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STRAWBERRY RIVER WATERSHED-BASED MANAGEMENT PLAN

NOVEMBER 18, 2016

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Prepared for

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EXECUTIVE SUMMARY

The Strawberry River in north central Arkansas is a tributary of the Black River within the White River basin. The river originates in Fulton County, Arkansas and its 761.2 square mile watershed includes portions of Fulton, Izard, Sharp, Independence, and Lawrence Counties. The watershed is primarily rural. Approximately 60% of the watershed is forested. Animal agriculture is widespread in the watershed, including beef and dairy cattle, and poultry and swine feeding operations. Poultry operations are expanding in north Arkansas, including the Strawberry River watershed. Pasture accounts for 29% of the land cover in the watershed, often along streams.

The Strawberry River is considered a high quality water resource and is designated as Extraordinary Resource Waters and a Natural and Scenic Waterway. The river supports over 100 species of fish, including the indigenous Strawberry River darter, and over 30 species of mussels. The majority of the Strawberry River and the Little Strawberry River are also designated as Ecologically Sensitive Waterbodies.

The Strawberry River and its tributaries have many designated uses set forth by the Arkansas Pollution Control and Ecology Commission, including aquatic Life Support, Primary and Secondary Contact Recreation, and Domestic, Industrial, and Agricultural Water Supply. However, portions of the Strawberry River and its tributaries have been identified as not achieving one or more of these designated uses due to high levels of E. coli, and/or turbidity from sediment. Nonpoint sources have been identified as the primary sources of the E. coli and sediment impairing uses in the Strawberry River watershed. Nonpoint sources of these pollutants that have been identified in the watershed include runoff from animal feeding operations, livestock access to streams, and erosion from: pasture, unpaved roads, streambanks, stream channels, and forest harvest operations.

Through the 1998 Arkansas Unified Watershed Assessment, the Strawberry River watershed was identified as a priority area for water quality protection and restoration. A Watershed Restoration Action Strategy was prepared for the Strawberry River watershed in 2003. Recently, the Strawberry River watershed was selected as a priority for the 2011 – 2016

Arkansas Nonpoint Source Pollution Management Plan. As an action item of the Arkansas Nonpoint Source Pollution Management Plan, this nine-element, watershed-based, nonpoint source pollution management plan was prepared as an update of the 2003 Watershed Restoration Action Strategy for the Strawberry River watershed.

This plan is intended to address the entire Strawberry River watershed. It includes discussion of current and historical water quality and quantity data from the watershed, as well as recent research within the watershed. The significant work that has been done in the Strawberry River watershed since 2000, implementing nonpoint source pollution management practices, building relationships, and raising awareness, is summarized. Existing and currently planned nonpoint source pollution management and outreach activities are also summarized.

The 12-digit HUC subwatersheds of the Strawberry River are ranked in terms of the presence of turbidity/sediment, and bacteria issues. These rankings are illustrated in Figures ES.1 and ES.2 (figures included at end of summary). Based on these rankings, four subwatersheds are highly recommended for future nonpoint source pollution management. Table ES.1 lists these subwatersheds along with the pollutants and sources to be targeted. Through several watershed meetings, stakeholders identified suites of nonpoint source pollution management practices that could be implemented in the recommended subwatersheds (Table ES.2). These practices, along with estimates of associated pollutant load reductions and relative costs for their implementation, are included in the plan. Examples of available sources of technical and funding assistance for implementation of management practices are also identified.

Watershed processes and systems are dynamic. Therefore, an adaptive management approach is proposed for the Strawberry 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 Strawberry River watershed can be tracked. The proposed schedule and milestones for implementing the activities outlined in this plan is shown in Table ES.3.

Table ES.1 Subwatersheds recommended for nonpoint source pollution management in the Strawberry River.

Subwatershed name (HUC)	Target pollutants	Target sources	% Pollutant Load Reduction Target*
Bullpen Creek-Strawberry River (110100120204)	Turbidity & E. coli	Runoff from animal feeding operations, livestock access to streams, pasture runoff, sheet/rill/wind erosion	58%
Meeks Branch-Strawberry River (110100120306)	Turbidity	Streambank erosion, concentrated flow erosion	50%
Clayton Creek-Strawberry River (110100120307)	Turbidity	Streambank erosion, unpaved roads, livestock access to streams	50%
Reeds Creek-Strawberry River (110100120405)	E. coli	Runoff from animal feeding operations, livestock access to streams	0%

* Reduction targets are for TSS load as determined in a TMDL for turbidity in the watershed. Load reduction targets were not determined in the TMDL for bacteria (i.e., E. coli) in the watershed.

Table ES.2. Management practices recommended by stakeholders.

Practice	Comments
Fencing	This includes cross fencing for prescribed grazing and fencing off streams in pastures. At least one attendee stated that fencing along rivers is not always the best choice of practices. Another reported that hot wires work better than non-electrical fencing.
Prescribed/rotation grazing and sacrificial plots	Farmers using rotation grazing see improvement in cattle and pasture health, and find it to be a more efficient use of their resources. It was noted that it is counter-productive to put all pasture land in prescribed grazing. Areas are needed for sacrificial plots, etc.
Alternative water sources	Water source alternatives to pasture streams used in the watershed include ponds and water tanks, along with piping and valves to move water.
Heavy use area re-vegetation	This practice is used by area farmers. It may become more important as the number of poultry houses in the area increases.
Nutrient management plans	It was noted that the Sharp County technician who assists with nutrient management plans is currently covering 7 counties in the area.
Fertilizer application technology	There is interest in precision application of poultry litter and other fertilizers in the watershed, including GPS technology. Training for farmers and use of services are options.
Dry stacks, composters, incinerators	This equipment is required for all newly constructed poultry houses.
Streambank restoration	Streambank erosion is widespread
Training on gravel road water control measures	There are lots of unpaved county roads in the watershed that can be a source of sediment. In the 1990s, Fulton County road crews were given training in gravel road maintenance and water control for erosion reduction. However, there is a lot of turnover in county road crews, so another round of training is warranted. It was suggested that this training be a recurring, rather than one-time event, either annually or biennially. The information/training provided needs to be appropriate for roads in hilly terrain. Gravel road water control measures for hilly terrain are different from those for flat lands.
Forestry BMPs	Use of forestry BMPs for forest land owners in the watershed is widespread. One attendee suggested that Streamside Management Zones could be more actively managed, e.g., thinning may make them more effective.
Silvipasture	This practice is not widespread in the watershed.

Table ES.3. Plan implementation schedule and milestones.

Activity	Action (lead)	Start	Anticipated Completion	Milestone (3-5 yrs)	Indicator	Long Term Goal
Monitoring	E. coli data collection for removal of Reeds Creek and Strawberry River from state impaired waters list (ADEQ)	2017	2022	Biennial 305(b) assessments, 303(d) lists	Attainment or nonattainment classification	Determine if Reeds Creek and Strawberry River meet state E. coli standards
	Synoptic surveys in recommended subwatersheds to characterize TSS/sediment loads (County Conservation Districts)	2018	2020	Survey completed Data analyzed Target areas identified	Critical areas and sources designated for TSS loading	Identify target areas for erosion control management strategies to achieve state turbidity standards
	Annual ambient water quality monitoring (ADEQ, USGS)	2017	2050	Four years of water quality data collected	Number of long term water quality stations Number of sampling events	Identify and track changes in water quality over time
	Fish survey of Strawberry River (AGFC)	2016	2018	Fish survey completed Survey results published	Number of survey sites Number of surveys	Characterize distribution, status, and abundance of selected fish species in the Strawberry River watershed
Information and Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	2012	2030	3 to 5 conferences held	Number of conference attendees from Strawberry River watershed	Increased awareness and adoptions of pasture BMPs in Strawberry River Watershed
	Field Days (Conservation Districts)	2016	2030	1 to 3 field days held in recommended 12-digit HUC subwatersheds	Number of field days in recommended subwatersheds Number of attendees	Increase acceptance and use of BMPs that protect and improve water quality
	15-1100: Strawberry River subwatersheds project (Fulton County Conservation District)	2015	2018	At least 1 field day held in Bullpen Creek subwatershed	Number of field days Number of attendees from recommended subwatersheds	Increase acceptance and use of BMPs that protect and improve water quality
	2015 Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (Fulton & Izard County Conservation Districts)	2015	2018	3 to 5 field days	Number of attendees from recommended subwatersheds	Increase acceptance and use of BMPs that protect and improve water quality

Table ES.3. Plan implementation schedule and milestones (cont.).

Activity	Action (lead)	Start	Anticipated Completion	Milestone (3-5 yrs)	Indicator	Long Term Goal
Information and Education (cont.)	2016 Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (Sharp County Conservation District)	2016	2018	3 to 5 field days	Number of attendees from recommended subwatersheds	Increase acceptance and use of BMPs that protect and improve water quality
	Strawberry River Preserve and Demonstration Ranch (TNC)	2002	2050	At least one workshop on grazing techniques	Number of workshops Number of attendees from recommended subwatersheds	Increase acceptance and use of BMPs that protect and improve water quality
	Training in unpaved road BMPs (Arkansas Rural Services)	2017	2022	Representatives from each of the counties in the watershed attend free a training session	Number of attendees from Strawberry River watershed	Increase use of BMPs that protect and improve water quality in the Strawberry River watershed
Supplemental Watershed Implementation Plans	Prepare and implement supplemental watershed implementation plans in recommended 12-digit HUC subwatersheds (stakeholders)	2017	2022	Watershed implementation plan developed for at least one recommended 12-digit HUC subwatershed	Impaired stream reaches in recommended subwatersheds	All water quality criteria met in impaired stream reaches listed in final 2008 and 2014 303(d) lists
Implement Management Strategies	15-1100 Strawberry River Subwatershed Improvement (Fulton County Conservation District)	2015	2018	Contracts for management practices in Bullpen Creek subwatershed	Number of contracts Number of practices planned Number of practices implemented Area treated	Turbidity and E. coli water quality criteria met in Bullpen Creek subwatershed
	Controlled Access for Livestock Fencing (CALF) (Association of Arkansas Conservation Districts)	2015	2022	Contracts for management practices in at least one recommended 12-digit HUC subwatershed	Number of contracts Number of practices planned Number of practices implemented Area treated	Turbidity and E. coli water quality criteria met in recommended subwatersheds
	Riparian easements (FSA)	2017	2022	New contracts for riparian easements in recommended subwatersheds	Number of new contracts Miles/acres of easements	Turbidity and E. coli water quality criteria met in recommended subwatersheds

Table ES.3. Plan implementation schedule and milestones (cont.).

Activity	Action (lead)	Start	Anticipated Completion	Milestone (3-5 yrs)	Indicator	Long Term Goal
Implement Management Strategies (cont.)	EQIP General (NRCS)	2015	2022	New contract for erosion and bacteria management practices in at least one recommended 12-digit HUC subwatershed	Number of new contracts Number of practices planned Number of practices implemented Area treated	Turbidity and E. coli water quality criteria met in recommended subwatersheds
	Management practices in recommended 12-digit HUC subwatersheds (County Conservation Districts)	2018	2022	Begin implementation of management practices identified in watershed implementation plan	Implementation goals outlined in watershed implementation plan	All water quality criteria met in impaired stream reaches listed in final 2008 and/or 2014 303(d) lists
	BMPs for unpaved roads (Sharp and Lawrence Counties)	2017	2022	Initiate use of BMPs for unpaved roads in routine county road maintenance within the Clayton Creek subwatershed	Miles of county roads in watershed properly graded, Number of crossings improved Number of training attendees	Strawberry River meeting turbidity water quality criteria
	Forestry BMPs (Arkansas Forestry Commission)	2008	2022	Increased implementation of forestry BMPs in Bullpen Creek, Meeks Branch, and/or Clayton Creek subwatersheds	Amount of BMPs added since 2015	Strawberry River meeting turbidity water quality criteria
Evaluate	Biennial water quality assessment (ADEQ)	2016	2022	EPA approved final 303(d) list post 2008	Attaining and nonattaining stream reaches in Lower Little River watershed	All water quality criteria met in Strawberry River impaired stream reaches listed in final 2008 and/or 2014 303(d) lists
	Annual voluntary forestry BMP assessment (Arkansas Forestry Commission)	2016	2022	Two biennial surveys completed (2017 and 2020)	Published assessment reports	Estimate and document extent of forestry BMP implementation, and identify areas to focus BMP education efforts

Table ES.3. Plan implementation schedule and milestones (cont.).

Activity	Action (lead)	Start	Anticipated Completion	Milestone (3-5 yrs)	Indicator	Long Term Goal
Evaluate (cont)	Track implementation of BMPs in Strawberry River watershed (ANRC)	2016	2022	Biennial report of implementation activities in watershed	Linear feet/acres of BMPs implemented Water quality improvement	All water quality criteria met in Strawberry River impaired stream reaches listed in final 2008 and/or 2014 303(d) lists
Update Strawberry River Watershed-based Management Plan	Public Meetings (County Conservation Districts)	2023	2023	Organize public meetings	Number of attendees	Stakeholder input to watershed management planning
	Update Watershed Management Plan (County Conservation Districts)	2023	2023	Collect implementation data	Updated watershed management plan completed Recommended 12-digit HUC subwatersheds identified Stakeholder relationships continued/ improved	Maintain watershed management plan as a living document that reflects stakeholder interest and concerns related to improving water quality in the Strawberry River watershed

Figure ES.1. Ranking of Strawberry River 12-digit HUCs for turbidity/sediment issues.

Figure ES.2. Ranking of Strawberry River 12-digit HUCs for bacteria issues.

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1.0 INTRODUCTION

1.1 Document Overview

The Strawberry River watershed has been identified as a nonpoint source priority watershed by the Arkansas Natural Resources Commission (ANRC) 2011-2016 NPS Pollution Management Plan. The goal of the priority watershed program is to reduce nonpoint source pollutants so that all streams achieve their designated uses through implementation of a watershed-based management plan that includes the nine elements recommended by the US Environmental Protection Agency (EPA) (EPA 2008). This document contains the nine-element watershed-based plan for the Strawberry River watershed.

Formal watershed management planning in the Strawberry River watershed began in the early part of the 21st Century. In 2003, a Watershed Restoration Action Strategy (WRAS) was developed for the Strawberry River watershed (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003). Watershed restoration efforts and study have been largely guided by this document since that time.

This document serves as an update to the WRAS. As such, it provides an opportunity to review the work that has occurred in the watershed, and evaluate progress. This includes review of information that has been developed since the WRAS was written, much of which was collected as part of implementation of the WRAS.

This document follows the organization developed by the EPA Watershed Plan Builder (EPA 2011). Section 2 describes many of the features of the watershed. Much of the background information in Section 2 of this plan is taken from the WRAS, with newly available information added where appropriate. Section 3 lists water quality standards along with available monitoring and resource data. Section 4 discusses pollutant sources in the watershed, utilizing information from a number of studies that were initiated as a result of the WRAS. Section 5 provides information on pollutant loads in the watershed, and identifies critical areas of the watershed for addressing nonpoint source pollution. Section 6 identifies watershed goals and objectives. Section 7 discusses management strategies for controlling nonpoint source pollution in the

Strawberry River watershed. Section 8 outlines the overall management plan, with schedule, list of activities, and identification of indicators and monitoring to track progress and effects.

Watershed-based management plans developed using 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	Description	Location in this plan
1	The identification of causes, sources of pollution, and extent of water quality impairment	Sections 3.1 and 4.0
2	Expected load reductions once management actions are implemented	Sections 6.2 and 7.7
3	A description of nonpoint source pollution management actions that stakeholders can participate in and help to implement, especially in critical areas	Section 7.0
4	An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon	Section 9.0
5	Education and outreach strategies to encourage stakeholders to learn more about selecting, designing and implementing management actions	Section 8.3
6	A schedule for implementing identified management measures	Section 8.1
7	A description of measureable milestones along the way to a fully implemented vision	Section 8.1
8	A set of criteria that can be used to determine if water quality is improving towards attaining water quality standards	Sections 6.2 and 8.6
9	A monitoring component to determine if implemented management actions are really improving water quality	Sections 3.2 and 8.2

1.2 Process

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

1. Building partnerships,
2. Characterizing the watershed,

3. Finalizing management goals and identifying solutions, and
4. Designing an implementation program.

1.2.1 Team

ANRC worked with consultants to develop this watershed-based management plan, utilizing the input of watershed stakeholders. Stakeholders who participated in development of this plan include US Army Corps of Engineers, US Fish and Wildlife Service, Natural Resources Conservation Service, Arkansas Department of Environmental Quality, Arkansas Department of Health, Arkansas Forestry Commission, Arkansas Game and Fish Commission, University of Arkansas Cooperative Extension Service, County Conservation Districts, farmers, and ranchers.

1.2.2 Public Participation

Four public meetings were held as part of the process of developing the Strawberry River watershed-based management plan. The purposes of these public meetings were to inform stakeholders of the plan and the process for developing it, and to request and obtain stakeholder input for the plan. In particular, stakeholder input was sought in identifying priority issues in the watershed, and selecting management strategies for addressing nonpoint source pollution in the watershed. Sign-in sheets for the public meetings are included as Appendix A.

1.3 Adaptive Watershed Management

This Watershed-Based Plan for the Strawberry River watershed was developed to include the adaptive management concept. This plan was developed using information available as of 2015, based on the current understanding of the condition of, and processes at work in, the watershed. Watershed processes and systems are dynamic, and our understanding of them changes over time. Adaptive management is an iterative process of evaluating the results of management, and adjusting actions based on what has been learned, in order to achieve sustainable watershed management. Adaptive management involves goal-setting, implementation of management strategies to work toward the goals, monitoring the results of management, evaluation of the results of management, and revision of goals and/or management strategies, which are then implemented, monitored, evaluated, and so on. All of these elements of adaptive watershed management are included in this plan.

2.0 WATERSHED DESCRIPTION

2.1 Physical and Natural Features

2.1.1 Watershed Boundaries

The Strawberry River, a tributary of the Black River in the White River basin, is located in the Ozark Highland ecoregion in north central Arkansas, with a small area in the Mississippi Alluvial Plain ecoregion (Figure 2.1). The headwaters arise near the town of Salem in Fulton County. The river flows southeasterly through Izard, and Sharp Counties before in enters the Black River in Lawrence County near Strawberry, Arkansas. The watershed drains 761.2 square miles of the Salem Plateau province of the Ozarks, and is identified by the US Geological Survey (USGS) Hydraulic Unit Code (HUC) 11010012.

2.1.2 Hydrology

The Strawberry River, a perennial stream, and its major tributaries are all free-flowing streams. Average annual flow in the Strawberry River at Poughkeepsie (USGS 07074000) is 499.7 cubic feet per second (cfs) (US Fish and Wildlife Service 2012). Analysis of flow data from seven years during the period 1990 – 2004 (flow data were not available for several years during this time period) indicated an average annual flow rate of 530 cfs, with approximately 50% of the flow as base flow and the other 50% as surface runoff flow (Saraswat, et al. 2013). Springs are common in the watershed and contribute to base flow of perennial streams (Kresse and Fazio 2004). Groundwater is suspected to contribute flow to South Big Creek and Reeds Creek. Irrigation return flow is believed to contribute flow to Caney Creek (ADEQ n.d.).

2.1.3 Climate/Precipitation

Precipitation estimates for the Strawberry River subbasin are estimated using the Newport, Mammoth Springs, and Mountain Home weather stations. Annual average rainfall is approximately 40 inches. Mean monthly precipitation totals for the three weather stations are shown on Figure 2.2. The mean monthly precipitation values are the lowest in January highest during the months March through August (EPA Region VI 2007).

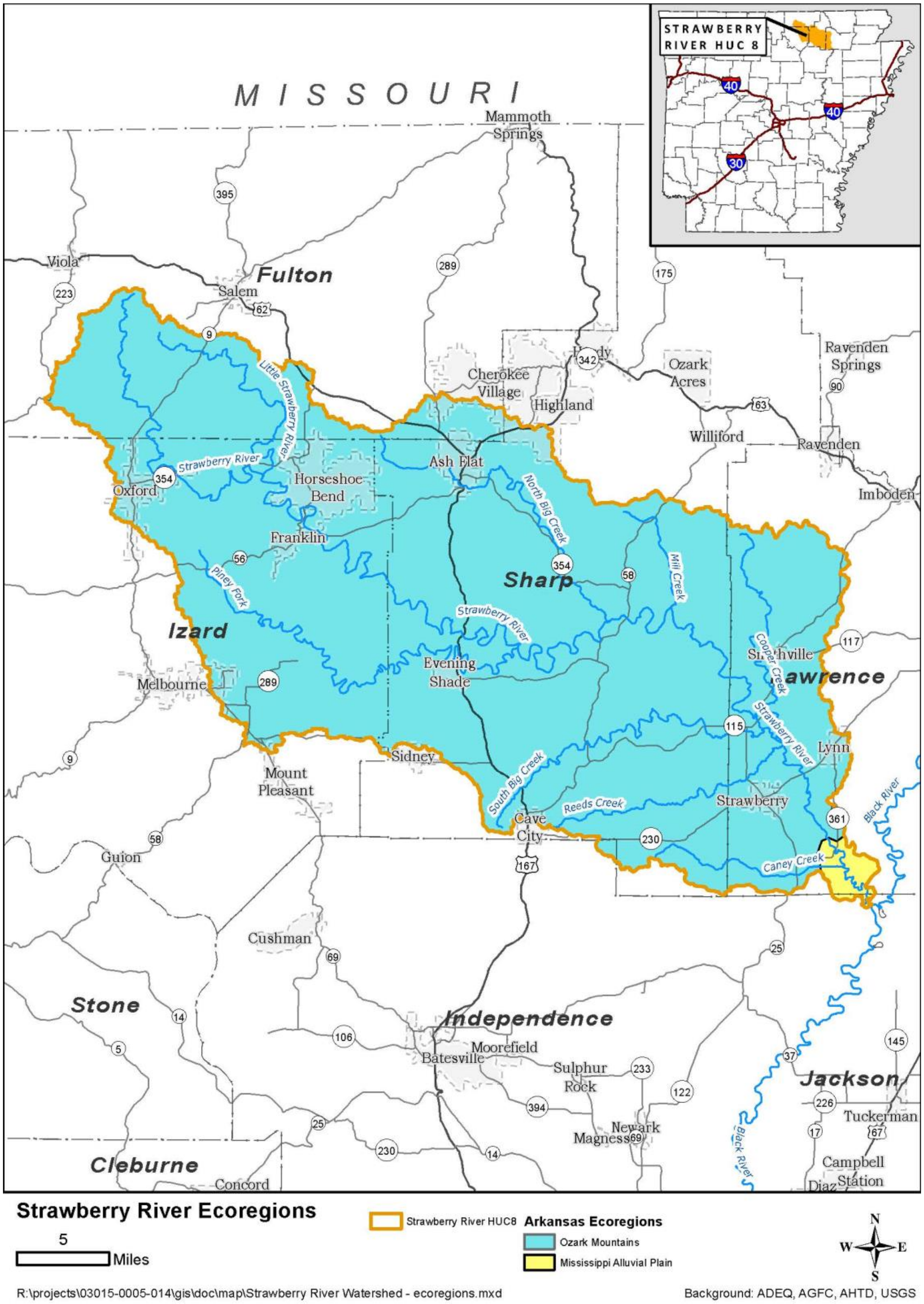


Figure 2.1. Strawberry River watershed map.

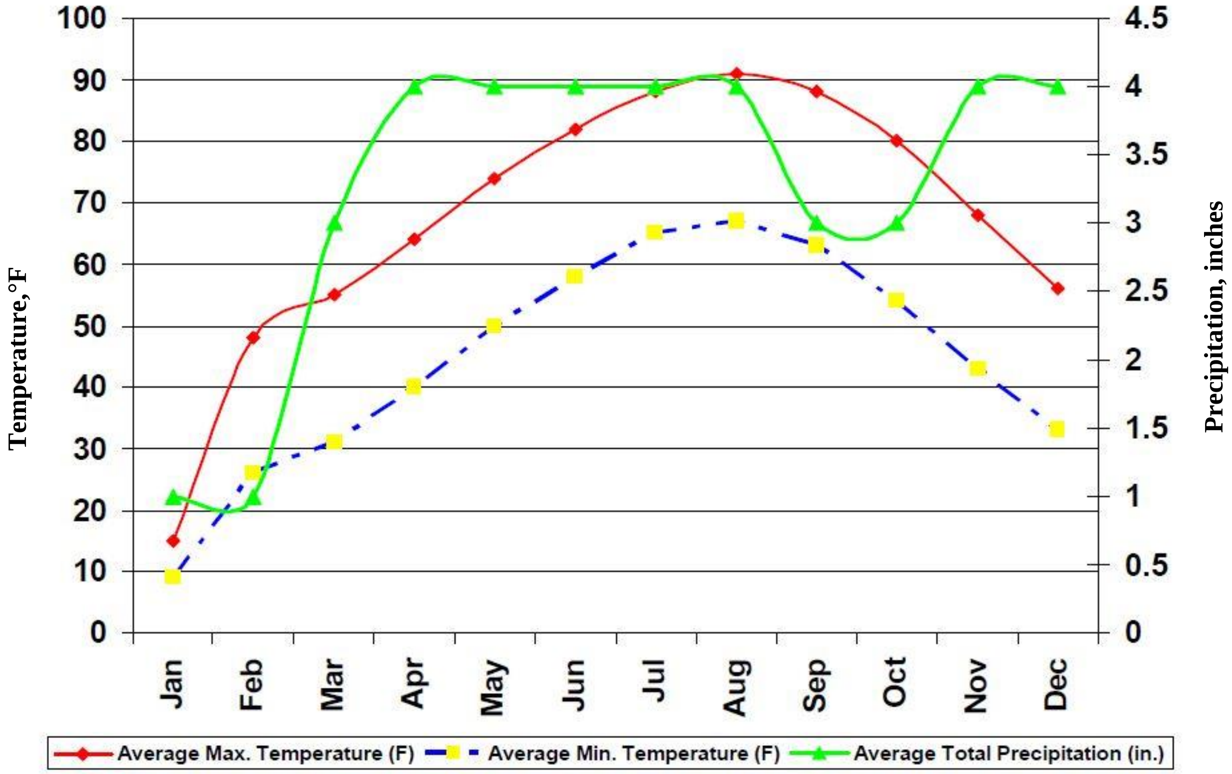


Figure 2.2. Climate conditions in the Strawberry River watershed (from EPA Region VI 2007).

2.1.4 Surface Water Resources

The Strawberry River watershed contains 211.6 miles of stream as identified by the River Reach 3 system (ADEQ n.d.). The State Watershed Information System reports 1,190 miles of streams in the watershed (Center for Advanced Spatial Technologies 2006). Perennial tributaries to the Strawberry River include Little Strawberry River, Piney Fork, North Big Creek, Mill Creek, South Big Creek, Reeds Creek, Cooper Creek, and Caney Creek. There are several relatively small reservoirs in the watershed, the largest of which are Crown Lake and Diamond Lake in Horseshoe Bend. There are a number of springs in the watershed, including Evening Shade Spring (Kresse and Fazio 2004).

2.1.5 Groundwater Resources

The Ozark aquifer, which underlies the Strawberry River watershed, is the largest aquifer and most important source of fresh groundwater in the Ozark region of northern Arkansas and southern Missouri. This aquifer is a thick sequence of water-bearing rock ranging in age from the Late Cambrian to Middle Devonian. In the Strawberry River watershed, only Ordovician-aged and older rock formations of the aquifer are present, with Ordovician formations exposed at the surface (see Section 2.1.7). As a result, recharge to the Ozark aquifer in the Strawberry River watershed occurs through direct infiltration. Groundwater levels in the watershed are strongly influenced by local topography, and groundwater supplies base flow for the Strawberry River and its major tributaries (Kresse and Fazio 2004).

Groundwater flow and hydraulic properties vary considerably throughout the aquifer. Yields from shallow wells in the watershed range from 1 to 60 gallons per minute (gpm). Yields from wells drawing from deeper formations tend to be greater, and have been reported in some locations to be over 600 gpm (Czarneki, Pugh and Blackstock 2014, Kresse and Fazio 2004).

2.1.6 Topography and Elevation

The Strawberry River watershed is located within Salem Plateau province of the Ozark Highlands physiographic region. Within the watershed, this province is characterized by highly dissected, steeply sloping wooded hills and narrow, gravelly valleys.

The mean elevation for the Strawberry River watershed is approximately 577 ft, with a standard deviation of 169 ft. The minimum elevation is 220 ft. and the maximum elevation is 1,024 ft. A large portion of the land area in the watershed (81.3%) falls in the medium-high (3 -8%) to high (>8%) sloping category in Table 2.1 (Saraswat, et al. 2013).

Table 2.1. Slope distribution within the Strawberry River watershed (from Saraswat, et al. 2013).

Slope %	Area of watershed%	Slope Category
0 to 1	4.6	Flat
1 to 3	14.1	Medium
3 to 8	42.4	Medium-high
>8	38.9	High

2.1.7 Geology

The Strawberry River watershed lies almost entirely within the Salem Plateau section of the Ozark Plateaus physiographic province. Lower and Middle Ordovician rocks are exposed at the surface within the watershed boundaries and extend out of the study area to the west and north of the watershed (Figure 2.3). Sparse erosional remnants of Mississippian rocks cap the hills along the southern watershed divide and form the boundary between the Salem and Springfield Plateaus to the south. Thin exposures of Cretaceous rocks are present in the southeastern and extreme northeastern portions of the watershed. Pleistocene deposits extend into the lower reaches of the Strawberry River and Caney Creek valleys and are truncated at their confluence by unconsolidated Holocene sediments of the Mississippi alluvial plain. Small remnants of Tertiary gravels are scattered on hilltops throughout the watershed (Haley et al. 1993).

The geology of the Strawberry River watershed rests on thick deposits of mainly calcareous sediments deposited during the Cambrian and Lower Ordovician. Diagenetic processes involving the mixing of freshwater and seawater resulted in the conversion of limestone in these formations to dolostone. Uplift at the end of the Early Ordovician caused deep and pervasive erosion of the exposed landmass and development of an extensive karst surface now observable as paleokarst. Advancing seas during the Middle Ordovician resulted in widespread deposition of sand and calcareous sediments, which constitute the sedimentary rocks attributed to this period of inundation (Imes & Emmett 1994).

Regional dip of the rock units is to the south into Arkansas, generally resulting in progressively younger rock formations exposed at the surface as one traverses south. Greater degree of uplift and erosion to the north contributed to overall thickening of the units to the south (Imes & Emmett, 1994). Within the eastern portion and along the southeastern boundary of the Strawberry River watershed, the rocks are normally faulted, resulting in increased dips in the vicinity of the faults (Glick 1972a,b,c; Glick 1973a,b).

Collectively, the Lower and Middle Ordovician rocks represent the vast majority of strata represented at the surface in the Strawberry River watershed (Figure 2.3). The stratigraphy and lithology of these formations are summarized in Table 2.2.

Table 2.2. Stratigraphic column with descriptions of lithology for Ordovician formations in the Strawberry River watershed (after Schrader 2001).

Era	Period	Geologic Unit	Lithology	Thickness, feet
Paleozoic	Ordovician	Kimmswick Limestone	Limestone, dolomite, sandstone	0 – 2,000
		Plattin Limestone		
		Joachim Dolomite		
		St. Peter Sandstone		
		Everton Formation		
		Powell Dolomite	Dolomite and minor amounts of sandstone and shale	100 – 1,000
		Cotter Dolomite		
		Jefferson City Dolomite		
		Roubidoux Formation	Sandstone and sandy dolomite	100 – 250
		Gasconade Formation	Dolomite, sandy dolomite, and sandstone.	350 – 360

Thin intervals of Upper Cretaceous rocks [are present] in the southeastern portion of the watershed. These rocks consist of black, shaley clay and gravel, and unconformably overlie the Everton Formation in this area (Glick 1973b). Fossils present in this sequence suggest a possible correlation with the Ozan Formation. This sequence has not been assigned to a specific stratigraphic unit (McFarland 1998).

Unconsolidated Holocene alluvium [occurs] near the extreme southeastern boundary of the watershed. The lower portion of the sediments consists of coarse sands and gravels, and the upper portion is made up of fine to medium sands. Almost everywhere the sequence fines upward, but not in a uniform manner. The sequence is confined where the fine grained top stratum is thin and continuous, but is an otherwise open hydrologic system. The alluvial deposits have a nominal thickness of approximately 125 feet (Kresse & Fazio 2002).

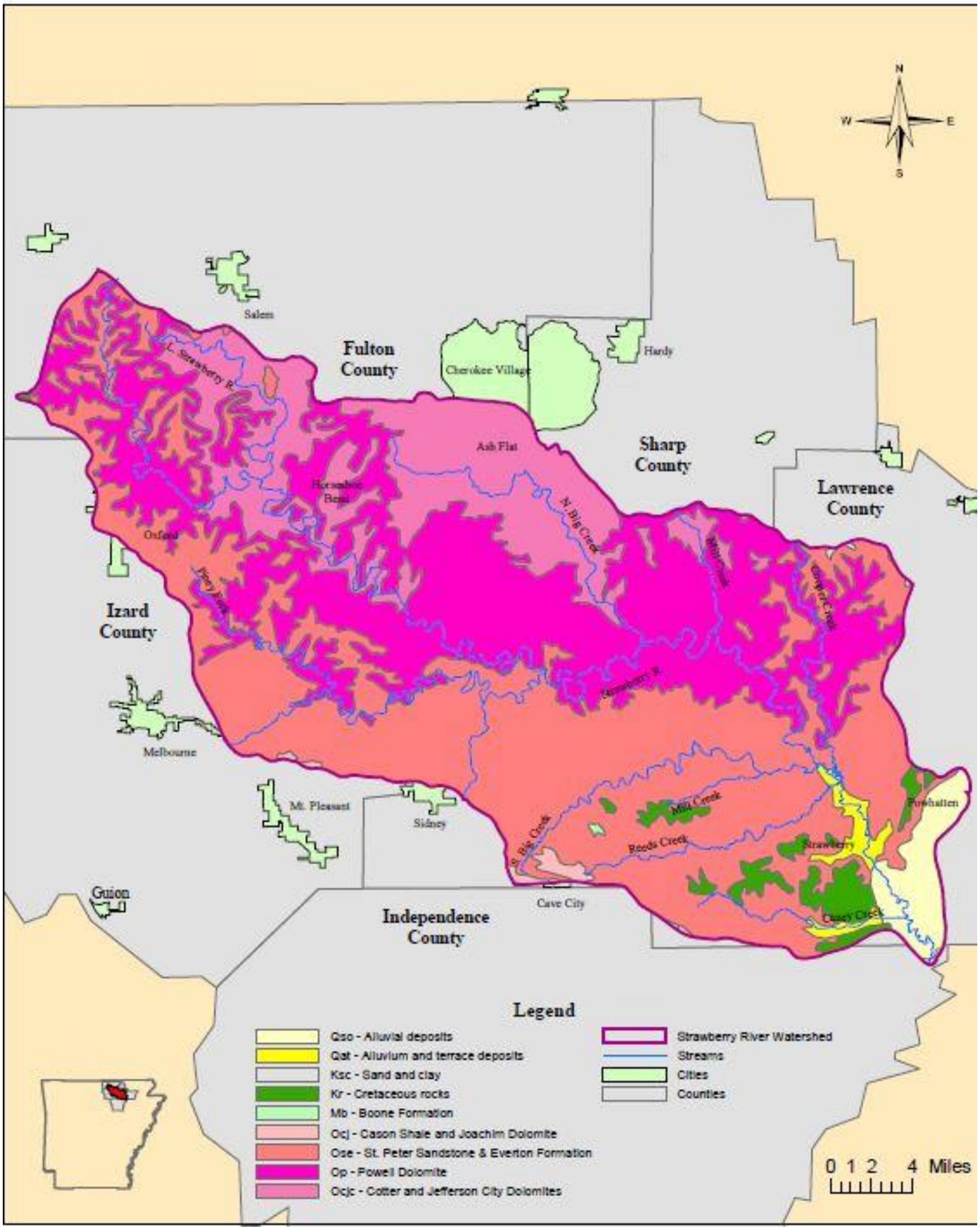


Figure 2.3. Geologic map of the Strawberry River watershed (from Kresse and Fazio 2004).

2.1.8 Soils

The soils in the Strawberry River watershed range from deep stony soils to shallow clay and loamy soils (EPA Region VI 2007). Major soils on uplands are Agnos, Doniphan, Gepp, Portia, Brockwell and Captina (Figure 2.4). These soils have cherty, loamy, or stony surface layers over loamy or clayey sub-soils. They have moderate to low natural fertility and medium to high available water capacity. Major soils on stream terraces and flood plains are Healing, Razort, Britwater and Wideman. These soils have medium to high natural fertility and medium to high available water capacity (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003). Soil hydrologic group C and D occupy the majority (59.5%) of the watershed, suggesting medium to large runoff potential can be expected (Saraswat, et al. 2013).

2.1.9 Vegetation

Oak, hickory, and shortleaf pine are the major tree species found in the forested areas of the uplands of the Strawberry River watershed. Eastern red cedar is a common invader in abandoned fields and glades. Most of the less sloping areas have been cleared and planted to cool-season grasses. Fescue is the dominant introduced grass species. Glade openings support warm-season grasses, primarily big bluestem, Indiangrass, little bluestem, and dropseeds (NRCS 2006).

In the portion of the Strawberry River watershed within the Delta/Mississippi Alluvial Plain, historically, bottomland hardwood deciduous forests and mixed hardwood and cypress swamps were present (NRCS 2006). Currently, the majority of this area is cropland, planted in soybeans, rice, and/or wheat (USDA National Agricultural Statistics Service 2014).

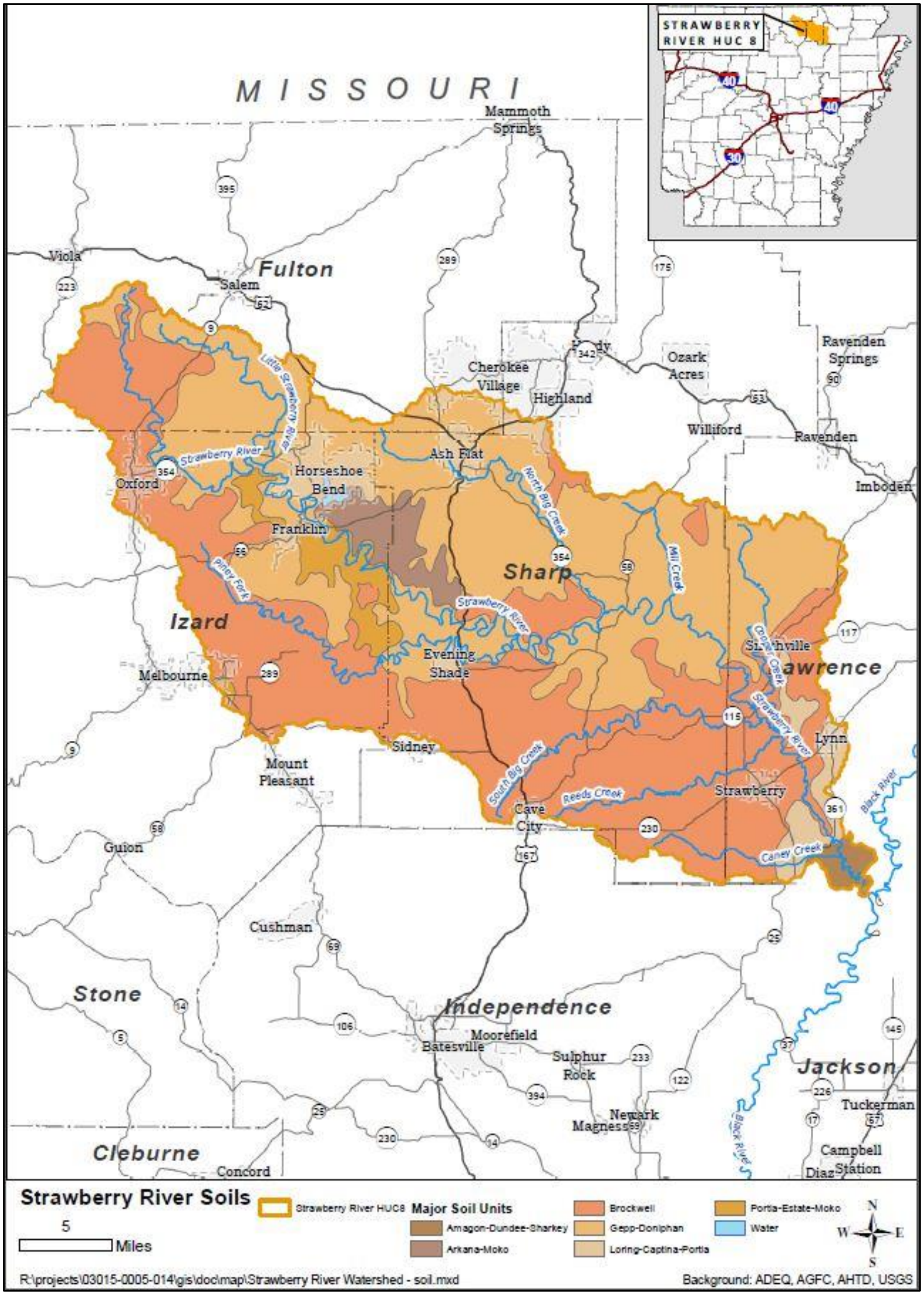


Figure 2.4. Major soil units in the Strawberry River watershed.

2.1.10 Wildlife

The Strawberry River contains one of the greatest concentrations of aquatic biodiversity in the United States (The Nature Conservancy 2015). More than half of the fish species native to Arkansas are found in the Strawberry River watershed. The Strawberry River is well known to anglers for its smallmouth bass. However, the Strawberry River also harbors 107 other species of fish, as well as 39 freshwater mussel species. Sixteen of these species are not found anywhere outside the Ozark Mountains ecoregion. One fish, the Strawberry River darter (*Etheostoma fragi*), lives only in this river system (The Nature Conservancy 2015).

2.1.11 Exotic, Invasive Species

The USGS Nonindigenous Aquatic Species database lists six species that are found in the Strawberry River watershed in Table 2.3 (USGS 2015d). The University of Georgia Center for Invasive Species and Ecosystem Health lists one invasive aquatic plant species that has been found in the counties of the Strawberry River watershed in Table 2.3 (University of Georgia Center for Invasive Species and Ecosystem Health 2015). The nonindigenous species Rainbow Trout is stocked in the Strawberry River watershed. One of the nonindegenous species identified for the Strawberry River watershed has been classified as an Aquatic Nuisance Species (ANS) in Arkansas by the AGFC; Asian clam (Corbicula fluminea) (AGFC 2013, USGS 2015d). None of the aquatic nuisance plant species for Arkansas have been reported in the Strawberry River watershed (University of Georgia Center for Invasive Species and Ecosystem Health 2015, AGFC 2013).

Table 2.3. Nonindigenous and invasive aquatic species found in the Strawberry River watershed (University of Georgia Center for Invasive Species and Ecosystem Health 2015, USGS 2015d).

Common name	Scientific name	Source	Notes
Grass Carp	*Ctenopharyngodon idella*	USGS	
Common Carp	*Cyprinus carpio*	USGS	
Fathead Minnow	*Pimephales promelas*	USGS	
Rainbow Trout	*Oncorhynchus mykiss*	USGS	stocked
Asian clam	*Corbicula fluminea*	USGS	AR nuisance
Watercress	*Nasturtium officinale*	University of GA	

2.1.12 Protected Species

There are several state and federally listed threatened and endangered species occurring in the Strawberry River watershed, including Snuffbox, Curtis's Pearlymussel, and the Rabbitsfoot mussel (ADEQ n.d., Harris et al. 2009). Table 2.4 lists state and federally protected species found within the Strawberry River watershed.

Table 2.4. Protected species found in the Strawberry River watershed (Arkansas Natural Heritage Commission 2014, NatureServe 2015).

Common name	Scientific name	Category	State Status	Federal status
Curtis pearlymussel	*Epioblasma florentina curtisi*	Invertebrate	Endangered	Endangered
Rabbitsfoot	*Quadrula cylindrica cylindrica*	Invertebrate	Endangered	Threatened
Scaleshell	*Leptodea leptodon*	Invertebrate	Endangered	Endangered
Snuffbox	*Epioblasma triquetra*	Invertebrate	Endangered	Endangered
Missouri bladderpod	*Physaria filiformis*	Plant	None	Threatened
Gray myotis	*Myotis grisescens*	Vertebrate	Endangered	Endangered

2.1.13 Sensitive Areas

Strawberry River has been designated by USFWS as critical habitat for Rabbitsfoot mussel (USFWS 2014). From the confluence of the Strawberry River with Mill Creek, to the headwaters of the Strawberry, the river is also an "Ecologically Sensitive Waterbody" (Arkansas Pollution Control and Ecology Commission 2014).

