Intensive Water Quality Survey of Warrior River Basin Reservoirs 1998

Environmental Indicators Section
Field Operations Division
Alabama Department of Environmental Management

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FINAL REPORT

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Preface

This project was funded or partially funded by the Alabama Department of Environmental Management utilizing a Clean Water Act Section 319(h) nonpoint source demonstration grant provided by the U.S. Environmental Protection Agency - Region 4.

Comments or questions related to this report should be addressed to:

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EXECUTIVE SUMMARY

In 1998, intensive monitoring of reservoirs in the Warrior basin was conducted to align reservoir monitoring with the ADEM nonpoint source basin schedule. Objectives of the intensive survey were to:

a) assess water quality and trophic state of reservoir and tributary embayment locations in the Black Warrior River Basin;
b) identify tributary embayments most impacted by point and nonpoint source (NPS) pollution;
c) assist the Nonpoint Source Unit of ADEM in prioritization of subwatersheds by determining the water quality of tributary embayments; and,
d) determine concentrations of bioaccumulative contaminants in fish of mainstem reservoir and tributary embayment locations.

Tributary embayment locations were targeted because embayments usually exhibit water quality characteristics that are more indicative of the tributary than of the mainstem reservoir. Selecting mainstem reservoir stations allows a determination of the effects of the tributary inflows on the main body of the reservoir.

Sampling stations were determined using historical data and preliminary results of the Black Warrior River basin screening assessment conducted in 1997. A maximum of 20 mainstem and tributary embayment sampling locations were determined by available funding. Water quality assessments were conducted at locations throughout the Warrior basin at monthly intervals April-October.

Chemical, physical, and biological variables were measured at each location to determine water quality and trophic state. Water quality data selected for further discussion consist of the following:

a) total nitrogen (TN) and total phosphorus (TP), used as indicators of nutrient content in the waterbody;

b) algal growth potential tests (AGPT), used as a determinant of the total

quantity of algal biomass supportable by test waters and of the limiting nutrient;

c) corrected chlorophyll *a* (chl. a), used as an indicator of algal biomass;

d) Carlson Trophic State Index (TSI), calculated from corrected chlorophyll *a* concentrations as a means of trophic state classification of a reservoir or embayment;

e) dissolved oxygen (DO) concentrations, used as a more direct indicator of water quality;

f) total suspended solids (TSS), used as an indicator of sediment inflow; and,

g) bioaccumulative contaminant concentrations in fish tissue.

With the exception of fish contaminant concentrations, these variables were selected because of their relationship to the process of eutrophication and their interest to the regulatory and scientific communities that stems from this relationship.

Bioaccumulative contaminant concentrations in fish tissue were selected because waterbodies are among the ultimate repositories of pollutants released by intensifying urbanization, industrial development, and use of agricultural chemicals (EPA 1995). Once these toxic contaminants reach surface waters, they may concentrate through aquatic food chains and bioaccumulate in fish tissues.

Smith Reservoir. With the exception of the Crooked Creek embayment, mean nutrient, chlorophyll *a*, and TSS concentrations in Smith Reservoir were among the lowest of Warrior basin locations. AGPT results indicated that the Sipsey, mid, and lower reservoir locations were phosphorus limited, with mean maximum standing crop (MSC) values well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes. Mean TP concentrations were higher in 1998 than in 1995, however, indicating the need for future monitoring to determine water quality trends. Trophic state index values of these locations were within the oligotrophic to mesotrophic range during the course of this study. For a more detailed discussion of water quality in Lewis Smith Reservoir, including tributary embayment locations other than Crooked Creek, consult the Lewis Smith Lake Phase I Diagnostic/Feasibility Final Report (ADEM 1998).

Nutrient and chlorophyll *a* concentrations in the Crooked Creek embayment are a concern and should be investigated further. Mean values from the embayment were much higher than those of other locations in Smith Reservoir with TP values among the higher values in the Warrior basin. Though DO concentrations were well above the ADEM Water Criteria (1997) limit of 5.0 mg/l when sampled, 63-81% of the water column at this sampling location was essentially deoxygenated from July-October.

Funding constraints prevented fish tissue sample collection in Smith Reservoir during the course of this study. Results of sampling conducted in the Ryan and Rock Creek embayments and the Sipsey Fork of Smith Reservoir during 1993 indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits in all fish collected.

Tuscaloosa Reservoir. Water quality data from Tuscaloosa Reservoir indicated few concerns. Mean TN and TP concentrations were the lowest overall of Warrior basin locations. Algal growth potential tests indicated that phosphorus was either the limiting or co-limiting nutrient at all reservoir locations with the mean MSC from these locations well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes. Lake mean TN and TP concentrations increased for several months as mean lake discharge decreased, usually indicative of the presence of point source contributions though only one semi-public/private permitted discharge is listed for the lower North River sub-watershed (ADEM 1999). The origins of these nutrient concentrations should be the subject of further study.

Mean chlorophyll *a* and TSS concentrations were among the lowest of basin locations. However, upper and mid reservoir locations reached eutrophic levels in certain months while the lower reservoir ranged from oligotrophic to mesotrophic levels during the study. DO concentrations were above the criterion limit in all months sampled, however the majority of the water column in the upper reservoir was essentially deoxygenated May-September. Given the eutrophic conditions and low oxygen concentrations of the upper reservoir, continued monitoring is advised to determine water quality trends in this reservoir.

Laboratory analyses of largemouth bass and catfish collected from the North River location of Tuscaloosa Reservoir indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits.

Bankhead Reservoir. Water quality concerns for Bankhead Reservoir are centered primarily in the Locust Fork and Valley Creek embayments. The highest mean TN concentrations measured in the basin occurred in these locations. The highest mean TP value measured in the basin occurred in the Valley Creek embayment with that of the Locust Fork among the highest. The highest mean chlorophyll *a* concentrations measured in the basin occurred in these locations with that of the Valley Creek embayment greater than twice that of the next highest location, the Locust Fork. TSI values in the Valley Creek embayment reached hypereutrophic levels in June and were near these levels August-September. TSI values in Locust Fork were highly eutrophic in August. DO concentrations in the Locust Fork were near criterion limits in May and September. DO concentrations in the upper water column of the Valley Creek embayment exceeded the measuring capacity of monitoring equipment on two occasions because of high algal densities.

From May-July and September-October, conductivity values in the Lost Creek embayment often increased an order of magnitude or more below a depth of 3 meters. An increase of this magnitude was not observed at any other location in the basin. Further research is suggested in the sub-watershed to more specifically determine origins of the increase in conductivity values and the effect on biological communities.

Laboratory analyses of largemouth bass and catfish collected from all locations of Bankhead Reservoir indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits.

Holt Reservoir. Water quality data from mainstem Holt Reservoir indicated few concerns. Mean TN and TP concentrations were similar to or below those of other mainstem Warrior reservoir locations. Phosphorus was indicated as the limiting nutrient at both locations with mean MSC values well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes. Lake mean TN and TP concentrations increased for several months as mean lake discharge decreased, indicating that point sources may be a major contributor to nutrient concentrations.

Mean chlorophyll *a* concentrations in Holt Reservoir were similar to or below those of most other mainstem Warrior reservoir locations. TSI values in the upper reservoir were within the eutrophic range May-September, while those of the lower reservoir were within the eutrophic range in June, August, and September. Given the eutrophic conditions observed, continued monitoring is advised to determine trophic state trends.

Mean TSS concentrations were similar to or far below those of most other mainstem Warrior reservoir locations.

DO concentrations at both locations in Holt Reservoir remained above the criterion limit on all dates sampled though values from the lower reservoir in October were near the limit. Most of the water column remained oxygenated throughout the study period.

Laboratory analyses of largemouth bass and catfish collected from Holt Reservoir indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits.

Oliver Pool. Water quality data from Oliver Pool indicated concerns based on higher mean TP concentrations, lower mean chlorophyll *a* concentrations, and higher mean TSS concentrations than in upstream mainstem Warrior locations in addition to low dissolved oxygen concentrations in July and August. Data collected during September influenced the mean values greatly.

TP concentrations increased sharply in August and September though mean lake discharge remained low. Mean chlorophyll *a* concentrations declined sharply during

September though algal densities typically remain relatively high in reservoirs during this month of the growing season. TSS concentrations were also much higher in September than in other months. The source of the suspended solids is unknown though area rainfall estimates indicate that runoff may have been involved. It is likely that the high TSS concentrations and resulting lack of available light played a role in the sharp drop in temperatures observed in September at the lower reservoir location. The reduction in available light caused by high TSS concentrations may have also had a detrimental effect on algal populations, resulting in a decrease in chlorophyll *a* concentrations. DO concentrations in the upper reservoir were below criterion limits during July and August.

Laboratory analyses of bass and catfish collected from Oliver Pool and catfish collected from the Hurricane Creek embayment indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits. The scarcity of fish at the Hurricane Creek location was especially noteworthy and should be investigated further.

Warrior Reservoir. Water quality data from Warrior Reservoir indicated concerns based on mean TP concentrations, mean chlorophyll *a* concentrations, and mean TSS concentrations that were among the highest of Warrior basin locations. In addition, DO concentrations were near or below criterion limits when sampled in October.

Mean TP concentrations of the upper reservoir were second highest of all Warrior basin locations and highest of mainstem reservoir locations. The mean TP concentrations of the upper reservoir did not persist into the mid and lower reservoir locations. Lake mean TP concentrations increased sharply as lake discharge decreased, indicating that point sources were a major contributor to the concentrations.

The effect of the TP concentrations in the upper reservoir were observed in the mean chlorophyll *a* concentrations of the upper and mid reservoir, which were among the highest of Warrior basin locations.

DO concentrations in the lower reservoir were near criterion limits July-August and below the limits in October. In October, DO concentrations in the lower reservoir were below 5.0 mg/l from the surface to the lake bottom.

Laboratory analyses of bass and catfish collected from Warrior Reservoir indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits.

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INTRODUCTION

ADEM Reservoir Water Quality Monitoring Program

The Alabama Department of Environmental Management (ADEM) has defined publicly-owned lakes/reservoirs as those that are of a multiple-use nature, publicly-accessible, and exhibit physical/chemical characteristics typical of impounded waters. Lakes designated strictly for water supply, privately owned lakes, or lakes managed by the Alabama Department of Conservation and Natural Resources (ADCNR) strictly for fish production are not included in this definition. Lakes meeting the above definition are listed in Figure 1.

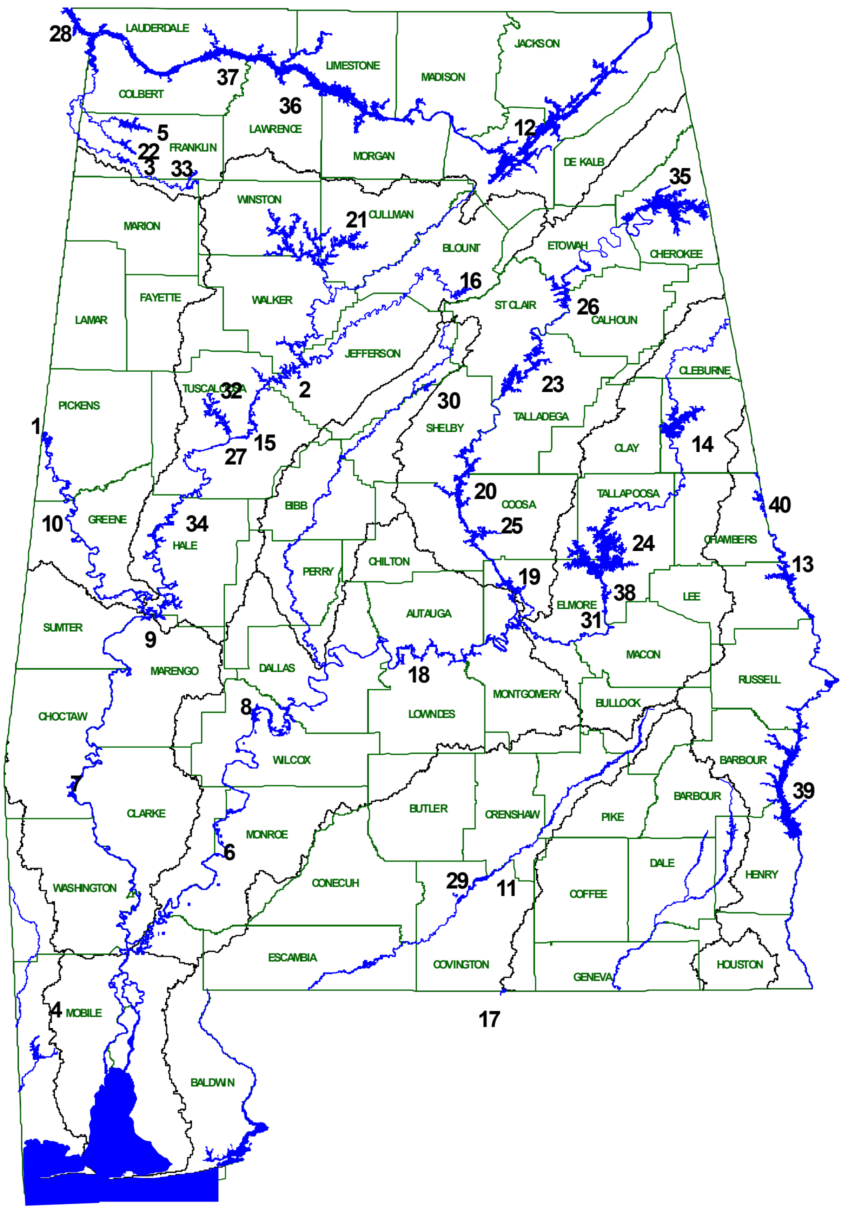
In 1990, the Reservoir Water Quality Monitoring (RWQM) Program was initiated by then Special Studies Section of the Field Operations Division of ADEM. Objectives of the program are as follows:

a) to develop an adequate water quality database for all publicly-owned lakes in the state;
b) to establish trends in lake trophic status that can only be established through long-term monitoring efforts; and,
c) to satisfy the requirement of Section 314(a)(1) of the Water Quality Act of 1987 that states conduct assessments of the water quality of publicly-owned lakes and report the findings as part of their biennial Water Quality Report to Congress.

Acquiring this information enables the ADEM to determine lake water quality and identify those in which water quality may be deteriorating. Should a deterioration in lake water quality be indicated by collected data, more intensive study of the lake can be instituted to establish causes and extent of the deterioration.

Figure 1.

Alabama Publicly Accessible Reservoirs



1) Aliceville
2) Bankhead
3) Bear Creek
4) Big Creek
5) Cedar Creek
6) Claiborne
7) Coffeeville
8) Dannelly
9) Demopolis
10) Gainesville
11) Gantt
12) Guntersville
13) Harding
14) Harris
15) Holt
16) Inland
17) Jackson
18) Jones Bluff
19) Jordan
20) Lay
21) Lewis Smith
22) Little Bear Creek
23) Logan-Martin
24) Martin
25) Mitchell
26) Neely Henry
27) Oliver
28) Pickwick
29) Point A
30) Purdy
31) Thurlow
32) Tuscaloosa
33) Upper Bear Creek
34) Warrior
35) Weiss
36) Wheeler
37) Wilson
38) Yates
39) W. F. George
40) West Point

In 1996, the Nonpoint Source Unit (NPSU) of the Office of Education and Outreach of ADEM adopted a watershed assessment strategy. The intent of the watershed management approach is to synchronize water quality monitoring, assessment, and implementation of control activities on a geographic basis. In Alabama, the major drainage basins are monitored on a 5-year rotation basis. Concentrating monitoring efforts within one basin provides the NPSU with a framework for more centralized management and implementation of control efforts and provides consistent and integrated decision making for awarding Clean Water Act Section 319 NPS funds.

In 1997, the Environmental Indicators Section (EIS) of the Field Operations Division of ADEM initiated a screening assessment of the Black Warrior River sub-basin with the use of Section 319 NPS funds (ADEM 1998). The initial goal of the project was to provide data that would allow ADEM to estimate the current status in ecological conditions throughout the sub-basin using indicators of biological, habitat, and chemical/physical conditions. This information could then be used by the NPSU to prioritize sub-watersheds most impacted by nonpoint source pollution and to use resources most effectively by directing BMP implementation and demonstration within priority watersheds.

In 1998, intensive monitoring of reservoirs in the Warrior basin was proposed to align reservoir monitoring with the ADEM nonpoint source basin schedule. Location of sampling stations were determined using historical data and preliminary results of the Black Warrior River basin screening assessment conducted in 1997. The intent of the reservoir water quality assessment project was to provide data that would allow ADEM to estimate the current water quality and trophic state of impounded waters of the Black Warrior River Basin to the degree possible with the limited funding available.

As tributary embayments of reservoirs often exhibit water quality characteristics more indicative of the tributary than of the mainstem reservoir, the assessment would aid in the determination of the tributaries most affected by nonpoint source and point source pollution. Objectives of the intensive survey were to:

1) assess water quality and trophic state of reservoir and tributary embayment locations in the Black Warrior River Basin;
2) identify tributary embayments most impacted by point and nonpoint source (NPS) pollution;
3) assist the Nonpoint Source Unit of ADEM in prioritization of subwatersheds by determining the water quality of tributary embayments; and,
4) determine concentrations of bioaccumulative contaminants in fish of mainstem reservoir and tributary embayment locations.

Information collected by the Reservoir Water Quality Assessment of the Black Warrior Basin will also be used to update the 305(b) Water Quality Report to Congress as well as the ADEM Reservoir Water Quality and the ADEM Fish Tissue Monitoring Programs databases.

MATERIALS AND METHODS

Water Quality Sampling Locations

Intensive monitoring consisted of monthly water quality sampling, April-October, at multiple locations of reservoirs within the basin. Reservoirs sampled appear in Table 1. Locations of sampling sites appear in Table 2. Water quality measurements and water sample collections were conducted from boats positioned at the deepest point of the channel at each sampling site.

Water Quality Assessment

Water quality assessments were conducted at 20 mainstem reservoir and tributary embayment locations throughout the Warrior basin at monthly intervals April-October. All locations were sampled within a one-week period each month to reduce weather-related variability in water quality conditions. Chemical, physical, and biological variables were measured at each location to determine water quality and trophic state.

Monitoring and analyses were conducted in accordance with appropriate standard operating procedures. Water quality variables measured during 1998 appear in Table 3.

At each sampling site temperature, dissolved oxygen, specific conductance, and pH were measured in situ at multiple depths in the water column with Hydrolab Surveyor III instruments.

A standard, 20 cm diameter Secchi disk with attenuating black and white quadrants was used to measure visibility. Photic zone depth determinations were made by measuring the vertical illumination of the water column using an underwater

Table 1. Reservoirs sampled during the 1998 Intensive Water Quality Survey of Warrior Basin Reservoirs.

Year	**River Basin**	**Reservoir**	**Surface Area (acres)**	**Drainage Area (mi^2)**
1998				
	Warrior			
		Lewis Smith	21,200	944
		Tuscaloosa	5,885	416
		Bankhead	9,200	3,969
		Holt	3,296	4,232
		Oliver	800	4,820
		Warrior	7,800	5,810

Table 2. Monitoring sites for the 1998 Intensive Water Quality Survey of Warrior Basin Reservoirs.

Year	Basin	Reservoir	Site	Station Description
1998				
	Warrior			
		Smith	Sta. 1	Deepest point, main river channel, dam forebay .
			Sta. 2	Deepest point, main river channel, at Duncan Creek / Sipsey River confluence. Downstream of Alabama Highway 257 bridge.
			Sta. 3a	Deepest point, main river channel, approximately 0.5 miles downstream of the Sipsey Fork, Yellow Creek confluence.
			Sta. 4	Deepest point, main channel, Crooked Creek embayment. Approx. 1.5 miles upstream of Winston Cty. Rd. 22 bridge.
		Tuscaloosa	Sta. 1	Deepest point, main river channel, dam forebay .
			Sta. 2	Deepest point, main river channel, immediately downstream of Binion Creek confluence.
			Sta. 3	Deepest point, main river channel, approx. 1 mile downstream of Alabama Hwy. 69 bridge.
		Bankhead	Sta. 1	Deepest point, main river channel, dam forebay .
			Sta. 2	Deepest point, main river channel, mid-reservoir. Approx. 0.5 mi. upstream of Little Shoal Creek confluence.
			Sta. 3	Deepest point, main river channel, Locust Fork. Approx. 1.5 mi. upstream of Mulberry, Locust confluence
			Sta. 4	Deepest point, main river channel, Mulberry Fork. Approx. 1.5 mi. upstream of Mulberry, Locust confluence
			Sta. 5	Deepest point, main creek channel, Lost Creek embayment. Approx. 0.5 mi. downstream of Walker Cty. Rd. 53 bridge.
			Sta. 6	Deepest point, main creek channel, Valley Creek embayment. Approx. 1 mile upstream of confluence with Black Warrior.
		Holt	Sta. 1	Deepest point, main river channel, dam forebay .
			Sta. 2	Deepest point, main river channel, mid-reservoir. Immed. upstream of Pegues Creek, Black Warrior confluence
		Oliver	Sta. 1	Deepest point, main river channel, dam forebay.
			Sta. 2	Deepest point, main river channel, mid-reservoir. Immed. downstream of North River, Black Warrior confluence.
		Warrior	Sta. 1	Deepest point, main river channel, dam forebay.
			Sta. 2	Deepest point, main river channel, immediately downstream of Lock 8 Public Use Area.
			Sta. 3	Deepest point, main river channel, at Lock 9 Public Use Area.

Table 3. Water quality variables measured during the 1998 Intensive Water Quality Survey of Warrior Basin Reservoirs.

Variable	Method	Reference	Detection Limit
Physical			
Vertical illumination	Photometer, Secchi disk	Lind, 1979	---
Temperature	Thermistor	APHA et al. 1992	---
Turbidity	Nephelometer	APHA et al. 1992	---
Total dissolved solids	Filtration, drying	EPA-600/4-79-020	1 mg/l
Total suspended solids	Filtration, drying	EPA-600/4-79-020	1 mg/l
Specific conductance	Wheatstone bridge	APHA et al. 1992	---
Hardness	Titrametric, EDTA	EPA-600/4-79-020	1 mg/l
Alkalinity	Potentiometric titration	EPA-600/4-79-020	1 mg/l
Chemical			
Dissolved oxygen	Membrane electrode	APHA et al. 1992	---
pH	Glass electrode	APHA et al. 1992	---
Ammonia	Automated phenate	EPA-600/4-79-020	0.015 mg/l
Nitrate + Nitrite	Cadmium reduction	EPA-600/4-79-020	0.003 mg/l
Total Kjeldahl Nitrogen	Automated colorimetric	EPA-600/4-79-020	0.15 mg/l
Soluble reactive phosphorus	Automated single reagent	EPA-600/4-79-020	0.004 mg/l
Total phosphorus	Persulfate digestion	EPA-600/4-79-020	0.004 mg/l
Total organic carbon	Persulfate-ultraviolet	EPA-600/4-79-020	0.50 mg/l
Biological			
Chlorophyll a	Spectrophotometeric	APHA et al. 1992	0.1
Fecal coliform	Membrane filter	APHA et al. 1992	---
Algal growth potential test	Printz Algal Assay Test	ADEM 1993	---

photometer. The depth at which one percent of the surface illumination was measured by the photometer was considered the photic zone depth. A composited water sample of twenty liters was collected from the photic zone. The sample was collected by raising and lowering a plastic submersible pump-and-hose apparatus repeatedly through the photic zone while collecting the sample in a plastic container. Withdrawal of individual samples from the composited water sample occurred in the order presented in the following paragraph.

Chlorophyll a samples were collected by filtering a minimum of 500 ml of the composited photic zone sample through glass fiber filters immediately after collection of the composited sample. Immediately after filtering, each filter was folded once and placed in a 50 mm petri dish. Each petri dish was wrapped in aluminum foil, sealed in a ziploc bag, and placed on ice for shipment to the Field Operations Division to be frozen until analyzed. Corrected chlorophyll *a* concentrations were used in calculating Carlson's trophic state index (TSI) for lakes.

Soluble reactive phosphorus (formerly termed orthophosphate) samples were collected by vacuum filtering 200 ml of the composited sample through 0.45 micron Millipore membrane filters and collecting the filtrate in acid-washed 250 ml Nalgene containers.

In August, samples for Algal Growth Potential Tests (AGPT) were collected from the composite photic zone sample of each station by filling a properly prepared plastic container and preserving on ice.

Finally, two half-gallon portions of the composited sample were collected in plastic containers and properly preserved for laboratory analysis of water quality variables.

Subsurface grab samples were collected in properly prepared containers at each sampling site for fecal coliform analysis.

All samples were preserved, stored, and transported according to procedures in the ADEM Field Operations Division Standard Operating Procedures and Quality Control Assurance Manual Volume I Physical/Chemical (1992).

Trophic State Index. Corrected chlorophyll *a* concentrations were used in calculating Carlson's trophic state index (TSI) for lakes (Carlson 1977). Carlson's TSI provides limnologists and the public with a single number that serves as an indicator of a lake's trophic status. Corrected chlorophyll *a* is the parameter used in the RWQM Program to calculate TSI because it is considered to give the best estimate of the biotic response of lakes to nutrient enrichment when algae is the dominant plant community. The trophic state classification scale used is as follows:

Oligotrophic: TSI < 40

Mesotrophic: TSI 40 - 49

Eutrophic: TSI 50 - 69

Hypereutrophic: TSI ≥ 70

Algal Growth Potential Tests. The Algal Growth Potential Test (AGPT) determines the total quantity of algal biomass supportable by the test waters and provides a reliable estimate of the bioavailable and limiting nutrients (Raschke and Schultz 1987). In control samples, maximum algal standing crop (MSC) dry weights below 5.0 mg/l are thought to assure protection from nuisance algal blooms and fish-kills in southeastern lakes, with the exception of lakes in Florida (Raschke and Schultz 1987). In most freshwater lakes, phosphorus is the essential plant nutrient that limits growth and productivity of plankton algae (Wetzel 1983). Nitrogen usually becomes the limiting nutrient when bioavailable phosphorus increases relative to nitrogen, as in the case of waters receiving quantities of treated municipal waste (Raschke and Schultz 1987). The AGPT is helpful in identifying these common growth limiting nutrients.

Fish Tissue Analyses

Fish from reservoirs in the Warrior basin were collected for analysis of bioaccumulative contaminants during October and November 1997-1998. Fish tissue sampling locations appear in Table 4. Sample collection and preparation was performed according to the ADEM Field Operations Division Standard Operating Procedures For Fish Sampling and Tissue Preparation For Bioaccumulative Contaminants (1991). Contaminants for which composite fish samples were analyzed and their FDA consumption advisory levels appear in Table 5. Results of the analyses of fish tissue samples were forwarded to the Alabama Department of Public Health (ADPH), the agency responsible for issuance of all fish consumption advisories in the state.

Quality Control / Quality Assurances

For quality control / quality assurance purposes, field duplicates of each sample type were collected at ten percent of the sampling sites. Field duplicates were true duplicates of the complete collection process. Blanks were collected at the same frequency as duplicates by processing distilled water through the collection and filtration equipment in the same manner as regular samples. Measurements of water temperature, dissolved oxygen, specific conductance, and pH were replicated at sampling sites where duplicate samples are collected. Quality control / quality assurance procedures used in the Fish Tissue Monitoring Program were as stated in the ADEM Standard Operating Procedures For Fish Sampling and Tissue Preparation For Bioaccumulative Contaminants (1992).

Table 4. Fish tissue sampling locations in Warrior River Basin reservoirs, 1997-1998.

Water Body	Station	Location Description	County	Date Collected
BANKHEAD RESERVOIR	BAN1	UPSTREAM OF BANKHEAD LOCK AND DAM.DAM FOREBAY AREA	TUSCALOOSA	11/19/97
BANKHEAD RESERVOIR	BAN6	BLACK WARRIOR RIVER, BANKHEAD RESERVOIR VICINITY OF VALLEY CREE AND BLACK WARRIOR RIVER CONFLUENCE LAT LON CALCULATED AT CONLUENCE	JEFFERSON	11/18/97
BLACK WARRIOR LOCUST FK	BWR1	LOCUST FORK OF BLACK WARRIOR RIVER AT RIVER MILE 388.5 IN VICINITY OF BUDDY VINES FISH CAMP.	JEFFERSON	11/24/98
BIG YELLOW CREEK	BYEL1	UPSTREAM OF CONFLUENCE WITH WARRIOR RIVER	TUSCALOOSA	11/17/98
DEMOPOLIS RESERVOIR	DEM2	BLACK WARRIOR ARM OF DEMOPOLIS LAKE IN VICINITY OF US HW43 BRIDGI CROSSING, WARRIOR RIVER MILE 213.	MARENGO	12/2/97
HOLT RESERVOIR	HOL1	FOREBAY AREA, DOWNSTREAM OF DEERLICK CREEK PUBLIC ACCESS AREA, COES RIVER MILE 347.0-348.0	TUSCALOOSA	12/3/97
HOLT RESERVOIR	HOL3	BLACK WARRIOR RIVER, HOLT RESERVOIR,RM 353, CONFLUENCE OF DANIEL CK AND WARRIOR RIVER	TUSCALOOSA	12/9/97
HURRICANE CREEK	HUR1	UPSTREAM OF CONFLUENCE WITH WARRIOR RIVER	TUSCALOOSA	11/4/98
LOST CREEK	LOS1	UPSTREAM OF CONFLUENCE WITH WARRIOR RIVER	WALKER	12/1/98
NORTH RIVER	NOR1	UPSTREAM OF LAKE TUSCALOOSA	TUSCALOOSA	11/13/98
OLIVER RESERVOIR	OLI1	RESERVOIR WIDE	TUSCALOOSA	11/4/98
VALLEY CREEK	VAL1	UPSTREAM OF CONFLUENCE WITH WARRIOR RIVER	JEFFERSON	12/1/98
VILLAGE CREEK	VIL1	UPSTREAM OF CONFLUENCE WITH WARRIOR RIVER	JEFFERSON	11/24/98
WARRIOR LAKE	WAR3	BLACK WARRIOR RIVER, WARRIOR LAKE, IN VICINITY OF MOUNDVILLE STATE MONUMENT AT MOUNDVILLE RM 303	TUSCALOOSA	12/2/97

Table 5. Contaminants list for fish tissue analysis with FDA consumption advisory levels.

Contaminant	Advisory Levels (ppm)
Polychlorinated biphenyls (PCBs)	2.0
Mercury	1.0
Chlordane (total)	0.3
Toxaphene (mixture)	5.0
Mirex	0.1
DDT (total)	5.0
Dieldrin	0.3
Endrin	0.3
Heptachlor	0.3
Chlorpyrifos (Dursban)	None established

RESULTS AND DISCUSSION

Data Selection. Material in this section is divided by reservoir. Water quality data selected for further discussion consist of the following:

a) total nitrogen (TN) and total phosphorus (TP), used as indicators of nutrient content in the waterbody;
b) algal growth potential tests (AGPT), used as a determinant of the total quantity of algal biomass supportable by test waters and of the limiting nutrient;
c) corrected chlorophyll a (chl. a), used as an indicator of algal biomass;
d) Carlson Trophic State Index (TSI), calculated from corrected chlorophyll a concentrations as a means of trophic state classification of the reservoir ;
e) dissolved oxygen (DO) concentrations, used as a more direct indicator of water quality because severe depletion can damage aquatic vertebrate and macroinvertebrate communities and interfere with water supply and recreational uses;
f) total suspended solids (TSS), used as an indicator of sediment inflow; and,
g) bioaccumulative contaminant concentrations in fish tissue.

With the exception of fish contaminant concentrations, these data were selected because of their relationship to the process of eutrophication and their interest to the regulatory and scientific communities that stems from this relationship. The process of eutrophication and the effects on water quality will be discussed more fully in following paragraphs.

Bioaccumulative contaminant concentrations were selected because waterbodies are among the ultimate repositories of pollutants released by intensifying urbanization, industrial development, and use of agricultural chemicals (EPA 1995). Once these toxic contaminants reach surface waters, they may concentrate through aquatic food chains and bioaccumulate in fish tissues. Aquatic organisms may bioaccumulate environmental contaminants to more than 1,000,000 times the concentrations detected in the water column. Thus, fish tissue monitoring serves as an important indicator of contaminated sediments and water quality problems and enables state agencies to detect levels of contamination in fish tissue that may be harmful to human consumers.

Data not selected for further discussion in this report were done so in the interests of time, space, or data availability. However, all data collected during the intensive survey are available upon request.

Graphs. Bar graphs consist of means of the variables for all months depicted in the line graphs. Bar graphs with multiple reservoirs and reservoir stations are illustrated from upstream to downstream as the graph is read from left to right. Line graphs for each reservoir depict the monthly changes in the variables. Unless otherwise specified, reservoir location is referred to in the legends of graphs as **upper**, for the upper portion of each reservoir; **mid**, for the middle portion of the reservoir; and **lower,** for the dam forebay of each reservoir.

Line graphs of DO concentrations consist of measurements conducted at a depth of five feet because ADEM Water Quality Criteria pertaining to reservoir waters require a DO concentration of 5.0 mg/l at this depth (ADEM 1997). Under extreme natural conditions such as drought the DO concentration may be as low as 4.0 mg/l.

Eutrophication. For those unfamiliar with the process of eutrophication, it may be useful to discuss the relationship of the data to the process and how the process affects the water quality of lakes and reservoirs. Eutrophication is the process by which waterbodies become more productive through increased input of nutrients, primarily nitrogen and phosphorus (Welch 1992). Normally, increased plant (algae and/or macrophyte) productivity and biomass are considered part of the eutrophication process though nutrients can increase without an increase in plant growth if available light in the water column is limited by high concentrations of suspended solids.

The classical trophic succession sequence that occurs in natural lakes is as follows:

Oligotrophy: nutrient-poor, biologically unproductive;

Mesotrophy: intermediate nutrient availability and productivity;

Eutrophy: nutrient-rich, highly productive;

Hypereutrophic: the extreme end of the eutrophic stage.

Depending on the nature of the watershed however, eutrophication of natural lakes may take thousands of years or they may never become eutrophic.

All waterbodies monitored during the intensive survey are reservoirs rather than natural lakes. Trophic succession in reservoirs does not occur in the classical form as in natural lakes. After filling of the reservoir basin, trophic upsurge occurs, resulting in high productivity of algae and fish. The trophic upsurge is fueled by nutrient inputs from the watershed, leaching of nutrients from the flooded soils of the basin, and decomposition of terrestrial vegetation and litter. Eventually a trophic depression takes place with a decline in the productivity of algae and fish as these initially available nutrient sources decline. In time, a less productive but more stable trophic state is established. The trophic state that the reservoir eventually settles into (oligotrophic, mesotrophic, or eutrophic) is determined by the combination of the natural fertility of the watershed and the effects of the point and nonpoint sources of pollution within the watershed.

The concern about eutrophication from a water quality standpoint is more likely due to cultural eutrophication. Cultural eutrophication can be defined as eutrophication brought about by the increase of nutrient, soil, and /or organic matter loads to a lake or reservoir as a result of anthropogenic activities (EPA 1990). Activities that contribute to cultural eutrophication include wastewater treatment discharges, agricultural and silvicultural activities, residential and urban development, and road building. Nutrients introduced through these activities can prevent the trophic depression stage in reservoirs, leading to a continuation of the trophic upsurge. However, increased eutrophication in any waterbody occurring over a period of 10 to 50 years usually indicates cultural eutrophication (Welch 1992).

The effects of cultural eutrophication to a reservoir that is highly productive, or eutrophic, can lead to hypereutrophic conditions. Hypereutrophic conditions are characterized by the following:

a) dense algal populations;
b) low dissolved oxygen concentrations;
c) increased likelihood of fish kills; and,
d) interference with public water supply and recreational uses.

Regardless of whether a reservoir is oligotrophic, mesotrophic, or eutrophic, however, cultural eutrophication negatively affects biological communities of these waterbodies through sedimentation and changes in water quality variables such as dissolved oxygen, pH, water temperature, and light availability.

