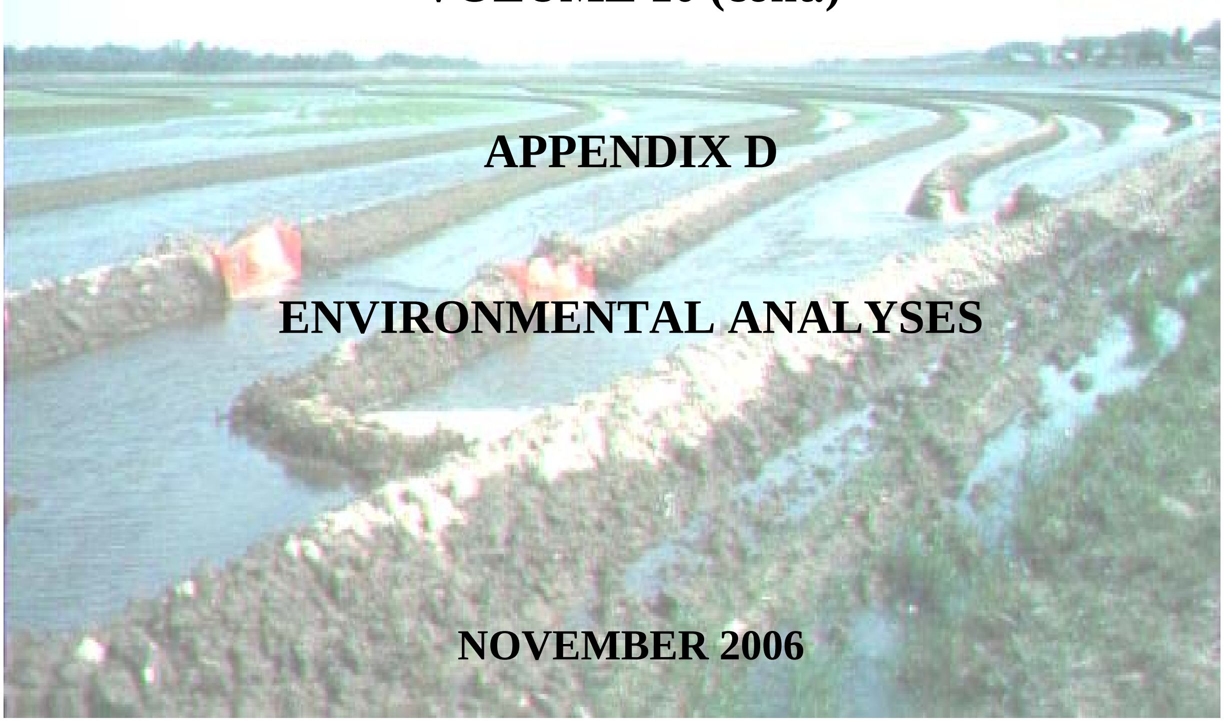
US Army Corps of Engineers®
Memphis District

GRAND PRAIRIE REGION AND BAYOU METO BASIN, ARKANSAS PROJECT

BAYOU METO BASIN, ARKANSAS

GENERAL REEVALUATION REPORT

VOLUME 10 (cont.)



APPENDIX D

ENVIRONMENTAL ANALYSES

NOVEMBER 2006

US Army Corps
of Engineers®
Memphis District

GRAND PRAIRIE REGION AND BAYOU METO BASIN, ARKANSAS PROJECT

BAYOU METO BASIN, ARKANSAS

GENERAL REEVALUATION REPORT

VOLUME 10 (cont.)

APPENDIX D

ENVIRONMENTAL ANALYSES

NOVEMBER 2006

SECTION XIII

TERRESTRIAL ANALYSIS

MARCH 2005

Section I

TERRESTRIAL HABITAT EVALUATION PROCEDURE BAYOU METO WATER SUPPLY AND FLOOD CONTROL STUDY BAYOU METO BASIN, ARKANSAS

US Army Corps of Engineers
Vicksburg District

Section I

TERRESTRIAL HABITAT EVALUATION PROCEDURE BAYOU METO WATER SUPPLY AND FLOOD CONTROL STUDY BAYOU METO BASIN, ARKANSAS

Contract No. DACW38-97-D-0004
Order No. WMC2
GEC Project No. 27311318

Submitted to
U.S. ARMY CORPS OF ENGINEERS
VICKSBURG DISTRICT
VICKSBURG, MISSISSIPPI

MARCH 2005

Submitted by
G.E.C., INC.
9357 INTERLINE
BATON ROUGE, LOUISIANA

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

TERRESTRIAL HABITAT EVALUATION PROCEDURES

TERRESTRIAL HABITAT EVALUATION PROCEDURE
BAYOU METO WATER SUPPLY AND FLOOD CONTROL STUDY
BAYOU METO BASIN, ARKANSAS

1.0 INTRODUCTION

Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service [USFWS], 1980) were used to evaluate potential impacts to terrestrial habitat within the Grand Prairie Region and Bayou Meto basin. The proposed plans incorporate the diversion of surface water from the Arkansas River through a network of new canals, existing streams, and new pipelines. Included in this evaluation are impacts to bottomland hardwoods, cypress/tupelo swamps, and forested riparian areas.

HEP is a quantitative system of evaluating habitat for a specific species, a group of species, or community types. Through the use of HEP the existing habitat quality of a project site can be calculated and the future conditions of that same project site can be predicted. The existing conditions and future conditions can then be compared to determine the impacts to the habitat by the proposed project. This system can also be used to determine quality and quantity of habitat needed to mitigate the impacts of the proposed project.

These procedures are based on habitat suitability index (HSI) models for specific species, groups of species, or community types. The models assign a suitability index (SI), ranging from 0.0 (unsuitable) to 1.0 (optimal), to the individual variables for the evaluation species. Through equations provided in the models, these SIs are combined to determine the HSI for the evaluation species in the habitat sampled. The HSIs represent the quality of the habitat sampled on a scale of 0.0 (unsuitable) to 1.0 (optimal) for each evaluation species.

The objectives of this HEP were to (1) determine the existing habitat quality of the project area for seven evaluation species and (2) estimate the potential impacts on the habitat quality from implementation of the various action alternatives. Direct impacts to the habitat such as land clearing, construction, and maintenance activities within the project area were the only impacts evaluated during this analysis.

2.0 PROJECT LOCATION

The Bayou Meto Basin project area includes portions of Arkansas, Jefferson, Lonoke, Prairie, and Pulaski counties in east central Arkansas. The area encompasses approximately 780,000 acres between the Arkansas and White rivers. A total of 11 hydrologic reaches were delineated for the flood damage reduction alternatives. The land use within the project boundaries includes a total of approximately 863,712 acres of land and water.

2.1 Background

Major problems identified in the Bayou Meto project area are the depletion of the alluvial aquifer and flooding. The aquifer, which is the principal source of irrigation water for most farms, may be permanently damaged if an alternative irrigation source is not located. The area's greatest need for flood relief is in the lower portion of the project area, and to a minor degree, in the upper part of the basin west of Lonoke, Arkansas.

The objective of this study is to develop a plan to protect ground-water resources and reduce flooding in the area while producing a supplemental agricultural water supply for irrigation; fish farming; and fish, wildlife, and waterfowl management and conservation. The project consists of four components: (1) a ground-water import system, (2) a multipurpose distribution and flood control system, (3) on-farm conservation measures, and (4) a ground-water evacuation system. Preliminary plans include diverting surface water from the Arkansas River immediately north of the David D. Terry Lock and Dam through a network of 159 miles of new canals, 363 miles of existing streams, and 640 miles of new pipelines. Floodwater would be eliminated at the existing Bayou Meto outlet with a pumping station. Additional structures required for efficient distribution and drainage includes numerous gated check structures, inverted siphons, and re-lift pumps.

3.0 ALTERNATIVES

Structural and non-structural measures were considered and evaluated in the formulation of alternative plans. Measures that had been determined either not feasible, unacceptable, or did not meet the needs of the area during feasibility studies were not considered in the general reevaluation. The measures not considered included groundwater artificial recharge, intensified mining of deeper aquifers, and construction of large reservoirs

The following is a presentation of the final alternatives developed for the Bayou Meto General Reevaluation. Some of the alternatives were carried forward through complete and detailed engineering, economic, and cost analyses. All alternatives were based on groundwater providing approximately 221,295 acre-feet annually, the long-term sustained yield of the alluvial aquifer from groundwater studies that will allow for aquifer recharge.

3.1 Water Supply (WS) Alternatives

3.1.1 Alternative WS-1 - No Action

This alternative establishes conditions that are expected to occur in the proposed project area in the absence of a project. The supply of irrigation water is decreasing as the groundwater reserves are being depleted. The desired land use and demand for irrigation water in the future will remain the same as present conditions; however, only about 45 percent of the project area can be irrigated during an average year. Alternative WS-1 was carried through detailed hydrologic and economic analyses and used as the base with which to compare the effects of all other alternatives.

3.1.2 Alternative WS-2 – Conservation with Storage

Alternative WS-2 consists of additional on-farm storage and conservation measures without any import water. Conservation measures would be implemented to maximize the use of existing water sources to the extent practical. These measures would be designed to increase the efficiency or usage of irrigation water from the current 60 percent efficiency rate to 70 percent efficiency rate. With this alternative the availability of existing runoff for capture would limit new reservoir construction to 4,941 acres and conservation measures could only be implemented on approximately 60 percent of the area's current irrigated acreage. This would mean that when the groundwater is depleted or regulated at the safe yield, only about 60 percent of the area could remain in irrigation in the absence of some form of supplemental source of irrigation water. The remainder of the area would convert to dryland agriculture.

3.1.3 Alternative WS-3 – 1,650 cfs Import System Plus Conservation and Storage

This alternative consists of a combination of conservation measures, on-farm storage, and a 1,650 cubic feet per second (cfs) import system. The conservation measures would be designed to achieve the optimum level increasing the irrigation efficiencies from 60 percent to 70 percent for the entire project area. These features are analyzed with three levels of on-farm storage reservoirs, 5,954 acres, 8,832 acres, and 14,544 acres of new reservoirs in addition to the existing reservoirs. On-farm storage would be used to capture existing runoff and to store import water for use during peak demand periods or when other sources cannot provide the need. Import water is provided by transfer of excess water from the Arkansas River to the farms through a system of new canals, existing streams, and pipelines. These three components are not independent or stand alone features. They are related and depend on each other to function properly. The above three combinations are designated as:

- Alternative WS-3A – 5,954 acres of additional storage reservoirs
- Alternative WS-3B -- 8,832 acres of additional storage reservoirs
- Alternative WS-3C -- 14,544 acres of additional storage reservoirs

3.1.4 Alternative WS-4 – 1,750 cfs Import System Plus Conservation and Storage

This alternative is identical to Alternative WS-3 with the exception of using a 1,750 cfs import system instead of a 1,650 cfs. It consists of the same combination of conservation measures and on-farm storage reservoirs as AlternativeWS-3. The conservation measures are set at 70 percent for the entire project area with on-farm storage reservoirs of 5,954 acres, 8,832 acres, and 14,544 acres of new reservoirs in addition to the existing reservoirs. These combinations are designated as:

- Alternative WS-4A – 5,954 acres of additional storage reservoirs
- Alternative WS-4B -- 8,832 acres of additional storage reservoirs
- Alternative WS-4C -- 14,544 acres of additional storage reservoirs

3.1.5 Alternative WS-5 – 1,850 cfs Import System Plus Conservation and Storage

Alternative WS-5 also consists of the conservation features and on-farm storage levels used in alternatives WS-3 and WS-4. Alternative WS-5 uses a 1,850 cfs import system in addition to the conservation features and on-farm storage reservoirs. These combinations of Alternative 5 are designated as:

- Alternative WS-5A – 5,954 acres of additional storage reservoirs
- Alternative WS-5B -- 8,832 acres of additional storage reservoirs
- Alternative WS-5C -- 14,544 acres of additional storage reservoirs

3.2 Flood Control (FC) Alternatives

Five alternatives that would provide flood damage reduction were identified to be carried forward for investigation of this project. The flood damage reduction alternatives for Bayou Meto were divided into 11 hydrologic reaches. Detailed descriptions of the work to be done in the 11 reaches are shown in Table 1. The alternatives follow.

3.2.1 Alternative FC-2: Channel Cleanout/Enlargement

Consists of channel excavation to provide some flood relief for the more frequently flooded reaches. The work would be accomplished from one side of the channel and would not require any bank lines to be cut back since all material would be excavated from the bottom of the channel.

3.2.2 Alternative FC-2A: Alternative FC-2 with Water Supply Adjustments

This alternative would be the same as Alternative FC-2 with the exception of the Indian Bayou Ditch and Crooked Creek areas. Water supply and flood damage reduction channel work would overlap in these areas as discuss in the detailed description of the work to be done.

3.2.3 Alternative FC-3A: Alternative FC-2A with 1,000 cfs Pump on Little Bayou Meto (LBM)

This plan adds pump, structural, and channel features to Alternative FC-2A.

3.2.4 Alternative FC-3B: Alternative FC-2A with 3,000 cfs Pump on LBM

This alternative proposes the same features as indicated in Alternative FC-3A except with a 3,000 cfs pump.

3.2.5 Alternative FC-5

Two hinged crest gates would be used to divert flow from the Salt Bayou Channel to Dry Bayou then into a wildlife area located between Salt Bayou and Big Bayou Meto. A 100-foot hinged crest gate that would be constructed immediately downstream from the junction of Salt 50 and Dry Bayou (mile 13.65). This structure could be raised to divert flow and in a lowered position would pass flood flows down Salt Bayou without affecting stages. A smaller 25-foot hinged crest gate would be constructed in Dry Bayou that would divert flow into the wildlife area. This alternative was determined to have minimal impacts to terrestrial habitat; therefore, habitat analysis of this alternative was not carried any further.

Table 1. Bayou Meto Flood Control Alternatives

Alternative	Reaches	Area of Work	Mileage Improved	Type of Improvement
2-Channel Cleanout/ Enlargement	11-	Indian Bayou	17-29	No work
	11-	Indian Bayou Ditch	50-28	Excavation
	09-	Indian Bayou 50	0-13.4 13.4-16.6	Selective clearing Channel cleanout/ weirs placement
	09-	Wabbaseka Bayou 100	38.8-49.9	Excavation
	08 and 09	Wabbaseka Bayou 50	20.6-38.8 17.7-20.6 (the lower end of WABA)	Selective clearing Channel cleanout
	08-	Boggy Slough	11.5-17.7	Channel cleanout
	08-	Little Bayou Meto 100	7.5-11.5	Excavation
	08-	Salt Bayou (40 and 50)	SALT40-0-5.0 SALT50-5.0-13.66	Excavation Selective clearing
	04-	Crooked Creek Ditch	0.0-9.6	Excavation
	05-	Crooked Creek Channel	8.0-16.6 4.3-13.3	Excavation Weirs modification
	06-	Two Prairie Creek-Two Prairie 100	0-6.8 6.8-12.64	Excavation
	06-	Two Prairie 200 and Two Prairie 300	12.64-19.1	Excavation
	02-	Big Bayou Meto	92.9-100.8	Channel cleanout
	03-	Big Bayou Meto	132.8-146	Excavation
2A – Alt 2 w/water supply adjustment	11-	Indiana Bayou Ditch	50-58	Increasing the channel size, excavation
	04-	Crooked Creek Ditch 100	0-9.6	Increase channel bottom to 35, 45 and 55 feet
	05-	Crooked Creek	8-16.6	Increase channel bottom from 50 to 60 feet in the reach and modify weirs as in Alt 2
3A – Alt 2A w/1,000 cfs pump on LBM	07-	Little Bayou Meto 1	0 of LBM 50	Pump constructed adjacent to the LBM gravity floodgates
	07-	Little Bayou Meto 50	9.8	Replacement of two bridges that span the existing channel
	07-	Cannon Brake Structure modification		Second structure adjacent to the existing Cannon Brake
	08	Little Bayou Meto 100	9.8-11.5	Excavation
	08	Boggy Slough 40	11.5-12.7	Excavation
	08	Boggy Slough diversion	12.7-17.7	5-miles long channel with a 30-foot bottom width that would bypass the existing BS reach.

Table 1. Bayou Meto Flood Control Alternatives

Alternative	Reaches	Area of Work	Mileage Improved	Type of Improvement
	08	Boggy Slough diversion weirs and grad control structures		To prevent head cutting in the channel
3B – Alt 2A w/3,000 cfs pump on LBM	07	Cannon Brake Structure		Connecting channel down stream of the CBS. Replacement of two bridges that span the existing channel.
	07	Cannon Brake Structure		Increase the size to five 10x10 gates to pass the flow to the pump
	08	Upstream of the Cannon Brake Structure		Channel work would remain the same.
5 – Waterfowl features	08	Salt Bayou 50 and Dry Bayou	13.65	Divert flow from the Salt Bayou Channel into Dry Bayou

3.3 Recommended Plan

The recommended plan is the combination of measures which best meets the identified needs and opportunities of the project area consistent with the planning objectives and constraints. The agricultural water supply components include (1) conservation increased irrigation efficiencies, (2) groundwater protection, (3) additional on-farm storage reservoirs, and (4) an import water system. The waterfowl improvement component which also provides some flood damage reduction benefits includes (1) channel improvement, (2) a 1,000 cubic foot per second pump station, and (3) numerous other water management measures. The plan also includes reforestation of 23,000 acres of floodplain, (2) reforestation of 2,643 acres of riparian buffer, (3) restoration of 10,000 acres of prairie, and creation of 240 acres of moist soil habitat. For a detailed discussion of this plan see Section III of the main report.

4.0 TERRESTRIAL HABITAT EVALUATION PROCEDURES

HEP methodology was developed in the mid-1970s and has been revised over time by the USFWS. U.S. Army Corps of Engineers (USACE) contractor staff members, who have attended USFWS HEP training workshops and have been involved in a number of prior HEP projects, followed these methods for this study. Additionally, all procedures and related decisions were reviewed by or approved by the interagency HEP team, which was comprised of U.S. Army Corps of Engineers, USFWS, Environmental Protection Agency, Natural Resource Conservation Service, Arkansas Natural Heritage Commission, Arkansas Game and Fish Commission, and G.E.C., Inc. representatives.

4.1 Pre-Field Planning

The initial process of the HEP is to determine the cover types present within the project area. The project cover types surveyed were bottomland hardwoods and cypress/tupelo swamps. Next, evaluation species were chosen to represent various habitat requirements of the wildlife species occurring within the various cover types identified in the project area. The Vicksburg District, Corps of Engineers along with members of the HEP Team chose the gray squirrel (*Sciurus carolinensis*), mink (*Mustela vison*), barred owl (*Strix varia*), wood duck (*Aix sponsa*), Carolina chickadee (*Parus carolinensis*), and pileated woodpecker (*Dryocopus pileatus*) as the evaluation species for the study area. For the purposes of this analysis the riverine component of the mink model was utilized.

The project area consists of approximately 780,000 acres between the Arkansas and White Rivers in east central Arkansas. Bottomland hardwood stands and cypress/tupelo swamps within the project area were identified from U.S. Geological Survey (USGS) 7.5-minute quadrangles and numbered. The 80 tracts from the more than 300 tracts identified and numbered were randomly chosen using Microsoft Excel software. The scope of work stated that two plots per tract were to be sampled giving a total of 160 plots. Once the tracts of land were located, the following criteria had to be met: (1) tracts had to be at least 10 acres in size, (2) tracts had to be forested, defined as having at least 25 percent cover of trees, (3) data would be collected from two sample plots with radii of 37 and 53 feet per plot spaced at 300 feet intervals apart, (4) percent shoreline cover taken on tracts adjacent to the shores of a river bank or lake, and (5) in seasonally flooded areas the percent cover of emergent herbaceous vegetation and percent of water surface covered by potential wood duck brood and winter cover would be collected.

4.2 Field Data Collection Methodology

Bottomland hardwoods and cypress/tupelo swamps were sampled according to Terrestrial Habitat Sampling Protocol. All data was recorded on standard data sheets developed for this study. To ensure adequate sample size, data was collected within nested 1/10th and 1/5th-acre plots as specified on the data sheet. The center of each plot was marked with pink flagging and additional flags were hung at the 1/10th and 1/5th –acre plot boundaries, at 0, 90, 180, and 270 degrees for reference to plot boundaries. The tally person at plot center had a logger's tape to further confirm plot limits when needed. Estimates of percent cover were determined by consensus.

Tree heights were measured with a clinometer, and tree diameters were measured with a D-tape. The majority of "count data," such as *number of stumps*, were confirmed by other members of the sampling crew, and all "consensus data," such as *percent of water surface covered by potential brood cover*, were discussed and agreed upon by all crew members. Data for the variables such as *percent of year with water present* was determined from the elevation and hydrologic data provided by the Corps.

A total of 160 plots were sampled in the designated tracts during the month of September 2000. Raw data was entered into a spreadsheet and in this process; all data sheets were reviewed for completeness and consistency.

5.0 DATA ANALYSIS

Using the collected raw data, the variables for each evaluation species were assigned a SI. These SIs were combined using the equations provided in the evaluation species models, to determine the HSI for that species within the sampled habitat. The HSIs along with the acreage of each cover type utilized by the evaluation species were then entered into the HEP accounting software to calculate the Habitat Units (HU) provided by the project area for each evaluation species. Habitat units represent the number of acres within the project area that provide optimum habitat for the evaluation species. The software further averages these HUs over the economic life of the project to provide Average Annual Habitat Units (AAHU) available within the project area for each evaluation species under each alternative. These units can then be used to compare the impacts of each alternative on the terrestrial habitat within the project area.

The acreage of terrestrial habitat available for each of the proposed projects and within each reach was provided by the Vicksburg District, Corps of Engineers GIS Department. The direct impacts to the terrestrial habitat for each proposed project were also provided by the District. The HSIs for each evaluation species were assumed to remain the same throughout the life of the project. Attachment 1 contains tables for each project and hydrologic reach, which presents the HSIs and the acreage entered into the HEP software.

The HEP Accounting Software is also capable of providing the acres required to compensate for the losses calculated under each project alternative. In order to calculate required compensation acres, a management plan was entered into the software. This plan consists of 500 acres to be reforested. The HSIs utilized in the model were provided by the Vicksburg District, Corps of Engineers. These HSIs were standards that have been used in several past projects and represent the quality of the habitat for each of the evaluation species under reforested conditions.

6.0 RESULTS

The data was initially analyzed for the Water Supply Project and the Flood Damage Reduction Project. Under the Flood Damage Reduction Project the data was analyzed for the entire project area and for each hydrologic reach. Table 2 presents the available AAHUs calculated in the model for the existing conditions and each of the alternatives along with the net change from the existing conditions for each alternative. The available habitat within the project area provides favorable habitat for the Carolina chickadee and the mink with HSIs of 0.68 and 0.76, respectively. An average HSI of 0.49 was calculated for the barred owl indicating fair habitat conditions. However, the pileated woodpecker, wood duck, and gray squirrel have very low HSIs ranging from 0.06 to 0.38. These low HSIs reveal poor habitat conditions exist for these species within the project area. Attachment 2 contains tables for each evaluation species that presents the SIs for each of the variables collected at each sample plot. Table 3 presents the acres calculated by the HEP software that are required to compensate for the terrestrial impacts.

Following this initial analysis described above, an additional analysis was conducted to further determine the hydrologic impacts of flood reduction plan 3A. This analysis revealed that the flood reduction in the study area on bottomland hardwoods would have various effects. A substantial portion of the bottomland hardwood habitat in the study area would be improved by a

Table 2. Average Annual Habitat Units
Bayou Meto Habitat Evaluation Procedures

Category	No Action	Alternative FC2	Net Change	Alternative FC2A	Net Change	Alternative FC3A	Net Change	Alternative FC3B	Net Change
Water Supply	175,680.24	173,905.11	-1,775.13	173,905.11	-1,775.13	173,905.11	-1,775.13	173,905.11	-1,775.13
Flood Damage Reduction	300,968.73	295,829.36	-5,139.37	295,712.96	-5,255.77	291,543.55	-9,425.18	290,735.14	-10,233.59
Reach 1	37,309.87	37,279.27	-30.60	37,279.27	-30.60	36,880.29	-429.58	36,658.45	-651.42
Reach 2	40,363.03	40,273.28	-89.75	40,273.28	-89.75	40,273.28	-89.75	40,273.28	-89.75
Reach 3	14,431.51	14,354.68	-76.83	14,399.37	-32.14	14,399.37	-32.14	14,399.37	-32.14
Reach 4	20,606.73	20,531.52	-75.21	20,524.08	-82.65	20,524.08	-82.65	20,524.08	-82.65
Reach 5	9,741.44	9,426.15	-315.29	9,310.52	-430.92	9,310.52	-430.92	9,310.52	-430.92
Reach 6	39,674.86	39,204.84	-470.02	39,204.84	-470.02	39,674.86	0.00	39,204.84	-470.02
Reach 7	11,521.11	11,493.05	-28.06	11,493.05	-28.06	11,050.45	-470.66	10,933.93	-587.18
Reach 8	90,103.79	86,545.90	-3,557.89	86,545.90	-3,557.89	82,748.01	-7,355.78	82,748.01	-7,355.78
Reach 9	3,941.50	3,577.63	-363.87	3,577.63	-363.87	3,577.63	-363.87	3,577.63	-363.87
Reach 10	11,310.54	11,310.54	0.00	11,310.54	0.00	11,310.54	0.00	11,310.54	0.00
Reach 11	3,602.16	3,470.38	-131.78	3,432.34	-169.82	3,432.34	-169.82	3,432.34	-169.82

Table 3. Acres Required for Compensation

Category	Alternative FC2	Alternative FC2A	Alternative FC3A	Alternative FC3B
Water Supply	1,011	1,011	1,011	1,011
Flood Damage Reduction	2,526.58	2,992.86	5,367.11	5,827.4
Reach 1	17.42	17.42	244.62	570.95
Reach 2	51.11	51.11	51.11	51.11
Reach 3	43.75	18.30	18.30	18.30
Reach 4	48.83	47.86	47.06	47.06
Reach 5	179.54	245.58	245.38	245.38
Reach 6	267.65	267.65	0.00	267.65
Reach 7	15.98	15.98	268.01	334.36
Reach 8	2,026.02	2,026.02	4,188.70	4,188.70
Reach 9	207.20	207.20	207.20	207.20
Reach 10	0.00	0.00	0.00	0.00
Reach 11	75.04	96.70	96.70	96.70

reduction in flooding and another substantial portion would not be affected significantly, only a smaller portion of the woodlands would be adversely affected. It was determined after this analysis that only the direct impacts of alternative 3A should be calculated. According to this reanalysis of plan 3A a total of 1,691.22 terrestrial AAHUs would be lost and this loss would require the reforestation of 963 acres of frequently flooded cleared lands for compensatory mitigation.

7.0 DISCUSSION

7.1 Water Supply Project

Under the existing conditions the project area for the water supply project provides a combined total of 175,680.24 AAHUs. The implementation of each alternative would reduce the amount of available habitat by 798 acres; thereby, reducing the AAHUs to 173,905.11. Therefore, the selection of either of these alternatives would have no greater impacts on the terrestrial habitat than any of the other alternatives. In order to compensate for these losses, approximately 1,011 acres would need to be reforested for this alternative.

7.2 Flood Damage Reduction Project

This project was developed in an attempt to reduce the damage caused from frequent and prolonged flooding within the project area. As for terrestrial habitat, several forested stands within the project area remain inundated for extended periods of time. If the frequency and duration of the flooding in these stands are not reduced, the timber and terrestrial habitat currently existing within these stands could be damaged or lost. This project would control the flooding within these areas and protect the existing terrestrial habitat. Over an extended period of time the quality of the terrestrial habitat would increase due to the reduced flooding. Some of these areas are actively managed by state or federal agencies and would attain that higher quality much faster than those areas privately owned and not managed. A terrestrial analysis of this project was performed on the entire project area and within each of the hydrologic reaches identified by the Corps of Engineers. The entire project area provides a combined total of 300,968.73 AAHUs. The existing AAHUs for each reach are presented in Table 2.

7.3 Alternative FC2

If implemented, this alternative would impact approximately 776 acres of terrestrial habitat for the barred owl, gray squirrel, pileated woodpecker, and the Carolina chickadee. As for the wood duck, the alternative would reduce the amount of available acres from 11,080 to 10,914. The mink habitat would be reduced by 4,775 acres. These reductions in acres of terrestrial habitat would decrease the combined AAHUs for all the evaluation species to 295,829.36 within the entire flood damage reduction project area. This impact would require the reforestation of approximately 2,926 acres of non-forested land to compensate for the losses under this alternative.

Individual analyses were performed on each of the 11 hydrologic reaches. The net changes in AAHUs for each of these reaches and the acres required for compensation are presented in tables 2 and 3.

7.4 Alternative FC2A

Implementation of Alternative 2A would impact the same amount of acres for the wood duck as Alternative 2. Mink habitat would be reduced by 4,719 acres, which is somewhat less than Alternative 2. As for the other evaluation species, the available acres would decrease by 871 acres. The combined impacts equate to a reduction in AAHUs by 5,255.77 to give a total of 295,712.96 AAHUs within the project area. Approximately 2,993 acres of mitigation lands will be required to off set the impacts of this alternative.

Individual analyses were performed on each of the 11 hydrologic reaches. The net changes in AAHUs for each of these reaches and the acres required for compensation are presented in tables 2 and 3.

7.5 Alternative FC3A

Wetland impacts associated with FC2A and FC3A were initially assessed strictly through the use of hydraulic models and GIS mapping. Pre-project and post-project wetland scenes were generated that approximated jurisdictional wetland boundaries. The acreage differences between the pre-project scene and alternative wetland scenes were used as estimates of the areal extent of wetland impacts for each alternative. FC2A had relatively limited hydrologic impacts in comparison to FC3A because FC3A includes a 1,000-cfs pump station on Little Bayou Meto. During the review of preliminary impact evaluation results, the inter-agency planning team discovered that adverse impacts to bottomland hardwoods (BLH) were likely overstated. The inter-agency team determined that additional analyses were needed to identify the actual hydrologic effects of FC3A. FC3A was selected for reevaluation because it included the 1,000-cfs pump station and would have a relatively greater effect on hydrology than FC2A.

A subsequent evaluation of potential Alternative FC3A impacts on BLH was conducted by the University of Missouri's Gaylord Memorial Laboratory. This study found that many BLH tracts originally shown to be adversely affected by FC3A were actually being stressed from excessive flooding and inadequate drainage; this study concluded that these areas of BLH would benefit from FC3A. Also, most of the privately owned BLH areas shown to be impacted by FC3A are greentree reservoirs that are enclosed by levees and hydraulically manipulated for waterfowl hunting. These private greentree reservoirs would not be affected by FC3A. As a follow-up to the University of Missouri study, a hydrogeomorphic (HGM) evaluation was performed to assess the potential indirect (hydrologic) effects of FC3A on BLH and to determine appropriate mitigation for these impacts.

Based on the above studies, the planning team decided that the terrestrial HEP would be used solely for evaluating the direct impacts associated with FC3A. Consequently, 1,691.22 AAHUs would be lost instead of the 9,425.18 AAHUs shown as a loss in Table 2 and this loss would require the reforestation of approximately 963 acres of frequently flooded cleared lands instead of the 5,367.11 shown in Table 3 to compensate for the losses.

Individual analyses were performed on each of the 11 hydrologic reaches. The net changes in AAHUs for each of these reaches and the acres required for compensation are presented in tables 2 and 3.

7.6 Alternative FC3B

The implementation of Alternative 3B would result in the direct impact of approximately 10,173 acres of mink habitat, 184 acres of wood duck habitat, and 1,240 acres of habitat for the barred owl, gray squirrel, pileated woodpecker, and Carolina chickadee. The total AAHUs available within the project area after implementation of this alternative would be 290,735.14. This is a reduction of 10,233.59 AAHUs from the current available AAHUs. Reforested acres for this alternative will require the reforestation of approximately 5,827 acres to offset the terrestrial impacts from implementation of the alternative.

Individual analyses were performed on each of the 11 hydrologic reaches. The net changes in AAHUs for each of these reaches and the acres required for compensation are presented in tables 2 and 3.

8.0 MITIGATION

In order to compensate for the habitat losses realized through the implementation of the Flood Damage Reduction and Water Supply projects, cleared land would be restored to bottomland hardwood forest. As presented in Section 7.0 Discussion, the compensation acreage for the terrestrial impacts of the recommended plan for both Flood Damage Reduction and Water Supply would be 1,974 acres.

8.1 Restoration Features

The results of evaluating two features of the restoration measures using the species utilized in this HEP evaluation are given in Table 4.

Table 4. Total Acres and AAHUs Provided by Two Restoration Features

Feature	Acres to be Reforested	Average AAHUs/Acre	Total AAHUs Provided by Reforestation
Floodplain Reforestation	23,000	2.75	63,250
Riparian Buffers	2,643	2.75	7,268
Total	25,643		70,518

Attachment 1

DATA UTILIZED IN HEP SOFTWARE

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Bayou Meto Flood Damage Reduction (METOFLOD)

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	11080	0.1	Wood Duck	11080	0.1
Mink	28571	0.76	Mink	28571	0.76
Barred Owl	152733	0.49	Barred Owl	152733	0.49
Gray Squirrel	152733	0.38	Gray Squirrel	152733	0.38
Pileated Woodpecker	152733	0.06	Pileated Woodpecker	152733	0.06
Carolina Chickadee	152733	0.68	Carolina Chickadee	152733	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	11080	0.1	Wood Duck	10914	0.1
Mink	28571	0.76	Mink	23796	0.76
Barred Owl	152733	0.49	Barred Owl	151957.2	0.49
Gray Squirrel	152733	0.38	Gray Squirrel	151957.2	0.38
Pileated Woodpecker	152733	0.06	Pileated Woodpecker	151957.2	0.06
Carolina Chickadee	152733	0.68	Carolina Chickadee	151957.2	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	11080	0.1	Wood Duck	10914	0.1
Mink	28571	0.76	Mink	23852	0.76
Barred Owl	152733	0.49	Barred Owl	151861.9	0.49
Gray Squirrel	152733	0.38	Gray Squirrel	151861.9	0.38
Pileated Woodpecker	152733	0.06	Pileated Woodpecker	151861.9	0.06
Carolina Chickadee	152733	0.68	Carolina Chickadee	151861.9	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	11080	0.1	Wood Duck	10961	0.1
Mink	28571	0.76	Mink	19011	0.76
Barred Owl	152733	0.49	Barred Owl	151677.8	0.49
Gray Squirrel	152733	0.38	Gray Squirrel	151677.8	0.38
Pileated Woodpecker	152733	0.06	Pileated Woodpecker	151677.8	0.06
Carolina Chickadee	152733	0.68	Carolina Chickadee	151677.8	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	11080	0.1	Wood Duck	10896	0.1
Mink	28571	0.76	Mink	18398	0.76
Barred Owl	152733	0.49	Barred Owl	151493	0.49
Gray Squirrel	152733	0.38	Gray Squirrel	151493	0.38
Pileated Woodpecker	152733	0.06	Pileated Woodpecker	151493	0.06
Carolina Chickadee	152733	0.68	Carolina Chickadee	151493	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Bayou Meto Flood Damage Reduction Reach 1

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	115	0.1	Wood Duck	115	0.1
Mink	1457	0.76	Mink	1457	0.76
Barred Owl	19996	0.49	Barred Owl	19996	0.49
Gray Squirrel	19996	0.38	Gray Squirrel	19996	0.38
Pileated Woodpecker	19996	0.06	Pileated Woodpecker	19996	0.06
Carolina Chickadee	19996	0.68	Carolina Chickadee	19996	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	115	0.1	Wood Duck	115	0.1
Mink	1457	0.76	Mink	1457	0.76
Barred Owl	19996	0.49	Barred Owl	19977.9	0.49
Gray Squirrel	19996	0.38	Gray Squirrel	19977.9	0.38
Pileated Woodpecker	19996	0.06	Pileated Woodpecker	19977.9	0.06
Carolina Chickadee	19996	0.68	Carolina Chickadee	19977.9	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	115	0.1	Wood Duck	115	0.1
Mink	1457	0.76	Mink	1457	0.76
Barred Owl	19996	0.49	Barred Owl	19977.9	0.49
Gray Squirrel	19996	0.38	Gray Squirrel	19977.9	0.38
Pileated Woodpecker	19996	0.06	Pileated Woodpecker	19977.9	0.06
Carolina Chickadee	19996	0.68	Carolina Chickadee	19977.9	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	115	0.1	Wood Duck	100	0.1
Mink	1457	0.76	Mink	959	0.76
Barred Owl	19996	0.49	Barred Owl	19977.9	0.49
Gray Squirrel	19996	0.38	Gray Squirrel	19977.9	0.38
Pileated Woodpecker	19996	0.06	Pileated Woodpecker	19977.9	0.06
Carolina Chickadee	19996	0.68	Carolina Chickadee	19977.9	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	115	0.1	Wood Duck	100	0.1
Mink	1457	0.76	Mink	681	0.76
Barred Owl	19996	0.49	Barred Owl	19977.9	0.49
Gray Squirrel	19996	0.38	Gray Squirrel	19977.9	0.38
Pileated Woodpecker	19996	0.06	Pileated Woodpecker	19977.9	0.06
Carolina Chickadee	19996	0.68	Carolina Chickadee	19977.9	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 2

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	38	0.1	Wood Duck	38	0.1
Mink	2767	0.76	Mink	2767	0.76
Barred Owl	21075.6	0.49	Barred Owl	21075.6	0.49
Gray Squirrel	21075.6	0.38	Gray Squirrel	21075.6	0.38
Pileated Woodpecker	21075.6	0.06	Pileated Woodpecker	21075.6	0.06
Carolina Chickadee	21075.6	0.68	Carolina Chickadee	21075.6	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	38	0.1	Wood Duck	38	0.1
Mink	2767	0.76	Mink	2767	0.76
Barred Owl	21075.6	0.49	Barred Owl	21022.5	0.49
Gray Squirrel	21075.6	0.38	Gray Squirrel	21022.5	0.38
Pileated Woodpecker	21075.6	0.06	Pileated Woodpecker	21022.5	0.06
Carolina Chickadee	21075.6	0.68	Carolina Chickadee	21022.5	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	38	0.1	Wood Duck	38	0.1
Mink	2767	0.76	Mink	2767	0.76
Barred Owl	21075.6	0.49	Barred Owl	21022.5	0.49
Gray Squirrel	21075.6	0.38	Gray Squirrel	21022.5	0.38
Pileated Woodpecker	21075.6	0.06	Pileated Woodpecker	21022.5	0.06
Carolina Chickadee	21075.6	0.68	Carolina Chickadee	21022.5	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	38	0.1	Wood Duck	38	0.1
Mink	2767	0.76	Mink	2767	0.76
Barred Owl	21075.6	0.49	Barred Owl	21022.5	0.49
Gray Squirrel	21075.6	0.38	Gray Squirrel	21022.5	0.38
Pileated Woodpecker	21075.6	0.06	Pileated Woodpecker	21022.5	0.06
Carolina Chickadee	21075.6	0.68	Carolina Chickadee	21022.5	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	38	0.1	Wood Duck	38	0.1
Mink	2767	0.76	Mink	2767	0.76
Barred Owl	21075.6	0.49	Barred Owl	21022.5	0.49
Gray Squirrel	21075.6	0.38	Gray Squirrel	21022.5	0.38
Pileated Woodpecker	21075.6	0.06	Pileated Woodpecker	21022.5	0.06
Carolina Chickadee	21075.6	0.68	Carolina Chickadee	21022.5	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 3

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	200	0.1	Wood Duck	200	0.1
Mink	506	0.76	Mink	506	0.76
Barred Owl	7752	0.49	Barred Owl	7752	0.49
Gray Squirrel	7752	0.38	Gray Squirrel	7752	0.38
Pileated Woodpecker	7752	0.06	Pileated Woodpecker	7752	0.06
Carolina Chickadee	7752	0.68	Carolina Chickadee	7752	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	200	0.1	Wood Duck	145	0.1
Mink	506	0.76	Mink	450	0.76
Barred Owl	7752	0.49	Barred Owl	7736.4	0.49
Gray Squirrel	7752	0.38	Gray Squirrel	7736.4	0.38
Pileated Woodpecker	7752	0.06	Pileated Woodpecker	7736.4	0.06
Carolina Chickadee	7752	0.68	Carolina Chickadee	7736.4	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	200	0.1	Wood Duck	145	0.1
Mink	506	0.76	Mink	506	0.76
Barred Owl	7752	0.49	Barred Owl	7736.4	0.49
Gray Squirrel	7752	0.38	Gray Squirrel	7736.4	0.38
Pileated Woodpecker	7752	0.06	Pileated Woodpecker	7736.4	0.06
Carolina Chickadee	7752	0.68	Carolina Chickadee	7736.4	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	200	0.1	Wood Duck	145	0.1
Mink	506	0.76	Mink	506	0.76
Barred Owl	7752	0.49	Barred Owl	7736.4	0.49
Gray Squirrel	7752	0.38	Gray Squirrel	7736.4	0.38
Pileated Woodpecker	7752	0.06	Pileated Woodpecker	7736.4	0.06
Carolina Chickadee	7752	0.68	Carolina Chickadee	7736.4	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	200	0.1	Wood Duck	145	0.1
Mink	506	0.76	Mink	506	0.76
Barred Owl	7752	0.49	Barred Owl	7736.4	0.49
Gray Squirrel	7752	0.38	Gray Squirrel	7736.4	0.38
Pileated Woodpecker	7752	0.06	Pileated Woodpecker	7736.4	0.06
Carolina Chickadee	7752	0.68	Carolina Chickadee	7736.4	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 4

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	70	0.1	Wood Duck	70	0.1
Mink	110	0.76	Mink	110	0.76
Barred Owl	11371.6	0.49	Barred Owl	11371.6	0.49
Gray Squirrel	11371.6	0.38	Gray Squirrel	11371.6	0.38
Pileated Woodpecker	11371.6	0.06	Pileated Woodpecker	11371.6	0.06
Carolina Chickadee	11371.6	0.68	Carolina Chickadee	11371.6	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	70	0.1	Wood Duck	68	0.1
Mink	110	0.76	Mink	77	0.76
Barred Owl	11371.6	0.49	Barred Owl	11342.8	0.49
Gray Squirrel	11371.6	0.38	Gray Squirrel	11342.8	0.38
Pileated Woodpecker	11371.6	0.06	Pileated Woodpecker	11342.8	0.06
Carolina Chickadee	11371.6	0.68	Carolina Chickadee	11342.8	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	70	0.1	Wood Duck	68	0.1
Mink	110	0.76	Mink	77	0.76
Barred Owl	11371.6	0.49	Barred Owl	11338.4	0.49
Gray Squirrel	11371.6	0.38	Gray Squirrel	11338.4	0.38
Pileated Woodpecker	11371.6	0.06	Pileated Woodpecker	11338.4	0.06
Carolina Chickadee	11371.6	0.68	Carolina Chickadee	11338.4	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	70	0.1	Wood Duck	68	0.1
Mink	110	0.76	Mink	77	0.76
Barred Owl	11371.6	0.49	Barred Owl	11338.4	0.49
Gray Squirrel	11371.6	0.38	Gray Squirrel	11338.4	0.38
Pileated Woodpecker	11371.6	0.06	Pileated Woodpecker	11338.4	0.06
Carolina Chickadee	11371.6	0.68	Carolina Chickadee	11338.4	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	70	0.1	Wood Duck	68	0.1
Mink	110	0.76	Mink	77	0.76
Barred Owl	11371.6	0.49	Barred Owl	11338.4	0.49
Gray Squirrel	11371.6	0.38	Gray Squirrel	11338.4	0.38
Pileated Woodpecker	11371.6	0.06	Pileated Woodpecker	11338.4	0.06
Carolina Chickadee	11371.6	0.68	Carolina Chickadee	11338.4	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 5

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	205	0.1	Wood Duck	205	0.1
Mink	534	0.76	Mink	534	0.76
Barred Owl	5137.5	0.49	Barred Owl	5137.5	0.49
Gray Squirrel	5137.5	0.38	Gray Squirrel	5137.5	0.38
Pileated Woodpecker	5137.5	0.06	Pileated Woodpecker	5137.5	0.06
Carolina Chickadee	5137.5	0.68	Carolina Chickadee	5137.5	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	205	0.1	Wood Duck	205	0.1
Mink	534	0.76	Mink	241	0.76
Barred Owl	5137.5	0.49	Barred Owl	5089.3	0.49
Gray Squirrel	5137.5	0.38	Gray Squirrel	5089.3	0.38
Pileated Woodpecker	5137.5	0.06	Pileated Woodpecker	5089.3	0.06
Carolina Chickadee	5137.5	0.68	Carolina Chickadee	5089.3	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	205	0.1	Wood Duck	205	0.1
Mink	534	0.76	Mink	241	0.76
Barred Owl	5137.5	0.49	Barred Owl	5020.9	0.49
Gray Squirrel	5137.5	0.38	Gray Squirrel	5020.9	0.38
Pileated Woodpecker	5137.5	0.06	Pileated Woodpecker	5020.9	0.06
Carolina Chickadee	5137.5	0.68	Carolina Chickadee	5020.9	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	205	0.1	Wood Duck	205	0.1
Mink	534	0.76	Mink	241	0.76
Barred Owl	5137.5	0.49	Barred Owl	5020.9	0.49
Gray Squirrel	5137.5	0.38	Gray Squirrel	5020.9	0.38
Pileated Woodpecker	5137.5	0.06	Pileated Woodpecker	5020.9	0.06
Carolina Chickadee	5137.5	0.68	Carolina Chickadee	5020.9	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	205	0.1	Wood Duck	205	0.1
Mink	534	0.76	Mink	241	0.76
Barred Owl	5137.5	0.49	Barred Owl	5020.9	0.49
Gray Squirrel	5137.5	0.38	Gray Squirrel	5020.9	0.38
Pileated Woodpecker	5137.5	0.06	Pileated Woodpecker	5020.9	0.06
Carolina Chickadee	5137.5	0.68	Carolina Chickadee	5020.9	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 6

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	665	0.1	Wood Duck	665	0.1
Mink	534	0.76	Mink	534	0.76
Barred Owl	21709.1	0.49	Barred Owl	21709.1	0.49
Gray Squirrel	21709.1	0.38	Gray Squirrel	21709.1	0.38
Pileated Woodpecker	21709.1	0.06	Pileated Woodpecker	21709.1	0.06
Carolina Chickadee	21709.1	0.68	Carolina Chickadee	21709.1	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	665	0.1	Wood Duck	600	0.1
Mink	534	0.76	Mink	241	0.76
Barred Owl	21709.1	0.49	Barred Owl	21573.4	0.49
Gray Squirrel	21709.1	0.38	Gray Squirrel	21573.4	0.38
Pileated Woodpecker	21709.1	0.06	Pileated Woodpecker	21573.4	0.06
Carolina Chickadee	21709.1	0.68	Carolina Chickadee	21573.4	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	665	0.1	Wood Duck	600	0.1
Mink	534	0.76	Mink	241	0.76
Barred Owl	21709.1	0.49	Barred Owl	21573.4	0.49
Gray Squirrel	21709.1	0.38	Gray Squirrel	21573.4	0.38
Pileated Woodpecker	21709.1	0.06	Pileated Woodpecker	21573.4	0.06
Carolina Chickadee	21709.1	0.68	Carolina Chickadee	21573.4	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	665	0.1	Wood Duck	665	0.1
Mink	534	0.76	Mink	534	0.76
Barred Owl	21709.1	0.49	Barred Owl	21709.1	0.49
Gray Squirrel	21709.1	0.38	Gray Squirrel	21709.1	0.38
Pileated Woodpecker	21709.1	0.06	Pileated Woodpecker	21709.1	0.06
Carolina Chickadee	21709.1	0.68	Carolina Chickadee	21709.1	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	665	0.1	Wood Duck	600	0.1
Mink	534	0.76	Mink	241	0.76
Barred Owl	21709.1	0.49	Barred Owl	21573.4	0.49
Gray Squirrel	21709.1	0.38	Gray Squirrel	21573.4	0.38
Pileated Woodpecker	21709.1	0.06	Pileated Woodpecker	21573.4	0.06
Carolina Chickadee	21709.1	0.68	Carolina Chickadee	21573.4	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 7

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	36	0.1	Wood Duck	36	0.1
Mink	239	0.76	Mink	239	0.76
Barred Owl	6274.2	0.49	Barred Owl	6274.2	0.49
Gray Squirrel	6274.2	0.38	Gray Squirrel	6274.2	0.38
Pileated Woodpecker	6274.2	0.06	Pileated Woodpecker	6274.2	0.06
Carolina Chickadee	6274.2	0.68	Carolina Chickadee	6274.2	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	36	0.1	Wood Duck	36	0.1
Mink	239	0.76	Mink	239	0.76
Barred Owl	6274.2	0.49	Barred Owl	6257.6	0.49
Gray Squirrel	6274.2	0.38	Gray Squirrel	6257.6	0.38
Pileated Woodpecker	6274.2	0.06	Pileated Woodpecker	6257.6	0.06
Carolina Chickadee	6274.2	0.68	Carolina Chickadee	6257.6	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	36	0.1	Wood Duck	36	0.1
Mink	239	0.76	Mink	239	0.76
Barred Owl	6274.2	0.49	Barred Owl	6257.6	0.49
Gray Squirrel	6274.2	0.38	Gray Squirrel	6257.6	0.38
Pileated Woodpecker	6274.2	0.06	Pileated Woodpecker	6257.6	0.06
Carolina Chickadee	6274.2	0.68	Carolina Chickadee	6257.6	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	36	0.1	Wood Duck	33	0.1
Mink	239	0.76	Mink	197	0.76
Barred Owl	6274.2	0.49	Barred Owl	6015.8	0.49
Gray Squirrel	6274.2	0.38	Gray Squirrel	6015.8	0.38
Pileated Woodpecker	6274.2	0.06	Pileated Woodpecker	6015.8	0.06
Carolina Chickadee	6274.2	0.68	Carolina Chickadee	6015.8	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	36	0.1	Wood Duck	33	0.1
Mink	239	0.76	Mink	155	0.76
Barred Owl	6274.2	0.49	Barred Owl	5966.7	0.49
Gray Squirrel	6274.2	0.38	Gray Squirrel	5966.7	0.38
Pileated Woodpecker	6274.2	0.06	Pileated Woodpecker	5966.7	0.06
Carolina Chickadee	6274.2	0.68	Carolina Chickadee	5966.7	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 8

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	9542	0.1	Wood Duck	9542	0.1
Mink	21665	0.76	Mink	21665	0.76
Barred Owl	39149.2	0.49	Barred Owl	39149.2	0.49
Gray Squirrel	39149.2	0.38	Gray Squirrel	39149.2	0.38
Pileated Woodpecker	39149.2	0.06	Pileated Woodpecker	39149.2	0.06
Carolina Chickadee	39149.2	0.68	Carolina Chickadee	39149.2	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	9542	0.1	Wood Duck	9542	0.1
Mink	21665	0.76	Mink	17688	0.76
Barred Owl	39149.2	0.49	Barred Owl	38921.9	0.49
Gray Squirrel	39149.2	0.38	Gray Squirrel	38921.9	0.38
Pileated Woodpecker	39149.2	0.06	Pileated Woodpecker	38921.9	0.06
Carolina Chickadee	39149.2	0.68	Carolina Chickadee	38921.9	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	9542	0.1	Wood Duck	9542	0.1
Mink	21665	0.76	Mink	17688	0.76
Barred Owl	39149.2	0.49	Barred Owl	38921.9	0.49
Gray Squirrel	39149.2	0.38	Gray Squirrel	38921.9	0.38
Pileated Woodpecker	39149.2	0.06	Pileated Woodpecker	38921.9	0.06
Carolina Chickadee	39149.2	0.68	Carolina Chickadee	38921.9	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	9542	0.1	Wood Duck	9542	0.1
Mink	21665	0.76	Mink	13094	0.76
Barred Owl	39149.2	0.49	Barred Owl	38843.9	0.49
Gray Squirrel	39149.2	0.38	Gray Squirrel	38843.9	0.38
Pileated Woodpecker	39149.2	0.06	Pileated Woodpecker	38843.9	0.06
Carolina Chickadee	39149.2	0.68	Carolina Chickadee	38843.9	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	9542	0.1	Wood Duck	9542	0.1
Mink	21665	0.76	Mink	13094	0.76
Barred Owl	39149.2	0.49	Barred Owl	38843.9	0.49
Gray Squirrel	39149.2	0.38	Gray Squirrel	38843.9	0.38
Pileated Woodpecker	39149.2	0.06	Pileated Woodpecker	38843.9	0.06
Carolina Chickadee	39149.2	0.68	Carolina Chickadee	38843.9	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 9

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	28	0.1	Wood Duck	28	0.1
Mink	104	0.76	Mink	104	0.76
Barred Owl	2135	0.49	Barred Owl	2135	0.49
Gray Squirrel	2135	0.38	Gray Squirrel	2135	0.38
Pileated Woodpecker	2135	0.06	Pileated Woodpecker	2135	0.06
Carolina Chickadee	2135	0.68	Carolina Chickadee	2135	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	28	0.1	Wood Duck	18	0.1
Mink	104	0.76	Mink	94	0.76
Barred Owl	2135	0.49	Barred Owl	1925.1	0.49
Gray Squirrel	2135	0.38	Gray Squirrel	1925.1	0.38
Pileated Woodpecker	2135	0.06	Pileated Woodpecker	1925.1	0.06
Carolina Chickadee	2135	0.68	Carolina Chickadee	1925.1	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	28	0.1	Wood Duck	18	0.1
Mink	104	0.76	Mink	94	0.76
Barred Owl	2135	0.49	Barred Owl	1925.1	0.49
Gray Squirrel	2135	0.38	Gray Squirrel	1925.1	0.38
Pileated Woodpecker	2135	0.06	Pileated Woodpecker	1925.1	0.06
Carolina Chickadee	2135	0.68	Carolina Chickadee	1925.1	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	28	0.1	Wood Duck	18	0.1
Mink	104	0.76	Mink	94	0.76
Barred Owl	2135	0.49	Barred Owl	1925.1	0.49
Gray Squirrel	2135	0.38	Gray Squirrel	1925.1	0.38
Pileated Woodpecker	2135	0.06	Pileated Woodpecker	1925.1	0.06
Carolina Chickadee	2135	0.68	Carolina Chickadee	1925.1	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	28	0.1	Wood Duck	18	0.1
Mink	104	0.76	Mink	94	0.76
Barred Owl	2135	0.49	Barred Owl	1925.1	0.49
Gray Squirrel	2135	0.38	Gray Squirrel	1925.1	0.38
Pileated Woodpecker	2135	0.06	Pileated Woodpecker	1925.1	0.06
Carolina Chickadee	2135	0.68	Carolina Chickadee	1925.1	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 10

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	71	0.1	Wood Duck	71	0.1
Mink	169	0.76	Mink	169	0.76
Barred Owl	6188.3	0.49	Barred Owl	6188.3	0.49
Gray Squirrel	6188.3	0.38	Gray Squirrel	6188.3	0.38
Pileated Woodpecker	6188.3	0.06	Pileated Woodpecker	6188.3	0.06
Carolina Chickadee	6188.3	0.68	Carolina Chickadee	6188.3	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	71	0.1	Wood Duck	71	0.1
Mink	169	0.76	Mink	169	0.76
Barred Owl	6188.3	0.49	Barred Owl	6188.3	0.49
Gray Squirrel	6188.3	0.38	Gray Squirrel	6188.3	0.38
Pileated Woodpecker	6188.3	0.06	Pileated Woodpecker	6188.3	0.06
Carolina Chickadee	6188.3	0.68	Carolina Chickadee	6188.3	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	71	0.1	Wood Duck	71	0.1
Mink	169	0.76	Mink	169	0.76
Barred Owl	6188.3	0.49	Barred Owl	6188.3	0.49
Gray Squirrel	6188.3	0.38	Gray Squirrel	6188.3	0.38
Pileated Woodpecker	6188.3	0.06	Pileated Woodpecker	6188.3	0.06
Carolina Chickadee	6188.3	0.68	Carolina Chickadee	6188.3	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	71	0.1	Wood Duck	71	0.1
Mink	169	0.76	Mink	169	0.76
Barred Owl	6188.3	0.49	Barred Owl	6188.3	0.49
Gray Squirrel	6188.3	0.38	Gray Squirrel	6188.3	0.38
Pileated Woodpecker	6188.3	0.06	Pileated Woodpecker	6188.3	0.06
Carolina Chickadee	6188.3	0.68	Carolina Chickadee	6188.3	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	71	0.1	Wood Duck	71	0.1
Mink	169	0.76	Mink	169	0.76
Barred Owl	6188.3	0.49	Barred Owl	6188.3	0.49
Gray Squirrel	6188.3	0.38	Gray Squirrel	6188.3	0.38
Pileated Woodpecker	6188.3	0.06	Pileated Woodpecker	6188.3	0.06
Carolina Chickadee	6188.3	0.68	Carolina Chickadee	6188.3	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Flood Damage Reduction Reach 11

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	110	0.1	Wood Duck	110	0.1
Mink	486	0.76	Mink	486	0.76
Barred Owl	1761.4	0.49	Barred Owl	1761.4	0.49
Gray Squirrel	1761.4	0.38	Gray Squirrel	1761.4	0.38
Pileated Woodpecker	1761.4	0.06	Pileated Woodpecker	1761.4	0.06
Carolina Chickadee	1761.4	0.68	Carolina Chickadee	1761.4	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	110	0.1	Wood Duck	76	0.1
Mink	486	0.76	Mink	373	0.76
Barred Owl	1761.4	0.49	Barred Owl	1738.9	0.49
Gray Squirrel	1761.4	0.38	Gray Squirrel	1738.9	0.38
Pileated Woodpecker	1761.4	0.06	Pileated Woodpecker	1738.9	0.06
Carolina Chickadee	1761.4	0.68	Carolina Chickadee	1738.9	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	110	0.1	Wood Duck	76	0.1
Mink	486	0.76	Mink	373	0.76
Barred Owl	1761.4	0.49	Barred Owl	1716.4	0.49
Gray Squirrel	1761.4	0.38	Gray Squirrel	1716.4	0.38
Pileated Woodpecker	1761.4	0.06	Pileated Woodpecker	1716.4	0.06
Carolina Chickadee	1761.4	0.68	Carolina Chickadee	1716.4	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	110	0.1	Wood Duck	76	0.1
Mink	486	0.76	Mink	373	0.76
Barred Owl	1761.4	0.49	Barred Owl	1716.4	0.49
Gray Squirrel	1761.4	0.38	Gray Squirrel	1716.4	0.38
Pileated Woodpecker	1761.4	0.06	Pileated Woodpecker	1716.4	0.06
Carolina Chickadee	1761.4	0.68	Carolina Chickadee	1716.4	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	110	0.1	Wood Duck	76	0.1
Mink	486	0.76	Mink	373	0.76
Barred Owl	1761.4	0.49	Barred Owl	1716.4	0.49
Gray Squirrel	1761.4	0.38	Gray Squirrel	1716.4	0.38
Pileated Woodpecker	1761.4	0.06	Pileated Woodpecker	1716.4	0.06
Carolina Chickadee	1761.4	0.68	Carolina Chickadee	1716.4	0.68

Acres and Habitat Suitability Indexes Utilized in HEP Software for Each Alternative and Evaluation Species
Bayou Meto Water Supply

Existing Conditions (PA1)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	63505	0.1	Wood Duck	63505	0.1
Mink	63505	0.76	Mink	63505	0.76
Barred Owl	63505	0.49	Barred Owl	63505	0.49
Gray Squirrel	63505	0.38	Gray Squirrel	63505	0.38
Pileated Woodpecker	63505	0.06	Pileated Woodpecker	63505	0.06
Carolina Chickadee	63505	0.68	Carolina Chickadee	63505	0.68

Alternative 2 (PA 2)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	63505	0.1	Wood Duck	62707	0.1
Mink	63505	0.76	Mink	62707	0.76
Barred Owl	63505	0.49	Barred Owl	62707	0.49
Gray Squirrel	63505	0.38	Gray Squirrel	62707	0.38
Pileated Woodpecker	63505	0.06	Pileated Woodpecker	62707	0.06
Carolina Chickadee	63505	0.68	Carolina Chickadee	62707	0.68

Alternative 2A (PA 3)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	63505	0.1	Wood Duck	62707	0.1
Mink	63505	0.76	Mink	62707	0.76
Barred Owl	63505	0.49	Barred Owl	62707	0.49
Gray Squirrel	63505	0.38	Gray Squirrel	62707	0.38
Pileated Woodpecker	63505	0.06	Pileated Woodpecker	62707	0.06
Carolina Chickadee	63505	0.68	Carolina Chickadee	62707	0.68

Alternative 3A (PA 4)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	63505	0.1	Wood Duck	62707	0.1
Mink	63505	0.76	Mink	62707	0.76
Barred Owl	63505	0.49	Barred Owl	62707	0.49
Gray Squirrel	63505	0.38	Gray Squirrel	62707	0.38
Pileated Woodpecker	63505	0.06	Pileated Woodpecker	62707	0.06
Carolina Chickadee	63505	0.68	Carolina Chickadee	62707	0.68

Alternative 3B (PA 5)

TY 0, 1			TY 6, 10, 20, 30, 56		
Evaluation Species	Acres of Suitable Habitat	HSI	Evaluation Species	Acres of Suitable Habitat	HSI
Wood Duck	63505	0.1	Wood Duck	62707	0.1
Mink	63505	0.76	Mink	62707	0.76
Barred Owl	63505	0.49	Barred Owl	62707	0.49
Gray Squirrel	63505	0.38	Gray Squirrel	62707	0.38
Pileated Woodpecker	63505	0.06	Pileated Woodpecker	62707	0.06
Carolina Chickadee	63505	0.68	Carolina Chickadee	62707	0.68

Attachment 2

HABITAT DATA CALCULATIONS PROVIDING SI AND HSI VALUES FOR EACH EVALUATION SPECIES

Table 1. Habitat Data Calculations Providing SI and HSI Values for the Wood Duck

Tract Number	Plot Number	Cover Type	Wood Duck SIV3 - Density of potential nest sites	SIV4 - % potential brood cover	SIV5 - % potential winter cover	SIV6 - Distance between cover types	SIV7 - % of area providing equivalent optimum nesting habitat	SIV8 - % of area providing equivalent optimum brood-rearing habitat	HSI Winter	HSI Breeding	% Area Optium Nesting	% Area Optimum Brood-rearing
2	1	BLH	0.00	0.50	0.50	1.00	0.00	0.50	0.50	0.00	0.0	50.0
	2	BLH	0.00	0.30	0.30	1.00	0.00	0.30	0.30	0.00	0.0	30.0
4	1	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
	2	BLH	0.00	0.90	0.90	1.00	0.00	0.90	0.90	0.00	0.0	90.0
7	1	BLH	0.00	0.80	1.00	1.00	0.00	0.80	1.00	0.00	0.0	80.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
9	1	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
	2	BLH	0.00	1.00	0.50	1.00	0.00	1.00	0.50	0.00	0.0	100.0
12	1	BLH	0.00	0.30	0.30	1.00	0.00	0.30	0.30	0.00	0.0	30.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
14	1	BLH	1.00	0.60	0.60	1.00	1.00	0.60	0.60	0.60	100.0	60.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
16	1	BLH	0.00	0.40	1.00	1.00	0.00	0.40	1.00	0.00	0.0	40.0
	2	BLH	0.00	0.40	1.00	1.00	0.00	0.40	1.00	0.00	0.0	40.0
19	1	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
	2	BLH	1.00	0.70	0.60	1.00	1.00	0.70	0.60	0.70	100.0	70.0
20	1	BLH	1.00	0.60	0.60	1.00	1.00	0.60	0.60	0.60	100.0	60.0
	2	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
21	1	S/S	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
	2	S/S	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
23	1	BLH	0.00	0.50	0.50	1.00	0.00	0.50	0.50	0.00	0.0	50.0
	2	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
32	1	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
33	1	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
37	1	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
	2	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
40	1	BLH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.0	100.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
42	1	BLH	1.00	0.60	0.60	1.00	1.00	0.60	0.60	0.60	100.0	60.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
43	1	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
	2	BLH	1.00	1.00	0.90	1.00	1.00	1.00	0.90	1.00	100.0	100.0

Table 1. Habitat Data Calculations Providing SI and HSI Values for the Wood Duck

44	1	BLH	1.00	0.50	0.50	1.00	1.00	0.50	0.50	0.50	100.0	50.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
46	1	BLH	0.00	0.90	0.90	1.00	0.00	0.90	0.90	0.00	0.0	90.0
	2	BLH	0.00	0.40	0.30	1.00	0.00	0.40	0.30	0.00	0.0	40.0
49	1	BLH	0.00	0.20	0.20	1.00	0.00	0.20	0.20	0.00	0.0	20.0
	2	BLH	0.00	0.30	0.30	1.00	0.00	0.30	0.30	0.00	0.0	30.0
52	1	TUPELO	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0	0.0
	2	TUPELO	0.00	0.10	0.10	1.00	0.00	0.10	0.10	0.00	0.0	10.0
54	1	BLH	0.00	0.20	0.20	1.00	0.00	0.20	0.20	0.00	0.0	20.0
	2	BLH	0.00	0.20	0.20	1.00	0.00	0.20	0.20	0.00	0.0	20.0
57	1	BLH	0.00	0.90	0.90	1.00	0.00	0.90	0.90	0.00	0.0	90.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
62	1	BLH	0.00	0.80	0.20	1.00	0.00	0.80	0.20	0.00	0.0	80.0
	2	BLH	0.00	0.90	0.30	1.00	0.00	0.90	0.30	0.00	0.0	90.0
63	1	TUPELO	1.00	0.80	0.80	1.00	1.00	0.80	0.80	0.80	100.0	80.0
	2	BLH	0.00	0.20	0.20	1.00	0.00	0.20	0.20	0.00	0.0	20.0
64	1	BLH	0.00	0.60	1.00	1.00	0.00	0.60	1.00	0.00	0.0	60.0
	2	BLH	1.00	0.80	0.70	1.00	1.00	0.80	0.70	0.80	100.0	80.0
65	1	BLH	1.00	0.10	0.10	1.00	1.00	0.10	0.10	0.10	100.0	10.0
	2	BLH	0.00	0.40	0.30	1.00	0.00	0.40	0.30	0.00	0.0	40.0
66	1	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
71	1	BLH	1.00	0.60	1.00	1.00	1.00	0.60	1.00	0.60	100.0	60.0
	2	BLH	1.00	0.60	0.60	1.00	1.00	0.60	0.60	0.60	100.0	60.0
75	1	BLH	0.00	0.20	0.20	1.00	0.00	0.20	0.20	0.00	0.0	20.0
	2	BLH	0.00	0.50	0.50	1.00	0.00	0.50	0.50	0.00	0.0	50.0
76	1	BLH	0.00	0.30	0.30	1.00	0.00	0.30	0.30	0.00	0.0	30.0
	2	BLH	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	100.0	0.0
77	1	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
81	1	BLH	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0	0.0
	2	BLH	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0	0.0
84	1	BLH	0.00	0.40	1.00	1.00	0.00	0.40	1.00	0.00	0.0	40.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
89	1	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
	2	BLH	1.00	0.40	0.40	1.00	1.00	0.40	0.40	0.40	100.0	40.0
91	1	BLH	1.00	0.60	0.30	1.00	1.00	0.60	0.30	0.60	100.0	60.0
	2	BLH	1.00	0.40	0.40	1.00	1.00	0.40	0.40	0.40	100.0	40.0
93	1	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
	2	BLH	1.00	0.50	0.50	1.00	1.00	0.50	0.50	0.50	100.0	50.0
101	1	BLH	0.00	0.30	0.30	1.00	0.00	0.30	0.30	0.00	0.0	30.0
	2	BLH	0.00	0.50	0.50	1.00	0.00	0.50	0.50	0.00	0.0	50.0
104	1	CY/TU	1.00	0.40	0.50	1.00	1.00	0.40	0.50	0.40	100.0	40.0
	2	TUPELO	0.00	0.40	0.40	1.00	0.00	0.40	0.40	0.00	0.0	40.0
114	1	BLH	1.00	0.40	0.40	1.00	1.00	0.40	0.40	0.40	100.0	40.0
	2	BLH	1.00	0.60	0.60	1.00	1.00	0.60	0.60	0.60	100.0	60.0

Table 1. Habitat Data Calculations Providing SI and HSI Values for the Wood Duck

116	1	BLH	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0	0.0
	2	BLH	0.00	0.60	1.00	1.00	0.00	0.60	1.00	0.00	0.0	60.0
117	1	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
	2	BLH	0.00	1.00	0.70	1.00	0.00	1.00	0.70	0.00	0.0	100.0
125	1	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
	2	BLH	0.00	0.50	0.50	1.00	0.00	0.50	0.50	0.00	0.0	50.0
129	1	BLH	0.00	0.40	0.80	1.00	0.00	0.40	0.80	0.00	0.0	40.0
	2	BLH	0.00	0.60	1.00	1.00	0.00	0.60	1.00	0.00	0.0	60.0
131	1	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
	2	BLH	0.00	0.30	0.30	1.00	0.00	0.30	0.30	0.00	0.0	30.0
136	1	BLH	1.00	0.80	0.80	1.00	1.00	0.80	0.80	0.80	100.0	80.0
	2	BLH	0.00	0.90	0.90	1.00	0.00	0.90	0.90	0.00	0.0	90.0
140	1	BLH	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0	0.0
	2	BLH	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	100.0	0.0
143	1	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
	2	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
153	1	BLH	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0	0.0
	2	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
156	1	BLH	1.00	1.00	0.90	1.00	1.00	1.00	0.90	1.00	100.0	100.0
	2	BLH	0.00	1.00	0.90	1.00	0.00	1.00	0.90	0.00	0.0	100.0
157	1	BLH	0.00	1.00	0.60	1.00	0.00	1.00	0.60	0.00	0.0	100.0
	2	BLH	0.00	1.00	0.70	1.00	0.00	1.00	0.70	0.00	0.0	100.0
175	1	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
189	1	BLH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.0	100.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
200	1	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
	2	BLH	0.00	0.20	0.20	1.00	0.00	0.20	0.20	0.00	0.0	20.0
206	1	BLH	1.00	0.40	0.40	1.00	1.00	0.40	0.40	0.40	100.0	40.0
	2	BLH	1.00	0.50	0.50	1.00	1.00	0.50	0.50	0.50	100.0	50.0
213	1	BLH	1.00	1.00	0.70	1.00	1.00	1.00	0.70	1.00	100.0	100.0
	2	BLH	1.00	1.00	0.80	1.00	1.00	1.00	0.80	1.00	100.0	100.0
218	1	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
	2	BLH	1.00	0.40	0.40	1.00	1.00	0.40	0.40	0.40	100.0	40.0
221	1	CYPR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.0	100.0
	2	CYPR	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
223	1	BLH	0.00	0.50	0.50	1.00	0.00	0.50	0.50	0.00	0.0	50.0
	2	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
224	1	BLH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.0	100.0
	2	BLH	0.00	0.10	0.10	1.00	0.00	0.10	0.10	0.00	0.0	10.0
231	1	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
	2	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
241	1	BLH	0.00	0.40	0.40	1.00	0.00	0.40	0.40	0.00	0.0	40.0
	2	BLH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.0	100.0
243	1	TUPELO	1.00	0.10	0.10	1.00	1.00	0.10	0.10	0.10	100.0	10.0
	2	TUPELO	1.00	0.10	0.10	1.00	1.00	0.10	0.10	0.10	100.0	10.0

Table 1. Habitat Data Calculations Providing SI and HSI Values for the Wood Duck

245	1	CYPR	1.00	0.20	0.90	1.00	1.00	0.20	0.90	0.20	100.0	20.0
	2	CYPR	1.00	0.20	0.70	1.00	1.00	0.20	0.70	0.20	100.0	20.0
251	1	BLH	0.00	0.50	0.50	1.00	0.00	0.50	0.50	0.00	0.0	50.0
	2	BLH	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.0	0.0
265	1	BLH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.0	100.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
266	1	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
	2	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
277	1	BLH	0.00	0.30	0.10	1.00	0.00	0.30	0.10	0.00	0.0	30.0
	2	BLH	0.00	1.00	0.40	1.00	0.00	1.00	0.40	0.00	0.0	100.0
288	1	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
295	1	BLH	0.00	0.40	0.40	1.00	0.00	0.40	0.40	0.00	0.0	40.0
	2	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
309	1	BLH	1.00	0.90	0.60	1.00	1.00	0.90	0.60	0.90	100.0	90.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
331	1	BLH	0.00	0.20	0.20	1.00	0.00	0.20	0.20	0.00	0.0	20.0
	2	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
336	1	BLH	1.00	0.90	0.90	1.00	1.00	0.90	0.90	0.90	100.0	90.0
	2	BLH	0.00	0.70	0.70	1.00	0.00	0.70	0.70	0.00	0.0	70.0
340	1	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
343	1	CY/TU	1.00	0.40	0.30	1.00	1.00	0.40	0.30	0.40	100.0	40.0
	2	CY/TU	1.00	0.50	0.50	1.00	1.00	0.50	0.50	0.50	100.0	50.0
346	1	BLH	0.00	0.60	0.60	1.00	0.00	0.60	0.60	0.00	0.0	60.0
	2	BLH	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	0.0	100.0
349	1	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
	2	BLH	0.00	0.80	0.80	1.00	0.00	0.80	0.80	0.00	0.0	80.0
357	1	BLH	0.00	0.30	0.30	1.00	0.00	0.30	0.30	0.00	0.0	30.0
	2	BLH	0.00	0.10	0.10	1.00	0.00	0.10	0.10	0.00	0.0	10.0
358	1	BLH	1.00	0.10	0.10	1.00	1.00	0.10	0.10	0.10	100.0	10.0
	2	BLH	0.00	0.10	0.10	1.00	0.00	0.10	0.10	0.00	0.0	10.0
360	1	BLH	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.0	100.0
	2	BLH	0.00	0.40	1.00	1.00	0.00	0.40	1.00	0.00	0.0	40.0
AVERAGE OF PLOT HSIs									0.62	0.16		
STANDARD DEVIATION									0.316	0.314		
COEFFICIENT OF VARIATION									50.9	195.4		

Table 2. Habitat Data Calculations Providing SI and HSI Values for the Mink

		Mink						SI				
Tract Number	Plot Number	**SIV1** - % of Year with Water Present	**SIV2** - % Tree Canopy Cover	**SIV3** - % Shrub Canopy Cover	**SIV4** - % Canopy Cover of Herb. Veg.	**SIV5** - % Cover of Trees and Shrubs within 100M of Wetland Edge	**SIV6** - % Shoreline Cover	Water	Forested <= 1000 Acres	Forested >= 1000 Acres	River and Lake Cover Types	**HSI - Lowest of Life Requisites**
2	1	1.00	1.00	0.34	1.00	1.00	0.90	1.00	1.00	1.00	0.95	1.00
	2	1.00	1.00	0.34	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	1	0.00	0.70	0.52	0.96	0.82	1.00	0.00	0.91	1.00	0.91	0.00
	2	0.00	0.82	0.94	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
7	1	1.00	0.64	1.00	0.60	1.00	0.70	1.00	1.00	1.00	0.84	1.00
	2	1.00	1.00	0.70	0.60	1.00	0.30	1.00	1.00	1.00	0.55	1.00
9	1	1.00	0.94	0.70	0.60	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	2	1.00	1.00	0.46	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1	1.00	1.00	0.16	0.30	1.00	0.30	1.00	1.00	1.00	0.55	1.00
	2	1.00	0.88	0.46	0.20	0.94	0.25	1.00	0.97	1.00	0.48	0.97
14	1	1.00	1.00	0.64	0.30	1.00	0.95	1.00	1.00	1.00	0.97	1.00
	2	1.00	1.00	0.40	0.30	1.00	0.95	1.00	1.00	1.00	0.97	1.00
16	1	1.00	0.88	0.64	0.84	0.94	0.95	1.00	0.97	1.00	0.94	0.97
	2	1.00	0.76	0.64	0.92	0.88	0.95	1.00	0.94	1.00	0.91	0.94
19	1	1.00	1.00	0.64	0.30	1.00	0.50	1.00	1.00	1.00	0.71	1.00
	2	1.00	0.94	0.40	0.90	1.00	0.70	1.00	1.00	1.00	0.84	1.00
20	1	1.00	1.00	0.52	1.00	1.00	0.95	1.00	1.00	1.00	0.97	1.00
	2	1.00	1.00	0.46	0.90	1.00	0.90	1.00	1.00	1.00	0.95	1.00
21	1	1.00	1.00	0.46	0.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.52	0.00	1.00	0.40	1.00	1.00	1.00	0.63	1.00
23	1	1.00	1.00	0.34	0.20	1.00	0.75	1.00	1.00	1.00	0.87	1.00
	2	1.00	1.00	0.52	0.60	1.00	0.60	1.00	1.00	1.00	0.77	1.00
32	1	0.12	0.34	1.00	0.20	1.00	1.00	0.12	1.00	1.00	1.00	0.12
	2	0.12	0.64	0.82	0.92	0.94	1.00	0.12	0.97	1.00	0.97	0.12
33	1	0.12	1.00	0.58	0.20	1.00	0.60	0.12	1.00	1.00	0.77	0.12
	2	1.00	1.00	0.82	0.30	1.00	0.50	1.00	1.00	1.00	0.71	1.00
37	1	1.00	0.82	0.46	1.00	0.88	0.90	1.00	0.94	1.00	0.89	0.94
	2	1.00	1.00	0.58	0.88	1.00	0.85	1.00	1.00	1.00	0.92	1.00
40	1	1.00	1.00	1.00	0.10	1.00	0.45	1.00	1.00	1.00	0.67	1.00
	2	1.00	1.00	0.88	0.20	1.00	0.90	1.00	1.00	1.00	0.95	1.00
42	1	0.13	1.00	0.58	0.60	1.00	1.00	0.13	1.00	1.00	1.00	0.13
	2	0.13	0.64	0.88	0.20	1.00	1.00	0.13	1.00	1.00	1.00	0.13
43	1	1.00	1.00	0.64	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.58	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 2. Habitat Data Calculations Providing SI and HSI Values for the Mink

44	1	0.13	1.00	0.88	1.00	1.00	1.00	0.13	1.00	1.00	1.00	0.13
	2	0.13	1.00	0.88	0.30	1.00	1.00	0.13	1.00	1.00	1.00	0.13
46	1	1.00	1.00	0.64	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.58	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
49	1	1.00	1.00	0.28	0.10	1.00	0.95	1.00	1.00	1.00	0.97	1.00
	2	1.00	1.00	0.64	0.10	1.00	0.90	1.00	1.00	1.00	0.95	1.00
52	1	1.00	1.00	0.10	0.00	1.00	0.95	1.00	1.00	1.00	0.97	1.00
	2	1.00	1.00	0.16	0.00	1.00	0.95	1.00	1.00	1.00	0.97	1.00
54	1	0.11	1.00	0.34	0.20	1.00	1.00	0.11	1.00	1.00	1.00	0.11
	2	1.00	1.00	0.46	0.30	1.00	0.75	1.00	1.00	1.00	0.87	1.00
57	1	0.11	0.64	0.82	0.88	0.94	1.00	0.11	0.97	1.00	0.97	0.11
	2	0.11	0.34	0.70	0.88	0.82	1.00	0.11	0.91	1.00	0.91	0.11
62	1	1.00	1.00	0.22	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	0.94	0.16	1.00	0.94	1.00	1.00	0.97	1.00	0.97	0.97
63	1	1.00	1.00	0.58	0.00	1.00	0.40	1.00	1.00	1.00	0.63	1.00
	2	1.00	1.00	0.16	1.00	1.00	0.75	1.00	1.00	1.00	0.87	1.00
64	1	1.00	1.00	1.00	0.30	1.00	0.90	1.00	1.00	1.00	0.95	1.00
	2	1.00	0.94	0.46	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00
65	1	1.00	1.00	0.28	0.00	1.00	0.90	1.00	1.00	1.00	0.95	1.00
	2	1.00	1.00	0.22	0.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
66	1	1.00	0.94	0.40	0.00	0.94	0.80	1.00	0.97	1.00	0.87	0.97
	2	1.00	1.00	0.46	0.00	1.00	0.85	1.00	1.00	1.00	0.92	1.00
71	1	1.00	1.00	0.88	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	0.94	0.40	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00
75	1	1.00	1.00	1.00	0.10	1.00	0.75	1.00	1.00	1.00	0.87	1.00
	2	1.00	1.00	0.52	0.20	1.00	0.95	1.00	1.00	1.00	0.97	1.00
76	1	1.00	1.00	0.52	0.20	1.00	0.80	1.00	1.00	1.00	0.89	1.00
	2	0.12	1.00	0.76	1.00	1.00	1.00	0.12	1.00	1.00	1.00	0.12
77	1	0.12	1.00	0.64	0.92	1.00	1.00	0.12	1.00	1.00	1.00	0.12
	2	0.12	1.00	0.58	0.92	1.00	1.00	0.12	1.00	1.00	1.00	0.12
81	1	1.00	1.00	0.46	0.96	1.00	0.85	1.00	1.00	1.00	0.92	1.00
	2	1.00	1.00	0.34	1.00	1.00	0.75	1.00	1.00	1.00	0.87	1.00
84	1	0.14	1.00	0.40	1.00	1.00	0.95	0.14	1.00	1.00	0.97	0.14
	2	0.14	0.70	0.64	0.20	0.82	0.95	0.14	0.91	1.00	0.88	0.14
89	1	1.00	1.00	0.64	0.40	1.00	0.25	1.00	1.00	1.00	0.50	1.00
	2	0.14	1.00	0.46	0.10	1.00	1.00	0.14	1.00	1.00	1.00	0.14
91	1	1.00	1.00	0.46	1.00	1.00	0.95	1.00	1.00	1.00	0.97	1.00
	2	0.14	1.00	0.46	1.00	1.00	1.00	0.14	1.00	1.00	1.00	0.14
93	1	0.11	1.00	0.64	0.10	1.00	1.00	0.11	1.00	1.00	1.00	0.11
	2	0.11	1.00	0.70	0.00	1.00	1.00	0.11	1.00	1.00	1.00	0.11
101	1	1.00	1.00	0.58	0.50	1.00	0.45	1.00	1.00	1.00	0.67	1.00
	2	1.00	1.00	0.76	0.20	1.00	0.40	1.00	1.00	1.00	0.63	1.00
104	1	1.00	1.00	0.22	0.00	1.00	0.95	1.00	1.00	1.00	0.97	1.00
	2	1.00	1.00	0.10	0.00	1.00	0.95	1.00	1.00	1.00	0.97	1.00
114	1	1.00	1.00	0.46	0.10	1.00	0.95	1.00	1.00	1.00	0.97	1.00
	2	1.00	1.00	0.46	0.00	1.00	0.90	1.00	1.00	1.00	0.95	1.00

Table 2. Habitat Data Calculations Providing SI and HSI Values for the Mink

116	1	0.11	1.00	0.94	0.10	1.00	1.00	0.11	1.00	1.00	1.00	0.11
	2	0.11	0.70	0.88	1.00	1.00	1.00	0.11	1.00	1.00	1.00	0.11
117	1	0.14	0.76	1.00	0.10	1.00	1.00	0.14	1.00	1.00	1.00	0.14
	2	1.00	0.82	0.52	1.00	0.88	1.00	1.00	0.94	1.00	0.94	0.94
125	1	0.14	1.00	0.58	0.00	1.00	1.00	0.14	1.00	1.00	1.00	0.14
	2	0.14	1.00	0.70	0.00	1.00	1.00	0.14	1.00	1.00	1.00	0.14
129	1	1.00	0.40	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	0.64	0.82	1.00	0.94	1.00	1.00	0.97	1.00	0.97	0.97
131	1	1.00	1.00	0.46	0.00	1.00	0.80	1.00	1.00	1.00	0.89	1.00
	2	1.00	1.00	0.16	0.10	1.00	0.50	1.00	1.00	1.00	0.71	1.00
136	1	1.00	1.00	0.64	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.58	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
140	1	1.00	0.94	0.46	0.60	1.00	0.40	1.00	1.00	1.00	0.63	1.00
	2	0.12	0.94	0.82	0.40	1.00	0.40	0.12	1.00	1.00	0.63	0.12
143	1	0.50	1.00	0.82	0.30	1.00	0.90	0.50	1.00	1.00	0.95	0.50
	2	0.00	0.94	0.46	0.20	1.00	1.00	0.00	1.00	1.00	1.00	0.00
153	1	0.11	0.94	0.58	0.00	1.00	1.00	0.11	1.00	1.00	1.00	0.11
	2	0.11	1.00	0.76	0.00	1.00	1.00	0.11	1.00	1.00	1.00	0.11
156	1	1.00	1.00	0.46	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	0.14	1.00	0.58	0.90	1.00	1.00	0.14	1.00	1.00	1.00	0.14
157	1	0.14	1.00	0.40	0.90	1.00	1.00	0.14	1.00	1.00	1.00	0.14
	2	0.14	1.00	0.46	0.70	1.00	1.00	0.14	1.00	1.00	1.00	0.14
175	1	1.00	0.82	0.82	0.30	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.76	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00
189	1	0.60	0.82	0.82	0.10	0.94	1.00	0.60	0.97	1.00	0.97	0.60
	2	0.00	1.00	0.64	0.50	1.00	1.00	0.00	1.00	1.00	1.00	0.00
200	1	0.00	0.82	0.64	0.60	0.94	1.00	0.00	0.97	1.00	0.97	0.00
	2	0.00	0.64	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
206	1	1.00	1.00	0.34	0.30	1.00	0.85	1.00	1.00	1.00	0.92	1.00
	2	1.00	1.00	0.28	0.30	1.00	0.85	1.00	1.00	1.00	0.92	1.00
213	1	0.14	0.82	0.40	0.96	0.82	1.00	0.14	0.91	1.00	0.91	0.14
	2	0.14	1.00	0.52	1.00	1.00	1.00	0.14	1.00	1.00	1.00	0.14
218	1	1.00	1.00	0.46	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.28	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
221	1	1.00	1.00	0.64	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	0.46	0.64	1.00	0.94	1.00	1.00	0.97	1.00	0.97	0.97
223	1	1.00	1.00	0.28	0.30	1.00	0.95	1.00	1.00	1.00	0.97	1.00
	2	1.00	0.70	0.46	0.92	0.82	0.60	1.00	0.91	1.00	0.70	0.91
224	1	0.70	1.00	0.88	0.10	1.00	1.00	0.70	1.00	1.00	1.00	0.70
	2	1.00	1.00	0.28	0.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00
231	1	1.00	1.00	0.64	0.30	1.00	0.80	1.00	1.00	1.00	0.89	1.00
	2	1.00	1.00	0.58	0.10	1.00	0.80	1.00	1.00	1.00	0.89	1.00
241	1	1.00	1.00	0.52	0.30	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	0.70	0.94	0.70	0.92	1.00	1.00	0.70	1.00	1.00	1.00	0.70
243	1	1.00	1.00	0.10	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.10	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 2. Habitat Data Calculations Providing SI and HSI Values for the Mink

245	1	1.00	0.58	0.52	0.84	0.76	1.00	1.00	0.88	1.00	0.87	0.88
	2	1.00	0.58	0.52	0.84	0.76	1.00	1.00	0.88	1.00	0.87	0.88
251	1	0.50	1.00	0.46	0.40	1.00	1.00	0.50	1.00	1.00	1.00	0.50
	2	0.70	1.00	0.28	0.90	1.00	1.00	0.70	1.00	1.00	1.00	0.70
265	1	0.13	0.46	0.46	0.96	1.00	1.00	0.13	1.00	1.00	1.00	0.13
	2	0.13	0.76	0.52	0.80	0.82	1.00	0.13	0.91	1.00	0.91	0.13
266	1	0.13	1.00	0.40	0.00	1.00	1.00	0.13	1.00	1.00	1.00	0.13
	2	0.13	1.00	0.52	0.00	1.00	1.00	0.13	1.00	1.00	1.00	0.13
277	1	1.00	1.00	0.16	1.00	1.00	0.40	1.00	1.00	1.00	0.63	1.00
	2	1.00	1.00	0.22	1.00	1.00	0.35	1.00	1.00	1.00	0.59	1.00
288	1	0.00	0.88	1.00	0.20	1.00	1.00	0.00	1.00	1.00	1.00	0.00
	2	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
295	1	0.00	0.76	0.34	0.04	0.76	1.00	0.00	0.88	1.00	0.87	0.00
	2	0.00	0.94	0.46	1.00	1.00	0.55	0.00	1.00	1.00	0.74	0.00
309	1	0.12	1.00	0.40	0.70	1.00	1.00	0.12	1.00	1.00	1.00	0.12
	2	0.12	1.00	0.52	0.60	1.00	1.00	0.12	1.00	1.00	1.00	0.12
331	1	0.40	1.00	0.34	1.00	1.00	1.00	0.40	1.00	1.00	1.00	0.40
	2	0.00	1.00	0.64	0.10	1.00	1.00	0.00	1.00	1.00	1.00	0.00
336	1	0.00	1.00	0.64	0.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
	2	0.00	1.00	0.52	0.30	1.00	1.00	0.00	1.00	1.00	1.00	0.00
340	1	1.00	1.00	0.52	0.04	1.00	0.15	1.00	1.00	1.00	0.39	1.00
	2	1.00	1.00	0.52	0.40	1.00	0.60	1.00	1.00	1.00	0.77	1.00
343	1	1.00	1.00	0.28	0.84	1.00	0.90	1.00	1.00	1.00	0.95	1.00
	2	1.00	1.00	0.22	0.10	1.00	0.90	1.00	1.00	1.00	0.95	1.00
346	1	1.00	1.00	0.40	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.58	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
349	1	1.00	1.00	0.58	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2	1.00	1.00	0.52	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
357	1	0.30	1.00	0.34	0.30	0.34	1.00	0.30	0.67	1.00	0.58	0.30
	2	0.40	1.00	0.22	1.00	1.00	1.00	0.40	1.00	1.00	1.00	0.40
358	1	0.40	1.00	0.40	0.10	1.00	1.00	0.40	1.00	1.00	1.00	0.40
	2	1.00	1.00	0.46	0.00	0.46	0.80	1.00	0.73	1.00	0.61	0.73
360	1	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
	2	0.00	1.00	1.00	0.88	1.00	1.00	0.00	1.00	1.00	1.00	0.00
AVG. PLOT HSIs		0.67				0.98	0.88					0.66
STANDARD DEVIATION												0.4232
COEFFICIENT OF VARIATION												63.9

Table 3. Habitat Data Calculations Providing SI and HSI Values for the Barred Owl

Tract Number	Plot Number	Barred Owl				
		SIV1 - # trees >= 20 in./acre	SIV2 - Mean dbh of Overstory trees	SIV3 - % cover of Overstory trees		HSI
2	1	0.10	0.27	1.00		0.17
	2	0.10	0.34	1.00		0.18
4	1	1.00	0.40	0.75		0.48
	2	0.10	0.20	1.00		0.14
7	1	0.10	0.07	0.63		0.05
	2	1.00	0.75	1.00		0.87
9	1	0.10	0.49	1.00		0.22
	2	0.10	0.45	1.00		0.21
12	1	1.00	0.54	1.00		0.73
	2	0.10	0.56	1.00		0.24
14	1	0.10	0.60	1.00		0.25
	2	0.10	0.74	1.00		0.27
16	1	1.00	0.94	1.00		0.97
	2	1.00	0.65	0.88		0.71
19	1	1.00	1.00	1.00		1.00
	2	0.10	0.66	1.00		0.26
20	1	0.10	0.45	1.00		0.21
	2	0.10	0.60	1.00		0.25
21	1	0.10	0.00	1.00		0.00
	2	0.10	0.80	1.00		0.28
23	1	1.00	0.70	1.00		0.83
	2	1.00	0.84	1.00		0.92
32	1	0.10	0.29	0.00		0.00
	2	1.00	0.69	0.63		0.52
33	1	0.10	0.32	1.00		0.18
	2	0.10	0.40	1.00		0.20
37	1	1.00	0.37	1.00		0.61
	2	0.10	0.20	1.00		0.14
40	1	0.10	0.25	1.00		0.16
	2	1.00	1.00	1.00		1.00
42	1	1.00	1.00	1.00		1.00
	2	1.00	1.00	0.63		0.63
43	1	1.00	1.00	1.00		1.00
	2	1.00	0.71	1.00		0.84
44	1	1.00	0.56	1.00		0.75
	2	0.10	0.59	1.00		0.24
46	1	0.10	0.58	1.00		0.24
	2	0.10	0.69	1.00		0.26
49	1	0.10	0.39	1.00		0.20
	2	1.00	0.63	1.00		0.79
52	1	1.00	0.89	1.00		0.94
	2	1.00	0.84	1.00		0.92
54	1	0.10	0.56	1.00		0.24
	2	1.00	0.86	1.00		0.93

Table 3. Habitat Data Calculations Providing SI and HSI Values for the Barred Owl

57	1	0.10	0.13	0.63		0.07
	2	0.10	0.03	0.00		0.00
62	1	1.00	0.88	1.00		0.94
	2	1.00	0.62	1.00		0.79
63	1	1.00	0.62	1.00		0.79
	2	1.00	1.00	1.00		1.00
64	1	0.10	0.77	1.00		0.28
	2	1.00	1.00	1.00		1.00
65	1	1.00	0.60	1.00		0.77
	2	1.00	0.72	1.00		0.85
66	1	0.10	0.49	1.00		0.22
	2	0.10	0.17	1.00		0.13
71	1	1.00	1.00	1.00		1.00
	2	1.00	0.77	1.00		0.88
75	1	0.10	0.00	1.00		0.00
	2	0.10	0.13	1.00		0.11
76	1	1.00	0.89	1.00		0.94
	2	1.00	0.82	1.00		0.91
77	1	0.10	0.31	1.00		0.18
	2	0.10	0.34	1.00		0.18
81	1	1.00	0.79	1.00		0.89
	2	0.10	0.36	1.00		0.19
84	1	0.10	0.49	1.00		0.22
	2	0.10	0.43	0.75		0.16
89	1	0.10	0.50	1.00		0.22
	2	0.10	0.38	1.00		0.20
91	1	1.00	0.82	1.00		0.90
	2	0.10	0.34	1.00		0.18
93	1	0.10	0.09	1.00		0.10
	2	0.10	0.70	1.00		0.27
101	1	1.00	0.68	1.00		0.82
	2	0.10	0.36	1.00		0.19
104	1	0.10	0.35	1.00		0.19
	2	0.10	0.52	1.00		0.23
114	1	0.10	0.39	1.00		0.20
	2	0.10	0.40	1.00		0.20
116	1	1.00	0.72	1.00		0.85
	2	0.10	0.44	0.75		0.16
117	1	0.10	0.24	0.88		0.14
	2	1.00	0.57	1.00		0.75
125	1	0.10	0.54	1.00		0.23
	2	1.00	0.55	1.00		0.74
129	1	0.10	0.27	0.13		0.02
	2	0.10	0.25	0.63		0.10
131	1	0.10	0.53	1.00		0.23
	2	0.10	0.46	1.00		0.22

Table 3. Habitat Data Calculations Providing SI and HSI Values for the Barred Owl

136	1	0.10	0.54	1.00		0.23
	2	0.10	0.46	1.00		0.21
140	1	1.00	1.00	1.00		1.00
	2	1.00	0.86	1.00		0.93
143	1	0.10	0.43	1.00		0.21
	2	0.10	0.44	1.00		0.21
153	1	1.00	0.42	1.00		0.64
	2	1.00	0.30	1.00		0.55
156	1	1.00	0.88	1.00		0.94
	2	1.00	0.89	1.00		0.94
157	1	1.00	0.82	1.00		0.90
	2	1.00	0.62	1.00		0.79
175	1	1.00	0.72	1.00		0.85
	2	1.00	0.50	1.00		0.71
189	1	1.00	1.00	1.00		1.00
	2	1.00	0.86	1.00		0.93
200	1	1.00	1.00	1.00		1.00
	2	0.10	0.52	0.63		0.14
206	1	0.10	0.49	1.00		0.22
	2	0.10	0.46	1.00		0.21
213	1	1.00	0.46	1.00		0.67
	2	1.00	0.64	1.00		0.80
218	1	1.00	0.96	1.00		0.98
	2	1.00	0.46	1.00		0.67
221	1	1.00	0.62	1.00		0.79
	2	1.00	1.00	0.25		0.25
223	1	0.10	0.58	1.00		0.24
	2	0.10	0.56	0.75		0.18
224	1	1.00	0.88	1.00		0.94
	2	1.00	0.58	1.00		0.76
231	1	1.00	1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00
241	1	1.00	0.90	1.00		0.95
	2	1.00	0.67	1.00		0.82
243	1	1.00	0.63	1.00		0.79
	2	1.00	0.57	1.00		0.75
245	1	1.00	0.80	0.50		0.45
	2	1.00	0.52	0.50		0.36
251	1	0.10	0.14	1.00		0.12
	2	0.10	0.13	1.00		0.12
265	1	0.10	0.47	0.25		0.05
	2	0.10	0.46	0.88		0.19
266	1	1.00	0.73	1.00		0.85
	2	1.00	1.00	1.00		1.00
277	1	1.00	0.91	1.00		0.95
	2	1.00	0.98	1.00		0.99

Table 3. Habitat Data Calculations Providing SI and HSI Values for the Barred Owl

288	1	0.10	0.44	1.00		0.21
	2	0.10	0.49	1.00		0.22
295	1	1.00	0.64	0.88		0.70
	2	1.00	0.62	1.00		0.79
309	1	0.10	0.52	1.00		0.23
	2	0.10	0.56	1.00		0.24
331	1	0.10	0.50	1.00		0.22
	2	1.00	0.54	1.00		0.73
336	1	0.10	0.29	1.00		0.17
	2	0.10	0.27	1.00		0.16
340	1	0.10	0.56	1.00		0.24
	2	1.00	0.84	1.00		0.92
343	1	0.10	0.44	1.00		0.21
	2	0.10	0.30	1.00		0.17
346	1	1.00	0.49	1.00		0.70
	2	0.10	0.00	1.00		0.00
349	1	1.00	0.34	1.00		0.58
	2	1.00	1.00	1.00		1.00
357	1	0.10	0.32	1.00		0.18
	2	0.10	0.30	1.00		0.17
358	1	0.10	0.19	1.00		0.14
	2	0.10	0.33	1.00		0.18
360	1	1.00	1.00	1.00		1.00
	2	1.00	0.80	1.00		0.90
AVERAGE OF PLOT HSIs						0.50
STANDARD DEVIATION						0.349359
COEFFICIENT OF VARIATION						69.9

Table 4. Habitat Data Calculations Providing SI and HSI Values for the Gray Squirrel

Tract Number	Plot Number	Gray Squirrel					SI for Life Requisites		HSI
		SIV1 - % of Tree Canopy Hard Mast >10 in.	**SIV2** - # of Hard Mast Species	**SIV3** - % Canopy Cover of Trees	**SIV4** - % Tree Canopy Cover	**SIV5** - Mean DBH of Overstory Trees	**Winter Food**	**Cover/Reprduction**	**Lower of Life Requisites**
2	1	0.24	0.20	0.84	1.00	0.41	0.18	0.64	0.18
	2	0.64	0.20	0.84	1.00	0.51	0.30	0.71	0.30
4	1	0.10	0.10	1.00	1.00	0.60	0.10	0.77	0.10
	2	0.10	0.20	1.00	1.00	0.30	0.14	0.55	0.14
7	1	0.10	0.10	1.00	1.00	0.10	0.10	0.32	0.10
	2	0.10	0.10	0.96	1.00	1.00	0.10	1.00	0.10
9	1	0.33	0.20	1.00	1.00	0.73	0.25	0.85	0.25
	2	0.33	0.20	0.88	1.00	0.67	0.22	0.82	0.22
12	1	0.10	0.10	0.96	1.00	0.80	0.10	0.89	0.10
	2	0.10	0.10	1.00	1.00	0.83	0.10	0.91	0.10
14	1	0.10	0.10	1.00	1.00	0.90	0.10	0.95	0.10
	2	0.10	0.10	0.92	1.00	1.00	0.09	1.00	0.09
16	1	0.10	0.10	1.00	1.00	1.00	0.10	1.00	0.10
	2	0.10	0.10	1.00	1.00	0.97	0.10	0.98	0.10
19	1	0.60	0.50	1.00	1.00	1.00	0.55	1.00	0.55
	2	0.64	0.50	1.00	1.00	0.98	0.57	0.99	0.57
20	1	0.33	0.20	1.00	1.00	0.67	0.25	0.82	0.25
	2	0.33	0.10	0.88	1.00	0.90	0.16	0.95	0.16
21	1	0.10	0.10	0.88	1.00	0.00	0.09	0.00	0.00
	2	0.10	0.10	0.84	1.00	1.00	0.08	1.00	0.08
23	1	0.19	0.20	0.84	1.00	1.00	0.16	1.00	0.16
	2	0.55	0.50	0.84	1.00	1.00	0.44	1.00	0.44
32	1	0.15	0.10	0.50	0.50	0.43	0.06	0.46	0.06
	2	0.24	0.80	1.00	1.00	1.00	0.43	1.00	0.43
33	1	0.19	0.50	0.92	1.00	0.48	0.28	0.69	0.28
	2	0.10	0.20	1.00	1.00	0.60	0.14	0.77	0.14
37	1	0.10	0.10	1.00	1.00	0.55	0.10	0.74	0.10
	2	0.10	0.10	1.00	1.00	0.30	0.10	0.55	0.10
40	1	0.28	0.20	1.00	1.00	0.37	0.24	0.61	0.24
	2	0.10	0.10	0.96	1.00	1.00	0.10	1.00	0.10
42	1	0.55	0.20	1.00	1.00	1.00	0.33	1.00	0.33
	2	0.46	0.50	1.00	1.00	1.00	0.48	1.00	0.48

Table 4. Habitat Data Calculations Providing SI and HSI Values for the Gray Squirrel

43	1	0.28	0.50	0.96	1.00	1.00	0.36	1.00	0.36
	2	0.60	0.50	0.92	1.00	1.00	0.50	1.00	0.50
44	1	0.82	1.00	0.92	1.00	0.84	0.83	0.92	0.83
	2	0.60	1.00	1.00	1.00	0.88	0.77	0.94	0.77
46	1	0.42	0.50	1.00	1.00	0.86	0.46	0.93	0.46
	2	0.69	0.50	0.88	1.00	1.00	0.52	1.00	0.52
49	1	0.69	0.50	0.88	1.00	0.58	0.52	0.76	0.52
	2	0.78	0.80	0.88	1.00	0.94	0.69	0.97	0.69
52	1	0.10	0.10	0.88	1.00	1.00	0.09	1.00	0.09
	2	0.10	0.10	0.84	1.00	1.00	0.08	1.00	0.08
54	1	0.82	0.20	0.96	1.00	0.83	0.39	0.91	0.39
	2	0.82	0.50	0.92	1.00	1.00	0.59	1.00	0.59
57	1	0.37	0.50	1.00	1.00	0.19	0.43	0.44	0.43
	2	0.10	0.20	0.50	0.50	0.04	0.07	0.14	0.07
62	1	0.82	0.50	0.88	1.00	1.00	0.56	1.00	0.56
	2	0.60	0.80	1.00	1.00	0.93	0.69	0.96	0.69
63	1	0.10	0.10	0.88	1.00	0.92	0.09	0.96	0.09
	2	0.60	0.50	0.92	1.00	1.00	0.50	1.00	0.50
64	1	0.42	0.50	1.00	1.00	1.00	0.46	1.00	0.46
	2	0.55	0.80	1.00	1.00	1.00	0.66	1.00	0.66
65	1	0.82	0.50	0.92	1.00	0.89	0.59	0.94	0.59
	2	0.69	0.80	1.00	1.00	1.00	0.74	1.00	0.74
66	1	0.10	0.10	1.00	1.00	0.73	0.10	0.85	0.10
	2	0.10	0.10	0.92	1.00	0.26	0.09	0.51	0.09
71	1	0.78	1.00	1.00	1.00	1.00	0.88	1.00	0.88
	2	0.73	0.80	1.00	1.00	1.00	0.76	1.00	0.76
75	1	0.10	0.50	0.84	1.00	0.00	0.19	0.00	0.00
	2	0.33	0.20	0.96	1.00	0.19	0.24	0.44	0.24
76	1	0.91	0.50	0.88	1.00	1.00	0.59	1.00	0.59
	2	0.78	0.80	0.88	1.00	1.00	0.69	1.00	0.69
77	1	0.55	0.80	0.88	1.00	0.47	0.58	0.69	0.58
	2	0.28	0.50	0.88	1.00	0.51	0.33	0.71	0.33
81	1	0.87	1.00	0.84	1.00	1.00	0.78	1.00	0.78
	2	0.91	1.00	0.84	1.00	0.53	0.80	0.73	0.73
84	1	0.42	0.50	0.88	1.00	0.73	0.40	0.85	0.40
	2	0.46	0.80	1.00	1.00	0.64	0.61	0.80	0.61
89	1	0.33	0.50	0.88	1.00	0.75	0.35	0.87	0.35
	2	0.55	0.80	1.00	1.00	0.57	0.66	0.75	0.66
91	1	0.51	0.80	0.88	1.00	1.00	0.56	1.00	0.56
	2	0.37	0.80	1.00	1.00	0.51	0.54	0.71	0.54
93	1	0.19	0.50	0.88	1.00	0.14	0.27	0.37	0.27
	2	0.51	0.80	0.88	1.00	1.00	0.56	1.00	0.56
101	1	0.10	0.80	0.96	1.00	1.00	0.27	1.00	0.27
	2	0.33	1.00	1.00	1.00	0.54	0.57	0.73	0.57
104	1	0.10	0.10	0.92	1.00	0.52	0.09	0.72	0.09
	2	0.10	0.10	0.84	1.00	0.78	0.08	0.88	0.08

Table 4. Habitat Data Calculations Providing SI and HSI Values for the Gray Squirrel