2.2 Land Use/Land Cover

The predominant land covers in the Strawberry River watershed are forest and pasture (Figure 2.5). Land cover is mapped on Figure 2.6. Some areas of the watershed have been or are experiencing increases in urban/developed area at the expense of pasture (Saraswat, et al. 2013). Land use in the watershed is primarily forestry/silviculture and livestock/poultry production (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003).

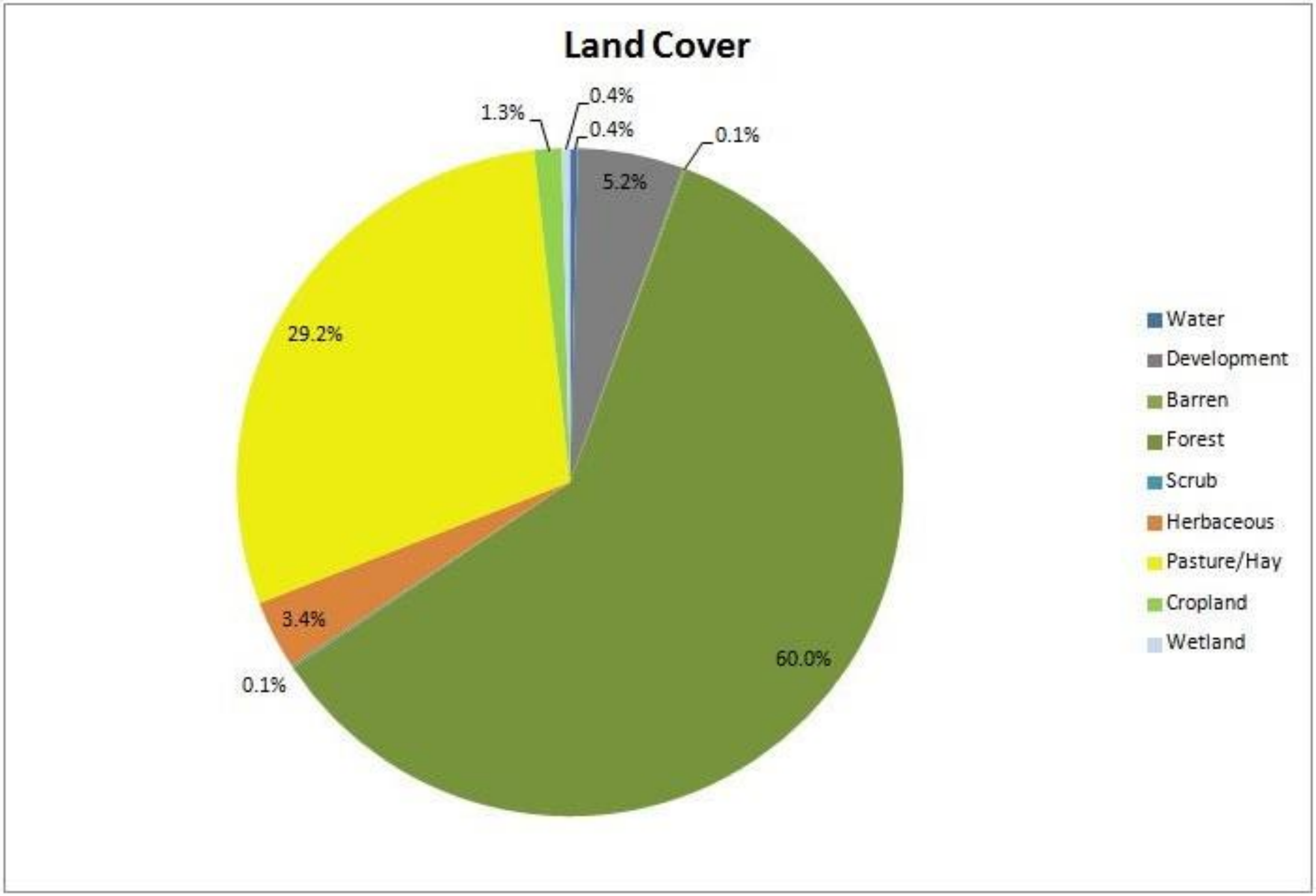


Figure 2.5. Land cover in the Strawberry River watershed.

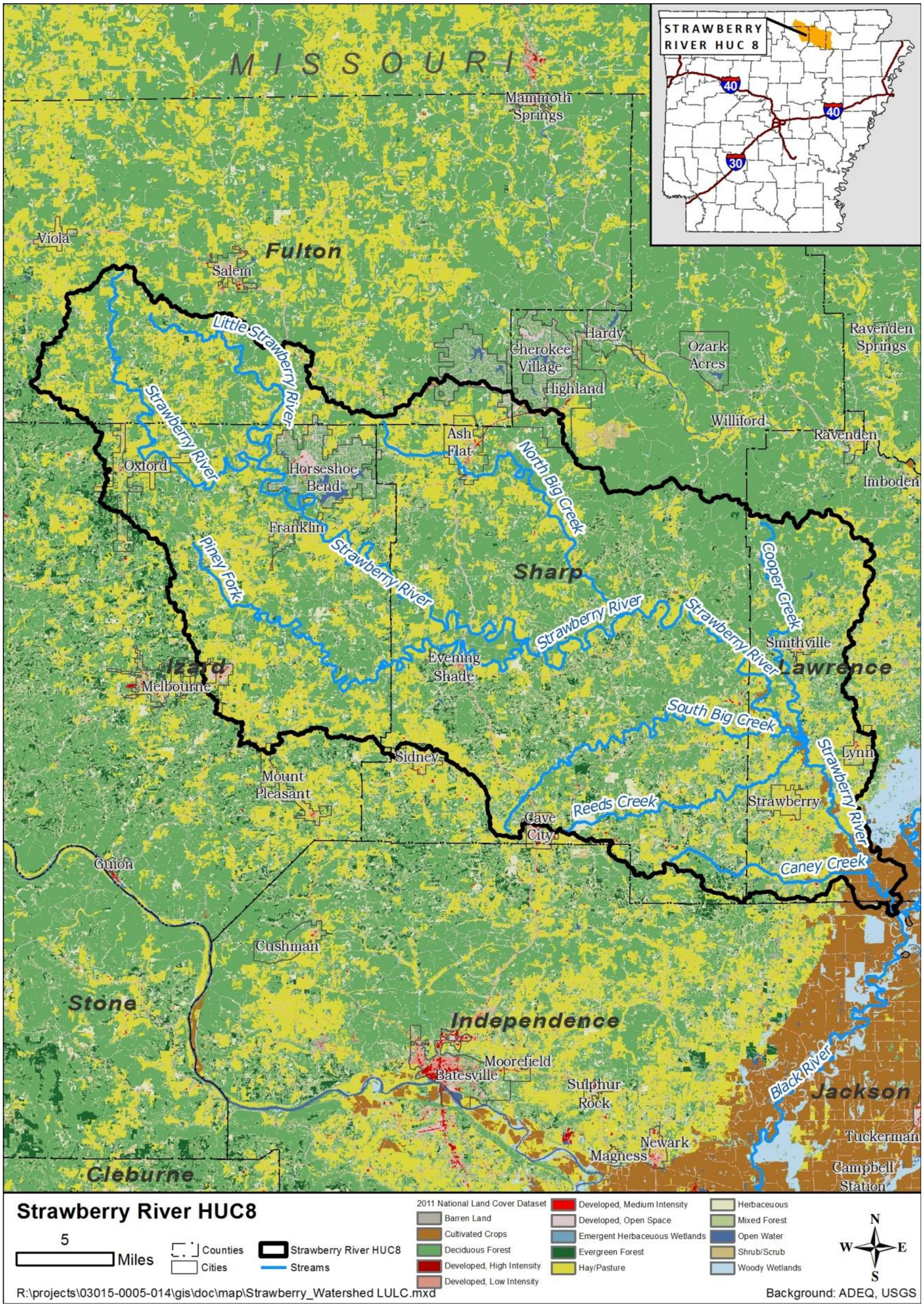


Figure 2.6. Land cover map of the Strawberry River watershed from 2011 (Homer, et al. 2015).

2.2.1 Agriculture

The primary agricultural land in the Strawberry River watershed is pasture, and animal production is prevalent. Table 2.5 compares numbers for livestock and poultry production in the counties of the Strawberry River watershed from 2002 and 2012. In 2002, a Watershed Restoration Action Strategy was prepared for the Strawberry River watershed. The most recent census of agriculture was conducted in 2012.

Table 2.5. Livestock inventories for counties of the Strawberry River watershed.

	Fulton		Izard		Lawrence		Sharp	
Livestock	**2012[a]**	**2002[b]**	**2012**	**2002**	**2012**	**2002**	**2012**	**2002**
Cattle & calves	39,345	51,265	30,079	35,607	18,109	22,237	30,119	31,940
Beef cows	17,250	24,057	14,565	18,101	9,660	10,467	14,824	D[c]
Milk cows	320	755	182	255	0	0	0	D[c]
Swine	353	160	D[c]	D[c]	77	363	47	214
Horses	1,006	1,127	1,063	1,040	573	750	670	1,058
Chickens	2,382	+1,073	1,611,295	+1,208,250	+975,060	+1,542,907	3,465,499	2,887,814
Layers	1,908	947	1,431	D[c]	D[c]	D[c]	285,521	425,190
Pullets	181	126	144	D[c]	D[c]	82	167,597	255,116
Broilers	293	D	1,609,720	1,208,250	975,060	1,542,825	3,012,381	2,207,508
Goats	3,301	94	161	D[c]	718	48	680	14
Sheep	735	395	136	98	69	127	140	126

[a] (USDA National Agricultural Statistics Service 2014)
[b] (USDA National Agricultural Statistics Service 2004)
[c] data withheld by USDA NASS to avoid disclosure of data for individual farms

Swine and dairy cow numbers declined between 2002 and 2012 in the counties within the Strawberry River watershed. In all of the counties, except Sharp County, beef cattle numbers also declined between 2002 and 2012. Chicken production increased between 2002 and 2012 in all of the counties within the Strawberry River watershed (USDA National Agricultural Statistics Service 2004, USDA National Agricultural Statistics Service 2014).

Timber is an important crop in the Strawberry River watershed. Figure 2.7 shows sawtimber harvests for the counties in the watershed, for the years 2005 through 2014.

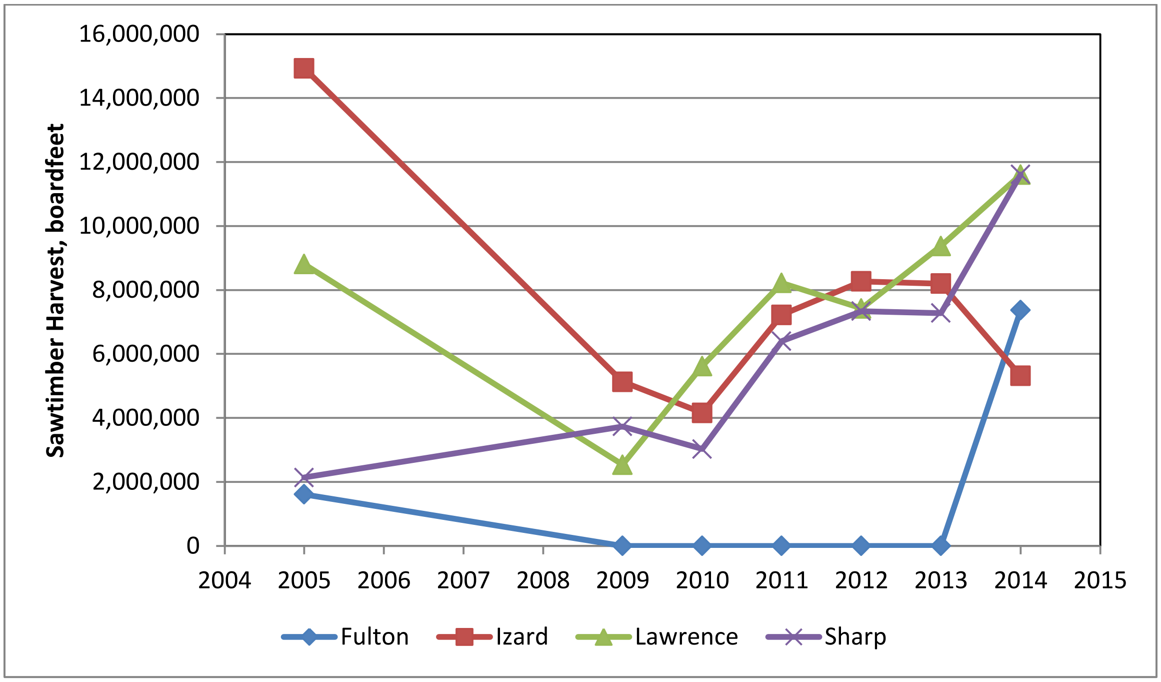


Figure 2.7. Annual sawtimber harvest for counties in the Strawberry River watershed (USFS 2015).

2.2.2 Mining

There are a number of active permitted mines in the Strawberry River watershed (see Table 2.6). The Arkansas Geological Survey also reports several active mines in the watershed (Table 2.7), most of which appear to be different from the permitted mines (Arkansas Geological Survey 2015). Mining in the watershed includes sand and gravel operations and rock quarries.

Table 2.6. ADEQ permitted mines (ADEQ 2015a).

Permit No.	Facility Name	County	Nearest town	Material Mined
0432-MQ-A3	Trico Quarry	Izard	Violet Hill	Rock
0071-MQ-A2	Endurance Sands	Izard	Sage	Rock
0779-MN	Spring Creek Materials	Izard	Oxford	Sand and gravel
0078-MQ-A1	Arkansas Quality Stone	Fulton	Hardy	Rock

Table 2.7. Active mines reported by Arkansas Geological Survey (Arkansas Geological Survey 2015).

Facility Name	County	Nearest town	Material Mined
Myron Quarry	Izard	Myron	Crushed stone
Gravel Pit	Izard	Oxford	Sand and gravel
Edward Brothers Quarry	Izard	Violet Hill	Crushed stone
Arkansas Quality Stone	Sharp	Ash Flat	Crushed stone

2.2.3 Recreation

The Strawberry River is a popular stream for canoeists and fishers (Lancaster 2012). The North Big Creek Watershed of the Strawberry River is an excellent recreation stream for residents of Arkansas. (Agricultural Watershed Project—Reach III (North Big Creek) (05-800) n.d.). Canoe and kayak rentals are available at Evening Shade, and the most frequently canoed stretch is between US Highway 167 and state Highway 58. This section is classified as Class I and II rapids (Stratus-Pikpuk, Inc. 2015).

Hunting is also popular in the watershed. There are also caves and hiking trains in the watershed. Horseshoe Bend is a resort retirement community located in the watershed on the Strawberry River. Recreational opportunities here include golf, two reservoirs, swimming pools, spa, tennis, shopping, and camping. There are a number of small, historic towns in the watershed that also attract tourists.

2.2.4 Developed Areas

There are a number of smaller towns and communities located in the Strawberry River watershed. The largest city is Ash Flat, with an area of 5.6 sq mi, and 2010 population of 1,082 people. Total developed area in the watershed is 25,093 acres (Homer, et al. 2015).

2.2.5 Transportation

US Highways 167 and 412 are the only national highways in the watershed. Cave City, Evening Shade, and Ash Flat are located on Highway 167. Highway 412 intersects Highway 167 at Ash Flat. The remainder of the communities in the watershed are served by state highways and county roads. There are no major railway lines in the watershed.

2.2.6 Public Lands

The only government-owned land in the Strawberry River watershed is a portion of the Harold Alexander Spring River State Wildlife Management Area. Outside of incorporated communities, land in the watershed is privately owned.

2.2.7 Relevant Authorities

Waters of the Strawberry River watershed are under the jurisdiction of federal and state agencies and regulations. Lands in the watershed are under the jurisdiction of state, county, and local agencies and regulations.

2.2.7.1 Federal Authorities

There are 10 federal agencies responsible for water-related activities in the Strawberry River watershed. These agencies are listed in Table 2.8, along with their water-related activities in the watershed.

2.2.7.2 State Authorities

There are eight state agencies and one state nonprofit organization with responsibilities in the Strawberry River watershed related to water resources. These entities are listed in Table 2.9, along with their water-related responsibilities.

Table 2.8. Federal agencies with water resource-related responsibilities in the Strawberry River watershed.

Federal Agency	Responsibility
EPA	• Oversees state agencies in implementation of management and funding programs under: ○ Clean Water Act, ○ Safe Drinking Water Act, ○ RCRA, ○ Superfund, ○ Federal Insecticide, Fungicide, and Rodenticide Act, and ○ Surface Mining Control and Reclamation Act. • Conducts TMDL studies and other water quality studies in the watershed. • Implements programs under the Toxic Substances Control Act.
FEMA	• Prepares flood hazard maps for the region and encourages local governments to guide development decisions away from defined flood hazard risk areas through participation in the National Flood Insurance Program. • Ash Flat, Horseshoe Bend, and Viola participate in the program, as well as unincorporated areas of Fulton, Izard, and Sharp Counties (Federal Emergency Management Agency 2015).
NOAA	Participates in monitoring precipitation and climate
NRCS National Water Management Center	• Located in Little Rock • Serves as a water resources information exchange • Provides support and training related to ○ environmental compliance, ○ hydrology and hydraulics, ○ stream geomorphology and restoration, ○ water quality and quantity, ○ watershed and dam rehabilitation, and ○ technology outreach.
USDA	• Conducts the Census of Agriculture • Conducts the Natural Resources Inventory • Manages Conservation Effects Assessment Projects (watershed and regional)
USDA Farm Services Agency	Implements the Conservation Reserve Program for erosion control and habitat restoration
USFS	• Forest management incentive programs • Participates in forest inventory • Manages Urban and Community Forestry Program

Table 2.8. Federal agencies with water resource-related responsibilities in the Strawberry River watershed. (continued).

Federal Agency	Responsibility
NRCS	• Implements Farm Bill erosion control and habitat restoration funding and technical assistance programs in the Strawberry River watershed. • Appraises the status and trends of soil, water, and related resources on non-federal land in the state and assesses their capability to meet present and future demands.
USFWS	• Implements the Endangered Species Act and programs to: ○ Promote management of ecosystems, ○ Promote conservation of migratory birds, ○ Promote preservation of wildlife habitat, ○ Promote restoration of fisheries, ○ Combat invasive species, and ○ Promote international wildlife conservation. • Oversees state wildlife planning through the State Wildlife Grant Program.
USGS	• Flow and stage monitoring of rivers and streams • Groundwater level monitoring • Water quality monitoring • Groundwater modeling • Water quality modeling • National Water Quality Assessment Program • Water data storage and management

Table 2.9. State entities with water resource-related responsibilities in the Strawberry River watershed.

State Entity	Responsibility
ADEQ	• Implements state water quality policy and the Clean Water Act NPDES program • Develops and enforces water quality standards • Investigates citizen complaints regarding water pollution • Oversees solid waste management • Operates the hazardous waste management program • Manages contaminated site clean-up and redevelopment programs • Develops and enforces mining and mine site reclamation regulations • Manages the storage tank regulation program • Permits no-discharge facilities and underground injection operations • Water quality monitoring and assessment
ANRC	• Regulates, permits, and tracks water use and dam construction • Monitors climate • Administers federal water resources funding programs • Prepares water resources and nonpoint source pollution management plans • Develops and maintains mitigation banking and restoration incentive programs for aquatic resources • Supports conservation districts • Registers poultry feeding operations • Certifies nutrient management planners and applicators • Promotes public health and safety and minimize flood losses through ○ training, ○ education, ○ technical assistance in floodplain management, and ○ accrediting floodplain administrators
Arkansas Department of Health (ADH)	• Regulates public water supply systems • Implements the Safe Drinking Water Act source water protection programs • Issues fish consumption advisories • Implements state health rules and regulations that apply to water resources • Regulates septic tanks and licenses septic tank cleaners • outdoor bathing and swimming • Implements state marine sanitation program
Arkansas Forestry Commission	• Provides guidelines for protection of water resources in forestry operations • Monitors use of forestry BMPs • Participates in forest inventory • Implements forest management incentive programs • Implements Urban and Community Forestry program

Table 2.9. State entities with water resource-related responsibilities in the Strawberry River watershed (continued).

State Entity	Responsibility
Arkansas Game and Fish Commission (AGFC)	• Manages protection, conservation and preservation of various species of fish and wildlife in Arkansas through o habitat management, o wildlife management areas, o fish stocking, o hunting and fishing regulations, and o education and outreach programs • Prepares state Wildlife Action Plan • Implements conservation grant program • Manages Harold Alexander Spring River Wildlife Management Area
Arkansas Geological Survey	• Participates in research of, and provides information and education about, state water resources • Mapping • Water well construction records
Arkansas Livestock and Poultry Commission	Regulates disposal of livestock carcasses, which helps protect water quality.
Arkansas Natural Heritage Commission (ANHC)	• Surveys and conducts research on natural communities in the state • Manages the Arkansas Natural and Scenic Rivers system, of which the Strawberry River is a part

2.2.7.3 Local Authorities

There are a number of local and regional organizations that are involved in water-related activities in the Strawberry River watershed. Examples are included in Table 2.10.

Table 2.10. Local and regional organizations with water-related responsibilities in the Strawberry River watershed.

Regional or Local Entity	Water Resources Involvement
County Conservation Districts	Work with state and federal agencies to implement measures for the control of erosion and flooding, and conservation of soil and water resources
County Government	Responsible for unincorporated areas, including floodplain management and zoning
Regional Solid Waste Management Districts	Manage collection, disposal, and recycling of solid waste. Strawberry River watershed is in the White River district, except for areas in Lawrence County, which is in the Northeast district.
Water districts and associations	Water supply planning and management, and supply water and wastewater services

2.3 Demographics

2.3.1 Population

Demographic information from the US Census Bureau for the counties within the Strawberry River watershed is presented below. Numbers of people are presented in Table 2.11 The watershed is rural, with no urbanized areas nor urban clusters as defined by the US Census Bureau (US Census Bureau 2012). Between 2000 and 2010, population increased slightly in the watershed. However, between 2010 and 2014, population in all of the counties declined slightly. Additional decline is projected for 2020 in Izard and Sharp counties.

Table 2.11. Numbers of people in the counties of the Strawberry River watershed.

County	2000[a]		2010[a]		2014 population estimate[a]	2020 projection[b]
	Total population	Percent urban[c]	Total Population	Percent urban[d]		
Fulton	11,642	9.1	12,245	7.1	12,125	11,556 – 13,386
Izard	13,249	0	13,696	0	13,486	11,872 – 13,134
Lawrence	17,774	36.6	17,415	36.4	16,931	16,268 – 17,783
Sharp	17,119	17.5	17,264	19.9	16,906	14,115 - 15,153

[a] (US Census Bureau 2014)
[b] (UALR Institute for Economic Advancement 2013)
[c] (US Census Bureau 2003)
[d] (US Census Bureau 2012)

Additional demographic information for the counties in the Strawberry River watershed is listed in Table 2.12. This includes percentages for commuting, household structure, age, gender, race, median income, poverty, workers, and education. The majority of commuters drive alone. The majority of households consist of two-parent families. The percentages of single parent households are lower in the counties of the Strawberry River watershed than for the state as a whole. The majority of single parent households are headed by mothers. The median age in the watershed is around 47. Percentages of people 65 and older, and 18 and younger are similar, as are the percentages of males and females. The majority of the people in the watershed consider themselves White.

Whites account for a higher percentage of the population in the Strawberry River counties than in the state over all. Median household incomes in the counties of the Strawberry River watershed are below the state average. Percentage of people and families below poverty level are higher than the state percentages in some counties and higher in others. Unemployment is higher than the state average. High school graduate percentages are higher than the state average, but college graduate percentages are lower.

Table 2.12. Additional demographic information.

	Fulton County	**Izard County**	**Lawrence County**	**Sharp County**	**Arkansas**
Commuting (number of persons)[b]					
Drove alone	78.0%	79.4%	79.4%	75.1%	82.2%
Carpooled	13.8%	13.2%	11.2%	15.6%	11.1%
Walk or other	3.5%	2.8%	3.5%	4.6%	1.8%
Mean travel time (minutes)	25.5	23.4	25.1	27.9	21.3
Worked at home	4.6%	4.6%	6.0%	4.6%	3.2%
Household structure[a]					
Family households	67.9%	66.7%	68.6%	67.8%	67.6%
Two parent families	54.6%	54.9%	53.3%	53.8%	49.5%
Single parent families	13.3%	11.8%	15.3%	14.0%	18.1%
Single person household	28.1%	29.7%	27.7%	28.2%	27.1%
Other nonfamily household	1.3%	5.9%	3.4%	1.1%	5.3%
Age (number of persons)[a]					
Median age	47.0	47.3	40.9	47.0	37.4
65 and older	22.4%	23.6%	18.1%	23.9%	14.4%
Under 18	21.2%	19.2%	22.9%	21.5%	24.4%
Gender (number of persons)[a]					
Female	51.0%	48.5%	51.4%	50.6%	50.9%
Male	49.0%	51.5%	48.6%	49.4%	49.1%
Race (number of persons)[a]					
White non-Hispanic	96.4%	95.0%	96.7%	95.0%	74.5%
Hispanic	0.8%	1.5%	0.9%	1.7%	6.4%
Black non-Hispanic	0.3%	1.3%	0.8%	0.5%	15.3%
Native American	0.6%	0.7%	0.4%	0.9%	0.7%
Asian	0.2%	0.3%	0.1%	0.3%	1.2%
Other race	0.3%	0.6%	0.2%	0.4%	0.1%
>1 race non-Hispanic	1.6%	1.2%	1.1%	1.5%	1.6%

Table 2.12. Additional demographic information (continued).

	Fulton County	Izard County	Lawrence County	Sharp County	Arkansas
Income[b]					
Median household income	$35,522	$30,661	$32,239	$30,861	$40,768
Families below poverty level	12%	15.5%	19.3%	16.9%	14.4%
People below poverty level	18.7%	18.7%	25.4%	23.9%	19.2%
Employment[b]					
Unemployed	10.6%	11.4%	9.5%	9.8%	8.9%
Mgt, business, science, arts	27.0%	29.3%	25.2%	27.5%	31.2%
Service	22.2%	18.3%	21.4%	21.5%	17.2%
Sales, office	20.2%	23.6%	20.9%	17.8%	24.1%
Resources, construction, maintenance	14.7%	11.4%	13.0%	16.7%	10.9%
Production, transportation, material moving	15.9%	17.3%	19.5%	16.5%	16.6%
Self-employed	14.4%	12.6%	10.1%	11.1%	6.4%
Education (population 25 or older)[b]					
High School graduate	83.7%	79.8%	77.4%	83.0%	35.1%
Bachelor degree	10.0%	7.2%	6.7%	5.9%	13..3%
Graduate degree	4.3%	4.5%	3.7%	5.1%	6.8%

[a] (US Census Bureau 2012)

[b] (US Census Bureau 2015a)

2.3.2 Economics

Agriculture, tourism, light manufacturing, and timber are important economic contributors in the Strawberry River watershed (Association of Arkansas Counties 2015). The value of sales and receipts reported for the counties within the Strawberry River watershed in the 2012 economic census is summarized in Table 2.13 Agriculture and timber are not economic sectors reported in the economic census. However, they contribute value to manufacturing, real estate, wholesale trade, and transportation and warehousing economic sectors (U of A Divison of Agriculture 2012).

Table 2.13. Sales and receipts for counties in the Strawberry River watershed in $1,000 (US Census Bureau 2015b).

Economic Sector	Fulton	Izard	Lawrence	Sharp	Total
Manufacturing	$10,713	$383	$73,738	$454	$85,288
Wholesale Trade	$9,263	D*	$159,148	D*	$159,148
Retail Trade	$64,429	$113,748	$201,781	$158,694	$538,652
Transportation & Warehousing	$4,755	$25,671	$22,177	$13,794	$66,397
Accommodation & Food Service	$5,879	$240	$9,511	$13,595	$29,225
Total	$95,039	$139,659	$466,355	$186,083	$878,710

* data withheld by US Census Bureau to avoid disclosure of data for individual businesses

In all of the counties, retail trade accounts for the majority of the total value of sales and receipts from businesses. There is little manufacturing or wholesale trade in Izard and Sharp Counties, which account for the majority of the Strawberry River watershed area.

Agriculture is the largest industry in Arkansas. Arkansas is the second largest broiler producer in the country (US Department of Agriculture Economic Research Service 2012). The values of sales of selected agricultural commodities for each of the counties in the Strawberry River watershed are shown in Table 2.14. Poultry and eggs account for the majority of the livestock sales in all of the counties except Fulton County.

Tourism is the second largest industry in Arkansas, and contributes to the economy of the Strawberry River watershed. Tourism economic impacts for 2014 are summarized by county in Table 2.15.

Table 2.14. Value of sales in $1,000 of agricultural commodities for counties in the Strawberry River watershed.

Commodity	Fulton	Izard	Lawrence	Sharp	Total
All ag products	$27,725	$49,402	$149,140	$75,561	$301,828
Livestock	$26,621	D*	$22,961	$74,530	$97,491
Cattle & calves	$24,226	D*	$6,220	$16,099	$22,319
Poultry & eggs	$35	$27,273	$16,485	$58,287	$102,080
Hay	$985	D*	$8,147	$888	$9,035
Milk from cows	$837	-	-	-	$837

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

Table 2.15. Preliminary 2014 tourism economic impacts for counties in the Strawberry River watershed (Arkansas Department of Parks and Tourism 2015).

	Fulton	Izard	Lawrence	Sharp
Travel expenditures	$26,042,491	$27,055,143	$16,214,972	$48,619,530
Travel-generated payroll	$4,487,431	$4,021,106	$2,432,513	$7,282,613
Travel-generated employment	244 jobs	211 jobs	133 jobs	381 jobs
Travel-generated local tax	$627,691	$677,447	$361,770	$1,264,013

3.0 WATERSHED CONDITIONS

3.1 Water Quality Standards

3.1.1 Designated Uses

All of the Little Strawberry River and the Strawberry River are designated as "Extraordinary Resource Waters". From the confluence of the Strawberry River with Mill Creek, to the headwaters of the Strawberry, and the Little Strawberry River are designated as "Ecologically Sensitive Waterbodies". The Strawberry River is a "Natural and Scenic Waterway" from the Sharp-Izard County Line to its headwaters (Arkansas Pollution Control and Ecology Commission 2014).

Designated uses of the streams in the watershed are primary contact recreation (>10 Sq. Mi), secondary contact recreation (<10 Sq. Mi), Domestic, Industrial and Agricultural Water Supply, Perennial Ozark Highlands and Delta Fisheries (>10 Sq. Mi), Seasonal Ozark Highlands and Delta Fisheries (<10 Sq. Mi.). There are no use variations granted in the watershed (Arkansas Pollution Control and Ecology Commission 2014).

3.1.2 Numeric and Narrative Criteria

Numeric water quality criteria for selected parameters are listed in Table 3.1. 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 Strawberry River watershed.

Table 3.1 Numeric water quality criteria for the Strawberry River watershed.

Parameter	Conditions			Criteria
Temperature				29°C
Turbidity	Base flow			10 NTU
	All flows			17 NTU
Dissolved Oxygen	Primary season			6 mg/L
	Critical season	< 10 sq mi		2 mg/L
		10 – 100 sq mi		5 mg/L
		> 100 sq mi		6 mg/L
pH				6.0 – 9.0 su
E. coli	Primary Contact	Extraordinary Resource Waters, Ecologically Sensitive Waterbodies, Natural and Scenic Waterway, lakes, reservoirs	Individual sample	298 col/100mL
			Geometric mean	126 col/100mL
		All other waters	Individual sample	410 col/100mL
	Secondary Contact	Extraordinary Resource Waters, Ecologically Sensitive Waterbodies, Natural and Scenic Waterway, lakes, reservoirs	Individual sample	1490 col/100mL
			Geometric mean	630 col/100mL
		All other waters	Individual sample	2050 col/100mL
Fecal coliform	Primary Contact	All waters	Individual sample	400 col/100mL
			Geometric mean	200 col/100mL
	Secondary Contact	All waters	Individual sample	2000 col/100mL
			Geometric mean	1000 col/100mL
Chloride				20 mg/L
Sulfate				30 mg/L
TDS				270 mg/L

Turbidity criteria that apply in the Strawberry River watershed are listed in Table 3.1. Separate turbidity criteria are specified for base flow conditions. The base flow criteria should not be exceeded in more that 20% of samples collected June to October. The all flow criteria should not be exceeded in more than 25% of all samples collected over an entire year (Arkansas Pollution Control and Ecology Commission 2014).

Bacteria water quality criteria that apply in the Strawberry River watershed are summarized in Table 3.1. These criteria are considered to be met if less than 25% of no less than 8 samples collected during each season are below the criteria.

3.1.3 Antidegradation Policy

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

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

3.2 Available Monitoring/Resource Data

This section describes available data for water quality, flow, and biological parameters in the Strawberry River watershed.

3.2.1 Surface Water Quality Data

This section describes and discusses available surface water quality data in the Strawberry River watershed. This includes water quality monitoring and modeling, surface water impairments, and water quality characteristics.

3.2.1.1 Monitoring

Over the last 10 years surface water quality data have been collected in the Strawberry River watershed by ADEQ, Arkansas State University (ASU), the University of Arkansas at Fayetteville (U of A),EPA, and the USGS.

ADEQ monitors surface water quality in the Strawberry River watershed through several programs. There is one ADEQ ambient water quality monitoring network site in the watershed that is sampled monthly. There are also six roving water quality monitoring network sites in the watershed. 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 (ADEQ 2014). Three of the ADEQ stations in the Strawberry River watershed classified as roving stations have not been sampled since 2005. The other three roving stations were sampled in 2014. In addition, there are sites in the watershed where ADEQ is collecting water quality data as part of special projects, including the nutrient ERW Ozark Highlands Project, and the Type B Lakes Project (ADEQ 2014). Thirteen additional sites in the watershed were sampled by ADEQ from 2001 through 2003 as part of an intensive physical, chemical, and biological assessment of the Strawberry River watershed (ADEQ n.d.).

Through its nonpoint source management program, ANRC has overseen two projects that included collection of surface water quality samples in the Strawberry River watershed; one conducted by the ASU Ecotoxicology Research Facility (ANRC project number 07-1000), and the U of A Arkansas Water Resources Center (ANRC project number 11-800). The purpose of the ASU project was to evaluate water quality at headwater sites on the Strawberry and Little Strawberry Rivers where management practices to improve water quality had been implemented. The water quality data collection performed by the U of A was for evaluation of a SWAT model of sediment and nutrients in the Strawberry River watershed (Massey, et al. 2013).

The USGS collects surface water quality data, usually at flow gage stations. Historically, the USGS has collected water quality at 13 sites within the Strawberry River watershed. Water quality data have not been collected at the majority of these sites since 1988. Water quality data have been collected at four sites since 1988, only one of which was sampled within the last 10 years. The USGS collected in situ parameters on one date in one location in the Strawberry River watershed in 2010 (USGS 2015a).

In 2004 and 2005, EPA worked with states to conduct a nation-wide assessment of the biological condition of small streams, the Wadeable Streams Assessment. For this EPA program, probability-based surveys of the condition of the nation’s water resources were conducted. Water quality sampling was conducted at a site on Piney Fork in Izard County in 2004 as part of the survey (EPA 2013).

The locations where surface water quality monitoring has occurred in the watershed within the last 10 years (i.e., sampled within 2004 to 2014) are shown on Figure 3.1. The periods of record for water quality data from these monitoring sites are listed in Table 3.2. A detailed water quality data inventory that includes older water quality data is available in Appendix B.

3.2.1.2 Modeling

Saraswat et al. (2013) prepared and calibrated a SWAT model of the Strawberry River watershed to aid in prioritizing subwatersheds for implementation of nonpoint source best management practices (BMPs). The parameters sediment, total phosphorus, and nitrate nitrogen were modeled for the period 2001 through 2003.

Table 3.2. Periods of record for recently sampled surface water quality monitoring stations in the Strawberry River watershed (ADEQ 2014, 2015a).

Station ID	Waterbody	Monitoring Agency/ Organization	Date of first sample	Date of most recent sample	Program/ project
WHI0143H	Little Strawberry R	ADEQ	2001	2014	Special study
UWSBR01	Strawberry R.	ADEQ	1994	2014	Roving
WHI0143A	Strawberry R.	ADEQ	2001	2014	Special study
UWSBR02	Strawberry R.	ADEQ	1994	2014	Roving
UWSBR03	Strawberry R.	ADEQ	1994	2014	Roving
WHI0024	Strawberry R.	ADEQ	1990	2014	Ambient
WHI0160	Strawberry R.	ADEQ	1999	2014	Special Study
[20 stations]	Strawberry R. and tributaries	U of A	2011	2013	11-800
[6 stations]	Strawberry R., Little Strawberry R.	ASU	2008	2012	07-1000
LWHI028	Crown Lake	ADEQ	2012	2014	Type B Lakes special study
LWHI027	Diamond Lake	ADEQ	2012	2012	Type B Lakes special study
07074060	Wilson Cr.	USGS	2015	2015	Routine
OWW04440-0313	Piney Fork	EPA	2004	2004	National Aquatic Resources Survey

Figure 3.1 Surface water quality monitoring locations in the Strawberry River watershed where data has been collected within the last 10 years (2004 – 2014).

3.2.1.3 Impaired Uses and Water Quality Threats

3.2.1.3.1. Pollutants of Concern

Sediment, nutrients, and bacteria have been identified as threats to surface water quality in the Strawberry River watershed. Streams in the watershed are also suspected of being a mechanism for the spread of disease among livestock (ANRC 2011, Fulton County Conservation District n.d., ADEQ 2014).

3.2.1.3.2. Impaired Surface Waters

The last EPA approved state impaired waters list (i.e., 303(d) list) for Arkansas was from 2008. Impaired waters in the Strawberry River watershed from the 2008 list are given in Table 3.3 and mapped on Figure 3.2. On the 2008 303(d) list, almost 122 miles of streams in the Strawberry River watershed were classified as impaired (ADEQ 2008).

Table 3.3. Impaired waters of the Strawberry River watershed, 2008 303(d) list.

Stream name	Segment(s)	Impaired use	Pollutant(s)	Pollutant source	Category
Strawberry River	002, 004-006, 008, 009, 011	Aquatic life	Siltation/turbidity	Surface erosion	TMDL completed
Little Strawberry River	010	Aquatic life	Siltation/turbidity	Surface erosion	TMDL completed
Strawberry River	009	Primary contact	Bacteria	Unknown	Added by EPA
South Big Creek	013	Primary contact	Bacteria	Unknown	Added by EPA

The most recent state biennial assessment of water quality was conducted in 2014. Waterbodies in the Strawberry River watershed included on the 2014 impaired waters list resulting from that assessment are shown in Table 3.4. A total of 102.6 miles of streams in the Strawberry River watershed were classified as impaired in 2014 (ADEQ 2014).

There has not been much change in the impairments in the Strawberry River watershed over time. Caney Creek, Cooper Creek, Mill Creek, and Reed's Creek bacteria impairments were included in the 303(d) lists prior to 2008. It is possible they were not included in the 2008 303(d) list because the TMDL addressing these impairments were in the process of being approved (EPA Region VI 2007). EPA added the bacteria impairments for Strawberry River stream segment 009 and South Big Creek to the 2008 303(d) list. ADEQ has not included them in the 2014 303(d) list.

Below, pollutants of concern within the Strawberry River watershed are discussed. Available data is examined to characterize water quality differences within the watershed, and changes in water quality over time. In addition, existing pollutant loads are estimated.

Table 3.4. Impaired waters of the Strawberry River watershed, draft 2014 303(d) list (ADEQ 2014).

Stream name	Segment(s)	Impaired use	Pollutant(s)	Pollutant source	Category
Strawberry River	002, 004-006, 008, 009, 011	Fisheries	Turbidity	Surface erosion	TMDL completed
Little Strawberry River	010	Fisheries	Turbidity	Surface erosion	TMDL completed
		No information*	Bacteria	Surface erosion	TMDL completed
Strawberry River	011	No information*	Bacteria	Surface erosion	TMDL completed
Caney Creek	015	No information*	Bacteria	No information	TMDL completed
Cooper creek	003	No information*	Bacteria	No information	TMDL completed
Mill Creek	016	No information*	Bacteria	No information	TMDL completed
Reed’s Creek	014	No information*	Bacteria	No information	TMDL completed

*The impaired use was not identified in the 303(d) list. A subsequent TMDL stated that the impaired use was primary contact recreation.

3.2.1.4 Sediment Water Quality

Turbidity and TSS are typically monitored as indicators of sediment water quality issues. TSS is used as a surrogate for turbidity in TMDLs. Turbidity and/or TSS measurements have been collected in all of the water quality studies and monitoring programs in the Strawberry

River watershed. Only the USGS has measured suspended sediment concentration, at one station (Strawberry River near Poughkeepsie) during 1994 and 1995. Arkansas water quality standards include numeric criteria for turbidity, but not TSS, nor sediment.

3.2.1.4.1. Measured Sediment Parameters around the Watershed

Both turbidity and TSS data have been collected in the Strawberry River watershed during the time period from 2010 through 2014.

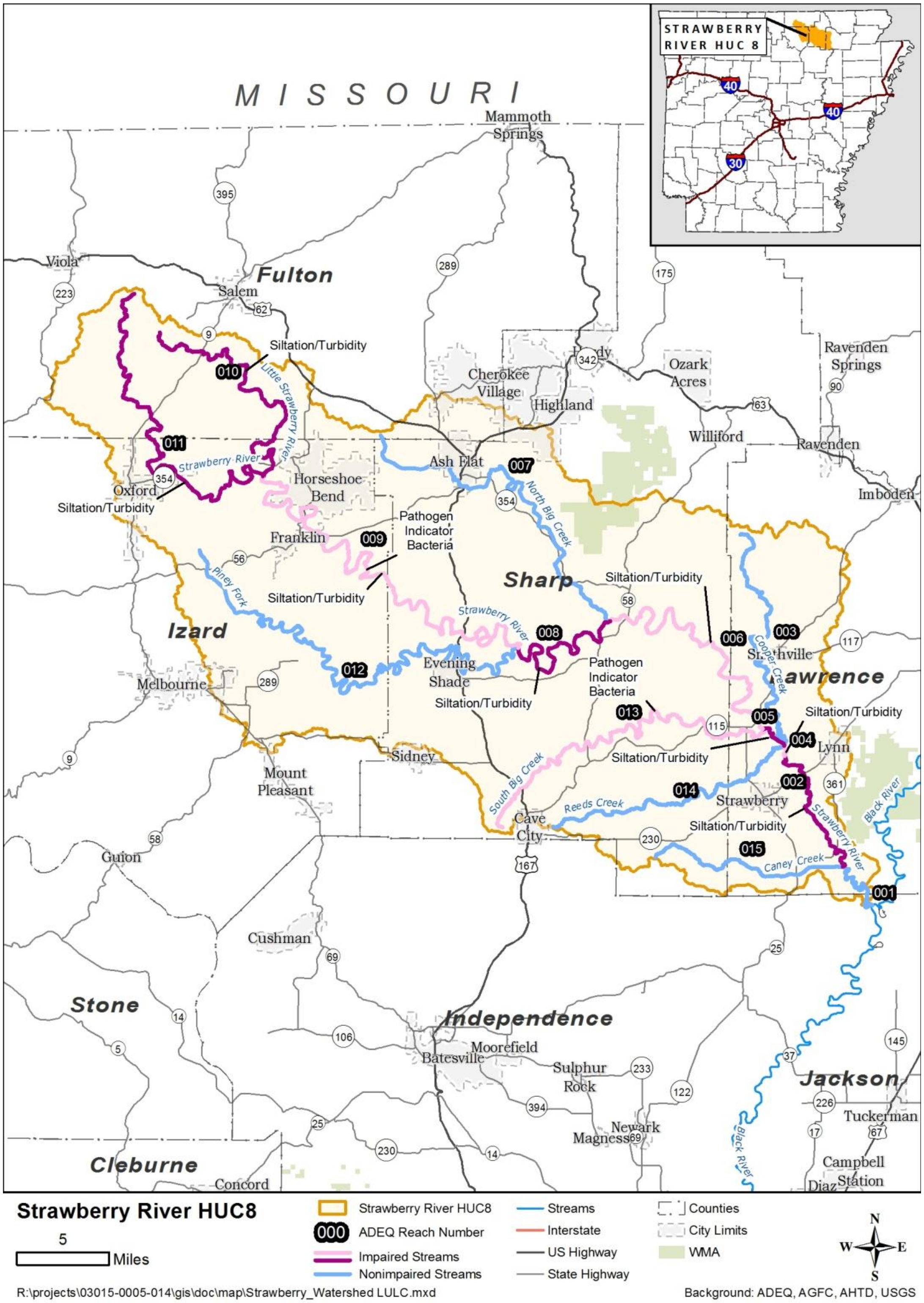


Figure 3.2. Impaired waterbodies in the Strawberry River watershed identified in the 2008 303(d) list.