For the fishery, the long-term effect of eutrophication will be one of changed species composition, a result largely of the changed DO status (Welch 1992). However, an increased food supply, in the form of more detritus, would tend to favor detritus/bottom-feeding fish such as suckers and carp. As eutrophication increases, DO concentrations will continue to decrease and the incidence of low DO concentrations will occur earlier. Fish activity and growth will decrease progressively with decreasing DO. Fish will evacuate the epilimnion when temperatures exceed their preferred level. If adequate DO exists in the hypolimnion, it can be a healthy refuge during the warm summer period. If there is inadequate DO, the fish will be subjected to either stressful DO in the hypolimnion or, if excluded from the cooler deoxygenated hypolimnion, to stressful temperature in the epilimnion.

Smith Reservoir

Nitrogen. Mean TN concentrations in Smith Reservoir were, overall, the second lowest of Warrior basin locations (Fig. 3). Within the reservoir, mean concentrations in the Crooked Creek embayment were highest, followed by those of the lower reservoir, mid reservoir, and the Sipsey Fork embayment, respectively. Graphs of mean TN data collected at 1995 and 1998 from comparable stations indicate that mean TN concentrations in the lower reservoir during 1995 were below those of 1998 while concentrations at mid reservoir and the Sipsey embayment were higher in 1995 than in 1998 (Appendix Fig. 1).

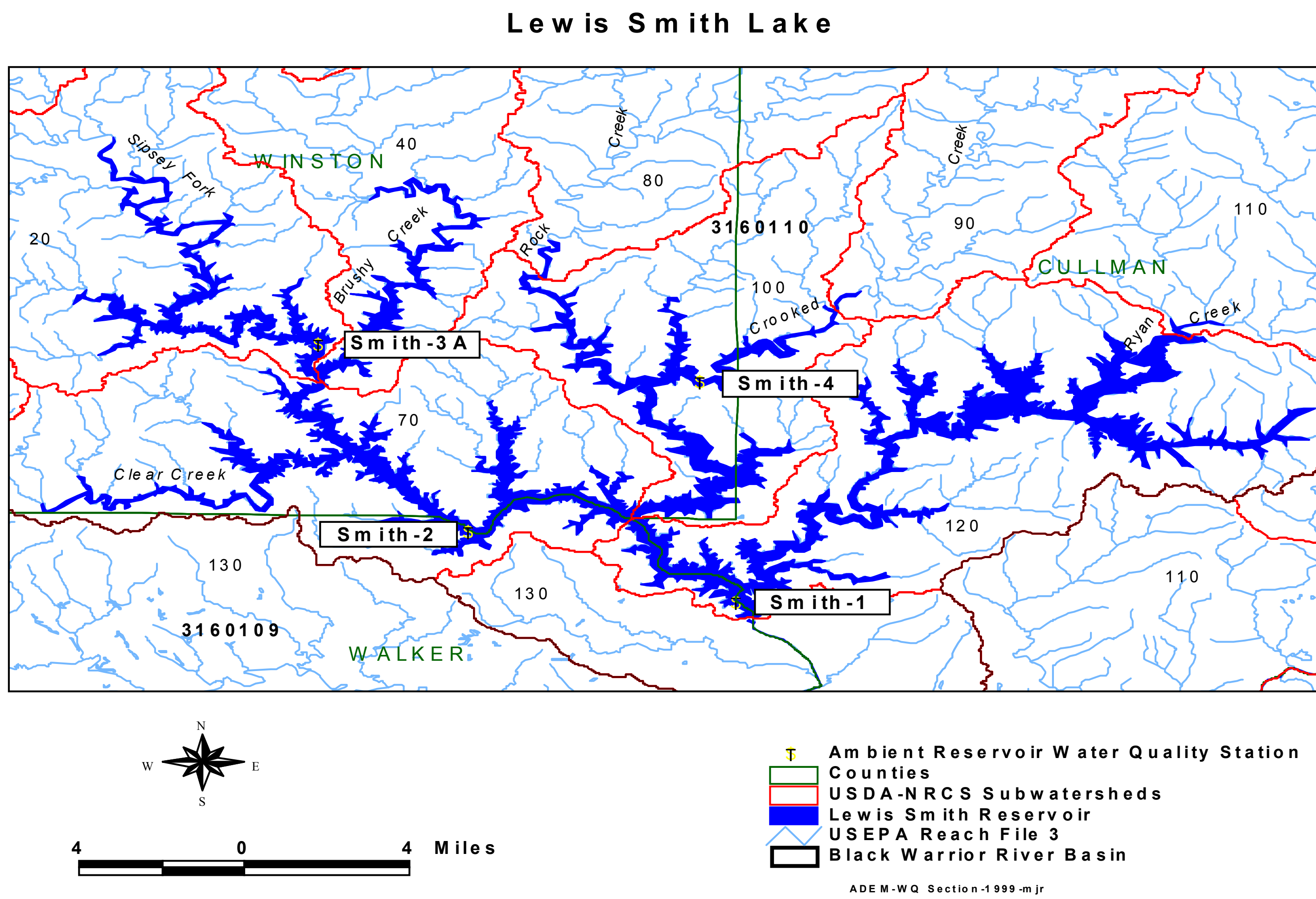
Monthly TN values at all Smith locations generally decreased from April through July then increased in August with values from the Crooked Creek embayment continuing to increase in September (Fig. 7). TN values at Crooked Creek decreased to earlier levels in October while those of other locations decreased in September and October.

No obvious relationship appeared to exist between mean TN concentrations and mean lake discharge (Fig. 7). Lake mean TN concentrations decreased April-July, increased sharply in August, and declined afterward. Mean lake discharge peaked in June then declined consistently afterward.

Phosphorus. Mean TP concentrations in Smith Reservoir were, with the exception of the Crooked Creek embayment, among the lowest of Warrior basin locations (Fig. 4). Mean TP concentrations for the Crooked Creek embayment were among the highest of Warrior basin locations. Graphs of mean TP data collected during 1995 and 1998 from comparable locations in Smith Reservoir indicate that concentrations were higher in 1998 (Appendix Fig. 1)

Monthly TP values generally increased April-August with those of Crooked Creek embayment increasing sharply through September (Fig. 7), as was the case with TN concentrations at this location. Concentrations at the Sipsey, mid, and lower reservoir locations decreased September-October with the concentration at Crooked Creek decreasing in October.

Figure 2. Map of Smith Reservoir with sampling locations.



No obvious relationship appeared to exist between mean TP concentrations and mean lake discharge (Fig. 7). Lake mean TP concentrations increased April-August then declined September-October, while mean lake discharge increased April-June then decreased afterward.

Algal Growth Potential Tests. Phosphorus was indicated as the limiting nutrient at the Sipsey, mid, and lower reservoir locations with nitrogen the limiting nutrient in the Crooked Creek embayment (Table 6). The Crooked Creek embayment was the only Warrior basin location in which nitrogen was strictly indicated as the limiting nutrient. Mean MSC values for the Sipsey, mid, lower and Crooked Creek locations (1.58, 1.62, 1.29, and 1.73 mg/l, respectively) were well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes.

Chlorophyll a. Mean chlorophyll *a* concentrations in Smith Reservoir were, with the exception of the Crooked Creek embayment, among the lowest of Warrior basin locations (Fig. 5). Mean chlorophyll *a* concentrations in Smith Reservoir were similar in all locations with the exception of the Crooked Creek embayment, which was highest of the four locations. Graphs of mean chlorophyll *a* data collected during 1995 and 1998 from comparable locations in Smith Reservoir indicate that concentrations in the lower reservoir were the same both years while those of the mid reservoir were higher in 1995. Concentrations in the Sipsey Fork embayment were higher in 1998 than in 1995 (Appendix Fig. 1).

Monthly chlorophyll *a* concentrations at the Sipsey Fork embayment location decreased slightly April-October while those of the mid reservoir location were variable (Fig. 8). Concentrations from the lower reservoir generally increased during the study period. Monthly concentrations from the Crooked Creek embayment were highest April-May then declined substantially afterward.

No obvious relationship appeared to exist between mean chlorophyll *a* concentrations and mean lake discharge (Fig. 8). Lake mean chlorophyll *a* concentrations were highest April-May then declined generally through September and increased in October. Mean lake discharge increased sharply April-June then decreased sharply afterward.

Total Suspended Solids. Mean TSS concentrations from Smith Reservoir were lowest overall of Warrior basin locations (Fig. 6). Within the reservoir, highest mean concentrations occurred in the Crooked Creek embayment. Graphs of mean TSS data collected during 1995 and 1998 from comparable locations in Smith Reservoir indicate that concentrations in the lower reservoir and the Sipsey Fork embayment were higher in 1998 than in 1995 (Appendix Fig. 1). Mean concentrations in the mid reservoir were slightly higher in 1995 than in 1998.

Monthly TSS concentrations were variable at all locations during the study with highest concentrations occurring in the Crooked Creek embayment in April, June, and October (Fig. 8).

Lake mean TSS concentrations increased along with mean lake discharge April-June then decreased sharply through August (Fig. 8). Mean TSS increased September-October as mean lake discharge continued to decline.

Trophic State. Monthly TSI values for the Sipsey, mid, and lower reservoir locations were generally within the oligotrophic to mesotrophic range during the study period (Fig. 9). TSI values in the Crooked Creek embayment were within the eutrophic range April-July and October and decreased into the mesotrophic range August-September.

Dissolved oxygen/Temperature. Dissolved oxygen concentrations generally decreased at all Smith locations April-October (Fig. 9). DO concentrations at all locations were similar when sampled each month. Concentrations were above the criterion limit of 5.0 mg/l on all dates sampled.

Depth profiles of temperature and DO from the Smith dam forebay indicated that a strong thermocline and chemocline(s) existed at various depths in the water column April-October (Fig. 10). Temperature profiles were very similar June-August with slightly higher temperatures in the epilimnion in June. Lowest hypolimnetic DO concentrations occurred August-October. Deoxygenation of the hypolimnion occurred immediately below the thermocline September-October and in the bottom 15-40m of the water column April-October.

Depth profiles of temperature and DO from the Crooked Creek embayment indicated that a thermocline and chemocline(s) existed April-October, intensifying each month until 63-81% of the water column was essentially anoxic July-October (Fig.11). Highest water temperatures occurred in July.

In the Sipsey Fork embayment, depth profiles of temperature and DO indicated the existence of a weak thermocline in April that intensified each month through October (Fig. 12). Highest water temperatures occurred June-July. A single chemocline existed near the lake bottom in April, with a second chemocline developing in later months nearer the surface. From June-October, the portion of the water column at the upper chemocline was essentially anoxic while the portion of the water column between the upper and lower chemoclines was usually oxygenated.

Fish Tissue Analysis. Funding constraints prevented fish tissue sample collection in Smith Reservoir during the course of this study. Results of sampling conducted in the Ryan and Rock Creek embayments and the Sipsey Fork of Smith Reservoir during 1993 indicated that bioaccumulative contaminant concentrations in all fish collected were below FDA advisory limits (ADEM 1996).

Discussion. With the exception of the Crooked Creek embayment, mean nutrient, chlorophyll *a*, and TSS concentrations in Smith Reservoir were among the lowest of Warrior basin locations. AGPT results indicated that the Sipsey, mid, and lower reservoir locations were phosphorus limited, with mean MSC values well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes. Higher mean TP concentrations in 1998 over those measured in 1995 may be cause for concern and should be monitored in the future. Trophic state index values indicated that these locations were within the oligotrophic to mesotrophic range during the course of this study. For a more detailed discussion of water quality in Lewis Smith Reservoir, including tributary embayment locations other than Crooked Creek, consult Lewis Smith Lake Phase I Diagnostic/Feasibility Final Report (ADEM 1998).

Nutrient and chlorophyll *a* concentrations in the Crooked Creek embayment are a concern and should be investigated further. Mean values from the embayment were much higher than those of other locations in Smith Reservoir with TP values among the higher values in the Warrior basin. Though DO concentrations were well above the

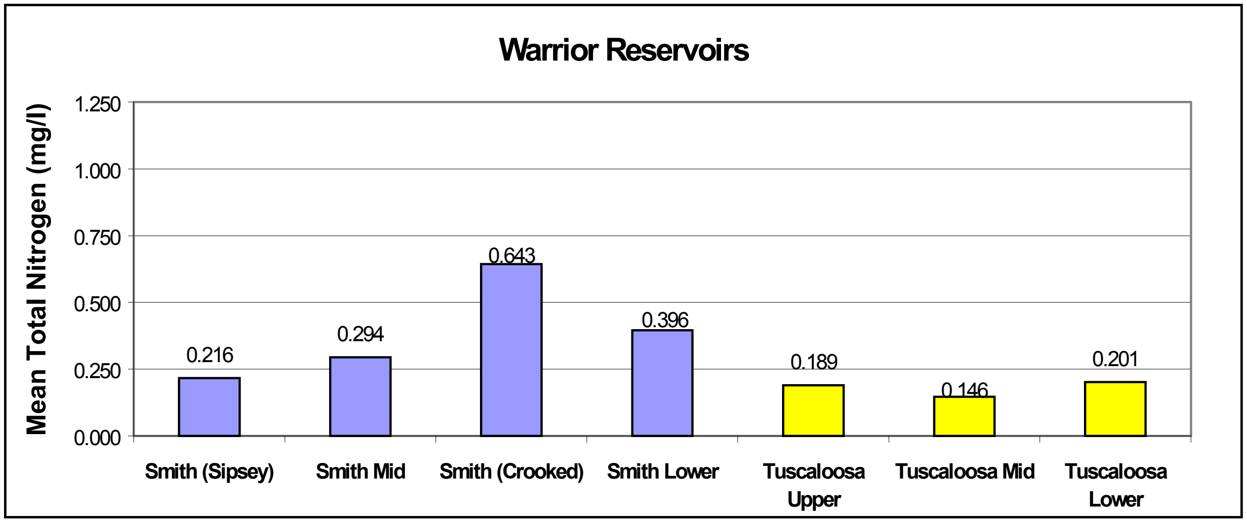
ADEM Water Criteria (1997) limit of 5.0 mg/l when sampled, 63-81% of the water column at the sampling location was essentially deoxygenated July-October.

Crooked Creek was listed in the 1996 303(d) list of priority waterbodies for ammonia, nutrient enrichment, pathogens, and dissolved oxygen violations with the sources of these pollutants listed as feedlots and animal holding management areas (ADEM 1996). In addition, low dissolved oxygen concentrations and elevated nutrient levels were measured in 1997 (ADEM 1999). Potential nonpoint sources are indicated in the landuse estimates for the Crooked Creek sub-watershed as follows (EPA 1997):

a) 33% deciduous forest;
b) 13% evergreen forest;
c) 20% mixed forest;
d) 27% pasture/hay; and,
e) 7% row crop.

One semi-public/private permitted discharge is located in the sub-watershed.

Funding constraints prevented fish tissue sample collection in Smith Reservoir during the course of this study. Results of sampling conducted in the Ryan and Rock Creek embayments and the Sipsey Fork of Smith Reservoir during 1993 indicated that bioaccumulative contaminant concentrations in all fish collected were below FDA advisory limits.



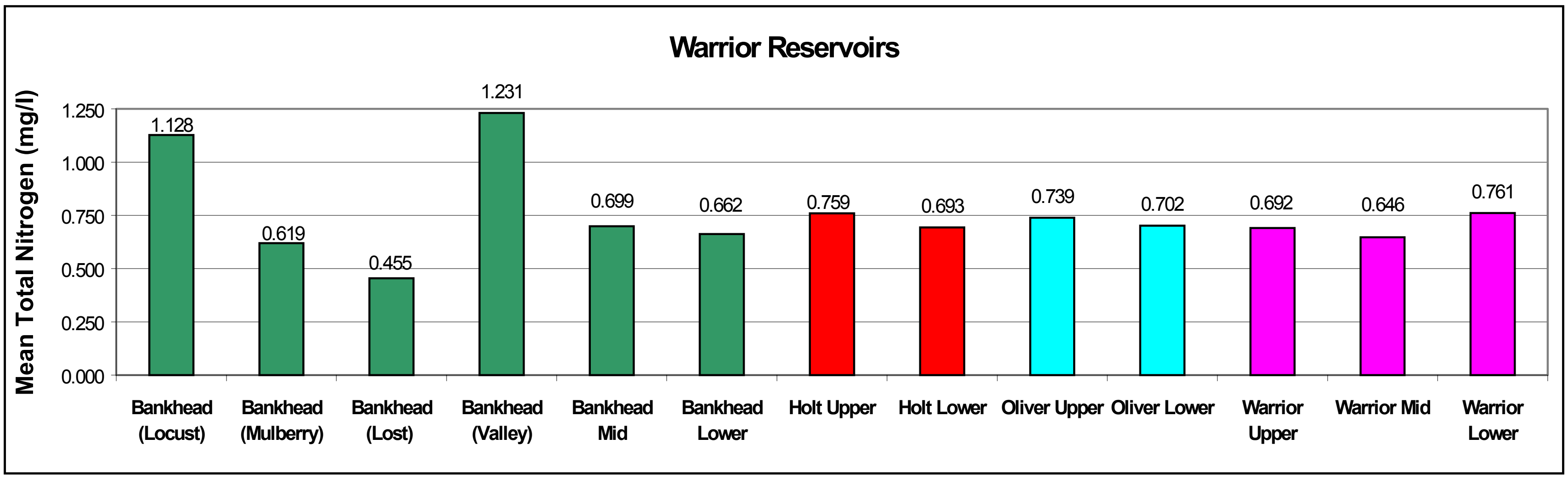
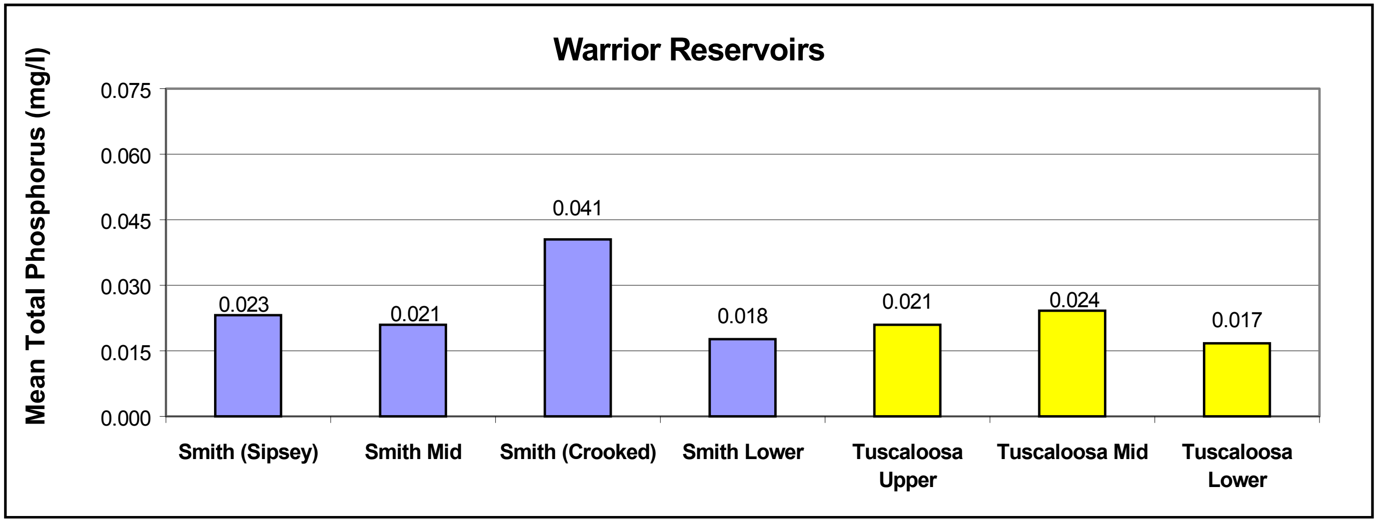


Figure 3. Mean total nitrogen (TN) concentrations of Warrior reservoir locations, April October 1998.



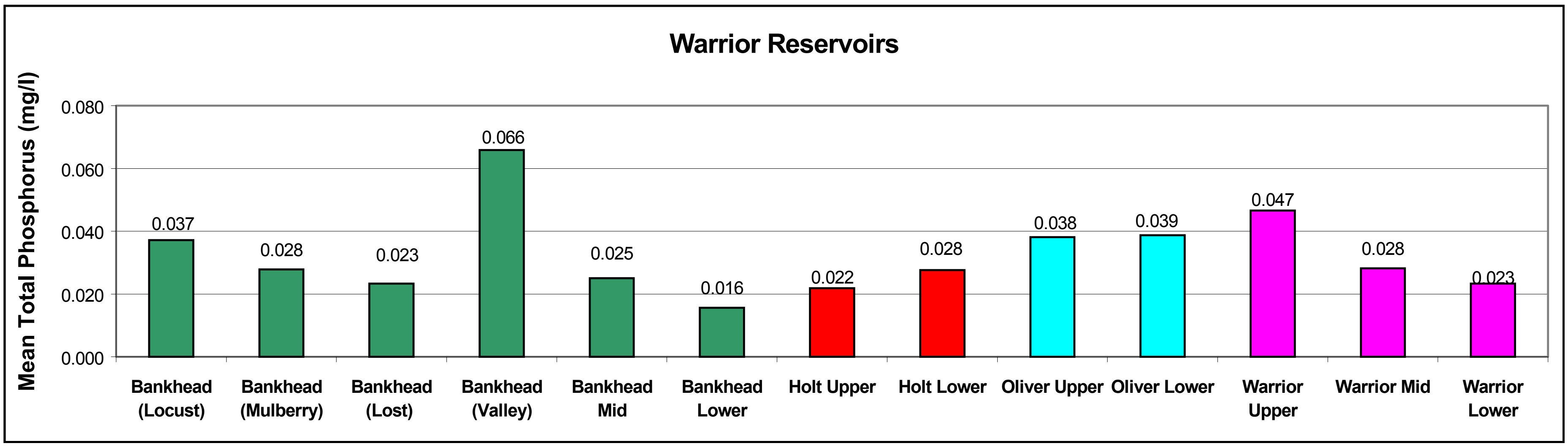
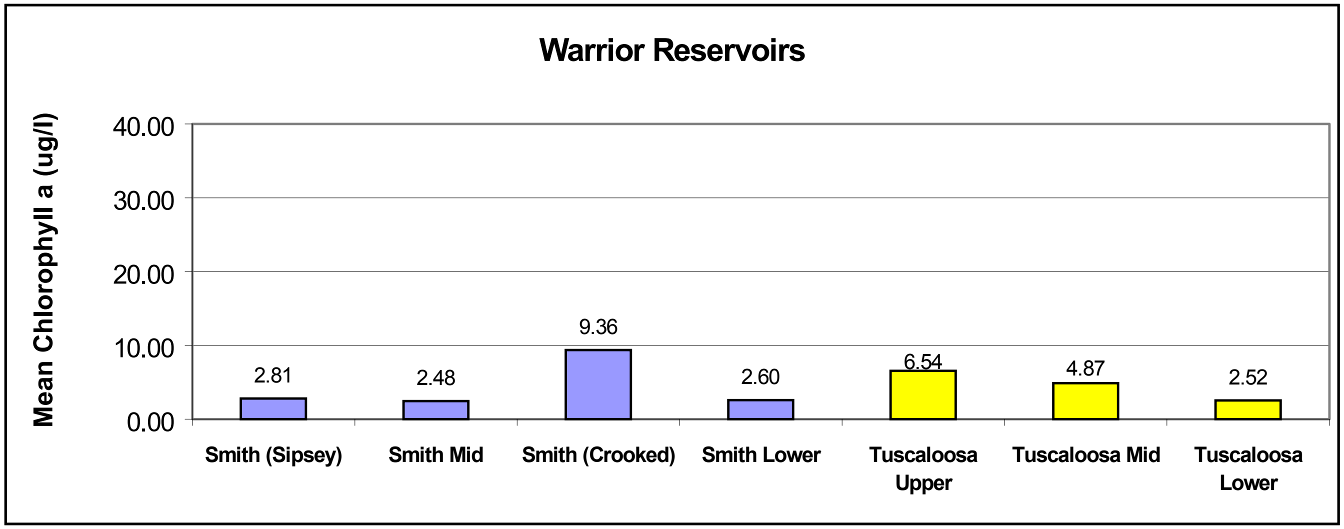


Figure 4. Mean total phosphorus (TP) concentrations of Warrior reservoir locations April-October 1998.

Table 6. Algal Growth Potential Testing (AGPT) of Warrior basin reservoirs, August 1998.

Reservoir	Location	Collection Date	Mean MSC (mg/l) C	C+N	C+P	Limiting Nutrient
Warrior	Lower	8/25/98	2.90	2.81	**21.94**	Phosphorus
Warrior	Mid	8/25/98	3.57	3.58	**19.13**	Phosphorus
Warrior	Upper	8/25/98	3.12	3.36	**15.30**	Phosphorus
Oliver	Lower	8/25/98	2.27	2.34	**23.37**	Phosphorus
Oliver	Upper	8/25/98	2.79	2.53	**23.93**	Phosphorus
Holt	Lower	8/25/98	2.60	2.46	**10.65**	Phosphorus
Holt	Upper	8/25/98	2.66	2.76	**5.12**	Phosphorus
Tuscaloosa	Lower	8/26/98	2.31	2.32	1.62	Co-limiting
Tuscaloosa	Mid	8/26/98	2.18	2.17	**4.20**	Phosphorus
Tuscaloosa	Upper	8/26/98	2.49	2.75	**4.77**	Phosphorus
Bankhead	Lower	8/25/98	2.65	2.69	**22.48**	Phosphorus
Bankhead	Mid	8/25/98	4.52	3.54	**23.12**	Phosphorus
Bankhead	Locust Fork	8/25/98	24.74	26.98	**34.78**	Phosphorus
Bankhead	Mulberry Fork	8/25/98	2.31	2.10	**19.53**	Phosphorus
Bankhead	Lost Creek	8/25/98	1.95	1.89	**16.77**	Phosphorus
Bankhead	Valley Creek	8/25/98	29.09	**31.74**	**35.20**	Co-limiting
Smith	Lower	8/26/98	1.29	1.30	**3.30**	Phosphorus
Smith	Mid	8/26/98	1.62	1.58	**3.08**	Phosphorus
Smith	Sipsey	8/26/98	1.58	1.60	**1.93**	Phosphorus
Smith	Crooked	8/26/98	1.73	**4.55**	1.67	Nitrogen

MSC = Maximum Standing Crop
C = Control; C+N = Control + Nitrogen; C+P = Control + Phosphorus
Values in **bold** print are significantly different from control.



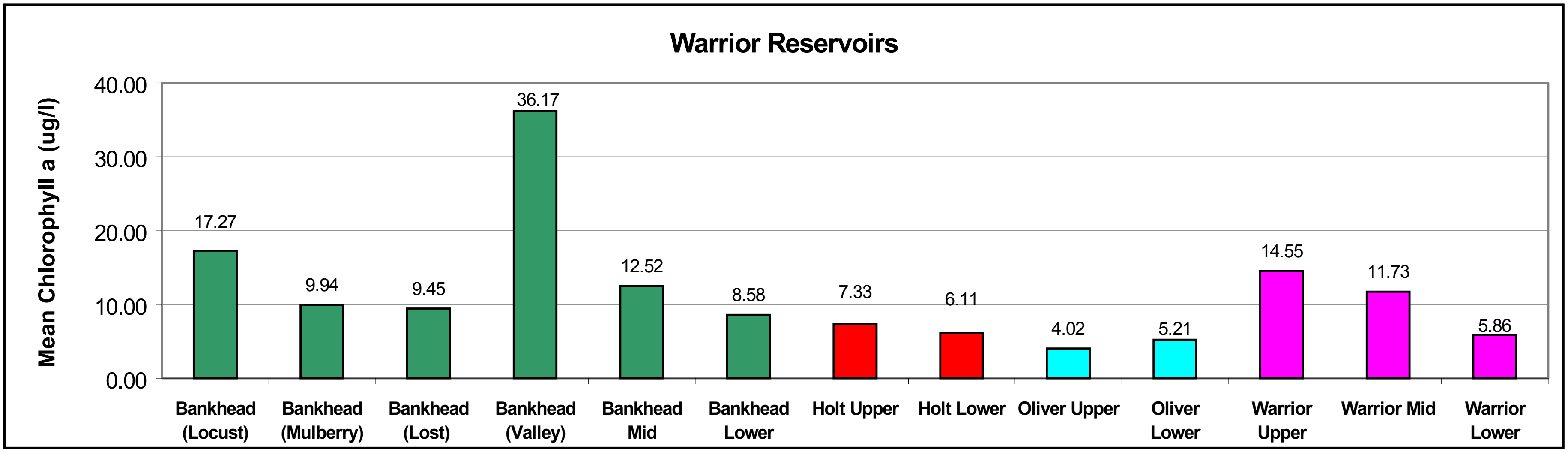
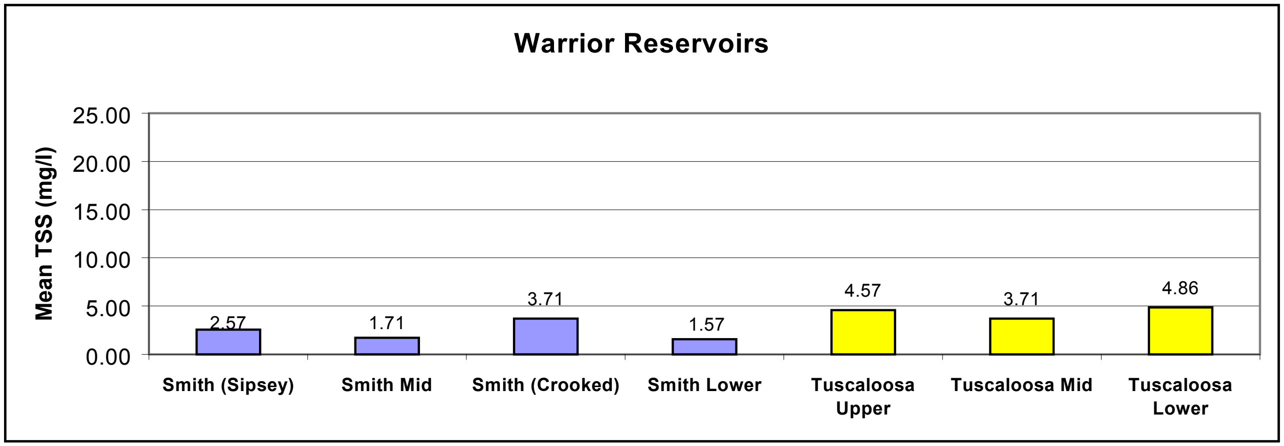


Figure 5. Mean chlorophyll *a* concentrations of Warrior reservoir locations April-October 1998.



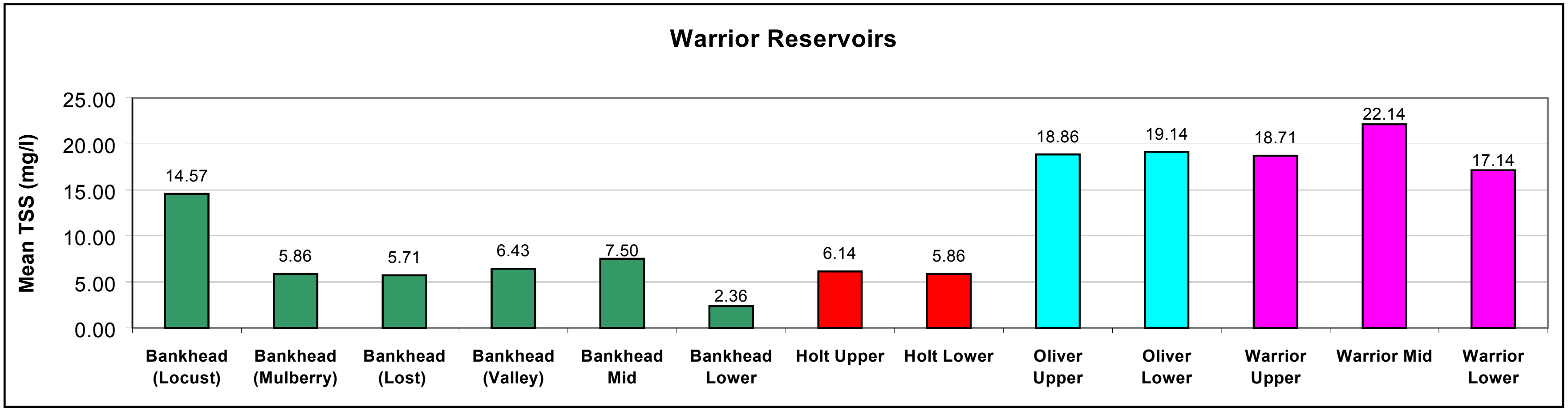


Figure 6. Mean total suspended solids (TSS) concentrations of Warrior reservoir locations April-October 1998.

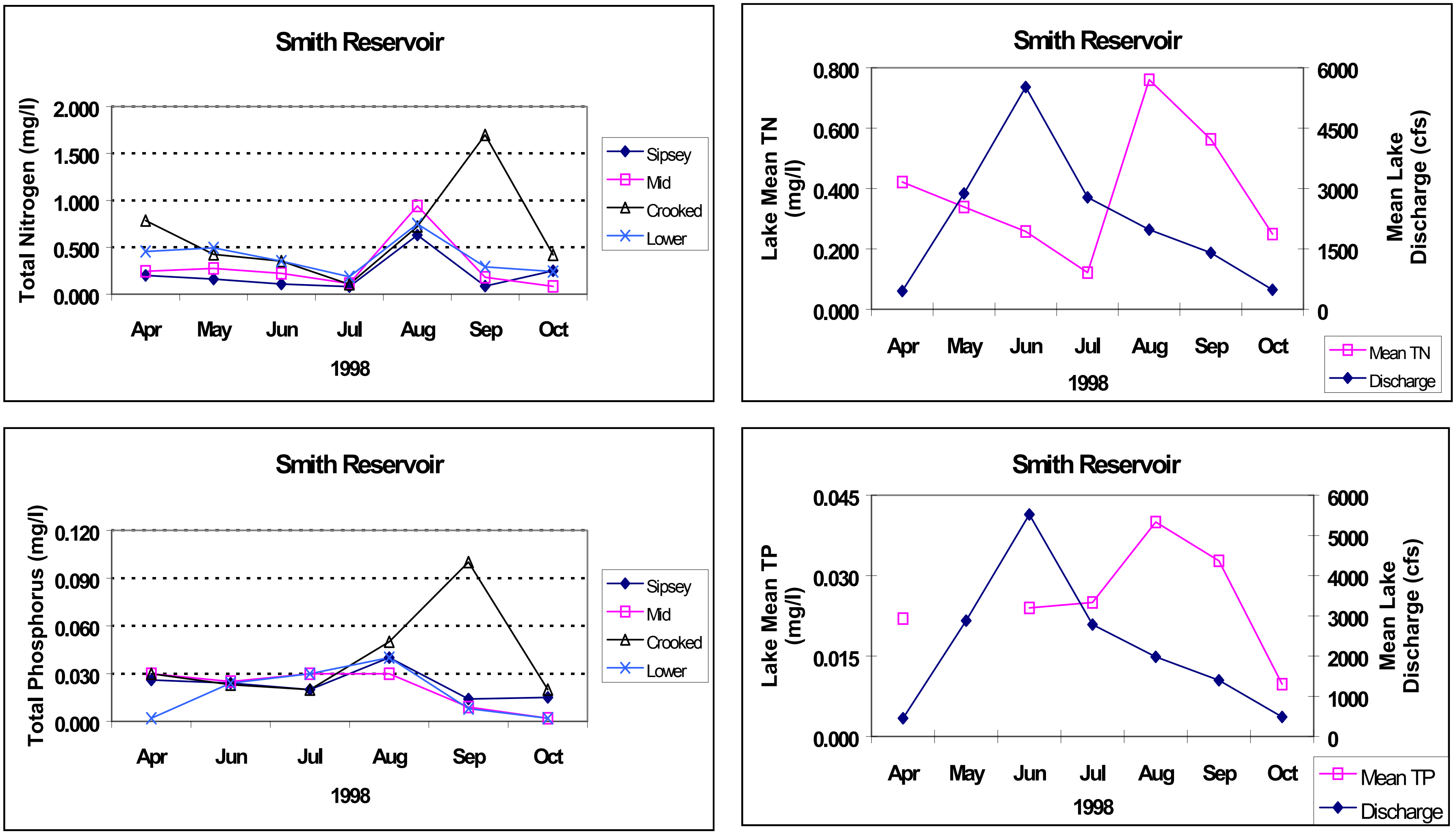


Figure 7. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Smith Reservoir, April-October 1998.

