8
1993 12 11
1994 1 10.6
1994 2 10.3
1994 3 10.1
1994 5 10.4
1994 6 10
1994 8 8.5
1994 10 10.2
1995 3 9.9
1995 4 9.5
1995 5 7.3
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1998 9 8.9

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2007 9 7.55
2007 10 8.51
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2008 2 11.9
2008 3 11.8
2008 4 10.2
2008 5 10.1
2008 6 10.5
2008 7 10.1
2008 8 10.4
2008 9 7.84
2008 10 10
2008 11 10.4

2008 12 12.8
2009 1 13.1
2009 2 14.9
2009 3 10.4
2009 4 12.7
2009 5 10.4
2009 6 9.47
2009 8 9.56
2009 9 8.47
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2010 1 13
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2010 4 10
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2010 7 10.4
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2011 11 10.1
2011 12 11.5
2012 1 9.77
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2012 4 10.9
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2012 6 8.98
2012 7 8.1
2012 8 8.53
2012 9 8.89
2012 10 9.07
2012 11 10.7
2012 12 10.8
2013 1 12
2013 2 12.7
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2013 4 10.4
2013 5 9.92
2013 6 10.3

2013 7 9.02
2013 8 9.9
2013 9 9.66
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2014 7 9.8
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2014 9 9.97
2014 10 10.3
2014 11 12.3
2014 12 11.8
2015 1 11.8
2015 2 9.76
2015 3 10.1
2015 4 9.25
2015 5 11
2015 6 8.02
2015 7 8.53
2015 8 10.3
2015 9 9.91
2015 10 9.24
2015 11 9.27
2015 11 10.6
2015 12 9.74
2016 1 12.2
2016 2 11.9
2016 3 7.98
2016 4 9.88
2016 5 9.21
2016 6 9.07
2016 7 9.25
2016 8 4.05
2016 9 8.48
2016 11 8.62
2016 11 8.12
2016 11 7.69
2016 12 12.7
2017 1 13.1
2017 2 12.1
2017 3 11.5
2017 4 10
2017 5 8.62
2017 6 8.48
2017 7 6.94
2017 8 9.21
2017 9 8.88
2017 10 8.88

2017 11 8.28
2017 12 11.9

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO WHI0029 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.128
S = 354.
z = 2.872
p = 0.0041
p = 0.1623 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 9.499 + 0.3087E-01 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO WHI0029 2004-2017
2004 1 11.5
2004 2 9.26
2004 6 9.16
2004 7 8.84
2004 8 9.49
2004 9 8.67
2004 10 9.4
2004 12 11.1
2005 1 12.6
2005 2 11.2
2005 3 10.8
2005 4 10.6
2005 5 9.11
2005 7 8.53
2005 8 8.89
2005 9 8.03
2005 10 9.8
2005 11 10.6
2005 12 11.8
2006 1 14.6
2006 3 11
2006 4 9.53
2006 5 10.2
2006 6 9.4
2006 7 9.86
2006 8 9.67
2006 9 9.75
2006 10 9.95
2006 11 10.8
2006 12 9.95
2007 1 13.2
2007 2 9.9
2007 3 12.3
2007 4 12.5
2007 5 9.81
2007 6 9.46
2007 7 10.2
2007 8 10.1
2007 9 7.55
2007 10 8.51
2007 11 10.8
2007 12 12.8
2008 1 14
2008 2 11.9
2008 3 11.8
2008 4 10.2
2008 5 10.1
2008 6 10.5
2008 7 10.1
2008 8 10.4
2008 9 7.84
2008 10 10

2008 11 10.4
2008 12 12.8
2009 1 13.1
2009 2 14.9
2009 3 10.4
2009 4 12.7
2009 5 10.4
2009 6 9.47
2009 8 9.56
2009 9 8.47
2009 10 8.7
2009 11 9.66
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2011 3 9.85
2011 4 8.53
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2011 8 10.4
2011 9 9.46
2011 11 10.1
2011 12 11.5
2012 1 9.77
2012 2 11.9
2012 3 9.78
2012 4 10.9
2012 5 8.78
2012 6 8.98
2012 7 8.1
2012 8 8.53
2012 9 8.89
2012 10 9.07
2012 11 10.7
2012 12 10.8
2013 1 12
2013 2 12.7
2013 3 11.2
2013 4 10.4
2013 5 9.92

2013 6 10.3
2013 7 9.02
2013 8 9.9
2013 9 9.66
2013 10 10.5
2013 11 11.2
2013 12 11.8
2014 1 12.6
2014 2 11.7
2014 3 11.9
2014 4 10.8
2014 5 10.6
2014 6 10
2014 7 9.8
2014 8 9.55
2014 9 9.97
2014 10 10.3
2014 11 12.3
2014 12 11.8
2015 1 11.8
2015 2 9.76
2015 3 10.1
2015 4 9.25
2015 5 11
2015 6 8.02
2015 7 8.53
2015 8 10.3
2015 9 9.91
2015 10 9.24
2015 11 9.27
2015 11 10.6
2015 12 9.74
2016 1 12.2
2016 2 11.9
2016 3 7.98
2016 4 9.88
2016 5 9.21
2016 6 9.07
2016 7 9.25
2016 8 4.05
2016 9 8.48
2016 11 8.62
2016 11 8.12
2016 11 7.69
2016 12 12.7
2017 1 13.1
2017 2 12.1
2017 3 11.5
2017 4 10
2017 5 8.62
2017 6 8.48
2017 7 6.94
2017 8 9.21
2017 9 8.88

2017 10 8.88
2017 11 8.28
2017 12 11.9

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO WHI0029 2004-2017

The record is 15 complete water years with 12 seasons per year
beginning in water year 2004.

The tau correlation coefficient is -0.057
S =   -55.
z = -0.934
p = 0.3504
p = 0.5510 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   10.20   + -0.2000E-01 * Time

where Time = Year (as a decimal) - 2003.75
(beginning of first water year)

2 0 DO WHI0046 1993-2017
1993 1 11.5
1993 2 11.4
1993 3 10.5
1993 4 9.7
1993 5 9.4
1993 6 8.5
1993 7 8.3
1993 8 9.1
1993 9 10
1993 10 8.2
1993 11 9.8
1993 12 11.7
1994 1 10
1994 2 11.9
1994 3 10.2
1994 4 9.5
1994 5 9.6
1994 6 9.7
1994 7 8.6
1994 8 8.9
1994 9 8.1
1994 10 8.3
1994 11 10.3
1995 1 11.1
1995 2 10
1995 3 11.2
1995 4 10.6
1995 5 9
1995 6 8.1
1995 7 9.5
1995 8 8
1995 9 7.6
1995 10 7.9
1995 10 8.3
1995 11 11.5
1996 1 12.3
1996 2 9.8
1996 3 12.2
1996 4 12
1996 5 11.1
1996 6 10.8
1996 7 11.6
1996 8 11.5
1996 9 10.8
1996 10 12.1
1996 11 8.5
1996 12 8.6
1997 1 14.8
1997 2 11.6
1997 3 10.9
1997 4 10.6
1997 5 10.8

1997 6 9.9
1997 8 12.6
1997 9 9.2
1997 10 9.1
1997 11 10.2
1997 12 12.2
1998 1 10.2
1998 2 11.1
1998 4 10.8
1998 5 10.8
1998 6 11
1998 7 10.3
1998 8 8.4
1998 9 7.7
1998 10 9.6
1998 11 11
1998 12 10.7
1999 1 13
1999 2 11.4
1999 3 10.4
1999 4 10.2
1999 5 9.9
1999 7 11.06
1999 8 7.75
1999 9 8.03
1999 10 9.1
1999 11 9
1999 11 12.6
2000 1 12.1
2000 2 12.9
2000 3 10.1
2000 4 8.9
2000 5 8.8
2000 6 7.8
2000 7 8.7
2000 8 9.5
2000 9 9.82
2000 10 10.7
2000 10 11.6
2000 12 10.2
2001 1 12.2
2001 2 11.7
2001 3 12.5
2001 4 10.1
2001 5 9.5
2001 6 9.1
2001 7 11.8
2001 8 10.6
2001 9 9.5
2001 10 10.6
2001 11 10.2
2001 12 9.9
2002 1 12.1
2002 2 11.5

2002 3 12.9
2002 4 11
2002 5 10.8
2002 6 9.9
2002 7 9.3
2002 8 7.8
2002 10 7.76
2002 11 11.5
2002 12 10.1
2003 1 11.5
2003 2 12.4
2003 3 12.6
2003 4 10.4
2003 5 10.6
2003 6 10.9
2003 7 11
2003 8 10
2003 9 9.48
2003 10 9.69
2003 12 10.9
2004 1 13.7
2004 2 12.9
2004 3 11.2
2004 4 11.5
2004 5 10.6
2004 6 10.9
2004 7 8.85
2004 8 9.39
2004 9 9.47
2004 10 9.18
2004 11 8.72
2004 12 8.46
2005 1 9.87
2005 2 12.1
2005 3 12.2
2005 4 11
2005 5 10
2005 6 8.05
2005 7 9.2
2005 8 10.3
2005 9 9.74
2005 10 9.67
2005 11 11.9
2005 12 12.9
2006 1 13.1
2006 2 13
2006 2 13.7
2006 4 9.52
2006 5 8.58
2006 6 10.4
2006 7 9.68
2006 8 10.5
2006 9 10.6
2006 10 8.98

2006 11 10.7
2006 12 11
2007 1 13.5
2007 2 13
2007 3 11.1
2007 4 11.7
2007 5 10
2007 6 10.9
2007 7 10.9
2007 8 10.2
2007 9 11.6
2007 10 9.84
2007 11 12.9
2007 12 11.5
2008 1 9.87
2008 2 14.8
2008 3 11.6
2008 4 10.1
2008 5 10.7
2008 6 9.86
2008 7 8.77
2008 8 9.76
2008 9 7.22
2008 10 6.75
2008 11 7.63
2008 12 9.63
2009 1 12.2
2009 2 11.9
2009 3 10.7
2009 4 9.85
2009 5 9.49
2009 6 9.26
2009 7 8.53
2009 8 8.28
2009 9 9.45
2009 10 10.1
2009 11 10.5
2009 12 7.48
2010 1 10.3
2010 2 11.6
2010 3 11.6
2010 4 10.2
2010 5 10.1
2010 6 11.9
2010 7 8.33
2010 8 8.23
2010 9 9.92
2010 10 10
2010 11 9.58
2010 12 9.58
2011 1 13.1
2011 2 13.2
2011 3 13.4
2011 4 10.5

2011 5 9.94
2011 6 8.56
2011 7 9.81
2011 8 10.3
2011 9 8.9
2011 10 10.6
2011 11 12
2011 12 10.3
2012 1 10.4
2012 2 12.1
2012 3 9.97
2012 4 8.87
2012 5 9.54
2012 6 11.3
2012 7 9.25
2012 8 9.77
2012 9 10.2
2012 10 12.3
2012 11 10.4
2012 12 9.66
2013 1 12.8
2013 2 11.5
2013 3 13.1
2013 4 10.4
2013 5 13.4
2013 6 12.7
2013 7 11.2
2013 8 8.31
2013 9 9.08
2013 12 11.5
2014 1 10.6
2014 2 13.7
2014 3 11.6
2014 4 10.2
2014 5 12.1
2014 6 10.9
2014 7 10.9
2014 8 12.7
2014 9 10.2
2014 10 9.11
2014 11 11.6
2014 12 8.73
2015 1 11.9
2015 2 12.6
2015 3 11
2015 4 11.9
2015 5 13.1
2015 6 11.3
2015 7 11.2
2015 8 9.89
2015 9 8.89
2015 10 7.5
2015 11 9.03
2016 1 11.1

2016 2 10.9
2016 3 10.9
2016 4 11.2
2016 5 8.89
2016 6 10
2016 7 9.26
2016 8 7.48
2016 9 7.83
2016 10 9.83
2016 11 10.5
2016 12 11.5
2017 1 11.9
2017 2 13.9
2017 3 10.4
2017 4 9.77
2017 5 10.1
2017 6 9.25
2017 7 8.93
2017 8 8.34
2017 9 7.9
2017 10 8.82
2017 11 10.1
2017 12 8.36

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO WHI0046 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.065
S =   215.
z =   1.537
p = 0.1244
p = 0.3358 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   10.11   +   0.1429E-01 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO WHI0065 1993-2017
1993 1 13.2
1993 2 12.3
1993 3 12.4
1993 4 10.2
1993 5 7.9
1993 6 7.1
1993 7 5.8
1993 8 9.3
1993 9 9.8
1993 10 9
1993 11 10.5
1993 12 11.2
1994 1 12.3
1994 2 11.8
1994 3 10.8
1994 4 10.3
1994 5 10.4
1994 6 9
1994 7 7.2
1994 8 8.2
1994 9 8.3
1994 10 7.7
1994 11 9.2
1995 1 13.8
1995 2 11.2
1995 3 10.6
1995 4 12.4
1995 5 10.9
1995 6 8.7
1995 7 8.7
1995 8 7.2
1995 9 7.3
1995 10 8.3
1995 10 10.2
1995 11 12.2
1996 1 12.2
1996 2 14.4
1996 3 12.8
1996 4 12.7
1996 5 10.1
1996 6 11.4
1996 7 7.5
1996 8 8.3
1996 9 10.8
1996 10 9.8
1996 11 10.1
1996 12 10.5
1997 1 15.3
1997 2 12.5
1997 3 12.1
1997 4 12.4
1997 5 9.8

1997 6 10.9
1997 8 8.8
1997 9 7.4
1997 10 7.4
1997 11 12.2
1997 12 12.9
1998 1 11.8
1998 2 11.4
1998 4 12.9
1998 5 9.9
1998 6 10.4
1998 7 9.8
1998 8 8.3
1998 9 6.9
1998 10 10.4
1998 11 12.2
1998 12 12.2
1999 1 12
1999 2 11.7
1999 3 11.7
1999 4 10.2
1999 5 9.6
1999 7 7.08
1999 8 7.04
1999 9 7.42
1999 10 7.8
1999 11 9.2
1999 11 12.2
2000 1 13.1
2000 2 13.3
2000 3 11.2
2000 4 12.8
2000 5 11.5
2000 6 10.8
2000 7 9.2
2000 8 9.5
2000 9 10.05
2000 10 10.2
2000 10 10.8
2000 12 12.1
2001 1 12.9
2001 2 12.4
2001 3 13.2
2001 4 13.3
2001 5 10.2
2001 6 8.9
2001 7 10.4
2001 8 11.2
2001 9 9.1
2001 10 10.1
2001 11 12.8
2001 12 11.1
2002 1 13.5
2002 2 12.4

2002 3 13.1
2002 4 13.3
2002 5 10.2
2002 6 9.1
2002 7 9.7
2002 8 6.7
2002 10 9.16
2002 11 11.2
2002 12 13.2
2003 1 13.5
2003 2 13.2
2003 3 13.7
2003 4 12.3
2003 5 10.9
2003 6 10.9
2003 7 6.96
2003 8 9.9
2003 9 9.52
2003 10 9.06
2003 12 11.6
2004 1 13.1
2004 2 14
2004 3 13
2004 4 13.1
2004 5 11.5
2004 6 10.3
2004 7 8.59
2004 8 9.69
2004 9 8.67
2004 10 9.62
2004 11 9.48
2004 12 10.3
2005 1 10.7
2005 2 13.1
2005 3 13
2005 4 12.9
2005 5 11.2
2005 6 8.5
2005 7 8.46
2005 8 9.96
2005 9 9.36
2005 10 9.98
2005 11 11.4
2005 12 14.1
2006 1 12.9
2006 2 14
2006 2 13.3
2006 4 13.4
2006 5 9.38
2006 6 9.38
2006 7 7.41
2006 8 8.14
2006 9 9.12
2006 10 9.02

2006 11 12.5
2006 12 14.4
2007 1 13.9
2007 2 13.7
2007 3 13.9
2007 4 12.5
2007 5 14.9
2007 6 11.5
2007 7 8.94
2007 8 8.14
2007 9 10.1
2007 10 9.23
2007 11 14
2007 12 11.5
2008 1 10.7
2008 2 15.3
2008 3 14.9
2008 4 10.8
2008 5 9.9
2008 6 8.72
2008 7 7.32
2008 8 9.05
2008 9 7.73
2008 10 8.89
2008 11 11.3
2008 12 10.2
2009 1 15
2009 2 12.8
2009 3 12.7
2009 4 8.65
2009 5 10.6
2009 6 8.44
2009 7 8.42
2009 8 7.68
2009 9 8.98
2009 10 10.4
2009 11 11.2
2009 12 10.2
2010 1 13.8
2010 2 16.1
2010 3 14
2010 4 11
2010 5 8.91
2010 6 8.86
2010 7 7.66
2010 8 7.89
2010 9 9.55
2010 10 11
2010 11 10.9
2010 12 16.6
2011 1 14.8
2011 2 15.5
2011 3 14.6
2011 4 11.2

2011 5 9.17
2011 6 9.37
2011 7 8.47
2011 8 10.2
2011 9 10.8
2011 10 11.3
2011 11 12.6
2011 12 11.7
2012 1 12.2
2012 2 16.2
2012 3 11
2012 4 8.24
2012 5 8.02
2012 6 9.54
2012 7 8.88
2012 8 8.24
2012 9 8.58
2012 10 11.1
2012 11 8.56
2012 12 9.37
2013 1 16.5
2013 2 15.4
2013 3 16.2
2013 4 12.5
2013 5 13.3
2013 6 11.4
2013 7 9.63
2013 8 7.86
2013 9 9.61
2013 12 15.2
2014 1 15
2014 2 18.6
2014 3 12
2014 4 13.1
2014 5 12.3
2014 6 8.64
2014 7 8.03
2014 8 10.6
2014 9 8.21
2014 10 8.59
2014 11 11.2
2014 12 7.78
2015 1 13.9
2015 2 17.1
2015 3 12.3
2015 4 12.1
2015 5 11.8
2015 6 10.3
2015 7 9.27
2015 8 8.95
2015 8 8.15
2015 9 7.56
2015 10 9.84
2015 11 9.98

2015 11 9.07
2016 1 12.3
2016 2 12.2
2016 3 11
2016 4 12.8
2016 5 8.93
2016 6 8
2016 7 8.56
2016 8 7.71
2016 9 8.4
2016 10 10.8
2016 11 9.91
2016 12 14.1
2017 1 16
2017 2 13.7
2017 3 12.9
2017 4 9.15
2017 5 10.1
2017 6 9.06
2017 7 8.28
2017 8 6.85
2017 9 8.02
2017 10 10.2
2017 11 12.3
2017 12 7.21

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO WHI0065 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.105
S = 346.
z = 2.476
p = 0.0133
p = 0.0944 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 10.19 + 0.3174E-01 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO 07060500 1993-2017
1993 1. 12.00
1993 3. 13.20
1993 4. 9.100
1993 6. 8.100
1993 8. 8.200
1993 11 9.900
1993 12 10.20
1994 3. 10.60
1994 4. 11.00
1994 6. 8.700
1994 6. 8.700
1994 6. 8.600
1994 6. 8.600
1994 6. 8.700
1994 6. 8.700
1994 6. 8.800
1994 6. 8.800
1994 6. 8.900
1994 6. 8.900
1994 7. 9.800
1994 8. 10.90
1994 10 4.500
1995 1. 10.20
1995 2. 11.70
1995 4. 10.90
1995 7. 9.900
1995 9. 8.500
1995 9. 7.700
1995 9. 7.500
1995 9. 7.400
1995 9. 7.400
1995 9. 7.600
1995 9. 7.500
1995 9. 7.700
1995 9. 7.700
1995 9. 7.800
1995 9. 7.600
1995 10 8.600
1995 11 10.70
1996 2. 9.300
1996 2. 11.30
1996 2. 10.80
1996 2. 10.60
1996 2. 10.60
1996 2. 10.50
1996 2. 10.60
1996 2. 10.60
1996 2. 10.70
1996 2. 10.70
1996 2. 10.70
1996 4. 9.900
1996 6. 8.600

1996 8. 9.800
1996 10 7.300
1996 12 9.500
1997 2. 11.20
1997 4. 11.00
1997 7. 8.400
1997 8. 7.900
1997 11 11.20
1998 1. 14.20
1998 3. 12.40
1998 4. 9.300
1998 6. 9.200
1998 6. 9.200
1998 6. 9.000
1998 6. 9.100
1998 6. 9.100
1998 6. 9.000
1998 6. 9.100
1998 6. 9.200
1998 6. 9.200
1998 6. 9.300
1998 6. 9.300
1998 8. 8.800
1998 11 10.50
1999 1. 11.80
1999 3. 10.70
1999 6. 10.40
1999 7. 8.200
1999 9. 7.600
1999 11 8.200
2000 1. 10.00
2000 3. 10.60
2000 5. 7.900
2000 7. 9.300
2000 8. 8.300
2000 11 12.10
2001 1. 12.90
2001 3. 11.60
2001 5. 10.10
2001 8. 9.400
2001 10 9.300
2001 12 10.00
2002 2. 13.30
2002 4. 11.60
2002 6. 8.100
2002 8. 9.900
2002 8. 9.700
2002 8. 9.400
2002 8. 9.400
2002 8. 9.400
2002 8. 9.400
2002 8. 9.300
2002 8. 9.300
2002 8. 9.300

2002 8. 9.200
2002 8. 9.300
2002 10 10.20
2002 12 6.500
2003 3. 11.90
2003 3. 11.30
2003 3. 11.50
2003 3. 11.60
2003 3. 11.50
2003 3. 11.70
2003 3. 11.50
2003 3. 11.50
2003 3. 11.30
2003 3. 11.20
2003 3. 11.10
2003 5. 8.800
2003 7. 9.800
2003 7. 10.00
2003 7. 9.800
2003 7. 9.800
2003 7. 9.800
2003 7. 9.700
2003 7. 9.700
2003 7. 9.700
2003 7. 9.700
2003 7. 9.600
2003 7. 9.700
2003 8. 9.300
2003 11 8.300
2003 11 8.200
2003 11 8.200
2003 11 8.100
2003 11 8.100
2003 11 8.200
2003 11 8.200
2003 11 8.100
2003 11 8.100
2003 11 8.000
2003 11 8.200
2004 1. 11.90
2004 1. 11.90
2004 1. 13.20
2004 1. 11.80
2004 1. 11.70
2004 1. 11.60
2004 1. 11.50
2004 1. 11.60
2004 1. 11.60
2004 1. 11.70
2004 1. 11.80
2004 2. 10.60
2004 4. 9.600
2004 6. 8.800
2004 8. 9.200

2004 8. 9.200
2004 8. 9.400
2004 8. 9.300
2004 8. 9.200
2004 8. 9.200
2004 8. 9.300
2004 8. 9.200
2004 8. 9.200
2004 8. 9.200
2004 8. 9.200
2004 10 9.000
2004 10 9.100
2004 10 10.00
2004 10 9.100
2004 10 8.900
2004 10 9.700
2004 10 9.300
2004 10 9.200
2004 10 9.400
2004 10 9.300
2004 10 9.300
2005 1. 8.800
2005 3. 11.00
2005 4. 10.00
2005 6. 9.600
2005 8. 9.300
2005 10 9.500
2006 1. 10.80
2006 3. 10.00
2006 5. 9.000
2006 7. 8.700
2006 8. 8.400
2006 11 8.100
2007 1. 11.20
2007 3. 11.60
2007 4. 11.40
2007 6. 10.70
2007 8. 8.100
2007 11 10.60
2007 12 10.30
2008 2. 10.00
2008 4. 10.80
2008 6. 10.20
2008 8. 8.600
2008 10 7.700
2008 12 10.20
2009 1. 11.90
2009 3. 12.30
2009 4. 11.00
2009 8. 8.300
2009 11 10.30
2010 2. 11.80
2010 3. 11.20
2010 3. 11.40

2010 3. 11.40
2010 3. 11.20
2010 3. 10.90
2010 3. 10.20
2010 3. 9.300
2010 3. 11.60
2010 6. 10.40
2010 8. 8.500
2010 10 9.200
2010 12 10.30
2011 2. 12.10
2011 4. 9.500
2011 6. 10.50
2011 8. 8.900
2011 10 8.500
2012 2. 12.10
2012 6. 10.00
2012 8. 9.700
2012 11 10.20
2013 3. 12.60
2013 5. 9.900
2013 9. 9.800
2013 11 10.20
2014 3. 11.40
2014 4. 12.10
2014 7. 10.60
2014 11 9.800
2015 3. 11.50
2015 5. 12.30
2015 12 9.200
2016 3. 11.10
2016 5. 11.70
2016 8. 8.600
2016 11 10.60
2017 2. 9.500
2017 5. 9.500
2017 8. 8.100
2017 11 9.700

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO 07060500 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.034
S = 28.
z = 0.489
p = 0.6247
p = 0.6481 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 9.916 + 0.6458E-02 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO 07060710 1993-2017
1993 1. 10.90
1993 3. 12.20
1993 4. 9.000
1993 5. 9.100
1993 6. 6.800
1993 7. 8.800
1993 8. 6.600
1993 9. 6.800
1993 12 11.50
1993 12 12.00
1994 1. 12.20
1994 2. 12.90
1994 3. 10.80
1994 4. 9.900
1994 5. 10.70
1994 6. 10.00
1994 6. 7.300
1994 6. 7.500
1994 6. 8.500
1994 6. 9.000
1994 6. 9.000
1994 6. 8.700
1994 6. 8.900
1994 6. 9.000
1994 6. 9.000
1994 6. 9.000
1994 7. 8.000
1994 8. 5.200
1994 8. 5.600
1994 10 8.900
1994 11 9.600
1994 12 10.80
1995 1. 8.000
1995 2. 12.80
1995 3. 10.20
1995 3. 8.700
1995 4. 8.800
1995 5. 7.200
1995 6. 8.100
1995 7. 8.200
1995 8. 12.30
1995 10 9.600
1995 11 9.300
1996 1. 12.00
1996 1. 12.10
1996 1. 10.20
1996 1. 7.800
1996 1. 6.900
1996 1. 11.40
1996 1. 12.10
1996 1. 12.60
1996 1. 12.80

1996	1.	12.90
1996	1.	13.30
1996	2.	11.30
1996	4.	11.30
1996	5.	9.800
1996	6.	6.700
1996	7.	6.800
1996	8.	7.400
1996	9.	10.50
1996	10	7.400
1997	2.	10.20
1997	4.	10.20
1997	5.	10.50
1997	6.	9.100
1997	7.	8.900
1997	8.	9.700
1997	9.	9.000
1997	10	10.40
1997	11	8.200
1997	12	12.60
1998	1.	10.80
1998	2.	14.00
1998	3.	11.50
1998	4.	9.800
1998	5.	8.500
1998	6.	7.200
1998	7.	7.300
1998	8.	6.900
1998	9.	10.40
1998	10	10.40
1998	11	11.00
1998	12	9.500
1999	1.	9.800
1999	2.	12.20
1999	3.	8.900
1999	4.	10.30
1999	5.	10.50
1999	6.	7.200
1999	7.	6.600
1999	8.	4.600
1999	9.	5.400
1999	10	8.300
1999	11	12.00
1999	12	12.20
2000	1.	10.20
2000	2.	10.10
2000	3.	11.20
2000	4.	10.50
2000	5.	7.300
2000	6.	9.600
2000	7.	8.400
2000	8.	9.500
2000	9.	5.900
2000	10	9.600

2000 11 10.30
2000 12 8.200
2001 2. 9.400
2001 3. 10.80
2001 4. 10.20
2001 5. 7.000
2001 6. 7.200
2001 7. 5.500
2001 8. 6.300
2001 9. 7.200
2001 11 10.20
2001 12 10.40
2002 1. 13.20
2002 2. 12.70
2002 3. 10.70
2002 5. 9.400
2002 7. 6.300
2002 9. 9.500
2002 11 11.20
2002 12 12.20
2003 1. 13.70
2003 2. 10.80
2003 3. 12.10
2003 5. 10.90
2003 7. 8.800
2003 9. 8.200
2003 11 9.200
2003 12 10.50
2004 1. 11.70
2004 2. 13.20
2004 3. 9.700
2004 3. 10.00
2004 5. 7.100
2004 7. 6.000
2004 8. 9.600
2004 11 11.90
2005 1. 9.500
2005 3. 11.80
2005 5. 11.70
2005 7. 6.900
2005 9. 9.200
2005 11 10.90
2006 1. 13.00
2006 3. 12.00
2006 5. 9.700
2006 6. 9.200
2006 7. 7.500
2006 9. 10.60
2007 2. 13.00
2007 3. 10.00
2007 5. 10.20
2007 5. 9.900
2007 6. 8.000
2007 7. 8.600

2007 8. 6.800
2007 9. 8.400
2007 10 9.100
2007 12 12.10
2008 1. 15.50
2008 2. 10.30
2008 3. 11.90
2008 5. 9.900
2008 6. 8.200
2008 9. 9.200
2009 3. 11.20
2009 4. 10.10
2009 6. 8.900
2009 8. 7.400
2009 11 10.70
2010 2. 12.70
2010 3. 10.40
2010 6. 10.10
2010 8. 10.50
2010 10 11.10
2010 12 12.80
2011 2. 12.90
2011 4. 10.80
2011 6. 9.800
2011 8. 10.10
2011 10 13.30
2011 12 11.60
2012 2. 12.90
2012 4. 10.80
2012 6. 11.30
2012 8. 6.100
2012 11 11.10
2013 1. 13.60
2013 3. 11.90
2013 5. 9.200
2013 7. 10.00
2013 9. 10.10
2013 11 14.00
2014 1. 15.20
2014 3. 11.40
2014 4. 11.60
2014 5. 10.60
2014 7. 10.70
2014 9. 8.400
2014 11 10.50
2015 1. 12.50
2015 3. 11.60
2015 5. 9.900
2015 7. 9.700
2015 8. 10.20
2015 10 9.400
2015 11 11.90
2015 12 12.30
2016 1. 12.60

2016	1.	13.40
2016	2.	12.40
2016	2.	11.60
2016	3.	11.60
2016	4.	11.40
2016	4.	9.800
2016	5.	9.900
2016	5.	10.20
2016	7.	9.400
2016	7.	7.400
2016	8.	9.000
2016	9.	8.300
2016	10	9.700
2016	10	10.20
2016	11	11.20
2016	11	11.60
2016	12	13.30
2017	3.	10.00
2017	3.	11.70
2017	4.	10.60
2017	5.	9.700
2017	5.	10.70
2017	6.	9.600
2017	6.	9.400
2017	7.	10.20
2017	8.	10.30
2017	9.	9.500
2017	10	9.800
2017	10	11.00
2017	11	10.40

ATTACHMENT 2

Dissolved Oxygen Saturation Seasonal Mann-Kendall Input and Output

2 0 DO saturation WHI0011 1993-2017
1993 5. 94.11
1993 7. 83.82
1993 8. 91.64
1993 9. 95.61
1993 10 99.24
1993 11 109.4
1993 12 96.01
1994 1. 100.1
1994 2. 89.95
1994 3. 105.3
1994 5. 112.1
1994 6. 145.2
1994 8. 77.45
1994 10 83.03
1995 5. 98.06
1995 6. 97.21
1995 7. 94.40
1995 8. 101.0
1995 9. 78.50
1995 10 76.53
1996 2. 110.7
1996 3. 94.28
1996 4. 106.2
1996 5. 92.62
1996 7. 93.19
1996 9. 93.07
1996 10 98.06
1996 11 107.6
1996 12 102.1
1997 2. 94.28
1997 3. 96.76
1997 4. 119.4
1997 8. 131.9
1997 10 96.20
1998 1. 117.8
1998 3. 98.37
1998 4. 66.62
1998 5. 114.6
1998 10 113.7
1998 12 106.2
1999 1. 103.7
1999 2. 104.5
1999 4. 75.25
1999 5. 130.5
1999 7. 119.2
1999 8. 59.30
1999 9. 88.04
1999 10 69.52
1999 11 109.3
2000 1. 92.87
2000 2. 74.75
2000 3. 76.15

2000 4. 73.42
2000 5. 75.47
2000 6. 104.2
2000 8. 93.79
2000 8. 86.74
2000 9. 71.54
2000 10 67.56
2000 11 88.31
2000 12 79.96
2001 2. 64.59
2001 3. 82.92
2001 4. 65.85
2001 5. 72.41
2001 6. 60.46
2001 7. 63.24
2001 8. 82.47
2001 9. 70.58
2001 10 59.84
2001 11 58.87
2001 12 71.07
2002 1. 66.17
2002 2. 69.11
2002 3. 65.11
2002 4. 80.38
2002 5. 77.81
2002 6. 69.01
2002 7. 66.81
2002 8. 53.13
2002 10 70.69
2002 12 89.79
2003 3. 119.5
2003 4. 114.4
2003 4. 82.14
2003 5. 102.2
2003 6. 84.39
2003 7. 73.10
2003 8. 98.95
2003 9. 111.4
2003 10 95.71
2003 11 97.19
2003 12 89.23
2004 1. 100.5
2004 2. 80.87
2004 6. 91.70
2004 7. 121.1
2004 8. 96.16
2004 9. 111.6
2004 10 87.93
2004 11 98.66
2004 12 104.2
2005 1. 106.3
2005 2. 114.7
2005 3. 128.0
2005 4. 110.0

2005 5. 124.1
2005 5. 113.8
2005 7. 110.7
2005 8. 110.5
2005 9. 89.95
2005 10 88.22
2005 11 85.81
2005 12 111.8
2006 1. 117.9
2006 3. 109.7
2006 4. 172.6
2006 5. 115.5
2006 6. 154.9
2006 7. 101.7
2006 8. 99.56
2006 9. 112.4
2006 10 105.4
2006 11 97.17
2006 12 110.6
2007 1. 117.6
2007 2. 102.9
2007 3. 115.9
2007 4. 115.7
2007 5. 108.7
2007 6. 113.3
2007 7. 92.78
2007 8. 77.20
2007 9. 115.5
2007 10 93.54
2007 11 120.2
2007 12 112.5
2008 1. 103.4
2008 2. 96.00
2008 3. 94.67
2008 4. 96.97
2008 5. 102.2
2008 6. 86.72
2008 7. 93.05
2008 8. 84.22
2008 9. 96.16
2008 10 96.55
2008 11 113.5
2008 12 105.1
2009 1. 110.0
2009 2. 119.0
2009 3. 100.7
2009 4. 114.7
2009 5. 107.4
2009 6. 102.9
2009 8. 91.56
2009 9. 96.29
2009 10 106.5
2009 11 103.4
2009 12 106.2

2010 1. 119.8
2010 2. 132.6
2010 3. 108.8
2010 4. 110.2
2010 5. 114.7
2010 6. 116.9
2010 7. 115.1
2010 8. 109.2
2010 9. 88.62
2010 10 84.64
2010 11 83.11
2010 12 99.25
2011 1. 117.0
2011 2. 125.9
2011 3. 117.1
2011 4. 93.36
2011 5. 92.43
2011 6. 97.62
2011 7. 89.34
2011 8. 109.3
2011 9. 107.9
2011 10 103.0
2011 11 114.5
2011 12 94.55
2012 1. 106.7
2012 2. 103.1
2012 3. 99.02
2012 4. 85.78
2012 5. 73.40
2012 6. 100.4
2012 7. 102.3
2012 8. 96.57
2012 9. 85.71
2012 10 104.5
2012 11 85.50
2012 12 79.96
2013 1. 108.0
2013 2. 123.1
2013 3. 107.9
2013 4. 110.5
2013 5. 117.4
2013 6. 104.8
2013 7. 110.9
2013 8. 84.92
2013 9. 89.82
2013 12 97.78
2014 1. 101.2
2014 2. 112.7
2014 3. 105.2
2014 4. 92.95
2014 5. 107.0
2014 6. 88.92
2014 7. 92.60
2014 8. 122.0

2014 9. 68.20
2014 10 74.63
2014 11 84.09
2014 12 77.75
2015 1. 99.51
2015 2. 101.3
2015 3. 114.7
2015 4. 99.46
2015 5. 115.0
2015 6. 109.4
2015 7. 126.8
2015 8. 91.63
2015 9. 72.19
2015 10 81.29
2015 11 82.33
2016 1. 96.41
2016 2. 99.76
2016 3. 90.00
2016 4. 100.7
2016 5. 92.71
2016 6. 91.54
2016 7. 94.03
2016 8. 87.19
2016 9. 80.17
2016 10 101.3
2016 11 96.62
2016 12 102.2
2017 1. 106.1
2017 2. 107.1
2017 3. 84.16
2017 4. 86.11
2017 5. 100.2
2017 6. 104.8
2017 7. 92.69
2017 8. 95.21
2017 9. 91.09
2017 10 88.02
2017 11 95.55
2017 12 80.77

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO saturation WHI0011 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.048
S = 121.
z = 1.049
p = 0.2941
p = 0.6128 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 95.99 + 0.1487 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO saturation WHI0011 2004-2017
2004 1. 100.5
2004 2. 80.87
2004 6. 91.70
2004 7. 121.1
2004 8. 96.16
2004 9. 111.6
2004 10 87.93
2004 11 98.66
2004 12 104.2
2005 1. 106.3
2005 2. 114.7
2005 3. 128.0
2005 4. 110.0
2005 5. 124.1
2005 5. 113.8
2005 7. 110.7
2005 8. 110.5
2005 9. 89.95
2005 10 88.22
2005 11 85.81
2005 12 111.8
2006 1. 117.9
2006 3. 109.7
2006 4. 172.6
2006 5. 115.5
2006 6. 154.9
2006 7. 101.7
2006 8. 99.56
2006 9. 112.4
2006 10 105.4
2006 11 97.17
2006 12 110.6
2007 1. 117.6
2007 2. 102.9
2007 3. 115.9
2007 4. 115.7
2007 5. 108.7
2007 6. 113.3
2007 7. 92.78
2007 8. 77.20
2007 9. 115.5
2007 10 93.54
2007 11 120.2
2007 12 112.5
2008 1. 103.4
2008 2. 96.00
2008 3. 94.67
2008 4. 96.97
2008 5. 102.2
2008 6. 86.72
2008 7. 93.05
2008 8. 84.22

2008 9. 96.16
2008 10 96.55
2008 11 113.5
2008 12 105.1
2009 1. 110.0
2009 2. 119.0
2009 3. 100.7
2009 4. 114.7
2009 5. 107.4
2009 6. 102.9
2009 8. 91.56
2009 9. 96.29
2009 10 106.5
2009 11 103.4
2009 12 106.2
2010 1. 119.8
2010 2. 132.6
2010 3. 108.8
2010 4. 110.2
2010 5. 114.7
2010 6. 116.9
2010 7. 115.1
2010 8. 109.2
2010 9. 88.62
2010 10 84.64
2010 11 83.11
2010 12 99.25
2011 1. 117.0
2011 2. 125.9
2011 3. 117.1
2011 4. 93.36
2011 5. 92.43
2011 6. 97.62
2011 7. 89.34
2011 8. 109.3
2011 9. 107.9
2011 10 103.0
2011 11 114.5
2011 12 94.55
2012 1. 106.7
2012 2. 103.1
2012 3. 99.02
2012 4. 85.78
2012 5. 73.40
2012 6. 100.4
2012 7. 102.3
2012 8. 96.57
2012 9. 85.71
2012 10 104.5
2012 11 85.50
2012 12 79.96
2013 1. 108.0
2013 2. 123.1
2013 3. 107.9

2013 4. 110.5
2013 5. 117.4
2013 6. 104.8
2013 7. 110.9
2013 8. 84.92
2013 9. 89.82
2013 12 97.78
2014 1. 101.2
2014 2. 112.7
2014 3. 105.2
2014 4. 92.95
2014 5. 107.0
2014 6. 88.92
2014 7. 92.60
2014 8. 122.0
2014 9. 68.20
2014 10 74.63
2014 11 84.09
2014 12 77.75
2015 1. 99.51
2015 2. 101.3
2015 3. 114.7
2015 4. 99.46
2015 5. 115.0
2015 6. 109.4
2015 7. 126.8
2015 8. 91.63
2015 9. 72.19
2015 10 81.29
2015 11 82.33
2016 1. 96.41
2016 2. 99.76
2016 3. 90.00
2016 4. 100.7
2016 5. 92.71
2016 6. 91.54
2016 7. 94.03
2016 8. 87.19
2016 9. 80.17
2016 10 101.3
2016 11 96.62
2016 12 102.2
2017 1. 106.1
2017 2. 107.1
2017 3. 84.16
2017 4. 86.11
2017 5. 100.2
2017 6. 104.8
2017 7. 92.69
2017 8. 95.21
2017 9. 91.09
2017 10 88.02
2017 11 95.55
2017 12 80.77

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO saturation WHI0011 2004-2017

The record is 15 complete water years with 12 seasons per year
beginning in water year 2004.

The tau correlation coefficient is -0.261
S =   -254.
z = -4.327
p = 0.0000
p = 0.0138 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   109.9   +   -1.144   * Time

where Time = Year (as a decimal) - 2003.75
(beginning of first water year)

2 0 DO saturation WHI0029 1993-2017
1993 1. 84.85
1993 2. 93.72
1993 3. 96.01
1993 4. 88.21
1993 5. 101.2
1993 6. 96.08
1993 7. 93.07
1993 8. 105.2
1993 9. 125.7
1993 10 103.2
1993 11 111.9
1993 12 97.43
1994 1. 91.68
1994 2. 91.23
1994 3. 97.96
1994 5. 112.0
1994 6. 107.7
1994 8. 93.45
1994 10 105.4
1995 5. 83.47
1995 6. 89.05
1995 7. 81.89
1995 8. 95.65
1995 9. 88.36
1995 10 101.1
1996 2. 103.6
1996 3. 102.4
1996 4. 103.4
1996 5. 96.44
1996 7. 94.41
1996 9. 111.9
1996 10 101.7
1996 11 96.10
1996 12 103.8
1997 2. 87.36
1997 3. 93.00
1997 4. 96.02
1997 7. 109.9
1997 8. 138.3
1997 9. 126.1
1997 10 107.0
1998 3. 84.43
1998 4. 96.76
1998 5. 105.5
1998 6. 95.02
1998 7. 127.0
1998 8. 112.5
1998 9. 101.7
1998 10 126.0
1998 11 90.66
1998 12 100.9
1999 1. 96.87

1999 4. 92.18
1999 5. 90.83
1999 6. 114.3
1999 7. 120.0
1999 8. 108.6
1999 9. 97.56
1999 11 98.24
2000 1. 102.5
2000 2. 76.81
2000 3. 78.07
2000 4. 90.59
2000 6. 97.38
2000 8. 88.35
2000 8. 85.88
2000 9. 91.25
2000 10 85.34
2000 11 95.35
2000 12 83.48
2001 2. 68.56
2001 3. 75.70
2001 4. 74.75
2001 5. 71.27
2001 6. 72.84
2001 7. 69.12
2001 8. 83.47
2001 9. 71.02
2001 10 75.55
2001 11 75.23
2001 12 69.80
2002 1. 67.91
2002 2. 71.88
2002 3. 70.77
2002 5. 72.73
2002 6. 64.81
2002 7. 74.01
2002 8. 71.58
2002 10 63.03
2002 12 102.7
2003 3. 111.6
2003 4. 111.3
2003 4. 100.0
2003 5. 83.99
2003 6. 101.2
2003 7. 95.59
2003 8. 103.1
2003 9. 99.97
2003 10 103.8
2003 11 97.98
2003 12 98.82
2004 1. 97.10
2004 2. 80.09
2004 6. 104.7
2004 7. 101.0
2004 8. 112.7

2004 9. 95.32
2004 10 99.24
2004 12 98.31
2005 1. 116.8
2005 2. 103.8
2005 3. 102.4
2005 4. 105.0
2005 5. 112.3
2005 7. 101.3
2005 8. 109.5
2005 9. 93.60
2005 10 97.34
2005 11 95.43
2005 12 101.8
2006 1. 126.8
2006 3. 105.5
2006 4. 111.0
2006 5. 122.0
2006 6. 114.8
2006 7. 120.4
2006 8. 114.8
2006 9. 112.5
2006 10 100.7
2006 11 105.8
2006 12 94.39
2007 1. 111.4
2007 2. 82.57
2007 3. 121.9
2007 4. 123.9
2007 5. 118.7
2007 6. 113.4
2007 7. 109.9
2007 8. 122.2
2007 9. 91.37
2007 10 85.26
2007 11 110.5
2007 12 117.3
2008 1. 115.3
2008 2. 96.82
2008 3. 109.4
2008 4. 101.1
2008 5. 102.2
2008 6. 110.8
2008 7. 108.8
2008 8. 109.8
2008 9. 90.51
2008 10 108.8
2008 11 103.0
2008 12 105.4
2009 1. 114.6
2009 2. 125.8
2009 3. 105.3
2009 4. 117.8
2009 5. 105.3

2009 6. 110.3
2009 8. 115.7
2009 9. 94.05
2009 10 88.10
2009 11 95.75
2009 12 113.8
2010 1. 107.1
2010 2. 103.8
2010 3. 108.6
2010 4. 103.4
2010 5. 107.5
2010 6. 111.9
2010 7. 128.2
2010 8. 124.5
2010 9. 97.44
2010 10 107.7
2010 10 90.98
2010 11 102.4
2010 11 102.4
2011 1. 112.8
2011 2. 96.39
2011 3. 101.8
2011 4. 97.54
2011 5. 106.9
2011 6. 106.3
2011 7. 108.0
2011 8. 116.6
2011 9. 99.06
2011 11 99.68
2011 12 99.71
2012 1. 86.13
2012 2. 110.1
2012 3. 101.7
2012 4. 109.9
2012 5. 101.7
2012 6. 110.7
2012 7. 101.6
2012 8. 104.3
2012 9. 114.8
2012 10 98.92
2012 11 100.6
2012 12 97.46
2013 1. 109.0
2013 2. 110.1
2013 3. 106.2
2013 4. 108.6
2013 5. 107.7
2013 6. 123.7
2013 7. 112.0
2013 8. 108.4
2013 9. 107.0
2013 10 103.4
2013 11 109.3
2013 12 104.2

2014 1. 97.41
2014 2. 103.1
2014 3. 98.76
2014 4. 102.0
2014 5. 124.0
2014 6. 113.9
2014 7. 115.5
2014 8. 110.4
2014 9. 113.1
2014 10 117.0
2014 12 105.2
2015 1. 98.18
2015 2. 81.40
2015 3. 97.31
2015 4. 89.32
2015 5. 109.9
2015 6. 98.14
2015 7. 103.4
2015 8. 110.9
2015 9. 104.4
2015 10 95.16
2015 11 93.87
2015 11 98.54
2015 12 95.29
2016 1. 106.7
2016 2. 114.6
2016 3. 78.92
2016 4. 108.6
2016 5. 97.24
2016 6. 107.1
2016 7. 108.2
2016 8. 52.68
2016 9. 97.71
2016 11 111.3
2016 11 104.8
2016 11 99.32
2016 11 106.4
2016 11 100.2
2016 11 94.97
2016 11 102.5
2016 11 96.64
2016 11 91.52
2016 12 109.3
2017 1. 116.5
2017 2. 115.3
2017 3. 100.9
2017 4. 106.4
2017 5. 95.15
2017 6. 97.34
2017 7. 81.05
2017 8. 98.44
2017 9. 96.66
2017 10 97.04
2017 11 85.09

2017 12 106.6

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO saturation WHI0029 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.148
S = 386.
z = 3.257
p = 0.0011
p = 0.0970 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 97.27 + 0.3450 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO saturation WHI0029 2004-2017
2004 1. 97.10
2004 2. 80.09
2004 6. 104.7
2004 7. 101.0
2004 8. 112.7
2004 9. 95.32
2004 10 99.24
2004 12 98.31
2005 1. 116.8
2005 2. 103.8
2005 3. 102.4
2005 4. 105.0
2005 5. 112.3
2005 7. 101.3
2005 8. 109.5
2005 9. 93.60
2005 10 97.34
2005 11 95.43
2005 12 101.8
2006 1. 126.8
2006 3. 105.5
2006 4. 111.0
2006 5. 122.0
2006 6. 114.8
2006 7. 120.4
2006 8. 114.8
2006 9. 112.5
2006 10 100.7
2006 11 105.8
2006 12 94.39
2007 1. 111.4
2007 2. 82.57
2007 3. 121.9
2007 4. 123.9
2007 5. 118.7
2007 6. 113.4
2007 7. 109.9
2007 8. 122.2
2007 9. 91.37
2007 10 85.26
2007 11 110.5
2007 12 117.3
2008 1. 115.3
2008 2. 96.82
2008 3. 109.4
2008 4. 101.1
2008 5. 102.2
2008 6. 110.8
2008 7. 108.8
2008 8. 109.8
2008 9. 90.51
2008 10 108.8

2008 11 103.0
2008 12 105.4
2009 1. 114.6
2009 2. 125.8
2009 3. 105.3
2009 4. 117.8
2009 5. 105.3
2009 6. 110.3
2009 8. 115.7
2009 9. 94.05
2009 10 88.10
2009 11 95.75
2009 12 113.8
2010 1. 107.1
2010 2. 103.8
2010 3. 108.6
2010 4. 103.4
2010 5. 107.5
2010 6. 111.9
2010 7. 128.2
2010 8. 124.5
2010 9. 97.44
2010 10 107.7
2010 10 90.98
2010 11 102.4
2010 11 102.4
2011 1. 112.8
2011 2. 96.39
2011 3. 101.8
2011 4. 97.54
2011 5. 106.9
2011 6. 106.3
2011 7. 108.0
2011 8. 116.6
2011 9. 99.06
2011 11 99.68
2011 12 99.71
2012 1. 86.13
2012 2. 110.1
2012 3. 101.7
2012 4. 109.9
2012 5. 101.7
2012 6. 110.7
2012 7. 101.6
2012 8. 104.3
2012 9. 114.8
2012 10 98.92
2012 11 100.6
2012 12 97.46
2013 1. 109.0
2013 2. 110.1
2013 3. 106.2
2013 4. 108.6
2013 5. 107.7

2013 6. 123.7
2013 7. 112.0
2013 8. 108.4
2013 9. 107.0
2013 10 103.4
2013 11 109.3
2013 12 104.2
2014 1. 97.41
2014 2. 103.1
2014 3. 98.76
2014 4. 102.0
2014 5. 124.0
2014 6. 113.9
2014 7. 115.5
2014 8. 110.4
2014 9. 113.1
2014 10 117.0
2014 12 105.2
2015 1. 98.18
2015 2. 81.40
2015 3. 97.31
2015 4. 89.32
2015 5. 109.9
2015 6. 98.14
2015 7. 103.4
2015 8. 110.9
2015 9. 104.4
2015 10 95.16
2015 11 93.87
2015 11 98.54
2015 12 95.29
2016 1. 106.7
2016 2. 114.6
2016 3. 78.92
2016 4. 108.6
2016 5. 97.24
2016 6. 107.1
2016 7. 108.2
2016 8. 52.68
2016 9. 97.71
2016 11 111.3
2016 11 104.8
2016 11 99.32
2016 11 106.4
2016 11 100.2
2016 11 94.97
2016 11 102.5
2016 11 96.64
2016 11 91.52
2016 12 109.3
2017 1. 116.5
2017 2. 115.3
2017 3. 100.9
2017 4. 106.4

2017 5. 95.15
2017 6. 97.34
2017 7. 81.05
2017 8. 98.44
2017 9. 96.66
2017 10 97.04
2017 11 85.09
2017 12 106.6

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO saturation WHI0029 2004-2017

The record is 15 complete water years with 12 seasons per year
beginning in water year 2004.