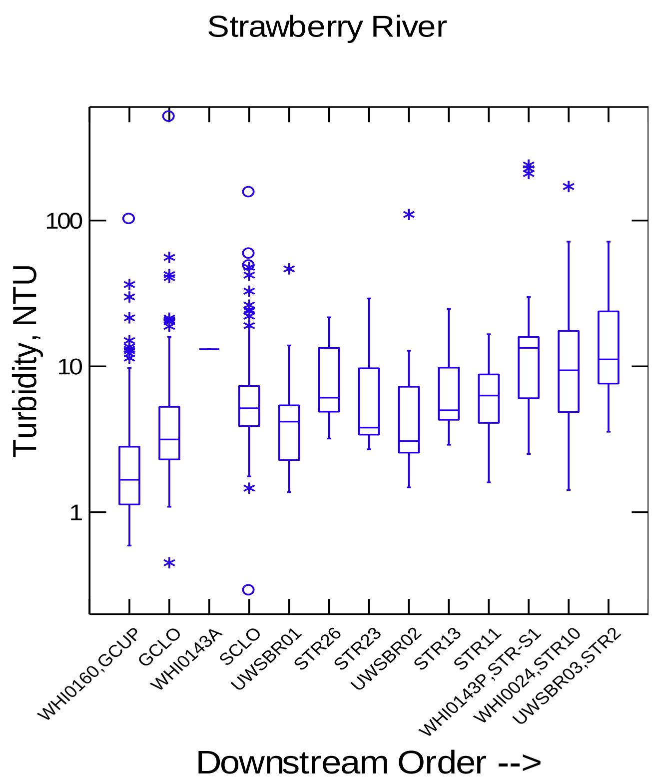
3.2.1.4.1.1. Turbidity

Turbidity data have been collected by ADEQ, ASU, and U of A at over 30 locations in the Strawberry River watershed during the time period from 2010 through 2014 (see Figure 3.1 for sampling locations). Summary plots of these data are shown on Figure 3.3.

Overall, turbidity levels in the Strawberry River become higher downstream. Median turbidity values (indicated by the mark through the boxes on Figure 3.3) at the two upstream-most water quality monitoring locations (WHI0160 and GCUP) are statistically significantly less than the median turbidity values at most of the downstream locations. A single turbidity measurement was taken at WHI0143A during the target time period, which is why only a line is shown for that location on Figure 3.3. Analysis of variance does not indicate that the mean turbidity levels at the upstream locations are statistically significantly different from mean turbidity levels at downstream locations, except for STR-S1. The analysis indicates that the mean turbidity level at STR- S1 is statistically significantly greater than mean turbidity levels at several of the most upstream locations.

Measured turbidity levels in the Strawberry River tributaries are also shown on Figure 3.3. Turbidity levels in the headwater tributaries (unnamed tributary, Little Strawberry River, Piney Fork) appear to be fairly similar, and do not appear to change from upstream to downstream along the tributaries. In North Big Creek, turbidity levels appear to be lower downstream than upstream. Turbidity levels in the downstream tributaries (South Big Creek, Cooper Creek, Reeds Creek, and Caney Creek) appear to be higher than in the upstream tributaries.

Analysis of variance indicates that mean turbidity levels in Caney Creek and Reeds Creek are statistically significantly higher than the other monitored streams in the watershed. This is not surprising given that the monitoring locations on these streams are located in the Delta ecoregion rather than the Ozark Highlands ecoregion. Delta streams overall generally have higher turbidity levels than Ozark Highlands streams. Mean turbidity levels in the rest of the tributaries are not statistically significantly different from the overall mean turbidity level in the Strawberry River.



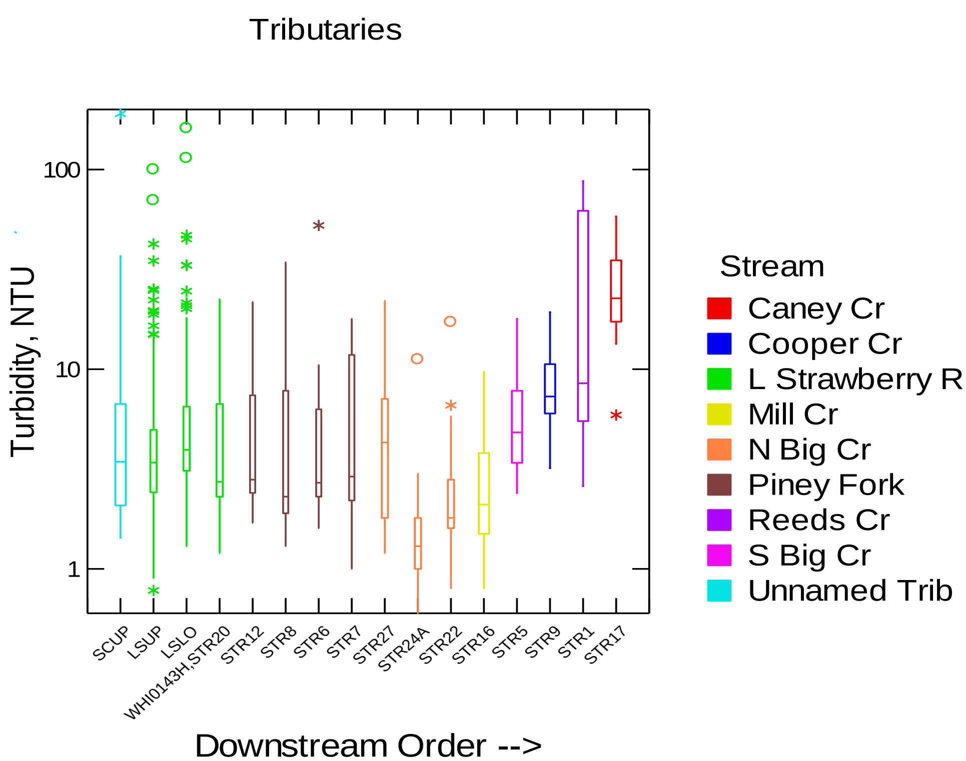


Figure 3.3. Turbidity data from the Strawberry River watershed 2010 – 2014.

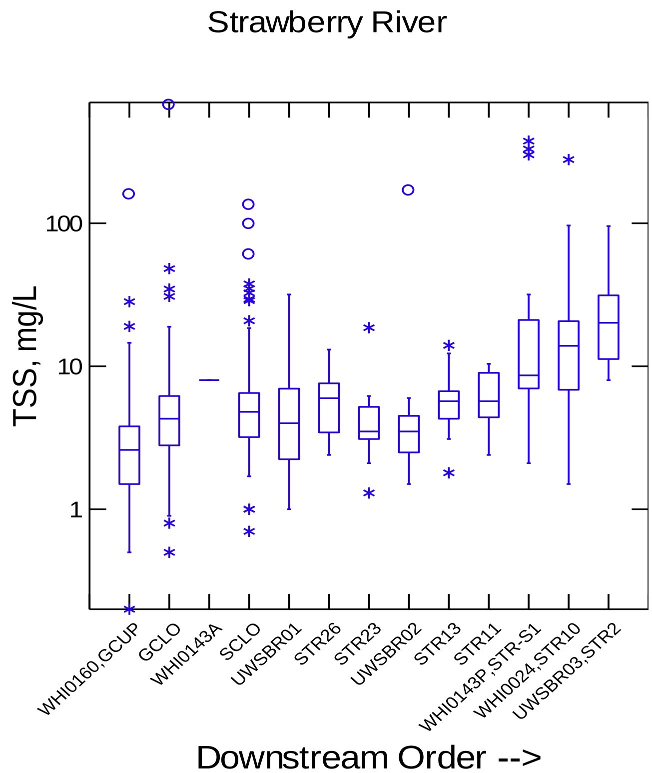
The assessment of the intensive data collected during 2001 through 2003 found that turbidity measurements in a number of tributaries located in the upper watershed exceeded the state water quality criteria. Overall, the assessment found that maximum turbidity measurements from tributaries where greater in the upper watershed, and that the number of exceedences of turbidity criteria at tributary monitoring sites gradually declined moving downstream. However, turbidity levels in the Strawberry River increased in the downstream direction (ADEQ n.d.).

3.2.1.4.1.1. TSS

TSS data have been collected in the Strawberry River watershed at 29 sites by ADEQ, U of A, and ASU during the time period from 2010 through 2014. Summary plots of these data are shown on Figure 3.4. Overall, TSS concentrations in the Strawberry River become higher downstream. Median TSS concentrations at the two downstream-most stations (Smithville and Highway 361) are statistically significantly greater than the median TSS concentrations at most of the upstream stations, particularly the two upstream-most stations. A single TSS measurement was taken at Highway 9 (station WHI0143A) during the target time period. Analysis of variance indicates that the mean TSS concentration at Poughkeepsie is statistically significantly higher than mean TSS concentrations at the majority of upstream stations.

Measured TSS concentrations in the Strawberry River tributaries are also shown on Figure 3.4. TSS concentrations in the upper tributaries (unnamed tributary, Little Strawberry River, Piney Fork, North Big Creek) appear to be fairly similar, although TSS concentrations at upstream Little Strawberry River stations tend to be higher than at the other headwater tributary stations. TSS concentrations in the downstream tributaries (South Big Creek, Cooper Creek, Reeds Creek, and Caney Creek) appear to be higher than in the upstream tributaries.

Analysis of variance indicates that mean TSS concentrations in Caney Creek and Reeds Creek are statistically significantly higher than the other monitored streams in the watershed. This is not surprising given that the monitoring stations on these streams are located in the Delta ecoregion rather than the Ozark Highlands ecoregion. Delta streams overall generally have higher TSS concentrations than Ozark Highlands streams. Mean turbidity levels in the rest of the tributaries are not statistically significantly different from the overall mean turbidity level in the Strawberry River.



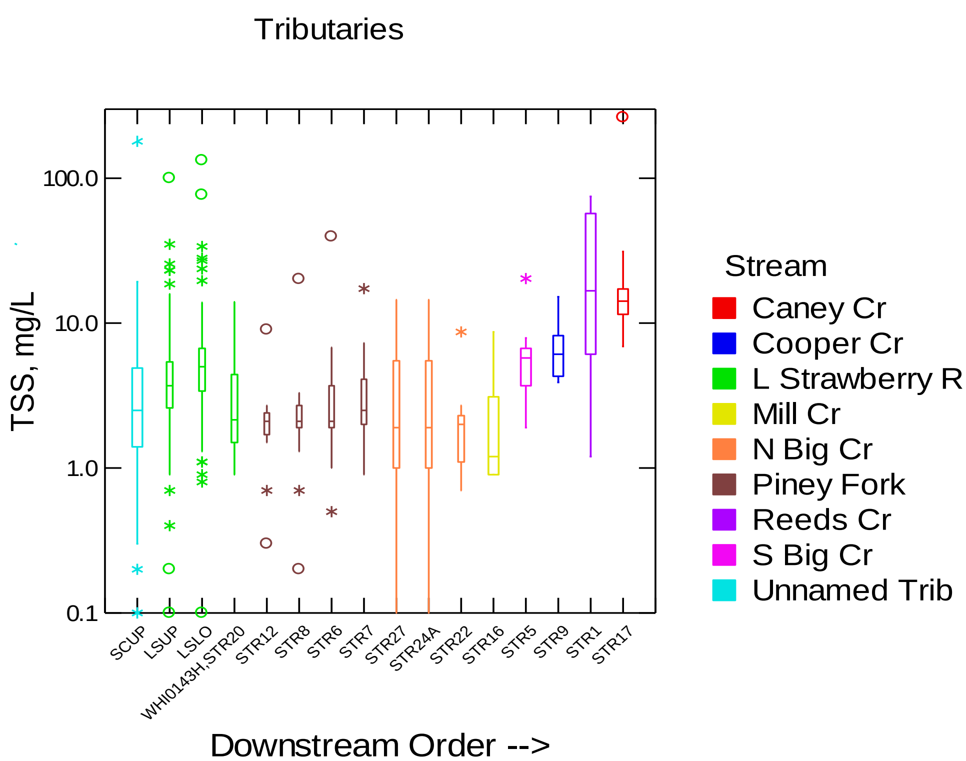


Figure 3.4. TSS data from Strawberry River watershed 2010 – 2014.

The assessment of the intensive data collected during 2001 through 2003 found that, overall, maximum TSS concentrations from tributaries where greater in the upper watershed. However, TSS concentrations in the Strawberry River increased in the downstream direction (ADEQ n.d.).

3.2.1.4.2. Comparison of Measured to Modeled Sediment Parameters

Prioritization of the Strawberry River subwatersheds based on modeled sediment concentrations is shown on Figure 3.5. Higher numbers indicate higher priority, with highest priority shown as red on Figure 3.5. The majority of the highest sediment concentrations estimated by the model are in the headwaters of the watershed. The six highest priority subwatersheds account for 23% of the area of the Strawberry River watershed, but contribute around 55% of the sediment load in the model (Saraswat, et al. 2013).

A comparison of the SWAT model prioritization for sediment to ADEQ impaired waters assessments are shown in Table 3.5. Note that “80-100” in the SWAT sediment priority column indicates highest priority. The fact that a number of stream reaches classified as impaired due to turbidity are also classified as a low priority for sediment in the SWAT output suggests that the source of the sediment that may be causing high turbidity is upstream of the reach.

There are also a couple tributaries that have not been classified as impaired due to turbidity that are classified as highest priority for sediment based on the SWAT model output, North Big Creek and Caney Creek. Massey et al. (2013) did not find that the Strawberry River SWAT model output for TSS correlated to TSS measurements from the watershed, suggesting that, while the SWAT model can be used to assist with prioritizing subwatersheds of the Strawberry River for sediment BMPs, it should not be the only tool used.

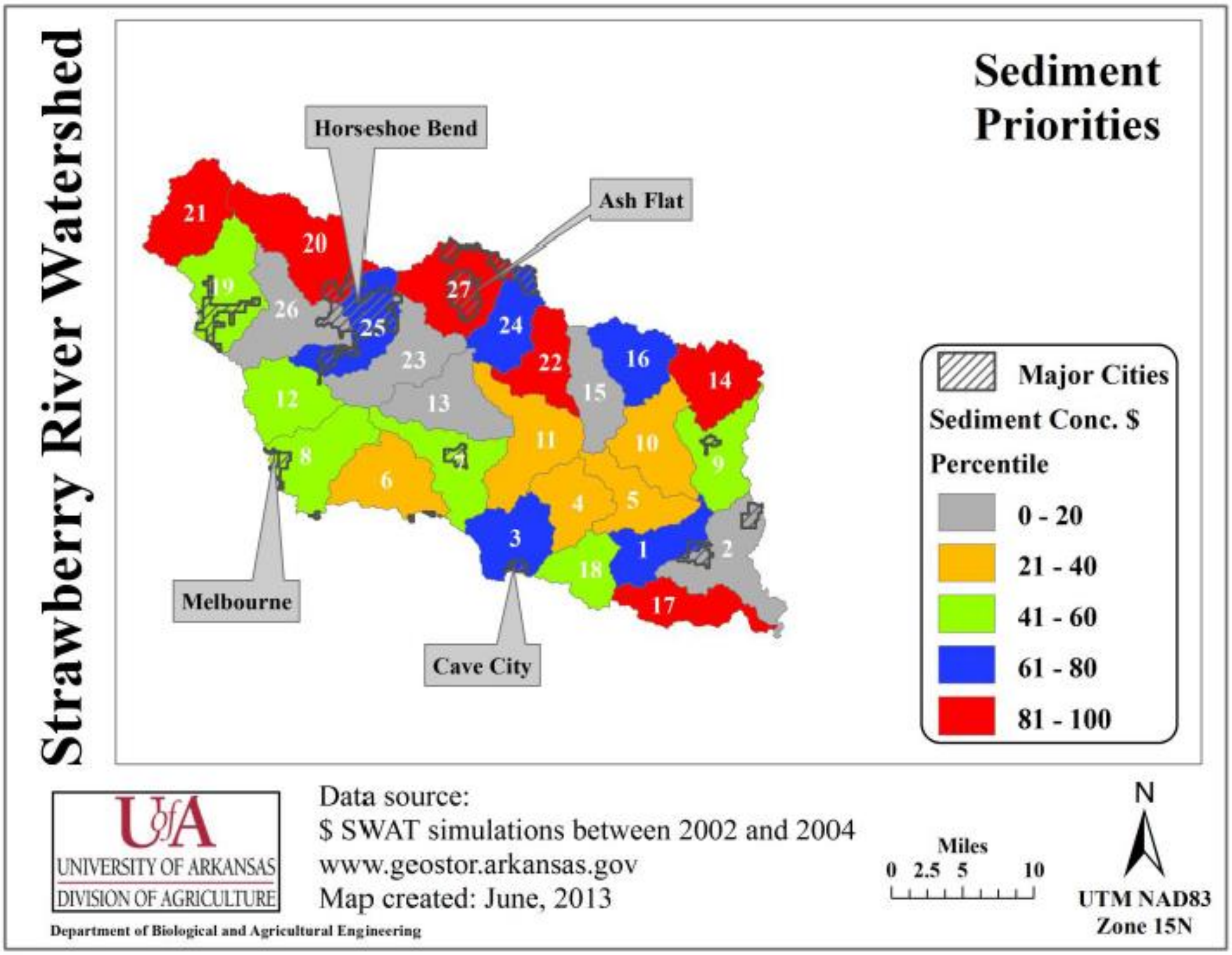


Figure 3.5. Prioritization of Strawberry River subwatersheds for sediment based on SWAT model (from Saraswat, et al.2013).

Table 3.5 Comparison of SWAT model sediment priorities to ADEQ turbidity impairments in the Strawberry River watershed.

Subwatershed name (number on Figure 3.5)	ADEQ reach number	SWAT sediment priority	Turbidity impaired ADEQ	ADEQ monitoring
Reeds Cr – Strawberry R (1)	014	61 – 80	No	UWRDC01
Sleep Bank Cr – Strawberry R (2)	001,002,004	0 – 20	002 and 004 yes	UWSBR03
Hamilton Branch – S Big Cr (3)	013	61 – 80	Yes	WHI0143K
Fool Cr – S Big Cr (4)	013	21 – 40	Yes	none
Mill Cr – S Big Cr (5)	013	21 – 40	Yes	WHI0143J
Mays Branch – Piney Fork (6)	012	21 – 40	No	None
Mill Cr – Piney Fork (7)	012	41 – 60	No	WHI0143M
Caney Cr – Piney Fork (8)	None	41 – 60	NA	NA
Cooper Cr (9)	003,005	41 – 60	No	WHI0143S
Clayton Cr – Strawberry R (10)	006	21 – 40	Yes	WHI0024
Whaley Cr – Strawberry R (11)	008	21 – 40	Yes	None
Philadelphia Cr – Piney Fork (12)	012	41 – 60	No	None
Lave Cr – Strawberry R (13)	009	0 – 20	Yes	UWSBR02
E Cooper Cr (14)	003	81 – 100	No	None
Meeks Branch – Strawberry R (15)	006	0 – 20	Yes	WHI0143N, WHI0143P
Mill Cr – Strawberry R (16)	None	61 – 80	NA	NA
Caney Cr – Strawberry R (17)	015	81 – 100	No	WHI0143Q
North Prong – Reeds Cr (18)	014	41 – 60	No	None
Sandy Cr – Strawberry R (19)	011	41 – 60	Yes	WHI0143A
Little Strawberry R (20)	010	81 – 100	Yes	WHI0143E, WHI0143H
Greasy Cr – Strawberry R (21)	011	81 – 100	Yes	WHI0160
Bames Branch – N Big Cr (22)	007	81 – 100	No	UWNBC01
Hars Cr – Strawberry R (23)	009	0 – 20	Yes	None
Little Cr – N Big Cr (24)	007	61 – 80	No	None
Bens Cr – Strawberry R (25)	009	61 – 80	Yes	WHI0143B
Bullpen Cr – Strawberry R (26)	011	0 – 20	Yes	UWSBR01
Hackney Cr – N Big Cr (27)	007	81 – 100	No	WHI0143I

3.2.1.4.3. Sediment Parameters over Time

Entire periods of record of turbidity and TSS measurements collected by ADEQ, USGS, ASU, and U of A at locations in the Strawberry River watershed with data records of at least 10 years are shown on Figures 3.6 and 3.7. The majority of these monitoring locations are sampled only periodically. Only one location has a fairly continuous data record, Strawberry River near Smithville.

Turbidity in the Strawberry River near Smithville exhibits variability over time, apparently increasing from around 1995 to 2005, and then declining since 2005 (Figure 3.6). Turbidity levels in the upper Strawberry River, near Wiseman and at Highway 167, appear to have decreased over time. The only other site where turbidity levels appear to have changed over the period record is Reeds Creek, where the most recent set of turbidity measurements appears slightly higher than previous turbidity measurements.

TSS concentrations in the Strawberry River near Smithville appear to have declined from 1975 to around 1995 (Figure 3.7). Since 1996, TSS concentrations at this location appear to have remained relatively constant. TSS concentrations at other Strawberry River monitoring locations exhibit patterns very similar to the turbidity data. Several tributary locations appear to exhibit declines in TSS concentration where increases or no change in turbidity levels were apparent; Little Strawberry River, the upstream Piney Fork location, North Big Creek, and South Big Creek.

3.2.1.4.4. Sediment Parameters Data Gaps

Overall, there is currently relatively good coverage of data for sediment parameters around the Strawberry River watershed. The recent data collections by the U of A and ASU have provided large datasets of recent measurements. However, at most of the monitoring locations in the watershed, sediment parameter data is not collected in such a way as to adequately represent water quality during high flow conditions, when it is believed the majority of sediment loading occurs in the watershed. Long term data records are available for several locations along the Strawberry River, and from the major tributaries.

It appears that the SWAT model developed to predict/estimate sediment loads to the Strawberry River may not represent the processes occurring in the watershed very well. It may be possible to use the recently collected data for sediment parameters to improve the predictive power of the model.

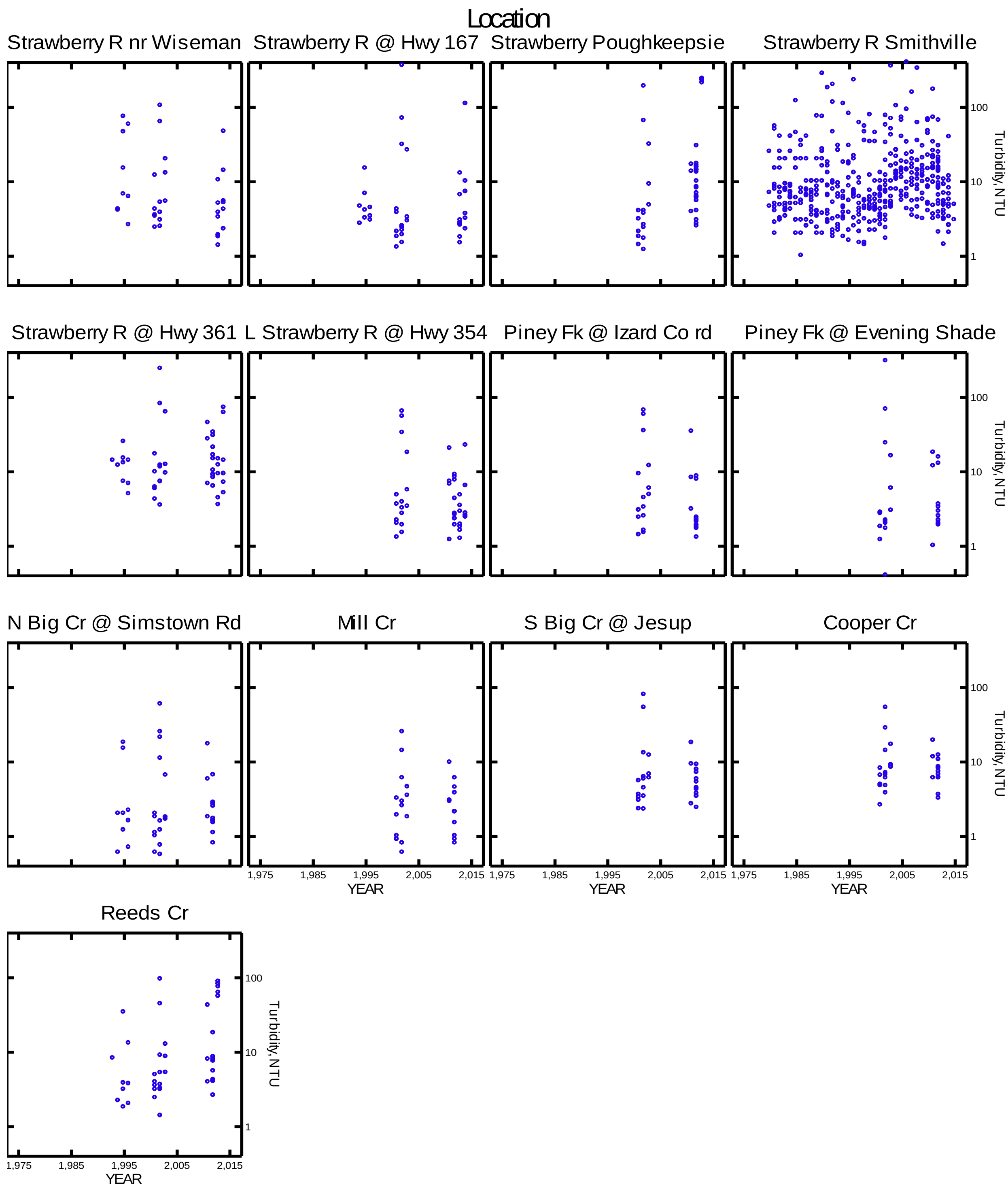


Figure 3.6. Long term turbidity data from Strawberry River watershed.

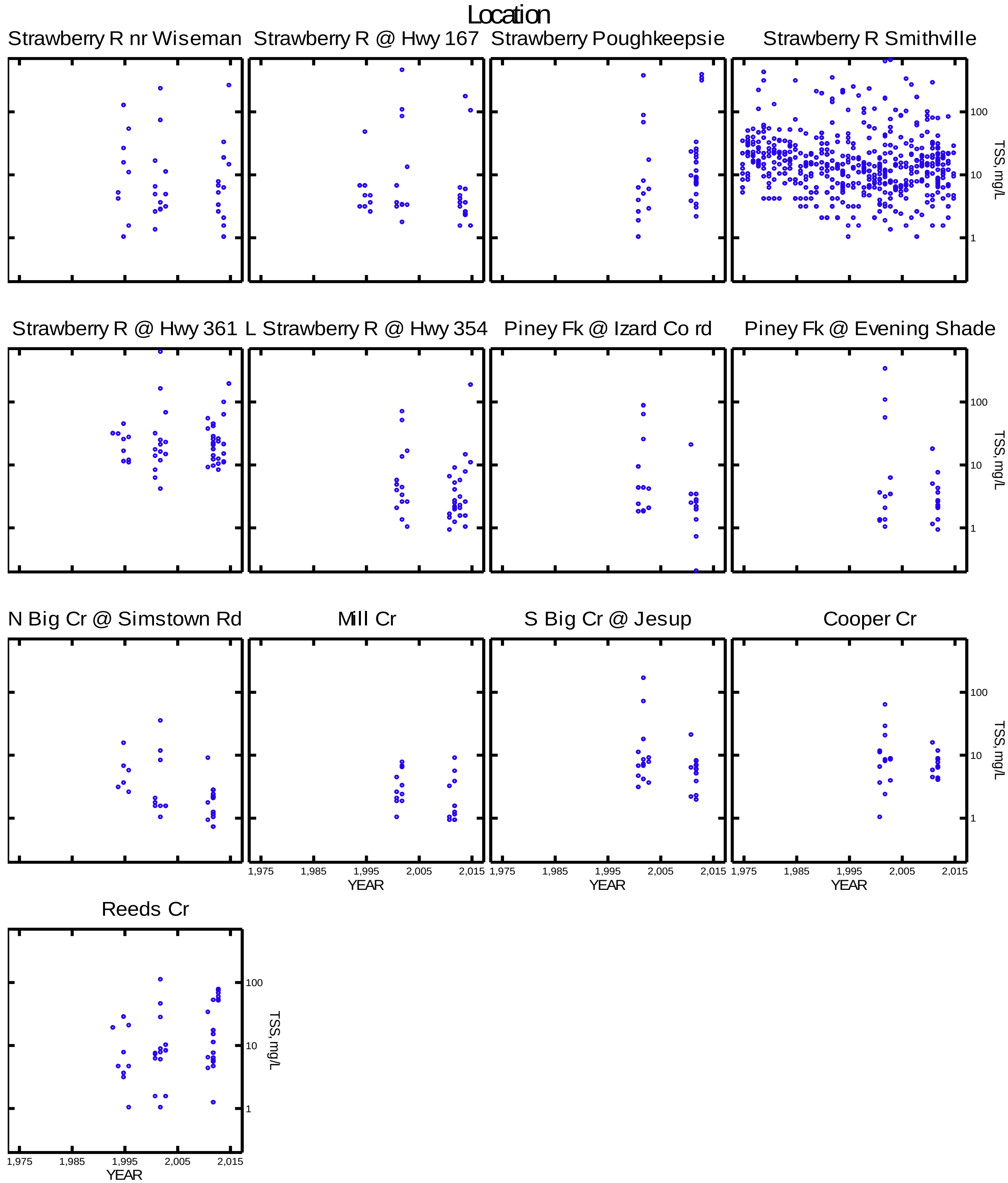


Figure 3.7. Long term TSS data from the Strawberry River watershed.

3.2.1.4.5. Sediment Parameters Summary

- Levels of turbidity and TSS in the Strawberry River are higher at downstream stations than at the headwater stations. This pattern is more pronounced in the turbidity data.
- Levels of turbidity and TSS in headwater tributaries are lower than in the downstream-most tributaries that cross the Delta physiographic region. This pattern is more pronounced in the turbidity data than in the TSS measurements.
- A number of stream reaches classified as impaired due to turbidity are also classified as a low priority for sediment in the SWAT output. This may indicate that sediment sources affecting the stream reach are located upstream of the reach.
- Four of the six SWAT sediment priority subwatersheds contain no stream segments that have been classified as impaired by turbidity by ADEQ. ADEQ does not monitor water quality within all of the Strawberry River subwatersheds.
- A turbidity TMDL completed in 2006 determined that base flow TSS loads did not cause turbidity criteria to be exceeded. However, TSS loads during storm flow did result in violations of turbidity criteria and need to be reduced.
- TSS loads estimated for monitoring locations within the Delta physiographic region tend to be higher than those for monitoring locations within the Ozark Highlands.
- Different patterns are shown in long term turbidity and TSS data from the Strawberry River at Smithville. Turbidity increased from around 1995 to 2005, and has declined since 2005. TSS declined from 1975 to around 1995, and has since remained relatively consistent.
- Apparent declines in turbidity levels and TSS concentrations are seen in long term data from the Strawberry River at Highway 167 (UWSBR02).
- Turbidity and TSS levels appear to have increased over time at Strawberry River near Poughkeepsie and Reeds Creek.
- Several tributary locations appear to exhibit declines in TSS concentration where increases or no change in turbidity levels were apparent; Little Strawberry River, the upstream Piney Fork location, North Big Creek, and South Big Creek.

3.2.1.5 Bacteria Water Quality

ADEQ, USGS, and ASU have collected bacteria data in the Strawberry River watershed. Fecal and total coliforms were historically monitored as an indicator of fecal contamination of waters. Currently, E. coli is the most commonly monitored indicator of fecal contamination of waters. ADEQ began monitoring E. coli around 2000, and stopped monitoring fecal coliforms around 2003. USGS collected fecal and total coliforms data from the Strawberry River watershed in the 1970s, and E. coli data in the 1990s. Due to the change in monitoring parameters, and the lack of recent data collection, there is no long-term data record of comparable bacteria data in the Strawberry River watershed.

3.2.1.5.1. E. coli around the Strawberry River Watershed

At the majority of the Strawberry River watershed water quality monitoring sites, the most recent measurements of E. coli are from 2005. ASU collected E. coli measurements at six sites in the upper Strawberry River watershed 2009 through mid 2012.

3.2.1.5.2. ASU Data

Geometric means of E. coli concentrations measured at the ASU monitoring sites during BMP installation (January 2009 – June 2011) were relatively similar, ranging from 20.3 to 44.3 colony forming units/100 mL (cfu/100 mL) (Figure 3.8). The highest geometric mean concentration was from the upstream Little Strawberry River site (LSUP). The lowest geometric mean concentration was from GCUP, the farthest upstream monitoring site on the Strawberry River. The largest percentage of E. coli concentrations exceeding the water quality criteria in a season during this period were measured at the downstream Little Strawberry River site (LSLO), 44%. Thirty-three percent of the E. coli concentrations measured during this period at the upstream Little Strawberry River site (LSUP) exceeded the criteria.

Geometric means of E. coli concentrations measured at the ASU monitoring sites after BMP installation (July 2011 – June 2012) were greater than those measured during the BMP installation period, ranging from 53.6 to 285.8 cfu/100 mL (Figure 3.8). During this period, the geometric means of E. coli concentrations at the upstream site of the monitoring pairs (i.e., GCUP, LSUP, SCUP) were at least two times greater than the geometric means at the downstream sites of the pairs (i.e., GCLO, LSLO, SCLO).

3.2.1.5.3. ADEQ 2005 Data

The geometric means of E. coli concentrations measured by ADEQ during 2005 are summarized on Figure 3.9. The highest geometric means are from upper Caney Creek and Cooper Creek. The geometric means from the remaining monitoring sites are relatively similar. Note that all E. coli measurements from 2005 were collected during the summer primary season.

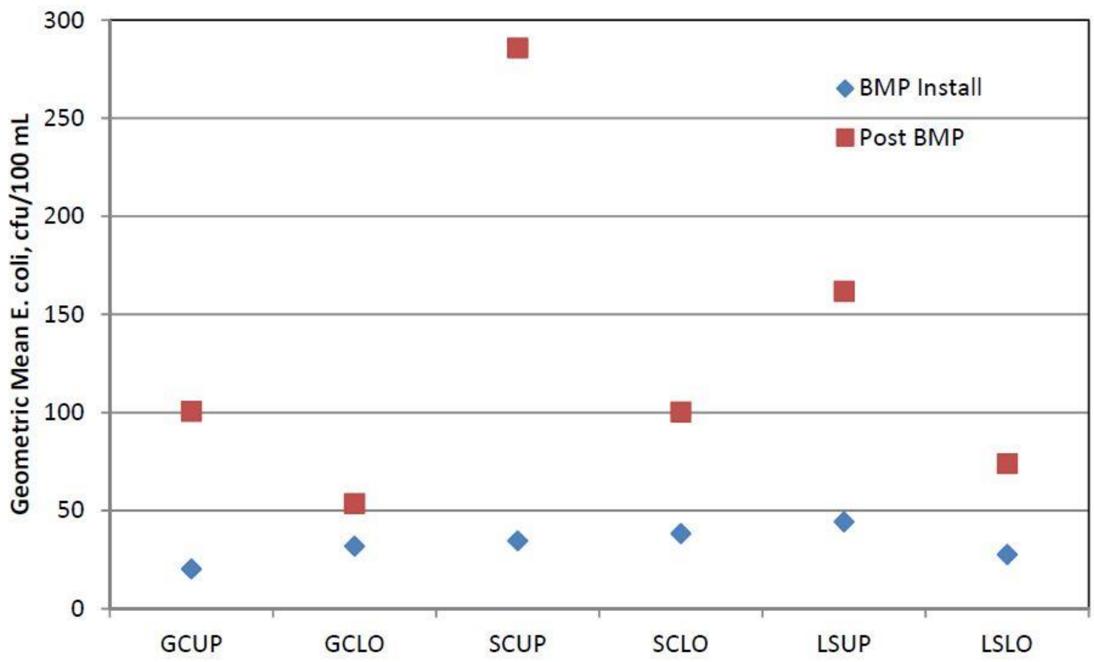


Figure 3.8. Summary of E. coli measurements collected by ASU in the Strawberry River watershed 2009 – 2012.

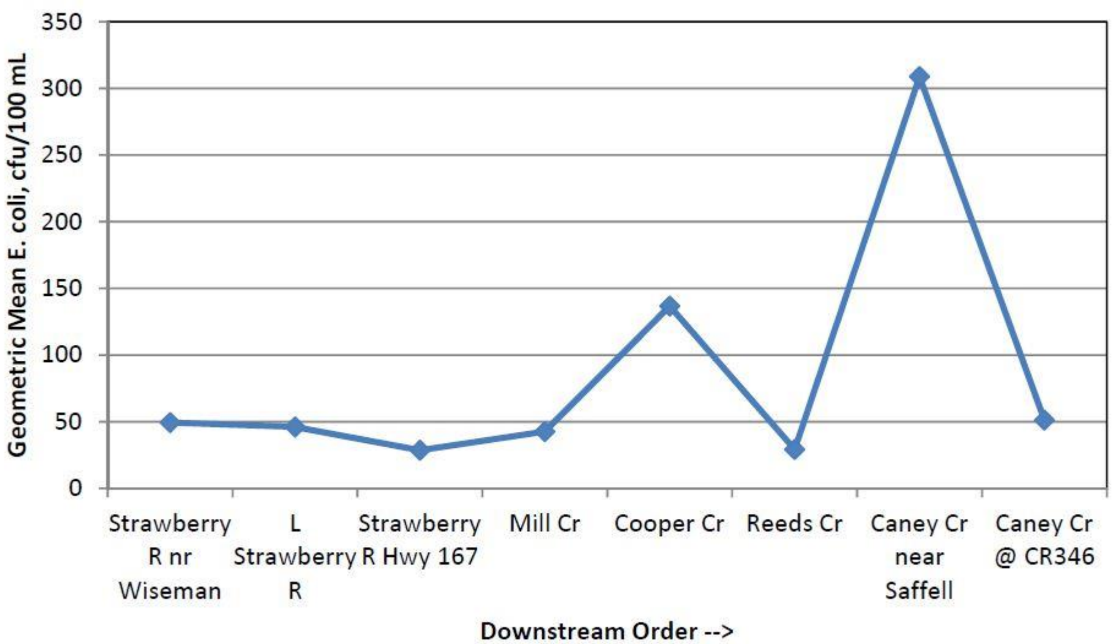


Figure 3.9. Summary of 2005 measurements of E. coli collected by ADEQ in the Strawberry River watershed.

3.2.1.5.4. Bacteria Data Gaps

There have been very few measurements of bacterial indicators in the Strawberry River watershed during the period from 2010 through 2014. The majority of the bacteria data from the watershed is from the ADEQ water quality intensive conducted during 2001 and 2002, over 10 years ago.

3.2.1.5.5. Bacteria Data Summary

- At the headwater locations monitored by ASU, the geometric means of E. coli levels during the time BMPs were being installed were lower than the geometric means of E. coli levels measured during the period after BMPs were installed.
- Estimated winter E. coli loads from the TMDL tended to be greater than the estimated summer E. coli loads.
- E. coli levels have been measured at few locations in the Strawberry River watershed since 2002.

3.2.1.6 Nitrogen Water Quality

No surface water quality impairments related to nitrogen have been identified in the Strawberry River watershed, and there are currently no numeric nitrogen water quality criteria for Arkansas surface waters. However, stakeholders are concerned about nutrient contamination of surface waters, and entities monitoring water quality in the watershed collect data on nitrogen concentrations. Nitrate and inorganic-nitrogen levels in surface water are discussed below.

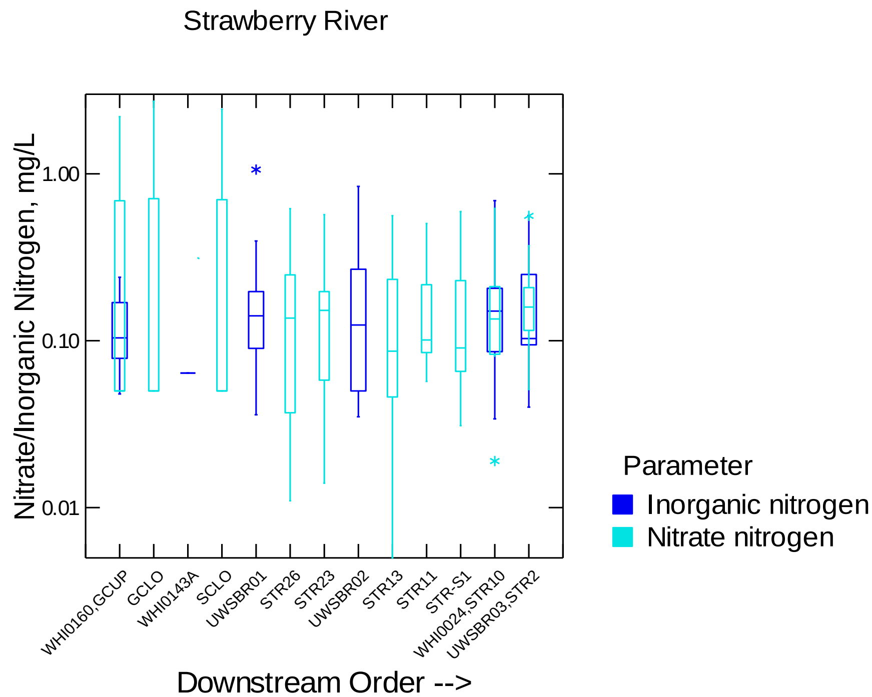
3.2.1.6.1. Nitrogen around the Watershed

Nitrate-nitrogen measurements have been collected in the Strawberry River watershed by U of A and ASU during the period from 2010 through 2014. ADEQ measures inorganic nitrogen (i.e., nitrate plus nitrite) at its monitoring locations. Because nitrite concentrations in Arkansas surface waters are usually low or less than detection, in this evaluation the inorganic nitrogen data from ADEQ is considered comparable to nitrate-nitrogen measurements collected by U of A and ASU. These data are summarized together on Figure 3.10.

Concentrations of nitrate and inorganic nitrogen in the Strawberry River appear to be fairly consistent along the entire length of the river (Figure 3.10). Nitrate concentrations in the tributaries exhibit variability. All data shown for tributaries on Figure 3.10 is nitrate nitrogen, except for station WHI0143H, which is inorganic nitrogen. Nitrate nitrogen concentrations in Piney Fork, North Big Creek, and Cooper Creek are relatively similar to those in the Strawberry River. The greatest median nitrate nitrogen concentrations are from the upper Little Strawberry River (LSUP), the unnamed tributary (SCUP), and Reeds Creek (STR1). These median values are higher than any in the Strawberry River. The lowest median nitrate nitrogen concentrations are from Mill Creek and Caney Creek. These median values are lower than any in the Strawberry River.

3.2.1.6.2. Comparison of Measured to Modeled Nitrate Nitrogen Concentrations

Prioritization of the Strawberry River subwatersheds based on modeled nitrate nitrogen concentrations is shown on Figure 3.11. Higher numbers indicate higher priority, with highest priority subwatersheds shown in red on Figure 3.11. The majority of the highest priority nitrate nitrogen subwatersheds identified by the model are middle and lower tributary subwatersheds. The six highest priority subwatersheds account for 21% of the area of the Strawberry River watershed, but contribute around 37% of the nitrate nitrogen load in the model (Saraswat, et al. 2013).



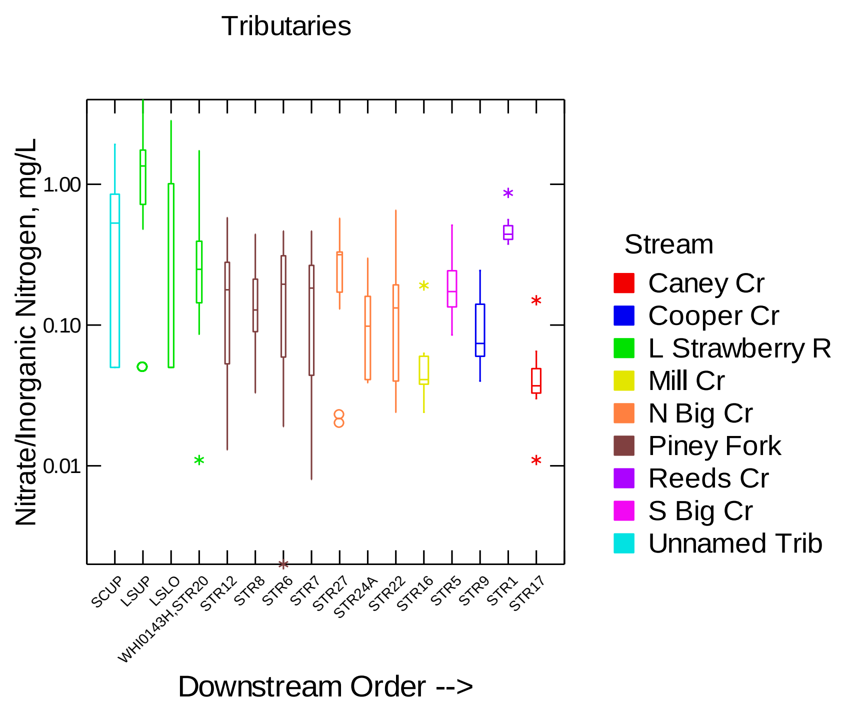


Figure 3.10. Nitrate and inorganic nitrogen data from the Strawberry River watershed 2010 – 2014.