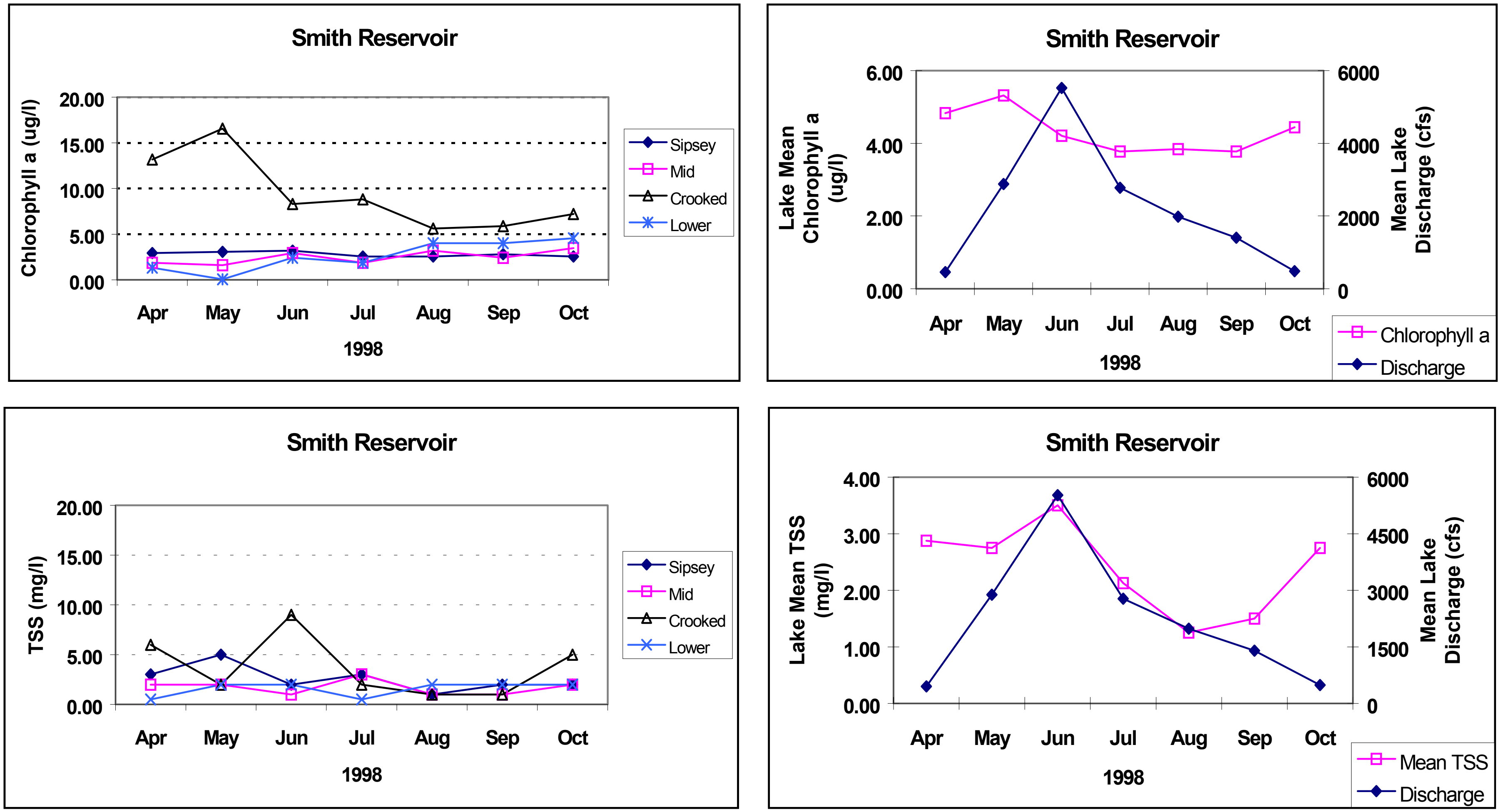
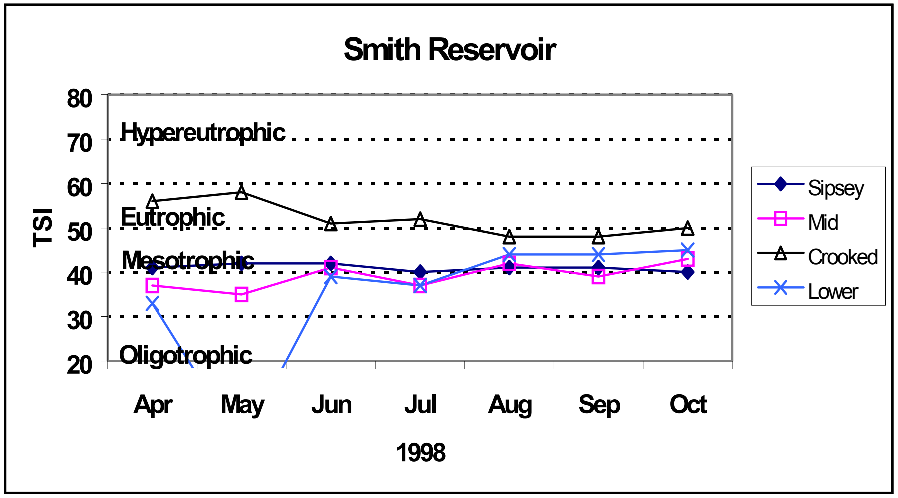


Figure 8. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS), and TSS vs. discharge of Smith Reservoir, April-October 1998.



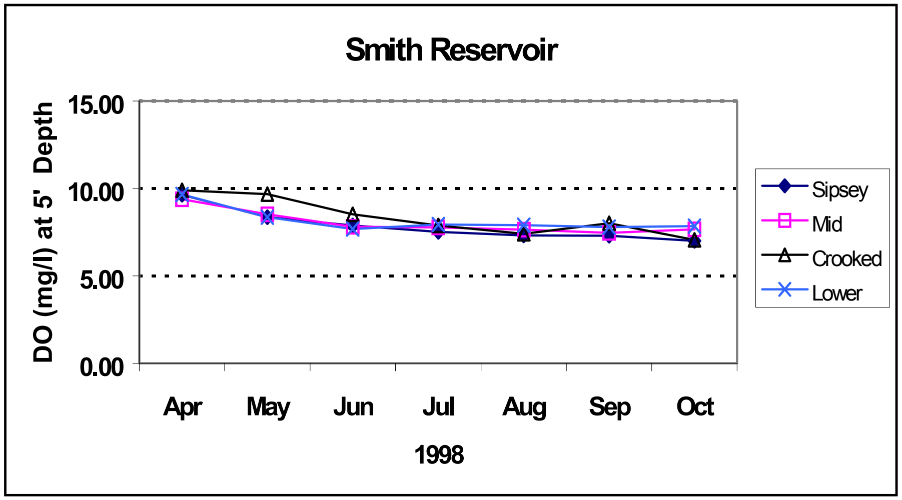


Figure 9. Trophic state index (TSI), and dissolved oxygen (DO) of Smith Reservoir, April-October 1998.

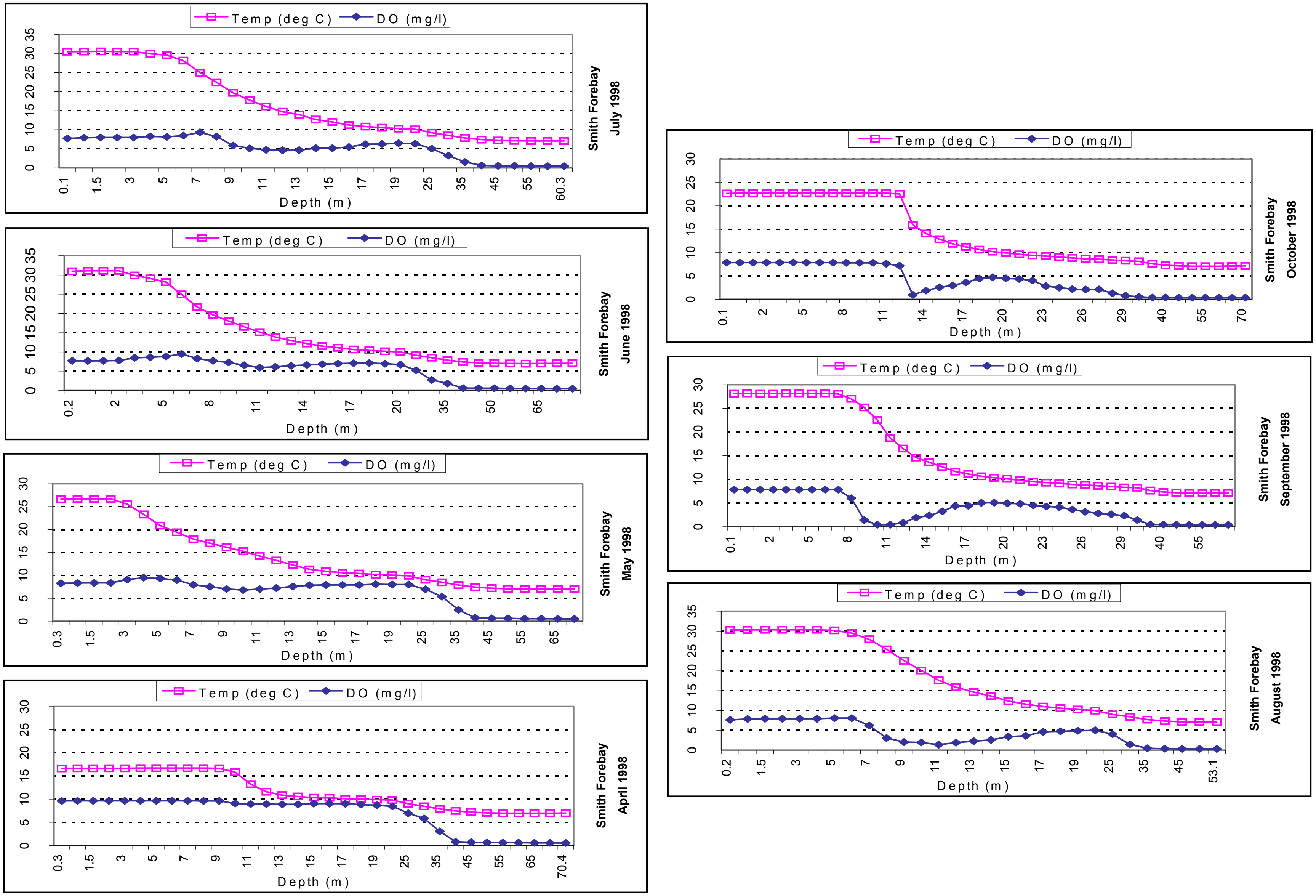


Figure 10. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Smith Reservoir, April-October 1998.

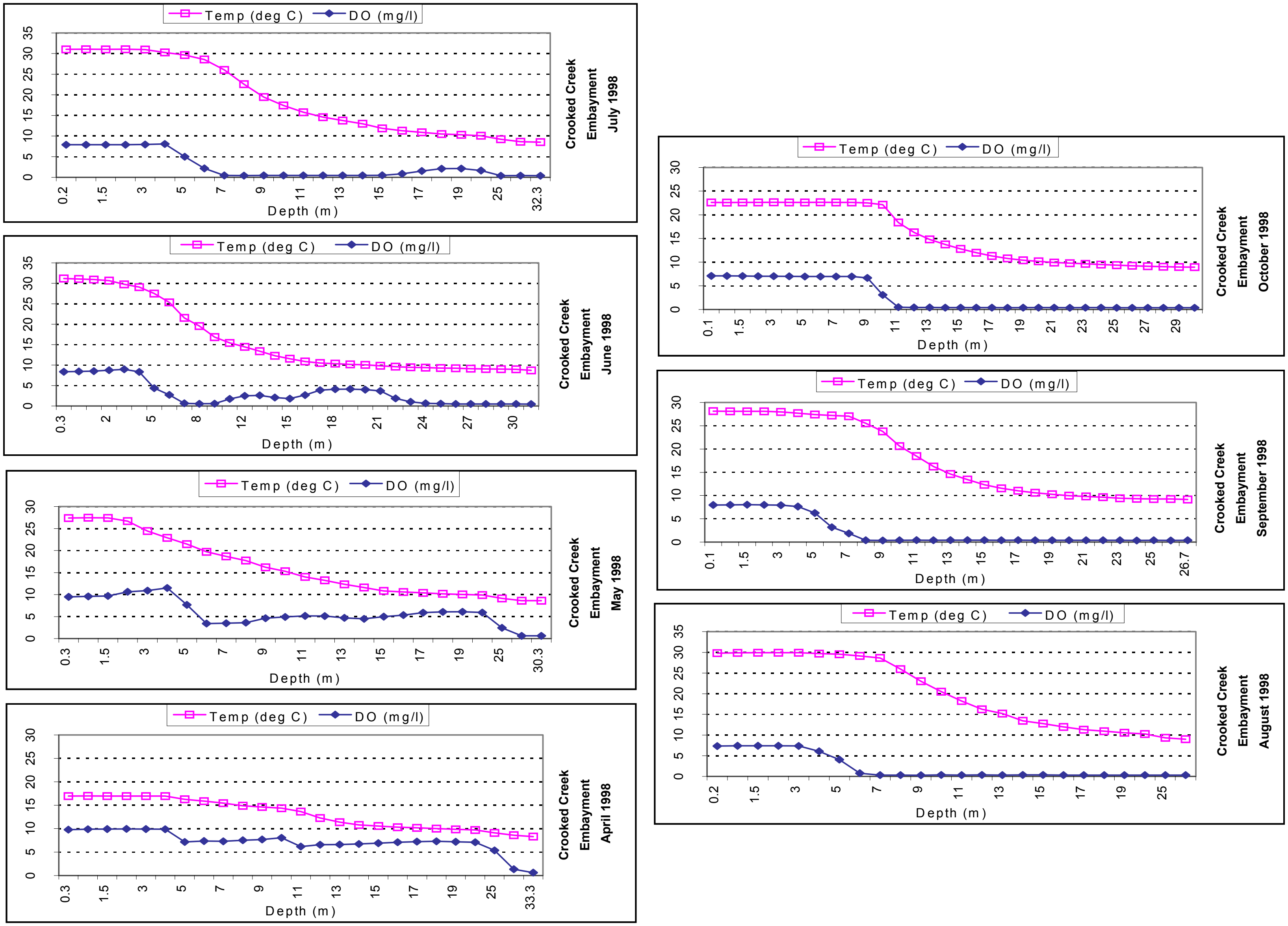


Figure 11. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the Crooked Creek embayment of Smith Reservoir, April-October 1998.

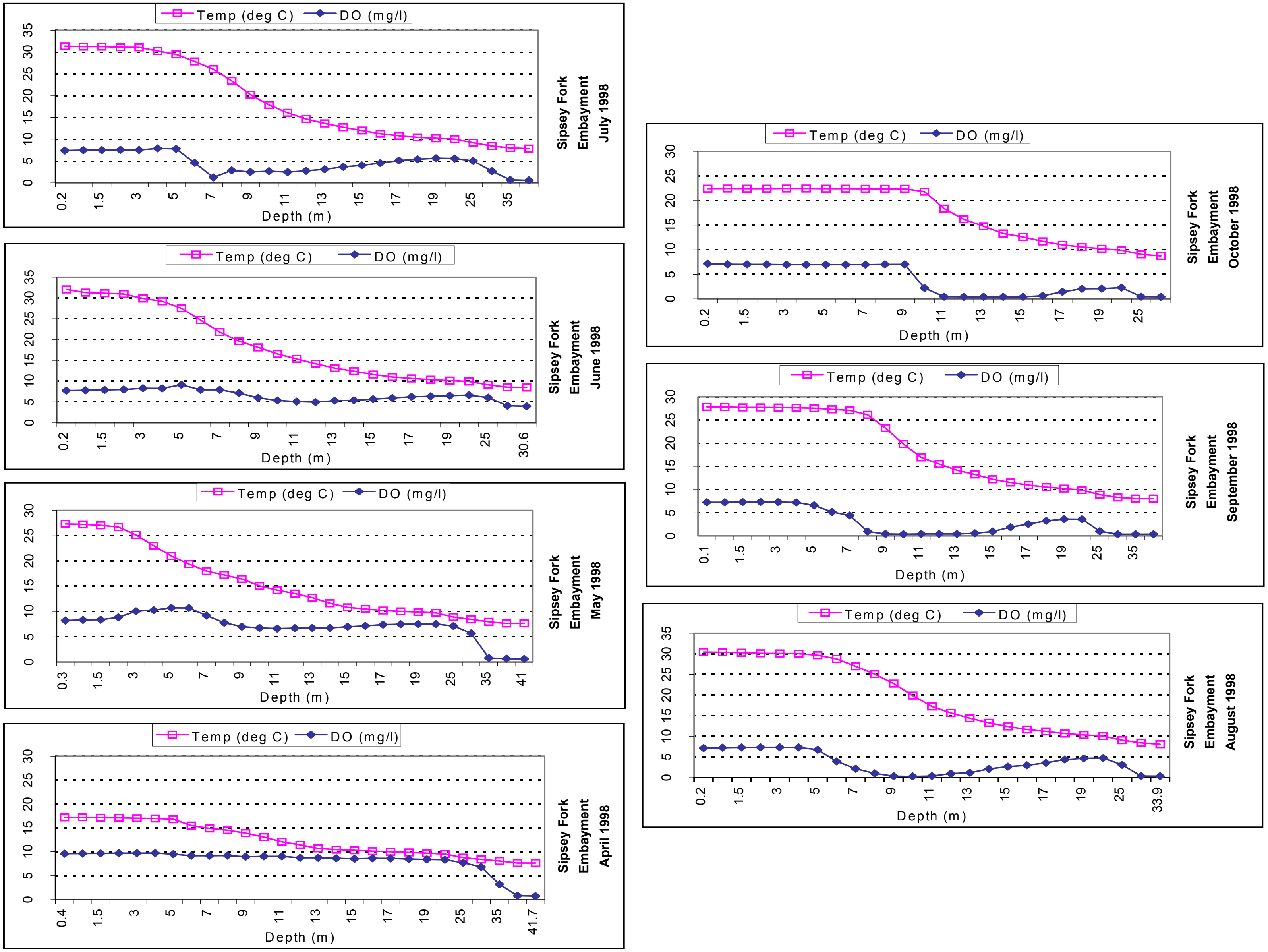


Figure 12. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the Sipsey Fork embayment of Smith Reservoir, April-October 1998.

Tuscaloosa Reservoir

Nitrogen. Mean TN concentrations in Tuscaloosa Reservoir were the lowest of Warrior basin locations (Fig. 3). Within the reservoir, mean concentrations in the upper and lower reservoir were similar and greater than those of the mid reservoir.

Monthly TN values varied during the study period with highest values for the upper reservoir recorded in July and highest values for the mid and lower reservoir recorded in August (Fig. 14). Lowest values for the upper and lower reservoir locations occurred September-October while lowest values at mid reservoir occurred in May and October.

Lake mean TN concentrations increased May-August as discharge in the North River declined (Fig. 14). TN concentrations decreased September-October as discharge continued its gradual decline.

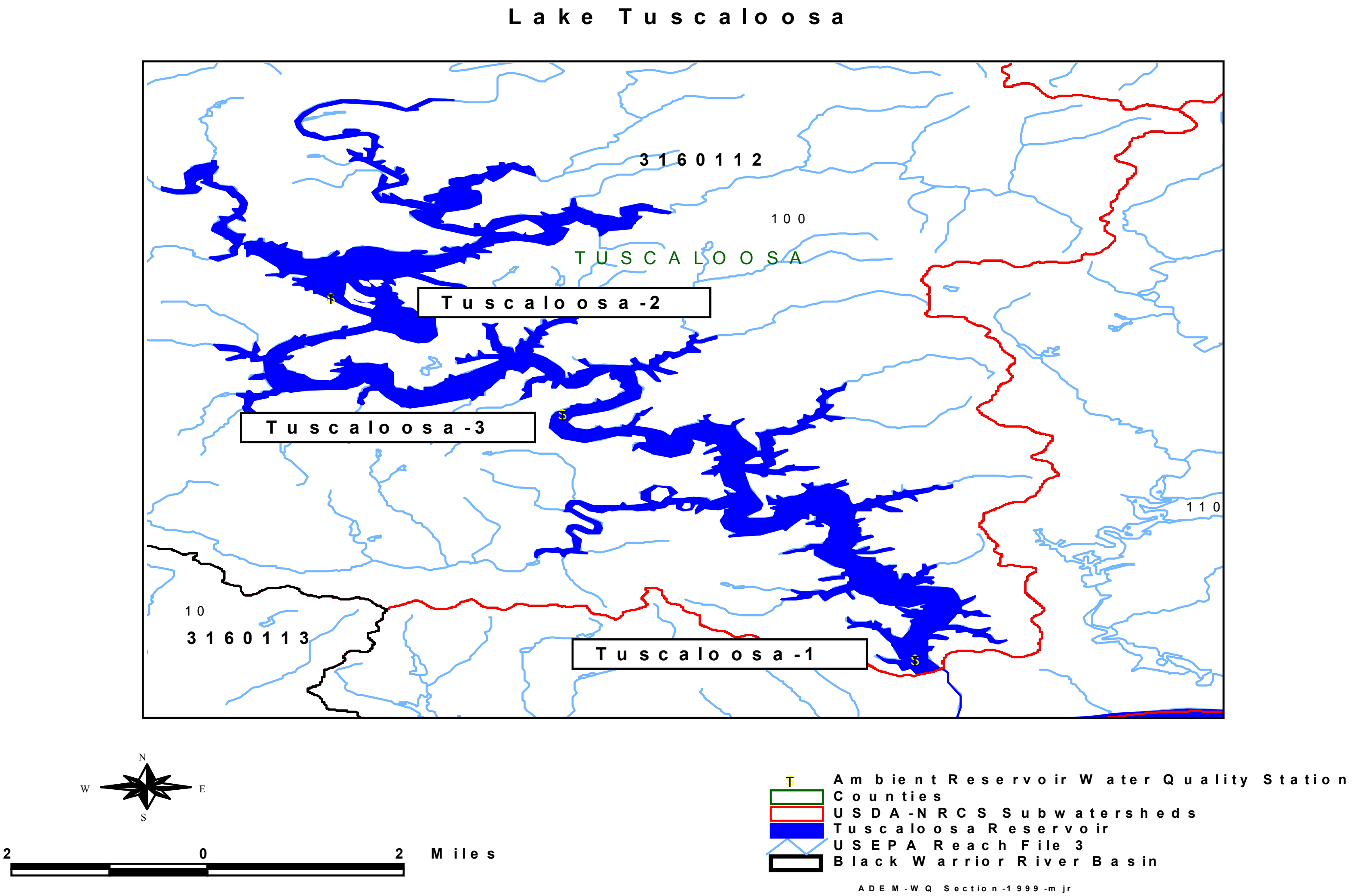
Phosphorus. Mean TP concentrations in Tuscaloosa Reservoir were the lowest overall of Warrior basin locations (Fig. 4). Mean concentrations were similar in the upper and mid reservoir and slightly higher than that of the lower reservoir.

Monthly TP concentrations at all locations increased overall April-August and declined September-October (Fig. 14). Concentrations in the upper reservoir were most consistent in the pattern of increase and decrease.

Lake mean TP concentrations increased sharply April-August as discharge in the North River declined (Fig. 14). TP concentrations decreased September-October as discharge continued its gradual decline.

Algal Growth Potential Tests. Phosphorus was indicated as the limiting nutrient in the upper and mid reservoir locations with nitrogen and phosphorus co-limiting in the lower reservoir (Table 6). Mean MSC values for the upper, mid, and lower reservoir locations (2.49, 2.18, and 2.31 mg/l, respectively) were well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes.

Figure 13. Map of Tuscaloosa Reservoir with sampling locations.



Chlorophyll a. Mean chlorophyll *a* concentrations in Tuscaloosa Reservoir were, along with those of Smith and Oliver, among the lowest of Warrior basin locations (Fig. 5). Mean concentrations declined from the upper reservoir location to the lower reservoir location. Mean concentrations of the lower location were second lowest to mid Smith reservoir of Warrior basin locations.

Monthly chlorophyll *a* concentrations in the upper reservoir were variable with highest concentrations occurring in May and lowest concentrations occurring in April and October (Fig. 15). Monthly concentrations in the mid reservoir were variable with highest concentrations occurring in July and lowest concentrations occurring in October. In the lower reservoir, monthly concentrations increased gradually April-July then decreased gradually thereafter. Concentrations at all locations decreased September-October.

Lake mean chlorophyll *a* concentrations increased sharply April-May then decreased overall through October (Fig. 15). Discharge in the North River decreased April-October with a sharp decrease April-May and a very gradual decrease in the following months.

Total Suspended Solids. Mean TSS concentrations in Tuscaloosa Reservoir were second lowest to those of Smith Reservoir and lower Bankhead Reservoir (Fig. 6). Within the reservoir, mean concentrations in the lower reservoir were greatest with those of the mid reservoir least of the three locations.

Monthly TSS concentrations in the upper reservoir were variable April-October with highest concentrations occurring in June and August and lowest concentrations occurring in September-October (Fig. 15). At mid reservoir, TSS concentrations were variable with highest concentrations occurring June-July and lowest concentrations occurring in May and September. Monthly TSS concentrations in the lower reservoir increased April-July then decreased through October.

Lake mean TSS concentrations increased overall April-July then decreased through October (Fig. 15). Discharge in the North River decreased April-October with a sharp decrease April-May and a very gradual decrease in the following months.

Trophic State. Monthly TSI values in the upper reservoir were in the eutrophic range May and August and in the mesotrophic range in other months (Fig.16). At mid reservoir, TSI values were in the eutrophic range in July and in the mesotrophic range in other months. TSI values for the lower reservoir increased from the oligotrophic range to the mesotrophic range April-July then decreased to the mesotrophic range September-October.

Dissolved Oxygen/Temperature. Dissolved oxygen concentrations at all reservoir locations changed little April-October (Fig. 16). In general, concentrations were highest in April and lowest in October. DO concentrations were above the criterion limit of 5.0 mg/l on all dates sampled.

Depth profiles of temperature and DO from the Tuscaloosa dam forebay indicated that a strong thermocline existed April-October (Fig. 17). Highest water column temperatures occurred June-August. A weak chemocline began to develop in May and intensified in the months following. Deoxygenation of the hypolimnion occurred for several meters immediately below the thermocline September-October and at the bottom in July and September-October.

Depth profiles of temperature and DO from upper Tuscaloosa Reservoir indicated that a weak thermocline and chemocline existed near the bottom in April (Fig. 18). The thermocline and chemocline moved nearer the surface and intensified May-August, with highest water column temperatures occurring June-August. From May-September, more than half the water column was deoxygenated at this reservoir location. In September-October, both the thermocline and chemocline began to sink in the water column, increasing the depth of the hypolimnion and improving water column DO concentrations.

Fish Tissue Analysis. Largemouth bass and catfish were collected from the North River upstream of Tuscaloosa Reservoir in November 1998 (Appendix Table 1). Laboratory analyses indicated that contaminant concentrations in both species of fish were well below FDA advisory limits (Appendix Table 2).

Discussion. Water quality data from Tuscaloosa Reservoir indicated few water quality concerns. Mean TN and TP concentrations were the lowest overall of Warrior basin locations. Algal growth potential tests indicated that phosphorus was either the limiting or co-limiting nutrient at all reservoir locations with the mean MSC from these locations well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes.

Lake mean TN and TP concentrations increased for several months as discharge in the North River decreased, usually indicative of important point source contributions though only one semi-public/private permitted discharge is listed for the lower North River sub-watershed (ADEM 1999). The origins of these nutrient concentrations should be the subject of further study. In addition to the above discharge, thirteen construction/stormwater authorizations and six mining discharges have been permitted in this sub-watershed. Percent landcover within the sub-watershed is estimated as follows (EPA 1997):

a) 3% open water;
b) 3% transitional barren;
c) 35% deciduous forest;
d) 17% evergreen forest;
e) 31% mixed forest;
f) 6% pasture/hay; and,
g) 6% row crop.

Based on bioassessments conducted on Binion Creek and Carroll Creek, the lower North River sub-watershed was identified as a priority sub-watershed (ADEM 1999).

Mean chlorophyll *a* and TSS concentrations were among the lowest of basin locations. However, upper and mid reservoir locations reached eutrophic levels in certain months while the lower reservoir ranged from oligotrophic to mesotrophic levels during the study.

DO concentrations were above the criterion limit in all months sampled, however the majority of the water column in the upper reservoir was essentially deoxygenated May-September.

Given the eutrophic conditions and low oxygen concentrations of the upper reservoir, continued monitoring is advised to determine water quality trends in this reservoir.

Laboratory analyses of largemouth bass and catfish indicated that bioaccumulative contaminant concentrations in both species of fish were well below FDA advisory limits.

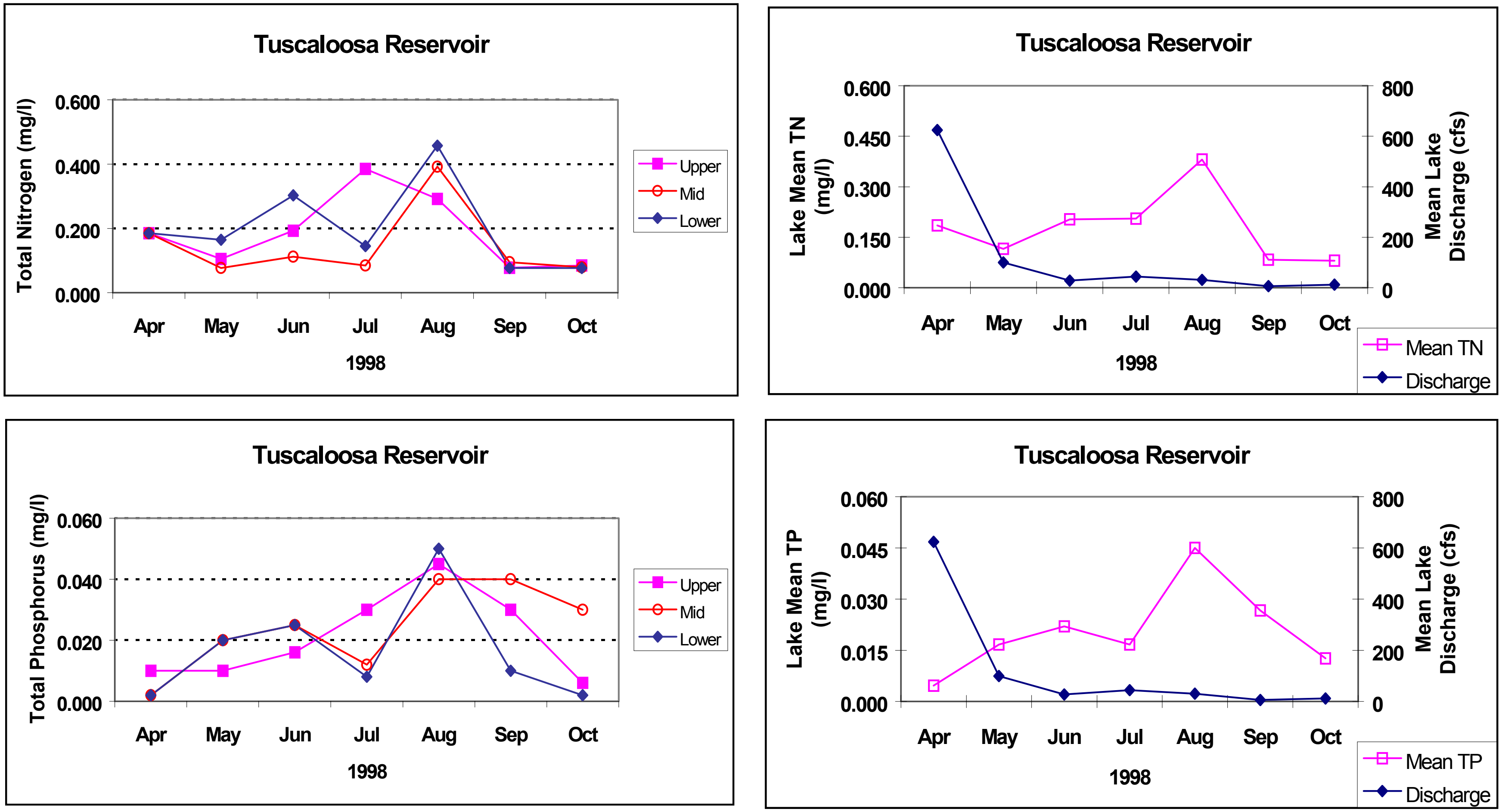


Figure 14. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Tuscaloosa Reservoir, April-October 1998.

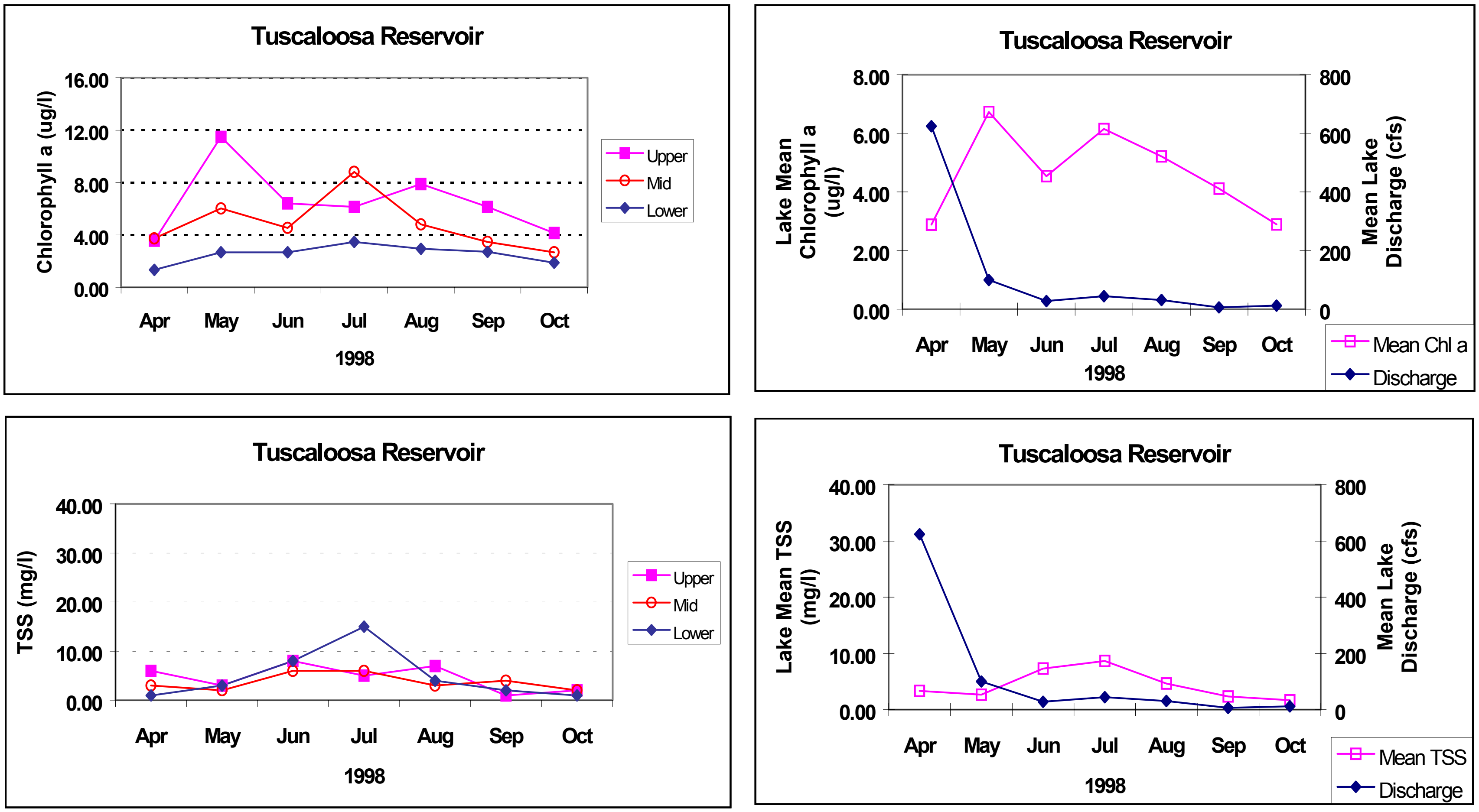
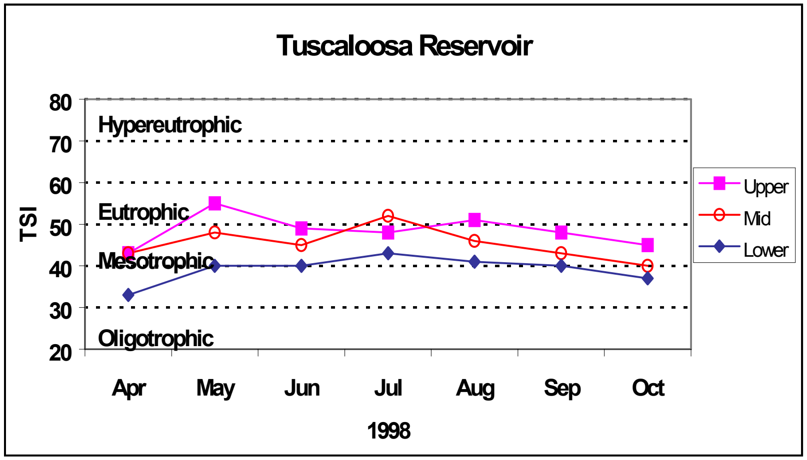


Figure 15. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS), and TSS vs. discharge of Tuscaloosa Reservoir, April-October 1998.