114	1	0.24	0.50	1.00	1.00	0.58	0.34	0.76	0.34
	2	0.10	0.50	0.96	1.00	0.60	0.21	0.77	0.21
116	1	0.73	0.50	0.96	1.00	1.00	0.58	1.00	0.58
	2	0.51	0.80	1.00	1.00	0.65	0.64	0.81	0.64
117	1	0.33	0.80	1.00	1.00	0.36	0.51	0.60	0.51
	2	0.46	0.80	1.00	1.00	0.85	0.61	0.92	0.61
125	1	0.42	0.20	0.84	1.00	0.80	0.24	0.89	0.24
	2	0.55	0.50	0.84	1.00	0.82	0.44	0.91	0.44
129	1	0.10	0.10	0.63	0.63	0.40	0.06	0.50	0.06
	2	0.19	0.20	1.00	1.00	0.38	0.19	0.62	0.19
131	1	0.78	0.50	0.96	1.00	0.79	0.60	0.89	0.60
	2	0.82	0.50	0.96	1.00	0.69	0.61	0.83	0.61
136	1	0.78	0.80	0.92	1.00	0.80	0.72	0.89	0.72
	2	0.82	0.80	0.96	1.00	0.68	0.78	0.82	0.78
140	1	0.46	0.80	1.00	1.00	1.00	0.61	1.00	0.61
	2	0.60	0.80	1.00	1.00	1.00	0.69	1.00	0.69
143	1	0.46	0.50	1.00	1.00	0.64	0.48	0.80	0.48
	2	0.37	1.00	1.00	1.00	0.65	0.61	0.81	0.61
153	1	0.60	0.80	1.00	1.00	0.62	0.69	0.79	0.69
	2	0.55	1.00	0.96	1.00	0.45	0.71	0.67	0.67
156	1	0.73	0.80	1.00	1.00	1.00	0.76	1.00	0.76
	2	0.37	0.20	0.92	1.00	1.00	0.25	1.00	0.25
157	1	0.10	0.10	0.88	1.00	1.00	0.09	1.00	0.09
	2	0.73	0.50	0.92	1.00	0.93	0.56	0.96	0.56
175	1	0.19	0.20	1.00	1.00	1.00	0.19	1.00	0.19
	2	0.24	0.20	1.00	1.00	0.75	0.22	0.87	0.22
189	1	0.33	0.10	1.00	1.00	1.00	0.18	1.00	0.18
	2	0.73	0.80	0.96	1.00	1.00	0.73	1.00	0.73
200	1	0.37	0.20	1.00	1.00	1.00	0.27	1.00	0.27
	2	0.19	0.50	1.00	1.00	0.77	0.31	0.88	0.31
206	1	0.33	0.80	0.96	1.00	0.73	0.49	0.85	0.49
	2	0.64	0.80	1.00	1.00	0.68	0.72	0.82	0.72
213	1	0.42	0.50	1.00	1.00	0.68	0.46	0.82	0.46
	2	0.73	1.00	0.96	1.00	0.96	0.82	0.98	0.82
218	1	0.10	0.10	0.96	1.00	1.00	0.10	1.00	0.10
	2	0.10	0.10	0.92	1.00	0.68	0.09	0.82	0.09
221	1	0.10	0.10	1.00	1.00	0.93	0.10	0.96	0.10
	2	0.10	0.10	0.75	0.75	1.00	0.08	0.87	0.08
223	1	0.10	0.20	1.00	1.00	0.87	0.14	0.93	0.14
	2	0.15	0.10	1.00	1.00	0.83	0.12	0.91	0.12
224	1	0.33	0.20	1.00	1.00	1.00	0.25	1.00	0.25
	2	0.10	0.10	0.84	1.00	0.87	0.08	0.93	0.08
231	1	0.10	0.20	0.96	1.00	1.00	0.14	1.00	0.14
	2	0.10	0.20	0.96	1.00	1.00	0.14	1.00	0.14
241	1	0.51	0.50	0.96	1.00	1.00	0.48	1.00	0.48
	2	0.60	0.80	1.00	1.00	1.00	0.69	1.00	0.69

Table 4. Habitat Data Calculations Providing SI and HSI Values for the Gray Squirrel

243	1	0.10	0.10	1.00	1.00	0.94	0.10	0.97	0.10
	2	0.10	0.10	0.88	1.00	0.85	0.09	0.92	0.09
245	1	0.10	0.10	1.00	1.00	1.00	0.10	1.00	0.10
	2	0.10	0.10	1.00	1.00	0.78	0.10	0.88	0.10
251	1	0.28	0.50	0.84	1.00	0.21	0.31	0.46	0.31
	2	0.19	0.80	0.96	1.00	0.20	0.37	0.45	0.37
265	1	0.37	0.50	0.75	0.75	0.70	0.32	0.72	0.32
	2	0.46	0.50	1.00	1.00	0.68	0.48	0.82	0.48
266	1	0.42	0.50	0.96	1.00	1.00	0.44	1.00	0.44
	2	0.42	0.50	0.92	1.00	1.00	0.42	1.00	0.42
277	1	0.91	0.20	0.84	1.00	1.00	0.36	1.00	0.36
	2	0.28	0.20	0.88	1.00	1.00	0.21	1.00	0.21
288	1	0.33	0.50	1.00	1.00	0.65	0.40	0.81	0.40
	2	0.37	0.80	0.96	1.00	0.73	0.52	0.85	0.52
295	1	0.55	1.00	1.00	1.00	0.96	0.74	0.98	0.74
	2	0.73	0.50	1.00	1.00	0.93	0.60	0.96	0.60
309	1	0.10	0.10	0.88	1.00	0.78	0.09	0.88	0.09
	2	0.10	0.10	0.92	1.00	0.83	0.09	0.91	0.09
331	1	0.69	0.50	1.00	1.00	0.75	0.59	0.87	0.59
	2	0.69	0.80	1.00	1.00	0.80	0.74	0.89	0.74
336	1	0.46	1.00	0.96	1.00	0.43	0.65	0.66	0.65
	2	0.64	0.80	0.96	1.00	0.40	0.69	0.63	0.63
340	1	0.37	0.50	0.96	1.00	0.83	0.41	0.91	0.41
	2	0.78	0.50	0.92	1.00	1.00	0.57	1.00	0.57
343	1	0.10	0.10	1.00	1.00	0.65	0.10	0.81	0.10
	2	0.10	0.10	0.88	1.00	0.45	0.09	0.67	0.09
346	1	0.78	0.80	0.84	1.00	0.73	0.66	0.85	0.66
	2	0.10	0.50	0.84	1.00	0.00	0.19	0.00	0.00
349	1	0.46	0.80	0.84	1.00	0.50	0.51	0.71	0.51
	2	0.69	0.80	0.88	1.00	1.00	0.65	1.00	0.65
357	1	0.69	0.80	0.96	1.00	0.48	0.71	0.69	0.69
	2	0.55	1.00	1.00	1.00	0.45	0.74	0.67	0.67
358	1	0.55	0.80	0.92	1.00	0.28	0.61	0.53	0.53
	2	0.64	0.50	0.92	1.00	0.49	0.52	0.70	0.52
360	1	0.28	0.20	0.88	1.00	1.00	0.21	1.00	0.21
	2	0.37	0.20	0.96	1.00	1.00	0.26	1.00	0.26
AVERAGE OF PLOT HSIs									0.38
STANDARD DEVIATION									0.241487
COEFFICIENT OF VARIATION									63.6

Table 5. Habitat Data Calculations Providing SI and HSI Values for the Pileated Woodpecker

Tract Number	Plot Number	Pileated Woodpecker					HSI		
		SIV1 - % cover of trees	SIV2 - # trees >= 20 in./acre	SIV3 - # stumps and logs	SIV4 - # snags > 15 in. dbh/acre	SIV5 - Avg. dbh of snags > 15 in.	$(V1*V2*V3)^{1/2}$	$(V4*V5)^{1/2}$	Lower of Equations
2	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	0.50	0.00	1.00	0.00	0.00	0.00	0.00	0.00
4	1	0.70	0.29	1.00	0.00	0.00	0.38	0.00	0.00
	2	0.40	0.00	1.00	0.00	0.00	0.00	0.00	0.00
7	1	1.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
	2	0.90	0.29	1.00	0.00	0.00	0.54	0.00	0.00
9	1	1.00	0.00	1.00	1.00	0.49	0.00	0.70	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
12	1	0.80	0.29	1.00	1.00	0.49	0.54	0.70	0.54
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
14	1	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.00
	2	0.80	0.00	1.00	0.00	0.00	0.00	0.00	0.00
16	1	0.60	1.00	1.00	0.00	0.00	0.89	0.00	0.00
	2	1.00	0.69	1.00	0.00	0.00	0.64	0.00	0.00
19	1	0.90	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
20	1	1.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
21	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
23	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	0.00	0.69	1.00	0.00	0.00	0.83	0.00	0.00
32	1	0.40	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.34	0.00	0.00
33	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	0.70	0.00	1.00	1.00	0.25	0.00	0.50	0.00
37	1	1.00	0.29	1.00	0.00	0.00	0.45	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
40	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
42	1	0.40	0.69	1.00	0.00	0.00	0.83	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.34	0.00	0.00
43	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
44	1	1.00	0.29	1.00	1.00	0.49	0.54	0.70	0.54
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00

Table 5. Habitat Data Calculations Providing SI and HSI Values for the Pileated Woodpecker

46	1	1.00	0.00	1.00	1.00	0.61	0.00	0.78	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
49	1	1.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
52	1	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
54	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	0.40	1.00	1.00	0.00	0.00	1.00	0.00	0.00
57	1	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
62	1	0.90	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.51	0.00	0.00
63	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	1.00	0.69	1.00	0.00	0.00	0.83	0.00	0.00
64	1	0.90	0.00	1.00	1.00	0.79	0.00	0.89	0.00
	2	1.00	1.00	1.00	1.00	0.49	0.95	0.70	0.70
65	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	0.90	0.29	1.00	0.00	0.00	0.54	0.00	0.00
66	1	1.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
71	1	0.90	0.69	1.00	1.00	0.37	0.83	0.61	0.61
	2	1.00	0.29	1.00	0.00	0.00	0.51	0.00	0.00
75	1	1.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
76	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
77	1	1.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
81	1	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
84	1	0.50	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
89	1	1.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
91	1	1.00	0.29	1.00	1.00	0.25	0.54	0.50	0.50
	2	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.00
93	1	1.00	0.00	1.00	1.00	0.25	0.00	0.50	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
101	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
104	1	1.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
114	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
116	1	0.50	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	0.60	0.00	1.00	0.00	0.00	0.00	0.00	0.00

Table 5. Habitat Data Calculations Providing SI and HSI Values for the Pileated Woodpecker

117	1	0.70	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.29	1.00	1.00	0.61	0.45	0.78	0.45
125	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
129	1	0.40	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
131	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
136	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	0.90	0.00	1.00	0.00	0.00	0.00	0.00	0.00
140	1	0.90	0.69	1.00	1.00	1.00	0.79	1.00	0.79
	2	1.00	0.69	0.30	0.00	0.00	0.43	0.00	0.00
143	1	0.90	0.00	0.30	0.00	0.00	0.00	0.00	0.00
	2	0.90	0.00	1.00	0.00	0.00	0.00	0.00	0.00
153	1	1.00	0.29	1.00	0.00	0.00	0.51	0.00	0.00
	2	1.00	0.29	1.00	1.00	0.37	0.54	0.61	0.54
156	1	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	1.00	0.29	1.00	1.00	0.37	0.54	0.61	0.54
157	1	1.00	0.69	1.00	1.00	0.61	0.83	0.78	0.78
	2	0.70	0.29	1.00	0.00	0.00	0.54	0.00	0.00
175	1	1.00	0.29	1.00	0.00	0.00	0.45	0.00	0.00
	2	0.70	0.29	1.00	1.00	0.61	0.54	0.78	0.54
189	1	1.00	0.29	1.00	1.00	1.00	0.45	1.00	0.45
	2	0.70	0.69	1.00	0.00	0.00	0.83	0.00	0.00
200	1	0.40	0.29	1.00	0.00	0.00	0.45	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
206	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	0.70	0.00	1.00	1.00	0.49	0.00	0.70	0.00
213	1	1.00	0.69	1.00	1.00	0.49	0.69	0.70	0.69
	2	1.00	0.69	1.00	1.00	0.73	0.83	0.85	0.83
218	1	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
221	1	0.10	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	1.00	0.29	1.00	1.00	1.00	0.17	1.00	0.17
223	1	0.50	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.00
224	1	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
231	1	1.00	1.00	0.65	1.00	0.37	0.81	0.61	0.61
	2	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
241	1	0.90	0.69	1.00	0.00	0.00	0.83	0.00	0.00
	2	1.00	0.29	0.30	0.00	0.00	0.28	0.00	0.00
243	1	1.00	1.00	1.00	0.00	0.00	1.00	0.00	0.00
	2	0.30	0.69	1.00	0.00	0.00	0.83	0.00	0.00
245	1	0.30	1.00	0.30	0.00	0.00	0.30	0.00	0.00
	2	1.00	0.69	0.65	0.00	0.00	0.37	0.00	0.00

Table 5. Habitat Data Calculations Providing SI and HSI Values for the Pileated Woodpecker

251	1	1.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
	2	0.10	0.00	1.00	0.00	0.00	0.00	0.00	0.00
265	1	0.60	0.00	1.00	1.00	0.49	0.00	0.70	0.00
	2	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.00
266	1	1.00	0.69	1.00	1.00	0.61	0.83	0.78	0.78
	2	1.00	0.69	1.00	0.00	0.00	0.83	0.00	0.00
277	1	1.00	0.69	1.00	0.00	0.00	0.83	0.00	0.00
	2	0.80	1.00	1.00	0.00	0.00	1.00	0.00	0.00
288	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	0.60	0.00	1.00	0.00	0.00	0.00	0.00	0.00
295	1	0.90	0.29	1.00	1.00	0.00	0.42	0.00	0.00
	2	1.00	0.29	0.30	0.00	0.00	0.28	0.00	0.00
309	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	1.00	0.37	0.00	0.61	0.00
331	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
336	1	1.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
340	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.69	1.00	0.00	0.00	0.83	0.00	0.00
343	1	1.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
346	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	1.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00
349	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
357	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
358	1	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	2	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
360	1	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
	2	1.00	0.29	1.00	0.00	0.00	0.54	0.00	0.00
AVERAGE OF PLOT HSIs									0.06
STANDARD DEVIATION									0.190117
COEFFICIENT OF VARIATION									302.5

Table 6. Habitat Data Calculations Providing SI and HSI Values for the Carolina Chickadee									
			Carolina Chickadee						
						SI			HSI
Tract Number	Plot Number	SIV1 - % cover of trees	SIV2 – Avg. Height of trees	SIV3 - # trees with 1 in. cavities and # of snags > 4 in. dbh/ha		Food SI	Nest SI		Lower of Food and Nest
2	1	1.00	0.76	1.00		0.76	1.00		0.76
	2	1.00	0.77	1.00		0.77	1.00		0.77
4	1	0.72	0.53	0.00		0.38	0.00		0.00
	2	0.86	0.50	1.00		0.43	1.00		0.43
7	1	0.64	0.35	0.00		0.23	0.00		0.00
	2	1.00	0.65	0.00		0.65	0.00		0.00
9	1	1.00	0.73	1.00		0.73	1.00		0.73
	2	1.00	0.95	1.00		0.95	1.00		0.95
12	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	0.93	0.88	1.00		0.82	1.00		0.82
14	1	1.00	0.80	1.00		0.80	1.00		0.80
	2	1.00	0.13	1.00		0.13	1.00		0.13
16	1	0.93	1.00	1.00		0.93	1.00		0.93
	2	0.79	1.00	1.00		0.79	1.00		0.79
19	1	1.00	0.73	1.00		0.73	1.00		0.73
	2	1.00	0.73	1.00		0.73	1.00		0.73
20	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
21	1	1.00	0.05	1.00		0.05	1.00		0.05
	2	1.00	0.13	1.00		0.13	1.00		0.13
23	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
32	1	0.29	0.61	1.00		0.17	1.00		0.17
	2	0.64	0.61	0.00		0.39	0.00		0.00
33	1	1.00	0.74	1.00		0.74	1.00		0.74
	2	1.00	0.65	1.00		0.65	1.00		0.65
37	1	0.86	0.65	1.00		0.56	1.00		0.56
	2	1.00	0.61	1.00		0.61	1.00		0.61
40	1	1.00	0.74	1.00		0.74	1.00		0.74
	2	1.00	1.00	1.00		1.00	1.00		1.00
42	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	0.64	1.00	1.00		0.64	1.00		0.64
43	1	1.00	0.89	1.00		0.89	1.00		0.89
	2	1.00	0.71	0.00		0.71	0.00		0.00
44	1	1.00	0.88	1.00		0.88	1.00		0.88
	2	1.00	0.82	1.00		0.82	1.00		0.82

Table 6. Habitat Data Calculations Providing SI and HSI Values for the Carolina Chickadee

46	1	1.00	0.95	1.00		0.95	1.00		0.95
	2	1.00	0.88	1.00		0.88	1.00		0.88
49	1	1.00	0.86	1.00		0.86	1.00		0.86
	2	1.00	0.85	1.00		0.85	1.00		0.85
52	1	1.00	1.00	0.00		1.00	0.00		0.00
	2	1.00	1.00	0.00		1.00	0.00		0.00
54	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	0.94	1.00		0.94	1.00		0.94
57	1	0.64	0.44	1.00		0.29	1.00		0.29
	2	0.29	0.31	0.00		0.09	0.00		0.00
62	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
63	1	1.00	0.79	1.00		0.79	1.00		0.79
	2	1.00	0.97	1.00		0.97	1.00		0.97
64	1	1.00	0.74	1.00		0.74	1.00		0.74
	2	1.00	0.94	1.00		0.94	1.00		0.94
65	1	1.00	0.88	1.00		0.88	1.00		0.88
	2	1.00	1.00	1.00		1.00	1.00		1.00
66	1	1.00	0.73	1.00		0.73	1.00		0.73
	2	1.00	0.89	1.00		0.89	1.00		0.89
71	1	1.00	0.94	1.00		0.94	1.00		0.94
	2	1.00	0.95	1.00		0.95	1.00		0.95
75	1	1.00	0.31	0.00		0.31	0.00		0.00
	2	1.00	0.64	1.00		0.64	1.00		0.64
76	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	0.88	1.00		0.88	1.00		0.88
77	1	1.00	1.00	0.00		1.00	0.00		0.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
81	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
84	1	1.00	0.88	1.00		0.88	1.00		0.88
	2	0.72	0.79	1.00		0.56	1.00		0.56
89	1	1.00	0.74	0.00		0.74	0.00		0.00
	2	1.00	0.83	1.00		0.83	1.00		0.83
91	1	1.00	0.79	1.00		0.79	1.00		0.79
	2	1.00	0.76	1.00		0.76	1.00		0.76
93	1	1.00	0.59	1.00		0.59	1.00		0.59
	2	1.00	0.56	1.00		0.56	1.00		0.56
101	1	1.00	0.83	1.00		0.83	1.00		0.83
	2	1.00	0.88	1.00		0.88	1.00		0.88
104	1	1.00	0.58	0.00		0.58	0.00		0.00
	2	1.00	0.86	0.00		0.86	0.00		0.00
114	1	1.00	0.76	1.00		0.76	1.00		0.76
	2	1.00	0.68	1.00		0.68	1.00		0.68
116	1	1.00	0.89	1.00		0.89	1.00		0.89
	2	0.72	0.88	1.00		0.63	1.00		0.63

Table 6. Habitat Data Calculations Providing SI and HSI Values for the Carolina Chickadee

117	1	0.79	0.62	1.00		0.49	1.00		0.49
	2	0.86	0.61	1.00		0.52	1.00		0.52
125	1	1.00	0.89	1.00		0.89	1.00		0.89
	2	1.00	0.70	1.00		0.70	1.00		0.70
129	1	0.36	0.32	0.00		0.12	0.00		0.00
	2	0.64	0.35	0.00		0.23	0.00		0.00
131	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	0.95	1.00		0.95	1.00		0.95
136	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
140	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
143	1	1.00	0.46	1.00		0.46	1.00		0.46
	2	1.00	0.70	1.00		0.70	1.00		0.70
153	1	1.00	0.79	1.00		0.79	1.00		0.79
	2	1.00	0.88	1.00		0.88	1.00		0.88
156	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
157	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	0.83	1.00		0.83	1.00		0.83
175	1	0.86	0.71	0.00		0.61	0.00		0.00
	2	1.00	0.80	1.00		0.80	1.00		0.80
189	1	0.86	1.00	1.00		0.86	1.00		0.86
	2	1.00	1.00	1.00		1.00	1.00		1.00
200	1	0.86	1.00	1.00		0.86	1.00		0.86
	2	0.64	1.00	1.00		0.64	1.00		0.64
206	1	1.00	0.95	1.00		0.95	1.00		0.95
	2	1.00	0.94	1.00		0.94	1.00		0.94
213	1	0.86	0.71	1.00		0.61	1.00		0.61
	2	1.00	0.77	1.00		0.77	1.00		0.77
218	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
221	1	1.00	0.61	1.00		0.61	1.00		0.61
	2	0.43	0.98	1.00		0.42	1.00		0.42
223	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	0.72	0.80	1.00		0.57	1.00		0.57
224	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
231	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
241	1	1.00	0.55	1.00		0.55	1.00		0.55
	2	1.00	1.00	1.00		1.00	1.00		1.00
243	1	1.00	0.88	1.00		0.88	1.00		0.88
	2	1.00	0.89	1.00		0.89	1.00		0.89
245	1	0.57	0.88	1.00		0.50	1.00		0.50
	2	0.57	0.88	1.00		0.50	1.00		0.50

Table 6. Habitat Data Calculations Providing SI and HSI Values for the Carolina Chickadee

251	1	1.00	0.53	1.00		0.53	1.00		0.53
	2	1.00	0.55	1.00		0.55	1.00		0.55
265	1	0.43	1.00	1.00		0.43	1.00		0.43
	2	0.79	1.00	1.00		0.79	1.00		0.79
266	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
277	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	1.00	1.00		1.00	1.00		1.00
288	1	0.93	0.79	0.00		0.73	0.00		0.00
	2	1.00	1.00	0.00		1.00	0.00		0.00
295	1	0.79	1.00	1.00		0.79	1.00		0.79
	2	1.00	0.94	1.00		0.94	1.00		0.94
309	1	1.00	0.80	1.00		0.80	1.00		0.80
	2	1.00	0.88	1.00		0.88	1.00		0.88
331	1	1.00	1.00	1.00		1.00	1.00		1.00
	2	1.00	0.91	1.00		0.91	1.00		0.91
336	1	1.00	0.73	1.00		0.73	1.00		0.73
	2	1.00	0.95	1.00		0.95	1.00		0.95
340	1	1.00	0.88	1.00		0.88	1.00		0.88
	2	1.00	0.94	1.00		0.94	1.00		0.94
343	1	1.00	0.58	0.00		0.58	0.00		0.00
	2	1.00	0.73	1.00		0.73	1.00		0.73
346	1	1.00	0.79	1.00		0.79	1.00		0.79
	2	1.00	0.65	0.00		0.65	0.00		0.00
349	1	1.00	0.65	1.00		0.65	1.00		0.65
	2	1.00	0.47	0.00		0.47	0.00		0.00
357	1	1.00	0.83	1.00		0.83	1.00		0.83
	2	1.00	0.77	0.00		0.77	0.00		0.00
358	1	1.00	0.80	1.00		0.80	1.00		0.80
	2	1.00	0.70	1.00		0.70	1.00		0.70
360	1	1.00	0.55	1.00		0.55	1.00		0.55
	2	1.00	0.55	1.00		0.55	1.00		0.55
AVERAGE OF PLOT HSIs									0.69
STANDARD DEVIATION									0.33674
COEFFICIENT OF VARIATION									48.7

SECTION XIV

AQUATIC EVALUATIONS

Part A. Fisheries
Part B. Mussels

SECTION XIV

AQUATIC EVALUATIONS

Part A. Fisheries

Volume 10 – Appendix D

BAYOU METO WATER SUPPLY AND FLOOD CONTROL PROJECT

FISH EVALUATION

K. Jack Killgore, Jan J. Hoover, and Catherine E. Murphy

U. S. Army Engineer Research and Development Center
Waterways Experiment Station
Vicksburg, Mississippi

24 Feb 05

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Water supply and flood control alternatives are being evaluated in the Bayou Meto Basin, central Arkansas. This document analyzes benefits and impacts to fish habitat, and provides mitigation requirements. During summer and autumn, low water prevails in the bayous and ditches that traverse a largely agricultural landscape. Irrigation demands are depleting the aquifers, so there is a greater reliance on surface water withdrawal that further reduces water levels in streams and bayous. Stagnant, shallow water results in hypoxia (dissolved oxygen < 3.0 mg/l), cleared stream banks adjacent to agricultural fields increase water temperatures, and excessive sedimentation further degrades the aquatic environment.

The fish community reflects anthropogenic disturbances. Approximately 75% of the total numbers of fish collected in the basin is comprised of tolerant, widespread taxa: mosquitofish, bluegill, red shiner, green sunfish, orangespotted sunfish, and golden shiner. However, there are stream reaches in the basin that are less disturbed and support a more diverse assemblage of fishes. Overall, 43 species of fish have been documented in the streams and canals of the basin. These include benthic minnows and darters that prefer stable substrates, wetland species that dominate pools and backwaters, and exploitable fishes in the larger streams.

Diversion of water from the Arkansas River to an irrigation delivery system in the Basin will increase water volume in streams, ditches, and canals. Water will be diverted from the Arkansas River into a 30-acre reservoir for regulating flow to a central canal and a system of distributaries. Larval fish could be entrained during diversion, but ichthyoplankton collections in 2000 and 2001 in the Arkansas River indicate that the risk is low (<3.0%) during the peak irrigation season (summer). Of the ten species that were collected in the drift and potentially susceptible to entrainment, widespread, tolerant taxa (gizzard shad and drum) were numerically abundant. However, buffalo and carpsuckers were also prevalent during April collections, and these species are not adapted to smaller streams in the Bayou Meto Basin.

A regulation reservoir and numerous smaller, on-farm storage reservoirs will be constructed as part of the irrigation system. These waterbodies can benefit lacustrine and backwater fishes that prefer slackwater conditions. As part of the Habitat Evaluation Procedure, Habitat Units (HUs) were used to quantify benefits. Depending on alternative, 988 to 2,909 acres of functional, lacustrine habitat will be created resulting in a gain of 741 to 2,182 HUs. We assumed that only 20% of on-farm reservoirs would actually retain water year around; the remaining 80% will periodically become dewatered preventing establishment of permanent fish populations. Construction impacts of storage reservoirs were also considered; 180 acres of reforested lands are required to mitigate these impacts.

Over 90 miles of bayous and ditches will receive irrigation water diverted from the Arkansas River, and almost 100 miles of new canals will be constructed as distributaries. Over 60 weirs will be constructed to maintain minimum pool elevations and provide riffle-like habitat

immediately downstream. Sediment removal will occur when channels are widened or deepened to facilitate design flows for the irrigation delivery system. Removal of unconsolidated substrates will improve biotic integrity of degraded streams. Habitat models developed from field data collected over several years in the basin substantiates benefits of irrigation water to fish habitat. Gain in HUs for receiving streams ranged from 42 to 92%. Overall, a total of 316 acres (296 HUs) of additional stream habitat will be created post-project.

Despite low water problems in the basin, flooding does occur in some reaches during the spring. As part of the comprehensive study of Bayou Meto, flood control alternatives are being evaluated that includes channel work to increase discharge capacity and different pump capacities at Little Bayou Meto. Floodplain larval fish fauna is diverse (over 20 taxa), consisting of river species that spawn in flooded forests (buffalo, gar), rear in floodplain waterbodies (sunfish, other suckers, minnows), and other wetland specialists that are permanent inhabitants of floodplains and backwaters (pirate perch, silversides, flier, topminnows, certain minnow and darters). Hydraulic models and GIS landuse classifications were used to determine changes in duration and magnitude of flooding for each alternative, and HUs were calculated to quantify impacts to fish habitat. Currently, 15,689 acres of functional, reproductive habitat is flooded at least once every 2-years. Depending on reach, cultivated agricultural land and bottomland hardwood forests are the dominant landuse category in the 2-year floodplain. Alternative Flood Control (FC) 2 had the least impact on flood reduction (1,024 acres) and Alternative FC3B had the greatest (1,406). Direct, construction impacts to the riparian zone were also considered, and losses were greatest for Alternative FC3B (1,186 acres). Overall, HU loss was less for the non-pump alternatives (Alternatives FC2 and FC2A) and greatest for the pump alternatives (FC3A and FC3B).

Mitigation of impacts will likely occur through reforestation and establishment of riparian buffer strips. For indirect impacts, mitigation requirements ranged from 894 acres of reforestation for Alternative FC2 to 1,307 acres for Alternative FC3B. For direct impacts, mitigation requirements ranged from 685 acres of reforestation for Alternative FC2 to 1,186 acres for Alternative FC3B. Cumulative reforestation requirement (direct and indirect) for Alternative FC3B, which provides maximum flood protection, is 2,493 acres. Creation of permanent floodplain pools for wetland fishes, frogs, and salamanders are also recommended by excavating shallow depressions during reforestation of agricultural lands. Floodplain pools are easy to create and inexpensive, they can function as wetlands independently of river stage (e.g., from receding water or from rainfall), and they provide distinctive habitat that has been substantially reduced in the lower Mississippi Basin.

INTRODUCTION

Bayou Meto and its tributaries encompass over 700,000 square acres in central Arkansas, primarily in Arkansas and Jefferson counties. Within the basin, there are over 640 miles of streams and bayous that flow adjacent to agricultural land and bottomland hardwood forests. The lower reach of the basin lies within a wildlife management area with contiguous forested lands, but the majority of lands have been cleared for production of cotton, soybeans, rice and aquaculture. Consequently, agricultural demands for water are depleting the alluvial aquifer. In 1998, Congress authorized the Corps of Engineers to evaluate water supply in the basin. The U.S. Army Engineer Districts, Vicksburg (CELMK) and Memphis (CELMM) began investigating alternative sources of water for agricultural irrigation, baitfish production, commercial withdrawal, and duck management. The alternatives include diverting up to 1,850 cfs from the Arkansas River immediately upstream of Joe Hardin L&D into the Bayou Meto basin (Table 1). Water will be pumped into a 30-acre reservoir for regulating flow to a central canal and a system of streams, canals, and pipelines in the surrounding delta.

The Corps is also developing flood control alternatives as part of this comprehensive study. Headwater flooding in the basin forms a sump near the mouth of Bayou Meto, which currently has a gravity outlet structure that empties into the Arkansas River. To reduce the sump area, an alternative gravity outlet and pumping station at Little Bayou Meto are being considered. In addition, channel modifications are planned for certain flood-prone reaches of the basin to increase flow efficiency during high stages. Alternatives being considered include selective clearing and snagging and excavation of the channel, both of which will reduce duration of flooding.

The potential impacts and benefits of the projects on aquatic habitat and fish were studied during 2000-2003. Ichthyoplankton (fish eggs and larvae) may be diverted from the Arkansas River into Bayou Meto during the irrigation season and possibly affect abundance of some taxa in the Arkansas River. However, potential benefits of the water supply project are creation of permanent waterbodies (i.e., regulation reservoir and on-farm storage reservoirs) and replenishment of streams in the delta that would improve fish habitat during summer. Flood control activities would alter channel geomorphology, remove woody debris along the stream banks, and effect habitat quality of channel fishes. Once channel modifications are completed, floodplain hydrology will be altered that may influence spawning and rearing success of fishes. To address these potential impacts and benefits, field studies were conducted with the following objectives: (1) evaluate potential losses of fishes from the Arkansas River during water diversion to the Bayou Meto basin, (2) estimate benefits of increased water levels in receiving streams and canals on fish, and (3) quantify impacts and mitigation requirements of flood control activities on reproduction of fishes in the floodplain.

METHODS

Water Diversion

Potential losses of ichthyoplankton (eggs and larvae) from the Arkansas River were evaluated from field collections during the irrigation season (April-September) near the diversion site at Arkansas River Mile 108.5 immediately upstream of David D. Terry Lock and Dam (Pool 6). The dam uses 17, 60' by 27' gates along its 1,190 foot spillway to maintain a normal navigation pool of 231 ft-msl. The navigation design flood stage elevation is 240.9 ft-msl. At normal elevation, the pool has 59 miles of shoreline with a surface area of 4,710 acres. Field collections occurred over two successive years (1999-2000). In the first year, samples were taken monthly beginning the last week of March 1999 and ending mid-May 1999. In the second year, samples were taken monthly from April 2000 to September 2000, which encompassed the irrigation season (April to September).

Larval fishes were collected from a 26-ft boat with paired "bongo" nets that were 0.5-m diameter with 505-µm mesh. A General Oceanics flow meter was mounted in the mouth of each net to quantify velocity of water passing through the net. Each sample was of 5-min duration. Net collections were stratified vertically (surface, mid-column, and bottom) and horizontally (both shores and mid-channel) to assess different densities of larvae relative to the entire cross-sectional assemblage. Samples were fixed and preserved in 5% buffered formaldehyde. In the laboratory, fishes were identified to the lowest practical taxon and enumerated.

Meter readings and duration of sampling were converted to an estimate of volume filtered for each sample. Resulting data was used to document spatial (vertical and horizontal) and temporal (monthly, interannual) composition of larval fish near the diversion site, and to quantify numbers of fish potentially entrained during water diversion. Potential losses were expressed volumetrically (number of larval fishes/m^3) and as a percentage of the total number of larval fish in a cross section of river. Potential impacts for different periods in the spawning season and as a function of different volumes of water diverted into Bayou Meto were determined.

Receiving Waterbodies

Benefits of water diversion from the Arkansas River to streams, canals, regulation reservoir, and on-farm storage reservoirs in the Bayou Meto Basin were quantified using the Habitat Evaluation Procedure (HEP); Habitat Units (HU) are the output of HEP. Habitat Suitability Index (HSI) models, which are used in HEP to express habitat quality to the fish community, were determined using two different approaches depending on waterbody type. For newly constructed lacustrine habitats that retain water year around (regulation reservoir and some on-farm storage reservoirs), we assumed that the HSI would not exceed 0.75 (1.0 is optimum) because these waterbodies will fluctuate up to 4-6 feet (pers. com., A. Rees, NRCS, Lonoke, AR) during periods of peak irrigation demands. Fluctuating water levels are an impediment to spawning for many fish species, particularly those that construct nests in littoral areas. We assumed that only 20% of on-farm storage reservoirs will retain water on a permanent basis based on observations made by NRCS (pers. com., A. Rees, NRCS;) this estimate was used to determine acres of functional habitat for this waterbody type. Fish species that would typically colonize newly constructed lacustrine habitats were estimated from field collections made in Willow Bend Cut-off and Cox-Cypress Lake in 1999-2001.

The original water diversion plan was to route water from the Arkansas River through Willow Bend Cutoff, a waterbody adjacent to the Arkansas River at Terry L&D, to a central canal. Willow Bar Cutoff is a backwater of the Arkansas River adjacent to David D. Terry Lake. The entrance to the cutoff is located approximately 1500 feet upstream of the dam on the east bank. Fish samples were taken in the lower, middle, and upper reaches of Willow Bend cutoff to determine potential impacts of water diversion on this waterbody. Although it was determined later to route water to a newly-constructed reservoir, we continued to sample Willow Bend Cutoff because it could represent fish assemblages associated with permanent, floodplain waterbodies. Sample frequency was the same as the Arkansas River schedule. In addition to bongo net samples, three other sampling gears were used to evaluate all life stages: larval light traps, seines, and gill nets. Floating, Plexiglas light traps were baited with a 12-hour Cyalume® yellow chemical light stick. Traps were deployed along the shoreline and captured phototactic larval and juvenile fishes. Juvenile and adult fishes were collected with a 10 ft X 8 ft seine with 3/16 inch mesh; 90-ft experimental mesh (¾ to 2½ inch mesh) gill nets were also used at stations where water depths exceeded 6 ft. Standard effort was 10 seine hauls and 1-3 gill nets stratified among all apparent macrohabitats at each sampling station. Cox-Cypress Lake, located in the Bayou Meto WMA, was sampled once in May 2001 using light traps, seines, and gill nets. These data were used to further characterize lacustrine fish assemblages in Bayou Meto basin.

HSI values were determined empirically for streams and canals receiving irrigation water. Field collections were made at representative sites in the delta and used to develop statistical relationships between fish composition and hydraulic variables influenced by water supply. Data were collected during summer 1999 and 2000 when effects of water diversion will be most pronounced. Juvenile and adult fishes were collected as described in the previous paragraph. Larger fish were identified, measured, and released. Smaller fish were fixed in 10% formaldehyde. In the laboratory, fishes were washed, identified, enumerated, and preserved in 70% ethanol. Representative species were catalogued into the Museum of Zoology, University of Louisiana at Monroe.

Concurrent with all fish collections, physical parameters were measured so that habitat conditions can be described synoptically for all macrohabitats. Water temperature, conductivity, pH, and dissolved oxygen were measured with a Hydrolab near the center of the sampling site. Turbidity was measured with a Hach 2100P turbidimeter. A representative transect was established across each site and measurements of depth and velocity were taken at 10 equidistant points. A Marsh-McBirney Flo-Mate 2000 was used to measure mean channel velocity at a point 60% from the water's surface (depths < 0.9 m), or in depths greater than 0.9 m, averaged from measurements 20% and 80% from water's surface. Channel width was measured at each transect location using a laser rangefinder. Substrate and instream cover (e.g., aquatic vegetation, woody debris) were visually estimated.

Development of HSI's for receiving streams and canals emphasized water depth or wetted width as the independent variable in a HSI model. Hydraulic variables were significantly correlated to species diversity in the Grand Prairie Water Supply Project, AR (Killgore et al. 1998). Depth and width are directly related to increased water supply, and can be predicted for each alternative using standard hydraulic models. We used correlation analysis to confirm a significant relationship between depth/width and fish diversity. If a significant correlation existed, we assumed that fish diversity is a direct expression of water depth/wetted width and HSI values were determined from the univariate depth/width curve.

Fish diversity, which can be expressed as species richness, heterogeneity, or equitability of abundance ("evenness"), was calculated for each sample and used as the dependent variable in HSI models. The independent variables in the HSI models were predicted for each alternative by MVK using standard hydraulic models. HSI values were multiplied by area (i.e., acres) to obtain Habitat Units (HU) for baseline conditions and each alternative.

Weirs

Over 60 weirs will be constructed to pool water and selected stream reaches will be enlarged to accommodate design flows for irrigation demands. A study was conducted to address potential benefits of weirs and channel improvements on aquatic habitat and fish. Weirs have the potential of increasing habitat value by maintaining minimum pools in the streams and providing rock substrates immediately below the structure. Channel enlargement, which includes sediment removal, can provide stable substrates in streams that have been degraded for decades due to sediment accretion.

We re-sampled stream reaches in the Upper Steele Bayou system, Mississippi Delta, that were improved beginning in 1992, and compared these data with previous evaluations we made in the same reaches prior to improvements. Improvements consisted of weir construction and sediment removal. The hydrology, geomorphology, and land-use characteristics of streams in the Upper Steele Bayou system are similar to those in the Bayou Meto Basin. The results of this study were used to help predict long-term habitat quality in streams where weir construction and sediment removal are implemented as part of the Bayou Meto Water Supply Project.

Seven sites in the upper Steele Bayou system (i.e., Main Canal and Black Bayou including a reach through Leroy Percy State Park) that were sampled in 1991 were re-evaluated. Fourteen additional sites were also sampled in 2000-2001; most were associated with newly constructed weirs. From 1992 to 1999, weirs were constructed near four of these sites, and 61 miles of channel improvements were completed. Juvenile and adult fishes were collected with seines and gill nets as described previously for streams in the Bayou Meto delta. Overall, information from these sampling sites provided a summary of faunal and habitat benefits associated with weirs and sediment removal in delta streams.

Flood Control

Channel modifications are being considered for the lower reaches of seven streams to reduce flooding: Bayou Meto, Little Bayou Meto, Two Prairie Bayou, Wabbeseka Bayou, Indian Bayou, Indian Bayou Ditch, Salt Bayou, Boggy Slough, and Crooked Creek. Using drag lines, sediment will be removed and the channel will be widened to increase discharge capacity of the streams. Direct impacts of construction activities on forested buffer strips and availability of woody structure in the stream, were quantified by MVK using GIS (Dave Johnson, MVK). Indirect, hydrologic impacts of flood reduction on fish spawning and rearing were determined by MVK (Barry Sullivan, MVK) for the following floodplain habitats:

1. seasonally inundated agricultural land
2. seasonally inundated fallow land
3. seasonally inundated bottomland hardwoods
4. large, permanent waterbodies (e.g., oxbow lakes) seasonally connected to the mainstream river
5. small, permanent backwaters (scatters, brakes, pools, and tributary mouths) seasonally connected to the river.

Floodplain acres were determined using three criteria: defining the upper limit of the functional floodplain, identifying the areal extent of each floodplain habitat, and incorporating variation in the hydroperiod during the spawning and rearing season within the upper limit of the floodplain. First, a flood frequency value was be necessary to represent the upper limit of a typical flood that is biologically meaningful to fish over a long time period. A 2-year frequency flood was considered the most appropriate value for two primary reasons:

(1) Most floodplain species reach sexual maturity at Age One or Two. Thus, a flood that typically occurs once every two years is considered necessary to maintain reproductive populations in the system. The more extreme hydrologic events may result in higher fish abundance, but do not represent flooding regimes that maintain baseline population levels over the life of the project (e.g., 50 year project life).

(2) The life span of small-sized species is 2-3 years and some may only reproduce once. Thus, a flood frequency less than 2-years may result in successive reproductive failures by species with short life spans. Flood frequencies greater than two years is an overestimate of the usable floodplain utilized by species with short life spans. Larger-sized species can live up to 10

years, but those that utilize floodplains to reproduce on an annual basis require regular flooding to maintain population integrity.

Flood frequency analysis provides a basis to select the 2-year flood using statistical principles commonly applied by hydraulic engineers; Engineering Manual 1110-2-1415, titled "Engineering and Design-Hydrologic Frequency Analysis" is the primary reference. The upper limit of the two-year floodplain was determined using the Log-Pearson Type III distribution. This analysis compiled the maximum stage, regardless of time period, that occurs during a given year and these values were ranked in descending order of magnitude. The median stage value (50 percent percentile) of the ranked data corresponded to the upper limit of the 2-year frequency flood and this elevation was used as a maximum flood stage in subsequent analysis. Satellite imagery that closely corresponds to the 2-year floodplain was used to determine percent of each floodplain habitat type.

Using a program called ENVIROFISH, MVK computed average daily acres flooded during the reproductive period of fishes over the period of record. Collectively, the peak reproductive period of most fishes in the lower Mississippi Valley extends from March through June when water temperature ranges from 15-25 °C (Hoover and Killgore 1998). Therefore, the daily averages incorporate variation in the hydroperiod (onset, duration, and magnitude of flooding), including flood peaks, within the 2-year floodplain from March through June. Percentages of each habitat in the 2-year floodplain, determined from satellite imagery, were multiplied by average daily acres to obtain acres of each habitat.

Suitable spawning habitat for fishes is defined as areas inundated for at least 8 consecutive days with a minimum depth of 1 ft. These hydraulic criteria are applicable to cleared, agricultural lands, and ensures minimal water depth (for movement of gravid adult fishes) and duration (for successful incubation and hatching of eggs) before flooding recedes. However, we assumed that fallow fields, bottomland hardwood forests, and permanent waterbodies could be used for spawning and rearing (larval stage) without hydraulic restrictions within the 2-year floodplain. This is a conservative assumption since fish may not construct nests or deposit eggs in extremely shallow water (<1.0 ft), but uncertainly in spawning behavior when structure and shade are available, and the potential that free swimming larvae can use any water depth, justifies lack of hydraulic restrictions in uncleared lands.

RESULTS AND DISCUSSION

Water Diversion

Seasonal composition of larval fish

We collected a total of 4,929 larval fish: 3,558 fish in 227 net samples, 1,371 fish in 78 light traps (Table 2). Nets collected more individuals than light traps in Willow Bar Cutoff, but light traps yielded more taxa. Light traps were not used in the main channel of the Arkansas River. Nets were more effective in collecting individuals in the families Clupeidae (shad), Catostomidae (suckers), and Sciaenidae (freshwater drum), indicating that larvae of species in these families occurred in the pelagic drift rather than along the shoreline where light traps were set. Total number of confirmed taxa collected between the two gears was 16: 10 in the river, 13 in the cutoff. Taxa collected only by nets were shortnose gar (river only), temperate bass (river only), sauger, and freshwater drum. Taxa collected only by light traps were blacktail shiner, chubsucker, redhorse, topminnow, and bass.

The dominant families in the river were Catostomidae, Sciaenidae and Clupeidae, accounting for approximately 52, 32 and 10% of the total number, respectively. Clupeidae dominated the cutoff, accounting for 59% of the total number, while Centrarchidae (sunfish) and Atherinidae (silversides) were also abundant, comprising 21% and 15%, respectively. Catostomidae were common to the river and the cutoff, comprising at least 2 and 4 species, respectively, though abundance was higher in the river.

Specimens in the family Clupeidae that could not be identified to species accounted for greater than 45% of the total catch. Approximately 16% of the total catch was comprised of Catostomidae, 90% of which were carpsuckers and 8% buffalo. Most of the buffalo specimens (85%) were collected in the cutoff, while approximately 94% of the carpsuckers were collected in the river. Of the Cyprinidae specimens collected, only common carp (38%) and blacktail shiner (5%) could be identified to species. All Centrarchidae collected were identified to genus and *Lepomis* sunfish were most abundant, accounting for over 97% of the specimens.

Sanders et al. (1984) collected 48 species of adult fishes in Pool 5 (river miles 89-102) of the Arkansas River and characterized fishes in both open river and side channel habitats during high- (June) and low- (September) water conditions. The data from Pool 5 showed that relative abundance of adult gar, catfish, suckers, mosquitofish, sunfish, temperate bass and freshwater drum was higher during the swift, high water conditions of June in both open-river and side channel habitats. Relative abundance of catfish declined dramatically in September in both habitats from nearly 30% to around 2%. During June and September abundance of freshwater drum in the river was half that in the side channels. Temperate bass were more abundant in the channels in June and in the river in September. Relative abundance of silversides and shad for both habitats was higher in the slower, low waters of September. Silversides were more abundant in the channels in June and in the river in September, while shad abundance was slightly higher in the channels both seasons.

Our collection of ichthyoplankton showed similar seasonal preferences for the swift current of the river and slack water of the cutoff. While we collected no identifiable catfish specimens, our samples did show that relative abundance of larvae of both carpsuckers and drum was notably higher in the river than in the cutoff and no drum were collected in August or September. The disparity between our collections of larval freshwater drum almost exclusively in the river and the apparent preference of side channels by adults (Sanders, et al, 1984) may be due to the fact that spawning takes place in moving water where the eggs and larvae are planktonic. Gar and temperate bass larvae were collected only in the river. Our collections indicated relative abundance of sunfish, bass, buffalo and silversides was higher in the cutoff than in the river. The only group for which there was an increase in August or September was sunfish, but their relative abundance and preference for the cutoff was fairly consistent throughout the sampling period. This may be due to the varied spawning periods among the Centrarchidae. In general, ichthyoplankton collections reflected the taxonomic composition typical to the Arkansas River and its backwaters.

In terms of ichthyoplankton density (number per 100 cubic meters), freshwater drum, suckers and shad predominated in the main channel from late spring to mid summer (Figure 1). The highest densities of drum and suckers occurred in June whereas shad densities were lower but fairly constant from April into July. Shad densities for May and June were dramatically higher in the cutoff than in the channel (Figure 2). The cutoff also yielded significant densities of silversides in May and sunfish in June. The demersal, adhesive eggs of these taxa are typically found in slack waters, whereas the planktonic eggs and larvae of benthic suckers and drum are better adapted to the flowing waters of the channel.

While temporal trends in appearance and peak abundance of larval fish in Willow Bar Cutoff were similar to that of the main channel, densities were 2-3 times higher in the cutoff (Table 3). Peak abundance for both sampling areas occurred in June with a mean density of 88 larval fish per 100 m^3 in the channel and 243 per 100 m^3 in the cutoff. Overall, the spawning period for fishes in the Arkansas River and its backwaters during 1999-2000 began in late April and ended in September.

Adult spawning and subsequent appearance of larval fish are associated with flooding (Finger and Stewart 1987; Copp and Cellot 1988; Killgore and Baker 1996; Hoover et al. 1995), water temperature (Hontela and Stacy 1990; Wallus et al. 1990), and photoperiod (Sumpter 1990). Rising waters need to coincide with rising temperatures and lengthening daylight to be of maximum benefit to fishes, as this is the period of gonadal maturation. Water temperatures measured in the cutoff and the channel showed similar temporal trends (Figures 1 & 2). Storage volume in David D. Terry Lake is regulated and fluctuates very little throughout the spawning season, but release from the dam is determined by inflow of water and, therefore, can indicate water level fluctuations. Rainfall was generally lower for the spring and summer months in 2000 than the previous year resulting in much higher releases from David D. Terry Lock & Dam in 1999 (Little Rock District, Monthly Reservoir Report). This may have contributed to the disparity in our April collections for the two years (Table 3).

Potential Entrainment of Larval Fish

The Bayou Meto Water Supply Project will divert water from the Arkansas River (David D. Terry Lake) via a gravity inlet into a 30-acre reservoir for regulating flow to a central canal and a system of distributaries. Our collections indicate that a portion of the larval fish assemblage drifting near the diversion site along the east bank can be entrained in the water that is moved from the Arkansas River into the regulation reservoir. However, ichthyoplankton collections in 1999 and 2000 in the Arkansas River indicate that the risk is low (less than 3%) during the peak irrigation season (summer) (Table 4). Most of the larval fish susceptible to entrainment are widespread, tolerant taxa including suckers, drum and gizzard shad that comprised over 90% of the ichthyoplankton collected. Entrainment potential for members of the family Percidae was also high, but this extrapolation was based on only three specimens, none of which was identified to genus. Some larval fish may remain in the regulation reservoir, but others can potentially be entrained in the gravity outlet into the central canal. Survival of larval fish in the central canal may be relatively high, but likely diminishes once fish drift into the smaller receiving streams and canal, particularly carpsuckers and buffalo.

Bongo net samples collected in the Arkansas River at David D. Terry Lake (Pool 6) were used to quantify numbers of larval fish potentially entrained. Since the entrance canal will be located on the east bank and water will be diverted via a gravity inlet, we assume that larvae collected along the east bank are most susceptible to entrainment. Percent of larvae potentially entrained was determined by comparing total number of larvae in a river cross-section with total number of larvae in diverted water by month and project alternative. Total number of larvae in a river cross-section was calculated by multiplying mean number of larvae in bongo net samples taken in locations along the west bank and mid channel (number/cfs) for each sampling period times mean base discharge. For our purposes, mean base 'discharge' was calculated as the mean monthly storage volume in acre-feet per day for David D. Terry Lake (Little Rock District, Monthly Reservoir Report) converted to cubic feet per second. Total number of larvae in diverted water was calculated by multiplying mean number of larvae in bongo net samples taken along the east bank times the amount of water diverted (cfs).

Total number of larvae (all taxa) potentially entrained ranged from 0 to 8.9 percent depending on project alternative and month (Table 4). Entrainment potential increased at higher diversion capacities and potential was greatest in April when Percidae and shad densities along the east bank were higher than other months (Figure 3).

Receiving Waterbodies

Regulation and On-Farm Storage Reservoirs

The regulation reservoir and the numerous smaller, on-farm storage reservoirs will provide newly created aquatic habitat for species that prefer slackwater conditions. Collections in Cox-Cypress Lake and Willow Bend cut-off resulted in 41 species of fish (Table 5). Almost 80% of the species were comprised of mosquitofish, orangespotted sunfish, golden topminnow, and black crappie. These species are relatively tolerant of changing habitat conditions, and are likely to dominate the fish assemblage in newly constructed reservoirs. In addition, other lacustrine and backwater species were relatively abundant: gizzard and threadfin shad, largemouth bass, spotted gar, and taillight shiner. Some species collected were more representative of riverine fish, and are unlikely to establish reproductive populations in reservoirs: skipjack herring, carpsuckers, blue catfish, white bass, yellow bass, striped bass, and freshwater drum.

Assuming that the HSI value for newly created reservoirs is 0.75, which reflects a potentially diverse fish assemblage in a periodically fluctuating waterbody, there will be substantial benefits of the regulation and on-farm storage reservoirs to lacustrine and backwater fishes. Those alternatives that include the regulation reservoir will accrue 30 acres of lacustrine habitat resulting in a gain of 22.5 HUs (Table 6). Depending on alternative, 5,000 to 14,400 acres of new reservoir habitat will be created in the Bayou Meto basin. However, we assumed that only 20% of these reservoirs would actually retain water year around and sustain an HSI of 0.75. The remaining 80% will periodically become dewatered preventing establishment of permanent fish populations. Therefore, acres of lacustrine habitat gained from creation of on-farm storage reservoirs ranged from 988 to 2,909 depending on alternative, which results in HUs gained ranging from 741 to 2,182 (Table 6).

Construction of reservoirs will impact floodplain habitat. A total of 108 forested acres and 92 cleared acres will be lost during construction. These losses are equivalent to a reduction in 126.4 HUs based on the following calculations:

108 forested acres x 1.0 (HSI for hardwood forests) = 108 HUs
92 cleared acres x .2 (HSI for agricultural land) = 18.4 HUs

Since these are permanent losses of floodplain habitat, HUs are equivalent to Average Annual Habitat Units (AAHU). AAHUs, as used in the Habitat Evaluation Procedure (HEP), are typically calculated to depict long-term changes in habitat quality. To determine mitigation, calculation of AAHUs gained per acre of reforested agricultural land is required (see Mitigation-Reforestation). Based on a 50-year project life, reforestation will result in a gain of 0.70 AAHU per acre of reforested, agricultural land. Therefore, a total of 180 acres of reforested lands is required to offset losses.

Delta Streams and Canals

Forty-three species of fish were collected (Table 7) at 22 sites (Table 8) in the Bayou Meto delta. The majority of collections were made in streams that will receive some allocation of water. Community was dominated taxonomically by sunfishes (13 species), minnows (9 species) and darters (6 species). There were at least 2-4 species each of suckers, catfishes, and topminnows. Also observed were taxa characteristic of forested wetlands, such as grass pickerel and pirate perch, and flowing water, such as red shiner and redfin shiner. Most fishes documented are considered tolerant or moderately tolerant of degraded water quality (27/43 species), but fewer of degraded physical habitat (20/43 species). Numerically dominant species were western mosquitofish (37.2 %), green sunfish (11.5%), and bluegill (8.6%) all of which are classified as tolerant species. Species diversity of the fish community, quantified using the Shannon function, ranged from H' = 0.562 to H' = 2.328. Mean value was H' = 1.540.

Fish community of the Bayou Meto tributaries is similar to that of the tributary streams of the White River Grand Prairie Project, but differs in several respects indicating a substantially more diverse fish community of higher biological integrity (Table 7). Only 30 species of fish were collected in the White River tributaries despite a greater level of sampling effort (26 versus 22 samples; only 19 samples were used in subsequent analysis) and a greater number of fishes collected (8395 versus 4167 fish). Fewer than half the number of minnow and darter species was collected, and no species of catfishes or suckers were observed. The three first-ranked species in the White River were also mosquitofish (49.9%), green sunfish (20.0 %), and bluegill (11.2%), but their cumulative relative abundance (81.1%) is substantially higher than in Bayou Meto streams (57.3%). There were fewer species of intermediate abundance (1-8%) in the White River tributaries (5 species) than in Bayou Meto (13 species), and fewer rare (0.1-1%) species (9 versus 25 species). This was reflected in values for fish diversity, which were also lower for White River tributaries. Shannon function values ranged from H' = 0.024 to H' = 1.966; mean value was H' = 1.196.

Tributaries were highly variable in water quality but typically narrow, shallow, and slack, but other physical characteristic were highly variable (Table 9). Most locations were < 35 feet wide, < 3 ft deep, and <5 cm/s. Dissolved oxygen ranged from hypoxic to normoxic, and turbidity from moderately clear to moderately turbid. Hydraulic parameters were typically not correlated with water quality, but turbidity was positively correlated with depth and width ($r > 0.60$, $p < 0.01$), suggesting greater sediments loads with greater increased water volume.

Species diversity was significantly correlated ($p < 0.05$) with habitat variables. Species diversity was positively correlated with turbidity ($r = 0.72$, $p = 0.0006$) and wetted stream width ($r = 0.66$, $p = 0.002$). A nonsignificant positive trend existed between species diversity and water depth ($r = 0.41$, $P = 0.08$) and negative trend between species diversity and conductivity ($r = -0.41$, $p = 0.08$). There was no relation between species diversity and water velocity ($r = -0.01$, $p = 0.98$), but there was a positive trend indicated between diversity and water temperature (r =

0.44, $p = 0.06$). Correlations and trends indicate that as water volume increases, irrespective of water velocity, species diversity will increase. Also, there may be a seasonal influence, with water volume effects on diversity more pronounced when stream temperatures are comparatively warm. The best one-variable model relating diversity to physical habitat was:

$$H' = 0.493 + 0.789(\text{Log 10 Width}),\ r^2 = 0.44.$$

The best two-variable model was:

$$H' = -1.104 + 0.753(\text{Log10Width}) + 0.062(\text{Water Temperature}),\ r^2 = 0.59.$$

The best three-variable model was

$$H' = -0.083 + 0.662(\text{Log10Width}) + 0.068(\text{Water Temperature}) - 0.001(\text{Conductivity}),\ r^2 = 68.$$

Gains in the percentage variance accounted for multiple variables were significant but relatively small and explainable as seasonal effects (water temperature) or covariate of hydraulic variables (conductivity). The single variable model was considered to have the greatest utility in forecasting project-related changes in fish-habitat.

The fish-habitat model for Bayou Meto is very similar to that developed for the White River tributaries (Table 10). Predicted values for species diversity are somewhat higher for streams of low and moderate width. This may be due to zoogeographic factors (i.e., higher diversity in that region), statistical phenomena (i.e., a wider range of stream widths was sampled for Bayou Meto), or to factors unrelated to stream characteristics (e.g., land use). The availability of certain habitats, lotic (e.g., small, flowing streams) and lentic (e.g., small floodplain pools), will act as a source of colonists for fishes exploiting newly created area of aquatic habitat.

Wetted width of the channel was used as the independent variable in the HSI model to predict diversity (H') for streams and canals (Figure 4). Width can be predicted for any alternative, and was significantly and positively correlated with H'. The one-variable regression model was transformed to an HSI equation by using a y-intercept=0 and dividing the output by the maximum H' measured during the study:

$$HSI = 1.16\ (\text{Log}_{10}\text{Width})/2.33$$

Gain in HUs for receiving streams range from 42 to 92% (Table 11). The greatest gains occurred for narrow reaches (5-10 feet bottom width) of streams that will be widened to facilitate increased water conveyance. Overall, a total of 316 acres (296 HUs) of additional stream habitat will be created post-project. At least 24 canals will be constructed to convey irrigation water. Total length of canals is 99 miles (Table 12). Water depth ranges from 2.5 to 11.5 feet, with a mean (±SD) of 5.5±2.3 (Table 12). Based on bottom width of canals, 229 acres of additional flowing water habitat will be created resulting in a gain of 152 HUs (Table 12).

Weirs

A component of the Bayou Meto study was to evaluate long-term benefits of weirs in delta habitats by re-sampling degraded reaches in the Yazoo Basin after weirs were constructed. The study area corresponded to channel improvements on fishes in the Upper Steele Bayou System (Main Canal and Black Bayou). Main Canal and Black Bayou were degraded streams characterized by in-channel deposition of fine sediments, low water levels, and poor water quality. Fish sampling was conducted in these waterbodies in 1990 prior to channel improvements. Ichthyofauna was depauperate, and over 80% of the fishes were dominated by four sediment-tolerant species that typically occur in disturbed systems:

Mosquitofish
Orangespotted sunfish
Bluegill
Red shiner

These waterbodies were re-sampled in the mid- and late 1990's after channel improvements. Weirs provided higher water levels during the low flow season, and sediment excavation resulted in stable substrates. Overall species richness increased from 21 species to 31 species. The same four species were numerically dominant, but sediment-intolerant and exploitable species not collected prior to channel improvements were documented:

Bigmouth and Black Buffalo
Golden topminnow
Blue catfish
White Bass
Bantam sunfish
Largemouth bass

Numerous weirs will be constructed in streams and canals as part of the water supply project that will benefit biological communities. Stable pools are maintained during the low-water season, which is particularly relevant to delta streams that may become totally dewatered. Rip-rap used in weir construction and adjacent bank stabilization have several benefits. Rock substrates provide sites for attachment of invertebrates that fish feed upon, and the placement of rip-rap creates interstial spaces used by fish for predator avoidance and spawning crevices. The tailwater below weirs are comparable to riffles in streams, and may become colonized by rheophilic fish such as madtoms and darters. As a group, rheophilic fish are generally intolerant to anthropogenic alterations (Jester et al. 1992), and have declined in abundance throughout the lower Mississippi river delta.

Flood Control

Habitat Suitability Index Values

HSI values for spawning and rearing fishes were based on expert consensus supplemented by larval fish collections in delta habitats. Larval fish collections were made in each of the five floodplain habitats during the mid 1990's (Hoover and Killgore 1998). Results were used to recommend spawning and rearing HSI values to interagency teams of biologists for individual species that represented the overall fish community. This approach was used for the Yazoo River flood control projects and the New Madrid, Missouri flood control project. More recently, a single spawning and rearing HSI value per habitat type was recommended for restoration projects in the lower Mississippi. This approach eliminates the need for species selection, which is often biased towards exploitable fishes, and results may have confounding biological responses. A community level analysis, using a single value per habitat type for spawning and rearing combined is straightforward, more robust (i.e., less sensitive to individual species values), and applicable to species-rich waterbodies that typically occur in the lower Mississippi River basin. This rational and expert consensus indicated that agricultural land has the lowest habitat value (HSI=0.2) for spawning and rearing. Habitat value increases as floodplains become more structurally complex. Therefore, fallow fields were rated as intermediate (HSI=0.5) and bottomland hardwoods were considered optimum habitat for fish reproduction (HSI=1.0). Permanent waterbodies on the floodplain were also considered optimum (HSI=1.0) habitat primarily because larval fish densities were often highest in these locations (Hoover and Killgore 1998).

Fish communities reflected HSI scores assigned to different wetland types (Table 13). Seasonal wetlands harbored 19 species, permanent wetlands 30 species. In all wetlands, numerically dominant species included mosquitofish (> 30%) and bluegill and orangespotted sunfish (cumulatively > 4%), but substantial differences in composition were observed for other taxa. Permanent wetlands were inhabited by 4 species of darters, two species of sunfishes, largemouth bass, and black crappie which were absent from seasonal wetlands. Also present in permanent wetlands were species of commercial importance (e.g., buffalo, channel catfish). Two species currently listed as "inventory elements" by the Arkansas Natural Heritage program (http://www.naturalheritage.com/publications/rare/pdfs/Inventory_List-Animals.pdf), and previously classified as "species of special concern" in Arkansas and other states (Hoover and Killgore 1988) were collected: swamp darter (*Etheostoma fusiforme*) and taillight shiner (*Notropis maculatus*). Swamp darter were found in seasonal and permanent wetlands, but taillight shiner, was restricted to permanent wetlands. The high species richness, occurrence of habitat specialists like sunfishes and darters, presence of commercially and recreationally important fishes, and populations of taillight shiner and swamp darter support HSI scores of 1.0 for large permanent wetlands.

Variation in fish communities of seasonal wetlands also reflected differences in HSI scores assigned to different wetland categories. Although total numbers of fish were an order of magnitude higher in agricultural land, community was overwhelmingly dominated (> 90 %) by the ubiquitous, invasive, environmentally tolerant mosquitofish. This species was less prevalent in fallow land (52%) and least in bottomland hardwoods (> 31 %). Correspondingly, representation and relative abundance of characteristic wetland taxa like topminnows, silversides, sunfishes were lowest in agricultural land (cumulatively 2 families comprising < 6 % of fish), moderate in fallow land (3 families, 28.6 %), highest in bottomland hardwoods (3 families, 64.7 %). These reflect respective HSI values assigned of 0.2, 0.4, and 1.0. Seasonal wetlands, at time of sampling, were all shallow (< 4 ft), normoxic (6.3-9.8 ppm), moderately turbid (53-74 NTUs), and low in conductance (< 80 mS). Variation in habitat quality among seasonal wetland types, then, is attributable principally to variation in submersed structure: none or monospecific crops in agricultural land, multi-specific forbs in fallow, and large woody debris in bottomland hardwoods.

Differences in fish communities between isolated and connected large permanent wetlands were less pronounced. Abundance of mosquitofish was comparable in both (64.2 vs 52.8 % respectively), as were sunfishes (14.3 vs 17.4 %) and darters (2.3 vs 3.3 %). Similarity of isolated and connected permanent wetlands to each other, and to bottomland hardwoods, justify an HSI score of 1.0. Principal differences in composition between isolated and connected wetlands were for two obligate wetland species: the taillight shiner (2.1 vs 0 %) and golden topminnow (0 vs 17.8 %). In Arkansas, both inhabit quiet, vegetated waters with fine substrates Robison and Buchanan 1988). Disparities in their abundance (and of other fish species) may result from varying degrees of lateral floodplain dispersal (e.g., higher in taillight shiner, lower in golden topminnow). They may also reflect differences in water quality preferences. Isolated and connected wetlands were both moderately deep (approx 6 ft), but isolated wetlands were normoxic (6.6-6.9 ppm), moderately clear (21-25 NTUs), and low in conductance (61-63 mS); connected wetlands were sometimes hypoxic (2.4-6.2 ppm), clear to turbid (11.2 – 183 NTUs), and high in conductance (111-363 mS). Taillight shiner school midwater and feed selectively on certain species of plankton (Cowell and Barnett 1974; Robison and Buchanan 1988). Golden topminnow, however, occur near the surface of the water and feed principally on insects (Hunt, 1953). Taillight shiner, because of their compressed body and terminal mouth, are poorly adapted for respiration at the water's surface during hypoxia; golden topminnow, with their flat dorsum, and superior mouth are well-adapted for "piping" the oxygen-rich surface film during periods of low dissolved oxygen (Lewis 1970; Hoover and Killgore 1998). Because of these differences in vertical microhabitat, morphology, and food habits, golden topminnow may be more tolerant of (and better-adpated to) water of greater turbidity, and wetlands more strongly influenced by seasonally pulsed flow of rivers. Variation in habitat quality between isolated and connected large permanent wetlands is attributable principally to variation in water quality associated with hydrologic connection (i.e., variable BOD, increased sediment loads, and increased dissolved solids associated with elevated river stages).

Habitat Units

There are currently 15,689 acres of functional, reproductive habitat (i.e., depth/duration restrictions in agricultural land, none for other habitats) in the 2-year floodplain as calculated by the EnviroFish model (Table 14). Reach 8 was excluded from indirect hydraulic impacts of the flood control project because water elevations are mostly controlled by gates or levees, either as part of the Wildlife Management Area (WMA) or private greentree reservoirs (PGTR). Portions of the WMA and PGTR that extend into other reaches were included because EnviroFish could not separate out these areas using stage-elevation models. Direct impacts to Reach 8 were included because riparian clearing during channel work will impact reproductive habitat of riverine fishes.

Agricultural land and bottomland hardwoods are the dominant habitats, both of which exceed 80% of the landuse depending on hydraulic reach (Table 15). BLH is more prevalent in the lower reaches, and agricultural land increases northward. Reduction in flooded acres is least for Alternative FC2 (1,024 acres) and highest for Alternative FC3B (1,406) (Table 14). Percent landuse values (Table 15) were used to weight average daily acres flooded in the 2-year floodplain (Table 14), and the respective HSI values were multiplied by acres to determine HUs. Indirect impacts, related to reduction in depth and duration of flooding, ranged from a HU loss of approximately 6% for the non-pump alternatives (Alternatives 2 and 2A), to 9% for the pump alternative FC3B (Table 16). The other pump alternative, FC3A, had slightly lower impacts because work in Two Prairie Bayou (Reach 6) was omitted. Direct impacts were also considered, which accounts for loss of land (primarily BLH) along the riparian corridor of streams and placement of canals during construction activities (Table 17). Direct impacts ranged from a loss of 642 acres (527 HUs) to 1,216 acres (912 HUs).

Mitigation - Reforestation

Average Annual Habitat Units (AAHUs), as used in the Habitat Evaluation Procedure (HEP), are typically calculated to depict long-term changes in habitat quality. AAHUs were calculated to determine mitigation requirements of reforesting frequently flooded agricultural fields over the 50-year project life. In general, trees would be planted within the 2-year floodplain to ensure that lands are periodically flooded between March and June, which is the reproductive season of fishes. Studies of the Mississippi River (Baker et al. 1991), Steele Bayou (Killgore and Hoover 1991), Upper Yazoo River (Killgore and Hoover 1993), and Big Sunflower River (Hoover and Killgore 1994) indicate that a diverse ichthyofauna can potentially utilize the floodplain for spawning and rearing. Many of these fishes undergo regular migrations to utilize inundated floodplains as spawning, nursery, and foraging areas (Guillory 1979, Ross and Baker 1983, Finger and Stewart 1987, Copp 1989, Scott and Nielson 1989), while others reside year-round in permanent pools and oxbow lakes on the floodplain (Lietman et al. 1991).

Riparian buffer strips can also be created either independently or along with reforesting large tracts of land. Forested riparian zones benefit fishes and other aquatic organisms by filtering sediments during runoff, and increasing bank stability, food availability, and structural complexity of stream channels (Fischer and Fischenich 2000; Herbonne and Vondracek 2001; Rabeni 1995; Schlosser 1995; Wang and Lyons 1998). As trees mature, limbs and branches will fall into the channel. Some of the woody structure will form larger debris piles, trapping leaves and twigs. Macroinvertebrates will quickly colonize the structure and serve as a food source for other aquatic species. Instream structure increases habitat diversity, may pool water or otherwise enhance water quality, and provides velocity refugia and stable substrates for fish and fish food organisms.

Calculation of AAHUs per acre of reforested agricultural land assumed a 20-year transition from cleared to forested lands. The HSI for the transition period is 0.75, which is the median value between fallow and BLH. Based on a 50-year project life, reforestation will result in a gain of 0.70 AAHU per acre of reforested, agricultural land. For indirect impacts, mitigation requirements ranged from 894 acres of reforestation for Alternative FC2 to 1,307 acres for Alternative FC3B (Table 16). For direct impacts, mitigation requirements ranged from 685 acres of reforestation for Alternative FC2 to 1,186 acres for Alternative FC3B (Table 17). Cumulative reforestation requirement (direct and indirect) for Alternative FC3B, which provides maximum flood protection, is 2,493 acres.

Mitigation - Floodplain Pools

Small floodplain pools are frequently overlooked in mitigation efforts because of low acreages and undocumented habitat value. They offer several advantages as a mitigation technique, however. They are easy to create and inexpensive (i.e., by excavating shallow depressions during reforestation of agricultural lands). They can function as wetlands independently of river stage (e.g., from receding water or from rainfall). They provide distinctive habitat that has been substantially (> 90 %) reduced in the lower Mississippi Basin (Baker et al. 1991). We sampled pools in the Wrape Plantation Refuge in Spring 2001 and 2002 to determine criteria for creating small floodplain pools as a mitigation technique. Pools were small (< 35 feet minimum diameter), shallow (< 3 ft deep), and adjacent to the river channel (< 200 yards), but were highly variable in physical habitat, depending principally on proximity to woodlands and pool morphometry.

Communities were comprised largely of diminutive fish species characteristic of southern forested wetlands (Hoover and Killgore, 1998) and small floodplain pools (Baker et al. 1991): mosquitofish, topminnows, pirate perch, pygmy sunfish (Table 18) . Pools occurring at the edge of hardwood stands were also inhabited by predatory gar and bowfin, and by dense populations of tadpoles of the southern leopard frog (*Rana sphenocephala*). Woodland pools were inhabited by large populations of sunfishes or by larval stages of the marble salamander (*Ambystoma opacum*). Most of these species grow quickly (e.g., 2-4 months for bowfin from Bayou Meto) or develop rapidly (e.g., 12 weeks for marble salamander in Arkansas) and are capable of exploiting impermanent habitats for short periods prior to occupying their adult habitats (Hoover and

Strange 2002, Petranka 1998). Pools on agricultural lands did not harbor fishes, frog tadpoles, or larval salamanders, although toad tadpoles were occasionally observed.

Multiple regression models indicate that water depth, pool dimensions, and availability of woody cover influenced fish communities and amphibian populations. Shannon diversity function (Ludwig and Reynolds 1988) for fish was correlated positively with maximum pool depth and negatively with pool width,

$$\text{Fish Diversity} = 2.676 + 2.157\ (\text{Log}_{10}\ \text{Maximum Depth}_{\text{ft}}) - 1.251\ (\text{Log}_{10}\ \text{Width}_{\text{ft}}),$$

indicating that fish diversity was significantly higher in deeper, smaller pools (d.f. = 13, $r^2 = 0.65$, $p = 0.003$). Number of larval marble salamanders caught per trap/night, by contrast, was not correlated with any morphometric characteristic of pools, but rather the type of submersed cover in the pools (Hoover and Killgore 2002),

$$\text{Log}_{10}\ \text{Abundance} = 0.006 + 0.206\ (\text{Index of Cover Diameter})$$

reflecting the significant positive correlation between abundance of larval salamanders and cover diameter: low in open water, intermediate in twigs and forbs, high near large woody debris (d.f. = 64, $r^2 = 0.33$, $p = 0.0001$). These data indicate that small pools can be created at varying distances from reforested lands to create habitat for wetland fishes, frogs, or salamanders. Habitat value on agricultural or recently planted lands will be comparatively low, but will increase with development of wooded areas. Multiple regression models presented here can be used as Suitability Index formula to calculate mitigation acreages by standardizing output on a 0-1 scale: using 2.00 as the divisor in the fish diversity model; using 0.85 (for mean values) or 1.5 (for individual point measurements) as the divisor in the marble salamander model.

ACKNOWLEDGEMENTS

Assistance in field work was provided by Larry Sanders, Steven George, Bradley Lewis, and Catherine Murphy, ERDC. Neil Douglas also provided assistance in the field and identified juvenile and adult fishes. Bob Wallace identified larval fish. Tracy James, MVM provided irrigation channel/canal information. Barry Sullivan, MVK, provided floodplain acreage data. Dave Johnson, MVK, provided landuse data. Corps Biologists assisting on this project included Mark Smith, MVM, Marvin Cannon, MVK, and Erwin Roemer (field work), MVM. Funding to develop criteria for floodplain pools was provided by the Ecosystem Management and Restoration Research Program at ERDC.

LITERATURE CITED

Baker, J.A., K.J. Killgore, and R.A. Kasul. 1991. Aquatic habitats and fish communities in the lower Mississippi River. Rev.s Aquatic Sci.s 3(4): 313-356.

Cowell, B.C. and B.S. Barnett. 1974. Life history of the taillight shiner, *Notropis maculatus*, in central Florida. Am. Midl. Nat. 91: 282-292.

Hoover, J.J. and K.J. Killgore. 1998. Fish communities. Pp. 237-260 in Southern forested wetlands – ecology and management, M.G. Messina and W.H.Conner (ed.s), Lewis Publishers, Boca Raton, FL.

Hoover, J.J. and K.J. Killgore, 2002. Small floodplain pools as habitat for fishes and amphibians: method for evaluation. Tech Note Ecosystem Management and Restoration Research Program EM-03, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Hoover, J.J. and K.J. Strange, 2002. Growth, condition, and color of juvenile bowfin in medium-sized aquaria. American Currents 28(2): 1-6.

Hunt, B.P. 1953. Food relationships between Florida spotted gar and other organisms in the Tamiami Canal, Dade County, Florida. Trans. Am. Fish. Soc. 82: 13-33.

Jester, D. B. and 5 co-authors. 1992. The fishes of Oklahoma, their gross habitats and their tolerance of degradation in water quality and habitat. Proceedings of the Oklahoma Academy of Science 72: 7-19.

Jurajda, P. 1995. Effects of channelization and regulation on fish recruitment in a flood plain river. Regulated Rivers: Research and Management 10: 207-215.

Lewis, W.M., Jr. 1970. Morphological adaptations of cyprinodontoids for inhabiting oxygen-deficient waters. Copeia 1970: 319-326.

Page, L. M. 1983. Handbook of darters. TFH Publications, Neptune City, NJ.

Petranka, J.W. 1998. Salamanders of the eastern United States and Canada. Smithsonian Institution Press, Washington, D.C., 587 pp.

Portt, C. B., E. K. Balon, and D. L. G. Noakes. 1986. Biomass and production of fishes in natural and channelized streams. Canadian Journal of Fisheries and Aquatic Science 43: 1926-1934.

Robison, H.W. and T.M. Buchanan. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville, AR, 536 pp.

Ross, S. T. 2001. The inland fishes of Mississippi. University Press of Mississippi, Oxford, Mississippi.

Shankman, D. and T. B. Pugh. 1992. Discharge response to channelization of a coastal plain stream. Wetlands 12: 157-162.

Shields, F. D., S. S. Knight, C. M. Cooper. 1995. Use if the index of biotic integrity to assess physical habitat degradation in warmwater streams. Hydrobiologia 312: 191-208.

Shields, F. D., S. S. Knight, C. M. Cooper. 1998. Rehabilitation of aquatic habitats in streams damaged by channel incision in Mississippi. Hydrobiologia 382: 63-86.

Shields, F. D., S. S. Knight, C. M. Cooper. 1999. Cyclic perturbation of lowland river channels and ecological response. Regulated Rivers: Research and Management 16: 307-325.

Shields, F. D., S. S. Knight, C. M. Cooper. 2000. Warmwater stream bank protection and fish habitat: A comparative study. Environmental Management 26: 317-328.

Swales, S. 1998. Fish populations of a small lowland channelized river in England subject to long-term river maintenance and management works. Regulated Rivers: Research and Management 2: 493-506.

Table 1. Description of alternatives for the Bayou Meto water supply and flood control project. Alternatives are labeled as Water Supply (WS) or Flood Control (FC).

WATER SUPPLY

ALTERNATIVE WS1 - NO ACTION
- Additional Reforested Acres (WRP) – 2,000
- Additional Riparian Buffer Strips (CREP) – 973

ALTERNATIVE WS2 - CONSERVATION WITH STORAGE
- Import Water – None
- Regulation Reservoir - None
- On-farm storage reservoirs – 4,941 acres

ALTERNATIVE WS3 – 1,650 IMPORT SYSTEM PLUS CONSERVATION AND STORAGE
- Import Water – 1,650 cfs
- Regulation Reservoir – 30 acres
- On-farm Storage Reservoirs:
  - Alternative 3A – 5,954 acres of additional storage reservoirs
  - Alternative 3B -- 8,832 acres of additional storage reservoirs
  - Alternative 3C -- 14,544 acres of additional storage reservoirs

ALTERNATIVE WS4 – 1,750 IMPORT SYSTEM PLUS CONSERVATION AND STORAGE
- Import Water – 1,750 cfs
- Regulation Reservoir – 30 acres
- On-farm Storage Reservoirs:
  - Alternative 4A – 5,954 acres of additional storage reservoirs
  - Alternative 4B -- 8,832 acres of additional storage reservoirs
  - Alternative 4C -- 14,544 acres of additional storage reservoirs

ALTERNATIVE WS5 – 1,850 IMPORT SYSTEM PLUS CONSERVATION AND STORAGE
- Import Water – 1,850 cfs
- Regulation Reservoir – 30 acres
- On-farm Storage Reservoirs:
  - Alternative 5A – 5,954 acres of additional storage reservoirs
  - Alternative 5B -- 8,832 acres of additional storage reservoirs
  - Alternative 5C -- 14,544 acres of additional storage reservoirs

FLOOD CONTROL

ALTERNATIVE FC2 - Channel cleanout/enlargement: Indian Bayou, Indian Bayou Ditch, Wabbaseka Bayou, Boggy Slough, Little Bayou Meto, Salt Bayou, Crooked Creek, Two-Prairie Creek, Big Bayou Meto

ALTERNATIVE FC2A - Alternative 2 with additional work in Indian Bayou Ditch, Crooked Creek Ditch, and Crooked Creek

ALTERNATIVE FC3A - Alternative 2A with 1,000 cfs pump on Little Bayou Meto

ALTERNATIVE FC3B - Alternative 2A with 3,000 cfs pump on Little Bayou Meto

Table 2. Comparison of taxa and total numbers of larval fishes collected by ichthyoplankton net and light traps in the Arkansas River Pool 5 and Willow Bar Cutoff from April-May, 1999 and April-September, 2000.

Scientific name	Common name	Net		Light Traps	Total
		River	Cutoff	Cutoff	
Family Lepisosteidae					
Lepisosteus platostomus	Shortnose gar	1			1
Family Clupeidae					
Unidentified Clupeidae	---	134	2083	34	2251
Family Cyprinidae					
Cyprinus carpio	Common carp	12		3	15
Cyprinella venusta	Blacktail shiner			2	2
Unidentified Cyprinidae	---	4	10	8	22
Family Catostomidae					
Carpiodes sp.	YOY carpsuckers	682		44	726
Erimyzon sp.	YOY chubsucker			1	1
Ictiobus sp.	YOY buffalo	10	2	54	66
Moxostoma sp.	YOY redhorse			2	2
Unidentified Catostomidae	YOY suckers	8			8
Family Fundulidae					
Fundulus chrysotus	Golden topminnow			1	1
Fundulus sp.	YOY topminnow			10	10
Family Atherinidae					
Menidia beryllina	Inland silverside		1	65	66
Unidentified Atherinidae	YOY silverside	1	16	438	455
Family Moronidae					
Morone chrysops	White bass	1			1
Morone sp.	YOY temperate bass	28			28
Family Centrarchidae					
Lepomis sp.	YOY sunfish	12	77	678	767
Micropterus sp.	YOY bass			12	12
Pomoxis sp.	YOY crappie	5		1	6
Family Percidae					
Unidentified Percidae	---	6	6		12
Stizostedion canadense	Sauger	1			1
Family Sciaenidae					
Aplodinotus grunniens	Freshwater drum	429	2		431
Unidentified Larvae	---	20	7	18	45
Sample Size		182	45	78	305
Total Number of Individuals		1354	2204	1371	4929
Total Number of Taxa		10	5	12	16

Table 3. Mean ± SE net (number/100 m^3) and light trap (number/night) catches of larval fish from the Arkansas River above David D. Terry Lock & Dam and Willow Bar Cutoff, 1999 and 2000.

Location/Taxa	Mar 1999	Apr 1999	May 1999	Apr 2000	May 2000	Jun 2000	Jul 2000	Aug 2000	Sep 2000
Arkansas River-Net									
(n=20/Month)									
All Species	0.0	0.0	13.4 ± 2.3	7.2 ± 1.8	21.3 ± 5.7	88.0 ± 17.9	25.2 ± 7.6	0.2 ± 0.2	0.1 ± 0.1
Catostomidae	0.0	0.0	9.4 ± 1.9	6.5 ± 1.8	6.3 ± 2.7	8.9 ± 3.9	21.2 ± 7.0	0.2 ± 0.2	0.1 ± 0.1
Sciaenidae	0.0	0.0	0.3 ± 0.1	0.0	10.7 ± 3.0	76.7 ± 14.5	3.0 ± 0.8	0.0	0.0
Clupeidae	0.0	0.0	2.8 ± 0.6	0.6 ± 0.6	4.3 ± 1.4	2.4 ± 1.3	1.0 ± 0.4	0.0	0.0
Willow Cutoff-Net									
(n=5/Month)									
All Species	0.0	0.0	154.5 ± 34.6	0.0	26.0 ± 8.1	241.7 ± 86.7	1.7 ± 1.7	0.0	0.8 ± 0.8
Clupeidae	0.0	0.0	151.6 ± 34.4	0.0	23.7 ± 8.6	226.2 ± 86.6	0.8 ± 0.8	0.0	0.4 ± 0.4
Centrarchidae	0.0	0.0	2.1 ± 0.4	0.0	0.0	14.8 ± 2.3	0.6 ± 0.6	0.0	0.4 ± 0.4
Atherinidae	0.0	0.0	0.4 ± 0.3	0.0	2.3 ± 1.2	0.7 ± 0.5	0.3 ± 0.3	0.0	0.0
Willow Cutoff-LT									
(n=6/Month)[1]									
All Species	0.0	0.0	69.7 ± 12.7	0.7 ± 0.7	27.8 ± 8.8	12.5 ± 4.2	1.8 ± 0.7	25.3 ± 9.9	37.2 ± 5.3
Clupeidae	0.0	0.0	3.0 ± 2.1	0.0	0.3 ± 0.2	0.3 ± 0.2	0.0	0.0	0.0
Centrarchidae	0.0	0.0	9.6 ± 2.5	0.2 ± 0.2	24.5 ± 8.3	11.2 ± 4.3	1.3 ± 0.5	25.2 ± 10.0	36.8 ± 5.4
Atherinidae	0.0	0.0	47.5 ± 10.7	0.5 ± 0.5	2.8 ± 1.0	0.8 ± 0.5	0.0	0.2 ± 0.2	0.3 ± 0.3

[1]Sample number varied for 1999 (March n=12, April n=20, May n=10).

Table 4. Percent number of larval fish potentially entrained by month in the Arkansas River behind David D. Terry Lock & Dam (Lock & Dam 6) for the Bayou Meto water supply alternatives.

Month	Mean No. in River (No/cfs)[1]	Mean Base Discharge (cfs)[2]	Total No. in River X-section per second	Mean No. in Diverted Water (No/cfs)[3]	Amount of Water Diverted (cfs)	Total No. in Water Diverted per second	Percent No. of Larval Fish Entrained[4]
			1650 cfs				
APR	0.38227	24334.88	9302.49	0.49271	1650	812.97	8.0
MAY	1.64379	24616.41	40464.20	0.31856	1650	525.62	1.2
JUN	8.31669	24756.54	205892.46	0.31431	1650	518.61	0.2
JUL	2.33615	25045.80	58510.74	0.93446	1650	1541.85	2.5
AUG	0.25485	25364.06	6464.03	0.00000	1650	0.00	0.0
			1750 cfs				
APR	0.38227	24334.88	9302.49	0.49271	1750	862.24	8.4
MAY	1.64379	24616.41	40464.20	0.31856	1750	557.48	1.3
JUN	8.31669	24756.54	205892.46	0.31431	1750	550.04	0.2
JUL	2.33615	25045.80	58510.74	0.93446	1750	1635.30	2.7
AUG	0.25485	25364.06	6464.03	0.00000	1750	0.00	0.0
			1850 cfs				
APR	0.38227	24334.88	9302.49	0.49271	1850	911.51	8.9
MAY	1.64379	24616.41	40464.20	0.31856	1850	589.33	1.4
JUN	8.31669	24756.54	205892.46	0.31431	1850	581.47	0.2
JUL	2.33615	25045.80	58510.74	0.93446	1850	1728.75	2.8
AUG	0.25485	25364.06	6464.03	0.00000	1850	0.00	0.0

[1] Mean number does not include bongo net samples collected along left bank
[2] Mean base discharge converted from storage volume behind David D. Terry Lock & Dam in acre-feet per day
[3] Mean number represents bongo net samples collected along left bank
[4] Percent loss = [Total in Diverted Water/(Total in Cross Section + Total in Diverted Water)] * 100

Table 5. Fish species collected in Cox-Cypress lake and Willow Bend Cut-off by seines and gill nets. Fish community represents probable species composition and abundance in the proposed regulation and on-farm storage reservoirs.

Scientific name	Common name	Number Collected
Amiidae	Bowfin	
Amia calva	Bowfin	1
Lepisosteidae	Gars	
Lepisosteus platostomus	Shortnose gar	2
Lepisosteus oculatus	Spotted gar	51
Clupeidae	Herrings	
Alosa chrysochloris	Skipjack herring	1
Dorosoma cepedianum	Gizzard shad	56
D. petenense	Threadfin shad	33
Family Cyprinidae	Minnows	
Cyprinus carpio	Common carp	1
Notemigonus crysoleucas	Golden shiner	5
Notropis maculatus	Taillight shiner	25
Opsopoeodus emiliae	Pugnose minnow	8
Family Catostomidae	Suckers	
Carpiodes carpio	River carpsucker	2
C. cyprinus	Quillback	1
Ictiobus bubalus	Bigmouth buffalo	7
Ictiobus cyprinellus	Smallmouth buffalo	2
I. spp.	Buffalo young-of-yr	1
Minytrema menalops	Spotted sucker	
Family Ictaluridae	Catfishes	
Ameiurus natalis	Yellow bullhead	1
Ictalurus furcatus	Blue catfish	11
Ictalurus punctatus	Channel catfish	19
Family Cyprinodontidae	Topminnows	
Fundulus chrysotus	Golden topminnow	113
F. dispar	Starhead topminnow	2
F. olivaceus	Blackspotted topmn.	4

Table 5. Concluded

Scientific Name	Common Name	Number Collected
Family Poeciliidae	Livebearers	
Gambusia affinis	Mosquitofish	999
Family Atherinidae	Silversides	
Labidesthes sicculus	Brook silverside	6
Family Moronidae		
Morone chrysops	White bass	6
M. mississippiensis	Yellow bass	2
M. saxatilis	Striped bass	2
Family Centrarchidae	Sunfishes	
Lepomis cyanellus	Green sunfish	3
L. gulosus	Warmouth	2
L. humilus	Orangespotted sunf.	151
L. macrochirus	Bluegill	10
L. megalotis	Longear sunfish	1
L. microlophus	Redear sunfish	3
L. miniatus	Redspotted sunfish	1
L. symmetricus	Bantam sunfish	3
Micropterus salmoides	Largemouth bass	33
Pomoxis annularis	White crappie	17
P. nigromaculatus	Black crappie	102
Family Percidae	Darters	
Etheostoma asprigene	Mud darter	6
Etheostoma chlorosomum	Bluntnose darter	8
E. fusiforme	Swamp darter	7
E. proeliare	Cypress darter	6
Sciaenidae	Drums	
Aplodinotus grunniens	Freshwater drum	1
Total Number of Species		41
Total Number of Fish		1733

Table 6. Fish Habitat Units gained for regulation and on-farm storage reservoirs by water supply alternative. Acres were multiplied by the HSI value for reservoirs (0.75) to obtain Habitat Units (HU).

Alternative	Regulation Reservoir		On-farm storage Reservoirs		Total HU Gained
	Acres	Habitat Units	Acres[1]	Habitat Units	
WS1	0	0	0	0	0
WS2	0	0	988	741	741
WS3A, WS4A, WS5A	30	22.5	1191	893	916
WS3B, WS4B, WS5B	30	22.5	1766	1324	1347
WS3C, WS4C, WS5C	30	22.5	2909	2182	2205

[1] Acres of on-farm storage reservoirs are 20% of the total acreage proposed by alternative

Table 7. Fish communities of the tributary streams of the White River (Grand Prairie Project) and Bayou Meto, AR. Values are percentages of total fish collected. A plus sign (+) indicates percentages less than 0.1 % of the total number of fish collected. Classifications of tolerance to water quality (WQ) and physical habitat (HAB) degradation are according to Jester et al. (1992): T=tolerant, MT=moderately tolerant, MI=moderately intolerant, and I=intolerant.

Scientific name	Common name	Tolerance: WQ / HAB	White River N=26	Bayou Meto N=19
Lepisosteidae	Gars			
Lepisosteus oculatus	Spotted gar	T / MT	0.1	0.1
Clupeidae	Herrings			
Dorosoma cepedianum	Gizzard shad	MT / T	5.3	2.0
D. petenense	Threadfin shad	MI / MT	0.1	
Esocidae	Pickerels			
Esox americanus	Grass pickerel	MI / MI		+
Family Cyprinidae	Minnows			
Cyprinus carpio	Common carp	T / T	+	0.2
Cyprinella lutrensis	Red shiner	T / T		8.0
Hybognathus hayi	Cypress minnow	I / I		0.1
Lythrurus umbratilis	Redfin shiner	MI / MI		3.2
Notemigonus crysoleucas	Golden shiner	T / T	0.6	5.0
Notropis maculatus	Taillight shiner	MI / I	0.1	0.1
Opsopoeodus emiliae	Pugnose minnow	MI / MI	0.1	1.5
Pimephales promelas	Fathead minnow	T / T		0.2
P. vigilax	Bullhead minnow	T / T		+
Family Catostomidae	Suckers			
Ictiobus bubalus	Smallmouth buffalo	MT / MT		0.1
I. spp.	Buffalo young-of-yr	---		0.1
Minytrema menalops	Spotted sucker	MI / I		0.1
Family Ictaluridae	Catfishes			
Ameiurus melas	Black bullhead	T / T		0.5
A. natalis	Yellow bullhead	T / MT		0.1
Ictalurus punctatus	Channel catfish	MT / MT		0.4
Noturus gyrinus	Tadpole madtom	MI / I		0.3
Family Cyprinodontidae	Topminnows			
Fundulus chrysotus	Golden topminnow	MT / I	0.3	0.4
F. olivaceus	Blackspotted topmn.	MT / MI	0.2	1.6

Table 7. Concluded				
Scientific name	Common name	Tolerance: WQ / HAB	White River N=26	Bayou Meto N=19
Family Poeciliidae	Livebearers			
Gambusia affinis	Mosquitofish	T / T	49.9	37.7
Family Atherinidae	Silversides			
Labidesthes sicculus	Brook silverside	MT / MI	0.9	0.5
Elassomatidae	Pygmy sunfishes			
Elassoma zonatum	Banded pygmy sunf.	I / I	0.7	0.2
E. spp.	Pygmy sunfish y-o-y	--		+
Family Centrarchidae	Sunfishes			
Centrarchus macropterus	Flier	I / I	0.1	+
Lepomis cyanellus	Green sunfish	T / T	20.0	11.5
L. gulosus	Warmouth	MT / MT	1.7	3.7
L. humilus	Orangespotted sunf.	T / MT	1.2	1.5
L. macrochirus	Bluegill	MT / MT	11.2	8.6
L. marginatus	Dollar sunfish	MT / MI	0.6	0.9
L. megalotis	Longear sunfish	MT / MT		1.7
L. microlophus	Redear sunfish	MT / MT	0.2	
L. miniatus	Redspotted sunfish	MT / I	0.3	0.2
L. symmetricus	Bantam sunfish	I / I	+	1.3
L. spp.	Young-of-year sunf.	--	2.3	
L. sp.Xsp.	Sunfish hybrids	--	+	0.3
Micropterus punctulatus	Spotted bass	MI / MI		+
Micropterus salmoides	Largemouth bass	MT / MT	0.1	0.5
Pomoxis annularis	White crappie	T / MT	2.7	3.0
P. nigromaculatus	Black crappie	MT / MT	0.7	1.4
Family Percidae	Darters			
Etheostoma asprigene	Mud darter	MI / MI		0.2
Etheostoma chlorosomum	Bluntnose darter	MI / I	+	1.9
E. gracile	Slough darter	MT / I	0.1	0.1
E. proeliare	Cypress darter	MI / I	0.1	0.9
Percina caprodes	Logperch	MI / MI		+
P. maculata	Blackside darter	MI / I		0.1
Family Sciaenidae	Drums			
Aplodinotus grunniens	Freshwater drum	MT / MT	0.1	
Total Number of Species			30	43
Total Number of Fish			8395	4167

Table 8. Fish sampling locations in the Bayou Meto Basin that were used to develop habitat models for receiving streams and canals.			
Stream/Bayou	**Location**	**Coordinates**	**Date Sampled**
Willow Bar Cutoff	Upper Backwater, 0.25 mi NW of Pilgrims Rest	S25 T1S R11W	1999-2000
Indian Bayou	1/2 mi E of Oakgrove Church, 4 mi WSW of Pettus, AR	S33 T1N R9W	26 Jul 00
Indian Bayou	4 mi NNE of England, AR	S23/26 T1S R9W	26 Jul 00
Indian Bayou	Hwy 14 Bridge, 1 mi S of Bevis Corner	S19/20 T1N R1W	13 Jul 00
Indian Bayou	At Tomberlin, AR	S21/28 T2S R8W	14 Jul 00
Caney Creek	3 mi E of Bishops Chapel, 1 mi E of Hwy 31	S5/8 T1S R8W	13 Jul 00
Caney Creek	2 mi S of Perry's Chapel, 6 mi NE of England, AR	S35 T1S R8W	14 Jul 00
Caney Creek	3 mi. E. of Tomberlin, AR	S24/25 T2S R7W	14 Jul 00
Skinners Branch	1/2 mi N of Robinson Cem., 5 1/2 mi ENE Bayou Meto, AR	S17 T1N R7W	13 Jul 00
Crooked Creek Ditch	2 mi NE of Pettus, AR	S20 T1N R8W	27 Jul 00
Crooked Creek Ditch	2.5 mi S of Culver, AR, 1.5 mi N of Seaton, AR	S18 T1S R7W	27 Jul 00
Crooked Creek Ditch	2 mi S of Geridge, AR	S25 T2S R7W	27 Jul 00
Bayou Meto	Hwy 130 at Brummitt, AR	S15 T25 R6W	27 Jul 00
Bayou Meto	2.75 mi N of Geridge, AR	S311 T1S R6W	27 Jul 00
Blue Point Ditch	1 mi SW of Parkers Corner, at Blue Point Ditch Road	S11 T1S R7W	27 Jul 00
Rickey's Branch	1 mi W of Chamber's Church	S10 T2N R8W	28 Jul 00
Rickey's Branch	2.1 mi N I-40, 5.5 mi NW of Carlisle	S3 T2N R8W	14 Sep 00
Shumaker Branch	2 mi SW of Carlisle, AR	S32 T2N R7W	28 Jul 00
White Oak Branch	2 mi SW of Carlisle, AR, Upstream of Weir	S30 T2N R7W	13 Sep 00
White Oak Branch	2 mi SW of Carlisle, AR, downstream of Weir	S30 T2N R7W	13 Sep 00
White Oak Branch	4.25 mi W of Carlisle, AR, 1 mi S of Hwy 70	S26 T2N R8W	13 Sep 00
Bayou Two Prairie	3 mi NE of Carlisle, AR	S19 T2N R7W	14 Sep 00

Table 9. Hydraulic and water quality variables of Bayou Meto tributary streams 07 Jul 2000 to 14 Sep 2000 and 02 May 2001 (N = 19).

Variable	Mean	Minimum	Maximum
Water Depth, ft	1.7	0.3	10.5
Water Velocity, cm/sec	0.3	0.0	61.4
Width, ft	20.9	5.1	46.9
Water Temperature, °C	26.5	20.6	30.3
Dissolved Oxygen, mg/l	5.5	0.5	13.7
Conductivity, µmhos/cm	433.0	58.0	798.0
pH	7.5	6.5	9.0
Turbidity, NTU	31.8	7.7	70.8

Table 10. Relationship between fish diversity (H') and physical habitat based on stepwise linear regression.

System	N	Model	R^2	p
White River	26	$H' = -0.26 + 1.197(Log_{10}Width)$	0.42	0.0003
Bayou Meto	19	$H' = 0.49 + 0.789(Log_{10}Width)$	0.44	0.0020

Table 11. Gain in Habitat Units (HU) (average by month) for tributary streams in the Bayou Meto basin, Arkansas. Habitat Units for base (pre-project) and post-project are the product of Habitat Suitability Index (HSI) and acres. HSI is the ratio between predicted and maximum observed (2.33) species diversity. Predicted HSI value, formulated with y intercept=0.0, is calculated as: HSI =1.16 (Log_{10}Width)/2.33.

STREAM	BEGIN MILE	STOP MILE	PURPOSE	LEGNTH (FT)	PREWIDTH (FT)	PRE ACRES	PRE-HSI	PRE-HU	POST WIDTH (FT)	POST ACRES	POST HSI	POST-HU	PERCENT GAIN
Indian_Bayou	20.34	28.30	Ag_Water	42029	10	9.6	0.50	4.8	39.5	38.1	0.79	30.3	84.1
Indian_Bayou	16.40	20.34	Ag_Water	20803	5	2.4	0.35	0.8	25.0	11.9	0.70	8.3	90.0
Indian_Bayou	49.80	58.30	Flood_Control	44880.0	15	15.5	0.58	9.1	30.0	30.9	0.74	22.7	60.2
Caney_Creek	10.84	11.94	Ag_Water	5808.0	10	1.3	0.50	0.7	39.0	5.2	0.79	4.1	83.9
Caney_Creek	8.34	10.84	Ag_Water	13200.0	10	3.0	0.50	1.5	30.5	9.2	0.74	6.8	77.9
Caney_Creek	0.00	8.34	Ag_Water	44035.2	5	5.1	0.35	1.8	26.5	26.8	0.72	19.0	90.7
Crooked_Creek	12.00	18.64	Ag_Water	35059.2	20	16.1	0.65	10.4	65.0	52.3	0.90	47.2	77.9
Crooked_Creek	10.10	12.00	Ag_Water	10032.0	15	3.5	0.59	2.0	62.0	14.3	0.89	12.7	84.1
Crooked_Creek	0.00	10.10	Flood_Control	53328.0	15	18.4	0.59	10.7	68.0	83.3	0.91	76.0	85.8
Big_Ditch	6.84	17.10	Ag_Water	54172.8	25	31.1	0.70	21.6	49.0	60.9	0.84	51.3	57.8
Skinner_Branch	5.54	9.10	Ag_Water	18796.8	10	4.3	0.50	2.1	30.5	13.2	0.74	9.7	77.9
Skinner_Branch	3.30	5.54	Ag_Water	11827.2	10	2.7	0.50	1.3	30.5	8.3	0.74	6.1	77.9
Skinner_Branch	0.00	3.30	Ag_Water	17424.0	15	6.0	0.59	3.5	22.5	9.0	0.67	6.1	42.0
White_Oak	0.34	7.74	Ag_Water	39072.0	15	13.5	0.59	7.9	32.0	28.7	0.75	21.5	63.4
Shumaker_Branch	3.24	7.50	Ag_Water	22492.8	10	5.2	0.50	2.6	22.5	11.6	0.67	7.8	67.1
Rickey_Branch	6.02	9.04	Ag_Water	15945.6	10	3.7	0.50	1.8	70.5	25.8	0.93	23.7	92.3
Rickey_Branch	5.32	6.02	Ag_Water	3696.0	15	1.3	0.59	0.7	49.0	4.2	0.84	3.5	78.7
Rickey_Branch	3.30	5.32	Ag_Water	10665.6	15	3.7	0.59	2.1	40.5	9.9	0.80	7.9	72.9
Blue_Point	1.74	5.80	Ag_Water	21436.8	10	4.9	0.50	2.4	42.0	20.7	0.81	16.7	85.3
Blue_Point	0.00	1.74	Ag_Water	9187.2	10	2.1	0.50	1.0	22.0	4.6	0.67	3.1	66.1

Table 12. Gain in Habitat Units (HU) (average by month) for canals that will be constructed in the Bayou Meto basin, Arkansas. Hydraulic features of canals were provided by MVM. HSI is the ratio between predicted and maximum observed (2.33) species diversity. Predicted HSI value, formulated with y intercept=0.0, is calculated as: HSI =1.16 Log_{10}Width)/2.33.

Canal	Depth (ft)	Miles	Bottom Width (ft)	Acres	HSI	HU
500	11.5	0.9	60	6.6	0.89	5.9
1000/2000	11.0	1.9	40	9.2	0.80	7.3
1000/2000	11.0	2.6	40	12.4	0.80	9.9
1000/2000	11.0	2.2	40	10.6	0.80	8.4
1000/2000	11.0	1.3	40	6.4	0.80	5.1
1000/2000	9.0	2.5	35	10.4	0.77	8.0
1000/2000	9.0	3.5	35	14.7	0.77	11.3
1000/2000	8.0	0.3	25	1.0	0.70	0.7
1000/2000	8.0	1.7	25	5.3	0.70	3.7
1400	5.0	1.9	20	4.6	0.65	3.0
1400	5.0	2.1	20	5.0	0.65	3.3
1410	4.0	1.9	20	4.6	0.65	3.0
1410	4.0	1.8	20	4.4	0.65	2.9
1530	3.5	5.7	15	10.4	0.58	6.1
2100	8.0	2.8	25	8.6	0.70	6.0
2100	8.0	1.0	25	3.0	0.70	2.1
2100	5.0	0.9	20	2.2	0.65	1.4
2100	5.0	0.5	20	1.3	0.65	0.9
2110	7.0	0.8	25	2.5	0.70	1.7
2110	7.0	0.8	25	2.3	0.70	1.6
2140/2160	4.5	6.0	20	14.6	0.65	9.4
2140/2160	4.0	5.8	10	7.1	0.50	3.5
2140/2160	2.5	1.3	5	0.8	0.35	0.3
2140/2160	2.5	1.4	5	0.9	0.35	0.3
2220	4.0	1.0	15	1.7	0.59	1.0
2220	4.0	0.8	15	1.4	0.59	0.8
2260	4.0	2.8	10	3.4	0.50	1.7
2260	4.0	1.2	10	1.4	0.50	0.7
2280	4.0	3.8	10	4.6	0.50	2.3
2280	4.0	1.6	10	2.0	0.50	1.0
2500	6.0	1.0	20	2.3	0.65	1.5
2500	6.0	0.8	20	1.8	0.65	1.2
2500	5.0	1.1	20	2.8	0.65	1.8
2500	5.0	1.3	20	3.2	0.65	2.1
2500	5.0	1.0	20	2.5	0.65	1.6
2500	5.0	1.1	20	2.7	0.65	1.8
2510	4.0	0.5	8	0.5	0.45	0.2
2510	4.0	0.7	8	0.7	0.45	0.3
2520	3.5	1.9	8	1.8	0.45	0.8
2520	3.5	0.7	8	0.7	0.45	0.3

Table 12. Concluded.						
Canal	Depth (ft)	Miles	Bottom Width (ft)	Acres	HSI	HU
2531	3.0	1.9	10	2.3	0.50	1.1
2531	3.0	0.4	10	0.5	0.50	0.2
2533	4.0	0.5	15	0.9	0.59	0.5
2533	4.0	0.2	15	0.4	0.59	0.2
3000	6.0	1.9	20	4.6	0.65	3.0
3000	6.0	3.4	20	8.2	0.65	5.3
3000	6.0	1.3	20	3.3	0.65	2.1
3000	6.0	2.8	20	6.8	0.65	4.4
4000/4100	5.0	1.9	20	4.6	0.65	3.0
4000/4100	5.0	0.3	20	0.7	0.65	0.4
4000/4100	5.3	0.7	18	1.6	0.62	1.0
4111	4.0	3.8	10	4.6	0.50	2.3
4111	4.0	1.4	10	1.7	0.50	0.9
4111	4.0	3.9	10	4.8	0.50	2.4
4111	4.0	1.2	10	1.4	0.50	0.7
4112	5.0	2.8	20	6.9	0.65	4.5
4112	5.0	2.8	20	6.9	0.65	4.5
4113	3.5	0.4	8	0.4	0.45	0.2
4113	3.5	0.6	8	0.6	0.45	0.3
TOTAL		98.6		228.7		152.4

Table 13. Fishes of floodplain wetlands of the Bayou Meto system. Numbers are percentages of total catch in each wetland category. Categories are agricultural land (AG), fallow land (FAL), bottomland hardwood (BLH), large, isolated wetlands (LG-ISO) and large, connected wetlands (LG-CONN).

