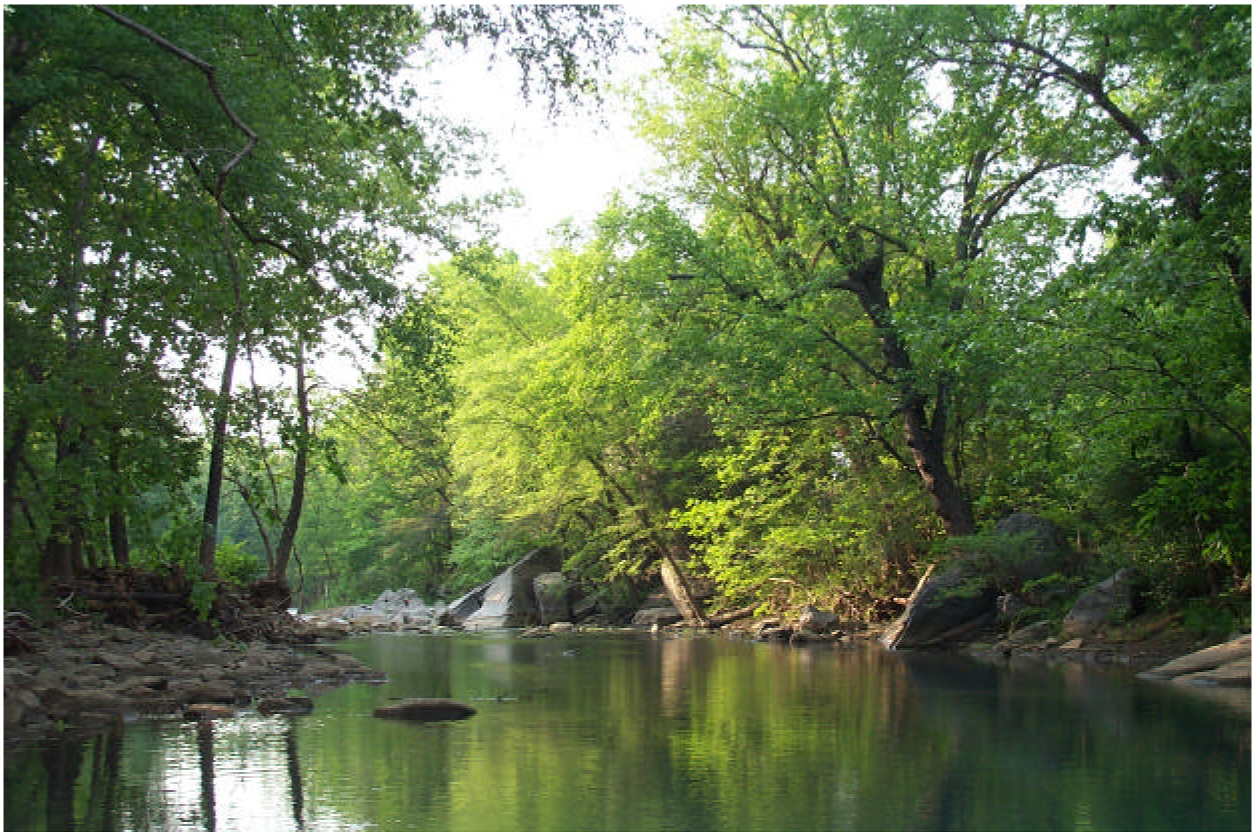
West Fork White River Watershed

Data Inventory and Nonpoint Source Pollution Assessment



Prepared by the Arkansas Department of Environmental Quality

Environmental Preservation Division

for the

Arkansas Soil and Water Conservation Commission

December 3, 2004

WEST FORK-WHITE RIVER WATERSHED - DATA INVENTORY AND NONPOINT SOURCE POLLUTION ASSESSMENT

ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY
ENVIRONMENTAL PRESERVATION DIVISION

Final Report
FY99 CWA Section 319(h)

December 3, 2004

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West Fork White River Project Partners & Acknowledgements

Contributors - the project team would like to thank the contributors for their time, expertise, and the work they performed in the WFWR watershed in cooperation with this project:

- Continuous Monitoring Station: Dr. Marc Nelson, AWRC
- Biological Assessment Survey: Dr. Art Brown, Andrea Radwell, and Robin Reese
- Bank Material Characterization: Dr. Kris Brye

Technical Assistance - the project team would like to thank the following people for providing assistance and their expertise on the project:

- Allen Clingingpeel of the Ouachita National Forrest Service (ONFS) was invaluable in providing information and guidance on evaluating the roadways in the watershed. Allen provided us with methods developed by ONFS on relevant field data collection and assistance on how to use the WEPP: Roads model. With Allen's guidance, the data collected along with the modeling effort can be used to develop a maintenance plan and to track improvements. Allen also provided us with his expertise and experience on evaluating sediment on a watershed scale. We would also like to thank Kelly Whitsett of ONFS for training us on collecting the road data needed for the project and helping us to collect the data. Kelly proved to be an excellent instructor with patience and hands-on experience.
- Chuck Meyer of the National Soil Erosion Research Laboratory (USDA Agriculture Research Service) donated his expertise on using the WEPP model for predicting soil loss from pastures. Chuck provided us assistance whenever we needed it, we picked his brain, and found him to be our ideal pasture WEPP model mentor for this project.
- Lee Silvey of Western Hydrology for his assistance in developing an approach to evaluate the fluvial geomorphology and sediment contributions from stream instability on a watershed basis and his assistance in evaluating the historical flow data.
- Julie Speight and Tom Troxel of the University of Arkansas Cooperative Extension Service for their assistance in evaluating the agricultural activities and estimating cattle numbers in the watershed
- Dr. Tommy Daniel of the University of Arkansas for providing assistance in evaluating phosphorus on a watershed basis. Tommy directed us to information in the literature and how it has been developed and used.
- Dr. H. Don Scott, Marty Mckinney, and Dr. Ralph Davis of the University of Arkansas for their assistance in the area of land use analyses and locating GIS data.

- Dr. Finnley Edwards and Paul Sturm of the Center for Watershed Protection for their assistance with evaluating construction stormwater quality and BMPs; Martin Maner of ADEQ assisting with the evaluation of the West Fork WWTP; and Tim Kresse of ADEQ for his assistance with the septic tank evaluation.

Cooperators - the project team would like to acknowledge the following people for their cooperation on the project:

- The landowners who worked with us to conduct the geomorphologic assessment. Several landowners gave us permission to install permanent cross-sections and then access to their land to collect data during the project. The geomorphologic assessment was an important component of the project that could not have been accomplished without landowner participation.
- The landowners who volunteered to be interviewed on their perspective of the WFWR watershed and how it had changed over the years. These people provided the unique opportunity to provide a local perspective on the WFWR watershed resources and environmental concerns. Also, Aubrey Shepherd for helping the project team to find people to interview for the project and Ellen McNulty of ADEQ for helping with the summary.
- The Beaver Lake Watershed 319 project group which consisted of local conservation districts; local agencies; and the Beaver Lake Watershed Partnership for their input during the course of the project.
- Ken Smith, Rob Fisher, and Melissa Terry of Audubon Arkansas for their willingness to partner with us and do public outreach. Their excellent accomplishments in this area during the course of this project have help to keep stakeholders involved and informed. Also, Ellen McNulty of ADEQ in providing her assistance on effective stakeholder involvement and watershed group activities..
- Arkansas Soil & Water Conservation Commission (ASWCC) and US Environmental Protection Agency (EPA) for providing funding and support for this project. Bob Morgan, who was at ASWCC at the beginning of the project, provided assistance in initiating the project and developing the workplan. Tony Ramick and Bart Dudley of ASWCC also provided assistance during the course of the project.
- Several people spent a considerable amount of time reviewing the draft report and providing us with comments. These people are Martin Maner, Steve Drown, Jim Wise, and Bob Singleton of the ADEQ Water Division; Dick Cassat of ADEQ Technical Services Division; Mary Leath of ADEQ; Allen Clingingpeel and Kelly Whitsett of ONFS; Tom Davenport of US EPA; Tony Ramick of ASWCC; and Chuck Meyer of USDA – ARS. The project team found their comments to be invaluable and helpful in refining the final report.

Finally, the project team is very grateful to everyone who participated in this project. The project has been so successful, because of the willingness of all of these partners to work together to understand environmental conditions, problems, and solutions. The project team looks forward to continuing the watershed approach process and contributing to the restoration of the West Fork White River watershed. Also, a big thanks to anyone who helped that we forgot to include on our list. If we accidentally forgot you, we can still include you by changing the electronic file! So let us know!

Executive Summary

The West Fork White River (WFWR) in Northwest Arkansas has the potential to be an outstanding resource for both the watershed residents and those who reside in this Ozark Mountain region. The quality and beauty of the WFWR watershed's natural environment is one reason that people have been drawn to the area. At the same time, the WFWR watershed is host to a variety of land uses that have the potential to adversely affect local water quality as well as impact the downstream drinking water resources of Beaver Reservoir. Impacts to water quality of the WFWR can affect aesthetics, aquatic biology, water treatment costs, and the recreational opportunities that it provides along with the downstream impoundments.

A watershed-based assessment was conducted to evaluate the conditions that have the potential to impact water resources of WFWR. The following activities were conducted: 1) existing water quality and flow data were reviewed, summarized, and evaluated; 2) natural characteristics and land uses of the watershed were evaluated and summarized; 3) land use changes, stream geomorphology, and channel pattern changes were evaluated; 4) Using GIS data, existing data, published coefficients, and field data collected during the project, potential causes and sources of contaminants were identified; and 5) sediment and nutrient loads from potential sources were estimated and BMPs were recommended to reduce sources of contamination. This study provides information, data, and assessment needed for local watershed planning by a WFWR stakeholder group. The results of this study can be used to prioritize critical areas; secure funding for BMP implementation and restoration; and develop long-range strategies for pollution prevention and environmental protection for the WFWR watershed.

The following is a summary of highlighted results and recommendations from the study:

The WFWR watershed is a 124 square mile area or 79,629 acres. Based on a detailed land use evaluation, the majority of the land in the WFWR watershed is forested (59%) with the remaining portions of the watershed being composed of agricultural (29%) and urban land uses 12%. Results of reviewing historical and recent water quality data included 1) the WFWR is a Arkansas 303 (d) listed stream, because the ADEQ had assessed aquatic life use as "not supported" in 33.4 miles from "high turbidity levels and excessive silt loads;" 2) historically, average turbidity values in the WFWR are higher that other streams in the Upper White River basin; and 3) the fish species have declined since 1963 with an increase in tolerant species and a decline in sensitive species.

Urban land-use has increased in the WFWR watershed since 1977. Based on a comparison of land-use data from 1977 to data from 2000, urban areas have increased in the watershed by 22%. Increases in urban land-use area generally results in greater amounts of impervious surface. Impervious surfaces cause changes in local hydrology and have the potential to increase downstream erosion and reduce aquatic habitat. As the urban areas within the watershed continue to expand, modern concepts of development, such as low impact development, should be considered to minimize the increase of impervious surfaces in the watershed.

Fluvial geomorphologic surveys were conducted throughout the watershed and along the main stem of the WFWR. Permanent Survey Site #5 was by far the most unstable site of all sites that

were surveyed. A natural channel design approach could be used to restore this site to ensure long-term stability, maintain natural aesthetics, and to maximize aquatic habitat.

Several cross-sections of permanent survey sites would be suitable for use as references for stream channel cross-section dimensions and for stream restoration using a natural channel design approach. Some surveyed sites would also provide a good example for riparian area restoration.

Significant changes to stream pattern have occurred over the past 40 years. Floodplain areas that were cleared of vegetation were frequently sites where the river has formed a meander cut-off. Several meander cut-offs have resulted in an overall shortening of the length of the WFWR. It appeared that streambank erosion accelerated for a number of evaluated areas during the period from 1980 to 2000. In general, it appeared that the amount of forested floodplain increased during the period from 1942 to 2000. Two sites where in-stream gravel mining is known to have occurred in the past have undergone significant changes in channel pattern.

Several long-time residents of the WFWR were interviewed. Many of those interviewed, described the WFWR as appearing muddier or murkier. There was a general opinion that the depths of pools in the watershed had decreased. Most of those interviewed believe that the quality of the water in the WFWR has declined based on their visual observations over the years.

Arkansas Audubon has initiated the formation of a stakeholder-based watershed group and a technical advisory group to collect input about areas of concern in the watershed. The group is in the process of creating a watershed restoration business plan.

Sediment

Potential causes and sources of sediment that could contribute to the high turbidity values in the WFWR watershed were identified and are shown in Table ES-1. Sediment loads of particles that were 2 mm or less were estimated for the potential sources. Please note that the sediment load values in the table are not absolute values. The estimates were made using logical assumptions for the existing watershed conditions; literature values; field and existing environmental data; and simple to complex models. Assumptions, data, and ranges of literature values can be found in Section 5.1 for each source category. The purpose of these estimates is for planning only, so that restoration efforts and BMP implementation can be better directed to where the most likely beneficial sediment reduction can occur. Results of this study should be used to prioritize critical areas for treatment or restoration, so that sediment reduction is maximized as resources become available. A paper was presented on the WFWR sediment evaluation at the ASAE Conference "Self-Sustaining Solutions for Streams, Wetlands, and Watersheds" held in St. Paul, Minnesota, September 12-15, 2004. This paper can be found in Appendix – ES.

Table ES-1 Summary of potential sources of sediment, estimated loads for the WFWR watershed. Please see Section 5.1 for assumptions, data, and range of literature values.

Land Use	Annual Sediment Load for each Subcategory (tons)		Percent of total estimated Sediment Load		Total % for Land use
	Total	=2mm	=2mm	>2mm	
Pasture	1,709	1,709	4.8%	n/a	4.8%
Forest	391	391	1.1%	n/a	1.1%
* Harvested	8	8			
Urban	1,104	1,104	10.9%	n/a	10.9%
* Construction	2,787	2,787			
NPDES Permits			0.02%	n/a	0.02%
* WF-WWTP	0.5	0.5			
* WF Quarry	7.5	7.5			
Roadways & Ditches			14.4%	2.7%	17.1%
* Unpaved (gravel, spot, native)	4,500	4,500			
* Paved highways	122	122			
* Residential	34	34			
* I - 540	272	272			
* Gullies from I - 540	1,210	240			
Streambank Erosion			43.0%	23.1%	66.1%
* Main Branch	18,532	12,375			
* Tributaries	5,118	3,016			

The average annual sediment load from sources evaluated for the WFWR watershed was estimated to be 35,795 tons. Particles with a diameter of less than or equal to 2 mm were 26,566 tons per year, or 74% of the total sediment load. Natural erosion processes were estimated to be contributing 1,439 tons per year or 4% of the total sediment load. Based on these sediment load estimates, one can conclude that excessive amounts of sediment are entering the WFWR and need to be addressed.

Using the data collected at the AWRC WFWR CM station near the confluence of the river, the average TSS load for 2002 and 2003 was 14,870 tons/yr. Applying the relationship between TSS and SSC resulted in an average annual SSC load of 21,690 tons/yr, which is 82% of the study estimated sediment load of 26,566 tons/yr (particles less than or equal to 2 mm) from the watershed assessment. Also, based on the water quality data collected, a reduction in sediment from sources in the WFWR watershed should result in a reduction in TSS concentrations and improve turbidity.

As shown in Table ES-1, sediment from streambanks showing indications of accelerated erosion was found to contribute 66.1% of the total sediment load. Sediment load estimates of roadways & ditches (including I-540 gullies) contributed 17.1%; the urban area (including construction) sediment load estimate contributed 10.9%; the pasture area sediment load estimate contributed 4.8%; and other sources contributed 1.1%. The results of this study are a valuable resource for watershed planning, and each source's contribution to the total sediment load should be considered during the prioritization process. Other factors to be considered with sediment load contribution include sub-watershed impacts, habitat impact, size of affected area to be addressed, potential improvement to water quality, etc. Also, local stakeholder involvement in the watershed planning process is a key element for 1) developing a successful sediment reduction plan and watershed restoration strategies and 2) successfully implementing the plan and strategies. Causes of excessive sediment from the sources evaluated are complex and difficult to define and do not point to any single source in the watershed.

Effective solutions that will address turbidity and sediment issues in the WFWR watershed will require 1) an understanding of the sediment sources and their impact on water quality and habitat and 2) the development of partnerships between stakeholders. Sediment loads, causes of excessive sediment, priority areas, BMPs needed to reduce sediment loads, expected reductions, and management implications are summarized below:

Pasture

The sediment load estimate for pasture in the WFWR watershed was 1,709 tons/year coming from the 19,417 acres of pasture in the watershed. The cause of sediment loads from pastures is rill and sheet erosion of pasture soils. Higher erodibility of soils and steep slopes will generate greater sediment loads from erosion of pastures. The sediment from erosion of pastures can be compounded when permanent feeding areas during the winter months are created for cattle. Manure and cattle hoof shear destroy the forage, expose the bare ground, and create an additional source of sediment.

- **Priority Areas:** Pastures with Enders soils and an average slope of 8% or greater comprised, approximately, 78% of the estimated pasture sediment load. These pastures comprise only 38% of the total pasture area. Because of the high erodibility of the Enders soils and the steep slopes; the high ratio of sediment load to affected area; and the reduction of landowners needing to be involved these pastures should be given high priority for implementation of conservation BMPs.
- **Recommended BMPs:** To reduce sediment from pastures the following BMPs could be considered for implementation: Pasture renovation during the Spring or Fall seasons to increase the soil infiltration rate; vegetative filters of 50 feet or more near drainage areas; rotational grazing; alternative watering sources, such as, movable containers; shrub buffers or grass buffers with a fence; and planting both cool and warm season forage to promote growth all year.
- **Expected Reduction:** Depending on the practice, expected sediment reductions range from 30% to 74% (U.S. EPA, 2003) and (ADEQ, 2004). If one or more of these practices are implemented within the critical areas and taking an average of the percent reduction range, the expected reduction in sediment delivery to the stream is approximately 52 %.
- **Management Implications:** Improvement in pasture management to reduce sediment will also help to reduce nutrient runoff and improve wildlife habitat. For example, rotational grazing and alternative watering sources not only promote healthy forage which will reduce sediment runoff, but it helps to distribute cattle manure over the entire pasture which will reduce destruction of forage and subsequent soil disturbance associated with loafing areas. Creating riparian buffers along drainages and the stream not only filters sediment and nutrients, but it creates habitat for both terrestrial and aquatic life. Riparian buffers go beyond BMP implementation and actually contribute to the restoration process. Another

factor that should be considered regarding improved pasture management is the number of landowners that would be involved to address the source. Well over a hundred landowners would be involved and working with this number of landowners to change current or add new management practices presents a challenge to reducing sediment from pastures.

Forest

The forests in the WFWR watershed comprise approximately 58.5% of the total watershed area. Most of the forest in the watershed remains undisturbed and the load shown in Table 5-15, is the background level of sediment that would result from natural erosion processes. The coefficient is 0.008 tons/acre/year. If the watershed was completely forested, this is the natural erosion or the background level that would be expected for sediment.

- **Priority Areas:** Forests do not need to be targeted for BMPs to reduce sediment. But, forest may be harvested for its lumber or it could be cut for the development of a building site. The clearing of forest for development purposes will be discussed under urban/construction. All sites that are harvested for lumber should be done so with care, but again the sites with Enders soils and slopes of 8% or greater should be given priority.
- **Recommended BMPs:** It is recommended for any silviculture activities in the WFWR watershed, that BMPs be implemented that follow the AFC's guidelines (AFC, 2002).
- **Management Implications:** The estimate for harvested forest contributed a very small percentage to the total sediment load, but it can have a significant local impact to the area where the cut takes place. A landowner downstream of a forest cut without BMPs on a steep slope can loose the clarity of his pond and stream. Also, these types of cuts are an eyesore for watershed residents and visitors. Harvesting trees in an environmentally sensitive manner can minimize the impact on habitat and water quality and help to retain the monetary value of the landowner's property.

Urban and Construction

Urban land use in the watershed was 12.2% of the total area and the total sediment load, excluding roads, was estimated to be 3,891 tons/year. This was the third highest estimated annual load of sediment being delivered to the WFWR. The estimated sediment load for construction activity was 72% of the total estimated load from urban areas (without roads). On a per acre basis, it was estimated that construction sites without BMPs are contributing 9.9 tons/acre of sediment, annually. Forest and pasture land uses were estimated to contribute 0.02 tons/acre and 0.09 tons/acre, respectively.

- **Priority Areas:** On a per acre basis, sediment contributions from construction sites without BMPs are, approximately, 100 and 1000 times greater than pasture and forest land uses, respectively. Therefore, all construction sites should be made a priority for BMP implementation. Also, they should be made a priority because developers and builders are required by federal and state regulations to implement BMPs to reduce sediment during the construction activities.
- **Recommended BMPs:** Edwards, et al. found a 94% reduction in sediment concentrations in stormwater runoff by using straw mulch at construction sites; therefore, this practice

should be included in the BMP implementation plan for construction sites. Also, it is recommended that developers and builders minimize the trees and other vegetation they remove and incorporate as many of the natural features as possible into the site design, including the minimization of soil disturbance and the importing of materials. Construction activities at large sites should be phased to reduce the amount of exposed soils. All of these activities will help to minimize the exposure of soils and destruction of habitat. Trees that have to be cut should be used for lumber, fiber, or firewood instead of burned, which creates unnecessary air pollutants. Also, using materials and designs that reduce the percent impervious area created at a development site is recommended.

- **Expected Reduction:** Data shows that with proper BMP implementation at construction sites, the sediment load from these sites can be reduced by as much as 94%.
- **Management Implications:** Environmentally sensitive development methods can result in increased property values for developers and builders as well as support local environmental stewardship. Developing land without BMPs may be one of the most drastic means of changing land use in a watershed that result in destruction of habitat, exposure of erodible material, and reduced infiltration rates at the sites. First, construction sites, generally, are next to storm water diversions that lead to our streams; therefore, there is little buffer to filter sediment or other contaminants from these sites. Second, the land use of the sites being developed are typically forest, transition, or pasture, which on a per acre basis, generates much less sediment when compared to construction sites or even the final land use. Also, the original land use, especially forest, are providing habitat to wildlife that is lost during construction. It is not uncommon, either, that during construction, small headwater streams, channelized, hardened, routed through concrete pipes, or filled-in. This results in changes in downstream hydrology, such as higher flows and more frequent flood events, as stormwater is delivered more rapidly to receiving streams. And, finally, the finished development site, a home/commercial building/parking lot, creates additional impervious area in the watershed, further increasing the effect of the development on watershed ecology. Infiltration rates are drastically changed by the time the development is completed. Therefore, developing these sites using low impact development methods to minimize the impacts to the overall ecology of the watershed should be a priority.

Permitted Facilities

Facilities that have NPDES permits are required to meet their permit limits. Any additional measures taken would be on a voluntary basis by the facility. If these facilities are interested, assistance can be provided to evaluate the possibility of further decreasing their TSS loads.

Roadways and Ditches

With an estimated sediment load of 5,168 tons/year, roadways and ditches were the second highest contributed of sediment in the WFWR watershed. The unpaved roads are contributing 87% of the sediment from roadways and ditches. I-540 and the gullies along its corridor are contributing 10% of the sediment from roadways and ditches, while the highways and residential are contributing approximately 3%.

- **Priority Areas:** The roadway and ditches evaluation showed that 75% of the sediment from unpaved roads was from roads with gravel and spot (native & gravel) surface with ditches. These roads should be given priority for BMP implementation with the focus being on the roads with the highest slopes first. Also, the gullies on the I-540 corridor were less than 0.3% of the affected area, but it was estimated that they were contributing 5% of the sediment from this category. Therefore, addressing the gullies should be given priority.
- **Recommended BMPs:** If there is an interest from the Washington County Road Government, a sediment reduction program could be developed and implemented in the WFWR watershed. BMPs that would be considered include hydro-mulching ditches; routine maintenance of culverts and wing ditches; elimination of creating roadside berms; improving wing ditch placement; and modifying grading methods to minimize availability of sediment for transport to streams; and installing fish passages. I-540 has two sources of sediment associated with it: ditches and gullies. If the ADHT was interested, a sediment control program that includes habitat improvement could be developed and implemented for the highway corridor. Sediment reduction of the residential area could be decreased, if the city was interested in using a sweeping unit as part of their maintenance program.
- **Expected Reduction:** The expected reduction in sediment would be 29% for unpaved roads. Expected reduction from the highway ditches would be 29%. If 50% of the gullies were addressed, the gully erosion input would be reduced by 50%.
- **Management Implications**: Sediment can be reduced from roadways and ditches if an effective management plan is developed and implemented. But it is important to note that roadway drainage systems commonly create fish passage barriers. Therefore, to improve aquatic habitat, the management plan needs to include installing fish passages in needed areas. The project team observed that the paved highways had good vegetative cover in the ditches. This practice should be implemented throughout the road system. This would involve working with the county, the city, and the ADHT. In fact, a cohesive roadway management plan that addresses both sediment reduction and habitat could be developed by these three entities. This would save resources and promote cooperation in the WFWR watershed.

Stream Bank Erosion Increase from riparian removal, channel alteration, increase runoff

The study showed stream bank erosion sediment loads to be the largest contributed to sediment in the watershed. The total annual sediment load estimate for the WFWR watershed was 26,550 tons for particles less than or equal to 2 mm in size. Streambank erosion contributed 58% of this total load and was approximate 3 times the sediment load from roadways and ditches, which were the second highest, contributed of sediment to the WFWR. Also, 80% of the sediment from streambank erosion came from seven miles of banks along the main stem of the WFWR. This is a relatively small area to address when compared to the number of acres of pasture and urban areas and the number of miles of roadways and ditches. Because of its high sediment contribution and small affected area, further discussion on the causes of increased streambank erosion is warranted.

The cause of stream instability, which results in increase streambank erosion, involves all of the land uses of the watershed. Generally, stream instability it is not something that occurs in a short period of time, but it is the result of an accumulation of changes in a watershed over a period of time (see Chapter 4). But, a stream can become unstable "over night" if drastic alterations to its dimension, pattern, profile, and/or sediment supply are made. Also, no land use, both past and present, can escape having some connection with this problem. For example, increases in runoff from land, increases the energy input into the stream channels, which in turn can increase erosion. Increase runoff from the land occurs from changing the infiltration rates of the watershed by the conversion of forest land to pasture, urban land, roadways, or any land use that results in lower infiltration rates. These activities have a cumulative affect, and it is difficult to reverse this process once the land use change has occurred. In fact this process began over 100 years ago with the harvesting of the great white oak trees and the ability to export the lumber with the completion of the railroad (see Chapters 3 & 4). Changing the stream channel geometry resulted from the straightening of the river; gravel mining within the bankfull channel; redesigning natural channels to be concrete conduits for urban runoff; etc. These types of changes can result in the system not being able to transport its sediment load. Once this happens, the stream works away at it own channel to find an equilibrium or balance again. Last, the removal of established riparian contributes to instability. Established, healthy riparian contributes to the system's ability to maintain its dimension, pattern, and profile with natural levels of erosion occurring. Removal of riparian decreases the bank protection needed for energy dissipation during high flow events and can initiate the instability process, which can then be compounded by the other causes listed above. As mentioned in the Section 5.1.1, the solutions to stream instability are confined to the current land uses and, typically, are a response to the current watershed condition. For example, repairing the changes in the watershed hydrology would be very difficult, but restoration designs can address current and projected future conditions of the WFWR watershed.

- **Priority Areas:** Inventoried streambanks including WF3, WF4, WF5, and WF6 contributed 25% of the sediment (particles less than 2 mm) from streambank erosion. These banks were a combined 0.67 miles in length, and the reach containing these banks should be given "high" priority for restoration. Other reaches that should be considered priority areas include those with banks having combinations of very high to extreme BEHI ratings and moderate to extreme NBSS ratings.
- **Recommended BMPs/Restoration:** It is recommended that reach restoration should be used to reduce streambank erosion to natural level using a natural channel design approach. The natural channel design not only reduces erosion rates and subsequent sediment loads, but it will improve both aquatic and terrestrial habitat. Specific BMPs that would be part of the restoration design include the installation of grade control structures; development of bankfull benches; re-establishing channel geometry for existing bankfull discharge; and restoring riparian areas.
- **Expected Reduction:** Restoring the reach that includes inventoried streambanks WF3, WF4, WF5, and WF6 would result in a 25% reduction of sediment resulting from the erosion of inventoried banks.
- **Management Implications**: Using a natural channel design approach to restore reaches that are no longer stable can reduce the sediment load to the WFWR, can improve fish and wildlife habitat, and will help to improve the recreation quality of the WFWR. Implementation of a restoration design on most reaches will require the cooperation of several landowners and resource organizations. Restoration designs utilizing a natural channel design approach are often more costly than simple streambank stabilization.

However, natural channel designs will result in a long-term, holistic solution for the watershed as opposed to streambank stabilization which generally does not improve habitat and has a potentially high failure rate when applied to unstable fluvial systems. Though it is important to restore unstable reaches, it is also important to include watershed management activities that can reduce causes of stream instability and prevent future problems. Some of the other BMPs that have been recommended for other sources will also help to promote stream stability, such as, increasing infiltration rates for pastures and urban areas and maintaining healthy stream riparian areas and, when possible, restoring stream corridors. Restoration of the stream channel at selected reaches will be ineffective if gravel mining, that is not part of a restoration maintenance plan, continues within the bankfull channel or near enough to the channel to influence sediment transport during high flow events. While performing watershed planning it is important to consider natural channel design over traditional engineering designs for urban streams needing restoration and to consider the natural channel system, when constructing new bridges.

Nutrients

Nutrients have not been identified by the ADEQ as causing a water quality problem in the WFWR watershed. But, part of watershed planning is to evaluate potential problems and look to reduce loads of any contaminant that may cause impairment in the future. Also, the WFWR watershed is located in a nutrient rich watershed; therefore, nutrients were evaluated to provide information for planning purposes. Sources of nutrients and estimated loads can be found in Table ES-2. Again, these values are not absolute, but are estimates based on available data, watershed conditions, and literature values. They are to be used for planning purposes only. Assumptions, data, and ranges of literature values can be found in Section 5.2 for each source category.

Table ES-2 Estimated annual nutrient loads for land uses in the WFWR watershed. Please see Section 5.2 for assumptions, data, and range of literature values.

Land Use	Effected Area (ac)	Estimated Annual Load for Total Phosphorus (Tons)	Estimated Annual Load for Total Nitrogen (Tons)
Pasture • **Runoff** • **Congregated cattle (10% of total cattle)**	19,413	10.2 1.1	42.7 2.9
Forest	46,539	0.8	7.8
Urban (fertilizers, yard clippings, wastewater infrastructure leakage, pets, litter, etc.)	9,710	3.8	25.3
Permitted Facilities: • WF-WWTP	N/A	0.9	3.2
Septic Tanks	N/A	0.5	1.2
Other Sources • **Golf course**	110	0.05	0.2

Pasture: The phosphorus and nitrogen loads estimated for pasture was 10.2 and 58.2 tons/year, respectively, over 19,413 acres. The critical areas for nutrient loads from pasture would be similar to the areas critical for erosion, pastures with an average slope of 8% or greater. It is recommended that BMPs be focus in these areas, but for nutrients, it is important that manure and fertilizer application methods minimize runoff. BMPs recommended to reduce nutrients are: vegetative filters of 100 feet or more near drainage areas, where manures and fertilizers are not applied; increasing infiltration rates; not applying manures on slopes of 15% or greater; adjusting application rates to minimize over-application of phosphorus; applying manures and fertilizers during the time of year for optimum forage growth; and promoting forage growth all year. Also, nutrient inputs can be reduced by minimizing the time cattle spend near drainage areas by providing alternative watering and shade sources away from the drainage areas. Pasture renovation should be considered, also.

Forest: Most of the forest in the watershed remains undisturbed and the estimated values of 0.8 tons of phosphorus and 7.8 tons of nitrogen represent the background levels you would expect from the acres of forest in the watershed.

Urban and Construction: The urban land use of the watershed was 12.2% of the total area. The estimated nutrient loads load for urban land use was estimated to be 3.8 and 25.3 tons of total phosphorus and nitrogen, respectively. It is recommended that public outreach on reducing nitrogen and phosphorus contributions from urban areas be conducted.

Permitted Facilities: Facilities that have NPDES permits are required by law to meet the conditions stated in the facility permit. Any additional measures taken would be performed on a voluntary basis by the facility as a pollution prevention effort. Additional phosphorus treatment could be incorporated into the WF-WWTP to reduce effluent concentration to 1 mg/L; however, such an upgrade would likely be prohibitively expensive.

Septic Tanks: There are 1400 septic systems in the watershed and nutrient inputs from these systems are a concern. Conservative estimates indicate that the load of phosphorus from failing septic systems could be as high as 0.5 ton/yr. It is recommended that the condition of septic systems in the watershed be evaluated and this potential source be further evaluated.

Other Sources: The golf course was the only other source that was considered significant. Reducing nutrient loads from the golf course could be easily done by providing information and training to the facility.

In summary, the data and information presented in this report are fundamental for performing successful, long-range watershed planning. Potential causes and sources of sediment have been identified along with critical areas that need to be given priority for BMP implementation and restoration. The larger sediment contributors, such as, streambank erosion from stream instability, are not the only sources that need to be addressed. There are several smaller sources of sediment that were identified that could be having a more localized impact on the smaller tributaries. It is important to note, that the largest contributor of sediment involves the land use of several entities; therefore, to restore the stream stability in critical areas will involve several partners working together, cooperatively. Potential sources of nutrients were also identified and came from a wide variety of land use activities. Again, the smaller source contributors still need to be addressed, because of their potential local impact to water quality. An array of BMPs has been recommended that will reduce nutrient loads to the WFWR watershed. Again, addressing sediment and other contaminants in the WFWR will involve several partners working together to better inform watershed residents, both urban and rural, on voluntary measures they can take to improve the condition of the WFWR watershed.

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Chapter 1: Introduction

1.1 Project Description

Understanding the causes and sources of water quality problems is critical to developing practical solutions and long-term strategies that can result in watershed restoration. The West Fork White River (WFWR) watershed, located in Northwest Arkansas, covers an area of 124 mi^2. The river is a major tributary of Beaver Lake, which is the primary drinking water source for over 300,000 people in Northwest Arkansas (Fortenberry, 2004). Both of these drainages are located in the Beaver Reservoir Hydrologic Unit Area (HUA) – 11010001 as shown in Figure 1-1. The State Water Quality Inventory Report of 1998, prepared by ADEQ pursuant to section 305(b) of the Federal Water Pollution Control Act, had assessed aquatic life use as "not supported" in 33.4 miles of the WFWR. The major causes cited were 'high turbidity levels and excessive silt loads.' The probable sources listed were: (1) agricultural land clearing; (2) road construction and maintenance; and (3) gravel removal from stream beds. Based on the results of the inventory report, the WFWR was added to the State's list of impaired waters known as 303(d) list by the ADEQ in 1998 (ADPC&E, 1998).

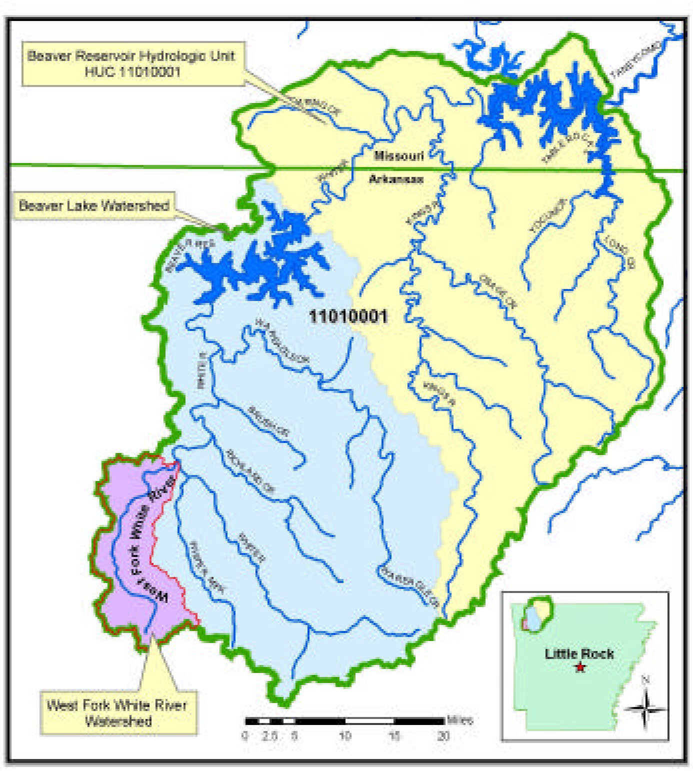

Figure 1-1 Location of the West Fork White River Assessment Project, Beaver Lake Watershed, Beaver Reservoir HUA

The purpose of this study was to perform a watershed-based assessment to help address the causes of "high turbidity levels and excessive silt loads" and other potential problems in the WFWR watershed. Potential causes and sources of water quality contamination were identified and the pollution potentials of identified sources were estimated. The results of the watershed analysis of the WFWR are to be used for planning purposes, so that available resources can be directed to problem areas where the most benefit to the watershed will occur. This assessment was funded through the U.S. Environmental Protection Agency's 319 grant program, administered by the Arkansas Soil and Water Conservation Commission. Specific objectives of this watershed-based assessment include:

- Develop a resource inventory of existing water quality and GIS data
- Perform a geomorphologic assessment of the WFWR
- Identify probable causes and sources of water quality contaminants in the WFWR watershed

- Determine pollution potential of identified sources of water quality contaminants
  Extensive amounts of data were collected throughout the watershed, which included information about streambanks, gravel roads, pastures, urban areas, as well as other land uses in the watershed. Collected field data along with modeling methods were used to estimate sediment loads. In addition, other contaminant source loads were estimated using environmental data, GIS data, simple models, and complex models. Management practices that will effectively control contaminant loading to the WFWR were identified. The results of this study will be used by a local stakeholder group to prioritize source reduction efforts and to develop restoration strategies as part of a WFWR watershed management plan.

The WFWR is part of the headwaters of the White River Basin, which winds its way through NW Arkansas, SW Missouri, and then back to Arkansas where it eventually converges with the Mississippi River. The WFWR watershed has an area of approximately 124 square miles or 79,360 acres and is nestled in the Boston Mountains of Washington County (Figure1-2). The watershed is in large part, steep and stony, and covered with hardwoods. The watershed includes the cities of West Fork, Greenland, and Winslow, along with the southwest corner of the city of Fayetteville. Historically, the stream has been used as a drinking water source, as well as a much loved recreational site by the local people. The river, in the past, was known for its deep swimming holes and the quality of its smallmouth bass fishery. The watershed has seen many changes over the past 100 years. Around the turn of the 20th century, its virgin timber became a major source of railroad ties and other wood products (Figure 1-3). As use of resources have changed over time, the watershed faces new challenges. One of the major new challenges includes an increasing human population of the area. Without adequate and forward-thinking planning, increases in the population can strain the remaining resources and integrity of the WFWR watershed.

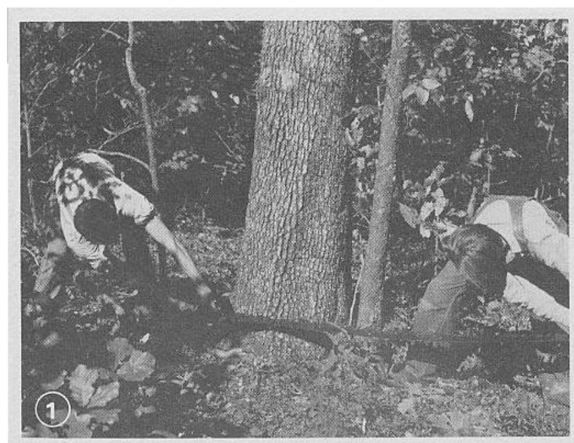

Figure 1-2 Harvesting of significant amounts of hardwoods occurred in the West Fork White River watershed at the turn of the century.

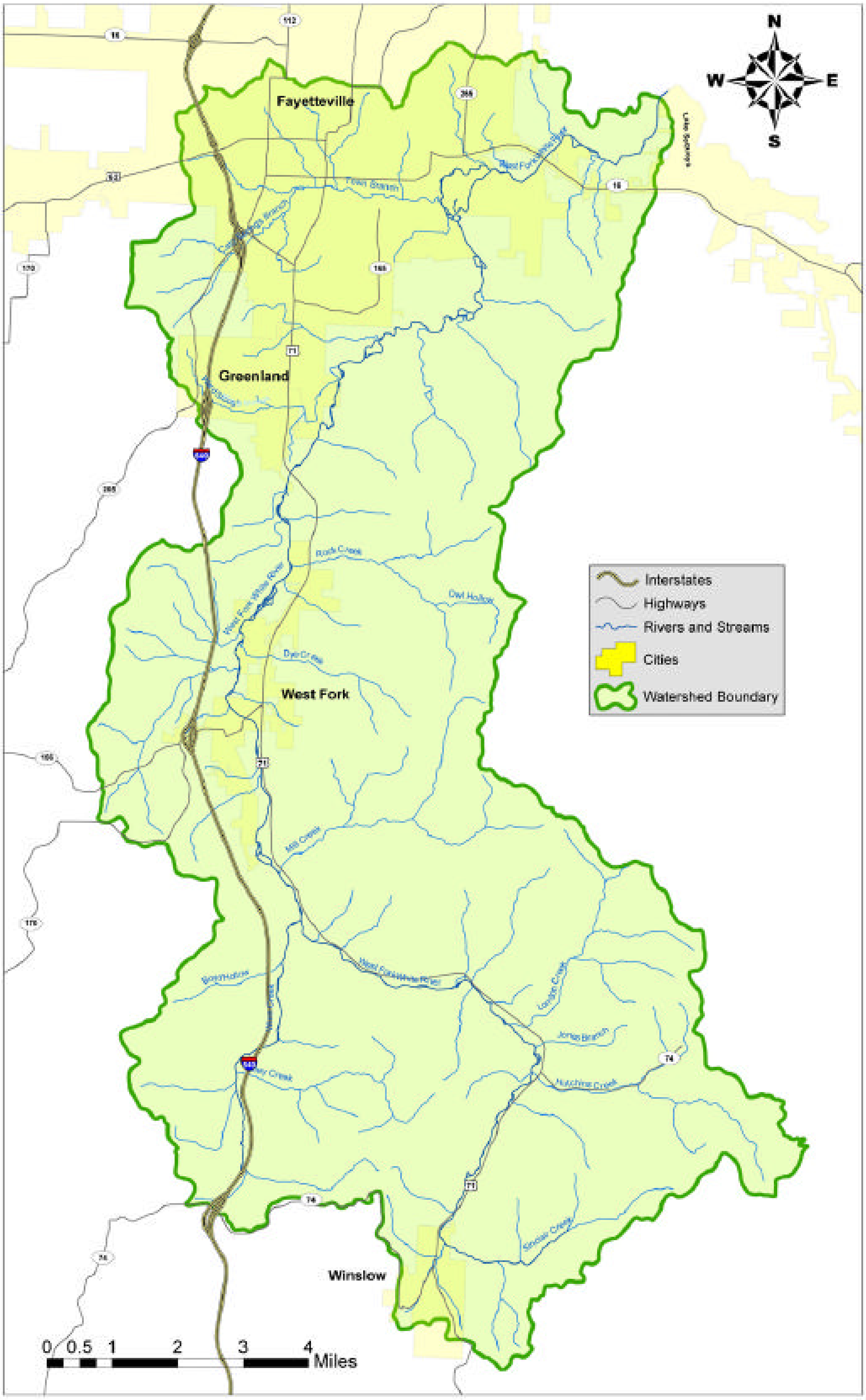

Figure 1-3 The WFWR watershed in Northwest Arkansas

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1.2 References

1. Arkansas Department of Pollution Control and Ecology. Water Quality inventory Report. Agency Report Prepared pursuant to Section 305(b) of the Federal Water Pollution Control Act. 1998.

2. Fortenberry, Alan, 2004, Beaver Water District, Personal Communication

Chapter 2: Water Quality and Flow Data

2.1 Literature Search

A literature search was performed to identify sources of water quality data and other environmental data that was related to the WFWR. Twenty-seven sources were found that were related to the Upper White River Basin (Appendix 2-A), but only a few of these sources had data or information specific to the WFWR. Most of the sources found focused on Beaver Lake or Washington County as a whole. Sources related to the WFWR and Washington County were used to evaluate the watershed conditions and are referenced throughout this report.

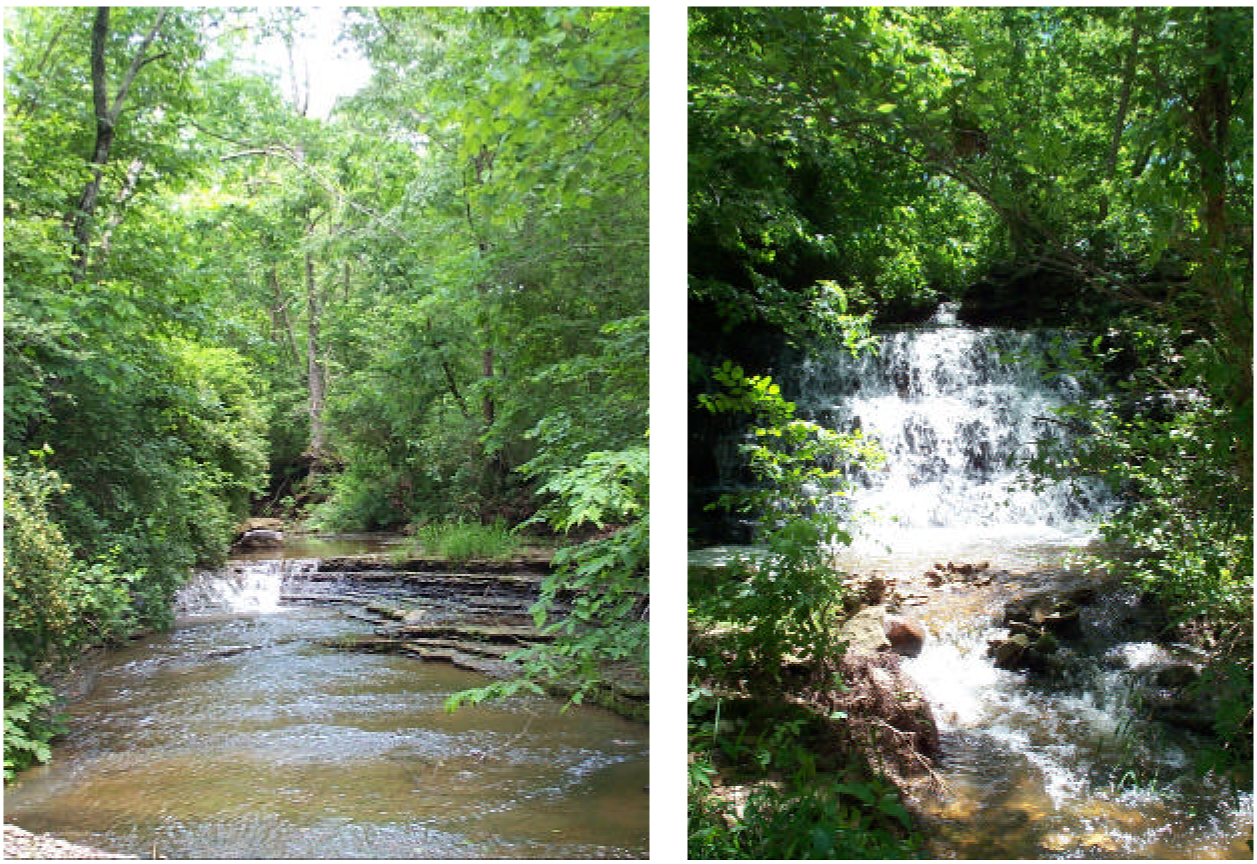

Figure 2-1 Photos of WFWR. Headwaters on mainstem (left) and waterfall on unnamed tributary in the lower part of the watershed (right)

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2.2 WFWR Water Quality

The WFWR is part of ADEQ's planning Segment 4K – Upper White River and Kings River, which includes portions of Washington, Benton, Madison, and Carroll Counties (Figure 2-2). As defined by Regulation 2, the WFWR is designated for propagation of fish and wildlife; primary and secondary contact recreation; and domestic, agricultural and industrial water supplies. The aquatic life use was assessed as not supported in 33.4 miles of the WFWR (Figure 2-2), because of high turbidity levels and excessive silt loads (ADEQ, 2002) and was placed on the State's 303 (d) list of impaired streams in 1998 (ADPC&E, 1998).

At the beginning of this project, water quality data specific to the WFWR had been collected primarily by the Arkansas Department of Pollution Control & Ecology (ADPC&E). (Please note that the ADPC&E changed its name to ADEQ in 1999. With the exception of dated references, in all cases, the Department will be referred to as ADEQ for the remainder of this report.) There is one permanent monitoring station located on the WFWR where monthly grab samples are collected as part of the ADEQ Ambient Monitoring Network, (ADEQ, 2002). Also, from 1992 through 1994, the ADEQ performed a comprehensive study of the water quality in the Upper White River Basin in which both water samples were collected along with biological samples (ADPC&E, 1995). After the WFWR assessment project was initiated, the project team worked with the ASWCC and the Arkansas Water Resource Center (AWRC) to establish a continuous monitoring station on the WFWR near the confluence with the White River. The project team also worked with the University of Arkansas, Biology Department, to secure funding to perform an intensive aquatic biological assessment of the WFWR watershed. The ASWCC agreed to use EPA Section 319(h) funds to conduct both of these efforts.

2.2.1 ADEQ Data

ADEQ has an established water quality monitoring station (WHI51) on the WFWR at Washington County Road 195 Bridge, one-half mile north of Highway 16, just east of Fayetteville (Figure 2-2). ADEQ began collecting monthly grab samples at this site in 1974. The station is located near the confluence of the WFWR with the mainstem of the White River. The upstream drainage area for the station is approximately 123 mi^2. Samples from this station are analyzed for several constituents including turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Ammonia-Nitrogen (NH_3-N), Nitrite + Nitrate-Nitrogen (NO_3^--N), Total Kjeldahl Nitrogen (TKN), Soluble Phosphate-Phosphorus ($P0_4^-$-P), Total Phosphate-Phosphorus (TP), Five-Day Biochemical Oxygen Demand (BOD_5), Total Organic Carbon (TOC), Dissolved Oxygen (DO), Saturated DO (DO_{Sat}), pH, Chloride (Cl^-), Sulfate (SO_4^-), Bromide (Br^-), and Fluoride (Fl^-). Refer to Appendix 2-B for a complete description (including abbreviations and units) of parameters analyzed. The maximum, minimum and mean values of the parameters analyzed for samples collected from station WHI51 are shown in Table 2-1 along with the period of record.

For the period of record, the sampling results for the parameters verses time were plotted and can be found in Appendix 2-C along with a table containing the raw data for sampling station WHI51. TSS concentrations over the period of record ranged from a minimum of 1 mg/L to a maximum of 316 mg/L. The average TSS concentration for samples collected from the station was 25.5 mg/L. The minimum and maximum observed turbidity values were 1.4 NTU and 760 NTU. The mean turbidity observation for the period of record was 31 NTU. The mean turbidity value at Station WHI51 for the period of record exceeds the water quality standard of 10 NTU (ADPC&E Commission, 2001). Comparing the WFWR water quality data for turbidity collected from October 1998 to January 2002, to other streams in the Upper White River basin showed that the WFWR consistently had higher turbidity values when compared to other streams sampled (Figure 2-3) (ADEQ, 2002).

Figure 2-2 Locations of monitoring stations in ADEQ Planning Segment 4K

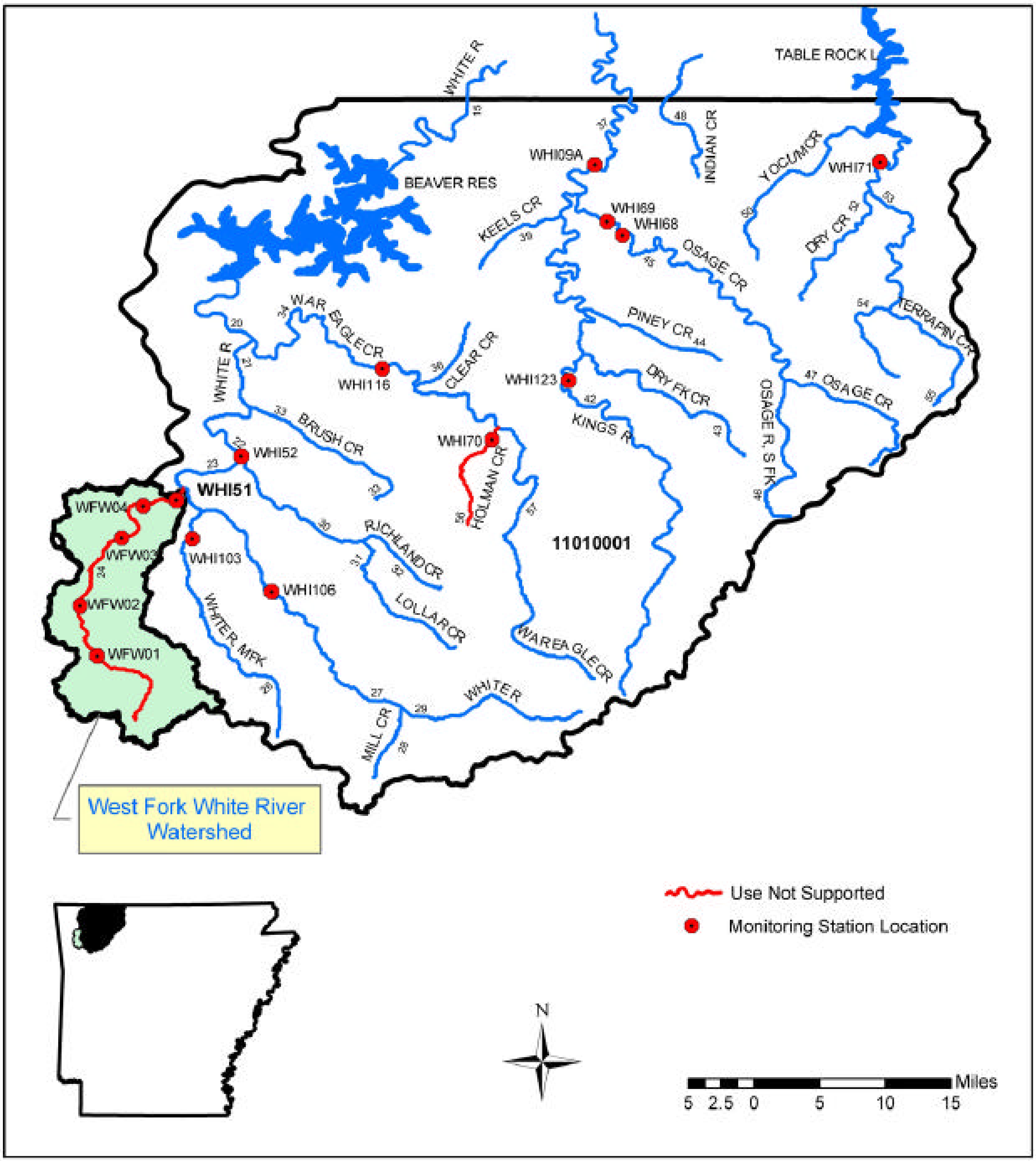

Table 2-1 Summary of Grab Sample Analysis for Samples Collected from ADEQ Water Quality Monitoring Station WHI51

	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3^--N (mg/L)	TKN (mg/L)	PO_4^--P (mg/L)	TP (mg/L)	BOD_5 (mg/L)
Minimum	1.4	1.0	47	0.005	0.01	0.08	0.005	0.01	0.10
Mean	31	25	127	0.08	0.5	0.57	0.043	0.083	1.87
Maximum	760	316	224	2.5	6.1	3.5	0.45	0.87	10.4
Period of Record	1977 - 2004	1974 - 2004	1977 - 2004	1977 - 2004	1977 - 2004	1986 - 2004	1980 - 2004	1974 - 2004	1974 - 2004
Number of Observations	307	339	306	276	286	161	229	308	276

	TOC (mg/L)	DO (mg/L)	DO $_{Sat}$	pH	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
Minimum	1.07	3.1	54.80%	6.17	2.55	11.37	0.01	0.05
Mean	3.72	9.0	88.92%	7.58	6.09	32.47	0.06	0.12
Maximum	10.7	14.3	115.2%	9.64	26.8	66.53	0.16	0.33
Period of Record	1986 - 2004	1974 - 2004	1999 - 2004	1974 - 2004	1999 - 2004	1999 - 2004	1999 - 2004	1999 - 2004
Number of Observations	184	319	59	324	64	64	25	63

From 1992 to 1994, the Planning Branch of the Water Division at ADEQ performed a comprehensive survey in the Upper White River basin, because of the potential for increased pollution from non point sources in the area (ADPC&E 1995). The purpose of the study was to determine water quality base-line conditions; quantify pollutants in the streams; identify sources of pollution; and characterize macroinvertebrate and fish communities in key waters. The WFWR was one of the streams evaluated during this study. Water samples were collected at four sites (WFW01, WFW02, WFW03, and WFW04) and biological samples were collected at one site (WFW03). The sampling locations are shown on Figure 2-2. Grab samples were collected at all four stations (beginning with the upstream station and working downstream) for seven sampling events over a two-year period. The sampling event dates and conditions are described in Table 2-2. The results of the sample analyses are summarized in Table 2-3. A table of all analytical data from the sampling events can be found in Appendix 2-D

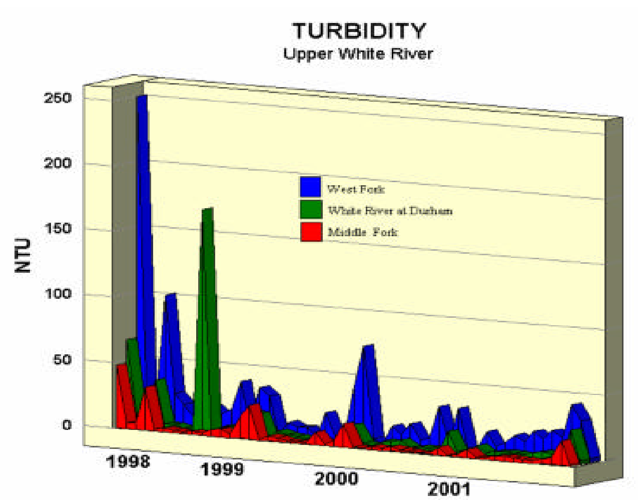

Figure 2-3 Comparison of turbidity for the WFWR and other branches of the White River

Table 2-2 WFWR sampling events for 1992-94 Survey (ADPC&E, 1995).

Date	**Season**	**Sampling Conditions**
05/20/92	Spring	3-days following storm event
08/18/92	Summer	Upper End – low flow Lower End – following storm event
12/15/92	Early Winter	During storm event
05/19/93	Spring	Following storm event
08/16/93	Summer	Low flow
11/30/93	Early Winter	Low flow
04/11/94	Spring	Low flow

Mean concentrations were calculated for the sampling events at each station and are shown in Table 2-3 along with maximum and minimum values. The following is a summary of observations and conclusions made in the report that are relevant to the WFWR (ADPC&E, 1995):

- Mean NO_3^--N concentrations, calculated from all of the sampling events, for the three downstream stations, were higher when compared to the upstream station near the headwaters.
- Mean TP concentrations at all study stations within the Upper White River basin in the study were below the phosphorous guideline value (0.10 mg/L); however, maximum concentrations, particularly in the WFWR, are very high.
- The WFWR had the highest turbidity and TSS concentrations, which were most likely due to the runoff from construction of Highway 71 (I-540).
- Average turbidity values in the WFWR exceeded water quality standards by two to four times.
- The WFW03 station appeared to have higher bacteria levels, when compared, on a storm-to-storm basis, to the other WFWR stations.

Table 2-3 Summary of WFWR sampling results from the 1992-94 ADEQ Survey (ADPC&E, 1995).

Station No. (Drainage Area)		WFW01 (49 mi^2) Upstream	WFW02 (68 mi^2)	WFW03 (93 mi^2)	WFW04 (118 mi^2) Downstream
TOC (mg/L)	*min*	1.0	1.2	1.5	1.7
	mean	**3.7**	**3.9**	**4.6**	**5.8**
	max	8.4	10	11	14
DO (mg/L)	*min*	3.1	4.7	4.8	7.1
	mean	**8.7**	**8.6**	**8.5**	**8.9**
	max	12	12	11	11
BOD_5 (mg/L)	*min*	0.20	0.20	0.20	0.30
	mean	**0.33**	**0.40**	**0.53**	**0.67**
	max	0.50	0.60	0.90	0.90
pH	*min*	6.7	6.4	6.0	6.9
	mean	**7.1**	**7.1**	**7.0**	**7.4**
	max	7.5	7.4	7.7	7.9
Turbidity (NTU)	*min*	2.6	4.2	3.0	6.8
	mean	**20**	**34**	**35**	**46**
	max	78	155	170	200
TSS (mg/L)	*min*	1.0	3.0	1.0	2.0
	mean	**16**	**49**	**59**	**81**
	max	102	291	345	452
TDS (mg/L)	*min*	37	53	64	79
	mean	**51**	**87**	**95**	**115**
	max	102	122	117	157
NH_3-N (mg/L)	*min*	>0.05	>0.05	>0.05	>0.05
	mean	**0.03**	**0.04**	**0.03**	**0.03**
	max	0.07	0.07	0.06	0.09
NO_3^--N (mg/L)	*min*	0.04	>0.02	>0.02	0.02
	mean	**0.13**	**0.30**	**0.30**	**0.30**
	max	0.20	0.60	0.61	0.58
PO_4^--P (mg/L)	*min*	>0.03	>0.03	>0.03	>0.03
	mean	**0.04**	**0.04**	**0.04**	**0.04**
	max	0.10	0.11	0.13	0.15
TP (mg/L)	*min*	>0.03	>0.03	0.03	>0.03
	mean	**0.04**	**0.08**	**0.09**	**0.09**
	max	0.15	0.33	0.39	0.48
FECAL (#100/ml)	*min*	30	40	10	10
	mean	**151**	**415**	**250**	**575**
	max	620	1900	430	3000
E. COLI (#100/ml)	*min*	1.0	10	20	10
	mean	**90**	**220**	**272**	**385**
	max	430	870	1010	1730

For this study, the results of the ADEQ 1992-94 survey were plotted for each sampling event. Parameter concentrations that were most impacted by the December 15, 1992 storm event were turbidity, TSS, PO_4^--P, and TP as shown in Figures 2-4 through 2-7. Also for the Dec. 15, 1992 storm event, comparing results from upstream stations to downstream stations, concentrations for the parameters mentioned above increased, with the exception of PO_4^--P. The same trend was seen with the May 20, 1992 event, which was sampled during the receding limb of the storm hydrograph. Looking at all four stations, TSS concentrations for the December 15, 1992 storm event ranged from nine to 345 times higher than concentrations of samples collected during the other sampling events (Table 2-2). A similar trend was observed for the other parameters plotted in Figures 2-5 through 2-7. Graphs of the remaining data for each sampling event can be found in Appendix 2-E

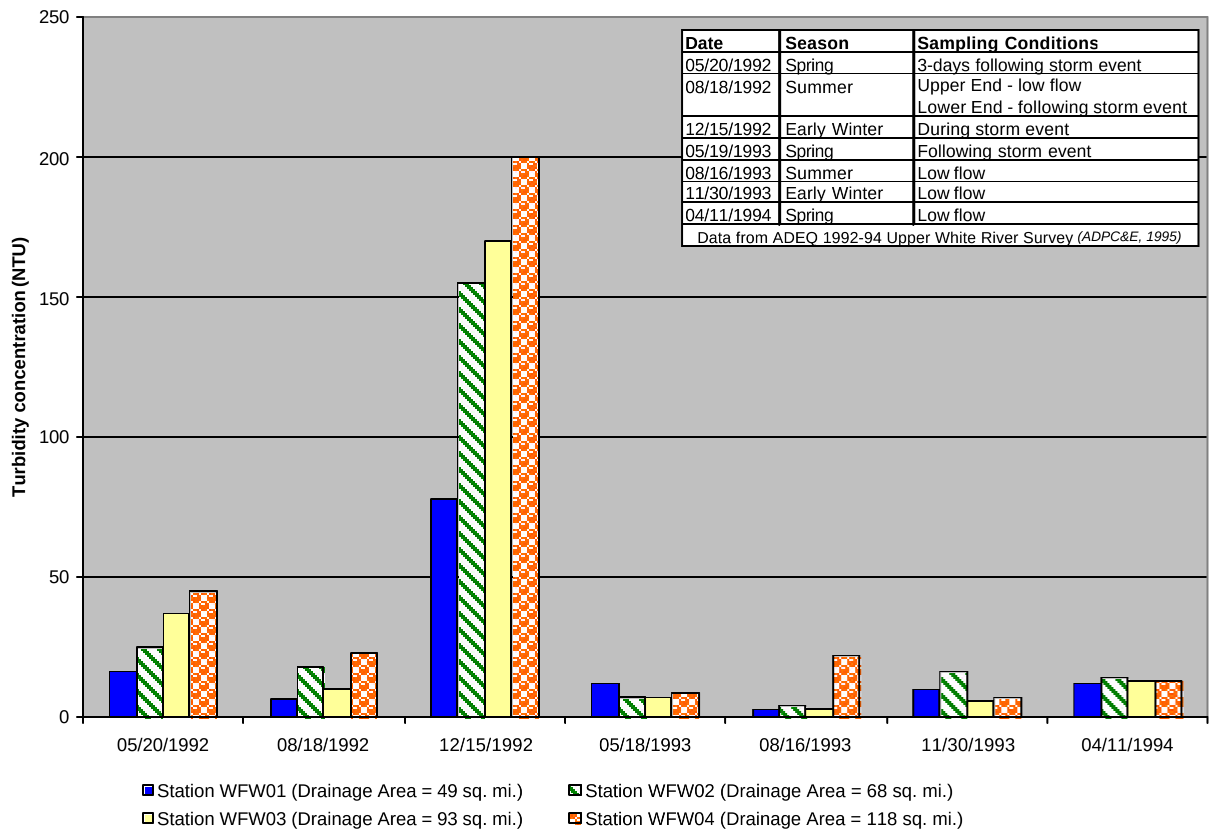

Figure 2-4 Turbidity concentrations for given sampling events on the WFWR

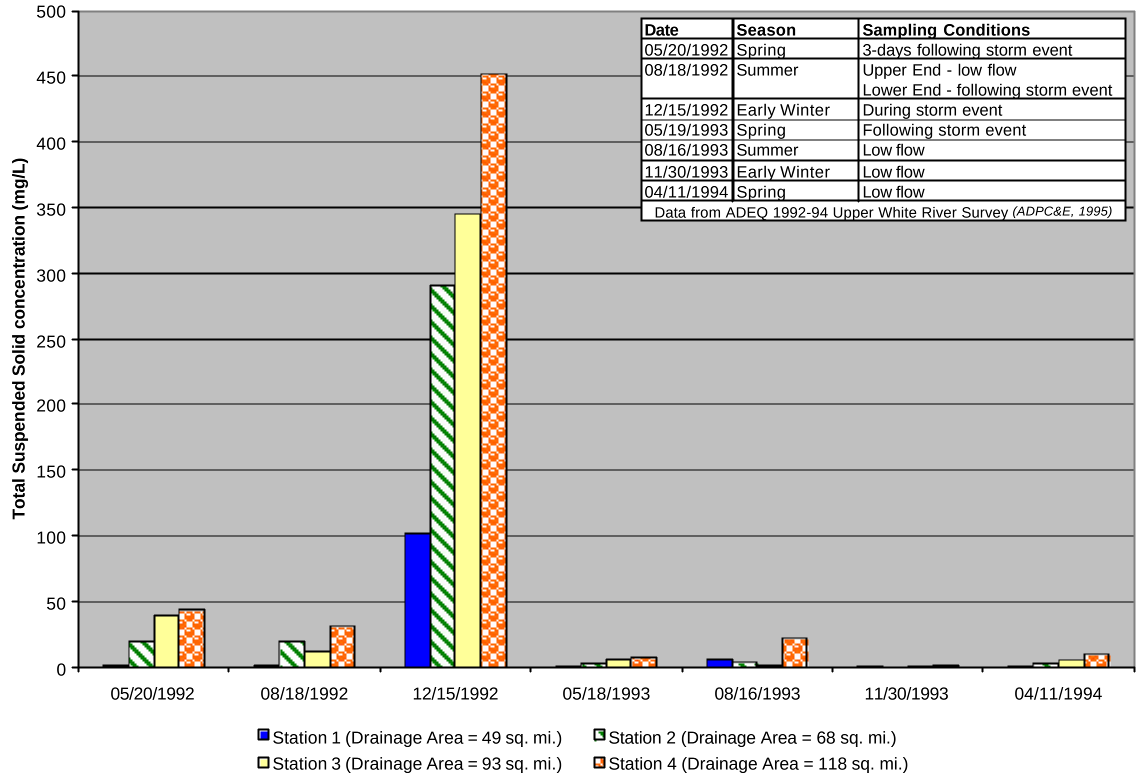

Figure 2-5 Total suspended solids concentrations for given sampling events on the WFWR

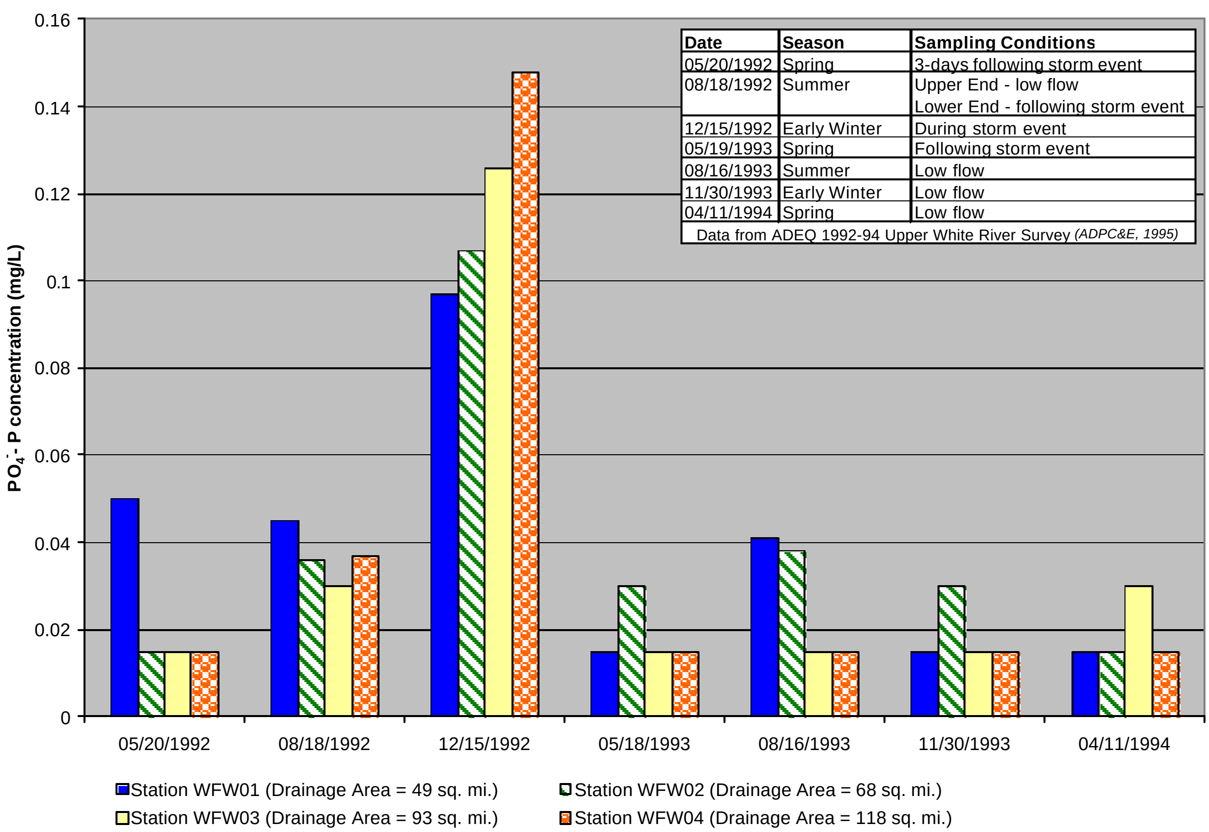

Figure 2-6 Soluble-Phosphorus concentrations for given sampling events on the WFWR

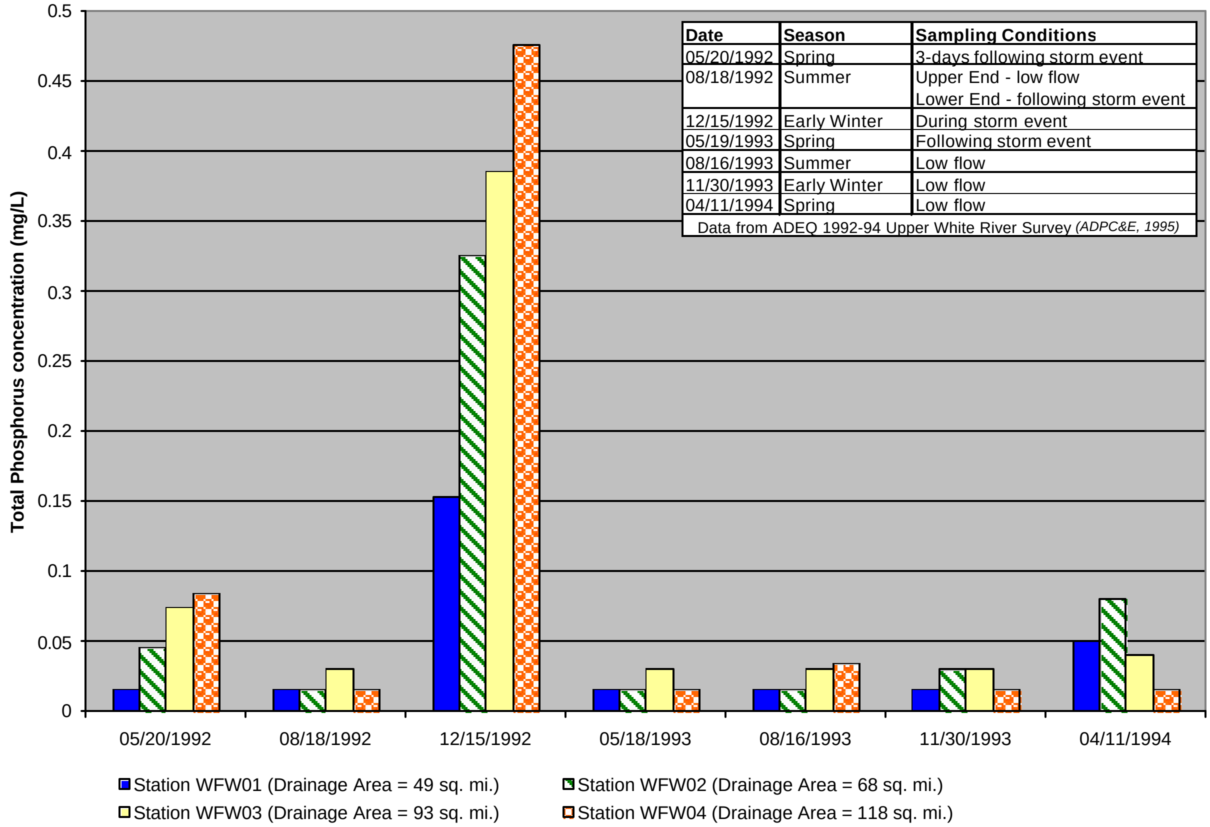

Figure 2-7 Total phosphorus concentrations for given sampling events on the WFWR

The 1992-94 ADEQ survey included an evaluation of macroinvertebrates and the fish community at sampling station WFW03 (Figure 2-2). Based on a one-time sampling event to evaluate conditions at that time, moderate impairment was indicated by the results of the macro-invertebrate sampling. The fish community sampling results showed that fish species dropped from 35 in 1963 to 26 in 1993. "Important species which were collected in 1963, but were absent in 1993 include the horneyhead chub, telescope shiner, Ozark bass, yoke darter, and stippled darter." Over-grazed pastures, cattle movement into and across the stream, and loss of riparian vegetation were listed as potentially causing the severe stream bank erosion, which has a direct impact on fish habitat. The study also indicates that a major highway construction project (I-540) along the western edge of the WFWR watershed caused substantial increases in stream turbidity and heavy silt deposition at the bottom of the stream channel. The fish community diversity was found to be declining due to loss of several species and the excessive dominance in the number of a few species (ADPC&E, 1995).

2.2.2 Arkansas Water Resource Center Continuous Monitoring Station (Nelson, et al., 2004)

The Arkansas Water Resource Center (AWRC) maintains a continuous water quality monitoring station on the WFWR at the Washington County Road 195 Bridge just above the confluence with the White River. The drainage area at this site is 123 mi^2. One reason the AWRC established this station was to provide water quality data for this assessment project, so that annual loads of contaminants could be estimated. Another purpose for establishing this station was to collect baseline data that could be used for future evaluation of restoration efforts and management practices implemented in the WFWR watershed. The WFWR continuous water quality monitoring station is funded through the EPA 319 grant program administered by ASWCC.

A detailed description of the WFWR sampling station, sampling methodology, data evaluation methods, and sampling results can be found in the AWRC report to the ASWCC in Appendix 2-F (Nelson, et., al., 2004). Sampling methodology followed a US EPA approved Quality Assurance Project Plan (QAPP). Sample collection at the continuous monitoring station (WFWR CM), was initiated in March of 2002. Both discreet samples and flow-weighted composite samples were collected and used to estimate annual loads of the following parameters for "below 4-ft stage" flow and storm (equal to or above 4-ft stage) flow conditions: TSS, TP, PO_4^{-}P, NO_3^{-}N, NH_3-N, and TKN. A time series presentation of the data collected during 2002 is displayed in Figure 2-8.

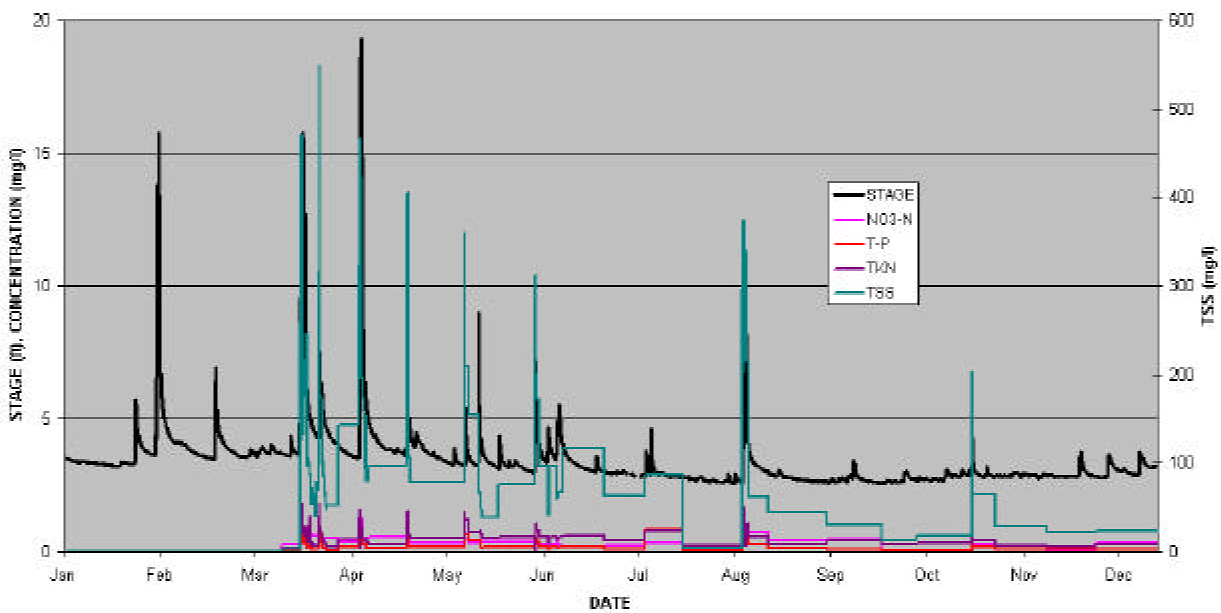

Figure 2-8 River stage and concentrations of selected parameters analyzed from samples collected at the AWRC WFWR CM station during 2002 (Nelson, et al.,2004)

During October, 2003, a problem with the intake line on the automatic sampler was discovered. Samples collected from March 11, 2002 through October 15, 2003 had been contaminated with sediment trapped in the 2-inch outer pipe. Using paired samples collected by the United States Geological Survey (USGS) and the AWRC for both storm flows and "below 4-ft stage" flows during 2002 though 2003, the data was corrected to more accurately reflect the conditions in the WFWR (Nelson, et al., 2004). Due to the fact that adjustments had to be made to account for problems with the sampling intake configuration, loads for both years are not as accurate as they would have been without this problem, but they still reflect the general condition of the WFWR for those two years. The 2002 data was impacted more from this problem. As additional data is collected, these values can be re-estimated to better reflect the conditions of the WFWR.

A summary of load estimates and flow-weighted mean concentrations for each parameter measured for the year 2002 and 2003 are shown in Table 2-4 and Table 2-5, respectively. Because sampling was not initiated until March of 2002, the annual load for 2002 was prorated using the flow data collected the entire year and the water quality data collected March through December of 2002 (Nelson, et al., 2004).

Table 2-4 WFWR estimated loadings and flow-weighted mean concentrations for constituents measured in 2002 at AWRC WFWR CM station (drainage area=123 mi^2) (Nelson, et al, 2004).

Parameter	Partial Year Load (Tons)	Pro-rated Annual Load (Tons)	Flow-weighted Mean Concentration (mg/L)
NO_3^--N	41.2	57.5	0.43
T-P	32.7	45.7	0.34
NH_3-N	4.71	6.58	0.05
TKN	66.9	93.6	0.70
PO_4^--P	2.98	4.17	0.03
TSS	15,244	21,315	158

Table 2-5 WFWR estimated loadings and flow-weighted mean concentrations for constituents measured in 2003 at AWRC WFWR CM station (drainage area=123 mi^2) (Nelson, et al, 2004).

Parameter	Annual Load (Tons)	Flow-weighted Mean Concentration (mg/l)
NO_3^--N	36.8	0.37
T-P	16.2	0.16
NH_3-N	3.00	0.03
TKN	54.7	0.55
PO_4^--P	1.19	0.01
TSS	8,403	84.59

The annual loads for constituents estimated in 2003 were 36% to 71% lower than annual loadings estimated in 2002 even though the water yield was similar for both years. For 2002, the water yield was 23,167 million gallons (71,096 ac-ft/yr), and for 2003, the water yield was 23,805 million gallons (73,054 ac-ft/yr). The difference in annual loadings could be due to the differences in meteorological conditions including rainfall intensity, duration, and time of the year individual storm events occurred. For example, sediment from erosion processes enters the stream system during storm events. In 2002, approximately, 75% of the flow that year was from storm events, while in 2003, just over 50% of the flow was from storm events. As expected, the average TSS storm flow concentrations were approximately 8 to 10 times higher than "below 4-foot stage" flow concentrations (Tables 2-6 and 2-7). Therefore, when comparing 2002 TSS loads to 2003 TSS loads, one would expect the loads to be higher in 2002.

Table 2-6 and Table 2-7 summarize the "storm-flow" loads and mean concentrations and the "below 4-ft stage" (referred to as base-flow in Nelson's report) loads and mean concentrations for measured parameters for both 2002 and 2003, respectively. It should be noted that in Nelson's report, the term "base-flow" is in reference to the 4-ft trigger level on the sampler. Though for most of the time, below this level is baseflow, during low flow months, storm influenced events that did not reach the 4-ft stage, could have been sampled. A grab sample collected during this type of an event would have a higher TSS concentration than baseflow.

Therefore, these numbers actually represent flows that were "below 4-ft stage," and the average TSS concentration for 2002 and 2003 was 18.5 mg/L and 17.1 mg/L, respectively. These average TSS concentrations were still lower than the average value at the ADEQ station WHI51of 25 mg/L for the period of record. The ADEQ average value includes samples collected during both base flow and storm flow events at any stage, which would explain why the ADEQ value is higher.

Both the ADEQ and AWRC have meaningful monitoring programs, but it is difficult to compare the ADEQ monthly water quality data with the AWRC continuous monitoring data, because the sampling methodologies are completely different. Also, the ADEQ data focuses on constituent concentrations that can be used to evaluate water quality standards, while the AWRC data focuses on estimating loads as a means to evaluate watershed sources of contamination. However, taking a closer look at the 1992-1994 ADEQ Survey, some comparisons can be made. The ADEQ sampling station WFW04 has a similar size watershed, 118 mi^2 to Nelson's CM station, which is 123 mi^2. Of the seven events sampled during the ADEQ Survey, the first four events were associated with storms. The remaining three events were classified as low-flow events. Using the data from Appendix 2-D, the average storm-influenced TSS concentration (four samples) is 134 mg/L and the average low-flow TSS concentration (three samples) is 11 mg/L. Comparing these two values, the average concentration of TSS in samples collected during storm events is approximately 12 times higher than the average low-flow concentration. This is similar to Nelson's results (over 300 samples – Tables 2-6 and 2-7), where the storm flow average TSS concentrations were 8 to 10 times higher than the "below 4-ft stage" average TSS concentrations.

For all parameters, the "below 4-ft stage" loads were lower than storm flow loads in 2002. But in 2003, for some parameters, the "below 4-ft stage" loads were higher than or similar to storm-flow loadings. For example, the NO_3^--N "below 4-ft stage" load was approximately twice the value of the storm-load value. Both "below 4-ft stage" and storm-flow mean concentrations for all parameters were higher in 2002 when compared to the 2003 mean values. These differences are most likely due to the differences in meteorological conditions for the two years as previously described.

Table 2-6 WFWR Estimated loadings and concentrations for storm-flow and "below 4-ft stage" conditions during 2002 (March-December) at AWRC WFWR CM Station (drainage area=123 mi^2) (Nelson, et al., 2004).

Parameter	Storm-flow Load (ton)	"Below 4-ft Stage" (ton)	Storm Concentration (mg/L)	"Below 4-ft Stage" Concentration (mg/L)
NO_3^--N	34.2	7.04	0.45	0.33
TP	32.4	0.27	0.43	0.01
NH_3-N	4.13	0.58	0.05	0.03
TKN	61.6	5.33	0.82	0.25
PO_4^--P	2.88	0.11	0.04	0.01
TSS	14,850	394	197.10	18.5
	Storm-flow	"Below 4 ft Stage"	Total	
2002 Water Yield (M-gal)	18,056	5,111	23,167	

Table 2-7 WFWR Estimated loadings and concentrations for storm-flow and "below 4 ft. stage" conditions during 2003 at AWRC WFWR CM Station (drainage area=123 mi^2) (Nelson, et al., 2004).

Parameter	Storm-flow Load (ton)	"Below 4 ft Stage" (ton)	Storm-flow Concentration (mg/L)	"Below 4 ft Stage" Concentration (mg/L)
NO_3^--N	20.7	16.1	0.38	0.36
TP	15.1	1.10	0.28	0.02
NH_3-N	1.92	1.07	0.04	0.02
TKN	43.5	11.1	0.81	0.25
PO_4^--P	0.94	0.25	0.02	0.01
TSS	7,627	776	141.15	17.1
	Storm-flow	"Below 4 ft Stage"	Total	
2003 Water Yield (M-gal)	12,950	10,855	23,805	

Continuous turbidity data (every 15 minutes) was collected at the WFWR CM station beginning in 2003. For 2003, the turbidity ranged from 0.0 NTU to 1,500 NTU with an average of 27 NTU. A TSS verses turbidity linear regression plot for the samples collected in 2003 is shown in Figure 2-9. With an R value of 0.76, the regression analysis supports that a reduction in TSS in the system will lead to improved water clarity.

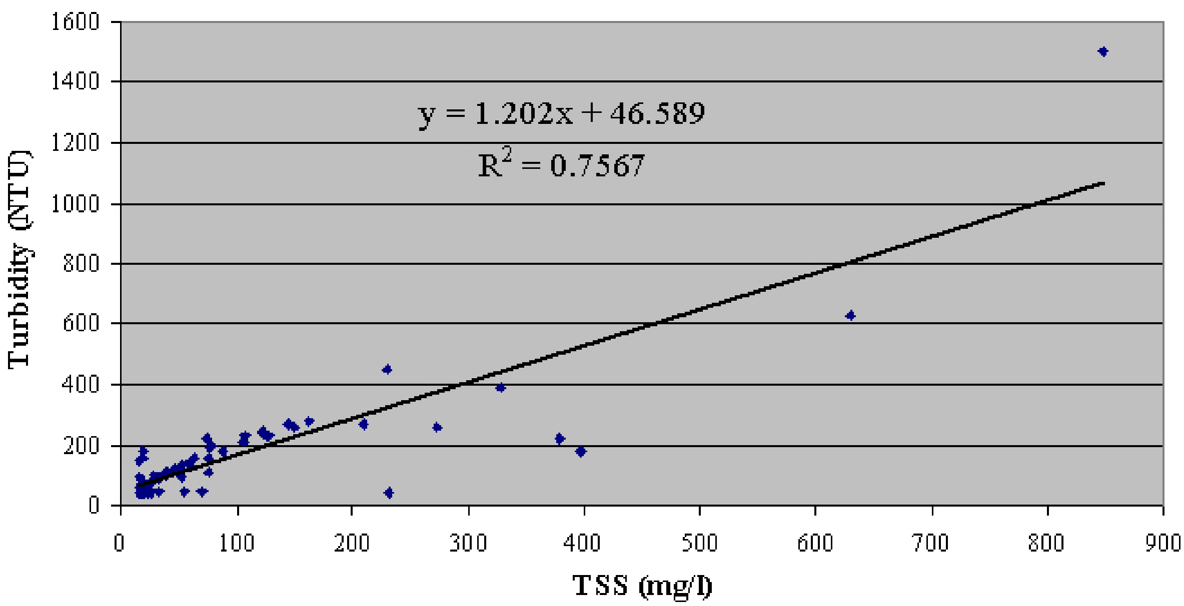

Figure 2-9 Plot of TSS versus Turbidity for samples collected on the WFWR in 2003.

Suspended Sediment concentration (SSC) was measured by the USGS for seven paired samples collected during storm flow conditions. Standard USGS laboratory procedures were used to collected and analyzed SSC. The average relationship between paired TSS and SSC determined from these paired samples can be described by the following relationship (Nelson, et al., 2004):

SSC = 1.46 TSS

Applying this relationship to the average TSS load for 2002 and 2003 of 14,870 tons/yr, results in an average annual SSC load of 21,690 tons/yr. The AWRC is continuing to collect paired storm flow samples to further develop the relationship between TSS and SSC.

2.2.3 University of Arkansas, Biology Department Biological Assessment

Brown et al. (2003) conducted a biological assessment of fishes, macroinvertebrates, and meiofauna (organisms smaller than macroinvertebrates; for this study collected meiofauna were larger than 80-µ) of the WFWR. The results of the study are summarized in Appendix 2-G. The study was part of the holistic evaluation of the WFWR and was initiated through this assessment project. The purpose of the biological assessment was to establish baseline data that could be used for future evaluation of restoration efforts and management practices in the WFWR watershed. The reaches where biological evaluations were conducted were the same reaches where the geomorphology of the river was evaluated (see Figure 4-1).

Fish assemblages were compared to historical information gathered from four sources dating as far back as 1894, and to current conditions in less disturbed streams in the Boston Mountains ecoregion. The four sources of historical data produced a total of 63 fish species recorded in the WFWR. The current biological assessment identified 39 fish species. Of special concern is that nine fish species missing from the WFWR survey are commonly found in other Boston Mountain streams and two species are endemic to the White River basin. The range of diversity indices for two previous ADEQ surveys and this survey was small (3.34 – 3.66) and according to Brown et al., all three values should be considered moderate.

Environmental stress has influenced the composite of fish assemblages with an increase in tolerant species and a decline of sensitive species. Riparian corridors were very disturbed in the lower sampling sites. The relationship between physical habitat and major fish taxonomic categories suggested that tolerant species are replacing sensitive species in degraded habitats. There were, however, a few sport fish, such as bass, crappie, and catfish, indicating that the aquatic life would benefit from restoration. A headwater site (site #8) was comparable to least disturbed Boston Mountain streams in environmental measures of health. Table 2-8 shows the fish assemblages found in 2002 by Brown et al. at each site.

Macroinvertebrate and meiofauna assemblages showed the same pattern as fish assemblages, with tolerant species dominant. Table 2-9 shows the macroinvertebrate assemblages found in 2002 by Brown et al. at each site. When compared to least disturbed streams in the ecoregion, species richness was lower at the West Fork study sites. The assessment of meiofauna is a fairly new practice used to determine environmental quality of a stream. The West Fork assessment of meiofauna will provide useful baseline data for future bioassessment and provide another evaluation tool of restoration and management efforts. Table 2-10 lists the major classes of meiofauna found at site #8 in 2002.

Although the West Fork bioassessment has revealed some significant impairment to the WFWR; species richness remains moderately high indicating that the biological communities remain capable of responding to restoration and management efforts. The current study also notes that the biological integrity of the headwaters has been maintained and should be protected from further degradation.

Table 2-8 Fish collected at 8 WFWR sites in summer 2002. *Reproduced from Brown et al. (2003)*

		2002 SITES								
		1	2	3	4	5	6	7	8	Total
Lepisosteidae	**Gars**									
Lepisosteus osseus	Longnose Gar	0	0	0	0	0	0	1	0	1
Clupeidae	**Herrings**									
Dorosoma cepedianum	Gizzard shad	0	0	0	0	0	0	8	0	8
Cyprinidae	**Minnows**									
*Campostoma spp.**	Central and largescale stonerollers*	67	257	167	218	505	15	104	365	1698
Cyprinella whipplei	Steelcolor shiner	0	0	0	0	3	6	22	0	31
Luxilus pilsbryi	Duskystripe shiner	8	0	0	80	164	0	0	204	456
Notropis boops	Bigeye shiner	0	0	8	13	30	38	28	0	117
Notropis nubilus	Ozark minnow	0	3	0	2	0	6	9	0	20
Notropis rubellus	Rosyface shiner	0	0	0	0	0	2	6	0	8
Pimephales notatus	Bluntnose minnow	0	0	4	1	1	16	2	0	24
Semotilus atromaculatus	Creek chub	35	28	21	2	0	0	10	31	127
Catostomidae	**Suckers**									
Hypentelium nigricans	Northern hogsucker	1	1	7	3	4	3	11	4	34
*Moxostoma spp.***	Black and golden redhorses**	0	0	0	0	0	69	17	0	86
Ictaluridae	**Freshwater catfish**									
Ictalurus melas	Black bullhead	1	0	3	0	1	0	0	0	5
Ictalurus natalis	Yellow bullhead	1	0	7	0	0	1	0	1	10
Noturus albater	Ozark madtom	0	0	0	3	0	0	6	0	9
Noturus exilis	Slender madtom	1	37	2	46	12	1	1	25	125
Cyprinodontidae	**Killifishes**									
Fundulus olivaceus	Blackspotted topminnow	7	0	1	1	0	3	1	4	17
Atherinidae	**Silversides**									
Labidesthes sicculus	Brook silversides	0	0	0	0	0	0	8	0	8

(Continued on next page)

* Campostoma anomalum and Campostoma oligolepis were not differentiated and were included as two species in the species count.
** Moxostoma Duquesnei and Moxostoma erythrurum were not differentiated and were included as two species in the species count.

Table 2-8 Continued. *Reproduced from Brown et al. (2003)*

		2002 SITES								
		1	2	3	4	5	6	7	8	Total
Centrarchidae	**Sunfishes**									
Ambloplites ariommus	Shadow bass	0	0	0	0	1	0	0	2	3
Ambloplites constellatus	Ozark bass	0	0	0	0	0	11	1	0	12
Ambloplites rupestris	Rock Bass	0	0	0	0	3	0	0	6	9
Lepomis cyanellus	Green sunfish	19	1	28	2	15	6	10	11	92
Lepomis gulosus	Warmouth	0	0	0	0	0	0	1	1	2
Lepomis macrochirus	Bluegill	4	0	4	3	1	19	39	1	71
Lepomis megalotis	Longear sunfish	0	2	20	51	84	59	6	63	285
Lepomis sp.	Hybrid Green sunfish/Bluegill	0	0	0	0	2	21	13	0	36
Micropterus dolomieui	Smallmouth bass	0	0	0	1	1	0	0	4	6
Micropterus punctulatus	Spotted bass	0	0	0	0	1	2	3	0	6
Micropterus salmoides	Largemouth bass	0	0	0	0	0	0	2	0	2
Percidae	**Perches**									
Etheostoma blennioides	Greenside darter	0	0	1	20	50	11	13	18	113
Etheostoma caeruleum	Rainbow darter	9	14	12	37	84	8	34	67	265
Etheostoma punctulatum	Stippled darter	2	0	24	25	14	1	4	24	94
Etheostoma spectabile	Orangethroat darter	33	76	44	70	37	4	17	86	367
Etheostoma zonale	Banded darter	13	2	18	14	0	2	4	12	65
Percina caprodes	Logperch	0	0	0	0	0	0	12	0	12
Poeciliidae	**Livebearers**									
Gambusia affinis	Mosquitofish	0	0	0	0	0	0	3	0	3
Moronidae	**Temperate basses**									
Morone saxatilis	Striped Bass	0	0	0	0	0	0	1	0	1
Cottidae	**Sculpins**									
Cottus carolinae	Banded Sculpin	0	0	0	1	0	0	0	0	1
Total Individuals		202	423	374	597	1,018	310	404	929	4,229
Species Count		15	11	18	21	21	24	33	20	

Table 2-9 Macroinvertebrates collected at eight WFWR sites in summer 2002. *Reproduced from Brown et al. (2003)*

Order	Family	Genus	2002 Sites 1	2	3	4	5	6	7	8	RBA
Ephemeroptera											
	Baetidae	*Beatis*	1	2	29	37	29	28	110	21	2
	Caenidae	*Brachycercus*	0	0	1	2	0	7	35	5	0
		Caenis	26	45	230	114	320	113	29	143	10
	Ephemeriidae	*Ephemera*	0	1	0	0	0	0	0	0	0
	Isonychiidae	*Isonychia*	22	0	1	4	24	55	15	105	5
	Heptageniidae	*Cinygmula*	0	0	7	4	0	6	0	1	0
		Stenacron	2	16	4	35	12	2	15	84	0
		Stenonema	2	2	4	38	57	15	48	123	15
	Leptophlebiidae	*Choroterpes*	0	0	6	37	38	5	17	5	0
		Leptophlebia	0	0	1	0	0	0	0	0	0
		Neochoroterpes	0	0	0	0	0	0	0	0	0
		Immature	0	0	1	0	0	0	0	0	0
	Tricorythidae	*Tricorythodes*	0	0	2	2	1036	27	39	3	0
Plecoptera											
	Perlidae	*Acroneuria*	0	1	0	0	0	0	0	0	0
		Neoperla	0	0	0	2	0	0	0	0	0
	Taeniopoterygidae	*Strophopteryx*	1	0	0	0	0	0	0	0	0
Trichoptera											
	Glossosomatidae	*Agapetus*	0	0	0	0	0	0	0	0	0
	Hydropsychidae	*Cheumatopsyche*	3	0	27	182	55	70	206	56	15
		Smicridea	0	0	0	0	1	0	0	0	0
	Leptoceridae	*Oecetis*	1	0	0	0	0	0	0	0	0
	Philopotamidae	*Chimarra*	0	4	0	46	3	81	12	3	4
	Polycentropodidae	*Cernotina*	1	0	8	2	0	0	0	10	0
		Neuroelipsis	1	0	0	0	1	2	0	0	0
Diptera											
	Ceratopogonidae		0	1	0	0	1	0	0	0	0
	Chironomidae		17	83	71	94	92	170	346	13	7
	Empididae		0	0	0	0	7	0	0	0	0
	Simuliidae	*Simulium*	0	0	0	3	0	0	0	0	0
		Prosimulium	0	0	0	0	0	0	0	0	0
	Tanyderidae		1	1	1	0	0	0	0	0	0
	Tipulidae	*Hexatoma*	1	5	3	1	0	0	12	2	4
		Tipula	2	0	0	0	0	4	0	0	6
	Diptera pupa		5	0	1	7	5	6	11	4	0
Coleoptera											
	Elmidae	*Macronychus*	0	0	0	0	0	0	2	2	0
		Stenelmis	0	0	0	0	0	1	123	1	0
	Hydrophilidae	*Berosus*	0	0	0	0	0	0	1	0	0
	Psephenidae	*Psephenus*	0	0	0	0	0	3	0	29	5
Hemiptera											
	Veliidae	*Rhagovelia*	0	0	2	0	0	0	0	1	10
Megaloptera											
	Corydalidae	*Corydalus*	5	1	2	0	9	5	2	5	7
		Nigronia	0	0	6	0	0	0	0	8	0
	Sialidae	*Sialis*	0	0	0	0	0	0	0	0	5
Odonata											
	Coenagrionidae	*Argia*	0	0	0	0	0	4	4	2	7
	Gomphidae	*Gomphus*	0	7	0	0	0	0	0	0	0
		Stylogomphus	0	3	0	0	0	0	0	1	0
Decapoda											
	Cambaridae	*Orconectes*	0	1	4	0	0	0	0	1	0
		Immature	0	0	0	0	0	0	0	1	0
Isopoda											
	Asellidae	*Lirceus*	0	0	0	0	0	0	0	0	0
Veneroida											
	Corbiculidae	*Corbicula fluminea*	0	0	0	0	0	0	12	0	8
Gastropoda											
	Hydrobiidae		0	0	0	2	4	0	0	0	0
Oligochaeta											
	Lumbricidae		8	37	6	4	0	0	1	0	3
Tricladida											
	Dendrocoelidae		0	0	0	0	3	0	0	0	0
Prostigmata											
	subcohort Hydrachnidia		0	0	0	0	0	1	2	3	0
		Totals	99	210	417	616	1697	605	1042	632	113

Table 2-10 Densities of major taxonomic categories of meiofauna from site 8 in WFW R, collected in summer 2002. *Reproduced from Brawn et al. (2003)*

Taxonomic Category	Organisms/L
Copepoda*	114
Rotifera	34
Caldocera	1
Ostracoda	20
Nematoda	83
Oligochaeta	90
Hirudinea	2
Hydrachnidia	303
Chironomidae**	1112
Ephemeroptera	217
Other ***	69
Mean Density = 2045 Organisms/L	

* Immature stages (nauplii and copepodites) included.

** Temporary meiofauna including individuals less than 1 mm in any

*** Temporary meiofauna from Insecta orders Coleoptera, Trichopte

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2.3 WFWR Hydraulic Information and Data

There are three active and three inactive USGS gage stations within the WFWR watershed. A summary of gage station information can be found in Table 2-11, and their locations are shown in Figure 2-10.

The USGS gage station 07048000 (Greenland Gage), located on the main branch of the WFWR at old HWY 71 bridge at Greenland, had daily stream flow data collected over a 37 year period. The hydraulic evaluation for this study focuses on the Greenland Gage data, because the other stations all had less than seven years of daily stream or real-time flow data. Also, a 10-year minimum period of record is required to use a gage station to estimate bankfull discharge associated with the watershed area and physiographic area from the USGS flow data. The watershed area at the Greenland Gage is 83.1 square miles. For the period of record, annual mean flows ranged from 17.7 c.f.s. in 1963 to 268 c.f.s. in 1973. The annual water yield ranged from 12,814 ac-ft to 194,126 ac-ft with an average of 78,005 ac-ft.

Table 2-11 WFWR Watershed Gage Stations' Summary

USGS #	07048490	07048480	07048550	07048500	07048000	07047990
Description	Town Branch Tributary Hwy 16 at Fayetteville	Town Branch Tributary B.R. 62 at Fayetteville	WFWR Main Branch East of Fayetteville	WFWR Main Branch Hwy 16 at Fayetteville	WFWR - Main Branch Old Hwy 71 B.R. at Greenland	Tributary of WFWR Near Greenland
Gage Status	Active	Active	Active	Inactive	Inactive	Inactive
Drainage Area	1.36 mi^2	0.86 mi^2	123 mi^2	118 mi^2	83.1 mi^2	0.67 mi^2
Data Type						
Peak Stream Flow	06/17/1997 - 06/28/2000	06/17/1997 - 06/28/2000	n/a	02/18/1938 – 04/14/1945, 05/06/1960	05/24/1946 - 12/03/1982	05/05/1960 – 11/19/1985
Counts	4	4	-	9	38	27
Daily Stream Flow	10/01/1996-09/30/2003	10/01/1996 - 09/30/2003	10/10/2001 - 09/30/2003	10/01/1937-09/30/1945	10/01/1945 - 11/08/1983	n/a
Counts	2,556	2,191	730	2,922	13,918	-
Real-time	No	No	Yes	n/a	n/a	n/a

The average amount of runoff per acre was 17.6 in/ac-yr, with a minimum of 2.9 in/ac in 1963 and a maximum of 43.8 in/ac in 1973. The variability of mean monthly stream flow is shown in Figure 2-11, where the water years 1946 though 1949 are plotted by month. For example, the highest mean monthly flow for 1949 was in November at approximately 500 c.f.s. For the other three years plotted, the month of November had a low mean monthly flow of less than 30 c.f.s. The same pattern was also seen in the month of August.

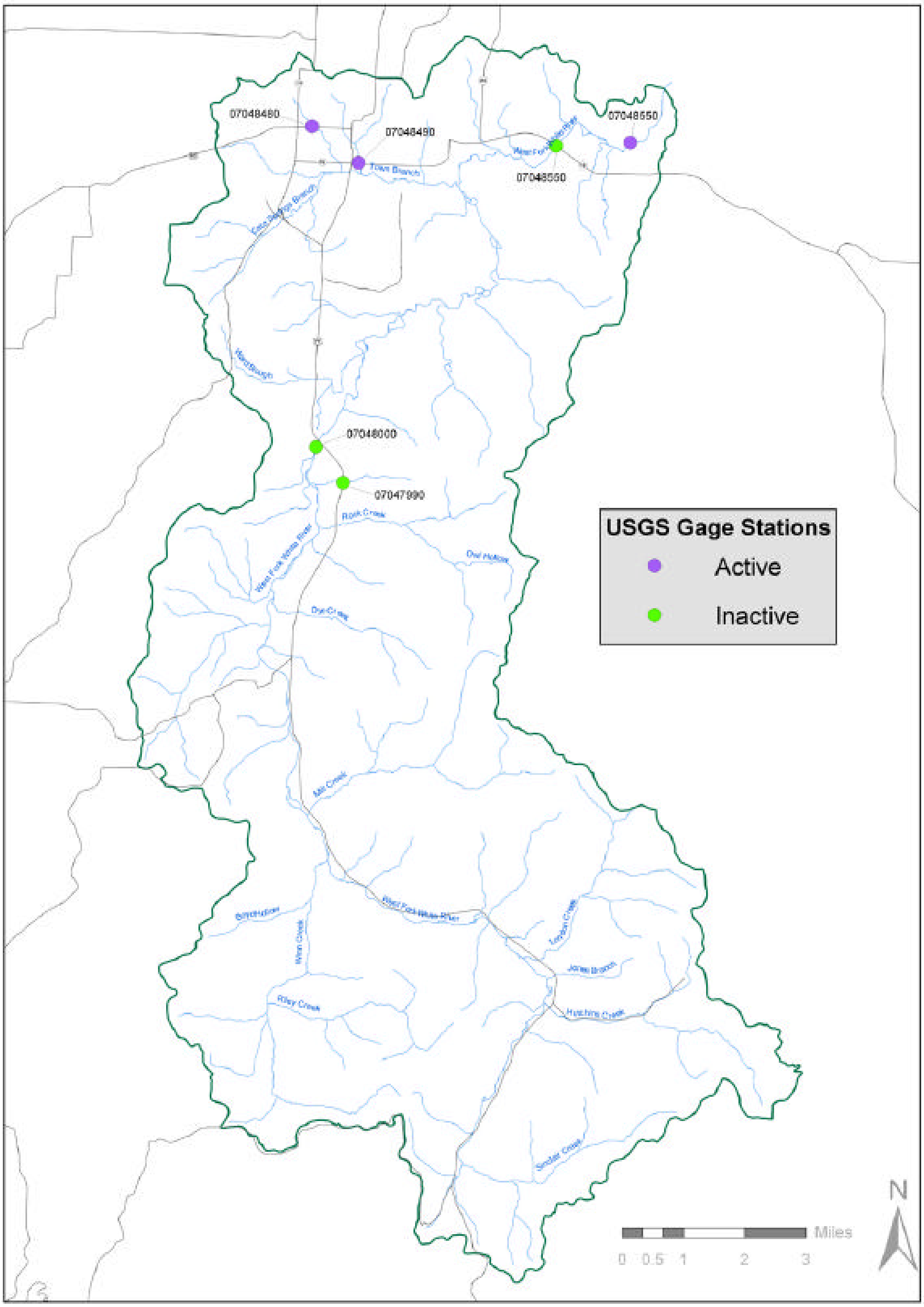

Figure 2-10 Locations of Active and Inactive USGS Gauging Stations in the WFWR watershed

This analysis demonstrates the variability of weather in the physiographic region and Arkansas in general. This variability greatly affects when and how pollutants enter surface waters and the affect of pollutants in the WFWR watershed and in watersheds across the region.

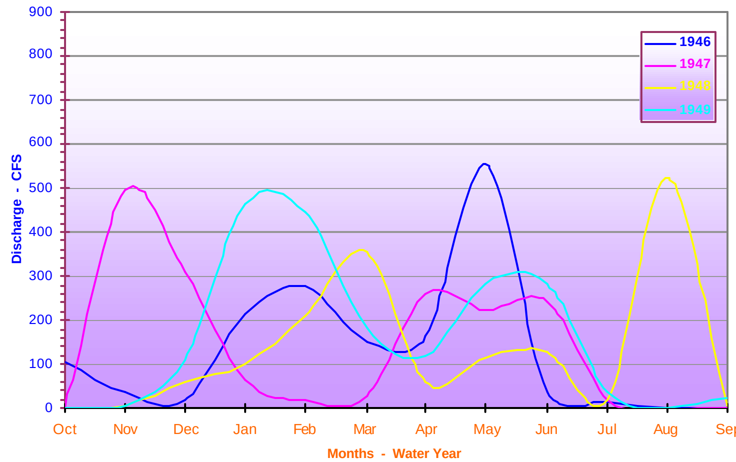

Figure 2-11 Mean Monthly Streamflow for 1946 through 1949 at the USGS Gage Station at Greenland, AR

The close proximity of southeastern Fayetteville to the WFWR and its tributaries subjects urban areas to potential flooding from the WFWR. Because of this hazard, the WFWR main branch and its tributary, Town Branch, were included in a 1971 floodplain analysis performed for the city of Fayetteville (USCOE, 1971). At the time of the study, the greatest record flood on the WFWR had occurred in April 1945. A peak flow of 53,000 c.f.s. was recorded at the Hwy 16 gage station (07048500). Peak flows for the period of record recorded at the Greenland Gage are shown in Figure 2-12 with the greatest peak flows occurring in 1960 and 1974 at 34,700 c.f.s. and 33,300 c.f.s., respectively. Just recently, during April 2004, the period of record flood event appears to have been broken. Over 18 inches of rain fell in less than 96 hours (based on landowners rain gages) and the flow at the Greenland Gage was over the bridge. Based on the USCOE's 1971 study, this event would result in a "standard project flood." The peak flow on the WFWR for a standard project flood at the Greenland gage is estimated to be 69,000 c.f.s. Based on a survey of flood debris adjacent to the Greenland gage station, the maximum river stage during the flood of April 2004 was estimated to be 20.2 ft. This stage would correspond to a discharge of 62,000 c.f.s. based on an evaluation of gage height versus discharge for yearly observed maximum flow for the gage station. Estimated velocities for an event of this magnitude are 15 ft/s within the channel and 4 ft/s over the bank (USCOE, 1971).

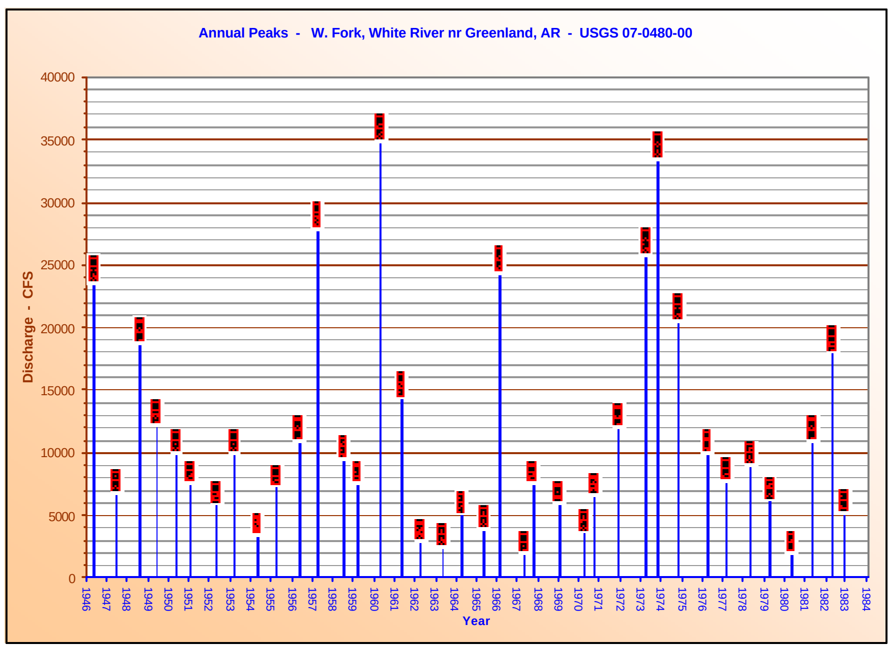

Figure 2-12 Annual Maximum flow observed at USGS Gage Station near Greenland Arkansas

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2.4 References:

1. ADEQ. Integrated Water Quality Monitoring and Assessment Report. Agency Report Prepared pursuant to Section 305(b) and 303(d) of the Federal Water Pollution Control Act. Agency Report. 2002.

2. ADPC&E Commission. Regulation 2: Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas. July, 2001.

3. ADPC&E. Water Quality inventory Report. Agency Report Prepared pursuant to Section 305(b) of the Federal Water Pollution Control Act. 1998.

4. ADPC&E. Water Quality, Macroinvertebrate, and Fish Community Survey of the Upper White River Watershed. Agency Study and Report. August, 1995

5. Brown, Arthur, Andrea Radwell, and Robin Reese. Bioassessment of the West Fork of the White River, Northwest, Arkansas. Publication No. MSC-307. Arkansas Water Resources Center, University of Arkansas, Fayetteville, AR. 2003.

6. Nelson, M., W. Cash and S. Formica. Water Quality Sampling, Analysis and Annual Load Determinations for TSS, Nitrogen and Phosphorus at the Washington County Road 195 Bridge on the West Fork of the White River. 2003 Annual Report to the ASWCC. July, 2004.

7. USCOE. Flood Plain Information, West Fork White River, Town, Mud, Scull, and Clear Creeks. Fayetteville, Arkansas. U.S. Army Corp of Engineers. March 1971.

Chapter 3: Watershed Characteristics and GIS Analyses

Understanding the natural features of a watershed is fundamental to understanding how the watershed is impacted from land used. In the past 200 years, the West Fork White River (WFWR) watershed has gone from being a remote-undisturbed area inhabited by a few Native Americans to a watershed that drains a portion of one of the fastest growing areas in the United States (US Census, 2000).

3.1 Watershed Characteristics

3.1.1. Ecoregions

The WFWR watershed is located within two of the Ecoregions found in Arkansas, the Boston Mountains and the Ozark Highlands, as seen in Figure 3-1. The southern area of the WFWR watershed is located in the Boston Mountains and is 77.6 mi^2, or 62.5% of the watershed. The northern area of WFWR watershed is located in the Ozark Highlands and is 46.6 mi^2, or 37.5% of the watershed. Descriptions of Arkansas' ecoregions can be found in the ADEQ Arkansas Watershed Planning Guide (2003). The Boston Mountain region of the WFWR watershed has "gently sloping to broad rolling mountaintops with steep side slopes and long, narrow valleys" (Figure 3-2). Elevations range from 650 to 2400 feet. The Ozark Highlands region of the WFWR watershed has "gently sloping to rolling ridges that break sharply to steep side slopes and narrow valleys with steep gradients" (Figure 3-3). Elevations in the watershed range from 500 to 1800 feet.

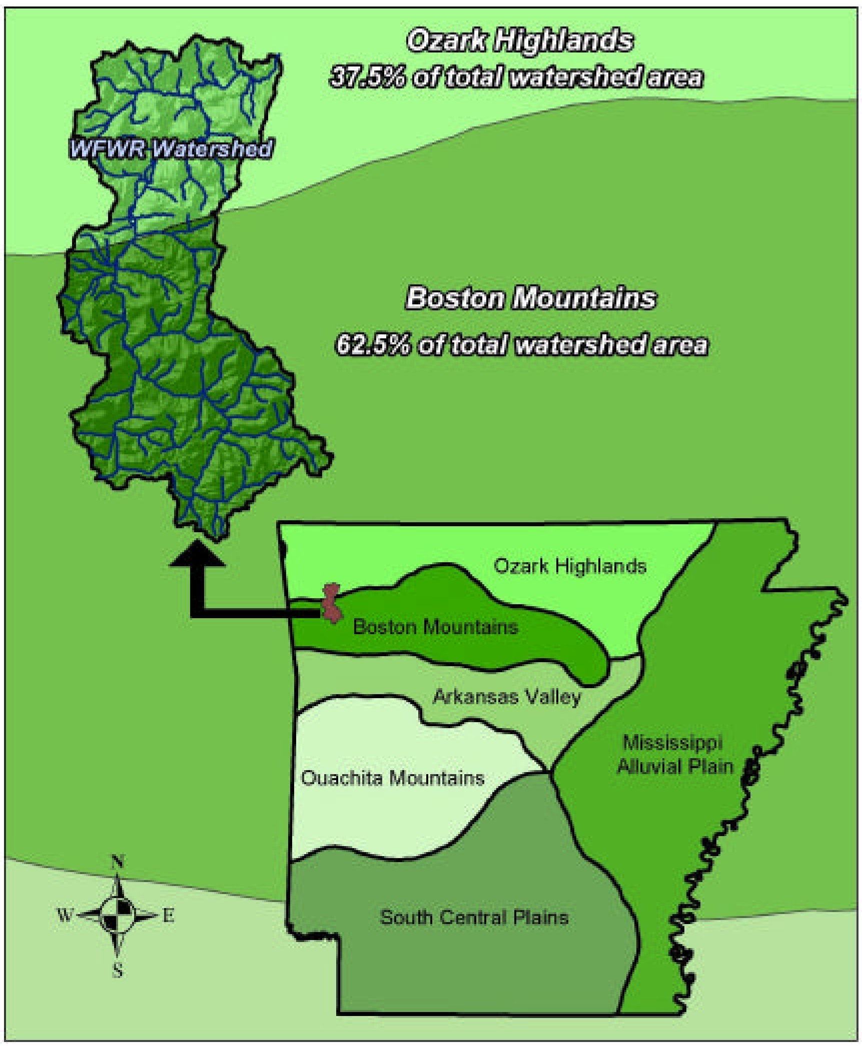

Figure 3-1 Location of WFWR watershed within Arkansas Ecoregions.

Figure 3-2 View of WFWR Watershed in Boston Mountain Ecoregion near Woolsey

Figure 3-3 View of WFWR Watershed in the Ozark Highlands Ecoregion. Taken at Project Site 7

3.1.1.1 Climate

The climate of the WFWR watershed is mild with warm humid summers and cool winters. Relatively frequent frontal passages occur in spring, winter and fall, which are associated with dramatic temperature changes and precipitation events. A stagnant weather pattern develops in summer months with warm and humid conditions predominating and most precipitation occurring as convection driven thunderstorms. The National Weather Service at the Fayetteville airport recorded the following climatology data for the period of 1961 through 1990.

July and August are the warmest months of the year with an average of 18 and 19 days, respectively, above 90° F. Annually, there is an average of 56 days each year with a temperature above 90° F. There is an average of 105 days each year with below freezing temperatures. The last average killing frost occurs by April 15, while the average first killing frost occurs by October 17.

Precipitation occurs throughout the year with an annual average of 46.02 inches. May and June are the wettest months with over 5 inches of rainfall, while January is the driest month with just over 2 inches of precipitation. The area receives an average of 6.3 inches of snowfall each winter.

3.1.1.2 Surface Water

Natural surface water quality for both ecoregions is quite good. In relatively undisturbed conditions, streams in each ecoregion tend to have excellent clarity, relatively cool summer time high temperatures and relatively high minimum dissolved oxygen concentrations. Table 3-1 lists general water quality indicator parameters considered to be the maximum observed values naturally occurring in reference streams in each of the ecoregions (ADEQ, 2004).

Table 3-1 Maximum Observed Values of Water Quality Parameters by Ecoregion for undisturbed sites. *(ADEQ, 2004)*

Water Quality Parameter	**Boston Mountains Ecoregion**	**Ozark Highlands Ecoregion**
Temperature (Max)	31° C	29° C
DO (Min)	6 mg/L	6 mg/L
Cl^-	13 mg/L	13 mg/L
SO_4^-	9 mg/L	17 mg/L
TDS	85 mg/L	240 mg/L

3.1.1.3 Ground Water

Virtually all of the WFWR drainage basin lies within the hydrogeologic unit referred to by the United States Geologic Survey as the Western Interior Plains confining system (Renkin, 1998). This area is composed of over 700 feet of sandstone, shale and limestone of upper Mississippian to Pennsylvanian age. Although the hydrogeologic unit is referred to as a confining system, individual units, or portions of units, generally produce adequate quantities of water for most domestic uses. Ground water occurrence and flow typically occurs in an upper zone within soil and highly weathered bedrock and in a deeper zone of less weathered to unweathered bedrock. These water table aquifers are recharged from precipitation, which falls on topographically high areas and flows toward valleys where it discharges to streams. Ground water quality can be quite variable depending upon the producing formation and the residence time of the water within the formation. In general, water produced from shale units tends to be of poorer quality. Table 3-2 lists ranges of typical values of water quality indicator parameters observed in these shallow water table aquifers.

Table 3-2 Ranges of typical water quality values found in WFWR ground water.

Water Quality Parameter	**Interior Plains Confining System Aquifer**	
	Range (mg/L)	Median (mg/L)
pH	5.7 - 8.3	7.2
Hardness	4 - 412	69
Cl^-	2.5 - 288	22
TDS	24 - 870	175
NO_3^- -N	0 - 34	1.4

3.1.2 Geology

The WFWR drainage basin is located on the northern flank of the Boston Mountains, which is topographically the highest of three distinct plateaus of the Ozark Highlands (Croneis, 1930). Most of the watershed lies within this physiographic region, with the exception of small portions of the lower part of the basin, where the river has exposed sections of the Springfield Plateau. The watershed is composed of horizontally- to near-horizontally-bedded sedimentary rocks of Mississippian- to Pennsylvanian-aged sandstone, shale, limestone and chert. The higher elevations of the plateau are underlain by alternating, erosion-resistant sandstone and more easily eroded shale, which produce a characteristic bench and bluff topography (Purdue, 1916). Erosional dissection by the major streams has resulted in deep hollows and stream valleys with as much as 500 to 700 feet of relief.

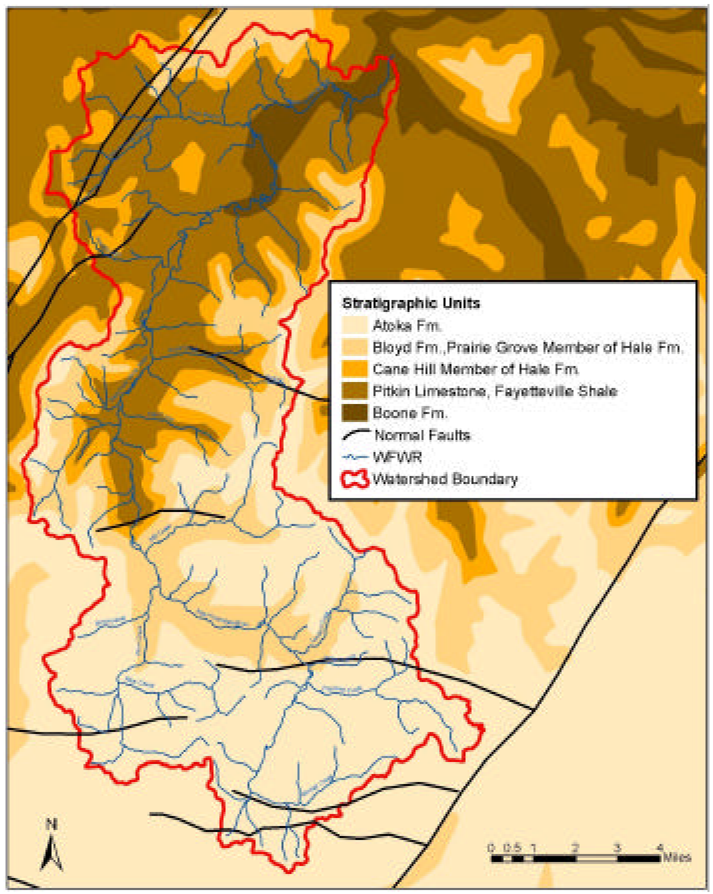

Figure 3-4 Geological Formations found in WFWR watershed

The stratigraphy of the watershed can be divided into sedimentary rocks of Mississippian age consisting of in ascending order, the Boone Formation, the Batesville Sandstone/Hindsville Limestone Member, the Fayetteville Shale, the Weddington Sandstone and the Pitkin Limestone, and rocks of Pennsylvanian age including the Hale Formation, Bloyd Formation and the Atoka Formation (Figure 3-4). The Boone Formation outcrops in the river valley at the lower end of the river, while the Atoka Formation caps the highest elevations of the plateau. Important cliff-forming units include the Weddington Sandstone, the Pitkin Limestone, and sandstone units within the Bloyd and Atoka formations (Figure 3-5). Shales within the Fayetteville, Hale, Bloyd and Atoka formations are important slope-forming units. The Pitkin Limestone is important as a source of limestone used in construction within the region.

