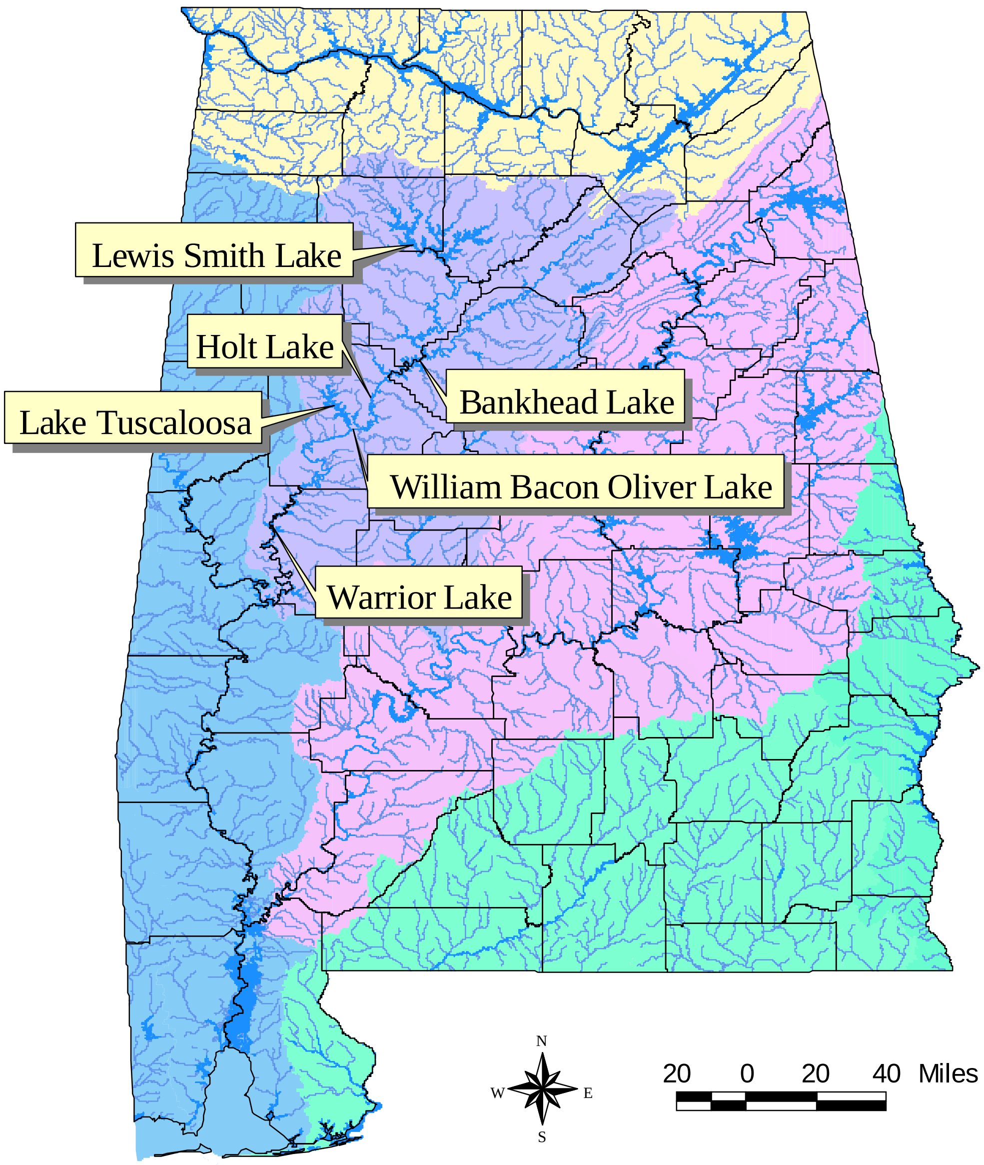
Intensive Water Quality Survey of Black Warrior River Reservoirs 2002



Environmental Indicators Section
Field Operations Division
Alabama Department of Environmental Management

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FINAL REPORT

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.

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Executive Summary

In 2002, intensive monitoring of the reservoirs in the Warrior basin was conducted with the following objectives:

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; and,
c) assist the Nonpoint Source Unit of ADEM in prioritization of subwatersheds by determining the water quality of tributary embayments.

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 upstream and downstream of the tributary confluence 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 a previous assessment of the Black Warrior River conducted in 1998. Water quality assessments were conducted at 37 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; and,
f) total suspended solids (TSS), used as an indicator of sediment inflow.

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.

Smith Reservoir. Mean nutrient and chlorophyll *a* in Smith Reservoir were among the lowest of Warrior basin locations. AGPT results indicated that 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 (Raschke, 1987). Mean TP and TSS concentrations were higher in 2002 than 1998 or 1995. Trophic state index values of these locations were within the oligotrophic to mesotrophic range during the course of this study.

Nutrient, chlorophyll *a*, and TSS concentrations of Smith tributaries were among the lowest of all the Black Warrior tributaries. Mean TN was similar to 1995 or 1998 concentrations, with Crooked Creek having the highest concentrations among Smith Reservoir tributaries. Mean TP, chlorophyll *a* and TSS were higher in 2002 than 1995 or 1998 concentrations, indicating the need for future monitoring to closely determine water quality trends. Though DO concentrations were well above the ADEM Water Criteria (1997) limit of 5.0 mg/l when sampled, 53-84% of the water column at five of the six tributaries (Brushy, Dismal, Rock, Crooked, and Ryan Creeks) were essentially deoxygenated in September and October.

Tuscaloosa Reservoir. Water quality data from Tuscaloosa Reservoir indicated few concerns. Mean TN, chlorophyll *a*, and TSS concentrations were among the lowest of all Warrior basin locations. Algal growth potential tests indicated that phosphorus was either the limiting or co-limiting nutrient at the Lower and Upper 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. Mean TN, and chlorophyll *a* concentrations results in 2002 were similar to concentrations found in 1998, however; mean TP and TSS increased. The origins of these nutrient concentrations should be the subject of further study.

Trophic status values indicate oligotrophic to mesotrophic levels for the Lower, Mid, and Upper reservoir stations, while the North River reached eutrophic levels in several months during the study. DO concentrations were above the criterion limit in all months sampled, however the majority of the water column in the Upper and Mid reservoir locations were essentially deoxygenated for most of the sampling season. Given the eutrophic conditions and low oxygen concentrations of the Upper and Mid reservoir, continued monitoring is advised to determine water quality trends in this reservoir.

