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Poteau River Comprehensive Watershed Management Program

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The Water Quality Division of the Oklahoma Conservation Commission (OCC) prepared the primary sections of this report, in association with LeFlore County Conservation District and Natural Resources Conservation Service. LeFlore County Conservation District and NRCS personnel were essential to the project. Their efforts were the foundation of the project, without them, no best management practices would have been installed. District Conservationist Kenneth Risenhoover and District Manager Stony Brown with LeFlore County were the primary points of contact with landowners and worked with landowners to develop plans and implement practices. Stony also conducted much of the water quality monitoring associated with the project. The Conservation District and NRCS are responsible for procuring the extensive landowner participation that occurred in this project. Hilda Culver, the district secretary worked with Kenneth, Stony and Otis Bennett of the OCC to track expenditures and issue payments to cooperators. The district also conducted numerous education and training programs.

The OCC Water Quality Division contributed to the project in many ways:

Otis Bennett	program coordinator, troubleshooter, information source
Phil Moershel	workplan development, quality assurance, and proofreading
Jim Leach	coordination among project cooperators
Dan Butler	water quality monitoring plan development and implementation
Shanon Haraughty	quality assurance plan drafting, report writing, data analysis
Kelly Mockabee	data entry person
Kendra Eddlemon	data manager, monitored cost-share implementation at OCC
Geoff Canty, Nikole Witt	advisors and information sources for technical writing

Joe Bullard of the Oklahoma State Cooperative Extension Service was essential in implementing the education portions of the project. He scheduled and provided trainings, worked with landowners one-on-one, wrote and published newspaper articles, and held education fairs to inform citizens of the watershed about water quality. Joe also worked with the landowners and with Stony and Kenneth to develop the farm plans and animal waste management plans. The expertise Mike Smolen and Jim Britton of the Oklahoma State University Extension Service was instrumental in providing guidance for the design and implementation of Animal Waste Utilization Plans and other technical details. Troy Pierce of OSU prepared a report summarizing the results of follow-up surveys conducted to evaluate the success of education efforts. Tim Probst of OSU Cooperative Extension Service prepared a report summarizing the efforts of OSU Extension in the project, detailing the education effort, including the follow-up survey report, and detailing other pertinent activities associated with the project.

Dan Storm of the Oklahoma State University Department of Biosystems and Agricultural Engineering was responsible for modeling the watershed and developing the TMDL. He worked with numerous OSU staff and students to compile extensive watershed data into a watershed model to be used to predict current loading from various sources in the watershed, along with necessary reductions to protect the overall watershed. OSU collaborated with Raghavan Srinivasan and associates of the Blacklands Research Center in Temple, Texas to develop the model using the Soil and Water Assessment Tool Model (SWAT).

The Poteau Valley Improvement Association, the Lake Wister Advisory Association, the residents of the Haw Creek Valley Watershed, and the Lake Wister/Poteau River Steering committee have also been critical to the success of the project and to the success of future efforts to reduce pollution in the watershed.

The United States Geological Survey was instrumental to the project in that data collected at their Poteau River Watershed monitoring stations was used to supplement data collected in conjunction with the implementation project and to develop and calibrate OSU's watershed model.

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INTRODUCTION

This project was intended to establish a comprehensive watershed management program for one of Oklahoma's highest priority waterbodies. The program then implemented this program, for demonstration and educational purposes, in one subwatershed of the Poteau River Watershed. The implemented program included four components: 1) Assessment- monitoring to determine source and extent of water quality problems and to document success of the program; 2) Planning- developing a watershed strategy based on Total Maximum Daily Loadings (TMDL) for each source and source area. This watershed strategy is more likely to have long-term success if local stakeholders are active in its development; 3) Education- an overall water quality educational program to improve knowledge and affect long-term changes in behavior among area farmers and residents; and 4) Implementation- BMP demonstrations in priority subwatersheds to determine the most successful mechanisms by which to reduce NPS pollution in the Poteau River Watershed.

Project Area Description

The Upper Poteau River, consisting of Wister Lake and its tributaries, is identified among the state's top priorities for NPS implementation in Oklahoma's Section 319 Nonpoint Source Management Program. The Poteau River was also cited in the 319 Assessment Report as having impaired recreational and drinking water uses, and it is included on the 303(d) list as one of the watersheds that is highest priority for establishment of a TMDL.

The Wister Lake basin covers approximately 260,000 ha (640,000 acres) in LeFlore and Latimer Counties in Oklahoma, and Scott and Polk Counties in Arkansas (Figure 1). The watershed drains into Wister Lake in LeFlore County. Most of the residents in LeFlore and three adjacent counties depend solely upon Wister Lake and the Poteau River for their drinking water supply. In addition Wister Lake is the major recreational resource in the area.

Wister Lake was characterized as eutrophic in the National Eutrophication Survey (EPA 1977), and as hypereutrophic in a 1995 § 314 Clean Lakes Study (OWRB 1996) and it was listed as partially supporting for designated uses in the Oklahoma 319 Assessment. The 319 Assessment Report lists nutrients and sediment as the major concern NPS concerns. Predominant sources of nitrogen and phosphorus appear to be associated with broiler production, a poultry processing plant, several publicly owned wastewater treatment plants, urban storm water, and private septic tank systems. Sediment sources appear to be associated with silviculture, mining, oil and gas exploration, and county roads. Point sources are known to exist at Waldron, AR and Red Oak, OK and several other locations along the Poteau River and Fourche Maline Creek. The Waldron, AR contribution includes a large poultry processing plant (OSU Report, 1993).

LeFlore County, which includes about one-half the watershed, is the most rapidly growing poultry-producing area of the state. Currently it produces more than 36 million broilers, which generate about 55,000 tons of litter per year, containing about 3.3 million pounds of nitrogen and 2.8 million pounds of phosphorus. As much as 50% increase in poultry production is anticipated in this area in the next few years putting additional stress on the Poteau River and Wister Lake.

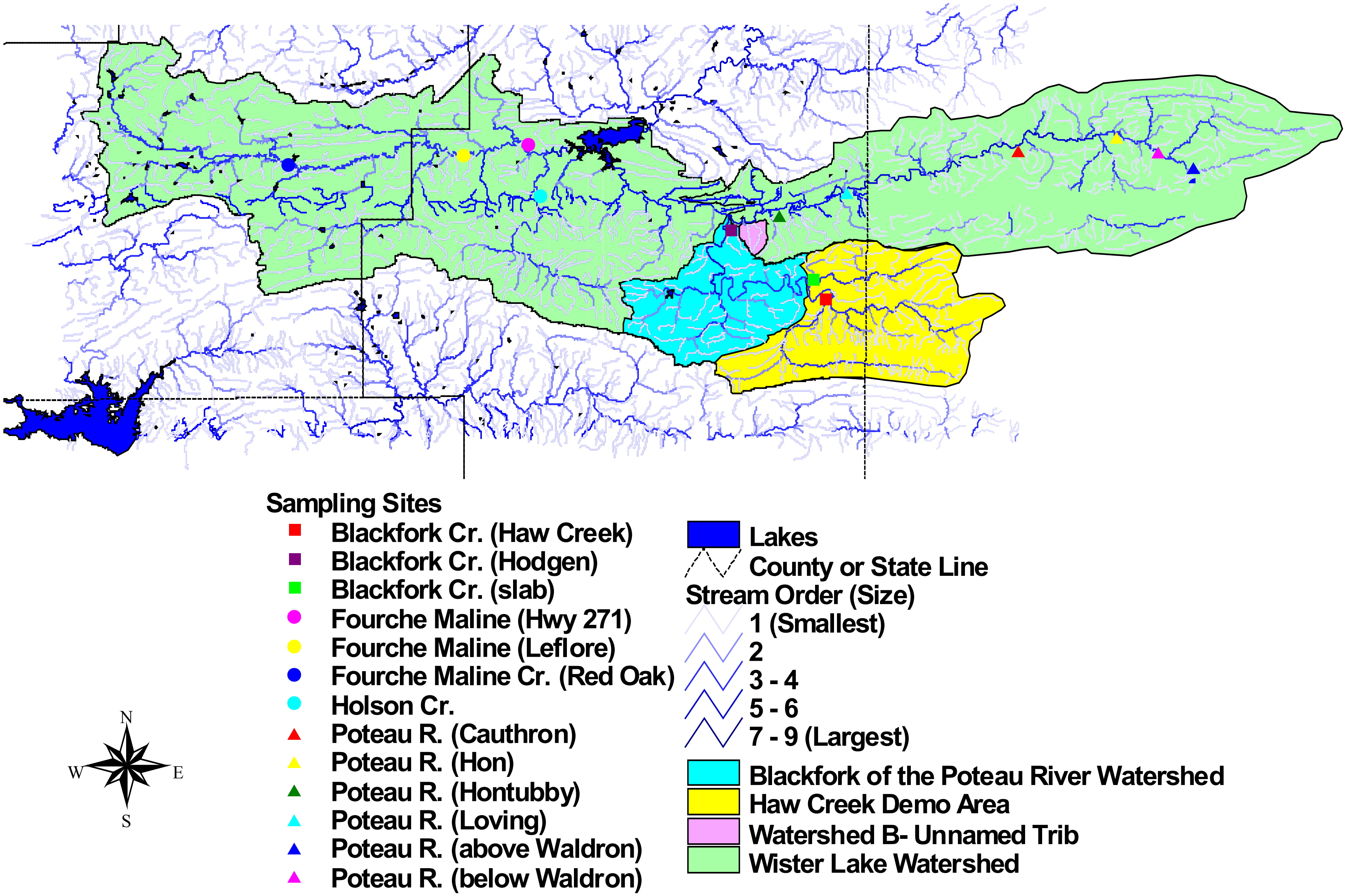

Figure 1. Wister Lake Watershed.

Preliminary work for this project included establishment of a network of state-supported stream monitoring stations (Figure 1), a Clean Lakes Phase I project, a state-supported Geographic Information System, and a low-level educational program and water quality incentive payments to farmers through the USDA Water Quality Incentive Program. At least two years of baseline monitoring were completed before this project began, and area conservation agencies and residents were enthusiastic about participating in demonstration programs.

The Comprehensive Watershed Management Plan

The plan to address NPS pollution concerns in the Upper Poteau River Watershed in Oklahoma, and ultimately in Wister Lake consists of four main components, assessment, planning, education, and implementation/demonstration. These four components were demonstrated primarily in a subwatershed of the Poteau River, rather than over the entire watershed, to increase the likelihood of detectable success during the project period and in keeping with Section 319 guidance that projects are intended for education and demonstration rather than soley for implementation. The long-term success of the plan relies, not only upon the abilities of federal, state, and local agency personnel, but more importantly, upon the participation of the local stakeholders throughout the process.

The plan is intended to be implemented in cycles. The first cycle will focus in a subwatershed, for the reasons stated above. The first cycle also focused in a subwatershed because the formal TMDL for the watershed has not been finalized. The first cycle is based on the results of an informal TMDL that was heavily utilized in developing the formal TMDL. The next cycles will spread the plan into the remainder of the watershed to achieve the goals set by the formal TMDL.

The following section describes the components of the plan. Details about each component and the activities and results associated with that component follow in the body of the report.

Assessment

The Assessment component of the plan involves monitoring water quality, land use, and even attitudes and knowledge in the watershed to determine the causes, sources, and extent of NPS pollution-related problems in the watershed. The data collected from this monitoring fit into two main categories, data collected outside the project, and data collected specifically for the project.

As a high priority watershed for the State of Oklahoma, considerable data exists concerning water quality, landuse, geology, and other important factors in the Poteau River Watershed. Much of this data collection had been completed prior to the project and still additional data was collected concurrent to the project. This historical data includes a Clean Lakes Phase I Diagnostic and Feasibility Study conducted on Lake Wister, development of a Geographical Information Systems (GIS) database on the watershed, and long-term monitoring conducted by the U.S. Geological Survey. The concurrent data, although outside the project guidance, was still useful in evaluating the success of the project and the feasibility of the plan.

The current and historical data from outside sources included U.S. Geological Survey Data on the Poteau River and its tributaries, discharge data from point sources in the watershed, background NRCS landuse data, soils data, hydrology data, and climatological data. This data was primarily used to assess watershed loadings, estimate expected load reductions due to BMP implementations, to estimate whether water quality standards could be maintained if all BMPs were implemented within the Poteau River Watershed, and to continue long-term monitoring in the priority watershed.

The data collected specifically as part of the project, summarized later in the report as pre- and post-implementation monitoring, consisted primarily of water quality data on the Poteau River and Blackfork Creek. This data was collected to evaluate changes in water quality over time that may be attributable to the project. Other data collected specifically as part of the project included number, type, and location of installed best management practices, changes in attitude and knowledge levels based on the education program, further delineation of landuses in the subwatershed, and a variety of less formal information. This less formal information, although not housed in a database, will nonetheless be critical to later implementation of the plan and similar programs in the larger Poteau River and Wister Lake Watershed. This type of information includes information about the stakeholders in the watershed including information about who is willing to cooperate, who is willing to go beyond minimum program guidance and who really just wants the incentive payments, and how educated the average watershed citizen is about the problems. This less formal information also includes important lessons for agency personnel implementing the program concerning what were the successes, failures, and mistakes of the program and which of these were general to the type of project compared to those that were due to the region and nature of the problem.

Planning

Planning involves the who, what, and where of the project. Who will implement the program, where will the demonstration and monitoring take place, and what types of activities will occur? Planning is a multi-level process where the first level federal, state, and local agencies provide guidance, technical assistance, and approval to the activities of the second tier of local level planners, the steering committee or local watershed advisory group. The local steering committee insures that the program ultimately put in place by the first level group will likely be acceptable to the local community because it meets their needs in addition to protecting water quality. The local agency, in many cases the local NRCS and Conservation Districts, serves as a liasson between the first and second tiers and is also generally the party responsible for sign-up of cooperators, drafting of actual plans of implementation of the best management plans to be demonstrated, monitoring whether or not those plans have been implemented, and cost-share reimbursement to the cooperators.

Planning can also involve consideration of multiple options for implementation of a program. Planners consider all the options and hopefully pick the one that is likely to be the most successful, cost-effective, or easiest to implement. One of the best means of determining the "best" option is through computer modeling. Modeling, although not without uncertainty, allows planners to "try-it-before-they-buy-it". A model or computer simulation of the watershed is developed based on known processes (such nutrient concentrations in runoff) and factors (like soil nutrient concentrations or monthly rainfall amounts) in the watershed (using real-time data and literature values). Expected changes in those processes due to changes in users practices and habits (like no till cultivation or buffer strip establishment) can be estimated using a computer. This type of planning is generally part of the first tier. The second tier uses the information provided by the first tier planners to make their decisions.

The planners consider the goals established by the TMDL to develop their plan. In the first cycle of the plan, they will use the rough-cut developmental TMDL to help them decide which practices to support and which areas to target. In later cycles of the project, they will use the formal TMDL to target areas and estimate levels of success.

The planning activities and decisions of these tiers of planners are discussed in more detail later in the document.

Education

Long-term water quality improvement involves affecting behavioral changes on the part of watershed users. Although this may be accomplished through regulation and permitting, in many cases a more feasible and palatable alternative is through education. If watershed users are educated on the importance of water quality, things that affect water quality, actions they can take to protect water quality, and benefits they receive due to those actions, most users will begin to change their behaviors. Without that knowledge, demonstration will not be an effective long-term solution because once incentive payments cease and the project presence is no longer felt in the area, practices are generally not maintained and conditions revert to pre-implementation status.

Like planning, success of education activities often relies upon participation of local groups in the program. Information is more palatable coming from local people than from unknown officials. For this reason, local groups, such as NRCS, Conservation Districts, and County Extension Agents implemented the education programs, rather than state agency personnel from another area.

Implementation/Demonstration

This component of the program consists of putting practices in place that are designed to reduce nonpoint source pollution in a watershed. These practices should be targeted to affect the highest priority and most significant sources of pollution. In some circumstances it may only be possible for these practices to be demonstrated in one small area, in which case they are implemented on a demonstration plot. Data is collected from this plot to estimate the effectiveness of the practice and the results are shared via tours of the site. In many cases, however, these practices are demonstrated on a wider scale in the watershed with the purposes of demonstrating water quality improvements. Cost-share assistance and incentive payments are offered to landowners willing to participate in the program. The idea behind demonstration projects is that users are more likely to change behaviors if they are shown the benefits of those changes rather than just hearing about the expected benefits.

These four components of the plan describe a process that will likely continue beyond the life of this project. As stated previously, the process is cyclical because initial efforts are learning efforts. Initial programs rarely succeed in addressing all of the issues in a complex system. Therefore, the assessment through implementation cycle repeats itself with followup cycles that gage and address the holes left by the first cycles. The key to sustaining the cycle beyond the framework of one specific project is to create much of the project framework at a local level rather than a state level. Although the State will still have to assist the local agencies with tasks such as monitoring and with some of the funding, the local groups will sustain the education efforts and continue to lead the planning efforts.

Activities

The major project activities and the plan components they addressed were as follows:

1. assess watershed loadings (Assessment),
2. quantification using modeling for each type of load reductions anticipated with each type of BMP implemented (Planning),
3. use modeling to estimate expected load reductions if BMPs were implemented on all impacted land within the watershed (Planning),
4. determination that water quality standards could be maintained if all BMPs within the watershed protection strategy were implemented (Planning),
5. conduct demonstrations and educational programs (Education and Demonstration / Implementation), and
6. continuation of monitoring program (Assessment).

Overall project management was provided by the Oklahoma Conservation Commission. A local steering committee was established with representatives of the LeFlore County Conservation District and the LeFlore County Cooperative Extension serving as co-chairs of this committee. The Committee helped to direct the program and was the decision making body which dictated the direction of the program. The steering committee (also called the Poteau River/Lake Wister Advisory Committee) met regularly (monthly) during the project period to discuss pertinent events and watershed issues. They were also provided updates by the District, NRCS, and OSU Extension on the progress of the project. The steering committee made decisions on which subwatershed to demonstrate practices in, which practices to demonstrate, and what percentage should be cost-shared by the landowner.

The steering committee met regularly throughout the length of the project (and beyond) to discuss details of the program and make decisions. Copies of the agendas and minutes of their meetings are attached in Appendix C, pages A-3 through A-49.

A technical advisory group, chaired by Oklahoma Conservation Commission, was formed to provide assistance to the local steering committee. This advisory group included representatives of the Oklahoma Conservation Commission, Oklahoma State University Cooperative Extension, USDA Natural Resources Conservation Service, Oklahoma State Department of Agriculture and other groups as necessary. This group met with the local steering committee to provide input as requested to insure that the goals and objects of the project are met.

A third group chaired by the Office of Secretary of Environment and made up of agency administrators met on a periodic basis to discuss the ongoing work being conducted at the local level. This third group made recommendations to legislative decision-makers on the needs that have been identified in order to insure the success of the project. Members of this group included personnel from the Oklahoma Conservation Commission, Oklahoma State Department of Agriculture, Oklahoma State University Cooperative Extension, Oklahoma Department of Environmental Quality, Oklahoma Corporation Commission, U. S. Geological Survey, Oklahoma Water Resources Board and the Office of the Secretary of Environment.

The Oklahoma Conservation Commission coordinated the project in cooperation with the Poteau River Advisory Committee. The LeFlore County Conservation District and the Natural Resources Conservation Service (NRCS) representative in LeFlore County undertook primary operational responsibilities for:

(1) soliciting landowner participation in the project with a goal of at least 70% land-owner participation,
(2) implementing detailed landowner specific management plans using appropriate combinations of water quality BMPs,
(3) providing technical assistance in installing the BMPs, and
(4) exercising oversight to assure that BMPs were correctly installed and maintained.

The Oklahoma Conservation Commission coordinated with the district to administer the distribution of project funds to landowners participating in the demonstration project and carried out pre- and post-implementation monitoring work to document the impacts of the project on water quality.

TASK ONE Select Priority Watersheds, Estimate Pollutant Loading to Lake Wister, and Evaluate Impacts of the Project on Water Quality (Assessment and Planning)

<u>Selection of Demonstration or Priority Watersheds</u>

The entire Wister Lake Watershed is too large for the scope and resources of this project and as such, it was necessary to select a subwatershed to focus demonstration efforts in. This subwatershed must satisfy several conditions. These conditions include:

1) the subwatershed must contain the typical landuse practices believed to contribute to NPS pollution in the greater Wister Watershed
2) water quality in the subwatershed should be consistent with NPS related water quality problems in the remainder of the watershed
3) the subwatershed must be of manageable size based on the resources available for the project
4) landowners in the subwatershed should be willing to cooperate in the program
5) the subwatershed should be located within appropriate boundaries to control for varying programs in within different political boundaries (i.e. not cross state lines, if possible).

With these requirements in mind, OCC reviewed historical studies, available data, and planned activities of other state and federal agencies in the Wister watershed to select three potential subwatersheds as possible implementation watersheds. This was not an easy task because the morphometry and location of the watershed near the State line limits the number of appropriate demonstration watersheds in Oklahoma. The OCC presented the pros and cons of each of these subwatersheds as implementation sites to the Poteau River Steering Committee and on May 11, 1995, the committee recommended the Haw Creek/Big Creek area of the Blackfork Creek subwatershed for implementation. The local citizens have named the area Haw Creek, although they are really speaking about the Blackfork Creek Watershed which includes the confluence of the Blackfork and Haw Creek and ranges upstream to the headwaters of the Blackfork in Arkansas. For the remainder of the report, references to Haw Creek are generally referring to the Haw Creek area of the Blackfork Creek.

The committee chose the Haw Creek area of the Blackfork Creek subwatershed for several reasons:

- landuse in the subwatershed was representative of the most notable problem areas in the Poteau River Watershed,
- pastureland where poultry litter could be applied was concentrated and was generally adjacent to the stream and therefore more likely to impact the stream,
- historical data existed on the Blackfork Creek, which suggested that the Blackfork contributed a small, though not insignificant portion of the loading to the Poteau River Watershed,
- most of the privately owned land in the watershed was pastureland, while public and corporate lands were largely forested. Forested land represents more of a natural condition in the watershed and therefore is not the most efficient place to implement practices. Because the intent of the demonstration effort was to show private landowners more efficient means of addressing nonpoint source pollution, the watershed was a good fit,
- No point source dischargers existed in the subwatershed,
- No urban areas existed in the watershed. Previous watershed modeling suggested that the bulk of the nonpoint source loading came from rural areas, rather than urban runoff,
- a considerable portion of the watershed was in Oklahoma, and
- people in the watershed were receptive to the program.

The other two watersheds, although representative of the landuse, were more ephemeral in nature and the location of monitoring sites would have been very difficult. The committee decided however, that if funds remained after the Haw Creek implementation, Lewis Creek was to be targeted. Table 1 and figure 1 characterize the 3 subwatersheds. Figure 2 characterizes the Haw Creek subwatershed.

Table 1. Characterization of Three Potential Demonstration Watersheds.

Subwatershed	Characterization	Pros	Cons
A- Haw Cr./ Big Cr. Area	17 +4 nearby poultry houses; 2.9 million annual poultry	Possible monitoring site on upper Big	Poultry houses in located in Arkansas in upstream

Tribs to the Blackfork	capacity, >35,000 acres in watershed (poultry concentrated in about 4000 acres, 1000+ acres pastureland in watershed, 3000 acres forestland in watershed, 40 homesites in watershed	Creek (Big Creek flows from U.S. Forest land (good reference)), Isolation may result in most litter being used in concentrated area, community center for meetings	drainage area; very large drainage area; pasture land is fairly limited.
B. 2 unnamed branches (1 ½ miles w of Hontubby) Sec. 4, 5, 8, 9 T4N, R26E	East Branch: 8 Poultry houses, 935,000 annual poultry capacity West Branch: 6 + 4 nearby poultry houses, 1.4 million annual capacity. 2000 acres in watershed, 1020 acres pastureland, 980 acres forested land, 17 homesites	Concentration of poultry houses, limited number of growers (6), paved accessibility	Very intermittent stream flow, numerous small land owners, location of monitoring site, lack of nearby comparison watershed
C. Lewis Creek (2 ½ miles east of Summerfield)	15 poultry houses, 3000 acres in watershed, 1430 acres pastureland, 1570 acres forestland, 38 homes	Availability (2 miles west) of established comparison monitoring site (Holson Creek), limited number of growers, larger acreage per land owner	Intermittent stream flow, very difficult monitoring site location (forks of creek converge on Corp land), comparison creek does have 4 poultry houses.

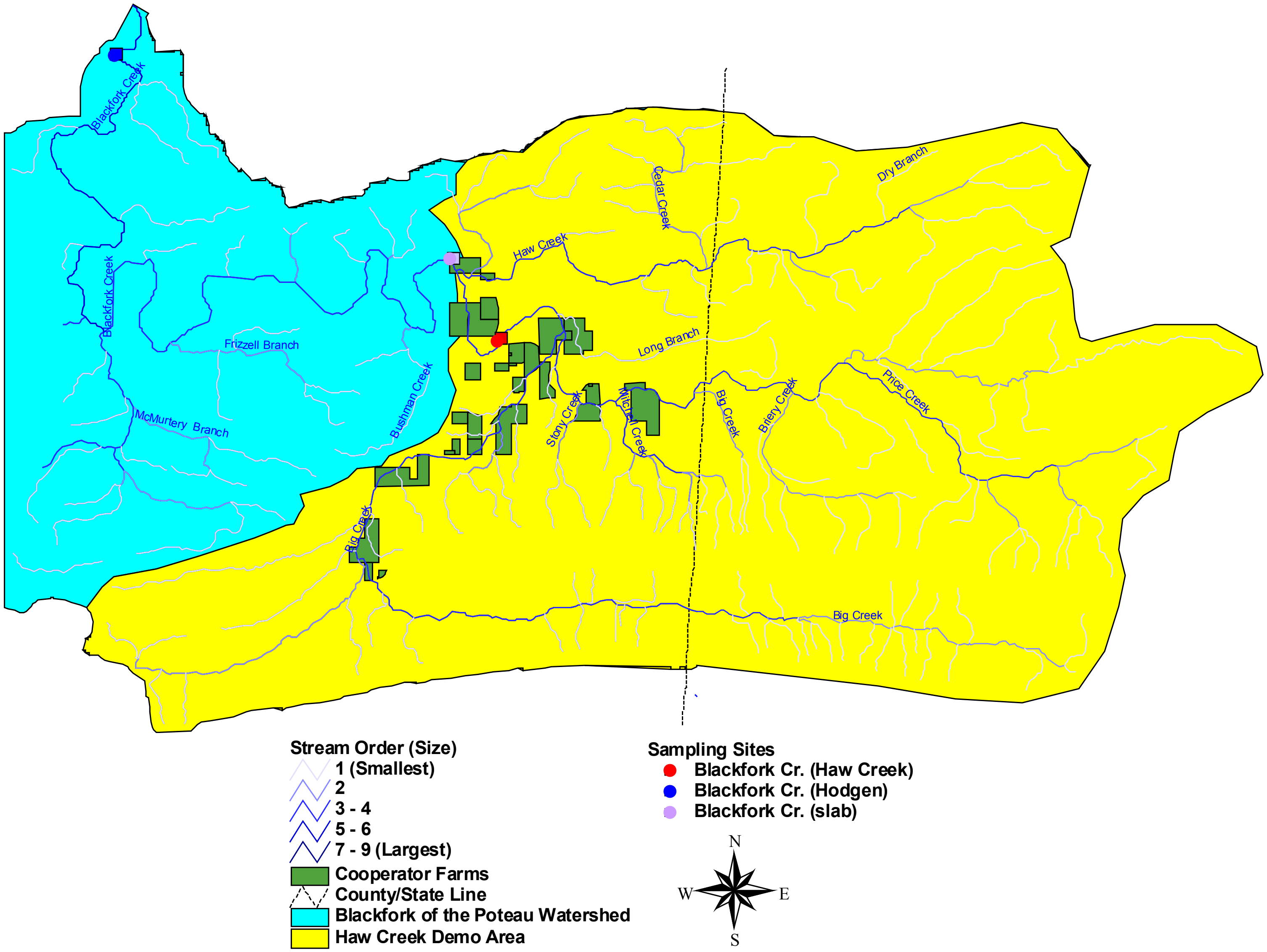

Figure 2. Haw Creek Demonstration Watershed.

Conduct Modeling Studies to Estimate Pollutant Loadings from Subwatersheds.

The results of this phase of the project are summarized in detail in two reports; 1) Poteau River Comprehensive Watershed Management Program, TMDL Component, from Oklahoma State University, and 2) Modeling Wister Lake Watershed with the Soil and Water Assessment Tool (SWAT), from the Blacklands Research Center. These reports are included as Appendices A and B. This TMDL component is not the official TMDL to satisfy the Clean Water Act Requirements for 303(d) listed streams. This TMDL was a developmental TMDL, the first stages of which were initiated before the recent lawsuit-driven effort to complete TMDLs was begun. However, the results and processes of this TMDL have been heavily utilized by the contractor who is developing the official TMDL for the responsible state agency, the Oklahoma Department of Environmental Quality. Therefore, the recommendations of this informal developmental TMDL will not be dramatically different from the formal TMDL. It is likely that the formal TMDL will just set more specific guidelines.

These modeling exercises concentrated on phosphorus as the critical parameter because phosphorus is believed to be the most deleterious pollutant to the system. In addition, many of the practices that reduce phosphorus loading also reduce loadings of the other significant pollutants in the system such as sediment and organic matter. Overall State goals for the watershed include a forty percent reduction in phosphorus loading to the system.

The modeling exercises consisted of substantial data gathering and development of a GIS database. This data included information on landuse, soil types, water quality, flow, elevation, topography, and many other variables. This GIS database will be useful for many applications beyond the life of this project. If updated, this GIS database can continue to help with the planning and assessment components of the Watershed Management Program.

Considerable detail relative to the mechanisms of the modeling exercises and the assumptions made to conduct the models is included in the Appendices. However, the salient details of the modeling exercises with respect to the planning of the Comprehensive Management Plan relate to the estimates of which subwatersheds and land uses are contributing the bulk of the phosphorus load to the system. The salient details also include recommendations on the level of reduction necessary to protect the resource.

The modeling exercises concluded that pastureland, which accounts for only 17% of the total basin area, contributed approximately 40% of the total phosphorus load to the watershed. In addition, the modeling exercises found that subwatersheds with more pastureland contributed most to the total watershed loading. The subwatersheds that contribute most to the load on an area basis include the Poteau River above Cauthron, and the Poteau River between Loving and the headwaters of Lake Wister. These subwatersheds received the bulk of the point source contribution of the load, and also represented approximately half of the watershed area. The subwatersheds that contribute the least to the total watershed load on an area basis include the Blackfork subwatersheds. These watersheds contained much of the U.S. Forest Service Lands and represented approximately 30% of the watershed area. The Poteau River above Cauthron was estimated to contribute the greatest mass of phosphorus to the annual load.