The tau correlation coefficient is -0.116
S = -110.
z = -1.896
p = 0.0579
p = 0.1441 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 108.1 + -0.3709 * Time

where Time = Year (as a decimal) - 2003.75
(beginning of first water year)

2 0 DO saturation WHI0046 1993-2017
1993 1. 94.74
1993 2. 89.28
1993 3. 88.65
1993 4. 92.02
1993 5. 89.17
1993 6. 84.25
1993 7. 82.27
1993 8. 98.06
1993 9. 105.5
1993 10 83.03
1993 11 92.97
1993 12 103.6
1994 1. 80.34
1994 2. 102.9
1994 3. 90.34
1994 4. 92.14
1994 5. 101.3
1994 6. 102.4
1994 7. 87.08
1994 8. 101.7
1994 9. 82.02
1994 10 84.05
1994 11 102.0
1995 1. 93.72
1995 2. 84.43
1995 3. 101.5
1995 5. 95.02
1995 6. 89.05
1995 7. 102.3
1995 8. 86.20
1995 9. 81.89
1995 10 83.41
1995 10 82.27
1995 11 99.47
1996 1. 98.82
1996 2. 78.73
1996 3. 110.6
1996 4. 111.3
1996 5. 112.4
1996 6. 104.7
1996 7. 119.9
1996 8. 113.9
1996 9. 118.7
1996 10 117.3
1996 11 82.44
1996 12 81.58
1997 1. 112.9
1997 2. 100.3
1997 3. 92.03
1997 4. 100.5
1997 5. 104.7
1997 6. 106.6

1997 8. 124.8
1997 9. 99.13
1997 10 90.20
1997 11 90.34
1997 12 93.09
1998 1. 81.95
1998 2. 91.44
1998 4. 102.4
1998 5. 109.3
1998 6. 104.3
1998 7. 106.5
1998 8. 86.87
1998 9. 79.63
1998 10 101.3
1998 11 106.6
1998 12 92.55
1999 1. 104.4
1999 2. 98.60
1999 3. 94.28
1999 4. 96.76
1999 5. 102.3
1999 7. 119.1
1999 8. 78.48
1999 9. 81.31
1999 10 92.15
1999 11 91.13
1999 11 114.2
2000 1. 102.1
2000 2. 114.2
2000 3. 95.81
2000 4. 93.97
2000 5. 112.4
2000 6. 90.92
2000 7. 95.65
2000 8. 102.3
2000 9. 112.2
2000 10 115.3
2000 10 132.6
2000 12 84.03
2001 1. 100.5
2001 2. 101.2
2001 3. 113.3
2001 4. 100.1
2001 5. 106.5
2001 6. 108.1
2001 7. 116.9
2001 8. 111.9
2001 9. 106.5
2001 10 102.8
2001 11 101.1
2001 12 93.92
2002 1. 104.6
2002 2. 94.74
2002 3. 108.9

2002 4. 113.7
2002 5. 114.0
2002 6. 108.8
2002 7. 96.18
2002 8. 78.98
2002 10 83.62
2002 11 109.0
2002 12 89.46
2003 1. 97.10
2003 2. 102.1
2003 3. 108.9
2003 4. 100.8
2003 5. 114.2
2003 6. 112.7
2003 7. 109.0
2003 8. 99.12
2003 9. 104.2
2003 10 100.2
2003 12 98.82
2004 1. 115.6
2004 2. 101.0
2004 3. 101.5
2004 4. 109.0
2004 5. 116.5
2004 6. 105.7
2004 7. 95.36
2004 8. 101.1
2004 9. 102.0
2004 10 94.93
2004 11 90.18
2004 12 78.47
2005 1. 93.63
2005 2. 102.1
2005 3. 103.0
2005 4. 106.6
2005 5. 116.5
2005 6. 92.05
2005 7. 109.2
2005 8. 104.3
2005 9. 107.0
2005 10 102.1
2005 11 130.8
2005 12 106.2
2006 1. 110.6
2006 2. 107.1
2006 2. 127.0
2006 4. 100.5
2006 5. 90.59
2006 6. 105.3
2006 7. 108.5
2006 8. 110.8
2006 9. 109.6
2006 10 87.09
2006 11 103.7

2006 12 99.72
2007 1. 111.2
2007 2. 107.1
2007 3. 105.3
2007 4. 115.9
2007 5. 112.1
2007 6. 122.2
2007 7. 106.8
2007 8. 102.1
2007 9. 119.9
2007 10 99.64
2007 11 114.2
2007 12 104.2
2008 1. 91.55
2008 2. 134.1
2008 3. 100.3
2008 4. 89.46
2008 5. 108.3
2008 6. 95.63
2008 7. 92.59
2008 8. 98.83
2008 9. 79.38
2008 10 68.35
2008 11 74.00
2008 12 81.31
2009 1. 95.54
2009 2. 110.3
2009 3. 101.5
2009 4. 97.63
2009 5. 98.14
2009 6. 95.76
2009 7. 90.06
2009 8. 87.42
2009 9. 97.73
2009 10 100.1
2009 11 97.39
2009 12 69.38
2010 1. 91.23
2010 2. 88.51
2010 3. 90.84
2010 4. 96.76
2010 5. 93.68
2010 6. 115.4
2010 7. 95.25
2010 8. 88.68
2010 9. 102.5
2010 10 99.33
2010 11 90.68
2010 12 90.47
2011 1. 109.2
2011 2. 106.3
2011 3. 119.2
2011 4. 98.94
2011 5. 91.99

2011 6. 79.76
2011 7. 91.41
2011 8. 110.5
2011 9. 91.46
2011 10 112.6
2011 11 124.6
2011 12 91.01
2012 1. 90.17
2012 2. 103.6
2012 3. 95.64
2012 4. 81.34
2012 5. 103.2
2012 6. 112.4
2012 7. 108.8
2012 8. 113.0
2012 9. 112.5
2012 10 121.9
2012 11 97.56
2012 12 92.66
2013 1. 108.8
2013 2. 99.47
2013 3. 113.0
2013 4. 97.12
2013 5. 125.7
2013 6. 119.1
2013 7. 113.1
2013 8. 91.54
2013 9. 93.31
2013 12 105.2
2014 1. 86.89
2014 2. 115.3
2014 3. 103.7
2014 4. 100.8
2014 5. 124.0
2014 6. 115.0
2014 7. 105.4
2014 8. 128.3
2014 9. 99.36
2014 10 95.00
2014 11 108.0
2014 12 79.69
2015 1. 99.25
2015 2. 114.7
2015 3. 104.5
2015 4. 107.6
2015 5. 118.2
2015 6. 107.6
2015 7. 126.8
2015 8. 97.18
2015 9. 88.69
2015 10 77.56
2015 11 87.19
2016 1. 94.18
2016 2. 97.00

2016 3. 100.4
2016 4. 106.9
2016 5. 91.36
2016 6. 102.7
2016 7. 96.56
2016 8. 86.85
2016 9. 78.61
2016 10 99.96
2016 11 95.41
2016 12 104.7
2017 1. 108.1
2017 2. 127.1
2017 3. 92.11
2017 4. 96.21
2017 5. 103.5
2017 6. 98.26
2017 7. 96.42
2017 8. 89.32
2017 9. 89.63
2017 10 87.99
2017 11 95.81
2017 12 80.90

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO saturation WHI0046 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.076
S = 248.
z = 1.781
p = 0.0749
p = 0.2996 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 98.11 + 0.1803 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO saturation WHI0065 1993-2017
1993 1. 98.07
1993 2. 91.39
1993 3. 109.8
1993 4. 101.1
1993 5. 83.41
1993 6. 81.18
1993 7. 70.19
1993 8. 120.9
1993 9. 107.7
1993 10 93.07
1993 11 97.39
1993 12 94.56
1994 1. 93.85
1994 2. 109.4
1994 3. 109.3
1994 4. 106.5
1994 5. 114.3
1994 6. 110.9
1994 7. 88.76
1994 8. 101.0
1994 9. 91.25
1994 10 84.65
1994 11 89.23
1995 1. 113.6
1995 2. 92.27
1995 3. 105.0
1995 5. 124.6
1995 6. 95.65
1995 7. 109.2
1995 8. 93.65
1995 9. 86.71
1995 10 93.07
1995 10 101.1
1995 11 100.5
1996 1. 95.54
1996 2. 106.9
1996 3. 129.6
1996 4. 117.8
1996 5. 111.0
1996 6. 125.3
1996 7. 94.15
1996 8. 96.75
1996 9. 123.4
1996 10 101.3
1996 11 100.1
1996 12 97.39
1997 1. 119.8
1997 2. 113.3
1997 3. 112.2
1997 4. 130.9
1997 5. 105.6
1997 6. 119.8

1997 8. 106.5
1997 9. 79.74
1997 10 74.93
1997 11 100.5
1997 12 98.43
1998 1. 94.80
1998 2. 93.91
1998 4. 133.4
1998 5. 108.8
1998 6. 116.6
1998 7. 123.0
1998 8. 100.4
1998 9. 80.43
1998 10 105.3
1998 11 115.7
1998 12 105.5
1999 1. 96.41
1999 2. 106.0
1999 3. 110.9
1999 4. 98.93
1999 5. 105.5
1999 7. 88.87
1999 8. 82.06
1999 9. 78.34
1999 10 78.98
1999 11 97.13
1999 11 108.0
2000 1. 110.6
2000 2. 112.3
2000 3. 111.0
2000 4. 129.6
2000 5. 105.4
2000 6. 130.7
2000 7. 111.3
2000 8. 119.2
2000 9. 114.9
2000 10 109.9
2000 10 123.4
2000 12 92.32
2001 1. 103.6
2001 2. 107.2
2001 3. 130.8
2001 4. 155.0
2001 5. 118.8
2001 6. 105.7
2001 7. 132.9
2001 8. 140.5
2001 9. 104.0
2001 10 104.4
2001 11 135.1
2001 12 107.6
2002 1. 111.2
2002 2. 102.1
2002 3. 116.0

2002 4. 140.4
2002 5. 114.3
2002 6. 106.0
2002 7. 130.6
2002 8. 81.09
2002 10 104.7
2002 11 106.2
2002 12 108.7
2003 1. 108.4
2003 2. 108.7
2003 3. 124.2
2003 4. 127.2
2003 5. 127.0
2003 6. 131.9
2003 7. 85.80
2003 8. 126.5
2003 9. 108.8
2003 10 95.65
2003 12 102.7
2004 1. 110.6
2004 2. 104.0
2004 3. 123.3
2004 4. 132.6
2004 5. 131.5
2004 6. 124.6
2004 7. 107.8
2004 8. 117.2
2004 9. 101.0
2004 10 101.5
2004 11 98.04
2004 12 95.54
2005 1. 99.25
2005 2. 105.2
2005 3. 115.1
2005 4. 132.0
2005 5. 133.0
2005 6. 100.9
2005 7. 106.2
2005 8. 122.7
2005 9. 113.2
2005 10 118.5
2005 11 125.3
2005 12 113.2
2006 1. 106.2
2006 2. 115.3
2006 2. 128.9
2006 4. 135.6
2006 5. 103.1
2006 6. 107.2
2006 7. 91.34
2006 8. 104.0
2006 9. 100.2
2006 10 91.34
2006 11 123.9

2006 12 130.5
2007 1. 114.5
2007 2. 110.0
2007 3. 137.7
2007 4. 140.1
2007 5. 173.6
2007 6. 144.3
2007 7. 106.2
2007 8. 104.0
2007 9. 115.7
2007 10 97.45
2007 11 118.2
2007 12 104.2
2008 1. 106.0
2008 2. 138.7
2008 3. 131.9
2008 4. 102.4
2008 5. 113.2
2008 6. 105.5
2008 7. 93.55
2008 8. 107.5
2008 9. 88.39
2008 10 97.74
2008 11 95.41
2008 12 92.47
2009 1. 114.4
2009 2. 118.7
2009 3. 131.3
2009 4. 95.10
2009 5. 111.9
2009 6. 100.2
2009 7. 103.8
2009 8. 96.41
2009 9. 100.7
2009 10 105.3
2009 11 101.5
2009 12 86.12
2010 1. 122.2
2010 2. 119.6
2010 3. 112.4
2010 4. 118.5
2010 5. 90.22
2010 6. 111.2
2010 7. 97.89
2010 8. 99.04
2010 9. 102.9
2010 10 113.9
2010 11 97.90
2010 12 130.6
2011 1. 120.1
2011 2. 122.9
2011 3. 134.8
2011 4. 118.9
2011 5. 87.77

2011 6. 114.4
2011 7. 105.1
2011 8. 130.1
2011 9. 125.4
2011 10 120.7
2011 11 125.7
2011 12 98.54
2012 1. 103.2
2012 2. 139.1
2012 3. 113.2
2012 4. 87.89
2012 5. 89.76
2012 6. 113.1
2012 7. 110.4
2012 8. 77.12
2012 9. 97.16
2012 10 110.7
2012 11 80.12
2012 12 90.88
2013 1. 131.5
2013 2. 137.3
2013 3. 146.5
2013 4. 114.8
2013 5. 140.7
2013 6. 130.6
2013 7. 122.4
2013 8. 96.71
2013 9. 108.6
2013 12 136.8
2014 1. 104.3
2014 2. 161.6
2014 3. 112.5
2014 4. 142.8
2014 5. 139.5
2014 6. 104.7
2014 7. 95.57
2014 8. 131.1
2014 9. 91.16
2014 10 91.25
2014 11 105.0
2014 12 67.45
2015 1. 110.8
2015 2. 147.9
2015 3. 130.4
2015 4. 122.0
2015 5. 131.5
2015 6. 112.5
2015 7. 121.0
2015 8. 112.7
2015 8. 89.42
2015 9. 83.61
2015 10 101.1
2015 11 99.99
2015 11 83.56

2016 1. 100.8
2016 2. 118.0
2016 3. 109.0
2016 4. 130.9
2016 5. 90.43
2016 6. 98.62
2016 7. 105.1
2016 8. 93.31
2016 9. 99.78
2016 10 116.1
2016 11 89.84
2016 12 123.4
2017 1. 140.3
2017 2. 136.6
2017 3. 112.1
2017 4. 98.20
2017 5. 111.7
2017 6. 108.2
2017 7. 107.7
2017 8. 83.52
2017 9. 100.6
2017 10 96.55
2017 11 114.3
2017 12 68.24

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO saturation WHI0065 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.126
S = 413.
z = 2.970
p = 0.0030
p = 0.0446 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 102.5 + 0.4000 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO saturation 07060500 1993-2017
1993 1. 95.
1993 3. 114
1993 4. 81.
1993 6. 82.
1993 8. 95.
1993 11 88.
1993 12 88.
1994 3. 90.
1994 4. 93.
1994 6. 84.
1994 6. 83.
1994 6. 82.
1994 6. 81.
1994 6. 82.
1994 6. 82.
1994 6. 84.
1994 6. 83.
1994 6. 84.
1994 6. 85.
1994 7. 96.
1994 8. 110
1994 10 43.
1995 1. 86.
1995 2. 104
1995 4. 99.
1995 7. 95.
1995 9. 88.
1995 9. 79.
1995 9. 77.
1995 9. 76.
1995 9. 76.
1995 9. 77.
1995 9. 77.
1995 9. 79.
1995 9. 80.
1995 9. 81.
1995 9. 80.
1995 10 85.
1995 11 102
1996 2. 86.
1996 2. 109
1996 2. 104
1996 2. 100
1996 2. 98.
1996 2. 97.
1996 2. 97.
1996 2. 97.
1996 2. 98.
1996 2. 98.
1996 2. 99.
1996 4. 100
1996 6. 89.

1996 8. 110
1996 10 70.
1996 12 86.
1997 2. 91.
1997 4. 101
1997 7. 82.
1997 8. 75.
1997 11 97.
1998 1. 116
1998 3. 100
1998 4. 85.
1998 6. 89.
1998 6. 89.
1998 6. 87.
1998 6. 88.
1998 6. 88.
1998 6. 87.
1998 6. 88.
1998 6. 89.
1998 6. 88.
1998 6. 90.
1998 6. 90.
1998 8. 98.
1998 11 97.
1999 1. 99.
1999 3. 95.
1999 6. 101
1999 7. 81.
1999 9. 79.
1999 11 82.
2000 1. 90.
2000 3. 93.
2000 5. 91.
2000 7. 99.
2000 8. 81.
2000 11 109
2001 1. 101
2001 3. 99.
2001 5. 105
2001 8. 108
2001 10 90.
2001 12 93.
2002 2. 113
2002 4. 107
2002 6. 89.
2002 8. 94.
2002 8. 93.
2002 8. 90.
2002 8. 89.
2002 8. 89.
2002 8. 89.
2002 8. 89.
2002 8. 88.
2002 8. 88.

2002 8. 88.
2002 8. 88.
2002 10 101
2002 12 60.
2003 3. 107
2003 3. 101
2003 3. 103
2003 3. 103
2003 3. 102
2003 3. 103
2003 3. 102
2003 3. 102
2003 3. 100
2003 3. 99.
2003 3. 97.
2003 5. 87.
2003 7. 92.
2003 7. 94.
2003 7. 91.
2003 7. 92.
2003 7. 92.
2003 7. 91.
2003 7. 91.
2003 7. 91.
2003 7. 91.
2003 7. 91.
2003 7. 91.
2003 8. 86.
2003 11 80.
2003 11 79.
2003 11 79.
2003 11 78.
2003 11 78.
2003 11 79.
2003 11 78.
2003 11 78.
2003 11 77.
2003 11 77.
2003 11 78.
2004 1. 92.
2004 1. 93.
2004 1. 103
2004 1. 93.
2004 1. 93.
2004 1. 92.
2004 1. 91.
2004 1. 92.
2004 1. 92.
2004 1. 92.
2004 1. 93.
2004 2. 84.
2004 4. 95.
2004 6. 85.
2004 8. 94.

2004 8. 94.
2004 8. 95.
2004 8. 94.
2004 8. 93.
2004 8. 93.
2004 8. 93.
2004 8. 92.
2004 8. 93.
2004 8. 92.
2004 8. 93.
2004 10 90.
2004 10 91.
2004 10 100
2004 10 91.
2004 10 89.
2004 10 97.
2004 10 93.
2004 10 92.
2004 10 94.
2004 10 93.
2004 10 93.
2005 1. 76.
2005 3. 99.
2005 4. 91.
2005 6. 101
2005 8. 93.
2005 10 90.
2006 1. 90.
2006 3. 92.
2006 5. 91.
2006 7. 88.
2006 8. 82.
2006 11 78.
2007 1. 93.
2007 3. 109
2007 4. 101
2007 6. 103
2007 8. 79.
2007 11 92.
2007 12 87.
2008 2. 83.
2008 4. 100
2008 6. 96.
2008 8. 85.
2008 10 78.
2008 12 92.
2009 1. 102
2009 3. 100
2009 4. 104
2009 8. 90.
2009 11 100
2010 2. 94.
2010 3. 102
2010 3. 102

2010 3. 101
2010 3. 99.
2010 3. 96.
2010 3. 90.
2010 3. 82.
2010 3. 103
2010 6. 96.
2010 8. 87.
2010 10 93.
2010 12 91.
2011 2. 103
2011 4. 97.
2011 6. 100
2011 8. 90.
2011 10 90.
2012 2. 102
2012 6. 109
2012 8. 113
2012 11 97.
2013 3. 105
2013 5. 96.
2013 9. 96.
2013 11 94.
2014 3. 102
2014 4. 113
2014 7. 104
2014 11 92.
2015 3. 98.
2015 5. 108
2015 12 87.
2016 3. 97.
2016 5. 119
2016 8. 95.
2016 11 102
2017 2. 92.
2017 5. 97.
2017 8. 82.
2017 11 95.

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO saturation 07060500 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.119
S = 97.
z = 1.742
p = 0.0815
p = 0.1330 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 90.25 + 0.2500 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DO saturation 07060710 1993-2017
1993 1. 88.
1993 3. 105
1993 4. 81.
1993 5. 87.
1993 6. 78.
1993 7. 107
1993 8. 77.
1993 9. 76.
1993 12 94.
1993 12 102
1994 1. 100
1994 2. 111
1994 3. 101
1994 4. 93.
1994 5. 108
1994 6. 129
1994 6. 91.
1994 6. 96.
1994 6. 111
1994 6. 116
1994 6. 115
1994 6. 111
1994 6. 114
1994 6. 115
1994 6. 115
1994 6. 115
1994 7. 95.
1994 8. 58.
1994 8. 65.
1994 10 97.
1994 11 94.
1994 12 102
1995 1. 63.
1995 2. 98.
1995 3. 90.
1995 3. 88.
1995 4. 95.
1995 5. 71.
1995 6. 94.
1995 7. 96.
1995 8. 155
1995 10 97.
1995 11 92.
1996 1. 98.
1996 1. 91.
1996 1. 77.
1996 1. 59.
1996 1. 52.
1996 1. 86.
1996 1. 91.
1996 1. 95.
1996 1. 97.

1996 1. 97.
1996 1. 100
1996 2. 102
1996 4. 109
1996 5. 100
1996 6. 79.
1996 7. 82.
1996 8. 89.
1996 9. 117
1996 10 75.
1997 2. 90.
1997 4. 96.
1997 5. 114
1997 6. 107
1997 7. 116
1997 8. 121
1997 9. 96.
1997 10 106
1997 11 67.
1997 12 98.
1998 1. 89.
1998 2. 115
1998 3. 99.
1998 4. 99.
1998 5. 91.
1998 6. 83.
1998 7. 90.
1998 8. 82.
1998 9. 128
1998 10 105
1998 11 103
1998 12 93.
1999 1. 82.
1999 2. 108
1999 3. 87.
1999 4. 99.
1999 5. 117
1999 6. 84.
1999 7. 79.
1999 8. 55.
1999 9. 63.
1999 10 83.
1999 11 115
1999 12 102
2000 1. 77.
2000 2. 92.
2000 3. 109
2000 4. 99.
2000 5. 83.
2000 6. 111
2000 7. 105
2000 8. 122
2000 9. 69.
2000 10 87.

2000 11 97.
2000 12 58.
2001 2. 85.
2001 3. 96.
2001 4. 90.
2001 5. 73.
2001 6. 81.
2001 7. 66.
2001 8. 73.
2001 9. 77.
2001 11 83.
2001 12 92.
2002 1. 105
2002 2. 104
2002 3. 92.
2002 5. 97.
2002 7. 75.
2002 9. 115
2002 11 88.
2002 12 97.
2003 1. 104
2003 2. 89.
2003 3. 102
2003 5. 107
2003 7. 103
2003 9. 92.
2003 11 86.
2003 12 90.
2004 1. 94.
2004 2. 112
2004 3. 103
2004 3. 91.
2004 5. 74.
2004 7. 69.
2004 8. 119
2004 11 112
2005 1. 88.
2005 3. 96.
2005 5. 116
2005 7. 82.
2005 9. 103
2005 11 113
2006 1. 129
2006 3. 102
2006 5. 99.
2006 6. 119
2006 7. 91.
2006 9. 126
2007 2. 102
2007 3. 97.
2007 5. 106
2007 5. 112
2007 6. 91.
2007 7. 100

2007 8. 84.
2007 9. 93.
2007 10 84.
2007 12 100
2008 1. 110
2008 2. 84.
2008 3. 106
2008 5. 106
2008 6. 94.
2008 9. 99.
2009 3. 104
2009 4. 103
2009 6. 102
2009 8. 81.
2009 11 101
2010 2. 105
2010 3. 96.
2010 6. 129
2010 8. 128
2010 10 115
2010 12 99.
2011 2. 118
2011 4. 101
2011 6. 124
2011 8. 134
2011 10 144
2011 12 104
2012 2. 108
2012 4. 116
2012 6. 138
2012 8. 73.
2012 11 105
2013 1. 105
2013 3. 102
2013 5. 93.
2013 7. 134
2013 9. 130
2013 11 118
2014 1. 105
2014 3. 100
2014 4. 120
2014 5. 104
2014 7. 137
2014 9. 85.
2014 11 103
2015 1. 103
2015 3. 100
2015 5. 106
2015 7. 109
2015 8. 117
2015 10 93.
2015 11 109
2015 12 102
2016 1. 97.

2016 1. 109
2016 2. 107
2016 2. 105
2016 3. 107
2016 4. 110
2016 4. 103
2016 5. 101
2016 5. 112
2016 7. 115
2016 7. 90.
2016 8. 100
2016 9. 96.
2016 10 109
2016 10 110
2016 11 110
2016 11 108
2016 12 111
2017 3. 101
2017 3. 100
2017 4. 105
2017 5. 102
2017 5. 113
2017 6. 114
2017 6. 114
2017 7. 128
2017 8. 126
2017 9. 104
2017 10 110
2017 10 105
2017 11 98.

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DO saturation 07060710 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.254
S = 440.
z = 4.948
p = 0.0000
p = 0.0019 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 92.06 + 0.6111 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

ATTACHMENT 3

Dissolved Inorganic Nitrogen Seasonal Mann-Kendall Input and Output

2 0 NOx WHI0011 1993-2017
1993 5.0 0.428
1993 7.0 0.629
1993 8.0 0.354
1993 9.0 0.288
1993 10. 0.652
1993 11. 0.840
1993 12. 0.619
1994 1.0 0.641
1994 2.0 0.377
1994 4.0 0.379
1994 5.0 0.419
1994 6.0 0.580
1994 7.0 0.603
1994 8.0 0.439
1994 9.0 0.339
1994 10. 0.491
1994 11. 0.722
1994 12. 0.694
1995 1.0 0.671
1995 2.0 0.618
1995 3.0 0.395
1995 4.0 0.554
1995 5.0 0.417
1995 6.0 0.459
1995 7.0 0.582
1995 8.0 0.042
1995 9.0 0.380
1995 10. 0.393
1995 11. 0.485
1995 12. 1.101
1996 1.0 0.803
1996 2.0 0.555
1996 3.0 0.475
1996 4.0 0.681
1996 5.0 0.760
1996 6.0 0.610
1996 7.0 0.485
1996 8.0 0.435
1996 9.0 0.714
1996 10. 0.997
1996 11. 0.879
1996 12. 0.650
1997 1.0 0.540
1997 2.0 0.645
1997 3.0 0.546
1997 4.0 0.146
1997 5.0 0.532
1997 6.0 0.436
1997 7.0 0.317
1997 8.0 0.402
1997 9.0 0.375
1997 10. 0.441

1997 11. 0.543
1997 12. 0.980
1998 1.0 0.815
1998 2.0 0.647
1998 3.0 0.394
1998 4.0 0.136
1998 5.0 0.120
1998 10. 0.971
1998 12. 0.800
1999 1.0 0.233
1999 2.0 0.726
1999 3.0 0.519
1999 4.0 0.320
1999 5.0 0.112
1999 7.0 0.305
1999 8.0 0.287
1999 9.0 0.256
1999 10. 0.418
1999 11. 0.390
1999 12. 1.546
2000 1.0 0.765
2000 2.0 0.939
2000 3.0 0.381
2000 4.0 0.430
2000 5.0 1.159
2000 6.0 1.107
2000 8.0 0.330
2000 8.0 0.138
2000 9.0 0.036
2000 10. 0.290
2000 11. 1.135
2000 12. 1.463
2001 1.0 1.540
2001 2.0 1.392
2001 3.0 0.703
2001 4.0 0.670
2001 5.0 0.655
2001 6.0 0.417
2001 7.0 0.190
2001 8.0 0.062
2001 9.0 0.233
2001 10. 0.470
2001 11. 0.475
2001 12. 1.065
2002 1.0 1.302
2002 2.0 0.879
2002 3.0 0.406
2002 4.0 0.390
2002 5.0 0.526
2002 6.0 0.646
2002 7.0 0.487
2002 8.0 0.245
2002 9.0 0.291
2002 10. 0.383

2002 11. 0.662
2002 12. 0.772
2003 1.0 0.300
2003 3.0 0.819
2003 4.0 0.468
2003 4.0 0.581
2003 5.0 0.618
2003 6.0 0.551
2003 7.0 0.725
2003 8.0 0.633
2003 9.0 0.522
2003 10. 0.707
2003 11. 0.694
2003 12. 0.996
2004 1.0 0.879
2004 2.0 0.633
2004 3.0 0.662
2004 5.0 0.472
2004 6.0 0.457
2004 7.0 0.313
2004 8.0 0.284
2004 9.0 0.150
2004 10. 1.050
2004 11. 0.825
2004 12. 0.975
2005 1.0 0.896
2005 2.0 0.601
2005 3.0 0.427
2005 4.0 0.389
2005 5.0 0.293
2005 5.0 0.550
2005 7.0 0.242
2005 8.0 0.128
2005 9.0 0.714
2005 10. 0.316
2005 11. 0.913
2005 12. 0.587
2006 1.0 0.882
2006 2.0 0.419
2006 3.0 0.490
2006 4.0 0.278
2006 5.0 0.595
2006 6.0 0.230
2006 7.0 0.139
2006 8.0 0.000
2006 9.0 0.086
2006 10. 0.971
2006 11. 0.877
2006 12. 0.894
2007 1.0 0.843
2007 2.0 0.659
2007 3.0 0.627
2007 4.0 0.343
2007 5.0 0.157

2007 6.0 0.164
2007 7.0 0.446
2007 8.0 0.227
2007 9.0 0.642
2007 10. 0.438
2007 11. 0.306
2007 12. 0.508
2008 1.0 0.875
2008 2.0 0.604
2008 3.0 0.528
2008 4.0 0.639
2008 5.0 0.394
2008 6.0 0.387
2008 7.0 0.278
2008 8.0 0.282
2008 9.0 0.935
2008 10. 0.553
2008 11. 0.583
2009 1.0 0.609
2009 2.0 0.696
2009 3.0 0.343
2009 4.0 0.415
2009 5.0 0.502
2009 6.0 0.497
2009 7.0 0.396
2009 8.0 0.290
2009 9.0 0.897
2009 10. 0.814
2009 11. 0.611
2009 12. 0.427
2010 1.0 0.672
2010 2.0 0.462
2010 3.0 0.605
2010 4.0 0.609
2010 5.0 0.575
2010 6.0 0.526
2010 7.0 0.272
2010 8.0 0.271
2010 9.0 0.166
2010 10. 0.443
2010 11. 0.309
2010 12. 0.535
2011 1.0 0.464
2011 2.0 0.738
2011 3.0 1.010
2011 4.0 0.632
2011 5.0 0.412
2011 6.0 0.324
2011 7.0 0.423
2011 8.0 0.257
2011 9.0 0.248
2011 10. 0.320
2011 11. 0.324
2011 12. 0.831

2012 1.0 0.779
2012 2.0 0.836
2012 3.0 0.616
2012 4.0 0.431
2012 5.0 0.407
2012 6.0 0.364
2012 7.0 0.138
2012 8.0 0.051
2012 9.0 0.204
2012 10. 0.392
2012 11. 0.240
2012 12. 0.384
2013 1.0 1.300
2013 2.0 0.871
2013 3.0 1.200
2013 4.0 0.409
2013 5.0 0.405
2013 6.0 0.964
2013 7.0 0.368
2013 8.0 0.780
2013 9.0 0.483
2013 10. 0.644
2013 11. 0.596
2013 12. 0.610
2014 1.0 1.200
2014 2.0 0.696
2014 3.0 0.847
2014 4.0 0.706
2014 5.0 0.713
2014 6.0 0.560
2014 7.0 0.568
2014 8.0 0.462
2014 9.0 0.316
2014 10. 0.503
2014 11. 0.434
2014 12. 0.572
2015 1.0 1.380
2015 2.0 0.647
2015 3.0 0.516
2015 4.0 0.532
2015 5.0 0.469
2015 6.0 0.601
2015 7.0 0.417
2015 8.0 0.372
2015 9.0 0.338
2015 10. 0.348
2015 11. 0.664
2016 1.0 1.050
2016 2.0 0.518
2016 3.0 0.382
2016 4.0 0.355
2016 5.0 0.632
2016 6.0 0.598
2016 7.0 0.508

2016	8.0	0.974
2016	9.0	0.564
2016	10.	0.642
2016	11.	0.734
2016	12.	0.755
2017	1.0	0.727
2017	2.0	0.511
2017	3.0	0.811
2017	4.0	0.555
2017	6.0	0.580
2017	7.0	0.421
2017	8.0	0.432
2017	9.0	0.265
2017	10.	0.388
2017	11.	0.391
2017	12.	0.359

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: NOx WHI0011 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is -0.004
S = -12.
z = -0.081
p = 0.9351
p = 0.9436 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.5242 + -0.1667E-03 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DNOx WHI0029 1993-2017
1993 1.0 0.324
1993 2.0 0.315
1993 3.0 0.327
1993 4.0 0.326
1993 5.0 0.288
1993 6.0 0.293
1993 7.0 0.377
1993 8.0 0.365
1993 9.0 0.248
1993 10. 0.275
1993 11. 0.276
1993 12. 0.265
1994 1.0 0.266
1994 2.0 0.190
1994 4.0 0.300
1994 5.0 0.328
1994 6.0 0.437
1994 7.0 0.477
1994 8.0 0.431
1994 9.0 0.398
1994 10. 0.376
1994 11. 0.511
1994 12. 0.275
1995 1.0 0.462
1995 2.0 0.245
1995 3.0 0.189
1995 4.0 0.241
1995 5.0 0.260
1995 6.0 0.277
1995 7.0 0.314
1995 8.0 0.190
1995 9.0 0.415
1995 10. 0.291
1995 11. 0.086
1995 12. 0.283
1996 1.0 0.345
1996 2.0 0.149
1996 3.0 0.257
1996 4.0 0.249
1996 5.0 0.238
1996 6.0 0.406
1996 7.0 0.309
1996 8.0 0.218
1996 9.0 0.166
1996 10. 0.262
1996 11. 0.404
1996 12. 0.238
1997 1.0 0.438
1997 2.0 0.295
1997 3.0 0.276
1997 4.0 0.185
1997 5.0 0.336

1997 6.0 0.276
1997 7.0 0.392
1997 8.0 0.342
1997 9.0 0.435
1997 10. 0.391
1997 11. 0.222
1997 12. 0.216
1998 1.0 0.387
1998 2.0 0.290
1998 3.0 0.269
1998 4.0 0.242
1998 5.0 0.270
1998 6.0 0.045
1998 7.0 0.295
1998 8.0 0.329
1998 9.0 0.438
1998 10. 0.246
1998 11. 0.166
1998 12. 0.143
1999 1.0 0.396
1999 2.0 0.179
1999 3.0 0.246
1999 4.0 0.255
1999 5.0 0.290
1999 6.0 0.315
1999 7.0 0.354
1999 8.0 0.388
1999 9.0 0.288
1999 10. 0.365
1999 11. 0.135
1999 12. 0.474
2000 1.0 0.190
2000 2.0 0.299
2000 3.0 0.128
2000 4.0 0.046
2000 6.0 0.631
2000 8.0 0.150
2000 8.0 0.153
2000 9.0 0.111
2000 10. 0.000
2000 11. 0.135
2000 12. 0.230
2001 1.0 0.110
2001 2.0 0.180
2001 3.0 0.217
2001 4.0 0.060
2001 5.0 0.143
2001 6.0 0.028
2001 7.0 0.120
2001 8.0 0.185
2001 9.0 0.149
2001 10. 0.180
2001 11. 0.182
2001 12. 0.360

2002 1.0 0.494
2002 2.0 0.284
2002 3.0 0.295
2002 5.0 0.244
2002 6.0 0.439
2002 7.0 0.314
2002 8.0 0.400
2002 9.0 0.457
2002 10. 0.352
2002 11. 0.427
2002 12. 0.280
2003 3.0 0.396
2003 4.0 0.264
2003 4.0 0.169
2003 5.0 0.387
2003 6.0 0.234
2003 7.0 0.264
2003 8.0 0.294
2003 9.0 0.307
2003 10. 0.267
2003 11. 0.262
2003 12. 0.252
2004 1.0 0.226
2004 2.0 0.194
2004 3.0 0.296
2004 5.0 0.371
2004 6.0 0.229
2004 7.0 0.401
2004 8.0 0.259
2004 9.0 0.298
2004 10. 0.332
2004 11. 0.383
2004 12. 0.265
2005 1.0 0.259
2005 2.0 0.298
2005 3.0 0.464
2005 4.0 0.280
2005 5.0 0.212
2005 7.0 0.283
2005 8.0 0.333
2005 9.0 0.411
2005 10. 0.356
2005 11. 0.212
2005 12. 0.260
2006 1.0 0.083
2006 2.0 0.121
2006 3.0 0.127
2006 4.0 0.098
2006 5.0 0.171
2006 6.0 0.067
2006 7.0 0.131
2006 8.0 0.189
2006 9.0 0.101
2006 10. 0.138

2006 11. 0.394
2006 12. 0.461
2007 1.0 0.197
2007 2.0 0.667
2007 3.0 0.229
2007 4.0 0.139
2007 5.0 0.092
2007 6.0 0.079
2007 7.0 0.250
2007 8.0 0.195
2007 9.0 0.355
2007 10. 0.205
2007 11. 0.218
2007 12. 0.198
2008 1.0 0.183
2008 2.0 0.384
2008 3.0 0.235
2008 4.0 0.358
2008 5.0 0.313
2008 6.0 0.310
2008 7.0 0.442
2008 8.0 0.580
2008 9.0 0.571
2008 10. 0.550
2008 11. 0.304
2009 1.0 0.274
2009 2.0 0.322
2009 3.0 0.352
2009 4.0 0.238
2009 5.0 0.251
2009 6.0 0.221
2009 7.0 0.375
2009 8.0 0.309
2009 9.0 0.537
2009 10. 0.444
2009 11. 0.425
2009 12. 0.249
2010 1.0 0.290
2010 2.0 0.311
2010 3.0 0.300
2010 4.0 0.366
2010 5.0 0.229
2010 6.0 0.345
2010 7.0 0.371
2010 8.0 0.372
2010 9.0 0.622
2010 10. 0.424
2010 10. 0.236
2010 11. 0.207
2010 11. 0.347
2011 1.0 0.189
2011 2.0 0.352
2011 3.0 0.278
2011 4.0 0.249

2011	5.0	0.470
2011	6.0	0.380
2011	7.0	0.347
2011	8.0	0.371
2011	9.0	0.453
2011	11.	0.229
2011	12.	0.430
2012	1.0	0.549
2012	2.0	0.251
2012	3.0	0.500
2012	4.0	0.331
2012	5.0	0.497
2012	6.0	0.257
2012	7.0	0.231
2012	8.0	0.210
2012	9.0	0.224
2012	10.	0.224
2012	11.	0.161
2012	12.	0.157
2013	1.0	0.375
2013	2.0	0.326
2013	3.0	0.360
2013	4.0	0.212
2013	5.0	0.118
2013	6.0	0.220
2013	7.0	0.296
2013	8.0	0.319
2013	9.0	0.349
2013	10.	0.297
2013	11.	0.227
2013	12.	0.257
2014	1.0	0.400
2014	2.0	0.217
2014	3.0	0.329
2014	4.0	0.234
2014	5.0	0.155
2014	6.0	0.338
2014	7.0	0.239
2014	8.0	0.270
2014	9.0	0.258
2014	10.	0.332
2014	11.	0.228
2014	12.	0.216
2015	1.0	0.267
2015	2.0	0.242
2015	3.0	0.566
2015	4.0	0.135
2015	5.0	0.172
2015	6.0	0.321
2015	7.0	0.336
2015	8.0	0.358
2015	9.0	0.412
2015	10.	0.398
2015	11.	0.446

2015	11.	0.392
2015	12.	0.329
2016	1.0	0.317
2016	2.0	0.314
2016	3.0	0.206
2016	4.0	0.306
2016	5.0	0.303
2016	6.0	0.278
2016	7.0	0.297
2016	8.0	0.330
2016	9.0	0.414
2016	10.	1.600
2016	11.	0.000
2016	11.	10.80
2016	11.	0.369
2016	12.	0.243
2017	1.0	0.221
2017	2.0	0.230
2017	3.0	0.224
2017	4.0	0.158
2017	5.0	0.117
2017	6.0	0.300
2017	7.0	0.215
2017	8.0	0.356
2017	9.0	0.375
2017	10.	0.282
2017	11.	0.244
2017	12.	0.113

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DNOx WHI0029 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.003
S =   10.
z =   0.064
p = 0.9489
p = 0.9704 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.2813   +   0.5159E-04 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DNOx WHI0046 1993-2017
1993 1.0 0.240
1993 2.0 0.289
1993 3.0 0.210
1993 4.0 0.183
1993 5.0 0.260
1993 6.0 0.366
1993 7.0 0.442
1993 8.0 0.405
1993 9.0 0.322
1993 11. 0.336
1993 12. 0.230
1994 1.0 0.173
1994 3.0 0.280
1994 4.0 0.242
1994 5.0 0.202
1994 6.0 0.411
1994 7.0 0.504
1994 8.0 0.280
1994 9.0 0.494
1994 10. 0.581
1994 11. 0.400
1994 12. 0.343
1995 1.0 0.381
1995 2.0 0.282
1995 3.0 0.237
1995 4.0 0.075
1995 5.0 0.175
1995 6.0 0.214
1995 7.0 0.334
1995 8.0 0.401
1995 9.0 0.406
1995 10. 0.327
1995 10. 0.239
1995 11. 0.081
1996 1.0 0.205
1996 2.0 0.224
1996 3.0 0.265
1996 4.0 0.097
1996 5.0 0.276
1996 6.0 0.279
1996 7.0 0.381
1996 8.0 0.281
1996 9.0 0.202
1996 10. 0.455
1996 11. 0.292
1996 12. 0.258
1997 1.0 0.191
1997 2.0 0.408
1997 3.0 0.270
1997 4.0 0.126
1997 5.0 0.359
1997 6.0 0.122

1997 7.0 0.459
1997 8.0 0.439
1997 9.0 0.212
1997 10. 0.431
1997 11. 0.229
1997 12. 0.229
1998 1.0 0.455
1998 2.0 0.172
1998 3.0 0.286
1998 4.0 0.242
1998 5.0 0.224
1998 6.0 0.340
1998 7.0 0.365
1998 8.0 0.438
1998 9.0 0.481
1998 10. 0.184
1998 11. 0.146
1998 12. 0.497
1999 1.0 0.484
1999 2.0 0.332
1999 3.0 0.188
1999 4.0 0.263
1999 5.0 0.298
1999 6.0 0.330
1999 7.0 0.400
1999 8.0 0.483
1999 9.0 0.464
1999 10. 0.435
1999 11. 0.336
1999 11. 0.173
2000 1.0 0.336
2000 2.0 0.132
2000 3.0 0.041
2000 4.0 0.000
2000 5.0 0.034
2000 6.0 0.333
2000 7.0 0.203
2000 8.0 0.216
2000 9.0 0.158
2000 10. 0.060
2000 10. 0.000
2001 1.0 0.080
2001 2.0 0.244
2001 3.0 0.180
2001 5.0 0.125
2001 6.0 0.077
2001 7.0 0.170
2001 8.0 0.208
2001 9.0 0.204
2001 10. 0.238
2001 11. 0.265
2001 12. 0.271
2002 1.0 0.369
2002 2.0 0.399

2002 3.0 0.232
2002 4.0 0.400
2002 5.0 0.240
2002 6.0 0.241
2002 7.0 0.349
2002 8.0 0.399
2002 9.0 0.492
2002 10. 0.465
2002 11. 0.324
2002 12. 0.202
2003 1.0 0.333
2003 2.0 0.204
2003 3.0 0.219
2003 4.0 0.066
2003 5.0 0.121
2003 6.0 0.194
2003 7.0 0.290
2003 8.0 0.317
2003 9.0 0.255
2003 10. 0.217
2003 12. 0.228
2004 1.0 0.144
2004 2.0 0.152
2004 3.0 0.237
2004 4.0 0.132
2004 5.0 0.217
2004 6.0 0.233
2004 7.0 0.232
2004 8.0 0.328
2004 9.0 0.297
2004 10. 0.337
2004 11. 0.371
2004 12. 0.301
2005 1.0 0.438
2005 2.0 0.265
2005 3.0 0.233
2005 4.0 0.283
2005 5.0 0.215
2005 6.0 0.317
2005 7.0 0.234
2005 8.0 0.392
2005 9.0 0.333
2005 10. 0.414
2005 11. 0.221
2005 12. 0.232
2006 1.0 0.101
2006 2.0 0.176
2006 2.0 0.053
2006 4.0 0.069
2006 5.0 0.343
2006 6.0 0.163
2006 7.0 0.099
2006 8.0 0.170
2006 9.0 0.199

2006 10. 0.189
2006 11. 0.489
2006 12. 0.428
2007 1.0 0.426
2007 2.0 0.209
2007 3.0 0.127
2007 4.0 0.200
2007 5.0 0.078
2007 6.0 0.081
2007 7.0 0.217
2007 8.0 0.255
2007 9.0 0.866
2007 10. 0.295
2007 11. 0.261
2007 12. 0.205
2008 1.0 0.196
2008 2.0 0.138
2008 3.0 0.403
2008 4.0 0.304
2008 5.0 0.432
2008 6.0 0.341
2008 7.0 0.457
2008 8.0 0.657
2008 9.0 0.600
2008 10. 0.588
2008 11. 0.290
2008 12. 0.307
2009 1.0 0.233
2009 2.0 0.273
2009 3.0 0.217
2009 4.0 0.177
2009 5.0 0.389
2009 6.0 0.239
2009 7.0 0.440
2009 8.0 0.409
2009 9.0 0.394
2009 10. 0.490
2009 11. 0.330
2009 12. 0.247
2010 1.0 0.344
2010 2.0 0.408
2010 3.0 0.297
2010 4.0 0.461
2010 5.0 0.371
2010 6.0 0.392
2010 7.0 0.398
2010 8.0 0.495
2010 9.0 0.471
2010 10. 0.526
2010 11. 0.364
2010 12. 0.262
2011 1.0 0.228
2011 2.0 0.207
2011 3.0 0.353

2011 4.0 0.211
2011 5.0 0.407
2011 6.0 0.316
2011 7.0 0.258
2011 8.0 0.503
2011 9.0 0.501
2011 10. 0.407
2011 11. 0.155
2011 12. 0.566
2012 1.0 0.328
2012 2.0 0.501
2012 3.0 0.325
2012 4.0 0.338
2012 5.0 0.243
2012 6.0 0.398
2012 7.0 0.285
2012 8.0 0.272
2012 9.0 0.275
2012 10. 0.374
2012 11. 0.357
2012 12. 0.180
2013 1.0 0.084
2013 2.0 0.241
2013 3.0 0.181
2013 4.0 0.215
2013 5.0 0.115
2013 6.0 0.179
2013 7.0 0.215
2013 8.0 0.600
2013 9.0 0.385
2013 10. 0.344
2013 11. 0.347
2013 12. 0.237
2014 1.0 0.261
2014 2.0 0.219
2014 3.0 0.494
2014 4.0 0.273
2014 5.0 0.172
2014 6.0 0.214
2014 7.0 0.272
2014 8.0 0.273
2014 9.0 0.326
2014 10. 0.309
2014 11. 0.309
2014 12. 0.229
2015 1.0 0.477
2015 2.0 0.184
2015 3.0 0.440
2015 4.0 0.207
2015 5.0 0.191
2015 6.0 0.291
2015 7.0 0.305
2015 8.0 0.397
2015 9.0 0.473

2015 10. 0.533
2015 11. 0.324
2016 1.0 0.713
2016 2.0 0.337
2016 3.0 0.300
2016 4.0 0.262
2016 5.0 0.262
2016 6.0 0.400
2016 7.0 0.389
2016 8.0 0.318
2016 9.0 0.468
2016 10. 0.517
2016 11. 0.268
2016 12. 0.193
2017 1.0 0.162
2017 2.0 0.150
2017 3.0 0.260
2017 4.0 0.182
2017 6.0 0.229
2017 7.0 0.231
2017 8.0 0.376
2017 9.0 0.344
2017 10. 0.136
2017 11. 0.069
2017 12. 0.109

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DNOx WHI0046 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.022
S = 75.
z = 0.526
p = 0.5991
p = 0.7749 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.2672 + 0.6000E-03 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DNOx WHI0065 1993-2017
1993 1.0 2.290
1993 2.0 1.590
1993 3.0 1.840
1993 4.0 1.650
1993 5.0 2.990
1993 6.0 6.770
1993 7.0 6.860
1993 8.0 4.680
1993 9.0 2.400
1993 11. 2.300
1993 12. 2.360
1994 1.0 2.990
1994 3.0 2.320
1994 4.0 0.994
1994 5.0 3.560
1994 6.0 6.090
1994 7.0 3.930
1994 8.0 12.50
1994 9.0 14.60
1994 10. 14.20
1994 11. 0.967
1994 12. 2.510
1995 1.0 2.435
1995 2.0 4.270
1995 3.0 2.802
1995 4.0 2.807
1995 5.0 2.277
1995 6.0 2.155
1995 7.0 0.173
1995 8.0 13.50
1995 9.0 13.70
1995 10. 4.290
1995 10. 10.10
1995 11. 11.40
1996 1.0 3.219
1996 2.0 4.060
1996 3.0 8.720
1996 4.0 2.151
1996 5.0 2.623
1996 6.0 10.30
1996 7.0 15.50
1996 8.0 15.70
1996 9.0 5.440
1996 10. 7.410
1996 11. 4.520
1996 12. 2.481
1997 1.0 2.570
1997 2.0 2.504
1997 3.0 1.954
1997 4.0 2.981
1997 5.0 5.950
1997 6.0 10.40

1997 8.0 6.638
1997 9.0 9.310
1997 10. 9.504
1997 11. 9.810
1997 12. 5.421
1998 1.0 3.070
1998 2.0 5.959
1998 3.0 1.592
1998 4.0 2.466
1998 5.0 3.802
1998 6.0 12.80
1998 7.0 13.54
1998 8.0 4.266
1998 9.0 5.310
1998 10. 4.381
1998 11. 4.680
1998 12. 3.080
1999 1.0 2.150
1999 2.0 2.340
1999 3.0 1.968
1999 4.0 1.610
1999 5.0 2.240
1999 6.0 2.780
1999 7.0 3.840
1999 8.0 2.730
1999 9.0 4.290
1999 10. 4.460
1999 11. 1.110
1999 11. 4.430
2000 1.0 2.590
2000 2.0 3.060
2000 3.0 3.220
2000 4.0 3.690
2000 5.0 3.645
2000 6.0 1.849
2000 7.0 2.767
2000 8.0 3.431
2000 9.0 3.810
2000 10. 2.370
2000 10. 2.240
2001 1.0 1.830
2001 2.0 1.812
2001 3.0 1.223
2001 5.0 2.878
2001 6.0 3.897
2001 7.0 2.980
2001 8.0 3.254
2001 9.0 3.104
2001 10. 4.001
2001 11. 3.937
2001 12. 2.794
2002 1.0 2.047
2002 2.0 2.479
2002 3.0 2.011

2002 4.0 1.510
2002 5.0 2.140
2002 6.0 2.233
2002 7.0 2.672
2002 8.0 1.502
2002 9.0 2.857
2002 10. 3.410
2002 11. 1.540
2002 12. 3.550
2003 1.0 2.330
2003 2.0 2.540
2003 3.0 1.960
2003 4.0 1.940
2003 5.0 2.180
2003 6.0 3.150
2003 7.0 1.340
2003 8.0 3.860
2003 9.0 3.490
2003 10. 1.200
2003 11. 3.850
2003 12. 2.260
2004 1.0 2.260
2004 2.0 1.850
2004 3.0 1.630
2004 4.0 2.320
2004 5.0 0.883
2004 6.0 3.430
2004 7.0 1.810
2004 8.0 4.400
2004 9.0 3.840
2004 10. 4.200
2004 11. 1.500
2004 12. 0.940
2005 1.0 0.556
2005 2.0 1.990
2005 3.0 1.690
2005 4.0 2.160
2005 5.0 2.620
2005 6.0 3.300
2005 7.0 2.660
2005 8.0 4.420
2005 9.0 4.370
2005 10. 3.800
2005 11. 4.220
2005 12. 2.970
2006 1.0 1.330
2006 2.0 2.120
2006 2.0 2.260
2006 4.0 2.180
2006 5.0 1.570
2006 6.0 3.150
2006 7.0 1.560
2006 8.0 4.540
2006 9.0 3.190

2006 10. 1.110
2006 11. 1.990
2006 12. 1.350
2007 1.0 1.790
2007 2.0 2.050
2007 3.0 2.010
2007 4.0 4.590
2007 5.0 2.340
2007 6.0 6.080
2007 7.0 2.160
2007 8.0 6.290
2007 9.0 5.250
2007 10. 2.360
2007 11. 3.620
2007 12. 2.020
2008 1.0 1.300
2008 2.0 3.670
2008 3.0 1.920
2008 4.0 1.950
2008 5.0 2.880
2008 6.0 2.230
2008 7.0 2.450
2008 8.0 4.930
2008 9.0 2.090
2008 10. 1.260
2008 11. 3.180
2008 12. 1.140
2009 1.0 2.300
2009 2.0 1.180
2009 3.0 1.610
2009 4.0 1.980
2009 5.0 1.510
2009 6.0 2.300
2009 7.0 1.750
2009 8.0 1.810
2009 9.0 3.010
2009 10. 1.550
2009 11. 1.120
2009 12. 2.030
2010 1.0 1.350
2010 2.0 1.280
2010 3.0 1.200
2010 4.0 1.470
2010 5.0 1.290
2010 6.0 2.410
2010 7.0 1.250
2010 8.0 2.670
2010 9.0 3.380
2010 10. 3.010
2010 11. 2.820
2010 12. 3.760
2011 1.0 2.350
2011 2.0 1.500
2011 3.0 1.510

2011 4.0 2.470
2011 5.0 1.490
2011 6.0 2.290
2011 7.0 2.160
2011 8.0 2.810
2011 9.0 3.250
2011 10. 7.300
2011 11. 3.070
2011 12. 0.900
2012 1.0 1.710
2012 2.0 2.270
2012 3.0 1.030
2012 4.0 1.620
2012 5.0 3.160
2012 6.0 3.370
2012 7.0 2.550
2012 8.0 0.431
2012 9.0 2.350
2012 10. 6.600
2012 11. 0.416
2012 12. 0.720
2013 1.0 2.600
2013 2.0 1.990
2013 3.0 2.160
2013 4.0 2.290
2013 5.0 4.070
2013 6.0 2.200
2013 7.0 2.320
2013 8.0 1.930
2013 9.0 3.850
2013 10. 3.590
2013 11. 2.400
2013 12. 1.850
2014 1.0 1.620
2014 2.0 1.150
2014 3.0 0.994
2014 4.0 1.430
2014 5.0 0.229
2014 6.0 1.190
2014 7.0 0.988
2014 8.0 2.230
2014 9.0 2.580
2014 10. 3.240
2014 11. 1.810
2014 12. 2.320
2015 1.0 1.380
2015 2.0 1.330
2015 3.0 1.210
2015 4.0 0.998
2015 5.0 1.350
2015 6.0 1.760
2015 7.0 1.590
2015 8.0 1.930
2015 8.0 0.643

2015 9.0 2.180
2015 10. 2.400
2015 11. 2.220
2015 11. 2.000
2016 1.0 1.640
2016 2.0 1.770
2016 3.0 1.470
2016 4.0 1.530
2016 5.0 0.589
2016 6.0 1.400
2016 7.0 2.360
2016 8.0 1.100
2016 9.0 2.700
2016 10. 4.080
2016 11. 0.669
2016 12. 1.700
2017 1.0 7.050
2017 2.0 1.010
2017 3.0 2.290
2017 4.0 1.940
2017 6.0 1.960
2017 7.0 4.300
2017 8.0 0.754
2017 9.0 3.850
2017 10. 6.450
2017 11. 3.740
2017 12. 4.730

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DNOx WHI0065 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is -0.353
S = -1181.
z = -8.385
p = 0.0000
p = 0.0001 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 3.414 + -0.8106E-01 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DNOx WHI0065 1999-2017
1999 1.0 2.150
1999 2.0 2.340
1999 3.0 1.968
1999 4.0 1.610
1999 5.0 2.240
1999 6.0 2.780
1999 7.0 3.840
1999 8.0 2.730
1999 9.0 4.290
1999 10. 4.460
1999 11. 1.110
1999 11. 4.430
2000 1.0 2.590
2000 2.0 3.060
2000 3.0 3.220
2000 4.0 3.690
2000 5.0 3.645
2000 6.0 1.849
2000 7.0 2.767
2000 8.0 3.431
2000 9.0 3.810
2000 10. 2.370
2000 10. 2.240
2001 1.0 1.830
2001 2.0 1.812
2001 3.0 1.223
2001 5.0 2.878
2001 6.0 3.897
2001 7.0 2.980
2001 8.0 3.254
2001 9.0 3.104
2001 10. 4.001
2001 11. 3.937
2001 12. 2.794
2002 1.0 2.047
2002 2.0 2.479
2002 3.0 2.011
2002 4.0 1.510
2002 5.0 2.140
2002 6.0 2.233
2002 7.0 2.672
2002 8.0 1.502
2002 9.0 2.857
2002 10. 3.410
2002 11. 1.540
2002 12. 3.550
2003 1.0 2.330
2003 2.0 2.540
2003 3.0 1.960
2003 4.0 1.940
2003 5.0 2.180
2003 6.0 3.150

2003 7.0 1.340
2003 8.0 3.860
2003 9.0 3.490
2003 10. 1.200
2003 11. 3.850
2003 12. 2.260
2004 1.0 2.260
2004 2.0 1.850
2004 3.0 1.630
2004 4.0 2.320
2004 5.0 0.883
2004 6.0 3.430
2004 7.0 1.810
2004 8.0 4.400
2004 9.0 3.840
2004 10. 4.200
2004 11. 1.500
2004 12. 0.940
2005 1.0 0.556
2005 2.0 1.990
2005 3.0 1.690
2005 4.0 2.160
2005 5.0 2.620
2005 6.0 3.300
2005 7.0 2.660
2005 8.0 4.420
2005 9.0 4.370
2005 10. 3.800
2005 11. 4.220
2005 12. 2.970
2006 1.0 1.330
2006 2.0 2.120
2006 2.0 2.260
2006 4.0 2.180
2006 5.0 1.570
2006 6.0 3.150
2006 7.0 1.560
2006 8.0 4.540
2006 9.0 3.190
2006 10. 1.110
2006 11. 1.990
2006 12. 1.350
2007 1.0 1.790
2007 2.0 2.050
2007 3.0 2.010
2007 4.0 4.590
2007 5.0 2.340
2007 6.0 6.080
2007 7.0 2.160
2007 8.0 6.290
2007 9.0 5.250
2007 10. 2.360
2007 11. 3.620
2007 12. 2.020

2008 1.0 1.300
2008 2.0 3.670
2008 3.0 1.920
2008 4.0 1.950
2008 5.0 2.880
2008 6.0 2.230
2008 7.0 2.450
2008 8.0 4.930
2008 9.0 2.090
2008 10. 1.260
2008 11. 3.180
2008 12. 1.140
2009 1.0 2.300
2009 2.0 1.180
2009 3.0 1.610
2009 4.0 1.980
2009 5.0 1.510
2009 6.0 2.300
2009 7.0 1.750
2009 8.0 1.810
2009 9.0 3.010
2009 10. 1.550
2009 11. 1.120
2009 12. 2.030
2010 1.0 1.350
2010 2.0 1.280
2010 3.0 1.200
2010 4.0 1.470
2010 5.0 1.290
2010 6.0 2.410
2010 7.0 1.250
2010 8.0 2.670
2010 9.0 3.380
2010 10. 3.010
2010 11. 2.820
2010 12. 3.760
2011 1.0 2.350
2011 2.0 1.500
2011 3.0 1.510
2011 4.0 2.470
2011 5.0 1.490
2011 6.0 2.290
2011 7.0 2.160
2011 8.0 2.810
2011 9.0 3.250
2011 10. 7.300
2011 11. 3.070
2011 12. 0.900
2012 1.0 1.710
2012 2.0 2.270
2012 3.0 1.030
2012 4.0 1.620
2012 5.0 3.160
2012 6.0 3.370

2012	7.0	2.550
2012	8.0	0.431
2012	9.0	2.350
2012	10.	6.600
2012	11.	0.416
2012	12.	0.720
2013	1.0	2.600
2013	2.0	1.990
2013	3.0	2.160
2013	4.0	2.290
2013	5.0	4.070
2013	6.0	2.200
2013	7.0	2.320
2013	8.0	1.930
2013	9.0	3.850
2013	10.	3.590
2013	11.	2.400
2013	12.	1.850
2014	1.0	1.620
2014	2.0	1.150
2014	3.0	0.994
2014	4.0	1.430
2014	5.0	0.229
2014	6.0	1.190
2014	7.0	0.988
2014	8.0	2.230
2014	9.0	2.580
2014	10.	3.240
2014	11.	1.810
2014	12.	2.320
2015	1.0	1.380
2015	2.0	1.330
2015	3.0	1.210
2015	4.0	0.998
2015	5.0	1.350
2015	6.0	1.760
2015	7.0	1.590
2015	8.0	1.930
2015	8.0	0.643
2015	9.0	2.180
2015	10.	2.400
2015	11.	2.220
2015	11.	2.000
2016	1.0	1.640
2016	2.0	1.770
2016	3.0	1.470
2016	4.0	1.530
2016	5.0	0.589
2016	6.0	1.400
2016	7.0	2.360
2016	8.0	1.100
2016	9.0	2.700
2016	10.	4.080
2016	11.	0.669

2016 12. 1.700
2017 1.0 7.050
2017 2.0 1.010
2017 3.0 2.290
2017 4.0 1.940
2017 6.0 1.960
2017 7.0 4.300
2017 8.0 0.754
2017 9.0 3.850
2017 10. 6.450
2017 11. 3.740
2017 12. 4.730

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DNOx WHI0065 1999-2017

The record is 20 complete water years with 12 seasons per year
beginning in water year 1999.