		Seasonal			Permanent	
Scientific name	Common name	AG	FAL	BLH	LG-ISO	LG-CONN
Family Lepisosetidae						
Lepisosteus oculatus	Spotted gar	0.33				1.11
L. platostomus	Shortnose gar	0.50				
L. spp.	Juvenile gar				1.97	
Family Amiidae						
Amia calva	Bowfin				0.09	
Family Cyprinidae						
Cyprinella lutrensis	Red shiner	1.16		3.92		
Lythrurus fumeus	Ribbon shiner		3.17			
Notemigonus crysoleucas	Golden shiner				0.43	
Notropis atherinoides	Emerald shiner		6.35			
N. maculatus	Taillight shiner				2.14	
Opsopoeodus emiliae	Pugnose minnow	0.17	6.35		0.68	0.63
Family Catostomidae						
Ictiobus sp.	Juvenile buffalo					2.21
Family Ictaluridae						
Ameiurus natalis	Yellow bullhead				0.09	
Ictalurus punctatus	Channel catfish					0.16
Family Cyprinodontidae						
Fundulus chrysotus	Golden topminnow	0.66				17.8
F.dispar	Starhead topminnow	0.66	3.17		0.17	
F. notatus	Blackstrp. topminnow					0.16
F. olivaceus	Blackspot. topminnow		11.1	7.8	0.34	0.16
Family Poeciliidae						
Gambusia affinis	Mosquitofish	92.2	52.4	31.4	64.2	52.8
Family Atherinidae						
Labidesthes sicculus	Brook silverside		3.17	1.96	0.51	
Family Percichthyidae						
Morone chrysops	White bass					0.16
Family Elassomatidae						
Elassoma zonatum	Banded pygmy sunfish	0.17				

Table 13. Concluded

Species	Common name	AG	FAL	BLH	LG-ISO	LG-CONN
Family Centrarchidae						
Lepomis cyanellus	Green sunfish			1.96	0.26	
L. gulosus	Warmouth	0.17	1.59		0.17	0.47
L.humilus	Orangespot. sunfish	0.50		33.3	12.9	9.16
L. macrochirus	Bluegill	3.48	9.52	11.8	0.68	5.85
L. megalotis	Longear sunfish			7.8		1.74
L. miniatus	Redspotted sunfish				0.09	
L. symmetricus	Bantam sunfish				0.17	0.16
Micropterus salmoides	Largemouth bass				2.65	0.32
Pomoxis annularis	White crappie		1.59		1.45	0.32
P. nigromaculatus	Black crappie				8.72	0.16
P. spp.	Juvenile crappie					3.32
Family Percidae						
Etheostoma asprigene	Mud darter				0.51	1.90
Etheostoma chlorosomum	Bluntnose darter				0.68	0.16
Etheostoma fusiforme	Swamp darter		1.59		0.60	
E. proeliare	Cypress darter				0.51	
Percina caprodes	Logperch					1.26
Number of Species		11	11	8	23	20
Number of Fish/sample		604	63	51	390	208

Table 14. Average daily acres flooded in the 2-year floodplain by flood control alternative and reach[1] in the Bayou Meto Basin. Acres represent functional spawning and rearing habitat (i.e., spawning acres for agricultural fields, rearing acres for all other floodplain habitats).

Reach	Existing	Alternative FC2	Alternative FC2A	Alternative FC3A	Alternative FC3B
1	1134.22	1134.22	1134.22	1134.22	1134.22
2	4831.10	4831.10	4831.10	4831.10	4831.10
3	547.79	431.31	431.31	431.31	431.31
4	333.52	173.61	168.50	168.50	168.50
5	1174.33	748.26	722.14	722.14	722.14
6	4164.91	3996.34	3996.34	4164.91	3996.34
7	1120.82	1120.82	1120.82	790.49	769.61
9	161.80	130.63	130.63	130.79	130.79
10	828.96	828.96	828.96	828.961	828.96
11	1391.71	1270.01	1270.01	1270.01	1270.01
Total	15,689	14,665	14,634	14,472	14,283

[1] Reach 8 was excluded from indirect hydraulic impacts of the flood control project because water elevations are mostly controlled by gates or levees, either as part of the Wildlife Management Area or private greentree reservoirs.

Table 15. Percent land use within the 2-year floodplain for existing conditions in the Bayou Meto Basin

Reach Number	1	2	3	4	5
Reach Name	Little Bayou Meto 1	Big Bayou Meto 3	Two Prairie Bayou	Little Bayou Meto 2	Wabeseca Indian Bayou
Agricultural Land	18.87	51.77	37.30	35.24	80.49
Fallow Land	1.84	13.77	12.08	3.25	4.20
Bottomland Hardwoods	79.28	33.60	48.75	60.71	11.11
Large Permanent Water Bodies	0.00	0.00	0.00	0.00	0.00
Small Permanent Water Bodies	0.32	8.44	5.31	0.31	0.09

Table 14. (concluded)

Reach Number	6	7	8	9	10	11
Reach Name	Indian Bayou Ditch	Crooked Creek Ditch	Crooked Creek	Salt Caney Baker	Big Bayou Meto 2	Big Bayou Meto 1
Agricultural Land	76.78	60.15	78.20	84.10	35.38	37.60
Fallow Land	4.87	6.93	5.91	2.51	7.80	6.12
Bottomland Hardwoods	17.90	28.83	14.62	12.61	55.78	54.93
Large Permanent Waterbodies	0.00	0.02	0.01	0.02	0.00	0.01
Small Permanent Water Bodies	1.02	5.85	1.24	1.58	1.81	3.85

Table 16. Indirect (hydrologic) impacts and mitigation requirements of flood control in Bayou Meto, Arkansas for fish spawning and rearing combined. Reach 8 was excluded from indirect hydraulic impacts of the flood control project because water elevations are mostly controlled by gates or levees, either as part of the Wildlife Management Area or private greentree reservoirs.					
Alternative	Total Acres	Total Habitat Units	Acres Lost	Habitat Units Lost	Reforestation Requirements
Baseline	15689	11405	0	0	0
FC2	14665	10717	1024	688	894
FC2A	14634	10699	1055	706	918
FC3A	14472	10530	1217	875	1138
FC3B	14283	10399	1406	1006	1307

Table 17. Direct (construction) impacts and mitigation requirements of flood control in Bayou Meto, Arkansas for fish spawning and rearing combined, including Reach 8.			
Alternative	Acres Lost	Habitat Units Lost	Reforestation Requirements
Baseline	0	0	0
FC2	642	527	685
FC2A	735	582	756
FC3A	1058	765	995
FC3B	1216	912	1186

Table 18. Fishes and amphibians of small floodplain pools of the Bayou Meto system collected in 2000 - 2001.

Scientific name	Common name	Woodland Edge (N = 11)	Woodland (N = 4)
Family Lepisosetidae			
Lepisosetus oculatus	Spotted gar	0.13	
Family Amiidae			
Amia calva	Bowfin	3.52	
Family Esocidae			
Esox americanus	Grass pickerel	0.63	2.11
Family Cyprinidae			
Cyprinus carpio	Common carp	0.19	
Notemigonus crysoleucas	Golden shiner	2.51	5.91
Cyprinidae sp.	Unidientified minnow	0.13	
Family Catostomidae			
Ictiobus cyprinellus	Bigmouth buffalo	0.06	
Family Ictaluridae			
Ameiurus mela	Black bullhead		2.11
Family Aphredoderidae			
Aphredoderus sayanus	Pirate perch	0.19	5.06
Family Cyprinodontidae			
F. chrysotus	Golden topminnow	0.44	
F.dispar	Starhead topminnow	0.69	
Family Poeciliidae			
Gambusia affinis	Mosquitofish	35.07	30.80
Family Elassomatidae			
Elassoma zonatum	Banded pygmy sunfish	3.21	0.84
Family Centrarchidae			
Centrarchus macropterus	Flier	0.57	3.80
Lepomis cyanellus	Green sunfish	2.83	2.53
L. gulosus	Warmouth		21.94
L.humilus	Orangespotted sunfish		0.84
L. macrochirus	Bluegill		1.69
L.marginatus	Dollar sunfish		18.14
L. symmetricus	Bantam sunfish	0.06	
Pomoxis nigromaculatus	Black crappie	0.06	2.11

Table 17. Concluded.

Scientific name	Common name	Woodland Edge	Woodland
Family Percidae			
Etheostoma gracile	Slough darter		0.42
E. sp.	Unidentified darter		0.42
Family Ranidae			
Rana catesbiana	Bullfrog	0.06	
R. clamitans	Bronze frog	0.06	
R. sphenocephala	Southern leopard frog	49.04	
R. sp.	Unidentified frog tadpoles		1.27
Family Ambystomidae			
Ambystoma opacum	Marble salamander	+ *	+
Family Salamandridae			
Notophthalmus viridescens	Central newt	0.19	+
Total Number of Species		20	16
Total Number of Individuals		1591	237

* An asterisk indicates species observed in light-traps and not collected by seine.

Figure 1. Mean Density of Fish per Month Relative To Temperature and Discharge in the Arkansas River Main Channel, David D. Terry Lake

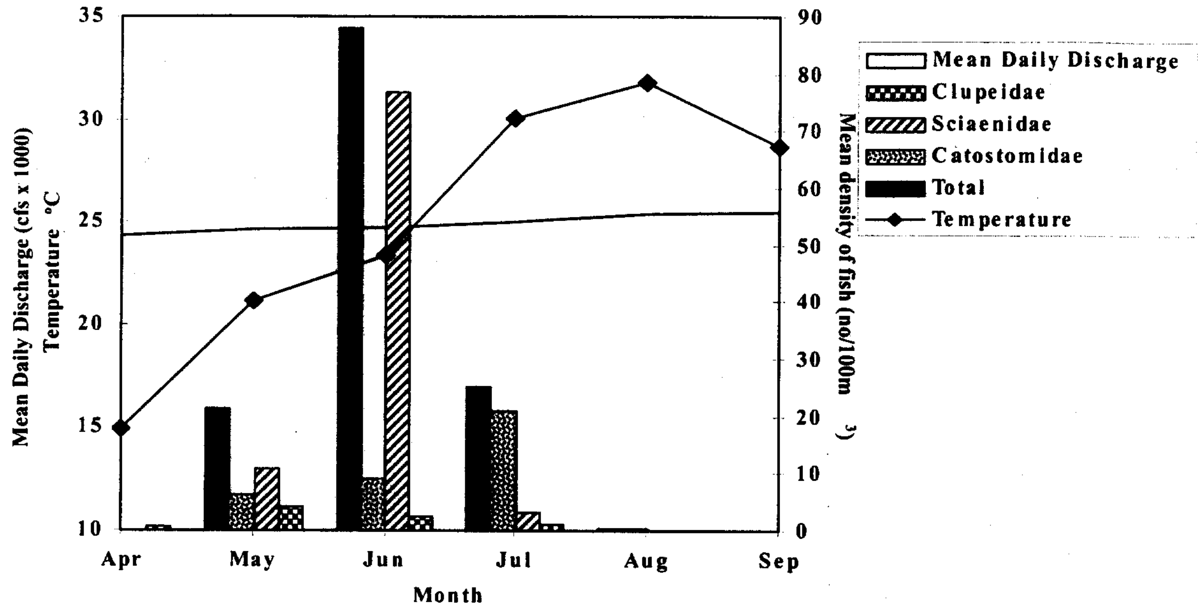


Figure 2. Mean Density of Fish per Month Relative To Temperature in Willow Bar Cutoff near David D. Terry Lock & Dam

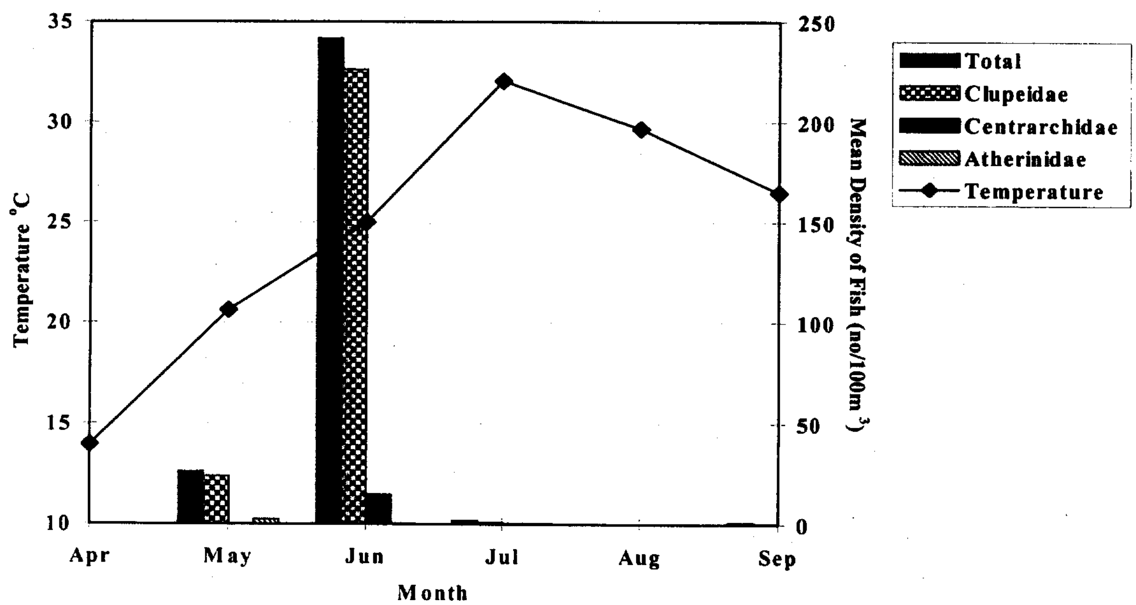


Figure 3. Relationship between number of larval fish in the Arkansas River behind David D. Terry Lock and Dam to those potentially entrainable in the diverted water.

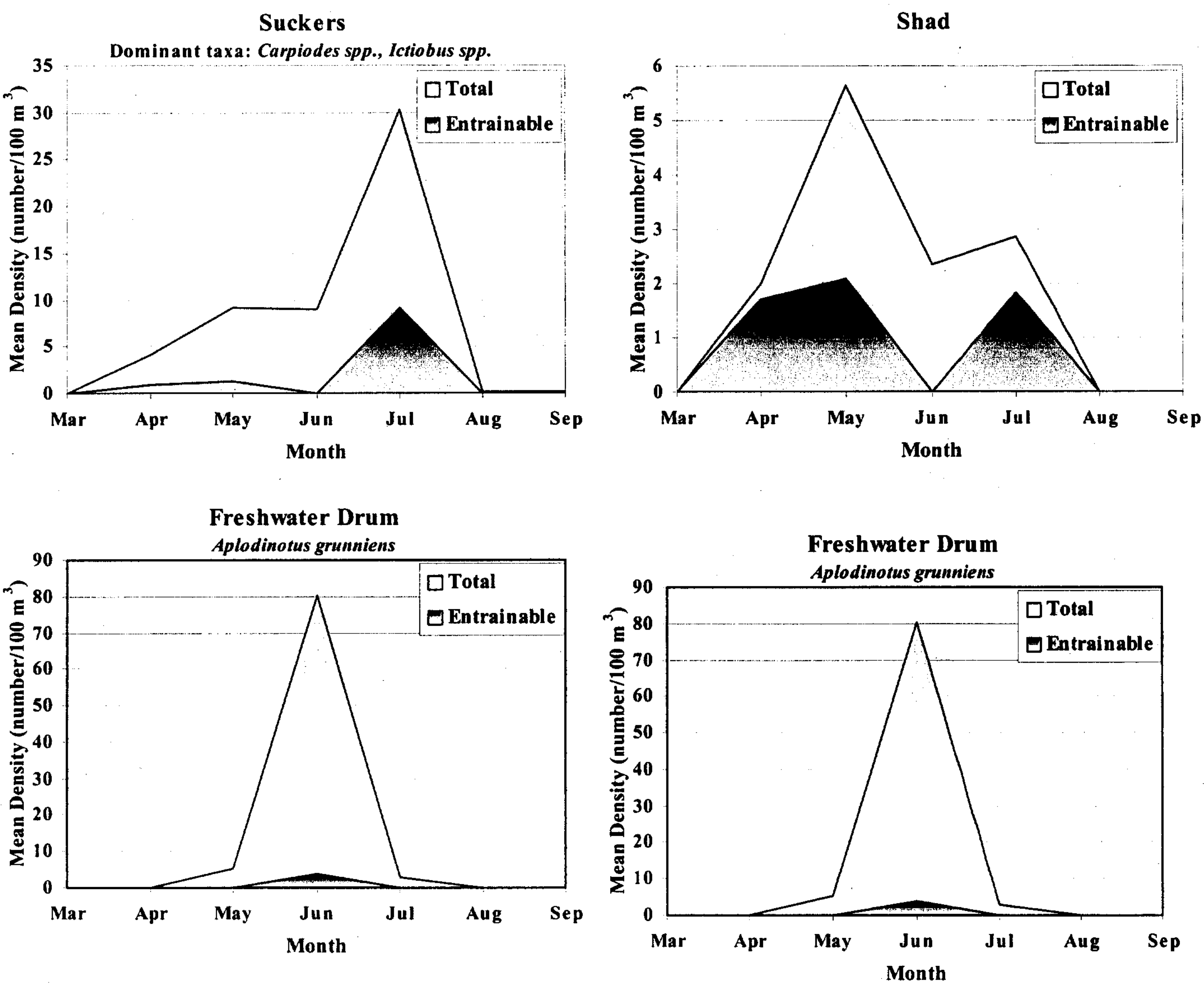
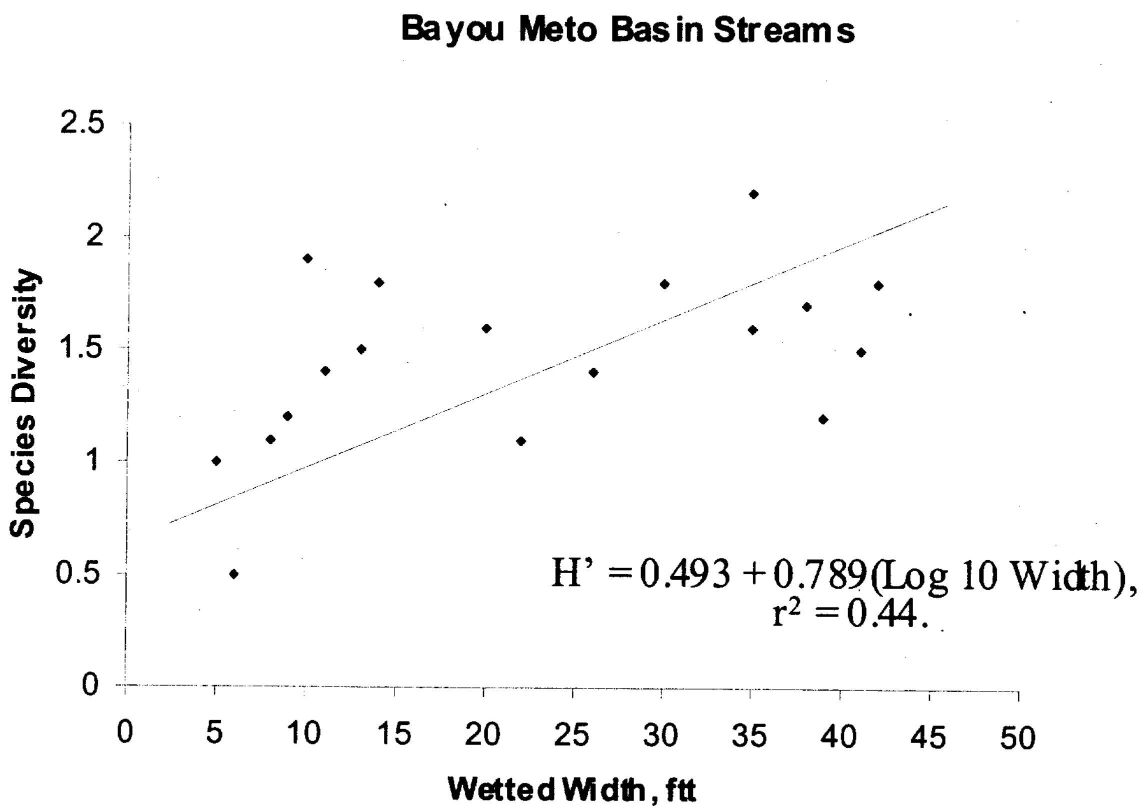


Figure 4. Bivariate plot and regression equation of species diversity and wetted width of the channel used to develop HSI equation for streams and canals of Bayou Meto Basin.



SECTION XIV

AQUATIC EVALUATONS

Part B. Mussels

ERDC/EL TR-02-34

Environmental Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Effects of Channel Modification and Flow Augmentation on Freshwater Mussels in the Bayou Meto Area, Arkansas

Andrew C. Miller and Barry S. Payne

September 2002

ERDC/EL TR-02-34
September 2002

Effects of Channel Modification and Flow Augmentation on Freshwater Mussels in the Bayou Meto Area, Arkansas

by Andrew C. Miller, Barry S. Payne

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Prepared for U.S. Army Engineer District, Memphis
167 North Main St., Memphis, TN 38103-1894

Contents

List of Figures

List of Tables

Preface

The U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, conducted these studies in 2001 for the U.S. Army Engineer District, Memphis. The purpose of these studies was to assess impacts to the mussel fauna of dredging, clearing, snagging, channel enlargement, and flow augmentation in the Bayou Meto area (including Bayou Meto, Bayou Two Prairie, Crooked Creek, Indian Bayou, Salt Bayou Ditch, Wabbaseka Bayou, and associated miscellaneous ditches) near Stuttgart, AR. The field crew from ERDC consisted of Dr. Andrew C. Miller, Dr. Barry S. Payne, Mr. Will Green, and Ms. Kathryn Barko. A four-person crew from Mainstream Commercial Divers, Paducah, KY, collected mussels at some of the sites. Mr. Mark R. Smith, Memphis District, supplied maps and background information on the project area. Authors of this report were Drs. Miller and Payne.

During the conduct of this study, Dr. Edwin A. Theriot was Director, Environmental Laboratory (EL), ERDC; Dr. David J. Tazik was Chief, Ecosystem Evaluation and Engineering Division, EL, ERDC; and Dr. Al Cofrancesco was Chief of the Aquatic Ecology and Invasive Species Branch, EL.

Commander and Executive Director of ERDC during publication of this report was COL John W. Morris III, EN. Director was Dr. James R. Houston.

This report should be cited as follows:

> Miller, A. C., and Payne, B. S. (2002). "Effects of channel modification and flow augmentation on freshwater mussels in the Bayou Meto Area, Arkansas," ERDC/EL TR-02-34, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

1 Introduction

Background

Bayou Meto and its tributaries encompass over 700,000 acres (283,280 ha) in Arkansas, Jefferson, Lonoke, and Prairie Counties, central Arkansas. Within the basin, there are over 640 miles (1,030 km) of streams and bayous adjacent to agricultural land and bottomland hardwood forests. The U.S. Army Engineer Districts, Vicksburg, and Memphis, are evaluating water supply, ecosystem restoration, and flood control in the Bayou Meto Basin.

There is a need to increase the quantity of water in streams and bayous in the watershed. Water supply could be augmented with flow from the Arkansas River, immediately upstream of David D. Terry Lock and Dam. Water could then be carried via a system of streams, canals, and pipelines to the surrounding delta. Maximum diversion from the Arkansas River would range from 2,000 to 2,500 cfs (57 to 71 cms). Water would be used for agricultural irrigation, commercial withdrawal, and waterfowl management.

In addition, a flood-control project is proposed for the lower reaches of Bayou Meto. Flood-control alternatives will be developed for the outlet of Bayou Meto that currently has a gravity structure that empties into the Arkansas River. To reduce the sump area, an alternative gravity outlet and pumping station will be considered. In addition, channel modifications (selective clearing and snagging and channel excavation) are being evaluated to reduce flood duration in the lower reaches of Bayou Meto, Little Bayou Meto, Wabbaseka Bayou, Indian Bayou, Salt Bayou, and Crooked Creek.

As required by the National Environmental Policy Act and the Endangered Species Act of 1972, as amended, the U.S. Army Corps of Engineers must evaluate the environmental effects of these actions on freshwater mussels (Family: Unionidae). Freshwater mussels are an important component of the ecosystem; they stabilize benthic substrates, filter organic matter out of the water column, and provide food for certain species of fishes, mammals, and waterfowl. While their shells were once used to make buttons, now certain thick-shelled species are used for culturing pearls.

With respect to the native freshwater mussels, there are several environmental concerns associated with this project. First, District personnel want to ensure that proposed channel modifications do not damage mussels or their habitat. Second, there is concern that the nonindigenous zebra mussel (*Dreissena polymorpha*) could be accidentally introduced into the project area and, therefore, negatively affect the native mussels.

Currently, there are no zebra mussels in the project area, although there are high-density populations in the Arkansas River. There are commercial shelling operations for the cultured pearl business near the project area. In addition, the project area is within the range of two endangered species of mussels, the pink pearly mucket (*Lampsilis abrupta*) and the fat pocketbook (*Potamilus capax*).

Study Area

The Bayou Meto Drainage is in central Arkansas, southeast of Little Rock. Mussel collections were made at the site of the pumping plant on the Arkansas River (Figure 1), at a series of streams associated with Bayou Meto proper west of Stuttgart (Figure 2), in Indian Bayou east of England (Figure 3), in Salt Bayou Ditch west of Wabbaseka (Figure 4), and in Wabbaseka Bayou (Figure 5).

Methods

Two to four individuals working simultaneously collected mussels by hand via timed searches. Since visibility was low, this had to be done principally by feel. Collectors were instructed to search the top few centimeters of substratum and retrieve all live mussels that were encountered. Dead mussels and live *Corbicula fluminea* were excluded. Qualitative sampling is useful for obtaining species composition, including presence/absence of endangered or very uncommon species. Typically it can be biased toward the larger, easier-to-find species, although every effort is made to avoid this. However, it should be noted this bias will be reduced in fine-grained sediments that characterize the study area. The amount of time expended searching was recorded and results are expressed as mussels collected per minute, or catch per unit effort (CPUE). More information on sampling methods can be found in Miller et al. (1993).

Quantitative samples were taken at Waypoint 6 (the Prison Farm site) on Indian Bayou using a 0.25-sq-m quadrat (50 cm on a side), constructed of 0.6- by 100-mm aluminum stock. Quantitative samples were taken specifically to provide estimates of density as well as unbiased estimates of recent recruitment. Quadrats were placed haphazardly on the substratum and then all sand, silt, mud, gravel, live mussels, and shells was removed and placed into a 20-L bucket. Sediments were screened, live mussels were identified, and total shell length was measured. Bivalve nomenclature followed Williams et al. (1993).

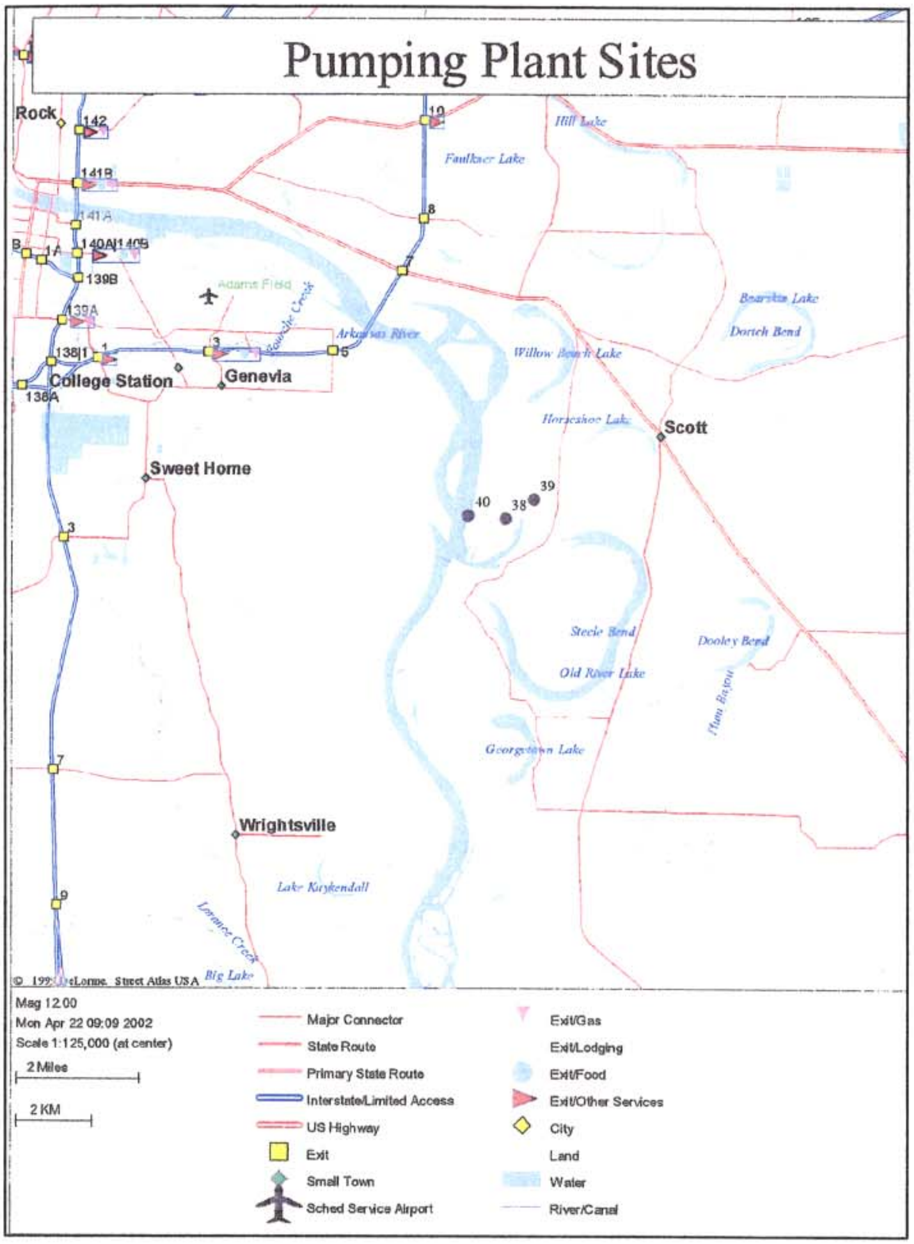


Figure 1. Study sites (38, 39, 40) near the proposed intake plant on the Arkansas River

Figure 2. Study sites in the Bayou Meto area, including Bayou Two Prairie, Bayou Meto, Crooked Creek, and other adjacent streams

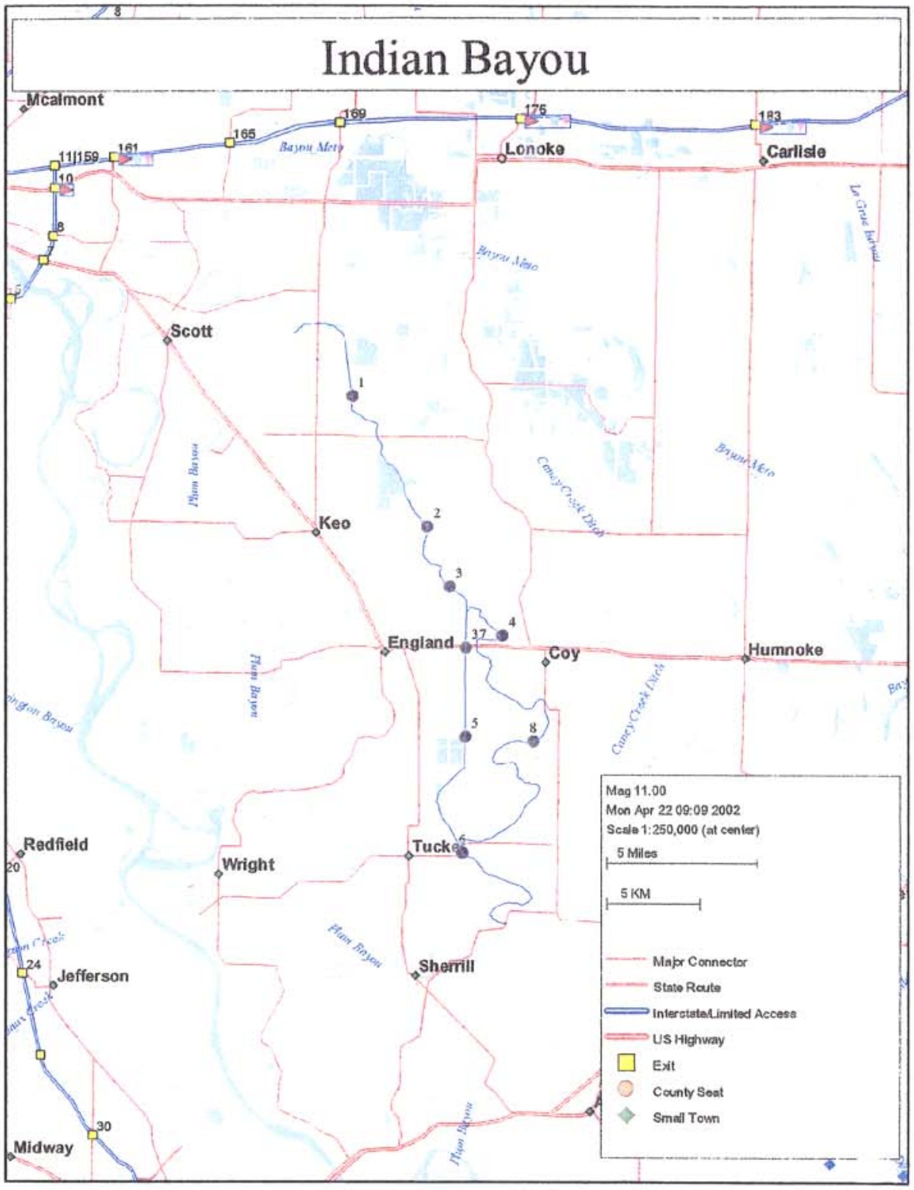


Figure 3. Sample sites on Indian Bayou and Indian Bayou Ditch

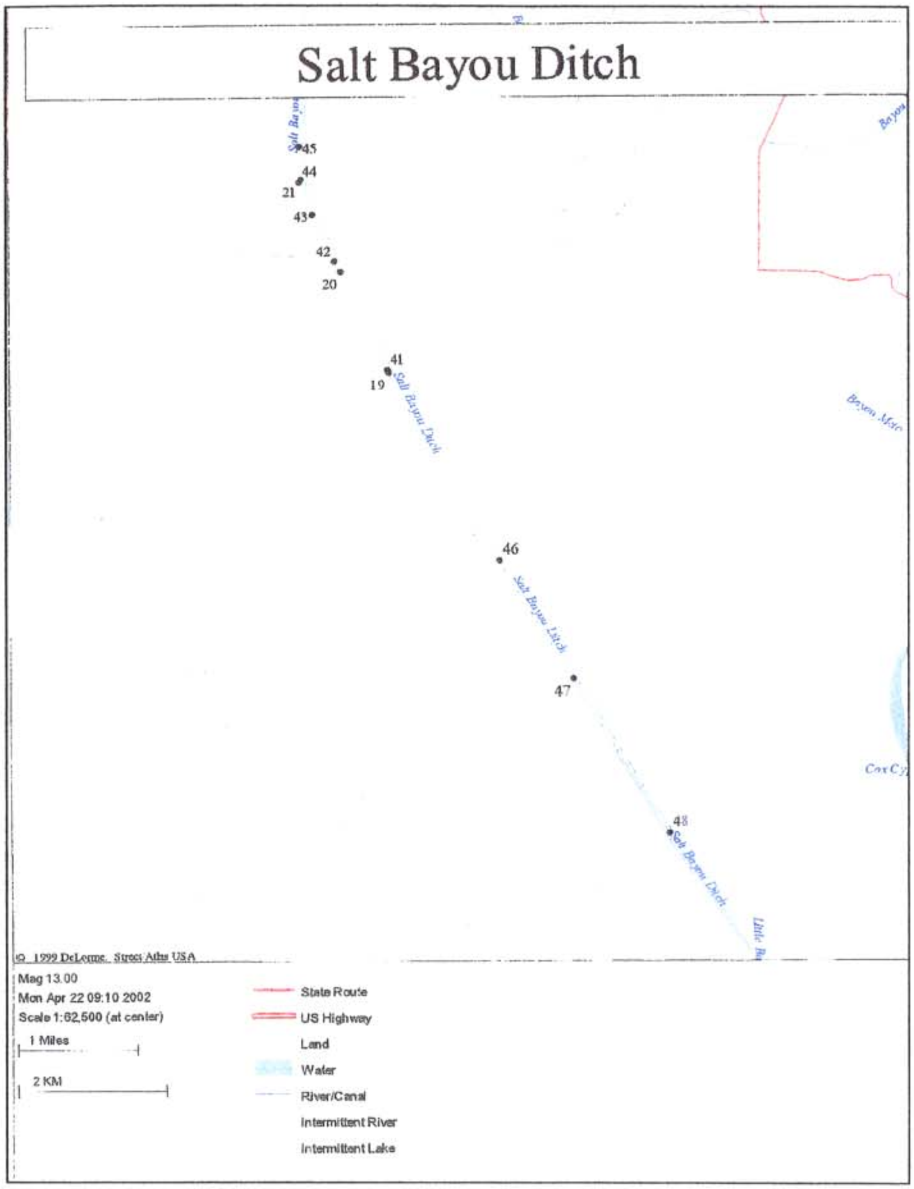


Figure 4. Sample sites along Salt Bayou Ditch

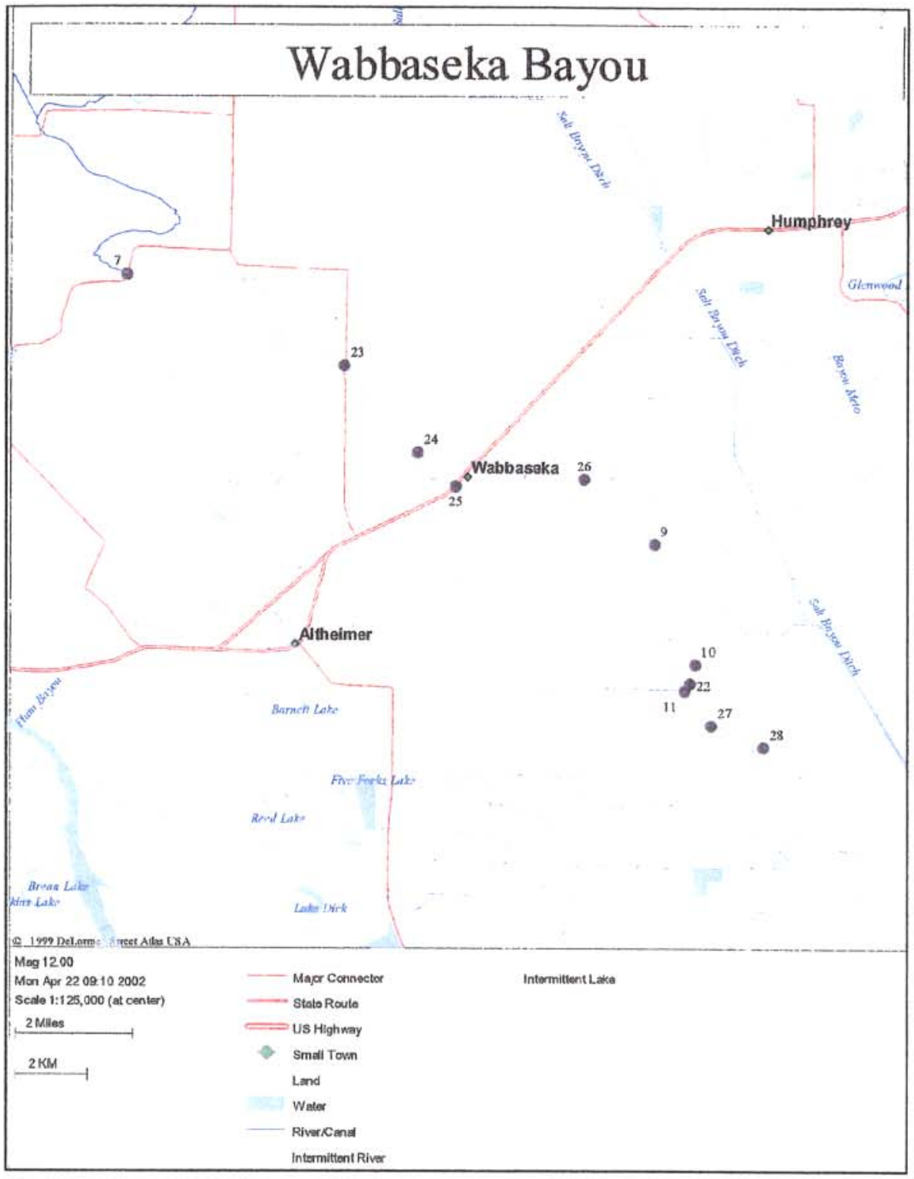


Figure 5. Sample sites along Wabbaseka Bayou

After collecting, live mussels were kept cool and moist. When work was completed, mussels were returned to the water unharmed, as close to the location where they were collected as possible. All quantitative and qualitative collections in Indian Bayou were obtained without diving since the water was less than 1 m deep.

A global positioning system (GPS) was used to mark each site where either qualitative or quantitative samples were obtained. All tables and figures are keyed to the waypoints collected with the GPS (Table 1).

Table 1
Sample Sites in the Bayou Meto Drainage, 2001

Waypoint	Longitude (E)	Latitude (N)	Location
38	92.140006	34.677084	Arkansas River Pump Point
39	92.131927	34.681596	Arkansas River Pump Point
40	92.150638	34.677824	Arkansas River Pump Point
17	91.717311	34.740164	Bayou Two Prairie
18	91.718390	34.688156	Bayou Two Prairie
29	91.646292	34.538022	Bayou Meto
30	91.647043	34.569018	Bayou Meto
31	91.691991	34.576646	Bayou Meto
32	91.669407	34.237593	Long Pond Access
33	91.627613	34.209414	Bayou Meto Control Structure
34	91.561545	34.248843	Pond
35	91.739016	34.556036	Bayou Meto
36	91.730325	34.540270	Bayou Meto
12	91.718781	34.435728	Crooked Creek
13	91.700547	34.467378	Crooked Creek
14	91.697168	34.456902	Crooked Creek
15	91.722863	34.488621	Crooked Creek
16	91.758751	34.486604	Crooked Creek
1	91.987705	34.669059	Indian Bayou Ditch
2	91.944248	34.605458	Indian Bayou Ditch
3	91.930751	34.576083	Indian Bayou Ditch
4	91.899642	34.552013	Indian Bayou
5	91.921572	34.502633	Indian Bayou Ditch
6	91.923568	34.445867	Indian Bayou Ditch
8	91.881108	34.500348	Indian Bayou
37	91.921386	34.546162	Indian Bayou Ditch
19	91.704211	34.344597	Salt Bayou Ditch: Boat Ramp
20	91.711233	34.356850	Salt Bayou Ditch
21	91.716882	34.368061	Salt Bayou Ditch
41	91.704442	34.344935	Salt Bayou Ditch
42	91.712097	34.358073	Salt Bayou Ditch
43	91.715300	34.363791	Salt Bayou Ditch
44	91.717134	34.367782	Salt Bayou Ditch
45	91.717091	34.372026	Salt Bayou Ditch
46	91.688238	34.321621	Salt Bayou Ditch
47	91.677439	34.307168	Salt Bayou Ditch
48	91.663252	34.288352	Salt Bayou Ditch
7	91.897733	34.410617	Wabbaseka Bayou
9	91.739772	34.344260	Wabbaseka Bayou
10	91.729703	34.314026	Wabbaseka Bayou
11	91.730830	34.307840	Wabbaseka Bayou
22	91.729204	34.309648	Wabbaseka Bayou
23	91.833027	34.388258	Wabbaseka Bayou
24	91.810915	34.366854	Wabbaseka Bayou
25	91.799478	34.358481	Wabbaseka Bayou
26	91.760978	34.360326	Wabbaseka Bayou
27	91.722890	34.299268	Wabbaseka Bayou
28	91.707387	34.293909	Wabbaseka Bayou

2 Results

Pumping Plant Sites

Water for the Bayou Meto project will be taken from the Arkansas River southwest of Scott, AR (Figure 1). Divers searched the intake area in the Arkansas River for 30 min and found no live native mussels. However, there were zebra mussels attached to rocks, shells, and submersed woody vegetation. Zebra mussel densities at the point of the intake structure were estimated at 150 individuals/m^2.

A total of 15 min were also expended searching for mussels at sites about 1 to 2 km from the river that will be modified to handle increased discharge (Waypoints 38 and 39, Figure 1). Water will be taken from the river and then sent through a man-made canal system to streams in the area. Two *Pyganodon grandis* were collected at Waypoint 38, and no live mussels were found at Waypoint 39.

Bayou Meto Area

The Bayou Meto Area included Bayou Two Prairie, Crooked Creek, and portions of Bayou Meto proper (Figure 2). A total of 170 min were expended searching for mussels at 15 sites (Tables 1 and 2), and no live mussels were found. None of these sites had firm substratum or adequate flow necessary to support freshwater mussel assemblages. The following paragraphs provide a detailed description of the study sites.

Bayou Two Prairie, Waypoint 17

The channel at this site was approximately 10 m wide and in a naturally meandering reach. Depth was approximately 0.7 m. The mud bottom was firmer than in most sites in the bayous and creeks of the project area. Large woody debris was abundant – both immersed and submersed. Canopy cover was approximately 60 percent. Although there was no flow, the nature of the substratum suggested occasional flushing flows. A single large *P. grandis* shell

Table 2
Percent Abundance of Mussel Species Collected in Different Sections of the Bayou Meto Drainage, 2001

Species	Indian Bayou	Bayou Meto Area	Wabbaseka Bayou	Salt Bayou Ditch	Total
A. plicata	59.19	0.00	8.33	77.04	60.89
Q. quadrula	24.97	0.00	8.33	10.37	22.92
Q. pustulosa	3.41	0.00	8.33	0.74	3.13
U. declivus	3.30	0.00	16.67	0.00	3.03
L. teres	2.64	0.00	0.00	0.00	2.27
A. confragosus	1.65	0.00	8.33	2.22	1.80
T. parvus	1.21	0.00	0.00	0.00	1.04
P. purpuratus	0.66	0.00	8.33	2.22	0.95
Q. apiculata	0.77	0.00	0.00	0.74	0.76
L. fragilis	0.55	0.00	16.67	0.00	0.66
M. nervosa	0.11	0.00	0.00	3.70	0.57
L. recta	0.55	0.00	0.00	0.00	0.47
F. flava	0.44	0.00	0.00	0.00	0.38
P. grandis	0.11	0.00	16.67	0.00	0.28
T. verrucosa	0.00	0.00	0.00	2.22	0.28
L. subrostrata	0.22	0.00	0.00	0.00	0.19
P. ohiensis	0.00	0.00	0.00	0.74	0.09
A. suborbiculata	0.00	0.00	8.33	0.00	0.09
Total individuals	909	0	12	135	1056
Total species	15	0	9	9	18
Total time	566	170	207	188.5	1131.5
CPUE	1.61	0.00	0.06	0.72	0.93
No. of sites	8	15	11	11	45

was found on the shore, but a 20-min search yielded no mussels and no other shells.

Bayou Two Prairie, Waypoint 18

This site was just south of a catfish farm complex of ponds. Channel dimensions were similar to site Waypoint 17, but the bottom substratum was softer. Large woody debris and other debris (many old tires and other trash) clogged the channel. No shells were evident along the shore, and a 10-min search yielded no mussels or shells.

Bayou Meto, Waypoint 31

This site was located north of the 165 Bridge (Figure 2). Water was shallow and less than 25 cm deep in most places. Canopy coverage was less than 15 percent. There was no flow, and the majority of the 30- to 50-m-wide channel was choked with sediment, aquatic plants, and woody vegetation. A total of 10 min of searching yielded no live mussels.

Bayou Meto, Waypoint 30

This site was located off a wooden bridge located 1 to 2 miles (1.6 to 3.2 km) north of Highway 165 (Figure 2). At this site the water was 1 to 2 m deep with little or no flow. There were a few logs and woody debris in the water. No live mussels were found, although shells of *Toxolasma parva, Ligumia subrostrata,* and *Uniomerus tetralasma* were collected. These three species are all tolerant of organic debris, low flow, and sand/silt substratum. A total of 10 min was expended searching at this site.

Bayou Meto, Waypoint 29

This site was located just off the Highway 165 bridge west of Stuttgart, AR (Figure 2). A total of 10 min of searching yielded no live mussels and only a single dead *A. plicata* shell. Canopy coverage was 10 to 15 percent at this location, and flow was at or near zero. Considerable organic matter, consisting of twigs and leaves, covered the mud and silt substratum. A total of 10 min was spent searching at this site.

Crooked Creek Ditch, Waypoint 35

The ditch at this site was 1 to 2 m wide, had approximately 0 to 10 cm of water, and was choked with emergent vegetation. This was not suitably aquatic for mussels. A total of 30 min was spent searching at this site.

Crooked Creek Ditch, Waypoint 36

This site was located immediately south of the Highway 165 crossing over the straight ditch through a buried culvert. The highway partially impounds the ditch, making it wider and deeper on the south than north side of the highway. The channel on the south side was approximately 12 m wide and 0.7 m deep. The substratum was muck with much moderate-to-small submersed woody debris. Canopy coverage was less than 5 percent. There was no perceivable flow. Hydrogen sulfide smell was moderately strong when the bottom was disturbed. A 20-min search yielded no mussels or shells. No shells were evident on the ditch banks.

Crooked Creek Ditch, Waypoint 15

The channel was a wet ditch with only isolated, very shallow, and stagnant small pools choked with large woody debris. Habitat was not suitable for mussels and no collecting was done.

Crooked Creek Ditch, Waypoint 16

This location was virtually identical to the Waypoint 15. No collecting was done at this site.

Crooked Creek, Waypoint 12

This site was located slightly northwest of the town of Humphrey, AR. The creek in this reach is a meandering slough with cypress trees in and along its course. There was no perceptible flow. At this location, the channel was at least 60 m wide but less than 0.7 m deep. Substratum was mud with a large amount of detritus (mostly cypress needles, other leaves, and twiggy debris). The bottom smelled of hydrogen sulfide when disturbed. A total of 40 min was expended searching at this location.

Crooked Creek, Waypoints 13 and 14

The creek at these locations was virtually identical in basic characteristics to those at Waypoint 12. This reach of the creek north of Humphrey is part of the same meandering reach as Waypoint 12. A 5-min search at each location by two waders (10 min total at each site) confirmed that the substratum was the same as at Waypoint 12; no mussels were found and no shells were observed.

Miscellaneous sites south of Humphrey – Waypoints 32, 33, and 34

No mussels or suitable habitat for mussels were found at these sites (Figure 2). All sites had shallow water, much woody debris, and lacked suitable substratum and current velocity to support mussel assemblages. No sampling was done at these sites.

Indian Bayou and Indian Bayou Ditch

Indian Bayou and Indian Bayou Ditch (Figure 3) flow due south between England and Coy, AR. These water bodies join Wabbaseka Bayou southeast of Altheimer, AR. Wabbaseka Creek joins Little Bayou Meto, which then enters the Arkansas River near Reydell, AR. The channel of the upper section of Indian Bayou has been dredged; hence, Waypoints 1, 2, and 3 are actually in Indian Bayou Ditch (Table 1). The unmodified section south of Coy is referred to as Indian Bayou (Waypoints 4 and 8). The straight reach that starts just north of

Highway 165 carries most of the flow of Indian Bayou (to the east) and is referred to as Indian Bayou Ditch (Waypoints 37, 5, and 6). Live mussels were found at five of the eight sites surveyed in this area.

Indian Bayou Ditch, Waypoint 1

This site was in the upper reach of Indian Bayou Ditch. Access was at a bridge crossing along Chaney Road east of Highway 15. The survey was conducted within a reach approximately 150 m upstream of the bridge. At this location the channel was straight with old dredged material clearly forming the mounded left descending bank. Stream width was approximately 5 m; depth was less than 0.4 m and usually less than 0.25 m. Old *C. fluminea* and unionid shell material was abundant, suggesting that live mussels were also present.

Water velocity was approximately 10 to 15 cm/sec in the stream that flows in a southerly direction. Substratum was soft clay/mud with much filamentous green algae attached to old shell and small woody debris that littered the bottom. *Corbicula fluminea* were abundant here – both live individuals and empty shells. Dead *C. fluminea* shell comprised a substantial portion of the substratum, helping to armor the soft bottom. Live native mussels collected in a 25-min search by two individuals included *Amblema plicata* (n = 8), *Leptodea fragilis* (1), *Lampsilis teres* (2), *Quadrula quadrula* (a 30-mm-long recent recruit), *Ligumia subrostrata* (2), and *Ligumia recta* (1). Other species observed as dead shells included *Uniomerus tetralasmus*, *U. declivus*, and *Fusconaia flava*.

Indian Bayou Ditch, Waypoint 2

Access to this site was from a bridge crossing along C. Jeans Road. The channel was approximately 20 m wide; water depth was approximately 0.7 m. The channel follows a slightly winding and more natural-looking course than in the very straight reach sampled at Waypoint 1. However, flow at Waypoint 2 was only barely perceivable. Substratum was very deep and soft mud that smelled strongly of hydrogen sulfide when disturbed. Submersed large woody debris was abundant. Some discarded debris was also present. The potential for this site to support unionids was very low.

Two waders each searched for 20 min. The only live mussel found was a large *Leptodea fragilis*. *Corbicula fluminea* were not present, perhaps indicating low dissolved oxygen conditions that presumably are common at this site. Only a few dead shells were found, including large *L. fragilis*, *A. plicata*, and *Pyganodon grandis*. All were old shells, deeply submersed in the mud, and stained black by reducing conditions.

Indian Bayou Ditch, Waypoint 3

This site was slightly west of Jabb, AR, and had essentially the same characteristics as Waypoint 2 except for being more choked with discarded debris and very abundant submersed and immersed large woody debris. A 5-min search by two waders yielded no mussels or shells; no shells were observed along the banks.

Indian Bayou, Waypoint 4

This site was near the 135-deg bend that the bayou makes just north of Highway 165. Two waders conducted a 10-min search where the ditch turned west toward the town of England. The bayou at this location is a very stagnant cypress slough – a shallow pond without flow that supported many cypress trees in the water and along the shores. Indian Bayou Ditch diverts stream flow due south at a point not too far upstream of this location, and greatly reduces flushing of Indian Bayou in its natural course just east of Indian Bayou Ditch.

Substratum consisted of 15-cm-thick flocculent material covering hard mud. Hydrogen sulfide smell was strong when the mud was disturbed. No shells or live mussels were found.

Indian Bayou Ditch, Waypoint 37

This site was at the Highway 165 crossing over the ditch, just east of the town of England, AR. A pooled area caused by a small logjam was located upstream of the highway bridge. There was a riffle just downstream of the logjam and under the bridge for a considerable distance farther downstream. The pool and riffle were searched for a total of 70 min. Substratum in the pool was a soft mud probably too flocculent to support many mussels. Depth of the pool was only 60 to 90 cm. The pool yielded few live mussels.

Water in the riffle was about 30 cm deep. Water velocities in the swifter braids in the riffle were approximately 20 cms. Substratum was soft mud, with sand, buckshot clay, and some gravel and cobble. The coarsest particles were probably associated with bridge construction and road maintenance. More than 100 mussels representing 10 species were obtained in 70 min in the pool and riffle. *Amblema plicata* and *Q. quadrula* shared dominance. Both populations showed ample evidence of occasional recruitment. *Corbicula fluminea* was also present in moderate abundance. Unionid density ranged from approximately 1 to 5 individuals/sq m.

Indian Bayou Ditch, Waypoint 5

This site was in the perfectly straight portion that originates just north of Highway 165 east of England and continues south for several kilometers. The site at Waypoint 5 was at a bridge crossing along Tar Bottom Road. The area survey was slightly downstream of the bridge. Riparian trees were not present at this location.

The channel here was approximately 8 m wide. Substratum and flow were similar to that described for Waypoint 1. Namely, substratum was soft clay/mud with much filamentous green algae attached to old shell and small woody debris that littered the bottom. *Corbicula fluminea* were abundant here – both live individuals and empty shells. Dead *C. fluminea* shell comprised a substantial portion of the substratum, helping to armor the soft bottom. Uniformly large *A. plicata* comprised nearly all of the live mussel assemblage; the modal length was approximately 100 mm. *Amblema plicata* were moderately dense (approximately 5 to 10 individuals per square meter). A total of 28 *A. plicata* were recovered in an 18-min search by each of two waders. In addition, five *U. declivus* were obtained live as well as a single *Arcidens confragosus*.

Indian Bayou, Waypoint 8

This site was in the long and winding portion of the bayou upriver of its confluence with Indian Bayou Ditch near the Tucker Prison Farm. The bayou throughout this reach (from just north of 165 to the Prison Farm area) was a stagnant shallow series of swamps and sloughs. There was no perceivable flow. A 10-min search by each of two waders yielded no live mussels or shells.

Indian Bayou, Waypoint 6

This site was at the bridge crossing of the entry into Tucker State Prison Farm and was located slightly downstream of where Indian Bayou Ditch joins again with Indian Bayou. The most dense and species-rich mussel assemblage encountered in the project area was at this location.

The channel was approximately 15 m wide and very shallow (less than 30 cm deep at the deepest points and typically less than 0.1 m deep). An abundance of large dead shells of native mussels and *C. fluminea* suggested the presence of live mussels as well as the likelihood of mortality associated with stranding of mussels during extremely low water. Both banks were closely mowed all the way to the shoreline, and no trees were present for hundreds of meters in any direction (Figure 6). Despite the lack of any canopy, water was cool. Water velocity was approximately 35 cms. Substratum was shell material mixed with soft mud.

A 15-min search by each of two waders yielded at total of 57 native mussels. *Amblema plicata* (n = 26) and *Q. quadrula* (25) were both abundant. Three *Q. pustulosa* were obtained as were one each of *A. confragosus*, *Megalonaias nervosa* (a relatively young specimen although not a recent recruit), and *Potamilus purpuratus*. Considerable variation in size of individuals comprising the two dominant populations suggested moderately good recruitment. Eight *Q. quadrula* measured less than 60 mm long, with the smallest individuals

Figure 6. Indian Creek at Tucker (Waypoint 6)

measuring only 30 mm. Four *A. plicata* measured less than 70 mm long; the smallest of these was 61 mm.

Additional studies were done at this location because of the large number of mussels and species present (Tables 2 and 3). Ultimately, 300 min were spent searching for mussels at this site; 11 native species and over 700 live individuals were collected. The fauna was dominated by *Q. quadrula* and *A. plicata*; the remaining species each comprised less than approximately 4 percent of the assemblage. The CPUE was 2.5, which was greater than for any other site on Indian Bayou or Indian Bayou Ditch.

Mean density of native mussels was 14.7 individuals/m^2, and mean density of *C. fluminea* was more than 10 times greater, 168 individuals/m^2 (Table 4). Eight species were taken in the quantitative collections, more than 80 percent consisted of two common species, *Q. quadrula* and *A. plicata*.

Summary of conditions in Indian Bayou and Indian Bayou Ditch

More than 500 min were spent searching Indian Bayou and Indian Bayou Ditch (Table 2). Slightly more than 900 mussels were collected, and 15 species were identified. No mussels were taken at Waypoints 2, 3, and 8, and comparatively few individuals were collected at Waypoints 1, 2, and 5 (Table 3). The best locations for mussels were at the Prison Farm near Tucker (Waypoint 6) and at Waypoint 37 located at Highway 165.

Table 3 Percent Abundance of Mussel Species Collected in Indian Bayou and Indian Bayou Ditch, 2001									
	Waypoint Number								
Species	1	2	3	4	5	6	8	37	Total
A. plicata	53.33	0.00	0.00	0.00	82.35	62.37	0.00	30.84	59.19
Q. quadrula	6.67	0.00	0.00	0.00	0.00	26.20	0.00	27.10	24.97
Q. pustulosa	0.00	0.00	0.00	0.00	0.00	4.12	0.00	0.00	3.41
U. declivus	0.00	0.00	0.00	0.00	14.71	0.80	0.00	17.76	3.30
L. teres	13.33	0.00	0.00	0.00	0.00	2.79	0.00	0.93	2.64
A. confragosus	0.00	0.00	0.00	0.00	2.94	1.86	0.00	0.00	1.65
T. parvus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.28	1.21
Q. apiculata	0.00	0.00	0.00	0.00	0.00	0.13	0.00	5.61	0.77
P. purpuratus	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.66
L. fragilis	6.67	100.00	0.00	0.00	0.00	0.27	0.00	0.93	0.55
L. recta	6.67	0.00	0.00	0.00	0.00	0.00	0.00	3.74	0.55
F. flava	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.44
L. subrostrata	13.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
M. nervosa	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.11
P. grandis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.11
U. tetralasmus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.87	0.22
Total individuals	15	1	0	0	34	752	0	107	909
Total species	6	1	0	0	3	11	0	10	16
Total time	50	40	30	20	36	300	20	70	566
CPUE	0.30	0.03	0.00	0.00	0.94	2.51	0.00	1.53	1.61

The mussel fauna was dominated by *A. plicata* and *Q. pustulosa*, which together comprised nearly 75 percent of all mussels collected (Tables 2 and 3).

Mean density of mussels was 14.7 individuals/m^2, which is low compared with mussel beds in the Ohio or upper Mississippi Rivers where density can exceed 75 individuals/m^2. There was evidence of recent recruitment at this location. Nearly 30 percent of the individuals were less than 30 mm in total shell length. Three species (*A. plicata, Q. quadrula,* and *Q. apiculata)* had at least one representative less than 30 mm in total shell length.

All of the mussels collected at this location are commonly collected in southern streams and are designated at "current stable" (Williams 1993) except for *Ligumia recta*, which is considered to be of "special concern" (although not listed as threatened or endangered). All the other species at this location were listed as "currently stable" by Williams (1993). This was one of the better

Table 4
Results of Quantitative Sampling at Waypoint 6, the Tucker Prison Farm Site on Indian Bayou Ditch

Species	Quadrat Number												Total	Percent Abundance
	1	2	3	4	5	6	7	8	9	10	11	12		
Q. quadrula	1		2	1		4	5	3		1	3	1	21	47.73
A. plicata			1	2	1	2			1	4	4		15	34.09
Q. apiculata		2				1							3	6.82
A. confragosus				1									1	2.27
F. flava								1					1	2.27
L. fragilis				1									1	2.27
Q. pustulosa	1												1	2.27
T. parvus			1										1	2.27
Total species	2	1	3	4	1	3	1	2	1	2	2	1	8	
Total individuals	2	2	4	5	1	7	5	4	1	5	7	1	44	

% Individuals < 30 mm total SL: 29.54

% Species < 30 mm total SL: 37.75

Density (individuals/sq m)

Species / group	N	Mean	Standard Deviation
C. fluminea	12	167.7	62.2
Unionidae	12	14.7	8.9

stream reaches for mussels in the Bayou Meto drainage because of the moderately high density and evidence of recent unionid recruitment.

Size demography of dominant populations at Waypoint 6

The *A. plicata* population at Waypoint 6 (Indian Bayou Ditch at Tucker Prison Farm) ranged in size from recent recruits (<30 mm) to commercially valuable, very large adults (>100 mm) (Figure 7). Although large adults dominated the population, the presence of some individuals throughout much of the length range of 25 to 75 mm indicated that occasional recruitment occurs.

This situation was essentially the same as observed for this species at Site 37 (Indian Bayou Ditch at Highway 165). However, at Waypoint 5 (Indian Bayou Ditch at Tar Bottom Road), all individuals were of relatively uniform, large size. At Waypoint 1 (Chaney Road), the population size structure suggested less recruitment than at Waypoint 6 but was not nearly as uniform as at Waypoint 5. It should be noted that only at Waypoint 6 was quantitative sampling done that involved substratum removal (the best method of obtaining accurate, detailed information on size demography). At the other sites, notes concerning size distribution were based on individuals obtained by carefully searching the muddy bottom by feel.

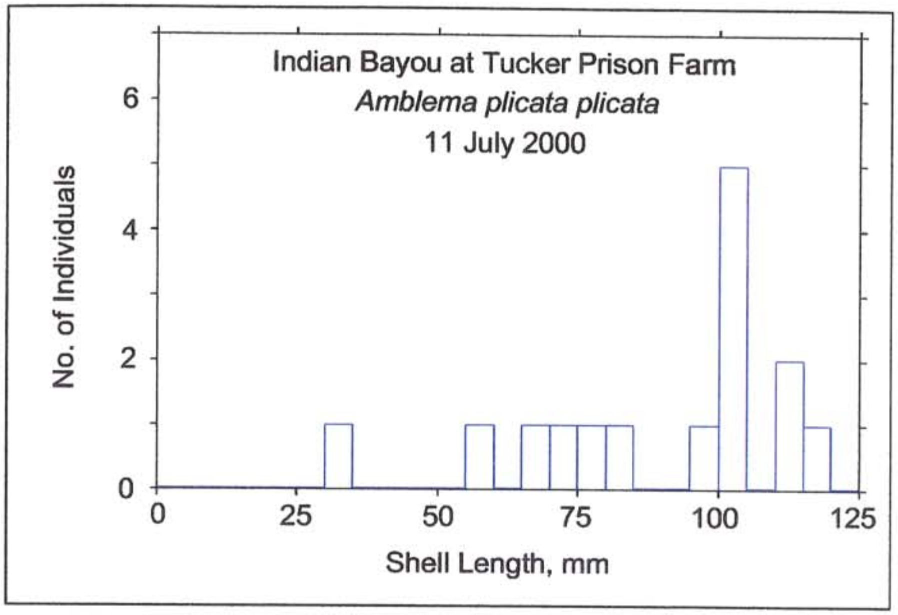


Figure 7. Length-frequency data for *A. plicata*

The size structure of *Q. quadrula* at Waypoint 6 suggested moderately strong recent recruitment (Figure 8). Nine of twenty mussels obtained by quantitative sampling measured less than 30 mm long, and ranged to as little as 15 to 20 mm. The remainder of the population ranged from 45 to 70 mm. Large adults of this species included individuals ranging from 55 to 70 mm.

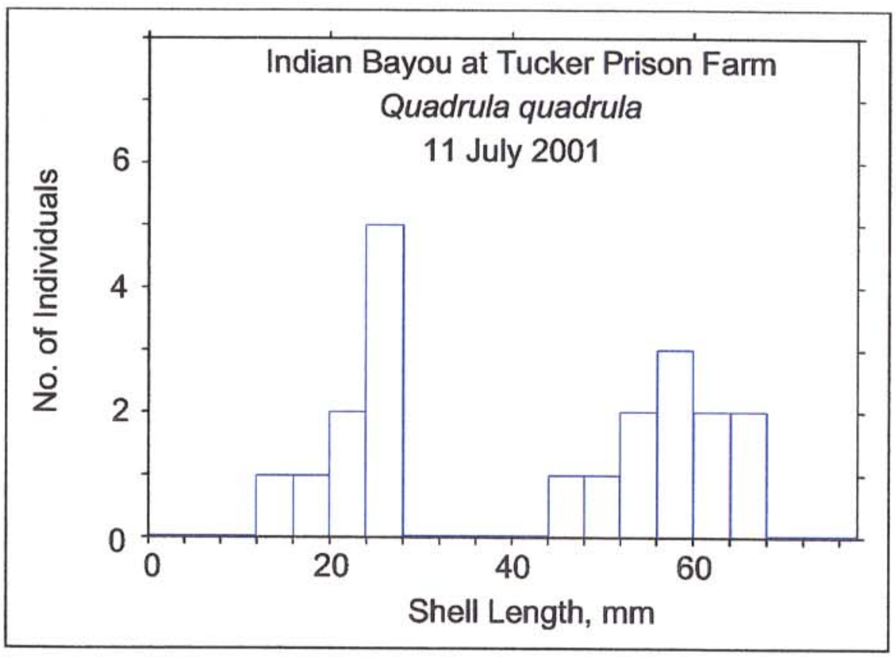


Figure 8. Length-frequency data for *Q. quadrula*

A single individual of this species was included among qualitative samples at Waypoint 1 (Chaney Road). This individual was <30 mm long and indicated that recruitment does occur at that location. The size distribution suggested by qualitative sampling at Waypoint 37 was similar to that at Site 6, except that even larger adults were obtained at the former location. No individuals of this species were taken in qualitative samples at Waypoint 5 (Tar Bottom Road).

The population of *C. fluminea* at Waypoint 6 was comprised of four distinct cohorts (Figure 9). The smallest was centered at 8.5 mm and ranged from 7 to 11 mm. The next and most abundant cohort was centered at 14.5 mm and ranged from 11 to 17 mm. A third cohort was centered at 20.5 mm and ranged from 17 to 23 mm. The final cohort was centered at 27.5 mm and ranged from 23 to 30 mm. It is likely that the smallest cohort represented spring 2001 recruitment. The two cohorts of intermediate-sized individuals probably represented periods of fall and spring recruitment in 2000. The cohort of the largest adults probably represented fall 1999 recruitment. Longevity of 1.5 to 2 years for this species is not uncommon; in warm habitats of the southern United States, reproduction typically ceases in summer (Aldridge and McMahon 1978). Because this species is not especially tolerant of low dissolved oxygen, the presence of dense populations with complex age structure suggests that water is usually present in Indian Bayou Ditch.

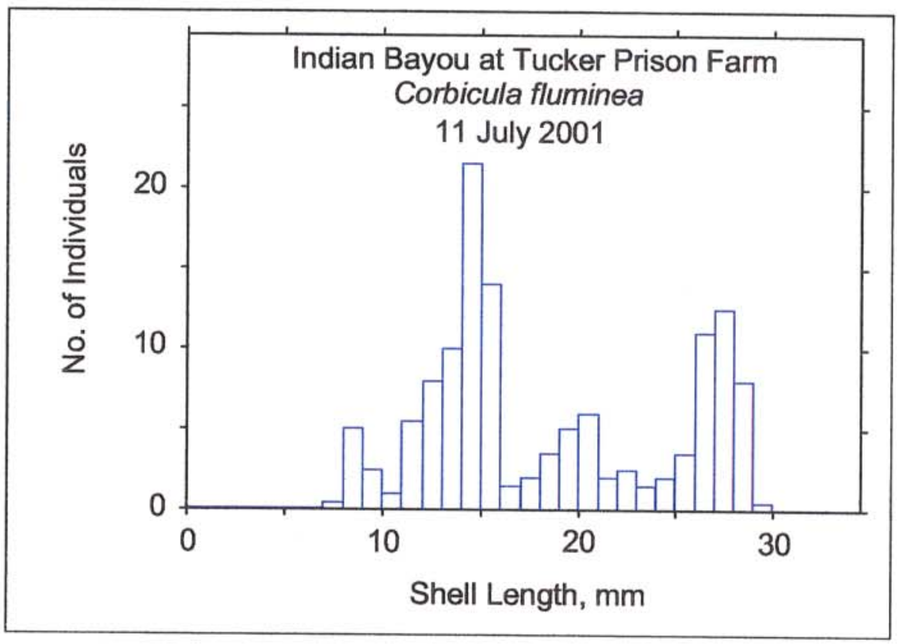


Figure 9. Length-frequency data for the nonindigenous bivalve, *C. flumina*

Salt Bayou Ditch

Salt Bayou Ditch runs southeast and is located just west of Bayou Meto (Figure 4). For the most part, the ditch was straight with little or no woody vegetation or submersed vegetation present. Substratum consisted mainly of sand and silt. There was little or no perceptible current during the study period. Water depth was approximately 1 to 2 m deep in the center of the ditch between Waypoints 46 and 42 (Figure 4). Upriver and downriver of this reach, the water became gradually more and more shallow and in places was less than 1 m deep. Eleven sites were searched for mussels in Salt Bayou Ditch, and live mussels were found at eight of those sites. Waders and divers collected mussels at all sites in this water body.

The mussel fauna in Salt Bayou Ditch consisted mainly of *A. plicata*, which comprised more than 75 percent of the assemblage (Table 5). *Quadrula quadrula* made up approximately 10 percent of the fauna, and the remaining nine species each comprised less than 5 percent of the assemblage. The fauna consisted of species tolerant of fine-grained substratum and low water velocity such as *Potamilus ohienis*, *Pyganodon suborbicula*, *Uniomerus* spp., and *Toxolasma parva*.

High-density assemblages were found at Waypoints 21, 42, 43, 44, and 45, where CPUE ranged from 0.53 to 1.47. Farther upriver of these waypoints the water in the ditch became shallow (less than 1 m deep) and the numbers declined. No mussels were found at Waypoints 46, 47, and 48. At these locations the water became more shallow, and the percentage of organic matter in the substratum increased.

Wabbaseka Bayou

Wabbaseka Bayou flows southeast through the town of Wabbaseka, AR (Figure 5). A total of 11 sites were searched for mussels along this Bayou. More than 200 min were expended searching, and only 12 individuals (CPUE = 0.06 overall) were collected (Table 2). Mussels were found at only 2 of the 11 sites surveyed. The fauna in this water body consisted of species that were tolerant of fine-grained substratum and low water velocity. The following paragraphs provide more detailed information on study sites in this bayou.

Wabbaseka Bayou, Waypoint 7

This site was at the Highway 31 Bridge. Only a few *C. fluminea* shells (old and darkened) were seen; no mussel shells were observed. The channel was 15 m wide, with trees along both banks and canopy coverage was approximately 75 percent. Abundant large woody and smaller debris littered the streambed. Substratum was a very soft muck with large and small woody debris. There was

Table 5
Percent Abundance of Mussel Species Collected in Salt Bayou Ditch, 2001

Species	Waypoint Number										Total
	20	21	41	42	43	44	45	46	47	48	
A. plicata	0.00	77.27	75.00	92.59	71.43	62.50	75.00	0.00	0.00	0.00	76.30
Q. quadrula	0.00	6.82	25.00	3.70	21.43	12.50	14.29	0.00	0.00	0.00	10.37
Q. pustulosa	0.00	0.00	0.00	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.74
U. declivus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. teres	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A. confragosus	0.00	2.27	0.00	3.70	0.00	0.00	3.57	0.00	0.00	0.00	2.22
T. parvus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. purpuratus	0.00	4.55	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	2.22
Q. apiculata	0.00	0.00	0.00	0.00	7.14	0.00	0.00	0.00	0.00	0.00	0.74
L. fragilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M. nervosa	50.00	6.82	0.00	0.00	0.00	6.25	0.00	0.00	0.00	0.00	3.70
L. recta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F. flava	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. grandis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T. verrucosa	0.00	2.27	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	2.22
L. subrostrata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. ohiensis	0.00	0.00	0.00	0.00	0.00	0.00	3.57	0.00	0.00	0.00	0.74
A. suborbiculata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U. tetralasma	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total individuals	2	44	4	27	14	16	28	0	0	0	135
Total species	2	6	2	3	3	5	5	0	0	0	9
Total time	10	30	15	25	25	25	25	15	8.5	10	188.5
CPUE	0.20	1.47	0.27	1.08	0.56	0.64	1.12	0.00	0.00	0.00	0.72

no perceivable flow; substratum smelled strongly of hydrogen sulfide when disturbed. Depth was generally less than 60 cm. A total of 30 min of searching yielded no live mussels or shells.

Wabbaseka Bayou, Waypoint 23

This site was accessed from a bridge on S. Gilliand Road. Water was shallow, less than 1 m deep, and substratum consisted of mud and organic material. Canopy coverage was less than 50 percent and banks were stable and well vegetated. A total of 20 min of searching yielded a single live *Potamilus purpuratus*. This was not a good site for live mussels.

Wabbaseka Bayou, Waypoint 24

This site was accessed from a bridge crossing just east of the town of Wabbaseka, AR. Substratum consisted of mud and organic matter with considerable large woody debris. There was little or no flow at the time of the survey. A total of 10 min of searching at this location yielded no mussels. This was not a good site for live mussels.

Wabbaseka Bayou, Waypoint 25

This site was accessed from Highway 79 at the town of Wabbaseka, AR (Figure 5). Conditions were similar to those at Waypoints 23 and 24. Substratum consisted of mud and organic matter, and there was little to no discharge at the time of the survey. Ten minutes of searching yielded no mussels. This river reach was not suitable for mussels.

Wabbaseka Bayou, Waypoint 26

This site was east of Wabbaseka, AR, and located farther downstream of Waypoint 25 (Figures 5 and 10). Substratum consisted of organic matter, mud, woody debris, and trash. There was no flow at the time of the survey. Ten minutes of searching yielded no live mussels or shells.

Figure 10. Waypoint 26 on Wabbaseka Bayou

Wabbaseka Bayou, Waypoint 9

This site is in the lower part of Wabbaseka Bayou approximately 4 km south of the town of Wabbaseka, AR. The channel was 20 m wide and 0.6 m deep. The substratum was deep soft mud overlain by at least a 0.3 m layer of fine and coarse detritus. A strong odor of hydrogen sulfide was associated with substratum disturbance. Water velocity was zero; this reach almost certainly exists as a series of intermittent pools during extremely low water. Canopy coverage was approximately 80 percent.

A few very old *A. plicata* shells were present on the shore, but a total of 30 min of searching by two waders yielded no shells or mussels from the channel.

Wabbaseka Bayou, Waypoint 10

The site was accessed alongside the road that travels generally along the east side of the bayou below Waypoint 9. The channel here was less than 0.75 m deep. There was no water flow. Canopy coverage was approximately 50 percent. The substratum was soft mud overlain by very fine flocculent detritus. The flocculent layer was approximately 20 cm thick. The bottom smelled of hydrogen sulfide on disturbance. No mussels or shells were found in 20 min of searching.

Wabbaseka Bayou, Waypoint 22

The site was located slightly south of Waypoint 10. There was no flow, and the substratum consisted almost entirely of organic matter (leaves and twigs) and fine detritus. Considerable woody debris was in the water at the time of the survey. No live mussels or shells were found, and the area did not provide appropriate habitat for freshwater mussels. A total of 17 min of searching was expended at this location.

Wabbaseka Bayou, Waypoint 11

This site was similar to Waypoint 10 except that it occurred at a bridge crossing where canopy coverage was sparse (approximately 10 percent). A few mussel shells were evident along the shore. A total of 40 min of searching yielded a few live mussels. These included *Leptodea fragilis* (n = 2), *Pyganodon grandis* (n = 2), and one each of *A. confragosus*, *Q. pustulosa*, *Q. quadrula*, *U. declivus*, and *P. suborbiculata*. All were large adults except *L. fragilis*. These two individuals were only 24 and 30 mm long, representing recruitment than has occurred within the last 1 to 2 years.

Wabbaseka Bayou, Waypoint 27

Ten minutes of searching at this location yielded no live mussels or shells. Flow was nonexistent, and the water was less than 50 cm deep at the time of the survey. There was considerable trash in the water, and it is extremely unlikely that any live mussels would be taken at this location (Figure 11).

Figure 11. Waypoint 27 on Wabbaseka Bayou

Wabbaseka Bayou, Waypoint 28

A single *P. grandis* shell was found after 10 min of searching. No live mussels were found, and it is unlikely that live mussels would be found here. The water was shallow, flow was almost nonexistent, and considerable woody debris was in the water.

Plum Bayou

On 18 September 2001, five sites along Plum Bayou, located northwest of Pine Bluff, AR, were evaluated for zebra mussels. The purpose was to look for zebra mussel habitat and evaluate a previous report made by Jim Petereson, U. S. Geological Survey, Little Rock, that there were live zebra mussels in the area. The five sites visited (PB-1 through PB-5) are discussed below and depicted in Figure 12. Search times for Plum Bayou were not included in tabular material for this report.

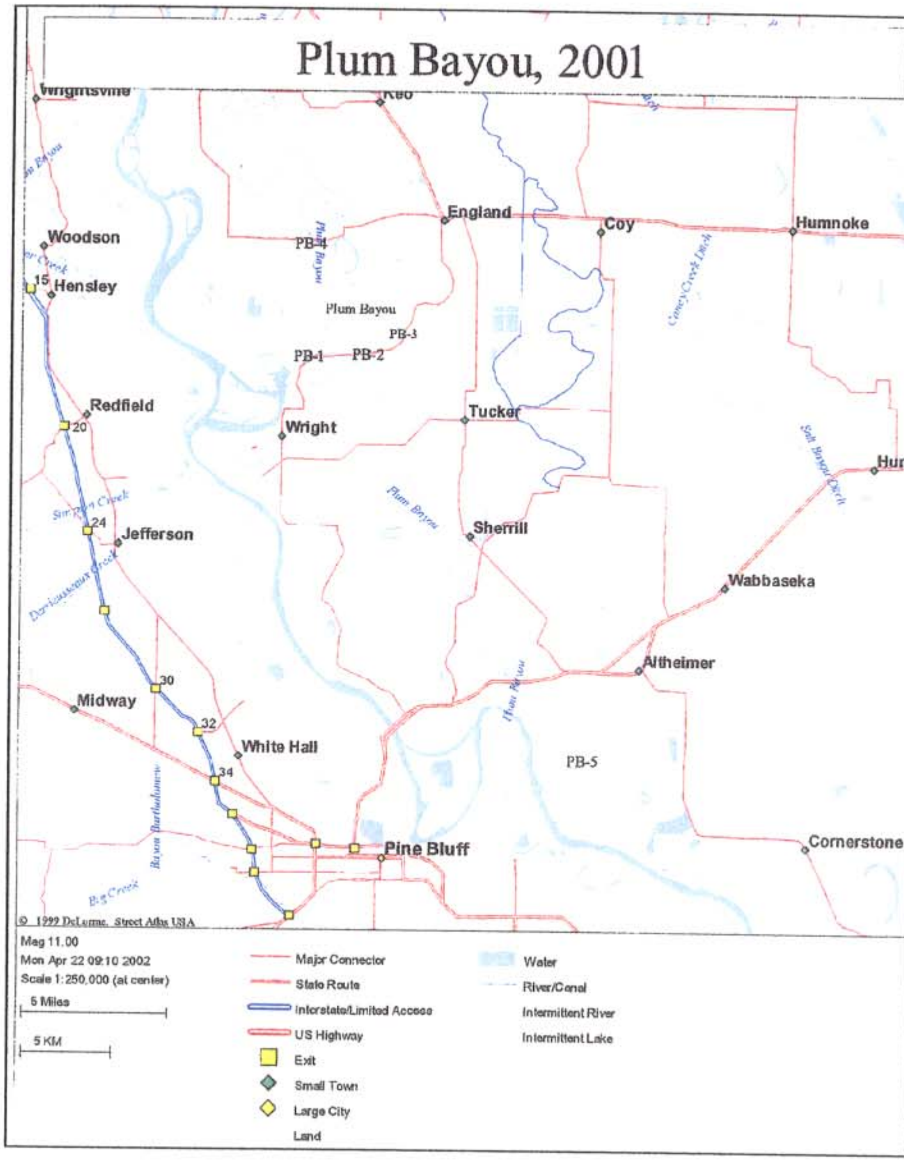


Figure 12. Five sites (PB-1 through PB-5) searched for zebra mussels along Plum Bayou, 18 September 01

PB-1

The first location inspected was the outlet channel immediately downstream of the receiving end of the four pipes at the Plum Bayou pump station off Highway 256 slightly north of Wright, AR. The pumps were not operating during the inspection. The outlet embayment is a riprapped channel for approximately 40 m. Downstream of the riprapped reach the channel is approximately 15 m wide with moderately steep clay banks. Channel substratum, excluding the riprap, is a mix of buckshot clay and relatively hard clay with some shell debris (*C. fluminea* and some native mussels). Channel depth was approximately 1.75 m; recent high-water marks on the riprapped banks were approximately 1 m. The channel was probably near ordinary low water at the time of inspection.

Approximately 20 min were spent lifting riprap, inspecting it for zebra mussels and byssal bundles left by previously attached mussels, and scooping sediment from the nonriprapped channel with D-framed nets. Approximately four byssal bundles were noticed on rocks. Approximately 5 unbleached *D. polymorpha* shell valves or substantial fragments of valves and 10 bleached shell valves or fragments of valves were observed. None of the unbleached (i.e., more recently dead) valves were bysally attached to substratum or had any soft tissue or adductor muscle remaining. No live *D. polymorpha* were found.

The density of live *C. fluminea* was low to moderate; a scoop with a D-frame over a 0.5-m length typically yielded <10 live *C. fluminea* but many more empty shell valves. Native mussel shells recovered included *Lampsilis hydiana*, *Uniomerus tetralasmus*, *Pyganodon grandis*, and *Toxolasma parvus* (this was the only species obtained alive).

BP-2

This site was at Morton's Weir, a structure northeast of Wright, AR, on Plum Bayou designed to hold water in Plum Bayou to support irrigation withdrawals. The weir is in the center of an earthen dam and is a shallow concrete trough approximately 10 m wide; the weir gate is approximately 0.75 m high. A 1- to 3-cm-deep flow of water was running through the trough downstream of the weir and spilled into a very sluggish and depositional slough on the downstream side. Upstream of the weir, the impounded bayou was a very wide cypress slough (a shallow reservoir). Depth was at least 1.75 m downstream of the weir structure. Researchers inspected riprap along the upstream face of the weir for approximately 20 min. No zebra mussels, zebra mussel shells, or byssal threads were observed. Many limpets and leeches occurred on the rocks. The natural substratum of the impoundment was soft mud.

BP-3

This site was at a wooden bridge along Wells Road, south of Clear Lake, AR, and approximately 8 km upstream of BP-2. The bayou resembled that at BP-2 – a wide, shallow impoundment with a soft mud bottom. Wells Road crossed the bayou along an earthen dam; it constricted channel flow under the 15-m-wide bridge. Several fishermen were fishing from the bridge and from small boats just upstream of the bridge. No sampling was done here to avoid disrupting the fishermen; the only available substratum for zebra mussel was the wooden bridge pilings. No shells were evident along the shore.

BP-4

This site was at the Highway 161 Bridge over the bayou, due west of the town of England, AR. The characteristics of the bayou here were similar to those upstream of the weir and bridge at BP-2 and BP-3, respectively. The bridge at Highway 161 was wide and supported by sets of concrete pilings; the bridge did not constrict the channel. A 20-min search of woody debris and the concrete pilings was conducted here. No evidence of zebra mussels was found. The bottom was very soft and smelled strongly of hydrogen sulfide once disturbed. Substratum was mud with much leaf litter and fine particulate detritus. Limpets and leeches were abundant. Limpets were especially abundance on emergent rush stems.

BP-5

This site was well downstream of Morton's Weir at a low-water crossing approximately 1 km upstream of the Highway 79 Bridge over Plum Bayou. The low-water crossing was an old paved road that is now a spillway of the impounded bayou upstream and the straight channel downstream. Water was approximately 1.75 m deep below the spillway and 5 to 15 cm deep running over the old roadbed. The downstream slope from the roadway was riprapped. The riprap and streambed were searched with a D-frame net for approximately 30 min at this site. Flow was swift over the roadbed (approximately 1 m/sec). Invertebrates were abundant on the riprap and included stoneflies, helgammites, hydrophsychid caddisflies, limpets, and attached fingernail clams. The fingernails clams were a small, mottled species (approximately 6 mm maximum length) and seemed to be attached to the rocks by singular or few byssal threads (not secreted by a true byssus gland as in *Dreissena* spp.). This observation is noteworthy because someone in the future conceivably could mistake these small, attached bivalves for zebra mussels if they were not familiar with *D. polymorpha* but simply knew they live attached to rocks. Asian clams were moderately dense in gravel trapped between the roadbed and riprapped downstream slope. Substratum below the spillway was gravel and *C. fluminea* shell and shell debris. No evidence of *D. polymorpha* was found; this site should be an excellent zebra mussel monitoring station as it provides appropriate flow and substratum conditions.

Summary

This survey confirms the zebra mussel sittings near the pump outlet previously reported by Jim Petereson, U. S. Geological Survey, Little Rock, AR. Dense populations of *D. polymorpha* in the Arkansas River almost certainly provide juveniles to Plum Bayou via the pump station near Wright, AR. Continued introductions are likely, especially during peak periods of reproduction that may occur in spring and fall. However, habitat for *D. polymorpha* is poor in Plum Bayou. Lack of flow and high water temperatures during sustained low-water conditions in summer and fall are stressful. Additionally, very little firm substratum for zebra mussel attachment is available in Plum Bayou. Despite continued introductions via the pump station, it is unlikely that this species will establish high-density populations in Plum Bayou. The pump outlet channel, Morton's Weir, and the low-water crossing upstream of Highway 79 represent ideal locations to monitor zebra mussel infestation; these locations provide the best substratum in a system that is generally too depositional to support zebra mussels in abundance.

3 Discussion

Summary of Major Findings

Approximately 19 hr (1,131.5 min) were spent searching for native mussels at 45 sites in the Bayou Meto Drainage in the spring of 2001. A total of 18 species of mussels were identified, and more than 1,000 individuals were collected using qualitative and quantitative methods combined. In addition to native species, the Asian clam, *C. fluminea,* was found in the project area. The nonindigenous zebra mussel, *D. polymorpha*, was not found in the project area, although it was collected in the Arkansas River where the pumping plant will be placed. Approximately 75 percent of all mussels collected during this survey were found at a single site, Waypoint 6, located in Indian Bayou. Live mussels were found at 15 of the 45 sites surveyed. No Federally listed endangered or threatened mussels were found.

Total species richness in the study area (18 species based on quantitative and qualitative methods) is only slightly less than at most mussel beds in large rivers. In a survey of the lower Tennessee River Miller, Payne, and Tippit (1992) collected 4,768 individuals and identified 23 species. While low quality habitat can be partially to blame in the project area, it is also true that the lower species richness is caused in part by the overall nature of the habitat. This is a comparatively small river, and it lacks the habitat diversity (extensive pools and riffles, cobble and gravel substratum), which can support many fish species and ultimately high unionid species richness.

Mean unionid density at Waypoint 6 (14.7 individuals/m^2) is much less than that reported by other workers in medium-sized to large rivers in the United States. At an inshore and offshore site sampled in 1986 at river mile (RM) 18.6 in the lower Tennessee River (32 quantitative samples were collected at each), total mussel density was 187.7 and 79.7 individuals/m^2, respectively (Way, Miller, and Payne 1989). In the middle Ohio River near Cincinnati, mussel density ranged from 4.4 to 52.4 individuals/m^2 (Miller and Payne 1993).

Southern rivers in the south often vary from extremely high to extremely low mussel densities. At a narrow mussel bed in the White River near De Valls Bluff, AR, mean density (10 samples per subsite) ranged from 0.8 to 19.6 individuals/m^2 with an overall average of 6.4 individuals/m^2. In the Big Sunflower River, MS, an alluvial river smaller in size than either the White River or the Ouachita River, mean density at a site below a lock and dam (10 samples per subsite) was greater than 200 individuals/m^2 (Miller and Payne 2001). These high density values were not common throughout the river however; mean density at two shoals was less than 50 individuals/m^2, and density throughout most of the river was less than 20 individuals/m^2 (Miller and Payne 1995).

Possible Effects of Zebra Mussels in the Bayou Meto Area

The first report of *D. polymorpha* in North America was from Lake St. Clair in June 1988 (Hebert, Muncaster, and Mackie 1989). By the late summer of 1989, *D. polymorpha* had spread into the Detroit River, Lake Erie, Niagara River, and western Lake Erie (Griffiths, Kovalak, and Schloesser 1989). By late September 1990, these mussels had spread though Lake Ontario and down the St. Lawrence River to Massena, NY. They were also collected in Lake Huron, Lake Superior at Duluth, MN, and in western Lake Michigan at Gary, IN (*Dreissena polymorpha Information Review* 1990).

In June 1991, biologists from the Illinois Natural History Survey found adult *D. polymorpha* at Illinois RM 50, 60, and 110 (Moore 1991; Sparks and Marsden 1991). By early January 1993, *D. polymorpha* had spread throughout most of the inland waterway system. During that year they were found in the lower Mississippi River as far south as New Orleans, and in the upper Mississippi River near St. Paul, MN. Probably commercial and recreational navigation traffic had, and will continue to have, an important role in transporting and sustaining zebra mussels in the upper Mississippi River (see Keevin, Yarbrough, and Miller 1992).

A single zebra mussel introduction does not necessarily lead to infestation although obviously this can happen. Johnson and Carlton (1992) emphasized this point to quell an unfounded level of anxiety about the incipience of infestation at any particular location. Johnson and Carleton cite Karataev and Burlakova (1995), who reported that 80 percent of suitable lakes in Belarus remain uncolonized by zebra mussels. Regardless, if basic water quality and habitat conditions are suitable, the following conclusion of Morton (1997) is reasonable: "Undoubtedly, *Dreissena polymorpha* will spread to the remaining rivers of North America, as has *C. fluminea*, the only debate about this being the timetable."

There can be little doubt that *D. polymorpha,* mainly because of its high fecundity and ability to attach tenaciously to hard surfaces, has had severe impacts on native mussels in the Great Lakes and large rivers in this country (Nalepa 1994; Schloesser 1996; Schloesser and Nelepa 1994; and Schloesser, Nalepa, and Mackie 1996). However, it must be remembered that unionids are specifically adapted to large rivers; hence, they have an advantage over *D. polymorpha* throughout much of their range. Zebra mussels do not sustain themselves well in medium-sized to small rivers; these habitats are likely to be refugia for many (although certainly not all) native unionids. Many native unionids live 30 or more years, tolerate long periods of desiccation, have an extremely strong shell, and can move about to a limited extent. Zebra mussels live 1 to 2 years at the most, are virtually intolerant of desiccation, and have a weak, easily broken shell.

With respect to concerns over zebra mussels in the Bayou Meto area, neither the habitat nor the temperature are particularly suitable to these species. Zebra mussels typically attach to firm substratum in large river or lake habitats. Typically, they are found attached to cobble or gravel, shells of live or dead native mussels, submersed woody vegetation, or any hard substratum. The substratum in the Bayou Meto drainage consists mainly of fine-grained sediments with little submersed hard surfaces.

Second, and perhaps most important, the zebra mussel is a northern species and does not tolerate higher water temperatures. The upper incipient lethal temperature for zebra mussels is approximately 29 °C – if this temperature is sustained for months in summer, zebra mussels will die (Claudi and Mackie 1993 and references within). Mean tolerance time to 30 °C exposure of mussels from Lakes Erie and St. Clair was approximately 4 days when acclimated to 25 °C (summer acclimated) and 3 days when acclimated to 2.5 °C (winter-acclimated) (Iwanyzki and McCauley 1992). Exposure to 33 °C water reduced tolerance time to only 18 hr even among summer-acclimatized mussels. McMahon and Ussery (1995) were able to acclimate zebra mussels from the Great Lakes to 30° C for 2 weeks with little or no mortality. Aldridge, Payne, and Miller (1995) were able to keep Great Lakes mussels alive at 32 °C for 42 days in an experimental study of sublethal effects of temperature. Both of these studies suggest substantially higher tolerance times than those observed by Iwanyzki and McCauley (1992). However, Aldridge, Payne, and Miller (1995) clearly showed that positive scope for growth could not be maintained even at 28 °C. Summer water temperatures in the Bayou Meto system probably routinely exceed 32 °C and stay above 30 °C for perhaps 2 months or more. Thus, it is relatively certain that zebra mussel populations cannot thrive in this system of shallow ditches and creeks, although it is possible that a few highly stressed individuals might be able to survive for a few weeks.

Live zebra mussels are in the Arkansas River where water will be taken for the Bayou Meto project. Therefore, it is certain that live zebra mussels, their larvae, as well as even live sperm and eggs will be carried into the project area. It is also likely that at least some live zebra mussels will be observed on firm substratum in the streams in the project area. However, because of the overall high temperatures in this region of the country, and the lack of suitable substratum in these comparatively small streams, it is extremely unlikely that zebra mussels will achieve even moderately high densities and are unlikely to have any effect on the native mussel populations.

Conditions for freshwater mussels are likely to show net improvement if flow augmentation occurs in the drainages of the Bayou Meto irrigation project, despite potential introduction of zebra mussels from the Arkansas River. Presently, low discharge greatly limits mussel habitat in the Bayou Meto system. In their existing condition, the potential negative effects to these drainages of zebra mussel introduction are unlikely to be more deleterious to mussels than the extreme low flows that now limit flow and habitat. It is likely that native mussels have substantial competitive advantages over zebra mussels in this drainage system. Small stream size, stressfully high summer and early fall water temperatures, and lack of much firm substratum for byssal attachment characterize the streams and ditches of the Bayou Meto system. Zebra mussels, a species adapted to large lakes, are severely stressed by sustained, moderately high water temperature. Zebra mussels form sizable drusses in which a few individuals attach to small pieces of debris or hard substratum and then one to another. However, habitats with a moderate system-wide abundance of firm substratum are needed to support ubiquitous, high-density populations of zebra mussels.

If this project were taken place farther north (the Great Lakes Area), and all conditions (except temperature) were similar to those in Bayou Meto, water augmentation could introduce sustaining populations of zebra mussels that could negatively affect native mussels. However, it is very unlikely that the Bayou Meto water augmentation project will result in high-density populations of zebra mussels that are detrimental to the native mussel fauna.

Effects of Channel Modification on the Mussel Fauna

Dredging to deepen and enlarge the channel at sites with moderate- to high-density assemblages (Waypoints 6 and 37, as well as parts of Salt Bayou Ditch) will certainly negatively affect native mussels at these locations. Direct effects include either being killed by the dredge or being disposed of in an upland site. Indirect effects, which might not necessarily be lethal, include stress caused by elevated suspended sediments or partial burial. Since mussels are located across the channel it is difficult to avoid all of them. Mussels along the edge of the water will probably not be damaged by the dredge, as will those in the center of the channel.

Dredging in reaches of the bayous that are clogged with vegetation and sediments would be beneficial to mussels and the aquatic habitat. Conditions would be improved not only for mussels, but also for aquatic insects, aquatic worms, and fishes. Increased flow as a result of clearing and snagging would scour the substratum and remove settled sediments.

References

Aldridge, D. W., and McMahon, R. F. (1978). "Growth, fecundity, and bioenergetics in a natural population of the Asiatic freshwater clam, *Corbicula manilensis* Philippi, from North Central Texas," *Journal of Molluscan Studies* 44, 49-70.

Aldridge, D. W., Payne, B. S., and Miller, A. C. (1995). "Oxygen consumption, nitrogenous excretion, and filtration rates of *Dreissena polymorpha* at acclimation temperatures between 20 and 32 °C," *Canadian Journal of Fisheries and Aquatic Sciences* 52, 1761-1767.

Claudi, R., and Mackie, G. L. (1993). *Practical manual for zebra mussel control.* Lewis Publishers, Boca Raton, FL.

Dreissena polymorpha Information Review. (1990). Published by the Zebra Mussel Information Clearing House of New York Sea Grant, Brockport, NY.

Griffiths, R. W., Kovalak, W. P., and Schloesser, D. W. (1989). "The zebra mussel, *Dreissena polymorpha* (Pallas, 1771), in North America: Impacts on raw water users," *Service water system problems affecting safety-related equipment.* Charlotte, NC, Nuclear Power Division, Electric Power Institute, Palo Alta, CA, 11-26.

Hebert, P. D. N., Muncaster, B. W., and Mackie, G. L. (1989). "Ecological and genetic studies on *Dreissena polymorpha* (Pallas): A new mollusc in the Great Lakes," *Canadian Journal of Fisheries and Aquatic Sciences* 46, 1587-1561.

Iwanyzki, S., and McCauley, R. W. (1992). "Upper lethal temperatures of adult zebra mussels," *Zebra mussels: Biology, impacts, and control.* T.F. Nalepa and D.W. Schloesser, ed., Lewis Publishers, Boca Raton, FL, 537-554.

Johnson, L. E., and Carlton, J. T. (1992). "Counter-productive public information: The Noah fallacy and mussel myths," *Dreissena polymorpha Information Review* 3(3), 2-6.

Karataev, A. Yu., and Burlakova, L. E. (1995). "The role of *Dreissena* in lake ecosystems," *Russian Journal of Ecology* 26, 207-211.

Keevin, T. M., Yarbrough, R. E., and Miller, A. C. (1992). "Long-distance dispersal of zebra mussels (*Dreissena polymorpha*) attached to hulls of commercial vessels," *Journal of Freshwater Ecology* 7, 437.

McMahon, R. F., and Ussery, T. A. (1995). "Thermal tolerance of zebra mussels (*Dreissena polymorpha*) relative to rate of temperature increase and acclimation temperature," Technical Report EL-95-10, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, A. C., and Payne, B. S. (1993). "Qualitative versus quantitative sampling to evaluate population and community characteristics at a large-river mussel bed," *The American Midland Naturalist* 130, 133-145.

______. (1995). "An analysis of freshwater mussels (Unionidae) in the Big Sunflower River, Mississippi, for the Big Sunflower River Maintenance Project: 1993 Studies," Technical Report EL-95-26, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, A. C., Payne, B. S., and Farr, M. D. (2001). "Mussel survey in the Arkansas River for the Grand Prairie Area Demonstration Project Inlet Channel, White River, Arkansas," unpublished report, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Miller, A. C., Payne, B. S., and Tippit, R. (1992). "Characterization of a freshwater mussel community immediately downriver of Kentucky Lock and Dam in the Tennessee River," *Transactions of the Kentucky Academy of Sciences* 53(3-4), 154-161.

Miller, A. C., Payne, B.S., Shafer, D. S., and Neill, L. T. (1993). "Techniques for monitoring bivalve communities and populations in large rivers," *Conservation and management of freshwater mussels*. K. S. Cummings, A. C. Buchanan, and L. M. Koch, ed., Proceedings of a UMRCC Symposium, October 1993, 147-158.

Moore, S. G. (1991). "Zebra mussels enter riverine systems," *Dreissena polymorpha Information Review* 2(4), 9.

Morton, B. (1997). "The aquatic nuisance species problem: A global perspective and review," *Zebra mussels and aquatic nuisance species*. F. M. D'Itri, ed., Ann Arbor Press, Chelsea, MI, 1-54.

Nalepa, T. F. (1994). "Decline of native unionid bivalves in Lake St. Clair after infestation by the zebra mussel, *Dreissena polymorpha*," *Canadian Journal of Fisheries and Aquatic Sciences* 51, 2227-2233.

Schloesser, D. W. (1996). "Mitigation of unionid mortality caused by zebra mussel infestation: Cleaning of unionids," *North American Journal of Fisheries Management* 16, 942-946.

Schloesser, D. W., and Nalepa, T. F. (1994). "Dramatic decline of unionid bivalves in offshore waters of western Lake Erie after infestation by the zebra mussel, *Dreissena polymorpha*," *Canadian Journal of Fisheries and Aquatic Sciences* 51, 2234-2242.

Schloesser, D. W., Nalepa, T. F., and Mackie, G. L. (1996). "Zebra mussel infestation of unionid bivalves (Unionidae) in North America," *American Society of Zoologists* 36, 300-310.

Sparks, R., and Marsden, E. (1991). "Zebra mussel alert," *Illinois Natural History Survey Reports* 310, 1-2.

Way, C. M., Miller, A. C., and Payne, B. S. (1989). "The influence of physical factors on the distribution and abundance of freshwater mussels (Bivalvia: Unionidae) in the lower Tennessee River," *The Nautilus* 103, 96-98.

Williams, J. D., Warren, M. L., Jr., Cummins, K. S., Harris, J. L., and Neves, R. J. (1993). "Conservation status of freshwater mussels of the United States and Canada," *Fisheries* 18(9), 6-22.

SECTION XV

BAYOU METO WILDLIFE MANAGEMENT AREA MANAGEMENT PLAN

BAYOU METO
WILDLIFE MANAGEMENT AREA
WETLAND MANAGEMENT PLAN

Prepared For:

U.S. ARMY CORPS OF ENGINEERS
MEMPHIS DISTRICT

By:

Mickey E. Heitmeyer, Belinda Ederington, and Leigh H. Fredrickson
Gaylord Memorial Laboratory
University of Missouri - Columbia
Puxico, MO 63960

March 2004

Illustrations and photos from:
USFWS National Image Library
Missouri Department of Conservation
Mickey Heitmeyer
Belinda Ederington
Karen Kyle

Original cover artwork courtesy of wildlife artist Maynard Reece and Millpond Press.

Alterations to the original were made for this publication.

The original painting is named "Morning Light - Mallards"©, by Maynard Reece, 11"x17", as shown below.

TABLE OF CONTENTS

TABLE OF CONTENTS, Cont'd.

EXECUTIVE SUMMARY

The Bayou Meto Wildlife Management Area (WMA) is a ca. 32,000 acre bottomland hardwood wetland (BLH) owned and operated by the Arkansas Game and Fish Commission (AGFC) in east-central Arkansas. This WMA contains one of the largest contiguous areas of BLH in the Upper Mississippi Alluvial Valley (MAV) and it retains many valuable ecological processes and features. Management of the WMA historically has attempted to achieve multiple, sometimes competing, objectives including: 1) maintaining a functional BLH ecosystem, 2) supporting endemic populations of fish and wildlife species, and 3) providing public use opportunities, especially waterfowl hunting. Beginning in the 1950s a series of 8 greentree reservoir (GTR) impoundments were developed on the WMA using a complex network of levees, ditches, and water-control structures. These GTR impoundments cover most of the WMA and water levels are manipulated annually in each impoundment primarily to provide habitat for, and hunting of, waterfowl.

Native vegetation communities, hydrology, and topography in the Bayou Meto Basin and Bayou Meto WMA have been altered greatly since the Presettlement period. Changes of special concern on the WMA are: 1) degraded forest health, composition, and regeneration; 2) altered timing, depth, and duration of flooding; 3) decreased abundance and availability of BLH resources; and 4) lower diversity and abundance of fish and wildlife populations, especially wintering ducks. An updated evaluation of the status of resources and management in Bayou Meto WMA is needed because of continued changes in the WMA and surrounding lands, new information on BLH ecosystem ecology, and structural developments proposed in the Bayou Meto Basin and within the WMA to provide water supplies for flooding agricultural lands and to allow more timely and efficient drainage. Certain large developments recently have been proposed as part of the U.S. Army Corps of Engineers (USACE) Bayou Meto Basin Improvement Project and a cooperative USACE/AGFC 1135 restoration project.

This report provides analyses of historic and existing habitat conditions and resources in the Bayou Meto WMA and offers recommendations for future water management. Objectives include: 1) describe the Presettlement BLH ecosystem and ecological processes in Bayou Meto WMA, 2) identify how the structure and function of the BLH ecosystem have been altered in the WMA since the Presettlement period, 3) determine the current composition, distribution, and health of BLH forests in WMA GTR impoundments, 4) recommend water and timber management options and strategies for GTR impoundments, and 5) evaluate proposed USACE projects for structural developments to improve water delivery and drainage on the WMA.

Bayou Meto WMA contains diverse geomorphic surfaces formed 10-14,000 years ago by channel dynamics of former Arkansas River courses. Backswamp deposits with fine Portland-Perry silty clays 40-50 feet thick cover 90.8% of the WMA. These backswamp areas have relative flat (0-1% slopes) topography and a slightly sloping "bowl-shaped" depression is present in the south-central part of the WMA where many tributary streams merge and "scatter" across this flat "bowl." Bayou Meto and Little Bayou Meto are the 2 primary drainages through the WMA and maintain hydraulic connection with the current Arkansas River floodplain.

Historically, much of the Bayou Meto floodplain (including the WMA area) flooded annually during winter and spring from overbank flooding of Bayou Meto, Little Bayou Meto, and their tributaries. Long term winter precipitation and stream discharge data suggest peak flows in these streams and extensive flooding in the Bayou Meto area on average every 6-7 years and low discharge and limited flooding on average every 5-6 years. Extensive backwater flooding of the Arkansas River into the southern Bayou Meto Basin occurred at least once each decade from the mid-1800s until the 1940s when locks and dams were built on the Arkansas River.