The drainage basin lies within the Northern Arkansas structural platform (Shinn and Konig, 1973). Broad, subtle folds trending in a northeast-southwest direction with dips of 1 to 3 degrees characterize this area. There are two sets of major faults within the structural platform, formed by stress release associated with the Ouachita Orogeny. These structural features are important hydrologically and as landscape-shaping features. The first sets of normal faults are regional features, which are downthrown to the south with up to 200 feet of displacement, and trend approximately north 20-30 degrees east. The second sets of normal faults are local, trend roughly east west, and are downthrown to the south. Fracture systems associated with the faults provided preferential pathways for streams, resulting in hollows and valleys being formed along the faults. In addition, the fracture systems can create pathways for ground-water movement along the fault trace or create ground-water barriers by bringing rocks of different water-transmitting properties into contact. The larger-volume springs in the basin are located along faults. Cato Springs, which flows into Town Branch, is located along the Fayetteville fault.

Figure 3-5 Weddington Sandstone along the river at the West Fork Park

3.1.3 Soils and Slopes

Soils within the WFWR drainage basin are closely associated with the geology since soil is derived from the weathering of the parent rock. Most of the watershed is located within the Boston Mountains physiographic province, which is composed primarily of sandstone, mudstone, limestone and shale. The lower portion of the basin is within the Springfield Plateau physiographic province and is comprised primarily of limestone and chert. Except for drag folding near a few normal faults, most of the region is underlain by horizontally bedded rocks, which over geologic time, have been deeply incised by erosion from the major streams. Soils tend to be shallow on the mountaintops and steeper side slopes, and deeper on benches and in the valleys.

The major soil associations in the watershed are shown in Figure 3-6 and are listed below with a brief description of soil depth, hydraulic conductivity characteristics and typical location (SCS, 1969):

- Enders-Allegheny-Hector association: Deep and shallow soils with a moderate to high hydraulic conductivity found on the side slopes of mountains.

- Linker-Apison-Hector association: Moderately deep and shallow with high to very high hydraulic conductivity commonly found on level to rolling mountaintops.

- Fayetteville-Hector-Mountainburg association: loamy soils that are deep and shallow with a high to very high hydraulic conductivity, found on slopes on mountaintops.

- Savannah-Cleora-Razort association: Deep loamy soils with a high to very high hydraulic conductivity found on flat to gently sloping alluvial terraces and flood plains.

Elevations in WFWR watershed range from 1136 to 2248 feet. The watershed slopes are shown in Figure 3-7. Based on the 2000 land use delineated for this project, the WFWR watershed contains 19,413 acres (33 miles^2) of pastureland. The slopes within pasture areas ranged from 0% to 47%. The overall average slope of all pasture areas in the WFWR watershed was 7%. Based on the 2000 land use delineated for this project, the WFWR watershed contains 46,539 acres (73 miles^2) of forestland. The slopes within forested areas ranged from 0% to 64%. The overall average slope of all forested areas in the WFWR watershed was 17%.

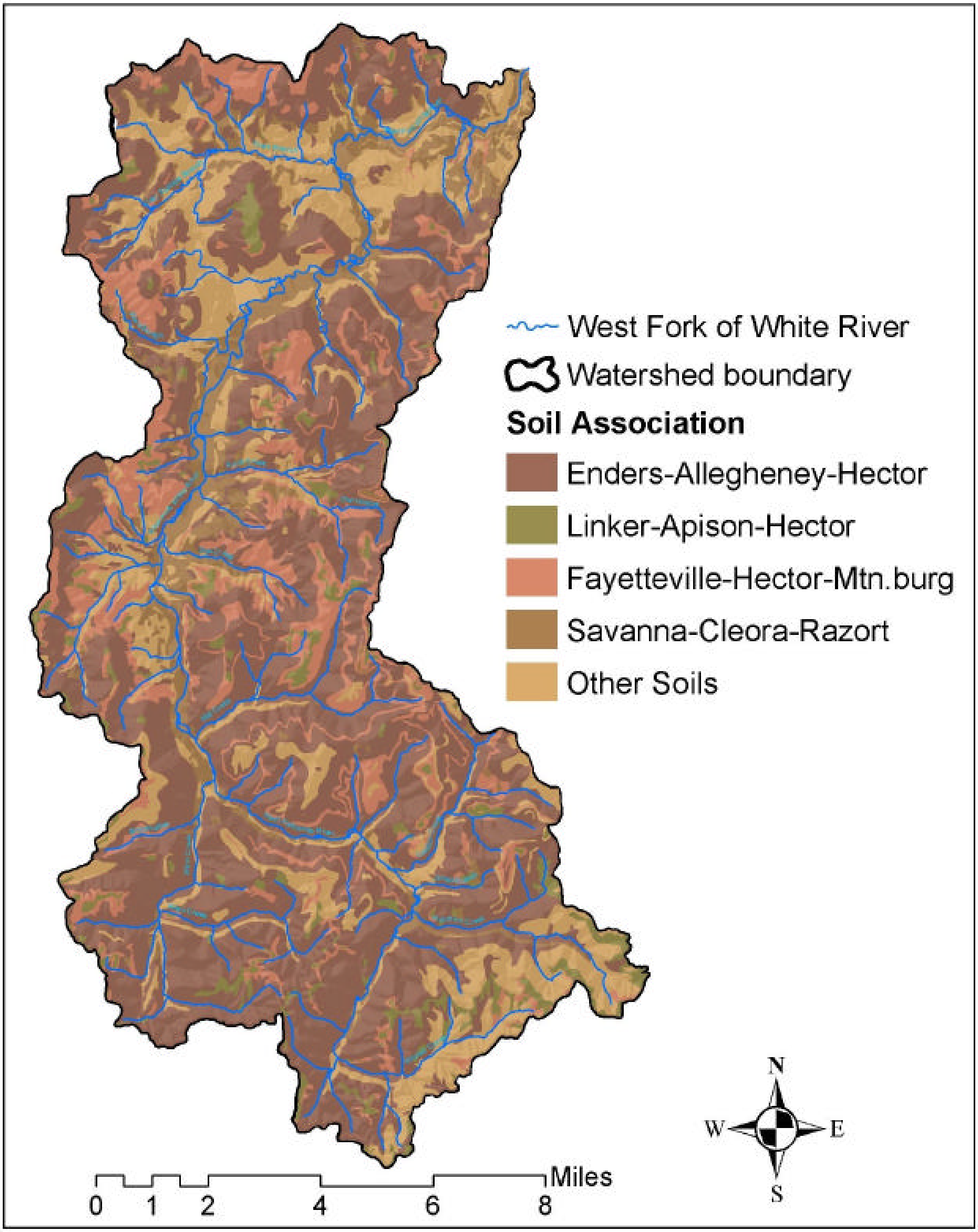

Figure 3-6 Soil associations found in WFWR

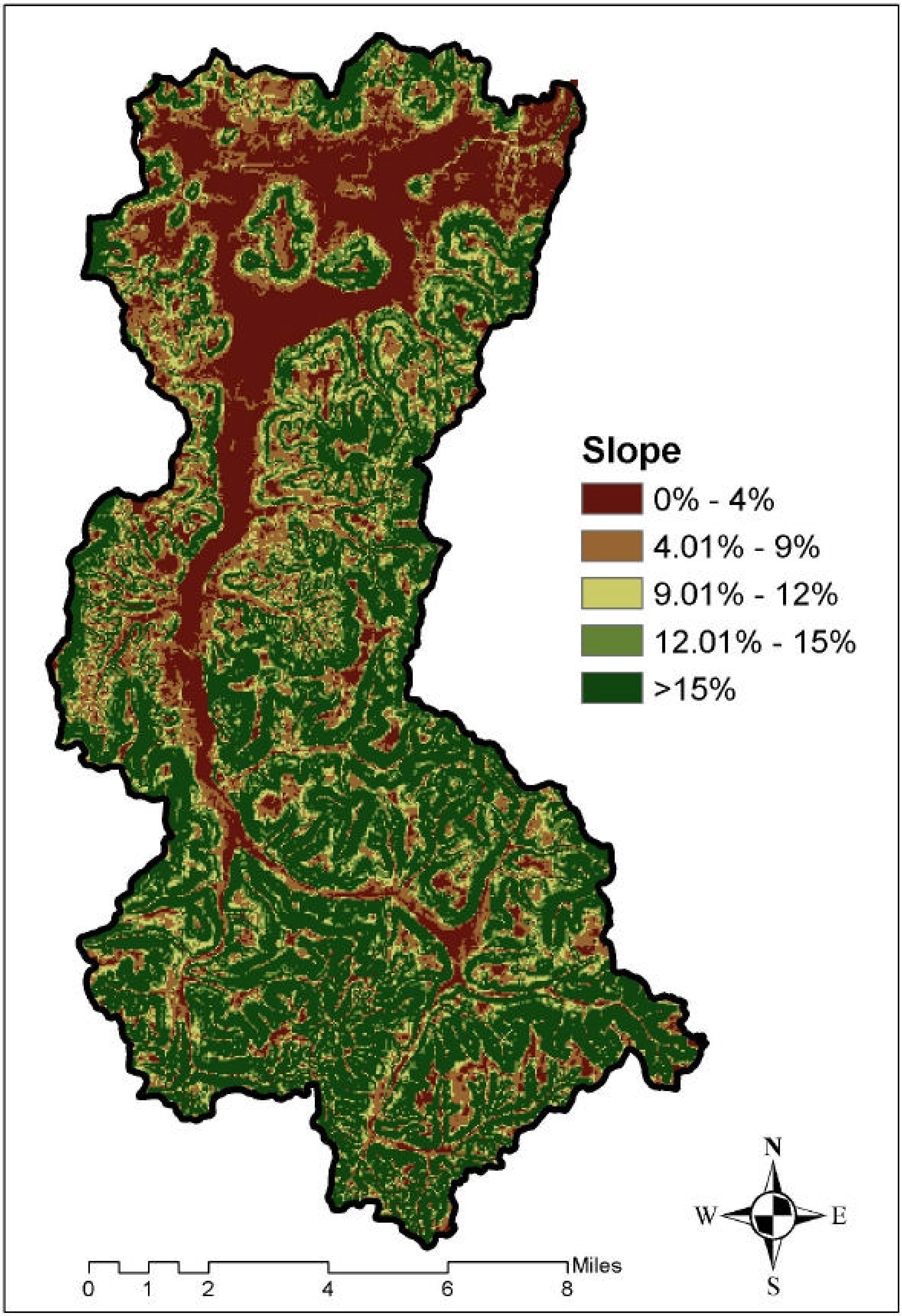

Figure 3-7 WFWR watershed slopes

3.2 Land Use in the WFWR Watershed

A land use analysis of a watershed provides important information for understanding the watershed's hydrological characteristics, water quality, and sources and causes of environmental problems. Often, changes in a watershed's hydrology can be traced back to changes in land use. For example, as a watershed becomes more urbanized, the impervious area increases, leading to less infiltration of rainwater and faster delivery of water to the stream. These hydrologic changes can result in instability of the stream's morphology. Forested areas in a watershed are important for reducing runoff. Forest canopy softens the raindrop impact, leaf litter slows runoff and encourages infiltration, and tree roots uptake the infiltrated water reducing sub-surface flow. When trees are harvested from forested areas, these hydrologic benefits are surrendered.

Land use changes also affect the water quality and the ecological systems within a stream. Forest and pasture areas around a stream serve as a wildlife habitat and buffer areas for runoff of sediment and nutrients. Forest canopy maintains water temperature and preserves the stream's dissolved oxygen levels, maintaining habitat for oxygen sensitive aquatic species. Streams subject to urban runoff can have higher concentrations of metals and bacteria and support a less rich aquatic community (Schuler and Holland 2000).

Also, watershed restoration and general environmental improvements usually occur within the boundaries set by the land use. For example, once an area becomes urbanized, in almost every case, it will not be converted back to a forested area. Instead, environmental restoration would be designed based on and limited to the conditions set by an urban environment.

3.2.1 Historical Land Use

The abundance of natural resources has made Washington County a natural habitat for humans for thousands of years. Historically, the landscape supported hardwood forests as well as grasslands and a variety of plants that attracted wildlife. Water was consistently abundant, and caves and bluff overhangs made good shelters for early human. Later Indian civilizations hunted, planted crops, and lived in the fertile river bottoms (Shiloh Museum, 1989).

In the early 1800's, white settlers had started to move west across the United States, and this raised tension regarding land rights between the white settlers and the native Indians. In 1817, a large Cherokee Indian reservation was created between the Arkansas and White Rivers in northwestern Arkansas, which included the lands of Washington County. Some white settlers began to move into the area at this time, despite the government restrictions on settling the area. The reservation belonged to the Cherokee for the next ten years, but increasing pressure from new American citizens convinced the U.S. government to renegotiate the reservation boundaries. By 1827, white settlers were free to move into what is now Washington County, and the area became settled rapidly. Later, beginning in 1831, the Cherokee Indians were moved out (Shiloh Museum, 1989).

As the population of Washington County grew, the agriculture activity increased. The census of 1840 shows that just over 7,000 people lived in the county and details agricultural production. Corn, oats, potatoes, and wheat were the major crops. Farmers also produced apples, tobacco, and cotton. The settlers depended on a variety of livestock for food, transportation, farm work, and clothing. Hogs, chickens, sheep, horses, mules, cattle, and oxen were common (Shiloh Museum, 1989).

The northern lands of Washington County were open grasslands with a few scattered trees, while the southern lands were hilly and forested. Leo Lesquereux was a botanist who visited the southern part of Washington County in the late 1850's. He described the landscape as follows (Shiloh Museum, 1989).

> *"From the banks of the White River, where the Shellbark Hickory, the Sweet Gum, the Maple, with Red, Black and Spanish Oaks abound, the divide, to the high waters of Lee's Creek is still a broad ridge…It supports a very luxuriant growth of timber. The trees grow here at an equal distance from each other, just as though they had been planted by hand, raising their straight, large trunks to a height of sixty to eighty feet, and supporting immense pyramids of branches, forming there an arch of plashing boughs. They are of the same species formerly enumerated with the addition of the thick Shellbark Hickory, and without any underwood but some shrubs of the Chincapin."*

In 1881, the San Francisco railroad opened the first line in Washington County. The first track ran through the WFWR watershed, from Fayetteville to Winslow. The company used the county's timber for the railroad ties. The railroad enabled goods to be exported from the county. Fruit and other agricultural goods were sold, but the number one export became the huge white oaks from the county's southern forests. Roads that had been built during the initial rail construction made the timber accessible for logging (Figure 3-8) and demand was high, due to expansion of the rail system throughout the country. One of the earliest loggers in the area was Hugh McDanield, who alone sold $12 million worth of timber from 1870 to 1880. The "timber boom" continued into the 1900's (Shiloh Museum, 1989).

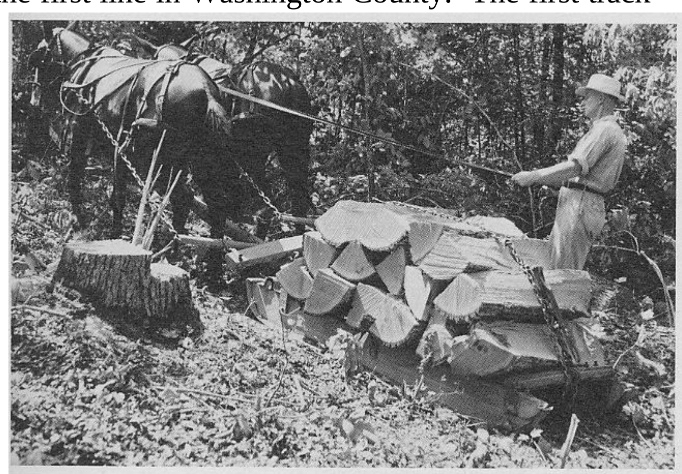

Figure 3-8 Sledding timber to the haul road. Reproduced from *For the Trees* (Bass, 1981)

3.2.2 GIS Analyses: 1994 & 2000

Methods: GIS data was collected and developed in order to characterize land use in the WFWR watershed. To get a sense of how the land use has changed recently, the 1994 and 2000 series of digital ortho-quarter quads (DOQQ) were both collected for land use delineation. Through cooperative meetings between the ADEQ project team, University of Arkansas, NRCS, conservation district, and other people familiar with the watershed, a land classification system was developed. The group used the Anderson Classification system as a base and then modified it to include specific activities in the watershed that would be of interest as shown in Table 3-3.

After the classification system was established, the watershed boundary and DOQQs were used for heads-up digitizing of the land use in the watershed. Heads-up digitizing is done by zooming to a visible scale on the DOQQs and drawing polygons around separate areas of land use.

Table 3-3 West Fork of the White River Land use Classification System

1	Urban or Built-Up land
11	Residential
111	Construction Sites
112	Developing Residential
113	Single House Site
12	Commercial Services
121	Construction Sites
122	Junk Yards
13	Industrial
131	Construction Sites
14	Transportation
141	Construction Sites
142	I-540
143	I-540 Construction
15	Industrial and Commercial
151	Construction Sites
16	Mixed Urban or Built-Up Land
161	Construction Sites
162	University of Arkansas
163	Public Schools
17	Utilities (telephone, gas, water, power lines etc.)
171	Construction Sites
18	Recreational
181	Golf Course
182	Football Field
183	Baseball Field
184	Other Managed Turf Areas
2	Agricultural Land
21	Pasture
22	Orchards
23	Vineyards
24	Chicken House Pads
25	Confined Poultry Operations
26	Confined Swine Operations
27	Other Agricultural Lands
28	Pasture/Forest - Transitional Area
29	Feeding areas
3	Rangeland
31	Shrub and Brush Rangeland
4	Forest land
5	Water
51	Streams and Canals
52	Lakes or Reservoirs
53	Ponds
54	Potential Hydric Soils (Wetlands)
6	Barren Land
61	Bare Exposed Rocks
62	Strip Mines, Quarries, and Gravel Pits
63	Bare ground areas (disturbed areas)
64	Clear Cut
99	Unknowns

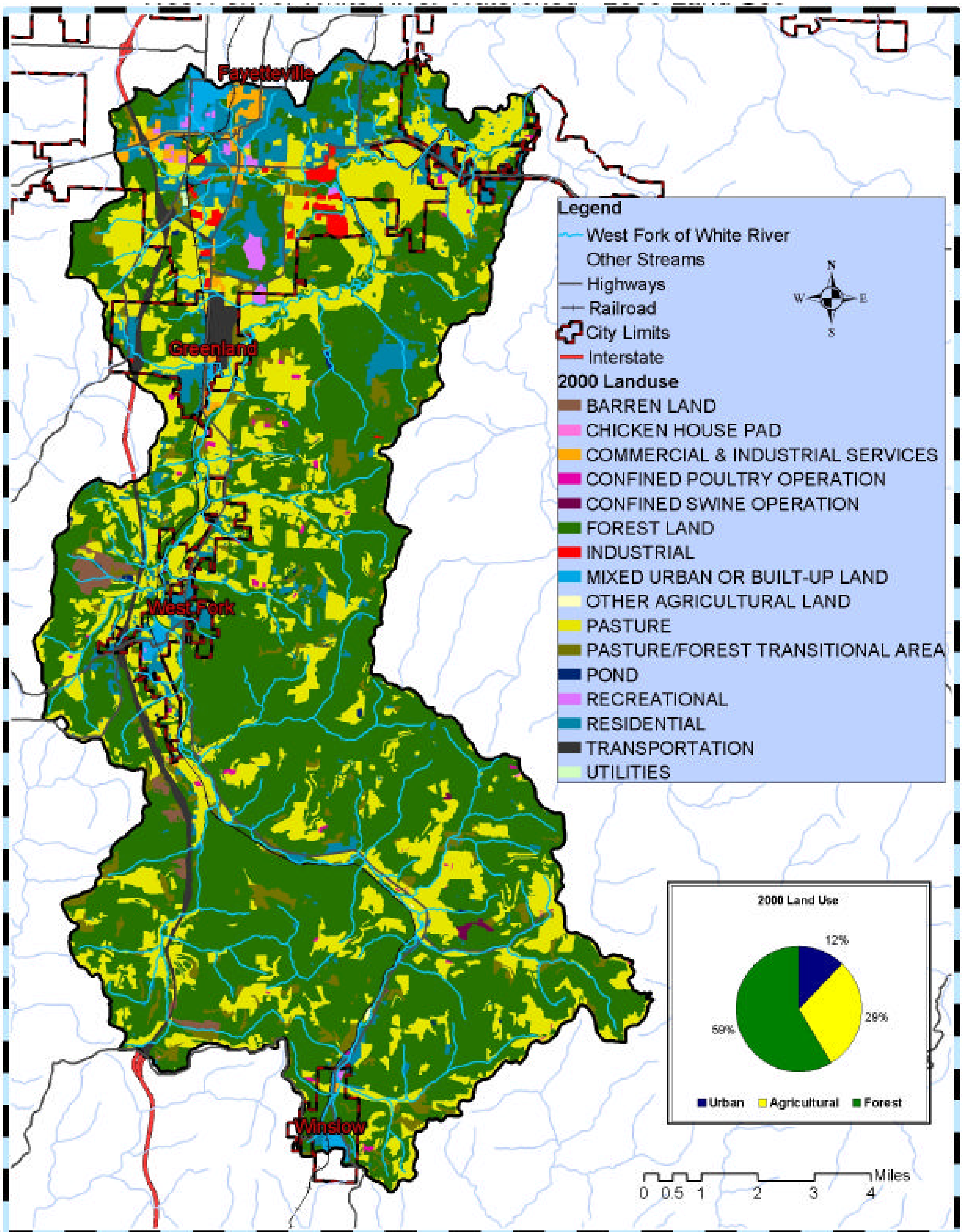

Figure 3-9 Land uses in WFWR based on 2000 DOQQs

Results: The WFWR watershed covers 124 square miles or approximately 79,628 acres. The 1994 DOQQs were digitized by the University of Arkansas' Department of Agronomy. The 2000 DOQQs were digitized by ADEQ project staff and the results . The WFWR watershed 2000 land uses are shown in Figure 3-9.

The 1994 land use delineation showed the WFWR watershed was 10.0% urban (8009.5 acres), 30.7% agriculture (24,420.2 acres), and 59.3% forested (47,197.8 acres). In the urban category, 4,424 acres were residential, 739 acres were commercial, 453 acres were industrial, 1,095 acres were transportation, 133 acres were industrial and commercial, 539 acres were mixed urban, 23 acres were utilities, and 284 acres were recreational land uses. In the agriculture category, 18,942 acres were pasture, 5 acres were orchard, 15 acres were chicken house pads, 205 acres were confined poultry operations, 59 acres were confined swine operations, 10 acres were other agricultural land, and 5,080 acres were pasture-forest transitional areas.

The 2000 land use delineation showed the WFWR watershed was 12.2% urban (9709.9 acres), 29.3% agriculture (23,337.6 acres), and 58.5% forested (46,539.5 acres). In the urban category, 5,336 acres were residential, 695 acres were commercial, 451 acres were industrial, 1,366 acres were transportation, 139 acres were industrial and commercial, 666 acres were mixed urban, 27 acres were utilities, and 316 acres were recreational land uses. In the agriculture category, 19,413 acres were pasture, 5 acres were orchard, 10 acres were vineyard, 14 acres were chicken house pads, 228 acres were confined poultry operations, 59 acres were confined swine operations, 14 acres were other agricultural land, 3,501 acres were pasture-forest transitional areas and 5 acres were feeding areas. A detailed comparison of 1994 and 2000 land uses are shown in Table 3-4. The general level 1 comparison, below, shows the fraction of each land use compared to the total watershed area:

	1994	**2000**
Urban	10.0%	12.2%
Agriculture	30.7%	29.3%
Forest	59.3%	58.5%

Comparing 1994 land use to 2000, urban area in the watershed increased by 21%, while agriculture and forest lands decreased by 5% and 1%, respectively. Residential areas increased 20.6% overall due to growth in cities and increase in the number of single house sites. Transportation increased 24.7% within the watershed. This is because construction on Interstate 540 was only partially completed in 1994, but totally completed in 2000. There is also a large difference in pasture-forest transitional areas showing a 31.1% decrease from 1994 to 2000. These areas were cleared for agricultural use or made into single house sites.

Table 3-4 West Fork of the White River 1994/2000 Land Use Comparison

Land use category			1994		2000	
Level 1	**Level 2**	**Level 3**	**Area (ac)**	**% of Total**	**Area (ac)**	**% of Total**
Urban	Residential		3,072	3.9%	3,838	4.8%
		Residential Construction Site	39	0.0%	0	0.0%
		Developing Residential	451	0.6%	104	0.1%
		Single House Site	861	1.1%	1,394	1.8%
	Commercial Services		610	0.8%	570	0.7%
		Junk Yard	130	0.2%	125	0.2%
	Industrial		453	0.6%	451	0.6%
	Transportation		341	0.4%	342	0.4%
		Transportation Construction Site	78	0.1%	0	0.0%
		I 540	116	0.1%	1,020	1.3%
		I 540 Construction	559	0.7%	4	0.0%
	Industrial and Commercial		133	0.2%	139	0.2%
	Mixed Urban or Built-Up Land		117	0.1%	245	0.3%
		University of Arkansas	330	0.4%	363	0.5%
		Public School	93	0.1%	59	0.1%
	Utilities		23	0.0%	27	0.0%
	Recreational		81	0.1%	100	0.1%
		Golf Course	111	0.1%	111	0.1%
		Football Field	7	0.0%	2	0.0%
		Baseball Field	16	0.0%	29	0.0%
		Other Managed Turf Area	69	0.1%	74	0.1%
Agriculture	Pasture		18,942	23.8%	19,413	24.4%
	Orchard		5	0.0%	5	0.0%
	Vineyard		0	0.0%	10	0.0%
	Chicken House Pad		15	0.0%	14	0.0%
	Confined Poultry Operations		205	0.3%	228	0.3%
	Confined Swine Operations		59	0.1%	59	0.1%
	Other Agricultural Land		10	0.0%	14	0.0%
	Pasture/Forest - Transitional Area		5,080	6.4%	3,501	4.4%
	Feeding Area		0	0.0%	5	0.0%
Forest Land			47,198	59.3%	46,539	58.5%
Water	Pond		105	0.1%	117	0.1%
Barren Land	Bare Exposed Rock		9	0.0%	0	0.0%
	Strip Mines, Quarries, and Gravel Pits		255	0.3%	342	0.4%
	Bare Ground Area (disturbed area)		53	0.1%	255	0.3%
	Clear Cut		0	0.0%	89	0.1%

3.2.2.1 Sub-watershed Evaluation

The WFWR watershed consists of smaller sub-watersheds. Twelve major sub-watersheds were delineated using contour lines and DEMs. Location and areas of sub-watersheds are shown in Figure 3-10. Land use for each sub-watershed was evaluated, using the 2000 land use delineated for this project, to determine areas that have the greatest potential for affecting the river. The sub-watershed land use analyses are summarized in Table 3-5. and Figure 3-11.

Forest in the sub-watersheds ranged from 24% - 86%, although 10 of the 12 sub-watersheds were over 50% forestland. Mill Creek and Wilson Branch sub-watersheds had the highest percent forest with 86% and 82%, respectively.

Agriculture land was consistent ranging from 24% to 39% in 10 of the 12 watersheds. "Wilson Branch" and Mill Creek sub-watersheds both had less agriculture land with 16% and 13%, respectively. Ward Slough sub-watershed had the highest percentage of agricultural land (39%).

The range of urban land varied from 0.3% to 45%; however, 10 of the 12 sub-watersheds had less than 7% urban area and of those, six had 1% or less. Three sub-watersheds have significant urban area, Town Branch, Cato Springs Branch, and Ward Slough. All three are located in the Fayetteville area. In addition, Town Branch's urban area comprises 35% of the total urban area in the WFWR watershed, while the total Town Branch sub-watershed is only 9.4% of the total WFWR watershed. 91 acres of the 125 total acres of junk yards in the WFWR watershed are located in the Ward Slough sub-watershed.

"West Mountain Branch" was the only sub-watershed with a significant amount of barren land, because of the quarry that is located in the sub-watershed.

Table 3-5 Land uses in WFWR sub-watersheds

Sub-Watershed	FOREST LAND (ac)	AGRICULTURAL LAND (ac)	URBAN OR BUILT-UP LAND (ac)	BARREN LAND (ac)	Total Area (ac)
Town Branch	2154.8	1941.2	3370.9	0.0	7467
*Cato Springs Branch	1012.2	1206.8	726.0	0.0	2945
Ward Slough	478.2	783.7	723.7	0.0	1986
"Wilson Branch"	1717.9	343.6	35.1	0.0	2097
Rock Creek	2451.3	1293.7	33.9	0.0	3779
"West Mountain Branch"	1684.7	814.0	130.8	369.5	2999
Dye Creek	1538.0	614.7	172.5	0.0	2325
Mill Creek	4054.3	607.0	41.1	0.0	4702
London Creek	2407.0	846.0	28.7	0.0	3282
Winn Creek	6532.9	2232.6	319.8	152.5	9238
**Riley Creek	2016.4	485.2	30.5	0.0	2532
Jones Branch	326.8	193.6	3.8	3.7	528
Hutchins Creek	2421.0	1350.3	12.4	2.2	3786
Sinclair Creek	2137.8	1071.0	36.2	0.0	3245

*discharges to Town Branch
**discharges to Winn Creek

Major Sub-watersheds of the WFWR Watershed

Sub-Watershed	Drainage Area acres	Drainage Area mi²
Winn Creek	9238	14.4
Mill Creek	4702	7.3
London Creek	3282	5.1
Hutchins Creek	3786	5.9
Sinclair Creek	3245	5.1
"West Mountain Branch"	2999	4.7
Dye Creek	2325	3.6
Rock Creek	3779	5.9
"Wilson Branch"	2097	3.3
Ward Slough	1986	3.1
Cato Springs Branch	2945	4.6
Town Branch	7467	11.7
Riley Creek	2532	4.0

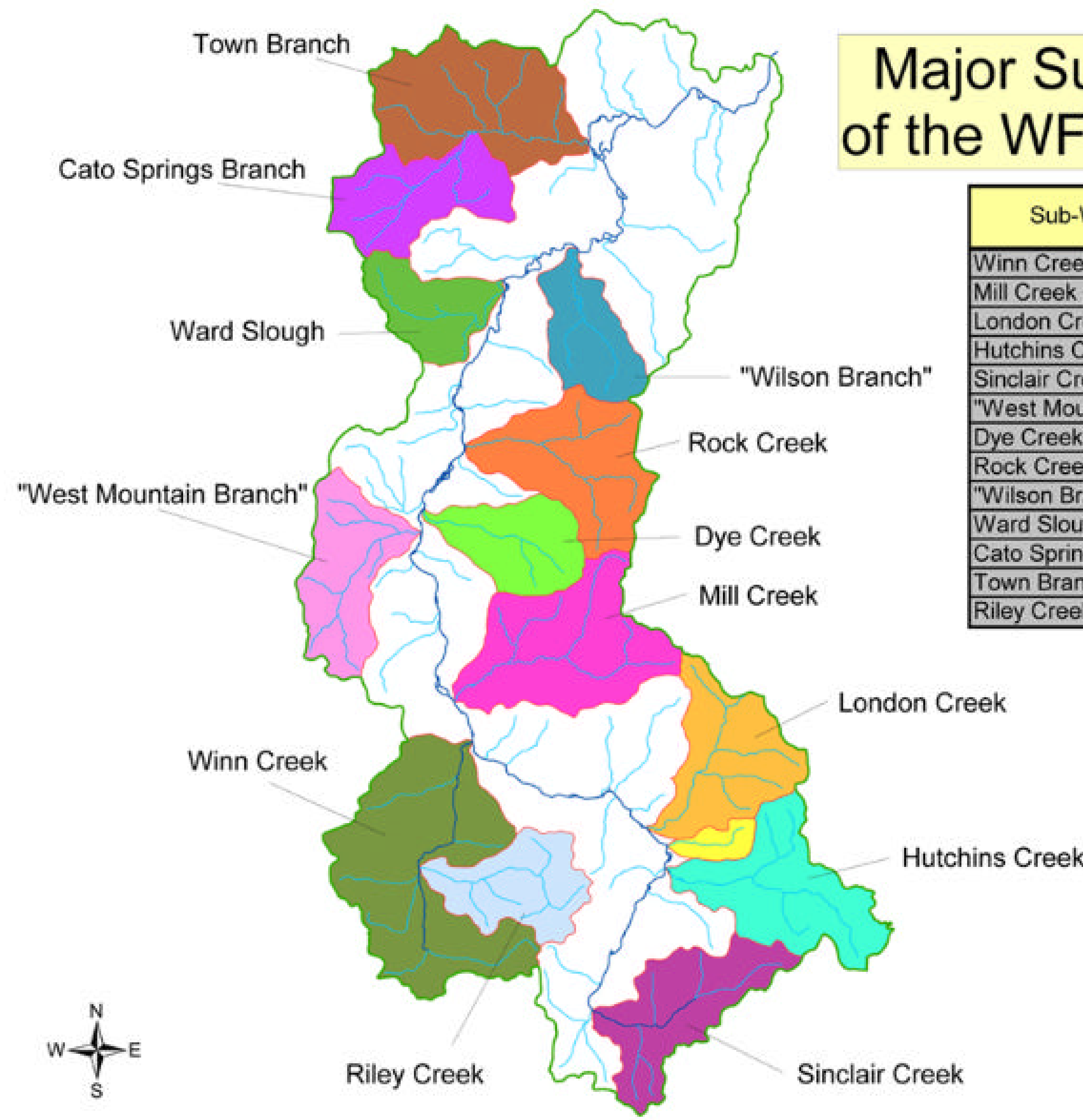

Figure 3-10 Location and Area of WFWR Subwatersheds

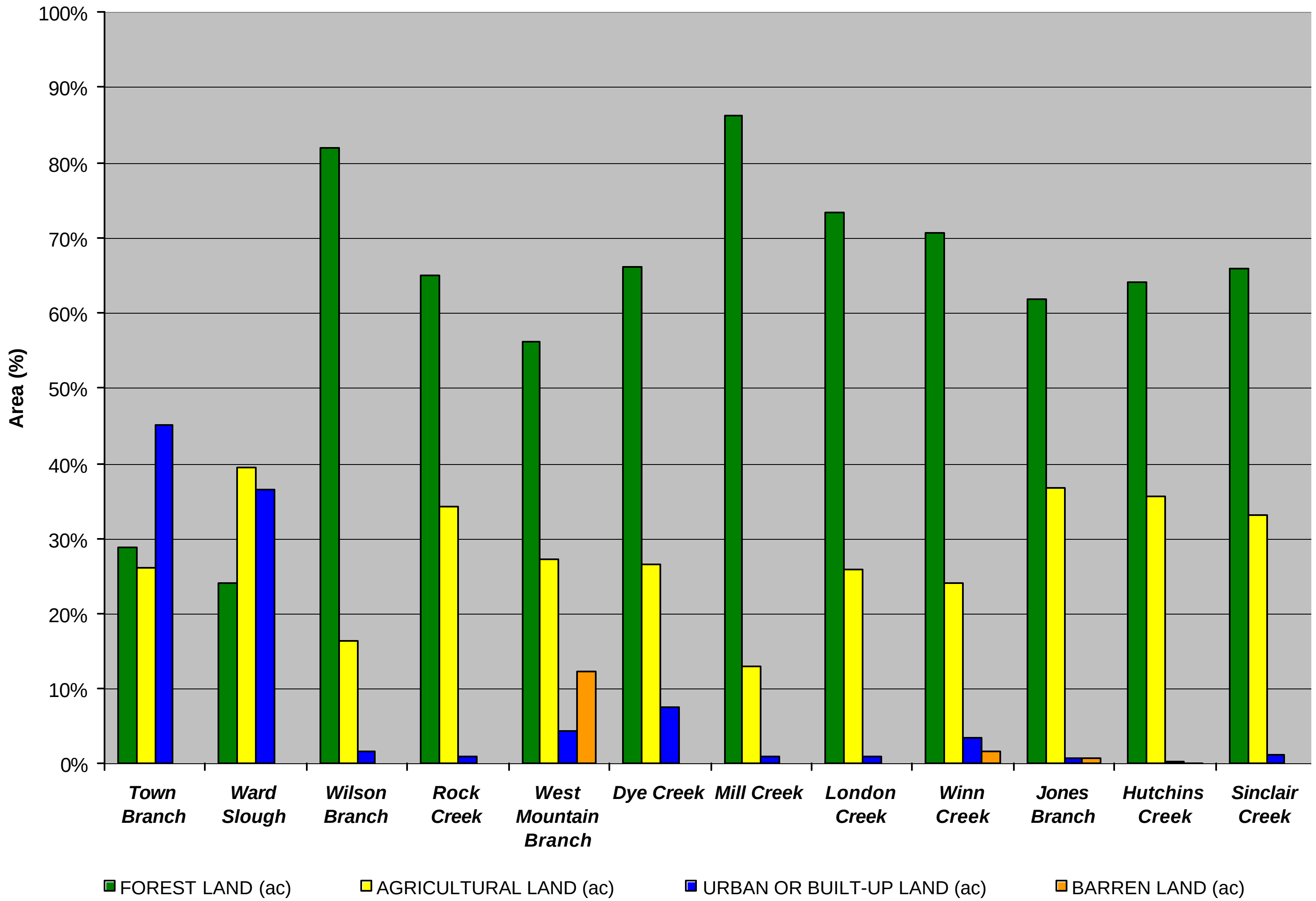

Figure 3-11 Relative Level 1 Land Uses for WFWR Subwatersheds

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3.3. NPDES Permitted Facilities

The National Pollutant Discharge Elimination System (NPDES) is the program established by the Clean Water Act that requires all point sources of pollution discharging into any "waters of the United States" to obtain a permit issued by the U.S. Environmental Protection Agency (EPA) or a state agency authorized by EPA. The NPDES permit lists permissible discharges and/or the level of cleanup technology required for treated wastewater. There are two facilities in the WFWR watershed that have NPDES permits (Figure 3-12), the West Fork quarry and the West Fork wastewater treatment plant (WF-WWTP). Detailed permit information and the discharge monitoring reports (DMR) for each facility can be found on the internet at http://www.epa.gov/enviro/html/pcs/pcs_query_java.html.

The West Fork quarry is operated by McClinton-Anchor, a division of APAC of Arkansas, and produces more than 650,000 tons per year of cut stone and stone products. The quarry's NPDES permit number is AR00456967 with the address 12274 Campbell Road, West Fork, AR 72774. A tributary of the WFWR receives the wastewater from the quarry. The permitted parameters for the quarry are reported on a quarterly basis and include turbidity, pH, TSS, oil & grease, and flow.

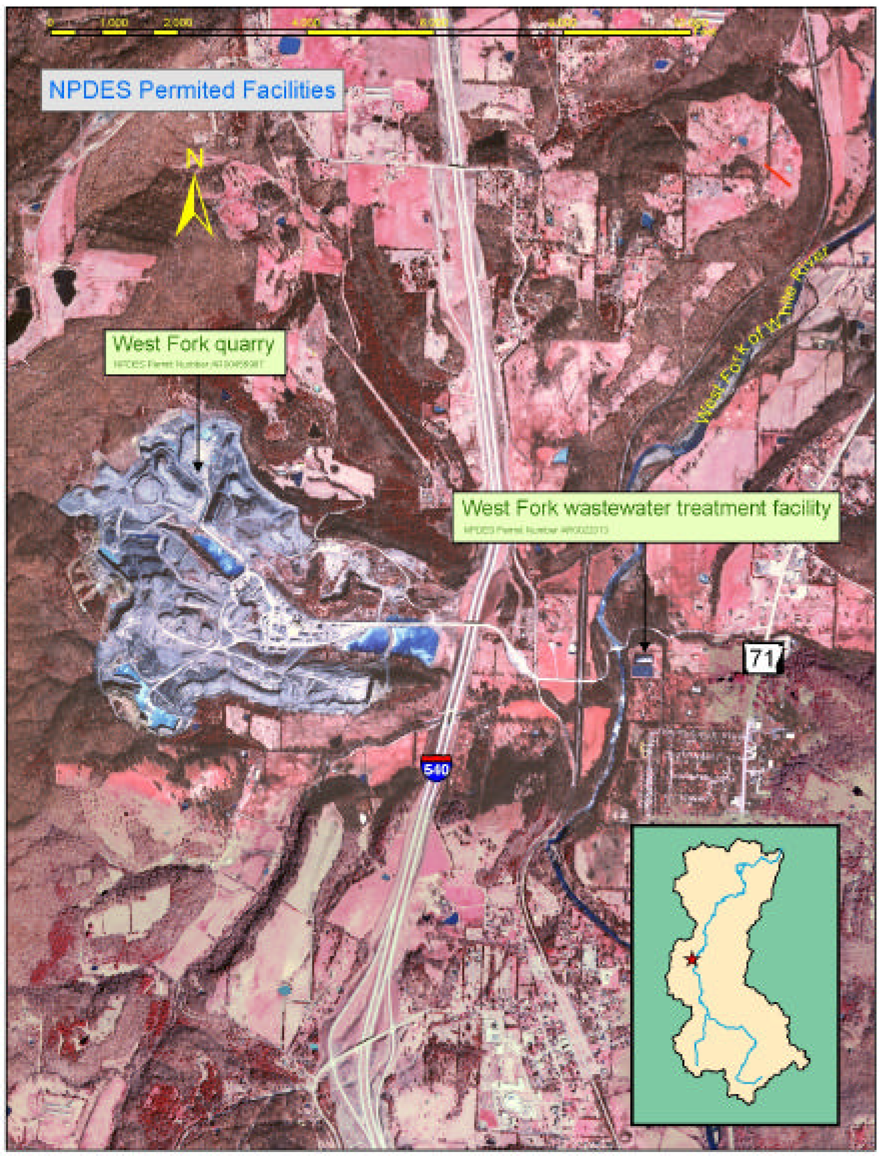


Figure 3-12 Location of NPDES permitted facilities in WFWR watershed

The city of West Fork operates a publicly owned wastewater treatment facility under NPDES permit number AR0022373, and discharges wastewater to the WFWR. The address for the plant is 323 Northwood Avenue, West Fork, AR 72774. The outfall for the plant is located approximately 14 miles upstream of the confluence of the West Fork with the main fork of the White River. The plant receives wastewater from residential and commercial sources within the West Fork City limits and does not receive waste from industrial dischargers. The facility is designed to treat 0.1 million gallons of wastewater per day. The permitted parameters for this facility are: BOD_5, TSS, NH_3-N, DO, Fecal Coliform Bacteria, pH, and flow (See Appendix 2-B for parameter names, symbols, and units).

3.4. Agriculture

Agriculture is a major contributor to the economy of the WFWR watershed. The University of Arkansas Cooperative Extension Service (UA-CES) performed a landowner survey of the residents of the WFWR watershed as part of a Best Management Education and Training Project for the watershed (UA-CES, 2004). The survey report can be found in Appendix 3-A. Over 300 landowners responded to the survey, which focused on agricultural activities in the watershed. Some of the information from the survey was used to assess watershed conditions and land use.

3.4.1 Confined Animal Operations

Northwest Arkansas is known for its confined poultry and swine production. For decades, poultry production and processing has been a foundation of the regional agricultural economy. Poultry is produced by independent farmers who grow under contract for a major corporation. Confined swine production in the region began in the mid 1970's; production peaked in the late 1990's and has been in decline since that time (Staton, 2004). Swine production within the WFWR watershed was corporate owned farms. The location of confined animal operations within the watershed is depicted on Figure 3-13. A discussion of nutrients generated by confined animal operations and manure management within the WFWR drainage basin can be found in Chapter 5 of this report.

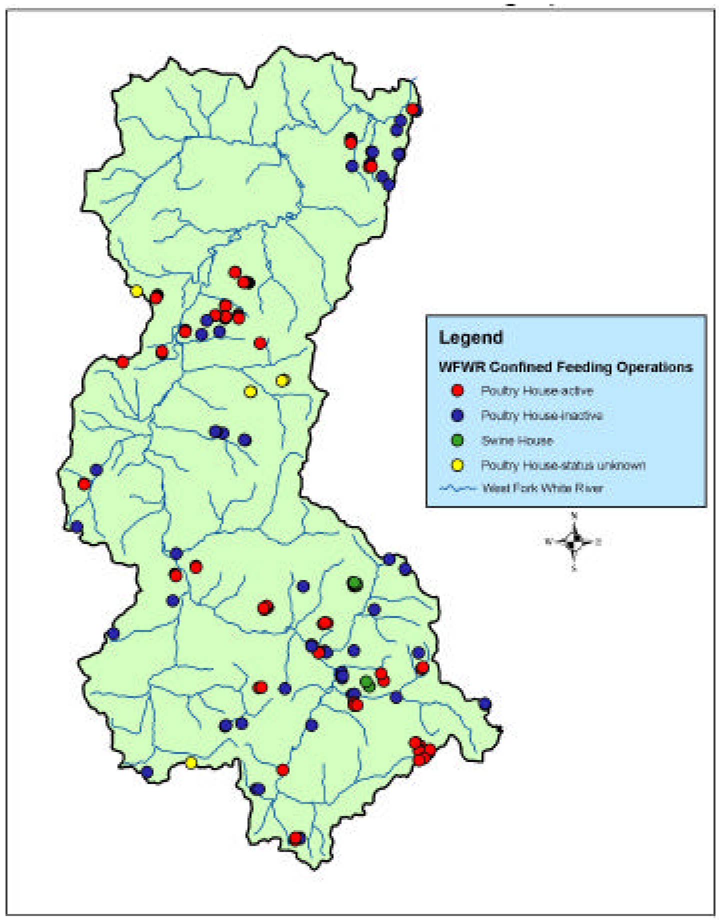


Figure 3-13 Location of confined feeding operations in WFWR watershed

There are 79 active and 57 inactive poultry houses located within the WFWR drainage basin. Individual farms typically have between two and six houses with 20,000 to 30,000 birds confined within each building. Chicks are received within 24 hours of hatching and begin a 7-week growing cycle. At the end of the growing cycle, birds typically weigh 6-8 pounds and are collected and shipped to a local plant where they are processed within hours of leaving the farm. A typical poultry farm will produce six batches of birds each year. Once the growing cycle is complete, birds are shipped to be processed. The houses are prepared for the next growing cycle. In this process, the thin veneer of compacted manure is removed from the underlying bedding material and land applied as a fertilizer to nearby pasture land (Figure 3-14). At least once annually, the manure and bedding material (litter) are completely removed from the houses and land applied to pasture. On farm mortality or dead chickens are stored in freezers until a collection truck transports the material to a rendering plant.

Figure 3-14 Spreading litter on a typical poultry farm

There were two corporate owned and operated swine farms within the watershed, however both have recently closed. A 2400-sow 7360-pig farrowing/nursery operation located in the Landon Creek sub-basin, and a 4000 animal finishing farm, which was located within the Hutchins Creek sub-basin. Both farms utilized water to flush waste to under house storage pits where manure was stored until it could be land applied to forage crops. These farms operated their wet waste systems under state permits, which have recently been voided. On farm mortality was stored in freezers and periodically transported to a rendering plant.

3.4.2 Cattle Operations

The cattle industry within the WFWR drainage basin consists exclusively of brood cow operations for the production of beef (Figure 3-15). According to the Arkansas Cooperative Extension Service, there are 211 of the 300 landowners surveyed had beef cattle operations in the WFWR watershed (UA-CES, 2004). With these agricultural

Figure 3-15 Cattle operations are common in the WFWR watershed

operations, brood cows are grazed and maintained on improved pasture and produce calves at approximately one-year intervals. Bulls are kept for breeding purposes, with a single bull servicing 20 to 30 cows. The offspring are raised to around 400 to 600 pounds and sold off the farm. Much of the annual calf crop is sold to Midwestern feedlots; however, some animals are kept on the farm or sold locally as replacement cows.

In order to prevent undue stress on animals, water and shade is made available at short walking distances. Sources of water include man made ponds, tanks and streams. Summer time heat stress can cause animals to spend a considerable portion of the day loafing in or near water.

The two primary types of waste from cattle operations include on farm mortality and manure. On farm mortality is typically managed by burying, burning or removal to a remote location on the farm. As with other forms of animal agriculture, manure is an obvious byproduct. According to the NRCS Agricultural Waste Management Handbook, brood cows will produce as much as 60 pounds of manure per day. From the cows grazing activity, much of the manure is spread over the pasture; however, during hot dry weather much of the manure is concentrated near shade and water sources. A more detailed discussion of cattle manure derived nutrients can be found in Chapter 5 of this report.

3.4.3 Pasture Management and Forage Production

There are two basic grazing strategies utilized by farmers within the watershed. Cows are either continuously grazed or rotationally grazed. With continuous grazing, animals are allowed to graze on forage crops at will, year round. This production method requires less capitol input into production in the form of labor, fencing and sources of water. Rotational grazing involves dividing pasture into smaller paddocks, which are intensively grazed for short periods. After a relatively short period of intense grazing pressure, all animals are removed to an un-grazed paddock, and the field from which cattle were removed is allowed to recover. This management method allows for increased production; however, it requires more input in the form of labor, fencing and water sources.

Pasture forage crops consist of a variety of grasses, forbs and legumes; however, fescue and Bermuda grass are common at most farms. Bermuda over-seeded with fescue provides spring and fall cool season growth from the fescue and hot weather growth from the Bermuda. The Cooperative Extension Service estimates forage production within the WFWR drainage basin to be approximately 4 tons dry mass/acre/ year. For total of 19,413 acres of pasture, the total forage yield within the watershed would be approximately 77,652 tons dry mass/year. In order to boost forage production and

Figure 3-16 Typical Pasture Land

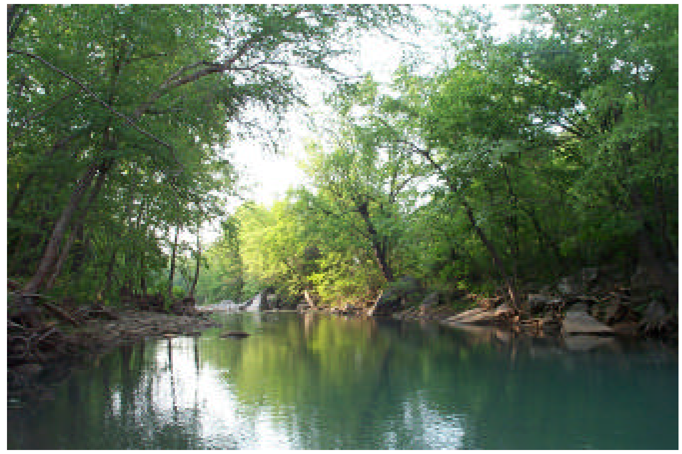
therefore increase the carrying capacity of pastures, soil fertility is enhanced with essential nutrients in the form of animal manure and/or commercial fertilizer. Fertilizer is land applied during the active growing season of the cover crop. Many of the beef cattle operations are integrated with poultry operations, which provide an additional source of farm income as well as animal manure fertilizer for forage production.

Most farms set aside certain fields for the production of hay, which is cut, dried and baled during the growing season and used to supplement the cow's diet during the winter months, when forage crops are dormant (Figure 3-16). For smaller operations, the purchase, operation and maintenance of haying equipment is cost prohibitive. Smaller farms typically purchase over-wintering forage from commercial hay operations.

3.5 County Roads, septic tanks, and other critical areas

3.5.1 Critical Riparian Area Evaluation.

Riparian areas are an essential to overall watershed condition. Riparian areas provide shade for streams, filter out contaminants, help prevent streambank failures and provide habitat for wildlife. By providing these services, riparian areas protect water quality and improve ecological diversity in the watershed where they exist. Figure 3-17 shows an example of a healthy riparian vegetation community, and Figure 3-18 shows an example of a riparian area that is in need of restoration.



Figures 3-17, 18 Riparian vegetation community on the WFWR near West Fork (top) and near Fayetteville (bottom)

The widths of the riparian areas along the main stem of the WFWR were evaluated to determine areas that could be a priority for riparian restoration. The evaluation was based on both sides of the river from the C.R. 38 bridge over the WFWR to the confluence with the White River. This length represents a total of 30.4 miles of river and 61 miles of riverbank. The riparian area width was determined for the following categories: areas less than 10 ft, less than 50 ft., and less than 100 ft. wide. Many riparian areas were greater than 100 ft. wide. Areas that were less than 100 ft. wide, where there was existing infrastructure, i.e. roads, railroads, or houses, that would prevent the restoration of the riparian community, were not included in the evaluation.

Widths of the riparian areas were determined by first creating a line file in GIS to represent the left and right edge of the active steam channel using the 2000 DOQQs. Using ArcGIS, 10 ft, 50 ft, and 100 ft buffers were created from both stream channel lines. Using the DOQQs, the width of the riparian canopy was then placed in the appropriate category. The analysis revealed that there were 7.3 miles of riverbanks that had riparian areas with a width of 10 ft or less. Many of these areas had no riparian vegetation at all. Including those areas that were less than 10 ft wide, there were approximately 11.3 miles of riverbanks that had a riparian area width less than 50 ft. There were a total of 20.2 miles of riverbank that had riparian areas less than 100 ft. wide, including the other narrower categories. Figure 3-19 indicates the riparian areas along the mainstem of the WFWR that have riparian areas less than 10 ft. in width. These areas should be considered a priority for watershed restoration.

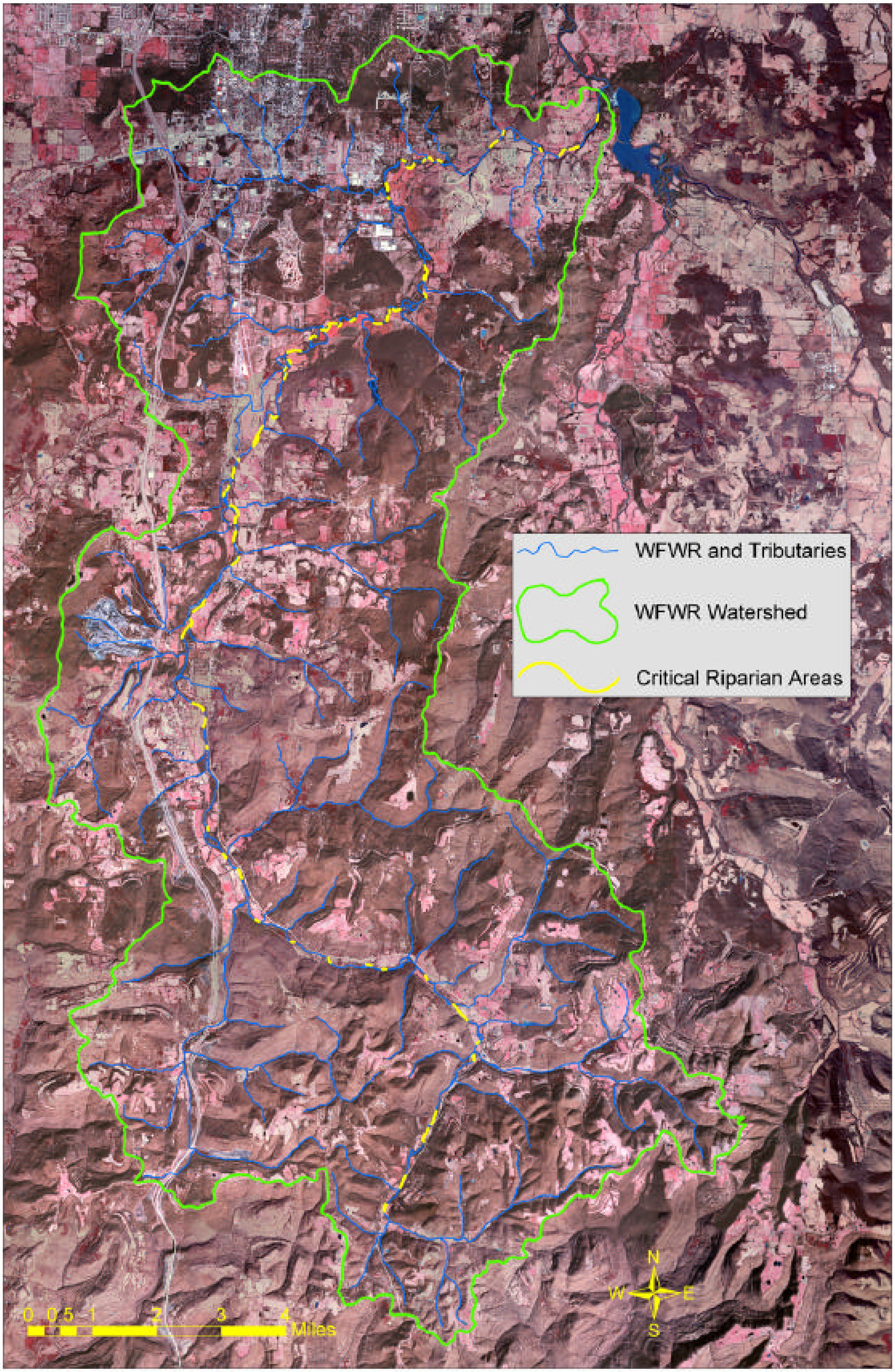


Figure 3-19 Locations of riparian areas along the mainstem of the WFWR that are less than 10 feet wide. .

3.5.2 Septic Tanks

Figure 3-20 The potential for septic tank effluent to reach the WFWR increases for systems located near the river.

Septic tanks have the potential to become a source of nutrients and pathogens if the systems fail or are sited improperly (Figure 3-20). The locations of septic tanks in the WFWR watershed are presented in Figure 3-21. The locations of septic tanks are based on the location of rural residences in the WFWR watershed as determined by data from the Source Water Assessment Program inventory ("Conceptual", 2002). Residences in this dataset are located outside of city/town limits of incorporation and are therefore assumed to be using an on-site septic system for treatment of household effluent. In the WFWR watershed, there are an estimated 1,427 septic systems. Approximately, 189 of the total are located within 300 ft. of the WFWR or one of the tributaries to the WFWR. There are 354 septic tanks are located within 500 ft. of the mainstem or a tributary to the WFWR.

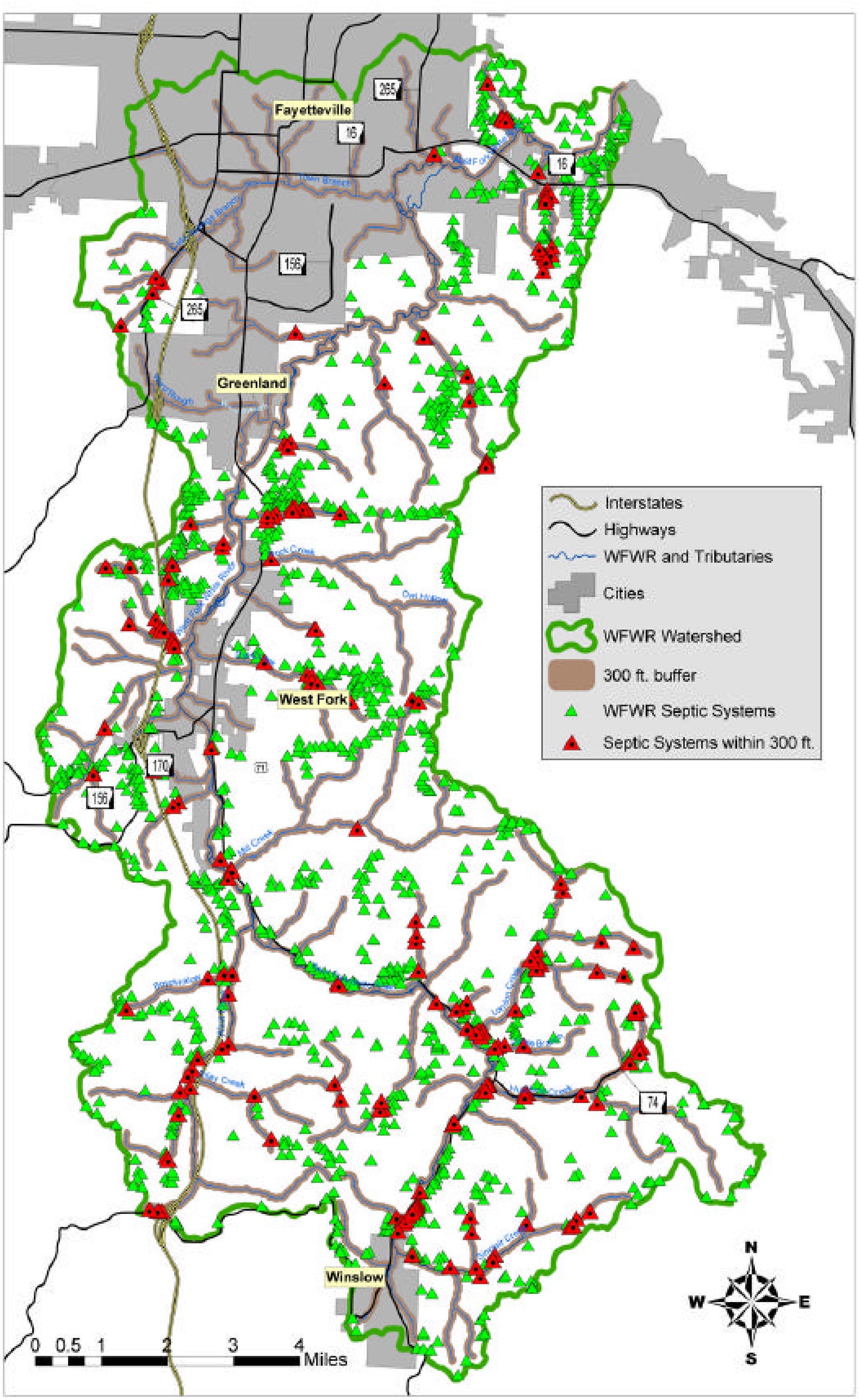


Figure 3-21 Locations of septic tanks in the WFWR watershed

3.6 References

1. ADEQ. Regulation No. 2; Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas. http://www.adeq.state.ar.us/regs/default.htm. Accessed June, 2004.

2. Arkansas Dept. of Environmental Quality, Environmental Preservation Division. Arkansas Watershed Planning Guide. Available ADEQ Manual developed under a USEPA Section 104(b) (3) grant. September, 2003.

3. Bass, S. M. W. 1981. For the Trees; An illustrated History of the Ozark-St. Francis National Forest 1908-1978. USDS Forest Service. (129).

4. Chinn, A.A. and Konig, R.H. 1973. Stress Inferred from Calcite Twin Lemellae in Relation to Regional Structure of Northwest Arkansas: Geological Society of AmericaBull. 84 (3731-3736).

5. Conceptual Model Development Beaver Lake Watershed, Northwest Arkansas. CD-ROM. AWRC. September, 2002.

6. Croneis, C.C. Geology of the Arkansas Paleozoic Areas: Arkansas Geological Survey Annual Report. 4 (457). 1930.

7. National Weather Service. Tulsa, OK. June 2004. http://www.srh.noaa.gov.tulsa/climate/washington.html

8. Perdue, A.H. and Miser, H.D. Description of the Eureka Springs and Harrison Quadrangles. U.S. Geological Survey Geologic Atlas. Eureka Springs-Harrison Folio #202 (22). 1916.

9. Renkin, R. Groundwater Atlas of the United States, Arkansas, Louisiana, Mississippi. USGS Publication No. HA 730-F. 1998.

10. Schuler, T. R. and H. K. Holland. “Basic Concepts in Watershed Planning”. The Practice of Watershed Protection. Ed. Center for Watershed Protection. Elliot City, MD. 2000. (145-161).

11. Shiloh Museum. History of Washington County Arkansas. Springdale, Arkansas, 1989. (41-96).

12. Staton, Billy. ADEQ Water Division State Permits Branch Permit Engineer. Personal communication. May, 2004.

13. University of Arkansas Cooperative Extension Service (UA-CES). 2004. Final Report: Agricultural Best Management Practice Education and Training. 319 Incremental Funding for Beaver Lake Watershed. Grant #C99610307. Project 1100.

14. United States Census. 2000. Ranking tables for metropolitan areas: population in 2000 and population change from 1990 to 2000. Table 5. Accessed July, 2004. http://www.census.gov/population/www/cen2000/phc-t3.html

15. USDA Soil Conservation Service (SCS), USDA Forest Service, and Arkansas Agricultural Experiment Station. Soil Survey Washington County, Arkansas and associated General Soil Map of Washington County. 1969.

Chapter 4: Historical Land use Comparison, River Geomorphology and Landowner Perception

4.1 History and Changes

A review of available sources of historic information was conducted to develop a basic timeline of human activity in the WFWR watershed. Many of the activities that occurred in the past 150 years shown in the timeline in Figure 4-1 have the potential to affect watershed hydrology and water quality in the WFWR. The timeline provides a general idea of the activity of humans in the watershed but cannot provide direct cause and effect relationships between watershed activities and watershed condition.

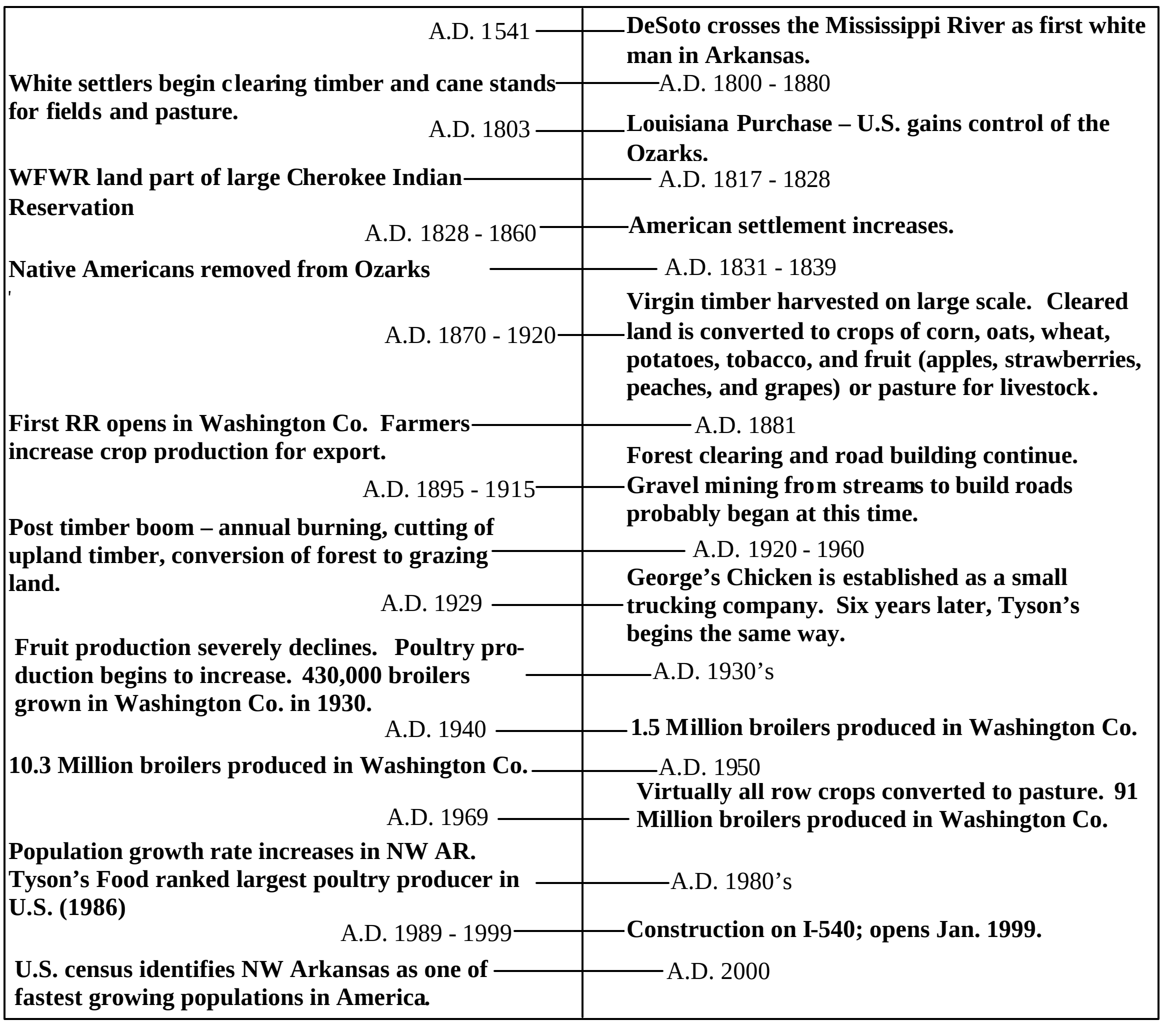


Figure 4-1 Timeline of human activity in the WFWR watershed

4.1.1 Land Use Comparison: 1977 to Present

A land use description from 1977 was found during the literature search (Gilliam, 1977). The author of the 1977 report delineated the watershed using USGS topographical maps. The 1977 land use analysis is a valuable resource for examining land use changes that have occurred in the WFWR watershed over a longer timeframe. Gilliam evaluated land use by driving through the watershed and visually assessing each site. Areas were then hand calculated using maps. The land use analyses for 1994 and 2000 in this study were carried out with far greater precision compared to the 1977 analysis, due to the development of GIS and other tools for spatial analysis. Some latitude must be afforded when comparing land use data developed using current technology to data developed over 25 years ago. Nonetheless, the 1977 data opens a window to assess the general land use changes over a 23 year period. For comparative purposes, the 2000 land use was reclassified into three general categories; urban, agriculture and forest, so 2000 land use data presented in this discussion may differ slightly from values shown in Chapter 3.

The results of the land use change analysis for 1977 to 2000 are shown in Table 4-1. The calculated watershed area for 1977 is greater than the area calculated for 2000. This is probably due to different delineation and measurement methodologies used. Analysis shows the urban area in WFWR watershed increased 22%, from 7,940 acres in 1977 to 9,710 acres in 2000. The amount of land in use as agricultural land increased 18%, from 19,802 acres in 1977 to 23,338 acres in 2000. The area of the watershed that is composed of forest decreased 12%, from 53,110 acres in 1977 to 46,540 acres in 2000. Gilliam also reported the 1977 area of the cities in the watershed (part of Fayetteville, Greenland, West Fork, and Winslow). The areas within city boundaries have increased, as well as the city populations (see Table 4-2 and Table 4-3, respectively).

The observed changes in land use from 1977 to 2000, including increases in urban land use, and the reduction in forested areas may have affected the watershed by changing watershed hydrology and creating additional non-point source pollution from the urban areas. The impacts of these changes could possibly be reduced by implementing BMPs such as vegetative filters or "bio-swales" at large parking areas to reduce hydrologic impacts and pollutant loads. Approaches to reduce the effects of future land use changes could include the use of low impact development techniques in development, encouragement to maintain riparian corridors, and avoiding channelization of small creeks and streams.

Table 4-1 Level 1 Land Use in WFWR - 1977 and 2000

Land Use	***1977 Area (ac)***	***% of Total Area***	***2000 Area (ac)***	***% of Total Area***
Urban	7,940	9.8%	9,710	12.2%
Agricultural	19,802	24.5%	23,338	29.3%
Forest	53,110	65.7%	46,539	58.5%
Total	80,852		79,587	

Table 4-2 City Areas in WFWR - 1977 and 2000

City	***1977 Area (ac)***	***2000 Area (ac)***	***% Increase***
Fayetteville*	11,009	11,423	3.8%
Greenland	621	1,646	165.3%
West Fork	737	1,894	156.8%
Winslow	500	772	54.4%

* Numbers shown represent only the area of Fayetteville within the watershed boundary.

Table 4-3 Population Change in Watershed Cities Over Four Decades

Population	**1970**	**1980**	**1990**	**2000**
Fayetteville	30,729	36,608	42,099	58,047
Greenland	650	622	757	907
West Fork	919	1,526	1,607	2,042
Winslow	227	247	342	399

(Population data from IEA Census State Data Center)

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4.2 Fluvial Geomorphologic Surveys

A general assessment of fluvial geomorphologic conditions was conducted as part of the overall assessment of the WFWR watershed. The collection of detailed geomorphologic data provides valuable information regarding the dimension, pattern, and profile of the WFWR; provides a baseline fluvial geomorphologic data to track improvements in the watershed; and for developing stream restoration designs using a natural channel design approach. In addition to tracking changes in the geomorphologic character of the WFWR, the data can be used to relate the aquatic biology to local changes in stream stability. The data collected during the fluvial geomorphologic assessment was used in this study to develop a graphical model to predict the annual lateral erosion rate for streambanks in the WFWR watershed. (See Chapter 5.1.1)

Selecting the locations to characterize the fluvial geomorphology of the WFWR watershed was a challenging task. Several visits were made to the headwater drainages, the main branch, and some of the main tributaries. Maps and other data were reviewed. The entire main branch of the river was floated or walked. Based on the observed geomorphological characteristics along with the available time and manpower, eight reaches were eventually selected for evaluation that represented a variety of the geomorphologic qualities of the WFWR (Figure 4-2). Seven reaches were located on the main stem and one was on a large tributary, Winn Creek. Each of these reaches were surveyed in detail and the surveys were conducted so the reaches could be re-surveyed in subsequent years. For each reach, the following was established: 1) permanent survey monuments; 2) one or more pool cross section sites; 3) one or more riffle cross-section sites; and 4) several bank profiles sites. Elevation benchmarks and permanent cross-section end points were installed away from the active channel. Both stable and unstable reaches were included, to measured changes over time for both conditions. A biological assessment was performed for each of the eight reaches by the University of Arkansas, Department of Biology (Brown, et al, 2003) (See Section 2.2.3).

For each of the eight reaches, a Rosgen Level II survey was conducted (Rosgen, 1996). General fluvial geomorphologic variables evaluated included those required to determine the Rosgen stream classification type, i.e. bankfull width, bankfull cross-section area, D_{50} of the channel materials, channel slope, sinuosity, etc. Table 4-4 lists the measured Rosgen Level II variables and stream classification types for the eight reaches surveyed. An example of a site map

Table 4-4 Fluvial geomorphologic variables assessed at Reaches 1 through 8.

Station Location	Site # 1	Site # 2	Site # 3	Site # 4	Site # 5	Site # 6	Site # 7	Site # 8
Latitude (d,m,s)	35° 49' 01.32"	35° 50' 24.10"	35° 51' 58.86"	35° 54' 59.5"	35° 56' 47.17"	36° 0' 51.79"	36° 2' 59.61"	35° 52' 19.12"
Longitude (d,m,s)	94° 07' 40.45"	94° 06' 53.84"	94° 10' 30.00"	94° 10' 30.0"	94° 11' 07.58"	94° 8' 41.82"	94° 7' 30.97"	94° 08' 57.78"
Rosgen Level II Variable								
Stream Type	**B4c**	**B4c**	**B4c**	**C4**	**C4**	**C4**	**C4**	**B4c**
Drainage Area: (mi^2)	7.3	10.2	12	58.6	70.8	92	116	31
Bankfull Width: W_{bkf} (ft)	41.8	50.4	43.3	114	152.9	89	136	54.2
Mean Depth: d_{bkf} (ft)	1.7	1.5	2.7	3.4	3.3	6.4	3.8	3.8
Bankfull X-Section Area: A_{bkf} (ft^2)	70.8	76.1	118	392	504.3	574	517	206
Width / Depth Ratio: W_{bkf}/d_{bkf} (ft/ft)	24.7	33.4	15.9	33.5	46.3	13.8	36	14.3
Maximum Depth: d_{mbkf} (ft)	3	2.2	4.4	5.5	5.7	7.9	5.9	5.2
Width of Flood-Prone Area: W_{fpa} (ft)	92	112	~ 100	750	~ 900	~ 3000	700	80
Entrenchment Ratio: W_{fpa}/W_{bkf} (ft/ft)	2.2	2.2	2.3	6.6	5.9	34	5.1	1.5
Channel Material: **D50** (mm)	23.4	58	47.7	46	45	23.3	32.6	43.1
Water Surface Slope: **S** (ft/ft)	0.008	0.008	0.0064	0.0024	0.0022	0.0018	0.0005	0.005
Channel Sinuosity: **K** (ft/ft)	1.08	1.13	1.07	1.08	1.25	1.4	1.4	1.14

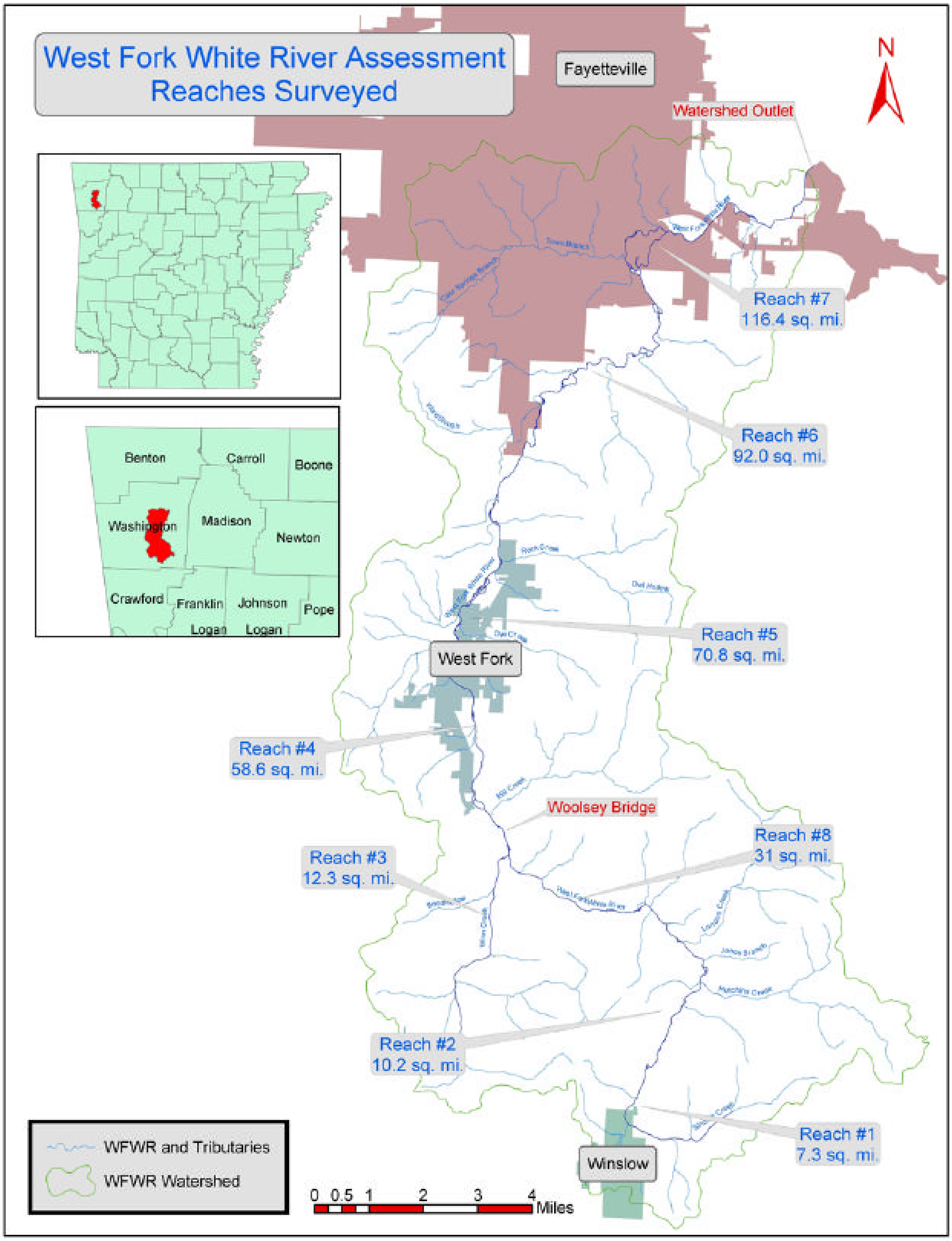

Figure 4-2 Locations of Eight Reaches that were surveyed.

for one of the reaches (#7) is shown in Figure 4-3. The site maps show the locations of benchmarks, cross-section end-points, and the locations of toe-pins used for the measurement of annual streambank erosion rates. Site maps for all of the reaches can be found in Appendix 4-A.

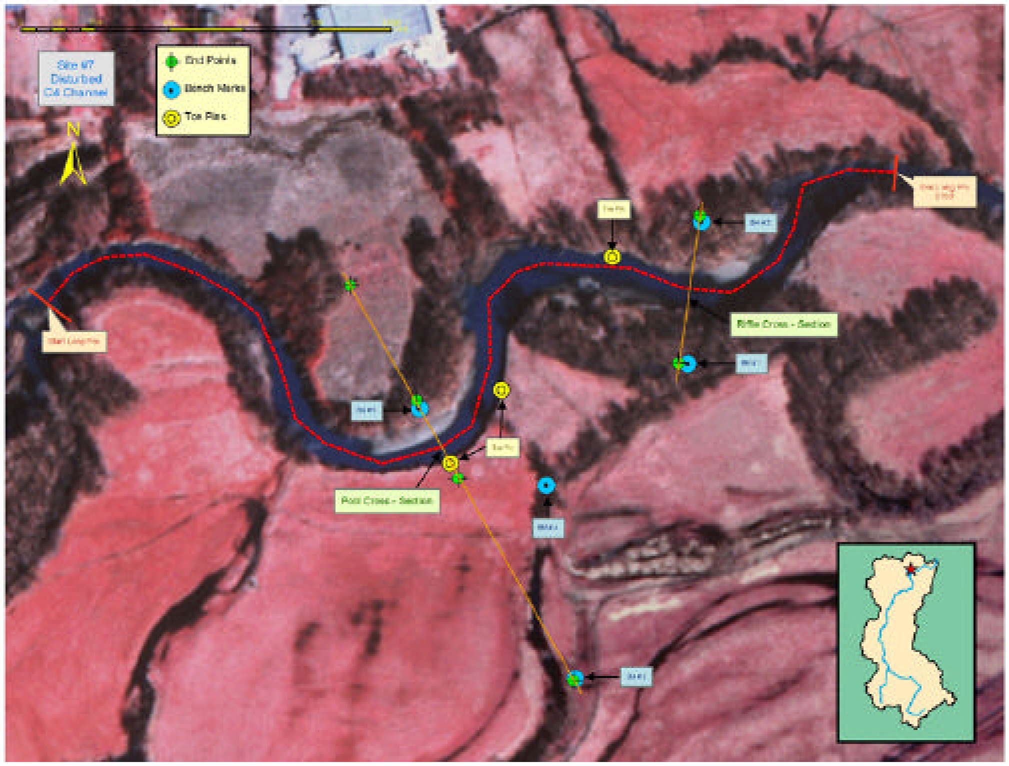

Figure 4-3 Site map for Reach #7.

Stream reaches that were surveyed above the Woolsey Bridge (County Road 35) (see Figure 4-2) were “B4c” type streams, were moderately entrenched, had relatively little sinuosity, and had water surface slopes ranging from 0.008 $^{ft}/_{ft}$ to 0.005 $^{ft}/_{ft}$. Reaches surveyed below the Woolsey Bridge were “C4” type streams having water surface slopes ranging from .0024 $^{ft}/_{ft}$ to 0.0005 $^{ft}/_{ft}$.

Over a one year period, many of the reaches that were surveyed did not undergo a significant change in channel pattern, profile, or dimension. Potential natural channel design references were identified at some surveyed locations. The following is a brief discussion on the data and information collected for each of the eight reaches:

Figure 4-4 Riffle cross-section at Reach #1

Reach #1 (Figure 4-4) appeared to be generally stable. This reach was slightly incised as the left-bank (the outside of the meander) elevation at the riffle cross-section was greater than the bankfull elevation. The left bank in the vicinity of the cross-section locations was vertical and eroding, but a sufficient riparian community existed at the time that reduced the erosion rate of this bank. The general shape of the riffle cross-section, aside from the high bank, may make a suitable reference for a "B" type cross-section dimension at a meander bend for a natural channel design in the WFWR watershed. The average distance between pools for this reach was 99 ft. with a minimum of 62 ft. and a maximum of 135 ft.


Figure 4-5 Riffle cross-section at Reach #2

Reach #2 (Figure 4-5) appeared to be generally stable. The reach extended through an area of valley slope transition, where the valley went from being relatively broad to becoming very narrow. The upper portion of the reach was more characteristic of a "C" type channel. Compared to the lower portions of the reach, the slope was flatter, mean particle sizes were smaller (D_{50} = 27.8 mm). An arcing meander bend with a well-developed point bar and associated pool were found in the upper portion of the reach. The pool cross-section dimensions in this reach may be suitable for use as a reference for natural channel design restoration of "C" type channels in the WFWR watershed and the physiographic region in general. There is a section of exposed bedrock near the middle of the surveyed reach. At the point where bedrock becomes exposed, the characteristics of the stream change. The lower end of the reach was steeper, had little sinuosity, and had a larger mean particle diameter (D_{50} = 69.7 mm), when compared to the upper portion of the reach. The riffle cross-section was very stable and did not indicate any lateral adjustment between successive surveys. The dimensions of the riffle cross-section may be suitable for use as a reference for a riffle cross-section for a straight reach in a "B" type channel in the WFWR watershed. The average distance between pools for this reach was 112 ft. with a minimum of 60 ft. and a maximum of 155 ft.

Reach #3 was located on Winn Creek. A wide range of fluvial geomorphologic characteristics we observed from the upper to lower ends of the reach. Two riffle and two pool cross-sections were established on this reach as one section of the reach appeared to be unstable and another displayed characteristics of a stable reach. There was a long, straight stretch of stream with a bedrock bottom in the upper-half of the surveyed reach. This section appeared to be very stable. Below that stretch there was a section of instability. The unstable section was largely defined by head-cutting of the stream through an alluvial fan, shown in Figure 4-6. The width to depth ratio was 52 for the riffle cross-section located in the area of the head-cut. Just below the unstable riffle cross-section, the channel bottom became stair-stepped bedrock. The unstable pool cross-section was located in that area. The characteristics of the channel changed above and below the areas where bedrock was exposed. Downstream of the bedrock the channel bottom became gravel again and the channel appeared to have a stable cross-section geometry. The riffle and pool cross-sections had well defined bankfull benches, and although the channel was vegetated only with young willows, the channel appeared to be stable, maintaining the cross-section dimensions, through at least a few years of flood events. Figure 4-7 shows the general cross-section dimension of the stable riffle on Reach #3. The general dimensions of the riffle-cross section for the stable area at Reach #3 would be usable as a reference for natural channel restoration designs for a low gradient "B" or high gradient "C" stream type in the WFWR watershed.

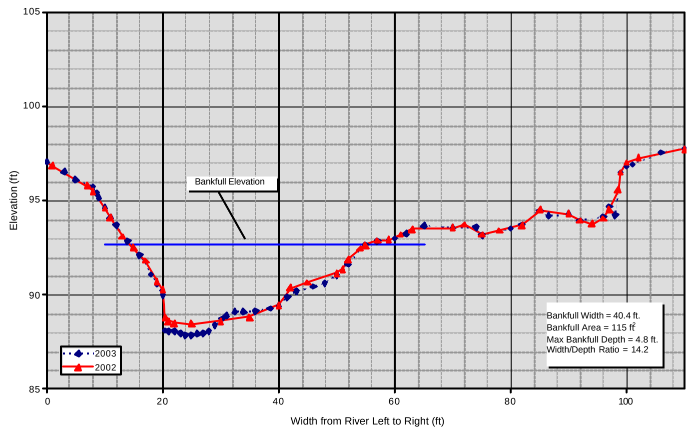

Figure 4-7 Cross-section dimensions of stable riffle at Reach #3 as measured in 2002 and 2003

Reach #4 (Figure 4-8) appeared to be relatively stable. The upper end of the reach appeared to be stable based on visual estimates. The longitudinal profile for the upper reach remained consistent for the surveys of both 2002 and 2003. No cross-section surveys were performed in the upper end of the reach. However, the cross-section dimensions and riparian community in the upper reach may provide a useful reference for natural channel restoration design and should, at some time, be surveyed to establish a permanent record of the dimensions. The lower end of the reach showed signs that once deep pools have been filled in with sediment. Anecdotal information from individuals interviewed about the reach indicated that pools in the reach had filled in. Observations made after the large flood event of April 2004 indicated that significant change in both the cross-section geometry and longitudinal profile of the lower end of the reach underwent significant change. Where the riffle cross-section was located during 2002 and 2003, a pool had formed. Also, the thalweg had moved from the left side of the river to the right. This reach should be resurveyed to determine the actual extent of change that occurred.

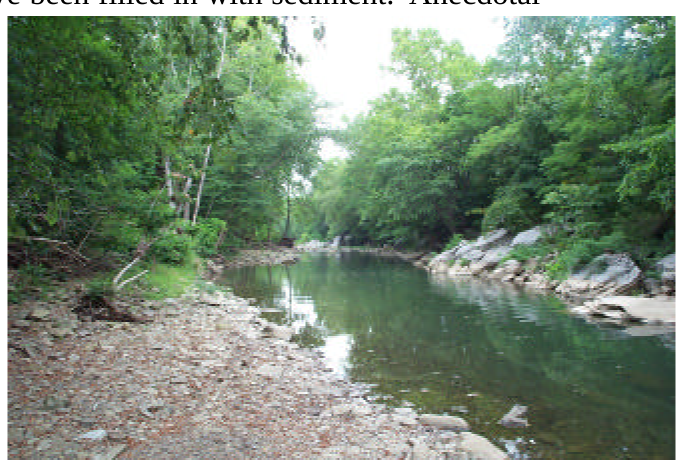
Figure 4-8 Reference riparian area at Reach #4

The average pool spacing for Reach #4 ranged from 342 ft. to 697 ft. and averaged approximately 500 ft. This was approximately 4 times the measured bankfull width for the riffle cross-section at Reach #4. Water clarity at this site appeared to be excellent and there was little or no algae growth on rocks in the channel at the low flow conditions that existed for both the survey in 2002 and 2003.

Reach #5 was, by far, the most unstable of all of the reaches surveyed during the fluvial geomorphology surveys. The cross-section surveys of Reach #5 showed a significant increase in active channel width over a one-year period, eroding laterally as much a 15 feet. Figure 4-9 shows cross-section surveys from July 2002 and July 2003 at the pool cross-section for Reach #5. Figure 4-10 provides visual evidence of the lateral erosion that occurred along the river-right streambank at the same location. The surveyors in the photograph are standing at the location where the toe of the streambank was located one year earlier. The scale of the site made it difficult for the investigators to perceive the lateral erosion with visual observation when returning after a one-year period. Without permanently established cross-section endpoints, even such large changes could have gone unnoticed, illustrating the importance of establishing permanent monuments and benchmarks for fluvial geomorphologic surveys. There is an area of exposed bedrock upstream of the pool cross-section as well as below the surveyed reach. The exposed bedrock indicates changing geology below the stream channel. The exposure of this bedrock may have an effect on local stream stability or may only be a result of the instability. After the flood of April 2004, severe erosion was observed to have occurred throughout the reach. The stream laterally eroded approximately 100 feet and avulsions began to develop on the downstream end of the meander through this reach. Left unchecked, without the implementation of a restoration design utilizing a natural channel design approach, the river will cut off this meander, begin to incise and continue a widening process until an equilibrium between sediment transport and river energy is achieved. This process will likely take decades at a minimum to reach equilibrium. In the interim, habitat will be lost, water quality will be impacted, and property will be washed away to the benefit of none. The cause of the instability is unclear. Evaluation of aerial photography shows that lateral erosion has been occurring in the area since 1964. Once the river began eroding into pasture areas, remaining

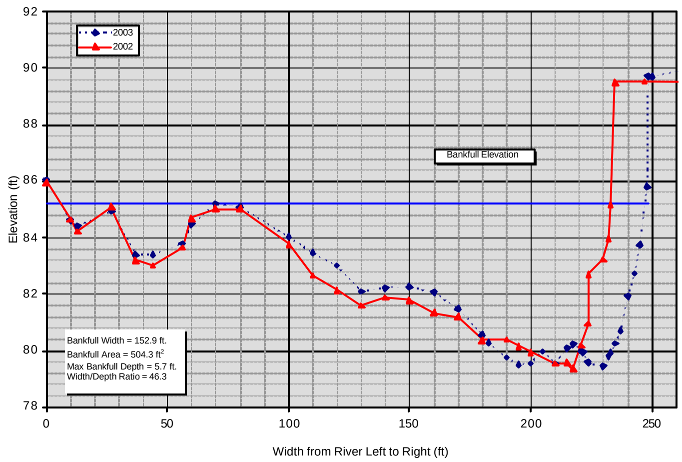

Figure 4-9 Comparison of surveyed riffle cross-section at Reach #5 for 2002 and 2003

Figure 4-10 Lateral erosion of channel at Reach #5. Surveyors are standing where the toe of the streambank was located the previous year.

riparian vegetation has done little to slow the erosion process. During the most recent storm event nearly 2 acres of mature hardwood riparian forest was lost to stream erosion processes. The loss of mature riparian forest serves to illustrate that restoration of unstable sites, such as Reach #5, requires more than bank sloping and re-establishment of riparian vegetation alone. This site should be a high priority for restoration. Water quality in this reach seems to be impacted by excess nutrients. Surveyors noticed that the water clarity degraded significantly from morning to early afternoon. At daybreak, water clarity was excellent, as the morning wore on the water took on a green tint and visibility dropped to less than 1 ft. in the pools. The biological survey in this reach also found that Campostoma (stonerollers) composed 50% of the fish population, further indicating the presence of excess of nutrients (Brown, et al., 2003).

Reach #6 was, in general, stable although some signs of instability were evident. The reach is being affected by the presence of the bridge that carries C.R. 69 over the WFWR and significant effects from unrestricted cattle access to the river channel. The configuration of the bridge does not allow bankfull flows to pass through. This results in back-water deposition upstream of the bridge, reducing habitat and creating a source of fine sediment that is re-suspended during moderate flows. Additionally the bridge results in road flooding during less-than-bankfull-flow and causes bank and channel scour immediately downstream of structure. The cross-section dimensions of the surveyed riffle may be suitable for use as reference dimensions for a straight reach in a natural channel restoration design for a “C” type channel. The surveyed cross-section dimensions for the riffle at Reach #6 are shown in Figure 4-11. Pool to pool spacing for this reach ranged from 175 ft. to 360 ft. with an average of 248 ft. This spacing is approximately 2.8 times the bankfull width as measured at the riffle cross-section. Water clarity at this site was visually degraded. At low-flow conditions in the summer of 2002 and 2003, visibility was less than 1 foot as observed by the surveying crew. During the surveys, many cattle were observed loitering in the creek. Programs should be promoted to encourage landowners to put into place practices that reduce the amount of time spent by cattle in the creek. Reducing the amount of time cattle spend in the river would undoubtedly improve water quality conditions, reduce streambank erosion, and improve riparian vegetation in this area and in the lower reaches of the WFWR in general.

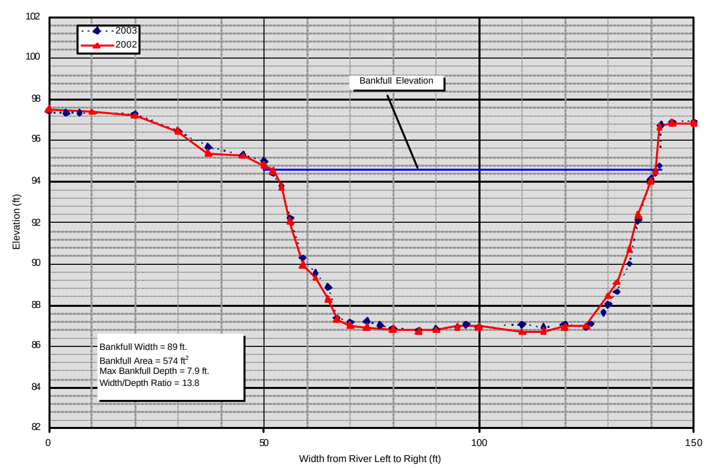

Figure 4-11 Survey data from riffle cross-section at Reach #6

Reach #7 is showing signs of instability in the form of lateral erosion. The owner of the property made attempts to stabilize the right bank of the pool cross-section area in the time between the 2002 and 2003 surveys. This precluded any measurement of lateral erosion at the pool cross-section. The channel through the pool cross-section area of Reach #7 is incised and at bankfull flows, the river cannot access the floodplain on the outside of the meander bend. The use of construction debris to stabilize the eroding bank may provide temporary stability to the streambank. However, the use of such materials without regard to channel dimension generally will not result in long-term stability. Additionally the use of such material impacts the aesthetics of the river corridor (Figure 4-12). A natural channel design approach could be implemented in this reach that could eliminate property loss associated with streambank erosion, increase aquatic habitat, and improve aesthetics. Such a design would likely require the development of a "bankfull bench" and the use of rock veins on the outside of the meander bend to reduce near-bank shear stresses causing streambank erosion. The water quality at this site appeared to be affected by local and upstream activities. The water clarity was poor, estimated to be less than 1 ft. the water temperature also appeared to be elevated compared to other sites. This was likely due to the lack of riparian canopy along a large portion of the reach.

Figure 4-12 Eroding bank at Reach #7 and the use of construction debris for bank stabilization

Reach #8 was selected in order to provide a site that allowed a comparison of biological data to other watersheds in the region. The reach has a stable riffle cross-section (Figure 4-13) that did not shift in any significant amount over the 1-year monitoring period. The dimensions of the cross-section riffle may be useful for reference dimensions of a stable "B" type stream channel. The pools spacing for the reach averaged 225 ft. At the upper end of the monitored reach, a low-water ford seems to be having an impact on channel stability. The ford has resulted in an over-widened channel that, due to increased friction, cannot efficiently transport river sediment through the reach. Below the immediate area of the ford, the left bank laterally eroded 5 ft. during the monitoring period. The erosion will be affecting infrastructure and will have to be stabilized in the near future. Stabilization of the site should seek to reduce the impact of the ford and restore some semblance of natural dimension to the reach. Stabilization should also seek to increase habitat and improve aesthetics.

Figure 4-13 Reach #8 riffle cross-section

4.3 Changes in Main Branch River Pattern: 1942 to Present

As part of the WFWR watershed assessment, historic aerial photographs of the watershed were obtained. The photographs allow an opportunity to evaluate gross changes that have taken place along the mainstem of the WFWR over time. Photographs series for 1942, 1964, 1971, 1980, and 1986 were obtained as part of the project. Photos from 1942 cover only the areas adjacent to the mainstem of the river and do not cover areas on the periphery of the watershed. The photos arrived without georeference data. Photos were georeferenced in-house using the georeferencing tool found in Spatial Analyst for ArcGIS. The 2000 DOQQ image series was used as the control for establishing georeferences for the historical aerial photography. After georeferencing, the left and right bank of the active channel for the photo series of interest was developed by creating an ArcGIS shapefile. The active channel boundaries were then used to compare river pattern changes over the past 60 years. Figure 4-14 illustrates a generalized view of the type of changes that could be detected through this analysis.

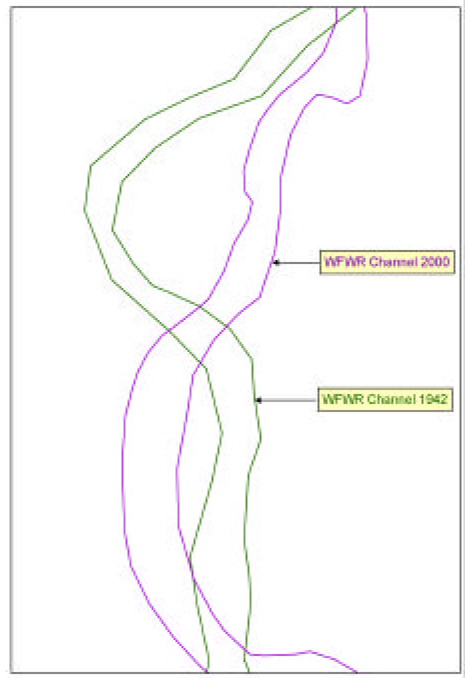

Figure 4-14 Channel shifts observed near Baptist Ford from 1942 to 2000

The following is a summary of conclusions about the historical changes that were observed to have taken place during the evaluation of historical aerial photographs and comparison between photographs series.

In general, it appears that there has been an overall increase in the amount of forested land in the floodplain immediately adjacent to the mainstem of the WFWR when comparing the aerial photography of 1942 to that of 2000. This may be due to the reduction in the amount of row-

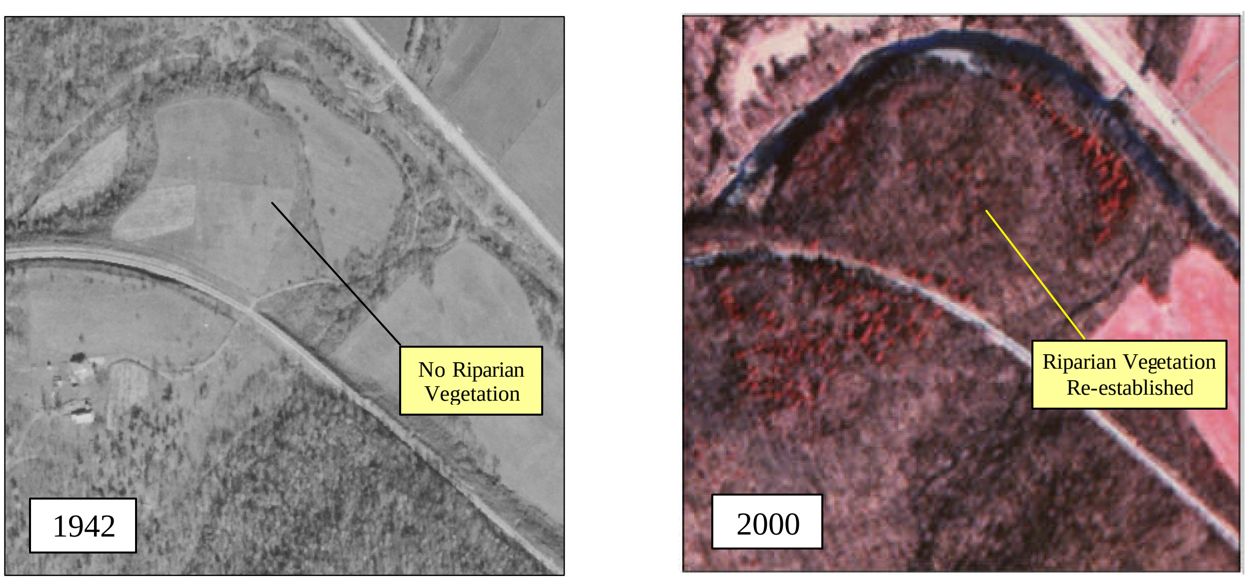

Figure 4-15 Vegetation in the Floodplain of the WFWR has tended to increase over the past 60 years

crop agriculture that has taken place in the watershed. As the profitability of row crop agriculture declined in the area, it is likely that these areas were frequently allowed to go fallow and over time developed in to woodlands again. Figure 4-15 illustrates the increase in forested area adjacent to the WFWR at one particular location. There were some areas in the watershed where forest vegetation has been removed from the floodplain in the past 60 years, however, this has been the exception and not the rule.

Removal of riparian vegetation in the floodplain that took place prior to 1942 reduced the capacity of the river to maintain the historic natural pattern associated with the river. In some instances, fields in the floodplain were cleared up to the rivers edge. Sites where the riparian vegetation was completely removed were often the sites of fluvial avulsions, or meander cut-offs. Without a stand of large diameter riparian vegetation, these sites were eventually overwhelmed by the river. At many other sites, a thin band of riparian vegetation remained after clearing. These narrow bands of riparian vegetation were insufficient in width to attenuate lateral adjustments made by the river following upstream changes in hydrologic regime, increases in sediment supply, or increases in stream energy grades. At sites where small amounts of riparian vegetation remained, especially on the outside of river meanders, the river channel often made significant lateral adjustments.

The overall sinuosity of the river has tended to decrease based on the evaluation of the aerial photographs from 1942 to 2000. Figure 4-16 illustrates a meander cut-off that developed between 1964 and 1980 near the confluence of Town Branch and the WFWR. Riparian vegetation had been removed from this area prior to 1942. The river began to work its way across the cleared area likely creating an avulsion. The avulsion developed over time to become the main channel for river flow, until the meander had bee completely cutoff. This meander cutoff resulted in a loss of 629 feet of river length. Every meander that is cutoff from the river system results in greater downstream energy that must be dissipated. To re-establish equilibrium, the river channel will adjust by channel incision (deepening) or channel enlargement (widening) to dissipate this additional energy. A potential solution for eliminating

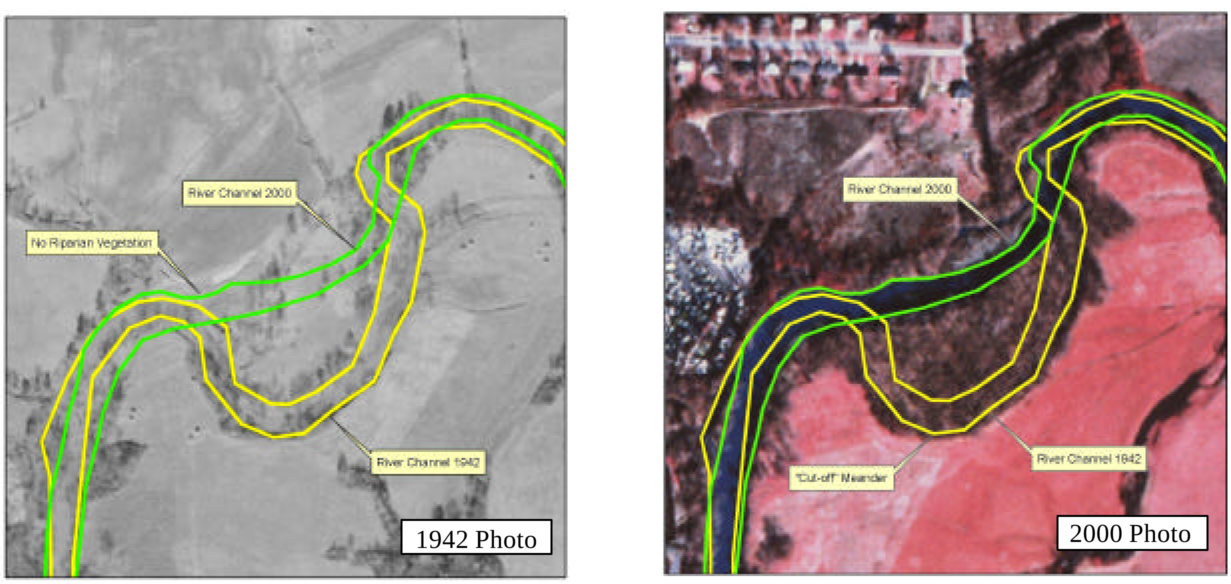

Figure 4-16 Meander cutoff resulting from riparian vegetation removal

the occurrence of meander cutoffs in the future is to develop channel restoration designs for priority sites. These designs should account for the rivers energy grade, hydrologic regime, and sediment supply using a natural channel design approach.

There are additional locations in the watershed present good examples of meander cutoff and the effects of riparian vegetation removal. An evaluation of photographs for a location in the WFWR watershed just upstream of Reach #6 illustrates the changes to the river pattern that occurred when bottomland was cleared to the edge of the river channel (Figure 4-17). In the 1942 photograph, the area to the northeast of the highlighted meander bend has been cleared. Some evidence of the river beginning to cutoff the meander pattern during high discharge can be seen in the form of small gullies in the field. By 1964 a well defined channel had formed. The 1980 aerial photographs indicate that the new channel had developed to the point that the

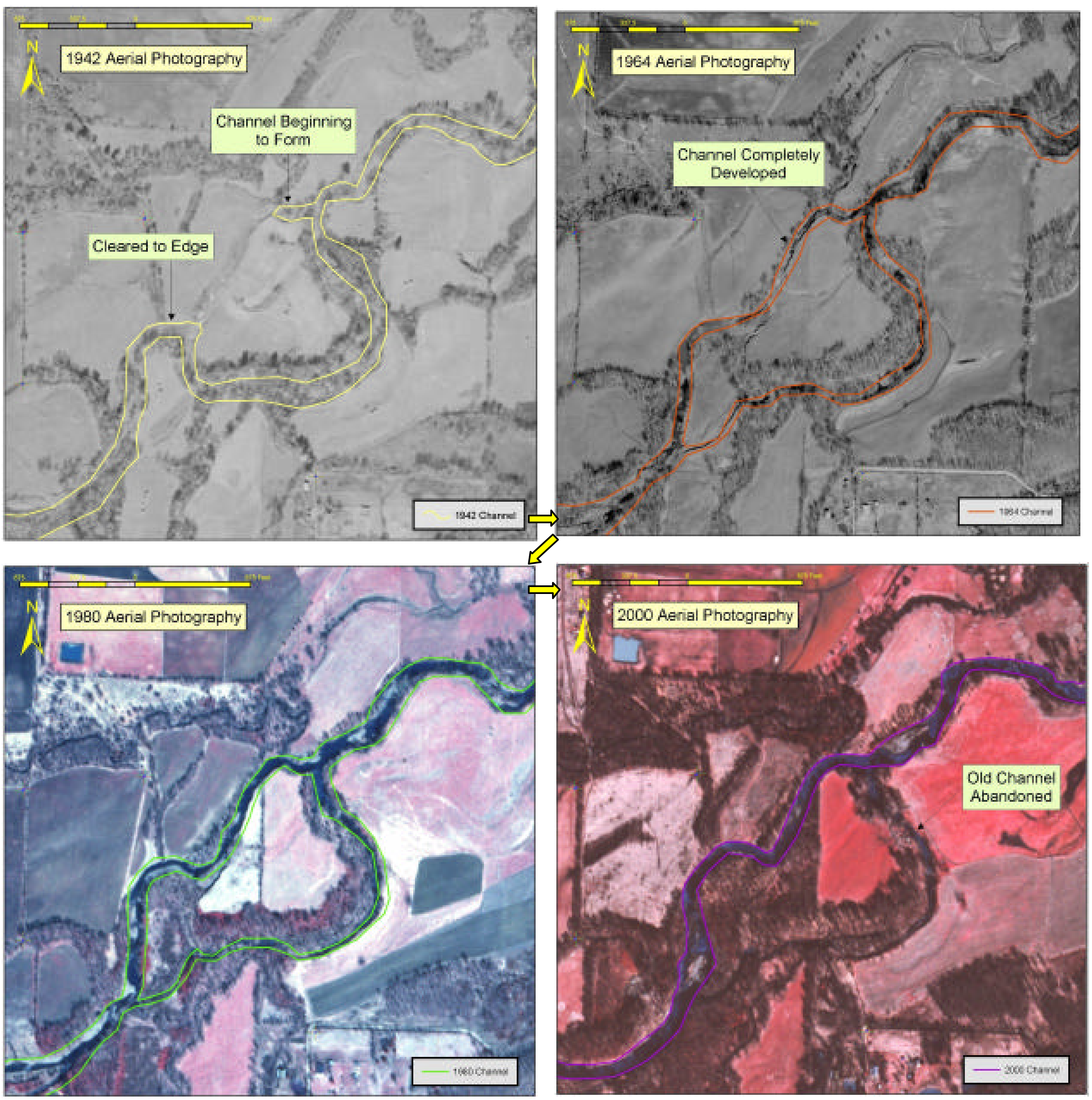

Figure 4-17 Meander cutoff evolution on the WFWR as seen from historic aerial photographs

majority of discharge of the WFWR was carried by this channel. The 2000 aerial photography shows that the channel had, by that time, evolved to point that the meander had been entirely cut off except at high flows. The cutoff of this meander has reduced the length of WFWR by slightly over 1,000 ft. The straightening of the river results in a greater energy grade that downstream reaches must accommodate.

The additional energy frequently results in lateral erosion of streambanks downstream of the meander cutoff. This can be seen when looking at the outside streambank of the meander that is immediately located downstream of the previous example. Figure 4-18 shows the lateral erosion of the streambank located at the pool cross-section of Reach #7. This streambank eroded at increasingly greater rates over the 60 year period. The estimated annual erosion rate for the period from 1942 to 1964 was 1.1 feet per year. The rate during the period from 1964 to 1980 was 1.4 feet per year. During the period from 1980 to 2000 the erosion rate increased to 2.1 feet per year. Most of the meander cutoffs that were observed to have developed in the watershed occurred during the period from 1942 through 1980. It stands to reason that as more and more meanders were became cutoff, lateral erosion rates increased at downstream locations. Areas susceptible to high shear stress, primarily the outside of the meander bends that remain in the watershed, are subjected to greater erosive forces due to overall increase in river energy created by the straighter river.

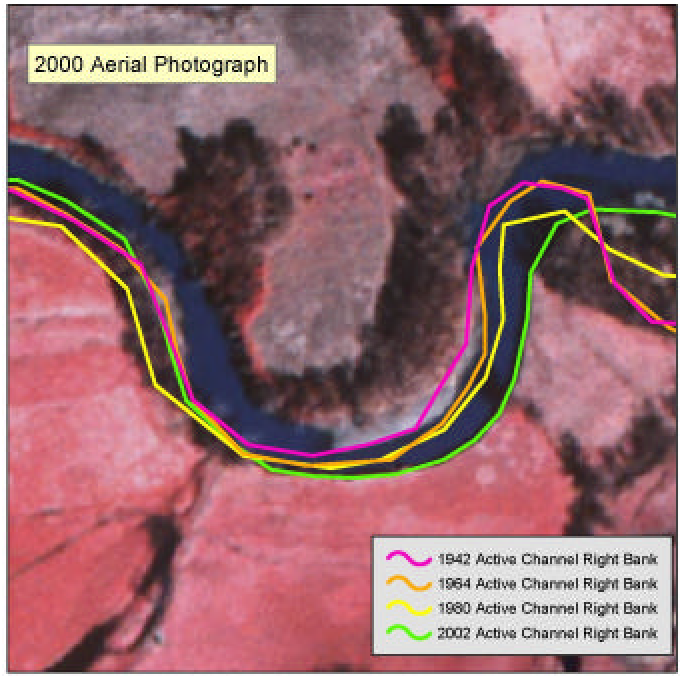

Figure 4-18 Lateral erosion from 1942 to 2000 as seen from historical aerial photos at the pool-cross section at Reach #7

Reach #5 and the reaches below have shown a trend to increasing instability over the past 20 years. The increase of instability since the 1980 photos can be observed in the form of increased lateral erosion rates. Based on the evaluation of aerial photographs from 1942, 1964, 1980, and 2000, the lateral erosion rates for the periods in between photographs can be estimated. Between 1942 and 1964, the annual lateral erosion rate was estimated to be 1.9 feet per year. This is similar to the estimated rate for the period between the 1964 and 1980 photo series. The rate for the period between 1964 and 1980 was 2.1 feet per year. Between 1980 and 2000 the estimated annual lateral erosion rate was 5.8 feet per year. The location of the river channel for the different photograph series can be seen in Figure 4-19. The causes of the accelerated instability cannot be definitively stated based on the evaluation of aerial photographs alone. Many changes, both local and throughout the watershed, have the potential to cause the increased stream instability observed during the period between 1980 and 2000. During the period, a low water bridge was constructed upstream of the site. The river in the vicinity of the bridge seems to have become oriented in a more linear pattern. The linearity of the river may be increasing downstream velocities due to the increased energy grade. The construction and completion of Interstate 540 has changed the upstream hydrology of the watershed as well as increased the sediment load that must be transported by the river system. Finally, in-stream gravel mining has occurred in the vicinity of the site. Previous mining activities may have removed gravel bars that were essential for the river to dissipate energy. While there may be some excess sediment load in the river, large volume, in-stream gravel mining without regard to channel geometry, will in nearly all cases result in river instability, water quality impacts, and habitat loss. It is likely that a combination of some or all of these factors has resulted in the instability observed at this site. Additionally, the instability of this site has migrated down stream and the river channel in this area will continue to become increasingly unstable until a comprehensive restoration design using a natural channel design approach is implemented.

Many changes have taken place in the WFWR watershed including changes in land-use, hydrology, sediment supply, and riparian vegetation. These changes have led to a straighter river channel and channel instability. The river pattern in most cases cannot be returned to previous configurations due to the fact that watershed characteristics have are not the same today as they were 50 years ago. The instability of certain high sediment yield reaches could be addressed through the application of natural channel design approach. Such an approach works within the current hydrologic regime and sediment load of the watershed to achieve equilibrium between sediment supply and river energy. The use of the natural channel design approach to stabilize high priority sites will result in long-term solutions that will reduce land loss due to erosion, increase habitat, and improve water quality in the WFWR watershed.

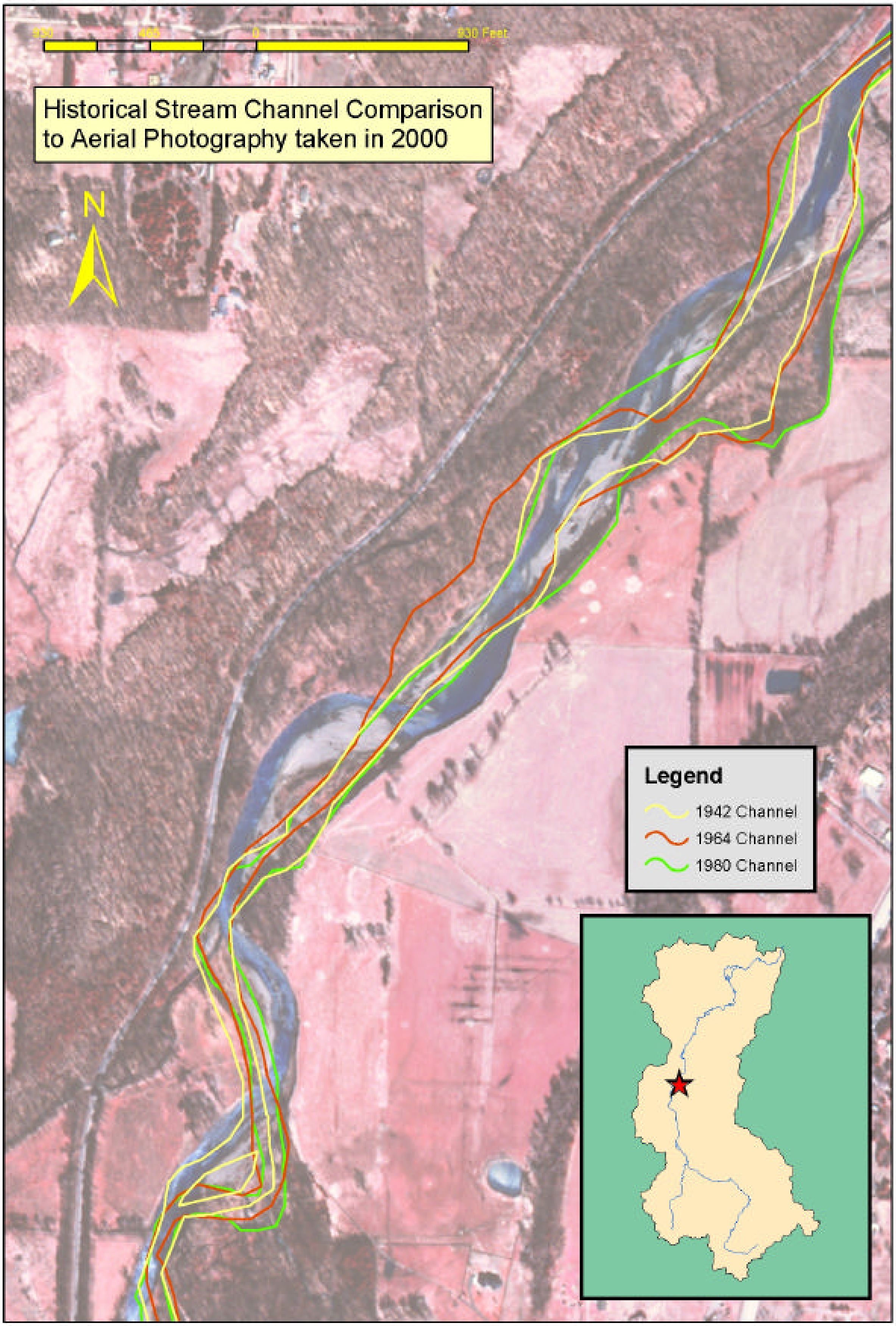

Figure 4-19 Shifts in the active channel of the WFWR as determined from historic aerial photos

4.4 Landowner Perception and Public Involvement

4.4.1 Interviews of Watershed Landowners

Understanding the attitude and perceptions of watershed residents regarding environmental conditions is important in watershed assessment and planning. Long-term residents can hold key information to causes of environmental degradation (ADEQ, 2003) and are, generally, interested in local environmental issues and potential solutions. Eight long-time watershed residents were interviewed by the project team to gain an understanding their perspectives of the WFWR watershed. Long-time residents of the watershed were identified with the help of the Audubon Arkansas watershed group, the neighborhood association and the University of Arkansas Cooperative Extension Service. Residents were contacted and, if willing, interviewed. The interviews were conducted at the home of each resident, with the exception of one resident, who preferred to conduct the interview over the telephone. The interview questions and a summary of the responses can be found in Appendix 4-B. A summary of the interviews follows:

Five interviewees lived along the main branch of the West Fork White River. Two have lived on the main branch for 47 years, two for 50 years, and one for 60 years. Of the three remaining respondents; two respondents have lived in the Town Branch watershed, one for 15 years and the other for 45 years; and one respondent lived in Winn Creek watershed for the past 20 years as a permanent resident, but had lived there, on and off, for 35 years.

Figure 4-20 Historical photo of a baptism at Baptist Fond on the WFWR.

The interviewees indicated that land use had changed along the river. Residents have noticed a slight increase in cattle, the number of homes, off-road vehicle use, and more intensive agriculture. There has been development in the area, including I-540, an industrial park, and a golf course. One resident noticed excavation of top soil. The West Fork resident that has lived along the main branch of the West Fork for the past 60 years stated that grass has replaced row crops in the river bottoms. Recreation was listed as the primary use of the river in the past and present. The river is still used to water livestock by some and at one time the river was used as Fayetteville's water source.

All interviewees had noticed changes in the river's appearance. Changes in the general appearance of the river were described by several interviewees as muddier or murkier now. Half of the interviewees believed that the river flows at the same level it always has. A majority of the respondents had noticed a change in depth of the river, mentioning that pools or holes have filled with sediment. Five of eight interviewees believed that flood frequency has changed.

Respondents also believed that there are fewer trees because of erosion, flooding, and cutting for firewood. All eight interviewees had noticed that the shape or location of the river channel has changed over time. Human impact was believed to be the cause of the observed changes. Specific causes identified by the interviewees include; channelization, gravel mining, dozing, bridge placement, and field erosion.

Most residents have springs or small tributaries on their property (Figure 4-21). Three of the residents have perennial springs or tributaries on their property. One property owner had a spring dry up between 1952 and 1954 because of severe drought. One property owner has seasonal flow and believed there was less water flowing in the tributaries. One property owner believed the recent reduction of flow in two springs on his property was caused by the construction of I-540.

Figure 4-21 Long-term resident of the WFWR watershed shows Amy Cotter of ADEQ his spring, which is his drinking water source.

One resident noted that the closing of a food processing plant improved the water quality, but most residents believed that the quality of the water has deteriorated. All interviewees were concerned about the WFWR. Some concerns mentioned were increasing population, development and urban sprawl, trash, decreasing buffer zones, and decreasing wildlife habitat. Clean water was the primary vision for the West Fork White River.