Bankhead Reservoir. Water quality concerns for mainstem Bankhead Reservoir are centered primarily in the Locust Fork embayment. The highest mean TN and TP concentrations measured in the basin occurred in this location. Chlorophyll *a* concentrations measured were among the highest in the basin. TSI values indicate that Locust Fork, Mulberry Fork, Mid, and Lower reservoir locations were at the eutrophic level throughout the sampling season with Locust Fork increasing to hypereutrophic levels during August and September. AGPT reveals phosphorus to be the limiting or co-limiting factor at all stations. Mulberry Fork, Locust Fork, and Mid reservoir stations had mean MSC values well above the suggested maximums. DO concentrations were generally above 2.0 mg/l for most of the water column with DO violations occurring in September and/or October for the Mid and Lower reservoir locations. Historical graphs indicate similar to higher concentrations of all nutrients in 2002 when compared to those of 1998.

For Bankhead Reservoir tributaries, Village and Valley Creeks had the two highest mean TN and TP concentrations recorded of any tributary in the basin. Valley Creek had the highest recorded mean chlorophyll *a* concentration followed by Lost Creek. Mean TSS concentrations were generally higher than other tributaries upstream of Bankhead Reservoir. DO profiles reveal deoxygenated conditions existing during months when temperatures were the greatest in Lost and Valley Creeks. Concentrations in Valley Creek increased from 1998 to 2002 for TN, TP and TSS. TN concentrations were similar/lower in Lost Creek in 2002 when compared to 1998.

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 lower Warrior reservoir locations. Phosphorus was indicated as the limiting nutrient at both locations with mean MSC values below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes. Comparison to historical data indicates higher phosphorus concentrations in 2002. Higher phosphorus concentrations may have contributed to higher chlorophyll *a* concentrations in 2002 when compared to previous data. TSI values indicate eutrophic conditions in most months sampled. DO concentrations were near or below criterion limits towards the end of the growing season. 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.

Oliver Pool. The second highest mean TN concentrations of Warrior mainstem reservoir locations were noted in Lower Oliver Reservoir. Elevated levels in 2002 over those measured in 1998 indicate the need for future monitoring to determine trends. TP concentrations were similar to Holt Reservoir with only a slight increase in mean TP concentration observed when comparing 1998 and 2002 data. Chlorophyll *a* concentrations were lower than other nearby reservoirs and decreased from Upper to Lower reservoir stations. TSI values indicated eutrophic conditions at the Upper stations while the Mid and Lower stations maintained mesotrophic or oligotrophic status for most months. Chlorophyll *a* concentrations were essentially the same in 1998 as in 2002. Low DO concentrations were near or below criteria limits for the Upper and Mid stations July-October. TSS concentrations were low and less than half the concentrations in 1998.

Warrior Reservoir. Mean TN concentrations from the Upper reservoir location were among the highest of mainstem reservoir locations. Mean TP concentrations of the lower reservoir were among the highest of Warrior basin locations and higher than those of 1998. The effects of elevated TP concentrations were observed in the mean chlorophyll *a* concentrations, which were among the highest of the Black Warrior basin locations. Higher mean chlorophyll *a* concentrations were also evident in the historic graphs. TSI values indicated upper eutrophic conditions during most months. Mean TSS concentrations in Warrior were among the highest in the basin, but were lower than concentrations in 1998. DO concentrations remained adequate throughout the water column during the growing season although values were near the criteria limit in September.

For the three tributaries monitored in Warrior Reservoir, the mean TSS concentration in Big Sandy was the highest of any tributary or mainstem reservoir location. The reduction in available light caused by high TSS concentrations may have had a detrimental effect on algal populations, resulting in the lowest mean chlorophyll *a* concentration measured in the basin. Mean TN and TP concentrations in Warrior Reservoir tributaries were among the highest values of tributaries in the basin. DO concentrations at all locations remained above criterion limits on all months sampled although values in the lower reservoir were near the limit in September.

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INTRODUCTION

ADEM Reservoir Water Quality Monitoring Program

Section 314(a) of the Water Quality Act of 1987 requires states to conduct assessments of the water quality of publicly-owned lakes and report the findings as part of their biennial 305(b) Water Quality Report To Congress. Prior to 1997, funding for the assessments was provided by Lake Water Quality Assessment (LWQA) grants administered through the Clean Lakes Program of the United States Environmental Protection Agency (EPA). Submittal to the EPA of approved lakes assessment information from states ensured continued eligibility for financial assistance under the Clean Lakes Program. With the discontinuance of Clean Lakes Program funding, water quality assessments are currently conducted using funding from a variety of sources, including Clean Water Act Section 319 funds.

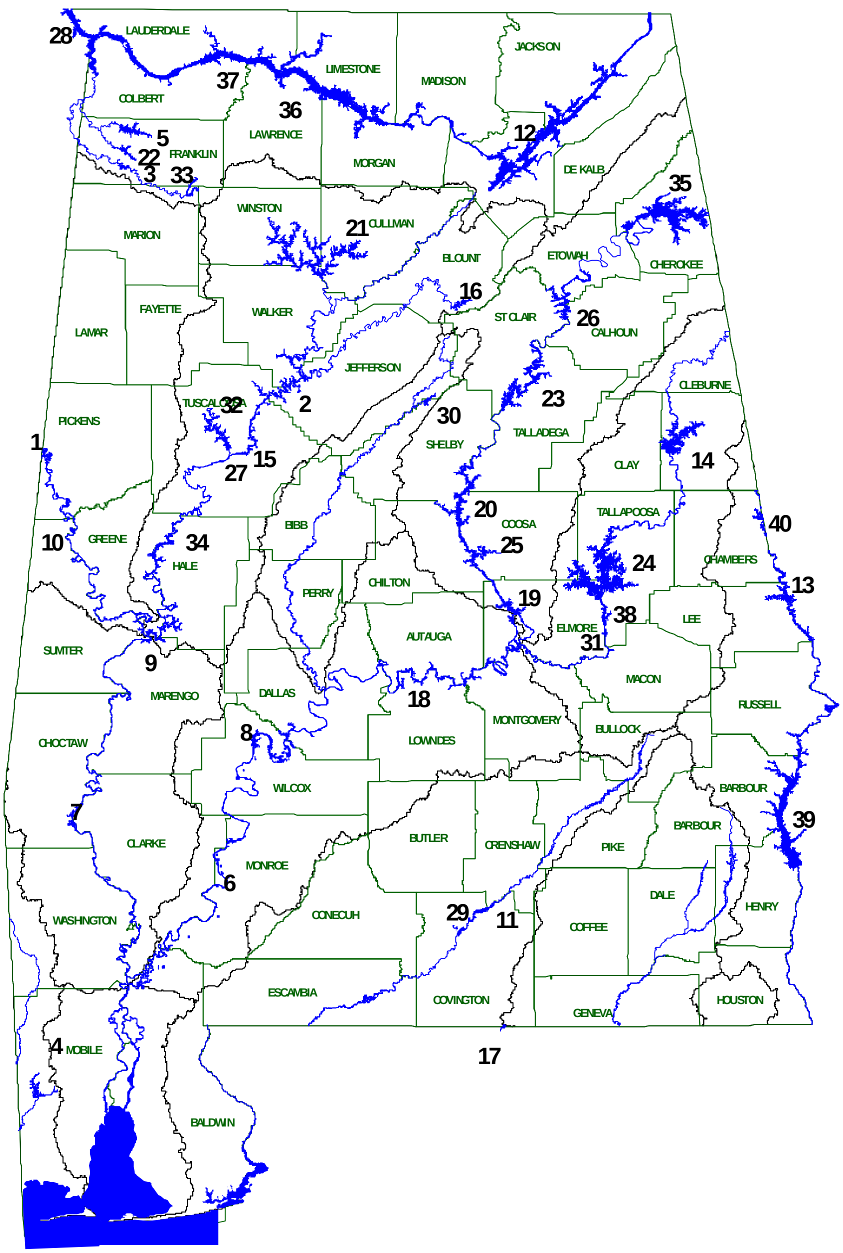
The Alabama Department of Environmental Management (ADEM) has defined publicly-owned lakes/reservoirs as those that are of a multiple-use nature, publicly-accessible, and exhibit physical/chemical characteristics typical of impounded waters. Lakes designated strictly for water supply, privately owned 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 1985, the need for information on the trophic state of Alabama's publicly-owned lakes led to an initial survey conducted by ADEM with the assistance of the Environmental Protection Agency (EPA), Region IV. The survey established limited baseline information on the lakes and was used to rank them according to trophic condition.