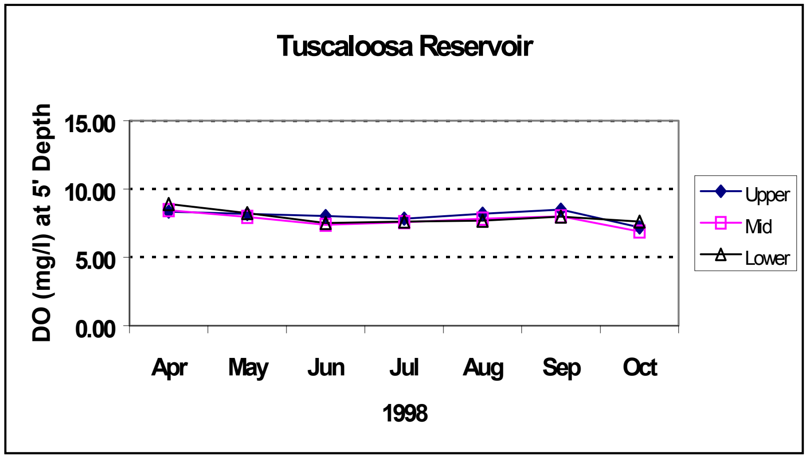


Figure 16. Trophic state index (TSI), and dissolved oxygen (DO) of Tuscaloosa Reservoir, April-October 1998.

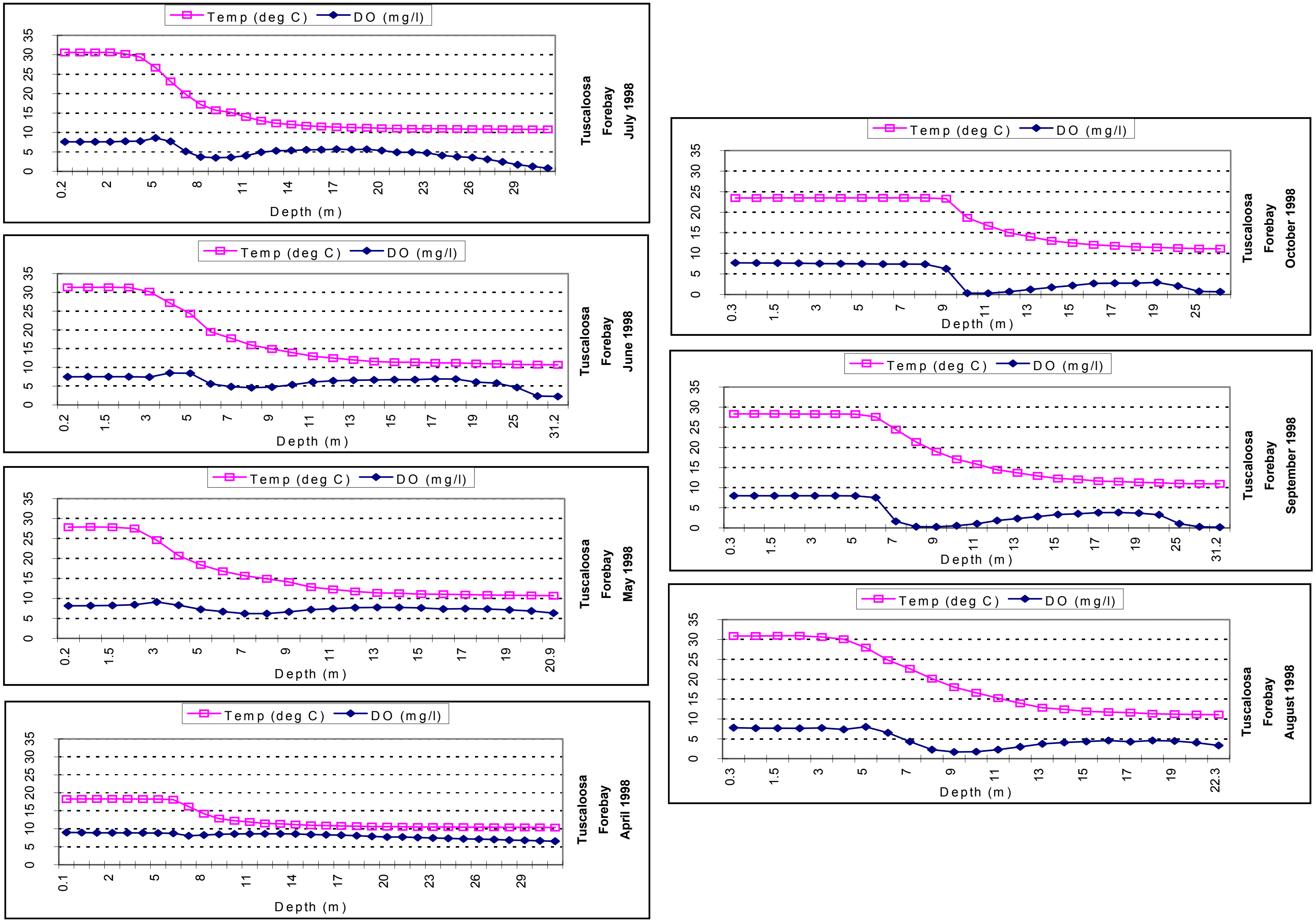


Figure 17. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Tuscaloosa Reservoir, April-October 1998.

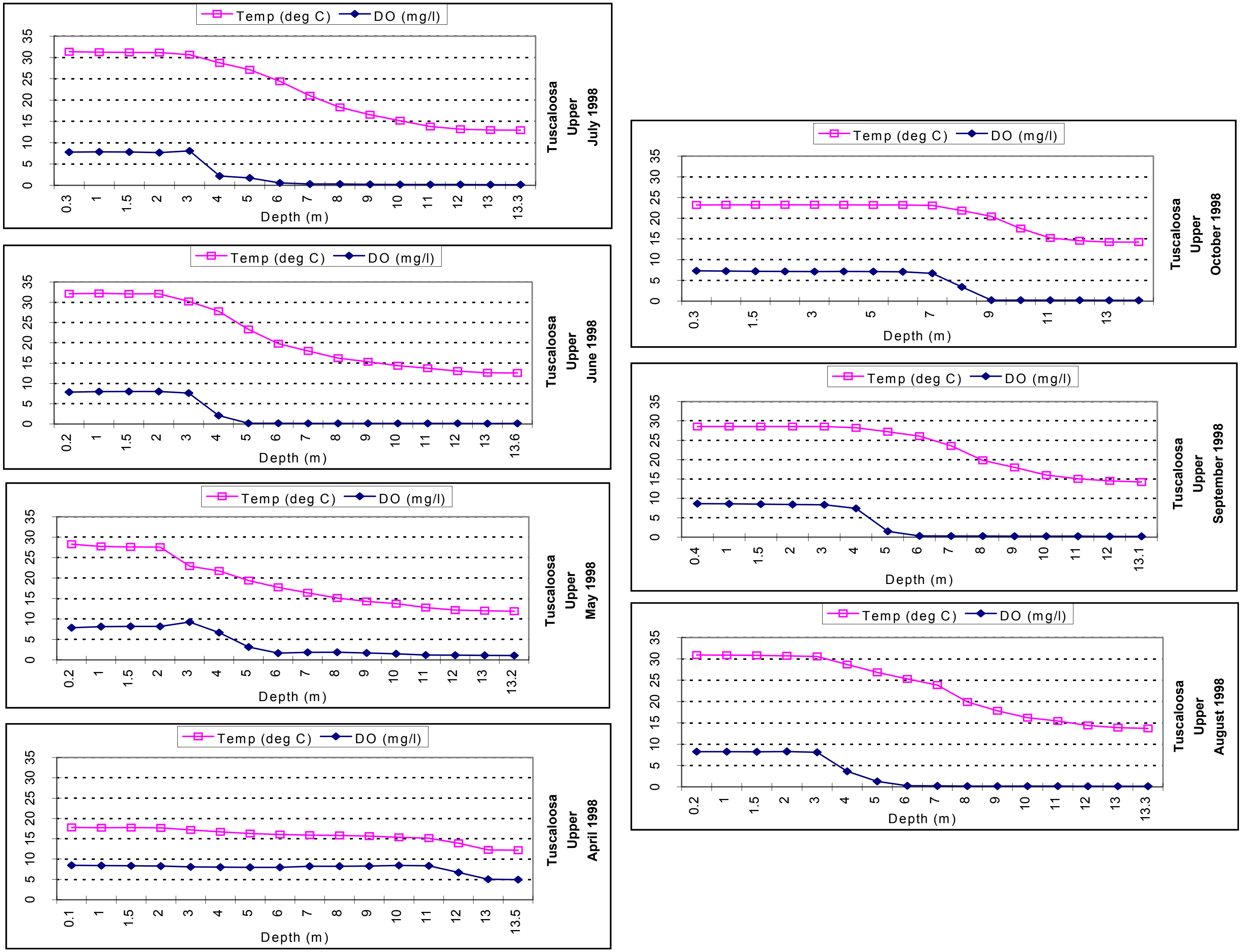


Figure 18. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in upper Tuscaloosa Reservoir, April-October 1998.

Bankhead Reservoir

Nitrogen. Mean TN concentrations in Bankhead Reservoir were, overall, the highest of Warrior basin locations (Fig. 3). Within the reservoir, mean concentrations in the Valley Creek embayment and the Locust Fork were highest, followed by those of mid reservoir, lower reservoir, Mulberry Fork, and Lost Creek, respectively.

Monthly TN values varied during the study period but were highest in Valley Creek and Locust Fork during most months (Fig. 20). TN values for Valley Creek embayment were much higher than those of other Bankhead Reservoir locations when sampled in September and October.

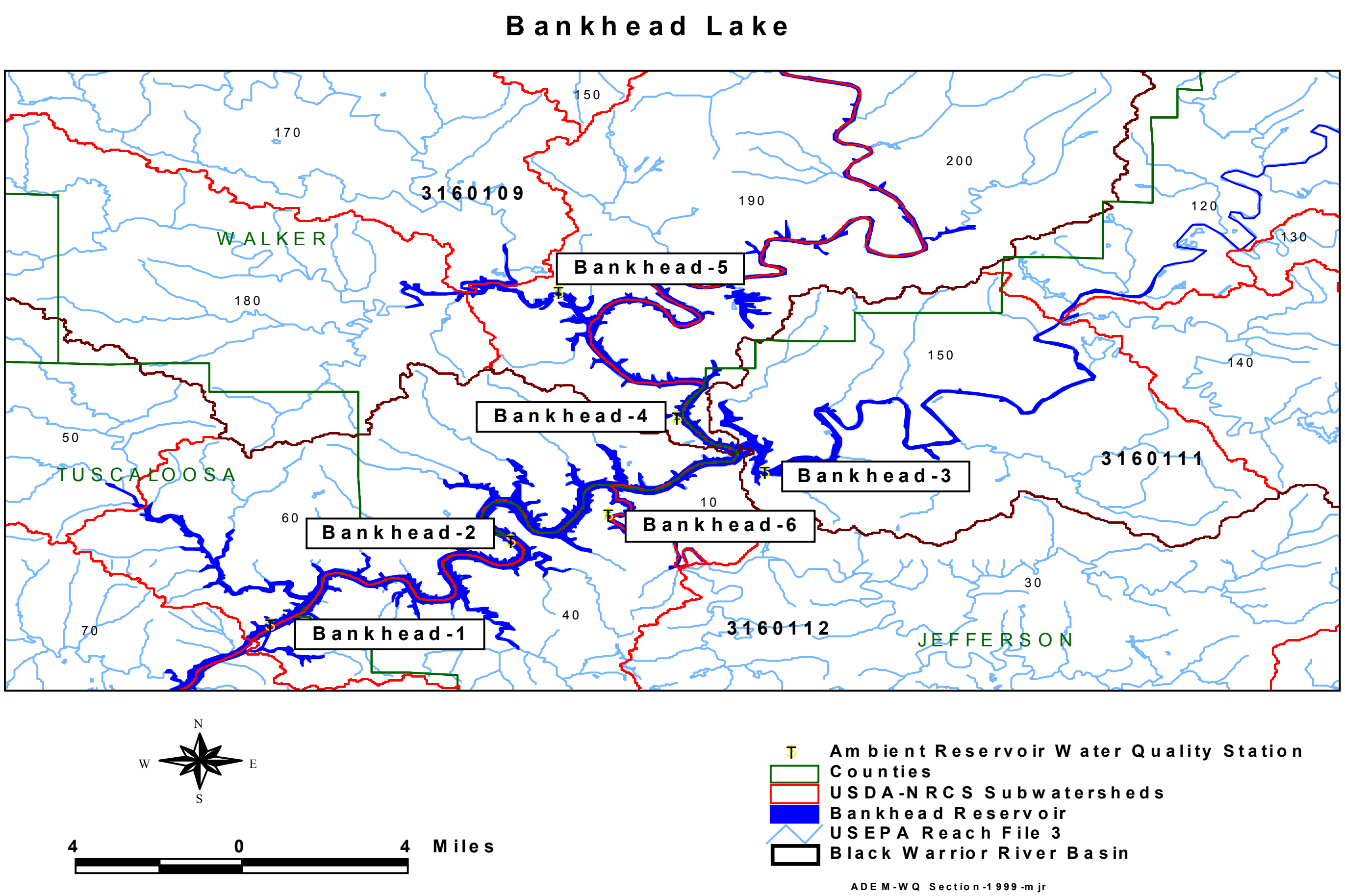
To more clearly view the result of plotting nutrients vs. discharge at Bankhead locations, tributaries to the reservoir (Locust Fork, Mulberry Fork, Valley Creek, and Lost Creek) were graphed separately. In the graphs for Locust Fork, Mulberry Fork, and the mid and lower reservoir locations, discharge was measured through the Bankhead reservoir dam. In the graphs of Valley and Lost Creeks, discharge data was obtained from USGS gage stations located upstream of each embayment sampling location.

No obvious relationship appeared to exist between mean TN concentrations and mean lake discharge (Fig. 20). Lake mean TN concentrations (mean of mid, and lower reservoir locations) varied during the study period as mean lake discharge declined sharply April-May then declined slowly through October. Highest lake mean TN concentrations occurred during October with lowest concentrations occurring in July.

In the Locust Fork location, TN concentrations increased through August as mean discharge decreased (Fig. 22). In September-October, TN concentrations decreased as discharge continued to decline. Highest TN concentrations occurred during August with lowest concentrations occurring in September.

In the Mulberry Fork location, no obvious relationship appeared to exist between mean TN concentrations and mean lake discharge (Fig. 23). TN concentrations were variable during the study period with mean discharge decreasing sharply April-May, then declining slowly through October. Highest TN concentrations occurred in October with lowest concentrations occurring in September.

Figure 19. Map of Bankhead Reservoir with sampling locations.



In the Lost Creek embayment, no obvious relationship appeared to exist between mean TN concentrations and mean discharge (Fig. 24). TN concentrations were variable during the study period with mean discharge decreasing April-June, increasing July-August, then decreasing to lowest levels in September-October. Highest TN concentrations occurred in May and October with lowest concentrations occurring in April and July.

In the Valley Creek embayment, TN concentrations appeared to increase overall as mean discharge decreased (Fig. 25).

Phosphorus. Mean TP concentrations in Bankhead Reservoir were highest in the Valley Creek embayment, followed by the Locust Fork, Mulberry Fork, mid reservoir, Lost Creek, and lower reservoir, respectively (Fig. 4). Mean values for the Valley Creek embayment were highest of Warrior basin locations.

To more clearly view the result of plotting nutrients vs. discharge at Bankhead locations, tributaries to the reservoir (Locust Fork, Mulberry Fork, Valley Creek, and Lost Creek) were graphed separately. In the graphs for Locust Fork, Mulberry Fork, and the mid and lower reservoir locations, discharge was measured through the Bankhead reservoir dam. In the graphs of Valley and Lost Creeks, discharge data was obtained from USGS gage stations located upstream of each embayment sampling location.

Monthly TP values were variable during the study period (Fig. 20). TP values in the Valley Creek embayment were highest May-October. Highest values at most sampling locations occurred April and/or August.

Both lake mean TP values concentrations (mean of mid, and lower reservoir locations) and mean discharge were highest during April and lower in the following months (Fig. 20).

In the Locust Fork, TP values declined sharply April-May along with mean lake discharge (Fig. 22). From June-October, TP values increased overall as mean lake discharge decreased.

In the Mulberry Fork, lake mean TP values declined sharply April-July along with mean lake discharge (Fig. 23). TP values increased in August then declined through October as mean discharge continued to decline.

In the Lost Creek embayment, no relationship was apparent between lake mean TP concentrations and mean discharge (Fig. 24). TP values were variable April-October with highest values occurring in August and lowest values occurring in July. Mean discharge decreased sharply April-June, increased July-August then decreased to lowest levels September-October.

In the Valley Creek embayment, a strong relationship appeared to exist between lake mean TP concentrations and mean discharge (Fig. 25). TP values were much higher May-October as mean discharge decreased through the period.

Algal Growth Potential Tests. With the exception of the Valley Creek embayment, phosphorus was indicated as the limiting nutrient at all locations of Bankhead Reservoir (Table 6). Nitrogen and phosphorus were co-limiting nutrients in the Valley Creek embayment. The mean MSC of Valley Creek and the Locust Fork (29.09 and 24.74 mg/l, respectively) were well above the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes. The mean MSC of the mid reservoir location (4.52 mg/l) was near the maximum 5.0 mg/l level. The mean MSC of the lower reservoir, Mulberry Fork, and Lost Creek locations (2.65, 2.31, and 1.95 mg/l, respectively) were well below the maximum 5.0 mg/l level.

Chlorophyll a. Mean chlorophyll *a* concentrations of the Valley Creek embayment were more than twice that of the next highest location, the Locust Fork (Fig. 5), with these two locations having the highest mean concentrations of Warrior basin locations. The mean value of the mid reservoir was the fourth highest of basin locations. Mean values in the mid-reservoir were followed by Mulberry Fork, Lost Creek, and lower reservoir locations.

To more clearly view the result of plotting chlorophyll *a* vs. discharge at Bankhead locations, tributaries to the reservoir (Locust Fork, Mulberry Fork, Valley Creek, and Lost Creek) were graphed separately. In the graphs for Locust Fork, Mulberry Fork, and the mid and lower reservoir locations, discharge was measured through the Bankhead reservoir dam. In the graphs of Valley and Lost Creeks, discharge data was obtained from USGS gage stations located upstream of each embayment sampling location.

Monthly chlorophyll *a* concentrations in the lower, mid, Lost Creek, and Mulberry Fork followed similar patterns, increasing April-June/July, then decreasing through October (Fig. 21). In the Valley Creek embayment, concentrations increased sharply April-June then declined sharply in July. Concentrations increased once again August-September before declining for the second time in October. In the Locust Fork, concentrations increased April-August then declined through October.

Lake mean chlorophyll *a* concentrations (mean of mid and lower reservoir) steadily increased April-July as mean lake discharge decreased (Fig. 21). Concentrations declined August-October as mean discharge continued to decrease.

In the Locust Fork, chlorophyll *a* concentrations increased steadily April-August as mean lake discharge decreased (Fig. 22). Mean concentrations decreased September-October as mean discharge continued to decline.

In the Mulberry Fork, chlorophyll *a* concentrations increased April-June as mean discharge decreased (Fig. 23). Concentrations decreased July-October as mean discharge continued to decline.

In the Lost Creek embayment, chlorophyll *a* concentrations increased gradually April-June as mean discharge decreased (Fig. 24). Concentrations slowly declined July-October with mean discharge variable but reaching its lowest levels September-October.

In the Valley Creek embayment, chlorophyll *a* concentrations were much higher May-October as mean discharge declined (Fig. 25).

Total Suspended Solids. Mean TSS concentrations in Bankhead were higher overall than those of Smith and Tuscaloosa Reservoirs, similar to those of Holt Reservoir, and much lower than those of Oliver and Warrior Reservoirs (Fig. 6). Within the reservoir, mean TSS concentrations were much higher in Locust Fork, followed by mid reservoir, Valley Creek, Mulberry Fork, Lost Creek, and the lower reservoir, respectively.

Monthly TSS concentrations were highest during April at most Bankhead locations and varied similarly at the locations during the study period (Fig. 21). Concentrations in the Locust Fork were highest in the reservoir during May, July, August, and along with Valley Creek, in May and October.

Lake mean TSS concentrations (mean of mid and lower reservoir) decreased sharply April-May along with mean lake discharge (Fig. 21). Mean TSS concentrations varied only slightly June-October as mean discharge slowly declined. Highest lake mean TSS concentrations occurred in April with lowest concentrations occurring in September.

In the Locust Fork, TSS concentrations followed a pattern very similar to that of mean discharge, decreasing sharply April-May then changing little through October (Fig. 22). Highest TSS concentrations in the Locust Fork occurred in April with lowest concentrations occurring in September.

In the Mulberry Fork, TSS concentrations followed a pattern very similar to that of mean discharge (Fig. 23). TSS concentrations and mean discharge decreased sharply April-May. From June-October, TSS concentrations changed little as mean discharge slowly declined. Highest TSS concentrations in the Mulberry Fork occurred in April with lowest concentrations occurring in September.

In the Lost Creek embayment, TSS concentrations varied monthly but decreased overall during the study period (Fig. 24). Mean discharge in Lost Creek decreased April-June, increased July-August, then declined to lowest levels September-October. Highest TSS concentrations in Lost Creek occurred in April with lowest concentrations occurring in September.

In the Valley Creek embayment, TSS concentrations varied monthly but declined overall during the study period (Fig. 25). Mean discharge in Valley Creek declined sharply April-May, then gradually through October. Highest TSS concentrations occurred in June with lowest concentrations occurring in September/October.

Trophic State. Monthly TSI values for the lower reservoir, mid reservoir, Lost Creek, Locust Fork, and Mulberry Fork increased from oligotrophic to eutrophic levels April-July (Fig. 26). The trophic state of the Locust Fork reached highly eutrophic levels in August. At all locations except the lower reservoir, TSI values declined August-October but remained within the eutrophic range. In the lower reservoir, TSI values declined from the eutrophic range in July to the mesotrophic range September-October. In Valley Creek, TSI values increased from oligotrophic levels to hypereutrophic levels April-June. The trophic state declined in July but remained within the upper half of the eutrophic range. From August-September TSI values for Valley Creek increased to highly eutrophic levels then declined in October, remaining within the upper half of the eutrophic range.

Dissolved Oxygen/Temperature. With the exception of Valley Creek, DO concentrations at Bankhead locations followed a similar pattern during the study period, generally decreasing April-October (Fig. 26). DO concentrations in the lower reservoir were below the criterion limit September-October (3.95 and 3.85 mg/l, respectively). DO concentrations in the mid reservoir were below the criterion limit in September and just above the limit in October (3.86 and 5.29 mg/l, respectively). In the Locust Fork, DO concentrations were above the criterion limit when sampled, though concentrations measured in May (5.79 mg/l) and September (5.52 mg/l) were near the limit. In the Mulberry Fork, Lost Creek, and Valley Creek, DO concentrations were above the criterion limit in all months sampled. DO concentrations in the Valley Creek embayment were extremely high during the study period, at times exceeding the measuring capacity of equipment when measuring near the surface.

Depth profiles of temperature and DO in the dam forebay of Bankhead Reservoir indicated that the water column was essentially isothermal and isochemical in April (Fig. 27). Thermal stratification began to develop in May and strengthened June-July with the thermocline developing in the lower portion of the water column. Thermal stratification began to break down in August with isothermal conditions returning September-October. Highest water column temperatures occurred in July. Chemical stratification began to develop in May in the lower portion of the water column. The anoxic portion of the water column increased June-July then decreased August-September with essentially isochemical conditions returning in October. DO concentrations September-October were below 5.0 mg/l from the surface to the bottom of the water column. It should be noted that the dam forebay sampling location lies in the path of barge traffic through the Bankhead Lock and Dam. Mixing of portions of the water column by barge traffic likely affects stratification to some degree.

Depth profiles of temperature and DO in the Locust Fork indicated that the water column was essentially isothermal and isochemical in April (Fig. 28). Very weak thermal and chemical stratification developed May-September with essentially isothermal and isochemical conditions returning in October. Highest water column temperatures occurred in June with lowest DO concentrations occurring in September. It should be noted that the Locust Fork sampling location lies in the path of barge traffic. Mixing of the relatively shallow water column at this location by barge traffic likely affects stratification to a considerable degree.

Depth profiles of temperature and DO in the Mulberry Fork indicated that the water column was essentially isothermal and isochemical in April (Fig. 29). Weak thermal and chemical stratification developed May-September with essentially isothermal and isochemical conditions returning in October. Highest water column temperatures occurred in July with lowest DO concentrations occurring in September.

Depth profiles of temperature and DO in the Lost Creek embayment indicated that the water column was essentially isothermal and isochemical in April (Fig. 30). Thermal and chemical stratification began to develop in May and strengthened June-October. Highest water column temperatures occurred in June with lowest DO concentrations occurring in June and September.

Depth profiles of temperature and DO in the Valley Creek embayment indicated that the water column was essentially isothermal and isochemical in April (Fig. 31). Thermal and chemical stratification began to develop in May and strengthened June-October. Highest water column temperatures occurred in June with lowest DO concentrations occurring in June.

Fish Tissue Analysis. Largemouth bass and catfish were collected from 3 mainstem and 4 tributary embayment locations in Bankhead Reservoir November and December 1997-1998 (Appendix Table 1). Laboratory analyses indicated that bioaccumulative contaminant concentrations in both species of fish were well below FDA advisory limits (Appendix Table 2).

Discussion. Water quality concerns for Bankhead Reservoir are centered primarily in the Locust Fork and Valley Creek embayments. The highest mean TN concentrations measured in the basin occurred in these locations. The highest mean TP value measured in the basin occurred in the Valley Creek embayment with that of the Locust Fork among the highest. Lake mean TN and TP concentrations at Locust Fork and Valley Creek locations were much higher after mean discharge declined, indicating that point sources are an important contributor to nutrient concentrations. The highest mean chlorophyll *a* concentrations measured in the basin occurred in these locations with that of the Valley Creek embayment greater than twice that of the next highest location, the Locust Fork. TSI values in the Valley Creek embayment reached hypereutrophic levels in June and were near these levels August-September. TSI values in Locust Fork were highly eutrophic in August. DO concentrations in the Locust Fork were near criterion limits in May and September. DO concentrations in the upper water column of the Valley Creek embayment exceeded the measuring capacity of monitoring equipment on two occasions because of high algal densities.

The Locust Fork of the Black Warrior River contains 15 sub-watersheds, 7 of which were designated as priority sub–watersheds based on nonpoint source impacts to macroinvertebrate and fish communities (ADEM 1999). Percent landcover of the upper Locust Fork sub-watershed was estimated as follows (EPA 1997b):

a) 33% deciduous forest;
b) 17% evergreen forest;
c) 25% mixed forest;
d) 17% pasture/hay; and,
e) 8% row crop.

Poultry production operations are also common in the upper sub-watershed (Shepard et al. 1997). In the middle Locust Fork, landcover was estimated as follows:

a) 26% deciduous forest;
b) 12% evergreen forest;
c) 21% mixed forest;
d) 29% pasture/hay; and,
e) 12% row crop.

In the lower Locust Fork, landcover was estimated as follows:

a) 50% deciduous forest;
b) 19% evergreen forest; and,
c) 31% mixed forest.

In addition, the Locust Fork drains much of Birmingham and surrounding suburbs. Permitted discharges in the Locust Fork watershed consist of the following:

a) 9 major municipal discharges;
b) 4 major industrial discharges;
c) 57 mining permits; and,
d) 129 construction/stormwater authorizations.

Because the Valley Creek watershed lies largely within urban/suburban Jefferson County, no nonpoint source assessment was conducted (ADEM 1999). A number of potential nonpoint sources were indicated by landcover estimates in the upper and lower Valley Creek sub-watershed. In the upper Valley Creek sub-watershed, landcover was estimated as follows (EPA 1997):

a) 20% low intensity residential/industrial;
b) 8% high intensity residential/industrial;
c) 12% commercial/industrial/transportation;
d) 20% deciduous forest;
e) 4% pasture/hay; and,
f) 4% row crop.

In the lower Valley Creek sub-watershed, landcover was estimated as follows (EPA 1997):

a) 3% low intensity industrial/residential;
b) 39% deciduous forest;
c) 24% evergreen forest;
d) 29% mixed forest;
e) 3% pasture/hay; and,
f) 3% row crop.

Permitted discharges in the Valley Creek watershed consist of the following:

a) 1 major municipal discharge;
b) 3 major industrial discharges;
c) 29 construction/stormwater authorizations; and,
d) 28 mining permittees.

From May-July, September, and October, conductivity values in the Lost Creek embayment often increased an order of magnitude or more below a depth of 3 meters (Appendix Fig. 2). An increase of this magnitude was not observed at any other location in the basin. Lost Creek was listed as a priority sub-watershed by the Nonpoint Source Program of ADEM because of impairment from agricultural sources (ADEM 1989). Other possible sources are indicated by a review of landcover and permitted discharges. Percent landcover within the Lost Creek sub-watershed was recently estimated as follows (EPA 1997):

a) 2% quarry/surface mine;
b) 2% transitional barren;
c) 41% deciduous forest;
d) 18% evergreen forest;
e) 27% mixed forest;
f) 6% pasture/hay; and,
g) 4% row crop.

Permitted discharges in the sub-watershed are as follows (ADEM 1999):

a) 43 mining NPDES permits; and,
b) 6 construction/stormwater authorizations.

Further research is suggested in the sub-watershed to more specifically determine origins of high conductivity values and effects to biological communities.

Laboratory analyses of largemouth bass and catfish from all locations in Bankhead Reservoir indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits.

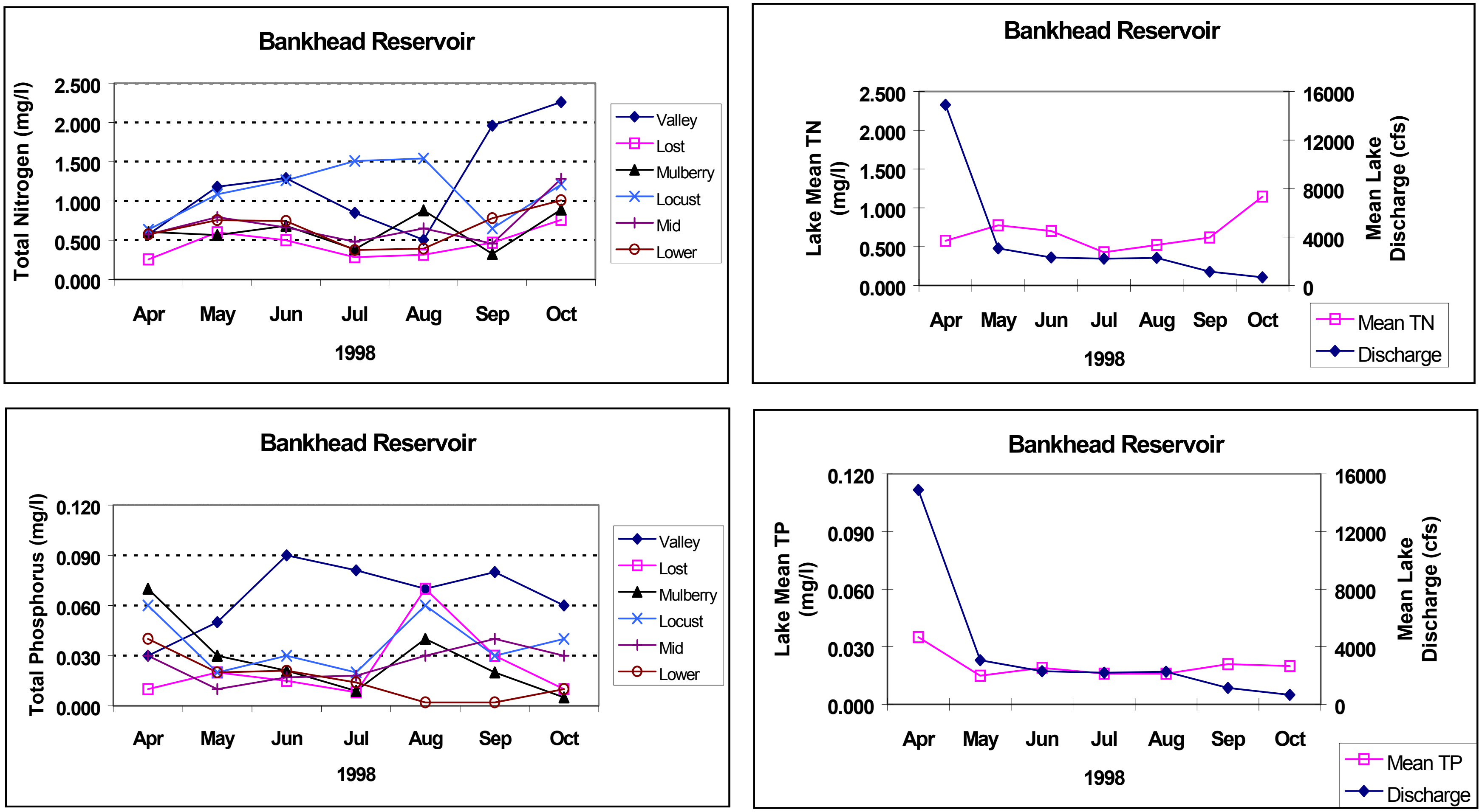


Figure 20. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Bankhead Reservoir, April-October 1998.