4.4.2 Watershed stakeholders and Public Outreach

The heart of the watershed approach to conservation and restoration of natural resources is stakeholder involvement through watershed partnerships. During the course of this project, the Beaver Lake Watershed Partnership (BLWP) formed and became involved in watershed activities throughout the Beaver Lake watershed, including the WFWR. Members of the project team along with other staff from the Environmental Preservation Division of ADEQ, provided assistance to the BLWP. Also, the project team gave status reports on the WFWR project periodically to the BLWP and other entities involved in the ASWCC 319 project. During the course of this project, it became evident that the WFWR watershed needed its own stakeholder represented group to engage in the watershed planning process. The Audubon Arkansas and the ADEQ in 2001 decided to work together in promoting this type of effort. The Audubon Arkansas received a grant from the ASWCC to initiate public outreach and watershed planning. Since that time, Audubon Arkansas has worked towards collecting social and subjective data from the WFWR watershed community. Audubon Arkansas has initiated the formation of a watershed group and a technical advisory group to collect input on issues of concern in the watershed. Through this process, citizens helped rank their watershed concerns and proved invaluable to the creation of a watershed restoration business plan. The public input that Audubon Arkansas has received shows that the non-scientific community often recognizes the same problems as the technical community and that, when given a means to communicate their concerns, watershed residents are willing to adopt responsible restoration strategies. The WFWR project team has been active with the watershed group by giving presentations on the project and participating on the technical advisory team.

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4.5 References

1. Arkansas Dept. of Environmental Quality, Environmental Preservation Division. Arkansas Watershed Planning Guide. Available ADEQ Manual developed under a USEPA Section 104(b) (3) grant. September, 2003.

2. Bayless, M. and C. Vitello. White River Watershed Inventory and Assessment. "Landuse". Missouri Dept. of Conservation. Accessed July 2004. http://www.mdc.missouri.gov/fish/watershed/whriver/contents/390cotxt.htm

3. Brown, Arthur, Andrea Radwell, and Robin Reese. Bioassessment of the West Fork of the White River, Northwest, Arkansas. Publication No. MSC-307. Arkansas Water Resources Center, University of Arkansas, Fayetteville, AR. 2003.

4. Gilliam, L.G. *Land Use of the West Fork Watershed.* University of Arkansas Press. Fayetteville, AR, 1977.

5. National Park Service. "Native Cultures". Accessed July 2004. http://www.nps.gov/buff/his-culture.htm

6. Shiloh Museum. History of Washington County Arkansas. Springdale, Arkansas, 1989.

7. Rosgen, D. Applied River Morphology. Wildland Hydrology. 1996

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Chapter 5: Source Identification and Load Estimates

5.1 Sediment Sources, Causes, and Load Estimates

High turbidity values and siltation are listed by the ADEQ as the cause of impairment for the WFWR (ADEQ, 2000). Turbidity and siltation can be associated with sediment entering into the stream system; therefore, potential sources of sediment were identified and sediment loads from these sources were estimated using field data, prediction models, and erosion coefficients and water quality data from the literature associated with different land uses. The sediment loads in this study are estimates of an annual average mass of sediment delivered to the stream and, generally, represent particles equal to or less than 2 mm in size.

PLEASE NOTE: THE SEDIMENT LOAD ESTIMATES IN THIS REPORT ARE "ONLY" ESTIMATES AND ARE FOR PLANNING PURPOSES ONLY! THEY ARE BASED ON THE INFORMATION GATHERED IN THIS STUDY, AVAILABLE DATA, PUBLISHED COEFFICIENTS, OTHER RELEVANT SOURCES OF INFORMATION, AND THE TIME ALLOTTED FOR THE STUDY. AS MORE INFORMATION, DATA, AND METHODS ARE MADE AVAILABLE, THE LOAD ESTIMATES SHOULD BE UPDATED TO REFLECT NEW DATA, METHODS, AND INFORMATION.

A summary of the sediment sources that were evaluated along with the data and methods used to estimate loads are shown in Table 5-1. A detailed explanation of the data collected and methods for each source evaluated follows this section.

Table 5-1 Sediment sources and load estimation methods used for WFWR watershed assessment.

Potential Source of Sediment	Data	Method for Estimating Load
Stream Bank Erosion from banks showing increases from riparian removal, channel alteration (gravel mining, etc), increase runoff (change in flow regime), etc.	• Bank Erosion Hazard Index • Near Bank Shear Stress • Surveyed bank profiles • Riffle/pool X-sections • Longitudinal profiles • Bank material characterization	Graphical Erosion Prediction Model developed for the WFWR watershed
Roads and Ditches	• Road, buffer, ditch, and road fill characteristics • GPS road locations; stream crossing; cross drains and wing ditches	WEPP: Road Model and published coefficients
Pastures	• Land use • Watershed characteristics • Management practices	Hill Slope version of WEPP Model and published coefficients
Gullies from I-540 Construction	• Field data on gully length and depth	Simple model
Construction	• Permit information	Simple model and local study
Forest Lands and Harvest	• Land Use	Simple model and local study
Urban	• Land use data	Published coefficients
NPDES permitted facilities	• Permit information	Simple model

5.1.1 Watershed Evaluation of Sediment from Streambank Erosion

Stream instability and resulting lateral erosion was observed throughout the WFWR watershed (Figure 5-1). Streambank erosion contributions of sediment have been found to constitute a majority of total sediment supplies in some watersheds (Rosgen, 1976). Lateral streambank erosion may be accelerated in systems that have been hydraulically affected by changes in land-use or in channel dimension. Accelerated lateral erosion contributes additional sediment to the stream system in the form of bedload and suspended load and can impact water quality and increase the potential for river instability. The causes of accelerated streambank erosion can be attributed to a number of factors, such as, removal of riparian vegetation, change in the flow regime from increase in runoff, and channel alteration, such as, gravel mining. All of these causes are complex in nature and have an accumulative affect on the stream system and, in some cases, have been occurring over decades. For example, changes in the flow regime could be due to the harvesting of the virgin timber during the late 1800's and early 1900's as described in Chapters 3 and 4 of this report. Even though parts of the WFWR watershed are still forested, the infiltration rates and other hydrologic characteristics associated with an old growth hardwood forest are different from the forest today in the watershed. Restoring the flow regime to its state before the virgin timber was removed is unlikely to occur. Therefore, addressing the causes of accelerated streambank erosion or stream instability will take unique restoration designs that will have to function with current land uses and watershed conditions.

Figure 5-1 Eroding streambank at inventoried reach WF4

Accelerated lateral streambank erosion was identified as a potential sediment source contributing to the water quality problems in the WFWR watershed. Sediment generated from lateral streambank erosion has two general components, bedload and suspended load. For the purposes of this report, sediment is defined as consisting of bedload, particles with mean diameters greater than 2 mm, and suspended load, particles with mean diameters equal to or less than 2 mm. Suspended sediment does not refer to a load calculated from a TSS concentration for a water sample and instantaneous flow rate. Suspended materials can include sand, silt and clay. In addition to adversely affecting water quality in the form of reduced water clarity and decreased aesthetics, excessive amounts of suspended sediment have the potential to affect aquatic habitat. Suspended sediment loads impact benthic habitats through clogging and burying of interstitial spaces of gravel bed stream networks and aquatic biology by clogging fish gills, suffocating eggs and benthic insect larvae (Schueler and Holland, 2000). Bedload is defined as the portion of the total sediment load that moves on or near the streambed by siltation, rolling, or sliding in the bed layer and is mobile only during high flow events (Fogg and Wells, 1998). Bedload does not directly contribute to turbidity as the particles do not remain suspended in the water column for a sufficient amount of time to affect overall water clarity. However, excessive bedload can contribute to increased streambank erosion, which can generate particles that can affect turbidity, if bedload production exceeds the transport capacity of the stream network.

Using methods proposed by Rosgen (2001), both the annual bedload and suspended load of sediment resulting from accelerated streambank erosion in the WFWR watershed was estimated. The general method used to estimate sediment loads from excessive stream bank erosion in the WFWR involved: 1) Conducting an inventory of streambanks for erosion potential based on a bank erosion hazard index (BEHI) and the near-bank shear stress (NBSS), 2) Developing a graphical model to predict streambank erosion rates in the watershed by measuring erosion rates at permanent survey sites representing the various BEHI and NBSS values observed during the streambank erosion inventory, and 3) Applying the graphical model to the streambank erosion inventory.

5.1.1.1 Streambank Erosion Inventory

Methods: An inventory of eroding streambanks in the WFWR watershed involved traveling the entire length of the main stem and several miles of tributary streams of major sub-watersheds. The banks inventoried or evaluated were streambanks where there were indications of accelerated erosion including hanging roots, exposed bank material, or sod mats at the toe of the bank. The erosion potential was estimated for each inventoried bank by estimating ratings for erosion risk (BEHI) and NBSS. BEHI variables included bank angle, bank height ratio, root density, rooting depth, percent of bank protected by boulders or logs, and bank materials. The height of the streambank was measured with a survey rod and the length of the streambank was determined using a range finder. A rating for NBSS was estimated for each inventoried bank based on the general cross-section shape of the channel and local stream slope conditions. All of the BEHI variables and NBSS information were electronically cataloged using ArcPad GIS software on a water-resistant, Cassiopeia EG-800 handheld PC. Forms were developed for the ArcPad software which allowed for the input of the streambank BEHI and other data. The general locations of streambanks were created in the GIS environment by adding a feature to a streambank line shapefile previously loaded into ArcPad. In the office, the data was downloaded from the handheld PC and then managed in ArcGIS. This approach reduced the amount of time required to transfer raw field data into a digital format. It also allowed for rapid manipulation and presentation of the results of the field work. Photographs of each of the eroding banks that were inventoried were taken using a Kodak DC5000 water resistant 2.1 MP digital camera.

During the spring of 2002, the main stem of the WFWR, 30.3 miles, and the lower 2.4 miles of Winn Creek, a major tributary, were inventoried. The lower 1.4 miles of Mill Creek was inventoried in February of 2003 and the lower 2.3 miles of Town Branch were inventoried in January of 2004. A map highlighting the areas of the WFWR stream network where the streambank inventory was performed is shown in Figure 5-2. Once the field data had been collected, a spreadsheet was used to convert the recorded BEHI variable values of each streambank into points using the scoring system proposed by Rosgen (2001) (Figure 5-3). Based

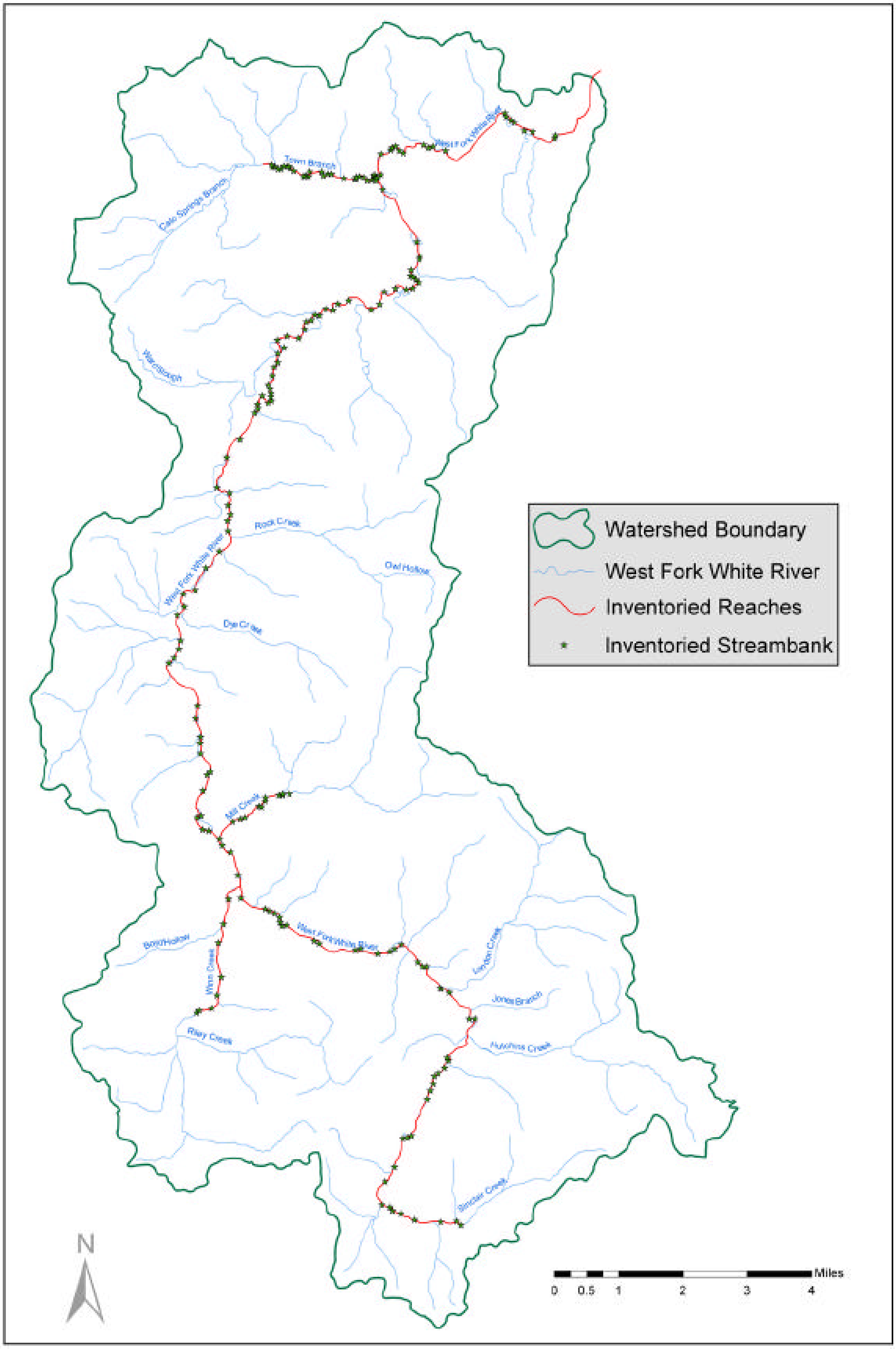

Figure 5-2 Locations of inventoried streambanks in the WFWR

Bank Erodibility Hazard Rating Guide

Stream Reach Date Crew

Bank Erosion Potential

Bank Height (ft): Bankfull Height (ft):		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
V = value, I = index					**SUB-TOTAL** (Sum one index from each column)	

Bank Material Description:

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL

BEHI RATING

Figure 5-3 BEHI data collection and ranking form. Reproduced from *Wildland Hydrology, 2001* on the total number of points a streambank received, a general rating of the erosion risk was assigned. As the number of points increased, the erosion risk increased. The BEHI risk ratings included low, moderate, high, very high, and extreme. Some streambanks that did not display obvious signs of active erosion were included in the inventory to allow comparison of erosion rates between streambanks of lower and higher erosion risk ratings. Evaluation of NBSS was based on rating categories that ranged from low to extreme.

Inventory Results: During the inventory process, 192 individual streambanks were evaluated. The sum of the lengths of inventoried streambanks along the main stem was 7.5 miles or about 12% of the total length of streambanks on the main stem. The length of eroding streambanks for tributary streams was estimated to be 3.1 miles. This estimate was made by calculating the average percentage of inventoried tributary stream length that had eroding streambanks. The average percentage was then applied to non-inventoried tributaries. Town branch was excluded from the average because of the urban nature of the watershed. On Town Branch, approximately 37% of the inventoried stream length was found to be eroding. In contrast, Winn Creek, a rural sub-watershed, had only 14% of the streambank length in an eroding condition. Based on the field evaluated BEHI variables, the erosion risk of the streambanks along the main stem of the WFWR and selected tributaries was estimated. Table 5-2 indicates the number of streambanks within each erosion risk rating category that were cataloged.

Table 5-2 Erosion risk (BEHI) ratings for inventoried streambanks.

Number of Inventoried Streambanks	Erosion Risk Rating
4	Low
44	Moderate
113	High
28	Very High
3	Extreme

Table 5-3 NBSS ratings for inventoried streambanks.

Number of Inventoried Streambanks	Degree of Near-Bank Shear Stress
34	Low
64	Moderate
56	High
33	Very High
5	Extreme

The estimated ratings for NBSS of inventoried streambanks are shown in Table 5-3. The combination of a streambank erosion risk rating (BEHI) and local NBSS affects the degree of lateral migration observed for an eroding streambank. For streambanks with similar erosion risk ratings, higher NBSS will result in greater amounts of lateral erosion.

The combined NBSS category and erosion risk rating (BEHI) are shown for each inventoried streambank in Figures 5-4a, 5-4b, and 5-4c for the upper, middle and lower ends of the WFWR watershed, respectively.

Based upon the results of the stream bank inventory, some of the most critical areas of stream instability on the WFWR main stem include streambanks WF3 through WF10a (Figure 5-4b) and streambanks WF12a through WF23a (Figure 5-4a).

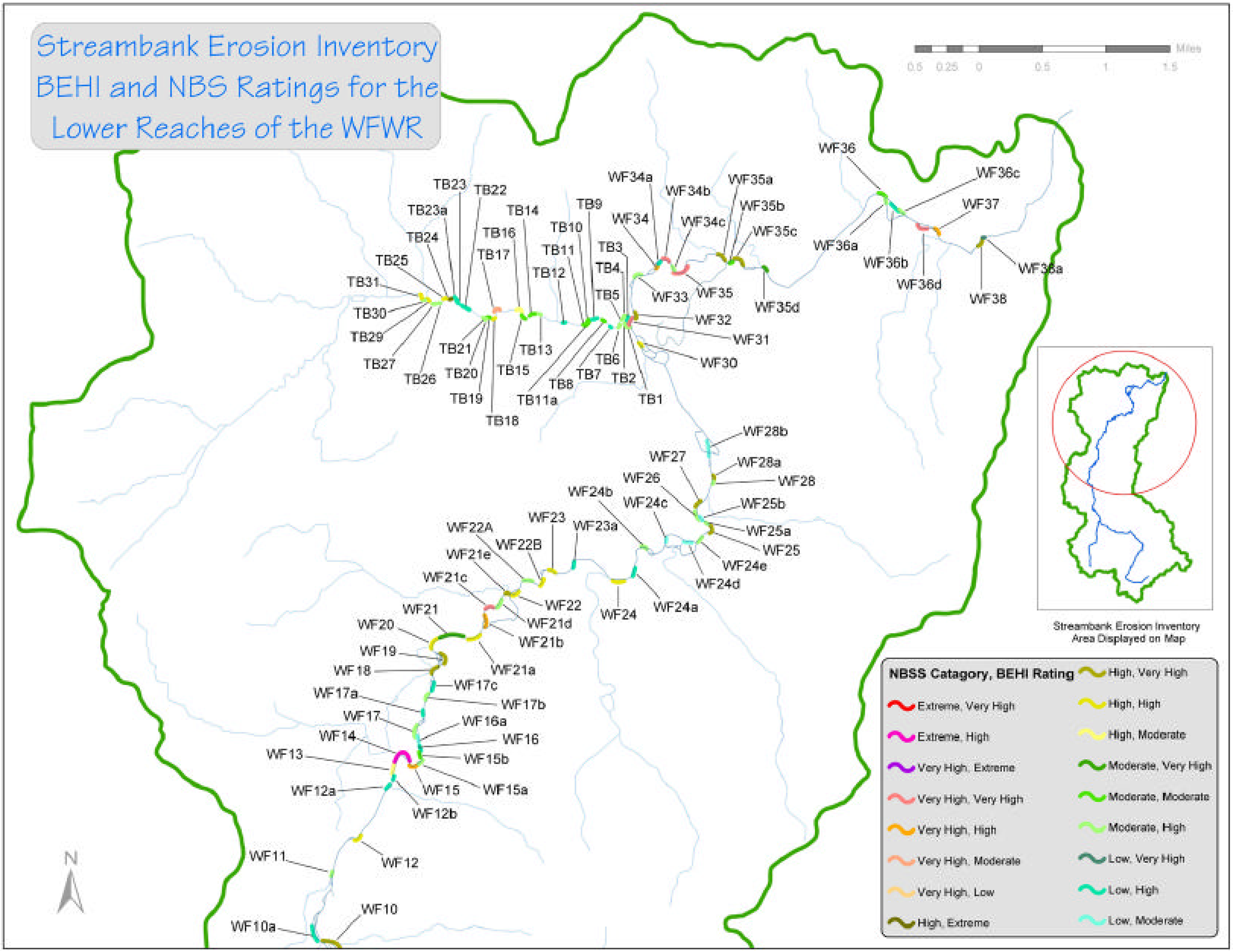

Figure 5-4a Locations of inventoried streambanks and the NBSS and BEHI results for the lower one third of the WFWR

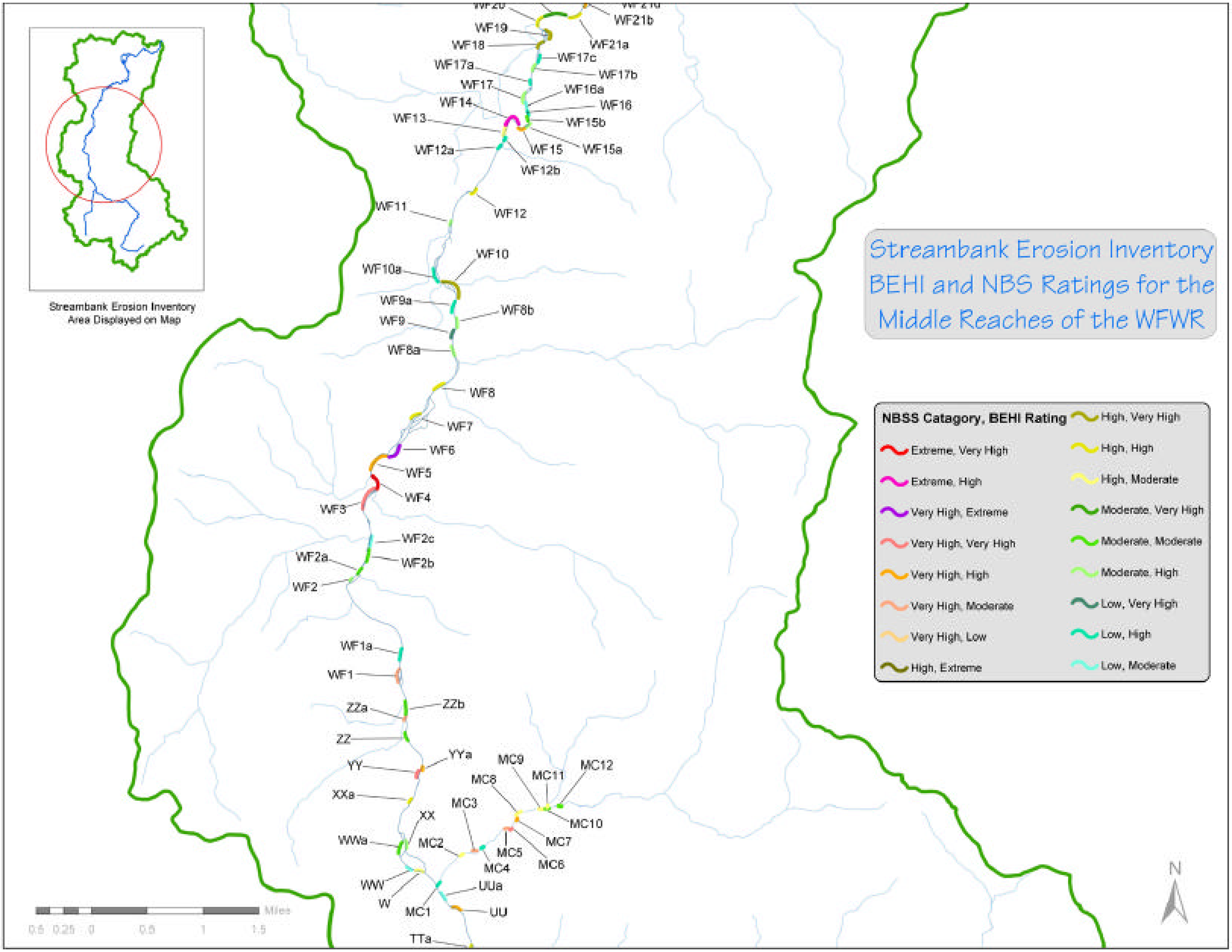

Figure 5-4b Locations of inventoried streambanks and the NBSS and BEHI results for the middle one third of the WFWR

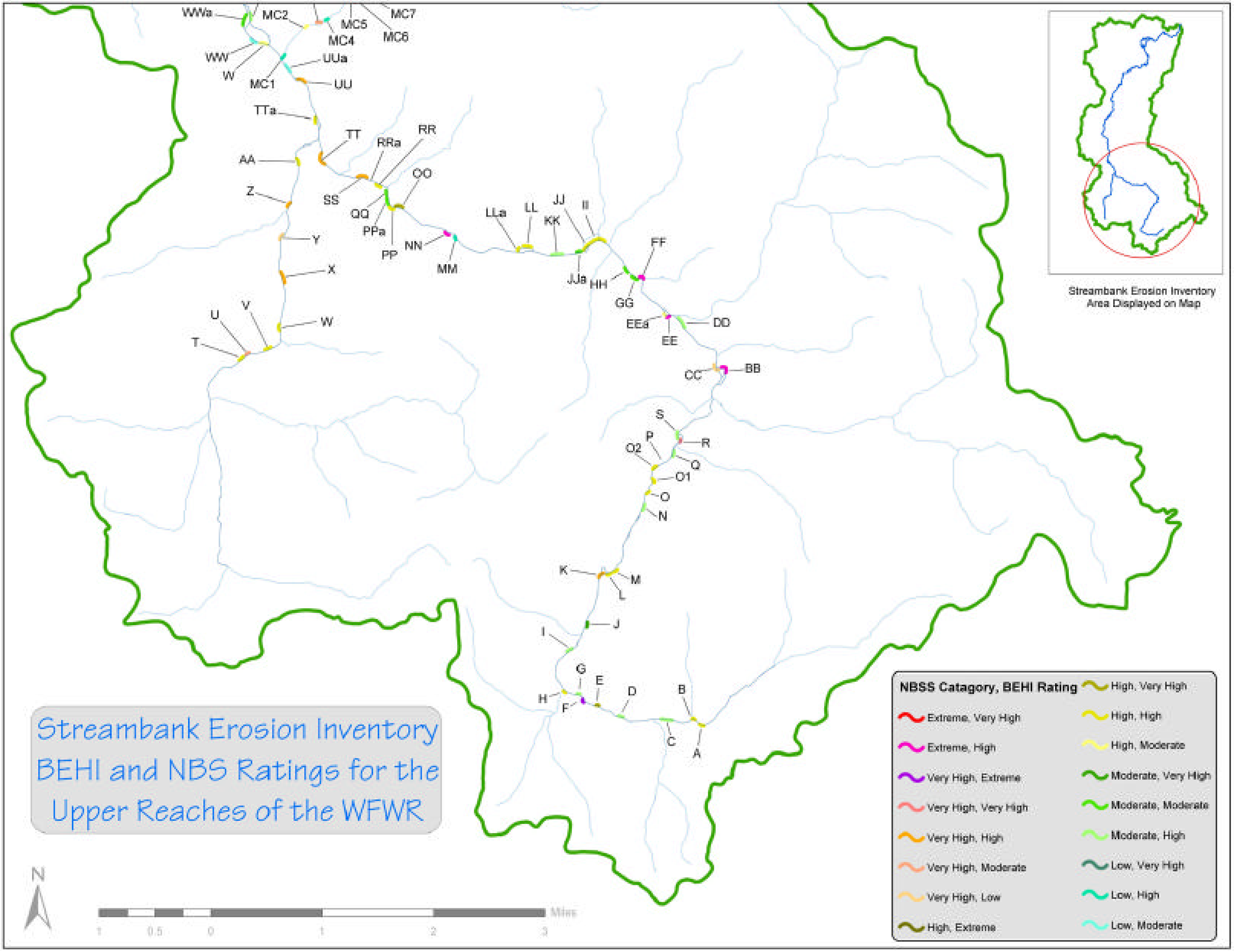

Figure 5-4c Locations of inventoried streambanks and the NBSS and BEHI results for the upper one third of the WFWR

5.1.1.2 Graphical Model for Predicting Streambank Erosion Rates

To estimate the lateral erosion rates of inventoried streambanks using the BEHI and NBSS ratings, a graphical prediction model based on physical measurements of streambank erosion was developed for the WFWR watershed using methods described by Rosgen (2001).

Methods: The graphical model was developed based on measurements taken at the eight reaches where detailed fluvial geomorphological surveys were conducted (Figure 4-1). Within these reaches, 24 survey sites were established. The survey sites were selected based on the various combinations of BEHI and NBSS ratings representing the variety of streambank conditions along the main stem of the WFWR observed during the streambank erosion inventory process. The general fluvial geomorphological character of the river channel at the selected reaches is discussed in Chapter 4.

Annual lateral erosion rates at the permanent survey sites were determined by installing vertical pins at the toe of the streambanks. A map indicating the location of the toe pins associated with the survey sites for survey reach #1 is shown in Figure 5-5. Site maps indicating the locations of other toe pins can be found in Appendix 4-A. The toe pins were installed by driving sections of 4 ft. long ¾ inch thick rebar vertically into the channel bed immediately adjacent to the streambank of interest. The BEHI variables and NBSS condition for each bank where toe pins had been installed were evaluated and recorded. Using a pair of flat-edged survey rods and a framing level, the profile of the eroding streambank was surveyed by measuring the horizontal distance from the landward side of the toe pin to the streambank for various heights above the toe pin cap, depending on the shape of the bank profile (Figure 5-6). The toe pins were resurveyed after one year to determine annual erosion rates. The range of stream discharge during the one-year period was monitored by using data from a USGS gage station (07048550) at the downstream end of the watershed. This allowed for a determination of the discharge conditions represented by the graphical model.

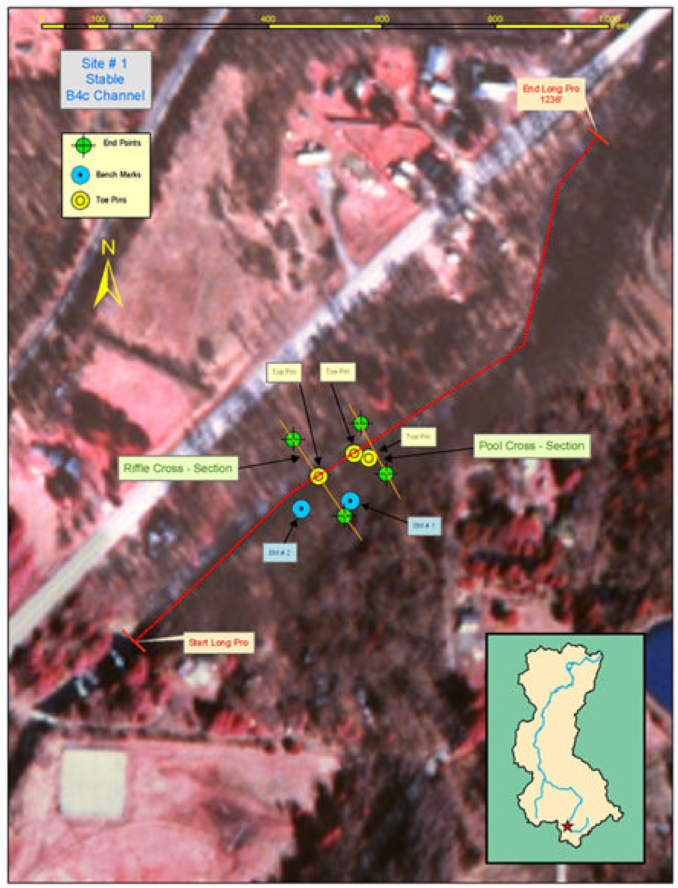

Figure 5-5 Toe Pin locations at Reach #1

Bank profile survey data from 2002 and 2003 were placed into a spreadsheet and plotted. Using the graphed data, the average lateral erosion for the entire height of the streambank was calculated by taking the average of the lateral erosion data measured every two tenths of a foot of vertical elevation above each toe pin. By relating the BEHI rating, the local NBSS, and the measured erosion rate at each permanent survey site, a graphical model to predict streambank erosion rates was developed. Using the graphical model, erosion rates were predicted for all the streambanks included in the streambank erosion inventory. The volume of sediment generated due to erosion of individual streambanks was calculated by multiplying the predicted annual lateral erosion rate by the length and height of the bank as measured during the inventory.

Figure 5-6 Lateral erosion measurements taken for a toe pin at survey reach #5

Results: A total of 24 streambanks were surveyed within the eight reaches evaluated for this assessment. Measurements of bank profiles were collected for each streambank in both 2002 and 2003. A graphical representation of the results of 2002 and 2003 streambank profiles for toe pins located on Reach #1 and Reach #7 are shown in Figure 5-7. The BEHI and NBSS evaluations, photographs of the surveyed streambanks, and the 2002 and 2003 bank profile results measured at the toe pins for this assessment can be found in Appendix 5-B.

Table 5-4 displays the measured lateral erosion data along with the BEHI and NBSS ratings. The graphical model for predicting streambank erosion rates in the WFWR watershed is shown in Figure 5-8. Using the graphical model, Figure 5-8, along with the BEHI and NBSS ratings, lateral erosion rates were estimated for all the streambanks included in the inventory. Streambank erosion rates increase with more severe BEHI risk ratings and greater NBSS. The maximum erosion rate predicted for streambanks inventoried along the mainstem of the WFWR was 12.9 feet for streambank WF4 (Figure 5-4b). The average erosion rate for inventoried banks, where the rated erosion potential was moderate or greater, was 0.6 feet.

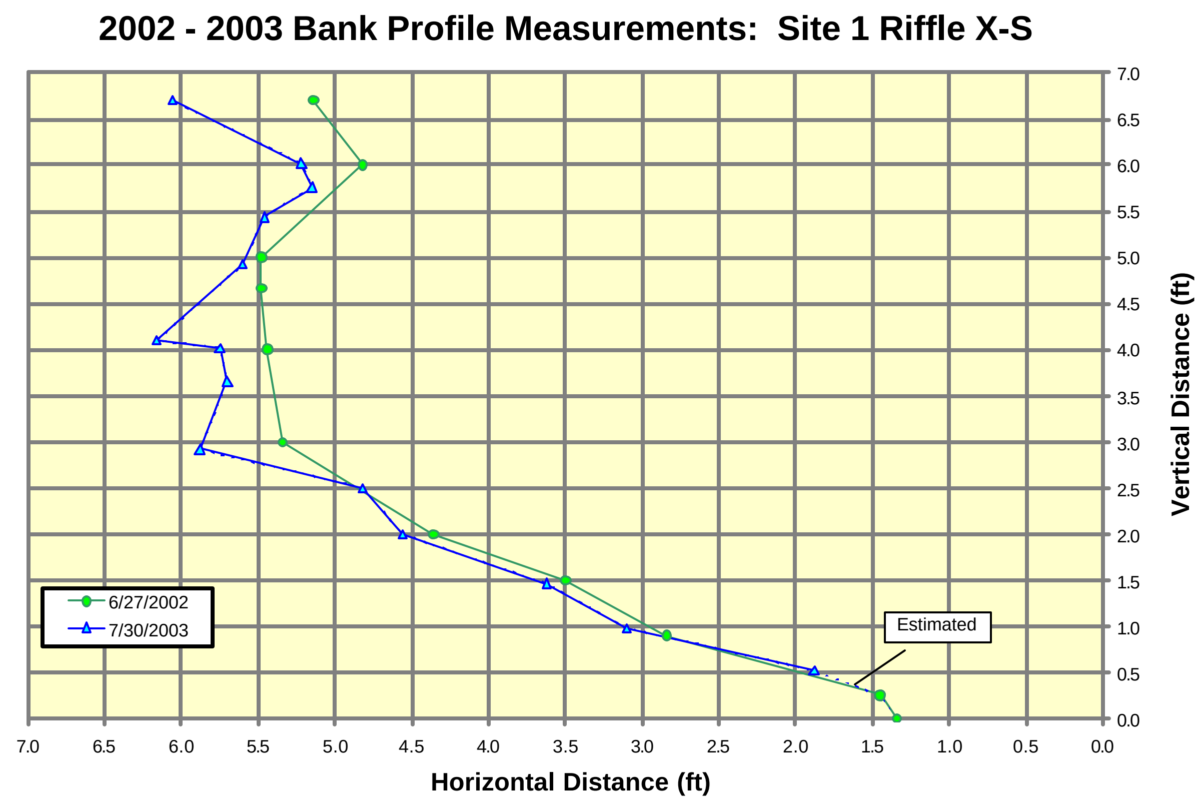

Figure 5-7 Lateral erosion measurements of the streambank profile at Reach #1

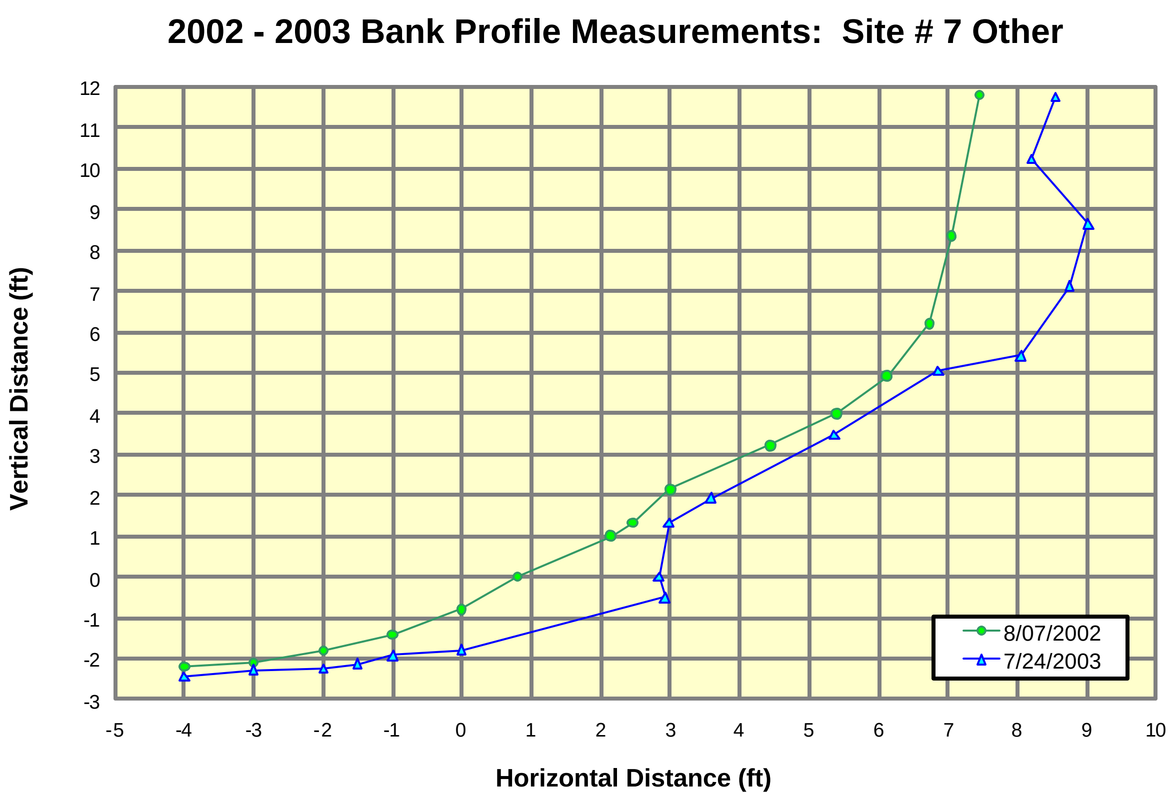

Figure 5-7a Lateral erosion measurements of the streambank profile at Reach #7

Table 5-4 Results of BEHI and NBSS evaluations and measured lateral erosion of streambanks at surveyed reaches in the WFWR watershed.

Reach #	Toe Pin Location	BEHI Score	BEHI Risk Rating	Estimated Near Bank Shear Stress (NBSS)	Lateral Erosion (ft)
1	Other (between riffle & pool X-S)	31.5	High	High	0.18
	Pool	26	Moderate	High	0.29
	Riffle	32.4	High	High	0.34
2	Other (US of riffle X-S	27.9	Moderate	Moderate	0.12
	Pool (DS of pool X-S)	28.9	Moderate	High	0.18
	Riffle	16.8	Low	Low	0.05
3	Pool (disturbed)	39.9	High/Very High	Very High	0.7
	Pool (stable)	30.9	Moderate/High	High	0.41
	Riffle (disturbed)	30.8	Moderate/High	Very High	0.35
4	Pool	22.2	Moderate	Moderate	0.2
	Riffle	27	Moderate	Moderate	0.19
5	"D" Type Head Cut	41.9	Extreme	Extreme	14.4
	Pool	45	Extreme	Extreme	16.6
	Riffle	45	Extreme	Extreme	15.3
6	Other (0' on long pro)	41.7	Very High	Moderate	0.46
	Other (670' on long pro)	39.6	High/Very High	High	0.6
	Pool	20	Low/Moderate	High	0.1
	Riffle	31.7	High	Low	0.1
7	Other (DS of pool X-S)	44.7	Very High	Very High	1.4
	Riffle (227' US of riffle X-S)	34.4	High	Moderate	0.28
8	DS Riffle (left bank)	29.4	Moderate/High	Low	0.11
	Riffle (right bank)	16.1	Low	Low	0.03
	Riffle X-S Left	18.3	Low	Low	0.01
	US of Pool X-S	31.8	High	Extreme	3.4

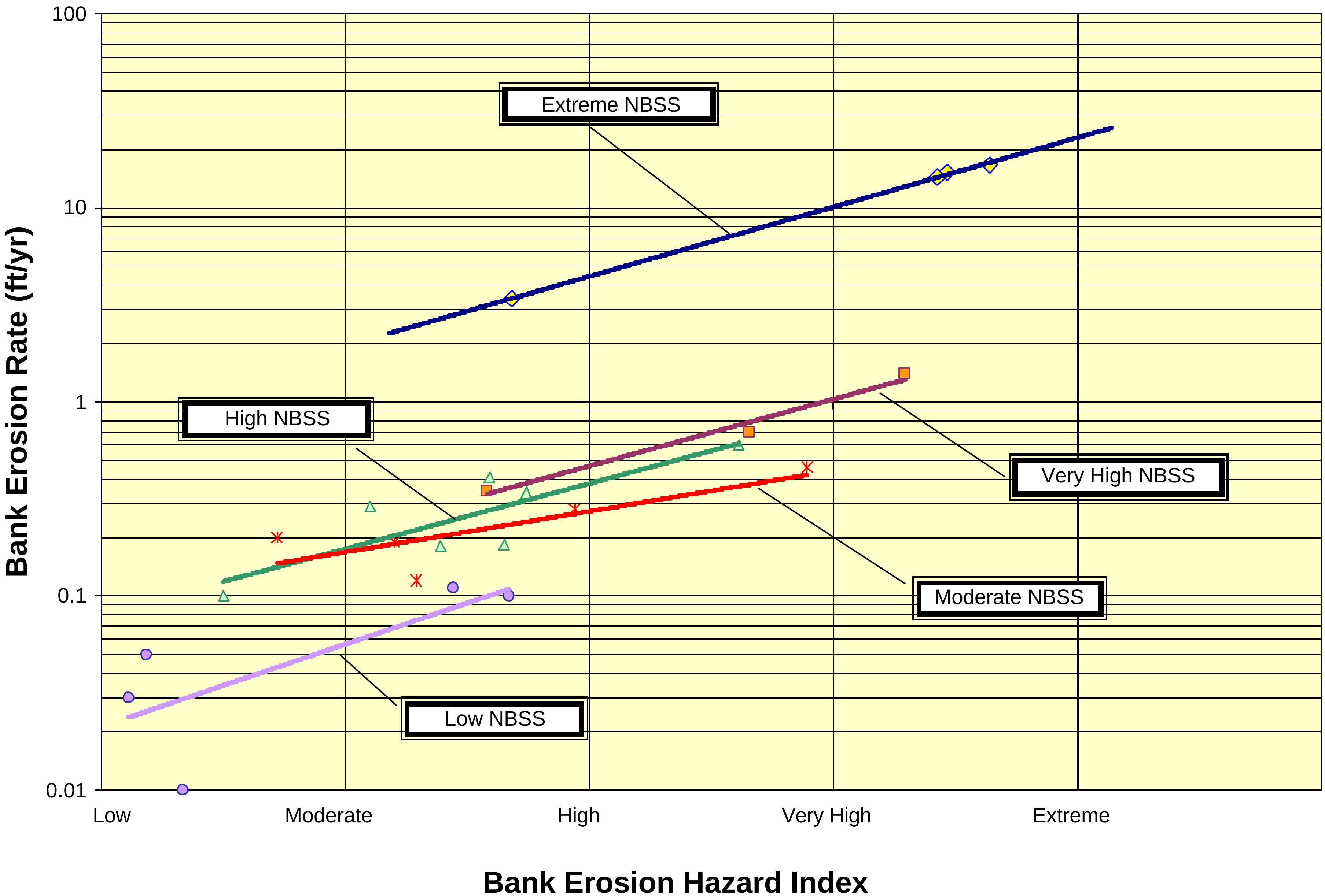

Figure 5-8 Graphical model for estimating lateral streambank erosion rates in the WFWR watershed

The maximum measured flow during the period between surveys was 4,120 cfs as measured on the WFWR at the USGS gage station. This discharge exceeds the bankfull discharge based on regional curves (ADEQ, 2002) by approximately 27%. In addition, project team members observed bankfull discharge and slightly greater than bankfull discharge at several of the reaches during the time that the 4,120 cfs discharge was recorded. Since the discharge during the period between the surveys was at or slightly above bankfull, the survey data should represent erosion rates for years where bankfull flow is approached, equaled, or slightly exceeded. In years where the discharge is either well below or greatly exceeds the bankfull discharge, the graphical model will lose accuracy.

The lateral erosion estimates along with the dimensions of the evaluated stream banks (length and height) were used to estimate the volume of sediment from the streambanks that were inventoried along the mainstem of the WFWR and was found to be 315,959 ft^3 or 11,702 yd^3 (Table 5-5). This volume would be equivalent to 650 dump truck loads of sediment being introduced to the WFWR on an annual basis, assuming a truck capacity of 18 yd^3. The estimated erosion volumes for the tributary streambanks that were inventoried are shown in Table 5-5.

Table 5-5 Estimated streambank material volume eroded from inventoried streambanks in the WFWR watershed.

	ft^3	yd^3
Mainstem WFWR	315,959	11,702
Winn Creek	4,366	162
Mill Creek	4,479	166
Sinclair Creek	3,582	133
Town Branch	10,228	379

5.1.1.3 Characterization of Streambank Material

In order to relate streambank erosion to water quality impacts and to be able to compare the overall impact of sediment from streambank erosion to other sources of sediment in the watershed, the bulk density and particle size distribution of the sediment supplied through streambank erosion in the WFWR watershed needed to be determined. Characterization of the streambank material in the WFWR watershed was needed to determine sediment loads. For uniform material that was generally less than 2 mm in size, streambank samples were collected using a hammer-driven Shelby tube. Typically, two to four samples were collected in the general area of the main riffle and pool cross-sections. Each of these discreet samples was analyzed for bulk density and particle size. Dr. Kris Brye, Department of Crop Soil and Environmental Sciences, University of Arkansas, developed a method to evaluate the in-situ bulk density of streambanks that consisted of coarse materials that could not be sampled with a Shelby tube (Brye, et. al., 2004). The process involved the excavation and collection of bank material in the exposed streambank. The remaining void was then filled with expanding liquid foam, that when dried, represented the volume of the excavated void. The bank material excavated from the streambank was weighed, and analyzed to determine the particle size distribution. Samples were collected from various strata of streambank material at each of the surveyed reaches as shown in Figure 5-9. The in-situ bulk density of samples collected from various streambank strata are shown in Tables 5-6a and 5-6b. Table 5-6a and Table 5-6b show the results of samples collected from streambank strata that were composed of fine sized particles and of coarse sized particles, respectively. Also presented in Table 5-6a and 5-6b are generalized particle size distributions. The distributions are presented as the percentage of the sample mass that had particles greater than 2 mm, equal to 2 mm and between 2 mm and 0.02 mm, and equal to or less than 0.02 mm. These fractions represent, in general, the bedload,

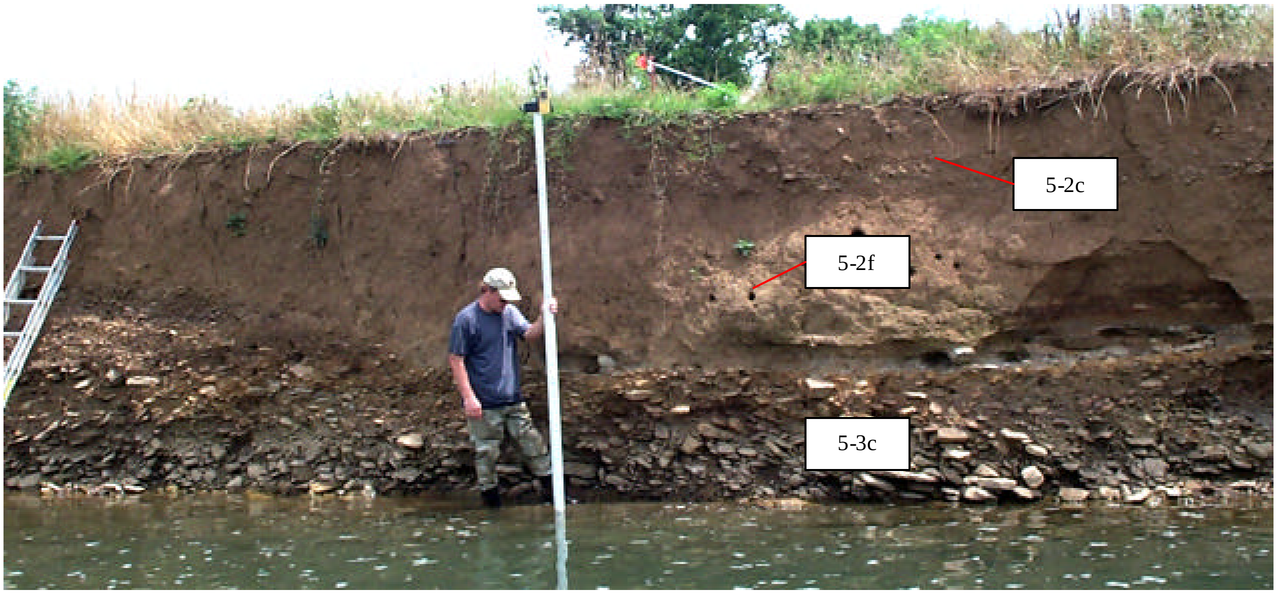

Figure 5-9 Examples of streambank material sample locations at Reach #5

suspended load, which was broken down in to two classes including the size class of particles that are usually reported in TSS concentrations. A summary of all of the streambank material samples collected as part of this assessment can be found in Appendix 5-C.

The in-situ bulk density and particle size distributions of streambank materials sampled during streambank material characterization activities were related to inventoried streambanks as follows. Photographs of the individual banks were examined. Based on the photographic evidence, the numbers of exposed strata or sediment layers were determined. The relative thickness of exposed layers was estimated as a percentage of the total bank height. The physical appearance, including the sizes of coarse particles, color of soils, and texture of soils of each identified stratum on the photograph was matched with an indexed bank material that had similar physical characteristics. Priority was given to associating the physical properties of the strata of interest to strata that had been indexed if they were located in the same general area within the watershed. The in-situ bulk density and particle size distribution of the indexed streambank strata was used to estimate the unknown physical properties of the stratum for the inventoried streambanks.

Table 5-6a Bulk density and particle size distribution for fine-grained streambank material samples

Fine Grained Samples	Bulk Density (g/cm^3)	Bulk Density (lb/ft^3)	Bulk Density (ton/ft^3)	Bulk Density (ton/yd^3)	Percent > 2 mm	Percent 2 <x> .02 mm	Percent ≤ .02 mm
1-1f	1.12	70.15	0.04	0.95	2.8	53.6	43.6
1-2f	1.46	91.03	0.05	1.23	12.1	57.4	30.5
2-1f	1.38	85.93	0.04	1.16	28.9	42.7	28.4
2-2f	1.26	78.64	0.04	1.06	32.0	36.7	31.3
3-1f	1.50	93.50	0.05	1.26		25.0	75.0
3-2f	1.59	99.43	0.05	1.34	15.3	36.2	48.5
3-3f	1.37	85.43	0.04	1.15	31.5	29.6	38.9
5-1f	1.39	86.95	0.04	1.17	5.9	49.9	44.2
5-2f	1.47	91.49	0.05	1.24		52.4	47.6
5-3f	1.54	95.90	0.05	1.29		51.3	48.7
5-4f	1.36	84.91	0.04	1.15		72.4	27.6
6-1f	1.50	93.74	0.05	1.27		42.8	57.2
6-2f	1.44	89.85	0.04	1.21		73.6	26.4
6-3f	1.35	84.12	0.04	1.14		67.5	32.5
6-4f	1.30	81.20	0.04	1.10		59.9	40.1
6-5f	1.41	88.20	0.04	1.19		76.6	23.4
7-1f	1.39	86.56	0.04	1.17		44.1	55.9
7-2f	1.26	78.64	0.04	1.06		73.1	26.9
7-3f	1.43	89.54	0.04	1.21		74.7	25.3
8-1f	1.41	87.84	0.04	1.19	29.4	36.3	34.3
8-2f	1.46	91.25	0.05	1.23	17.2	49.9	32.9
8-3f	1.42	88.72	0.04	1.20		60.3	39.7

Table 5-6b Bulk Density and particle size distribution for coarse-grained streambank material samples

Coarse Samples	Bulk Density (g/cm^3)	Bulk Density (lb/ft^3)	Bulk Density (ton/ft^3)	Bulk Density (ton/yd^3)	Percent > 2 mm	Percent 2 ≤x> .02 mm	Percent ≤ .02 mm
1-1c	2.54	158.66	0.08	2.14	77.5	13.5	9.0
1-2c	1.96	122.37	0.06	1.65	82.3	14.7	3.0
2-1c	3.12	194.51	0.10	2.63	82.5	11.8	5.7
2-2c	2.13	132.88	0.07	1.79	86.6	7.1	6.3
3-1c	2.44	152.30	0.08	2.06	79.8	8.3	11.9
3-2c	5.25	327.91	0.16	4.43	67.6	12.3	20.1
4-1c	2.76	172.25	0.09	2.33	88.0	6.1	5.9
4-2c	1.79	111.63	0.06	1.51	83.1	8.0	8.9
5-1c	2.01	125.33	0.06	1.69	83.3	15.3	1.4
5-2c	1.44	89.97	0.04	1.21	82.6	14.2	3.2
5-3c	2.99	186.52	0.09	2.52	69.2	24.5	6.3
5-4c	1.71	106.53	0.05	1.44	89.6	6.0	4.4
6-1c	2.64	164.92	0.08	2.23	77.8	15.5	6.7
6-2c	3.46	215.95	0.11	2.92	81.0	12.8	6.2
7-1c	3.28	204.86	0.10	2.77	70.0	23.8	6.2
7-2c	2.32	145.00	0.07	1.96	78.9	17.2	3.9
8-1c	2.67	166.86	0.08	2.25	84.1	13.3	2.6
8-2c	2.21	137.63	0.07	1.86	82.0	12.6	5.4

5.1.1.4 Estimate of Annual Sediment Loads from Streambank Erosion

Based on the streambank inventory, the development of the graphical model, and the measurement of in-situ bulk density, an estimate of the annual load of sediment resulting from streambank erosion was made. Sediment loads generated by streambank erosion for major tributaries of the WFWR that were not included in the streambank inventory process were estimated by developing streambank erosion export coefficients from inventoried tributaries having similar characteristics. Export coefficients were applied to the length of the tributaries that were 3rd order or greater streams. For the WFWR watershed, it was estimated that on an annual basis, a total of 23,650 tons of sediment enter the river network from streambanks where accelerated streambank erosion was observed. Natural erosion rates for the WFWR watershed were assumed to be equivalent to the rate predicted by the graphical model for a BEHI-NBSS rating of low-low. Using this assumption, the sediment load for natural erosion from streambanks included in the streambank erosion inventory would be 815 tons/yr, which is 3% of the total load estimate.

Using the particle size distribution of streambank materials, bedload (greater than 2 mm) and suspended loads (equal to or less than 2 mm) were determined and are shown in Table 5-7. The mass of bedload and suspended load from streambanks included in the watershed inventory was 8,259 ton/yr and 15,391 ton/yr, respectively. Suspended sediment represented 65 percent of the estimated total sediment load. The sediment load that consisted of particles less than 0.02 mm in size was 7,234 ton/yr.

The estimated sediment load resulting from erosion of streambanks along the main stem of the WFWR that were included in the inventory was 18,532 ton/yr. Of that amount, 12,375 tons/yr or 67% of the load consisted of sediment 2 mm or less in size. 80 percent of the estimated suspended sediment load for the watershed resulted from erosion of streambanks along the main stem of the WFWR that were included in the inventory. The reach along the main stem of the WFWR that included inventoried streambanks WF3 through WF6 contributed 25% of the total load of particles less than 2 mm in size.

Table 5-7 Estimated sediment loads from eroding streambanks in the WFWR watershed

Main Stem and Tributaries	Length mi	Area mi^2	Sediment Load (ton/yr)		
			> 2 mm	= 2 mm	Total
Main Stem	30.3	124	6,157	12,375	18,532
Wilson Branch	1.3	3.3	20	265	285
Dye Creek	2.2	3.6	183	209	392
Riley Creek	2.5	4.0	216	103	319
Cato Springs	1.9	4.6	29	383	412
West Mtn Creek	2.6	4.7	216	247	463
Sinclair Creek	2.3	5.1	251	140	391
London Creek	2.3	5.1	191	219	411
Rock Creek	2.6	5.9	219	251	470
Hutchins Creek	3.2	5.9	269	308	577
Mill Creek	2.5	7.3	215	246	460
Town Branch	2.6	11.7	39	522	561
Winn Creek	3.0	14.4	255	122	377
		Total	**8259**	**15391**	**23650**

5.1.2 Watershed Evaluation of Sediment from Roadways

"Gravel" or unpaved roads have been identified as potential sources of sediment (Figure 5-10) that are adversely affecting water quality in the WFWR watershed (ADPC&E, 1995 and ADEQ, 2002). The annual sediment loads from unpaved roads as well as paved roadways in the WFWR watershed were estimated. To estimate sediment from roadways in the watershed, a comprehensive inventory of publicly owned roads was developed. Publicly owned, unpaved roads and paved state highways were included in the inventory. The focus of the inventory however, was on unpaved roads, due to the identification of this road type as a source of sediment. Randomly selected segments of inventoried roads were surveyed for various parameters, and then using the surveyed parameters, sediment yield was estimated using the web-based FSWEPP model, "WEPP: Road" module (Elliot, et al, 1999). Estimates of sediment loads from residential and secondary paved roads in urban areas along with Interstate I-540 and unpaved private roads and driveways were developed based on published data for urban areas and data from the Ouachita National Forest Service.

Figure 5-10 Sediment entering ditch and detailed survey of County Road 156

5.1.2.1 Inventory of Roadways

Roadways in the WFWR were inventoried using vehicle mounted Trimble GPS receivers with Trimble XT data logging devices. A table listing the variables that were collected as part of the inventory is shown in Appendix 5-D. The variables were selected based on work performed by the United State Forrest Service (USFS), Ouachita National Forest, in Hot Springs, Arkansas (Clingenpeel, 2004). Existing road conditions were inventoried based on variables that were being logged as attributes in the GPS file. As road conditions changed, new road segments were created in the GPS file. For example, field staff would begin logging the GPS location road segment with a given set of existing conditions. If one of the critical variables, such as, road surface material, surface erosion, etc., changed, staff would then suspend the collection of data and create a new road segment having a new set of attributes that reflected the change in road condition. The road inventory data can also be used later for BMP implementation planning. Publicly owned, unpaved and paved state highways were included in the road inventory. Interstate 540, residential and secondary paved roads (urban), and private un-paved drives were not included in the inventory; however, sediment loads were estimated for these road types.

The results of the road inventory showed that there were 95 miles of unpaved and 109 miles of paved public roads in the WFWR watershed. Of the unpaved roads, 41 miles had a gravel surface, 48 miles had spotty gravel (spot) surface, and 6 miles had a surface of native material (native). The GPS locations of road features, such as cross-drains and wing-ditches, which direct stormwater runoff from the roadways, were also collected as part of the inventory. Figure 5-11 shows the location of unpaved and paved roads along with the cross-drains and wing-ditches for the WFWR watershed.

On many of the out-sloped designed unpaved roads, berms had been formed along the edge of the road from improper grading practices. The berms prevented stormwater from leaving the road prism resulting in increased erosion of the road surface. The locations of the unpaved roads where berms had formed were identified during the road inventory and are shown in Figure 5-12.

The non-urban road inventory also included identifying point features, such as, the locations of stream crossings. Stream crossings included bridges, fords, low-water crossings using culverts, and concrete slab low-water crossings. The amount of drop from the outlet or downstream edge of these crossings was measured during the inventory process to determine fish passage barrier potential. Frequently, considered to only be of consequence to anadromous fish species, fish passage barriers can affect the migration and reproduction of many fish species in Arkansas including centrachids, cyprinids, and fundulids. Research in the Ouachita Mountains has shown that migration of these species was an order of magnitude less for these species through culvert stream crossings (Melvin, 1997). Removal of fish passage barriers to allow these and other fish to reproduce is critical to maintaining biological diversity and encouraging a sustainable ecosystem. Collection of the locations of stream crossings in the watershed may allow for planners to reduce the fish barriers on a sub-watershed basis. The locations of the stream crossings that pose a potential fish passage barrier are shown in Figure 5-13

5.1.2.2 Estimating Sediment Loads from Roadways

The web-based, "WEPP: Road" model, was used to estimate sediment yield of inventoried roads in the WFWR watershed (Elliot, 2004). The WEPP: Road model is one in a series of the U.S.D.A Forest Service's internet-based computer programs based on the Agricultural Research Service's Water Erosion Prediction Project (WEPP) model. The project team was introduced to the model by the USFS Ouachita National Forest staff, who has been using WEPP: Road to model unpaved roads in the Ouachita National Forest (ONF) (Clingenpeel, 2004). In addition to estimating soil erosion and sediment yield, the ONF uses the model along with road inventory data to develop BMP implementation plans that minimize erosion from unpaved roads. Input data requirement s for WEPP: Road are extensive and include the following: climate, soil and gravel addition; local topography; drain spacing; road design and surface condition; and ditch condition (Elliot, 1999).

Methods: The WEPP: Road model was utilized for a watershed based assessment of sediment yield from inventoried roads following a methodology developed by the Ouachita National Forest Service (Clingenpeel, 2004). This methodology required that inventoried roads be separated into "road groups" based on combinations of selected variables or road characteristics. A percentage of the road segments from each of the individual "road groups" were

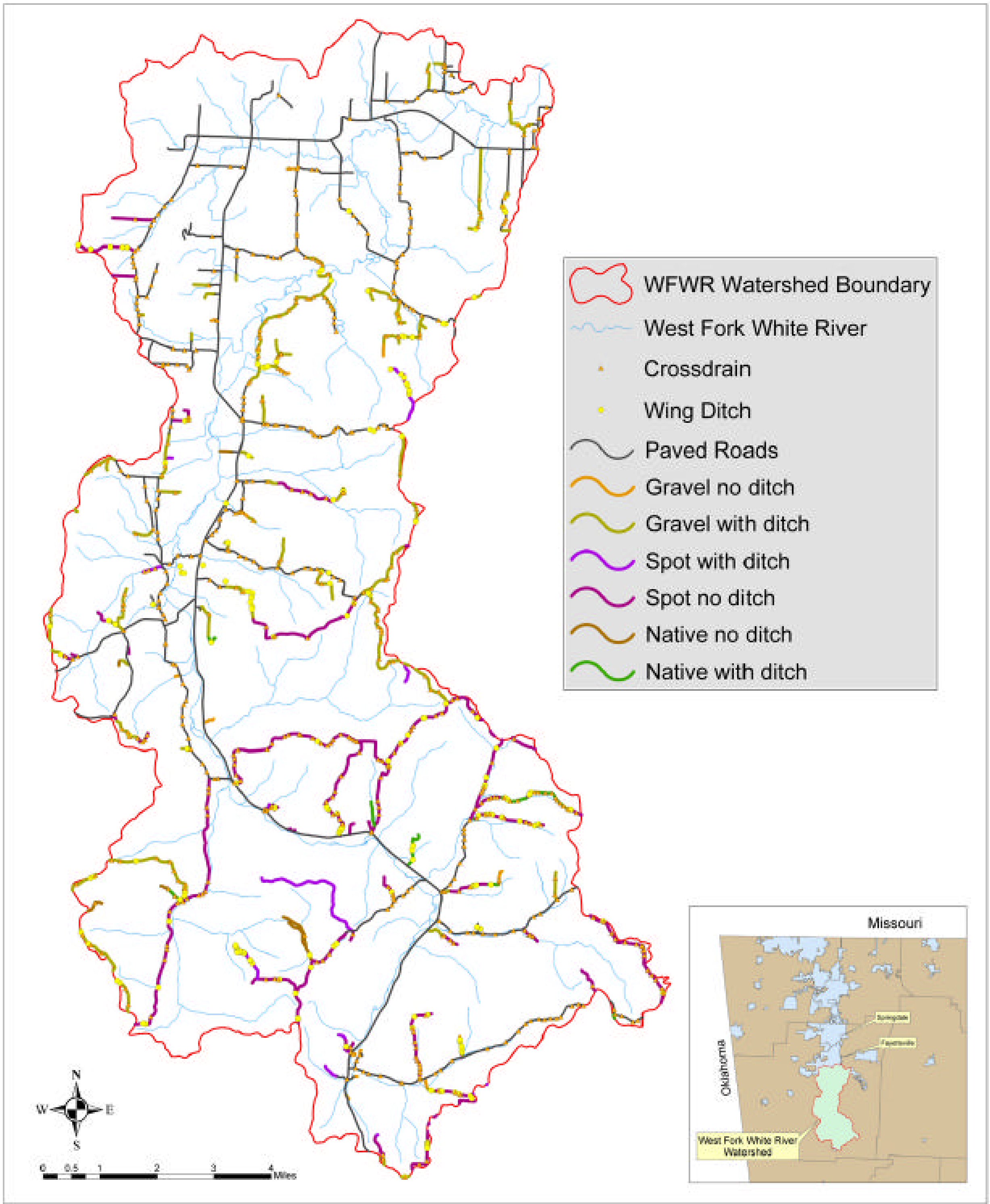

Figure 5-11 Location of unpaved and paved roads with cross-drains and wing ditches indicated from the non-urban road inventory.

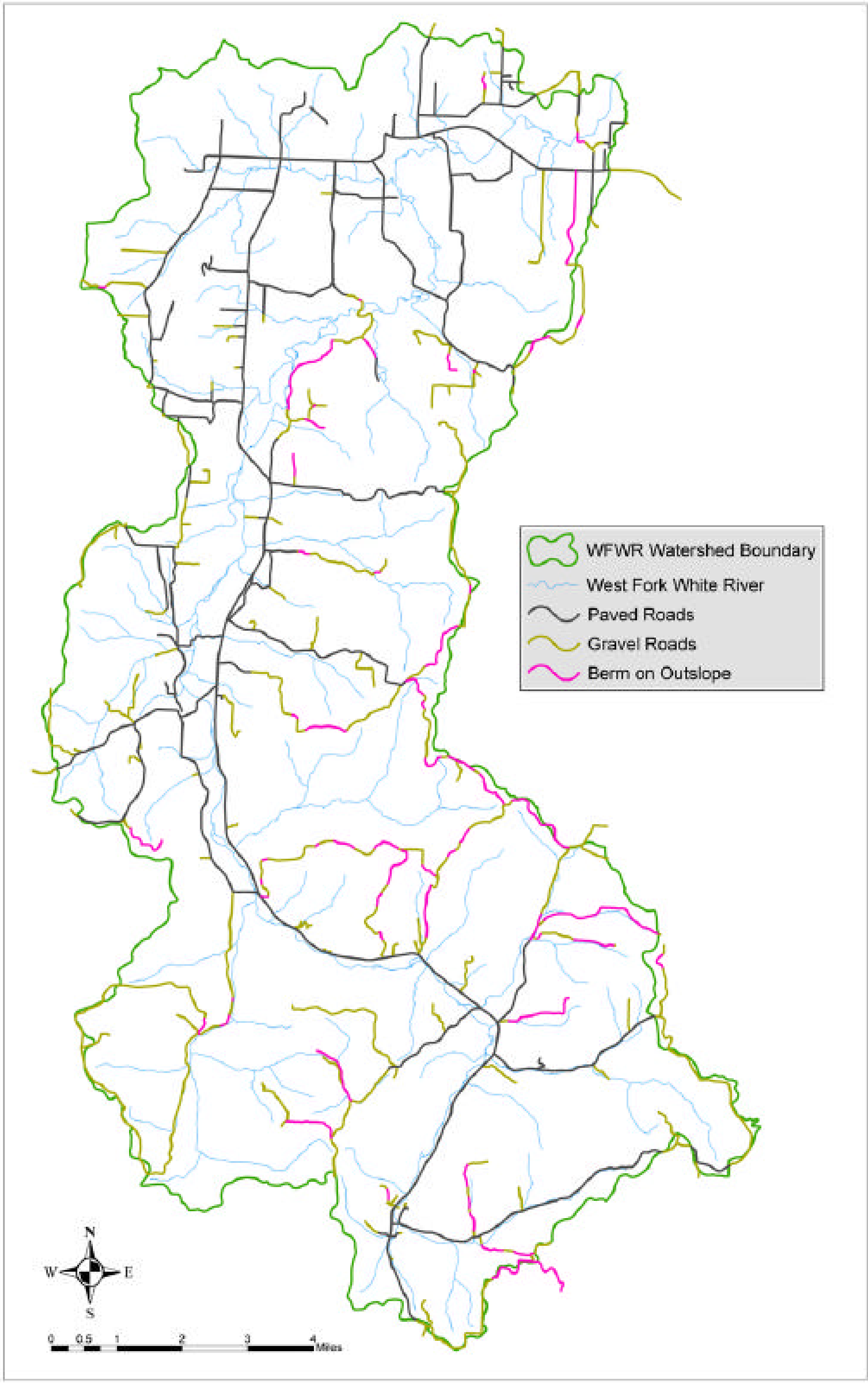

Figure 5-12 Locations of un-paved roads where berms have formed on the road outslope

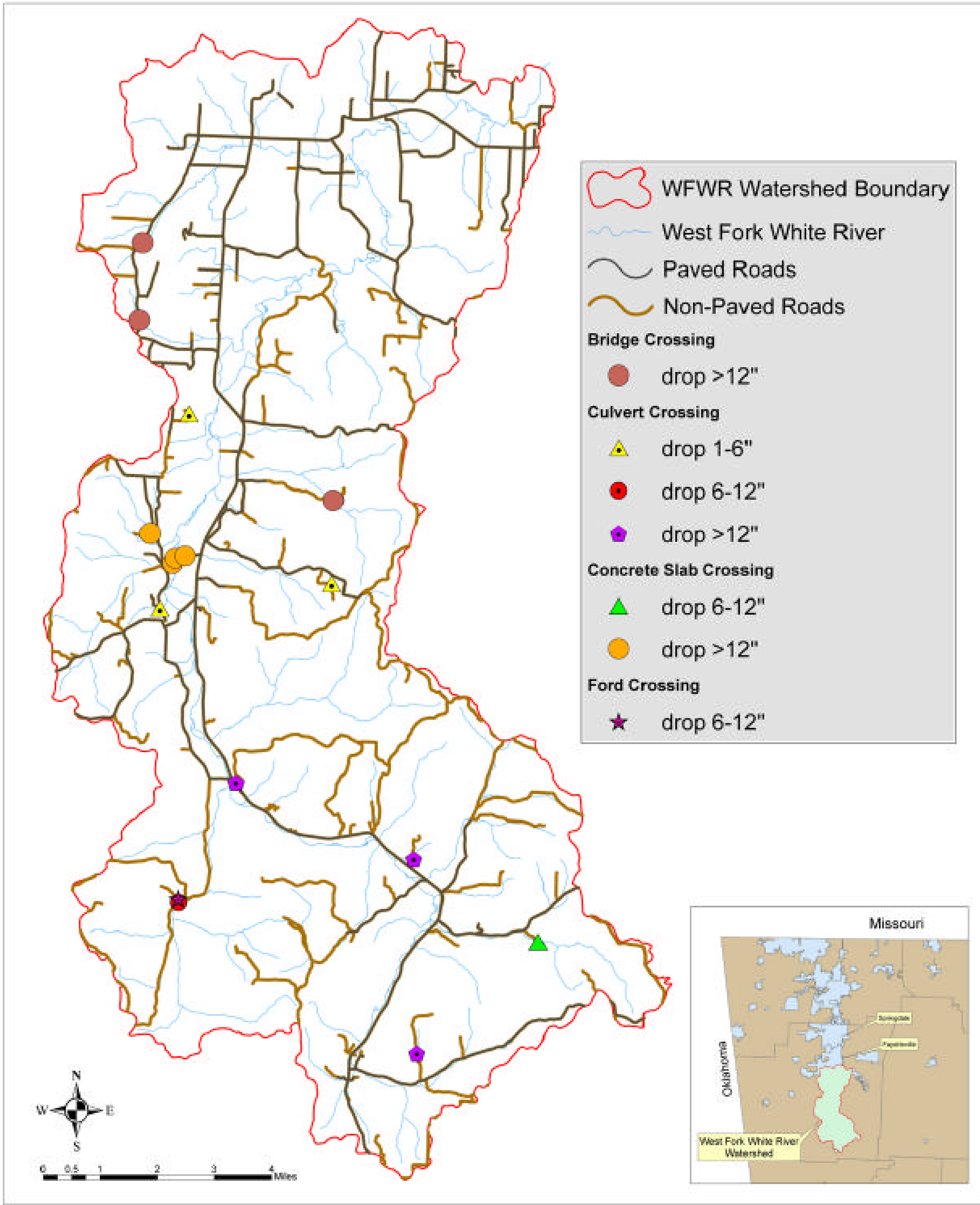

Figure 5-13 Location of potential fish passage barriers at stream-crossings in the WFWR watershed

selected, randomly, for detailed field surveys, which provided the input data to run the WEPP model.

Using the data collected from the road inventory, it was determined that the majority of the variability observed between road segments was a function of the road surface and the presence or lack of ditches for a particular road segment. Therefore, road segments were grouped according to road surface type and the presence of ditches. This resulted in six unpaved "road groups," shown in Table 5-8. The number of miles of road segments for each "road group" is shown in Table 5-9. Ten percent of the segments from each "road group" were randomly selected for detailed field surveys, their locations are shown in Appendix 5-E. Paved roads that were inventoried were classified as a singular "road group." Only 1% of paved roads were surveyed in detail due to the uniformity of paved surfaces, uniform condition of the road-side ditches and small variability of road slope that was observed throughout the watershed.

Table 5-8 Road groups included in the WFWR road inventory

Inventoried "Road Groups"
Spot (no ditch)
Spot (with ditch)
Gravel (no ditch)
Gravel (with ditch)
Native (no ditch)
Native (with ditch)
Paved

In order to model the road segments using the WEPP: Road module, each randomly selected road segment had to be surveyed in detail. Figure 5-14 shows the input parameters required to run the WEPP: Road model. Extensive field measurements were made for each road segment. First, the selected road segment was divided into a "left" and a "right" side at the peak of the road crown. If the road did not have a crown, then it was not divided. The width of each side was measured and recorded. The length of the road segment was divided based on the road features where the water drained from the road surface. These features included, cross-drains, wing-ditches, stream crossings, and openings or "breaks" in the berms previously mentioned. Figure 5-15 illustrates a surveyed gravel road segment. For each side, the length between drainage features was determined using a range finder, and the slope was determined using an inclinometer. The width and slopes of road fill was measured and recorded. The width and slopes of buffer areas adjacent to the road system were determined using aerial photographs and DEM data. The data for each randomly

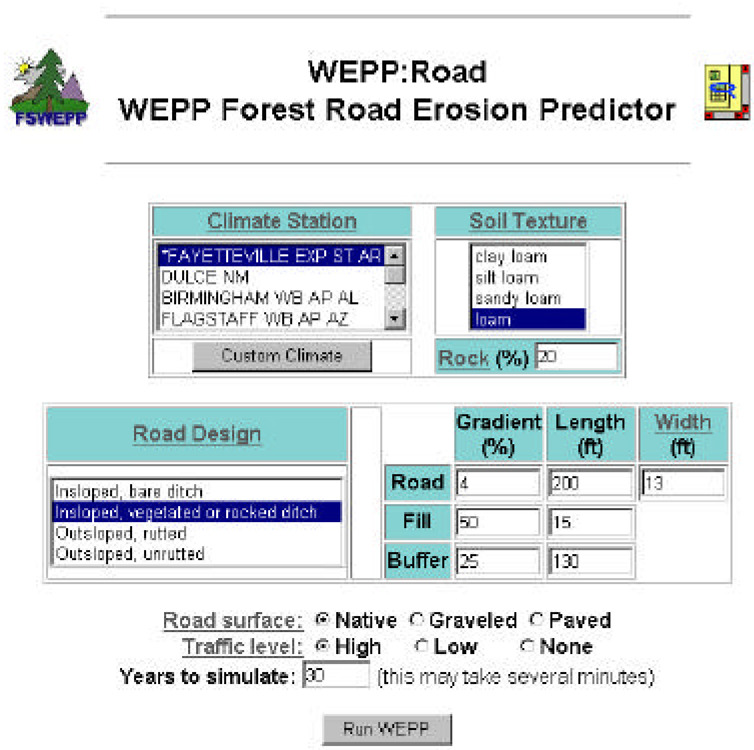

Figure 5-14 Input screen and input parameters for WEPP: Road web-based graphic user interface.

selected segment was recorded on a data collection sheet shown in Appendix 5-F. A model run was performed for each length between water diverting features for each side. An average export coefficient for each "road group" was estimated by averaging the sediment yield for each road segment modeled from that "road group." The average sediment export coefficient was then applied to all roads in the "road group" to determine total sediment loads.

Figure 5-15 Illustration of surveyed gravel road segment

Results: Based on the road inventory and the WEPP: Road modeling effort, sediment loadings to streams from roads in the WFWR were estimated and are shown in Table 5-9. The average sediment export coefficient (weighted by segments for each "road group") for unpaved roads in the WFWR watershed was 35.9 ton/mi/yr. The sediment export coefficients for native surfaced roads were 3.1 and 4.4 ton/mi/yr, which was low compared to the other "road groups," which ranged from 21 to 55 ton/mi/yr. Although 10% of the road segments were surveyed in detail, only three segments of the total were native. These three may not have been representative of native surface roads in the watershed. Roads having native surfaces were a very small percentage of the total unpaved roads; therefore, this has a negligible effect on the total sediment load estimate.

Methods and Results from Roadways not Inventoried: The sediment loads for other roadways not included in the inventory were determined. This included residential streets, secondary paved roads, unpaved driveways, and I-540. The lengths of these roads were determined using existing GIS road layer data. Using an assumed width of 30 feet and sediment export coefficient of 209 lbs/paved-acre/year (Schueler and Holland, 2000), the load was estimated to be 34 tons/yr for residential and secondary paved roads. Eroding ditches were not observed for residential and secondary paved roads. However, eroding ditches were observed in several locations along I-540; therefore, a coefficient developed by the U.S. Forest Service using WEPP on paved roads in the Boston Mountains (16 tons/mi/yr) was used to calculate sediment from I-540 (Clingingpeel, personnel communication, 2004). The load from I-540 was estimated to be 272 tons/yr. Also, a sediment load was estimated for un-paved private roads and driveways. The length of these roads was estimated based on existing GIS road layer data and the average unpaved road export coefficient, 35.9 ton/mi/yr, determined from the unpaved road survey.

Table 5-9 summarizes the estimated sediment loads for roads included in the non-urban inventory as well as the other roadways. Estimated sediment loads are accurate to ±50% at best (Elliot, 1999). The total load of sediment entering streams from roadways in the WFWR watershed was estimated to be 4,928 ton/yr with unpaved roads contributing an estimated 4,500 ton/yr or 91% of the total load and with paved roads contributing an estimated 428 ton/yr or 9% of the total load.

Table 5-9 Sediment export coefficients and estimated sediment loads to the WFWR from roadways.

Road Surface	Total Road Segments	Total Miles	Road Segments Surveyed	Miles Surveyed	Erosion Coefficient (ton/mi/yr)	Esimated Erosion (ton/yr)	Estimated Export Coefficient (ton/mi/yr)	Estimated Load to Stream (ton/yr)
Unpaved Roads								
Spot (no ditch)	19	6.6	2	0.3	28.1	185	25	164
Spot (with ditch)	153	41.8	17	4.0	73.8	3,088	55	2,307
Gravel (no ditch)	17	2.1	2	0.2	23.5	49	21	43
Gravel (with ditch)	147	38.7	16	5.0	70.2	2,716	28	1,064
Native (no ditch)	7	2.7	1	0.4	3.1	8	3.1	8
Native (with ditch)	13	3.3	2	0.2	11.4	38	4.4	15
Other Unpaved*		25.0					35.9	899
							Unpaved Total	**4,500**
Paved Roads								
Paved Highways	117	109.2	3	1.0	9.2	1,005	1.1	122
Other Paved*								
Secondary & Residential		90					0.38	34
I-540		17					16	272
							Paved Total	**428**
							Total	**4,928**

* These roads were not inventoried or modeled using WEPP. Export coefficients for these roads are based on published data.

5.1.3. Pasture

Soil erosion from pasture lands in the WFWR watershed were considered as a potential source of sediment. Pasture areas are susceptible to erosion because livestock traffic and farm equipment reduce infiltration and there is less ground cover than in a forested area. Surface water runoff carries the sediment from eroding soils to the WFWR.

Based on the 2000 land use delineated for this project, the WFWR watershed contains 19,413 acres (33 miles^2) of pasture land, with average slopes ranging from 0% to 38%. The States Soil Geographic (STATSGO) Database was used for modeling the pasture areas in the WFWR watershed. STATSGO is a very general soil layer digitized by the NRCS at a 1:250,000 scale. Full metadata is available in the *STATSGO Database; Data use information* (USDA, 1994). The STATSGO layer was chosen to simplify the modeling process. The NRCS generalized the soil types within the WFWR into three STATSGO soils: Enders, Linker, and Clarksville. Pasture slopes and soil types are shown in Figure 5-16. The detailed soils description for the WFWR watershed (Chapter 3) was not used for the hill slope model, due to time and data constraints.

5.1.3.1. WEPP Model

The Watershed Erosion Prediction Project (WEPP) model was used to estimate soil loss from pastures in the WFWR watershed. The WEPP model was developed by USDA to simulate sediment erosion and deposition from a landscape. WEPP can be used to model erosion from a single hill slope or a small watershed area. The hill slope model version was used in this project due to restrictions on the allowable area that can be used with the watershed version of WEPP. The WEPP model can estimate soil loss spatially (at a given point on the hill slope) and temporally (on a daily, monthly, or annual basis). The WEPP hill slope model is process-based, simulating rill and inter-rill erosion, sediment transport and deposition, infiltration, residue and canopy effects on soil detachment and infiltration, rill hydraulics, surface runoff, plant growth, residue decomposition, percolation, evaporation, transpiration, climate, and other processes. Detailed model documentation can currently be found at http://topsoil.nserl.purdue.edu/nserlweb/weppmain/docs/readme.htm (U.S.D.A., 1995).

Required inputs by the user for the hill slope model are; pasture management practices and slope profile (consisting of distance and slope between points on a hill slope and field width). Soil properties and climate station are also required, but WEPP has built-in databases for both. Assistance in developing this model for the WFWR pastures was provided by USDA-ARS (Meyer, personal communication, 2004).

The RUSLE model was considered as a possible tool to model sediment loss from pasture. The WEPP model was chosen over the RUSLE because WEPP provided more detailed soils database, had the climate station data that was closest to the WFWR watershed (Fayetteville Experiment Station), and had the option to specify field width. The RUSLE model also has a soil and climate database, however, soil properties are given by texture rather than soil name, and the closet available climate data was over 30 miles away in Fort Smith, AR. Sediment coefficients in RUSLE are given on a unit width basis.

5.1.3.2. Method

Applying the WEPP hill slope model to every pasture in the WFWR watershed would have been time consuming and tedious, and would not have, necessarily, yielded more accurate soil loss from pastures. Therefore, a method similar to the approach taken for estimating sediment loads from the roads within the WFWR watershed was used for pastures. The most sensitive input variables in the WEPP hill slope model are land management, slope, soils, and slope length. Since pastures in the WFWR watershed are managed similarly, a single management was chosen to represent all pastures. The average slope of each pasture was determined using DEM data. For screening purposes, a soil loss coefficient was calculated for a generic, square pasture for each slopes ranging from 1 to 30 at one unit intervals. The results showed that the soil loss coefficient increased proportionally to percent slope. Therefore, it was decided to group the pastures in the WFWR into categories based on average slope, number of acres of pasture, and soil type. Then, representative pasture(s) for each slope category (minimum of 10% of the total acres) were modeled and the estimated soil loss coefficient was applied to the entire pasture area for each slope category and soil type. For the WFWR watershed, landscape dimensions, such as slope length, were limited within the slope categories selected for the model. It was assumed, that average slope length for the pastures modeled represented typical values for each slope category and soil type.

As discussed, the WFWR pastures were separated into nine slope categories as shown in Table 5-10. Also, Table 5-10 shows the soil types, acres of pasture, and the number of acres modeled to represent the slope category - soil type for the WFWR pastures. The location and average slope of WFWR pastures can be seen in Figure 5-16. A minimum of 10% of the area in each

Table 5-10 Slope category, soils, and area of pastures in the WFWR watershed

Slope Category (Average Pasture Slope)	Soil Type	Area (ac)	No. of Acres Modeled	No. of WEPP Modeled Areas
0 - 2%	Enders	1372	181	9
2 - 4%	Enders	3291	265	7
	Linker	32	73	1
	Clarksville	207	70	8
4 - 6%	Enders	2960	374	3
	Linker	328	145	5
	Clarksville	200	54	5
6 - 8%	Enders	2273	59	6
	Linker	541	205	4
	Clarksville	154	33	3
8 - 10%	Enders	3235	292	12
	Linker	471	227	5
10 - 13%	Enders	2008	136	6
	Linker	87	76	4
13 - 16%	Enders	1507	435	5
	Linker	152	40	1
16 - 19%	Enders	397	129	1
	Linker	20	47	2
>19%	Enders	182	22	1
	Totals	19,413	2,863	88

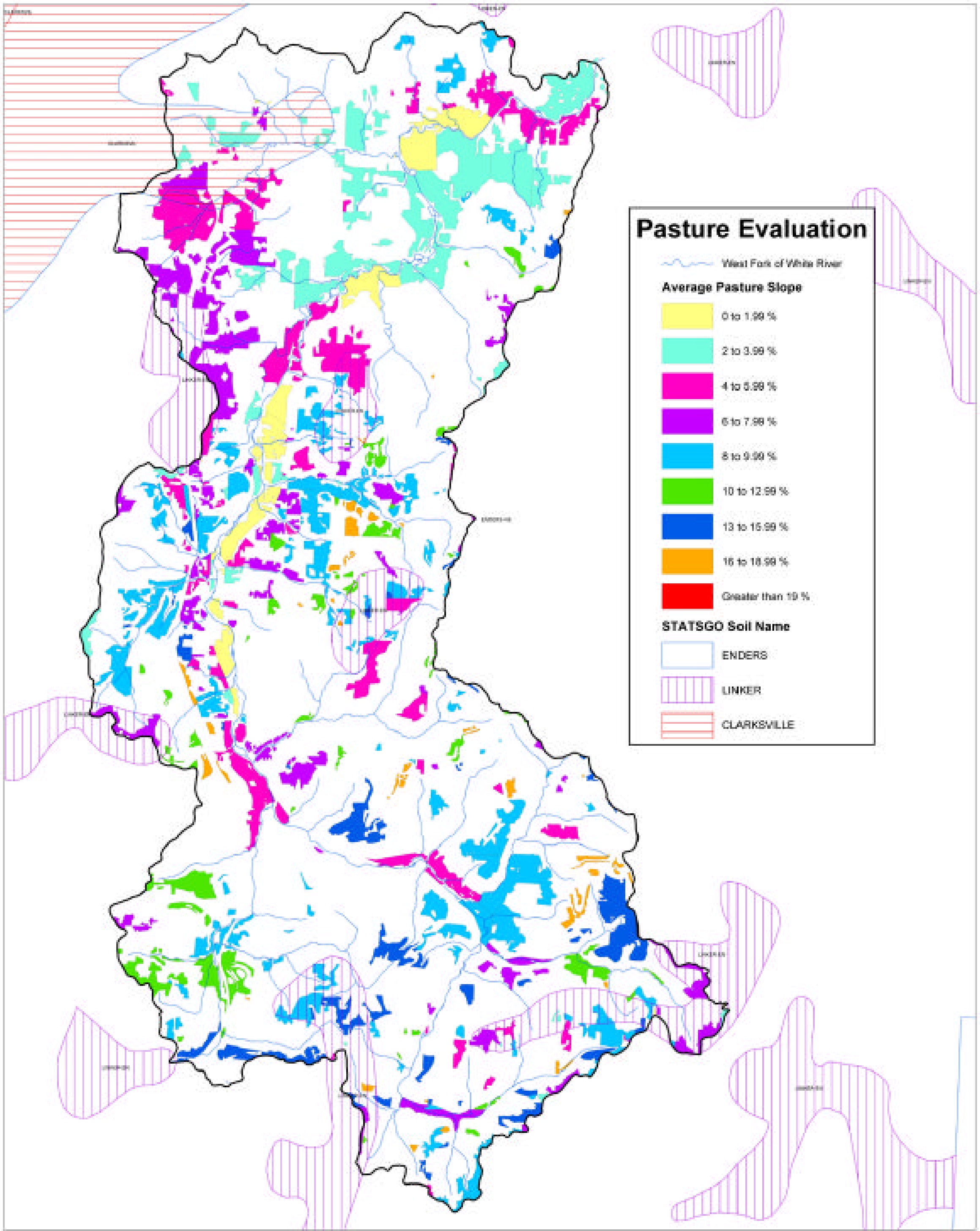

Figure 5-16 WFWR watershed slope-categorized pastures with soil types

slope category was modeled, and at least one model run was made for each soil type in the slope category (Table 5-10). A representative pasture was selected to be modeled from each slope category.

The selected pasture was divided into different flow areas based on the topography of the pasture. An example of a modeled pasture showing the different flow areas with corresponding flow paths is presented in Figure 5-17. This example shows one pasture with nine separate flow areas, which required nine WEPP model runs. Flow areas with similar slope lengths were combined into one model run, although they were spatially separated (note areas 5a and b, or 6a, b, and c, or 7a and b). Field width of the composite slope profiles was defined as the sum of the widths of each similar flow area. For example, the field width for area-5 slope profile was the sum of area 5a width and area 5b width. Combined flow areas always had the same soil type. ArcView was used with a DEM for the area to determine the change of elevation and distance between several points along the flow path. The field width and buffer lengths were also measured using ArcView. A slope profile (Figure 5-18) was developed in the WEPP model for each flow area in the pasture.

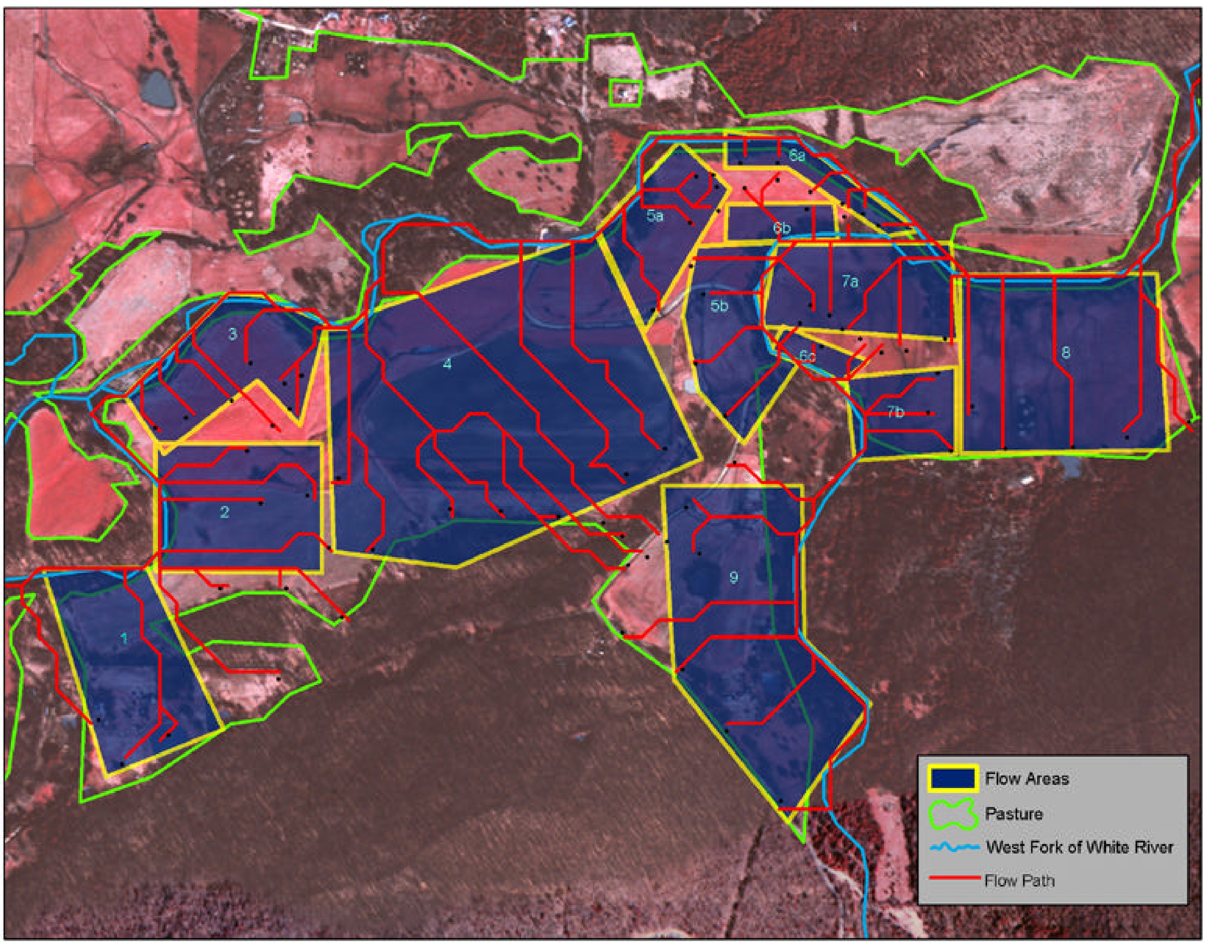

Figure 5-17 Example of WEPP modeled pasture showing flow paths and areas.

Weather data from the Fayetteville Experiment Station (included in the WEPP database) was selected to simulate climate for the model run. The WEPP soil database did not include two major soil types, Enders and Linker, in the watershed. The USDA ARS laboratory recommended that appropriate substitutes be used, a common practice in WEPP model applications (Meyer, personal communication, 2004). A substitute soil with similar physical and runoff characteristics was selected for the soils that were not represented in the WEPP soil database. Pastures having Enders soils were modeled using Tiak soil; Hartsells was used as the surrogate soil type for Linker (Laurent, personal communication, 2004). Clarksville soil properties were in the database. Landowners in the WFWR, generally, grow fescue for grazing, although Bermuda and other grasses are grown in warm months and is sometimes cut for hay. Pasture management is not a sensitive parameter in the WEPP model; therefore, pasture management was designated as "fescue with grazing". When buffers were present between pastures and receiving waters, they were included in the model simulation by inserting the measured flow path length of the area managed as forest after the pasture. Each model run simulated erosion on the hill slope for 30 years and resulted in an average annual soil loss rate and a sediment coefficient. Figure 5-18 shows a screen captured image of the WEPP model slope profile for flow area-3 for the pasture (Figure 5-17). Area-3 had a concave slope with 371 feet of pasture and 82 feet of forest buffer. The results summary of this run can be seen in the upper right hand box of the interface. Areas of erosion along the slope are shown in red, while areas of deposition are green.

As shown in the example, a single pasture could need several representative flow areas. In this case, the overall pasture soil loss was calculated by finding the area-weighted average of the individual flow area coefficients using equation 5.1.

$$X_{Pasture} = \frac{\left(X_1 A_1 + X_2 A_2 + \ldots + X_i A_i\right)}{\sum_i^1 A} \qquad (5.1)$$

Where X = Annual soil loss, from WEPP, for flow areas 1 - i $\left(\frac{tons}{acre}\right)$

A = Area of flow areas 1-i $(acre)$

This method resulted in an average annual soil loss for pastures of each soil in each slope category. However, the amount of sediment actually delivered to the WFWR is less due to further deposition and settling that occurs within the system. Roehl's work indicated that there is a relationship between the amount of soil loss and the amount of sediment delivered to the stream based on watershed characteristics in southeastern states (Roehl, 1962). According to this research, we can expect 7% of the soil loss to actually be delivered to the WFWR. The sediment load for each slope-soil category was calculated by first multiplying the soil loss by the total area of pasture with the same soil and slope conditions, then multiplying by 0.07 to estimate the amount of sediment delivered to WFWR from pastures.

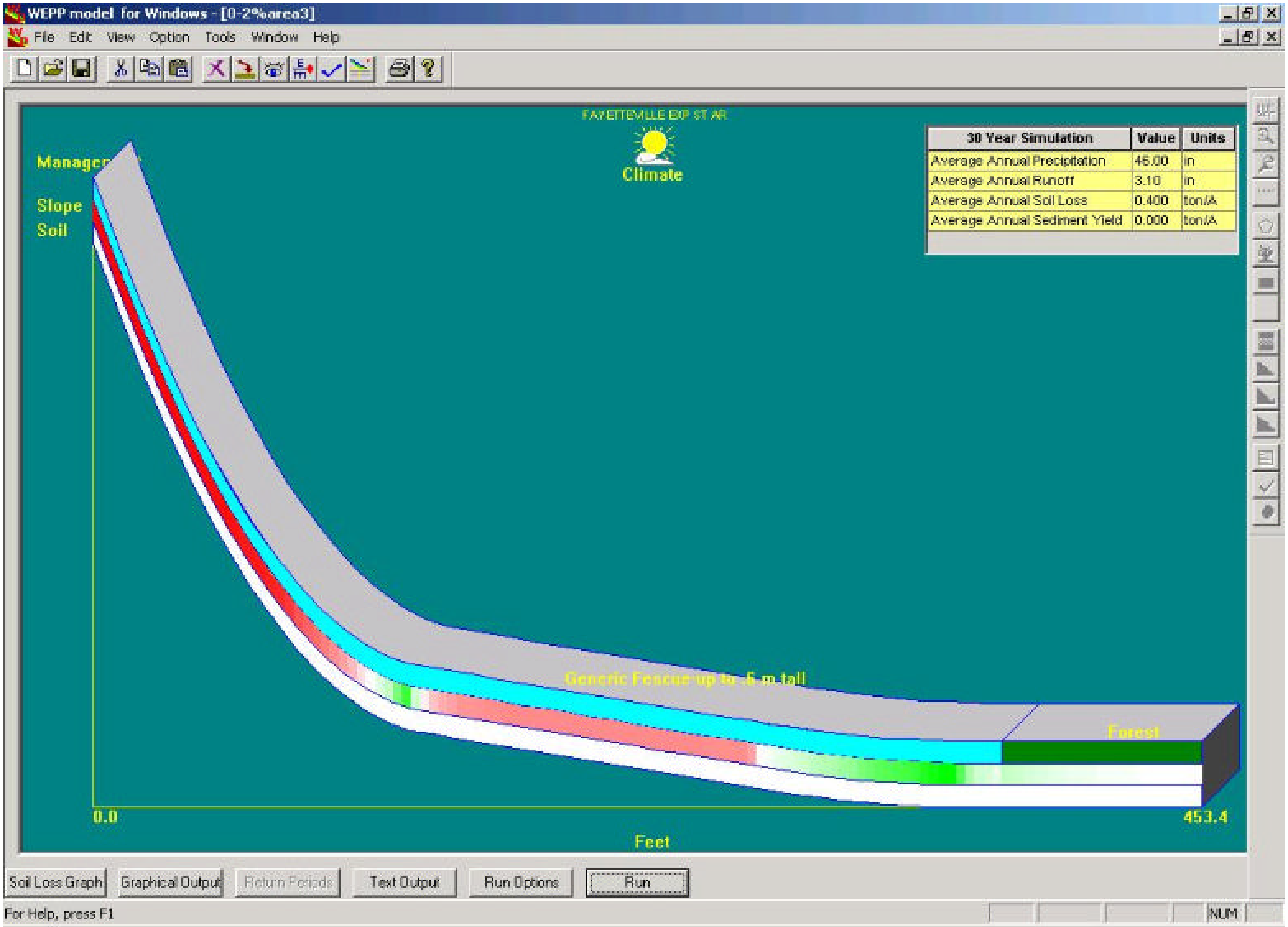

Figure 5-18 Example slope profile in WEPP model interface for Area 3 shown in Figure 5-17

5.1.3.3. Results and Discussion

A total of 23 pastures were modeled with 88 separate flow areas, which required 88 WEPP model runs. Detailed tables of model runs can be found in Appendix 5-G. Resulting soil loss coefficients and sediment loads for each slope category and soil type are shown in Table 5-11. The average area-weighted soil loss coefficient for the WFWR watershed was 1.3 tons/acre. Sediment loss rates ranged from 0.083 to 5.3 tons/acre/year. The five largest soil loss rates were associated with Enders soil on slopes from 8% to greater than 19%. The total soil loss for pasture areas of WFWR was estimated to be 24,408 tons/year. Applying Roehl's delivery ratio of 7% (Roehl, 1962) to the annual soil loss, the sediment delivered to the WFWR from pasture erosion was estimated to be 1,709 tons/year. The three largest contributors to the pasture sediment load are all on Enders soil; slope categories 13-15.99%, 10-12.99%, and 8-9.99% contribute 24.3%, 20.8%, and 20.5% of the total annual sediment load, respectively. These three slope categories with Enders soil make up only 35% of the total pasture area in the watershed, but they contribute 66% of the sediment load to the system from pastures. BMPs to reduce erosion on Enders pastures in these slope categories should be considered in order to reduce the overall sediment load to the WFWR.

Table 5-11 Sediment load for WFWR pastures by slope category and soil type using WEPP model results for soil loss and Roehl's findings.

Slope Class	Soil Type	Area (ac)	WEPP Soil Loss (ton/ac/yr)	Sediment Loss (tons)	Sediment Delivered to WFWR (tons)	% of Total Sediment Load
0 - 2%	Enders	1372	0.083	113	8	0.5%
2 - 4%	Enders	3291	0.25	742	52	3.0%
	Linker	32	0.20	6	0.5	0.0%
	Clarksville	207	0.47	97	7	0.4%
4 - 6%	Enders	2960	0.42	1,255	88	5.1%
	Linker	328	0.89	292	20	1.2%
	Clarksville	200	0.79	158	11	0.6%
6 - 8%	Enders	2273	0.99	2,144	150	8.8%
	Linker	541	0.27	145	10	0.6%
	Clarksville	154	0.88	135	9	0.6%
8 - 10%	Enders	3235	1.5	5,005	350	**20.5%**
	Linker	471	0.29	134	9	0.6%
10 - 13%	Enders	2008	2.5	5,082	356	**20.8%**
	Linker	87	0.29	25	2	0.1%
13 - 16%	Enders	1507	3.9	5,921	414	**24.3%**
	Linker	152	1.00	152	11	0.6%
16 - 19%	Enders	397	5.1	2,023	142	8.3%
	Linker	20	0.69	14	1	0.1%
>19%	Enders	182	5.3	963	67	3.9%
	Totals	19,413		24,408	1,709	100.0%

Dissmeyer and Stump predicted that the erosion rates or soil loss coefficients for grazing lands in the Boston Mountain Physiographic Region range from 0.04 to 88.7 tons/ac/yr with an average value of 5.2 ton/ac/yr (Dissmeyer and Stump, 1978). Work conducted by Roehl (Roehl, 1962) suggests that the actual sediment yield to streams from the work by Dissmeyer and Stump is approximately 7% of the predicted erosion rates. Using the average soil loss value of Dissmeyer for the Boston Mountains and applying Roehl's findings, the sediment delivery to the WFWR from pastures would be estimated at 7000 tons/year. This value is 4.1 times higher than the sediment load estimated for this study using the WEPP model.

A 1988 U.S. Army Corps of Engineers report published sediment yield coefficients for the Upper White River Basin's sub-watersheds (U.S. Army Corps of Engineers, 1998). The "Upper White River and Kings River" segment of the report was a 1,830 mi^2 sub-watershed that included the WFWR watershed. The annual soil loss coefficient for grassland is reported as 3.43 tons/year. Although the average slope of the grassland is not given, this coefficient would fall in between values for the WEPP model slope categories (Enders soils) of 10-13% and 13-16% of 2.5 and 3.9 tons/acre/year, respectively, of the WFWR pasture analysis.

The WEPP model calculations included determining a sediment yield coefficient. These coefficients were very similar to the soil loss coefficients. Because field data was not collected for buffers, but generalized based on DOQQs and based on the research performed by Roehl (Roehl, 1962), it was decided that these coefficients were too high with respect to sediment delivery to the stream.

5.1.4 Interstate 540

Construction on I-540 from Winslow to Fayetteville began in 1989 and opened for traffic on January 8, 1999. Dan Flowers, Director of the Arkansas State Highway and Transportation Department, said: "From an engineering standpoint, the 42-mile road between Alma and Fayetteville has been one of the most challenging projects ever undertaken by the Department. For example, bridges at five locations along the route are among the highest in the state."

Figure 5-19 Winn Creek Bridge south of the town of West Fork

Even though the construction phase of I-540 is complete, the interstate corridor remains a potential source of sediment. The straightening and channelization of natural drainage flow paths and the movement of entire hillsides, creating areas of steep and exposed soil, has created potential for erosion and an additional source of sediment that previously did not exist. Changes in hydrology due to increased impervious area and the rerouting of natural drainages has increased the potential for erosion of ditches and small creek channels and the development of gullies in areas of steep, exposed soil or fill material. The additional sediment generated as a result of the interstate and corridor was visually evident. For example, during the geomorphological survey of the stream, fans of sediment associated with fill materials from the interstate construction were observed at the mouth of tributaries and other small drainages in the WFWR. Steep hillslopes of exposed bedrock and soil and shorter drainage path lengths replaced natural features in the area impacted by the construction of the interstate. Potential sources of sediment from the interstate corridor associated with erosion processes include steep hillsides with erodible soils, mass wasting of hillslopes, the formation of gullies, erosion of ditches, and erosion of downstream channels. For this study, sediment generated by the formation of gullies associated with the corridor was evaluated. Sediment generated from erosion of ditches adjacent to the interstate was estimated in section 5.1.2. Sediment sources from mass wasting and erosion of slopes associated with the corridor were not estimated. Also, changes of impervious areas in the sub-watershed that are affected by the interstate corridor was evaluated.

5.1.4.1 Land Cover Changes in Sub-watersheds

The building of I-540 resulted in land cover change for the WFWR watershed. The changes are especially evident when viewed at the sub-watershed scale. When evaluating the entire watershed, the environmental impact from the construction of I-540 may appear small,

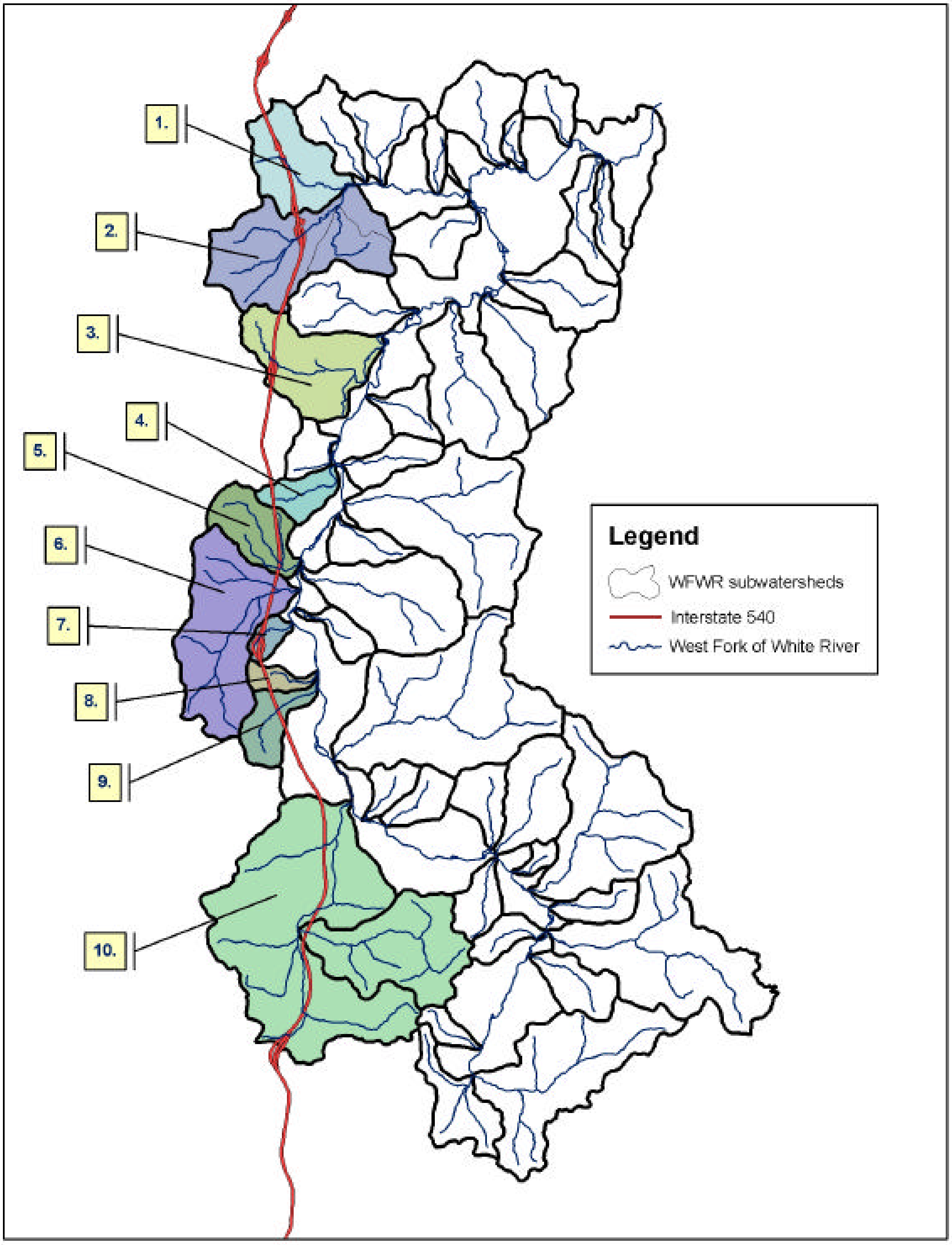

Figure 5-20 Sub-watersheds of the WFWR watershed affected by I-540

considering the interstate and its corridor are less than 1% of the total watershed area. But, the smaller sub-watersheds that now drain the interstate underwent considerable change, and some of those changes will be presented in this section.

Sub-watersheds of the WFWR were delineated using contour lines and DEMs of the area. The sub-watersheds that were affected by I-540 are shown in Figure 5-20. Prior to the construction of I-540, the land use in most of these watersheds was forest and agriculture. The percent forest lost and the percent increase in impervious area was estimated, and the values are shown in Table 5-12. The percent forest loss was estimated by comparing 1994 aerial photographs to the 2000 DOQQs. The width of the impervious area of I-540 was estimated to have a total width of 110 feet (33.5 m) and included the paved interstate, its shoulders, and concrete drainage ditches. The length of the paved area was measured using ArcView, and included clovers. Both forest loss and increased impervious area can have an impact on the flow regime and the natural biological systems of the WFWR (Schueler and Holland, 2000). Also, traveling along I-540 between Fayetteville and the I-540 exit to Winslow, it appears that a considerable amount of the natural drainage system had to be rerouted to concrete ditches or other drainage structures. In nearly all cases, stormwater runoff from I-540 is discharged to small streams. The increased runoff from the impervious and altered landscape of the I-540 corridor results in increased erosion of these small channels.

Table 5-12 Changes in land cover in watersheds affected by I-540

Sub-watershed No.	Sub-watershed area (ac)	I-540 corid. Area (ac)	% area affected	I-540 pavement length (m)	I-540 paved Area (ac)	Increase of subwatershed impervious area (%)
1	1486	100	6.7%	3042	25.2	1.7%
2	2945	102	3.5%	3041	25.2	0.9%
3	1986	114	5.7%	4024	33.3	1.7%
4	557	19	3.3%	656	5.4	1.0%
5	1041	53	5.1%	1958	16.2	1.6%
6	2999	38	1.3%	1365	11.3	0.4%
7	257	81	31.7%	3209	26.6	10.4%
8	285	27	9.4%	772	6.4	2.2%
9	715	57	7.9%	1151	9.5	1.3%
10	9238	260	2.8%	8424	69.7	0.8%

5.1.4.2 Sediment Load Estimate for Gullies

Gullies that have formed along the I-540 corridor can be easily observed when traveling between Fayetteville and Winslow. These gullies have formed in areas where streams and stormwater have been redirected and where excess cut materials have been disposed of creating large areas of steep and erodible slopes. These gullies are a source of sediment to the WFWR watershed that was accounted for in the watershed assessment.

Method: A survey was conducted on April 27-29, 2004 to evaluate gully erosion along the I-540 corridor in the WFWR watershed. The section of interstate evaluated was from mile marker 45 at the Winslow exit to mile marker 62 at the HWY 62 Fayetteville exit. The majority of the drainage for this section of I-540 is to the WFWR, with a small section south of Greenland draining to the Illinois River. The southern half of the corridor is steep and rugged in many places as it leaves the Boston Mountains heading towards Fayetteville. The soils in this area are predominately of the Enders-Allegheny-Hector association. The Washington County Soil Survey lists the erosion hazard of this association as very severe (USDA, 1969). Due to the steep slopes and highly erodable soils in this section, the potential for excessive soil erosion is high.

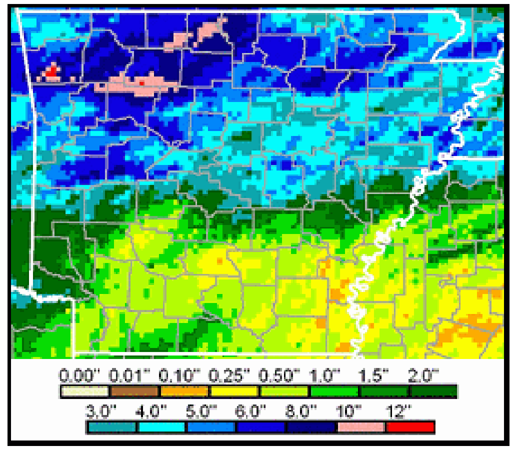

Figure 5-21 Seven day estimated rainfall total ending April 24, 2003

Identification of the potential erosion areas were primarily made from observations from the interstate. Other areas were identified using aerial photography and also by hiking to places obscured from view. Eroding gullies were identified and physical measurements were taken to evaluate soil loss and the slope of the area. Slope measurements were taken with a hand-held, line-of-sight inclinometer. The width and depth of the gullies were measured with a measuring tape, and the length was measured using a laser range finder. The length and width of the eroding slopes and slides were also measured using a laser range finder. Pictures of the eroding areas were taken and their locations were recorded on a map.


Figure 5-22 Example of a gully having a rectangular channel shape

Results: According to the National Weather Service, Washington County had received a large amount of rainfall the week before the survey was conducted as shown in Figure 21. The five day rainfall total for Fayetteville at Drake Field was 9.66 inches, ending on April 24, 2004. The twenty four hour rainfall total on April 24th was 3.01 inches and the West Fork of the White River at Greenland had a greater than fifty year flood event the same day. This record rainfall event may have resulted some significant erosion; however, project staff have observed gullies along I-540 throughout the entire project period.


Figure 5-23 Example of a gully having a triangular channel shape

Gullies less than 3 inches in depth and width were not measured due to time constraints and their relatively low contribution when compared to larger gullies. Soil losses from gullies greater than 3 inches deep were calculated by determining the approximate volume of the gully. Volume was estimated by multiplying the

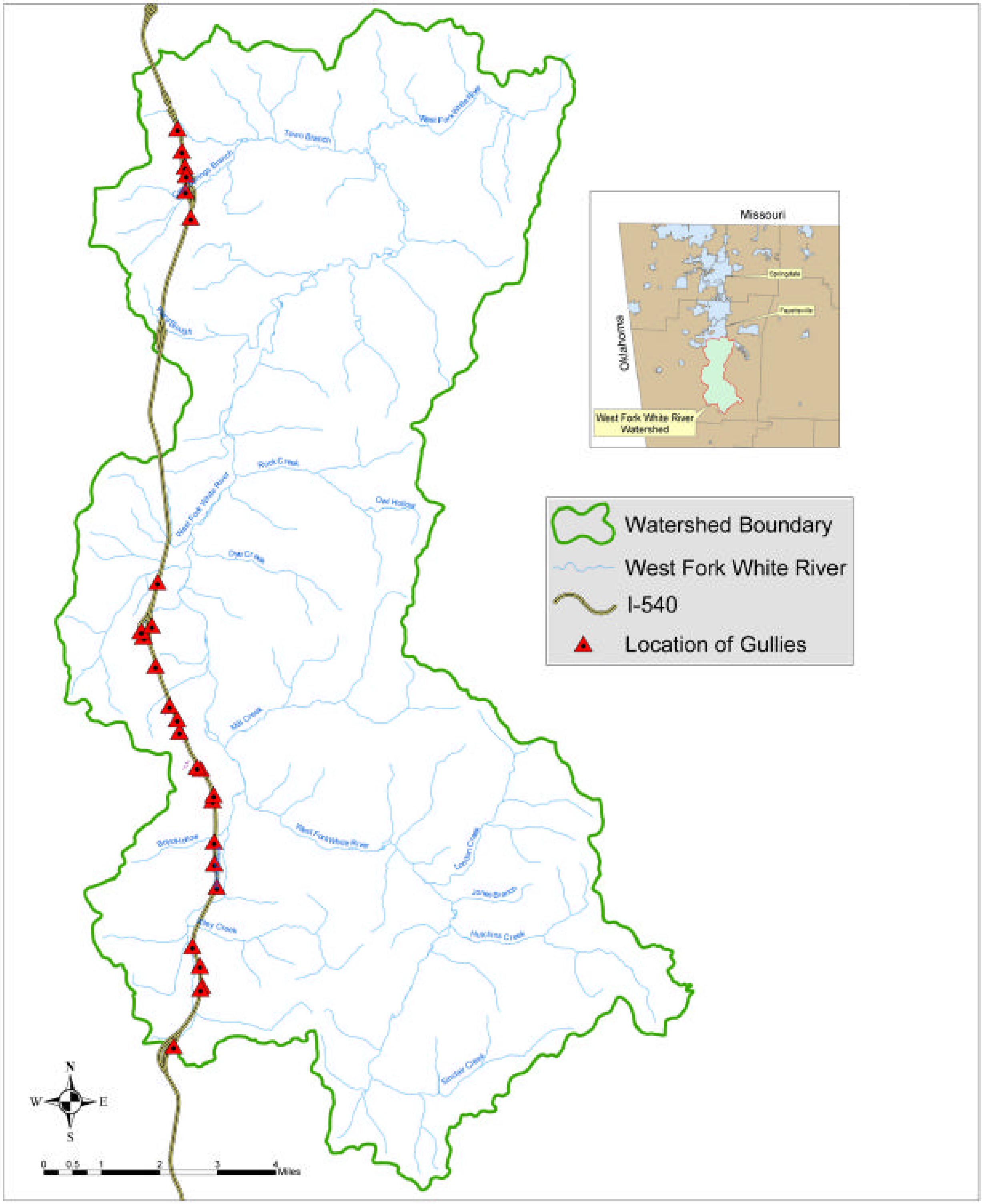

Figure 5-24 Location of measured gullies formed by stormwater runoff from I-540 in the WFWR watershed

cross sectional area by the length. Cross sectional area was determined by identifying the shape of the gully channel from its picture as either rectangular (Figure 5-22) or triangular (Figure 5-23) for each gully. Gully measurements and their corresponding volumes are shown in Table 5-13.

The locations of gullies identified during the inventory can be found on Figure 5-24. The total measured gully volume in the I-540 corridor located inside the WFWR watershed was 130,248 cubic feet. The sediment load from gullies was then estimated using the bulk density of Enders soils of 1.49 g/cm^3 or 92.8 lbs/ft^3. The total sediment yield from the gullies was estimated to be 6040 tons. This number was then divided by the number of years that had passed since I-540 had opened, which was five years. The average annual sediment loads from gullies was estimated to be 1,210 tons/year. This value would include all particle sizes from fine material to cobble. Using the stream bank material characterization results for course materials, approximately 20 % of this material would be less equal to or less than 2 mm (Section 5.1.1), Applying this value to the average sediment yield, an average of 242 tons/year of sediment equal to or less than 2 mm in size would come from gullies. Also, this value is conservative, because portions of the interstate were completed before the final opening date; therefore, some of the gully erosion could have started before the opening date.

Table 5-13: Gully measurements and volume calculations

Gully Measurements Results Summary							
Location	Length (ft)	Depth (ft)	Width (ft)	Slope (%)	Name	Channel Shape	Volume (ft^3)
1	75	3	3	57	Gully 1	Rectangle	675
2	120	2	2	11	Gully 1	Rectangle	480
3	120	3	2	25	Gully 1	Rectangle	720
3	84	2	1	18	Gully 2	Triangle	84
4	35	2	2	36	Gully 1	Rectangle	140
5	40	2	2	40	Gully 1	Rectangle	160
5	240	12	20	55	Gully 2	Rectangle	57600
6	10	1	3	55	Gully 1	Rectangle	30
6	40	1	2	30	Gully 2	Rectangle	80
7	110	1	1	5	Ditch 1	Rectangle	110
7	50	4	10	20	Gully 1	Rectangle	2000
7	210	1	2	36	Gully 3	Triangle	210
7	75	1	1	34	Gully 4	Rectangle	75
7	35	1	1	25	Gully 5	Rectangle	35
7	20	3	4	22	Gullly 2	Rectangle	240
8	150	10	10	30	Gully 1	Rectangle	15000
9	30	4	5	18	Gully 1	Triangle	300
9	10	5	4	17	Gully 2	Triangle	100
9	90	2	2	27	Gully 3	Triangle	180
10	45	4	5	42	Gully 1	Triangle	450
11	110	2	6	33	Gully 1	Triangle	660
12	100	2	3	32	Gully 1	Triangle	300
12	190	8	20	30	Gully 2	Triangle	15200
12	50	5	8	32	Gully 3	Triangle	1000
12	265	3	3	36	Gully 4	Triangle	1193
12	40	4	5	28	Gully 5	Triangle	400
12	60	1	1	38	Gully 6	Triangle	30
12	110	1	2	40	Gully 7	Triangle	110
12	50	2	3	35	Gully 8	Triangle	150
13	220	1	3	3	Ditch 1	Rectangle	660
13	140	1	2	30	Gulley 1	Triangle	140
13	130	2	2	28	Gully 2	Rectangle	520
13	90	3	3	27	Gully 3	Rectangle	810
13	20	2	5	35	Gully 4	Rectangle	200
13	120	1	2	50	Gully 5	Rectangle	240
13	65	1	3	52	Gully 6	Rectangle	195
15	150	5	6	35	Gully 1	Triangle	2250
15	75	5	15	30	Gully 2	Triangle	2813
15	150	4	20	40	Gully 3	Rectangle	12000
15	75	3	6	45	Gully 4	Rectangle	1350
15	63	4	8	50	Gully 5	Triangle	1008
16	75	1	1	20	Gully 1	Triangle	38
16	96	10	5	40	Gully 2	Triangle	2400
17	75	1	2	55	Gully 1	Triangle	75
18	40	2	1	50	Gully 1	Rectangle	80
18	20	1	8	50	Gully 2	Rectangle	160
20	250	3	1	2	Ditch 1	Rectangle	750
21	300	2	2	5	Ditch 1	Triangle	600
22	120	6	8	29	Gully 1	Triangle	2880
22	115	5	8	28	Gully 2	Triangle	2300
23	60	4	4	37	Gully 1	Triangle	480
26	147	4	2	3	Ditch 1	Triangle	588

5.1.5. Urban and Construction

Activities in the urban environment can contribute to the overall sediment loads found in the WFWR. Suspended sediment from urban areas can come from a variety of sources including streets, lawns, landscaping, driveways, construction, atmospheric deposition, and erosion of drainage channels (USEPA, 1999). Sediment from streets and roads within the urban areas of the WFWR watershed was accounted for in section 5.1.1.2. Sediment from construction and the remaining sediment loads from urban areas were estimated separately.