Historic vegetation communities in the Bayou Meto WMA were distributed in relation to geomorphic surface, soils, topography, and hydrological regime (especially flood frequency). The extensive backswamp areas on the WMA contained seasonally flooded Low and Intermediate BLH communities dominated by overcup oak, willow oak, Nuttall oak, bitter pecan, cedar elm, green ash, and sugarberry. Deeper abandoned channels (oxbows) of the former Arkansas River cover 4% of the WMA and contain baldcypress, buttonbush, water tupelo, and swamp privet. Natural levees and point bar surfaces cover 1.2% and 0.6% of the WMA, respectively and had diverse plant composition including water oak, cherrybark oak, cedar elm, persimmon, and shagbark hickory on ridges and Nuttall oak and green ash in swales.

The diversity and abundance of fish, amphibian, reptile, bird, and mammal species in BLH ecosystems is among the greatest of any ecosystem in North America. Animal species are distributed in relation to flooding regime and habitat type; in general, species richness is highest in Low, Intermediate, and High BLH areas. Fish and wildlife species present at Bayou Meto WMA have diverse adaptations to abundant, yet seasonally available, BLH resources. Many species capitalize on major system events such as winter flooding to obtain new, previously unavailable, and concentrated food. For example, mallards and wood ducks move quickly to shallow newly flooded BLH areas to forage on acorns, terrestrial insects, aquatic macroinvertebrates, and seeds from herbaceous plants. Maintenance of animal abundance and diversity in BLH areas such as Bayou Meto WMA requires: 1) large contiguous patches of BLH that include all historic habitat types, 2) areas that provide temporal and spatial refuge from excessive disturbance and predation, 3) natural hydrological regimes, and 4) functional detrital bases.

Over 85% of native vegetation communities in the Bayou Meto Basin have been destroyed since the Presettlement period. Historically, BLH on Bayou Meto WMA represented almost 5% of the total area of BLH in the Bayou Meto Basin. Because of regional habitat loss, remnant BLH in the WMA now comprises 28.6% of BLH in the basin. Low and Intermediate BLH account for most remaining forest types in the WMA and represent 31% of the remaining habitat of these types in the basin.

Intense timber harvest in the Bayou Meto Basin began in the early 1900s and one large lumber operation (the Long Bell Lumber Company) was present within the WMA area until 1927 when extensive flooding destroyed their facilities. Several small lumber companies continued to cut timber in the WMA area until the 1950s. Most of the large trees in High and Intermediate BLH areas of the WMA had been cut and "high-graded" by the time AGFC initially purchased parts of the WMA in 1948. Lands initially purchased for the WMA also contained deed restrictions that reserved rights for the selling landowner to harvest all timber > 12" diameter at breast height (dbh) for specified periods of time, usually 10 years. Most of these timber rights were not exercised completely, but some select timber harvest, including cuts for management purposes, continued on portions of the WMA until the 1980s.

The topography and hydrology of the Bayou Meto Basin and WMA have been extensively altered by land clearing, road and railroad construction, extensive ditching, channelization and diversion of bayous, levees, floodgates at the confluences of Bayou Meto and Little Bayou Meto with the Arkansas River, and development of GTRs with associated levees and water-control structures. Over time, these changes have increased water flows into and through the WMA and prolonged flooding from fall through early summer. These changes have created extended and unnatural water regimes within the WMA and damaged BLH stands and reduced resources used by many wildlife. Waterfowl numbers in the Bayou Meto Basin and WMA have declined substantially from the 1960s to the present; < 5,000 mallards were counted during January 2002.

Development of GTRs on Bayou Meto WMA began in the late 1940s. The Lower and Upper Vallier GTR impoundments were the first to be operational following construction of the Vallier School levee and water-control structure on Little Bayou Meto in the early 1950s. Government Cypress and Buckingham Flats GTRs were developed shortly thereafter. Levees in the Beaver Dam Slough area were constructed in the 1960s. Temple Island GTR was constructed in the early 1980s. A large levee and water-control structure was built on Little Bayou Meto in the Cannon Brake area in the 1990s and created the Cannon Brake impoundment that usurped the former Beaver Dam Slough area and also flooded about 2200 acres of private land. The last GTR development on the WMA was construction of the Bear Bayou impoundment which became fully operational in 2001.

The Wrape Plantation area on Bayou Meto WMA was initially developed for agricultural crop and moist-soil vegetation management in the late 1940s. Since early development this area has been reconfigured and now includes 7 ponds with relatively independent water-control. Halowell Reservoir was purchased in 1957 and was originally impounded for public fishing. In 1976, the reservoir was drained, fishing was eliminated, and the reservoir was used for rice production and native vegetation management. In 1992, Halowell was renovated and in 1994 two interior levees were constructed for moist-soil management. Today, the WMA has 16 all-weather roads covering 21 miles, 25 non-graveled roads covering 41 miles, 30 miles of levees, 1 large dam, 6 large stoplog structures, 83 gated pipes, and 3 relift pumps to manage about 13,600 acres of GTRs and 1137 acres of moist-soil and rice for rest areas in the Wrape Plantation and at Halowell Reservoir.

Early management of GTR impoundments on Bayou Meto WMA simply sought to impound as much surface water as possible for waterfowl hunting in fall and winter. Timing and extent of flooding were determined largely by local fall/winter rainfall, streamflows, and timing of duck hunting seasons. Generally, water-control structures were closed beginning in early fall (as early as 1 September) with the intent of capturing local surface water. During high flow events, water-control structures were partly opened to reduce flooding of private lands adjacent to the WMA. Structures typically were opened to drain the impoundments immediately after duck season ended. Prior to cleaning and enlargement of the double Salt Bayou ditches in the 1950s and 1960s, this water management regime caused variable floodup in fall. After enlargement of the Salt Bayou ditches, the WMA became flooded earlier in fall and drained later in spring creating altered hydrological conditions that degraded BLH stands. WMA personnel began noticing significant mortality of red oaks in the late 1970s.

Concerns about water scarcity in early fall, increased and extended flooding in winter and spring, sedimentation, continued damage to infrastructure, poor and delayed drainage, declining health of BLH stands, and decreased waterfowl use caused the AGFC to develop more comprehensive management plans for the WMA beginning in the late 1960s. Revisions to this plan in the early 1990s identified specific water level management activities in each GTR impoundment, Halowell Reservoir, and the Wrape Plantation ponds.

Most GTR impoundments on Bayou Meto WMA do not have independent flood and drain capabilities. For example, the Lower Vallier water-control structure on Little Bayou Meto controls flooding and draining of Lower Vallier and other impoundments upstream including Government Cypress and Upper Vallier. Water draining through the Lower Vallier structure ultimately flows down Little Bayou Meto through the Cannon Brake GTR impoundment and into the Wasteways Ditch below the Cannon Brake structure. At this point further drainage from the WMA depends on water levels in Bayou Meto (where the Wasteways Ditch drains) and the Arkansas River because the Little Bayou Meto channel below the Cannon Brake structure is filled and obstructed with debris and is inoperable. The interconnectedness of the GTR impoundments complicate water management throughout the WMA.

The current condition of BLH forests in GTRs on Bayou Meto was determined by a random sample of 30 1/8-acre plots in each of 8 GTR units. All plots were located in backswamp areas with Low and Intermediate BLH communities to represent the largest part of BLH on the WMA and to reduce variation in plant community composition related to elevation and hydrogeomorphic condition. All trees > 3 inches dbh were identified and their dbh recorded. The number and percentage of red oaks on the plots that had evidence of basal swelling, chlorosis of leaves, tip die-back, or that were dead were recorded. Regeneration on plots was assessed by counting the number of young seedlings > 0.5 m tall. Percentage canopy, shrub, and herbaceous cover was recorded. Infrared aerial photographs and observations by WMA personnel were used to determine the location and size of larger dead timber patches. All data were analyzed to determine differences among the 8 GTRs and their respective flood and drain regimes.

Red oaks (combined willow and Nuttall oak) comprised 22.4% of total trees in GTR impoundments on Bayou Meto WMA followed by elm (21.0%), overcup oak (19.5%), green ash (15.1%), bitter pecan (10.2%), sugarberry (7.0%), hickory (3.9%), and red maple (0.9%). Tree species composition was different among the GTR impoundments. Bear Bayou and Temple Island contain large amounts of hickory, bitter pecan, and elm. Cannon Brake and Buckingham Flats have more sugarberry than other GTRs and also have large amounts of elm, willow oak, Nuttall oak, and overcup oak and small amounts of green ash. Beaver Dam Slough is dominated by overcup oak and green ash and has the lowest proportion of red oaks among impoundments. Lower Vallier has the highest red oak component on WMA impoundments, but also contains large amounts of overcup oak and green ash. Upper Vallier and Government Cypress both have high amounts of green ash and overcup oak.

A total of 735 living red oaks were present on the random plots. Of these trees, 19.7% had evidence of basal swelling, 22.3% had tip die-back, and 14.4% had some chlorotic leaves. Nuttall oak had more damage than willow oak in all of these variables. Upper Vallier consistently had the greatest amount, and Buckingham Flats the least amount, of damage based on these indicators of tree stress.

Over 9% of all trees on random plots were dead, ranging from 13.2% mortality in Government Cypress to 4.4% mortality in Buckingham Flats. Mortality was highest for red oaks; 21% of willow oak were dead and 24.9% of Nuttall oak were dead. Three large areas of dead timber exist on the WMA; a 500-acres area in Government Cypress, a 100-acre area behind an old abandoned levee on Bubbling Slough in Lower Vallier, and a 50-acre area in Temple Island. Tree mortality in other impoundments was scattered, especially in Upper Vallier.

Regeneration is highly variable among GTR impoundments. Bear Bayou and Buckingham Flats have the highest proportion of red oak seedlings and regeneration of many age-classes of red oaks is present. In contrast, Cannon Brake, Beaver Dam Slough West, and Upper Vallier all have relatively poor regeneration of red oaks.. Tree species composition in many impoundments is gradually shifting from a red oak-dominated stand to a more water tolerant community composed of overcup oak and green ash.

Canopy coverage is relatively closed in 5 of 9 GTR impoundments. High tree mortality and dead timber patches exist in Temple Island, Lower Vallier, Upper Vallier, and Government Cypress. Amount of shrub coverage was reciprocal to canopy coverage. Herbaceous cover is high in Bear Bayou and comprised of poison ivy. Beaver Dam Slough West, Upper Vallier, Lower Vallier, and Government Cypress have small amounts of herbaceous cover comprised of rice cutgrass and sedges.

Both early flooding and late drainage were associated with a high incidence of basal swelling, tip die-back, leaf chlorosis, and mortality of red oaks in GTR impoundments on Bayou Meto WMA. The relative ranks of 6 indicators of stress and damage to GTR forest stands also suggested that the combined effects of early flooding and late drainage caused most damage in the GTRs on Bayou Meto WMA.

Overall GTR condition is best in Buckingham Flats, Bear Bayou, and Cannon Brake, moderate in Lower Vallier, and poor in Temple Island, Government Cypress, Beaver Dam Slough West, and Upper Vallier. Red oak damage and mortality is relatively old and confined to the low elevation sump in Government Cypress, but widespread and recent in other impoundments. Tree condition in Cannon Brake appears to be on the verge of rapid deterioration unless water management is changed to a more natural regime.

General observations on Bayou Meto WMA indicate that:

1. Water regimes in GTRs are more prolonged than occurred historically and flooding occurs earlier and extends later than in pre-GTR periods.
2. Both early flooding and late drainage cause damage to red oaks and when both conditions occur in an impoundment, damage and mortality is severe.
3. Consistent timing of flooding and drainage over many years, without substantial annual variation, contributes to BLH damage (i.e., GTRs with variable flood and drain schedules have reduced damage).
4. A lack of independent water-control to flood and drain individual GTR impoundments creates situations where flooding occurs earlier, and/or drainage later, than natural conditions.
5. Infrastructure on the WMA (and some adjacent private duck clubs) has altered natural water flow across the WMA and created situations where drainages have been obstructed and water has become impounded for long periods.
6. Regeneration of red oaks in GTR impoundments is compromised because of prolonged flooding.

Given these observations we suggest the following general management recommendations for Bayou Meto WMA:

1. Where possible, water regimes in GTRs should be changed to more closely emulate natural timing, depth, duration, and extent of flooding.

2. Improve water flow across, and drainage of, GTR impoundments in late winter and spring.
3. Curtail construction of additional levees or further compartmentalization of GTR impoundments.
4. Carefully manage existing BLH stands to improve red oak regeneration and vigor by reducing flood duration to a more natural regime in all GTR impoundments.
5. Regularly monitor BLH condition and water levels in GTR impoundments.
6. Develop a forest management plan to compliment the water management plan.

Specific recommendations for individual GTR impoundments on Bayou Meto WMA are provided in the report (pages 57-62). Management of Buckingham Flats should attempt to maintain the relatively healthy condition of BLH by emulating natural timing and duration of flooding. Flooding regimes in Bear Bayou should seek to emulate short duration and annually dynamic flood pulses in winter. Cannon Brake is on the verge of rapid and severe damage and mortality to red oaks. The primary problem in Cannon Brake is poor and late drainage and management should quickly seek remediation for this problem. Temple Island should delay flooding until late November, vary annual flooding schedules, and improve internal drainage problems. Rehabilitation of the red oak component in Beaver Dam Slough West may require several decades of drier water regimes, changed water management in Cannon Brake, cooperation with adjacent private landowners, and experimental planting container-grown seedlings. Water regimes in Lower Vallier should be shorter duration and staggered flooding schedules using a 5-7 year regime. The old abandoned levee in Bubbling Slough should be removed. Rehabilitation of red oaks in Upper Vallier will require the above changes in management of Lower Vallier and many years of staggered, and relatively short, flooding. Management of Government Cypress should focus on improving drainage in and around the dead timber area in the south-central part of the impoundment.

Based on data analyses in this water management plan, proposals to construct a 1000 cfs pump station adjacent to the gravity floodgates at mile 0 of Little Bayou Meto and cleaning and enlarging Little Bayou Meto from this pump station to the Cannon Brake structure seem beneficial to improving drainage of Bayou Meto WMA and helping management to rehabilitate red oak components to BLH stands on the WMA. We recommend that AGFC and USACE jointly develop a cooperative agreement for operation of the pump to facilitate drainage of GTRs on Bayou Meto WMA in late winter and spring. The agreement should not compromise changes in water management recommended in this report or regional water conditions adjacent to the WMA that are desirable in late fall and winter.

We also recommend: 1) developing dependable and independent water sources for flooding Bear Bayou and Temple Island GTR impoundments, 2) improving internal drainage of Government Cypress and Upper Vallier impoundments, 3) improving drainage down Long Pond Slough, and 4) cleaning ditches along the perimeter of Upper Vallier.

INTRODUCTION

Bayou Meto WMA is a ca. 32,000 acre bottomland hardwood wetland (BLH) owned and managed by the AGFC in east-central Arkansas (Fig. 1). The WMA is located in the southern Arkansas River Lowland portion of the 1500 mi^2 Bayou Meto Basin and lies on fluvial surfaces created by channel dynamics of the Arkansas River during the Holocene period. Acquisition of land for Bayou Meto WMA began in 1948 with the purpose of protecting one of the largest remaining contiguous areas of BLH in Arkansas and to provide public hunting opportunity. Bayou Meto WMA is among the largest state-owned BLH area in the U.S. and is the largest WMA owned by AGFC.

Historically, extensive BLH habitats covered most of the Bayou Meto Basin (including the area now in Bayou Meto WMA). These BLH habitats supported diverse plant and animal communities and provided numerous local, regional, and continentally important ecological functions and values including groundwater recharge, flood water retention, C storage and fixation, biogeochemical cycling, filtration of waters and nutrients, biodiversity, and habitat for unique and threatened plant and animal species (Gandy et al. 2000, Heitmeyer et al. 2002). Bayou Meto WMA is renowned for supporting large numbers of migratory birds, especially wintering mallards. This area has been identified as one of the largest "core" areas of critical wintering waterfowl habitat in the Lower Mississippi Alluvial Valley Habitat Joint Venture by the North American Waterfowl Management Plan (Yaich 1990) and as critical habitat for many neotropical migrant bird species of concern (Twedt et al. 1999, Mueller et al. 2000).

Native vegetation communities, hydrology, and topography have been altered greatly throughout the Bayou Meto Basin since the Presettlement period (Heitmeyer et al. 2002). Many changes to ecosystem structure and processes have occurred in the Basin even within the past 2-3 decades - the most dramatic being continued deforestation and degradation of remnant forest and alteration of hydrologic regime from extensive roads, ditches, levees, and water-control structures. Today, Bayou Meto WMA constitutes the largest contiguous patch of BLH remaining in the Bayou Meto Basin and it retains many valuable ecological processes and features. However, long-term management activities on the WMA, land use changes, and local and regional water developments for agricultural production, drainage, and flood control have altered the ecological condition of the WMA. Changes of special concern on the WMA are: 1) degraded forest health, composition, and regen-

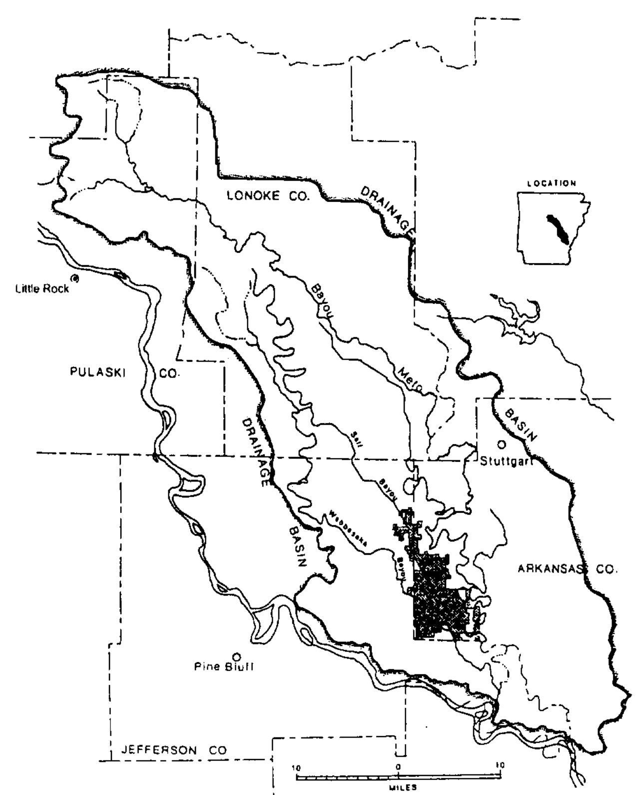


Figure 1. Location of the Bayou Meto Wildlife Management Area, Arkansas.

eration; 2) altered timing, depth, and duration of flooding; 3) decreased abundance and availability of BLH resources; and 4) lower diversity and abundance of fish and wildlife populations, especially wintering waterfowl.

Management of Bayou Meto WMA historically has attempted to achieve multiple, sometimes competing, resource objectives and uses including: 1) maintaining a functional BLH ecosystem, 2) supporting populations of endemic fish and wildlife species, and 3) providing public use opportunities, especially waterfowl hunting. Primary management on Bayou Meto WMA traditionally has involved manipulating seasonal flooding in 8 GTR impoundments using a complex network of levees, ditches, and water-control structures. Since initial purchases and development of the area, the AGFC has identified many water management concerns and made periodic adjustments to flooding and draining schedules and renovated or constructed water-control and delivery structures. An updated evaluation of the status of resources and management objectives in the WMA is needed because of continued changes to the WMA and surrounding lands and new information on BLH ecosystem ecology. Also, several structural developments have been proposed in the Bayou Meto Basin and within the WMA to provide reliable water supplies for flooding agricultural lands (and GTR impoundments on the WMA) and to allow more timely and efficient seasonal drainage. Certain developments recently have been proposed as part of the USACE Bayou Meto Basin Improvement Project (U.S. Army Corps of Engineers 1998) and a cooperative USACE/AGFC 1135 restoration project (U.S. Army Corps of Engineers 1998).

This report provides analyses of historic and existing habitat conditions and resources in Bayou Meto WMA and offers recommendations for future water management strategies including evaluation of proposed structural developments and modifications. Objectives include:

1. Describe the Presettlement BLH ecosystem and ecological processes in the Bayou Meto WMA area.
2. Identify how the structure and function of the BLH ecosystem have been altered in the WMA since the Presettlement period.
3. Determine the current composition, distribution, and health of BLH in WMA GTR impoundments.
4. Recommend water and general timber management options and strategies for the GTR impoundments.
5. Evaluate proposed USACE projects for structural developments to improve water delivery and drainage on the WMA.

THE PRESETTLEMENT BAYOU METO ECOSYSTEM

Geological, Hydrological, and Climatic History

Bayou Meto WMA lies in the southeastern part of the Arkansas River Lowland portion of the 1500 mi^2 Bayou Meto Basin in east-central Arkansas. Five major Arkansas River courses were active in the Bayou Meto Basin during the last 14,000 years of the Holocene period and 2 were in the vicinity of Bayou Meto WMA (Saucier 1994). These courses occupied the current Boggy Bayou area about 11-13,000 years before present (BP) and then shifted to, and occupied, the current Bayou Meto floodplain 10-12,000 years BP (Fig. 2). Consequently, most geomorphic surfaces in the WMA were formed 10-14,000 years BP and subsequently have been shaped and occupied by bayous and drainages occupying former river courses since that time. Elevations in the WMA are relatively flat (mostly 0-1% slopes) and range from 175-185 feet above mean sea level (amsl). Surface Quaternary deposits are underlain by Claiborne, Jackson, and Wilcox Tertiary deposits (Saucier 1994).

Geomorphic features in the WMA include abandoned channels of the Arkansas River, point bars, natural levees, backswamp, and undifferentiated alluvial deposits. Many areas have a veneer of silt, originating from floodwaters, that overlies older deposits. Bayou Meto and Little Bayou Meto (the 2 primary drainages through the WMA) maintain hydraulic connection with the current Arkansas River floodplain and carry low stage flows. Bayou Meto and Little Bayou Meto receive tributary flows from Salt Bayou, Hurricane Slough, Bubbling Slough, Government Cypress Slough, Wabbaseka Slough, Long Pond Slough, Five Forks, and Beaver Dam Slough (Fig. 3). These tributaries merge within the WMA via a labyrinth of "cross bayous." Most of the WMA is on backswamp deposits covered with fine Portland-Perry silty clays 40-50 feet thick (Fig. 4, Table 1). Backswamp areas have relatively flat topography and a slightly sloping "bowl-shaped" depression is present in the south-central part of the area where many tributary streams merge and "scatter" across this flat "bowl."

Several abandoned Arkansas River channels occur in the WMA (Fig. 4). Most of these "oxbows" are not directly connected to bayous or streams. These abandoned channels receive surface water flows and sediments during high water flood events and from local runoff. Some subsurface water input into abandoned channels also may occur when the Arkansas River is high. Abandoned channels typically contain finer sediments than active bayous because they receive sediments mostly during flood

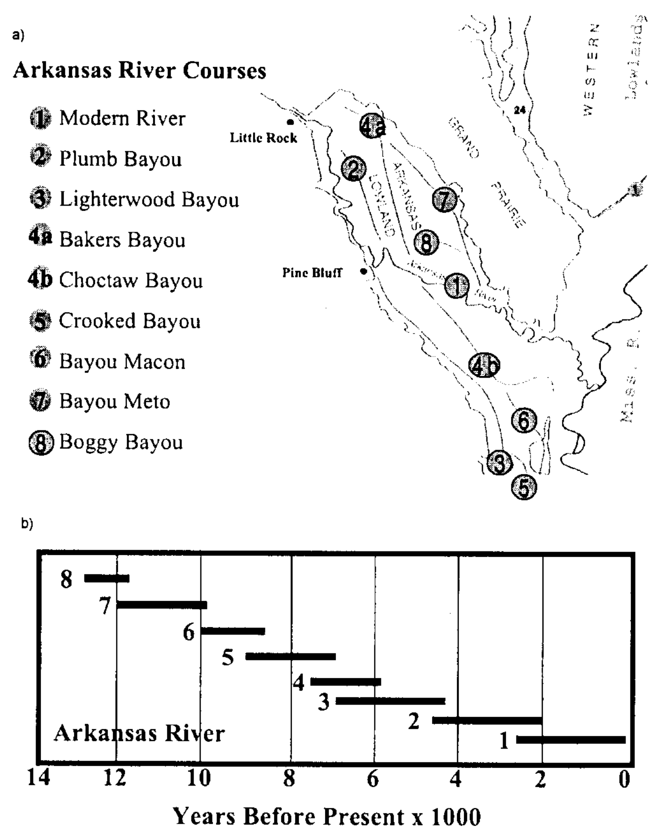


Figure 2. a) Major Holocene Arkansas River courses, and b) estimated chronology (from Saucier 1994).

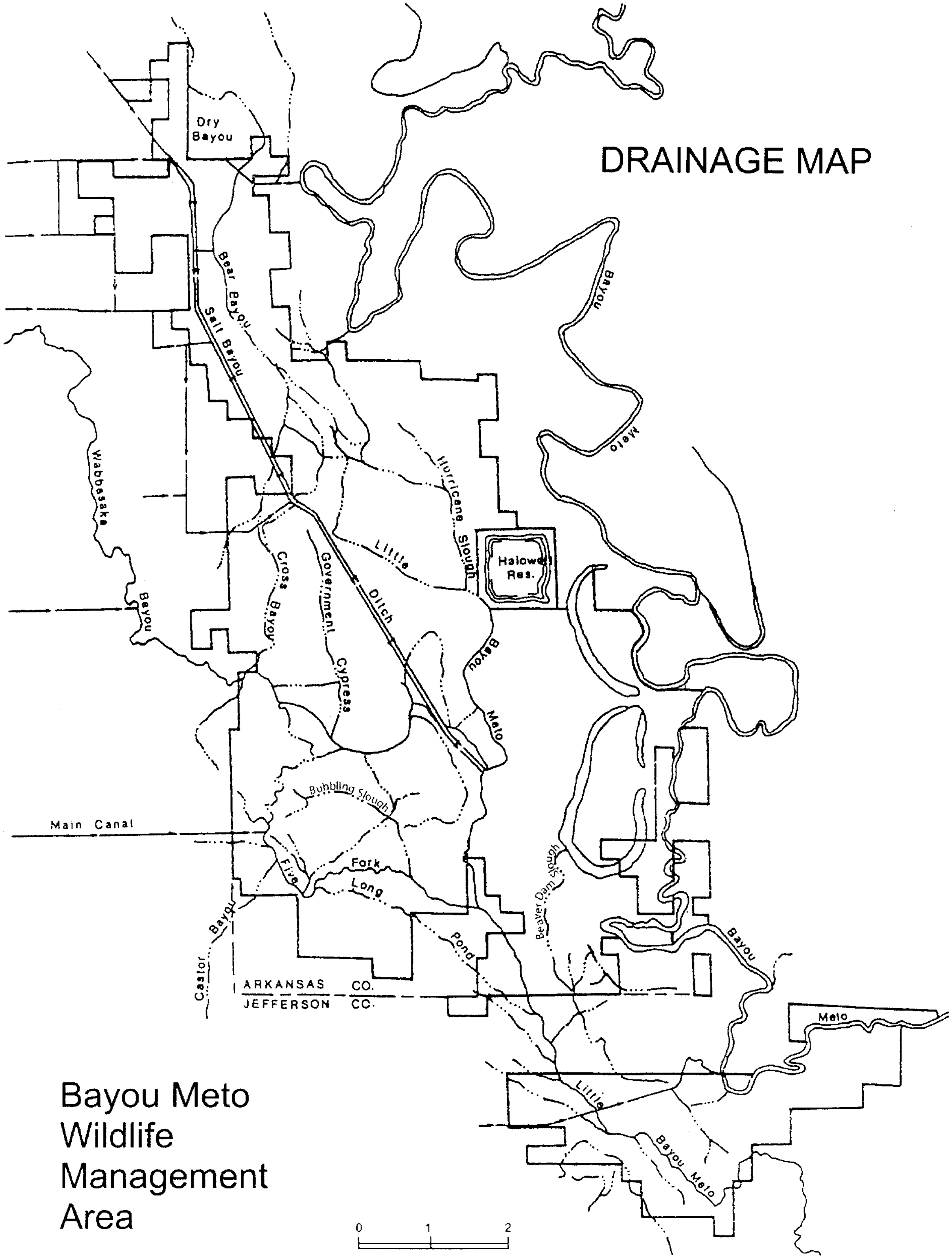


Figure 3. Primary drainages through the Bayou Meto Wildlife Management Area, Arkansas.

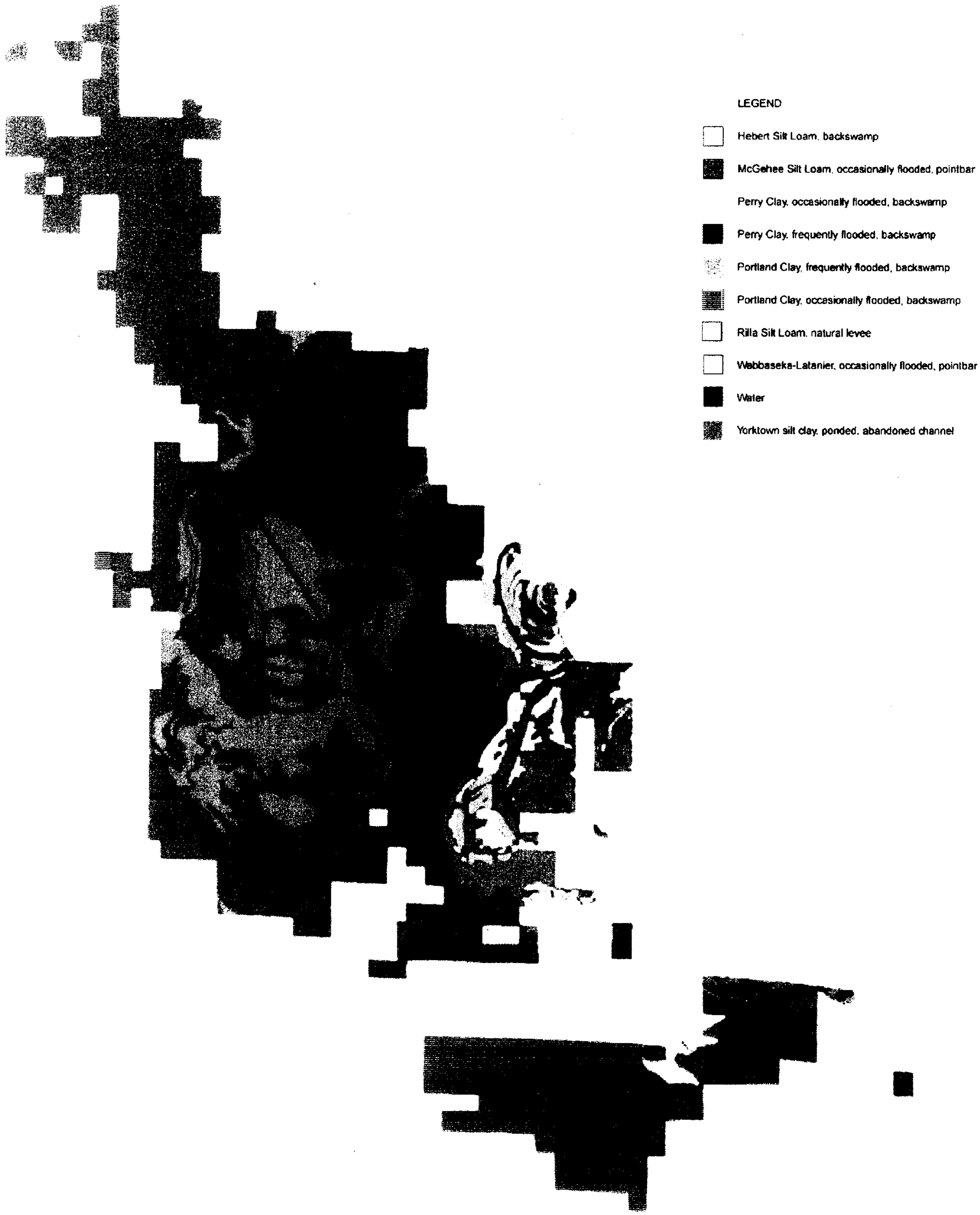


Figure 4. Presettlement natural habitat communities in the Bayou Meto Wildlife Management Area, Arkansas (from Pagan et al. 2002).

Table 1. Area (acres) of hydrogeomorphic (HGM) habitat types[a] in the Bayou Meto Wildlife Management Area, Arkansas.

Geomorphic Setting, Soils, -HGM Category	Area	%
Backswamp		
Hebert Silt Loam – F1, F4	1,095.2	3.4
Perry Clay – RB1, RB2, RO1	18,844.2	58.7
Portland Clay – RB1, RB2, RO1	9,220.1	28.7
Subtotal	29,159.5	90.8
Natural levee		
Rilla Silt Loam – RO1, F3, F4	396.7	1.2
Subtotal	396.7	1.2
Point bar and undifferentiated alluvium		
McGehee Silt Loam – F4	50.7	0.2
Wabbeaseka-Latanier Complex – F4	124.9	0.4
Calhoun Silt Loam – RO3	1.0	<0.1
Subtotal	176.6	0.6
Abandoned channel		
Yorktown Silty Clay – D2, LF2	1,291.0	4.0
Subtotal	1,291.0	4.0
Open water[b]	1,070.2	3.3
TOTAL	32,094.0	100.0

[a]HGM Category descriptions from Klimas et al. 2002, Pagan et al. 2002.
[b]Open water sites do not have a soil or HGM category.

events. Generally, a sand or silty sand wedge forms in the arms of the cutoff during early stages of separation from the historic river. Following separation, silts and silty clays are deposited on top of sands and form a "plug" that fills the abandoned channel. Consequently, distinct layers of silts and clays occur in these cutoffs; most soils are Yorktown clays.

Small areas of natural levees are present in Bayou Meto WMA where floodwaters overtopped banks of stream channels and dropped suspended sediments (Fig. 4). Natural levees are low ridges and decrease in height and thickness away from the levee crest. Natural levees merge with backswamp and point-bar deposits and were formed from old Arkansas River courses and modern bayous and streams. Natural levees may be as high as 5 feet above active stream channels and are mostly Rilla silt loam soils.

Small areas of point bar deposits are distributed throughout Bayou Meto WMA (Fig. 4). Point bar deposits are as thick as the depth of the river channel that formed them (up to 50 ft. thick in some areas). Coarse sand and gravel are present at deeper depths in point bar areas and silts and clays are present immediately below current surfaces. Depositional accretions create "ridge-and-swale" topography in point bar areas; most swales are adjacent to the current Bayou Meto channel, relatively narrow and shallow, and contain only a few feet of silty or sandy clay. Soils in old point bar environments are Rilla, Hebert, Wabbaseka, Latanier, and McGhee types with some Perry soils in swales.

Historically, at least some portions of the Bayou Meto floodplain (including the area in Bayou Meto WMA) flooded annually during winter and spring. Much of the area now in the WMA was especially prone to seasonal flooding because of the relatively flat low topography, interconnected tributary drainages, and close proximity to the confluences of Bayou Meto and Little Bayou Meto with the Arkansas River. Little Bayou Meto is the primary source of flood water for Bayou Meto WMA and carries about 41% of all drainage water in the Bayou Meto Basin (Arkansas Soil and Water Conservation Commission 1988). Consequently, even small flows in Little Bayou Meto regularly connected bayous and inundated extensive amounts of BLH in the WMA area, often for extended periods.

The WMA area also was periodically flooded by backwater from the Arkansas River. The historic frequency of backwater flooding of the Bayou Meto Basin and WMA from high flows in the Arkansas River is not entirely known. Apparently extensive backwater flooding throughout the Bayou Meto Basin occurred at least once in each decade from the mid-1800s until the 1940s when locks and dams were built on the Arkansas River (Heitmeyer et al. 2002).

Some overbank flooding of Bayou Meto (Lonoke and Stuttgart gage stations) also occurs almost annually (Fig. 5). Increased precipitation causes overbank flooding in the WMA area from December to April in most years (Fig, 5, Tables 2,3). Since 1955, peak annual discharge of Bayou Meto at the Lonoke gage station has occurred on average every 6-7 years and low annual discharge has occurred on average every 5-6 years (Fig. 6). Long-term winter (Nov-Feb) precipitation data (Fig. 7) suggest similar patterns of annual changes in peak and low flows and flood events.

Distribution and Ecological Processes of Historic Vegetation Communities

Historic vegetation communities in the Bayou Meto Basin were distributed in relation to geomorphic surface, soils, topography, and hydrological regime (especially flood frequency) (Klimas et al. 2002). Previous sampling of vegetation communities at locations representing combinations of these abiotic factors (e.g., point bar surfaces with McGehee soils of 0-1% slope within the 2-year flood frequency zone) throughout the Bayou Meto Basin characterized habitats in a hydrogeomorphic (HGM) model that predicted historic distribution and area of vegetation communities (Klimas et al. 2002, Pagan et al. 2002). These data allow determination of historic habitat types on Bayou Meto WMA (Table 1, Fig. 4).

Backswamp surfaces with 0-1% slopes cover 90.8% of Bayou Meto WMA (Table 1). Perry and Portland clay soils dominate backswamp areas and are in low elevations within the 1-5 year flood frequency zone; most are within the 2-year flood frequency area. Hebert silt loams occur on higher elevation backswamp flats outside the 5-year flood frequency zone. All backswamp areas on the WMA are seasonally flooded Low and Intermediate BLH habitats (HGM categories Riverine Overbank Subtype RO-1 and Riverine Backwater Subtypes RB-1 and RB-2) and are dominated by overcup oak, Nuttall oak, willow oak, bitter pecan, cedar elm, green ash, and sugarberry (Table 4). Abandoned channels comprise 1,291 acres (4%) of the WMA and contain mainly Cypress/Tupelo BLH that is dominated by baldcypress, tupelo, buttonbush, and swamp privet. Abandoned channels sites are permanently flooded with seasonal drawdowns on margins. Natural levees (1.2%) and point bar surfaces (0.6%) in the WMA are on edges of larger drainages (e.g., margins of the Bayou Meto channel) and the old Arkansas River abandoned course in the current Bayou Meto floodplain. These sites have diverse plant composition including water oak, cherrybark oak, cedar elm, persimmon, shagbark hickory on ridges, and Nuttall oak and green ash in swales (Table 4). Delta post oak, bur oak, and southern red oak occur occasionally on these sites. Natural levees also have water oak, cherrybark oak, sycamore, sweet pecan, and sweetgum. Current HGM mapping of the WMA indicates 1070 acres of open water mostly in bayou channels and in Halowell Reservoir. Before impoundment, the Halowell site was backswamp, mostly within the 5-year flood frequency zone and with a few isolated point bar deposits.

BLH communities at Bayou Meto WMA typically are inundated for at least some period in most years. Specific plant species composition at a site reflects the frequency, depth, duration, and extent of flooding (Fig. 8). Cypress/tupelo habitats occur in the lowest elevations in the WMA mostly in abandoned channel sites and low depressions and swales where water ponds for extended periods each year. These habitats are flooded at least 3 months annually and soils are saturated most of the year; abandoned channels are flooded year-round. Baldcypress and tupelo trees dominate these sites (Table 4).

Low BLH habitats occupy extensive parts of Bayou Meto WMA. These habitats occur in low areas that typically flood 1 to 3 months in late winter

Table 2. Monthly mean stream flow (ft^3/sec), October 1954 – 2001 at the Bayou Meto gage near Lonoke, Arkansas.

Month	Mean stream flow
January	414.0
February	514.0
March	553.0
April	499.0
May	423.0
June	154.0
July	55.5
August	46.8
September	65.2
October	60.4
November	240.0
December	452.0

Table 3. Mean daily maximum temperature (°F) and precipitation (inches) for the Bayou Meto Wildlife Management Area, Arkansas (Stuttgart recording station).

Month	Temperature	Precipitation
January	52.6	4.60
February	56.4	4.30
March	65.3	5.39
April	74.3	5.30
May	81.6	4.91
June	89.6	3.90
July	92.9	3.39
August	92.6	2.99
September	87.1	3.26
October	77.3	3.45
November	64.4	4.29
December	54.6	5.13

Table 4. Dominant plant species in forested habitats of the Bayou Meto Basin, Arkansas. Data from Godfrey and Wooten (1979a,b).

		Habitat				
Species	Common name	Cypress/ tupelo	Low BLH	Inter-mediate BLH	High BLH	Natural levee
Saururus cernus	Lizard's tail	X	X			
Carya illinoensis	Pecan				X	X
Carya aquatica	Bitter pecan		X			
Carya cordiformis	Bitternut hickory				X	X
Carya ovata	Shagbark hickory				X	
Populus deltoides	Eastern cottonwood					X
Populus heterophylla	Swamp cottonwood	X	X	X		
Salix nigra	Black willow					X
Salix interior	Sandbar willow					
Betula nigra	River birch					X
Carpinus caroliniana	Ironwood			X	X	X
Quercus lyrata	Overcup oak		X			
Quercus michauxii	Swamp chestnut oak				X	X
Quercus falcata	Cherrybark oak				X	X
Quercus macrocarpa	Bur oak				X	X
Quercus palustris	Pin oak			X		
Quercus nutalli	Nuttall oak			X		
Quercus phellos	Willow oak			X	X	X
Quercus nigra	Water oak			X	X	X
Quercus stellata	Post oak					
Boehermia cylindrica	False-nettle	X	X			X
Morus rubra	Red mulberry				X	X
Celtis laevigata	Sugarberry			X	X	X
Planera aquatica	Water elm	X	X			
Ulmus crassifolia	Cedar elm				X	
Ulmus americana	American elm			X	X	X
Brunnichia ovata	Ladie's eardrop		X		X	X
Polygonum spp.	Smartweed	X	X			
Brasenia schreberi	Water-shield	X				
Nymphaea odorata	Pond-lily	X				
Nuphar luteum	Spatter-dock	X				
Itea virginica	Virginia willow	X				
Liquidambar styraciflua	Sweetgum		X	X	X	
Hamamelis virginiana	Witch hazel				X	
Platanus occidentalis	Sycamore					X
Crataegus viridus	Green haw			X	X	X
Crataegus aestivalis	May haw	X	X			
Gleditisia aquatica	Water locust		X			X
Gleditisia triacanthos	Honey locust				X	
Impatiens capensis	Jewel weed	X	X			X
Toxicodendron radicans	Poison ivy		X	X	X	X
Ilex decidua	Possum-haw			X	X	
Acer negundo	Box elder					X
Acer rubrum	Red maple			X	X	X
Acer saccharinum	Silver maple			X	X	X
Berchemia scandens	Rattan-vine		X	X	X	X
Ampelipsis arborea	Pepper-vine		X	X	X	X
Vitis rotundifolia	Muscadine grape		X	X	X	X
Hibiscus spp.	Marsh mallow	X	X	X		X
Nyssa aquatica	Water tupelo	X				
Nyssa sylvatica	Black gum			X	X	
Cornus spp.	Dogwood		X	X		X
Styrax americana	Mock-orange	X	X	X	X	
Diospyros virginiana	Persimmon			X	X	
Fraxinus caroliniana	Carolina ash	X	X	X		X
Fraxinus pennsylvanica	Green ash		X	X		X
Forestiera acuminata	Swamp-privet	X	X			
Trachelospermum difforme	Climbing dogbane				X	X
Bignomia capreolata	Cross-vine		X		X	X
Catalpa bignonioides	Indian-bean			X	X	X
Campsis radicans	Trumpter-creeper		X	X	X	X
Cephalanthus occidentalis	Common buttonbush	X	X			
Viburnum dentatum	Arrowwoods			X		X
Lobelia cardinalis	Cardinal flower	X	X	X		X
Arundinaria gigantea	Giant cane					X
Smilax spp.	Greenbriar		X	X	X	X
Cocculus carolinus	Carolina moonseed				X	X
Taxodium distichum	Baldcypress	X	X			

and spring and are within the 1 to 2-year flood frequency zone. These areas include extensive areas of backswamp and low swales in point bar surfaces. Dominant vegetation in Low BLH includes cedar elm, water hickory, overcup oak, water locust and swamp privet (Table 4). Understory vegetation in Low BLH usually is sparse because of extended inundation and, where present, usually includes scattered stands of rice cutgrass and various sedges. Low BLH areas also have inclusions of baldcypress and buttonbush in low depressions.

Intermediate BLH habitats are present on extensive areas of the WMA and occur where flooding lasts for a few weeks to 2 months annually during the dormant season and early spring. During wet years when extensive and extended flooding occurs, Intermediate BLH sites may be flooded for 3-4 months. Conversely, during dry years these sites flood for short periods (< 1 month) if at all. Soils in Intermediate BLH habitats often are saturated for 3 to 4 months, but summer drying is essential to maintain dominant species such as Nuttall oak, willow oak, sugarberry, and elm (Table 4). Depressions in Intermediate BLH include overcup oak, bitter pecan, green ash, and swamp privet. Most Intermediate BLH habitats are in backswamp and point bar areas and higher edges of abandoned courses. Herbaceous vegetation often covers extensive areas and includes poison ivy, greenbrier, common privet, and Japanese honeysuckle.

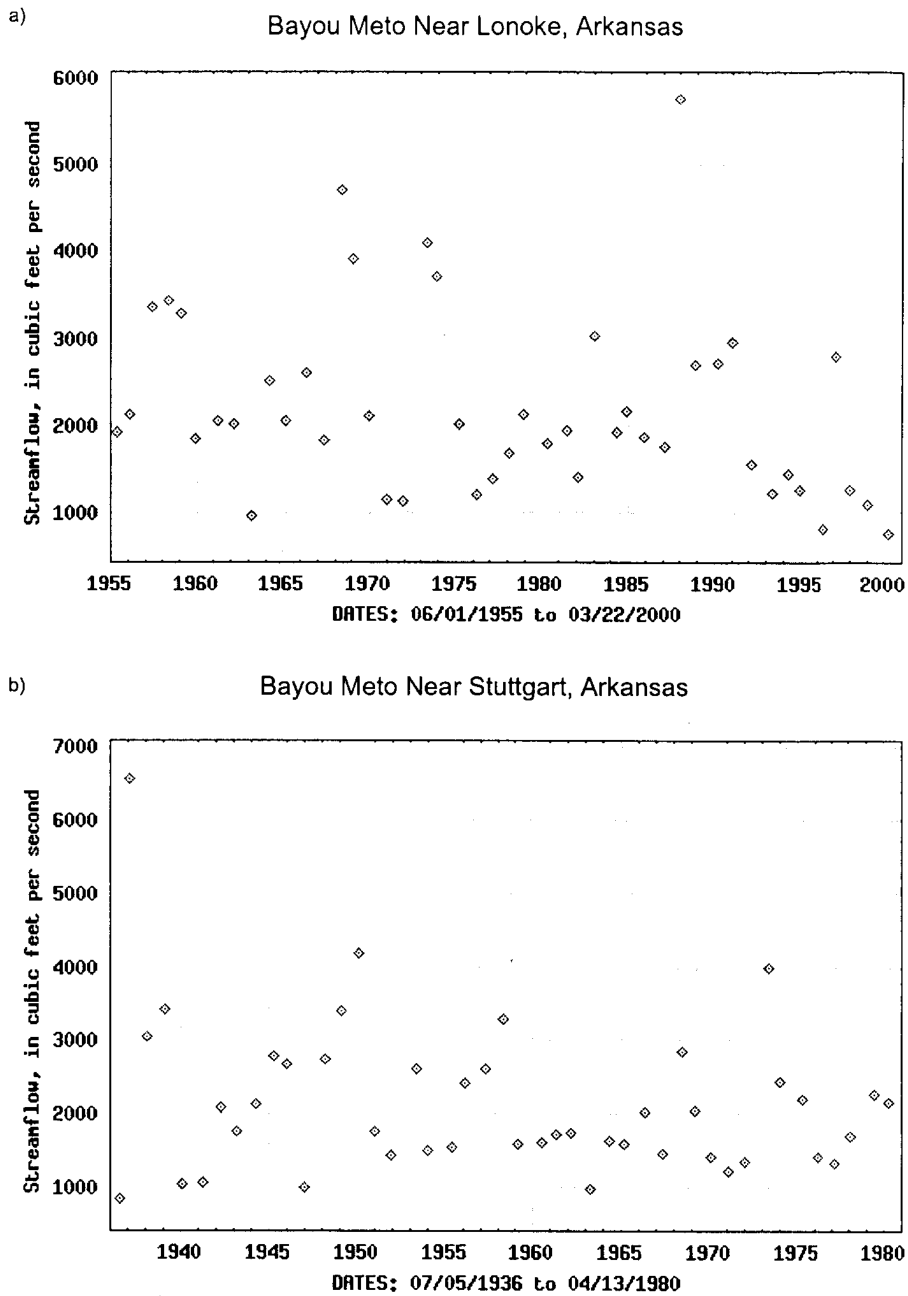


Figure 5. Peak annual streamflow of Bayou Meto at a) Lonoke, and b) Stuttgart Arkansas.

High BLH habitats occupy high elevations within the WMA mostly on point bar ridges and next to natural levees. These habitats historically were flooded for a few weeks in some, but not all, years usually during high flow events of the Arkansas River or major streams. While some High BLH habitats may not flood every year, soils usually are saturated for some periods annually. Generally, the dividing point between Intermediate and High BLH is the 5-year flood frequency zone. Soils in High BLH in the WMA are mostly Herbert silt loam in backswamp sites and McGehee and Wabbaseka-Latanier silt loams in point bar flats. Dominant plant species in High BLH include water oak, willow oak, cherrybark oak, shagbark hickory, mockernut

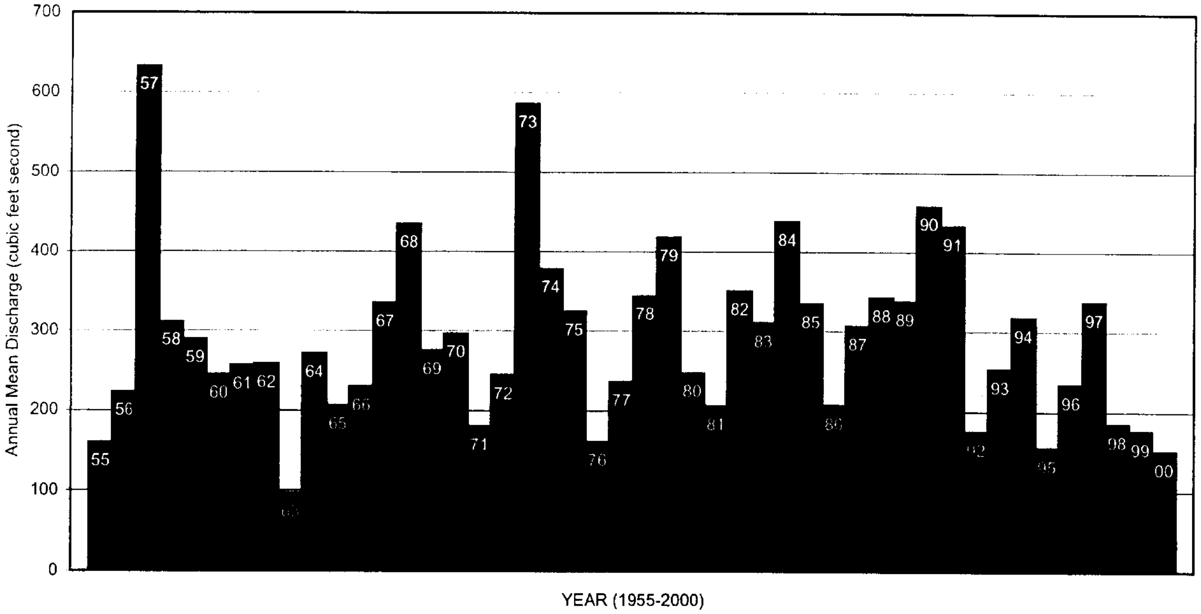


Figure 6. Annual mean discharge of Bayou Meto near Lonoke, Arkansas 1955-2000 (from Arkansas Soil and Water Conservation Commission, 1988).

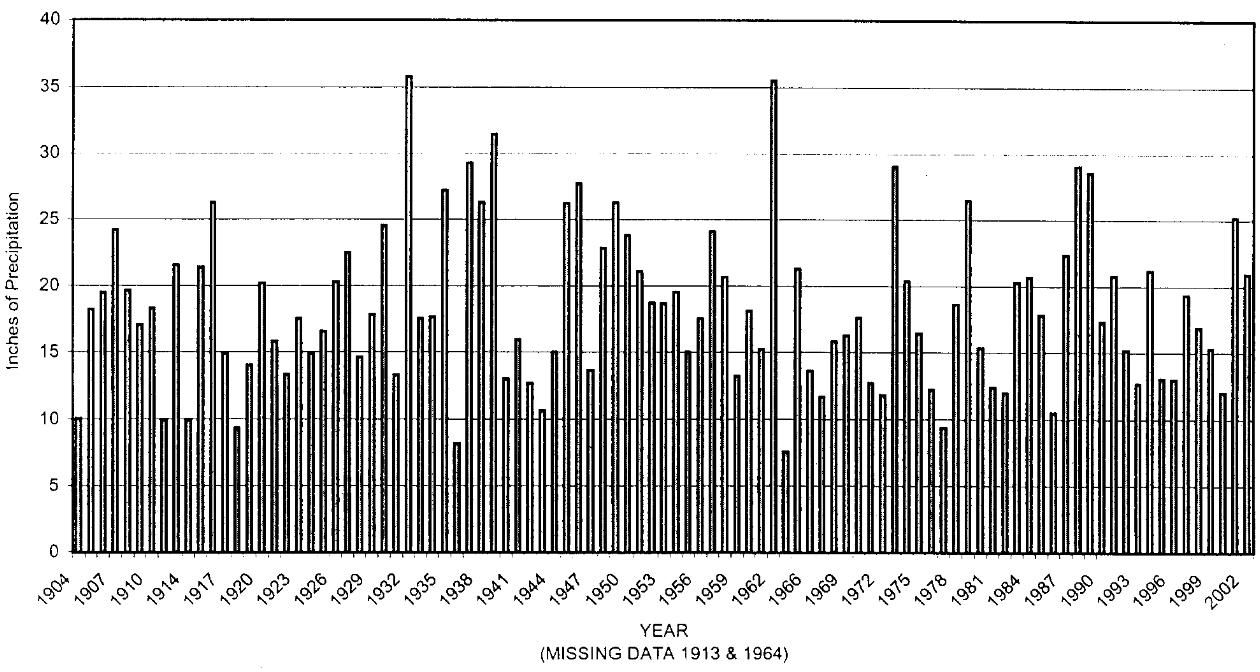


Figure 7. Total winter (Nov.-Feb) precipitation at Stuttgart, Arkansas 1904-2002.

hickory, sweetgum, American elm, persimmon, and scattered Delta post oak (Table 4). Herbaceous coverage in High BLH usually is extensive and includes poison ivy, climbing dogbane, and Virginia creeper.

Natural levee sites in the WMA support unique communities that include cottonwood, box elder, cow oak, cherrybark oak, and Delta post oak (Table 4). Common vines in these sites include greenbrier, poison ivy, and Carolina moonseed. Giant cane is present in scattered locations.

BLH ecosystems have high primary and secondary productivity (Wharton et al. 1982). Diverse multi-layered plant communities, dynamic water regimes, and a warm-temperate climate create high plant diversity and biomass and strong seasonal pulses of food resources used by diverse animal communities (Fig. 9). BLH habitats have especially rich detrital bases that support complex nutrient cycling and inter-trophic level food webs (Fig. 10). High plant biomass contributes extensive leaf litter (and other tree parts) to the forest floor. This leaf and woody biomass is decomposed mainly from fall through spring by rich fungal, bacterial, and invertebrate communities (Batema et al. 2004). Seasonal flooding and warm temperature promote rapid decomposition and seasonal energy flows. Extensive and shallow root systems of BLH trees support fungal filaments and mycorrihizal fungi in top soil layers that conserve and capture nutrients. Consequently, if detrital layers are reduced or extensive tree death occurs in BLH, nutrients may be exported from the system and food webs and energy flow may be degraded. Seasonal flooding, especially periodic slow backwater floods, imports nutrients and sediments to BLH systems, however, high flow floods with greater water velocity may occasionally scour and export nutrients and sediments. Wide contiguous stands of BLH trees in floodplains slow flood flows and cause sediments to be deposited and nutrients conserved.

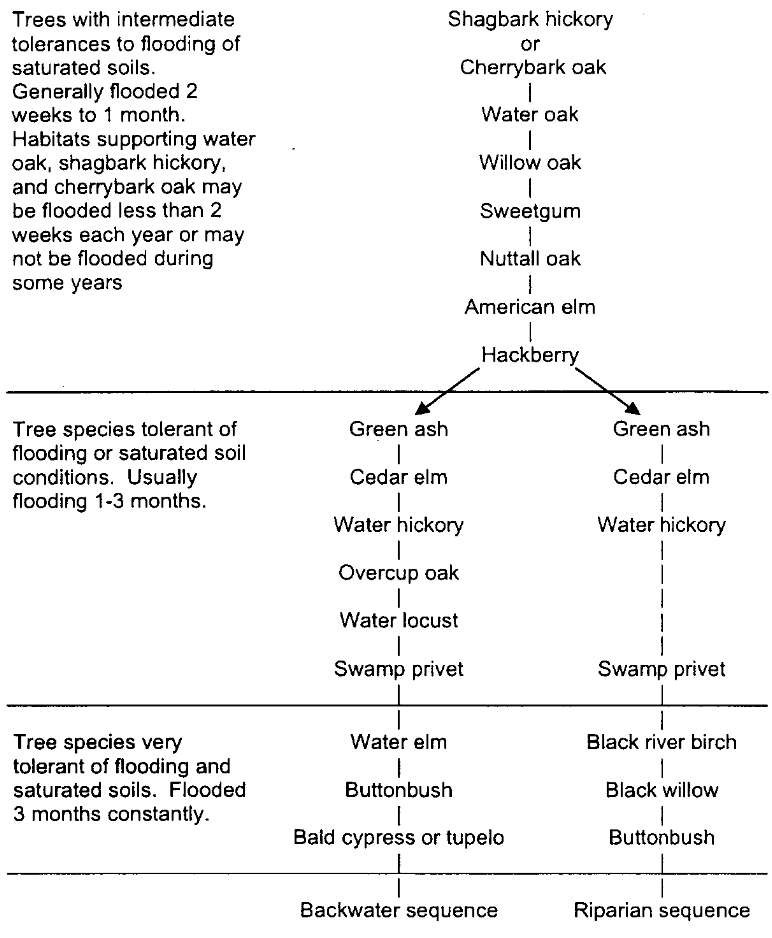


Figure 8. Relative sequences of common bottomland hardwood forest tree species along an elevation and moisture gradient at Bayou Meto Wildlife Management Area, Arkansas (adapted from Huffman 1976, Dale 1998).

The biodiversity, high production and ecological integrity of BLH communities in Bayou Meto WMA is sustained by diverse geomorphic surfaces and soils, topography, and periodic flooding and drying events. If flood regimes are altered (either wetter or drier), then plant communities shift to either wetter or drier-type tree species composition. For example, when flooding is prolonged, Low and Intermediate BLH shift to Low BLH, Cypress/Tupelo, or Open Water conditions. Major hydrologic changes caused by ditches, levees, roads, and water-control structures accelerate changes in BLH communities.

Fish and Wildlife Communities

The diversity and abundance of fish, amphibian, reptile, bird, and mammal species in BLH systems is among the greatest of any ecosystem in North America (Heitmeyer et al. 2004). Species are distributed in relation to flooding regime and habitat type (Tables 5-8); in general species richness is highest in Low, Intermediate, and High BLH habitats except for fish which use the more permanently flooded Cypress/Tupelo sites. Many vertebrate species use all BLH habitats, capitalizing on different resources present in different seasons.

Fish and wildlife species present at Bayou Meto WMA have diverse adaptations to abundant, yet seasonally available, BLH resources. The most abundant warmblooded species are relatively long-lived and highly mobile (Heitmeyer et al. 2004). Also, many species are omnivorous (e.g., raccoon and mallard), have diverse diets within a trophic level (e.g., otter), or are present only during pulses of specific foods (e.g., migrant insectivorous songbirds). Omnivory and mobility allows animals to take advantage of many different pulses of food availability (e.g., insect emergence, acorn drop, macroinvertebrate blooms, rodent reproduction, etc.) and

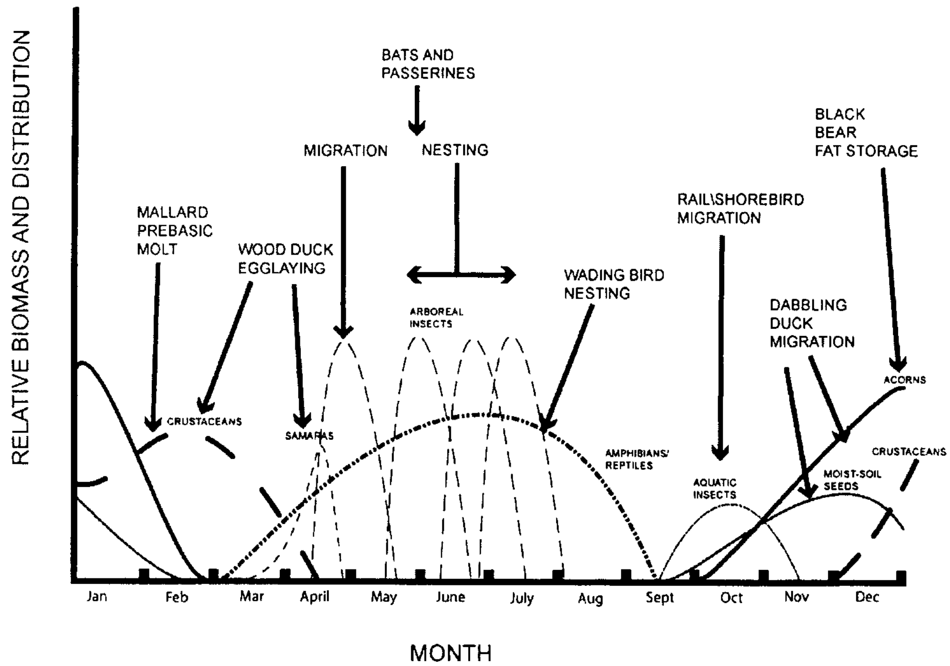


Figure 9. Examples of seasonal pulses of food types in bottomland hardwood forests and key annual cycle events of some species that coincide with these pulses (from Heitmeyer et al. 2004.).

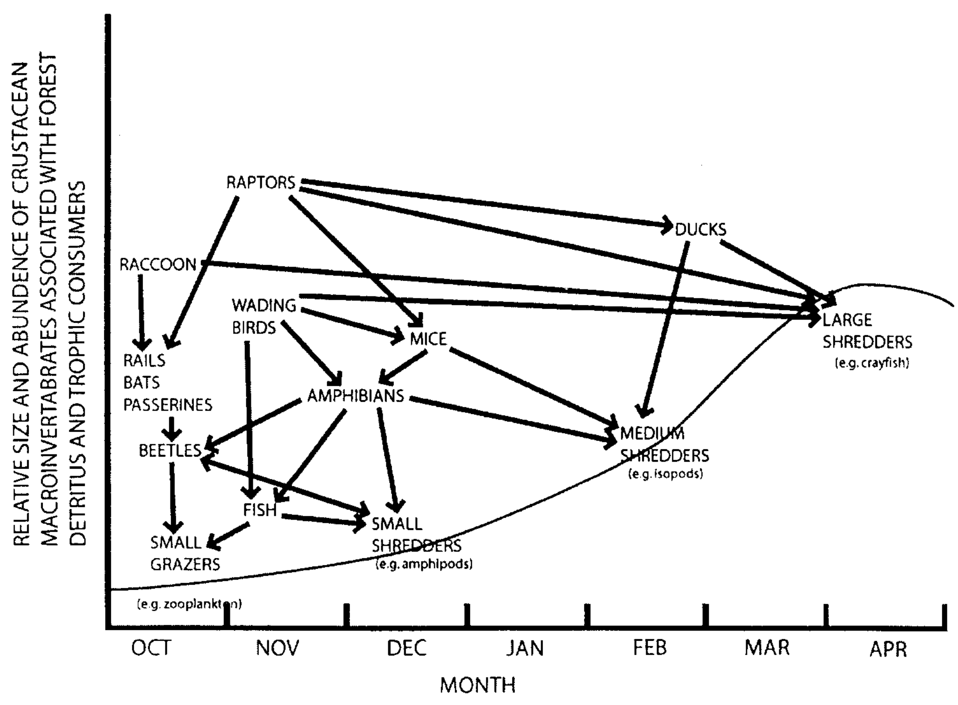


Figure 10. An example of a detrital-based food chain in bottomland hardwood forests that begins with crustaceans (from Heitmeyer et al. 2004).

Table 5. Native fish species in the Arkansas River and bottomland hardwood forest (BLH) habitat types in the Bayou Meto Basin, Arkansas. Data are from Robison and Buchanan (1988) and Baker and Kilgore (1994).

		Habitat		
Species	Common name	Arkansas River	Cypress/ Tupelo	Flooded BLH
Scaphirhynchus platorynchus	Shovelnose sturgeon	X	?	
Polyodon spathula	Paddlefish	X	?	
Atractosteus spatula	Alligator gar	X	X	?
Lepisosteus oculatus	Spotted gar	X	X	?
Lepisosteus osseus	Longnose gar	X	X	?
Lepisosteus platostomus	Shortnose gar	X	X	?
Amia calva	Bowfin	X	X	X
Anguilla rostrata	American eel	X	X	
Alosa chrysochloris	Skipjack herring	X	?	?
Dorosoma cepedianum	Gizzard shad	X	X	X
Dorosoma petenense	Threadfin shad	X	?	?
Esox americanus	Grass pickeral	X	X	X
Hybognathus hayi	Cypress minnow	X	X	?
Hybognathus nuchalis	Mississippi silvery minnow	X	X	?
Notemmigonus crysoleucas	Golden shiner	X	X	X
Notropis amnis	Pallid shiner	X	?	
Notropis atherinoides	Emerald shiner	X	X	X
Opsopoeodus emiliae	Pugnose minnow	X	X	X
Lythrurus fumeus	Ribbon shiner	X	X	X
Notropis maculatus	Taillight shiner	X	X	X
Cyprinella venusta	Blacktail shiner	X	X	X
Pimephales vigilax	Bullhead minnow	X	X	X
Carpiodes carpio	River carpsucker	X	X	X
Erimyzon sucetta	Lake chubsucker	X	?	?
Ictiobus bubalus	Smallmouth buffalo	X	X	?
Ictiobus cyprinellus	Bigmouth buffalo	X	X	?
Ictiobus niger	Black buffalo	X	X	?
Minytrema melanops	Spotted sucker	X	X	X
Ictaluras furcatus	Blue catfish	X	X	?
Ameiurus natalis	Yellow bullhead	X	X	X
Ictaluras punctatus	Channel catfish	X	X	X
Noturus gyrinus	Tadpole madtom	X	X	X
Pylodictis olivaris	Flathead catfish	X	X	X
Aphreadoderus sayanus	Pirate perch	X	X	X
Fundulus chrysotus	Golden topminnow	X	?	?
Fundulus dispar	Northern starhead minnow	X	?	?
Fundulus olivaceus	Blackspotted topminnow	X	X	X
Gambusia affinis	Mosquitofish	X	X	X
Morone mississippiensis	Yellow bass	X	?	?
Centrarchus macropterus	Flier	X	X	X
Lepomis cyanellus	Green sunfish	X	X	X
Lepomis gulosus	Warmouth	X	X	X
Lepomis humilis	Orangespotted sunfish	X	X	?
Lepomis macrochirus	Bluegill	X	X	X
Lepomis marginatus	Dollar sunfish	X	X	?
Lepomis megalotis	Longear sunfish	X	X	?
Lepomis microlophus	Redear sunfish	X	?	?
Lepomis punctatus	Spotted sunfish	X	X	?
Lepomis symmetricus	Bantam sunfish	X	X	X
Micropterus salmoides	Largemouth bass	X	X	X
Pomoxis annularis	White crappie	X	X	X
Pomoxis nigromaculatus	Black crappie	X	X	X
Elassoma zonatum	Banded pygmy sunfish	X	X	X
Etheostoma asprigene	Mud darter	X	X	X
Etheostoma chlorosomum	Bluntnose darter	X	X	X
Etheostoma gracile	Slough darter	X	X	X
Etheostoma proeliare	Cypress darter	X	X	X
Etheostoma stigmaeum	Speckled darter	X	X	X
Percina caprodes	Logperch	X	X	X
Percina shumardi	River darter	X	X	X
Aplodinotus grunniens	Freshwater drum	X	X	X

Table 6. Selected common reptile and amphibian species present in bottomland hardwood forest (BLH) habitat types in the Bayou Meto Basin, Arkansas. Species were selected from range maps and habitat descriptions of several field guides.

Species	Common name	Habitat: Cypress/ tupelo	Low BLH	Inter-mediate BLH	High BLH
Chelydra serpentina	Common snapping turtle	X	X		
Macroclemys temminickii	Alligator snapping turtle	X	X		
Sternotherus carinatus	Razorback musk turtle	X			
Kinsosternon subrubrum	Mississippi mud turtle	X	X		
Graptemys kohnii	Mississippi map turtle	X			
Graptemys pseudogeographica	False map turtle	X			
Trachemys scripta elegans	Red-eared slider	X			
Pseudemys concinna	River cooter	X			
Chrysemys picta	Painted turtle	X			
Deirochelys reticularia	Chicken turtle	X			
Apalone mutica	Smooth softshell	X			
Apalone spinifera	Spiny softshell	X			
Cnemidophorus sexlineatus	Racerunner		X	X	X
Scinella lateralis	Ground skink		X	X	X
Eumeces laticeps	Five-lined skink			X	X
Nerodia cyclopion	Mississippi green water snake	X	X	X	X
Nerodia rhombifer	Diamond back water snake	X	X	X	X
Nerodia erythrogaster	Yellowbelly water snake	X	X	X	X
Nerodia fasciata	Broad-banded water snake	X	X	X	X
Regina grahamii	Graham's crayfish snake	X	X		
Thamnophis sirtalis	Eastern garter snake			X	X
Thamnophis proximus	Western ribbon snake				X
Heterodon platirhinos	Eastern hognose snake				X
Farancia abacura	Mud snake	X	X	X	X
Coluber constrictor	Black racer		X	X	X
Opheodrys aestivus	Rough green snake		X	X	X
Elaphe obsoleta	Rat snake		X	X	X
Lampropeltis getula	Speckled king snake		X	X	X
Agkistrodon controtix	Southern copperhead				X
Agkistrodon piscivorus	Western cottonmouth	X	X	X	X
Sistrurus miliarius	Western pygmy rattlesnake				X
Necturus maculosus	Mudpuppy	X			
Amphiuma tridactylum	Three-toed amphiuma	X			
Siren intermedia	Lesser siren	X			
Ambystoma opacum	Marbled salamander	X	X	X	X
Ambystoma texanum	Smallmouth salamander	X	X	X	X
Ambystoma maculatum	Spotted salamander	X	X	X	X
Notophthalmus viridescens	Eastern newt	X	X	X	X
Bufo americanus	American toad		X	X	X
Bufo woodhousii	Woodhouse's toad	X	X	X	X
Acris crepitans	Northern cricket frog	X	X	X	X
Hyla cinerea	Green treefrog	X	X	X	X
Hyla versicolor	Common gray treefrog	X	X	X	X
Hyla chrysolscelis	Cope's gray treefrog	X	X	X	X
Pseudacris crucifer	Spring peeper	X	X	X	X
Pseudacris triseriata	Upland chorus frog	X	X	X	X
Gastrophrine carolinensis	Eastern narrowmouth toad	X	X	X	X
Rana catesbiana	Bullfrog	X	X	X	X
Rana clamitans	Bronze frog	X	X	X	X
Rana utricularia	Southern leopard frog	X	X	X	X
Rana palustris	Pickeral frog	X	X	X	X

Table 7. Selected common native mammal species present in bottomland hardwood forest (BLH) habitat types in the Bayou Meto Basin, Arkansas. Species were selected from range maps and habitat descriptions in Lowery (1974), Sealander (1979), and Cochran (1999).

		Habitat			
Species	Common name	Cypress/ tupelo	Low BLH	Intermediate BLH	High BLH
Didelphis virginiana	Opossum		X	X	X
Blarina brevicauda	Short-tailed shrew	X	X	X	X
Myotis lucifugus	Little brown bat	X	X	X	X
Myotis austroriparius	Southeastern myotis	X	X	X	X
Lasionycteris noctivagans	Silver-haired bat		X	X	X
Pipistrellus subflavus	Eastern pipistrelle	X	X	X	X
Eptesicus fuscus	Big brown bat	X	X	X	X
Lasiurus borealis	Eastern red bat		X	X	X
Lasiurus seminolus	Seminole bat	X	X	X	X
Nycticeius humeralis	Evening bat	X	X	X	X
Corynorhinus rafinesquii	Rafinesque's big-eared bat	X	X	X	X
Dasypus novemcinctus	Nine-banded armadillo			X	X
Sylvilagus floridanus	Eastern cottontail				X
Sylvilagus aquaticus	Swamp rabbit	X	X	X	X
Sciurus carolinensis	Eastern gray squirrel	X	X	X	X
Sciurus niger	Eastern fox squirrel	X	X	X	X
Glaucomys volans	Southern flying squirrel	X	X	X	X
Castor canadensis	American beaver	X	X	X	X
Oryzomys palustris	Marsh rice rat	X	X	X	X
Peromyscus leucopus	White-footed mouse		X	X	X
Peromyscus gossypinus	Cotton mouse		X	X	X
Peromyscus nuttalli	Golden mouse		X	X	X
Microtus pinetorum	Woodland vole				X
Ondatra zibethicus	Muskrat	X			
Canis latrans	Coyote		X	X	X
Urocyon cinereoargenteus	Gray fox				X
Ursus americanus	Black bear	X	X	X	X
Procyon lotor	Racoon	X	X	X	X
Mustela frenata	Long-tailed weasel			X	X
Mustela vison	Mink	X	X		
Mephitus mephitus	Striped skunk	X	X	X	X
Lutra canadensis	River otter	X	X		
Lynx rufus	Bobcat		X	X	X
Odocoileus hemionus	White-tailed deer	X	X	X	X

Table 8. Selected common bird species present in bottomland hardwood forest (BLH) habitat types in the Bayou Meto Basin, Arkansas. Species were selected from range maps, habitat descriptions of several field guides, data in Wakeley and Roberts (1996), and personal communication with W. Barrow. Y= year-round resident, S = summer breeding species, W= winter resident, and E = extirpated. Birds that stop-over only during migration are not included.

Species	Common name	Habitat			
		Cypress/ tupelo	Low BLH	Intermediate BLH	High BLH
Botaurus lentiginosus	American bittern	W	W		
Ixobrychus exilis	Least bittern	S	S		
Nycticorax nycticorus	Black-crowned night-heron	S	S	S	
Nycticorax violacea	Yellow-crowned night-heron	S	S	S	
Butorides virescens	Green heron	S	S		
Egretta caerulea	Little blue heron	S	S		
Bulbulcus ibis	Cattle egret	S	S		
Egretta thula	Snowy egret	S	S		
Ardea alba	Great egret	S	S		
Ardea herodias	Great blue heron	S	S		
Ictinia mississippiensis	Mississippi kite	S	S	S	S
Haliaeetus leucocephalus	Bald eagle	Y	Y	Y	Y
Accipiter striatus	Sharp-shinned hawk	W	W	W	W
Accipiter cooperii	Cooper's hawk	Y	Y	Y	Y
Buteo lineatus	Red-shouldered hawk	Y	Y	Y	Y
Buteo jamaicensis	Red-tailed hawk	Y	Y	Y	Y
Falco sparverius	American kestrel	Y	Y	Y	Y
Meleagris gallopava	Wild turkey	Y	Y	Y	Y
Scolopax minor	American woodcock		W	W	Y
Coccyzus americanus	Yellow-billed cuckoo		S	S	S
Otus asio	Eastern screech owl	Y	Y	Y	Y
Bubo virginianus	Great horned owl	Y	Y	Y	Y
Strix varia	Barred owl	Y	Y	Y	Y
Chordeiles minor	Common nighthawk			S	S
Archilochus colubris	Ruby-throated hummingbird	S	S	S	S
Ceryle alcyon	Belted kingfisher	Y			
Melanerpes erythrocephalus	Red-headed woodpecker		Y	Y	Y
Melanerpes carolinus	Red-bellied woodpecker		Y	Y	Y
Sphyrapicus varius	Yellow-bellied sapsucker	W	W	W	W
Picoides pubescens	Downy woodpecker		Y	Y	Y
Picoides villosus	Hairy woodpecker		Y	Y	Y
Colaptes auratus	Northern flicker		Y	Y	Y
Dryocopus pileatus	Pileated woodpecker	Y	Y	Y	Y
Contopus virens	Eastern wood-pewee	S	S	S	S
Empidonax virescens	Acadian flycatcher	S	S	S	S
Sayornis phoebe	Eastern phoebe	Y	Y	Y	Y
Myiarchus crinitus	Great crested flycatcher	S	S	S	S
Tyrannus tyrannus	Eastern kingbird		S	S	S
Vireo griseus	White-eyed vireo		S	S	S
Vireo flavifrons	Yellow-throated vireo	S	S	S	S
Vireo olivaceous	Red-eyed vireo	S	S	S	S
Vireo bellii	Bell's vireo		S	S	
Vireo gilvus	Warbling vireo			S	S
Cyanocitta cristata	Blue jay	Y	Y	Y	Y
Corvus ossifragus	Fish crow	Y	Y	Y	Y
Stelgidopteryx serripennis	Northern rough-winged swallow	S			S
Baeolophus bicolor	Tufted titmouse	Y	Y	Y	Y
Poecile carolinesis	Carolina chickadee	Y	Y	Y	Y
Troglodytes troglodytes	Winter wren	W	W	W	W
Thryothorus ludovicianus	Carolina wren	Y	Y	Y	Y
Regulus satrapa	Golden-crowned kinglet	W	W	W	W
Regulus calendula	Ruby-crowned kinglet		W	W	W

Table 8, *cont'd.*

Species	Common name	Habitat: Cypress/ tupelo	Low BLH	Intermediate BLH	High BLH
Polioptila caerulea	Blue-gray gnatcatcher	S	S	S	S
Catharus guttatus	Hermit thrush		W	W	W
Parula americana	Northern parula	S	S	S	S
Dendroica pensylvanica	Chestnut-sided warbler	S	S	S	S
Dendroica coronada	Yellow-rumped warbler	W	W	W	W
Dendroica discolor	Prairie warbler		S		
Oporonis formosus	Kentucky warbler		S	S	S
Wilsonia citrina	Hooded warbler		S	S	S
Mniotilta varia	Black-and-white warbler	S	S	S	S
Dendroica petechia	Yellow warbler	S			
Limnothlypis swainsonii	Swainson's warbler			S	S
Seiurus motacilla	Louisiana water thrush	S	S		
Geothlypis trichas	Common yellowthroat		S		
Icteria virens	Yellow-breasted chat		S		
Setophaga ruticella	American redstart	S	S	S	S
Piranga rubra	Summer tanager	S	S	S	S
Piranga olivacea	Scarlet tanager		S	S	S
Melospiza georgiana	Swamp sparrow			W	W
Zonotrichia albicollis	White-throated sparrow			W	W
Junco hyemalis	Dark-eyed junco		W	W	W
Guiraca caerulea	Blue grosbeak	S	S	S	S
Passerina cyanea	Indigo bunting			S	S
Passerina ciris	Painted bunting			S	S
Icterus spurius	Orchard oriole		S	S	S
Icterus galbula	Baltimore oriole		S	S	S
Carduelis tristis	American goldfinch		Y		

buffers species against periodic reductions in specific foods (e.g., acorn failure). Many species capitalize on major system events, especially flooding, to obtain new, previously unavailable, or concentrated prey. For example, wood ducks and mallards move quickly to newly flooded Intermediate and High BLH areas to forage on acorns, terrestrial insects, and seeds from herbaceous plants. Raptors and bobcats quickly move to higher ridges during floods to escape flooding and forage on concentrated small mammals. Black bear movements among BLH habitats are closely linked to abundance of seasonal fruits.

While fish, amphibian, and reptile species are residents in BLH, many bird and mammal species are present only seasonally. For example, about 130 species of songbirds and woodpeckers regularly use BLH but only about 1/4 of the total are: 1) residents, 2) migrate to BLH in summer to breed, 3) migrate to BLH to winter, or 4) use BLH only in spring and fall migration (Heitmeyer et al. 2004). Overall, >75% of bird species using the area are present only during certain seasons. Timing of movement to the area/region, and annual events engaged in while there, coincide with pulses of specific resources (mostly food) in the system (Fig. 9). The most notable animals that are seasonally present are waterbirds, especially ducks.

Mallards are the most abundant duck to use Bayou Meto WMA, and are present primarily from mid-November to late-February. Historically, early migrants arrived in late fall when BLH habitats began to flood as water levels increased in local streams (Table 2). These flood events gradually inundated BLH habitats and made invertebrates, seeds, and acorns available. These abundant and newly available foods allowed mallards to forage efficiently on high energy foods (acorns and seeds) to replenish nutrients used in migration to the area and to obtain high protein foods (aquatic insects) needed to initiate and complete the pre-alternate molt (Fig. 11). Mallards form pair bonds in late fall and early winter. Acorns provide lipids for fat storage and courtship activities that are energetically expensive (e.g., courtship flights) (Heitmeyer 1988). Following

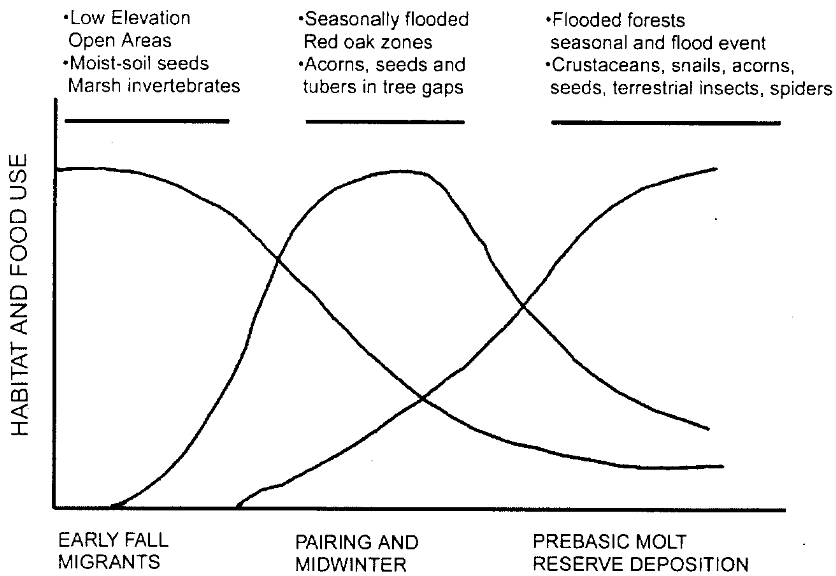


Figure 11. Relationships of seasonal food and habitat use by mallards in bottomland hardwood wetlands during the nonbreeding season (from Heitmeyer 2001).

pair formation, females initiate the prebasic molt which takes 6 to 7 weeks to complete. During prebasic molt females seek high protein foods such as forest crustaceans (isopods, amphipods, crayfish, etc.) to meet high protein requirements of feather production (feathers are >90% protein) (Heitmeyer 1987) which they obtained mainly in Intermediate and High BLH areas. During latter stages, or following completion, of the prebasic molt, female mallards begin storing large quantities of fat and protein reserves in body tissues to prepare for spring migration and reproductive activities culminating in egg production on northern breeding grounds (Heitmeyer 1988).

Winter flooding and food availability for mallards at Bayou Meto and throughout the MAV were seasonally and annually dynamic. Furthermore, gradual flooding within extensive BLH areas provide specific resources (acorns, forest crustaceans, etc.) at key periods from fall through spring and allow mallards to efficiently complete annual events and avoid extended resource shortages or overlapping nutrient-demanding periods. When BLH areas are modified either by destruction or fragmentation, or with modified water regimes, resources for mallards (and other fish and wildlife species) are reduced and these resource reductions have detrimental consequences to populations. Maintaining species diversity and productivity in BLH areas such as Bayou Meto WMA requires: 1) large contiguous patches of BLH that include all habitat types, 2) areas that provide temporal and spatial refuge from excessive disturbance and predation, 3) natural hydrological regimes that support native plant communities and seasonal food resources, and 4) functional detrital bases (Heitmeyer et al. 2004).

Despite the high productivity and diversity of BLH systems, many species using BLH have relatively high amplitude population dynamics caused by major episodic events, especially flooding. For these species (such as mice, muskrat, wading birds, waterfowl) there may be crucial points in the low ebbs of population cycles that can cause significant reduction (and perhaps extirpation) in species occurrence, at least locally such as within Bayou Meto WMA. "Thresholds" of these points are not known, but may be critical for maintaining resident species that rely solely on WMA resources. Some species using the WMA, especially those present in winter (when resources are most limited) may be periodically limited (e.g., mallards) by conditions associated with annual system dynamics. For these species, changes to system function and process (e.g., water regimes) may be highly detrimental and at the very least must be documented and understood.

CHANGES TO THE PRESETTLEMENT BAYOU METO ECOSYSTEM

Extensive changes have occurred in land use, habitat composition, hydrology, topography, and fish and wildlife communities in the Bayou Meto Basin since the Presettlement period. A complete review of these changes is provided in Heitmeyer et al. (2002). Specific changes that directly impact the WMA are summarized below.

Regional Landscape Changes

Native Vegetation Communities. — Over 85% of native vegetation communities in the Bayou Meto Basin have been destroyed since the Presettlement period (Heitmeyer et al. 2002). Percentage loss is >95% for prairie grassland, seasonal herbaceous wetland, savanna, and High BLH habitat types but <50% for Cypress/Tupelo and Riparian habitats. The majority of these native habitats were converted to agricultural land. While Bayou Meto WMA historically did not contain prairie or savanna habitats, its ca. 32,000 acres of BLH represented almost 5% of the total historic area of BLH in the Basin (ca. 690,000 acres). Because of regional habitat loss, remnant BLH in Bayou Meto WMA now comprises 28.6% of remaining BLH in the Basin (Table 9). Low and Intermediate BLH account for most remaining forest in the WMA and represent 31% of the remaining habitat of these types in the Basin.

In addition to extensive loss of BLH throughout the Bayou Meto Basin, remnant tracts are small, disjunct, and highly fragmented. The 2 exceptions are BLH habitats in or near Bayou Meto WMA. The largest contiguous tract of BLH is within and immediately adjacent to the WMA (about 45,000 acres). A second relatively large (ca. 10,000 acres) tract of BLH is located about 5 miles north of the WMA along the Bayou Meto drainage.

Destruction of some BLH on higher elevations along the Arkansas River in the Bayou Meto Basin apparently began in the 1880s (McNeilly 2000), but intense timber harvest throughout the Basin did not begin until 1900-20 (Holder 1970, Gandy et al. 2000). At this time large tracts of forest were purchased by lumber companies that established numerous sawmills to process the timber. One large lumber operation was operated within the current Bayou Meto WMA by the Long Bell Lumber Company, which had a large mill and company village located on Section 7 of Wabbaseka Bayou (near the current site of the Long Bell access parking lot). Other smaller operations were scattered throughout the WMA. Most of the large Presettlement trees, especially in High and Intermediate BLH in the Basin were cut by the late 1920s, with the exception of low elevation areas. A large flood along the Arkansas and Mississippi rivers in 1927 devastated many local lumber operations, including the Long Bell Company which discontinued activities in the WMA immediately after the flood. About 85-90% of BLH on low elevation Perry clay soils (which comprises 59% of WMA lands, Table 1)

Table 9. Area (% of total) of bottomland hardwood (BLH) habitats in the Bayou Meto Basin and Bayou Meto Wildlife Management Area, Arkansas, 2003.

Habitat type	Current in Basin[a]	Current in WMA[b]
Cypress/Tupelo	5,000	1,291 (25.8)
Low and Intermediate BLH[c]	96,500	28,064 (31.0)
High BLH	11,000	1,271 (11.6)
Natural Levee	2,000	397 (19.8)
Total	108,500	31,023 (28.6)

[a]Area is in acres (Heitmeyer et al. 2002).

[b]from Pagan et al. 2002.

[c]combined.

in the Bayou Meto Basin were still forested by 1921; most of this was Low BLH (Knobel 1921).

After the 1927 flood, many small lumber operations continued to exist in Bayou Meto WMA and their cutting, combined with earlier cutting from 1900-1927 by the Long Bell Company, caused most BLH stands in the WMA to be "high-graded" and the largest and highest quality trees were removed by the time AGFC initially purchased parts of the WMA in 1948. Lands initially purchased for the WMA contained deed restrictions and provisions that reserved rights for the selling landowner to harvest all timber >12" dbh for specified periods of time, usually 10 years. Most of these timber cutting rights were not exercised completely and some portions of the standing timber was purchased from original landowners by AGFC. Some select timber harvest, including cuts for management purposes, continued on the WMA until the 1980s (Griffee 2002).

Extensive timber cutting and clearing land for agriculture in the Bayou Meto Basin outside of the WMA occurred from the mid-1950s to about 1975 (Holder 1970, MacDonald et al. 1979). Arkansas State Act 153 passed in 1955 increased taxation on forest lands compared to cropland causing many landowners to clear forests. Increased commodity prices, especially soybeans in the early 1970s, stimulated further clearing. Almost 160,000 acres of BLH was cleared in the Bayou Meto Basin from 1950-90 (Gandy et al. 2000). By 1990, BLH in and around Bayou Meto WMA became largely isolated from other small and highly fragmented patches of BLH in the Bayou Meto Basin. With the exception of BLH in duck clubs, most land adjacent to the WMA is intensively farmed, primarily in a rice-soybean rotation. The WMA has 88 miles of exterior boundary and bordering lands are in >100 separate ownerships.

Topography and Hydrology. — The topography and hydrology of the Bayou Meto Basin and the WMA have been extensively altered. Increased timber harvest and agricultural production in the Bayou Meto Basin in the early 1900s created a need for roads and railroads to move products and labor (Griffee 2002). Railroads were built to Stuttgart and DeWitt in the early 1890s, and by 1893 an extension of the Stuttgart-Arkansas Railroad was constructed to the village of Bayou Meto (Griffee 2002). Subsequent railroad lines were built and operated in the lower part of the Bayou Meto Basin by the Walstein Company (Pine Bluff to Clayton Cypress Swamp on the west bank of Bayou Meto) and St. Louis Southwestern Railroad (former Stuttgart-Arkansas Railroad lines). Many lines were abandoned after the 1927 flood and railbeds and bridges subsequently were used as roads by local residents. Early railbeds often were constructed as much as 6 feet above ground surface and disrupted water flow across the low Bayou Meto Basin, often slowing or rerouting drainage in this relatively flat landscape.

In addition to creating demands for railroad and road/bridge construction, increasing lumber and agricultural activities in the lower Bayou Meto Basin also created a need for further land clearing and drainage. Large-scale levee and ditch work, to alleviate flooding problems and provide access and travelways, began in the Bayou Meto area in the early 1900s. The largest organized effort to drain lands and provide some flood control was the establishment of the Farelly Lake Levee and Drainage District in 1913. This district included 99,852 acres in Arkansas and Jefferson counties in the lower part of the Bayou Meto Basin. The district taxed landowners and constructed a levee at the confluence of Bayou Meto and the Arkansas River with the intention of reducing and preventing backwater flooding from the Arkansas River into the Bayou Meto Basin. Benefits to landowners from this initial levee were not substantial and increasing tax burdens eventually caused the District to go into receivership in the early 1920s.

In 1919, the Arkansas General Assembly enacted Act 658 which created the 53,751 acre Salt Bayou Drainage District with the intent of channelizing Salt Bayou and excavating other local drainage ditches to relieve flooding in Lonoke, Arkansas, and Jefferson counties. By 1923, Salt Bayou was channelized in 2 parallel ditches (double ditch) and extended north to Bakers Bayou. To the south, the double Salt Bayou ditches extended 8 miles south into the current WMA and connected with Little Bayou Meto in the Vallier School area. This work increased water flow in Salt Bayou and Little Bayou Meto within the WMA and generally increased flooding in the lower basin. Consequently, in 1923 the U.S. Army Corps of Engineers awarded a contract to reroute Bayou Meto and construct a floodgate near the former mouth of Bayou Meto to keep the Arkansas River from backing into the lower Bayou Meto Basin, yet allow drainage of Bayou Meto during lower flows on the Arkansas. The floodgate construction also caused additional rail spur lines, roads, bridges, and levees to be built in the region. The floodgate was completed in 1929 and the old channel was filled in and a levee built across it. The current structure consists of three 22.5 x 32 foot gated culverts at river mile 66.

Following construction of the Bayou Meto floodgate, an additional floodgate structure was built at the mouth of Little Bayou for a similar purpose of prohibiting Arkansas River backwater floods into the Bayou Meto Basin. This structure currently includes two 12 x 32 foot gated culverts at river mile 82. In the 1970s an old slough (locally called the wasteways diversion ditch) was excavated to connect Little Bayou Meto and Bayou Meto and redirect some drainage flows from Little Bayou Meto into Bayou Meto.

Mainstem levees were constructed and subsequently enlarged along the Arkansas River from 1940-1970. Other major changes occurred following the construction of the McClellan-Kerr Arkansas River Navigation System which constructed 17 locks and dams on a 445-mile stretch of the Arkansas River from the mouth upstream. In the Bayou Meto Basin, 4 locks and dams were built from 1958 to 1969 and they reduced seasonal and annual variation in Arkansas River flows.

The Salt Bayou double ditches were cleaned and the western ditch substantially enlarged in 1958. This clean-out extended 8 miles into the Bayou Meto WMA and greatly increased flow and sedimentation in the WMA. In 1968-69 these ditches were dredged again and this dredging coupled with other regional drainage projects caused water velocity, volume, sedimentation, and flood duration to increase greatly in the WMA and lower Bayou Meto Basin.

In addition to large levee, ditch, and water-control projects, hundreds of miles of ditches have been dug in the Bayou Meto Basin that redirect surface water flow around and into Indian, Salt, and Wabbaseka bayous. Major man-made canals include the extended Salt Bayou double ditches, Buffalo Ditch, Big Ditch, Main Canal, and Indian Bayou Ditch. Collectively, these ditches and canals accelerate water flow through the northern 2/3 of the Bayou Meto Basin while increasing water flow and flood potential in the southern 1/3. This runoff tends to "pond" water for extended periods in the vicinity of the current WMA in winter and spring when local precipitation and runoff is greatest.

Ironically, while flooding of the lower Bayou Meto Basin and within the WMA have increased over time, annual stream flows in the Basin generally are reduced and have somewhat different seasonal flows from historic periods. Many tributaries to Bayou Meto now are reduced to intermittent flow during summer and occasionally dry completely. Over 20 weirs are present in Bayou Meto alone; these are used to hold water in pools that are pumped for agricultural irrigation in summer. At times the AGFC had interest in 2 of these dams, with the intent of providing water to WMA in fall and winter. Streamflow in Bayou Meto is highly variable and mean annual discharge now is very low in some years (Arkansas Soil and Water Conservation Commission 1988). Some increase in stream flows occurs in August and early September when water is drained from local rice fields, but these flows quickly diminish in early fall. Reductions in flows of Bayou Meto and other drainages into the WMA alter timing of runoff and availability of water for management, especially in early fall.

Water quality also has been degraded in the Bayou Meto drainage. Turbidity as high as 27,000 NTU now occur in Bayou Meto and about 1/2 of dissolved oxygen measurements in Bayou Meto are less than state standards (Arkansas Soil and Water Conservation Commission 1988). Nitrogen and phosphorus concentrations in Bayou Meto are occasionally high as are concentrations of cadmium, copper, selenium, iron, and manganese. In the 1970s, Bayou Meto was contaminated by dioxin from Vertac Chemical, Inc. near Jacksonville, AR after metal drums buried on site began to leak. Dioxin concentrations have diminished since then but dioxin residues remain in some stretches of the bayou.

Local topography has been altered throughout the Bayou Meto Basin from: 1) construction of roads, levees, railbeds, and ditches; 2) siltation and filling of stream channels an natural depressions; 3) construction of fish ponds, irrigation reservoirs, and GTRs on duck clubs and Bayou Meto WMA; 4) leveling agricultural lands; and 5) urban construction projects. Each of these activities restricts and diverts overland water flows further altering flooding and drainage patterns in the Basin.

Fish and Wildlife Populations. — Few quantitative records of historic fish and wildlife populations exist for the Bayou Meto Basin. Systematic surveys of select species were not initiated in Arkansas until the 1950s (Holder 1951) and sampling has been discontinuous since that time. Nonetheless, certain information suggests trends in species and population levels over time.

The diversity of fish species in the Bayou Meto watershed has been reduced from 79 species to 64 species from the 1960's to the early 1990s (Ryckeley 2000). Loss of riparian and BLH corridors along streams has increased sediment and temperatures in bayous and negatively affected species that need relatively clear cool water such as top minnows, sunfish, bass, and crappie. In-stream flows are reduced in summer because stream water is pumped for agricultural irrigation; intermittent flows eliminate riffle habitats and concentrate fish in relatively stagnant pools that may concentrate prey and reduce species that require running water. Dominant fish in small streams and bayous now are mosquito fish, carp, buffalo, gar, bowfin, and some white crappie and largemouth bass.

Little is known about population trends of amphibians, reptiles, mussels, and invertebrates in bayous of BLH habitats in the Bayou Meto Basin. Recent sampling failed to find mussel populations in Crooked Creek, Bayou Two Prairie, or Wabbaseka Bayou, but limited numbers remain in Salt and Indian bayous (Miller and Payne 2002).

Several species of birds and mammals now are extirpated from the Bayou Meto Basin including bison, mountain lion, prairie chicken, red wolf, Carolina parakeet, and passenger pigeon (Arkansas Game and Fish Commission 1998). Only a few black bears now are present in the lower end of the Basin including the WMA, but apparently they were abundant until the early 1900s. Basin-wide, numbers of many large furbearers such as otter, beaver, and bobcat are reduced, but locally, numbers on Bayou Meto WMA may be greater than historic levels because the area contains the largest remaining tract of BLH and because large areas of semipermanent and permanent water conditions exist. The extensive ditch and levee system through the WMA creates many opportunities for beaver to impound water. New mammal species now found in the Basin include armadillo, ringtail, and nutria (Sealander and Heidt 1990).

Several bird species are in decline in BLH habitats throughout the MAV including the Bayou Meto Basin. Examples include Swainson's warbler which nest in giant cane interspersed in High BLH and on natural levees and black vultures which foraged throughout BLH habitats. Many forest birds that require large contiguous patches of BLH, such as cerulean warbler and Mississippi kites have greatly reduced populations (Mueller et al. 2000).

In general, waterbird numbers in the Bayou Meto Basin are reduced from historic levels, and some species have shown marked reduction in the last 2 to 3 decades. Mid-winter inventories of ducks in the Basin have gradually decreased from over 100,000 during the 1960s and 1970s to less than 50,000 in the 1990s (AGFC, unpublished records). Peak numbers of ducks (>90% mallards) counted in December and January on Bayou Meto WMA has declined from >70,000 in the early 1960s to <5,000 in 2001-2002

Acquisition and Development of Bayou Meto WMA

Acquisition of Bayou Meto WMA began in 1948 with initial purchases of 6035 acres from Brooks Henslee, 8369 acres from D.P. Marshall and 3318 acres from Gene Townsend (Griffee 2002). Soon after the initial purchases, the 2266-acre Buckingham Flats and 1305-acre Wrape Plantation were purchased from Ted Muller in 1948 and 1949, respectively. The WMA also obtained 2700 acres from forfeited lands administered by the State Lands Commission. In 1957, AGFC acquired 640 acres from Halowell Farms which included a 600-acre reservoir constructed in 1955-56. Acquisition of the Wrape Plantation and Halowell were made to provide sanctuary for waterfowl as required by the U.S. Fish and Wildlife Service Federal Aid Project which provided funds for these acquisitions. The last major land transaction on Bayou Meto WMA occurred in 1965 when AGFC obtained 600 acres in 2 tracts along Little Bayou Meto in the Beaver Dam Slough area from Harvey McGeorge's Cornerstone Farm and Gin Co. in exchange for 9 tracts totaling 595 acres on the western edge of the WMA. Several smaller land purchases, exchanges, and boundary settlements have occurred since that time. As of January 2001, the AGFC holds deeds on 31,490.6 acres in the WMA boundary. They also hold easements on certain flowage, roads, and access points. Thirteen legal easements involve WMA lands including an Arkansas Power and Light power line right-of-way, 4 levee construction and flowage areas, 3 private access routes, 4 AGFC access rights across private lands, and the use of the Halowell flood canal.

Following initial acquisitions, the AGFC began developments to impound water during fall and winter to provide public waterfowl hunting opportunity. Original plans called for impoundment of 13,000 acres of seasonal water at 179 feet amsl in a series of GTRs that would include exterior levees, water-control structures, and feeder canals. Also, the Wrape Plantation was to be leveed into compartments for crop and seed production. Development work began in 1949 with construction of levees to impound 2 "ponds" at the Wrape Plantation. In 1950, a dam was built at Buckingham Flats that included a levee and a 24 inch culvert. Also, in 1950 6.5 miles of Little Bayou Meto were cleaned (debris and sediment) to allow boat access into the interior of the area and to provide a flood and drain canal. In 1951, work began to build a levee and flood spillway structure on Vallier School road and by 1952 roads and levees were built along Vallier School (7 miles), Mulberry (3/4 mile), Wabbaseka (3 miles), and Benson Bridge (2 miles) roads. The primary water-control structure for impounding water in the area in the 1950s was the Lower Vallier structure located on Little Bayou Meto which provided flooding capability for Lower Vallier, Upper Vallier, and Government Cypress GTRs (Fig. 12). Later, small levees were built on Beaver Dam Slough and Bubbling Slough to impound additional water in the Beaver Dam Slough and Lower Vallier impoundments. The primary water source for flooding the GTRs was runoff from Little Bayou Meto and its tributaries. In 1953, Frazier Dam was built on Bayou Meto at mile 60 with the intent of diverting Bayou Meto water into the area via Dry Bayou. Fall and early winter flows in Bayou Meto generally were insufficient to back water through Dry Bayou. This dam was seldom effective as a flooding source unless high flood flows occurred, at which time the WMA was already inundated by backwater from Little Bayou Meto.

Most early development on the WMA was completed by 1955 and only sporadic small developments and repairs to existing structures and levees occurred on the area until the mid-1970s. By the early 1970s, the double Salt Bayou ditches had been dredged and enlarged twice and the volume of water and sediments flowing into the WMA had increased substantially and overwhelmed many of the older levees and water-control structures on the area. Also, levees, weirs, and water-control structures on adjacent lands, mostly duck clubs, further impeded drainage of WMA impoundments. An especially detrimental structure was a dam and levee constructed in the 1960s on Little Bayou Meto by the Swan Lake Duck Club. This levee held water on parts of the WMA for extended periods and delayed drainage of GTRs (Garver and Garver 1985). AGFC personnel began noticing extended flooding and especially slow drainage of GTRs in the early 1970s, especially in Government Cypress which had some surface flooding until late summer. Consequently, several development projects were initiated to help alleviate drainage problems on the WMA and reduce flooding on adjacent landowners. In 1972, a large drain structure was constructed on Five Forks Bayou to facilitate drainage from Lower Vallier. Other structures built in the 1970s and 1980s included larger water-control structures at Upper Vallier and Government Cypress.

An evaluation of hydrological problems on the WMA, mostly related to flooding and drainage problems on Little Bayou Meto, was completed in 1985 (Garver and Garver 1985). A compromise was eventually agreed upon whereby the Swan Lake levee was breached and not rebuilt. The old Beaver Dam Slough levee also was breached, and a new 1200 foot levee with concrete and wood stoplog water-control structure was built on Little Bayou Meto at Cannon Brake. The Cannon Brake structure was completed in 1995 and allowed flooding of about 5000 acres including 2160 acres of private land between the northern and southern parts of the WMA. Flowage easements from 13 landowners allowed flooding of their property by the Cannon Brake structure after late October. The original 8-hole water-control structure at Cannon Brake was incapable of discharging water quickly and the levee was damaged repeatedly. Subsequently, a 800 foot spillway was constructed on the levee in 2001 to relieve pressure and allow flood flows to drain (Garver, Inc., 2000a). Water-control structures in Little Bayou Meto in both Upper and Lower Vallier levees also were replaced and enlarged in 2001-2002 (Garver, Inc. 2000b).

The last GTR development on the WMA included construction of levees and water-control structures on the north end of the area. These developments created the Temple Island and Bear Bayou impoundments in 1980-82 and 1999-2001, respectively.

Following initial development of the Wrape Plantation, additional levees and ponds were constructed in the 1970s. In 1977, the Plantation system was reconfigured and a new pump station built. This development created 7 ponds with relatively independent water control using >60 water-control structures, 9200 feet of additional levee, 2000 feet of main levee along Bayou Meto, cleaning of 2500 feet of canal, and installation of an 18 inch lift pump to obtain water from Bayou Meto.