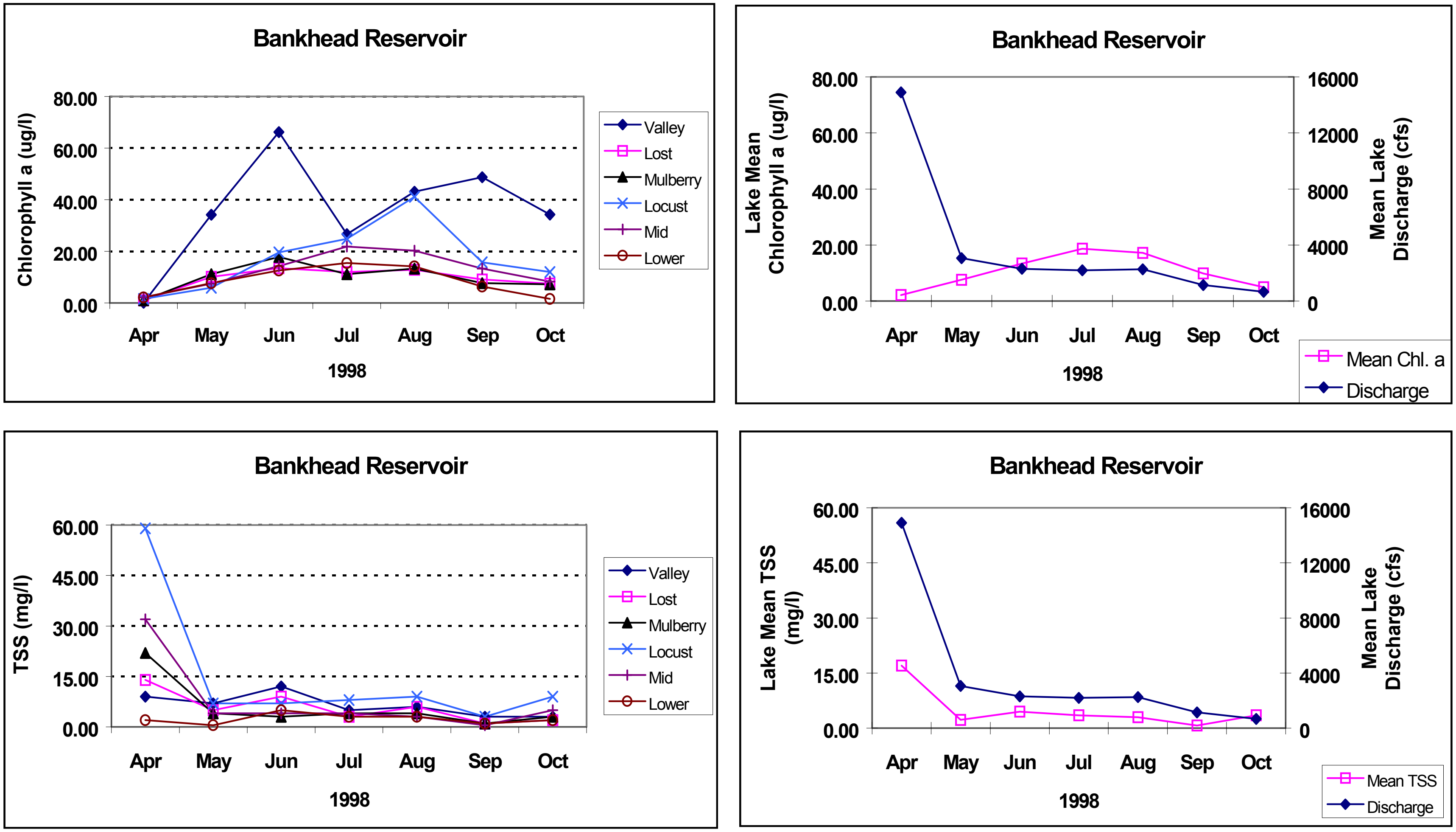


Figure 21. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS), and TSS vs. discharge of Bankhead Reservoir, April-October 1998.

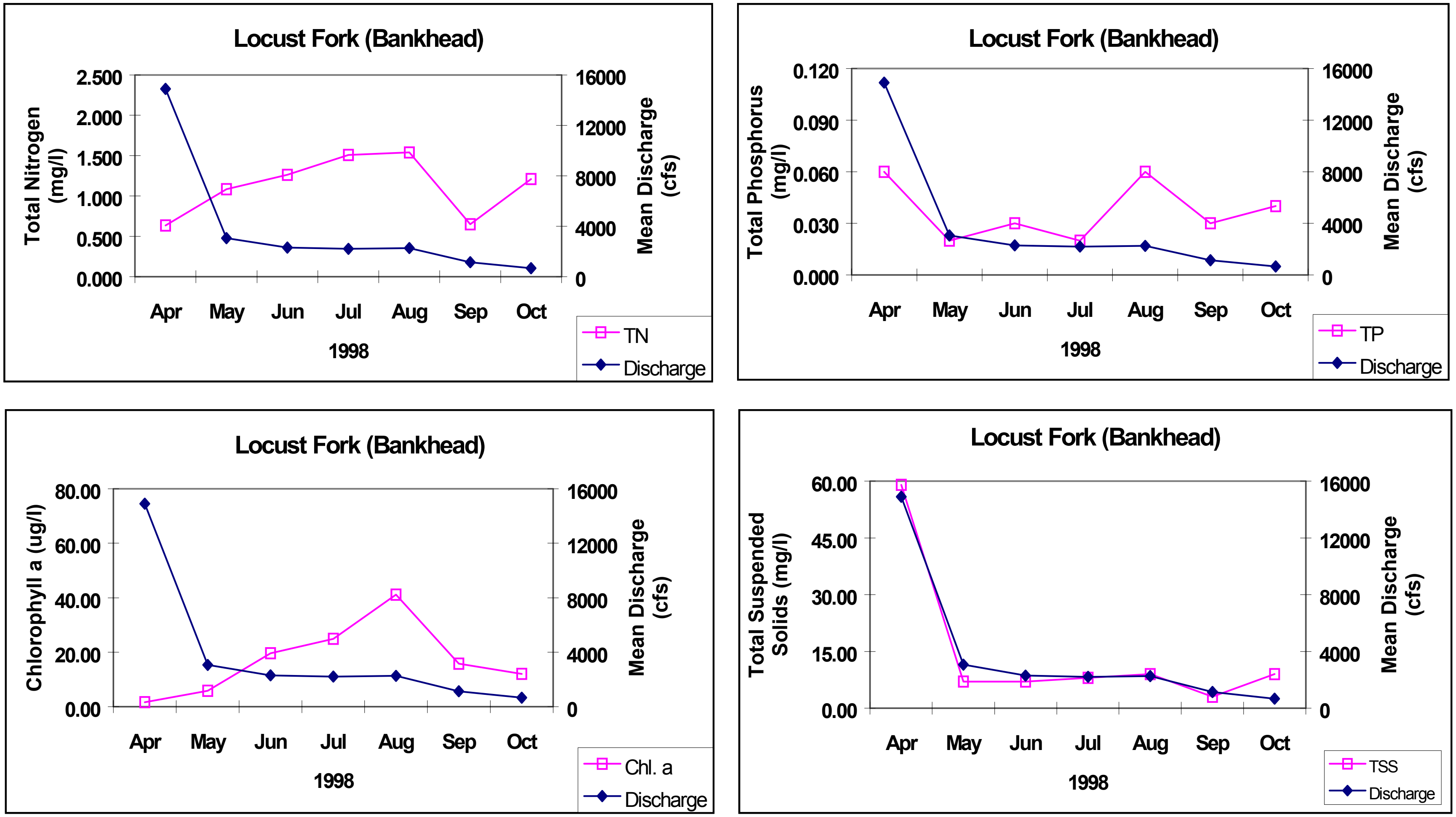


Figure 22. Total nitrogen (TN) vs. discharge, total phosphorus (TP) vs. discharge, chlorophyll *a* vs. discharge, and total suspended solids (TSS) vs. discharge of the Locust Fork embayment of Bankhead Reservoir, April-October 1998.

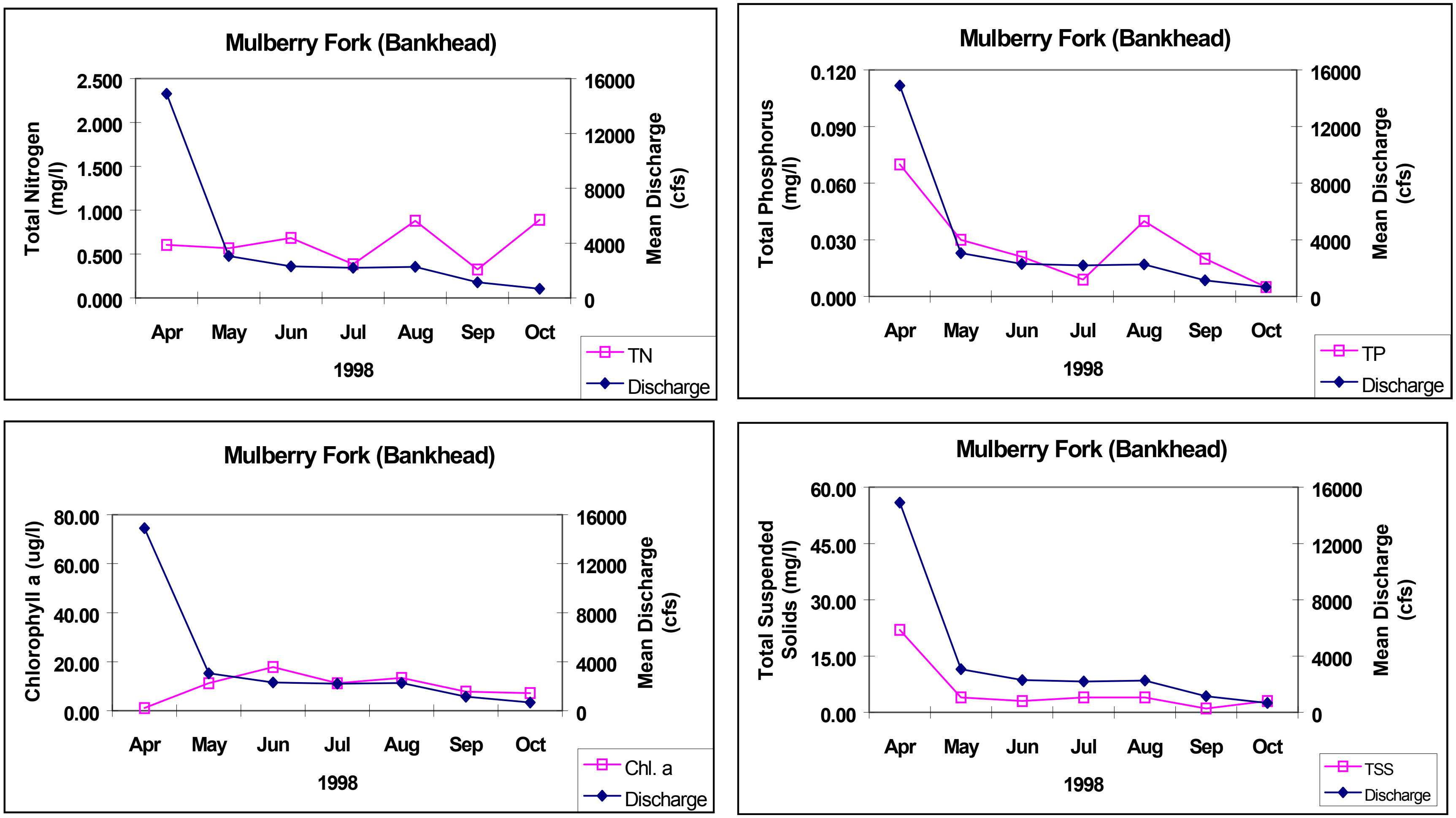


Figure 23. Total nitrogen (TN) vs. discharge, total phosphorus (TP) vs. discharge, chlorophyll *a* vs. discharge, and total suspended solids (TSS) vs. discharge of the Mulberry Fork embayment of Bankhead Reservoir, April-October 1998.

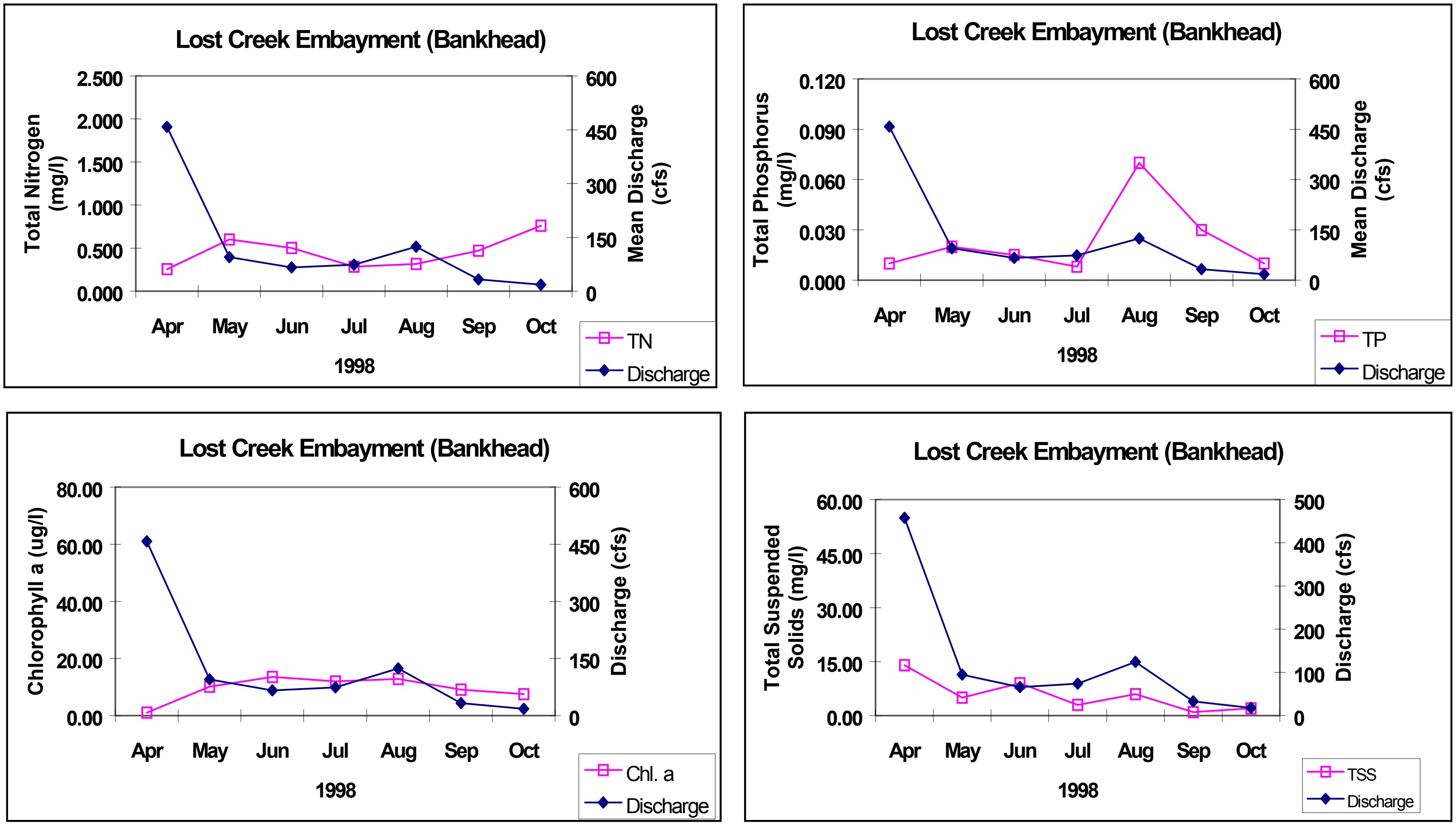


Figure 24. Total nitrogen (TN) vs. discharge, total phosphorus (TP) vs. discharge, chlorophyll *a* vs. discharge, and total suspended solids (TSS) vs. discharge of the Lost Creek embayment of Bankhead Reservoir, April-October 1998.

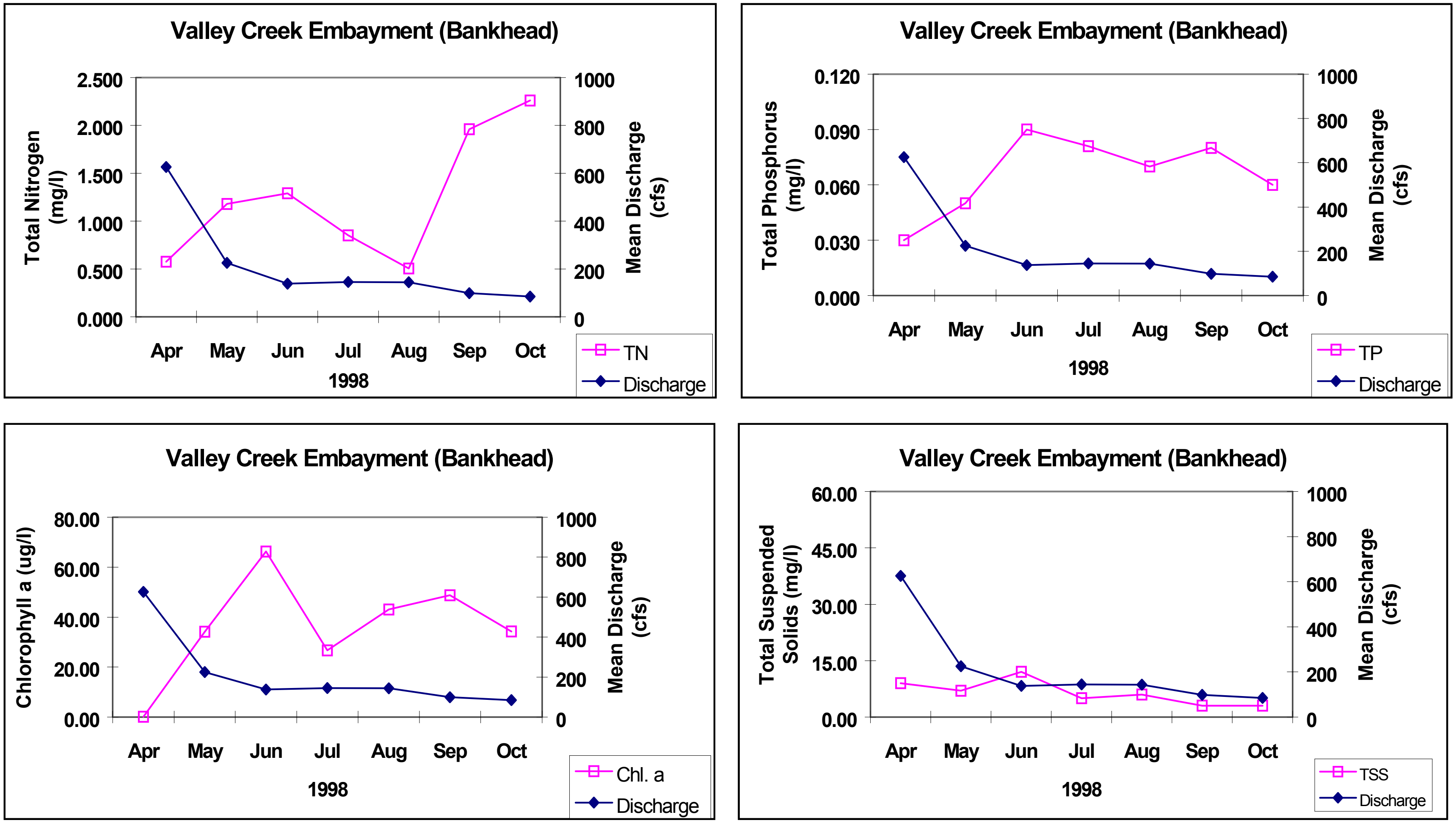
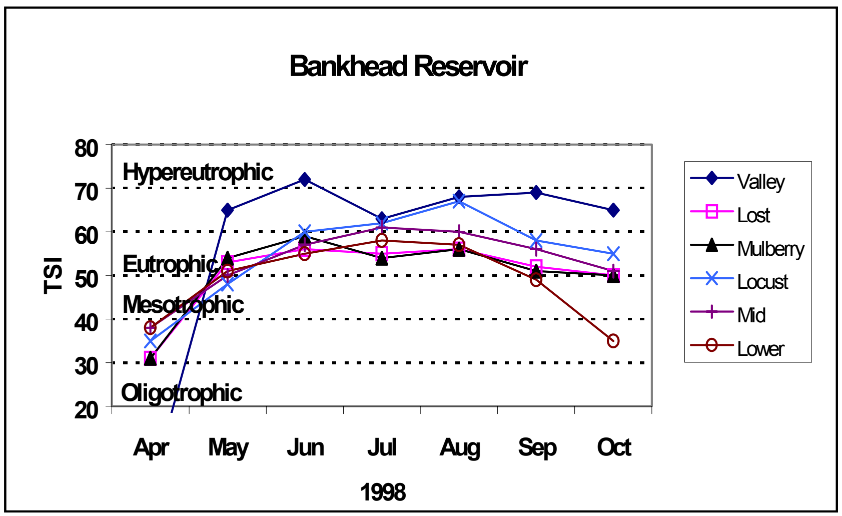


Figure 25. Total nitrogen (TN) vs. discharge, total phosphorus (TP) vs. discharge, chlorophyll *a* vs. discharge, and total suspended solids (TSS) vs. discharge of the Valley Creek embayment of Bankhead Reservoir, April-October 1998.



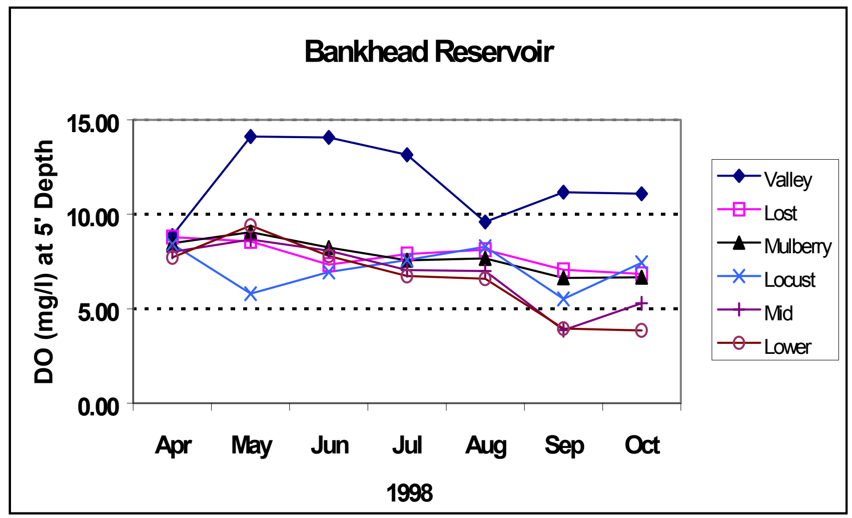


Figure 26. Trophic state index (TSI), and dissolved oxygen (DO) of Bankhead Reservoir, April-October 1998.

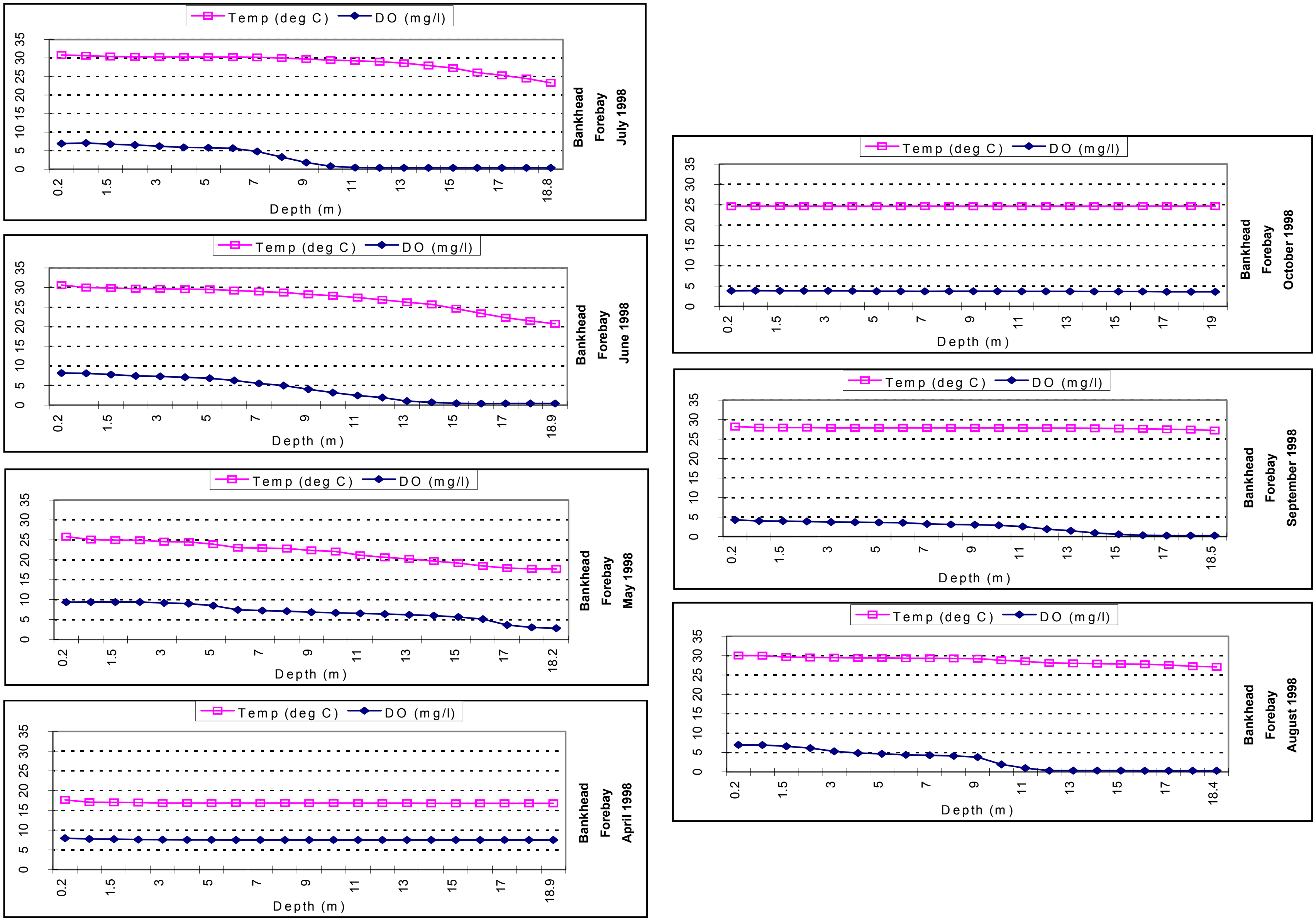


Figure 27. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Bankhead Reservoir, April-October 1998.

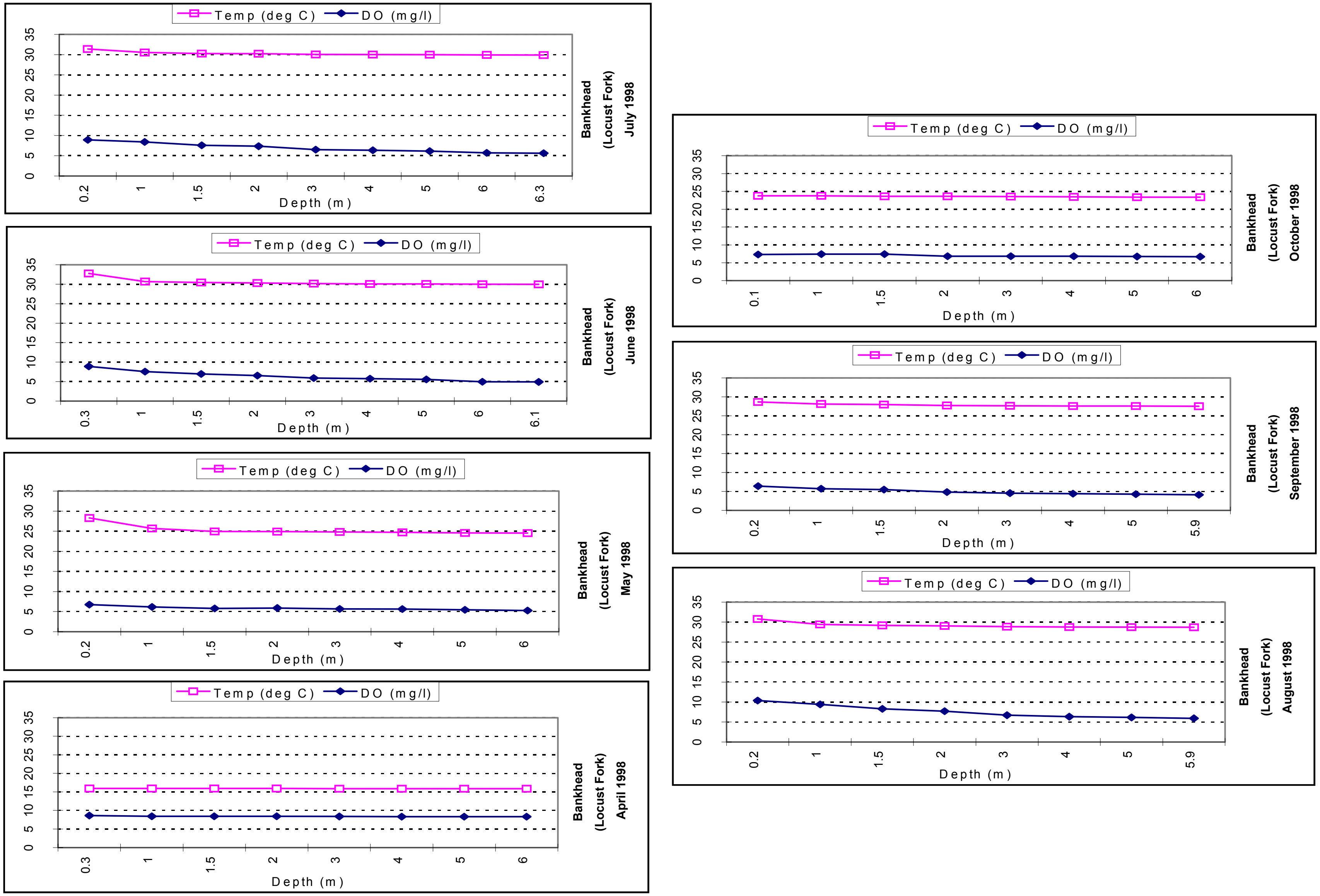


Figure 28. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the Locust Fork of Bankhead Reservoir, April-October 1998.

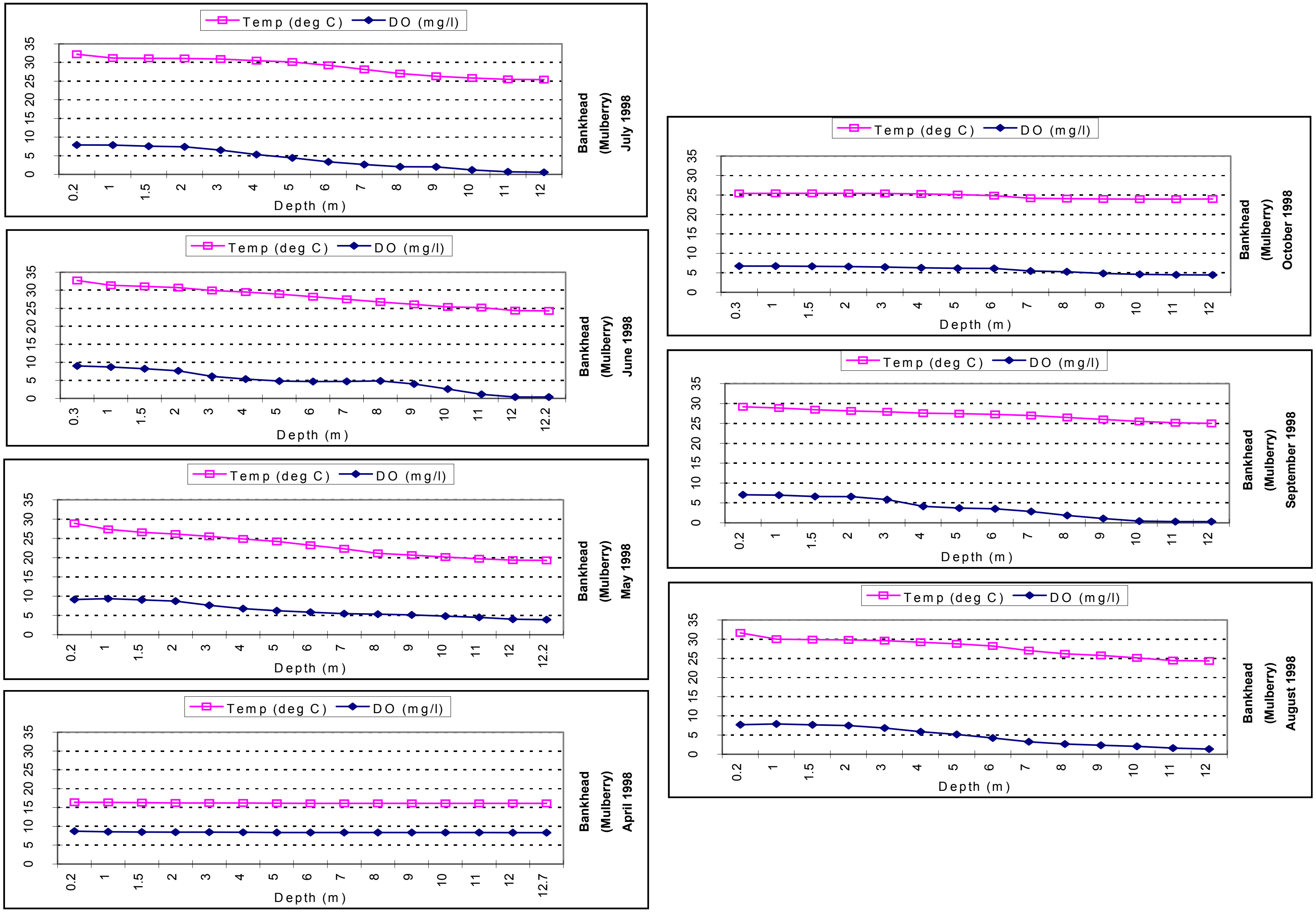


Figure 29. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the Mulberry Fork of Bankhead Reservoir, April-October 1998.