Figure 5-25 Urban sources of sediment include construction sites, lawns and parking lots

Urban without Construction: Sediment from urban areas, resulting from activities unrelated to construction, was estimated using data from the U.S. EPA Urban Stormwater BMP study (USEPA, 1999). The EPA coefficients, shown in parenthesis, represent typical sediment loads from various urban land uses including low and medium density residential (190 lb/ac), commercial (1000 lb/ac), industrial (860 lb/ac), and construction areas. Using the land-use data from the WFWR land-use evaluation and coefficients presented in the EPA study, the load of sediment from urban areas excluding construction was estimated to be approximately 1,104 tons per year.

Construction: Land disturbance from urban construction sites and other disturbed areas contribute to the overall sediment load to the WFWR (Figure 5-26). Construction activities were primarily located within the northern part of the watershed, around the city of Fayetteville. All construction sites one acre or more in size require a permit from the NPDES Storm Water section of ADEQ Water Division. Sites under five acres receive a general permit, but are not tracked by the agency. Sites greater than five acres must develop a site management plan and are issued a permit and tracked through ADEQ Water Division. Developers must submit a Notice of Intent at least two weeks prior to beginning construction and a Notice of Termination when construction is at least 75% complete. A search of active permits determined there were twelve ADEQ permitted construction sites in the WFWR watershed. The construction sites ranged from 5 to 40.5 acres with a total area of 174 acres. The total area of sites less than 5 acres could not be determined from permit records; therefore, the number of acres for sites less than five acres was estimated. Comparison of the 1994 and 2000 land use, delineated for this project showed an urban increase of 1700 acres over the 6 year period, or an average of 283 acres of construction for each year. The difference between the average total construction area and the area of ADEQ tracked/permitted sites (109 acres) was assumed to be construction sites less than 5 acres.

Water quality data was collected by Edwards et al. from construction sites to determine the effectiveness of BMPs being implemented (Edwards, 2003). Average TSS values ranged from 637 mg/L to 11,217 mg/L depending on the practice being implemented (Table 5-14). Other studies show similar concentrations of 365 mg/L and 680 mg/L, where effective BMPs have been installed at construction sites (Schueler and Holland, 2000).

Table 5-14 Average TSS results of water samples collected at construction sites (Edwards, et al, 2000).

Practice	TSS concentration (mg/L)	BMP Effectiveness
None: Bare Earth/Control Site	11,217	0%
Silt Fence	9,060	19%
Straw Waddle	8,212	27%
Straw Mulch	637	94%

Project lengths vary, but can be estimated based on the size of construction area. One to five acre construction sites are typically completed in 6 months or less. Areas from five to ten acres and greater than ten acres are typically completed in 1 year and up to 2 years, respectively (Fuller, Personal Communication, 2004). Therefore, it was assumed the average project length for the 109 acres of small sites was 6 months and the average project length for the 174 acres of larger sites was one year.

Sediment loads were estimated for two scenarios: 1) Sites with no BMPs and 2) Sites with adequate control measures. The rainfall to runoff conversion rates for construction sites was assumed to be 20%. The average rainfall for Fayetteville is approximately 46 inches per year. This would result in an estimated 9.2 inches of runoff from the construction sites. Using the average TSS concentration of 11,217 mg/L, the estimated load from construction sites without BMPs is 2,787 ton/yr. It is important to note that during Edwards' study, gullies did not form on the constructions sites where measurements were taken. If gullies do form on construction sites, the sediment loading can increase significantly. Sediment loads were also estimated assuming that BMPs are installed at the sites. Using Edwards' TSS value of 637 mg/L, the sediment loading from construction and disturbed sites can be reduced to 158 tons per year.

Figure 5-26 Construction site without proper BMPs in place to reduce sediment runoff.

5.1.6. Forest Land and Associated Harvest

Forested lands and associated harvesting of forest in the WFWR watershed were considered as a potential source of sediment. The WFWR land use delineated from 2000 DOQQs was used for this sediment load estimation. The land use analysis, presented in chapter 3, showed the watershed was 58.5% forest (Figure 5-27), and the total annual sediment yield from standing forest was estimated. In 2003, there was over 23.5 million tons of timber harvested in Arkansas. There were 34,505 tons of timber harvested in Washington County (14,272 tons of pine and 20,233 tons of hardwoods) (Levins, Personal communication, June 7, 2004), so conversion lands were also considered as potential sediment source.

Figure 5-27 A large portion (59%) of the WFWR is forested. These forested areas contribute a small amount to the overall sediment load in the river

The erosion rate for a natural forest is 0.12 ton/acre/year (Dissmeyer and Stump, 1978). Using Roehl (1962) findings for sediment delivery, estimated sediment yields would be approximately, 0.008 tons/acre/yr. The watershed consisted of 46,539 acres of forest, resulting in a sediment load of 370 tons/year. The erosion coefficients for logged forest land for the Boston Mountains ranged from 0.15 to 15.8 tons/acre/year with an average value of 1.08 tons/acre/year (Dissmeyer and Stump, 1978). A land use comparison from 1994 to 2000 showed 659 acres of forest was converted to other land uses during the six year period, or about 110 acres/year. The average coefficient for timber harvest activities in the Boston Mountains from Dissmeyer and Stump (1964) and Roehl's (1964) sediment delivery estimate of 7% were used to estimate the sediment load for forested areas that were converted to other land uses. This resulting in approximately 6 tons of sediment per year from harvested forest. The overall annual sediment load from standing forest land and forest conversion was estimated to be 376 tons.

5.1.7. Sediment Loads from Permitted Facilities

Two NPDES permitted facilities in the WFWR watershed are required to monitor for total suspended sediment (TSS) in the waste water discharged from the facilities to the WFWR (See Chapter 3). Using the reported permitted data from each facility, annual loadings of TSS were estimated. For the McClinton-Anchor West Fork quarry, the mean-maximum TSS concentration, calculated from the DMR, is 9.04 mg/L. No quarterly averages for TSS were available on the EPA Permit Compliance System website. The mean average flow value was 0.541 MGD. Using these two numbers to calculate an annual load gives an absolute maximum of 7.5 tons/year of TSS, with the actual number probably being considerably less. For the WFWR-WWTP, an average annual TSS load was estimated to be 0.5 tons per year based upon 10 years of DMR data (see Section 5.2). The total TSS load from permitted facilities is estimated to be 8.0 tons/year.

5.1.8 Sediment Loads to the WFWR: Priority Areas, Recommendations, Reductions, and Management Implications

The estimated sediment loads for identified potential sediment sources associated with various land uses are presented in Table 5-15a. ***Once again, the project team wants to make the point that these values are estimates and are for planning purposes only. As more data, methods, and information become available, these values should be updated.*** The loads presented in the fourth column of the table represent the mass loads for particles less than 2 mm in size that are delivered to the stream system. Sediment loads from natural erosion processes were estimated and are also shown in Table 5-15a. For pastures and urban areas, it was assumed that the sediment load from naturally occurring erosion would be represented by forested land, and the coefficients described in Section 5.1.6 were used to estimate the values. The calculation of natural erosion and the subsequent sediment load from inventoried streambanks is described in section 5.1.1.4.

Table 5-15a Estimated annual sediment loads for identified sources in the WFWR watershed

Land Use	Affected Area	Annual Sediment Load from Natural Erosion (Ton)	Annual Sediment Load for each Sub-Category (Tons) Total	=2 mm	Total Annual Sediment Load (Tons) = 2mm
Pasture:	19,413 ac.	**155**	**1,709**	**1,709**	**1,709**
Forest: • Harvested	46,539 ac. 110 ac.	**391**	**391** **8**	**391** **8**	**391**
Urban • Construction	9,710 ac. 283 ac.	**78**	**1,104** **2,787**	**1,104** **2,787**	**3,891**
NPDES Permits: • WF-WWTP • WF Quarry		**N/A**	**0.5** **7.5**	**0.5** **7.5**	**8**
Roadways & Ditches: • Unpaved (gravel, spot, native) • Paved highways • Residential • I-540 • Gullies from I-540	**Miles** 120 109 90 17 1.0	*****	**4,500** **122** **34** **272** **1,210**	**4,500** **122** **34** **272** **240**	**5,168**
Streambank Erosion Causes - riparian removal, channel alteration (gravel mining, etc), increase runoff (change in Q)	**Miles** Main Branch 7.5 Tributaries 3.1	**815****	**18,532** **5,118**	**12,375** **3,016**	**15,391**

* Erosion from natural processes is accounted for under pastures, urban, and forest.

** Calculated in Section 5.1.1.4.

The information in Table 5-15a can be used to assist in the watershed planning process. But, it is important to understand that the magnitude of the estimated loads does not always reflect its impact to the environment. Loads from some sources may appear to be relatively small compared to the entire watershed; however, the small sediment loads generated in small sub-watersheds could have a significant local impact on water quality and habitat. Also, the timing of when a sediment source enters the system can determine the extent of its impact to the biological system. For, example, streambank erosion is contributing over 3 times the amount of sediment than roadways and ditches. But these two sources enter the WFWR system at different times. Sediment from roadways & ditches moves easily during most rain events that produce runoff; therefore, it is entering the system even during the lower flow events. On the contrary, the bulk of the sediment from streambank erosion enters into the system during the high flow events. Though both are sediment sources, how they impact to the system can be different and difficult to define. Therefore, when developing solutions based on estimated loads, it is important to look beyond the numbers and consider the impact the sources and causes are having on the water quality and biological systems.

When developing solutions to address sediment loads, it is also important to recognize that sediment reductions will not always result in turbidity reductions. Data collected from Nelson, et. al. indicates that there is a correlation between TSS and turbidity, but this data is not specific to "sources of sediment." Further studies would need to be performed to understand the relationship between sediment sources and in-stream turbidity values.

Another factor that should be considered when developing solutions during the watershed planning process is determining the ease of implementation. Ease of implementation is directly related to 1) size of affected area; 2) number of landowners involved; 3) cost of implementation; and 4) practicality of the practice. Most solutions involve changing affected people's behavior; therefore, solutions have to make sense, be practical, and be cost effective.

For each land use outlined in Table 5-15a, potential BMPs, priority areas, implementation and/or restoration recommendations for sediment reduction, expected reductions, and management implications are discussed below. The values of sediment loads and percentages are all based on the results of this study as summarized in Table 5-15b. It was the beyond the scope of this study to develop a complete BMP/restoration plan for the WFWR watershed. The recommendations outlined below are to give some ideas and direction to the reader on what can be done to help reduce sediment runoff for the sources evaluated.

Table 5-15b Sediment loads and relative percentages

Land Use	Annual Sediment Load for each Subcategory (tons)		Percent of total estimated Sediment Load		Total % for Land use
	Total	=2mm	=2mm	>2mm	
Pasture	1,709	1,709	4.8%	n/a	4.8%
Forest	391	391	1.1%	n/a	1.1%
* Harvested	8	8			
Urban	1,104	1,104	10.9%	n/a	10.9%
* Construction	2,787	2,787			
NPDES Permits			0.02%	n/a	0.02%
* WF-WWTP	0.5	0.5			
* WF Quarry	7.5	7.5			
Roadways & Ditches			14.4%	2.7%	17.1%
* Unpaved (gravel, spot, native)	4,500	4,500			
* Paved highways	122	122			
* Residential	34	34			
* I - 540	272	272			
* Gullies from I - 540	1,210	240			
Sreambank Erosion			43.0%	23.1%	66.1%
* Main Branch	18,532	12,375			
* Tributaries	5,118	3,016			

Pasture

The sediment load estimate for pasture in the WFWR watershed was 1,709 tons/year coming from the 19,417 acres of pasture in the watershed. The cause of sediment loads from pastures is rill and sheet erosion of pasture soils. Higher erodibility of soils and steep slopes will generate greater sediment loads from erosion of pastures. The sediment from erosion of pastures can be compounded when permanent feeding areas during the winter months are created for cattle. Manure and cattle hoof shear destroy the forage, expose the bare ground, and create an additional source of sediment.

- **Priority Areas:** Pastures with Enders soils and an average slope of 8% or greater comprised, approximately, 78% of the estimated pasture sediment load. These pastures comprise only 38% of the total pasture area. Because of the high erodability of the Enders soils and the steep slopes; the high ratio of sediment load to affected area; and the reduction of landowners needing to be involved these pastures should be given high priority for implementation of conservation BMPs.
- **Recommended BMPs:** To reduce sediment from pastures the following BMPs could be considered for implementation: Pasture renovation during the Spring or Fall seasons to increase the soil infiltration rate; vegetative filters of 50 feet or more near drainage areas; rotational grazing; alternative watering sources, such as, movable containers; shrub buffers

or grass buffers with a fence; and planting both cool and warm season forage to promote growth all year.

- **Expected Reduction:** Depending on the practice, expected sediment reductions range from 30% to 74% (U.S. EPA, 2003) and (ADEQ, 2004). If one or more of these practices are implemented within the critical areas and taking an average of the percent reduction range, the expected reduction in sediment delivery to the stream is approximately 52 %.
- **Management Implications:** Improvement in pasture management to reduce sediment will also help to reduce nutrient runoff and improve wildlife habitat. For example, rotational grazing and alternative watering sources not only promote healthy forage which will reduce sediment runoff, but it helps to distribute cattle manure over the entire pasture which will reduce destruction of forage and subsequent soil disturbance associated with loafing areas. Creating riparian buffers along drainages and the stream not only filters sediment and nutrients, but it creates habitat for both terrestrial and aquatic life. Riparian buffers go beyond BMP implementation and actually contribute to the restoration process. Another factor that should be considered regarding improved pasture management is the number of landowners that would be involved to address the source. Well over a hundred landowners would be involved and working with this number of landowners to change current or add new management practices presents a challenge to reducing sediment from pastures.

Forest

The forests in the WFWR watershed comprise approximately 58.5% of the total watershed area. Most of the forest in the watershed remains undisturbed and the load shown in Table 5-15, is the background level of sediment that would result from natural erosion processes. The coefficient is 0.008 tons/acre/year. If the watershed was completely forested, this is the natural erosion or the background level that would be expected for sediment.

- **Priority Areas:** Forests do not need to be targeted for BMPs to reduce sediment. But, forest may be harvested for its lumber or it could be cut for the development of a building site. The clearing of forest for development purposes will be discussed under urban/construction. All sites that are harvested for lumber should be done so with care, but again the sites with Enders soils and slopes of 8% or greater should be given priority.
- **Recommended BMPs:** It is recommended for any silviculture activities in the WFWR watershed, that BMPs be implemented that follow the AFC's guidelines (AFC, 2002).
- **Management Implications:** The estimate for harvested forest contributed a very small percentage to the total sediment load, but it can have a significant local impact to the area where the cut takes place. A landowner downstream of a forest cut without BMPs on a steep slope can loose the clarity of his pond and stream. Also, these types of cuts are an eyesore for watershed residents and visitors. Harvesting trees in an environmentally sensitive manner can minimize the impact on habitat and water quality and help to retain the monetary value of the landowner's property.

Urban and Construction

Urban land use in the watershed was 12.2% of the total area and the total sediment load, excluding roads, was estimated to be 3,891 tons/year. This was the third highest estimated annual load of sediment being delivered to the WFWR. The estimated sediment load for construction activity was 72% of the total estimated load from urban areas (without roads). On a per acre basis, it was estimated that construction sites without BMPs are contributing 9.9 tons/acre of sediment, annually. Forest and pasture land uses were estimated to contribute 0.02 tons/acre and 0.09 tons/acre, respectively.

- **Priority Areas:** On a per acre basis, sediment contributions from construction sites without BMPs are, approximately, 100 and 1000 times greater than pasture and forest land uses, respectively. Therefore, all construction sites should be made a priority for BMP implementation. Also, they should be made a priority because developers and builders are required by federal and state regulations to implement BMPs to reduce sediment during the construction activities.
- **Recommended BMPs:** Edwards, et al. found a 94% reduction in sediment concentrations in stormwater runoff by using straw mulch at construction sites; therefore, this practice should be included in the BMP implementation plan for construction sites. Also, it is recommended that developers and builders minimize the trees and other vegetation they remove and incorporate as many of the natural features as possible into the site design, including the minimization of soil disturbance and the importing of materials. Construction activities at large sites should be phased to reduce the amount of exposed soils. All of these activities will help to minimize the exposure of soils and destruction of habitat. Trees that have to be cut should be used for lumber, fiber, or firewood instead of burned, which creates unnecessary air pollutants. Also, using materials and designs that reduce the percent impervious area created at a development site is recommended.
- **Expected Reduction:** Data shows that with proper BMP implementation at construction sites, the sediment load from these sites can be reduced by as much as 94%.
- **Management Implications:** Environmentally sensitive development methods can result in increased property values for developers and builders as well as support local environmental stewardship. Developing land without BMPs may be one of the most drastic means of changing land use in a watershed that result in destruction of habitat, exposure of erodible material, and reduced infiltration rates at the sites. First, construction sites, generally, are next to storm water diversions that lead to our streams; therefore, there is little buffer to filter sediment or other contaminants from these sites. Second, the land use of the sites being developed are typically forest, transition, or pasture, which on a per acre basis, generates much less sediment when compared to construction sites or even the final land use. Also, the original land use, especially forest, are providing habitat to wildlife that is lost during construction. It is not uncommon, either, that during construction, small headwater streams, channelized, hardened, routed through concrete pipes, or filled-in. This results in changes in downstream hydrology, such as higher flows and more frequent flood events, as stormwater is delivered more rapidly to receiving streams. And, finally, the finished development site, a home/commercial building/parking lot, creates additional impervious area in the watershed, further increasing the effect of the development on watershed ecology. Infiltration rates are drastically changed by the time the development is completed. Therefore, developing these

sites using low impact development methods to minimize the impacts to the overall ecology of the watershed should be a priority.

Permitted Facilities

Facilities that have NPDES permits are required to meet their permit limits. Any additional measures taken would be on a voluntary basis by the facility. If these facilities are interested, assistance can be provided to evaluate the possibility of further decreasing their TSS loads.

Roadways and Ditches

With an estimated sediment load of 5,168 tons/year, roadways and ditches were the second highest contributed of sediment in the WFWR watershed. The unpaved roads are contributing 87% of the sediment from roadways and ditches. I-540 and the gullies along its corridor are contributing 10% of the sediment from roadways and ditches, while the highways and residential are contributing approximately 3%.

- **Priority Areas:** The roadway and ditches evaluation showed that 75% of the sediment from unpaved roads was from roads with gravel and spot (native & gravel) surface with ditches. These roads should be given priority for BMP implementation with the focus being on the roads with the highest slopes first. Also, the gullies on the I-540 corridor were less than 0.3 % of the affected area, but it was estimated that they were contributing 5% of the sediment from this category. Therefore, addressing the gullies should be given priority.
- **Recommended BMPs:** If there is an interest from the Washington County Road Government, a sediment reduction program could be developed and implemented in the WFWR watershed. BMPs that would be considered include hydro-mulching ditches; routine maintenance of culverts and wing ditches; elimination of creating roadside berms; improving wing ditch placement; and modifying grading methods to minimize availability of sediment for transport to streams; and installing fish passages. I-540 has two sources of sediment associated with it: ditches and gullies. If the ADHT was interested, a sediment control program that includes habitat improvement could be developed and implemented for the highway corridor. Sediment reduction of the residential area could be decreased, if the city was interested in using a sweeping unit as part of their maintenance program.
- **Expected Reduction:** The expected reduction in sediment would be 29% for unpaved roads. Expected reduction from the highway ditches would be 29%. If 50% of the gullies were addressed, the gully erosion input would be reduced by 50%.
- **Management Implications**: Sediment can be reduced from roadways and ditches if an effective management plan is developed and implemented. But it is important to note that roadway drainage systems commonly create fish passage barriers. Therefore, to improve aquatic habitat, the management plan needs to include installing fish passages in needed areas. The project team observed that the paved highways had good vegetative cover in the ditches. This practice should be implemented throughout the road system. This would involve working with the county, the city, and the ADHT. In fact, a cohesive roadway management plan that addresses both sediment reduction and habitat could be developed by these three entities. This would save resources and promote cooperation in the WFWR watershed.

Stream Bank Erosion
Increase from riparian removal, channel alteration, increase runoff

The study showed stream bank erosion sediment loads to be the largest contributed to sediment in the watershed. The total annual sediment load estimate for the WFWR watershed was 26,550 tons for particles less than or equal to 2 mm in size. Streambank erosion contributed 58% of this total load and was approximate 3 times the sediment load from roadways and ditches, which were the second highest, contributed of sediment to the WFWR. Also, 80% of the sediment from streambank erosion came from seven miles of banks along the main stem of the WFWR. This is a relatively small area to address when compared to the number of acres of pasture and urban areas and the number of miles of roadways and ditches. Because of its high sediment contribution and small affected area, further discussion on the causes of increased streambank erosion is warranted.

The cause of stream instability, which results in increase streambank erosion, involves all of the land uses of the watershed. Generally, stream instability it is not something that occurs in a short period of time, but it is the result of an accumulation of changes in a watershed over a period of time (see Chapter 4). But, a stream can become unstable “over night” if drastic alterations to its dimension, pattern, profile, and/or sediment supply are made. Also, no land use, both past and present, can escape having some connection with this problem. For example, increases in runoff from land, increases the energy input into the stream channels, which in turn can increase erosion. Increase runoff from the land occurs from changing the infiltration rates of the watershed by the conversion of forest land to pasture, urban land, roadways, or any land use that results in lower infiltration rates. These activities have a cumulative affect, and it is difficult to reverse this process once the land use change has occurred. In fact this process began over 100 years ago with the harvesting of the great white oak trees and the ability to export the lumber with the completion of the railroad (see Chapters 3 & 4). Changing the stream channel geometry resulted from the straightening of the river; gravel mining within the bankfull channel; redesigning natural channels to be concrete conduits for urban runoff; etc. These types of changes can result in the system not being able to transport its sediment load. Once this happens, the stream works away at it own channel to find an equilibrium or balance again. Last, the removal of established riparian contributes to instability. Established, healthy riparian contributes to the system’s ability to maintain its dimension, pattern, and profile with natural levels of erosion occurring. Removal of riparian decreases the bank protection needed for energy dissipation during high flow events and can initiate the instability process, which can then be compounded by the other causes listed above. As mentioned in the Section 5.1.1, the solutions to stream instability are confined to the current land uses and, typically, are a response to the current watershed condition. For example, repairing the changes in the watershed hydrology would be very difficult, but restoration designs can address current and projected future conditions of the WFWR watershed.

- **Priority Areas:** Inventoried streambanks including WF3, WF4, WF5, and WF6 contributed 25% of the sediment (particles less than 2 mm) from streambank erosion. These banks were a combined 0.67 miles in length, and the reach containing these banks should be given “high” priority for restoration. Other reaches that should be considered priority areas include those with banks having combinations of very high to extreme BEHI ratings and moderate to extreme NBSS ratings.

- **Recommended BMPs/Restoration:** It is recommended that reach restoration should be used to reduce streambank erosion to natural level using a natural channel design approach. The natural channel design not only reduces erosion rates and subsequent sediment loads, but it will improve both aquatic and terrestrial habitat. Specific BMPs that would be part of the restoration design include the installation of grade control structures; development of bankfull benches; re-establishing channel geometry for existing bankfull discharge; and restoring riparian areas.
- **Expected Reduction:** Restoring the reach that includes inventoried streambanks WF3, WF4, WF5, and WF6 would result in a 25% reduction of sediment resulting from the erosion of inventoried banks.
- **Management Implications**: Using a natural channel design approach to restore reaches that are no longer stable can reduce the sediment load to the WFWR, can improve fish and wildlife habitat, and will help to improve the recreation quality of the WFWR. Implementation of a restoration design on most reaches will require the cooperation of several landowners and resource organizations. Restoration designs utilizing a natural channel design approach are often more costly than simple streambank stabilization. However, natural channel designs will result in a long-term, holistic solution for the watershed as opposed to streambank stabilization which generally does not improve habitat and has a potentially high failure rate when applied to unstable fluvial systems. Though it is important to restore unstable reaches, it is also important to include watershed management activities that can reduce causes of stream instability and prevent future problems. Some of the other BMPs that have been recommended for other sources will also help to promote stream stability, such as, increasing infiltration rates for pastures and urban areas and maintaining healthy stream riparian areas and, when possible, restoring stream corridors. Restoration of the stream channel at selected reaches will be ineffective if gravel mining, that is not part of a restoration maintenance plan, continues within the bankfull channel or near enough to the channel to influence sediment transport during high flow events. While performing watershed planning it is important to consider natural channel design over traditional engineering designs for urban streams needing restoration and to consider the natural channel system, when constructing new bridges.

Table 5-16 summarizes priority areas and the expected load reductions of sediment if BMPs/restorations are implemented. If, at a minimum, BMPs and restoration designs are implemented at priority areas, the annual sediment load to the WFWR could be reduced by a minimum approximately 8,472 tons of the total 26,550 tons (less than or equal to 2 mm particle size) estimated or by 32%. Priority Areas where BMP implementation and restoration will result in the highest sediment reduction and habitat restoration should be targeted. Of course, “ease of implementation” has to be considered when developing an overall watershed management priority list.

Table 5-16 Summary of sediment sources and BMPs to reduce sediment loads.

Land Use: Priority Area Description	Affected Area		Estimated Annual Sediment Load (Ton)		Estimated Annual Load Reduction	
	Land Use Total Area	Priority Area % of Total Area	Land Use Total Load	Priority Area % of Total Load	Priority Area % Reduction	Priority Area Tons of Sediment Reduced
Pasture: Enders soils with 8 % or greater slopes	19,413 ac	38% (7,377 ac)	1,709	78%	52% of 1330 tons	693
Forest: Harvested Areas	46,539 ac	0.3% (110 ac)	376	2%	N/A* of 6 tons	N/A
Urban: Construction Sites	9,710 ac	3% (283 ac)	3,890	72%	94% of 2,790 tons	2,623
Roadways & Ditches:	337 mi		5168			
1) Unpaved-County with gravel and spot surfaces		27% (90 mi)		87%	29% of 4,496 tons	1,304
2) I-540 Corridor Gullies		0.3 % (1 mi)		5 %	50% of 240 tons	120
Streambank Erosion: Banks with estimated erosion rates greater than 10 ft/year	10.6	6% (0.67 mi)	15,391	25%	97% of 3,848	3,732

*N/A – percentages not available.

5.1.9 Comparison of Watershed Sediment Load Estimate to Water Quality Data Collected at the AWRC CM Station

The average sediment load of 2 mm or less particle size delivered to the WFWR watershed from various sources and causes was estimated to be 26,550 tons/year (or 74% of the total estimated sediment load of 35,795 tons). The average TSS load estimated from approximately 21 months of data collect at the AWRC CM Station was 14,870 tons/year. Not all 2 mm or less particle size material would necessarily be represented as TSS in water samples collected at the mouth of the river. Suspended Sediment concentration (SSC) is a water quality parameter that better represents the 2 mm or less particle sizes. SSC was measured by the USGS for seven paired samples collected during storm flow conditions at the AWRC CM Station. The average relationship between paired TSS and SSC determined from these paired samples can be described by the following relationship (Nelson, et al., 2004):

SSC = 1.46 TSS

Applying this relationship to the average TSS load for 2002 and 2003 of 14,870 tons/yr, results in an average SSC load of 21,690 tons/yr. The estimated SSC load based on water quality data is 82% of the study estimated sediment load of 26,566 tons/yr (particles less than or equal to 2 mm). The AWRC is continuing to collect paired storm flow samples to further develop the relationship between TSS and SSC.

5.2 Nutrient Sources and Load Estimates

The purpose of this section is to discuss sources of nitrogen and phosphorus from land use in the WFWR watershed and estimate annual loads of these constituents based on existing data and relationships developed through research. Nutrients have not been identified by the ADEQ as causing a water quality problem in the WFWR watershed. Nevertheless, part of watershed planning is to evaluate potential problems and look to reduce loads of any contaminant that may cause impairment in the future. In addition, the WFWR watershed is located in a nutrient rich watershed; therefore, nutrients were evaluated to provide information for planning purposes.

PLEASE NOTE: THE NUTRIENT LOAD ESTIMATES IN THIS REPORT ARE "ONLY" ESTIMATES. THEY ARE FOR PLANNING PURPOSES ONLY! THEY ARE BASED ON THE INFORMATION GATHERED IN THIS STUDY, AVAILABLE DATA, PUBLISHED COEFFICIENTS, OTHER RELAVENT SOURCES OF INFORMATION, AND THE TIME ALLOTTED FOR THE STUDY. AS MORE INFORMATION, DATA, AND METHODS ARE MADE AVAILABLE, THE LOAD ESTIMATES SHOULD BE UPDATED TO REFLECT NEW DATA, METHODS, AND INFORMATION.

Natural cycles of nitrogen and phosphorus compounds in the environment are complex and difficult to model or predict. Load estimates of these compounds will be based on simple calculations using published water quality data, coefficients, and land use information specific to the WFWR watershed. In no way do these estimates represent modeled results of the fate and transport of nitrogen and phosphorus compounds in the environment, which is beyond the scope of this study. However, an evaluation of nutrient sources and estimated loads to the stream system is needed to prioritize methods for the reduction of nutrient runoff, so environmental problems associated with nitrogen and phosphorus can be avoided in the WFWR watershed.

A summary of the nutrient sources, associated with land use, that were evaluated along with the data and methods used to estimate loads are shown in Table 5-17. An explanation of the data used and methods for each source evaluated follows this section.

Table 5-17 Potential Sources of Nutrients associated with land use and data and methods used for estimating annual loads.

Potential Source of Nutrients	Data	Method for Estimating Load
Pastures • Cattle – Calf Operations • Poultry Operations • Commercial Fertilizers	• Survey of WFWR Landowners • State Statistics • NRCS Ag. Manual • GIS data with field verification • Water quality data • Litter samples	Simple model 1) Watershed Studies 2) Published Coefficients
Permitted Facility – WF-WWTP • Treated waste water • Overflows	• Permit information and reporting • Water quality samples • Expected treatment values	Simple model
Rural Residential • Septic Tanks	• Health Department Data • Published data	Simple model
Urban areas: • Fertilizers • Wastewater leakage • Pets • Etc.	• Published stormwater runoff concentrations	Simple model
Other Sources • Atmospheric • Wildlife • Golf Course	• Published data	Simple model

5.2.1 Manure, Litter, and Commercial Fertilizer

In the WFWR watershed, approximately, 29.3% or 23,340 acres of the total land is used for agriculture. Most of the farms have cattle-calf and/or confined poultry operations. Landowners in the watershed that generate income by farming, typically manage pastures for forage production to be used as feed for livestock or cut for hay. Nutrients are a very important part of livestock/forage farming. Nutrients are needed to grow both animals and forage. Nutrients are also a by-product of cattle and poultry farming. These manures are a valuable resource to the farming community and the watershed when they are utilized as a fertilizer and applied in a way that minimizes their impact to the environment. Manures not only provide nutrients for forage growth, but they also provide organic material that helps to replenish the thin, rocky soils typically found in the Ozarks. The project team has worked with several farmers in the state that have exceptional production rates at their farms and at the same time are environmentally conscience to minimize their impacts to the environment. But, if not handled properly, manure as well as chemical fertilizers can end up in our streams and lakes, where they will contribute to water quality degradation.

Agricultural activities in the WFWR watershed involve the generation of manures and/or the purchase of fertilizers; these items are sources of nutrients. Describing and quantifying nutrient cycle for agricultural operations is complex and beyond the scope of this project. However, we can easily discuss sources and estimate the amount of nutrients produced or brought into the watershed. Annual nutrient production or purchases within the WFWR watershed were estimated for:

- Animal Manure from Cattle-Calf Operations
- Chicken Litter from Broiler Operations
- Commercial Fertilizers

The University of Arkansas Cooperative Extension Service surveyed landowners in the WFWR watershed regarding on-farm nutrient use and production (UofA-CES, 2004). Because it is important to respect the privacy of landowners, a summary of the survey without reference to individual landowners or specific locations can be found in Appendix 3-A. The data from the survey was useful in evaluating the nutrients in the WFWR watershed and, the project team is appreciative of the landowners for participating in the survey.

Figure 5-28 Numerous cattle operations exist in the WFWR watershed

5.2.1.1 Cattle-Calf Operations

Cattle-calf operations are important to the economy of rural Arkansas (Figure 5-28). Sixty-six percent of those responding to the

CES survey indicated that they had cattle-calf operations (UofA-CES, 2004). Based on the CES landowner survey, it was assumed that 66% of the pasture area (19,413 acres) in the watershed was used for cattle and their calves, which is 12,813 acres. Using a stocking rate of one cow per two acres, which is typical for NW Arkansas (UA-CES, 2002), the number of cows in the watershed was estimated to be 6,406. The number of calves in the watershed was estimated to be equal to 72% of the cow population (Troxel, personal communication, 2004). Calves were assumed to have an average weight of 300 lbs and assumed to be on the farm for 213 days of the year, while cows were assumed to have an average weight of 1100 lbs and to be on the farm the entire year (Troxel, personal communication, 2004). An average annual manure production value for the WFWR watershed from cattle-calf operations was estimated using the NRCS Agriculture Waste Management Field Handbook (USDA NRCS, 1992). The total tons of manure, phosphorus, and nitrogen produced by cattle and calves annually are summarized in Table 5-18.

Table 5-18 Estimates of nutrients produced by cattle and calves in the WFWR watershed

Pasture area in WFWR	19,413
Acres used for cattle	12,813
Average cattle density (cow/ac)	0.5
Number of cows	6,406
Number of calves	4,613
Total # livestock	**11,019**
Average cow weight (lb)	1100
Average calve weight (lb)	300
Cow days on farm	365
Calve days on farm	213
Weight of Manure produced (ton/yr)	89,728
Total excreted P produced (ton/yr)	**170.5**
Total excreted N produced (ton/yr)	**470.1**

5.2.1.2 Poultry Operations

There are, approximately, 79 active poultry houses located within the WFWR watershed (see Section 3.4). The AWRC field verified the locations of active poultry houses during 1992. An average annual litter production value for the WFWR watershed was estimated using the NRCS Agriculture Waste Management Field Handbook (USDA NRCS, 1992) and typical poultry production values that are listed in Table 5-19. Based on the CES survey of the watershed landowners, most of the poultry litter is land applied as a fertilizer on pastures for forage production.

Table 5-19 Poultry litter production estimate in the WFWR watershed.

	Poultry Information	**Value Used**
Range of House Size	20,000 to 30,000	27,000 birds/house
Average growing cycle	6 to 8 weeks	49 days
Ave broiler age	28 days	28 days
Ave. Broiler weight	4.0 lbs	4.0 lbs
Days in Annual growing cycle	295 days	295 days
Litter production	35.0 lbs/d/1000lbs of birds	35.0 lbs/d/1000lbs of birds

Based on the production values assumed, approximately, 12,800,000 broilers are grown in the WFWR watershed each year. The annual litter production was estimated to be 44,000 tons/year. Using average values of actual litter samples collected from houses in the Piney Creek watershed during the ADEQ pasture renovation project (30.20 lbs of TP/ton of litter and 60.35 lbs of TN/ton of litter), the annual amounts of phosphorus and nitrogen produced by poultry operations in the form of litter were estimated to be 665.1 ton/year and 1,329 ton/year, respectively.

5.2.1.3 Commercial Fertilizer Use in the WFWR

Another source of nutrients associated with agricultural operations in the WFWR is commercial fertilizers used to fertilize pastures. Commercial fertilizer is sold in a wide range of formulations for various agricultural and landscaping uses and needs. Although the amount of fertilizer applied within the WFWR drainage basin is not known, the Arkansas Plant Board tracks commercial sales of the various formulations within Washington County. From June 30th, 2002 to July 1st, 2003, a total of 5,603 tons of fertilizer was sold within the county that was applied to pastures, orchards, row crops, lawns and golf courses (Arkansas Plant Board, 2004).

The most common formulations and associated nitrogen (N) and phosphorous (P) content, is listed in Table 5-20. The information in this table was obtained from the Arkansas Plant Board Feed and Fertilizer Division. It should be noted that the formulations identified as Specialty Blends and Other Blends did not have N and P contents listed. Therefore, the content was estimated by assuming that the average N and P values for the top 10 formulations represented the N and P values in these formulations. Table 5-20 includes estimates of the total amount of N and P that was in the fertilizers sold in Washington County during the reported one-year time period.

Table 5-20 Commercial fertilizer sales in Washington County for June 30, 2002 to July 1, 2003

Fertilizer Blend	Tons Sold	% N	Tons N	% P_2O_5	Tons P_2O_5	Tons P
17-17-17	1257.5	17	213.8	17	213.8	93.4
15-20-20	270.0	15	40.5	20	54.0	23.6
13-13-13	180.8	13	23.5	13	23.5	10.3
24-10-10	134.0	24	32.2	10	13.4	5.9
24-6-12	72.7	24	17.4	6	4.4	1.9
10-20-10	53.6	10	5.4	20	10.7	4.7
21-12-12	34.5	21	7.2	12	4.1	1.8
22-11-11	20.0	22	4.4	11	2.2	1.0
10-20-20	14.0	10	1.4	20	2.8	1.2
24-8-8	12.7	24	3.0	8	1.0	0.4
Ammonium Sulfate	89.0	21	18.7			
Nitrate of Soda	0.8					
N Solutions	0.7	28	0.2			
Ammonium Nitrate	1876.8	33	619.3			
Urea	292.4	46	134.5			
Other N	0.1					
Super phosphate	34.5			45	15.5	6.8
DAP	16.5	18	3.0	46	7.6	3.3
Sulfur	0.8					
Boron	0.2					
Misc. Materials	23.6					
Potassium Nitrate	0.1					
Muriate of Potash	309.2					
Other Blends	65.4	17	11.1	16	10.5	4.8
Specialty	841.4	17	143.0	16	134.6	58.8
Dried Manure	2.0					
Total Tons	5,603		1,279		498	218

The WFWR watershed represents, approximately, 13% of the land area of Washington County. This percentage was used to estimate the amount of commercial fertilizers that were applied in the WFWR watershed. Using these assumptions, the amount of commercial fertilizer applied in WFWR watershed was estimated to be 728 tons, consisting of 28.34 ton/yr and 166.3 ton/yr of phosphorus and nitrogen, respectively.

5.2.1.4 Summary of Fertilizers

The estimates of total masses of nutrients produced by livestock or imported into the watershed in the form of commercial fertilizers are shown in Table 5-21.

Table 5-21 Estimates of nutrient mass used as fertilizer in the WFWR watershed.

Source	Total Manure or Fertilizer (Ton)	Total Phosphorus (Ton)	Total Nitrogen (Ton)
Cattle-Calves Manure	89,728	170.5	470.1
Poultry Litter	44,046	665.1	1,329
Commercial Fertilizers	728	28.34	166.3
Total		**863.9**	**1,965**

5.2.1.5 WFWR Concentrations of Soil Phosphorus

As part of an overall project to improve watershed conditions in the Beaver Lake watershed, the University Cooperative Extension Service (CES), conducted various activities in the WFWR watershed (CES, 2003). The activities conducted by the CES involved agricultural best management practice education and training. One of the tasks included the collection and chemical analysis of soil samples from pastures in the WFWR watershed. During the course of the work, the CES collected and analyzed 202 samples from a combined total of 2,579 acres of pasture. The analysis of the soil samples indicated that the average phosphorus level in the WFWR watershed was 128 lb/ac and that the levels ranged from a minimum of 8 lb/ac to a maximum of 583 lb/ac. The following summarizes the observed phosphorus levels in pastures within the WFWR watershed:

- 919 acres had levels below 50 lb/ac
- 540 acres had levels between 50 and 100 lb/ac
- 642 acres had levels between 100 and 200 lb/ac
- 223 acres had levels between 200 and 300 lb/ac
- 144 acres had levels greater than 300 lb/ac

5.2.2 Nutrient Loads Estimated from Pastures

Pasture area was used to estimate nutrients loads from agriculture for the WFWR watershed. Manure from cattle-calf operations; litter from poultry facilities; and commercial fertilizers are typically applied as a fertilizer to pastures for forage production. Using pastures to estimate nutrient loads will also include the phosphorus in soil particles from soil erosion of pastures and other areas. Based on data from research performed to evaluate phosphorus and nitrogen from pastures, the amount of nutrients delivered to the WFWR from the pastureland use was estimated. First, it was assumed that most of the agricultural sources of nutrients are in some form applied to pastures. For example, chicken litter is applied to pasture for forage production. Cattle and calves spend their time in pastures consuming forage; therefore, it is assumed that most of their manure is distributed on the pastures. Exceptions to this assumption would be uncovered stored poultry litter and cattle manure that accumulates in the active channel of intermittent or perennial stream channels. The project team did not observe any uncovered piles of poultry litter throughout the life of the project in the watershed; therefore, it was assumed that this practice was not occurring. In the case of cow manure accumulating in drainage areas, nutrient loads were estimated, which is summarized later in this section. It is also assumed that some commercial fertilizers are being applied to pastures for improving forage growth.

The land area in the WFWR that was determined to be pasture was 19,413 acres. This area was used as the basis for the phosphorus and nitrogen loading estimates. Table 5-22 summarizes published phosphorus export coefficients from various watershed monitoring programs and studies. This data was used to estimate phosphorus loads from pastures. The phosphorus Runoff Coefficients ranged from 0.1 to 4.4 lb/ac/y with an average of 1.7 lb/ac/y. Applying these values to the pasture in the WFWR results in the following Total phosphorus loadings:

- Minimum – 0.97 ton
- Maximum – 42.7 ton
- Average – 16.5 tons

Table 5-22 Information sources for phosphorus export coefficients

Research Source	Information And Basis of Range	Total Phosphorus Runoff Coefficient Range (lb/ac/y)
Beaulac and Reckhow (1983)	Watershed conditions and management	0.12 to 4.4
Pickup et al. (2003)	Illinois River Watershed – no point source impact	0.6
Gillingham and Thorrold (2000)		0.1 to 1.5
Smith et al. (1992) and Sharpley et al.	Southern grasslands; poor to good pasture management	0.22 to 3.6

Phosphorus concentrations in runoff are related to pasture slope and soil properties, which are the same variables that affect sediment erosion rates. One would expect total phosphorus runoff to increase as pasture slope increases. An estimate of the total phosphorus loading can be made using the pasture soil loss coefficients developed from the WEPP model (Section 5.1.3) and the total phosphorus runoff coefficients from the literature. The highest phosphorus runoff coefficient was matched with the highest sediment yield coefficient, corresponding to the most erodable soils and the highest slope category. For the other slope-soil categories, P coefficients were proportioned on a linear basis, based on the sediment yield values in relationship to the highest value. Table 5-23 lists the total phosphorus runoff coefficients based on the WEPP sediment loss coefficients along with the acres for each slope-soil category for the WFWR watershed. Table 5-23 also shows the estimated total phosphorus annual loads per slope-soil category. A total of 10.2 tons of phosphorus per year was estimated to be delivered to the WFWR from agricultural sources using this method.

Table 5-23 Project phosphorus export coefficients based on sediment export rates for pasture in the WFWR as determined by application of the WEPP model.

Slope Class	Soil Type	Area (ac)	WEPP Soil Loss (ton/ac/yr)	% of Maximum Soil Loss Coeffecient	Projected P Coefficient based on 4.4 Max (lb/ac/yr)	TP Runoff (lbs/yr)
0 - 2%	Enders	1372	0.083	1.56%	0.068	94.0
2 - 4%	Enders	3291	0.25	4.69%	0.21	678.5
	Linker	32	0.20	3.77%	0.17	5.4
	Clarksville	207	0.47	8.87%	0.39	80.6
4 - 6%	Enders	2960	0.42	8.00%	0.35	1041.7
	Linker	328	0.89	16.8%	0.74	242.7
	Clarksville	200	0.79	14.9%	0.66	131.4
6 - 8%	Enders	2273	0.99	18.6%	0.82	1862.4
	Linker	541	0.27	5.06%	0.22	120.4
	Clarksville	154	0.88	16.6%	0.73	112.0
8 - 10%	Enders	3235	1.5	29.2%	1.3	4154.8
	Linker	471	0.29	5.39%	0.24	111.6
10 - 13%	Enders	2008	2.5	47.8%	2.1	4219.1
	Linker	87	0.29	5.54%	0.24	21.1
13 - 16%	Enders	1507	3.9	74.1%	3.3	4915.5
	Linker	152	1.00	18.9%	0.83	126.2
16 - 19%	Enders	397	5.1	96.2%	4.2	1679.6
	Linker	20	0.69	12.9%	0.57	11.2
>19%	Enders	182	5.3	100%	4.4	799.5
	Totals	19,413				20,408

Developing estimates for the total nitrogen loads coming from pastures in the WFWR watershed is even more difficult than total phosphorus. Nitrogen compounds go through a variety of chemical and biological processes, once they are introduced to the environment. Also, there is not as much data on total nitrogen runoff from pastures as there is for total phosphorus. Therefore, we will have to rely on data from the ADEQ pasture renovation project (ADEQ, 2004). Two small agricultural watersheds were continuously monitored for over 2 years. Each watershed represented different management conditions, one using swine manure for fertilization, the other using poultry litter. Both farms included grazing cattle operations. Using the results of the water quality data collected, a total nitrogen runoff coefficient was calculated for each watershed. The results were then averaged to represent the total nitrogen load from pastures in a general agricultural watershed. The average total nitrogen runoff coefficient of 4.4 lb/ac/yr was calculated from the collected data. This value was applied to the 19,413 acres of pasture in the watershed and results in a total nitrogen load of 42.7 ton.

5.2.2.1 Manure from concentrated areas

Cattle were observed loitering in the mainstem and drainage areas of the WFWR on several occasions, while collecting field data along the river. If there are no other sources of water or shade, cattle will use the stream and its drainages as a water source and for shade. The project team, generally, observed cattle in the stream during the summer months. The project team also observed areas in which cattle congregated along small drainages where there were trees. Figure 5-29 shows the result of cattle in the stream during the low flow time of the year. It is difficult to know how many cattle in the watershed have access to these areas and the amount of manure that is directly deposited within the channel or in a small drainage area. To illustrate the potential nutrients that can come from this activity, Table 5-24 was developed to show various percentages of cattle congregating in these areas and the resulting nitrogen and phosphorus loads. It was assumed that the cattle congregated near and in the stream channel or small drainages during the summer months for 6 hours during the day or 25% of the time.

Figure 5-29 Water quality impacts from cattle in streams as seen on the WFWR.

Table 5-24 Estimates of nutrients entering WFWR as a result of manure excreted directly to river

Scenario basis: 3 months; 25% of manure is in/near stream	Manure (tons)	Phosphorus (tons)	Nitrogen (tons)
10% Cattle in WFWR watershed	561	1.07	2.94
20%	1,121	2.13	5.88
30%	1,682	3.20	8.81
50%	2,404	5.33	14.69

5.2.3 Municipal Wastewater

Municipal wastewater (MWW) from residential homes, businesses, and industries is a source of nutrients in the WFWR watershed. MWW in the WFWR watershed is collected and treated through a municipal wastewater treatment plant (WWTP) or a septic system. For the city of Fayetteville, the MWW is collected and treated at the Fayetteville WWTP and the treated effluent is discharged outside of the WFWR watershed. Still, the area of Fayetteville that drains to the WFWR can be a source of nutrients to the river from leaking collection manholes and pipes. The City of West Fork collects and treats the MWW for its 2,042 residents. The treated effluent is discharged to the WFWR and is a source of nutrients. Watershed residents and businesses that are not connected to either of the WWTPs will generally have septic tank systems to handle their MWW. Septic system effluent does not completely remove all nutrients from MWW; therefore, it is also a source of nutrients in the WFWR watershed. There are approximately 1400 septic systems in the WFWR watershed.

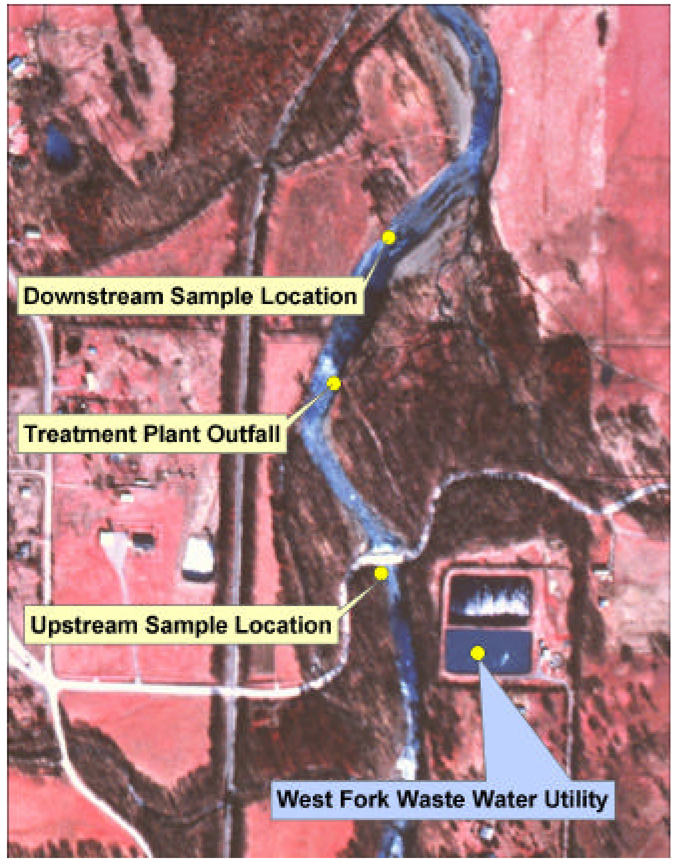

Figure 5-30 Map of West Fork Waste Water Facility, discharge location and grab sample collection points

5.2.3.1 Estimated Nutrient Loads from the West Fork Waste Water Treatment Plant

The city of West Fork operates a publicly owned wastewater treatment facility, under a NPDES permit from the ADEQ (permit number AR0022373), which discharges treated water to the WFWR. The outfall for the plant is located approximately 14 miles upstream of the confluence of the West Fork with the main fork of the White River. More specifically, the permitted outfall is located ¼ mile down stream of the CR240 Bridge, on the south side of the city of West Fork (Figure 5-30). The plant began operation in 1973 under a permit from the State of Arkansas and has been in continuous service since that time (Bartholomew, personal communication, 2004). The present permit became effective on December 1, 2001 and will expire on November 30, 2006.

The plant is a Dravo Package Treatment and employs elements of advanced or tertiary treatment. According to the permit Statement of Basis, the facility has a design flow of 0.1 million gallons per day. The plant receives wastewater from residential and commercial sources within the West Fork City limits and does not receive waste from industrial dischargers. Raw wastewater entering the plant passes through a grit chamber with comminutor to remove coarse matter prior to flowing to an activated sludge system where microorganisms synthesize the organic load. The water is then passed through a secondary clarifier and sand filter before being chlorinated to reduce the pathogens. The treated wastewater or effluent is then discharged to the WFWR. Inflows greater than the plant treatment capacity, along with waste from commercial septic tank haulers, are diverted to an equalization basin for storage prior to being metered into the system. Grit and sludge collected from the activated sludge system and sand filter is dried on beds and then disposed of at a permitted landfill (Bartholomew, personal communication, 2004).

The operator is required by permit to self-monitor the plant and ensuring effluent quality by collecting grab samples periodically. The samples are analyzed for a list of parameters and the analytical results submitted to the ADEQ Water Division in a monthly Discharge Monitoring Report (DMR). Table 5-25 lists the effluent monitoring parameters and sampling frequency required by the permit. Daily flow is not monitored.

Table 5-25 Required Monitoring and Permit Limits for West Fork Wastewater Treatment Facility

Effluent Characteristics Required to be Monitored	**Discharge Limitations**		
	Mass Monthly Average Lbs/day	**Concentration Monthly Average**	**Concentration 7-day Average**
$CBOD_5$ (May-October)	8.3	10 mg/L	15 mg/l
BOD_5 (November-April)	25.0	30 mg/L	45 mg/L
TSS (May-October) (November-April)	12.5 25	15 mg/L 30 mg/L	25 mg/L 45 mg/L
NH3-N (May-October)	4.2	5 mg/L	8 mg/L
DO (May-October)	N/A	6 mg/L	(Instantaneous Minimum)
Fecal Coliform Bacteria (April-September) (October-March)	N/A N/A	(Colonies/100 ml) 200 1000	(Colonies/100 ml) 400 2000
pH	N/A	Minimum 6 s.u.	Maximum 9 s.u.

The facility is also periodically inspected by a representative of the ADEQ Water Division. During unannounced site visits, the inspector conducts either a compliance monitoring inspection or less frequently, a compliance sampling inspection. Written reports of inspections are maintained in the ADEQ Central Records and are available for public review. The most recent compliance monitoring inspection occurred in March of 2003, at which time no operational problems or permit violations were noted. An inspection was conducted in January of 2002 at which time the following deficiencies were noted: the comminutor motor was not functional; the flow totalizer had not been calibrated; and the pH values were not being measured properly. The ADEQ Field Inspector and the Water Division Enforcement Coordinator summarized the compliance history of the facility as a well run plant with relatively infrequent permit violations or operational problems. When operational deficiencies or violations are noted they are promptly addressed by the facility operator. No formal compliance actions have been initiated by the ADEQ Water Division against the facility (Benson, Morgan, personal communication, 2004).

Based upon submitted DMR, the design flow for the facility of 0.1 million gallons per day, has been consistently exceeded for the past two and a half years. Figure 5-31 is a graph of the annual average of daily discharge of treated effluent from the facility to the WFWR. Despite discharges greater than the design flow, the operator has managed the facility with relatively few discharge limitation violations.

In early 2004, representatives of the Environmental Preservation Division initiated a water-quality sampling program in order to validate the phosphorous treatment efficiency of the West Fork wastewater treatment plant (WF-WWTP). Grab samples of the treatment plant outfall and of the West Fork White River upstream and downstream of the outfall were collected (see Figure 5-30). The upstream sample was collected at the CR240 Bridge, while the downstream sample

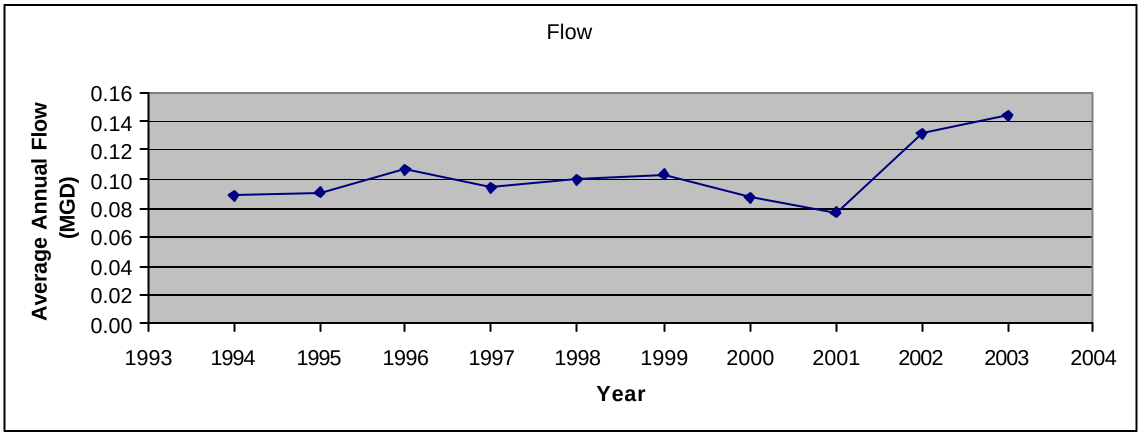

Figure 5-31 Annual average of daily discharge for treated effluent from the WF WWTP

was collected from the first riffle below the outfall. Table 5-26 lists water quality parameters and values obtained from the 3 sampling events.

Typical phosphorous effluent concentrations for activated sludge treatment plants of the type operated by the City of West Fork should range from 4.0 to 6.0 mg/L (Maner, Personal Communication, 2004). Based upon the samples collected, the West Fork plant discharge is operating within the expected phosphorous treatment range. It should be noted that the facility permit does not require phosphorous monitoring of the plant discharge.

Table 5-26 Results of three sampling events in 2004.

Location	Date	BOD_5 (mg/L)	Ammonia as N (mg/L)	Bromide (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Nitrite+ Nitrate-N (mg/L)
Upstream	1/6/2004	<1.00	<0.030	<0.01	4.21	0.06	0.514
Downstream	1/6/2004	<1.00	0.040	<0.01	4.96	0.08	0.449
Outfall	1/6/2004	8.20	6.90	0.03	21.1	0.30	1.29
Upstream	2/24/2004		<0.030	<0.01	4.45	0.07	0.501
Downstream	2/24/2004		0.045	<0.01	5.14	0.08	0.480
Outfall	2/24/2004		3.12	0.03	28.5	0.48	4.38
Upstream	3/29/2004	<1.00	<0.030	<0.01	2.58	0.05	0.488
Downstream	3/29/2004	<1.00	<0.030	<0.01	2.53	0.06	0.509
Outfall	3/29/2004	H>11.31	8.30	0.03	24.9	0.38	1.38

Table 5-26 Continued

Location	Date	Sulfate (mg/L)	Total Dissolved Solids (mg/L)	Total Kjeldahl Nitrogen as N (mg/L)	Ortho-P as P (mg/L)	Total P (mg/L)	Total Suspended Solids (mg/L)
Upstream	1/6/2004	15.4	88.5	<0.110	0.008	<0.030	<1.0
Downstream	1/6/2004	17.0	110	0.180	0.017	<0.030	5.2
Outfall	1/6/2004	32.2	245	9.90	1.67	1.74	7.0
Upstream	2/24/2004	15.2	78.0	?-0.0139	0.011	<0.030	<1.0
Downstream	2/24/2004	19.2	100.0	?0.187	0.022	0.052	2.5
Outfall	2/24/2004	40.0	263	?32.4	1.14	6.53	113
Upstream	3/29/2004	13.4	96.5	0.146	0.026	<0.110	5.8
Downstream	3/29/2004	8.06	79.5	0.169	0.026	<0.110	13.0
Outfall	3/29/2004	32.2	245	13.6	1.85	2.24	23.5

In order to estimate the nutrient and pollutant loads delivered to the river from the WF-WWTP the DMRs were evaluated. Monthly values for each monitoring parameter were averaged for the last ten years. Based upon the average daily discharge from the plant, an average annual load was calculated for several monitoring parameters. The data is summarized in Table 5-27.

Table 5-27 Annual averages loads estimated from monitored effluent parameter monthly DMR data at the WF-WWTP

Year	Flow (MGD)	NH3 (mg/L)	NH_3 Load (Ton)	CBOD (mg/L)	CBOD Load (Ton)	BOD_5 (mg/L)	BOD_5 Load (Ton)	Dissolved Oxygen (mg/L)	TSS (mg/L)	TSS Load (Ton)
1994	0.09	1.93	0.26	5.98	0.81	3.55	0.48	6.72	4.75	0.64
1995	0.09	3.23	0.45	10.92	1.51	12.63	1.74	6.45	5.44	0.75
1996	0.11	2.31	0.37	3.47	0.56	5.68	0.92	7.55	3.93	0.64
1997	0.09	2.03	0.29	6.68	0.96	6.23	0.89	7.00	3.52	0.50
1998	0.10	2.49	0.38	4.50	0.68	3.83	0.58	6.83	1.26	0.19
1999	0.10	2.01	0.32	2.30	0.36	7.96	1.25	6.76	2.32	0.36
2000	0.09	4.54	0.60	3.66	0.49	3.27	0.43	6.85	1.28	0.17
2001	0.08	3.31	0.39	2.14	0.25	2.14	0.25	6.84	2.27	0.27
2002	0.13	1.36	0.27	2.51	0.50	3.51	0.70	6.41	2.82	0.56
2003	0.14	1.74	0.38	2.67	0.59	5.20	1.14	6.18	2.67	0.59
10 Year Ave.	0.10		0.37		0.67		0.84			0.47

The average annual TSS load for the WF-WWTP was estimated to be about 0.5 tons per year. To estimate the average TP load, the higher end of the treatment value that would be expected for this facility, 6 mg/L, was used in addition to the ten-year average annual flow of 0.1 MGD. The average annual TP load was estimated to be 0.9 tons per year. TKN data was not available for the WF-WWTP, but nitrate data was available. To estimate Total N, the three samples taken at the outfall were averaged for TKN and Nitrite-Nitrate-N, which resulted in values of 18.6 mg/L and 2.35 mg/L, respectively. Using the average annual flow rate, a TKN load of 2.84 ton/year and a Nitrite-Nitrate-N of 0.4 ton/year were calculated. The TKN load was added to the Nitrate-N load to obtain an estimated average Total N load from the WFWWTP of average 3.2 tons/year.

Another possible source of Total P and N loads from the WFWWTP is when the system becomes overloaded during a flood event. At this time, untreated wastewater may be discharged into the WFWR. Because of the lack of data, loads that could occur from an event of this nature were not estimated.

5.2.3.2 Estimated Nutrient Loads from Septic Systems

Nutrient loads from septic tanks in the WFWR were estimated by using reported effluent concentrations and multiplying predicted annual loads from properly functioning septic systems by the number of septic systems located within 300 ft of a perennial stream channel as defined by the GIS layer for streams in the watershed (189 systems). Based on evaluation of impacts of septic systems on groundwater in the state and taking a conservative approach, this condition assumes that within 300 ft. of the stream, the nitrogen in the effluent discharging from the septic system will enter surface waters without significant attenuation (Kresse, personal communication, 2004). Because the mobility of phosphorus is very limited in ground water systems, it is assumed that the phosphorus does not enter the stream (annual TP load is 0 tons). Ortho-phosphate, the most stable form of phosphorus, strongly adsorbs or co-precipitates onto Mn and Fe oxyhydroxides (Hem, 1989). Effluent concentrations of total nitrogen and phosphorus from properly functioning septic systems was assumed to be 45 mg/l and 14.5 mg/l, respectively (Asbury, et. al., 1997). The daily flow for each septic system was estimated to be 116 gallons per day, assuming 2.5 persons per septic tank and 46.5 gallons generated per person (Schuler and Holland, 2000). Based on the assumptions and conditions stated, the annual TN load from septic tanks delivered to the WFWR was estimated to be 1.5 tons.

An alternative estimate of nutrients from septic systems can be made using EPA's STEPL model (U.S. EPA, 2003). Using 189 systems that are within 300 ft. of a perennial stream, and assuming a failure rate of 40%, the loads of total nitrogen and total phosphorus predicted by the model are 1.2 ton/yr and 0.5 ton/yr, respectively. Using the STEPL model, a phosphorus load is generated that was not produced by the former estimation method. In order to present a conservative estimate, the data from the STEPL model will be used for estimating a total phosphorus load from septic tanks for the watershed.

5.2.4 Other Urban Sources and Loads

Approximately, 12.2% or 9,710 acres of the WFWR watershed is urban. Urban areas have many sources of nutrients and it would be difficult to predict loads from the urban area on a source-by-source basis. Instead, data was used from urban areas were monitored for total phosphorus and total nitrogen concentrations and these values were applied to the urban areas of the WFWR. Schuler summarized phosphorus and nitrogen concentrations of stormwater from urban areas based on water quality monitoring of urban stormwater. Values of phosphorus were reported to range from 0.29 to 0.3 mg/L and total nitrogen values ranged from 1.87 to 2 mg/L (Schuler and Holland 2000). It was assumed the urban areas of WFWR, which is predominantly, the southeast side of Fayetteville, are composed of an effective 25% impervious area, which would result in rainfall to runoff conversion of approximately 25%. Using 9,710 acres of urban area and an average annual rainfall of 46 inches, the estimated total phosphorus and total nitrogen loads are 3.8 tons and 25.3 tons, respectively. Urban sources within the WFWR watershed of phosphorus and nitrogen that would contribute to these values are landscaping and resident fertilizers; pets, other animals, and wildlife; leakage from the WWTP infrastructure (Figure 5-32); decomposing plant materials; and litter.

Figure 5-32 Leaking wastewater infrastructure can contribute nutrients to the watershed

5.2.5 Forest

Forested landscapes produce a nutrient load to the WFWR. These values would be considered natural background levels that you would expect from a healthy forest ecosystem. Estimates for annual loads of TN and TP from forested areas in the WFWR are based on data collected by ADEQ as part of a 319 project performed in the Buffalo River watershed. Water quality data was collected at a continuous monitoring station for a small watershed that was 90% forested. From this work, annual export coefficients of TP and TN was 0.034 lb/ac/yr and 0.335 lb/ac/yr, respectively were estimated. Using these export coefficients, the annual load of total phosphorus and total nitrogen from the 46,539 acres of forested land in the WFWR watershed was 0.8 ton and 7.8 ton, respectively. The loads include nutrients from all sources found in the forest landscape including decaying leaf litter, atmospheric deposition, and nutrients excreted by wildlife.

5.2.6 Other Sources

Other sources of nutrients in the WFWR watershed are:

- 111 acre golf course
- Atmospheric deposition
- Wildlife

Golf courses can contribute a significant amount of nutrients in a watershed because of their fertilizer use. Loads from the golf course in the watershed were estimated using runoff concentrations of 3.94 mg/L and 0.93 mg/L for total nitrogen and total phosphorus, respectively

(Starrett, 2001). Using these concentrations and an assumed rainfall to runoff conversion of 10% for the 110 acres of the golf course, the total nitrogen and phosphorus loads were 0.22 ton and 0.05 ton, respectively.

Atmospheric deposition of nutrients is a source of nutrients for the WFWR watershed. These nutrients become entrained in rainfall as rain falls to earth. These nutrients are in the form of gases and particulate matter. The sources of the airborne nutrients include dust, exhaust from combustion engines, gases from livestock, wildfires, emissions from wetlands, decomposition of organic materials, industry discharges, and plant fragments and pollen (Jassby, 2003). Atmospheric deposition accounts for a portion of the total nitrogen input into the WFWR watershed. Based on the seasonal average of precipitation samples collected at the National Atmospheric Deposition Program's monitoring station in Fayetteville, AR, approximately 11.1 lbs/ac of inorganic nitrogen falls via atmospheric deposition in the WFWR watershed (NADP, 2004). This would be equivalent to a nitrogen input of 442 tons per year for the WFWR watershed. From a study conducted by the USGS in Western Michigan, the atmospheric deposition rate of phosphorus was estimated to be 0.18 lbs/ac (Robertson, 1996). This would be equivalent to a phosphorus input of 7 tons per year to the WFWR watershed. Plants and animals use a significant amount of the nitrogen and phosphorus from atmospheric deposition. The amount of nutrients actually transported to the WFWR is unknown. However, most of the atmospheric deposition of nutrients that enter the stream system would be included in the load estimates from forest, urban, and agriculture.

Wildlife is also a potential source of nutrients in the WFWR watershed, but their input is assumed to be low compared to the other sources evaluated. At the site where ADEQ conducted monitoring activities on the forested area in the Buffalo River watershed in North Arkansas, previously mentioned, project team members frequently observed or saw signs of a variety of wildlife including deer, birds, squirrels, raccoons, etc. The nutrient export numbers presented for forested areas include the various nutrient sources in a forested environment including leaf litter decay, atmospheric deposition, and nutrients from wildlife. Because of their large size and flocks, Canadian Geese can be a concern, but the project team did not observe them to be frequent visitors in the watershed.

5.2.7 Nutrient Load Summary, Sources-Causes, and Reduction

The estimated nutrient loads for identified potential sources associated with land uses are presented in Table 5-28. ***Once again, the project team wants to make the point that these values are estimates only and are for planning purposes only. As more data, methods, and information become available, these values should be updated.*** The total phosphorus load estimated was 17.4 tons per year; the total nitrogen load was 83.3 tons per year.

Table 5-28 Estimated annual nutrient loads for land uses in the WFWR watershed

Land Use	Effected Area (ac)	Estimated Annual Load for Total Phosphorus (Tons)	Estimated Annual Load for Total Nitrogen (Tons)
Pasture • **Runoff** • **Congregated cattle (10% of total cattle)**	19,413	10.2 1.1	42.7 2.9
Forest	46,539	0.8	7.8
Urban (fertilizers, yard clippings, wastewater infrastructure leakage, pets, litter, etc.)	9,710	3.8	25.3
Permitted Facilities: • WF-WWTP	N/A	0.9	3.2
Septic Tanks	N/A	0.5	1.2
Other Sources • **Golf course**	110	0.05	0.2

Pasture: The phosphorus and nitrogen loads estimated for pasture was 10.2 and 58.2 tons/year, respectively, over 19,413 acres. The critical areas for nutrient loads from pasture would be similar to the areas critical for erosion, pastures with an average slope of 8% or greater. It is recommended that BMPs be focus in these areas, but for nutrients, it is important that manure and fertilizer application methods minimize runoff. BMPs recommended to reduce nutrients are: vegetative filters of 100 feet or more near drainage areas, where manures and fertilizers are not applied; increasing infiltration rates; not applying manures on slopes of 15% or greater; adjusting application rates to minimize over-application of phosphorus; applying manures and fertilizers during the time of year for optimum forage growth; and promoting forage growth all year. Also, nutrient inputs can be reduced by minimizing the time cattle spend near drainage areas by providing alternative watering and shade sources away from the drainage areas. Pasture renovation should be considered, also.

Forest: Most of the forest in the watershed remains undisturbed and the estimated values of 0.8 tons of phosphorus and 7.8 tons of nitrogen represent the background levels you would expect from the acres of forest in the watershed.

Urban and Construction: The urban land use of the watershed was 12.2% of the total area. The estimated nutrient loads load for urban land use was estimated to be 3.8 and 25.3 tons of total phosphorus and nitrogen, respectively. It is recommended that public outreach on reducing nitrogen and phosphorus contributions from urban areas be conducted.

Permitted Facilities: Facilities that have NPDES permits are required by law to meet the conditions stated in the facility permit. Any additional measures taken would be performed on a voluntary basis by the facility as a pollution prevention effort. Additional phosphorus treatment could be incorporated into the WF-WWTP to reduce effluent concentration to 1 mg/L; however, such an upgrade would likely be prohibitively expensive.

Septic Tanks: There are 1400 septic systems in the watershed and nutrient inputs from these systems are a concern. Conservative estimates indicate that the load of phosphorus from failing septic systems could be as high as 0.5 ton/yr. It is recommended that the condition of septic systems in the watershed be evaluated and this potential source be further evaluated.

Other Sources: The golf course was the only other source that was considered significant. Reducing nutrient loads from the golf course could be easily done by providing information and training to the facility.

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5.3. Other Potential Sources of Contaminants

Sources of contamination that can be addressed on watershed basis have been discussed in Sections 5.1 and 5.2 of this report. As with any watershed that has a variety of land use and including an urbanized area, the WFWR watershed has other potential sources of contaminants that can impact surface and ground waters. These other sources of contaminants, including industrial facilities, factories, and commercial services, such as, dry cleaners, auto-body shops, are mainly located in Fayetteville and along Highway 71. Most of these sources would need to be addressed on a site-by-site basis if a problem is identified, but it is important in performing any watershed assessment to list as many of the potential sources of contamination as possible.

Potential sources of contamination (PSOCs) were originally defined by the EPA Office of Ground Water and Drinking Water. The Arkansas Department of Health - Source Water Protection Team refined and identified PSOCs for drinking water supplies in the state (ADH-DOE, 2001). The locations of PSOCs were ground truthed in 2001 by the Arkansas Water Resource Center. Based on this data there are 561 PSOCs in the WFWR watershed. Ground truthing showed 499 sources were active, 62 were inactive (though still potential sources).

The Arkansas Department of Health assigned health risk codes (HRC) to each source based on the risk presented to (1) surface water and (2) ground water. HRC range from 1 to 10, with 1 implying high risk assessment and 10 implying low risk assessment. Table 5-29. shows the number of sources in each HRC. For surface water, HRC ranged from 1 to 6. There were 50 high risk sources (HRC = 1), including industrial plants, factories (food processing plants), and commercial services (dry cleaners, auto-body shops). Figure 5-33 shows the locations of the surface water PSOCs. For ground water, HRC ranged from 1 to 8. There were 82 high risk sources (HRC = 1), including leaking underground storage tanks and all of the above surface water sources. Figure 5-34 shows the locations of the ground water PSOCs.

Table 5-29 Number of potential sources assessed for each Health Risk Code (HRC). (ADH-DOE, 2001)

	HRC	No. Surface Water PSOC	No. Ground Water PSOC
high risk	1	50	82
	2	40	326
	3	90	57
	4	51	22
	5	306	2
	6	24	64
	7	0	2
	8	0	6
	9	0	0
low risk	10	0	0
	Total	***561 PSOC***	

Figure 5-33 Location of potential surface water contaminants in WFWR (ADH-DOE, 2001)

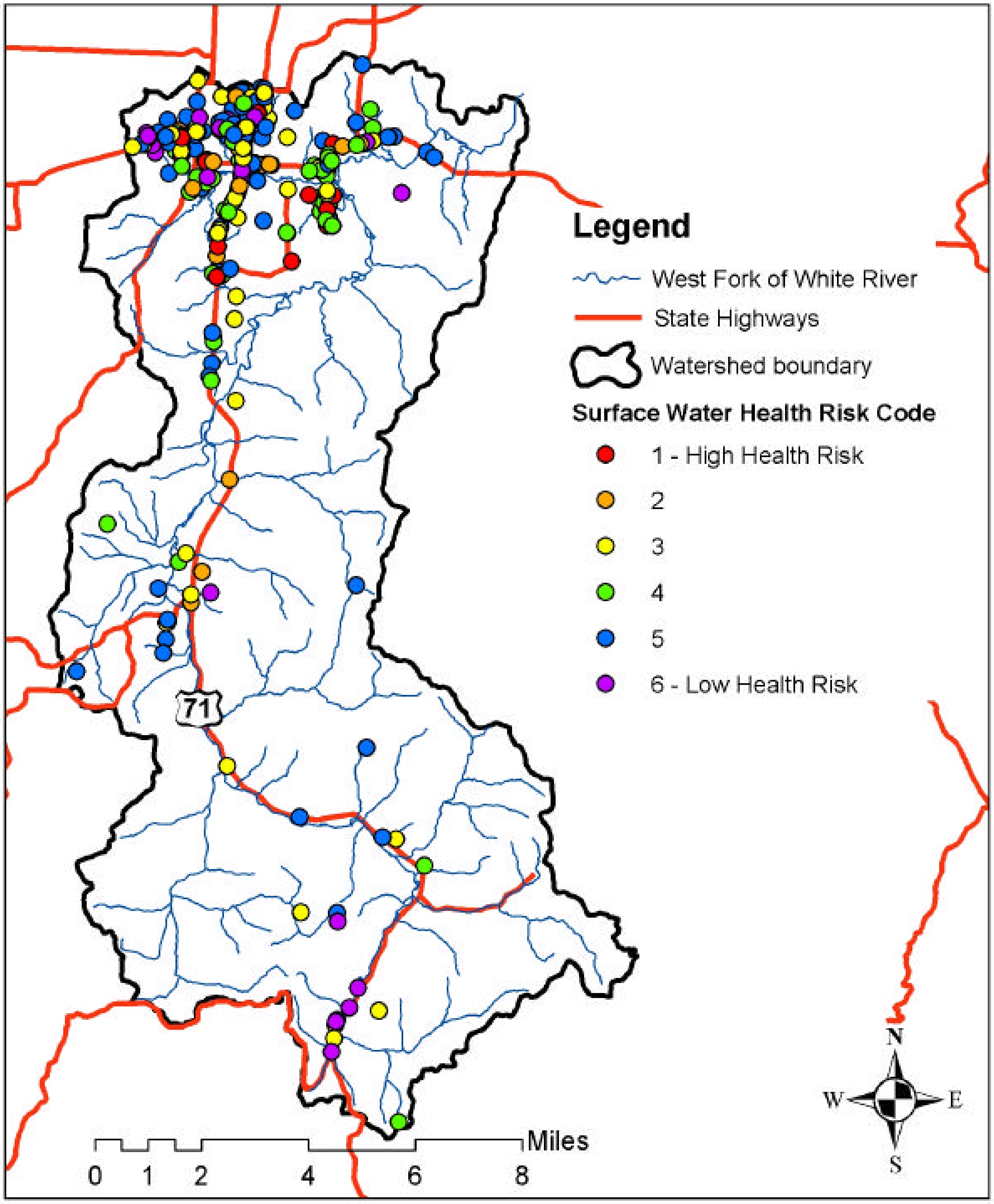
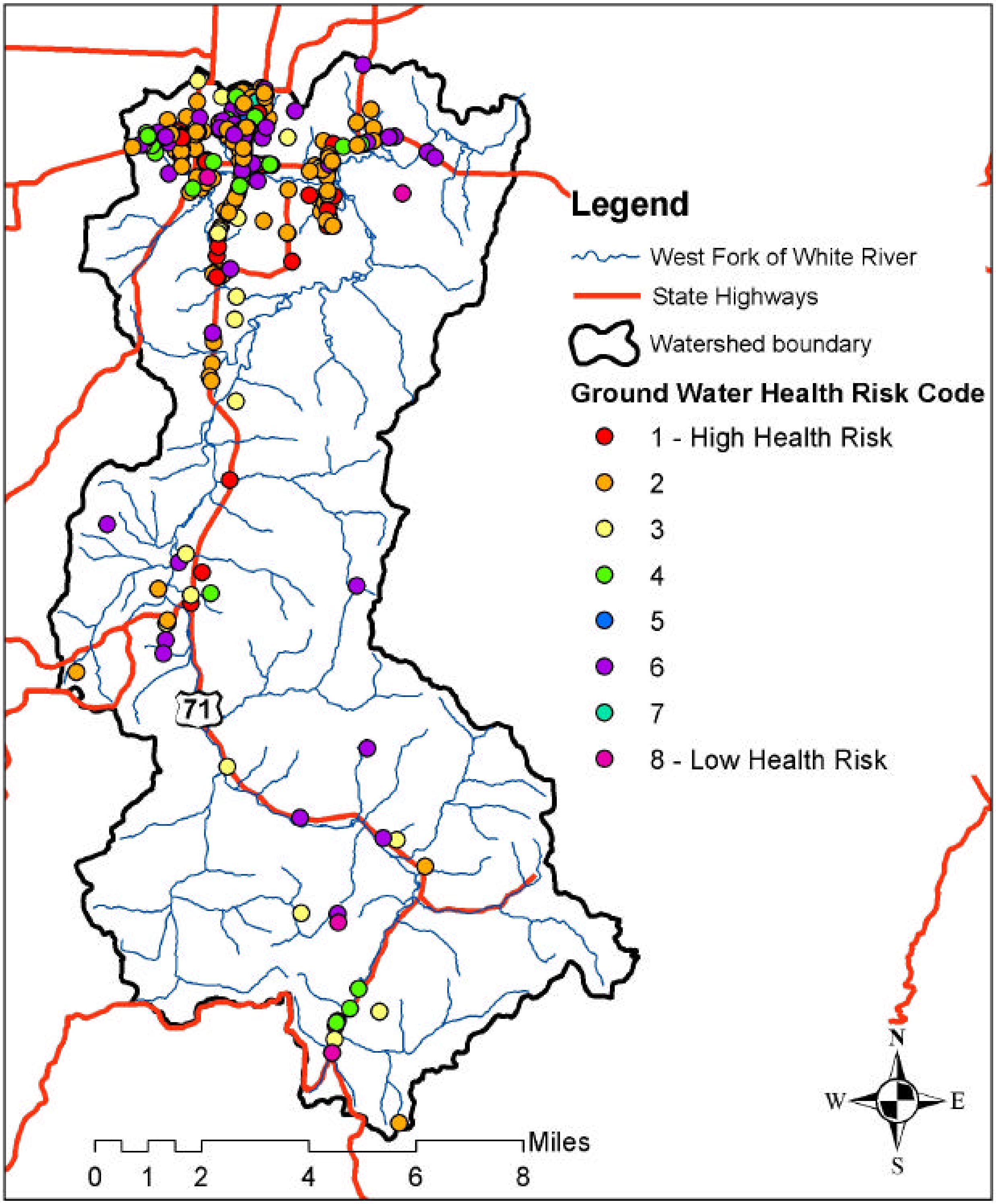


Figure 5-34 Location of potential ground water contaminants in WFWR (ADH-DOE, 2001)



5.3.1 Hazardous Substances

Originally known as Plating Park Incorporated, R & P Electroplating operated as a metal plating facility from 1974 to until it closed in 1997. R & P's function was to electroplate chromium, zinc, silver, nickel, tin, brass, and copper on various products manufactured elsewhere. The five building, 45,000 square foot manufacturing facility sits on a 5.77 acre site at 2000 Pump Station Road, adjacent to the West Fork of the White River. Currently, the site is abandoned and the immediate area around the buildings is fenced and locked. Because of the nature of the contaminants and the levels of contamination at the site, the project team felt a summary of the information of this facility should be included in this assessment.

In August of 1998, the inactive R & P facility was vandalized and an undetermined amount of various hazardous substances were released. The Hazardous Waste Division of ADEQ conducted a Brownsfield Assessment in 2000 and a groundwater sampling event of the site in 2003. The 2003 report also included a brief history of the site and the results of samples taken in 2000. The following two paragraphs are a short summary of the 2003 report. In January of 1999, the EPA's START (Superfund Technical Assessment and Response Team) provided removal support at the site. Approximately 42,081 gallons of liquid waste and 410,200 pounds of solid/sludge were removed from the site and deposited at an out of state hazardous waste-disposal facility. In May of 2000, a targeted Brownsfield Assessment was conducted by ADEQ. This study concluded that soils at the facility contained elevated levels of arsenic, chromium, copper, nickel, lead, and zinc. Soil boring samples indicated that concentrations were above DAF 10 (dilution-attenuation factor) for 1,1-dichloroethene, 1,1,1-trichloroethene, beryllium, cadium, chromium, and nickel (ADEQ 2003).

ADEQ performed a subsequent sampling event from the site's five monitoring wells in September of 2003. Analysis of the groundwater samples indicated that concentrations were above the EPA Maximum Contaminant Levels (MCL) for vinyl chloride, trichloroethene, cis, 1,2-dichloroethene, 1,1,1-trichloroethane, 1,1-dichloroethene, 1,2- dichloroethane, benzene, 1,2,4-trichlorobenzene, beryllium, cadmium, and chromium. Prior to sampling activities, groundwater elevations were measured and they indicated that groundwater flow was toward the West Fork of the White River. This sampling event showed that the condition of the groundwater has been seriously impacted by the electroplating operation. The 2003 results showed that the condition of the groundwater had continued to worsen since the 2000 sampling event or that the 2000 samples were not a representative groundwater sample due to the groundwater not having enough time to flow through the sand pack of the recently installed monitoring wells (ADEQ 2003).

The R & P site is on the State Priority List in chapter three of APC&EC Regulation No. 30. Regulation 30 is the "Arkansas Remedial Action Trust Fund Hazardous Substances Site Priority List." As defined in chapter 3, "Hazardous substance sites listed in the chapter are those which pose a potential substantial endangerment to human health and/or the environment, but which do not meet the criteria for listing on the National Priority List. These sites have been designated as eligible for State-funded investigation and necessary remedial actions on a case-by-case as determined by the Director. Criteria for listing a particular site is governed by APC&EC Regulation No. 23 §§ 26 (g), 26 (h), and 26 (i)."

5.4 References

1. Arkansas Department of Environmental Quality. Ground Water Sampling Event & Site Conditions Dated 9/02/03 and 9/03/03. R & P Electroplating, Inc, Fayetteville, AR. 2003.

2. Arkansas Department of Environmental Quality, Environmental Preservation Division. Arkansas Watershed Planning Guide. Available ADEQ Manual developed under a USEPA Section 104(b) (3) grant. September, 2003.

3. Arkansas Department of Environmental Quality, Environmental Preservation Division. Demonstration of Pasture Renovation to Reduce Phosphorus and Nitrogen Runoff from Fields Fertilized With Animal Manure. October 2004.

4. Arkansas Department of Environmental Quality, Environmental Preservation Division. Included as course materials for Applied Fluvial Geomorphology training course, Fayetteville, AR, 2002.

5. Arkansas Department of Environmental Quality. Integrated Water Quality Monitoring and Assessment Report. Agency Report Prepared pursuant to Section 305(b) and 303(d) of the Federal Water Pollution Control Act. Agency Report. 2002.

6. Arkansas Dept. of Health. Department of Engineering-Source Water Protection Program. Complete report available in house. http://www.healthyarkansas.com/eng/swp/swapexsum.htm

7. Arkansas Department of Pollution Control and Ecology. Water Quality, Macroinvertebrate, and Fish Community Survey of the Upper White River Watershed. Agency Study and Report. August, 1995.

8. Arkansas Forestry Commission. Best Management Practices for Water Quality Protection. The Arkansas Forestry Commission. March 16, 2002.

9. Arkansas Plant Board, Statistics for Fertilizer use 2002-2003, 2004.

10. Asbury, C.E., E.T. Oaksford. 1997. A Comparison of Drainage Basin Nutrient Inputs with Instream Nutrient Loads for Seven Rivers in Georgia and Florida, 1986-90. USGS Water-Resources Investigations Report 97-4006.

11. Bartholomew, Michael. Personal Communication. 2004. West Fork Waste Water Utility Manager. City of West Fork.

12. Beaulac, M.N., and K.H. Reckhow. An examination of land use – Nutrient export relationships. Water Res. Bull. 18:1013-1024. 1982.

13. Brye, K.R., T.L. Morris, D.M. Miller, S.J. Formica, M.A. Van Eps. 2004. Estimating bulk density in vertically exposed stoney alluvium using a modified excavation method. J. Environ. Qual. In Press.

14. Benson, Dennis. Water Division Enforcement Coordinator. Morgan, Don. Water Division Field Inspector. Personal Communication. Arkansas Dept. of Environmental Quality. 2004.

15. Charles R. Meyer. Personal communication. Information Technology Specialist, National Soil Erosion Research Laboratory, USDA-ARS, West Lafayette, IN. 2004.

16. Clingenpeel, A., K. Whitsett. Personal Communication. Methods and assistance for performing watershed roadway inventory and integrating with the WEPP: Road model. 2004.

17. Dissmeyer, G. E. and R. F. Stump. Predicted erosion rates for forest management activities in the southeast. 1978.

18. Edwards, Findlay G., Stormwater Pollution Prevention BMP Workshop, Demonstration, and Evaluation, Project 700 FY01 CWA Section 319(h). Final Report. Arkansas Soil and Water Conservation Commission. 2003.

19. Elliot, W.J., D. Hall and D. Schelle. WEPP: Road (DRAFT) - Interface for Predicting Forest Road Runoff, Erosion and Sediment Delivery, Technical Documentation. U.S.D.A. Forest Servie. Rocky Mountain Research Station and San Dimas Technology and Development Center. December, 1999.

20. "Erosion". U.S. E.P.A. June 7, 2004. <http://www.epa.gov/owow/watershed/wacademy/wam/erosion.html>

21. Fogg, Jim and Wells, Gary. Stream Corridor Restoration: Principles, Processes, and Practices. USDA, USEPA, TVA, FEMA, USDC, USDD, USDHUD, USDI. October 1998.

22. Fuller, Kim. Personal Communication. NPDES Storm Water Engineer. ADEQ. Little Rock, AR. 2004.

23. Gillingham, A.G. and B.S. Thorrold. A review of New Zealand research measuring phosphorus in runoff from pastures. J. Environ. Qual. 29:88-96. 2000.

24. Glen Laurent. Personal communication. Resource Soil Scientist, NRCS, Fayetteville, AR. 2004.

25. Hem, J.D. Study and Interpretation of the Chemical Characteristics of Natural Water. U. S. Geological Survey, Water-Supply Paper 2254, 253. 1989.

26. Jassby, A.D., Atmospheric Transport and Deposition of Nitrogen and Phosphorus, Center for Ecological Health Research, University of California Davis, 2003.

27. Kresse, Tim. Personal Communication. Water Division. ADEQ. 2004.

28. Levins, Bob. Arkansas Forestry Commission. Personal Communication. June 7, 2004.

29. Maner, Martin. Personal Communication. ADEQ Water Division Chief. Arkansas Dept. of Environmental Quality. 2004.

30. Melvin L. Warren, Jr. and Mitzi G. Pardew. Road Crossings as Barriers to Small-Stream Fish Movement. 1997. <http://www.srs.fs.usda.gov/pubs/viewpub.jsp?index=762>

31. National Atmospheric Deposition Program. Fayetteville, Arkansas Monitoring Station Data. <http://nadp.sws.uiuc.edu/>. 2004.

32. Pickup, B.E., W.J. Andrews, B.E. Haggard, and W.R. Green. Phosphorus concentrations, loads, and yields in the Illinois River Basin, Arkansas and Oklahoma, 1997-2001. U.S. Geological Survey Water-Resources Investigations Report 03-4168. 2003.

33. Robertson, D.M. Sources and Transport of Phosphorus in the Western Lake Michigan Drainages, USGS Fact Sheet FS-208-96. 1996.

34. Roehl, J. W. Sediment source areas, delivery ratios and influencing morphological factors. International Assoc. of Scientific Hydrology. 59 (202-213). 1962.

35. Rosgen, David L. The Use of Color Infrared Photography for the Determination of Suspended Sediment Concentrations and Source Areas. In: Proceedings of the Third Inter-Agency Sediment Conference, Water Resources Council. Chap. 7, 30-42. 1976.

36. Schueler, T. R. and H. K. Holland. The Practice of Watershed Protection. Center for Watershed Protection. 2000.

37. Sharpley, A.N., S.J. Smith, O.R. Jones, W.A. Berg, and G.A. Coleman. The transport of bioavailable phosphorus in agriculture runoff. J. Environ. Qual:21:30-35. 1992.

38. Smith, S.J., A.N. Sharpley, W.A. Berg, J.W. Naney, and G.A. Coleman. Water quality characteristics associated with southern plains grasslands. J. Environ. Qual. 21:595-601. 1992.

39. Starrett, S. Comparing Nutrient Losses Via Runoff from a New Golf Course and the Golf Course Site's Previous Native Condition. USGA Turfgrass and Environmental Research Summary. 2001.

40. Troxel, Tom. Personal Communication. University of Arkansas Cooperative Extension Service (UA-CES). Little Rock, AR. 2004.

41. United States Army Corps of Engineers. Arkansas state water plan: Upper White River basin/prepared for Arkansas Soil and Water Conservation Commission. Little Rock, AR. 1988.

42. United States Department of Agriculture. State Soil Geographic (STATSGO) Data Base. Natural Resources Conservation Service. 1994.

43. United States Department of Agriculture. Water Erosion Prediction Project Hillslope Profile and Watershed Model Documentation. NSERL report #10. 1995.

44. United State Environmental Protection Agency, STEPL – Spreadsheet Tool for Estimating Pollutant Loads, 2003.

45. United State Environmental Protection Agency, National Management Measures to Control Nonpoint Pollution from Agriculture. EPA-841-B-03-004. July 2003.

46. University of Arkansas Cooperative Extension Service (UofA-CES). Arkansas Grazing Manual. 2002.

47. University of Arkansas Cooperative Extension Service (UofA-CES). Final Report: Agricultural Best Management Practice Education and Training. 319 Incremental Funding for Beaver Lake Watershed. Grant #C99610307. Project 1100. 2004.

48. USDA NRCS. Agricultural Waste Management Field Handbook. National Engineering Handbook. Part 651. April 1992.

49. Wildland Hydrology, Inc: Research and Educational Center for River Studies. River Assessment: Field Book. Pagosa Springs. 2001.

Appendix – ES

Paper presented and prepared for the ASAE Conference
"Self-Sustaining Solutions for Streams, Wetlands, and Watersheds"
St. Paul, Minnesota, September 12-15, 2004

WEST FORK WHITE RIVER WATERSHED - SEDIMENT SOURCE INVENTORY AND EVALUATION

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ABSTRACT

Understanding the causes and sources of our water quality problems is critical to developing practical solutions and long-term strategies that can result in watershed restoration. The West Fork of the White River (WFWR) located in Northwest Arkansas has been identified by the Arkansas Department of Environmental Quality (ADEQ) as an impaired stream and has been placed on the Arkansas 303 (d) list, because its "aquatic life" use designation was not being supported due to "high turbidity levels and excessive silt loads." Through the U.S. Environmental Protection Agency's (EPA) 319 grant program, which is administered by the Arkansas Soil and Water Conservation Commission, a comprehensive watershed assessment has been performed to identify probable sources of point and non-point source contamination and to estimate pollution potential of identified sources. An extensive compendium of field and GIS data along with modeling methods were used to estimate sediment source loads from streambank erosion, roads, pastures, and other land uses in the watershed. The WFWR watershed average annual sediment load from these sources was estimated to be 35,795 tons. 26,566 tons per year were particles with a diameter of less than or equal to 2 mm. Sediment from streambanks showing indications of accelerated erosion; roadways & ditches; urban area (including construction); pasture area; and other sources were found to contribute 66.1%, 17.1%, 10.9%, 4.8%, and 1.1%. Also, a long-term, strategic water quality monitoring program strategy was initiated that included the installation of a continuous water quality monitoring station and the collection of baseline data near the mouth of the river. Data collected at the monitoring station included flow; turbidity; and total suspended solids (TSS). The average TSS load for 2002 and 2003 was 14,870 tons/yr, and applying the WFWR TSS - Suspended Sediment concentration (SSC) relationship (developed from this study) resulted in an average annual SSC load of 21,690 tons/yr. The estimated SSC load based on the water quality data for the WFWR is 82% of the study estimated sediment load of 26,566 tons/yr (particles less than or equal to 2 mm) from the watershed assessment. The results of this study are being used by a local stakeholder group to prioritize source reduction efforts and to develop restoration strategies as part of a WFWR watershed management plan.

KEYWORDS. Sediment, watershed assessment, sediment sources, erosion, sediment loads, land use

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Introduction

Understanding the causes and sources of water quality problems is critical to developing practical solutions and long-term strategies that can result in watershed restoration. The West Fork White River (WFWR) is located in Northwest Arkansas and is a major tributary of Beaver Lake, which is the primary drinking water source for over 300,000 people in Northwest Arkansas (Fortenberry, 2004). Both the WFWR and Beaver Lake watersheds are located in the Beaver Reservoir Hydrologic Unit Area (HUA) – 11010001 as shown in Figure 1. The State Water Quality Inventory Report of 1998, prepared by the Arkansas Department of Environmental Quality (ADEQ) pursuant to section 305(b) of the Federal Water Pollution Control Act, had assessed aquatic life use as "not supported" in 33.4 miles of the WFWR. The major causes cited were 'high turbidity levels and excessive silt loads.' The probable sources listed were: (1) agricultural land clearing; (2) road construction and maintenance; and (3) gravel removal from stream beds. The ADEQ has designated the WFWR as impaired and added it to the State's 303(d) list (ADPC&E, 1998).

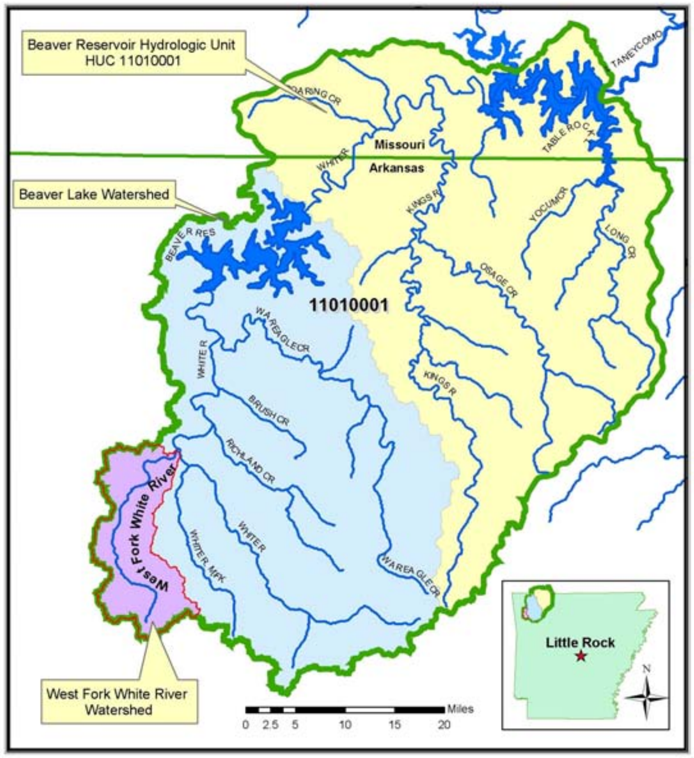


Figure 1. Location of the West Fork White River Assessment Project, Beaver Lake Watershed, Beaver Reservoir HUA

As part of a watershed-based assessment of the WFWR, conducted from October 1999 through June 2004, an evaluation of sources of sediment loads in the watershed that could contribute to the "high turbidity levels and excessive silt loads" was performed. The WFWR watershed assessment was funded by a U.S. Environmental Protection Agency (EPA) 319 grant through the Arkansas Soil and Water Conservation Commission (ASWCC). The watershed assessment included evaluations of other water quality contaminants, but this paper presents only the results of the sediment evaluation. Potential sources of sediment were identified, and their pollution potential was estimated using field, GIS, water quality, and other environmental data along with modeling methods. Also, the Arkansas Water Resource Center (AWRC) installed a continuous water quality monitoring station just above the confluence of the WFWR with the White River to collect water quality and flow data, so that annual loads of contaminants could be estimated and to collect baseline water quality data that could be used for future evaluation of restoration efforts and management practices implemented.

The results of this study are being used by a local stakeholder group for planning purposes, which includes the development of restoration strategies as part of a WFWR watershed management plan. The intent of the watershed planning is to direct available resources to problem areas where the greatest benefit to the watershed will occur.

WFWR Watershed Description and Land Use Analysis

The WFWR watershed has an area of approximately 124 square miles and is nestled in the Boston Mountains of Washington County (Figure 2). The watershed is in large part, steep and stony and lies in two of the ecoregions found in Arkansas, the Boston Mountains and the Ozark Highlands. Elevations in WFWR watershed range from 1,136 to 2,248 feet. The watershed includes the cities of West Fork, Greenland, and Winslow, along with the southwest corner of the city of Fayetteville.

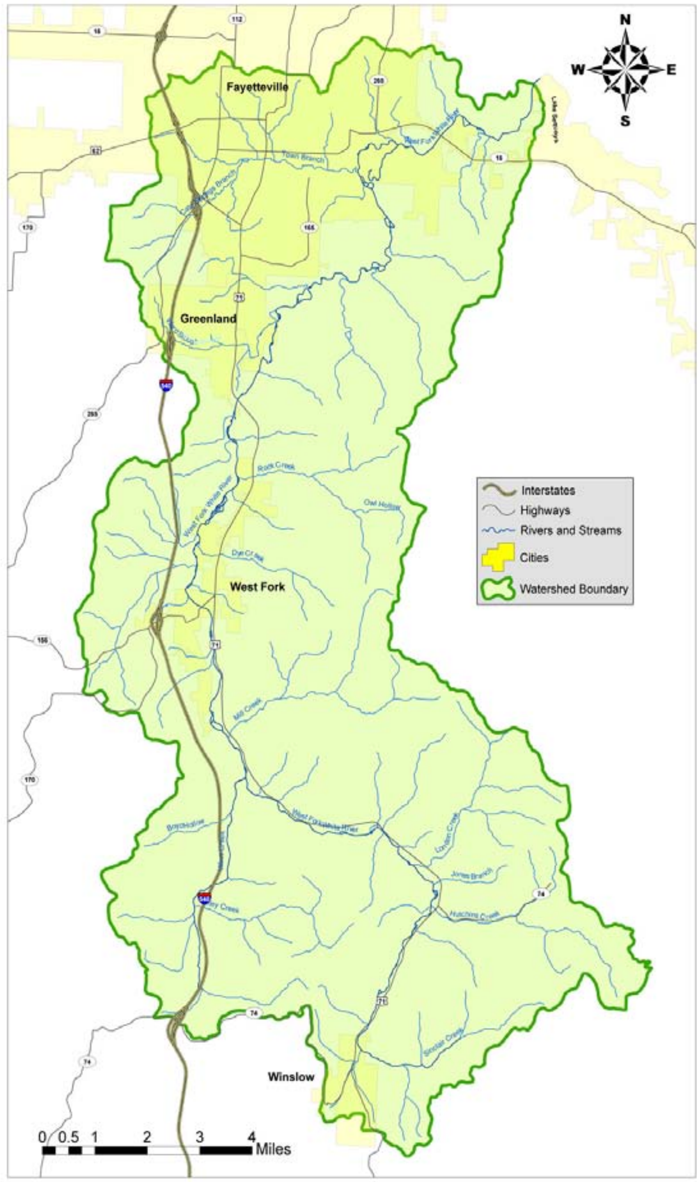


Figure 2. The WFWR watershed in Northwest Arkansas

Historically, the WFWR had been used as a drinking water source, as well as for recreation by the local people. The river was known for its deep swimming holes and the quality of its smallmouth bass fishery. Around the turn of the 20^{th} century, the watershed' s virgin timber became a major source of railroad ties and other wood products and much of the cleared land was used for row crop farming. Today, agricultural land is used mostly for poultry production, cow-calf operations, and forage production. With the 2000 U.S. census identifying Northwest Arkansas as one of the fastest growing populations in America (US Census, 2000), the newest challenge the watershed faces is the expansion of its urban areas.

GIS data was collected and developed in order to characterize land use in the WFWR watershed. Land use delineation was performed using 1994 and 2000 digital ortho-quarter quads (DOQQ). A land use classification system was developed by modifying the Anderson Classification system to include land uses specific to the WFWR watershed and that were of interest to this study. Using the watershed boundary and DOQQs, heads-up digitizing of the watershed land use was performed by zooming to a visible scale on the DOQQs and drawing polygons around separate land use areas. Also, a literature search revealed a 1977 analysis of the WFWR watershed, in which land-use was evaluated by driving through the watershed and visually assessing each site (Gilliam, 1977). Areas were then hand calculated using United States Geological Survey (USGS) topographic maps. Though the 1977 analysis may not be as precise as the 1994 and 2000 analyses, the 1977 data allow assessment of the general land-use changes over a 23 year period.

The WFWR watershed covers approximately 79,628 acres of land. For comparative purposes, the land use for all three years was classified into three general categories: urban, agriculture, and forest. The results of the three land use analyses are shown in Table 1. The results of the detailed analyses of 1994 and 2000 can be found in the project report (ADEQ, 2004). The urban area in the WFWR watershed increased from 9.8% of the total area in 1977 to 12.2% in 2000; most of that increase occurred between 1994 and 2000. The amount of agricultural land has also increased, with the largest change occurring between 1977, 24.5% of the total area, and 2000, 30.7% of the total area. Subsequently, during that same time period, the forest land area in 1977 decreased from 65.7% of the total area to 59.3% in 1994.

Table 1. Land Use Summary for the WFWR Watershed.

Land Use	***1977*** (Gilliam, 1977)	***1994***	***2000***
Urban	9.8%	10.0%	12.2%
Agricultural	24.5%	30.7%	29.3%
Forest	65.7%	59.3%	58.5%

Sediment Sources and Load Estimates

High turbidity values and siltation are listed by the ADEQ as the cause of impairment for the WFWR (ADEQ, 1998). Turbidity and siltation can be associated with sediment entering the stream system; therefore, potential sources of sediment were identified and sediment loads from these sources were estimated using field data, prediction models, erosion coefficients and water quality data from the literature. Sources evaluated included pastures; forests and forest conversion; urban areas and construction; NPDES (National Pollutant Discharge Elimination System) permitted facilities; roadways, ditches and Interstate 540 (I-540) corridor gullies; and streambank erosion caused by riparian removal, channel alteration, and increased runoff. The sediment loads in this study are estimates of the annual average mass of sediment delivered to the stream and, generally, represent particles equal to or less than 2 mm in size. Sediment loads having particle sizes greater than 2 mm are presented in some cases. It should be noted that the sediment load estimates were generated for planning purposes only, and as more information, data, and methods become available, the load estimates should be updated.

Watershed Evaluation of Sediment from Pasture: Soil erosion from pasture lands in the WFWR watershed was considered a potential source of sediment. Highly erodible soils and steep slopes, which are both present in the WFWR watershed, will generate greater sediment loads from erosion of pasture lands. Based on the 2000 land use analysis, the WFWR watershed contains 19,413 acres of pasture land, with average slopes ranging from 0% to 38%. The States Soil Geographic (STATSGO) database, a general soil layer digitized by the United State Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) at a 1:250,000 scale, was used to describe the soils (USDA, 1994). The STATSGO layer was chosen to simplify the modeling process. The NRCS generalized the soil types within the WFWR into three STATSGO soils: Enders, Linker, and Clarksville.

The Watershed Erosion Prediction Project (WEPP) model, hill slope version, was used to estimate soil loss from pastures in the WFWR watershed. The WEPP model can estimate soil loss spatially (at a given point on the hill slope) and temporally (on a daily, monthly, or annual basis). The WEPP hill slope model is process-based, simulating rill and inter-rill erosion, sediment transport and deposition, infiltration, residue and canopy effects on soil detachment and infiltration, rill hydraulics, surface runoff, plant growth, residue decomposition, percolation, evaporation, transpiration, climate, and other processes (USDA, 1995). Required inputs for the hill slope model are; pasture management practices and slope profile (consisting of distance and slope between points on a hill slope and field width). Soil properties and climate station data are also required, but WEPP has built-in databases for both. Assistance in developing this model for the WFWR pastures was provided by USDA Agriculture Research Services (ARS) (Meyer, personal communication, 2004).

Applying the WEPP hill slope model to every pasture in the WFWR watershed would have been time consuming and tedious, and would not have, necessarily, yielded more accurate soil loss estimates from pastures. The most sensitive input variables in the WEPP hill slope model are land management, slope, soil type, and slope length. Since pastures in the WFWR watershed are managed similarly, a single management was chosen to represent all pastures. The average slope of each pasture was determined using DEM data. For screening purposes, a soil loss coefficient was calculated for a generic, square pasture for each slopes ranging from 1% to 30% at one unit intervals. The results showed that the soil loss coefficient increased proportionally to percent slope. Therefore, it was decided to group the pastures in the WFWR into categories based on average slope and soil type. Representative pasture(s) for each slope category and soil type (minimum of 10% of the total acres) were modeled, and the estimated soil loss coefficient was applied to the entire pasture area for each slope category and soil type. For the WFWR watershed, landscape dimensions, such as slope length, were limited within the slope categories selected for the model. It was assumed, that average slope length for the pastures modeled represented typical values for each slope category and soil type.

Table 2 shows the slope class, soil type, and the number of acres in each slope category - soil type for the WFWR pastures. A minimum of 10% of the area in each slope category was modeled, and at least one model run was made for each soil type in the slope category. Each selected pasture was divided into different flow areas based on the topography of the pasture. For example, if a modeled pasture had nine separate flow areas, it would require nine WEPP model runs. Spatially separated flow areas with similar slope lengths and the same soil type were combined into one model run. The field width of the composite slope profiles was defined as the sum of the widths of each similar flow area. Arc View was used with a DEM for the area to determine the slope, field width, and buffer lengths. A slope profile was developed in the WEPP model for each flow area in the pasture. Details on the other methods and assumptions used to simulate modeled pastures and estimate average annual soil loss can be found in the project report (ADEQ, 2004).

The amount of sediment actually delivered to the WFWR is less than the soil loss from pastures due to further deposition and settling that occurs within the system. Roehl' s work indicated that there is a relationship between the amount of soil loss and the amount of sediment delivered to the stream based on watershed characteristics in southeastern states (Roehl, 1962). According to this research, 7% of the soil loss will actually be delivered to the WFWR. The sediment delivered to the WFWR for each slope-soil category was calculated by first multiplying the soil loss coefficient by the total area of pasture with the same soil and slope conditions. This value was then multiplied by 0.07 to estimate the amount of sediment delivered to WFWR from pastures.

Table 2. Sediment load estimate from pasture lands in the

Slope Class	Soil Type	Area (ac)	WEPP Soil Loss Coefficient (ton/ac/yr)	Soil Loss (tons)	Sediment Delivered to WFWR (tons)	% of Total Sediment Load
0 - 2%	Enders	1372	0.083	113	8	0.5%
2 - 4%	Enders	3291	0.25	742	52	3.0%
	Linker	32	0.20	6	0.5	0.0%
	Clarksville	207	0.47	97	7	0.4%
4 - 6%	Enders	2960	0.42	1,255	88	5.1%
	Linker	328	0.89	292	20	1.2%
	Clarksville	200	0.79	158	11	0.6%
6 - 8%	Enders	2273	0.99	2,144	150	8.8%
	Linker	541	0.27	145	10	0.6%
	Clarksville	154	0.88	135	9	0.6%
8 - 10%	Enders	3235	1.5	5,005	350	**20.5%**
	Linker	471	0.29	134	9	0.6%
10 - 13%	Enders	2008	2.5	5,082	356	**20.8%**
	Linker	87	0.29	25	2	0.1%
13 - 16%	Enders	1507	3.9	5,921	414	**24.3%**
	Linker	152	1.00	152	11	0.6%
16 - 19%	Enders	397	5.1	2,023	142	8.3%
	Linker	20	0.69	14	1	0.1%
>19%	Enders	182	5.3	963	67	3.9%
	Totals	19,413		24,408	1,709	100.0%

A total of 23 pastures were modeled with 88 separate flow areas. Soil loss coefficients, soil loss, and sediment loads for each slope category and soil type are shown in Table 2. The average area-weighted soil loss coefficient for the WFWR watershed was 1.3 tons/acre/year. Sediment loss rates ranged from 0.083 to 5.3 tons/acre/year. The five largest soil loss rates were associated with Enders soil on slopes from 8% to greater than 19%. The total soil loss for pasture areas of the WFWR was estimated to be 24,408 tons/year. Applying Roehl's delivery ratio of 7% (Roehl, 1962) to the annual soil loss, the sediment delivered to the WFWR from pasture erosion was estimated to be 1,709 tons/year. The three largest sediment loads are contributed from pasture groups on Enders soil with slope categories 13-15.99%, 10-12.99%, and 8-9.99%. These areas constitute only 35% of the total pasture area in the watershed, but they contribute 66% of the sediment load to the system from pastures.

Watershed Evaluation of Sediment from Forest Land and Associated Harvest: Forested lands and associated harvesting of forest in the WFWR watershed were considered potential sources of sediment. The WFWR land use delineated from 2000 DOQQs showed the watershed was 58.5% forest. The total annual sediment yield from standing forest was estimated using an erosion rate for a natural forest of 0.12 ton/acre/year (Dissmeyer and Stump, 1978) and applying Roehl's (1962) findings for sediment delivery for an estimated sediment yield of 0.0084 tons/acre/yr. The sediment load from the watershed's 46,539 acres of forest was estimated to be 391 tons/year. Sediment contributions from forested areas is considered to be part of a watershed's natural erosion process, but harvested forest areas, especially, on highly erodible soils and steep slopes, which are both present in the WFWR watershed, can result in excessive amounts of sediment entering into the system. The erosion coefficients for logged forest land in the Boston Mountains ranged from 0.15 to 15.8 tons/acre/year with an average value of 1.08 tons/acre/year (Dissmeyer and Stump, 1978). A land use comparison from 1994 to 2000 showed 659 acres of forest was converted to other land uses during the six year period, or about 110 acres/year. Using Dissmeyer and Stump (1978) and Roehl's (1962) findings, the sediment load for forested areas that were converted to other land uses was 8 tons per year.

Watershed Evaluation of Sediment from Urban Areas and Construction Sites: Activities in the urban environment can contribute to overall sediment loads found in the WFWR. Suspended sediment from urban areas can come from a variety of sources including streets, lawns, landscaping, driveways, construction, atmospheric deposition, and erosion of drainage channels (USEPA, 1999). Sediment from streets and roads within the urban areas of the WFWR watershed was accounted for under "roadways and ditches." Sediment from construction and other urban sources were estimated as follows.

Sediment from urban areas, resulting from activities unrelated to construction, was estimated using data from the U.S. EPA Urban Stormwater BMP study (USEPA, 1999). The following EPA coefficients represent typical sediment loads from various urban land uses including low and medium density residential (190 lb/ac), commercial (1000 lb/ac), industrial (860 lb/ac). Using the land-use data from the WFWR land-use evaluation and coefficients presented in the EPA study, the load of sediment from urban areas excluding construction was estimated to be approximately 1,104 tons per year.

Land disturbance from urban construction sites and other disturbed areas contribute to the overall sediment load to the WFWR. Construction activities were primarily located within the northern part of the watershed, around the city of Fayetteville. Using permit records from the NPDES storm water section of the ADEQ Water Division, there was a total of 174 acres of construction sites ranging from 5 to 40.5 acres. The number of acres for sites less than five acres was estimated to be 109 acres using the land use analysis. Water quality data was collected by Edwards et al. from construction sites to determine the effectiveness of BMPs being implemented (Edwards, 2003). Average TSS values ranged from 637 mg/L to 11,217 mg/L. The average project length for the 174 acres of 5 acres or greater sites was assumed to be one year and for the 109 acres of less than 5 acres it was assumed to be 6 months.

Sites with no BMPs being implemented were regularly observed in the watershed; therefore, sediment delivered to the stream from construction was estimated based on data from sites with no BMPs. The rainfall to runoff conversion rates for construction sites was assumed to be 20%, and the average rainfall for Fayetteville is approximately 46 inches per year. Using the average TSS concentration of 11,217 mg/L of runoff, the estimated load from construction sites without BMPs was 2,787 ton/yr.

NPDES Permitted Facilities: There are two NPDES permitted facilities in the WFWR watershed, and they are required to monitor total suspended sediment (TSS) in their waste water discharged to the WFWR. Using the reported permitted data from each facility, annual loadings of TSS were estimated. For the McClinton-Anchor West Fork quarry, the mean-maximum TSS concentration, calculated from the required reporting data, is 9.04 mg/L. With a mean average flow value of 0.541 MGD, the estimated annual load was 7.5 tons/year of TSS. For the city of West Fork Waste Water Treatment Plant, an average annual TSS load was estimated to be 0.5 tons per year based upon 10 years of required reporting data. The total TSS load from permitted facilities was estimated to be 8.0 tons/year.

Watershed Evaluation of Sediment from Roadways, Ditches, and I-540 Gullies: "Gravel" or unpaved roads have been identified as potential sources of sediment that are adversely affecting water quality in the WFWR watershed (ADPC&E, 1995 and ADEQ, 2002). Poor maintenance practices of unpaved road surfaces and ditches can result in excessive amounts of sediment entering into the WFWR. The annual sediment load from unpaved and paved roads and their ditches was estimated. A comprehensive inventory of publicly owned unpaved roads and paved state highways was developed based on work performed by the United State Forrest Service (USFS), Ouachita National Forest, in Hot Springs, Arkansas (Clingenpeel, 2004). Randomly selected segments of inventoried roads were surveyed in the field for various parameters. Using the surveyed parameters, sediment yield was estimated using the web-based Forest Service (FS) WEPP model, "WEPP: Road" module (Elliot, et al, 1999). Estimates of sediment loads from residential and secondary paved roads in urban areas along with Interstate 540 (I-540) and unpaved private roads and driveways were developed based on published data for urban areas and data from the Ouachita National Forest Service (Clingenpeel, 2004). For details on methods used, data collected, and modeling performed see the project report (ADEQ, 2004).

Using data collected from the road inventory, it was determined that the majority of the variability observed between road segments was a function of the road surface and the presence or lack of ditches for a particular road segment. Therefore, road segments were grouped according to road surface type and the presence of ditches. This resulted in six unpaved "road groups," shown in Table 3. Ten percent of the segments from each "road group" were randomly selected for detailed field surveys. Paved roads included in the inventory were classified as a singular "road group." It was observed throughout the watershed that the paved roads had a uniform surface, uniform condition of the road-side ditches, and small variability of road slope; therefore, only one percent was surveyed in detail.

Table 3. Road groups included in the WFWR road inventory

Inventoried "Road Groups"
Spot (no ditch)
Spot (with ditch)
Gravel (no ditch)
Gravel (with ditch)
Native (no ditch)
Native (with ditch)
Paved

In order to model the road segments using the WEPP: Road module, extensive field measurements were made for each randomly selected road segment, such as road width, road slope, width and slope of road fill, and ditch width. The length of the road segment was divided based on the road features where the water drained from the road surface. These features included, cross-drains, wing-ditches, stream crossings, and openings or "breaks" in the berms. A model run was performed for each road segment length between water diverting features for each side. An average export coefficient for each "road group" was estimated by averaging the sediment yield for each road segment modeled from that "road group." The average sediment export coefficient was then applied to all roads in the "road group" to determine total sediment loads.

Using the road inventory and the modeling results, sediment loadings to the WFWR from public roads in the WFWR were estimated and are shown in Table 4. The average sediment export coefficient (weighted by segments for each "road group") for unpaved roads watershed was 35.9 ton/mi/yr. The sediment export coefficients for native surfaced roads were 3.1 and 4.4 ton/mi/yr, which was low compared to the other "road groups," which ranged from 21 to 55 ton/mi/yr. The total sediment load for inventoried unpaved roads was estimated to be 3,601 tons/yr. The sediment export coefficient for inventoried paved roads was 1.1 ton/mi/yr, and the total sediment load was estimated to be 122 tons/yr.

The sediment loads for other roadways not included in the inventory were estimated and are shown in Table 4. This included residential streets, secondary paved roads, unpaved driveways, and I-540. The lengths of these roads were determined using existing GIS road layer data. Using an assumed width of 30 feet and sediment export coefficient of 209 lbs/paved-acre/year (Schueler and Holland, 2000), the load was estimated to be a total of 34 tons/yr for residential and secondary paved roads. Eroding ditches were not observed for residential and secondary paved roads. However, eroding ditches were observed in several locations along I-540. Therefore, a coefficient developed by the U.S. Forest Service using WEPP on paved roads in the Boston Mountains (16 tons/mi/yr) was used to calculate sediment from I-540 (Clingingpeel, personal communication, 2004) and was estimated to be 272 tons/yr. Also, a sediment load of 899 tons per year was estimated for un-paved private roads and driveways using a length derived from existing GIS road layer data and the average unpaved road export coefficient, 35.9 ton/mi/yr, determined from this study. The total load of sediment entering streams from roadways in the WFWR watershed was estimated to be 4,928 ton/yr with unpaved roads contributing an estimated 4,500 ton/yr or 91% of the total load and paved roads contributing 428 ton/yr or 9% of the total load.

Table 4. Sediment Export Coefficients and Estimated Sediment Loads to the WFWR from Roadways & Ditches.

Road Surface	Total Miles	Estimated Sediment Export Coefficient (ton/mi/yr)	Estimated Sediment Load to Stream (ton/yr)
Unpaved Roads			
Spot (no ditch)	6.6	25	164
Spot (with ditch)	41.8	55	2,307
Gravel (no ditch)	2.1	21	43
Gravel (with ditch)	38.7	28	1,064
Native (no ditch)	2.7	3.1	8
Native (with ditch)	3.3	4.4	15
Other Unpaved*	25.0	35.9	899
		Unpaved Total	**4,500**
Paved Roads			
Paved Highways	109.2	1.1	122
Other Paved*			
Secondary & Residential	90	0.38	34
I-540	17	16	272
		Paved Total	**428**
		Total	**4,928**

* These roads were not inventoried or modeled using WEPP, and Export coefficients were based on available data.

The construction of I-540 from Winslow to Fayetteville began in 1989 and opened for traffic on January 8, 1999. Even though the construction phase of I-540 is complete, the interstate corridor remains a potential source of sediment to the WFWR. Gullies that have formed along the I-540 corridor can be easily observed when traveling between Fayetteville and Winslow. These gullies have formed in areas where streams and stormwater have been redirected and where excess cut materials have been disposed, creating large areas of steep and erodible slopes. These gullies are a source of sediment to the WFWR watershed that was accounted for in the watershed assessment.

A survey was conducted on April 27-29, 2004 to evaluate gully erosion along the I-540 corridor, which drains to the WFWR watershed. The southern half of the corridor is steep and rugged in many places as it leaves the Boston Mountains heading towards Fayetteville. The soils in this area are predominately of the Enders-Allegheny-Hector association. The Washington County Soil Survey lists the erosion hazard of this association as very severe (USDA, 1969). Due to the steep slopes and highly erodible soils in this section, the potential for excessive soil erosion is high. Identification of the gullies were primarily made from observations from the interstate and by hiking to places obscured from view. Slope measurements of gullies were taken with a handheld, line-of-sight inclinometer. The width and depth of the gullies were measured with a measuring tape, and the length was measured using a laser range finder.

Soil losses from gullies greater than 3 inches deep were calculated by estimating the volume of the gully. Gully cross sectional area was approximated by identifying the shape of the gully channel from its picture as either rectangular or triangular. The total measured gully volume in the I-540 corridor located inside the WFWR watershed was 130,248 cubic feet. The sediment load from gullies was then estimated using the bulk density of Enders soils of 1.49 g/cm^3 or 92.8 lbs/ft^3. The total sediment yield from the gullies, during the five years since the interstate opened, was estimated to be 6,040 tons. Dividing the total by five yielded an estimated average annual sediment load from gullies of 1,210 tons/year. This value would include all particle sizes from fine material to cobble. Using the stream bank material characterization results for coarse materials, approximately 20 % of this material would be less equal to or less than 2 mm. Applying this value to the average sediment yield, an average of 240 tons/year of sediment equal to or less than 2 mm in size would come from gullies.

Watershed Evaluation of Sediment from Streambank Erosion: Stream instability and resulting lateral streambank erosion was observed throughout the WFWR watershed. Accelerated lateral streambank erosion was identified as a potential sediment source in the WFWR watershed. The causes of accelerated streambank erosion in the WFWR watershed can be attributed to a number of factors, such as, removal of riparian vegetation, change in the flow regime due to increases in runoff, and channel alteration, such as gravel mining. All of these causes are complex in nature and have a cumulative effect on the stream system and, in some cases, have been occurring over decades.

Using methods proposed by Rosgen (Wildland Hydrology, 2001), both the annual bedload (particles with mean diameters greater than 2 mm) and suspended load of sediment (particles with mean diameters equal to or less than 2 mm) resulting from accelerated streambank erosion in the WFWR watershed were estimated. For details on methods used and data collected see the project report (ADEQ, 2004). The general method used to estimate sediment loads involved:

1) conducting an inventory of streambanks for erosion potential based on a bank erosion hazard index (BEHI) and the near-bank shear stress (NBSS),
2) developing streambank erosion prediction curves for the watershed (prediction curves) by measuring erosion rates at permanent survey sites representing the various BEHI and NBSS values observed during the inventory, and
3) applying the prediction curves to the streambank inventory. For details on the methods, data collected, and resulting graphical model see the ADEQ (2004) final report or Van Eps, et al. (2004) paper.

Based on the streambank inventory, the development of the erosion prediction curves, and the measurement of in-situ bulk density, an estimate of the annual load of sediment resulting from streambank erosion was generated. For the WFWR watershed, it was estimated that on an annual basis, a total of 23,650 tons of sediment enter the river network from streambanks where accelerated streambank erosion was observed. For the purpose of this paper, “natural erosion” of streambanks refers to stable banks or least disturbed watershed conditions. Natural erosion rates for the WFWR watershed were assumed to be equivalent to the BEHI-NBSS rating of low-low rate from the erosion prediction curves. Using this assumption, the sediment load for natural erosion from streambanks included in the streambank erosion inventory would be 815 tons/yr, which is 3% of the total load estimate.

Using the particle size distribution of streambank materials (Brye, et. al., 2004), bedload (greater than 2 mm) was 8,259 ton/yr and suspended load (equal to or less than 2 mm) was 15,391 ton/yr. The suspended load of sediment represented 65 percent of the estimated total sediment load. The sediment load that consisted of particles less than 0.02 mm in size was 7,234 ton/yr. Eighty percent of the estimated suspended sediment load for the watershed resulted from erosion of inventoried streambanks along the main stem of the WFWR. A reach along the main stem of the WFWR that included 0.67 mile of inventoried streambanks contributed approximately 25% of the total load of particles less than 2 mm in size.

Estimated Sediment Load Summary and Discussion

A summary of the estimated sediment loads for identified potential sediment sources associated with various land uses are presented in Table 5. (These values are estimates and are for planning purposes only. As more data, methods, and information become available, these values should be updated.) The total sediment load estimated for all particle sizes was 35,795 tons per year. Sediment loads from natural erosion processes (streambanks are defined in previous section; other values were determined by assuming land use was forest) were estimated to be 1,439 tons per year or 4% of the total sediment load. The total sediment load of particles with diameters that are less than or equal to 2 mm is 26,566 tons per year or 74% of the total sediment load.

The information in Table 5 is a valuable resource for the watershed planning process, but, it is important to understand that the magnitude of the estimated loads does not always reflect its impact to the environment. Loads from some sources may appear to be relatively small compared to the entire watershed; however, if these sediment loads are being generated in a single sub-watershed, it could be enough to adversely impact the sub-watershed's water quality. Also, the timing of when a sediment source enters the system can determine the extent of its impact to the biological system. For example, sediment from roadways & ditches moves easily during most rain events that produce runoff; therefore, it is entering the system even during the lower flow events. Therefore, when developing solutions based on estimated loads, it is important to look beyond the numbers and consider the impact the sources and causes are having on the water quality and biological systems.