The tau correlation coefficient is -0.216
S = -416.
z = -4.376
p = 0.0000
p = 0.0101 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 2.743 + -0.5131E-01 * Time

where Time = Year (as a decimal) - 1998.75
(beginning of first water year)

2 0 DNOx 07060500 1993-2017
1993 1. 0.230
1993 3. 0.210
1993 4. 0.240
1993 6. 0.370
1993 8. 0.400
1993 11 0.290
1993 12 0.280
1994 3. 0.310
1994 4. 0.280
1994 7. 0.240
1994 8. 0.490
1994 10 0.180
1995 1. 0.290
1995 2. 0.220
1995 4. 0.200
1995 7. 0.450
1995 9. 0.430
1995 10 0.170
1995 11 0.100
1996 2. 0.060
1996 4. 0.050
1996 6. 0.140
1996 8. 0.240
1996 10 0.320
1996 12 0.220
1997 2. 0.280
1997 4. 0.200
1997 7. 0.410
1997 8. 0.480
1997 11 0.220
1998 1. 0.400
1998 3. 0.350
1998 4. 0.230
1998 6. 0.340
1998 8. 0.290
1998 11 0.100
1999 1. 0.310
1999 3. 0.240
1999 6. 0.340
1999 7. 0.410
1999 9. 0.450
1999 11 0.170
2000 1. 0.180
2000 3. 0.040
2000 5. 0.030
2000 7. 0.150
2000 8. 0.210
2000 11 0.180
2001 1. 0.190
2001 3. 0.150
2001 5. 0.100
2001 8. 0.170

2001 10 0.180
2001 12 0.250
2002 2. 0.190
2002 4. 0.220
2002 6. 0.330
2002 8. 0.440
2002 10 0.360
2002 12 0.220
2003 3. 0.150
2003 5. 0.160
2003 7. 0.280
2003 8. 0.310
2003 11 0.220
2004 1. 0.170
2004 2. 0.160
2004 4. 0.110
2004 6. 0.260
2004 8. 0.350
2004 10 0.400
2005 1. 0.230
2005 3. 0.270
2005 4. 0.320
2005 6. 0.310
2005 8. 0.340
2005 10 0.230
2006 1. 0.130
2006 3. 0.080
2006 5. 0.190
2006 7. 0.170
2006 8. 0.200
2006 11 0.260
2007 1. 0.250
2007 3. 0.130
2007 4. 0.170
2007 6. 0.210
2007 8. 0.300
2007 11 0.210
2007 12 0.540
2008 2. 0.450
2008 4. 0.300
2008 6. 0.410
2008 8. 0.670
2008 10 0.590
2008 12 0.290
2009 1. 0.320
2009 3. 0.250
2009 4. 0.200
2009 8. 0.410
2009 11 0.590
2010 2. 0.330
2010 3. 0.390
2010 6. 0.420
2010 8. 0.380
2010 10 0.260

2010 12 0.250
2011 2. 0.180
2011 4. 0.170
2011 6. 0.240
2011 8. 0.450
2011 10 0.231
2012 2. 0.443
2012 6. 0.313
2012 8. 0.351
2012 11 0.292
2013 3. 0.384
2013 5. 0.133
2013 9. 0.348
2013 11 0.178
2014 3. 0.214
2014 4. 0.273
2014 7. 0.320
2014 11 0.338
2015 3. 0.383
2015 5. 0.181
2015 12 0.295
2016 3. 0.359
2016 5. 0.168
2016 8. 0.422
2016 11 0.220
2017 2. 0.118
2017 5. 0.369
2017 8. 0.443
2017 11 0.186

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DNOx 07060500 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.138
S =   111.
z =   2.010
p = 0.0445
p = 0.2247 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.2096   +   0.3107E-02 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 DNOx 07060710 1993-2017
1993 1. 0.380
1993 3. 0.240
1993 4. 0.057
1993 5. 0.072
1993 6. 0.059
1993 7. 0.053
1993 8. 0.050
1993 9. 0.057
1993 10 0.110
1993 12 0.065
1993 12 0.180
1994 1. 0.120
1994 2. 0.055
1994 3. 0.078
1994 5. 0.055
1994 6. 0.050
1994 7. 0.050
1994 8. 0.050
1994 8. 0.056
1994 10 0.050
1994 11 0.070
1994 12 0.060
1995 1. 0.070
1995 2. 0.070
1995 3. 0.250
1995 3. 0.060
1995 4. 0.070
1995 5. 0.050
1995 6. 0.050
1995 7. 0.050
1995 8. 0.050
1995 10 0.050
1995 11 0.060
1996 1. 0.050
1996 2. 0.050
1996 4. 0.050
1996 5. 0.070
1996 6. 0.070
1996 7. 0.110
1996 8. 0.080
1996 9. 0.100
1996 10 0.080
1997 2. 0.060
1997 4. 0.080
1997 5. 0.050
1997 6. 0.070
1997 7. 0.050
1997 8. 0.070
1997 9. 0.060
1997 10 0.050
1997 11 0.060
1997 12 0.050

1998 1. 0.170
1998 2. 0.050
1998 3. 0.090
1998 4. 0.050
1998 5. 0.050
1998 6. 0.050
1998 7. 0.050
1998 8. 0.050
1998 9. 0.050
1998 10 0.070
1998 11 0.060
1998 12 0.060
1999 1. 0.070
1999 2. 0.050
1999 3. 0.080
1999 4. 0.080
1999 5. 0.060
1999 6. 0.100
1999 7. 0.060
1999 9. 0.100
1999 10 0.050
1999 11 0.050
1999 12 0.050
2000 1. 0.050
2000 2. 0.050
2000 3. 0.050
2000 4. 0.050
2000 5. 0.060
2000 6. 0.080
2000 7. 0.050
2000 8. 0.050
2000 9. 0.050
2000 10 0.040
2000 11 0.090
2000 12 0.070
2001 2. 0.070
2001 3. 0.070
2001 4. 0.030
2001 5. 0.100
2001 6. 0.050
2001 7. 0.060
2001 8. 0.030
2001 9. 0.060
2001 11 0.040
2001 12 0.100
2002 1. 0.100
2002 2. 0.060
2002 3. 0.070
2002 5. 0.070
2002 7. 0.080
2002 9. 0.070
2002 11 0.060
2002 12 0.040
2003 1. 0.070

2003 2. 0.050
2003 3. 0.070
2003 5. 0.060
2003 7. 0.120
2003 9. 0.100
2003 11 0.030
2003 12 0.070
2004 1. 0.070
2004 2. 0.070
2004 3. 0.040
2004 5. 0.060
2004 7. 0.050
2004 8. 0.040
2004 11 0.070
2005 1. 0.270
2005 3. 0.040
2005 5. 0.040
2005 7. 0.060
2005 9. 0.070
2005 11 0.060
2006 1. 0.040
2006 3. 0.060
2006 5. 0.040
2006 6. 0.048
2006 7. 0.054
2006 9. 0.040
2007 2. 0.054
2007 3. 0.035
2007 5. 0.025
2007 5. 0.014
2007 6. 0.025
2007 7. 0.026
2007 8. 0.037
2007 9. 0.044
2007 10 0.038
2007 12 0.160
2008 1. 0.070
2008 2. 0.080
2008 5. 0.030
2008 6. 0.040
2008 9. 0.040
2009 3. 0.040
2009 4. 0.030
2009 6. 0.070
2009 8. 0.080
2009 11 0.150
2010 2. 0.130
2010 3. 0.140
2010 6. 0.130
2010 8. 0.060
2010 10 0.060
2010 12 0.060
2011 2. 0.050
2011 4. 0.090

2011 6. 0.060
2011 8. 0.080
2011 10 0.060
2011 12 0.137
2012 2. 0.160
2012 4. 0.051
2012 6. 0.058
2012 8. 0.070
2012 11 0.030
2013 1. 0.060
2013 3. 0.080
2013 5. 0.040
2013 7. 0.080
2013 9. 0.040
2013 11 0.030
2014 3. 0.080
2014 4. 0.050
2014 5. 0.030
2014 7. 0.040
2014 9. 0.100
2014 11 0.060
2015 1. 0.050
2015 3. 0.090
2015 5. 0.040
2015 7. 0.030
2015 10 0.060
2015 11 0.060
2015 12 0.070
2016 1. 0.060
2016 1. 0.040
2016 2. 0.040
2016 2. 0.020
2016 3. 0.030
2016 4. 0.020
2016 4. 0.070
2016 5. 0.040
2016 5. 0.050
2016 7. 0.050
2016 7. 0.060
2016 8. 0.090
2016 9. 0.080
2016 10 0.070
2016 11 0.050
2016 12 0.060
2017 1. 0.060
2017 3. 0.050
2017 3. 0.150
2017 4. 0.110
2017 5. 0.130
2017 6. 0.060
2017 6. 0.100
2017 7. 0.070
2017 8. 0.080
2017 9. 0.090

2017 10 0.100
2017 10 0.050
2017 11 0.030
2017 11 0.040

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: DNOx 07060710 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is -0.072
S =   -121.
z = -1.406
p = 0.1597
p = 0.3220 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.6000E-01 +   0.000   * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

ATTACHMENT 4

Total Nitrogen Seasonal Mann-Kendall Input and Output

2 0 TN WHI0011 2000-2017
2000 1. 0.8580
2000 2. 0.9390
2000 3. 0.6500
2000 5. 1.2910
2000 6. 1.2540
2000 8. 0.4700
2000 8. 0.1380
2000 9. 0.0930
2000 10 0.4890
2000 11 1.1350
2000 12 1.4630
2001 1. 1.6400
2001 2. 1.5280
2001 3. 1.1630
2001 4. 0.8930
2001 5. 0.7790
2001 6. 0.5670
2001 7. 0.3110
2001 8. 0.2430
2001 9. 0.3530
2001 10 0.5970
2001 11 0.4750
2001 12 1.0650
2002 2. 0.8790
2002 3. 1.7160
2002 4. 0.6000
2002 5. 0.7530
2002 6. 0.8550
2002 7. 0.8400
2002 8. 0.2450
2002 9. 0.3760
2002 10 0.3830
2002 11 0.6620
2002 12 1.4320
2003 1. 0.4120
2003 4. 0.6690
2003 4. 0.7360
2003 5. 0.6180
2003 6. 0.7910
2003 7. 0.8870
2003 8. 0.7530
2003 9. 0.6490
2003 10 0.7070
2003 11 0.9820
2003 12 0.9960
2004 1. 0.9900
2004 2. 0.6330
2004 3. 0.8800
2004 5. 0.6460
2004 6. 0.5800
2004 7. 0.4850
2004 8. 0.3900

2004 9. 0.1500
2004 10 1.2200
2004 11 0.9970
2004 12 1.0500
2005 1. 1.0300
2005 2. 0.7410
2005 3. 0.5230
2005 4. 0.5910
2005 5. 0.4860
2005 5. 0.6530
2005 7. 0.3500
2005 8. 0.2990
2005 9. 0.7140
2005 11 1.0900
2005 12 0.7160
2006 1. 1.0800
2006 2. 0.5060
2006 3. 0.5980
2006 4. 0.4630
2006 5. 0.7310
2006 6. 0.4380
2006 7. 0.2890
2006 8. 0.1590
2006 9. 0.1650
2006 10 1.2800
2006 11 1.0100
2006 12 0.9560
2007 1. 0.9030
2007 2. 1.1300
2007 3. 0.7910
2007 4. 0.4260
2007 5. 0.3240
2007 6. 0.2950
2007 7. 0.5910
2007 8. 0.3740
2007 9. 0.7600
2007 10 0.5500
2007 11 0.4130
2007 12 0.6870
2008 1. 1.0100
2008 2. 1.2600
2008 3. 1.1100
2008 4. 0.7700
2008 5. 0.4990
2008 6. 0.6290
2008 7. 0.4110
2008 8. 0.3700
2008 9. 1.3000
2008 10 0.6650
2008 11 0.7840
2009 1. 0.7370
2009 2. 0.7760
2009 3. 0.4580
2009 4. 0.6770

2009 5. 0.6100
2009 6. 0.6700
2009 7. 0.4850
2009 8. 0.4690
2009 9. 1.0700
2009 10 1.0400
2009 11 0.8150
2009 12 0.4900
2010 1. 0.7780
2010 2. 0.6140
2010 3. 0.7900
2010 4. 0.7660
2010 5. 0.7100
2010 6. 0.7280
2010 7. 0.4780
2010 8. 0.4420
2010 9. 0.3720
2010 10 0.6300
2010 11 0.4750
2010 12 0.6500
2011 1. 0.5920
2011 2. 0.9010
2011 3. 1.2300
2011 4. 1.0800
2011 5. 0.8110
2011 6. 0.5000
2011 7. 0.4230
2011 8. 0.3840
2011 9. 0.3450
2011 10 0.4000
2011 11 0.4160
2011 12 1.2300
2012 1. 0.9190
2012 2. 0.9050
2012 3. 0.7830
2012 4. 0.5310
2012 5. 0.5460
2012 6. 0.5370
2012 7. 0.2490
2012 8. 0.1830
2012 9. 0.3160
2012 10 0.5210
2012 11 0.3550
2012 12 0.5780
2013 1. 1.5200
2013 2. 1.0900
2013 3. 1.3000
2013 4. 0.5510
2013 5. 0.4050
2013 6. 1.1800
2013 7. 0.5270
2013 8. 1.0400
2013 9. 0.6240
2013 10 0.7460

2013 11 0.7240
2013 12 0.7330
2014 1. 1.3900
2014 2. 0.9370
2014 3. 1.0500
2014 4. 0.9500
2014 5. 0.8690
2014 6. 0.8330
2014 7. 0.7100
2014 8. 0.6240
2014 9. 0.6650
2014 10 0.7340
2014 11 0.5280
2014 12 0.6590
2015 1. 1.8200
2015 2. 0.8660
2015 3. 0.7110
2015 4. 0.9390
2015 5. 0.6070
2015 6. 0.8150
2015 7. 0.7190
2015 8. 0.5670
2015 9. 0.3380
2015 10 0.5340
2015 11 0.8450
2016 1. 1.1400
2016 2. 0.5180
2016 3. 0.4740
2016 4. 0.4140
2016 5. 0.6940
2016 6. 0.7020
2016 7. 0.7300
2016 8. 1.2900
2016 9. 0.6940
2016 10 0.8340
2016 11 1.0600
2016 12 0.8860
2017 1. 0.8810
2017 2. 0.6570
2017 3. 0.9620
2017 4. 0.6960
2017 6. 0.8910
2017 7. 0.6700
2017 8. 0.4320
2017 9. 0.6710
2017 10 0.5060
2017 11 0.3910
2017 12 0.4680

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TN WHI0011 2000-2017

The record is 19 complete water years with 12 seasons per year
beginning in water year 2000.

The tau correlation coefficient is 0.001
S =   1.
z =   0.000
p = 1.0000
p = 1.0000 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.6940   +   0.000   * Time

where Time = Year (as a decimal) - 1999.75
(beginning of first water year)

2 0 TN WHI0029 2000-2017
2000 1. 0.4320
2000 2. 0.6680
2000 3. 0.3970
2000 6. 0.9600
2000 8. 0.5690
2000 8. 0.3180
2000 9. 0.4040
2000 10 0.3340
2000 11 0.3420
2000 12 0.5200
2001 1. 0.4000
2001 2. 0.4260
2001 3. 1.0570
2001 4. 0.5800
2001 5. 0.3510
2001 6. 0.3880
2001 7. 0.3560
2001 8. 0.1850
2001 9. 0.3610
2001 10 0.4080
2001 11 0.4190
2001 12 0.5540
2002 1. 0.6850
2002 2. 0.6090
2002 3. 0.5750
2002 5. 0.5470
2002 6. 1.0060
2002 7. 0.7730
2002 8. 0.5400
2002 9. 0.6660
2002 10 0.7470
2002 11 0.6140
2002 12 0.8930
2003 3. 0.5720
2003 4. 0.5590
2003 4. 0.4720
2003 5. 0.3870
2003 6. 0.5890
2003 7. 0.5460
2003 8. 0.5440
2003 9. 0.5580
2003 10 0.5590
2003 11 0.9580
2003 12 0.4930
2004 1. 0.4360
2004 2. 0.4030
2004 3. 0.6700
2004 5. 0.5600
2004 6. 0.4650
2004 7. 0.6060
2004 8. 0.5100
2004 9. 0.5030

2004 10 0.5230
2004 11 0.7110
2004 12 0.4770
2005 1. 0.5010
2005 2. 0.5420
2005 3. 0.7110
2005 4. 0.6620
2005 5. 0.4680
2005 7. 0.5040
2005 8. 0.5700
2005 9. 0.5290
2005 11 0.3940
2005 12 0.4760
2006 1. 0.3620
2006 2. 0.3370
2006 3. 0.3490
2006 4. 0.3460
2006 5. 0.3580
2006 6. 0.2120
2006 7. 0.4090
2006 8. 0.4080
2006 9. 0.2970
2006 10 0.4220
2006 11 0.5430
2006 12 0.6540
2007 1. 0.4270
2007 2. 0.9280
2007 3. 0.5230
2007 4. 0.3660
2007 5. 0.3670
2007 6. 0.2950
2007 7. 0.4200
2007 8. 0.4050
2007 9. 0.7360
2007 10 0.4450
2007 11 0.5310
2007 12 0.4520
2008 1. 0.4390
2008 2. 0.9290
2008 3. 0.4680
2008 4. 0.6340
2008 5. 0.5130
2008 6. 0.5850
2008 7. 0.6810
2008 8. 0.7930
2008 9. 0.9700
2008 10 0.6770
2008 11 0.6420
2009 1. 0.4590
2009 2. 0.5020
2009 3. 0.7110
2009 4. 0.5990
2009 5. 0.5340
2009 6. 0.4580

2009 7. 0.5530
2009 8. 0.5840
2009 9. 0.8410
2009 10 0.8270
2009 11 0.6290
2009 12 0.4190
2010 1. 0.5270
2010 2. 0.6020
2010 3. 0.6990
2010 4. 0.6550
2010 5. 0.4350
2010 6. 0.6270
2010 7. 0.7030
2010 8. 0.6210
2010 9. 0.9050
2010 10 0.5800
2010 10 0.4840
2010 11 0.5470
2010 11 0.5920
2011 1. 0.4320
2011 2. 0.6350
2011 3. 0.6320
2011 4. 0.9940
2011 5. 0.7500
2011 6. 0.6120
2011 7. 0.6090
2011 8. 0.6160
2011 9. 0.7940
2011 11 0.4930
2011 12 0.5370
2012 1. 0.8580
2012 2. 0.3660
2012 3. 0.6220
2012 4. 0.5820
2012 5. 0.8500
2012 6. 0.6090
2012 7. 0.4660
2012 8. 0.4500
2012 9. 0.4900
2012 10 0.3720
2012 11 0.3850
2012 12 0.4190
2013 1. 0.5740
2013 2. 0.5610
2013 3. 0.6030
2013 4. 0.4230
2013 5. 0.3530
2013 6. 0.4730
2013 7. 0.5970
2013 8. 0.5340
2013 9. 0.5630
2013 10 0.4950
2013 11 0.4500
2013 12 0.4210

2014 1. 0.5850
2014 2. 0.4610
2014 3. 0.5530
2014 4. 0.5460
2014 5. 0.3480
2014 6. 0.6340
2014 7. 0.5010
2014 8. 0.4290
2014 9. 0.5070
2014 10 0.5880
2014 11 0.3950
2014 12 0.4220
2015 1. 0.4720
2015 2. 0.4420
2015 3. 0.8860
2015 4. 0.3010
2015 5. 0.3680
2015 6. 0.5690
2015 7. 0.6160
2015 8. 0.5580
2015 9. 0.7500
2015 10 0.6510
2015 11 0.6820
2015 11 0.6650
2015 12 0.6340
2016 1. 0.5590
2016 2. 0.6810
2016 3. 0.5650
2016 4. 0.5230
2016 5. 0.6990
2016 6. 0.5030
2016 7. 0.5600
2016 8. 0.5250
2016 9. 0.6790
2016 10 2.5900
2016 11 0.5090
2016 11 11.309
2016 11 0.8780
2016 11 1.7500
2016 11 12.550
2016 11 2.1190
2016 11 0.4050
2016 11 11.205
2016 11 0.7740
2016 12 0.4110
2017 1. 0.4560
2017 2. 0.4790
2017 3. 0.3910
2017 4. 0.6210
2017 5. 0.6580
2017 6. 0.4740
2017 7. 0.4430
2017 8. 0.5970
2017 9. 0.5910

2017	10	0.5100
2017	11	0.4710
2017	12	0.3230

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TN WHI0029 2000-2017

The record is 19 complete water years with 12 seasons per year
beginning in water year 2000.

The tau correlation coefficient is 0.053
S = 86.
z = 1.007
p = 0.3140
p = 0.5829 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.5189 + 0.1750E-02 * Time

where Time = Year (as a decimal) - 1999.75
(beginning of first water year)

2 0 TN WHI0046 2000-2017
2000 1. 0.4260
2000 3. 0.1290
2000 4. 0.2010
2000 5. 0.7980
2000 6. 0.6990
2000 7. 0.2030
2000 8. 0.2680
2000 10 0.3160
2000 10 0.2550
2001 1. 0.3090
2001 2. 0.4080
2001 3. 0.3900
2001 5. 0.4140
2001 6. 1.4670
2001 7. 0.4160
2001 8. 0.5620
2001 9. 0.3440
2001 10 0.4640
2001 11 0.6130
2001 12 0.5520
2002 1. 0.7690
2002 2. 0.6810
2002 3. 0.3720
2002 4. 0.6460
2002 5. 0.5500
2002 6. 0.5090
2002 7. 0.7980
2002 8. 0.6390
2002 9. 0.7830
2002 10 0.6450
2002 11 1.0680
2002 12 0.4350
2003 1. 0.6360
2003 2. 0.4570
2003 3. 0.5760
2003 4. 0.4430
2003 5. 0.3510
2003 6. 0.5080
2003 7. 0.5360
2003 8. 0.6890
2003 9. 0.7390
2003 10 1.4870
2003 12 0.4760
2004 1. 0.3280
2004 2. 0.4370
2004 3. 0.4640
2004 4. 0.3440
2004 5. 0.3910
2004 6. 0.4690
2004 7. 0.5280
2004 8. 0.7270
2004 9. 0.5230

2004 10 0.6720
2004 11 0.7240
2004 12 0.5280
2005 1. 1.1200
2005 2. 0.6120
2005 3. 0.4480
2005 4. 0.4780
2005 5. 0.5320
2005 6. 0.6920
2005 7. 0.5880
2005 8. 0.5570
2005 9. 0.5630
2005 10 0.6890
2005 11 0.3780
2005 12 0.6500
2006 1. 0.3270
2006 2. 0.4720
2006 2. 0.2210
2006 4. 0.5380
2006 5. 0.6430
2006 6. 0.6170
2006 7. 0.4260
2006 8. 0.4970
2006 9. 0.4100
2006 10 0.5950
2006 11 0.6470
2006 12 0.6400
2007 1. 0.5710
2007 2. 0.4260
2007 3. 0.3610
2007 4. 0.4140
2007 5. 0.2840
2007 6. 0.4700
2007 7. 0.4410
2007 8. 0.5260
2007 9. 1.1400
2007 10 0.5950
2007 11 0.4430
2007 12 0.4100
2008 1. 0.4430
2008 2. 0.5130
2008 3. 0.6470
2008 4. 0.5540
2008 5. 0.7430
2008 6. 0.6050
2008 7. 0.6880
2008 8. 0.8780
2008 9. 0.9420
2008 10 0.8260
2008 11 0.6210
2008 12 0.5660
2009 1. 0.4440
2009 2. 0.3910
2009 3. 0.4960

2009 4. 0.4380
2009 5. 0.5970
2009 6. 0.5380
2009 7. 0.6640
2009 8. 0.7120
2009 9. 0.6760
2009 10 0.6660
2009 11 0.5440
2009 12 0.4770
2010 1. 0.6200
2010 2. 0.6660
2010 3. 0.5900
2010 4. 0.7860
2010 5. 0.6020
2010 6. 0.6760
2010 7. 0.7400
2010 8. 0.7750
2010 9. 0.8240
2010 10 0.7930
2010 11 0.6530
2010 12 0.5050
2011 1. 0.4640
2011 2. 0.3830
2011 3. 0.5640
2011 4. 0.4860
2011 5. 0.7940
2011 6. 0.5590
2011 7. 0.5480
2011 8. 1.0100
2011 9. 0.7250
2011 10 0.7900
2011 11 0.5650
2011 12 0.8530
2012 1. 0.5710
2012 2. 0.6800
2012 3. 0.5750
2012 4. 0.5460
2012 5. 0.4960
2012 6. 0.6590
2012 7. 0.5550
2012 8. 0.4580
2012 9. 0.6390
2012 10 0.5920
2012 11 0.7460
2012 12 0.5030
2013 1. 0.4520
2013 2. 0.4550
2013 3. 0.4060
2013 4. 0.4440
2013 5. 0.2600
2013 6. 0.4540
2013 7. 0.4920
2013 8. 0.8750
2013 9. 0.6460

2013 10 0.6210
2013 11 0.6850
2013 12 0.5430
2014 1. 0.5050
2014 2. 0.4720
2014 3. 0.8450
2014 4. 0.5830
2014 5. 0.4640
2014 6. 0.5410
2014 7. 0.4780
2014 8. 0.4900
2014 9. 0.6910
2014 10 0.6250
2014 11 0.4950
2014 12 0.4170
2015 1. 1.0000
2015 2. 0.4680
2015 3. 0.6970
2015 4. 0.4590
2015 5. 0.4090
2015 6. 0.4800
2015 7. 0.5730
2015 8. 0.5830
2015 9. 0.8660
2015 10 0.8890
2015 11 0.5230
2016 1. 0.8410
2016 2. 0.5340
2016 3. 0.4520
2016 4. 0.3830
2016 5. 0.3830
2016 6. 0.6080
2016 7. 0.5750
2016 8. 0.4640
2016 9. 0.6790
2016 10 0.7430
2016 11 0.4660
2016 12 0.3710
2017 1. 0.3750
2017 2. 0.4380
2017 3. 0.5440
2017 4. 0.3820
2017 6. 0.5080
2017 7. 0.4840
2017 8. 0.5710
2017 9. 0.8970
2017 10 0.3660
2017 11 0.2560
2017 12 0.2930

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TN WHI0046 2000-2017

The record is 19 complete water years with 12 seasons per year
beginning in water year 2000.

The tau correlation coefficient is 0.023
S =   38.
z =   0.430
p = 0.6674
p = 0.7588 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.5333   +   0.1333E-02 * Time

where Time = Year (as a decimal) - 1999.75
(beginning of first water year)

2 0 TN WHI0065 2000-2017
2000 1. 3.5770
2000 3. 3.3850
2000 4. 4.5100
2000 5. 4.2560
2000 6. 2.1380
2000 7. 2.9780
2000 8. 4.2460
2000 10 2.9540
2000 10 2.6810
2001 1. 2.5400
2001 2. 1.9920
2001 3. 1.5230
2001 5. 3.5460
2001 6. 6.3870
2001 7. 3.5460
2001 8. 3.9000
2001 9. 3.4140
2001 10 4.5650
2001 11 4.5890
2001 12 3.0070
2002 2. 2.5780
2002 4. 1.8680
2002 5. 2.7000
2002 6. 3.0960
2002 7. 3.8810
2002 8. 2.3320
2002 9. 3.9230
2002 10 4.1860
2002 11 2.3680
2003 4. 2.4040
2003 6. 3.8530
2003 7. 2.1150
2003 9. 4.1700
2003 10 1.8310
2003 11 4.5300
2003 12 2.4530
2004 1. 2.5570
2004 2. 2.4060
2004 3. 1.7660
2004 4. 2.7230
2004 5. 1.0230
2004 6. 3.8500
2004 7. 2.2900
2004 8. 5.2300
2004 9. 4.3400
2004 10 4.9500
2004 11 2.0200
2004 12 1.3000
2005 1. 1.2300
2005 2. 2.3300
2005 3. 2.0800
2005 4. 2.1600

2005 5. 3.0400
2005 6. 4.1000
2005 7. 3.4800
2005 8. 5.3000
2005 9. 5.0500
2005 10 4.2500
2005 11 4.6000
2005 12 4.8100
2006 1. 1.8700
2006 2. 2.4900
2006 2. 2.7000
2006 4. 2.9200
2006 5. 2.1000
2006 6. 4.0800
2006 7. 2.2500
2006 8. 5.1200
2006 9. 3.8400
2006 10 1.5400
2006 11 2.3200
2006 12 1.6100
2007 1. 1.9600
2007 2. 2.4500
2007 3. 2.3100
2007 4. 6.1000
2007 5. 2.8900
2007 6. 6.6500
2007 7. 2.5300
2007 8. 7.0000
2007 9. 6.0500
2007 10 2.8900
2007 11 4.1450
2007 12 2.1000
2008 1. 1.6200
2008 2. 4.2600
2008 3. 2.1100
2008 4. 2.2400
2008 5. 3.3500
2008 6. 2.7800
2008 7. 2.8300
2008 8. 5.2000
2008 9. 2.8400
2008 10 1.5000
2008 11 3.8000
2008 12 1.6700
2009 1. 2.7500
2009 2. 1.5700
2009 3. 2.2400
2009 4. 2.6300
2009 5. 1.8400
2009 6. 2.7800
2009 7. 2.0200
2009 8. 2.4000
2009 9. 3.4800
2009 10 1.8700

2009 11 1.5000
2009 12 2.6000
2010 1. 1.8800
2010 2. 1.6000
2010 3. 1.6900
2010 4. 1.9200
2010 5. 1.7900
2010 6. 2.9500
2010 7. 1.7900
2010 8. 3.4400
2010 9. 4.0400
2010 10 3.7500
2010 11 3.5900
2010 12 4.4850
2011 1. 3.2900
2011 2. 1.9500
2011 3. 1.8900
2011 4. 3.1700
2011 5. 2.0000
2011 6. 2.7600
2011 7. 2.8200
2011 8. 3.5700
2011 9. 3.7300
2011 10 7.7500
2011 11 3.8200
2011 12 1.3000
2012 1. 2.3300
2012 2. 2.6000
2012 3. 1.5600
2012 4. 2.0300
2012 5. 4.1350
2012 6. 3.8350
2012 7. 3.8500
2012 8. 0.5550
2012 9. 2.9400
2012 10 7.5000
2012 11 0.6720
2012 12 1.3000
2013 1. 3.3900
2013 2. 2.2000
2013 3. 2.4800
2013 4. 2.7600
2013 5. 4.6850
2013 6. 2.6700
2013 7. 2.9600
2013 8. 2.2400
2013 9. 4.4500
2013 10 4.2350
2013 11 3.1300
2013 12 2.4100
2014 1. 1.9200
2014 2. 1.6900
2014 3. 1.4100
2014 4. 2.0600

2014 5. 0.4820
2014 6. 1.9600
2014 7. 1.4200
2014 8. 2.8600
2014 9. 3.3800
2014 10 3.8100
2014 11 2.4600
2014 12 3.0300
2015 1. 1.7500
2015 2. 2.0000
2015 3. 1.5700
2015 4. 1.6100
2015 5. 1.7800
2015 6. 2.1700
2015 7. 2.0600
2015 8. 2.3350
2015 8. 3.9830
2015 9. 3.2200
2015 10 3.5400
2015 11 2.9000
2015 11 2.5700
2016 1. 1.8000
2016 2. 2.4500
2016 3. 1.9340
2016 4. 1.7800
2016 5. 1.0600
2016 6. 1.8200
2016 7. 2.7600
2016 8. 1.4500
2016 9. 2.7000
2016 10 4.5450
2016 11 1.2000
2016 12 2.1500
2017 1. 8.0500
2017 2. 1.5300
2017 3. 2.4800
2017 4. 2.5700
2017 6. 2.3100
2017 7. 4.5300
2017 8. 1.2900
2017 9. 8.2500
2017 10 7.2500
2017 11 4.2700
2017 12 5.8000

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TN WHI0065 2000-2017

The record is 19 complete water years with 12 seasons per year
beginning in water year 2000.

The tau correlation coefficient is -0.163
S =   -257.
z = -3.119
p = 0.0018
p = 0.0335 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y =   3.136   + -0.4750E-01 * Time

where Time = Year (as a decimal) - 1999.75
(beginning of first water year)

2 0 TN 07060500 2000-2017
2000 1. 0.400
2000 3. 0.240
2000 5. 0.230
2000 7. 0.350
2000 8. 0.430
2000 11 0.660
2001 1. 0.490
2001 3. 0.370
2001 5. 0.330
2001 8. 0.370
2001 10 0.480
2001 12 0.450
2002 2. 0.590
2002 4. 0.420
2002 6. 0.830
2002 8. 0.640
2002 10 0.660
2002 12 0.620
2003 3. 0.350
2003 5. 0.360
2003 7. 0.480
2003 8. 0.510
2003 11 0.620
2004 1. 0.470
2004 2. 0.360
2004 4. 0.310
2004 6. 0.460
2004 8. 0.570
2004 10 0.590
2005 1. 0.410
2005 3. 0.450
2005 4. 0.560
2005 6. 0.550
2005 8. 0.540
2005 10 0.410
2006 1. 0.400
2006 3. 0.300
2006 5. 0.380
2006 7. 0.420
2006 8. 0.410
2006 11 0.520
2007 1. 0.460
2007 3. 0.320
2007 4. 0.320
2007 6. 0.440
2007 8. 0.540
2007 11 0.390
2007 12 0.770
2008 2. 0.660
2008 4. 0.580
2008 6. 0.610
2008 8. 0.870

2008 10 0.790
2008 12 0.500
2009 1. 0.500
2009 3. 0.430
2009 4. 0.400
2009 8. 0.650
2009 11 0.770
2010 2. 0.480
2010 3. 0.580
2010 6. 0.620
2010 8. 0.610
2010 10 0.520
2010 12 0.470
2011 2. 0.350
2011 4. 0.600
2011 6. 0.440
2011 8. 0.600
2011 10 0.540
2012 2. 0.560
2012 6. 0.540
2012 8. 0.550
2012 11 0.470
2013 3. 0.580
2013 5. 0.370
2013 9. 0.560
2013 11 0.440
2014 3. 0.360
2014 4. 0.570
2014 7. 1.400
2014 11 0.530
2015 3. 0.590
2015 5. 0.430
2015 12 0.510
2016 3. 0.580
2016 5. 0.320
2016 8. 0.660
2016 11 0.450
2017 2. 0.270
2017 5. 0.530
2017 8. 0.680
2017 11 0.390

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TN 07060500 2000-2017

The record is 19 complete water years with 12 seasons per year
beginning in water year 2000.

The tau correlation coefficient is 0.227
S =   87.
z =   2.588
p = 0.0097
p = 0.0486 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.4188   +   0.7500E-02 * Time

where Time = Year (as a decimal) - 1999.75
(beginning of first water year)

ATTACHMENT 5

Total Phosphorus Seasonal Mann-Kendall Input and Output

2 0 TP WHI0011 1993-2017
1993 5. 0.1110
1993 7. 0.0740
1993 8. 0.0637
1993 9. 0.0606
1993 10 0.0744
1993 11 0.0650
1993 12 0.1100
1994 1. 0.0740
1994 2. 0.4480
1994 3. 0.0000
1994 4. 0.0316
1994 5. 0.0423
1994 6. 0.0712
1994 7. 0.1080
1994 8. 0.0873
1994 9. 0.0481
1994 10 0.0428
1994 11 0.1210
1994 12 0.0566
1995 1. 0.0389
1995 2. 0.0383
1995 3. 0.0384
1995 4. 0.1080
1995 5. 0.0372
1995 6. 0.0559
1995 7. 0.0751
1995 8. 0.0870
1995 9. 0.0810
1995 10 0.0700
1995 11 0.0500
1995 12 0.1000
1996 1. 0.0000
1996 2. 0.0000
1996 4. 0.0760
1996 5. 0.1160
1996 6. 0.0650
1996 7. 0.0600
1996 8. 0.0720
1996 9. 0.1200
1996 10 0.0340
1996 11 0.0610
1996 12 0.0390
1997 1. 0.0000
1997 2. 0.0320
1997 3. 0.0000
1997 4. 0.0310
1997 5. 0.0550
1997 6. 0.0900
1997 7. 0.0600
1997 8. 0.0700
1997 9. 0.0860
1997 11 0.0800

1997 12 0.0640
1998 1. 0.0000
1998 2. 0.1060
1998 3. 0.0710
1998 4. 0.0490
1998 5. 0.0600
1998 10 0.0600
1998 12 0.0360
1999 1. 0.0500
1999 2. 0.0360
1999 3. 0.0390
1999 4. 0.0950
1999 5. 0.0460
1999 7. 0.0500
1999 8. 0.0640
1999 9. 0.0540
1999 11 0.0840
1999 12 0.0940
2000 1. 0.0230
2000 2. 0.0990
2000 3. 0.0640
2000 5. 0.0420
2000 6. 0.0410
2000 8. 0.1110
2000 8. 0.0560
2000 9. 0.0000
2000 10 0.0340
2000 11 0.0870
2000 12 0.0300
2001 1. 0.0300
2001 2. 0.0240
2001 3. 0.0300
2001 4. 0.0510
2001 5. 0.0710
2001 6. 0.0500
2001 7. 0.0000
2001 8. 0.0000
2001 9. 0.0560
2001 10 0.0640
2001 11 0.0390
2001 12 0.0320
2002 1. 0.0470
2002 2. 0.0000
2002 3. 0.3600
2002 4. 0.0200
2002 5. 0.0360
2002 6. 0.0660
2002 7. 0.0560
2002 8. 0.0700
2002 9. 0.0590
2002 10 0.0940
2002 11 0.1070
2002 12 0.1400
2003 1. 0.0000

2003 3. 0.0000
2003 4. 0.0550
2003 4. 0.0950
2003 5. 0.0430
2003 6. 0.0590
2003 7. 0.0590
2003 8. 0.0660
2003 9. 0.3100
2003 10 0.1260
2003 11 0.0580
2003 12 0.0300
2004 1. 0.0000
2004 2. 0.0000
2004 3. 0.0000
2004 5. 0.0470
2004 6. 0.0520
2004 7. 0.0470
2004 8. 0.0390
2004 9. 0.0270
2004 10 0.1870
2004 11 0.0600
2004 12 0.0260
2005 1. 0.0370
2005 2. 0.0400
2005 3. 0.0280
2005 4. 0.0410
2005 5. 0.0340
2005 5. 0.0540
2005 7. 0.0360
2005 8. 0.0590
2005 9. 0.0830
2005 10 0.0480
2005 11 0.0920
2005 12 0.0660
2006 1. 0.0810
2006 2. 0.0640
2006 3. 0.0460
2006 4. 0.0710
2006 5. 0.0830
2006 6. 0.1050
2006 7. 0.0840
2006 8. 0.0670
2006 9. 0.0850
2006 10 0.1180
2006 11 0.0730
2006 12 0.0660
2007 1. 0.0370
2007 2. 0.1500
2007 3. 0.0450
2007 4. 0.0600
2007 5. 0.0480
2007 6. 0.0750
2007 7. 0.1010
2007 8. 0.0950

2007 9. 0.1010
2007 10 0.1040
2007 11 0.1030
2007 12 0.1200
2008 1. 0.0540
2008 2. 0.2400
2008 3. 0.1850
2008 4. 0.0460
2008 5. 0.0350
2008 6. 0.0600
2008 7. 0.0880
2008 8. 0.0670
2008 9. 0.0520
2008 10 0.0720
2008 11 0.0780
2009 1. 0.0380
2009 2. 0.0440
2009 3. 0.0340
2009 4. 0.0300
2009 5. 0.0530
2009 6. 0.0570
2009 7. 0.0620
2009 8. 0.0660
2009 9. 0.0530
2009 10 0.0610
2009 11 0.0580
2009 12 0.0260
2010 1. 0.0420
2010 2. 0.0370
2010 3. 0.0460
2010 4. 0.0500
2010 5. 0.0380
2010 6. 0.0500
2010 7. 0.0660
2010 8. 0.0720
2010 9. 0.0560
2010 10 0.0750
2010 11 0.0500
2010 12 0.0540
2011 1. 0.0460
2011 2. 0.0550
2011 3. 0.0630
2011 4. 0.0670
2011 5. 0.3920
2011 6. 0.0550
2011 7. 0.0240
2011 8. 0.0580
2011 9. 0.0700
2011 10 0.0710
2011 11 0.0760
2011 12 0.2470
2012 1. 0.0370
2012 2. 0.0400
2012 3. 0.0400

2012 4. 0.0400
2012 5. 0.0780
2012 6. 0.0640
2012 7. 0.0640
2012 8. 0.0640
2012 9. 0.0790
2012 10 0.0850
2012 11 0.0680
2012 12 0.0560
2013 1. 0.0540
2013 2. 0.0470
2013 3. 0.0420
2013 4. 0.0350
2013 5. 0.0440
2013 6. 0.0640
2013 7. 0.0550
2013 8. 0.0710
2013 9. 0.0600
2013 10 0.0590
2013 11 0.0720
2013 12 0.0540
2014 1. 0.0530
2014 2. 0.2390
2014 3. 0.1630
2014 4. 0.2210
2014 5. 0.0570
2014 6. 0.0870
2014 7. 0.0510
2014 8. 0.0580
2014 9. 0.0710
2014 10 0.0830
2014 11 0.0640
2014 12 0.0540
2015 1. 0.0520
2015 2. 0.0260
2015 3. 0.0390
2015 4. 0.0650
2015 5. 0.0350
2015 6. 0.0360
2015 7. 0.0510
2015 8. 0.0600
2015 9. 0.0450
2015 10 0.0570
2015 11 0.0620
2016 1. 0.0460
2016 2. 0.0000
2016 3. 0.0220
2016 4. 0.0300
2016 5. 0.0400
2016 6. 0.0510
2016 7. 0.0550
2016 8. 0.0720
2016 9. 0.0700
2016 10 0.0380

2016 11 0.0930
2016 12 0.0510
2017 1. 0.0720
2017 2. 0.0000
2017 3. 0.0370
2017 4. 0.0320
2017 6. 0.0680
2017 7. 0.0840
2017 8. 0.0380
2017 9. 0.0800
2017 10 0.0670
2017 11 0.0670
2017 12 0.0860

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TP WHI0011 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is -0.030
S = -92.
z = -0.687
p = 0.4924
p = 0.6490 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.5894E-01 + -0.7208E-04 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 TP WHI0029 1993-2017
1993 1. 0.0953
1993 2. 0.0000
1993 3. 0.0000
1993 4. 0.0000
1993 5. 0.0484
1993 6. 0.0426
1993 7. 0.0735
1993 8. 0.0000
1993 9. 0.0000
1993 10 0.0000
1993 11 0.1260
1993 12 0.0692
1994 1. 0.0540
1994 2. 0.0930
1994 3. 0.0000
1994 4. 0.0524
1994 5. 0.0322
1994 6. 0.0410
1994 7. 0.0380
1994 8. 0.0470
1994 9. 0.0000
1994 10 0.0000
1994 11 0.0593
1994 12 0.0357
1995 1. 0.1400
1995 2. 0.0000
1995 3. 0.0000
1995 4. 0.0878
1995 5. 0.0474
1995 6. 0.0559
1995 7. 0.0751
1995 8. 0.0460
1995 9. 0.0400
1995 10 0.0490
1995 11 0.0000
1995 12 0.0600
1996 1. 0.0000
1996 2. 0.0300
1996 4. 0.0760
1996 5. 0.0750
1996 6. 0.0000
1996 7. 0.0500
1996 8. 0.0000
1996 9. 0.0390
1996 10 0.0000
1996 11 0.0500
1996 12 0.0000
1997 1. 0.0530
1997 2. 0.0000
1997 3. 0.0000
1997 4. 0.0310
1997 5. 0.0750

1997 6. 0.0600
1997 7. 0.0400
1997 8. 0.0500
1997 9. 0.0580
1997 11 0.0000
1997 12 0.0310
1998 1. 0.0000
1998 2. 0.0830
1998 3. 0.0750
1998 4. 0.0460
1998 5. 0.1340
1998 6. 0.0310
1998 7. 0.0270
1998 8. 0.0430
1998 9. 0.0530
1998 10 0.0680
1998 11 0.0330
1998 12 0.0360
1999 1. 0.0440
1999 2. 0.0000
1999 3. 0.0360
1999 4. 0.0990
1999 5. 0.0390
1999 6. 0.0430
1999 7. 0.0250
1999 8. 0.0410
1999 9. 0.0300
1999 11 0.0420
1999 12 0.1070
2000 1. 0.0600
2000 2. 0.1080
2000 3. 0.0530
2000 6. 0.0610
2000 8. 0.0970
2000 8. 0.0380
2000 9. 0.0000
2000 10 0.0370
2000 11 0.0600
2000 12 0.0200
2001 1. 0.0000
2001 2. 0.0500
2001 3. 0.0200
2001 4. 0.0660
2001 5. 0.0700
2001 6. 0.0500
2001 7. 0.0000
2001 8. 0.0000
2001 9. 0.0000
2001 10 0.0000
2001 11 0.0000
2001 12 0.0280
2002 1. 0.0230
2002 2. 0.0000
2002 3. 0.1000

2002 5. 0.0240
2002 6. 0.0410
2002 7. 0.0250
2002 8. 0.0300
2002 9. 0.0230
2002 10 0.0700
2002 11 0.0710
2002 12 0.2490
2003 3. 0.0000
2003 4. 0.0690
2003 4. 0.0960
2003 5. 0.0410
2003 6. 0.0540
2003 7. 0.0300
2003 8. 0.0000
2003 9. 0.3590
2003 10 0.0000
2003 11 0.0000
2003 12 0.0000
2004 1. 0.0000
2004 2. 0.0000
2004 3. 0.0000
2004 5. 0.0370
2004 6. 0.0440
2004 7. 0.0330
2004 8. 0.0270
2004 9. 0.0380
2004 10 0.0280
2004 11 0.1070
2004 12 0.0170
2005 1. 0.0210
2005 2. 0.0410
2005 3. 0.0300
2005 4. 0.0390
2005 5. 0.0320
2005 7. 0.0260
2005 8. 0.0230
2005 9. 0.0280
2005 10 0.0480
2005 11 0.0200
2005 12 0.0470
2006 1. 0.0400
2006 2. 0.0610
2006 3. 0.0620
2006 4. 0.0440
2006 5. 0.0450
2006 6. 0.2050
2006 7. 0.0480
2006 8. 0.0280
2006 9. 0.0470
2006 10 0.0530
2006 11 0.0480
2006 12 0.0530
2007 1. 0.0320

2007 2. 0.0320
2007 3. 0.0310
2007 4. 0.0490
2007 5. 0.0430
2007 6. 0.0410
2007 7. 0.0290
2007 8. 0.0310
2007 9. 0.1120
2007 10 0.0440
2007 11 0.0620
2007 12 0.0540
2008 1. 0.0310
2008 2. 0.1690
2008 3. 0.0440
2008 4. 0.0680
2008 5. 0.0340
2008 6. 0.0430
2008 7. 0.0580
2008 8. 0.0300
2008 9. 0.0670
2008 10 0.0380
2008 11 0.0510
2009 1. 0.0350
2009 2. 0.0410
2009 3. 0.1050
2009 4. 0.0200
2009 5. 0.0760
2009 6. 0.0270
2009 7. 0.0290
2009 8. 0.0320
2009 9. 0.0580
2009 10 0.0690
2009 11 0.0400
2009 12 0.0320
2010 1. 0.0350
2010 2. 0.0480
2010 3. 0.0840
2010 4. 0.0400
2010 5. 0.0210
2010 6. 0.0300
2010 7. 0.0450
2010 8. 0.0280
2010 9. 0.0470
2010 10 0.0410
2010 10 0.0290
2010 11 0.0410
2010 11 0.0860
2011 1. 0.0520
2011 2. 0.0940
2011 3. 0.0770
2011 4. 0.2140
2011 5. 0.0550
2011 6. 0.0360
2011 7. 0.0330

2011 8. 0.0170
2011 9. 0.0330
2011 11 0.0410
2011 12 0.0330
2012 1. 0.0360
2012 2. 0.0240
2012 3. 0.0350
2012 4. 0.0300
2012 5. 0.0400
2012 6. 0.0440
2012 7. 0.0220
2012 8. 0.0320
2012 9. 0.0380
2012 10 0.0260
2012 11 0.0280
2012 12 0.0360
2013 1. 0.0220
2013 2. 0.0230
2013 3. 0.0270
2013 4. 0.0370
2013 5. 0.0420
2013 6. 0.0280
2013 7. 0.0380
2013 8. 0.0000
2013 9. 0.0000
2013 10 0.0230
2013 11 0.0440
2013 12 0.0210
2014 1. 0.0380
2014 2. 0.0360
2014 3. 0.0310
2014 4. 0.0510
2014 5. 0.0400
2014 6. 0.0670
2014 7. 0.0310
2014 8. 0.0000
2014 9. 0.0270
2014 10 0.0340
2014 11 0.0000
2014 12 0.0000
2015 1. 0.0000
2015 2. 0.0000
2015 3. 0.0350
2015 4. 0.0000
2015 5. 0.0000
2015 6. 0.0510
2015 7. 0.0320
2015 8. 0.0000
2015 9. 0.0000
2015 10 0.0000
2015 11 0.0240
2015 11 0.0810
2015 12 0.0450
2016 1. 0.0280

2016 2. 0.0640
2016 3. 0.0520
2016 4. 0.0000
2016 5. 0.0450
2016 6. 0.0250
2016 7. 0.0240
2016 8. 0.0370
2016 9. 0.0220
2016 10 1.1300
2016 11 0.0310
2016 11 2.7000
2016 11 0.1910
2016 12 0.0000
2017 1. 0.0000
2017 2. 0.0000
2017 3. 0.0340
2017 4. 0.1240
2017 5. 0.0990
2017 6. 0.0360
2017 7. 0.0380
2017 8. 0.0000
2017 9. 0.0310
2017 10 0.0410
2017 11 0.0290
2017 12 0.1040

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TP WHI0029 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is -0.060
S = -196.
z = -1.418
p = 0.1561
p = 0.3157 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.3830E-01 + -0.1000E-03 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 TP WHI0065 1993-2017
1993 1. 0.4850
1993 2. 0.2900
1993 3. 0.4830
1993 4. 0.6900
1993 5. 0.5880
1993 6. 1.2300
1993 7. 1.2100
1993 8. 1.1100
1993 9. 0.4780
1993 10 0.9390
1993 11 0.4360
1993 12 0.4060
1994 2. 0.5890
1994 3. 0.6320
1994 5. 0.7050
1994 6. 1.0500
1994 7. 0.7300
1994 8. 2.2200
1994 9. 2.3600
1994 10 2.8500
1994 11 0.1820
1994 12 0.3730
1995 1. 0.3930
1995 2. 0.6380
1995 3. 0.5280
1995 4. 0.6720
1995 5. 0.4820
1995 6. 0.4820
1995 7. 0.8880
1995 8. 2.2800
1995 9. 2.7400
1995 10 0.6720
1995 10 2.0900
1995 11 2.0900
1996 1. 0.6260
1996 2. 0.7810
1996 4. 0.8790
1996 5. 0.6240
1996 6. 1.8360
1996 7. 2.3380
1996 8. 2.6200
1996 9. 0.8280
1996 10 1.1520
1996 11 0.7030
1996 12 0.4510
1997 1. 0.7450
1997 2. 0.4660
1997 3. 0.3380
1997 4. 0.8410
1997 5. 1.5600
1997 6. 1.6100
1997 8. 1.2800

1997 9. 2.8200
1997 10 1.8300
1997 11 1.9420
1997 12 0.8800
1998 1. 0.4250
1998 2. 1.1060
1998 3. 0.2010
1998 4. 0.3820
1998 5. 0.6720
1998 7. 2.7140
1998 8. 2.2940
1998 9. 2.6780
1998 10 2.0000
1998 11 1.5840
1998 12 1.2500
1999 1. 0.6000
1999 2. 0.8080
1999 3. 0.8380
1999 4. 0.4620
1999 5. 0.8450
1999 6. 1.7300
1999 7. 2.4300
1999 8. 1.9360
1999 9. 3.3000
1999 10 3.3400
1999 11 0.9470
1999 11 2.8210
2000 1. 1.4900
2000 3. 1.6040
2000 4. 2.2320
2000 5. 2.8250
2000 6. 0.8140
2000 7. 1.5150
2000 8. 2.8890
2000 10 1.7600
2000 10 1.5820
2001 1. 0.9140
2001 2. 0.8580
2001 3. 0.5600
2001 4. 1.7190
2001 5. 1.6630
2001 6. 2.1100
2001 7. 1.7980
2001 8. 2.3990
2001 9. 1.5400
2001 10 2.2600
2001 11 2.0450
2001 12 0.8140
2002 1. 0.7750
2002 2. 0.4360
2002 3. 0.5300
2002 4. 0.3960
2002 5. 1.0100
2002 6. 1.1150

2002 7. 1.8200
2002 8. 0.7500
2002 9. 2.2140
2002 10 2.2000
2002 11 0.7220
2002 12 2.0900
2003 1. 0.5630
2003 2. 1.7800
2003 3. 0.8660
2003 4. 0.9840
2003 5. 0.8980
2003 6. 1.8700
2003 7. 0.5280
2003 8. 2.6600
2003 9. 2.2800
2003 10 0.6980
2003 11 2.7900
2003 12 0.8730
2004 1. 1.1400
2004 2. 0.8350
2004 3. 0.6540
2004 4. 1.3400
2004 5. 0.0000
2004 6. 2.1200
2004 7. 1.3500
2004 8. 2.9800
2004 9. 2.7400
2004 10 3.0600
2004 11 0.6430
2004 12 0.2560
2005 1. 0.1880
2005 2. 0.6850
2005 3. 0.5340
2005 4. 0.5250
2005 5. 0.9010
2005 6. 1.9400
2005 7. 1.5600
2005 8. 3.2100
2005 9. 2.8800
2005 10 2.1800
2005 11 2.5000
2005 12 1.6800
2006 1. 0.6770
2006 2. 0.7900
2006 2. 1.0000
2006 4. 1.1800
2006 5. 0.5520
2006 6. 2.0200
2006 7. 0.9320
2006 8. 3.1900
2006 9. 2.3100
2006 10 0.3820
2006 11 0.7240
2006 12 0.5610

2007 1. 0.3660
2007 2. 0.6990
2007 3. 1.0200
2007 4. 2.4300
2007 5. 1.0100
2007 6. 2.6100
2007 7. 1.1100
2007 8. 4.4000
2007 9. 3.4700
2007 10 1.8000
2007 11 0.5120
2007 12 1.2500
2008 1. 0.6810
2008 2. 1.3900
2008 3. 0.3890
2008 4. 0.3350
2008 5. 0.9030
2008 6. 0.9610
2008 7. 1.0700
2008 8. 2.3600
2008 9. 0.7250
2008 10 0.7900
2008 11 2.0700
2008 12 0.5230
2009 1. 1.7800
2009 2. 0.2130
2009 3. 0.6770
2009 4. 1.0900
2009 5. 0.8440
2009 6. 1.2800
2009 7. 0.8340
2009 8. 1.0700
2009 9. 1.5800
2009 10 0.3830
2009 11 0.2470
2009 12 0.3440
2010 1. 0.1470
2010 2. 0.3630
2010 3. 0.3650
2010 4. 0.6110
2010 5. 0.5790
2010 6. 0.9430
2010 7. 1.0300
2010 8. 1.1600
2010 9. 1.8400
2010 10 2.4600
2010 11 1.2600
2010 12 1.7000
2011 1. 1.0300
2011 2. 0.7460
2011 3. 0.7940
2011 4. 1.0100
2011 5. 0.2740
2011 6. 1.0900

2011 7. 1.4700
2011 8. 0.8130
2011 9. 0.4540
2011 10 4.4400
2011 11 1.9800
2011 12 0.3830
2012 1. 0.8460
2012 2. 0.5040
2012 3. 0.4550
2012 4. 1.0200
2012 5. 3.1500
2012 6. 2.0600
2012 7. 2.8200
2012 8. 0.0000
2012 9. 1.9900
2012 10 3.2600
2012 11 0.0000
2012 12 0.2790
2013 1. 2.1700
2013 2. 0.6360
2013 3. 0.7760
2013 4. 1.1600
2013 5. 1.3900
2013 6. 1.3000
2013 7. 2.8600
2013 8. 0.6080
2013 9. 4.3800
2013 10 2.2000
2013 11 1.1700
2013 12 0.6000
2014 1. 0.6750
2014 2. 0.4460
2014 3. 0.5230
2014 4. 0.9170
2014 5. 0.1280
2014 6. 0.8520
2014 7. 0.6470
2014 8. 2.0300
2014 9. 2.8800
2014 10 2.3100
2014 11 1.2800
2014 12 0.7410
2015 1. 0.2640
2015 2. 0.9990
2015 3. 0.2790
2015 4. 0.5790
2015 5. 0.9420
2015 6. 0.6910
2015 7. 0.6410
2015 8. 1.9400
2015 8. 3.8800
2015 9. 1.5000
2015 10 2.1900
2015 11 1.7400

2015 11 1.4000
2016 1. 0.2970
2016 2. 0.5970
2016 3. 0.9820
2016 4. 0.6740
2016 5. 0.1710
2016 6. 0.7760
2016 7. 1.0700
2016 8. 0.5300
2016 9. 2.3700
2016 10 0.8100
2016 11 0.3780
2016 12 0.2650
2017 1. 2.0100
2017 2. 0.5350
2017 3. 0.8220
2017 4. 0.7950
2017 6. 0.5090
2017 7. 2.1600
2017 8. 0.4730
2017 9. 5.4300
2017 10 3.6000
2017 11 1.5000
2017 12 2.3100

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: TP WHI0065 1993-2017

The record is 26 complete water years with 12 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.000
S = -1.
z = 0.000
p = 1.0000
p = 1.0000 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 0.9425 + 0.000 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

ATTACHMENT 6

Fecal Coliform Seasonal Mann-Kendall Input and Output

2 0 FC 07060500 1993-2017
1993 1 10.
1993 2 1.0
1993 2 4.0
1993 3 170
1993 3 10.
1993 4 4.0
1993 1 14.
1994 2 32.
1994 2 5.0
1994 3 8.0
1994 4 6.0
1995 1 45.
1995 1 4.0
1995 2 36.
1995 3 37.
1995 4 140
1995 4 53.
1995 4 39.
1996 1 5.0
1996 2 600
1996 3 100
1996 3 420
1996 4 110
1996 1 11.
1997 1 58.
1997 2 3.0
1997 3 160
1997 3 120
1997 4 17.
1998 1 3.0
1998 2 140
1998 3 57.
1998 3 23.
1998 4 7.0
1999 1 1.0
1999 2 7.0
1999 3 10.
1999 3 60.
1999 4 1.0
1999 4 15.
2000 1 35.
2000 2 4.0
2000 2 27.
2000 3 150
2000 3 33.
2000 4 32.
2001 1 1.0
2001 2 5.0
2001 2 7.0
2001 3 55.
2001 4 10.
2001 1 12.