Halowell Reservoir has gone through several management and development stages since initial purchase. In 1959, the exterior levees of Halowell were raised 2 feet and water was permanently impounded for public fishing. In 1976, the reservoir

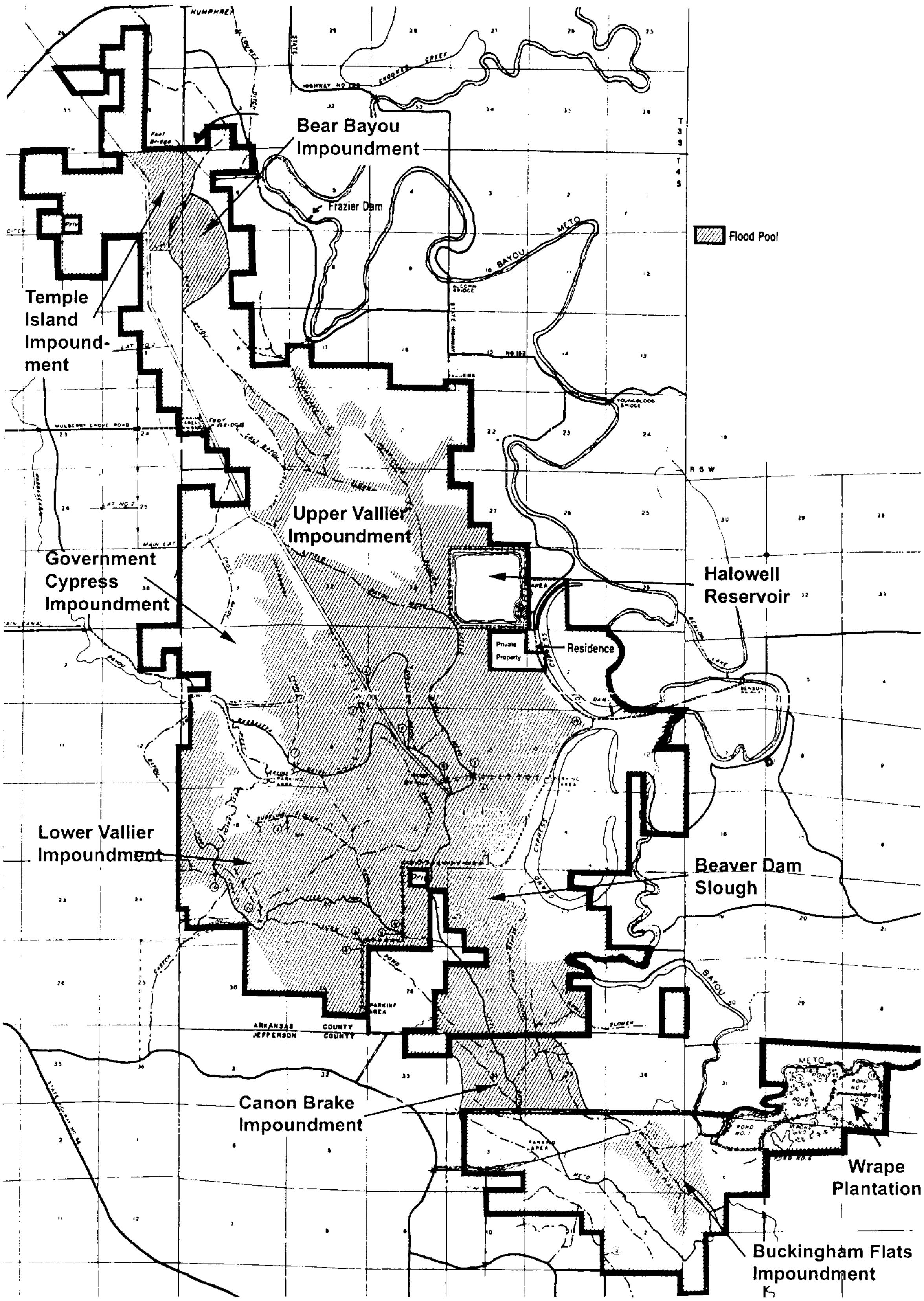


Figure 12. Location of greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas.

was drained, fishing was eliminated, and the reservoir was used for rice production and native vegetation management. In 1992, Halowell was renovated and in 1994, two interior levees were constructed for the purpose of managing the reservoir for moist-soil impoundments.

In addition to the larger developments outlined above, periodic smaller structural modifications of roads, levees, water-control structures, and ditches in the WMA have been made since initial acquisition. Today, the WMA has 16 all-weather roads covering 21 miles, 25 non-graveled roads covering 41 miles, 30 miles of levees, 1 large dam, 6 large stoplog structures, 83 gated pipes, and 3 relift pumps to manage ca. 13,600 acres of GTRs and 1137 acres of rest area in the Wrape Plantation and at Halowell Reservoir.

Impoundment Management

Management of Bayou Meto WMA following initial acquisitions and development simply sought to impound as much surface water as possible for waterfowl hunting in fall and winter. Timing and extent of flooding were determined largely by local fall/winter rainfall and streamflow in streams, primarily Little Bayou Meto, and by rudimentary water-control structures and levees. Generally, water-control structures were closed beginning in early fall (as early as 1 September) with the intent of capturing local surface water and stream runoff, and flooding as much of the impoundments as possible by the opening of duck hunting season (usually the 3rd week of November). During high flow events, water-control structures were partly opened to reduce flooding of private lands adjacent to the WMA. Structures typically were completely opened following the close of duck hunting seasons in late January. Prior to cleaning and enlargement of the double Salt Bayou ditches in the 1950s and 1960s, this water management regime caused variable floodup in fall depending on rainfall, with most impoundments not completely flooded until late November, followed by relatively rapid dewatering of impoundments in early spring. After enlargement of the double ditches (and other local and regional land changes including more levees, etc. on the WMA) the WMA was flooded earlier in fall and drained later in spring and summer creating altered hydrological conditions that degraded BLH stands. WMA personnel began noticing considerable dying of red oaks in the late 1970s and increasing mortality has occurred since.

Timber management on Bayou Meto WMA has been relatively limited with periodic cuts designed to create openings for food plots and to encourage regeneration (Griffee 2002). Most early cuts were small clear cuts, later cuts removed select trees and used uneven-aged management techniques. Most cutting in the WMA was discontinued in the mid-1980s.

Concerns about water scarcity in early fall, increased and extended flooding in winter and spring, sedimentation, continued damage to infrastructure, poor and delayed drainage, declining health of BLH stands, and decreased waterfowl use caused the AGFC to develop more comprehensive and integrated management plans for the WMA beginning in the late 1960s (e.g., Holder 1968). Revisions to this plan in the early 1990s identified specific water level management activities in each of the GTR impoundments, Halowell Reservoir, and the Wrape Plantation ponds (Arkansas Game and Fish Commission 1992). Current management regimes are described below:

Lower Vallier. — Lower Vallier GTR is the largest impoundment in Bayou Meto WMA flooding about 4525 acres at a floodpool of 179 foot amsl. It has 3.5 miles of levee on its southern boundary with a primary 150 foot stoplog water-control structure located on Little Bayou Meto. A 60-foot gated pipe is adjacent to the above structure. Other drain structures are located on Five Forks Bayou and Long Pond Slough. Lower Vallier receives water from Little Bayou Meto and its tributaries including Salt Bayou Ditch; Main Canal which receives water from Wabbaseka Bayou, Boggy Slough, Bubbling Slough, and Five Forks Bayou; and Long Pond Slough. Lower Vallier and Upper Vallier GTRs are the oldest impoundments on the WMA.

Flooding Lower Vallier seeks to reach a target floodpool of 179.5 foot by the beginning of duck season. The management plan followed since the early 1990s calls for water-control structures to be closed beginning 15 October and stoplogs are set at 178 foot. On 1 November, stoplogs are inserted to a 179 foot level and then raised to a 179.5 foot level on 15 November. Management of Lower Vallier controls water levels in Salt Bayou Ditch which backs water into Upper Vallier and Government Cypress impoundments. The Lower Vallier structure also controls seasonal water levels upstream on private lands in the Salt Bayou Ditch and Little Bayou Meto drainages. Consequently water levels in Lower Vallier are monitored closely to reduce flooding potential. During the first phases of flooding in Lower Vallier (when stoplogs are set at 178 foot) emergency dewatering of Lower Vallier occurs when 2 or more of the following conditions occur: 1) rainfall in the watershed area >2 inches, 2) water levels on Salt Bayou Ditch rise >3 feet in a 12-hour period, or 3) water level at the LV-1A gage is > 178.5 feet. Emergency dewatering historically was accomplished by removing some stoplogs in the Long Pond structure and was discontinued after flood waters crested and the LV-1A gage was below 178 feet. Levee and water-control structures on adjacent private lands now compromise drainage from Long Pond Slough and the Five Forks structure is the primary outlet currently used. After 1 November, when stoplogs are inserted to a 179 foot level, emergency dewatering occurs when water levels at Lower Vallier are >180 feet or rainfall exceeds 3 inches over a 12-hour period in the watershed area. At this time, both the Long Pond and Five Forks structures are partly opened to reduce water levels.

Dewatering Lower Vallier after the end of duck hunting season is accomplished by opening all control structures 1-15 February with the intent of reducing water levels to < 172 feet amsl by onset of budbreak (usually early March). Drainage to this level depends on rainfall, water levels in Little Bayou Meto, and whether floodgate structures on the Arkansas River at Bayou Meto and Little Bayou Meto are open. Generally large spring rains delay dewatering all of Lower Vallier until late spring. Drainage also is compromised in the Bubbling Slough area within Lower Vallier by an old abandoned levee and water-control structure constructed across the slough that now is filled with silt and is inoperable.

Since the mid-1990s, personnel at Bayou Meto WMA have monitored water levels at gauges on water-control structures in impoundments weekly (more often during rain and flood events). In recent winters a 179-foot water level in Lower Vallier has been reached by early November in every year except 1999-00 when this level was not attained until 16 December. In the wet year of 2001-02 a 179 foot water level occurred as early as 16 October. In all years, water level in Lower Vallier was still at 179 feet by mid-February and in 2000-01 water level was at 179 feet until mid-April. Low areas in Lower Vallier commonly hold surface water until late May in most years.

Upper Vallier. — Upper Vallier is about 3347 acres at a floodpool of 180 feet amsl. It has 12.1 miles of exterior levee to the south, west, and east. Water-control structures include a 100 foot concrete stoplog structure on Little Bayou Meto, 24- and 48-inch pipes at the mouth of Salt Lake, a 48-inch pipe 1 mile southeast of Salt Lake, and a 36-inch gated pipe 2.5 miles southeast of Salt Lake adjacent to Duck Pond Slough. Two other 36-inch pipes drain water into minor drainages.

The primary water source for flooding Upper Vallier is Salt Bayou Ditch and water backs into the impoundment when the Lower Vallier structure is closed on Little Bayou Meto. Small amounts of water from Marshal and Dry Bayou ditches and Hurricane Slough also flow into Upper Vallier as does drain water from private agricultural lands along the north and east side of the unit. Since the early 1990s management has attempted to increase water levels in Upper Vallier beginning 15 October to a target floodpool of 180 feet by the beginning of duck season. When water levels reach 176 feet at the Lower Vallier guage, water has the potential for backing northward into Upper Vallier. At this point, stoplogs are inserted in Upper Vallier structures to catch and hold this backwater. All structures are fully closed when water levels reach 180 feet. If high water and flooding on private land occurs, stoplogs on Upper Vallier structures are opened to drop water to 180 feet and then are reinserted when water levels drop below that point. An electric relift pump is located in the northwest corner of the Gill Levee that is adjacent to Upper Vallier and is used to pump water from private property into Upper Vallier at the landowners discretion.

Drainage of Upper Vallier occurs through Little Bayou Meto and Salt Bayou Ditch and can not occur until the Lower Vallier water-control structure is opened and water levels in Salt Bayou Ditch drop below 179 feet amsl. The goal for dewatering Upper Vallier is to remove all stoplogs by 15 February and reduce water levels to 176 feet by early March. At the end of the duck season stoplogs in the structure are partly removed to reduce water levels if possible and provide additional furbearer hunting opportunity.

Since the mid-1990s, a water level of 180 feet typically has occurred in Upper Vallier by early December, ranging from 26 November in 2000 to 22 December in 1999. This timing reflects water levels in Lower Vallier and winter rainfall and runoff. In recent years, full pool in Upper Vallier has been maintained until at least mid-late February in every year. In the wet spring of 2001, full pool occurred until nearly May and some surface water remained in the impoundment until July. Poor drainage below the Lower Vallier structure and some beaver activity have delayed drainage of Upper Vallier since the late 1960s. Typically, some surface water has been present in Upper Vallier, especially in low swales and internal sloughs, until at least mid-summer.

Government Cypress. — Government Cypress impoundment is ca. 1440 acres at a floodpool of 179.5 feet amsl. It has 2 miles of levee - a short portion to the south and a longer part to the east along Salt Bayou Ditch. The 2 levee parts are connected by a slightly higher natural ridge. Water-control structures include a 10 foot stoplog structure along Wabbaseka Bayou on the south, a 5-foot stoplog structure on the middle part of the east levee and a 36-inch gated pipe on the west side of Salt Bayou Ditch at the north end of the east levee.

Government Cypress receives floodwater from 3 sources. The largest source is backwater from Salt Bayou Ditch and it enters Government Cypress when the Lower Vallier structure is closed and water level in Salt Bayou Ditch is at least 176.5 feet. Wabbaseka Bayou empties into Cross Bayou and subsequently flows into the north end of Government Cypress. Small amounts of water also flow into the impoundment from Government Cypress Slough. Since the early 1990's, the management goal for flooding Government Cypress has been to back water into the impoundment via the Lower Vallier structures and then close stoplog structures beginning 1 November to attain floodpool level of 179.5 feet by the beginning of duck season. Flooding in parts of Government Cypress is earlier than in Upper Vallier because of runoff from Wabbaseka Bayou and because a low "sump" exists in the south-central part of the impoundment which traps surface water earlier and for longer periods through spring (and into summer in some years). Since the mid-1990s, water levels in Government Cypress have mirrored annual variation observed in Upper Vallier except that some surface water has been present in Government Cypress 1-2 weeks earlier (on average) than in Upper Vallier.

Drainage of Government Cypress occurs through Salt Bayou Ditch and is controlled by the Lower Vallier structure and water levels in Little Bayou Meto and Salt Bayou Ditch. Water-control structures draining into Salt Bayou Ditch are opened by 1 February with the intent of reducing water level to 175 feet by early March. Drainage of Government Cypress generally is slow and late in spring or early summer because of high water levels in Little Bayou Meto. Also, water that ponds in the lower sump in the south-central part of the impoundment does not drain well and is impeded by extensive beaver activity along levees, structures, and internal drainage paths. Since the 1960s, complete drainage of Government Cypress seldom has occurred until early summer and in some years surface water was present in the south-central portion year round. In recent years, extensive trapping has removed large numbers of beaver and efforts have made to clear obstructions and beaver dams to accelerate drainage. For example, in 2003, over 500 beavers were removed and most water was drained by 1 August despite summer 2003 being extremely wet.

Temple Island. — The Temple Island GTR impoundment has been operational since 1982 and floods 401 acres at a floodpool of 186 feet amsl. It is completely surrounded by 3.8 miles of levee and includes 5 water-control structures. The largest structure is a 48-inch gated pipe in the southeast corner that acts as the primary drain. The goal for flooding Temple Island is to increase water levels in early fall and reach a 186 foot level by the beginning of duck season. Temple Island is flooded by a relift pump that transfers water from Dry Bayou Ditch into the impoundment. Local rainfall has little effect on impoundment water levels except when water levels increase in Dry Bayou Ditch which provide enough water to allow pumping. From 1982 to the mid-1990s, water was pumped into Temple Island as early as late August when drain water from local rice fields flowed down Dry Bayou Ditch and provided adequate water for pumping. Since the mid-1990s, water has not been pumped into Temple Island until at least 1 October. Nonetheless, Temple Island had some flooding earlier than other impoundments on the WMA in most years.

Water drains from Temple Island down Bear Bayou and Salt Bayou Ditch. Because of its higher elevation, drainage of Temple Island is less constrained by water levels in Salt Bayou Ditch and Lower Vallier water-control structures than other GTRs on the WMA. In most years control structures on Temple Island have been opened in late January or early February with the intent of reducing water level to 181 feet by early March. Recently, drawdown dates have been staggered with drainage occurring as early as mid-January in some years and as late as mid-February in others.

Beaver Dam Slough/Cannon Brake. — Prior to construction of the Cannon Brake levee and water-control structure on Little Bayou Meto in the mid -1990s, the Beaver Dam Slough area was intermittently flooded by backwater flooding from Bayou Meto, runoff from Lower Vallier impoundment, and backwater from Little Bayou Meto caused by the

Swan Lake levee. The area contained about 700 acres of water at a floodpool of 179.5 feet amsl. Water was impounded primarily by a non-maintained half-mile levee constructed at the south border of the area in the mid-1960s. This levee crossed Beaver Dam Slough on the WMA and transected Little Bayou Meto and Long Pond Slough on privately-owned property. Two ungated pipes were located in this levee and drained the Beaver Dam Slough area when water levels in Little Bayou Meto and Long Pond Slough dropped below a 179 foot level. Consequently, flooding and draining of Beaver Dam Slough was highly variable among years depending on local rainfall and water levels in Little Bayou Meto. In recent years, the southwestern part of the Beaver Dam Slough area located west of Little Bayou Meto has drained late in spring or summer because of obstructions and high water in Little Bayou Meto and private levees and water-control structures on Long Pond Slough.

After construction of the Cannon Brake levee and structure, the private Swan Lake levee was breached and concurrently the old levee on Beaver Dam Slough was not maintained. Subsequently, the Cannon Brake structures flooded about 5000 acres, including the former Beaver Dam Slough area, at a floodpool of 177 feet amsl. About 2200 acres of this land is privately owned. Cannon Brake now is comprised of a 1.5-mile levee that connects with the privately owned Goose Lake levee on the east and high ground on the WMA to the west. Water-control structures include a 50-foot concrete stoplog structure at the juncture of Little Bayou Meto and the Wasteways Ditch and 2 gated pipes on the east end of the Goose Lake Levee. An 800-foot spillway that is 2 feet lower than the crown of the main levee is present on the east end of the WMA levee.

The goal for flooding Cannon Brake (and old Beaver Dam Slough area) is to increase water levels in late October and to drain the impoundment beginning 1 February. Timing of annual flooding of the GTR is contingent on receiving permission for flooding of private lands from 13 different landowners. Letters requesting permission to flood are sent to landowners on 1 October; if written permission is not received by 26 October it is assumed that crops have been harvested on affected private lands and the WMA will close water-control structures and begin flooding the area. Cannon Brake is flooded from Long Pond Slough, Five Forks Bayou, Wabbaseka Bayou, and Little Bayou Meto (and Salt Bayou Ditch). Limited flood water also drains into the area from West and Newton bayous and Beaver Dam and Swartz sloughs. Since its initial operation, Cannon Brake has reached floodpool of 177 feet as early as mid-November and it never reached this level in 1999-2000 (maximum level of 176 feet).

The goal for draining Cannon Brake is to reduce water level to 166.5 feet by early March. On 1 February all water-control structures are fully opened, however, drainage depends on water levels in Little Bayou Meto, the Wasteways Ditch, and Bayou Meto below the Cannon Brake structure. In recent years, water levels in the lower end of Little Bayou Meto have been extremely variable and often high in late winter and spring. Spring flows in Little Bayou Meto, the Wasteways Ditch and Bayou Meto drainages also have been obstructed by debris in the old channel and closure of the floodgate structures on Bayou Meto and Little Bayou Meto at their confluences with the Arkansas River. Water levels in Cannon Brake have not dropped below 177 feet until after 15 February since 1999 and was as late as mid-April in 2001. The west side of the old Beaver Dam Slough area (west of Little Bayou Meto) has been especially impacted by delayed drainage and water-control structures on adjacent private lands and has considerably later drainage than the rest of Cannon Brake.

Buckingham Flats. — Buckingham Flats impounds about 400 acres at a floodpool of 180 feet amsl. It is bordered by a naturally occurring ridge at 180 feet and the spoilbank of the Wasteways Ditch which functions as a levee on the northwest part of the impoundment. The only water-control structure is a 24-inch gated pipe located in the northeast part of the Wasteways Ditch spoilbank.

Buckingham Flats is flooded by a relift pump located on the north end of the Wrape Plantation which transfers water through a series of canals to an inlet point at the northeast side of the unit. When water in Bayou Meto and the Wasteways Ditch is high, water can be backed through the gated pipe structure to flood Buckingham Flats. The goal for flooding this impoundment is to increase water levels beginning in mid-October to a target floodpool level of 179 feet amsl by the beginning of duck season. Water subsequently is held in the impoundment until early February, when the gated pipe is opened and water drained into the Wasteways Ditch. An attempt is made to reduce water levels to <176 feet by late February. Water level management in Buckingham is mostly independent from water levels in other GTRs. The relift pump provides flood water when desired and drainage is usually accomplished by late February except in wet springs when water levels in Bayou Meto and the Wasteways Ditch are high.

Bear Bayou. — Bear Bayou impoundment lies southeast of Temple Island GTR and impounds about 1000 acres at a floodpool of 182 feet amsl. Bear Bayou has over 3 miles of levee to the east and south and is bordered by 3 miles of spoil bank from Salt Bayou Ditch on the west. Control structures include a 16-foot stoplog structure in the north, three 36-inch pipes with stoplogs in the drainage ditch on the southeast corner, and 24- and 48-inch pipes through the dam at Salt Lake where it empties into Salt Bayou Ditch.

Bear Bayou can be flooded by gravity flow from Dry Bayou Ditch if it contains adequate flow or by relifting water from Dry Bayou Ditch or from Salt Bayou Ditch at the southwest corner of Temple Island. When Section 404 permits were obtained to construct levees and make Bear Bayou a GTR, the USACE required that this GTR be kept dry 1 of every 3 years. In years when flooding occurs, the goal for Bear Bayou is to begin flooding the impoundment to a water depth of about 16 inches deep on 15 November or thereafter, depending on water availability. Drainage of Bear Bayou is staggered among years from mid-January to mid-February. Since initial operation in 2000, Bear Bayou was not flooded in 2001. In 2000 and 2002, floodpool was not achieved until early December and drainage occurred by late February.

Halowell Reservoir. — Halowell Reservoir contains about 600 acres at a floodpool of 181.5 feet amsl. It is enclosed by 4 miles of levee and 2 cross levees divide the reservoir from north to south. Seven stoplog and 2 gated-pipe structures control water levels in the reservoir. Flooding Halowell is accomplished by relifting water from Bayou Meto with a pump located about 1.25 miles north of the Hampton Research Center. This water is transferred underneath the road just south of the relift location and moved 50 feet to a transfer canal that drains into the northeast portion of the reservoir.

Halowell Reservoir has been managed as a waterfowl sanctuary since its purchase. In early years, the reservoir was flooded year round and water levels were held relatively constant by pumping water into the reservoir when waters receded. In 1976, the reservoir was drained and the area was managed for waterfowl food including rice and native vegetation. Since the mid-1990s, the reservoir has been managed as a seasonally-flooded impoundment for the purpose of providing moist-soil vegetation. Water levels in Halowell generally are increased beginning 1 September and are drained in spring or early summer depending on the desired moist-soil vegetation and disturbance management. Undesirable and woody plants, especially willow, Sesbania, and cocklebur are controlled by periodic extended flooding, burning, and chemical injection or spraying.

Wrape Plantation. — The Wrape Plantation includes 7 units separated by levees to provide agricultural grains and moist-soil foods for waterfowl (Fig. 13). Historically, the Wrape Planatation has not been hunted and has served as a waterfowl sanctuary. The 7 units contain about 600 acres of annually flooded habitat. A cooperative farming agreement was initiated on these units in 1988 to annually rotate rice and moist-soil plant production. Units 1-4 and 7 are rotated between rice and moist soil. Each of these units is farmed for rice for 2

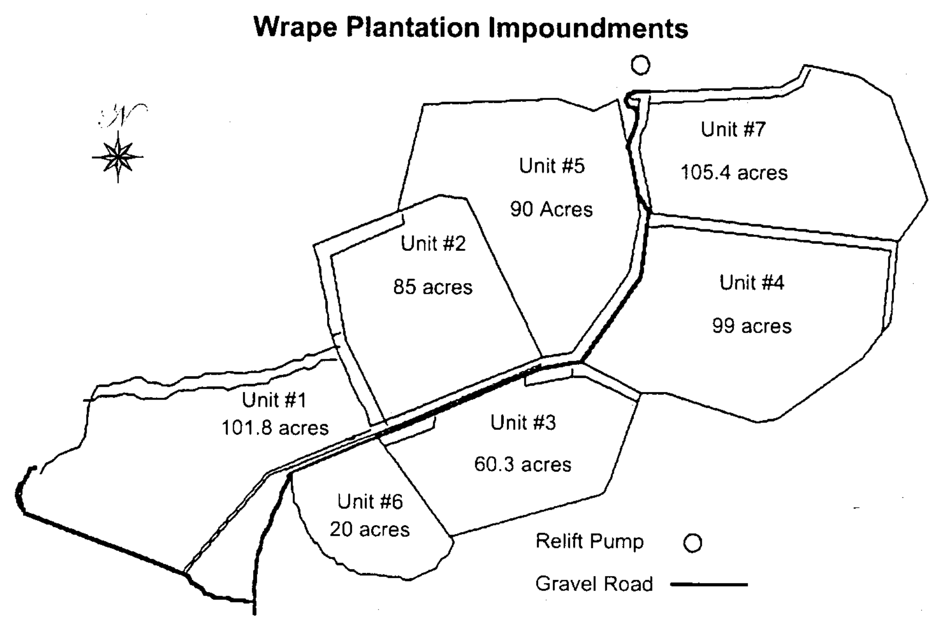


Figure 13. Management units on the Wrape Plantation, Bayou Meto Wildlife Management Area, Arkansas.

Timing of Drainage

Timing of Flooding	Early	Mid	Late
Early		Temple Island	Government Cypress
Mid	Buckingham Flats	Lower Vallier	Upper Vallier
Late	Cannon Brake	Bear Bayou	Beaver Dam Slough

Figure 14. Matrix of relative timing of flooding and draining in greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas.

consecutive years and then rotated to moist-soil production for the next 2 years. Each year 2-3 units are in rice and 2-3 units are in moist-soil production. When rice is grown, 25% of the standing rice is left unharvested to provide food for waterfowl. Unit 5 is a 90-acre reservoir used for fishing; it provides some shallow water habitat in the eastern part. Unit 6 is maintained as semi-permanent marsh to provide extended flooding conditions and habitat for nonwaterfowl species including wading and marsh birds, alligators, and aquatic mammals.

Flooding of the Wrape Plantation units is accomplished by relifting water from Bayou Meto into a series of canals that feed the individual units. Gated pipes in units provide flood and drain capabilities. Timing of flooding and draining is variable among units depending on whether rice or moist-soil resources are being produced and to control undesirable vegetation.

Summary of GTR History and Management. —The GTR impoundments on Bayou Meto WMA have different histories of development and management. The Lower and Upper Vallier impoundments were the first to be operational following construction of the Vallier School levee and water-control structure on Little Bayou Meto in the early 1950s. Government Cypress and Buckingham Flats GTR's were developed shortly thereafter. The Beaver Dam Slough area received intermittent flooding beginning in the early 1960s. Temple Island was constructed in the early 1980s. Cannon Brake structures were completed in the mid-1990s and usurped the former Beaver Dam Slough area although structural developments on private duck clubs have caused the area west of Little Bayou Meto to have different water regimes than the rest of Cannon Brake. The last GTR development on Bayou Meto WMA was construction of the Bear Bayou GTR which became fully operational in 2001.

Each GTR impoundment on Bayou Meto WMA had slightly different histories of water-level management depending on age and development of the impoundment. While annually variable, the water regimes in impoundments can be separated into relative categories of early-late flooding and early-late drainage (Fig. 14). Impoundments with early flooding usually begin flooding September to mid-October. In contrast, impoundments with mid-date flooding do not close water-control structures until 15 October-1 November and do not consistently reach full pool until late November. Structures on impoundments with late flooding are closed in early November and full pool usually is not reached until mid-December if at all. Impoundments that purposefully, and practically, can drain early begin opening water-control structures in mid-January. These impoundments lose most surface water by early March. In contrast, impoundments with mid-date drainage rarely (or did not purposefully attempt to), drain most surface water until mid-March-April in most years. Impoundments with late drainage consistently have extensive surface water present until early-mid-summer.

CURRENT STATUS OF GTR FORESTS

Most of the BLH habitat in Bayou Meto WMA is within GTRs. Because of an emphasis on providing a maximum amount of flooded habitat for duck hunting, most GTR impoundments historically had flooding schedules related to the timing of duck seasons. Consequently, initial flooding generally was earlier than would occur naturally (Fig. 15). Draining schedules in GTR impoundment historically sought to dewater areas immediately after the close of duck seasons. However, local and regional changes in timing, depth, and duration of winter and spring flows in and out of the WMA coupled with structural developments and obstructions to natural drainage in local bayous has delayed drainage much later than historic patterns.

Specific changes to GTR forests caused by altered and prolonged flooding conditions include a shift to more water-tolerant plant communities, loss of system productivity, decreased acorn production, lack of regeneration, and declines in waterfowl use (Table 10). Typical indicators of flooding stress in BLH systems and within GTRs include yellowing (chlorosis) of leaves, loss of flowering, canopy thinning, basal swelling of red oaks, tip die-back, large dead branches, mortality of less water tolerant trees, and poor regeneration (Table 11). Red oak species (such as willow and Nuttall oak) seem especially sensitive to altered hydrologic regimes and are of management concern because of the food and cover they provide to many BLH animals, particularly mallards and wood ducks.

The resilience of BLH stands to modifications within GTRs varies in relation to the severity of the perturbation (Table 11). Likewise, the potential for recovery and the type and intensity of management actions needed to reverse modifications also depends on the type and extent of perturbation. Consequently, careful monitoring of forests in GTRs is critical to understand how management strategies affect resources and to make management changes if necessary (Covington and Laubhan 2004).

We undertook an evaluation of BLH conditions within each of the GTR impoundments on Bayou Meto WMA in summer 2003 using the indicators of flooding stress identified above. The diversity of water regimes in the WMA impoundments (Fig. 14) allowed comparison of units with various combinations of flooding and draining dates. It also provides a unique opportunity to understand causal mechanisms of stress and damage to BLH stands and to develop recommendations for remediation of GTR impoundments on Bayou Meto WMA and other GTR impoundments throughout the southern U.S.

Study Design and Methods

BLH forests in each GTR impoundment on Bayou Meto WMA were sampled to determine their relative health and condition. Eight distinct units (Temple Island, Bear Bayou, Upper Vallier, Lower Vallier, Government Cypress, Beaver Dam

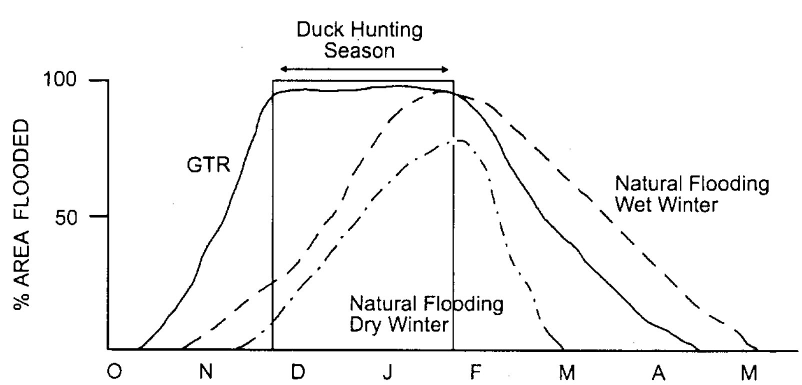


Figure 15. Water regimes in greentree reservoir impoundments compared to natural timing and annual variation of rainfall and overbank flooding of bottomland hardwood habitats in the lower Bayou Meto floodplain, Arkansas.

Table 10. Management practices in greentree reservoirs: causes and mechanisms to minimize impacts. (Modified from Fredrickson and Batema 1992).

Impacts	Causes of impacts	Mechanisms to minimize impact	Management practices
Altered hydrology	Constant water levels; water levels too deep	Mimic natural flooding regime; stoglog structure required	Precise water level control
Shift to more water tolerant plant community	Water levels too deep; flooding into growing season	Shallow flooding; flooding through dormant season only; stoplog structure required	Precise water level control
Loss of productivity	Nutrient loss; nutrients unavailable; reduced decomposition	Mimic natural flooding regime, depth and duration of flooding; stoplog structure required	Control timing of flooding
Decreased acorn production	Forest stands too dense; prolonged flooding	Silvicultural treatment; mimic natural flooding regime	Thin stands; shorten flooding
Lack of regeneration	Reduced light; stands too dense	Silvicultural treatment; flooding does not overtop seedlings	Thin stands; unit not flooded deeply year following treatment
Decline in waterfowl use	Reduced productivity, food resources; lack of water; monotypic habitat, lack of diversity	Ensure habitat diversity; provide wetland complex	Variable flooding regimes within and among years

Slough West, Cannon Brake, and Buckingham Flats) were sampled. Beaver Dam Slough West was separated from the rest of Cannon Brake because of its different water regime (see above section on impoundment management).

A random sample of 30 1/8-acre plots (73.8' x 73.8') was selected in each of the 8 GTR units (for a total of 240 plots) on the WMA. A geometric grid was placed across the RB1, RB2, and RO-1 Backswamp HGM category locations (Table 1, Fig. 4) in each impoundment and 15 points were randomly chosen. At each point a 1/8-acre plot was drawn and a second 1/8-acre plot was randomly selected at one of the 8 clockwise compass bearing points adjacent to that plot. For example, a random compass bearing of #1 placed the second plot at the northwest corner of the first plot, a selection of compass bearing #3 placed the second plot at the northeast corner, and so on. Locating all plots within HGM Backswamp categories represented the largest part of the BLH plant community on the WMA and reduced variation in plant community composition related to elevation and hydrogeomorphic condition.

All random plots were visited in July and August of 2003 to collect data on select indicators of forest condition (Table 11). All trees > 3 inches dbh on plots were identified and their dbh recorded. Only species comprising > 0.5% of the total trees were included in analyses except that American and cedar elm were grouped as "elm" and shagbark, mockernut and shellbark hickories were grouped as "hickory." Willow and Nuttall oak comprised >99.5% of red oaks on study plots and were analyzed separately and combined as "red oaks." The number and percentage of red oaks on plots that had evidence of basal swelling (Fig. 16), chlorosis of leaves (Fig. 17), tip-die back (Fig. 18), or that were dead (Fig. 19) were recorded. Dead trees were identified where possible by bark and structural characteristics. The most subjective indicator of flooding stress is chlorosis of leaves because of varying light conditions, heights >15 m for some trees, and time of leaf senescence. In this study all data were collected by 1 investigator and within a 4-week period in late July and early August prior to leaf senescence. Consequently, designation of leaf chlorosis was a relatively constant comparison among sites.

Regeneration on plots was assessed by counting the number of young seedlings (<3 inch dbh) > 0.5 m on each plot. The 0.5 m height was used as a cut-off between young trees that were at least 2 to 3 years old and had a higher probability

Table 11. Indicators of flooding stress on bottomland hardwood trees and potential for recovery (from King and Fredrickson 1998).

Condition	Probably cause	Potential for recovery
Yellowing of leaves (Chlorosis)	Saturated soil and/or shallow flooding during the growing season	Good if flooding frequency and duration reduced. Do not flood for at least 2-3 years or longer if trees do not recover.
Loss of flowering	Saturated soils and/or shallow flooding for extended period during dormant and growing season	Good if flooding frequency and duration reduced
Canopy thinning (fewer leaves produced)	Saturated soils and/or shallow flooding for part of the growing season for 2 or more years	Fair if flooding frequency, duration reduced. Do not flood for at least 2-3 years or longer if trees do not recover
Butt swelling on red oaks	Dormant season flooding at same depth, duration and timing for 10 or more years	Fair if flooding frequency, duration, and depth is changed to be dynamic within and among years
Tip die-back	Long-deep flooding in dormant season and extended flooding in 2 or more growing seasons	Fair when first noticed, but trees most likely have reduced vigor and will have increased mortality in next 5 to 7 years. Do not flood for at least 2-3 years or longer if trees do not recover
Large dead branches (2" or more in diameter)	Long-deep flooding in dormant season and well into and during the growing season	No reversal possible

of eventual survival compared to 1 to 2-year-old trees that most likely would not survive under current flooding regimes (Covington and Laubhan 2004, Denman and Karnuth 2004, Hertlein and Gates 2004).

Percentage canopy, shrub, and herbaceous cover on plots were recorded using standard Habitat Evaluation Procedures (e.g., Schroeder 1982, Sousa and Farmer 1983). Shrub vegetation was 1-5 m tall and herbaceous cover was < 1 m tall. The dominant species in herbaceous cover was recorded at plots.

In addition to randomly sampling the 8 GTR units, we obtained infrared aerial photographs taken in winter 2002 to determine areas of dead or dying timber in the WMA. These photographs and observations by WMA personnel were used to determine the location and size of larger "patches" of dead timber.

All plot data were analyzed to determine differences among the 8 GTR units. Tree and seedling species composition among units was analyzed using a 8 (GTR units) x 9 (tree species or groups with > 0.5% of total composition) chi-square contingency table. Raw data on number trees/species were used in chi-square tests and percentage composition data are presented in tabular form in the text. Species/impoundment categories with > 10% of the total chi-square statistic were noted as primary contributors to the observed significance among GTR units. Other variables were analyzed using 1-way analysis of variance (ANOVA) (SAS 2000) to determine if the GTR units had different conditions. Percentage data (canopy, shrub, and herbaceous cover) were arc-sine transformed before performing the ANOVA's. Duncan's multiple range tests (SAS 2000) were performed for all variables analyzed in ANOVA tests to determine specific differences or similarities between GTR units. A 2-way ANOVA was conducted on basal swelling, tip die-back, leaf chlorosis and tree mortality data among the units related to their position in the flood-drain matrix (Fig. 14). In this 2-way ANOVA

Figure 16. Examples of basal swelling damage to willow and Nuttall oaks on Bayou Meto Wildlife Management Area, Arkansas, 2003.

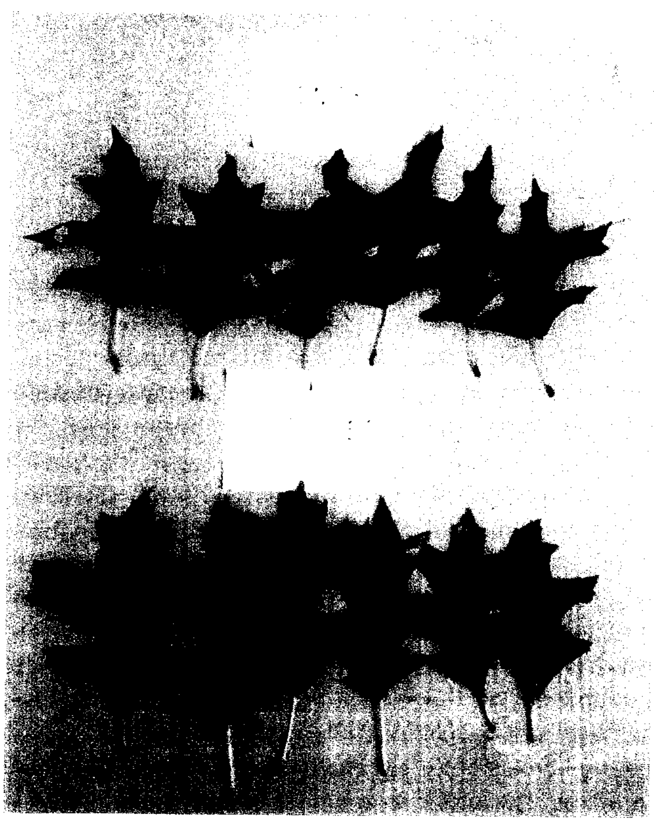


Figure 17. Comparison of leaf color and chlorosis of Nuttall oak in natural and prolonged flooding areas.

there were 2 classes (flood and drain) and 3 levels (early, mid, late). This analysis identifies relative importance of flooding vs. draining and interactions among variables.

Finally, the relative condition of red oaks in each of the 8 GTR units were ranked in relation to flood and drain regimes. The 8 units were ranked for each of 6 primary indicators of BLH health (% green ash, % red oaks with basal swelling, % red oaks with tip die-back, % red oaks with chlorosis of leaves, % dead red oaks, # young red oaks > 0.5 m) from 1 to 8 with 1 being the best condition and 8 the worst. Cumulative ranks of these variables were summed to determine the relative condition of the 8 GTRs and to assess the primary causes of degradation related to timing of flooding and draining.

Results

Tree Species Composition. — A total of 3279 living trees > 3 inches dbh (of species comprising at least 0.5% of the total observed) were recorded on the random study plots. Number of trees/30 plots in each unit ranged from 344 in Cannon Brake and Buckingham Flats to 551 in Temple Island. For all GTR units combined, red oaks (combined willow and Nuttall oak) comprised 22.4% of total trees followed by elm (21.0%), overcup oak (19.5%),

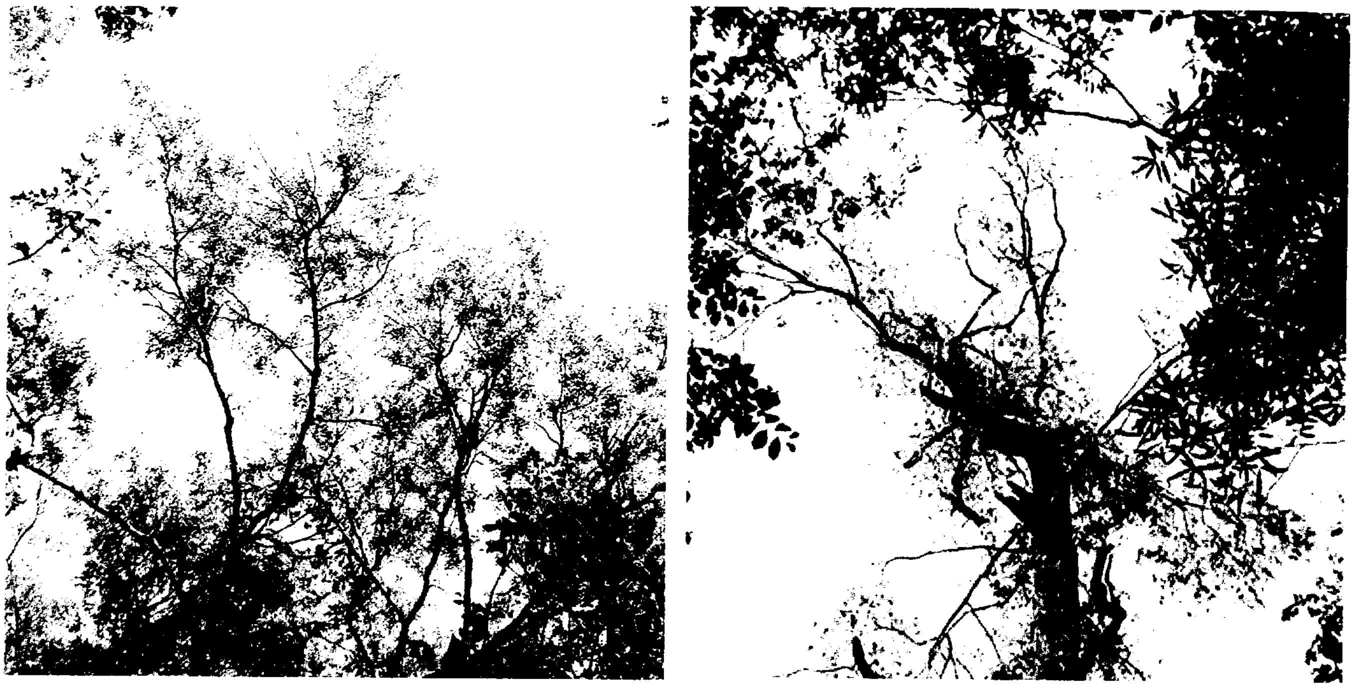


Figure 18. Examples of tip die-back of lateral branches of willow and Nuttall oaks on Bayou Meto Wildlife Management Area, Arkansas, 2003.

green ash (15.1%), bitter pecan (10.2%), sugarberry (7.0%), hickory (3.9%), and red maple (0.9%) (Table 12). Tree composition was different among GTR units (chi-square value = 88.5, $P < 0.001$) (Table 12). Bear Bayou contained large amounts of hickory, bitter pecan, elm and willow oak and low amounts of green ash and overcup oak. Temple Island also contained large amounts of hickory and bitter pecan, but had only 11.6% willow oak and high amounts of red maple. Cannon Brake and Buckingham Flats contained more sugarberry than other units and also had large amounts of elm, willow oak, Nuttall oak, and overcup oak yet low amounts of green ash. Beaver Dam Slough West was dominated by overcup oak (33.2%) and green ash (20.0%) and contained the least amount of red oak (15.1%) of any unit. In contrast, Lower Vallier had the most red oak (30.3%) of any unit but also had large amounts of overcup oak and green ash. Upper Vallier and Government Cypress had high amounts of green ash and overcup oak and little sugarberry or hickory.

Size (dbh) of living trees within a species was highly variable but means were similar ($P > 0.20$) among GTR units (Table 13). Average size of oaks was larger than other species and the similar average age classes of willow, Nuttall, and overcup oak (11.2-12.5 inch dbh) probably reflect regeneration and growth because most timber harvest operations were curtailed on the WMA in the 1930s to 1940s. In contrast to the larger oaks, the water tolerant green ash and red maple are of younger age classes (4.8-5.6 inch dbh) and reflect regeneration within the last 20 years.

Nonlethal Damage to Red Oaks. — A total of 735 living red oaks (406 willow oak and 329 Nuttall oak) were present on the random plots. Of these trees, 19.7% had evidence of basal swelling (Table 14), 22.3% had some type of tip die-back (Table 15), and 14.4% had at least some chlorotic leaves (Table 16). Nuttall oaks had more (chi-square test, $P < 0.01$) damage than willow oak in all of these variables (Table 17).

Nonlethal damage also was different (all P's < 0.001) among the 8 GTRs (Tables 14-16). Upper Vallier consistently had the greatest, and Buckingham Flats the least, amount of damage to red oaks for all variables. Government Cypress and Temple Island also had a high percentage of damaged red oaks and usually were grouped with Upper Vallier in Duncan's multiple range tests. Lower Vallier had 23% of red oaks with basal swelling (2nd highest) but only 16.5% tip die-back (3rd lowest) and 6.7% leaf chlorosis (2nd lowest). Beaver Dam Slough and Cannon Brake were consistently in the middle of damage rankings among units. Red oaks in Bear Bayou had either the 2nd or

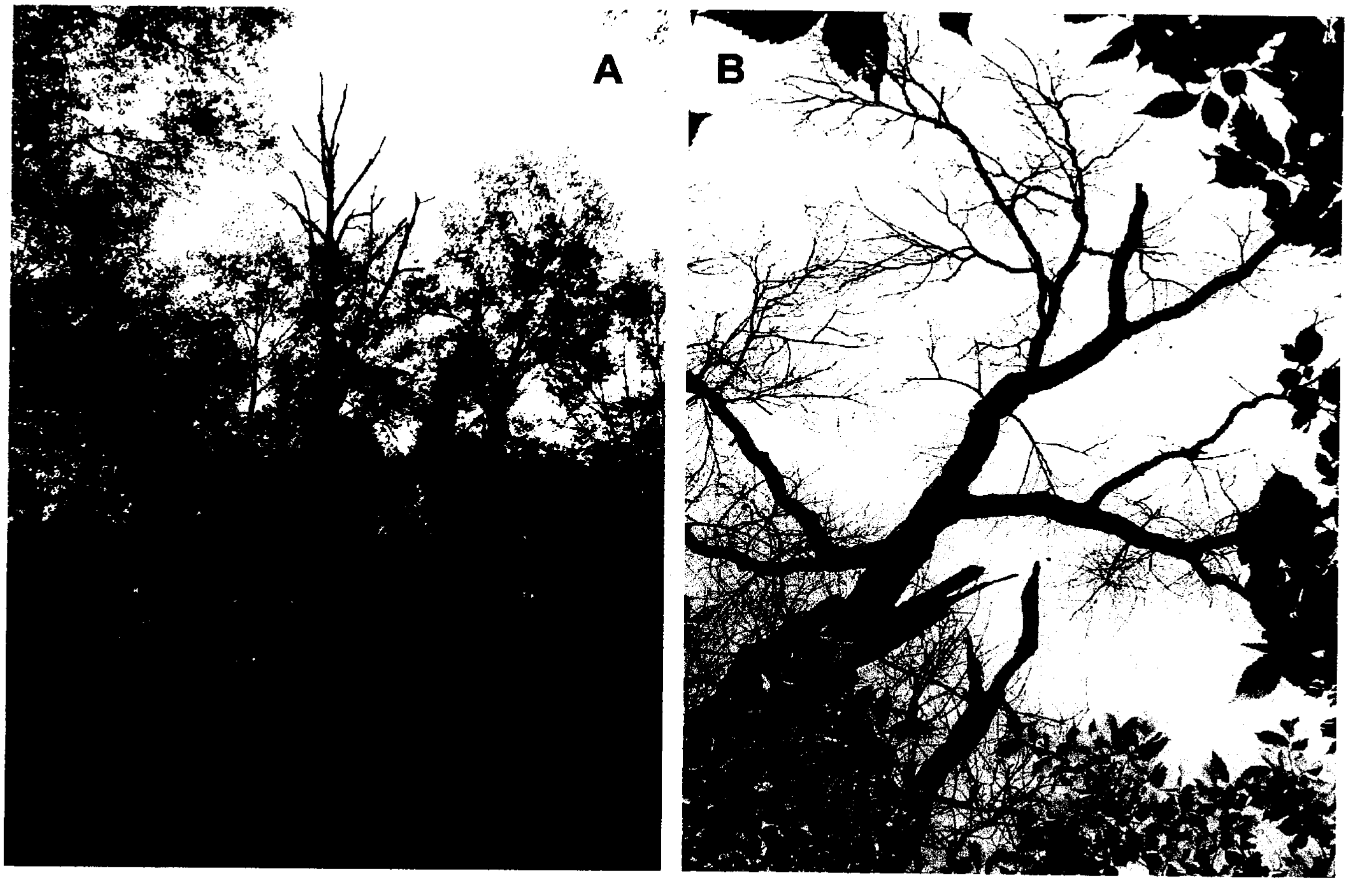
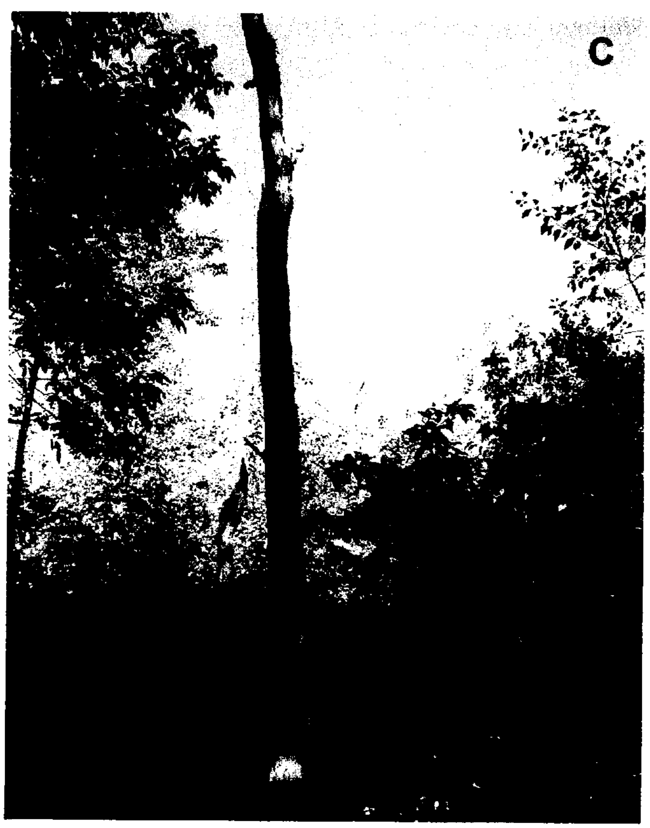


Figure 19. Red oak mortality in: a) Lower Vallier, b) Government Cypress, and c) Temple Island greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.



3rd lowest amounts of damage, generally similar to that in Buckingham Flats.

Tree Mortality. — A total of 336 dead trees > 3 inch dbh were observed on the random plots in the 8 GTRs (Table 18). This total was 9.3% of the combined living + dead trees on the plots and varied from 13.2% mortality in Government Cypress to 4.4% in Buckingham Flats. Mortality was different (P's < 0.001) among species and units. Mortality was highest for red oaks; 21% for willow oak, 24.9% for Nuttall, and 22.8% for combined willow and Nuttall; other species had 0-4.8% mortality.

Many dead trees were present in Government Cypress; most were in a ca. 500-acre dead timber patch in the south-central part of the unit (Fig. 20). Most of this timber appears to have been dead for at least 15 to 20 years. The median size of dead oaks in Government Cypress (Table 19) is relatively large compared to other GTR units probably because of the extensive death of older trees in this area and decomposition of smaller trees. Government Cypress has small amounts of willow oak compared to other units, but where it persists at higher elevations, percent

Table 12. Percentage composition of tree species[a] on 240 random plots in greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

	Unit[b]								
Species[c]	BB	CB	BK	TI	BDS	LV	UV	GC	Combined
HK	10.3	0.3	-	14.9	-	-	0.8	0.2	3.9
PC	18.1	5.2	11.3	16.2	7.3	4.0	6.9	10.0	10.2
Elm	30.0	19.8	18.3	20.9	15.2	16.2	24.3	23.0	21.0
SG	4.0	15.7	11.3	6.2	8.7	8.1	1.5	2.9	7.0
WO	19.6	14.8	11.9	11.6	5.0	14.1	14.3	7.7	12.4
NO	6.3	12.5	12.5	4.5	10.1	16.2	8.4	11.5	10.1
OO	8.6	21.5	23.2	10.2	33.2	23.8	24.3	16.6	19.5
GA	3.0	10.1	11.0	12.0	20.0	17.5	19.4	26.5	15.1
RM	-	-	0.3	3.6	0.3	-	-	1.5	0.9
# trees	397.0	344.0	344.0	551.0	355.0	445.0	391.0	452.0	3,279.0

[a] ≥3"dbh.
[b] BB - Bear Bayou, CB - Cannon Brake, BK - Buckingham Flats, TI - Temple Island, BDS – Beaver Dam Slough West, LV – Lower Vallier, UV-Upper Vallier, GC - Government Cypress.
[c] HK - hickories, PC – bitter pecan, SG - sugarberry, WO - willow oak, NO – Nuttall oak, OO – overcup oak, GA - green ash,
RM - red maple.

Table 13. Size of trees (mean dbh± SD) present on 240 random plots in greentree reservoir impoundments in Bayou Meto Wildlife Management Area, Arkansas, 2003.

	Unit[a]								
Species[b]	BB	CB	BK	TI	BDS	LV	UV	GC	Combined
HK	7.7±4.9	3.0	-	6.5±3.6	-	-	5.3±1.1	12.0	6.7±3.8
PC	9.8±4.7	9.9±6.2	5.8±2.7	9.5±5.3	8.1±4.6	6.1±4.2	10.1±4.8	9.1±4.8	9.1±5.0
Elm	5.8±4.0	4.8±3.1	4.5±2.8	7.2±5.1	6.4±4.2	10.6±4.9	5.8±3.7	4.8±2.7	5.8±4.0
SG	7.8±5.1	5.8±3.9	4.4±2.7	9.9±5.2	5.4±3.7	7.9±3.3	4.8±1.9	9.5±5.0	6.7±4.3
WO	14.6±7.2	8.7±6.9	9.8±8.0	14.8±7.2	15.1±6.1	11.0±6.3	11.7±7.3	9.9±5.7	12.1±7.3
NO	14.3±7.7	15.2±9.0	9.3±6.0	13.8±5.3	12.0±6.1	11.5±5.8	13.6±7.3	12.0±7.7	12.5±7.1
OO	15.2±5.7	11.7±7.0	12.7±5.6	13.8±6.6	8.9±5.9	10.0±7.6	10.1±6.9	11.3±6.0	11.2±6.7
GA	6.4±5.7	4.2±2.1	4.6±2.9	5.3±3.1	4.9±2.9	5.4±4.0	4.3±2.1	4.5±2.4	4.8±3.0
RM	-	-	6.0	5.5±2.6	3.0	-	5.1±3.1	6.4±3.9	5.6±2.9

[a] BB - Bear Bayou, CB - Cannon Brake, BK - Buckingham Flats, TI - Temple Island, BDS – Beaver Dam Slough West, LV – Lower Vallier, UV-Upper Vallier, GC - Government Cypress.
[b] HK - hickories, PC – bitter pecan, SG - sugarberry, WO - willow oak, NO – Nuttall oak, OO – overcup oak, GA - green ash, RM - red maple.

Table 14. Percentage and number of red oaks with evidence of basal swelling (BS) on 240 random plots in greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Variable	Unit[a]								
	UV	LV	TI	GC	BDS	BB	CB	BK	Combined
# Red Oaks	89.0	135.0	89.0	87.0	54.0	94.0	103.0	84.0	735.0
# w/BS	34.0	38.0	25.0	22.0	14.0	8.0	8.0	3.0	152.0
%	38.2	28.1	28.1	25.3	25.9	8.5	7.8	3.6	20.7
Duncan Multiple Range Groups[b]	A	A							
		B	B	B					
			C	C	C				
				D	D	D	D	D	

[a] BB – Bear Bayou, CB Cannon Brake, BK – Buckingham Flats, TI – Temple Island, BDS – Beaver Dam Slough, LV – Lower Vallier, UV-Upper Vallier, GC - Government Cypress.
[b] Units with the same underline are not significantly (P> 0.10) different.

Table 15. Percentage and number of red oaks with evidence of tip die-back (TD) on 240 random plots in greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Variable	Unit[a]								
	UV	GC	LV	TI	BB	BDS	CB	BK	Combined
# Red Oaks	89	87	135	89	103	54	94	84	735
# w/TD	36	26	25	21	17	15	21	3	164
%	40.4	29.9	18.5	23.6	16.5	27.8	22.3	3.6	22.3
Duncan's Multiple Range Groups[b]	A	A	A						
		B	B	B	B	B	B		
						C	C	C	

[a] BB – Bear Bayou, CB Cannon Brake, BK – Buckingham Flats, TI – Temple Island, BDS – Beaver Dam Slough, LV – Lower Vallier, UV-Upper Vallier, GC - Government Cypress.
[b] Units with the same underline are not significantly (P> 0.10) different.

Table 16. Percentage and number of red oaks with evidence of leaf chlorosis (LC) on 240 random plots in greetree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Variable	Unit[a]								
	UV	GC	TI	CB	BB	LV	BDS	BK	Combined
# Red Oaks	89	87	89	94	103	135	54	84	735
# w/LC	27	17	14	14	12	9	8	2	103
%	30.3	19.5	15.7	14.9	11.6	6.7	14.8	2.3	14.0
Duncan's Multiple Range Groups[b]	A								
		B	B	B	B	B	B	B	
			C	C	C	C	C	C	

[a] BB – Bear Bayou, CB Cannon Brake, BK – Buckingham Flats, TI – Temple Island, BDS- Beaver Dam Slough, LV - Lower Vallier, UV-Upper Vallier, GC - Government Cypress.
[b] Units with the same underline are not significantly (P> 0.10) different.

Table 17. Number (and percentage) of willow and Nuttall oaks that had evidence of basal swelling tip die-back, and leaf chlorosis on 240 random plots in greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Species	Type of Damage		
	Basal Swelling	Tip Die-Back	Leaf Chlorosis
Willow Oak N=406	164 (15.8)	79 (19.5)	40 (9.8)
Nuttall Oak N=329	81 (24.6)	85 (25.8)	63 (19.1)

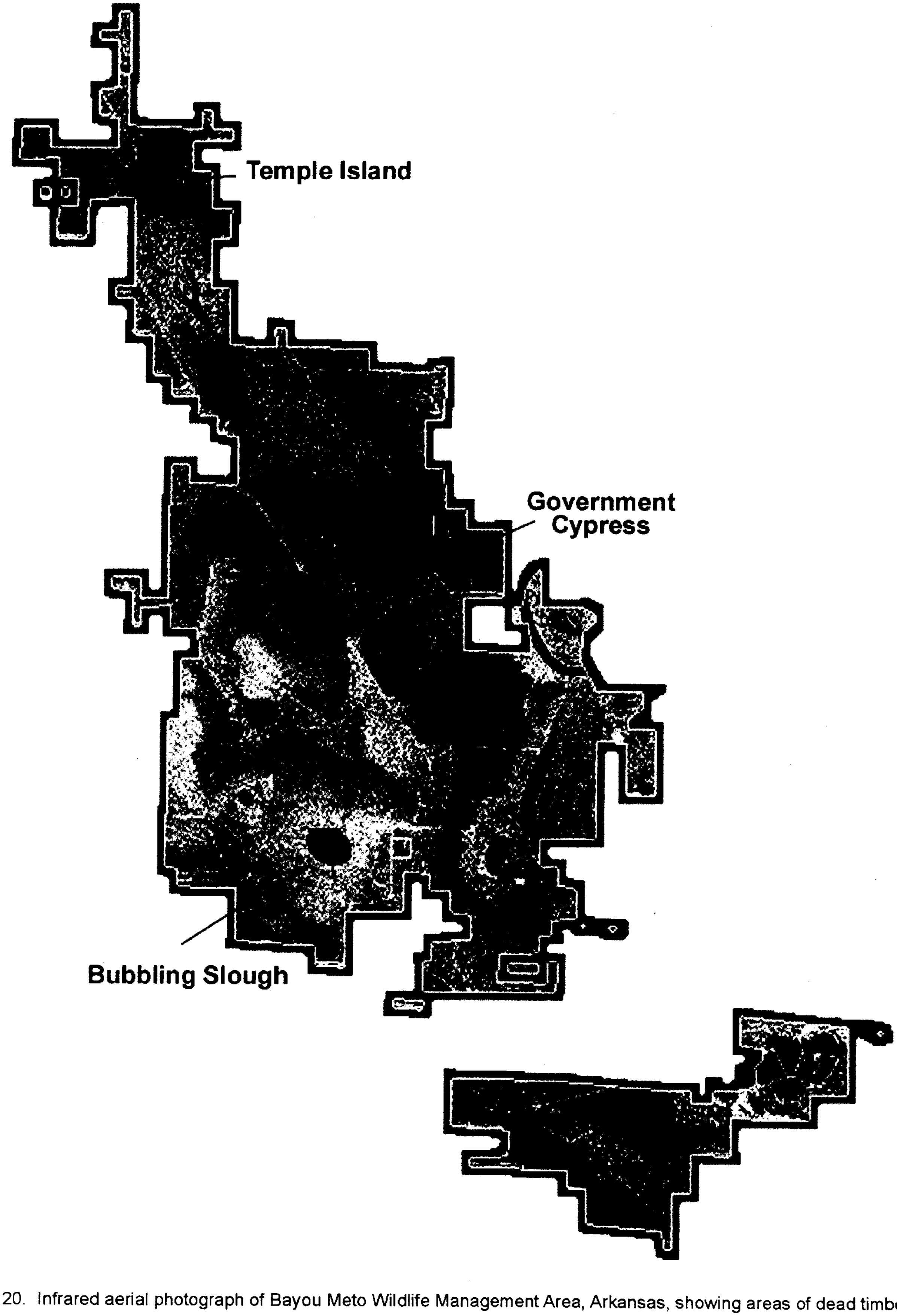


Figure 20. Infrared aerial photograph of Bayou Meto Wildlife Management Area, Arkansas, showing areas of dead timber.

Table 18. Number and percentage of trees[a] that were dead on 240 random plots in greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

	Unit[b]								
Species	GC	TI	BDS	UV	LV	BB	CB	BK	Combined
Willow Oak									
# Dead	5	21	1	17	41	13	7	3	108
%	12.5	24.7	5.3	23.3	39.4	14.3	12.1	6.8	21
Nuttall Oak									
# Dead	26	18	17	13	13	9	12	1	109
%	33.3	41.9	32.1	28.3	15.3	26.5	21.8	2.3	24.9
Overcup Oak									
# Dead	11	1	8	3	-	3	1	5	32
%	12.8	1.8	6.3	3.1	-	8.1	1.3	5.9	4.8
Bitter Pecan									
# Dead	2	1	-	2	1	2	2	2	12
%	4.3	1.1	-	6.9	5.3	2.7	10.0	4.9	3.5
Green Ash									
# Dead	5	1	3	3	2	1	-	3	18
%	4.0	1.5	4.1	3.8	2.5	7.7	-	7.3	3.5
Hickory									
# Dead	-	1	-	-	-	-	-	-	1
%	-	1.5	-	-	-	-	-	-	0.8
Elm									
# Dead	4	-	3	5	-	5	9	2	28
%	3.7	-	5.3	5.0	-	4.4	11.7	3.1	3.9
Sugarberry									
# Dead	-	1	-	-	1	1	-	-	3
%	-	2.9	-	-	2.7	5.9	-	-	1.3
Red Maple									
# Dead	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-
Unidentified									
# Dead	16	5	-	2	-	1	1	-	25
Total # Dead	69	49	32	45	58	35	32	16	336
%	13.2	8.2	8.3	10.3	11.5	8.1	8.5	4.4	9.3

[a] ≥3" dbh.
[b] BB - Bear Bayou, CB - Cannon Brake, BK - Buckingham Flats, TI - Temple Island, BDS – Beaver Dam Slough West, LV - Lower Vallier, UV-Upper Vallier, GC - Government Cypress.

Table 19. Size (dbh) of dead oak trees observed on 240 random plots in 8 greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

	Unit[a]								
Species	GC	TI	BDS	UV	LV	BB	CB	BK	Combined
Willow Oak									
Median dbh	20	14	4	8	6	14	12	6	12
Range	16-24	4-20	4	3-26	3-18	4-32	3-21	3-12	3-32
Nuttall Oak									
Median dbh	12	22	8	8	6	20	8	12	14
Range	6-26	18-30	3-40	3-24	3-30	12-24	4-30	12	3-40
Overcup Oak									
Median dbh	10	18	4	10	-	18	24	12	14
Range	4-20	18	3-8	8-12	-	14-31	24	3-25	3-31

[a] BB – Bear Bayou, CB Cannon Brake, BK – Buckingham Flats, TI – Temple Island, BDS – Beaver Dam Slough, LV – Lower Vallier, UV-Upper Vallier, GC - Government Cypress.

mortality is relatively moderate (12.5%). In contrast, mortality of Nuttall and overcup oak in Government Cypress is the highest among the GTR units.

Much of the tree mortality in Temple Island occurs in a large patch (ca. 50 acres) along a low slough in the west-central part of the unit (Fig. 20) and relative size of dead trees is large (Table 19). Mortality of red oaks, especially Nuttall, is high in Temple Island (Table 18). Lower Vallier also has a large area of dead timber (ca. 120 acres) located along Bubbling Slough where water has been impounded behind an old abandoned levee (Fig. 20). Other tree mortality in Lower Vallier is scattered and mainly confined to red oaks, especially willow oak. The range of red oak age-classes dying in Lower Vallier is highly variable, but most young willow and Nuttall oak do not appear to survive above 3-6 inch dbh (Table 19). In contrast to red oaks, overcup oak in Lower Vallier apparently survive at high rates (no dead overcup were observed). Tree death in Beaver Dam Slough West also is mostly in younger age classes and includes all oaks, especially Nuttall.

Tree mortality in Upper Vallier is widely scattered throughout the unit and no large contiguous patches of dead timber exist. Relatively equal amounts of willow and Nuttall oak mortality occur in this unit along with relatively high numbers of dead bitter pecan and elm (Table 18). More large red oaks appear to be dead in Upper Vallier compared to Lower Vallier. Many scattered large oaks are dead in Bear Bayou; most dead Nuttall are >20 inches dbh. Green ash apparently do not survive as well in Bear Bayou as in other units (except Buckingham Flats which also has high mortality of green ash). Larger oak trees also appear to be dying at high rates in Cannon Brake (Table 19). Buckingham Flats has relatively low mortality of all tree species with only 6.8% and 2.3% mortality of willow and Nuttall oak, respectively.

Regeneration. — The number of seedlings > 0.5 m in height on the 30 random plots in each of the 8 GTR units was highly variable and contained different species mixes (chi-square test, $P < 0.001$) (Table 20). Bear Bayou and Buckingham Flats both had relatively large numbers of seedlings that survived to at least 0.5 m and contained the most red oaks (both willow and Nuttall oak). Buckingham Flats also had large numbers of young overcup oak. These units also had low numbers of seedlings of water tolerant trees (green ash, water locust, and red maple). Temple Island had large numbers of seedlings, but only moderate numbers of red oak seedlings and high numbers of young overcup oak. Temple Island also had relatively high numbers of water locust, green ash, and red maple seedlings. Cannon Brake, Beaver Dam Slough West, and Upper Vallier all had relatively poor regeneration. Cannon Brake had many young Nuttall and overcup oak but low numbers of willow oak. Cannon Brake also had high numbers of sugarberry and cedar elm. Regeneration in Beaver Dam Slough and Upper Vallier was dominated by green ash; Upper Vallier also had several young overcup oak. Regeneration in Lower Vallier and Government Cypress was dominated by young overcup oak and green ash, but Government Cypress also had good Nuttall survival in some areas.

Vegetation Coverage. — Canopy, shrub, and herbaceous cover on random plots all were different (P's ≤ 0.001) among the 8 GTR units (Tables 21-23). BLH stands in most of the GTR units were relatively closed (>85% canopy coverage) except in Temple Island, Upper Vallier and Government Cypress (Table 21). Open canopies in these 3 impoundments apparently reflects relatively high mortality rates and large patches of dead timber. Amount of shrub cover was the reciprocal of canopy coverage with Temple Island and Government Cypress having significantly more shrubs than other GTRs (Table 22). In these 2 impoundments the dead timber areas had (or were in process of) transitioned into shrub/scrub communities dominated by buttonbush, willow, and swamp privet. Herbaceous cover was highly variable among units (Table 23). Extensive poison ivy cover was present in Bear Bayou and this site had the highest herbaceous cover of all units. Most other units had moderate herbaceous cover (27-45%), but Government Cypress was mostly devoid of ground cover. Herbaceous vegetation was dominated by poison ivy in all units except Beaver Dam Slough, Upper and Lower Vallier, and Government Cypress where ground cover was almost exclusively rice cutgrass and various sedges.

Effects of Flooding vs. Draining Regimes on Red Oaks. — Both early flooding and late drainage were associated with high incidences of basal swelling, tip die-back, leaf chlorosis, and mortality of red oaks (Table 24). The relative ranks of 6 indicators of stress and damage (Table 25) also suggest that the combined effect of early flooding and late drainage caused the most damage to red oaks in GTRs (Fig. 21). Not all indicators of damage are affected the same way by flooding vs. drainage timing, however. For example, nonlethal damage indicators (e.g., basal swelling, tip die-back, leaf chlorosis) may be more

Table 20. Number of seedlings 0.5 - 5.0 m in 240 random plots in 8 greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Species[b]	Unit[a]							
	BB	CB	BK	TI	BDS	LV	UV	GC
WO	856	74	253	160	26	130	188	72
NO	576	356	663	250	32	310	10	470
OO	340	264	1880	1292	82	1850	476	1296
HK	306	-	-	60	-	-	-	-
PC	830	26	200	386	-	50	40	230
CE	332	236	200	202	351	132	180	70
WL	30	6	20	50	36	70	-	156
GA	112	96	340	846	461	617	717	371
SG	-	210	30	-	64	80	70	70
RM	-	50	30	190	-	-	6	120
Combined	3382	1318	3616	3436	1052	3239	1687	2855

[a] BB – Bear Bayou, CB Cannon Brake, BK – Buckingham Flats, TI – Temple Island, BDS – Beaver Dam Slough, LV - Lower Vallier, UV-Upper Vallier, GC – Government Cypress.
[b] HK - hickories, PC – bitter pecan, SG - sugaryberry, WO - willow oak, NO – Nuttall oak, OO – overcup oak, GA - green ash, RM - red maple, CE – Cedar Elm, WL – Water Locust.

susceptible to early flooding while mortality, regeneration, and green ash regeneration appear more related to late drainage.

Impoundment Comparisons

Early studies of GTR forest stands suggested that stress and mortality of red oaks were caused primarily by late flooding in spring and management recommendations called for early drainage of GTRs immediately following duck seasons (Merz and Brakhage 1964, Rudolph and Hunter 1964, Brakhage 1966, Broadfoot and Williston 1973,, McQuilken and Musbach 1977). Later investigations implicated early flooding in fall as detrimental to GTR stands because BLH trees may not be dormant by time of initial flooding (Newling 1981, Mitchell and Newling 1986, Heitmeyer et al. 1991, Karr et al. 1990, Fredrickson and Batema 1992, King 1995). These studies also pointed out that BLH trees are adapted to relatively dry (low rainfall and overbank flooding) conditions in fall and wet (high rainfall and frequent overbank floods) conditions in late winter and spring, further suggesting that early flooding was more detrimental than late drainage. Recent information now suggests that GTRs that have consistent flooding schedules among years and is either earlier or later than natural flooding regimes has the potential for significant damage to BLH health (King and Fredrickson 1998, Fredrickson 2004). Our data from Bayou Meto support the contention that the combination of early flooding and late drainage is detrimental to the long-term sustainability of red oaks in GTRs.

Red oak trees in GTRs may initially respond to early flooding by altering physiological processes that create the visible indicators of basal swelling and leaf chlorosis (Black 1984, Smith 1984), reducing acorn production (Minckler and McDermott 1960, McQuilken and Musbach 1977, Francis 1983), and growth rates (Francis 1983, Black 1984, Schlaegel 1984) and then gradually begin to die, first with tip and branch die-back, and finally mortality (Karr et al. 1990, King 1995, Wigley and Filer 1989). Prolonged flooding regimes also prohibit or reduce regeneration of young red oaks and shifts in stand composition ultimately occur where red oaks are replaced with more water tolerant species such as overcup oak, red maple, and green ash (Fredrickson 1979). If water regimes are too prolonged, death of many trees including oak, elm, pecan, and sugarberry occurs and plant communities shift to a shrub/scrub or cypress/tupelo type. GTRs on Bayou Meto WMA have varying evidence of all of the above symptoms and damages and reflect relative degrees of forest deterioration. Specific conditions and causes of damage in each GTR impoundment are discussed below.

Buckingham Flats. — BLH stands in Buckingham Flats appear to be in the best condition (i.e., the least damage as indicated by measurements taken in this study) of any of the GTRs on Bayou Meto WMA. Although this impoundment was initially developed in the early 1950s and seasonal flooding has occurred for over 50 consecutive years, red oaks in this GTR have survived and regenerated at good rates. Nonlethal indicators of stress to red oaks also are limited. The good condition of BLH in Buckingham Flats probably has been maintained because the impoundment has independent flood and drain capabilities that allowed it to be flooded late in fall and drained early in spring. Buckingham Flats also has the most diverse geomorphic and topographic setting of any GTR on the WMA and

Table 21. Percentage canopy cover on 240 random plots in greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Variable	Unit[a]								
	LV	BDS	BB	BK	CB	TI	UV	GC	Combined
% cover	92.2	91.5	87.2	85.8	84.7	79.8	78.2	67.4	83.4
Duncan's Multiple Range Groups[b]	A	A	A	A	A				
			B	B	B	B	B		
						C	C	C	

[a] BB – Bear Bayou, CB Cannon Brake, BK – Buckingham Flats, TI – Temple Island, BDS – Beaver Dam Slough, LV - Lower Vallier, UV-Upper Vallier, GC - Government Cypress.
[b] Units with the same underline are not significantly (P> 0.10) different.

Table 22. Percentage shrub cover on 240 random plots in greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Variable	Unit[a]								
	TI	GC	BK	BB	UV	BDS	LV	CB	Combined
% cover	41.8	35.1	21.3	13.3	10.6	9.4	8.8	7.4	18.5
Duncan's Multiple Range Groups[b]	A	A							
			B	B	B	B	B	B	

[a] BB – Bear Bayou, CB Cannon Brake, BK – Buckingham Flats, TI – Temple Island, BDS – Beaver Dam Slough, LV - Lower Vallier, UV-Upper Vallier, GC - Government Cypress.
[b] Units with the same underline are not significantly (P> 0.10) different.

Table 23. Percentage herbaceous cover on 240 random plots in greetree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Variable	Unit[a]								
	BB	BK	CB	TI	BDS	UV	LV	GC	Combined
% cover	74.5	45.2	43.2	34.0	33.8	27.6	27.4	13.3	37.4
Ducan's Multiple Range Groups	A								
		B	B	B	B	B	B		
				C	C	C	C	C	

[a] BB – Bear Bayou, CB Cannon Brake, BK – Buckingham Flats, TI – Temple Island, BDS – Beaver Dam Slough, LV - Lower Vallier, UV-Upper Vallier, GC - Government Cypress.
[b] Units with the same underline are not significantly (P> 0.10) different.

Timing of Drainage

Timing of Flooding	Early	Mid	Late
Early		Temple Island **6.5**	Government Cypress **6.5**
Mid	Buckingham Flats **1**	Lower Vallier **4**	Upper Vallier **8**
Late	Cannon Brake **3**	Bear Bayou **2**	Beaver Dam Slough **5**

Figure 21. Cumulative rank (1-8, with 1 having the least and 8 the most) of 6 indicators of stress and damage in 8 greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

this diversity in turn supports diverse flooding depth and duration and tree species composition. Death and damage to red oaks in Buckingham Flats mostly is confined to the old slough that runs through the middle of the area. The forest canopy is mostly closed in Buckingham Flats and regeneration of oaks may be somewhat "light-limited." Excellent red oak and overcup oak regeneration occurs in openings created by past cuttings or tree death (Fig. 22) and many regenerated age classes occur throughout the impoundment.

Bear Bayou. — Bear Bayou is a new GTR impoundment and BLH stands are in relatively good condition. Bear Bayou and Temple Island GTRs occur at the highest elevations on Bayou Meto WMA and have large components of relatively water intolerant species including shagbark and mockernut hickory, American elm, and willow oak. Bear Bayou also has the largest mean dbh's of red oaks among GTR impoundments and it appears that timber harvest has not occurred in the impoundment for a long time. This older age class may explain why more mortality of red oaks occurs in Bear Bayou than in some other GTRs despite its recent impoundment. The amount of stress and damage to red oaks in Bear Bayou and Buckingham Flats may represent naturally occurring damage in local BLH stands in the absence of major GTR impacts. Herbaceous coverage in Bear Bayou is high (Fig. 23a) and indicates short flooding regimes. Bear Bayou has a relatively unpredictable water source (Dry Bayou Ditch) and is kept dry 1 of every 3 years, consequently flooding is later and more variable than other impoundments. Drawdown dates in Bear Bayou also have been staggered and drainage is relatively independent of water levels in areas to the south along Salt Bayou Ditch. Regeneration of red oaks in Bear Bayou is good, but may be somewhat light-limited because most regeneration occurs in tree gap openings. Areas along Bear Bayou show evidence of more prolonged flooding and higher incidences of overcup oak, water locust, and green ash.

Cannon Brake. — Red oaks in Cannon Brake do not have high levels of basal swelling or leaf chlorosis but many older Nuttall oak are dying or experiencing substantial tip die-back in the southern end of the impoundment next to the Cannon Brake levee. Also, few willow oak seedlings are germinating or surviving in this area. These data suggest fairly recent and rapid deterioration in the condition of red oaks in Cannon Brake and probably reflect

Table 24. F-values (and significance levels) from 2-way ANOVA's of basal swelling, tip die-back, leaf chlorosis, and mortality of willow and Nuttall oak in relation to timing of flooding vs. timing of draining in 8 greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

	Source of Variation		
Variable	Flood	Drain	Flood * Drain
Basal Swelling	17.4 (<0.001)	4.8 (0.009)	1.9 (0.14)
Tip Die-Back	8.8 (<0.001)	6.1 (0.003)	3.2 (0.02)
Leaf chlorosis	3.4 (0.03)	3.7 (0.02)	5.7 (<0.001)
Mortality	3.9 (0.02)	7.2 (0.01)	1.8 (0.15)

the impact of water regimes created after construction and operation of the Cannon Brake levee and structure. Prior to construction of the Cannon Brake levee and water-control structure on Little Bayou Meto, BLH stands in the area (including the old Beaver Dam Slough area) were flooded irregularly, often as late as December. Since development the impoundment now is consistently flooded in late October-Early November each year.

Stress and damage to red oaks in Cannon Brake appear relatively recent and are related to periodic late drainage rather than early flooding. Flooding is late in Cannon Brake because flood easements on adjoining private lands prevent early flooding. Draining Cannon Brake is variable among years but often is late (spring) and depends on water levels in Bayou Meto (where the Wasteways Ditch drains into). Also, Little Bayou Meto currently will not drain past the Cannon Brake structure because its old channel is heavily silted and obstructed with debris. Furthermore, because Cannon Brake is at the south end of the WMA, all water draining from other GTRs upstream on Little Bayou Meto must flow through it.

Cannon Brake has considerable topographic variation and many ridges and swales are present along with small natural levees along Goose Lake, Little Bayou Meto, Beaver Dam Slough, Long Pond Slough, and Five Forks Bayou. The higher sites have relatively good regeneration, and less stress or mortality, of red oaks. In particular the northeast part of the old Beaver Dam Slough area grades into high, non-flooded, land and has excellent stands of diverse age-class willow oak (Fig 23b).

Lower Vallier. — Lower Vallier is the largest and oldest GTR on Bayou Meto WMA and has the highest composition of red oak, especially Nuttall oak, among the GTR impoundments on the area. Red oaks in Lower Vallier are dominated by older age classes (15-20 inch dbh, Fig. 23c) and have moderate amounts of nonlethal damage, except that 28% have basal swelling.

Despite relatively large amounts of red oak, tree species composition in Lower Vallier appears to be slowly shifting to an overcup dominated stand as is indicated by large numbers of young overcup throughout the impoundment. Regeneration of Nuttall oak is fair on higher sites in Lower Vallier, however, most willow oak are dying before they reach 6 inch dbh. Overall mortality rate of Nuttall oak is the 2nd lowest among impoundments. Nuttall oak generally is slightly more water tolerant than willow oak in most BLH areas (e.g., Bedinger 1979, Hinckley et al. 1978, Huffman 1976, Dale 1998) and this appears to be the case in Lower Vallier also.

Flooding of Lower Vallier consistently has begun in mid-October, however flooding has usually been gradual depending on amount of fall precipitation and water levels in Salt Bayou Ditch and Little Bayou Meto. In some years, floodpool in Lower Vallier is not reached until mid-December. Because the water-control structure on Little Bayou Meto at Lower Vallier controls flooding and draining of large areas of the WMA upstream, water levels fluctuate considerably in Lower Vallier during both flooding and draining periods. This "master control" function, causes water regimes in Lower Vallier to vary among years and probably has helped reduce some damage to red oaks in the impoundment

Beaver Dam Slough West.— The portion of the old Beaver Dam Slough area west of Little Bayou Meto is slightly (1-2 foot) lower elevation than the east side of the area and parts of the southern end of Cannon Brake. Flooding in this area occurs historically occurred from backwater flooding along Long Pond Slough, Five Forks Bayou, and Little Bayou Meto. Now, closure of the Cannon Brake

Table 25. Relative ranks (1-8, 1 having the least and 8 the most) of 6 indicators of stress and damage to the red oak component of the 8 greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

	Unit[a]							
Variable	BK	BB	CB	LV	TI	BDS	GC	UV
% Green Ash	3	1	2	5	4	7	8	6
% Basal Swelling	1	2	3	7	6	5	4	8
% Tip Die-Back	1	2	4	3	5	6	7	8
% Leaf Chlorosis	1	3	5	2	6	4	7	8
% Dead Red Oak	1	3	2	7	8	4	6	5
# Young Red Oak	2	1	5	4	6	8	3	7
ΣRanks	9	12	21	28	35	34	35	42

[a] BB - Bear Bayou, CB - Cannon Brake, BK - Buckingham Flats, TI - Temple Island, BDS – Beaver Dam Slough West, LV - Lower Vallier, UV-Upper Vallier, GC - Government Cypress.

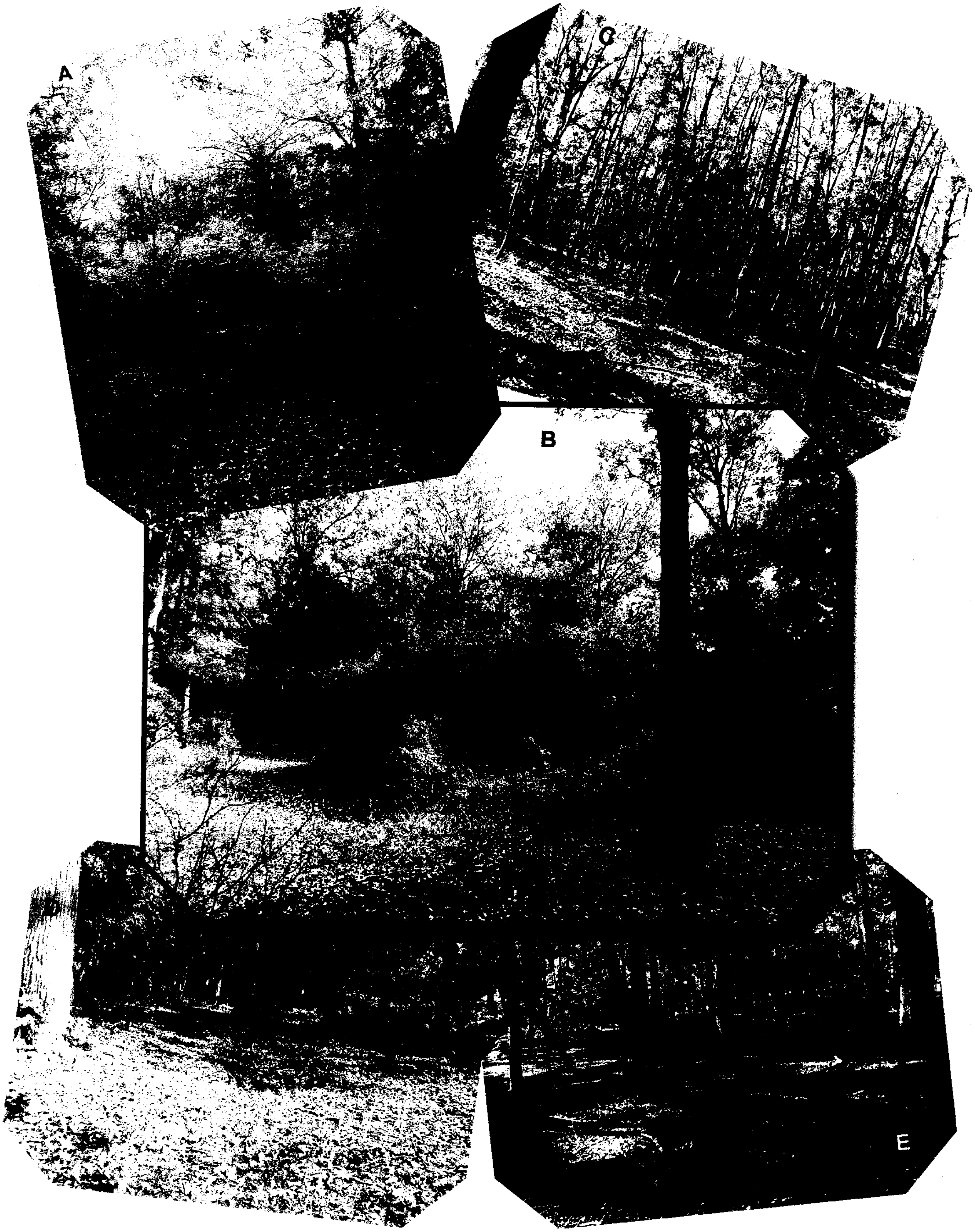


Figure 22. Examples of regeneration in: a) Buckingham Flats, b) Buckingham Flats, c) Beaver Dam Slough West, d) Government Cypress, and e) Upper Vallier greentree reservoir impoundments on Bayou Meto Wildlife Management Area, Arkansas, 2003.

Figure 23. Examples of herbaceous ground cover in: a) Bear Bayou, b) Beaver Dam Slough, c) Lower Vallier, and d) Beaver Dam Slough West greentree reservoir impoundments on Bayou Meto Wildlife Area, Arkansas, 2003.

water-control structures causes Beaver Dam Slough West to flood consistently among years. This unit tends to flood later and longer than other parts of Beaver Dam Slough and much of Cannon Brake. Drainage of this area is controlled by operation of the Cannon Brake structure and by levees and water-control structures on private duck clubs along Long Pond Slough. Late drainage below Cannon Brake in some years (see above section on Cannon Brake) and private water-control structures on Long Pond Slough often delay drainage of the Beaver Dam Slough West area until mid-summer. In summer 2003, standing water was present in the area along Long Pond Slough until mid-August.

Although Beaver Dam Slough West ranked 5th among Bayou Meto GTRs (Fig. 21), its cumulative rank score of damage and stress to red oaks (34) was almost the same as Temple Island and Government Cypress (both had ranks of 35) and indicated poor health. Significant damage has, and is, occurring to red oaks in Beaver Dam Slough West. Nonlethal damage to surviving red oaks is high and 37% of all red oaks are dead. Few willow oak remain in Beaver Dam Slough West and most regenerating willow oak die before they reach 4 inch dbh. Regeneration in Beaver Dam Slough is poor for all species except green ash (Fig. 22c), and forest composition has shifted to an overcup oak- and green ash-dominated stand. Even overcup oak regeneration is poor in Beaver Dam Slough West at present and eventually much of this area may change to shrub/scrub or ash-maple-cypress habitats. Openings and tree gaps

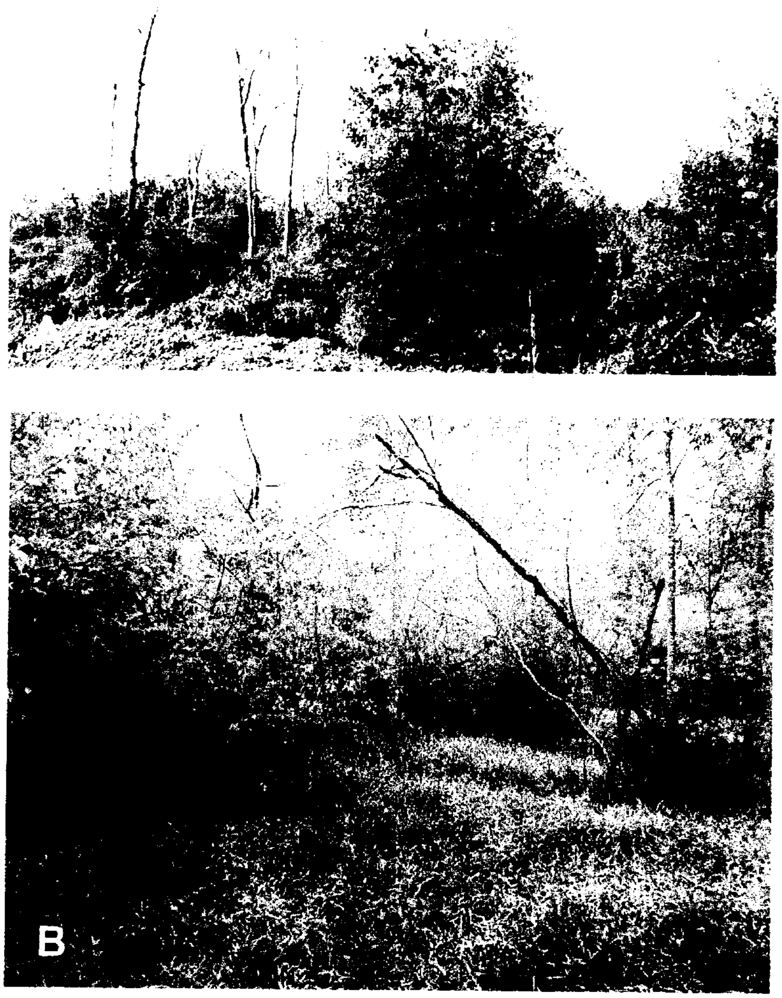


Figure 24. Dead timber and shrub/scrub areas in: a) Temple Island and b) Government Cypress greentree reservoir impoundments in Bayou Meto Wildlife Management Area, Arkansas, 2003.

in Beaver Dam Slough have few seedlings except green ash, button bush, and swamp privet (Fig. 22c, 23c).

Temple Island. — The Temple Island GTR is an enigma among the GTR impoundments on Bayou Meto WMA. It sits at the highest elevation on the WMA, has relatively good drainage that is independent of other units, and is relatively new (built in the early 1980s), yet it has the 2nd worst damage (tied with Government Cypress). The apparent cause of most damage in Temple Island is early flooding and poor internal drainage through an old slough that runs from the north central to the west part of the impoundment (Fig. 20, Fig. 24a). Until recently, rice drain water was pumped from Dry Bayou Ditch into Temple Island beginning in late August and September and surface water often ponded in the slough system until late spring or early summer. This extended flooding regime caused most BLH trees in this slough area to die, and become converted to shrub/scrub habitats.

Because of its higher elevation, the Temple Island area (prior to GTR development) was not historically flooded until early winter, had highly variable flooding duration (including not flooding in some winters), and drained in late winter or early spring. Consequently, trees that were established on this site were less water tolerant species including shagbark and mockernut hickory, American elm, pecan, and willow oak. After development, water regimes in Temple Island became significantly wetter and quickly damaged or caused death of the water intolerant species and tree species composition quickly shifted to a more water tolerant community. Even though Temple Island historically had small amounts of Nuttall oak, those present have died at a very high rate (>41% mortality). The relatively large size of dead red oaks in Temple Island (Table 19) reflects recent death of many old age class trees. Today, regeneration in Temple Island is dominated by overcup oak and green ash, although good numbers of red oak seedlings do occur at the highest elevations.

Government Cypress. — A large portion of the red oak trees in Government Cypress GTR are badly damaged and/or dead. Many overcup oak trees also are damaged or dead in the impoundment suggesting very wet conditions in the unit for an extended period. Most of the damage and death of red oaks and overcup oak in Government Cypress is in, or adjacent to, a large low elevation area in the south-central part of the impoundment (Fig. 21). This ca. 500-acre sump area has become a dead timber area that floods earlier and drains later than other areas and most mortality apparently began nearly 30 years ago. This dead timber area does not appear to be increasing in size. Internal drainage of this dead timber area is poor because of its slightly lower elevation and because beaver have consistently dammed drainage outlets. The dead timber area has transitioned into a shrub/scrub community that is dominated by buttonbush and swamp privet in the middle and green ash, water locust, and willow thickets on the edges (Fig. 24b).

While drainage of much of Government Cypress is late, the impoundment has some higher elevation ridges. On these higher sites, recent (1-2 m tall seedlings) regeneration of overcup oak and Nuttall oak is good (Fig. 22d), especially in openings, suggesting that water conditions may be improving and that remediation of some red oak damage is possible if late drainage can be curtailed. In the last 5 years, WMA personnel have attempted to control beaver populations by intensive trapping and have inspected (and removed dams) drainage areas for obstructions caused by beavers weekly.

Upper Vallier. — Red oaks in Upper Vallier are extensively damaged. Upper Vallier is large, relatively flat, and historically had large amounts of willow oak. Flooding of Upper Vallier requires the Lower Vallier structure to be closed to back water into Salt Bayou Ditch and then into the impoundment. Likewise, draining Upper Vallier requires that Lower Vallier structure be open and water levels in Lower Vallier be reduced to allow flow from Upper Vallier. Consequently, drainage of Upper Vallier is late and water regimes have been relatively prolonged and consistent for over 50 years. Thus, large areas of willow and Nuttall oak have been inundated for long periods each year. About 25% of these red oaks are now dead. No single large patch of dead timber exists in the unit, but mortality is scattered throughout the unit. Water levels in Upper Vallier also are held high (180 feet amsl) and the flat topography results in consistently deeper water over a greater proportion of the impoundment compared to other GTRs on the WMA.

Forest composition of Upper Vallier has shifted from a willow oak-dominated stand to one that includes mostly overcup oak, cedar elm, and green ash. Regeneration of all trees is poor (Fig. 22c) and seedlings that survive primarily are overcup oak and green ash. Regeneration of oaks is not light-limited in Upper Vallier; openings have few seedlings and regeneration that occurs is mostly green ash. Herbaceous cover in Upper Vallier is very low and comprised almost exclusively of rice cutgrass and sedges except at the highest elevations.

MANAGEMENT RECOMMENDATIONS

General

BLH habitats and resources in Bayou Meto WMA are extremely important for maintaining ecological functions and values in the Bayou Meto Basin and Upper MAV. BLH forests have been extensively destroyed and degraded in the Bayou Meto Basin and most remnant patches are highly fragmented, small, and have altered hydrology. Consequently BLH in Bayou Meto WMA and adjacent private lands are increasingly important to sustain both local and regional plant and animal communities.

Careful management of GTRs on Bayou Meto is needed in the future because BLH habitats in GTRs are badly degraded, some more than others. Some damage in GTRs is old and relatively confined to specific areas (e.g., Government Cypress), but other impoundments have recent damage that is expanding rapidly (e.g., Cannon Brake, Beaver Dam Slough). GTRs on Bayou Meto WMA have retained an average of 22.4% red oaks which provide critical resources for many fish and wildlife species, especially wintering mallards and wood ducks. However, tree species composition in the GTRs is shifting to a more water tolerant community dominated by overcup oak and green ash. The presence of green ash is an especially important indicator of prolonged periods of inundation. Another important indicator of prolonged flooding regimes is limited herbaceous cover (mean of 37% in the GTRs) comprised of rice cutgrass and sedges (Fig. 23). Surviving red oak trees in Bayou Meto WMA GTRs have many indicators of declining tree health - 20.7% of red oaks have basal swelling, 14.0% have evidence of leaf chlorosis, and 22.3% have at least some death of terminal branches (tip die-back). Furthermore, 24.9% of Nuttall oak and 21.0% of willow oak have died. This mortality includes large old trees as well as young regenerated trees. In most GTR impoundments, few newly regenerated red oaks survive to be larger than 4-6 inches dbh.

Analysis of data from the 8 GTRs on Bayou Meto WMA provide important insights into causes of damage and mortality to red oaks and the overall forest species composition. Each impoundment has somewhat unique water management and hydrological regimes and damage is not similar among them. Certain general observations and recommendations are common for all units and suggest the following:

1. Water regimes in GTRs are more prolonged than occurred historically. Flooding occurs earlier and extends later than in pre-GTR periods.
2. Both early flooding and late drainage cause damage to red oaks and when both conditions occur in an impoundment, damage and mortality is severe.
3. Consistent timing of flooding and drainage over many years, without substantial annual variation, contributes to BLH damage. GTR impoundments with variable flood and drainage schedules have reduced damage relative to overall flood duration.
4. Lack of independent water-control to flood and drain individual GTR impoundments creates situations where flooding occurs earlier or drainage is later than under natural conditions
5. Infrastructure on the WMA (and some adjacent private duck clubs) has altered natural water flow across the WMA and created situations where drainages have become obstructed and water has become impounded for long periods. Obstructions include levees across natural channels, under-sized and inappropriately placed water-control structures, debris and dead tree material, silt, and extensive beaver dams and plugs.
6. Regeneration of red oaks is compromised because of prolonged flooding. In a few units

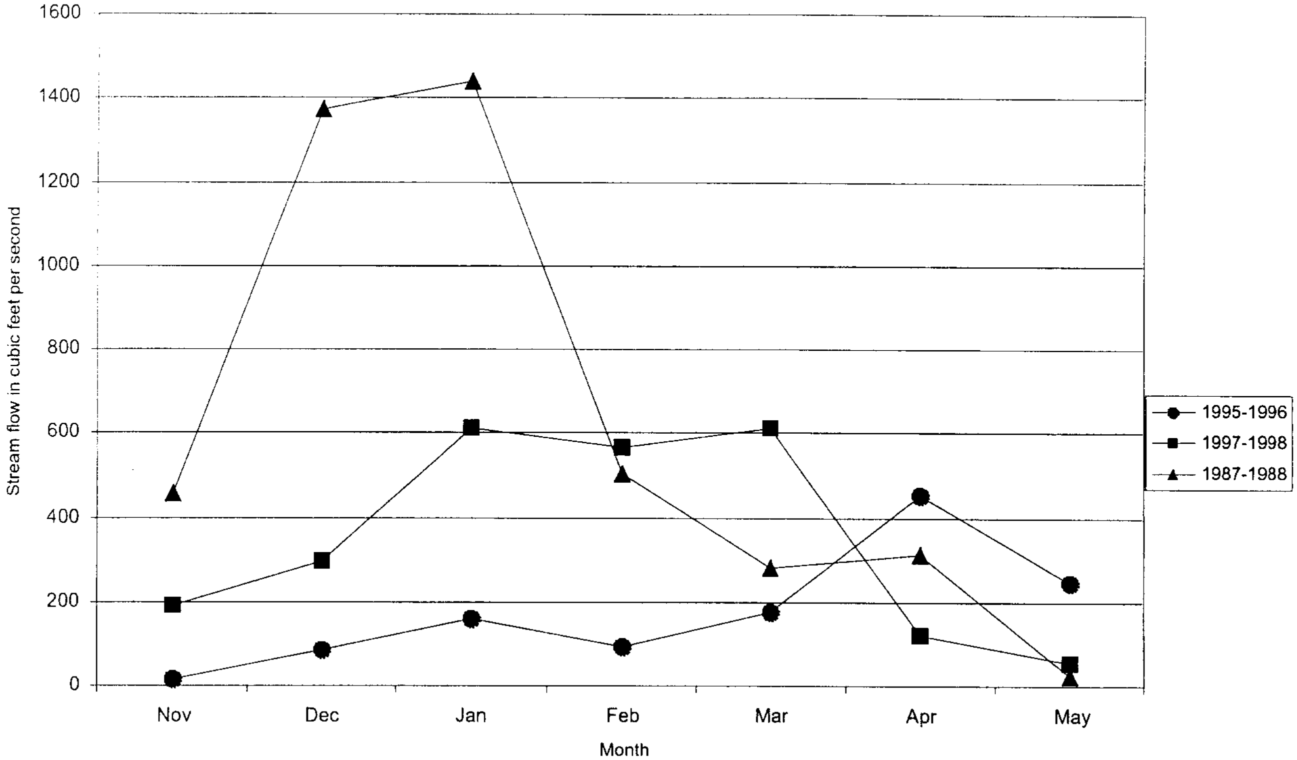


Figure 25. Example of mean monthly streamflow (cubic feet/second) from November to May in Bayou Meto at Lonoke, Arkansas in dry and wet years.

older, relatively even-age, stands have created light limitations for young seedlings. However, extensive tree mortality occurs in most units and has created many scattered openings. With the exception of Buckingham Flats and Bear Bayou, even these light-rich openings continue to have poor red oak regeneration indicating that factors other than light are prohibiting regeneration.

Given these observations, we suggest the following general management recommendations:

1. *Emulate natural flooding regimes.*

Where possible, water regimes in GTRs should be changed to more closely emulate natural timing, depth, duration, and extent of flooding. Winter flooding of natural BLH stands is highly variable within and among years (e.g. Fig. 25) and management should attempt to vary flooding schedules among years in all GTRs on Bayou Meto WMA. On average, natural BLH habitats in the southern Bayou Meto floodplain are not >50% flooded until after 20 November and most areas are draining rapidly by late January to mid-February (Table 26). In wet years, extensive natural flooding may occur as early as late October and remain until March. In contrast, significant flooding in dry years may not occur until late December, if at all, and flood duration is short (Table 26). Long term precipitation and streamflow data suggest that flooding periodicity in the southern Bayou Meto floodplain follows a fairly regular pattern of peak highs or lows about every 5-7 years (Figs. 5,6; Table 2). Consequently, a rotation of flooding and draining schedules similar to that proposed for other GTR areas (Fig. 26) might be useful on Bayou Meto WMA.

2. *Improve water flow across, and drainage of, GTR impoundments in late winter and spring.*

The causes of red oak stress and mortality varies among Bayou Meto WMA impoundments. Stress/mortality in some units such as Cannon Brake, Beaver Dam Slough West, and Government Cypress are caused largely by an inability to drain water quickly in late winter and spring. One impoundment, Temple Island, has high mortality and stress of red oaks because of artificially early flooding schedules. The remaining impoundments exhibit varying degrees of damage from multiple causes including early flooding, unvaried flood and drain dates, deep flood pools during hunting seasons, and inability to drain early (from flooded streams, silted and obstructed drainage channels, and beaver activity).

3. *Curtail construction of additional levees or further compartmentalization of GTR impoundments.*
   Additional levees would further disrupt water movement and drainage across Bayou Meto WMA, add maintenance time and cost, and provide more opportunities for beaver damage. Control of beavers in GTRs should continue and internal drainage of some GTRs should be improved. Major drainage channels should be cleared of obstructions and silt. Infrastructure changes that could improve drainage capabilities should be evaluated.
4. *Carefully manage existing BLH stands to improve red oak regeneration.*
   Long-term sustainability of BLH stands on Bayou Meto WMA requires periodic regeneration of red oaks in GTR impoundments (e.g., Johnson 1975). A primary management change that is needed to improve regeneration of red oaks is to reduce the flood duration to a more natural regime with periodic dry conditions. GTR impoundments do not necessarily need to be completely dry in some years, but they need variable flooding schedules that delay flooding until mid-winter or initiate drainage by late winter on a regular basis (e.g., Fig. 26). Red oak regeneration in most impoundments is not "light-limited" and substantial openings already occur in most units because of past mortality. Until hydrologic improvements are made, the only impoundments that might benefit from timber harvest under current hydrological conditions are Buckingham Flats and Bear Bayou. In these impoundments, timber cutting should select trees for uneven-aged stand management (e.g., Denman and Karnuth 2004). Planting container-grown trees >5 feet tall should be evaluated to stimulate reestablishment of red oaks in some badly damaged areas, assuming that water regimes in these impoundments can be changed to more natural conditions. Evaluation of container-grown seedlings in northern parts of the MAV has been initiated and suggest that they survive at high rates even in extensively flooded areas, and grow quickly to an acorn producing size.
5. *Regularly monitor BLH condition and water levels in GTR impoundments.*
   WMA personnel initiated weekly water-level monitoring in GTR impoundments from October through February in the mid-1990s. This monitoring should continue to determine progress in shifting flooding and drainage schedules to more natural regimes. We also suggest that water levels be monitored at least weekly through mid-summer to document delayed drainage and to identify obstructions such as beaver dams. Condition of BLH stands in the GTRs should be monitored periodically, at least once every 5 to 10 years. Random plots used in this study could be used as permanent sites

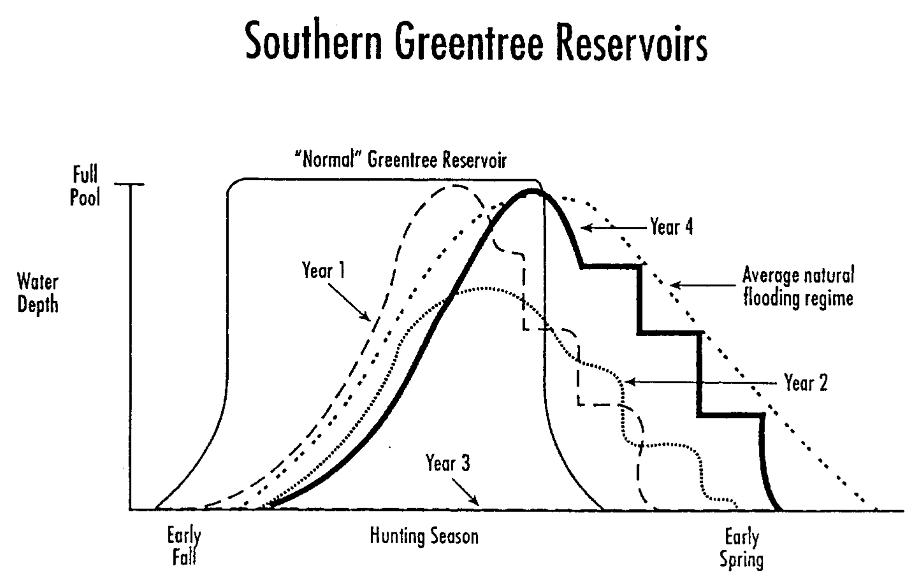


Figure 26. Hypothetical flooding regimes for greentree reservoirs that emulate natural winter flooding periodicities in the Mississippi Alluvial Valley (modified from Fredrickson and Reid 1988, Heitmeyer et al. 1996).

for periodic data collection. Long-term data on changes in GTR condition and species composition is one important measurement of management effectiveness and will help assure the maintenance of critical functions and values of the WMA. Because waterfowl use is important in the WMA, we suggest intensive evaluation of waterfowl use within GTR impoundments throughout fall, winter and spring. Data should be collected on bird use, behavior, nutrition, and physiology.