When developing solutions to address sediment loads, it is also important to recognize that sediment reductions will not always result in turbidity reductions. Data collected from Nelson, et al., indicates that there is a correlation between TSS and turbidity, but this data is not specific to "sources of sediment." Further studies would need to be performed to understand the relationship between sediment sources and in-stream turbidity values. Another factor that should be considered when developing solutions during the watershed planning process is determining the ease of implementation. Ease of implementation is directly related to 1) size of affected area; 2) number of landowners involved; 3) cost of implementation; and 4) practicality of the practice. Most solutions involve changing people's behavior; therefore, solutions have to make sense, be practical, and be cost effective.

Table 5. Summary of Estimated Annual Sediment Loads for Identified Sources in the WFWR Watershed.

Land Use	Affected Area	Annual Sediment Load from Natural Erosion (Ton)	Annual Sediment Load for each Sub-Category (Tons) Total =2 mm		Total Annual Sediment Load (Tons) = 2mm
Pasture:	19,413 ac.	155	1,709	1,709	1,709
Forest: ? Harvested	46,539 ac. 110 ac.	391	391 8	391 8	399
Urban ? Construction	9,710 ac. 283 ac.	78	1,104 2,787	1,104 2,787	3,891
NPDES Permits: ? WF-WWTP ? WF Quarry		N/A	0.5 7.5	0.5 7.5	8.0
Roadways & Ditches: ? Unpaved (gravel, spot, native) ? Paved highways ? Residential ? I-540 ? Gullies from I-540	**Miles** 120 109 90 17 1.0	Accounted for under pastures, urban and forest	4,500 122 34 272 1,210	4,500 122 34 272 240	5,168
Streambank Erosion Causes - riparian removal, channel alteration (gravel mining, etc), increase runoff (change in Q)	**Miles** Main Branch 7.5 Tributaries 3.1	815	18,532 5,118	12,375 3,016	15,391

For each land use outlined in Table 5, priority areas, BMP implementation and/or restoration recommendations for sediment reduction, expected reductions, and management implications are outlined and discussed in the ADEQ (2004) report. Priority areas were based on data collected, modeling results for each sediment source, and the amount of sediment that would be reduced with the implementation of BMPs or restoration. Just treating the most critical areas identified in this study, which was 38% of the pasture lands; all construction sites (3% of the urban lands); 27.3% of the roads & ditches including I-540 gullies; and 6.3% of the accelerated streambank erosion, would result in, approximately, a 22.6% reduction of the sediment load to the WFWR.

Water Quality Data Collected at the AWRC Continuous Monitoring Station (Nelson, et al., 2004)

The AWRC installed and operated a continuous monitoring (CM) station near the confluence of the WFWR with the White River beginning in March of 2002. A detailed description of the WFWR CM station, sampling methodology, data evaluation methods, and sampling results can be found in the AWRC report to the ASWCC (Nelson, et al., 2004). Both discreet water samples and flow-weighted composite water samples were collected and analyzed for Total Suspended Solids (TSS). This data was used to estimate annual loads of TSS for "below 4-ft stage" flow and storm (equal to or above 4-ft stage) flow conditions. During October, 2003, a problem with the intake line on the automatic sampler was discovered. Samples collected from March 11, 2002 through October 15, 2003 had been contaminated with sediment trapped in the 2-inch outer pipe. Using paired samples collected by the USGS and the AWRC for both storm flows and “below 4-ft stage” flows during 2002 though 2003, the data was corrected to more accurately reflect the conditions in the WFWR (Nelson, et al., 2004). As additional water quality data is collected, these values will be re-estimated to better reflect the conditions of the WFWR.

Over 300 water samples were collected during 2002 and 2003. Table 6 summarizes the TSS loads, TSS mean concentrations, and the water yield for the “below 4-ft stage” and storm flow conditions for 2002 and 2003. In general, the “below 4-ft stage” represents base-flow conditions for the WFWR, but, during low flow months, storm influenced events that did not reach the 4-ft stage, could have been sampled. A grab sample collected during this type of an event would have a higher TSS concentration than one collected during an event not influence by storm flow (base-flow). The average TSS concentration for flows “below 4-ft stage” for 2002 and 2003 was 18.5 mg/L and 17.1 mg/L, respectively. The average TSS concentration for storm flows for 2002 and 2003 was 197 mg/L and 141 mg/L, respectively. Nelson’s sampling results showed that storm flow average TSS concentrations were 8 and 11 times higher than the “below 4-ft stage” average TSS concentrations in 2002 and 2003, respectively. Also, the “below 4-ft stage” TSS loads were approximately 10 to 38 times lower than storm flow loads for 2002 and 2003, respectively. Table 6 also shows the water yields at the WFWR CM station for 2002 and 2003. Even though the water yields were similar for both years, 2002 had 28% more storm flow and 53% less “below 4-ft stage” flow when compared to values in 2003.

Table 6. WFWR Estimated loadings and concentrations for “storm” flow and “below 4-ft stage” flow conditions during 2002 (March-December) and 2003 at AWRC WFWR CM Station (drainage area=123 mi^2) (Nelson, et al., 2004).

	Year - 2002	Year - 2003
TSS Load (ton)		
Storm-flow	14,850	7,627
Below 4-ft Stage	394	776
TSS Concentration (mg/L)		
Storm-flow	197	141
Below 4-ft Stage	18.5	17.1
Water Yield (M-gal)		
Storm-flow	18,056	12,950
Below 4-ft Stage	5,111	10,855
Total Water Yield (M-Gal)	23,167	23,805

A summary of annual load estimates and flow-weighted mean concentrations for TSS during 2002 and 2003 are shown in Table 7. Because sampling was not initiated until March of 2002, the annual TSS load for 2002 was prorated using the flow data collected the entire year and the water quality data collected March through December of 2002 (Nelson, et al.)

Table 7. WFWR Estimated loadings and flow-weighted mean concentrations for constituents measured in 2002 and 2003 at AWRC WFWR CM station (drainage area=123 mi^2) (Nelson, et al,) 2004).

Year	TSS Partial Year Load (tons)	TSS Pro-rated Annual Load (Tons)	TSS Flow-weighted Mean Concentration (mg/L)
2002	15,244	21,315	158
2003	Not applicable	8,403	84.6

The estimated annual TSS load for 2003 was 28% lower than the annual loading estimated for 2002 even though the water yields were similar for both years (Table 6). The difference in annual loadings could be due to the differences in meteorological conditions including rainfall intensity, duration, and time of the year individual storm events occurred. For example, most of the sediment from erosion processes enters the stream system during storm events. In 2002, approximately, 75% of the flow that year was from storm events, while in 2003; just over 50% of the flow was from storm events (see Table 6). As previously indicated, the average TSS storm flow concentrations were higher than "below 4-foot stage" flow concentrations. Therefore, when comparing 2002 TSS loads to 2003 TSS loads, one would expect the loads to be higher in 2002, even though the water yields are similar.

Turbidity data was collected every 15 minutes at the WFWR CM station beginning in 2003. For 2003, the turbidity ranged from 0.0 NTU to 1,500 NTU with an average of 27 NTU. A TSS turbidity linear regression plot for the samples collected in 2003 is shown in Figure 3. With an R value of 0.76, the regression analysis supports that a reduction in TSS in the system should lead to improved water clarity.

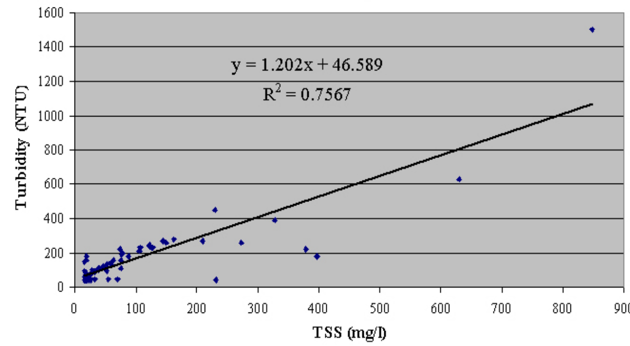


Figure 3. Plot of TSS versus Turbidity for samples collected on the WFWR in 2003

Suspended Sediment concentration (SSC) was measured by the USGS for seven paired samples collected during storm flow conditions. The average relationship between paired TSS and SSC determined from these paired samples can be described by the following relationship (Nelson, et al., 2004):

$$SSC = 1.46\ TSS$$

Applying this relationship to the average TSS load for 2002 and 2003 of 14,870 tons/yr, results in an average annual SSC load of 21,690 tons/yr. The estimated SSC load is 82% of the study estimated sediment load of 26,566 tons/yr (particles less than or equal to 2 mm). The AWRC is continuing to collect paired storm flow samples to further develop the relationship between TSS and SSC.

Conclusions and Recommendations

Sources of sediment evaluated in the WFWR watershed for this study included pastures; forests and forest conversion; urban areas and construction; NPDES permitted facilities; roadways, ditches, and I-540 corridor gullies; and streambank erosion caused by riparian removal, channel alteration, and increased runoff. The average annual sediment load from these sources for the WFWR watershed was estimated to be 35,795 tons. 26,566 tons per year were particles with a diameter of less than or equal to 2 mm (74% of the total sediment load estimated.) Natural erosion processes were estimated to be contributing 1,439 tons per year or 4% of the total sediment load. Based on these sediment load estimates, one can conclude that excessive amounts of sediment are entering the WFWR and need to be addressed. It is recommended that a BMP implementation plan along with restoration strategies that focus on the reduction of sediment be developed as part of an overall watershed management plan. Results of this study should be used to prioritize critical areas for treatment or restoration, so that sediment reduction is maximized as resources become available.

The AWRC operates and maintains a WFWR CM station near the confluence of the WFWR with the White River. Based on water samples and flow data collected, annual TSS loads were estimated for the years 2002 and 2003. The annual TSS load for 2002 was 21,315 tons, and for 2003, the annual TSS load was 8,403 tons. Water yield for both years was similar, but the total storm flow volume was much higher in 2002 than 2003, which explains the higher TSS loads. Tying sediment loads to water quality data used to evaluate stream conditions is a challenge. Sediment loads estimated through the source inventory cannot be directly compared to TSS loads, but the measured TSS loads support the magnitude of the total load determined through the sediment source inventory. The average TSS load for 2002 and 2003 was 14,870 tons/yr, and applying the relationship between TSS and SSC resulted in an average annual SSC load of 21,690 tons/yr. The estimated SSC load based on the water quality data for the WFWR is 82% of the study estimated sediment load of 26,566 tons/yr (particles less than or equal to 2 mm) from the watershed assessment. Also, based on the water quality data collected, a reduction in sediment from sources in the WFWR watershed should result in a reduction in TSS concentrations and improve turbidity.

Sediment from streambanks showing indications of accelerated erosion was found to contribute 66.1% of the total sediment load. Sediment load estimates of roadways & ditches (including I-540 gullies) contributed 17.1%; the urban area (including construction) sediment load estimate contributed 10.9%; the pasture area sediment load estimate contributed 4.8%; and other sources contributed 1.1%. The results of this study are a valuable resource for watershed planning, and each source’ s contribution to the total sediment load should be considered during the prioritization process. But, there are other factors that should be considered in addition to sediment load contribution, such as, sub-watershed impacts, habitat impact, size of affected area that would be addressed, potential improvement to water quality, etc. Also, local stakeholder involvement in the watershed planning process is a key element for 1) developing a successful sediment reduction plan and watershed restoration strategies and 2) successfully implementing the plan and strategies. Causes of excessive sediment from the sources evaluated are complex and difficult to define and do not point to any single source in the watershed. Effective solutions that will address turbidity and sediment issues in the WFWR watershed will require 1) an understanding of the sediment sources and their impact on water quality and habitat and 2) the development of partnerships between stakeholders.

References

Arkansas Department of Environmental Quality. Integrated Water Quality Monitoring and Assessment Report. Agency Report Prepared pursuant to Section 305(b) and 303(d) of the Federal Water Pollution Control Act. Agency Report. 2002.

ADEQ, Environmental Preservation Division. West Fork – White River Watershed – Data Inventory and Nonpoint Source Pollution Assessment (Draft). 2004.

ADPC&E. Water Quality inventory Report. Agency Report Prepared pursuant to Section 305(b) of the Federal Water Pollution Control Act. 1998.

Brye, K.R., T.L. Morris, D.M. Miller, S.J. Formica, M.A. Van Eps. 2004. Estimating bulk density in vertically exposed stony alluvium using a modified excavation method. J. Environ. Qual. In Press.

Clingenpeel, A., K. Whitsett. Personal Communication. Methods and assistance for performing watershed roadway inventory and integrating with the WEPP: Road model. 2004.

Dissmeyer, G. E. and R. F. Stump. Predicted erosion rates for forest management activities in the southeast. 1978.

Edwards, Findlay G., Stormwater Pollution Prevention BMP Workshop, Demonstration, and Evaluation, Project 700 FY01 CWA Section 319(h). Final Report. Arkansas Soil and Water Conservation Commission. 2003.

Elliot, W.J., D. Hall and D. Schelle. WEPP: Road (DRAFT) - Interface for Predicting Forest Road Runoff, Erosion and Sediment Delivery, Technical Documentation. U.S.D.A. Forest Servie. Rocky Mountain Research Station and San Dimas Technology and Development Center. December, 1999.

Fortenberry, Alan, 2004, Beaver Water District, Personal Communication

Gilliam, L.G. *Land Use of the West Fork Watershed.* University of Arkansas Press. Fayetteville, AR, 1977.

Meyer, Charles R. Personal communication. Information Technology Specialist, National Soil Erosion Research Laboratory, USDA-ARS, West Lafayette, IN. 2004.

Nelson, M., W. Cash and S. Formica. Water Quality Sampling, Analysis and Annual Load Determinations for TSS, Nitrogen and Phosphorus at the Washington County Road 195 Bridge on the West Fork of the White River. 2003 Annual Report to the ASWCC. July, 2004.

Roehl, J. W. Sediment source areas, delivery ratios and influencing morphological factors. International Assoc. of Scientific Hydrology. 59 (202-213). 1962.

Schueler, Thomas R. and Heather K. Holland. The Practice of Watershed Protection. Center for Watershed Protection. 2000.

United States Census. 2000. Ranking tables for metropolitan areas: population in 2000 and population change from 1990 to 2000. Table 5. Accessed July, 2004. http://www.census.gov/population/www/cen2000/phc-t3.html

USDA Soil Conservation Service (SCS), USDA Forest Service, and Arkansas Agricultural Experiment Station. Soil Survey Washington County, Arkansas and associated General Soil Map of Washington County. 1969.

United States Department of Agriculture. State Soil Geographic (STATSGO) Data Base. Natural Resources Conservation Service. 1994.

United States Department of Agriculture. Water Erosion Prediction Project Hillslope Profile and Watershed Model Documentation. NSERL report #10. 1995.

U.S. Environmental Protection Agency. Urban Stormwater Best Management Practices Study. EPA-821-R-99-012. 1999.

Wildland Hydrology, Inc: Research and Educational Center for River Studies. River Assessment: Field Book. Pagosa Springs. 2001.

Paper presented and prepared for the ASAE Conference "Self-Sustaining Solutions for Streams, Wetlands, and Watersheds" held in St. Paul, Minnesota, September 12-15, 2004.

Appendix 2-A

Sources of Information and Data for the West Fork of the White River Project

1. Ashworth R. and Dee Mitchell. 1982. An Annotated Bibliography of Beaver Reservoir. University of Arkansas

2. E&GCI. 1994. Beaver Lake, Arkansas, Water Quality Enhancement Project, Water Quality Monitoring Study, Year 1 (May, 1992-April, 1993) and Year 2 (May 1993-May, 1994). Environmental and GIS Consulting, Incorporated, Bentonville, Arkansas. June 1994.

3. FTN. 1992. Final Report for Beaver Lake – Phase I, Diagnostic/Feasibility Study, Volume 1, Book A, Report Text. FTN Associates, Ltd., Little Rock, Arkansas. October 1992.

4. USGS. 1998(a). Water-Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma-Nutrients, Bacteria, Organic Carbon, and Suspended Sediment in Surface Water, 1993-1995. Water-Resources Investigations Report 98-4164.

5. USGS. 1997(a). Water-Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma-Organic Compounds in Surface Water, Bed Sediment, and Biological Tissue, 1992-1995. Water-Resources Investigations Report 97-4031.

6. USGS. 1998(b). Water-Quality in the Ozark Plateaus, Arkansas, Kansas, Missouri, and Oklahoma, 1992-1995. USGS Circular 1158.

7. USGS. 1998(c). Water-Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma-Fish Communities in Streams and Their Relations to Selected Environmental Factors. Water-Resources Investigations Report 98-4155.

8. USGS. 1996. Water-Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma-Summary of Information on Pesticides, 1970-90. Water-Resources Investigations Report 98-4003.

9. USGS. 1997(b). Water-Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma-Habitat Data and Characteristics at Selected Sites, 1993-1995. Water-Resources Investigations Report 97-236.

10. Scott, H.D. and J.M. McKimmey. 1992. GIS Characterization of Beaver Watershed. AWRC Publication No. 159. Arkansas Water Resources Center.

11. McKimmey, J.M. and H.D. Scott. 1993. Prediction and Management of Sediment Load and Phosphorus in the Beaver Reservoir Watershed Using a Geographic Information System. ARWC Publication No. 165. Arkansas Water Resources Center.

12. Soerens, T.S., B.E. Haggard, and D.G. Parker. 1997. Beaver Lake, Water Quality Enhancement Project Data Analysis. AWRC Publication No. MSC-201. Arkansas Water Resources Center.

Appendix 2-A (continued)

13. COE. 1997. Beaver Lake, Arkansas, Water Quality Enhancement Project. Special Summary Completion Report. US Army Corps of Engineer. May 1997.Teague, W., P. Tacker, and S. Chapman. ----. Nitrates in Arkansas Private Rural Water Supplies. U of A Cooperative Extension Service, Little Rock, Arkansas

14. Maner, M. 1997. Turbidity in Beaver Dam Tailwaters. Arkansas Department of Environmental Quality, Little Rock, Arkansas.

15. ADPC&E. 1995. Water Quality, Macroinvertebrate, and Fish Community Survey of the Upper White River Watershed. Arkansas Department of Environmental Quality, Little Rock, Arkansas. August 1995.

16. Holmes, P.D. 1964. The Helminth and Copepod Parasites of Roccus Chrysops (Rafinesque), Micropterus Dolomieui Lacepede, M. Punctulatus (Rafinesque), and M. Salmoides (Lacepede) (Preciformes) of the Beaver Lake Watershed in Arkansas. M.S. Thesis, University of Arkansas, Fayetteville, Arkansas.

17. Mitchell, D.T. 1974. Northwest Arkansas Regional Water Quality Management Plan for Basin 3H and Portions of Basin 4J. Department of Civil Engineering, University of Arkansas, Fayetteville, Arkansas. May 1974.

18. USDA-SCS and FS. 1986. Summary Report: A Study of Erosion, Animal Wastes, and Nutrient Transport Associated with Agricultural Areas within the Beaver Lake Watershed, Arkansas/Arkansas Critical Erosion Cooperative River Basin Study. USDA, Soil Conservation Service and Forest Service.

19. USGS. 1982. Water Quality Assessment of White River Between Lake Sequoyah and Beaver Reservoir, Washington County, Arkansas. Water Resource Investigations 82-4063.

20. Garner, D.E. 1965. Pre-impoundment Studies of Soils and Waters of the Beaver Reservoir. M.S. Thesis, University of Arkansas, Fayetteville, Arkansas.

21. USCOE. 1939. Report to WAR Department on White River Development. Compiled Under Direction of Carl E. Bailey, Governor.

22. Horn, M.E. and J.S. Runsick. 1966. Water Quality in Beaver Reservoir Watershed, Post-Impoundment Investigations, July, 1964-July, 1966. Department of Agronomy and University of Arkansas Agricultural Experiment Station. August 1966.

23. USCOE. 1971. Flood Plain Information, West Fork White River, Town, Mud, Scull, and Clear Creeks. Fayetteville, Arkansas. U.S. Army Corp of Engineers. March 1971.

24. Gilliam, L.G. 1977. Land Use of the West Fork Watershed. M.S. Thesis. University of Arkansas, Fayetteville, Arkansas.

25. ADPC&E. 1998. Water Quality inventory Report. Agency Report Prepared pursuant to Section 305(b) of the Federal Water Pollution Control Act.

Appendix 2-A (continued)

26. ADEQ. 2002. Integrated Water Quality Monitoring and Assessment Report. Agency Report Prepared pursuant to Section 305(b) and 303(d) of the Federal Water Pollution Control Act. Agency Report.

27. R. L. Meyer, W. R. Green, K. F. Steele and D Wickliff. ALGAL GROWTH POTENTIALS AND HEAVY METAL CONCENTRATIONS OF THE PRIMARY STREAMS TO UPPER BEAVER LAKE. Arkansas Water Resources Center, 1986. <http://www.uark.edu/depts/awrc/Publications/PUB0122.pdf>

Appendix 2-B

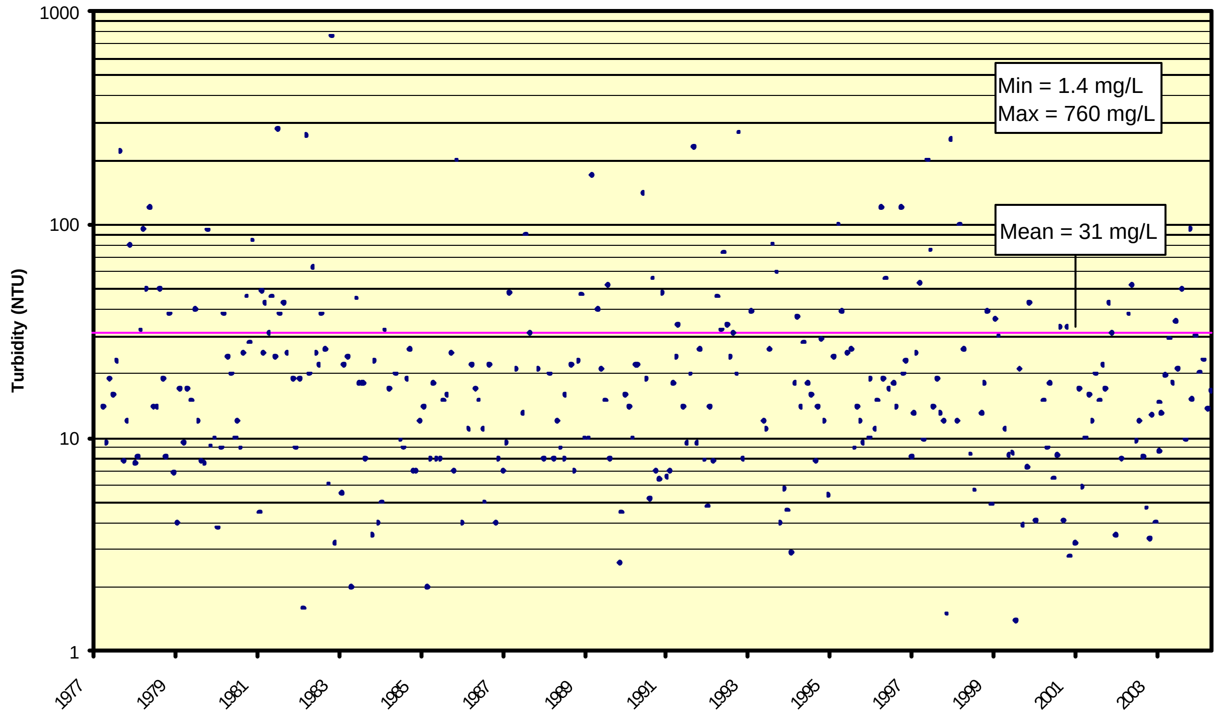
Table Parameter Name, Abbreviation, and Units for Concentration for ADEQ 1992-1994.

Parameter	**Abbreviation**	**Units for Concentration**
Ammonia as Nitrogen	NH_3-N	Milligram per Liter (mg/L)
Total Nitrogen	TN	Milligram per Liter (mg/L)
Five-Day Biochemical Oxygen Demand	BOD_5	Milligram per Liter (mg/L)
Dissolved Oxygen	DO	Milligram per Liter (mg/L)
Escherichia coli	E. coli	Number per Milliliter (#/mL)
Fecal Coliform Bacteria	Fecal Coliform	Number per Milliliter (#/mL)
Nitrite + Nitrate as Nitrogen**	NO_3^--N**	Milligram per Liter (mg/L)
Soluble Phosphorus as Phosphorus	PO_4^--P	Milligram per Liter (mg/L)
Total Phosphate as Phosphorus	TP	Milligram per Liter (mg/L)
pH	pH	Ec
Total Dissolved Solids	TDS	Milligram per Liter (mg/L)
Total Kjeldahl Nitrogen	TKN	Milligram per Liter (mg/L)
Total Organic Carbon	TOC	Milligram per Liter (mg/L)
Total Suspended Solids	TSS	Milligram per Liter (mg/L)
Turbidity	Turbidity	Nephelometric turbidity unit (NTU)
Chloride	Cl^-	Milligram per Liter (mg/L)
Sulfates	SO_4^-	Milligram per Liter (mg/L)
Bromide	Br^-	Milligram per Liter (mg/L)
Fluoride	F^-	Milligram per Liter (mg/L)

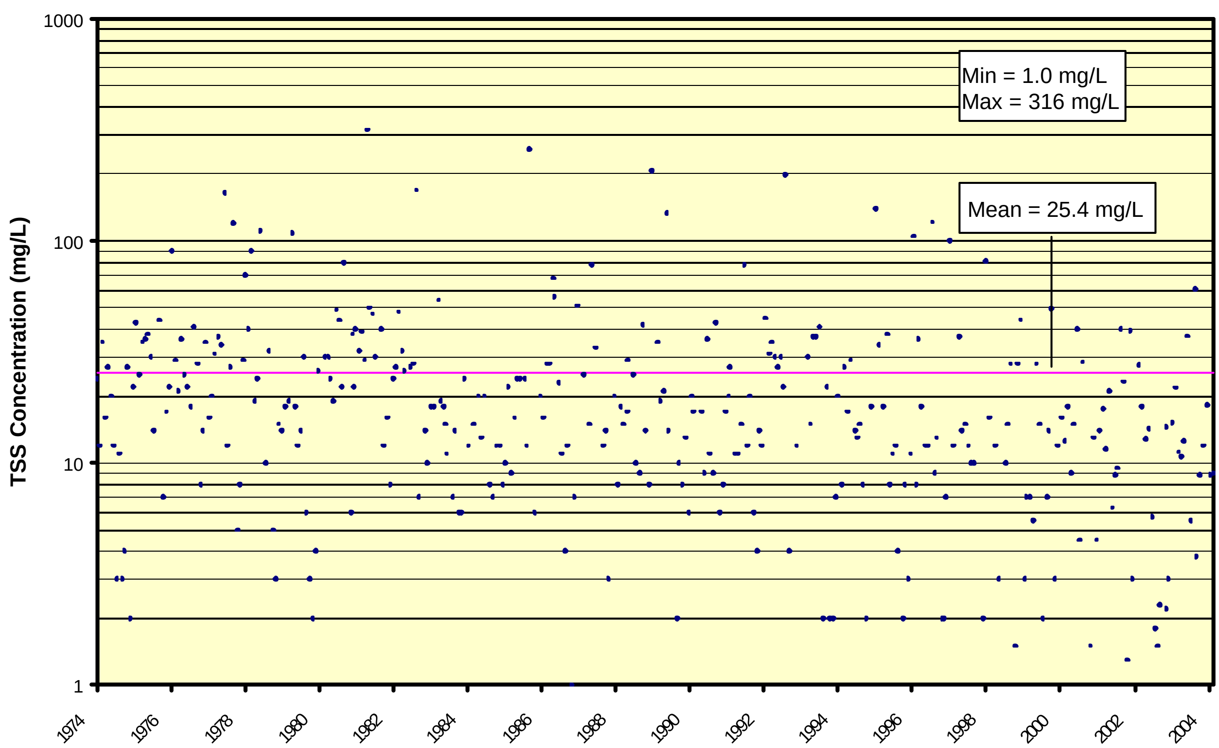
**Because the percent of nitrite is very low, this value is typically assumed to be nitrate and is some times referred to as “nitrates.”

Appendix 2-C
Water Quality Data for ADEQ Station WHI51

Turbidity of Grab Samples Collected from ADEQ Station WHI51

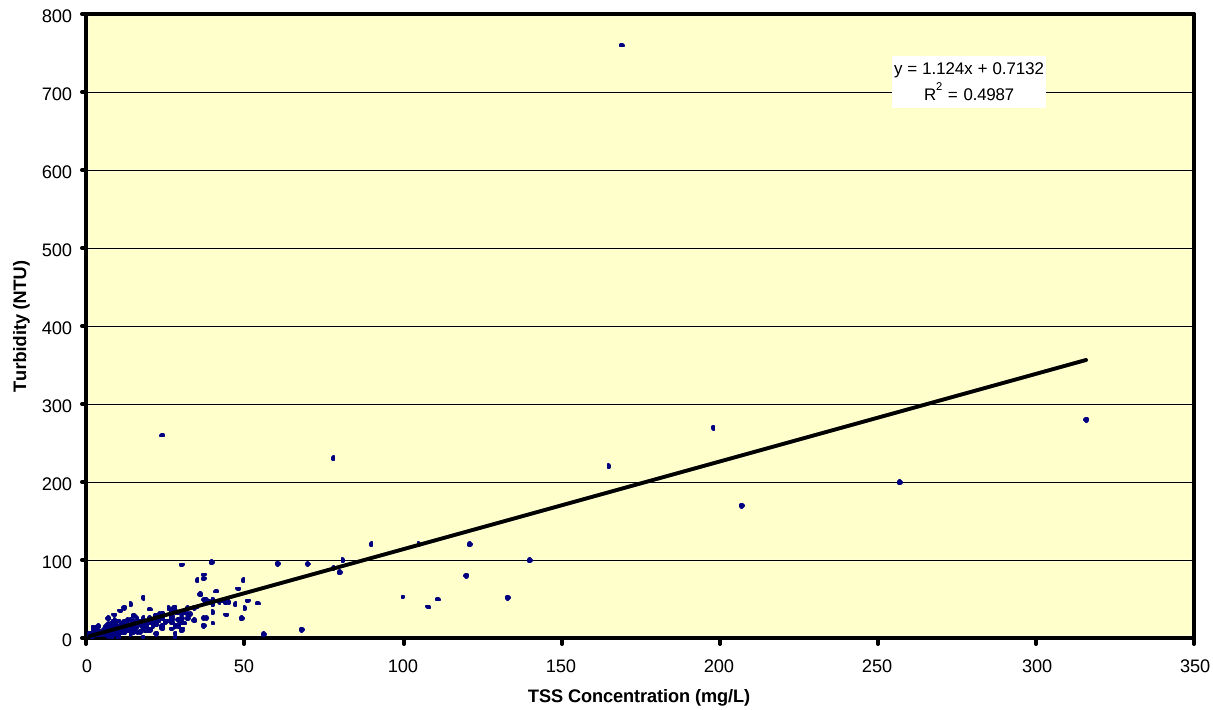


TSS Concentrations of Grab Samples Collected from ADEQ Station WHI51

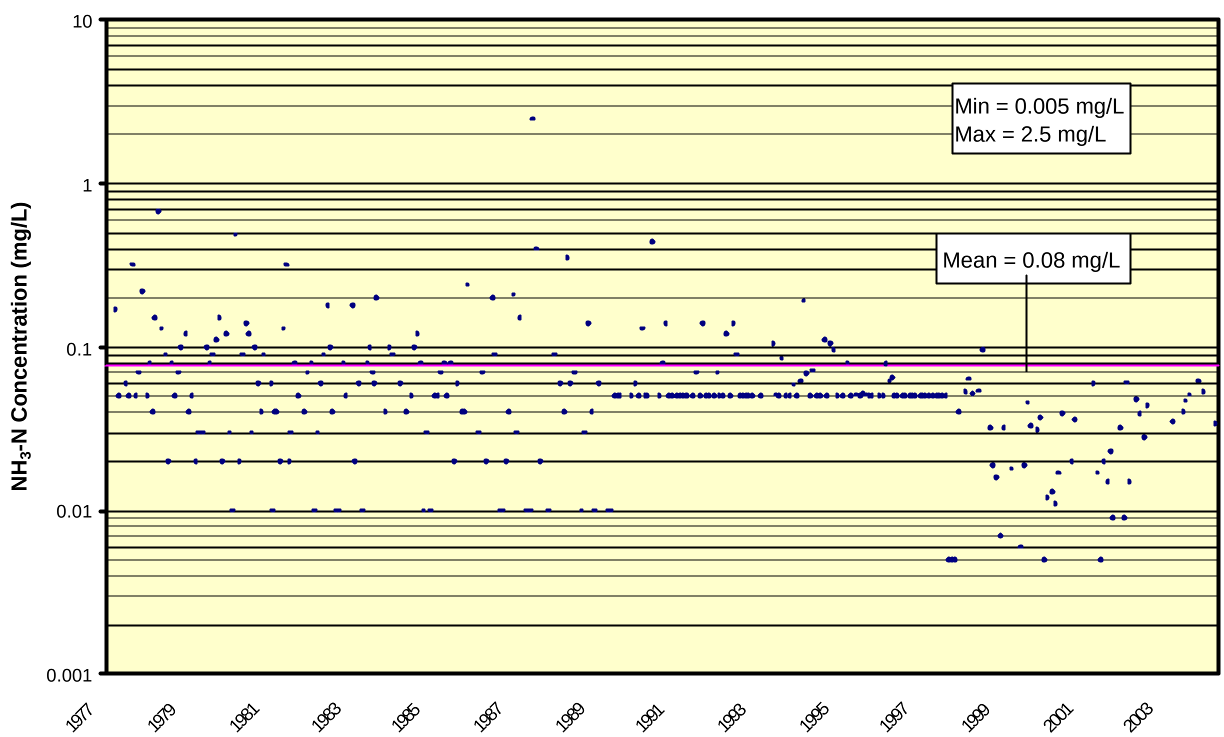


Appendix 2-C (continued)

TSS Concentration vs Turbidity of Grab Samples Collected from ADEQ Station WHI51

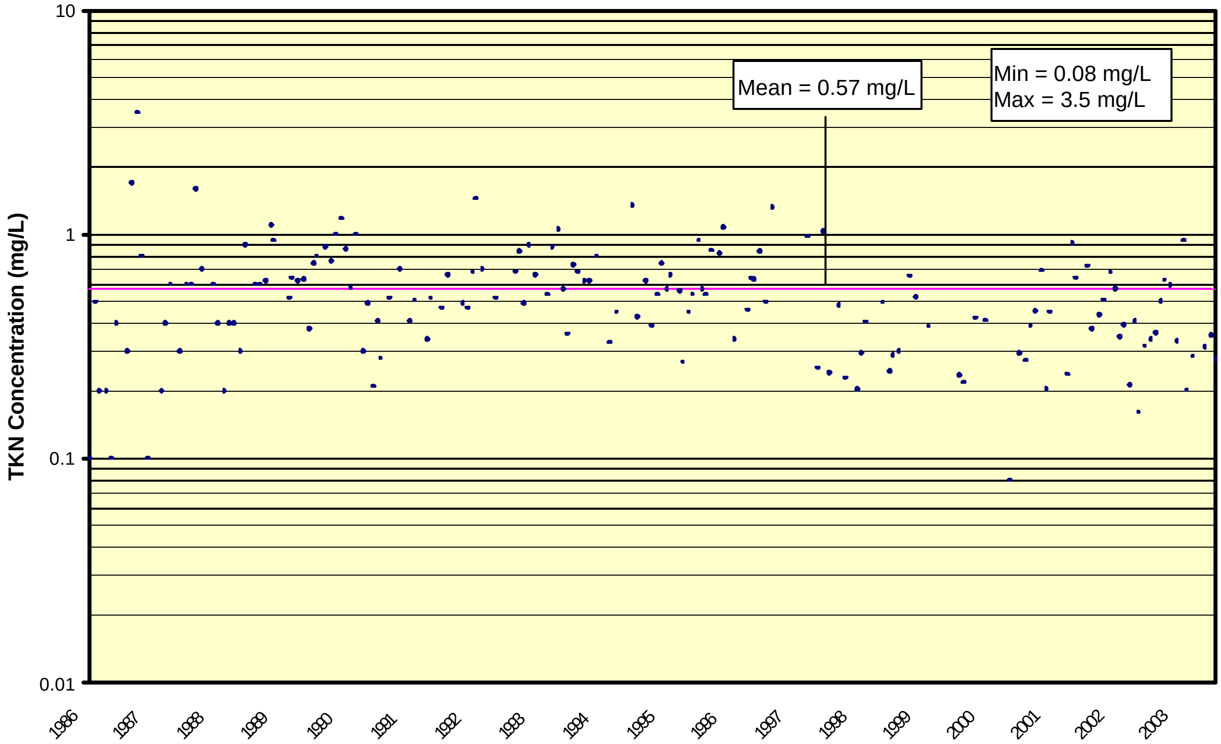


NH_3-N Concentrations of Grab Samples Collected from ADEQ Station WHI51

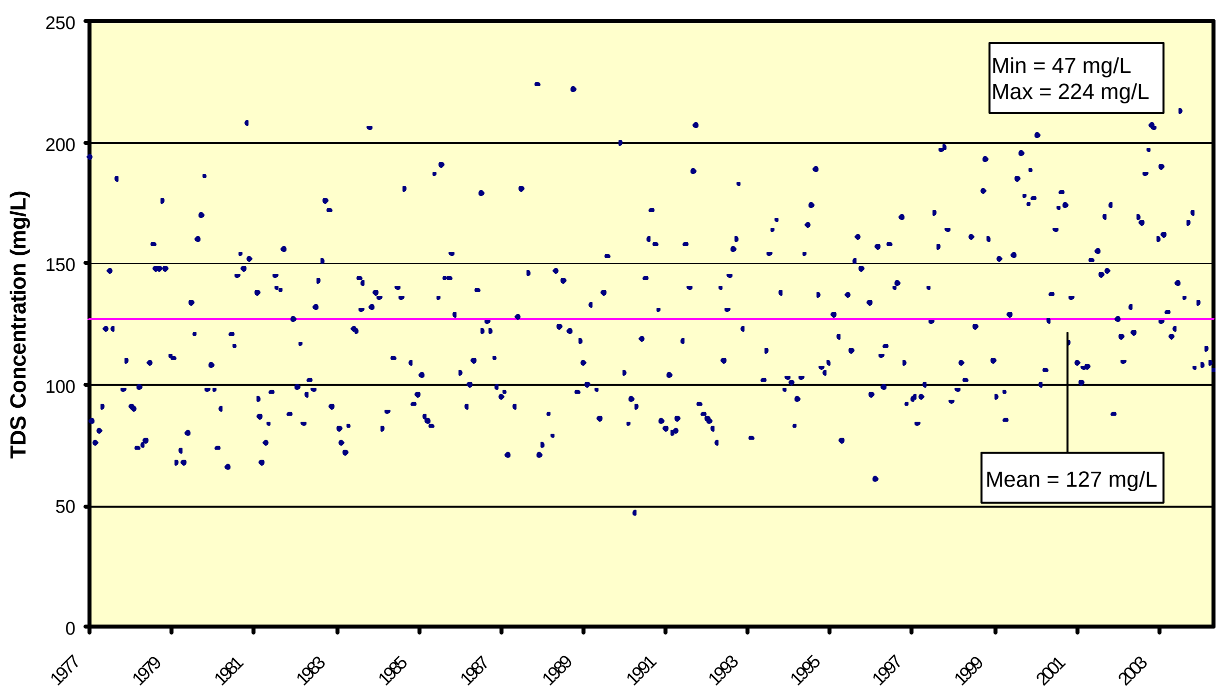


Appendix 2-C (continued)

TKN Concentrations of Grab Samples Collected from ADEQ Station WHI51



TDS Concentrations of Grab Samples Collected from ADEQ Station WHI51



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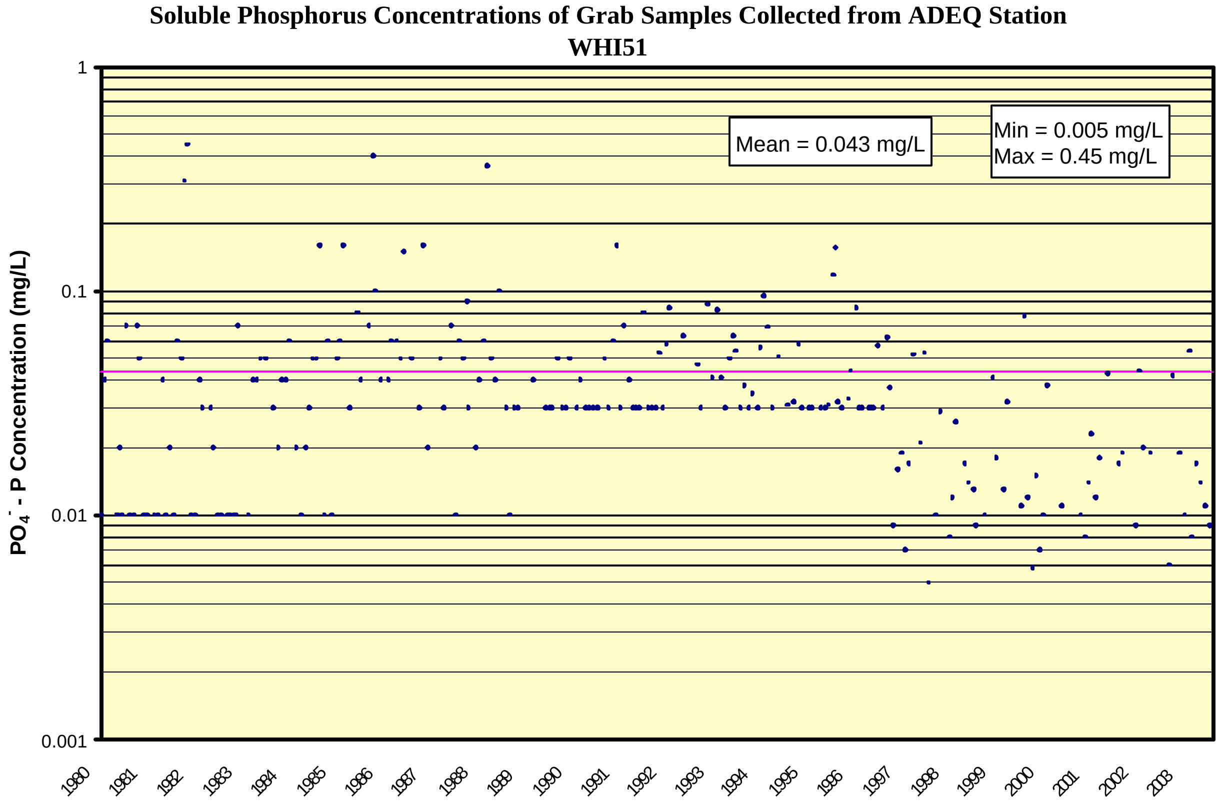
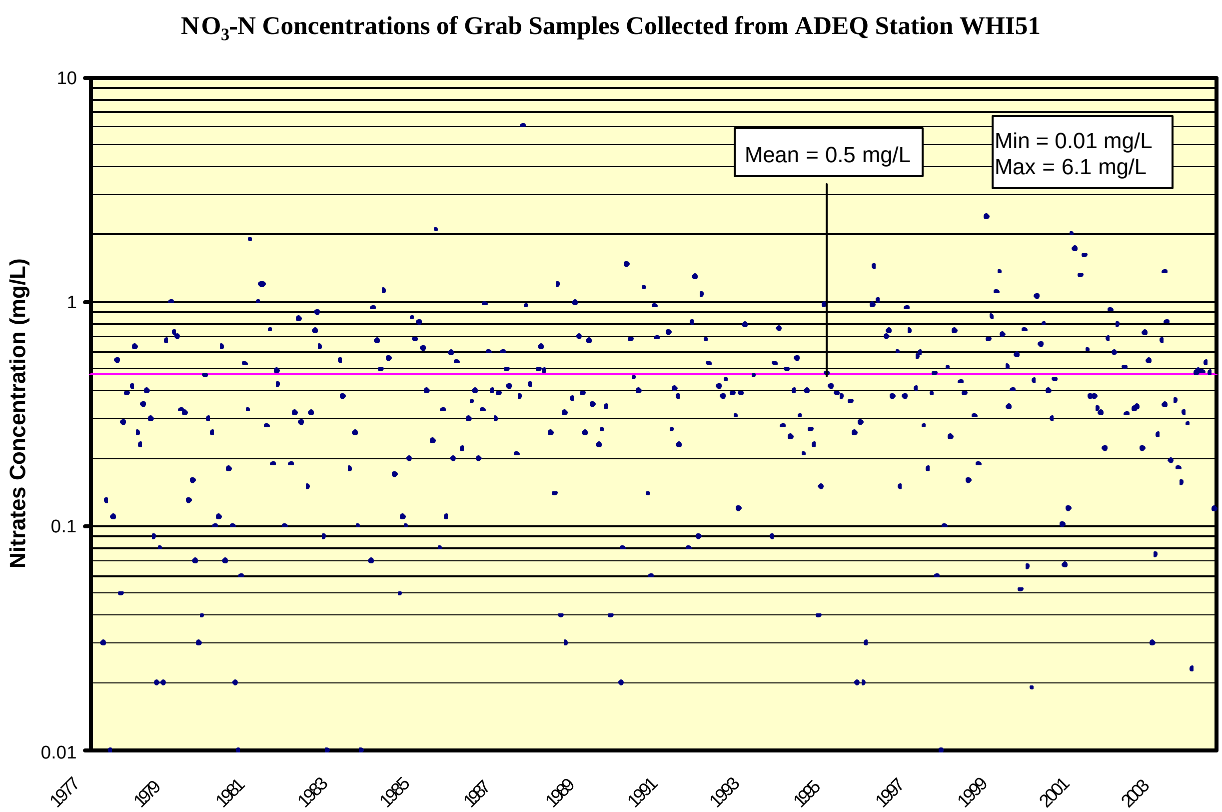
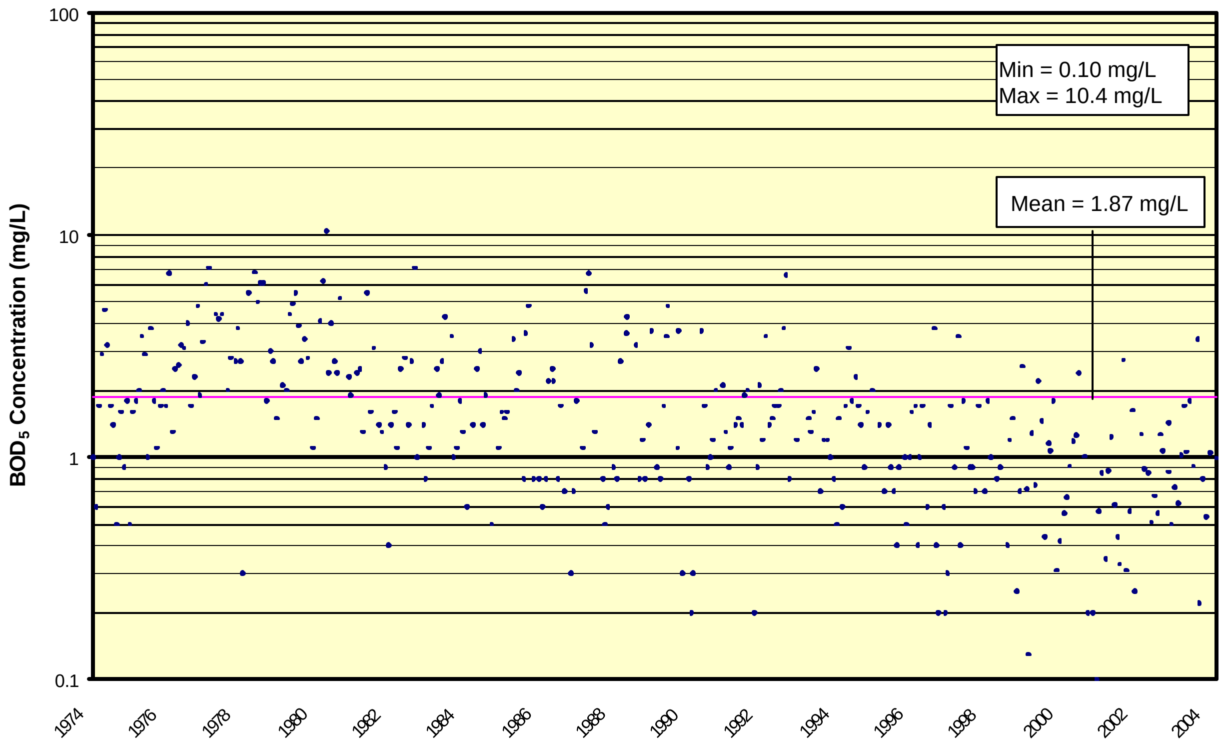


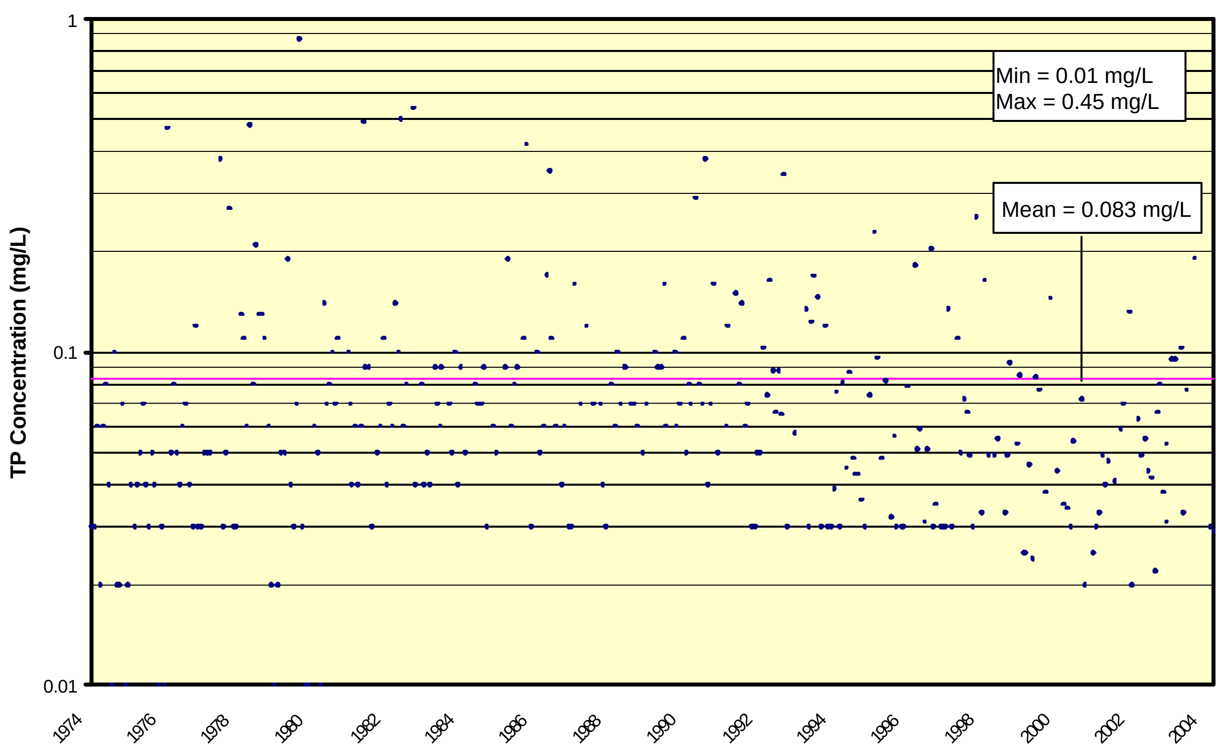


Appendix 2-C (continued)

BOD$_5$ Concentrations of Grab Samples Collected from ADEQ Station WHI51

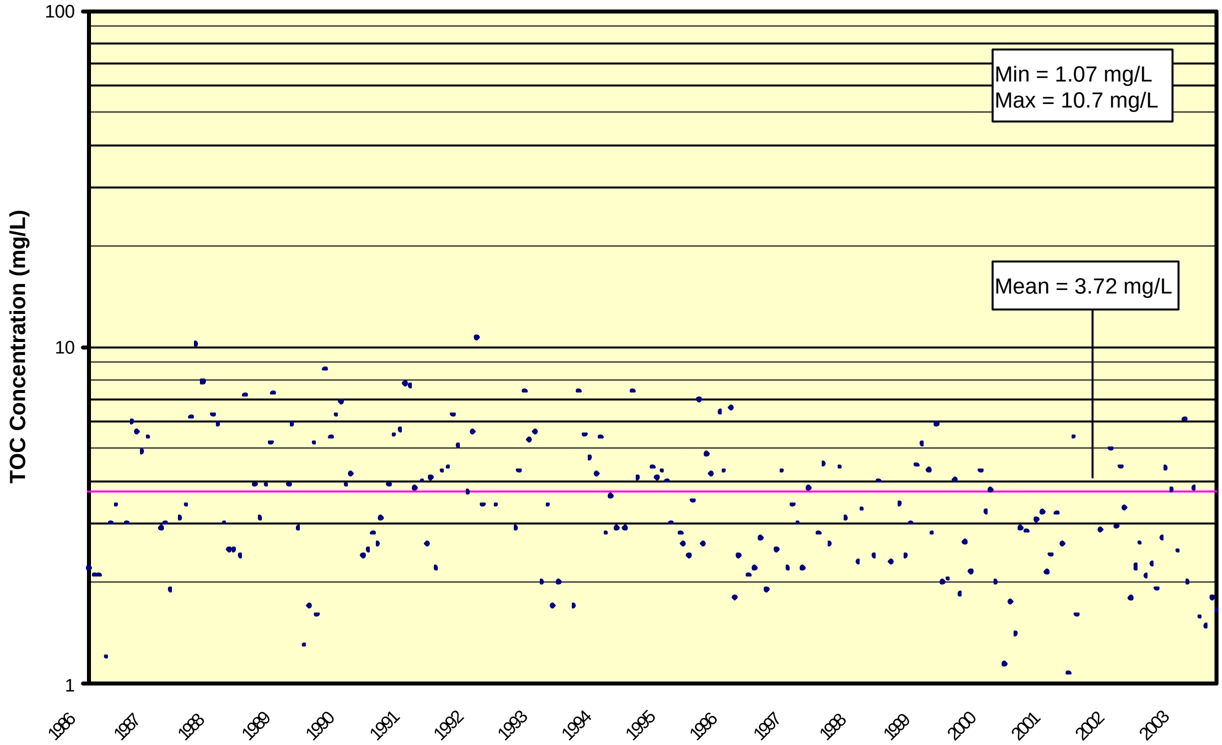


TP Concentrations of Grab Samples Collected from ADEQ Station WHI51

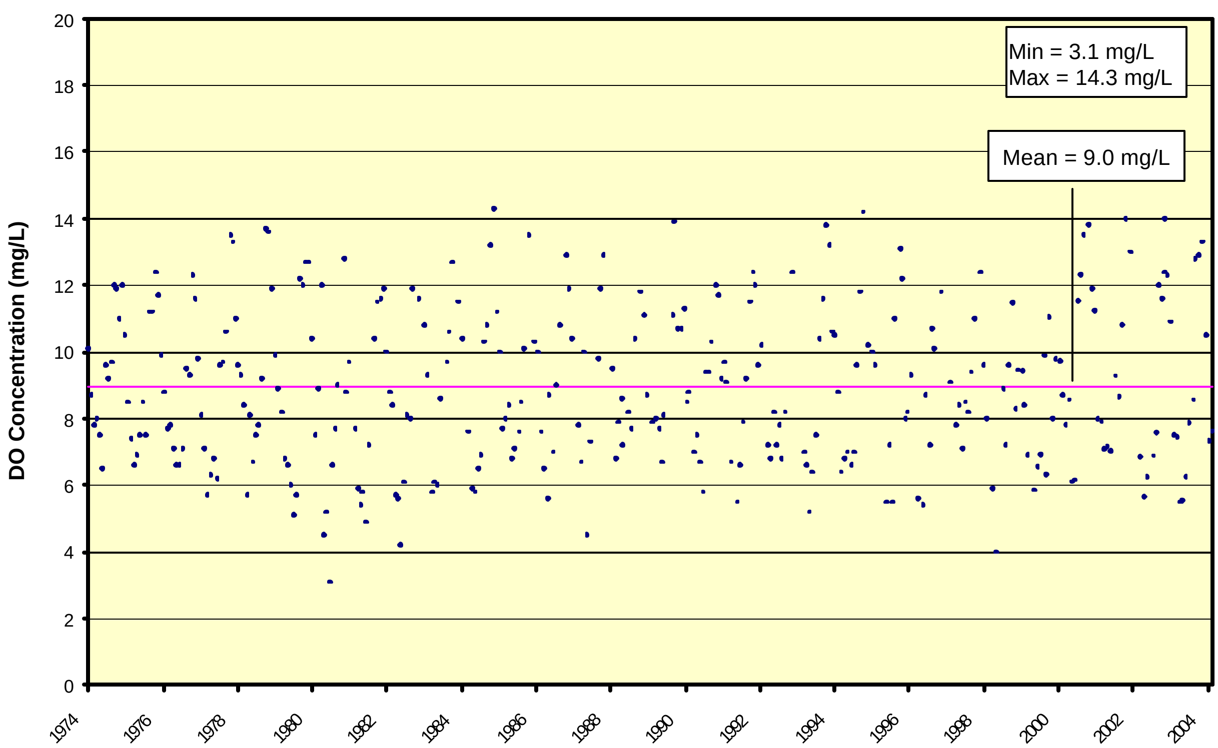


Appendix 2-C (continued)

TOC Concentrations of Grab Samples Collected from ADEQ Station WHI51

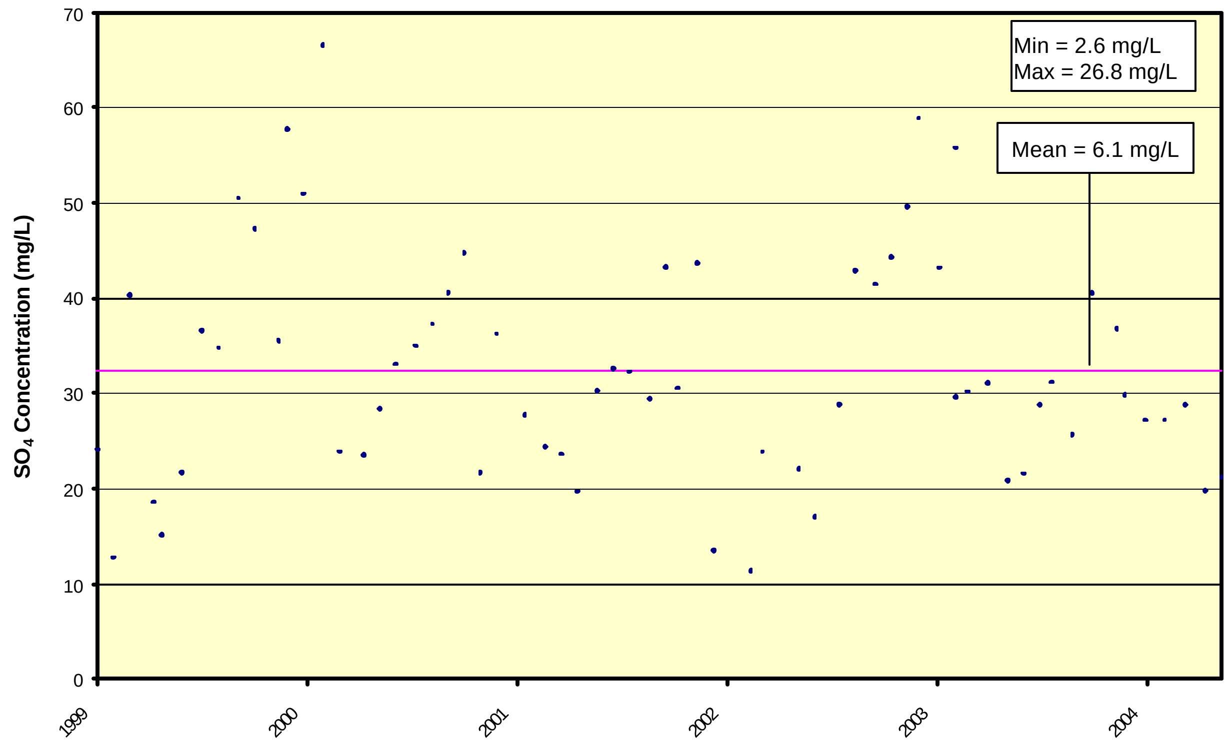


DO Concentrations of Grab Samples Collected from ADEQ Station WHI51

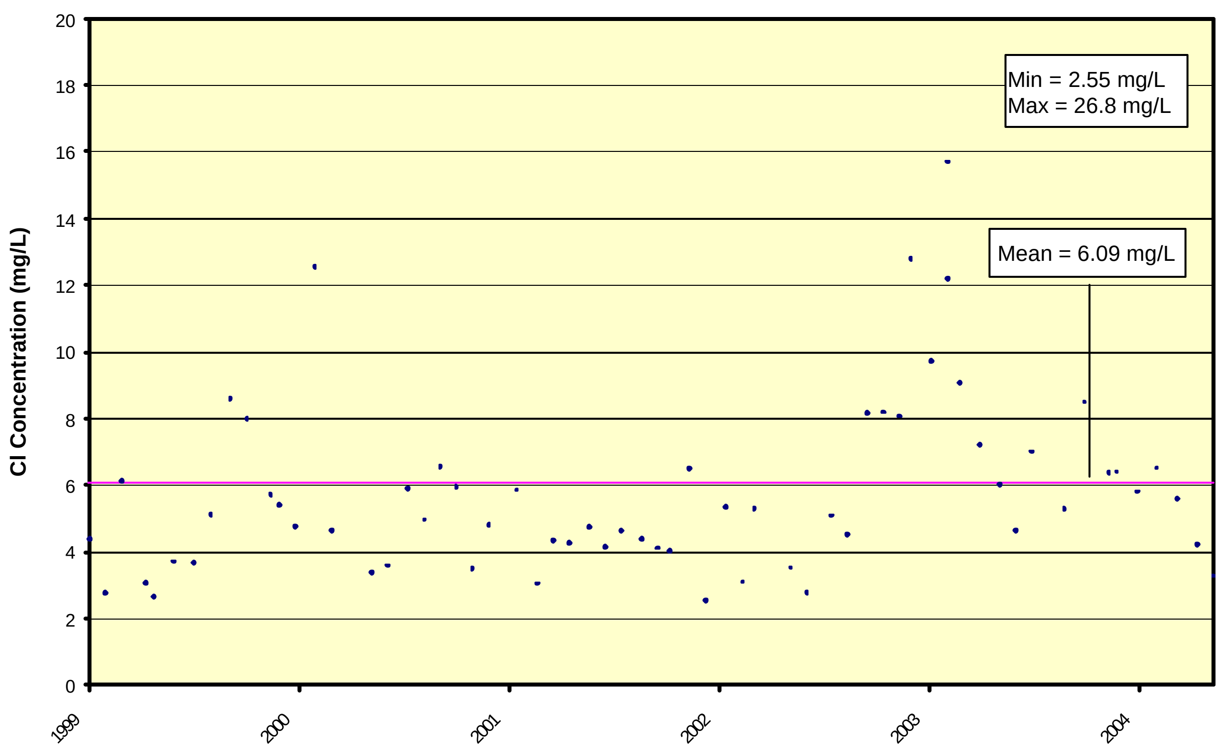


Appendix 2-C (continued)

SO_4 Concentrations of Grab Samples Collected from ADEQ Station WHI51



Cl Concentrations of Grab Samples Collected from ADEQ Station WHI51



Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO SAT (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
4/9/1974	WHI51		10.1		1	7.58		24						0.03				
5/7/1974	WHI51		8.7		0.6	7.55		12						0.03				
6/4/1974	WHI51		7.8		1.7	7.52		35						0.06				
7/2/1974	WHI51		8		2.9	7.59		16						0.02				
7/30/1974	WHI51		7.5		4.6	7.11		27						0.06				
8/27/1974	WHI51		6.5		3.2	7.5		20						0.08				
9/24/1974	WHI51		9.6		1.7	7.4		12						0.04				
10/22/1974	WHI51		9.2		1.4	7.41		3						0.01				
11/19/1974	WHI51		9.7		0.5	7.49		11						0.1				
12/17/1974	WHI51		12		1	7.38		3						0.02				
1/7/1975	WHI51		11.9		1.6	7.53		4						0.02				
2/4/1975	WHI51		11		0.9	7.3		27						0.07				
3/4/1975	WHI51		12		1.8	7.34		2						0.01				
4/1/1975	WHI51		10.5		0.5	7.3		22						0.02				
4/29/1975	WHI51		8.5		1.6	7.42		43						0.04				
6/4/1975	WHI51		7.4		1.8	7.49		25						0.03				
7/1/1975	WHI51		6.6		2	7.51		35						0.04				
7/29/1975	WHI51		6.9		3.5	7.5		36						0.05				
8/26/1975	WHI51		7.5		2.9	7.39		38						0.07				
9/23/1975	WHI51		8.5		1	7.49		30						0.04				
10/21/1975	WHI51		7.5		3.8	7.4		14						0.03				
11/24/1975	WHI51		11.2		1.8	7.59								0.05				
12/17/1975	WHI51		11.2		1.1	7.52		44						0.04				
1/27/1976	WHI51		12.4		1.7	7.7		7						0.01				
2/24/1976	WHI51		11.7		2	7.62		17						0.03				
3/23/1976	WHI51		9.9		1.7	7.7		22						0.01				
4/20/1976	WHI51		8.8		6.7	7.55		90						0.47				
5/24/1976	WHI51		7.7		1.3	7.6		29						0.05				
6/21/1976	WHI51		7.8		2.5	7.66		21						0.08				
7/21/1976	WHI51		7.1		2.6	7.55		36						0.05				
8/18/1976	WHI51		6.6		3.2	7.66		25						0.04				
9/15/1976	WHI51		6.6		3.1	7.82		22						0.06				
10/19/1976	WHI51		7.1		4	7.69		18						0.07				
11/23/1976	WHI51		9.5		1.7	7.42		41						0.04				
12/27/1976	WHI51		9.3		2.3	7.7		28						0.03				
1/26/1977	WHI51		12.3		4.8	7.61		8	194					0.12				
2/15/1977	WHI51		11.6		1.9	7.66		14	85					0.03				
3/16/1977	WHI51		9.8		3.3	7.5		35	76					0.03				
4/19/1977	WHI51		8.1		6	7.68	14	16	81	0.17				0.05				
5/17/1977	WHI51		7.1		7.1	7.61	9.5	20	91	0.05	0.03			0.05				
6/14/1977	WHI51		5.7			7.69	19	31	123		0.13			0.05				
7/19/1977	WHI51		6.3		4.4	7.73	16	37	147	0.06	0.01							

Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO SAT (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
8/16/1977	WHI51		6.8		4.2	7.87	23	34	123	0.05	0.11							
9/20/1977	WHI51		6.2		4.4	7.48	220	165	185	0.32	0.55			0.38				
10/18/1977	WHI51		9.6			7.65	7.8	12		0.05	0.05			0.03				
11/15/1977	WHI51		9.7		2	7.42	12	27	98	0.07	0.29			0.05				
12/14/1977	WHI51		10.6		2.8	7.63	80	120	110	0.22	0.39			0.27				
1/30/1978	WHI51		13.5		2.7	7.09	7.6	5	91	0.05	0.42			0.03				
2/20/1978	WHI51		13.3		3.8	7.54	8.2	8	90	0.08	0.63			0.03				
3/20/1978	WHI51		11		2.7	7.45	32	29	74	0.04	0.26							
4/11/1978	WHI51		9.6		0.3	7.21	95	70	99	0.15	0.23			0.13				
5/9/1978	WHI51		9.3			7.42	50	40	75	0.68	0.35			0.11				
6/6/1978	WHI51		8.4		5.5	7.59	120	90	77	0.13	0.4			0.06				
7/11/1978	WHI51		5.7			7.2	14	19	109	0.09	0.3			0.48				
8/8/1978	WHI51		8.1		6.8	7.6	14	24	158	0.02	0.09			0.08				
9/5/1978	WHI51		6.7		5	7.51	50	111	148	0.08	0.02			0.21				
10/3/1978	WHI51		7.5		6.1	7.55	19		148	0.05	0.08			0.13				
10/31/1978	WHI51		7.8		6.1	7.46	8.2	10	176	0.07	0.02			0.13				
11/28/1978	WHI51		9.2		1.8	7.48	38	32	148	0.1	0.67			0.11				
1/9/1979	WHI51		13.7		3	7.25	6.9	5	112	0.12	1			0.06				
2/5/1979	WHI51		13.6		2.7	7.42	4	3	111	0.04	0.73			0.02				
3/5/1979	WHI51		11.9		1.5	7.26	17	15	68	0.05	0.7			0.01				
4/10/1979	WHI51		9.9			7.38	9.5	14	73	0.02	0.33			0.02				
5/8/1979	WHI51		8.9		2.1	7.5	17	18	68	0.03	0.32			0.05				
6/12/1979	WHI51		8.2		2	7.6	15	19	80	0.03	0.13			0.05				
7/17/1979	WHI51		6.8		4.4	7.21	40	108	134	0.1	0.16			0.19				
8/14/1979	WHI51		6.6		4.9	7.38	12	18	121	0.08	0.07			0.04				
9/10/1979	WHI51		6		5.5	7.43	7.8	12	160	0.09	0.03			0.03				
10/9/1979	WHI51		5.1		3.9	7.4	7.6	14	170	0.11	0.04			0.07				
11/6/1979	WHI51		5.7		2.7	7.23	94	30	186	0.15	0.47			0.87				
12/4/1979	WHI51		12.2		3.4		9.2	6	98	0.02	0.3			0.03				
1/8/1980	WHI51		12		2.8	7.38	10	3	108	0.12	0.26			0.01				
2/5/1980	WHI51		12.7			7.51	3.8	2	98	0.03	0.1			0.01				
3/4/1980	WHI51		12.7		1.1	7.53	9	4	74	0.01	0.11							
4/1/1980	WHI51		10.4		1.5	7.3	38	26	90	0.49	0.63			0.06				
5/6/1980	WHI51		7.5		4.1	7.57	24			0.02	0.07			0.05				
6/3/1980	WHI51		8.9		6.2	7.1	20	30	66	0.09	0.18			0.01				
7/8/1980	WHI51		12		10.4	7.86	10	30	121	0.14	0.1			0.14				
7/29/1980	WHI51		4.5		2.4	7.71	12	24	116	0.12	0.02			0.07				
8/26/1980	WHI51		5.2		4	7.72	9	19	145	0.03	0.01			0.08				
9/23/1980	WHI51		3.1		2.7	7.61	25	49	154	0.1	0.06			0.1				
10/21/1980	WHI51		6.6		2.4	7.55	46	44	148	0.06	0.53		0.01	0.07				
11/18/1980	WHI51		7.7		5.2	7.4	28	22	208	0.04	0.33		0.04	0.11				
12/9/1980	WHI51		9			7.45	84	80	152	0.09	1.9		0.06					

Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO SAT (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
2/17/1981	WHI51		12.8		2.3	7.8	4.5	6	138	0.06	1		0.01					
3/3/1981	WHI51		8.8		1.9	7.46	49	38	94	0.01			0.01	0.1				
3/17/1981	WHI51					7.63	25	22	87	0.04	1.2		0.02	0.07				
3/31/1981	WHI51		9.7			7.61	43	40	68	0.04	1.2		0.01	0.04				
5/5/1981	WHI51				2.4	7.52	31	32	76	0.02	0.28		0.07	0.06				
6/2/1981	WHI51		7.7		2.5	7.65	46	39	84	0.13	0.75		0.01	0.04				
6/30/1981	WHI51		5.9		1.3	7.42	24	29	97	0.32	0.19		0.01	0.06				
7/28/1981	WHI51		5.4			7.56	280	316	145	0.02	0.49		0.07	0.49				
8/11/1981	WHI51		5.8		5.5	7.56	38	50	140	0.03	0.43		0.05	0.09				
9/15/1981	WHI51		4.9		1.6	7.56	43	47	139	0.08			0.01	0.09				
10/13/1981	WHI51		7.2		3.1	7.66	25	30	156	0.05	0.1		0.01	0.03				
12/8/1981	WHI51		10.4		1.4	7.99	19	40	88	0.04	0.19		0.01	0.05				
1/5/1982	WHI51		11.5		1.3	7.89	9	12	127	0.07	0.32		0.01	0.06				
2/9/1982	WHI51		11.6		0.9	7.69	19	16	99	0.08	0.84		0.04	0.11				
3/9/1982	WHI51		11.9		0.4	9.64	1.6	8	117	0.01	0.29		0.01	0.04				
4/6/1982	WHI51		10		1.4	7.48	260	24	84	0.03			0.02	0.07				
5/4/1982	WHI51		8.8		1.6	7.51	20	27	96	0.06	0.15		0.01	0.06				
6/1/1982	WHI51		8.4		1.1	7.33	63	48	102	0.09	0.32		0.06	0.14				
7/6/1982	WHI51		5.7		2.5	6.9	25	32	98	0.18	0.74		0.05	0.1				
7/27/1982	WHI51		5.6			7.54	22	26	132	0.1	0.9		0.31	0.5				
8/17/1982	WHI51		4.2		2.8	7.38	38		143	0.04	0.63		0.45	0.06				
9/21/1982	WHI51		6.1		1.4	7.45	26	27	151	0.01	0.09		0.01	0.08				
10/19/1982	WHI51		8.1		2.7	7.65	6.1	28	176	0.01	0.01		0.01					
11/23/1982	WHI51		8		7.1	7.49	760	169	172	0.08			0.04	0.54				
12/14/1982	WHI51		11.9		1	7.35	3.2	7	91	0.05			0.03	0.04				
2/15/1983	WHI51		11.6		1.4	7.53	5.5	14	82	0.18	0.55		0.03	0.08				
3/8/1983	WHI51				0.8	7.53	22	10	76	0.02	0.38		0.02	0.04				
4/12/1983	WHI51		10.8		1.1	7.56	24	18	72	0.06			0.01	0.05				
5/10/1983	WHI51		9.3		1.7	7.65	2	18	83	0.01	0.18		0.01	0.04				
6/28/1983	WHI51		5.8		2.5	7.4	45	54	123	0.08	0.26		0.01	0.09				
7/19/1983	WHI51		6.1		1.9	7.56	18	19	122	0.1	0.1		0.01	0.07				
8/16/1983	WHI51		6		2.7	7.46	18	18	144	0.07	0.01		0.01	0.06				
8/30/1983	WHI51					7.81	18	15	131	0.06			0.01	0.09				
9/13/1983	WHI51		8.6		4.3	7.45	8	11	142	0.2			0.07					
11/15/1983	WHI51		9.7		3.5	7.63	3.5	7	206		0.07			0.07				
12/6/1983	WHI51		10.6		1	7.56	23	14	132	0.04	0.94		0.01	0.05				
1/10/1984	WHI51		12.7		1.1	7.43	4	6	138	0.1	0.67		0.04	0.1				
2/7/1984	WHI51				1.8	7.61	5	6	136	0.09	0.5		0.04	0.04				
3/6/1984	WHI51		11.5		1.3	7.2	32	24	82		1.12		0.05	0.09				
4/17/1984	WHI51		10.4		0.6	7.52	17	12	89	0.06	0.56		0.05	0.05				
6/12/1984	WHI51		7.6		1.4	7.61	20	15	111	0.04	0.17		0.03					
7/24/1984	WHI51		5.9		2.5	7.53	9.8	20	140	0.05	0.05		0.02	0.08				

Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO SAT (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
8/21/1984	WHI51		5.8		3	7.4	9	13	136	0.1	0.11		0.04	0.07				
9/18/1984	WHI51		6.5		1.4	7.72	19	20	181	0.12	0.1		0.04	0.07				
10/16/1984	WHI51		6.9		1.9	7.6	26			0.08	0.2		0.06	0.09				
11/13/1984	WHI51		10.3			7.45	7	8	109	0.01	0.85			0.03				
12/11/1984	WHI51		10.8		0.5	7.54	7	7	92	0.03	0.68		0.02					
1/15/1985	WHI51		13.2			7.33	12	12	96	0.01	0.81		0.01	0.06				
2/19/1985	WHI51		14.3		1.1	7.39	14	12	104	0.05	0.62		0.02	0.05				
3/19/1985	WHI51		11.2		1.6	7.65	2	8	87	0.05	0.4		0.03					
4/16/1985	WHI51		10		1.5	7.62	8	10	85	0.07			0.05					
5/14/1985	WHI51		7.7		1.6	7.61	18	22	83	0.08	0.24		0.05	0.09				
6/11/1985	WHI51		8			7.94	8	9	187	0.05	2.1		0.16	0.19				
7/15/1985	WHI51		8.4		3.4	7.75	8	16	136	0.08	0.08		0.01	0.06				
8/13/1985	WHI51		6.8		2	7.87	15	24	191	0.02	0.33		0.06	0.08				
9/10/1985	WHI51		7.1		2.4	7.79	16	24	144	0.06	0.11		0.01	0.09				
10/22/1985	WHI51		7.6		0.8	7.68	25	24	144	0.04	0.59		0.05					
11/12/1985	WHI51		8.5		3.6	7.8	7	12	154	0.04	0.2		0.06	0.11				
12/10/1985	WHI51		10.1		4.8	7.83	200	257	129	0.24	0.54		0.16	0.42				
1/28/1986	WHI51		13.5		0.8	7.81	4	6	105		0.22		0.03	0.03				
3/25/1986	WHI51		10.3		0.8	7.77	11	20	91	0.03	0.3		0.08	0.1				
4/22/1986	WHI51		10		0.6	7.42	22	16	100	0.07	0.36		0.04	0.05				
5/27/1986	WHI51		7.6		0.8	7.68	17	28	110	0.02	0.4			0.06				
6/24/1986	WHI51		6.5		2.2	7.7	15	28	139		0.2		0.07	0.17				
7/29/1986	WHI51		5.6		2.5	7.65	11	68	179	0.2	0.33		0.4	0.35				
8/12/1986	WHI51		8.7		2.2	8.18	5	56	122	0.09	0.98		0.1	0.11				
9/23/1986	WHI51		7		0.8	7.91	22	23	126	0.01	0.6		0.04	0.06				
10/21/1986	WHI51	2.2	9		1.7	7.8		11	122	0.01	0.4	0.1						
11/24/1986	WHI51	2.1	10.8		0.7	7.76	4	4	111	0.02	0.3	0.5	0.04	0.04				
12/16/1986	WHI51	2.1				7.66	8	12	99	0.04	0.39	0.2	0.06	0.06				
1/27/1987	WHI51	1.2	12.9		0.3	7.8	7	1	95	0.21	0.6	0.2	0.06	0.03				
2/24/1987	WHI51	3	11.9		0.7	7.88	9.5	7	97	0.03	0.5	0.1	0.05	0.03				
3/24/1987	WHI51	3.4	10.4		1.8	7.68	48	51	71	0.15	0.42	0.4	0.15	0.16				
5/26/1987	WHI51	3	7.8		1.1	7.79	21	25	91	0.01	0.21	0.3	0.05	0.07				
6/23/1987	WHI51	6	6.7		5.6	7.71			128	0.01	0.38	1.7						
7/21/1987	WHI51	5.6	10		6.7	8.26	13	15	181	2.5	6.1	3.5	0.03	0.12				
8/18/1987	WHI51	4.9	4.5		3.2	7.37	90	78		0.4	0.96	0.8	0.16					
9/22/1987	WHI51	5.4	7.3		1.3	7.77	31	33	146	0.02	0.43	0.1	0.02	0.07				
12/8/1987	WHI51	2.9	9.8		0.8	7.74	21	12	224	0.01	0.5	0.2		0.07				
12/29/1987	WHI51	3	11.9		0.5	7.56		14	71		0.63	0.4	0.05	0.04				
1/26/1988	WHI51	1.9	12.9		0.6	7.77	8	3	75	0.09	0.49	0.6	0.03	0.03				
3/22/1988	WHI51	3.1			0.9	7.85	20	20	88	0.06	0.26	0.3	0.07	0.08				
4/26/1988	WHI51	3.4	9.5		0.8	8.01	8	8	79	0.04	0.14	0.6	0.01	0.06				
5/24/1988	WHI51	6.2	6.8		2.7	7.72	12	18	147	0.35	1.2	0.6	0.06	0.1				
6/21/1988	WHI51	10.2	7.9			7.83	9	15	124	0.06	0.04	1.6	0.05	0.07				
7/26/1988	WHI51	7.9	8.6		3.6	7.76	8	17	143	0.07	0.32	0.7	0.09	0.09				
8/2/1988	WHI51	7.9	7.2		4.3	7.81	16	29		0.07	0.03		0.03	0.09				

Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO $_{SAT}$ (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
9/27/1988	WHI51	6.3	8.2			7.63	22	25	122	0.01	0.37	0.6	0.02	0.07				
10/25/1988	WHI51	5.9	7.7		3.2	7.49	7	10	222	0.03	0.99	0.4	0.04	0.07				
11/29/1988	WHI51	3	10.4		0.8	7.96	23	9	97	0.14	0.7	0.2	0.06	0.06				
12/27/1988	WHI51	2.5			1.2	7.88	47	42	118	0.04	0.39	0.4	0.36					
1/24/1989	WHI51	2.5	11.8		0.8	8.07	10	14	109	0.01	0.26	0.4	0.05	0.05				
2/28/1989	WHI51	2.4	11.1		1.4	6.91	10	8	100	0.06	0.67	0.3	0.04	0.07				
3/28/1989	WHI51	7.2	8.7		3.7	7.67	170	207	133		0.35	0.9	0.1					
5/23/1989	WHI51	3.9	7.9		0.9	7.83	40	35	98	0.01	0.23	0.6	0.03	0.1				
6/20/1989	WHI51	3.1	8		0.8	7.76	21	19	86	0.01	0.27	0.6	0.01	0.09				
7/25/1989	WHI51	3.9	7.7		1.7	7.95	15	21	138	0.05	0.34	0.62	0.03	0.09				
8/22/1989	WHI51	5.2	6.7		3.5	7.81	52	133	153	0.05		1.1	0.03	0.16				
9/5/1989	WHI51	7.3	8.1		4.8	7.85	8	14		0.05	0.04	0.94		0.06				
12/5/1989	WHI51	3.9	11.1		1.1	7.93	2.6	2			0.02	0.52		0.1				
12/19/1989	WHI51	5.9	13.9		3.7	8.18	4.5	10	200	0.05	0.08	0.64	0.04	0.06				
1/23/1990	WHI51	2.9	10.7		0.3	7.92	16	8	105	0.06	1.47	0.62		0.07				
2/27/1990	WHI51	1.3	10.7			8.11	14	13	84	0.05	0.68	0.63		0.11				
3/27/1990	WHI51	1.7	11.3		0.8	8.07	10	6	94	0.13	0.46	0.38	0.03	0.05				
4/24/1990	WHI51	5.2	8.5		0.2	7.95	22	20	47	0.05		0.74	0.03	0.08				
5/8/1990	WHI51	1.6	8.8		0.3	7.94	22	17	91	0.05	0.4	0.8	0.03	0.07				
6/26/1990	WHI51	8.6	7			7.75	140		119	0.44	1.16	0.88	0.05	0.29				
7/31/1990	WHI51	5.4	7.5		3.7	7.81	19	17	144		0.14	0.76	0.03	0.08				
8/28/1990	WHI51	6.3	6.7		1.7	7.98	5.2	9	160	0.05	0.06	1	0.03	0.07				
9/25/1990	WHI51	6.9	5.8		0.9	7.66	56	36	172	0.08	0.96	1.18	0.05	0.38				
10/23/1990	WHI51	3.9	9.4		1	7.95	7	11	158	0.14	0.69	0.86		0.04				
11/19/1990	WHI51	4.2	9.4		1.2	7.77	6.4	9	131	0.05		0.58	0.03	0.07				
12/18/1990	WHI51		10.3		2	7.62	48	43	85	0.05		1	0.04	0.16				
1/29/1991	WHI51	2.4	12			7.72	6.6	6	82	0.05	0.73	0.3	0.03	0.05				
2/26/1991	WHI51	2.5	11.7		2.1	7.93	7	8	104	0.05	0.27	0.49	0.03					
3/26/1991	WHI51	2.8	9.2		1.3	7.75	18	17	80	0.05	0.41	0.21	0.03					
4/23/1991	WHI51	2.6	9.7		0.9	7.72	24	20	81	0.05	0.38	0.41	0.03	0.06				
5/7/1991	WHI51	3.1	9.1		1.1	7.77	34	27	86	0.05	0.23	0.28	0.03	0.12				
6/25/1991	WHI51	3.9	6.7		1.4	7.84	14	11	118	0.05		0.52	0.05					
7/23/1991	WHI51	5.5			1.5	7.99	9.4	11	158	0.07	0.08		0.03	0.15				
8/27/1991	WHI51	5.7	5.5		1.4	7.66	20	15	140	0.05	0.81	0.7	0.06	0.08				
9/24/1991	WHI51	7.8	6.6		1.9	7.83	230	78	188	0.14	1.29		0.16	0.14				
10/22/1991	WHI51	7.7	7.9		2	7.78	9.4	12	207	0.05	0.09	0.41	0.03	0.06				
11/19/1991	WHI51	3.8	9.2			7.75	26	20	92	0.05	1.08	0.51	0.07	0.07				
12/30/1991	WHI51	4	11.5		0.2	7.94	7.9	6	88	0.05	0.68		0.04	0.03				
1/28/1992	WHI51	2.6	12.4		0.9	9.06	4.8	4	86	0.07	0.53	0.34	0.03	0.03				
2/18/1992	WHI51	4.1	12		2.1	8.9	14	14	85	0.05		0.52	0.03	0.05				
3/17/1992	WHI51	2.2	9.6		1.2	8.46	7.8	12	82	0.05			0.03	0.05				
4/21/1992	WHI51	4.3	10.2		3.5	7.73	46	45	76	0.12	0.42	0.47	0.08	0.103				
5/26/1992	WHI51	4.4			1.4	7.8	32	31	140	0.05	0.38	0.66	0.03	0.074				
6/22/1992	WHI51	6.3	7.2		1.5	7.68	74	35	110	0.14	0.45		0.03	0.164				

Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO SAT (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
7/21/1992	WHI51	5.1	6.8		1.7	7.54	34	30	131	0.09			0.03	0.088				
8/18/1992	WHI51		8.2		1.7	7.58	24	27	145	0.05	0.39	0.49	0.053	0.066				
9/15/1992	WHI51	3.7	7.2		2	7.42	31	30	156	0.05	0.31	0.47	0.03	0.088				
10/13/1992	WHI51	5.6	7.8		3.8	7.13	20	22	160	0.05	0.12	0.68	0.058	0.065				
11/3/1992	WHI51	10.7	6.8		6.6		270	198	183	0.05	0.39	1.45	0.084	0.341				
12/8/1992	WHI51	3.4	8.2		0.8		8	4	123	0.05	0.79	0.7		0.03				
2/22/1993	WHI51	3.4	12.4		1.2	7.12	39	12	78	0.05	0.47	0.52	0.063	0.057				
6/15/1993	WHI51	2.9	7		1.5	7.23	12	30	102	0.105		0.68	0.047	0.134				
7/6/1993	WHI51	4.3	6.6		1.3	7.02	11	15	114	0.051		0.84	0.03	0.03				
8/3/1993	WHI51	7.4	5.2		1.6	7.21	26	37	154	0.05	0.09	0.49		0.123				
8/30/1993	WHI51	5.3	6.4		2.5	7.58	81	37	164	0.085	0.53	0.9	0.087	0.169				
10/5/1993	WHI51	5.6	7.5		0.7	7.25	60	41	168	0.05	0.76	0.66	0.041	0.146				
11/9/1993	WHI51	2	10.4		1.2	7.07	4	2	138	0.05	0.28		0.082	0.03				
12/14/1993	WHI51	3.4	11.6		1.2	6.88	5.8	22	98	0.059	0.5	0.54	0.041	0.12				
1/11/1994	WHI51	1.7	13.8		1		4.6	2	103	0.05	0.25	0.88	0.03	0.03				
2/14/1994	WHI51	2	13.2		0.8	7.28	2.9	2	101	0.062	0.4	1.05	0.05	0.03				
3/15/1994	WHI51		10.6		0.5	7.67	18	7	83	0.192	0.56	0.57	0.063	0.039				
4/6/1994	WHI51		10.5		1.5		37	20	94	0.069	0.31	0.36	0.054	0.076				
5/10/1994	WHI51	1.7	8.8		0.6	7.2	14	8	103	0.05	0.21	0.73	0.03	0.03				
6/7/1994	WHI51	7.4	6.4		1.7	7.35	28	27	154	0.072	0.4	0.68	0.038	0.081				
7/12/1994	WHI51	5.5	6.8		3.1	7.28	18	17	166	0.05	0.27	0.62	0.03	0.045				
8/9/1994	WHI51	4.7	7		1.8	7.31	16	29	174	0.05	0.23	0.62	0.035	0.087				
9/19/1994	WHI51	4.2	6.6		2.3		7.8	14	189	0.11	0.04	0.8	0.03	0.048				
10/10/1994	WHI51	5.4	7		1.7	6.97	14	13	137	0.05	0.15		0.056	0.043				
11/8/1994	WHI51	2.8	9.6		1.4	6.8	29	15	107	0.106	0.97		0.095	0.043				
12/6/1994	WHI51	3.6	11.8		0.9	7.02	12	8	105	0.096	0.48	0.33	0.069	0.036				
1/10/1995	WHI51	2.9	14.2		1.6	7.71	5.4	2	109	0.05	0.42	0.45	0.03	0.03				
2/27/1995	WHI51	2.9	10.2		2	7.28	24	18	129	0.05	0.39		0.051	0.074				
4/11/1995	WHI51	7.4	10			7.28	100	140	120	0.08	0.38	1.35		0.229				
5/9/1995	WHI51	4.1	9.6		1.4	7.15	39	34	77	0.05		0.43	0.031	0.096				
6/27/1995	WHI51				0.7		25	18	137	0.051	0.36	0.62	0.032	0.048				
8/1/1995	WHI51	4.4			1.4		26	38	114	0.05	0.26	0.39	0.058	0.082				
8/29/1995	WHI51	4.1	5.5		0.9	7.57	9	8	151	0.052	0.02	0.54	0.03					
9/25/1995	WHI51	4.3	7.2		0.7	7.57	14	11	161	0.051	0.29	0.74		0.032				
10/24/1995	WHI51	4	5.5		0.4	7.9	12	12	148	0.05	0.02	0.57	0.03	0.056				
11/14/1995	WHI51	3	11		0.9	8.01	9.5	4		0.05	0.03	0.66	0.03	0.03				
1/9/1996	WHI51	2.8	13.1		1	7.15	10	2	134		0.97	0.56		0.03				
1/22/1996	WHI51	2.6	12.2		0.5	7.35	19	8	96	0.05	1.44	0.27	0.03	0.03				
2/27/1996	WHI51	2.4	8		1	7.67	11	3	61	0.05	1.02	0.45	0.03	0.079				
3/19/1996	WHI51	3.5	8.2		1.6	7.43	15	11	157	0.079		0.54	0.031					
4/23/1996	WHI51	7	9.3		1.7	7.71	120	105	112	0.062		0.94	0.118					
5/14/1996	WHI51	2.6			0.4		19	8	99	0.065	0.7	0.57	0.156	0.182				
6/4/1996	WHI51	4.8			1	7.65	56	36	116	0.05	0.74	0.54	0.032	0.051				

Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO SAT (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
7/2/1996	WHI51	4.2	5.6		1.7	7.5	17	18	158	0.05	0.38	0.85	0.03	0.059				
8/20/1996	WHI51	6.4	5.4		0.6	7.54	18	12	140	0.05	0.6	0.82	0.033	0.031				
9/10/1996	WHI51	4.3	8.7		1.4	7.78	14	12	142	0.05	0.15	1.07	0.044	0.051				
10/22/1996	WHI51	6.6	7.2		3.8	7.54	120	121	169	0.05	0.38		0.084	0.204				
11/12/1996	WHI51	1.8	10.7		0.4	8.06	20	9	109	0.05	0.94	0.34	0.03	0.03				
12/3/1996	WHI51	2.4	10.1		0.2	7.9	23	13	92	0.05	0.74		0.03	0.035				
1/27/1997	WHI51	2.1			0.6	7.62	8.2	2	94	0.05	0.41	0.46	0.03	0.03				
2/11/1997	WHI51		11.8		0.2	7.42	13	2	95	0.05	0.57	0.64	0.03	0.03				
3/4/1997	WHI51	2.2			0.3	7.3	25	7	84	0.05	0.59	0.63	0.03	0.03				
4/8/1997	WHI51	2.7			1.7	8.83	53	100	95	0.05	0.28	0.84	0.057	0.135				
5/13/1997	WHI51	1.9	9.1		0.9	7.86	9.8	12	100	0.05	0.18	0.5	0.03	0.03				
6/17/1997	WHI51				3.5	7.61	200		140	0.05	0.39	1.32	0.062					
7/8/1997	WHI51	2.5	7.8		0.4	7.58	76	37	126	0.05	0.48		0.037	0.11				
8/5/1997	WHI51	4.3	8.4		1.8	7.81	14	14	171	0.05	0.06		0.009	0.05				
9/9/1997	WHI51	2.2	7.1		1.1	8.09	19	15	157	0.05	0.01		0.016	0.072				
10/7/1997	WHI51	3.4	8.5		0.9	7.7	13	12	197	0.005	0.1		0.019	0.066				
11/4/1997	WHI51	3	8.2		0.9	6.91	12	10	198	0.005	0.51		0.007	0.049				
12/2/1997	WHI51	2.2	9.4		0.7	7.62	1.5	10	164	0.005	0.25		0.017	0.03				
1/6/1998	WHI51	3.8	11		1.7	7.79	250		93	0.04	0.74	0.982	0.052	0.255				
3/3/1998	WHI51	2.8	12.4		0.7	7.45	12	2	98	0.053	0.44	0.254	0.021	0.033				
3/31/1998	WHI51	4.5	9.6		1.8	7.3	100	81	109	0.064	0.39	1.03	0.053	0.164				
5/5/1998	WHI51	2.6	8		1	7.72	26	16	102	0.052	0.16	0.242	0.005	0.049				
6/30/1998	WHI51	4.4	5.9		0.8	7.33	8.4	12	161	0.054	0.31	0.483	0.01	0.049				
8/4/1998	WHI51	3.1	4		0.9	7.28	5.7	3	124	0.096	0.19	0.229	0.029	0.055				
10/13/1998	WHI51	2.3	8.9		0.4	7.7	13	10	180	0.032	2.39	0.203	0.008	0.033				
11/3/1998	WHI51	3.3	7.2		1.2	7.51	18	15	193	0.019	0.68	0.295	0.012	0.049				
12/1/1998	WHI51		9.6		1.5	7.5	39	28	160	0.016	0.86	0.406	0.026	0.093				
1/12/1999	WHI51	2.4	11.48	96.90%	0.25	7.32	4.9	1.5	110	0.007	1.11	VOID	(BDL)	(BDL)	4.39	24.1	(BDL)	0.079
2/8/1999	WHI51	4	8.29	76.90%	0.7	7.45	36	28	95	0.032	1.36		0.017	0.053	2.76	12.77	0.029	0.052
3/8/1999	WHI51		9.46	79.90%	2.57	6.78	30	44.2	152	(BDL)	0.714	0.498	0.014	0.085	6.12	40.3	0.066	0.096
4/19/1999	WHI51	2.3	9.43		0.72	6.9		3	97	0.018	0.512	0.245	0.013	0.025	3.06	18.6	0.06	0.113
5/3/1999	WHI51	void	8.4	88.70%	0.13	7.26	11	7	85.5	(BDL)	0.34	0.288	0.009	0.025	2.66	15.1	0.058	0.115
6/7/1999	WHI51	3.43	6.9	88.20%	1.28	7.08	8.3	7	129	(BDL)	0.405	0.3	(BDL)	0.046	3.71	21.7	0.052	0.143
7/12/1999	WHI51	2.4			0.75		8.5	5.5	153.5	0.006	0.58		0.01	0.024	3.68	36.6	0.057	0.101
8/10/1999	WHI51	3	5.86	77.50%	2.2	7.21	1.4	28	185	0.019	0.052	0.652	(BDL)	0.084	5.12	34.8	0.058	0.139
9/13/1999	WHI51	4.47	6.56	72.20%	1.46	7.41	21	15	195.5	0.046	0.751	0.525	0.041	0.077	8.6	50.5	0.062	0.237
10/12/1999	WHI51	5.17	6.92	82.20%	0.44	7.37	3.9	2	178	0.033	0.066		0.018		7.99	47.3	(BDL)	0.172
11/22/1999	WHI51	4.31	9.88	98%	1.15	8.84	7.3	7	174.5	(BDL)	0.019	0.389	(BDL)	0.038	5.72	35.57	0.06	0.16
12/7/1999	WHI51	2.8	6.33	54.80%	1.07	7.7	43	14	188.5	0.031	0.445		0.013	(BDL)	5.4	57.72	(BDL)	0.09
1/4/2000	WHI51	5.9	11.04	88.70%	1.8	7.14	74	49.5	177	0.037	1.06		0.032	0.145	4.77	50.95	(BDL)	0.097
2/7/2000	WHI51	2	8.01	67.60%	0.31	7.61	4.1	3	203	0.005	0.648		(BDL)		12.56	66.53	0.054	0.094
3/7/2000	WHI51	2.05	9.77	94.80%	0.42			12	100	0.012	0.798		(BDL)	0.044	4.64	23.9	(BDL)	0.06

Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO SAT (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
4/18/2000	WHI51	4.03	9.72	104.80%	0.56	7.35	15	16	106	0.013	0.401		0.011			23.5	(BDL)	0.056
5/16/2000	WHI51	1.84	8.7	95.70%	0.66		9	12.5	126.5	0.011	0.302	0.235	0.077	0.035	3.39	28.4	(BDL)	0.073
6/13/2000	WHI51	2.628	7.81	89.30%	0.91	6.97	18	18	137.5	0.017	0.451	0.219	0.012	0.034	3.59	33.1	(BDL)	0.088
7/18/2000	WHI51	2.15	8.57	109.50%	1.18	7.71	6.5	9	164	0.0393			0.0058	0.03	5.91	35.01	(BDL)	0.13
8/15/2000	WHI51		6.11	72.60%	1.25	6.95	8.3	15	173	(BDL)	0.102	0.424	0.015	0.054	4.97	37.31	(BDL)	0.13
9/12/2000	WHI51	4.3	6.16	73.20%	2.39	7.91	33	40	179.5	(BDL)	0.067		0.007		6.56	40.6	(BDL)	0.17
10/10/2000	WHI51	3.24	11.53	107%		7.86	4.1	4.5	174	0.02	0.12	0.414	0.01	(BDL)	5.94	44.76	(BDL)	0.15
11/7/2000	WHI51	3.751	12.32	114.30%	1.01		33	28.5	117.5	0.036	2.012		0.038	0.072	3.5	21.74	(BDL)	0.08
12/5/2000	WHI51	2	13.52	105.90%	0.2	7.95	2.8	(BDL)	136	(BDL)	1.722	(BDL)	(BDL)	0.02	4.8	36.27	(BDL)	0.08
1/23/2001	WHI51	1.14	13.82	102.70%	0.2	8.26	3.2	1.5	109	(BDL)	1.31		(BDL)	(BDL)	5.85	27.72	(BDL)	0.08
2/27/2001	WHI51	1.747	11.9	103%	0.1	7.69	17	13	101	(BDL)	1.615	0.08	0.011	0.025	3.05	24.4	(BDL)	0.07
3/27/2001	WHI51	1.41	11.24	101.90%	0.57	7.79	5.9	4.5	107	(BDL)	0.612		(BDL)	0.03	4.35	23.65	0.04	0.09
4/24/2001	WHI51	2.89	7.98	87.80%	0.85	7.63	10	14	107.5	0.06	0.38	0.294	(BDL)	0.033	4.26	19.68	(BDL)	0.08
5/29/2001	WHI51	2.836	7.91	87%	0.35	7.52	16	17.5	151.5	0.017	0.379	0.274	(BDL)	0.049	4.75	30.29	NA	0.1
6/26/2001	WHI51		7.09	90.60%	0.87	7.4	12	11.5		0.005	0.335	0.39	(BDL)	0.04	4.15	32.6	(BDL)	0.12
7/24/2001	WHI51	3.07	7.16	99.70%	1.24	7.52	20	21	155	0.02	0.32	0.454	0.01	0.047	4.63	32.27	(BDL)	0.11
8/28/2001	WHI51	3.226	7.02	91.30%	0.61	7.49	15	6.3	145.5	0.015	0.222	0.69	0.008	(BDL)	4.39	29.45	(BDL)	0.19
9/25/2001	WHI51	2.139			0.44	7.63	22	8.8	169.5	0.023	0.686	0.204	0.014	0.041	4.12	43.23	(BDL)	0.1
10/16/2001	WHI51	2.415	9.29	90.10%	0.33	7.62	17	9.5	147	0.009	0.922	0.451	0.023	(BDL)	4.03	30.59	0.03	0.08
11/19/2001	WHI51	3.209	8.67	82.30%	2.74	7.51	43	40	174	(BDL)	0.593		0.012	0.059	6.5	43.69	(BDL)	0.33
12/18/2001	WHI51	2.6	10.81	95.80%	0.31	7.14	31	23.2	88	0.032	0.796		0.018	0.07	2.55	13.54	(BDL)	0.05
1/22/2002	WHI51	1.074	14	112.50%	0.57		3.5	1.3	127	0.009		0.238	(BDL)	(BDL)	5.34		0.04	
2/20/2002	WHI51	5.42			1.63	6.92	97	39.5	120	0.061	0.51	0.913	0.043	0.132	3.1	11.37	(BDL)	0.06
3/12/2002	WHI51	1.6	13	115.20%	0.25	7.9	8	3	109.5	0.015	0.317	0.64	(BDL)	0.02	5.31	23.89	(BDL)	
5/14/2002	WHI51				1.27	7.4	38	27.5	132	0.048	0.333	0.723	0.017	0.063	3.53	22.04	(BDL)	0.12
6/11/2002	WHI51		6.85	79.90%	0.89	7.17	52	18	121.5	0.039	0.34	0.38	0.019	0.049	2.79	17.03	(BDL)	0.1
7/23/2002	WHI51	2.865	5.65	72.20%	0.85	7.17	9.7	12.8	169	0.028	0.222	0.437	(BDL)	0.055	5.09	28.84	0.03	0.17
8/20/2002	WHI51		6.24	76.90%	0.51	7.13	12	14.3	167	0.044	0.727	0.51	(BDL)	0.044	4.52	42.93	0.05	0.13
9/24/2002	WHI51	4.99			0.67	6.89	8.2	5.7	187	(BDL)	0.544	0.677	0.009	0.042	8.16	41.5	0.16	0.26
10/22/2002	WHI51	2.93	6.89	66.90%	0.56	7.7	4.71	1.8	197	(BDL)	0.03	0.572	0.044	0.022	8.2	44.3	0.16	0.19
11/19/2002	WHI51	4.41	7.58	62.40%	1.27	6.89	3.38	1.5	207	(BDL)	0.075	0.35	0.02	0.066	8.08	49.6	0.11	0.2
12/9/2002	WHI51	3.33	12	94%	1.07	7.97	12.8	2.3	206	(BDL)	0.255	0.396	(BDL)	0.08	12.8	58.9	0.09	0.17
1/14/2003	WHI51	1.79	11.6	90.80%	(BDL)	8.58	4.04	(BDL)	160	(BDL)	0.674	0.213	0.019	0.038	9.72	43.2	(BDL)	0.1
2/11/2003	WHI51	2.25	12.4	94.60%	0.86	7.8	8.66	2.2	190	(BDL)	0.346	0.408	(BDL)	0.031	15.7	55.8	0.1	0.12
2/11/2003	WHI51	2.2	14	109.60%	1.43	6.17	14.7	14.5	126	(BDL)	1.36	void	(BDL)	0.053	12.2	29.6	(BDL)	0.16
3/4/2003	WHI51	2.62	12.3	96.30%	0.5	7.32	13	3	162	(BDL)	0.815	0.161	(BDL)	(BDL)	9.07	30.2	(BDL)	0.05
4/8/2003	WHI51	2.09	10.9	101.10%	0.73	7.53	19.6	15.2	130	0.035	0.196	0.318	(BDL)	0.095	7.21	31.1	(BDL)	0.11
5/13/2003	WHI51	2.27	7.5	84.10%	0.62	7.41	29.3	21.8	120	(BDL)	0.364	0.339	(BDL)	0.095	6.02	20.9	0.01	0.09
6/10/2003	WHI51	1.91	7.43	85%	1.02		18.2	11.2	123	(BDL)	0.182	0.365	0.006	0.238	4.65	21.6	(BDL)	0.1
7/8/2003	WHI51	2.71	5.49	67.70%	1.7	7.69	35.2	10.7	142	0.04	0.157	0.503	0.042	0.103	7.01	28.8	(BDL)	0.22
7/29/2003	WHI51	4.37	5.54	69.50%	1.06	7.41	21.1	12.5	213	0.047	0.323	0.626	(BDL)	0.033	26.8	31.2	0.13	0.21
9/2/2003	WHI51	3.78	6.25	75.60%	1.8	7.55	49.8	37.2	136	0.051	0.285	0.595	0.019	0.077	5.28	25.7	0.05	0.18

Appendix 2-C (continued)

Date	Station	TOC (mg/L)	DO (mg/L)	DO SAT (%)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TKN (mg/L)	PO_4-P (mg/L)	TP (mg/L)	Cl^- (mg/L)	SO_4^- (mg/L)	Br^- (mg/L)	F^- (mg/L)
10/7/2003	WHI51	2.48	7.87	81.40%	0.91	7.6	9.78	5.5	167	(BDL)	0.023	0.334	0.01	(BDL)	8.5	40.5	0.04	0.13
11/18/2003	WHI51	6.12	8.57	83.20%	3.38	6.78	95.3	60.5	171	0.062	0.483	0.941	0.054	0.191	6.38	36.8	(BDL)	0.15
12/2/2003	WHI51	2	12.8	102.80%	0.22	6.41	15.2	3.8	107	(BDL)	0.491	0.202	0.008	(BDL)	6.41	29.8	(BDL)	0.1
1/6/2004	WHI51	3.81	12.9	95.80%	0.8		30	8.8	134	0.053	0.488	0.286	0.017	(BDL)	5.81	27.2	(BDL)	0.08
2/10/2004	WHI51	1.58	13.3	98.80%	0.54		20.3	12	108	(BDL)	0.535	?0.458	0.014	(BDL)	6.52	27.2	0.01	0.09
3/16/2004	WHI51	1.48	10.5	93%	1.05		23.2	18.2	115	(BDL)	0.481	0.315	0.011	?<0.03	5.59	28.8	(BDL)	0.1
4/20/2004	WHI51	1.8	7.32	80.50%	VOID	7.39	13.7	8.8	109	0.034	0.119	0.354	0.009	0.03	4.23	19.8	(BDL)	0.09
5/18/2004	WHI51	1.65	7.64	85.70%	0.99	7.61	16.7	9	106			0.279		0.029	3.28	21.2	(BDL)	0.11

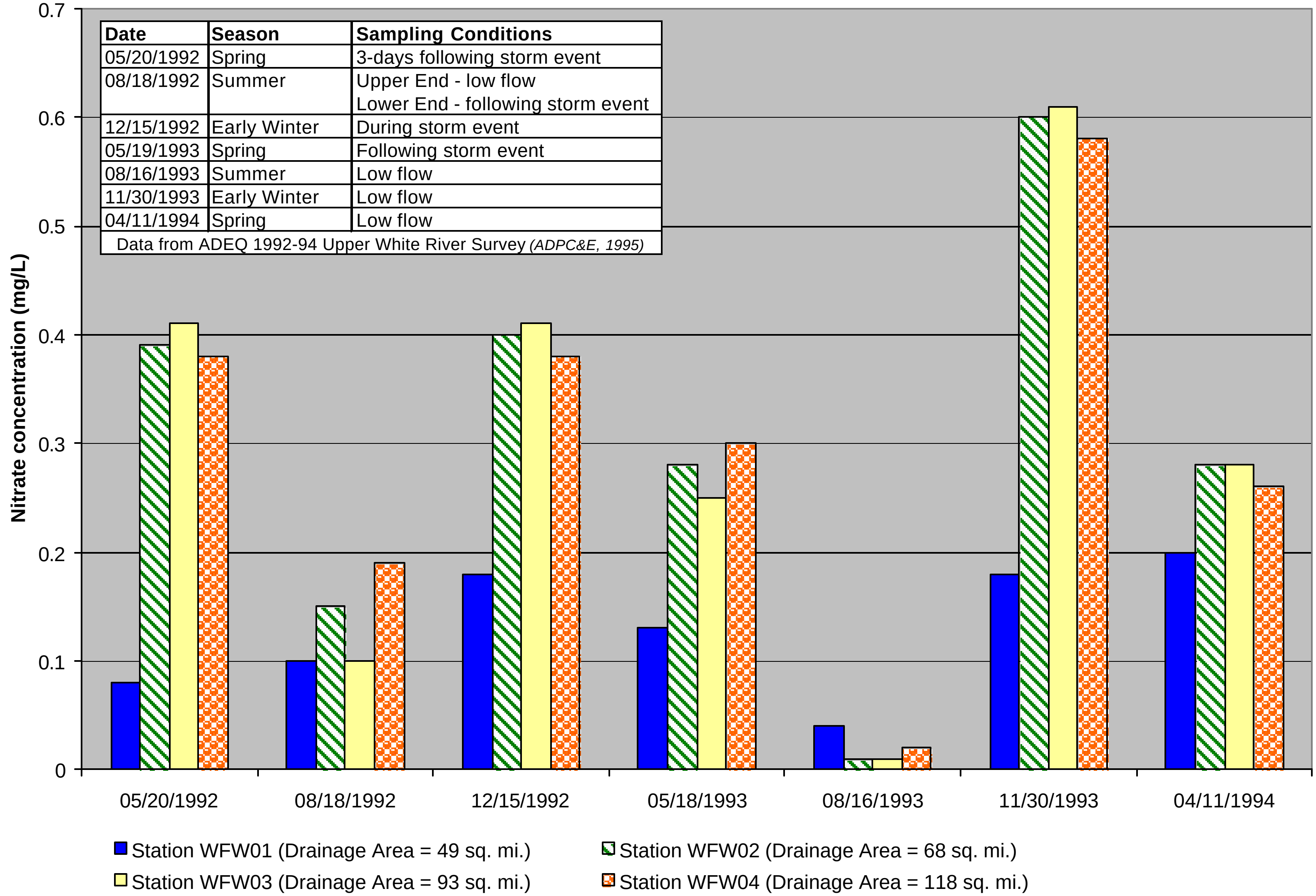
Appendix 2-D

Water Quality Data Collected During the 1992-1994 ADEQ Study of the WFWR

Date	Station	TOC (mg/L)	DO (mg/L)	BOD_5 (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	NH3-N (mg/L)	NO_3^--N (mg/L)	TKN (mg/L)	PO_4^--P (mg/L)	TP (mg/L)	FECAL (#100/mL)	ECOLI (#100/mL)	FLOW (% bank)
05/20/92	WFW01	1.6	8.8		6.98	16	2	41	0.05	0.08		0.05	0.03	80	70	70
	WFW02	3.1	8		7.18	25	20	104	0.05	0.39		0.03	0.045	290	200	85
	WFW03	3.8	8		7.18	37	40	115	0.05	0.41		0.03	0.074	320	340	100
	WFW04	4.8	7.7		7.29	45	44	126	0.05	0.38		0.03	0.084	400	290	100
08/18/92	WFW01	8.4	8.2		6.67	6.5	2	53	0.05	0.1		0.045	0.03	30	30	35
	WFW02	3.8	6.7		6.75	18	20	102	0.05	0.15		0.036	0.03	390	250	30
	WFW03	3.8	7.4		6.78	10	12	117	0.05	0.1		0.03	0.03	90	20	85
	WFW04	3.3	8.4		7.15	23	31	135	0.05	0.19		0.037	0.03	60	10 k	80
12/15/92	WFW01	6.7	10.7		7.51	78	102	48	0.07	0.18		0.097	0.153	620	430	100
	WFW02	10.1	11.5		7.42	155	291	70	0.05	0.4		0.107	0.325	1900	870	200
	WFW03	11.2	11.2		7.65	170	345	83	0.056	0.41		0.126	0.385		1010	200
	WFW04	13.8	10.6		7.5	200	452	98	0.091	0.38		0.148	0.476	3000	1730	200
05/18/93	WFW01	1	9.5	0.3	7.41	12	1	40	0.05	0.13		0.03	0.03	150	40	70
	WFW02	1.3	8.6	0.6	7.28	7.2	3	71	0.05	0.28		0.03	0.03	100	80	80
	WFW03	3.2	8.2	0.5	7.02	6.9	6	81	0.05	0.25		0.03	0.03	430	330	80
	WFW04	4.5	8.4	0.8	7.47	8.8	8	98	0.05	0.3		0.03	0.03	370	260	60
08/16/93	WFW01	3.3	3.1		7.07	2.6	6	102	0.05	0.04		0.041	0.03	70	1 k	25
	WFW02	4.1	4.7		7.1	4.2	4	122	0.051	0.02		0.038	0.03	40	10	25
	WFW03	4.3	4.8		6.7	3	2	108	0.05	0.02		0.03	0.03	380	20	25
	WFW04	6.4	7.1		7.53	22	22	157	0.05	0.02		0.03	0.034	10	10	25
11/30/93	WFW01	1.1	11.6	0.5	6.67	9.6	1	39	0.05	0.18		0.03	0.03	40	30	20
	WFW02															
	WFW03	1.5	11.2	0.9	5.98	6	1	97	0.05	0.61		0.03	0.03	10	20	20
	WFW04	1.7	11.4	0.9	6.89	6.8	2	111	0.05	0.58		0.03	0.03	10	10	20
04/11/94	WFW01		9.3	0.2	7.16	12	1	37	0.05	0.2		0.03	0.05	64	27	20
	WFW02		9.2	0.2	7.36	14	3	53	0.069	0.28		0.03	0.08	72	91	30
	WFW03		8.6	0.2	7.34	13	5	64	0.05	0.28		0.03	0.04	270	163	30
	WFW04		9	0.3	7.93	13	10	79	0.05	0.26		0.03	0.03	172		40

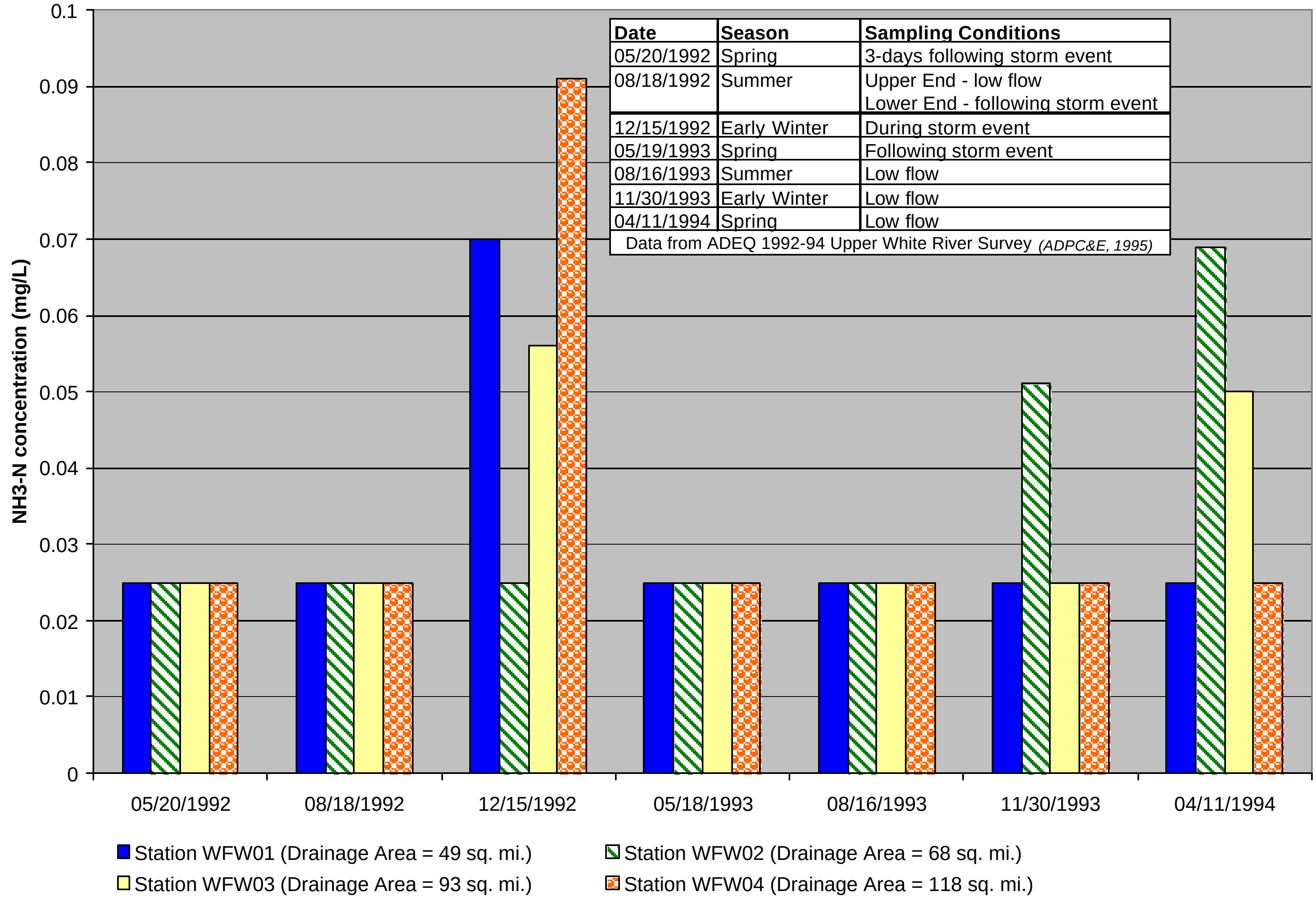
Appendix 2-E
ADEQ Water Quality Data

Figure 1 WFWR Nitrate Concentrations for Given Sampling Events



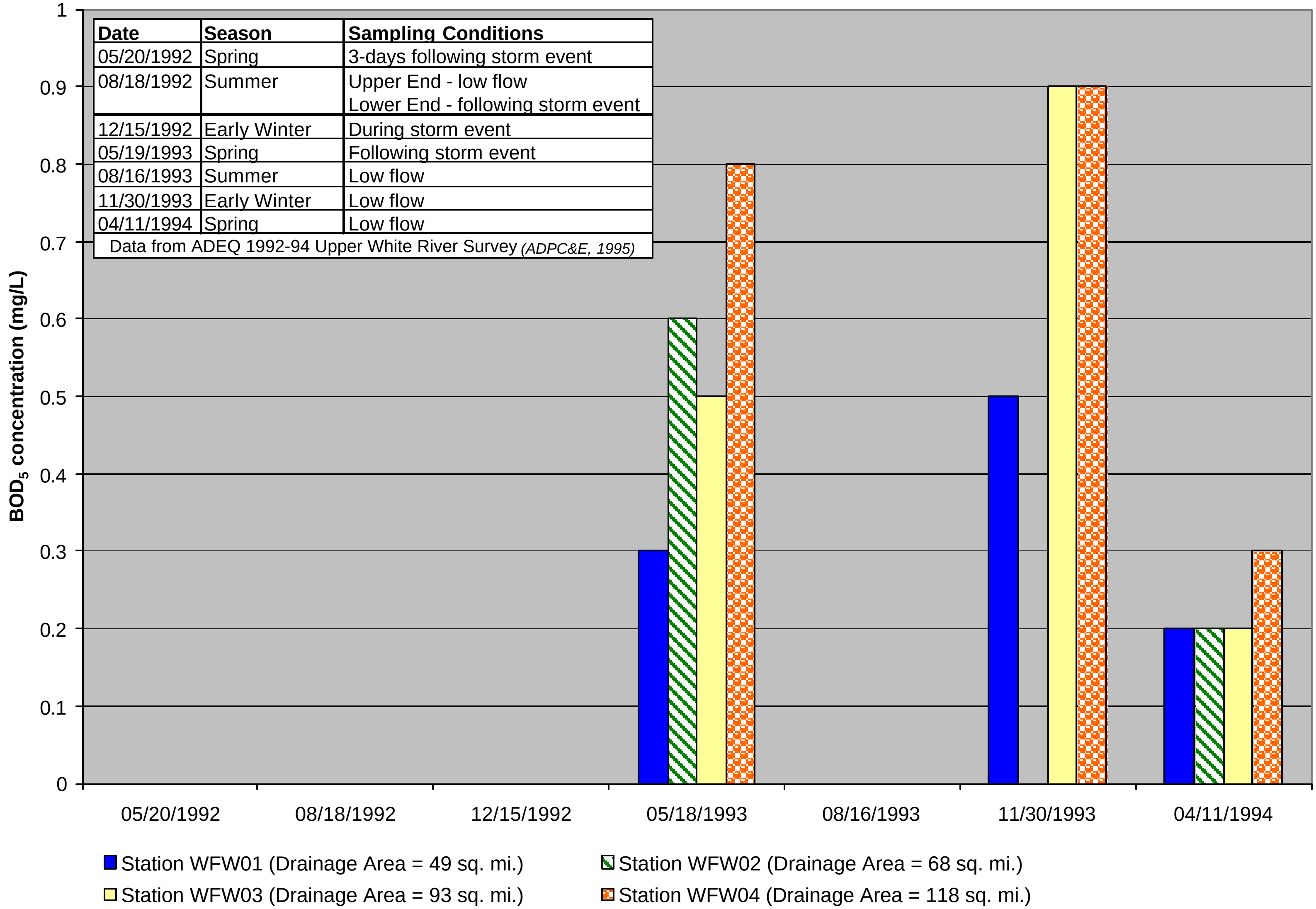
Appendix 2-E (continued)

Figure 2 WFWR Ammonia Concentrations for Given Sampling Events



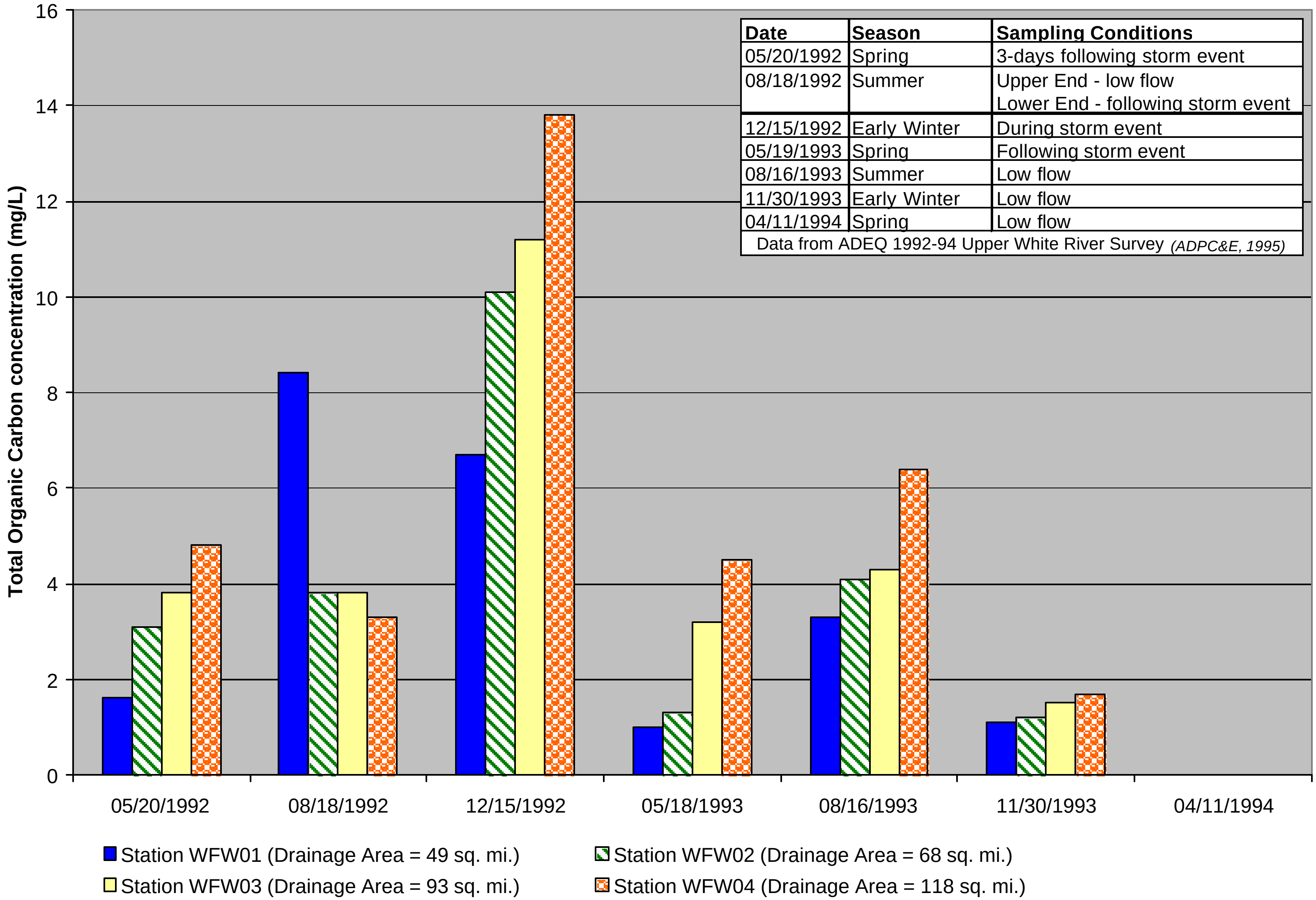
Appendix 2-E (continued)