2002 1 8.0
2002 2 12.
2002 3 280
2002 3 11.
2002 4 23.
2002 1 10.
2003 2 22.
2003 2 26.
2003 3 71.
2003 3 49.
2003 4 160
2004 1 170
2004 1 8.0
2004 2 14.
2004 3 94.
2004 3 56.
2004 4 54.
2005 1 7.0
2005 2 150
2005 2 330
2005 3 120
2005 3 120
2005 4 4.0
2006 1 42.
2006 2 12.
2006 2 25.
2006 3 66.
2006 3 110
2006 4 31.
2007 1 7.0
2007 2 150
2007 2 28.
2007 3 56.
2007 3 60.
2007 4 100
2007 1 76.
2008 1 110
2008 2 260
2008 3 9.0
2008 3 31.
2008 4 160
2008 1 56.
2009 1 5.0
2009 2 10.
2009 2 20.
2009 3 60.
2009 4 57.
2010 1 4.0
2010 2 5.0
2010 3 24.
2010 3 69.
2010 4 23.
2010 1 22.
2011 1 1.0

2011 2 60.
2011 3 40.
2011 3 24.
2011 4 63.
2012 1 12.
2012 3 150
2012 3 27.
2012 4 10.
2013 2 3.0
2013 2 7.0
2013 4 18.
2013 4 42.
2014 2 4.0
2014 2 2.0
2014 3 170
2014 4 16.
2015 2 110
2015 2 16.
2015 1 15.
2016 2 62.
2016 2 5.0
2016 3 110
2016 4 30.
2017 1 4.0
2017 2 47.
2017 3 9.0
2017 4 23.

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: FC 07060500 1993-2017

The record is 26 complete water years with 4 seasons per year
beginning in water year 1993.

The tau correlation coefficient is 0.048
S = 48.
z = 0.627
p = 0.5307
p = 0.5526 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 28.40 + 0.2000 * Time

where Time = Year (as a decimal) - 1992.75
(beginning of first water year)

2 0 FC 07060500 2000-2017
2000 1 35.
2000 2 4.0
2000 2 27.
2000 3 150
2000 3 33.
2000 4 32.
2001 1 1.0
2001 2 5.0
2001 2 7.0
2001 3 55.
2001 4 10.
2001 1 12.
2002 1 8.0
2002 2 12.
2002 3 280
2002 3 11.
2002 4 23.
2002 1 10.
2003 2 22.
2003 2 26.
2003 3 71.
2003 3 49.
2003 4 160
2004 1 170
2004 1 8.0
2004 2 14.
2004 3 94.
2004 3 56.
2004 4 54.
2005 1 7.0
2005 2 150
2005 2 330
2005 3 120
2005 3 120
2005 4 4.0
2006 1 42.
2006 2 12.
2006 2 25.
2006 3 66.
2006 3 110
2006 4 31.
2007 1 7.0
2007 2 150
2007 2 28.
2007 3 56.
2007 3 60.
2007 4 100
2007 1 76.
2008 1 110
2008 2 260
2008 3 9.0
2008 3 31.

2008 4 160
2008 1 56.
2009 1 5.0
2009 2 10.
2009 2 20.
2009 3 60.
2009 4 57.
2010 1 4.0
2010 2 5.0
2010 3 24.
2010 3 69.
2010 4 23.
2010 1 22.
2011 1 1.0
2011 2 60.
2011 3 40.
2011 3 24.
2011 4 63.
2012 1 12.
2012 3 150
2012 3 27.
2012 4 10.
2013 2 3.0
2013 2 7.0
2013 4 18.
2013 4 42.
2014 2 4.0
2014 2 2.0
2014 3 170
2014 4 16.
2015 2 110
2015 2 16.
2015 1 15.
2016 2 62.
2016 2 5.0
2016 3 110
2016 4 30.
2017 1 4.0
2017 2 47.
2017 3 9.0
2017 4 23.

Seasonal Kendall Test for Trend
US Geological Survey, 2009

Data set: FC 07060500 2000-2017

The record is 19 complete water years with 4 seasons per year
beginning in water year 2000.

The tau correlation coefficient is -0.085
S = -41.
z = -0.895
p = 0.3707
p = 0.3492 adjusted for correlation among seasons
(such as serial dependence)
The adjusted p-value should be used only for data with
more than 10 annual values per season.

The estimated trend may be described by the equation:

Y = 36.75 + -0.5000 * Time

where Time = Year (as a decimal) - 1999.75
(beginning of first water year)

APPENDIX C

Calculations for pollutant load estimates based on export coefficients from White et al. 2015

APPENDIX C. CALCULATIONS FOR POLLUTANT LOAD ESTIMATES BASED ON EXPORT COEFFICIENTS FROM WHITE ET AL. 2015

Appendix C Calculations for load estimates based on export coefficients from White et al. 2015

Loads were calculated for each HUC12 subwatershed by multiplying land use export coefficients by the area of the appropriate land use. Land use areas used in these calculations are for 2011, from Homer et al. 2015. The data values and resulting loads for HUC12s are shown in Tables C.1. through C.3.

REFERENCES

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.

White, M., Harmel, D., Yen, H., Arnold, J., Gambone, M., & Haney, R. (2015, June). Development of sediment and nutrient export coefficients for U.S. ecoregions. *Journal of the American Water Resources Association*, 758-775.

Table C.1. Data and load estimates for sediment by HUC12 subwatershed.

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		
Ozark Highlands export coefficient (kg/ha/yr)		**1.04**		**4.83**		**0**		**0.03**		
HUC12 ID	**HUC12 Name**	**Area (acres)**	**Load (kg/yr)**	**Area (acres)**	**Load (kg/yr)**	**Area (acres)**	**Load (kg/yr)**	**Area (acres)**	**Load (kg/yr)**	**Total Load (kg/yr)**
110100040101	Indian Creek-Piney Creek	2,233,800	940,147	0	0	39,058,200	0	16,114,500	195,639	1,135,786
110100040102	Upper Piney Creek	1,929,600	812,117	0	0	52,371,000	0	7,733,700	93,892	906,009
110100040103	Middle Piney Creek	1,972,800	830,299	0	0	44,975,700	0	13,005,000	157,888	988,187
110100040104	Knob Creek	3,337,200	1,404,539	72,000	140,734	59,625,900	0	22,854,600	277,468	1,822,741
110100040105	Mill Creek-Piney Creek	5,924,700	2,493,549	0	0	76,687,200	0	23,488,200	285,160	2,778,709
110100040106	Lower Piney Creek	3,416,400	1,437,872	26,100	51,016	58,140,900	0	17,657,100	214,367	1,703,255
110100040201	Hicks Creek	23,779,800	10,008,286	41,400	80,922	51,740,100	0	29,656,800	360,051	10,449,259
110100040202	Perry Creek-White River	2,837,700	1,194,313	0	0	67,878,000	0	15,618,600	189,619	1,383,931
110100040203	Farris Creek-White River	3,120,300	1,313,251	20,700	40,461	44,289,000	0	8,568,900	104,031	1,457,744
110100040204	Moccasin Creek-White River	2,863,800	1,205,297	62,100	121,383	43,659,900	0	16,277,400	197,617	1,524,297
110100040205	Sneeds Creek-White River	4,059,000	1,708,325	18,900	36,942	86,096,700	0	12,655,800	153,649	1,898,917
110100040206	Sugarloaf Creek-White River	5,850,000	2,462,110	0	0	83,406,600	0	20,063,700	243,585	2,705,695
110100040301	Headwaters North Sylamore Creek	2,978,100	1,253,403	0	0	1.14E+08	0	1,492,200	18,116	1,271,519
110100040302	Headwaters Roasting Ear Creek	2,999,700	1,262,494	0	0	76,626,000	0	11,356,200	137,871	1,400,365
110100040303	Outlet Roasting Ear Creek	3,371,400	1,418,933	21,600	42,220	49,565,700	0	21,172,500	257,046	1,718,199
110100040304	Headwaters South Sylamore Creek	3,041,100	1,279,918	23,400	45,738	44,178,300	0	26,576,100	322,649	1,648,306
110100040305	Outlet North Sylamore Creek	3,207,600	1,349,994	0	0	74,766,600	0	2,210,400	26,836	1,376,829
110100040306	Outlet South Sylamore Creek	9,375,300	3,945,815	19,800	38,702	96,351,300	0	23,847,300	289,520	4,274,037
110100040401	Livingston Creek	1,782,900	750,375	0	0	52,928,100	0	459,900	5,583	755,959
110100040402	Wideman Creek-White River	2,097,900	882,950	0	0	60,503,400	0	4,608,900	55,955	938905
110100040403	Prong Cove-Rocky Bayou	5,445,000	2,291,656	0	0	87,368,400	0	17,758,800	215,602	2,507,258
110100040404	East Twin Creek-White River	4,374,000	1,840,900	0	0	78,769,800	0	8,569,800	104,042	1,944,943
110100040405	West Rocky Bayou-Rocky Bayou	3,567,600	1,501,508	49,500	96,754	69,209,100	0	18,708,300	227,130	1,825,392
110100040406	Hidden Creek-White River	1,914,300	805,678	0	0	60,364,800	0	4,196,700	50,950	856,628
110100040407	West Lafferty Creek	2,589,300	1,089,768	34,200	66,848	59,616,000	0	17,317,800	210,248	1,366,864
110100040408	Lafferty Creek	2,765,700	1,164,010	0	0	55,494,900	0	18,637,200	226,266	1,390,276
110100040409	Cagens Creek-White River	4,490,100	1,889,764	125,100	244,525	1.01E+08	0	17,991,900	218,432	2,352,721
110100040501	Upper Poke Bayou	4,560,300	1,919,309	29,700	58,053	39,202,200	0	41,301,900	501,429	2,478,791
110100040502	Sullivan Creek	4,652,100	1,957,945	174,600	341,279	66,755,700	0	28,231,200	342,743	2,641,967
110100040503	Middle Poke Bayou	3,587,400	1,509,841	0	0	70,929,000	0	17,183,700	208,620	1,718,461
110100040504	Miller Creek	11,417,400	4,805,280	81,000	158,325	56,826,000	0	41,477,400	503,560	5,467,165
110100040505	Lower Poke Bayou	6,253,200	2,631,806	134,100	262,116	44,073,000	0	6,568,200	79,742	2,973,664
110100040601	Mill Creek-White River	3,546,900	1,492,796	704,700	1,377,430	59,103,000	0	24,300,900	295,027	3,165,253
110100040602	Wolf Bayou	2,183,400	918,935	0	0	63,971,100	0	20,219,400	245,475	1,164,410
110100040603	Brier Creek-White River	2,674,800	1,125,752	1,497,600	2,927,259	54,198,000	0	18,629,100	226,168	4,279,179
110100040604	Greenbriar Creek	6,556,500	2,759,457	2,835,000	5,541,386	46,916,100	0	30,557,700	370,988	8,671,831
110100040605	Sprint Creek	6,597,000	2,776,502	577,800	1,129,387	41,887,800	0	39,138,300	475,162	4,381,051

Table C.1. Data and load estimates for sediment by HUC12 subwatershed (continued).

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		
Ozark Highlands export coefficient (kg/ha/yr)		**1.04**		**4.83**		**0**		**0.03**		
HUC12 ID	**HUC12 Name**	**Area (acres)**	**Load (kg/yr)**	**Area (acres)**	**Load (kg/yr)**	**Area (acres)**	**Load (kg/yr)**	**Area (acres)**	**Load (kg/yr)**	**Total Load (kg/yr)**
110100040606	Betsey Gill Creek-White River	4,904,100	2,064,005	2,649,600	5,178,997	41,591,700	0	17,072,100	207,265	7,450,267
110100040701	Upper Salado Creek	3,962,700	1,667,795	461,700	902,454	87,143,400	0	30,544,200	370,824	2,941,074
110100040702	Middle Salado Creek	2,847,600	1,198,479	131,400	256,839	71,920,800	0	19,498,500	236,723	1,692,041
110100040703	Lower Salado Creek	6,302,700	2,652,639	1,262,700	,2468,116	37,853,100	0	28,251,900	342,994	5,463,749
110100040704	Big Creek-White River	10,776,600	4,535,585	9,083,700	17,755,303	41,075,100	0	39,478,500	479,292	22,770,180
110100040705	Goodie Creek-White River	3,223,800	1,356,812	21,703,500	42,422,386	22,713,300	0	14,147,100	171,754	43,950,951
110100040706	Mud Creek-White River	6,428,700	2,705,669	49,392,900	96,545,011	7,780,500	0	12,654,000	153,627	99,404,307

Table C.2. Data and load estimates for total nitrogen by HUC12 subwatershed.

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		
Ozark Highlands export coefficient (kg/ha/yr)		10.5		23.2		1.27		1.36		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Total Load (kg/yr)
110100040101	Indian Creek-Piney Creek	2,233,800	9,491,870	0	0	39,058,200	20,074,010	16,114,500	8,868,985	38,434,864
110100040102	Upper Piney Creek	1,929,600	8,199,262	0	0	52,371,000	26,916,139	7,733,700	4,256,419	39,371,821
110100040103	Middle Piney Creek	1,972,800	8,382,828	0	0	44,975,700	23,115,316	13,005,000	7,157,600	38,655,744
110100040104	Knob Creek	3,337,200	14,180,440	72,000	675,988	59,625,900	30,644,804	22,854,600	12,578,554	58,079,786
110100040105	Mill Creek-Piney Creek	5,924,700	25,175,253	0	0	76,687,200	39,413,480	23,488,200	12,927,270	77,516,003
110100040106	Lower Piney Creek	3,416,400	14,516,977	26,100	245,046	58,140,900	29,881,586	17,657,100	9,717,990	54,361,599
110100040201	Hicks Creek	23,779,800	1.01E+08	41,400	388,693	51,740,100	26,591,888	29,656,800	16,322,301	1.44E+08
110100040202	Perry Creek-White River	2,837,700	12,057,963	0	0	67,878,000	34,885,981	15,618,600	8,596,055	55,539,999
110100040203	Farris Creek-White River	3,120,300	13,258,788	20,700	194,346.4	44,289,000	22,762,386	8,568,900	4,716,091	40,931,611
110100040204	Moccasin Creek-White River	2,863,800	12,168,868	62,100	583,039	43,659,900	22,439,059	16,277,400	8,958,641	44,149,606
110100040205	Sneeds Creek-White River	4,059,000	17,247,515	18,900	177,447	86,096,700	44,249,504	12,655,800	6,965,410	68,639,876
110100040206	Sugarloaf Creek-White River	5,850,000	24,857,838	0	0	83,406,600	42,866,924	20,063,700	11,042,518	78,767,279
110100040301	Headwaters North Sylamore Creek	2,978,100	12,654,551	0	0	1.14E+08	58,385,218	1,492,200	821,266	71,861,036
110100040302	Headwaters Roasting Ear Creek	2,999,700	12,746,334	0	0	76,626,000	39,382,026	11,356,200	6,250,145	58,378,506
110100040303	Outlet Roasting Ear Creek	3,371,400	14,325,763	21,600	202,796	49,565,700	25,474,352	21,172,500	11,652,771	51,655,683
110100040304	Headwaters South Sylamore Creek	3,041,100	12,922,251	23,400	219,696	44,178,300	22,705,491	26,576,100	14,626,767	50,474,205
110100040305	Outlet North Sylamore Creek	3,207,600	13,629,744	0	0	74,766,600	38,426,385	2,210,400	1,216,544	53,272,673
110100040306	Outlet South Sylamore Creek	9,375,300	39,837,553	19,800	185,897	96,351,300	49,519,868	23,847,300	13,124,909	1.03E+08
110100040401	Livingston Creek	1,782,900	7,575,904	0	0	52,928,100	27,202,462	459,900	253,116	35,031,482
110100040402	Wideman Creek-White River	2,097,900	8,914,403	0	0	60,503,400	31,095,796	4,608,900	2,536,614	42,546,813
110100040403	Prong Cove-Rocky Bayou	5,445,000	23,136,910	0	0	87,368,400	44,903,096	17,758,800	9,773,963	77,813,969
110100040404	East Twin Creek-White River	4,374,000	18,586,014	0	0	78,769,800	40,483,835	8,569,800	4,716,586	63,786,435
110100040405	West Rocky Bayou-Rocky Bayou	3,567,600	15,159,457	49,500	464,741	69,209,100	35,570,101	18,708,300	10,296,542	61,490,842
110100040406	Hidden Creek-White River	1,914,300	8,134,249	0	0	60,364,800	31,024,563	4,196,700	2,309,750	41,468,562
110100040407	West Lafferty Creek	2,589,300	11,002,461	34,200	321,094	59,616,000	30,639,716	17,317,800	9,531,249	51,494,520
110100040408	Lafferty Creek	2,765,700	11,752,021	0	0	55,494,900	28,521,672	18,637,200	10,257,411	50,531,103
110100040409	Cagens Creek-White River	4,490,100	19,079,346	125,100	1,174,528	1.01E+08	51,883,992	17,991,900	9902,255	82,040,122
110100040501	Upper Poke Bayou	4,560,300	19,377,640	29,700	278,845	39,202,200	20,148,019	41,301,900	22,731,449	62,535,953
110100040502	Sullivan Creek	4,652,100	19,767,717	174,600	1,639,270	66,755,700	34,309,173	28,231,200	15,537,689	71,253,850
110100040503	Middle Poke Bayou	3,587,400	15,243,591	0	0	70,929,000	36,454,046	17,183,700	9,457,444	61,155,081
110100040504	Miller Creek	11,417,400	48,514,850	81,000	760,486	56,826,000	29,205,792	41,477,400	22,828,039	1.01E+08
110100040505	Lower Poke Bayou	6,253,200	2,6571,116	134,100	1,259,027	44,073,000	22,651,372	6,568,200	3,614,960	54,096,475
110100040601	Mill Creek-White River	3,546,900	15,071,498	704,700	6,616,228	59,103,000	30,376,059	24,300,900	13,374,558	65,438,343
110100040602	Wolf Bayou	2,183,400	9,277,710	0	0	63,971,100	32,878,025	20,219,400	11,128,211	53,283,946
110100040603	Brier Creek-White River	2,674,800	11,365,768	1,497,600	14,060,540	54,198,000	27,855,128	18,629,100	10,252,953	63,534,389
110100040604	Greenbriar Creek	6,556,500	27,859,899	2,835,000	26,617,008	46,916,100	24,112,587	30,557,700	16,818,132	95,407,626
110100040605	Sprint Creek	6,597,000	28,031,992	577,800	5,424,800	41,887,800	21,528,286	39,138,300	2,154,0662	76,525,740
110100040606	Betsey Gill Creek-White River	4,904,100	20,838,516	2,649,600	24,876,340	41,591,700	21,376,105	17,072,100	9,396,022	76,486,983

Table C.2. Data and load estimates for total nitrogen by HUC12 subwatershed (continued).

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		
Ozark Highlands export coefficient (kg/ha/yr)		10.5		23.2		1.27		1.36		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Total Load (kg/yr)
110100040701	Upper Salado Creek	3,962,700	16,838,317	461,700	4,334,770	87,143,400	44,787,457	30,544,200	16,810,702	82,771,245
110100040702	Middle Salado Creek	2,847,600	12,100,030	131,400	1,233,677	71,920,800	36,963,783	19,498,500	10,731,447	61,028,938
110100040703	Lower Salado Creek	6,302,700	26,781,452	1,262,700	11,855,131	37,853,100	19,454,647	28,251,900	15,549,082	73,640,311
110100040704	Big Creek-White River	10,776,600	45,791,961	9,083,700	85,284,272	41,075,100	2,111,0598	39,478,500	21,727,899	1.74E+08
110100040705	Goodie Creek-White River	3,223,800	13,698,581	21,703,500	2.04E+08	22,713,300	11,673,528	14,147,100	7,786,181	2.37E+08
110100040706	Mud Creek-White River	6,428,700	27,316,851	49,392,900	4.64E+08	7,780,500	3,998,797	1,2654,000	6,964,419	5.02E+08

Table C.3. Data and load estimates for total phosphorus by HUC12 subwatershed.

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		
Ozark Highlands export coefficient (kg/ha/yr)		1.8		2.21		0.059		0.437		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Total Load (kg/yr)
110100040101	Indian Creek-Piney Creek	2,233,800	1,627,178	0	0	3,9058,200	932,572	16,114,500	2,849,814	5,409,563
110100040102	Upper Piney Creek	1,929,600	1,405,588	0	0	52,371,000	1,250,435	7,733,700	1,367,688	4,023,710
110100040103	Middle Piney Creek	1,972,800	1,437,056	0	0	44,975,700	1,073,861	13,005,000	2,299,905	4,810,823
110100040104	Knob Creek	3,337,200	2,430,933	72,000	64,394	59,625,900	1,423,656	22,854,600	4,041,785	7,960,768
110100040105	Mill Creek-Piney Creek	5,924,700	4,315,758	0	0	76,687,200	1,831,020	23,488,200	4,153,836	10,300,614
110100040106	Lower Piney Creek	3,416,400	2,488,625	26,100	23,343	58,140,900	1,388,200	17,657,100	3,122,619	7,022,786
110100040201	Hicks Creek	23,779,800	17,322,034	41,400	37,026	51,740,100	1,235,371	29,656,800	5,244,739	23,839,171
110100040202	Perry Creek-White River	2,837,700	2,067,079	0	0	67,878,000	1,620,687	15,618,600	2,762,115	6,449,882
110100040203	Farris Creek-White River	3,120,300	2,272,935	20,700	18,513	44,289,000	1,057,465	8,568,900	1,515,391	4,864,304
110100040204	Moccasin Creek-White River	2,863,800	2,086,092	62,100	55,540	43,659,900	1,042,444	16,277,400	2,878,622	6,062,698
110100040205	Sneeds Creek-White River	4,059,000	2,956,717	18,900	16,903	86,096,700	2,055,686	12,655,800	2,238,150	7,267,456
110100040206	Sugarloaf Creek-White River	5,850,000	4,261,344	0	0	83,406,600	1,991,456	20,063,700	3,548,221	9,801,020
110100040301	Headwaters North Sylamore Creek	2,978,100	2,169,352	0	0	1.14E+08	2,712,384	1,492,200	263,892	5,145,628
110100040302	Headwaters Roasting Ear Creek	2,999,700	2,185,086	0	0	76,626,000	1,829,559	11,356,200	2,008,319	6,022,963
110100040303	Outlet Roasting Ear Creek	3,371,400	2,455,845	21,600	19,318	49,565,700	1,183,454	21,172,500	3,744,310	7,402,927
110100040304	Headwaters South Sylamore Creek	3,041,100	2,215,243	23,400	20,928	44,178,300	1,054,822	26,576,100	4,699,924	7,990,917
110100040305	Outlet North Sylamore Creek	3,207,600	2,336,527	0	0	74,766,600	1,785,163	2,210,400	390,904	4,512,595
110100040306	Outlet South Sylamore Creek	9,375,300	6,829,295	19,800	17,708	96,351,300	2,300,529	23,847,300	4,217,342	13,364,874
110100040401	Livingston Creek	1,782,900	1,298,726	0	0	52,928,100	1,263,736	459,900	81,332	2,643,795
110100040402	Wideman Creek-White River	2,097,900	1,528,183	0	0	60,503,400	1,444,608	4,608,900	815,074	3,787,865
110100040403	Prong Cove-Rocky Bayou	5,445,000	3,966,327	0	0	87,368,400	2,086,049	17,758,800	3,140,604	9,192,981
110100040404	East Twin Creek-White River	4,374,000	3,186,174	0	0	78,769,800	1,880,745	8,569,800	1,515,550	6,582,469
110100040405	West Rocky Bayou-Rocky Bayou	3,567,600	2,598,764	49,500	44,271	69,209,100	1,652,469	18,708,300	3,308,521	7,604,025
110100040406	Hidden Creek-White River	1,914,300	1,394,443	0	0	60,364,800	1,441,299	4,196,700	742,177	3,577,918
110100040407	West Lafferty Creek	2,589,300	1,886,136	34,200	30,587	59,616,000	1,423,420	17,317,800	3,062,615	6,402,758
110100040408	Lafferty Creek	2,765,700	2,014,632	0	0	55,494,900	1,325,023	18,637,200	3,295,947	6,635,602
110100040409	Cagens Creek-White River	4,490,100	3,270,745	125,100	111,884	1.01E+08	241,0359	17,991,900	3,181,828	8,974,815
110100040501	Upper Poke Bayou	4,560,300	3,321,881	29,700	26,562	39,202,200	936,010	41,301,900	7,304,149	11,588,603
110100040502	Sullivan Creek	4,652,100	3,388,752	174,600	156,155	66,755,700	1,593,891	28,231,200	4,992,625	10,131,422
110100040503	Middle Poke Bayou	3,587,400	2,613,187	0	0	70,929,000	1,693,534	17,183,700	3,038,899	7,345,621
110100040504	Miller Creek	11,417,400	8,316,831	81,000	72,443	56,826,000	1,356,805	41,477,400	7,335,186	17,081,265
110100040505	Lower Poke Bayou	6,253,200	4,555,048	134,100	119,933	44,073,000	1,052,308	6,568,200	1,161,572	6,888,861
110100040601	Mill Creek-White River	3,546,900	2,583,685	704,700	630,253	59,103,000	1,411,171	24,300,900	4,297,560	8,922,670
110100040602	Wolf Bayou	2,183,400	1,590,465	0	0	63,971,100	1,527,404	20,219,400	3,575,756	6,693,625
110100040603	Brier Creek-White River	2,674,800	1,948,417	1,497,600	1,339,388	54,198,000	1,294,057	18,629,100	3,294,515	7,876,377
110100040604	Greenbriar Creek	6,556,500	4,775,983	2,835,000	2,535,499	46,916,100	1,120,191	30,557,700	5,404,061	13,835,735
110100040605	Sprint Creek	6,597,000	4,805,484	577,800	516,759	41,887,800	1,000,133	39,138,300	6,921,522	13,243,898

Table C.3. Data and load estimates for total phosphorus by HUC12 subwatershed (continued).

Land Use		Urban (developed)		Cultivated crops		Forest		Grassland (pasture/hayland)		
Ozark Highlands export coefficient (kg/ha/yr)		1.8		2.21		0.059		0.437		
HUC12 ID	HUC12 Name	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Area (acres)	Load (kg/yr)	Total Load (kg/yr)
110100040606	Betsey Gill Creek-White River	4,904,100	3,572,317	2,649,600	2,369,686	41,591,700	993,063	17,072,100	3,019,163	9,954,229
110100040701	Upper Salado Creek	3,962,700	2,886,569	461,700	412,924	87,143,400	2,080,677	30,544,200	5,401,674	10,781,844
110100040702	Middle Salado Creek	2,847,600	2,074,291	131,400	117,518	71,920,800	1,717,215	19,498,500	3,448,266	7,357,291
110100040703	Lower Salado Creek	6,302,700	4,591,106	1,262,700	1,129,303	37,853,100	903,799	28,251,900	4,996,286	11,620,494
110100040704	Big Creek-White River	10,776,600	7,850,050	9,083,700	8,124,062	41,075,100	980,729	39,478,500	6,981,685	23,936,526
110100040705	Goodie Creek-White River	3,223,800	2,348,328	21,703,500	19,410,657	22,713,300	542,314	14,147,100	2,501,883	24,803,182
110100040706	Mud Creek-White River	6,428,700	4,682,889	49,392,900	44,174,839	7,780,500	185,771	12,654,000	2,237,832	51,281,331

APPENDIX D

Calculations for pollutant load estimates based on water quality measurements from 2013-2015

Table D.1. Available TSS data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0168	WHI0202	WHI0166	WHI0167	WHI0162	WHI0090
1/8/2013	1	-	-	-	-	-	-
2/19/2013	1.5	-	-	-	-	-	-
3/5/2013	U	-	-	-	-	-	-
4/2/2013	1	-	-	-	-	-	-
5/7/2013	0.5 U	-	-	-	-	-	-
5/13/2013	-	0.5 U	-	-	-	0.5 U	-
5/14/2013	-	-	0.5 U	10.5	17.5	-	0.5 U
6/4/2013	1.2	-	-	-	-	-	-
7/9/2013	2	-	-	-	-	-	-
8/13/2013	1.5	-	-	-	-	-	-
8/19/2013	-	2.5	-	-	-	1.5	-
8/20/2013	-	-	1	14	-	-	2
9/16/2013	-	-	0.5 U	-	-	-	0.5 U
9/17/2013	0.5 U	-	-	-	-	-	-
10/15/2013	0.5 U	0.5 U	-	-	-	7	-
11/5/2013	1.5	-	-	-	-	-	-
12/2/2013	U	-	-	-	-	-	-
1/7/2014	0.5 U	-	-	-	-	-	-
1/27/2014	-	0.5 U	0.5 U	3.5	27.5	0.5 U	0.5 U
2/18/2014	1.5	-	-	-	-	-	-
3/18/2014	2.5	-	-	-	-	-	-
4/7/2014	-	5.5				1.8	
4/8/2014	-	-	0.5 U	9.5	17	-	4.5
4/29/2014	1	-	-	-	-	-	-
5/6/2014	0.5 U	-	-	-	-	-	-
5/12/2014	-	-	2	8.5	-	-	-
6/23/2014	4.5	-	-	-	-	-	-
6/24/2014	-	-	-	15.5	-	-	-
7/7/2014	-	11.8	0.5 U	-	7.5	5.7	0.5 U
7/8/2014	3.5	-	-	-	-	-	-
8/4/2014	4.7	-	-	-	-	-	-
9/16/2014	1.3	-	-	-	-	-	-
9/29/2014	-	2.3	-	-	-	4.8	
9/30/2014	-	-	0.5 U	-	-	-	1.5
10/14/2014	-	-	-	5.7	2.7	-	-
10/28/2014	0.5 U	-	-	-	-	-	-
11/3/2014	1	-	-	-	-	-	-
11/18/2014	-	-	-	3.2	-	-	-
12/1/2014	1	3	-	-	-	1	-
12/2/2014	-	-	0.5 U	-	-	-	1.2
1/6/2015	U	-	-	-	-	-	-
2/9/2015	-	-	-	8.5	7.2	-	-
2/10/2015	1.5	-	-	-	-	-	-
3/2/2015	-	1.5	-	-	-	5.5	-
3/3/2015	-	-	0.5 U	-	-	-	0.5 U

Table D.1. Available TSS data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0168	WHI0202	WHI0166	WHI0167	WHI0162	WHI0090
3/31/2015	2.7	-	-	-	-	-	-
4/14/2015	2	-	-	-	-	-	-
4/27/2015	-	-	-	7.5	11	-	-
5/5/2015	3	-	-	-	-	-	-
6/2/2015	2	-	-	-	-	-	-
6/29/2015	-	-	-	9.3	12.5	-	-
7/13/2015	1.8	-	-	-	-	-	-
8/11/2015	2.5	-	-	-	-	-	-
8/17/2015	-	-	-	5.5	13.3	-	-
8/25/2015	1	-	-	-	-	-	-
9/15/2015	U	-	-	-	-	-	-
9/21/2015	-	-	-	4.5	6.5	-	-
10/13/2015	1.3	-	-	-	-	-	-
11/2/2015	U	-	-	-	-	-	-
11/16/2015	U	-	-	-	-	-	-
12/28/2015	-	-	-	29	19.8	-	-
1/5/2016	1.5	-	-	-	-	-	-
2/2/2016	16.5	-	-	-	-	-	-
3/8/2016	1.5	-	-	-	-	-	-
4/5/2016	1.3	-	-	-	-	-	-
5/17/2016	22.3	-	-	-	-	-	-
6/28/2016	7	-	-	-	-	-	-
7/12/2016	2	-	-	-	-	-	-
8/16/2016	3.5	-	-	-	-	-	-
9/13/2016	3.5	-	-	-	-	-	-
10/11/2016	U	-	-	-	-	-	-
11/28/2016	12.3	-	-	-	-	-	-
12/13/2016	1.8	-	-	-	-	-	-
1/10/2017	1.3	-	-	-	-	-	-
2/7/2017	7.5	-	-	-	-	-	-
3/13/2017	1	-	-	-	-	-	-
4/18/2017	2.7	-	-	-	-	-	-
5/9/2017	2.5	-	-	-	-	-	-
6/6/2017	2	-	-	-	-	-	-
7/25/2017	2.2	-	-	-	-	-	-
8/15/2017	7.7	-	-	-	-	-	-
9/26/2017	1.5	-	-	-	-	-	-
10/31/2017	2.8	-	-	-	-	-	-
11/28/2017	1.3	-	-	-	-	-	-
12/4/2017	U	-	-	-	-	-	-

Table D.2. Available total phosphorus data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0090	WHI0162	WHI0166	WHI0167	WHI0168	WHI0202
1/8/2013	2.17	-	-	-	-	-	-
2/19/2013	0.636	-	-	-	-	-	-
3/5/2013	0.776	-	-	-	-	-	-
4/2/2013	1.16	-	-	-	-	-	-
5/7/2013	1.39	-	-	-	-	-	-
5/13/2013	-	-	0.026	-	-	0.028	-
5/14/2013	-	0.052	-	0.061	0.104	-	0.028
6/4/2013	1.3	-	-	-	-	-	-
7/9/2013	2.86	-	-	-	-	-	-
8/13/2013	0.608	-	-	-	-	-	-
8/19/2013	-	-	0.025	-	-	0.031	-
8/20/2013	-	0.054	-	0.069	-	-	0.026
9/16/2013	-	0.051	-	-	-	-	0.024
9/17/2013	4.38	-	-	-	-	-	-
10/15/2013	2.2	-	0.041	-	-	0.028	-
11/5/2013	1.17	-	-	-	-	-	-
12/2/2013	0.6	-	-	-	-	-	-
1/7/2014	0.675	-	-	-	-	-	-
1/27/2014	-	0.034	0.029	0.041	0.064	0.032	0.023
2/18/2014	0.446	-	-	-	-	-	-
3/18/2014	0.523	-	-	-	-	-	-
4/7/2014	-	-	0.038	-	-	0.042	-
4/8/2014	-	0.056	-	0.058	0.118	-	0.038
4/29/2014	0.917	-	-	-	-	-	-
5/6/2014	0.128	-	-	-	-	-	-
5/12/2014	-	-	-	0.729	-	-	0.495
6/23/2014	0.852	-	-	-	-	-	-
6/24/2014	-	-	-	0.073	-	-	-
7/7/2014	-	0.047	0.027	-	0.086	0.031	0.025
7/8/2014	0.647	-	-	-	-	-	-
8/4/2014	2.03	-	-	-	-	-	-
9/16/2014	2.88	-	-	-	-	-	-
9/29/2014	-	-	0.031	-	-	0.029	-
9/30/2014	-	0.053	-	-	-	-	0.024
10/14/2014	-	-	-	0.046	0.114	-	-
10/28/2014	2.31	-	-	-	-	-	-
11/3/2014	1.28	-	-	-	-	-	-
11/18/2014	-	-	-	0.001 U	-	-	-
12/1/2014	0.741	-	0.001 U	-	-	0.027	-
12/2/2014	-	0.041	-	-	-	-	0.001 U
1/6/2015	0.264	-	-	-	-	-	-
2/9/2015	-	-	-	0.001 U	0.030	-	-

Table D.2. Available total phosphorus data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0090	WHI0162	WHI0166	WHI0167	WHI0168	WHI0202
2/10/2015	0.999	-	-	-	-	-	-
3/2/2015	-	-	0.065	-	-	0.060	-
3/3/2015	-	0.141	-	-	-	-	0.200
3/31/2015	0.279	-	-	-	-	-	-
4/14/2015	0.579	-	-	-	-	-	-
4/27/2015	-	-	-	0.026	0.050	-	-
5/5/2015	0.942	-	-	-	-	-	-
6/2/2015	0.691	-	-	-	-	-	-
6/29/2015	-	-	-	0.023	0.061	-	-
7/13/2015	0.641	-	-	-	-	-	-
8/11/2015	1.94	-	-	-	-	-	-
8/17/2015	-	-	-	0.059	0.118	-	-
8/25/2015	3.88	-	-	-	-	-	-
9/15/2015	1.5	-	-	-	-	-	-
9/21/2015	-	-	-	0.039	0.060	-	-
10/13/2015	2.19	-	-	-	-	-	-
11/2/2015	1.74	-	-	-	-	-	-
11/16/2015	1.4	-	-	-	-	-	-
12/28/2015	-	-	-	0.114	0.156	-	-
1/5/2016	0.297	-	-	-	-	-	-
2/2/2016	0.597	-	-	-	-	-	-
3/7/2016	-	-	-	U	U	-	-
3/8/2016	0.982	-	-	-	-	-	-
4/5/2016	0.674	-	-	-	-	-	-
4/25/2016	-	-	-	1.17	1.23	-	-
5/17/2016	0.171	-	-	-	-	-	-
6/28/2016	0.776	-	-	-	-	-	-
7/12/2016	1.07	-	-	-	-	-	-
8/16/2016	0.53	-	-	-	-	-	-
9/13/2016	2.37	-	-	-	-	-	-
10/11/2016	0.81	-	-	-	-	-	-
11/28/2016	0.378	-	-	-	-	-	-
12/13/2016	0.265	-	-	-	-	-	-
1/10/2017	2.01	-	-	-	-	-	-
2/7/2017	0.535	-	-	-	-	-	-
3/13/2017	0.822	-	-	-	-	-	-
4/18/2017	0.795	-	-	-	-	-	-
6/6/2017	0.509	-	-	-	-	-	-
7/25/2017	2.16	-	-	-	-	-	-
8/15/2017	0.473	-	-	-	-	-	-
9/26/2017	5.43	-	-	-	-	-	-
10/31/2017	3.6	-	-	-	-	-	-

Table D.2. Available total phosphorus data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0090	WHI0162	WHI0166	WHI0167	WHI0168	WHI0202
11/28/2017	1.5	-	-	-	-	-	-
12/4/2017	2.31	-	-	-	-	-	-

Table D.3. Available total nitrogen data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0162	WHI0168	WHI0202	WHI0090	WHI0166	WHI0167
1/7/2013	3.39	-	-	-	-	-	-
2/18/2013	2.2	-	-	-	-	-	-
3/4/2013	2.48	-	-	-	-	-	-
4/1/2013	2.76	-	-	-	-	-	-
5/6/2013	4.685	-	-	-	-	-	-
5/13/2013	-	0.146	0.258	-	-	-	-
5/14/2013	-	-	-	0.217	0.376	0.445	0.788
6/3/2013	2.67	-	-	-	-	-	-
7/8/2013	2.96	-	-	-	-	-	-
8/12/2013	2.24	-	-	-	-	-	-
8/19/2013	-	0.182	0.435	-	-	-	-
8/20/2013	-	-	-	0.362	1.04	0.717	-
9/16/2013	4.45	-	-	0.281	0.404	-	-
10/15/2013	4.235	0.349	0.265	-	-	-	-
11/4/2013	3.13	-	-	-	-	-	-
12/1/2013	2.41	-	-	-	-	-	-
1/6/2014	1.92	-	-	-	-	-	-
1/27/2014	-	0.117	0.331	0.276	0.919	0.663	1.04
2/17/2014	1.69	-	-	-	-	-	-
3/17/2014	1.41	-	-	-	-	-	-
4/7/2014	-	0.146	0.356	-	-	-	-
4/8/2014	-	-	-	0.093	0.597	0.428	0.833
4/28/2014	2.06	-	-	-	-	-	-
5/5/2014	0.482	-	-	-	-	-	-
5/12/2014	-	-	-	0.280	-	0.524	-
6/22/2014	1.96	-	-	-	-	-	-
6/24/2014	-	-	-	-	-	0.679	-
7/7/2014	1.42	0.438	0.384	0.403	0.614	-	0.814
8/3/2014	2.86	-	-	-	-	-	-
9/15/2014	3.38	-	-	-	-	-	-
9/29/2014	-	0.314	0.389	-	-	-	-
9/30/2014	-	-	-	0.381	0.336	-	-
10/14/2014	-	-	-	-	-	0.423	0.452
10/27/2014	3.81	-	-	-	-	-	-
11/2/2014	2.46	-	-	-	-	-	-
11/18/2014	-	-	-	-	-	1.23	-
11/30/2014	3.03	-	-	-	-	-	-
12/1/2014	-	0.200	0.218	-	-	-	-
12/2/2014	-	-	-	0.229	0.535	-	-
1/5/2015	1.75	-	-	-	-	-	-
2/9/2015	2	-	-	-	-	0.531	0.763
3/2/2015	-	0.294	0.385	-	-	-	-

Table D.3. Available total nitrogen data from 2013-2017 at target monitoring stations.

Date	WHI0065	WHI0162	WHI0168	WHI0202	WHI0090	WHI0166	WHI0167
3/3/2015	-	-	-	0.219	0.681	-	-
3/30/2015	1.57	-	-	-	-	-	-
4/13/2015	1.61	-	-	-	-	-	-
4/27/2015	-	-	-	-	-	0.439	0.668
5/4/2015	1.78	-	-	-	-	-	-
6/1/2015	2.17	-	-	-	-	-	-
6/29/2015	-	-	-	-	-	0.465	0.494
7/12/2015	2.06	-	-	-	-	-	-
8/10/2015	2.335	-	-	-	-	-	-
8/17/2015	-	-	-	-	-	0.453	0.832
8/24/2015	3.983	-	-	-	-	-	-
9/14/2015	3.22	-	-	-	-	-	-
9/21/2015	-	-	-	-	-	0.475	0.575
10/12/2015	3.54	-	-	-	-	-	-
11/1/2015	2.9	-	-	-	-	-	-
11/15/2015	2.57	-	-	-	-	-	-
12/28/2015	-	-	-	-	-	0.512	0.407
1/4/2016	1.8	-	-	-	-	-	-
2/1/2016	2.45	-	-	-	-	-	-
3/7/2016	1.934	-	-	-	-	0.126	0.179
4/4/2016	1.78	-	-	-	-	-	-
4/25/2016	-	-	-	-	-	0.245	0.332
5/16/2016	1.06	-	-	-	-	-	-
6/27/2016	1.82	-	-	-	-	-	-
7/11/2016	2.76	-	-	-	-	-	-
8/15/2016	1.45	-	-	-	-	-	-
9/12/2016	2.7	-	-	-	-	-	-
10/10/2016	4.545	-	-	-	-	-	-
11/27/2016	1.2	-	-	-	-	-	-
12/12/2016	2.15	-	-	-	-	-	-
1/9/2017	8.05	-	-	-	-	-	-
2/6/2017	1.53	-	-	-	-	-	-
3/12/2017	2.48	-	-	-	-	-	-
4/17/2017	2.57	-	-	-	-	-	-
6/5/2017	2.31	-	-	-	-	-	-
7/24/2017	4.53	-	-	-	-	-	-
8/14/2017	1.29	-	-	-	-	-	-
9/25/2017	8.25	-	-	-	-	-	-
10/30/2017	7.25	-	-	-	-	-	-
11/27/2017	4.27	-	-	-	-	-	-
12/3/2017	5.8	-	-	-	-	-	-

Table D.4. Calculations of TSS load and yield at selected ADEQ water quality monitoring stations.

Water Quality Station ID	Stream	Station Drainage Area (sq mi)	Harmonic Mean Flow (cfs)	Harmonic Mean Concentration (mg/L [n])	Estimated Annual Load (kg/yr)	Estimated Annual Yield (kg/yr/sq mi)
WHI0090	South Sylamore Creek	142	39.5	0.74 (9)	433	3.0
WHI0202	North Sylamore Creek	9.22	9.22	0.57 (10)	78.4	1.1
WHI0065	Hicks Creek	14.1	2.92	0.87 (11)	37.9	2.7
WHI0168	Piney Creek	174	25.7	1.3 (8)	425	2.4
WHI0162	Wideman Creek	13.2	3.81	1.3 (9)	73.6	5.6
WHI0167	Greenbrier Creek	32.5	2.1	7.5 (6)	236	7.2
WHI0166	Salado Creek	112	2.87	6.7 (9)	286	2.6

Table D.5. Calculations of total phosphorus load and yield at selected ADEQ water quality monitoring stations.

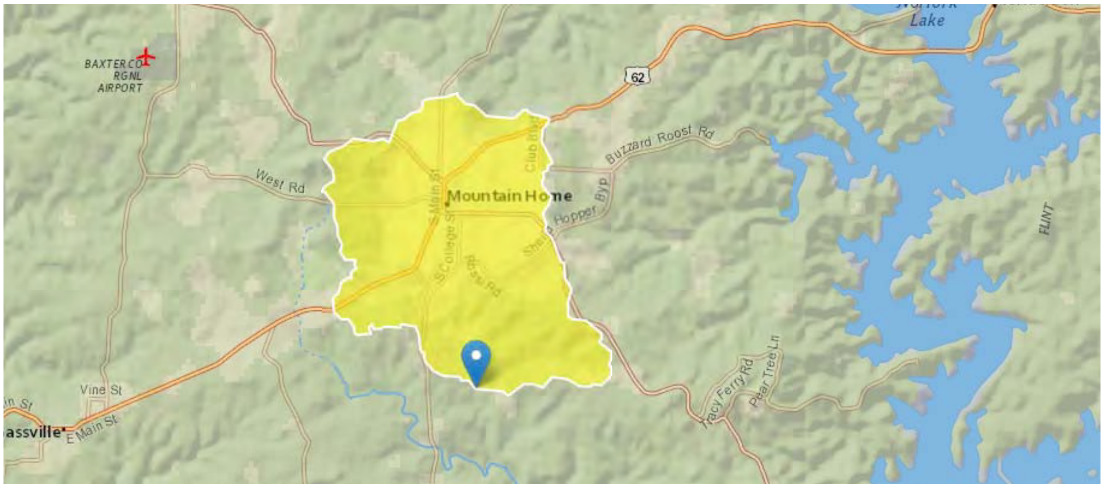
Water Quality Station ID	Stream	Station Drainage Area (sq mi)	Harmonic Mean Flow (cfs)	Harmonic Mean Concentration (mg/L [n])	Estimated Annual Load (kg/yr)	Estimated Annual Yield (kg/yr/sq mi)
WHI0090	South Sylamore Creek	142	39.5	0.051 (9)	19.5	0.11
WHI0202	North Sylamore Creek	9.22	9.22	0.008 (10)	4.61	0.03
WHI0065	Hicks Creek	14.1	2.92	0.945	41.1	2.9
WHI0168	Piney Creek	174	25.7	0.032	1.83	0.14
WHI0162	Wideman Creek	13.2	3.81	0.007	1.00	0.01
WHI0167	Greenbrier Creek	32.5	2.1	0.069	2.14	0.06
WHI0166	Salado Creek	112	2.87	0.004	0.18	0.001

Table D.6. Calculations of total nitrogen load and yield at selected ADEQ water quality monitoring stations.