6. *Develop a forest management plan to compliment the water management plan.*

   Regeneration and maintenance of bottomland hardwood plant species within disrupted landscapes requires treatments that emulate historic disturbances to forests, in addition to emulation of historic hydrologic regimes. Because red oaks in BLH forests are shade intolerant, treatments that disrupt the canopy to allow more light to reach the forest floor may be necessary for the establishment and regeneration of red oaks and other shade intolerant plants, if openings are not present. A forest management plan that incorporates strategies to address complex interactions between hydrologic condition and other factors elated to the establishment and regneration of forests assures that the structure and foods required by animal species common to the Bayou Meto Basin remain a part of this system into the future.

Specific Impoundments

Specific management recommendations for individual GTR impoundments on Bayou Meto WMA are provided below:

Table 26. Long-term average time of flooding and drainage of low and high elevation bottomland hardwood forest areas in the southern Bayou Meto floodplain, Arkansas.

	Lower elevation		Higher elevation	
	50% Flood	50% Drain	50% Flood	50% Drain
Wet	10 Nov	15 Mar	1 Dec	15 Feb
Average	20 Nov	20 Feb	15 Dec	10 Jan
Dry	15 Dec	1 Feb	1 Jan	19 Jan

Buckingham Flats. — Management should attempt to maintain the relatively healthy condition of BLH in this impoundment. Specific recommendations include:

- Delay initial flooding of the unit until after 1 November and attempt to completely drain the impoundment by the end of February.
- Maintain independent flood and drain capabilities and gradually flood the impoundment over a 3- to 4-week period using the lift pump on Bayo Meto and delivery ditch system through the Wrape Plantation pools.
- Stagger flood dates among years ranging from 15 October to 15 November.
- Improve the internal drainage of the slough system in the middle of the impoundment.
- Evaluate survival of red oak seedlings in existing openings and eventually begin select cuts.

Bear Bayou. — Flooding regimes in this new GTR impoundment should seek to emulate short duration and annually dynamic flood pulses that occurred naturally on this higher elevation site. Bear Bayou contains the greatest proportion of water intolerant tree species and will be highly susceptible to damage if flooding regimes become long and consistent. Specific recommendations include:

- Flood the impoundment gradually from late November to late December with variation in timing among years.
- Stagger drainage schedules from mid-January to mid-February with an attempt to completely drain the area by mid-March.
- Do not close water-control structures or purposefully flood the impoundment every 3rd year in accordance with USACE permit requirements.
- Develop a predictable water source for flooding the impoundment in late fall and early winter.
- Monitor regeneration carefully and begin small selective cuts in closed canopy areas if small red oaks consistently die before reaching 2 inch dbh.

Cannon Brake. — This GTR impoundment is on the verge of rapid and severe damage and mortality to red oaks. The primary problem in Cannon Brake is poor and late drainage and management should quickly seek remediation for this problem. Recommendations include:

- Continue late flooding in accordance with private landowner easement agreements. Vary annual flooding (via closing water-control structures) from 1-30 November.
- Monitor the status of red oaks annually. If damage is not reversed and if additional red oaks begin to die within the next 3 years, the impoundment should not be flooded for at least 1 to 2 years and thereafter only 2 of every 3 years until timber health improves.
- Open water-control structures and begin drainage by late January each year. Monitor water levels weekly through spring to make sure drainage channels and structures are open and that beaver dams are removed.
- Improve drainage through Little Bayou Meto south of the Cannon Brake levee by removing obstructions and silt to its mouth at the Arkansas River.
- Cooperate with private landowners to improve timely and efficient drainage of their lands and identify private structures that impede drainage of WMA land in Cannon Brake.
- The health of existing red oaks needs to be stabilized before forest management is implemented.

Temple Island. – Temple Island sits at a high elevation and its pre-GTR forest included species characteristic of drier sites. Early prolonged flooding has caused BLH in Temple Island to be badly damaged and tree species composition has shifted to more water tolerant communities in low areas. Recommendations include:

- Delay flooding the impoundment until late November. Manage for annually variable flooding schedules with flooding delayed until mid-December in some years.
- Develop a more dependable water source for the impoundment other than the agricultural drain flows pumped from Dry Bayou Ditch in early fall.
- Open water-control structures and begin draining the impoundment in late January.
- Improve internal drainage, especially in the old slough system, by careful ditching to connect low areas with drain channels, remove debris and obstructions from drain channels, and enlarge the water-control structure on the west levee to increase discharge capacity.
- After water regimes are shortened and internal drainage is improved, begin selective cuts especially in areas that have been converted to green ash, water locust, and willow. Experimentally plant some container grown willow and Nuttall oak seedlings 4-5 feet tall in these clearings and monitor survival and growth.

Beaver Dam Slough West. — BLH health in Beaver Dam Slough West has deteriorated because of late and inefficient drainage. Existing damage and mortality must be reversed and then rehabilitation of the red oak component of this area can begin. Because of the extensive mortality, it may take several decades (if it can be done at all) to reestablish 20-30% red oaks in the area. Recommendations include:

- Operate the Cannon Brake structure and alter flooding regimes in Cannon Brake as identified above.
- Clean obstructions and silt from Little Bayou Meto throughout the Beaver Dam Slough area to improve and accelerate drainage. This work also will help drainage for upstream GTRs especially Lower Vallier, Upper Vallier, and Government Cypress.
- Remove obstructions and silt from ca. 2 miles of Long Pond Slough from the control structure on the Lower Vallier Levee to its juncture with Five Forks Bayou.
- Remove the old abandoned levee and water-control structures on Beaver Dam Slough.
- Cooperate with adjacent private landowners to increase water flow down Long Pond Slough and drain their lands early in spring if possible. Early drainage also will improve degraded private BLH stands.
- After drainage is improved, begin selective cuts especially in the low areas that now are dominated by green ash, water locust, and buttonbush. Experimentally plant container-grown seedling 4-5 feet tall in these openings and monitor their survival and growth.

Lower Vallier. — Flow and impoundment of water in Lower Vallier controls the hydrologic regimes in large areas of Bayou Meto WMA. Considerable damage and mortality of red oaks has occurred in Lower Vallier and species composition has slowly shifted to an overcup dominated stand. Nonetheless, water levels fluctuate considerably in the impoundment and apparently have reduced damage compared to Upper Vallier and Government Cypress. Recommendations include:

- Stagger flood and drain schedules using a 5-7 year regime similar to that suggested in Fig.

25 where early flooding is not initiated before 15 October and drainage is not later than 15 February. Flooding in most years should not begin before 1 November.

- Continue the process of initially inserting stoplogs to a 178 foot level and then not raising water levels to 179.5 feet until at least mid-November.
- Upgrade primary water-control structures on Long Pond Slough, Five Forks Bayou, and Little Bayou Meto to mechanically-controlled systems to increase efficiency of drainage.
- Remove (or at least cut 100-300 foot notches in) the old levee and slough blockages on Bubbling Slough

Upper Vallier. — Rehabilitation of the red oak component of Upper Vallier GTR will require many years of staggered and relatively short, flooding regimes. Recommendations include:

- Manage water levels in Lower Vallier GTR as recommended above and do not initiate flooding of Upper Vallier until at least early November. Flooding Upper Vallier should be gradual if possible so that full pool is not reached until 3 to 4 weeks after initial floodup.
- Improve efficiency of drainage in Cannon Brake, Beaver Dam Slough, and Lower Vallier as stated above and open all water-control structures in Upper Vallier by late January.
- Clean ditches on the perimeter of Bayou Meto to divert water away from Upper Vallier; this includes areas around Tipton Access and Halowell Reservoir.
- Remove obstructions and silt from internal drainages, especially Little Bayou Meto and Hurricane Slough.
- Regularly monitor all drainages and water-control structures to remove beaver dams and debris that prohibit efficient drainage in late winter and spring.
- Considerable openings exist in the unit because of tree mortality, thus no additional cutting is needed to improve light conditions for potential red oak germination and seedling survival in these areas.
- Begin annual monitoring in the unit to determine changes in red oak damage and mortality, increasing composition of overcup oak and green ash, and red oak regeneration. If damage increases, the unit should not be flooded for several sequential years to reverse problems.

Government Cypress. — Management of Government Cypress should focus on improving drainage in and around the dead timber area in the south-central part of the impoundment. Recommendations include:

- Manage water levels in Lower Vallier as suggested above. Stagger initial flooding of Government Cypress between mid-November and mid-December over a 5- to 7-year period. Initiate drainage of the unit by late January.
- Improve internal drainage by cutting small drainage ditches into the middle of the dead timber area to move water to outlets on Salt Bayou Ditch and Government Cypress Slough.
- Continue active monitoring and control of beaver.
- Evaluate drainage elevations of the Government Cypress Slough water-control structure to determine if lowering the outlet by 1 to 2 feet could facilitate drainage.
- After water regimes are altered and drainage is improved, begin clearing small areas of dead timber and shrub/scrub vegetation on the perimeter of the dead timber area to provide areas for red oak regeneration. Experimentally plant container-grown Nuttall oak seedlings in these openings and monitor survival and growth rates.

Proposed U.S. Army Corps of Engineers Projects

The USACE Bayou Meto Basin Improvement Project EIS has recommended several flood control projects in or around Bayou Meto WMA. The preferred alternative #3A specifically includes:

- Constructing a 1000 cubic-feet/second pump adjacent to the Little Bayou Meto gravity floodgates at mile 0 where Little Bayou Meto connects with the Arkansas River.
- Increasing the size of 9.8 miles of Little Bayou Meto from Cannon Brake to the pump station at mile 0 by lowering the channel bottom grade and widening the channel to 30 feet.
- Adding a second water-control structure (3 10-feet x 10-feet gates) adjacent to the existing Cannon Brake structure to divert drainage water down Little Bayou Meto to the pump station.
- Excavating 1 to 2 feet of Little Bayou Meto with a 40-foot bottom between miles 9.8 and 11.5.

- Diverting Boggy Slough around the WMA to bypass flows into the WMA between miles 12.7 and 17.7.
- Constructing diversion weirs and grade control structures on Boggy Slough and Castor Bayou to prevent headcutting and ensure balanced flow. This would facilitate water level control in Lower Vallier GTR.

In addition to the above proposals, a cooperative USACE/AGFC 1135 project has been proposed that would :

- Rehabilitate 3.5 miles of the Lower Vallier levee by raising the levee to 182 feet amsl with a 12-foot crown width.
- Add mechanically-controlled gates to the Cannon Brake and Lower Vallier water-control structures on Little Bayou Meto.

Based on data analyses in this water management plan, almost all of the above proposals would be beneficial to improve drainage of GTRs on Bayou Meto WMA and will help future management to rehabilitate red oak components to BLH stands if they are constructed and operated appropriately. The most severe (and expanding) damage and mortality to red oaks in Bayou Meto WMA GTRs has been caused by prolonged and unnatural water regimes, especially late and slow drainage in late winter and spring. Of the structural proposals listed above, several are specifically recommended and discussed in preceding sections of this report and in individual GTR impoundment management recommendations. The proposed pump station and enlarged channel sections of Little Bayou Meto are among the most beneficial if pumping and drainage through Little Bayou Meto coincides with timing of drainage of GTRs in late winter (late January through spring). Pumping water from Little Bayou Meto prior to GTR drainage is not desirable except during periods of high floods that jeopardize the integrity of WMA levees and water-control structures or causes extensive flooding of private lands adjacent to the WMA (Arkansas Game and Fish Commission 1992). We recommend that AGFC and USACE jointly develop a cooperative agreement for operation of the pump at mile 0 of Little Bayou Meto to facilitate drainage of GTRs in late winter and spring. The agreement should not compromise intentional flooding schedules of the GTRs or regional water conditions adjacent to the WMA that are desirable in late fall and winter.

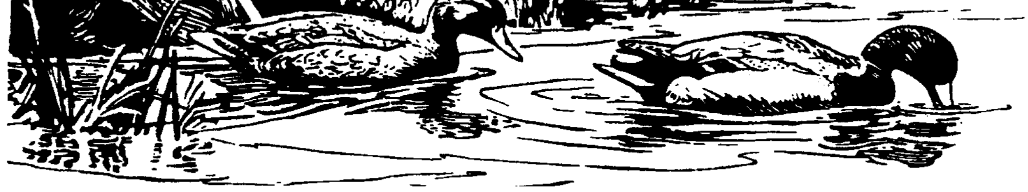
In addition to the above proposed projects, we recommend that other structural developments be considered by AGFC and USACE including:

- Removal or notching of the abandoned levee on Bubbling Slough.
- Development of dependable and independent water sources for flooding Bear Bayou and Temple Island.
- Improving internal drainage of Government Cypress and Upper Vallier and evaluating base drainage levels of these units.
- Improving drainage down Long Pond Slough.
- Clean ditches along the perimeter of Upper Vallier to prevent excessive drainage of water from private agricultural land into Upper Vallier.

ACKNOWLEDGMENTS

This project was conducted via a grant from the USACE Memphis District to Tetra Tech, Inc. and subcontract to Mickey E. Heitmeyer. The project was initiated at the request and recommendation of the Environmental Team Working Committee for the Bayou Meto Basin Irrigation and Flood Control Project and included important assistance from staff of USACE, AGFC, U.S. Fish and Wildlife Service (USFWS), U. S. Natural Resources Conservation Service (NRCS), Arkansas Natural Heritage Commission (ANHC), Arkansas Soil and Water Conservation Service, and Bayou Meto Irrigation District (BMID). Ed Lambert, Ken Bright, and Mark Smith (USACE) provided administrative assistance and coordination of all aspects of the study. Gene Sullivan and the BMID encouraged the initiation of the project and provided administrative and financial assistance. Craig Uyeda, Jo Ann Holder, and Roger Milligan (AGFC) provided administrative and field assistance and extensive information and data on Bayou Meto WMA. We especially thank Roger Milligan and the staff of Bayou Meto WMA for providing access to the WMA, helping with field work, and encouraging the development of this management plan. Tom Foti (ANHC) and Jody Pagan (NRCS) helped with field work and along with Chuck Klimas developed the HGM models that were used to develop habitat maps and calculate habitat acreage for the WMA. They also provided critical insights into BLH community distribution and dynamics of the region and offered valuable suggestions throughout the project. Allan Mueller and Jason Phillips (USFWS) provided support and field assistance for the project and they and Roger Milligan helped develop the flood/drain matrix study design to sample the 240 random GTR plots to determine status of BLH in the WMA. Karen Kyle (University of Missouri) helped prepare the manuscript, tables and figures for the report. Mary Ann Hartman and Ben Kyle also helped prepare tables and figures.

We sincerely thank Maynard Reece and Millpond Press for permission to use Reece's painting, "Morning Light - Mallards" for the cover art of this publication.



LITERATURE CITED

Arkansas Game and Fish Commission. 1992. Bayou Meto Wildlife Management Area Water Management Plan. Arkansas Game and Fish Commission, Little Rock.

Arkansas Game and Fish Commission. 1998. Arkansas wildlife: a history. Arkansas Game and Fish Commission, Little Rock.

Arkansas Soil and Water Conservation Commission. 1988. Arkansas state water plan: Eastern Arkansas Basin. Arkansas Soil and Water Conservation Commission, Little Rock.

Baker, J. A. and K. J. Kilgore. 1994. Use of a flooded bottomland hardwood wetland by fishes in the Cache River system, Arkansas. Wetland Research Program Technical Report WRP-CP-3, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Batema, D. L., R. M. Kaminski and P. A. Magee. 2004. Wetland invertebrate communities and management of hardwood bottomlands in the Mississippi Alluvial Valley. Pages - in L. H. Fredrickson, S. L. King and R. M. Kaminski, eds. Ecology and management of bottomland hardwood ecosystems: the state of our understanding. University of Missouri Printing, Columbia (In press).

Bedinger, M. S. 1979. Relation between forest species and flooding. Pages 427-435 in P. C. Greeson, J. R. Clark and J. E. Clark, eds. Wetland functions and values: the state of our understanding. American Water Resources Association Technical Publication 79-2. Minneapolis, MN.

Black, R. A. 1984. Water relations of Quercus palustris: field measurements on an experimentally flooded stand. Oecologia 64: 14-20.

Brakhage, G. K. 1966. Management of mast crops for wood ducks. Pages 75-80 in J. B. Trefethen, ed. Wood duck management and research: a symposium. Wildlife Management Institute, Washington, DC.

Broadfoot, W. M. and H. L. Williston. 1973. Flooding effects of southern forests. Journal of Forestry 71:584-587.

Cochran, S. M. 1999. Roosting and habitat use by Rafinesque's big-eared bat and other species in a bottomland hardwood forest ecosystem. M.S. thesis, Arkansas State University, Jonesboro.

Covington, P. and M. L. Laubhan. 2004. Monitoring as a key to adaptive management of a greentree reservoir in Missouri. Pages - in L. H. Fredrickson, S. L. King and R. M. Kaminski, eds. Ecology and management of bottomland hardwood ecosystems: the state of our understanding. University of Missouri Printing, Columbia (In press).

Dale, E. D. 1998. Evaluation of vegetation in Bayou Meto Game Management Area. In M. A. Gross, D. C. Wolfe, and J. Murdock, eds. Bottomland hardwood investigations, Nevins Creek Mitigation Project TRC-9603, Prepared for Arkansas Highway and Transportation Department in cooperation with U.S. Department of Transportation and Federal Highway Administration, Fayetteville, AR.

Denman, J. B. and L. Karnuth. 2004. Fifty years of uneven-aged regeneration of oaks in bottomland hardwood forests. Pages - in L. H. Fredrickson, S. L. King and R. M. Kaminski, eds. Ecology and management of bottomland hardwood ecosystems: the state of our understanding. University of Missouri Printing, Columbia (In press).

Francis, J. M. 1983. Acorn production and tree growth of Nuttall oak in a green-tree reservoir. U. S. Forest Service Research Note SO-289.

Fredrickson, L. H. 2004. Greentree reservoir management: contemporary considerations. Pages - in L. H. Fredrickson, S. L. King and R. M. Kaminski, eds. Ecology and management of bottomland hardwood ecosystems: the state of our understanding. University of Missouri Printing, Columbia (In press).

Fredrickson, L. H. 1979. Impacts of water management on the resources of lowland hardwood forests. Pages 51-61 in R. H. Chabreck and R. H. Mills, eds. Integrating timber and wildlife management in southern forests. 29th Annual Forest Symposium, Louisiana State University, Baton Rouge.

Fredrickson, L. H. and D. L. Batema. 1992. Greentree reservoir management handbook. Wetland Management Series 1, Gaylord Memorial Laboratory, University of Missouri-Columbia, Puxico.

Fredrickson, L. H. and F. A. Reid. 1988. Waterfowl use of wetland complexes. U. S. Fish and Wildlife Service, Fish and Wildlife Leaflet 13.2.1.

Gandy, L., S. Holbrook and G. Tucker. 2000. Bayou Meto Wetland Planning Area Report. FTN Associates, Ltd., Prepared for Arkansas Multi-Agency Wetland Planning Team. Little Rock, AR.

Garver and Garver, Inc. 1985. Bayou Meto Wildlife Management Area hydrologic and hydraulic study. Garver and Garver, Inc., Little Rock.

Garver, Inc. 2000a. Bayou Meto Wildlife Management Area Cannon Brake levee overflow spillway specifications and contract documents, prepared for Arkansas Game and Fish Commission., Garver, Inc., Little Rock.

Garver, Inc. 2000b. Bayou Meto Wildlife Management Area Upper Vallier Water-control structure specifications and contract documents, prepared for Arkansas Game and Fish Commission, Garver, Inc., Little Rock.

Godfrey, R. K. and J. W. Wooten. 1979a. Aquatic and wetland plants of southeastern United States: monocotyledons. University of Georgia Press, Athens.

Godfrey, R. K. and J. W. Wooten. 1979b. Aquatic and wetland plants of southeastern United States: dicotyledons. University of Georgia Press, Athens.

Griffee, C. 2002. From the scatters to Buckingham Flats: a history of Bayou Meto Wildlife Management Area. Arkansas Game and Fish Commission, Little Rock.

Heitmeyer, M. E. 1987. The prebasic moult and basic plumage of female mallards (*Anas platyrhynchos*). Canadian Journal of Zoology 65:2248-2261.

Heitmeyer, M. E. 1988. Body composition of female mallards in winter in relation to annual cycle events. Condor 90:669-680.

Heitmeyer, M. E. 2001. Waterfowl. Pages 209-223 in J. G. Dickson, ed. Wildlife of southern forests. Hancock House Publishing Company, Blaine, WA.

Heitmeyer, M. E., L. H. Fredrickson, B. Ederington and S. L. King. 2002. An evaluation of ecosystem restoration options for the Bayou Meto Basin of Arkansas. Special Publication No. 5, Prepared for U. S. Army Corps of Engineers Memphis District, Gaylord Memorial Laboratory, University of Missouri-Columbia, Puxico.

Heitmeyer, M. E., L. H. Fredrickson and G. F. Krause. 1991. Water relationships among wetland habitat types in the Mingo Swamp, Missouri. Wetlands 11: 55-66.

Heitmeyer, M. E., R. J. Cooper, J. G. Dickson and B. D. Leopold. 2004. Ecological relationships of warm-blooded vertebrates in bottomland hardwood ecosystems. Pages - in L. H. Fredrickson, S. L. King and R. M. Kaminski, eds. Ecology and management of bottomland hardwood ecosystems: the state of our understanding. University of Missouri Printing, Columbia (In press).

Heitmeyer, M. E., P. J. Caldwell, B. D. J. Batt and J. W. Nelson. 1996. Waterfowl conservation and biodiversity in North America. Pages 125-138 in J. T. Ratti, ed. 7th International Waterfowl Symposium, Ducks Unlimited, Inc., Memphis, TN.

Hertlein, D. M. and R. J. Gates. 2004. Condition, species composition, and oak regeneration in a pin oak forest managed as a greentree reservoir in southern Illinois. Pages - in L. H. Fredrickson, S. L. King and R. M. Kaminski, eds. Ecology and management of bottomland hardwood ecosystems: the state of our understanding. University of Missouri Printing, Columbia (In press).

Hinckley, D. D., J. P. Lassoie and S. W. Running. 1978. Temporal and spacial variations in the water status of forest trees. Forest Science Monographs 20: 1-72.

Holder, T. H. 1951. A survey of Arkansas game. Arkansas Game and Fish Commission, Little Rock.

Holder, T. H. 1968. Special report on Bayou Meto Area and basin problems. Unpublished report to Arkansas Game and Fish Commission, Little Rock

Holder, T. H. 1970. Disappearing wetlands in eastern Arkansas. Arkansas Planning Commission, Little Rock.

Huffman, R. T. 1976. Vegetational analysis of the Bayou Meto Wildlife Management Area. Final report prepared for Department of Local Services, State of Arkansas, Little Rock, Arkansas. Department of Botany and Bacteriology, University of Arkansas, Fayetteville.

Johnson, R. L. 1975. Natural regeneration and development of Nuttall oak and associated species. U. S. Forest Service Research Paper SO-104, Southern Forest Experiment Station, New Orleans, LA.

Karr, B. L., G. L. Young, J. D. Hodges, B. D. Leopold and R. M. Kaminski. 1990. Effect of flooding on green-tree reservoirs. U. S. Department of the Interior Technical Completion Report G1571-03, Washington, DC.

King, S. L. 1995. Effects of flooding regimes on two impounded bottomland hardwood stands. Wetlands 15: 272-284.

King, S. L. and L. H. Fredrickson. 1998. Bottomland hardwood guidebook: the decision making process, design, management, and monitoring of

GTR's. Report prepared for The Environmental Protection Agency, Dallas, TX.

Klimas, C., J. Pagan and T. Foti. 2002. Hydrogeomorphic site classification, Bayou Meto Basin, Arkansas. Appendix A in Landscape-scale approach for evaluating wetland restoration alternatives in Bayou Meto Basin, Arkansas. Report to U.S. Army Corps of Engineers, Memphis District.

Knobel, E. W. 1921. Soil survey of Lonoke County, Arkansas. Field Operations of the Bureau of Soils, Washington, DC.

Lowery, G. H. 1974. The mammals of Louisiana and its adjacent water. Louisiana State University Press, Baton Rouge.

MacDonald, P. O., W. E. Frayer and J. K. Clauser. 1979. Documentation, chronology and future projections of bottomland hardwood habitat losses in the Lower Mississippi Alluvial Plain, Vols 1 and 2. U. S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

McNeilly, D. P. 2000. The old south frontier: cotton plantations and the formation of Arkansas society, 1819-1861. University of Arkansas Press, Fayetteville.

McQuilken, R. A. and R. A. Musbach. 1977. Pin oak acorn production on green tree reservoirs in southeastern Missouri. Journal of Wildlife Management 41: 218-225.

Merz, R. W. And G. K. Brakhage. 1964. The management of pin oak in a duck shooting area. Journal of Wildlife Management 28: 233-239.

Miller, A. C. and B. Payne. 2002. Effects of channel modification and flow augmentation on freshwater mussels in the Bayou Meto Area, Arkansas. U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS.

Minckler, L. S. and R. E. McDermott. 1960. Pin oak acorn production and regeneration as affected by stand density, structure, and flooding. Missouri Agricultural Experiment Station Bulletin 750, University of Missouri-Columbia, Columbia.

Mitchell, W. A. and C. J. Newling. 1986. Greentree reservoirs. Section 5.5.3 in C. O. Martin, ed. Wildlife resources management manual. U. S. Army Corps of Engineers Waterways Experiment Station Technical Report EL-86-9.

Mueller, A. J., C. R. Loesch and D. J. Twedt. 2000. Development of management objectives for breeding birds in the Mississippi Alluvial Valley. In R. Bonney, D. N. Pashley, D. Cooper and L. Niles, eds., Strategies for bird conservation: the Partners in Flight planning process. Cornell Laboratory of Ornithology, New York.

Newling, C. J. 1981. Ecological investigation of a greentree reservoir in the Delta National Forest, Mississippi. U. S. Army Corps of Engineers Waterways Experiment Station Miscellaneous Paper EL-81-5.

Pagan, J., C. Klimas, and T. Foti. 2002. Potential plant community distribution, Bayou Meto Basin, Arkansas. Appendix B in Landscape-scale approach for evaluating wetland restoration alternatives in Bayou Meto Basin, Arkansas. Report to U.S. Army Corps of Engineers, Memphis District.

Robison, H. W. and T. M. Buchanan. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville.

Rudolph, R. R. and C. G. Hunter. 1964. Green trees and greenheads. Pages 611-618 in J. P. Linduska, ed. Waterfowl tomorrow. U. S. Department of the Interior, Washington, DC.

Ryckeley, D. 2000. A planning aid report on the eastern Arkansas region comprehensive reevaluation study, Bayou Meto subarea, Arkansas. U. S. Fish and Wildlife Service, Conway, AR.

SAS Institute, Inc. 2000. SAS user's guide: statistics: 2000 edition. SAS Institute, Inc., Cary, NC.

Saucier, R. T. 1994. Geomorphology and quaternary geological history of the lower Mississippi Valley, Volumes I and II. U. S. Army Corps of Engineers Waterways Experiment Station, U. S. Department of the Army, Vicksburg, MS.

Schlaegel, B. E. 1984. Long-term artificial annual flooding reduces Nuttall oak bole growth. U. S. Forest Service Research Note SO-309

Schroeder, R. L. 1982. Habitat suitability index models: yellow warbler. U. S. Department of the Interior, Fish and Wildlife Service FWS/OBS-82/10.27, Washington, DC.

Sealander, J. A. 1979. A guide to Arkansas mammals. River Road Press, Conway, AR.

Sealander, J. A. and G. A. Heidt. 1990. Arkansas mammals. River Road Press, Conway, AR.

Smith, D. E. 1984. The effects of greentree reservoir management of the development of basal swelling damage and in the forest dynamics of Missouri bottomland hardwoods. Ph.D. Dissertation, University of Missouri-Columbia, Columbia.

Sousa, P. J. and A. H. Farmer. 1983. Habitat suitability index models: wood duck. U. S. Department of the Interior, Fish and Wildlife Service FWS/OBS-82/10.43, Washington, DC.

Twedt, D. J., D. N. Pashley, W. C. Hunter, A. J. Mueller, C. R. Brown and R. P. Ford. 1999. Partners in Flight Bird Conservation Plan for the Mississippi Alluvial Valley. (http://www.blm.gov/wildlifeplan/MAV plan.html).

U. S. Army Corps of Engineers. 1998. Eastern Arkansas region comprehensive study. Grand Prairie and

Bayou Meto Basin, Arkansas Project. Bayou Meto Basin, Arkansas general reevaluation. U. S. Army Corps of Engineers, Memphis District.

Wakeley, J. S. and T. H. Roberts. 1996. Bird distributions and forest zonation in a bottomland hardwood wetland. Wetlands 16:296-308.

Wharton, C. H., W. M. Kitchens, E. C. Pendleton and T. W. Sipe. 1982. The ecology of bottomland hardwood swamps of the southeast: a community profile. FWS/OBS - 81/37, U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. 133pp.

Wigley, T. B., Jr. and T. H. Filer, Jr. 1989. Characteristics of greentree reservoirs: a survey of managers. Wildlife Society Bulletin 17: 136-142.

Yaich, S. C. 1990. "Habitat Arkansas 2000," Arkansas Implementation plan for the Lower Mississippi Valley Joint Venture of The North American Waterfowl Management Plan. Arkansas Game and Fish Commission, Little Rock.

SECTION XVI

EVALUATION OF BOTTOMLAND HARDWOODS

AN EVALUATION OF BOTTOMLAND HARDWOOD FORESTS IN THE BAYOU METO BASIN IMPROVEMENT PROJECT AREA

Prepared For:

U.S. ARMY CORPS OF ENGINEERS

MEMPHIS DISTRICT

By:

Mickey E. Heitmeyer and Belinda Ederington
Gaylord Memorial Laboratory
University of Missouri - Columbia
Puxico, MO 63960

June 2004

INTRODUCTION

The proposed U.S. Army Corps of Engineers (USACE) Bayou Meto Basin Improvement Project (USACE 1998) includes flood control developments that would potentially change the timing and duration of surface water inundation in certain bottomland hardwood forest (BLH) areas in floodplains in the Bayou Meto Basin. The preferred Alternative 3A of the proposed project includes channel cleanout and enlargement of streams and ditches, modification of the channel bottom width of select stream sections, construction of diversion weirs and grade control structures, adding a second water-control structure adjacent to the existing Cannon Brake structure on Little Bayou Meto, and a 1000 cfs pump station constructed adjacent to the Little Bayou Meto gravity floodgates at mile 0 where Little Bayou Meto connects with the Arkansas River (USACE 2004). If all of the Alternative 3A developments occur, approximately 10,000 acres in nearly 50 locations in the Bayou Meto Basin would change from a ≥ 5% wetland duration (i.e., sites flooded for at least 5% of the growing season) to a drier condition that is < 5% duration (Fig. 1). Approximately 7000 acres of this affected area currently is BLH.

A reduction in flood frequency and duration to < 5% growing season might negatively impact ecological functions and values of affected BLH stands if changes substantially alter natural hydroperiods of the sites and change timing and availability of resource used by endemic plant and animal communities. Conversely, if affected sites currently are inundated for periods longer than natural hydroperiods because of anthropogenic modifications (e.g., roads, levees, ditches, greentree reservoirs (GTR)) then reduced flooding might be beneficial and could help return sites to more natural and drier flooding regimes.

An evaluation of the current condition (health) of BLH potentially affected by Alternative 3A of the Bayou Meto Basin Improvement Project is needed to determine potential impacts of flood control developments. A previous study of the condition of BLH within the Bayou Meto Wildlife Management Area (WMA) identified ecological indicators of flooding stress on BLH stands (Heitmeyer et al. 2004) and provides a basis for expanding analyses of BLH condition to the entire project area. These indicators in conjunction with measurements typically used in hydrogeomorphic (HGM) assessments by the Arkansas Multi-Agency Wetland Planning Team provide evaluation of "relative condition" of BLH in areas of varying geomorphic surfaces, soils, topography, and hydrology.

This study provides analyses of relative condition of BLH areas potentially affected by Alternative 3A through sampling of the ecological attributes identified above. Certain of the affected sites within the Bayou Meto WMA were previously sampled (Heitmeyer et al. 2004) and new samples were obtained for other affected sites. Collectively, these data provide a comprehensive evaluation of effects of flood control developments on BLH in the Bayou Meto Basin.

METHODS

All BLH areas within the Bayou Meto Improvement Project boundary that currently have ≥5%

flood duration (pre-project) were identified on maps produced by the Vicksburg District of USACE. This "base" wetland map was then compared with a map identifying the same ≥ 5% flood duration predicted "post-project" if all flood control developments identified in Alternative 3A were constructed. Base wetland areas that changed to < 5% flood duration were considered the "affected" sites where reduced flood duration might negatively affect wetland functions and values (Fig. 1). In general, these affected sites were at higher elevations on ridges, natural levees, and upper ends of floodplains where seasonal flooding is typically of short and dynamic duration (Heitmeyer et al. 2002) and consequently where reductions in flooding from the 3A flood control developments would occur first. Aerial photographs were used to identify where the affected sites contained BLH. In total 52 affected BLH locations or groups were identified and their areas were determined by digitizing maps that delineated the affected areas (Appendix A). Each BLH group was a distinct contiguous area of BLH; had similar geomorphology, soil, and topographic features; had similar hydrological influences (e.g., within GTRs, common ditches or drains, etc.); and had similar water and timber management if any occurred. Groups were described as in relation to their geographic and ecological position (e.g., natural levee, riparian corridor, small isolated or large connected), ownership and water control (e.g., privately-owned or on Bayou Meto WMA and whether in a GTR or not), and edge or interior of a BLH patch (Table 1). Groups 39 and 40 contained BLH in both private and Bayou Meto WMA ownership and the area in each ownership was analyzed separately (Table 1).

Data on forest condition in all 52 BLH groups were obtained using a random sample of 1/10 or 1/8-acre plots. Four of the groups (#25, 35, 46, 52) were within GTR impoundments on Bayou Meto WMA that were previously sampled in July and August 2003 using randomly located 1/8th-acre plots (Table 1). These 4 groups contained 66 plots. The remaining 48 BLH groups were sampled in April 2004 using a random sample of 186 1/10th-acre plots. For all locations, a grid matrix was placed over maps of the affected BLH groups and a random point was selected to locate a plot. Then, a second plot was randomly selected adjacent to the first plot at 1 of 9 compass coordinates around the first plot. For example, a random number of 1 selected a second plot at the northwest corner of the first plot, a random number of 3 was at the northeast corner, and so on. The number of plots sampled varied among BLH groups based on relative size and configuration of the group location; a minimum of 2 plots were sampled in each group (Table 1).

Data previously collected from the 66 plots in BLH groups #25, 35, 46, and 52 included: 1) tree species composition and their diameter at breast height (dbh); 2) percentage of red oaks (willow, Nuttall, southern red, water, cherrybark) that had basal swelling, tip die-back, leaf chlorosis, and mortality; 3) canopy, shrub, and herbaceous ground coverage; 4) # and species of tree seedlings > 0.5 m as an indicator of regeneration. These data (except for leaf chlorosis) also were collected from the 186 plots in the remaining 48 BLH groups. Leaf chlorosis information was not collected in April 2004 because most trees were in early stages of leaf development and identification and comparison of variation in relative color of leaves among trees was not consistent. In addition to the above data, other BLH measurements used in HGM analyses also were collected on the 186 plots. These included: 1) # shrub stems < 4.5 m tall and up to 4 inch dbh within a 1/100th acre subplot located in the center of each 1/10th acre plot; 2) number of down dead stems > 3 inch dbh, 1-3 inch dbh, and 0.25-1 inch dbh that lay across 50 foot, 12 foot, and 6 foot transects, respectively, running north-south from the south-center of each plot; and 3) number of standing dead snags.

All data were summarized by BLH group to provide analyses and evaluation of forest composition and indication of flooding stress for the specific location. Data from groups 25, 35, 46, and 52 were analyzed previously (Heitmeyer et al. 2004) and indicate significant deterioration and stress from prolonged flooding and delayed drainage on Bayou Meto WMA. Data from the other 48 groups were summarized as means/plot. Based on previous analyses from Bayou Meto WMA we used the following 8 primary indicators of relative condition of BLH stands in the Bayou Meto Basin: 1) % red oaks, 2) % green ash, 3) % hickory (mockernut, shellbark, and shagbark hickory combined), 4) % of red oaks with tip die-back, 5) % of red oaks with basal swelling, 6) % of red oaks that were dead, 7) % herbaceous coverage, and 8) relative regeneration of tree species indicating more natural drier hydroperiods (i.e., red oaks, American elm, and hickory) vs. regeneration of species indicating more prolonged flooding (i.e., overcup oak and green ash).

Each of the above 8 indicators of BLH condition was ranked for each BLH group from +2 (indicating relatively dry water regimes during the growing season with no indication of flooding stress) to -2 (indicating significant damage and stress from prolonged or artificial flooding during the growing season) (Table 2). Assignment of relative ranks (Table 2) was based on mean conditions of healthy and unhealthy BLH areas within the Bayou Meto Basin. For example, data from Buckingham Flats and Bear Bayou GTRs were used as a reference for good conditions, and data from Upper Vallier and Government Cypress GTRs were used as a reference for poor conditions (Heitmeyer et al. 2004).

Ranks for the above 8 indicators were summed for each group to provide a composite rank evaluation of the relative condition of BLH in each group and the potential impact of reducing flood duration to < 5% from flood control developments proposed in Alternative 3A. Consequently, a group with a high + value indicates the BLH stand currently has short duration flooding during the growing season and suggests a reduction in flooding to < 5% would reduce hydroperiods to a point where species composition might shift to a more upland type and thus negatively impact the BLH functions and values of that site. In contrast, a group with a high - value indicates the site currently is flooded for unnaturally prolonged periods during the growing season and is negatively impacting intermediately water tolerant trees species such as red oaks and thus a reduction in flooding from Alternative 3A developments would be beneficial. Groups with near neutral summed rank scores suggest periodic changes in both wet and dry conditions that probably closely resemble naturally occurring dynamics. For these "neutral" groups impacts from Alternative 3A developments might be slightly negative (if scores are slightly +), slightly positive (if scores are slightly -), or little or no impact depending on the magnitude in reduction of flooding duration. For example, if a site currently has 5-7% duration and will change to 3-5% duration after Alternative 3A developments, the plant and animal communities and thus BLH values probably will not change significantly. For the highly negatively impacted groups (high + values), an HGM analyses can then be used to determine lost values and mitigation requirements.

RESULTS

Tree Species Composition

All of the BLH areas that are projected to have flood duration reduced to <5% post-project under the 3A Alternative are at slightly higher elevations (e.g., ridges, natural levees, etc.) and in upper parts of floodplain watersheds in the Bayou Meto Basin. Because of this higher elevation position, tree species that naturally occupy these sites tend to be less tolerant of flood duration during the growing season (Heitmeyer et al. 2002, Fig. 2). The tree species composition of the 52 BLH groups sampled was variable (Table 3), but on average tended to reflect communities that had intermediate tolerances to flooding or saturated soils (Fig. 2). For all sites combined, red oaks and cedar elm each composed 22% of total trees followed by overcup oak (17%), green ash (10%), sugarberry (8%), American elm (7.5%), and hickory (6%). Variability of the 52 groups reflected topographic position and water management of the individual sample plots. BLH groups that were not in, or at the edge of, GTRs and that were on natural levees had the highest percentage red oak (29-31%) and lowest green ash (1.7-8.3%) and overcup oak (1.7-6.2%) composition. In contrast, privately-owned GTRs consistently had low red oak (19.2%) but high overcup oak (26.3%) composition (Table 4). Red oaks on sites were predominantly willow oak (55.6%) and Nuttall oak (32.2%), but cherrybark and water oaks were common on natural levees, riparian corridors, and large connected groups (Table 5).

Indicators of Water Stress to Red Oaks

BLH groups had variable evidence of water stress to red oaks caused by prolonged flood duration. In total 31.4%, 27.4%, and 18.0% of red oaks on the 52 sampled BLH groups had tip die-back, basal swelling, and were dead, respectively (Tables 6-8). Damage was greatest in GTRs and least in natural levees. Most (67%) standing dead snags (Table 9) on sampled plots were red oaks, therefore patterns of snag density among BLH groups was similar to the distribution of red oak mortality.

Canopy and Herbaceous Coverage

Canopy coverage was relatively high (mean of 83.5%) for all BLH groups (Table 9). Groups that had low (<70%) canopy cover were along Bakers Bayou (#2), a small isolated patch (#5), in private GTRs (#7,10,16), within a GTR in Bayou Meto WMA (#23), and one area on the edge of Bayou Meto where timber harvest had occurred (#26). In contrast to canopy cover, herbaceous ground cover was highly variable and relatively low in BLH groups (Table 9). Eleven of the groups had <20% herbaceous cover; these were in GTRs.

Shrub and Dead Stems

Number of shrub stems/plot ranged from none to 10.5 and the variation showed little pattern among habitat types (Table 10). Number of dead stems/plot, especially for the smallest size (0.25-1 inch) also had considerable variation among BLH groups with the greatest amount occurring in private GTRs (Table 10).

Regeneration

Relative regeneration of less water tolerant (American elm, hickory, red oak) compared to more water tolerant (green ash, overcup oak) trees was variable among BLH groups (Table 11) and closely matched their habitat type (Table 12). Regeneration of elm, hickory and red oaks was good in riparian corridors, small and large non-leveed BLH patches, and on natural levees. In contrast, regeneration in GTRs was dominated by green ash and overcup oak (Table 12). Regeneration on the edges of GTRs was intermediate between GTRs and higher natural levees.

Summary of Rank Scores

All of the riparian corridor, natural levee, and large interconnected BLH groups had strongly positive rank scores indicating these sites had little to no indication of flooding stress or damage and that they supported relatively healthy BLH stands intermediately tolerant of flooding and soil saturation during the growing season (Table 13). Only 2 of the small isolated groups (#5, 22) had indication of flooding stress. Group #5 is near an above ground water storage reservoir and is surrounded by ditches that convey both irrigation and drainage water into, and through, the site. Also, this site has a field ditch draining into the BLH patch that apparently floods at least part of this area frequently during the summer. Group #22 also is surrounded by ditches and 2 ditches directly drain water from surrounding agricultural fields into this BLH area.

All of the private GTRs sampled had strong indication of prolonged flooding and water stress except groups #14, 19, and 40 which had relatively neutral scores indicating mixed condition of BLH trees (Table 13). The affected BLH area within the GTR in Group #14 was at the highest elevation end of this GTR where artificial flooding by water control structures in the GTR seldom occurred. The GTR in group #19 has been intensively managed for artificial flooding only in the last few years (personal communication with landowners and neighbors) and although the tree species composition is relatively healthy (high red oak and hickory and low green ash and overcup oak), the red oaks are beginning to show signs of basal swelling and tip die-back.

GTR groups on Bayou Meto WMA have considerable evidence of prolonged flooding except in groups #29, 30, and 46 (Table 13) Group #29 is a high ridge within Upper Vallier which is seldom flooded at the elevations where managed "full-pool" water typically is held (Heitmeyer et al. 2004). This site is surrounded by highly damaged BLH stands, however. Group #30 is a high natural levee along Beaver Dam Slough that is not flooded at flood pool level in Cannon Brake (which controls water levels in this area) and is inundated only by high natural floods. Group #46 is within Buckingham Flats where managed water regimes have historically emulated more natural timing and duration of dormant season flooding (Heitmeyer et al. 2004).

The non-leveed edges of private and Bayou Meto GTRs have varied BLH condition (Table 13). In groups #11, 34, 26, and 43 water from the adjacent GTR either drains into, or levees and water control-structures associated with the GTR prohibits drainage from, the site. Consequently, in effect, BLH in these groups are artificially flooded. In contrast, the other group areas on the edges of GTRs are not effected by GTR flooding and drainage.

DISCUSSION AND CONCLUSION

Evidence of prolonged flooding and water stress during the growing season was apparent in 29 (55.8%) of the 52 BLH groups sampled (Table 13). These 29 groups contained 4073.4 acres and 58.0% of the total affected BLH in the Bayou Meto Basin. All of these 29 groups had artificial flooding and poor or late drainage because they were within, or were hydrologically connected to, GTRs or they regularly received drain water from surrounding agricultural fields during spring and summer. For these BLH groups reduced flooding duration during the growing season from flood control developments associated with Alternative 3A of the USACE Bayou Meto Basin Improvement Project would be beneficial or of neutral impact because water regimes are artificially managed.

Only 5 BLH areas within GTRs showed positive or neutral rank values. These 5 GTR areas contained 1447.9 acres and 20.6% of the affected BLH area. Three groups with positive rank values and limited evidence of water stress were within GTR impoundments of Bayou Meto WMA. While these areas have relatively healthy stands of BLH, the hydrology of the sites are primarily influenced by the highly interconnected hydrological and infrastructure system and by water management regimes on the WMA. Furthermore, previous analyses of GTRs on the WMA (Heitmeyer et al. 2004) have suggested overall positive benefits of certain flood control developments to BLH stands on the WMA, especially the pump station located on Little Bayou Meto at its confluence with the Arkansas River. Also, 2 BLH groups within private GTRs had neutral rank scores. Because water regimes in all GTRs, whether on Bayou Meto WMA or on private lands are artificially controlled, potential reduction in flooding of GTR areas from flood control developments associated with Alternative 3A are mitigated and unlikely to affect resource availability and values and may actually be beneficial if drainage is enhanced during late winter and spring when BLH stands in the affected areas naturally dry. For this reason, we suggest flood control developments associated with Alternative 3A will not substantially change the GTR sites with positive (#29,30, 46) or neutral (#14,19) rank values.

In contrast to the above BLH areas, 18 groups outside of GTRs had highly positive (16) or neutral (2) rank scores. These areas contained 1497 acres and 21.3% of the total affected BLH area. For each of these groups, flood control developments associated with Alternative 3A would reduce flood frequency and duration of the sites and potentially cause the tree species composition to change to a drier community. Also, reduced flooding would potentially reduce resource availability and values. Consequently, the impacts of Alternative 3A would be negative on these sites. Standards for mitigating reduced values on the 1497 acres in these groups should be determined using HGM models that incorporate the data collected in this study.

ACKNOWLEDGMENTS

This project was conducted via a grant Modification to Task Order No. 0004, Contract No. DACW66-02-D-001 from the USACE Memphis District to Tetra Tech, Inc. and subcontract to Mickey E. Heitmeyer. The concept of sampling BLH sites potentially affected by flood control developments associated with Alternative 3A of the Bayou Meto Basin Improvement Project was initially conceived by Tom Foti of the Arkansas Natural Heritage Commission (ANHC) and Ed Lambert (USACE). The project was supported by the Environmental Team Working Committee of the Bayou Meto Basin Irrigation and Flood Control Project and included important assistance from staff of the USACE, Arkansas Game and Fish Commission, U.S. Fish and Wildlife Service, U.S. Natural Resources Conservation Service, ANHC, Arkansas Soil and Water Conservation Commission, and Bayou Meto Irrigation District. Ed Lambert, Mark Smith, Tracy James and Ken Bright (USACE) provided administrative assistance and coordination of all aspects of the study. Maps were produced and provided by Jennifer Redden, Paul Eagles, and Dave Johnson (USACE). Jennifer Redden digitized all affecte BLH areas to determine magnitude of impact of the Alternative3A post-project reduction in flooding. Tom Foti, Chuck Klimas, and Jody Pagan encouraged this study, provided valuable insight into sampling BLH stands, and helped define the data needed to support HGM analyses of affected BLH sites. Gene Sullivan and the Bayou Meto Irrigation District encouraged the study and provided administrative and financial assistance. Gene also arranged contact with many landowners to obtain permission for access and sampling. Numerous landowners graciously allowed access to their properties for data collection and several helped with actual data collection. Roger Milligan and staff of the Bayou Meto WMA provided access to the WMA and helped with field work on the area. Karen Kyle (University of Missouri) helped prepare the report including drafting of figures.

LITERATURE CITED

Dale, E. D. 1998. Evaluation of vegetation in Bayou Meto Game Management Area. *In* M.A. Gross, D.C. Wolfe, and J. Murdock, eds. Bottomland hardwood investigations, Nevins Creek Mitigation Project TRC-9603 Prepared for Arkansas Highway and Transportation Department in cooperation with U:S. Department of Transportation and Federal Highway Administration, Fayetteville.

Heitmeyer, M. E., B. Ederington and L. H. Fredrickson. 2004. Bayou Meto Wildlife Management Area wetland management plan. Gaylord Memorial Laboratory Special Publication No. 7. Prepared for U.S. Army Corps of Engineers, Memphis District. University of Missouri - Columbia, Puxico, MO.

Heitmeyer, M.E., L.H. Fredrickson, B. Ederington and S.L. King. 2002. An evaluation of ecosystem restoration options for the Bayou Meto Basin of Arkansas. Special Publication

No. 5., Prepared for U.S. Army Corps of Engineers, Memphis District. University of Missouri - Columbia. Puxico. MO.

Huffman. R.T. 1976. Vegetational analysis of the Bayou Meto Wildlife Management Area. Final report prepared for Department of Local Services, State of Arkansas, Little Rock, Arkansas. Department of Botany and Bacteriology, University of Arkansas, Fayetteville.

U.S. Army Corps of Engineers. 2004. Bayou Meto Basin, Arkansas draft reevaluation report. U.S. Army Corps of Engineers, Memphis District, TN.

U.S. Army Corps of Engineers. 1998. Eastern Arkansas region comprehensive study. Grand Prairie Region and Bayou Meto Basin, Arkansas Project. Bayou Meto Basin, Arkansas general reevaluation. U.S. Army Corps of Engineers, Memphis District, TN.

Table 1. Location, habitat type, and acreage of 52 groups of bottomland hardwood forest (BLH) areas sampled in the Bayou Meto Basin

Group #	Quadrangle and Plot #'s	Habitat type[1]	Acreage
1	Pettus 15-16	RCD	2.1
2	Pettus 3-10, England 7-8	RCBB	18.4
3	Pettus 17-18	SI	8.1
4	Pettus 19-20	SI	40.2
5	England 11-12	SI	11.1
6	Humnoke 1-2	PGTR	16.5
7	Humnoke 3-4	PGTR	15.5
8	Humnoke 5-6	SI	2.3
9	Humnoke 7-10	PGTR	31.5
10	Geridge 3-8	PGTR	38.7
11	Geridge 9-10	EPGTR	24.4
12	Geridge 11-14	EPGTR	16.9
13	Geridge 15-16	PGTR	23.9
14	Geridge 17-20	PGTR	95.2
15	Geridge 21-24	PGTR	179.3
16	Geridge 25-26	PGTR	34.3
17	Geridge 27-28	PGTR	35.3
18	Altheimer 1-6	PGTR	243.0
19	Altheimer 7-10	PGTR	190.5
20	Altheimer 27-28	SI	20.7
21	Altheimer 35-36	PGTR	58.0
22	Altheimer 37-38	SI	93.7
23	Humphrey SW 1-6	BMGTR	101.4
24	Humphrey SW 7-16	BMGTR	226.2
25	Humphrey SW (UV[2] 1-30)	BMGTR	1084.2
26	Humphrey SW 17-22	EBMGTR	47.3
27	Humphrey SW 23-24	EBMGTR	2.3
28	Humphrey SW 25-34	BMGTR	83.0
29	Humphrey SW 35-44	BMGTR	853.3
30	Humphrey SW 45-48	BMGTR	233.6
31	Humphrey SW 49-50	SI	8.9
32	Humphrey SW 51-52	BMGTR	60.5
33	Humphrey 5-6	EBMGTR	52.7
34	Humphrey 7-8	EPGTR	110.6
35	Humphrey (TI[3] 11-30)	BMGTR	246.7
36	Humphrey 9-10	PGTR	26.4
37	Lodge Corner 1-6	NL	227.7
38	Lodge Corner 7-8	NL	40.2

Table 1. continued.

Group #	Quadrangle and plot #'s	Habitat type[1]	Acreage
39a[4]	Cornerstone 5-6	PGTR	73.8
39b	Cornerstone 1-4	BMGTR	31.6
40a	Cornerstone 7-8	EPGTR	56.5
40b	Cornerstone 7-8	EBMGTR	56.5
41	Cornerstone 9-10	BMGTR	133.8
42	Reydell 1-2	PGTR	428.5
43	Reydell 3-4	EBMGTR	108.7
44	Reydell 5-6	EBMGTR	86.9
45	Reydell 7-8	BMGTR	117.7
46	Reydell (BK[5] 14-20)	BMGTR	75.2
47	Reydell 9-12	PGTR	181.2
48	Reydell 13-18	PGTR	225.8
49	Reydell 19-28	LC	414.9
50	Reydell 29-30	LC	70.1
51	One Horse Store	RCMB	262.8
52	Humphrey SW (LV[6] 21-30)	BMGTR	89.8
Combined			7018.3

[1] RCD - riparian corridor along a drainage ditch, RCBB - riparian corridor along Baker's Bayou, RCMB - riparian corridor along Mill Bayou, SI - small isolated patch of BLH, LC - large connected patch of BLH, PGTR - privately-owned and leveed greentree reservoir (GTR), EPGTR - non-leveed edge of BLH immediately adjacent to a privately-owned GTR, BMGTR - leveed GTR unit on Bayou Meto Wildlife Management Area (WMA), EBMGTR - non-leveed edge of BLH immediately adjacent to a GTR unit on Bayou Meto WMA, NL - natural levee along Bayou Meto.

[2] Plots previously sampled in Upper Vallier GTR unit on Bayou Meto WMA.

[3] Plots previously sampled in Temple Island GTR unit on Bayou Meto WMA.

[4] Groups 39 and 40 contained area in both private and Bayou Meto WMA ownership. The area of each ownership was determined separately. Sample plots in Group 40 were used as indication of BLH condition in each ownership because the habitat was not in a GTR and was similar between areas.

[5] Plots previously sampled in Buckingham Flats GTR unit on Bayou Meto WMA.

[6] Plots previously sampled in Lower Vallier GTR unit on Bayou Meto WMA.

Table 2. Assignment of rank scores of ecological indicators of relative wetness (+) vs. dryness (-) of BLH groups.

Rank	Ecological Indicator[1]							
	%RO	%BS	%TB	%MT	%HC	%GA	%HK	RG
-2	< 6	> 25	> 25	> 25	< 21	> 21	< 3	0/> 3
-1	6-15	16-25	16-25	16-25	21-40	11-20	3-6	3-6/>6
0	16-25	11-15	11-15	11-15	41-60	6-10	6-10	>6/10-20
+1	26-35	6-10	6-10	6-10	61-80	3-6	11-20	>6/5-10
+2	> 35	< 6	< 6	< 6	81-100	< 3	> 21	>6/<5

[1] %/RO - percentage of red oaks/group, %BS- percentage of red oaks with basal swelling, %TB - percentage of red oaks with tip die-back, %MT - percentage of total red oaks (living + dead) that are dead, %HC - percentage herbaceous ground coverage, %GA - percentage of green ash/group, %HK - percentage of mockernut, shellbark and shagbark hickory/group, RG - regeneration index of mean # American elm, hickory, and red oak seedlings > 0.5 m per plot/mean # overcup oak and green ash seedlings > 0.5 m per plot.

Table 3. Tree Species Composition of 52 groups of bottomland hardwood forest areas sampled in the Bayou Meto Basin Arkansas, April 2004

Group number	1		2		3		4		5		6		7	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tree species														
American elm	0	0.00	28	20.74	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Bald cypress	0	0.00	0	0.00	0	0.00	0	0.00	5	21.74	0	0.00	0	0.00
Beech	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Black willow	0	0.00	10	7.41	0	0.00	0	0.00	1	4.35	0	0.00	0	0.00
Cedar elm	7	21.88	23	17.04	10	32.26	10	31.25	0	0.00	11	36.67	6	23.08
Cottonwood	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Green Ash	0	0.00	20	14.81	1	3.23	0	0.00	7	30.43	4	13.33	0	0.00
Hickory	0	0.00	1	0.74	17	54.84	12	37.50	0	0.00	0	0.00	9	34.62
Overcup oak	5	15.63	12	8.89	0	0.00	0	0.00	10	43.48	10	33.33	0	0.00
Pecan	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Persimmon	2	6.25	2	1.48	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Maple	0	0.00	6	4.44	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sassafras	0	0.00	7	5.19	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sugarberry	9	28.13	7	5.19	1	3.23	5	15.63	0	0.00	1	3.33	3	11.54
Swamp chestnut oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Swamp privet	0	0.00	1	0.74	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sweet gum	3	9.38	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sycamore	0	0.00	2	1.48	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wing elm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
White oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Oaks:														
Cherrybark oak	0	0.00	5	3.70	0	0.00	0	0.00	0	0.00	2	6.67	1	3.85
Nuttall oak	5	15.63	2	1.48	0	0.00	1	3.13	0	0.00	2	6.67	0	0.00
Southern red oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Water oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Willow oak	1	3.13	9	6.67	2	6.45	4	12.50	0	0.00	0	0.00	7	26.92
Total per group	32		135		31		32		23		30		26	
% RO	18.80		11.90		6.50		25.00		0.00		13.30		30.80	

Table 3. cont.

Group number	8		9		10		11		12		13		14	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tree species														
American elm	9	30.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	9	13.64
Bald cypress	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Beech	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Black willow	0	0.00	0	0.00	6	7.69	0	0.00	0	0.00	0	0.00	0	0.00
Cedar elm	0	0.00	7	14.29	6	7.69	5	20.00	15	31.25	0	0.00	4	6.06
Cottonwood	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Green Ash	0	0.00	0	0.00	19	24.36	5	20.00	0	0.00	0	0.00	0	0.00
Hickory	0	0.00	17	34.69	0	0.00	0	0.00	1	2.08	0	0.00	8	12.12
Overcup oak	0	0.00	2	4.08	35	44.87	6	24.00	14	29.17	16	84.21	21	31.82
Pecan	0	0.00	0	0.00	0	0.00	0	0.00	9	18.75	2	10.53	0	0.00
Persimmon	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.52
Red Maple	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sassafras	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sugarberry	7	23.33	5	10.20	9	11.54	4	16.00	0	0.00	0	0.00	0	0.00
Swamp chestnut oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Swamp privet	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sweet gum	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sycamore	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wing elm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
White oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Oaks														
Cherrybark oak	0	0.00	1	2.04	0	0.00	0	0.00	0	0.00	0	0.00	11	16.67
Nuttall oak	3	10.00	2	4.08	3	3.85	4	16.00	4	8.33	1	5.26	4	6.06
Southern red oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Water oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Willow oak	11	36.67	15	30.61	0	0.00	1	4.00	5	10.42	0	0.00	8	12.12
Total per group	30		49		78		25		48		19		66	
% RO	46.70		36.70		4.80		20.00		18.80		5.30		34.80	

Table 3. cont.

Group number	15		16		17		18		19		20		21	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tree species														
American elm	0	0.00	0	0.00	0	0.00	7	5.83	5	8.93	4	15.38	0	0.00
Bald cypress	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Beech	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Black willow	0	0.00	0	0.00	1	4.55	0	0.00	0	0.00	0	0.00	0	0.00
Cedar elm	0	0.00	0	0.00	0	0.00	48	40.00	27	48.21	7	26.92	11	31.43
Cottonwood	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Green Ash	5	12.50	12	41.38	8	36.36	0	0.00	0	0.00	0	0.00	8	22.86
Hickory	0	0.00	0	0.00	0	0.00	11	9.17	0	0.00	2	7.69	0	0.00
Overcup oak	26	65.00	11	37.93	9	40.91	25	20.83	7	12.50	0	0.00	5	14.29
Pecan	1	2.50	0	0.00	0	0.00	8	6.67	0	0.00	0	0.00	0	0.00
Persimmon	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Maple	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sassafras	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sugarberry	0	0.00	0	0.00	0	0.00	15	12.50	5	8.93	0	0.00	5	14.29
Swamp chestnut oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Swamp privet	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sweet gum	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sycamore	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wing elm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
White oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Oaks														
Cherrybark oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Nuttall oak	4	10.00	4	13.79	2	9.09	3	2.50	5	8.93	8	30.77	2	5.71
Southern red oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Water oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Willow oak	4	10.00	2	6.90	2	9.09	3	2.50	7	12.50	5	19.23	4	11.43
Total per group	40		29		22		120		56		26		35	
% RO	20.00		20.70		18.20		5.00		21.40		50.00		17.10	

Table 3. cont.

Group number	22		23		24		25		26		27		28	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tree species														
American elm	0	0.00	2	2.99	0	0.00	0	0.00	2	3.33	6	28.57	14	14.74
Bald cypress	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Beech	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Black willow	0	0.00	0	0.00	1	0.99	2	0.49	0	0.00	0	0.00	2	2.11
Cedar elm	9	28.13	25	37.31	10	9.90	95	23.46	9	15.00	7	33.33	26	27.37
Cottonwood	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Green Ash	8	25.00	8	11.94	13	12.87	76	18.77	8	13.33	1	4.76	11	11.58
Hickory	0	0.00	5	7.46	0	0.00	3	0.74	6	10.00	0	0.00	6	6.32
Overcup oak	0	0.00	10	14.93	25	24.75	96	23.70	18	30.00	2	9.52	16	16.84
Pecan	0	0.00	0	0.00	5	4.95	27	6.67	1	1.67	0	0.00	2	2.11
Persimmon	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Maple	0	0.00	0	0.00	2	1.98	7	1.73	1	1.67	0	0.00	0	0.00
Sassafras	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sugarberry	7	21.88	6	8.96	5	4.95	6	1.48	0	0.00	0	0.00	1	1.05
Swamp chestnut oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Swamp privet	0	0.00	0	0.00	1	0.99	4	0.99	0	0.00	0	0.00	0	0.00
Sweet gum	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sycamore	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wing elm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
White oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Oaks														
Cherrybark oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Nuttall oak	2	6.25	3	4.48	25	24.75	32	7.90	0	0.00	0	0.00	0	0.00
Southern red oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Water oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Willow oak	6	18.75	8	11.94	14	13.86	57	14.07	15	25.00	5	23.81	17	17.89
Total per group	32		67		101		405		60		21		95	
% RO	25.00		16.40		38.60		22.00		25.00		23.80		17.90	

Table 3. cont.

Group number	29		30		31		32		33		34		35	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tree species														
American elm	16	17.02	5	14.71	4	18.18	0	0.00	3	11.11	0	0.00	20	6.10
Bald cypress	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Beech	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.30
Black willow	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	13.33	2	0.61
Cedar elm	15	15.96	0	0.00	0	0.00	9	25.00	6	22.22	0	0.00	65	19.82
Cottonwood	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Green Ash	0	0.00	0	0.00	0	0.00	8	22.22	1	3.70	0	0.00	30	9.15
Hickory	11	11.70	3	8.82	4	18.18	0	0.00	4	14.81	0	0.00	25	7.62
Overcup oak	8	8.51	1	2.94	0	0.00	6	16.67	5	18.52	11	73.33	53	16.16
Pecan	3	3.19	0	0.00	0	0.00	4	11.11	0	0.00	0	0.00	63	19.21
Persimmon	0	0.00	1	2.94	0	0.00	0	0.00	0	0.00	0	0.00	1	0.30
Red Maple	1	1.06	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	1.22
Sassafras	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sugarberry	2	2.13	0	0.00	1	4.55	5	13.89	0	0.00	0	0.00	4	1.22
Swamp chestnut oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Swamp privet	0	0.00	1	2.94	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sweet gum	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sycamore	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wing elm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	0.91
White oak	0	0.00	2	5.88	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Oaks														
Cherrybark oak	0	0.00	2	5.88	11	50.00	0	0.00	0	0.00	0	0.00	0	0.00
Nuttall oak	6	6.38	0	0.00	0	0.00	2	5.56	0	0.00	1	6.67	19	5.79
Southern red oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Water oak	0	0.00	2	5.88	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Willow oak	32	34.04	17	50.00	2	9.09	2	5.56	8	29.63	1	6.67	38	11.59
Total per group	94		34		22		36		27		15		328	
% RO	40.40		61.80		59.10		11.10		29.60		13.30		17.40	

Table 3. cont.

Group number	36		37		38		39		40		41		42	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tree species														
American elm	2	6.25	8	14.55	6	20.69	1	1.20	3	10.00	0	0.00	0	0.00
Bald cypress	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Beech	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Black willow	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Cedar elm	9	28.13	2	3.64	3	10.34	27	32.53	10	33.33	9	37.50	19	79.17
Cottonwood	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Green Ash	3	9.38	0	0.00	1	3.45	17	20.48	4	13.33	0	0.00	0	0.00
Hickory	0	0.00	3	5.45	7	24.14	0	0.00	0	0.00	0	0.00	0	0.00
Overcup oak	6	18.75	0	0.00	1	3.45	17	20.48	2	6.67	0	0.00	2	8.33
Pecan	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Persimmon	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Maple	0	0.00	3	5.45	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sassafras	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sugarberry	5	15.63	0	0.00	1	3.45	11	13.25	8	26.67	14	58.33	0	0.00
Swamp chestnut oak	0	0.00	9	16.36	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Swamp privet	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sweet gum	0	0.00	10	18.18	2	6.90	0	0.00	0	0.00	0	0.00	0	0.00
Sycamore	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wing elm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
White oak	0	0.00	1	1.82	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Oaks														
Cherrybark oak	0	0.00	10	18.18	3	10.34	0	0.00	0	0.00	0	0.00	0	0.00
Nuttall oak	2	6.25	5	9.09	0	0.00	8	9.64	1	3.33	0	0.00	0	0.00
Southern red oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Water oak	0	0.00	3	5.45	5	17.24	0	0.00	0	0.00	0	0.00	0	0.00
Willow oak	5	15.63	1	1.82	0	0.00	2	2.41	2	6.67	1	4.17	3	12.50
Total per group	32		55		29		83		30		24		24	
	21.90		34.50		27.60		12.00		10.00		4.20		12.50	

Table 3. cont.

Group number	43		44		45		46		47		48		49	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tree species														
American elm	2	7.69	0	0.00	1	3.45	0	0.00	14	26.42	16	17.20	5	4.00
Bald cypress	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Beech	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Black willow	1	3.85	0	0.00	0	0.00	1	1.75	0	0.00	0	0.00	0	0.00
Cedar elm	15	57.69	6	25.00	9	31.03	7	12.28	14	26.42	30	32.26	43	34.40
Cottonwood	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Green Ash	6	23.08	0	0.00	2	6.90	4	7.02	0	0.00	3	3.23	10	8.00
Hickory	0	0.00	7	29.17	3	10.34	0	0.00	0	0.00	0	0.00	10	8.00
Overcup oak	1	3.85	0	0.00	3	10.34	20	35.09	4	7.55	4	4.30	10	8.00
Pecan	0	0.00	0	0.00	0	0.00	6	10.53	0	0.00	0	0.00	0	0.00
Persimmon	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Maple	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sassafras	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sugarberry	0	0.00	4	16.67	9	31.03	6	10.53	11	20.75	9	9.68	14	11.20
Swamp chestnut oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Swamp privet	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sweet gum	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Sycamore	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wing elm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
White oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Red Oaks														
Cherrybark oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	8	6.40
Nuttall oak	0	0.00	0	0.00	0	0.00	7	12.28	10	18.87	12	12.90	9	7.20
Southern red oak	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Water oak	0	0.00	5	20.83	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Willow oak	1	3.85	2	8.33	2	6.90	6	10.53	0	0.00	19	20.43	16	12.80
Total per group	26		24		29		57		53		93		125	
	3.80		29.20		6.90		22.80		18.90		33.30		26.40	

Table 3. cont.

Group number	50		51		52		Total	Percent
	#	%	#	%	#	%		
Tree species								
American elm	5	17.86	38	29.01	0	0.00	235	7.20
Bald cypress	0	0.00	0	0.00	0	0.00	5	0.15
Beech	0	0.00	0	0.00	0	0.00	1	0.03
Black willow	0	0.00	2	1.53	0	0.00	31	0.95
Cedar elm	11	39.29	4	3.05	31	23.66	722	22.13
Cottonwood	0	0.00	2	1.53	0	0.00	2	0.06
Green Ash	0	0.00	5	3.82	17	12.98	324	9.93
Hickory	0	0.00	3	2.29	0	0.00	178	5.46
Overcup oak	0	0.00	0	0.00	28	21.37	563	17.26
Pecan	0	0.00	0	0.00	2	1.53	133	4.08
Persimmon	0	0.00	0	0.00	2	1.53	9	0.28
Red Maple	0	0.00	0	0.00	0	0.00	24	0.74
Sassafras	0	0.00	0	0.00	0	0.00	7	0.21
Sugarberry	3	10.71	41	31.30	15	11.45	264	8.09
Swamp chestnut oak	0	0.00	0	0.00	0	0.00	9	0.28
Swamp privet	0	0.00	0	0.00	1	0.76	8	0.25
Sweet gum	0	0.00	0	0.00	0	0.00	15	0.46
Sycamore	0	0.00	0	0.00	0	0.00	2	0.06
Wing elm	0	0.00	0	0.00	0	0.00	3	0.09
White oak	0	0.00	0	0.00	0	0.00	3	0.09
Red Oaks								
Cherrybark oak	2	7.14	1	0.76	0	0.00	57	1.75
Nuttall oak	0	0.00	0	0.00	27	20.61	230	7.05
Southern red oak	0	0.00	2	1.53	0	0.00	2	0.06
Water oak	2	7.14	13	9.92	0	0.00	30	0.92
Willow oak	5	17.86	20	15.27	8	6.11	405	12.42
Total per group	28		131		131		3262	
	32.10		25.90		21.90			

Table 4. Select tree species composition (percentage of total trees ≥ 3 inches dbh) for 52 bottomland hardwood forest areas sampled in the Bayou Meto Basin, Arkansas April 2004 in relation to habitat type.

	Species[1]				
Habitat type[2] (*N*)	RO	GA	OO	AE	HK
Riparian corridor (3)	18.9	6.2	8.2	16.6	1.0
Small isolated (7)	30.3	8.3	6.2	9.1	17.1
Large connected (2)	29.2	4.0	4.0	11.0	4.0
Natural levee (2)	31.0	1.7	1.7	17.6	14.8
Private GTR (17)	19.2	10.1	26.3	4.7	5.4
Bayou Meto GTR (13)	22.9	10.3	16.8	4.7	4.1
Edge private GTR (4)	15.6	8.4	33.3	2.5	0.5
Edge Bayou Meto GTR (6)	16.9	9.8	13.8	15.2	9.0

[1] RO - combined red oak, GA - green ash, OO - overcup oak, AE - American elm, HK - combined mockernut, shellbark, and shagbark hickory.

[2]Site descriptions taken from Table 1.

Table 5. Number and distribution of red oaks of 52 bottomland hardwood forest areas sampled in the Bayou Meto Basin Arkansas, April 2004.

	Group number													
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
# Red Oaks	6	16	2	8	-	4	8	14	18	3	5	9	1	23
Cherrybark Oak	-	5	-	-	-	2	1	-	1	-	-	-	-	23
Nuttall Oak	5	2	-	4	-	2	7	3	2	3	4	4	1	11
Water Oak	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Willow Oak	1	9	2	4	-	-	-	11	15	-	1	5	-	-
x̄ Red oaks per plot	3.0	2.0	1.0	4.0	-	2.0	4.0	7.0	4.5	1.5	2.5	2.3	0.5	8

	Group number												
Variable	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
# Red Oaks	8	6	4	6	12	13	6	8	11	39	89	15	5
Cherrybark Oak	-	-	-	-	-	-	-	-	-	-	-	-	-
Nuttall Oak	8	4	2	3	5	8	2	2	3	25	32	-	-
Water Oak	-	-	-	-	-	-	-	-	-	-	-	-	-
Willow Oak	4	2	2	3	7	5	4	6	8	14	57	15	5
x̄ Red oaks per plot	2.0	3.0	2.0	1.0	3.0	6.5	3.0	4.0	1.8	3.9	3.0	2.5	2.5

	Group number												
Variable	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
# Red Oaks	17	38	21	13	4	8	2	57	7	19	8	10	3
Cherrybark Oak	-	-	2	11	-	-	-	-	-	10	3	-	-
Nuttall Oak	-	6	-	-	2	-	1	19	2	5	-	8	1
Water Oak	-	-	2	-	-	-	-	-	-	3	5	-	-
Willow Oak	17	32	17	2	2	8	1	38	5	1	-	2	2
x̄ Red oaks per plot	1.7	3.8	4.8	6.5	2.0	4.0	1.0	2.9	3.5	3.2	4.0	1.7	1.5

	Group number												
Variable	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**Total**
# Red Oaks	1	3	1	7	2	13	10	31	33	9	34	27	714
Cherrybark Oak	-	-	-	5	-	-	-	-	8	2	1	-	57
Nuttall Oak	-	-	-	-	-	7	10	12	9	-	-	27	230
Water Oak	-	-	-	-	-	-	-	-	-	2	13	-	30
Willow Oak	1	3	1	2	2	6	-	19	16	5	20	-	397
x̄ Red oaks per plot	1.5	1.5	0.5	3.5	1.0	2.3	2.5	5.2	3.3	4.5	3.4	2.7	2.8

Table 6. Percentage of red oaks on 52 bottomland hardwood forest areas sampled in the Bayou Meto Basin Arkansas, April 2004, that had tip die-back.

	Group number																			
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
# Red Oaks	6	16	2	8	0	4	8	14	18	3	5	9	1	23	8	6	4	6	12	13
#w/TD	1	-	-	-	-	4	4	2	12	2	2	1	1	5	7	6	3	2	2	3
%	16.7	-	-	-	-	100.0	50.0	14.3	66.7	66.7	40.0	11.1	100.0	21.7	87.5	100.0	75.0	33.3	16.7	23.1

	Group number																			
Variable	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
# Red Oaks	6	8	11	39	89	15	5	17	38	21	13	4	8	2	57	7	19	8	10	3
#w/TD	3	5	8	8	38	4	1	7	8	1	-	2	4	2	13	2	2	-	7	2
%	50.0	62.5	72.7	20.5	42.7	26.7	20.0	41.2	21.1	4.8	-	50.0	50.0	100.0	22.8	28.6	10.5	-	70.0	66.7

	Group number												
Variable	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**Total**
# Red Oaks	1	3	1	7	2	13	10	31	33	9	34	27	714
#w/TD	1	2	-	2	1	-	5	6	2	-	2	11	227
%	100.0	66.7	-	28.6	50.0	-	50.0	19.4	6.1	-	5.9	40.7	31.44

Table 7. Percentage of red oaks on 52 bottomland forest areas sampled in the Bayou Meto Basin Arkansas, April 2004, that had basal swelling.

	Group number																			
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	20
# Red Oaks	6	16	2	8	0	5	8	14	18	3	5	9	1	23	8	6	4	6	12	13
#w/BS	-	-	-	-	-	3	4	2	13	3	1	-	1	4	6	5	2	1	2	2
%	-	-	-	-	-	60.0	50.0	14.3	72.2	100.0	20.0	-	100.0	17.4	75.0	83.3	50.0	16.7	16.7	15.4

	Group number																			
Variable	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
# Red Oaks	6	8	11	39	89	15	5	17	38	21	13	4	8	2	57	7	19	8	10	3
#w/BS	4	3	7	6	39	2	-	6	6	1	-	3	1	1	18	3	-	-	6	-
%	66.7	37.5	63.6	15.4	43.8	13.3	-	35.3	15.8	4.7	-	75.0	12.5	50.0	31.6	42.8	-	-	60.0	-

	Group number												
Variable	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**Total**
# Red Oaks	1	3	1	7	2	13	10	31	33	9	34	27	714
#w/BS	-	1	-	-	-	0	6	9	2	0	1	10	198
%	-	33.3	-	-	-	-	60.0	29.0	6.1	-	2.9	37.0	27.36

Table 8. Percentage of red oaks (live + dead) on 52 bottomland forest areas sampled in the Bayou Meto Basin Arkansas, April 2004, were dead.

	Group number																	
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
# Red Oaks (live + dead)	6	16	2	8	0	6	10	16	24	7	6	10	1	27	14	9	5	7
#w/MT	-	-	-	-	-	1	2	2	6	4	1	1	-	4	6	3	1	1
%	-	-	-	-	-	16.7	20.0	12.5	25.0	57.1	16.7	10.0	-	14.8	42.9	33.3	20.0	14.3

	Group number																
Variable	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**
# Red Oaks (live + dead)	12	17	9	11	25	46	118	18	5	22	42	21	14	7	9	4	71
#w/MT	-	4	3	3	14	7	29	3	-	5	4	-	1	3	1	1	14
%	-	23.5	33.3	27.3	56.0	15.2	24.6	16.7	-	22.7	9.5	-	7.1	42.9	11.1	25.0	19.7

	Group number																	
Variable	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**Total**
# Red Oaks (live + dead)	9	19	8	19	3	2	3	1	7	4	13	13	31	35	9	36	40	907
#w/MT	2	1	-	9	-	1	-	-	-	2	-	3	-	2	-	2	13	163
%	22.2	5.3	-	47.4	-	50.0	-	-	-	50.0	-	23.1	-	5.7	-	5.5	32.5	18.0

Table 9. Mean number of standing dead snags and percentage canopy and herbaceous ground coverage/plot of 52 bottomland forest areas sampled in the Bayou Meto Basin Arkansas, April 2004.

	Group number														
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
# standing snags	2	4	-	-	1	1	2	2	1	17	1	2	1	6	4
$\bar{x}$ per plot	1.0	0.4	-	-	0.5	0.5	1.0	1.0	0.3	2.8	0.5	0.5	0.5	1.5	1.0
$\bar{x}$ % canopy cover	90.0	67.0	90.0	97.5	65.0	92.5	67.5	70.0	66.3	57.5	95.0	76.3	82.5	92.5	81.3
$\bar{x}$ % herbaceous cover	100.0	53.5	90.0	95.0	10.0	100.0	15.0	45.0	7.5	1.7	50.0	28.8	5.0	22.5	0.5

	Group number														
Variable	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
# standing snags	1	-	-	-	4	3	1	7	7	-	9	2	4	4	1
$\bar{x}$ per plot	0.5	-	-	-	2.0	1.5	0.5	1.2	0.7	-	1.5	1.0	0.4	0.4	0.3
$\bar{x}$ % canopy cover	62.5	95.0	85.8	93.8	75.0	92.5	90.0	66.7	84.0	78.2	65.8	82.5	82.0	93.0	98.8
$\bar{x}$ % herbaceous cover	-	3.5	54.2	12.5	100.0	20.0	15.0	53.3	17.0	27.6	51.7	97.5	56.5	62.0	97.5

	Group number												
Variable	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**
# standing snags	1	1	1	1	-	1	-	-	5	-	1	-	1
$\bar{x}$ per plot	0.5	0.5	0.5	0.5	-	0.5	-	-	0.8	-	0.5	-	0.5
$\bar{x}$ % canopy cover	100.0	90.0	90.0	70.0	77.8	92.5	100.0	100.0	86.7	77.5	97.5	90.0	97.5
$\bar{x}$ % herbaceous cover	87.5	7.5	87.5	2.5	23.0	15.0	99.2	77.5	29.7	100.0	97.5	85.0	100.0

	Group number									
Variable	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**Total**
# standing snags	1	-	-	2	1	6	1	1	-	116
$\bar{x}$ per plot	0.5	-	-	0.3	0.2	0.6	0.5	0.1	-	
$\bar{x}$ % canopy cover	92.5	72.5	91.7	90.0	95.0	89.5	97.5	95.5	91	83.5
$\bar{x}$ % herbaceous cover	100.0	87.5	47.8	5.0	1.3	78.5	92.5	74.7	12.2	43.4

Table 10. Mean number of shrub and dead stems/plot of 52 bottomland hardwood forest areas sampled in the Bayou Meto Basin Arkansas, April 2004.

	Group number																			
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
# shrub stems	4	80	2	5	8	12	4	13	7	47	5	7	11	12	27	8	6	9	19	6
x̄ per plot	2.0	8.0	1.0	2.5	4.0	6.0	2.0	7.5	1.7	7.8	2.5	1.8	5.5	3.0	6.8	4.0	3.0	1.5	4.8	3.0
# dead stems >3	2	20	2	1	2	3	3	1	8	22	-	4	5	6	8	9	5	7	5	5
x̄ >3 per plot	1.0	2.0	1.0	0.5	1.0	1.5	1.5	0.5	2.0	3.7	-	1.0	2.5	1.5	2.0	4.5	2.5	1.2	1.5	2.5
# dead stem 1-3	3	38	6	3	4	7	10	11	22	48	16	3	7	26	20	19	11	13	14	11
x̄ 1-3 per plot	1.5	3.8	3.0	1.5	2.0	3.5	5.0	5.5	5.5	8.0	8.0	0.8	3.5	6.5	5.0	9.5	5.5	2.2	3.5	5.5
# dead stems 0.25-1	9	93	6	8	3	18	24	20	66	84	18	12	17	32	20	10	14	23	13	5
x̄ 0.25-1 per plot	4.5	9.3	3.0	4.0	1.5	9.0	12.0	10.0	16.5	14.0	9.0	3.0	8.5	8.0	5.0	5.0	7.0	3.8	3.3	2.5

	Group number																			
Variable	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
# shrub stems	4	7	11	18	-	32	1	38	22	5	5	6	6	11	-	4	13	5	63	8
x̄ per group	2.0	3.5	1.8	1.8	-	5.3	0.5	3.8	2.2	1.3	2.5	3.0	3.0	5.5	-	2.0	6.5	2.5	10.5	4.0
# dead stems >3	6	2	13	17	-	18	5	17	12	2	1	5	6	9	-	6	9	2	13	3
x̄ >3 per group	3.0	1.0	2.1	1.7	-	3.0	2.5	1.7	1.2	0.3	0.5	2.5	3.0	4.5	-	3.0	4.5	1.0	2.2	1.5
# dead stem 1-3	7	8	23	45	-	20	14	58	44	11	4	8	12	24	-	6	15	6	29	4
x̄ 1-3 per group	3.5	4.0	3.8	4.5	-	3.3	7.0	5.8	4.4	2.8	2.0	4.0	6.0	12.0	-	3.0	7.5	3.0	4.8	2.0
# dead stems 0.25-1	5	12	42	48	-	31	18	30	34	5	13	10	16	24	-	4	5	0	32	9
x̄ 0.25-1 per group	2.5	6.0	7.0	4.8	-	5.2	9.0	3.0	3.4	1.3	6.5	5.0	8.0	12.0	-	2.0	2.5	-	17.5	4.5

	Group number												
Variable	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**Total**
# shrub stems	7	1	5	12	16	-	9	12	17	4	55	-	689
x̄ per group	3.5	0.5	2.5	6.0	8.0	-	4.5	2.0	1.7	2.0	5.5	-	2.8
# dead stems >3	5	5	3	1	5	-	13	15	17	3	22	-	355
x̄ >3 per group	2.5	2.5	1.5	0.5	2.5	-	6.5	2.5	1.7	1.5	2.2	-	1.5
# dead stem 1-3	5	5	4	6	10	-	14	21	31	12	43	-	781
x̄ 1-3 per group	2.5	2.5	2.0	3.0	5.0	-	7.0	3.5	3.1	6.0	4.3	-	3.2
# dead stems 0.25-1	8	4	4	6	3	-	9	36	18	9	25	-	955
x̄ 0.25-1 per group	4.0	2.0	2.0	3.0	1.5	-	4.5	6.0	1.8	4.5	2.5	-	3.9

Table 11. Number of seedlings >0.5m regenerating on 52 bottomland forest areas sampled in the Bayou Meto Basin Arkansas, April 2004.

	Group number																			
Tree species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
American Elm	-	72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black Willow	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cherrybark Oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cedar Elm	-	40	3	6	-	-	-	-	-	-	-	26	-	30	-	-	-	-	-	26
Green Ash	-	20	-	-	20	-	-	-	-	40	-	-	-	-	90	140	20	-	-	-
Hickory	-	-	16	12	-	-	-	-	-	-	-	-	-	20	-	-	-	60	-	-
Nuttall Oak	-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	--
Overcup Oak	6	13	-	-	6	12	-	-	-	12	16	-	260	100	4	30	30	12	-	-
Pecan	-	-	-	-	-	-	-	-	-	-	-	-	60	-	-	-	-	38	-	-
Red maple	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sassafras	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sugar Berry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swamp chestnut oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swamp privet	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sweet gum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White Oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30
Willow Oak	-	4	-	-	-	-	-	22	-	-	-	12	-	4	-	-	-	-	26	56
# of trees in group	15	213	19	18	26	24	-	22	-	52	16	38	320	154	94	170	50	110	26	
$\bar{x}$ AE, HK, RO/plot	4.5	7.6	8.0	6.0	-	-	-	2.8	-	-	-	3.0	-	6.0	-	-	-	-	6.5	15.0
$\bar{x}$ GA, OO	3.0	3.3	-	-	13.0	6.0	-	-	-	8.7	8.0	-	130.0	25.0	23.5	85.0	25.0	12.0	-	-

Table 11. continued.

	Group number																
Tree species	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**
American Elm	-	-	-	-	-	-	-	56	8	46	10	-	-	-	40	-	26
Black Willow	-	-	-	-	-	-	-	10	-	-		-	-	-	-	-	-
Cherrybark Oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Cedar Elm	-	10	46	43	40	59	76	32	66	-	-	4	10	-	90	-	-
Green Ash	50	40	80	155	33	-	-	12	-	-	-	50	-	-	370	26	-
Hickory	-	-	-		5	10	-	-	18	6	55	-	-	-	-	-	80
Nuttall Oak	-	-	-	56	-		6	-	-	6	-	-	-	-	80	-	-
Overcup Oak	40	-	10	270	-	100	10	-	10	-	-	10	20	10	400	12	-
Pecan	-	-	-	-	10	-	-	-	-	-	-	-	-	-	116	-	-
Red maple	-	-	-	40	-	-	-	-	13	-	-	-	-	-	110	-	80
Sassafras	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sugar Berry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swamp chestnut oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40
Swamp privet	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-
Sweet gum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Water Oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White Oak	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Willow Oak	90	-	3	56	56	4	28	94	35	-	-	-	6	-	43	-	-
# of trees in group		50	139	620	471	173	120	204	150	60	65	64	36	10	1249	38	242
x̄ AE, HK, RO/plot	-	-	0.5	11.2	1.9	2.3	17.0	15.0	6.1	3.0	32.5	-	3.0	-	8.2	-	18.7
x̄ GA, OO	45.0	20.0	15.0	42.5	11.2	16.7	5.0	1.2	1.0	-	-	30.0	10.0	5.0	38.5	19.0	-

Table 11. continued.

	Group number															
Tree species	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**Total**
American Elm		-	-	-	-	-	-	-	-	20	-	-	10	100	-	388
Black Willow		-	-	-	-	-	-	-	-	-	-	-	-	-	-	36
Cherrybark Oak	10	-	-	-	-	-	-	-	-	-	-	10	-	-	-	26
Cedar Elm	20	64	10	40	6	10	60	-	-	20	-	22	50	-	76	985
Green Ash	-	48	6	-	-	-	-	80	-	-	18	-	-	-	132	1732
Hickory	30	-	-	-	-	-	30	-	-	-	-	100	-	40	-	477
Nuttall Oak	-	3	-	-	-	-	-	-	-	-	-	20	-	-	-	180
Overcup Oak	-	140	50	-	-	-	-	60	-	20	-	120	-	-	-	1783
Pecan		-	-	-	-	-	-	-	50	-	-	20	-	-	20	314
Red maple	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	245
Sassafras	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30
Sugar Berry	-	-	-	25	-	-	-	-	-	-	-	-	-	48	-	73
Swamp chestnut oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40
Swamp privet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42
Sweet gum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Water Oak	-	-	-	-	-	-	20	-	-	-	-	-	-	30	-	50
White Oak	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Willow Oak	-	-	26	-	-	-	20	10	-	-	-	130	20	32	-	661
# of trees in group	60	255	92	65	6	10	130	150	50	60	18	422	80	250	228	7074
$\bar{x}$ AE, HK, RO/plot	20.0	0.5	13.0	-	-	-	25.0	5.0	-	-	3.0	16.0	15.0	20.2	-	7.5
$\bar{x}$ GA, OO	-	31.3	28.0	-	-	-	-	70.0	-	5.0	-	22.0	-	-	12.2	14.0

Table 12. Number of regenerating seedlings > 0.5 m/plot of relatively water intolerant (hickory, American elm, red oak) and water tolerant (green ash and overcup oak) tree species for 52 bottomland hardwood forest areas sampled in the Bayou Meto Basin, Arkansas April 2004 in relation to habitat type

	Species[1]	
Habitat type[2] (*N*)	HK/EL/RO	GA/OO
Riparian corridor (3)	10.8	2.1
Small isolated (7)	9.2	4.7
Large connected (2)	15.5	11.0
Natural levee (2)	19.4	-
Private GTR (17)	0.9	17.6
Bayou Meto GTR (13)	3.9	19.4
Edge private GTR (4)	4.0	10.2
Edge Bayou Meto GTR (6)	10.1	9.9

[1] RO - combined red oak, GA - green ash, OO - overcup oak, AE - American elm, HK - combined mockernut, shellbark, and shagbark hickory.

[2]Site descriptions taken from Table 1.

Table 13. Sum of rank scores (-2 to +2) for 8 variables indicating relative health of 52 groups of bottomland hardwood forest areas sampled in the Bayou Meto Basin, Arkansas April 2004 in relation to habitat type.

Habitat type and group[1]		Sum of 8 variables ranks[2]	Acreage
Riparian corridor	1	+9	2.2
	2	+4	18.4
	51	+7	262.8
	mean subtotal	+6.7	283.4
Small isolated	3	+10	8.1
	4	+14	40.2
	5	-4	11.1
	8	+3	2.3
	20	+6	20.7
	22	-14	93.7
	31	+10	8.9
	mean subtotal	+3.6	185.0
Natural levee	37	+12	227.7
	38	+11	40.2
	mean subtotal	+11.5	267.9
Large connected	49	+7	414.9
	50	+11	70.1
	mean subtotal	+9	485.0
Private GTR	6	-8	16.5
	7	-4	15.5
	9	-4	31.5
	10	-16	38.7
	13	-8	23.9
	14	+1	95.2
	15	-13	179.3
	16	-14	34.3
	17	-13	35.2
	18	-5	243.0
	19	0	190.5
	21	-10	58.0
	36	-11	26.4
	39a[3]	-13	73.8

Table 13. continued

Habitat type and group		Sum of 8 variables ranks	Acreage
Private GTR	42	-3	428.5
	47	-8	181.2
	48	-1	225.8
	mean subtotal	-7.6	1897.3
Bayou Meto GTR	23	-9	101.4
	24	-6	226.2
	25	-11	1084.1
	28	-4	83.0
	29	+6	853.3
	30	+15	233.6
	32	-15	60.5
	35	-7	246.7
	39b	-13	31.6
	41	-4	133.8
	45	-3	117.7
	46	+2	75.2
	52	-13	89.8
	mean subtotal	-4.8	3336.9
Edge private GTR	11	-9	24.4
	12	+4	16.9
	34	-10	110.6
	40a	0	56.5
	mean subtotal	-5	208.4
Edge BM GTR	26	-5	47.3
	27	+6	2.3
	33	+3	52.7
	40b	0	56.5
	43	0	108.7
	44	+11	86.9
	mean subtotal	+ 3	354.4
Combined total		-1.8	7018.3

[1] Site descriptions taken from Table 1.

[2] Variables were each ranked -2 to +2 and included: 1) % of total trees $\geq$ 3 inches dbh that were red oak. 2) % of red oaks with tip die-back. 3) % of red oaks with basal swelling. 4) % of red oaks that were dead. 5) % herbaceous ground cover. 6) % of total trees $\geq$ 3 inches dbh that were green ash. 7) % of total trees $\geq$ 3 inches dbh that were mockernut. shellbark. and shagbark hickory. and 8) ratio of number of seedlings > 0.5 m of relatively water intolerant to water tolerant tree species.

[3] Groups 39 and 40 contained BLH in both private and Bayou Meto WMA ownership.

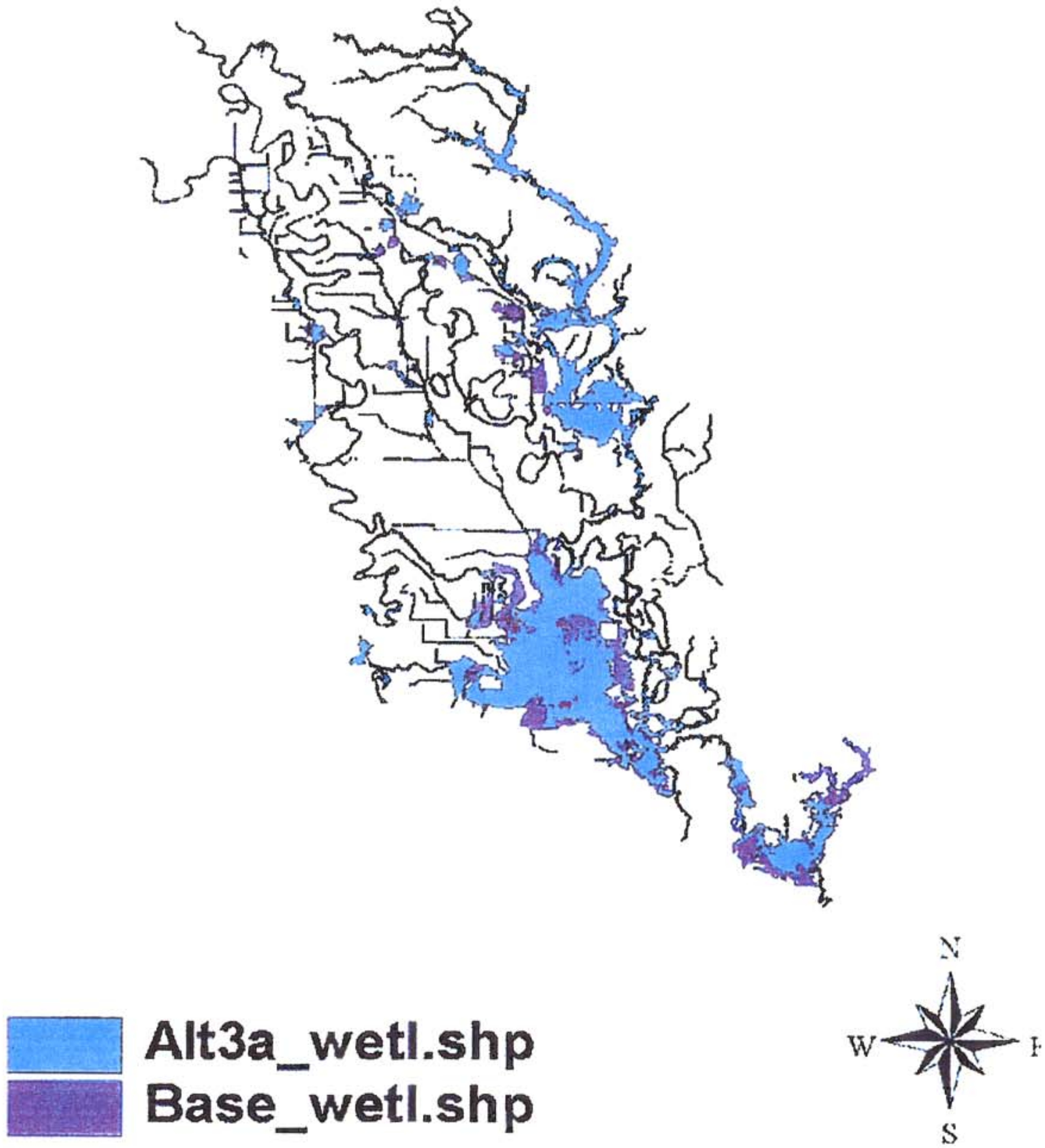
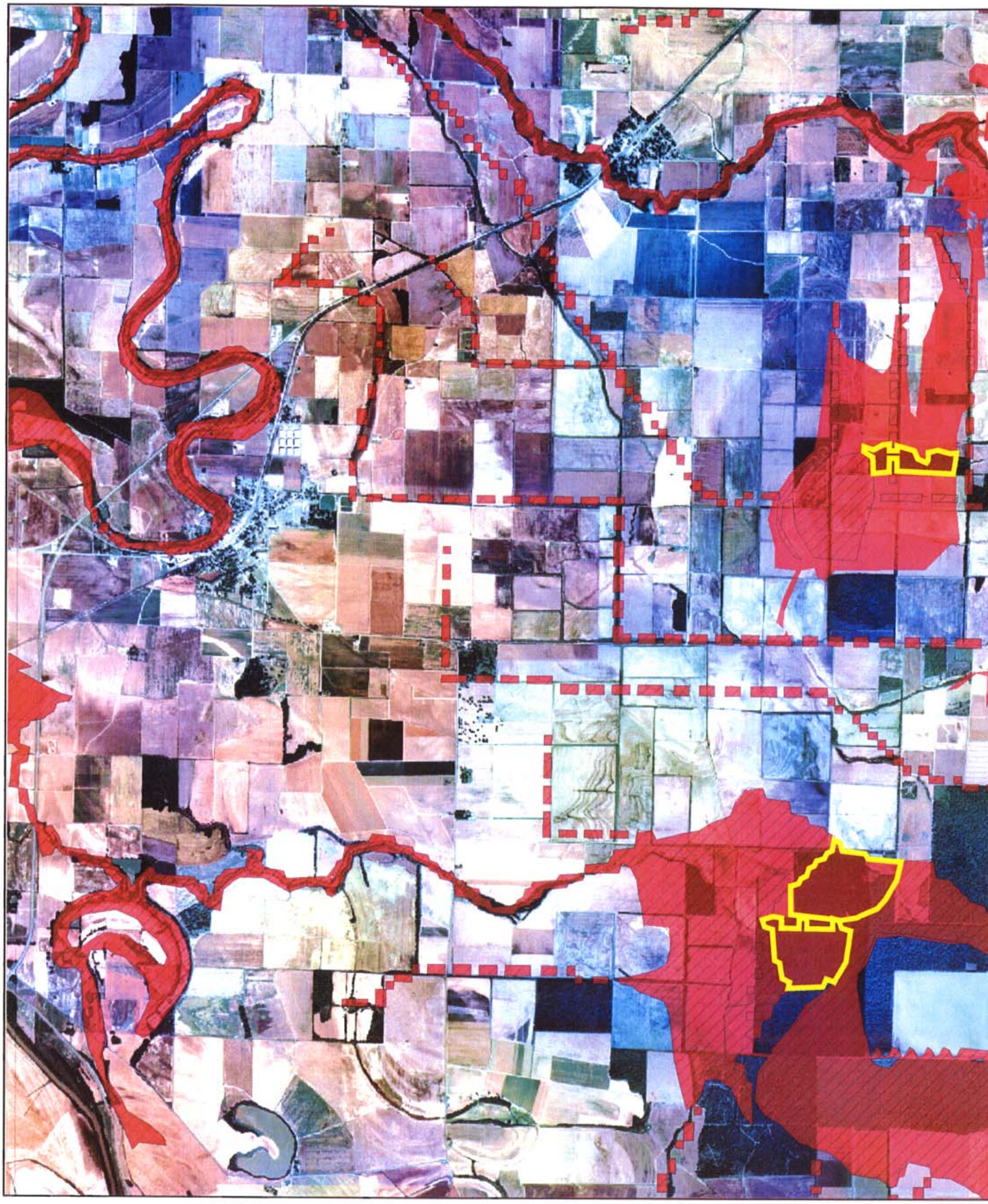


Figure 1. Areas within the Bayou Meto Basin, Arkansas that have a pre-project (base wetland) and post-project (alternative 3A) $\geq$ 5% flooding duration during the growing season. Areas shown in the purple base wetland are those sites where flooding duration will change to < 5%.

APPENDIX A. Quadrangle maps of the Bayou Meto Basin Improvement Project Area indicating current (pre-project) base wetland areas that have ≥ 5% flooding duration during the growing season and areas where base wetland will change to < 5% flooding duration during the growing season (post-project) if flood control developments associated with Alternative 3A are completed.