In 1989, LWQA funds enabled the ADEM to conduct required water quality assessments of thirty-four publicly-owned lakes in the state and submit the collected information as part of the 1990 305(b) Water Quality Report to Congress (ADEM 1989). Trophic state index (TSI) values calculated from data gathered for the water quality assessments indicated potentially significant increases when compared to TSI values from the study conducted in 1985.

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 1990, the Reservoir Water Quality Monitoring (RWQM) Program was initiated by the 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.

Thirty-one publicly-owned lakes in the state were monitored at least once during the three-year period 1990-1992. In 1991, additional funding received through the Clean Lakes Program enabled the expansion of the RWQM Program to include all of the 31 publicly-owned lakes in the state, with the exception of those in the Tennessee River system. Expansion of the program allowed more extensive monitoring of certain lakes for which water quality concerns were greatest and the inclusion of Alabama/Georgia border lakes that were not included in earlier water quality assessments.

Beginning in 1994, the frequency of reservoir monitoring in the RWQM Program was increased to a minimum of once every two years so that the water quality database and trends in trophic status could be developed more rapidly. Lakes indicated to be use-threatened or impaired from previously collected data continued to be monitored annually. Realignment of the reservoir sampling schedule was also begun in 1994 so that reservoir sampling by basin could be instituted.

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 conducted to align reservoir monitoring with the ADEM nonpoint source basin schedule. Locations 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.

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.

During 2002, reservoirs of the Warrior River basin were intensively monitored for the second time with Warrior, Oliver, Holt, Bankhead, Tuscaloosa, and Smith Reservoirs sampled. Data collected from Warrior basin reservoirs and the additional reservoirs will be used to develop lake-specific nutrient criteria in an effort to address nutrient effects and to assist in development of total maximum daily loads as required by Section 303(d) of the Clean Water Act.

MATERIALS AND METHODS

Sampling Locations. Reservoirs sampled during 2002 appear in Table 1. Locations of sampling sites appear in Table 2. All reservoirs were sampled at the dam forebay. Multiple sites were sampled at each reservoir. Water quality measurements and water sample collections were conducted from boats positioned at the deepest point of the channel at each sampling site.

Sample Collection. Intensive monitoring of reservoirs consisted of monthly sampling of all stations from April through October in the Black Warrior basin. Reservoirs within the basin were sampled within a one-week period to reduce weather-related variability in water quality conditions.

Monitoring and analyses were conducted in accordance with appropriate standard operating procedures. Water quality variables measured during 2002 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 photometer. The depth at which one percent of the surface illumination was measured by the photometer was considered the photic zone depth. A composite 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 composite water sample occurred in the order presented in the following paragraphs.

Chlorophyll *a* samples were collected by filtering a minimum of 500 ml of the composite photic zone sample through glass fiber filters immediately after collection of the composite 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. A more detailed discussion of Carlson's TSI appears later in this section.

Table 1. Reservoirs sampled during the Intensive Water Quality Survey of Black Warrior River Reservoirs, 2002.

River Basin	Reservoir	Surface Area (acres)	Drainage Area (mi^2)
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 Intensive Water Quality Survey of Black Warrior River Reservoirs, 2002.

Basin	Reservoir	Station #	Legend (For Graphs)	Latitude	Longitude	Description
Warrior	Smith	1	Lower*	33.9495	-87.1108	Deepest point, main river channel, dam forebay.
		2	Mid*	33.9860	-87.2053	Deepest point, main river channel, at Duncan Creek/Sipsey River confluence. Downstream of Alabama Hwy 257 bridge.
		3	Upper*	34.0635	-87.2584	Deepest point, main river channel, immediately. downstream of Brushy Creek confluence.
		4	Brushy Cr.^	34.0754	-87.2506	Deepest point, main creek channel, Brushy Creek embayment.
		5	Sipsey*	34.0821	-87.2581	Deepest point, main river channel, approx. 0.5 miles downstream of the Sipsey Fork, Yellow Creek confluence.
		6	Clear Cr.^	34.021	-87.263	Deepest point, main creek channel, Clear Creek embayment.
		7	Dismal Cr.^	34.0135	-87.1912	Deepest point, main creek channel, Dismal Creek embayment.
		8	Rock Cr.^	33.99874	-87.1197	Deepest point, main creek channel, Rock Creek embayment.
		9	Crooker Cr.^	34.0627	-87.123	Deepest point, main creek channel, Crooked Creek embayment. Approx. 1.5 miles upstream of Winston Co. Rd. 22 bridge.
		10	Ryan Cr.^	33.9619	-87.1008	Deepest point, main creek channel, Ryan Creek embayment.
	Tuscaloosa	1	Lower*	33.2685	-87.5084	Deepest point, main river channel, dam forebay .
		2	Upper*	33.3746	-87.5945	Deepest point, main river channel, immediately downstream of Binion Creek confluence.
		3	Mid*	33.3405	-87.5604	Deepest point, main river channel, approx. one mile downstream of Alabama Hwy. 69 bridge.
		4	North R.*	33.3979	-87.5795	Deepest point, main river channel, North River, immediately upstream of Bull Slough Rd crossing.
		5	Binion Cr.^	33.3972	-87.6101	Deepest point, main creek channel, Binion Creek, immediately upstream of HWY 43 crossing.