Major Land Uses	Percent of Total Watershed	Percent of Total P Loading to Watershed
Pastureland	17.2%	40%
Uncut Forest	70%	40%
Bare Ground	2%	11%
Other (urban, cut forest, roads, etc.)	11%	9%

The initial development of this TMDL was coordinated with a Clean Lakes Section 314 Phase I Study on Lake Wister conducted by the Oklahoma Water Resources Board. The Phase I study documented water quality problems in the lake and recommended solutions to those problems. The estimates of loading reduction necessary to improve water quality in the Lake (Phase I Study) were combined with estimates of loading reductions necessary to improve water quality in its tributaries using a modified EUTROMOD model. Details of this exercise and its findings are summarized in Chapter 8 (pages 211-216) of Appendix A. These results estimated that at least a 40% reduction in phosphorus loading to Lake Wister was necessary to slow the accelerated eutrophication that had begun and protect the resource.

Based on these findings, the project determined that pastureland should be targeted for implementation efforts prior to other landuse types. Pastureland is likely the greatest contributor because it is one of the most intensively used lands in the watershed.

Forestland in the watershed is not intensively used and silviculture is not extensive in the watershed. In addition, three separate efforts to estimate the background portion of the loading all predicted background loading to be about 40% of the total load. Two of these efforts were associated directly with this project, another was part of the Clean Lakes Phase I Study. Forested land was estimated to contribute approximately 40% of the background load, which could be expected, given that natural conditions (pre-settlement) in the watershed were forested slopes. The background portion of the loading was estimated using three separate methods which all arrived at approximately the same conclusions. These methods included: 1) computer modeling to estimate the load to the watershed if it was entirely converted to forest land; 2) loadings calculated by applying the load from of a watershed with very little development (few homes, no poultry houses, very little pasture) to the entire watershed area; and 3) use of a morphoedaphic index during the Clean Lakes Phase I Study. The morphoedaphic index was developed by comparing the chemistry of numerous lakes of varying stages of eutrophication and anthropogenic impact and developing a relationship between alkalinity, conductivity, and phosphorus loads.

Other more intensive land uses such as urban areas are not as prevalent as pasture land. Pasture in the watershed adds nutrients and sediment associated with grazing activities and poultry litter spreading. The general goal of the implementation was to reduce loading from pastureland to a level more similar with that contributed by other landuses in the watershed.

Haw Creek Area Preimplementation Monitoring

Water quality problems in the Wister Lake and Poteau River Watershed stem primarily from excessive sediment and nutrient loading. The Poteau River is listed on the 1998 303(d) list as being threatened or impaired by causes of metals, nutrients, siltation, organic enrichment/dissolved oxygen, taste and odor, suspended solids, and noxious aquatic plants. Wister Lake is listed for nutrients, siltation, flow alteration, taste and odor, and suspended solids. The 1996 Clean Lakes Study found the lake to be hypereutrophic and to violate the State's turbidity standard for lakes. The lake experienced hypolimnetic anoxia from May to September and was anoxic below four meters between July and August. The Poteau River Valley Improvement Authority documented taste and odor problems with its water in May 1993 that was not linkable to an algal bloom, but was likely related to hypolimnetic anoxia and organic enrichment.

Data collections on the Poteau River suggest that during summer low flow conditions, the flow on the river is reduced such that it behaves more like a reservoir than a river, stratifying thermally in places and setting up anoxic conditions. The effects of this stratification on the biological community of the river is not known, although it likely limits the community during low flow periods.

Data has been collected in the Poteau River Watershed in conjunction with a number of projects. It was determined that data collected between 1991 and 1996 would be the most appropriate for characterizing the pre-implementation water quality conditions in the watershed. Implementation began in 1996 and some practices were still being finalized in early 1999. The pre-implementation data was collected from two sites on Blackfork Creek, Blackfork at Hodgen and Blackfork at Haw Cr. and at one site on the Poteau River, the Poteau at Loving (Figure 1, Table 2, Appendix A). This data included OCC standard chemical and physical water quality monitoring which was supplemented by USGS water quality and stream flow monitoring at the same stations to lengthen the period of record. These data include standard monthly collections, supplemented by additional stormwater collections. The six year period of record, supplemented by stormwater collections insures a wide variety of flow conditions were represented. Data is summarized to include ranges and Oklahoma Water Quality Standards criteria violations. All of the water quality data analyzed is included in Appendix D.

Table 2. Preimplementation data summaries from the Poteau River and Blackfork Creek.

Poteau River @ Loving OK220100-02-0020M 1991-1996										
		min	**25% quartile**	**Median**	**75% quartile**	**max**	**n**	**ave**	**std**	**Violations ***
Field DO	mg/l	3.9	5.3	6	7.7	13.2	92	6.77	2.19	1
Field pH	S.U.	6.2	6.79	7	7.32	7.73	99	7.05	0.28	1
Field Cond	us/cm	37	70	81	92.5	141	98	86.22	26.50	
Field Temp	C	4.6	19.1	26.1	29.5	32.3	91	23.20	8.20	
% DO Saturation	Calc.	49.89	62.35	76.66	84.19	118.38	91	75.48	12.82	7 < 60%
Field Turb	NTU									
Field Alk	mg/l									

Flow	Est.									
Flow	cfs									
Chloride	mg/l	2.5	3.225	4.35	6.23	31	26	5.76	5.44	
sulfate	mg/l	1	1	2	19.48	22.5	34	7.24	8.48	
total hardness	mg/l	9	13	16.5	20	32	26	17.96	6.38	
Na	mg/l									
TDS	mg/l									
TSS	mg/l	35	67.3	119.5	167	434	26	140.87	93.94	25 > 50
VSS	mg/l									
Total P	mg/l	0.04	0.09	0.143	0.25	0.64	72	0.18	0.12	7 > 0.36
ortho P	mg/l									
nitrate	mg/l	0.05	0.13	0.25	0.25	0.51	26	0.22	0.11	
nitrite	mg/l	0.002	0.00575	0.01	0.01	0.04	36	0.01	0.01	
nitrate/nitrite	mg/l	0.05	0.1	0.13	0.18	0.99	37	0.17	0.16	
TKN	mg/l	0.2	0.4	0.695	0.975	1.93	76	0.72	0.36	
ammonia	mg/l	0.001	0.0225	0.045	0.08625	0.49	38	0.07	0.09	
specific conductance	us/cm									
chlor-a	ug/l									
phaeophytin-a	ug/l									

Blackfork River near Page (HAW) OK220100-02-0040M 1991-1995										
		min	**25% quartile**	**Median**	**75% quartile**	**max**	**n**	**ave**	**std**	Violations*
Field DO	mg/l	3.7	5.9	6.4	8.9	13.2	81	7.38	2.15	1
Field pH	S.U.	6	6.595	6.83	7.02	7.9	87	6.83	0.38	5
Field Cond	us/cm	21	33	37	42	103	85	37.95	10.84	
Field Temp	C	5.9	15.6	25.4	26.8	33.7	81	21.94	7.90	
% Saturation	Calc.	44.78	74.79	78.89	90.16	121.48	81	81.14	12.19	2 > 60%
Field Turb	NTU									
Field Alk	mg/l									
Flow	Est.									
Flow	cfs									
Chloride	mg/l									
sulfate	mg/l									
total hardness	mg/l									
Na	mg/l									
TDS	mg/l									
TSS	mg/l	6.5	30	48.5	118	241	12	75.6	70.01	5 > 50
VSS	mg/l									
Total P	mg/l	0.01	0.02	0.04	0.06	0.26	57	0.05	0.05	
ortho P	mg/l									
nitrate	mg/l	0.1	0.2125	0.25	0.25	0.28	12	0.215	0.07	
nitrite	mg/l	0.01	0.01	0.01	0.01	0.03	26	0.01	0.006	
nitrate/nitrite	mg/l	0.05	0.07075	0.09	0.1375	0.24	34	0.10	0.05	
TKN	mg/l	0.2	0.2	0.4	0.5	1.1	61	0.42	0.22	
ammonia	mg/l	0.001	0.02	0.04	0.05	0.41	25	0.06	0.08	
specific conductance	us/cm									

chlor-a	ug/l									
phaeophytin-a	ug/l									

Black Fork @ Hodgen OK220100-02-0030G 1991-1996										
		min	**25% quartile**	**median**	**75% quartile**	**max**	**n**	**ave**	**std**	violations
Field DO	mg/l									
Field pH	S.U.									
Field Cond	us/cm									
Field Temp	C									
% Saturation	Calc.									
Field Turb	NTU	12	14.75	18	38	120	8	34.375	36.27	1
Field Alk	mg/l									
Flow	Est.									
Flow	cfs									
Chloride	mg/l									
sulfate	mg/l									
total hardness	mg/l									
Na	mg/l									
TDS	mg/l									
TSS	mg/l	10	17.5	45	107.5	240	8	82.5	93.46	3 > 50
VSS	mg/l									
Total P	mg/l	0.01	0.05	0.13	0.15	0.25	5	0.118	0.09	
ortho P	mg/l									
nitrate	mg/l	0.1	0.2	0.3	1	1	5	0.52	0.44	
nitrite	mg/l									
nitrate/nitrite	mg/l									
TKN	mg/l	0.44	0.57	0.7	1.35	2	3	1.05	0.84	
ammonia	mg/l									
specific conductance	us/cm									
chlor-a	ug/l									
phaeophytin-a	ug/l									

* Violations refer, generally to violations of Oklahoma's Water Quality Standards (WQS). However, no criteria exist for TSS, nutrients, or dissolved oxygen saturation. Violations for those parameters are based on literature suggested values.

Although preimplementation data showed that the Blackfork and Poteau River violated water quality standards criteria on several occasions, they were still meeting beneficial uses at most stations. However, Blackfork Creek at Haw was not meeting pH criteria and therefore not supporting the aquatic life beneficial use. Data also suggested potential problems with total suspended solids, phosphorus, and dissolved oxygen saturation.

TASK TWO Implement Cost-Share Program with Producers in Priority Watersheds. Provide Educational and Technical Assistance to Assure BMP Implementation is Suitable for Demonstration (Implementation)

Demonstration / Implementation Activities

As the pre-implementation monitoring showed, there was a definite need for BMP implementation in this area. To address the identified problems, the Poteau River Water Quality Management Program demonstration project promoted the installation of water quality oriented BMPs designed to address the high priority problems identified in the Haw Creek Area of the Blackfork River drainage. The priority BMPs selected by the Poteau River Advisory Group were as follows:

(1) animal waste control facilities
(2) proper storage and disposal of animal waste
(3) rural waste systems
(4) pasture and hayland management.

These activities were chosen because they targeted phosphorus and addressed the majority of improper management practices related to pastures in the watershed. Although rural waste systems are not a contributor to the calculated load from pastures, they do contribute to the overall phosphorus loading in the watershed. Forty percent of the loading was estimated to originate from pastureland, forty percent from background loading, leaving 10% from point sources and 10% from other sources such as urban runoff, and rural wastewater systems.

The WAG members believed it was important for participators to be interested in implementing all the necessary practices, rather than just the ones they could pick and choose, such as a new water tank or pasture sprigging. They believed that a cooperator must be willing to also put in practices such as cross fencing and an appropriately sized septic system. Therefore, the decision was made that cooperators must be willing to implement all the recommended practices in the farm plan in order to qualify for cost-share assistance.

With these priority BMPs, the idea that comprehensive participation was necessary, and with the understanding that the goals of the program were to focus on phosphorus management, primarily from pasture land in mind, the Advisory Group developed the following implementation goals for the program:

1. develop total water quality plans on all farms in the demonstration area
2. install 6 waste control facilities
3. install 10 rural waste systems
4. install 10 animal waste storage structures.

These goals were not based quantitatively on the expected reductions to the TMDL's established goals. Rather, these goals were based on what the WAG felt would be possible given the available resources, the number of producers in the watershed, and a certain level of best professional judgment regarding the optimal levels of participation a program could expect. For example, they chose to recommend that every farm should have a total water quality plan developed. This effort may or may not be necessary or even recommended in other similar programs. The WAG felt this would be possible given the small size of the watershed, and they believed it would help gauge the need for implementation in the remainder of the Poteau River Watershed. In addition, it is believed that the successes or failures in reaching these goals should provide insight for implementation of the Comprehensive Management Plan to address the formal TMDL in the next cycles of the program.

Following these goals, and with the knowledge that the major problems in the watershed were nutrients and sediment believed to be related to improper waste management, the implementation effort focused first on poultry producers in the area. Secondly, they targeted household nutrients, such as those from insufficient septic systems. Finally, they focused on practices that would improve grass cover to increase nutrient uptake and reduce overland erosion. These practices focused on pasture management (approximately 40% of the phosphorus load) and rural waste systems (a portion of 10% of the load) which combined to address approximately 50% of the total phosphorus load and 55% of the NPS load to the system.

This project drew from the water quality BMPs listed in Table 3 and contained in Oklahoma's Section 319 NPS Management Plan. The cost-share rates listed in Table 3 were set by the WAG based on the incentives they believed to be necessary to encourage landowners to participate in the program.

Table 3. BMPs promoted for implementation in Poteau River project.

BMP Description	BMP # for Project	Cost-share Rate
Permanent Vegetative Cover Establishment	1	80%
Agricultural Waste Control Facility	2	80%
Sod Waterways	3	80%
Water Impoundment Reservoir	4	80%
Diversion Terraces	5	80%
Permanent Vegetative Cover on Critical Areas	6	80%
Rural Waste System	7	80%
Forest Tree Plantations	8	80%
Sediment Retention Erosion or Water Quality Structure	9	80%
Management Incentive Practice	10	100%
Riparian Area Establishment	11	80%

Implementation began in the summer of 1995. The funding allowed the implementation of the BMPs listed in Table 4 in the demonstration watershed.

Table 4. BMPs implemented in Haw Creek Area of the Blackfork Watershed.

BMP	Component	# of jobs	Area or other unit
Permanent Vegetative Cover Establishment	Bermuda grass sprigging	2	40 acres
	Fertilizer application- nitrogen	2	40 acres
	Fertilizer application- potash	1	10 acres

	Agricultural lime application	1	10 acres
	Fencing (4 wire)	4	652 fence posts
Agricultural Waste Control Facility	Waste holding facility	2	4080 sq. ft.
	Poultry composting facility	8	13,560 sq. ft.
Water Impoundment Reservoir	Construction	14	20,664 yd^3
	Livestock watering pipeline	1	650 ft.
	Freezeproof watering tank and installation	1	2 tanks
Rural Waste System	Septic tank and lateral lines	13	
Management Incentive Practice	Planned Grazing System	4	130 acres
	Pasture and hayland management	4	494 acres
	Pasture and hayland planting	5	155 acres
	Waste Utilization	13	650.5 acres
Riparian Area Establishment	Fencing	4	899 fence posts

Twenty six producers and landowners participated in the program. Four more initially signed up but failed to participate for various reasons. These landowners were targeted for participation for the following reasons:

- They owned pastureland along the creeks,
- They were poultry producers or applied poultry litter,
- A potentially significant source of phosphorus existed on their land in close proximity to the creek,
- There was a need for riparian zone development on their property, and
- They agreed to implement all the recommended practices of the farm plan, rather than merely the ones they preferred.

Six cooperators implemented permanent vegetative cover establishment practices including Bermuda grass sprigging, fertilizer application, fencing, or agricultural lime application. These BMPs were implemented to reduce water pollution from soil erosion, animal waste disposal and other nonpoint sources. These practices were recommended in the newly developed farm plan because these pastures had significant areas of bare soil or poor existing vegetation. Fertilizer and lime application were only recommended in areas where the existing soil content was too poor to support vegetation. Application of these practices was scheduled in a timely manner with respect to weather and seasonal events to limit the potential impacts of fertilizer application to the stream. Approximate location of farms where these practices have been implemented is shown in Figure 3. Costs associated with implementation of these practices are detailed in Table 5.

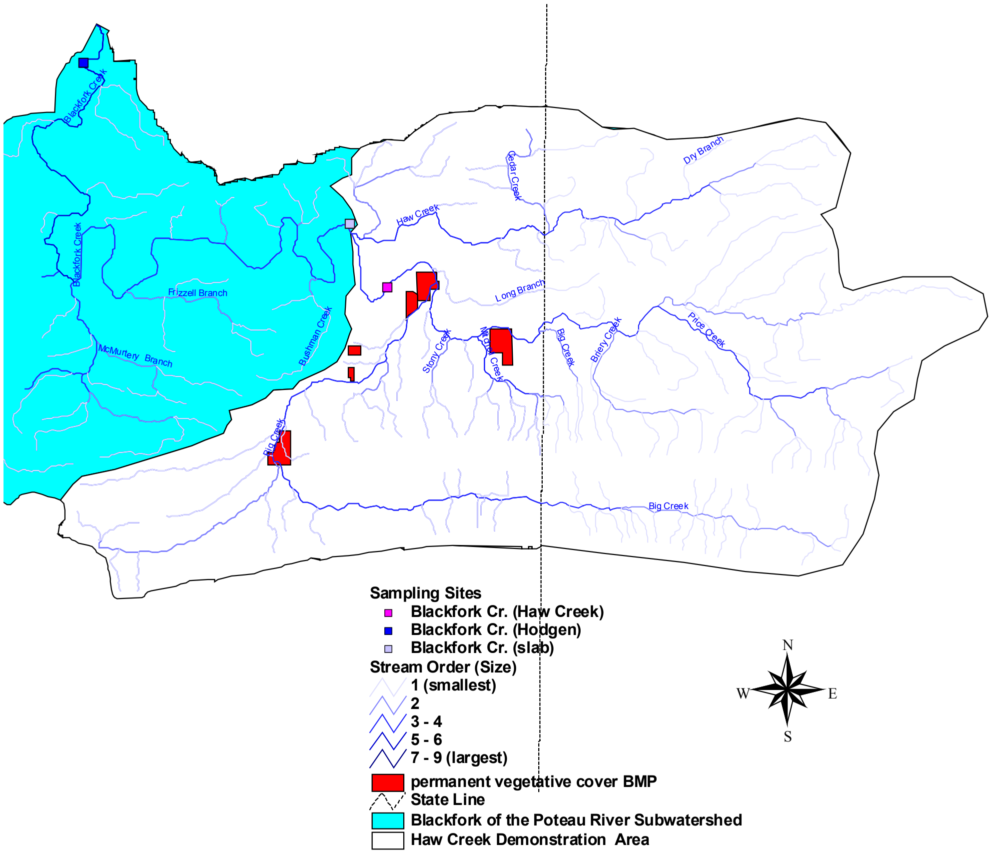

Figure 3. Cooperator Farms Implementing Permanent Vegetative Cover Establishment.

Table 5. Costs and Expenditures of BMP Implementation.

BMP	Component	319 Funds	Cost Share	Total Cost
Permanent Vegetative Cover Establishment	Bermuda grass sprigging	$790	$198	$988
	Fertilizer application- nitrogen	$141	$35	$176
	Fertilizer application- potash	$17	$4	$21
	Agricultural lime application	$340	$85	$425
	Fencing (4 wire)	$4872	$562	$5434
Agricultural Waste Control Facility	Waste holding facility	$13,350	$4,130	$17,480
	Poultry composting facility	$53,218	$23,337	$76,555
Water Impoundment Reservoir	Construction	$13,202	$3,627	$16,829
	Livestock watering pipeline	$109	$28	$137
	Freezeproof watering tank and installation	$736	$214	$950
Rural Waste System	Septic tank and lateral lines	$18,193	$4,679	$22,872
Management Incentive Practice	Planned grazing system	$260	$0	$260
	Pasture and hayland mngmnt	$3,458	$0	$3,458
	Pasture and hayland planting	$2,325	$592	$2,917
	Waste Utilization	$6,505	$2,251	$8,756
Riparian Area Establishment	Fencing	$6,733	$3,200	$9,933
Total Expenditures		$123,459	$42,942	$167,191
Percent of Total Expenditures		74%	26%	100%

The second type of BMPs implemented were animal waste control facilities. These facilities are intended to reduce runoff from animal waste by storing it out of the weather until it can be correctly applied. These facilities allow for carcass digestion which is a disposal method with much lower environmental impact than traditional methods. Eight landowners constructed new animal waste control facilities, either poultry composters or litter storage sheds. These landowners were targeted for these practices because the lack of adequate litter storage was noted on their land and it was believed that the proximity to the stream of their current litter storage and carcass management facilities warranted steps to reduce the potential for runoff. The approximate location of their farms is shown in Figure 4.

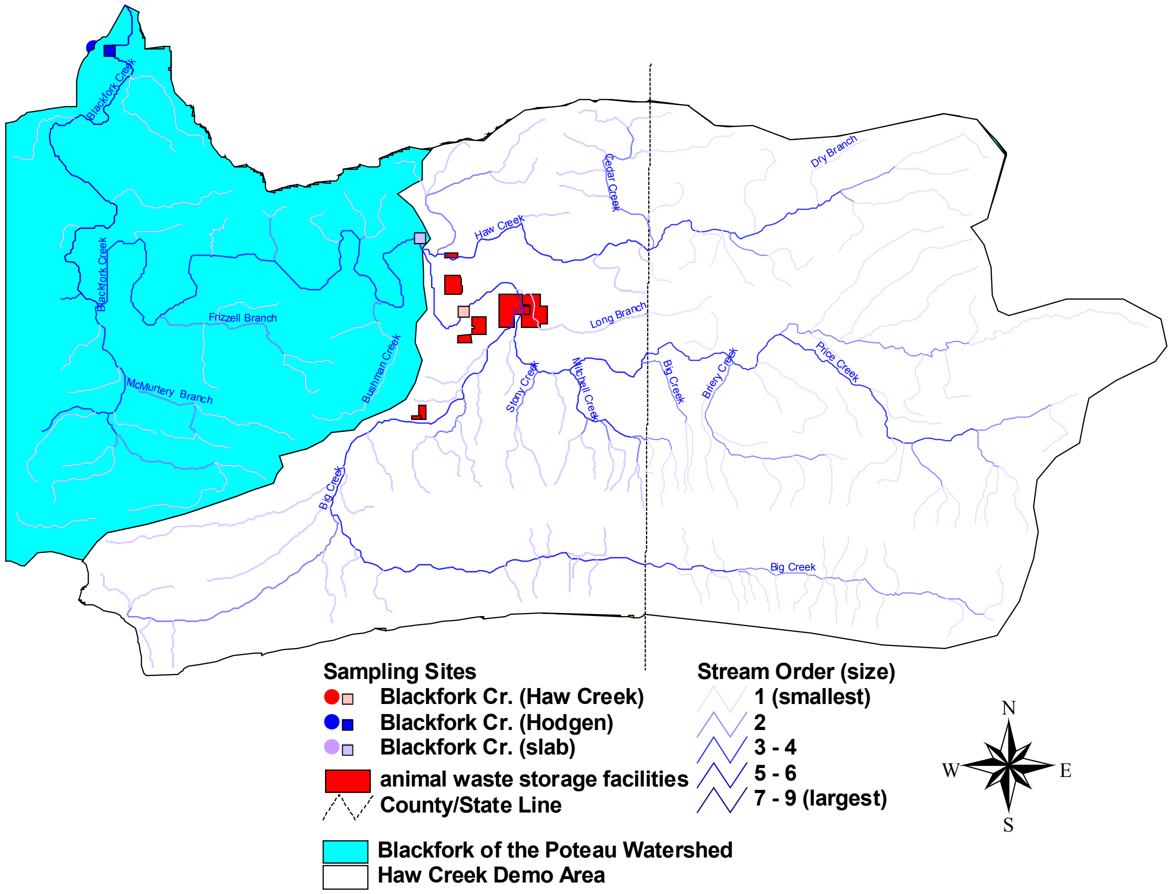

Figure 4. Cooperator Farms with New Animal Waste Control Facilities.

Eight landowners opted to construct water impoundment reservoirs or install watering tanks as alternative water sources. Use of alternative water sources reduces livestock usage of the creek and encourages livestock to frequent upland areas rather than congregating in the creek. Livestock generally prefer fresh groundwater in a stock tank to creek water that during the summer months may become stagnant. Fewer livestock in the creek translates to less streambank erosion and reduces sediment and nutrient delivery to the creek. Location of farms where ponds or tanks were installed is shown in Figure 5. Freeze-proof tanks are also beneficial to farmers in that they decrease the likelihood of cattle contracting waterborne illnesses like bluegreen algae toxicity and they eliminate the need to chop ice during winter months.

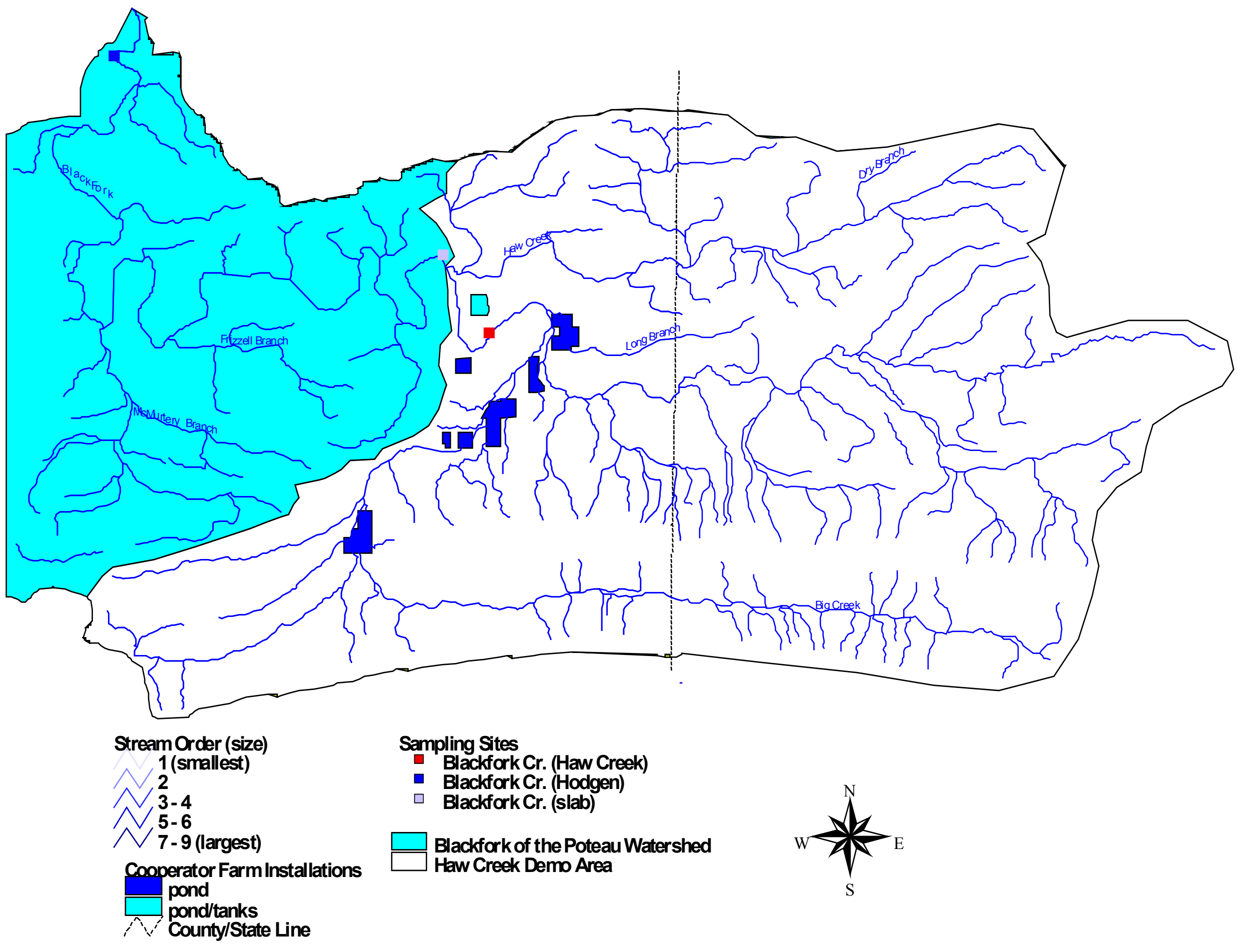

Figure 5. Cooperator Farms Constructing New Ponds or Installing New Watering Tanks.

One of the most frequently implemented BMPs was installation or upgrade of septic systems. Thirteen landowners chose to upgrade or install a new septic system and lateral lines. Three more landowners initially signed up for septic upgrades, but later chose not to participate. Surveys of similar rural areas in other parts of Oklahoma suggest that many rural landowners have substandard septic systems, either due to age, improper construction, or improper location. Septic upgrades reduce NPS pollution from human waste. Approximate locations of farms where septic systems were upgraded are shown in Figure 6. These landowners were targeted for septic tank upgrades due to their proximity to stream channels. It is likely that many other

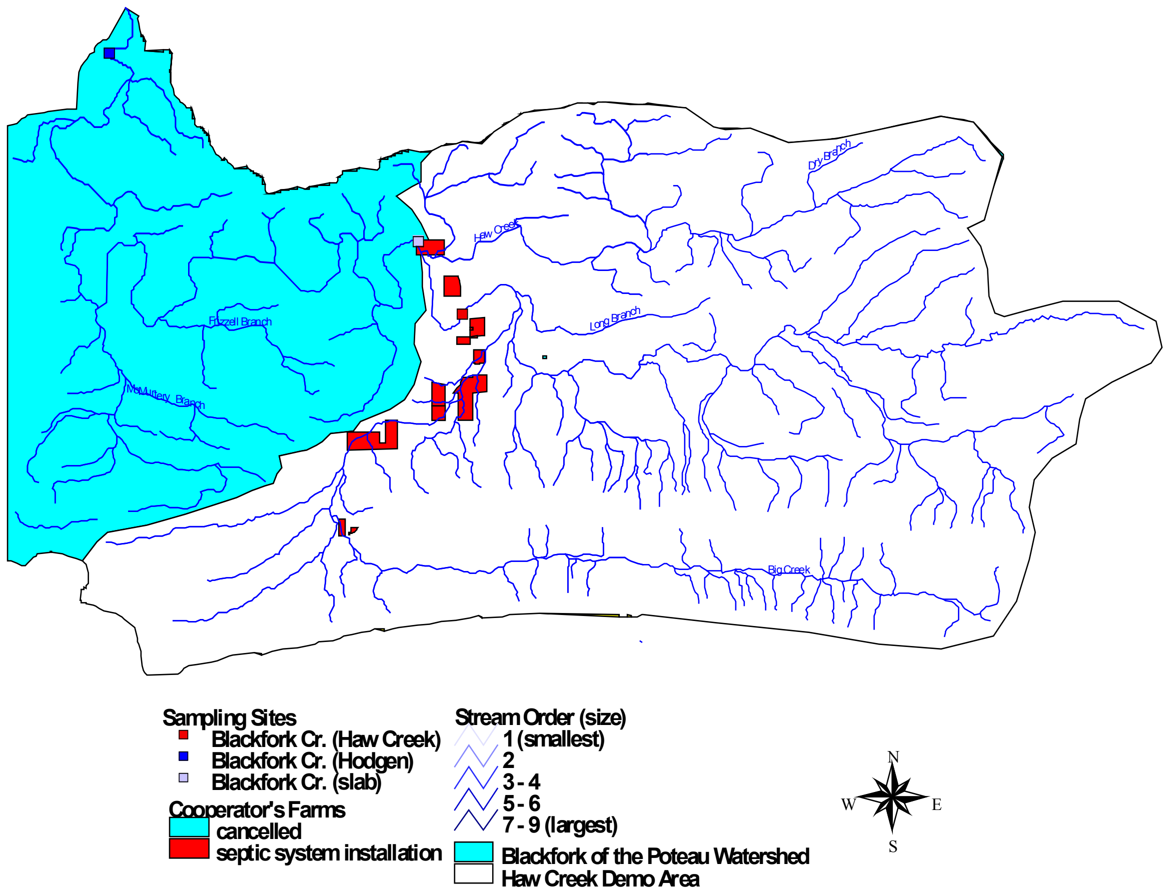

Figure 6. Location of Landowners Implementing Septic Upgrades.

landowners in the watershed also have substandard septic systems. However, because the location of their tanks is farther from the stream channels, they were not targeted in this project. Upgrades to those systems might be something to consider for later cycles of the program.