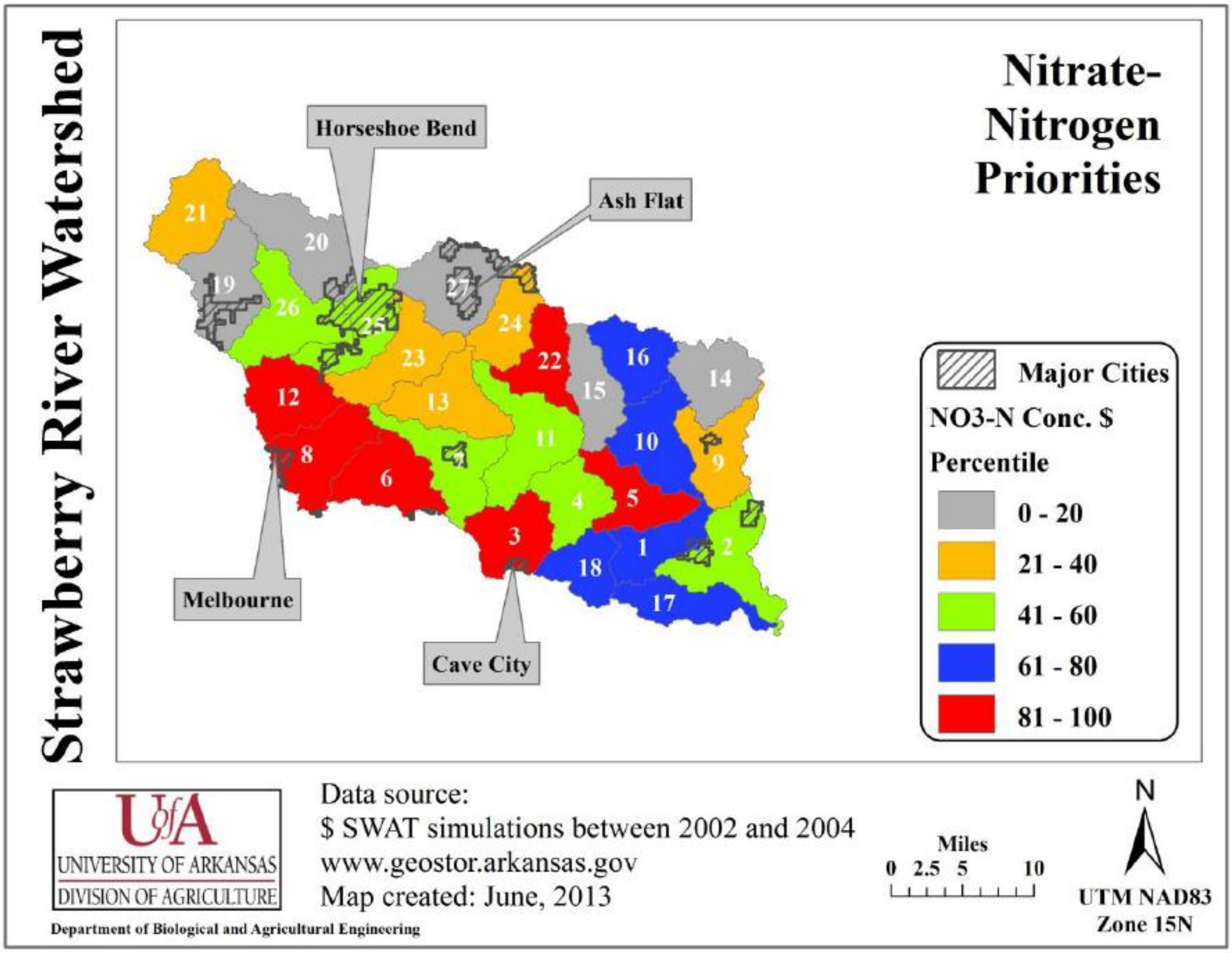


Figure 3.11. Prioritization of Strawberry River subwatersheds for nitrate nitrogen based on SWAT model (from Saraswat, et al.2013).

Massey et al. (2013) compared mean base flow nitrate nitrogen concentrations measured during the period from October 2011 through March 2012, to mean base flow concentrations estimated by the SWAT model for the year 2010 around the Strawberry River watershed. No correlation was found between the measured and modeled concentrations.

3.2.1.6.3. Nitrate Nitrogen Over Time

Entire periods of record of inorganic and nitrate nitrogen measurements collected by ADEQ, USGS, ASU, and U of A at locations in the Strawberry River watershed with data records of at least 10 years are shown on Figure 3.12. The majority of these monitoring locations are sampled only periodically. Only one location has a fairly continuous data record, Strawberry River near Smithville. The majority of the data shown are inorganic nitrogen (shown in blue on Figure 3.12), including the data for the Strawberry River near Smithville. Only the most recent data are measurements of nitrate nitrogen (shown in aqua on Figure 3.12).

There is no apparent strong trend in inorganic nitrogen concentrations at the Strawberry River near Smithville (Figure 3.12). At several of the locations with long term data, the most recent inorganic and nitrate nitrogen concentrations appear to indicate possible increasing trends, including Reeds Creek, North Big Creek, and Little Strawberry River. There are also several locations where the most recent data appear to indicate a possible decreasing trend, such as the Piney Fork locations, Mill Creek, and Cooper Creek. However, the recent data at these locations are nitrate concentrations, while the older data are inorganic nitrogen concentrations. As a result, it is uncertain if the apparent difference over time is a result of the difference in parameters.

3.2.1.6.4. Nitrogen Data Gaps

Overall, there is currently relatively good coverage of data for nitrate nitrogen around the Strawberry River watershed. The recent data collections by the U of A and ASU have provided large datasets of recent nitrate nitrogen measurements. A SWAT model has also been set up to predict nitrate loads and concentrations in the watershed. The fact that ADEQ measures inorganic nitrogen instead of nitrate nitrogen may mean that the recent data are less compatible with ADEQ data. Only ADEQ has monitored water quality long term in the Strawberry River watershed. If the two nitrogen parameters (inorganic nitrogen and nitrate nitrogen) can be combined, long term data records are available for several locations along the Strawberry River, and from the major tributaries.

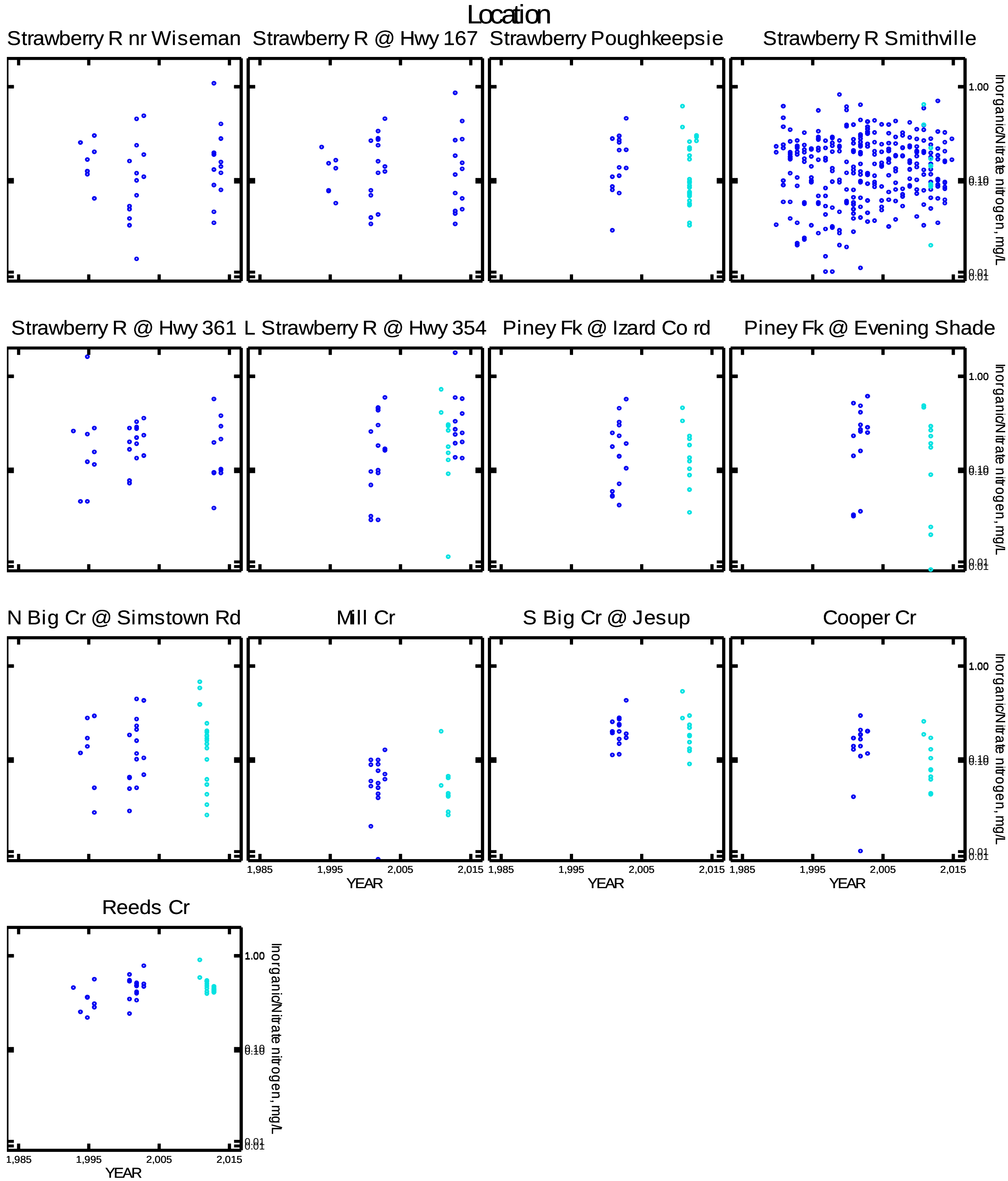


Figure 3.12. Long term inorganic (blue) and nitrate (aqua) nitrogen data from Strawberry River watershed.

3.2.1.6.5. Nitrogen Summary

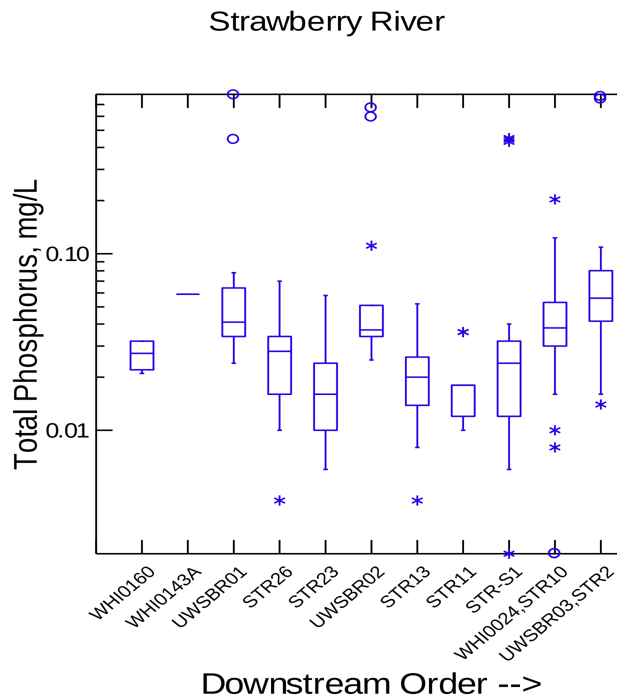
- Concentrations of nitrate in the Strawberry River appear to be fairly consistent along the entire length of the river.
- Nitrate concentrations in tributaries vary considerably.
- The highest nitrate nitrogen concentrations occur in the upper Little Strawberry River, and Reeds Creek.
- The lowest nitrate nitrogen concentrations occur in Caney Creek and Mill Creek.
- There does not appear to be much variability in estimated nitrate nitrogen loads in the Strawberry River watershed.
- The greatest load estimated was for Reeds Creek.
- There is no apparent trend in inorganic nitrogen concentrations at the Strawberry River near Smithville, the location with the most complete data set.
- At several of the locations with long term data, the most recent inorganic and nitrate nitrogen concentrations appear to indicate possible increasing trends, including Reeds Creek, North Big Creek, Little Strawberry River, and several locations on the Strawberry River.
- At locations where the most recent nitrate nitrogen concentrations are less than historical inorganic nitrogen concentrations, it is unclear if this is the result of the difference in parameters, or an actual decline in nitrogen levels.
- Differences in the parameters monitored by different entities makes evaluation of long term trends at some locations difficult.

3.2.1.7 Phosphorus Water Quality

No surface water quality impairments related to phosphorus have been identified in the Strawberry River watershed, and there are currently no numeric phosphorus water quality criteria for Arkansas Surface waters. However, stakeholders are concerned about nutrient contamination of surface waters, and entities monitoring water quality in the watershed collect data on phosphorus concentrations. Total phosphorus levels in surface water are discussed below.

3.2.1.7.1. Total Phosphorus Around the Watershed

Total phosphorus measurements have been collected in the Strawberry River watershed by ADEQ and U of A during the period from 2010 through 2014. These data are summarized in Figure 3.13.



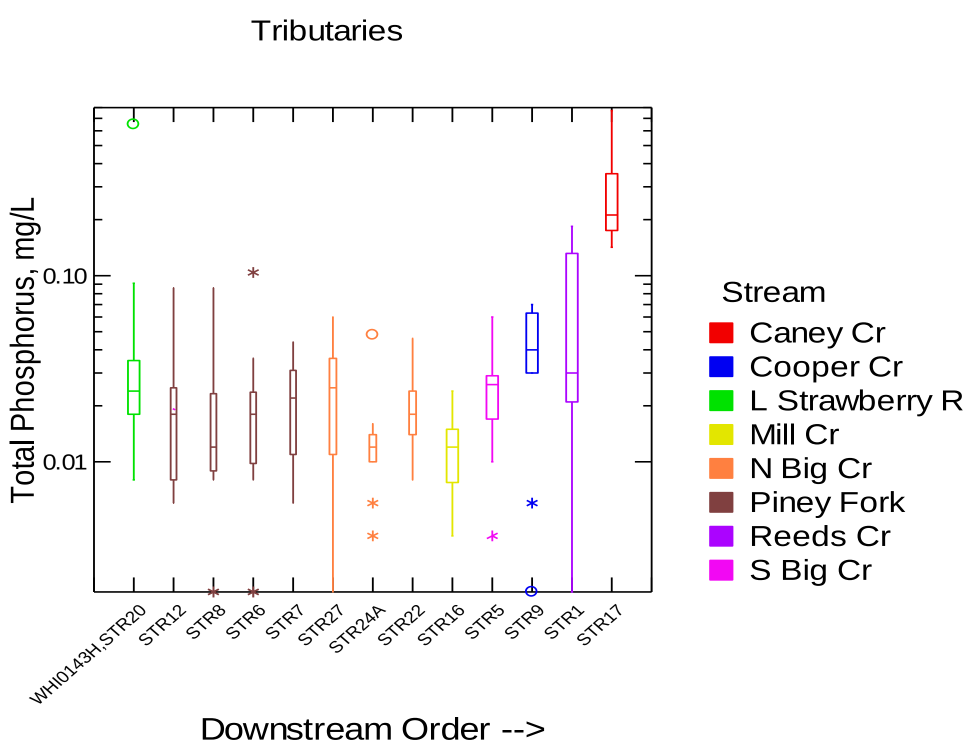


Figure 3.13. Total phosphorus data from Strawberry River watershed 2010-2014.

For most of the locations along the Strawberry River, the total phosphorus concentrations measured by the U of A are lower than those measured by ADEQ. It is unclear if this is natural variability, or some artifact of differences in sample collection or analysis techniques. The U of A data show higher total phosphorus concentrations in the headwaters and the farthest downstream locations on the Strawberry River, with a “sag” in total phosphorus concentrations in the middle portions of the river. The ADEQ data shows a gradual increase in total phosphorus concentrations from the headwaters to the farthest downstream locations on the Strawberry River.

Total phosphorus concentrations in larger tributaries with multiple monitoring locations appear to exhibit increasing total phosphorus concentrations moving downstream. Overall, total phosphorus concentrations in tributaries at the lower end of the Strawberry River tend to be higher than in the other tributaries. Median and average total phosphorus concentrations in Caney Creek are statistically significantly higher than at the rest of the monitoring locations in the watershed.

3.2.1.7.2. Comparison of Measured to Modeled Total Phosphorus Concentrations

Prioritization of the Strawberry River subwatersheds based on modeled total phosphorus concentrations are shown on Figure 3.14. Higher numbers indicate higher priority, with highest priority subwatersheds shown in red on Figure 3.14. The majority of the highest priority total phosphorus subwatersheds are the lower tributary subwatersheds. The six highest priority subwatersheds account for 17.7% of the area of the Strawberry River watershed, but contribute around 32% of the total phosphorus load in the model. The priority subwatersheds encompass Caney Creek, Reeds Creek, and portions of South and North Big Creeks (Saraswat, et al. 2013).

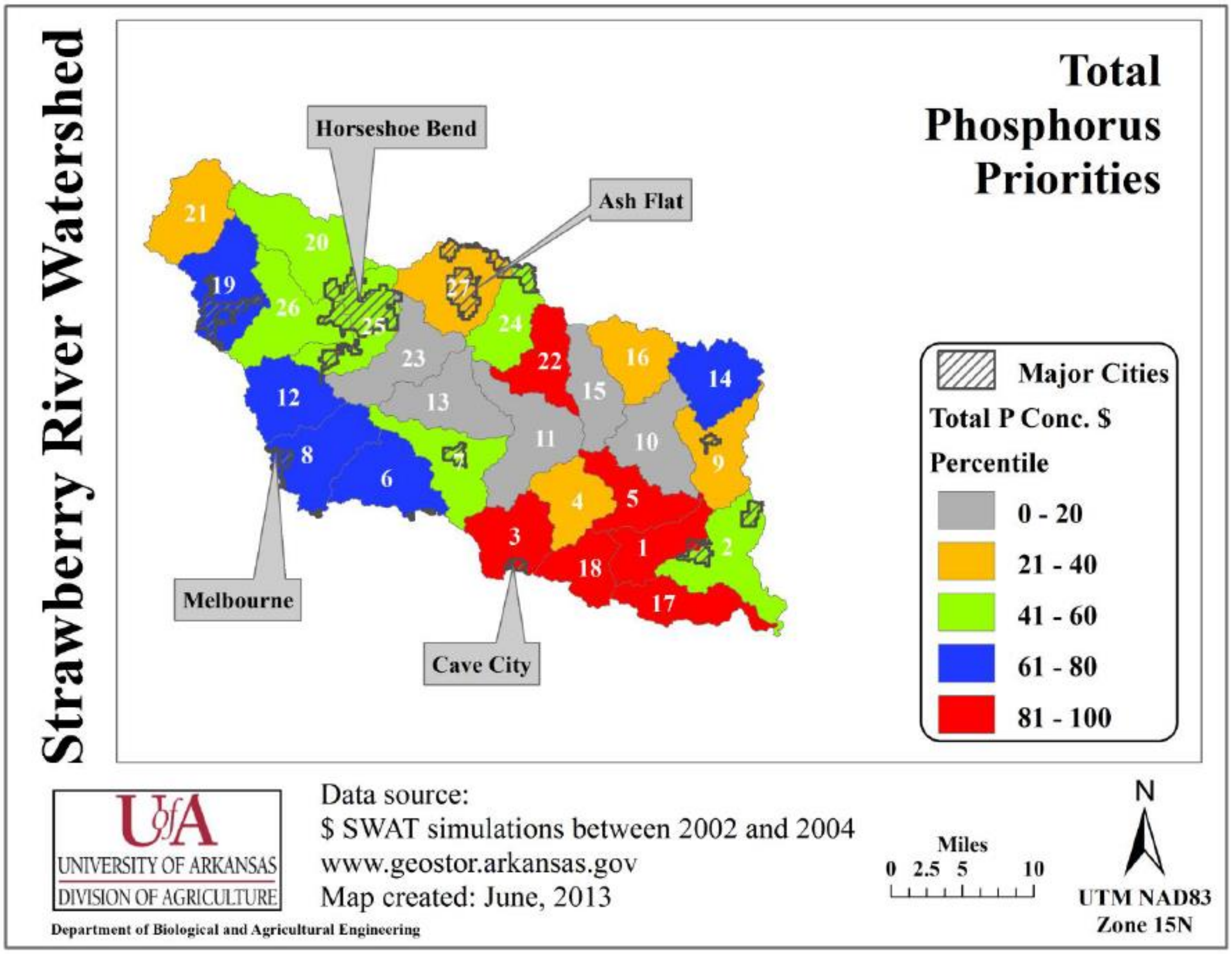


Figure 3.14. Prioritization of Strawberry River subwatersheds for total phosphorus based on SWAT model (from Saraswat, et al. 2013).

Massey et al. (2013) compared mean base flow total phosphorus concentrations measured during the period from October 2011 through March 2012, to mean base flow concentrations estimated by the SWAT model for the year 2010 around the Strawberry River watershed. No correlation was found between the measured and modeled concentrations.

3.2.1.7.3. Total Phosphorus Over Time

Entire periods of record of total phosphorus measurements collected by ADEQ, USGS, and U of A at locations in the Strawberry River watershed with data records of at least 10 years are shown on Figure 3.15. The majority of these monitoring locations are sampled only periodically. The location with the most complete data record is Strawberry River near Smithville. The total phosphorus data from all of the monitoring locations in the watershed appear to exhibit declining trends. Declining trends are most evident in the total phosphorus data from the Strawberry River at Smithville and Highway 361, and the Little Strawberry River.

3.2.1.7.4. Total Phosphorus Data Gaps

Overall, there is currently relatively good coverage of data for total phosphorus around the Strawberry River watershed. The recent data collection by the U of A has provided a large dataset of recent total phosphorus measurements that augments the routine monitoring data collected by ADEQ. A SWAT model has also been set up to predict total phosphorus loads and concentrations in the watershed. Only ADEQ has monitored water quality long term in the Strawberry River watershed at five locations. It could help expand the total phosphorus data record if any future water quality studies in the watershed would include total phosphorus monitoring.

3.2.1.7.5. Total Phosphorus Summary

- Overall, current total phosphorus concentrations in the Strawberry River watershed tend to be higher at headwater locations, lower in the middle portion of the stream, and then increase again at the downstream end.
- Total phosphorus concentrations tend to be higher in the tributaries in the lower Strawberry River watershed.
- The highest total phosphorus concentrations measured in the Strawberry River watershed were from Caney Creek.
- The estimated total phosphorus load for Caney Creek is low because the watershed for the monitoring location is small.
- The greatest estimated total phosphorus loads appear to be at the farthest upstream Strawberry River location, and at locations on the lower half of the Strawberry River, as well as in Reeds Creek.
- At all of the locations in the watershed with data records longer than 10 years, total phosphorus concentrations appear to have declined over time.

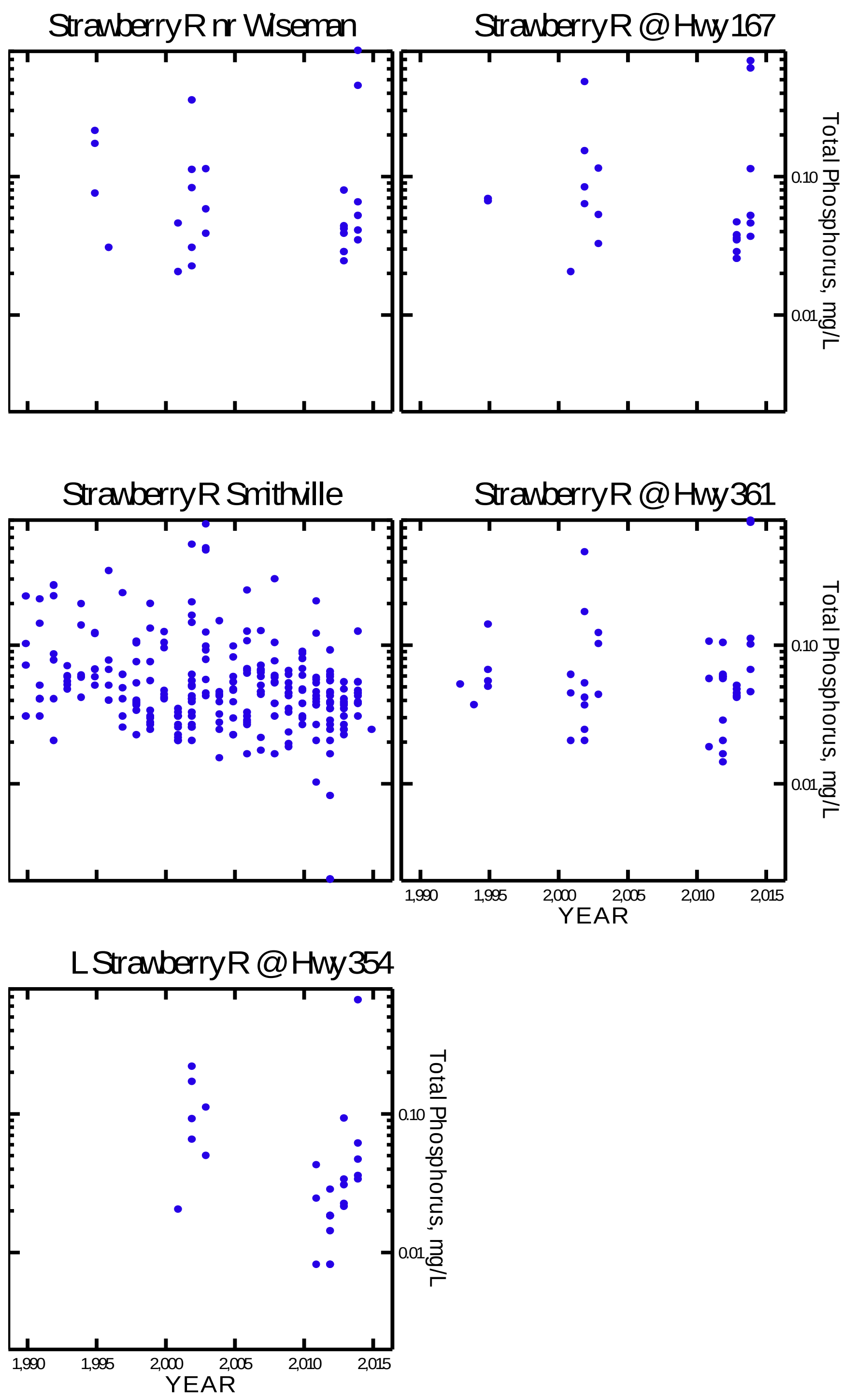


Figure 3.15. Long term total phosphorus data from the Strawberry River watershed.

3.2.2 Groundwater Quality

This section describes and discusses available groundwater quality data in the Strawberry River watershed. This includes water quality monitoring, water quality characteristics, and water quality threats.

3.2.2.1 Monitoring

Groundwater quality data have been collected in the Strawberry River watershed by ADEQ and USGS. ADEQ administers mandated groundwater monitoring programs at various sites across the state that are regulated by state and federal programs. The purpose of this monitoring is to evaluate potential and actual impacts to groundwater resulting from human activities, e.g., solid waste landfills and underground storage tanks, and natural phenomenon (ADEQ 2014).

ADEQ developed the Arkansas Ambient Ground Water Monitoring Program in 1986. This program currently consists of 12 monitoring areas and approximately 250 wells and springs throughout the state (Kresse, et al. 2014, ADEQ 2014). Eleven wells located in the Strawberry River watershed are part of the Hardy groundwater monitoring area (ADEQ 2015b). This monitoring area was established in 1998 to characterize the groundwater of the "lower Ordovician aquifers along the eastern end of the Ozark Plateaus physiographic region" (ADEQ 2014). Five of these wells have been continuously active since 1998, sampled once every five years, the last time in 2013. The remaining wells have only partial records, including three wells that were sampled only once (USGS 2014, ADEQ 2015b).

In 2002, ADEQ conducted a groundwater assessment within the Strawberry River watershed. During this assessment, groundwater samples were collected from nine springs and 53 wells within the watershed. The purposes of the assessment included evaluating the potential impact of nonpoint sources on groundwater quality, documenting the chemistry and overall quality of the groundwater, and evaluating groundwater quality trends (Kresse and Fazio 2004).

The USGS has collected groundwater quality data at 13 wells and two springs in the Strawberry River watershed. The most recent groundwater quality data collected by the USGS in the watershed is from 2002 (USGS 2014).

The periods of record for water quality data from the monitoring wells within the Strawberry River watershed that have been sampled within the last 10 years are listed in Table 3.6. A detailed water quality data inventory that includes older data is available in Appendix B.

Table 3.6. Periods of record for recently sampled groundwater quality monitoring wells in the Strawberry River watershed.

Well ID	Monitoring Agency/ Organization	Date of first sample	Date of most recent sample
SHA003	ADEQ	5/18/1998	7/16/2013
FUL007	ADEQ	5/19/1998	7/8/2013
SHA002	ADEQ	5/18/1998	7/8/2013
SHA150	ADEQ	4/11/2005	7/8/2013
SHA001	ADEQ	5/18/1998	1/28/2013
SHA017	ADEQ	5/20/1998	1/28/2013

3.2.2.2 Groundwater Quality Characteristics

Groundwater quality in the Strawberry River watershed is good with respect to drinking water standards. However, water from the Ozark aquifer tends to be hard. In the ADEQ study of groundwater quality in the Strawberry River watershed, 57 of 62 groundwater samples were classified as very hard water (Kresse and Fazio 2004).

During the 2002 ADEQ groundwater assessment, samples from 18 wells had nitrate concentrations above 1 mg/L. Samples from two of these wells (from the Ozark aquifer in Lawrence County) had nitrate concentrations greater than the 10 mg/L drinking water maximum contaminant level. Samples from all of the wells with nitrate concentrations above 1 mg/L were tested for bacterial contamination. These samples were negative for fecal coliforms and E. coli (Kresse and Fazio 2004).

Parameters measured in the groundwater samples from monitoring wells within the ADEQ Hardy Monitoring Area include hardness and inorganic nitrogen (ADEQ 2014). In the wells within the Strawberry River watershed, hardness levels have ranged from 175 to 366 mg/L. Inorganic nitrogen concentrations have ranged from 0.3 to 2.9 mg/L. Inorganic nitrogen levels greater than 1 mg/L have been measured in samples from four of the 11 wells. Note that the wells sampled by ADEQ in the Hardy study area appear to be different from the wells utilized in the ADEQ 2002 groundwater quality assessment (Kresse and Fazio 2004, USGS 2014).

3.2.2.3 Groundwater Quality Threats

The Strawberry River watershed is located within a karst region of Arkansas. In this type of geology, groundwater can be vulnerable to contamination from surface activities, such as land application of animal waste, and septic systems. Researchers have found positive correlations between the amount of pasture land within one mile of a well in the Ozark aquifer and levels of nitrate in the groundwater, and negative correlation between the amount of forest land within one mile of a well and levels of nitrate in Ozark aquifer groundwater (Kresse and Fazio 2004, Adamski 1997). A 2003 study of groundwater quality in the Strawberry River watershed concluded that the most likely source of high nitrate levels observed in some of the sampled wells was septic systems. Bacteria indicators of fecal contamination were not found in any of the groundwater samples collected during this study (Kresse and Fazio 2004).

3.2.3 Hydrologic Data

This section describes available surface water flow and groundwater level data from the Strawberry River watershed.

3.2.3.1 Surface Water Flow Data

The USGS monitors stream flow in the Strawberry River watershed. Table 3.7 lists active and historical USGS flow gages located in the watershed. There is one active USGS gage station within the Strawberry River watershed, Strawberry River near Poughkeepsie, AR. This gage is a continuous monitoring site.

Table 3.7. Active and historical USGS flow gages located within the Strawberry River watershed (USGS 2015b).

Gage No.	Stream	Continuous dates	Daily dates	Peak dates	Measurement Dates	Agency
07073000	Strawberry R.	--	3/1/1939 – 10/17/1979	4/17/1939 – 4/11/1979	9/3/1987 – 9/11/2002	07073000
07074000	Strawberry R.	10/1/2007 – 3/2/2015	4/1/1936 – 9/30/2004	10/25/1936 - 1/13/2013	10/4/1951 – 10/6/2014	07074000
07073500	Piney Fork	--	3/1/1939 – 1/30/1985	4/16/1939 – 7/12/1998	9/14/1983 – 5/21/2003	07073500
07073595	Evening Shade Spring	--	--	12-16-2001	10/18/2000 – 10/21/2002	07073595
07074200	Dry Branch Tributary	--	--	5/7/1961 – 12/3/1982	5/7/1961 – 4/23/1966	07074200
07074250	Reeds Creek	--	--	5/26/1963 – 12/3/1982	3/9/1964 – 5/22/2003	07074250
07072875	Strawberry R.	--	--	--	2/16/2001 – 5/20/2003	07072875
07072880	Little Strawberry R.	--	--	--	2/16/2001 – 5/20/2003	07072880
07072900	Strawberry R.	--	--	--	7/8/1964 – 10/5/1988	07072900
07073600	Mill Creek	--	--	--	9/18/1956 – 10/3/1988	07073600
07073995	North Big Creek	--	--	--	7/8/1964 – 5/21/2003	07073995
07074050	Mill Creek	--	--	--	2/17/2001 – 5/21/2003	07074050
07074100	Strawberry R.	--	--	--	2/17/2001 – 9/11/2002	07074100
7074248	South Big Creek	--	--	--	7/8/1964 – 5/22/2003	7074248
7074260	Cooper Creek	--	--	--	7/8/1964 – 10/19/1989	7074260
7074300	Strawberry R.	--	--	--	10/28/1965 – 10/19/1989	7074300

Smaller tributaries in the Strawberry River watershed often experience flows less than one cfs during the late summer and early fall. Larger tributaries, such as South Big Creek, and Reeds Creek, maintain flows during the drier times of the year as a result of groundwater inputs. Irrigation return flows from irrigated crop land adjacent to Caney Creek influence flows in this tributary, maintaining flow during late summer and early fall (ADEQ n.d.).

Saraswat et al. (2013) evaluated streamflow data from the USGS flow gage on the Strawberry River near Poughkeepsie (0707400). They determined that the mean annual flow rate at this gage was 15 cu m/sec, and that the flow was split evenly between groundwater base flow and surface runoff flow (Saraswat, et al. 2013).

3.2.3.2 Groundwater Levels

The USGS monitors water levels in the Ozark aquifer of north Arkansas, which underlies the Strawberry River watershed (Czarneki, Pugh and Blackstock 2014). Wells located within the Strawberry River watershed where the USGS has taken water level measurements in the last 10 years are listed in Table 3.8. Since 2001, water levels have been collected at most of these wells every three years (USGS 2015c).

Table 3.8. Periods of record for active groundwater level monitoring wells in the Strawberry River watershed (USGS 2015c).

Well ID	Date of first sample	Date of most recent sample
18N06W10CBC1	5/10/1966	11/13/2014
15N05W06DDD1	8/22/1966	2/11/2013
16N05W06DCC1	3/30/2001	2/11/2013
16N05W07AAD1	3/29/2001	2/11/2013
17N06W29ABC1	5/16/2001	2/11/2013
17N05W12BDC1	1/17/2001	2/11/2013
16N06W27ACC1	5/15/2001	2/23/2010

The USGS evaluated groundwater levels in the Ozark aquifer in northern Arkansas in 2010. During this study, water levels were measured in eight wells in the Strawberry River watershed. Water levels in the majority of these wells had declined since the previous evaluation in 2007, most less than two feet. Aquifers that experienced water level declines in wells in the Strawberry River watershed included the Everton Formation, Roubidoux Formation, and Cotter Dolomite. In one well completed in the Cotter Dolomite near Cave City, water level declined over 50 ft between 2007 and 2010. Water levels increased between 2007 and 2010 in two of the wells, one in the Gunter Sandstone and one in the Cotter Dolomite (Czarneki, Pugh and Blackstock 2014).

3.2.3.3 Surface Water Groundwater Interaction

There is significant interaction between surface water and groundwater in the Strawberry River watershed. Evaluation of groundwater levels in the watershed indicate that groundwater discharges to many of the streams in the watershed, including Strawberry River and Piney Fork (ADEQ n.d.). Groundwater also discharges to the surface as springs in the watershed.

3.2.4 Biological Data

This section describes available biological data from the Strawberry River watershed, including information on aquatic nuisance species, species of concern, and migratory patterns. The diverse and high quality biological communities present in the Strawberry River watershed have been, and continue to be, studied and documented. Entities that have conducted biological sampling in the watershed include ADEQ, EPA, ASU, and University of Arkansas at Pine Bluff (UAPB).

3.2.4.1 Benthic Macroinvertebrate Sampling

ADEQ has conducted macroinvertebrate surveys in the Strawberry River watershed in the 1990s and 2000s (Brueggen-Boman and Bouldin 2012, Harp and Robinson 2006). ADEQ conducted macroinvertebrate surveys at 35 sites in the Strawberry River watershed during the 2001 through 2003 assessment of the watershed (ADEQ n.d.). ADEQ has not collected macroinvertebrate data in the Strawberry River watershed since 2003 (ADEQ 2015c).

As part of the Wadeable Streams Assessment, EPA collected macroinvertebrates in June 2004 at a site on the Piney Fork in the Strawberry River watershed. Indices of biological condition were calculated by EPA using these data (EPA 2015a).

ASU conducted macroinvertebrates surveys and collected chlorophyll a measurements at six locations in the Strawberry and Little Strawberry River headwaters during 2009 as part of the nonpoint source project for ANRC (number 07-1000) (Brueggen-Boman and Bouldin 2012). These same sites were surveyed again by ASU researchers in 2010, 2011, and 2012 (T. R. Brueggen-Boman 2012).

Researchers from ASU, UAPB, and the Arkansas Game and Fish Commission (AGFC) have done, and continue to do, studies in the watershed to document the macroinvertebrate communities in the watershed, e.g., Harp and Robinson 2006, Robison and Beadles 1974, 2015 State Wildlife Action Plan proposals (AGFC 2015a).

3.2.4.2 Condition of Benthic Macroinvertebrate Communities

ADEQ found that the 35 sites they sampled in the Strawberry River watershed in 2002 and 2003 were fully supporting ecoregion reference macroinvertebrate communities. However, there were several locations where the macroinvertebrate communities appeared to be impacted by one or more stressors, however, the communities were still not significantly different from the ecoregion reference. At the Strawberry River near Horseshoe Bend (WHI0143B) the macroinvertebrate community was altered due to the impacts of increased periphyton production, sedimentation, and loss of instream habitat from eroding streambanks, cattle in the stream, and pasture runoff. The macroinvertebrate communities at sampling sites on Mill Creek (WHI0143N), North Big Creek (UWNBC01), lower Piney Fork (WHI0143M), upper Big South Creek (WHI0143K), and the lower Little Strawberry River (WHI0143H) were impacted by similar stressors, as well as lower than normal flow in the spring. The Ash Flat wastewater treatment plant (WWTP) on North Big Creek impacted the macroinvertebrate community up to three miles downstream (ADEQ n.d.).

Benthic macroinvertebrate communities surveyed by ASU at four sites in the headwaters of the Strawberry River and two sites on the Little Strawberry River from 2009 through 2012 were evaluated by Brueggen-Boman (2012). Comparison of benthic macroinvertebrate indices from these communities to indices from communities typical of Ozark Highlands reference streams, and the Arkansas Macroinvertebrate Index for Small Watersheds, indicated habitat and water quality impairment at the sampling locations. In addition, Brueggen-Boman compared the benthic macroinvertebrate indices calculated from the 2009 through 2012 collections to indices calculated from ADEQ collections at nearby locations on the same streams from 1995, 2002, and 2003. She found statistically significant differences in the indices from the historical and recent collections, indicating increasing impacts and declining habitat and water quality over time (T. R. Brueggen-Boman 2012).

3.2.4.3 Fish Sampling

ADEQ conducted fish community surveys at 19 sites in the Strawberry River watershed during the 2001 through 2003 assessment of the watershed (ADEQ n.d.). ADEQ also conducted fish community surveys at two sites in the watershed during a 2011 aquatic life study and in 2013 as an ecoregion reference (ADEQ 2015d). Researchers from ASU, UAPB, and the Arkansas Game and Fish Commission (AGFC) have done, and continue to do, studies in the watershed to document the fish communities in the watershed, e.g., Harp and Robinson 2006, Robison and Beadles 1974, 2015 State Wildlife Action Plan proposals (AGFC 2015a).

3.2.4.4 Condition of Fisheries

ADEQ collected 86 fish species from 19 sites during their intensive study of the watershed in 2002 – 2003. Over 50% of the fish collected were minnows or shiners, and almost 25% were stonerollers. Darters accounted for 21% of the fish collected, and 18% of the fish collected were sunfish. Approximately 13% of the fish collected in the watershed were longear sunfish. This fish community composition is somewhat different from the average fish community composition of the Ozark Highlands ecoregion reference streams. The reference streams generally have a greater abundance of minnows and madtoms, and fewer sunfish and darters. However, there is no indication in this data that the fish communities in the Strawberry River watershed are impaired. Fish community metric scores calculated from this fish collection effort indicated that all of the sites sampled were supporting the appropriate ecoregion reference fishery (ADEQ n.d.).

ADEQ conducted fish community sampling at four sites on North Big Creek to evaluate the effect of the Ash Flat WWTP. There were some slight differences in community composition upstream versus downstream of the WWTP. However, the sites both upstream and downstream of the WWTP were determined to be supporting a typical Ozark Highlands ecoregion fishery (ADEQ n.d.).

3.2.4.5 Chlorophyll Sampling

ASU collected chlorophyll a measurements at six locations in the Strawberry and Little Strawberry River headwaters during 2009 as part of the nonpoint source project for ANRC (number 07-1000) (Brueggen-Boman and Bouldin 2012). The highest mean chlorophyll a concentration was measured at the upstream site on the Little Strawberry River (LSUP). This was the only site where chlorophyll a concentrations were measured that exceeded the reference stream mean of 2.67 ug/L. The lowest mean chlorophyll a concentration was measured at the upstream site on Greasy Creek (GCUP). The mean chlorophyll a concentration at the upstream Little Strawberry River was statistically significantly greater than the mean chlorophyll a concentration at the downstream Little Strawberry River site (LSLO). The mean chlorophyll a concentration at the upstream Greasy Creek site was statistically significantly lower than the mean chlorophyll a concentration at the downstream Greasy Creek site (GCLO). Overall, chlorophyll a concentrations were highest in the summer months (T. R. Brueggen-Boman 2012).

3.2.4.6 Aquatic Nuisance Species

The only state identified aquatic nuisance species that has been found in the Strawberry River watershed is the Asian Clam (*Corbicula fluminea).*

3.2.4.7 Species of Concern

A number of protected species occur in the Strawberry River watershed (see Section 2.1.12). The Arkansas Game and Fish Commission has identified additional non-plant species of greatest conservation need in the state, and Arkansas Natural Heritage Commission has identified rare plant and animal species for the state. These species of concern that are known to occur in the Strawberry River watershed are listed in Table 3.9.

Table 3.9. Species of concern from the Strawberry River watershed (AGFC 2015b, Arkansas Natural Heritage Commission 2014, NatureServe 2015, Harp and Robison 2006).