* Mainstem sampling location   ^ Tributary sampling location

Table 2. Monitoring sites for the Intensive Water Quality Survey of Black Warrior River Reservoirs, 2002

Basin	Reservoir	Station #	Legend (For Graphs)	Latitude	Longitude	Description
Warrior	Bankhead	1	Lower*	33.4663	-87.3481	Deepest point, main river channel, dam forebay .
		2	Mid*	33.5094	-87.2637	Deepest point, main river channel, mid-reservoir. Approx. 0.5 mi. upstream of Little Shoal Creek confluence.
		3	Locust Fork*	33.5448	-87.1749	Deepest point, main river channel, Locust Fork. Approx. 1.5 mi. upstream of Mulberry, Locust confluence.
		4	Mulberry Fork*	33.5732	-87.2055	Deepest point, main river channel, Mulberry Fork. Approx. 1.5 mi. upstream of Mulberry, Locust confluence.
		5	Lost Cr.^	33.6379	-87.2470	Deepest point, main creek channel, Lost Creek embayment. Approx. 0.5 mi. downstream of Walker Co. Rd. 53 bridge.
		6	Valley Cr.^	33.5231	-87.2298	Deepest point, main creek channel, Valley Creek embayment. Approx. 1 mile upstream of confluence with Warrior River.
		7	Big Yellow Cr.^	33.4876	-87.3443	Deepest point, main creek channel, Big Yellow Creek embayment. Approx. 1 mile upstream of confluence with Warrior River.
		8	Village Cr.^	33.6228	-87.0706	Deepest point, main creek channel, Village Creek embayment. Approx. 0.5 mile upstream of confluence with Warrior River.
	Holt	1	Lower*	33.2541	-87.4442	Deepest point, main river channel, dam forebay .
		2	Mid*	33.3464	-87.4155	Deepest point, main river channel, mid-reservoir. Immediately upstream of Pegues Creek, Black Warrior confluence.
		3	Upper*	33.4490	-87.3657	Deepest point, main river channel, approximately 0.5 miles downstream of Big Indian Creek, Black Warrior confluence.
	Oliver	1	Lower*	33.2113	-87.5834	Deepest point, main river channel, dam forebay.
		2	Mid*	33.2425	-87.5042	Deepest point, main river channel, mid-reservoir, immediately downstream of North River, Black Warrior confluence.
		3	Upper*	33.2532	-87.4610	Deepest point, main river channel, approximately 0.5 miles downstream of Hurricane Creek, Black Warrior confluence.

* Mainstem sampling location ^ Tributary sampling location

Table 2. Monitoring sites for the Intensive Water Quality Survey of Black Warrior River Reservoirs, 2002

Basin	Reservoir	Station #	Legend (For Graphs)	Latitude	Longitude	Description
Warrior	Warrior	1	Lower*	32.7796	-87.8392	Deepest point, main river channel, dam forebay.
		2	Mid*	32.8949	-87.7872	Deepest point, main river channel, immediately downstream of Lock 8 Public Use Area.
		3	Upper*	32.9950	-87.7056	Deepest point, main river channel, at Lock 9 Public Use Area.
		4	Above I-59*	33.1338	-87.6826	Deepest point, main river channel, approximately 3.5 miles upstream of I-59 crossing.
		5	Big Sandy Cr.^	33.0447	-87.6231	Main creek channel, Big Sandy Creek 0.5 miles upstream of confluence with Black Warrior River
		6	Five Mile Cr.^	32.8999	-87.7559	Main creek channel, Five Mile Creek 0.5 miles upstream of confluence with Black Warrior River
		7	Big Brush Cr.^	32.8334	-87.8038	Main creek channel, Big Brush Creek 0.5 miles upstream of confluence with Black Warrior River

* Mainstem sampling location   ^ Tributary sampling location

Table 3. Water quality variables measured during the Intensive Water Quality Survey of Black Warrior River Reservoirs, 2002.

Variable	Method	Reference	Detection Limit
Physical			
Vertical illumination	Photometer, Secchi disk	Lind, 1979	---
Temperature	Thermistor	APHA et al. 1998	---
Turbidity	Nephelometer	APHA et al. 1998	---
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. 1998	---
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. 1998	---
pH	Glass electrode	APHA et al. 1998	---
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
Dissolved 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. 1998	0.1 μg/l
Fecal coliform *	Membrane filter	APHA et al. 1998	---
Algal growth potential test **	Printz Algal Assay Test	ADEM 1993	---

* August only.

** Mainstem reservoir locations, August only.

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

Finally, two half-gallon portions of the composite 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.

During August, samples for Algal Growth Potential Tests (AGPT) were collected from the composite photic zone sample of mainstem reservoir sampling locations by filling a properly prepared plastic container and preserving on ice. A more detailed discussion of AGPT appears later in this section.

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 (2000).

Quality Control / Quality Assurance. 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 were collected.

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 $\geq$ 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.

RESULTS AND DISCUSSION

Data Selection. Material in this section is by reservoir. Water quality data presented 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; and,

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; and,

f. total suspended solids (TSS), used as in an indicator of sediment flow.

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. Topics not selected for further discussion in this report were done so in the interests of time, space, or data availability.

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 topics to the process and how the process affects the water quality of lakes and reservoirs. Eutrophication is the process by which water bodies 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. Increased eutrophication in a 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;