Landowners also chose to implement BMPs known as Management Incentive Practices. This category of BMP included planned grazing systems, pasture and hayland management, pasture and hayland planting, proper litter application (based on timing, rate, and soil tests). This type of BMP reduces NPS pollution by keeping soil and nutrients near their point of origin through maintenance of upland vegetation and avoiding incorrect application of litter. In addition, proper management of upland areas generally improves its rate of sustained production. This type of BMP is important because it generally represents minimal cost to the landowner (perhaps fencing or sprigging) but results in significant long-term returns. Fifteen landowners implemented at least one category of this type of BMP and one more originally signed up but later decided not to participate. Again, these landowners were targeted based on their proximity to the stream, because they were poultry producers or used poultry litter, and based on the overall need for improved pasture management. Approximate location of this land is shown in Figure 7.

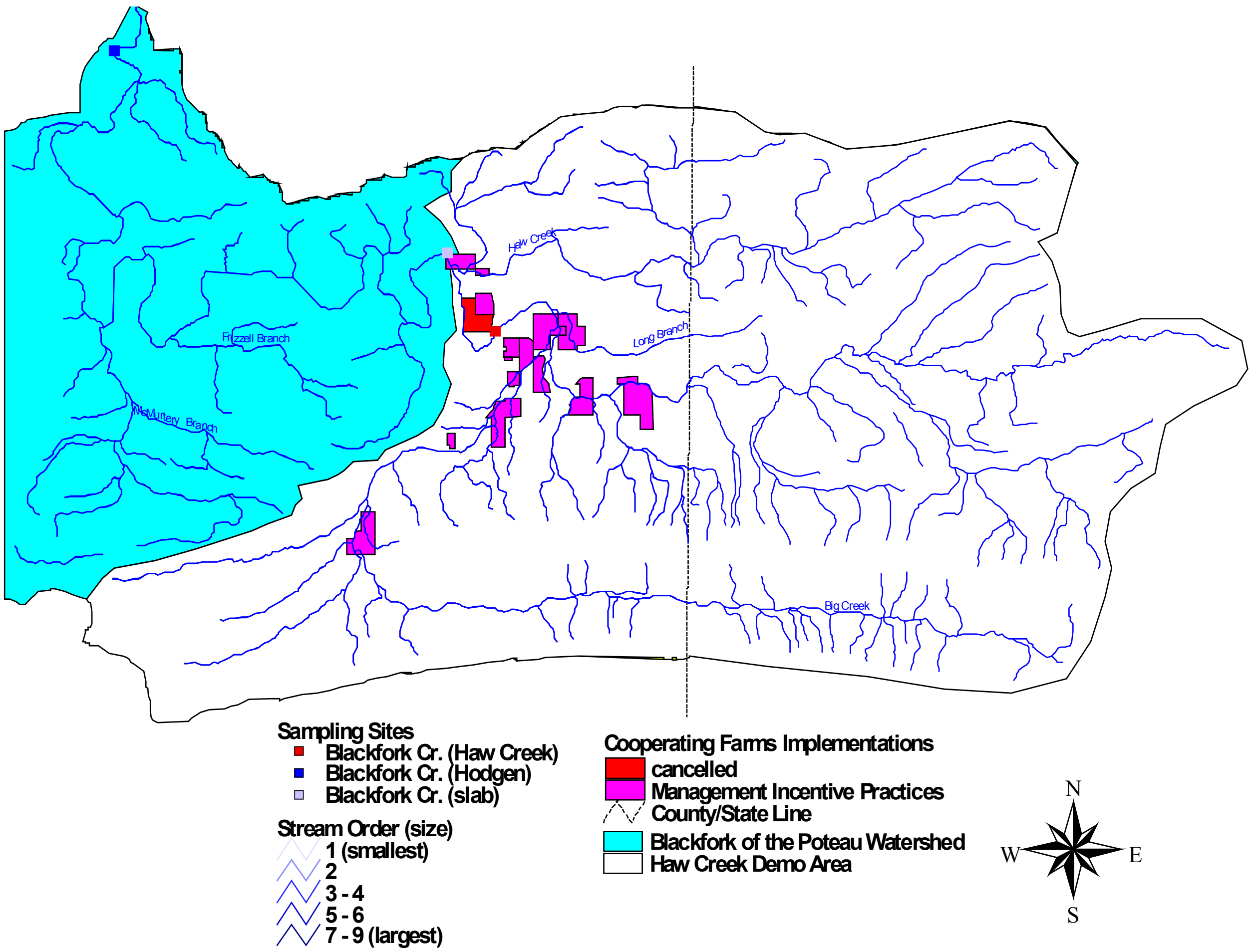

Figure 7. Approximate Location of Cooperators Implementing Management Incentive Practices.

The final class of BMPs implemented was riparian area establishment. Riparian areas have been shown to be successful at removing up to 90% of the sediment and nutrients in runoff from upland areas and as such represent the last chance to remove NPS pollution from runoff before it reaches the stream. Riparian areas also serve as important habitat for wildlife. Vegetation in riparian areas reduces streambank erosion and an established riparian zone can control flooding and reduce its long term impacts by absorbing and dispersing the force of the water. Riparian areas generally require intensive management to farm in the form of time, effort, and money. Therefore, although restoration may result in a reduction of useable land, it often results in an improved profit margin because less land is lost to the force of the creek and less maintenance is required when the area is established as a natural area. Four landowners chose to establish or protect riparian areas on their property. These landowners were targeted because a substantial portion of the creek ran through their property and the current management of the riparian area favored NPS pollution. Location of those properties is shown in Figure 8.

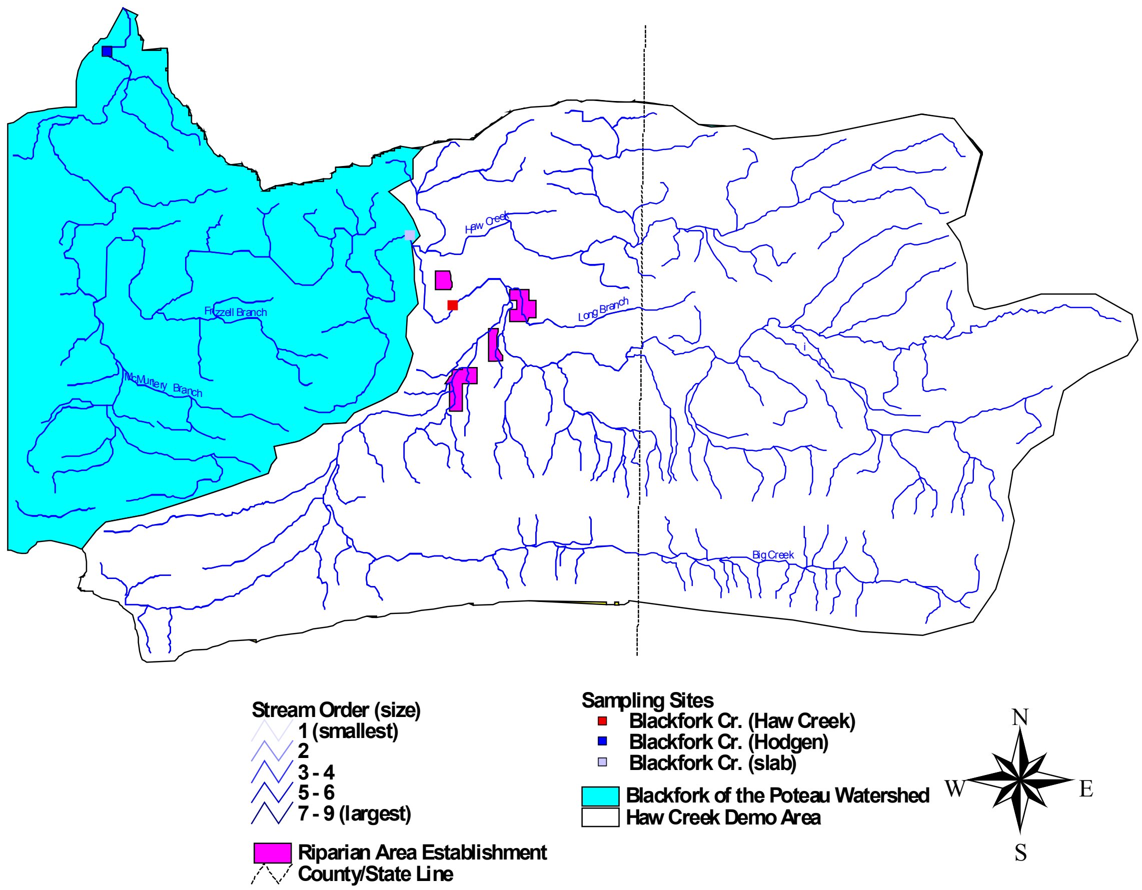

Figure 8. Cooperators Implementing Riparian Area Protection.

TASK THREE Conduct Workshops, Public Meetings, Field Trips, and Tours to Demonstrate BMPs and Teach Producers How to Write Their Own Pollution Prevention Plans. Sample Soil and Poultry Litter in Priority Watersheds to Teach Nutrient Management and to Improve Modeling Estimates of Project Impact. (Education)

Task three was subcontracted to the Oklahoma Cooperative Extension Service (OCES). Most of the educational activities conducted through the project were under direct supervision of Joe Bullard, the OSU Extension Water Quality Educator. Results of the significant efforts towards education and demonstration of BMPs in the watershed are thoroughly detailed in the report attached as Appendix C.

These goals were accomplished through significant and numerous one-on-one meetings and education with landowners along with group presentations and other forms of technical assistance. The Water Quality Educator contacted each landowner and operator in the Haw Creek watershed and provided technical assistance and education. He also developed a set of test plots in the Haw Creek watershed to demonstrate production of forage in high phosphorus soils without the addition of poultry litter. The plots demonstrated how slowly normal and intensive production practices reduce soil test phosphorus levels. This demonstration plot helped educate producers, as well as the WAG about the how infrequently land in the area actually needed phosphorus fertilization.

In addition to all-around technical assistance, OCES personnel made 26 various slide presentations or other displays on activities of the project and water quality in general to various groups. These events ranged from a general water quality display for approximately 700 people at the LeFlore County Fair to a slide presentation for 38 members of the Oklahoma Corporation Commission. In addition, a large number of public meetings and workshops were held to educate producers on Haw Creek on topics such as litter management, pollution prevention during oil and gas exploration activities, and general BMPs.

Youth education was a significant portion of this task. Most youth education activities focused on general water quality maintenance and improvement. These activities included 4-H group water quality monitoring and education, "Earth-Day-Every-Day" activities fair where almost 1000 elementary school children and 150 parents were exposed to environmental education, and various other training sessions.

Newspaper articles and other media were also used to educate citizens of the watershed about water quality. OCES wrote 27 articles that were released to local papers, covering a wide range of topics related to water quality. Many articles served as promotions for various upcoming trainings or other events. Some of these articles are included on pages G-1 through H-45 of Appendix C of this report. In addition, three radio spots were produced and a logo contest was held to produce a mascot for the program. Examples of the logo contest entries are shown on pages H-1 – H-5 of Appendix C.

Several poultry producers in the area requested assistance researching the possibilities of pelleting litter from their operations. OCES provided technical assistance on this matter, organizing tours of various facilities and collecting information.

Attendance at educational meetings and field trips scheduled as part of the education program suggests that a large number of individuals were presented information relating to water quality in the watershed. The number of participants in formal events is detailed below. These numbers do not include all of the people educated in one-one-one technical assistance meetings or through newspaper articles. Page C-1 of Appendix C contains more information about the number of presentations made associated with the project.

Date	**Meeting**	**Attendance**
March 1995	Poultry Growers	6
June 1995	Haw Creek Tour	200
April 1996	Haw Creek Tour	60
June 1996	Rainfall simulation	75
October 1996	Litter feeding conference	125
February 1997	Home*A*Syst Meetings	16
June 1995	Youth WQ- Robbers Cave	120

July 1995	Youth WQ- LeFlore County Day Camp	46
September 1995	Youth WQ monitors- county vo-ag	12
April 1996	Youth WQ- Arkoma	30
July 1996	Youth WQ- 4H day camps	100
August 1996	WQ classes- vo-ag	4
February 1997	Youth WQ monitor- OWRB, Wister, McCurtain	71
April 1997	Earth Day- Every Day Fair	941 students, 150 adults
June 1997	WQ & Env. Issues camp	18

The participation of LeFlore County Conservation District was critical to addressing the education task. The district recognized the importance of and the need for education activities and, both independently and in cooperation with OCES, conducted and coordinated numerous education events and programs in addition to those required by the grant. Specifically, the district 1) provided one on one assistance to the cooperators with BMPs to protect water quality, 2) made presentations at numerous public meetings and workshops on topics such as soil fertility and litter management, 3) assisted in organizing numerous field trips & tours to present information and demonstrate the effectiveness of BMPs, 4) assisted OCES with collection of soil and litter samples in demonstration watershed and with development and maintenance of test plots in the demonstration area, and 5) the district was featured in two issues of "Progressive Farmer" and wrote numerous news articles to educate the public about the program and water quality issues in the area.

Perhaps one of the most successful results of the education program was the working relationships it established or strengthened between the Conservation District, OCES, Eastern Oklahoma State College, and the NRCS. The success of their collaborations have encouraged the various groups to continue their education effort beyond the life of the project. The group is continuing to develop new demonstration sites addressing many of the watershed management issues ranging from soil testing and variable fertilizer application rates to forest management. Field days, newspaper articles, and other presentations continue to address water quality issues in the watershed. Classes are being offered at the State College related to the program. Volunteer monitoring programs are being developed to continue to collect data on the system and to teach the volunteers more about aquatic systems. These activities are being funded through a variety of state, federal, and private funds.

TASK FOUR Evaluate Educational Impact Through Follow-up Surveys.

Task Four was also subcontracted to OCES and summarized in a report by Pierce et. al, which is included on page D-21 of Appendix C of this document.

The objective of this task was to determine if any differences existed over time among agricultural producers who were targeted by a water quality education program. Much of this education program was aimed at the poultry industry and adoption of best management practices.

In 1995, the Landuser/Producer Survey of the Poteau River Project was administered by the NRCS. The survey was developed by the NRCS representative in LeFlore County and was approved by the WAG. Most of the questions were targeted at poultry producers. The questions were "fill in the blank" and "circle answer" types. The population for the survey was all of the agricultural producers in the Blackfork Creek Watershed.

In 1997, the LeFlore County Water Quality Extension Agent administered the Haw Creek Agricultural Producer Survey. This survey was developed by OCES and NRCS, was reviewed by a panel of experts, and was approved by the WAG. Certain questions from the 1995 survey were included in the 1997 survey in order to track changes over time. The '97 survey had specific sections that targeted poultry and livestock producers, but it also had a water quality attitude portion. The 1997 survey was administered to eighteen producers in the Haw Creek Demonstration Area Watershed. Seventeen of these producers had participated in the '95 survey.

In addition to the seventeen Haw Creek producers, seventeen producers from a similar area (Spiro) that did not receive an intensive education program were also presented the 1997 survey. By comparing the results of the '95 and '97 surveys, OCES was able to estimate whether or not the educational effort had changed producers perceptions about water quality.

In evaluating the results of the surveys, OCES considered many diverse factors to insure that the watersheds were similar. Results suggested that producers in both Haw Creek and Spiro farmed a similar amount of acreage and had similar amounts of farming income from cattle and poultry. One notable difference between the two communities was that all of the Haw Creek residents received drinking water from a private well while Spiro producers had access to a rural water system. Another difference was that Spiro producers typically had a higher cattle stocking rate than Haw Creek producers. More of the Haw Creek producers used streams as a watering source than Spiro producers, probably because more of the Haw Creek producers had streams running through their properties. However, Haw Creek producers seemed to be using more BMPs than Spiro producers in that, when compared to Spiro, more Haw Creek producers practiced rotational grazing, fewer allowed their cattle direct access to streams, and less intensive forms of weed control.

Comparison between the poultry producers in the two areas suggested that although houses were similarly sized, most Spiro producers had two rather than the one house and that most Haw Creek producers managed. As a result, the Spiro area produced almost twice as many birds annually as the Haw Creek area. Haw Creek producers again practiced a few more BMPs than Spiro producers in that they cleaned cake out less often, were more concerned about litter disposal, had litter nutrient tested more often, and more producers had litter storage facilities. In addition, less litter was spread in Haw than in Spiro.

The results of the comparisons between the two surveys suggested that residents of the targeted watershed were more aware of water quality concerns than other people in their area. This was evident in heightened sensitivity to water quality in their area and realization of their own responsibility for maintenance of water quality. The targeted watershed producers used more BMPs and were more aware of the potential impacts to water quality from their actions.

In addition, during the course of the project, 26 landowners either enrolled in or continued participation with the local NRCS in BMP implementation. The producers in a targeted watershed thought more strongly than those in a similar area that more labor and financial investment was needed to protect water quality.

It was also evident that the education program had made positive changes in the attitudes and behaviors of individuals over time. More producers were employing BMPs after the program than before, but producers were also more likely to recognize and report problems such as erosion on their own farms than before.

TASK FIVE- Prepare Final Report- Evaluate Measures of Success

Measures of Success

Overall project success can be evaluated by improvement in water quality of the Poteau River, Fourche-Maline Creek, and Wister Lake. This impact will be measured at a later date, beyond the project period, depending on the availability of funds. Local success can be evaluated in the Blackfork watersheds through periodic chemical and biological assessments of Blackfork Creek.

Other measures of success include:

- Extent of implementing BMPs inside the designated priority watersheds.
- Extent of adoption of BMPs in other sub-watersheds
- Number of Pollution Prevention Plans prepared.
- Attendance at educational meetings and field trips
- Knowledge gained concerning fertilizer value of poultry litter and acceptable rates of application
- Knowledge of environmental protection issues

Haw Creek Area Post-implementation Monitoring

Post-implementation monitoring was collected between 1997 and 1999. Data was primarily collected by the OCC, although USGS data from the same site was used to supplement OCC collections. This monitoring included standard monthly collections of water quality, along with targeted storm event sampling. Due to the smaller number of post-implementation samples and the shorter time frame available, few storms were collected during the post-implementation monitoring than during pre-implementation monitoring. Although implementation was ongoing during this period, a significant number of practices were put in place in 1996. Results of post-implementation monitoring are seen in Table 6.

Table 6. Post Implementation Monitoring.

Poteau River @ Loving OK220100-02-0020M 1997-1999										
		min	**25% quartile**	**median**	**75% quartile**	**max**	**n**	**ave**	**std**	violations*
Field DO	mg/l	4.62	5.19	6.21	7.65	13.5	51	6.80	2.03	0
Field pH	S.U.	6.3	6.545	6.8	7.1	7.4	23	6.82	0.33	4
Field Cond	us/cm	36.8	71.5	86.1	86.9	119	51	78.30	18.13	
Field Temp	C	4.3	18.05	23.9	25.15	28.3	51	21.08	6.07	
% Saturation	Calc.	53.86	61.39	68.44	79.75	91.77	32	71.29	11.69	1<60%
Field Turb	NTU	1.7	4	6.7	19.75	41	18	12.14	11.33	
Field Alk	mg/l	6	11.5	18	23	31	19	17.58	7.90	
Flow	Est.	12	256.5	501	745.5	990	2	501.00	691.55	
Flow	cfs	5.1	12	104	344	1550	17	322.48	485.26	
Chloride	mg/l	2.5	4.05	5.9	6.6	10	39	5.49	1.76	
Sulfate	mg/l	0.27	1	5.4	7.1	14	37	4.55	3.52	
Total hardness	mg/l	12	16	18	24	36	18	20.56	6.46	
Na	mg/l	2.9	4.6	6	7.6	12	19	6.29	2.38	
TDS	mg/l	20	47	51	60	73	19	51.89	11.51	
TSS	mg/l	7.5	55.975	82	92.25	376	36	90.21	71.85	27 > 50
VSS	mg/l									
Total P	mg/l	0.045	0.0885	0.1535	0.2275	0.59	38	0.18	0.13	4 > 0.36
ortho P	mg/l	0.01	0.02575	0.0395	0.078	0.281	20	0.07	0.07	
Nitrate	mg/l	0.002	0.077	0.11	0.18	0.739	37	0.15	0.15	
Nitrite	mg/l	0.0018	0.003	0.007	0.01	0.07	38	0.01	0.01	
nitrate/nitrite	mg/l	0.05	0.074	0.115	0.15225	0.75	18	0.17	0.18	
TKN	mg/l	0.27	0.44	0.605	0.8175	1.57	38	0.64	0.28	
Ammonia	mg/l	0.004	0.02125	0.0455	0.05	0.364	38	0.05	0.06	
Specific conductance	us/cm	42	57.5	72	94	119	19	75.21	21.36	
chlor-a	ug/l	0.01	1	1	1	6.27	21	1.39	1.29	
Phaeophytin-a	ug/l	2	3	6	8.48	16.85	19	5.88	3.74	

Blackfork River near Page (HAW) OK220100-02-0040M 1997-1999										
		min	**25% quartile**	**median**	**75% quartile**	**max**	**n**	**Ave**	**std**	violations*
Field DO	Mg/l	6.6	7.8	8.8	10.65	12	15	9.15	1.77	
Field pH	S.U.	6.3	6.55	6.6	6.9	7.3	15	6.75	0.33	3
Field Cond	us/cm	22	26	28	32.5	52	15	30.67	8.16	
Field Temp	C	6.3	10.55	16.3	20.5	30.1	15	16.79	7.51	
% Saturation	Calc.									
Field Turb	NTU	0.9	3.425	5.15	7.7	26	14	7.10	6.37	
Field Alk	Mg/l	1	5	6	9.5	33	15	8.67	7.99	
Flow	Est.									
Flow	Cfs									
Chloride	Mg/l									

Sulfate	Mg/l									
Total hardness	Mg/l									
Na	Mg/l									
TDS	Mg/l									
TSS	Mg/l	75	84.5	92.5	95.5	100	14	89.71	8.38	14 > 50
VSS	Mg/l									
Total P	Mg/l	0.01	0.01	0.023	0.05	0.154	15	0.03	0.04	
Ortho P	Mg/l	0.01	0.01	0.01	0.0205	0.087	15	0.02	0.02	
Nitrate	Mg/l	0.036	0.0565	0.099	0.1435	0.48	15	0.14	0.13	
Nitrite	Mg/l	0.01	0.01	0.01	0.01	0.045	15	0.01	0.01	
nitrate/nitrite	Mg/l	0.05	0.0695	0.109	0.1535	0.49	15	0.15	0.13	
TKN	Mg/l	0.11	0.13	0.2	0.285	0.73	15	0.25	0.17	
Ammonia	Mg/l	0.015	0.02	0.022	0.0325	0.053	15	0.03	0.01	
Specific conductance	us/cm									
Chlor-a	ug/l									
phaeophytin-a	ug/l									

Black Fork @ Hodgen OK220100-02-0030G 1997-1999										
		min	**25% quartile**	**median**	**75% quartile**	**max**	**n**	**ave**	**std**	violations*
Field DO	mg/l	3	6.8	7.9	9.45	11.5	19	7.93	2.34	1
Field pH	S.U.	6.3	6.4	6.8	6.9	7.2	19	6.70	0.28	6
Field Cond	us/cm	28	34	37	52	60	19	42.05	10.23	
Field Temp	C	6.8	14.75	18.8	24.95	29.3	19	19.05	7.47	
% Saturation	Calc.									
Field Turb	NTU	1	2.55	5.55	11.75	23	18	7.55	6.39	0
Field Alk	mg/l	4	5	11	14.5	22	19	10.68	6.01	
Flow	est.									
Flow	cfs									
Chloride	mg/l									
Sulfate	mg/l									
Total hardness	mg/l									
Na	mg/l									
TDS	mg/l									
TSS	mg/l	41	78	88	97	100	17	85.65	15.74	
VSS	mg/l									
Total P	mg/l	0.013	0.0245	0.043	0.088	0.35	19	0.07	0.08	0
ortho P	mg/l	0.014	0.0235	0.1	0.1	0.988	19	0.13	0.22	
Nitrate	mg/l	0.04	0.05	0.054	0.1055	0.504	19	0.10	0.11	
Nitrite	mg/l	0.01	0.01	0.01	0.01	0.059	19	0.01	0.01	
nitrate/nitrite	mg/l	0.05	0.0535	0.069	0.1155	0.514	19	0.11	0.11	
TKN	mg/l	0.11	0.19	0.3	0.375	0.99	19	0.35	0.25	
Ammonia	mg/l	0.015	0.02	0.023	0.0555	1.12	19	0.10	0.25	
Specific conductance	us/cm									
chlor-a	ug/l									
phaeophytin-a	ug/l									

* Violations refer, generally to violations of Oklahoma's Water Quality Standards (WQS). However, no criteria exist for TSS, nutrients, or dissolved oxygen saturation. Violations for those parameters are based on literature suggested values.

Comparisons between pre-and post- implementation data for the Poteau River station does not suggest statistically significant water quality changes over time. This is probably not to be expected during the life of this project due to the relatively small area of the watershed in which the program was implemented. However, lack of change over the project time period does suggest that any changes detected in the demonstration area water quality parameters are less likely to be due to differences in climate patterns and more likely to be an effect of changes in the watershed.

Table 7. Comparison between pre- and post- implementation values for Poteau River at Loving.

Parameter	units	Preimplementation median	Postimplementation median	Significantly Different?
Field DO	mg/l	6.00	6.21	No
Field pH	S.U.	7.0	6.8	No
Field Cond	us/cm	81.0	86.1	No
Field Temp	C	26.1	23.9	No
% Saturation	* Calculated	76.6	68.4	No
Field Turb	NTU		6.7	Na
Field Alk	mg/l		18	Na
Flow	estimated		501	Na
Flow	cfs		104	Na
Chloride	mg/l	4.35	5.90	No
sulfate	mg/l	2.0	5.4	No
total hardness	mg/l	16.5	18.0	No
Na	mg/l		6	Na
TDS	mg/l		51	Na
TSS	mg/l	119.5	82.0	Na
Total P	mg/l	0.143	0.154	No
ortho P	mg/l		0.04	Na
nitrate	mg/l	0.25	0.11	No
nitrite	mg/l	0.010	0.007	No
nitrate/nitrite	mg/l	0.13	0.12	No
TKN	mg/l	0.70	0.60	No
ammonia	mg/l	0.045	0.0455	No
specific conductance	us/cm		72	Na
chlor-a	ug/l		1	Na
phaeophytin-a	ug/l		6	Na

Comparison between pre- and post- implementation data collected in the Blackfork Creek does not suggest statistically significant water quality improvements related to critical parameters including sediment and total phosphorus. Differences are notable between pre- and post-implementation data for other parameters including nitrogen series, and temperature, however, we cannot positively link these water quality improvements to implementation.

Table 8. Comparison between pre- and post- implementation monitoring in Blackfork Creek.

Parameter	units	Preimplementation median	Postimplementation median	Significantly Different?
Field DO	mg/l	6.4	8.8	yes
Field pH	S.U.	6.8	6.6	yes
Field Cond	us/cm	37	28	yes
Field Temp	C	25.4	16.3	yes
% Saturation	* Calculated	78.9	106.5	yes
Field Turb	NTU		5.15	Na
Field Alk	mg/l		6	Na
TSS	mg/l	48.5	92.5	Yes
Total P	mg/l	0.04	0.023	No
ortho P	mg/l		0.01	Na
Nitrate	mg/l	0.25	0.099	Yes
Nitrite	mg/l	0.01	0.01	No
nitrate/nitrite	mg/l	0.09	0.109	No
TKN	mg/l	0.4	0.2	Yes
Ammonia	mg/l	0.04	0.022	Yes

For instance, median dissolved oxygen (DO) concentrations in the Blackfork are higher in 1997-99 than between 1991 and 1996 (Figure 9). Although this could, and should be an artifact of increased canopy cover or decreased organic loading due to riparian zone protection, we cannot positively draw this conclusion at this time because of the limited amount of data available from post-implementation. USGS analysis of data needs suggests at least three years of data may be necessary to accurately describe water quality conditions if the data is collected in standard monthly grabs, supplemented with stormwater collections. Therefore, at least one more year of data should be collected, post-implementation, before a conclusion can positively be made that water quality has improved in the Blackfork River.

Dissolved oxygen concentrations did not differ significantly in the Poteau River. This lack of change over time should not definitively be used to suggest that changes in the Blackfork were not due to climate, but rather due to landuse changes. This inference cannot be expressly made because changes are more quickly seen in a smaller watershed than a larger watershed. In other words, small changes in climatic factors such as runoff volumes and number of sunny days are more likely to be seen in smaller watersheds than in larger watersheds.

The statistically significant differences should also not be interpreted as ecologically significant until the data populations between pre- and post-implementation are more equivalent. The smaller number of storm samples collected during post-implementation could bias the medians towards a low estimate.