Common name	Scientific name	Category	USGS	State Rank	Counties
Ouachita Diving Beetle	*Heterosternuta ouachitus*	Insect	None	Very rare	Izard
Giant Stag Beetle	*Lucanus elaphus*	Insect	None	Very rare	Lawrence
Westfall's Snaketail	*Ophiogomphus westfalli*	insect	None	Extremely to very rare	Fulton, Izard, Sharp
Purple Wartyback	*Cyclonaias tuberculata*	Invertebrate	None	Rare to uncommon	Fulton, Izard, Lawrence, Sharp
Western Fanshell	*Cyprogenia aberti*	Invertebrate	SGCN	Very rare	Fulton, Izard, Lawrence, Sharp
Flutedshell	*Lasmigona costata*	Invertebrate	None	Very rare	Fulton, Izard, Lawrence, Sharp
Black sandshell	*Ligumia recta*	Invertebrate	None	Very rare	Fulton, Lawrence, Sharp
Southern Hickorynut	*Obovaria jacksoniana*	Invertebrate	None	Very rare	Lawrence, Sharp
Coldwater Crayfish	*Orconectes eupunctus*	Invertebrate	SGCN	Very rare	Fulton, Lawrence, Sharp
Ouachita Kidneyshell	*Ptychobranchus occidentalis*	Invertebrate	SGCN	Rare to uncommon	Fulton, Izard, Lawrence, Sharp
Monkeyface	*Quadrula metanevra*	Invertebrate	None	Rare to uncommon	Fulton, Lawrence, Sharp
Salamander Mussel	*Simpsonaias ambigua*	Invertebrate	SGCN	Extremely rare	Lawrence, Sharp
Squawfoot	*Strophitus undulatus,*	Invertebrate	None	Rare to uncommon	Information unavailable
Purple Lilliput	*Toxolasma lividum*	Invertebrate	SGCN	Very rare	Fulton, Izard, Lawrence
Bleedingtooth Mussel	*Venustaconcha pleasii*	Invertebrate	SGCN	Rare to uncommon	Izard, Lawrence, Sharp
Little Spectaclecase	*Villosa lienosa*	Invertebrate	None	Rare to uncommon	Fulton, Izard, Lawrence, Sharp
Western Wallflower	*Erysimum capitatum var. capitatum*	Plant	None	Very rare	Sharp
Leafy Barbara's-Buttons	*Marshallia caespitosa var. signata*	Plant	None	Extremely rare	Sharp
Celestial Lily	*Nemastylis geminiflora*	Plant	None	Rare to uncommon	Fulton, Izard, Lawrence, Sharp
Riddell's Goldenrod	*Oligoneuron riddellii*	Plant	None	Very rare	Sharp
Large Indian Breadroot	*Pediomelum esculentum*	Plant	None	Very rare	Fulton, Izard, Sharp
Showy Beardtongue	*Penstemon cobaea*	Plant	None	Rare to uncommon	Fulton, Izard, Sharp

Table 3.9. Species of concern from the Strawberry River watershed (continued).

Common name	Scientific name	Category	USGS	State Rank	Counties
American Squaw-Root	*Perideridia americana*	Plant	None	Very rare	Lawrence, Sharp
Brand's Scorpion-Weed	*Phacelia gilioides*	Plant	None	Very rare to uncommon	Lawrence
Capillary Beaksedge	*Rhynchospora capillacea*	Plant	None	Very rare	Sharp
Elliott's Sida	*Sida elliottii*	plant	none	Very rare to uncommon	Izard, Lawrence, Sharp
Shining Ladies'-Tresses	*Spiranthes lucida*	Plant	none	very rare	izard, Sharp
Ringed Salamander	*Ambystoma annulatum*	Vertebrate	None	Rare to uncommon	Sharp
Western Sand Darter	*Ammocrypta clara*	Vertebrate	None	Very rare	Lawrence
Northern Scarletsnake	*Cemophora coccinea copei*	Vertebrate	None	Rare to uncommon	Izard, Sharp
Rafinesque's Big-eared Bat	*Corynorhinus rafinesquii*	Vertebrate	None	Rare to uncommon	Lawrence
Crystal Darter	*Crystallaria asprella*	Vertebrate	None	Very rare	Lawrence
Spotfin Shiner	*Cyprinella spiloptera*	Vertebrate	None	Extremely rare	Izard, Lawrence
Ozark Chub	*Erimystax harryi*	Vertebrate	None	Rare to uncommon, believed extirpated in strawberry River watershed	Fulton, Izard, Lawrence, Sharp
Strawberry River Darter	*Etheostoma fragi*	Vertebrate	SGCN	Extremely rare	Fulton, Izard, Sharp
Bald Eagle	*Haliaeetus leucocephalus*	Vertebrate	None	Very rare	Fulton, Izard, Lawrence, Sharp
Least Brook Lamprey	*Lampetra aepyptera*	Vertebrate	SGCN	Very rare	Fulton, Izard, Lawrence, Sharp
American Brook Lamprey	*Lethenteron appendix*	Vertebrate	SGCN	Very rare	Izard, Sharp
Ozark Shiner	*Notropis ozarcanus*	Vertebrate	SGCN	Very rare	Izard, Lawrence, Sharp
Sabine Shiner	*Notropis sabinae*	Vertebrate	SGCN	Very rare	Izard, Lawrence, Sharp
Stargazing Darter	*Percina uranidea*	Vertebrate	SGCN	Rare to uncommon	Lawrence
Southern Cavefish	*Typhlichthys subterraneus*	Vertebrate	None	Extremely rare	Fulton

3.2.4.8 Migratory Patterns

Arkansas is located within the Mississippi Flyway bird migration route. The route is utilized by a wide variety of bird species including shorebirds, waterfowl, raptors, and songbirds. Monarch butterflies also pass through the state on their migrations.

3.2.4.9 Data Gaps

There has not been widespread biological assessment of water quality in the Strawberry River watershed since 2003. It would be useful to conduct biological assessments of impaired stream reaches to determine if the water quality impairments are impacting aquatic communities. A couple of proposed studies may provide some current information on fishery and/or macroinvertebrate communities in the watershed.

3.2.4.10 Biological condition Summary

- Benthic macroinvertebrate indices indicate that habitat condition and water quality have declined at sites on the upper Strawberry River and the upper Little Strawberry River.
- Fish communities evaluated at locations in the Strawberry River watershed during 2002-2003 indicated support of ecoregion appropriate fisheries.
- One Arkansas nuisance aquatic species has been identified in the Strawberry River watershed; Asian clam.

3.2.5 Stream Survey Data

Stream survey data include aspect, channel type, bedload, substrate, streambank stability, slump potential, large woody debris, and riparian vegetation. This data can be used to create maps of areas of concern such as slumping, wetlands, and erosion, as well as to establish trends within the watershed. Stream surveys within the Strawberry River watershed are described below.

ADEQ collects data on stream habitat when sampling macroinvertebrates and fish. See information on ADEQ macroinvertebrate and fish sampling in the Strawberry River watershed in Section 2.3. Information collected includes condition of streambanks, riparian vegetation, stream sinuosity, substrate, stream alteration, and index of habitat integrity (ADEQ 2015c,d). ADEQ also conducted a streambank stability survey along the Strawberry River, North Big Creek, and Piney Fork Creek in 2001 as part of their intensive study of the Strawberry River watershed. This survey identified 190 areas with unstable streambanks, a total of approximately 18.7 miles of unstable streambank (ADEQ n.d.).

ASU researchers evaluated streambank stability at selected locations along the Little Strawberry River and Strawberry River during 2010 through 2012.The areas evaluated were the stream segments between the project paired water quality sampling sites within the upper Strawberry River watershed. Annual assessments of the condition of streambanks along these stream segments were conducted (Brueggen-Boman and Bouldin 2012, T. R. Brueggen-Boman 2012). They found active erosion along 5% to 18% of the stream lengths evaluated, erosion rates of 24 millimeter/year to 81 mm/year (T. R. Brueggen-Boman 2012).

As part of the Wadeable Streams Survey, EPA collected information on the condition of riparian vegetation, streambed stability, bed sediment condition, and instream cover in Piney Fork in January 2004 (EPA 2015a).Interpretation of the results of these measurements was not available.

4.0 POLLUTANT SOURCE ASSESSMENT

This section summarizes available information on pollutant sources that are present in the watershed. This includes both nonpoint sources and point sources. The information presented in this section will be used to identify management strategies that can be implemented toimprove water quality.

4.1 Nonpoint Sources

Nonpoint source pollution generally results from pollutants associated with precipitation, land runoff, infiltration, drainage, seepage, hydrologic modification, or dry atmospheric deposition. As runoff from rainfall or snowmelt moves, it picks up and transports pollutants resulting from human activity, ultimately depositing them into rivers, lakes, wetlands, and groundwater. Nonpoint sources that have been identified for the Strawberry River watershed include runoff from confined animal agriculture operations, and erosion from pasture, unpaved roads, streambanks, stream channels, and silviculture (ANRC 2011, Izard County Conservation District 2001, Lawrence and Sharp County Conservation Districts 2008, ADEQ n.d., ADEQ 2014).

4.1.1 Animal Agriculture

Cattle grazing practices have been identified as a source of sediment impacting turbidity in the Strawberry River watershed (Izard County Conservation District 2001, Lawrence and Sharp County Conservation Districts 2008). Allowing cattle unrestricted access to pasture streams for drinking water and summer cooling has been a common practice at farms in the watershed (Fulton County Conservation District n.d.). In addition to allowing pollution of the stream by livestock waste, this practice can damage riparian and stream habitat, and change channel morphometry. These changes can cause changes in the stream sediment regime which can alter stream habitat downstream (Agourdis, et al. 2005) (Hoorman and McCutcheon 2005). Use of streams in the watershed by cattle has also been linked to spread of disease within herds, and potentially among farms (Fulton County Conservation District n.d., Brueggen-Boman and Bouldin 2012).

Animal waste management for dairy and poultry operations has been identified as an issue (Izard County Conservation District 2001, Lawrence and Sharp County Conservation Districts 2008). Sources of E. coli causing surface water impairments are believed to be runoff from pastures where cattle have grazed and/or pastures where animal wastes have been applied as fertilizer (Fulton County Conservation District 2008). There are five farms in the watershed with state permits for land disposal of animal waste, four in Izard County, and one in Fulton County (ADEQ 2015a).

Poultry operators in the Strawberry River watershed land apply manure from their poultry houses. This practice has the potential to create problems with excess nutrients (Fulton County Conservation District 2008). In Northwest Arkansas, an area with similar hydrogeology, this practice has resulted in nutrient issues in both surface water and groundwater. Peco Foods is constructing a new poultry plant and feed mill in Pocohontas, Arkansas. This action appears to be spurring recent expansion of poultry operations in northern Arkansas, including the Strawberry River watershed. As a result, poultry litter has the potential to become a greater problem in the watershed.

Recent livestock and poultry numbers reported by the USDA National Agricultural Statistics Service for the counties of the Strawberry River watershed are compared to numbers from 2002 in table 4.1. There have been some significant changes in livestock numbers during the ten years from 2002 to 2012. Numbers of cattle in the portion of these counties within the watershed were estimated for 2002 by Saraswat et al. (2013) for the SWAT model. These estimates are listed in Table 4.2. Cattle and poultry litter were included as sources of nutrients in the Strawberry River SWAT model (Saraswat, et al. 2013).

Table 4.1. Livestock inventories for counties of the Strawberry River watershed.

Livestock number (num per sq mi)	Fulton		Izard		Lawrence		Sharp	
	2002[a]	2012[b]	2002[a]	2012[b]	2002[a]	2012[b]	2002[a]	2012[b]
Cattle & calves	51,265 (82.93)	39,345 (63.65)	35,607 (70.00)	30,079 (59.13)	22,237 (37.91)	18,109 (30.87)	31,940 (52.85)	30,119 (49.84)
Beef cows	24,057 (38.92)	17,250 (27.91)	18,101 (35.58)	14,565 (28.63)	10,467 (17.84)	9,660 (16.47)	D[c]	14,824 (24.53)
Milk cows	755 (1.22)	320 (0.52)	255 (0.50)	182 (0.36)	0	0	D[c]	0
Swine	160 (0.26)	353 (0.57)	D[c]	D[c]	363 (0.62)	77 (0.13)	214 (0.35)	47 (0.08)
Horses	1,127 (1.82)	1,006 (1.63)	1,040 (2.04)	1,063 (2.09)	750 (1.28)	573 (0.98)	1,058 (1.75)	670 (1.11)
Chickens	+1,073 (1.74)	2,382 (3.85)	+1,208,250 (2,375)	1,611,295 (3,168)	+1,542,907 (2,630)	+975,060 (1,662)	2,887,814 (4,778)	3,465,499 (5,734)
Layers	947 (1.53)	1,908 (3.09)	D[c]	1,431 (2.81)	D[c]	D[c]	425,190 (703.6)	285,521 (472.4)
Pullets	126 (0.20)	181 (0.29)	D[c]	144 (0.28)	82 (0.14)	D[c]	255,116 (422.1)	167,597 (277.3)
Broilers	D[c]	293 (0.47)	1,208,250 (2,375)	1,609,720 (3,165)	1,542,825 (2,630)	975,060 (1,662)	2,207,508 (3,653)	3,012,381 (4,984)
Goats	94 (0.15)	3,301 (5.34)	D[c]	161 (0.32)	48 (0.08)	718 (1.22)	14 (0.02)	680 (1.13)
Sheep	395 (0.64)	735 (1.19)	98 (0.19)	136 (0.27)	127 (0.22)	69 (0.12)	126 (0.21)	140 (0.23)

[a] (USDA National Agricultural Statistics Service 2004)
[b] (USDA National Agricultural Statistics Service 2014)
[c] data withheld by USDA NASS to avoid disclosure of data for individual farms
Note: + indicates that this sum excludes data withheld to avoid disclosure of data for individual farms.

Table 4.2. Livestock estimates for Strawberry River watershed SWAT model. (Saraswat, et al. 2013).

County	Cattle population numbers		Cattle population in Strawberry R watershed
	Average	Standard deviation	
Fulton	52,167	3,545	4,777
Izard	30,167	2,401	6,036
Lawrence	18,617	1,942	10,903
Sharp	31,667	1,835	17,839
Total	187,617	19,210	39,555

Every 5 years the NRCS conducts state and national resource assessments to assess major concerns of agricultural practices on the environment. There are nine major resource concerns, ranging from soil erosion and soil quality degradation to water quality degradation and inadequate habitat for fish and wildlife to air quality degradation. The latest resource assessment for Arkansas was conducted in 2011. NRCS is currently planning for the 2016 resource assessment. The state resource assessments are conducted at the 12-DIGIT HUC watershed scale, which is consistent with the scale used by the ANRC for watershed management. Most of the major resource concerns are partitioned to account for specific factors contributing to the resource concern. For example, the soil erosion major resource concern is partitioned into sheet/rill/wind erosion; concentrated flow erosion, or gully formation; and streambank erosion. Multiple variables are considered as part of the resource concern assessment. For sheet/rill/wind erosion, the resource assessment considers: 1) parameters affecting soil erosion such as rainfall runoff erosivity factor (R), soil erodibility factor (K), slope length and steepness factor (LS), and a transport factor (T); 2) a soil erodibility class obtained from the state SURGO soils database; 3) soil vulnerability class; and 4) streams on the state 303(d) list that are impaired because of sediment related variables, such as turbidity. Similarly, concentrated flow erosion considers RKLST, soil vulnerability class, field observations and measurements, and 303(d) listed streams because of sediment related variables.

The NRCS relative ranking of the impacts of animal manure on surface water quality for the Strawberry River 12-digit HUC subwatersheds is shown on Figure 4.1. In this figure, green indicates little or no impact and red indicates a high potential for impact.

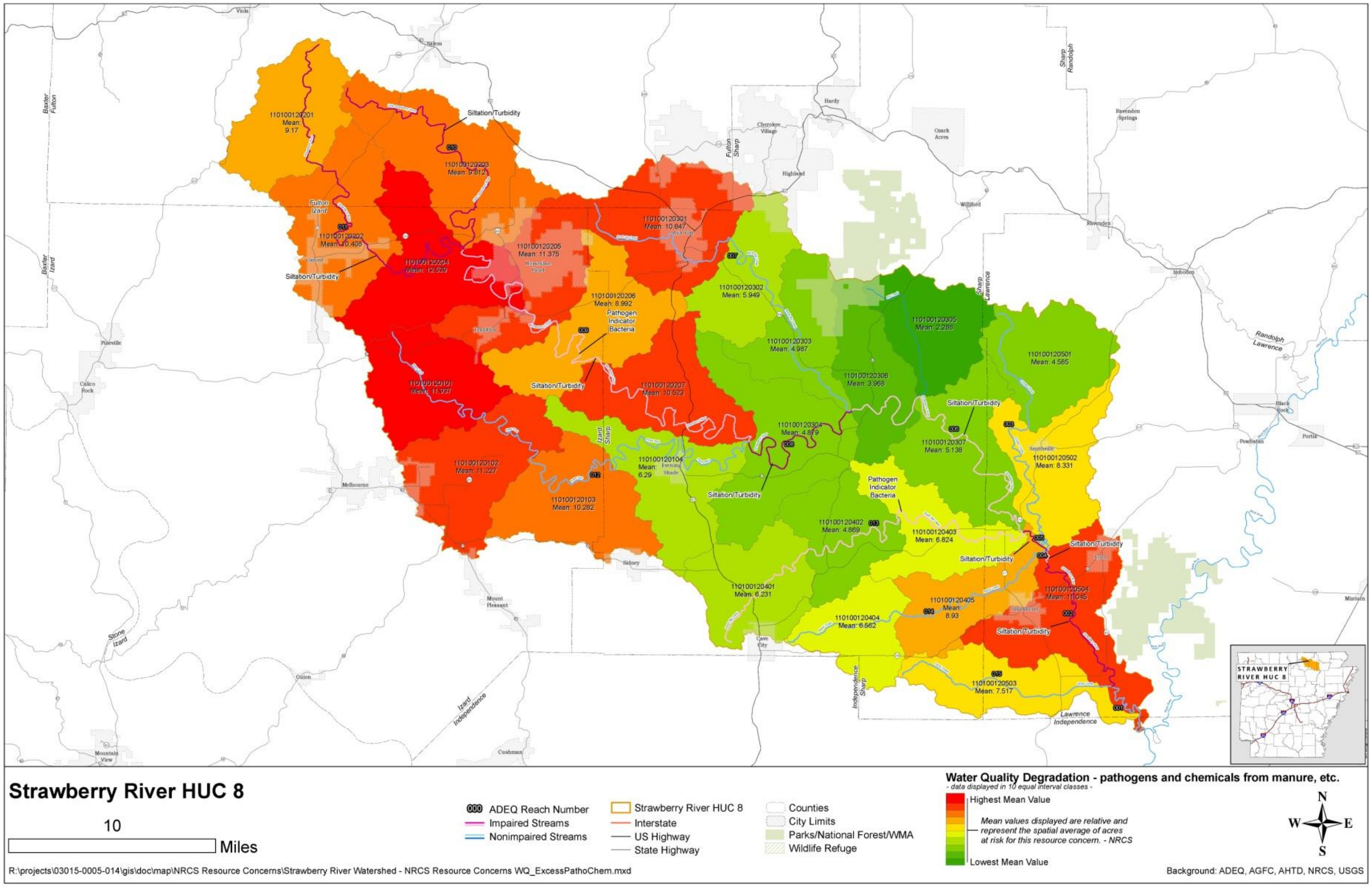


Figure 4.1. Rankings of 12-digit HUC subwatersheds of the Strawberry River based on the potential for water quality impacts from animal manure.

4.1.2 Pasture

ADEQ has identified surface erosion as the source of turbidity and bacteria causing impairment of stream segments in the Strawberry River watershed (see Tables 3.3 and 3.4). Poor quality pasture has been identified as a nonpoint source of pollution in the Strawberry River watershed (Izard County Conservation District 2001, Lawrence and Sharp County Conservation Districts 2008). The most fertile and least sloped land in most of the watershed occurs along streams, so much of this land has been cleared for pasture. In most cases, the land has been cleared all the way to the water's edge to maximize acreage (Fulton County Conservation District 2002). This practice maximizes the conveyance of eroded soils from pastures to streams. In the late 1970's ANRC (then the Arkansas Soil and Water Conservation Commission), estimated that gully and sheet and rill erosion contributed 79% of eroded sediment to surface waters in the Strawberry River watershed. A 2000 survey of potential nonpoint sources in the Strawberry River watershed conducted by the Fulton County Conservation District found 31% of pasture in poor condition and only 2% in excellent condition. The Fulton County Conservation District determined that approximately 65% of pasture erosion occurred on poor quality pasture (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003). Since this review, several projects to improve pasture condition in the watershed have been conducted. In 2011, 29% of the watershed was classified as hay or pasture land cover (Homer, et al. 2015).

The USGS conducted an evaluation of fisheries in the Ozark Plateaus National Water Quality Assessment (NAWQA) Program using data collected from 1992 through 1995. Analysis of these data found lower percentages of sunfish, black bass, and darters at sampling locations just downstream or within pasture areas, than at sites within forested areas. Sunfish, black bass, and darters tend to be sensitive to degradation of stream water quality or habitat. The analysis of the NAWQA data found that fish community composition in the Ozark Plateaus was related to stream size, canopy, the makeup of the stream bottom, and water quality (Petersen, et al. 1998).

During the 2001-2002 intensive water quality survey, ADEQ found that the majority of the exceedences of E. coli criteria occurred during high flow events associated with large storms. This pattern is consistent with the belief that storm runoff from pasture contributes E. coli to the surface waters of the Strawberry River watershed. ADEQ also found that higher nitrate concentrations in groundwater occurred in wells where over 30% of the land within a one mile radius was agricultural land (i.e., pasture) (ADEQ n.d., Kresse and Fazio 2004).

Massey et al. (2013) analyzed water quality and land use data to determine if a correlation could be found between the two. No relationships were identified between land use characteristics of subwatershed and levels of nitrate nitrogen, total phosphorus, or TSS (Massey, et al. 2013).

The NRCS relative rankings for sheet/rill/wind erosion and for concentrated flow erosion (i.e., potential gully formation) in the Strawberry River 12-digit HUC subwatersheds are shown on Figures 4.2 and 4.3. On these figures, watersheds colored red have the highest potential for erosion.

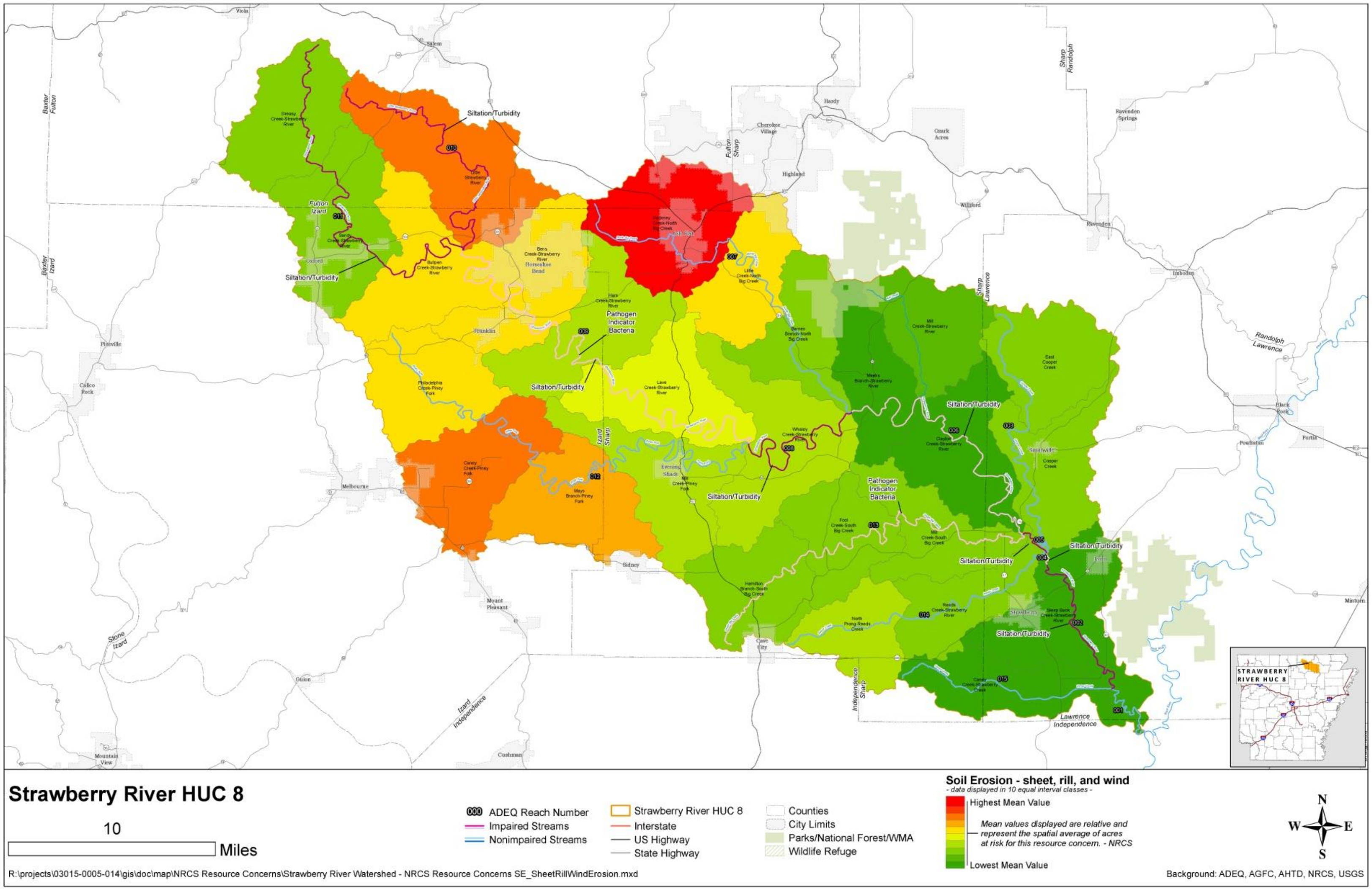


Figure 4.2. Rankings of 12-DIGIT HUC subwatersheds of the Strawberry River based on the potential for sheet/rill,/wind erosion.

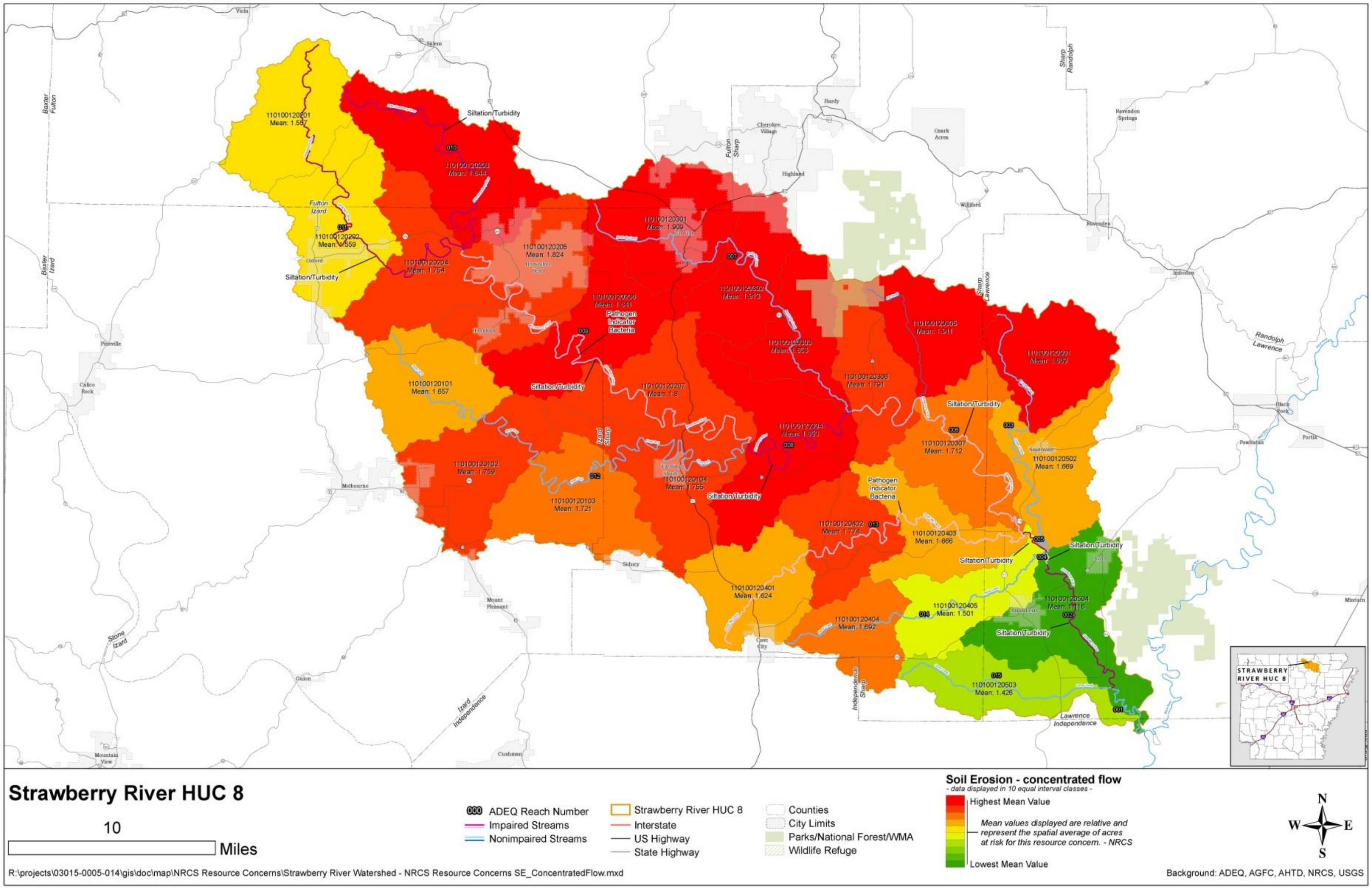


Figure 4.3. Rankings of 12-DIGIT HUC subwatersheds of the Strawberry River based on potential for concentrated flow erosion.

4.1.3 Cropland

Only 1.3% of the land in the Strawberry River watershed was classified as cultivated cropland in 2012, and the most prevalent crop was forage. The majority of the land in row crop production in the watershed is located in the lower watershed, in Lawrence County, where the Strawberry River crosses the Mississippi Alluvial Plain (Delta) before joining the Black River. Table 4.3 summarizes information on cropland for the counties that are part of the Strawberry River watershed, from the most recent Census of Agriculture.

Irrigation runoff from cropland affects the flow regime of Caney Creek (ADEQ n.d.). High phosphorus concentrations observed in Caney Creek could possibly be a result of the influence of irrigation runoff.

Table 4.3. Agricultural statistics for counties in the Strawberry River watershed (USDA National Agricultural Statistics Service 2014).

Crop	Fulton County	Izard County	Lawrence County	Sharp County
Forage	18,459	17,103	14,296	16,189
Grass seed	99	-	-	-
Vegetables	26	30	D*	49
Rice	-	-	74,009	-
Soybeans	-	-	68,171	-
Wheat	-	D*	6,523	-
Watermelons	3	D*	-	45

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

4.1.4 Streambank Erosion

There are approximately 2,400 miles of streambanks (i.e., 2 * stream miles) in the Strawberry River watershed (Center for Advanced Spatial Technologies 2006). Streambank erosion, particularly during high flow events, has been identified as a source of sediment that contributes to turbidity in the Strawberry River watershed. Stakeholders state that streambank erosion is widespread in the watershed (Perez, Higgins and Freyaldenhoven 2015; Stakeholder meeting 8/27/2015, Ash Flat, Arkansas). In the upper Strawberry River watershed, soil structure is such that, when water levels fall rapidly after storm flows, saturated banks collapse. Streambanks are more susceptible to this erosive force where landowner activities have reduced the streambank vegetation (Fulton County Conservation District 2008).

In the late 1970's ANRC (then the Arkansas Soil and Water Conservation Commission), estimated that streambanks contributed 14% of eroded sediment to surface waters in the Strawberry River watershed. A streambank inventory was conducted in the Strawberry River watershed in 2000. At that time, 44,759 ft of eroding streambank was identified, with an average streambank height of 11.9 ft. Based on this survey, it was estimated that streambank erosion contributed 25,000 to 50,000 tons of sediment per year to the Strawberry River (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003).

Over the period 2001 through 2003, ADEQ conducted a streambank stability survey and an intensive streambank survey. Streambanks along the Strawberry River, North Big Creek, Piney Fork Creek, and South Big Creek were surveyed. The streambank stability survey identified approximately 18.7 miles (98,736 ft) of unstable streambanks in the watershed. The intensive streambank survey was conducted along a 425 ft stretch of the Strawberry River determined to have very high bank erosion potential. The results of the intensive survey were extrapolated to estimate soil loss due to erosion of streambanks along the Strawberry River; approximately 65 cubic yards per year (ADEQ n.d.).

In 2010 and 2011, ASU researchers surveyed streambanks along the upper Little Strawberry and Strawberry Rivers. Overall, approximately 15% of the streambanks surveyed exhibited severe to very severe erosion (Table 4.4). The highest percentage of streambanks with severe erosion was found along the Little Strawberry River (Brueggen and Bouldin 2011).

Table 4.4. Summary of results of ASU 2010, 2011 streambank survey in the upper Strawberry River watershed (Brueggen and Bouldin 2011).

Stream name	Surveyed reach	Length of surveyed reach, km	Length of streambank surveyed, km	Length of streambank with severe to very severe erosion, km (%)
Little Strawberry R	LSUP to LSLO	2.74	5.48	1.74 (32%)
Strawberry R	GCUP to GCLO	3.17	6.34	1.08 (17%)
Strawberry R	SCUP to SCLO	6.63	13.2	1.02 (8%)
Total		12.54	25.02	3.84 (15%)

Streambank erosion is another resource concern evaluated by NRCS. The NRCS Arkansas resource assessment for streambank erosion considered factors related to soil erodibility, slope length and steepness, soil vulnerability, 303(d) listed streams with sediment related impairment, vegetative buffering of riparian habitat, and stream visual assessment protocol scores. The relative ranking of 12-digit HUC subwatersheds of the Strawberry River in terms of the potential for streambank erosion is shown on Figure 4.4. Subwatersheds with high potential for streambank erosion are shown in red. Darkest red indicates the presence of the greatest potential for streambank erosion.

4.1.5 Stream Channel Erosion

The ADEQ assessment of the intensive data collected during 2001 through 2003 found that, overall, maximum turbidity and TSS measurements from tributaries were greater in the upper watershed, and that the number of exceedences of turbidity criteria at tributary monitoring sites gradually declined moving downstream. It was concluded that this was at least partly due to differences in the geology of the upper and lower watershed. Tributaries in the upper watershed flow through sandstone, which is easily eroded, while those in the lower watershed flow through dolomite, which is more resistant to erosion (ADEQ n.d.).

4.1.6 Septic Systems

During the 2001-2002 intensive assessment of water quality in the Strawberry River watershed, ADEQ concluded that high nitrate concentrations measured in two wells was most likely the result of failing septic systems (ADEQ n.d.).

The Fulton County Conservation District conducted a survey of septic systems in the Strawberry River watershed. They determined that approximately 8% of septic tanks in the watershed were failing, and estimated the number of failing septic tanks to be between 300 and 350. Overall, they determined that septic tanks were not likely to be a watershed scale water quality issue (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003). Since that time, the number of septic systems may have declined, as a result of expansion of municipal wastewater systems. There are 3 permitted no discharge systems (i.e., septic systems) within the Strawberry River watershed (Table 4.5).

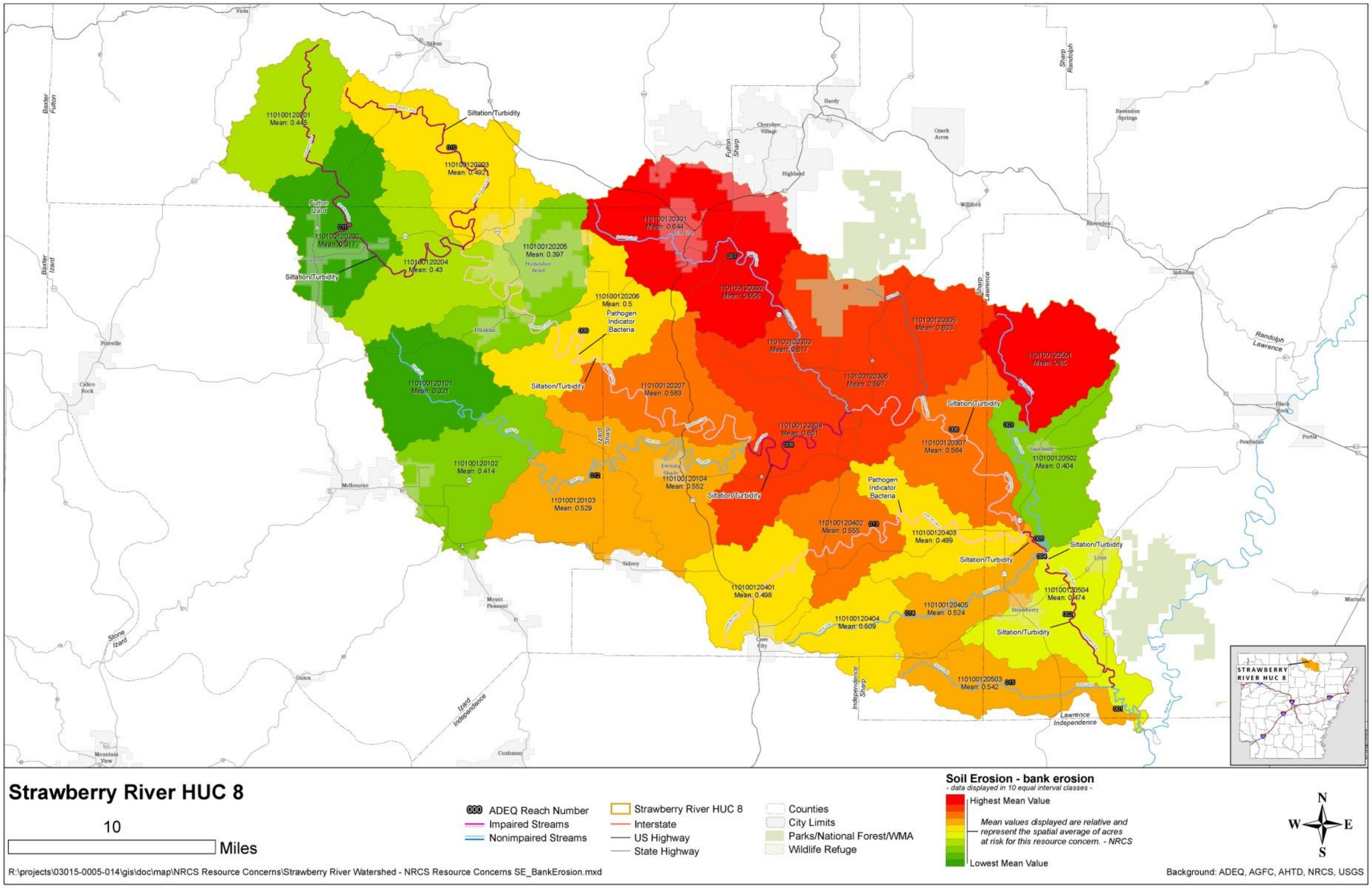


Figure 4.4. 12-digit HUC subwatersheds of the Strawberry River were ranked by NRCS for the presence of streambank erosion based on the 2011 natural resources inventory.

Table 4.5. Summary of permitted no discharge systems in the Strawberry River watershed.

County	Municipal	Industrial
Izard	1	1
Sharp	1	0
Total	2	1

4.1.7 Unpaved Roads

Erosion of unpaved roads has been identified as a source of sediment that can contribute to turbidity in the Strawberry River watershed (Sharp County Conservation District 2004, Izard County Conservation District 2003, Izard County Conservation District 2001, Fulton County Conservation District 2008). In the late 1970's ANRC (then the Arkansas Soil and Water Conservation Commission), estimated that roads contributed 7% of eroded sediment to surface waters in the Strawberry River watershed. An inventory of unpaved roads in Sharp County determined that approximately 1% of the roadways exhibited severe erosion, 13% exhibited moderate erosion, 59% exhibited slight erosion, and 27% had little or no erosion (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003). During the period 2004 – 2007, TNC inventoried and characterized the condition of unpaved roads in the Strawberry River watershed (Inlander et al. 2007). As part of this project, sediment contributions from unpaved roads were modeled (Inlander 2009). The results of this modeling are illustrated in Figure 4.5.There are currently around 1,363 miles of unpaved roads in the Strawberry River watershed (Center for Advanced Spatial Technologies 2006). Table 4.6 lists the miles of unpaved roads for each of the 12-digit HUC subwatersheds of the Strawberry River watershed.

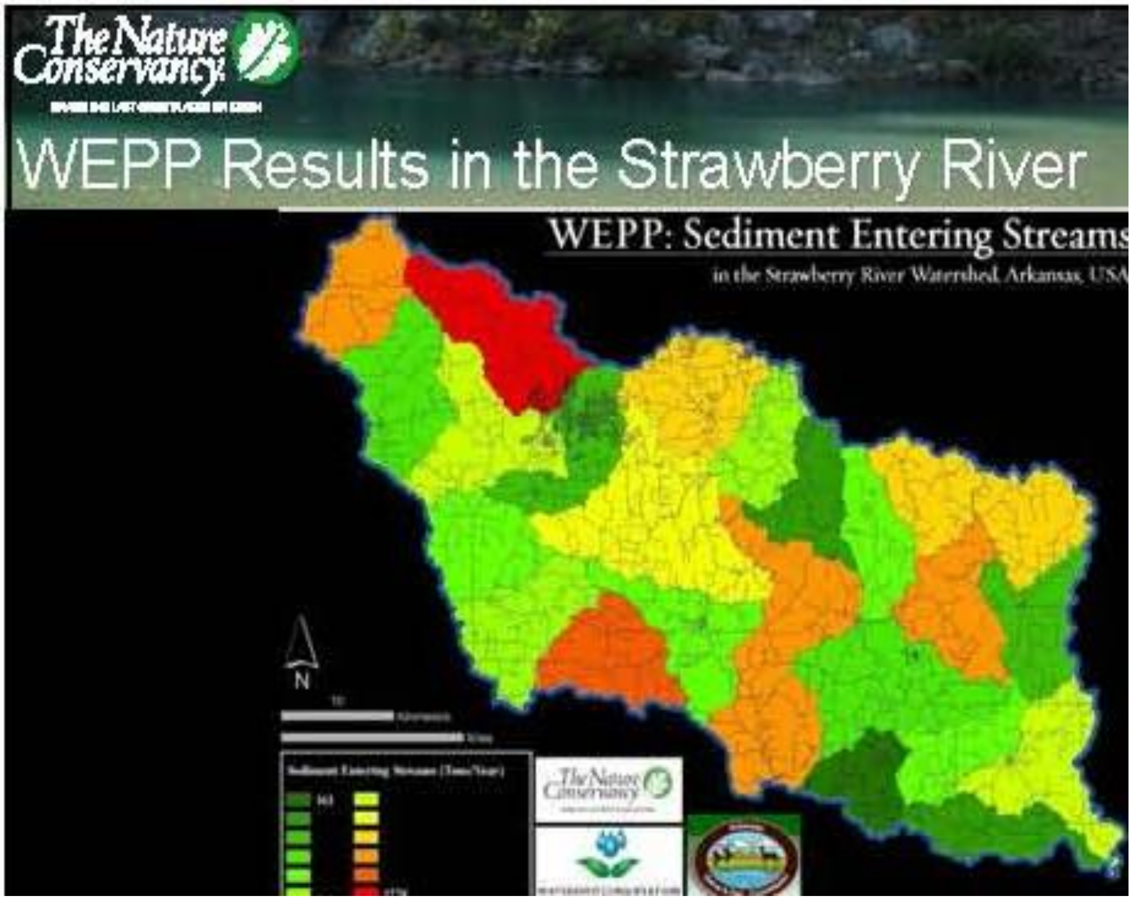


Figure 4.5 Watershed Erosion Prediction Project (WEPP) model results for sediment export from unpaved roads in the Strawberry River watershed (Inlander 2009).

Table 4.6. Miles of unpaved roads in the Strawberry River 12-digit HUC subwatersheds (Center for Advanced Spatial Technologies 2006).

12-digit HUC	Subwatershed name	Unpaved roads miles (miles/square miles)
110100120101	Philadelphia Creek-Piney Fork	55.47 (02.02)
110100120102	Caney Creek-Piney Fork	79.58 (02.49)
110100120103	Mays Branch-Piney Fork	65.65 (02.19)
110100120104	Mill Creek-Piney Fork	70.67 (02.33)
110100120201	Greasy Creek-Strawberry River	40.62 (01.45)
110100120202	Sandy Creek-Strawberry River	84.10 (02.49)

Table 4.6. Miles of unpaved roads in the strawberry river 12-digit HUC subwatersheds (continued).