Water Quality Station ID	Stream	Station Drainage Area (sq mi)	Harmonic Mean Flow (cfs)	Harmonic Mean Concentration (mg/L [n])	Estimated Annual Load (kg/yr)	Estimated Annual Yield (kg/yr/sq mi)
WHI0090	South Sylamore Creek	142	39.5	0.54	16.7	0.52
WHI0202	North Sylamore Creek	9.22	9.22	0.23	9.95	0.09
WHI0065	Hicks Creek	14.1	2.92	2.4	103	7.3
WHI0168	Piney Creek	174	25.7	0.32	43.9	0.60
WHI0162	Wideman Creek	13.2	3.81	0.20	77.4	0.44
WHI0167	Greenbrier Creek	32.5	2.1	0.73 (6)	431	3.0
WHI0166	Salado Creek	112	2.87	0.56	32.0	2.4

StreamStats Report

Region ID: AR
Workspace ID: AR20180702180713831000
Clicked Point (Latitude, Longitude): 36.29237, -92.37601
Time: 2018-07-02 13:07:30 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	14.1	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.37	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	45.7	feet per mi

General Flow Statistics Parameters [Harmonic Mean Flow Region 1 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	14.1	square miles	8	7350
BFI	Base Flow Index	0.37	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	45.7	feet per mi	2	95.8

General Flow Statistics Flow Report [Harmonic Mean Flow Region 1 2015 5031]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

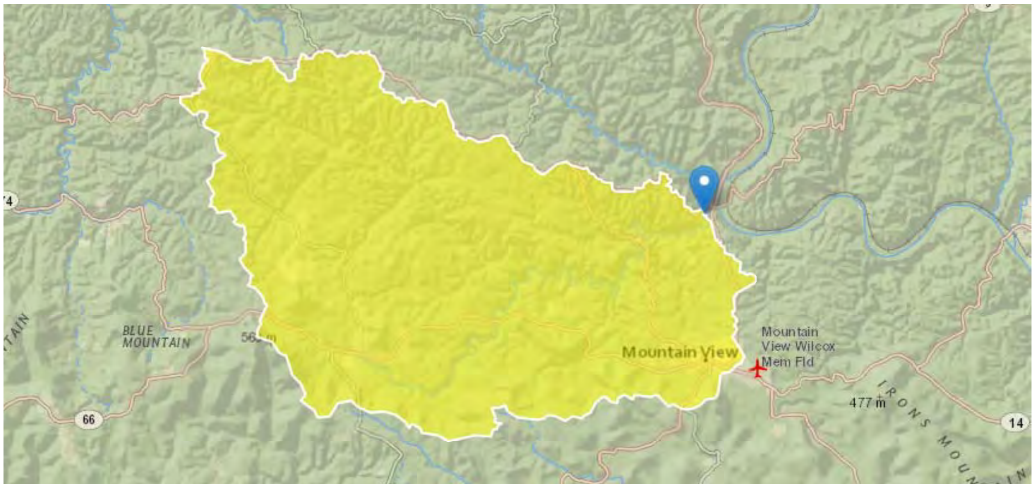
Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	2.92	ft^3/s	1.02	8.38	57.8

General Flow Statistics Citations

Breaker, B.K.,2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015–5031, 25 p. (http://pubs.usgs.gov/sir/2015/5031/)

StreamStats Report WHI0090

Region ID: AR
Workspace ID: AR20180702171721151000
Clicked Point (Latitude, Longitude): 35.93594, -92.12146
Time: 2018-07-02 12:17:37 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	142	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.35	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	16	feet per mi
ORDOMISS	Percent Surficial Geology as Ordovician and Mississippian Rocks	95	percent

General Flow Statistics Parameters [3 Percent (4.77 square miles) Harmonic Mean Flow Region 1 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	142	square miles	8	7350
BFI	Base Flow Index	0.35	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	16	feet per mi	2	95.8

General Flow Statistics Parameters [97 Percent (137 square miles) Harmonic Mean Flow Region 2 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	142	square miles	4.1	2090
BFI	Base Flow Index	0.35	dimensionless	0.1	0.4
ORDOMISS	Percent SurficialGeology Ordo and Miss	95	percent	0	100

General Flow Statistics Flow Report [3 Percent (4.77 square miles) Harmonic Mean Flow Region 1 2015 5031]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	SEp
Harmonic Mean Streamflow	19.5	ft^3/s	6.84	55.5	57.8

General Flow Statistics Flow Report [97 Percent (137 square miles) Harmonic Mean Flow Region 2 2015 5031]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	SEp
Harmonic Mean Streamflow	40.2	ft^3/s	24.6	65.5	76.6

General Flow Statistics Flow Report [Area-Averaged]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu
Harmonic Mean Streamflow	39.5	ft^3/s	24	65.1

General Flow Statistics Citations

Breaker, B.K.,2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015–5031, 25 p. (http://pubs.usgs.gov/sir/2015/5031/)

Application Version: 4.2.1

StreamStats Report WHI0162

Region ID: AR
Workspace ID: AR20180702181500959000
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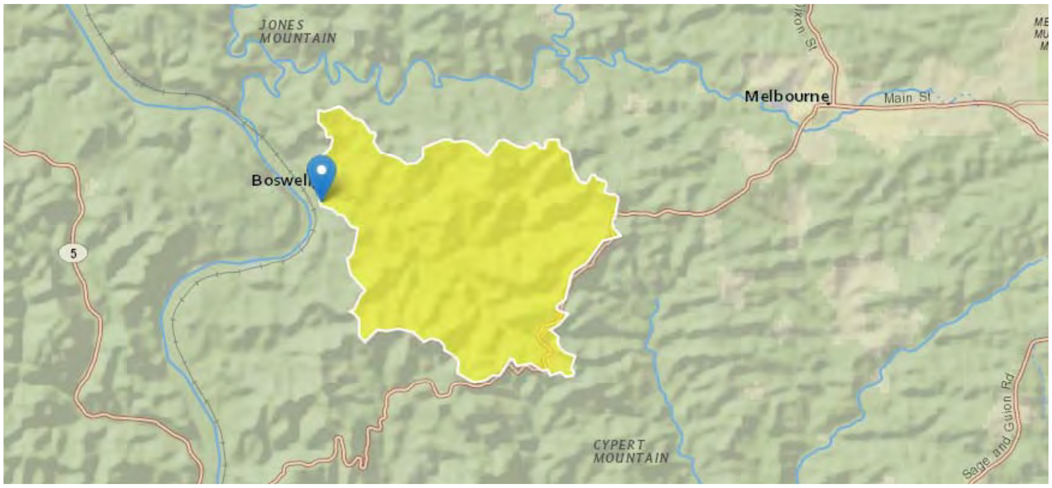
Time: 2018-07-02 13:15:16 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	13.2	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.37	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	56	feet per mi

General Flow Statistics Parameters [Harmonic Mean Flow Region 1 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	13.2	square miles	8	7350
BFI	Base Flow Index	0.37	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	56	feet per mi	2	95.8

General Flow Statistics Flow Report [Harmonic Mean Flow Region 1 2015 5031]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	SEp
Harmonic Mean Streamflow	3.81	ft^3/s	1.3	11.2	57.8

General Flow Statistics Citations

Breaker, B.K.,2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015–5031, 25 p. (http://pubs.usgs.gov/sir/2015/5031/)

StreamStats Report WHI0166

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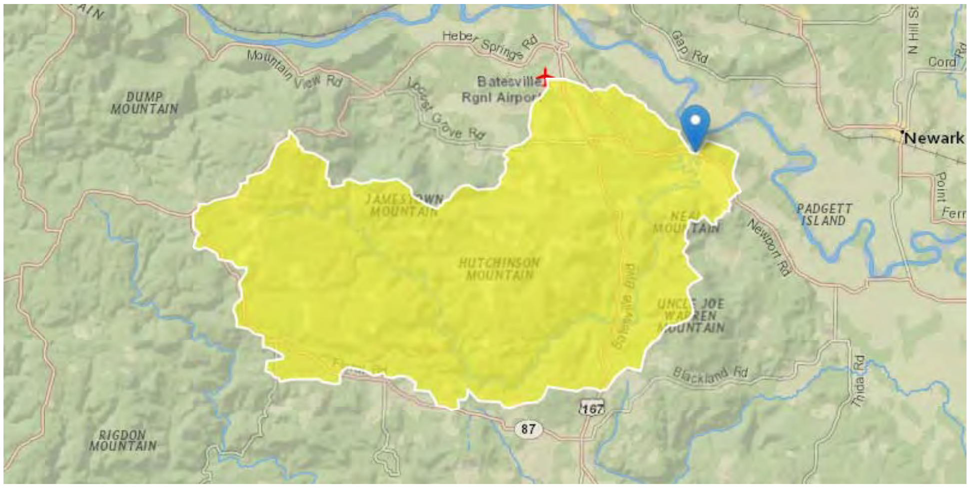


Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	112	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.29	dimensionless
ORDOMISS	Percent Surficial Geology as Ordovician and Mississippian Rocks	15.9	percent

General Flow Statistics Parameters [100 Percent (112 square miles) Harmonic Mean Flow Region 2 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	112	square miles	4.1	2090
BFI	Base Flow Index	0.29	dimensionless	0.1	0.4
ORDOMISS	Percent SurficialGeology Ordo and Miss	15.9	percent	0	100

General Flow Statistics Flow Report [100 Percent (112 square miles) Harmonic Mean Flow Region 2 2015 5031]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	2.87	ft^3/s	1.8	4.56	76.6

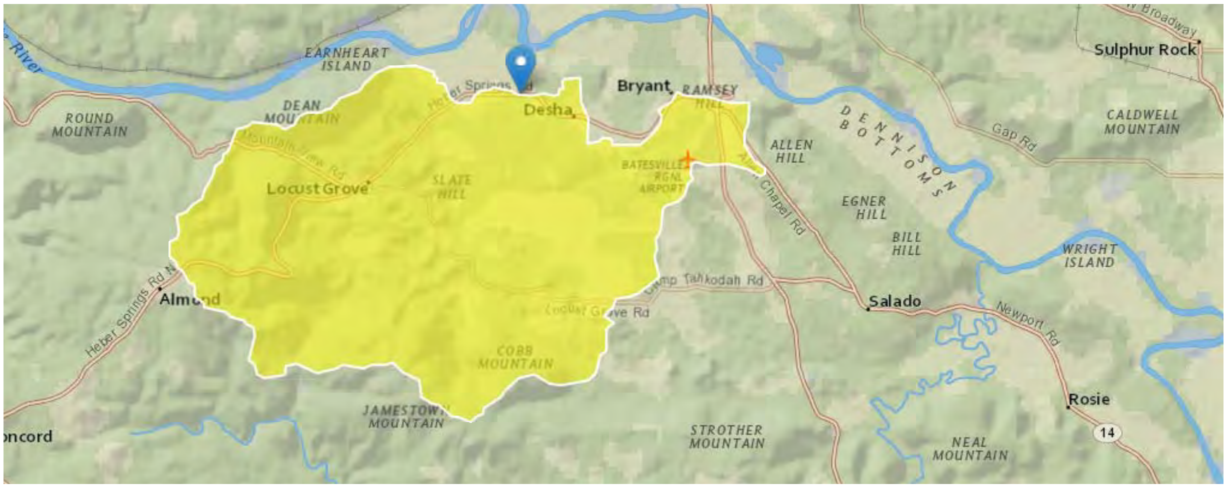
General Flow Statistics Citations

Breaker, B.K.,2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015–5031, 25 p. (http://pubs.usgs.gov/sir/2015/5031/)

Application Version: 4.2.1

StreamStats Report WHI0167

Region ID: AR
Workspace ID: AR20180702181804705000
Clicked Point (Latitude, Longitude): 35.74110, -91.69528
Time: 2018-07-02 13:18:20 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	32.5	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.29	dimensionless
ORDOMISS	Percent Surficial Geology as Ordovician and Mississippian Rocks	52.5	percent

General Flow Statistics Parameters [Harmonic Mean Flow Region 2 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	32.5	square miles	4.1	2090
BFI	Base Flow Index	0.29	dimensionless	0.1	0.4
ORDOMISS	Percent SurficialGeology Ordo and Miss	52.5	percent	0	100

General Flow Statistics Flow Report [Harmonic Mean Flow Region 2 2015 5031]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	Plu	SEp
Harmonic Mean Streamflow	2.1	ft^3/s	1.29	3.43	76.6

General Flow Statistics Citations

Breaker, B.K.,2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015–5031, 25 p. (http://pubs.usgs.gov/sir/2015/5031/)

Application Version: 4.2.1

StreamStats Report WHI0168

Region ID: AR
Workspace ID: AR20180702181225706000
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Time: 2018-07-02 13:12:41 -0500

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	174	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.37	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	12.7	feet per mi

General Flow Statistics Parameters [Harmonic Mean Flow Region 1 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	174	square miles	8	7350
BFI	Base Flow Index	0.37	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	12.7	feet per mi	2	95.8

General Flow Statistics Flow Report [Harmonic Mean Flow Region 1 2015 5031]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	25.7	ft^3/s	9.1	72.7	57.8

General Flow Statistics Citations

Breaker, B.K.,2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015–5031, 25 p. (http://pubs.usgs.gov/sir/2015/5031/)

StreamStats Report WHI0202

Region ID: AR
Workspace ID: AR20180702175908413000
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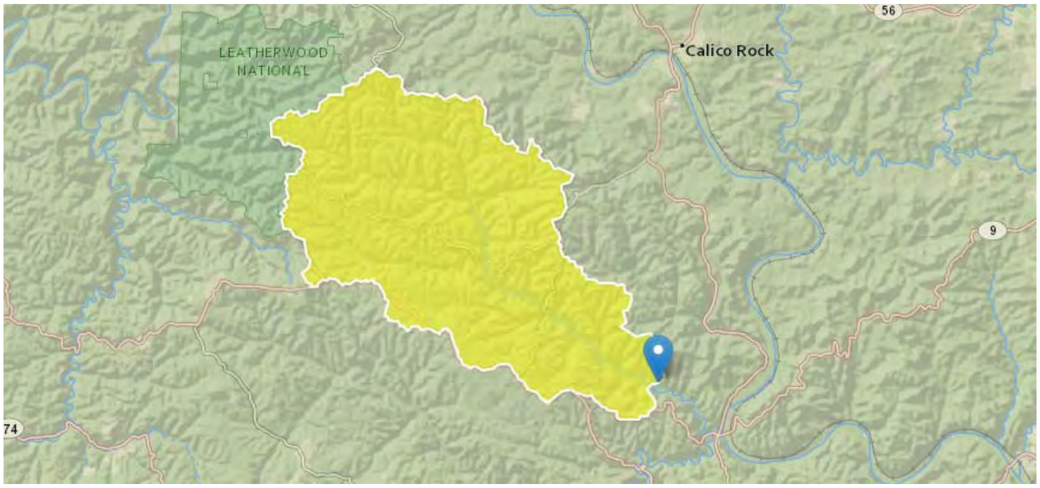
Time: 2018-07-02 12:59:25 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	72.5	square miles
BFI	Proportion of mean annual flow that is from ground water (base flow)	0.35	dimensionless
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	19.5	feet per mi
ORDOMISS	Percent Surficial Geology as Ordovician and Mississippian Rocks	100	percent

General Disclaimers

Parameter values have been edited, computed flows may not apply.

General Flow Statistics Parameters [99 Percent (71.6 square miles) Harmonic Mean Flow Region 1 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	72.5	square miles	8	7350
BFI	Base Flow Index	0.35	dimensionless	0.3	0.7
CSL1085LFP	Stream Slope 10 and 85 Longest Flow Path	19.5	feet per mi	2	95.8

General Flow Statistics Parameters [1 Percent (0.903 square miles) Harmonic Mean Flow Region 2 2015 5031]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	72.5	square miles	4.1	2090
BFI	Base Flow Index	0.35	dimensionless	0.1	0.4
ORDOMISS	Percent SurficialGeology Ordo and Miss	100	percent	0	100

General Flow Statistics Flow Report [99 Percent (71.6 square miles) Harmonic Mean Flow Region 1 2015 5031]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	SEp
Harmonic Mean Streamflow	9.05	ft^3/s	3.17	25.8	57.8

General Flow Statistics Flow Report [1 Percent (0.903 square miles) Harmonic Mean Flow Region 2 2015 5031]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SEp
Harmonic Mean Streamflow	23	ft^3/s	13.9	38	76.6

General Flow Statistics Flow Report [Area-Averaged]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu
Harmonic Mean Streamflow	9.22	ft^3/s	3.3	26

General Flow Statistics Citations

Breaker, B.K.,2015, Dry season mean monthly flow and harmonic mean flow regression equations for selected ungaged basins in Arkansas: U.S. Geological Survey Scientific Investigations Report 2015–5031, 25 p. (http://pubs.usgs.gov/sir/2015/5031/)

Application Version: 4.2.1

APPENDIX E

Linear Regression Analysis of Dissolved Oxygen and Nutrients at Selected Water Quality Monitoring Stations

Appendix E

Greenbrier Cr results of linear regression of DO to other parameters.

Parameter	N	p-value	R squared	equation
TKN	25	0.007	0.273	10.2-5.10 * TKN
Ammonia-N	25	0.008	0.266	9.07 – 36.2 * NH3N
NOx	25	0.712	0.006	-
TN (calculated)	25	0.078	0.129	-
TP	25	0.884	0.001	-
BOD	10	0.497	0.060	-
Temperature, C	25	0.000	0.634	13.2 – 0.35 * temperature
Turbidity	25	0.544	0.016	-
Ln(TP)	25	0.421	0.028	-
Ln(NOx)	25	0.789	0.003	-
LN(TKN)	25	0.002	0.339	5.12 – 3.16 * ln(TKN)
Ln(TN)	25	0.054	0.152	-
Ln(turbidity)	25	0.598	0.012	-
Ln(NH3)	17	0.154	0.131	-

Lower Salado Cr (WHI0166) results of linear regression of DO to other parameters

Parameter	N	p-value	R squared	equation
TKN	25	0.011	0.251	9.86 – 5.74 * TKN
Ammonia-N	26	0.000	0.525	9.22 – 59.0 * NH3N
NOx	26	0.003	0.308	5.51 + 10.1 * NOx
TN (calculated)	25	0.408	0.030	-
TP	26	0.496	0.020	-
BOD	10	0.245	0.164	-
Temperature, C	26	0.000	0.616	12.4 – 0.28 * temperature
Turbidity	26	0.574	0.013	-
Ln(TP)	26	0.086	0.118	-
Ln(NOx)	25	0.030	0.188	10.12 + 1.37 * ln(NOx)
LN(TKN)	25	0.002	0.359	4.22 – 3.23 * ln(TKN)
Ln(TN)	25	0.458	0.024	-
Ln(turbidity)	26	0.348	0.037	-
Ln(NH3)	12	0.047	0.338	-
Ln(BOD)	10	0.140	0.251	-

File: C:\local work\ANRC WMPs\Mid White\GreenbrierCr DO and nutrients.syz

> REGRESS
> MODEL DO_MGL = CONSTANT+TKN_RESULT

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.523
Squared Multiple R	0.273
Adjusted Squared Multiple R	0.242
Standard Error of Estimate	2.408

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	10.248	1.009	0.000	.	10.160	0.000
TKN_RESULT	-5.099	1.734	-0.523	1.000	-2.940	0.007

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	50.105	1	50.105	8.643	0.007
Residual	133.334	23	5.797		

WARNING

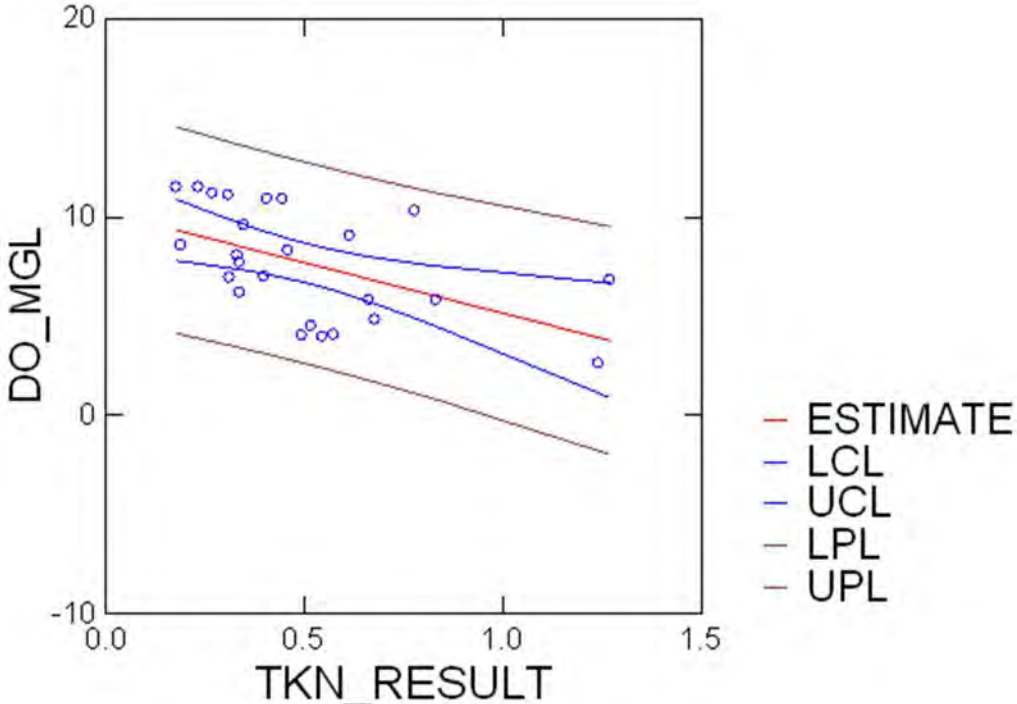
Case 5 has large Leverage (Leverage : 0.339)

Durbin-Watson D Statistic	1.867
First Order Autocorrelation	0.029

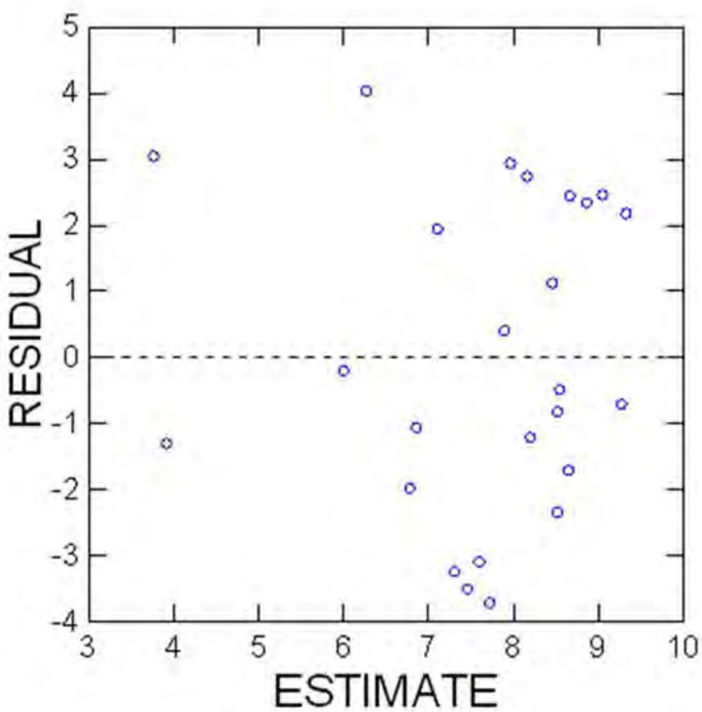
Information Criteria

AIC	118.796
AIC (Corrected)	119.939
Schwarz's BIC	122.453

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+NH3N_MGL

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.515
Squared Multiple R	0.266
Adjusted Squared Multiple R	0.234
Standard Error of Estimate	2.420

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	9.073	0.693	0.000	.	13.088	0.000
NH3N_MGL	-36.210	12.557	-0.515	1.000	-2.884	0.008

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	48.709	1	48.709	8.315	0.008
Residual	134.730	23	5.858		

WARNING

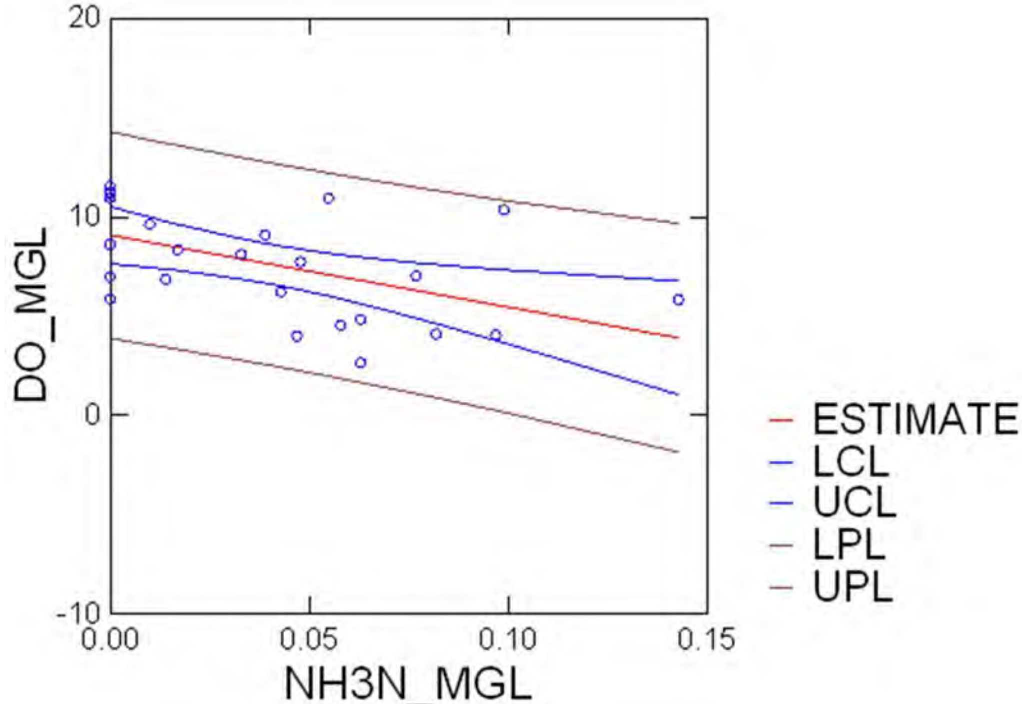
Case 10 has large Leverage (Leverage : 0.328)

Durbin-Watson D Statistic	1.410
First Order Autocorrelation	0.272

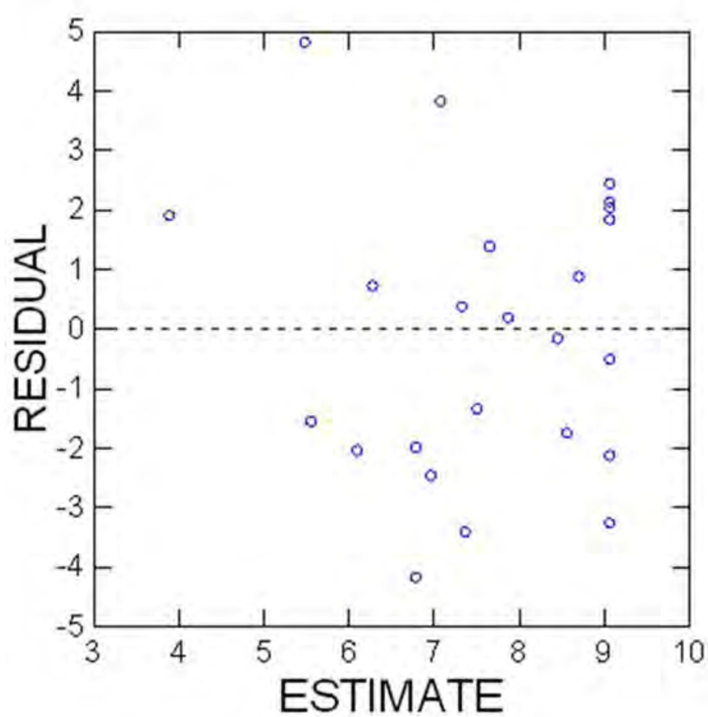
Information Criteria

AIC	119.057
AIC (Corrected)	120.200
Schwarz's BIC	122.713

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+NOX_RESULT

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.078
Squared Multiple R	0.006
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.816

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.318	1.035	0.000	.	7.073	0.000
NOX_RESULT	0.704	1.885	0.078	1.000	0.373	0.712

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	1.105	1	1.105	0.139	0.712
Residual	182.334	23	7.928		

WARNING

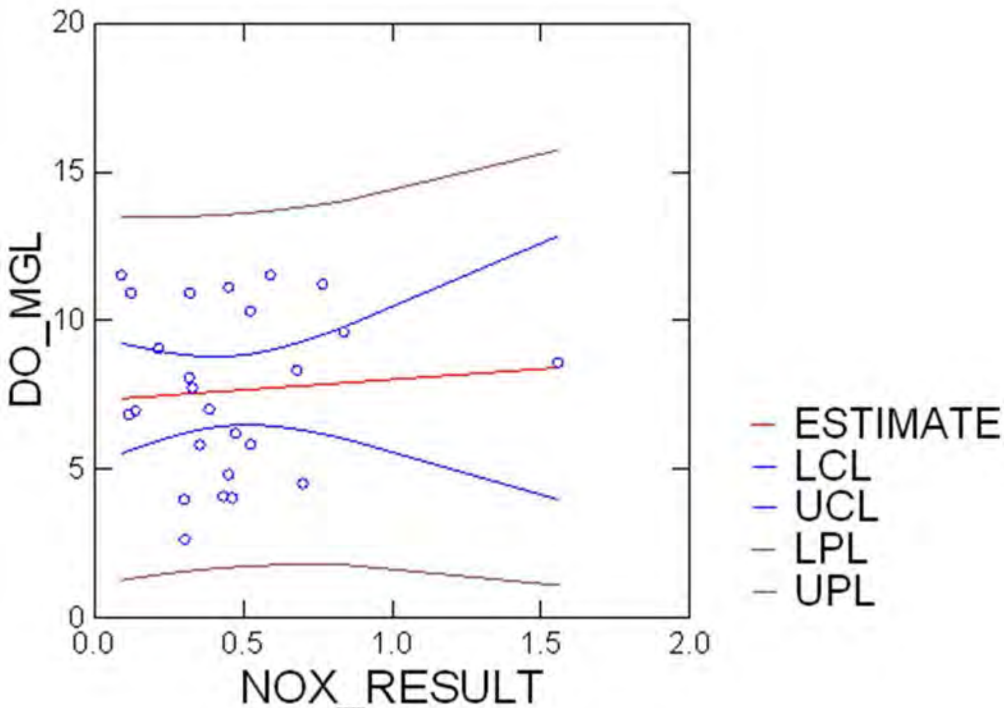
Case 13 has large Leverage (Leverage : 0.582)

Durbin-Watson D Statistic	1.749
First Order Autocorrelation	0.095

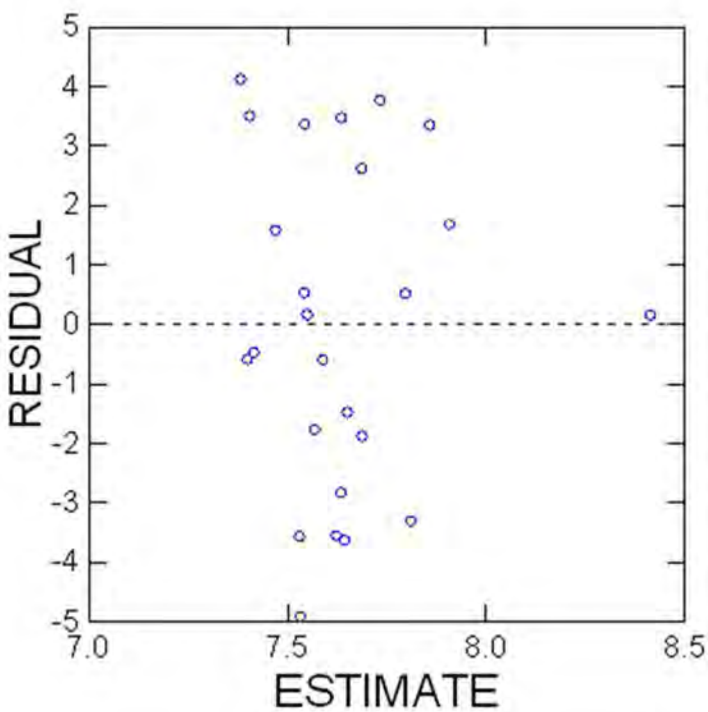
Information Criteria

AIC	126.621
AIC (Corrected)	127.764
Schwarz's BIC	130.278

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+TN_CALC

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.359
Squared Multiple R	0.129
Adjusted Squared Multiple R	0.091
Standard Error of Estimate	2.636

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	10.416	1.596	0.000		6.527	0.000
TN_CALC	-2.856	1.551	-0.359	1.000	-1.842	0.078

Analysis of Variance

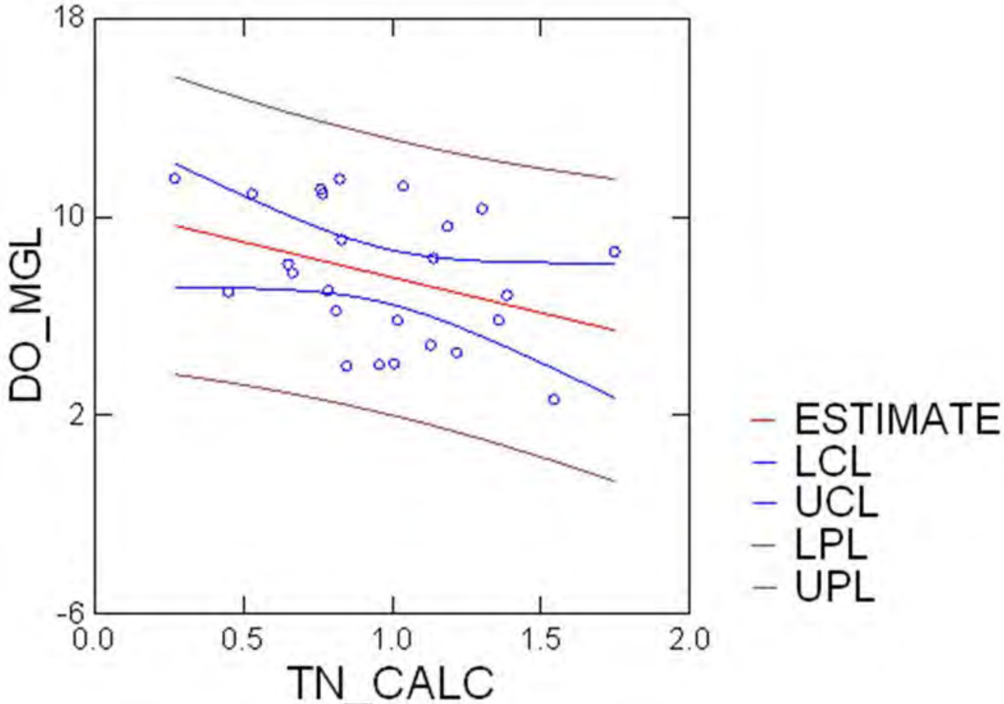
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	23.576	1	23.576	3.392	0.078
Residual	159.863	23	6.951		

Durbin-Watson D Statistic	2.128
First Order Autocorrelation	-0.083

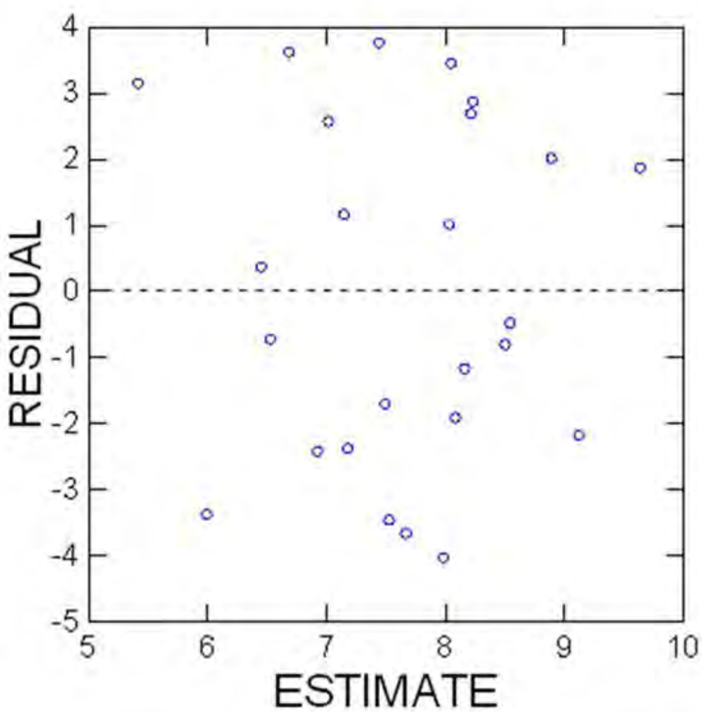
Information Criteria

AIC	123.333
AIC (Corrected)	124.476
Schwarz's BIC	126.990

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+TP_MGL

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.031
Squared Multiple R	0.001
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.823

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.690	0.648	0.000		11.861	0.000
TP_MGL	-0.263	1.776	-0.031	1.000	-0.148	0.884

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	0.174	1	0.174	0.022	0.884
Residual	183.265	23	7.968		

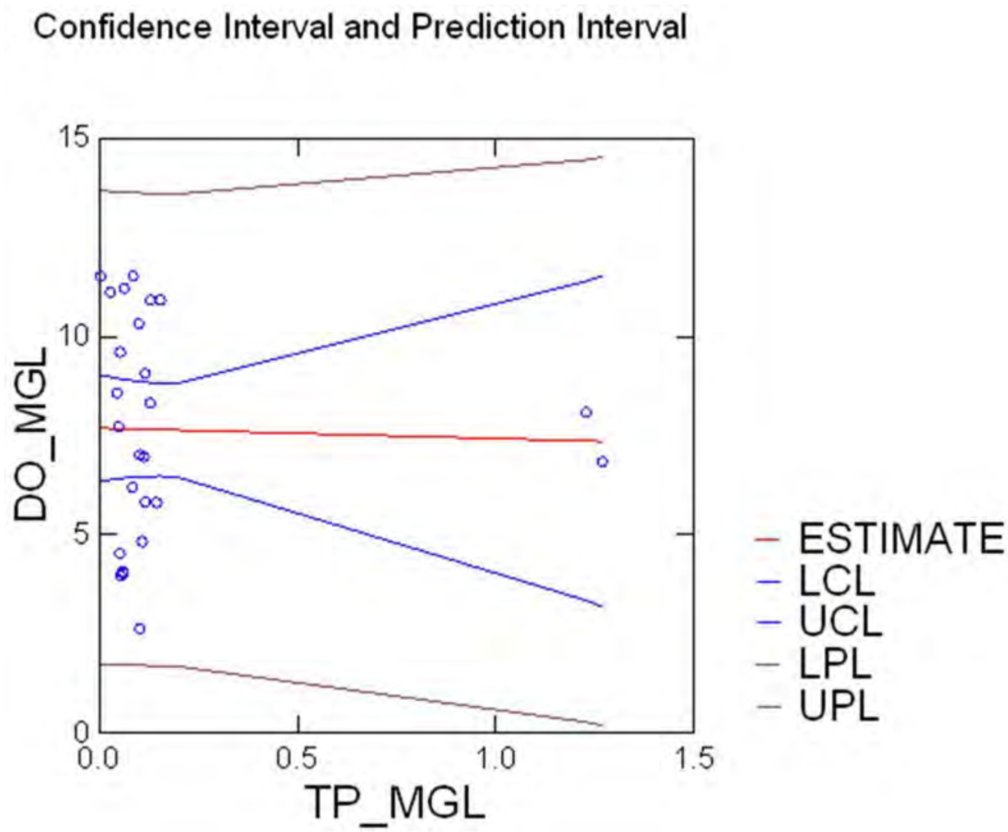
WARNING

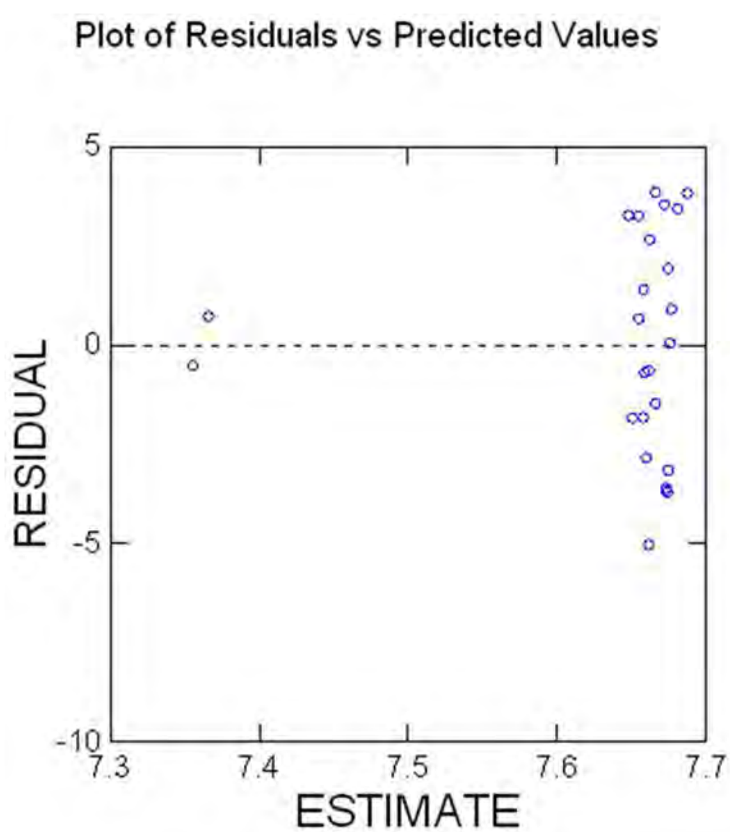
Case 5 has large Leverage (Leverage : 0.511)
Case 26 has large Leverage (Leverage : 0.477)

Durbin-Watson D Statistic	1.814
First Order Autocorrelation	0.064

Information Criteria

AIC	126.748
AIC (Corrected)	127.891
Schwarz's BIC	130.405


Confidence Interval and Prediction Interval
15
10
5
0
0.0
0.5
1.0
1.5
DO_MGL
TP_MGL
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
5
0
-5
-10
7.3
7.4
7.5
7.6
7.7
RESIDUAL
ESTIMATE

> REGRESS
> MODEL DO_MGL = CONSTANT+BOD_MGL

16 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	10
Multiple R	0.244
Squared Multiple R	0.060
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	3.348

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	8.444	2.016	0.000		4.189	0.003
BOD_MGL	-0.877	1.232	-0.244	1.000	-0.712	0.497

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	5.676	1	5.676	0.507	0.497
Residual	89.652	8	11.206		

WARNING

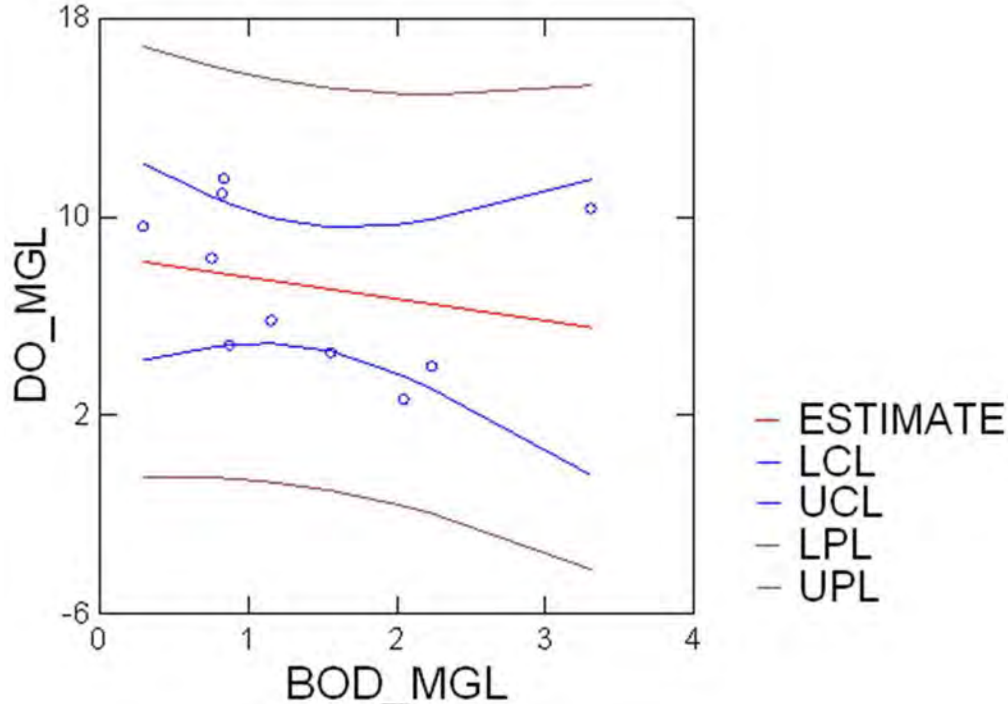
Case 8 has large Leverage (Leverage : 0.597)
Case 8 is an Outlier (Studentized Residual : 3.431)

Durbin-Watson D Statistic	1.286
First Order Autocorrelation	0.284

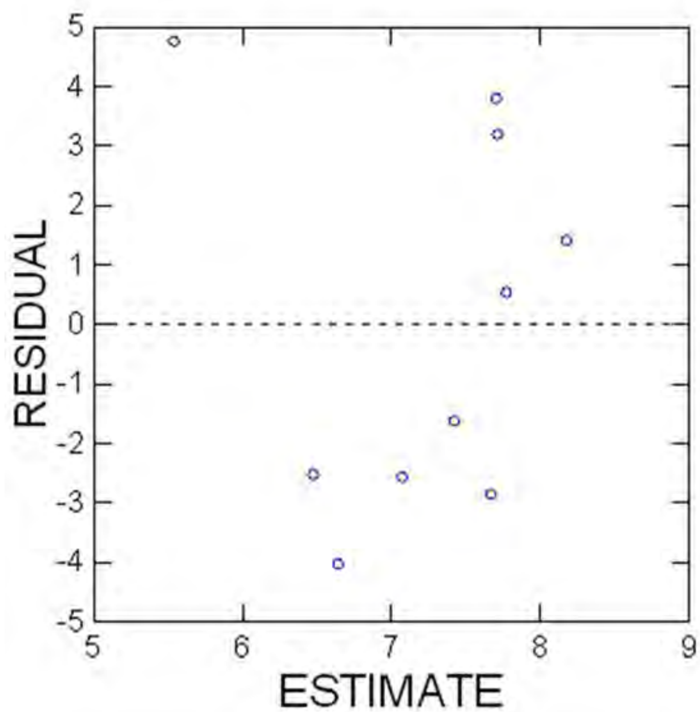
Information Criteria

AIC	56.312
AIC (Corrected)	60.312
Schwarz's BIC	57.220

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+TEMP_DEGC

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.796
Squared Multiple R	0.634
Adjusted Squared Multiple R	0.618
Standard Error of Estimate	1.708

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	13.240	0.950	0.000	.	13.942	0.000
TEMP_DEGC	-0.349	0.055	-0.796	1.000	-6.317	0.000

Analysis of Variance

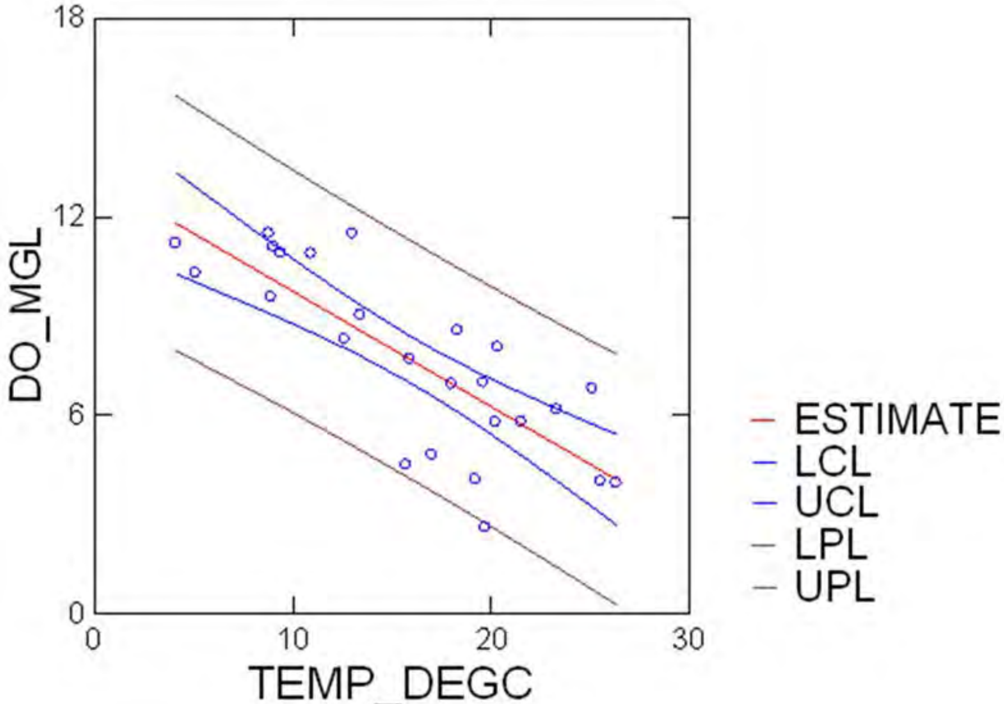
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	116.369	1	116.369	39.906	0.000
Residual	67.070	23	2.916		

Durbin-Watson D Statistic	2.213
First Order Autocorrelation	-0.213

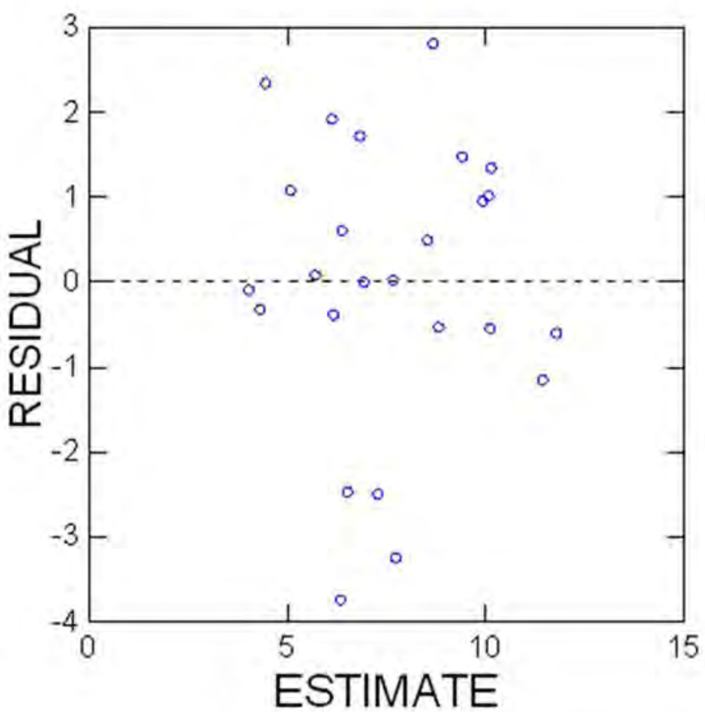
Information Criteria

AIC	101.618
AIC (Corrected)	102.761
Schwarz's BIC	105.275

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+TURBIDITY_NTU

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.127
Squared Multiple R	0.016
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.801

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.144	0.984	0.000	.	7.264	0.000
TURBIDITY_NTU	0.033	0.053	0.127	1.000	0.616	0.544

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	2.978	1	2.978	0.380	0.544
Residual	180.461	23	7.846		

WARNING

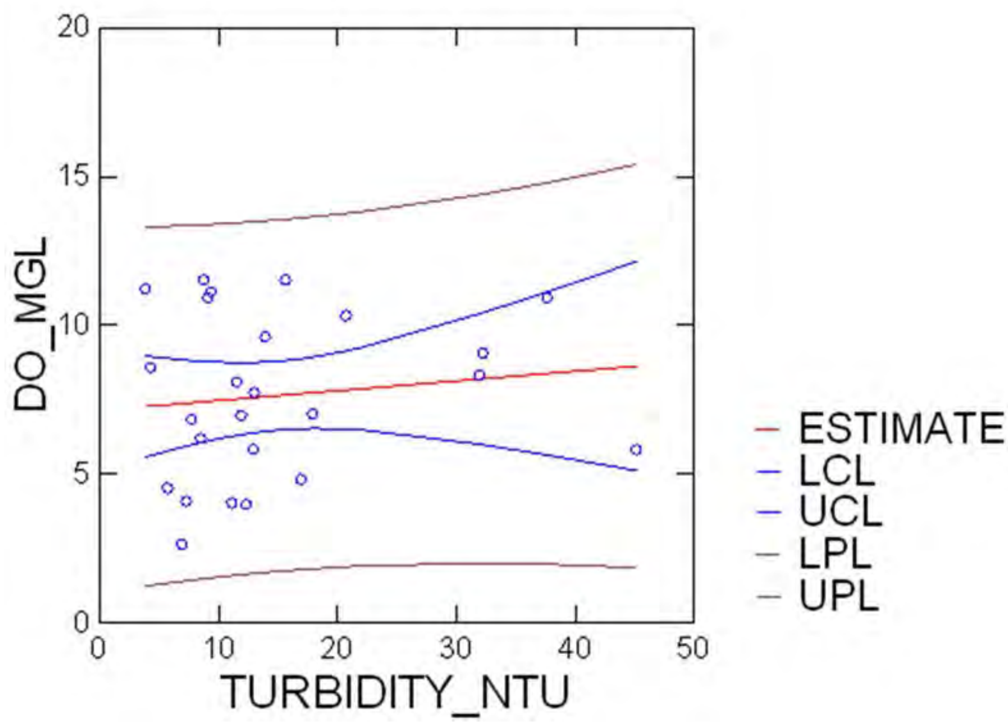
Case 10 has large Leverage (Leverage : 0.369)

Durbin-Watson D Statistic	1.863
First Order Autocorrelation	0.046

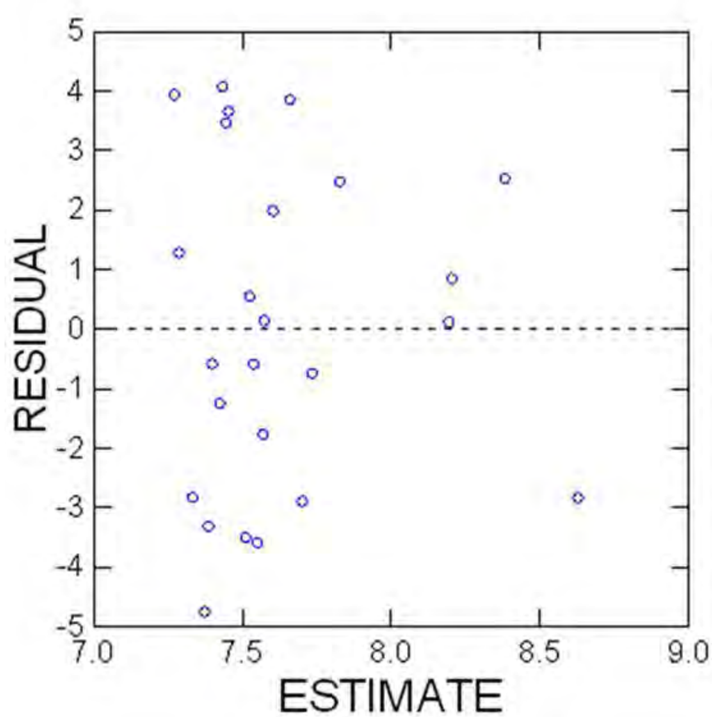
Information Criteria

AIC	126.363
AIC (Corrected)	127.506
Schwarz's BIC	130.020

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL =
CONSTANT+TURBIDITY_NTU+NOX_RESULT+TKN_RESULT+TN_CALC+TP_MGL+BOD_MGL+TEMP_DEGC

Stepwise Selection of Variables

16 case(s) are deleted due to missing data.
Unable to enter effect 4.
This effect may fail tolerance checks.

Step number : 0
R : 0.985
R-square : 0.970

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.063	0.056	0.235	0.228	1	1.255	0.344
3	NOX_RESULT	-5.081	5.691	-0.298	0.090	1	0.797	0.438
5	TN_CALC	0.000	2.060	0.000	0.435	1	6.079	0.090
6	TP_MGL	-5.080	29.074	-0.375	0.111	1	0.593	0.497
7	BOD_MGL	-22.383	0.697	-0.232	0.268	1	0.332	0.605
8	TEMP_DEGC	-0.401	0.111	-0.112	0.210	1	23.199	0.017

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	TKN_RESULT	.	.	0	.	.

Effect 4 lost 1 degree(s) of freedom.

Information Criteria	
AIC	31.942
AIC (Corrected)	175.942
Schwarz's BIC	34.363

The following effects have lost degrees of freedom.

Effect	Initial df	Lost df	Final df
TKN_RESULT	1	1	0

Dependent Variable : DO_MGL
Minimum Tolerance for Entry into Model : 0.000
Backward Stepwise with Alpha-to-Enter : 0.150
Backward Stepwise with Alpha-to-Remove : 0.150

Step number : 1
R : 0.983
R-square : 0.966
Term Removed : BOD_MGL

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.042	0.040	0.159	0.378	1	1.141	0.346
3	NOX_RESULT	-2.373	2.930	-0.139	0.284	1	0.656	0.463
5	TN_CALC	0.000	1.296	0.000	0.917	1	21.009	0.010
6	TP_MGL	-5.940	17.338	-0.439	0.259	1	0.313	0.606
8	TEMP_DEGC	-0.795	0.072	-0.221	0.409	1	45.585	0.003

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	TKN_RESULT	.	.	0	.	.
7	BOD_MGL	-0.316	0.268	1	0.332	0.605

Effect 4 lost 1 degree(s) of freedom.

Information Criteria	
AIC	30.991
AIC (Corrected)	86.991
Schwarz's BIC	33.110

Step number : 2
R : 0.982
R-square : 0.964
Term Removed : TP_MGL

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.025	0.023	0.094	0.987	1	1.196	0.324
3	NOX_RESULT	-1.147	1.806	-0.067	0.644	1	0.403	0.553
5	TN_CALC	0.000	1.181	0.000	0.952	1	26.496	0.004
8	TEMP_DEGC	0.022	0.053	0.006	0.663	1	77.205	0.000

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	TKN_RESULT	.	.	0	.	.
6	TP_MGL	-0.269	0.259	1	0.313	0.606
7	BOD_MGL	0.005	0.628	1	0.000	0.992

Effect 4 lost 1 degree(s) of freedom.