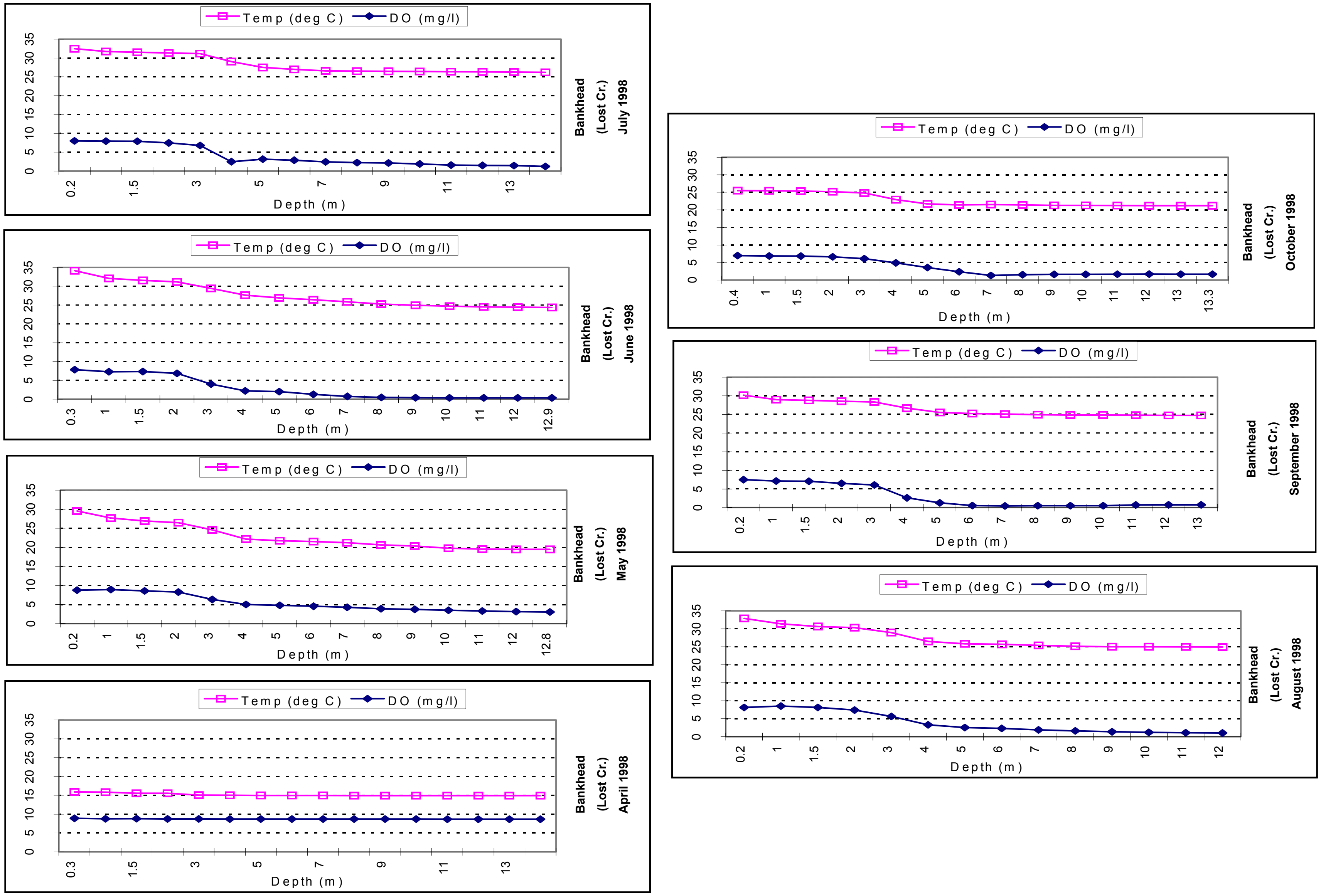


Figure 30. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the Lost Creek embayment of Bankhead Reservoir, April-October 1998.

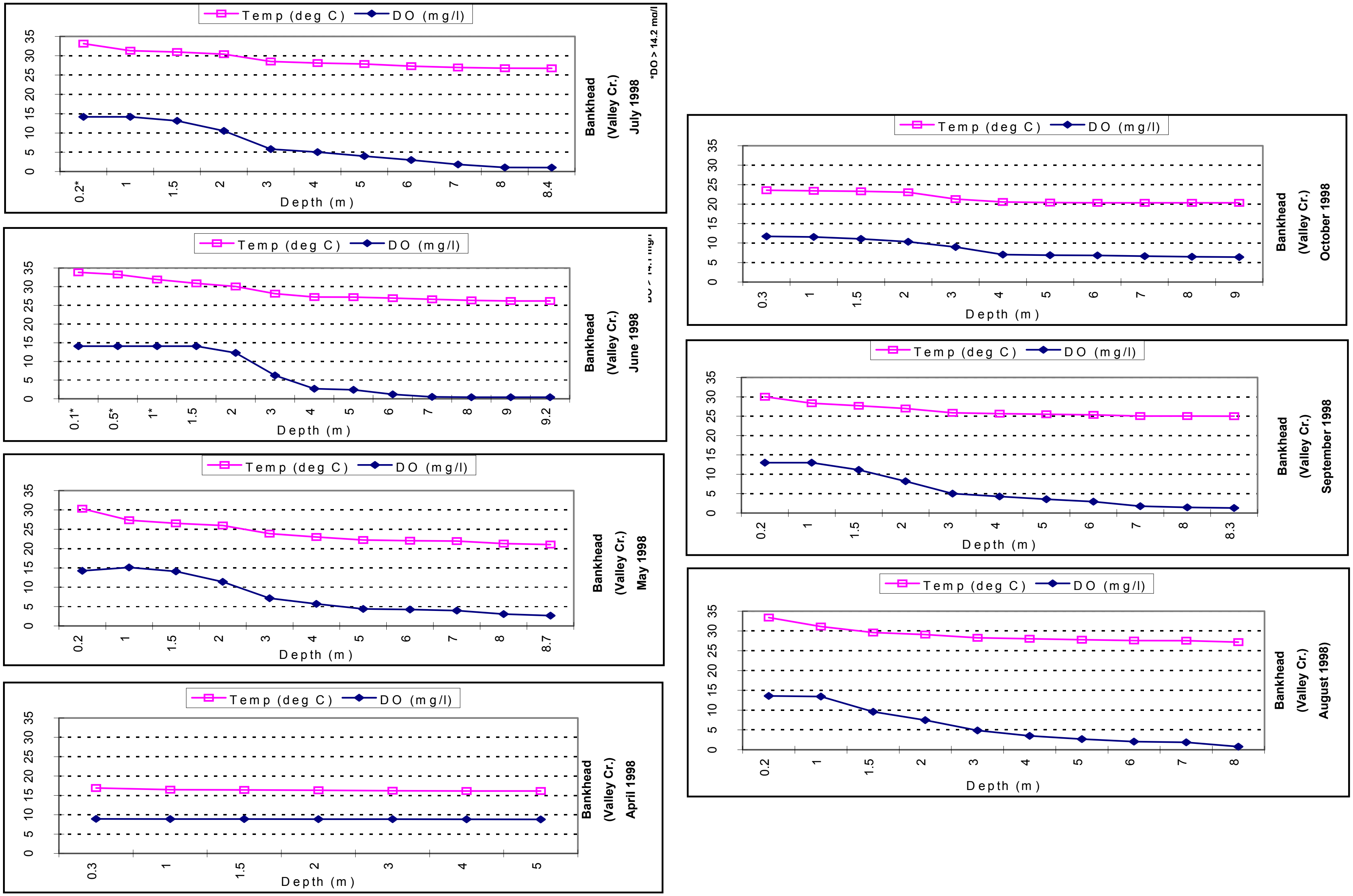


Figure 31. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the Valley Creek embayment of Bankhead Reservoir, April-October 1998.

Holt Reservoir

Nitrogen. Mean TN concentrations in Holt Reservoir were similar to those of other mainstem locations in Bankhead, Oliver, and Warrior Reservoirs (Fig. 3). Within the reservoir, mean concentrations in the lower reservoir were less than those of the upper reservoir location.

Monthly TN concentrations were variable during the months sampled (Fig. 33). Highest concentrations in the upper reservoir occurred in July with lowest concentrations occurring in May. In the lower reservoir, highest concentrations occurred in August with lowest concentrations occurring in September.

The lake mean TN concentration decreased April-May along with lake discharge then increased sharply through August as discharge continued to decline (Fig. 33). TN concentrations decreased sharply in September then increased once again in October as mean lake discharge continued to decrease.

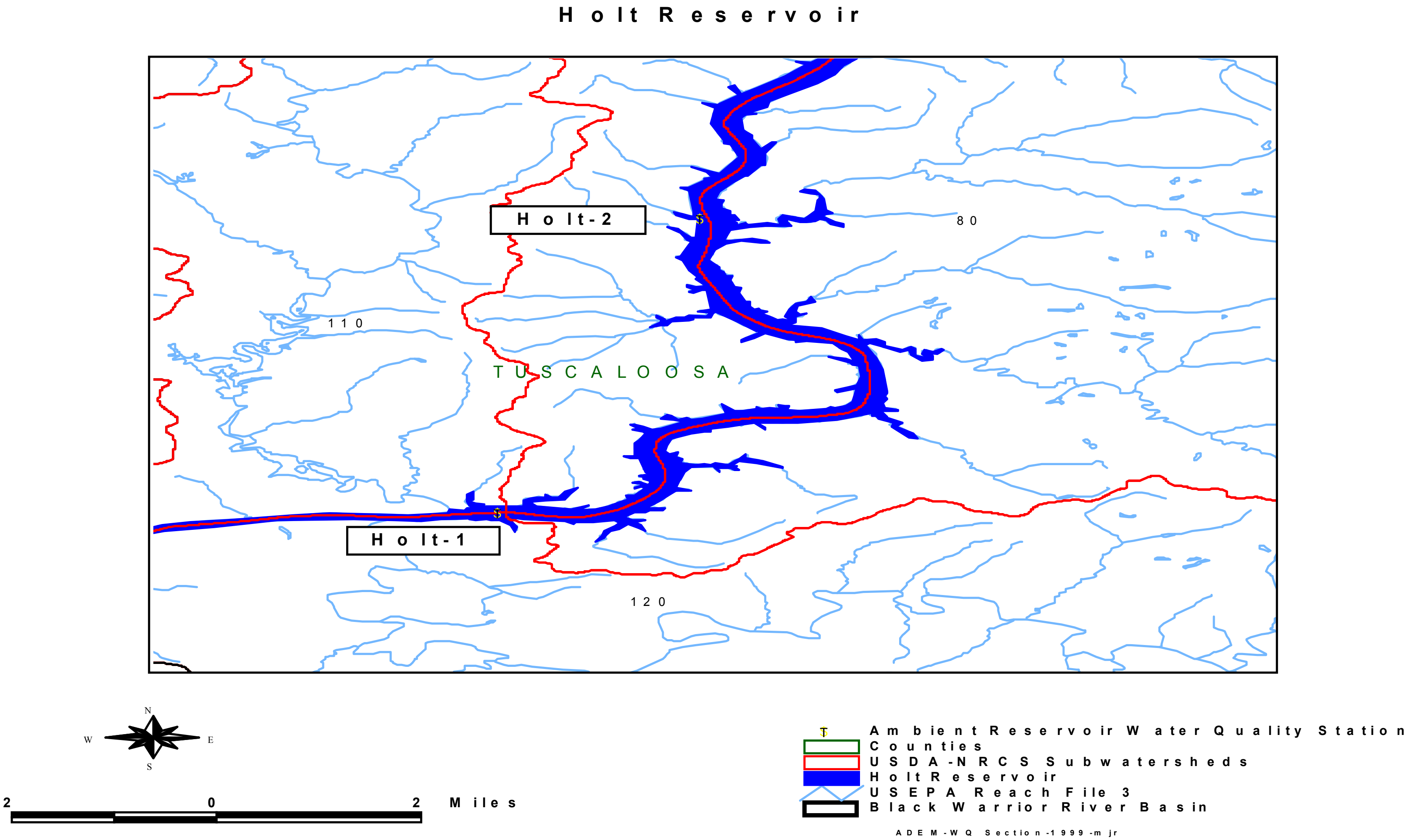
Phosphorus. Mean TP concentrations in Holt Reservoir were similar to those of mid and lower Bankhead and Warrior Reservoir locations but below those of Oliver and upper Warrior Reservoir (Fig. 4). Within the reservoir, mean concentrations in the upper reservoir were less than those of the lower reservoir.

Monthly TP concentrations in the upper reservoir were variable with highest concentrations occurring in April and August and lowest concentrations occurring in July (Fig. 33). In the lower reservoir, TP concentrations decreased April-May, increased through August, then declined September-October. Highest concentrations in the lower reservoir occurred in August with lowest concentrations occurring in October.

Lake mean TP concentrations decreased sharply April-May along with lake discharge then increased sharply through August as discharge continued to decline (Fig. 33). Lake mean TP concentrations decreased September-October, as lake discharge continued to decline.

Algal Growth Potential Tests. Phosphorus was indicated as the limiting nutrient in the upper and lower portions of Holt Reservoir (Table 6). Mean MSC values for the upper and lower reservoir (2.66 and 2.60 mg/l, respectively) were well below the

Figure 32. Map of Holt Reservoir with sampling locations.



maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes.

Chlorophyll a. Mean chlorophyll *a* concentrations in Holt Reservoir were below those of upstream Bankhead Reservoir and above those of downstream Oliver Reservoir (Fig. 5). Within the reservoir, mean concentrations in the upper reservoir were higher than those of the lower reservoir.

Monthly chlorophyll *a* concentrations in the upper reservoir were variable April-October with highest concentrations occurring in June and lowest concentrations occurring in April (Fig. 34). Concentrations in the lower reservoir were also variable April-October with highest values occurring in August and lowest values occurring in April.

Lake mean chlorophyll *a* concentrations were variable April-October with highest values occurring in June and August and lowest values occurring in April during very high flows (Fig. 34). Mean lake discharge decreased April-October, with a sharp decrease April-May then a gradual decrease through October.

Total Suspended Solids. Mean TSS concentrations in Holt Reservoir were above that of lower Bankhead Reservoir but well below those of downstream Oliver and Warrior Reservoirs (Fig. 6). Within the reservoir, mean concentrations in the upper reservoir were greater than those of the lower reservoir.

Monthly TSS concentrations were similar at both reservoir locations April-October with highest concentrations occurring in April and lowest concentrations in May and September (Fig. 34).

Lake mean TSS concentrations were variable April-October with highest values occurring in April and lowest values occurring in May and September (Fig. 34). Mean lake discharge decreased April-October, with a sharp decrease April-May then a gradual decrease through October.

Trophic State. TSI values for both reservoir locations were within the oligotrophic range when sampled during high flows in April (Fig. 35). In the upper reservoir, TSI values increased into the eutrophic range May-September before dropping into the mesotrophic range in October. TSI values for the lower reservoir were variable with values in the mesotrophic range in May and July and values in the eutrophic range June, August, and September.

Dissolved Oxygen/Temperature. DO concentrations were similar at both Holt Reservoir locations April-June (Fig. 35). Concentrations at both locations declined July-October but remained above the criterion limit of 5.0 mg/l on all dates sampled.

Depth profiles of temperature and DO from the Holt dam forebay indicated that strong thermoclines and chemoclines did not develop during most months with temperature and DO decreasing gradually with depth (Fig. 36). It should be noted that the dam forebay sampling location lies in the path of barge traffic through the Holt Lock and Dam. Mixing of portions of the water column by barge traffic likely affects stratification to some degree.

A thermocline developed near the surface in June. During September a thermocline and a chemocline developed near the surface. Deoxygenation occurred near the bottom only in June and July. Highest water column temperatures occurred June-August.

Fish Tissue Analysis. Largemouth bass and catfish were collected from 2 mainstem locations in Holt Reservoir in November and December 1997-1998 (Appendix Table 1). Laboratory analyses of these fish indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits (Appendix Table 2).

Discussion. Water quality data from mainstem Holt Reservoir indicated few water quality concerns. Mean TN and TP concentrations were similar to or below those of other mainstem Warrior reservoir locations. Phosphorus was indicated as the limiting nutrient at both locations with mean MSC values well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes. Lake mean TN and TP concentrations increased for several months as mean lake discharge decreased, indicating that point sources may be a major contributor to nutrient concentrations.

Mean chlorophyll *a* concentrations were similar to or below those of most other mainstem Warrior reservoir locations. TSI values in the upper reservoir were within the eutrophic range May-September, while those of the lower reservoir were within the eutrophic range in June, August, and September. Given the eutrophic conditions observed, continued monitoring is advised to determine trophic state trends.

Mean TSS concentrations were similar to or far below those of most other mainstem Warrior reservoir locations.

DO concentrations at both locations remained above the criterion limit on all dates sampled though values from the lower reservoir in October were near the limit. Most of the water column remained oxygenated throughout the study period.

Laboratory analyses of largemouth bass and catfish collected from Holt Reservoir indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits.

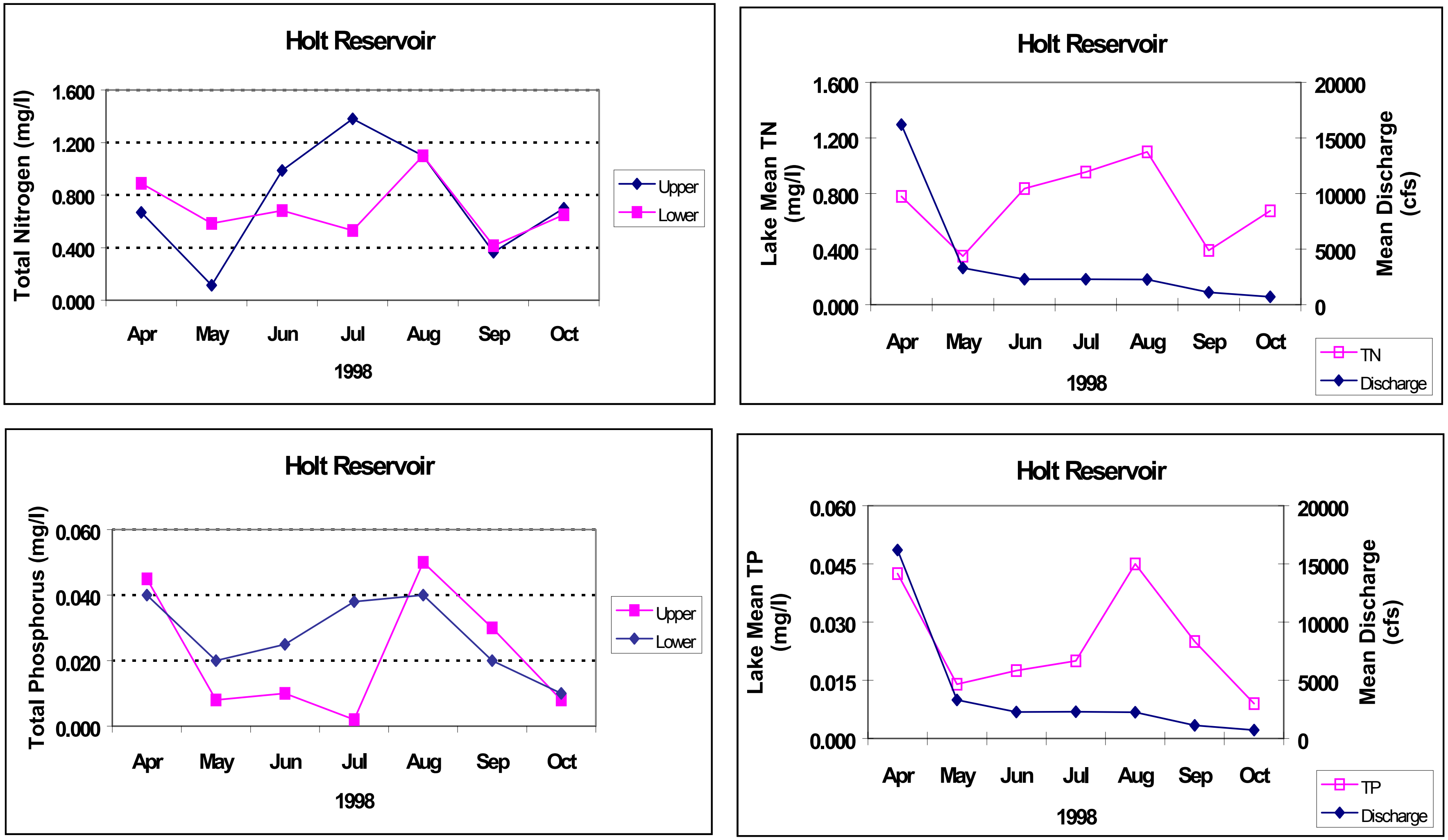


Figure 33. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Holt Reservoir, April-October 1998.

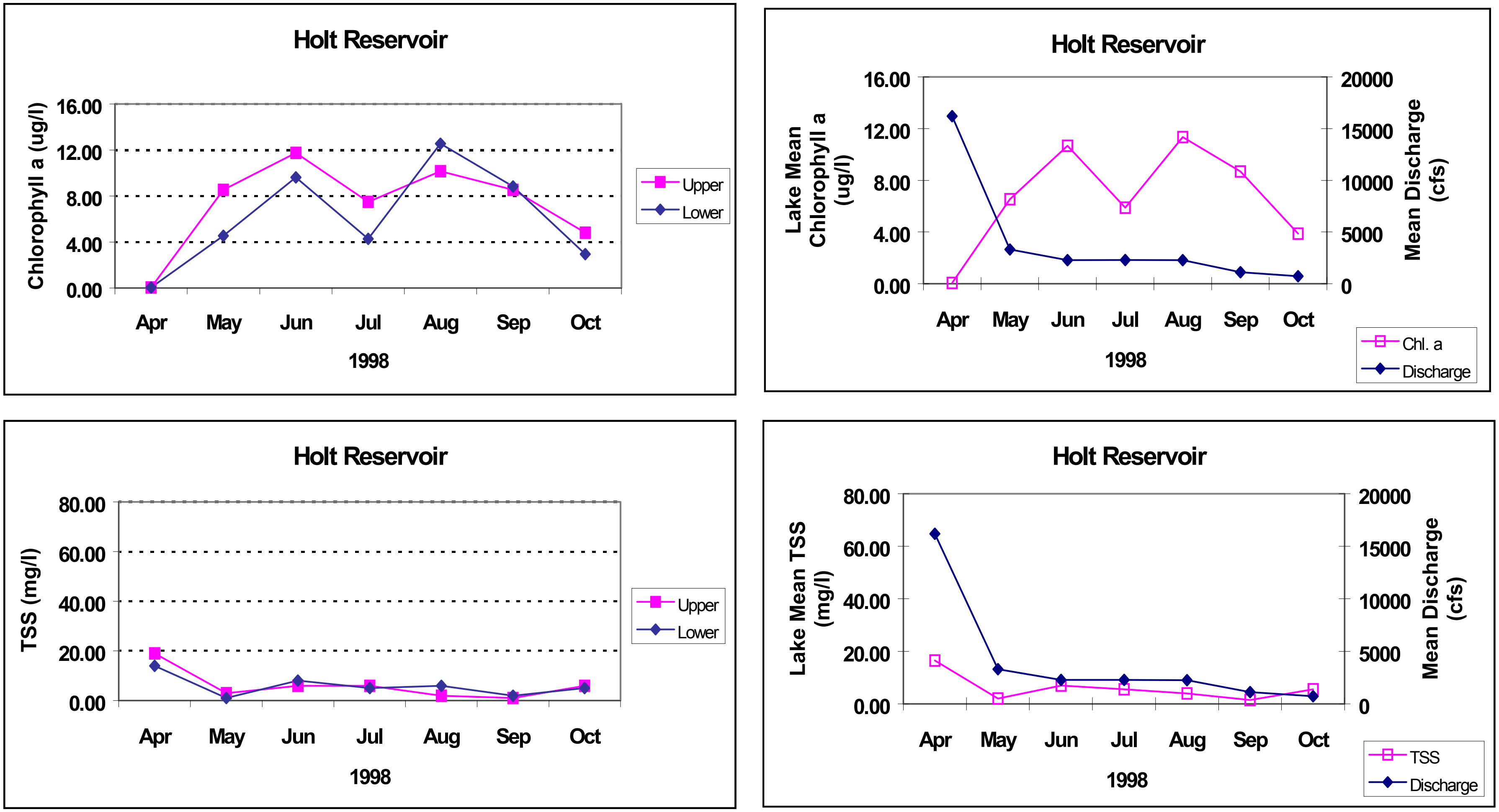
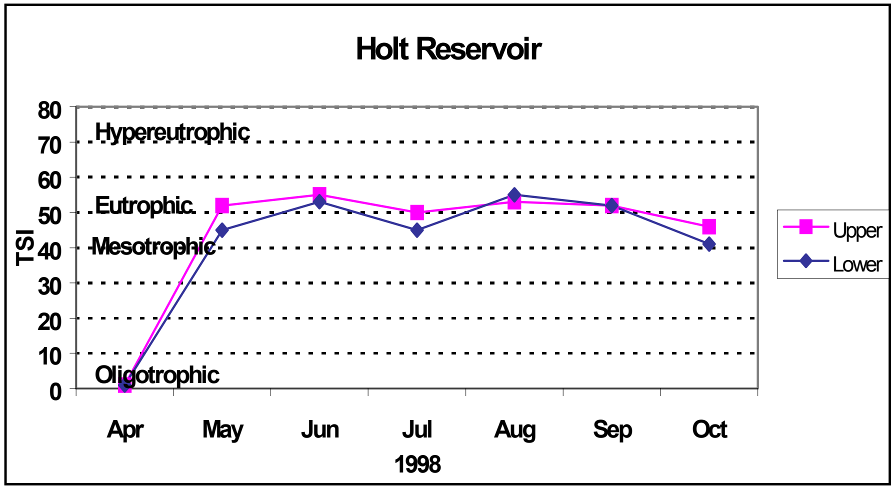


Figure 34. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS), and TSS vs. discharge of Holt Reservoir, April-October 1998.



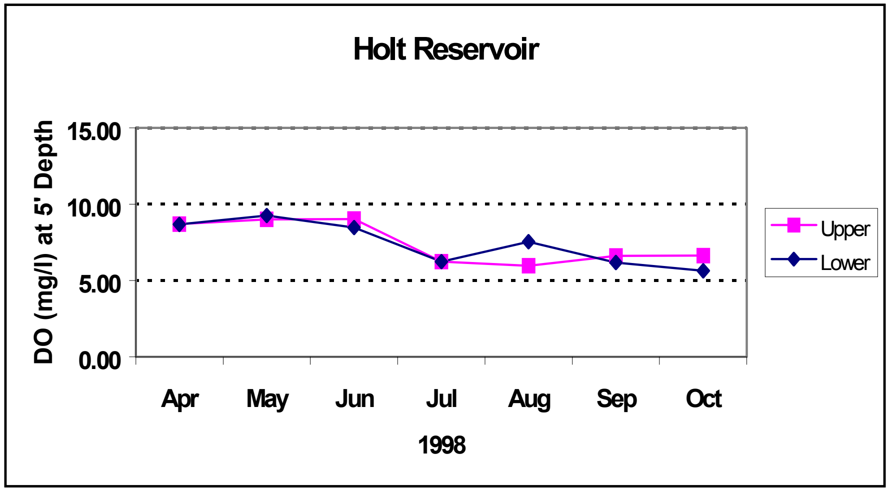


Figure 35. Trophic state index (TSI), and dissolved oxygen (DO) of Holt Reservoir, April-October 1998.

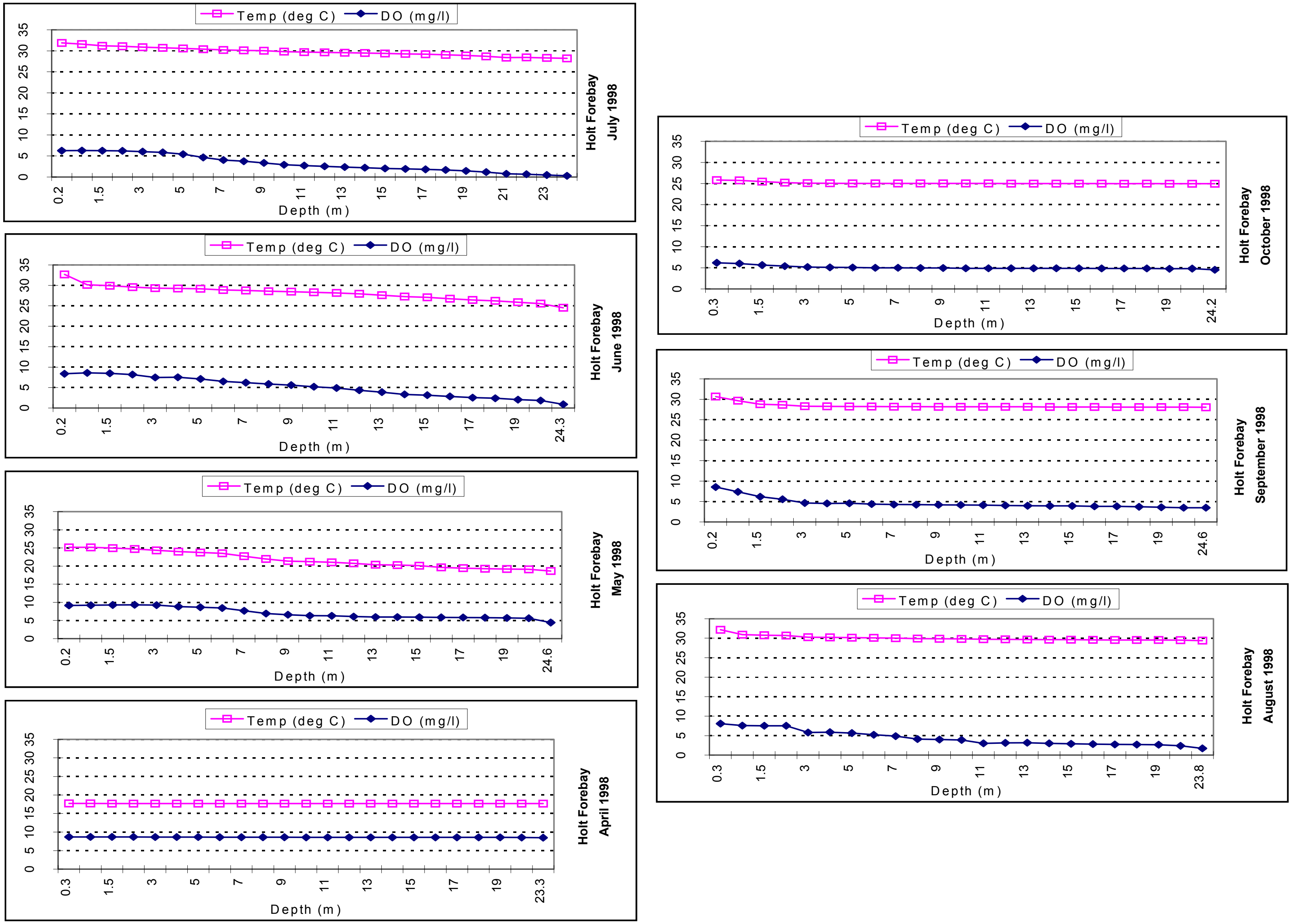


Figure 36. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Holt Reservoir, April-October 1998.

Oliver Pool

Nitrogen. Mean TN concentrations in Oliver Pool were similar to those of other mainstem Warrior reservoir locations (Fig. 3). Within the reservoir, the mean concentration in upper Oliver was greater than that of the lower reservoir location.

Monthly TN concentrations at both locations were variable April-October (Fig. 38). In the upper reservoir, highest concentrations occurred in October with lowest concentrations occurring in July and September. In the lower reservoir, highest concentrations occurred in August and October with lowest concentrations occurring in September.

Lake mean TN concentrations in Oliver Pool were variable April-October with lowest concentrations occurring in September and highest concentrations occurring October (Fig. 38). Mean discharge at Oliver Pool decreased April-October with a sharp decrease April-May and a gradual decrease May-October.

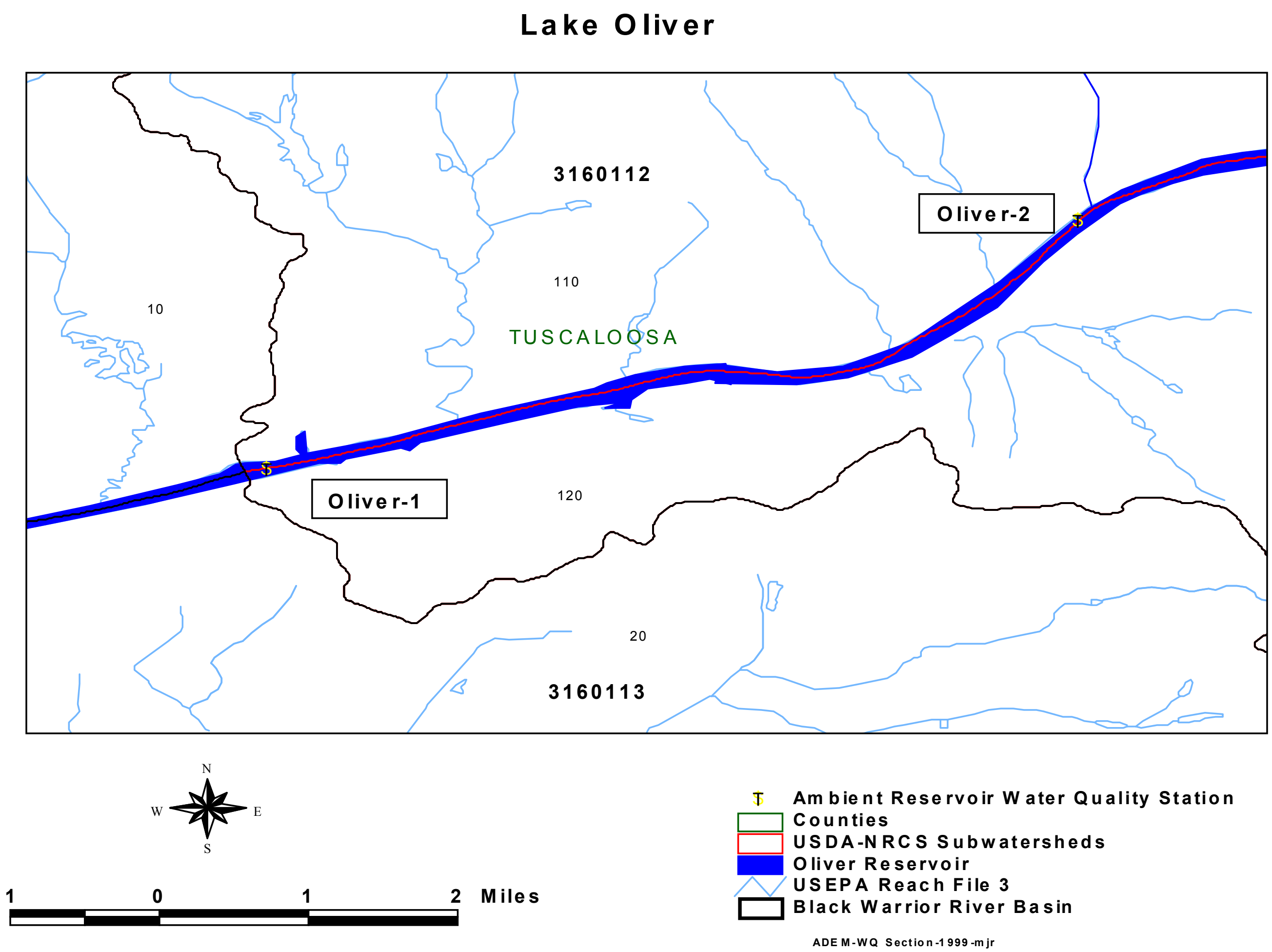
Phosphorus. Mean TP concentrations in Oliver Pool were higher than those of upstream mainstem Warrior locations (Fig. 4). Within the reservoir, mean concentrations were similar at both sampling locations.

Monthly TP concentrations were variable April-October and usually followed similar patterns at both locations (Fig. 38). Highest TP concentrations in the upper reservoir occurred in April and September with lowest concentrations occurring May-July. In the lower reservoir, highest concentrations occurred in April and August with lowest concentrations occurring May-July and October.

Lake mean TP concentrations followed a pattern similar to mean lake discharge April-July with values declining sharply April-May then changing little through July (Fig. 38). Lake mean TP increased greatly August-September then decreased sharply in October while mean lake discharge continued a gradual decline.

Algal Growth Potential Tests. Phosphorus was indicated as the limiting nutrient in the upper and lower portions of Oliver Reservoir (Table 6). Mean MSC values for the upper and lower reservoir (2.79 and 2.27 mg/l, respectively) were well below the

Figure 37. Map of Oliver Reservoir with sampling locations.



maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes.

Chlorophyll a. Mean chlorophyll *a* concentrations in Oliver Pool were lowest of mainstem Warrior reservoir locations (Fig. 5). Within the reservoir, the mean concentration in the upper reservoir was less than that of the lower reservoir.

Monthly chlorophyll *a* concentrations increased April-June then were variable through October with both locations following similar patterns (Fig. 39). In the upper reservoir, highest concentrations occurred in October with lowest concentrations occurring during high flows in April and in September. In the lower reservoir, highest concentrations occurred in June and August with lowest concentrations occurring during high flows in April and in September.