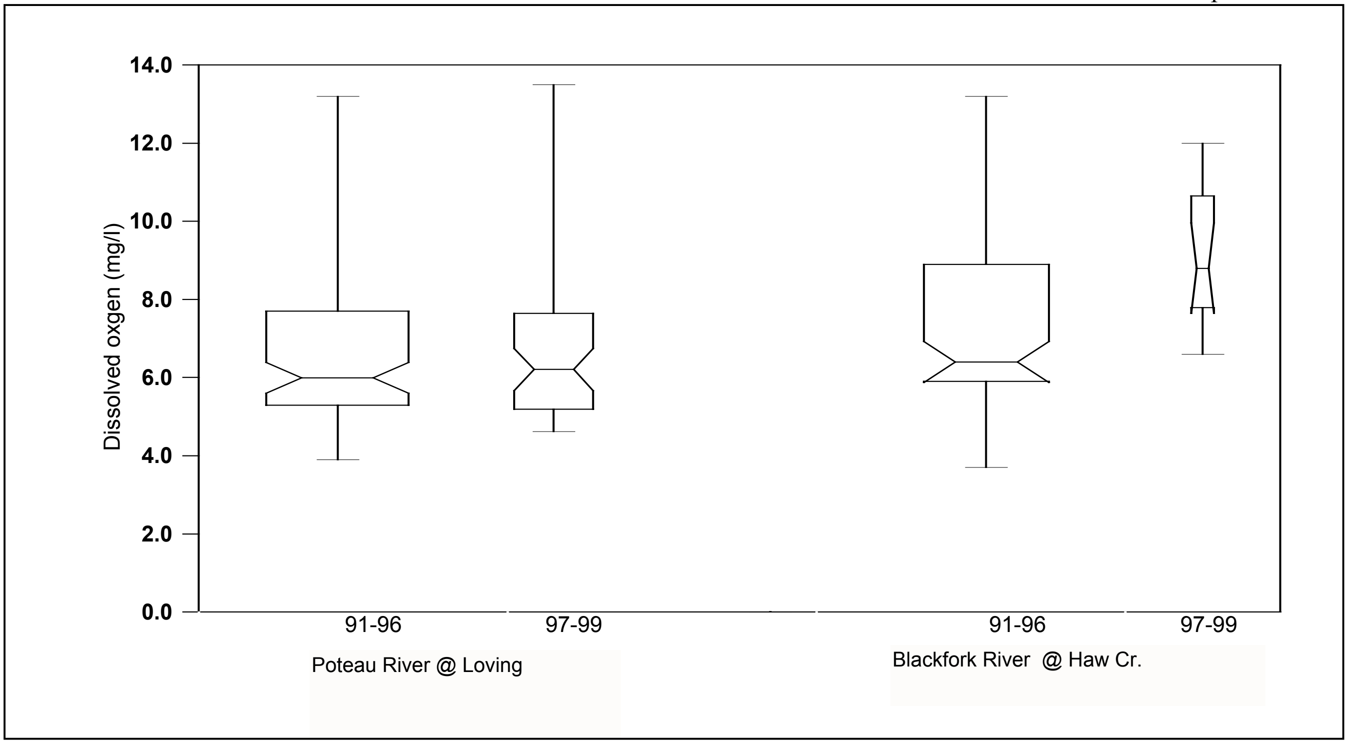

Figure 9. Comparison between pre- and post-implementation dissolved oxygen.

Comparison between pre- and post-implementation pH values suggests post-implementation values are significantly lower in the Blackfork (Figure 10). In addition, pH violated standards more often during post-implementation monitoring (3 of 15 or 20% of the time compared to 5 of 87 or 6% of the time during pre-implementation). This information suggests that the Blackfork is only partially supporting its aquatic life beneficial use due to low pH. Median pH values were not significantly different over time in the Poteau River. Again, at least one additional year of post-implementation monitoring data is suggested before the differences can be attributed to changes in practices in the watershed.

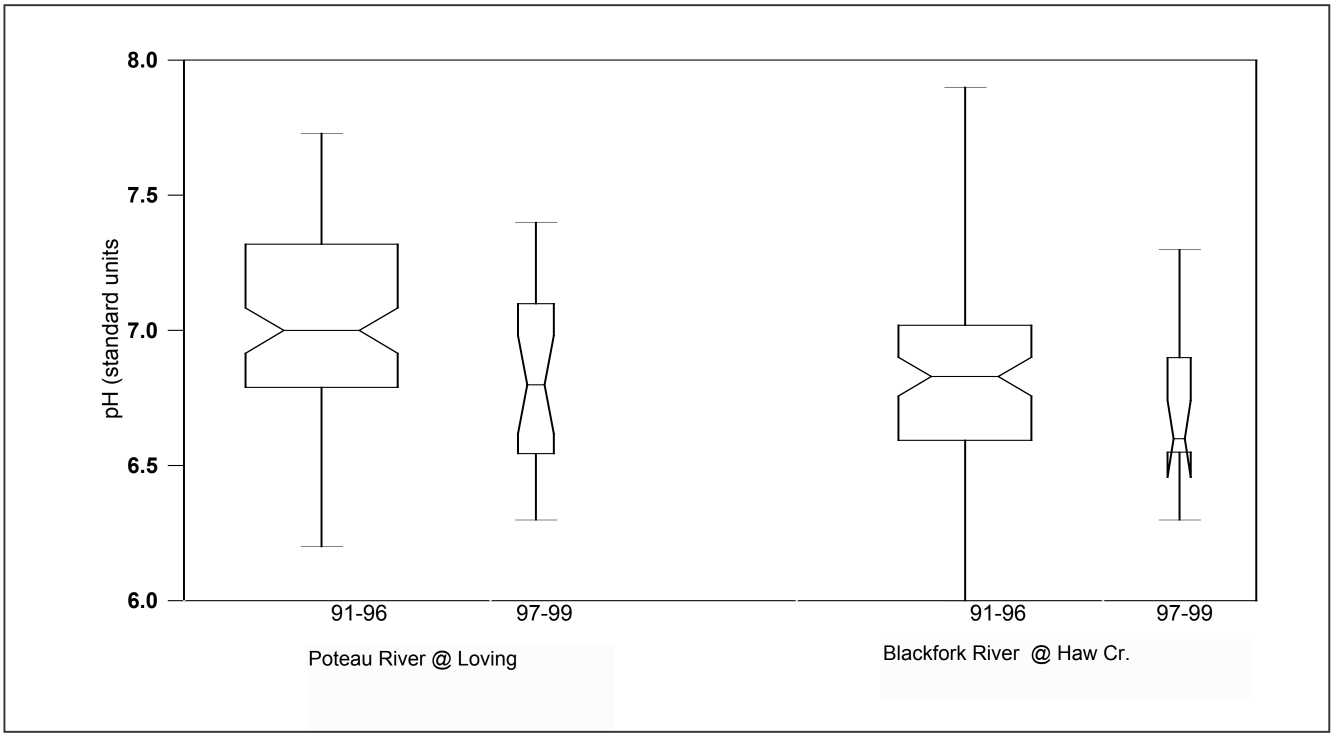

Figure 10. Comparison of pre- and post-implementation pH values.

Comparison between pre- and post-implementation total suspended solids median values suggests an increase in the Blackfork following implementation (figure 11). However, the 97-99 values were much more tightly distributed than pre-implementation values and the maximum values were lower following implementation. Median TSS values were lower in the Poteau River following implementation. These differences in Poteau River are probably related to the smaller number of storm samples collected during post-implementation compared to pre-implementation, rather than due to the affects of implementation in the Blackfork Watershed.

Median total phosphorus concentrations did not change significantly between implementation periods in either the Poteau River or the Blackfork (Figure 12). Maximum concentrations were slightly lower following implementation, although the difference was not statistically significant. Median total nitrogen concentrations decreased significantly with implementation in the Blackfork River but were not significantly different in the Poteau River (Figure 13).

This lack of a statistically significant difference between pre-and post implementation data does not necessarily indicate that the implementation was not successful, just that the currently available data was either unable or should not be used to show a positive relationship between implementation and water quality. One reason for this may be the inability to separate the effects of climate and implementation. Because this is not a paired watershed project, there is no way to show that water quality changes (or lack of changes) between pre- and post-implementation were not due to changes in the hydrologic cycle. We know that the pre-implementation database included more storm samples than the post-implementation database. Storm samples reflect when the bulk of the loading occurs in the Poteau watershed therefore fewer storm samples likely

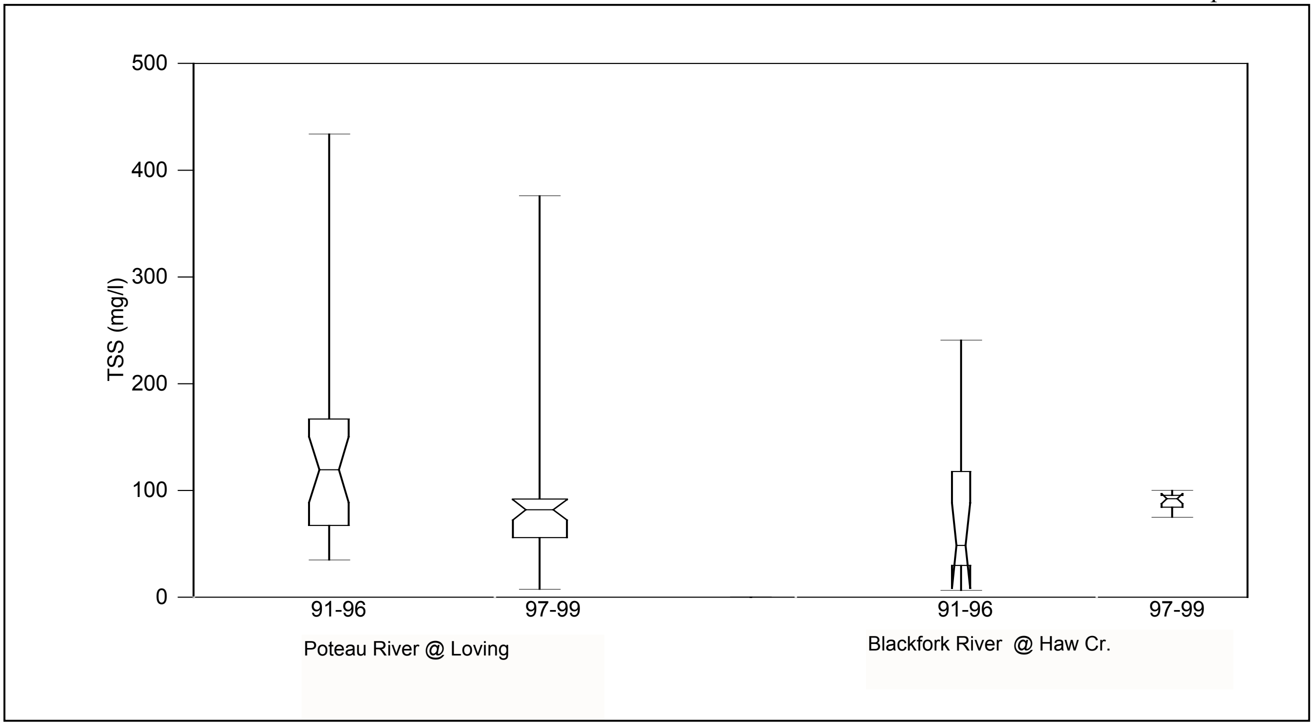

Figure 11. Comparison between pre- and post-implementation total suspended solids concentrations.

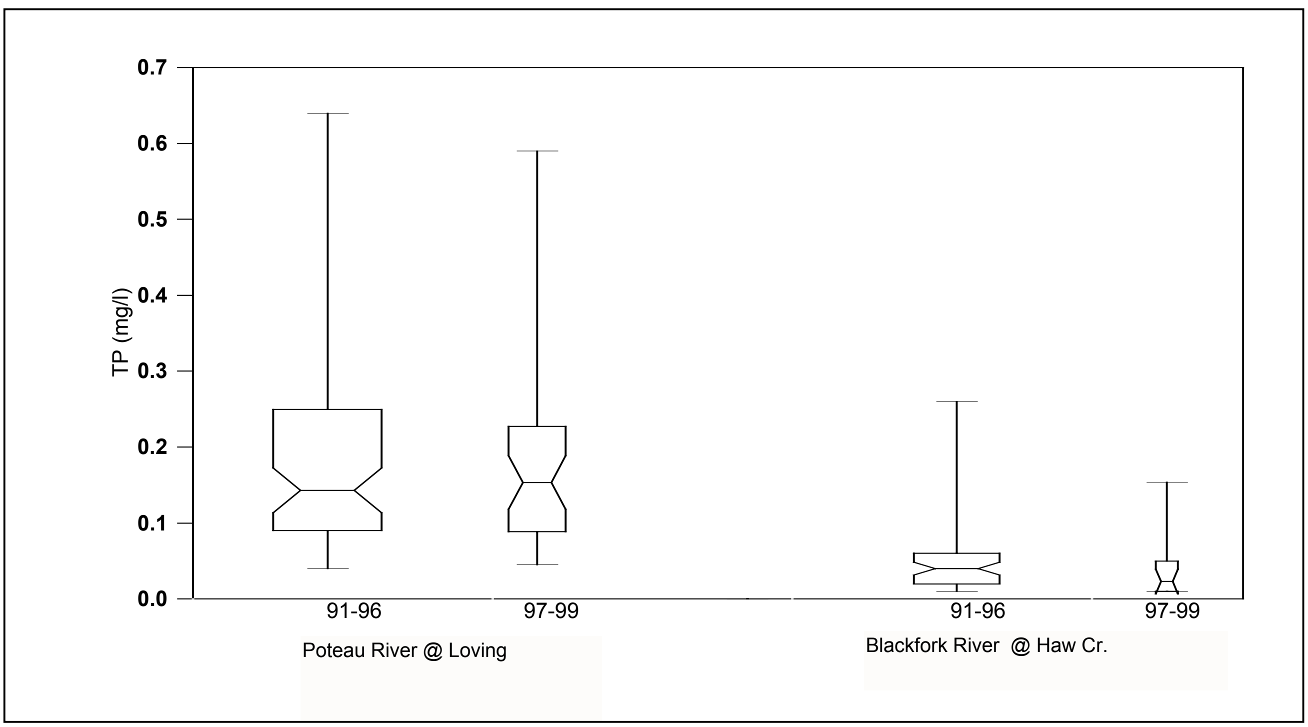

Figure 12. Comparison between pre- and post- implementation total phosphorus concentrations.

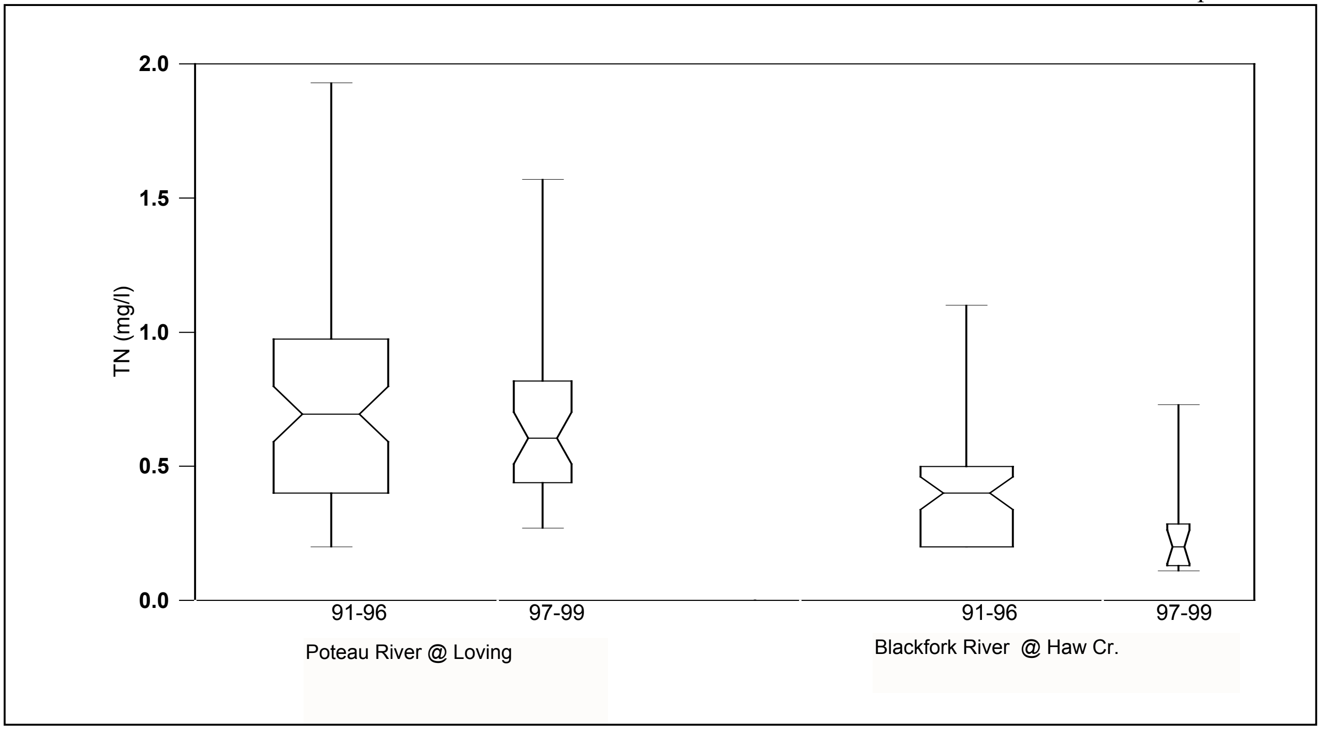

Figure 13. Comparison between pre- and post- implementation total nitrogen concentrations.

results in lower median values. In addition, the significantly greater volume (five or six years) of pre-implementation data versus the smaller volume (two years) of post-implementation data can bias the results. Perhaps with more data collection (facilitated by USGS gauging stations), we will be able to discern a more pronounced difference. As previously mentioned, recent USGS analysis of data requirements suggests at least three years of monthly grab samples supplemented with storm sampling is necessary to correctly document water quality conditions relative to loadings.

Perhaps additional parameters should have been monitored to show a more immediate statistical significance. Some of the most frequently implemented BMPs were septic tank upgrades. Upgrades were recommended for septic systems that were of insufficient quality, capacity, or design and were located near the creek. Although these may represent only a small portion of the phosphorus load, significant reductions in loading will require that all sources be addressed. However, the small amount of phosphorus loading these improvements represented would likely be difficult to detect. Perhaps fecal coliform should have been monitored to indicate positive results of this BMP. Perhaps streambank erosion and riparian area stabilization should have been documented to indicate potential successes of riparian buffer establishment.

Perhaps the mere fact that water quality didn't degrade significantly during the project period was an indication of the BMP success. In a watershed with a growing human population and growing agricultural industry, maintenance of water quality may be a significant success.

Finally, biological significance is not always equivalent to statistical significance. Slight improvements in water quality due to education and implementation could lead to pronounced improvements in the overall aquatic health of the system that are not yet detectable. The system may need to flush itself out and allow the biological community to acclimate and stabilize to new conditions. The system has been heavily loaded for a number of years; nutrients have accumulated in the watershed soils and in the stream bed and stream banks. A slight reduction in loading could have more significant effects as the accumulated pollutants wash out and degrade.

Best professional judgment and knowledge of the extent of implemented practices suggests that loading to Blackfork Creek in the Haw Creek area should be reduced. However, that best professional judgment also requires that sufficient data be used to verify water quality improvements. It is believed that an additional year of data is the minimum required to verify changes, although more may be necessary if stormwater samples are not sufficiently targeted.

Evaluation of other Measures of Success

Although current water quality data does not suggest overwhelming success of implementation efforts in the Haw Creek area, other potential measures of success indicate a much more positive relationship. The project's other specific goals included:

1. develop total water quality plans on all farms in the demonstration area
2. install 6 waste control facilities
3. install 10 rural waste systems
4. install 10 animal waste storage structures.

The project installed ten agricultural waste control facilities/animal waste storage structures (two holding facilities and 8 composters) and fourteen rural waste systems. All of the poultry producers in the demonstration watershed participated in the program, meaning 100% of the poultry producers in the demonstration area have updated waste management plans and farm plans. As a result, poultry growers in the Haw Creek Demonstration Area are managing poultry waste more appropriately than in the past as they follow the recommendations of their animal waste management plans. In addition, new state legislation requires that poultry growers in nutrient sensitive watersheds (such as Wister Lake) must now apply litter based on soil phosphorus values detected from mandated soils and litter testing. They must have a current animal waste management plan. The legislation also requires that growers attend a specified number of trainings each year and that litter spreaders must be certified with the state. Haw Creek Demonstration Area Growers are a step ahead of growers in other areas of the State due to the efforts of this program.

Cooperators owned approximately 2141 of 7475 acres or 29% of the total privately owned land in the demonstration area (Figure 14). The majority of the land in the demonstration area is U.S. Forest Service land. Because the program targeted riparian areas and landowners who were most likely to affect phosphorus and sediment delivery to the creek, the majority of participating landowners own land in the riparian areas of the demonstration area. Eight of 22 (36%) landowners along the Blackfork participated in the program, accounting for 45% of the acres of privately owned land parcels including riparian area along the Blackfork. Twelve of 34 (35%) landowners along Big Creek (tributary to the Blackfork) participated in the program, accounting for 48% of the acres of privately owned land parcels including riparian area along Big Creek. Two of the thirteen (15%) landowners along Haw Creek participated, accounting for nine percent of the acres of privately owned land parcels along Haw Creek. In total, landowners of 39% of the privately owned acreage along major waterways in the watershed participated in the program.

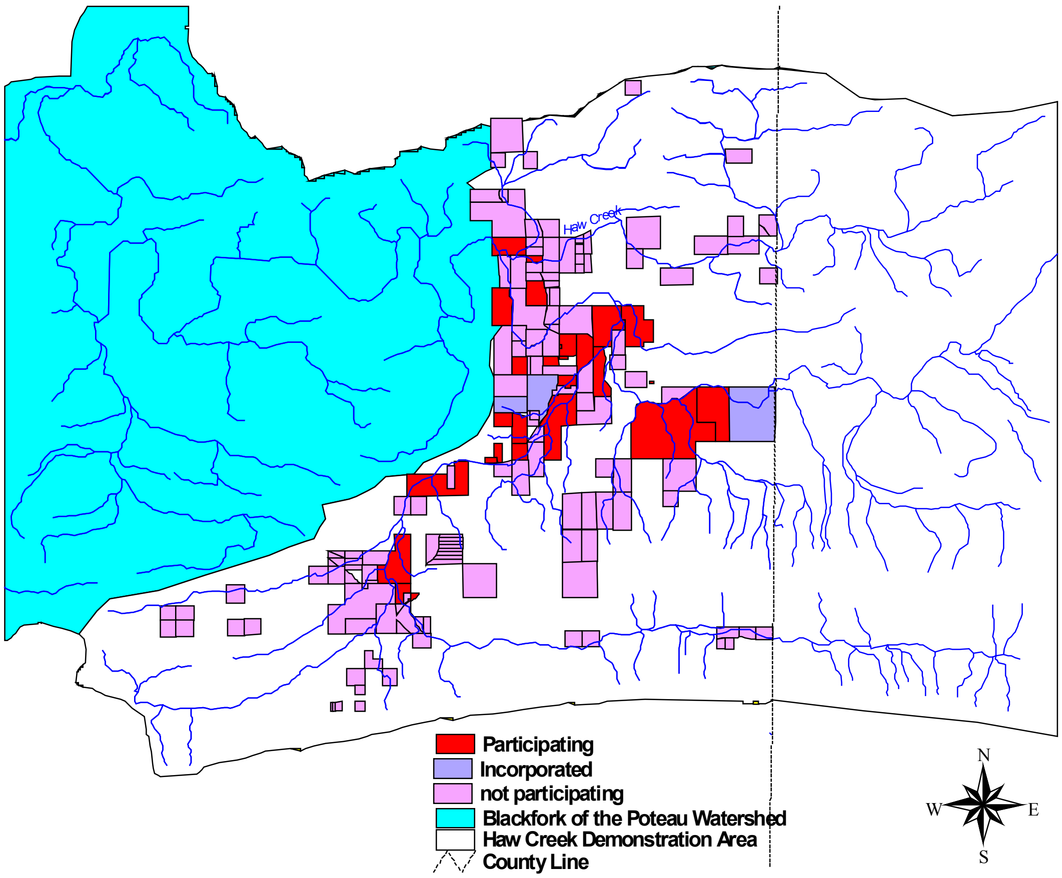

Figure 14. Division of Privately Owned land Between Participators and Nonparticipators.

Although only 39% of the private landowners participated, the majority of the landowners that weren't targeted owned largely forested land. Nearly all of the privately owned pastureland in or near riparian areas was targeted in the program (Figure 15). Of the privately owned pastureland in or near riparian areas that wasn't included in the program, much of it either involved land where the creek bordered the property (and the landowner on the other side participated) or else land where the landowner initially signed up, but later decided not to participate in the project.

Many of the targeted landowners who decided not to participate did so because the WAG determined that participants should be willing to implement all recommended practices rather than just the ones they preferred.

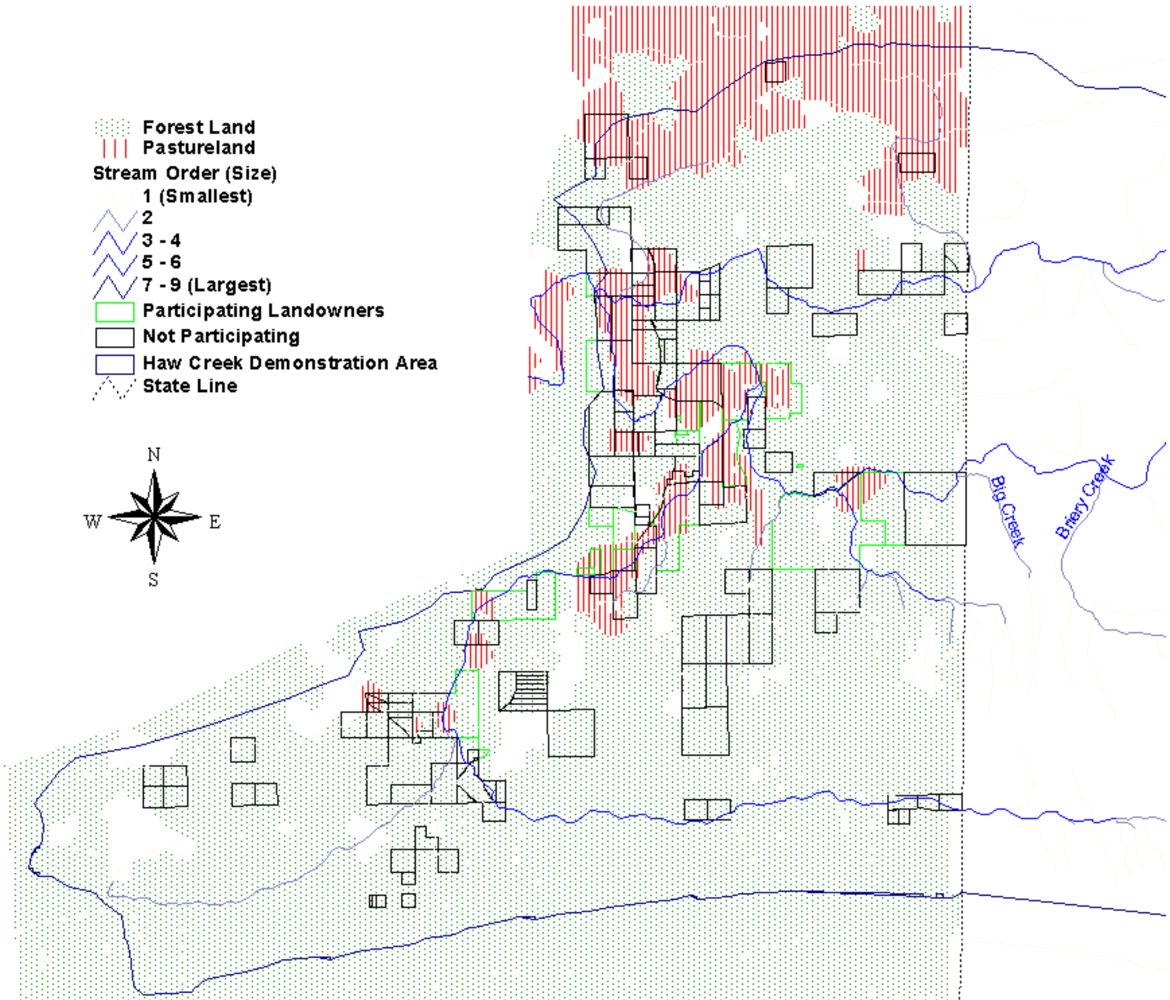

Figure 15. Landuse in the Demonstration Watershed.

Cooperators in the area provided twenty six percent of the funds used in implementing the program. The program was designed for landowners to provide twenty percent for most of the practices; however, some practices required no capital investment from the landowner. This is a notable success in that landowners contributed more than expected to the implementation effort, suggesting a greater likelihood of practice maintenance extending beyond the agreement period. This also suggests that landowners were willing to invest significant capital in these types of BMPs, rather than merely accepting incentives to implement certain practices.

In addition to the number of cooperators and BMPs implemented, follow-up surveys suggested that the significant education efforts of OSU Extension, the LeFlore County Conservation District, and associated organizations were successful in training citizens of the watershed about the importance of water quality and the importance of their role in the maintenance of that water quality. Landowners in treatment watersheds were more aware of and had more knowledge about water quality issues than landowners in nearby watersheds.

The designated objectives of the project, as established in the workplan, included:

1. assess the loadings;-
2. conduct demonstration and ed programs;-
3. quantify loads that could be reduced per proposed BMP;-
4. estimate expected load reductions if BMPs were implemented on all impacted land in the watershed;-
5. determine that WQ standards could be maintained if all BMPs were implemented;
6. continue monitoring.

These objectives were almost all accomplished, although some more thoroughly than others. Many of these objectives were accomplished through the efforts of the development of the initial TMDL, contracted to OSU Department of Biosystems and Agricultural Engineering and Blacklands Research Institute. These efforts estimated current loadings from nonpoint and point sources and estimated loads that could be reduced if BMPs were implemented (40% with pasture runoff controls). Efforts to determine that water quality standards could be maintained if all BMPs were implemented were more subjective. The significant standards violations in the Poteau River watershed are related to violations of narrative, rather than numerical criteria. Therefore, estimates of whether or not standards could be maintained with implemented BMPs are substantially influenced by best professional judgment. Demonstration and Education programs were successfully implemented.