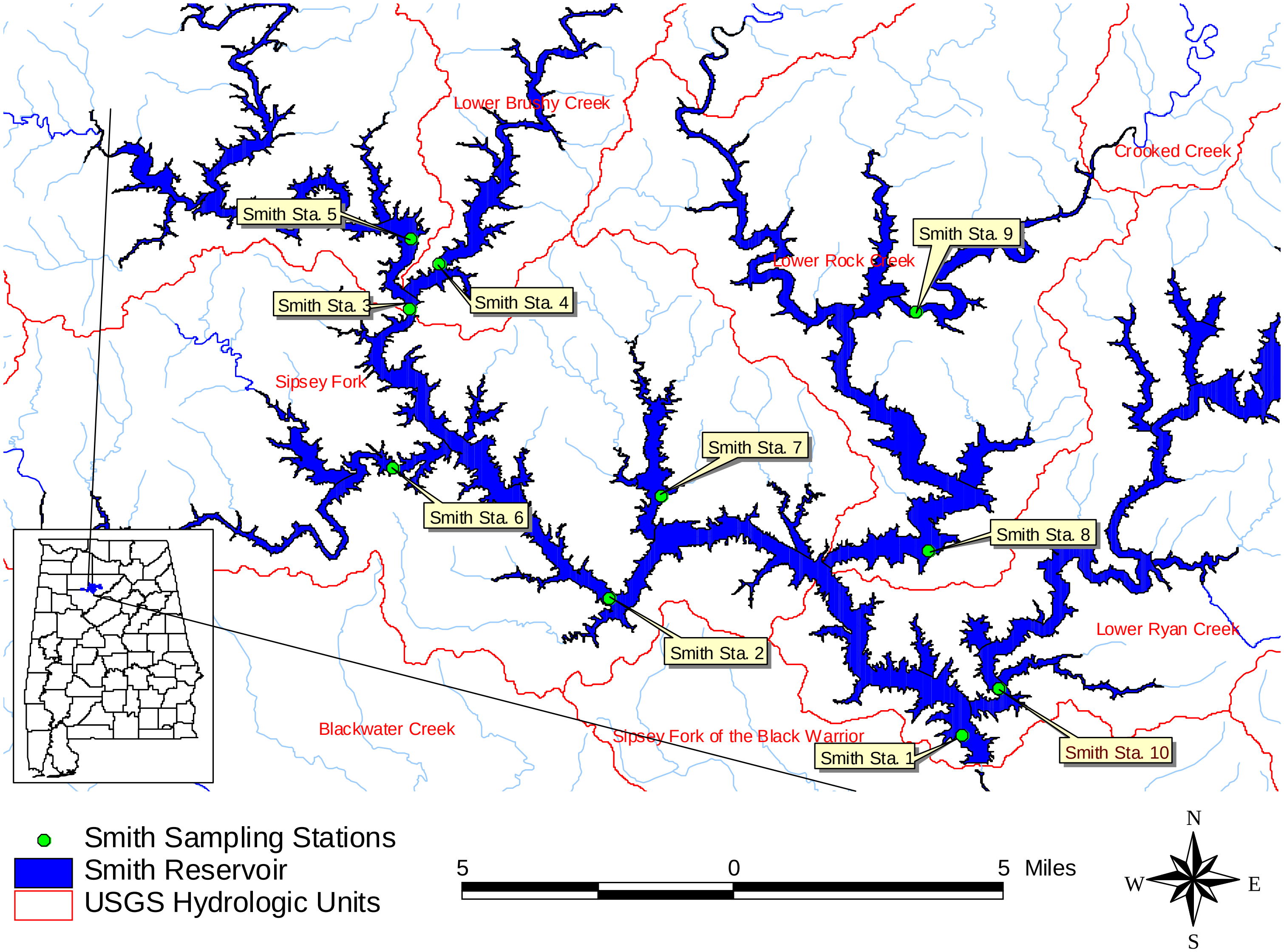
b) low dissolved oxygen concentrations;

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.

Figure 2. Smith Reservoir with 2002 sampling locations.



Smith Reservoir

Nitrogen.

Mainstem. Mean TN concentrations in Smith Reservoir were, overall, the lowest of Warrior basin locations (Fig. 3). Within the reservoir, mean concentration in the Lower reservoir was highest, followed by Mid, Sipsey, and Upper reservoir, respectively. Graphs of mean TN data collected in 1995, 1998 and 2002 from comparable stations indicate that concentrations in Sipsey, Upper, and Mid reservoir decreased each year sampled (Appendix Fig. 1). In the Lower reservoir, concentrations were similar to higher in the years sampled.

Monthly values at all reservoir locations followed similar patterns throughout the sampling season (Fig. 9). Highest concentrations at all stations were recorded in June and/or October. Sipsey station declined April-May, sharply increased in June, and then reached lowest levels in July-September. The Upper and Mid reservoir stations were similar to the Sipsey station, however, concentrations were less variable April-June. Lower reservoir reached much higher concentrations April-July, then dropped to lowest levels August-October.

An inverse relationship between lake mean TN concentrations and discharge existed May and June(Fig. 9). A similar pattern occurred between lake mean TN concentrations and discharge from July – October.

Tributaries. Mean TN concentrations in Smith Reservoir tributaries were among the lowest concentrations of the Warrior basin tributaries (Fig. 7). Brushy Creek reported the lowest mean TN concentration of any tributary, followed by Clear, Rock, Dismal, and Ryan Creeks. Highest concentrations were found in Crooked Creek, though these values were lower than many of the other basin tributaries. Graphs of mean TN data collected in 1995, 1998 and 2002 from comparable stations indicate that concentrations in Clear Creek, Dismal Creek, and Ryan Creek were similar in 1995 and 2002 (Appendix Fig.2). Brushy, Crooked, and Rock Creeks TN concentrations were lower in 2002 when compare to those concentrations in 1995. Concentrations in Crooked Creek were lower in 2002.

To more clearly view the results of plotting nutrients, Smith Reservoir tributaries were divided into upper and lower sections. Each tributary will be discussed individually. When a USGS gage station was located near the sampling location, discharge data was obtained and concentrations vs. discharge were graphed.

Monthly TN concentrations for Brushy Creek were variable throughout the sampling season (Fig. 10). Values decreased in May, July, and September. Conversely, concentrations increased June, August, and October. Highest concentrations occurred in June while lowest concentrations occurred in July and September.

Monthly TN concentrations for Clear Creek apparently responded inversely to discharge April-September then increased with flow in October (Fig. 10). As flows increased in May concentrations declined to lowest concentrations. When discharge was lowest in August, concentration increased.

Monthly TN concentrations for Dismal Creek were similar to other Smith Reservoir tributaries (Fig. 10). Concentrations appeared to have an inverse relationship with discharge April – June. Concentrations appeared to be related to discharge July – October. Highest concentrations occurred in April and lowest concentrations in September.

Monthly TN concentrations for Rock Creek were variable throughout the sampling season (Fig. 11). Concentrations declined April-May, increased to season highs in June, and then dropped to the lowest concentrations of the season July through September. A sharp increase in concentrations occurred in October.

Crooked Creek monthly TN concentrations were similar to downstream Rock Creek (Fig. 11). Concentrations were high April-June followed by a sharp decline to low concentrations July-September and a sharp increase to higher concentrations in October. Highest concentrations occurred in April with lowest occurring in September.

Monthly TN concentrations for Ryan Creek were variable as other lower Smith Reservoir tributaries (Fig. 11). Highest concentrations occurred in June as values increased from April-June. TN concentrations sharply decreased in July and continued to decline until reaching lowest levels in September, followed by a sharp increase in concentration in October.