Information Criteria	
AIC	29.745
AIC (Corrected)	57.745
Schwarz's BIC	31.561

Step number : 3
R : 0.980
R-square : 0.961
Term Removed : NOX_RESULT

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.025	0.022	0.093	0.987	1	1.297	0.298
5	TN_CALC	-6.221	1.101	-0.460	0.987	1	31.947	0.001
8	TEMP_DEGC	-0.443	0.041	-0.880	0.997	1	118.282	0.000

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
3	NOX_RESULT	-0.273	0.644	1	0.403	0.553
4	TKN_RESULT	0.273	0.302	1	0.403	0.553
6	TP_MGL	0.032	0.588	1	0.005	0.945
7	BOD_MGL	0.143	0.845	1	0.104	0.760

Information Criteria	
AIC	28.521
AIC (Corrected)	43.521
Schwarz's BIC	30.034

Step number : 4
R : 0.976
R-square : 0.952
Term Removed : TURBIDITY_NTU

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
5	TN_CALC	-6.353	1.118	-0.469	0.998	1	32.312	0.001
8	TEMP_DEGC	-0.442	0.042	-0.877	0.998	1	112.764	0.000

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
2	TURBIDITY_NTU	0.422	0.987	1	1.297	0.298
3	NOX_RESULT	-0.239	0.645	1	0.363	0.569
4	TKN_RESULT	0.239	0.302	1	0.363	0.569
6	TP_MGL	0.291	0.991	1	0.556	0.484
7	BOD_MGL	0.086	0.854	1	0.045	0.839

Information Criteria	
AIC	28.477
AIC (Corrected)	36.477
Schwarz's BIC	29.688

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.836
Squared Multiple R	0.699

Dependent Variable	DO_MGL
Adjusted Squared Multiple R	0.672
Standard Error of Estimate	1.584

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	14.983	1.192	0.000	.	12.575	0.000
TN_CALC	-2.043	0.940	-0.257	0.982	-2.173	0.041
TEMP_DEGC	-0.334	0.052	-0.762	0.982	-6.457	0.000

Analysis of Variance

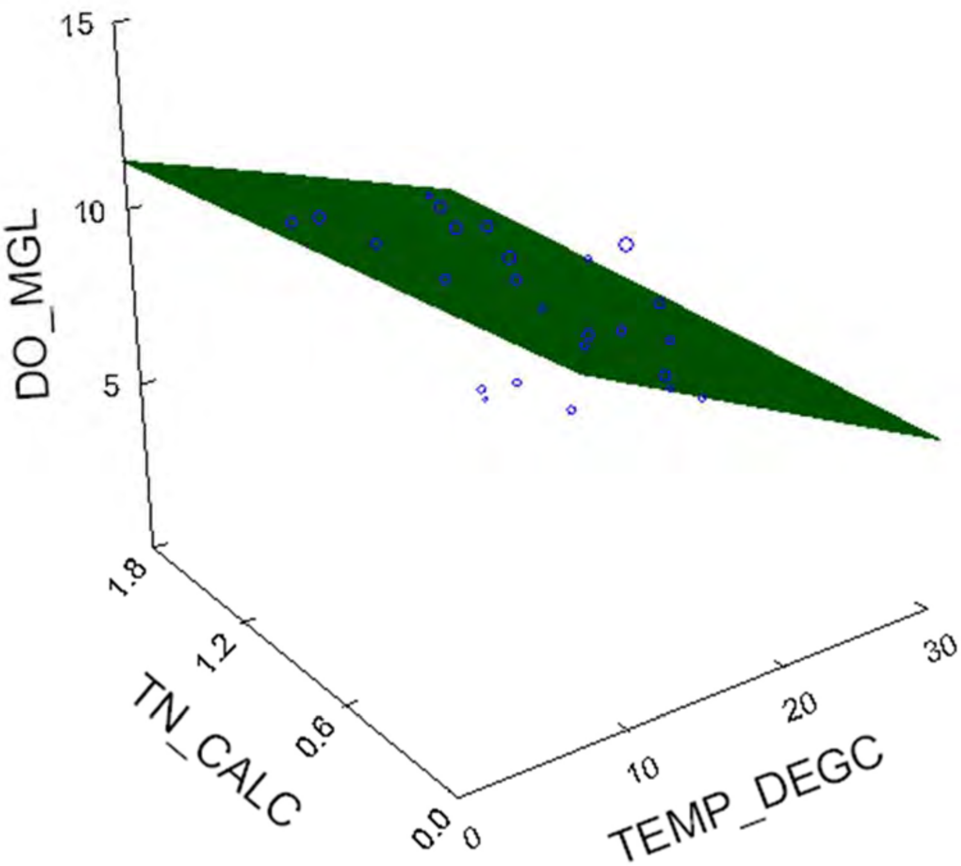
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	128.223	2	64.111	25.544	0.000
Residual	55.217	22	2.510		

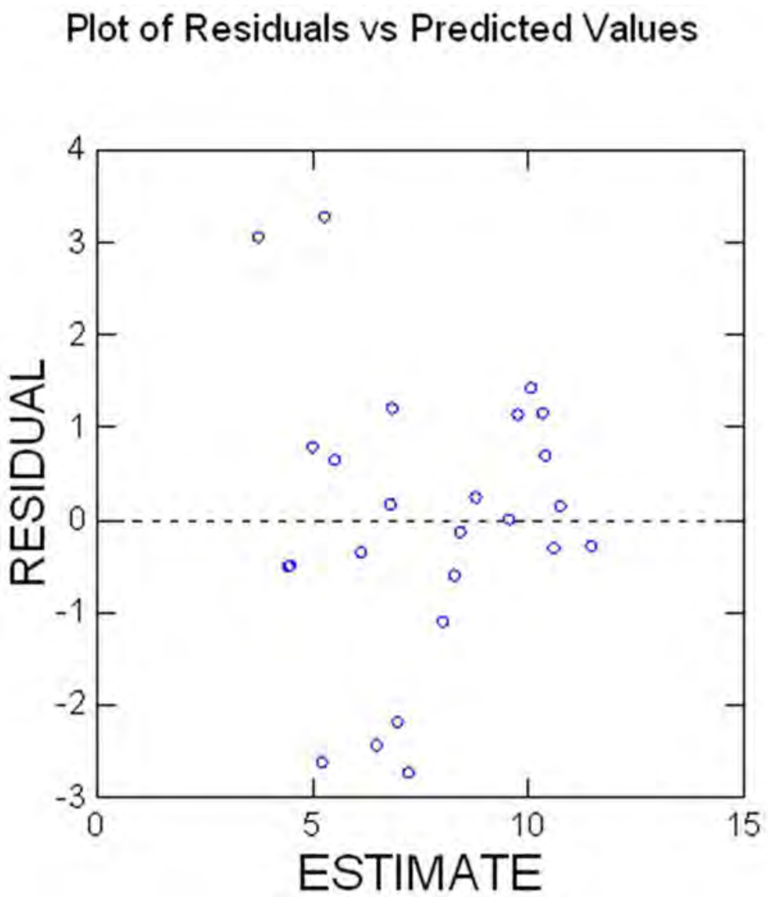
Durbin-Watson D Statistic	2.625
First Order Autocorrelation	-0.393

Information Criteria

AIC	98.757
AIC (Corrected)	100.757
Schwarz's BIC	103.632

Fitted Model Plot




Plot of Residuals vs Predicted Values
RESIDUAL
4
3
2
1
0
-1
-2
-3
0
5
10
15
ESTIMATE

> REGRESS
> MODEL DO_MGL = CONSTANT+LNTP

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.168
Squared Multiple R	0.028
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.784

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	6.584	1.407	0.000		4.678	0.000
LNTP	-0.443	0.541	-0.168	1.000	-0.819	0.421

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	5.195	1	5.195	0.670	0.421
Residual	178.244	23	7.750		

WARNING

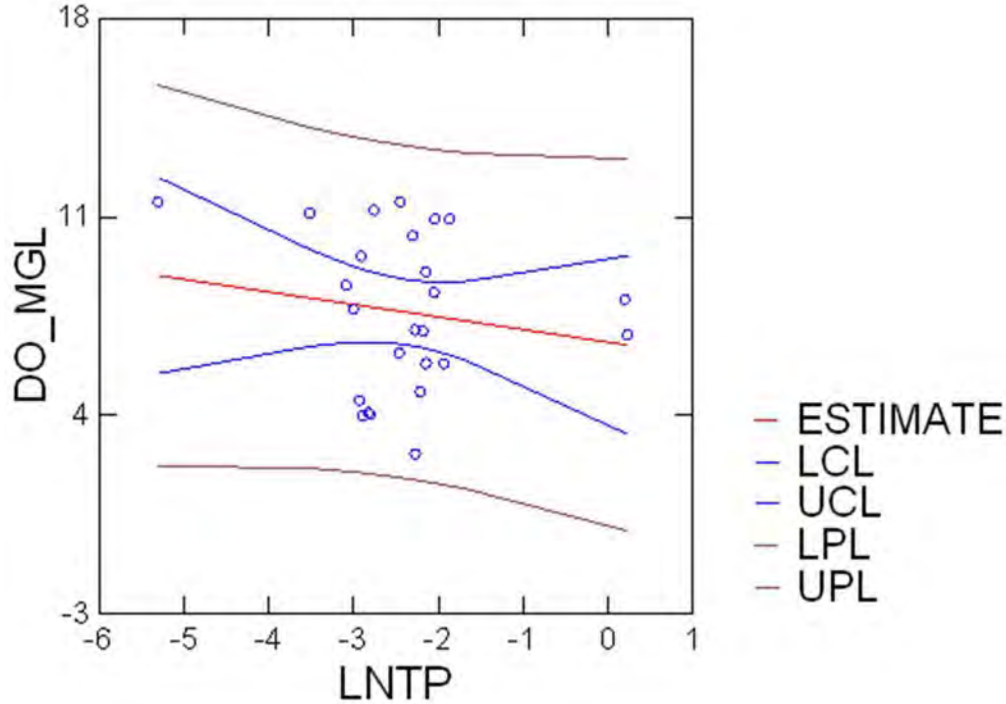
Case 25 has large Leverage (Leverage : 0.360)

Durbin-Watson D Statistic	1.879
First Order Autocorrelation	0.022

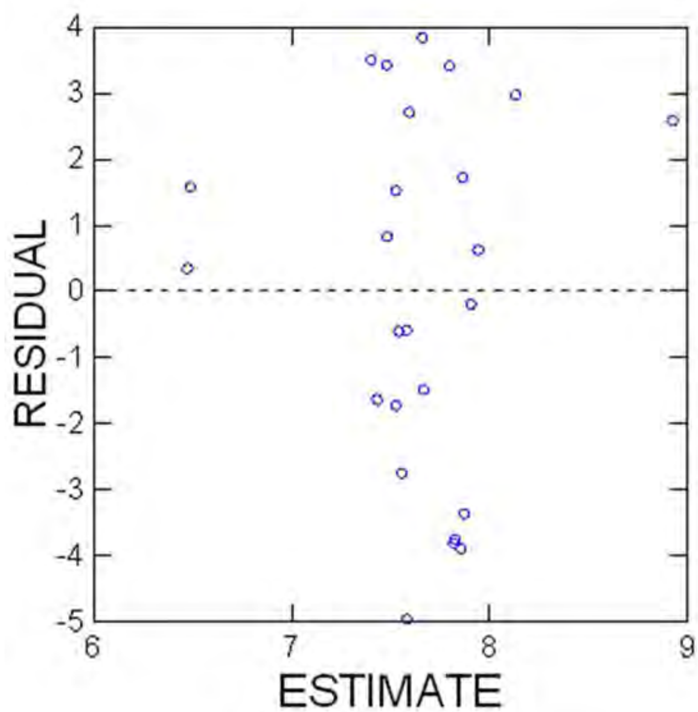
Information Criteria

AIC	126.054
AIC (Corrected)	127.197
Schwarz's BIC	129.710

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+LNNOX

▼OLS Regression

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.056
Squared Multiple R	0.003
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.820

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.414	1.015	0.000		7.308	0.000
LNNOX	-0.235	0.869	-0.056	1.000	-0.271	0.789

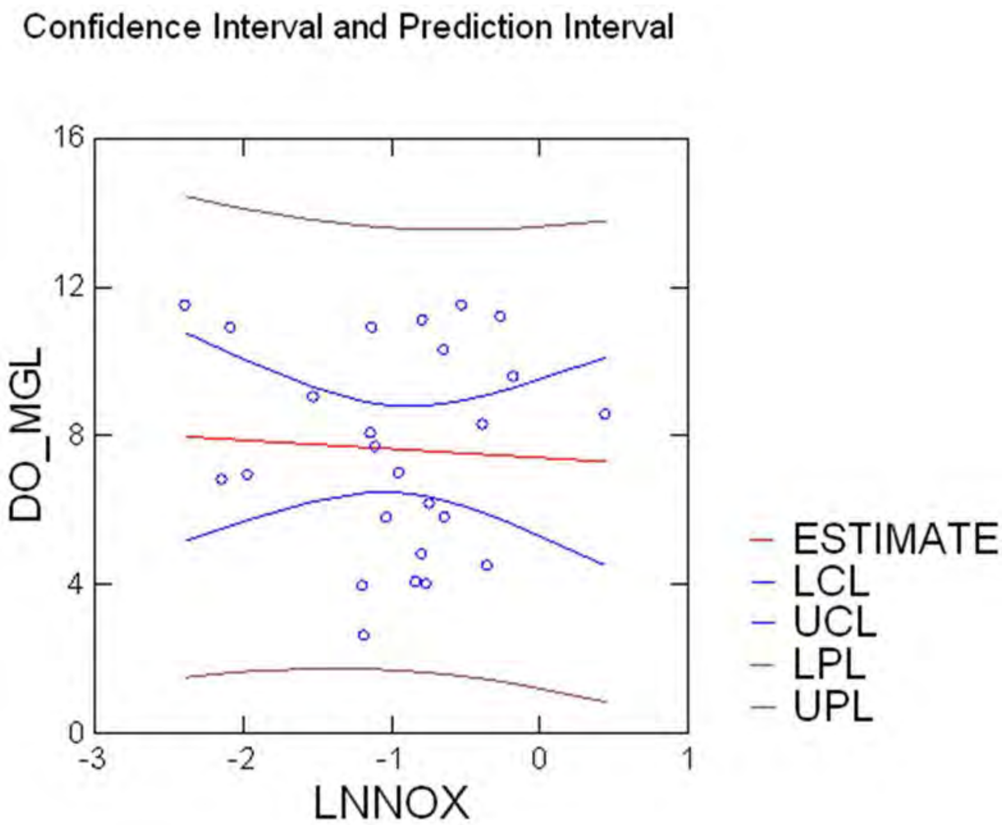
Analysis of Variance

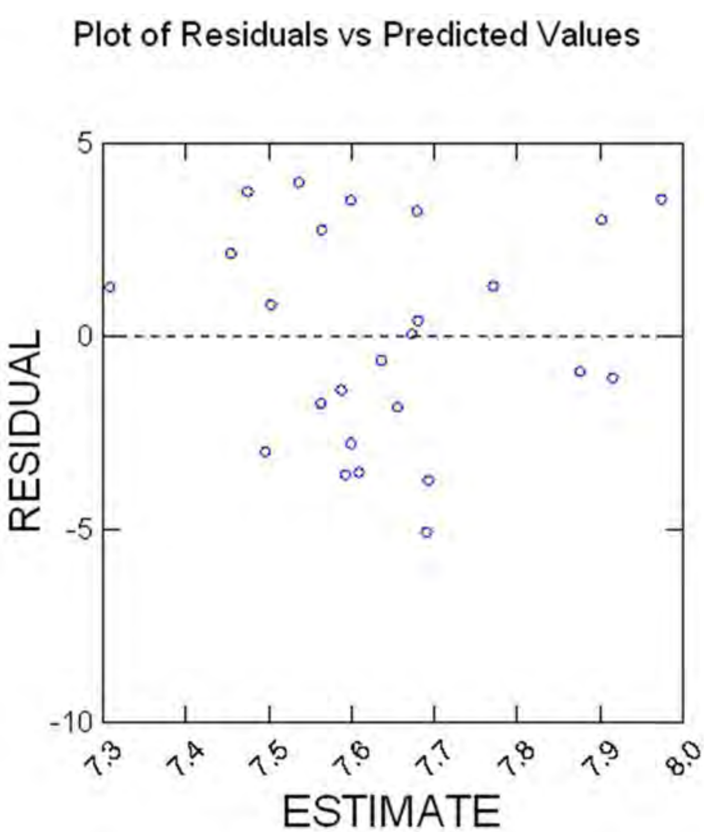
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	0.582	1	0.582	0.073	0.789
Residual	182.858	23	7.950		

Durbin-Watson D Statistic	1.823
First Order Autocorrelation	0.064

Information Criteria

AIC	126.693
AIC (Corrected)	127.836
Schwarz's BIC	130.349


Confidence Interval and Prediction Interval
DO_MGL
LNNOX
ESTIMATE
LCL
UCL
LPL
UPL
16
12
8
4
0
-3
-2
-1
0
1


Plot of Residuals vs Predicted Values
RESIDUAL
ESTIMATE
5
0
-5
-10
7.3
7.4
7.5
7.6
7.7
7.8
7.9
8.0

> REGRESS
> MODEL DO_MGL = CONSTANT+LNTKN

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.582
Squared Multiple R	0.339
Adjusted Squared Multiple R	0.310
Standard Error of Estimate	2.297

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	5.117	0.868	0.000		5.899	0.000
LNTKN	-3.157	0.920	-0.582	1.000	-3.431	0.002

Analysis of Variance

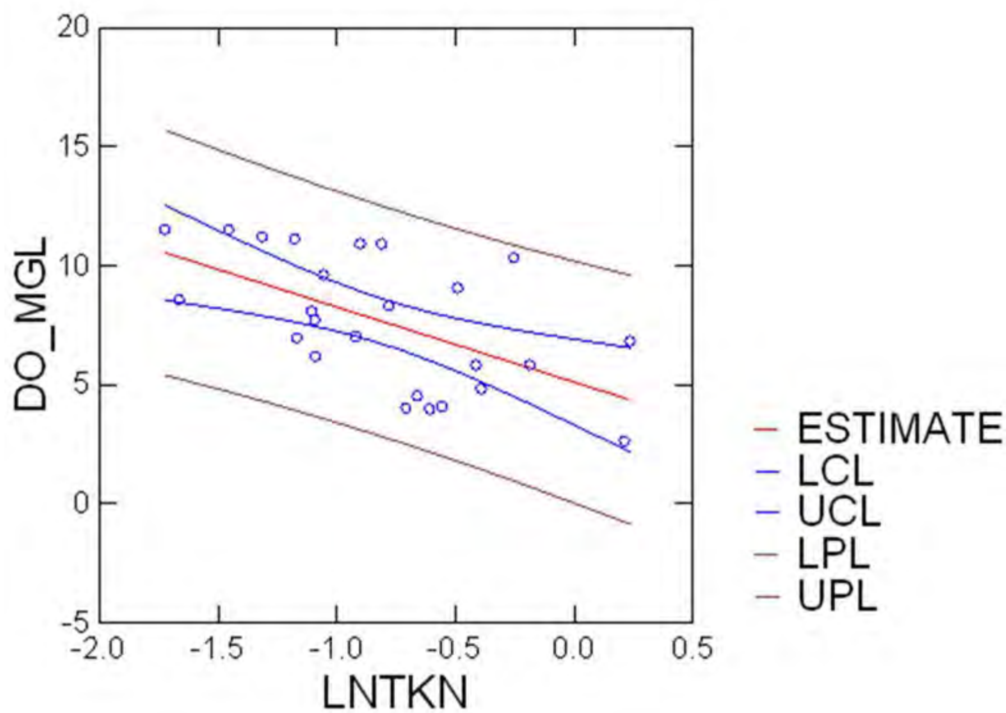
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	62.112	1	62.112	11.775	0.002
Residual	121.327	23	5.275		

Durbin-Watson D Statistic	1.868
First Order Autocorrelation	0.035

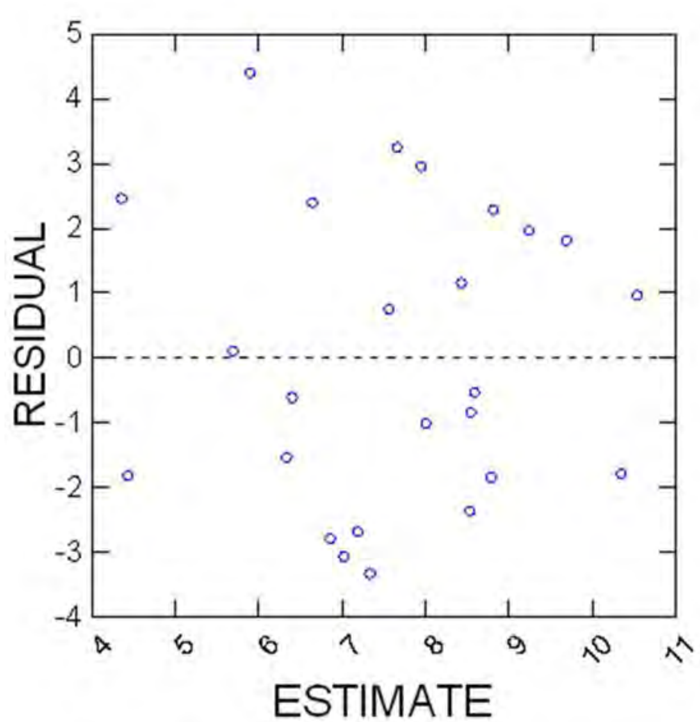
Information Criteria

AIC	116.437
AIC (Corrected)	117.580
Schwarz's BIC	120.094

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+LNTN

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.390
Squared Multiple R	0.152
Adjusted Squared Multiple R	0.115
Standard Error of Estimate	2.601

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.378	0.536	0.000		13.759	0.000
LNTN	-2.623	1.293	-0.390	1.000	-2.028	0.054

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	27.835	1	27.835	4.114	0.054
Residual	155.605	23	6.765		

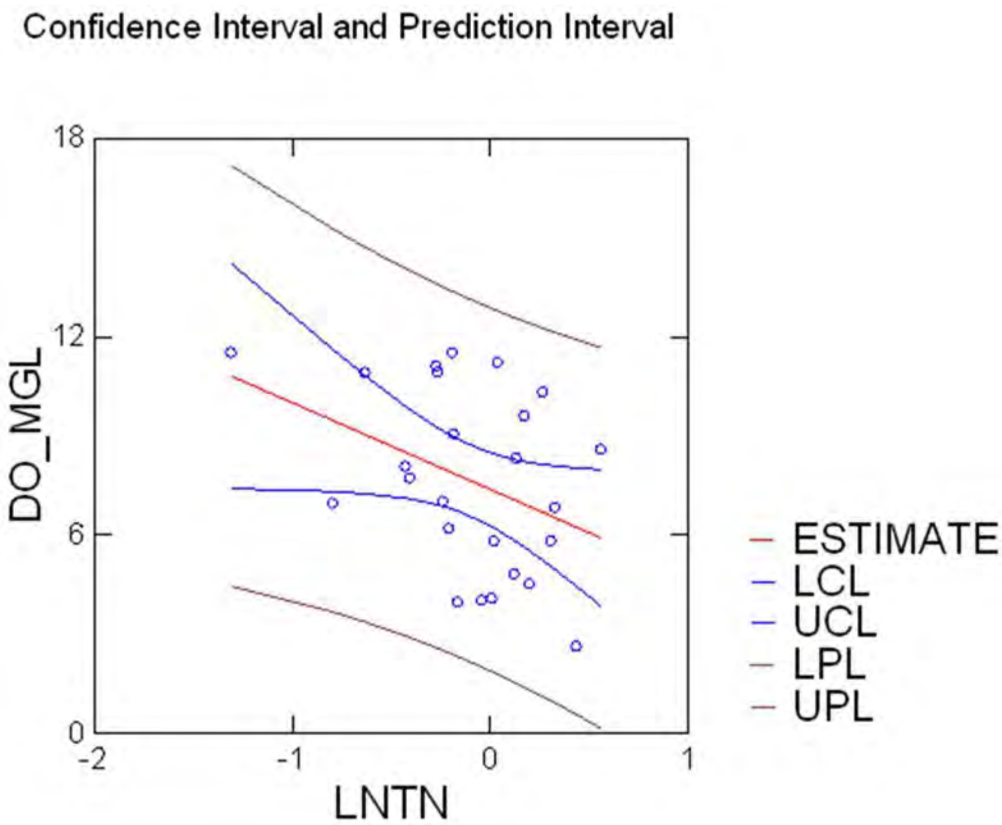
WARNING

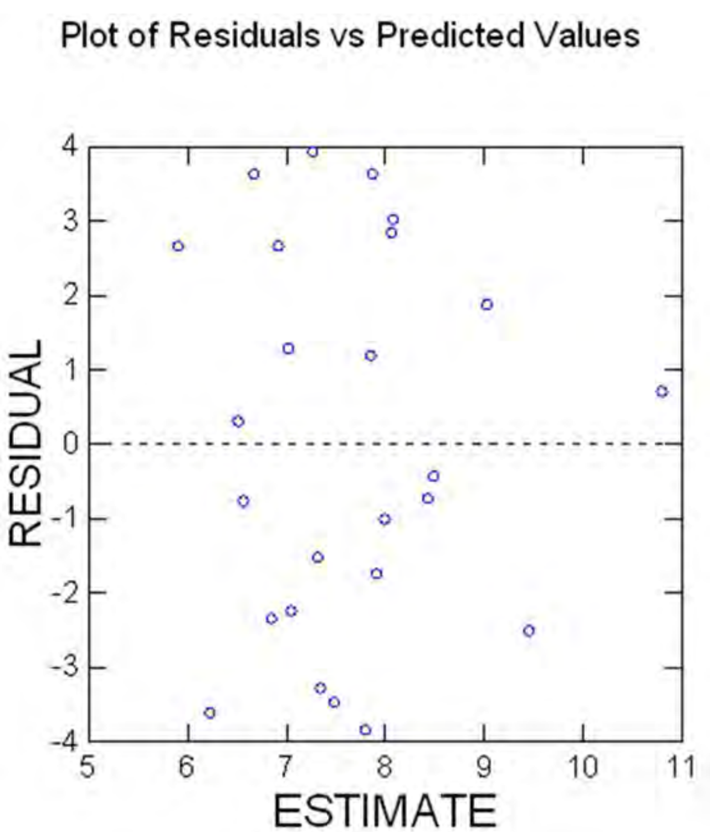
Case 25 has large Leverage (Leverage : 0.399)

Durbin-Watson D Statistic	2.105
First Order Autocorrelation	-0.071

Information Criteria

AIC	122.658
AIC (Corrected)	123.801
Schwarz's BIC	126.315


Confidence Interval and Prediction Interval
DO_MGL
LNTN
18
12
6
0
-2
-1
0
1
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
RESIDUAL
ESTIMATE
4
3
2
1
0
-1
-2
-3
-4
5
6
7
8
9
10
11

> REGRESS
> MODEL DO_MGL = CONSTANT+LNTURB

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.111
Squared Multiple R	0.012
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.807

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	6.419	2.357	0.000		2.724	0.012
LNTURB	0.486	0.909	0.111	1.000	0.535	0.598

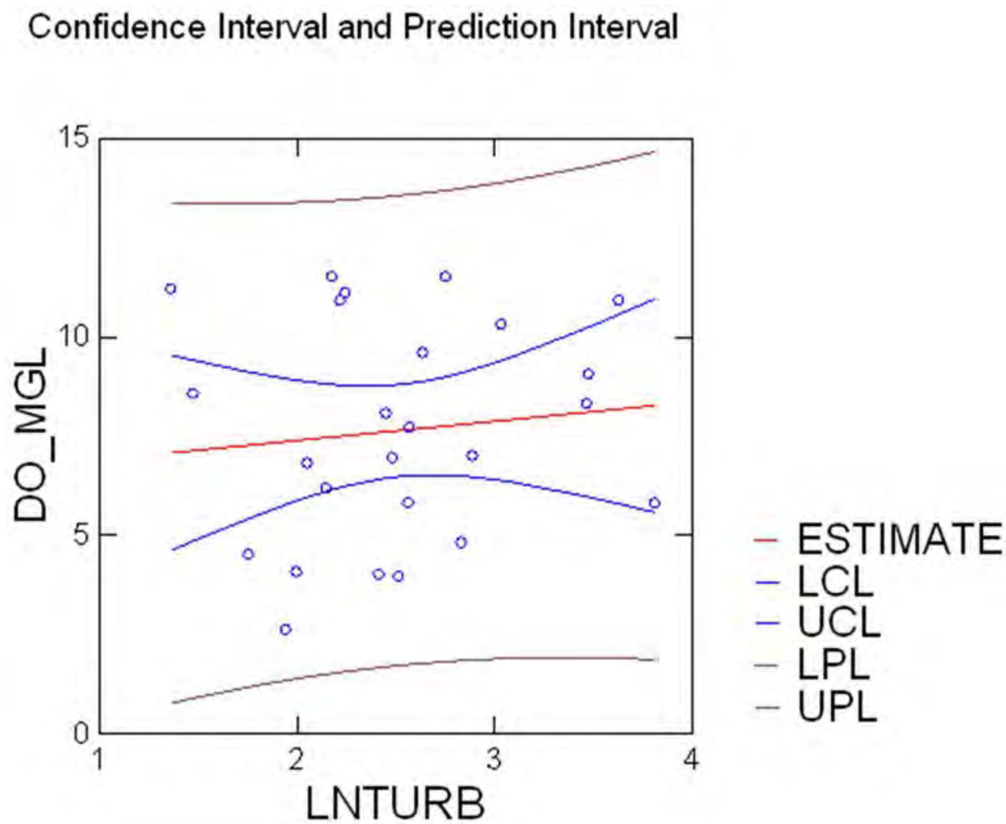
Analysis of Variance

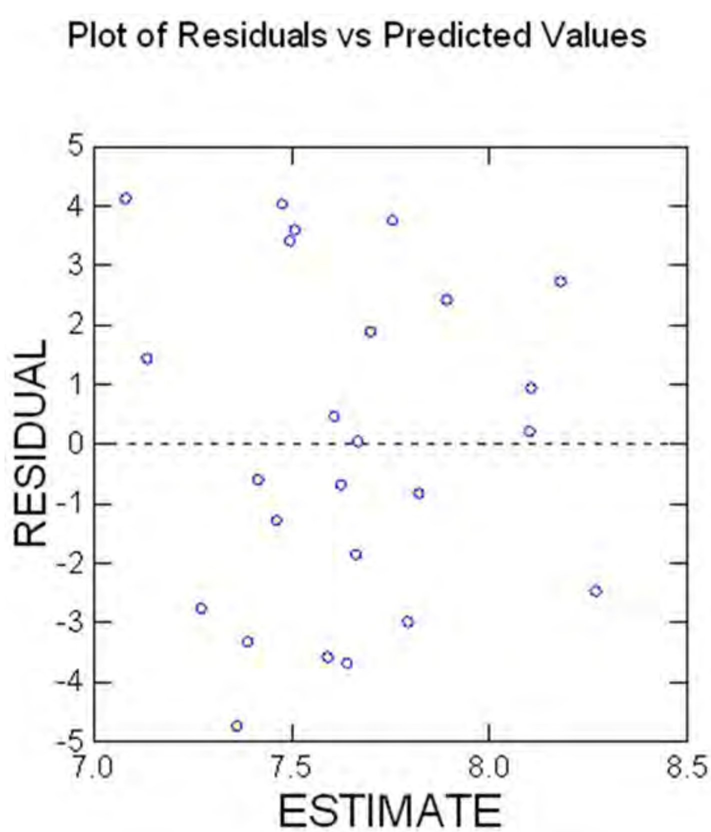
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	2.251	1	2.251	0.286	0.598
Residual	181.188	23	7.878		

Durbin-Watson D Statistic	1.869
First Order Autocorrelation	0.044

Information Criteria

AIC	126.463
AIC (Corrected)	127.606
Schwarz's BIC	130.120


Confidence Interval and Prediction Interval
DO_MGL
LNTURB
15
10
5
0
1
2
3
4
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
RESIDUAL
ESTIMATE
5
4
3
2
1
0
-1
-2
-3
-4
-5
7.0
7.5
8.0
8.5

> REGRESS
> MODEL DO_MGL = CONSTANT+LNNH3N

9 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	17
Multiple R	0.362
Squared Multiple R	0.131
Adjusted Squared Multiple R	0.073
Standard Error of Estimate	2.383

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	2.867	2.603	0.000		1.101	0.288
LNNH3N	-1.252	0.833	-0.362	1.000	-1.502	0.154

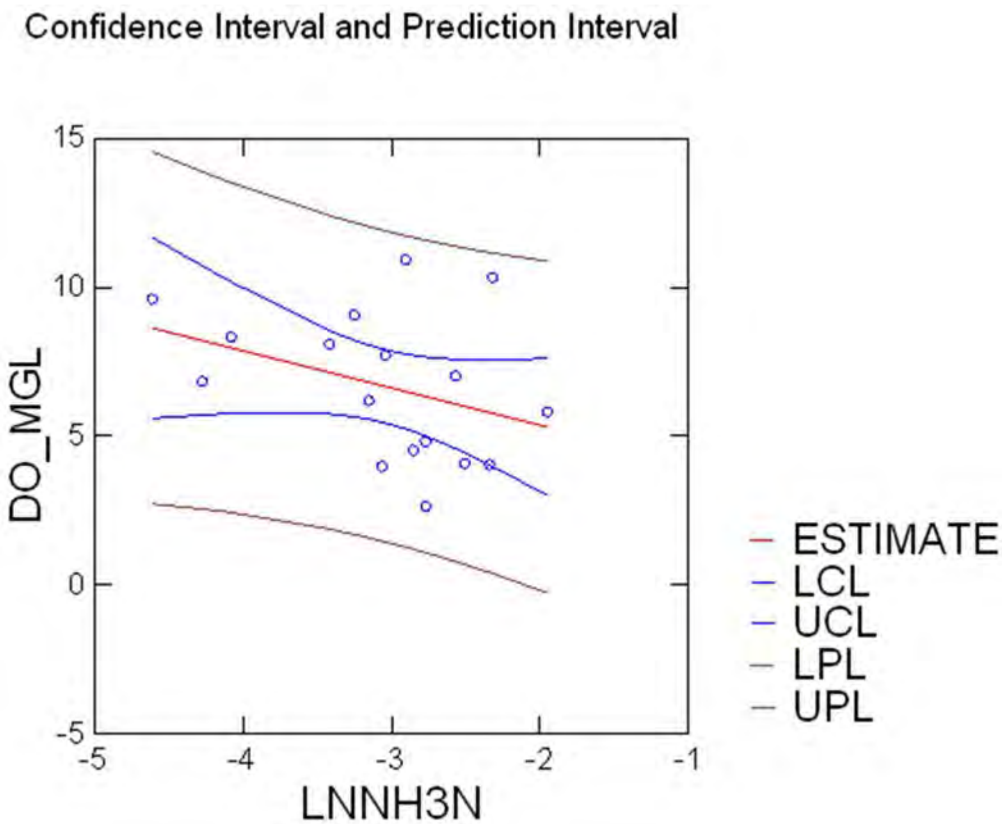
Analysis of Variance

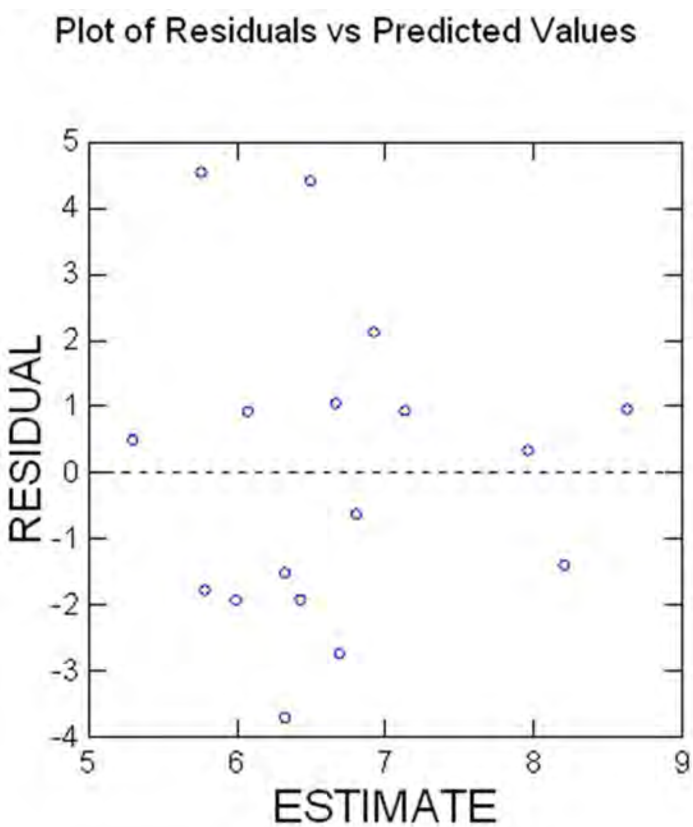
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	12.812	1	12.812	2.256	0.154
Residual	85.167	15	5.678		

Durbin-Watson D Statistic	1.780
First Order Autocorrelation	0.083

Information Criteria

AIC	81.638
AIC (Corrected)	83.484
Schwarz's BIC	84.137


Confidence Interval and Prediction Interval
15
10
5
0
-5
DO_MGL
-5
-4
-3
-2
-1
LNNH3N
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
5
4
3
2
1
0
-1
-2
-3
-4
RESIDUAL
5
6
7
8
9
ESTIMATE

> REGRESS
> MODEL DO_MGL = CONSTANT+LNNH3N+TEMP_DEGC+LNTP+LNNOX+LNTKN+LNTN+LNTURB

Stepwise Selection of Variables

9 case(s) are deleted due to missing data.

Step number : 0
R : 0.958
R-square : 0.917

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	LNNH3N	0.563	0.716	0.163	0.215	1	0.619	0.452
3	TEMP_DEGC	-0.372	0.050	-0.903	0.626	1	55.447	0.000
4	LNTP	0.534	0.338	0.207	0.536	1	2.493	0.149
5	LNNOX	-6.087	2.500	-1.140	0.042	1	5.927	0.038
6	LNTKN	-9.325	4.212	-1.549	0.019	1	4.902	0.054
7	LNTN	9.021	5.882	0.931	0.025	1	2.352	0.159
8	LNTURB	0.669	0.451	0.159	0.802	1	2.197	0.172

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
	none					

Information Criteria	
AIC	53.686
AIC (Corrected)	79.400
Schwarz's BIC	61.185

Dependent Variable : DO_MGL
Minimum Tolerance for Entry into Model : 0.000
Backward Stepwise with Alpha-to-Enter : 0.150
Backward Stepwise with Alpha-to-Remove : 0.150

Step number : 1
R : 0.955
R-square : 0.911
Term Removed : LNNH3N

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
3	TEMP_DEGC	-0.359	0.046	-0.873	0.696	1	59.898	0.000
4	LNTP	0.501	0.329	0.195	0.544	1	2.323	0.158
5	LNNOX	-4.507	1.461	-0.845	0.118	1	9.520	0.012
6	LNTKN	-6.489	2.135	-1.078	0.070	1	9.234	0.012
7	LNTN	5.090	3.040	0.525	0.090	1	2.802	0.125
8	LNTURB	0.631	0.440	0.150	0.812	1	2.057	0.182

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
2	LNNH3N	0.254	0.215	1	0.619	0.452

Information Criteria	
AIC	52.816
AIC (Corrected)	70.816
Schwarz's BIC	59.482

Step number : 2
R : 0.945
R-square : 0.893
Term Removed : LNTURB

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
3	TEMP_DEGC	-0.381	0.046	-0.925	0.778	1	68.621	0.000
4	LNTP	0.565	0.341	0.219	0.554	1	2.740	0.126
5	LNNOX	-4.070	1.496	-0.763	0.124	1	7.404	0.020
6	LNTKN	-5.709	2.162	-0.948	0.075	1	6.974	0.023
7	LNTN	3.801	3.041	0.392	0.099	1	1.562	0.237

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
2	LNNH3N	0.186	0.218	1	0.357	0.563
8	LNTURB	0.413	0.812	1	2.057	0.182

Information Criteria	
AIC	53.996
AIC (Corrected)	66.441
Schwarz's BIC	59.829

Step number : 3
R : 0.937
R-square : 0.878
Term Removed : LNTN

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
3	TEMP_DEGC	-0.379	0.047	-0.921	0.779	1	65.018	0.000
4	LNTP	0.716	0.327	0.278	0.633	1	4.798	0.049
5	LNNOX	-2.496	0.826	-0.468	0.425	1	9.133	0.011
6	LNTKN	-3.148	0.706	-0.523	0.739	1	19.883	0.001

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
2	LNNH3N	-0.211	0.807	1	0.513	0.489
7	LNTN	0.353	0.099	1	1.562	0.237
8	LNTURB	0.265	0.889	1	0.831	0.382

Information Criteria	
AIC	54.254
AIC (Corrected)	62.654
Schwarz's BIC	59.253

1 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.915
Squared Multiple R	0.838
Adjusted Squared Multiple R	0.805
Standard Error of Estimate	1.220

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	11.297	1.147	0.000	.	9.848	0.000
TEMP_DEGC	-0.322	0.043	-0.734	0.846	-7.498	0.000
LNTP	0.646	0.276	0.245	0.739	2.340	0.030
LNNOX	-0.986	0.385	-0.236	0.954	-2.560	0.019
LNTKN	-2.616	0.586	-0.482	0.695	-4.461	0.000

Analysis of Variance

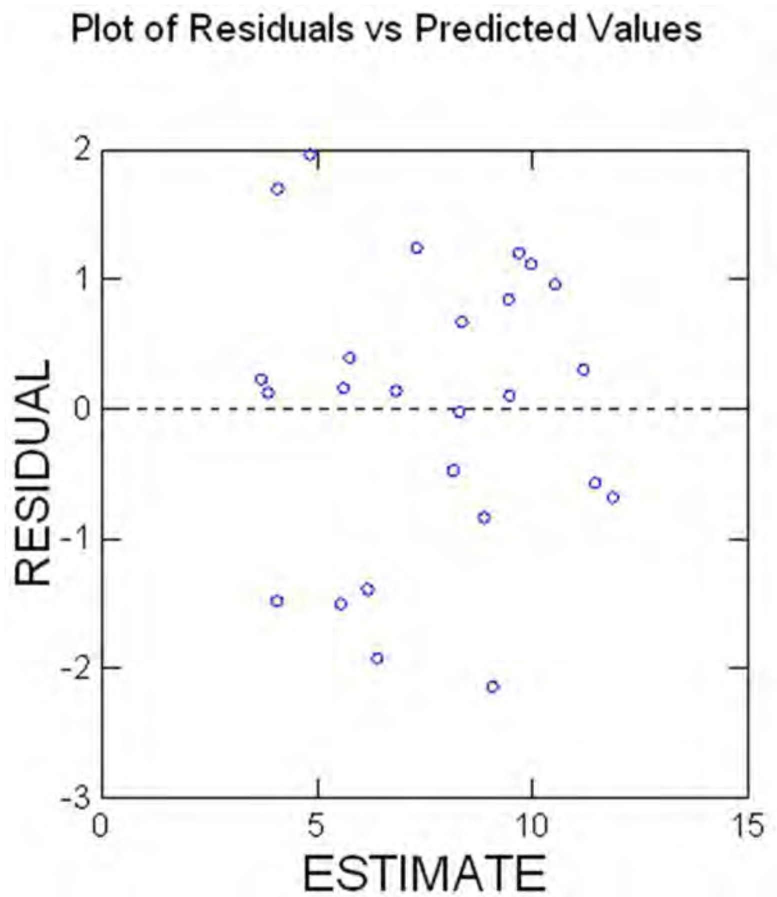
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	153.647	4	38.412	25.786	0.000
Residual	29.792	20	1.490		

WARNING

Case 25 has large Leverage (Leverage : 0.655)

Durbin-Watson D Statistic	2.706
First Order Autocorrelation	-0.427

Information Criteria	
AIC	87.331
AIC (Corrected)	91.998
Schwarz's BIC	94.644


Plot of Residuals vs Predicted Values
RESIDUAL
ESTIMATE
2
1
0
-1
-2
-3
0
5
10
15

File: C:\local work\ANRC WMPs\Mid White\LSaladoCr DO and nutrients.syz

> REGRESS
> MODEL DO_MGL = CONSTANT+TKN_RESULT

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.501
Squared Multiple R	0.251
Adjusted Squared Multiple R	0.218
Standard Error of Estimate	2.376

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	9.856	0.972	0.000		10.138	0.000
TKN_RESULT	-5.742	2.070	-0.501	1.000	-2.774	0.011

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	43.445	1	43.445	7.698	0.011
Residual	129.812	23	5.644		

WARNING

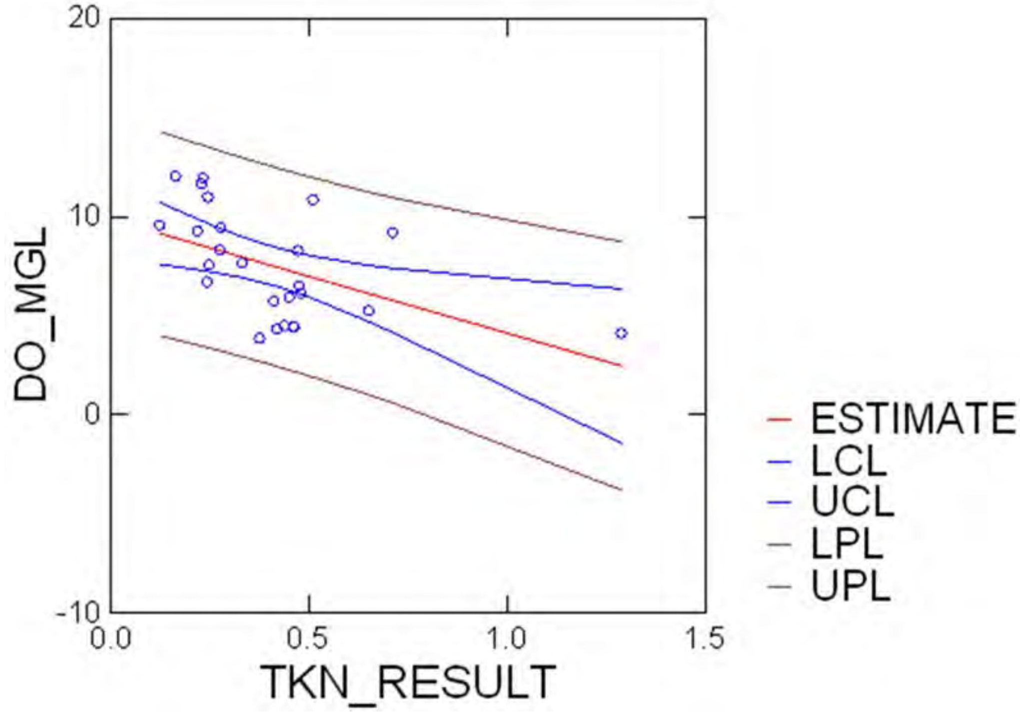
Case 6 has large Leverage (Leverage : 0.628)

Durbin-Watson D Statistic	2.130
First Order Autocorrelation	-0.080

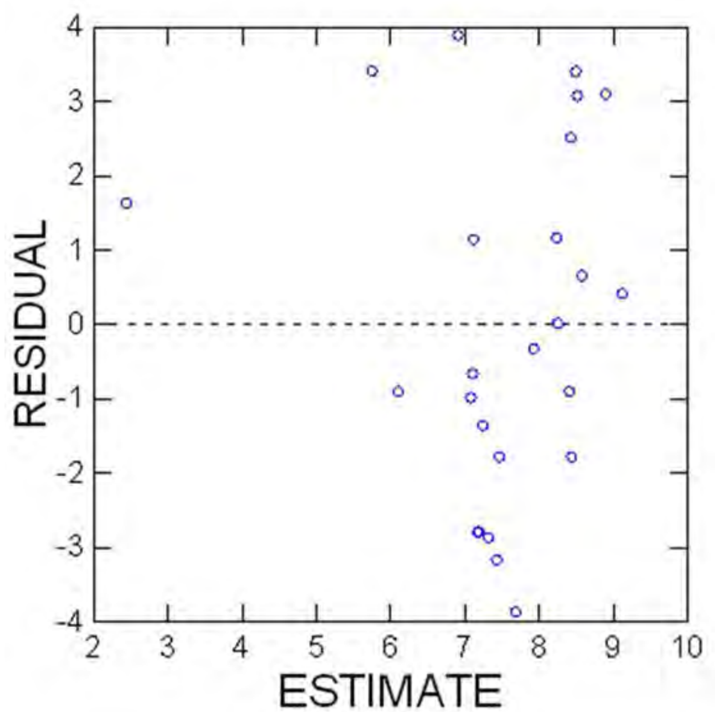
Information Criteria

AIC	118.127
AIC (Corrected)	119.270
Schwarz's BIC	121.784

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+NH3N_MGL

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.724
Squared Multiple R	0.525
Adjusted Squared Multiple R	0.505
Standard Error of Estimate	1.929

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	9.217	0.485	0.000	.	18.998	0.000
NH3N_MGL	-58.959	11.451	-0.724	1.000	-5.149	0.000

Analysis of Variance

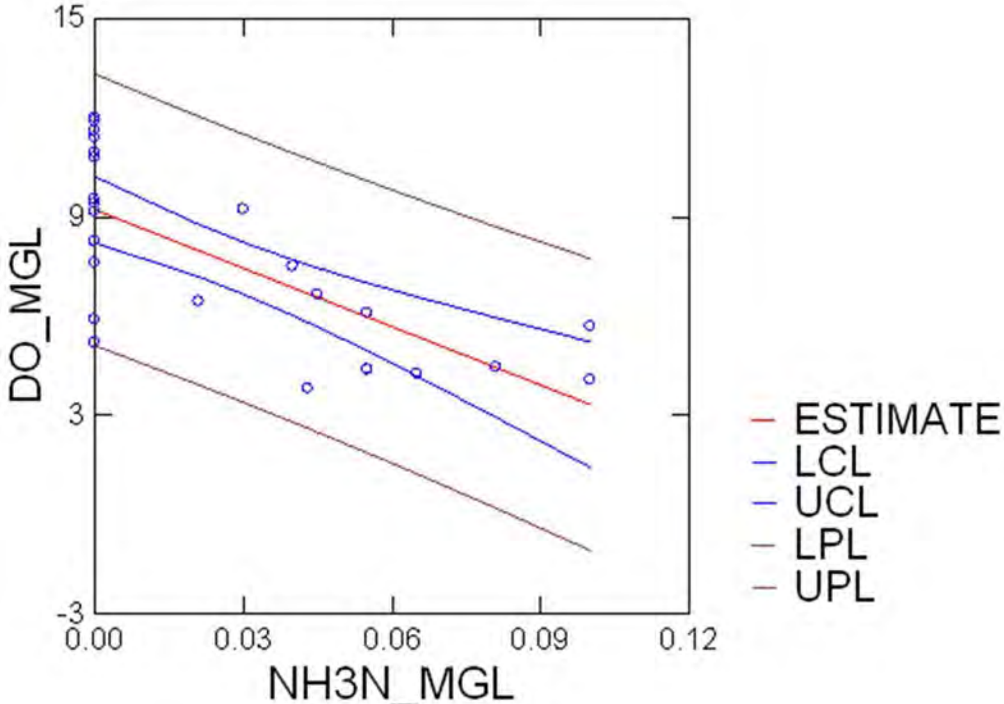
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	98.598	1	98.598	26.510	0.000
Residual	89.263	24	3.719		

Durbin-Watson D Statistic	1.546
First Order Autocorrelation	0.136

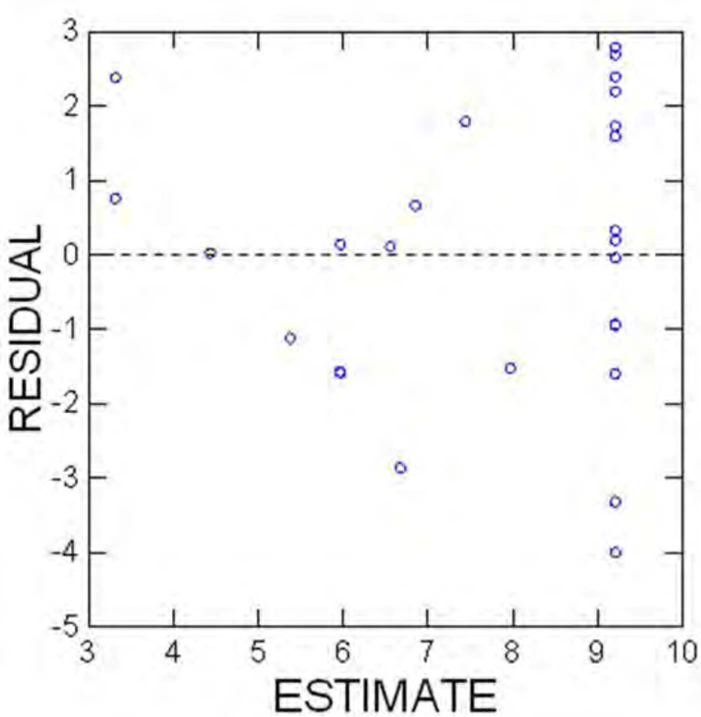
Information Criteria

AIC	111.856
AIC (Corrected)	112.947
Schwarz's BIC	115.630

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+NOX_RESULT

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.555
Squared Multiple R	0.308
Adjusted Squared Multiple R	0.279
Standard Error of Estimate	2.327

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	5.512	0.798	0.000	.	6.904	0.000
NOX_RESULT	10.058	3.076	0.555	1.000	3.269	0.003

Analysis of Variance

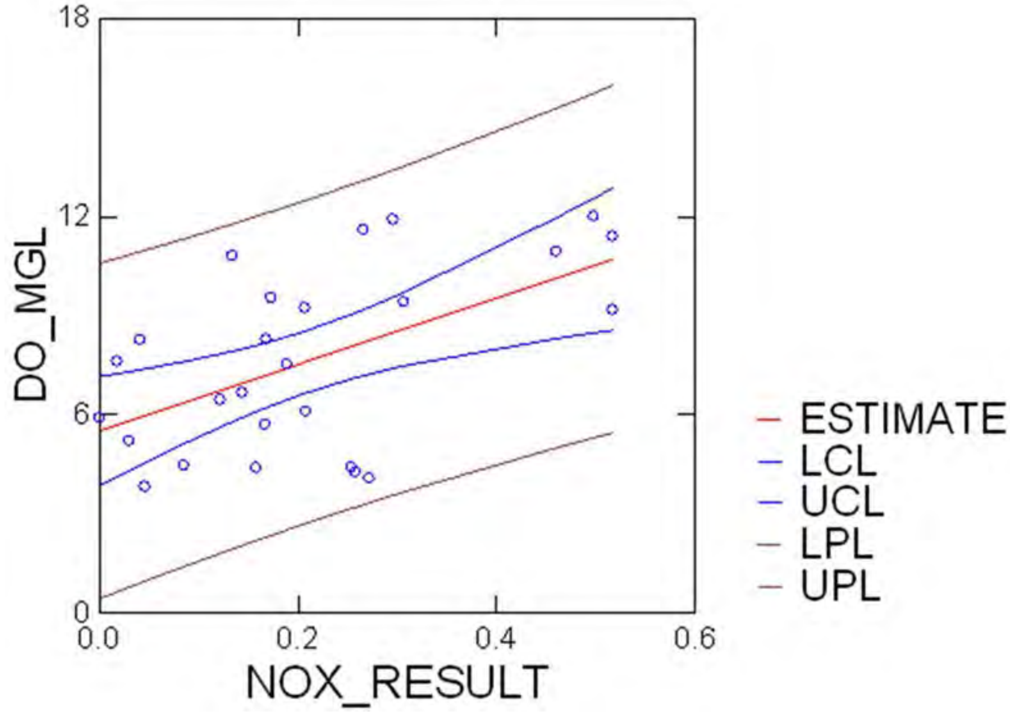
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	57.885	1	57.885	10.688	0.003
Residual	129.977	24	5.416		

Durbin-Watson D Statistic	1.777
First Order Autocorrelation	0.110

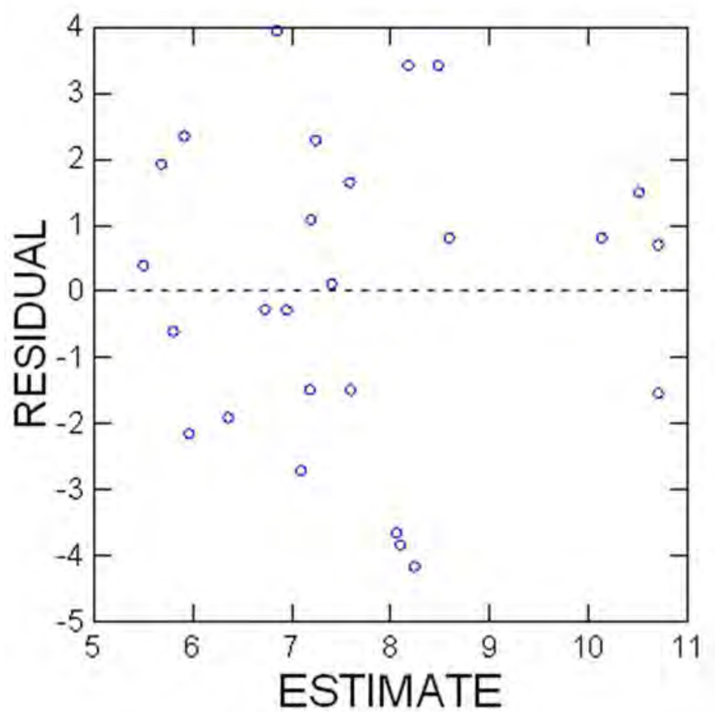
Information Criteria

AIC	121.626
AIC (Corrected)	122.716
Schwarz's BIC	125.400

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+TN_CALC

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.173
Squared Multiple R	0.030
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.703

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	8.560	1.366	0.000		6.265	0.000
TN_CALC	-1.732	2.055	-0.173	1.000	-0.843	0.408

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	5.189	1	5.189	0.710	0.408
Residual	168.068	23	7.307		

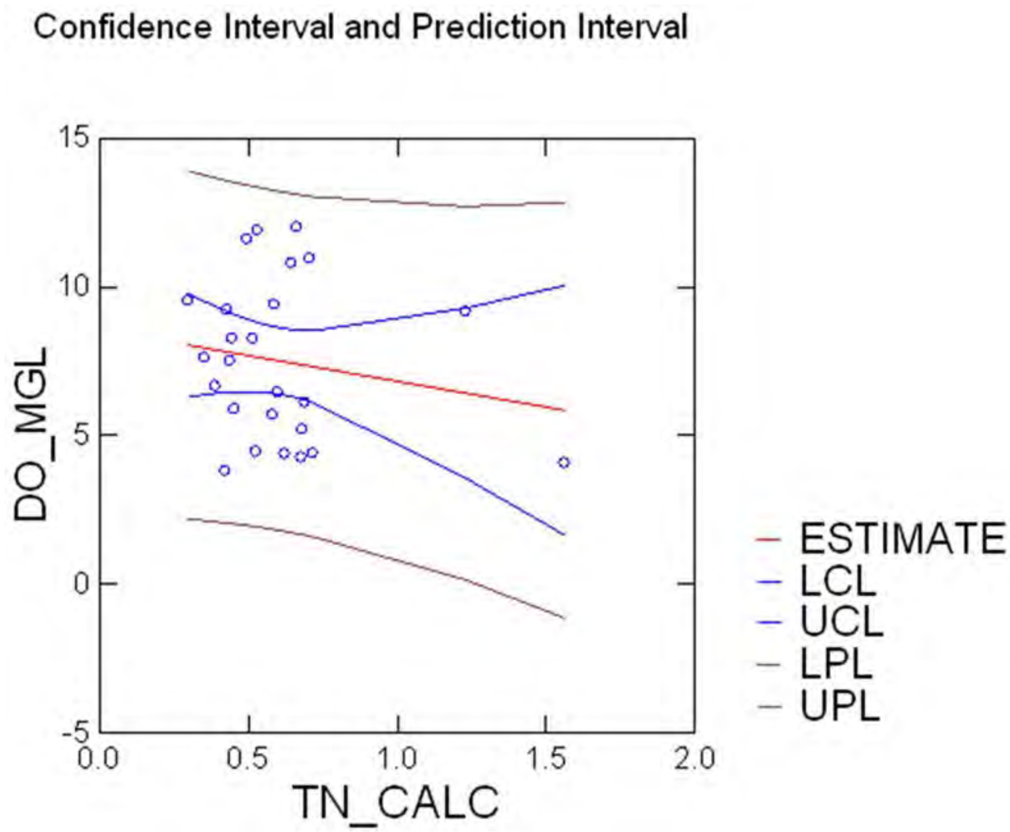
WARNING

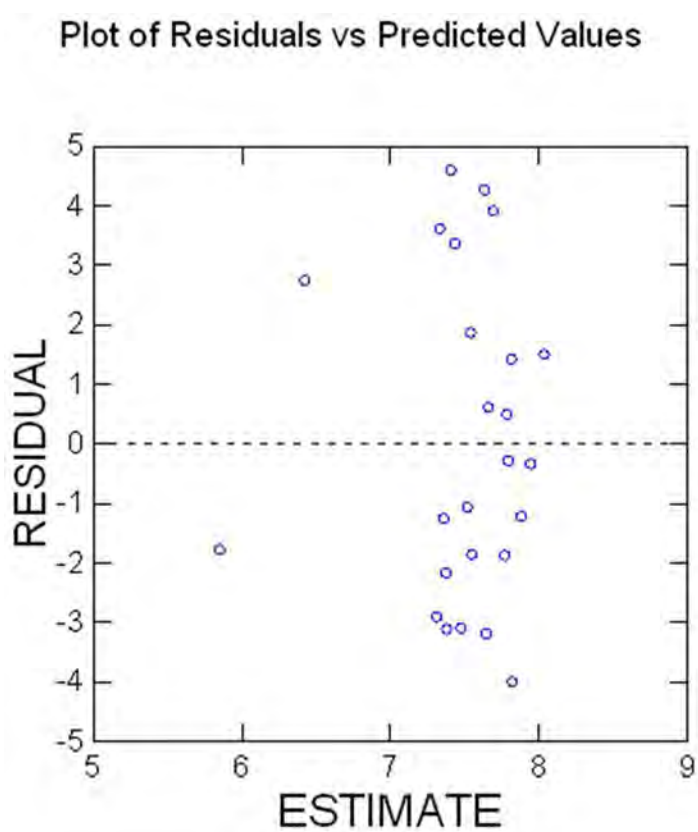
Case 6 has large Leverage (Leverage : 0.563)