Another measure of success is that the local Conservation District, NRCS, and other local partners have begun to spread the demonstrated practices and programs to other parts of the Poteau River Watershed. The District solicited monies from the State legislature to implement a cost-share program in another area of the Poteau River Watershed, the Potts and Fanny Creeks Watershed. These Creeks drain directly into the Poteau River arm of Lake Wister. The Districts were allotted $50,000 State money which they opted to use to demonstrate the same practices used in the Blackfork area. They targeted pastureland in riparian zones, poultry producers, and septic tanks near the creek. They are developing additional demonstration sites to educate producers and landowners about as many significant practices and issues as possible with five currently developed and at least three more planned.

In addition, the second phase of the Comprehensive Watershed Management Plan has been implemented with the FY 2000 319 Lake Wister Implementation Project. The lessons learned on successes and failures from the Blackfork Creek demonstration are being implemented on a wider scale in the entire Wister Lake Watershed which includes both the Poteau River Watershed and the Fourche Maline Creek Watershed. This effort includes State cost-share, EQIP funding, 319 monies, and landowner match. This plan will incorporate the formal goals of the TMDL, once it has been finalized. Implementation of the initial cycles of the plan have enabled us to get a head start on the goals of the TMDL. The rough cut developmental TMDL that was formulated as part of this project helped set the stage and interim goals. The finalized TMDL will set the final goals to restore beneficial use support to the waters.

Conclusions

The Poteau River and Lake Wister in LeFlore County are among Oklahoma's highest priority waters for remediation and protection. The goal of this project was to develop a comprehensive plan for the watershed to restore beneficial use support by educating citizens about water quality and best management practices to protect water quality and by demonstrating those practices. Although the project did not conclusively demonstrate significant short-term water quality improvements, participation and cooperation between the Conservation District and the local landowners was a notable success. In addition, a plan was developed for the Poteau River Watershed to restore beneficial use support.

The plan for the Poteau River Watershed was to use assessment, planning with a Watershed Advisory Group, education, and demonstration/implementation to correct water quality problems in the Poteau River/Wister Lake Watershed. The plan is to be implemented in a cyclical fashion. The first cycle, intended to educate plan implementers as much as citizens of the watershed, was intended to develop a goal nutrient reduction in the watershed, investigate some scenarios on how to implement that goal, and investigate how successful that implementation might be in a subwatershed. This cycle was implemented in the Haw Creek Area of the Blackfork Watershed.

The implementation effort of the initial cycle of the plan was highly successful due to the number and types of land that was targeted in the program. One hundred percent of the poultry producers participated and improved waste management practices. Most of the significant tracts of nonforested, privately owned land in the demonstration area were included in the program, with some type of implementation activity targeted, proper waste management, pasture management, or riparian management. In addition, participants in the program invested significantly more capital than the required cost-share percentages defined in the program guidance, suggesting a greater likelihood that the practices will be maintained beyond the agreement lifetimes.

These participators were not the only people to learn about water quality issues and the importance of reducing nonpoint source pollution. Watershed-wide education efforts were shown to have been successful at introducing watershed citizens to important water quality issues. In addition, the LeFlore County Conservation District and OSU Cooperative Extension

Service have developed water quality education programs that are continuing beyond the life of the project. The local entities involved in the project have formed partnerships that are lasting beyond the life of the project. They are seeking different sources of funding and employing similar levels of effort to implement the same programs from the first cycle of the plan into different parts of the Poteau River and larger Wister Lake Watershed.

This first cycle will lead the way in future cycles of the project in the larger Poteau River and Lake Wister Watershed. In fact, it already has. The second cycle was implemented in the Potts and Fanny Creek Watershed. The third cycle is being implemented in the FY 2000 319 Wister Watershed Implementation Project. The project has allowed us to understand more of the issues that are important to citizens of the watershed. We now know what types of practices citizens are receptive to implementing, as well as what kinds of help they need. We have a better grasp of what types of incentives are necessary to implement certain management practices. We can use the successes and lessons of this initial project to facilitate water quality improvement projects on a grander scale.

The maintenance of the practices and the education of the citizens of the watershed should lead to long-term improvements in water quality by decreasing the nutrient and sediment loads to Black Fork Creek. Successful practices demonstrated in the Haw Creek Demonstration Project and watershed-wide education efforts should facilitate the spread of those BMPs into the remainder of the Poteau River Watershed, which in turn should improve or at least slow degradation of water quality in the Poteau River and Lake Wister.

A plan is being implemented to address water quality issues in Wister Lake. That plan will continue to be implemented until beneficial use support is restored to the watershed. The plan will incorporate the results of the formal TMDL, once it has been completed. The plan will be implemented to reach the goals set by that TMDL to restore beneficial use support to the waters and remove the waterbodies from the 303(d) list.

Project Budget

PROJECT TASKS

Task 1.	Select priority watersheds, conduct modeling studies to estimate pollutant loadings from sub-watersheds before and after BMP implementation. Estimate total loading of N, P, and sediment to Wister Lake and evaluate the impact of project on water quality.	$418,212
Task 2.	Implement cost-share program with producers in priority watersheds. Provide educational and technical assistance to assure BMP implementation is suitable for demonstration.	$141.667
Task 3.	Conduct workshops, public meetings, field trips, and tours to demonstrate BMPs and teach producers how to	$260,122

	write their own pollution prevention plans. Sample soils and poultry litter in priority watersheds to teach nutrient management and to improve modeling estimates of project impact.	
Task 4.	Evaluate educational impact through follow-up surveys.	$5,000
Task 5.	Prepare final report. Summarize the watershed management strategy, results of educational program, educational accomplishments, and BMP installation. Analyze effectiveness with respect to follow-up surveys and any available water quality data.	$8,333

Budget breakdown between main cooperators.

Cooperator	Local Match	State Match	Federal	Total
OSU		$170,912	$245,000	$415,912
OCC	$42,942	$119,480	$255,000	$417,422
Project Total	$42,942	$290,392	$500,000	$833,334

Literature Cited

Oklahoma State University. 1994. Wister Lake Watershed Project Annual Report FY 93. Department of Biosystems and Agricultural Engineering. Oklahoma State University, Stillwater, OK.

Oklahoma Water Resources Board. 1996. Diagnostic and Feasibility Study of Wister Lake. Oklahoma Water Resources Board, Oklahoma City, OK

United States Environmental Protection Agency. 1977. Wister Reservoir LeFlore County Oklahoma, National Eutrophication Survey, Working Paper No. 595, Corvallis Environmental Research Laboratory, Corvallis, OR.

Appendix A

Poteau River Comprehensive Watershed Management Program
TMDL Component

Grant: FY 1994 319- OCC Task 54
Date: May 8, 2001
Final Report

Appendix B

MODELING WISTER LAKE WATERSHED WITH THE SOIL AND WATER ASSESSMENT TOOL (SWAT)

Grant: FY 1994 319- OCC Task 54
Date: May 8, 2001
Final Report

MODELING WISTER LAKE WATERSHED WITH THE SOIL AND WATER ASSESSMENT TOOL (SWAT)

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ABSTRACT

Basin scale hydrologic/water quality models that are capable of predicting long-term effects of land management are valuable tools for water quality assessment of river systems. SWAT is a GIS-linked basin scale model capable of simulating hydrology and water quality for 100 or more years. The in-stream kinetics of an in-stream water quality model (QUAL2E) has been incorporated into SWAT, improving the capability of the SWAT model. SWAT was used to simulate hydrology and water quality in the Wister Lake watershed in the Arkansas River basin. The analysis presented in this paper is a follow-up to the 'first-cut' preliminary analysis presented by Ramanarayanan *et al*. (1996). The SWAT model in this analysis satisfactorily predicted stream flow, water temperature, total nitrogen, and total phosphorus. Additional improvement is needed in prediction of dissolved oxygen.

INTRODUCTION

River systems are a major source of water for agricultural and urban needs. Water quality assessments of river systems have become critically important throughout the country, as there is a genuine concern about the sustainable supply of quality water and the health of water bodies. River systems should be continuously monitored to assess the effects of different land management practices on water quality. However, long-term continuous monitoring is not currently being conducted due to high costs. Therefore, there is a need for an alternative tool such as a basin-scale hydrologic/water quality model that is capable of predicting the effects of land management with a reasonable level of accuracy.

SWAT (Arnold *et al*., 1993) is a basin-scale hydrologic/water quality model developed to predict the effects of alternative river basin land use management decisions on water, sediment, and chemical yields. SWAT operates on a daily time step and is capable of simulating 100 or more years. Major components of the model include hydrology, weather, erosion, soil temperature, crop growth, nutrients, pesticides, subsurface flow, and agricultural management. SWAT offers distributed parameter and continuous time simulation with flexible watershed configuration, automatic irrigation and fertilization, inter-basin water transfer, and lake water quality simulation capabilities.

Until now the in-stream nutrient dynamics were not considered in the SWAT model. In order to simulate the in-stream dynamics, the kinetic routines from an in-stream water quality model, QUAL2E (Brown and Barnwell, 1987), were modified and incorporated into SWAT. In this paper we have described the in-stream water quality component of SWAT and presented the results from the application of the model to Wister Lake watershed in eastern Oklahoma and western Arkansas.

GIS has recently been playing an important role in natural resources modeling and has proven to be an effective tool for non-point source (NPS) pollution models (Pelletier, 1985; Hession and Shanholtz, 1988; Srinivasan and Arnold, 1994). A continuous time, distributed parameter model like SWAT overcomes some of the limitations of single-event models (Arnold *et al*., 1995). When modeling with

SWAT a basin or watershed is divided into subbasins based on topography, soil, and land use, thereby preserving the spatially distributed parameters of the entire basin and homogeneous characteristics within a subbasin. However, manual collection of inputs for such models is often difficult and tedious due to the level of aggregation and the nature of spatial distribution. GIS has proven to be an excellent tool to aggregate and organize input data for distributed parameter hydrologic/water quality models (Tim *et al*., 1991; Rewerts and Engel, 1991; Srinivasan *et al*., 1993; Rosenthal *et al*., 1995).

The SWAT model has been integrated with a raster-based GIS, GRASS (Shapiro *et al*., 1992), designed and developed by the Environmental Division of the U.S. Army Construction Engineering Research Laboratory. The SWAT/GRASS interface (Srinivasan and Arnold, 1994) consists of three modules: (a) project manager, (b) input extractor and aggregator, and (c) input editor. The project manager interacts with the user to collect, prepare, edit, and store the basin and subbasin information to be formatted into SWAT input files. The input extractor and aggregator uses a variety of hydrologic tools (Srinivasan and Arnold, 1993) to derive SWAT input information from GRASS raster/site map layers such as basin boundary map with subbasin delineation, digital elevation map (DEM), soils map, land use/land cover map, and weather generator/station location map. In addition, the reservoirs, inflow, pond and lake data are collected directly from the user. The input editor is used to either view, edit, or check the data collected from the previous phase. Rosenthal *et al*. (1995) used this interface to aggregate SWAT input data for the Lower Colorado River basin of Texas, and found that the SWAT/GRASS interface significantly reduced the data collection and manipulation time and allowed the user to modify and analyze various alternative management practices rather easily. Further details about the interface are given by Srinivasan and Arnold (1994).

IN-STREAM WATER QUALITY COMPONENT

The constituents which can be simulated are algae as Chlorophyll-A (Chl-a), dissolved oxygen (DO), carbonaceous biochemical oxygen demand (CBOD), organic nitrogen (OrgN), ammonium nitrogen (NH_4-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), organic phosphorus as P (OrgP), and soluble phosphorus as P (SolP). The basic mass transport equation used in QUAL2E is given by

$$\frac{\partial C}{\partial t} = \{dispersion\} + \{advection\} + \{reaction\} + \{source / sink\} \qquad \text{... 1}$$

where C is the constituent concentration (ML^{-3}) and t is time (T). In QUAL2E, each reach is divided into several computational elements and for each time step, the resultant differential equation is solved numerically by implicit backward difference technique. In the in-stream water quality component of SWAT, the diffusion is ignored assuming complete mixing within a reach. The advection part of the equation is based on SWAT water and sediment routing. The constituent transformation is simulated assuming general first-order rate reaction, which can be written as

$$\frac{\partial C}{\partial t} = r_i \, C_i^{n+1} + p_i \qquad \text{... 2}$$

where ‘i’ is the spatial element, ‘n’ is the time segment, ‘r’ is the first-order rate coefficient (T^{-1}), and ‘p’ is the internal constituent source/sink ($ML^{-3}T^{-1}$). Thus, only the first-order rate decay is considered, which depends on the travel time of the constituent within a reach. The first-order rate reactions for Chl-A, nutrients, CBOD, and DO used in QUAL2E were adopted in SWAT with necessary modifications.

Temperature

The stream temperature is not simulated in SWAT, but is estimated from the air temperature based on a relationship developed by Stefan and Preud'homme (1993) through regression analysis of many river observations. The relationship is given by

$$T_w = 5.0 + 0.75\,T_a \qquad \text{... 3}$$

where T_w and T_a are temperature of the water and air, respectively (^oC). It can be seen from the above equation that the water will be warmer than air if the air temperature is below 20^oC, which is consistent with most rivers. Exceptions to this will include small streams under heavy shading, places where the stream temperature is influenced by anthropological activity (e.g. discharge of waste heat from a power generation plant).

Temperature Effects on Rate Coefficients

The rate coefficients (r_i) depend on the water temperature. The temperature correction for the rate coefficients is given by:

$$X_T = X_{20}\,\theta^{(T-20)} \qquad \text{... 4}$$

where X_T is the temperature-corrected coefficient at the local water temperature T, X_{20} is the value of the coefficient at 20^oC, and θ is an empirical constant for each reaction coefficient. The default values for θ given by Brown and Barnwell (1987) are used in SWAT. Every temperature dependent first-order reaction rate coefficient is corrected using the above equation.

LOADING FUNCTIONS

Prior to the addition of the in-stream kinetics , SWAT did not predict Chl-A, CBOD, and DO loads from subbasins to the streams. Appropriate loading estimations for these were established from the available literature. Our aim is to define the loading of these variables as a function of flow, nitrogen, phosphorous, organic matter, and temperature, whose dynamics are already defined in SWAT. A brief description of these functions follows.

Algae/Chlorophyll-A

Chl-A is assumed to be directly proportional to suspended algal biomass concentration in water. Therefore, the algal biomass loading to the stream is estimated as Chl-A loading from the sub-basins. We used the relationship developed by Cluis *et al*. (1988). They developed relationships between nutrient enrichment index (TN:TP), Chl-a and algal growth potential in the North Yamaska river, Canada. This lead to the functional relationship of the form:

$$(AGP + Chl\_A)Q = a\left(\frac{TN}{TP}\right)^b \qquad \text{... 5}$$

where AGP is the algal growth potential (mg/l), Chl_A is Chl-A (μg/l), Q is flow (m^3/s), TN is the total kjeldhal nitrogen (TKN = OrgN + NH_4-N) load (kg) and TP is total phosphorous load (kg of P), and 'a' and 'b' are coefficient and exponent, respectively. Cluis *et al*. (1988) presented the values of 'a' and 'b' for different seasons, and in SWAT the summer values (a = 7.25 and b = -4.68) were used.

In addition, through their analysis they established that 1 mg/l of AGP is equivalent to 1 μg/l of Chl-A.
This relationship is based on regression analyses and not physically based. We resolved to use this type of expression because, (a) the actual physical relationships are very complex, and (b) studies conducted to define these actual physical relationships are very limited.

Carbonaceous Biochemical Oxygen Demand (CBOD)

The SWAT loading function for the ultimate CBOD is based on a relationship given by Thomann and Mueller (1987):

$$L_u = \frac{2.3\, C_{org}}{q} \qquad \text{... 6}$$

where L_u is ultimate CBOD (mg/l), C_{org} is organic carbon load (mg), and q is the flow (*l*). The organic carbon concentration is calculated as

$$C_{org} = OC_1 * ER * Y_d * 10^6 \qquad \text{... 7}$$

where OC_1 is the fraction of organic carbon content in surface layer of the soil profile (g-C/g-soil), ER is the enrichment ratio (g-C/g-sediment), and Y_d is the sediment yield (kg).

Dissolved Oxygen (DO)

Assuming initially that the water from rainfall is saturated with oxygen (100% saturation level), the dissolved oxygen loading from a sub-basin is calculated by subtracting the oxygen uptake by the oxygen demanding substance in the runoff. The amount of oxygen withdrawn from the water depends on the average time of overland flow. The DO loading from a sub-basin is estimated by

$$O_d = O_s - \left(K_l L_u + \alpha_n \beta_n N\right) * t_{ov} \qquad \text{... 8}$$

where O_d is dissolved oxygen concentration (mg/l), O_s is the oxygen saturation concentration at temperature Tw (mg/l), K_l is CBOD deoxygenation rate (day^{-1}), α_n is the oxygen uptake rate of organic nitrogen (mg-O/mg-N), β_n is the oxidation rate coefficient of organic nitrogen (day^{-1}), N is organic nitrogen concentration (mg/l) and t_{ov} is the overland travel time (day). For simplicity K_l and α_n is assumed to be 1.047 and β_n is 4.6 (Brown and Barnwell, 1987). The dissolved oxygen saturation concentration is given by

$$O_s = EXP[-139.34410 + \left(\frac{1.575701 \times 10^5}{T}\right) - \left(\frac{6.642308 \times 10^7}{T^2}\right) + \left(\frac{1.2438 \times 10^{10}}{T^3}\right) - \left(\frac{8.621949 \times 10^{11}}{T^4}\right)] \qquad \text{... 9}$$

where T is the water temperature in ^oK ($^oK = {}^oC + 273.15$), and this equation is valid only if T is between 273.15 and 313.15 ^oK (Brown and Barnwell, 1987).

DESCRIPTION OF STUDY AREA

We used the SWAT model with the in-stream water quality component to simulate the hydrology and water quality in the Wister Lake watershed (Figure 1). A detailed description of the watershed and the input data sets for the watershed was presented by Storm *et al*. (1994). The watershed covers approximately 260,000 ha (640,000 acres) in eastern Oklahoma and western Arkansas and is situated in the Arkansas River basin. At the outlet of the watershed is Wister Lake in Oklahoma. A survey of Wister Lake by EPA in 1974 categorized it as eutrophic and excessively turbid. A preliminary Total Maximum Daily Load (TMDL) analysis, which analyzes the sources of point and non-point source pollution, was prepared by Smolen *et al*. (1993).

Figure 1: Wister Lake Watershed and Sub-Watersheds.

The four primary stream systems flowing into Wister Lake are Poteau River, Black Fork, Fourche Maline, and Holson Creek. There are four continuous stream gage monitoring stations: two on Poteau River, and one each on Fourche Maline and Black Fork. In addition, there are three miscellaneous gages with stream flow measurements at approximately six-week intervals. Stream flow data has been recorded at all of these stations since about December 1991. Water quality data is also available for all seven stations at approximately six-week intervals. For this study, we used the data from two stations: Fourche Maline at Red Oak, OK (07247500) and Poteau River at Cauthron, AR (07247000). Both of these stations (Figure 1) have continuous stream flow data and six-week water quality data.

The Wister Lake watershed was divided into subbasins in such a way that the outlet of each subbasin coincides with one of the stream monitoring stations. Climate data (rainfall and temperature) is available at five climate stations near the watershed. The SWAT/GRASS interface selects the closest climate station for each subbasin. For this simulation the interface selected and loaded data from four of the available stations (Wilburton, Heavener, Fanshawe, and Waldron). The landuse map was obtained from USGS land use/land cover of the area. The soils layer was obtained from digitized county soil maps of Leflore and Latimer counties in Oklahoma, and Scott and Polk counties in Arkansas. The soils properties were derived from the STATSGO database (USDA-NRCS, 1994). The soils and land use maps are shown in Figures 2 and 3. The land use map shows that 75 % of the watershed is covered with forest, 23 % pasture, and the remainder is urban, agricultural, and rangeland. For this study, we used a 100-meter resolution for all data layers, although some of the data layers are actually lower resolution.

Figure 2: Soils Map of Wister Lake Watershed.

Figure 3: Land Use Map of Wister Lake Watershed.

Point source discharges were also input to SWAT for two point sources located at Waldron. The average monthly water quality discharge data was extrapolated to a daily input loading for the 1989 to 1995 simulation period. For periods when monthly data was not available, the overall average for each constituent was used.

SWAT simulations can be based on two possible subbasin configurations: dominant and virtual basin approach. The details of both approaches are given by Mamillapalli *et al*. (1996). For this simulation, we used the virtual basin approach.

RESULTS AND DISCUSSION

The SWAT model was used to simulate the hydrology and water quality in the Wister Lake watershed from 1991 through 1995. The model runs for water quality were begun in 1989 in order to "prime" the model.

Stream Flow

SWAT flow prediction was calibrated at two stream gauging stations: Fourche Maline at Red Oak (07247500) and Poteau River at Cauthron (07247000). The initial model run indicated that SWAT was under-estimating stream flow. Calibration was accomplished at Red Oak by increasing the soil evaporation compensation factor to 0.95 and reducing the curve number by 4 in subbasin 1. Calibration was accomplished at Cauthron by increasing the evaporation compensation factor to 0.95, increasing the curve number by 6, and decreasing the soil available water holding capacity by 0.06 mm/mm in subbasins 7 and 9.

The results of the model run for flow calibration are shown in Figures 4a and 4b. In general, simulated flow matched measured flow fairly well. One exception was November 1994 when SWAT over-predicted flow at both stations. The coefficient of determination (R^2) between measured and simulated monthly stream flow is 0.66 at Red Oak and 0.69 at Cauthron.

Figure 4a: Cumulative Monthly Average Measured and Simulated Stream Flow at Red Oak, OK (Streamgauge 07247500).

Figure 4b: Cumulative Monthly Average Measured and Simulated Stream Flow at Cauthron, AR (Streamgauge 07247000).

Water Temperature

Figures 5a and 5b show a daily time series plot of measured (six-week interval) and simulated water temperature. Simulated water temperatures compare reasonably well with observed data and the simulated trends match well with the observed.

Figure 5a: Measured and Simulated Daily Water Temperature at Red Oak.

Figure 5b: Measured and Simulated Daily Water Temperature at Cauthron.

Total Nitrogen

Two input parameters were adjusted for the nitrogen simulation. The nitrogen uptake distribution parameter was set to 40 and the percolation coefficient was set to 0.1. The time series plot of daily simulated total nitrogen and the six-week interval measured concentrations for the two stations are shown in Figures 6a and 6b. Both the simulated and measured total nitrogen fit within a reasonable range, and the trend of the simulated data can be reasonably correlated with observed data. However, many of the peak concentrations predicted by SWAT are much higher than observed. Review of the simulated output reveals that the nitrate concentrations are much higher than the organic nitrogen. This may be attributable to overestimation of nitrogen mineralization in the soil by SWAT. In addition, the six-week interval samples may not have picked up the peaks in total nitrogen that may have occurred.

Figure 6a: Measured and Simulated Daily Total Nitrogen at Red Oak.

Figure 6b: Measured and Simulated Daily Total Nitrogen at Cauthron.

Total Phosphorus

Two input parameters were also adjusted for the phosphorus simulation. The phosphorus uptake distribution parameter was set to 10 and the percolation coefficient was set to 17. Simulated and measured total phosphorus is shown in Figures 7a and 7b. The simulated and measured total phosphorus fit within a reasonable range and similar trends are evident.

It is generally known that phosphorus in runoff is related to sediment loads. In this analysis, we did not calibrate SWAT for sediment prediction because of insufficient observed data. However, input parameters related to sediment prediction were adjusted to typical values used in calibration of several central Texas watersheds (sediment concentration factor = 0.010 and stream channel erodibility factor = 0.28).

Figure 7a: Measured and Simulated Daily Total Phosphorus at Red Oak.

Figure 7b: Measured and Simulated Daily Total Phosphorus at Cauthron.

Dissolved Oxygen

Previous SWAT simulations on this watershed and others indicated that dissolved oxygen prediction by SWAT was reasonable. However, in the current simulations on the Wister Lake watershed, SWAT is under-predicting the dissolved oxygen concentration, as shown in Figures 8a and 8b. The cause of this erroneous prediction is not known at this time.

Figure 8a: Measured and Simulated Daily Dissolved Oxygen at Red Oak.

Figure 8b: Measured and Simulated Daily Dissolved Oxygen at Cauthron.

Analysis of Monthly Nutrient Loads

Additional analyses were performed using simulated monthly nutrient loads from SWAT and monthly estimated loads from the "Model For Estimating Constituent Loads" **(reference??)**. Measured six-week nutrient samples and measured flow were input to the "Estimator" to create the estimated monthly load. At Red Oak we analyzed the same period (1991-1995) as in previous simulations. Because of insufficient input data for the estimator in 1995, we analyzed the 1990 through September 1994 period at Cauthron.

Figures 9a and 9b show time series plots of measured (estimated) and simulated total nitrogen. The coefficient of determination between the measured and simulated data is 0.66 at Red Oak and 0.71 at Cauthron. The effect on nitrogen of over-prediction of flow at Red Oak in November 1994 is evident on the graph. SWAT over-predicted total nitrogen at Cauthron and under-predicted at Red Oak.

Figure 9a. Monthly Measured and Simulated Total Nitrogen at Red Oak.

Figure 9b. Monthly Measured and Simulated Total Nitrogen at Cauthron.

Time series plots of measured (estimated) and simulated total phosphorus for both stations is shown in Figures 10a and 10b. The coefficient of determination between measured and simulated total phosphorus is 0.64 at Red Oak and 0.57 at Cauthron. Although measured and simulated means are close, SWAT under predicted phosphorus at both stations.

Figure 10a. Monthly Measured and Simulated Total Phosphorus at Red Oak.

Figure 10b. Monthly Measured and Simulated Total Phosphorus at Cauthron.

SUMMARY AND CONCLUSIONS

The in-stream kinetics of QUAL2E was incorporated into the SWAT basin scale hydrologic/water quality model. We have described the in-stream water quality component of SWAT and presented the results from the application of the model to Wister Lake watershed in eastern Oklahoma and western Arkansas. The GRASS GIS was used to aggregate input data for SWAT.

SWAT predicted monthly stream flow at Red Oak, OK with reasonable accuracy after adjusting the soil evaporation compensation factor and runoff curve number. At Cauthron, AR available water holding capacity also needed adjustment before an acceptable correlation of simulated and observed stream flow was achieved. This could be caused by limitations in the available precipitation data or by differences in landuse between the eastern and western portions of the watershed.

The water temperature, total nitrogen, and total phosphorus predictions by SWAT are satisfactory. However, additional work is needed to ascertain the cause of the inaccurate prediction of dissolved oxygen.

There are only a very few models linked with a GIS and capable of simulating both hydrology and water quality on a river basin scale. Adding the in-stream water quality components to SWAT has effected a significant enhancement of basin-scale modeling. The GIS-linked SWAT model shows good potential for use in predicting the effects of land use activities on surface water bodies.

The SWAT model can be an effective tool for EPA TMDL analysis. If point-source discharge data is available for a watershed, SWAT is capable of analyzing the effects on surface water of both point and non-point source pollution. SWAT is also capable of estimating the effects of various land management alternatives, and can be a valuable aid to regulatory agencies developing water quality improvement strategies.

In summary the major strengths of SWAT are: (i) simple to use, yet complex enough to simulate the interactions between weather, crop growth, and land use and management on a river basin scale for long periods, (ii) linked to a GIS interface which is an efficient method of aggregating input data for large scale simulations, and (iii) a graphical output interface and analysis tool to visualize the simulation results.

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REFERENCES

Arnold, J.G., P.M. Allen, and G. Bernhardt, 1993. A comprehensive surface-groundwater flow model. J. Hydrol. 142:47-69.

Arnold, J. G., J. R. Williams, and D. R. Maidment, 1995. Continuous-Time Water and Sediment Routing Model for Large Basins. ASCE J. of Hydr. Engr. 121(2).

Brown, L.C. and T.O. Barnwell, Jr., 1987. The enhanced water quality models QUAL2E and QUAL2E-UNCAS documentation and user manual. EPA document #EPA/600/3-87/007, Cooperative Agreement #811883, Environmental Research Laboratory, U.S. Environmental Protection Agency, Athens, GA.

Cluis, D., P. Couture, R. Bégin, and S.A. Visser, 1988. Potential eutrophication assessment in rivers; relationship between produced and exported loads. Schweiz. Z. Hydrol. 50(2):166-181.

Hession, W.C., and V.O. Shanholtz, 1988. A geographic information system for targeting non-point source agricultural pollution. J. Soil Water Conserv. 43(3):264-266.

Mamillapalli, S., R. Srinivasan, J.G. Arnold, and B.A. Engel, 1996. Effect of spatial variability on basin scale modeling. To be presented at the Third International NCGIA Conference/Workshop on Integrating GIS and Environmental Modeling, Sante Fe, New Mexico, January, 21-25.

Pelletier, R. E., 1985. Evaluating nonpoint source pollution using remotely sensed data in soil erosion models. J. Soil Water Conserv. 40(4):332-335.

Ramanarayanan, T.S., R. Srinivasan, and J.G. Arnold, 1996. Modeling Wister Lake Watershed Using a GIS-Linked Basin-Scale Hydrologic/Water Quality Model. Proc. Third Intl. Conf. on Integrating

Geographic Information Systems and Environmental Modeling. NCGIA, Santa Fe, New Mexico.

Rewerts, C.C., and B.A. Engel, 1991. ANSWERS on GRASS: Integrating a watershed simulation with a GIS. ASAE paper #91-2621, ASAE, St. Joseph, MI.

Rosenthal, W.D., R. Srinivasan, and J.G. Arnold, 1995. Alternative river management using a linked GIS-hydrology model. Tran. ASAE, 38(3):783-790.

Shapiro, M., J. Westervelt, D. Gerded, M. Larson, and K.R. Brownfield, 1992. Geographic Resources Analysis Support System (GRASS) Reference Manual. U.S. Army CERL, Champaign, Illinois.

Smolen, M.D., R. Lakshminarayanan, W.C. Hession, and D.E. Storm, 1993. Estimating total maximum daily load (TMDL) for Wister Lake. ASAE paper # 93-2072, ASAE, St. Joseph, MI.

Srinivasan, R., and J.G. Arnold, 1994. Integration of a basin-scale water quality model with GIS. Water Resources Bulletin 30(3):453-462.

Srinivasan, R., J.G. Arnold, R.S. Muttiah, C. Walker, and P.T. Dyke, 1993. Hydrologic Unit Model of the United States (HUMUS). *In:* Adv. In Hydro-Science and Engineering, Sam Yang (Editor). Washington, D.C., June 7-11, Volume I, Part A, pp. 451-456.

Stefan, H.G. and E.B. Preud'homme, 1993. Stream temperature estimation from air temperature. Water Res. Bull. 29(1):27-45.

Storm, D.E., M.D. Smolen, R. Lakshminarayanan, W.C. Hession, 1994. Wister Lake watershed project: Annual Report FY 93. Agricultural Experiment Station and Cooperative Extension Service, Oklahoma State University, Stillwater, OK.