Phosphorus.

Mainstem. Mean TP concentrations in Smith Reservoir were the lowest of the Black Warrior mainstem reservoir stations (Fig. 4). Within the reservoir, highest concentrations occurred in the Sipsey River followed by the Upper, Mid, and Lower locations respectively. Graphs of mean TP data collected in 1995, 1998 and 2002 from comparable stations indicate that concentrations from Sipsey, Mid, and Lower reservoir stations increased each year sampled from

1995 to 2002 (Appendix Fig.1). No data was available in 1998 for Upper reservoir; however, concentrations increased from 1995 to 2002, similar to the other Smith Reservoir stations.

Monthly TP concentrations were variable April-October for all mainstem reservoir stations (Fig. 9). Concentrations in Upper reservoir fluctuated monthly with highest values occurring in June and August, and lowest values in July. Mid and Sipsey reservoir generally increased April-October with a decrease in September. Lower reservoir concentrations were highest in April and lowest in October.

No obvious relationship appeared to exist between TP concentrations and mean lake discharge (Fig. 9). Lake mean TP concentrations were consistent April-October while highest flows occurred in May and low flows occurred June through September.

Tributaries. Mean TP concentrations in Smith Reservoir tributaries were similar to other Black Warrior tributary locations (Fig. 7). Concentrations were among the lowest of any tributary and Brushy, Rock, and Dismal Creeks had the lowest three concentrations of the basin. All monitored tributary embayments appear to be contributing similar amounts of phosphorus to the reservoir. Graphs of mean TP data collected in 1995 and 2002 from comparable stations indicate that concentrations in Brushy, Clear, Dismal, Rock, and Ryan Creeks were at least three times higher in 2002 than in 1995 (Appendix Fig.2). Concentrations from Crooked Creek were slightly lower in 2002.

To more clearly view the results of plotting nutrients, Smith Reservoir tributaries were divided into upper and lower sections. Each tributary will be discussed individually. When a USGS gage station was located near the sampling location, discharge data was obtained and concentrations vs. discharge were graphed.

Monthly TP concentrations in Brushy Creek were variable April-October, decreasing one month and increasing the next (Fig. 10). Highest concentrations occurred in June and August while lowest concentrations occurred in September.

Monthly TP concentrations in Clear Creek were variable throughout the sampling season (Fig. 10). Discharge increased April to May, followed by a rapid decline and low flows through October. No obvious relationship appeared to exist between monthly TP concentrations as lowest values occurred in May, July, and August during which high and low discharge was recorded.

Monthly TP concentrations in Dismal Creek gradually increased April-July then slowly declined through October (Fig. 10). Highest concentrations occurred in July with lowest concentrations occurring in October.

Monthly TP concentrations in Rock Creek were similar April-October (Fig. 11). Values were highest in June and August as concentrations peaked above mean values.

Crooked Creek had similar monthly TP concentrations from April-October with the exception of July (Fig. 11). Concentrations in July were the lowest of the sampling season of any of the Smith Reservoir tributaries.

Monthly TP concentrations in Ryan Creek rose gradually from April to July then declined through October (Fig. 11). Values were lowest in April and peaked in July.

Algal Growth Potential Tests.

Phosphorus was indicated as the limiting nutrient at the Mid and Lower reservoir locations (Table 4). At the Upper reservoir location, both nitrogen and phosphorus were co-limiting. Mean MSC values for Upper, Mid, and Lower locations (1.69, 1.41, and 1.44 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*.

Mainstem. Mean chlorophyll *a* concentrations in Smith Reservoir were among the lowest of the Warrior basin (Fig. 5). Within the reservoir, mean chlorophyll *a* concentrations were low and consistent across the reservoir. Mean concentrations of the Sipsey and Lower location were second lowest of all Warrior basin locations. Graphs of mean chlorophyll *a* data collected in 1995, 1998 and 2002 from comparable stations indicate that concentrations in Sipsey, Mid, and Lower reservoir were similar or the same from 1995 to 1998 and increased in 2002 (Appendix Fig. 1). The Upper reservoir concentrations increased from 1995 to 2002.

Lowest monthly chlorophyll *a* concentrations for all four mainstem reservoir stations occurred in April (Fig. 12). Concentrations decreased slightly May-October for the Sipsey and Mid stations while the Lower station was variable. Highest concentrations occurred in May for Mid reservoir then June for Upper reservoir, July for Sipsey reservoir, and August for the Lower reservoir.

Lake mean chlorophyll *a* was highest in May then declined gradually through October (Fig. 12). Discharge was also highest in May, declined sharply in June with low flows occurring in September. In October, flows increased while lake mean chlorophyll *a* decreased.

Tributaries. Mean chlorophyll *a* concentrations were similar in all Smith Reservoir tributaries with the exception of Crooked Creek which was more than three times the next highest Smith Reservoir tributary location, Rock Creek (Fig. 8). Graphs of mean chlorophyll *a* data collected in 1995 and 2002 from comparable stations indicate that concentrations in Brushy, Clear, Dismal, Rock, Crooked, and Ryan Creeks were higher in 2002 (Appendix Fig. 2).

To more clearly view the results of plotting nutrients, Smith Reservoir tributaries were divided into upper and lower sections. Each tributary will be discussed individually. When a USGS gage station was located near the sampling location, discharge data was obtained and concentrations vs. discharge were graphed.

Monthly chlorophyll *a* concentration for Brushy Creek was lowest in April and sharply increased to highest values in May (Fig. 10). Concentrations varied June-October but generally decreased.

No obvious relationship existed between monthly chlorophyll *a* concentrations and discharge at Clear Creek (Fig. 10). Monthly chlorophyll *a* concentrations increased with flow April-May, but concentrations continued to increase as flows sharply decreased June-October.

Monthly chlorophyll *a* concentrations in Dismal Creek were highly variable April-October (Fig. 10.). Concentrations increased and decreased on a monthly basis. Highest concentrations occurred in July and lowest concentrations occurred in October.

Monthly chlorophyll *a* concentrations in Rock Creek gradually increased April-August from the lowest concentration to the highest concentration of the sampling season (Fig. 11).

Monthly chlorophyll *a* concentrations in Crooked Creek were higher and more variable than any other tributary on Smith Reservoir (Fig. 11). Concentrations in April were more than three times higher than any other lower tributary sampling station. Lowest concentrations occurred in May, August, and October.

Monthly chlorophyll *a* concentrations in Ryan Creek were low and generally increased throughout the sampling season (Fig. 11). Concentrations were lowest in May then gradually increased until highest concentrations occurred in August.