12-digit HUC	Subwatershed name	Unpaved roads miles (miles/square miles)
110100120203	Little Strawberry River	96.21 (02.35)
110100120204	Bullpen Creek-Strawberry River	93.55 (02.62)
110100120205	Bens Creek-Strawberry River	147.17 (05.50)
110100120206	Hars Creek-Strawberry River	78.86 (02.53)
110100120207	Lave Creek-Strawberry River	59.29 (01.96)
110100120301	Hackney Creek-North Big Creek	71.61 (02.06)
110100120302	Little Creek-North Big Creek	60.80 (02.71)
110100120303	Barnes Branch-North Big Creek	45.76 (02.05)
110100120304	Whaley Creek-Strawberry River	67.33 (01.83)
110100120305	Mill Creek-Strawberry River	50.58 (02.15)
110100120306	Meeks Branch-Strawberry River	45.69 (02.02)
110100120307	Clayton Creek-Strawberry River	67.97 (02.26)
110100120401	Hamilton Branch-South Big Creek	54.30 (02.11)
110100120402	Fool Creek-South Big Creek	42.17 (01.89)
110100120403	Mill Creek-South Big Creek	40.53 (01.75)
110100120404	North Prong-Reeds Creek	35.06 (01.86)
110100120405	Reeds Creek-Strawberry River	45.68 (02.14)
110100120501	East Cooper Creek	53.75 (02.02)
110100120502	Cooper Creek	41.11 (01.57)
110100120503	Caney Creek-Strawberry Creek	48.76 (02.13)
110100120504	Sleep Bank Creek-Strawberry River	75.59 (2.37)

4.1.8 Silviculture

Storm event erosion from silviculture activities has been identified as a source of sediment contributing to turbidity in the Strawberry River watershed (Izard County Conservation District 2001, Fulton County Conservation District 2008). Surface erosion during harvest and along forest roads is believed to be the source of turbidity-causing sediment from silviculture activities in the watershed (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003). Forestry best management practices are in widespread use in the watershed (Stakeholder meeting 8/27/2015, Ash Flat, Arkansas).

4.1.9 Developed/Urban Areas

Brueggen-Boman and Bouldin (2012), determined that increasing urbanization within the upper Strawberry River watershed (Sandy Creek subwatershed) during the period between 1995 and 2009 had resulted in impacts to aquatic habitat in the Strawberry River that caused changes in the macroinvertebrate community (Brueggen-Boman and Bouldin 2012).

Construction sites have been identified as potential sources of sediment/turbidity in the Strawberry River watershed (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003). Construction sites with active NPDES stormwater permits are identified in Section 4.2.2.

4.2 Point Sources

This section identifies point sources that have the potential to discharge pollutants in the Strawberry River watershed. This includes NPDES permitted discharges as well as locations with Phase I or Phase II stormwater permits, RCRA sites, and underground storage tanks. No active Brownfield’s sites, CAFO permits, current state priority hazardous waste contaminated sites, nor CERCLA superfund sites were identified within the Strawberry River watershed.

4.2.1 NPDES Permits

There are 7 NPDES permitted point sources discharging in the Strawberry River watershed (see Table 4.7). The majority of these are individual permits for municipal wastewater treatment plants. Permitted discharges have not been identified by ADEQ as sources of pollutants causing surface water impairment (ADEQ 2014). However, during the intensive water quality survey of the watershed conducted by ADEQ in 2002 - 2003, the Ash Flat WWTP discharge to North Big Creek was determined to be impacting the macroinvertebrate community up to three miles downstream. No impact to fishery communities was evident (ADEQ n.d.).

Table 4.7 NPDES permitted point sources discharging in the Strawberry River watershed (ADEQ 2015a).

Permit No.	Facility Name	Receiving Reach	Receiving Stream	Reported permit violations?
AR0035254	City of Horseshoe Bend WWTP	009	Strawberry River	Yes
AR0039608	City of Horseshoe Bend – Paradise Acres	010	Hubble Branch	Yes
AR0041742	City of Ash Flat	007	North Big Creek	No*
AR0048488	Western Lawrence County WWT District	002	Strawberry River	Yes
AR0049701	City of Oxford	011	Sandy Creek	Yes
AR0050261	Highland WWTF	007	Worthington Creek	Yes
ARG160025	Cherokee Landfill	--	Hackney Creek	Yes

*Sanitary sewer overflows reported

4.2.2 Phase I and II Stormwater Permits

Stormwater runoff from developed areas is a potential source of a variety of pollutants that can impact water quality. There are no communities in the Strawberry River watershed with active MS4 stormwater permits. However, there are a number of active construction and industrial stormwater permits for locations within the watershed (Tables 4.8 and 4.9). Note the construction permits for poultry producers, suggesting expansion of poultry production within the watershed (ADEQ 2015a).

Table 4.8. Active NPDES construction stormwater permits for locations within the Strawberry River watershed (ADEQ 2015a, e).

Permit No.	Facility Name	Receiving Stream
ARR150597	Nix Ridge Rd Development	Unknown
ARR151351	Secluded Estates	Unknown
ARR153462	Yancey Poultry Farm	Piney Fork
ARR153487	Arkansas Highway and Transportation Department (AHTD) Job No. 050187	Hackney Creek
ARR153664	AHTD Job No. 050012	Sandy Creek, Strawberry River
ARR153837	AHTD Job No. FA 6707	Mill Creek
ARR154044	Tate's Poultry Farm	Strawberry River
ARR154202	Johnson Farms Poultry Houses	Strawberry River
ARR154385	Eddie Walling Chicken Houses	Lick Branch
ARR154391	Walling Farms	Reeds Creek
ARR154422	Finley Farms	Piney Fork
ARR154428	Jimmy King	Mill Creek
ARR154432	Johnny King	Dog Branch Creek
ARR154573	Lankford Poultry Farm	Strawberry River
ARR154725	Circle N Farms	Unknown
ARR154752	Dexter Huckabee	Unknown
ARR154758	Bandy Branch Farms	Unknown
ARR154917	Tracy Farms	Unknown

Table 4.9. Active NPDES industrial stormwater permits for locations within the Strawberry River watershed (ADEQ 2015a, f).

Permit No.	Facility Name	Receiving Stream
ARR000255	Oxford Recycling	Unknown
ARR00B849	Ark Quality Stone Company	Unknown
ARR00B607	Trico Inc.	Piney Fork

4.3 Hazardous Waste

4.3.1 RCRA Facilities

There are 4 RCRA facilities within Strawberry River watershed, identified by EPA and classified by ADEQ as generating hazardous waste (Table 4.10) (ADEQ 2015g). Two of the RCRA facilities have been classified as conditionally exempt small quantity generators, meaning that they generate 100 kilograms or less per month of hazardous waste, or 1 kilogram or less per month of acutely hazardous waste. Small quantity generators generate between 100 and 1,000 kilograms of hazardous waste per month.

Table 4.10. RCRA facilities in the Strawberry River watershed identified by EPA and ADEQ (EPA 2015b, ADEQ 2015g).

ID	Facility Name	Type[1]	Status[2]	County
AR0000938670	Degroft Mfg Inc	CESQG	ND	Izard
ARR000022285	Oxford Superstop	NI	NI	Izard
ARR000017525	Mobil Pipeline Company - Strawberry Station	CESQG	N	Lawrence
AR0000027607	Walmart Supercenter # 160	SQ	N	Sharp

[1] CESQG = conditionally exempt small quantity generator, NI = no code given, SQ = small quantity
[2] ND = no separately defined state status, NI = no code given, TSD = treatment/storage/disposal facility

4.3.2 Underground Storage Tanks

ADEQ has identified over 50 underground storage tanks within the Strawberry River watershed (Table 4.11). Five of these tanks have been confirmed to be leaking. Most of the leaking tanks are located at gas stations. Two of the leaking tanks are temporarily not in use.

Table 4.11. Underground storage tanks identified in the lower Strawberry River watershed (ADEQ 2015h).

County	Number Underground Tanks	Temporarily out of service	Leaking
Fulton	5	0	1
Izard	20	3	2
Lawrence	10	0	0
Sharp	18	0	2
Total	53	3	5

4.3.3 Data Gaps

Updated inventories of active poultry, dairy, and beef cattle operations could be helpful for prioritizing nonpoint source pollution management activities, as well as identification of areas where cattle have access to streams.

5.0 POLLUTANT LOADS

This section includes a discussion of pollutant loads for the Strawberry River watershed, along with ranking of subwatersheds of the Strawberry River for nonpoint source management activities. The pollutant loads discussion addresses only the primary pollutants of concern, sediment and bacteria, and includes a summary of previous pollutant load estimation work, along with estimates of current pollutant loads.

5.1 Estimation of Pollutant Loads

This section discusses previous pollutant load estimation work, along with estimates of current pollutant loads.

5.1.1 TSS Loads

There have been several studies that address TSS loads in the Strawberry River watershed. It is not possible to calculate turbidity loads, so TSS load is used as a surrogate. TSS loads in the Strawberry River watershed have been estimated as part of TMDL studies, and studies conducted by ADEQ, ASU, and U of A.

5.1.1.1 TMDL

TMDLs have been completed addressing turbidity in the Strawberry River watershed. Existing pollutant loads were calculated as part of these TMDL studies. In these TMDLs, observed TSS loads were estimated at ADEQ water quality monitoring locations using measured TSS concentrations and estimated flows. The range of these calculated values are shown in Table 5.1, along with the percent reductions needed to meet the applicable water quality criteria in the impaired reaches (FTN Associates, Ltd. 2006).

Table 5.1 Estimated existing TSS loads at ADEQ water quality stations in the Strawberry River watershed from TMDLs.

Waterbody	ADEQ Station ID	Time period of data used	Estimated existing load range	
			lb/day/sq mi	kg/day
Little Strawberry River	WHI0143H	2001 – 2003	1.27 – 2,810	22.8 – 50,601
Strawberry River	WHI0024	1991 – 2005	0.73 – 34,983	178.5 – 8,552,857
Strawberry River	UWSBR02	1994 – 2003	0 – 25,348	0 – 2,494,990
Strawberry River	UWSBR01	1994 – 2003	0.71 – 7,696	27.0 – 293,231

5.1.1.2 U of A Study Load Estimates

Massey et al. (2013) estimated TSS loads by several methods using TSS and flow measurements from 2011 and 2012 at the Strawberry River near Poughkeepsie (USGS 07074000). The resulting annual TSS loads ranged from 11×10^6 kg to 199×10^6 kg (Massey, et al. 2013). This is equivalent to 3.0×10^4 to 5.4×10^5 kg/day.

5.1.1.3 ASU Study Load Estimates

Brueggen-Boman (2012) calculated median annual TSS loads for the six ASU water quality monitoring locations in the Strawberry and Little Strawberry River headwaters (Table 5.2). These loads were calculated using the median of measured discharge and TSS concentrations from the ASU study (T. R. Brueggen-Boman 2012).

Table 5.2. Estimated median annual TSS loads for Strawberry River headwaters.

Monitoring location ID	Median annual TSS load, metric tons/year	Equivalent TSS load, kg/day
LSUP	17.18	47.07
LSLO	14.95	40.96
SCUP	8.44	23.12
SCLO	72.01	197.29
GCUP	17.58	48.16
GCLO	11.26	30.85

5.1.1.4 Estimate of Current TSS Loads

Estimates of TSS loads were calculated using the average of the TSS data collected from 2010 through 2014 at selected monitoring locations in the Strawberry River watershed (Figure 5.1). Seven-day 10 year low-flow and 100 year peak flood values at each monitoring location were calculated using USGS StreamStats. For all of the locations except Strawberry River at STR-S1 (location of USGS gage 07074000), these flows were estimated using regional regression equations developed by USGS (Hodge and Tasker 1995, Funkhouser, Eng and Moix 2008). The loads shown on Figure 5.1 are cumulative, reflecting loads from the entire watershed upstream of the sampling location.

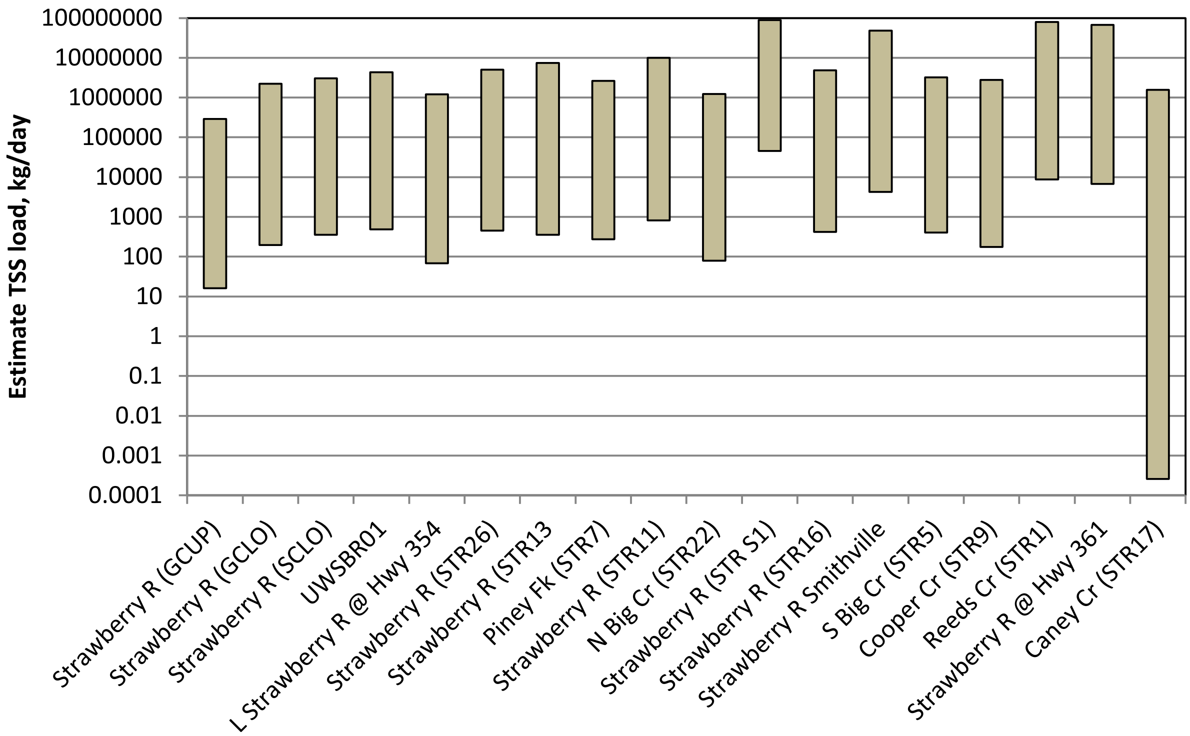


Figure 5.1. Estimates of TSS load ranges in the Strawberry River watershed 2010 – 2014.

5.1.1.5 Comparison of Loads

There are several locations in the Strawberry River watershed where TSS loads have been calculated more than once. These loads are compared in Table 5.3. Note that the upper value of the estimated current load is much higher than all other load estimates because the peak 100 year flow used to calculate the upper value is several orders of magnitude higher than the measured flows used in other studies to estimate loads. See Section 3.2.1.4.3 for a discussion of changes in TSS concentrations over time.

Table 5.3. Comparison of TSS loads, in kg/day, calculated for the Strawberry River watershed.

Station ID	Waterbody	TMDL load	ASU load	U of A load	Estimated current load
WHI0143H	Little Strawberry R	22.8 – 50,601	-	-	67.9 – 1,206,658
WHI0024	Strawberry R	178.5 – 8,552,857	-	-	4,210 – 48,050,430
UWSBR01	Strawberry R	27.0 – 293,231	-	-	481 – 4,351,747
GCUP	Strawberry R	-	48.16	-	16.0 – 290,313
GCLO	Strawberry R	-	30.85	-	197 – 2,226,018
SCLO	Strawberry R	-	197.29	-	357 – 3,043,273
STR-S1	Strawberry R	-	-	30,000 - 540,000	45,150 – 88,835,848

5.1.2 Bacteria Loads

A TMDL has been completed addressing bacteria impairments in the Strawberry River watershed (EPA Region VI 2007). Existing E. coli and fecal coliform loads were calculated as part of this TMDL study. In the TMDL the loads were calculated by multiplying measured concentrations from 2001 through 2003 by the flow on the sampling day. The actual load values are not included in the TMDL report. Observed load values estimated from the graphs in the TMDL report are summarized in Table 5.4. At all sites, except Mill Creek, maximum winter loads are greater than maximum summer loads. The highest maximum E. coli load estimate is from Little Strawberry River. The highest maximum fecal coliform load estimate is from Cooper Creek.

Table 5.4. Estimated existing bacteria loads in the Strawberry River watershed for 2001 through 2003 (EPA Region VI 2007).

Waterbody	Site ID	Season	Years	Parameter	Load Range, G-org/day
Caney Creek	WHI0143R	Summer	2001-2002	E. coli	2 – 100
Caney Creek	WHI0143R	Winter	2001-2002	E. coli	0.2 – 200
Little Strawberry River	WHI0143H	Summer	2001-2002	E. coli	0.01 – 70
Little Strawberry River	WHI0143H	Winter	2001-2002	E. coli	0.01 – 3,000
Mill Creek	WHI0143N	Summer	2001-2002	E. coli	0.02 – 200
Mill Creek	WHI0143N	Winter	2001-2002	E. coli	0.2 – 400
Reeds Creek	UWRDC01	Summer	2001-2002	E. coli	10 – 1,500
Reeds Creek	UWRDC01	Winter	2001-2002	E. coli	1 – 2,000
Strawberry River	UWSBR01	Summer	2001-2002	E. coli	0.07 – 100
Strawberry River	UWSBR01	Winter	2001-2002	E. coli	0.03 – 6,000
Cooper Creek	WHI0143S	Summer	2001-2002	Fecal coliform	30 – 4,000
Cooper Creek	WHI0143S	Winter	2001-2002	Fecal coliform	30 – 10,000
Little Strawberry River	WHI0143H	Summer	2001-2002	Fecal coliform	0.02 – 200
Little Strawberry River	WHI0143H	Winter	2001-2002	Fecal coliform	0.02 – 3,000
Mill Creek	WHI0143N	Summer	2001-2002	Fecal coliform	0.04 – 800
Mill Creek	WHI0143N	Winter	2001-2002	Fecal coliform	3 – 200
Reeds Creek	UWRDC01	Summer	1994-2002	Fecal coliform	10 – 2,000
Reeds Creek	UWRDC01	Winter	1994-2002	Fecal coliform	2 – 5,000

5.2 Future Conditions and Pollutant Loads

North-central Arkansas, including the Strawberry River watershed, is experiencing an increase in poultry houses. In Fulton County, approximately 30 new poultry houses have gone up over the last year. This is expected to increase the amount of poultry litter produced and applied in the watershed, with the potential for increasing nutrient and bacteria loads. Runoff from poultry house roofs also causes erosion (Stakeholder meeting 8/27/2015, Ash Flat, Arkansas).

5.3 Identification of Critical Areas

There have been studies and projects in the Strawberry River watershed that evaluated and/or prioritized subwatersheds based on water quality. These studies and projects each used different approaches to evaluate and prioritize. The following subsections summarize the existing work on prioritizing subwatersheds of the Strawberry River, and compare and synthesize their results. The studies are discussed in chronological order. Table 5.5 summarizes and compares results from the evaluation and prioritization approaches described below.

5.3.1 Impaired Streams

The highest rank (1) was given to 12-digit HUC subwatersheds that contain stream segments listed as impaired on the Arkansas 303(d) list. Impaired stream segments listed on the final 2008 and 2014 303(d) lists are shown in Tables 3.3 and 3.4. There are 17 subwatersheds associated with the 11 impaired stream reaches included on the final 2008 and 2014 303(d) lists. Those subwatersheds without impaired stream segments are assigned the lowest rank, 5.

5.3.2 SWAT Model

Saraswat et al. (2013) prepared and calibrated a SWAT model of the Strawberry River watershed to aid in prioritizing subwatersheds for implementation of nonpoint source best management practices (BMPs). The parameters sediment, total phosphorus, and nitrate nitrogen were modeled for the period 2001 through 2003. The subwatershed rankings based on the model results are summarized in Table 5.5.

5.3.3 U of A Water Quality Data Collection

The water quality data collection performed by the U of A was for evaluation of a SWAT model of sediment and nutrients in the Strawberry River watershed (Massey, et al. 2013).

Subwatershed rankings based on the mean concentrations measured during this study are summarized in Table 5.5.

5.3.4 NRCS Resources Concerns

Every 5 years the NRCS conducts state and national resource assessments to assess major concerns of agricultural practices on the environment. There are nine major resource concerns, ranging from soil erosion and soil quality degradation to water quality degradation and inadequate habitat for fish and wildlife to air quality degradation. The latest resource assessment for Arkansas was conducted in 2011. NRCS is currently planning for the 2016 resource assessment. The state resource assessments are conducted at the 12-digit HUC watershed scale, which is consistent with the scale used by the ANRC for watershed management. The resource assessment considers a variety of factors including, soil rainfall runoff erosivity factor (R), soil erodibility factor (K), slope length and steepness factor (LS), and a transport factor (T), a soil erodibility class obtained from the state SURGO soils database, soil vulnerability class, and the presence of streams on the state 303(d) list of impaired waterbodies.

Subwatershed rankings developed by NRCS for relevant resource concerns are summarized in Table 5.5. Resource concerns considered in the prioritization were “excess sediment” and “pathogens and chemicals from manure.”

Table 5.5. Priorities for 12-digit HUC subwatersheds of the Strawberry River watershed.

HUC name (12-digit HUC no.)	2014 turbidity impaired	SWAT Sediment rank	AWRC mean TSS rank	NRCS excess sediment rank	Overall sediment rank	2014 E. coli impaired	NRCS manure pathogens etc. rank	Overall bacteria rank	Past BMPs
Philadelphia Creek-Piney Fork (110100120101)	5	3	5	4	Low	5	1	Med	x
Caney Creek-Piney Fork (110100120102)	5	3	4	4	Low	5	1	Med	x
Mays Branch-Piney Fork (110100120103)	5	4	3	3	Low	5	2	Med	x
Mill Creek-Piney Fork (110100120104)	5	3	4	2	Low	5	4	Low	x
Greasy Creek-Strawberry River (110100120201)	1	1	-	5	Med	1	2	High	x
Sandy Creek-Strawberry River (110100120202)	1	3	-	5	Med	1	2	High	x
Little Strawberry River (110100120203)	1	1	4	5	Med	1	2	High	x
Bullpen Creek-Strawberry River (110100120204)	1	5	3	5	Low	1	1	High	
Bens Creek-Strawberry River (110100120205)	5	2	-	5	Med	5	1	Med	
Hars Creek-Strawberry River (110100120206)	5	5	3	3	Low	5	3	Low	
Lave Creek-Strawberry River (110100120207)	5	5	2	2	Med	5	2	Med	
Hackney Creek-North Big Creek (110100120301)	5	1	4	3	Low	5	1	Med	x
Little Creek-North Big Creek (110100120302)	5	2	5	1	Med	5	4	Low	x
Barnes Branch-North Big Creek (110100120303)	5	1	5	1	Med	5	5	Low	x
Whaley Creek-Strawberry River (110100120304)	1	4	3	1	Med	5	5	Low	
Mill Creek-Strawberry River (110100120305)	5	2	5	2	Med	1	5	Med	
Meeks Branch-Strawberry River (110100120306)	1	5	2	1	High	5	5	Low	
Clayton Creek-Strawberry River (110100120307)	1	4	1	2	High	5	4	Low	

Table 5.5. Priorities for 12-digit HUC subwatersheds of the Strawberry River watershed (continued).

HUC name (12-digit HUC no.)	2014 turbidity impaired	SWAT Sediment rank	AWRC mean TSS rank	NRCS excess sediment rank	Overall sediment rank	2014 E. coli impaired	NRCS manure pathogens etc. rank	Overall bacteria rank	Past BMPs
Hamilton Branch-South Big Creek (110100120401)	5	2	-	4	Med	5	4	Low	
Fool Creek-South Big Creek (110100120402)	5	4	-	3	Low	5	5	Low	
Mill Creek-South Big Creek (110100120403)	5	4	2	2	Med	5	3	Low	
North Prong-Reeds Creek (110100120404)	5	3	-	4	Low	1	4	Med	
Reeds Creek-Strawberry River (110100120405)	1	2	1	3	High	1	3	Med	
East Cooper Creek (110100120501)	5	1	-	5	Med	1	5	Med	
Cooper Creek (110100120502)	5	3	2	4	Low	1	3	Med	
Caney Creek-Strawberry River (110100120503)	5	1	1	1	Med	1	3	Med	equipment
Sleep Bank Creek-Strawberry River (110100120504)	1	5	1	1	High	5	1	Med	equipment

5.3.5 Recommended Subwatersheds for this Plan

Overall rankings of the 12-digit HUC subwatersheds of the Strawberry River for sediment and bacteria issues based on the rankings described above are included in Table 5.5. The overall ranks are based on the number of high ranks (i.e., ranks of 1 or 2) assigned to the subwatersheds. Subwatersheds where more than 66% of the sediment category ranks are 1 or 2 are ranked overall as high for sediment. Subwatersheds with 33% to 66% of high ranks in sediment categories have an overall sediment rank of medium, and those with less than 33% high ranks have a low overall sediment rank. Subwatersheds that do not include a stream segment listed as impaired by turbidity, but are ranked high by over 66% of the sediment-related ranking sources have a medium overall sediment rank. The overall sediment ranks for the Strawberry River 12-digit HUC subwatersheds are shown on Figure 5.2.

Subwatersheds with bacteria impaired waterbodies and a high rank for the NRCS pathogens and chemicals from manure resource concern, have a high overall bacteria rank. Subwatersheds with only one high rank in the bacteria categories have a medium overall bacteria rank, and those with no high ranks in bacteria categories have a low overall bacteria rank. The overall bacteria ranks for the Strawberry River 12-digit HUC subwatersheds are shown on Figure 5.3.

Based on ranking approach described above, there are four 12-digit HUC subwatersheds that have a high overall sediment rank, and four subwatersheds that have a high overall bacteria rank. To keep the number of recommended 12-digit HUCs at a manageable level, 12-digit HUC subwatersheds that have not yet been targeted for nonpoint source management practices, and that have high overall ranks, are recommended for the purpose of targeting nonpoint source management practices in this plan. There are five 12-digit HUC subwatersheds that meet these criteria. Table 5.6 displays the rankings for these five 12-digit HUC subwatersheds from each of the prioritization approaches discussed above. Note that the Strawberry River in the Reeds Creek subwatershed is also listed as impaired due to E. coli, and the Strawberry River reaches in the Bullpen Creek subwatershed are also listed as impaired due to turbidity. In addition, the sections of the Strawberry River within these recommended subwatersheds have been identified as critical habitat for the endangered Rabbitsfoot mussel (USFWS 2014).

Table 5.6. Rankings from multiple approaches for recommended 12-digit HUC subwatersheds.

HUC name (12-digit HUC no.)	**2014 turbidity impaired**	**SWAT Sediment rank**	**AWRC mean TSS rank**	**NRCS excess sediment rank**	**2014 E. coli impaired**	**NRCS manure pathogens etc. rank**	**Overall Sediment rank**	**Overall Bacteria rank**
Bullpen Creek-Strawberry River (110100120204)	1	5	3	5	1	1	Low	High
Meeks Branch-Strawberry River (110100120306)	1	5	2	1	5	5	High	Low
Clayton Creek-Strawberry River (110100120307)	1	4	1	2	5	4	High	Low
Reeds Creek-Strawberry River (110100120405)	1	2	1	3	1	3	High	Med.
Sleep Bank Creek-Strawberry River (110100120504)	1	5	1	1	5	1	High	Med.

Figure 5.2. Overall ranking of Strawberry River 12-digit HUC subwatersheds for sediment issues.

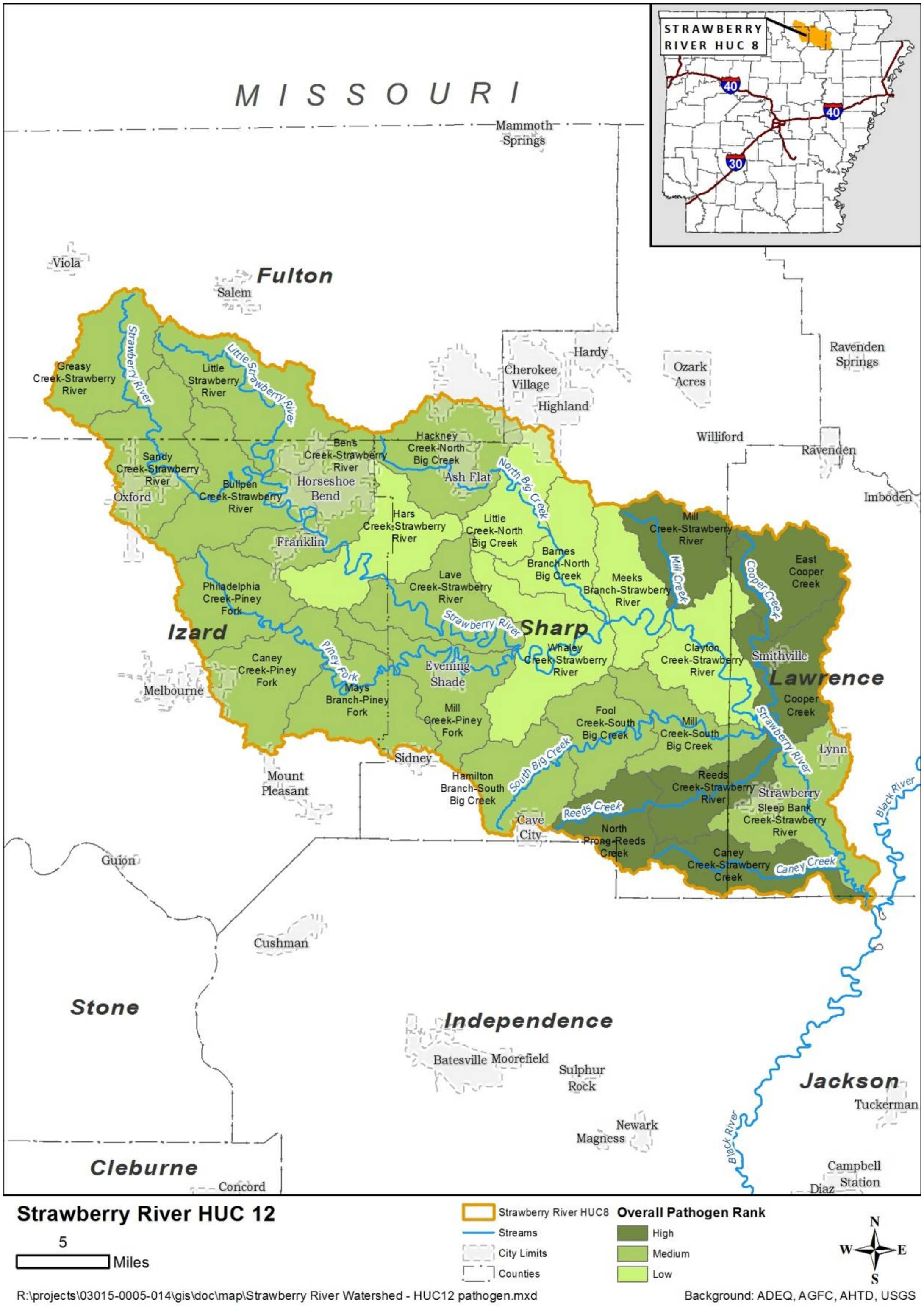


Figure 5.3. Prioritization of Strawberry River 12-digit HUC subwatersheds for pathogen issues.

5.3.6 Nonpoint Pollutant Sources in Recommended Subwatersheds for this Plan

The priority pollutants in the recommended subwatersheds are turbidity and E. coli. Table 5.7 summarizes pollutants of concern and priority nonpoint sources of these pollutants that are present in each of the recommended 12-digit HUC subwatersheds. These are discussed below.

Criteria used to identify critical areas for management in past Section 319 projects in the Strawberry River watershed will be used in implementing this plan. These criteria are:

- All farms that have riparian ownership along a blue line stream as indicated on the 7.5 USGS quadrangle maps, and
- All farms that lie within 0.5 miles of a blue line stream.

5.3.6.1 Turbidity

Turbidity is a priority pollutant in all five of the recommended 12-digit HUC subwatersheds because the All Flow turbidity criterion is not being met. ADEQ has identified surface erosion as the source of turbidity in the turbidity impaired stream reaches within these subwatersheds (Table 3.4). Table 5.8 shows NRCS rankings for erosion resource concerns for the recommended 12-digit HUC subwatersheds. In this table, a rank of 1 indicates the highest potential for the erosion source to contribute to water quality issues, and a rank of 5 indicates the lowest potential for this erosion source to contribute to water quality issues.

Table 5.7. Priority pollutants and nonpoint sources for recommended 12-digit HUC watersheds.

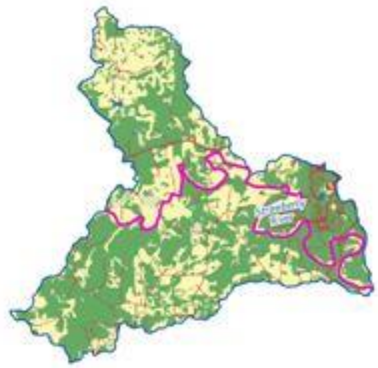
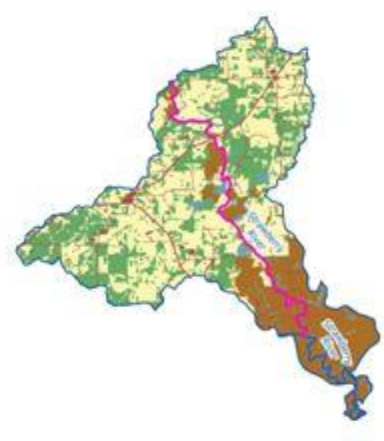
Land use	% Area	Priority Pollutants	Priority Nonpoint Sources	Land Use Map*
Bullpen Creek – Strawberry River, HUC 110100120204				
Developed	5.8%	Turbidity	Surface erosion	
Hay/pasture	32.6%	E. coli	Livestock (cattle in streams, animal feeding operations, manure storage), pasture runoff	
		Turbidity	Surface erosion, sheet/rill erosion, livestock access to streams	
Forest	57.4%	Turbidity	Surface erosion	
Meeks Branch – Strawberry River, HUC 110100120306				
Developed	4.1%	None	None	
Hay/pasture	14.7%	Turbidity	Surface erosion, gullies, streambank erosion	
Forest	77.4%	Turbidity	Surface erosion, streambank erosion	
Clayton Creek – Strawberry River, HUC 110100120307				
Developed	3.6%	None	None	
Hay/pasture	19.1%	Turbidity	Surface erosion, unpaved roads, streambank erosion, livestock access to streams	
Forest	71.9%	Turbidity	Surface erosion, streambank erosion, unpaved roads	

Table 5.7. Priority pollutants and nonpoint sources for recommended 12-digit HUC watersheds (continued).

Land use	% Area	Priority Pollutants	Priority Nonpoint Sources	Land Use Map*
Reeds Creek – Strawberry River, HUC 110100120405				
Developed	4.1%	None	None	
Hay/pasture	34.0%	E. coli	Animal feeding operations, manure storage, pasture runoff	
Forest	54.5%	None	None	
Sleep Bank Creek – Strawberry River, HUC 110100120504				
Developed	5.0%	None	None	
Hay/pasture	40.4%	None	None	
Cropland	20.0%	None	None	
Forest	28.8%	None	None	

* green = forest, yellow = hay/pasture, red = developed, brown = cropland, blue = stream, pink = impaired stream reach

Table 5.8. NRCS relative ranks for erosion resource concerns in the recommended 12-digit HUC subwatersheds.

HUC name (12-digit HUC no.)	NRCS streambank erosion rank	NRCS sheet/rill/wind erosion rank	NRCS concentrated flow erosion rank
Bullpen Creek-Strawberry River (110100120204)	5	1	3
Meeks Branch-Strawberry River (110100120306)	2	5	2
Clayton Creek-Strawberry River (110100120307)	2	5	4
Reeds Creek-Strawberry River (110100120405)	3	4	5
Sleep Bank Creek-Strawberry River (110100120504)	4	5	5

Based on the high relative ranks for streambank erosion in the Meeks Branch and Clayton Creek subwatersheds, streambank erosion is a priority nonpoint source of turbidity in these subwatersheds. Streambank erosion can be associated with both of the most prevalent land uses in these subwatersheds – pasture/hay and forest. The land use maps of these subwatersheds in Table 5.7 show that the impaired stream reach in these subwatersheds runs through pasture/hay land. Therefore, livestock access to streams is also a priority nonpoint source of turbidity for these subwatersheds. Modeling by TNC indicated that unpaved roads in the Clayton Creek subwatershed contribute a relatively high sediment load (see Figure 4.5). Therefore, unpaved roads are also a priority nonpoint source of turbidity for the Clayton Creek subwatershed.

The Meeks Branch 12-digit HUC subwatershed is also ranked high by NRCS for the concentrated flow erosion (i.e., gully erosion) resource concern. Therefore, gully erosion is also a priority nonpoint source for turbidity in this subwatershed.

NRCS assigned a high relative rank to the Bullpen Creek 12-digit HUC subwatershed for the sheet/rill/wind erosion resource concern. The land use map of the Bullpen Creek subwatershed in Table 5.7 shows that much of the impaired stream segment runs through pasture/hay land. Therefore, sheet/rill/wind erosion and livestock access to streams are priority nonpoint sources of turbidity in this subwatershed.

ADEQ has identified surface erosion as the source of turbidity in the turbidity-impaired stream segments in the Reeds Creek and Sleep Bank Creek recommended subwatersheds. However, the NRCS resource concern assessment relative ranks for erosion are low for these subwatersheds. These subwatersheds are at the downstream end of the Strawberry River watershed. As was noted in Section 3.2.1.4.1, turbidity levels increase in the downstream direction along the Strawberry River, indicating a cumulative impact from upstream sources. Implementation of management practices in these subwatersheds would not be expected to have an appreciable effect on turbidity levels in the impaired stream segments, since upstream sources account for the majority of the input (see Section 5.1.1). Therefore, turbidity will not be considered a priority pollutant for management in these subwatersheds. As a result, of this decision, the Sleep Bank Creek subwatershed is removed from the list of recommended subwatersheds for nonpoint source management in this plan.

5.3.7 E. coli

E. coli, is a priority pollutant in the Bullpen Creek and Reeds Creek recommended subwatersheds because E. coli levels exceed primary contact recreation water quality criteria in stream reaches within the subwatersheds (ADEQ 2014b, EPA Region VI 2007). ADEQ has not identified sources of the E. coli impairing these stream reaches in either the 2008 303(d) list or the draft 2014 303(d) list (see Tables 3.3 and 3.4). However, based on available information, several priority nonpoint sources have been identified for E. coli in the recommended subwatersheds that will be addressed in this plan.

The NRCS assigned the highest relative rank to the Bullpen Creek subwatershed for the resource concern of manure impacts on water quality (Table 5.6). Therefore, livestock and animal feeding operations are priority nonpoint E. coli sources in this subwatershed. The majority of this subwatershed is within Izard County, which had one of the highest concentrations of several types of agricultural animals, of the counties in the Strawberry Creek watershed in 2012 (see Table 4.1). As the impaired stream segment in this subwatershed runs through pasture/hay land, livestock access to streams is included as a priority nonpoint source of E. coli in this subwatershed.

The NRCS assigned a middle rank to the Reeds Creek subwatershed for the resource concern of manure impacts on water quality (Table 5.6). However, this subwatershed is located primarily in Sharp County, which had the highest concentrations of chickens of the counties in the Strawberry River watershed in 2012 (see Table 4.1). Therefore, animal feeding operations, and associated manure storage and runoff from pastures where manure is applied, are the priority sources of E. coli in this subwatershed.

6.0 GOALS AND OBJECTIVES

The overall objective of this watershed-based management plan is to restore and sustain the natural resources of the Strawberry River watershed so that the vision of its citizens can be achieved. The vision for the Strawberry River watershed is: The uses of the Strawberry River and its tributaries are attained and sustained as they flow through the rolling hills, fields, forests, pastures, wetlands, and local communities of the Strawberry River watershed, as its residents work together to improve the socioeconomic and natural amenities of Ozark life.

The management objective is to implement management practices so the designated uses of the waterbodies within the Strawberry River watershed are attained. Recently, several stream reaches in the watershed have been assessed as not supporting their designated uses. These stream reaches were placed on the final 2008 and 2014 Arkansas 303(d) lists. Management practices can reduce the pollutants identified on the 303(d) list as the sources of impairment of the designated uses, so that Arkansas water quality criteria are met and the designated uses of the streams are attained.

The primary focus of this plan is to address surface water quality. However, the intention is to manage the Strawberry River watershed holistically, so that addressing surface water quality does not adversely affect other management efforts (e.g., endangered species management), or give rise to, or exacerbate, other issues.

6.1 Management Objectives

The objective of this plan is to reduce target pollutants in impaired streams to achieve Arkansas water quality criteria. Surface water pollutants that will be targeted for reduction through implementation of management measures are those parameters for which the State of Arkansas has numeric limits as of January 2015, and that have been identified as being a cause of waterbody impairment in the Strawberry River watershed. ADEQ has identified waterbodies in the watershed where E. coli and turbidity water quality criteria are not being met (Tables 3.3 and 3.4). As a result, the pollutants targeted for reduction in this watershed-based management plan are turbidity and E. coli (Table 5.7).

6.2 Load Reduction Targets

TMDLs addressing turbidity and bacteria impairments in the Strawberry River watershed have been completed. Load reduction targets for this plan are taken from these TMDLs.

6.2.1 Turbidity

Percent load reduction targets are specified in the Strawberry River turbidity TMDL (FTN Associates, Ltd. 2006). In this TMDL, TSS is used as a surrogate for turbidity, because turbidity cannot be represented as a load. The TSS load reduction targets from the TMDL, to meet turbidity water quality criteria, that apply to the recommended 12-digit HUC subwatersheds, are summarized in Table 6.1. The target TSS loads to meet turbidity water quality criteria, from the turbidity TMDLs, that apply to the recommended 12-digit HUC subwatersheds where turbidity is a priority pollutant are shown in Table 6.2. Because nonpoint sources are the only turbidity sources for these stream reaches, the target TSS loads in Table 6.2 are nonpoint source loads.

The interim target for turbidity reduction is that the percentage of measurements from theimpaired stream reaches in the recommended subwatershed that exceed the water quality criteria, declines from the 2008 percentage (shown in Table 6.3).

6.2.2 E. coli

A TMDL has been completed that addresses the E. coli impaired stream segments in the Bullpen Creek and Reeds Creek recommended 12-digit HUC subwatersheds. This TMDL does not identify load reduction targets (EPA Region VI 2007). The target TMDL E. coli loads, total and nonpoint source load allocation, that apply in the recommended subwatersheds are listed in Table 6.4. Because ADEQ is currently using E. coli levels as the indicator of fecal contamination (ADEQ 2014a), fecal coliform loads from the TMDL are not given in Table 6.4.

Table 6.1. TMDL TSS load reductions for recommended 12-digit HUC subwatersheds (FTN Associates, Ltd. 2006).

HUC name (12-digit HUC no.)	Turbidity impaired ADEQ stream reaches	TSS load reduction targets	
		Base flow	Storm flow
Meeks Branch-Strawberry River (110100120306)	006	0	50%
Clayton Creek-Strawberry River (110100120307)	006	0	50%
Bullpen Creek-Strawberry River (110100120204)	009	0	53%
	011	0	58%

Table 6.2. TMDL TSS loads for recommended 12-digit HUC subwatersheds (FTN Associates, Ltd. 2006).

HUC name (12-digit HUC no.)	Turbidity impaired ADEQ stream reaches	Flow condition	TSS target load (tons/day)
Meeks Branch-Strawberry River (110100120306)	006	Base flow	3.52
Clayton Creek-Strawberry River (110100120307)		Storm flow	27.4
Bullpen Creek-Strawberry River (110100120204)	009	Base flow	2.0
		Storm flow	15.5

Table 6.3. Percentage of measurements exceeding turbidity criteria during the 2008 water quality assessment period (7/1/2002 – 6/30/2007),

HUC name (12-digit HUC no.)	ADEQ water quality station	Criterion	Percent exceedences
Meeks Branch-Strawberry River (110100120306), Clayton Creek-Strawberry River (110100120307), Reeds Creek-Strawberry River (110100120405)	WHI0024	Base flow	56%
	WHI0024	All flow	32%
Bullpen Creek-Strawberry River (110100120204)	UWSBR01, UWSBR02	All flow	20%

Table 6.4. E.coli TMDLs for recommended 12-digit HUC subwatersheds (EPA Region VI 2007).

Recommended Subwatershed	E. coli impaired ADEQ stream reach	Criterion	TMDL, cfu/day	NPS LA, cfu/day
Bullpen Creek	011	PCR-S*	2.87E+11	2.59E+11
		PCR-W*	14.4E+11	12.9E+11
Reeds Creek	014	PCR-S*	1.61E+11	1.45E+11
		PCR-W*	8.04E+11	7.24E+11

* PCR-S = summer primary contact, PCR-W = winter primary contact

Available E. coli measurements from ADEQ water quality stations associated with the E. coli impaired reaches of the recommended subwatersheds was compared to applicable numeric water quality criteria for E. coli (Appendix C). The results of these comparisons are shown in Table 6.5. Note that available data are from the period 2001 through 2005.