Thomann, R.V. and J.A. Mueller, 1987. Principles of surface water quality modeling and control pp 261-384. Harper & Row Publishers, New York.

Tim, U.S., S. Mostaghimi, V.O. Shanholtz, and N. Zhang, 1991. Identification of critical nonpoint pollution source area using geographic information systems and simulation modeling. ASAE paper #91-2114, ASAE, St. Joseph, MI.

USDA-NRCS, 1994. State Soil Geographic Data Base, US Department of Agriculture – Natural Resources Conservation Service, National Soil Survey Center, Publication #1492, Washington, DC.

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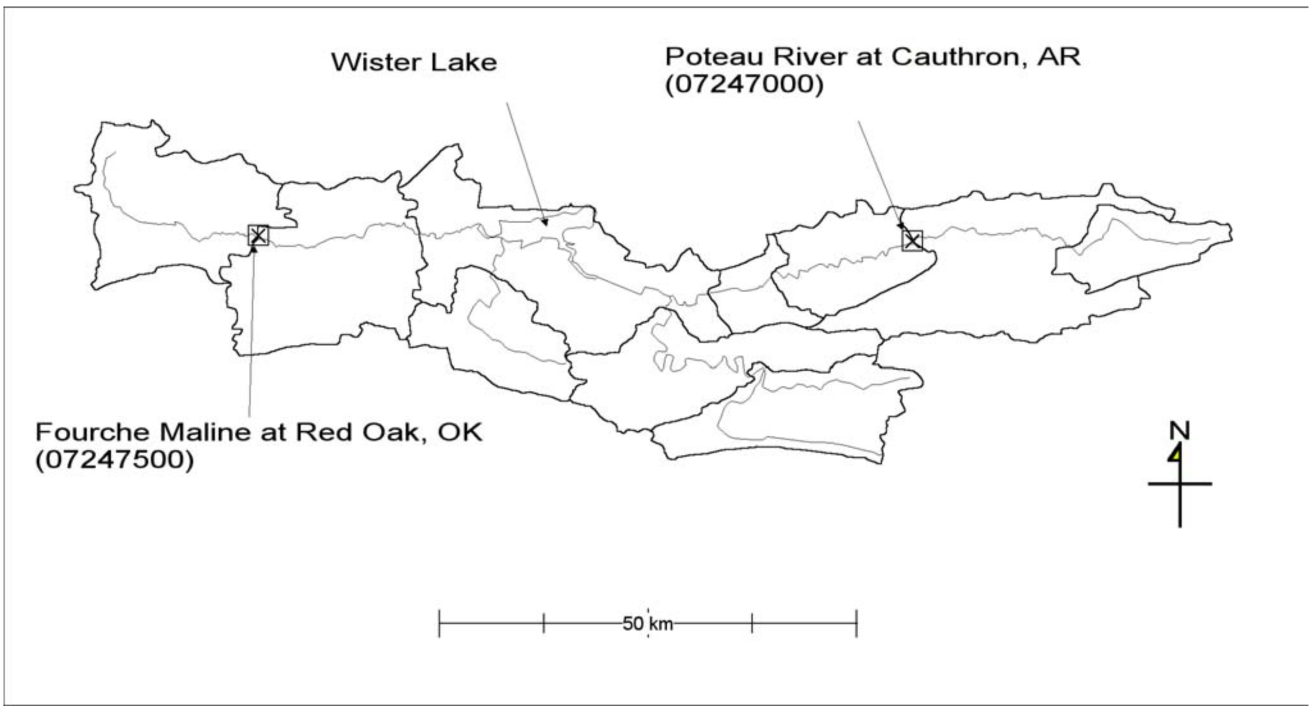

Figure 1. Wister Lake Watershed and Sub-Basins.

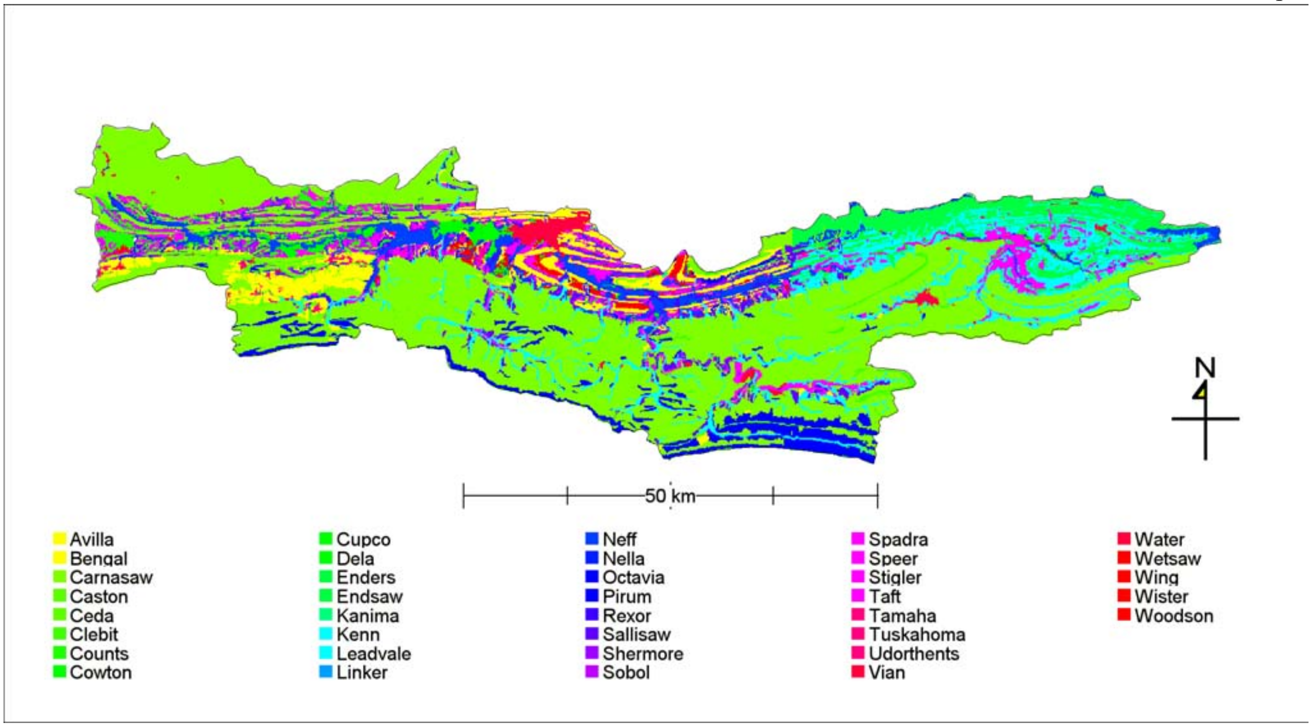

Figure 2. Soils Map of Wister Lake Watershed

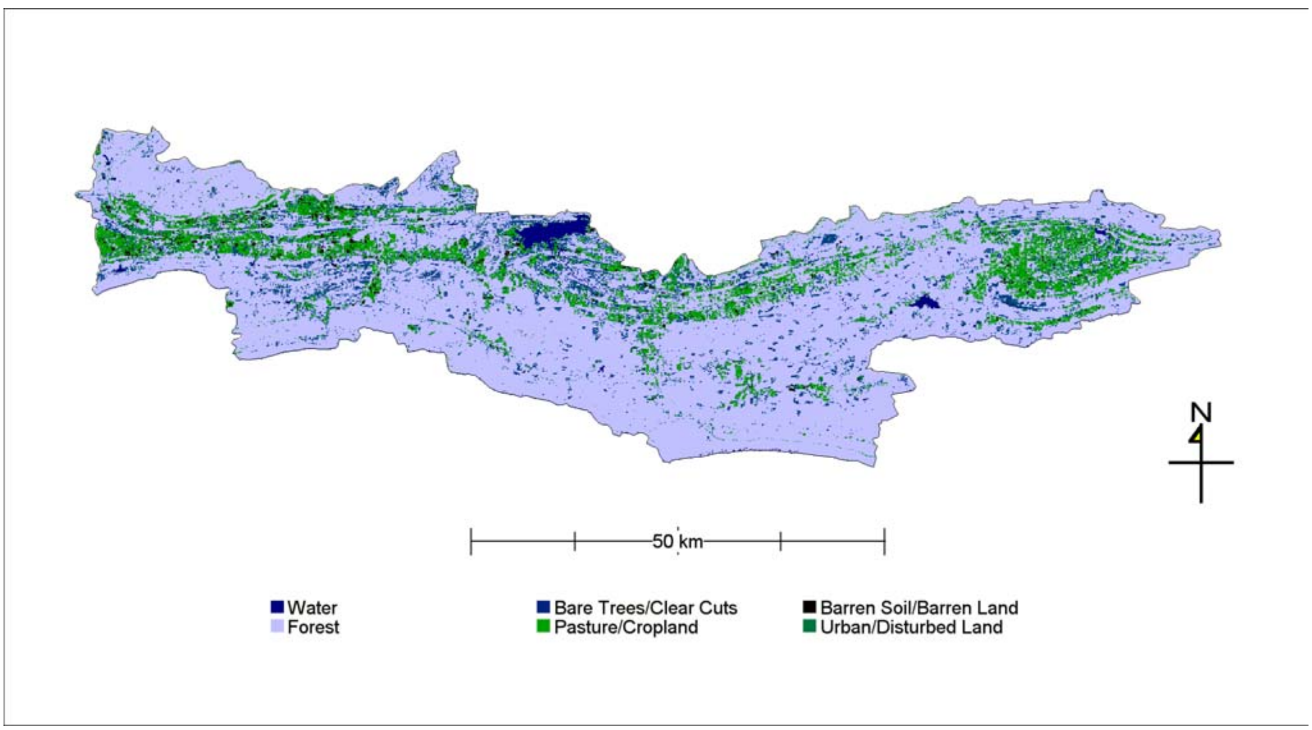

Figure 3. Land Use Map of Wister Lake Watershed.

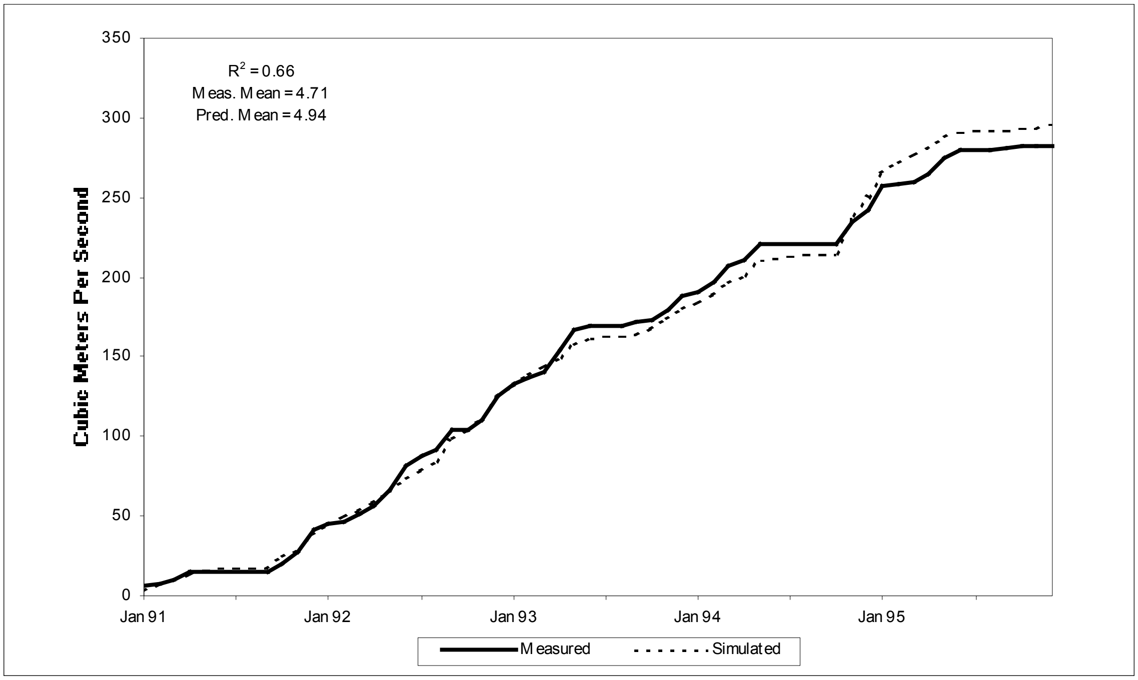

Figure 4a. Cumulative Monthly Average Measured and Simulated Stream Flow at Red Oak, OK (Streamgauge 07247500).

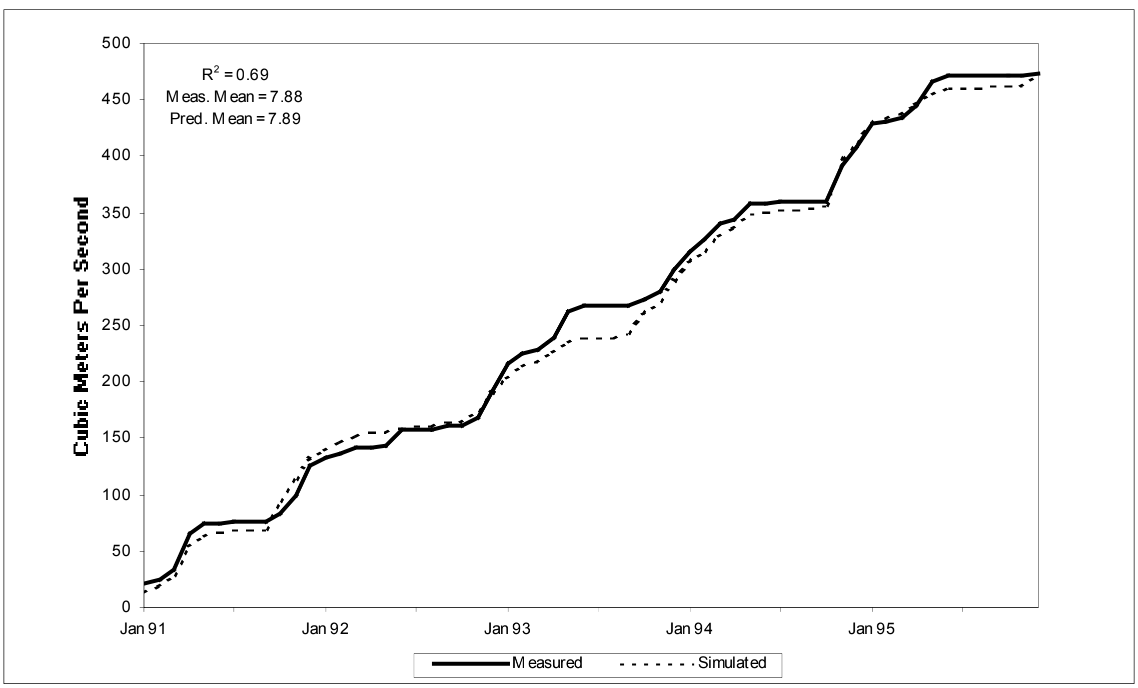

Figure 4b. Cumulative Monthly Average Measured and Simulated Stream Flow at Cauthron, AR (Streamgauge 07247000).

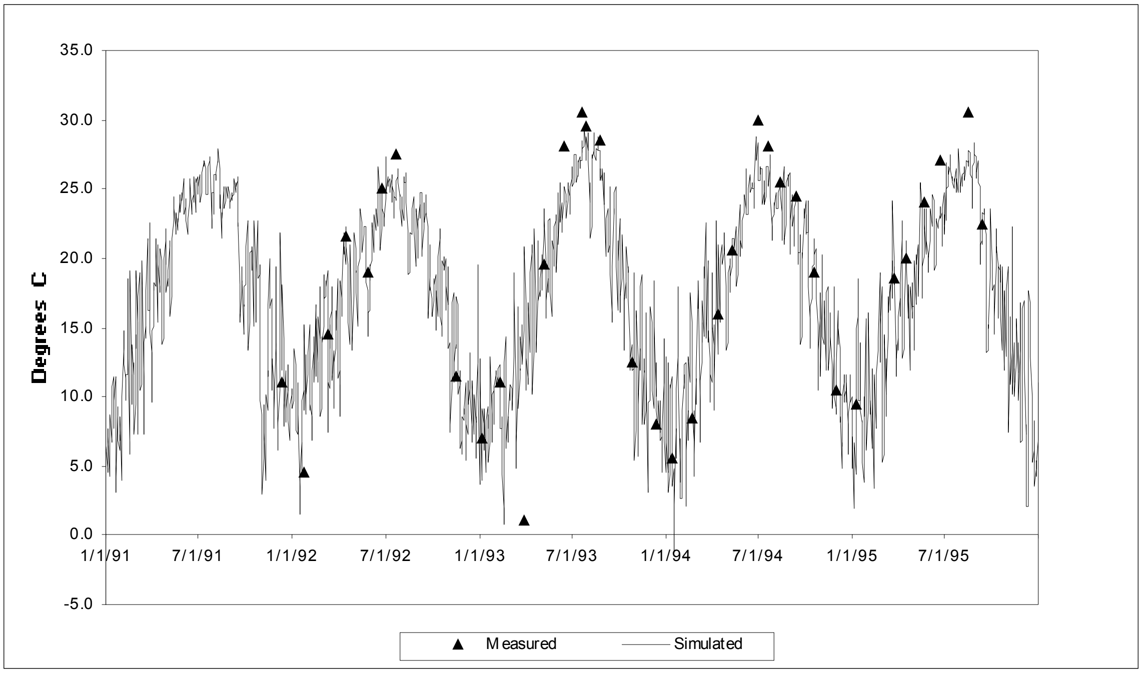

Figure 5a. Measured and Simulated Daily Water Temperature at Red Oak.

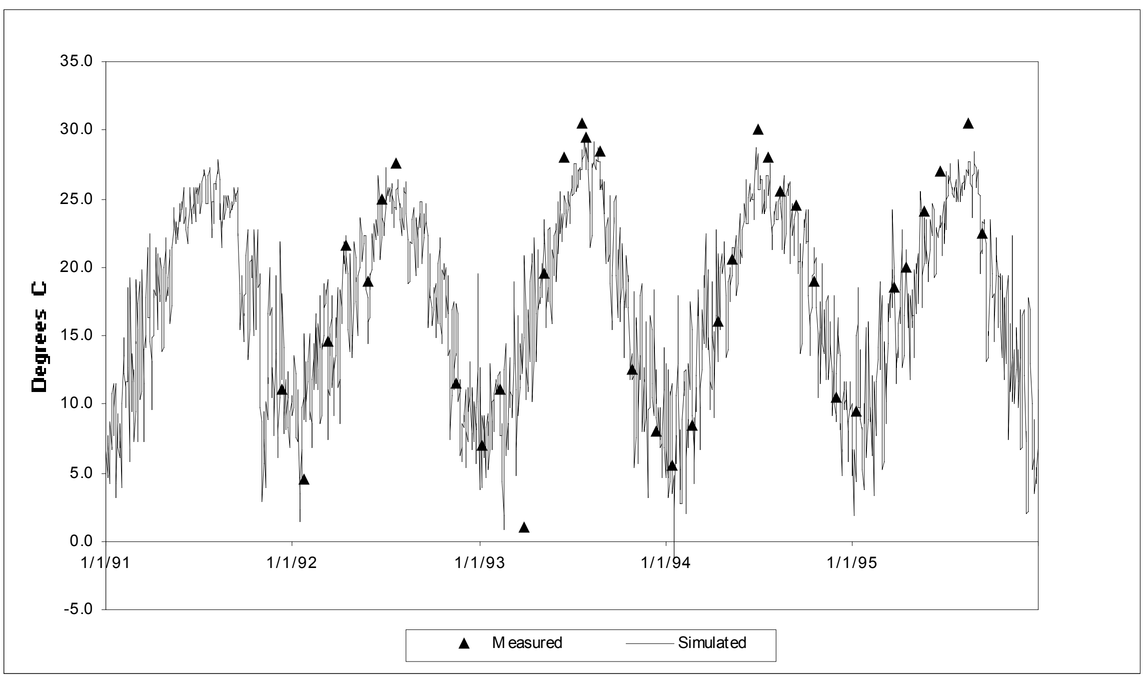

Figure 5b. Measured and Simulated Daily Water Temperature at Cauthron.

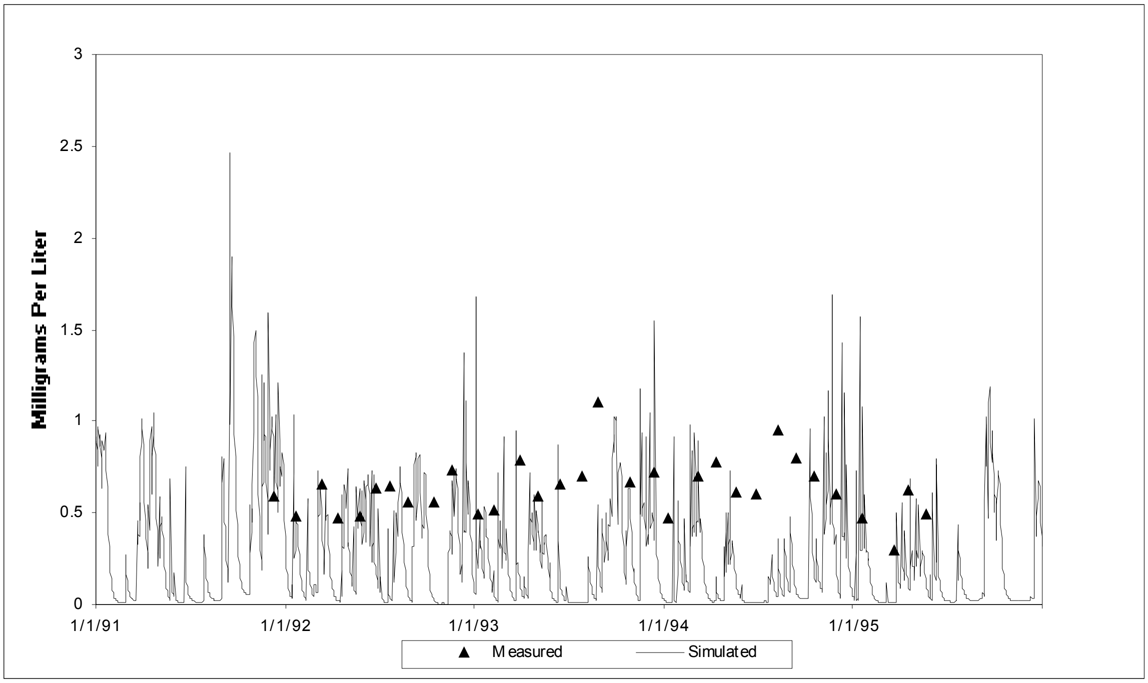

Figure 6a. Measured and Simulated Daily Total Nitrogen at Red Oak.

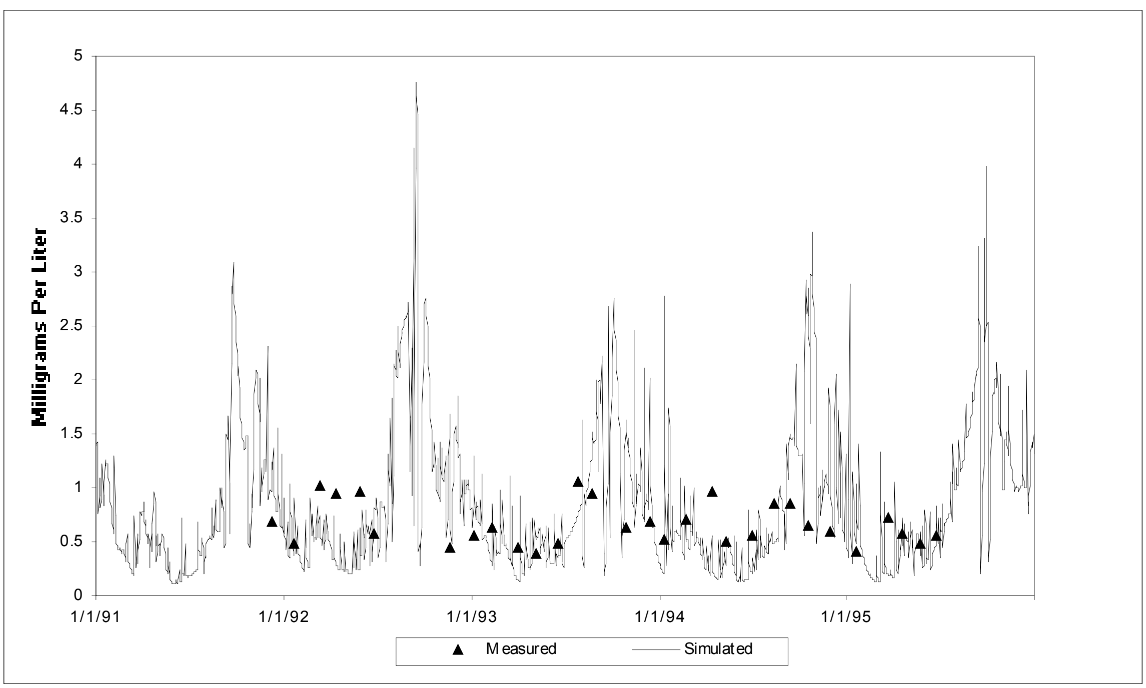

Figure 6b. Measured and Simulated Daily Total Nitrogen at Cauthron.

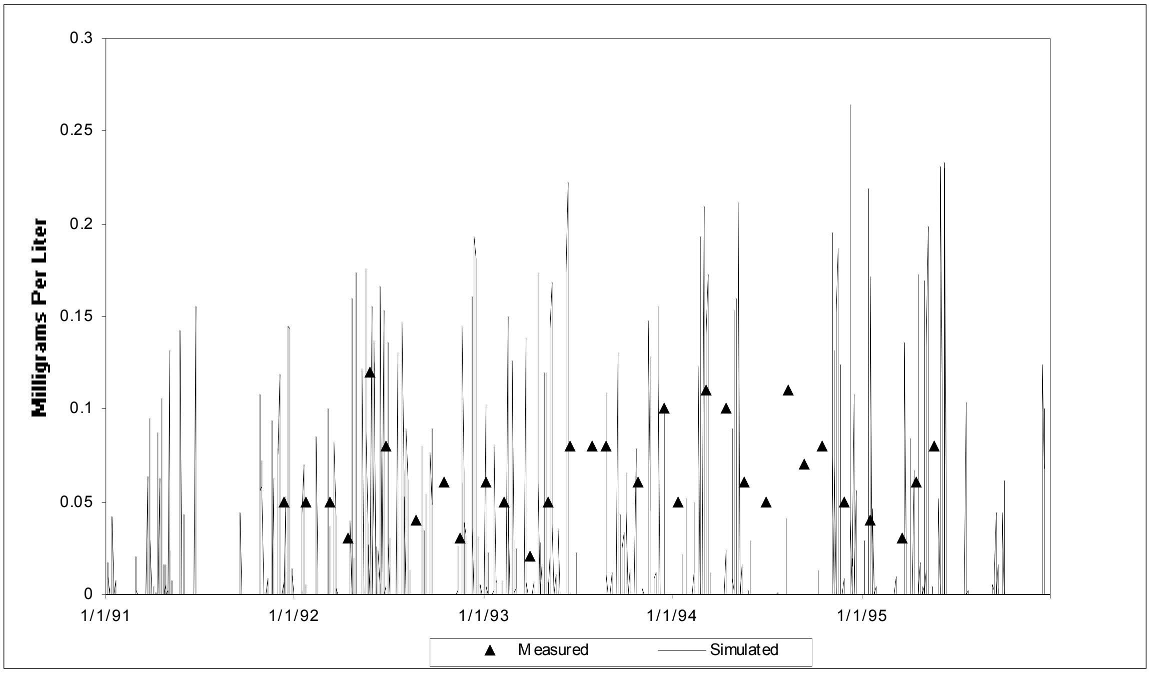

Figure 7a. Measured and Simulated Daily Total Phosphorus at Red Oak.

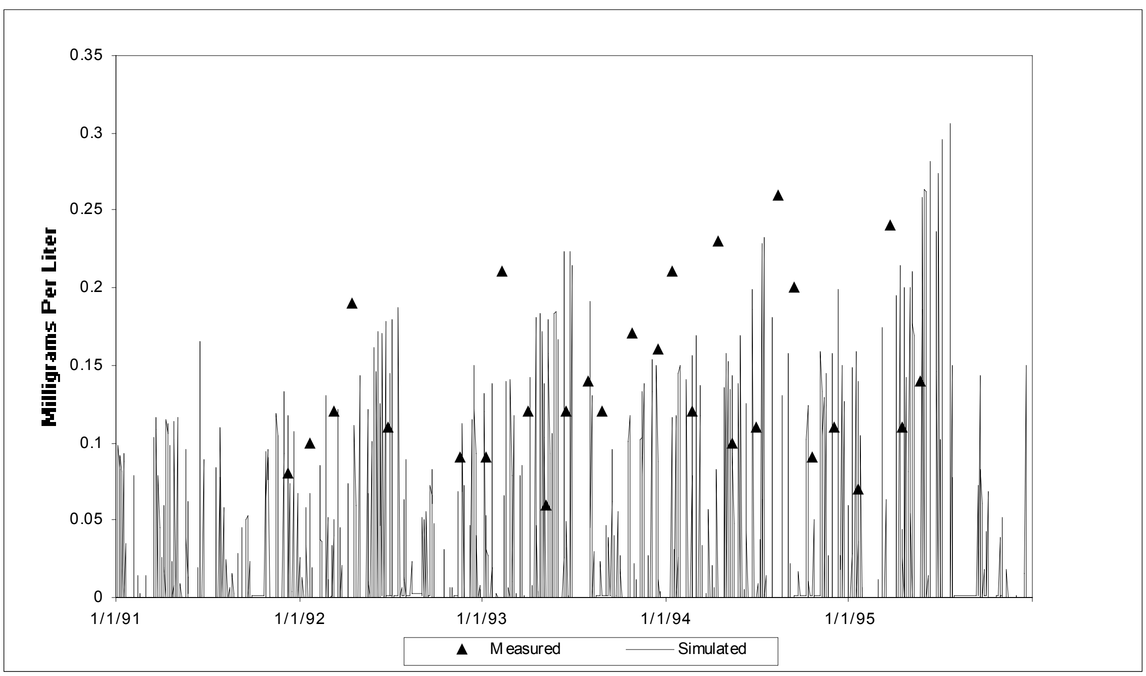

Figure 7b. Measured and Simulated Daily Total Phosphorus at Cauthron.