Total Suspended Solids

Mainstem. Mean TSS concentrations for Smith Reservoir were the lowest overall of Warrior basin locations (Fig. 6). Within the reservoir, concentrations decreased from the Sipsey reservoir to the Lower reservoir station. Mean concentrations of Mid and Lower reservoir locations were the second lowest of all mainstem basin locations. Graphs of mean TSS data collected in 1995, 1998 and 2002 from comparable stations indicate that concentrations at all 4 stations were much higher in 2002 than both 1995 and/or 1998 (Appendix Fig. 1).

Monthly TSS concentrations were variable at all locations April-October (Fig. 12). In the Sipsey reservoir station, highest concentrations occurred in April while the other three stations were at their lowest concentrations. Lowest concentrations in the Sipsey reservoir occurred in June and September while Upper, Mid, and Lower reservoir stations reached highest concentrations in October.

No obvious relationship exists between lake mean TSS concentrations and discharge (Fig. 12). When discharge reached its highest point in May, concentrations increased but they also increased when the lowest flows of the study were observed.

Tributaries. Mean TSS concentrations in Smith Reservoir tributaries were lower than most other tributary locations (Fig. 8). The lowest three mean TSS concentrations of any Black Warrior tributary were Ryan, Dismal, and Clear Creek (5.14, 5.29, and 5.71 mg/l, respectively), tributaries of Smith Reservoir. Graphs of mean TSS data collected in 1995, 1998 and 2002 from comparable stations indicate that concentrations in Brushy, Clear, Dismal, Rock, Crooked, and Ryan Creeks were much higher in 2002 (Appendix Fig. 2).

To more clearly view the results of plotting nutrients, Smith Reservoir tributaries were divided into upper and lower sections. Each tributary will be discussed individually. When a USGS gage station was located near the sampling location, discharge data was obtained and concentrations vs. discharge were graphed.

Monthly TSS concentrations in Brushy Creek were consistent April-August (Fig. 10). Concentrations declined to lowest values in September and then sharply rose to highest values in October.

Monthly TSS concentrations in Clear Creek varied April-October (Fig. 10). Lowest concentrations occurred in July and September. Highest discharge occurred in May with a decrease in concentration while lowest discharge occurred in August with an increase in concentration. This trend continued April-September, in October concentrations dramatically increased as flow increased.

Monthly TSS concentrations in Dismal Creek generally increased April-August (Fig. 10). Highest concentrations occurred in October with lowest concentrations occurring in May.

Monthly TSS concentrations in Rock Creek generally increased from April through October (Fig. 11). Highest values occurred when a large spike in concentration occurred in July. Concentrations were six times higher than June values.

Monthly TSS concentrations in Crooked Creek were variable but usually higher than the concentrations of other lower Smith Reservoir tributaries (Fig. 11). Lowest concentrations occurred in September with highest concentrations occurring in October.

Monthly TSS concentrations in Ryan Creek were low and consistent April-July (Fig. 11). Highest concentrations occurred when values increased in August and again in October. Lowest concentrations occurred in September.

Trophic state.

Monthly TSI values for all Smith Reservoir locations generally remained within the same range during the study period (Fig. 13). All four stations started within the oligotrophic range in April and moved into the mesotrophic range beginning in May. From May-September, TSI values varied within the mesotrophic range at all main reservoir stations. In October, Upper and Mid returned to the oligotrophic range while the Lower and Sipsey reservoir stations remained in mesotrophic range.

Dissolved oxygen/Temperature.

Mainstem. Dissolved oxygen concentrations generally decreased at all Smith Reservoir locations April-August (Fig. 13). In September and October, dissolved oxygen concentrations slightly increased. All locations were similar and concentrations were above the criterion limit of 5.0 mg/l on all dates sampled.

Depth profiles of temperature and dissolved oxygen from Sipsey station Smith Reservoir indicated a strong thermocline existed from April-October, moving deeper into the water column throughout the study (Fig. 14). Strong chemoclines were noted May-October at various depths in the water column. Deoxygenation of the hypolimnion occurred immediately below the thermocline and below 26m in September and October.

Depth profiles of temperature and dissolved oxygen from Upper reservoir showed a weak thermocline developing in April that intensified each month through October (Fig. 15). Highest temperatures occurred in July and August. A weak chemocline existed near the bottom in April, with a second chemocline developing in May and continuing through October. Deoxygenation occurred beneath the first chemocline and below 30m August-October.

Depth profiles of temperature and dissolved oxygen from Mid reservoir show a thermocline and chemocline(s) developed all months April-October (Fig. 16). Weak thermoclines existed in April and May, and intensified monthly to a strong thermocline in October. Highest temperatures occurred in July and August. A single strong chemocline below 35m in April and May created deoxygenated conditions below 45m. In June, a second chemocline developed closer to the surface and intensified through October. Deoxygenated conditions developed in the hypolimnion August-October and below 35m in September and October.

Depth profiles of temperature and dissolved oxygen from the dam forebay of Smith Reservoir indicated thermoclines and chemoclines developed in all months of the study (Fig. 17). A weak thermocline existed in April and intensified until a distinct thermocline occurred June-October. Highest temperatures occurred in July and August. A single strong chemocline occurred in April resulting in deoxygenated conditions from the 30m to the bottom. Profiles in May-July suggest the development of two chemoclines. By August, two well developed chemoclines existed and intensified through October. In September and October, deoxygenated conditions existed beneath the hypolimnion and below 30m.

Tributaries. Monthly dissolved oxygen concentrations, in all upper and lower Smith Reservoir tributaries, exhibited similar patterns (Fig. 10 & 11). Concentrations decreased April-July followed by a gradual increase August-October. Concentrations remained above the criterion limit of 5.0 mg/l on all dates sampled.

Depth profiles of temperature for Brushy, Clear, and Dismal Creeks show developing thermoclines in April moving deeper into the water column and strengthening through October (Appendix Fig. 3-5). In Clear and Dismal creeks, a chemocline developed near the bottom in

April. A second chemocline developed in May at 5m. In Clear and Brushy Creeks, the uppermost chemocline progressed deeper in the water column September and October while it dissipated in Dismal Creek.

Depth profiles of temperature and dissolved oxygen for Rock, Crooked, and Ryan Creeks show similar profiles (Appendix Fig. 6-8). Distinct thermoclines are evident near the surface in April and move deeper into the water column through October. Chemoclines follow the same pattern creating deoxygenated conditions immediately beneath the thermocline. DO concentrations recovered and a second thermocline was evident in most months.

Summary/Discussion.

Mean TN, TP, chlorophyll *a* and TSS concentrations in Smith Reservoir were among the lowest of the Warrior basin mainstem locations. AGPT results indicated that Mid and Lower reservoir locations were phosphorus limited, with mean MSN 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 2002 over those measured in 1995 and 1998 may indicate a need for future monitoring.