Durbin-Watson D Statistic	2.008
First Order Autocorrelation	-0.022

Information Criteria

AIC	124.584
AIC (Corrected)	125.727
Schwarz's BIC	128.241


Confidence Interval and Prediction Interval
15
10
5
0
-5
0.0
0.5
1.0
1.5
2.0
DO_MGL
TN_CALC
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
5
4
3
2
1
0
-1
-2
-3
-4
-5
5
6
7
8
9
RESIDUAL
ESTIMATE

> REGRESS
> MODEL DO_MGL = CONSTANT+TP_MGL

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.140
Squared Multiple R	0.020
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.770

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.834	0.603	0.000		12.992	0.000
TP_MGL	-1.640	2.369	-0.140	1.000	-0.692	0.496

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	3.676	1	3.676	0.479	0.496
Residual	184.185	24	7.674		

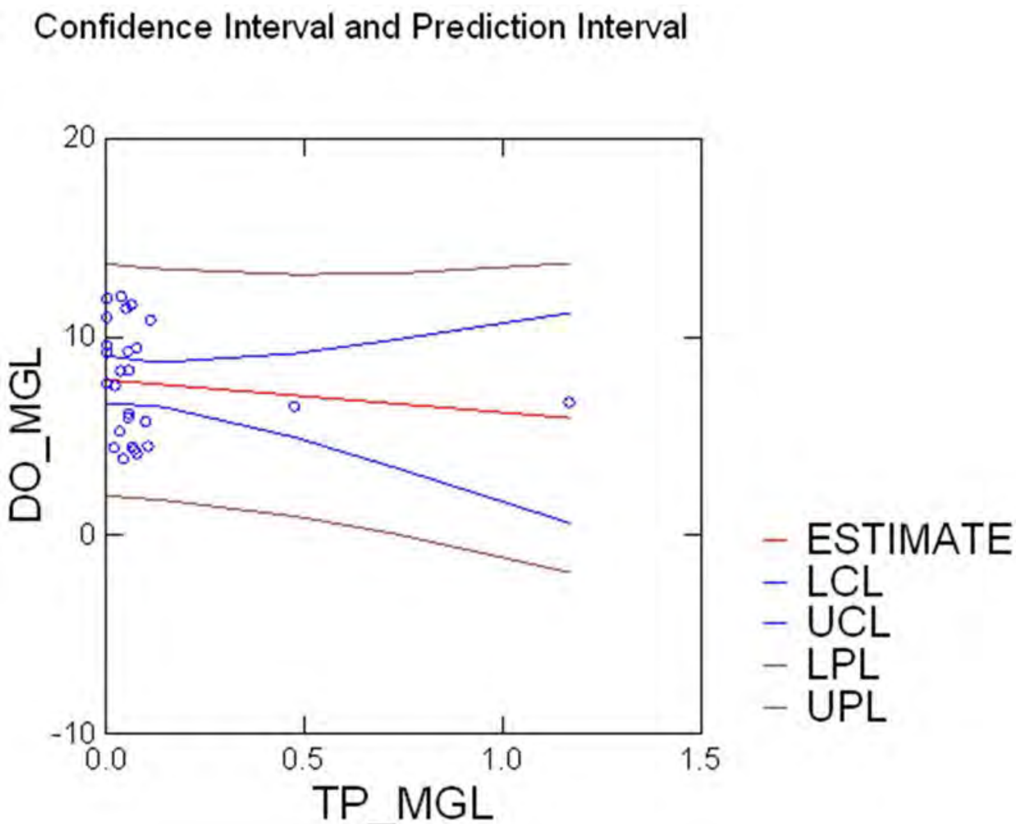
WARNING

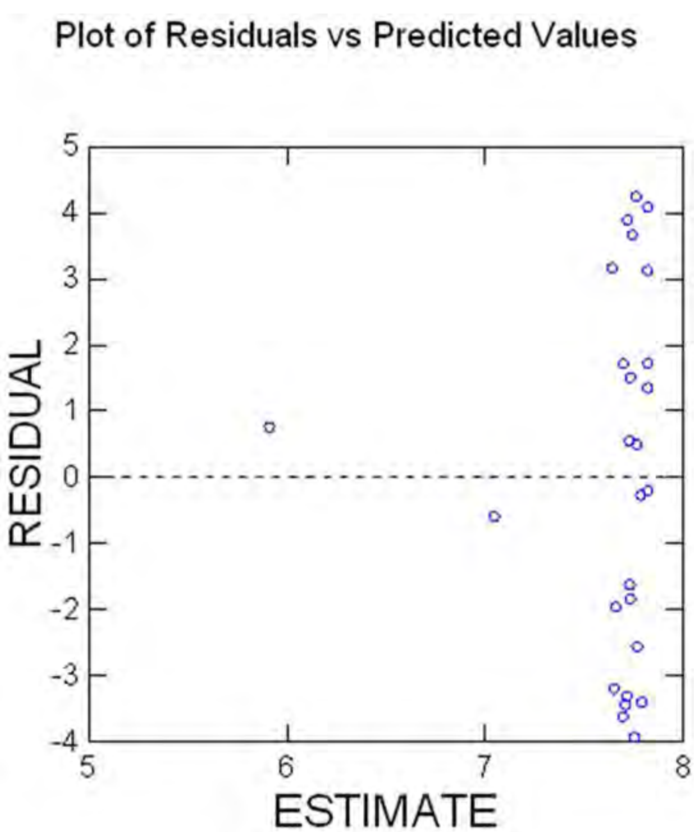
Case 17 has large Leverage (Leverage : 0.318)
Case 28 has large Leverage (Leverage : 0.860)

Durbin-Watson D Statistic	1.777
First Order Autocorrelation	0.092

Information Criteria

AIC	130.689
AIC (Corrected)	131.780
Schwarz's BIC	134.463


Confidence Interval and Prediction Interval
DO_MGL
TP_MGL
20
10
0
-10
0.0
0.5
1.0
1.5
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
RESIDUAL
ESTIMATE
5
4
3
2
1
0
-1
-2
-3
-4
5
6
7
8

> REGRESS
> MODEL DO_MGL = CONSTANT+BOD_MGL

18 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	10
Multiple R	0.405
Squared Multiple R	0.164
Adjusted Squared Multiple R	0.060
Standard Error of Estimate	2.870

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	9.054	1.444	0.000		6.269	0.000
BOD_MGL	-1.456	1.162	-0.405	1.000	-1.253	0.245

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	12.945	1	12.945	1.571	0.245
Residual	65.911	8	8.239		

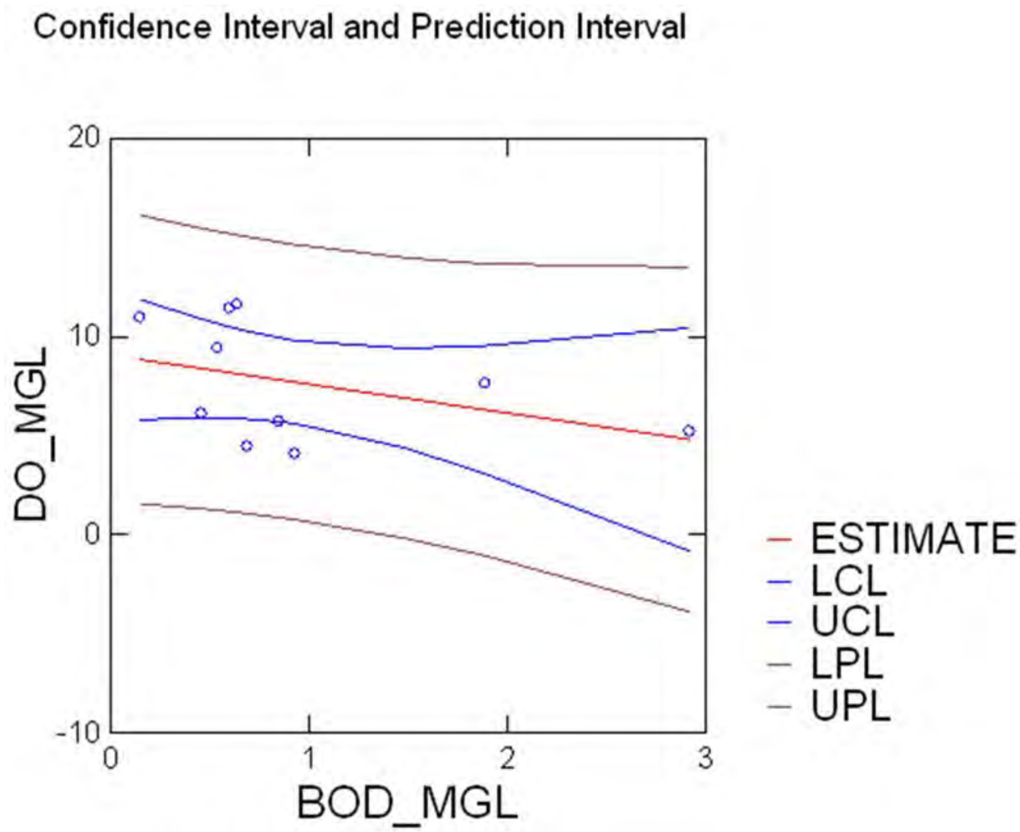
WARNING

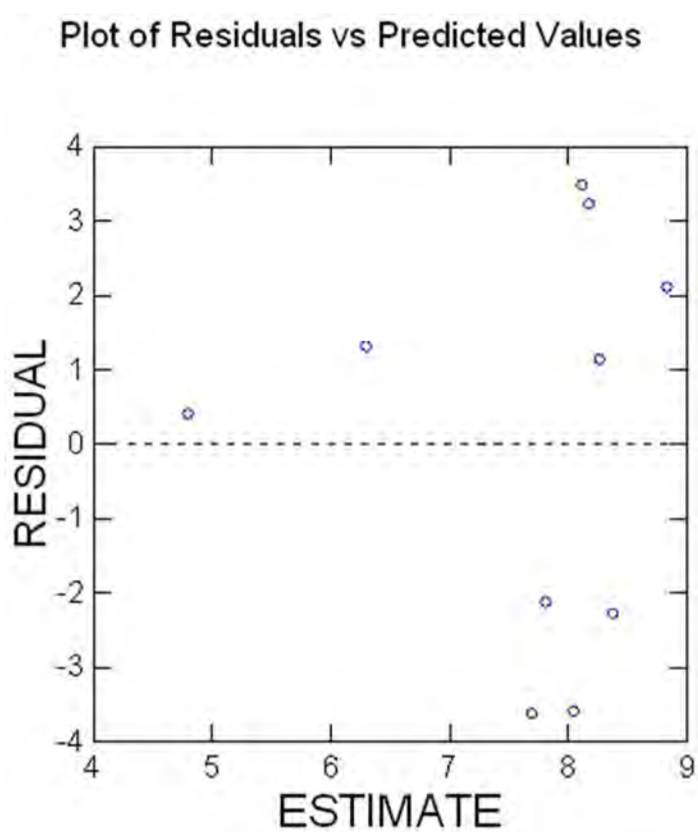
Case 1 has large Leverage (Leverage : 0.725)

Durbin-Watson D Statistic	1.625
First Order Autocorrelation	0.173

Information Criteria

AIC	53.236
AIC (Corrected)	57.236
Schwarz's BIC	54.144


Confidence Interval and Prediction Interval
20
10
0
-10
0
1
2
3
DO_MGL
BOD_MGL
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
4
3
2
1
0
-1
-2
-3
-4
4
5
6
7
8
9
RESIDUAL
ESTIMATE

> REGRESS
> MODEL DO_MGL = CONSTANT+TEMP_DEGC

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.785
Squared Multiple R	0.616
Adjusted Squared Multiple R	0.600
Standard Error of Estimate	1.733

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	12.358	0.831	0.000	.	14.875	0.000
TEMP_DEGC	-0.285	0.046	-0.785	1.000	-6.207	0.000

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	115.752	1	115.752	38.526	0.000
Residual	72.109	24	3.005		

WARNING

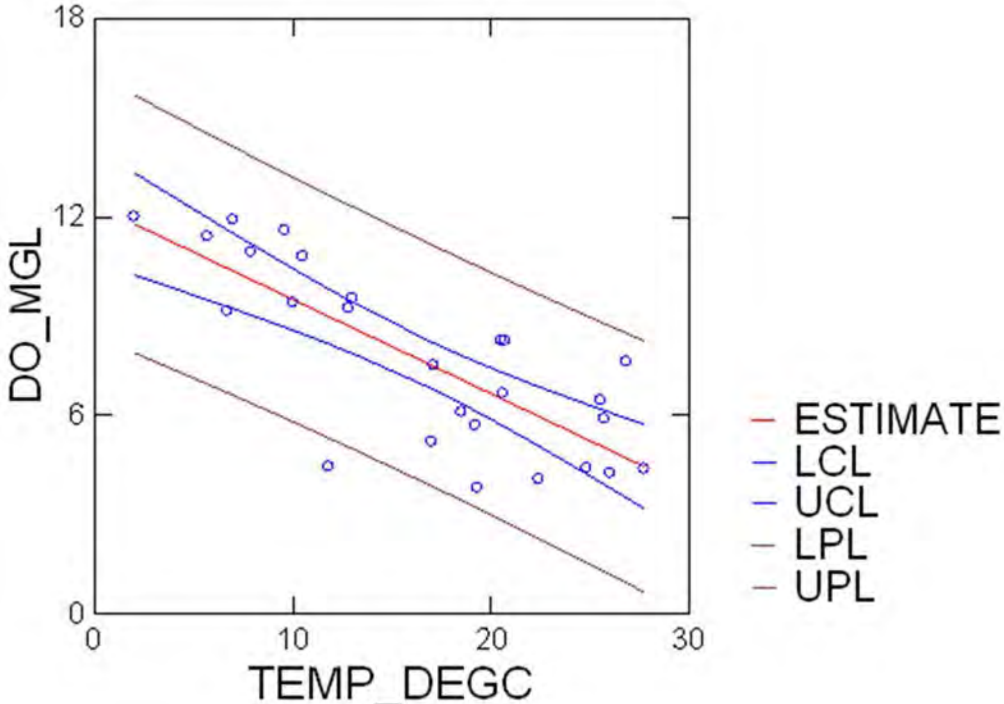
Case 7 is an Outlier (Studentized Residual : -3.157)

Durbin-Watson D Statistic	1.706
First Order Autocorrelation	0.110

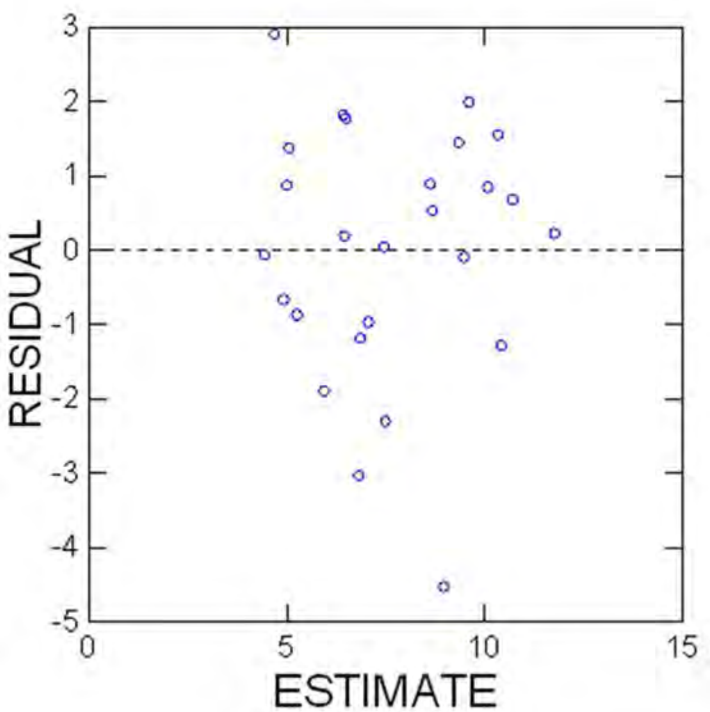
Information Criteria

AIC	106.307
AIC (Corrected)	107.398
Schwarz's BIC	110.081

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+TURBIDITY_NTU

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.116
Squared Multiple R	0.013
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.779

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	8.016	0.839	0.000	.	9.556	0.000
TURBIDITY_NTU	-0.028	0.049	-0.116	1.000	-0.570	0.574

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	2.508	1	2.508	0.325	0.574
Residual	185.354	24	7.723		

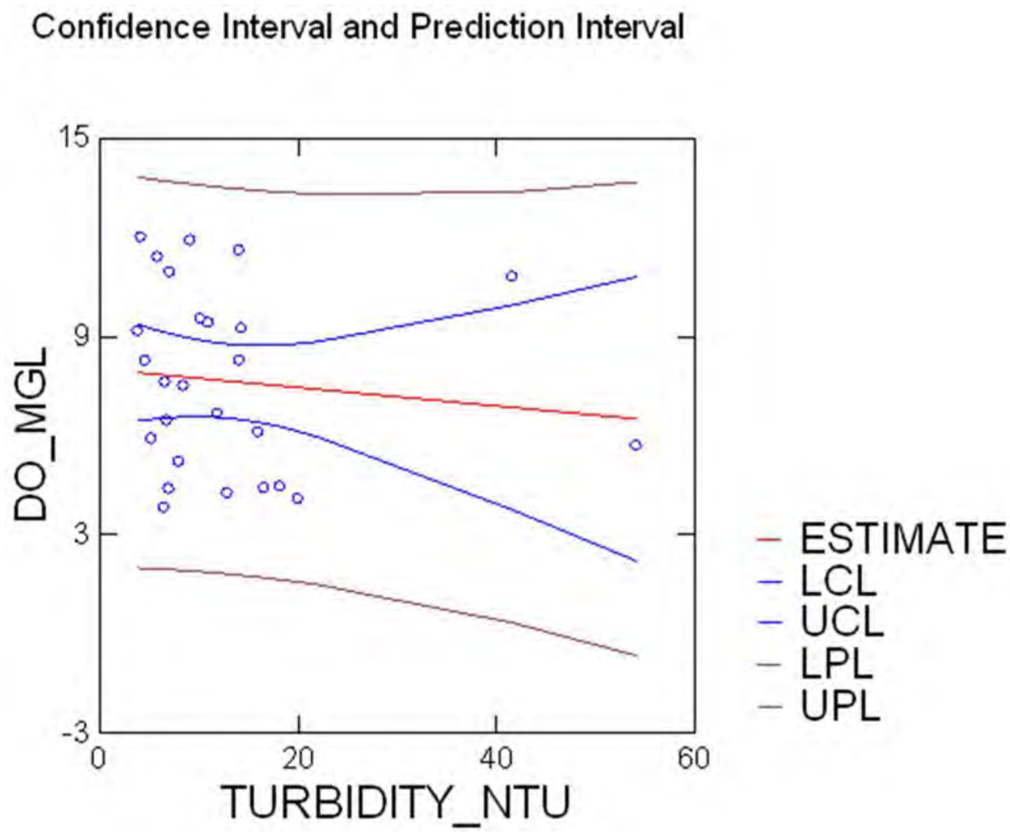
WARNING

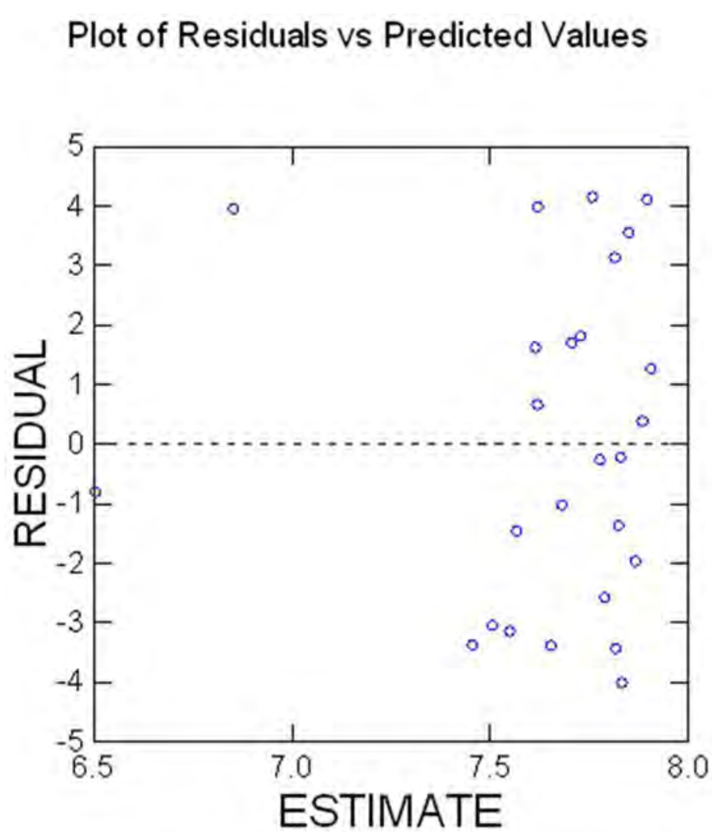
Case 10 has large Leverage (Leverage : 0.563)

Durbin-Watson D Statistic	1.695
First Order Autocorrelation	0.132

Information Criteria

AIC	130.853
AIC (Corrected)	131.944
Schwarz's BIC	134.627


Confidence Interval and Prediction Interval
15
9
3
-3
0
20
40
60
DO_MGL
TURBIDITY_NTU
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
5
4
3
2
1
0
-1
-2
-3
-4
-5
6.5
7.0
7.5
8.0
RESIDUAL
ESTIMATE

> REGRESS
> MODEL DO_MGL =
CONSTANT+TURBIDITY_NTU+NOX_RESULT+TKN_RESULT+TN_CALC+TP_MGL+BOD_MGL+TEMP_DEGC+N
H3N_MGL

Stepwise Selection of Variables

19 case(s) are deleted due to missing data.
Unable to enter effect 3.
This effect may fail tolerance checks.

Step number : 0
R : 0.993
R-square : 0.986

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TURBIDITY_NTU	0.369	0.166	1.923	0.019	1	4.955	0.269
4	TKN_RESULT	0.000	34.718	0.000	0.001	1	2.981	0.334
5	TN_CALC	59.941	25.055	7.029	0.001	1	2.822	0.342
6	TP_MGL	-42.089	44.562	-5.192	0.038	1	2.778	0.344
7	BOD_MGL	-74.278	4.076	-1.007	0.009	1	4.849	0.271
8	TEMP_DEGC	-8.975	0.262	-2.756	0.038	1	2.547	0.356
9	NH3N_MGL	-0.417	70.815	-0.962	0.010	1	7.603	0.221

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
3	NOX_RESULT	.	.	0	.	.

Effect 3 lost 1 degree(s) of freedom.

Information Criteria	
AIC	22.556
AIC (Corrected)	.
Schwarz's BIC	24.331

The following effects have lost degrees of freedom.

Effect	Initial df	Lost df	Final df
NOX_RESULT	1	1	0

Dependent Variable : DO_MGL
Minimum Tolerance for Entry into Model : 0.000
Backward Stepwise with Alpha-to-Enter : 0.150
Backward Stepwise with Alpha-to-Remove : 0.150

Nothing to do!

19 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	9
Multiple R	0.993
Squared Multiple R	0.986
Adjusted Squared Multiple R	0.889
Standard Error of Estimate	0.935

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	28.168	10.756	0.000	.	2.619	0.232
TURBIDITY_NTU	0.369	0.166	1.923	0.019	2.226	0.269
TKN_RESULT	59.941	34.718	7.029	0.001	1.727	0.334
TN_CALC	-42.089	25.055	-5.192	0.001	-1.680	0.342
TP_MGL	-74.278	44.562	-1.007	0.038	-1.667	0.344
BOD_MGL	-8.975	4.076	-2.756	0.009	-2.202	0.271
TEMP_DEGC	-0.417	0.262	-0.962	0.038	-1.596	0.356
NH3N_MGL	-195.261	70.815	-3.206	0.010	-2.757	0.221

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	62.323	7	8.903	10.184	0.237
Residual	0.874	1	0.874		

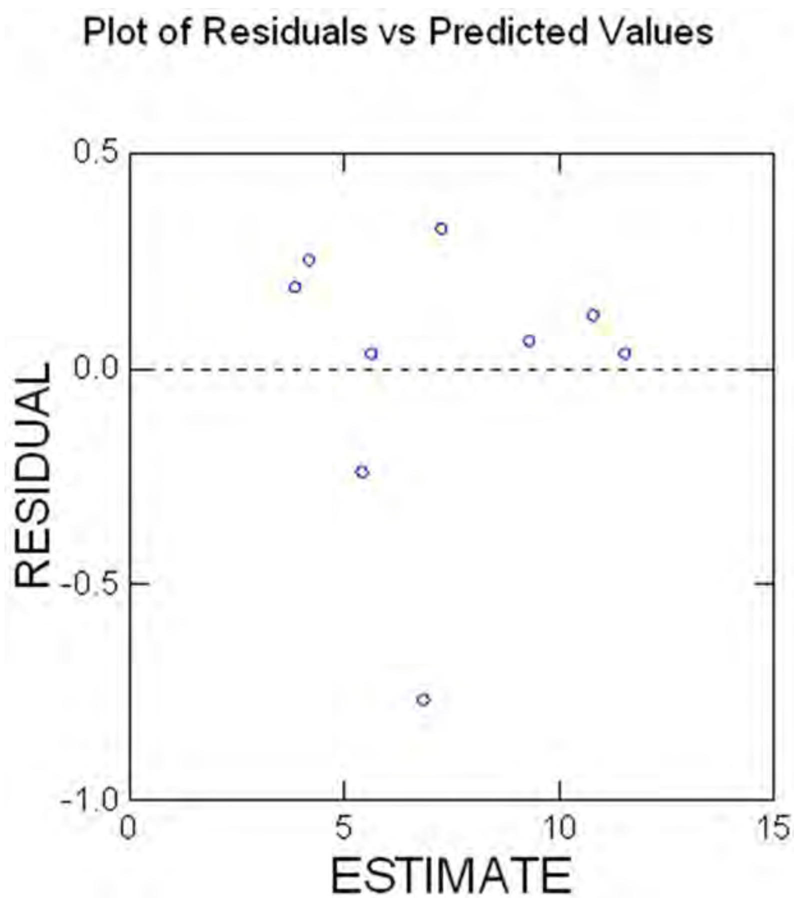
WARNING

Case	1	has large Leverage	(Leverage	: 0.933)
Case	1	has large Influence	(Studentized Residual	: 1.750)
Case	2	has large Leverage	(Leverage	: 0.983)
Case	2	has large Influence	(Studentized Residual	: 7.309)
Case	3	has large Leverage	(Leverage	: 0.996)
Case	3	has large Influence	(Studentized Residual	: 27.899)
Case	6	has large Leverage	(Leverage	: 0.960)
Case	6	has large Influence	(Studentized Residual	: 2.998)
Case	7	has large Leverage	(Leverage	: 0.928)
Case	7	has large Influence	(Studentized Residual	: 1.608)
Case	9	has large Leverage	(Leverage	: 0.999)
Case	9	has large Influence	(Studentized Residual	: 97.646)
Case	10	has large Leverage	(Leverage	: 0.999)
Case	10	has large Influence	(Studentized Residual	: 100.423)
Case	11	has large Leverage	(Leverage	: 12.917)
Case	12	has large Leverage	(Leverage	: 0.881)
Case	12	has large Influence	(Studentized Residual	: 0.922)

Durbin-Watson D Statistic	2.149
First Order Autocorrelation	-0.168

Information Criteria

AIC	22.556
AIC (Corrected)	.
Schwarz's BIC	24.331


Plot of Residuals vs Predicted Values
RESIDUAL
0.5
0.0
-0.5
-1.0
0
5
10
15
ESTIMATE

> REGRESS
> MODEL DO_MGL = CONSTANT+LNTP

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.343
Squared Multiple R	0.118
Adjusted Squared Multiple R	0.081
Standard Error of Estimate	2.628

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	5.462	1.328	0.000		4.114	0.000
LNTP	-0.701	0.392	-0.343	1.000	-1.791	0.086

Analysis of Variance

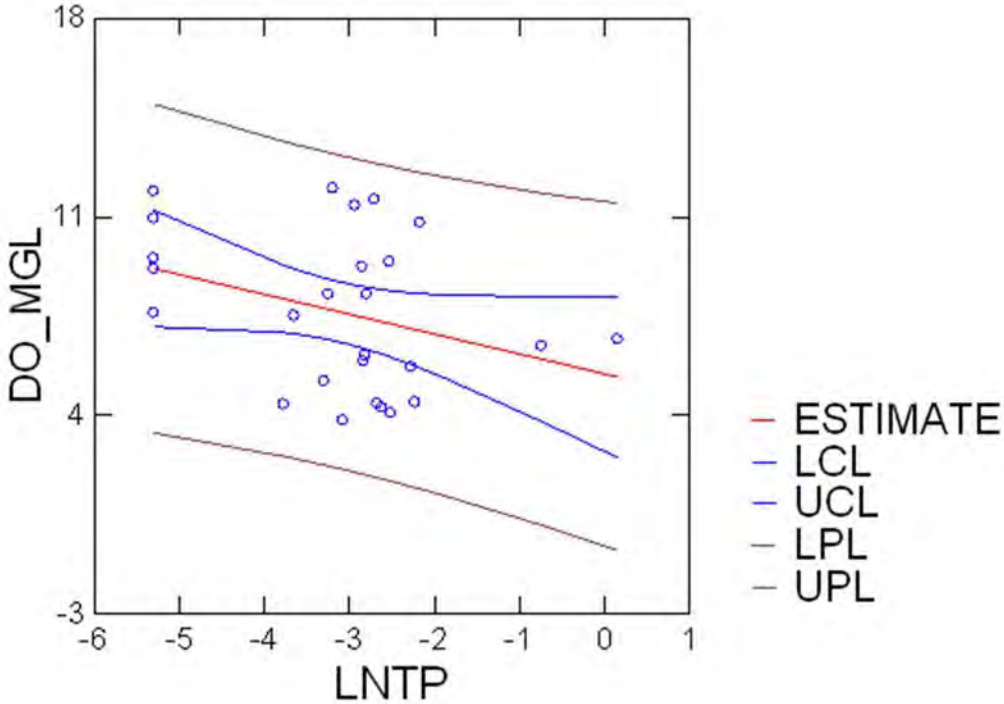
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	22.143	1	22.143	3.207	0.086
Residual	165.718	24	6.905		

Durbin-Watson D Statistic	1.806
First Order Autocorrelation	0.072

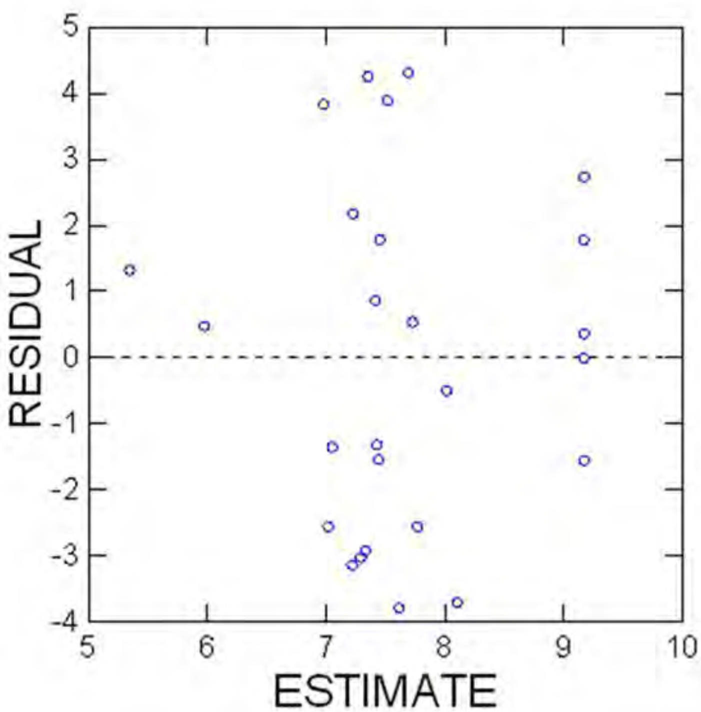
Information Criteria

AIC	127.942
AIC (Corrected)	129.033
Schwarz's BIC	131.716

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+LNNOX

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.434
Squared Multiple R	0.188
Adjusted Squared Multiple R	0.153
Standard Error of Estimate	2.553

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	10.176	1.179	0.000		8.633	0.000
LNNOX	1.368	0.592	0.434	1.000	2.309	0.030

Analysis of Variance

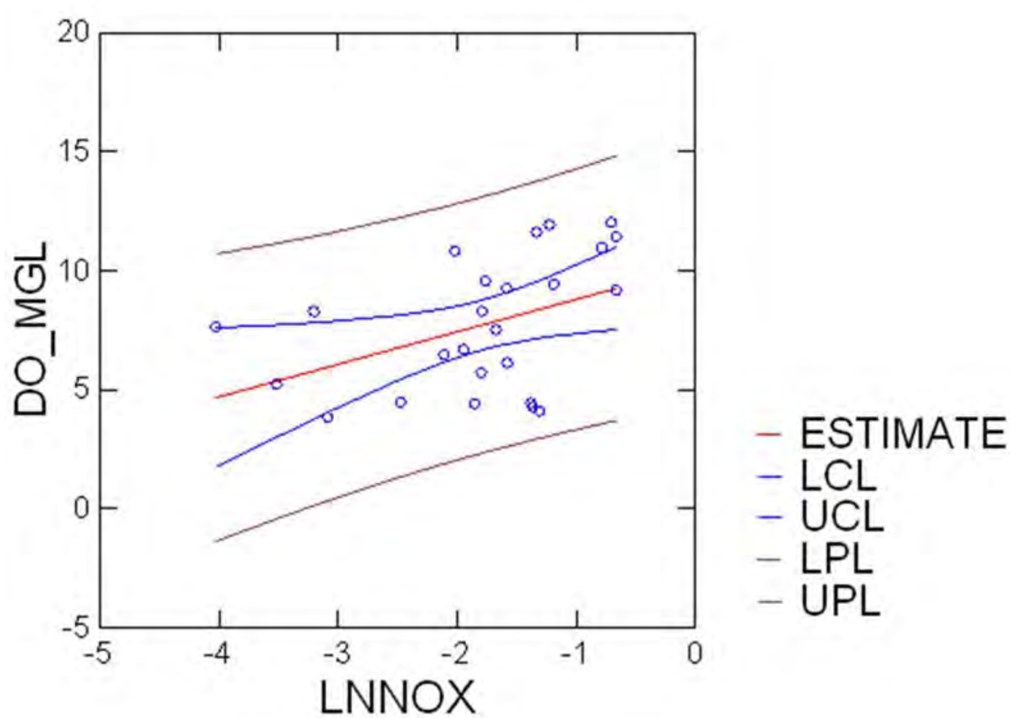
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	34.743	1	34.743	5.331	0.030
Residual	149.887	23	6.517		

Durbin-Watson D Statistic	1.932
First Order Autocorrelation	0.031

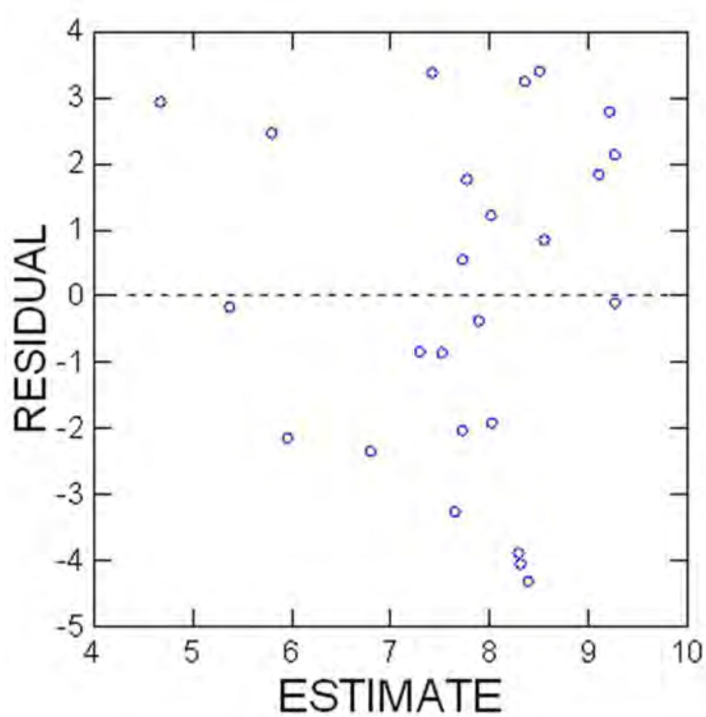
Information Criteria

AIC	121.722
AIC (Corrected)	122.865
Schwarz's BIC	125.379

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+LNTKN

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.599
Squared Multiple R	0.359
Adjusted Squared Multiple R	0.331
Standard Error of Estimate	2.197

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	4.221	1.014	0.000		4.163	0.000
LNTKN	-3.229	0.899	-0.599	1.000	-3.592	0.002

Analysis of Variance

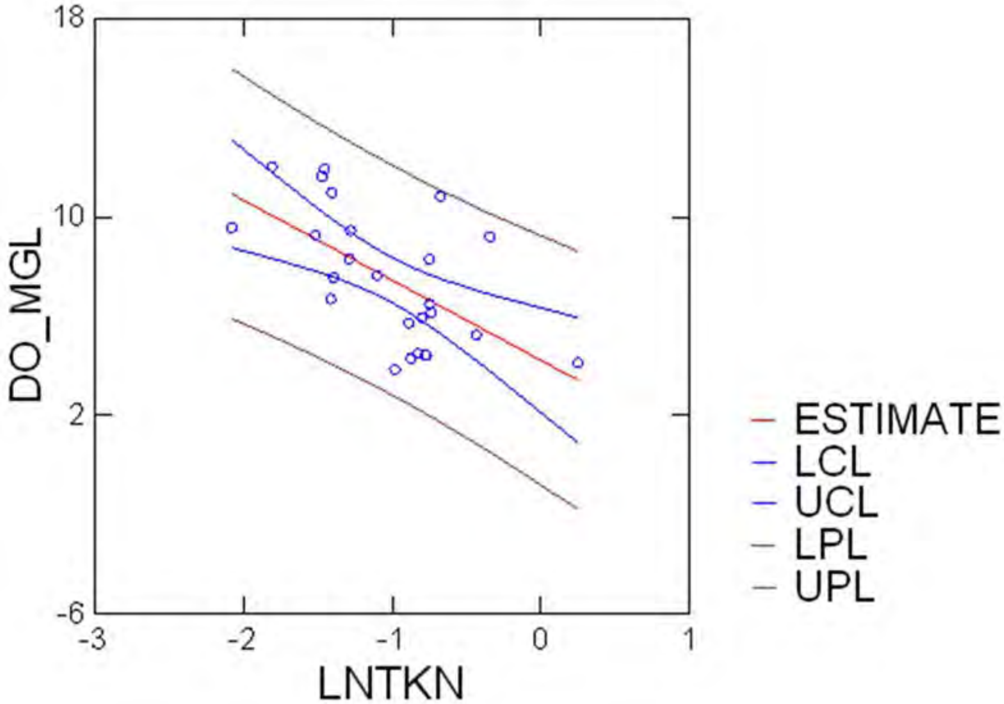
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	62.253	1	62.253	12.899	0.002
Residual	111.004	23	4.826		

Durbin-Watson D Statistic	2.021
First Order Autocorrelation	-0.031

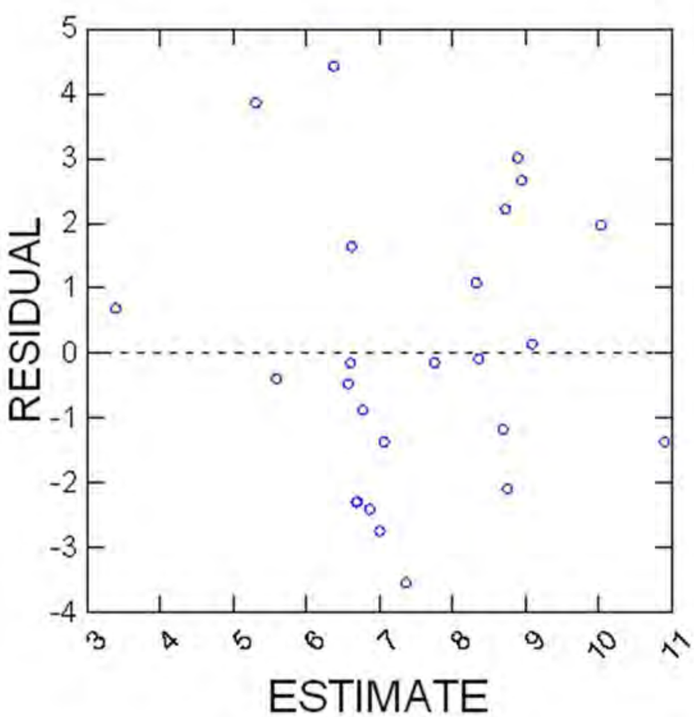
Information Criteria

AIC	114.214
AIC (Corrected)	115.357
Schwarz's BIC	117.871

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+LNTN

3 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	25
Multiple R	0.156
Squared Multiple R	0.024
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.711

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	6.844	1.028	0.000		6.660	0.000
LNTN	-1.173	1.554	-0.156	1.000	-0.755	0.458

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	4.191	1	4.191	0.570	0.458
Residual	169.066	23	7.351		

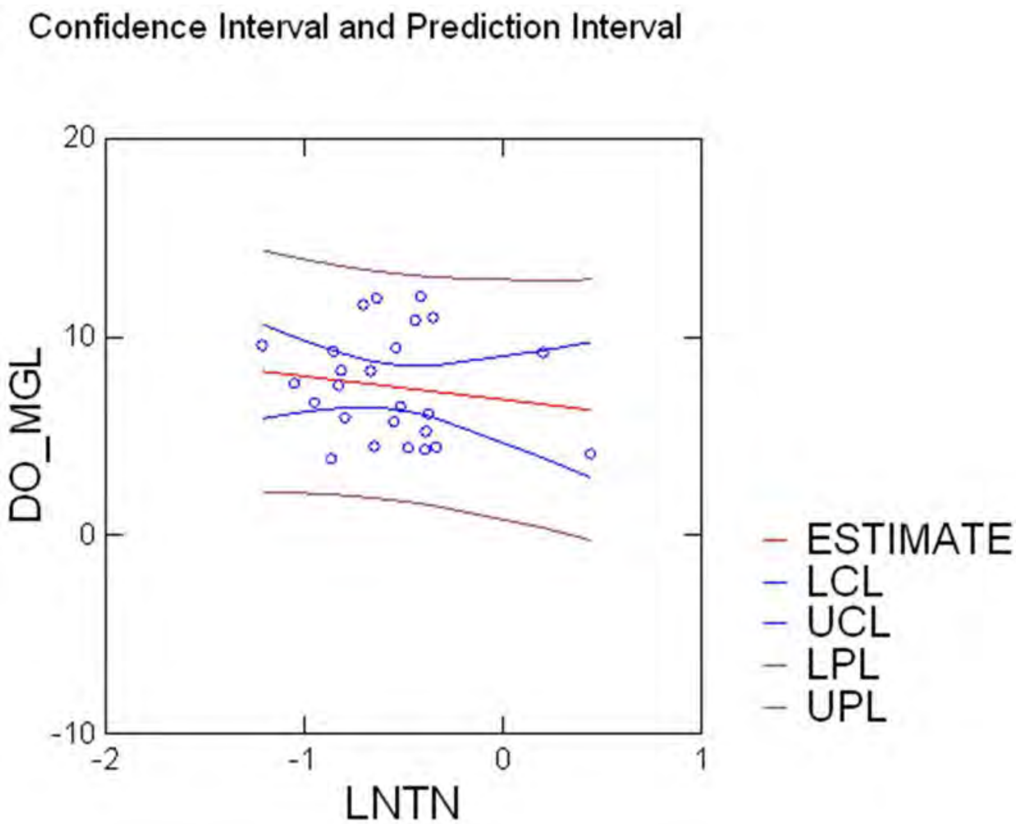
WARNING

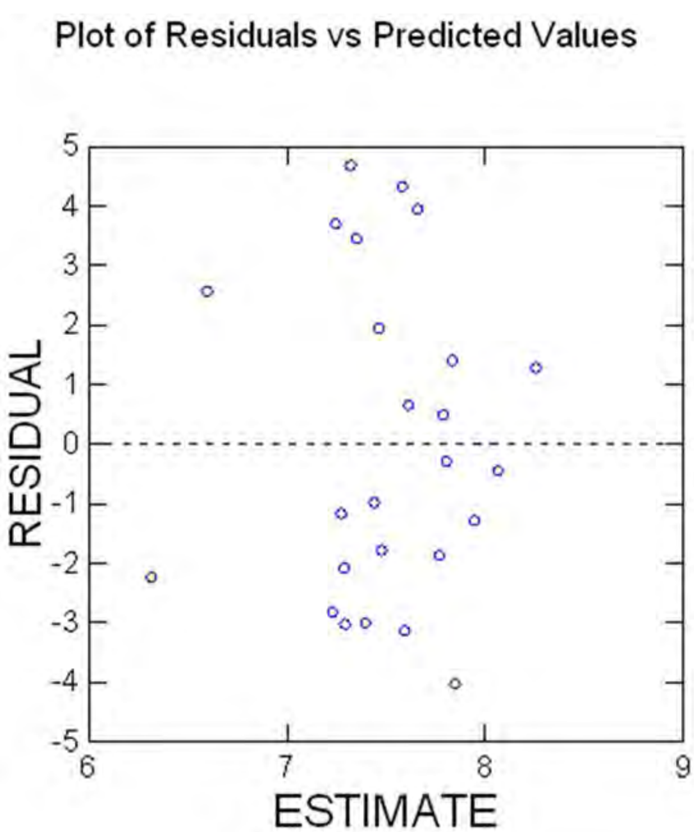
Case 6 has large Leverage (Leverage : 0.374)

Durbin-Watson D Statistic	1.982
First Order Autocorrelation	-0.009

Information Criteria

AIC	124.732
AIC (Corrected)	125.875
Schwarz's BIC	128.389


Confidence Interval and Prediction Interval
20
10
0
-10
-2
-1
0
1
DO_MGL
LNTN
ESTIMATE
LCL
UCL
LPL
UPL


Plot of Residuals vs Predicted Values
5
4
3
2
1
0
-1
-2
-3
-4
-5
6
7
8
9
RESIDUAL
ESTIMATE

> REGRESS
> MODEL DO_MGL = CONSTANT+LNTURB

2 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	26
Multiple R	0.192
Squared Multiple R	0.037
Adjusted Squared Multiple R	0.000
Standard Error of Estimate	2.746

Regression Coefficients B = $(X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	9.552	2.054	0.000		4.650	0.000
LNTURB	-0.814	0.850	-0.192	1.000	-0.958	0.348

Analysis of Variance

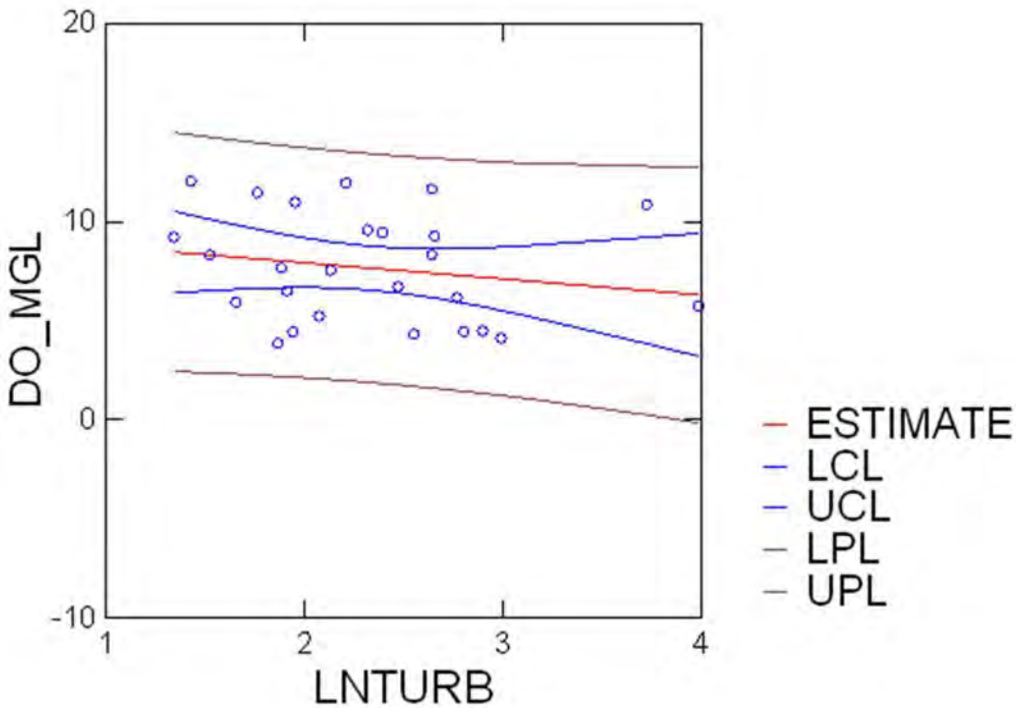
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	6.919	1	6.919	0.918	0.348
Residual	180.943	24	7.539		

Durbin-Watson D Statistic	1.647
First Order Autocorrelation	0.155

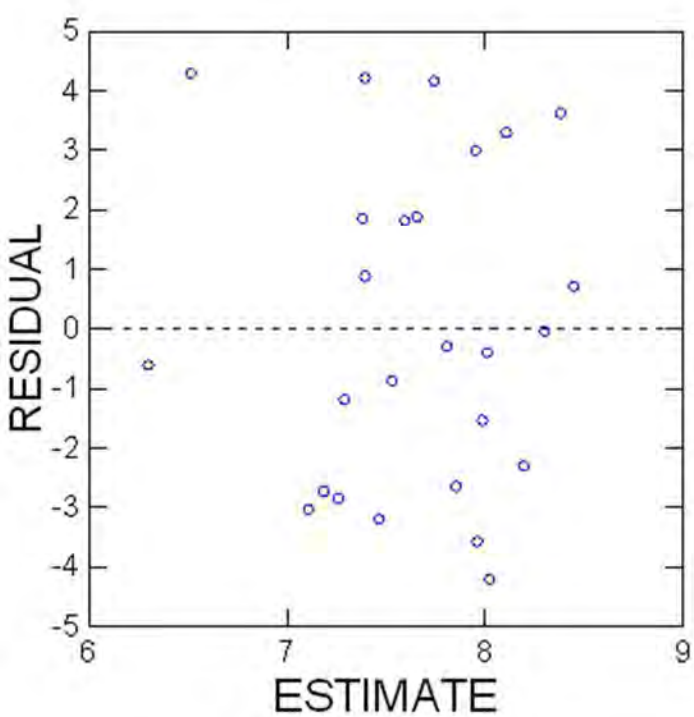
Information Criteria

AIC	130.227
AIC (Corrected)	131.318
Schwarz's BIC	134.001

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+LNNH3N

16 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	12
Multiple R	0.582
Squared Multiple R	0.338
Adjusted Squared Multiple R	0.272
Standard Error of Estimate	1.421

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-0.585	2.758	0.000		-0.212	0.836
LNNH3N	-2.092	0.925	-0.582	1.000	-2.262	0.047

Analysis of Variance

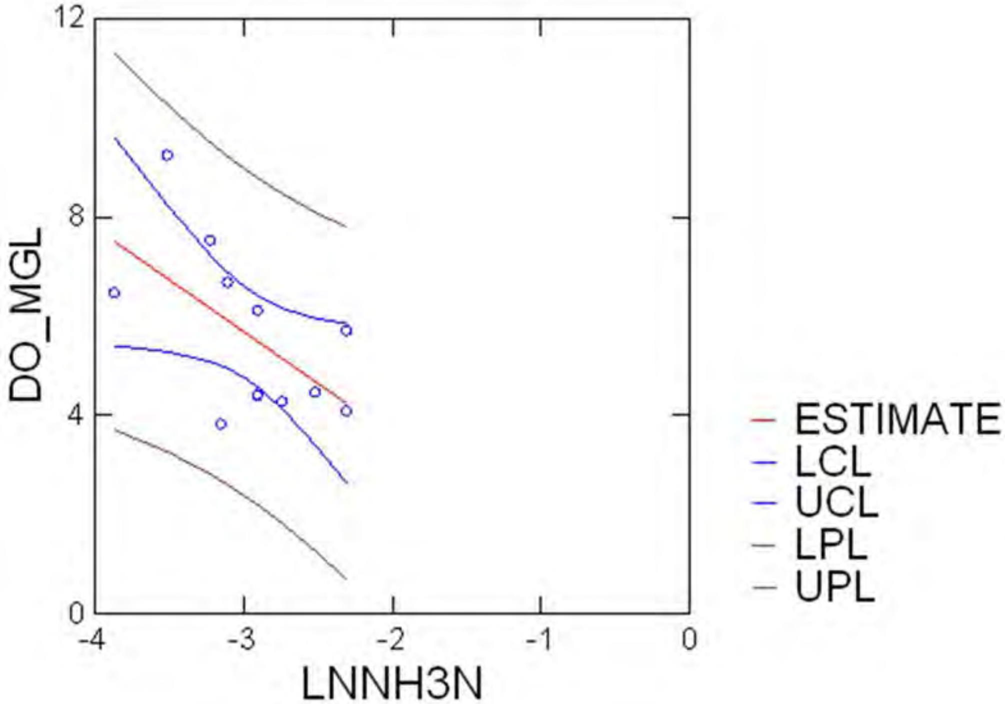
Source	SS	df	Mean Squares	F-ratio	p-value
Regression	10.330	1	10.330	5.117	0.047
Residual	20.188	10	2.019		

Durbin-Watson D Statistic	3.003
First Order Autocorrelation	-0.525

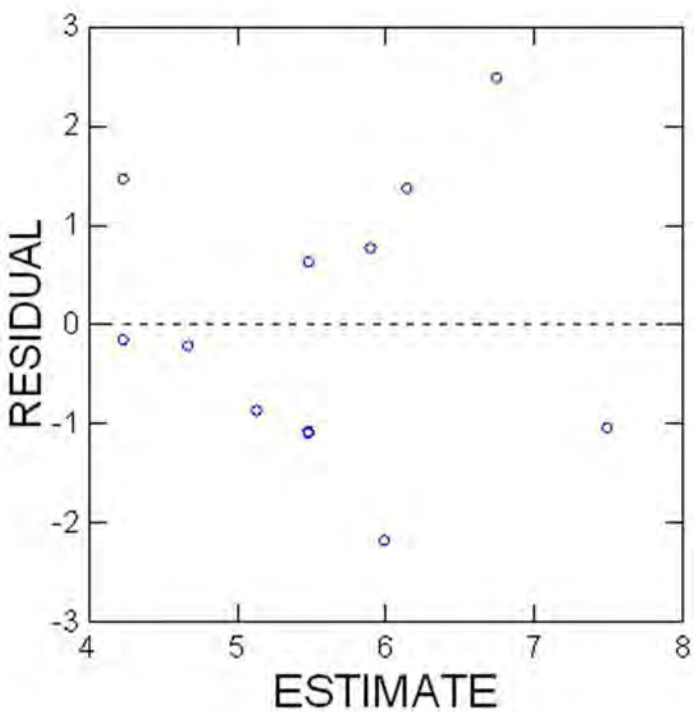
Information Criteria

AIC	46.297
AIC (Corrected)	49.297
Schwarz's BIC	47.752

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+LNBOD

18 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	10
Multiple R	0.501
Squared Multiple R	0.251
Adjusted Squared Multiple R	0.157
Standard Error of Estimate	2.717

Regression Coefficients B = (X'X)$^{-1}$X'Y

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	7.064	0.930	0.000	.	7.596	0.000
LNBOD	-1.851	1.131	-0.501	1.000	-1.637	0.140

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	19.794	1	19.794	2.681	0.140
Residual	59.062	8	7.383		

WARNING

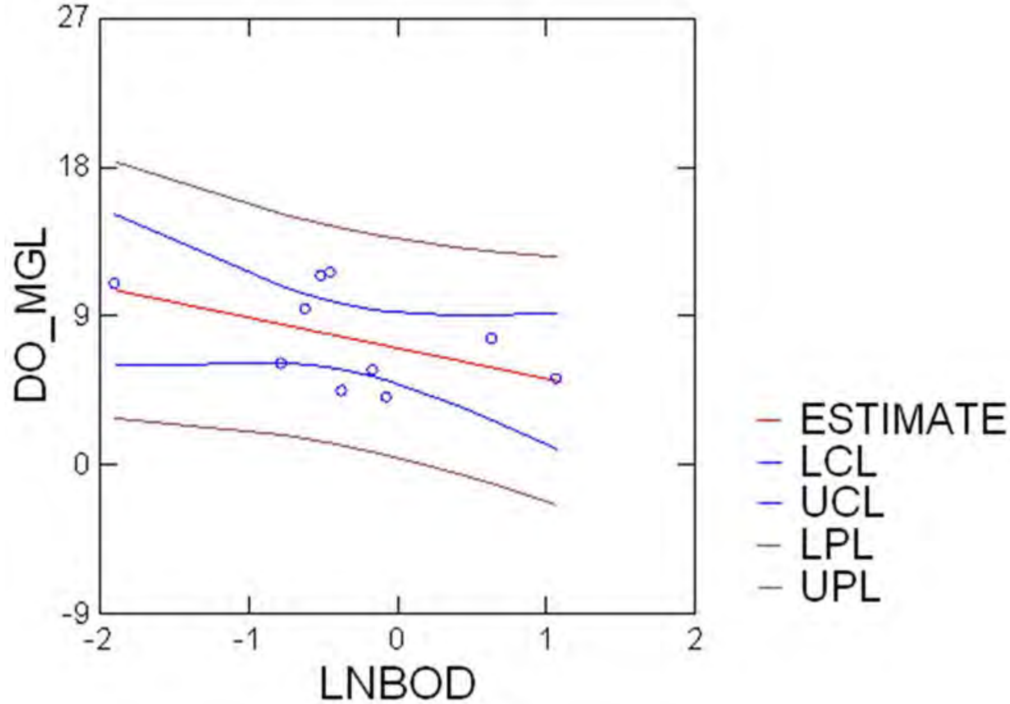
Case 2 has large Leverage (Leverage : 0.534)

Durbin-Watson D Statistic	1.688
First Order Autocorrelation	0.131

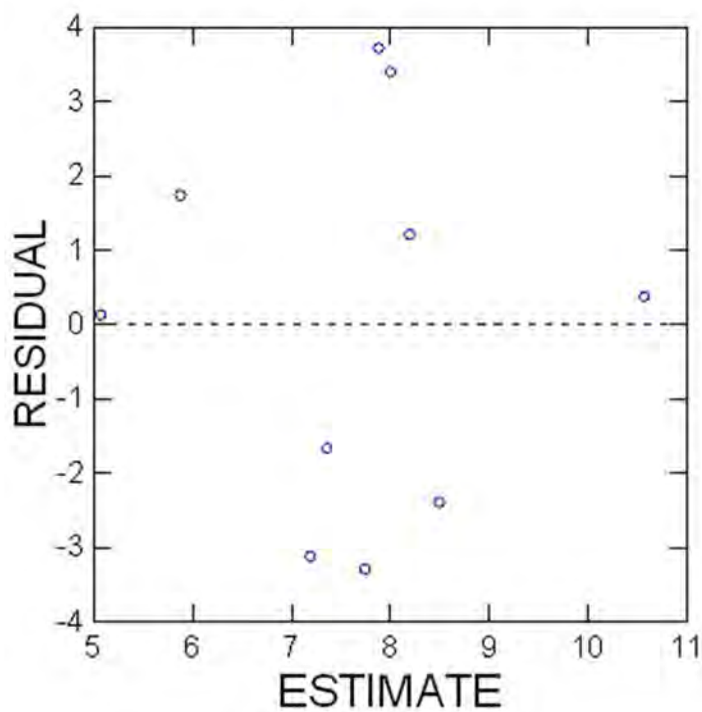
Information Criteria

AIC	52.139
AIC (Corrected)	56.139
Schwarz's BIC	53.046

Confidence Interval and Prediction Interval



Plot of Residuals vs Predicted Values



> REGRESS
> MODEL DO_MGL = CONSTANT+TEMP_DEGC+LNNOX+LNTKN+LNTN+LNTP+LNNH3N+LNTURB

Stepwise Selection of Variables

16 case(s) are deleted due to missing data.