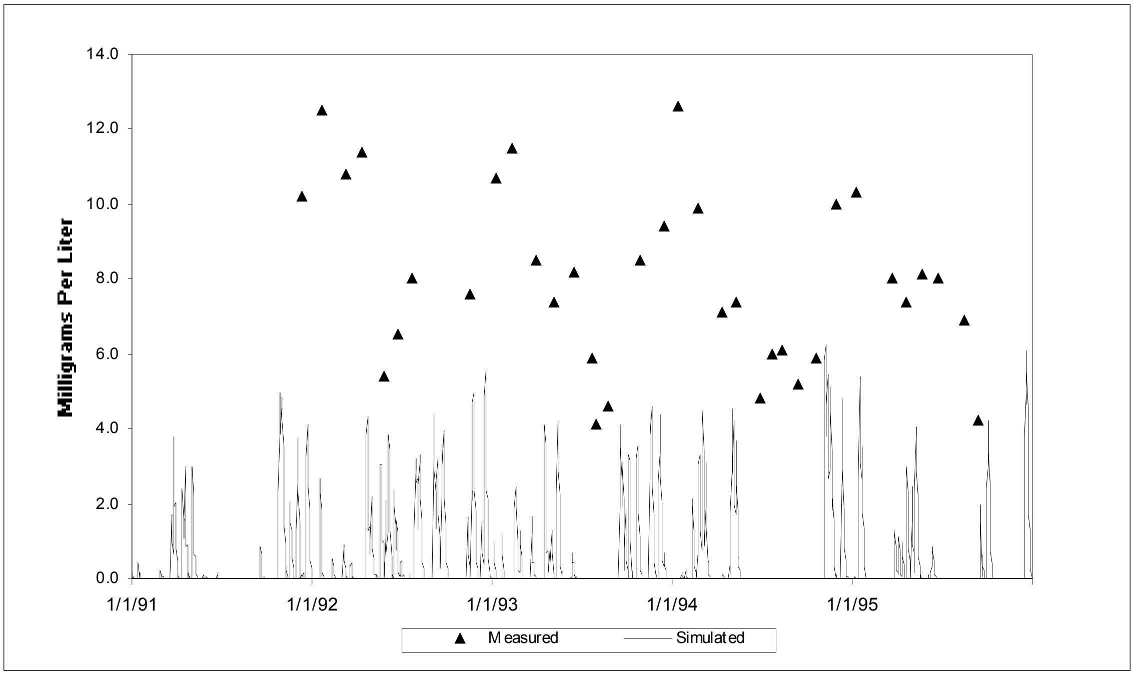

Figure 8a. Measured and Simulated Daily Dissolved Oxygen at Red Oak.

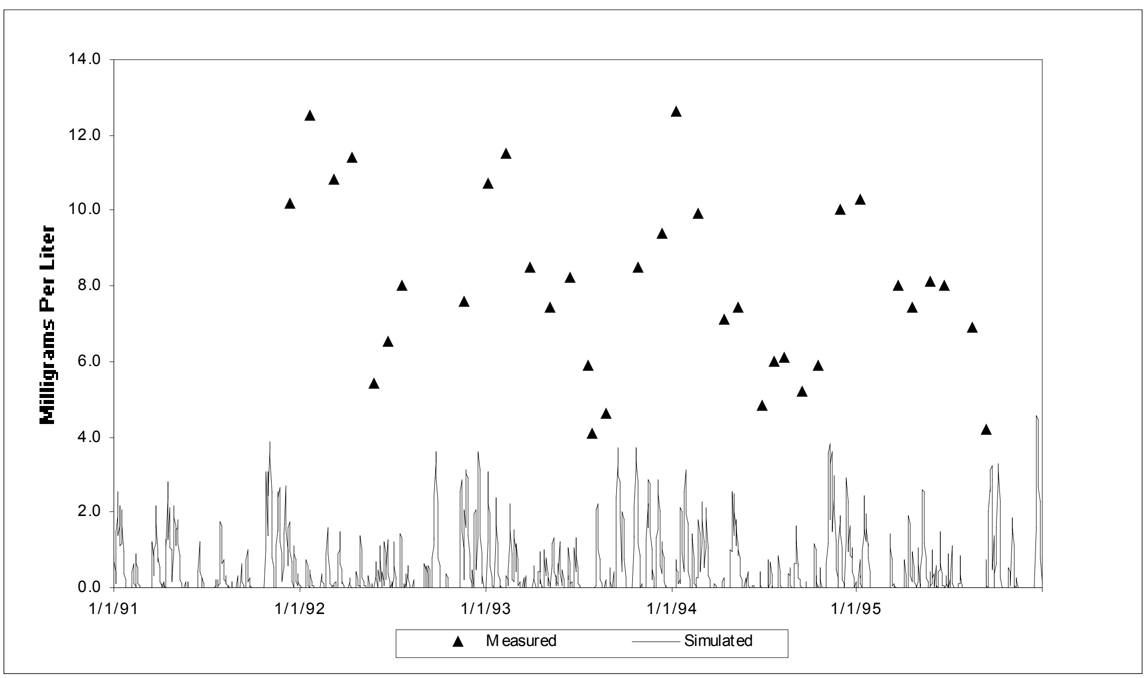

Figure 8b. Measured and Simulated Daily Dissolved Oxygen at Cauthron.

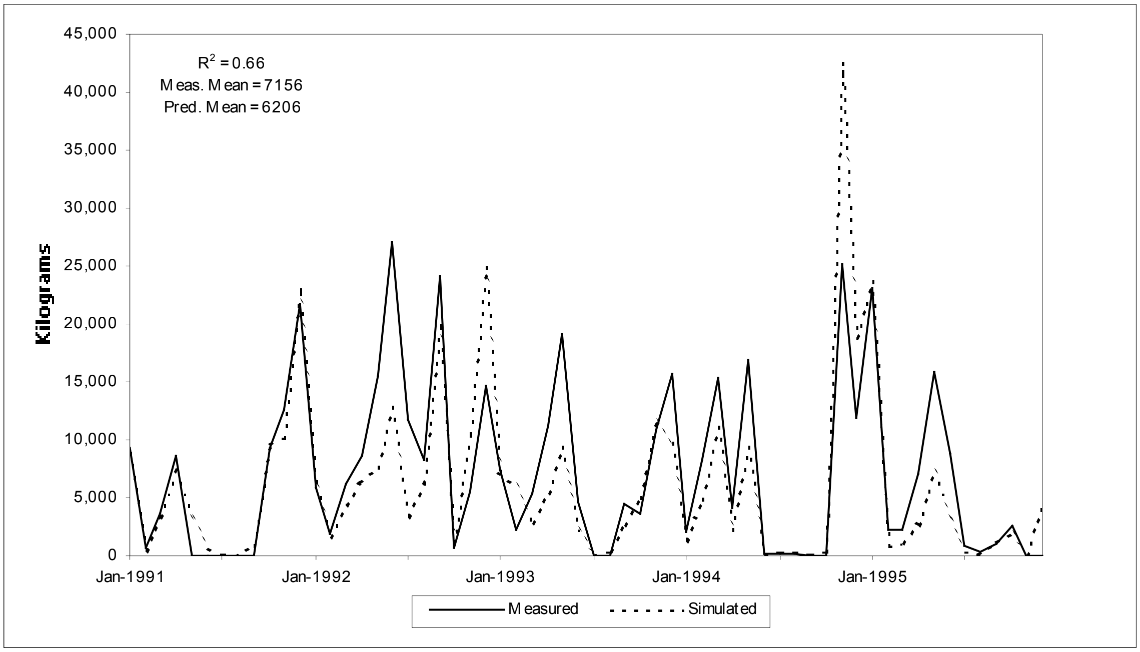

Figure 9a. Monthly Measured and Simulated Total Nitrogen at Red Oak.

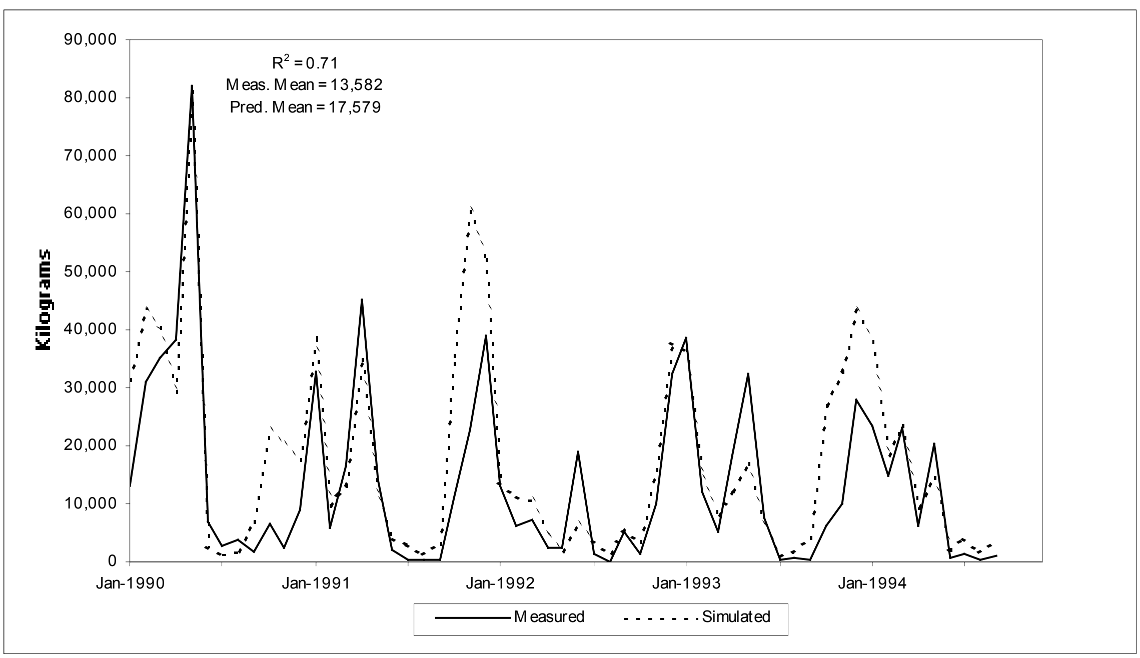

Figure 9b. Monthly Measured and Simulated Total Nitrogen at Cauthron.

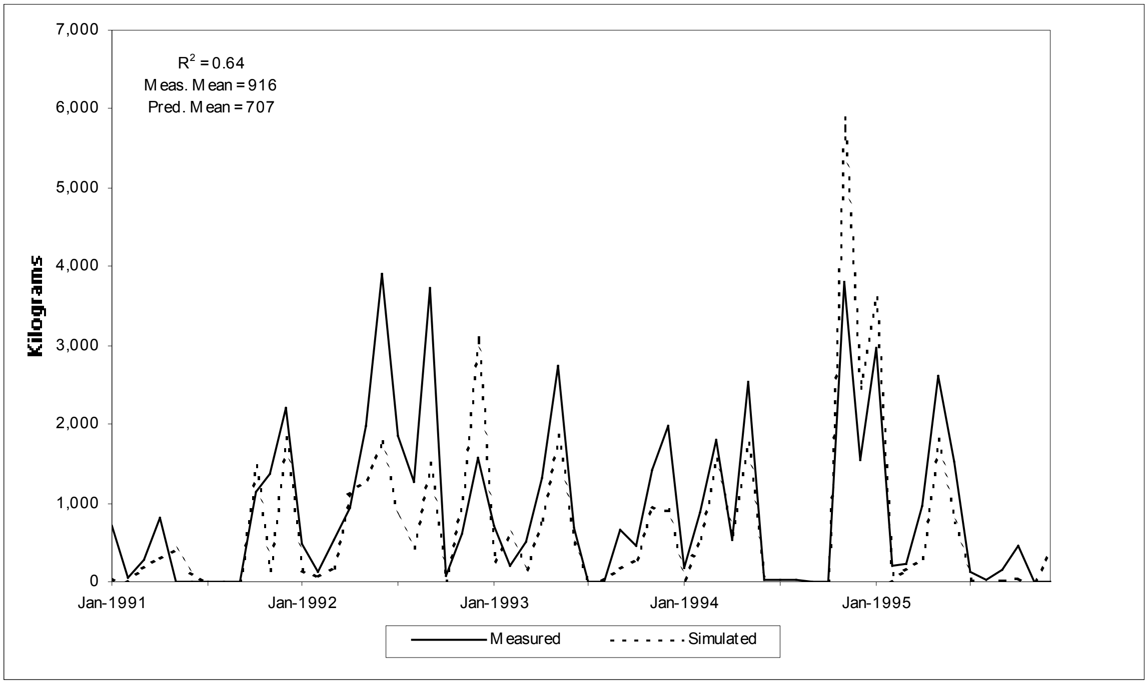

Figure 10a. Monthly Measured and Simulated Total Phosphorus at Red Oak.

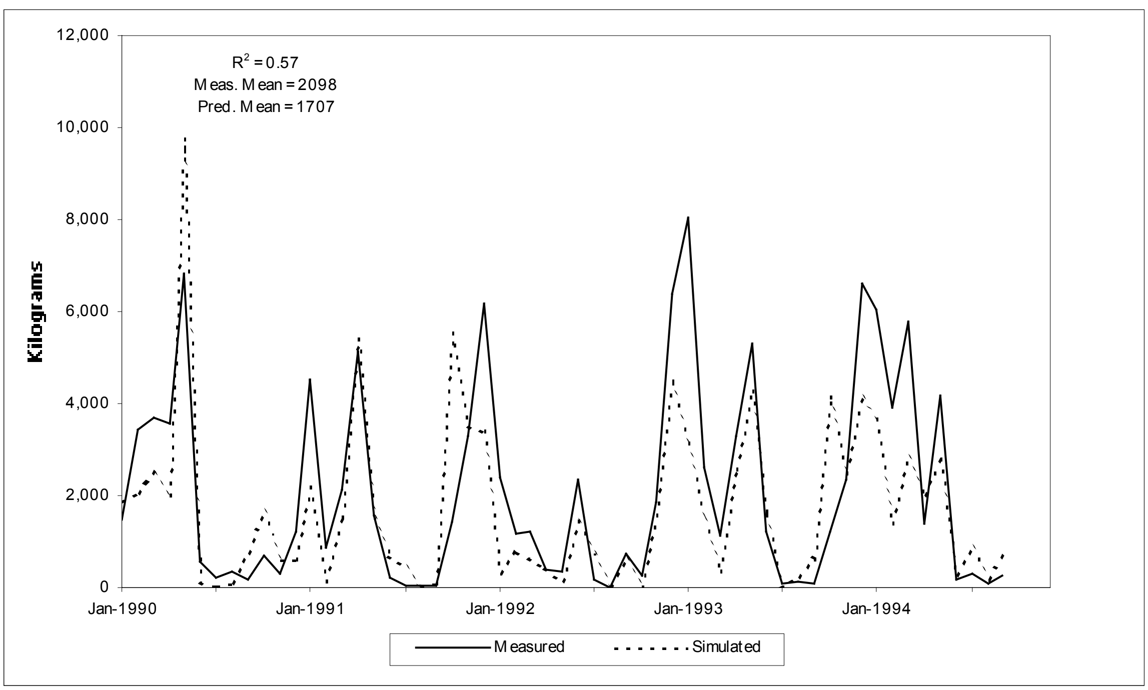

Figure 10b. Monthly Measured and Simulated Total Phosphorus at Cauthron.

Appendix C

Poteau River Comprehensive Watershed Management Program
Oklahoma Cooperative Extension Service

Appendix D

Poteau River Comprehensive Watershed Management Program
Pre- and Post-Implementation Data

Pre-Implementation Data: 1991-1996

Post-Implementation Data: 1997-1999

SITE	Date	Time 24 hr	DO mg/l	pH S.U.	Cond us/cm	Temp C	% Sat. * Calc.	Turb. NTU	Alk. mg/l	Chloride mg/l	Sulfate mg/l	Tot. Hard mg/l	Na mg/l	TDS mg/l	TSS mg/l	Total Phos mg/l	Ortho Phos mg/l	Nitrate (N) mg/l	Nitrite (N) mg/l	NO2/ NO3 mg/l	TKN (N) mg/l	Ammonia mg/l	Chl-a ug/l	pheophyton ug/l
Poteau @ Loving	12/11/91	1015	9.4	6.93	48	11.7	87									0.07			0.01	0.25	0.4	0.02		
Poteau @ Loving	01/22/92	1045	12.6	7.11	59	5.5	99									0.07			0.01	0.16	0.3			
Poteau @ Loving	03/11/92	745	10	7.26	86	9	87												0.01	0.28	0.5	0.04		
Poteau @ Loving	04/14/92	735	7.4	7	93	19.4	80									0.07			0.02	0.56	0.4	0.04		
Poteau @ Loving	05/27/92	1000	6	6.99	115	18.5	63									0.09			0.02	0.99	0.3	0.06		
Poteau @ Loving	06/24/92	1445	6.5	6.84	65	28.2	83												<0.01	0.14	0.3	0.03		
Poteau @ Loving	07/20/92	1340	6.6	7	81	29.5	86									0.06				0.065	0.5	0.04		
Poteau @ Loving	07/20/92	1415	6	6.94	80	29.5	78																	
Poteau @ Loving	07/20/92	1418	6	6.95	80	29.5	78																	
Poteau @ Loving	07/20/92	1422	6.2	6.95	80	29.5	81																	
Poteau @ Loving	07/20/92	1425	6.2	6.96	81	29.5	81																	
Poteau @ Loving	07/20/92	1428	6.2	6.96	81	29.5	81																	
Poteau @ Loving	07/20/92	1430	6.4	6.98	81	29.5	83																	
Poteau @ Loving	07/20/92	1433	6.4	6.98	81	29.5	83																	
Poteau @ Loving	07/20/92	1437	6.4	6.99	81	29.5	83																	
Poteau @ Loving	07/20/92	1440	6.6	7	81	29.5	86																	
Poteau @ Loving	07/20/92	1443	6.6	7	81	29.5	86																	
Poteau @ Loving	07/20/92	1446	6.6	7	81	29.5	86																	
Poteau @ Loving	07/20/92	1450	6.6	7	81	29.5	86																	
Poteau @ Loving	07/20/92	1453	6.4	7	81	29.5	83																	
Poteau @ Loving	08/25/92	755	4.8	6.99	114	24.7	58									0.05			<0.01	0.086	0.6	0.06		
Poteau @ Loving	10/13/92	1445	8	7.41	79	18.8	86				<20								<0.01	<0.05	0.4	0.03		
Poteau @ Loving	11/18/92	1010	6.5	7.14	91	12.1	60				<20					0.05			0.01	<0.05	0.3	0.02		
Poteau @ Loving	12/14/92	1530	9.3	6.7	79						<20					0.1			0.03	0.14	0.4	0.05		
Poteau @ Loving	12/15/92	1400	9.9	6.77	47	8.8	86									0.22			0.04	0.16	0.6	0.07		
Poteau @ Loving	12/16/92	1130	10.4	6.7	37	7.5	86									0.2			0.03	0.18	0.5	0.04		
Poteau @ Loving	01/06/93	1015	11.8	7.02		7.3	97				<20					0.09				0.16	0.4			
Poteau @ Loving	02/10/93	810	11	7.41	78	8.6	95				<20					0.1				0.12	0.3			
Poteau @ Loving	03/31/93	1530	8	7.38	83	15.5	78				<20					0.04					0.3			
Poteau @ Loving	05/06/93	930	7.6	7.13	61	19.7	84				<20									0.092	0.3			
Poteau @ Loving	06/17/93	815	5.4	7.34	68	26	67				<20					0.12				0.24	0.5			
Poteau @ Loving	07/21/93	1503	5.9	7.73	86	32.1	81																	
Poteau @ Loving	07/21/93	1506	6	7.61	86	32.3	82																	
Poteau @ Loving	07/21/93	1509	6	7.49	86	31.6	82																	

Poteau @ Loving	07/21/93	1512	5.5	7.48	86	31.5	73			
Poteau @ Loving	07/21/93	1515	5.7	7.31	86	31.5	75			
Poteau @ Loving	07/21/93	1518	5.7	7.31	86	31.3	75			
Poteau @ Loving	07/21/93	1521	5.5	7.25	86	31.2	73			
Poteau @ Loving	07/21/93	1524	5.5	7.25	86	31.4	73			
Poteau @ Loving	07/21/93	1527	5.6	7.25	86	31.6	77			
Poteau @ Loving	07/21/93	1530	5.6	7.25	86	31.7	77			
Poteau @ Loving	07/28/93	1130	5.7	7.3	96	29.9	75	0.11		1
Poteau @ Loving	08/25/93	1250	5	7.4	120	30.2	66	0.15	0.12	0.7
Poteau @ Loving	10/20/93	1600		6.7	52			0.23		0.7
Poteau @ Loving	10/27/93	1410	12.2	7.04	63	14	118	0.09	0.18	0.4
Poteau @ Loving	11/14/93	1034		6.7	96			0.39		0.9
Poteau @ Loving	12/02/93	1300		6.53	70			0.27		0.9
Poteau @ Loving	12/14/93	1100	10.3	6.9	69	7.8	87	0.17	0.19	0.6
Poteau @ Loving	01/11/94	1530	13.2	7.4	85	4.6	103	0.06		0.2
Poteau @ Loving	01/26/94	946		6.2	57			0.3		1.1
Poteau @ Loving	02/22/94	1400	10	6.82	70	11.6	93	0.19	0.12	0.7
Poteau @ Loving	02/22/94	1720	9.1	6.71	66.2	11.1	81	0.25	0.14	1
Poteau @ Loving	02/22/94	2315	9.1	6.79	63.3	10.1	81	0.39	0.13	1.1
Poteau @ Loving	02/23/94	1100	9.8	7.05	56	9.4	85	0.19	0.24	1
Poteau @ Loving	02/24/94	1430	10.4	7.04	54	8	88	0.09	0.19	0.6
Poteau @ Loving	02/25/94	745	10.4	6.83	58	7.3	86	0.09	0.11	0.5
Poteau @ Loving	03/08/94	1000		6.32	56			0.12		0.7
Poteau @ Loving	04/11/94	2009		6.61	73			0.15		0.8
Poteau @ Loving	04/13/94	845	8	7	68	15	78	0.1		0.4
Poteau @ Loving	04/29/94	649		6.51	58			0.2	0.11	1
Poteau @ Loving	05/11/94	1415	7.1	7.3	57	21.4	80	0.09	0.12	0.4
Poteau @ Loving	06/29/94	715	3.9	7.06	87	29.3	51	0.07		0.5
Poteau @ Loving	07/21/94	755	4.8	7.3	135	27.9	61			
Poteau @ Loving	07/21/94	759	4.8	7.33	134	27.9	61			
Poteau @ Loving	07/21/94	804	4.8	7.32	134	28	61			
Poteau @ Loving	07/21/94	807	4.8	7.33	134	27.9	61			
Poteau @ Loving	07/21/94	810	4.8	7.33	134	27.9	61			
Poteau @ Loving	07/21/94	814	4.8	7.33	135	27.8	61			
Poteau @ Loving	07/21/94	818	4.8	7.34	134	27.9	61			
Poteau @ Loving	07/21/94	822	4.7	7.33	134	28	60			

Poteau @ Loving	07/21/94	827	4.7	7.33	134	28	60										
Poteau @ Loving	07/21/94	831	4.8	7.33	134	28	61										
Poteau @ Loving	07/21/94	835	4.7	7.32	135	28	60										
Poteau @ Loving	07/21/94	839	4.8	7.33	134	28	61										
Poteau @ Loving	07/21/94	843	4.8	7.33	134	28	61										
Poteau @ Loving	07/21/94	846	4.8	7.33	134	27.9	61										
Poteau @ Loving	07/21/94	850	4.7	7.34	134	27.9	60										
Poteau @ Loving	08/12/94	800	4.6	7.26	113	25.6	57					0.05				0.4	
Poteau @ Loving	09/14/94	715	4.2	7.15	96	23.6	50					0.09			0.087	0.6	
Poteau @ Loving	10/18/94	1155	4.9	7.03	91	20.1	54					0.05			0.07	0.7	
Poteau @ Loving	12/01/94	955	11.2	6.92	58	9.5	97					0.1			0.1	0.4	
Poteau @ Loving	01/19/95	1015	10.8	6.92	50.5	7.4	89					0.08			0.12	0.4	
Poteau @ Loving	03/23/95	900	8	7.4	83	19.6	88					0.12				0.4	
Poteau @ Loving	04/11/95	800						8	<2	14	176	0.25	<0.25	<0.01		0.99	0.09
Poteau @ Loving	04/11/95	1550						7	<2	12	434	0.43	<0.25	<0.01		1.93	0.15
Poteau @ Loving	04/12/95	740						5	<2	9	91	0.17	<0.25	<0.01		0.8	0.06
Poteau @ Loving	04/18/95	1730	7	6.79	62	20.2	77					0.1			0.18	0.4	
Poteau @ Loving	04/20/95	945						2.5	22.5	13	58.5	0.13	<0.25	<0.01		0.81	0.25
Poteau @ Loving	04/20/95	1130						2.5	2.4	18	117	0.13	<0.25	<0.01		0.78	0.49
Poteau @ Loving	05/01/95	900						3.5	1.22	15	132	0.15	<0.25	<0.01		0.93	<0.02
Poteau @ Loving	05/01/95	2050						4.2	<1	16	136	0.13	<0.25	<0.01		0.9	<0.02
Poteau @ Loving	05/02/95	745						4.5	<1	17.6	98	0.16	<0.25	<0.01		0.89	<0.02
Poteau @ Loving	05/08/95	950						3.3	<5	12	264	0.267	0.1	<0.01		1.37	0.126
Poteau @ Loving	05/09/95	750						3	<5	13	258	0.261	0.1	<0.01		1.28	0.116
Poteau @ Loving	05/10/95	925						3	<5	12.5	65	0.136	0.1	<0.01		0.55	0.117
Poteau @ Loving	05/25/95	1140	6.9	6.73	58	24.2	82					0.04			0.1	0.2	
Poteau @ Loving	06/23/95	850	6	6.78	73	26.1	74					0.11			0.13	0.6	
Poteau @ Loving	06/23/95	855	5.6	6.78	73	26.1	69										
Poteau @ Loving	06/23/95	858	5.6	6.79	73	26.1	69										
Poteau @ Loving	06/23/95	903	5.8	6.79	73	26.1	71										
Poteau @ Loving	06/23/95	906	6	6.79	73	26.1	74										
Poteau @ Loving	06/23/95	910	5.4	6.78	73	26.1	67										
Poteau @ Loving	06/23/95	913	6.1	6.78	73	26.1	75										
Poteau @ Loving	06/23/95	916	5.8	6.78	73	26.1	71										
Poteau @ Loving	06/23/95	920	5.8	6.78	73	26.1	71										
Poteau @ Loving	06/23/95	923	6	6.78	73	26.1	74										

Poteau @ Loving	06/23/95	927	5.9	6.78	73	26.1	73																	
Poteau @ Loving	06/23/95	930	6	6.78	73	26.1	74																	
Poteau @ Loving	08/18/95	805	4.3	7.11	141	27.3	54									0.07				0.11	0.5			
Poteau @ Loving	09/13/95	805	4.6	7.46	140	21.3	52									0.05				0.07	0.6			
Poteau @ Loving	12/18/95	930								31	17.9	30			74.2	0.2		0.15			0.69	<0.001		
Poteau @ Loving	07/12/96	1200								5.5	<2	28			91	0.24		0.168	0.005		0.76	0.093		
Poteau @ Loving	07/12/96	1545								3	<2	18			125	0.31		0.11	0.004		1.2	0.101		
Poteau @ Loving	07/12/96	1945								4	<2	20			136	0.34		0.129	0.004		0.95	0.075		
Poteau @ Loving	08/27/96	1100								6.3	<1	22			98.5	0.31		0.07	<0.005		0.97	0.16		
Poteau @ Loving	09/26/96	1530								4	<1	20			122	0.42		0.29	0.006		1	0.06		
Poteau @ Loving	09/27/96	730								3	<1	12			286	0.28		0.22	0.01		1.6	0.04		
Poteau @ Loving	09/27/96	1020								3.2	<1	14			193	0.22		0.19	0.009		1.46	0.008		
Poteau @ Loving	10/28/96	820								8.3	<1	28			64	0.64		0.51	0.006		1	0.04		
Poteau @ Loving	10/28/96	1700								6.5	<1	28			140	0.43		0.31	0.002		1.41	0.03		
Poteau @ Loving	10/29/96	720								8	3.1	32			64	0.38		0.4			1.29	0.05		
Poteau @ Loving	11/17/96	700								5.5	<1	18			65	0.24		0.29	0.004		0.7	0.003		
Poteau @ Loving	11/17/96	1200								6	<1	17			278	0.5		0.36	0.004		1.09	0.02		
Poteau @ Loving	11/18/96	740								4	<1	16			61.5	0.28		0.14	0.003		0.75	0.001		
Poteau @ Loving	11/26/96	1520								5	<1	12			35	0.16		<0.05	<0.005		1.13	<0.05		
Poteau @ Loving	1/21/97	1510	13.5	7.4	104	4.3		5.8	21	8.1	14		8.6	63	97	0.17	0.15	0.07	0.01	0.08	0.3	<0.015	3	<1.00
Poteau @ Loving	02/20/97	700								7	<1	20			286	0.44		0.13	0.002		0.78	<0.01		
Poteau @ Loving	02/21/97	615								6	<1	16			230	0.41		0.08	0.002		0.83	<0.01		
Poteau @ Loving	02/23/97	730								5	<1	16			44	0.13		0.12	0.002		0.27	<0.01		
Poteau @ Loving	03/13/97	750								8	0.771	30			23.23	0.14		0.168	0.0018		0.504	<0.05		
Poteau @ Loving	03/13/97	2320								6	0.27	24			81	0.23		0.102	0.0025		0.719	<0.05		
Poteau @ Loving	03/14/97	810								8	<2	28			46	0.2		0.086	0.0019		0.719	<0.05		
Poteau @ Loving	4/9/97	805	8.8	6.8	55	13.4		20	10	3.3	7.3		4.2	20	79	0.09	0.04	0.1	<0.01	0.11	0.4	0.03	<1	6
Poteau @ Loving	5/27/97	1345	6.8	6.9	93	24.5		4.6	23	6.9	9.3		8.1	65	80	0.055	0.026	0.057	<0.01	0.067	0.6	0.044	<1	4
Poteau @ Loving	06/16/97	2340								8	<1	36			30.5	0.142		0.16	0.004		0.44	<0.05		
Poteau @ Loving	06/17/97	1650								6	<1	28			156	0.489		0.08	0.008		1.31	0.03		
Poteau @ Loving	06/18/97	735								4	1.72	24			59.3	0.27		0.05	0.006		1.03	<0.05		
Poteau @ Loving	7/17/97	725	5	7	71	27.9		5.2	19	4.3	5.9		6.2	50	91	0.065	0.032	0.04	<0.01	0.05	0.7	0.048	<1	6
Poteau @ Loving	8/18/97	1355	5.2	6.9	74	25.4		2.8	23	4.5	5.5		5.8	48	78	0.045	0.025	0.124	0.01	0.134	0.39	0.048	<1	2
Poteau @ Loving	09/09/97	1000	5.65		87.1	23.8	67																	
Poteau @ Loving	09/09/97	1040	5.43		84.2	23.8	65																	
Poteau @ Loving	09/09/97	1100	5.51		86.4	23.9	65																	