Lake mean chlorophyll *a* concentrations increased April-June and were variable thereafter (Fig. 39). Mean lake discharge decreased sharply April-May then gradually through October.

Total Suspended Solids. Mean TSS concentrations in Oliver Pool were, with the exception of mid Warrior reservoir, much higher than those of all other Warrior basin locations (Fig. 6). Mean concentrations of the upper and lower reservoir locations were similar.

Monthly TSS values varied April-October with highest concentrations at both locations occurring in September (Fig. 39). In the upper reservoir, lowest concentrations occurred in May and October with lowest concentrations in the lower reservoir occurring in May.

Lake mean TSS concentrations followed a pattern similar to that of mean lake discharge with a decrease April-May then similar to lower values June-August and October (Fig. 39). During September, mean TSS concentrations were much higher though mean lake discharge continued to decline.

Trophic State. TSI values for both reservoir locations were within the oligotrophic range when sampled during high flows in April (Fig. 40). In the upper reservoir, TSI values were within the mesotrophic range May-August, declined sharply into the oligotrophic range in September, then increased sharply into the eutrophic range in October. In the lower reservoir, TSI values were variable May-August, alternating from mesotrophic to eutrophic levels. TSI values declined to oligotrophic levels in September before increasing to eutrophic levels once again in October.

Dissolved Oxygen/Temperature. DO concentrations at both reservoir locations were similar April-October with concentrations of the upper reservoir less than those of the lower reservoir April-August (Fig. 41). In the upper reservoir, DO concentrations declined April-August with concentrations in July and August (4.74 and 4.59 mg/l, respectively) below the criterion limit of 5.0 mg/l. DO concentrations in the upper reservoir increased to levels above the criterion limit of 5.0 mg/l in September-October. In the lower reservoir, DO concentrations decreased overall April-September with values in September (5.22 mg/l) just above the criterion limit of 5.0 mg/l.

Depth profiles of temperature and dissolved oxygen indicate that the water column in the Oliver dam forebay was essentially isothermal and isochemical in all months except September (Fig. 41). It should be noted that the dam forebay sampling location lies in the path of barge traffic through the Oliver Lock and Dam. Mixing of portions of the water column by barge traffic likely affects stratification to some degree.

In September, an unusually high temperature differential of 5.66 ^{0}C existed in the dam forebay of Oliver Pool between the surface and one meter depth. The temperature differential may have been related to high turbidity and resulting lack of light penetration though the differential did not exist at the upper reservoir location. In addition, water column temperatures in Oliver in September were several degrees Centigrade lower that temperatures in Holt Reservoir dam forebay, located upstream of Oliver.

Fish Tissue Analysis. Largemouth bass and catfish were collected lakewide from Oliver Pool in November 1998 while catfish were collected from the Hurricane Creek embayment (Appendix Table 1). Laboratory analyses indicated that bioaccumulative contaminant concentrations in fish from both locations were well below FDA advisory limits (Appendix Table 2).

Two sampling trips to collect fish from Hurricane Creek produced only 5 catfish near the mouth of the creek, with no other fish of any species observed or collected during the process. Given the absence of any fish observed further upstream in the creek, these fish were likely transients from the Warrior River. Given the abundant habitat, the near absence of fish at the Hurricane Creek location was especially noteworthy and should be investigated further.

Discussion. Water quality data from Oliver Pool indicated concerns based on higher mean TP concentrations, lower mean chlorophyll *a* concentrations, and higher mean TSS concentrations than in upstream mainstem Warrior locations in addition to low dissolved oxygen concentrations in July and August. Data collected during September influenced the mean values greatly.

TP concentrations increased sharply in August and September though mean lake discharge remained low. Mean chlorophyll *a* concentrations declined sharply during September though algal densities typically remain relatively high in reservoirs during this month of the growing season. During September, TSS concentrations were also much higher than in other months. Turbidity measurements were much higher and visibility measurements (Secchi, photometer) much lower than those of other Warrior basin locations during September sampling. The source of the suspended solids is unknown, though runoff may have been a factor. Rainfall occurred in the area on the day before and the day of sampling in amounts of 0.48 in. and 0.27 in., respectively (personal communication, Tim Martin, ADEM). It is likely that rainfall, high turbidities, and the resulting lack of available light played a role in the sharp drop in temperatures observed in the lower reservoir location and may have had a detrimental effect on algal populations resulting in the decrease in chlorophyll *a* concentrations.

Laboratory analyses of bass and catfish collected from Oliver Pool and catfish collected from Hurricane Creek embayment indicated that bioaccumulative contaminant concentrations were well below FDA advisory limits. The scarcity of fish at the Hurricane Creek location was especially noteworthy and should be investigated further.

Figure 38. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Oliver Reservoir, April-October 1998.

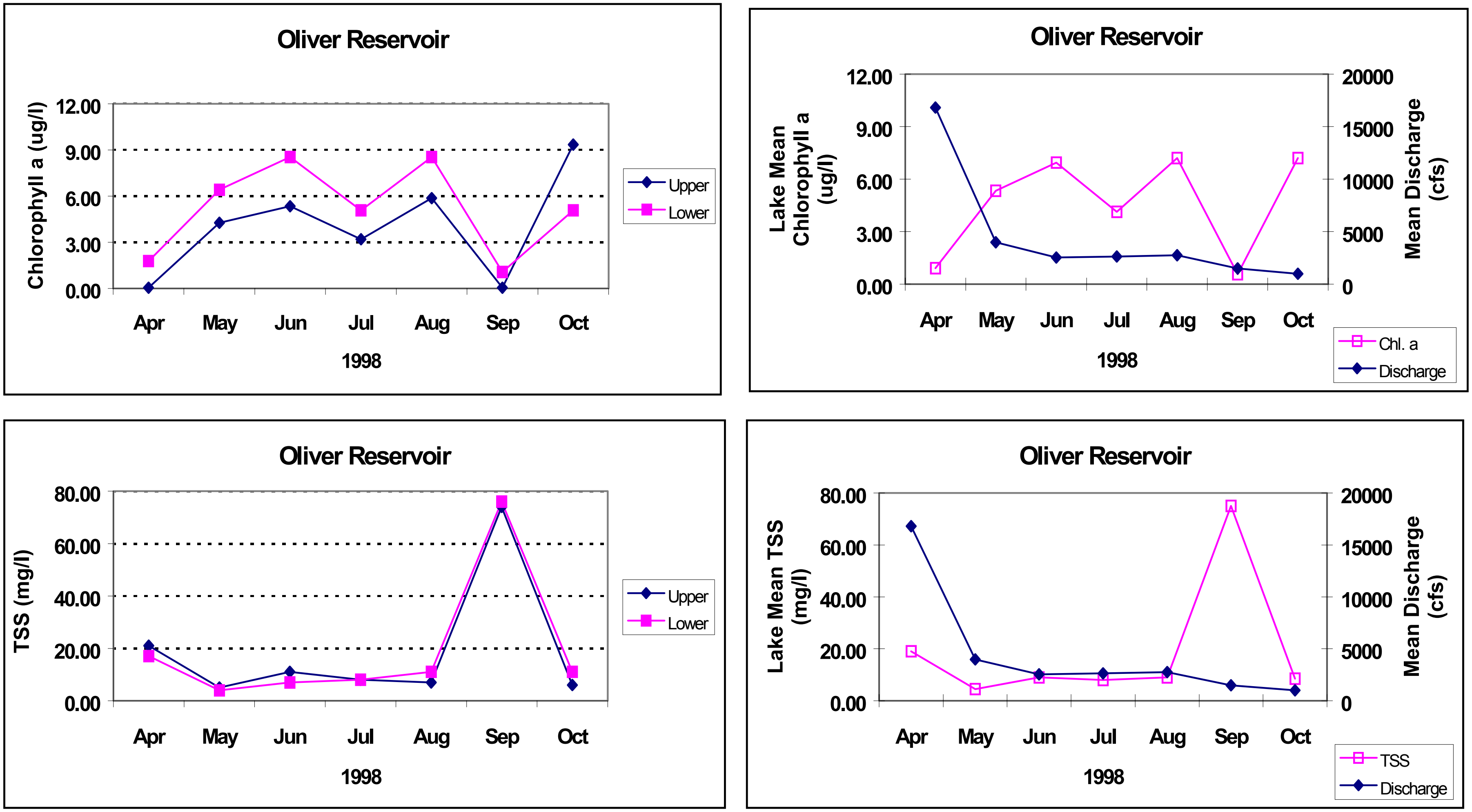
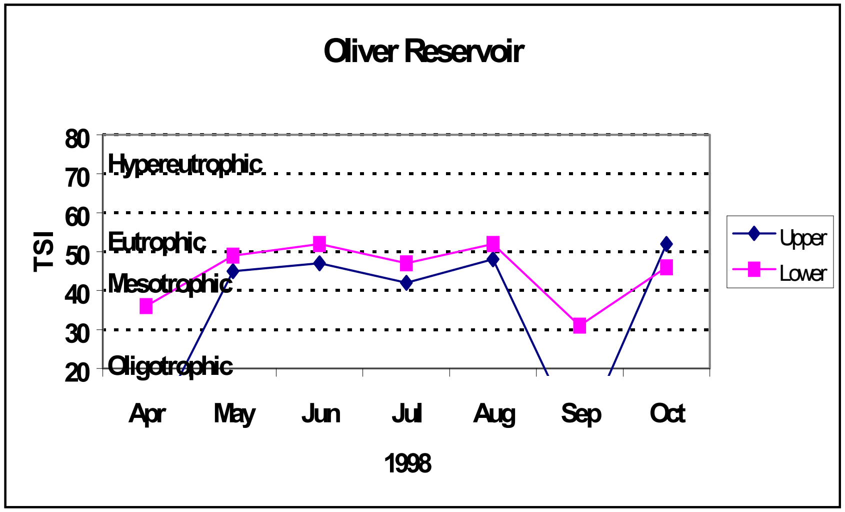


Figure 39. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS), and TSS vs. discharge of Oliver Reservoir, April-October 1998.



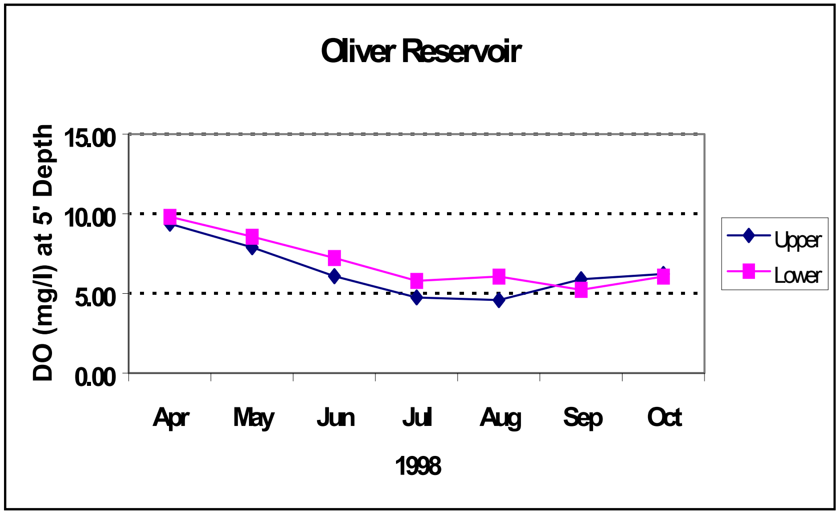


Figure 40. Trophic state index (TSI), and dissolved oxygen (DO) of Oliver Reservoir, April-October 1998.

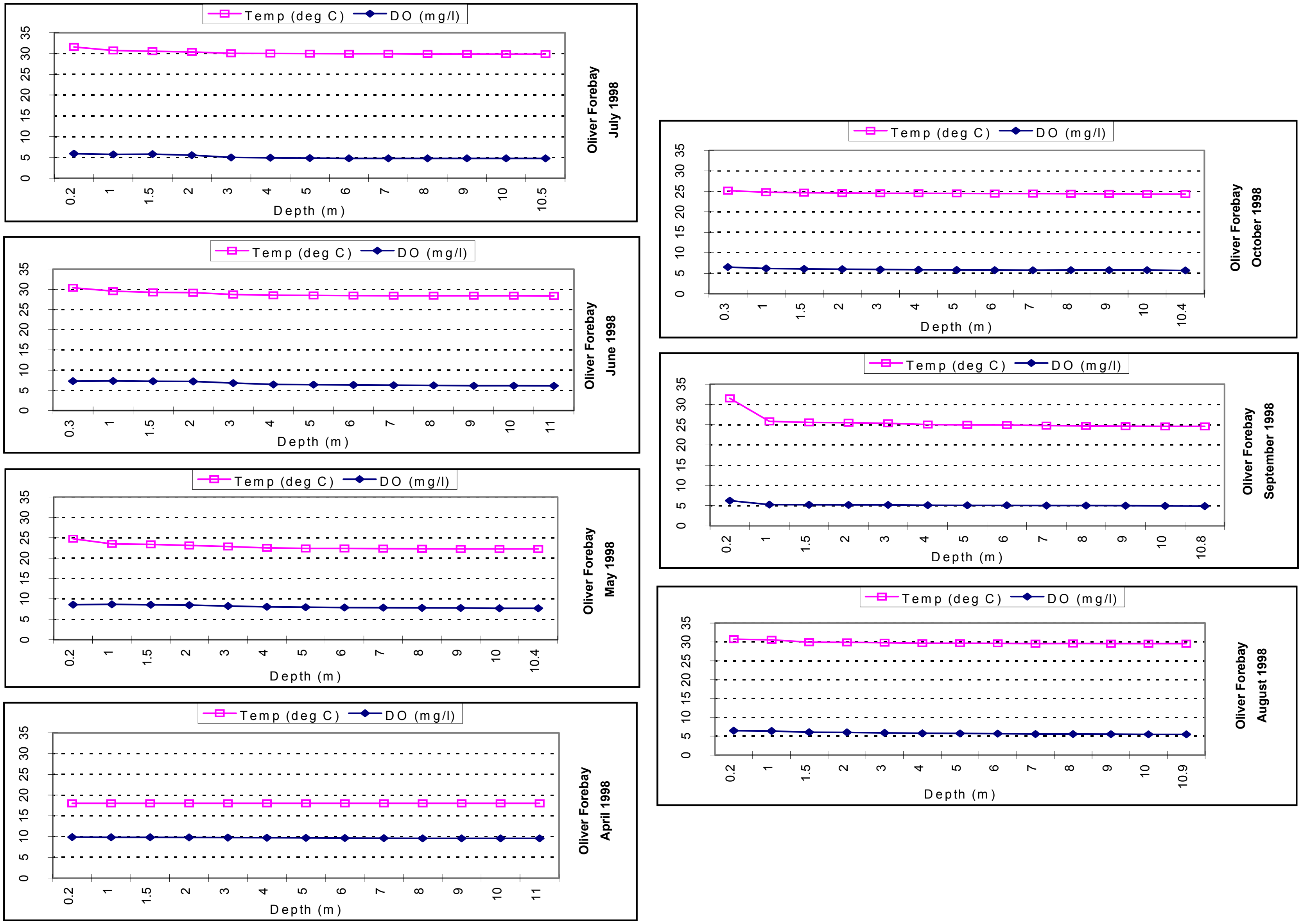


Figure 41. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Oliver Reservoir, April-October 1998.

Warrior Reservoir

Nitrogen. Mean TN concentrations in Warrior Reservoir were similar to those of other mainstem Warrior locations (Fig. 3). Within the reservoir, the mean concentration in the lower reservoir was greatest, followed by the those of the upper and mid reservoir, respectively.

Monthly TN concentrations at all reservoir locations varied during the months sampled (Fig. 43). Monthly TN concentrations were similar at all locations except July, when concentrations were much higher in the lower reservoir. Highest concentrations at all Warrior Reservoir locations occurred in October. Lowest concentrations at the upper and mid reservoir occurred in July and September with lowest concentrations in the lower reservoir occurring in May.

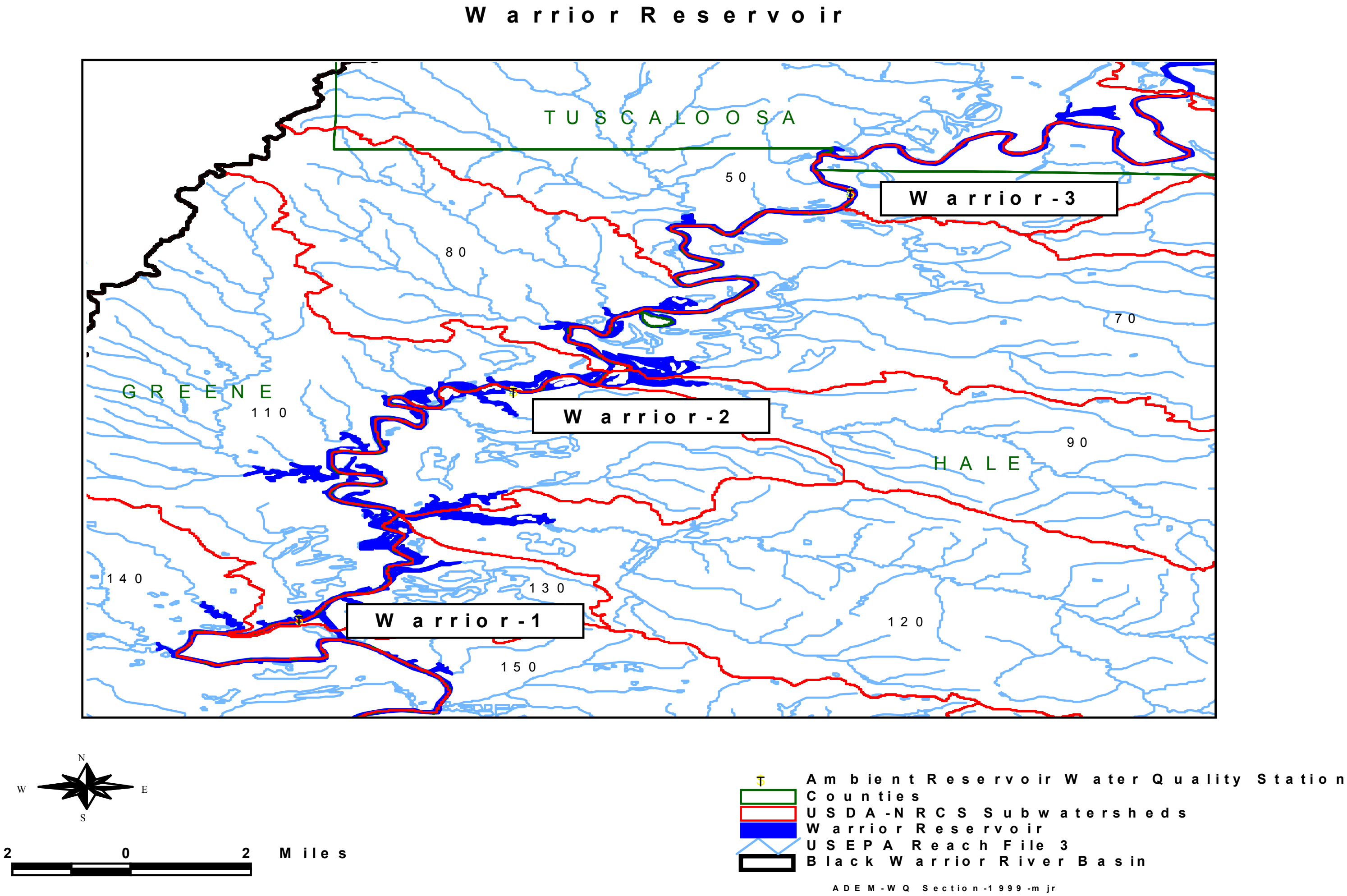
The lake mean TN concentration in Warrior Reservoir varied during the months sampled, with highest concentrations occurring in October and lowest concentrations occurring in September (Fig. 43). Mean lake discharge decreased sharply April-May then gradually through October.

Phosphorus. Mean TP concentrations in upper Warrior Reservoir were second highest of all Warrior basin locations and highest of mainstem locations (Fig. 4). Mean concentrations of the upper reservoir were followed by those of the mid and lower reservoir, respectively.

Monthly TP concentrations at all locations followed similar patterns in all months except October (Fig. 43). In the upper reservoir, highest concentrations occurred in October with lowest concentrations occurring in June. In the mid reservoir, highest concentrations occurred August-October with lowest concentrations occurring in May. In the lower reservoir, highest concentrations occurred August-September with lowest concentrations occurring in October.

Lake mean TP concentrations decreased April-June along with mean lake discharge (Fig. 43). From July-October, lake mean TP increased sharply as mean lake discharge continued to decrease.

Figure 42. Map of Warrior Reservoir with sampling locations.



Algal Growth Potential Tests. Phosphorus was indicated as the limiting nutrient in all Warrior Reservoir locations (Table 6). Mean MSC values for the upper, mid, and lower reservoir (3.12, 3.57, and 2.90 mg/l, respectively) were well below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes.

Chlorophyll a. Mean chlorophyll *a* concentrations in the upper reservoir were third highest of all Warrior basin locations and highest of mainstem locations (Fig. 5). Mean concentrations of the mid reservoir were fourth highest of all basin locations and second highest of mainstem locations.

Monthly chlorophyll *a* concentrations in the upper reservoir increased sharply overall April-August then declined September-October (Fig. 44). At mid reservoir, concentrations increased sharply overall April-July, then varied greatly through October. At the lower reservoir, concentrations increased April-June then decreased consistently through October.

Lake mean chlorophyll *a* concentrations increased sharply April-July then decreased through October (Fig. 44). Mean lake discharge decreased sharply April-May then gradually through October.

Total Suspended Solids. Mean TSS concentrations in mid Warrior Reservoir were highest of Warrior basin locations (Fig. 6). Upper and lower reservoir locations were third and fourth highest, respectively, of Warrior basin locations.

Monthly TSS concentrations varied at all locations during the months sampled (Fig. 44). Highest concentrations in the upper reservoir occurred in October with lowest concentrations occurring in May. In the mid reservoir, highest concentrations occurred in April with lowest concentrations occurring in May. In the lower reservoir, highest concentrations occurred in April with lowest concentrations occurring in May and September.

Lake mean TSS concentrations decreased along with mean lake discharge April-May (Fig. 44). Mean lake discharge decreased overall June-October while mean TSS increased May-June then decreased afterward.

Trophic State. TSI values in the upper reservoir increased from mesotrophic to eutrophic levels April-May then remained within the eutrophic range through October (Fig. 45). In the mid reservoir, TSI values were most variable, ranging from oligotrophic to eutrophic conditions April-October. In the lower reservoir, TSI values increased from oligotrophic levels to eutrophic levels April-June, then steadily decreased to oligotrophic levels in October.

Dissolved Oxygen/Temperature. DO concentrations in the lower reservoir were below those of the upper and mid reservoir locations April-October (Fig. 45). DO concentrations in the lower reservoir decreased to levels just above criterion limits in July-August (5.86, 5.86, and 5.74 mg/l, respectively) and were below limits in October (4.72 mg/l). DO concentrations in upper and mid Warrior Reservoir followed a similar pattern to those of the lower reservoir but remained above the criterion limit of 5.0 mg/l.

Depth profiles of temperature and dissolved oxygen indicate that the water column in the Warrior dam forebay was essentially isothermal and isochemical April-October (Fig. 46). Highest water column temperatures occurred in June and August with lowest DO concentrations occurring in October. DO concentrations in the dam forebay in October were below the criterion limit of 5.0 mg/l from the lake surface to the bottom. It should be noted that the dam forebay sampling location lies in the path of barge traffic through the Warrior Lock and Dam. Mixing of portions of the water column by barge traffic likely affects stratification to some degree.

Fish Tissue Analysis. Largemouth bass and catfish were collected from 1 mainstem location in Warrior Reservoir during December 1997 (Appendix Table 1). Laboratory analyses indicated that bioaccumulative contaminant concentrations in both species of fish were well below FDA advisory limits (Appendix Table 2).

Discussion. Water quality data from Warrior Reservoir indicated concerns based on mean TP concentrations, mean chlorophyll *a* concentrations, and mean TSS concentrations that were among the highest of Warrior basin locations. In addition, DO concentrations were near or below criterion limits when sampled in October.

The mean TP concentrations of the upper reservoir were second highest of all Warrior basin locations and highest of mainstem locations. The mean TP concentrations of the upper reservoir did not persist into the mid and lower reservoir locations, however. Lake mean TP concentrations increased sharply as lake discharge decreased, indicating that point sources were a major contributor to the concentrations.

The effect of the TP concentrations in the upper reservoir were observed in the mean chlorophyll *a* concentrations of the upper and mid reservoir, which were among the highest of Warrior basin locations.

Laboratory analyses of bioaccumulative bass and catfish collected from Warrior Reservoir indicated that contaminant concentrations were well below FDA advisory limits.

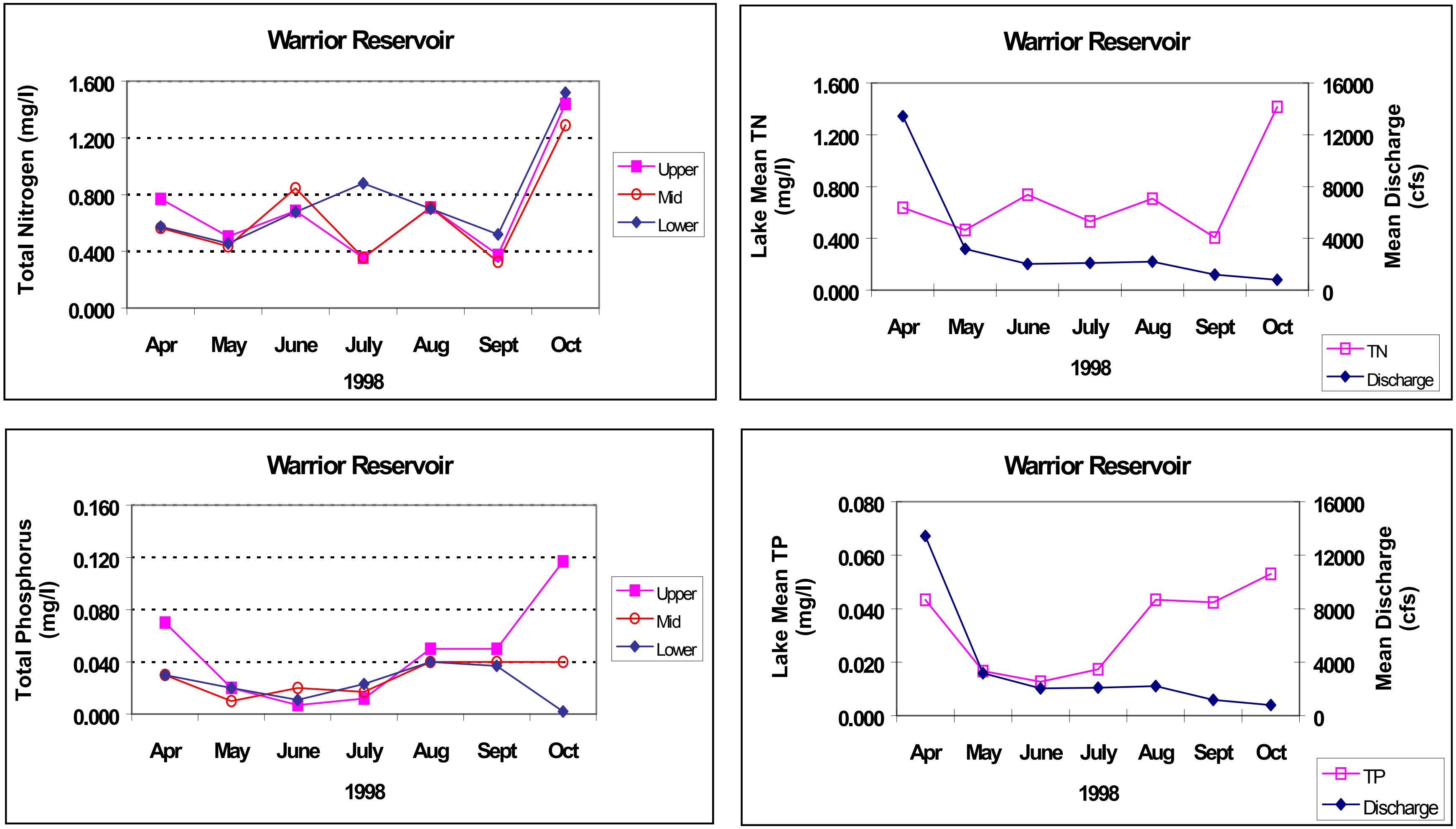


Figure 43. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Warrior Reservoir, April-October 1998.

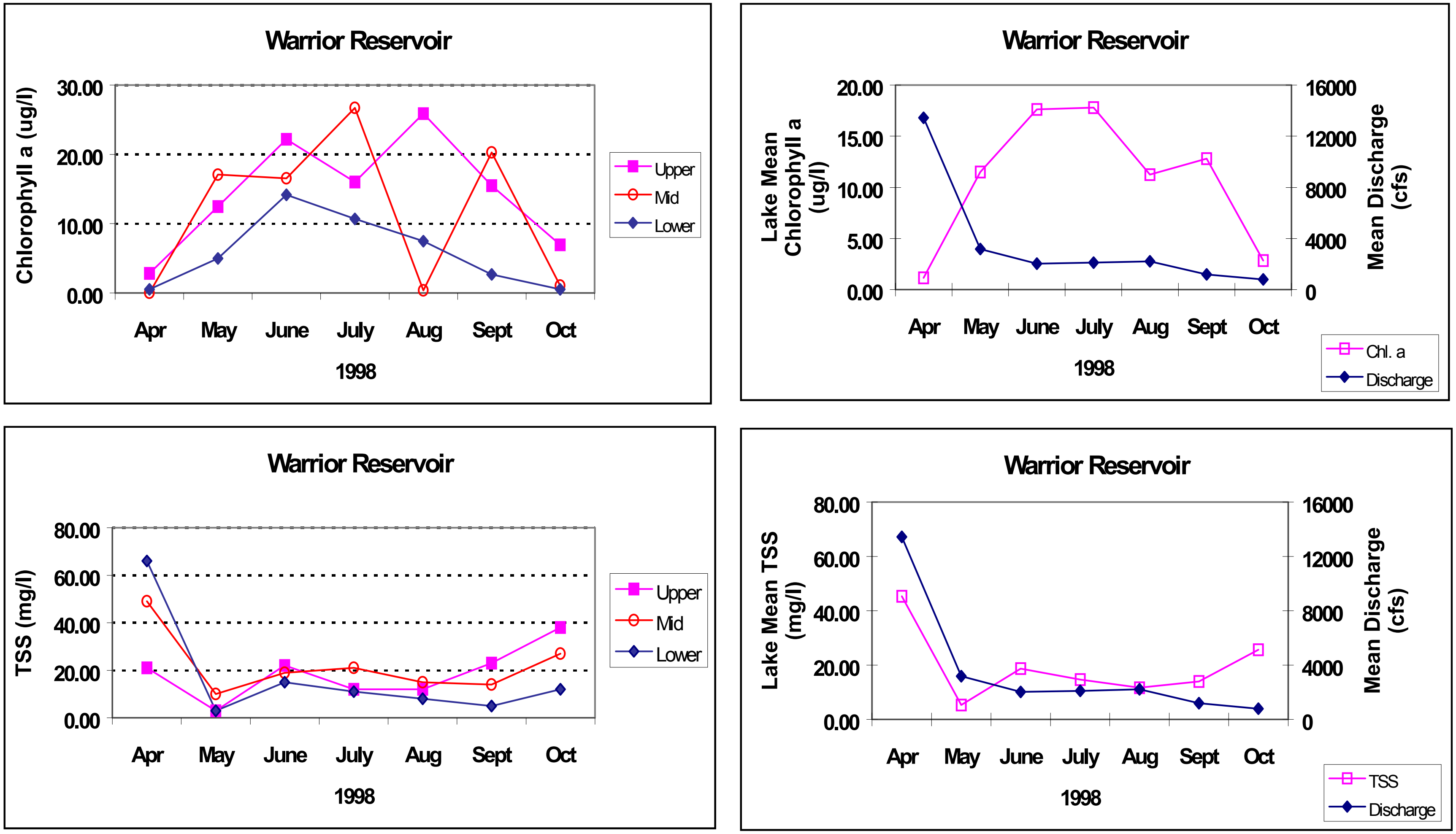
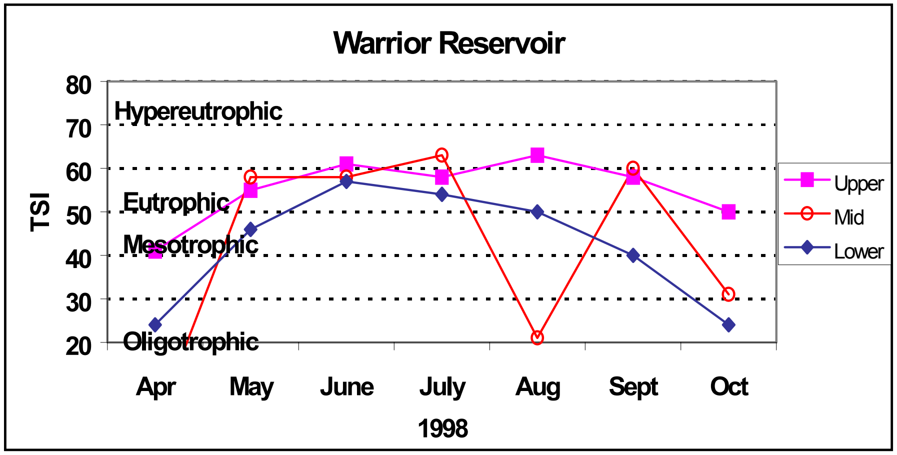


Figure 44. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS), and TSS vs. discharge of Warrior Reservoir, April-October 1998.



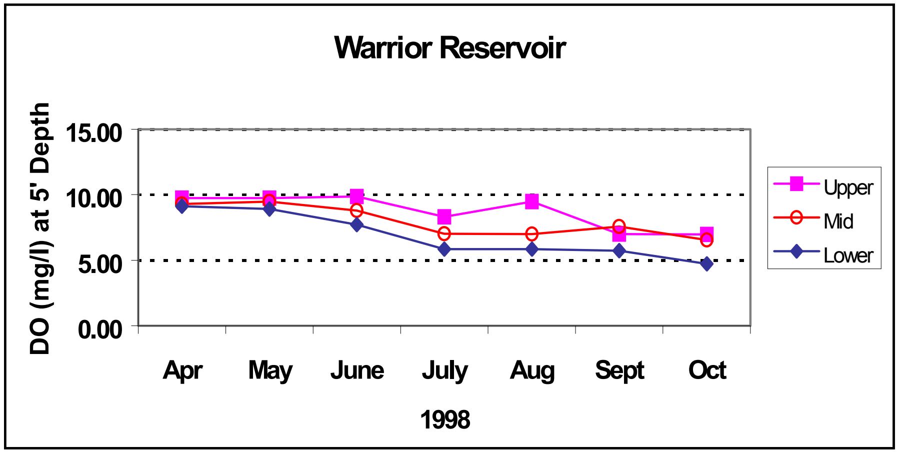


Figure 45. Trophic state index (TSI), and dissolved oxygen (DO) of Warrior Reservoir, April-October 1998.