Step number : 0
R : 0.949
R-square : 0.901

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.167	0.085	-0.507	0.374	1	3.884	0.120
3	LNNOX	2.655	3.184	0.822	0.026	1	0.695	0.451
4	LNTKN	2.396	8.768	0.657	0.004	1	0.075	0.798
5	LNTN	-4.503	11.975	-1.005	0.003	1	0.141	0.726
6	LNTP	0.029	0.290	0.020	0.652	1	0.010	0.925
7	LNNH3N	-2.684	1.098	-0.747	0.266	1	5.981	0.071
8	LNTURB	0.615	0.892	0.220	0.243	1	0.475	0.528

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
	none					

Information Criteria	
AIC	35.525
AIC (Corrected)	125.525
Schwarz's BIC	39.889

Dependent Variable : DO_MGL
Minimum Tolerance for Entry into Model : 0.000
Backward Stepwise with Alpha-to-Enter : 0.150
Backward Stepwise with Alpha-to-Remove : 0.150

Step number : 1
R : 0.949
R-square : 0.901
Term Removed : LNTP

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.166	0.076	-0.506	0.376	1	4.832	0.079
3	LNNOX	2.732	2.768	0.846	0.027	1	0.975	0.369
4	LNTKN	2.674	7.452	0.734	0.005	1	0.129	0.734
5	LNTN	-4.879	10.188	-1.090	0.004	1	0.229	0.652
7	LNNH3N	-2.736	0.866	-0.761	0.343	1	9.992	0.025
8	LNTURB	0.649	0.737	0.232	0.285	1	0.775	0.419

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
6	LNTP	0.050	0.652	1	0.010	0.925

Information Criteria	
AIC	33.555
AIC (Corrected)	81.555
Schwarz's BIC	37.434

Step number : 2
R : 0.948
R-square : 0.898
Term Removed : LNTKN

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.149	0.055	-0.455	0.602	1	7.331	0.035
3	LNNOX	1.764	0.569	0.546	0.548	1	9.618	0.021
5	LNTN	-1.239	0.882	-0.277	0.438	1	1.973	0.210
7	LNNH3N	-2.718	0.799	-0.756	0.344	1	11.574	0.014
8	LNTURB	0.746	0.635	0.267	0.329	1	1.380	0.285

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	LNTKN	0.158	0.005	1	0.129	0.734
6	LNTP	0.097	0.724	1	0.048	0.836

Information Criteria	
AIC	31.860
AIC (Corrected)	59.860
Schwarz's BIC	35.255

Step number : 3
R : 0.935
R-square : 0.875
Term Removed : LNTURB

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.178	0.051	-0.542	0.745	1	12.192	0.010
3	LNNOX	2.087	0.511	0.646	0.715	1	16.664	0.005
5	LNTN	-1.365	0.899	-0.305	0.445	1	2.305	0.173
7	LNNH3N	-2.075	0.598	-0.577	0.649	1	12.058	0.010

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	LNTKN	0.291	0.005	1	0.554	0.485
6	LNTP	0.284	0.941	1	0.528	0.495
8	LNTURB	0.432	0.329	1	1.380	0.285

Information Criteria	
AIC	32.344
AIC (Corrected)	49.144
Schwarz's BIC	35.254

Step number : 4
R : 0.913
R-square : 0.833
Term Removed : LNTN

In	Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	df	F-ratio	p-value
1	Constant							
2	TEMP_DEGC	-0.211	0.050	-0.643	0.913	1	18.083	0.003
3	LNNOX	1.756	0.499	0.544	0.873	1	12.396	0.008
7	LNNH3N	-2.584	0.534	-0.719	0.946	1	23.446	0.001

Out	Effect	Partial Correlation	Tolerance	df	F-ratio	p-value
4	LNTKN	-0.470	0.546	1	1.984	0.202
5	LNTN	-0.498	0.445	1	2.305	0.173
6	LNTP	0.266	0.943	1	0.533	0.489
8	LNTURB	0.433	0.334	1	1.613	0.245

Information Criteria	
AIC	33.760
AIC (Corrected)	43.760
Schwarz's BIC	36.184

16 case(s) are deleted due to missing data.

Dependent Variable	DO_MGL
N	12
Multiple R	0.913
Squared Multiple R	0.833
Adjusted Squared Multiple R	0.771
Standard Error of Estimate	0.798

Regression Coefficients $B = (X'X)^{-1}X'Y$

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	p-value
CONSTANT	5.513	1.992	0.000	.	2.768	0.024
TEMP_DEGC	-0.211	0.050	-0.643	0.913	-4.252	0.003
LNNOX	1.756	0.499	0.544	0.873	3.521	0.008
LNNH3N	-2.584	0.534	-0.719	0.946	-4.842	0.001

Analysis of Variance

Source	SS	df	Mean Squares	F-ratio	p-value
Regression	25.429	3	8.476	13.326	0.002

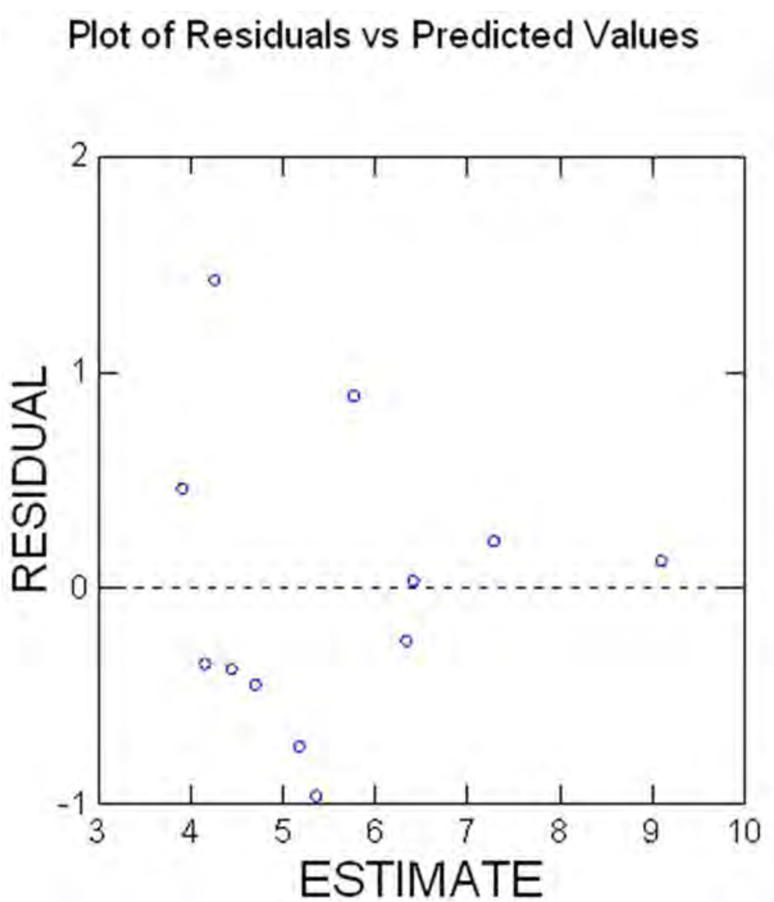
Analysis of Variance					
Source	**SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
Residual	5.089	8	0.636		

WARNING

Case 10 is an Outlier (Studentized Residual : 2.877)

Durbin-Watson D Statistic	2.523
First Order Autocorrelation	-0.344

Information Criteria	
AIC	33.760
AIC (Corrected)	43.760
Schwarz's BIC	36.184



APPENDIX F

Social Media Marketing Checklist

7 Steps in Creating a Winning Social Media Marketing Strategy in 2018

Alex York

Just a few years ago, you could get away with building a social media marketing strategy on the fly. As long as you were present, you were doing more than your competitors–right?

Well it's 2018 and not much of the same logic applies today. With 30% of millennials saying they engage with a brand on social at least once a month (https://sproutsocial.com/insights/data/q1-2017/), your strategy can't be only about existence. Brands must be fully invested in their social media marketing strategies and focus on engagement. Otherwise, you'll lose out on real customers, which means serious effects on your bottom line.

We're not here to scare your brand into the world of social media. Instead, we want to provide your marketing team with the right steps to take toward a successful social strategy so your brand isn't left in the dust.

Here are the seven steps to create a winning social media marketing strategy in 2018 (https://sproutsocial.com/insights/social-media-marketing-strategy/#infographic):

1. Create Social Media Marketing Goals That Solve Your Biggest Challenges

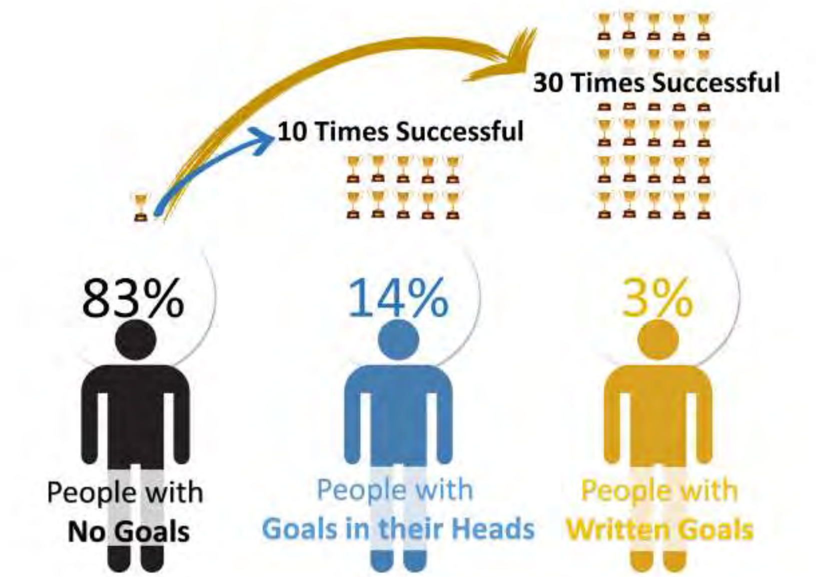
The first step to any strategy is to understand what you want out of your efforts. Social media marketing isn't about flipping a switch and calling it a day. Instead, social media planning should be looked at like cooking your favorite dish.

Once you have your ingredients, you follow a recipe and presto! But that's not always the case. What if you have guests and need to feed more people? What if someone is allergic to one of the ingredients? Suddenly, your goal goes from making a meal to ensuring it will feed enough people and be edible by all.

That's why creating goals is so critical to the first part of your social media strategy. At the same time, it's best to set goals that you know are attainable. Asking for 1 million new Instagram followers in 2018 is unrealistic. With achievable goals, you're more likely to stick to the original plan and continue to take on new hurdles as you complete old ones.

This is the same reason why brands should never take on every social media channel possible in their current marketing strategy. Try to choose the channels that have the most importance based on your brand's goals. Avoid over complicating a strategy with too many targets and objectives. Simplicity can take you a long way.

And also, don't forget to document your social media goals. Not only is it important to help you benchmark where you are, but it also improves your chances of achieving them. According to some statistics, people who write their goals down are 30 times more successful.



Social Media Goals to Consider in 2018

Goal setting is a staple of all marketing and business strategies. Social media is no exception. Of course, with a range of social capabilities, it can be difficult to determine exactly what your objectives should be. For guidance, here are some common social media goals to consider:

- **Increase brand awareness:** To create authentic and lasting brand awareness, avoid a slew of promotional messages. Instead, focus on meaningful content and a strong brand personality through your social channels.
- **Higher quality of sales:** Digging through your social channels is nearly impossible without monitoring or listening to specific keywords, phrases or hashtags. Through more efficient social media targeting, you reach your core audience much faster.
- **Drive in-person sales:** Some retailers rely on social media marketing efforts to drive in-store sales. Is your brand promoting enough on social to reward those who come to you? What about alerting customers to what's going on in your stores?
- **Improve ROI:** There's not a brand on social media that doesn't want to increase its return on investment (ROI). But on social media, this goal is specific to performing a thorough audit of your channels and ensuring cost of labor, advertisements and design stay on track.
- **Create a loyal fanbase:** Does your brand promote user-generated content? Do your followers react positively without any initiation? Getting to this point takes time and effort with creating a positive brand persona on social.
- **Better pulse on the industry:** What are your competitors doing that seems to be working? What strategies are they using to drive engagement or sales? Having a pulse on

the industry could simply help you improve your efforts and take some tips from those doing well.

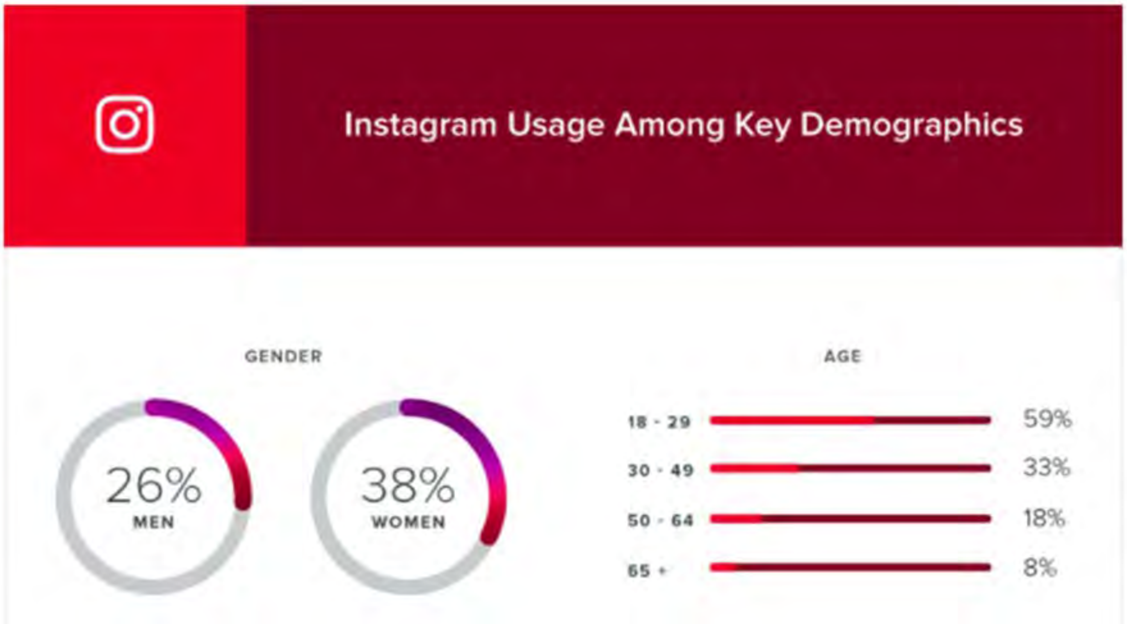
2. Research Your Social Media Audience

Approximately 79% of adults use Facebook–but are your customers actively engaging with your brand there? Understanding your audience is necessary to learn things like who buys your products, what age group is the toughest to sell and what income level makes up the most of your returning customers? As for social media, it's just as critical to know your audience.

First, your brand should look into the demographics of your most valuable social channels. Like we mentioned before, you should have a goal in mind for your social media marketing strategy. This is why you need to research the channels that correlate the most with your goals.

To help you find your focus channels: let's take a quick look at the essential demographics data for each major network:

- **Facebook's most popular demographics include:**
  - Women users (89%)
  - 18-29 year olds (88%)
  - Urban- and rural-located users (81% each)
  - Those earning less than $30,000 (84%)
  - Users with some college experience (82%)
- **Instagram's most popular demographics include:**
  - Women users (38%)
  - 18-29 year olds (59%),
  - Urban-located users (39%)
  - Those earning less than $30,000 (38%)
  - Users with some college experience (37%)



- **Twitter's most popular demographics include:**
  - Women users (25%)
  - 18-29 year olds (36%)
  - Urban-located users (26%)
  - Those earning $50,000-$74,999 (28%)
  - Users with college experience or more (29%)
- **LinkedIn's most popular demographics include:**
  - Men users (31%)
  - 18-29 year olds (34%)
  - Urban-located users (34%)
  - Those earning $75,000 or more (45%)
  - Users with college experience or more (50%)
- **Snapchat and other auto-delete app's most popular demographics include:**
  - Men users (24%)
  - 18-29 year olds (56%)
  - Those earning less than $50,000 (27%)
  - Users with some college experience (27%)

See even more demographics data on our in-depth guide! (https://sproutsocial.com/insights/new-social-media-demographics/)

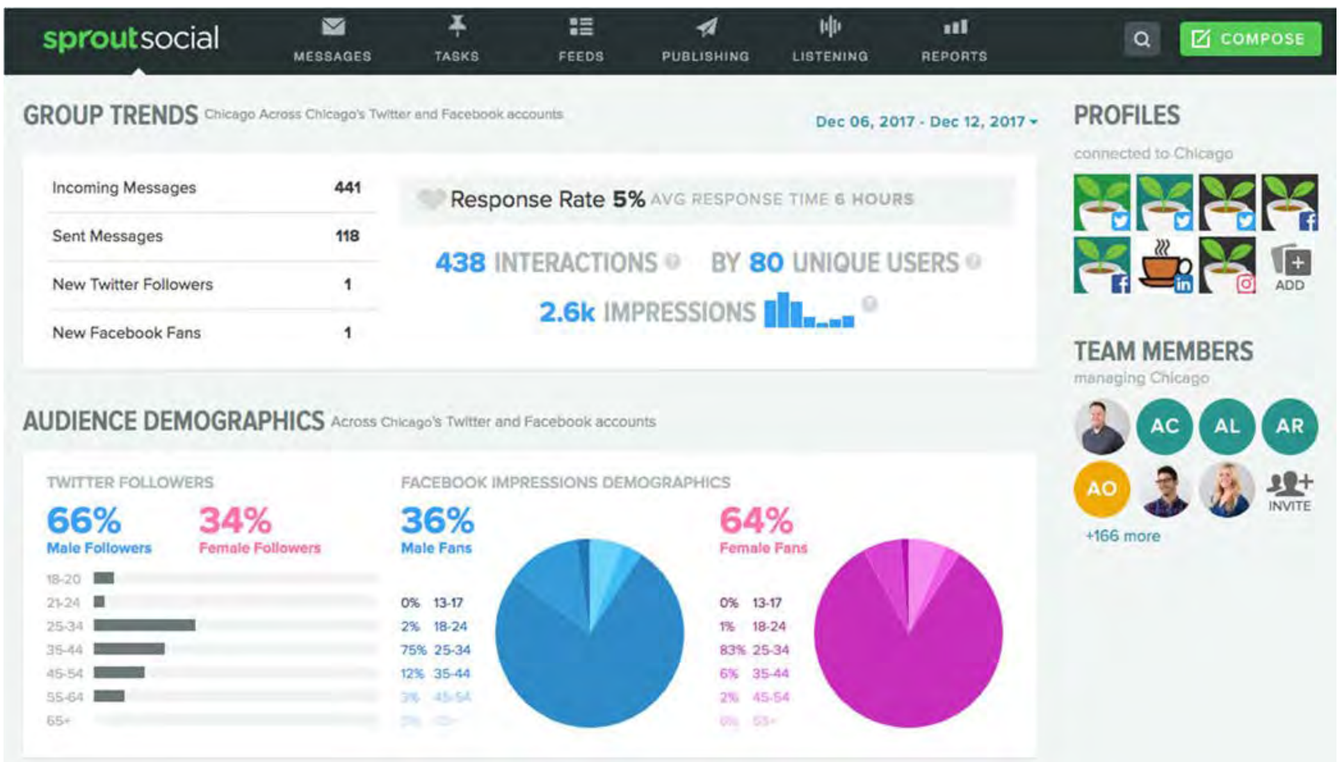
The best marketers you'll come across don't sleep until they have a better idea on their audience and segmentation strategy.

Identifying Customer Demographics

While the demographics data above give you insight into each channel, what about your own customers? Further analysis has to be completed before you can truly know your customer demographics on social media.

That's why many brands use a social media dashboard (Figure) that can provide an overview of who's following you and how they interact with you on each channel. Most brands today are using at least some sort of dashboard. However, does your dashboard address your specific goals?

Whether you're an agency providing insights for your clients or an enterprise company discovering your own demographics, an all-in-one dashboard solution is critical.



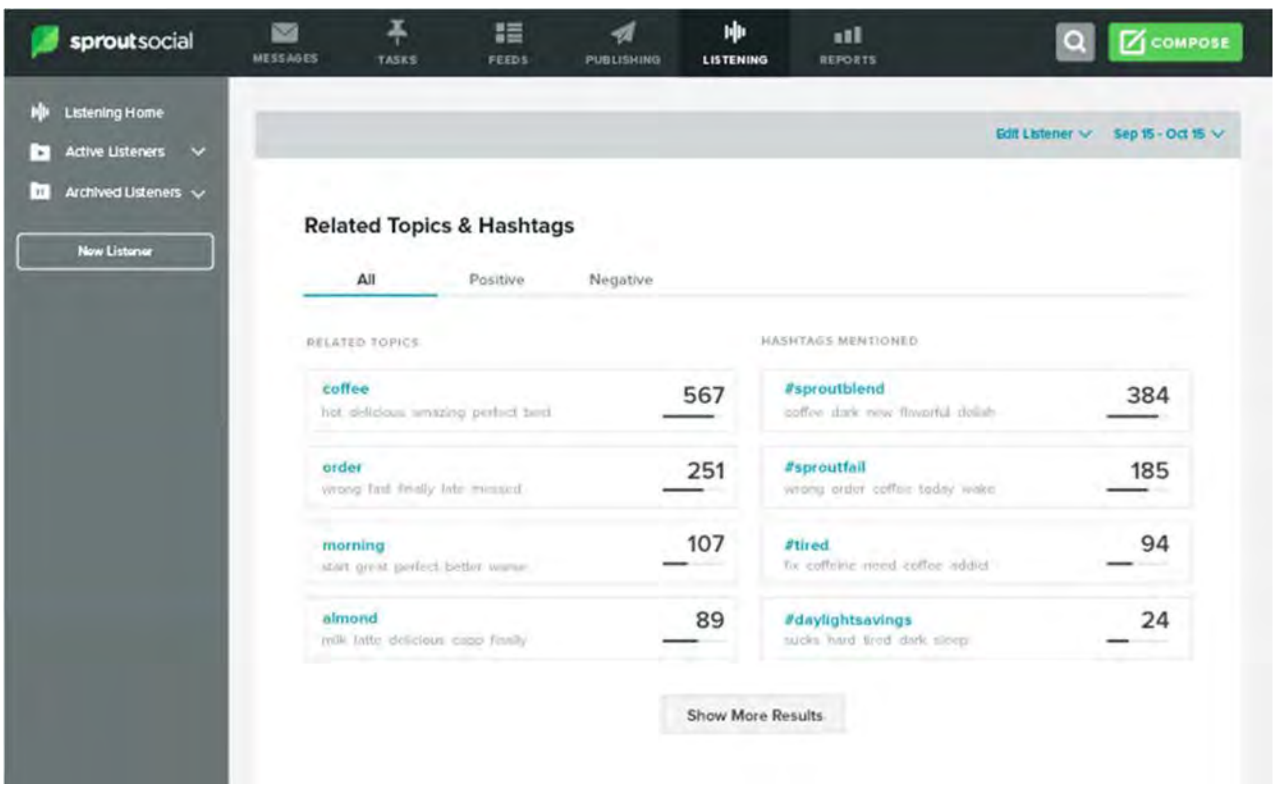
3. Establish Your Most Important Metrics

While your targeted social media metrics might be the most important step of a strategy, it's often the spot most veer off the path. Vanity metrics like follower count and likes are always good to measure, but does it tell you the **whole story of your brand** on social media?

We often get wrapped up in viewing followers and likes as the truth to a campaign, but it's smart to take a step back and evaluate the social metrics associated with your overall goals.

Engagement metrics sometimes paint a better picture, because as we've mentioned many times here, building lasting relationships works on social. Large audiences and likable content is absolutely great, but here are some other metrics you might want to pursue in 2018:

- **Reach:** Post reach is the number of unique users who saw your post. How far is your content spreading across social? Is it actually reaching user's feeds?
- **Clicks:** This is the amount of clicks on your content, company name or logo. Link clicks are critical toward understanding how users move through your marketing funnel. Tracking clicks per campaign is essential to understand what drives curiosity or encourages people to buy.
- **Engagement:** The total number of social interactions divided by number of impressions. For engagement, it's about seeing who interacted and if it was a good ratio out of your total reach. This sheds light on how well your audience perceives you and their willingness to interact.
- **Hashtag performance:** What were your most used hashtags on your own side? Which hashtags were most associated with your brand? Or what hashtags created the most engagement?



- **Sentiment:** This is the measurement of how users reacted to your content, brand or hashtag. Did customers find your recent campaign offensive? What type of sentiment are people associating with your campaign hashtag? It's always better to dig deeper and find what people are saying.
- **Organic and paid likes:** More than just standard Likes, these likes are defined from paid or organic content. For channels like Facebook, organic engagement is much harder to

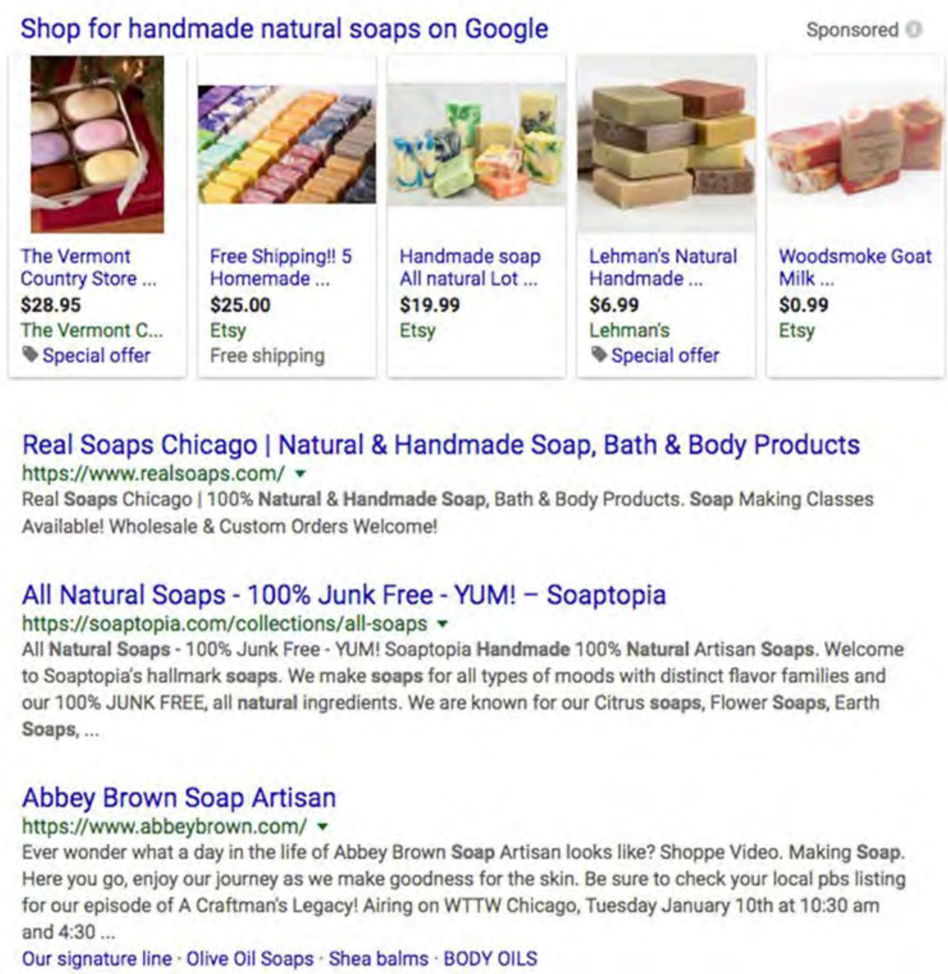
gain traction, which is why many brands turn to Facebook Ads. However, earning organic likes on Instagram isn't quite as difficult.

4. Research Your Social Competitive Landscape

Before you start creating content (we promise we're almost there!), it's really smart to investigate your competitors. We put this before the content creation process because you often find new ways to look at content by analyzing what's making your competitors successful.

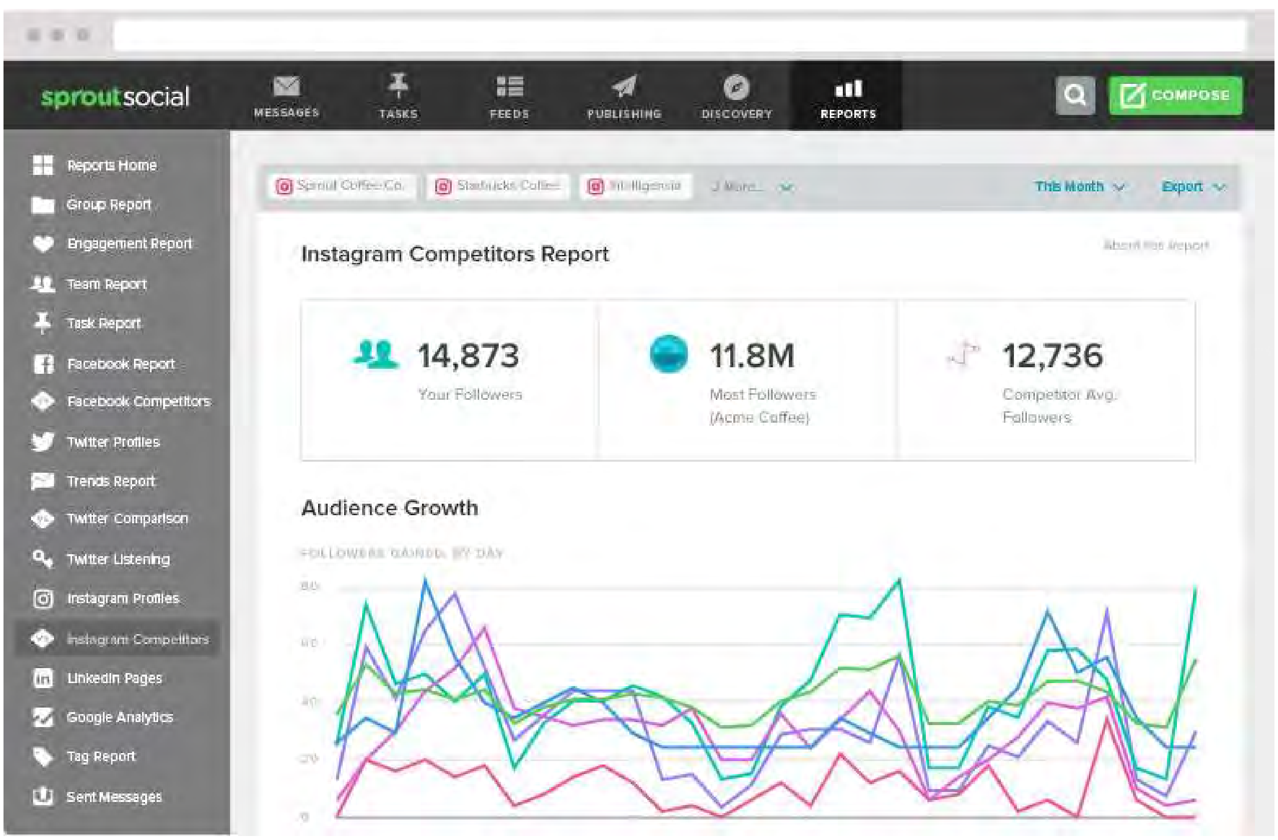
Again, we'll always believe you shouldn't steal your competitors' ideas, but instead learn and grow from their success and failures. So how do you find that information? The first step is to find out who's your competition in the first place.

The simplest way to find competitors is through a simple Google search. Look up your most valuable keywords, phrases and industry terms to see who shows up. For example, if you sold various soaps, "handmade natural soaps" would be a great keyword to investigate:



You can exclude the major retailers like Amazon and Bath & Body Works. Search for those who show up who are in your specific industry. Next you want to see who is active on social.

As you can see, Wild Soap has an active social presence, which means they're a great candidate to track. After gathering a handful of industry competitors, it's smart to use a social media competitive analysis tool like Sprout Social to track Facebook and Instagram content.



Here you can see post break downs of text, images and video to see what your competitors are doing to drive the most engagement. Once you dig through the competitive analysis, you'll have a better idea of what your potential customers want.

5. Build & Curate Engaging Social Media Content

Did someone say content? It's no lie–social media content is extremely important to your marketing strategy. However, it's best to follow the previous steps before planning out content (we caught you, blog skippers!) so you can start building more effective themes.

For starters, we recommend creating content that fits to your brand's identity. This means you should avoid things like reaching out to your unpopular demographics without a complete strategy in place.

It's necessary to find the perfect balance between target content and being overly promotional as well. In fact, 46% of users say they'll unfollow a brand if there's too many promotional messages. Additionally, 41% of users say they'd unfollow a brand that shared too much irrelevant content (https://sproutsocial.com/insights/data/q3-2016/).

Video Content or Bust

How important is video to your social media marketing strategy? Extremely–approximately 90% of online shoppers believe product videos help them make a purchasing decision (https://www.forbes.com/sites/forbesagencycouncil/2017/02/03/video-marketing-the-future-of-content-marketing/#744d94af6b53). Additionally, the average online video is completely watched end to end by 37% of viewers (https://blog.hubspot.com/marketing/video-marketing-statistics#sm.0000f7ujhkwrse8sqa62aq63w23fi).

These types of statistics should only enforce your reasoning to invest in social media video content. Brands can reach users through Instagram Stories, Facebook Live and other in-the-moment media.

Build Content Themes

One of the toughest challenges to visual content is creating it on a day-to-day basis. A Venngage infographic showed 36.7% of marketers said their No.1 struggle with creating visual content was doing so consistently (https://www.impactbnd.com/blog/visual-content-marketing-statistics-2017).

This truly shows how important highly-visual content is to marketers and the people they want to reach. That's why building content themes is a great approach to sectioning out your content. Instagram is one your premier channels to work off visual themes.

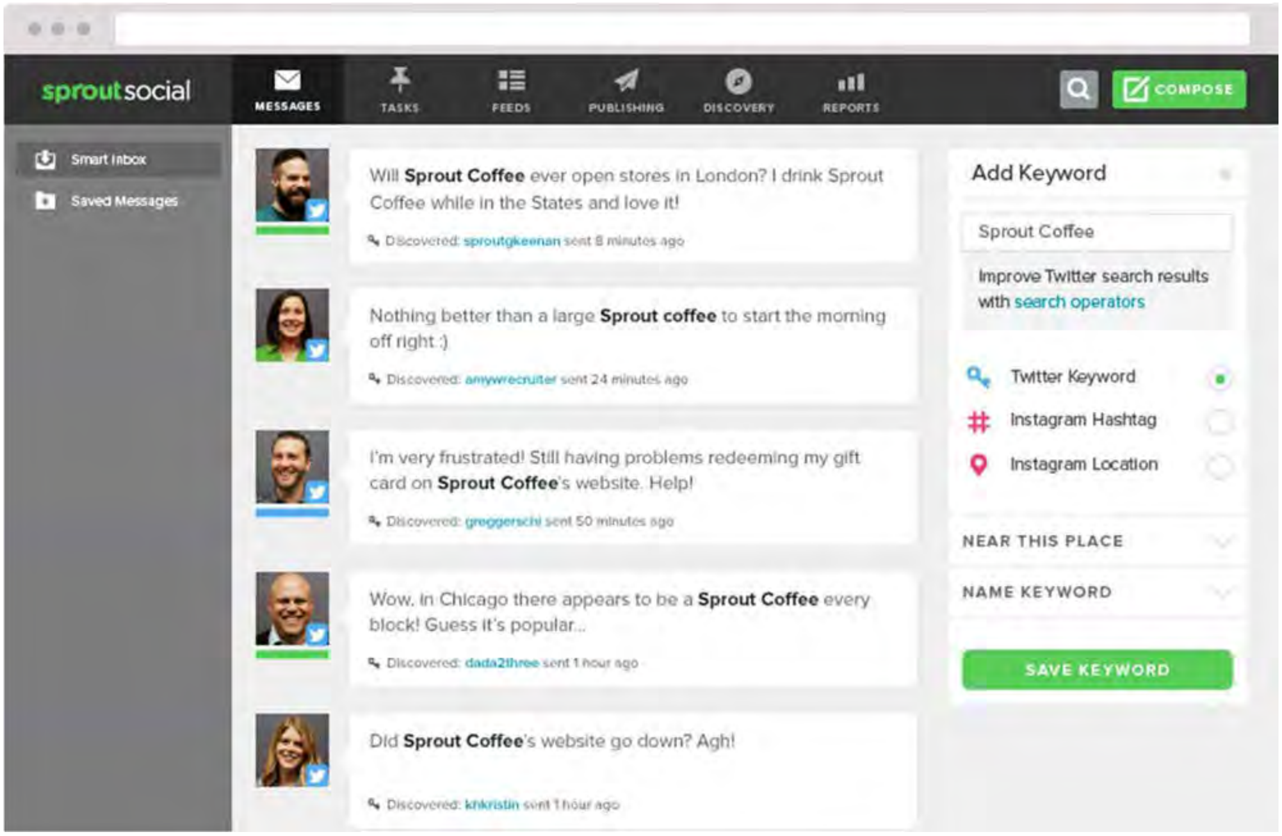
Anthropologie does an amazing job at keeping their Instagram feed consistent, colorful and eye-popping. Work in content themes to ensure you have a consistent schedule of excellent content to publish.

6. Engage With Your Audience & Don't Ignore

Social media channels are built as networks. This means their main purpose is to be a space to converse, discuss topics and share content. Your brand can't forget these core elements of "networking" and it takes effort to ensure conversations or engagement opportunities aren't left unattended.

Through social media, you gain respect as a brand by just being present and talking to your audience. That's why social customer care is so important to brands wanting to increase audience awareness. It's all about engagement.

For example, Seamless (https://twitter.com/Seamless) does a wonderful job of not only responding, but showing customer care is priority. Through the right social media monitoring tools, you can find instances across all your channels to interact, respond and gauge customer service inquiries.



Designating teams to specific tasks can help your staff run like a well-oiled social media team, whether you're a group of one or 100.

Post at the Best Times to Engage

When is your brand available to engage and interact with customers? You might see some recommending times to post late in the evening. But if your brand isn't there to communicate, what's the point of posting at the preferred time?

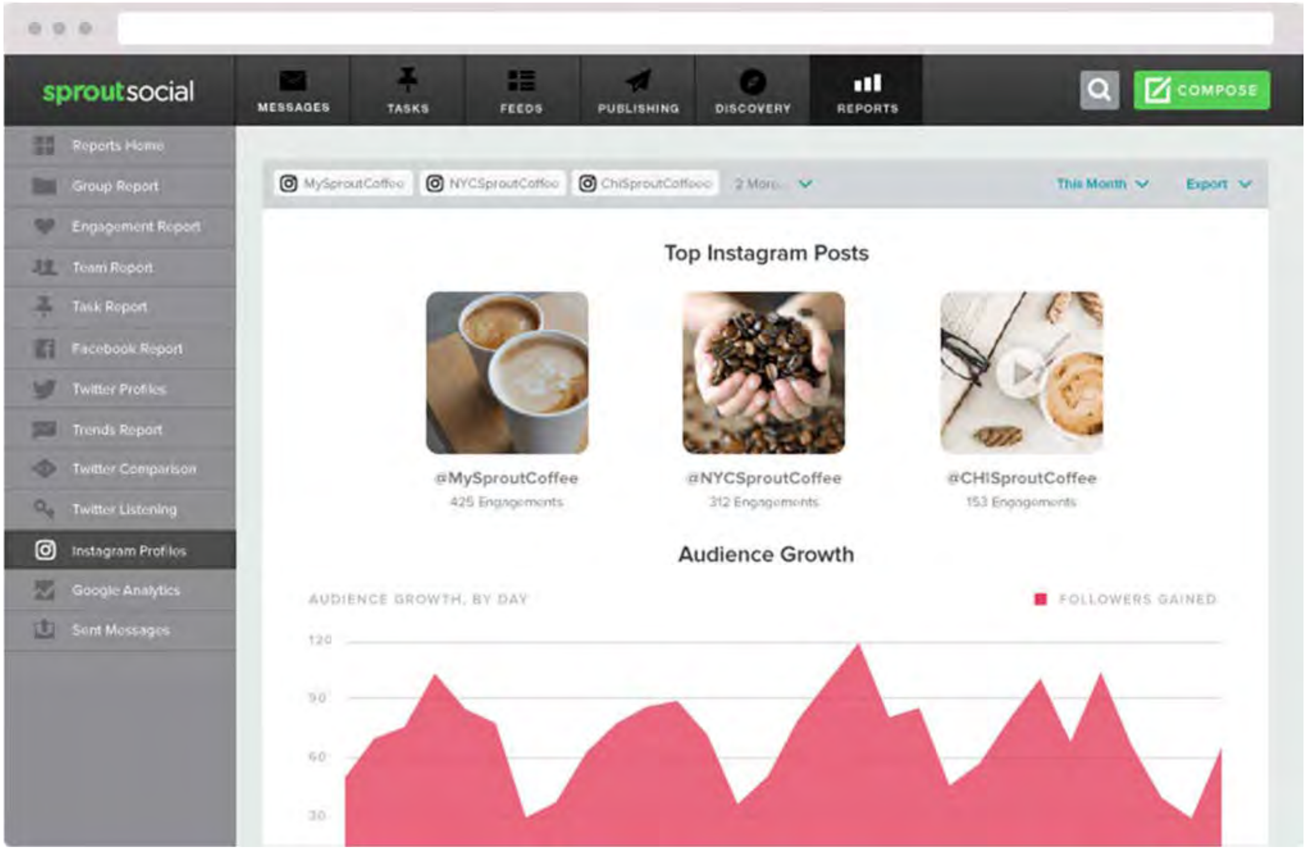
Instead, try to ensure your social media or community managers are available and ready to answer any product questions or concerns when you tweet or post. It's smart to learn the best times to post on social media, but it's just as critical to engage after posting.

According to our Index, a brand's average response time is around 10 hours. But did you know that most users believe brands should respond to social media messages within four hours?

With all the updated algorithms, organic content has a tough time reaching the majority of your audience. The last thing you want to do is ignore those who engage and lose out on sending more down your marketing funnel.

7. Track Your Efforts & Always Improve

So, how well did you do on your social media marketing strategy? Without continuously analyzing your efforts, you'll never know how one campaign did over another. Having a bird's-eye-view of your social media activity helps put things into perspective.



You've got down your most important goals, network preferences and metrics–now it's time to make sure you made the right decisions. Knowing you've made the right choices is still a difficult task in social media.

In fact, 46% of B2B marketers are unsure if their social strategy actually created revenue for their brand (https://www.business2community.com/social-media/47-superb-social-media-marketing-stats-facts-01431126#HT07K2mwjfUGsG2Z.99). But marketers are always trying and looking for the perfect connection. That's why the most commonly used metric (80%) for marketers is engagement.

If you work at building lasting relationships, there's a lot less room for failure with your social media marketing strategy.

Use a Tool to Track Success

Sprout Social was created with social media marketing in mind. Our social media tools offer a full suite of analytics and reporting features to help you pinpoint exactly which posts, messages and hashtags perform the best.

It's easy to connect other critical tools to our dashboard like Google Analytics, which helps you see which posts drove the most traffic, conversions and overall revenue.

Social Media Marketing Strategy Checklist

We wanted to give our readers a few resources to use moving forward. That's why we put together this 7-step social media marketing strategy checklist to help all of our readers creating and auditing their own strategies.

We encourage you to share it with colleagues or use the embed code to put it on your own site!

Social Media Checklist

What are your social media goals?

- ◻ Increase brand awareness
- ◻ Community engagement and education
- ◻ Increase volunteerism/public recruitment
- ◻ Fundraising
- ◻ Others?

Where will you reach your social media audience?

- ◻ Facebook
- ◻ Instagram
- ◻ Twitter
- ◻ Linked In
- ◻ Snapchat
- ◻ YouTube
- ◻ Google

What are your core demographics?

- ◻ Age (18-29; 30-49; 50-65; 65+
- ◻ Gender (M, F)
- ◻ Location (urban, suburban, rural)
- ◻ Income ($30K-49.9K: 50K-75K; 75K+)
- ◻ Education (High School or less; some college; college+)

What are your core metrics?

- ◻ No. of clicks
- ◻ Reach (how broadly discussed)
- ◻ Hashtag performance
- ◻ Engagement (total no of clicks or reviews/demographic core goals)
- ◻ Shares
- ◻ Retweets

What type of content will you produce?

□ Videos (YouTube)
□ Webinars
□ Blogs
□ Photos
□ Case studies
□ Gated guides
□ Post other nonprofits that promote your effort

What are your best times to post on media?

□ Facebook (Day, Time of day)
□ Instagram (Day, Time of day)
□ Twitter (Day, Time of day)
□ Linked In (Day, Time of day)
□ Snapchat (Day, Time of day)

How often will you assess your metrics?

□ Daily
□ Weekly
□ Monthly
□ Annually

Who is going to monitor and maintain the social media platform?

□ ANRC
□ Nonprofit partner
□ Contract
□ Other

APPENDIX G

Calculations of Cost Estimates for Implementation of Management Practices

APPENDIX G
COST ESTIMATE CALCULATIONS

1.0 MANAGEMENT PRACTICES FOR PASTURE AND HAYLAND IN LOWER SALADO CREEK SUBWATERSHED

Table G.1. Estimates of amount of practices required to achieve 21% reduction of nitrogen load in Lower Salado Creek Subwatershed.

Practice	Practice reduction efficiency[a]	Percentage of source to treat to achieve 21% reduction target[b]	Estimated amount of source present	Estimated extent of practice to achieve 21% reduction[c]
Forest riparian buffer	70%	30%	141,768 feet[d]	42,530 feet of 50-foot-wide buffer = 49 acres
Herbaceous riparian buffer	50%	42%	141,768 feet[d]	59,453 feet of 50-foot-wide buffer = 68 acres
Controlled access (fence)	60%	35%	283,536 feet[e]	99,000 feet of fence
Controlled access (alternate water supply)	60%	35%	283,536 feet[e]	99 water tanks[f]
Prescribed grazing	20%	100%	7,009 acres of pasture[g]	7,000 acres

[a] from Table 6.7 in Task 3 report
[b] calculated as target reduction (21%) divided by practice reduction efficiency
[c] Values calculated as the amount of source present (column 4) multiplied by percentage of source to treat to achieve 21% reduction target (column 3). Values rounded to two significant digits.
[d] GIS analysis of 2011 land use data identified 26.85 miles of stream associated with pasture. Based on 2017 aerial imagery, assumed 50% of pasture streams do not have adequate riparian buffer = 13.42 miles = 70,884 feet, multiplied by two streambanks = 141,768 feet.
[e] GIS analysis of 2011 land use data identified 26.85 miles of stream associated with pasture = 141,768 feet, multiplied by two streambanks = 283,536 feet.
[f] Assume 1 tank for every 1,000 feet of fence
[g] based on 2011 National Land Cover Database (Homer, et al. 2015)

Table G.2. Estimated cost for practices to reduce nitrogen load in Lower Salado Creek by 21%.

Practice	Extent/Amount of Practice[a]	Unit Cost[b]	Total Cost[c]
Forest riparian buffer	49 acres	$2,000 per acre	$98,000
Herbaceous riparian buffer	68 acres	$400 per acre	$27,000
Controlled access (fence)	99,000 feet	$1.75 per foot	$170,000
Controlled access (alternate water supply)	99 water tanks	$1,500 per tank	$150,000
Prescribed grazing	7,000 acres	$70 per acre	$490,000

[a] From Table B.1
[b] Based on EQIP reimbursement values for 2017
[c] Calculated as practice amount (column 2) multiplied by unit cost (column 3). Values rounded to two significant digits.

2.0 MANAGEMENT PRACTICES FOR RESIDENTIAL AND DEVELOPED AREAS IN LOWER SALADO CREEK SUBWATERSHED

Unit construction costs for urban stormwater management practices are reported as cost per cubic meter of runoff treated (see Table 8.2). Runoff from several developed catchments within the Lower Salado Creek subwatershed was estimated using information from the USGS StreamStats utility program (https://streamstats.usgs.gov/ss/) and the following equations from Claytor and Schueler (1996) reported in Weis, Gulliver, and Erickson (2007):

Water Quality Volume (in cubic meters) = 100 * rainfall depth (in centimeters) * ratio of runoff to rainfall * watershed area (in hectares),

and

Ratio of Runoff to Rainfall = 0.05 + 0.009 * percent impervious area (0-100).

The inputs and results from these calculations are shown in Table G.3.

Table G.3. Estimates of runoff from impervious areas for a 1-inch (2.54 centimeter) rainfall depth.

Stream	Drainage area (square miles)[a]	Drainage area (hectares)[b]	Percent impervious[a]	Ratio of runoff to rainfall	Water quality volume (cubic meters)[c]
Double Branch	4.87	1,261	5%	0.095	30,000
Tributary to Caney Creek	1.21	313	8%	0.122	9,700
Ladd Branch	0.69	179	4%	0.086	3,900
Total					**44,000**

[a] Estimated using USGS StreamStats,
[b] converted by multiplying area in square miles by 259
[c] values rounded to two significant digits

Table G.4 shows the calculations used to estimate the cost of implementing selected urban stormwater management practices, using the total water quality volume from Table G.3, 44,000 cubic meters.

Table G.4. Estimates of cost to reduce nitrogen load in storm runoff by 21%.

Practice	Practice reduction efficiency[a]	Percentage of volume to treat to achieve 21% reduction target[b]	Volume to treat (cubic meters)[c]	Cost per cubic meter treated[d]	Total Cost[e]
Media filter	25%	84%	37,000	$18	$660,000
Constructed wetland	20%	100%	44,000	$15	$660,000
Pond	22%	95%	42,000	$7	$290,000
Porous pavement	40%	52%	23,000	$5	$120,000

[a] From Table 6.6 in Task 3 report
[b] calculated as target reduction (21%) divided by practice reduction efficiency
[c] Values calculated as the runoff volume (44,000 cubic meters) multiplied by percentage of source to treat to achieve 21% reduction target (column 3). Values rounded to two significant digits.
[d] Based on costs reported in Table 8.2 of this report
[e] Calculated as volume to treat (column 4) multiplied by unit cost (column 5). Values rounded to two significant digits.

3.0 REFERENCES

Claytor, Richard A., and Thomas R. Schueler. 1996. *Design of stormwater filtering systems.* Silver Spring, MD: Center for Watershed Protection.

Homer, CG, JA Dewitz, L Yang, S Jin, P Danielson, G Xian, J Coulston, ND Herold, JD Wickham, and K Megown. 2015. C*ompletion 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.

Weiss, Peter T, John S Gulliver, and Andrew J Erickson. 2007. *Cost and pollutant removal of storm-water treatment practices.* Journal of Water Resources Planning and Management (American Society of Civil Engineers) 218-229.