Table 6.5. Summary of E. coli data from recommended subwatersheds.

HUC name (12-digit HUC no.)	Impaired ADEQ stream reach	ADEQ water quality station	Criterion description	Criterion value (colonies/ 100mL	Number of measurements	Number of exceedences
Bullpen Creek-Strawberry River (110100120204)	011	UWSBR01	PCR-S*	298	9	0
			PCR-W*	410	3	0
			Geometric mean	126	1	0
Reeds Creek-Strawberry River (110100120405)	014	USWRDC01	PCR-S*	410	9	0
			PCR-W*	2050	3	0
	005	WHI0024	PCR-W*	410	3	0

* PCR-S = summer primary contact, PCR-W = winter primary contact

It appears that reevaluation of the E. coli impairment for these stream reaches is warranted, as none of the available data appears to exceed the criteria. Therefore, there is no E. coli load reduction target for this plan, and E. coli will not be addressed through implementation of management practices. Rather, the E. coli impairment will be addressed through collection of E. coli measurements to determine if the E. coli impairment listing of stream reaches in the Bullpen Creek and Reeds Creek recommended subwatersheds is still valid.

7.0 IDENTIFICATION OF MANAGEMENT STRATEGIES

This section discusses nonpoint source management strategies for the recommended 12-digit HUC subwatersheds of the Strawberry River watershed. The proposed management units are identified. Management strategies that have been used in the Strawberry River watershed in the past are identified, along with management strategies selected by stakeholders, and those planned for the future. Structural and nonstructural strategies are discussed separately. Discussion of the management strategies is organized by the pollutant and/or pollutant source to be addressed in the recommended subwatersheds identified in Section 5.

7.1 Management Units

The 12-digit HUC watersheds in the Strawberry River watershed have been the basis for several previous prioritization approaches and are used to define management areas for this plan (see Section 5.3). There are 27 12-digit HUC subwatersheds in the Strawberry River watershed. The 12-digit HUC is a recommended sized unit for water quality improvement because: 1) it is small enough that improvements in water quality associated with implementing management practices can be observed within a reasonable time frame; 2) it is large enough that significant reductions in targeted pollutants can occur through management; and 3) it provides a sense of place and community involvement for stakeholders (APCEC 2011)

7.2 Management Strategies for Sheet/Rill/Wind Erosion and Concentrated Flow Erosion (Gullies) of Pasture Land

Poor quality pasture and pasture areas heavily used by livestock cause sheet/rill/wind and gully erosion of pasture land. Reducing sheet/rill/wind, and gully erosion reduces TSS load and stream turbidity to meet state water quality criteria. Reduced turbidity and TSS means improved visibility for predatory sport fish such as bass, and reduced sedimentation in stream channels, which also supports desirable sport fish and their prey. Table 7.1 is a summary of structural controls addressing erosion from pastures that have been implemented in the Strawberry River watershed. Table 7.2 is a summary of nonstructural controls addressing erosion from pastures that have been implemented in the watershed.

Table 7.1. Structural controls to reduce erosion of pasture land.

Project/program (lead agency/ organization)	Practices		Location	Status	Estimated soil saved
00-600 Strawberry River Watershed Project, Reach 1 (County Conservation Districts)	Fence	496,796 ft	Strawberry River watershed upstream of Piney Fork	Complete	2 tons/ac/yr
01-800: Piney Fork, Reach 2 (Sharp County Conservation District)	Critical area treatment	5 ac	Piney Fork watershed, Izard and Sharp Counties	complete	Not available
01-1900: Alternative livestock water demonstration (Fulton County Conservation District)	Fence	650,327 ft	Fulton County	Complete	Not available
	Use exclusion	528.05 ac			
	Heavy use area protection	9 ac			
03-151: Lawrence County Mini-grant (Lawrence County Conservation District)	Pasture drill	218 ac	Lawrence County	Complete	654 tons
05-800: Strawberry River agricultural watershed project reach III – North Big Creek (Lawrence and Sharp County Conservation Districts)	Fence	46,723 ft	North Big Creek watershed	Complete	3,528 tons
	Heavy use area protection	18			
08-500: Strawberry River subwatersheds (Fulton County Conservation District)	Fence	46,723 ft	Fulton County	Complete	58,647 tons/yr
	Heavy use area protection	1.4 ac			
09-2100: Strawberry River improvement project – supplemental cost-share, and 11-1000: Strawberry River improvement project (Sharp County Conservation District)	Fence	111,944 ft	Sharp County	Complete	Not available
	Heavy use area protection	10			
11-1100: Strawberry River subwatershed project (Izard County Conservation District)	Fence	59,065 ft	Izard County	Complete	7,541 tons/yr
	Heavy use area protection	2.826 ac			
15-1100: Strawberry River subwatersheds project (Fulton County Conservation District)	Fence and heavy use area protection		110100120201, 110100120202, 110100120203, 110100120204, 110100120205, and 110100120301	Ongoing	Not available
Strawberry River Preserve and demonstration ranch (TNC)	Fence		Whaley Creek – Strawberry River 12-digit HUC subwatershed	Ongoing	Not available
Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (NRCS)	Core practices include fence, heavy use area protection, and roof runoff structures		Little Strawberry River and Philadelphia Creek – Piney Fork 12-digit HUC subwatersheds	Ongoing	Not available
Controlled Access and Livestock Fencing (CALF) Initiative (US Fish and Wildlife Service)	Eligible practices include fencing and heavy use area protection		Entire watershed	Ongoing	Not available

Table 7.2. Non-structural controls to reduce erosion of pasture land.

Project/program (lead agency/ organization)	Practices		Location	Status	Estimated soil saved
00-600 Strawberry River Watershed Project, Reach 1 (County Conservation Districts)	Farm plans	188	Strawberry River watershed upstream of Piney Fork	Complete	Not available
	Pasture/hayland planting	2,093 ac			
	Pasture/halyand improvement	1,651 ac			
	No-till drill	3			
	Prescribed grazing	33,068 ac			
01-800: Piney Fork, Reach 2 (Sharp County Conservation District)	Conservation plans	30	Piney Fork watershed, Izard and Sharp Counties	Complete	Not available
	No-till drill	1			
	Grassed waterway	2 ac			
	Permanent pasture	79.2 ac			
01-1900: Alternative livestock water demonstration (Fulton County Conservation District)	Prescribed grazing	8,048 ac	Fulton County	Complete	Not available
	Use exclusion	528.05 ac			
	Water quality plans	85 farms			
03-151 Lawrence County Mini-grant (Lawrence County Conservation District)	No-till drill	590 ac	Lawrence County	Complete	654 tons
	Pasture drill	218 ac			
03-159 Fulton County Mini-grant (Fulton County Conservation District)	No-till drill	500 ac	Fulton County	Complete	3,394 tons/yr
	Pasture planting	549.2 ac			
	Tree planting	109.5 ac			
03-185: Fulton County Grass Promotion (Fulton County Conservation District)	Grassland conference	1 (75 attendees)	Fulton County	complete (annual conference continues?)	Not available
05-800: Strawberry River agricultural watershed project reach III – North Big Creek (Sharp and Lawrence County Conservation Districts)	Conservation plans	164	North Big Creek	Complete	3,528 tons
	Prescribed grazing	10,419.8 ac			
	Pasture establishment	339.3 ac			
	Tree planting	160.6 ac			
	Pasture management equipment rental				
07-2900: Lawrence County no-till (Lawrence County Conservation District)	No-till drill rental		Lawrence County	Complete	Not available
08-500: Strawberry River subwatersheds (Fulton County Conservation District)	Conservation plans	127	Fulton County	Complete	58,647 tons/yr
	Pasture planting	248 ac			
09-2100: Strawberry River improvement project – supplemental cost-share (Sharp County Conservation District)	Prescribed grazing	11,823.6 ac	Sharp County	Complete	Not available
10-600: Fulton County no-till (Fulton County Conservation District)	No-till drill rental		Fulton County	Complete	Not available
11-1000: Strawberry River improvement project (Sharp County Conservation District)	Conservation plans	125	Sharp County	Complete	Not available
	No-till drill rental				

Table 7.2. Non-structural controls to reduce erosion of pasture land (continued).

Project/program (lead agency/ organization)	Practices		Location	Status	Estimated soil saved
11-1100: Strawberry River subwatershed project (Izard County Conservation District)	Conservation plans	44	Izard County	Complete	7,541 tons/yr
	Prescribed grazing	4,424ac			
15-1100: Strawberry River subwatersheds project (Fulton County Conservation District)	No-till drill and sprayer rental		110100120201, 110100120202, 110100120203, 110100120204, 110100120205, and 110100120301	Ongoing	Not available
Strawberry River Preserve and demonstration ranch (TNC)	Prescribed grazing		Whaley Creek-Strawberry River 12-digit HUC subwatershed	Ongoing	Not available
Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (NRCS)	Core practices include conservation cover, critical area planting, filter strip, tree/shrub planting, and prescribed grazing		Little Strawberry River and Philadelphia Creek – Piney Fork 12-digit HUC subwatersheds	Ongoing	Not available

7.2.1 Past Management Strategies

There have been a number of Section 319 projects and NRCS practices implemented in the Strawberry River watershed to reduce erosion from pasture land. As specified in the 2002 Strawberry River Watershed Restoration Action Strategy, this work has been focused in headwater 12-digit HUC subwatersheds.

7.2.1.1 Structural Controls

There have been 13 Section 319 projects in the Strawberry River watershed to reduce erosion associated with pasture. Structural controls that have been implemented as part of these projects are listed in Table 7.1. Structural control practices that have been used in the watershed include fencing and heavy use area protection. Fencing can be used to keep livestock away from eroding and easily erodible areas. Areas heavily used by livestock often cannot support vegetation, leading to erosion. These areas are graveled to protect soils and prevent erosion.

7.2.1.2 Non-structural Controls

There have been 16 Section 319 projects in the Strawberry River watershed to reduce erosion associated with land using non-structural controls. Non-structural practices that have been used in the watershed include purchase of no-till drills and tree planters to be loaned to land owners, pasture and hayland improvement and planting, use exclusion, development of conservation plans, and prescribed grazing (Table 7.2). These practices are discussed below.

No-till drills allow planting to improve ground-cover, with minimal soil disturbance that could make soil subject to erosion. Landowners frequently do not have the funds to purchase this type of machinery for their own use, so purchasing the equipment and providing it for the use of landowners' aids in the improvement of pasture and reduction in erosion. Bare areas of pasture are planted to reduce erosion. Grassed waterways resist the erosive force of the water they carry. Prescribed grazing protects and improves the ground cover in pastures, making them less susceptible to erosion. Conservation plans can include practices to reduce erosion in pastures and/or filter runoff from pastures.

7.2.1.3 Effectiveness

Final reports for several (but not all) of the Section 319 projects include estimates of soil saved as a result of the implementation of the best management practices (BMPs) utilized in the projects. The sum of the reported amounts of soil saved is 77,712 tons per year.

Researchers from Arkansas State University studied the effectiveness of BMPs implemented in the upper Strawberry River watershed. BMPs implemented in the study area included fencing and planting of native grasses and brush. In this study, water quality was monitored prior to and during installation of the BMPs, and for one year after the BMPs were installed. For the most part, this study did not find that water quality improved in the year after implementation of the BMPs, although two of the three studied stream reaches did exhibit decreases in the total area of active erosion (T. R. Brueggen-Boman 2012). It can take 3 to 4 years, or longer, for transient effects of BMP implementation to dissipate, and for the BMP to become established (Meals et al. 2010).

7.2.2 Ongoing and Planned Management Strategies

One Section 319 project was initiated October 2015 (15-1100) to address erosion in the Strawberry River watershed. Practices targeted in this project include both structural controls such as fencing, planting, and heavy use area protection; and non-structural controls such as rental of equipment and conservation planning.

The Nature Conservancy has a preserve where they implement and demonstrate structural and non-structural control practices as summarized in Tables 7.1 and 7.2.

There are four 12-DIGIT HUC subwatersheds of the Strawberry River that are being targeted for nonpoint source management practices through the NRCS Mississippi River Basin Initiative (MRBI). Core practices that have been identified for implementation in these subwatersheds include structural controls such as critical area planting, filter strips, and restoration of riparian vegetation, as well as non-structural controls such as prescribed grazing. MRBI projects for two of the subwatersheds, one in Fulton County and one in Izard County, were initiated in early 2015, and will run through 2018 (NRCS 2015a). MRBI projects for two subwatersheds in Sharp County will be initiated in 2016 (NRCS 2015b).

7.2.3 Recommended Subwatersheds

One of the criteria used to select the recommended subwatersheds was that there has not been significant implementation of management practices to address nonpoint source pollution in the past. The management practices that have been implemented elsewhere in the Strawberry River watershed are applicable in the recommended subwatersheds. Therefore, the management practices to reduce sheet/rill/wind erosion and concentrated flow erosion of pasture in the recommended subwatersheds, are the same practices that have been and are being implemented in the Strawberry River watershed.

7.3 Management Strategies to Reduce Streambank Erosion

NRCS rankings of natural resource concerns identified streambank erosion as a high priority concern in a number of 12-digit HUC subwatersheds, including two of the recommended subwatersheds selected for this plan. Stakeholders have also stated that streambank erosion is widespread in the Strawberry River watershed. Removal of riparian vegetation to maximize productive area, and use of streams by livestock can contribute to streambank instability and erosion. Reducing streambank erosion reduces TSS load and stream turbidity to meet state water quality criteria. Reduced turbidity and TSS means improved visibility for predatory sport fish, such as bass, and reduced sedimentation in stream channels, which also supports desirable sport fish and their prey.

Table 7.3 is a summary of structural controls that address streambank erosion that have been implemented, or are planned for the Strawberry River watershed. Table 7.4 is a summary of nonstructural controls that address streambank erosion that have been implemented, or are planned, for the watershed

7.3.1 Past Management Strategies

There have been a number of Section 319 projects and NRCS practices implemented in the Strawberry River watershed to stabilize streambanks. As specified in the 2002 Strawberry River Watershed Restoration Action Strategy, this work has been focused in headwater 12-digit HUC subwatersheds.

7.3.1.1 Structural Controls

There have been seven Section 319 projects in the Strawberry River watershed to reduce erosion and sediment associated with use of pasture streams by livestock. Structural controls that have been implemented as part of these projects are listed in Table 7.3. Structural control practices that have been used in the watershed include fencing, alternative water supplies, and streambank protection. Each of these practices is discussed below.

Fencing installed along streams prevents livestock from damaging streambanks and allows riparian areas to revegetate and stabilize streambanks. When livestock are fenced off from streams, alternate water sources are developed streambank protection stabilizes streambanks, reducing bank erosion.

Table 7.3. Structural controls to reduce streambank erosion.

Project/program (lead agency/ organization)	Practices		Location	Status	Estimated soil saved
00-600 Strawberry River Watershed Project, Reach 1 (County Conservation Districts)	Fence	496,796 ft	Strawberry River watershed upstream of Piney Fork	Complete	Not available
	Tanks	193			
	Pipeline	40,958 ft			
	Pond	39			
01-800: Piney Fork, Reach 2 (Sharp County Conservation District)	Freeze-proof tanks	17	Piney Fork watershed, Izard and Sharp Counties	complete	Not available
	Streambank stabilization	25 ft			
	Electric fence sets	9			
01-1900: Alternative livestock water demonstration (Fulton County Conservation District)	Streambank exclusion	564,774 ft	Fulton County	Complete	Not available
	Fence	650,327 ft			
	Use exclusion	528.05 ac			
	Water tanks	152			
	Pipeline	60,061 ft			
	Spring development	7			
	Streambank protection	589,656 ft			
	Well	13			
	Pond	20			
05-800: Strawberry River agricultural watershed project reach III – North Big Creek (Lawrence and Sharp County Conservation Districts)	Fence	46,723 ft	North Big Creek	Complete	3,528 tons
	Water tanks	15			
	Pond	3			
	Pipeline	3,917 ft			
08-500: Strawberry River subwatersheds (Fulton County Conservation District)	Fence	46,723 ft	Fulton County	Complete	58,647 tons/yr
	Pond	2			
	Pipeline	2,817 ft			
	Well	2			
	Water tanks	15			
09-2100: Strawberry River improvement project – supplemental cost-share, and 11-1000: Strawberry River improvement project (Sharp County Conservation District)	Fence	111,944 ft	Sharp County	Complete	Not available
	Water facilities	10			
	Pond	2 (3,000 yds)			
	Pipeline	1,245 ft			

Table 7.3. Structural controls to reduce streambank erosion (continued).

Project/program (lead agency/ organization)	Practices		Location	Status	Estimated soil saved
11-1100: Strawberry River subwatershed project (Izard County Conservation District)	Fence	59,065 ft	Izard County	Complete	7,541 tons/yr
	Use exclusion	150.4 units			
	Water facilities	29			
	Pipeline	16,754 ft			
	Well	4			
	Pasture planting	669 ac			
	Pumping plant	4			
15-1100: Strawberry River subwatersheds project (Fulton County Conservation District)	Fence, pond, watering facilities, pipeline		110100120201, 110100120202, 110100120203, 110100120204, 110100120205, and 110100120301	Ongoing	Not available
Strawberry River Preserve and demonstration ranch (TNC)	Fence and water facilities			Ongoing	Not available
Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (NRCS)	Core practices include streambank protection, fence, and water facilities		Little Strawberry River and Philadelphia Creek – Piney Fork 12-digit HUC subwatersheds	Ongoing	Not available
Controlled Access and Livestock Fencing (CALF) Initiative (US Fish and Wildlife Service)	Eligible practices include fencing, stream crossings, alternative water supplies (pipe and pumps), and controlled access points		Entire watershed	Ongoing	Not available
Partners for Fish and Wildlife (US Fish and Wildlife Service)	Eligible practices include riparian fencing, streambank stabilization, stream restoration		Entire watershed	Ongoing	Not available
Forestry road BMPS (Arkansas Forestry Commission)	Stream crossings	2010 - Implementation all BMPs 83% in District 8, implementation road BMPs 88% in Ozark region	Private forest lands	Ongoing	Not available

Table 7.4. Non-Structural controls to reduce streambank erosion.

Project/program (lead agency/ organization)	Practices		Location	Status
00-600 Strawberry River Watershed Project, Reach 1 (County Conservation Districts)	Farm plans	188	Strawberry River watershed upstream of Piney Fork	Complete
	Forest stand improvement	2,384 ac		
	Prescribed grazing	33,068 ac		
01-800: Piney Fork, Reach 2 (Sharp County Conservation District)	Conservation plans	30	Piney Fork watershed, Izard and Sharp Counties	Complete
01-1900: Alternative livestock water demonstration (Fulton County Conservation District)	Prescribed grazing	8,048 ac	Fulton County	Complete
	Forest stand improvement	3,815 ac		
	Stream buffer	528.6 ft		
	Streambank restoration plans	10 farms		
03-159 Fulton County 2003 Mini-grant (Fulton County Conservation District)	Tree planter rental	109.5 acres planted	Fulton County	Complete
05-800: Strawberry River agricultural watershed project reach III – North Big Creek (Lawrence and Sharp County Conservation Districts)	Conservation plans	164	North Big Creek	Complete
	Prescribed grazing	10,419.8 ac		
	Tree planting	109.5 ac		
08-500: Strawberry River subwatersheds (Fulton County Conservation District)	Conservation plans	127	Fulton County	Complete
09-2100: Strawberry River improvement project – supplemental cost-share 11-1000: Strawberry River improvement project (Sharp County Conservation District)	Prescribed grazing	11,823.6 ac	Sharp County	Complete
	Conservation plans	125		
	Tree planting	160.6 ac		
11-1100: Strawberry River subwatershed project (Izard County Conservation District)	Conservation plans	44	Izard County	Complete
	Prescribed grazing	4,424 ac		
	Riparian tree planting			
Strawberry River Preserve and demonstration ranch (TNC)	Prescribed grazing		Whaley Creek-Strawberry River 12-digit HUC subwatershed	Ongoing
	Forested riparian buffer	0.5 mi		
Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (NRCS)	Core practices include prescribed grazing and riparian buffers		Little Strawberry River and Philadelphia Creek – Piney Fork 12-digit HUC subwatersheds	Ongoing
Forestry road BMPS (Arkansas Forestry Commission)	Streamside management zones (SMZ)	2010 - Implementation all BMPs 83% in District 8, implementation SMZs 82% in Ozark region	Private forest lands	Ongoing

7.3.1.2 Non-structural Controls

There have been 10 Section 319 projects in the Strawberry River watershed to reduce erosion and sediment associated with pasture and the use of pasture by livestock using non-structural controls (Table 7.4). Non-structural practices that have been used in the watershed include purchase of tree planters to be loaned to land owners, development of conservation plans, riparian buffers, and prescribed grazing. Tree planters can be used to plant riparian buffers to stabilize streambanks, while minimizing soil disturbance. Landowners frequently do not have the funds to purchase this type of machinery for their own use, so purchasing the equipment and providing it for the use of landowners' aids in the reduction in erosion. Riparian buffers help stabilize streambanks, reducing erosion. Prescribed grazing can protect riparian areas and reduce livestock access to streambanks. Conservation plans can include practices to protect riparian areas and stabilize streambanks.

7.3.2 Ongoing and Planned Management Strategies

There is one Section 319 project that was initiated October 2015 (15-1100) to address erosion in the Strawberry River watershed. Practices targeted in this project include both structural controls such as fencing and alternative water supplies, and non-structural controls such as rental of equipment and conservation planning.

The Nature Conservancy has a preserve where they implement and demonstrate structural and non-structural control practices as summarized in Tables 7.3 and 7.4.

There are two 12-DIGIT HUC subwatersheds of the Strawberry River that are being targeted for nonpoint source management practices through the NRCS Mississippi River Basin Initiative. Core practices that have been identified for implementation in these subwatersheds include structural controls such as restoration of riparian vegetation and streambank protection, as well as non-structural controls such as prescribed grazing. This project was initiated in early 2015, and will run through 2018.

The Arkansas Association of Conservation Districts has recently begun an initiative focused on assisting landowners in restricting livestock access to streams; Controlled Access and Livestock Fencing (CALF). The Strawberry River watershed is within the focus area for this initiative. Practices available through this program are primarily structural controls, including fencing, water transfer, alternative watering facilities, stream crossings, and controlled access points.

7.3.3 Recommended Subwatersheds

One of the criteria used to select the recommended subwatersheds was that there has not been significant implementation of management practices to address nonpoint source pollution. The management practices that have been implemented elsewhere in the Strawberry River watershed are applicable in the recommended subwatersheds. Therefore, the management practices to reduce streambank erosion in the recommened subwatersheds, are the same practices that have been and are being implemented in the Strawberry River watershed.

7.4 Management Strategies to Reduce Erosion of Unpaved Roads and Roadside Ditches

Erosion of unpaved roads and roadside ditches has been identified as a priority source of turbidity-causing sediment in the Clayton Creek recommended 12-digit HUC subwatershed. Reducing erosion from unpaved roads and roadside ditches reduces TSS load so stream turbidity levels meet state water quality criteria. Reduced turbidity means improved visibility for predatory sport fish such as bass, and reduced sedimentation in stream channels, which also supports desirable sport fish and their prey.

Table 7.5 is a summary of structural controls that address erosion from unpaved roads that have been implemented, or are planned, for the Strawberry River watershed. Table 7.6 summarizes nonstructural controls that address erosion from unpaved roads that have been implemented, or are planned, for the Strawberry River watershed.

Table 7.5. Structural controls to reduce erosion from unpaved roads.

Project/program (lead agency/ organization)	Practices		Location	Status
05-800 Strawberry River Agricultural Watershed Project Reach III – North Big Creek	Sediment basins		North Big Creek watershed	Completed
	Pipe drops			
	Culverts			
County Road maintenance program (Counties)	underdrains, check dams, belt diversions, chip seal		Entire watershed	Ongoing
Forestry road BMPs (Arkansas Forestry Commission)	Wing ditches, broad-based dips, rolling dips	2010 - Implementation all BMPs 83% in District 8, implementation road BMPs 88% in Ozark region	Private lands	Ongoing

Table 7.6. Nonstructural controls to reduce erosion from unpaved roads.

Project/program (lead agency/ organization)	Practices		Location	Status
00-600 Strawberry River Watershed Project, Reach 1 (County Conservation Districts)	Training for county road crews	1 meeting, 42 attendees	Fulton, Izard, and Sharp Counties	Complete
01-800: Piney Fork, Reach 2 (Sharp County Conservation District)	Assistance to county road crews	several	Piney Fork watershed, Izard and Sharp Counties	Complete
01-2100 Strawberry River Hydromulch (Izard County Conservation District)	Purchase & use of hydromulcher	3 sites	Fulton and Izard Counties	Complete
Arkansas unpaved roads program (Arkansas Department of Rural Services)	Training, financial assistance		Entire watershed	Ongoing

7.4.1 Past Management Strategies

There are programs in place to encourage and assist with construction and maintenance of unpaved roads to reduce sediment erosion. In addition, there have been three Section 319 projects that addressed erosion from unpaved roads.

7.4.1.1 Structural Controls

Structural controls that can be used to control and reduce erosion of unpaved roads have been developed by the Arkansas Forestry Commission. The results of annual surveys conducted by the Arkansas Forestry Commission indicate that the use of these BMPs by private forestland owners is widespread in the region of the Strawberry River watershed (Arkansas Forestry Commission 2011). The same, and other, practices can be used by county road crews. Information on the structural controls in use in the Strawberry River watershed was not located.

7.4.1.2 Nonstructural Controls

Three Section 319 projects have included activities to reduce erosion from unpaved roads in the Strawberry River watershed. These activities included providing training and technical assistance to road crews in the use of structural controls to reduce erosion from unpaved roads, and the use of a hydromulcher to stabilize and promote revegetation of bare road banks.

7.4.1.3 Effectiveness

The final report for Section 319 project 01-2100 included an estimate of erosion reduction resulting from the use of the hydromulcher on the three road banks, 56.7 tons/acre (Izard County Conservation District 2003). Proponents of the Arkansas Unpaved Roads Program have stated that effective BMPs can reduce erosion on roads by as much as 95% (The Nature Conservancy 2014).

7.4.2 Ongoing and Planned Management Strategies

The Arkansas Forestry Commission best management practice program, which includes practices for reducing erosion from unpaved roads, is ongoing. In addition, surveys to track BMP use are expected to continue into the future.

The Arkansas Unpaved Roads Program was initiated in 2013. Goals of this program include providing training to road maintenance professionals on practices to reduce erosion from unpaved roads, as well as identifying and demonstrating new practices (The Nature Conservancy 2014). In 2015, the Arkansas legislature passed the Arkansas Unpaved Roads Program Act to provide funding for the activities of the Arkansas Unpaved Roads Program.

7.4.3 Recommended Subwatershed

One of the criteria used to select the recommended subwatersheds was that there has not been significant implementation of management practices to address nonpoint source pollution. The management practices that have been implemented elsewhere in the Strawberry River watershed are applicable in the Clayton Creek recommended subwatershed. Therefore, the management practices to reduce concentrated flow erosion of unpaved roads and roadside ditches in the Clayton Creek subwatershed, are the same practices that have been and are being implemented in the Strawberry River watershed. The majority of the Clayton Creek subwatershed is in Sharp County, and the Sharp County Conservation District has experience with these BMPs, having already completed a project addressing erosion on unpaved roads in another subwatershed of the Strawberry River.

7.5 Management Strategies to Reduce Bacteria

On the final 2008 and the draft 2014 303(d) lists, stream segments are listed as impaired due to bacteria. No sources for this pollutant are identified by ADEQ on the 303(d) lists. Animal feeding operations, manure storage, runoff from pastures where manure is applied, and livestock access to streams are the priority nonpoint sources of E. coli in the recommended 12-digit HUC subwatersheds (Table 5.7).

Reducing the E. coli load to surface waters makes it possible for streams to meet state E. coli water quality standards. When E. coli water quality standards are met, the water is safe for human contact, and healthier for livestock.

Table 7.7 is a summary of structural controls that reduce bacteria loads that have been implemented, or are planned for the Strawberry River watershed. Table 7.8 is a summary of nonstructural controls that reduce bacteria loads that have been implemented, or are planned, for the watershed. Because some practices can address both erosion and bacteria, practices from Tables 7.1 through 7.4 are also shown in Tables 7.7 and 7.8.

7.5.1 Past Management Strategies

There have been a number of Section 319 projects and NRCS practices implemented in the Strawberry River watershed to control access of livestock to streams, filter pasture runoff, and manage animal waste. As specified in the 2002 Strawberry River Watershed Restoration Action Strategy, this work has been focused in headwater 12-digit HUC subwatersheds.

Table 7.7. Structural controls for bacteria and manure management.

Project/Program (lead agency/ organization)	Practices		Location	Status
00-600 Strawberry River Watershed Project, Reach 1 (County Conservation Districts)	Fence	496,796 ft	Strawberry River watershed upstream of Piney Fork	Complete
	Tanks	193		
	Pipeline	40,958 ft		
	Pond	39		
01-800: Piney Fork, Reach 2 (Sharp County Conservation District)	Freeze-proof tanks	17	Piney Fork watershed, Izard and Sharp Counties	Complete
	Electric fence sets	9		
	Dry stack facility	1		
01-1900: Alternative livestock water demonstration (Fulton County Conservation District)	Streambank exclusion	564,774 ft	Fulton County	Complete
	Fence	650,327 ft		
	Water tanks	152		
	Pipeline	60,061 ft		
	Spring development	7		
	Well	13		
	Pond	20		
05-800: Strawberry River agricultural watershed project reach III – North Big Creek (Lawrence and Sharp County Conservation Districts)	Fence	46,723 ft	North Big Creek	Complete
	Water tanks	15		
	Pond	3		
	Pipeline	3,917 ft		

Table 7.7. Structural controls for pathogen and manure management (continued).

Project/Program (lead agency/ organization)	**Practices**		**Location**	**Status**
08-500: Strawberry River subwatersheds (Fulton County Conservation District)	Fence	46,723 ft	Fulton County	Complete
	Pond	2		
	Pipeline	2,817 ft		
	Well	2		
	Water tanks	15		
09-2100: Strawberry River improvement project – supplemental cost-share, and 11-1000: Strawberry River improvement project (Sharp County Conservation District)	Fence	111,944 ft	Sharp County	Complete
	Water facilities	10		
	Pond	2		
	Pipeline	1,245 ft		
11-1100: Strawberry River subwatershed project (Izard County Conservation District)	Fence	59,065 ft	Izard County	Complete
	Water facilities	29		
	Pipeline	16,754 ft		
	Well	4		
	Pumping plant	2		
15-1100: Strawberry River subwatersheds project (Fulton County Conservation District)	Fence, pond, watering facilities, pipeline,		110100120201, 110100120202, 110100120203, 110100120204, 110100120205, and 110100120301	Ongoing
Strawberry River Preserve and demonstration ranch (TNC)	Fence		Whaley Creek-Strawberry River 12-digit HUC subwatershed	Ongoing
	Water facilities			
Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (NRCS)	Core practices include cover, critical area Supporting practices include animal mortality and waste storage facilities, fence, and alternative water supplies.		Little Strawberry River and Philadelphia Creek – Piney Fork 12-digit HUC subwatersheds	Ongoing
Controlled Access and Livestock Fencing (CALF) Initiative (US Fish and Wildlife Service)	Eligible practices include fencing, heavy use area protection, stream crossings, alternative water supplies (pipe and pumps), and controlled access points		Entire watershed	Ongoing

Table 7.8. Non-structural controls for bacteria and manure management.

Project/Program (lead agency/ organization)	Practices		Location	Status
00-600 Strawberry River Watershed Project, Reach 1 (County Conservation Districts)	Prescribed grazing	33,068 ac	Strawberry River watershed upstream of Piney Fork	Complete
	Nutrient management	27,559 ac		
	Pasture planting	2,093 ac		
01-1900: Alternative livestock water demonstration (Fulton County Conservation District)	Forested riparian buffer	528.6 ft	Fulton County	Complete
	Nutrient management	7,994 ac		
	Grassed waterway	1 site		
	Water quality plans	85 farms		
05-800: Strawberry River agricultural watershed project reach III – North Big Creek (Lawrence and Sharp County Conservation Districts)	Nutrient management	7,213 ac	North Big Creek	Complete
	Prescribed grazing	10,419.8 ac		
	pasture planting	339 ac		
	Pasture management equipment rental			
09-2100: Strawberry River improvement project – supplemental cost-share (Sharp County Conservation District)	Prescribed grazing	11,823.6 ac	Sharp County	Complete
11-1100: Strawberry River subwatershed project (Izard County Conservation District)	Nutrient management	3,194 ac	Izard County	Complete
	Prescribed grazing	4,424 ac		
15-1100: Strawberry River subwatersheds project (Fulton County Conservation District)	Forage and biomass planting		110100120201, 110100120202, 110100120203, 110100120204, 110100120205, and 110100120301	Ongoing
Strawberry River Preserve and demonstration ranch (TNC)	Forested riparian buffer	0.5 mi	Whaley Creek-Strawberry River 12-digit HUC subwatershed	Ongoing
Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (NRCS)	Core practices include prescribed grazing, riparian buffers, waste storage facility, and filter strips		Little Strawberry River and Philadelphia Creek – Piney Fork 12-digit HUC subwatersheds	Ongoing

7.5.1.1 Structural Controls

There have been five Section 319 projects in the Strawberry River watershed to reduce water quality impacts of livestock and animal feeding operations. Structural controls that have been implemented as part of these projects are listed in Table 7.7.

Structural control practices that have been used in the watershed that reduce bacteria loads to surface waters include fencing, alternative water supplies, and dry stack facility. Fencing installed along streams prevents livestock from defecating in streams. When livestock are fenced off from streams, alternate water sources are developed. A dry stack facility, i.e., covered waste storage facility, keeps stored animal waste out of runoff.

7.5.1.2 Non-structural Controls

There have been 10 Section 319 projects in the Strawberry River watershed to reduce water quality impacts of livestock and animal feeding operations using non-structural controls (Table 7.8). Non-structural practices that have been used in the watershed that reduce bacteria loads include development of nutrient plans, pasture planting, riparian buffers, and prescribed grazing. No-till drills allow planting to improve pasture ground-cover, reducing runoff and increasing filtering capacity. Tree planters can be used to plant riparian buffers to filter runoff. Landowners frequently do not have the funds to purchase this type of machinery for their own use, so purchasing the equipment and providing it for the use of landowner's aids in the improvement of pasture and runoff water quality. Prescribed grazing can include exclusion of livestock from streams. Prescribed grazing also reduces the concentrated build up of manure, and protects and improves the ground cover in pastures to reduce runoff and improve or maintain filtering capacity. Riparian buffers slow and filter runoff, reducing the amount of bacteria that end up in streams. Nutrient management plans can specify timing and practices for application of poultry litter, or manure from other animal feeding operations, on pasture that reduce bacteria in pasture runoff.

7.5.1.3 Effectiveness

Reductions in bacteria resulting from agricultural BMPs are rarely tracked. Bacteria reductions have not been reported for any of the Section 319 projects in the Strawberry River watershed.

Researchers from Arkansas State University studied the effectiveness of BMPs implemented in the upper Strawberry River watershed. BMPs implemented in the study area included fencing, alternative water supplies, and planting of native grasses and brush. In this study, water quality was monitored prior to and during installation of the BMPs, and for one year after the BMPs were installed. This study found significantly higher levels of Eschericia coli in samples collected after the BMPs were installed, compared to samples collected prior to BMP installation. The study concluded that additional BMPs would be needed to reduce bacteria (T. R. Brueggen-Boman 2012).

7.5.2 Ongoing and Planned Management Strategies

There is one Section 319 project that was initiated October 2015 (15-1100) to address erosion in the Strawberry River watershed. Practices targeted in this project include both structural controls such as fencing and alternative water supplies, and non-structural controls such as conservation planning. Though the project objective is to reduce erosion, many of the targeted practices can also reduce bacteria loads to surface waters.

There are four 12-DIGIT HUC subwatersheds of the Strawberry River that are being targeted for nonpoint source management practices through the NRCS Mississippi River Basin Initiative. Core practices that have been identified for implementation in these subwatersheds include structural controls such as filter strips, restoration of riparian vegetation, and streambank protection, as well as non-structural controls such as prescribed grazing. These practices can reduce bacteria in runoff. MRBI projects for two of the subwatersheds, one in Fulton County and one in Izard County, were initiated in early 2015, and will run through 2018 (NRCS 2015a). MRBI projects for two subwatersheds in Sharp County will be initiated in 2016 (NRCS 2015b).

The Arkansas Association of Conservation Districts, with the US Fish and Wildlife Service, has recently begun an initiative focused on assisting landowners in restricting livestock access to streams; Controlled Access and Livestock Fencing (CALF). The Strawberry River watershed is within the focus area for this initiative. Practices available through this program are primarily structural controls, including fencing, water transfer, alternative watering facilities, stream crossings, and controlled access points.

7.5.3 Recommended Subwatersheds

One of the criteria used to select the recommended 12-digit HUC subwatersheds for this plan was that there has not been significant implementation of management practices to address nonpoint source pollution. The management practices that have been implemented elsewhere in the Strawberry River watershed are applicable in the recommended subwatersheds.Therefore, the management practices to reduce E. coli inputs to surface water from animal feeding operations, livestock in streams, and pastures where manure is applied in the recommended subwatersheds, are the same practices that have been, and are being, implemented in the Strawberry River watershed.

7.6 Stakeholder Recommendations

A stakeholder meeting was held to get input on what management strategies are preferred and work in the Strawberry River watershed. Management strategies identified by the stakeholders are listed in Table 7.9, along with information and comments from stakeholders.

Table 7.9. Management practices recommended by stakeholders.

Practice	Comments
Fencing	This includes cross fencing for prescribed grazing and fencing off streams in pastures. At least one attendee stated that fencing along rivers is not always the best choice of practices. Another reported that hot wires work better than non-electrical fencing.
Prescribed/rotation grazing and sacrificial plots	Farmers using rotation grazing see improvement in cattle and pasture health, and find it to be a more efficient use of their resources. It was noted that it is counter-productive to put all pasture land in prescribed grazing. Areas are needed for sacrificial plots, etc.
Alternative water sources	Water source alternatives to pasture streams used in the watershed include ponds and water tanks, along with piping and valves to move water.
Heavy use area re-vegetation	This practice is used by area farmers. It may become more important as the number of poultry houses in the area increases.
Nutrient management plans	It was noted that the Sharp County technician who assists with nutrient management plans is currently covering 7 counties in the area.
Fertilizer application technology	There is interest in precision application of poultry litter and other fertilizers in the watershed, including GPS technology. Training for farmers and use of services are options.
Dry stacks, composters, incinerators	This equipment is required for all newly constructed poultry houses.
Streambank restoration	Streambank erosion is widespread
Training on gravel road water control measures	There are lots of unpaved county roads in the watershed that can be a source of sediment. In the 1990s, Fulton County road crews were given training in gravel road maintenance and water control for erosion reduction. However, there is a lot of turnover in county road crews, so another round of training is warranted. It was suggested that this training be a recurring, rather than one-time event, either annually or biennially. The information/training provided needs to be appropriate for roads in hilly terrain. Gravel road water control measures for hilly terrain are different from those for flat lands.
Forestry BMPs	Use of forestry BMPs for forest land owners in the watershed is widespread. One attendee suggested that Streamside Management Zones could be more actively managed, e.g., thinning may make them more effective.
Silvipasture	This practice is not widespread in the watershed.

7.7 Estimated Load Reductions

For a number of the management strategies identified in the sections above, information on the effectiveness in reducing selected pollutants has been published. This information is summarized in Table 7.10.

Table 7.10 Summary of available information on reduction efficiencies of management practices for plan target pollutants (turbidity/TSS and bacteria).

Practice	TSS reduction	Bacteria reduction
Stream exclusion (Fencing + alternative water supply)	83%[a]	30% - 95%
Alternative water supply	38%[a], 89%[b]	57%[b]
Heavy use area treatment	No information	Not applicable
Prescribed/rotational grazing	60%[b]	60% - 72%
Controlled stream access	No information	No information
Forested riparian buffer	76%[a], 94%[b]	30%[b]
Streambank stabilization/ restoration	Up to 100%[c]	Not applicable
Erosion control practices for unpaved roads	48% - 95%[d]	Not applicable
Forestry BMPs (SMZ, stream crossing, road BMPs)	See Forested riparian buffer, and erosion control for unpaved roads	Not applicable
Pasture planting	59%[a]	No information
Filter strips	53% - 91%[a], 31% - 98%[b]	30% - 100%[b]
Grassed waterway	17%[a]	No information
Stacking sheds	Not applicable	No information
Conservation plans	See other practices	See other practices
Nutrient management plans	See other practices	See other practices
Vegetated riparian buffer	See filter strips	41%[b]
Roof runoff structure	No information	No information
Pond	77%[a]	No information

[a] (Merriman, Gitau and Chaubey 2009)
[b] VT database
[c] Kings River bank restoration report
[d] (TNC n.d.)

Estimates of the extent of each practice that would be required to achieve the target TSS load reduction to meet turbidity water quality criteria for the recommended 12-digit HUC subwatersheds are listed in Table 7.11. Included in Table 7.11 are estimates of length of streams and area of pasture that are contributing to the excess turbidity in the Strawberry River. In these estimates, 15% of streambanks are assumed to be contributing to the TSS load, based on the findings of Brueggen and Bouldin (2011). Based on an inventory of unpaved roads in Sharp County (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003), 25% of unpaved roads in the Clayton Creek subwatershed are assumed to be contributing to the TSS load. Based on a 2000 inventory of pasture condition in the Strawberry River watershed (Strawberry River Watershed Reach I (FY-600) Restoration Action Strategy 2003), 15% of pasture is assumed to be contributing to the TSS load.

Table 7.11. Treatment to reduce TSS load to achieve turbidity numeric water quality criteria.

Treatment	Meeks Br-Strawberry	Clayton Cr-Strawberry	Reeds Cr-Strawberry	Bullpen Cr-Strawberry
Target percent load reduction	50%	50%	50%	58%
Feet of stream in subwatershed	205,973	273,610	210,830	268,118
Assume 15% of streambank contributing sediment, ft	61,792	82,083	63,249	80,436
Estimated feet of stream in pasture	39,135	53,627	78,218	103,494
Feet of unpaved road	160,565	265,162	161,938	324,509
Assume 25% of unpaved road contributing sediment, ft	NA	66,290	NA	NA
Acres pasture in subwatershed	2,972	3,741	5,251	8,932
Assume 15% of pasture is eroding, ac	419	561	788	1,340
Feet bank stabilization and/or riparian buffer (80% reduction)	38,620	51,302	39,531	58,316
Feet pasture stream exclusion (80% reduction)	48,918	67,034	97,773	150,066
Acres pasture planting (59% reduction)	355	476	667	1,317
Acres prescribed grazing (60% reduction)	349	768	656	1,295
Acres grassed waterway (17% reduction)	1,232	1,651	2,316	4,571
Acres 30 foot filter strips (65% reduction)	41.4	56.8	82.9	127
Feet unpaved road BMPs (70% reduction)	NA	47,350	NA	NA

The load reductions identified in Table 7.11 are estimates based on currently available information. Due to our incomplete understanding of the processes at work in the Strawberry River watershed, and the vagaries of weather and stakeholder participation, the results may differ from what is identified here.

7.7.1 Stream Fencing with Alternative Water Supply

Studies have shown that excluding livestock from streams can improve streambank stability, thus reducing sediment loads from an area (Agouridis, et al. 2005). In a decision tool for selecting BMPs for Arkansas, sediment reduction of 83% is assigned to use exclusion, with a 38% reduction assumed for use of just alternative watering facilities (Merriman, Gitau and Chaubey 2009).

7.7.2 Prescribed Grazing

Rotational grazing has been shown to reduce sediment loads (Sovell et al. 2000, Pennington et al. 2009). A paired watershed study in northwest Arkansas found that sediment levels in runoff from rotationally grazed pastures were at least half the levels from overgrazed pastures (Pennington et al. 2009). Prescribed grazing practices can also include alternative water sources and livestock exclusion. Load reductions for these practices are discussed above.

7.7.3 Riparian Buffers

An Arkansas agricultural BMP effectiveness tool uses a total sediment reduction of 76% for forested riparian buffer. Filter strips, or field borders, which would be equivalent to grassed buffers, are expected to reduce sediment loads by around 34% (Merriman, Gitau and Chaubey 2009).

7.7.4 Streambank Stabilization/Restoration

Several streambank restoration projects have been implemented in northwest Arkansas. Sediment load reductions of almost 100% have been achieved with these natural channel design restoration projects (Van Epps 2014).