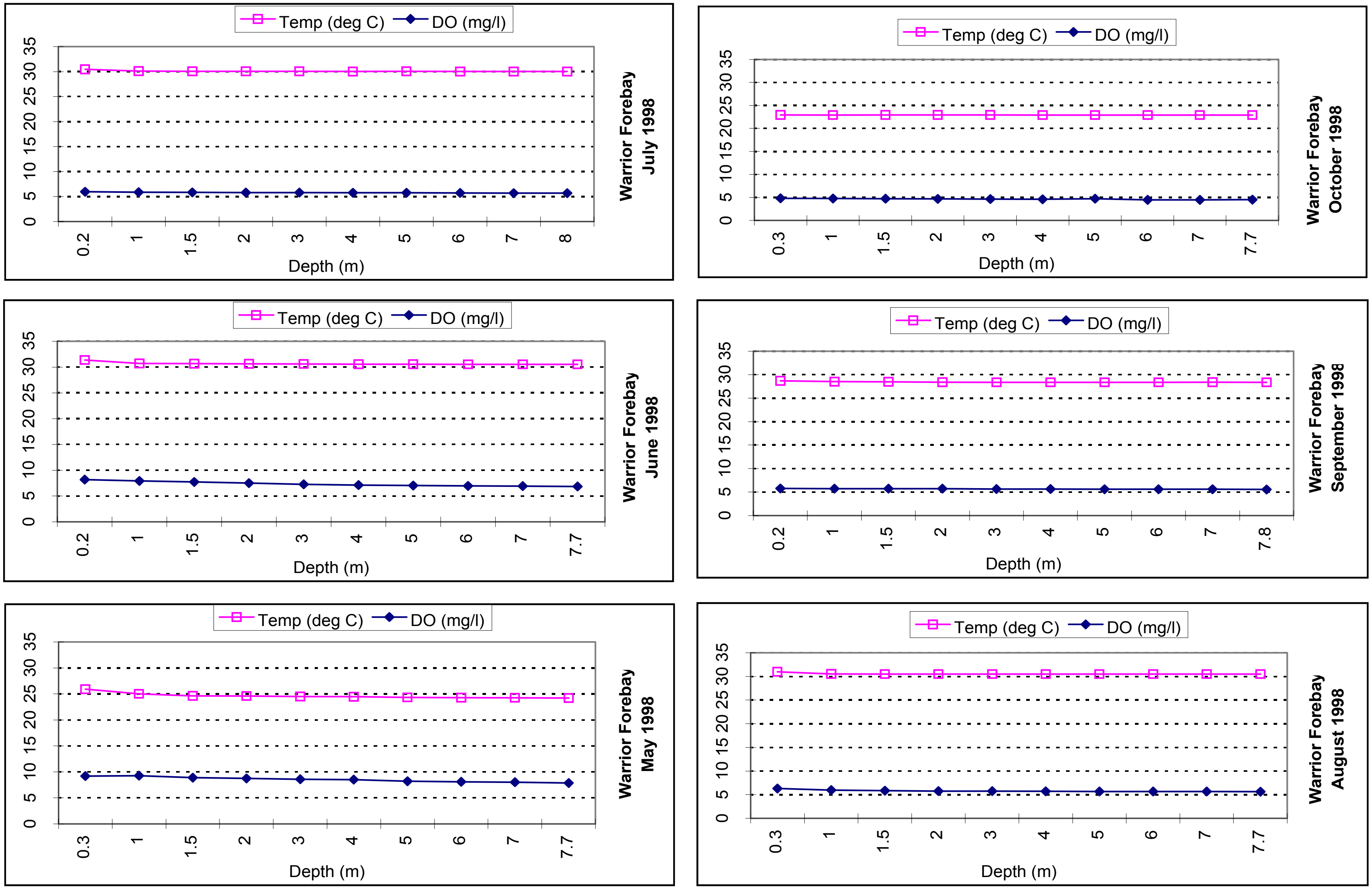


Figure 46. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Warrior Reservoir, April-October 1998.

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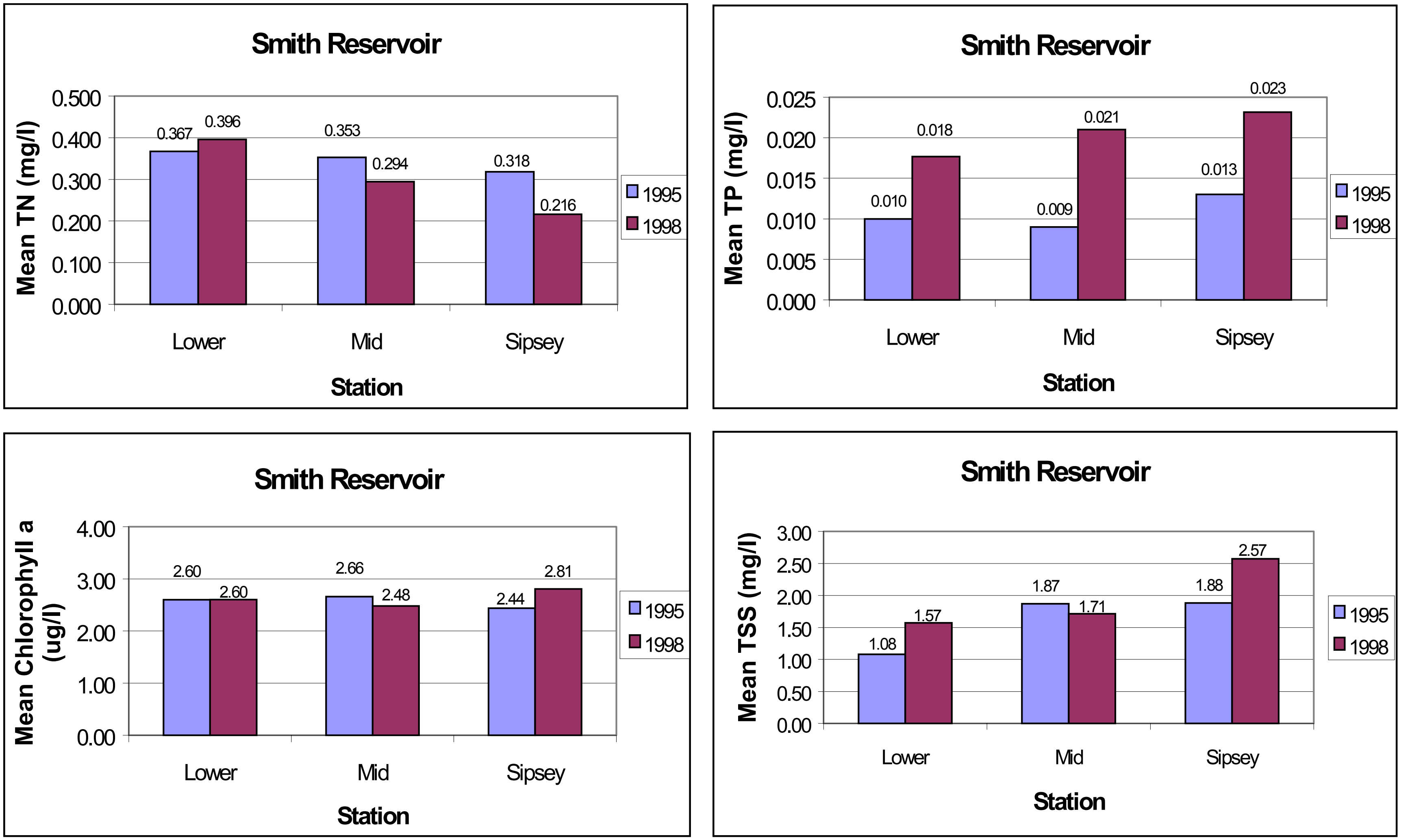
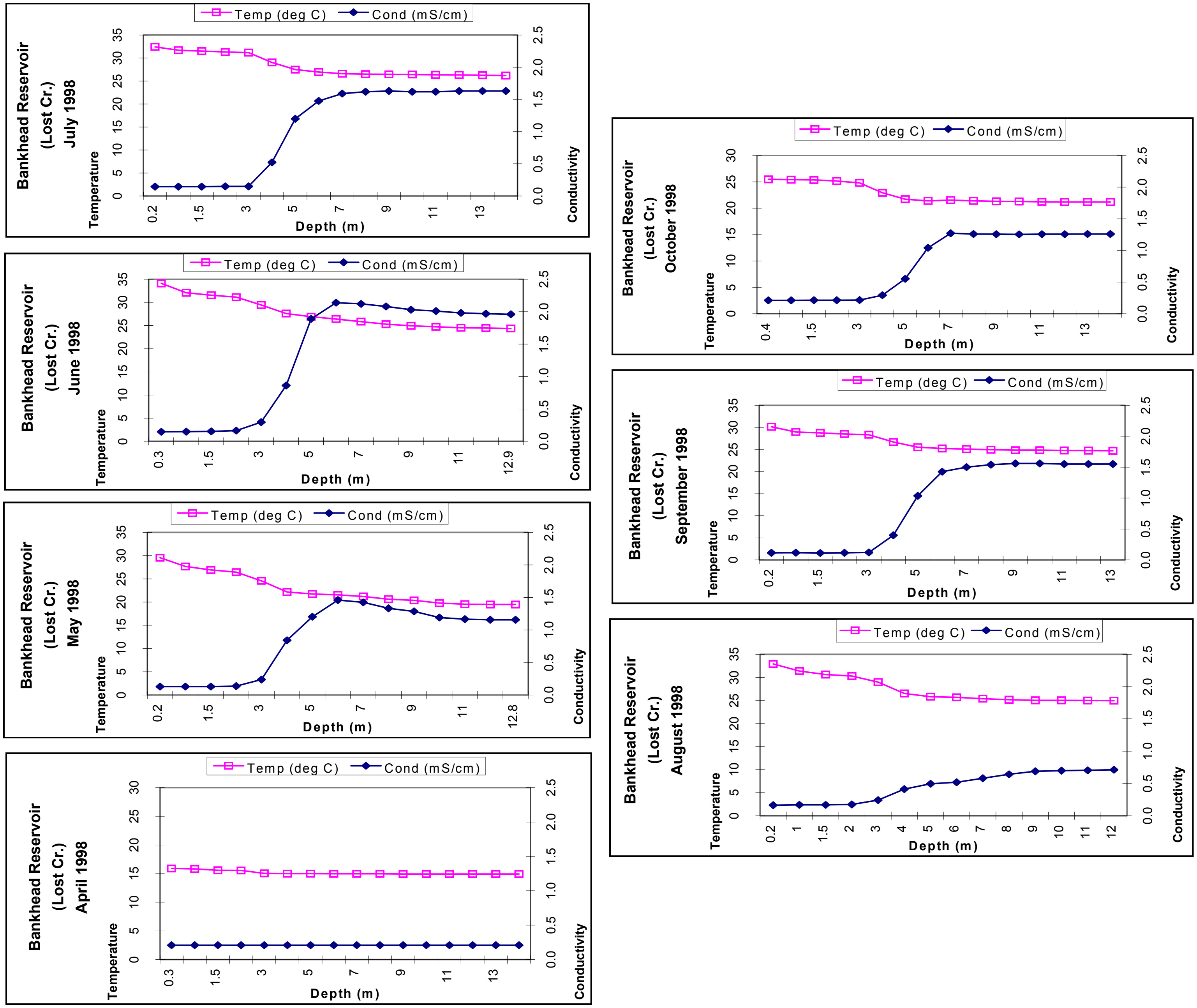
APPENDIX



Appendix Figure 1. Mean TN, TP, chlorophyll *a*, and TSS concentrations from Smith Reservoir, 1995 and 1998.



Appendix Figure 2. Temperature and conductivity profiles of the Lost Creek embayment of Bankhead Reservoir, April-October 1998.

Appendix Table 1. Length-weight measurements of fish from Warrior basin reservoirs, 1997-1998.

Date Collected	WATER BODY	Station	Species	Fish #	Length (mm)	Weight (gm)	Length (in)	Weight (oz)	Age (yrs+)
11/19/97	BANKHEAD RESERVOIR	BAN1	LMB	1	354	570	13.9	20.1	2
11/19/97	BANKHEAD RESERVOIR	BAN1	LMB	2	451	1650	17.8	58.2	5
11/19/97	BANKHEAD RESERVOIR	BAN1	LMB	3	354	660	13.9	23.3	3
11/19/97	BANKHEAD RESERVOIR	BAN1	LMB	4	370	760	14.6	26.8	3
11/19/97	BANKHEAD RESERVOIR	BAN1	LMB	5	434	1140	17.1	40.2	4
11/19/97	BANKHEAD RESERVOIR	BAN1	LMB	6	389	790	15.3	27.9	4
11/19/97	BANKHEAD RESERVOIR	BAN1	CCF	1	445	770	17.5	27.2	3
11/19/97	BANKHEAD RESERVOIR	BAN1	CCF	2	344	280	13.5	9.9	2
11/19/97	BANKHEAD RESERVOIR	BAN1	CCF	3	328	280	12.9	9.9	4
11/18/97	BANKHEAD RESERVOIR	BAN6	LMB	1	390	920	15.4	32.5	4
11/18/97	BANKHEAD RESERVOIR	BAN6	LMB	2	398	1140	15.7	40.2	2
11/18/97	BANKHEAD RESERVOIR	BAN6	LMB	3	424	1250	16.7	44.1	3
11/18/97	BANKHEAD RESERVOIR	BAN6	LMB	4	425	1250	16.7	44.1	4
11/18/97	BANKHEAD RESERVOIR	BAN6	LMB	5	365	830	14.4	29.3	4
11/18/97	BANKHEAD RESERVOIR	BAN6	LMB	6	356	620	14	21.9	4
11/18/97	BANKHEAD RESERVOIR	BAN6	CCF	1	405	550	15.9	19.4	3
11/18/97	BANKHEAD RESERVOIR	BAN6	CCF	2	460	900	18.1	31.7	3
11/18/97	BANKHEAD RESERVOIR	BAN6	CCF	3	452	900	17.8	31.7	3
11/18/97	BANKHEAD RESERVOIR	BAN6	CCF	4	457	970	18	34.2	4
11/18/97	BANKHEAD RESERVOIR	BAN6	CCF	5	375	360	14.8	12.7	3
11/18/97	BANKHEAD RESERVOIR	BAN6	CCF	6	370	380	14.6	13.4	3
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	LMB	1	405	1080	15.9	38.1	3
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	LMB	2	387	750	15.2	26.5	4
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	LMB	3	330	540	13	19	2
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	LMB	4	370	680	14.6	24	4
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	LMB	5	382	940	15	33.2	5
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	LMB	6	350	620	13.8	21.9	3
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	CCF	1	502	1440	19.8	50.8	7
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	CCF	2	480	1180	18.9	41.6	3
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	CCF	3	468	920	18.4	32.5	3
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	CCF	4	526	1420	20.7	50.1	4
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	CCF	5	575	2750	22.6	97	7
11/24/98	BLACK WARRIOR LOCUST FK	BWR1	CCF	6	445	860	17.5	30.3	4
11/17/98	BIG YELLOW CREEK	BYEL1	LMB	1	334	506	13.1	17.8	2
11/17/98	BIG YELLOW CREEK	BYEL1	LMB	2	336	501	13.2	17.7	2
11/17/98	BIG YELLOW CREEK	BYEL1	LMB	3	361	562	14.2	19.8	3
11/17/98	BIG YELLOW CREEK	BYEL1	LMB	4	335	495	13.2	17.5	2
11/17/98	BIG YELLOW CREEK	BYEL1	LMB	5	362	618	14.3	21.8	3
11/17/98	BIG YELLOW CREEK	BYEL1	LMB	6	394	853	15.5	30.1	4

Appendix Table 1. Length-weight measurements of fish from Warrior basin reservoirs, 1997-1998.

Date Collected	WATER BODY	Station	Species	Fish #	Length (mm)	Weight (gm)	Length (in)	Weight (oz)	Age (yrs+)
11/17/98	BIG YELLOW CREEK	BYEL1	CCF	1	389	423	15.3	14.9	3
11/17/98	BIG YELLOW CREEK	BYEL1	CCF	2	373	356	14.7	12.6	3
11/17/98	BIG YELLOW CREEK	BYEL1	CCF	3	525	1206	20.7	42.5	6
11/17/98	BIG YELLOW CREEK	BYEL1	CCF	4	435	483	17.1	17	5
11/17/98	BIG YELLOW CREEK	BYEL1	CCF	5	491	982	19.3	34.6	6
11/17/98	BIG YELLOW CREEK	BYEL1	CCF	6	367	329	14.4	11.6	6
12/2/97	DEMOPOLIS RESERVOIR	DEM2	LMB	1	395	900	15.6	31.7	3
12/2/97	DEMOPOLIS RESERVOIR	DEM2	LMB	2	337	530	13.3	18.7	2
12/2/97	DEMOPOLIS RESERVOIR	DEM2	LMB	3	370	640	14.6	22.6	2
12/2/97	DEMOPOLIS RESERVOIR	DEM2	LMB	4	431	1200	17	42.3	4
12/2/97	DEMOPOLIS RESERVOIR	DEM2	LMB	5	340	530	13.4	18.7	2
12/2/97	DEMOPOLIS RESERVOIR	DEM2	LMB	6	403	1020	15.9	36	4
12/2/97	DEMOPOLIS RESERVOIR	DEM2	BCF	1	464	870	18.3	30.7	3
12/2/97	DEMOPOLIS RESERVOIR	DEM2	BCF	2	471	910	18.5	32.1	3
12/2/97	DEMOPOLIS RESERVOIR	DEM2	BCF	3	502	1060	19.8	37.4	4
12/2/97	DEMOPOLIS RESERVOIR	DEM2	BCF	4	450	740	17.7	26.1	4
12/2/97	DEMOPOLIS RESERVOIR	DEM2	BCF	5	428	710	16.9	25	4
12/2/97	DEMOPOLIS RESERVOIR	DEM2	BCF	6	480	1040	18.9	36.7	4
12/3/97	HOLT RESERVOIR	HOL1	LMB	1	357	560	14.1	19.8	3
12/3/97	HOLT RESERVOIR	HOL1	LMB	2	490	1650	19.3	58.2	5
12/3/97	HOLT RESERVOIR	HOL1	LMB	3	390	710	15.4	25	2
12/3/97	HOLT RESERVOIR	HOL1	LMB	4	445	1530	17.5	54	4
12/3/97	HOLT RESERVOIR	HOL1	LMB	5	371	770	14.6	27.2	3
12/3/97	HOLT RESERVOIR	HOL1	LMB	6	350	520	13.8	18.3	2
12/3/97	HOLT RESERVOIR	HOL1	CCF	1	392	400	15.4	14.1	4
12/3/97	HOLT RESERVOIR	HOL1	CCF	2	356	320	14	11.3	3
12/3/97	HOLT RESERVOIR	HOL1	CCF	3	351	320	13.8	11.3	4
12/3/97	HOLT RESERVOIR	HOL1	BCF	1	345	290	13.6	10.2	3
12/3/97	HOLT RESERVOIR	HOL1	BCF	2	375	340	14.8	12	5
12/9/97	HOLT RESERVOIR	HOL3	LMB	1	457	1400	18	49.4	5
12/9/97	HOLT RESERVOIR	HOL3	LMB	2	443	1160	17.4	40.9	4
12/9/97	HOLT RESERVOIR	HOL3	LMB	3	395	930	15.6	32.8	4
12/9/97	HOLT RESERVOIR	HOL3	LMB	4	374	670	14.7	23.6	4
12/9/97	HOLT RESERVOIR	HOL3	LMB	5	465	1350	18.3	47.6	4
12/9/97	HOLT RESERVOIR	HOL3	LMB	6	415	1120	16.3	39.5	7
12/9/97	HOLT RESERVOIR	HOL3	CCF	1	444	720	17.5	25.4	5
12/9/97	HOLT RESERVOIR	HOL3	CCF	2	422	560	16.6	19.8	4
12/9/97	HOLT RESERVOIR	HOL3	CCF	3	363	300	14.3	10.6	3
12/9/97	HOLT RESERVOIR	HOL3	CCF	4	382	380	15	13.4	4

Appendix Table 1. Length-weight measurements of fish from Warrior basin reservoirs, 1997-1998.

Date Collected	WATER BODY	Station	Species	Fish #	Length (mm)	Weight (gm)	Length (in)	Weight (oz)	Age (yrs+)
11/4/98	HURRICANE CREEK	HUR1	CCF	1	472	960	18.6	33.9	6
11/4/98	HURRICANE CREEK	HUR1	CCF	2	558	1740	22	61.4	8
11/4/98	HURRICANE CREEK	HUR1	CCF	3	341	303	13.4	10.7	3
11/4/98	HURRICANE CREEK	HUR1	CCF	4	440	760	17.3	26.8	5
11/4/98	HURRICANE CREEK	HUR1	CCF	5	471	920	18.5	32.5	6
12/1/98	LOST CREEK	LOS1	LMB	1	430	1043	16.9	36.8	5
12/1/98	LOST CREEK	LOS1	LMB	2	401	813	15.8	28.7	5
12/1/98	LOST CREEK	LOS1	LMB	3	370	675	14.6	23.8	4
12/1/98	LOST CREEK	LOS1	LMB	4	480	1586	18.9	55.9	4
12/1/98	LOST CREEK	LOS1	LMB	5	485	1493	19.1	52.7	5
12/1/98	LOST CREEK	LOS1	LMB	6	472	1660	18.6	58.6	6
12/1/98	LOST CREEK	LOS1	CCF	1	517	1362	20.4	48	6
12/1/98	LOST CREEK	LOS1	CCF	2	464	866	18.3	30.5	6
12/1/98	LOST CREEK	LOS1	CCF	3	491	1156	19.3	40.8	6
12/1/98	LOST CREEK	LOS1	CCF	4	395	451	15.6	15.9	5
12/1/98	LOST CREEK	LOS1	CCF	5	487	1030	19.2	36.3	6
12/1/98	LOST CREEK	LOS1	CCF	6	464	898	18.3	31.7	5
11/13/98	NORTH RIVER	NOR1	LMB	1	334	415	13.1	14.6	2
11/13/98	NORTH RIVER	NOR1	LMB	2	332	412	13.1	14.5	2
11/13/98	NORTH RIVER	NOR1	LMB	3	343	496	13.5	17.5	3
11/13/98	NORTH RIVER	NOR1	LMB	4	358	414	14.1	14.6	2
11/13/98	NORTH RIVER	NOR1	LMB	5	329	409	13	14.4	2
11/13/98	NORTH RIVER	NOR1	LMB	6	380	671	15	23.7	3
11/13/98	NORTH RIVER	NOR1	CCF	1	510	1125	20.1	39.7	2
11/13/98	NORTH RIVER	NOR1	CCF	2	491	978	19.3	34.5	2
11/13/98	NORTH RIVER	NOR1	CCF	3	531	1215	20.9	42.9	5
11/13/98	NORTH RIVER	NOR1	CCF	4	485	991	19.1	35	3
11/13/98	NORTH RIVER	NOR1	CCF	5	475	1015	18.7	35.8	2
11/4/98	OLIVER RESERVOIR	OLI1	LMB	1	475	1780	18.7	62.8	5
11/4/98	OLIVER RESERVOIR	OLI1	LMB	2	444	1420	17.5	50.1	4
11/4/98	OLIVER RESERVOIR	OLI1	LMB	3	462	1760	18.2	62.1	7
11/4/98	OLIVER RESERVOIR	OLI1	LMB	4	415	1030	16.3	36.3	3
11/4/98	OLIVER RESERVOIR	OLI1	LMB	5	376	630	14.8	22.2	3
11/4/98	OLIVER RESERVOIR	OLI1	LMB	6	396	950	15.6	33.5	4
11/4/98	OLIVER RESERVOIR	OLI1	CCF	1	354	330	13.9	11.6	3
11/4/98	OLIVER RESERVOIR	OLI1	CCF	2	369	380	14.5	13.4	7
11/4/98	OLIVER RESERVOIR	OLI1	CCF	3	435	680	17.1	24	3
11/4/98	OLIVER RESERVOIR	OLI1	CCF	4	395	520	15.6	18.3	4
11/4/98	OLIVER RESERVOIR	OLI1	CCF	5	345	270	13.6	9.5	4

Appendix Table 1. Length-weight measurements of fish from Warrior basin reservoirs, 1997-1998.

Date Collected	WATER BODY	Station	Species	Fish #	Length (mm)	Weight (gm)	Length (in)	Weight (oz)	Age (yrs+)
11/4/98	OLIVER RESERVOIR	OLI1	BCF	1	421	610	16.6	21.5	3
11/4/98	OLIVER RESERVOIR	OLI1	BCF	2	509	1400	20	49.4	5
12/1/98	VALLEY CREEK	VAL1	LMB	1	426	1245	16.8	43.9	3
12/1/98	VALLEY CREEK	VAL1	LMB	2	388	1150	15.3	40.6	3
12/1/98	VALLEY CREEK	VAL1	LMB	3	452	1360	17.8	48	4
12/1/98	VALLEY CREEK	VAL1	LMB	4	392	1050	15.4	37	6
12/1/98	VALLEY CREEK	VAL1	LMB	5	372	850	14.6	30	2
12/1/98	VALLEY CREEK	VAL1	LMB	6	346	825	13.6	29.1	2
12/1/98	VALLEY CREEK	VAL1	CCF	1	415	620	16.3	21.9	3
12/1/98	VALLEY CREEK	VAL1	CCF	2	372	420	14.6	14.8	3
12/1/98	VALLEY CREEK	VAL1	CCF	3	480	398	18.9	14	3
12/1/98	VALLEY CREEK	VAL1	CCF	4	448	840	17.6	29.6	3
12/1/98	VALLEY CREEK	VAL1	BCF	1	523	1440	20.6	50.8	4
12/1/98	VALLEY CREEK	VAL1	BCF	2	407	660	16	23.3	4
12/1/98	VALLEY CREEK	VAL1	BCF	3	408	640	16.1	22.6	2
12/1/98	VALLEY CREEK	VAL1	BCF	4	342	340	13.5	12	2
11/24/98	VILLAGE CREEK	VIL1	LMB	1	391	1120	15.4	39.5	5
11/24/98	VILLAGE CREEK	VIL1	LMB	2	420	1250	16.5	44.1	5
11/24/98	VILLAGE CREEK	VIL1	LMB	3	400	1080	15.7	38.1	6
11/24/98	VILLAGE CREEK	VIL1	LMB	4	345	790	13.6	27.9	5
11/24/98	VILLAGE CREEK	VIL1	LMB	5	326	630	12.8	22.2	3
11/24/98	VILLAGE CREEK	VIL1	LMB	6	340	630	13.4	22.2	3
11/24/98	VILLAGE CREEK	VIL1	CCF	1	519	1300	20.4	45.9	8
11/24/98	VILLAGE CREEK	VIL1	CCF	2	443	820	17.4	28.9	5
11/24/98	VILLAGE CREEK	VIL1	CCF	3	446	820	17.6	28.9	5
11/24/98	VILLAGE CREEK	VIL1	CCF	4	463	760	18.2	26.8	7
11/24/98	VILLAGE CREEK	VIL1	CCF	5	472	1000	18.6	35.3	6
11/24/98	VILLAGE CREEK	VIL1	CCF	6	551	1620	21.7	57.1	4
12/2/97	WARRIOR LAKE	WAR3	LMB	1	320	480	12.6	16.9	2
12/2/97	WARRIOR LAKE	WAR3	LMB	2	361	560	14.2	19.8	3
12/2/97	WARRIOR LAKE	WAR3	LMB	3	332	440	13.1	15.5	2
12/2/97	WARRIOR LAKE	WAR3	LMB	4	362	620	14.3	21.9	2
12/2/97	WARRIOR LAKE	WAR3	LMB	5	328	420	12.9	14.8	2
12/2/97	WARRIOR LAKE	WAR3	LMB	6	378	680	14.9	24	2
12/2/97	WARRIOR LAKE	WAR3	CCF	1	449	700	17.7	24.7	4
12/2/97	WARRIOR LAKE	WAR3	CCF	2	483	1160	19	40.9	7
12/2/97	WARRIOR LAKE	WAR3	CCF	3	441	760	17.4	26.8	0
12/2/97	WARRIOR LAKE	WAR3	CCF	4	548	1700	21.6	60	6
12/2/97	WARRIOR LAKE	WAR3	CCF	5	440	800	17.3	28.2	6
12/2/97	WARRIOR LAKE	WAR3	CCF	6	396	500	15.6	17.6	4

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
11/13/98	Tuscaloosa Reservoir	NOR1	North River, upstream of Tuscaloosa Reservoir.	Tuscaloosa	Largemouth bass	6	Lipid		0.20	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury		0.55	PPM
							Toxaphene	<	0.05	PPM
							DDT	<	0.01	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
					Channel catfish	5	Lipid		2.40	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.10	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury		0.12	PPM
							Toxaphene	<	0.05	PPM
11/19/97	Bankhead Reservoir	BAN1	Dam forebay area. Upstream of Bankhead Lock and Dam.	Tuscaloosa	Largemouth bass	6	Lipid		0.96	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury		0.11	PPM
							Toxaphene	<	0.05	PPM
					Channel catfish	3	Lipid		2.24	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)		0.01	PPM
							Mercury	<	0.10	PPM
							Toxaphene	<	0.05	PPM
11/18/97	Bankhead Reservoir	BAN6	Bankhead Reservoir, in vicinity of Valley Creek confluence. Lat/Lon calculated at confluence.	Jefferson	Largemouth bass	6	Lipid		0.80	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury		0.14	PPM
							Toxaphene	<	0.05	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
					Channel catfish	6	Lipid		2.68	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD		0.02	PPM
							DDE		0.06	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)		0.07	PPM
							Mercury	<	0.10	PPM
							Toxaphene	<	0.05	PPM
11/24/98	Bankhead Reservoir	BWR1	Locust Fork of Bankhead Reservoir at Warrior River mile 388.5. In vicinity of Buddy Vines Fish Camp.	Jefferson	Largemouth bass	6	Lipid		0.60	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury		0.16	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
					Channel catfish	6	Lipid		4.10	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.14	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB		0.26	PPM
							Mirex	<	0.01	PPM
							Mercury	<	0.10	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
11/17/98	Bankhead Reservoir	BYEL1	Big Yellow Creek embayment, upstream of confluence with Warrior River	Tuscaloosa	Largemouth bass	6	Lipid		0.40	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE	<	0.01	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury		0.14	PPM
							Toxaphene	<	0.05	PPM
					Channel catfish	6	Lipid		1.20	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.01	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury		0.16	PPM
							Toxaphene	<	0.05	PPM
12/1/98	Bankhead Reservoir	LOS1	Lost Creek embayment, upstream of confluence with Warrior River.	Walker	Largemouth bass	6	Lipid		0.40	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.01	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury		0.40	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
					Channel catfish	6	Lipid		1.50	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury		0.17	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
12/1/98	Bankhead Reservoir	VAL1	Valley Creek embayment, upstream of confluence with Warrior River.	Jefferson	Largemouth bass	6	Lipid		1.20	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury		0.13	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
					Channel catfish	4	Lipid		2.50	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane		0.20	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD		0.01	PPM
							DDE		0.03	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury	<	0.10	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
					Blue catfish	4	Lipid		1.20	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD		0.04	PPM
							DDE		0.03	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury	<	0.10	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
11/24/98	Bankhead Reservoir	VIL1	Village Creek, upstream of confluence with Locust Fork of the Warrior River.	Jefferson	Largemouth bass	6	Lipid		0.60	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.03	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury		0.13	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
					Channel catfish	6	Lipid		2.90	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT		0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD		0.02	PPM
							DDE		0.10	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB		0.25	PPM
							Mirex	<	0.01	PPM
							Mercury		0.13	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
12/3/97	Holt Reservoir	HOL1	Dam forebay area, downstream of Deerlick Creek Public Use Area. Warrior River mile 347.0 - 348.0.	Tuscaloosa	Largemouth bass	6	Lipid		1.23	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD		0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury		0.27	PPM
							Toxaphene	<	0.05	PPM
					Channel catfish	3	Lipid		1.05	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury	<	0.10	PPM
							Toxaphene	<	0.05	PPM
					Blue catfish	2	Lipid		1.86	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE	<	0.01	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury	<	0.10	PPM
							Toxaphene	<	0.05	PPM
12/9/97	Holt Reservoir	HOL3	Holt Reservoir, in vicinity of Daniel Creek confluence.	Tuscaloosa	Largemouth bass	6	Lipid		0.90	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.03	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury		0.33	PPM
							Toxaphene	<	0.01	PPM
					Channel	4	Lipid		3.06	%

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
					catfish		Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD		0.01	PPM
							DDE		0.03	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.01	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)		0.01	PPM
							Mercury	<	0.10	PPM
							Toxaphene	<	0.05	PPM
11/4/98	Oliver Pool	HUR1	Hurricane Creek embayment, upstream of confluence with Warrior River.	Tuscaloosa	Channel catfish	5	Lipid		2.60	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.04	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury		0.16	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
11/4/98	Oliver Reservoir	OLI1	Reservoir-wide.	Tuscaloosa	Largemouth bass	6	Lipid		0.50	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.02	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Mercury		0.23	PPM
							Toxaphene	<	0.05	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
					Channel catfish	5	Lipid		0.80	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name	Value	Unit
							Cadmium	< 1.00	PPM
							Selenium	< 1.00	PPM
							DDT	< 0.01	PPM
							Chlordane	< 0.01	PPM
							Lindane(gamma BHC)	< 0.01	PPM
							Dieldrin	< 0.01	PPM
							Endrin	< 0.01	PPM
							DDD	< 0.01	PPM
							DDE	0.02	PPM
							Heptachlor	< 0.01	PPM
							Heptachlor-epoxide	< 0.01	PPM
							PCB	0.08	PPM
							Mirex	< 0.01	PPM
							Mercury	0.12	PPM
							Toxaphene	< 0.05	PPM
							Dursban(chlorpyrifos)	< 0.01	PPM
					Blue catfish	2	Endosulfan 1	< 0.01	PPM
							Endosulfan II	< 0.01	PPM
							Hexachlorobenzene	< 0.05	PPM
							Arsenic	< 1.00	PPM
							Cadmium	< 1.00	PPM
							Selenium	< 1.00	PPM
							DDT	< 0.01	PPM
							Chlordane	< 0.01	PPM
							Lindane(gamma BHC)	< 0.01	PPM
							Dieldrin	< 0.01	PPM
							Endrin	< 0.01	PPM
							DDD	0.01	PPM
							DDE	0.04	PPM
							Heptachlor	< 0.01	PPM
							Heptachlor-epoxide	< 0.01	PPM
							PCB	< 0.05	PPM
							Mirex	< 0.01	PPM
							Mercury	< 0.10	PPM
							Toxaphene	< 0.05	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name		Value	Unit
							Dursban(chlorpyrifos)	<	0.01	PPM
12/2/97	Warrior Reservoir	WAR3	Warrior Reservoir, in vicinity of Moundville State Monument. Warrior River mile 303.0.	Tuscaloosa	Largemouth bass	6	Lipid		1.21	%
							Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT		0.02	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM
							DDD	<	0.01	PPM
							DDE		0.12	PPM
							Heptachlor	<	0.01	PPM
							Heptachlor-epoxide	<	0.01	PPM
							PCB	<	0.05	PPM
							Mirex	<	0.01	PPM
							Dursban(chlorpyrifos)	<	0.01	PPM
							Mercury		0.15	PPM
							Toxaphene	<	0.05	PPM
					Channel catfish	6	Endosulfan 1	<	0.01	PPM
							Endosulfan II	<	0.01	PPM
							Hexachlorobenzene	<	0.05	PPM
							Arsenic	<	1.00	PPM
							Cadmium	<	1.00	PPM
							Selenium	<	1.00	PPM
							DDT	<	0.01	PPM
							Chlordane	<	0.01	PPM
							Lindane(gamma BHC)	<	0.01	PPM
							Dieldrin	<	0.01	PPM
							Endrin	<	0.01	PPM

Appendix Table 2. Bioaccumulative contaminant analyses of fish collected from Warrior River basin reservoirs, 1997-1998.

Date Collected	Waterbody	Station	Location Description	County	Species	Number Collected	Chemical Name	Value	Unit
							DDD	< 0.01	PPM
							DDE	< 0.01	PPM
							Heptachlor	< 0.01	PPM
							Heptachlor-epoxide	< 0.01	PPM
							PCB	< 0.05	PPM
							Mirex	< 0.01	PPM
							Dursban(chlorpyrifos)	< 0.01	PPM
							Mercury	0.15	PPM
							Toxaphene	< 0.05	PPM
							Lipid	5.15	%