Figure 3 WFWR 5-day Biochemical Oxygen Demand Concentrations for Given Sampling Events



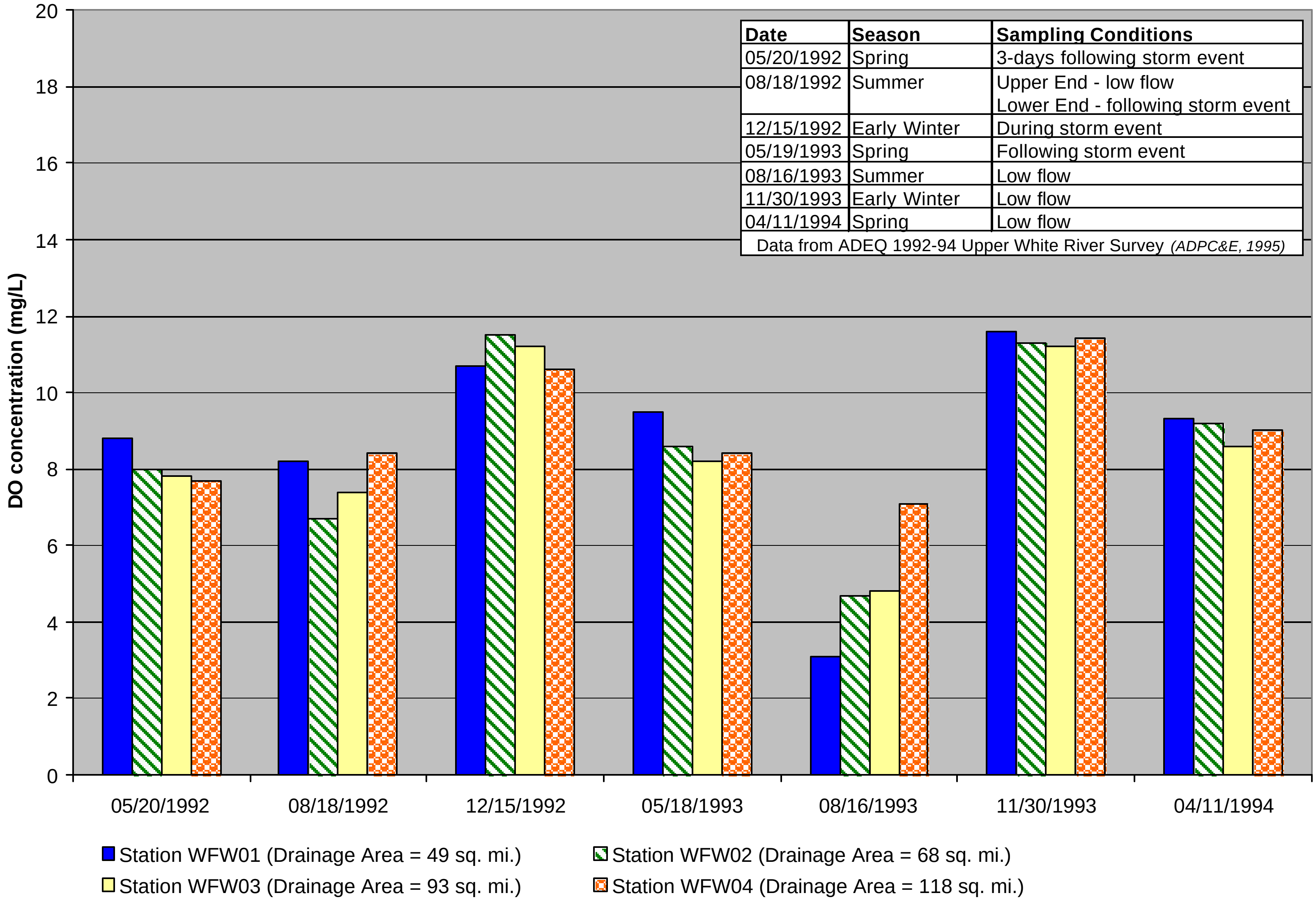
Appendix 2-E (continued)

Figure 4 WFWR Total Organic Carbon Concentrations for Given Sampling Events



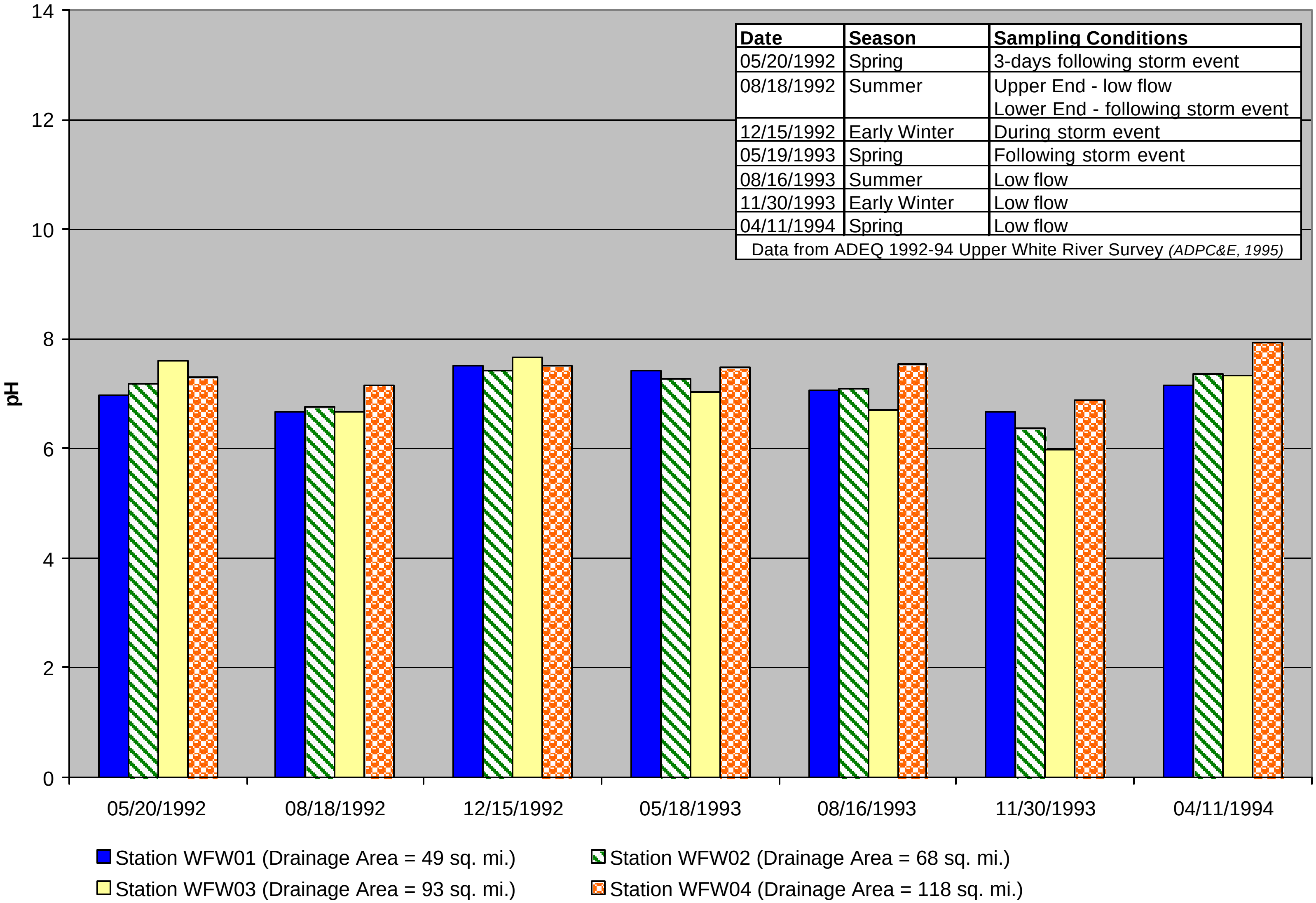
Appendix 2-E (continued)

Figure 5 WFWR Dissolved Oxygen Concentrations for Given Sampling Events



Appendix 2-E (continued)

Figure 6 WFWR pH for Given Sampling Events



Appendix 2-E (continued)

Figure 7 WFWR Total Dissolved Solid Concentrations for Given Sampling Events

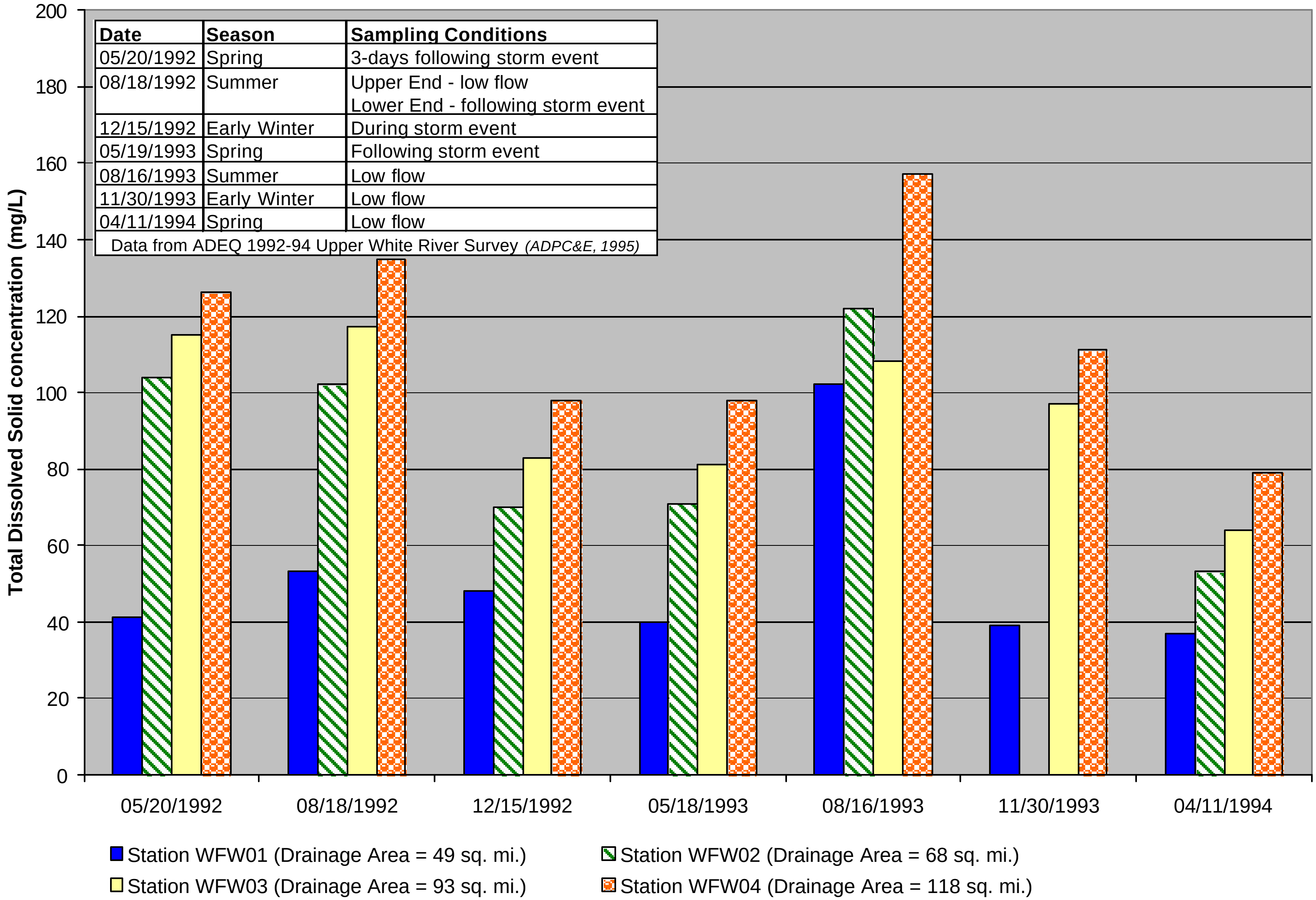


Figure 8 WFWR Fecal Coliform Concentrations for Given Sampling Events

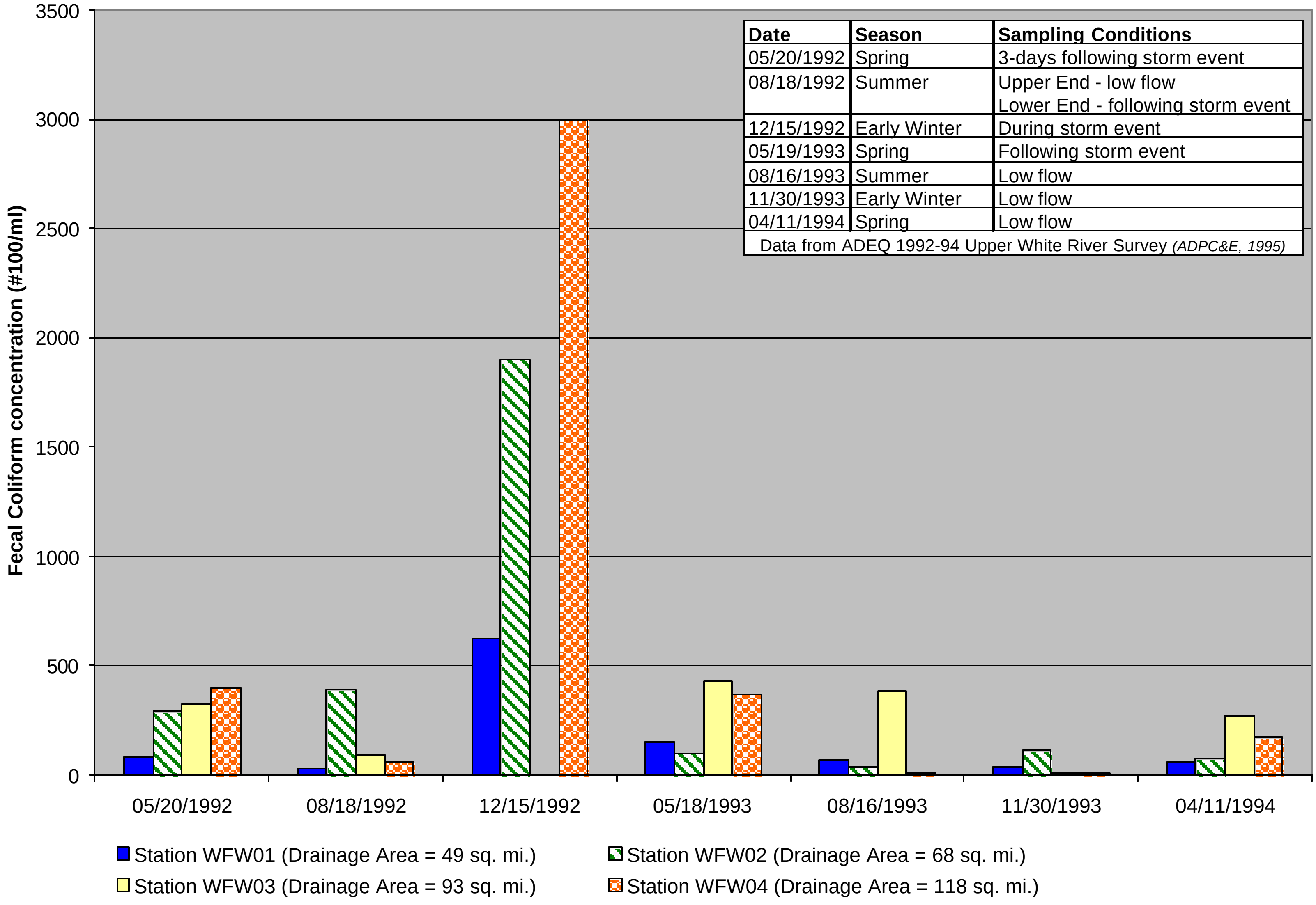
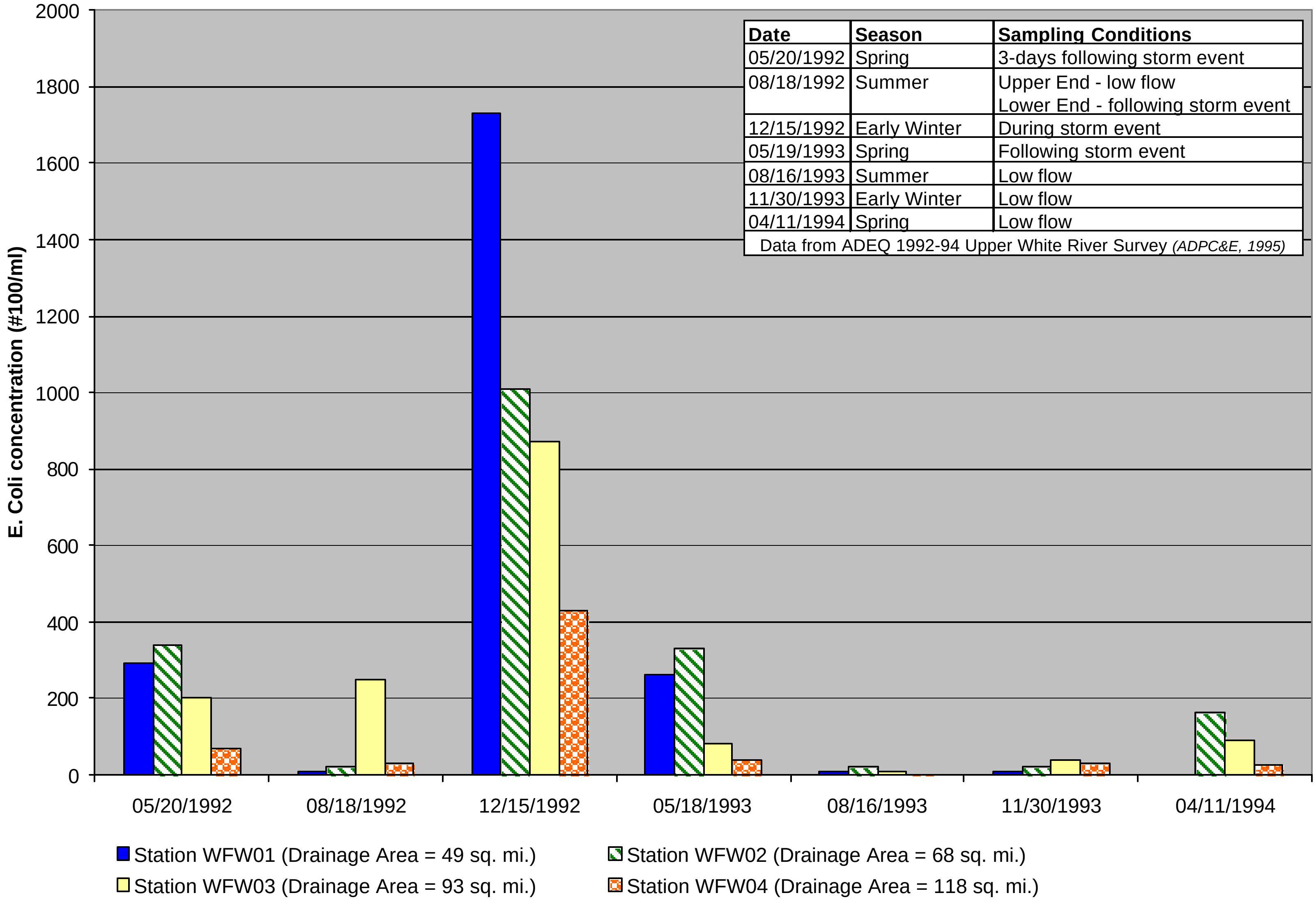


Figure 9 WFWR E. Coli Concentrations for Given Sampling Events

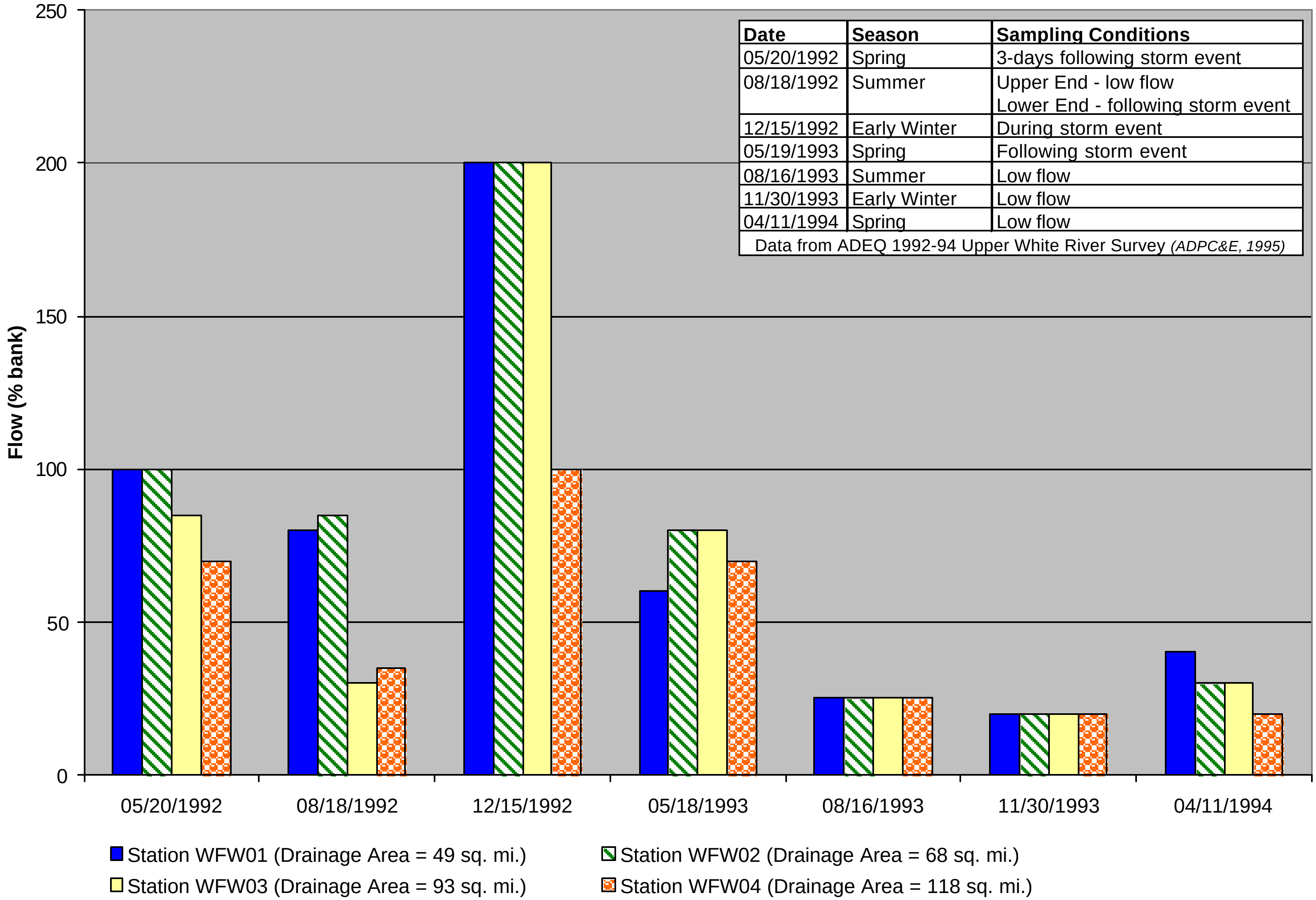


Date	Season	Sampling Conditions
05/20/1992	Spring	3-days following storm event
08/18/1992	Summer	Upper End - low flow Lower End - following storm event
12/15/1992	Early Winter	During storm event
05/19/1993	Spring	Following storm event
08/16/1993	Summer	Low flow
11/30/1993	Early Winter	Low flow
04/11/1994	Spring	Low flow

Data from ADEQ 1992-94 Upper White River Survey *(ADPC&E, 1995)*

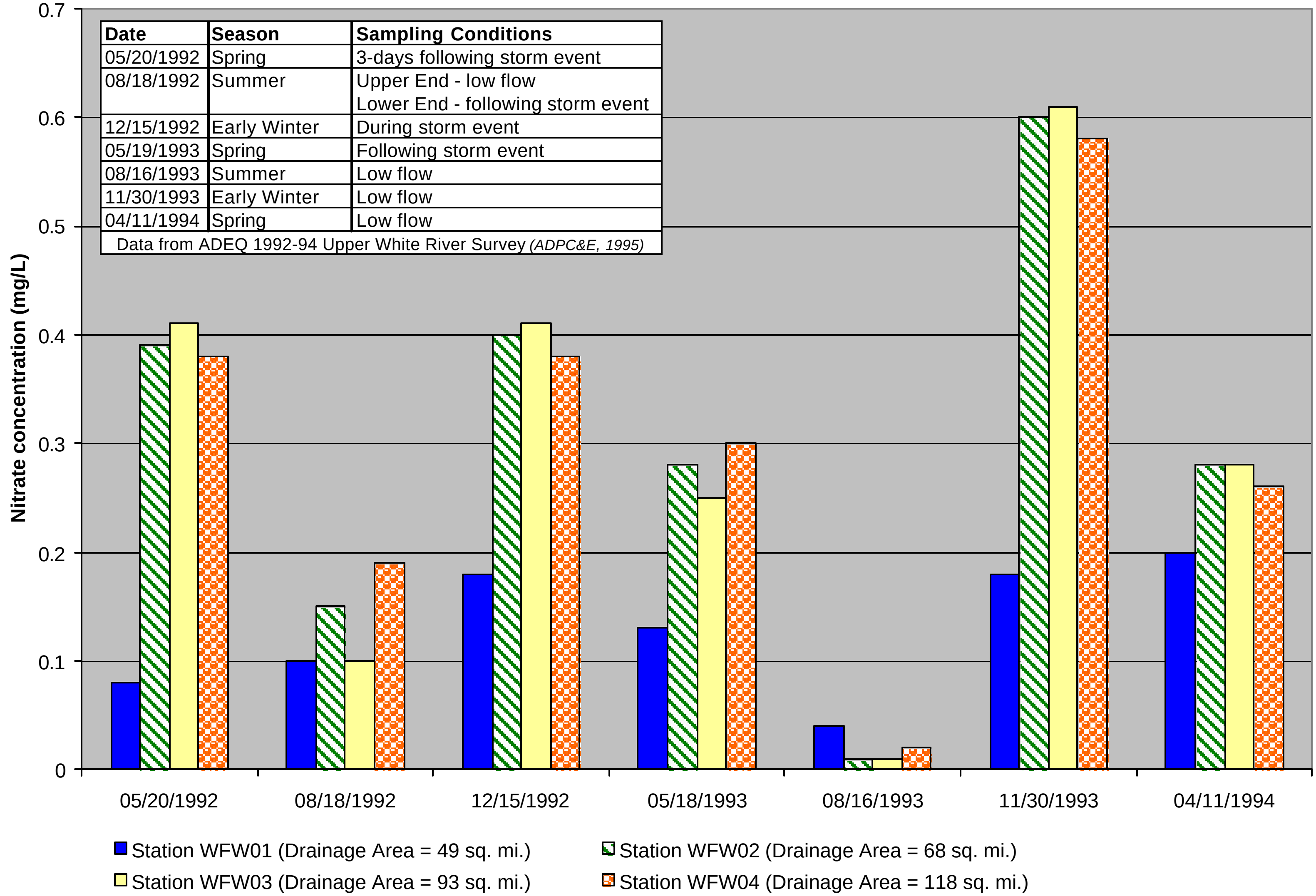
Appendix 2-E (continued)

Figure 10 WFWR Flow for Given Sampling Events



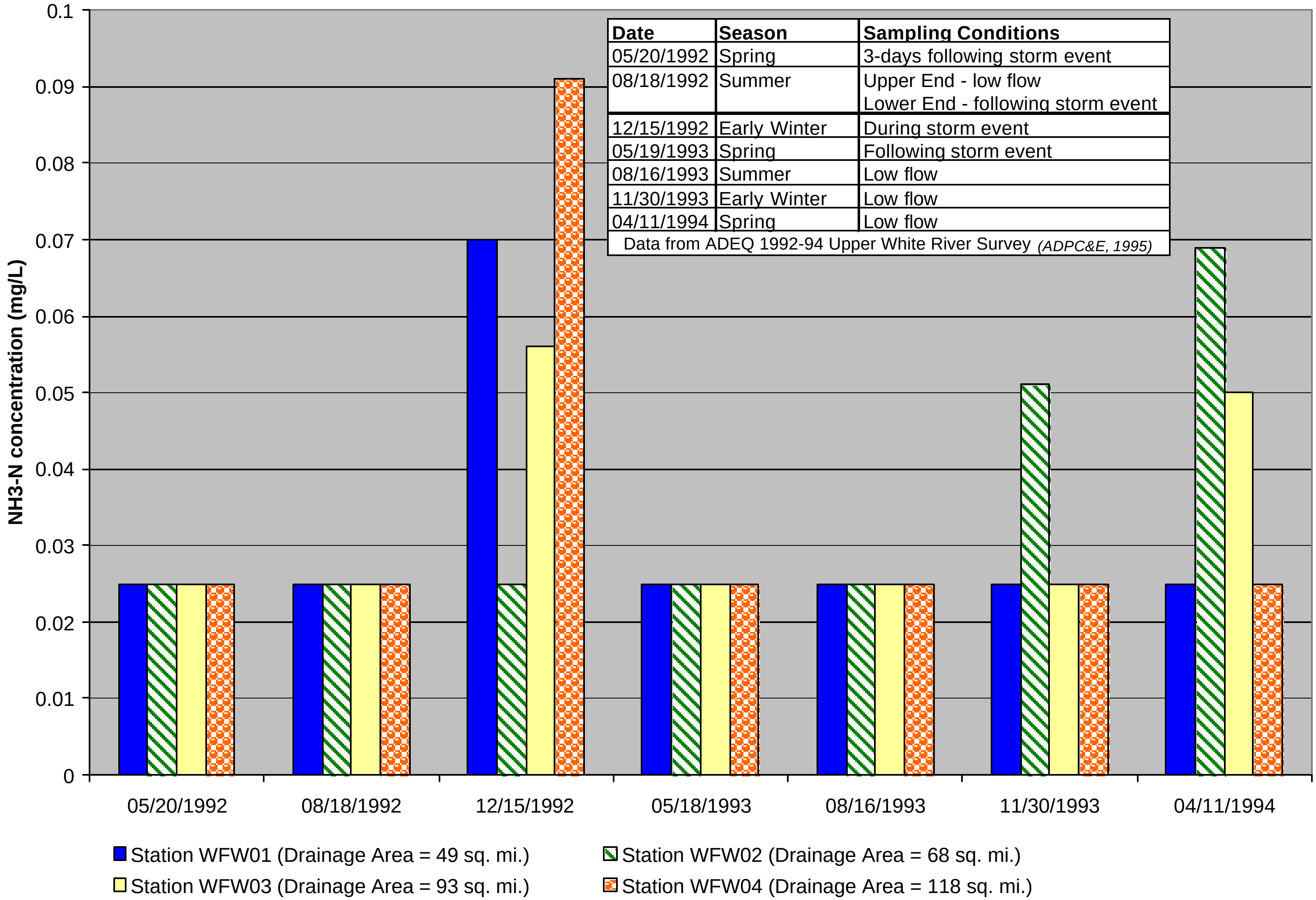
Appendix 2-E
ADEQ Water Quality Data

Figure 1 WFWR Nitrate Concentrations for Given Sampling Events



Appendix 2-E (continued)

Figure 2 WFWR Ammonia Concentrations for Given Sampling Events



Date	Season	Sampling Conditions
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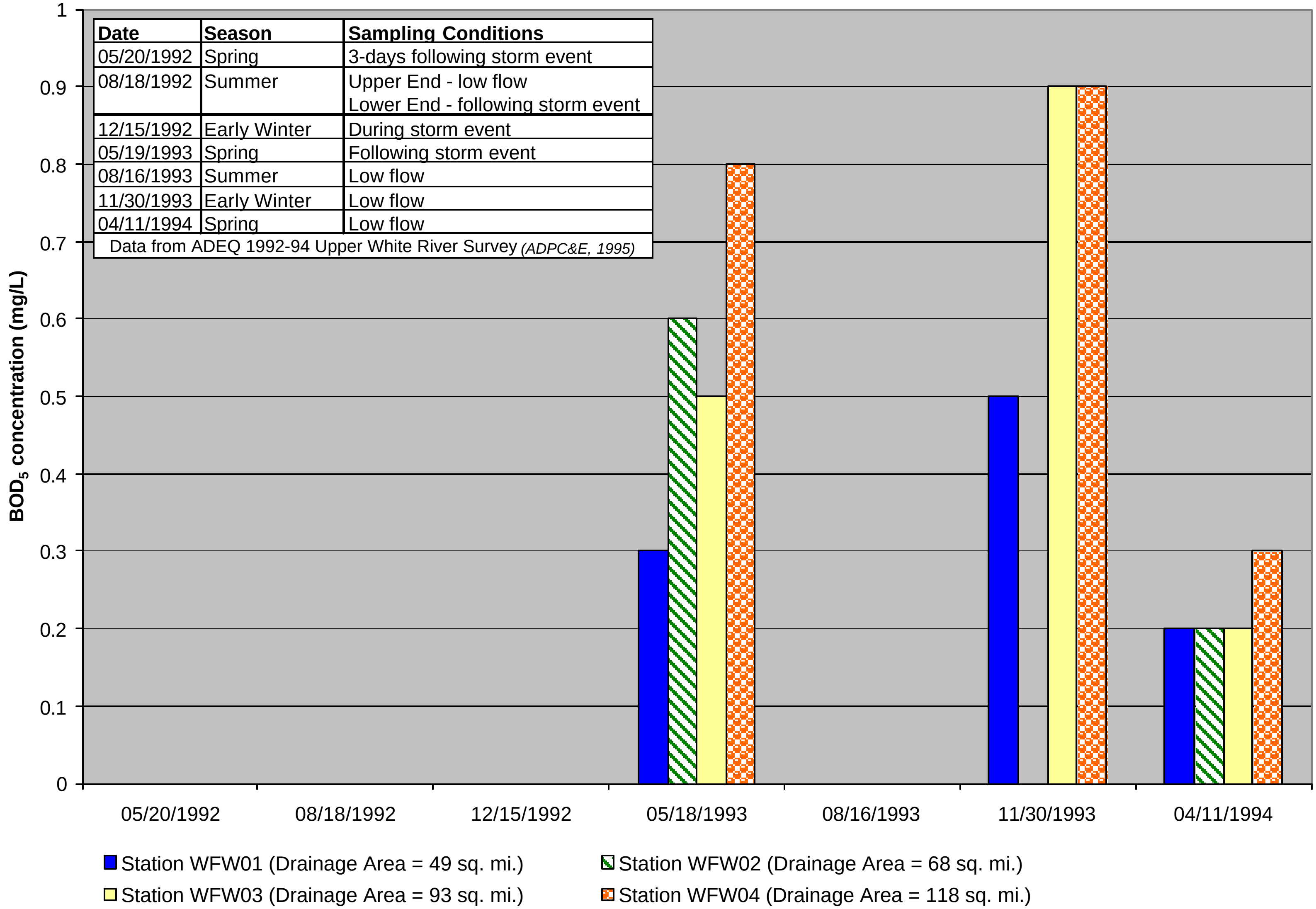
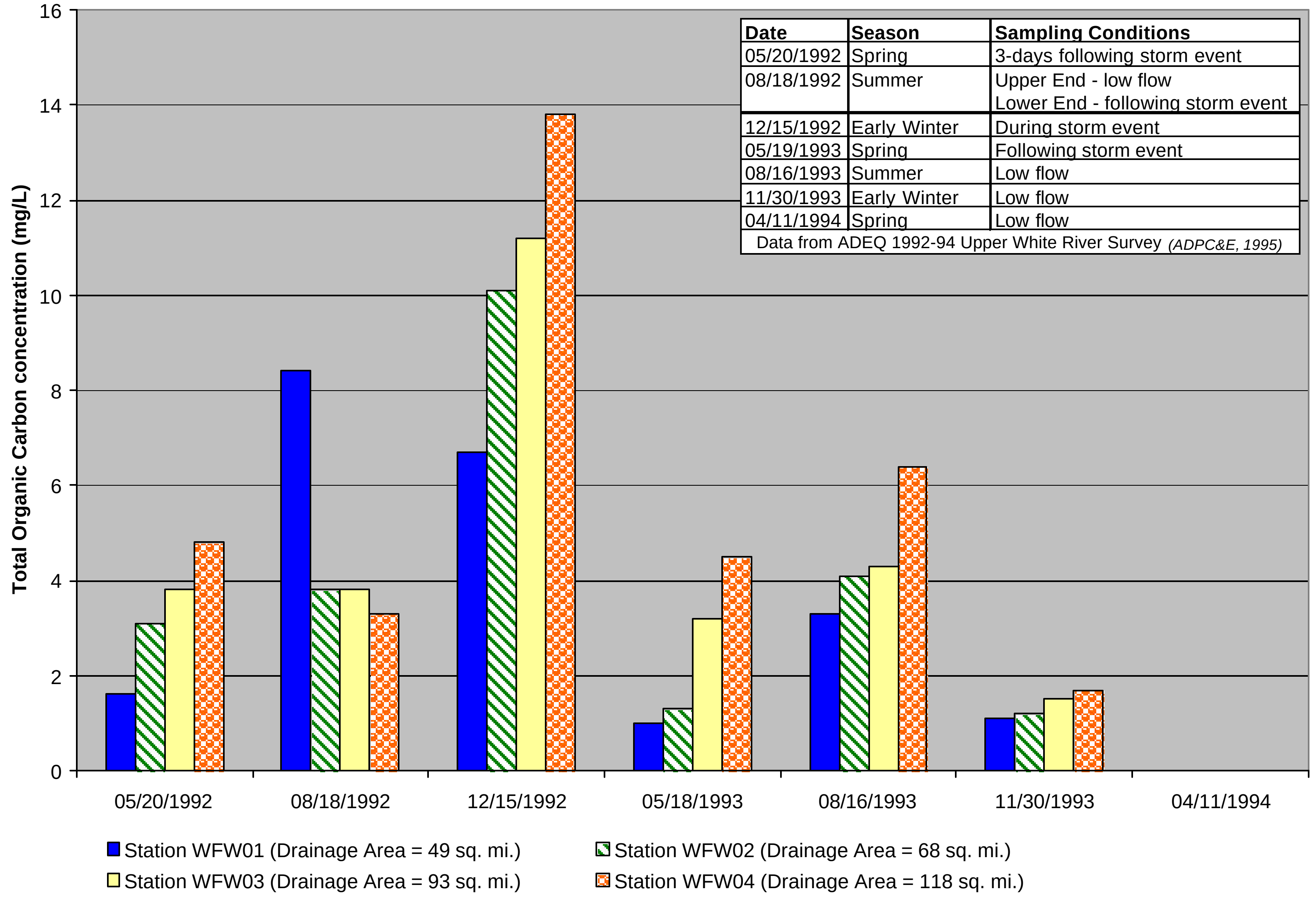
Data from ADEQ 1992-94 Upper White River Survey *(ADPC&E, 1995)*

Figure 3 WFWR 5-day Biochemical Oxygen Demand Concentrations for Given Sampling Events



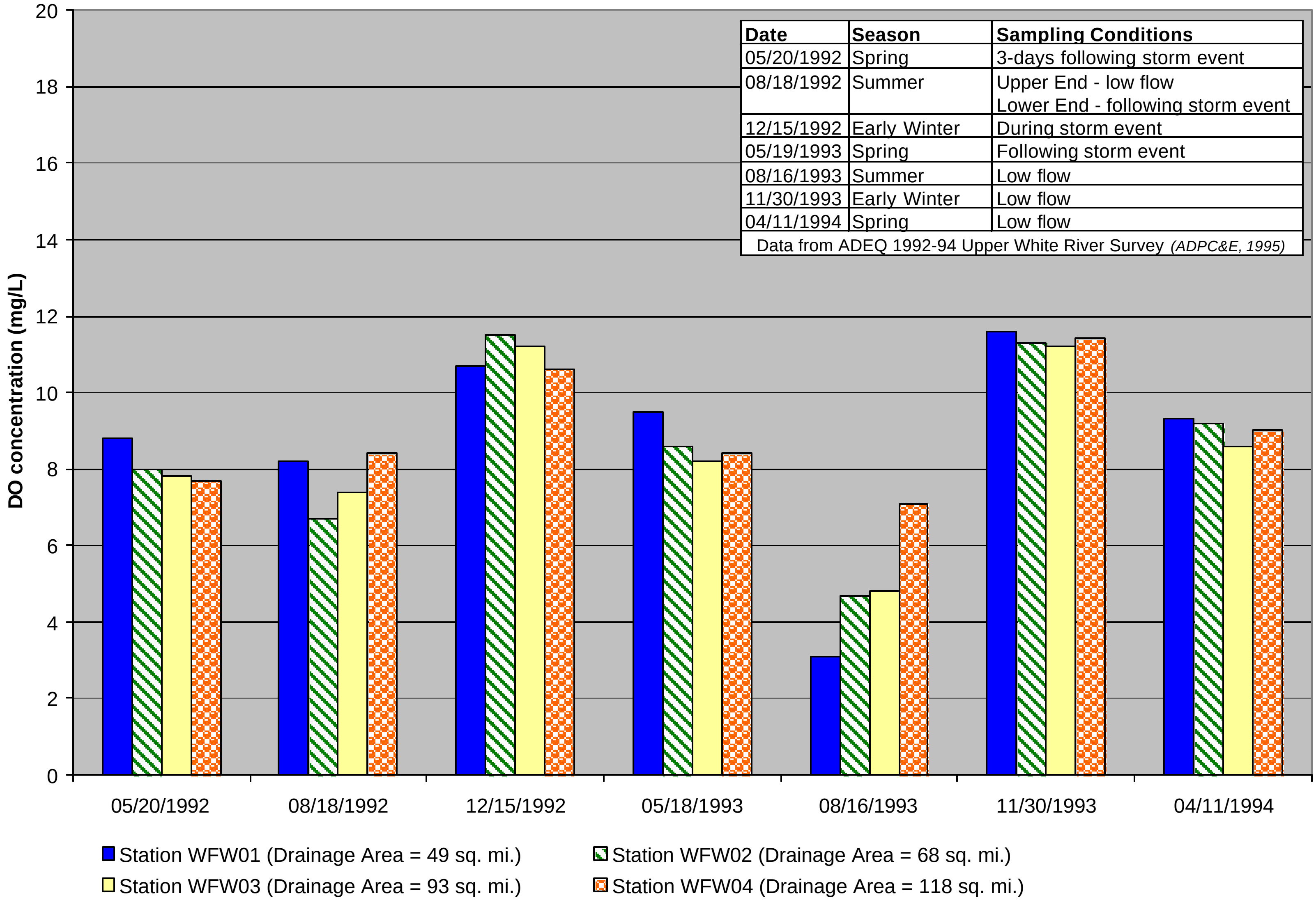
Appendix 2-E (continued)

Figure 4 WFWR Total Organic Carbon Concentrations for Given Sampling Events



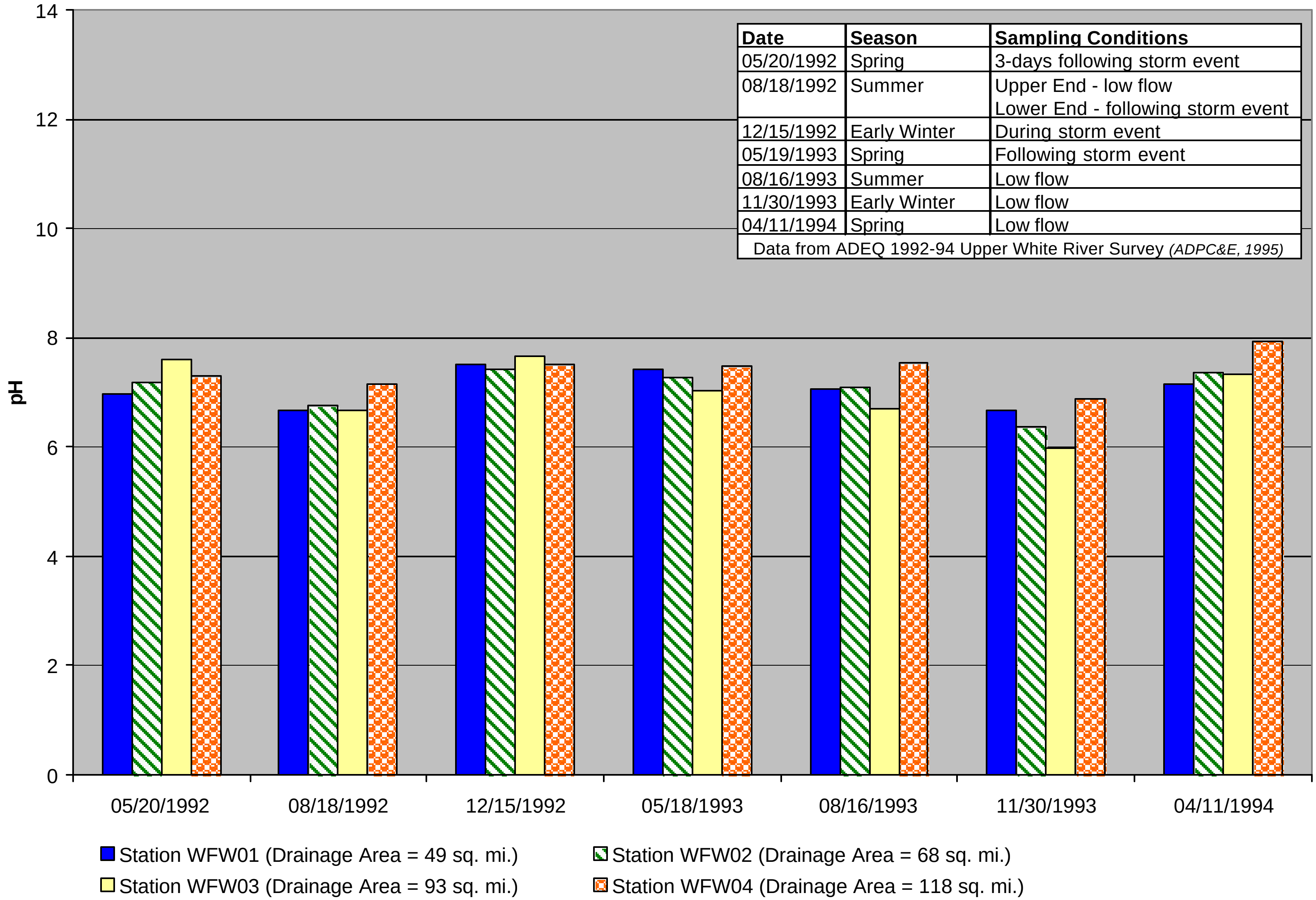
Appendix 2-E (continued)

Figure 5 WFWR Dissolved Oxygen Concentrations for Given Sampling Events



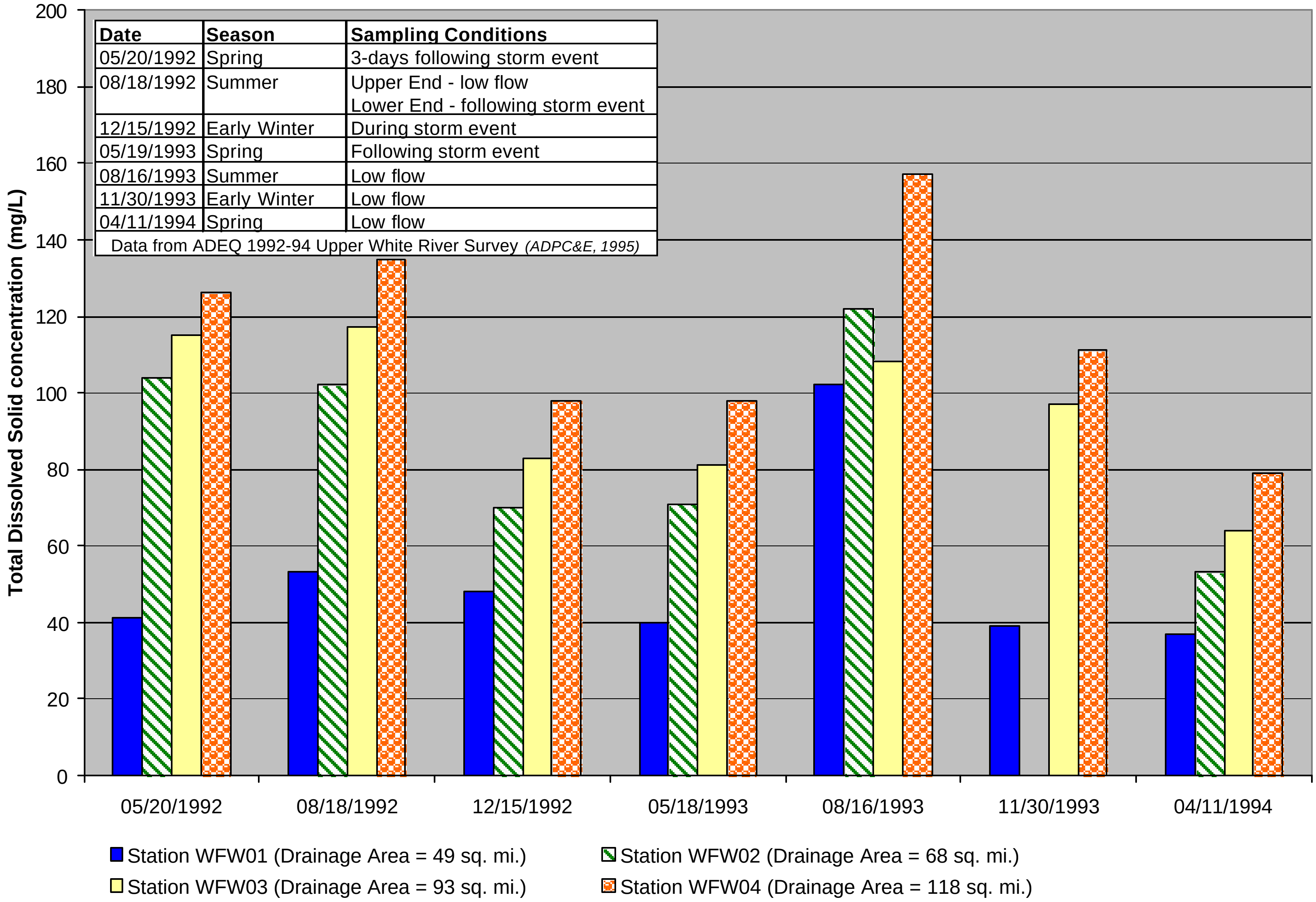
Appendix 2-E (continued)

Figure 6 WFWR pH for Given Sampling Events



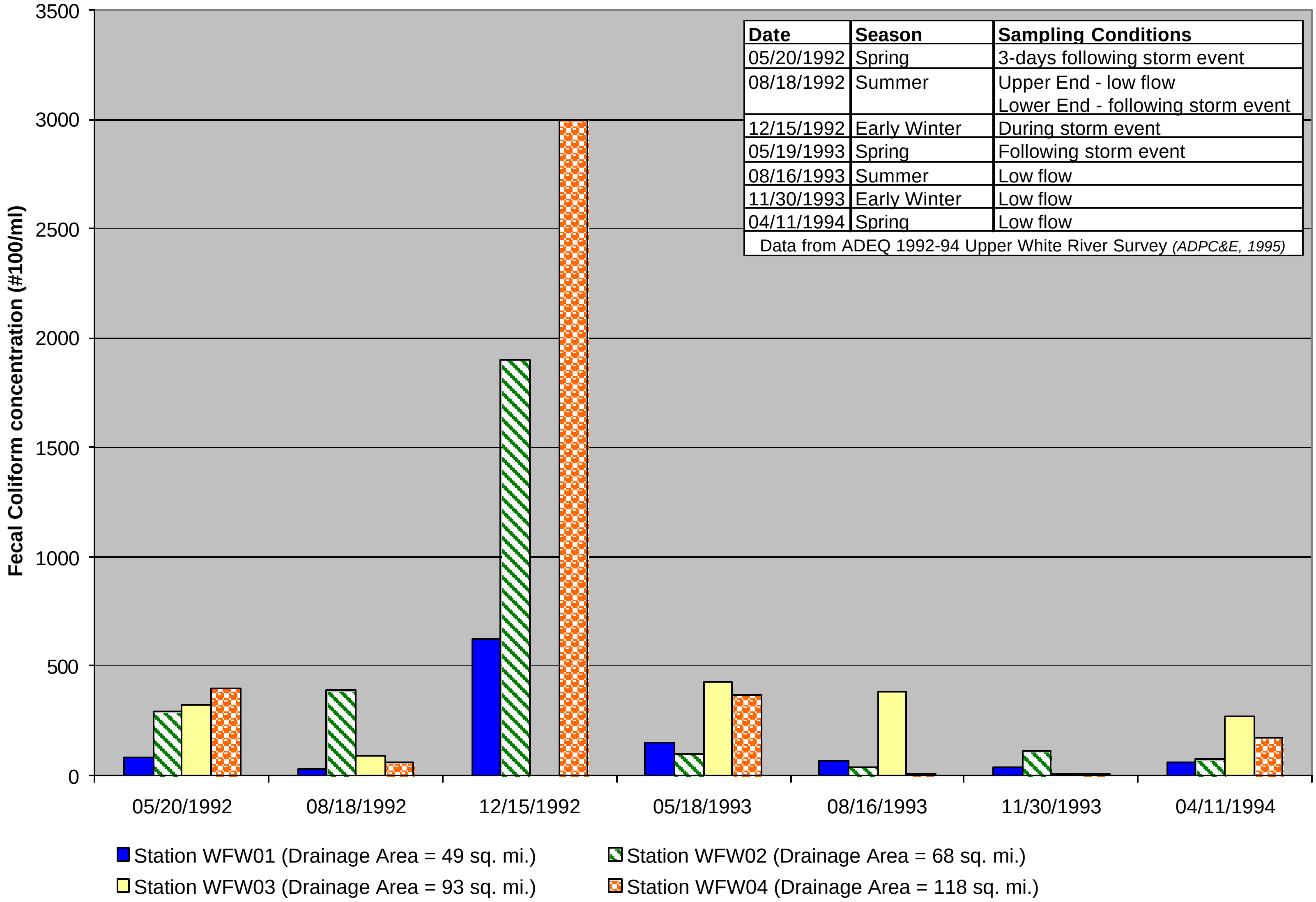
Appendix 2-E (continued)

Figure 7 WFWR Total Dissolved Solid Concentrations for Given Sampling Events



Appendix 2-E (continued)

Figure 8 WFWR Fecal Coliform Concentrations for Given Sampling Events



Date	Season	Sampling Conditions
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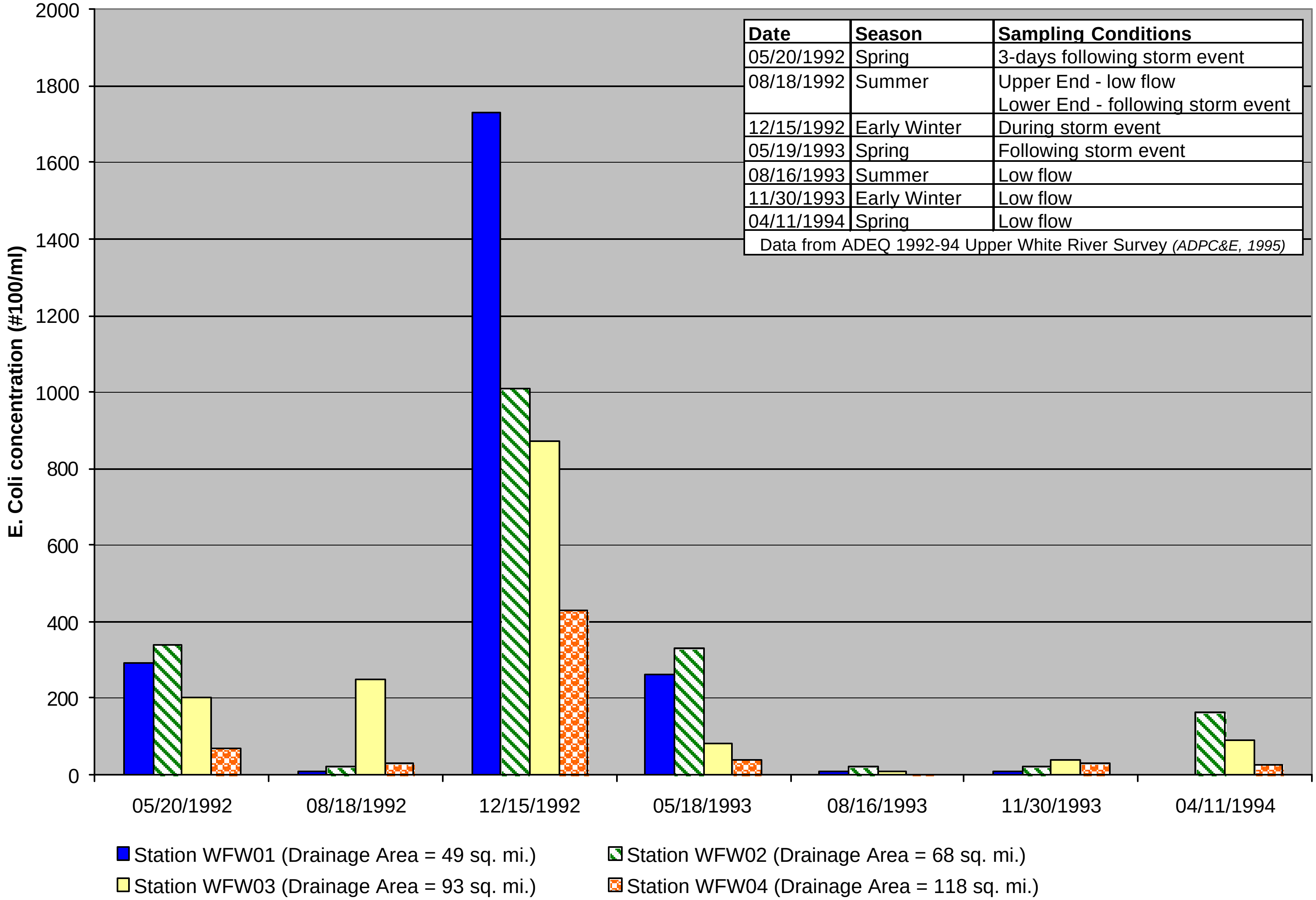
05/19/1993	Spring	Following storm event
08/16/1993	Summer	Low flow
11/30/1993	Early Winter	Low flow
04/11/1994	Spring	Low flow

Data from ADEQ 1992-94 Upper White River Survey *(ADPC&E, 1995)*

Appendix 2-E (continued)

Figure 9 WFWR E. Coli Concentrations for Given Sampling Events



Date	Season	Sampling Conditions
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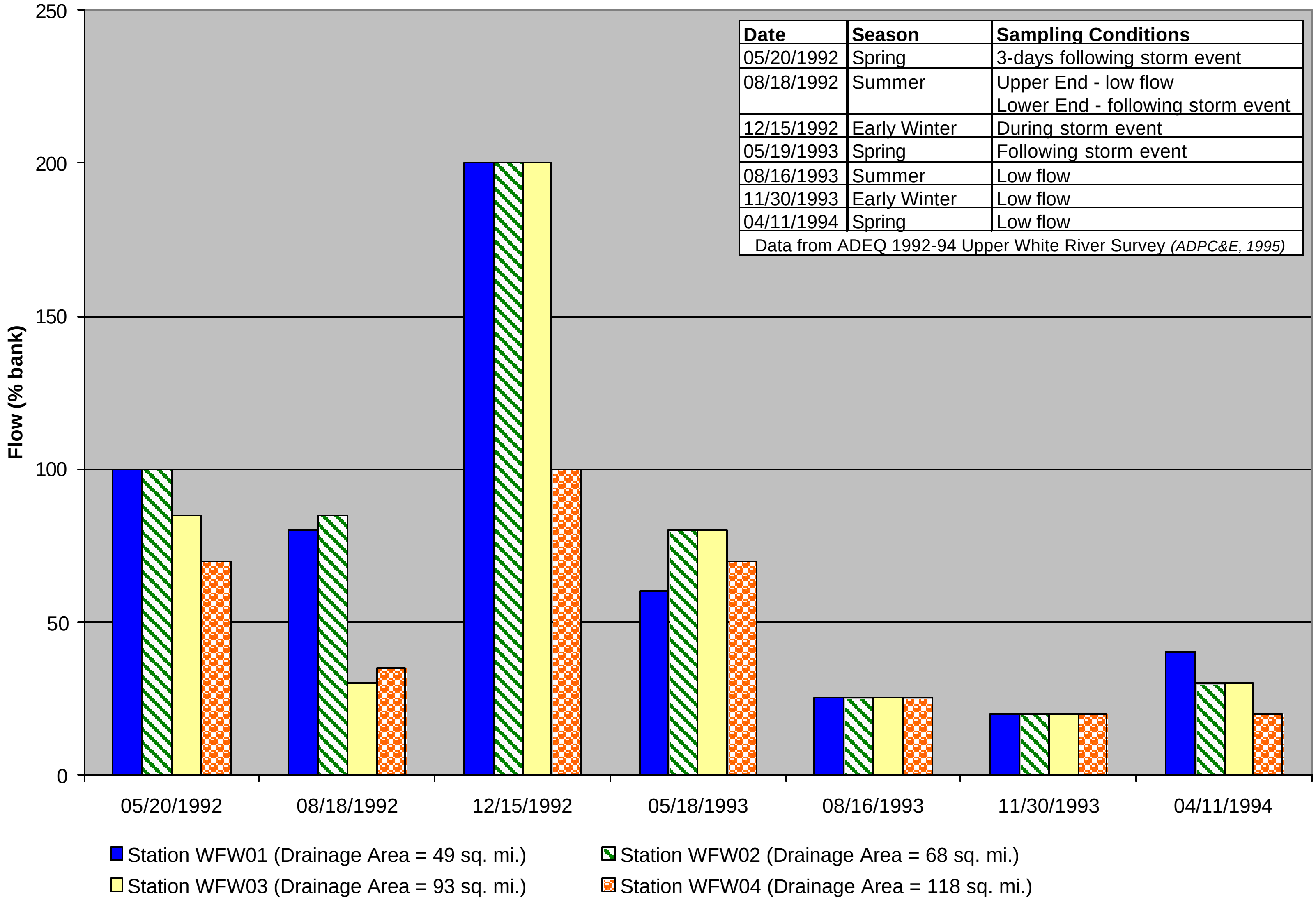
08/18/1992	Summer	Upper End - low flow Lower End - following storm event
12/15/1992	Early Winter	During storm event
05/19/1993	Spring	Following storm event
08/16/1993	Summer	Low flow
11/30/1993	Early Winter	Low flow
04/11/1994	Spring	Low flow

Data from ADEQ 1992-94 Upper White River Survey *(ADPC&E, 1995)*

Appendix 2-E (continued)

Figure 10 WFWR Flow for Given Sampling Events



Date	Season	Sampling Conditions
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05/19/1993	Spring	Following storm event
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04/11/1994	Spring	Low flow
Data from ADEQ 1992-94 Upper White River Survey *(ADPC&E, 1995)*		

WATER QUALITY SAMPLING, ANALYSIS AND ANNUAL LOAD DETERMINATIONS FOR TSS, NITROGEN AND PHOSPHORUS AT THE WASHINGTON COUNTY ROAD 195 BRIDGE ON THE WEST FORK OF THE WHITE RIVER

2003 ANNUAL REPORT

Presented to the Arkansas Soil and Water Conservation Commission
By
Marc Nelson
And
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AWRC- Water Quality Lab

And
Sandi Formica
Arkansas Department of Environmental Quality
Little Rock, Arkansas

July, 2004

INTRODUCTION

A water quality sampling station was installed at the Washington County road 195 bridge on the West Fork of the White River just above the confluence of the three main forks of the Upper White River in December 2001. The Quality Assurance Project Plan (QAPP) was approved by EPA Region six on March 2002 and sampling was begun at that time. This station is coordinated with a USGS gauging station at the same location. This station was instrumented to collect samples at sufficient intervals across the hydrograph to accurately estimate the flux of total suspended solids, nitrogen and phosphorus into the upper end of Beaver Lake from the West Fork of the White River. The West Fork is listed on Arkansas' 1998 303d list as impaired from sediment. The Upper White was designated as the states highest priority watershed in the 1999 Unified Watershed Assessment. Accurate determination of stream nutrients and sediment is critical for future determinations of TMDLs, effectiveness of best management practices and trends in water quality.

SCOPE

This project is a cooperative effort between AWRC and the ADEQ Environmental Preservation and Planning divisions. All aspects of the project are coordinated with and subject to technical review and comments from ADEQ. This report is for 2003 water quality sampling, water sample analysis and annual pollutant load calculations at the Washington County road 195 bridge on the West Fork of the White River. The parameters measured from collected samples were nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved reactive phosphorus and total suspended solids. In addition turbidity, conductivity and pH were measured in-situ and recorded in thirty-minute intervals. Also, the AWRC in conjunction with the USGS conducted cross-section sampling to determine the relationship between autosampler concentrations and cross-section concentrations.

In October 2003 it was determined that the sampling intake was being contaminated from sediment collected in the outer line. This report will detail the methods used to correct the data for this contamination and provide corrected data and results for 2002 and 2003.

METHODS

Initially the sampler was operated in a discrete mode taking samples at thirty-minute intervals for the first twenty four samples and sixty minute intervals for the next twenty four samples. The sampler was set to begin taking samples when the stage rose to ten percent over the prior base flow. Discrete samples were collected when all twenty-four bottles were filled or within forty-eight hours after the first sample. Grab samples were taken often enough to have three samples between each storm. The sampler was operated using this protocol until three storms were adequately sampled. The results from this initial sampling phase were used to determine the sampling start (trigger) and frequency for flow-weighted composite sampling. In addition, the results were used to develop rating curves to predict pollutant concentrations as a function of discharge in order to calculate loads for inadequately sampled storm events.

After the initial phase, the sampler was reconfigured to take flow-weighted composite samples. The sampler began sampling after the stage exceeded a set trigger level of four feet. It took a discrete sample after a fixed volume of water had passed. The volume of water used for the flow weighted composite samples, i.e. sampling frequency, was 4 million cubic feet, as determined from the initial sampling phase. The discrete samples were composited by combining equal volumes of each into a single sample for analysis. Discrete samples were collected for compositing when all twenty-four bottles were filled or within forty-eight hours after the first sample. Storms were sampled in this manner for the period when the river stage was above the trigger level. Grab samples were taken every two weeks after the initial sampling phase. All samples were collected by AWRC Field Services personnel and transported to the AWRC Water quality Laboratory for analysis. All samples were analyzed for nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved reactive phosphorus and total suspended solids.

In addition to the above sampling for load determination, the AWRC in conjunction with the USGS conducted cross-section sampling to determine the relationship between auto sampler concentrations and cross-section concentrations. The USGS collected evenly weighted integrated (EWI) cross section samples at the same time AWRC collected discrete auto samples. All samples were transported and analyzed by the AWRC Water Quality Lab and the results used to determine correction factors for the auto sample concentrations. Seven samples were taken and compared during both years. All samples taken and used for analysis were done in accordance with an approved quality assurance project plan. This QAPP was prepared by the AWRC and submitted to the ASWCC for approval. The ASWCC reviewed the plan for conformance to it's Quality Management Plan and submitted the QAPP to EPA, Dallas for review and approval. The plan was approved on March 19, 2002.

In October, 2003 it was determined that the sampler intake was being contaminated by sediment trapped in the 2 inch outer pipe. The intake line that is located inside the outer pipe was initially secured with the intake strainer outside the end of the outer pipe. This intake line at some point was pulled up into the outer line. In that position, sediments inside the outer line were disturbed during purging prior to taking a sample. This lead to samples with elevated levels of particulates relative to in-stream concentrations. The results for 2002 were reported as measured in the 2002 annual report. This report will provide the corrected results for 2002 and 2003.

The concentrations measured in this project were corrected using the seven USGS /AWRC paired grab samples taken in 2002 and 2003 for storm flows only. Storm flows are here defined as all discharges when the stage was above the 4-foot trigger level. This definition is an arbitrary distinction based upon sampling technique and does not represent the distinction between true storm and base flows. A linear regression analysis was performed on each of the parameters measured. The coefficients determined from the regression were used to correct measured storm flow concentrations. All storm flow concentrations from the beginning of the project until October 15, 2003 were corrected. Table 1 lists the equations used for correction.

Table 1. Regression equations determined from USGS /AWRC paired samples

Parameter	Regression equation	Regression coefficient
Nitrate-N	y = 0.874x	$R^2 = 0.0682$
Total Phosphorus	y = 0.7065x	$R^2 = 0.4002$
Ammonia-N	y = 1.0848x	$R^2 = 0.1666$
TKN	y = 0.7025x	$R^2 = 0.2201$
Phosphate-P	y = 0.436x	$R^2= 0.1339$
TSS	y = 0.5167x	$R^2 = 0.4742$

Base flow concentrations were corrected using twenty USGS routine grab samples collected approximately monthly during base flow conditions. The parameter measured by USGS was suspended sediment concentration (SSC). SSC and TSS are not equivalent and the relationship is not consistent between sites (Glysson, et al., 2001). However, paired samples can be used to develop a site-specific relation between the two. There were seven paired samples taken at this site in 2002 and 2003 where both TSS and SSC were measured. The average relation between paired TSS and SSC determined from these paired samples can be described by the following relationship:

(1) TSS = 0.685 SSC

The average value for SSC measured by the USGS during base-flow conditions in 2002 and 2003 was 27.2 mg/l. Using the relationship in formula 1, the average value for TSS during the time period was 18.5 mg/l. This value was applied as the TSS concentration for all base flows from the beginning of the project until October 15, 2003. Similarly, the other concentrations measured by USGS in their base flow grab samples during this time period were applied as the concentrations for the base flows. Table 2 summarizes the concentrations that were applied.

Table 2 Applied Base-flow Concentrations

Parameter	Concentration (mg/l)
Nitrate-N	0.33
Total Phosphorus	0.0125
Ammonia-N	0.027
TKN	0.25
Phosphate-P	0.005
TSS	18.5

RESULTS

Sampling began with the approval of the QAPP on March 11, 2002 and continued through the end of the year. During the first year, 220 individual samples were collected and analyzed. They include 20 base-flow grab samples, 143 discrete storm samples, and 4 USGS cross-section samples. The stage for 2002 as well as the corrected concentration results from the samples are summarized in Figure 1 and Table 2. Prorated loads listed in Table 2 were determined from partial year loads by multiplying by total annual discharge and dividing by the discharge from March 12 to the end of the year. That factor was 1.398

Figure 1. Corrected 2002 Stage and Concentrations

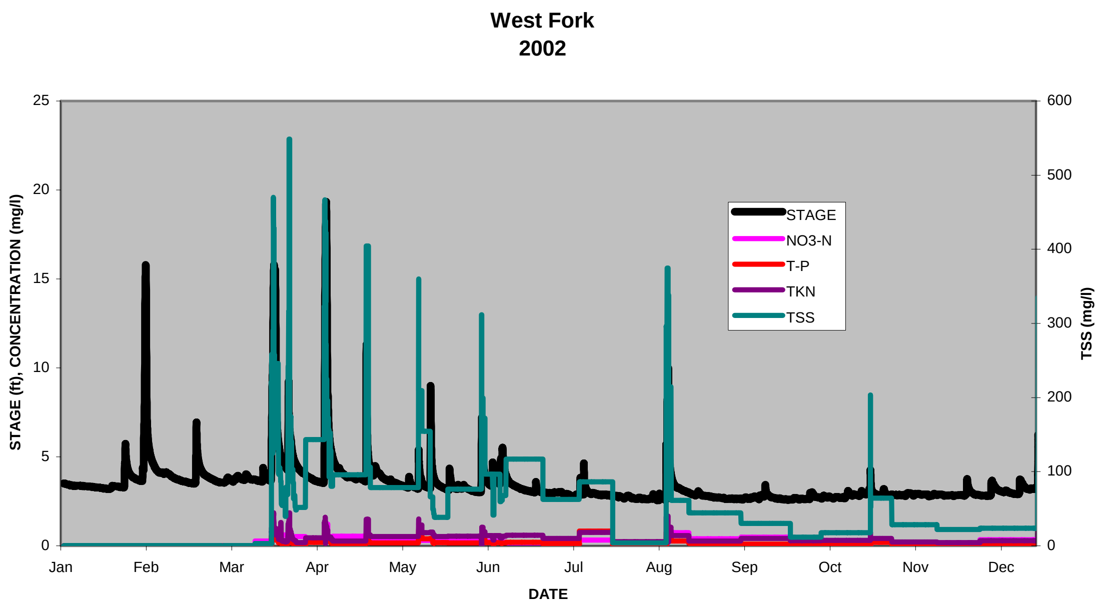


Table 2. Corrected 2002 loads and mean concentrations.

parameter	Partial Year Loads (kg)	Pro-rated Annual Load (kg)	Flow-weighted Mean Concentrations (mg/l)
Nitrate-N	37,366	52,245	0.43
Total Phosphorus	29,656	41,465	0.34
Ammonia-N	4,270	5,971	0.05
TKN	60,721	84,901	0.70
Phosphate-P	2,707	3,784	0.03
TSS	13,829,552	19,336,621	158

Discrete storm samples were collected on 5 storms in 2002 using 190 individual samples. The results from three of these storms are illustrated in Figure 3. These results were modeled using least-squares linear regressions to determine a relationship between concentrations and stage. These relationships can be used to predict concentrations of the different constituents as a function of stage during storm events if actual measured values are unavailable due to equipment failure. The relationships determined are summarized in Table 3. Although these relationships were determined, they were not used to model any of the storm events during the project since all storms were sampled adequately.

Figure 2.

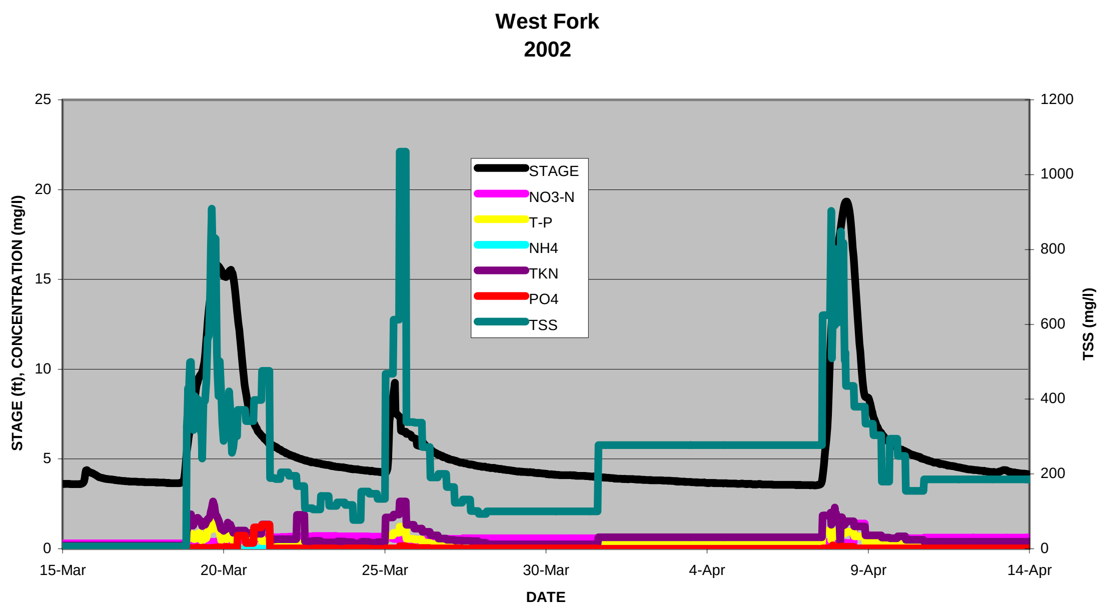


Table 3. Corrected Regression equations determined from discrete storm samples 2002

parameter	Regression equation	Regression coefficient
Nitrate-N	y = -0.054x + 0.416	R^2 = 0.0379
Total Phosphorus	y = 0.0299x + 0.1626	R^2 = 0.377
Ammonia-N	y = 0.003x + 0.0361	R^2 = 0.1248
TKN	y = 0.0424x + 0.4855	R^2 = 0.224
Phosphate-P	y = 0.002x + 0.0035	R^2= 0.2611
TSS	y = 16.008x + 53.214	R^2 = 0.443

The loads and mean concentrations can be segregated into storm-flow and base-flow using the trigger level as an arbitrary distinction between flow regimes. Using the trigger level value of 4 feet, the segregated loads and mean concentrations for 2002 are shown in Table 4.

Table 4. Corrected Storm flow and Base flow Loads and Mean Concentrations Partial Year 2002.

	Storm Loads (kg)	Base Loads (kg)	Storm Concentrations (mg/l)	Base Concentrations (mg/l)
VOLUME (M3)	68,348,038	19,347,203		
NO3-N	30,981	6,385	0.45	0.33
T-P	29,414	242	0.43	0.01
NH4	3,748	522	0.05	0.03
TKN	55,884	4,837	0.82	0.25
PO4	2,610	97	0.04	0.01
TSS	13,471,628	357,923	197.10	18.50

In 2003 there were 54 discrete storm samples, 22 composite storm samples, 26 base flow grab samples, 4 blank samples, 4 duplicate samples and 3 USGS / AWRC paired samples collected and analyzed. There were no significant storm events that were not sampled. The stage for 2002 as well as the corrected concentration results from the samples are summarized in Figure 3 and Table 5.

Figure 3 2003 Stage and Corrected concentrations.

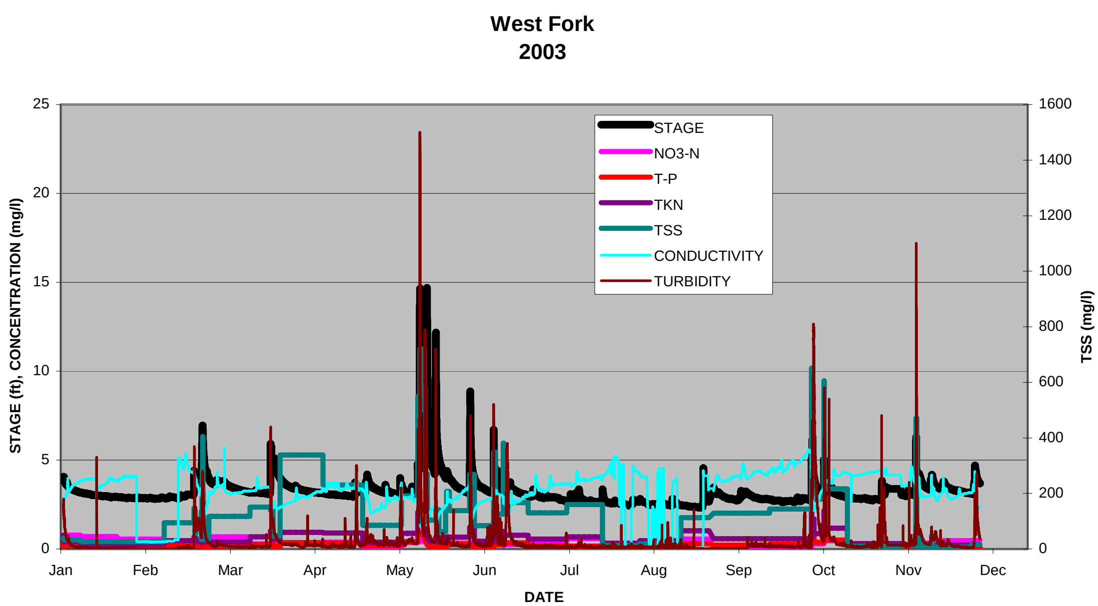


Table 5. Corrected 2003 loads and mean concentrations.

parameter	Annual Loads (kg)	Flow-weighted Mean Concentrations (mg/l)
Nitrate-N	33,377	0.37
Total Phosphorus	14,712	0.16
Ammonia-N	2,718	0.03
TKN	49,587	0.55
Phosphate-P	1,084	0.01
TSS	7,622,866	84.59

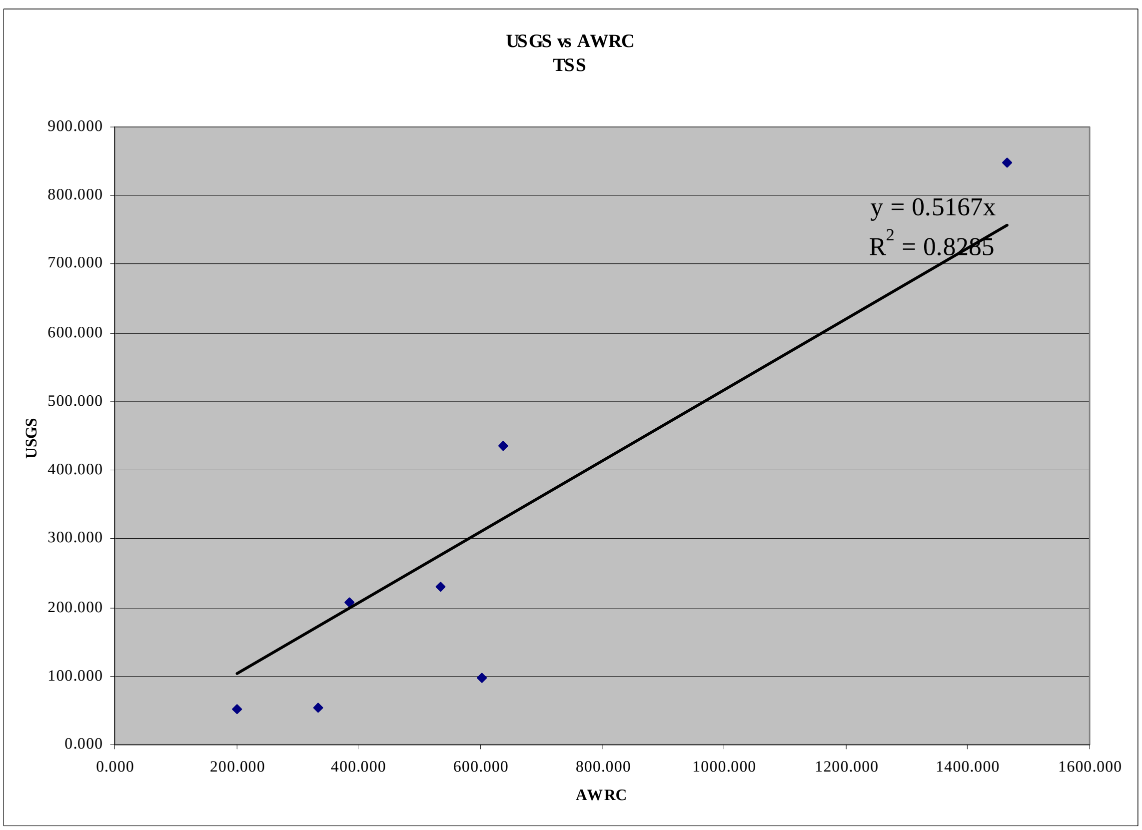
The loads and mean concentrations can be segregated into storm-flow and base-flow using the trigger level as an arbitrary distinction between flow regimes. Using the trigger level value of 4 feet, the segregated loads and mean concentrations for 2003 are shown in Table 6.

Table 6. Corrected Storm-flow and Base-flow Loads and Flow-weighted Mean Concentrations 2003.

	Storm Loads (kg)	Base Loads (kg)	Storm Concentrations (mg/l)	Base Concentrations (mg/l)
VOLUME (M3)	49,021,281	41,092,002		
NO3-N	18,789	14,588	0.38	0.36
T-P	13,716	996	0.28	0.02
NH4	1,744	975	0.04	0.02
TKN	39,483	10,103	0.81	0.25
PO4	855	229	0.02	0.01
TSS	6,919,208	703,658	141.15	17.12

The storm-flow concentrations measured in this project were corrected using the seven USGS /AWRC paired grab samples taken in 2002 and 2003. A linear regression analysis was performed on each of the parameters measured. The coefficients determined from the regression were used to correct initial storm flow concentrations. All concentrations from the beginning of the project until October 15, 2003 were corrected. Table 1 lists the equations used for correction. Figure 4 shows the regressed TSS concentrations and correction equation.

Figure 4. USGS / AWRC TSS Regression



In addition to measuring TSS, turbidity was measured and recorded every fifteen minutes during the project. Figure 5 shows the stage TSS and turbidity measured during the year. The Maximum value recorded during 2003 was 1500 NTUs. This value was above the calibration range for the meter (1 to 1000 NTUs) and was probably just an over maximum value reported by USGS. The average turbidity value for 2003 was 27 NTUs.

A linear regression was calculated for discrete samples with turbidity measurements. These results are shown in figure 6. Turbidity measurements appear to correlate well with storm TSS on the rising limb but tend to peak earlier and fall slower than TSS on the falling limb as exemplified in figure 7. This may be due to the effect of different particle sizes.

Figure 5 2003 Stage, TSS and Turbidity measurements

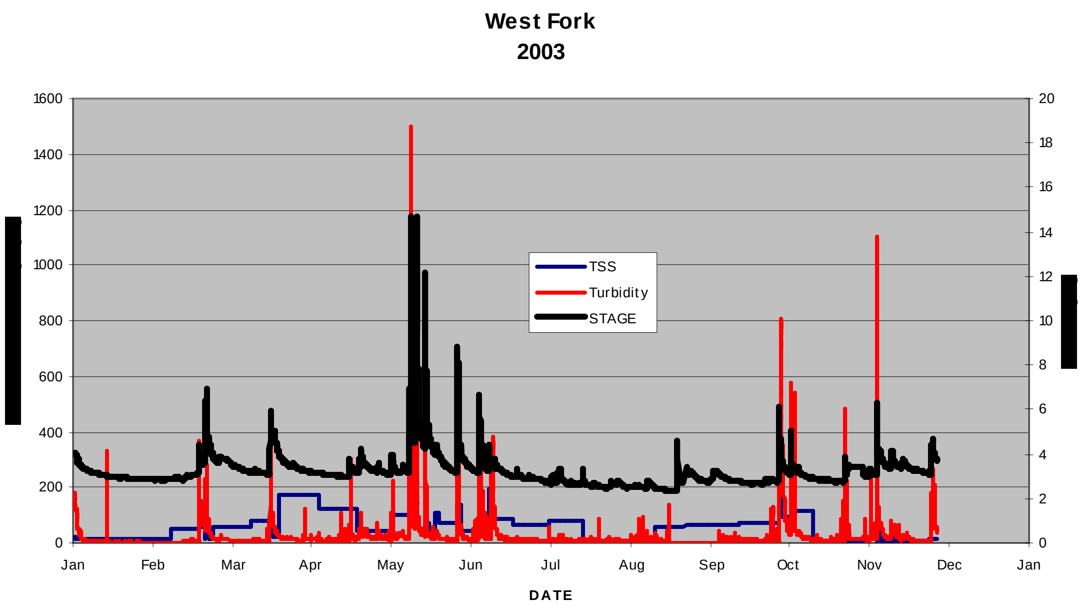


Figure 6 2003 measured TSS and Turbidity Regression.

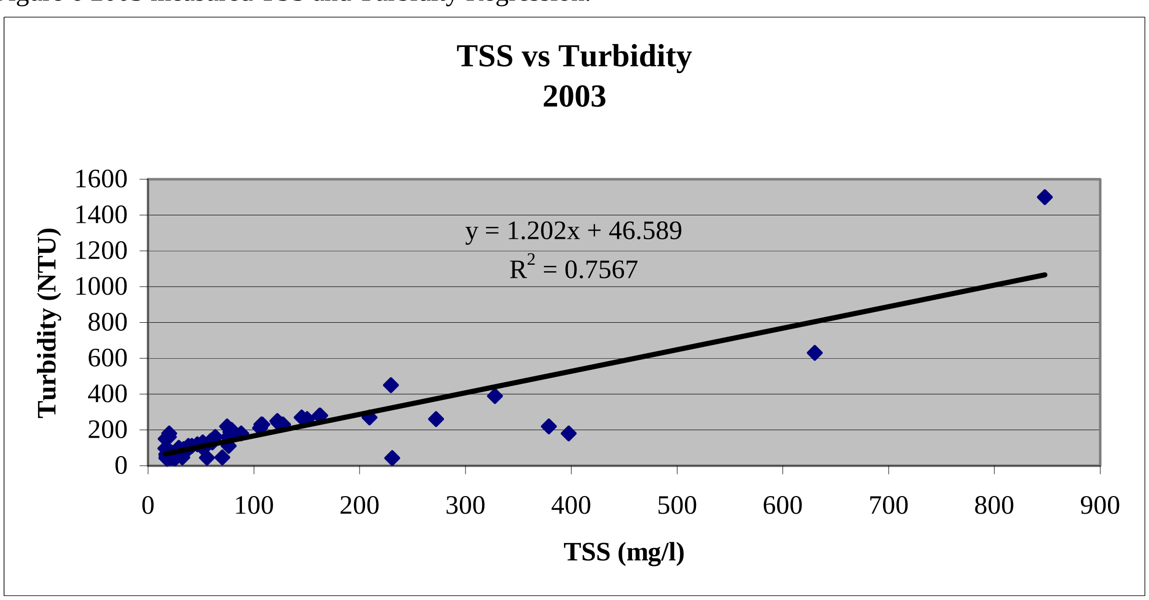
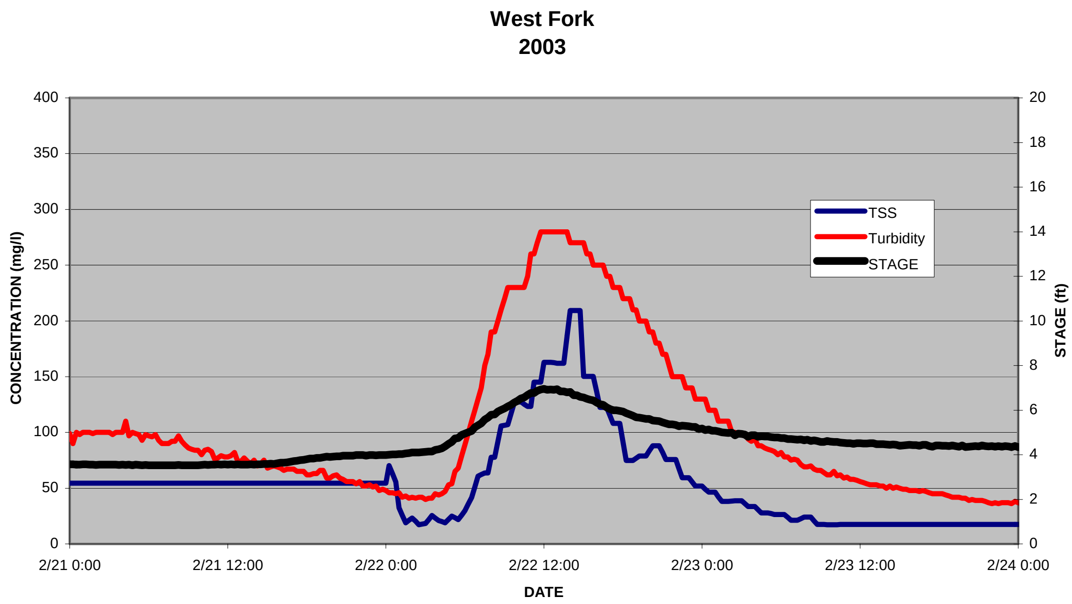


Figure 7. Storm event TSS and turbidity.



DISCUSSION

West Fork @ 195 Bridge site during 2002 and 2003 can be compared to loads and concentrations developed in other watersheds in Northwest Arkansas. Five other watersheds have been monitored using the same monitoring and load calculation protocols. The only differences between the protocols are that trigger levels and storm composite sample volumes are different for each site. This means that the distinction between storm and base flows (defined here as the trigger level) may be relatively different at each site.

The results for the six watersheds are summarized in Table 7 and Figure 8. The results shown for the West Fork are corrected pro-rated annual values for 2002 and corrected annual values for 2003. The table and figure show TSS and phosphorus as total annual loads per watershed acre, as storm loads per watershed acre and as base-flow concentrations. Normalizing total and storm loads to a per acre basis allows comparison between watersheds of differing sizes. The total loads indicate the mass of TSS or P that are being transported to a receiving water body. Storm loads per acre may be used to represent relative impacts from non-point sources. In Figure 8, a red line represents the total loads and blue diamonds represents the storm loads. The West Fork watershed has similar levels of total TSS compared to the others and while most of the TSS is transported during storm events, a significant percentage is transported during base-flow conditions. The base TSS values are significantly higher than most of the other studied watersheds except the White River at the Wyman bridge which is about a mile below the West fork sampling site after confluence with the main fork of the White.

The P load for the West Fork is similar to the other watersheds with the primary transport occurring during storm events. Base Flow P concentrations are higher than the other watersheds studied. This may be evidence of organic phosphorus bound to TSS measured particles. Phosphate concentrations were low with the storm and base flow mean concentrations of 0.1 mg/l.

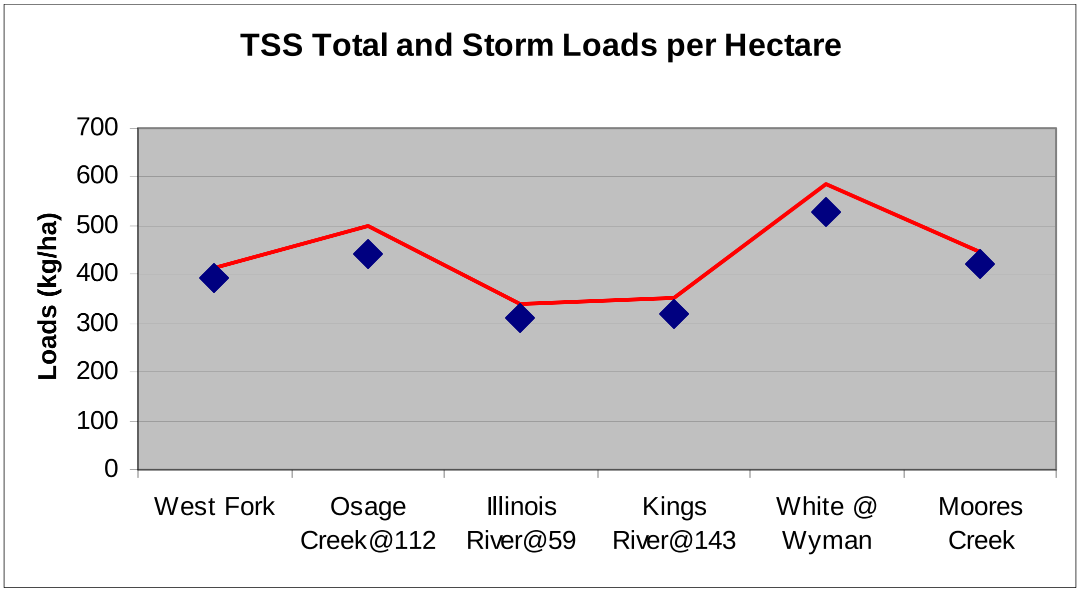
The base-flow concentrations show relative levels of TSS and P that are impacting in-stream biological activity during most of the year. These are the values that are of greatest interest for determining impacts to in-stream macro invertebrate habitat and nuisance algae production. The base-flow TSS is significantly higher than the other watersheds. The base-flow concentration of T-P is high and consistent with the other watersheds that have point-source discharges by WWTPs (all except Moores Creek).

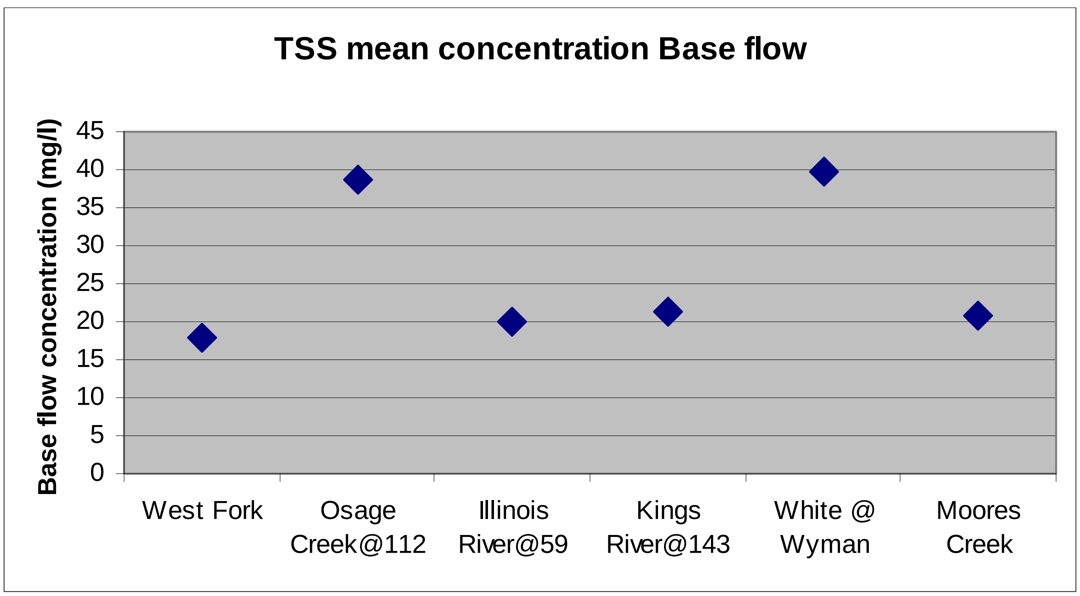
Table 7. Comparison of results to other Northwest Arkansas Watersheds.

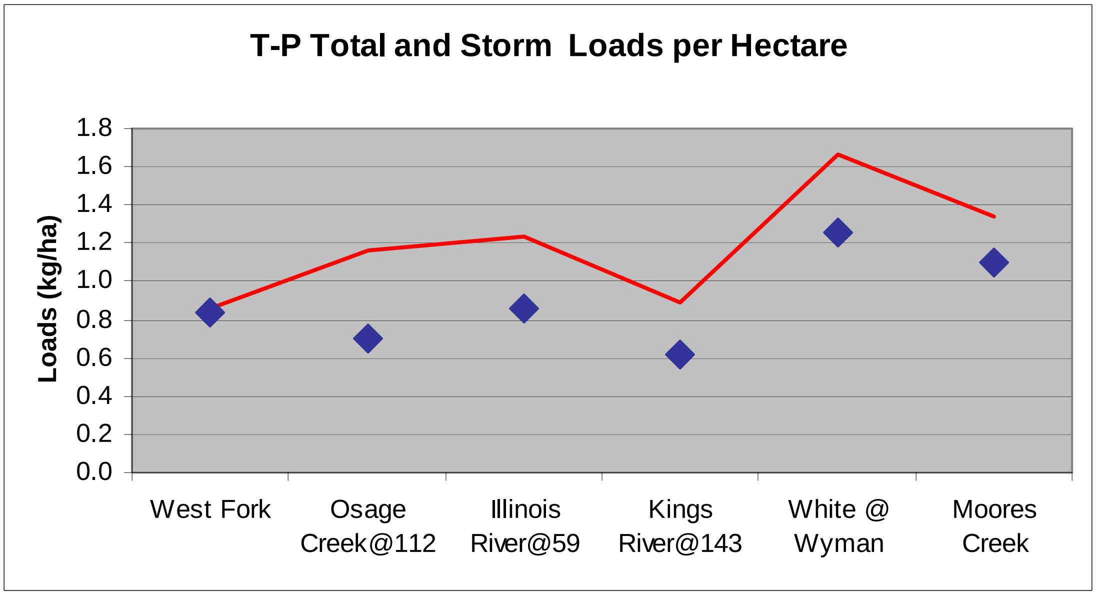
	West Fork	Osage Creek@112	Illinois River@59	Kings River@143	White @ Wyman	Moores Creek
Hectares	29,964	10,095	167,273	153,309	116,364	1,000
YEARS of data	2	2	6	4	2	3
tss load (kg/ha)	414	501	340	351	586	445
tss load storm (kg/ha)	394	442	312	320	528	420
tss conc. base (mg/l)	18	39	20	21	40	21
p load (kg/ha)	0.86	1.16	1.24	0.89	1.66	1.34
p storm load (kg/ha)	0.84	0.70	0.86	0.62	1.26	1.10
p base conc. (mg/l)	0.02	0.21	0.25	0.19	0.27	0.19
DISCHARGE (m^3)	99,226,522	38,827,312	545,516,682	419,567,171	413,400,011	2,457,683
DISCHARGE/AC (m^3/ha)	3,312	3,846	3,261	2,737	3,553	2,458

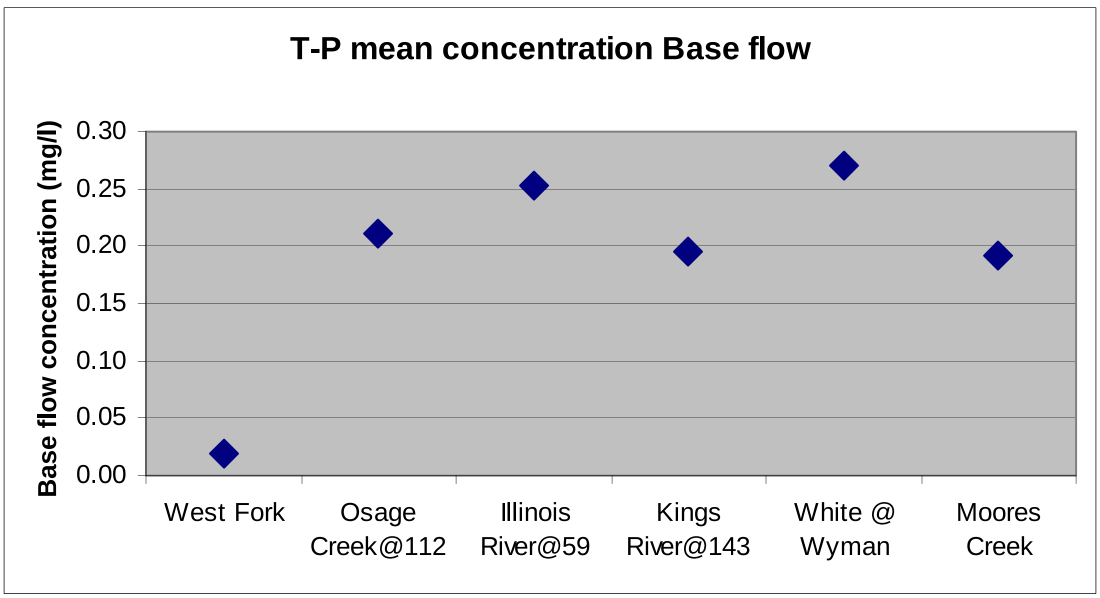
The correction factors that are detailed in this report and were applied to the data for the first 18 months of this project can be expected to add considerable uncertainty to the results. While the corrected results are certainly more accurate than the uncorrected results would have been, they should be used with caution. The correction factors were calculated from just seven paired samples. Those samples do not adequately characterize the variation during different flow regimes, which may be significant.

Figure 8. Comparisons between 6 watersheds.






T-P Total and Storm Loads per Hectare
Loads (kg/ha)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
West Fork
Osage Creek@112
Illinois River@59
Kings River@143
White @ Wyman
Moores Creek


T-P mean concentration Base flow
Base flow concentration (mg/l)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
West Fork
Osage Creek@112
Illinois River@59
Kings River@143
White @ Wyman
Moores Creek

REFERENCES

Glysson, D.G, J.R. Gray and L.M. Conge Adjustment of Total Suspended Sediment Data for use in Sediment Studies. U.S. Geological Survey, 2001

Nelson, M.A., T.S. Soerens, J. Spooner "Results of Investigation of Optimum Sample Interval for Determining Storm Water Pollutant Loads", Proceedings of the Water Environment Federation WEFTEK Conference, New Orleans, LA,, 1999
.

Nelson, M.A. , T.S. Soerens "1997 Pollutant Loads At. Arkansas Highway 59 Bridge" Presented at Arkansas-Oklahoma Arkansas River Compact Commission Meeting, September 1998.

Nelson, M.A. , T.S. Soerens "1998 Pollutant Loads At. Arkansas Highway 59 Bridge" Arkansas Water resources Center Publication, 1999.

Nelson, M.A. , T.S. Soerens "1999 Pollutant Loads At. Arkansas Highway 59 Bridge" Arkansas Water resources Center Publication, 2000.

Nelson, M.A. , T.S. Soerens "2000 Pollutant Loads At. Arkansas Highway 59 Bridge" Arkansas Water resources Center Publication, 2001.

Nelson, M.A. , T.S. Soerens "2001 Pollutant Loads At. Arkansas Highway 59 Bridge" Arkansas Water resources Center Publication, 2002.

Nelson, M.A., T.S. Soerens, J. Spooner " Preliminary Results of Investigation of Optimum Sample Interval for Determining Storm Water Pollutant Loads", Presented at ASCE Watershed Management Conference, Memphis, TN, 1998.

Nelson, M.A. , T.S. Soerens and D.G. Parker "Phosphorus Transport in the Illinois River: Preliminary Results of Intensive Sampling" Proceedings of the Arkansas Water Resource Center Annual Conference, 1998.

Parker, D.G., R. Williams and E. Teague "Illinois River Water Quality Automatic Sampler Installation" Arkansas Water Resource Center Miscellaneous Publication 0227, 1997.

Nelson, M.A., T.S. Soerens, J. Spooner "Investigation of Optimum Sample Number and Timing for Determining Storm Water Pollutant Loads Year [1998 and 1999}", Arkansas Water Resources Center Annual Report 1999-2000, August 2001.

Nelson, M.A., L.W. Cash "Water Quality Sampling , Analysis And Annual Load Determinations For TSS, Nitrogen And Phosphorus At The Wyman Road Bridge On The White River, Final Report" Arkansas Water Resources Center Publication , 2003.

Nelson, M.A., L.W. Cash "Illinois River 2002 Pollutant Loads at the Arkansas Highway 59 Bridge" Arkansas Water Resources Center Publication , 2003.

Nelson, M.A., L.W. Cash "Water Quality Sampling , Analysis And Annual Load Determinations For TSS, Nitrogen And Phosphorus At The 143 Bridge On The Kings River, 2002 Annual Report" Arkansas Water Resources Center Publication , 2003.

Nelson, M.A., S. L. Diffin "Water Quality Sampling , Analysis And Annual Load Determinations For TSS, Nitrogen And Phosphorus At The 112 Bridge On The Osage Creek, Final Report" Arkansas Water Resources Center Publication , 2003.

Nelson, M.A., L.W. Cash “Water Quality Sampling , Analysis And Annual Load Determinations For TSS, Nitrogen And Phosphorus On Moores Creek, 2002 Annual Report” Arkansas Water Resources Center Publication , 2003.

Appendix 2-G

Bioassessment of the West Fork of the White River, Northwest, Arkansas

AWRC Publication No. MSC-307

University of Arkansas, Fayetteville, AR

2003

Note: The following section contains abbreviated text and results from "Bioassessment of the West Fork of the White River, Northwest, Arkansas"; AWRC Publication No. MSC-307. The reader is strongly encouraged to read the document in its entirety for further explanation of the WFWR bioassessment.

EXECUTIVE SUMMARY

The West Fork-White River has been and continues to be an important water resource for northwest Arkansas. It is used recreationally for fishing and swimming, agriculturally as a source of water for livestock and irrigation of crops, it is mined for gravel, used as a receiving stream for municipal wastewater effluent, and contributes to Beaver Lake which provides water for treatment and distribution to most of northwest Arkansas. While these uses have benefited a large segment of the Arkansas population, they have also contributed to the decline in environmental quality of the river. To facilitate the development of appropriate management protocols and assess restoration potential, we provided a biological assessment of the West Fork-White River to complement studies of its physical and chemical properties. This holistic evaluation can be used presently, and to track changes in the environmental quality of the river in the future.

We compared the fish assemblages that we described at eight West Fork-White River sites to historical information dating back to 1894 and to current conditions in other Boston Mountain streams that are less disturbed. We identified 39 fish species in our survey, compared to 63 species from historical records. Nine of the fish species missing in our survey are of particular concern because these species appear consistently in historical records of the West Fork-White River, have been commonly reported in Boston Mountain streams, and two (checkered madtom and yoke darter) are endemic to the White River basin. We noted an increase in abundance of tolerant species and decline of sensitive species, which indicates that environmental stress is influencing the composition of the fish assemblages. The paucity of desirable sportfish and sunfish (e.g. bass, crappie, catfish) also suggests that restoration is needed. However, it is encouraging to note that a headwater site that we intensively sampled compared favorably with least-disturbed streams in the Boston Mountain ecoregion in some measures of environmental health including fish density, biomass, and species richness.

The assessment of environmental quality based on macroinvertebrate assemblages is consonant with the assessment based on fishes. Tolerant species again predominated, and the species richness was lower than what would be expected for less disturbed streams in this ecoregion. Meiofauna, a group of stream invertebrates smaller than

macroinvertebrates, are of increasing interest to stream ecologists and may become important tools for future bioassessment. While little is known about the influence of anthropogenic disturbance on meiofauna, we noted that the West Fork-White River assemblage was also dominated by tolerant taxa. We provided a baseline of information on this group of organisms at this time for subsequent evaluations. Riparian corridors were in good condition in some upstream reaches, but bank erosion was apparent where buffers were narrow or absent. Further downstream, extensive bank erosion has occurred contributing to open canopies, gravel substrate embedded with fine sediments, and excessive turbidity. The site downstream from the community of West Fork municipal wastewater outfall was in very poor condition and was dominated by tolerant fish and macroinvertebrate species.

Our overall assessment is that the biological community has been affected by the cumulative effect of disturbance over time, but that species richness remains moderately high over the course of the river, and headwater reaches have maintained sufficient biological integrity to suggest that restoration efforts at this time could be effective. Attention to the cumulative effects of physical and chemical disturbances on the biological community can provide information for setting benchmarks to evaluate the success of improved management protocols and restoration efforts.

Appendix 2-G (continued)

Table 1. Density and biomass estimates for fishes sampled at West Fork-White River Site 8 August 2002. Values in parentheses are ± 2 SE.

Species	Density (fish/ha)	Biomass (kg/ha)
Campostoma spp. Central (and large scale) stoneroller	10,357 (± 2824)	56.56 (± 16.03)
Luxilus pilsbryi Duskystripe shiner	4595 (± 848)	4.80 (± 0.69)
Semotilus atromaculatus Creek chub	539*	0.90*
Hypentelium nigricans Northern hogsucker	70 (± 9)	4.45 (± 4.82)
Ictalurus natalis Yellow bullhead	17*	1.35*
Noturus exilis Slender madtom	2638 (± 19,688)	10.71(± 79.97)
Fundulus olivaceus Blackspotted topminnow	70 (± 9)	0.17 (± 0.13)
Ambloplites ariommus Shadow bass	35*	3.32*
Ambloplites constellatus Rock bass	196 (± 539)	20.40 (± 56.65)
Lepomis cyanellus Green sunfish	322 (± 1122)	11.98 (± 41.95)
Lepomis gulosus Warmouth	17*	1.83*
Lepomis macrochirus Bluegill	17*	0.06*
Lepomis megalotis Longear sunfish	1014 (± 123)	12.97 (± 2.36)
Micropterus dolomieui Smallmouth bass	76 (± 36)	0.59 (± 0.55)
Etheostoma blennioides Greenside darter	629 (± 344)	2.07 (± 1.50)
Etheostoma caeruleum Rainbow darter	1455 (± 387)	1.46 (± 0.46)
Etheostoma punctulatum Stippled darter	571 (± 366)	2.25 (± 1.51)
Etheostoma spectabile Orangethroat darter	3956 (± 5769)	3.73 (± 4.59)
Etheostoma zonale Banded darter	214 (± 25)	0.21 (± 0.14)
Total	26,788 (± 20,774)	139.81 (± 108.06)

* population not depleted; minimum summing 3 passes

Table 2. Fish species historically reported in West Fork-White River from Cloutman and Olmsted (1976), Robison and Buchanan (1988), ADPCE (1995), and the 2002 survey.

Lepisosteidae	**Gars**
Lepisosteus osseus	Longnose gar
Clupeidae	**Herrings**
Dorosoma cepedianum	Gizzard shad
Cyprinidae	**Minnows**
Campostoma anomalum	Central stoneroller
Campostoma oligolepis	Largescale stoneroller
Cyprinella whipplei	Steelcolor shiner
Cyprinus carpio	Common carp
Hybopsis amblops	Bigeye chub
Luxilus chrysocephalus	Striped shiner
Luxilus pilsbryi	Duskystripe shiner
Nocomis biguttatus	Hornyhead chub
Notropis boops	Bigeye shiner
Notemigonus crysoleucas	Golden shiner
Notropis nubilus	Ozark minnow
Notropis rubellus	Rosyface shiner
Notropis telescopus	Telescope shiner
Pimephales notatus	Bluntnose minnow
Pimephales promelas	Fathead minnow
Pimephales tenellus	Slim minnow
Semotilus atromaculatus	Creek chub
Catostomidae	**Suckers**
Catostomus commersoni	White sucker
Hypentelium nigricans	Northern hogsucker
Moxostoma carinatum	River red horse
Moxostoma duquesnei	Black redhorse
Moxostoma erythrurum	Golden redhorse
Minytrema melanops	Spotted sucker

Table 4. Continued.

Ictaluridae	**Freshwater catfishes**
Ictalurus melas	Black bullhead
Ictalurus natalis	Yellow bullhead
Ictalurus punctatus	Channel catfish
Noturus albater	Ozark madtom
Noturus exilis	Slender madtom
Noturus flavater	Checkered madtom
Pylodictis olivaris	Flathead catfish
Cyprinodontidae	**Killifishes**
Fundulus catenatus	Northern studfish
Fundulus olivaceus	Blackspotted topminnow

(Continued on next page)

Appendix 2-G (continued)

Table 2 continued. Fish species historically reported in West Fork-White River from Cloutman and Olmsted (1976), Robison and Buchanan (1988), ADPCE (1995), and the 2002 survey.

Atherinidae	**Silversides**
Labidesthes sicculus	Brook silverside
Centrarchidae	**Sunfishes**
Ambloplites ariommus	Shadow bass
Ambloplites constellatus	Ozark bass
Ambloplites rupestris	Rock bass
Lepomis cyanellus	Green sunfish
Lepomis gulosus	Warmouth
Lepomis macrochirus	Bluegill
Lepomis megalotis	Longear sunfish
Lepomis sp.	Hybrid Green sunfish/Bluegill
Micropterus dolomieui	Smallmouth bass
Micropterus punctulatus	Spotted bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Percidae	**Perches**
Etheostoma blennioides	Greenside darter
Etheostoma caeruleum	Rainbow darter
Etheostoma juliae	Yoke darter
Etheostoma punctulatum	Stippled darter
Etheostoma spectabile	Orangethroat darter
Etheostoma stigmaeum	Speckled darter
Etheostoma zonale	Banded darter
Percina caprodes	Logperch
Stizostedion vitreum	Walleye
Poeciliidae	**Livebearers**
Gambusia affinis	Mosquito fish
Moronidae	**Temperate Basses**
Morone chrysops	White bass
Morone saxatilis	Striped bass
Cottidae	**Sculpins**
Cottus carolinae	Banded sculpin
Petromyzontidae	**Lampreys**
Ichthyomyzon castaneus	Chestnut lamprey
Ichthyomyzon gagei	Southern brook lamprey
Anguillidae	**Freshwater eels**
Anguilla rostrata	American eel

Appendix 2-G (continued)

Table 3. Fish species present historically in the West Fork-White River but not found in the 2002 survey.

Cyprinidae	**Minnows**
Cyprinus carpio	Common carp
Hybopsis amblops	Bigeye chub*
Luxilus chrysocephalus	Striped shiner*
Nocomis biguttatus	Hornyhead chub*
Notemigonus crysoleucas	Golden shiner*
Notropis telescopus	Telescope shiner*
Pimephales promelas	Fathead minnow
Pimephales tenellus	Slim minnow
Catostomidae	**Suckers**
Catostomus commersoni	White sucker
Moxostoma carinatum	River red horse
Minytrema melanops	Spotted sucker
Ictaluridae	**Freshwater catfishes**
Ictalurus punctatus	Channel catfish
Noturus flavater	Checkered madtom*
Pylodictis olivaris	Flathead catfish
Cyprinodontidae	**Killifishes**
Fundulus catenatus	Northern studfish*
Centrarchidae	**Sunfishes**
Pomoxis annularis	White crappie
Percidae	**Perches**
Etheostoma juliae	Yoke darter*
Etheostoma stigmaeum	Speckled darter*
Stizostedion vitreum	Walleye
Moronidae	**Temperate basses**
Morone chrysops	White bass
Petromyzontidae	**Lampreys**
Ichthyomyzon castaneus	Chestnut lamprey
Ichthyomyzon gagei	Southern brook lamprey
Anguillidae	**Freshwater eel**
Anguilla rostrata	American eel

* missing species of concern

Appendix 2-G (continued)

Table 4. Comparison of fishes collected from the WFWR at site 6 in 1963, 1993, 2002

		2002		1993		1963	
		No.	%	No.	%	No.	%
Lepososteidae	**Gars**						
Lepisisteus osseus	Longnose gar	1	0.3	2	0.2		
Clupeidae	**Herrings**						
Dorosoma cepedianum	Gizzard shad					15	0.7
Cyprinidae	**Minnows**						
*Campostoma spp.**	Central and largescale stonerollers*	15	4.9	422	38.8	313	14.7
Cyprinella whipplei	Steelcolor shiner	6	2	96	8.8	2	0.1
Luxilus chrysocephalus	Striped shiner			1	0.1	24	
Luxilus pilsbryi	Duskystripe shiner			137	12.6	171	1.1
Nocomis biguttatus	Horneyhead chub					26	1.2
Notropis boops	Bigeye shiner	38	12.4	34	3.1	11	0.5
Notemigonus crysoleucas	Golden shiner					1	0
Notropis nubilus	Ozark minnow	6	2	23	2.1	48	2.2
Notropis rubellus	Rosyface shiner	2	0.7				
Notropis telescopus	Telescope shiner					35	1.6
Pimephales notatus	Bluntnose minnow	16	5.2	12	1.1	18	0.8
Semotilus atromaculatus	Creek chub					3	0.1
Catostomidae	**Suckers**						
Hypentelium nigricans	Northern hogsucker	3	1	16	1.5	18	0.8
Moxostoma carinatum	River red horse					2	0.1
Moxostoma duquesnei	Black redhorse			30	2.8	16	1.7
Moxostoma erythrurum	Golden redhorse			62	5.7	7	0.3
*Moxostoma spp.***	Black and golden redhorses**	69	22.5				
Ictaluridae	**Freshwater catfishes**						
Ictalurus natalis	Yellow bullhead	1	0.3				
Noturus albater	Ozark madtom			27	2.5	201	9.4
Noturus exilis	Slender madtom	1	0.3	15	1.4	150	7
Cyprinodonidae	**Killifishes**						
Fundulus catenatus	Northern studfish					5	0.2
Fundulus olivaceus	Blackspotted topminnow	3	1	3	0.3	17	0.8
Centrarchidae	**Sunfishes**						
Ambloplites constellatus	Ozark bass	11	3.6			4	0.2
Lepomis cyanellus	Green sunfish	6	2	17	1.6	22	1
Lepomis macrochirus	Bluegill	19	6.2	11	1		
Lepomis Megalotis	Longear sunfish	59	19.2	41	3.8	93	4.4
Lepomis sp.	Hybrid Green sunfish/Bluegill	21	6.8				
Micropterus dolomieui	Smallmouth bass			3	0.3	5	0.2
Micropterus punctulatus	Spotted bass	2	0.7	27	2.5	35	1.6
Micropterus salmoides	Largemouth bass			3	0.3		
Percidae	**Perches**						
Etheostoma blenniodes	Greenside darter	11	3.6	20	1.8	69	3.2
Etheostoma caeruleum	Rainbow darter	8	2.6	49	4.5	591	27.7
Etheostoma juliae	Yoke darter					13	0.6
Etheostoma punctulatum	Stippled darter	1	0.3			9	0.4
Etheostoma spectabile	Orangethroat darter	4	1.3	9	0.8	126	5.9
Etheostoma stigmaeum	Speckled darter					1	0
Etheostoma zonale	Banded darter	2	0.7	23	2.1	75	3.5
Percina caprodes	Logperch	3	1	1	0.1	3	0.1
Stizostedion vitreum	Walleye					1	0
Cottidae	**Sculpins**						
Cottus carolinae	Banded sculpin					5	0.2
Petromyzontidae	**Lampreys**						
Ichthyomyzon sp.	Lampray species			4	0.4		
Species count		26		26		35	
Fish count		308		1088		2135	
Diversity index		3.57		3.34		3.66	
Similarity index		2002 vs. 1993 = 0.86		1993 vs. 1963 = 0.65			

* *Compostoma anomalum* and *Campostoma oligolepis* were not differentiated and were included as two species in the species count.

** *Moxostoma duquesnei* and *Moxostoma erythrurum* were not differentiated and were included as two species in the species count.

Table 5. Comparison of fish assemblage characteristics of West Fork-White River Site 8 to other Boston Mountain river reaches with comparable watershed size

	West Fork-White River Site 8	North Fork-Illinois Bayou	Middle Fork-Illinois Bayou	10 Boston Mountain Rivers Mean *	10 Boston Mountain Rivers Range*
Total Density (fish/ha)	26,788	18,140	17,965	22,328	8,676 to 46,150
Total Biomass (g/ha)	139.81	89.93	154.77	117.87	26.82 to 202.85
Species Richness	19	15	17	14.9	19 to 10
% Campostoma	38.6	7.3	4.2	22.1	0 to 42.1
% Other Cyprinidae	19.2	13.9	10.1	15.9	5.7 to 34.1
% Centrarchidae	6.3	40.4	53.1	22.8	0.1 to 53.1
% Percidae	25.6	32.8	25.2	30.7	10 to 61.5
% Lepomis cyanellus	1.2	0.26	0.67	2.13	0 to 5.75

* Big Piney Creek, Hurrican Creek, Kings River, Middle Fork-Illinois Bayou, Mulberry River, North Fork-Illinois Bayou, Richland Creek, War Eagle Creek, White River, Upper Buffalo River.
For specific location of sampling sites and watershed size, see Rambo (1998) and Radwell (2000).

Appendix 2-G (continued)

Table 6. Functional feeding groups of the insects collected from the West Fork-White River in July 2002.

Order	Family	Genus	Functional Feeding Group*
Ephemeroptera		*Leptophlebia*	
	Baetidae	*Baetis*	collectors-gatherers
	Caenidae	*Brachycercus*	collectors-gatherers
		Caenis	collectors-gatherers, scrapers
	Ephemeriidae	*Ephemera*	collectors-gatherers
	Isonychiidae	*Isonychia*	collectors-filterers
	Heptageniidae	*Cinygmula*	scrapers, collectors-gatherers
		Stenacron	collectors-gatherers
		Stenonema	scrapers, collectors-gatherers
	Leptophlebiidae	*Choroterpes*	collectors-gatherers, scrapers
		Leptophlebia	collectors-gatherers
		Neochorotorpes	collectors-gatherers, scrapers
		immature	
	Tricorythidae	*Tricorythodes*	collectors-gatherers
Plecoptera			
	Perlidae	*Acroneuria*	predator
		Neoperla	predator
	Taeniopoterygidae	*Strophopteryx*	scrapers, collectors-gatherers
Trichoptera			
	Glossosomatidae	*Agapetus sp.*	scrapers, collectors-gatherers
	Hydropsychidae	*Cheumatopsyche*	collectors-filterers
		Smicridea	collectors-filterers
	Leptoceridae	*Oecetis*	predators
	Philopotamidae	*Chimarra*	collectors-filterers
	Polycentropodidae	*Cernotina*	predators
			collectors-filterers.shredders
		Neuroclipsis	herbivores, engulfers
	Ceratopogonidae		predators, collectors-gatherers
	Chironomidae		varies with subfamily
	Empididae		predators, collectors-gatherers
	Simuliidae	*Simulium*	collectors- filterers
		Prosimulium	collectors- filterers
	Tanyderidae		
	Tipulidae	*Hexatoma*	predators
			shredders-detritovores and
			herbivores, collector-gatherers,
		Tipula	possibly some scrapers, predators
Coleoptera			
	Elmidae	*Macronychus*	collectors-detritovores
		Stenelmis	scrapers-collector, gatherers
			piercers-herbivores, collectors-
	Hydrophilidae	*Berosus*	gathers, shredders
	Psephenidae	*Psephenus*	scrapers, collectors-gatherers
Hemiptera			
	Veliidae	*Rhagovelia*	predators

(continued on next page)

Appendix 2-G (continued)

Table 6 continued.