7.7.5 Erosion Control Practices for Unpaved Roads

Information from the Arkansas Unpaved Roads Program states that effective BMPs can reduce erosion on roads by up to 95% (The Nature Conservancy 2014). Effective drainage practices can reduce sediment by 48% or more. Driving surface aggregate can reduce sediment by as much as 86% (Scheetz and Bloser 2008).

7.7.6 Pasture Planting

An Arkansas agricultural BMP effectiveness tool uses a total sediment reduction of 59% for pasture planting.

7.7.7 Filter Strips

An Arkansas agricultural BMP effectiveness tool uses a total sediment reduction of 34% for field borders.

8.0 IMPLEMENTATION PROGRAM

8.1 Schedule and Milestones

As shown in Chapter 7, there are numerous ongoing and planned activities in the Strawberry River watershed that will contribute to achieving the goals of this plan. Table 8.1 summarizes the schedules and milestones for activities required to implement this plan in the recommended 12-digit HUC subwatersheds. These are activities that are known and planned as of December 2015. These activities are discussed further in the following sections.

Table 8.1. Implementation schedule.

Activity	Action (lead)	Start	Milestone (3-5 yrs)	Indicator	Long Term Goal
Watershed Implementation Plans	Prepare and implement watershed implementation plans in recommended 12-DIGIT HUC subwatersheds (stakeholders)	2016	Watershed implementation plan developed for at least one recommended 12-DIGIT HUC subwatershed	Impaired stream reaches in recommended subwatersheds	All water quality criteria met in impaired stream reaches listed in final 2008 and 2014 303(d) lists
Implement Management Strategies	15-1100 Strawberry River Subwatershed Improvement (Fulton County Conservation District)	2015	Contracts for management practices	Numbers of practices	Turbidity and pathogen water quality criteria met
	Strawberry River Watershed Initiative (Fulton & Izard County Conservation Districts)	2015	Contracts for management practices	Numbers of practices	Turbidity and pathogen water quality criteria met
	Controlled Access for Livestock Fencing (CALF) (Association of Arkansas Conservation Districts)	2015	Contracts for management practices in at least one recommended 12-DIGIT HUC subwatershed	Miles of excluded streambank	Reduced streambank erosion, improved stream habitat, turbidity and pathogen water quality criteria met
	Strawberry River Watershed Initiative (Sharp County Conservation District)	2016	Contracts for management practices	Numbers of practices	Turbidity and pathogen water quality criteria met
	Management practices in recommended 12-DIGIT HUC subwatersheds (County Conservation Districts)	2018	Begin implementation of management practices identified in watershed implementation plan	Implementation goals outlined in watershed implementation plan	All water quality criteria met in impaired stream reaches listed in final 2008 and/or 2014 303(d) lists
	Annual county road maintenance crew training for unpaved roads (Counties)	2017	At least one county set up training program	County roads in watershed properly graded, Number of training session per year	Erosion of county roads reduced
	Forestry BMPs (Arkansas Forestry Commission)	2008	Increase use of BMPs in a recommended 12-DIGIT HUC subwatershed	Percent implementation	Turbidity water quality criteria met

8.2 Monitoring

Monitoring is an essential element of adaptive watershed management. The objectives of monitoring in the Strawberry River watershed include:

- Identify areas where water quality does and doesn't support designated uses,
- Identify sources of pollution impairing designated uses, and
- Track changes in water quality resulting from land use changes, development, land and water management practices, and other factors.

8.2.1 Existing Surface Water Quality Monitoring Programs

ADEQ and USGS have active water quality monitoring programs in the Strawberry River watershed. These monitoring programs are described in Section 3.2.1. Table 8.2 lists water quality parameters monitored through these programs, which include the priority pollutants identified in Section 5.3.6. These programs must be continued.

Table 8.2. Water quality parameters being monitored in the Strawberry River watershed.

Parameters	ADEQ ambient	ADEQ lakes	ADEQ roving	ADEQ special study	USGS
Metals	X	X	X		
Dissolved Oxygen	X	X	X	X	X
Turbidity	X	X	X		
Nutrients	X	X	X		
TSS	X	X	X	X	
E. coli			X		X
Alkalinity	X	X	X		
Minerals	X	X	X	X	
Temperature	X	X	X	X	X
Conductivity	X	X	X	X	X
pH	X	X	X	X	X
Hardness	X		X		
Total organic carbon	X		X	X	

Existing water quality monitoring stations associated with impaired stream segments within the recommended subwatersheds are listed in Table 8.3. Note that there are no routine water quality monitoring stations associated with impaired stream segment 005 in the Reeds Creek-Strawberry River subwatershed, nor with impaired stream segment 009 in the Bullpen Creek-Strawberry River subwatershed. Water quality stations that are part of the ADEQ ambient water quality monitoring program are sampled monthly. Water quality stations that are part of the ADEQ roving water quality monitoring program are sampled bimonthly for a two year period, every six years. It could be worthwhile to routinely monitor water quality at sites on Strawberry River segments 005 and 009, to better track changes in water quality from the Reeds Creek-Strawberry River and Bullpen Creek-Strawberry River subwatersheds over time. These sites could be added to the ADEQ roving water quality monitoring program, or sampled at a frequency similar to that of the ADEQ roving program, through special studies or other programs discussed below.

Table 8.3. Existing water quality monitoring in recommended subwatersheds.

Recommended subwatershed	ADEQ 2014 impaired stream segments	Water quality monitoring stations	Monitoring program
Meeks Branch-Strawberry River	006	WHI0024	ADEQ ambient
Clayton Creek-Strawberry River	006	WHI0024	ADEQ ambient
Reeds Creek-Strawberry River	014	UWRDC01	ADEQ roving
Bullpen Creek-Strawberry River	011	UWSBR01	ADEQ roving

8.2.2 Other Monitoring Opportunities

There are opportunities for expanding surface water quality monitoring in the Strawberry River watershed and recommended 12-digit HUC subwatersheds. Possibilities for additional water quality monitoring include special studies, sampling by volunteer stakeholders, and recommended watershed implementation plans.

8.2.2.1 ADEQ Roving Monitoring Network

ADEQ will be requested to assign at least one monitoring site in each 12-digit HUC priority watershed during the next round of their roving monitoring network in the Strawberry

River watershed. These data will assist in confirming which pollutants are contributing to water quality impairments and potential sources of these pollutants. Point source pollutants would be expected to have an inverse relationship with flow, particularly during the July – September low flow period. Although septic systems are not considered point sources, failing septic systems would also be expected to sustain bacteria loads during low flow periods. However, this is also expected if cattle have direct access to streams, particularly during low flow periods. Nonpoint source pollutants, particularly sediment and turbidity, would be expected to have a positive correlation with flow. Bacteria loads typically increase during and following storm events.
In situ monitoring of turbidity during this roving period will also confirm evaluated assessments of turbidity impairment.

8.2.2.2 Special Studies

There have been several Section 319 projects for collecting water quality data in the Strawberry River watershed. One of these was intended to track changes in water quality after implementation of BMPs (07-1000).

In addition to water chemistry data, there is considerable interest in the status of aquatic communities in the Strawberry River watershed. There are projects proposed and/or underway to characterize and monitor fisheries and mussels in the Strawberry River system. Aquatic communities are useful indicators of water quality.

Synoptic surveys will be conducted with in situ measurements of temperature, DO, conductivity, and turbidity taken at the mouth of each of the tributaries to the Strawberry River in each of the priority 12-digit HUC watersheds in the Strawberry River basin. In addition, duplicate E.coli samples will be collected at these same sites. These surveys will be conducted once during elevated flow in the winter and during low flow in the summer. These synoptic surveys will help identify critical subareas within the watershed where sediment (turbidity) and/or bacteria loads are greater than would be expected on a strictly areal basis. Within the critical subareas, sediment (turbidity) and/or bacteria sources will be evaluated to identify targets for management. These synoptic surveys can be conducted with volunteers from the priority 12-digit HUC watersheds as members of an AG&FC Stream Team, or contracted with a local community college or university using students. Each 12-digit HUC watershed can easily be sampled within a day.

8.2.2.3 Volunteer Monitoring

The agencies that traditionally have conducted water quality monitoring in Arkansas face budgetary constraints that make it difficult to expand, or even maintain existing, water quality monitoring networks. Trained stakeholder volunteers are one option for expanding water quality monitoring while working within budgetary constraints. The Arkansas Game and Fish Commission Stream Team program trains and guides volunteers in water quality monitoring of streams. Volunteer water quality monitoring programs have been able to effectively contribute to evaluation of water quality in Northwest Arkansas (Massey and Haggard 2009).

8.2.2.4 Implementation Plans

Ultimately, monitoring is the only approach that can document load reductions and support of designated uses and water quality standards. ANRC will coordinate with ADEQ and other agencies, such as the Arkansas Game and Fish Commission's Stream Team, to monitor water quality as part of watershed implementation planning. A minimal in situ monitoring program for temperature, DO, conductivity, and turbidity will be established at a site downstream from areas where management practices are to be implemented. When possible, at least one year of monitoring data will be collected prior to implementing management practices. Monitoring will be established as soon as an implementation site has been identified, even if one full year of monitoring is not achievable. Monitoring will be re-initiated one year following completed implementation of the management practices and continued for 2 consecutive years. Construction and transient effects have been observed up to a year following initiation of restoration, which confounds the analysis of practice effectiveness and efficiency. Monitoring will be discontinued for 2 consecutive years and then re-initiated during the 5th year after the initial re-initiation (Table 8.4). Where possible, an ADEQ roving monitoring site will be established downstream from the implementation site where a full suite of water quality constituents, including TSS and E.coli can be monitored and used to evaluate practice effectiveness and efficiency. Relationships among constituents such as TSS and turbidity will be evaluated for use at similar sites where only in situ monitoring might be feasible. For sites where recreational designated uses are impaired because of bacteria, at a minimum, duplicate E. coli samples will be collected each week for four consecutive weeks from mid-July to mid-August during the recreational season at each site monitored during each of the years noted above.

Table 8.4 Proposed schedule for BMP effectiveness monitoring.

Activity	Duration	Overall time period
Pre-implementation monitoring	1 year	1
BMP construction/implementation	Variable	1+x
Transient effects from construction/implementation	1 year	2+x
Water quality monitoring	2 years	4+x
No water quality monitoring	2 years	6+x
Resume water quality monitoring	1 year	7+x

If funds are available, in situ monitoring can be continuous throughout the 5 year period. Lag times following implementation of BMPs have been observed for years in larger catchments before improvements are observed (Meals et al., 2010). The main components of lag time include the time required for an installed practice to produce an effect, the time required for the effect to be delivered to the water resource, the time required for the water body to respond to the effect, and the effectiveness of the monitoring program to measure the response (Meals et.al., 2010). The magnitude of lag time is highly site and pollutant specific, but may range from months to years for relatively short-lived contaminants such as indicator bacteria, years to decades for excessive P levels in agricultural soils, and decades or more for sediment accumulated in river systems (Meals et al., 2010).

8.2.3 Existing Biological Monitoring Programs

There are no routine biological monitoring programs active in the Strawberry River watershed. However, university researchers have proposed biological studies of the watershed (AGFC 2015).

8.3 Information and Education

Watershed-based 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 improve water quality, implement management practices and restore streams are ultimately based on the socioeconomic perceptions, beliefs and values of landowners and stakeholders on how these technical solutions will affect them. The Information and Education objectives of this watershed-based plan, therefore, are to:

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

Information and Education programs and efforts by ANRC, County Conservation Districts, USDA Cooperative Extension Service, and NRCS have been working toward achieving these objectives in the Strawberry River watershed for over 10 years. These organizations will continue to promote water quality management in the watershed. These organizations are both stakeholders and implementation partners. Since they have been active in the watershed in the past, these organizations have established relationships with landowners in the watershed, who are also stakeholders, as well as with each other.

Following is a discussion of information and education activities in the Strawberry River watershed. The section on past outreach and education efforts is followed by a section that discusses ongoing and proposed future activities. Table 8.5 provides a summary of information and education activities within the Strawberry River watershed.

Table 8.5. Summary of information and education activities within the Strawberry River watershed.

Project/Program (lead agency/ organization)	Practices	Amount	Location	Status
00-600 Strawberry River Watershed Project, Reach 1 (County Conservation Districts)	Quarterly newsletter	12 quarters	Strawberry River watershed upstream of Piney Fork	Complete
	Field day	3, plus multiple mini-field days		
	Grassland conference	3		
	Road BMP training	1, 42 attendees		
01-800 Piney Fork Reach 2 (Sharp County Conservation District)	Newsletters	4 quarterly sent to 112landowners	Piney Fork watershed	Complete
	Technical assistance	30 landowners		
01-1900 Alternative livestock water demonstration (Fulton County Conservation District)	Quarterly newsletter		Fulton County	Complete
	Demonstration farms	3		
	Fact sheet			
	Presentation	Given 4 times		
	Article	1		
	Field day	7		
03-151 Lawrence County Mini-grant (Lawrence County Conservation District)	Display at county fair		Lawrence County	Complete
03-185 Fulton County Grass Promotion Project (Fulton County Conservation District)	Conference	75 attendees	Fulton County	Complete
	Farm signs			
05-800 Strawberry River agricultural watershed project reach III – North Big Creek (Lawrence and Sharp County Conservation Districts)	Technical assistance		North Big Creek	Complete
	Quarterly newsletter	12 quarters		
	Brochures			
	Radio programs			
	Newspaper ads/articles			
	Forest training	2		
	Grassland & farm bill educational meetings	3		
	FFA field days	2		
	Presentations	36		

Table 8.5. Summary of information and education activities within the Strawberry River watershed (continued).

Project/Program (lead agency/ organization)	Practices	Amount	Location	Status
09-2100: Strawberry River improvement project – supplemental cost-share, and 11-1000: Strawberry River improvement project (Sharp County Conservation District)	Demonstration farm	1	Sharp County	Complete
	Quarterly newsletter	12 quarters		
	Grazing meetings	3 meetings, 192 total attendees		
	Presentations			
11-1100 Strawberry River subwatershed project (Izard County Conservation District)	Display at county fair	3	Izard County	Complete
	Display at North Central Arkansas District Fair	3		
	Stream management workshop	1		
	Pasture/drought field day	1		
	Outreach meeting	1		
	Give away trees to students	2,159 seedlings		
	Quarterly Newsletter	12 quarters, 190/quarter		
15-1100: Strawberry River subwatersheds project (Fulton County Conservation District)	Field days, newsletter		110100120201, 110100120202, 110100120203, 110100120204, 110100120205, and 110100120301	Ongoing
Strawberry River Preserve and Demonstration Ranch (The Nature Conservancy)	Tours, demonstrations		Whaley Creek-Strawberry River 12-digit HUC subwatershed	Ongoing
Arkansas Unpaved Roads Program	Training, technical assistance		Entire watershed	Ongoing
Mississippi River Basin Initiative Healthy Watersheds Initiative Strawberry River Watershed (NRCS)	Field days		Little Strawberry River and Philadelphia Creek – Piney Fork 12-digit HUC subwatersheds	Ongoing

8.3.1 Previous Information and Education Efforts

Examples of information and education activities that have been occurring in the Strawberry River watershed since preparation of the watershed restoration action strategy are discussed below. Organizations that have been involved in these efforts include County Conservation Districts (with ANRC), NRCS, USDA Cooperative Extension Service, and The Nature Conservancy.

8.3.1.1 County Conservation Districts with ANRC

Section 319 projects in the Strawberry River watershed have been primarily implemented through the efforts of the County Conservation Districts. Projects in the Strawberry River watershed have included information and education elements (Table 8.5). These have taken the form of newsletters distributed to stakeholders, farm tours, field days, displays and demonstrations at fairs, newspaper articles, and educational talks at schools. Two projects included grassland conferences (projects 00-600 and 03-185). One of these projects (03-185) was solely an outreach effort that involved a conference to bring together landowners, contractors, and local, state, and federal agency personnel. County Conservation Districts have been integral to getting the word out about Section 319 projects in the Strawberry River watershed.

8.3.1.2 Cooperative Extension Service

The Cooperative Extension Service has hosted a series of public meetings in nonpoint source priority watersheds. The purpose of these meetings is to offer a forum for watershed residents to identify issues and discuss solutions, with the idea of stirring interest in watershed planning and management practice implementation. One of these meetings was held for the Strawberry River watershed in December 2014.

8.3.1.3 University of Arkansas Department of Agriculture

Field days and workshops are hosted at the agricultural experiment stations of the U of A Department of Agriculture for the transfer of information to producers and landowners.

8.3.1.4 The Nature Conservancy

The Strawberry River Preserve and Demonstration Ranch is an outreach and education project of The Nature Conservancy. This preserve showcases economically feasible specialized grazing techniques that protect streambanks and stream ecology. Training workshops in these techniques have been held by The Nature Conservancy (The Nature Conservancy 2015). The Nature Conservancy has also been involved with training programs for county road crews on maintenance practices to reduce erosion associated with unpaved roads.

8.3.1.5 Agricultural Interest Groups

Agricultural interest groups such as the Arkansas Farm Bureau, Arkansas Grazing Lands Coalition, and Arkansas Forage and Grasslands Council provide information to their constituents through a variety of means including websites, newsletters, and annual conferences.

8.3.2 Existing and Planned Information and Education

Education and information programs of the Cooperative Extension Service, University of Arkansas Department of Agriculture, The Nature Conservancy, and agricultural interest groups will continue. Education and information activities are also planned as part of the new Mississippi River Basin Initiative project in the Strawberry River watershed, and as part of the ANRC nonpoint source Section 319 project number 15-1100.

Two of the goals of the Strawberry River watershed MRBI projects are related to education and information. One is to "increase public interest in water quality and soil health by conducting educational workshops and field days." The second is to develop demonstration farms to promote soil health practices (NRCS 2015a). Education and/or outreach is a required element of all Section 319 projects.

Arkansas Economic Development Commission Rural Services Division manages the state Unpaved Roads Program. Approximately twice a month, Arkansas Rural Services provides free one-day training sessions on maintenance techniques for unpaved roads that reduce the impact of sediment and road runoff on water quality, as well as reducing road maintenance costs. The location of these training sessions alternates among all of the counties in the state. To maintain eligibility for grants for unpaved roads maintenance or improvement, at least one representative from each county must attend this training every 5 years (Arkansas Economic Development Commission Rural Services Division 2015).

8.4 Supplemental Watershed Implementation Plans

The process of developing a watershed implementation plan can increase the implementation of voluntary management practices by encouraging stakeholder buy-in and leveraging technical and financial resources. Locally developed watershed implementation plans are envisioned as the mechanism for implementing management practices in the Strawberry 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.

Watershed implementation plans are required under the Clean Water Act for waterbodies for which TMDLs have been completed. Therefore, watershed implementations plans are needed to address the turbidity and bacteria impairments in the Strawberry River watershed, including those in the recommended subwatersheds. The purpose of these plans is to provide a roadmap for how the water quality will be improved so that it meets state water quality standards.

A supplemental watershed implementation plan (WIP) will be prepared for each 12-digit HUC priority watershed in the Strawberry River as a supplement to this Watershed-Based Management Plan. The WIP will emphasize the management practices associated with the pollutants and sources that are being targeted within the watershed. Estimates of the sediment and bacteria load reductions expected through implementation of management practices will be included. ANRC will coordinate with the NRCS and Conservation Districts to track management practices implemented through the NRCS EQIP, FSA Conservation Reserve, Conservation Reserve Enhancement and similar programs to reduce pollutant loads. ANRC also coordinates with other organizations such as Ducks Unlimited and The Nature Conservancy, and with other agencies such as the US Fish and Wildlife Service and Arkansas Game and Fish Commission and will track their efforts at restoring stream and wetland habitat that also contribute to pollutant load reductions and increased aquatic assimilation capacity. Each participating organization/agency will be requested to provide information to ANRC on evaluated or monitored pollutant load reductions within the 12-digit HUC watersheds to supplement the Strawberry River Watershed-Based Management Plan.

8.5 Implement Management Strategies

Management strategies that are being and will be implemented in the Strawberry River watershed are listed in Table 8.6, along with an indication of the issues within the recommended 12-digit HUC subwatersheds that they address.

Table 8.6. Management strategies proposed for recommended subwatersheds of the Strawberry River.

Strategy	Streambank erosion	Concentrated flow and sheet/rill/wind erosion	Bacteria
Stream fencing	X		X
Alternative water supply	X		X
Heavy use area protection		X	
Prescribed grazing	X	X	X
Controlled stream access	X		X
Riparian buffers	X		X
Streambank stabilization/ restoration	X		
Manure/litter application training			X
Training on and use of erosion control for unpaved roads	X	X	
Forestry BMPs (SMZ, stream crossing, road BMPs)	X	X	
Pasture planting		X	X
Filter strips	X		X
Stacking sheds			X
Conservation plans	X	X	
Grassed waterway		X	
Roof runoff structure		X	

8.6 Evaluation

This Watershed-Based Plan for the Strawberry River watershed was developed to include the adaptive management concept. 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. The County Conservation Districts or other participating organization/agency will be responsible for evaluation of each supplemental watershed implementation plan. ANRC will provide information they have collected about implementation activities to the organization/agency for the evaluation. ANRC will be responsible for evaluation of the watershed management plan in 2023.

8.6.1 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 8.7. The stakeholders and organizations that participate in implementation of this plan will provide the ANRC with annual totals for these inputs indicators for the period 2017 through 2022 by April 2023.

Table 8.7. Indicators of inputs for implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Monitoring	Resources spent on monitoring in Strawberry River watershed Hours and number of personnel involved
Information/Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	Number of conference attendees from Strawberry River watershed
	Field Days (Conservation Districts)	Number of attendees Hours and number of people involved Cost
	Strawberry River Preserve and Demonstration Ranch	Number of attendees Hours and number of people involved Cost
	Training in unpaved road BMPs	Number of attendees Hours and number of people involved Cost
Implement management practices	Assistance programs in the Strawberry River watershed	Resources distributed to Strawberry River watershed Hours and number of people assisting stakeholders in Strawberry River watershed Number of Strawberry River watershed stakeholders requesting assistance

8.6.2 Outputs

The outputs for implementation of this plan are development of supplemental watershed implementation plans, implementation of nonpoint source management practices, information and education, and monitoring. Indicators that measure this component of the plan implementation are listed in Table 8.8. The stakeholders and organizations that participate in implementation of this plan will provide ANRC with annual totals for these indicators for the period 2017 through 2022 by April 2023.

Table 8.8. Indicators of outputs of implementation of this watershed management plan.

Implementation Task	Activity	Indicators
Monitoring	Monitoring	Number of active water quality monitoring stations Number of turbidity/sediment data collected Number of E. coli data collected Number of biological surveys
Information/Education	Arkansas grazing lands conference (Arkansas Grazing Lands Coalition)	Number of conferences
	Field Days (Conservation Districts)	Number of field days
	Strawberry River Preserve and Demonstration Ranch	Number of workshops
	Training in BMPs for unpaved roads	Number of workshops in Strawberry River counties
Implement management practices	Assistance programs in the Strawberry River watershed	Number/amount of management practices implemented Number of contracts/projects started and finished

8.6.3 Outcomes

The intended outcomes for this watershed-based management plan include improvement in water quality, and increased awareness of and interest in water quality concerns of the Strawberry River watershed. The long term goal of this watershed-based plan is that impaired waterbodies in the Strawberry River watershed will meet water quality criteria and attain their designated uses. The primary indicators for this goal are turbidity and E. coli levels. Secondary indicators are indicators of biological integrity, including the condition of populations of the endangered Rabbitsfoot mussel, and endemic species such as the Strawberry River Darter. These are the parameters that will be monitored to allow for evaluation of the overall effectiveness of nonpoint source pollution management within the Strawberry River watershed. Within the next three to five years, the goal of this plan is to reduce the percentage of turbidity and E. coli measurements that exceed applicable state water quality criteria.

The monitored waterbodies in the Strawberry 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. Progress toward achieving the goal will be evaluated during the Arkansas biennial integrated water quality assessment.

Implementation of this plan will be considered successful if:

- A watershed implementation plan has been developed and implemented for at least one recommended 12-digit HUC subwatershed by 2021,
- The percentage of E. coli and/or turbidity criteria exceedances has decreased from the percentage during the 2008 integrated water quality assessment by 2024, and
- Populations of Rabbitsfoot mussel and endemic fisheries remain stable or increase.

If these criteria are not satisfied, the management approaches, scientific knowledge, and stakeholder knowledge and opinions in the recommended subwatersheds will be re-evaluated and management elements adjusted accordingly. This evaluation will take into account the fact that it can take more than five years, or even decades, before water quality improvements resulting from implementation of management measures become apparent (Meals et al. 2010). The time period required to see significant changes in water quality is, in part, a function of how closely to management activities water quality is measured.

8.7 Update Watershed Management Plan

Development of the supplemental implementation plans for the recommended 12-digit HUC subwatersheds will be part of the update of this watershed management plan. The responsibility for updates to the supplemental implementation plans will be established in those plans. ANRC will be responsible for preparing a comprehensive update of this watershed management plan in 2023.

This update will consider and address the following information.

- Results of the evaluation of the implementation of this plan, described in Section 8.6,
- Relevant information about the Strawberry River system and how it works, nonpoint source management practices, and pollutant sources in the watershed that has been developed since 2016,

- 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.

ANRC will prepare a summary of the evaluation of implementation of the previous plan and changes in the watershed over the period since completion of the previous watershed management plan. This summary will be presented at one or more public stakeholder meetings. At this meeting(s), stakeholders will provide input on adjustments to management of and/or goals for the Strawberry River watershed. This may include a focus on management in other 12-digit HUC subwatersheds for water quality improvement or protection.

ANRC will prepare a draft update of this watershed management plan utilizing the information from the implementation evaluation and the public meeting(s), and any other information it deems appropriate. This update will also 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.

9.0 COSTS, BENEFITS, AND ASSISTANCE

This section discusses costs that will be associated with implementation of this watershed management plan, the economic and environmental benefits of implementing this plan, and technical and funding assistance that is available for implementing this plan.

9.1 Cost

The cost information provided below is estimates. Actual costs may differ from those given below for a variety of reasons.

9.1.1 Monitoring

Estimated costs for synoptic surveys (Section **Error! Reference source not found.**) are $5,000 for two in situ monitors, and $5,000 for personnel to collect and enter the information into www.arkansaswater.org. The E.coli samples would be transported to the Arkansas State University Ecotoxicology Research Facility for incubation and analysis within the 8 hour holding time requirements. Estimated cost for E. coli analyses is $4,000.

The cost of monitoring the effects of management practices (Section **Error! Reference source not found.**) can vary from the cost of in situ instrumentation with volunteer monitoring through the AG&FC Stream Team or similar volunteer arrangement (approximately $5,000 for an in situ instrument with four parameters plus a backup instrument) to $40-50,000 per year for the USGS to monitor the site. E. coli analyses are estimated at $4,000 per year if volunteers collect samples.

9.1.2 Supplemental Watershed Implementation Plans

Estimated costs for preparing watershed implementation plans to supplement the Strawberry River Watershed-Based Management Plan, is $15-20,000 for each recommended 12-digit HUC subwatershed.

9.1.3 Estimated Cost of Nonpoint Source Pollution Management

Over the years since the development of the original Watershed Restoration Action Strategy for the Strawberry River, funding has been provided for implementation of management practices in the watershed. Additional funding has been allocated for implementing management practices in the Strawberry River watershed over the next 3 years or so. There are a number of agencies and programs that offer financial assistance for implementation of nonpoint source pollution management practices in the Strawberry 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 9.1 lists available cost information for management practices identified in Section 7. Costs shown in Table 9.1 are the 2015 funding allocations specified for the NRCS Arkansas EQIP. While these allocations do not necessarily reflect the actual cost of implementing the practice (past 319 projects have offered funding assistance at 40% cost-share), they provide an idea of relative costs of the shown management practices.

Table 9.2 provides examples of potential relative costs for implementation of selected management practices to achieve target TSS load reductions to meet turbidity water quality criteria in the recommended 12-digit HUC subwatersheds.Bank stabilization is the most expensive option for reducing streambank erosion. Prescribed grazing appears to be a relatively low cost option for improving pasture and reducing erosion, although the $40/acre does not include the cost of any new fencing that may be required.

Table 9.1. Cost information for selected management practices for the Strawberry River watershed.

Pollutant Source	Practice	Cost
Streambank erosion	Stream exclusion (fencing + alternate water supply)	Fence: $0.86 - $1.49/ft Pipeline: $0.91- 2.46/ft Pond: $2.06 - $3.33/cu yd Pumping plant: $120 - $5,000 Watering facility: $0.80 - $2.41/gal Well: $10 - $88/ft
	Riparian buffers	$170 - $278/ac
	Streambank stabilization/ restoration	$7.47 - $107.45/ft
	Controlled stream access	Fence:$0.86 - $1.49/ft
	Filter strips	$66 - $468/ac
Pasture erosion/runoff	Prescribed grazing	$20.89 - $64.95/ac
	Heavy use area treatment	$0.45 - $2.02/sq ft
	Pasture planting	$188 - $257/ac
	Nutrient management	$3.77 - $27.01/ac
	Grassed waterway	$757.36 – $1,207/ac
	Stacking shed	$1.36 - $2.76/sq ft
	Cross-fencing	Fence: $0.86 - $1.49/ft
Unpaved roads	Training on water control for unpaved roads	Free

Table 9.2. Estimate of costs for implementing management practices to reduce sediment load in the Strawberry River watershed.

Practice	Assumed unit cost	Meeks Br-Strawberry		Clayton Cr-Strawberry		Reeds Cr-Strawberry		Bullpen Cr-Strawberry	
		Amount	Total cost	Amount	Total cost	Amount	Total cost	Amount	Total cost
Bank stabilization	$100/ft	38,620 ft	$3,862,000	51,302 ft	$5,130,200	39,531 ft	$3,953,100	58,316 ft	$5,831,600
50 ft riparian buffer	$200/ac	38,620 ft	$8,866	51,302 ft	$11,777	39,531 ft	$9,075	58,316 ft	$13,387
Pasture stream exclusion	$1.49/ft for fence, $1,000/ watering facility	48,918 ft fence, 48 watering facilities	$120,889	67,034 ft fence, 67 watering facilities	$166,881	97,773 ft fence, 97 watering facilities	$242,681	150,066 ft fence, 150 watering facilities	$373,598
Pasture planting	$200/ac	355 ac	$71,000	476 ac	$95,200	667 ac	$133,400	1,317 ac	$263,400
Prescribed grazing	$40/ac	349 ac	$13,960	468 ac	$18,720	656 ac	$26,253	1,295 ac	$51,800
Grassed waterway	$1,000/ac	1,232 ac	$1,232,000	1,651 ac	$1,651,000	2,316 ac	$2,316,000	4,571 ac	$4,571,000
30 ft filter strips	$250/ac	41.4 ac	$10,375	56.8 ac	$14,200	82.9 ac	$20,725	127 ac	$31,750

9.2 Estimated Economic and Environmental Benefits

There are costs associated with implementing best management practices, as noted in Section 9.1.3 above. However, there are also environmental benefits associated with these management practices, both to the landowner and to downstream users. Environmental benefits that humans receive from nature are called ecosystem services, and include goods or products (provisioning services) that typically have market value, such as timber production, commercial fisheries, agricultural production, and biochemical extracts. In addition, there are other services and benefits provided by ecosystems that are not as easy to value economically, but are critical to our quality of life, including regulating services such as erosion control, improved air and water quality through contaminant removal, and pollination; supporting services such as soil moisture retention, nutrient cycling, and soil formation; and cultural services such as fishing, bird watching, and wildflowers that provide aesthetic pleasure. Additional examples of environmental benefits associated with ecosystem services are listed in Table 9.3.

Table 9.3. Environmental benefits and ecosystem services associated with increased soil health and best management practices.

Ecosystem service or environmental benefit	Description
Contaminant removal	Contaminants (sediment, nutrients (N, P), heavy metals, pesticides) sorbed onto soils, chelated by organic matter, or filtered from runoff, or taken up by vegetation, reducing contaminant loading/concentrations in receiving waterbodies.
Erosion control	Vegetation, soil cover, or impounded water reduces impacts of rainfall in disrupting soil particles and/or reducing soil transport in runoff, including settling in impounded water, to receiving waterbodies.
Fish habitat	Riparian vegetation, organic debris reduce soil and bank erosion and provide structure in streams for fish and other aquatic organisms.
Flood mitigation	Soil organic matter, vegetation, retain water, slow water flow, and attenuate peak flow to reduce flooding.
Forage quality	Improved vegetative cover, soil organic matter, and nutrient cycling increase forage quality for grazing and increase animal production.
Nutrient retention -cycling	Nutrient retention and slow release to crops reduces fertilizer requirements and associated costs, improves yields and reduces nutrient loading to receiving waterbodies.
Soil formation	Vegetation, no/reduced tillage, and mulch add organic matter to soils, increase infiltration, reduce compaction, and improve soil structure and soil health, for potential increased crop yields or animal production.
Soil moisture retention	Increased soil organic matter from vegetative cover or residue retains water and increases soil moisture. Each 1 percent increase in soil organic matter helps soils hold about 20,000 gallons more water per acre, reducing irrigation costs.

Table 9.3. Environmental benefits and ecosystem services associated with increased soil health and best management practices (continued).

Ecosystem service or environmental benefit	Description
Timber production	Forested riparian buffers reduce soil/bank erosion, reduce nutrient and other contaminant loading, improve fish habitat , and provide harvestable timber for additional revenue.
Water purification	Contaminate sorption, filtering through soils and vegetative/organic debris, and uptake improves water quality by purifying the water.
Waterfowl habitat	Winter water retention, forested riparian buffers increase habitat for waterfowl and potential hunting leases.
Wildflower/wildlife habitat	Filter strips, buffers, riparian corridors, conservation reserves provide additional habitat for wildflowers, birds, and wildlife and can be leased for hunting.

Best management practices proposed for the Strawberry River subwatersheds are listed in Table 9.4 along with the environmental benefits that accrue from the implementation of these BMPs. While not all these benefits have directly marketable economic value, there have been economic assessments of several of them. For example, excluding cattle from streams, providing alternative water supplies, and rotational grazing have resulted in increased cattle production, which has a direct economic value. Alternative water supply alone was documented to improve production in steers and heifers from 0.6 to 1.8 lb/day through reduction in foot rot, bovine virus diarrhea, fever, tuberculosis, and environmental mastitis (Faulkner 2000, Zeckoski et al. 2007). In Missouri, beef cattle raised and finished on high quality pasture through prescribed grazing had an average daily gain of 2 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 9.4. Environmental benefits associated with implementing best management practices in the Strawberry River subwatersheds.

Best Management Practice	Contam. removal	Erosion control	Fish habitat	Flood mitig.	Forage qual.	Nut. reten.	Soil form.	Soil moist.	Timber prod.	Water purific.	Water-fowl	Wildlife-flower habitat
Bank stabilization/ stream restoration	•	•	•	•		•				•	•	•
Riparian buffer	•	•	•	•		•			•	•	•	•
Stream exclusion	•	•		•	•	•	•	•		•		•
Pasture planting	•	•		•	•	•	•	•		•		•
Prescribed grazing	•	•		•	•	•	•	•		•		•
Grassed waterway	•	•		•	•	•	•	•		•		•
Filter strips	•	•		•	•	•	•	•		•		•

Other ecosystem services have intrinsic environmental benefits and value that are more difficult to economically assess. An example of this type of benefit was documented on a Mississippi farm where filter strips were implemented. During a reconnaissance to assess the effectiveness of the filter strips, the farmer remarked that during the year he would sometimes just drive around the filter strips to look at the wildflowers. He said, “If you had told me that one of the major benefits of filter strips would have been wildlflowers, I would have looked at you like you were nuts and walked away. But, I enjoy their beauty.” (Thornton, personal communication, 2011).

9.3 Technical Assistance

9.3.1 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 Arkansas Game and Fish Commission Stream Team Program.

9.3.2 Information and Education

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

The ADEQ Public Outreach and Assistance Division offers technical assistance and resources to interested citizens and groups. The Watershed Outreach and Education program of this division provides "a variety of tools and services to facilitate and promote awareness, appreciation, knowledge, and stewardship of water resources" (ADEQ 2015c).

9.3.3 Supplemental Watershed Implementation Plans

EPA has a watershed planning website with links to a number of resources to assist watershed management plan developers (https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/watershed-plannning-builder-and-guides).

9.3.4 Technical Assistance for Nonpoint Source Pollution Management

There are a number of sources for technical assistance for management strategies in recommended subwatersheds. These are summarized in Table 9.5 and discussed below.

9.3.4.1 County Conservation Districts

Conservation Districts for the counties in the Strawberry 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.

9.3.4.2 Cooperative Extension Service

The University of Arkansas 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.

9.3.4.3 University of Arkansas Agricultural Experiment Station

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

9.3.4.4 NRCS

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 2015c).

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

9.3.4.6 EPA

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

Table 9.5. Sources of technical assistance for management strategies.

Practice/ Strategy	County Conservation Districts	U of A Cooperative Extension	U of A Experiment Stations	AGFC Stream Teams	NRCS FSA	EPA	Fish and Wildlife Service	TNC	Equipment and Service Companies	Arkansas Forestry Commission
Stream fencing	X	X	X		X			X		
Alternate water supply	X	X	X		X			X		
Prescribed grazing	X	X	X		X			X		
Riparian buffers	X	X	X		X	X	X	X		
Streambank stabilization/ restoration	X	X	X	X	X	X	X	X		
Heavy use area treatment	X	X	X		X					
Nutrient/ manure application training	X	X	X		X				X	
Pasture planting	X	X			X					
Conservation plan	X	X			X					
Nutrient management plan	X	X			X					
Training on water control for unpaved roads								X		X
Forestry BMPs										X
Filter strips	X	X	X		X	X				
Controlled stream access	X	X	X		X	X				

9.3.4.7 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.

9.3.4.8 Arkansas Game and Fish Commission Stream Teams

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

9.3.4.9 Arkansas Rural Services

Arkansas Rural Services manages the state Unpaved Roads Program. Approximately twice a month, Arkansas Rural Services provides free one-day training sessions on maintenance techniques for unpaved roads that reduce the impact of sediment and road runoff on water quality, as well as reducing road maintenance costs. The location of these training sessions alternates among all of the counties in the state. To maintain eligibility for grants for unpaved roads maintenance or improvement, at least one representative from each county must attend this training every 5 years (Arkansas Economic Development Commission Rural Services Division 2015).

9.4 Funding Assistance

9.4.1 Monitoring

ADEQ, USGS, and ANRC have funded water quality monitoring projects in the Strawberry River watershed. ADEQ’s monitoring is self-funded. Much of the funding for the

USGS monitoring program is provided by state and local cooperators. USGS flow and/or water quality monitoring sites could be added in the watershed if a local entity would provide funds. ANRC has provided funding for university water quality monitoring projects in the Strawberry River watershed. University researchers are seeking State Wildlife Grant funding from the Arkansas Game and Fish Commission for fishery and macroinvertebrate sampling projects (USDA National Agricultural Statistics Service 2014). The Arkansas Game and Fish Commission Stream Team program can also provide funding for volunteer monitoring programs through mini-grants.

9.4.2 Information and Education

Funding assistance for past outreach and education activities in the Strawberry River watershed have primarily come from the ANRC nonpoint source program. All projects funded through the ANRC NPS Program (Section 319(h) funds) are required to include an education and outreach component. This program funded one project in the watershed that was purely outreach and/or educational in nature (03-185).

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

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).

9.4.3 Supplemental Watershed Implementation Plans

The ANRC nonpoint source program has provided funding assistance for watershed planning in the past. It is possible that EPA will stipulate in the future that Section 319 funds be used only for implementation of management practices, not for watershed planning. However, state nonpoint source program funds will continue to be a source for assistance with the costs of watershed planning in the future. Other potential sources for funding assistance for watershed planning include private foundations, industries, and interest groups.

9.4.4 Funding Assistance for Nonpoint Source Pollution Management

There are a number of agencies and programs that offer financial assistance for implementation of nonpoint source pollution management practices in the Strawberry River watershed. The majority of these are grant programs, some of which require matching funds from the grant recipient. In addition, at least one tax incentive program is active that addresses practices that reduce nonpoint source pollution. Table 9.6 lists management practices for the recommended 12-digit HUC subwatersheds along with selected funding sources. The "$" symbol indicates a source that is known to fund a program in the recommended subwatersheds, however, information about the amount allocated was either not obtained or not available. The "X" symbol indicates other potential funding sources. Potential funding sources for the recommended subwatersheds are discussed below.

9.4.4.1 NRCS and FSA

There are NRCS programs active in Arkansas that provide funding assistance for development and installation of management practices that are applicable to the recommended 12-digit HUC subwatersheds of the Strawberry River. These programs provide funding to individuals rather than groups or organizations. This includes the Conservation Stewardship Program, the Healthy Forest Reserve Program, and the Environmental Quality Incentives Program (EQIP). In these programs, a cost-share is usually required. Information about these programs, including 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. The 2016 national budget for the EQIP program is $1,350 million. For the Conservation Stewardship Program, the 2016 national budget is $1,457 million (US Department of Agriculture 2015).

Table 9.6. Funding availability for management practices for the recommended 12-DIGIT HUC subwatersheds.

Practice	Fulton County Conservation District (15-1100)	Mississippi River Basin Initiative – Fulton, Izard & Sharp	CALF program	US Fish and Wildlife Service Partners for Wildlife	NRCS, FSA	AGFC Stream Team program	ANRC Nonpoint source program	TNC	Arkansas Unpaved Road Program
Fencing	$	$	$	X	X		X	X	
Alternate water supply	$	$	$		X		X	X	
Prescribed grazing	$	$			X		X	X	
Riparian buffers	$	$			X	X	X	X	
Streambank stabilization/ restoration	$	$			X	X	X	X	
Heavy use area protection	$	$	$		X		X		
Pasture planting	$	$			X		X		
Conservation plan					X		X		
Nutrient management					X		X		
Training on water control for unpaved roads							X		X
Filter strips		$			X		X		
Controlled stream access			$	X	X				
Stacking sheds		$			X				
Roof runoff structures		$			X				
Manure/litter application training					X		X		
Grassed waterways					X		X		

Monetary assistance is also available from the USDA FSA through the Conservation Reserve Program (CRP). The CRP includes initiatives that may be applicable in the Strawberry River watershed, including State Acres for Wildlife Enhancement, and Upland Bird Habitat. Additional information, including contract lengths and payment amounts, is available from the local USDA service center. The national CRP budget for 2016 is $1,834 million.

9.4.4.2 US Fish and Wildlife Service

There are two USFWS programs active in the Strawberry River watershed that provide funding assistance for development and installation of nonpoint source pollution management practices. Funding is available for individuals through the USFWS Partners for Fish and Wildlife program, and the CALF program (in cooperation with the Arkansas Association of Conservation Districts). Funding from these programs may require cost-share. The national 2016 budget for the Partners for Fish and Wildlife program is $54.2 million. It is unknown how much of these funds will be available for projects in Arkansas, or in the Strawberry River watershed.

9.4.4.3 EPA

EPA has several programs that offer funding assistance for restoration and conservation projects that reduce nonpoint source pollution. One of these is the Clean Water Act Section 319 program, through which ANRC is provided funding for the Arkansas Nonpoint Source Program.

9.4.4.4 ANRC

ANRC manages the state Section 319 grant program. This program provides grants to non-profit groups, organizations and academic institutions for projects related to reduction, control or abatement of nonpoint source pollution. Organizations seeking grants must be capable of implementing projects, and are typically required to provide a minimum of 43% non-federal matching contributions. In 2014, approximately $1.9 million in federal funds were spent on nonpoint source pollution projects in Arkansas through the ANRC 319 grant program. Forty-six percent of these funds were spent on implementation of management practices, 29% on water quality monitoring, 18% on planning, and 7% on outreach related to nonpoint source pollution

(ANRC 2015). There is no guarantee that this level of funding will be available in the future. The 2016 national budget for the Section 319 grant program is $164,915 thousand (EPA 2015). It is unknown how much of these funds will be available for Arkansas projects.

9.4.4.5 Other State Agency Grant Programs

There are at least two other state agencies that provide funding for activities included in the management measures of this plan. The AGFC Stream Team Mini-Grants can be used to fund stream clean-up and stream bank stabilization projects. State Wildlife Grants can be used to address habitat issues, such as erosion and sedimentation, that impact species of greatest conservation need. The Rural Services Division of the Arkansas Economic Development Commission provides grants to counties to help fund unpaved road projects through the Arkansas Unpaved Roads Program.

9.4.5 Non-monetary 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. Fulton, Izard, Lawrence, and Sharp County Conservation Districts have purchased equipment that is available to landowners for use in implementing management practices. The available equipment includes no-till drills for pasture planting, a tree planter, and sprayers for applying fertilizer and manure products to pasture.

9.4.6 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/).

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