Poteau @ Loving	09/09/97	1200	6.15		86.4	24.2	73																	
Poteau @ Loving	09/09/97	1300	6.34		86.2	24.5	75																	
Poteau @ Loving	09/09/97	1400	6.53		86	24.6	79																	
Poteau @ Loving	09/09/97	1500	6.77		86.1	24.9	82																	
Poteau @ Loving	09/09/97	1600	7.05		86	25.2	85																	
Poteau @ Loving	09/09/97	1700	7.51		83.6	25.5	91																	
Poteau @ Loving	09/09/97	1711	7.34		80.5	25.4	89																	
Poteau @ Loving	09/09/97	1800	6.44		85.9	25.3	78																	
Poteau @ Loving	09/09/97	1900	6.21		86.7	25.3	75																	
Poteau @ Loving	09/09/97	2000	6.1		87.1	25.6	75																	
Poteau @ Loving	09/09/97	2100	5.99		87	25.5	72																	
Poteau @ Loving	09/09/97	2200	5.73		86.7	25.3	69																	
Poteau @ Loving	09/09/97	2235	5.57		85.1	25.2	67																	
Poteau @ Loving	09/09/97	2300	5.58		86.8	25.1	68																	
Poteau @ Loving	09/09/97	2400	5.29		87	24.9	64																	
Poteau @ Loving	09/10/97	100	5.4		87.1	24.6	65																	
Poteau @ Loving	09/10/97	200	5.18		87.2	24.5	62																	
Poteau @ Loving	09/10/97	300	5.13		86.9	24.2	61																	
Poteau @ Loving	09/10/97	400	5.07		86.7	24	60																	
Poteau @ Loving	09/10/97	429	5.02		83.2	23.9	60			6.1						0.063	0.019	0.18	0.003		0.4	0.03	6.27	8.96
Poteau @ Loving	09/10/97	500	4.98		86.9	23.8	59																	
Poteau @ Loving	09/10/97	600	4.96		86.6	23.5	58																	
Poteau @ Loving	09/10/97	700	4.71		86.7	23.3	55																	
Poteau @ Loving	09/10/97	800	4.64		86.9	23	54																	
Poteau @ Loving	09/10/97	900	4.62		86.9	23	54																	
Poteau @ Loving	10/8/97	1400	4.9	7.1	95	21.7		1.7	28	5.9	6.4		7.1	49	20	0.165	0.281	0.078	<0.01	0.088	0.44	0.364	<1	2
Poteau @ Loving	12/8/97	1250	11.3	6.7	78	5.6		25	13	6.3	11		6.6	59	93	0.177	0.103	0.11	<0.01	0.12	0.58	<0.02	<1	9
Poteau @ Loving	01/04/98	1900								7	6.77	18			7.5	0.1		0.502	0.002		0.38	<0.05		
Poteau @ Loving	01/05/98	925	9.89	6.43	39	11.8	92																	
Poteau @ Loving	01/05/98	1000								6	<1	14			376	0.59		0.229	0.003		1.57	0.009		
Poteau @ Loving	01/05/98	1500	9.33	6.49	39.5	12.4	87																	
Poteau @ Loving	01/05/98	2100	9.87	6.47	36.8	12.5	92																	
Poteau @ Loving	01/06/98	319	8.97	6.4	39.2	12.5	83			4						0.34	0.084	0.18	0.004		0.85	<0.05	<0.01	16.85
Poteau @ Loving	01/06/98	1520								5	<1	12			65	0.22		0.236	0.003		0.93	0.004		
Poteau @ Loving	02/10/98	2215								6.2	<1	20			72	0.32		0.197	0.004		0.88	0.065		
Poteau @ Loving	02/11/98	1650								2.9	<1	18			70	0.26		0.084	0.003		0.69	0.053		

Poteau @ Loving	02/11/98	2100								3.6	<1	18			36	0.2		0.069	0.003		0.62	0.048		
Poteau @ Loving	2/13/98	750	11.1	6.3	42	7.6		19	6	2.7	6		3.2	41	89	0.082	0.07	0.134	<0.01	0.144	0.38	0.056	1	2
Poteau @ Loving	03/16/98	1020								7	<2	18			27.5	0.12		0.064	0.004		0.6	0.025		
Poteau @ Loving	03/17/98	1300								5	<2	16			59.9	0.2		0.077	0.004		0.83	0.04		
Poteau @ Loving	03/17/98	1630								5	<2	14			45.5	0.18		0.055	0.004		0.9	0.019		
Poteau @ Loving	4/7/98	1410	8.9	7.3	57	17.7		8.8	11	3.6	6.8		4.9	42	92	0.093	0.067	0.002	0.07	0.072	0.31	0.063	3	2
Poteau @ Loving	6/8/98	1255	6.3	7.1	69	23.3		7.5	18	4.1	7.1		5.6	51	87	0.118	0.038	0.203	<0.01	0.213	0.62	0.066	<1	9
Poteau @ Loving	8/12/98	1215	5.1	7.3	119	28.3		5.9	27	10	7.1		12	73	90	0.088	0.025	0.089	<0.01	0.099	0.74	0.069	<1	9
Poteau @ Loving	10/7/98	750	7.6	6.3	49	18.7		41	8	2.5	4.4		2.9	52	91	0.246	0.156	0.739	0.011	0.75	0.85	0.071	<1	7
Poteau @ Loving	11/30/98	1400	8.3	6.8	72	15.3		3.8	20	6.1	7.6		6.2	46	84	--	--		--	--	--	--	<1	4
Poteau @ Loving	2/11/99	800	8.5	6.6	75	15.2		22	12	5.3	9.9		6	56	90	0.1	0.076	0.232	<0.01	0.242	0.46	0.036	1	<1.00
Poteau @ Loving	4/13/99	1300	7.7	6.7	66	18.4		9.6	13	4.1	8.2		5.4	48	100	0.082	0.029	0.134	<0.01	0.144	0.37	<0.02	<1	8
Poteau @ Loving	6/1/99	1340	6.8	6.8	58	22.7		--	13	3.5	6.2		4.3	56	94	0.064	0.039	0.145	<0.01	0.155	0.44	0.025	<1	4
Poteau @ Loving	9/8/99	1145	4.9	7.1	100	25.7		3.6	31	6.1	5.4		8.8	61	83	0.046	<0.01		<0.01	<0.05	0.48	<0.02	<1	6
Poteau @ Loving	10/7/99	910	6.5	7.2	100	15.6		2.2	30	7.5	7.1		10	62	94	0.052	0.021	0.055	<0.01	0.065	0.46	0.033	<1	3
Poteau @ Loving	12/14/99	1315	10.4	6.8	52	8.8		30	8	3.5	5.6		3.7	44	--	0.177	0.054	0.546	<0.01	0.556	0.61	0.047	1	3
Poteau @ Cauthron	09/09/97	1035	5	7.04	178.8	25.25	61	7.63	28.6															
Poteau @ Cauthron	09/09/97	1615	6.4	7.07	179	27	80	8.4	36.8															
Poteau @ Cauthron	09/09/97	2200	6.8	6.83	180	26	84	6.44	35															
Poteau @ Cauthron	09/10/97	400	5.9	6.86	181	22	67	6.44	36.8	20.4						0.071	0.012	0.13	0.001		0.57	0.01	8.75	13.86
Poteau @ Cauthron	01/05/98	945	9.2	5.02	32.2	12.5	85																	
Poteau @ Cauthron	01/05/98	1530	9.2	4.77	32.7	12.6	87																	
Poteau @ Cauthron	01/05/98	2120	9.4	4.93	36.2	12.7	89																	
Poteau @ Cauthron	01/06/98	425	9.6	5.15	41.3	12.5	89			4						0.36	0.113	0.19	0.003		0.74	0.088	4.78	15.58
Poteau @ Hon	09/09/97	1155	6.2	7.36	494	25	75	9.1	60.7															
Poteau @ Hon	09/09/97	1700	6.3	7.58	498	26	78	8.45	75															
Poteau @ Hon	09/09/97	2245	5.4	7.31	483	22	62	8.67	56	65.3						3.21	3.1	1.34	0.031		1.43	0.05	11.29	15.6
Poteau @ Hon	09/10/97	420	5.4	7.36	492	22	62	8.3	65															
Poteau @ Hon	01/05/98	1235	9.4	4.98	36.5	12.3	87																	
Poteau @ Hon	01/05/98	1610	9.6	5.08	41.6	12.3	89																	
Poteau @ Hon	01/05/98	2155	10.4	5.14	48.1	12.9	99																	
Poteau @ Hon	01/06/98	520	9.8	5.26	48.2	12.1	91			5						0.32	0.157	0.3	0.004		0.67	0.027	3.64	10.05
Poteau blw. Waldron	09/09/97	1245	4.5	7.22	686	30	60	11.4	109															
Poteau blw. Waldron	09/09/97	1745	4.2	7.2	677	29.5	55	8.87	109															
Poteau blw. Waldron	09/09/97	2315	3.8	7.14	684	25	46	7.63	103															
Poteau blw. Waldron	09/10/97	500	3.8	7.23	718	25	46	10.5	110	82.1						13.3	12.9	4.79	0.343		2.26	2.05	<1.00	8.06

Poteau blw. Waldron	01/05/98	1040	9.6	5.5	45	11.4	85												
Poteau blw. Waldron	01/05/98	1635	10.2	5.3	46.2	12.7	97												
Poteau blw. Waldron	01/05/98	2225	11	5.32	44.6	12.2	102												
Poteau blw. Waldron	01/06/98	540	10.1	5.37	46.1	12	94		4		0.28	0.126	0.33	0.005		0.73	0.04	1.06	11.78
Poteau abv. Waldron	01/05/98	1105	9.8	5.33	39.3	12	91												
Poteau abv. Waldron	01/05/98	1700	10.1	5.24	45.5	13.9	98												
Poteau abv. Waldron	01/05/98	2250	10.8	5.21	45.1	13.1	102												
Poteau abv. Waldron	01/06/98	605	10.2	5.83	54.3	12.7	97		4		0.22	0.127	0.29	0.003		0.52	<0.05	<0.01	9.31
Black Fork @ Hogdon	03/04/81	100						12		40						0.7			
Black Fork @ Hogdon	05/11/81	100						18		20	0.05					0.44			
Black Fork @ Hogdon	06/08/81	100						15		10	0.15					2			
Black Fork @ Hogdon	02/01/82	100						37		50	0.13		<1						
Black Fork @ Hogdon	03/15/82	100						41		70	0.01		<1						
Black Fork @ Hogdon	05/13/82	100						120		240			0.3						
Black Fork @ Hogdon	12/10/82	100						14		10	0.25		0.2						
Black Fork @ Hogdon	05/16/83	100						18		220			0.1						
Black Fork @ Hogdon	09/09/97	1335	3.75		52.3	26.9	47												
Black Fork @ Hogdon	09/09/97	1919	4.05		54.8	26.7	51												
Black Fork @ Hogdon	09/09/97	2357	2.98		57.7	25.2	36												
Black Fork @ Hogdon	09/10/97	610	2.7		49.6	24	32		3.4		0.033	0.004	0.12	0.002		0.34	0.04	3.89	7.07
Black Fork @ Hodgen	01/05/98	1012	9.72	6.15	29.6	12.1	90												
Black Fork @ Hodgen	01/05/98	1535	10.05	6.21	25	12.6	95												
Black Fork @ Hodgen	01/05/98	2136	9.93	6.2	30.7	12.3	92												
Black Fork @ Hodgen	01/06/98	358	10.23	6.22	30.4	12.4	95		4		0.16	0.01	0.17	0.002		0.83	<0.05	<0.01	10.3
Black Fork (Haw)	12/16/91	1430	11	7.03	103	10	97							0.01	0.14	<0.2	0.03		
Black Fork (Haw)	01/22/92	1415	11.4	6.9	27	7.4	94				0.02			<0.01	0.1	<0.2	0.01		
Black Fork (Haw)	03/11/92	1445	11.6	6.95	28	10	103				<0.01			<0.01	<0.05	<0.2	0.02		
Black Fork (Haw)	04/14/92	1015	7.8	6.83	35	19.6	86				0.01			0.01	0.075	0.4	0.05		
Black Fork (Haw)	05/28/92	815	7.8	6.45	21	15	76				0.02			<0.01	0.07	<0.2	0.03		
Black Fork (Haw)	06/25/92	850	6.4	6.7	30	24.5	76				0.02			<0.01	<0.05	0.2	0.03		
Black Fork (Haw)	07/22/92	820	6.2	6.29	42	25.9	76							<0.01	<0.05	0.3	0.06		
Black Fork (Haw)	07/22/92	845	6.4	6.3	42	26	79												
Black Fork (Haw)	07/22/92	850	6.2	6.29	42	26	76												
Black Fork (Haw)	07/22/92	854	6.2	6.3	42	26	76												
Black Fork (Haw)	07/22/92	858	6.2	6.29	42	26.1	76												
Black Fork (Haw)	07/22/92	902	6.2	6.3	42	26	76												

Black Fork (Haw)	07/22/92	906	6.4	6.3	42	26.2	79						
Black Fork (Haw)	07/22/92	910	6	6.3	42	26.2	74						
Black Fork (Haw)	07/22/92	912	6	6.3	42	26.2	74						
Black Fork (Haw)	07/22/92	916	6.1	6.3	42	26.2	75						
Black Fork (Haw)	07/22/92	920	6	6.3	42	26.2	74						
Black Fork (Haw)	08/25/92	945	4.8		40	25.3	58		<0.01	<0.01	<0.05	0.4	
Black Fork (Haw)	10/15/92	915	7.5	7.15	38	19.4	81	<20	0.02	<0.01	0.063	0.3	0.05
Black Fork (Haw)	11/18/92	1130	9.5	7.01		13.5	90	<20		0.02	0.053	0.2	0.02
Black Fork (Haw)	12/14/92	1400	9.4	6.6	37	12	87	<20		0.03	0.24	0.5	
Black Fork (Haw)	12/14/92	2130	10.4	6.1		11.1	92		0.05	0.02	0.1	0.4	0.04
Black Fork (Haw)	12/15/92	700	10	6.3		9.6	89		0.07	0.03	0.1	0.7	0.04
Black Fork (Haw)	12/15/92	1630	10.9	6.3	21	9.1	94		0.03	0.02	0.11	0.2	0.03
Black Fork (Haw)	12/16/92	900	11.1	6.48	22	8.2	94		0.02	0.01	0.14	<0.2	0.02
Black Fork (Haw)	01/06/93	1230	11.2	6.75	23	8	95	<20	<0.01		0.12	<0.2	
Black Fork (Haw)	02/10/93	930	9.6	7.13	35	9.5	83	<20	0.01		0.14	<0.2	
Black Fork (Haw)	04/01/93	900	7	7.09	28	11.8	65	<20				0.3	
Black Fork (Haw)	05/04/93	1625	10.5	6.99	28	17.5	109	<20	0.02		0.05	0.6	
Black Fork (Haw)	06/17/93	940	6	7.25	36	26.4	74	<20	0.03			0.2	
Black Fork (Haw)	07/21/93	1403	5.9	7.9	49	33.7	84						
Black Fork (Haw)	07/21/93	1406	5.9	7.7	50	32.6	82						
Black Fork (Haw)	07/21/93	1409	5.8	7.5	49	32.3	79						
Black Fork (Haw)	07/21/93	1412	5.6	7.36	49	32	77						
Black Fork (Haw)	07/21/93	1415	5.7	7.29	50	32.1	78						
Black Fork (Haw)	07/21/93	1418	5.6	7.24	50	32.1	77						
Black Fork (Haw)	07/21/93	1421	5.6	7.24	50	32.1	77						
Black Fork (Haw)	07/21/93	1424	5.8	7.24	50	32.1	79						
Black Fork (Haw)	07/21/93	1427	5.8	7.23	50	31.9	79						
Black Fork (Haw)	07/28/93	1245	6.5	7.33	57	32.8	90		0.04			0.5	
Black Fork (Haw)	08/25/93	1430	7.4	7.25	58	31.7	101		0.06			0.5	
Black Fork (Haw)	10/20/93	1000		7.2	27				0.11			0.7	
Black Fork (Haw)	10/27/93	1510	12.8	6.93	33	13.5	121		0.01		0.14	<0.2	
Black Fork (Haw)	11/14/93	457		6.7	33				0.06			0.4	
Black Fork (Haw)	12/02/93	1115		6.61	33				0.06			0.4	
Black Fork (Haw)	12/14/93	1315	10.8	6.6	28	8.2	91		0.03		0.073	0.2	
Black Fork (Haw)	01/12/94	1030	13.2	6.88	35	5.9	106		0.01		0.17	<0.2	
Black Fork (Haw)	01/26/94	1111		6	27				0.06			0.5	

Black Fork (Haw)	02/22/94	700		6.8	35							0.06				0.4	
Black Fork (Haw)	02/22/94	1515	9.5	6.74	25.6	10.5	84					0.06			0.087	0.4	
Black Fork (Haw)	04/11/94	2116		6.28	42							0.13					
Black Fork (Haw)	04/13/94	1330	9.8	6.7	42	16	99					0.03			0.087	0.4	
Black Fork (Haw)	04/29/94	930	6.8	7.07	41	20	75					0.06			0.18	0.6	
Black Fork (Haw)	04/29/94	1515	7.6	7.03	46.8	18.6	82					0.26			0.19	1.1	
Black Fork (Haw)	04/29/94	2145	7.6	7	47	17.6	80					0.19			0.13	0.7	
Black Fork (Haw)	04/30/94	130		6.27	36							0.16			0.21	0.7	
Black Fork (Haw)	04/30/94	700	8.9	6.5	30	15.6	90					0.16			0.083	0.7	
Black Fork (Haw)	04/30/94	1100	8.9	6.5	30	15.2	86					0.12			0.084	0.7	
Black Fork (Haw)	05/12/94	815	7.6	7.14	29	19	82					0.01			0.077	<0.2	
Black Fork (Haw)	06/29/94	1140	6.3	6.99	41	30.3	83					0.04				0.5	
Black Fork (Haw)	07/22/94	800	5.2	6.99	36	26.8	65										
Black Fork (Haw)	07/22/94	804	5.2	7	34	26.7	65										
Black Fork (Haw)	07/22/94	808	5.3	6.99	33	26.8	67										
Black Fork (Haw)	07/22/94	813	5.3	7	33	26.8	67										
Black Fork (Haw)	07/22/94	817	5.3	7	33	26.8	67										
Black Fork (Haw)	07/22/94	821	5.4	6.99	33	26.8	68										
Black Fork (Haw)	07/22/94	825	5.4	6.99	33	26.8	68										
Black Fork (Haw)	07/22/94	828	5.4	6.99	33	26.8	68										
Black Fork (Haw)	07/22/94	833	5.4	7	33	26.7	68										
Black Fork (Haw)	07/22/94	837	5.4	6.99	33	26.7	68										
Black Fork (Haw)	08/11/94	1510	7.3	6.98	43	29.7	97					<0.01				0.4	
Black Fork (Haw)	09/13/94	1630	7.2	7.49	50	28.7	94					0.02				0.5	
Black Fork (Haw)	10/18/94	1400	8.3	6.97	46	20.6	93					0.02			0.06	0.5	
Black Fork (Haw)	12/01/94	1100	10.8	6.7	30	8.8	93					0.02			0.09	<0.2	
Black Fork (Haw)	01/19/95	1130	11.5	7.4	25.4	7.2	95					0.02			0.1	0.2	
Black Fork (Haw)	03/23/95	1005	7.8	6.82	29	20.1	86					0.02				<0.2	
Black Fork (Haw)	04/11/95	610						5	3	14	12	0.03	<0.25	0.01		0.21	<0.05
Black Fork (Haw)	04/11/95	1300						4	<2	10	58.7	0.04	<0.25	0.01		0.44	<0.05
Black Fork (Haw)	04/11/95	1500						5	<2	10	53	0.04	<0.25	0.01		0.41	<0.05
Black Fork (Haw)	04/19/95	1040	8.7	6.87	28	16.9	90					<0.01				<0.2	
Black Fork (Haw)	04/20/95	745						2	1.43	12	28.5	0.05	<0.25	0.01		0.35	0.41
Black Fork (Haw)	04/20/95	900						1.5	1.74	11	30.5	0.14	<0.25	0.01		0.32	0.18
Black Fork (Haw)	05/01/95	600						3	<1	9	155	0.07	<0.25	0.01		0.91	<0.02
Black Fork (Haw)	05/01/95	715						2.5	9.18	13	241	0.08	<0.25	0.01		0.95	<0.02

Black Fork (Haw)	05/01/95	1350						2	1.32	7	44	0.04	<0.25	0.01		0.48	<0.02
Black Fork (Haw)	05/08/95	575						1.9	<5	8	124	0.114	<0.1	0.01		0.81	0.088
Black Fork (Haw)	05/08/95	900						2	<5	8	116	0.138	<0.1	0.01		0.83	0.094
Black Fork (Haw)	05/08/95	1750						2.2	<5	8.6	38	0.059	0.1	0.01		0.38	0.107
Black Fork (Haw)	05/25/95	1235	6	6.59	32	23.7	71					<0.01			0.09	<0.2	
Black Fork (Haw)	06/23/95	725	6.4	6.78	38	25.1	77					0.03				0.4	
Black Fork (Haw)	06/23/95	733	6.2	6.78	37	25.3	75										
Black Fork (Haw)	06/23/95	736	6.1	6.79	37	25.3	74										
Black Fork (Haw)	06/23/95	739	6.4	6.78	37	25.4	77										
Black Fork (Haw)	06/23/95	742	37	6.78	37	25.4	448										
Black Fork (Haw)	06/23/95	745	6	6.78	37	25.4	73										
Black Fork (Haw)	06/23/95	748	6.2	6.78	37	25.4	75										
Black Fork (Haw)	06/23/95	753	6.2	6.79	37	25.4	75										
Black Fork (Haw)	06/23/95	755	6.2	6.78	37	25.4	75										
Black Fork (Haw)	06/23/95	758	6.2	6.78	37	25.4	75										
Black Fork (Haw)	08/18/95	710															
Black Fork (Haw)	09/13/95	720															
Black Fork (Haw)	12/18/95	840						3.5	<2	14	6.5	0.05	0.28			0.46	<0.001
Black Fork (Haw)	07/12/96	1100						3	<2	12	72	0.23	0.15	0.005		1.08	0.112
Black Fork (Haw)	07/12/96	1510						2.5	<2	9	155	0.28	0.085	0.004		1.48	0.057
Black Fork (Haw)	09/26/96	1450						3	<1	20	45.5	0.28	0.38	0.009		0.84	0.05
Black Fork (Haw)	09/26/96	2030						3.2	<1	12	43	0.24	0.24	0.007		0.92	0.02
Black Fork (Haw)	09/27/96	820						2.5	<1	10	42	0.16	0.21	0.005		0.76	0.001
Black Fork (Haw)	10/27/96	2350						3	5.84	10	10	0.06	0.16	0.004		0.24	0.02
Black Fork (Haw)	10/28/96	700						2.5	<1	10.4	277	0.38	0.43	0.002		1.92	0.01
Black Fork (Haw)	10/28/96	1245						2	<1	10	92	0.18	0.36	0.002		1.29	0.03
Black Fork (Haw)	11/17/96	245						3	1.2	10	168	0.31	<0.1	0.005		1.06	0.04
Black Fork (Haw)	11/17/96	634						3	<1	14	62	0.14	<0.1	0.002		0.75	<0.001
Black Fork (Haw)	11/18/96	710						3.5	<1	8	13.3	0.04	0.13	0.002		0.2	<0.001
Black Fork (Haw)	11/24/96	755						4	1.07	8	96	0.19	<0.05	<0.005		0.82	<0.05
Black Fork (Haw)	11/24/96	1430						3.5	1	6	63	0.13	0.068	<0.005		0.57	<0.05
Black Fork (Haw)	11/25/96	700						4	<1	8	18.5	0.07	0.14	<0.005		0.45	0.15
Black Fork (Haw)	02/20/97	540						6	<1	8	212	0.3	0.14	0.002		0.75	<0.01
Black Fork (Haw)	02/20/97	2315						5	<1	12	317	0.35	0.12	0.001		0.98	<0.01
Black Fork (Haw)	02/21/97	1405						5	<1	8	22	0.05	0.19	0.001		0.02	<0.01
Black Fork (Haw)	03/13/97	700						6	<2	16	3.03	0.03	0.145	0.0025		0.252	<0.05

Black Fork (Haw)	03/13/97	1330						5	0.199	18	13.13	0.06		0.084	0.0008	0.271	<0.05		
Black Fork (Haw)	03/13/97	2400						4	0.128	16	5	0.04		0.1	0.0014	0.168	<0.05		
Black Fork (Haw)	06/16/97	2305						5	1.16	32	4.2	0.032		0.16	0.002	0.19	<0.05		
Black Fork (Haw)	06/17/97	555						7	<1	36	76	0.165		0.09	0.007	0.78	<0.05		
Black Fork (Haw)	06/17/97	2355						5	0.652	28	11.5	0.055		0.11	0.004	0.44	<0.05		
Black Fork (Haw)	09/09/97	1030	6.81			24.9	82												
Black Fork (Haw)	09/09/97	1107	5.22		55.3	25.5	63												
Black Fork (Haw)	09/09/97	1130	6.87			26.1	85												
Black Fork (Haw)	09/09/97	1230	7.31			28.3	93												
Black Fork (Haw)	09/09/97	1330	7.5			29.7	99												
Black Fork (Haw)	09/09/97	1430	7.36			31.1	97												
Black Fork (Haw)	09/09/97	1530	7.3			31.6	100												
Black Fork (Haw)	09/09/97	1630	7.1			31.9	97												
Black Fork (Haw)	09/09/97	1730	7.08			30.8	94												
Black Fork (Haw)	09/09/97	1817	11.17		57	29.3	145												
Black Fork (Haw)	09/09/97	1830	7.03			29.3	91												
Black Fork (Haw)	09/09/97	1930	6.34			27.4	80												
Black Fork (Haw)	09/09/97	2030	6.18			26.3	76												
Black Fork (Haw)	09/09/97	2130	5.95			25.9	73												
Black Fork (Haw)	09/09/97	2230	5.72			25.2	69												
Black Fork (Haw)	09/09/97	2324	7.75		51.6	26.1	96												
Black Fork (Haw)	09/09/97	2400	5.47			24.2	65												
Black Fork (Haw)	09/10/97	100	5.44			25.5	66												
Black Fork (Haw)	09/10/97	200	5.38			23.2	63												
Black Fork (Haw)	09/10/97	300	5.52			22.8	64												
Black Fork (Haw)	09/10/97	400	5.63			22.3	64												
Black Fork (Haw)	09/10/97	500	5.69			21.8	65												
Black Fork (Haw)	09/10/97	505	4.7		56.7	23.4	55	3.3				0.022	0.001	0.068	0.001	0.38	0.02	3.54	13.92
Black Fork (Haw)	09/10/97	630	5.56			21.3	62												
Black Fork (Haw)	09/10/97	730	5.79			21.3	65												
Black Fork (Haw)	09/10/97	830	5.81			21	65												
Black Fork (Haw)	09/10/97	900	6.33			21.5	71												
Black Fork (Haw)	01/04/98	1820						5	<1	8	6.3	0.03		0.225	0.001	0.29	<0.05		
Black Fork (Haw)	01/05/98	120						4	<1	8	173	0.3		0.175	0.002	1.31	0.045		
Black Fork (Haw)	01/05/98	1120	10.05	6.17	29.6	11.7	93												
Black Fork (Haw)	01/05/98	1630	10.17	6.09	27.1	12.6	97												

Black Fork (Haw)	01/05/98	2235	10.12	6.15	29.9	12.4	94														
Black Fork (Haw)	01/06/98	426	10.24	6.17	27.6	12.1	95			4				0.06	0.005	0.2	0.001	0.44	<0.05	<0.01	4.2
Black Fork (Haw)	01/06/98	710								5	<1	10	9.8	0.04		0.221	0.001	0.31	<0.05		
Black Fork (Haw)	02/10/98	2130								3.1	<1	20	54.5	0.17		0.063	0.002	0.5	0.054		
Black Fork (Haw)	02/10/98	2430								3.1	<1	10	79.5	0.14		0.047	0.002	0.56	0.04		
Black Fork (Haw)	02/11/98	1715								2.6	<1	10	6.7	0.04		0.087	0.001	0.17	0.028		
Black Fork (Haw)	03/16/98	945								6	<2	10	9	0.03		0.078	0.002	0.47	0.021		
Black Fork (Haw)	03/17/98	700								5	<2	14	9.5	0.04		0.067	0.002	0.41	0.032		
Black Fork (Haw)	03/17/98	1400								6	<2	12	10.5	0.03		0.065	0.003	0.4	0.021		
Blackfork of Poteau	01/11/95	735	10.2	6.32	32	6.8	84	6.9	5.9	4	3.45	10	1.6	0.01		0.273	<0.01	0.25			
Blackfork of Poteau	07/18/95	1500	5.25	6.84	49.5	33.5	73	2.62	13	6	<2	14	1.6	0.01		<0.1		0.32			
Blackfork of Poteau	10/10/95	1345	8.4	5.2	45	22.5	96	2.72	19	4	<2	16	2	0.01		0.11		0.35	<0.1		
Blackfork of Poteau	02/08/96	1145	12.57	6.74	36	7.5	104	6.1	7	4.5	4.96	8	<0.5	0.007		0.29		0.1			
Blackfork of Poteau	04/11/96	1430	10.51	7.1	31.5	17.6	111	6.99	9	4	4.4	10	5	0.02		0.027		0.08			
Blackfork of Poteau	10/09/96	940	6.55	5.77	41	17.8	69	9.35	7.1	3.5	1.7	24	6	0.03	<0.005	0.27	<0.005	0.2			
Blackfork of Poteau	04/01/97	910	9.95	7.01	33	15.6	101	11	5.4	3.1	<1	10	2.67	0.017	0.004	0.04	0.002	0.07			
Blackfork of Poteau	07/07/97	1500	6.59	6.8	44	24.9	80	8.57	15	2.2	2.83	12	5.03	0.022	<0.001	0.12	<0.002	0.21			