Order	Family	Genus	Functional Feeding Group*
Megaloptera			
	Corydalidae	*Corydalus*	predators
		Nigronia	predators
	Sialidae	*Sialis*	predators
Odonata			
	Coenagrionidae	*Argia*	predators
	Gomphidae	*Gomphus*	predators
		Stylogomphus	predators

* All functional feeding groups as designated by Merritt and Cummins (1996)

Table 7. Functional feeding groups of the insects collected from the West Fork-White River in January 2003.

Order	Family	Genus	Functional Feeding Group*
Ephemeroptera			
	Baetidae	*Baetis*	collectors-gatherers
	Caenidae	*Brachycercus*	collectors-gatherers
		Caenis	collectors-gatherers, scrapers
	Ephemeriidae	*Ephemera*	collectors-gatherers
	Isonychiidae	*Isonychia*	collectors-filterers
	Heptageniidae	*Cinygmula*	scrapers, collectors-gatherers
		Eperorus	
		Stenacron	collectors-gatherers
		Stenonema	scrapers, collectors-gatherers
	Leptophlebiidae	*Choroterpes*	collectors-gatherers, scrapers
		Leptophlebia	collectors-gatherers
		Neochorotorpes	collectors-gatherers, scrapers
	Tricorythidae	*Tricorythodes*	collectors-gatherers
Plecoptera			
	Capniidae	*Allocapnia*	shredders-detritovore
		Isocapnia	
	Chloroperlidae	*Alloperla*	predators
	Perlidae	*Acroneuria*	predators
		Neoperla	predators
	Perlodidae	*Diploperla*	predators
		Diura	scrapers-predators
		Isoperla s	predators
		Hydroperla	predators
	Pteronarcyidae	*Immature*	
	Taeniopoterygidae	*Oemopteryx*	scrapers, collectors-gatherers

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Appendix 2-G (continued)

Table 7. Continued.

Order	Family	Genus	Functional Feeding Group*
		Strophopteryx	scrapers, collectors-gatherers
		Taeniopteryx	shredders-detritovores, facultative collectors-gatherers
	Leuctridae	*Zealeutra*	shredders-detritovore
Trichoptera			
	Glossosomatidae	*Agapetus*	scrapers, collectors-gatherers
	Hydropsychidae	*Cheumatopsychae*	collectors-filterers
		Smicridea	collectors-filterers
	Leptoceridae	*Oecetis*	predators, shredders-herbivores
	Philopotamidae	*Chimarra*	collectors-filterers
	Polycentropodidae	*Cernotina*	predators
		Neuroclipsis	collectors-filterers, shredders-herbivores, engulfers
Diptera			
	Ceratopogonidae	*Dashyelea*	collectors-gatherers, scrapers
	Chironomidae		varies by species
	Dixidae		collectors-gatherers
	Empididae	*Chelifera*	generally predators, some collectors-gatherers
	Simliidae	*Cnephia*	collector-filterers
		Prosimulium	collector-filterers
		Simulium	collector-filterers
	Tabanidae		generally predators
	Tanyderidae		
	Tipulidae	*Antocha*	collectors-gatherers
		Hexatoma	predators
		Tipula	shredders-detritivores, collectors-gatherers, predators
Coleoptera			
	Elmidae	*Ordobrevia*	
		Macronychus	collectors-detritovores
		Neoelmis	collectors-detritovores
		Stenelmis	
	Psephenidae	*Psephenus*	scrapers, collectors-gatherers
Megaloptera			
	Corydalidae	*Corydalus*	predators
	Sialidae	*Sialis*	predators
Odonata			
	Coenagrionidae	*Argia*	predators
	Gomphidae	*Gomphus*	predators
		Stylogomphus	predators

* All functional feeding groups as designated by Merritt and Cummins (1996)

Appendix 2-G (continued)

Table 8. Macroinvertebrates collected by Hess Sampler in WFWR in January 2003

			Site No.							
Order	Family	Genus	1	2	3	4	5	6	7	8
Ephemeroptera										
	Baetidae	*Baetis*	0	4	10	1	0	0	0	0
	Caenidae	*Brachycercus*	0	0	2	0	0	3	1	0
		Caenis	3	11	25	16	15	5	1	0
	Ephemeriidae	*Ephemera*	0	0	0	0	0	0	0	0
	Isonychiidae	*Isonychia*	1	6	0	1	0	0	0	2
	Heptageniidae	*Cyngymula*	0	0	0	0	0	2	0	0
		Eperorus	10	15	0	0	0	0	0	0
		Stenacron	1	4	2	0	0	2	0	6
		Stenonema	1	22	3	18	0	5	15	15
	Leptophlebiidae	*Choroterpes*	0	7	0	0	0	0	0	0
		Leptophlebia	0	0	0	0	0	0	0	0
		Neochoroterpes	0	0	0	0	0	0	0	0
	Tricorythidae	*Tricorythodes*	0	0	1	0	0	0	0	0
Plecoptera										
	Capniidae	*Allocapnia*	2	0	0	0	2	0	0	0
		Isocapnia	48	38	16	0	0	0	0	27
	Choloroperlidae	*Alloperla*	11	0	0	0	0	0	0	2
	Perlidae	*Acroneuria*	0	0	0	0	0	0	0	0
		Neoperla	0	0	0	0	0	0	0	0
	Perlodidae	*Diploperla*	0	0	0	0	0	0	0	0
		Diura	0	0	0	1	0	1	0	0
		Isoperla	201	32	0	0	0	0	0	0
		Hydroperla	0	0	0	0	0	0	0	0
	Taenipoterygidae	*Oemopteryx*	3	0	0	1	0	0	0	0
		Strophopteryx	1	0	0	0	0	0	0	0
		Teaniopteryx	0	0	1	0	0	1	1	0
		immature	0	0	7	0	0	0	0	0
	Leuctridae	*Zealeutra*	0	0	0	9	0	0	0	0
Trichoptera										
	Glossosomatidae	*Agapetus*	33	105	22	0	0	0	0	48
	Hydropsychidae	*Cheumatopsyche*	16	3	8	13	18	10	1	10
		Smicridae	0	0	0	0	0	0	0	0
	Leptoceridae	*Oecetis*	0	0	0	0	0	0	0	0
	Philopotamidae	*Chimarra*	14	0	0	24	0	0	0	7
	Polycentropodidae	*Cernotina*	6	23	3	0	0	0	0	1
		Neureclipsis	0	0	0	0	0	0	0	0
Diptera										
	Ceratopogonidae	*Dashyelea*	0	0	0	3	0	0	0	0
	Chironomidae		149	178	31	77	25	33	22	0
	Dixidae		0	0	0	0	0	0	1	0
	Empididae	*Chelifera*	0	1	0	0	0	0	0	0
	Simuliidae	*Cnephia*	0	0	0	1	0	1	0	0
		Prosimulium	0	0	4	0	2	0	0	0
		Simulium	0	0	1	0	0	0	0	0
	Tabanidae		0	0	0	0	0	1	1	0
	Tanyderidae		0	0	0	1	0	0	0	0
	Tipulidae	*Antocha*	0	0	0	0	0	0	0	0
		Hexatoma	2	0	1	0	0	7	0	0
		Tipula	4	13	1	0	0	0	5	0
	Diptera pupa		0	1	0	0	0	0	6	0
Coleoptera										
	Elmidae	*Ordobrevia*	0	0	0	0	0	1	1	0
		Macronychus	0	0	0	0	0	2	0	0
		Neoelmis	0	0	0	0	0	2	1	0
		Stenelmis	2	0	0	0	0	0	0	0
	Psephenidae	*Psephenus*	5	8	1	11	0	0	0	0

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Table 8 continued. Macroinvertebrates collected by Hess Sampler in WFWR in January 2003

			Site No.							
Order	Family	Genus	1	2	3	4	5	6	7	8
Megaloptera										
	Corydalidae	*Corydalus*	0	0	0	0	0	1	0	0
	Sialidae	*Sialis*	0	0	0	0	0	0	0	0
Odonata										
	Coenagrionidae	*Argia*	1	9	0	2	0	0	0	0
	Gomphidae	*Gomhpus*	0	13	0	0	0	0	0	0
		Stylogomphus	0	0	1	0	0	0	0	0
Decapoda										
	Cambaridae		0	0	0	1	0	0	0	0
Isopoda										
	Asellidae	*Lirceus*	0	0	0	12	0	0	0	0
Veneroida										
	Corbiculidae	*Corbicula fluminea*	0	0	0	3	0	0	1	0
Gastropoda										
	Hydrobiidae		0	0	0	0	1	0	0	0
Oligochaeta										
	Lumbricidae		13	22	2	5	2	0	17	0
Tricladida										
	Dendrocoelidae	*Procotyla*	0	0	0	0	4	0	0	0
Collembola			0	0	23	0	0	0	0	0
	Totals		**527**	**515**	**166**	**200**	**69**	**77**	**65**	**118**

Table 9. Biological indices for the West Fork-White River macroinvertebrate communities

	Jul-02								
	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	3P-INT	RBA
Total Organisms	99	210	417	618	1697	605	1042	632	113
Taxa Richness	17	18	22	18	18	19	21	25	16
Shannon-Wiener Diversity Index	3.116	2.493	2.472	3.3	2.088	3.164	3.151	3.273	3.814
% EPT	0.377	0.253	0.435	0.451	0.482	0.405	0.335	0.469	0.311
% Chironomidae	0.172	0.395	0.17	0.152	0.054	0.281	0.332	0.021	0.062

	Jan-03								
	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	3P-INT	RBA
Total Organisms	528	517	169	204	74	83	72	118	*
Taxa Richness	31	20	22	19	8	16	15	9	*
Shannon-Wiener Diversity Index	2.71	3.183	3.505	2.686	2.226	2.838	2.704	2.413	*
% EPT	0.4	0.344	0.378	0.296	0.337	0.274	0.133	0.5	*
% Chironomidae	0.282	0.344	0.183	0.377	0.338	0.398	0.306	0	*

* RBA was not performed in January 2003

Appendix 2-G (continued)

Table 10. Comparison of the results of Rapid Bioassassment Protocols in 1993 and 2002.

Order	Family	Genus	RBA 2002	RBA 1993
Ephemeroptera				
	Baetidae	*Baetis*	2	0
		Caenis	10	0
	Isonychiidae	*Isonychia*	5	30
	Heptageniidae	*Stenonema*	15	11
Trichoptera				
	Hydropsychidae	*Cheumatopsyche*	15	36
	Philopotamidae	*Chimarra*	4	14
Diptera				
	Chironomidae		7	1
	Tipulidae	*Hexatoma*	4	1
		Tipula	6	0
Coleoptera				
	Dryopidae	*Helichus*	0	1
	Psephenidae	*Psephenus*	5	2
Hemiptera				
	Veliidae	*Rhagovelia*	10	0
Megaloptera				
	Corydalidae	*Corydalus*	7	2
	Sialidae	*Sialis*	5	0
Odonata				
	Coenagrionidae	*Argia*	7	1
Decapoda				
	Cambaridae		0	1
Veneroida				
	Corbiculidae	*Corbicula fluminea*	8	0
Oligochaeta				
	Lumbricidae		3	0
Total numbers			113	100
Taxa Richness			16	12
Shannon H` (diversity index)			3.84	2.36

Appendix 3-A

University of Arkansas CES Survey of WFWR Landowners Summary

Incremental Funding, Beaver Lake Watershed
Grant #C99610307
Project 1100

Task 3: Agricultural Best Management Practice Education and Training

Summary

Introduction

The West Fork – White River is a 124 square mile area in the eastern portion of Washington County, Arkansas. This stream originates in the southern part of the county and flows north. The stream merges with the main stem of the White River and flows into Beaver Lake, which is the water source for over 200,000 people.

In 1998, this stream was placed on the Arkansas 303(d) list and was later slated for TMDL implementation by 2005.

The West Fork – White River watershed clientele are primarily very rural, most of which are located in somewhat secluded locations. This watershed is also consists of large levels of steep terrain and forested areas.

Project Limitations

At the time this grant was written, the overall goal was to ensure that producers in the watershed were not applying excess nutrients and were implementing practices to reduce nutrient loading into the stream. However, accessing data to support this was a difficult task. The landowners in this watershed wanted data provided to them that stated what the problem was and to what degree. It was over a year into the grant before information was obtained from the Arkansas Department of Environmental Quality (water sampling data 1998-1998), the Arkansas Water Resources Center monitoring station data at Wyman Bridge, and the EPA TMDL confirmation for 1998. Each of those sources all stated that the key problem was sediment loading, not nutrients.

Since this grant focuses on assisting landowners with BMP implementation, it was easy to incorporate sediment and nutrient loading into presentations and one-on-one programs. Approaching on-farm programs as " whole farm" management and focusing on economics and the environment, as a whole, was the key to success.

Another stumbling block for this project was the QAPP for the survey. According to the way the grant was written, no project work could begin until the surveys were sent out and baseline data was collected. The QAPP was not submitted and approved until 7 months into the project. This caused an incredible delay in implementation of BMPs.

The final limitation to this grant was the overall opinion that some landowners felt that they were being singled out. Many letters and phone calls were received detailing the problems people had with the pre-implementation survey or things going on in their area that they believed were a bigger problem than anything than a farmer could be doing with his or her land.

To address this, it was emphasized that any participation in this project was voluntary, that any information was confidential and that our office did not serve any regulatory purpose. I also referred many clients to the local EPA representative for them to discuss non-agricultural pollution issues.

Success

The strongest factor in the success of this grant was being able to establish a steering committee consisting of landowners in the watershed. This group was instrumental in providing input on topics that needed to be addressed, demonstrations and encouraging attendance at public meetings. This committee consisted of 8 members.

One of the producers was a member of the Fayetteville Chamber of Commerce and Farm Bureau. Because of his support of this grant, he contacted the Chamber and we were able to make a presentation to introduce the project to county leaders. He was also helpful in obtaining funds from Farm Bureau to help sponsor the meal at the first West Fork – White River Kickoff Meeting.

Another key to success was providing support to a majority of the clientele who had not utilized the Cooperative Extension service for assistance in the past. Due to the large concentration on watershed issues in the Illinois River in Washington County, a majority of the clientele served was from the western portion and urban portions of the county. Due to the lack of extensive Extension presence prior to this grant, it was important to incorporate subject matter into programs that would bring the people together. Forage selection, urban issues, and grazing management are a few examples of topics presented that were successful in obtaining attendance at meetings. These topics were also a gateway for promoting sound, environmental practices through simple management decisions. A total of 1054 landowners attended meetings designated for strictly watershed clientele. Another 541 landowners attended meetings that shared watershed boundaries.

The public meetings were also instrumental in providing contacts for youth programs in schools. Winslow, West Fork, Greenland and Fayetteville schools were all reached because of a contact made at a public meeting. This enabled us reach 2855 youth.

Beyond the grant

The most positive aspect of this grant has been that the individual farmers that received assistance during the course of the grant continue to utilize the Cooperative Extension Service for all aspects of farming management decision-making. Many landowners have gone for skeptics of this grant and unsure of our agency, to some of our largest supporters. Those landowners also serve as a contact point for those who may not have taken advantage of our services in the past.

By utilizing the educational approach of tying the "whole farm management" approach into our programs, not only were we able to reach a large clientele, but we were also able to provide a link between the environment, farming and economics with positive results.

Final Report

Objective 1:
Subtask 3.1
Pre-implementation Survey

In 2000, 639 surveys were sent to landowners in the West Fork – White River watershed. A total of 321 responded, which accounts for a 50% response rate.

Baseline producer data:

- ? 11,408 acres represented
- ? 5% of the producers were under age 35
- ? 39% of the producers were between 35-55
- ? 56% of the producers were over age 55
- ? 66% of the producers had beef cattle; of those producers, 22% also had poultry
- ? 3% of producers had poultry only
- ? 63% had soil sampled, but only 32% had been in the last 3 years
- ? 66% had used poultry litter as an alternative to commercial fertilizer alternative, but only 6% had had it tested for nutrient content
- ? 38% utilize herbicides as needed and 60% never utilize herbicides

Water quality terms and perceptions (all landowners):

- ? 77% knew what the term "watershed" meant
- ? 50% knew what the term "point source pollution" meant
- ? 44% knew what the term "non-point source pollution" meant
- ? 52% knew what a BMP was
- ? 96% said that water quality was an important issue to them
- ? Money and time were the largest reasons for respondents not preventing water pollution with 33% and 37% respectively

Subtask 3.2
Newsletter

A newsletter was mailed to producers in May 2000 detailing the project and how landowners could become involved with the project. 639 newsletters were mailed.

An update newsletter was mailed in November 2002 to encourage final year participation and provide updates on the current watershed activities. 404 newsletters were mailed.

Appendix 3-A (continued)

Subtask 3.3
Youth Education

Youth programs focusing on water quality issues were conducted in Winslow, West Fork, Greenland and Fayetteville schools. West Fork, Teen Leaders and countywide 4-Hers attended day camps.

Date	Event	Clientele
April 6, 2000	Farm Friends	502
May 12, 2000	Pasture Management Contest	10
June 6, 2000	Teen Leader Water Quality Training	8
June 20-21, 2000	Water Days Camp	23
June 7 & 23, 2000	Water Wonders Camp	52
July 5, 2000	Water Discovery	27
January 30, 2001	Winslow High School Science	16
February 12, 2001	West Fork 4-H	11
April 5, 2001	Butterfield Elementary	24
April 5, 2001	Arkansas Grassland Evaluation	8
April 12, 2001	Farm Friends	742
April 17, 2001	Butterfield Elementary	27
May 1, 2001	Butterfield Elementary	23
July 2001	Water Days Camp	84
July 12, 2001	West Fork 4-H Creekside Program	12
July 17, 2001	West Fork Field Day	22
April 12, 2002	Arkansas Grassland Evaluation	5
April 2002	Butterfield Elementary	96
May 11, 2002	Land O Goshen Water Camp	36
July 8, 2002	West Fork 4-H	12
October 14, 2002	Fayetteville High School – West	17
January 30, 2003	Greenland Elementary Teachers	18
March 7, 2003	Greenland Kindergarten	57
April 17, 2003	Arkansas Grassland Evaluation	6
April 22, 2003	Farm Friends	964
April 25, 2003	Greenland 3rd Grade	53

Subtask 3.4
Watershed Restoration Slide Set

Slide presentations were developed to assist in visualizing and conveying the overall project goals and accomplishments.

Date	Event
August 15, 2000	Fayetteville Chamber of Commerce – Agriculture
January 11, 2001	West Fork – White River Kickoff Meeting
May 25, 2001	Beaver Lake Project Meeting
February 18, 2002	Beef Cattle Short Course

March 5, 2002	West Fork – White River Update Meeting
February 10, 2003	Beef Cattle Short Course
March 18, 2003	West Fork – White River Update Meeting

Subtask 3.5
Individual Farm Visits

Farm visits were conducted from May 2000 – October 2003. Landowners received training in soil fertility, forage selection, fertilizer management, alternate water sources, stream bank stabilization, and fencing options.

Demonstrations were implemented on four farms to display weed control options, soil fertility and farm pond management. A public field day was also hosted that allowed area landowners to see the demonstrations and receive training in weed identification, soil sampling and sprayer calibration.

Fourteen farmers were referred to the Washington County Conservation District for assistance with implementation of a farm plan and/or to receive cost-share.

BMP Implementation:

? 49 farms implemented soil sampling practices (documented)
? Over 3400 acres in the watershed were soil sampled to determine fertility needs
? 5 farms implemented manure sampling (documented)
? 3 farms implemented water sampling
? 23 farmers received training on proper soil sampling procedures and interpretation of soil results
? 47 farmer received training on weed identification and control
? 87 farmers received training on forage variety selection and rotational grazing
? 23 farmers received training on pond management and nutrient runoff

Subtask 3.6
Follow-up Survey

The survey was mailed in October 2003. A total of 185 surveys received by West Fork – White River farmers.

Response data:

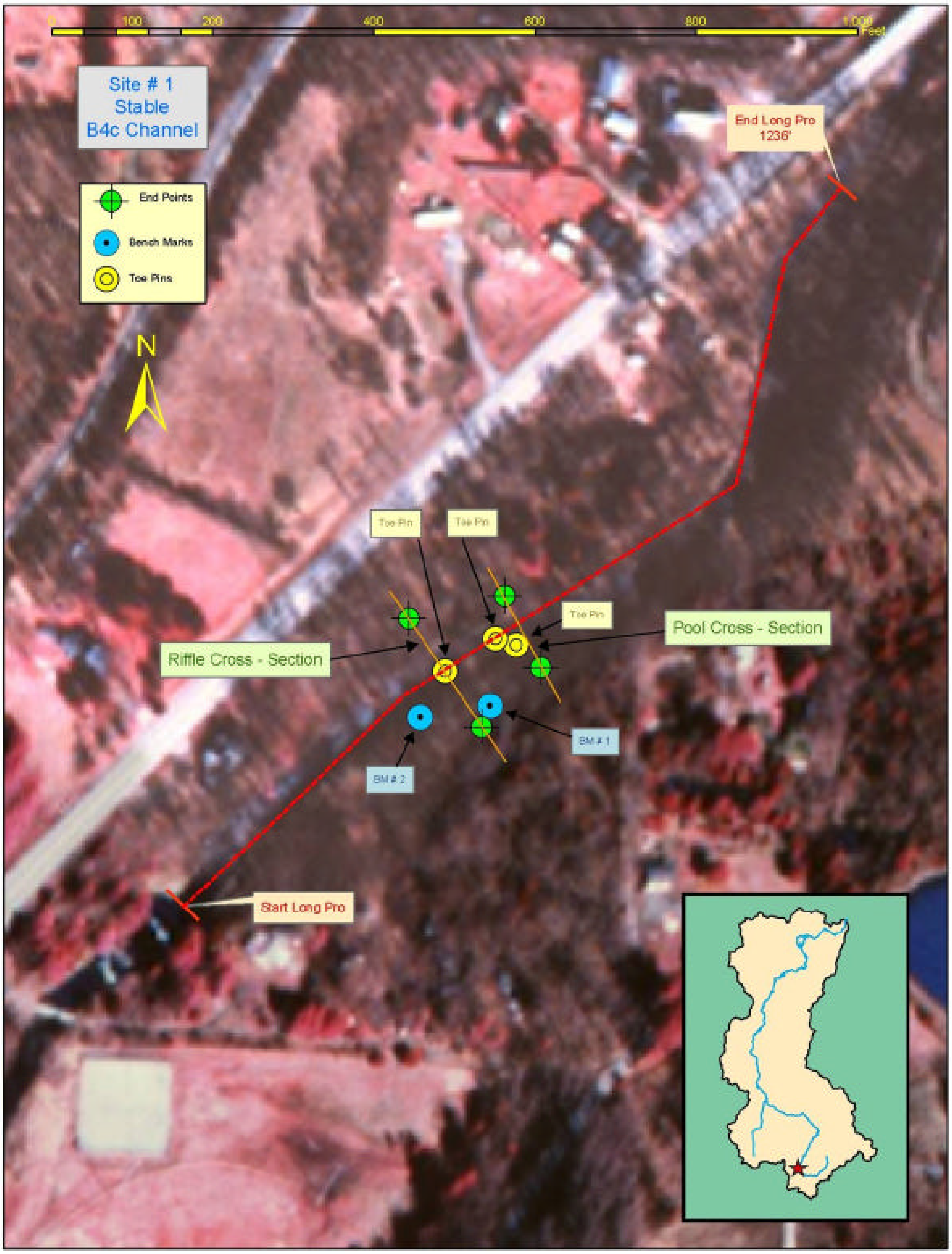
? 100% said they were aware of the public meetings held in the watershed, where 53% of the respondents said they attended any meeting
? 50% of the respondents indicated that they were aware of urban programs
? 65% of the responses indicated that awareness of water quality issues had increased over the course of this project and 56% stated that perceptions of water quality had improved
? 42% indicated that they had their soil tested, 5% had water and litter tested
? 16% received cost-share for pasture improvement and 0% received cost-share for a stacking shed

Subtask 3.7
Public Education Meetings

Date	Event	Clientele
2/14/2000	Beef Cattle Short Course	200
2/15/2000	UofA Conservation Class	27
3/9/2000	UofA Extension Ed. Class	9
3/16/2000	Super Chicken	33
4/4/2000	UofA Intro to Extension Class	11
8/15/2000	Fayetteville Chamber of Commerce	8
11/9/2000	WF-WR Steering Committee	4
1/11/2001	WF-WR Kickoff Meeting	42
2/22/2001	UofA Conservation Class	18
7/17/2001	WF-WR Field Day	23
10/28/2001	West Fest	356
11/13/2001	WF-WR Steering Committee	3
1/31/2002	WF-WR Steering Committee	6
2/18/2002	Beef Cattle Short Course	126
3/5/2002	WF-WR Public Meeting	72
8/22/2002	Beaver Lake Awareness Day	185
9/27/2002	West Fest	319
2/10/2003	Beef Cattle Short Course	117
3/18/2003	WF-WR Public Meeting	36

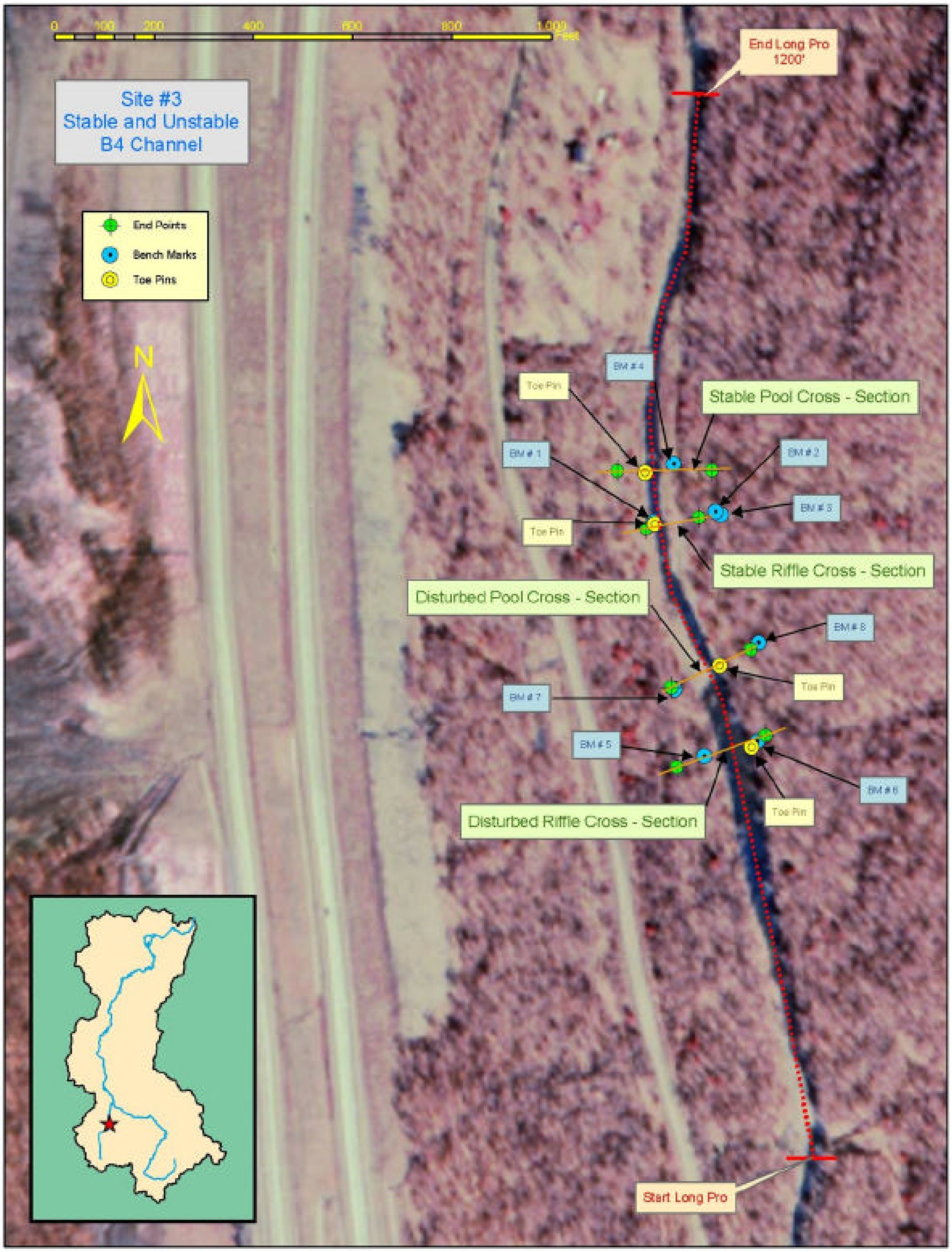
Appendix 4-A

Site Maps for Permanent Survey Sites



Appendix 4-A (continued)

Appendix 4-A (continued)



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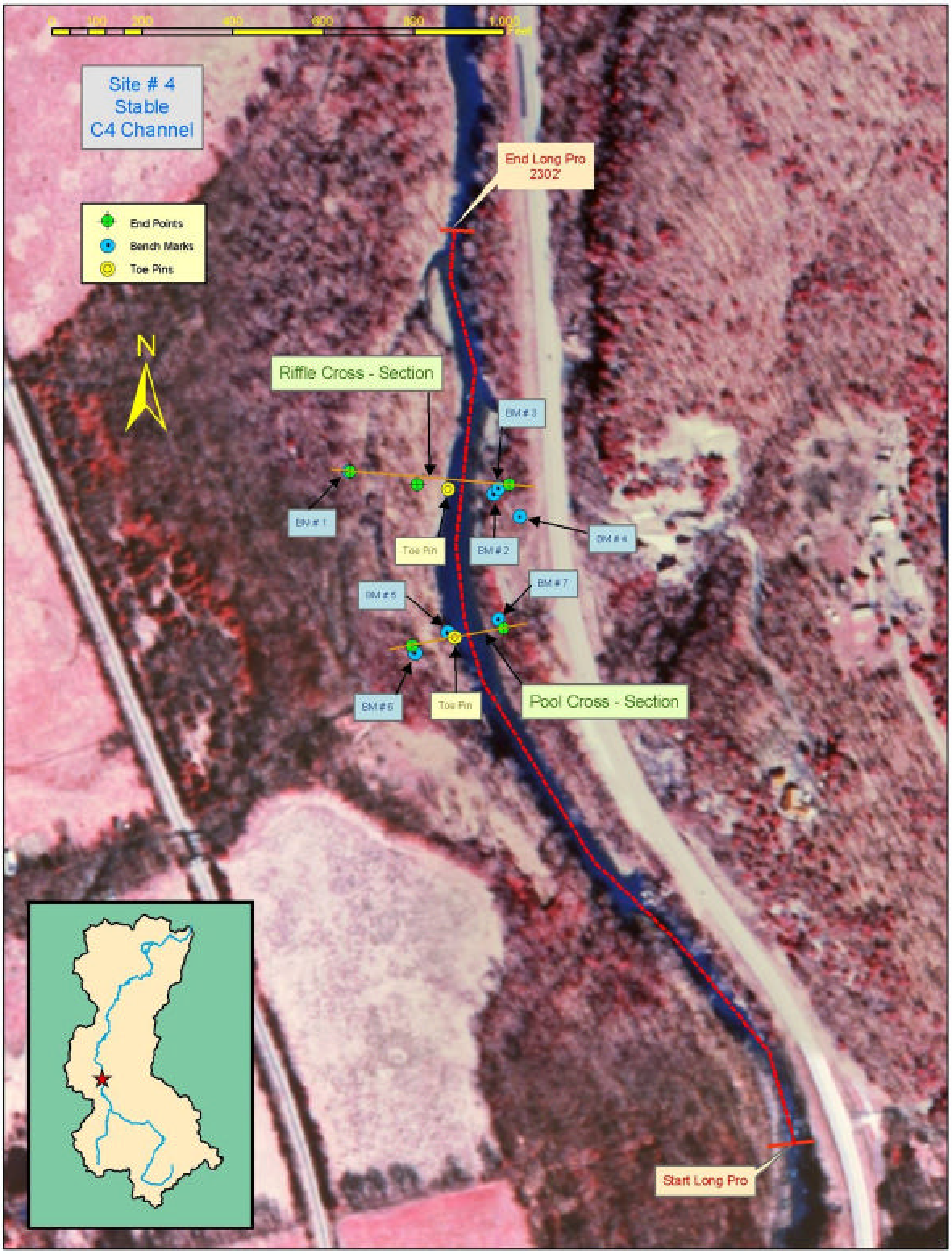

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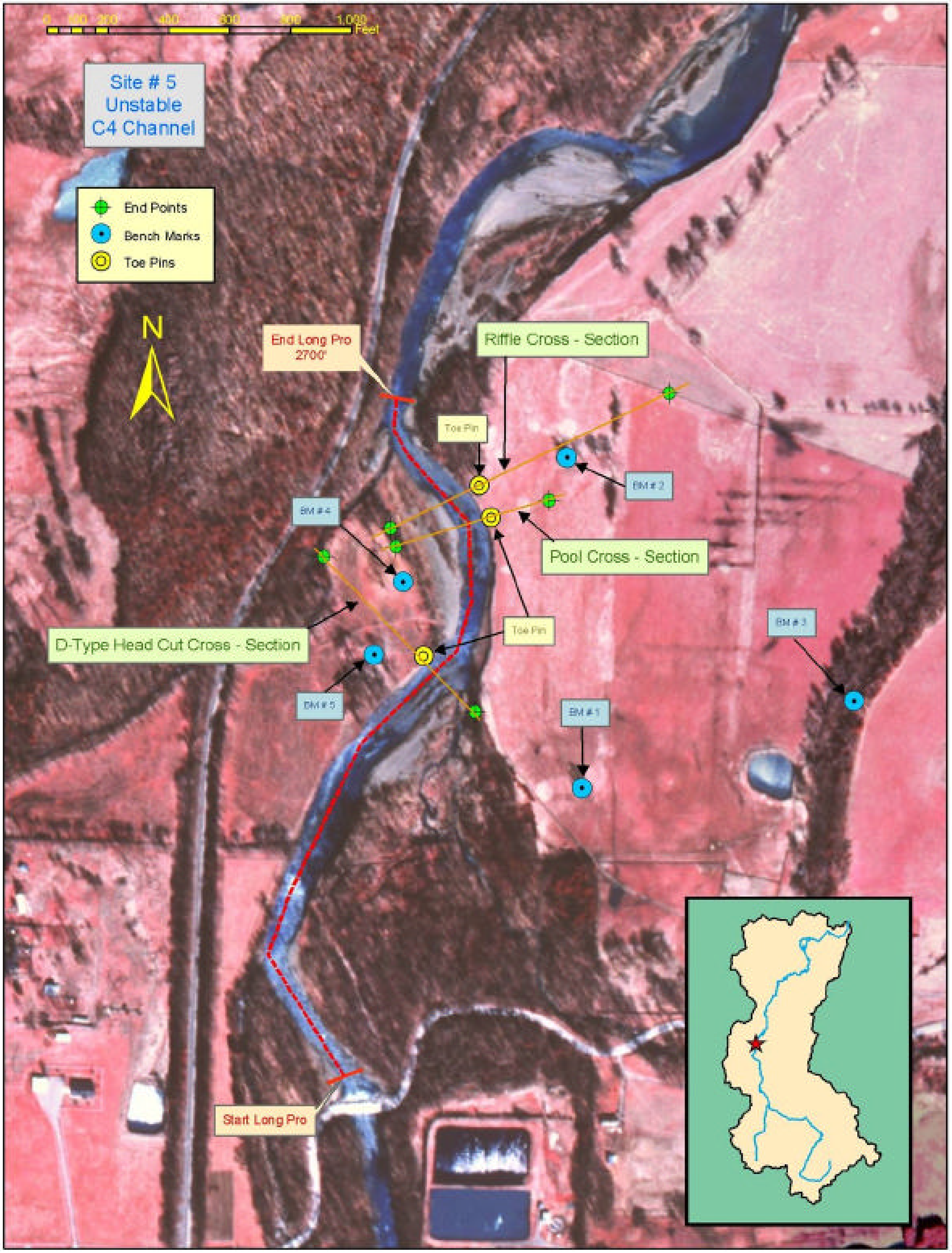

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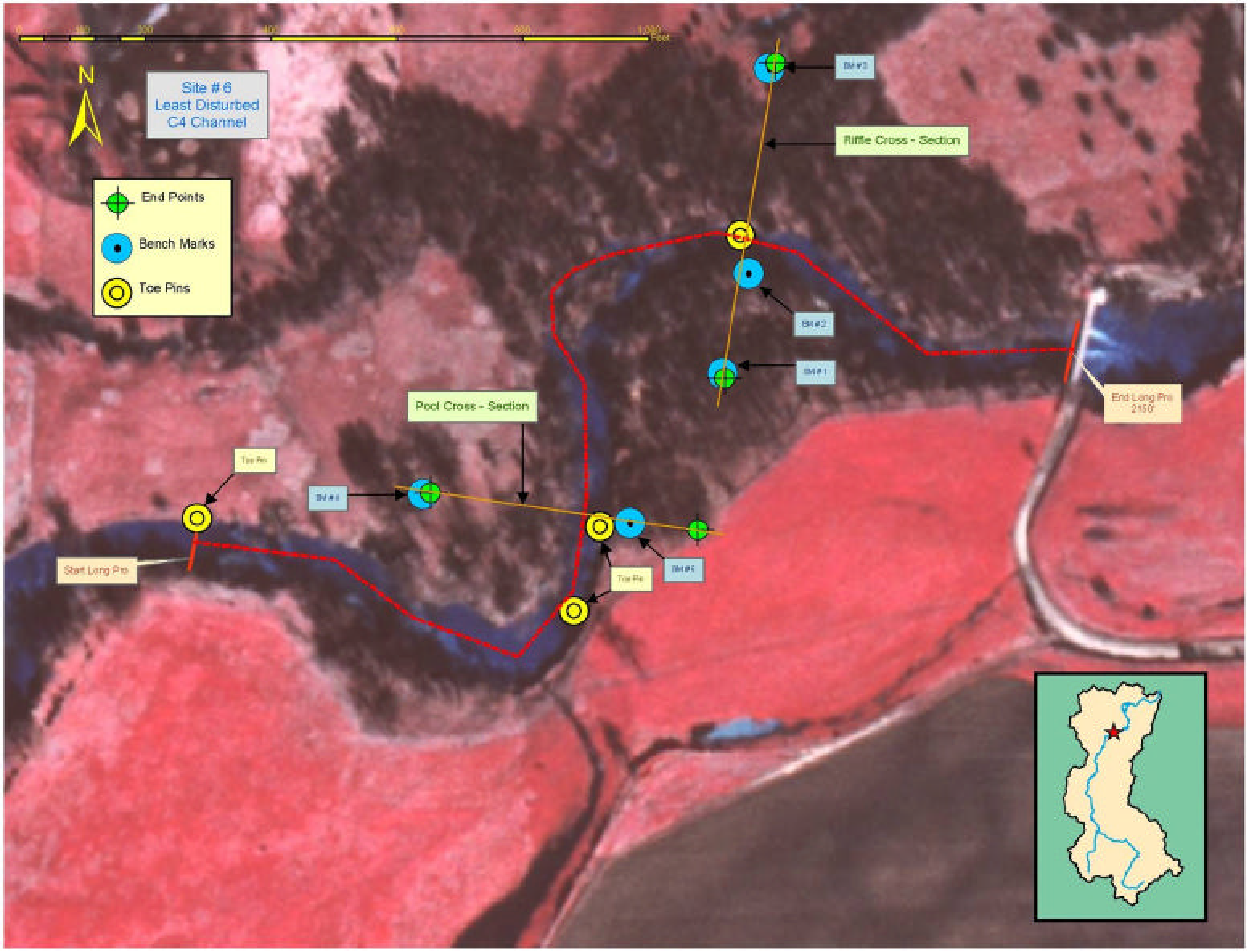

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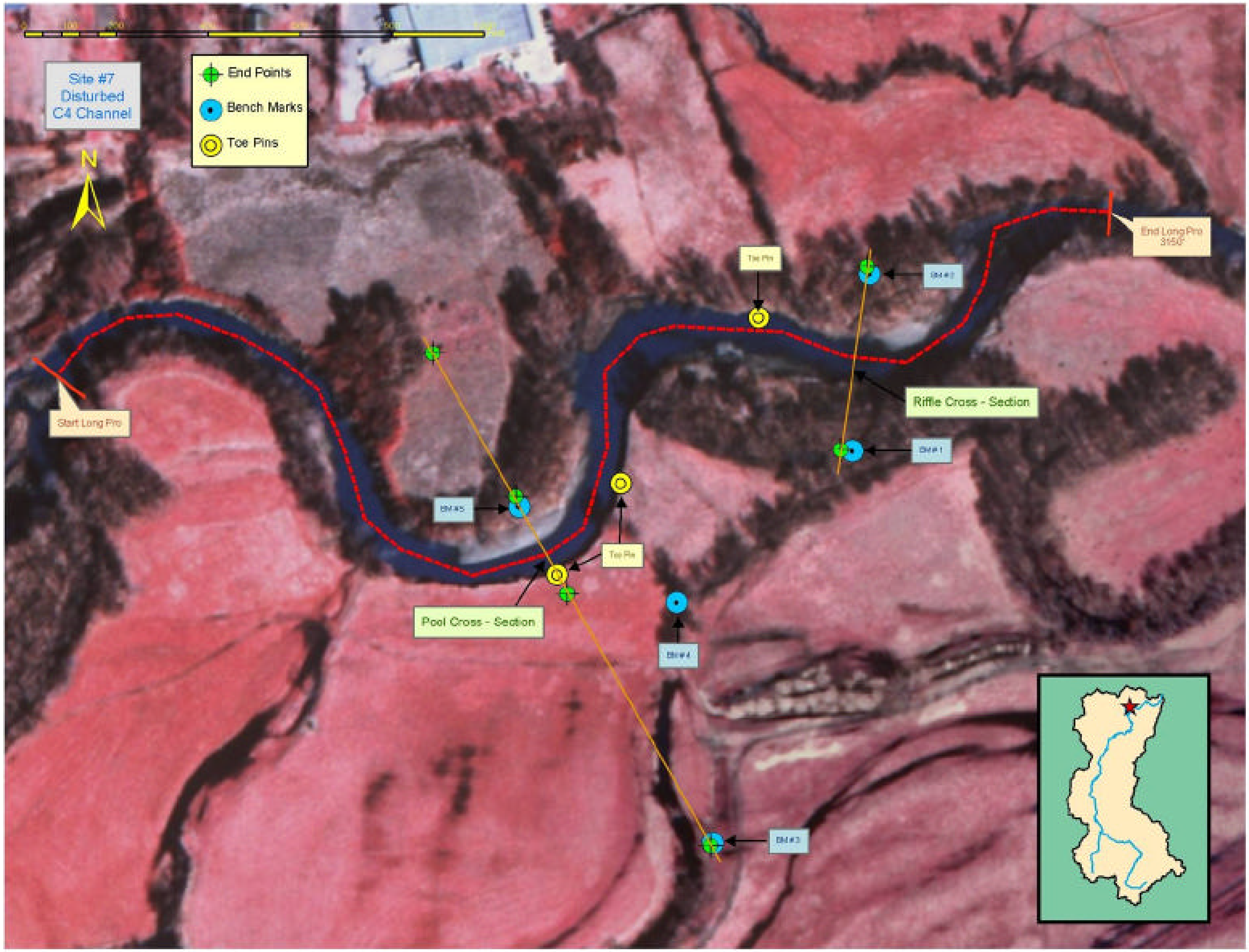

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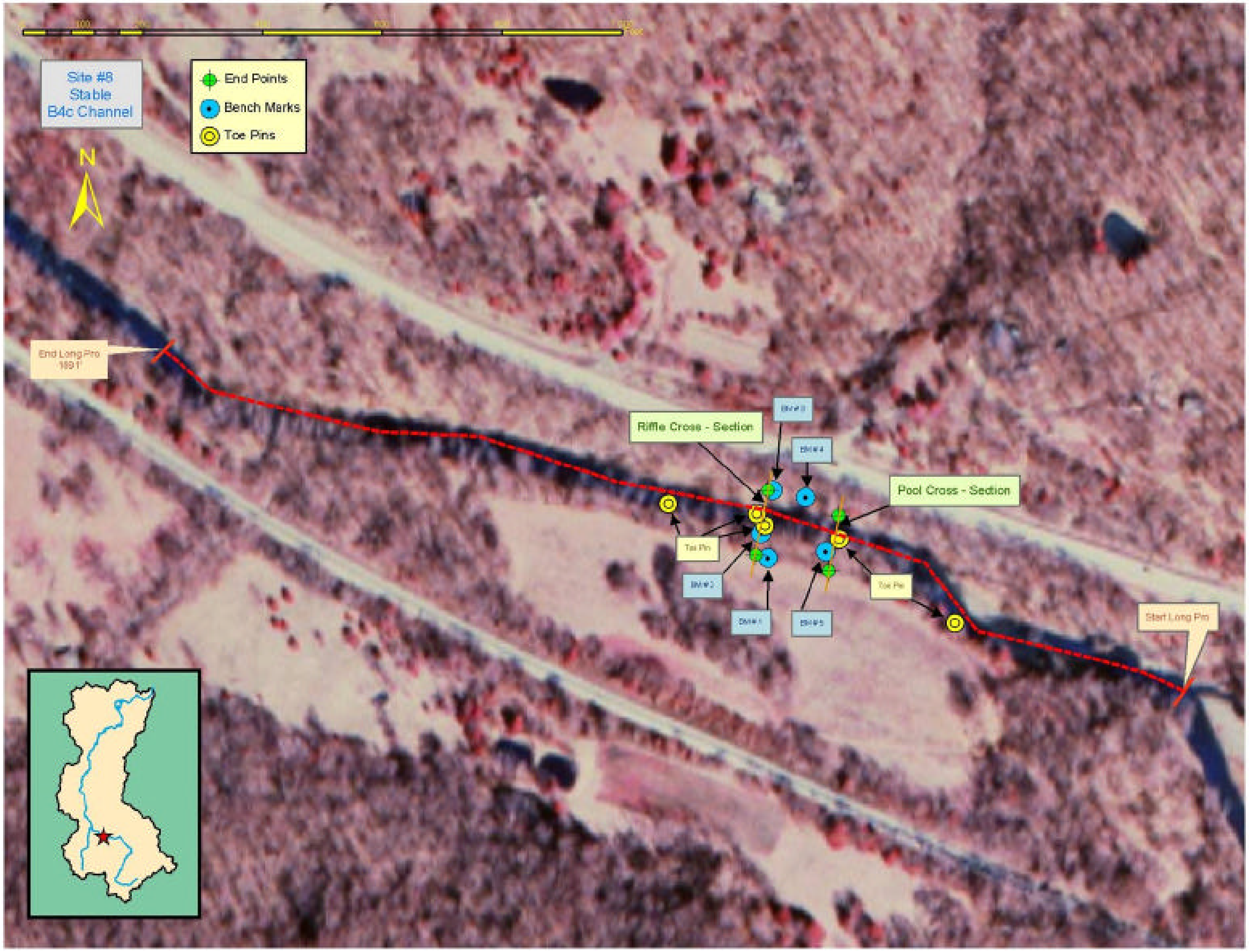
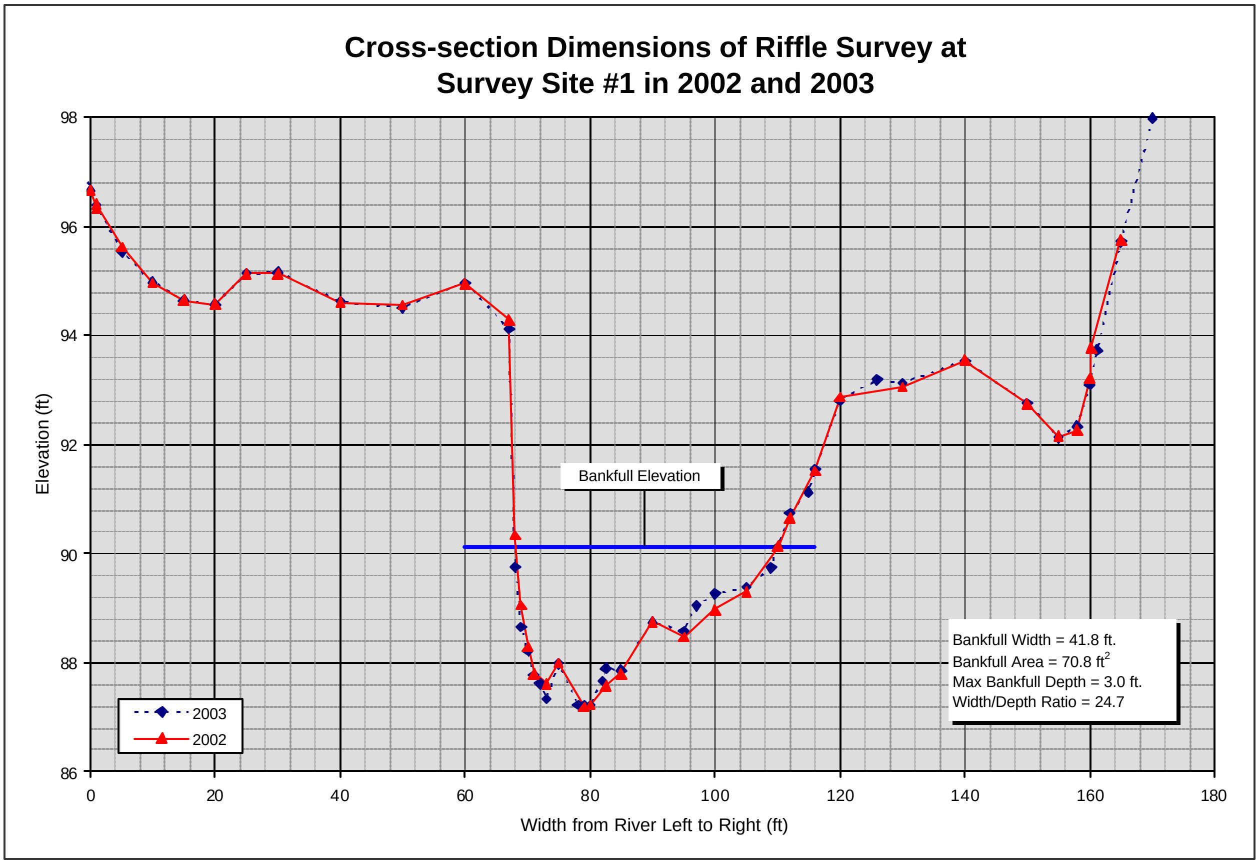
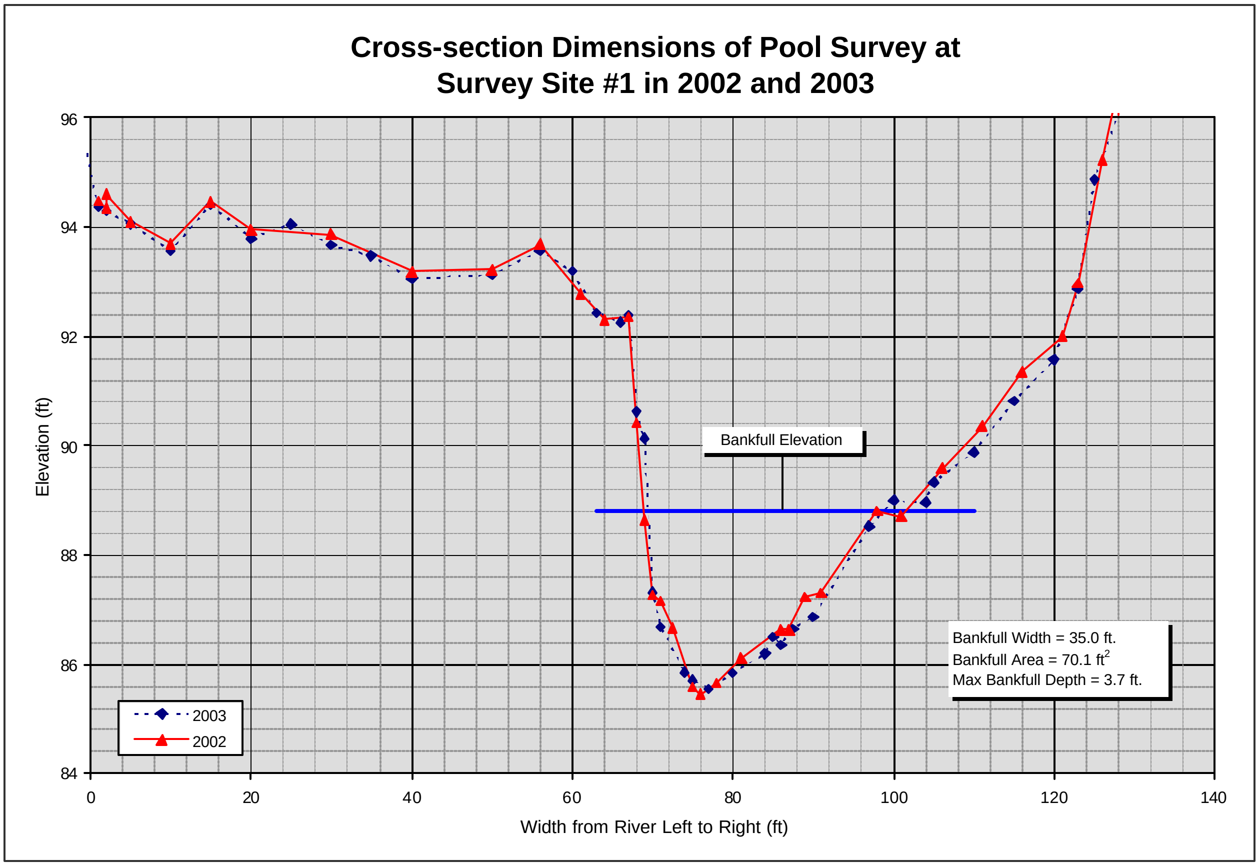


Appendix 4-B
Cross Section Data for Permanent Survey Sites





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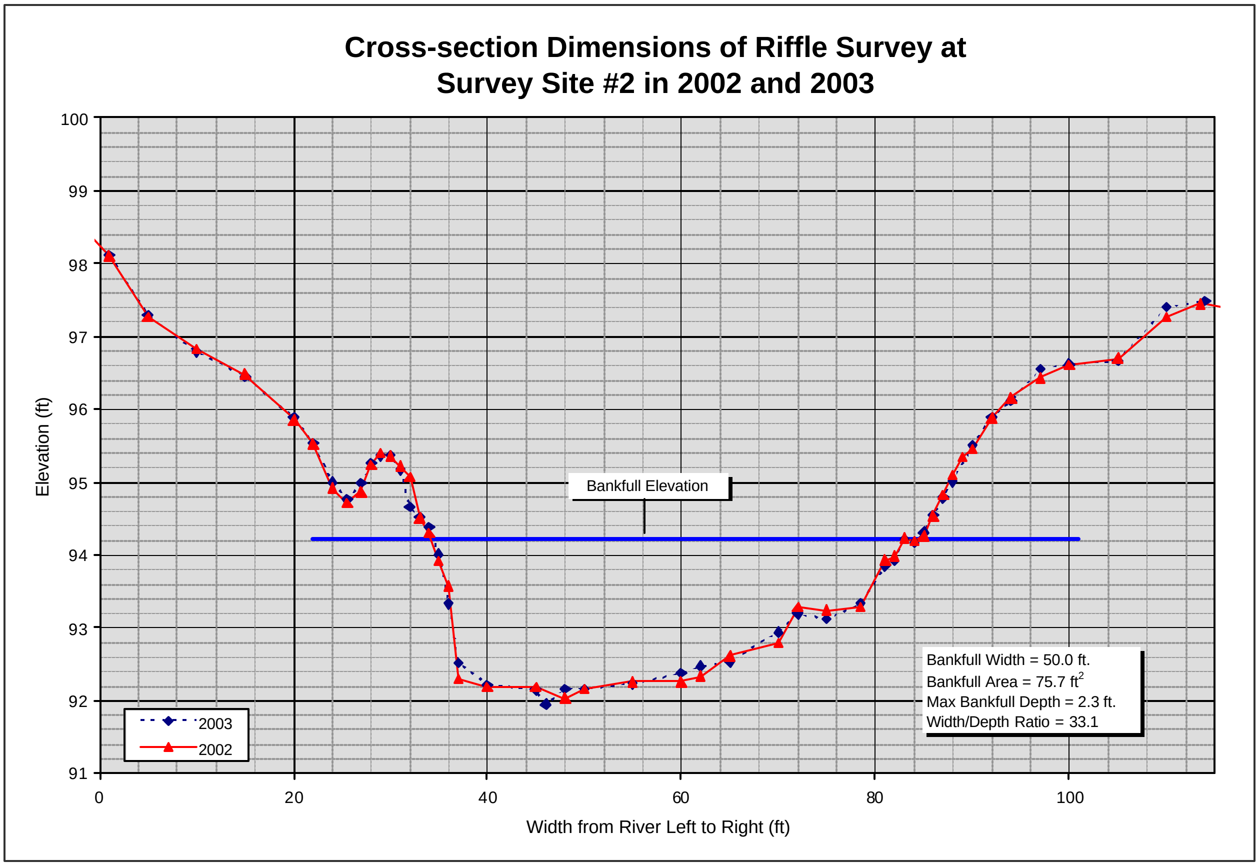

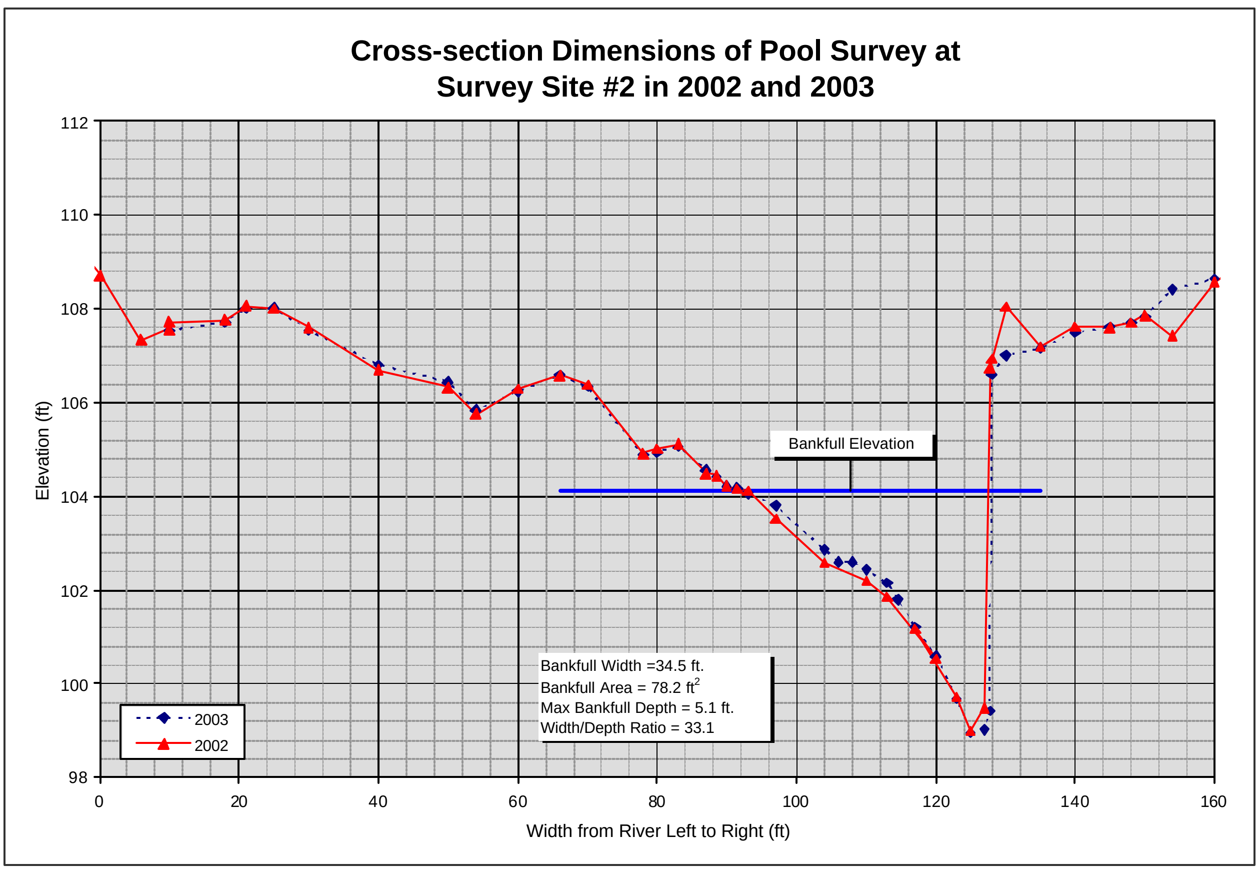

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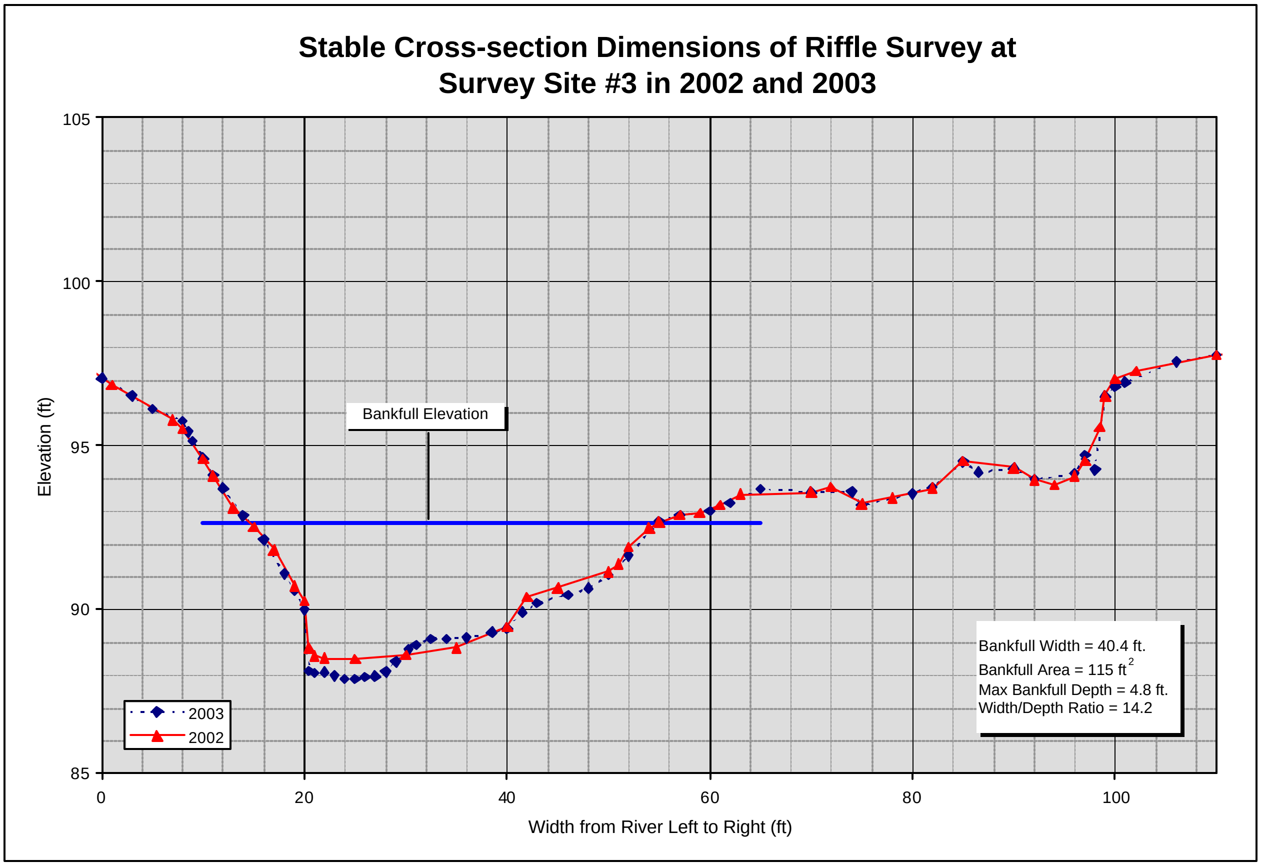

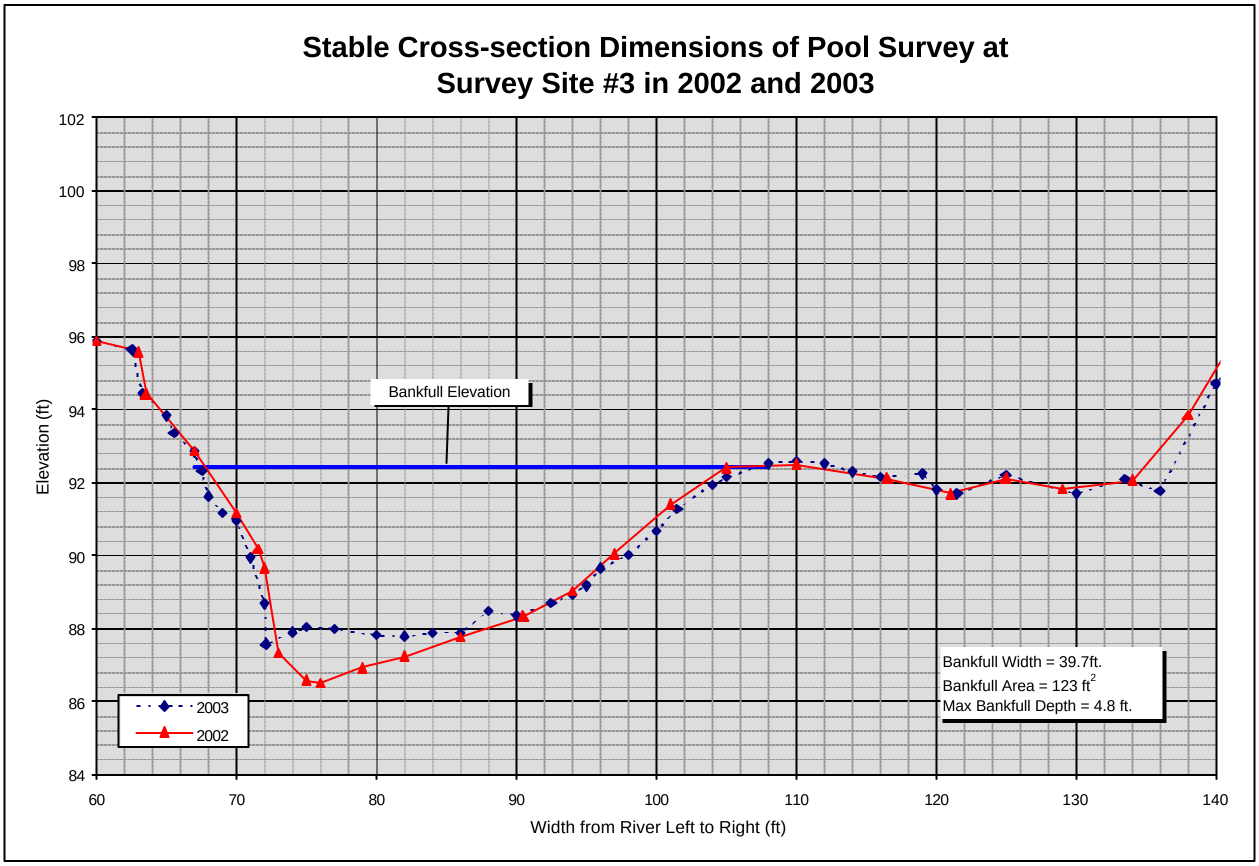

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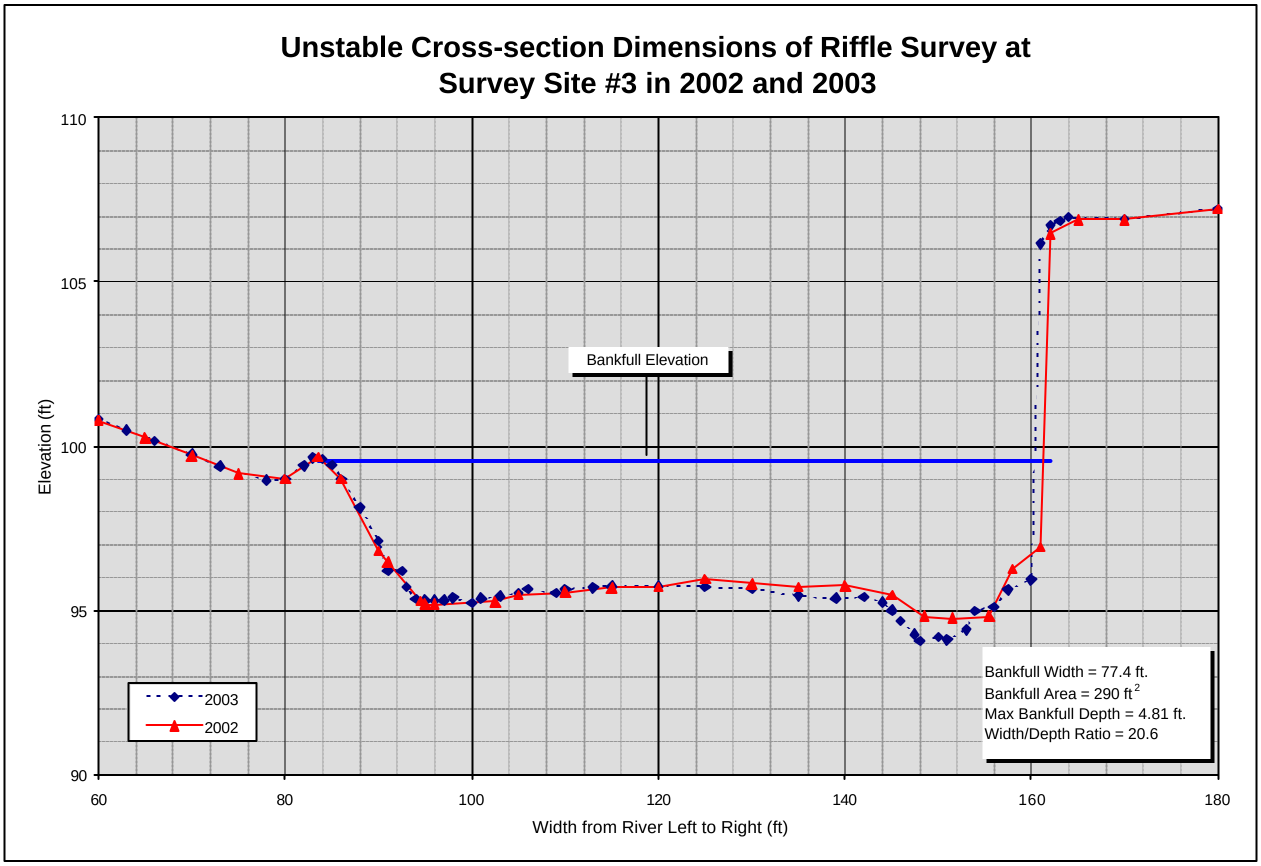

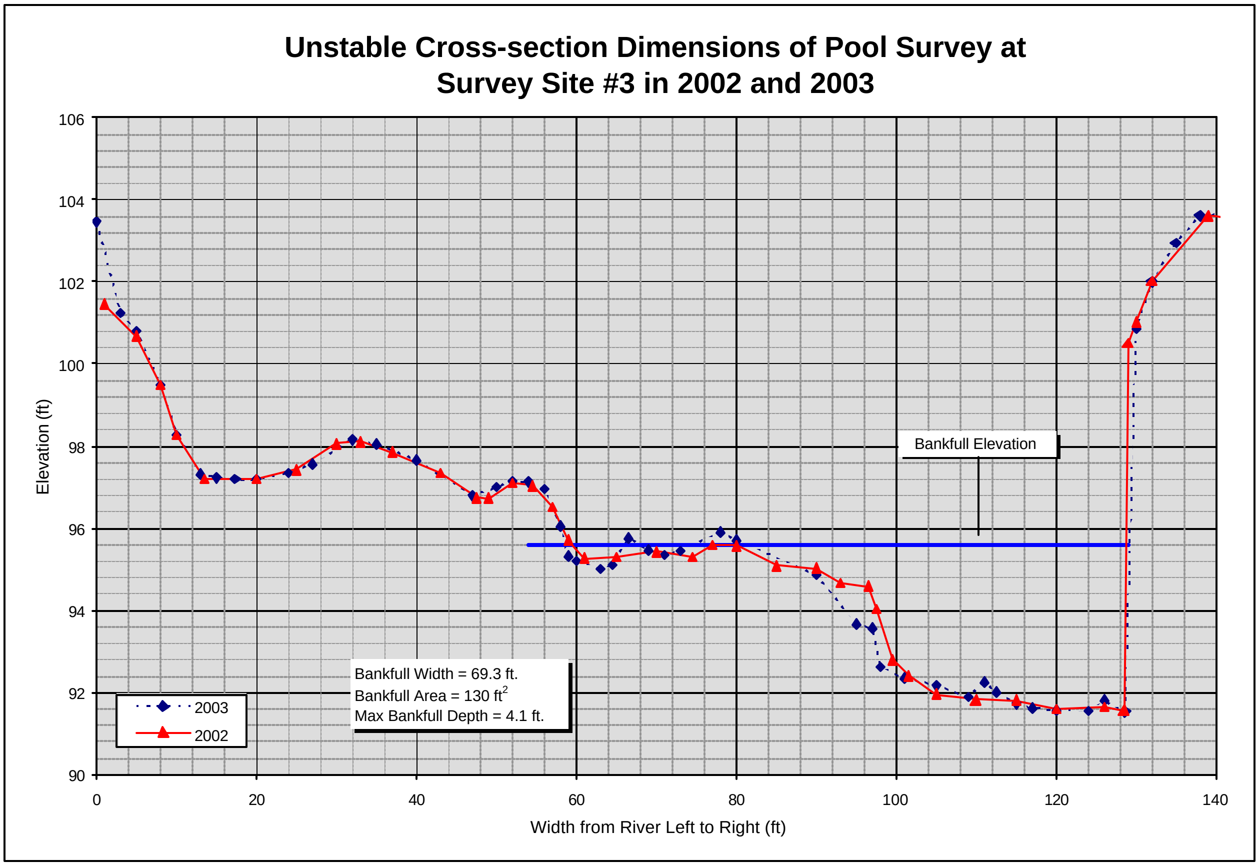

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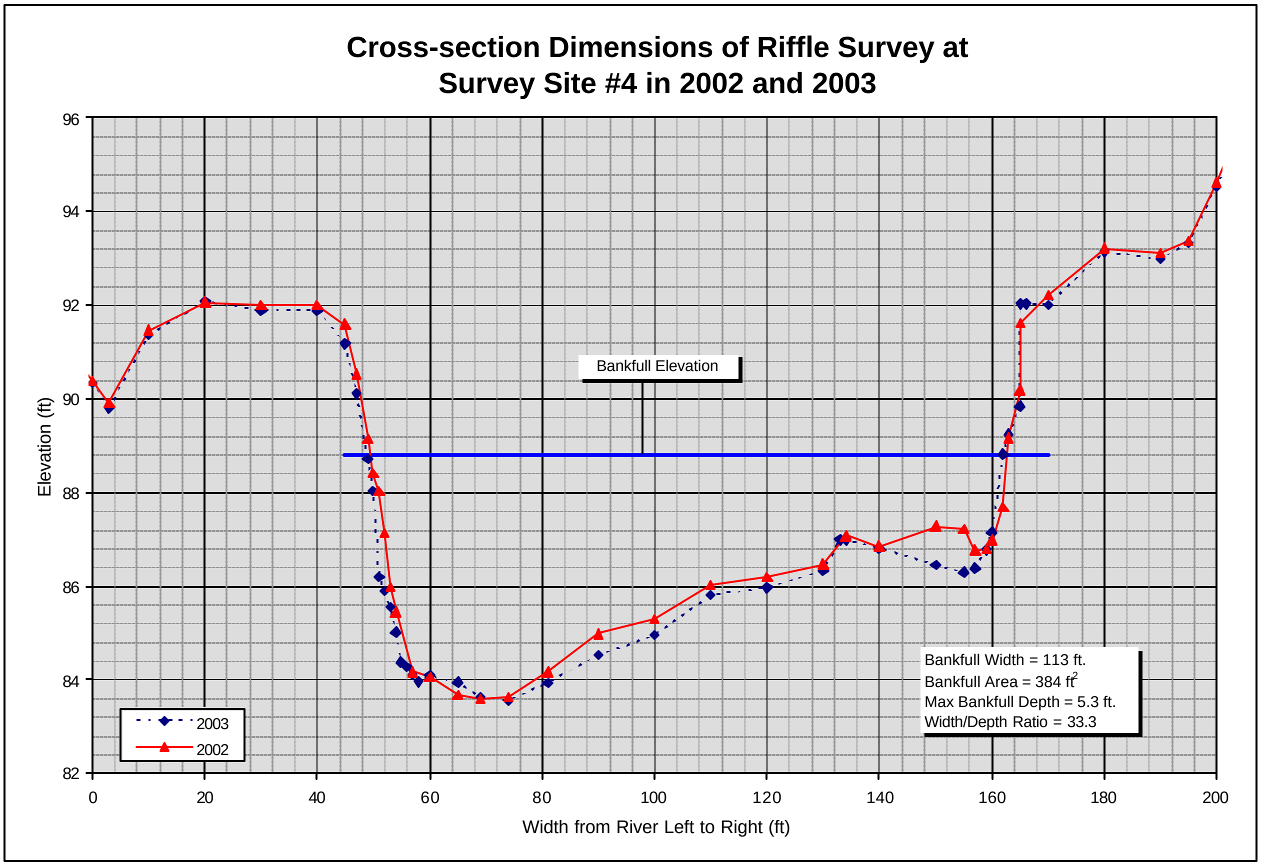

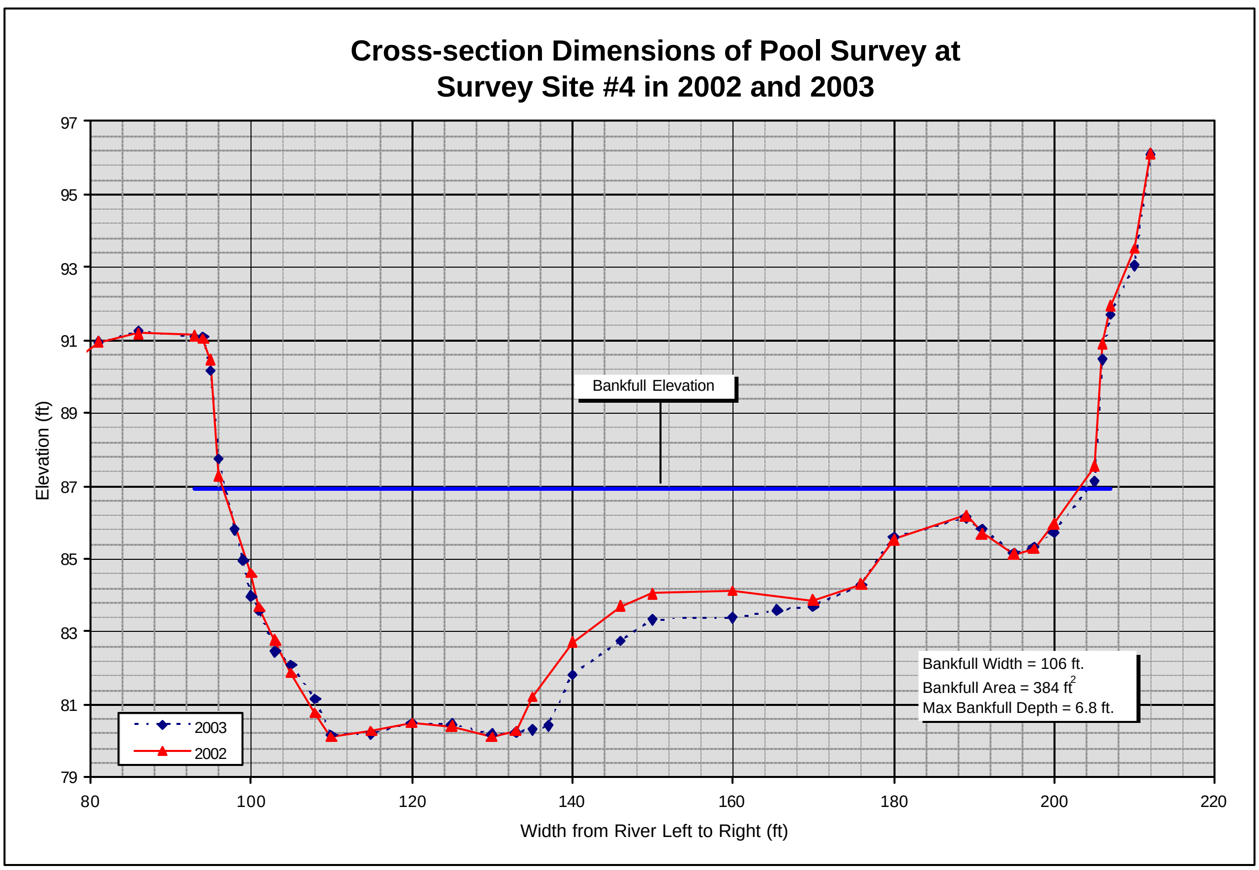

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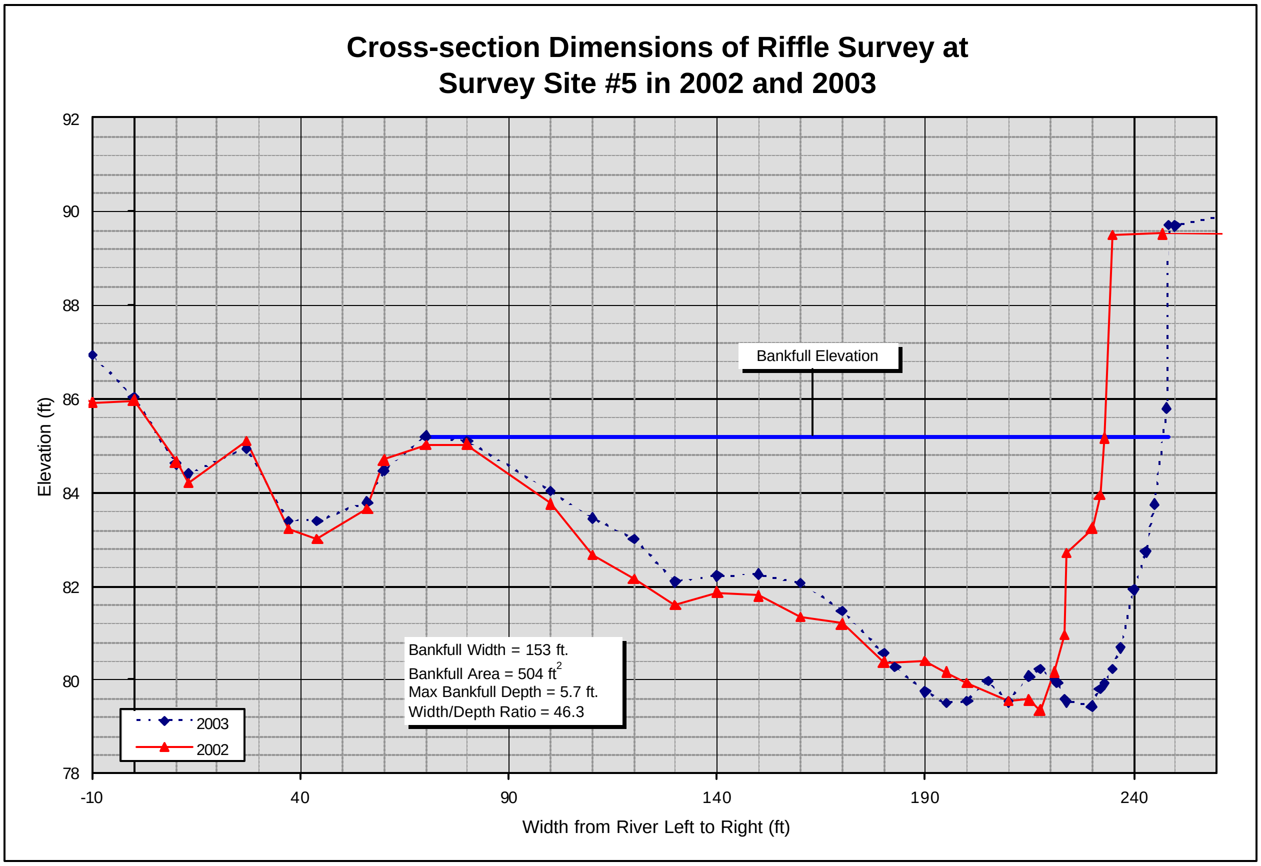

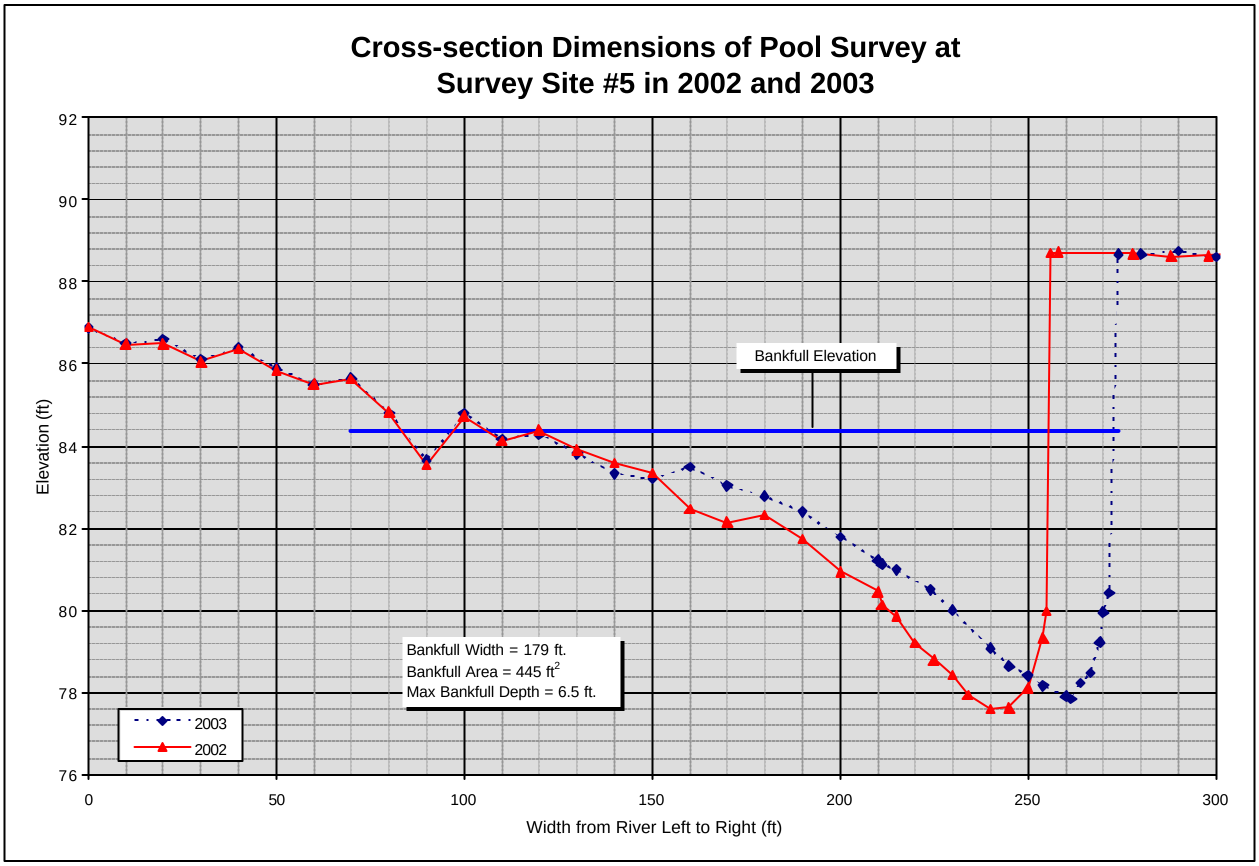

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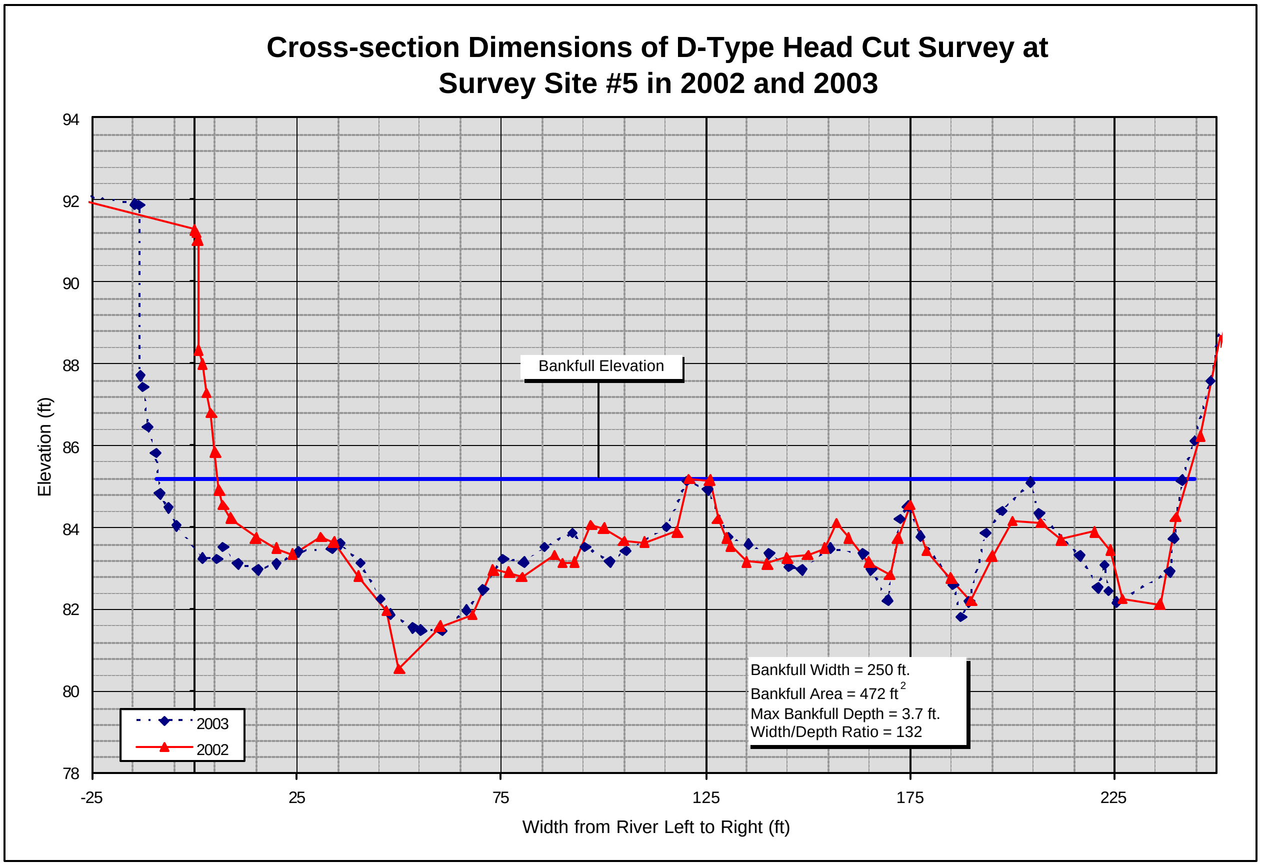

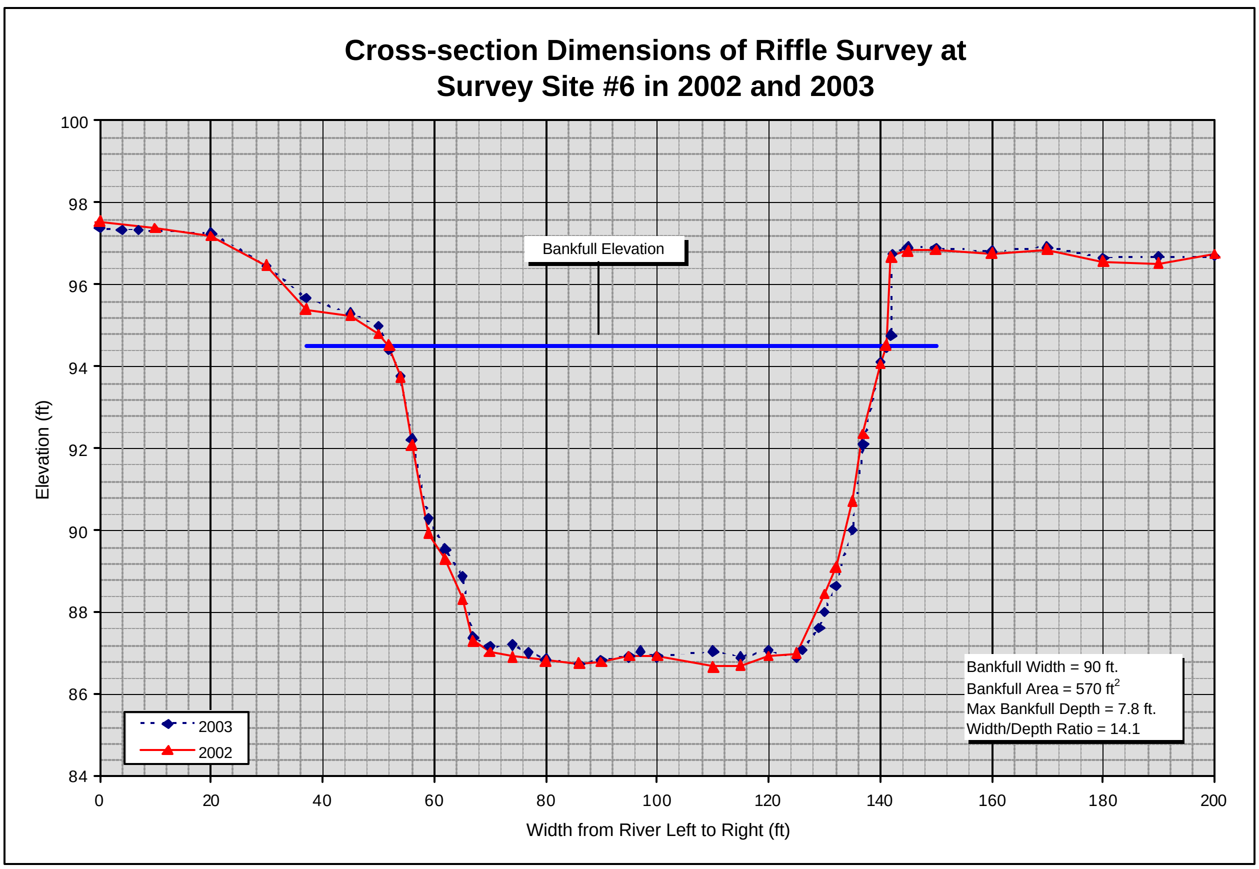

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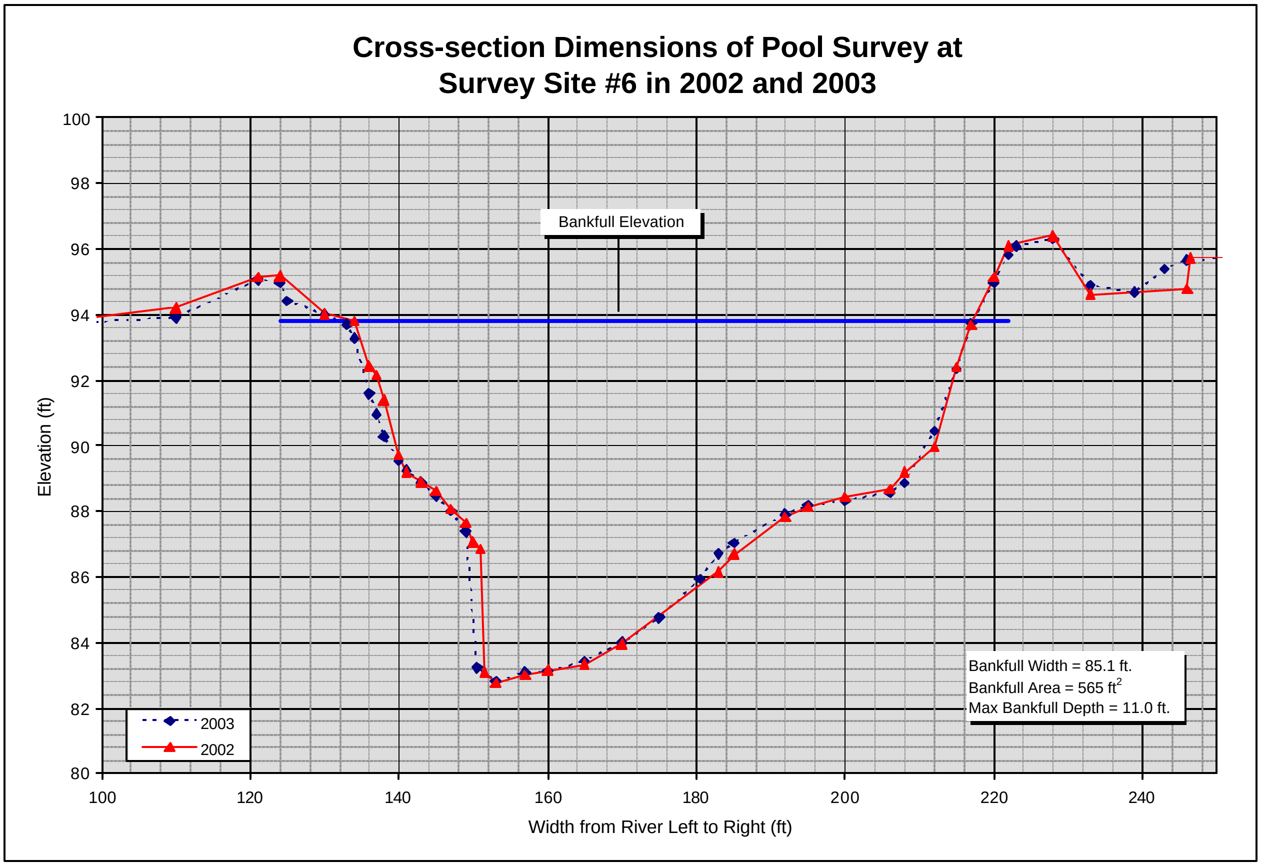

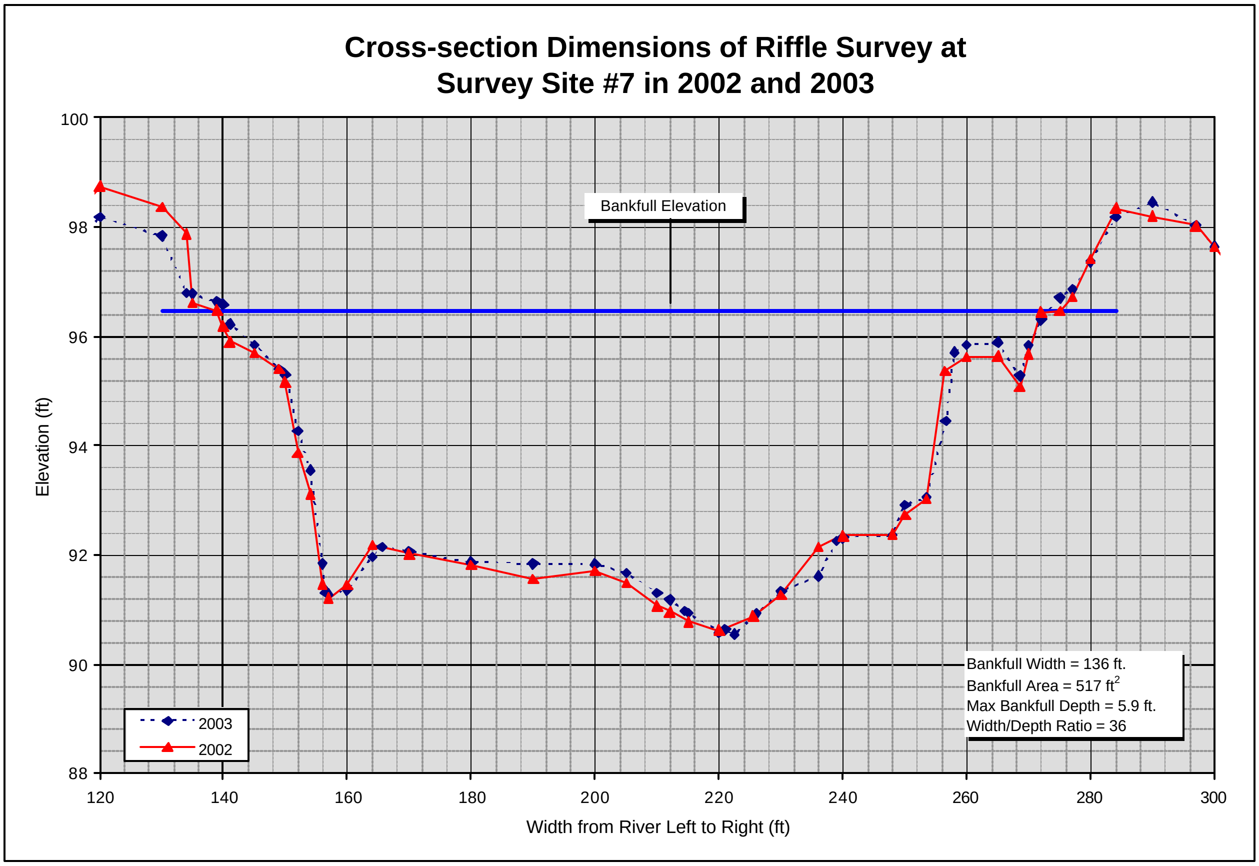

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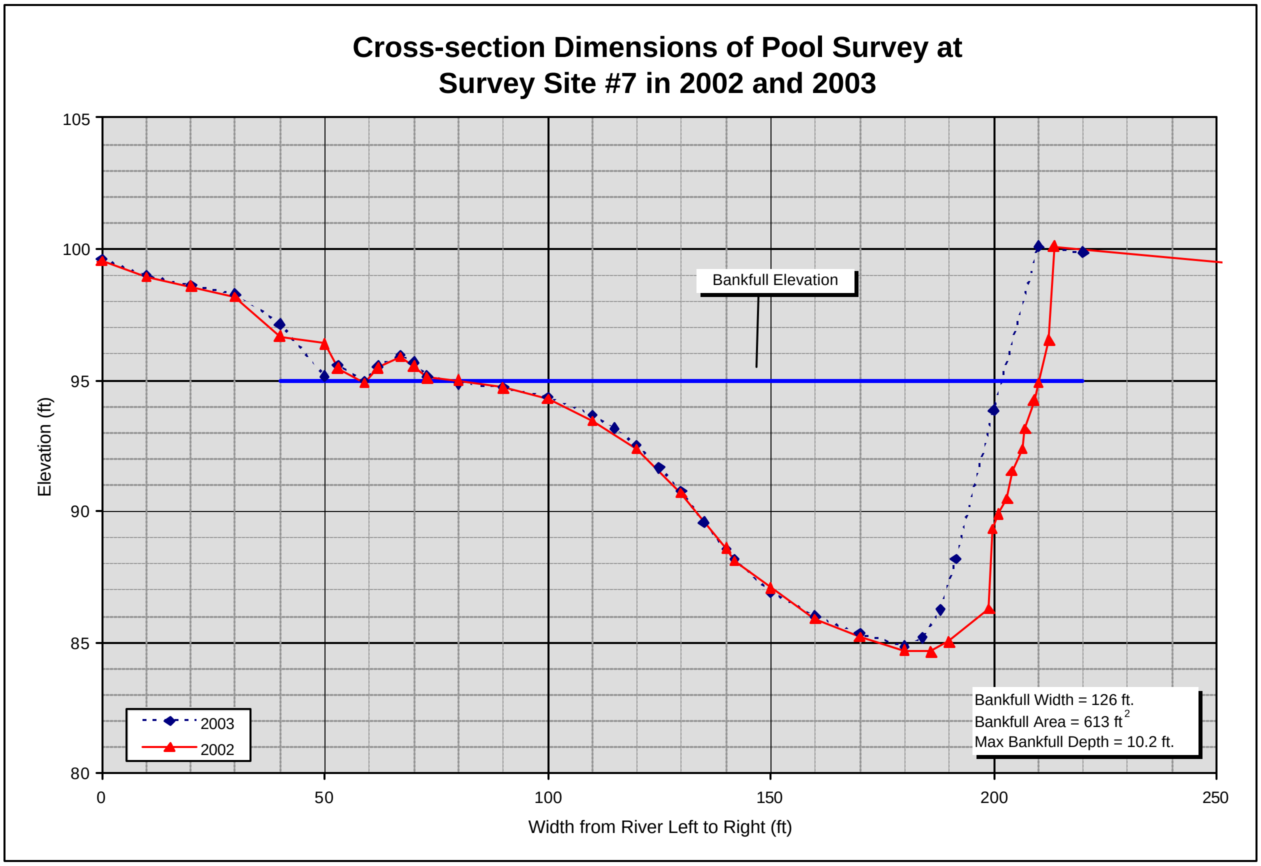

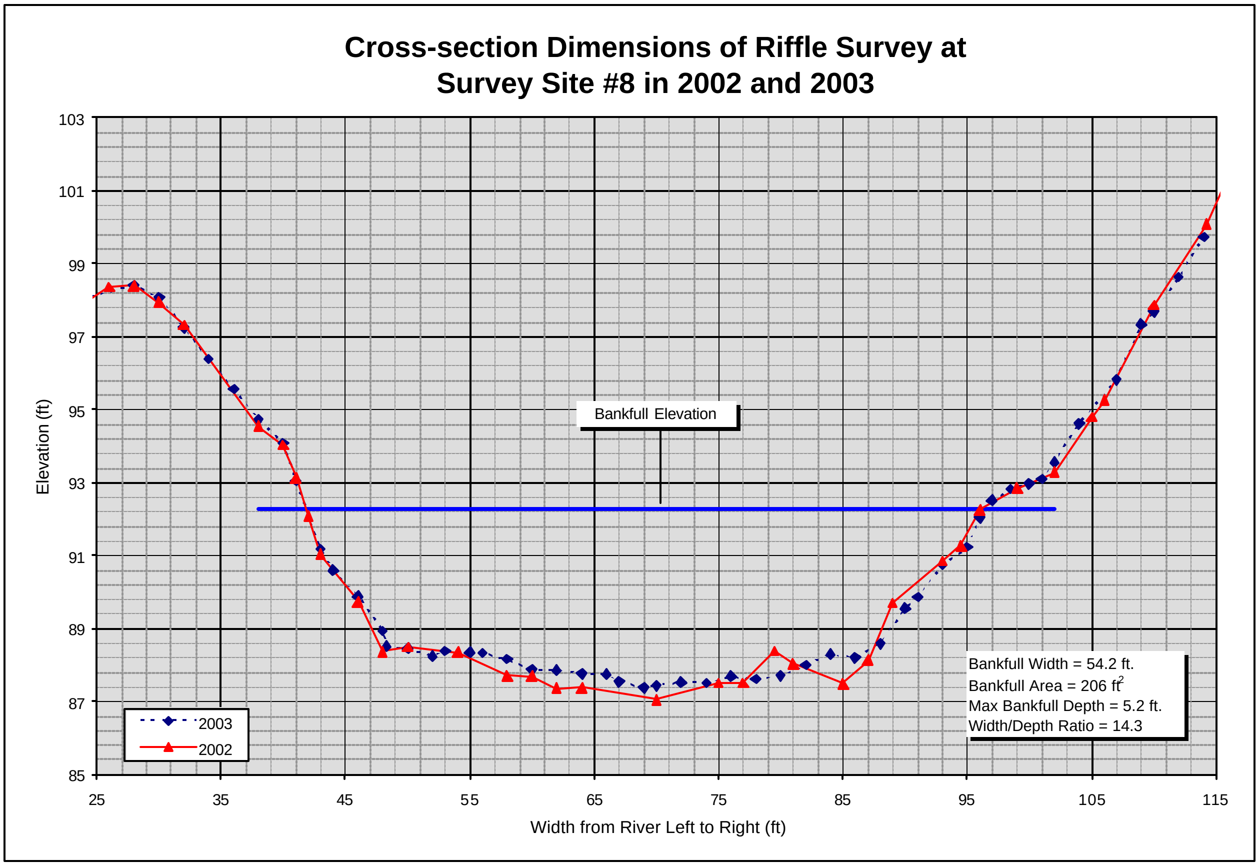

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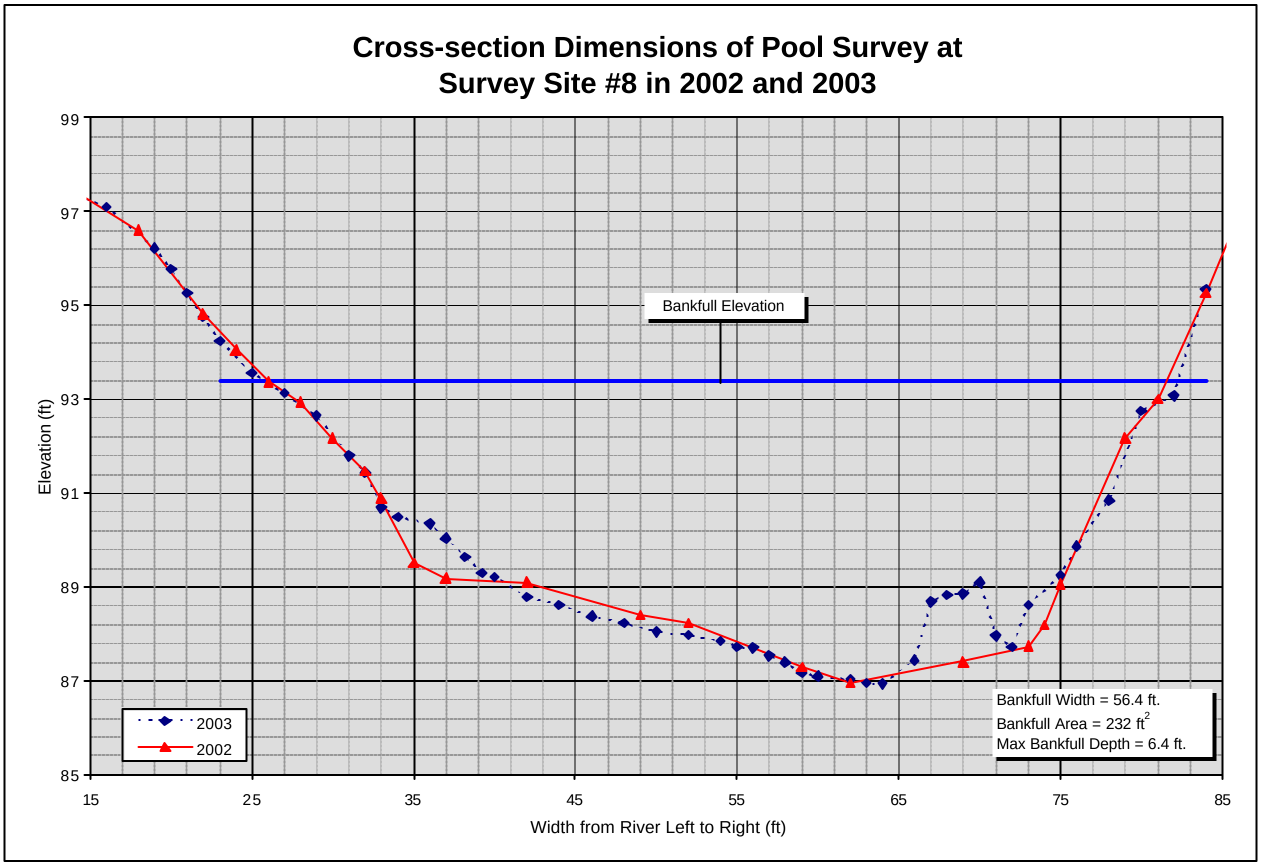


Appendix 4-C

West Fork White River Survey Questions and Responses

Question 1) How long have you lived near the river? Where?

Interviewee number	Where they reside in the watershed	How many years?
1	Town Branch	45
2	Winn Creek	35 years off and on, 20 permanently
3	Main branch	47
4	Main branch	47
5	Main branch	50
6	Main branch	60
7	Main branch	50
8	Town Branch	15

Question 2) Do you use the river (recreational, agricultural, land use)? Y/N
Fishing, swimming, canoeing, irrigation, water livestock, gravel mining, or other?

Interviewee	Yes or no?	How do you use the river?
1	No	
2	Yes	Wading, bathing, drinking, cooling (Winn Creek)
3	Yes	Recreation, stress management
4	No	* * *
5	No	* * *
6	Yes	Personal use (In 1970 a family member contracted spinal meningitis after swimming
7	Yes	Fishing, swimming, water livestock other uses include cook outs, water garden, mountain camping, and haul water
8	Yes	Hiking, rock hunting, and playing with the kids

Appendix 4-C (continued)

Question 3) Given that rivers naturally change over time, what changes have you noticed?

Interviewee	Water-shed	Changes?	Why?
1	Town Branch	Channelization, a change in bank slope, bank erosion and some flooding	Occurred because a neighbor dumped concrete slabs on the bank in the 1960s
2	Winn Creek	Increase in silt and erosion from Riley and Winn Creeks peak flow is higher, muddier, and harder to judge	I-540 construction is believed to have caused this change by changing the topography and clearing vegetation
3	Main branch	Course of the river has changed	A neighbor dozed riparian area 10 to 15 years ago
4	Main branch	Reduced water quality and clarity and higher turbidity	There was not a special event (storm, human impact, etc.) that caused the change
5	Main branch	River was once more polluted than it is now	Water laws and enforcement have resulted in improvement in water quality
6	Main branch	River is wider and shallower	River bottoms were cultivated into grass
7	Main branch	Channel is deeper and has moved, with holes filling up	A neighbor cleaned off the stream bank and pushed material, along with trash, in the channel
8	Town Branch	Town Branch Creek has been dredged and that upstream has been stabilized	Work was done by Corps of Engineers

Appendix 4-C (continued)

Question 4) Disregarding storm events, has the general appearance of the water changed? If yes, what's changed?

Interviewee number	Water-shed	Yes or no?	Comments
1	Town Branch	No	Creek is spring fed. Campbell's Soup used to dump fat into the creek, causing a decrease in wildlife, but the wildlife is now coming back.
2	Winn Creek	Yes	Riley Creek is muddier from erosion upstream and it takes longer to settle.
3	Main branch	No	Only seasonal changes can be detected.
4	Main branch	Yes	The water is murkier now and a local stream has been impacted. More algae are present.
5	Main branch	Yes	The river seems lower for longer periods and doesn't flood as often. The river used to be really clean then. About 20 years ago the water quality plummeted but there has been improvement.
6	Main branch	Yes	The water is dirtier and then it clears.
7	Main branch	Yes	The water is not as clear as it used to be. It is muddier and greener.
8	Town Branch	Doesn't know	* * *

Question 5) Excluding weather-related changes, does the river flow at about the same levels as it always has? If no, why not?

Interviewee number	Water-shed	Yes or no?	If no, why not?
1	Town Branch	Yes	* * *
2	Winn Creek	No	The level changed after construction, but is now getting back to levels since the 1960s and 1970s.
3	Main branch	Yes	* * *
4	Main branch	Yes	* * *
5	Main branch	No	The pools are shallower.
6	Main branch	No	The river is shallower, deep holes have filled up gradually since the 1970s. For example, there was a hole 18 feet deep that is now a gravel bar.
7	Main branch	Yes	* * *
8	Town Branch	Doesn't know	* * *

Appendix 4-C (continued)

Question 6) Have you noticed a change in how deep the river is? If yes, what changed (swimming hole, fishing hole, etc.)? Has the flood level changed over time? Has the frequency of streambank overflows changed?

Interviewee	Yes or no? If yes, what changed?	Has the flood level changed over time?	Has the frequency of streambank overflows changed?
1	Yes, swimming holes were deeper. Mother used to swim in Town Branch	* * *	Streambank overflows have decreased
2	Yes, fishing holes are not as deep	Not sure, but 2 inches of rain fills up Winn Creek	Yes, but weather patterns affect flow; bridges and liners are present in Riley Creek
3	Yes, the swimming hole is deeper than it used to be	It doesn't seem to flood as much as it used to	Yes, they have decreased
4	No	The flood level has changed. The St. Paul Railroad bed built in 1915, washed out	No
5	Yes, pools are shallower, and holes have filled in	Yes	Not really, if it has if floods less frequently
6	Yes, no more deep holes	The river hasn't flooded in 3 years	It doesn't flood as much as it used to; water used to get up into bottoms
7	Yes, the holes have filled up – the "Budd sign" historical swimming hole has filled in	Yes, the river doesn't get into bottomland field like it used to	Yes, not as often; the creek would flood 2-3 times in the spring and once or twice in the fall.
8	No	Yes, it used to flood over the road	It floods less often

Appendix 4-C (continued)

Question 7) Has the fishing on the river gotten better or worse? Why? Have the types of fish in the river changed?

Inverviewee	Fishing better or worse?	Why?	Have the types of fish changed?
1	Doesn't fish	* * *	* * *
2	Doesn't fish	* * *	* * *
3	Doesn't know	* * *	* * *
4	Doesn't know, probably worse	* * *	No – Mostly gar, carp, catfish
5	Fishing is better	Better water quality	More types of fish now
6	Doesn't know	* * *	Yes, now there are only catfish and bass, but there used to be catfish, bass, perch, crappie, and bream.
7	It's worse	The holes have filled in	The same types of fish are present, but the number of fish has dropped.
8	Doesn't know	* * *	* * *

Question 8) Has the plant life in the water changed? If so, how? Is there a difference in the number of trees along the river banks (canopy)? If yes, what's the difference?

Interviewee	Has the plant life in the water changed? If so, how?	Is there a difference in the number of trees along the river banks? Yes or no? If yes, what's the difference?
1	Hasn't noticed	* * *
2	No	Yes. Trees have been lost due to erosion
3	No	Yes. Fewer trees because of erosion of stream banks
4	There isn't much plant life and the water is murkier.	Yes. There are fewer large trees because they have been traded for firewood years ago.
5	No	Yes. Recent flooding has damaged stream side vegetation. It used to be better
6	Yes. The weeds and riffles have disappeared.	No.
7	Yes. Not as much stream side timber	Yes. There are fewer trees.
8	It looks about the same.	No answer

Appendix 4-C (continued)

Question 9) Have the shape (meanders) or location (lateral movement) of the West Fork changed over time?

Interviewee	Changes? Yes or No	When?	Why?
1	Yes	1965	Channelization
2	Yes	No answer	Winn and Riley Confluence The creek is cutting into bank 8 to 10 feet
3	Yes	Years ago	Dozing disturbance from upstream neighbor
4	Yes	Over the years	The river has changed near the stone bridge
5	Yes	Noticed changes more frequently 20 years ago	Water is filling industrial park, pushing the river east because of human impact
6	Yes	Late 40s and 50s	Field erosion caused a meander cut-off
7	Yes	10 to 12 years ago	The channel changed because the neighbor dozed his bank and because of the county gravel mining
8	Yes	Does not know	Does not know

Question 10) Have you noticed bank erosion anywhere on the river? If yes, have you lost land due to bank erosion? If yes, how much? If yes, why do you think you've lost your streambank? Was there a change in the way the land was used, prior to streambank loss? If so, what was the change? Have you ever altered the stream channel? If yes, when? Why?

Part 1 of Table 10

Interviewee	Yes or no?	Have you lost land? How much?	Why?	Change in way land used before loss?	What was the change?	Have you ever altered the stream channel?
1	Yes	Yes, About 10 feet	Concrete slabs were dumped by the neighbor	No	* * *	No
2	Yes, at Creek crossing	Yes, not sure how much	Riley Creek tends to flood more frequently	Doesn't know	* * *	No
3	Yes	Yes, not sure how much	River course changing and flooding	Yes	The land was used for gardening, but stopped	No

Table 10 continued on Page 7

Appendix 4-C (continued)

Part 2 of Question 10 table
Question 10) Have you noticed bank erosion anywhere on the river? If yes, have you lost land due to bank erosion? If yes, how much? If yes, why do you think you've lost your streambank? Was there a change in the way the land was used, prior to streambank loss? If so, what was the change? Have you ever altered the stream channel? If yes, when? Why?

Interviewee	Yes or no?	Have you lost land? How much?	Why?	Change in way land used before loss?	What was the change?	Have you ever altered the stream channel?
4	Yes, near dam area and stone bridge	No answer	Building dam and cutting riparian trees	No	* * *	No
5	Yes	Yes, but not sure how much	Streambank erosion is due to flooding	No	* * *	No
6	Yes	Yes, about ½ acre	Not sure, but Beavers may have killed trees. Beavers undermined bank	No, The land above the bank was in grass for years. Stopped farming in the 60s	* * *	No
7	Yes	No	* * *	Yes	Used to have cattle 20 years ago	No
8	Yes	No	* * *	Yes	Used to be cattle and horses, now it's over-grown and deserted. There is a new jail complex	No

Appendix 4-C (continued)

Question 11) In your opinion, has land use along the river in general changed? If yes, what changed?

Interviewee	Has land use changed?	What changed? (more or less agriculture, residences, roads, forest)
1	No	* * *
2	Yes	I-540, some gravel mining, and a slight increase in cattle
3	No	* * *
4	Yes	More intensive agriculture, more residences, increase in off road vehicle use
5	Yes	Excavation of top soil. Also a golf course and industrial park
6	Yes	It went from row crop to grass
7	Yes	There is not as much livestock, more houses, more roads, and not a prominent hardwood forest.
8	No	* * *

Question 12) Have you noticed an increase in gravel mining? If you think gravel mining has increased, why do you think that is?

Interviewee	Have you noticed an increase in gravel mining?	Why do you think gravel mining has increased?
1	No	* * *
2	Yes	Doesn’t know
3	No	* * *
4	Yes	Increased because of road building
5	No	* * *
6	No	* * *
7	No	* * *
8	No	* * *

Question 13) Do you have a well? If so, has it ever been tested?

Interviewee	Do you have a well?	If so, has it been tested?
1	Yes	No, it is only used for the garden, but a sulfur odor is present.
2	Yes	No, it is dry now.
3	Yes	It was tested by U of A Extension Service
4	No	* * *
5	Yes	No, it is not used anymore.
6	Yes	It was tested in the 90s for nitrates. It was OK. The water is now used for the house, but not for drinking
7	Yes	No, it is not used.
8	No	* * *

Appendix 4-C (continued)

Question 14) Do you have any springs or small tributaries on your property? If so, do they flow constantly or only certain times of the year? Has the flow of your spring or tributary changed? If yes, why do you think it changed?

Interviewee	Springs or small creeks?	Flow of spring?	Has flow changed?	If yes, why?
1	No	* * *		* * *
2	Two springs	Was constant before I-540	Yes, used to flow 160 g/hr, much slower now	I-540 construction decreased the recharge area of spring by 90%
3	Yes	Constant	No	* * *
4	Yes, creek	Constant	No	* * *
5	Yes	Constant	No	* * *
6	Yes, small tributary and spring	Constant for tributary the spring is dried up	Yes	The spring dried up in 1952/54 due to extreme drought
7	Yes	seasonally	Yes	There is less water flowing in the branches
8	No	* * *	* * *	* * *

Question 15) How has the community used the river in the past? And how does the community use the West Fork of the White River in the present?

Interviewee	Past uses of the river?	Present uses?
1	The kids play in it	The kids play in it
2	Property owner's spring was used for drinking water	Livestock watering and riding ATVs
3	Mostly for recreation. There is a park on the river. There is also a rest are on Hwy 71. The river has been popular for family gatherings	More recreational use of the river
4	There used to be a swimming hole in the river. It was used by Fayetteville for drinking water	Maybe some fishing
5	Recreational, fishing, swimming, and canoeing	Recreational, fishing, swimming, and canoeing
6	Swimming, fishing, hauling water for home use, water livestock	Fishing and water livestock
7	Recreation and mining	Recreation
8	Water livestock, recreation, landscaping rocks	It is not used much

Appendix 4-C (continued)

Question 16) How does the present condition of the West Fork compare to your first impression of the river?

Interviewee	How does the present condition of the West Fork compare to your first impression of the river?
1	Better due to stabilization
2	I first considered the river pristine, however, noise increased from the highway. I used to be able to hear a coyote family. Now I feel that the creek has been violated.
3	I have always loved, respected and enjoyed the river.
4	Feels that the river is somewhat better. There is no more sewage and fish kills. The river used to stink due to the waste water treatment plant.
5	The condition of the river has deteriorated. It was much cleaner.
6	The river is not as clean as it was; but the high flow events are not as muddy. The water is not drinkable anymore.
7	There is not as much water or it is better contained than it used to be.
8	Doesn't know

Question 17) Do you have a favorite story about the river?