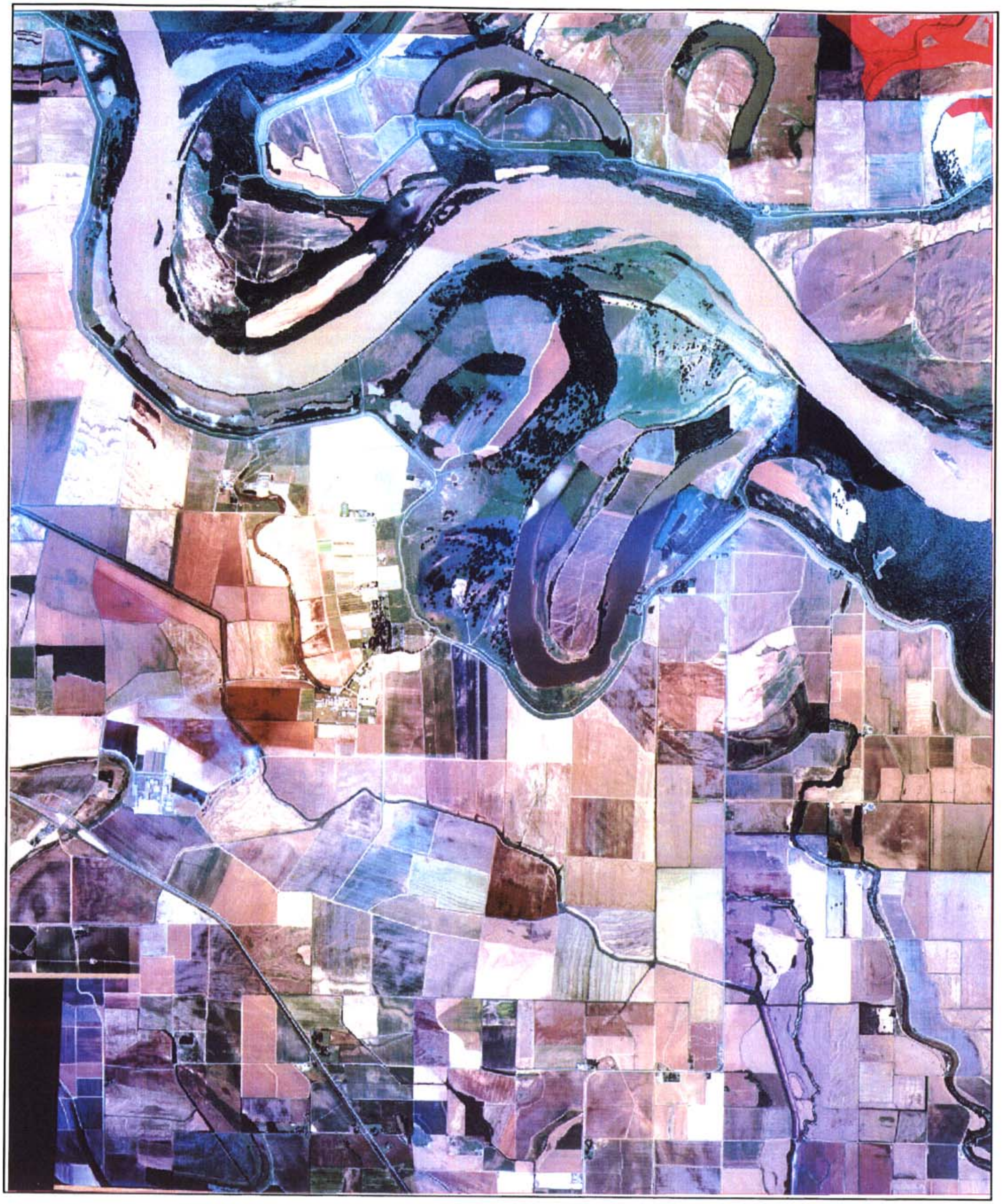


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Altheimer

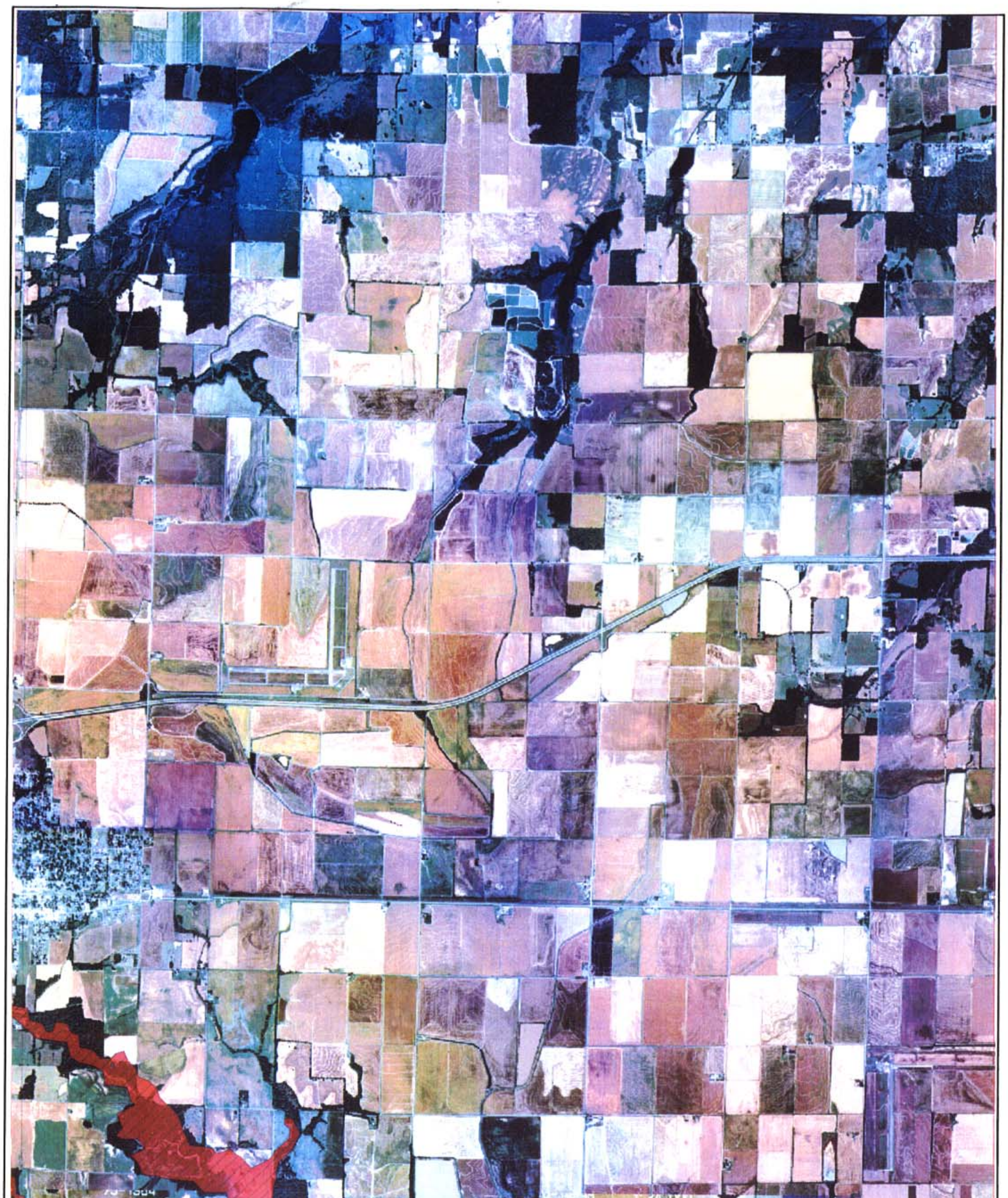


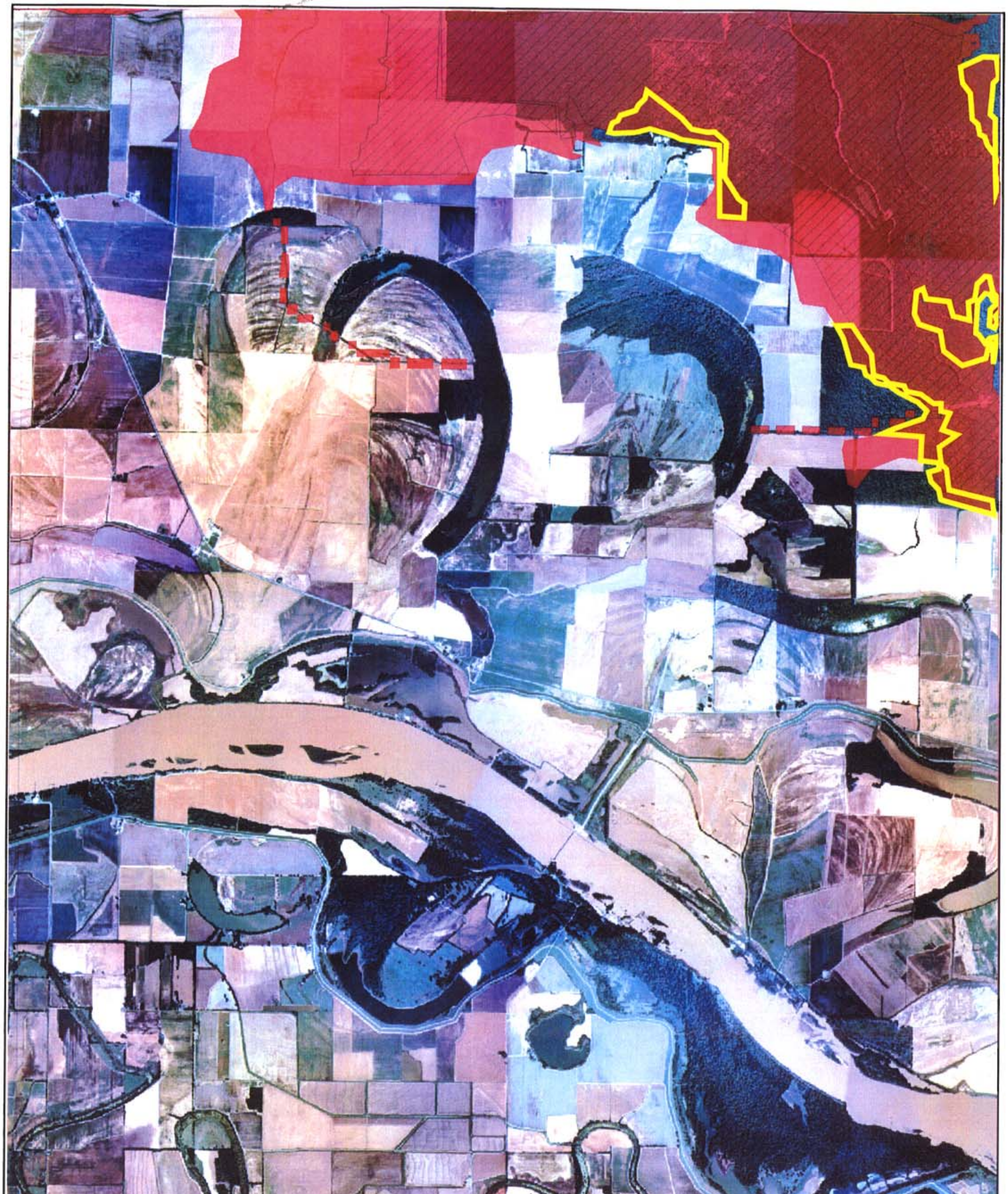
Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Cades



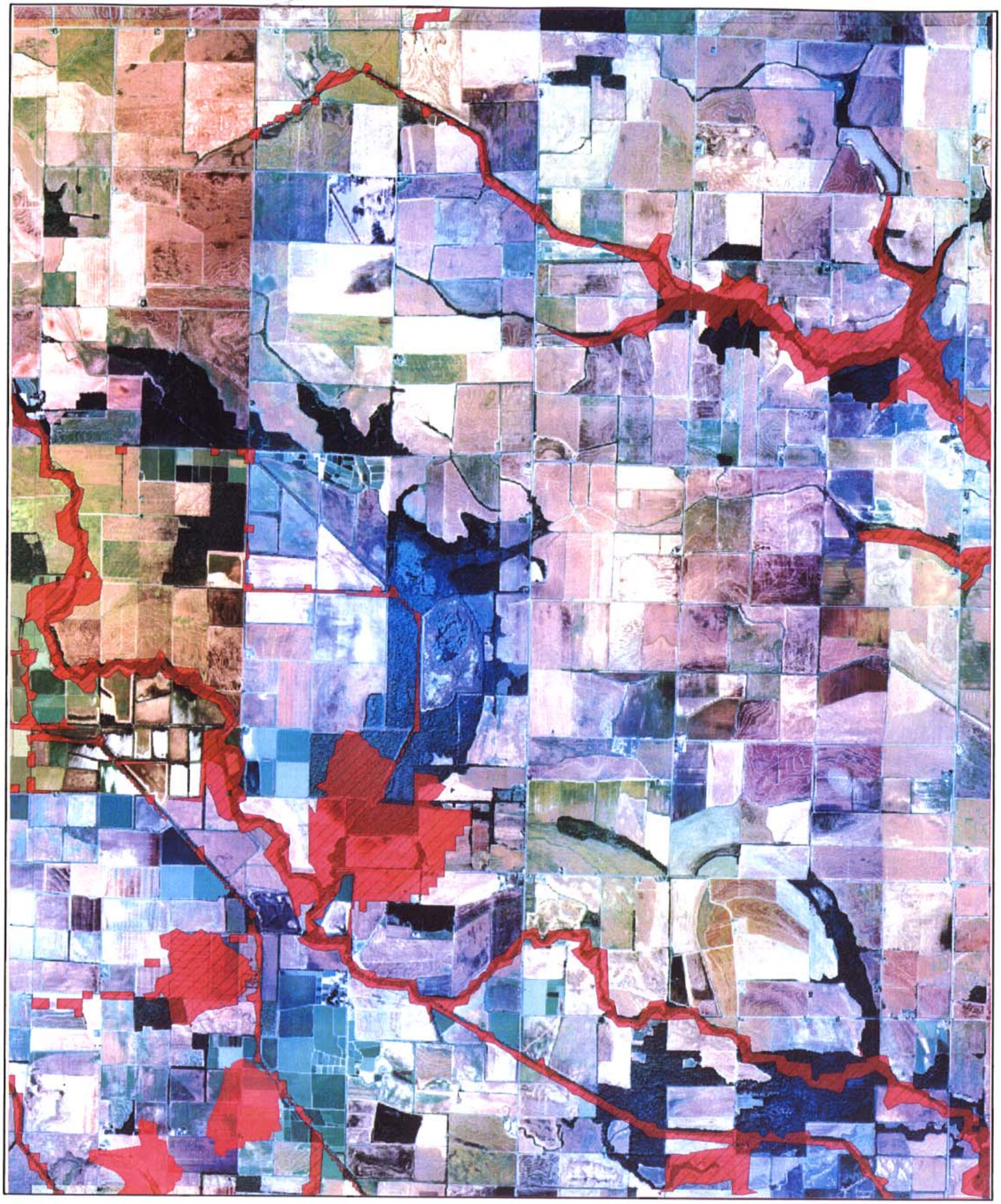


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Cornerstone

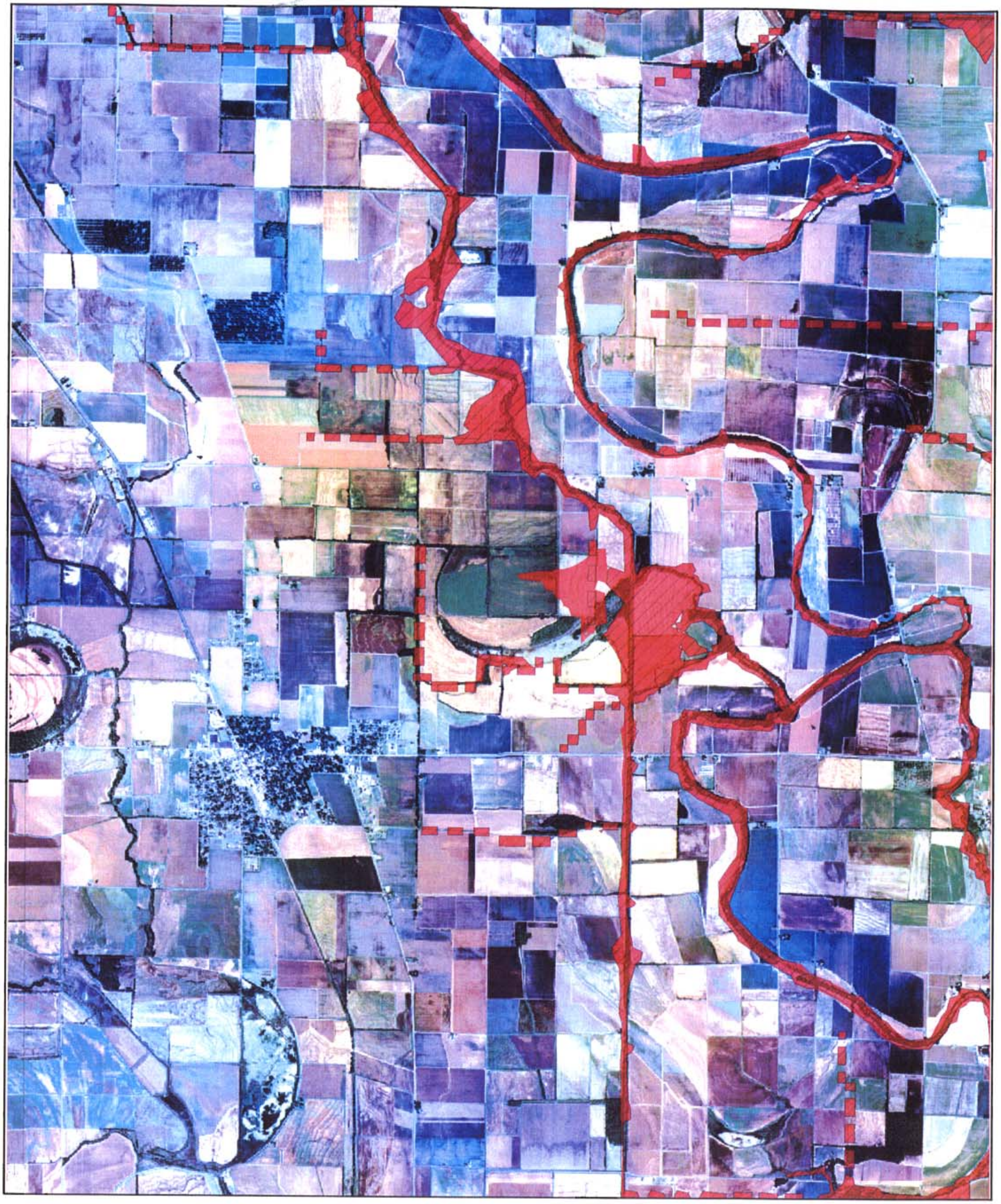


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Culler

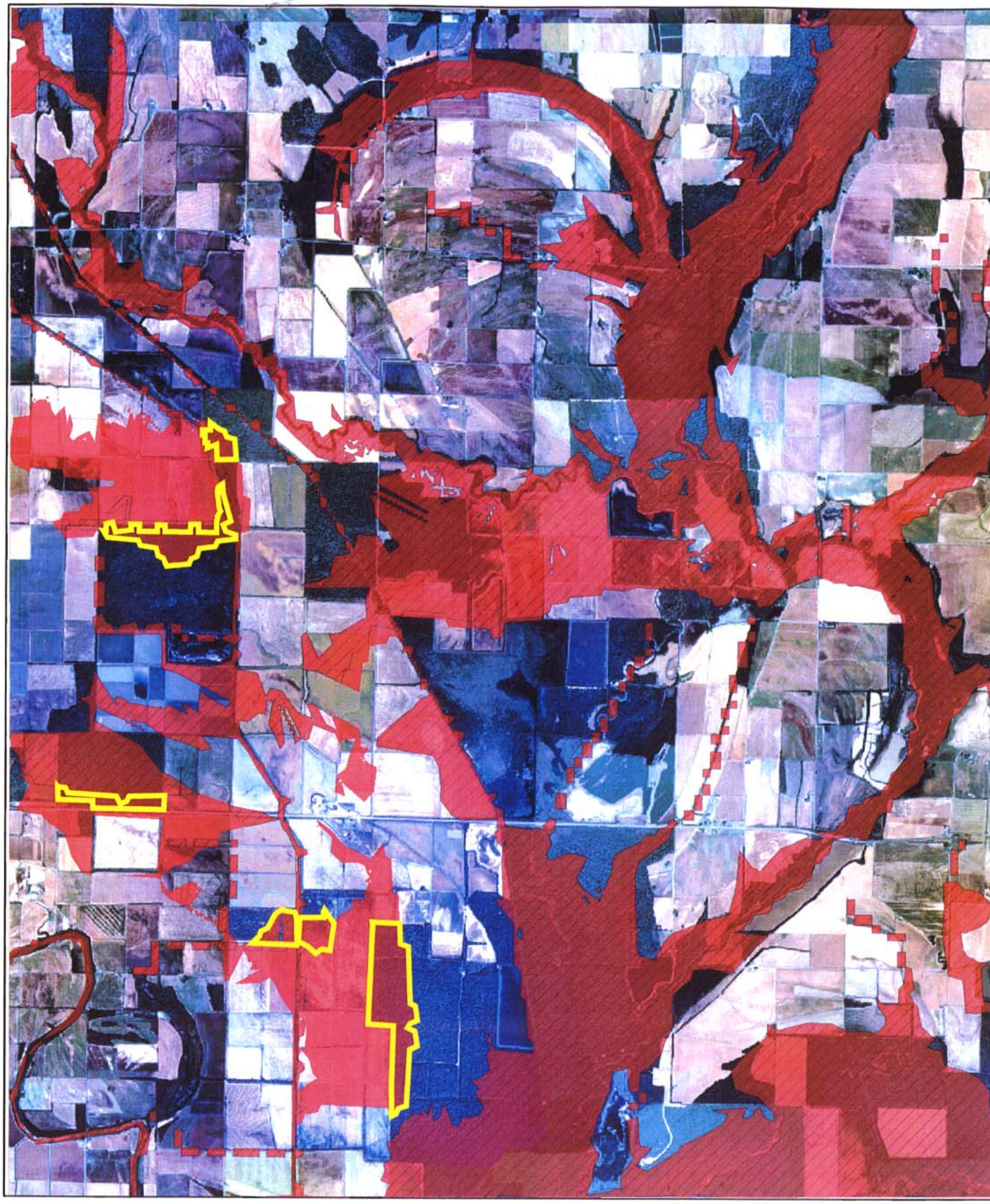


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

England

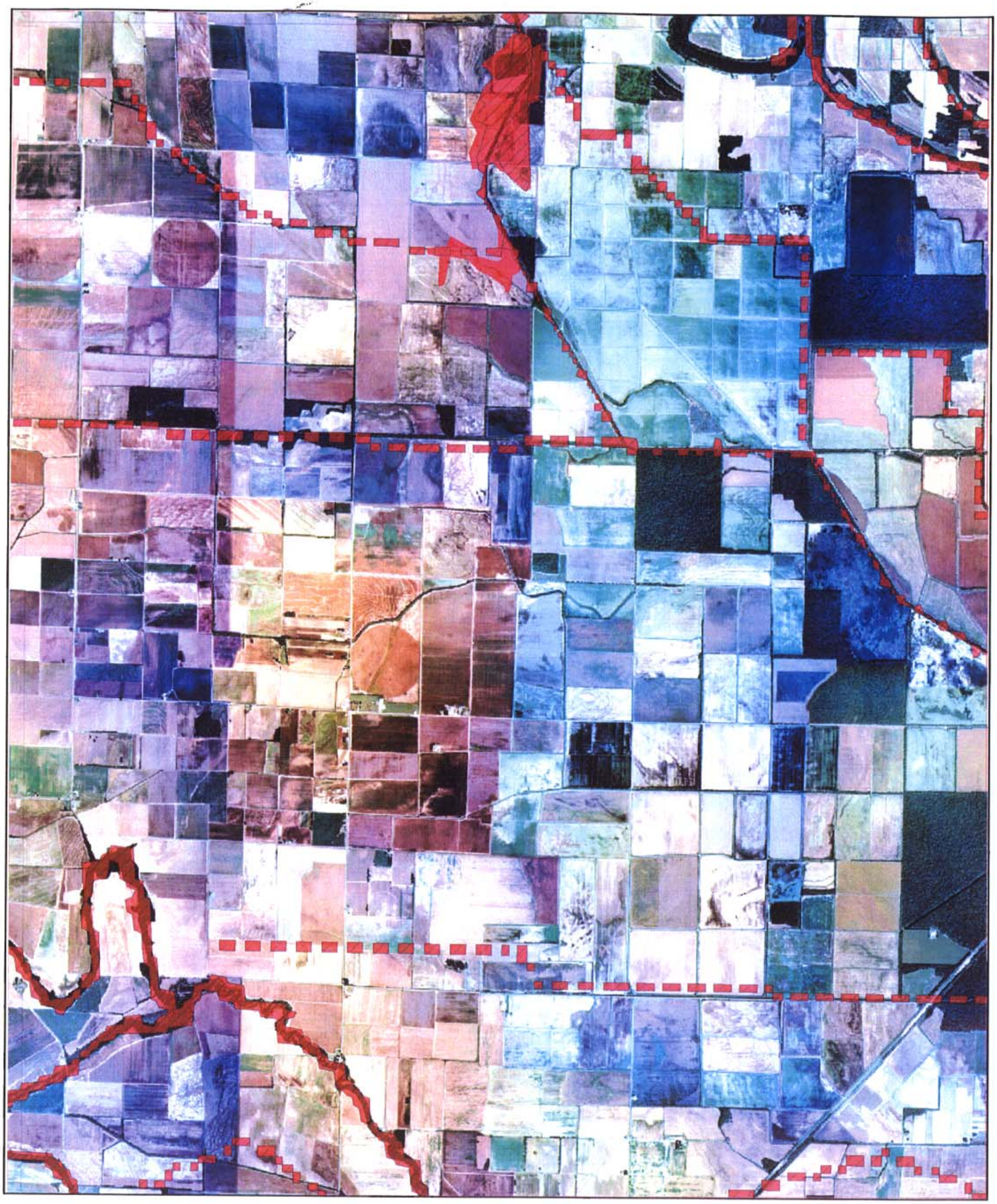


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Geridge



Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

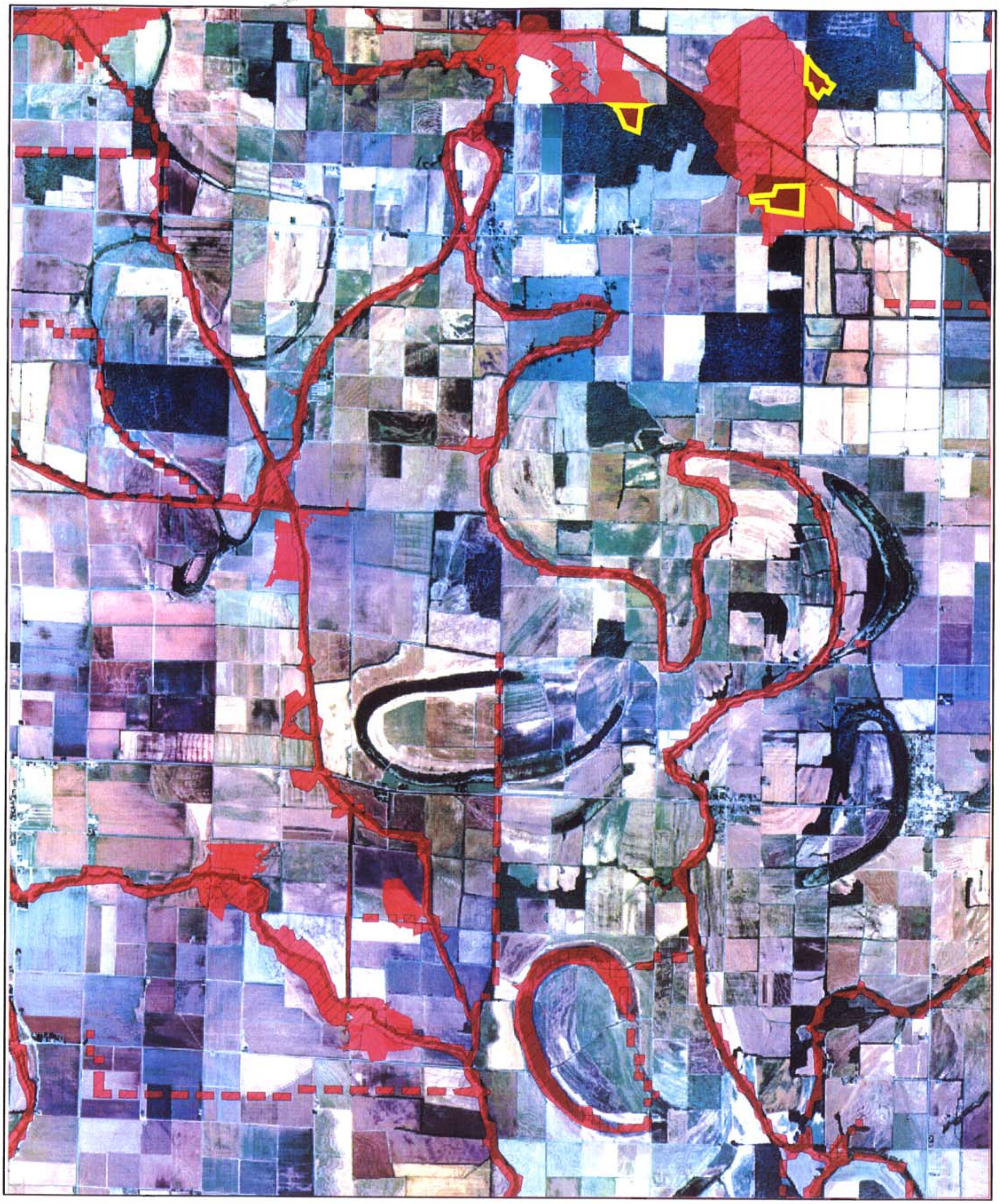
Gethsemane

Private Green Tree Reservoirs

Post Project Flood Scene

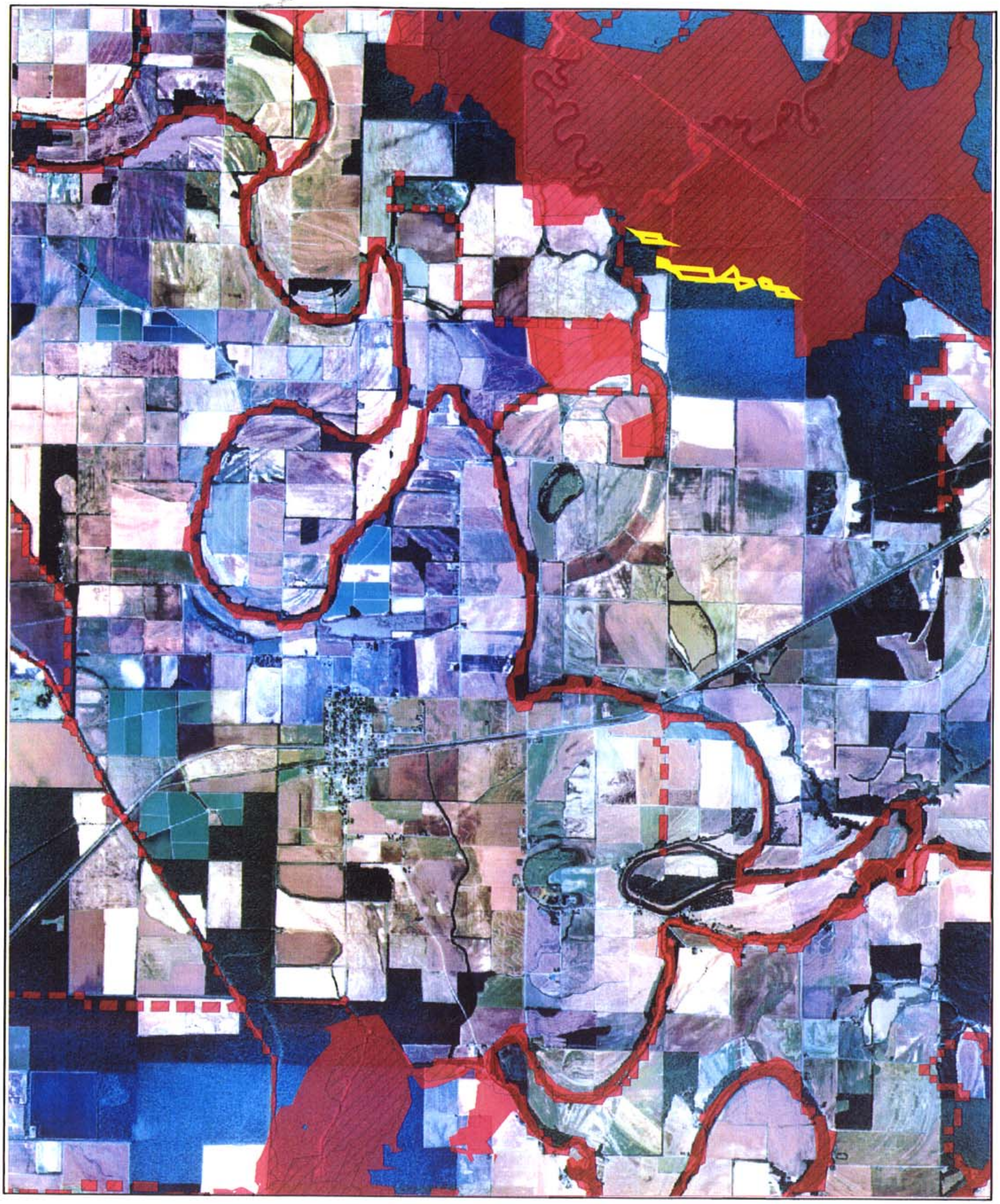
Pre Project Flood Scene

Gillett



Private Green Tree Reservoirs
Post Project Flood Scene
Pre Project Flood Scene

Humnoke



Private Green Tree Reservoirs
Post Project Flood Scene
Pre Project Flood Scene
Humphrey

Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

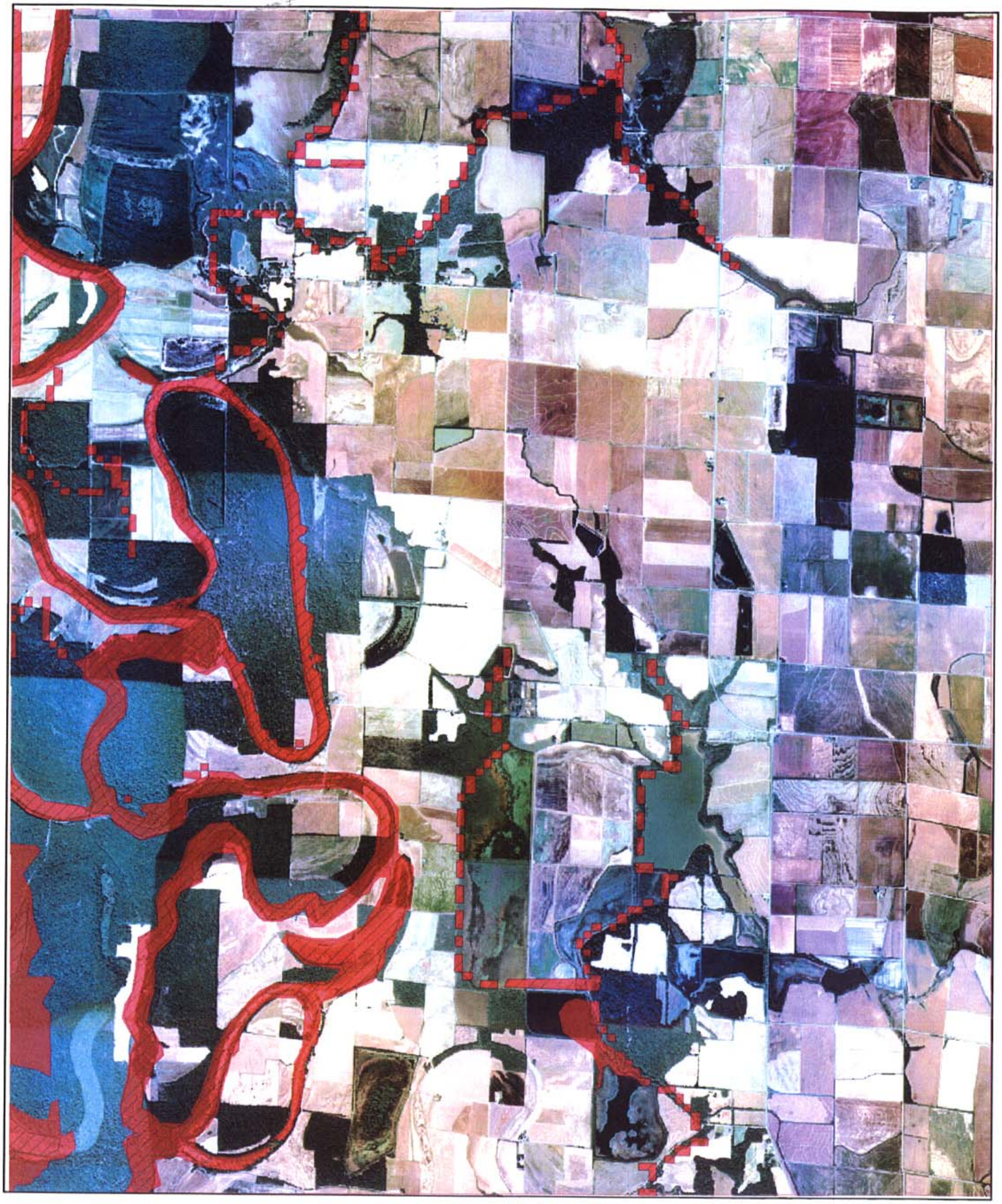
Humphrey SW

Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Jacksonville

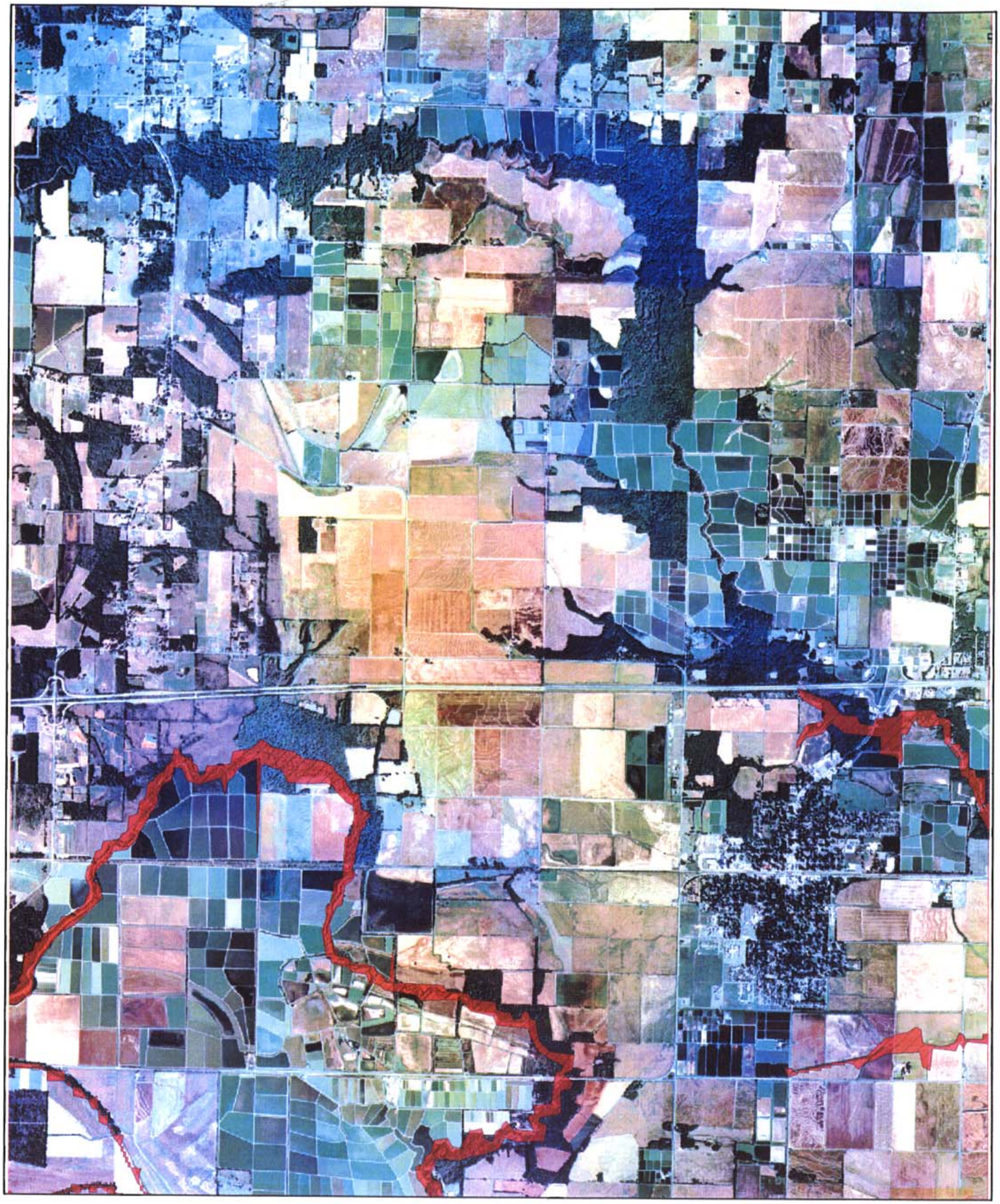


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Lodge Corner

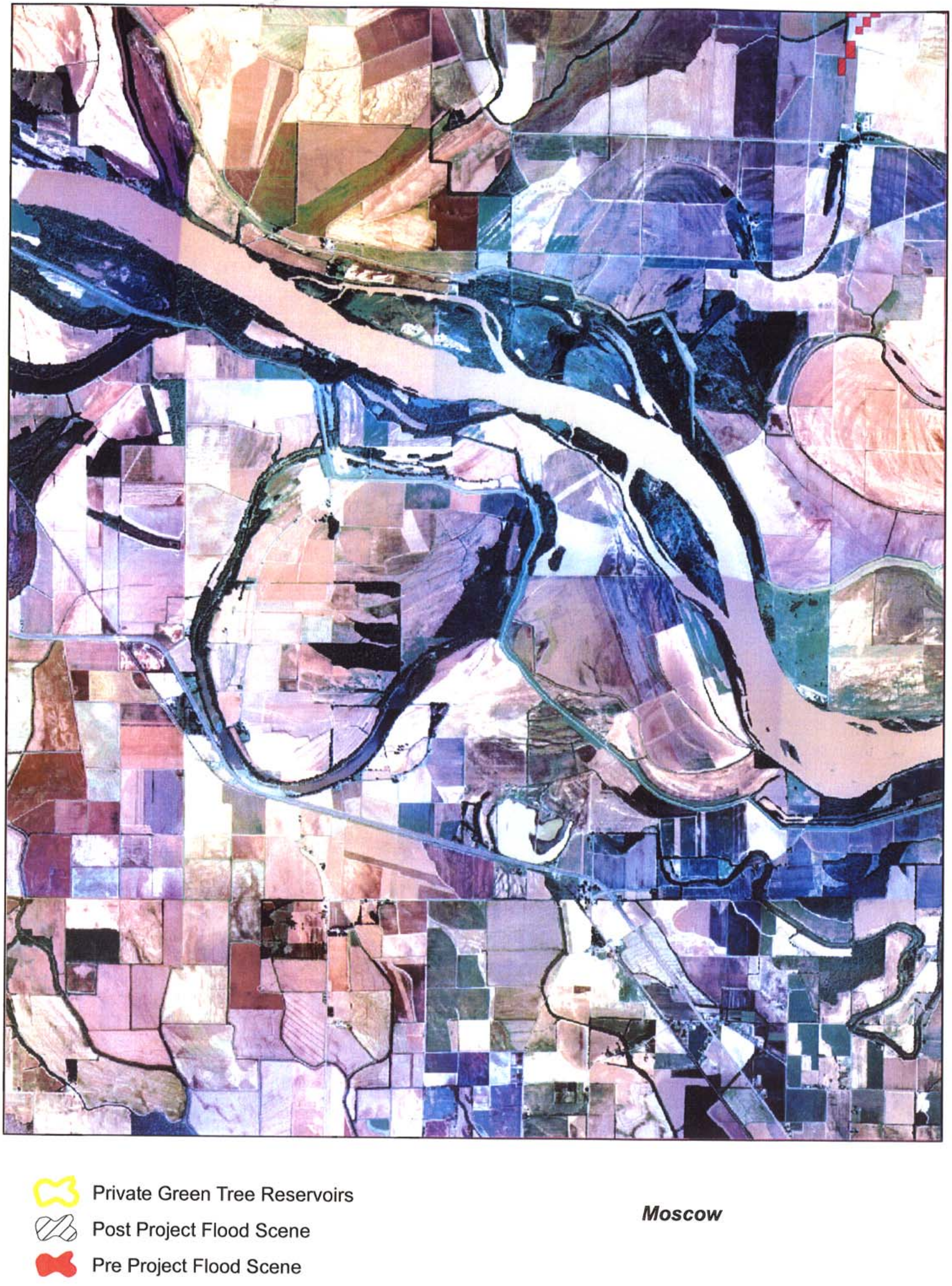


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

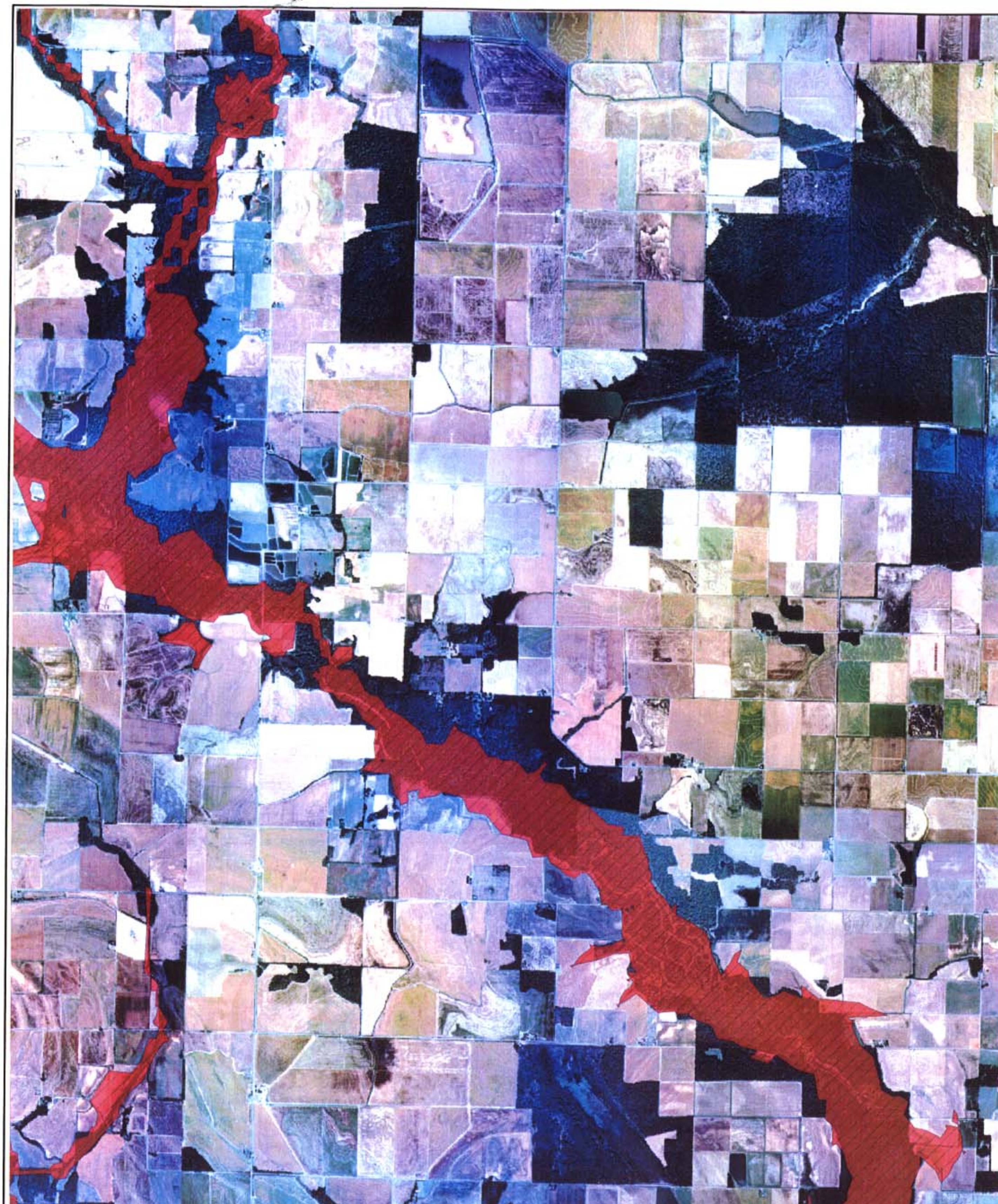
Lonoke


Private Green Tree Reservoirs
Post Project Flood Scene
Pre Project Flood Scene

Moscow

Private Green Tree Reservoirs
Post Project Flood Scene
Pre Project Flood Scene

One Horse Store

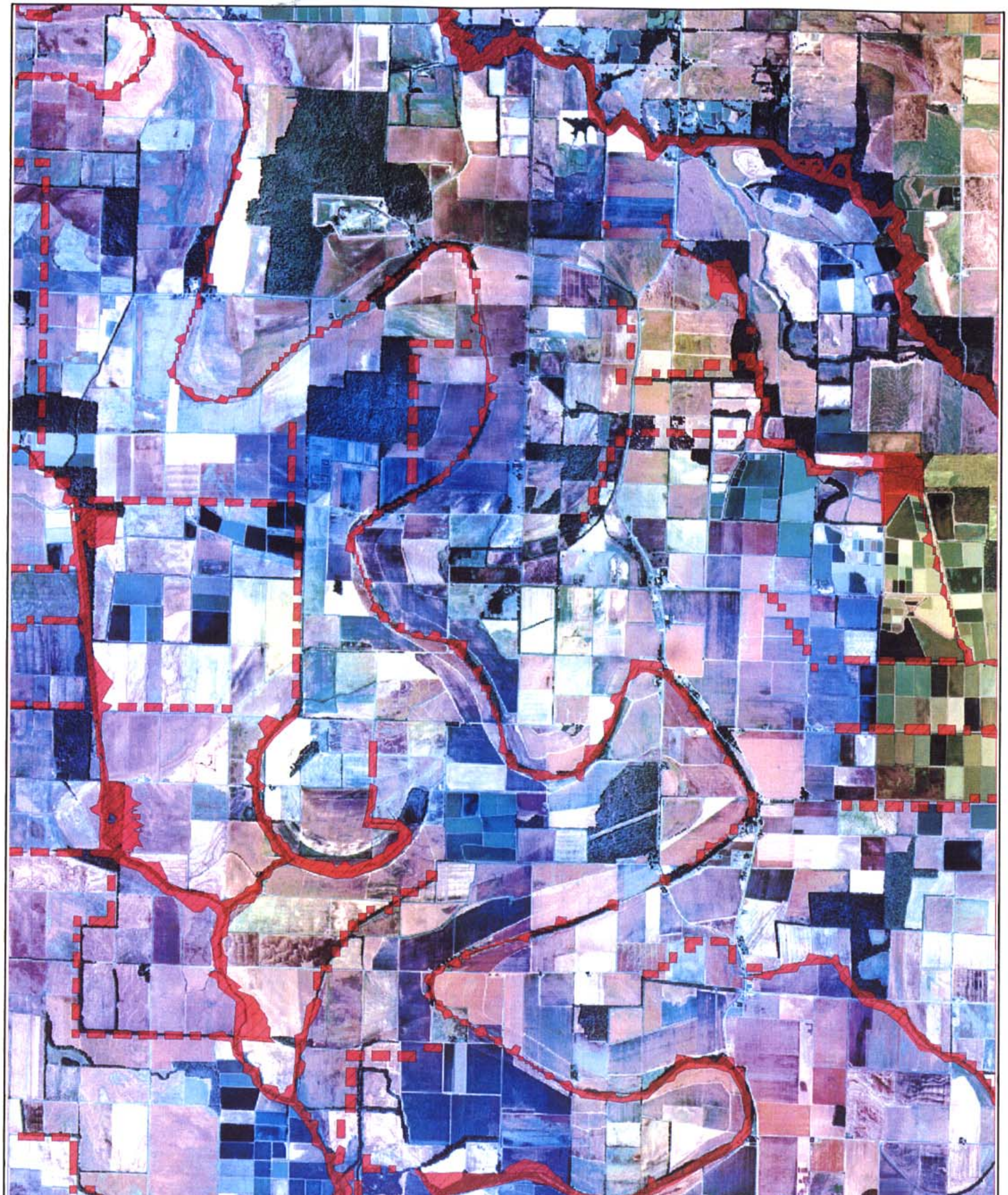


Private Green Tree Reservoirs

Post Project Flood Scene

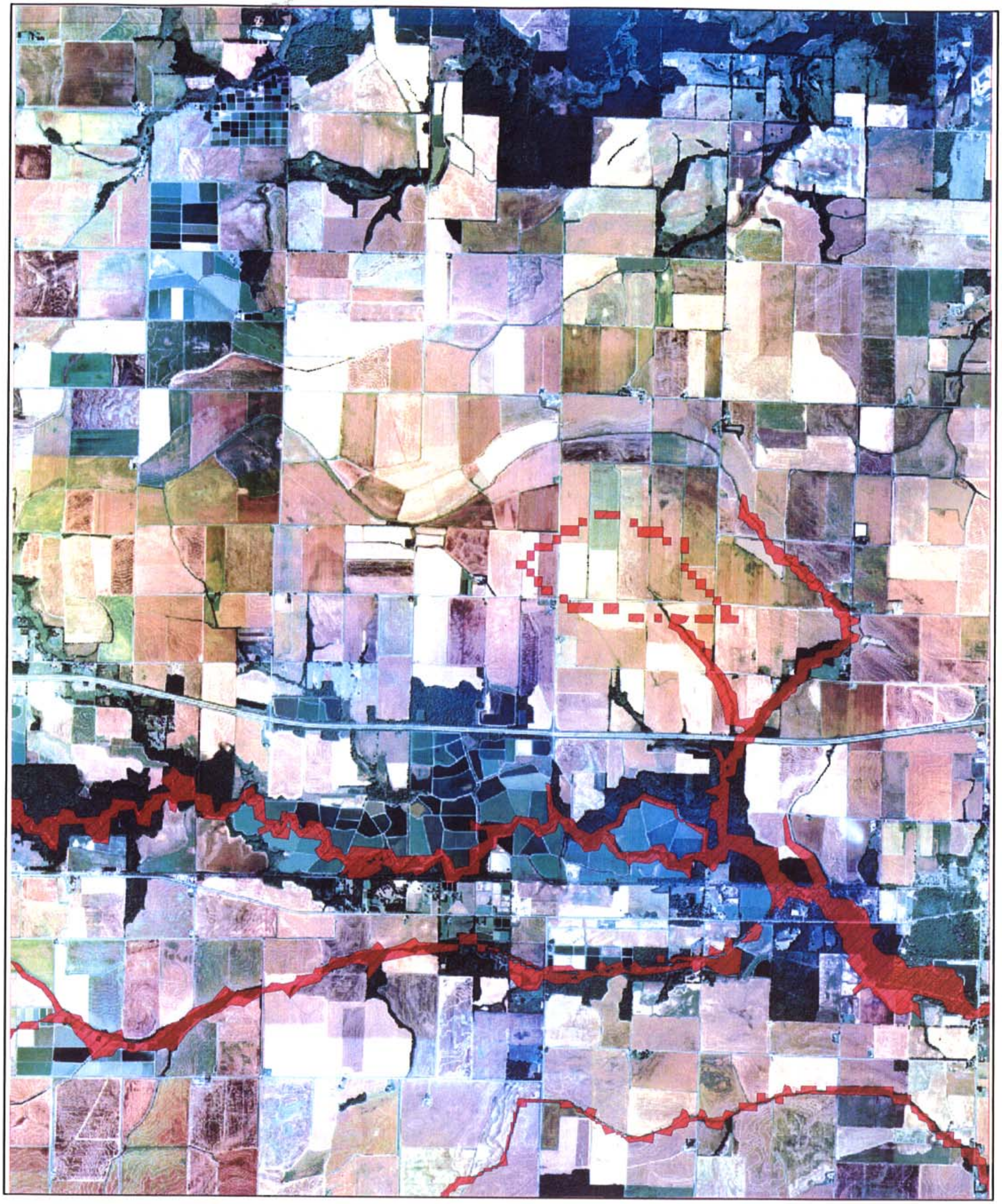
Pre Project Flood Scene

Parkers Corner



Private Green Tree Reservoirs
Post Project Flood Scene
Pre Project Flood Scene

Pettus



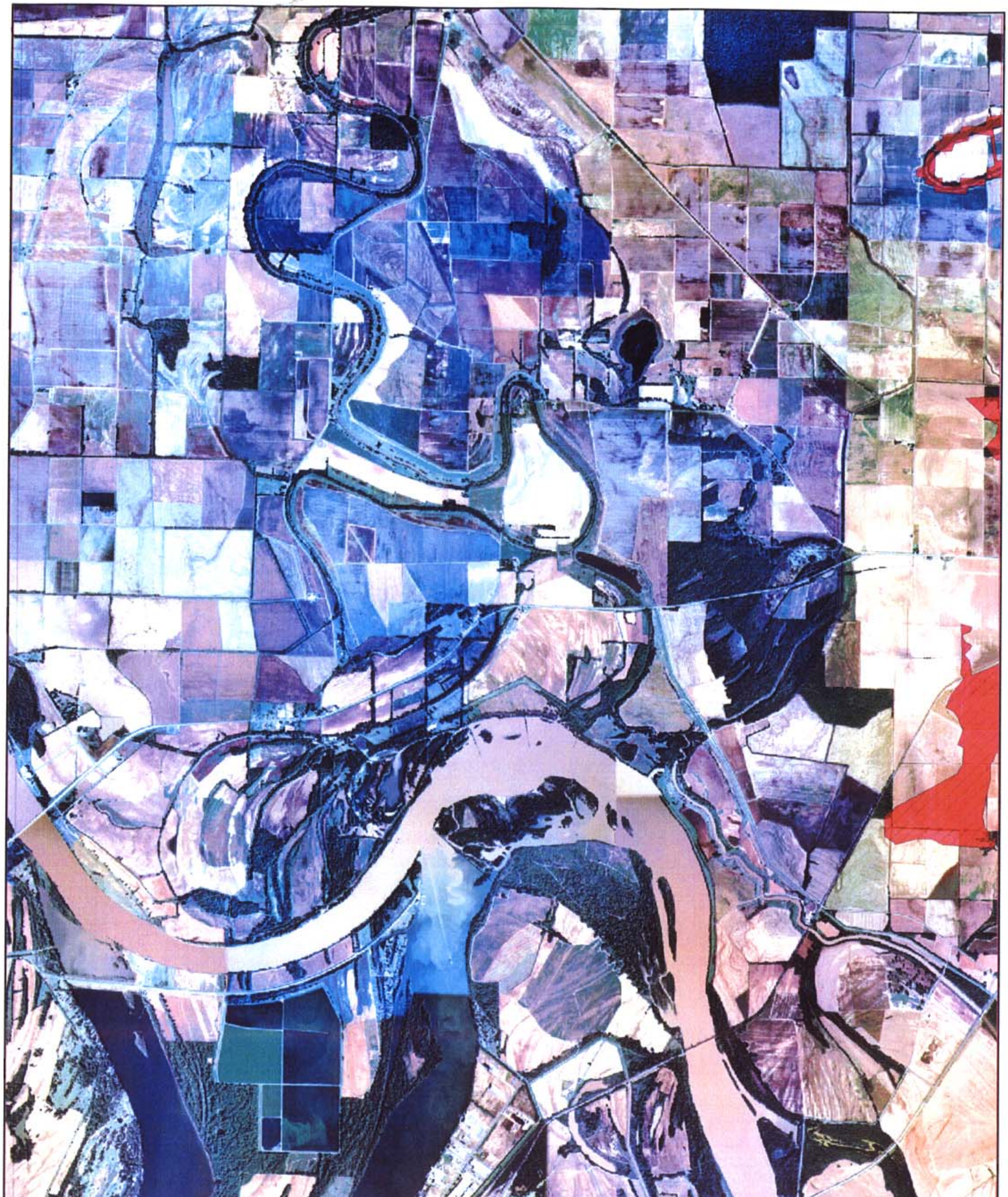
Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Pocket Prairie


Private Green Tree Reservoirs
Post Project Flood Scene
Pre Project Flood Scene
Reydell

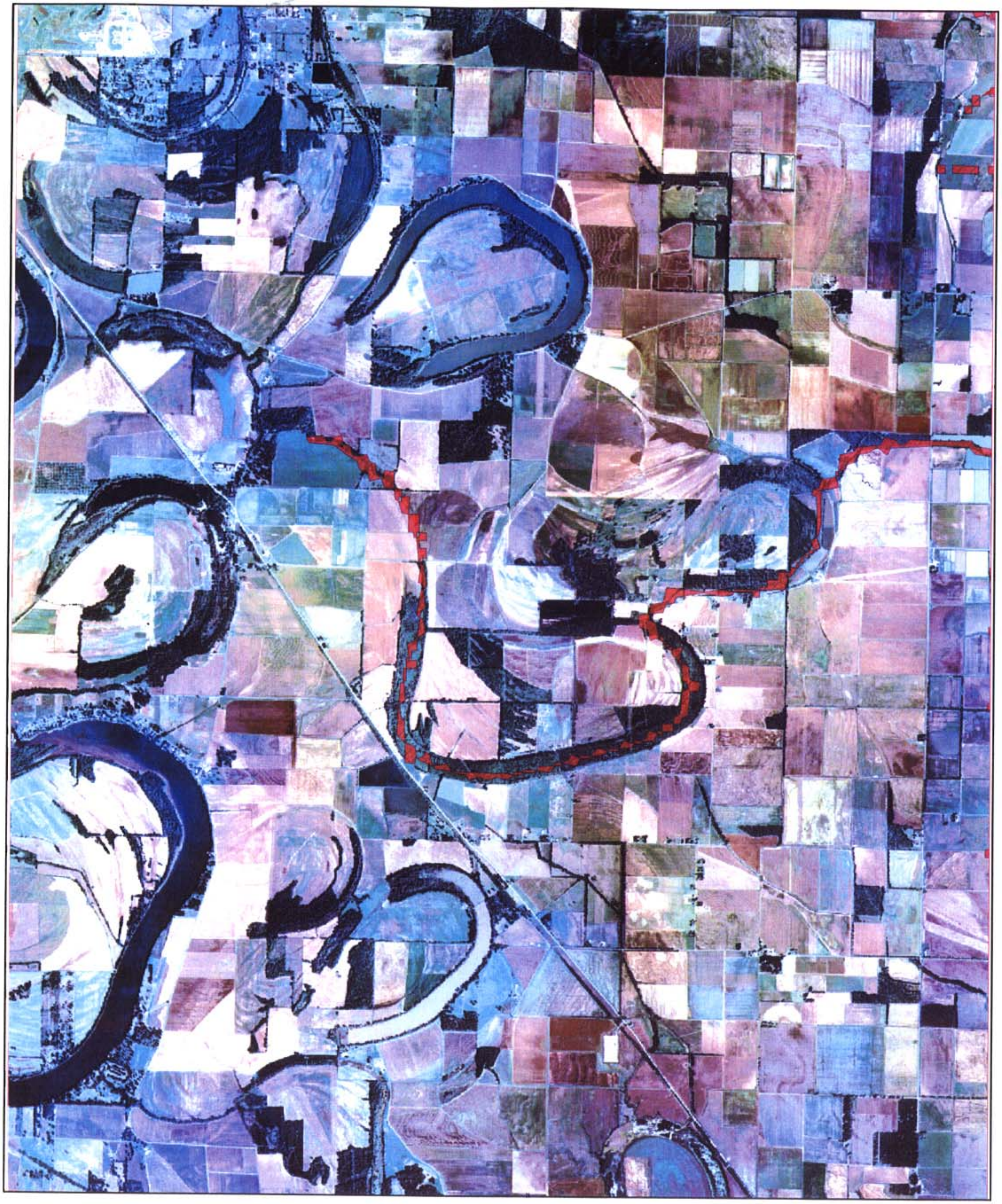


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Rob Roy

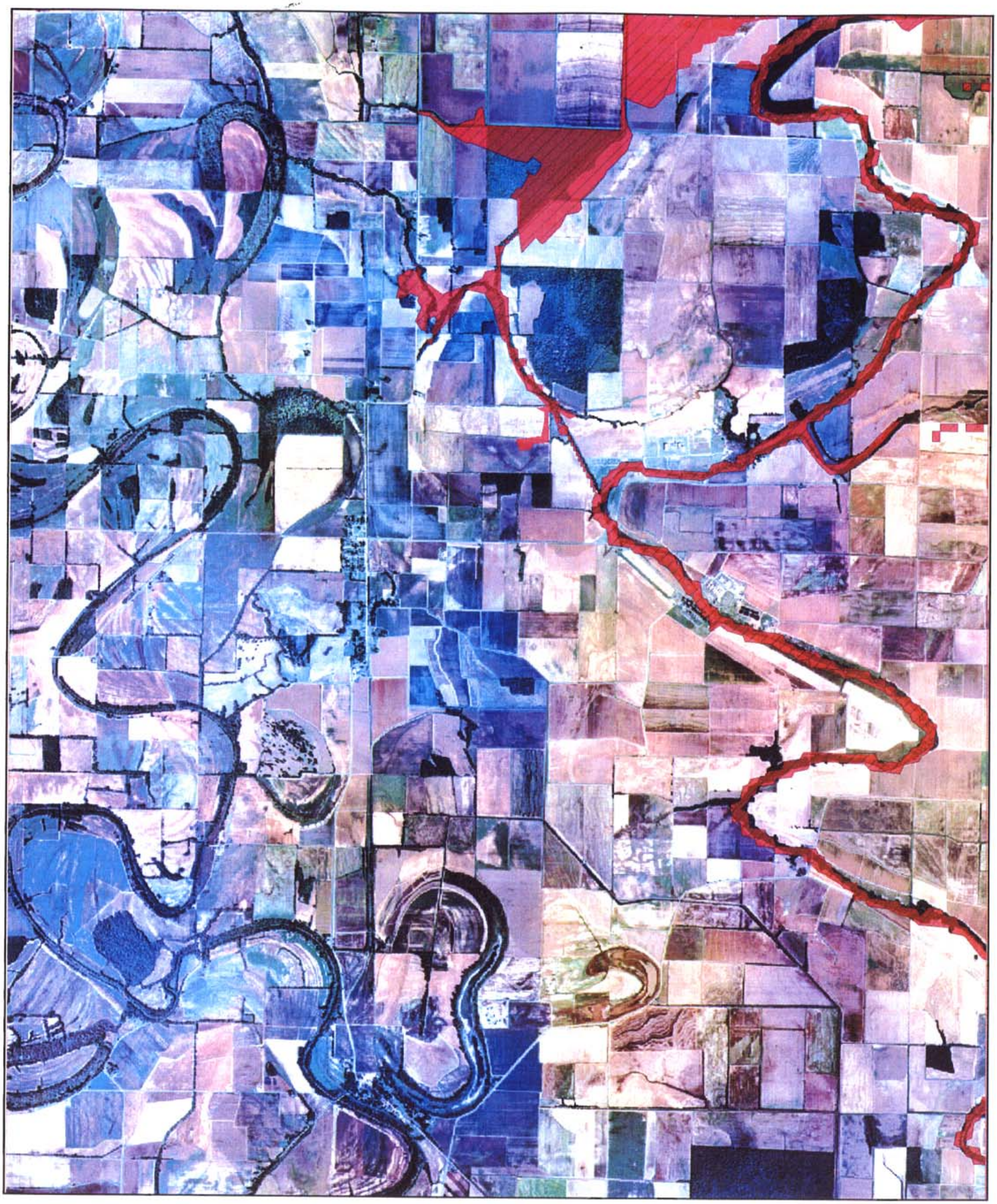


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Scott

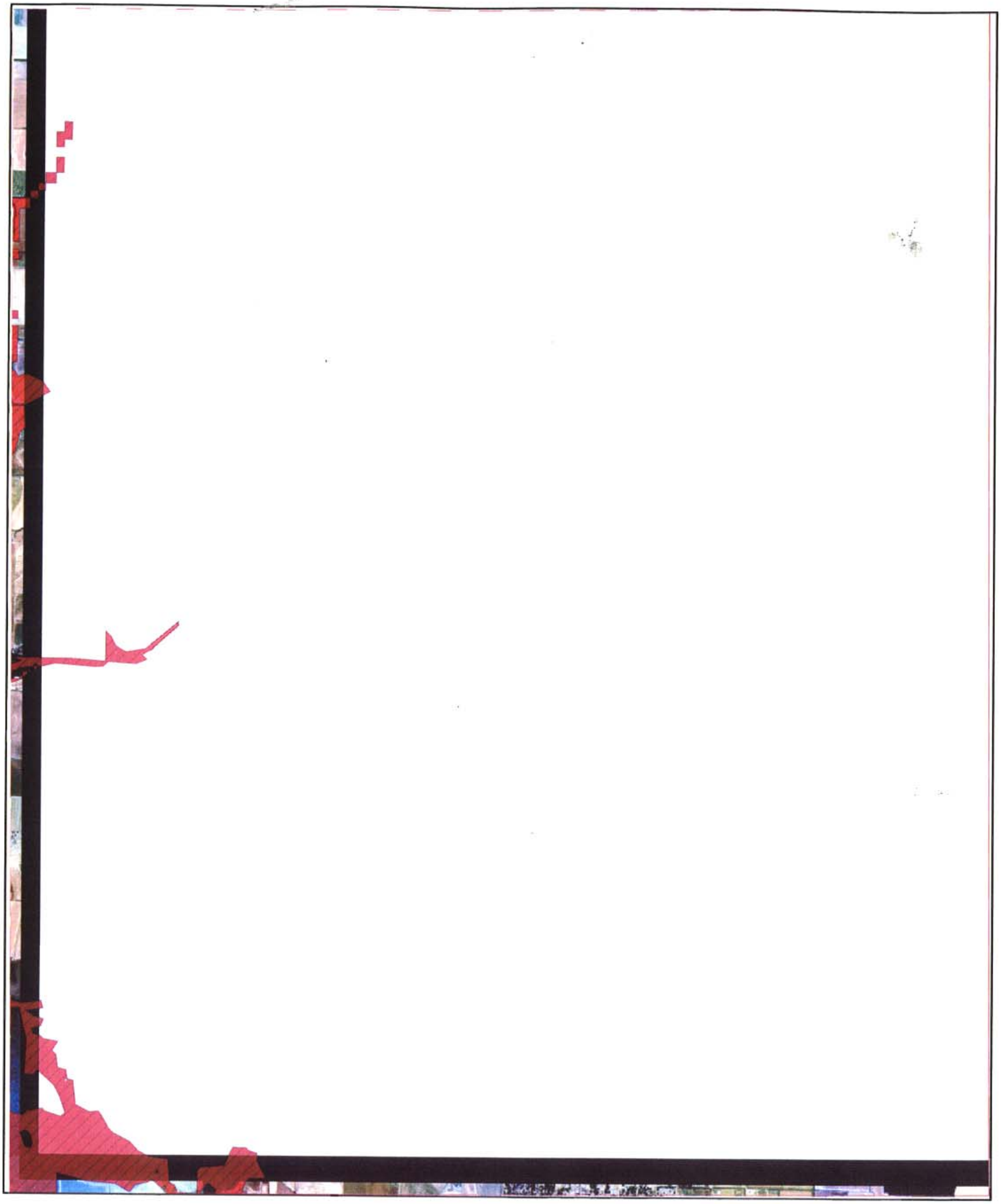


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Sherrill

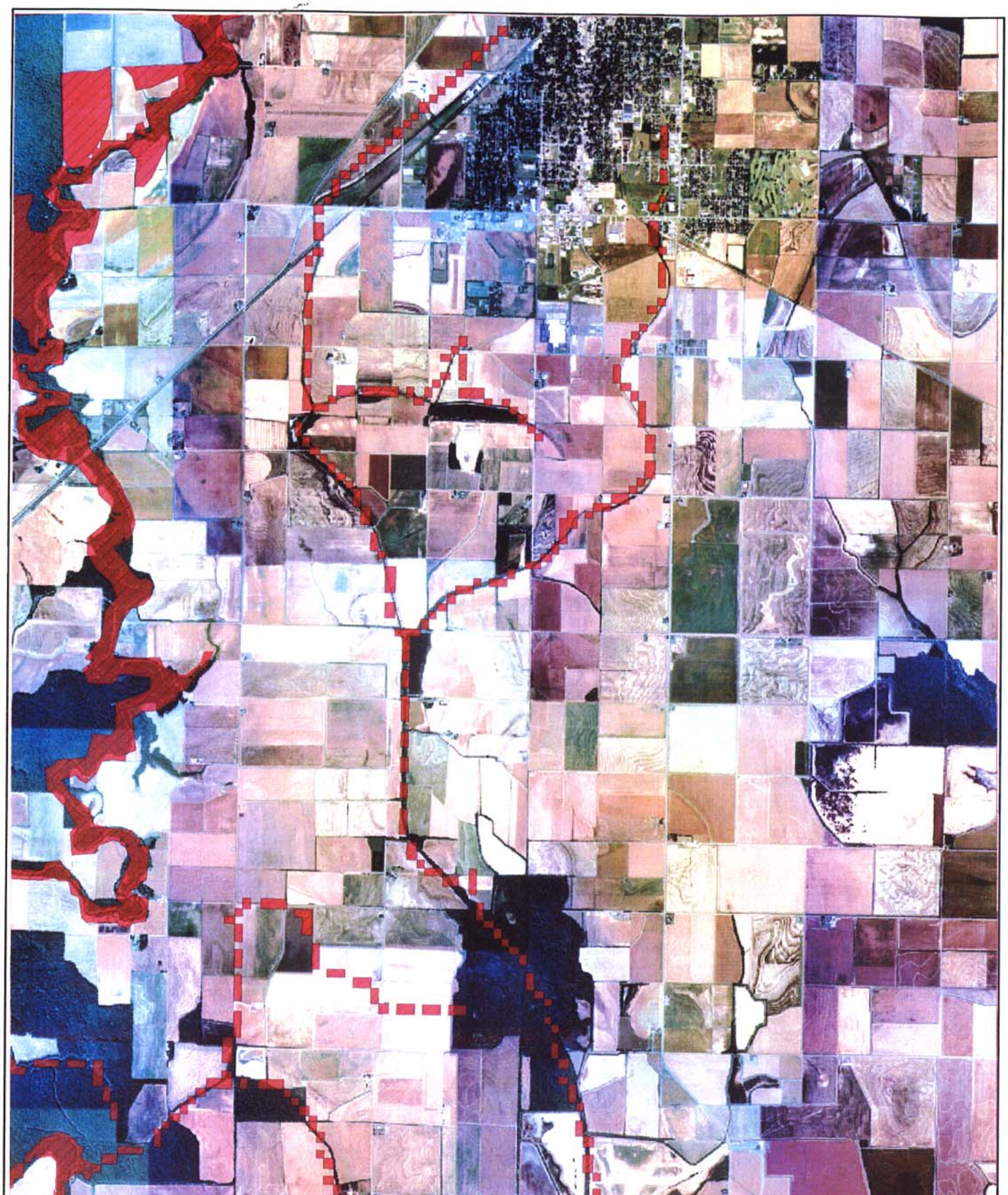


Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Stuttgart North



Private Green Tree Reservoirs

Post Project Flood Scene

Pre Project Flood Scene

Stuttgart South

SECTION XVII

CALCULATION OF WATERFOWL BENEFITS

CALCULATION OF WATERFOWL BENEFITS
Bayou Meto Basin, Arkansas, Project

A Report Prepared For
U. S. Army Corps of Engineers
Memphis District

By

Mickey E. Heitmeyer
Gaylord Memorial Laboratory
Rt. 1, Box 185
Puxico, MO 63960

Introduction

Waterfowl habitat restoration and management features will be constructed as part of the Bayou Meto Basin, Arkansas, Project. These features include enhancement and restoration of bottomland hardwood (BLH) and riparian forest, and restoration and creation of seasonal herbaceous and wet prairie wetlands. Waterfowl habitat benefits of these projects are calculated by determining the incremental gains in duck use-days (DUD) which is an index of foraging carrying capacity.

A DUD is defined as the amount of food available in a site that can supply the energy needs of one duck for one day. Evaluation of DUDs for various habitats in the Bayou Meto Basin requires information on: 1) area of specific habitats to be restored or enhanced, 2) amount of food produced and available to ducks from fall through spring in various habitat types, and 3) amount of food consumed by ducks per day during fall through spring. This report provides description of the habitats, food availability, and consumption by mallards in the Bayou Meto Basin. It also calculates DUD benefits/acre for specific features associated with enhancement projects in the Bayou Meto Wildlife Management Area (WMA).

Description of Habitat Types

BLH

BLH includes a gradient of vegetation communities related to elevation and frequency of flooding along drainages and in floodplains (Fig. 1). Cypress/tupelo habitats occur in the lowest elevations and are flooded for extended periods during the year. Flooding usually is at least 3 months duration and soils are saturated almost constantly. Vegetation in these areas is tolerant of flooding but needs occasional drying periods for regeneration of plant communities. Baldcypress and water tupelo are dominant species (Table 1). Cypress/tupelo habitats occur in a variety of locations including abandoned channels, isolated sumps or depressions, deeper swales in point-bar deposits, and along drainages.

Low BLH occurs in low elevations that typically flood each year and have extended soil saturation. Flooding and soil saturation is not as extended as in cypress/tupelo sites and low BLH habitats typically are flooded for 1-3 months usually in late winter and spring. Low BLH habitats are almost entirely within the 2-year flood frequency zone of the Bayou Meto Basin which includes predominantly backswamp deposits, swales in point bars, and abandoned courses. Dominant vegetation includes green ash, cedar elm, water hickory, overcup oak, water locust, and swamp privet (Table 1).

Intermediate BLH habitats occur in floodplain locations that are flooded on average for a few weeks to 1-2 months annually during the dormant season and early spring. Soil saturation in these sites often is extended for 2-3 months. Most intermediate BLH sites in the Bayou Meto Basin are between the 2- and 5-year flood frequency zone and some higher sites may not flood every year. Intermediate BLH are present mostly in backswamp and point bar areas and higher edges of abandoned courses. Dominant vegetation in intermediate BLH sites includes sugarberry, American elm, nuttall oak, willow oak, and sweetgum (Table 1).

High BLH habitats occur in high elevation areas in the Bayou Meto Basin that, at least historically, were flooded for up to a few weeks during some years, usually during high flow events on the Arkansas River or major tributaries such as Bayou Meto. High BLH occasionally may go several years between flood events, however, soils usually are saturated for some periods annually. High BLH commonly are called "flats" and they occur mostly on higher elevation point bar ridges and next to natural levees. Generally, the dividing point between intermediate and high BLH is the 5-year flood frequency contour. Dominant species include water oak, willow oak, cherrybark oak, shagbark and shellbark hickory, and sweetgum (Table 1).

Riparian and Natural Levee Forest

BLH corridors along streams and bayous support relatively unique communities commonly distinguished and classified as riparian or natural levee forest. Riparian corridors include abandoned courses of the Arkansas River such as Indian, Bakers, and Wabbaseka bayous and in narrow prairie terrace valleys such as Farras Run, Buck Creek, and Johnson Branch. In the Arkansas River Lowland, riparian forests are within the 5-year flood frequency zone and often are subjected to deep flooding and high velocity flows. Trees in riparian areas include a combination of species typically found in cypress/tupelo and low BLH habitats (Table 1). In narrow terrace stream floodplains, riparian forests represent a transition from slash-type vegetation at higher elevations to BLH types on low downstream ends. Natural levees are present immediately adjacent to current and former drainage floodplains and may be interspersed within riparian forest. Natural levees often are as much as five foot higher than surrounding lands and contain cottonwood, box elder, swamp chestnut oak, cherrybark oak, and delta post oak (Table 1). Generally, the tops of natural levees are not inundated except during larger floods.

Seasonal Herbaceous and Wet Prairie Wetlands

Seasonal herbaceous and wet prairie habitats occur in small topographic depressions, and near groundwater seeps along slopes, in prairie grassland terraces in the Bayou Meto Basin. These sites contain saturated soils and have short periods of surface flooding that support annual and perennial herbaceous vegetation. Generally, seasonal herbaceous wetland basins have small watersheds and receive water mainly from surface runoff following local rains. These seasonal wetlands typically are flooded for short periods each year from winter to early summer depending on timing of rainfall. In contrast, wet prairie sites seldom are flooded for more than a few weeks in late winter and early spring, but they do have extended periods of saturated soils. A gradient of vegetation occurs from low depressions which contain a wide diversity of annual and perennial herbaceous "moist-soil" plants to higher grassland which contains mostly prairie grasses and forbs (Table 1). Soils on prairie terraces have an impermeable clay layer 18-24 inches below the surface which allows seasonal basins to hold water while simultaneously retarding tree growth.

Food Availability in Habitats

Availability of food to waterfowl in BLH, riparian forest, and seasonal herbaceous wetlands is highly variable among years depending on annual temperature and rainfall, growing season days, timing of floods or droughts, depth of water, consumption by other wildlife (e.g., blackbirds), and composition of vegetation. Few long-term studies have estimated annual production of acorns, seeds, tubers, rootlets, and invertebrates in these wetlands. Consequently, estimates of food production and availability often are based on short time periods and habitat conditions (e.g., flooding regimes, management practices, species composition) that may not adequately reflect long-term dynamics of production. Given these caveats, mean and ranges of production from various studies are provided below.

BLH

Foods consumed by waterfowl, especially mallards, in BLH are predominantly red oak acorns; invertebrates; and seeds, tubers, and rootlets of moist-soil vegetation. Red oak composition, tree size and health, and flooding regime greatly influence acorn production. For example, in the longest term study of red oak production (pin oaks in southeast Missouri), pin oak acorn production ranged from 8-440 lbs/acre (mean of about 100 lbs/acre) over 14 years in a greentree reservoir (GTR) (McQuilkin and Musbach 1977). Generally acorn production was greater in non-GTR forests, with higher red oak composition, and larger tree size. Acorn production in most (10 of 14) years ranged from 100-250 lbs/acre. Acorn production in a short term study of nuttall oak (Francis 1983) were similar to the above estimates for pin oaks and also indicated higher production in naturally flooded BLH compared to GTR sites. Invertebrate production also is quite variable among BLH locations and years, but in sites with >30% red oak annual production averages about 22.3 lbs/acre (White 1985, Batema 1987, Duffy and LaBar 1994).

However, in some BLH areas this production may exceed 90 lbs/acre (Magee et al. 1993). Seed, tuber, and rootlet production in BLH depends on amount and type of herbaceous ground cover and often is greatest in small tree gaps created by windthrow or death of single or multiple trees. Open areas often cover > 5% of BLH areas and when production in these open areas is extrapolated from mean production in moist-soil impoundments (Fredrickson and Taylor 1982), an annual production of at least 50 lbs moist-soil foods/acre in BLH seems reasonable.

BLH forests in the lower Bayou Meto Basin that have relatively natural seasonal flooding regimes typically have >30% red oak composition, > 50% red oak basal area, < 10% damage from basal swelling, leaf chlorosis, and tip die-back, and > 50% herbaceous ground cover (Heitmeyer and Ederington 2004, Heitmeyer et al. 2004). In GTRs, such as at Bayou Meto WMA, mean annual production can be conservatively estimated at about 100 lbs acorns/acre; 22.3 lbs invertebrates/acre; and 50 lbs moist-soil seeds, tubers, and rootlet/acre (using above referenced data) for a total of ca. 172.3 lbs/acre. In BLH not in GTRs and with natural short duration dormant season flooding, annual production may average > 200 lbs acorns/acre, > 50 lbs invertebrates/acre, and > 50 lbs moist-soil foods/acre for at least 300 lbs/acre/year total production.

The availability of the above foods in BLH depends on annual flooding in fall through spring. Mallards and wood ducks may occasionally forage in dry BLH, however, almost all use and foraging by ducks occurs in shallowly flooded BLH. In the Bayou Meto Basin, most remaining (and proposed restorable) BLH is within the 2-year flood frequency zone and is, or will be, subject to annual flooding of varying duration. Consequently, the above estimates can be annualized for most existing and restored BLH sites. If BLH sites are at higher elevations with > 5-year flood frequencies, the annual production should be divided by mean years of flooding to provide availability estimates. For example, if a restored BLH site is flooded on average 2 of 5 winters (such as may occur with restorations of BLH in the 2- to 5-year floodplain), then mean annual production (e.g., 300 lbs/acre in naturally flooded sites) would be multiplied by 0.4 to estimate a mean of 120 lbs/acre on average/year.

Riparian and Natural Levee Forest

Few studies have estimated food production in riparian and natural levee BLH sites. Consequently, data must be extrapolated from the above BLH estimates and the few studies in locations with somewhat similar vegetation composition. Most riparian and natural levee sites in the Bayou Meto Basin have relatively low red oak composition (5-15%) and basal area (< 25%) (Heitmeyer and Ederington 2004). Often, these sites support some pioneer trees such as cottonwood, willow, and sycamore that have soft, not hard, mast which is not available to ducks in winter. These sites do have significant invertebrate production, however (e.g., Magee et al. 1993), and usually they also have much herbaceous ground cover. If we assume that red oak basal area in these forests is 15-25%, then a conservative estimate of ca. 50 lbs acorns/acre/year seems reasonable. Invertebrate production may be as high as 90 lbs/acre and moist-soil seeds, tubers, and rootlets is likely to be at least 75-100 lbs/acre. Consequently, a conservative estimate of food production is ca. 200 lbs/acre.

Seasonal Herbaceous and Wet Prairie Wetlands

Foods used by waterfowl in seasonal herbaceous wetlands includes seeds, tubers, rootlets, browse, other plant parts, and invertebrates. The best estimates of food production in seasonal herbaceous wetlands is from managed moist-soil impoundments. In these impoundments, seed production can be greater than 3,000 lbs/acre (Fredrickson and Taylor 1982, Laubhan and Fredrickson 1992), tuber production often exceeds 500 lbs/acre (Kelley and Fredrickson 1991), and over 300 lbs invertebrates are produced/acre (e.g., Duffy and LaBar 1994). These estimates may be high compared to non-managed seasonal wetlands in the Bayou Meto Basin, but they do provide a basis for making conservative estimates. Even if non-managed seasonal wetlands produced only 1/5 as much food as managed impoundments they would produce an annual average of > 750 lbs/acre.

Calculations of DUD in Various Habitats

DUD in the Mississippi Alluvial Valley typically are calculated as:

$$\frac{\text{(Area of habitat) (annualized food production for that habitat type)}}{\text{Daily consumption of a mallard in winter}}$$

The Bayou Meto Basin Project proposes to restore 23,000 acres of BLH (a likely mix would be 13,000 acres of low BLH within the post-project 2-year floodplain and 10,000 acres of intermediate BLH in the 2- to 5-year floodplain) that will not be in GTRs, enhance > 26,000 acres of BLH in Bayou Meto WMA GTRs, restore 2,643 acres of riparian forest, and restore and create 2,000 acres of seasonal herbaceous wetland and wet prairie. The goal for BLH forest restoration and enhancement is to provide relatively natural seasonal flooding regimes with > 30% red oak composition, > 50% red oak basal area, < 10% damage to red oaks, and > 50% herbaceous ground cover. Using the above food production estimates, sites within GTRs on Bayou Meto WMA would provide 172.3 lbs food/acre/year and natural BLH sites not in GTRs would provide at least 300 lbs/acre/year. Food production in riparian forest is estimated at 200 lbs food/acre. Annual food production in herbaceous wetlands is estimated at > 750 lbs/acre/year. Daily food consumption of a mallard in these habitats in winter is estimated at 0.44 lbs/day (Heitmeyer 2005).

Using the above data, the 13,000 acres of restored low BLH would provide 8,863,636 DUD annually. Restoring 10,000 acres of intermediate BLH with an estimated winter flooding frequency of 2 of 5 years would provide 2,727,272 DUD annually. Restoring 2,643 acres of riparian forest would provide 1,201,363 DUD annually. Restoring 2,000 acres of seasonal herbaceous wetland would provide 3,409,090 DUD annually (Table 2).

Estimating increased DUD in Bayou Meto WMA BLH habitats in GTRs requires understanding of current production of foods and what incremental gains will be achieved with enhancement features (Table 3). Consequently, production of foods in the WMA GTR impoundments was estimated by multiplying the percentage of desired condition by the above referenced food production (Table 4). For example, Buckingham Flats contains 24.4% red oaks (81.3% of the desired 30% composition), an average of 3.2% basal swelling, tip die-back, and leaf chlorosis (100% of desired < 10% damage), and 45.2% herbaceous ground cover (90.4% of desired > 50% ground cover). The average percentage composition and damage (i.e., 90.7%) was multiplied by objective acorns and forest invertebrates (122.3 lbs/acre) to estimate that 110.9 lbs acorns and invertebrates/acre were present in Buckingham Flats. The 90.4% herbaceous cover was multiplied by the objective 50 lbs moist-soil foods/acre to estimate that 45.2 lbs/acre were present. Combined, an estimated 139.9 lbs food/acre are present in Buckingham Flats which is 16.2 lbs/acre less than desired. Consequently, waterfowl management features that are designed for Buckingham Flats seek to increase food production by 16.2 lbs/acre. Current food production in Halowell Reservoir and the Wrape Plantation moist-soil impoundments are unknown, however, improved water management capabilities should achieve at least an additional 50 lbs moist-soil foods/acre (Fredrickson and Taylor 1982).

For Bayou Meto WMA, the potential increased DUD associated with each waterfowl management feature was calculated as:

$$\text{DUD} = \frac{\text{sum (acres affected in each impoundment) (food deficit in each impoundment)}}{\text{Daily food consumption of a mallard in winter}}$$

Daily food consumption of a mallards was estimated at 0.44 lbs food/day as is used in estimates for other habitats.

As an example, waterfowl management feature #2 would improve 4,293 acres in Lower Vallier GTR impoundment. Current food production in Lower Vallier is estimated at 49.4 lbs/acre lower than desired. Consequently, if waterfowl management feature #2 ultimately improves hydrology and habitat to meet desired condition, an additional 212,074 lbs food would be produced and provide an additional 481,987 DUD (212,074/0.44) as a result of the project. Similar calculations for all projects indicate increases from ca. 5,000 to over 4 million DUD (Table 5).

LITERATURE CITED

Batema, D. L. 1987. Relations among wetland invertebrate abundance, litter decomposition and nutrient dynamics in a bottomland hardwood ecosystem. Ph.D. Dissertation, University of Missouri, Columbia, MO.

Duffy, W. G. and D. J. LaBar. 1994. Aquatic invertebrate production in southeastern USA wetlands during winter and spring. Wetlands 14:88-97.

Francis, J. K. 1983. Acorn production and tree growth of nuttall oak in a green-tree reservoir. U. S. Department of Agriculture, Forest Service Southern Forest Experiment Station SO-289.

Fredrickson, L. H. and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U. S. Department of the Interior, Fish and Wildlife Service Resource Publication 148.

Heitmeyer, M. E. 2005. The importance of winter floods for mallards in the Mississippi Alluvial Valley. Journal of Wildlife Management 69: (in press).

Heitmeyer, M. E. and B. Ederington. 2004. An evaluation of bottomland hardwood wetlands in the lower Bayou Meto Basin. Report to U. S. Army Corps of Engineers, Memphis District, Memphis, TN.

Heitmeyer, M. E., B. Ederington and L. H. Fredrickson. 2004. Bayou Meto Wildlife Management Area Wetland Management Plan. Special Publication No. 7. Gaylord Memorial Laboratory, University of Missouri - Columbia. Puxico, MO.

Kelley, J. R., Jr. and L. H. Fredrickson. 1991. Chufa biology and management. U. S. Fish and Wildlife Service, Waterfowl Management Handbook Leaflet 13.4.18. 6pp.

Laubhan, M. K. and L. H. Fredrickson. 1992. Estimating seed production of common plants in seasonally flooded wetlands. Journal of Wildlife Management 56:329-337.

Magee, P. A., L. H. Fredrickson and D. D. Humburg. 1993. Aquatic macroinvertebrate association with willow wetlands in northeastern Missouri. Wetlands 13:304-310.

McQuilkin, R. A. and R. A. Musbach. 1977. Pin oak production on green tree reservoirs in southeastern Missouri. Journal of Wildlife Management 41:218-225.

White, D. C. 1985. Lowland hardwood wetland invertebrate community and production in Missouri. Archives fur Hydrobiologia 103:509-533.

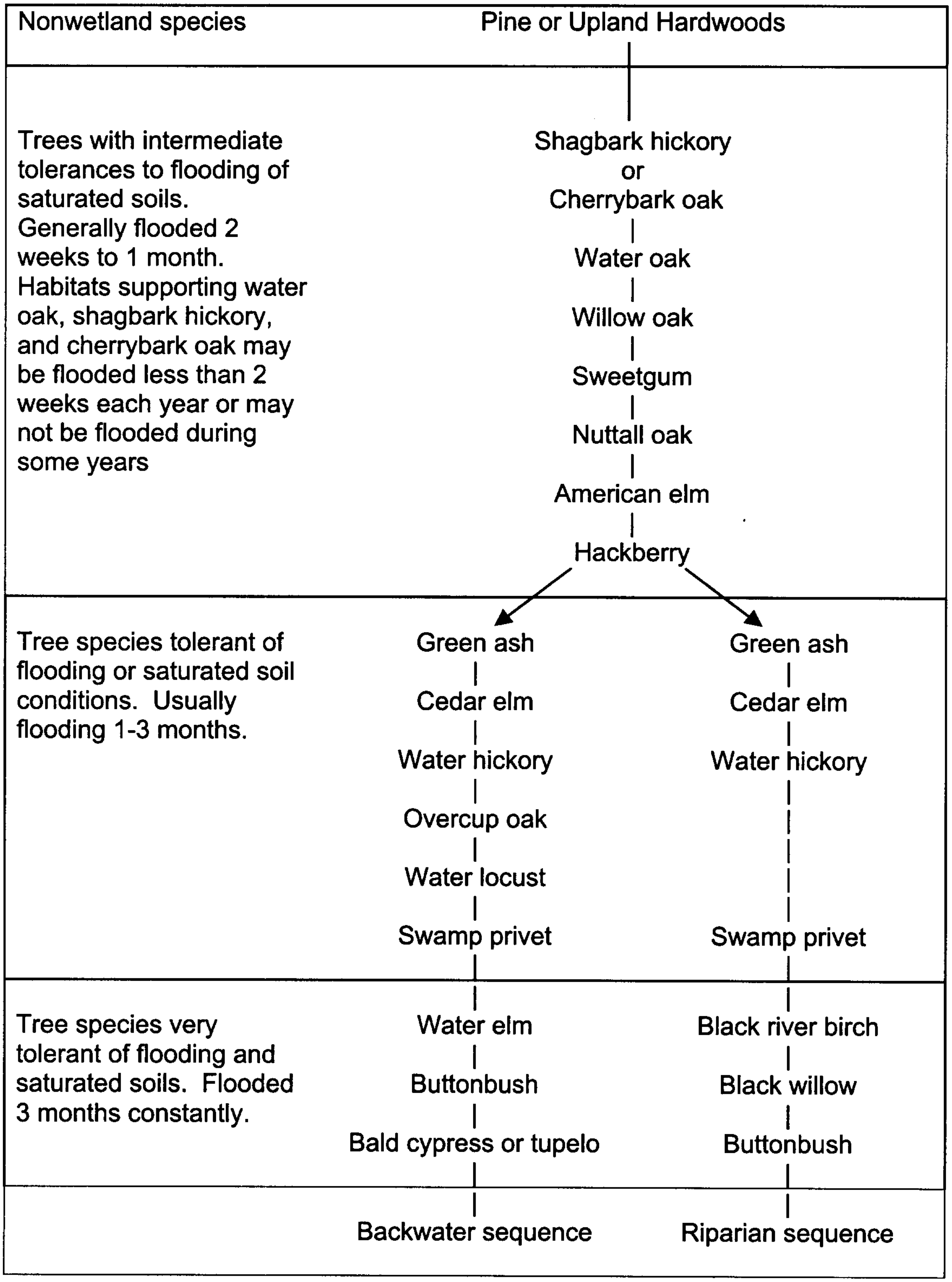


Fig. 1. Relative sequences of common bottomland hardwood forest tree species along an elevation and moisture gradient.

Table 1. Dominant plant species in habitats of the Bayou Meto Basin, Arkansas.

Species	Common name	Habitat						
		Cypress/ tupelo	Low BLH	Intermediate BLH	High BLH	Natural levee	Riparian forest	Seasonal herbaceous
Saururus cernus	Lizard's tail	X	X					
Carya illinoensis	Pecan				X	X		
Carya aquatica	Bitter pecan		X				X	
Carya cordiformis	Bitternut hickory				X	X		
Carya ovata	Shagbark hickory				X			
Populus deltoides	Eastern cottonwood					X		
Populus heterophylla	Swamp cottonwood	X	X	X			X	
Salix nigra	Black willow					X		
Salix interior	Sandbar willow							
Betula nigra	River birch					X		
Carpinus caroliniana	Ironwood				X		X	
Quercus lyrata	Overcup oak		X				X	
Quercus michauxii	Swamp chestnut oak				X	X		
Quercus falcata	Cherrybark oak				X	X	X	
Quercus macrocarpa	Bur oak				X	X		
Quercus palustris	Pin oak			X				
Quercus nutalli	Nuttall oak			X				
Quercus phellos	Willow oak			X	X	X	X	
Quercus nigra	Water oak			X	X	X	X	
Quercus stellata	Post oak				X			
Boehermia cylindrica	False-nettle	X	X			X	X	
Morus rubra	Red mulberry				X	X		
Celtis laevigata	Sugarberry			X	X	X		
Planera aquatica	Water elm	X	X				X	
Ulmus crassifolia	Cedar elm				X			
Ulmus americana	American elm			X	X	X	X	
Brunnichia ovata	Ladie's eardrop		X		X	X	X	
Polygonum spp.	Smartweed	X	X				X	X
Brasenia schreberi	Water-shield	X						X
Nymphaea odorata	Pond-lily	X						X
Nuphar luteum	Spatter-dock	X						X
Itea virginica	Virginia willow	X						X
Carex spp.	Sedges							X
Commelina virginica	Woods day-flower							X
Eleochais spp.	Spikerush							X
Juncus spp.	Rushes							X
Typha latifolia	Cattail							X
Echinochloa spp.	Millett							X
Leptachloa spp.	Sprangletop							X
Panicum spp.	Panic Grass							X
Bidens spp.	Beggartick							X
Liquidambar styraciflua	Sweetgum		X	X	X			
Hamamelis virginiana	Witch hazel				X			
Platanus occidentalis	Sycamore					X		
Crataegus viridus	Green haw			X	X	X		
Crataegus aestivalis	May haw	X	X				X	
Gleditisia aquatica	Water locust		X			X		
Gleditisia triacanthos	Honey locust				X			
Impatiens capensis	Jewel weed	X	X			X	X	
Toxicodendron radicans	Poison ivy		X	X	X	X	X	
Ilex decidua	Possum-haw			X	X			
Acer negundo	Box elder						X	
Acer rubrum	Red maple			X	X		X	
Acer saccharinum	Silver maple			X	X		X	
Berchemia scandens	Rattan-vine		X	X	X	X	X	
Ampelipsis arborea	Pepper-vine		X	X	X	X	X	
Vitis rotundifolia	Muscadine grape		X	X	X	X		
Hibiscus spp.	Marsh mallow	X	X	X		X	X	
Nyssa aquatica	Water tupelo	X					X	
Nyssa sylvatica	Black gum			X	X			
Cornus spp.	Dogwood		X	X		X		
Styrax americana	Mock-orange	X	X	X	X			
Diospyros virginiana	Persimmon			X	X		X	
Fraxinus caroliniana	Carolina ash	X	X	X		X		
Fraxinus pennsylvanica	Green ash		X	X		X	X	

Table 1, cont'd.

Species	Common name	Habitat						
		Cypress/ tupelo	Low BLH	Intermediate BLH	High BLH	Natural levee	Riparian forest	Seasonal herbaceous
Forestiera acuminata	Swamp-privet	X	X					
Trachelospermum difforme	Climbing dogbane				X	X		
Bignomia capreolata	Cross-vine		X		X	X		
Catalpa bignonioides	Indian-bean			X	X	X		
Campsis radicans	Trumpter-creeper		X	X	X	X	X	
Cephalanthus occidentalis	Common buttonbush	X	X				X	
Viburnum dentatum	Arrowwoods			X		X		
Lobelia cardinalis	Cardinal flower	X	X	X		X	X	
Arundinaria gigantea	Giant cane					X		
Smilax spp.	Greenbriar		X	X	X	X	X	
Cocculus carolinus	Carolina moonseed				X	X		
Taxodium distichum	Baldcypress	X	X				X	

[a] BLH = Bottomland hardwood forest

Table 2. Estimated annual production of foods[a] consumed by waterfowl in various habitat types and increased duck use-days (DUD)[b] for habitat restoration and enhancement projects in the Bayou Meto Basin, Arkansas.

Habitat type	Acres	Annual food production	Increased DUD
BLH[c] in greentree reservoirs	–[d]	172.3	–[d]
Low BLH natural flooded	13,000	>300	8,863,636
Intermediate BLH natural flooded	10,000	>300	2,727,272
Riparian forest	2,643	>200	1,201,363
Seasonal herbaceous	2,000	>750	3,409,090

[a] lbs of food/acre annualized for fall through spring. All habitats are assumed to be flooded annually in winter except Intermediate BLH natural flooded which is estimated to flood 2 of 5 winters. Foods include combined hard mast, seeds, rootlets, tubers, and macroinvertebrates.

[b] See text for explanation of calculations

[c] BLH = bottomland hardwood forest.

[d] See Table 5.

Table 3. Current red oak[a] composition, damage to red oaks, and herbaceous ground cover in greentree reservoirs on Bayou Meto Wildlife Management Area[b]

GTR	% red oaks	Average % damage[c]	% herbaceous cover
Buckingham Flats	24.4	3.2	45.2
Bear Bayou	25.9	12.2	74.5
Cannon Brake	27.3	15.0	43.2
Lower Vallier	30.3	17.8	27.4
Temple Island	16.1	22.5	34.0
Government Cypress	19.2	24.9	13.3
Upper Vallier	22.7	33.0	27.6

[a] Willow, nuttall, water, and cherrybark oaks.
[b] Data from Heitmeyer et al. 2004.
[c] average of % basal swelling, leaf chlorosis, and tip die-back.

Table 4. Estimated lbs/acre of acorns/macroinvertebrates and moist-soil seeds in greentree reservoirs currently in Bayou Meto Wildilfe Management Area compared to objective levels if these GTRs had > 30% red oak[a] composition, > 50% red oak basal area, < 10% damage to red oaks[b], and > 50% herbaceous ground cover.

	Acorns/inverts			Moist-soil seeds		
GTR	Current	Objective	Difference	Current	Objective	Difference
Buckingham Flats	110.9	122.3	11.4	45.2	50.0	4.8
Bear Bayou	102.9	122.3	19.4	>50.0	50.0	0.0
Cannon Brake	96.4	122.3	25.9	43.2	50.0	6.8
Lower Vallier	95.5	122.3	26.8	27.4	50.0	22.6
Temple Island	60.0	122.3	62.3	34.0	50.0	16.0
Government Cypress	63.7	122.3	58.6	13.3	50.0	36.7
Upper Vallier	64.8	122.3	57.5	27.6	50.0	22.4

[a] Willow, nuttall, water, and cherrybark oak.
[b] Average % basal swelling, leaf chlorosis, and tip die-back.

Table 5. Increased duck use days (DUD) potentially associated with waterfowl management features proposed for the Bayou Meto Basin, Arkansas.

NER Feature	Acreage	Increased DUD
0/1	417	46,818
2	4,293	481,987
3	2,157	467,187
4	611	132,337
5/6	941	203,812
7	1,746	196,028
8	1,869	138,901
9	5,071	948,942
10	7,829	1,449,770
11	615	139,772
12	764	138,735
13	3,235	587,447
14	695	30,643
15	108	4,762
16	779	34,347
17	137	6,040
19	112	4,938
20	128	14,371
21	982	110,252
22	29,103	3,579,219
23	1,039	38,254
25	1,207	127,922
26	96	10,778
27	2,337	487,709
28	137	24,878
29	1,045	226,338
30	1,869	138,901
31/32	36,000	4,244,557
33	1,850	81,568
34	1,850	81,568
35	555	41,247
36	22,629	3,169,232
37	1,850	81,568
38	48	8,542

SECTION XVIII

HGM ANALYSES

Part A. HGM Wetland Impact Assessment
Part B. HGM Ecosystem Restoration Analysis

SECTION XVIII

HGM ANALYSES

Part A. HGM Wetland Impact Assessment

HYDROGEOMORPHIC (HGM) ASSESSMENT OF SITES PROJECTED TO BE HYDROLOGICALLY ALTERED IN THE BAYOU METO IMPROVEMENT PROJECT AREA, ARKANSAS

Report to Memphis District, Corps of Engineers

February 2005

Charles Klimas and Matt Blake
US Army Engineer Research and Development Center
Waterways Experiment Station
Vicksburg, MS

EXECUTIVE SUMMARY

In 2004, Heitmeyer and Ederington conducted a study of selected sites in the Bayou Meto Improvement Project area. They evaluated the condition of bottomland hardwood forests that were expected to be affected by changes in growing-season flood duration as a result of the project. They determined that some of the forests they studied would be adversely affected by reduced flooding, but that others showed signs of stress and damage due to water management practices that have caused excessive growing-season flooding. Heitmeyer and Ederington determined that the stressed stands would likely benefit from the hydrological modifications associated with the proposed project. They also suggested that changes in hydrology due to the project are unlikely to influence sites located within private greentree reservoirs, because those areas have independent water management systems that are operated by the landowners.

Heitmeyer and Ederington (2004) developed a forest health rating system for the stands they studied, and they collected additional field data appropriate for use in the Hydrogeomorphic Approach to wetland assessment (HGM). The HGM approach considers a variety of physical and biological factors to estimate the extent to which a wetland or group of wetlands performs a set of ecological functions. We used the forest health ratings to modify existing HGM assessment models, and assessed the same areas studied earlier with regard to the hydrologic changes associated with the proposed project. The results indicated that the proposed project will have negative impacts to several wetland functions within the areas studied, but that most functions would be unaffected or positively affected. Based on recovery trajectories developed for a postulated mitigation site, we calculate that the negative hydrologic impacts can be offset by restoration of approximately 1,340 acres of bottomland hardwood forest, if the mitigation area is restored according to several specific guidelines.

This study also included a supplemental analysis of the potential mitigation requirements to offset the loss of function in farmed wetlands that will be hydrologically altered by the project. Using the same recovery trajectories and assumptions employed for the forested sites, this analysis indicated that a mitigation ratio of 1.1:1 would offset anticipated changes to farmed wetlands.

INTRODUCTION

Memphis District, CE requires a Hydrogeomorphic (HGM) Assessment of selected areas in the Bayou Meto Basin, Arkansas as part of the analyses being conducted relative to the Bayou Meto Improvement Project. A previous study (Heitmeyer and Ederington 2004) had examined approximately 7000 acres of bottomland hardwood forest where the flood control project was projected to cause significant changes in hydrology. That study used field indicators of flooding stress to establish that the projected hydrologic changes would have complex effects. About 20% of the study area supports forests that show little or no flooding stress under current hydrologic regimes, indicating that the pre-project flooding patterns are appropriate to the site conditions – these areas would be expected to suffer loss of wetland functions where flooding will be reduced. However, more than half of the study area shows signs of moderate to severe stress due to inappropriate flooding patterns, and would be expected to benefit from hydrologic changes that reduce growing season flooding. The remainder of the study area is made up of greentree reservoirs, where most of the existing forests show flooding stress. Water levels in the greentree reservoirs are manipulated, and the proposed project may not have any effect on them. However, because the environment outside the greentree reservoirs will change, the project may give water managers additional flexibility to change the operations within the reservoirs if they are so inclined.

The objective of this analysis is to use the Heitmeyer and Ederington (2004) conclusions and data as the basis of an HGM assessment, using modified versions of the assessment models presented in the Regional Guidebook for Assessment of Wetland Functions in the Arkansas Delta Region (Klimas et al. 2004a). Each of 7 wetland functions is assessed under pre-project and post-project conditions (Alternative 3A) for each of the 3 major groups of site types described by Heitmeyer and Ederington (i.e sites that are non-stressed, stressed, or in greentree reservoir management under the pre-project conditions). In addition, we present an estimate of the rate of functional recovery for a hypothetical mitigation site in the Bayou Meto Basin, for comparison to the estimates of functional loss that might be incurred due to the project. The mitigation site recovery estimates also are used in a supplemental analysis of the likely mitigation requirements associated with hydrologic changes to farmed wetlands.

This study is intended to serve as a supplement to other ecological studies already completed or underway within the project area. The Bayou Meto Basin is a complex ecological system, where previous private and public activities have modified water regimes, and where the proposed flood control project will further alter conditions in various ways. The HGM analysis presented here is an attempt to characterize the likely magnitude and direction of changes in functional performance for a suite of functions commonly associated with forested wetlands of the region. As with all HGM assessments, the analysis is based on relative changes in general indices of function. In the case of the fish and wildlife habitat function, detailed population and habitat data may exist that allow more specific analyses than the HGM assessment can provide (e.g., the detailed study of probable fish habitat losses developed by Killgore et al., 2003). However, for an overview of general ecological function, the HGM assessment approach is a well-documented and transparent method for estimating project impacts.

BACKGROUND: THE HGM ASSESSMENT APPROACH

The HGM assessment approach is described in detail in various documents (e.g. Smith et al. 1995) and the Arkansas Delta Regional Guidebook (Klimas et al. 2004a) provides specifics relevant to the models and reference data that are used in this report. However, the brief overview below, taken from Klimas (2004), may be helpful for anyone unfamiliar with the terminology and process of the HGM approach.

The HGM approach incorporates several components. Wetlands are first grouped into regional subclasses based on functional similarities, as represented by hydrogeomorphic setting. Thus, wetlands in isolated depressions function differently than wetlands on river floodplains in various respects. For example, a functional riverine wetland exports organic materials to downstream aquatic systems during floods, whereas a depression that lacks a surface connection to a stream does not perform that function. Therefore, a group of functions can be identified for each regional subclass, and other regional subclasses may not perform those functions, or may perform them to different degrees.

In order to estimate the degree to which a wetland performs a particular function, HGM represents each function in terms of a simple logic model made up of variables that can be measured in the field or derived from existing information sources. Thus, for the example above, the ability of a riverine wetland to export organic carbon can be represented by the equation below.

$$FCI = V_{FREQ} \times \frac{\left[\frac{(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG})}{4}\right] + \left[\frac{V_{TBA} + V_{SSD} + V_{GVC}}{3}\right]}{2}$$

In this case, a relative measure of functionality, the Functional Capacity Index (FCI), is determined by 3 primary model terms.

1. Flood frequency (V_{FREQ}) which represents how often the wetland is inundated by overflow from a stream system, and provides the export mechanism for delivering organic carbon to the stream;

2. Detrital pools, comprising litter (V_{LITTER}), O-horizon thickness (V_{OHOR}), woody debris (V_{WD}), and snags (V_{SNAG}), representing the current and future availability of mobile particulate organic matter and sources of dissolved organic matter; and

3. Organic production sources, represented by tree basal area (V_{TBA}), shrub and sapling density (V_{SSD}), and ground vegetation cover (V_{GVC}), which represent the major sources of material that will replenish the detrital pools.

In order to run the models, the variable values must be determined or estimated. The flood frequency component can be estimated for a specific site based on gauge data, flood zone mapping, and similar sources. Information on living and dead vegetation can be obtained using standard forest sampling methods. Models used to assess all of the other functions use similarly obtained information as model variables.

The FCI value generated by the assessment model is an index between zero and 1.0, where a value of 1.0 represents a fully functional condition. Under HGM methodology, the FCI is multiplied by a measure of the area of the wetland (e.g., acreage) to calculate the Functional

Capacity Units (FCU) present for the Carbon Export function. This is essentially the same process used in the Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980), where indicators of habitat quality are combined into simple models to calculate a Habitat Suitability Index (HSI) and multiplied by a measure of area to produce Habitat Units (HU). There is one fundamental difference between the way these two assessment approaches are developed, however. Whereas the indicators employed in HEP models are calibrated based on literature and expert opinion, the calibration curves for HGM indicators are derived from extensive field sampling of reference wetlands.

The model variables employed in the assessment models are calibrated based on field data collected in the applicable wetland subclass. The calibration curve (also called the "subindex curve") for each variable in each subclass relates the variable value to an index between zero and 1.0, where the maximum value is that found in wetlands that represent the least-disturbed examples of the wetland subclass within the region. The shape of the calibration curve is established by sampling a set of wetlands that represent a range of condition classes between the least-disturbed, and severely disturbed. Figure 1 presents the calibration curves developed for the variables used in the production component of the Organic Carbon Export model discussed above, for the Riverine Backwater subclass in the Arkansas Delta Region. Similar sets of curves were developed for the other variables and wetland subclasses in the region (Klimas et al. 2004), based on sampling of more than 100 field sites.