Interviewee	Favorite story
1	Kids playing in creek.
2	In 1985 or 86 it rained more than 6 inches and his truck washed away.
3	During a 4-wheeling ride on the river the truck got stuck and she had to climb out the window
4	Most memorable is when his uncle drown on the river while fishing
5	Doesn't really have a favorite story, but family has owned property on the river for 55-60 years and has enjoyed living on the river.
6	Enjoyed swimming in the river as a kid. He used to haul hay and would swim in the river after working. The Home Economics club would picnic on the river and people were baptized below the bridge.
7	Favorite memory is spending time on the river with his family. He remembers pumpkins being washed on the bank during high water. Once he was bitten by a cottonmouth while camping and fishing with his cousins.
8	Remembers watching beaver use trash and Styrofoam to build their homes.

Appendix 4-C (continued)

Question 18) Do you have any concern about the West Fork River? If yes, what are they?

Interviewee	Concerns? Yes/No	If yes, what are they?
1	Yes	Concerned that construction might affect creek and dry up spring
2	Yes	Population increase, new houses being built on the river, more litter, pollution. Feels that there is less concern for water quality and disregard for nature
3	Yes	The way it is changing, hopes it stays clean
4	Yes	The river needs to be cleaned up, protected from pollution, have buffer zones along the stream side. Concerned with fertilizer being applied along the river.
5	Yes	We should manage the river better. Water impacts from construction, gravel mining and selling fill. There needs to be more government assistance and more education regarding the river
6	Yes	There is a salvage yard on the banks of the river.
7	Yes	Water quality and changes
8	Yes	Development, urban sprawl, loss of wildlife habitat.

Question 19) Do you have a vision for how the river should look?

Interviewee	Vision for how the river should look?
1	That there are stable banks. Would like to see even, sloped banks and more vegetation.
2	Wants society to realize their affects on nature. He feels that the water table has dropped because there have been greater uses and misuses of the water.
3	Doesn't really have a vision for the river, but would hate to see it get polluted.
4	Would like to see the river clean, with big trees on both sides, as well as on the tributaries and would like to see reduced turbidity.
5	Would like to see the river provide refuge for related wildlife. Would like to see repairs made for flood damage.
6	Would like to see cleaner water and the banks stabilized.
7	Stay clean and maintain fish life
8	Would like for the river to have fish and more water, however, it looks the way it did when she got there.

Appendix 5-A
Bank Erosion Data Collection Sheet

Bank Erodibility Hazard Rating Guide

Stream Reach Date Crew

Bank Erosion Potential		Bank Height (ft): / Bankfull Height (ft):	Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
	VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	EXTREME	Value	>2.8	<0.05	<5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	V = value, I = index					**SUB-TOTAL** (Sum one index from each column)	

Bank Material Description:

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT ______

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT ______

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

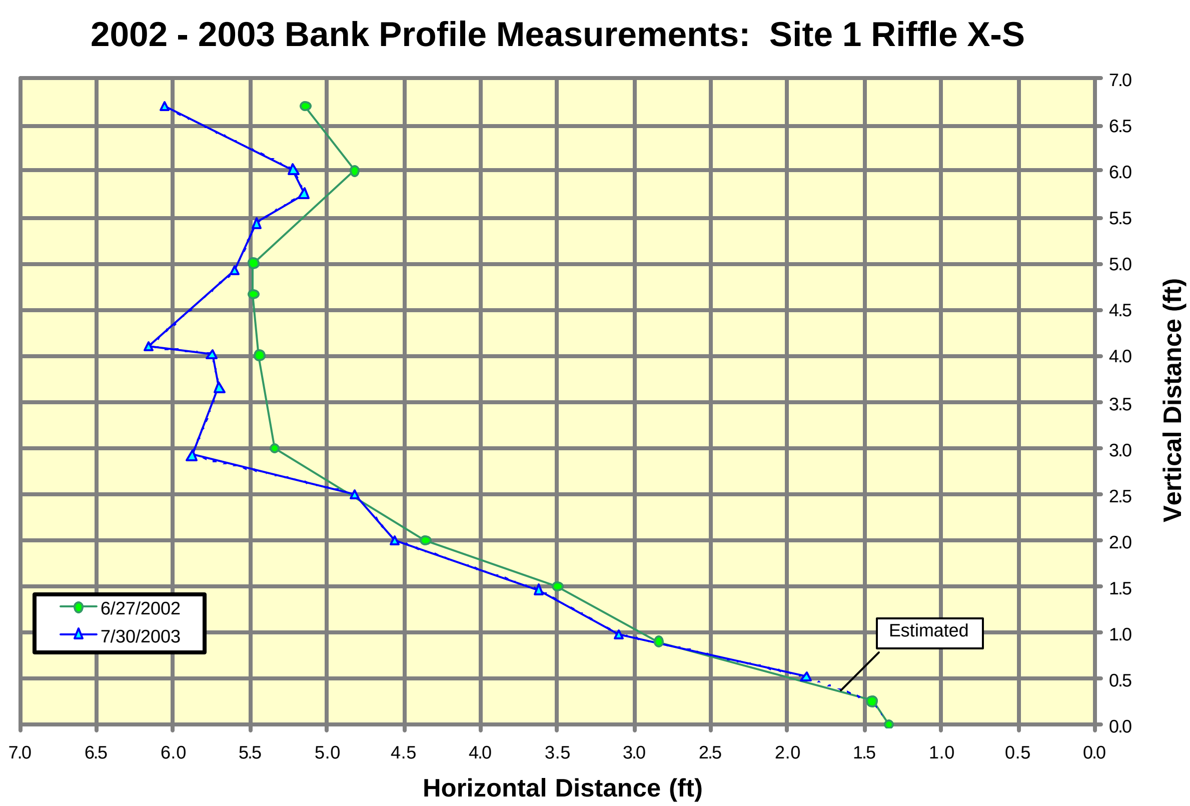
Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL
BEHI RATING

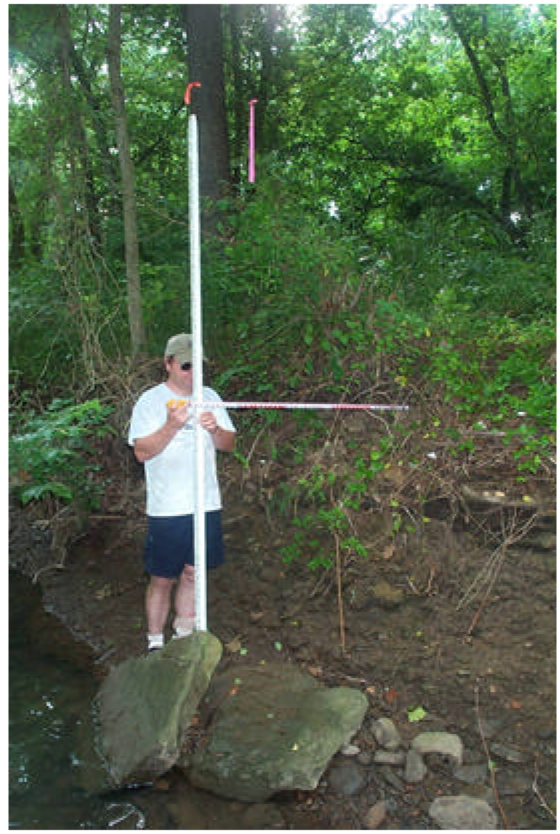
West Fork White River Annual Lateral Streambank Erosion Data

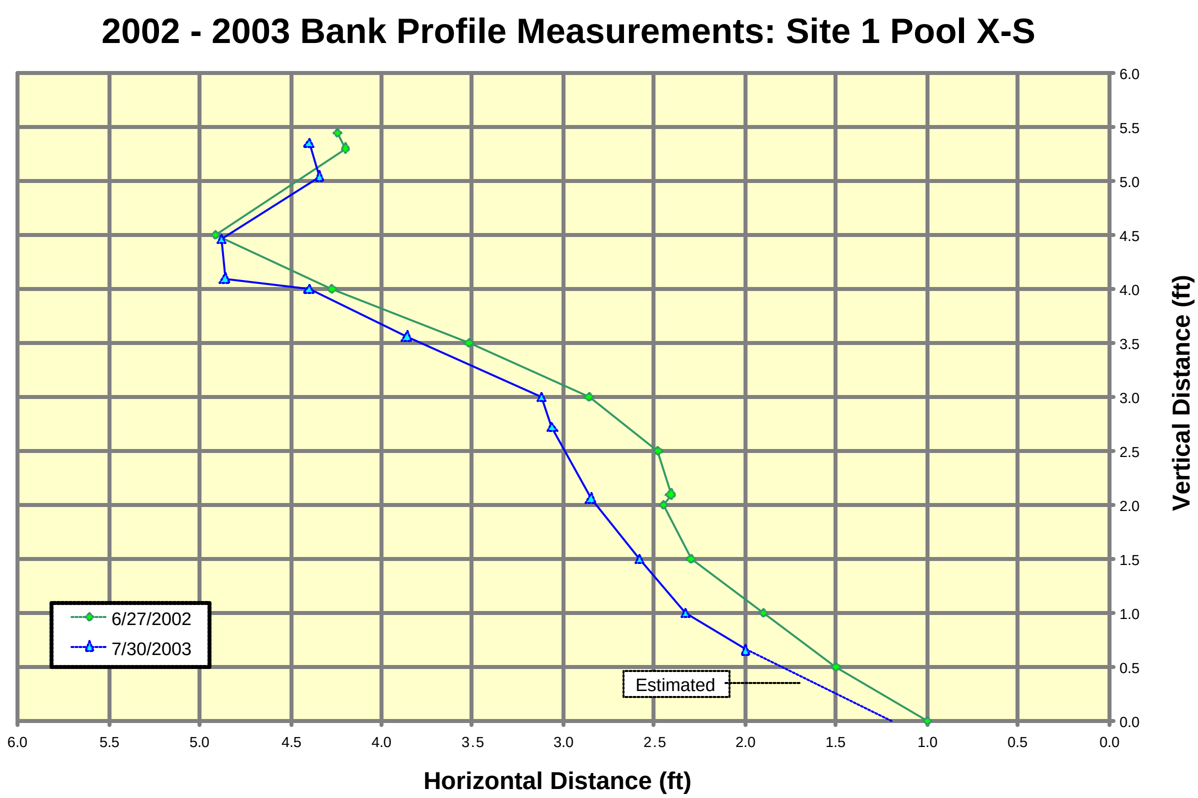
Site	1
Bank Toe Pin Location	Riffle
Bank	Left
Near Bank Shear Stress	High
BEHI Adjective	High
BEHI Total Score	32.4
Measured Lateral Erosion (ft/year)	0.34



West Fork White River Annual Lateral Streambank Erosion Data

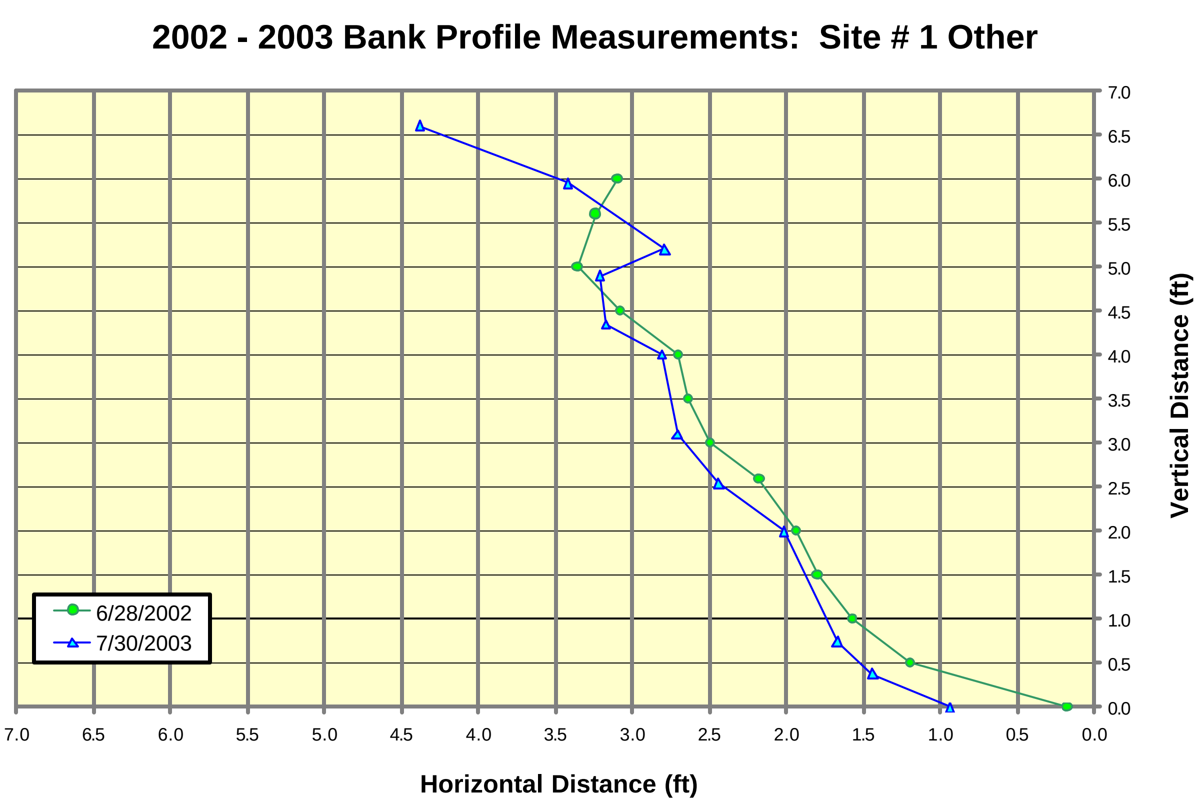
Site	1
Bank Toe Pin Location	Pool
Bank	Right
Near Bank Shear Stress	High
BEHI Adjective	Moderate
BEHI Total Score	26
Measured Lateral Erosion (ft/year)	0.29





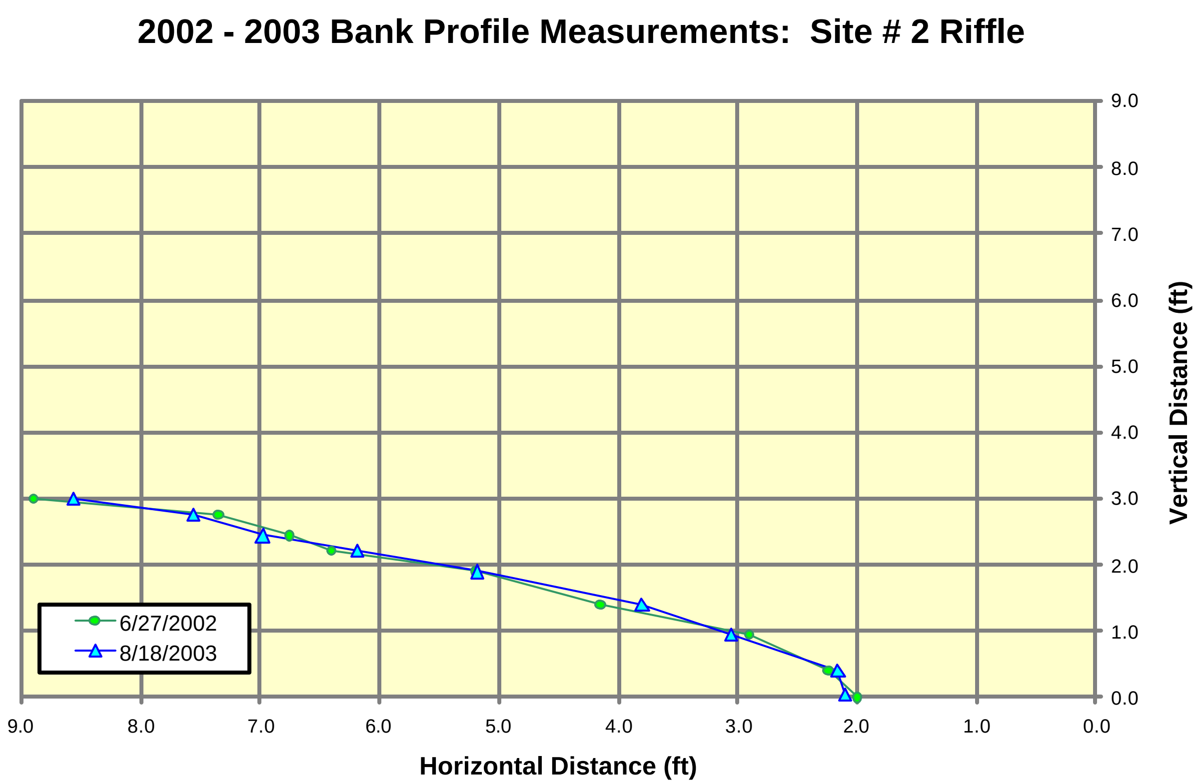
West Fork White River Annual Lateral Streambank Erosion Data

Site	1
Bank Toe Pin Location	Other
Bank	Left
Near Bank Shear Stress	High
BEHI Adjective	High
BEHI Total Score	31.5
Measured Lateral Erosion (ft/year)	0.185



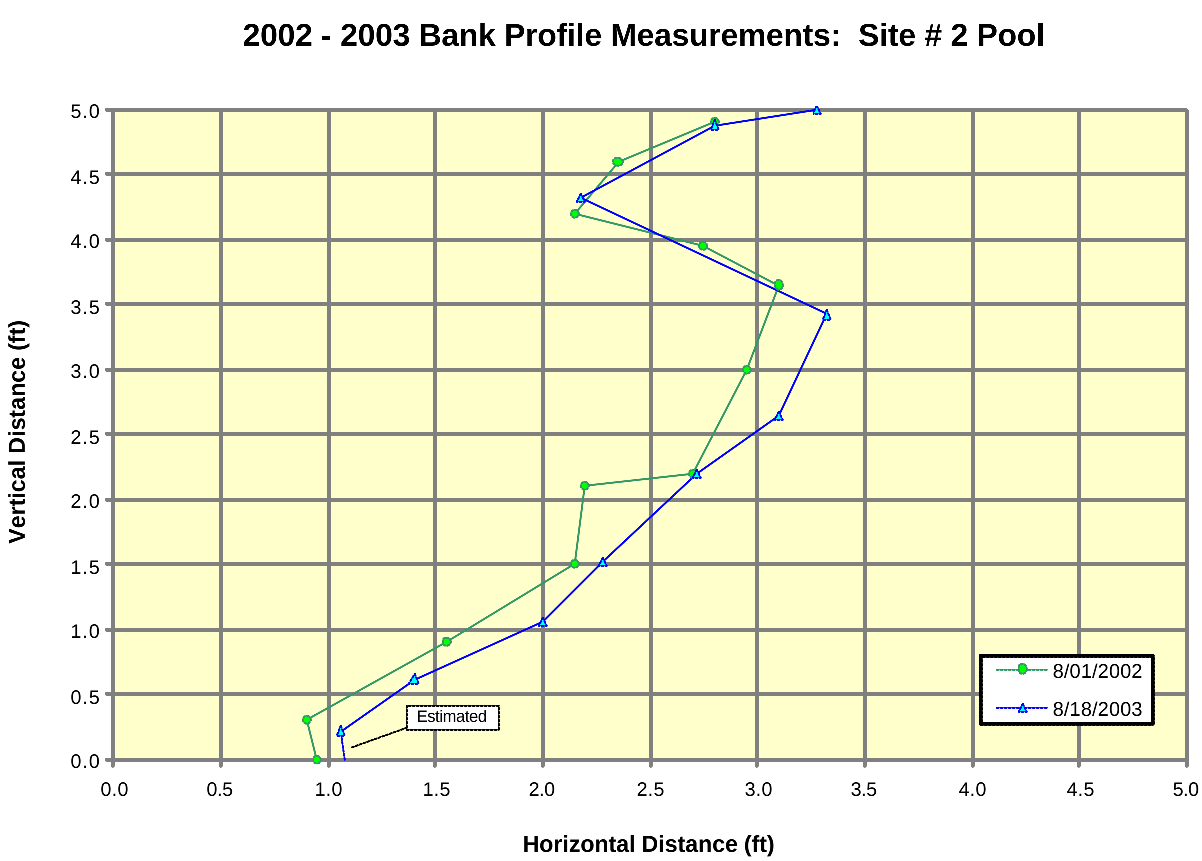
West Fork White River Annual Lateral Streambank Erosion Data

Site	2
Bank Toe Pin Location	Riffle
Bank	Left
Near Bank Shear Stress	Low
BEHI Adjective	Low
BEHI Total Score	16.8
Measured Lateral Erosion (ft/year)	0.05



West Fork White River Annual Lateral Streambank Erosion Data

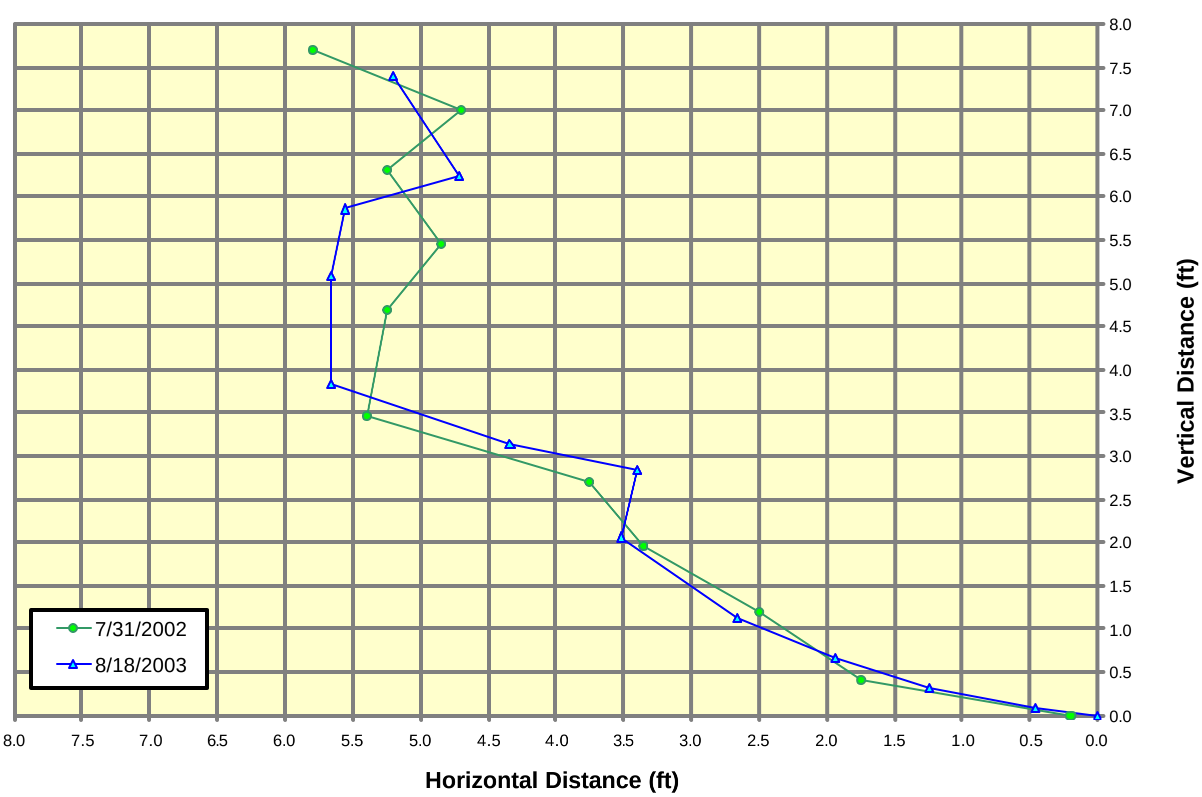
Site	2
Bank Toe Pin Location	Pool
Bank	Left
Near Bank Shear Stress	High
BEHI Adjective	Moderate
BEHI Total Score	28.9
Measured Lateral Erosion (ft/year)	0.18



West Fork White River Annual Lateral Streambank Erosion Data

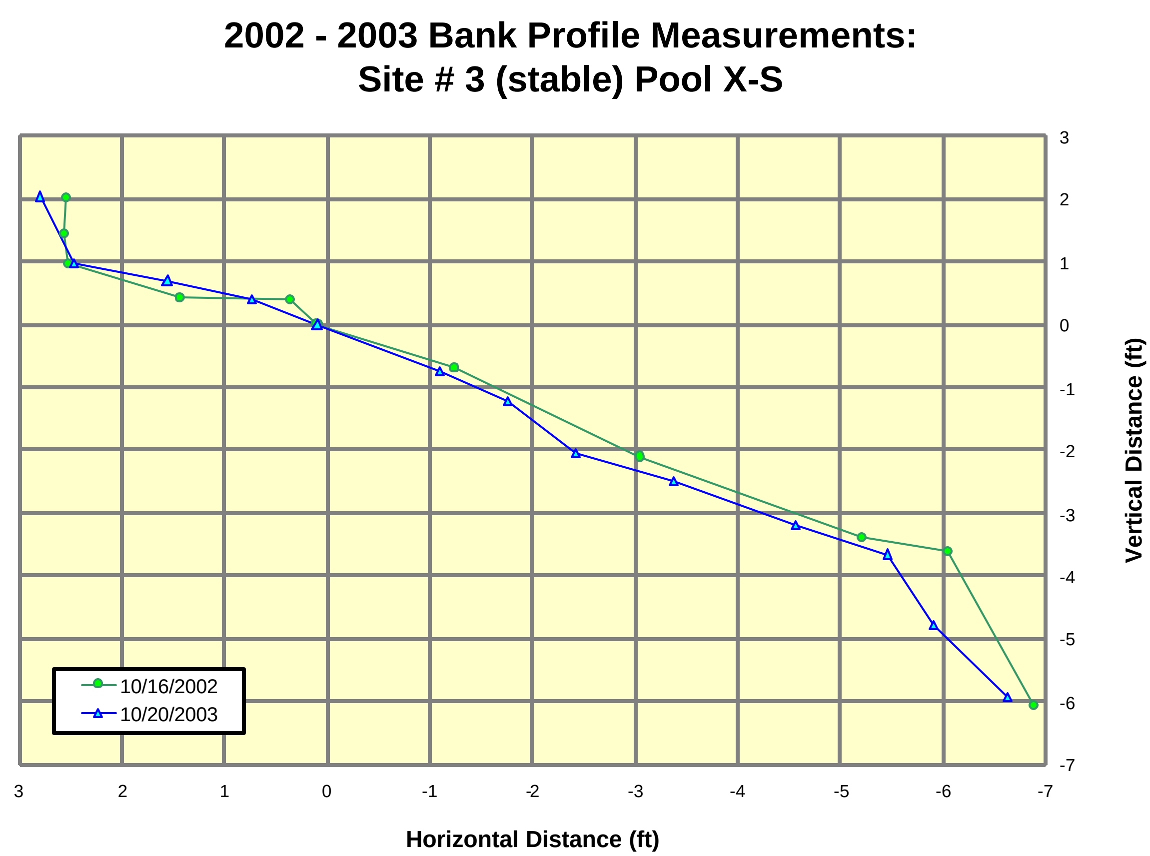
Site	2
Bank Toe Pin Location	Other
Bank	Left
Near Bank Shear Stress	Moderate
BEHI Adjective	Moderate
BEHI Total Score	27.9
Measured Lateral Erosion (ft/year)	0.12

2002 - 2003 Bank Profile Measurements: Site # 2 Other



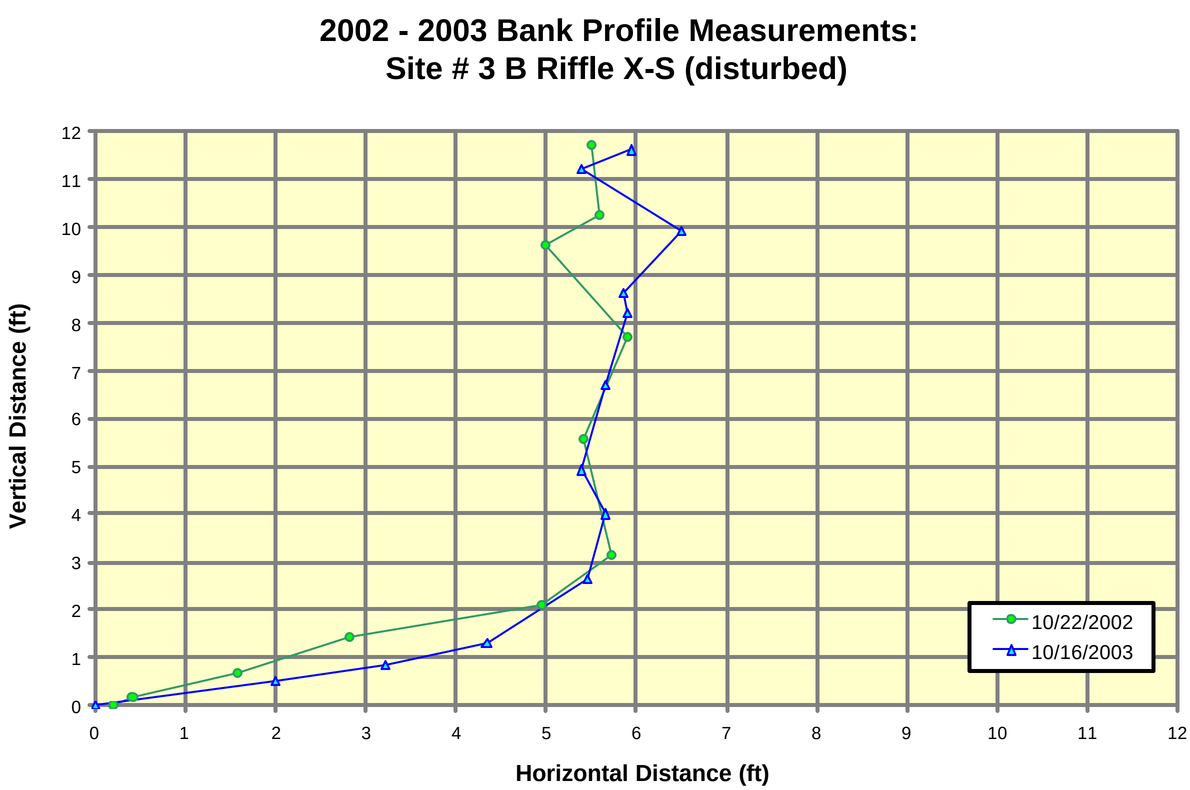
West Fork White River Annual Lateral Streambank Erosion Data

Site	3
Bank Toe Pin Location	Pool (stable)
Bank	Left
Near Bank Shear Stress	High
BEHI Adjective	Moderate / High
BEHI Total Score	30.9
Measured Lateral Erosion (ft/year)	0.41



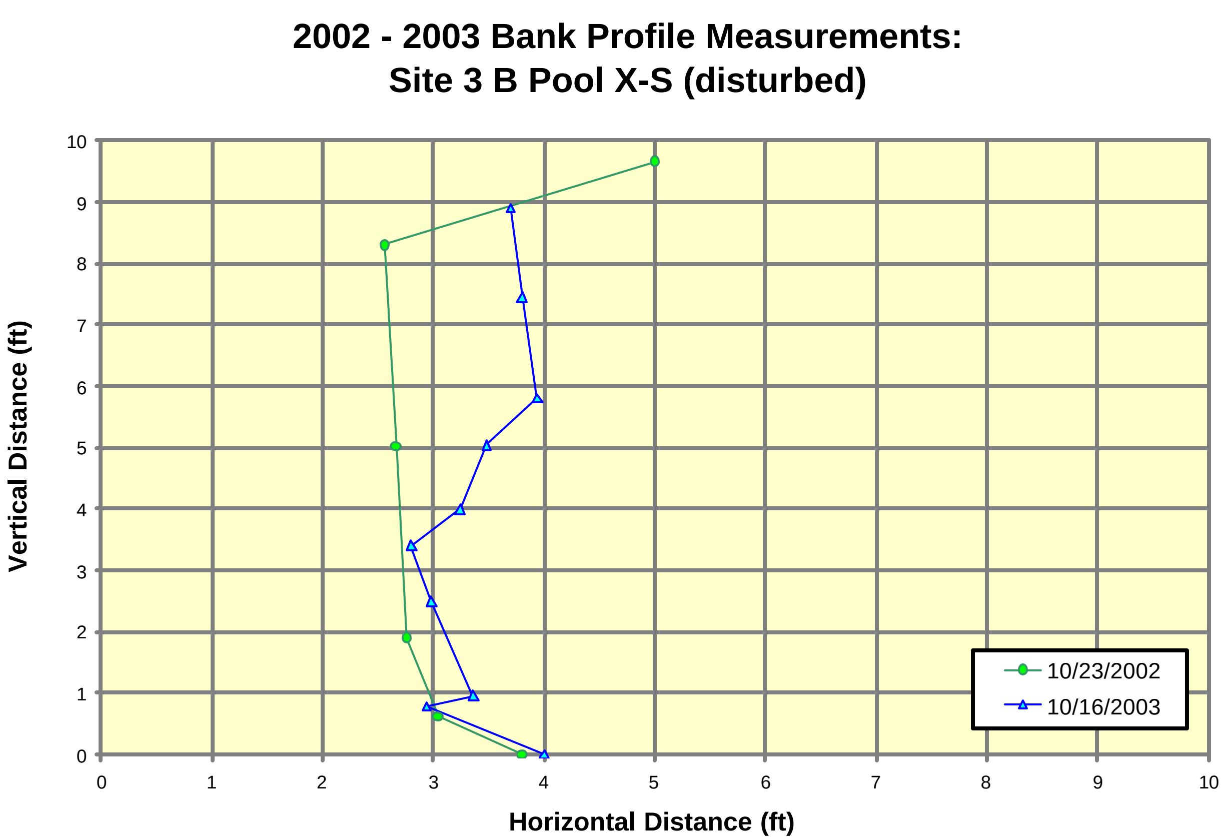
West Fork White River Annual Lateral Streambank Erosion Data

Site	3
Bank Toe Pin Location	Riffle (disturbed)
Bank	Right
Near Bank Shear Stress	Very High
BEHI Adjective	Moderate / High
BEHI Total Score	30.8
Measured Lateral Erosion (ft/year)	0.35



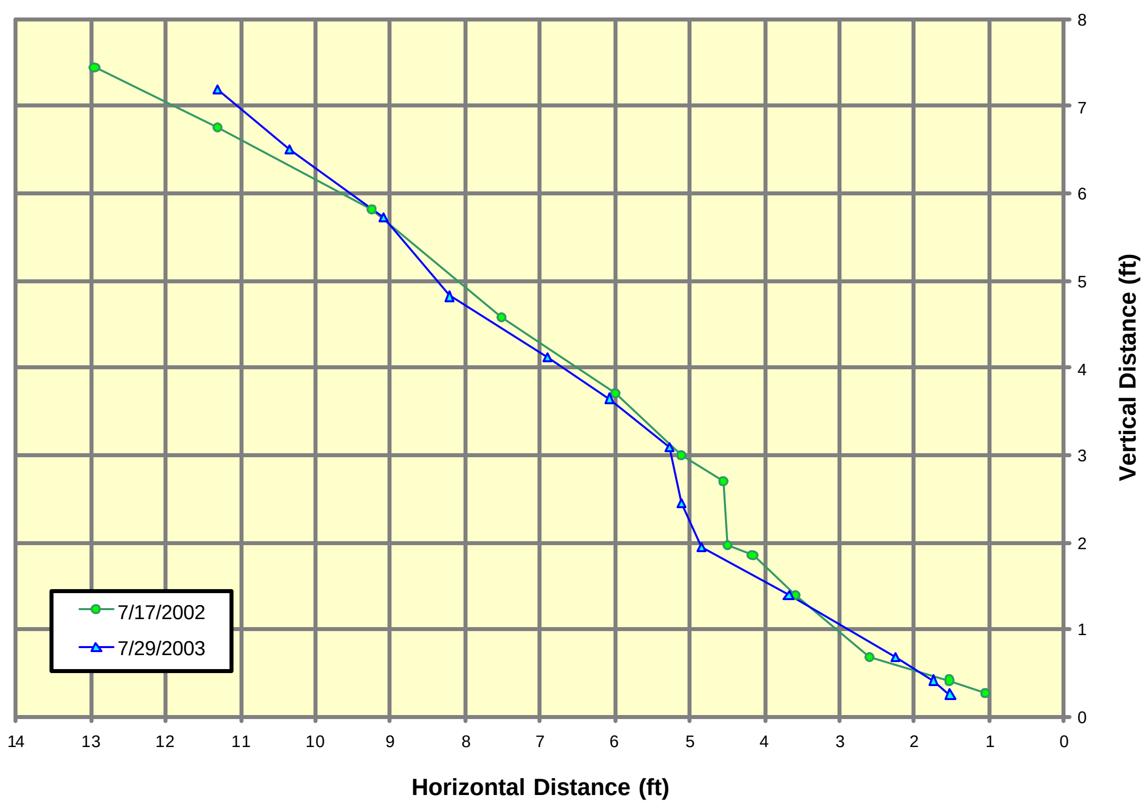
West Fork White River Annual Lateral Streambank Erosion Data

Site	3
Bank Toe Pin Location	Pool (disturbed)
Bank	Right
Near Bank Shear Stress	Very High
BEHI Adjective	High / Very High
BEHI Total Score	39.9
Measured Lateral Erosion (ft/year)	0.7



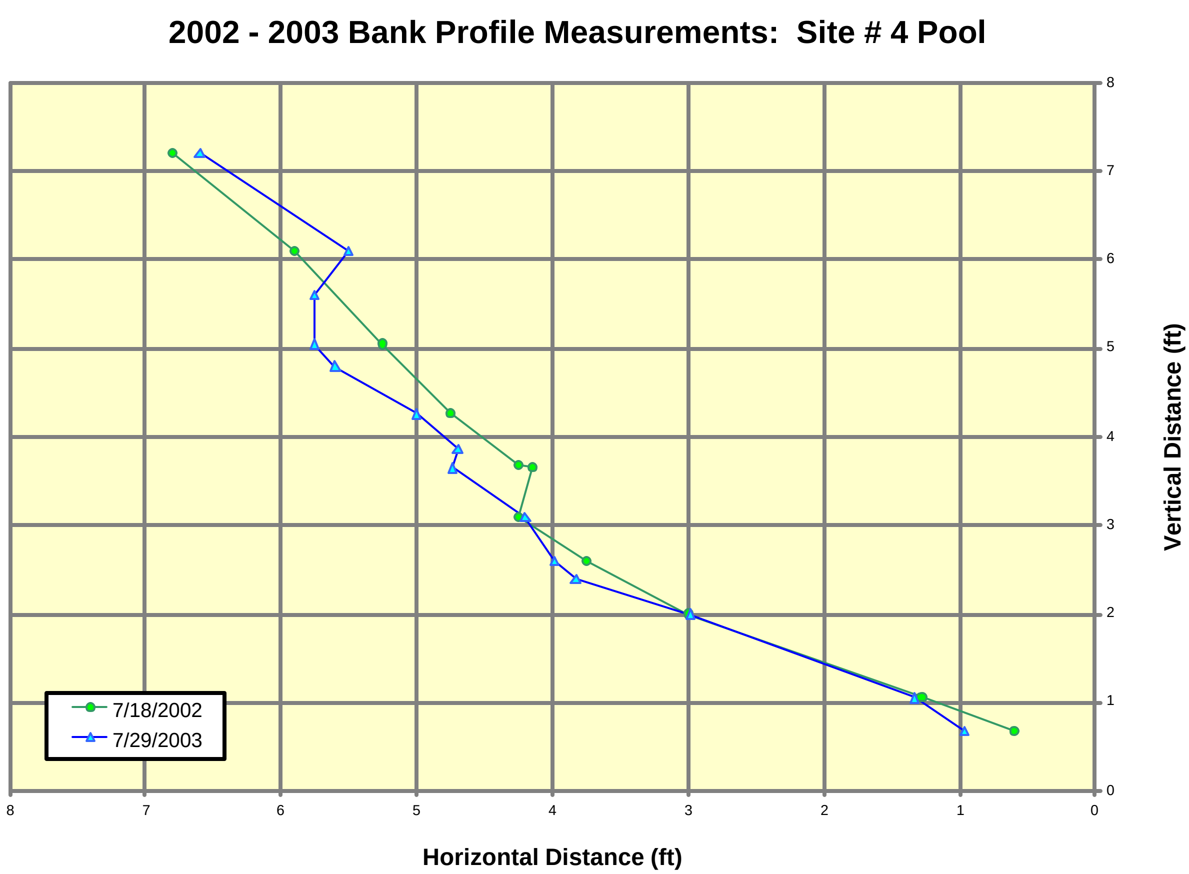
West Fork White River Annual Lateral Streambank Erosion Data

Site	4
Bank Toe Pin Location	Riffle
Bank	Left
Near Bank Shear Stress	Moderate
BEHI Adjective	Moderate
BEHI Total Score	27
Measured Lateral Erosion (ft/year)	0.19



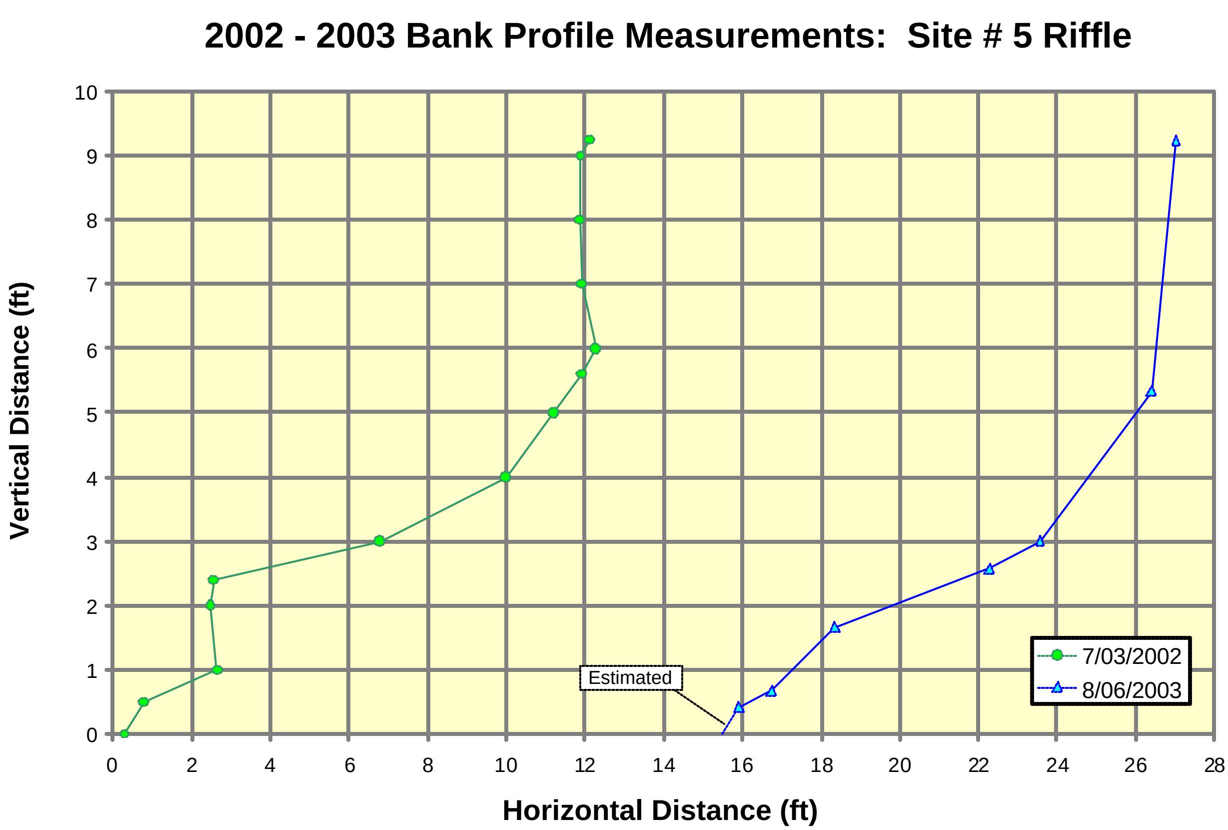
West Fork White River Annual Lateral Streambank Erosion Data

Site	4
Bank Toe Pin Location	Pool
Bank	Left
Near Bank Shear Stress	Moderate
BEHI Adjective	Moderate
BEHI Total Score	22.2
Measured Lateral Erosion (ft/year)	0.2



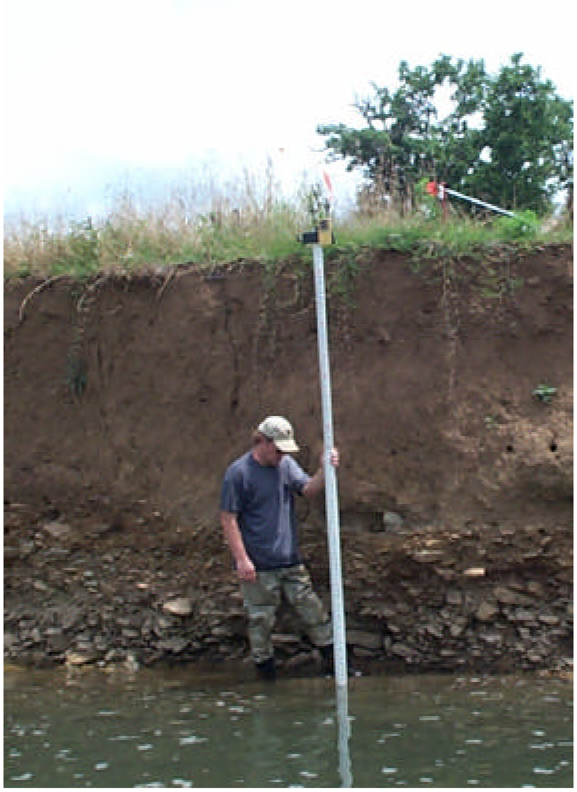
West Fork White River Annual Lateral Streambank Erosion Data

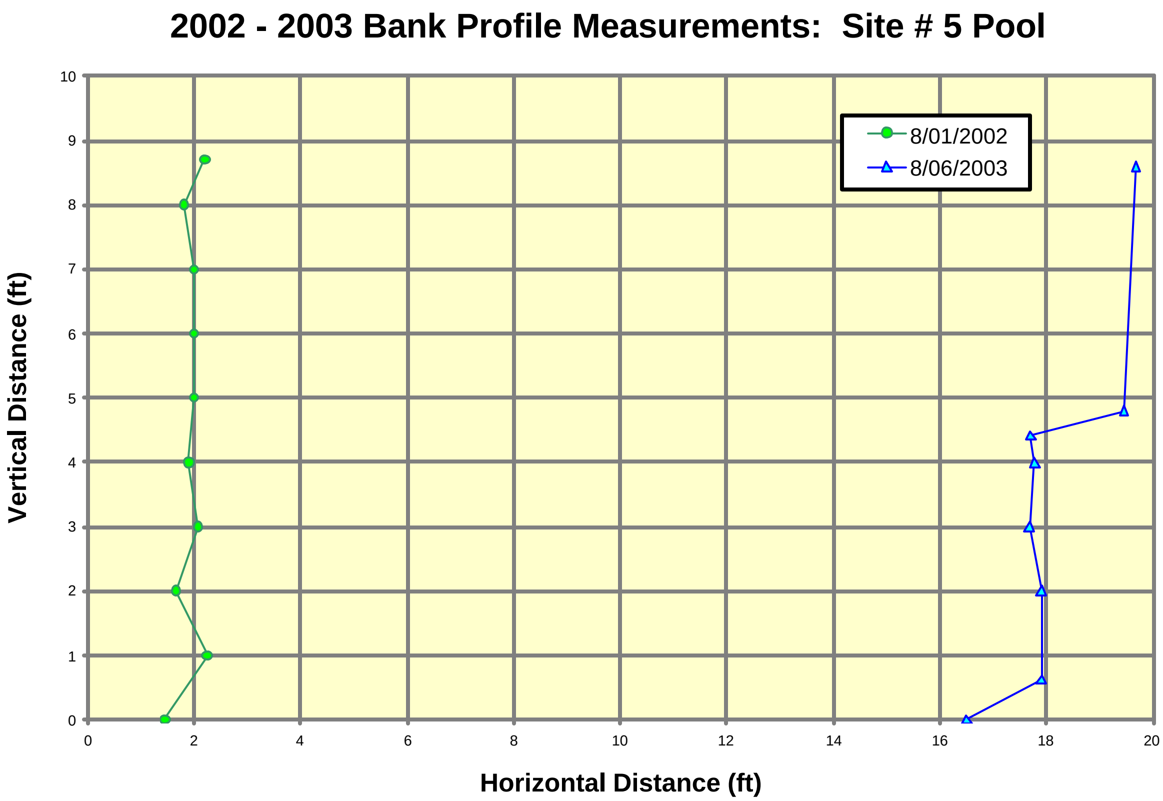
Site	5
Bank Toe Pin Location	Riffle
Bank	Right
Near Bank Shear Stress	Extreme
BEHI Adjective	Extreme
BEHI Total Score	45
Measured Lateral Erosion (ft/year)	15.3



West Fork White River Annual Lateral Streambank Erosion Data

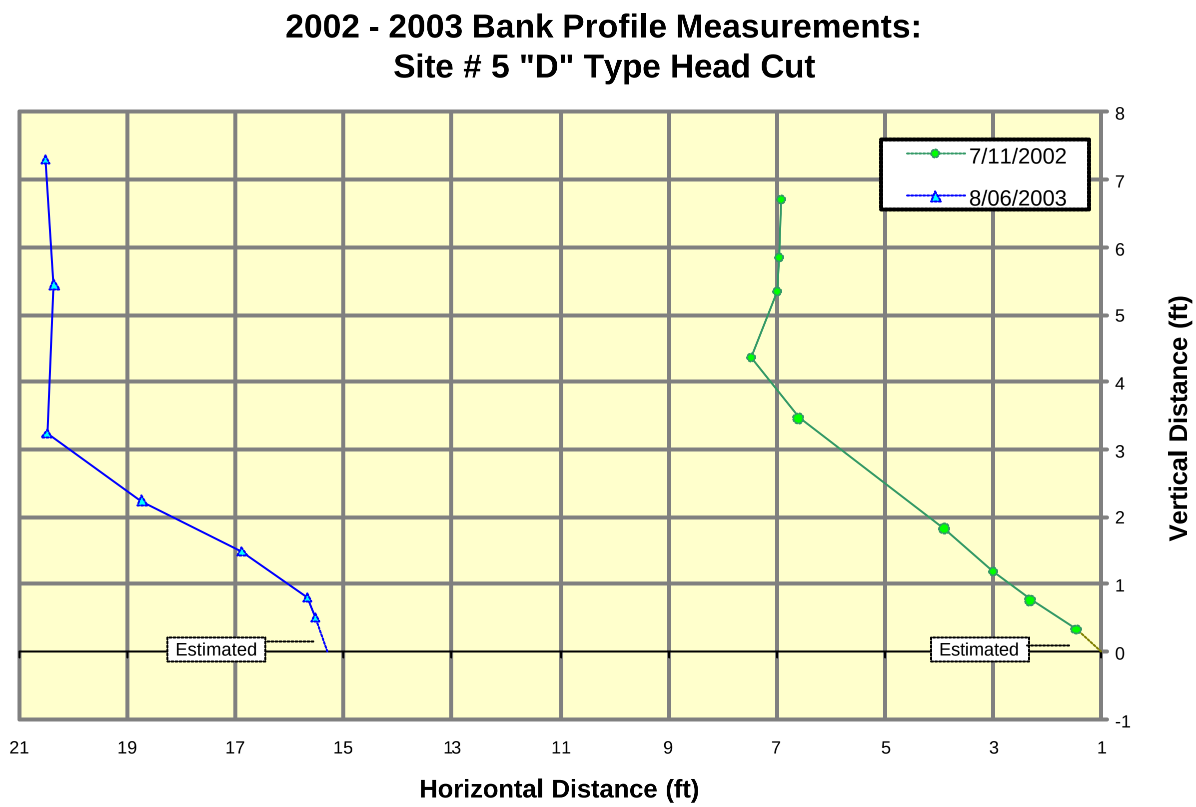
Site	5
Bank Toe Pin Location	Pool
Bank	Right
Near Bank Shear Stress	Extreme
BEHI Adjective	Extreme
BEHI Total Score	45
Measured Lateral Erosion (ft/year)	16.6





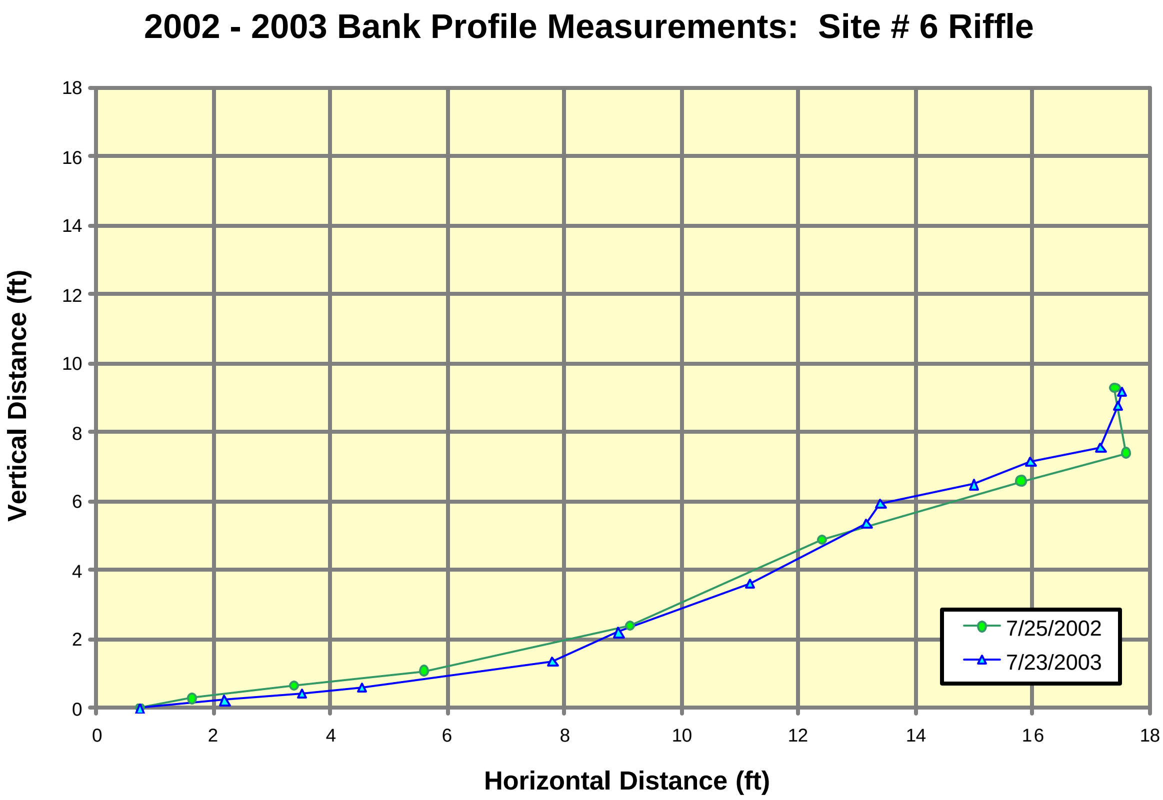
West Fork White River Annual Lateral Streambank Erosion Data

Site	5
Bank Toe Pin Location	D-Type Head Cut
Bank	Left
Near Bank Shear Stress	Extreme
BEHI Adjective	Extreme
BEHI Total Score	41.9
Measured Lateral Erosion (ft/year)	14.4



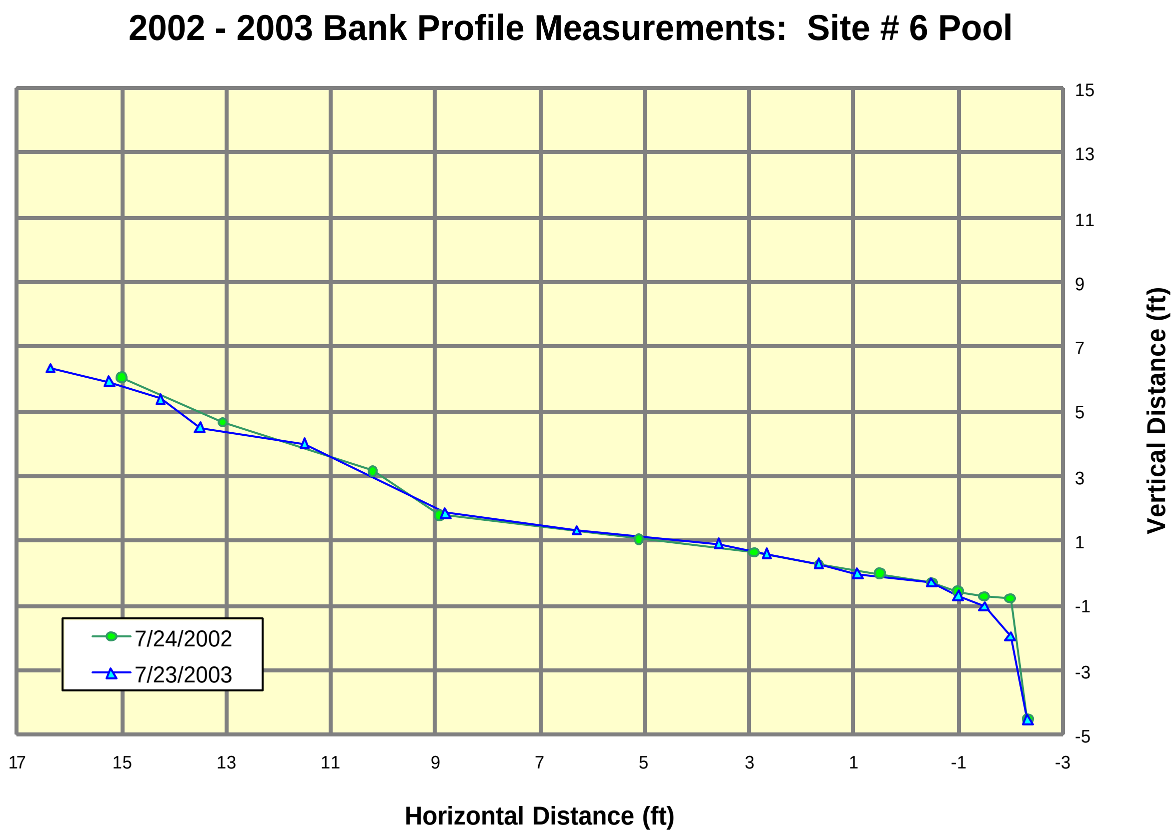
West Fork White River Annual Lateral Streambank Erosion Data

Site	6
Bank Toe Pin Location	Riffle
Bank	Right
Near Bank Shear Stress	Low
BEHI Adjective	High
BEHI Total Score	31.7
Measured Lateral Erosion (ft/year)	0.1



West Fork White River Annual Lateral Streambank Erosion Data

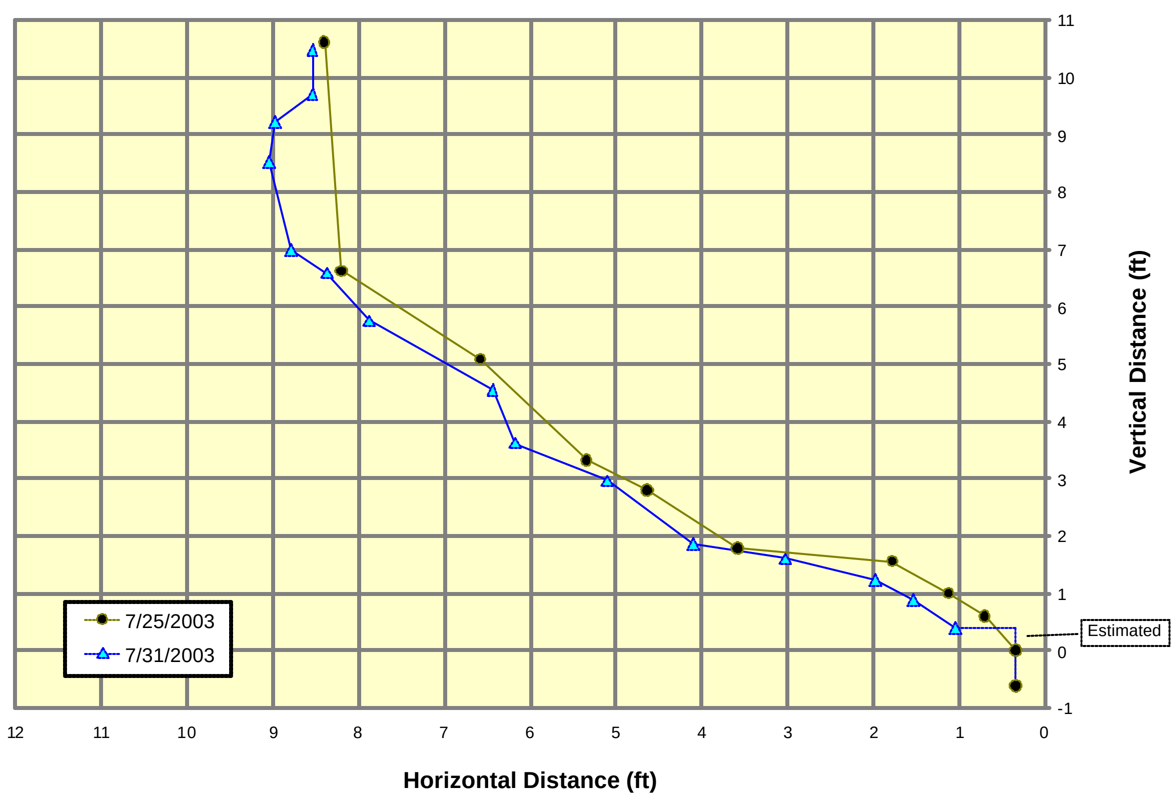
Site	6
Bank Toe Pin Location	Riffle
Bank	Left
Near Bank Shear Stress	High
BEHI Adjective	Low/Moderate
BEHI Total Score	20
Measured Lateral Erosion (ft/year)	0.1



West Fork White River Annual Lateral Streambank Erosion Data

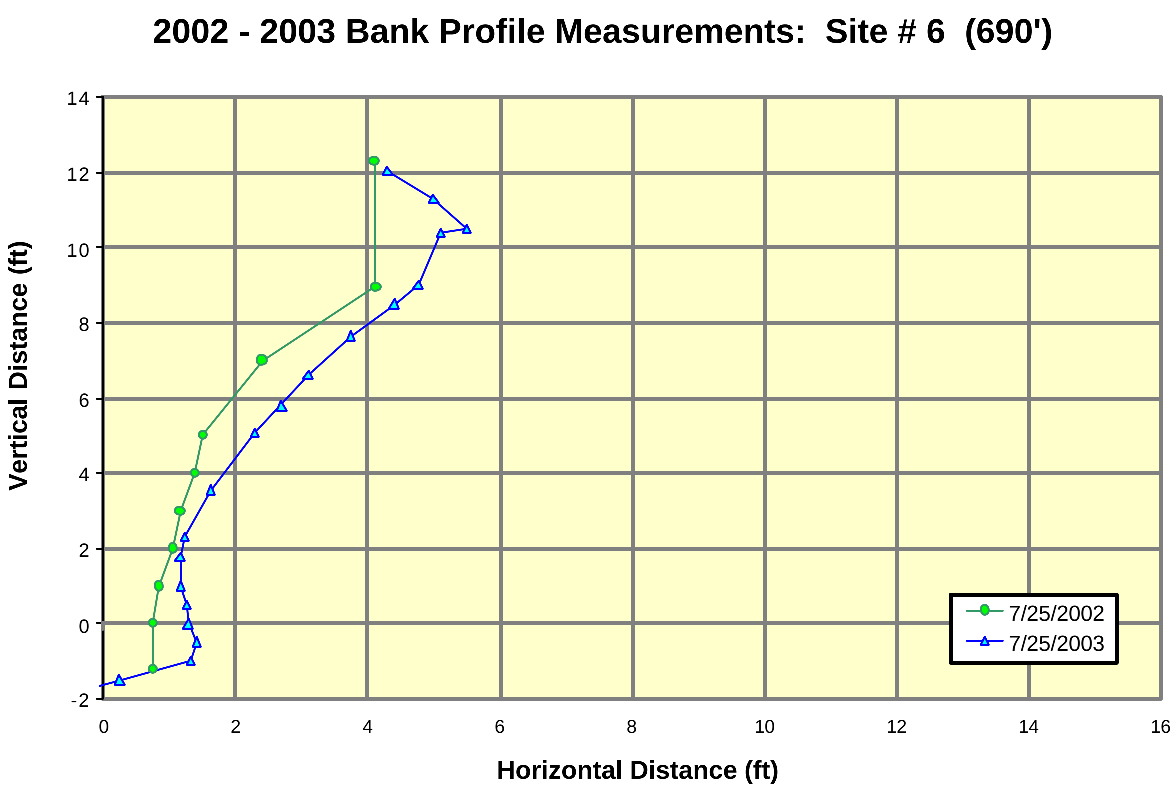
Site	6
Bank Toe Pin Location	Other (0’ on long pro)
Bank	Left
Near Bank Shear Stress	Moderate
BEHI Adjective	Very High
BEHI Total Score	41.7
Measured Lateral Erosion (ft/year)	0.46

2002 - 2003 Bank Profile Measurements: Site # 6 (0')



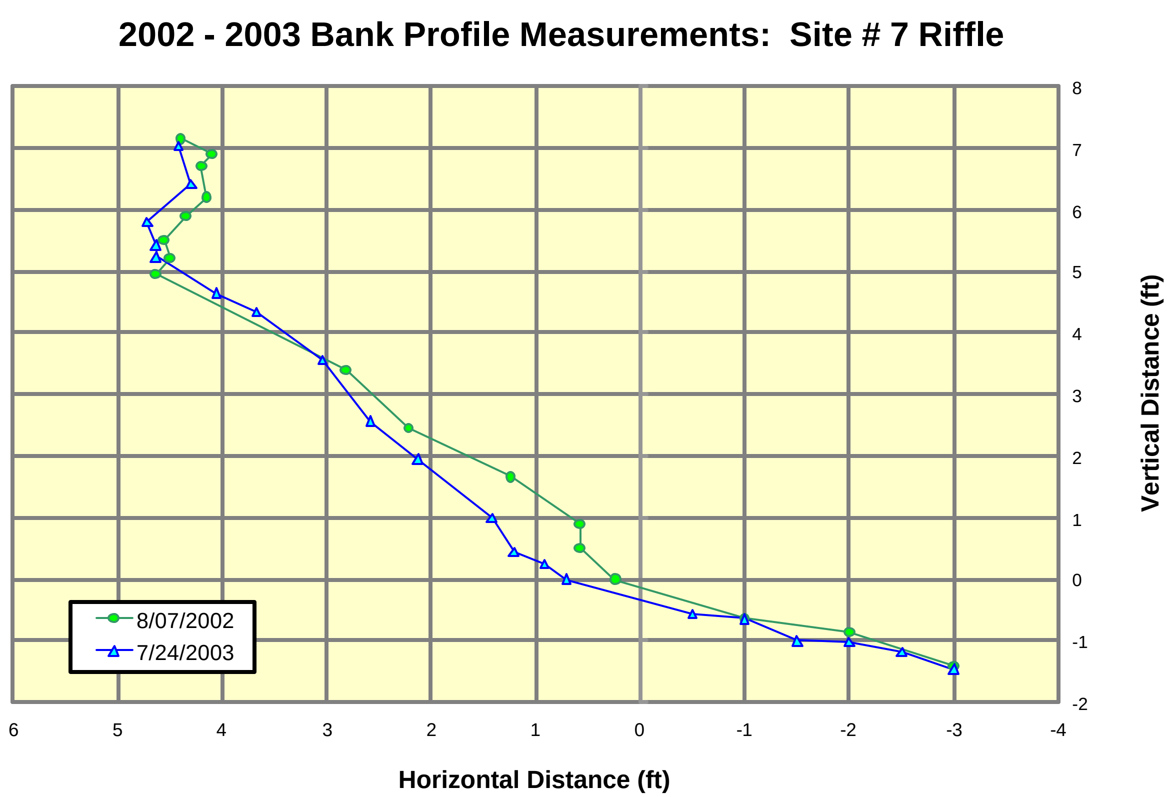
West Fork White River Annual Lateral Streambank Erosion Data

Site	6
Bank Toe Pin Location	Other (670' on long pro)
Bank	Right
Near Bank Shear Stress	High
BEHI Adjective	High/Very High
BEHI Total Score	39.6
Measured Lateral Erosion (ft/year)	0.6



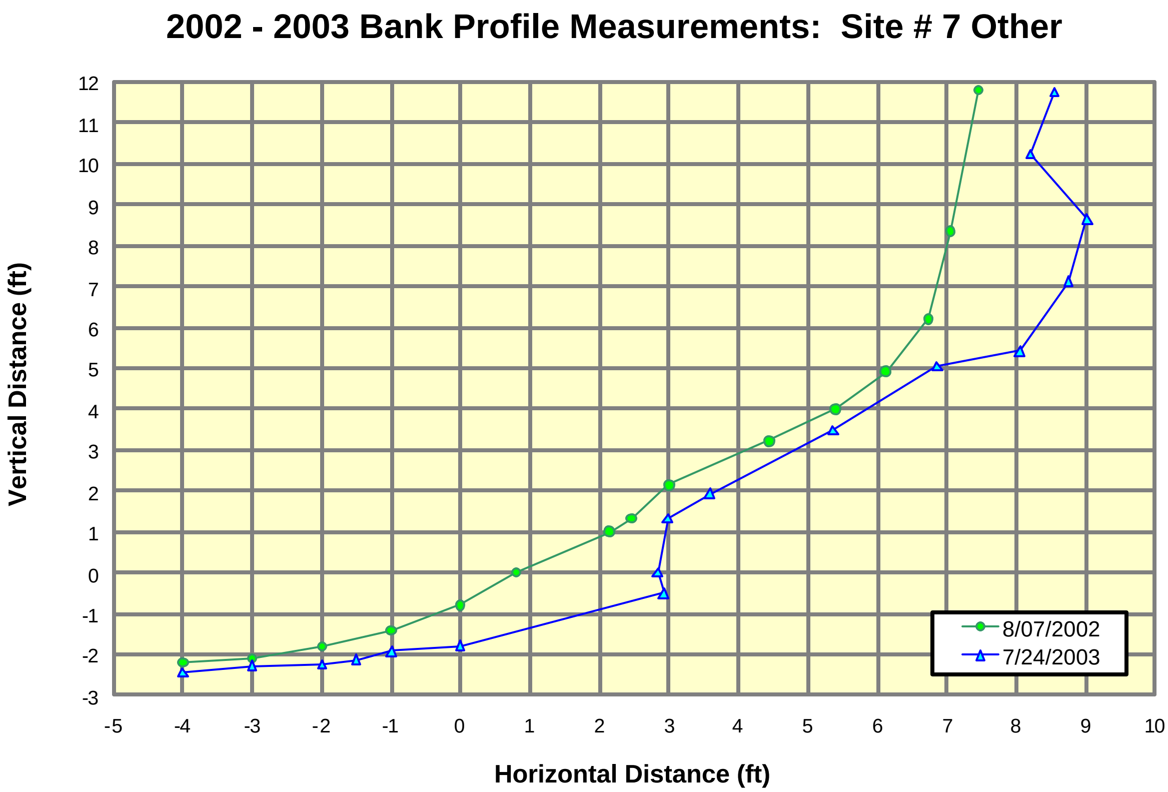
West Fork White River Annual Lateral Streambank Erosion Data

Site	7
Bank Toe Pin Location	Riffle
Bank	Left
Near Bank Shear Stress	Moderate
BEHI Adjective	High
BEHI Total Score	34.4
Measured Lateral Erosion (ft/year)	0.28



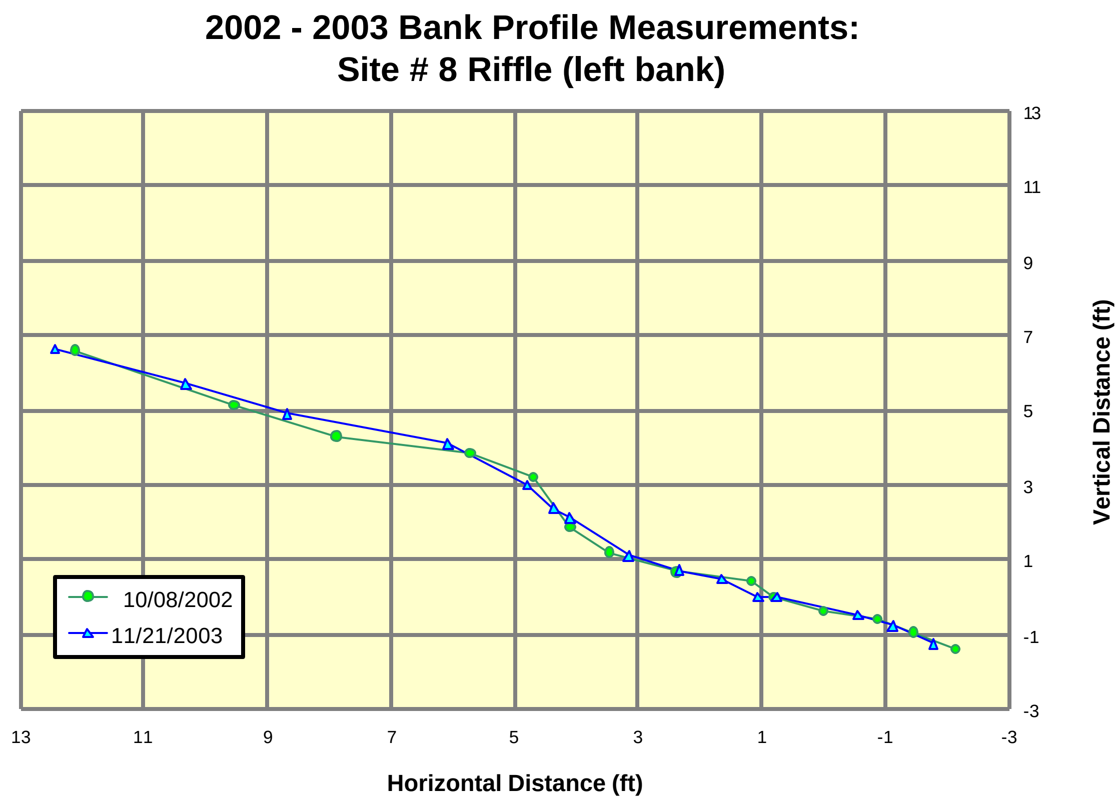
West Fork White River Annual Lateral Streambank Erosion Data

Site	7
Bank Toe Pin Location	Other (DS of Pool X-S)
Bank	Right
Near Bank Shear Stress	Very High
BEHI Adjective	Very High
BEHI Total Score	44.7
Measured Lateral Erosion (ft/year)	1.4



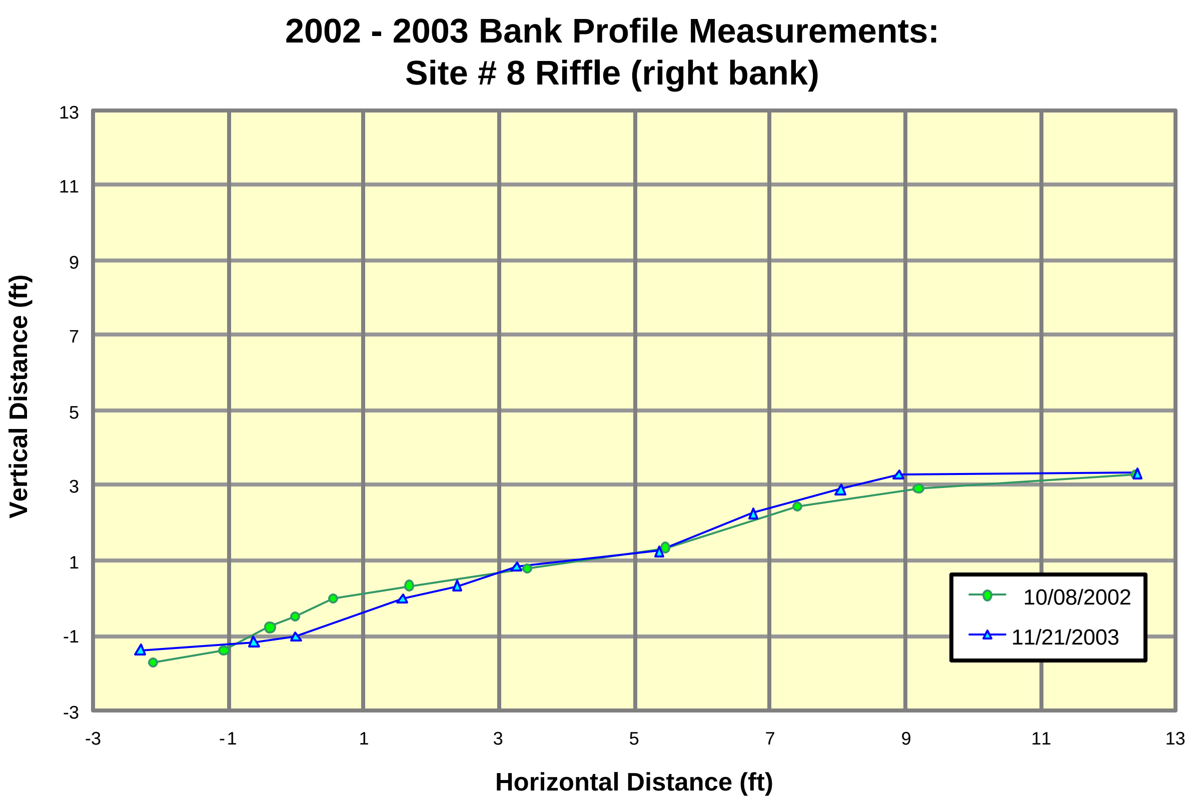
West Fork White River Annual Lateral Streambank Erosion Data

Site	8
Bank Toe Pin Location	Riffle (left)
Bank	Left
Near Bank Shear Stress	Low
BEHI Adjective	Low
BEHI Total Score	18.3
Measured Lateral Erosion (ft/year)	0.01



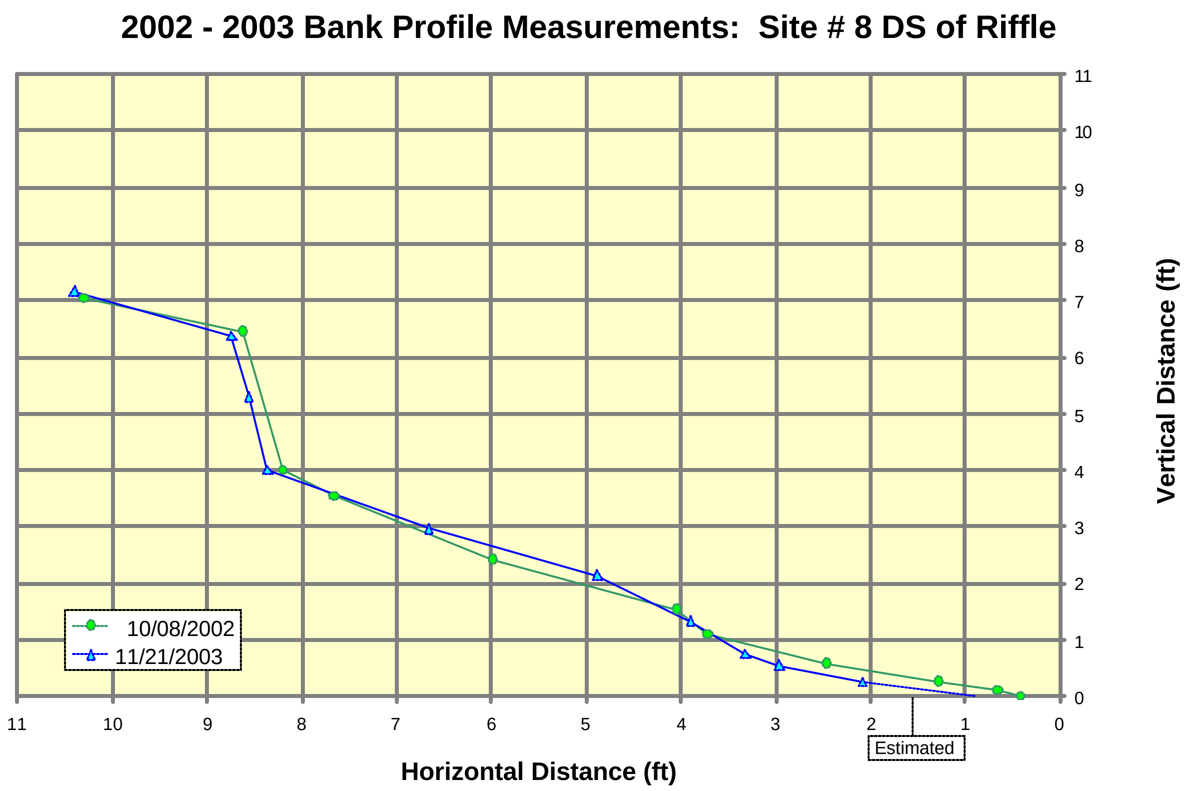
West Fork White River Annual Lateral Streambank Erosion Data

Site	8
Bank Toe Pin Location	Riffle (right)
Bank	Right
Near Bank Shear Stress	Low
BEHI Adjective	Low
BEHI Total Score	16.1
Measured Lateral Erosion (ft/year)	0.03



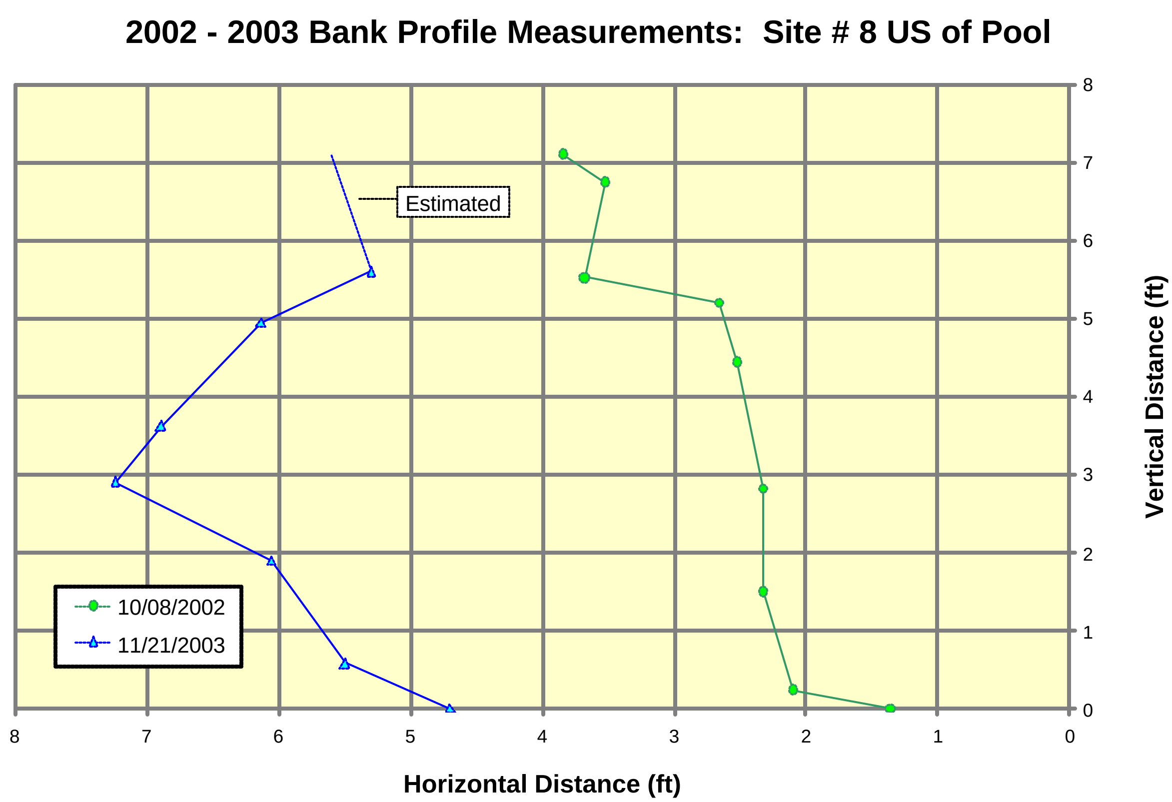
West Fork White River Annual Lateral Streambank Erosion Data

Site	8
Bank Toe Pin Location	DS of Riffle X-S
Bank	Left
Near Bank Shear Stress	Low
BEHI Adjective	Moderate/High
BEHI Total Score	29.4
Measured Lateral Erosion (ft/year)	0.11



West Fork White River Annual Lateral Streambank Erosion Data

Site	8
Bank Toe Pin Location	US of Pool X-S
Bank	Left
Near Bank Shear Stress	Extreme
BEHI Adjective	High
BEHI Total Score	31.8
Measured Lateral Erosion (ft/year)	3.4



Appendix 5-B (continued)

Appendix 5-C
Bank Materials Sampling

West Fork White River Stream Bank Materials Sampling
Permanent Cross Section Site #1

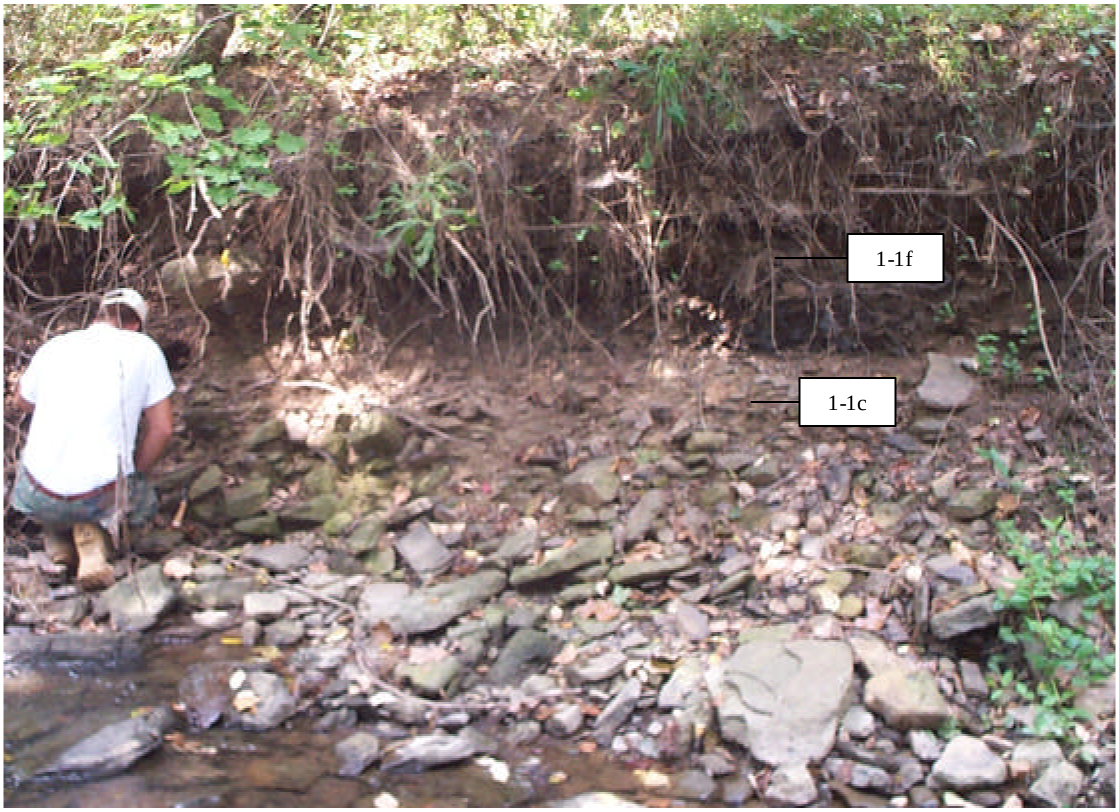


Photo of Left Bank near the Riffle Cross Section

Bank Material Bulk Density and Particle Size Summary

Sample I.D.		Sample Bulk Density (lbs/ft^3)	Percentage of Sample		
			>2mm	<2mm	<.02mm
Fine Grained	1-1f	69.9	2.8	53.6	43.6
	1-2f	91.1	12.1	57.4	30.5
Course Grained	1-1c	158.5	77.5	13.5	9.0
	1-2c	122.3	82.3	14.7	3.0

West Fork White River Stream Bank Materials Sampling
Permanent Cross Section Site #2

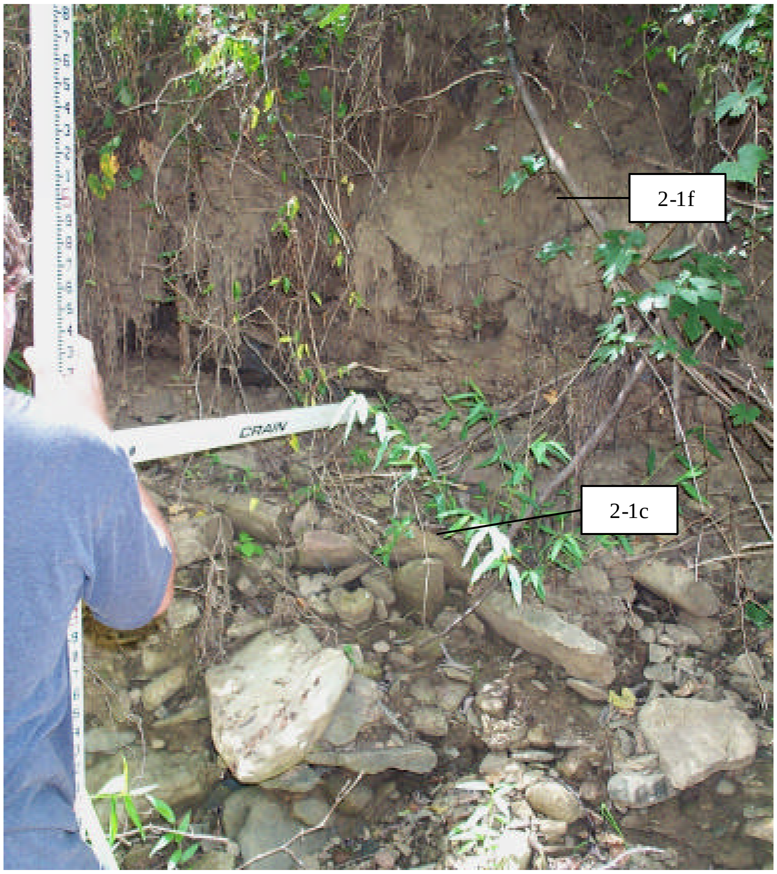


Photo of Right Bank near the Up-Stream Pool Cross Section

Bank Material Bulk Density and Particle Size Summary

Sample I.D.		Sample Bulk Density (lbs/ft^3)	Percentage of Sample		
			>2mm	2mm-.02mm	<.02mm
Fine Grained	2-1f	82.4	28.9	42.7	28.4
	2-2f	78.6	32.0	36.7	31.3
Course Grained	2-1c	194.7	82.5	11.8	5.7
	2-2c	132.9	86.6	7.1	6.3

Appendix 5-C (continued)

West Fork White River Stream Bank Materials Sampling
Permanent Cross Section Site #3

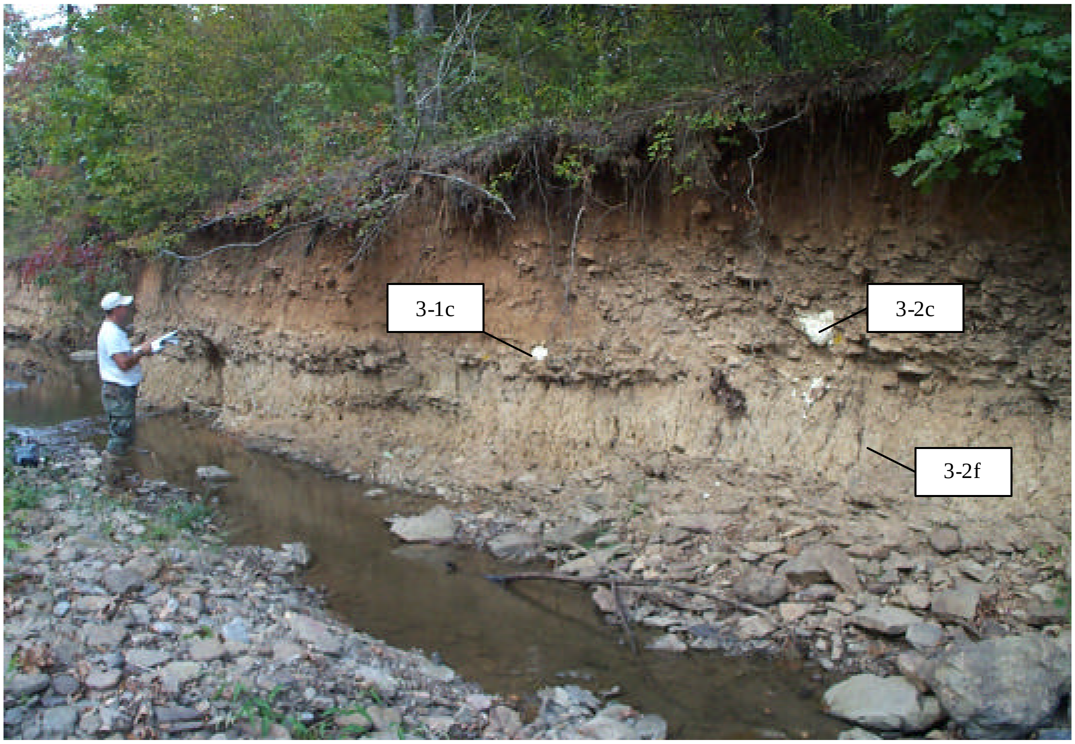


Photo of Right Bank near the Up-Stream Disturbed Riffle Cross Section

Bank Material Bulk Density and Particle Size Summary

Sample I.D.		Sample Bulk Density (lbs/ft^3)	Percentage of Sample		
			>2mm	2mm-.02mm	<.02mm
Fine Grained	3-1f	93.6	.007	25	75
	3-2f	99.2	15.3	36.2	48.5
	3-3f	85.5	31.5	29.6	38.9
Course Grained	3-1c	152.3	79.8	8.3	11.9
	3-2c	327.7	67.6	12.3	20.1

Appendix 5-C (continued)

West Fork White River Stream Bank Materials Sampling
Permanent Cross Section Site #4

Photo of Left Bank near the Riffle Cross Section

Bank Material Bulk Density and Particle Size Summary

Sample I.D.		Sample Bulk Density (lbs/ft^3)	Percentage of Sample		
			>2mm	2mm-.02mm	<.02mm
Course Grained	4-1c	172.3	88.0	6.1	5.9
	4-2c	111.7	83.1	8.0	8.9

Appendix 5-C (continued)

West Fork White River Stream Bank Materials Sampling
Permanent Cross Section Site #5

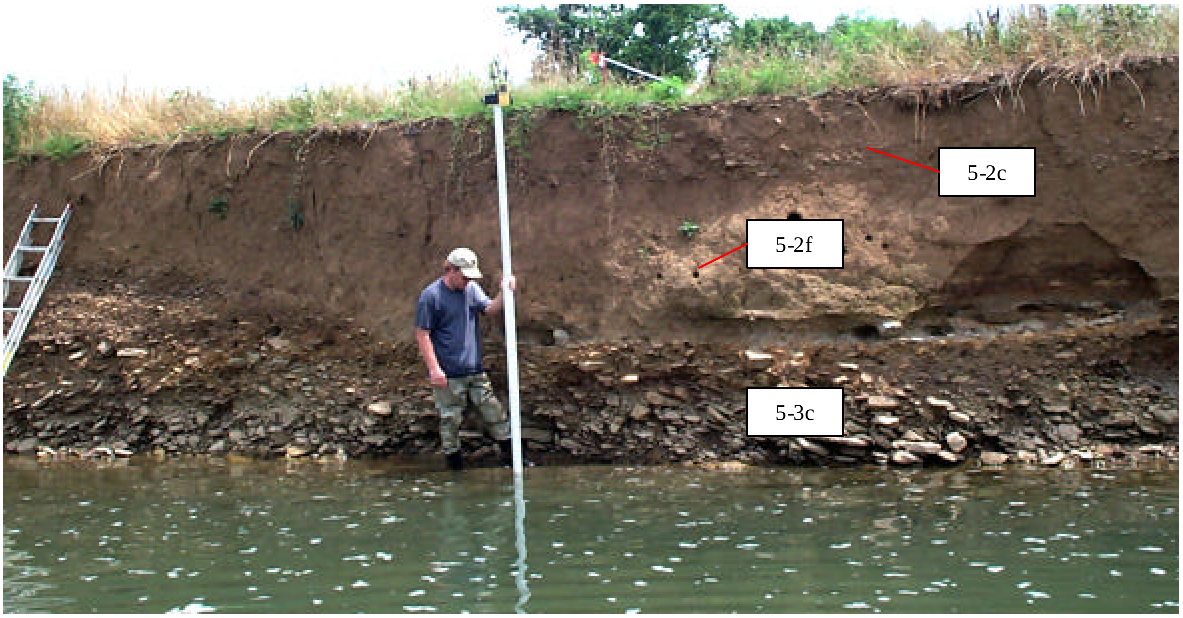


Photo of Right Bank near the Pool Cross Section

Bank Material Bulk Density and Particle Size Summary

Sample I.D.		**Sample Bulk Density** (lbs/ft^3)	**Percentage of Sample**		
			>2mm	**2mm-.02mm**	**<.02mm**
Fine Grained	5-1f	86.7	5.9	49.9	44.2
	5-2f	91.7	0	52.4	47.6
	5-3f	96.1	0	51.3	48.7
	5-4f	84.9	0	72.4	27.6
Course Grained	5-1c	125.4	83.3	15.3	1.4
	5-2c	89.9	82.6	14.2	3.2
	5-3c	186.6	69.2	24.5	6.3
	5-4c	106.7	89.6	6.0	4.4

Appendix 5-C (continued)

West Fork White River Stream Bank Materials Sampling
Permanent Cross Section Site #6

Photo of the Right Bank Up-Stream of the Riffle Cross Section

Bank Material Bulk Density and Particle Size Summary

Sample I.D.		Sample Bulk Density (lbs/ft^3)	Percentage of Sample		
			>2mm	2mm-.02mm	<.02mm
Fine Grained	6-1f	93.6	0	42.8	57.2
	6-2f	89.8	0	73.6	26.4
	6-3f	84.2	0	67.5	32.5
	6-4f	81.1	0	59.9	40.1
	6-5f	88.0	0	76.6	23.4
Course Grained	6-1c	164.8	77.8	15.5	6.7
	6-2c	216.0	81.0	12.8	6.2

Appendix 5-C (continued)

West Fork White River Stream Bank Materials Sampling
Permanent Cross Section Site #7

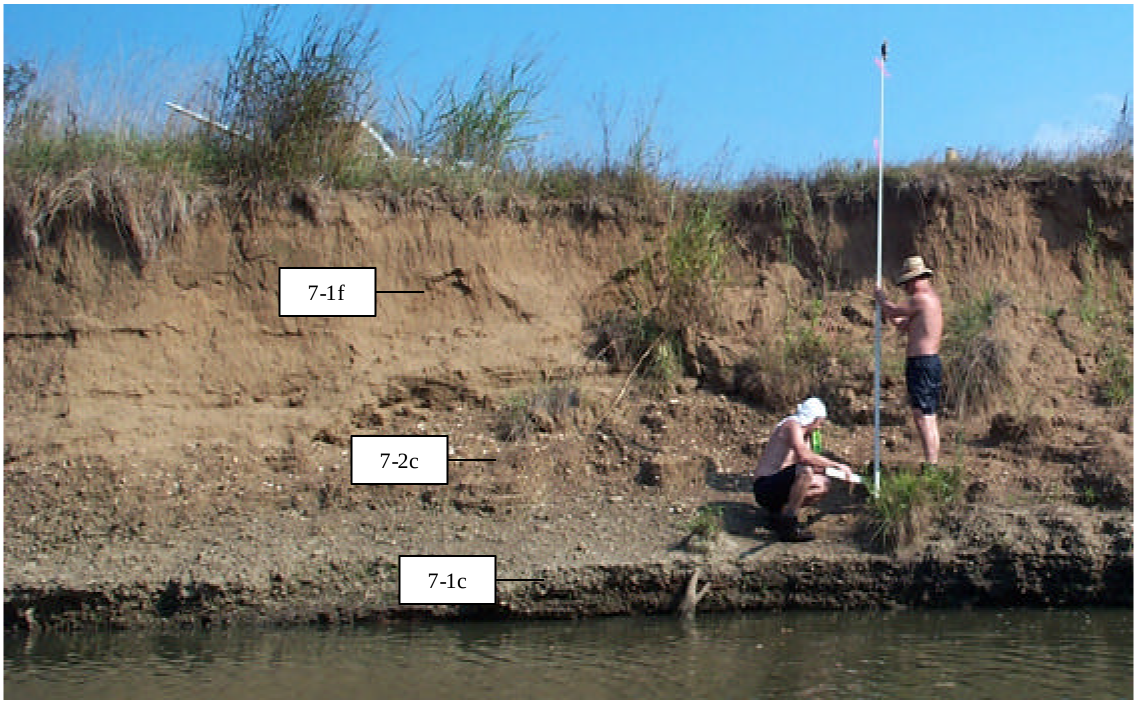


Photo of Right Bank at the Pool Cross Section

Bank Material Bulk Density and Particle Size Summary

Sample I.D.		Sample Bulk Density (lbs/ft^3)	Percentage of Sample		
			>2mm	2mm-.02mm	<.02mm
Fine Grained	7-1f	86.7	0	44.1	55.9
	7-2f	78.6	0	73.1	26.9
	7-3f	89.2	0	74.7	25.3
Course Grained	7-1c	204.7	70.0	23.8	6.2
	7-2c	144.8	78.9	17.2	3.9

Appendix 5-C (continued)

West Fork White River Stream Bank Materials Sampling
Permanent Cross Section Site #8

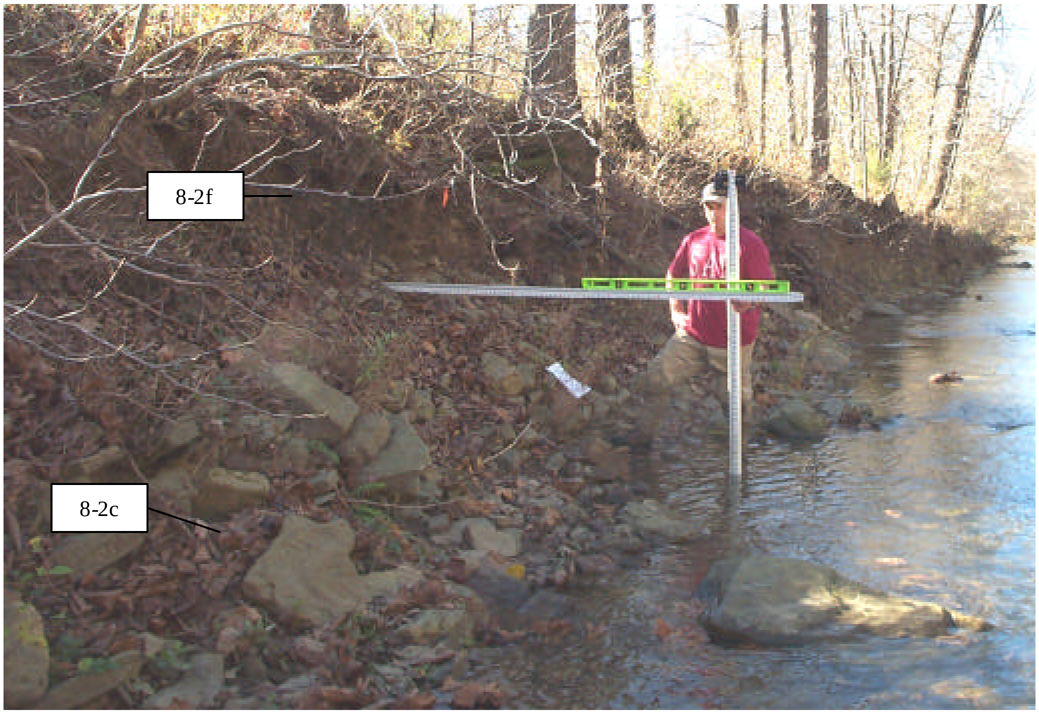


Photo of Left Bank at the Down-Stream Toe Pin

Bank Material Bulk Density and Particle Size Summary

Sample I.D.		Sample Bulk Density (lbs/ft^3)	Percentage of Sample		
			>2mm	2mm-.02mm	<.02mm
Fine Grained	8-1f	88.0	29.4	36.3	34.3
	8-2f	91.1	17.2	49.9	32.9
	8-3f	88.6	0	60.3	39.7
Course Grained	8-1c	166.6	84.1	13.3	2.6
	8-2c	137.9	82.0	12.6	5.4

Appendix 5-D
Road Survey Data Collection Variables

GPS Feature	Feature Attribute	Attribute Value
Road Segment	Road name	
	Road number	
	Surveyors/date	
	Road template	primitive 2 track
		single lane no ditch
		Dbl lane no ditch
		single lane with ditch
		dbl lane withditch
		other
	Status	open
		closed
	Ditch erosion	none
		1 - 12 inches
		> 12 inches
	Surface	native
		spot
		gravel
		asphalt
		other
	Functional class	local
		collector
		arterial
		other
		unclassified
	Road access	Drive in
		ATV access
		walk-in only
		other
	Road surface erosion	ruts < 2 inches
		ruts 2-6 inches
		rill erosion 6-12 inches
		rill erosion >12 inches
		no ruts
Crossdrains	Type	dip
		water bar
		culvert
		lead off ditch
		other
	Ditchblock	adequate
		inadequate
		not needed
	Culvert crossdrain	blocked
		properly functioning
		inlet bent
		undersized

Appendix 5-D (continued)

GPS Feature	Feature Attribute	Attribute Value
Wing ditch	Status	open
		blocked
	Outfall	forest floor
		stream course
Barrier	Type	berm
		gate
		cable
		other
	Status	adequate
		inadequate
Culvert -Stream Crossing	Culvert size	Diameter and # of Barrels
	Culvert Bottom	galvanized not rusted
		galvanized partly rusted
		galvanized badly rusted
		asphalt
		plastic
		concrete
		other
	Culvert lip	Step bevel
		Square
		Other
	Debris	Minor- hand clean
		Moderate
		heavy-need equipment
		none
	Inlet blockage	Gravel and cobble
		woody debris
		none
	Repairs needed	none
		clean up
		replacement
	Fish passage inlet	no drop
		drop 1-6 inches
		drop 6-12 inches
		drop >12 inches
	Fish passage outlet	no drop
		drop 1-6 inches
		drop 6-12 inches
		drop >12 inches
	Total Pipe Length	

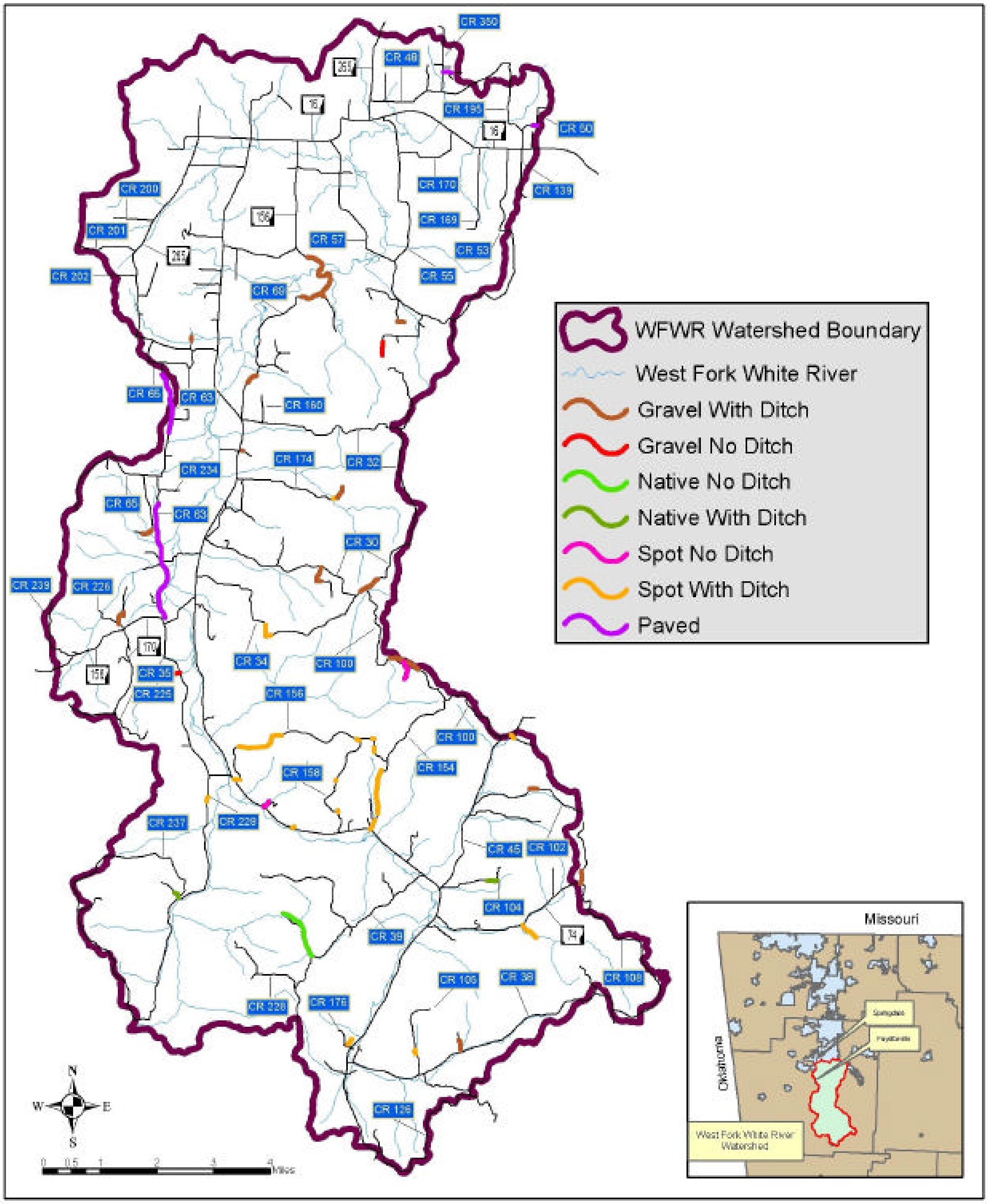
Appendix 5-D (continued)

GPS Feature	Feature Attribute	Attribute Value
Bridge or Box Culvert - Stream Crossing	Type	Bridge
		Box culvert
	Span	
	Number of lines	
	Condition	adequate
		inadequate
	Material	concrete
		wooden
		other
	Debris	minor- hand clean
		moderate
		heavy-need equipment
		none
	Fish passage inlet	no drop
		drop 1- 6 inches
		drop 6-12 inches
		drop >12 inches
	Fish passage outlet	no drop
		drop 1-6
		drop 6-12
		drop >12
	Total Pipe length	
Ford - Stream Crossing	Type	Natural
		Armoured
		other
	Condition	adequate
		inadequate
	Debris	minor- hand clean
		moderate
		heavy-need equipment
		none
	Fish passage inlet	no drop
		drop 1-6 inches
		drop 6-12 inches
		drop >12 inches
	Fish passage outlet	no drop
		drop 1-6 inches
		drop 6-12 inches
		drop >12 inches

Appendix 5-D (continued)

GPS Feature	Feature Attribute	Attribute Value
Slab - Stream Crossing	Type	slab w/ culverts
		slab w/out culverts
		other
	Span	
	Culvert condition	adequate
		inadequate
		blocked
	Debris	minor- hand clean
		moderate
		heavy-need equipment
		none
	Fish passage inlet	no drop
		drop 1-6 inches
		drop 6-12 inches
		drop >12 inches
	Fish passage outlet	no drop
		drop 1-6 inches
		drop 6-12 inches
		drop >12 inches
	Total Pipe Length	

Appendix 5-E
Locations of Randomly Selected Roads



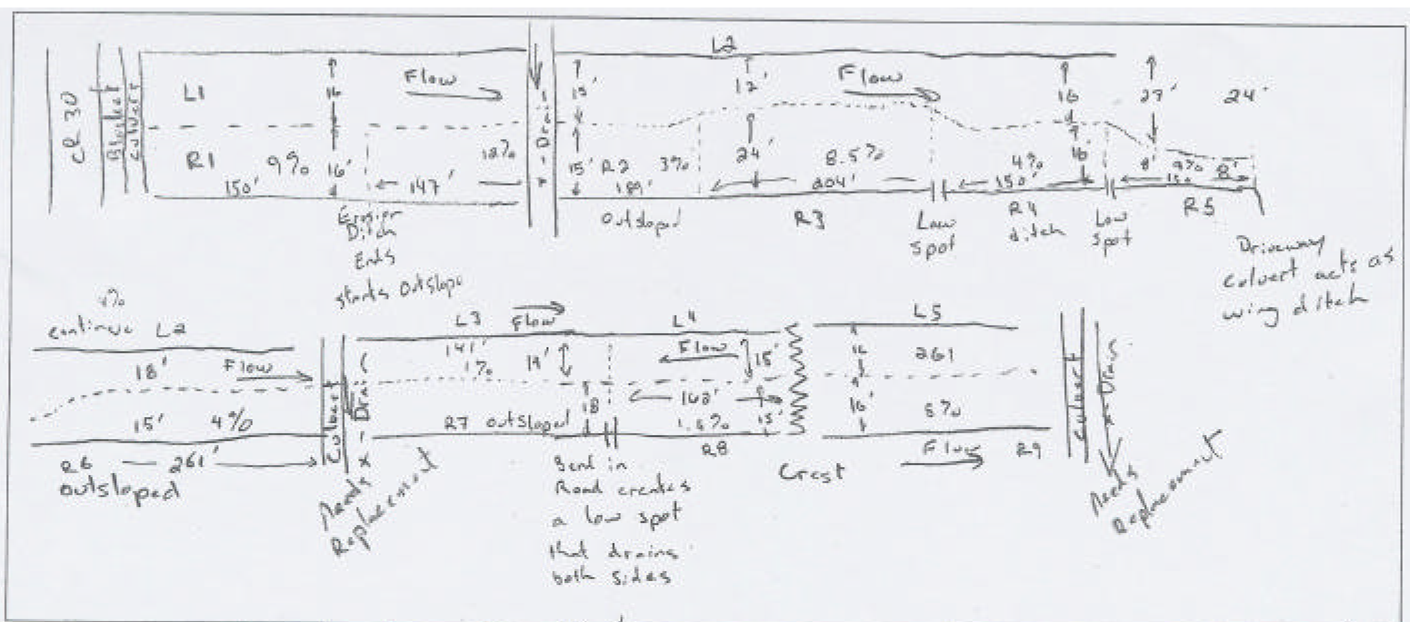
Appendix 5-F
WEPP Field Data
Version 03.26.2004

Date: 3/30/04
Survey Crew: TM, JB, MV
Road Number/Name: CR 1159
Location: Immediately off of CR 30

Road Surface: Native Spot → **Gravel** ← Paved

Ditches: → **Yes** ← No

Segment ID	**I**nslope **O**utslope **C**rown	Ruts? Yes or No	Ditch Bare or Vegetated	Road Grade (%)	Road Length (feet)	Road Width (feet)	Fill Grade (%)	Fill Width (feet)	Buffer Grade (%)	Buffer Length (feet)	Comments
L1	I		B	10.5	297	16					x-Drain Pond
R1	I		V	10.5	297	16	50	6			x-Drain Pond
R2	O			3	189	15			27	350	
R3	I		B	8.5	204	24			27	350	Low Spot
L2	I		B	5.5	954	17	75	4			x-Drain
R4	I		B	4	150	16			Check	Maps	Low Spot
R5	I		B	9	150	8			Check	Maps	As wing ditch
R6	O			4	261	15			Check	Maps	
L7	O			1	141	18					Low Spot
L3	I		V	1	141	14					Low Spot
R8	I		V	1.5	162	15					Low Spot
L4	I		B	1.5	162	15					Low Spot
R9	I		B	5	261	16					x-Drain
L5	I		B	5	261	16					x-Drain



ErF soil stony loam Ent...-Allegheny 40% Rock Content upper layers (Avg 20 to 60)
moderate use

Slope Class 0 - 2%

Enders Pasture Area (ac)	1372.4
Linker Pasture Area (ac)	0.0
Clarksville Pasture Area (ac)	0.0
Total Area in Class (ac)	**1372**
Total Area Modeled (ac)	181
Percent Area Modeled	13%
Arith. Avg. Sediment Yield (tons/ac)	0.10

Sediment Load ***arithmetic avg. coeff.*** ***(tons) =*** 21,272

Sediment Load ***area weight coeff. by soil type*** ***(tons) =*** 24,408

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	S-Shaped	14.0	0	0.1	0.1	113	0.1
		2	S-Shaped	16.6	10	0.0			0.0
		3	Concave	11.1	25	0.0			0.0
		4	S-Shaped	52.0	0	0.0			0.0
		5	S-Shaped	15.8	0	0.1			0.1
		6	Concave	9.3	0	0.1			0.1
		7	Concave	12.9	0	0.3			0.3
		8	S-Shaped	22.3	13	0.2			0.2
		9	S-Shaped	26.6	40	0.1			0.1

Appendix 5-G (continued).

Slope Class	2 - 4%
Enders Pasture Area (ac)	3290.8
Linker Pasture Area (ac)	32.3
Clarksville Pasture Area (ac)	206.7
Total Area in Class (ac)	**3530**
Total Area Modeled (ac)	453
Percent Area Modeled	13%
Arith. Avg. Sediment Yield (tons/ac)	0.34

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	S-Shaped	16.8	91	0.0	0.2	742	0.0
		2	S-Shaped	28.4	161	0.1			0.1
		3	S-Shaped	55.3	62	0.4			0.4
	2	1	Concave	43.2	0	0.1	0.2		0.1
		2	Concave	23.8	0	0.5			0.5
		3	S-Shaped	119.4	0	0.2			0.2
		4	Convex	23.1	0	0.1			0.1
LINKER	1	1	S-Shaped	72.7	884	0.2	0.2	6	0.2
CLARKSVILLE	1	1	Convex	7.8	0	0.2	0.5	97	0.2
		2	S-Shaped	5.0	0	0.2			0.2
		3	Convex	10.4	0	0.4			0.4
		4	Concave	7.6	0	1			1
		5	Concave	4.3	0	0.6			0.6
		6	S-Shaped	10.0	0	0.1			0.1
		7	S-Shaped	8.4	50	1			1
		8	S-Shaped	16.6	194	0.4			0.4

Appendix 5-G (continued).

Slope Class 4 - 6%

Enders Pasture Area (ac)	2959.5
Linker Pasture Area (ac)	327.6
Clarksville Pasture Area (ac)	199.8
Total Area in Class (ac)	**3487**
Total Area Modeled (ac)	573
Percent Area Modeled	16%
Arith. Avg. Sediment Yield (tons/ac)	0.67

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	Concave	89.6	40	0.5	0.4	1255	0.5
		2	S-Shaped	158.5	50	0.4			0.4
		3	S-Shaped	125.7	30	0.4			0.4
LINKER	1	1	S-Shaped	86.9	314	1.1	0.9	292	1.1
		2	Convex	37.4	0	0.7			0.7
		3	Convex	6.9	0	0.2			0.2
		4	Concave	6.3	0	0.8			0.8
		5	Convex	7.9	0	0.2			0.2
CLARKSVILLE	1	1	S-Shaped	19.0	0	0.8	0.8	158	0.8
		2	Convex	4.1	0	1.2			1.2
		3	Concave	11.2	0	0.7			0.7
		4	Convex	6.0	0	1.1			1.1
		5	Concave	13.7	0	0.6			0.6

Slope Class	6 - 8%	
Enders Pasture Area (ac)	2272.6	
Linker Pasture Area (ac)	541	
Clarksville Pasture Area (ac)	153.5	
Total Area in Class (ac)	**2967**	
Total Area Modeled (ac)	298	
Percent Area Modeled	10%	
Arith. Avg. Sediment Yield (tons/ac)		0.87

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	S-Shaped	3.9	0	1.3	1.0	2144	1.3
		2	Concave	4.1	0	1.1			0.8
		3	Concave	20.8	0	1.2			1.2
		4	Concave	9.2	0	0.9			0.9
		5	Convex	10.9	25	0.5			0.4
	2	1	Concave	10.5	0	0.9	0.9		0.9
LINKER	1	1	Convex	19.3	206	0.6	0.3	145	0.6
		2	Convex	11.4	470	1			1
		3	S-Shaped	53.5	615	0.6			0.6
		4	S-Shaped	121.2	541	0			0
CLARKSVILLE	1	1	Concave	2.0	17	1.5	0.9	135	1.5
		2	Concave	19.1	0	0.8			0.8
		3	Concave	12.3	0	0.9			0.9

Appendix 5-G (continued)

Slope Class	8 -10%
Enders Pasture Area (ac)	3235.1
Linker Pasture Area (ac)	470.6
Clarksville Pasture Area (ac)	0
Total Area in Class (ac)	**3706**
Total Area Modeled (ac)	518
Percent Area Modeled	14%
Arith. Avg. Sediment Yield (tons/ac)	1.06

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	Convex	9.9	60	0.9	1.2	5005	0.9
		2	Concave	32.8	10	1.2			1.0
		3	Concave	5.4	0	1.4			1.6
		4	S-Shaped	43.6	0	1.1			0.9
		5	Convex	32.0	0	1.0			1.0
		6	Concave	11.5	0	1.6			1.6
		7	Concave	13.5	0	2.1			2.1
		8	Concave	29.1	197	1.2			1.1
	2	1	Convex	38.3	0	2.9	1.9		2.9
		2	S-Shaped	59.4	115	1.6			0.5
		3	Concave	9.3	95	0.0			0.0
		4	Convex	6.8	0	1.0			1.0
LINKER	1	1	S-Shaped	39.3	593	0	0.3	134	0
		2	S-Shaped	97.2	748	0			0
		3	Convex	28.1	166	1.1			1.1
		4	Convex	24.4	58	0			0
		5	S-Shaped	37.6	484	0.9			0.9

Slope Class 10 - 13%

Enders Pasture Area (ac)	2007.6
Linker Pasture Area (ac)	86.7
Clarksville Pasture Area (ac)	0
Total Area in Class (ac)	**2094**
Total Area Modeled (ac)	212
Percent Area Modeled	10%
Arith. Avg. Sediment Yield (tons/ac)	1.67

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	Concave	23.3	15	1.2	3.1	5082	0.9
		2	Convex	24.2	130	2.9			2.9
		3	Concave	36.5	0	5.7			5.7
		4	Concave	21.3	0	2.0			2.0
		5	Convex	14.1	56	1.2			1.2
	2	1	Concave	16.7	0	2.0	2.0		2.0
LINKER	1	1	S-shaped	37.0	381	0.4	0.3	25	0.4
		2	Convex	6.8	98	0.6			0.6
		3	Convex	4.7	53	0.7			0.7
		4	S-shaped	27.0	376	0			0

Slope Class 13 - 16%

Enders Pasture Area (ac)	1506.7
Linker Pasture Area (ac)	152
Clarksville Pasture Area (ac)	0
Total Area in Class (ac)	**1659**
Total Area Modeled (ac)	475
Percent Area Modeled	29%
Arith. Avg. Sediment Yield (tons/ac)	3.40

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	S-shaped	93.5	417	3.7	3.9	5921	3.7
		2	Convex	59.8	314	0.0			0.0
		3	Convex	56.4	262	5.7			5.7
		4	Convex	154.9	594	4.0			3.8
		5	S-shaped	70.4	486	6.0			5.6
LINKER	1	1	Convex	39.9	257	1	1.0	152	1

Slope Class 16 - 19%

Enders Pasture Area (ac)	396.7
Linker Pasture Area (ac)	19.7
Clarksville Pasture Area (ac)	0
Total Area in Class (ac)	**416**
Total Area Modeled (ac)	176
Percent Area Modeled	42%
Arith. Avg. Sediment Yield (tons/ac)	2.37

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	Concave	129.0	495	5.1	5.1	2023	4.3
LINKER	1	1	S-shaped	38.5	815	0.5	0.7	14	0.3
		2	Convex	8.8	105	1.5			1.5

Slope Class > 19%

Enders Pasture Area (ac)	181.7
Linker Pasture Area (ac)	0
Clarksville Pasture Area (ac)	0
Total Area in Class (ac)	**181.7**
Total Area Modeled (ac)	22.0
Percent Area Modeled	12%
Arith. Avg. Sediment Yield (tons/ac)	5.30

Soil Type	Pasture number	Flow Segment	Slope Shape	Area (ac)	Buffer Length (m)	WEPP Soil Loss (ton/ac/yr)	Area Weighted WEPP coeff. (ton/ac/yr)	Sed load (tons)	WEPP Sediment Yield (ton/ac/yr)
ENDERS	1	1	Concave	22.0	0	5.3	5.30	963	4.3