As with all of the HGM guidebook development efforts, the Delta Region models, calibration curves, and application tools such as sampling methods and data summary spreadsheets were developed by a team of regional experts. Users of the guidebooks apply this information to specific assessment tasks, and can use the same models and reference data on various projects throughout the region. The models and calibration curves are applied in an assessment scenario by following detailed guidance presented in the Delta HGM Guidebook. The user collects field data from the assessment area, and compares that data to the calibration curve to derive a subindex. The subindex values are inserted into the model, generating an FCI for the function being assessed. Multiplying the FCI by acreage generates FCUs, which represent the functional units associated with the assessment area, and which can be compared among assessment areas of the same regional subclass. Pre- and post-project FCUs can be compared to determine impacts, and project alternatives can be compared to help identify the least-destructive alternative. However, in order to take into account the time required to recover functions following an impact or restoration actions, and to establish monitoring criteria that can be applied at intervals as the site matures, an additional set of curves representing recovery trajectories is required. Recovery trajectories were developed and published as part of the Delta Region Guidebook (Klimas et al. 2004a) and their use is discussed in detail in Klimas (2004).

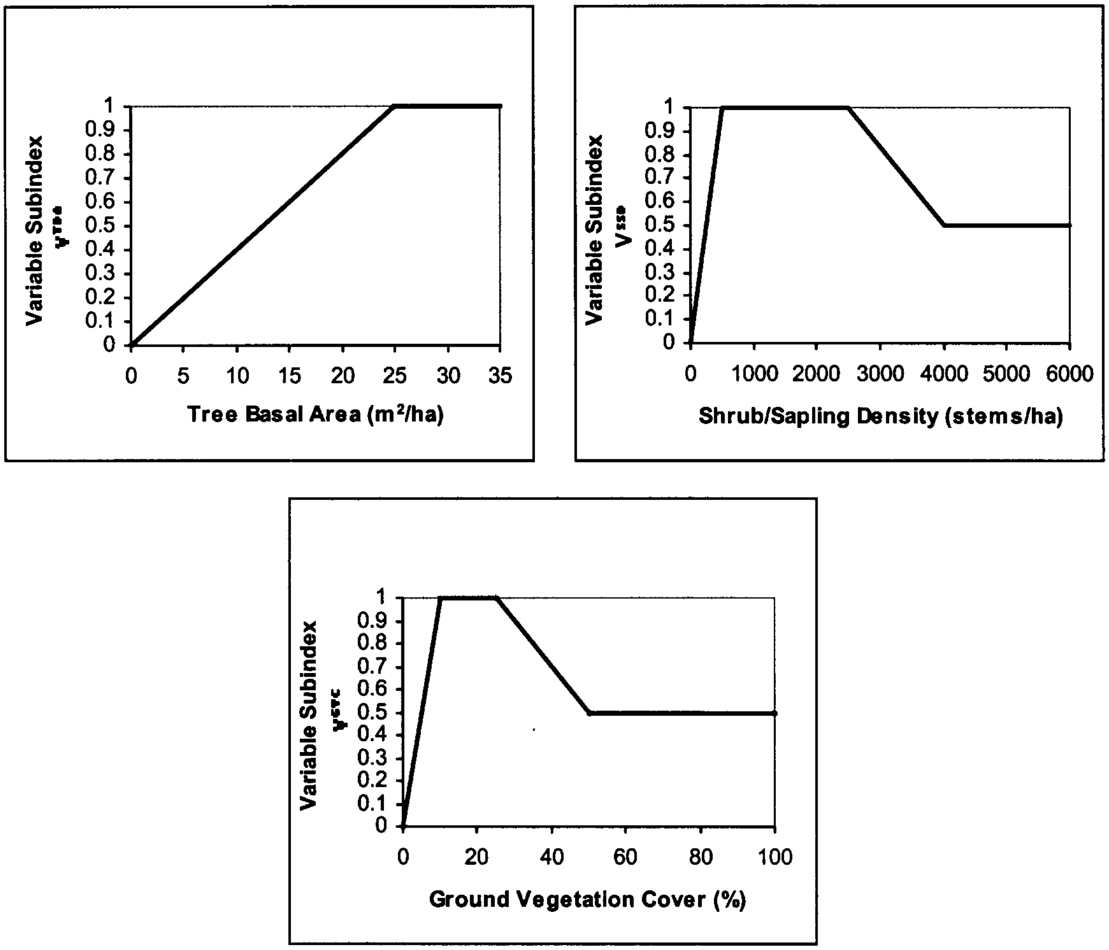


Figure 1. Subindex curves for 3 field indicators used as variables in the Organic Carbon Export functional assessment model.

METHODS

Data Collection and Summarization

All of the field data used in this analysis were collected and compiled by Mickey Heitmeyer and Belinda Ederington (Gaylord Memorial Laboratory, University of Missouri-Columbia). They studied past water management impacts on bottomland hardwood (BLH) forests in the Bayou Meto Basin and estimated potential effects of the proposed Improvement Project on forest health (Heitmeyer and Ederington 2004). As a supplement to that work, they collected field data appropriate for use in HGM analyses on their sample sites. The data they supplied for this analysis are included for reference in the Appendices to this report, but they are not responsible for any of the data manipulations and interpretations, or additional GIS-based data generation, done as part of this study. The field-data collection deviated in some respects from the field methods prescribed in the Regional Guidebook. For a discussion of the field methods employed, see Heitmeyer and Ederington (2004). Specific data sources and calculations are outlined below.

1. Levels of data summarization

Heitmeyer and Ederington (2004) collected and summarized their field data at two levels. Detailed data were collected at the plot level (similar in most aspects to the prescribed HGM sampling plot). They collected HGM-applicable data in 189 individual plots, of which 15 were discarded from this analysis due to incomplete or otherwise unclear information (see Appendix A for details). Some data were not collected according to HGM guidelines, but were adapted for that purpose as described below. Some other HGM plot-level data were not collected at all, but these data describe soil and litter-cover variables that are unlikely to have been changed by past or current management practices within the study are; therefore reference standard conditions (i.e. fully functional) are assumed to exist for those variables for the purposes of this study. Previous field studies in the area (Klimas et al. 2004a, 2004b) support that assumption.

The database accompanying this report presents all field data summaries at the plot level, but map- and photo-based summarizations were not possible at the plot level, because specific plot locations were not available for this analysis. However, the plots were organized into 52 separate "groups," and group locations were mapped. According to Heitmeyer and Ederington (2004): ..."Each BLH group was a distinct contiguous area of BLH; had similar geomorphology, soil, and topographic features; had similar hydrological influences...and had similar water and timber management..." In this regard, the group is conceptually equivalent to the Wetland Assessment Area as described in the HGM Guidebook, and is an appropriate level for summarization of the plot data. It differs somewhat from the HGM approach to designating assessment areas in that an individual group may consist of multiple sub-units, but this is not an obstacle to HGM analysis. Where multiple polygons represented a single group, the group classification and all spatial data required by the HGM models were assigned based on the predominant condition represented by the group. Group polygons were subdivided based on flood duration and frequency data, and the acreages associated with individual FCU calculations are based on those subunits.

The field data collected for five of the groups described by Heitmeyer and Edderington (2004) were deficient in one or more respects that precluded their use in the HGM analysis. However, rather than discard the five groups represented by incomplete field data, we decided to use estimates of the characteristics of those groups based on field data collected in areas that closely matched them in key ways. The matches were based on the habitat types and relative health variable ranks indicated in Table 13 in Heitmeyer and Ederington (2004), the overstory composition as indicated in the original field data, and pre-project flooding conditions. Using these criteria, the vegetation structure and detritus variables measured for Group 24 were used to calculate FCI scores for four groups in the "stressed" category (Groups 25, 35, 36, and 52). Group 29 field values were used to calculate FCI scores for Group 46, in the greentree reservoir category. These substitutions were considered reasonable based on the similarities noted above, and because, in each of these cases, the actual project impacts (pre- and post project flooding characteristics and acreages) were assigned to each group as indicated by the pertinent GIS coverages (i.e., they were site-specific, not estimated from other group data).

Data sources for plot and group data:

Raw plot data (contained in the following Excel spreadsheets provided by M. Heitmeyer)

Negative Bayou Meto Basin.exl (corresponds to the Non-stressed Site Type designation used in this document)
GTR Bayou Meto Basin.exl (corresponds to the Greentree Reservoir Site Type designation used in this document)
Stressed plots.exl (corresponds to the Stressed Site Type designation used in this document)

GIS data (provided by Memphis District, CE)

Wetland_subtractions.shp (polygons representing locations for groups)

2. Classification

All groups were examined relative to a detailed HGM-based site classification developed for the Bayou Meto Basin (Klimas et al. 2004b) and assigned to the appropriate HGM subclass. In many cases, the polygons representing an individual group (or plot cluster) spanned boundaries between different subclasses. In such cases, the predominant subclass designation was assigned to the entire group. Two groups were designated as the Riverine Overbank subclass – all others were designated as the Riverine Backwater subclass.

Data Sources for classification:

GIS data

Existing_condition.shp (HGM site classification from Klimas et al. 2004b)

Wetland subtractions_.shp (polygons representing locations for groups)

3. HGM Variables

The variables used in the HGM models and their data sources are summarized below.

a. V_{AHOR} - "A" horizon thickness: not sampled-reference standard conditions assumed.

b. V_{CEC} - Cation Exchange Capacity: not sampled-reference standard conditions assumed.

c. V_{COMP} and V_{TCOMP} - Composition / Tree Composition: calculated based on relative basal area by species derived from raw tree diameters contained in Heitmeyer field data Excel spreadsheets.

d. $V_{CONNECT}$ - Habitat connectivity: calculated by measuring (in GIS) the approximate distances between forest tracts using aerial photos (numerous tif files), provided by Memphis District.

e. V_{CORE} – Core area: calculated using GIS and aerial photos (tif files) to derive approximate percentage core area of wetland tracts containing group polygons.

f. V_{DUR} - Flood duration: Assigned by GIS examination of group polygons in relation to pre- and post-project growing-season flood durations, as mapped by Vicksburg District, CE and provided as the shapefile Base_3a_compwl.shp. That map presents the change between pre- and post-project growing season durations as a series of bands (or zones). In each case, the duration represents the median value of the highest stages observed for that period during the growing season, for a 50-year period of record. Note that the duration data are based on consecutive days of flooding, not total days of growing season flooding, but they are assumed here to be a reasonable reflection of total inundation.

The durations used and their corresponding number of days of flooding are as follows:

2.5% (7 days)

5% (14 days)

7.5% (20 days)

10% (27 days)

12.5% (34 days)

Group polygons were split as necessary where more than one duration zone occurred within a polygon. The V_{DUR} variable represents the change in growing season flooding duration projected for an area, in terms of how many "zone changes" will occur. In other words, a site that is currently in the 10% duration zone that will be in the 5% duration zone post project will have a 2-zone change in growing season flood duration.

g. V_{FREQ} – Flood frequency: Assigned by GIS examination of group polygons in relation to pre- and post-project flood frequency maps.

Data sources: flood frequency maps provided by Vicksburg District. No special consideration was given to altered flood frequencies or durations that may occur due to greentree reservoir operations. Groups were assigned to the 1, 2, 5, or 10-year flood frequency zones for the pre- and post-project conditions based on the following shapefiles:

Pre-project:

Fspre1.shp

Fspre2.shp

Fspre5.shp

Fspre10.shp

Post-project:

Fspost1yr.shp

Fs2yrpump.shp

Fs5yrpump.shp

Fspost10yr.shp

Group polygons were split as necessary where more than one flood frequency zone occurred within a polygon. The V_{FREQ} variable represents the change in frequency projected for an area, in terms of how many "zone changes" will occur.

In other words, a site that is currently in the 2-year floodplain that will be in the 10-year floodplain post project will have a 2-zone change in flood frequency.

h. V_{GVC} - Ground vegetation cover: averaged for groups from Heitmeyer plot data.

i. V_{LITTER} – Litter cover: not sampled-reference standard conditions assumed based on canopy cover data.

j. V_{LOG} - Log volume: recalculated from Heitmeyer plot data by converting to metric measurements, adjusting for partial sample, and entering data from each transect into the woody debris calculator provided as an appendix to the Delta HGM guidebook. Summarized at plot and stand levels.

k. V_{OHOR} – "O" horizon thickness: not sampled-reference standard conditions assumed.

l. V_{POND} – Percent ponded: not sampled-reference standard conditions assumed.

m. V_{SNAG} – Snag density: calculated from plot snag data and summarized at the group level.

n. V_{SOIL} – Soil integrity: not sampled-reference standard conditions assumed.

o. V_{SSD} - Shrub/sapling density: calculated from raw plot data adjusted for partial sample and summarized at plot and group levels.

p. V_{STRATA} – Number of vegetation strata: calculated at plot level based on raw canopy cover, shrub density and ground cover data and summarized at plot and group levels. Subcanopy cover was not sampled, but was assumed present in all plots, based on uneven size class structure of sampled trees. Shrub densities of 2 or more stems per plot were assumed to meet the 10% cover criterion based on comparisons to a reference database (Klimas et al. 2004a) that included both density and cover data.

q. V_{TBA} – Tree Basal Area: calculated by entering the raw tree diameters included in Heitmeyer plot data into the basal area calculator included in the Delta Regional HGM Guidebook. Summarized at plot and group levels.

r. V_{TDEN} – Tree density: calculated based on plot data and summarized at plot and group levels.

s. V_{TRACT} – Tract size: estimated using GIS tools from aerial photos of forest tracts containing sample group polygons. Calculated and recorded at the group level (tracts larger than 2500 ha are recorded as 2500 ha, which is the maximum value used in the models).

t. V_{WD} –Woody debris volume: recalculated from Heitmeyer plot data by converting to metric measurements, adjusting for partial sample, and entering data from each transect into the woody debris calculator provided as an appendix to the Delta HGM guidebook. Summarized at plot and stand levels.

Modification of HGM Models

Once a complete set of variables was assembled and summarized at the group level, the appropriate Functional Capacity Index (FCI) calculators (modified from the versions presented in the Delta HGM Guidebook) were used to calculate Functional Capacity Indices for each of 7 wetland functions. The models used are the same as those presented in the original Guidebook, except that the flood frequency variable has been redefined as described above, and a flood duration term (V_{DUR}) has been added to the Plant Community Maintenance and Wildlife Habitat models. Further, the variable subindex values used in the FCI and FCU calculations for V_{FREQ} and V_{DUR} are generated in the context of the Heitmeyer and Ederington (2004) study, which organized the study areas ("groups") into Site Types (Stressed, Non-stressed, or Greentree Reservoir), and assigned relative stress or health ratings to each sample group. The modified HGM models and the wetland functions they represent are as follows:

Function 1: Detain Floodwater

$$FCI = V_{FREQ} \times \left[\frac{(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN})}{4} \right]$$

Function 2: Detain Precipitation

$$FCI = \frac{\left[V_{POND} + \frac{(V_{OHOR} + V_{LITTER})}{2} \right]}{2}$$

Function 3: Cycle Nutrients

$$FCI = \frac{\left[\frac{(V_{TBA} + V_{SSD} + V_{GVC})}{3} + \frac{(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG})}{4} \right]}{2}$$

Function 4: Export Organic Carbon

$$FCI = V_{FREQ} \times \frac{\left[\frac{(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG})}{4} \right] + \left[\frac{V_{TBA} + V_{SSD} + V_{GVC}}{3} \right]}{2}$$

Function 5: Remove Elements and Compounds

$$FCI = V_{FREQ} \times \left[\frac{(V_{CEC} + V_{OHOR} + V_{AHOR})}{3} \right]$$

Function 6: Maintain Plant Communities

$$FCI = \left(\left\{ \left[\frac{\left[\frac{(V_{TBA} + V_{TDEN})}{2} + V_{COMP} \right]}{2} \right] \right\} \times \left[\frac{(V_{SOIL} + V_{DUR} + V_{POND})}{3} \right] \right)^{1/2}$$

Function 7: Provide Wildlife Habitat

$$FCI=\left\{\left[\frac{(V_{FREQ}+V_{DUR}+V_{POND})}{3}\right]\times\left[\frac{(V_{TCOMP}+V_{SNAG}+V_{STRATA}+V_{TBA})}{4}\right]\times\left[\frac{(V_{LOG}+V_{OHOR})}{2}\right]\times\left[\frac{(V_{TRACT}+V_{CONNECT}+V_{CORE})}{3}\right]\right\}^{1/4}$$

As noted previously, the variable subindex values that are used in the models are generated from reference data collected and summarized in the Arkansas Delta HGM Guidebook (Klimas et al. 2004a). However, for the purposes of this study, the hydrologic component of the models has been modified to take advantage of the detailed flood frequency and duration data available for the area, as well as the results of the Heitmeyer and Ederington (2004) study. The variable subindex values for V_{FREQ} are based on the projected change in flood frequency due to the project, in terms of "zone changes," where the zones are the flood frequency zones listed above. This means that, under current (pre-project) conditions, all of the study groups are assumed to experience flooding at approximately the same frequency (i.e., annually, one year in two, one year in five, one year in ten, or less frequently than one year in ten) that occurred historically. This assumption is based on the distribution of historic vegetation as described and mapped by Klimas et al. (2004b) and the review of historic flooding patterns presented by Heitmeyer et al. (2004). This is a crude indicator of the ability of a wetland to perform functions related to interactions between the forested wetlands and aquatic systems. For example, during floods, organic production is exported to stream systems (the Organic Carbon Export function) and various materials dissolved in the water column are transferred to the terrestrial system (the Removal of Elements and Compounds function). Similarly, fish and wildlife species that use flooded forests for reproduction or rearing require flooding of those forests frequently enough to prevent a critical drop in population size. For all of the models where flood frequency (V_{FREQ}) is a model component, any change (e.g., a change from the 5-year floodplain to the 10-year floodplain) is considered a negative factor in the assessment models. It is expressed as a change in the variable subindex, as represented in Figure 2. Note that the subindex is not scaled to specific flood zones, but rather to the number of zone changes that occur as a result of the project. A change from the 1-year flood zone to the 2-year flood zone is regarded as having the same effect as changing from the 5-year zone to the 10-year. While such changes are not proportional, the available flood frequency data does not allow a more sensitive approach to generating a V_{FREQ} subindex value, and this method reasonably captures the magnitude of changes likely to result from the project. Where the post-project flood frequency is predicted to be less frequent than 1 year in five, the site is no longer classified as riverine under the criteria established in the HGM Guidebook for the region. Therefore, on the small areas where this occurs in the study area, the V_{FREQ} variable is set to zero.

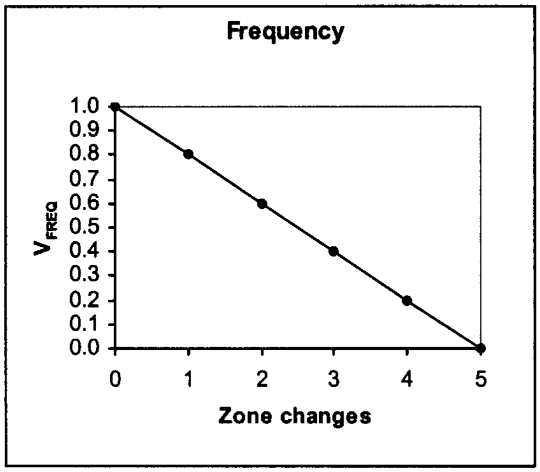


Figure 2. Subindex curve for the Flood Frequency variable (V_{FREQ}) used in the modified HGM models for all Site Types.

The subindex curves developed for use with the flood duration data take advantage of the field studies conducted by Heitmeyer and Ederington to establish an estimate of how current (pre-project) conditions differ from the historic conditions within the project area. For all of the sample groups designated as the Non-stressed Site Type, the pre-project growing–season flood duration is considered to be approximately the same as the historic condition, and where the project is expected to reduce flood durations, that is taken to be a negative effect, and scaled using the same zone-change concept used for flood frequency (Figure 3).

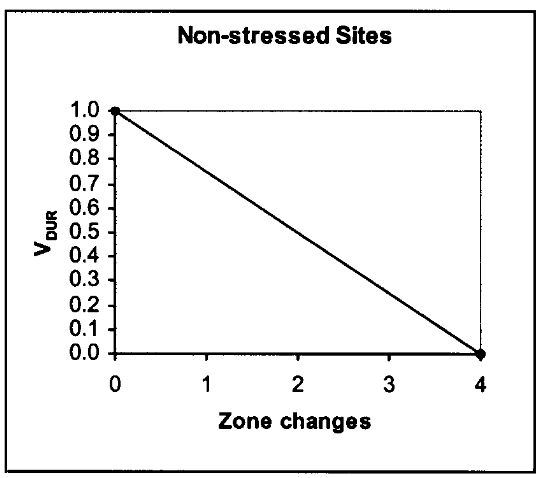


Figure 3. Subindex curve for the Flood Duration variable (V_{DUR}) used in the modified HGM models for the Non-stressed Site Type.

For all sample groups in the Stressed and Greentree Reservoir Site Types, changes in duration zones also were used to derive subindex values for the V_{DUR} variable, but the shape of the subindex curves vary depending on the severity of the stress observed by Heitmeyer and Ederington (2004). In that study, the authors assigned stress scores ranging from +15 to –16 to each group, indicating the magnitude of the damage observed, which was attributed to extended growing season flooding. Because the proposed project will reduce growing season flooding, the V_{DUR} variable modifies the Plant Community and Wildlife Habitat functional assessment models, which are concerned with the health of the plant community. Figure 4 illustrates how the V_{DUR} subindex varies depending on the initial condition of the wetland. For those sites considered seriously compromised by extended flooding (sites with scores of –12 to –16) any reduction in flooding is considered beneficial, and only extreme flood reductions produce subindex scores that reflect a fully functional condition. Sites with intermediate scores (-6 to –11) also benefit from any reduction in growing season flooding, but changes need not be so extreme to produce full functionality. Sites with low scores (zero to –5) are regarded as benefiting from some flood reduction, but extreme changes are likely to be detrimental as they are in the Non-stressed sites, as reflected in the subindex graph.

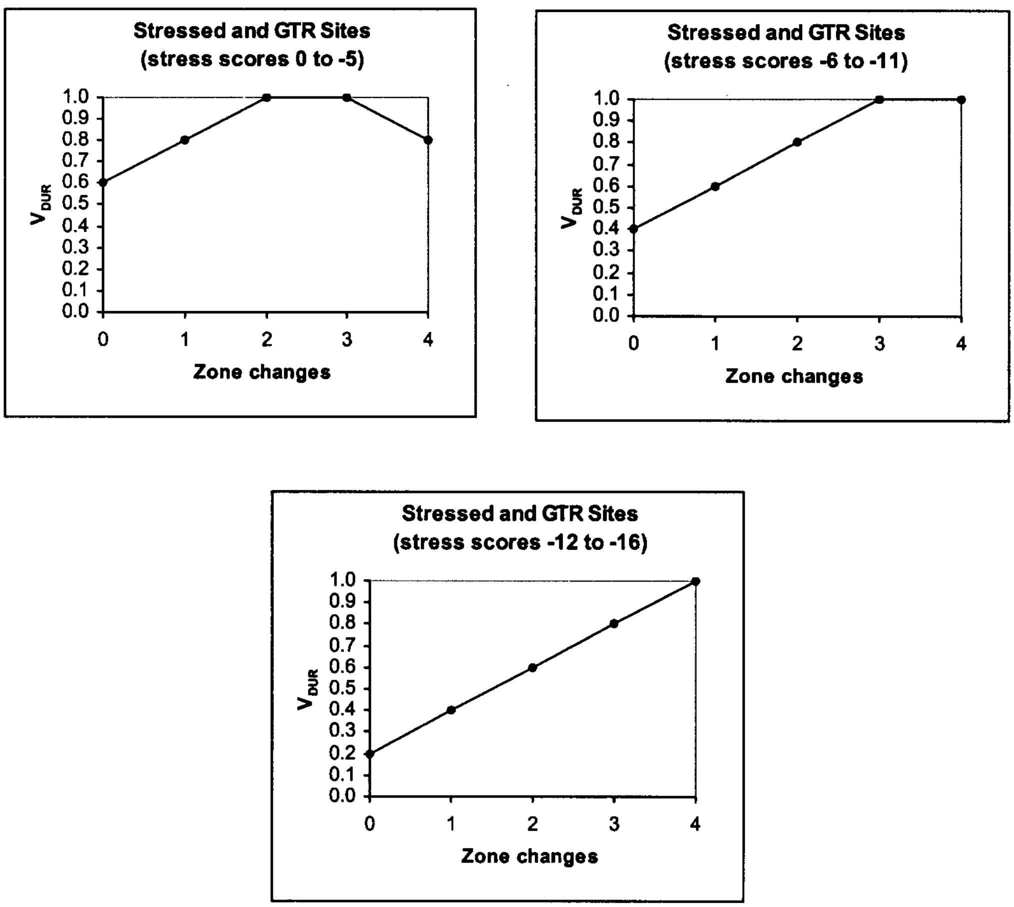


Figure 4. Subindex curve for the Flood Duration variable (V_{DUR}) used in the modified HGM models for the Stressed and Greentree Reservoir Site Types.

Development of Recovery Trajectories for Mitigation Sites

In order to estimate the rate and extent to which the establishment of mitigation wetlands will be effective in offsetting loss of function due to project effects, it is necessary to project changes over time in terms of the variables used in the functional assessment models. The following discussion (adapted from Klimas 2004) summarizes the procedure used to accomplish that.

The reference wetlands used to calibrate HGM indicators are selected to represent a full range of "conditions" in terms of wetland functionality. In practice, in forested wetlands of the Lower Mississippi Valley, the principal factors influencing wetland functionality are hydrologic changes, land use changes, and forest management. The first two of these are largely represented by "physical setting" variables. Flood reduction, drainage, and changes to soils (leveling, filling) have effects that can be described as essentially static for the foreseeable future, or that can be modified to a new static condition as part of a restoration effort (e.g., flooding can be restored by filling ditches, fill can be removed, or microtopography can be restored by surface contouring prior to planting). However, most of the other variables that relate to community structure and vegetation composition can be expected to follow predictable trajectories of recovery following restoration. This generally means that a restored forested wetland with all physical factors intact will gain function over time, and will be fully functional when it has reached a "mature" (or equilibrium) structure and composition. The gain in function may not be linear for all functions, but the changes in indicators will proceed in a consistent manner until the equilibrium condition is reached.

The approach used to create the functional recovery curves is to index a subset of sampled stands to their time of initiation. This means that, where possible, the time-since-establishment is determined or estimated based on direct knowledge (usually with reference to young planted stands), or on indirect evidence such as increment core data to estimate stand age based on the age of canopy trees. Figure 5 illustrates the process of establishing a recovery trajectory for a single HGM regional subclass and a single functional indicator. In this case, tree basal area is plotted against stand age for the Riverine Backwater regional subclass in the Delta Region of Arkansas. The ages of most young stands used in Figure 5 were established by consulting planting records, while older stands were mostly aged using increment core data.

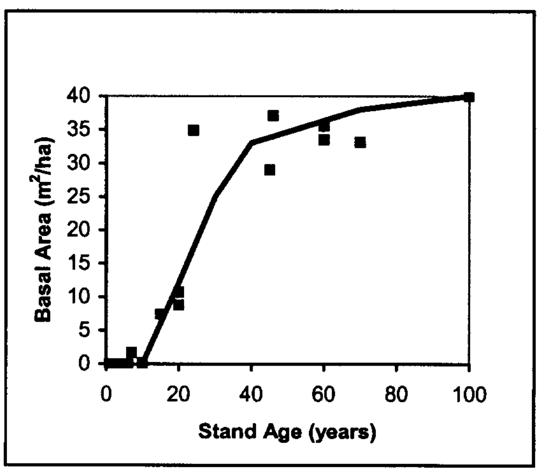


Figure 5. Changes in tree basal area (m^2/ha) over time, as based on increment core samples and restoration records in Riverine Backwater wetlands of the Arkansas Delta Region.

Figure 6 illustrates how the trajectory curve presented in Figure 5 is used in conjunction with the corresponding subindex curve presented in Figure 1 to estimate the basal area subindex values in all assessment models over time. In this example, the age trajectory for the Tree Biomass variable (V_{TBA}) indicates that a basal area of approximately 12m^2/ha is predicted for a restored site 20 years after planting. (Note: the trajectory curves assume specified minimum planting densities or colonization rates, as described in the Arkansas Delta HGM Guidebook). Consulting the corresponding subindex curve produces a predicted variable subindex of 0.5 at a stand age of 20 years.

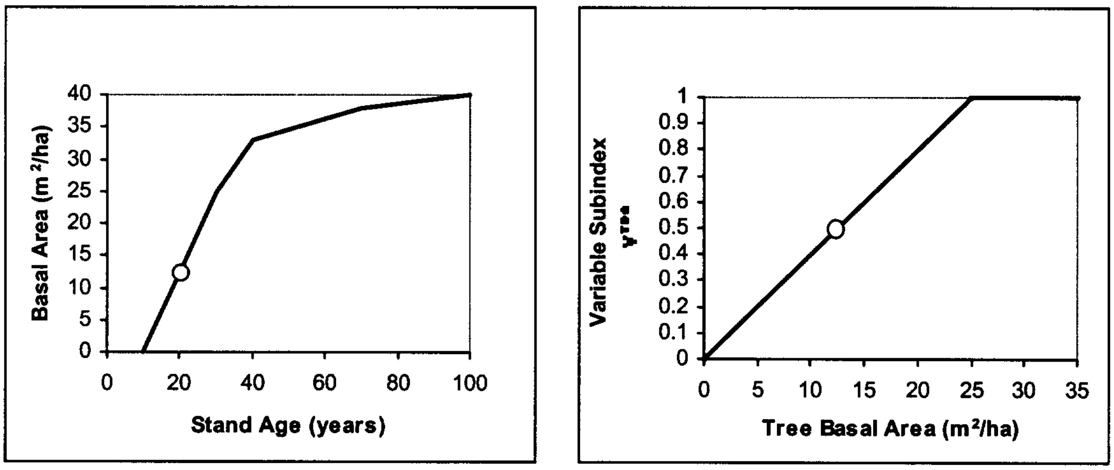


Figure 6. Use of the age trajectory curve for Basal Area to estimate a Tree Biomass subindex value for a Riverine Backwater wetland 20 years after restoration.

The same process used in Figure 6 is applied at other time intervals to generate additional predicted values for the Tree Biomass subindex, and for the other variables used in the assessment models.

RESULTS

Table 1 presents the HGM assessment scores calculated for 7 wetland functions for the Non-stressed and Stressed Site Types in their pre- and post-project conditions. The table includes the net change in Functional Capacity Units when both Site Types are considered together. The analysis indicates that two functions (Precipitation Detention and Nutrient Cycling) are expected to be unaffected by the project (net change in function = 0.0). This is because the models for these two functions consider plant community structure and the extent of ponding within the assessment areas, neither of which is expected to change as a result of altered flooding regimes. The Floodwater Detention, Organic Carbon Export, and Element and Compound Removal functions all are projected to be negatively affected by the project, with net losses of approximately 558, 495, and 648 FCUs, respectively. This reflects the fact that flood frequency is considered in those assessment models, and there will be a net reduction in flood frequency in about 35% of the Groups assessed. However, the changes in flood frequency are mostly small, and the models also consider a variety of vegetation, detritus, and site factors that will not change as a result of the project, so the overall net changes in FCUs are not large. The Plant Community and Wildlife Habitat functions are projected to show a net gain in function as a result of the project (approximately 449 and 75 FCUs, respectively). This reflects the fact that both of these models consider changes in growing-season flood duration, which will have a negative effect on the Non-stressed sites, but a significantly more positive effect on the Stressed sites, producing a net positive result overall.

Table 1. Summary of net changes in Functional Capacity Units for pre- and post project conditions in the Non-stressed and Stressed Site Types.

	Wetland Functions						
	Floodwater Detention	Precipitation Detention	Nutrient Cycling	Export Organic Carbon	Remove Elements & Compounds	Plant Community Maintenance	Wildlife Habitat Maintenance
Functional Capacity Units: Non-stressed Site Type							
Pre-project	1124.87	1407.74	1034.04	1028.19	1407.74	1262.58	1167.06
Post-Project	1091.76	1407.74	1034.04	994.76	1362.92	1227.23	1157.49
Net Change	−33.11	0.0	0.0	−33.43	−44.82	−35.35	−9.57
Functional Capacity Units: Stressed Site Type							
Pre-project	3479.18	4114.34	3104.31	3104.31	4114.34	2983.21	3239.70
Post-project	2954.58	4114.34	3104.31	2642.80	3511.56	3467.16	3324.38
Net change	−524.60	0.0	0.0	−461.51	−602.78	+483.95	+84.68
Functional Capacity Units: Sum of Non-stressed and Stressed Site Types							
Net change	**−557.71**	**0.0**	**0.0**	**−494.94**	**−647.60**	**+448.60**	**+75.11**

Table 2 presents the same analysis as Table 1, but for the Greentree Reservoir Site Type only. Like the Non-stressed and Stressed Site Types, this analysis indicates no net change due to the project for the Precipitation Detention and Nutrient Cycling functions. All of the other functions show a net loss of function post-project, ranging from 22 FCUs for the Wildlife Habitat function to 91 FCUs for the Plant Community function. However, this analysis is presented separately from the other Site Types due to uncertainty as to how the project will actually influence hydrology within the Greentree Reservoirs. Because these areas are privately owned, and are leveed and managed specifically to impound water, the projected changes to hydrology elsewhere in the basin may have little or no influence on the Greentree Reservoirs (Heitmeyer and Ederington 2004). Therefore, the discussion below is focused only on the project effects on the Stressed and Non-stressed Site Types, and does not consider the private Greentree Reservoir Site Type. The data in Table 2 indicate that, if negative effects occur in the Greentree Reservoir

Site Type due to the project, the net negative impacts will be less than 10% of those in the Stressed and Non-stressed Site Types.

Table 2. Summary of net changes in Functional Capacity Units for pre- and post project conditions in the Greentree Reservoir Site Type.

	Wetland Functions						
	Floodwater Detention	Precipitation Detention	Nutrient Cycling	Export Organic Carbon	Remove Elements & Compounds	Plant Community Maintenance	Wildlife Habitat Maintenance
Functional Capacity Units: Private Greentree Reservoir Site Type							
Pre-project	1207.34	1559.18	1171.61	1171.61	1559.18	1371.13	1219.62
Post-project	1177.88	1559.18	1171.61	1144.02	1521.54	1279.89	1197.27
Net change	**–29.46**	**0.0**	**0.0**	**–27.59**	**–37.64**	**–91.24**	**–22.35**

The Functional Capacity Units in Tables 1 and 2 can be interpreted directly as acreage, where a loss or gain of a single FCU is equivalent to the loss or gain of one acre of fully functional wetland. For example, the loss of 558 FCUs of the Organic Carbon Export function is the same as losing the Carbon Export function performed by 558 acres of fully-functional, frequently flooded, mature bottomland hardwood forest. However, replacing the lost function by restoring forest on agricultural land is not immediately effective, because of the lag time required for planted vegetation to mature and for detrital pools (litter, logs, snags) to accumulate. Therefore, in order to estimate mitigation requirements, recovery trajectory curves can be employed to predict the rate at which various community characteristics will develop following restoration. The predicted values of community characteristics at various time intervals following restoration can be used to run the relevant HGM models, and estimate the FCUs likely to be generated at each of those time intervals (Klimas 2004).

In order to develop the trajectories, and establish their starting points, the following assumptions were made. Deviation from these assumptions makes the analysis of future conditions inapplicable.

1. The mitigation will take place by converting agricultural land to native lowland forest, using appropriate species composition and planting densities.

2. The mitigation site will have native soils in place, will be within the post-project 1-5 year floodplain, and will be prepared prior to planting by establishing microtopography that will produce shallow, seasonal ponding over 20-70% of the restored area (based on reference sampling in the region reported by Klimas et al., 2004).

3. The mitigation site will not be subject to the prolonged growing-season flooding (especially fall flooding) inappropriate for the site and species being planted.

4. The mitigation site will consist of one or more large blocks of forest that are directly contiguous with existing large forest blocks, or are themselves large enough that the resulting total contiguous forested tract will exceed 7000 acres.

Based on the assumptions above, the Riverine Backwater HGM models were run for the postulated mitigation site at 10-year intervals. The input to the models was generated from trajectory curves provided in the Arkansas Delta HGM Regional Guidebook (Klimas et al. 2004). Figure 7 illustrates the recovery trajectories generated through this process for each of the 7 functions assessed in this study. The curves approximate the rate at which functionality will change over time following restoration in terms of a Functional Capacity Index (FCI) that ranges between 0.0 and 1.0. An area with an FCI of 1.0 is fully functional, and a single acre of that area has 1 FCU, ten acres has 10 FCUs, etc. Conversely, an area with an FCI of 0.5 functions at only half of its potential. Ten acres of such an area would have 5 FCUs for the function under consideration. Note that the trajectory curves in Figure 7 do not indicate the difference between the planted condition and the initial (pre-planting) condition. However, Table 3 summarizes the changes in FCIU over time for each function, and includes the pre-project condition. It demonstrates that only the Remove Elements and Compounds function is operating at a significant level (about 50% of capacity) prior to planting the mitigation site. This is because that function is partly dependent on soil characteristics, and intact soils are assumed to be present on the selected mitigation site.

The recovery trajectories illustrated in Figure 7 and summarized in Table 3 illustrate various patterns, depending on the function being assessed. As noted, the Removal of Elements and Compounds function will be operating at about half capacity even before the site is planted, because it is dependent in part on soil factors, and appropriate soils are assumed to be present on the mitigation site. Because of the required site preparation (microtopography), the Precipitation Detention and Removal of Elements and Compounds functions will be fully established within 20 and 30 years, respectively. Because the Precipitation Detention function actually suffered no net loss due to the project (Table 1), every acre planted as mitigation represents a net gain of that function over the pre-project condition. The Plant Community Maintenance function similarly achieves a high level of function immediately after planting, because the factors that control the long-term health of lowland plant communities (appropriate flooding regime, soils, ponding, species composition) are assumed to be in place when the mitigation site is established. Development of full function still requires approximately 50 additional years, because the HGM model for the Plant Community function also considers maturity and complexity, which require time to develop.

All of the other functional recovery curves illustrated in Figure 7 have low initial FCI values that climb gradually to reach full function within the 50-year life of the project. This reflects their dependence on mature, complex plant communities and accumulations of organic debris. In addition, the Wildlife Habitat model is heavily weighted by spatial factors such as tract size and the percentage of the area that is forest interior habitat, thus the basic assumption of continuity to large existing tracts makes the trajectory curve climb steeply as the forest matures. However, all of these functions are slow to reach full functionality, and those that have a net loss post-project also incur a "temporal debt" in the mitigation site as they slowly become fully functional.

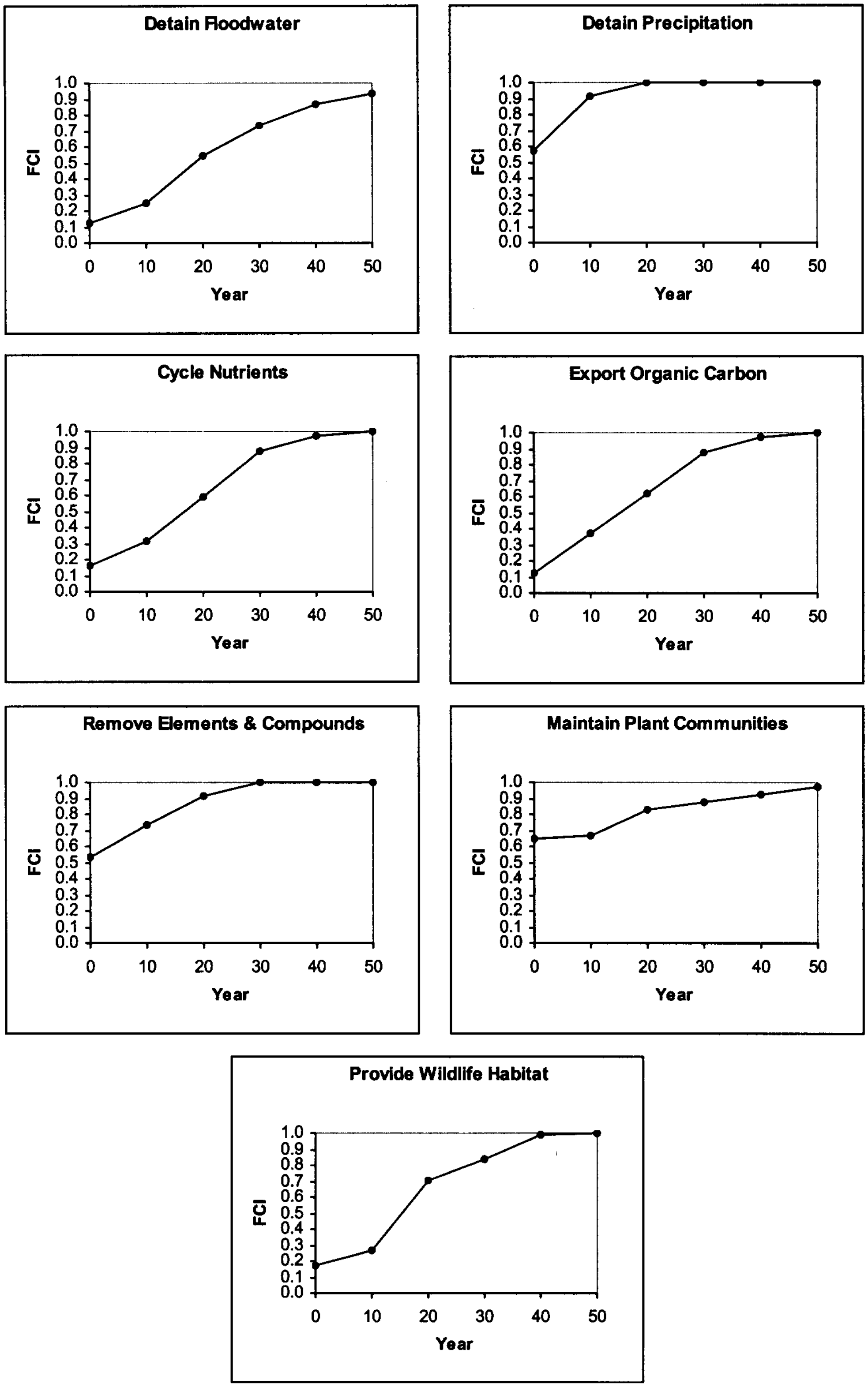


Figure 7. Estimated recovery trajectories for a postulated mitigation area expressed in terms of FCIs for each of the 7 functions assessed in the project impact analysis.

Table 3. Change in FCI for a postulated mitigation area at 10-year intervals over the life of the project.

Year	Wetland Functions						
	Floodwater Detention	Precipitation Detention	Nutrient Cycling	Export Organic Carbon	Remove Elements & Compounds	Plant Community Maintenance	Wildlife Habitat Maintenance
	Functional Capacity Index						
Pre-project	0.0	.025	.075	.013	.533	0.0	0.0
0	.125	.575	.158	.121	.533	.644	.170
10	.250	.910	.317	.372	.734	.663	.270
20	.543	1.0	.586	.618	.917	.831	.703
30	.735	1.0	.872	.872	1.0	.880	.835
40	.864	1.0	.976	.976	1.0	.922	.994
50	.938	1.0	1.0	1.0	1.0	.968	1.0

HGM assessment, coupled with trajectory curve analysis, provides a means for estimating mitigation requirements that take into account the slow recovery time of some functions following establishment of a mitigation site. For the three functions that are negatively impacted by the project (Table 1), the total mitigation debt over the life of the project can be estimated using the graphical approach illustrated in Figure 8. This figure shows the recovery trajectories for the Floodwater Detention, Organic Carbon Export, and Removal of Elements and Compounds functions, which had post-project net losses of 558, 495, and 648 FCU, respectively. Figure 8 shows the same recovery trajectory curves presented in Figure 7, except that the curves are scaled to reflect the recovery of a single FCU, which is the same as using the FCI scale. The dotted horizontal line on each graph approximates the level of function that must be achieved to offset the post-project losses over a 50-year period. That is, the area labeled A on each graph represents the temporal deficit associated with restoration of 1 acre, the area labeled B represents the time and area where losses are directly offset, and area C represents the additional time and area required to offset the temporal losses represented by A. Calculated as annualized changes in function, the required mitigation to replace lost function due to the project is summarized in Table 4.

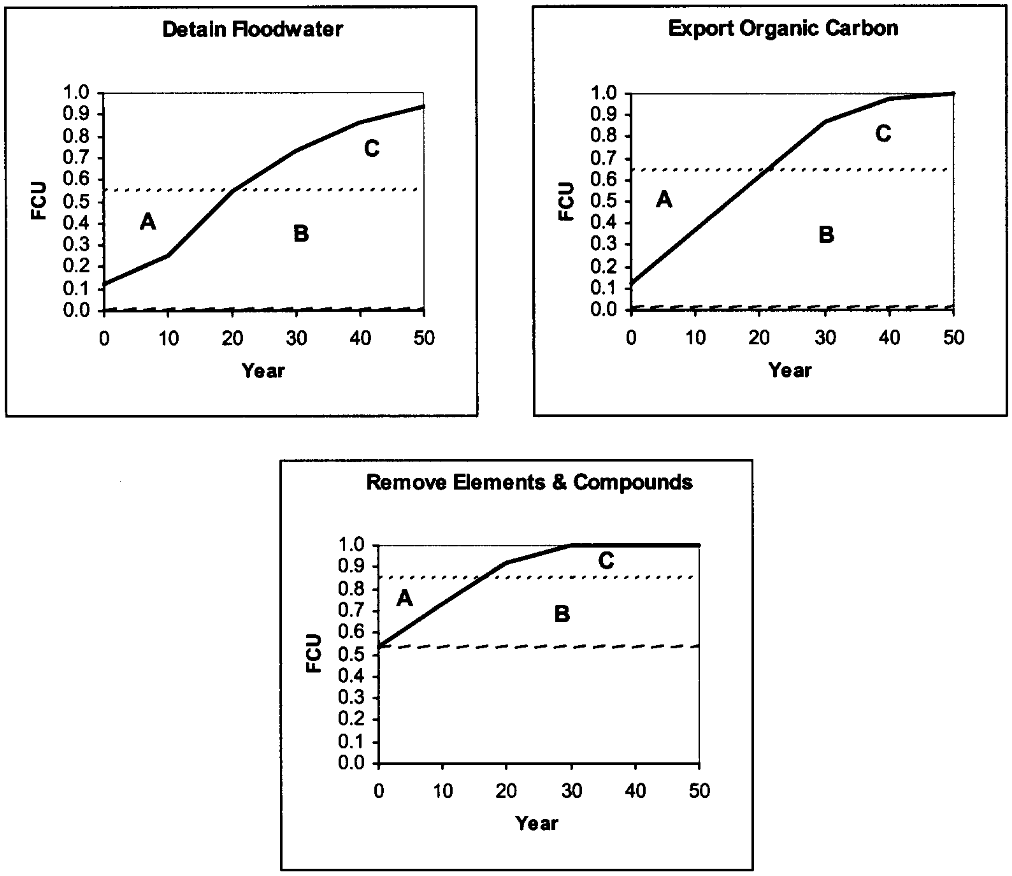


Figure 8. Recovery trajectory curves (solid lines) in relation to the FCU equivalent of a single acre of post-project functional losses (dotted line) for each of the 3 functions negatively affected by the proposed project. The baseline (pre-restoration) condition is indicated by the dashed line.

Table 4. Summary of mitigation acreage required to offset project losses over a 50-year period for three negatively-impacted functions in the Non-stressed and Stressed Site Types.

	Wetland Functions		
	Detain Floodwater	Export Organic Carbon	Remove Elements and Compounds
Net loss of function due to project (FCU) (assumed constant over life of project)	557.71	494.94	647.60
Annualized gain in FCUs/acre in mitigation site based on recovery trajectories	0.6097	0.7012	0.4834
Total mitigation acres required	**914.73**	**705.85**	**1,339.67**

Table 4 indicates that the largest mitigation debt is incurred for the Remove Elements and Compounds function. Further, that function will require the most acreage to mitigate for the loss, in part because any appropriate mitigation area already performs the function to some degree in the pre-project condition due to characteristics of the native soils in the area. The buildup of organic material on the soil surface after planting will quickly increase the performance of this function to its maximum capacity, but overall it represents the largest single mitigation acreage requirement. Planting of 1,339.67 acres of mitigation will meet this obligation, as well as the other, lesser mitigation debts associated with the Floodwater Detention and Organic Carbon Export functions.

This calculation is concerned only with the Stressed and Non-stressed Site Types identified by Heitmeyer and Ederington (2004). The Greentree Reservoir Site Type was not included, for the reasons discussed previously. However, if the Greentrees are included in this analysis, similar patterns of functional loss and gain occur, but of much smaller magnitude. The Remove Elements and Compounds function again has the largest functional deficit, but only 77.5 acres of mitigation would be required to offset that loss, for a total of 1,417.2 acres of mitigation overall.

SUPPLEMENTAL ANALYSIS OF MITIGATION REQUIREMENTS FOR FARMED WETLANDS

One anticipated effect of the project is that some farmed wetlands in the Bayou Meto Basin will experience changes in hydrology, in particular reduced flood frequency and duration. The acreages and degree of change on specific sites were not available for this analysis, but a conservative estimate of the likely mitigation ratio required to offset functional losses in farmed wetlands was generated based on a set of "worst-case" assumptions. Specifically:

1. The analysis assumes that all affected farmed wetlands will be completely converted to non-wetland (i.e., all growing-season flooding will be curtailed). No post-project wetland functions will exist on those sites.
2. All affected farmed wetlands are assumed to be partially functional under pre-project conditions, due to the presence of native soils and natural flooding patterns. Pre-project flood frequency and duration values are assumed to be optimal (V_{FREQ} and V_{DUR} =1.0).
3. All affected farmed wetlands are assumed to be completely unvegetated, and to have no significant microtopography (ponding sites) due to land leveling and tilling.
4. The mitigation sites used to offset functional losses are assumed to meet the same criteria described in the previous sections with respect to site selection, preparation, and planting. The recovery trajectories described previously are used to calculate the rate at which functionality will accrue on the mitigation area(s).

Table 5 summarizes the anticipated losses of function on impacted farmed wetland sites and annualized gains on mitigation sites for a suite of 7 wetland functions. Under pre-project conditions, farmed wetlands are partly functional with regard to some biogeochemical processes that involve interactions between floodwaters and soils. The greatest level of pre-project function is seen in the ability of the farmed wetland to remove materials such as nutrients from the water column during floods. Because the mitigation area also performs that function to the same extent in the pre-project condition, the loss of that function on the impact areas must be offset by increases in organic matter on the mitigation site. Based on reference data used to create the recovery trajectory for organic matter accumulation on restored sites, full functionality will be reached in a little over 20 years on the mitigation site. Therefore, for the most-impacted function (Remove Elements and Compounds), this analysis indicates that a mitigation ratio of 1.1:1 will fully offset losses over the 50-year life of the project. That is, for every acre of farmed wetland that will be subject to reduced inundation, 1.1 acres of mitigation must be established.

Table 5. Summary of functional losses on farmed wetlands subject to hydrologic change, and required mitigation.

	Wetland Functions						
	Floodwater Detention	Precipitation Detention	Nutrient Cycling	Export Organic Carbon	Remove Elements & Compounds	Plant Community Maintenance	Wildlife Habitat Maintenance
	Functional Capacity Index						
Pre-project	0.0	.025	.075	.013	.533	0.0	0.0
0	.125	.575	.158	.121	.533	.644	.170
10	.250	.910	.317	.372	.734	.663	.270
20	.543	1.0	.586	.618	.917	.831	.703
30	.735	1.0	.872	.872	1.0	.880	.835
40	.864	1.0	.976	.976	1.0	.922	.994
50	.938	1.0	1.0	1.0	1.0	.968	1.0
Annualized gain	.6097	.4495	.6826	.7012	.4834	.949	.7114
Mitigation factor (this number times FCU's lost = mitigation requirement	1.64	2.22	1.46	1.426	2.06	1.054	1.41
FCU's lost per acre on farmed wetland	0.0	0.025	0.075	0.013	0.533	0	0
Mitigation ratio (acres to be planted to offset 1 acre of lost farmed wetland	0.0	.055	0.111	0.019	1.098	0	0

LITERATURE CITED

Heitmeyer, M.E., and B. Ederington. 2004. An evaluation of bottomland hardwood forests in the Bayou Meto Basin Improvement Project area. Report to Memphis District, Corps of Engineers.

Heitmeyer, M.E., B. Ederington, and L.H. Fredrickson. 2004. Bayou Meto Wildlife Management Area Wetland Management Plan. Special Pblication No. 7, Gaylord Memorial Laboratory, University of Missouri-Columbia.

Killgore, K.J, J.J. Hoover, and C.E. Murphy. 2003. Bayou Meto water supply and flood control project fish evaluation (Draft). Volume 10, Appendix D.

Klimas, C.V. 2004. Development and aplication of functional recovery trajectories for wetland restoration assessment. Draft report to the Environmental Protection Agency Office of Water.

Klimas, C.V., E.O. Murray, J. Pagan, H. Langston, and T. Foti. 2004a. A regional guidebook for applying the hydrogeomorphic approach to assessing functions of forested wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley. ERDC/EL TR-04-XX. US Army Engineer Research and Development Center, Vicksburg, MS.

Klimas, C.V., J.B. Pagan, T. Foti, and M. Bishop. 2004b. An analysis of ecosystem restoration potential in the Bayou Meto basin of Arkansas based on hydrogeomorphic setting and soils. Report to Memphis Dictrict, Corps of Engineers.

Smith, R.D., A.A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Technical Report WRP-DE-9. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Fish and Wildlife Service. 1980. Habitat Evaluation Procedures (HEP). ESM 102, Division of Ecological Services, U.S. Fish and Wildlife Service, Washington, D.C.

Thanks to Mickey Heitmeyer and Belinda Ederington for collecting and providing the data used in this analysis.

APPENDICES

The following technical appendices (spreadsheets) are on file at Memphis District, CE.

APPENDIX A: Notes on data assembly procedures

This document describes the procedures used to handle discrepancies in the raw data, and to generate new variables required for the HGM analysis. See "Methods" section of report for additional data manipulation descriptions.

APPENDIX B: Conversion to HGM Variables –Plot Level: Stressed Plots Bayou Meto Basin

APPENDIX C: Conversion to HGM Variables – Plot Level: GTR Bayou Meto Basin

APPENDIX D: Conversion to HGM Variables – Plot Level: Negative bayou Meto Basin

These 3 appendices are Excel workbooks containing the applicable data extracted from the Heitmeyer and Ederington raw data spreadsheets, new variables derived from GIS analyses, and new variables calculated using the raw field data. The "Negative" file is terminology used in the original Heitmeyer and Ederington spreadsheets, and it corresponds to the groups called "Non-stressed" in this report. Each appendix corresponds to the original Heitmeyer and Ederington spreadsheet, but contains the following tabs:

Extracted cover and density data (raw)

Extracted tree data (raw)

Extracted woody debris data (raw)

New HGM variables

Calculated HGM variables

APPENDIX E: Conversion to HGM Variables (Group Level)

This Appendix includes the results of converting plot-level variables to group level, adding variables derived only at the group level, and generating the FCI scores that are included in the report as Table 1. It contains the following spreadsheets:

Groups and constituent plots

HGM classification/variable summary

Functional Capacity Indices (FCI)

APPENDIX F: Heitmeyer and Ederington (2004) original files: species codes

APPENDIX G: Heitmeyer and Ederington (2004) original files: Negative Bayou Meto

APPENDIX H: Heitmeyer and Ederington (2004) original files: GTR Bayou Meto

APPENDIX I: Heitmeyer and Ederington (2004) original files: Stressed Bayou Meto

These are the original Heitmeyer and Ederington (2004) spreadsheets. They are provided here to document the original data used to generate the analysis presented in this report. Other than the expanded file names assigned here, they have not been modified in any way. The "Negative" file corresponds to the "Non-stressed" groups discussed in this report.

APPENDIX J: Frequency Spreadsheet

This spreadsheet compiles all group acreages according to the number of flood frequency zone changes that are anticipated under the proposed project.

APPENDIX K: Duration spreadsheet

This spreadsheet compiles all group acreages according to the number of growing-season duration zone changes that are anticipated under the proposed project.

SECTION XVIII

HGM ANALYSES

Part B. HGM Ecosystem Restoration Analysis

AN ANALYSIS OF ECOSYSTEM RESTORATION POTENTIAL IN THE BAYOU METO BASIN BASED ON HYDROGEOMORPHIC SETTING AND SOILS

Prepared for the U.S. Army Corps of Engineers, Memphis District

by

Charles V. Klimas[1], Joe B. Pagan[2], Thomas L. Foti[3], and Michael J. Bishop[4]

April, 2004

Introduction

The Memphis District, US Army Corps of Engineers is conducting planning studies concerning potential water resource projects in the drainage basin of Bayou Meto, a tributary to the Arkansas River in the Delta Region of Arkansas. The objective of this study was to create a map and general description of the potential natural vegetation of the basin, with particular application to project mitigation planning efforts. Primary responsibility for the study was assigned to the US Army Engineer Research and Development Center (ERDC). The Arkansas Natural Heritage Commission (ANHC), and the USDA Natural Resources Conservation Service (NRCS) participated in this effort because of their cooperative and review responsibilities relative to water resource projects and because the products of this research are expected to have applications to NRCS wetland restoration efforts under the Wetland Reserve Program, and a variety of landscape restoration planning initiatives under consideration by the ANHC.

This study employs a landscape classification system based on the Hydrogeomorphic Approach to wetland classification and assessment (HGM) (Brinson 1993). An HGM-based classification of wetlands in the Delta Region of Arkansas was recently completed by the Arkansas Multi-Agency Wetland Planning Team (Klimas et al. 2004). That classification system was based largely on dominant hydrology (particularly stream flooding versus precipitation-dependent and depressional or lacustrine systems) and geomorphic setting, as mapped and defined by Saucier (1994). While the Delta Region classification forms the basic framework on which the Bayou Meto Basin classification presented here was constructed, it is not detailed enough to fully meet all of the study objectives. The Delta classification was supplemented with more detailed geomorphic, soil, and hydrology data to construct a classification system that allows mapping of potential natural vegetation at a level of detail sufficient to support site-specific as well as ecosystem-scale mitigation planning.

[1] Charles Klimas & Associates, Seattle WA
[2] Natural Resources Conservation Service, Litltle Rock AR
[3] Arkansas Natural Heritage Commission, Little Rock AR
[4] U.S. Army Engineer Research and Development Center, Vicksburg MS

A related study also was recently completed (Heitmeyer et al. 2002) that suggested restoration priorities for the basin, based partly on preliminary results of the work presented here. That study and this one should be used together in any ecosystem restoration planning for the Bayou Meto Basin. The report by Heitmeyer et al. (2002) also presented a thorough overview of the development of the basin, the geomorphic settings and soils present, hydrology, and native plant and animal communities. In addition, they describe how historic land use patterns have altered the original vegetation and how the water projects currently under consideration are expected to operate. Rather than reiterate that discussion here, the reader is referred to the earlier report for a full description of the study area.

Methods

This study proceeded in two stages. First, a hydrogeomorphic classification system was devised that applied to the entire Bayou Meto Basin, which allowed potential natural plant communities to be described regardless of current land use or vegetation condition. Then, three maps (Arcview themes) were created that employed the classification system in conjunction with land use data to depict the potential and existing condition of the basin from different perspectives, which in combination have various applications to planning objectives.

The existing HGM classification system for the Delta Region of Arkansas (Klimas et al. 2004) recognizes 4 wetland[5] classes that occur in the study area, defined as follows:

a. Riverine: all sites within the 5-year floodplain of any stream system, except for depressions and lacustrine fringe wetlands.

b. Flat: wetlands not within the 5-year floodplain, except for depressions and lacustrine fringe wetlands.

c. Depression: wetlands within large depressions (typically abandoned stream channels in the Bayou Meto Basin).

d. Lacustrine Fringe: wetlands on lake margins (typically oxbow lakes in the Bayou Meto Basin, but also man-made lakes and ponds).

In addition, a fourth landscape class (Upland) was created for the purposes of this project, comprising all sites not classified as wetland.

Within each of the five landscape classes, subclasses were defined based on previously established HGM criteria for the Arkansas Delta (Klimas et al. 2004), with some modifications. Eight subclasses were established:

a. Riverine Overbank: sites within the 5-year floodplain and subject to relatively high-velocity flows during floods.

b. Riverine Backwater: sites within the 5-year floodplain where floodwaters move slowly and tend to pool for long periods of time.

c. Flats: all sites in the Flats class are considered to be in a single subclass, which typically is made up of precipitation-maintained wetlands characterized by

[5] Note that the designation of sites as wetland is a general ecological characterization and does not imply that they necessarily meet the criteria for jurisdictional wetlands under Section 404 of the Clean Water Act.

shallow ponding of rainwater in vernal pools and microdepressions. Runoff is minimal and sluggish.

d. Connected Depression: wetlands in depressions that are within the 5-year floodplain of streams (i.e. they are ecologically "connected" to Riverine systems).

e. Isolated Depressions: wetlands in depressions outside the 5-year floodplain.

f. Connected Lacustrine Fringe: wetlands on the margins of lakes and ponds that are within the 5-year floodplain (i.e. they are ecologically "connected" to Riverine systems).

g. Isolated Lacustrine Fringe: wetlands of lake margins outside the 5-year floodplain.

h. Upland: all sites not meeting the criteria for the subclasses described above.

Beyond the subclass level, the Bayou Meto classification system employs more specific geomorphic, soils, and hydrologic data than the general Delta Region classification of Klimas et al. (2004). The Delta Region classification was based primarily on the geomorphic mapping of Saucier (1994), which was presented at a scale of 1:250,000. The 1994 geomorphic maps were modified from earlier 15-minute quad maps (Saucier1967) that contained more detail, so for the purposes of this project we used the original mapping to supplement the Saucier (1994) maps as necessary. This was particularly important with respect to recognizing features such as abandoned courses and natural levee deposits of the Arkansas River and Bayou Meto, which are not shown on the 1994 maps. We also made extensive use of soil mapping recently completed by the Natural Resources Conservation Service (NRCS). This mapping is an update and revision of the published Soil Surveys applicable to the study area, and further refined our understanding of the origins of various deposits. Finally, the Vicksburg District, CE, provided digital maps indicating the extent of flooding (2-year and 5-year floods) for both current conditions and projected post-water project conditions.

We assembled digital versions of the geomorphic, soils, and hydrologic mapping into an Arcview project and initiated field investigations in the summer of 2001. Within each HGM Class and Subclass, we searched for examples of relatively mature vegetation and developed plant community composition and dominance profiles associated with particular geomorphic settings, soils, and flooding regimes. Eighteen HGM Subtypes were designated upon synthesis of that information.

We then used the classification system in conjunction with the Arcview coverages and current Land Use/ Land Cover mapping provided by Memphis District, CE to develop three map themes. The map themes examine the natural vegetation of the Bayou Meto Basin from different perspectives, which can be used in conjunction to support mitigation planning and other resource restoration objectives within the study area. The details of how the maps were constructed and their component data sources are described in the detailed metadata presented in Appendix A.

Results

The classification system, including Subclass, Subtype, characteristic plant communities, mapping criteria, and a general description of each type is presented in Table 1. This system can be applied to various purposes. At the most detailed level, the system is designed to support restoration of plant communities in terms of the dominant species listed in the table, but with full consideration of the details of classification and mapping criteria, and with reference to the Delta Region HGM Guidebook (Klimas et al. 2004). For example, there are 7 wetland Subtypes within the Flat Subclass, each of which is unique in terms of dominant vegetation or other characteristics. In a restoration scenario, users should also consult the HGM Guidebook, which indicates the extent of ponding (vernal pool and microdepression) associated with different geomorphic surfaces. Typically, older surfaces such as the Grand Prairie will have less ponded area than the younger Deweyville surfaces, which in turn will be less topographically complex than the relatively recent Holocene terrain of the Bayou Meto and Arkansas River bottoms. Restoration design should consider both the compositional and the topographic characteristics of each subclass. The HGM Guidebook also contains general guidance as to the rate of recovery of various ecosystem structural characteristics following restoration.

In terms of functional assessment, the classification system should be applied at the Subclass level, with direct reference to the Delta HGM Guidebook. The Guidebook is not as compositionally specific as the Bayou Meto classification system, but the functional assessment variables derived on a regional basis (such as plant community structure, detrital accumulation, etc.) are applicable within the study area.

The classification system gains additional utility when it is used in a spatial analysis mode. The three maps created based on this system are different representations of post-project condition, and each has particular applicability to understanding either baseline conditions or restoration options. They are presented here as Figures 1, 2 and 3, but also are attached as digital Arcview themes (Appendix B), where considerably more detail can be discerned, and various spatial analyses can be performed. The three maps are:

a. Natural Communities (Figure 1) – This coverage represents application of the classification system to the entire basin, including areas currently classified in the Land Use/Land Cover map as agricultural or developed. Thus every surface within the basin is mapped as either water, or one of the18 subtypes described in Table 1.

b. Existing Condition (Figure 2) – The current Land Use/Land Cover theme was applied to the Natural Communities map to show the current distribution and classification of vegetation in the basin. All non-vegetated areas are classified as either water, agriculture, or developed.

c. Restorable Area (Figure 3) – This map shows the classification of all agricultural sites in the basin, illustrating what community types they could support if restored. Existing vegetation is shown as blank space, indicating it is unavailable for restoration, and developed areas and water also are shown as separate "unavailable" categories.

Discussion

The three Arcview maps described in the previous section are intended to be used individually and in combination to address a variety of potential restoration planning objectives. The Natural Communities map serves as the base from which other maps are derived, but it can also be used to estimate the original distribution of community types, particularly those that have been differentially converted to agriculture (e.g., prairie subtypes). This information can be used to prioritize potential restoration efforts where recovery of natural biodiversity is an objective. The Existing Condition map shows the distribution and characteristics of the current natural communities within the basin[6]. This has utility to a variety of analyses. For example, comparing this coverage to the Natural Communities coverage documents the extent to which many community types have been nearly eliminated from the study area, while the remaining vegetation is dominated by just a few community types (particularly the Riverine Backwater – RB1 subtype). The Existing Condition map also shows the extent of fragmentation in the basin, illustrating the distribution, size, and relative isolation of remaining patches.

The Restorable Area map is the key planning coverage that can be used in conjunction with the other coverages to plan and analyze various restoration options. It shows where opportunities exist to recover community types that have been differentially eliminated from the basin. It also illustrates where opportunities exist to fill gaps and connect or enlarge currently isolated fragments of native vegetation, and where stream corridors can be revegetated to improve riparian continuity.

In addition to the general spatial and community-type analyses that can be conducted with the maps described above, the classification system itself (Table 1) is intended to serve as a guide to the major plant species that should be restored on particular surfaces. This guidance is general, and should be supplemented with other information when designing specific restoration projects. Heitmeyer et al. (2002) presented details on the composition, structure, and function of plant communities in the Bayou Meto Basin, and correlated their classification with a draft of the system presented in Table1. Klimas et al. (2004) described communities throughout the Delta Region of Arkansas that encompass the Bayou Meto communities, and are classified using the same geomorphic and hydrologic criteria employed here. That document provides guidance on the extent of microdepressional ponding appropriate to different geomorphic settings, which should be a fundamental consideration in site preparation before planting, particularly in sites classified as precipitation-maintained flats. Klimas et al. (2004) also provided methods and timelines for estimating recovery of various ecological functions on restored wetlands that are applicable to the study area.

Summary

A detailed landscape classification system was created that covers all of the Bayou Meto Basin. It recognizes five Classes, eight Subclasses, and 18 Subtypes based on hydrogeomorphic criteria and soils, and describes the characteristics of each Subtype. Three Arcview themes also were created, using various combinations of the Subclasses and current Land Use/Land Cover data. The classification system and maps are constructed to be used in conjunction with existing reports on restoration priorities in the

[6] Note that, in all cases, mapping of current natural communities is in terms of the landscape classification described in the "Results" section, and represents the potential natural, mature vegetation. Communities that are currently in a degraded or early-successional condition, such as timber stands killed by impounded water, are not recognized on these maps.

study area and functional assessment of wetlands in the Delta Region of Arkansas to support water project planning and ecosystem restoration initiatives within the Bayou Meto Basin.

Acknowledgements

This study was initiated by Edward Lambert, Memphis District, CE, and managed by Dr. Morris Mauney, US Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The participation of Tom Foti and Jody Pagan was provided by the Arkansas Natural Heritage Commission and the USDA Natural Resources Conservation Service, respectively. Mark Smith and Jennifer Reddin (Memphis District, CE) provided Land Use/Land Cover data and other support. Elizabeth Murray (Arkansas Multi-Agency Wetland Planning Team) assisted with fieldwork. Dave Johnson and Kendall Smith (Vicksburg District, CE) provided the hydrologic data. Joseph Dunbar (ERDC) assisted with obtaining and interpreting the geomorphic mapping.

Literature Cited

Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands. TR-WRP-DE-4. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Heitmeyer, M.E., L.H. Fredrickson, B. Ederington, and S.L. King. 2002. An evaluation of ecosystem restoration options for the Bayou Meto Basin of Arkansas. Special Publication No. 5. Gaylord Memorial Laboratory, University of Missouri-Columbia.

Klimas, C.V., E.O. Murray, J. Pagan, H. Langston, and T. Foti. 2004. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of forested wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley. ERDC/EL TR-04-XX. US Army Engineer Research and Development Center, Vicksburg, MS.

Saucier, R.T. 1967. Geological Investigation of the Boeuf-Tensas Basin, Lower Mississippi Valley. TR3-737. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Saucier, R.T. 1994. Geomorphology and Quaternary geologic history of the Lower Mississippi Valley (two volumes). US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Table 1: Hydrogeomorphic site classification, Bayou Meto Basin, Arkansas

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
RIVERINE OVERBANK	**SUBTYPE RO-1** 5-year floodplain within abandoned courses of the Arkansas River.	overcup oak, bitter pecan baldcypress, water elm, buttonbush	**Hydrology:** within the 5-year floodplain, but dominated by deep, relatively high velocity flood flows rather than backwater flooding. **Geomorphic Setting:** Primarily within abandoned Holocene courses of the Arkansas River. **Soils:** Perry, Portland	Abandoned Holocene courses of the Arkansas River that are currently occupied by smaller streams have narrow floodplains confined within the banks of the former, larger river. Wetlands on the floodplain and banks of the modern stream are subject to deep, prolonged overbank flows. Examples include Wabbaseka and Indian Bayous.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
RIVERINE OVERBANK	**SUBTYPE RO-2** Riverfront natural levee sites within the 5-year floodplain.	Sycamore, sugarberry, sweetgum, American elm, sweet pecan on natural levees of Bayou Meto and tributaries. Cottonwood, boxelder, sugarberry, sycamore on natural levees of the Arkansas River Overcup oak and bitter pecan in swales between natural levees	**Hydrology:** within the 5 year floodplain on natural levees adjacent to or near active channels **Geomorphic Setting:** natural levee and riverfront point bar **Soils:** Crevasse Rilla Oklared Roxana Coushatta Wabbaseka Latania Commerce	Vegetation composition and structure on these sites is related to proximity to the channel and associated high flows, light availability, and sedimentation. Most of these sites are on substantial natural levee deposits, but point bar deposits with little or no natural levee are included if they are directly adjacent to the channel. Deposits of Arkansas River origin characteristically are dominated by eastern cottonwood, which is replaced by sycamore on sediments deposited by smaller streams.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
RIVERINE OVERBANK	**SUBTYPE RO-3** Riparian areas on tributary streams	Water oak, willow oak, green ash, American elm, persimmon, cherrybark oak	**Hydrology:** within the 5-year floodplain on narrow riparian areas. Flooding typically frequent, but short-duration. **Geomorphic Setting:** Usually mapped as Holocene (or Recent) undifferentiated alluvium. **Soils:** Tichnor narrow areas of Calhoun and Oaklimeter	This subtype occupies narrow valleys draining the Grand Prairie. Streams are small, with narrow floodplains, and transition to slash on the upstream end, and into the backwater zone of larger streams on the downstream end. Sideslope areas above the floodplain are mapped as components of the upland forest type (subtype U-2).

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
RIVERINE BACKWATER	**SUBTYPE RB-1** Lower backwater zone, within the 1-2 year floodplain.	Overcup oak dominant, Nuttall & willow oak common associates	**Hydrology:** Mostly within the 1 or 2-year floodplain, and the dominant flood pattern is deep, long-duration, low velocity flows. **Geomorphic Setting:** primarily backswamp with local natural levee veneers, isolated point bar deposits. **Soils:** Perry Portland Sharkey Desha Moreland Bowdre	This subtype constitutes much of the Bayou Meto backwater area, where frequent flooding, runoff from higher ground, and sluggish internal drainage supports an extensive overcup oak forest with inclusions of minor rises dominated by other oak species and green ash. RB-1 is also mapped along some tributary stream valleys within the Grand Prairie, between the valley walls and the RO-3 overbank floodplain.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
RIVERINE BACKWATER	**SUBTYPE RB-2** Upper backwater zone, within the 5-year floodplain.	Willow oak with overcup oak in vernal pools	**Hydrology:** Within the 5-year floodplain, and the dominant flood pattern is relatively shallow, low velocity flows with extensive ponding after floods or extended rainy periods. **Geomorphic Setting:** primarily backswamp with local natural levee veneers, isolated point bar deposits. **Soils:** Perry Portland Sharkey Desha Moreland Bowdre	This subtype is frequently flooded, but is also strongly influenced by ponding of flood and rainwater well into the growing season in vernal pools of varying sizes. RB-2 is also mapped in Prairie Terrace tributary headwater areas where water ponds or moves sluggishly. These latter areas may support the slash community type.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
FLATS	**SUBTYPE F-1** Backswamp and point bar deposits of Bayou Meto outside the 5-year floodplain.	Delta post oak, water oak, swamp chestnut oak, mockernut hickory vernal pools dominated by willow oak green ash, Nuttall oak	**Hydrology:** Not within the 5-year floodplain. **Geomorphic Setting**: backswamp with natural levee veneer and some point bar deposits. Bayou Meto and other small streams are the principal source of the sediments supporting this type. **Soils:** Hebert	This subtype contains species not commonly seen in the riverine subtypes. The diversity and wetland character of the type is strongly influenced by vernal pools that pond precipitation and local runoff. Soils and hydrology (above the 5-year flood zone) together are the principal mapping criteria.
FLATS	**SUBTYPE F-2** Bayou Meto and tributaries high natural levee	swamp chestnut oak, cherrybark oak, sycamore, shagbark hickory, sweetgum, some white oak	**Hydrology:** Not within the 5-year floodplain. Precipitation is the principal water source. **Geomorphic Setting:** natural levee adjacent to old channels (high levees, not thin veneer) **Soils:** Rilla 1 to 3 % slope	Diverse forest type usually found adjacent to oxbow lakes and large depressions. Precipitation is stored in microdepressions, but larger vernal pools do not commonly occur.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
FLATS	**SUBTYPE F-3** Arkansas River high natural levee on abandoned courses.	water oak, sweet pecan, cherrybark oak, sycamore	**Hydrology:** Not within the 5-year floodplain. Precipitation is the principal water source. **Geomorphic Setting:** high natural levees adjacent to abandoned courses of Arkansas River **Soils:** Rilla Small areas of Keo in the upper NW corner of the basin.	These are usually very high features of marginal wetland character, but high diversity. They may have substantial slope but are classified as flats because the principal source of water is precipitation. Microdepressions may be common, but larger vernal pools do not occur in this subtype.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
FLATS	**SUBTYPE F-4** Arkansas River point bar	water oak, cherrybark oak, cedar elm, sugarberry, sweet pecan, shagbark hickory on ridges and backslopes, Nuttall oak and ash in vernal pools Occasional components include Delta post oak, Bur oak and southern red oak Vernal pools may be extensive in large swales	**Hydrology:** Not within the 5-year floodplain. Precipitation is the principal water source. **Geomorphic Setting:** point bar, point bar swales, sometimes with a natural levee veneer. **Soils:** Rilla Hebert Keo Caspiana Roxana Coushatta Wabbaseka Latanier McGhee Perry in swales	Extensive areas of this subtype have been cleared, and often leveled, for agriculture. High species diversity is related to subtle microrelief and ponding of precipitation in vernal pools and microdepressions.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
FLATS	**SUBTYPE F-5** Deweyville flats	Delta post oak Post Oak willow oak, Nuttall oak, green ash in vernal pools	**Hydrology:** Not within the 5-year floodplain. Precipitation is the principal water source. **Geomorphic Setting:** Deweyville terrace **Soils:** Calhoun Calloway Perry Portland	Soils do not distinguish this setting from adjacent surfaces, but geomorphic origin was distinctly different and produced very large vernal pools and depressions that may have functioned differently from those elsewhere in the basin. Evidence regarding species composition is largely inferential from other similar sites outside the Bayou Meto Basin and small disturbed fragments within, since all Deweyville in the basin is currently in agriculture.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
FLATS	**SUBTYPE F-6** Prairie terrace - hardwood flats	willow oak, post oak among pimple mounds willow oak, green ash, American elm in vernal pools post oak, cherrybark oak, southern red oak on mounds	**Hydrology:** Not within the 5-year floodplain. Precipitation is the principal water source. **Geomorphic Setting:** Prairie terrace **Soils:** Stuttgart Dewitt Calhoun Calloway Midland	These forests are characterized by a high degree of interspersion among micro-habitats, including upland species on mounds, post oak or mixed hardwood flats between mounds, and and large, shallow vernal pools which are typically ringed by mosses. Similar sites with very shallow fragipans are likely to support wet prairie or savannah.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
FLATS	**SUBTYPE F-7** Prairie terrace -wet prairie and slash	wet prairie habitats: prairie cordgrass-eastern gamma grass slash habitats: sugarberry, green ash, green hawthorn, stiff dogwood, deciduous holly, American elm	**Hydrology:** Not within the 5-year floodplain. Precipitation and local runoff are the principal water source. **Geomorphic Setting:** prairie terrace in swales and other poorly drained sites (wet prairie), or in the head of drainages (slash) **Soils:** Tichnor, Calhoun (now Ethel)	Wet prairie typically was restricted to fairly small areas where soil conditions, the presence of relic depressional features (e.g. old Arkansas River channels and swales) and the size of the local drainage source area all promoted development of wet inclusions within larger dry prairies. Slash habitats occur in the heads of drainage systems, and boundaries between the typical slash vegetation and adjacent prairie or forest was influenced by varying moisture levels and fire frequencies

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
CONNECTED DEPRESSION	**SUBTYPE D-1** Connected Depressions	baldcypress, tupelo, buttonbush, swamp privet, Water elm Perimeter zones and some shallow depressions may be dominated by overcup oak and bitter pecan.	**Hydrology:** within the 5-year floodplain. Stream flooding, groundwater and local runoff are the principal water sources. **Geomorphic Setting:** Within Holocene alluvium in abandoned channels or large point bar and backswamp swales. **Soils:** Yorktown Perry	Most connected depressions are cypress-dominated sites where surface water is no longer present by late summer. During floods (< 5-year frequency) these sites are directly connected to stream systems.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
ISOLATED DEPRESSION	**SUBTYPE D-2** Isolated Depressions	baldcypress, tupelo, buttonbush, swamp privet dominate most depressions. Perimeter zones and some shallow depressions may be dominated by overcup oak and bitter pecan. Swamp cottonwood may have occurred within isolated depressions on the Deweyville terrace is	**Hydrology:** Not within the 5-year floodplain. Groundwater and local runoff are the principal water sources. **Geomorphic Setting:** abandoned channels and point bar and backswamp swales in Holocene Deweyville Prairie Terrace alluvium. **Soils:** Yorktown Perry	Isolated depressions are similar to connected depressions in most respects, but lack connections to stream systems during flooding events.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
CONNECTED LACUSTRINE FRINGE	**SUBTYPE LF-1** Connected Fringe Wetlands	baldcypress, tupelo, buttonbush, water elm emergent vegetation	**Hydrology:** Within the 5-year floodplain. Stream flooding, groundwater and local runoff are the principal water sources. **Geomorphic Setting:** abandoned channels in Holocene alluvium **Soils:** Yorktown	Natural connected fringe wetlands in the basin are forested and emergent communities within oxbow lakes and beaver ponds with significant open-water area, that are inundated by river water during 5-year flood events. For mapping purposes, this category also includes numerous man-made ponds that may support fringe wetlands of willows, buttonbush, or other native species, but are often maintained with grassed banks.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
ISOLATED LACUSTRINE FRINGE	**SUBTYPE LF-2** Isolated Fringe Wetlands	baldcypress, tupelo, buttonbush, water elm emergent vegetation	**Hydrology:** Not within the 5-year floodplain. Groundwater and local runoff are the principal water sources. **Geomorphic Setting:** Abandoned channels in Holocene and Pleistocene alluvium. **Soils:** Yorktown	Natural isolated fringe wetlands in the basin are forested and emergent communities within oxbow lakes and beaver ponds with significant open-water area, that are not inundated by river water during 5-year flood events. For mapping purposes, this category also includes numerous man-made ponds that may support fringe wetlands of willows, buttonbush, or other native species, but are often maintained with grassed banks.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
UPLAND	**SUBTYPE U-1** Prairie terrace -dry prairie	Big bluestem, little bluestem, Indian grass, switch grass. Associated forbs	**Hydrology:** N/A **Geomorphic Setting:** prairie terrace **Soils:** Stuttgart (0 to 1%) Dewitt (0 to 1%) (formerly Crowley) Loring (1 to 3%) Immanuel (0 to 1%) (formerly Grenada)	This is a non-wetland subtype. Historic distribution and soils are the principal tools used to identify potential dry prairie areas.

(continued)

HGM SUBCLASS	SUBTYPE MAP DESIGNATION	CHARACTERISTIC PLANT COMMUNITIES	MAPPING CRITERIA	COMMENTS
UPLAND	**SUBTYPE U-2** Prairie terrace - Upland Forest or Savanna	Southern red oak/post oak woodland or post oak savanna on surfaces of the prairie terrace not occupied by wetlands or prairie. Post oak savanna along rim and upper side slopes of prairie terrace, transitioning to Delta post oak on lower slopes and Holocene and Deweyville surfaces. Riparian sideslopes include mixed species, transitioning from white oak, swamp chestnut oak, persimmon, red maple on lower colluvial areas to post oak on upper slopes.	**Hydrology:** N/A **Geomorphic Setting:** prairie terrace **Soils:** (Loring 3 to 8% and 8 to 20%) Immanuel (3 to 8%, and 15 to 25%)(formerly Grenada) Stuttgart 1 to 3% slope Dewitt (formerly Crowley)	This upland subtype includes a range of community types that reflect differing soil and drainage conditions, as well as changes in fire patterns that have tended to reduce the former extent of savanna areas.

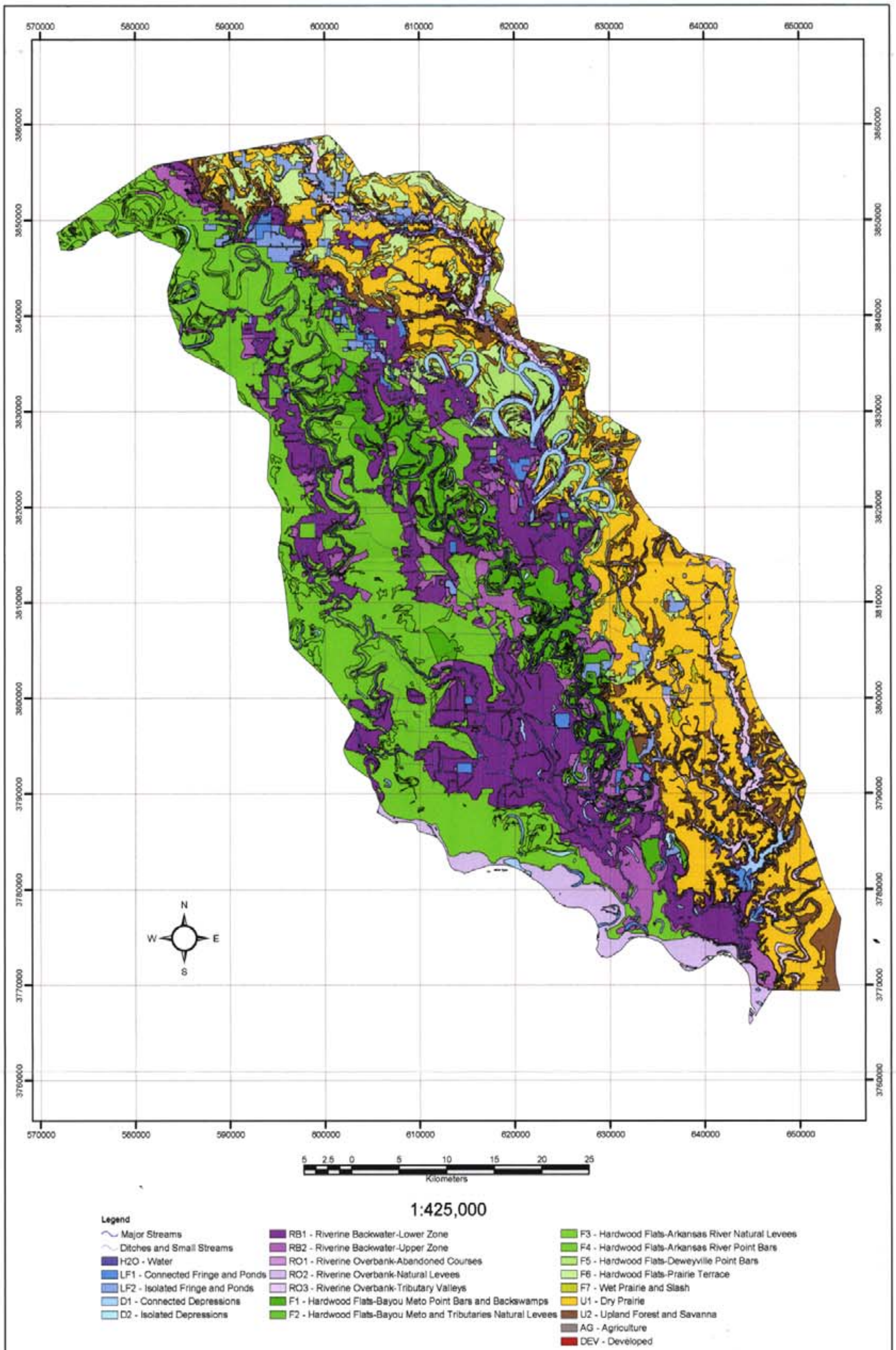


Figure 1. Arcview theme "Natural Communities" showing the potential natural vegetation of the Bayou Meto Basin, regardless of current land cover or land use.

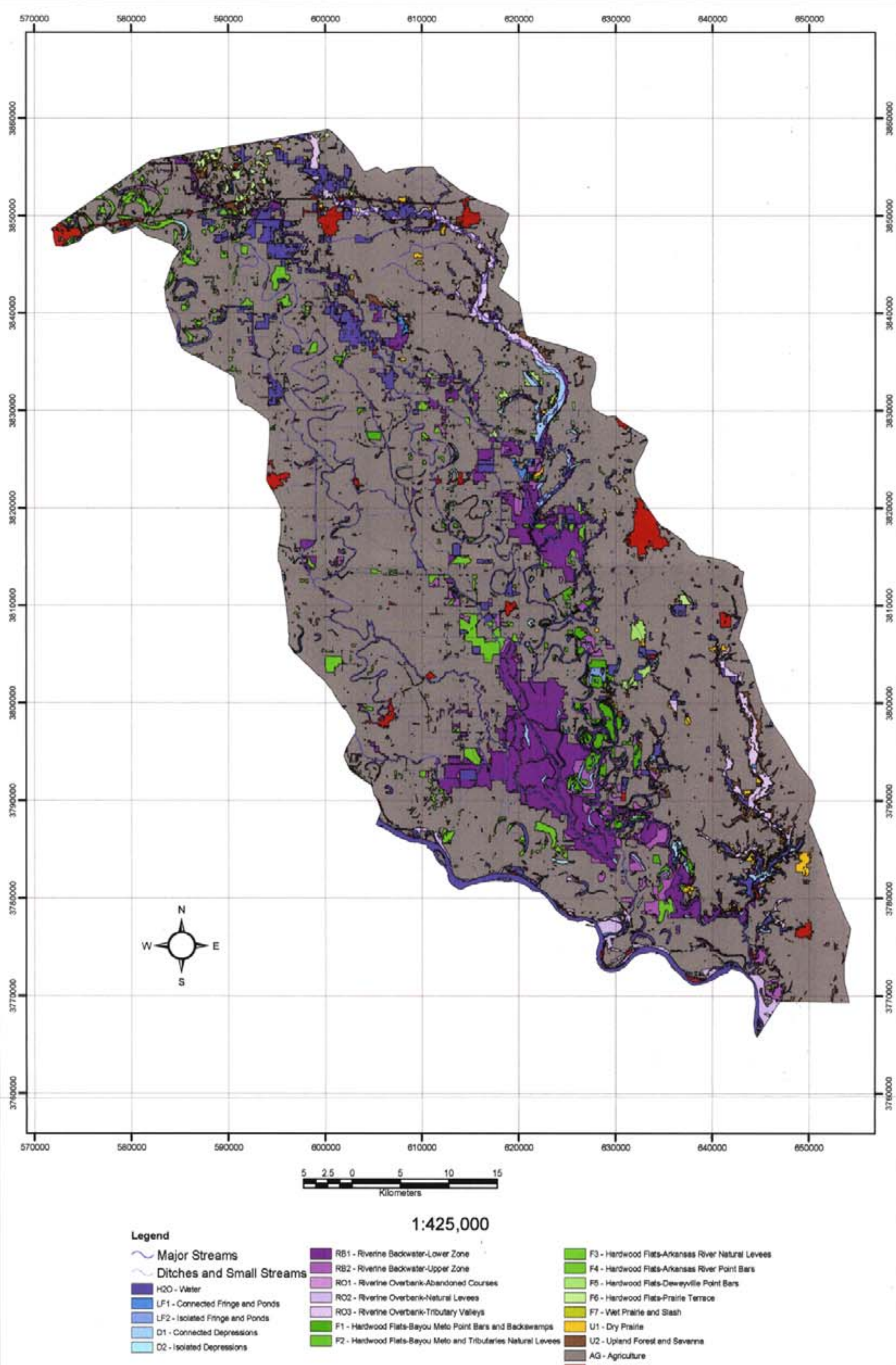


Figure 2. Arcview theme "Existing Condition" showing the current distribution of natural vegetation and other land uses in the Bayou Meto Basin.

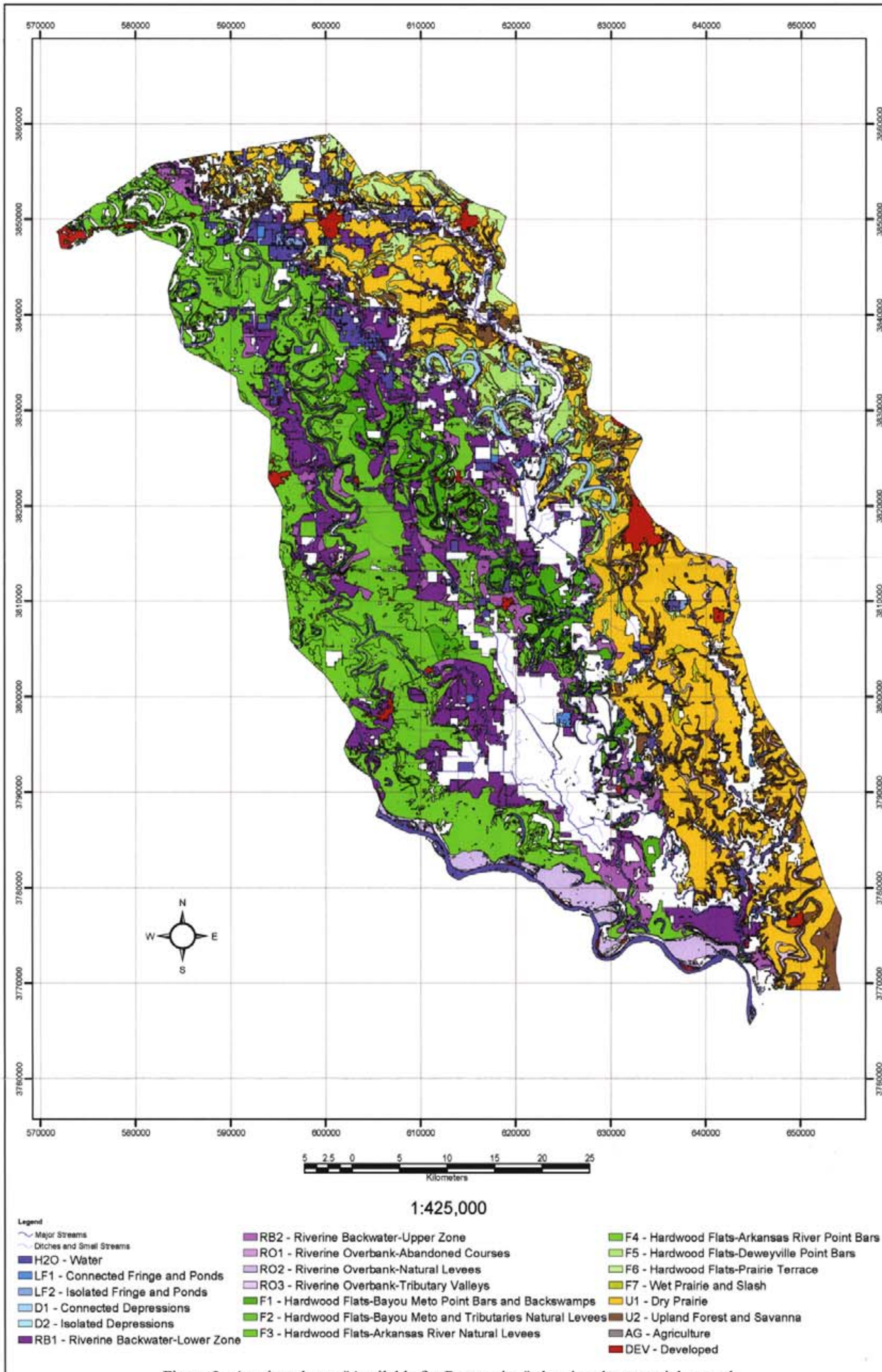


Figure 3. Arcview theme "Available for Restoration" showing the potential natural vegetation of areas that are currently in agriculture in the Bayou Meto Basin.

APPENDIX A

Metadata to accompany the Arcview themes illustrated in Figures 1,2, and 3, and provided in digital form within Appendix B.

Bayou Meto Restoration Alternatives Metadata
Metadata also available as

Metadata:

Identification_Information:
Citation:
Citation_Information:
Originator:
REQUIRED: The name of an organization or individual that developed the data set.
Publication_Date:
REQUIRED: The date when the data set is published or otherwise made available for release.
Title: natural_communities
Geospatial_Data_Presentation_Form: vector digital data
Online_Linkage: (none at this time)
Description:
Abstract:
Bayou Meto is a large drainage basin in the Arkansas Delta region with complex hydrology and geomorphic settings that supported diverse natural communities prior to European settlement. Over the past century, much of the Delta has been converted to agriculture, although extensive forested wetlands remain in the lower Bayou Meto drainage. The Bayou Meto Improvement Project will modify water regimes in portions of the basin, and is expected to generate compensatory mitigation obligations that will require wetland restoration within the boundaries of the study area.
Purpose:
This data set is an amalgamation of many data sets from many sources, brought together to perform an analysis of existing conditions and for the purpose of modeling wetland restoration alternative scenarios.
Supplemental_Information:
The suite of data files, in ESRI shape file format, that summarize this project are:
EXISTING_CONDITION.SHP
NATURAL_COMMUNITIES.SHP
RESTORABLE_AREA.SHP
MAJOR STREAMS.SHP

DITCHES AND SMALL STREAMS.SHP
Studies conducted by the Arkansas Multi-Agency Wetland Planning Team (MAWPT), have produced wetland classification and assessment tools that have direct applicability to planning and restoration prioritization within the proposed Bayou Meto Improvement Project area. The Arkansas wetland classification and assessment system is consistent with the Hydrogeomorphic (HGM) Approach being developed nationwide under guidelines established by the Corps of Engineers. This study employs the Arkansas HGM products (particularly the classification) in the context of a geographic information system to test restoration scenarios within the Bayou Meto basin. The planning tool provides a number of benefits in developing a restoration plan. These include: a. allowing proposed restoration scenarios to be clearly presented and documented in terms of appropriate vegetation and intended functional effectiveness for specific landscape settings b. allowing modifications to proposed restoration plans to be completed with minimal re-analysis and justification c. allowing consideration of ecosystem integrity and diversity on a landscape scale d. improving the efficiency and effectiveness of the final restoration plan. As mentioned in the PURPOSE section, this data set is the product of combining many data sets. The following are the sources of the original data sets: Land Use/Land Cover - LULC - data is from the University of Arkansas, Fayetteville Center for Advanced Spatial Technologies (CAST) website at: <http://www.cast.uark.org/>. This site is a consolidation of data, technologies, research and training for all aspects of geospatial data involving the state of Arkansas. U.S. Army Corps of Engineers, Vicksburg District produced and provided the data layers for flood returns at the intervals 10, 5, 2, and 1 year returns pre and post project. The point of contact was Mr. Dave Johnson. The data was retrieved from an anonymous ftp web site. A site for free downloads of Digital Raster Graphic data was found at www.pipeline.com/~rking/gobb.htm. This site provided USGS 7.5 minute quadrangle maps in digital, geo-rectified format. Information was also extracted from geomorphology maps for the Lower Bayou Meto basin. Two sources were referenced for this information; a 1994 publication of 1:250,000 geomorphology series of maps produced by Roger Saucier, and folio of maps for the Bouef - Tensas Basin at the USGS 15 minute series scale. A few maps beyond the extent of the Bouef - Tensas folio collection were included to complete coverage of the project area.
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 20040507
Currentness_Reference: publication date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: Irregular
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -92.223256

East_Bounding_Coordinate: -91.311935
North_Bounding_Coordinate: 34.869769
South_Bounding_Coordinate: 34.021169
Keywords:
Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: Wetlands
Theme_Keyword: Restoration
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: Bayou Meto Basin
Place_Keyword: Lower Mississippi Valley
Place_Keyword: Memphis District
Stratum:
Stratum_Keyword_Thesaurus: None
Stratum_Keyword: Terrestrial
Stratum_Keyword: Surface
Temporal:
Temporal_Keyword_Thesaurus: None
Temporal_Keyword: 2001
Access_Constraints:
These data and the complete data set are public domain data and as such access to these data is not restricted.
Use_Constraints:
These and the associated data sets were produced by contract for the U.S. Army Corps of Engineers, Memphis District. They are intended for the explicit use of the USACE Memphis District to assist the MAWPT in decision making for the Bayou Meto Improvement Project. No warranty is extended beyond the intended use of the data.
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Edward.P.Lambert
Contact_Organization: US Army Corps of Engineers, Memphis District, CEMVM-PM-E
Contact_Address:
Address_Type: mailing and physical address
Address: U.S. Corps of Engineers
Address: Memphis District Office CEMVM-PM-E
Address: Clifford Davis Federal Building
City: Memphis
State_or_Province: TN
Postal_Code: 38103-1894
Country: USA
Contact_Voice_Telephone: 901.544.0707
Contact_Electronic_Mail_Address: Edward.P.Lambert@MVM02.usace.army.mil

Hours_of_Service: 8:00 AM - 5:00 PM
Contact_Instructions: Phone or email
Data_Set_Credit:
Data Creation: Principal Investigator: Morris Mauney, Ph.D. Branch Chief US Army Engineer Research and Development Center CEERD-EE-W (Attn: Dr. Mauney) 3909 Halls Ferry Road Vicksburg, MS 39180-6199 Contact Voice Telephone: 601.634.4258 Contact facsimile Telephone: 601.634.3205 Contact Electronic Mail: Morris.Mauney@erdc.usace.army.mil Contract Wetlands Ecologist: Charles Klimas Klimas and Associates Inc. 12301 Second Avenue NE Seattle, WA 98125 Contact Voice Telephone: 206.365.2008 Contact facsimile Telephone: 206.365.2018 Contact Electronic Mail: cvklimas@attbi.com GIS/Remote Sensing Physical Scientist: Michael Bishop Engineer Research and Development Center CEERD-EE-C (Attn: Michael Bishop) 3909 Halls Ferry Road Vicksburg, MS 39180-6199 Contact Voice Telephone: 601.634.4258 Contact facsimile Telephone: 601.634.3205 Contact Electronic Mail: Michael.J.Bishop@erdc.usace.army.mil
Security_Information:
Security_Classification_System: None
Security_Classification: Unclassified
Security_Handling_Description: No Special Handling Instructions.
Native_Data_Set_Environment:
Microsoft Windows 2000 Version 5.0 (Build 2195) Service Pack 4; ESRI ArcCatalog 8.3.0.800

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
The Value Accuracy is entered as an interval scale assigned to kappa or overall percent correct ratio scales. The assigned values are as follows: 0 - kappa 96-100% overall 99-100% 1 - kappa 91-95% overall 96-99% 2 - kappa 86-90% overall 91-95% 3 - kappa 81-85% overall 86-90% 4 - kappa 76-80% overall 81-85% 5 - kappa 71-75% overall 76-80% 6 - kappa 66-70% overall 71-75% 7 - kappa 60-65% overall 65-70% 8 - kappa less than 60% or overall less than 65% 9 - attribute accuracy unknown
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value: 3
Attribute_Accuracy_Explanation:
The value 3 is an overall estimation of accuracy based upon the data sources used to produce the final GIS composite products.
Logical_Consistency_Report:
Polygon topology present. ESRI Arc/Info command BUILD <cover> POLY, completed successfully.
Completeness_Report: Complete
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:

When describing the horizontal accuracy, the input data sources must be considered. And as with significant digits in mathematical calculations, the horizontal accuracy is only as accurate as the least accurate input data source. In this study the horizontal accuracy is limited by those data generated from 30 meter pixel Landsat image data (i.e. Land Use/Land Cover). At best the horizontal accuracy for this input layer would be at or near one pixel which would limit the horizontal accuracy from 30 to 35 meters.
Lineage:
Process_Step:
Process_Description:
Theses data layers were assembled in this order (lower layers were added first): Riverine Overbank-Abandoned Courses Water Connected Depressions Isolated Depressions Riverine Overbank-Tributary Valleys Riverine Backwater-Lower Zone Riverine Backwater-Upper Zone Wet Prairie and Slash Riverine Overbank-Natural Levees Dry Prairie Hardwood Flats-Bayou Meto and Tributaries Natural Levees Hardwood Flats-Arkansas River Natural Levees Hardwood Flats-Bayou Meto Point Bars and Backswamps Hardwood Flats-Arkansas River Point Bars Hardwood Flats-Deweyville Point Bars Hardwood Flats-Prairie Terrace Upland Forest and Savanna
Process_Date: December, 2001
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Michael J. Bishop
Contact_Organization:
US Army Engineer Research and Development Center, Environmental Laboratory, Ecosystem Evaluation and Engineering Division
Contact_Address:
Address_Type: mailing and physical address
Address: Engineer Research and Development Center
Address: CEERD-EE-C (Attn: M. Bishop)
Address: 3909 Halls Ferry Road
City: Vicksburg
State_or_Province: MS
Postal_Code: 39180-6199
Country: USA
Contact_Voice_Telephone: 601.634.2569
Contact_Facsimile_Telephone: 601.634.3205
Contact_Electronic_Mail_Address: Michael.J.Bishop@erdc.usace.army.mil
Hours_of_Service: 8:00 AM - 5:00 PM
Contact_Instructions: Phone Direct or email

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:

SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 13493

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Universal Transverse Mercator
Universal_Transverse_Mercator:
UTM_Zone_Number: 15
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.999600
Longitude_of_Central_Meridian: -93.000000
Latitude_of_Projection_Origin: 0.000000
False_Easting: 500000.000000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000256
Ordinate_Resolution: 0.000256
Planar_Distance_Units: meters
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label:
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:

Attribute_Label: AREA
Attribute:
Attribute_Label: PERIMETER
Attribute:
Attribute_Label: UNIT
Attribute_Definition: Abreviated class description
Attribute:
Attribute_Label: DESCRIPT
Attribute_Definition: HGM class description
Attribute:
Attribute_Label: LABEL
Attribute_Definition: UNIT and DESCRIPTION added together
Overview_Description:

Distribution_Information:
Distributor:
Contact_Information:
Contact_Person_Primary:
Contact_Person: Edward P. Lambert
Contact_Organization: US Army Corps of Engineers, Memphis District, CEMVM-PM-E
Contact_Address:
Address_Type: mailing and physical address
Address: U.S. Army Corps of Engineers
Address: Memphis Discrict Office CEMVM-PM-E
Address: Clifford Davis Federal Building
City: Memphis
State_or_Province: TN
Postal_Code: 38103-1894
Country: USA
Contact_Voice_Telephone: 901.544.0707
Contact_Electronic_Mail_Address: Edward.P.Lambert@MVM02.usace.army.mil
Hours_of_Service: 8:00 AM - 5:00 PM
Resource_Description: Downloadable Data
Distribution_Liability:
These data were developed for the sole, intended use of the cited team listed under Data_Set_Credit and the US Army Corps of Engineers, Memphis District. No warranty exists nor is implied for any other use of this data.
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 13.307
Ordering_Instructions:
Inquire for details from US Army Corps of Engineers, Memphis District
Custom_Order_Process:
Inquire for details from US Army Corps of Engineers, Memphis District.

Technical_Prerequisites: Software/hardware that reads or imports ESRI formatted files.

Metadata_Reference_Information:
Metadata_Date: 20040507
Metadata_Review_Date: 20040507
Metadata_Future_Review_Date: unknown
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization:
US Army Engineer Research and Development Center, Environmental Laboratory, Ecosystem Evaluation and Engineering Division
Contact_Person: Michael J. Bishop
Contact_Address:
Address_Type: mailing and physical address
Address: U.S. Army Research and Development Center
Address: CEERD-EE-C (Attn: M. Bishop)
Address: 3909 Halls Ferry Road
City: Vicksburg
State_or_Province: MS
Postal_Code: 39180-6199
Country: USA
Contact_Voice_Telephone: 601.634.2569
Contact_Facsimile_Telephone: 601.634.4016
Contact_Electronic_Mail_Address: Michael.J.Bishop@usace.erdc.army.mil
Hours_of_Service: 8:00 AM - 5:00 PM
Contact_Instructions: Phone or email
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints:
To be determined by US Army Corps of Engineers, Memphis District
Metadata_Use_Constraints:
To be determined by US Army Corps of Engineers, Memphis District
Metadata_Security_Information:
Metadata_Security_Classification_System: None
Metadata_Security_Classification: Unclassified
Metadata_Security_Handling_Description:
To be determined by US Army Corps of Engineers, Memphis District
Metadata_Extensions:
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

Generated by mp version 2.7.33 on Fri May 07 13:11:38 2004

APPENDIX B

Document text and

Arcview shapefiles

(provided on separate disc)