Trophic state index values indicated that these locations were within the oligotrophic to mesotrophic range during the course of the study. Increased mean chlorophyll *a* and TSS concentrations in 2002 over those in 1998 and 1995 may result in higher TSI values in the future and should be further studied.

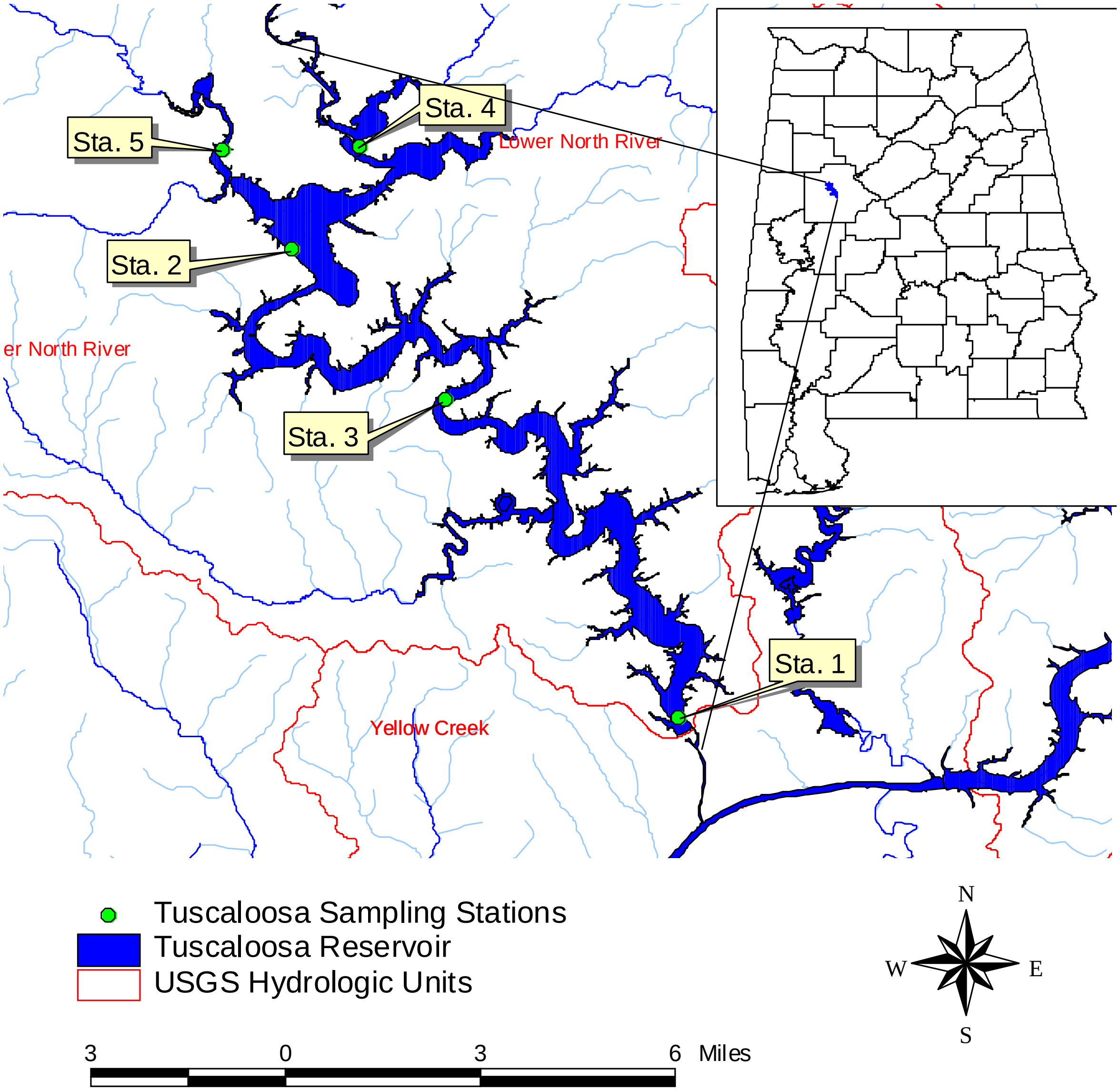
Six tributary embayments were monitored in Smith Reservoir including Brushy, Clear, Dismal, Rock, Crooked, and Ryan Creeks. The Lower Brushy Creek sub-watershed drains approximately 51 mi^2 in Winston County (ADEM 2004). Percent land cover of the Lower Brushy Creek sub-watershed was estimated as 33% deciduous forest, 25% evergreen forest, 33% mixed forest, and 8% pasture/hay. Estimates of land-use by the local SWCDs were lower for forest (77%) and higher for open water (7%) and urban (1%) land-uses. Three (3) current construction/stormwater authorizations have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.26 AU/Acre). Sedimentation estimates indicated a *low* potential for NPS impairment (1.5 tons/acre). The overall potential for impairment from nonpoint sources was estimated as *low*. Little impairment was detected in Brushy Creek. Concentrations for TN, TP, chlorophyll *a*, and TSS were near the lowest of all the tributaries. Mean TN concentration was the lowest of any tributary. DO concentrations were deoxygenated beneath the first hypolimnion and recovered May-October.

The Sipsey Creek sub-watershed drains approximately 78 mi^2 in Walker and Winston Counties (ADEM 2004). The Sipsey Creek sub-watershed includes both Clear and Dismal Creek tributary embayment stations. Percent land cover of the Sipsey Creek sub-watershed was estimated as 5% transitional barren, 30% deciduous forest, 20% evergreen forest, 25% mixed forest, 5% pasture/hay, and 5% row crop. Estimates of land-use by the local SWCDs was higher for open water (7%) landuses. Two (2) NPDES permits, one municipal and one semi-public/private, and seven (7) CAFO registrations have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.14 AU/Acre). Sedimentation estimates indicated a *moderate* potential for NPS impairment (8.2 tons/acre). The overall potential for impairment from nonpoint sources was estimated as *low*. Water quality analysis indicate no evident concerns as mean concentrations for TN, TP, chlorophyll *a* and TSS, for both Clear and Dismal Creeks, are among the lowest of any tributary in the Black Warrior basin. Even though the assessment indicated an increased potential for sedimentation, no elevated concentrations were found. Depth profiles of DO showed low concentrations beneath the hypolimnion and deoxygenated condition for the lower portion of the water column.

The Lower Rock Creek sub-watershed drains approximately 62 mi^2 in Cullman, Walker, and Winston Counties (ADEM 2004). The Lower Rock Creek sub-watershed includes both Rock and Crooked Creek tributary embayment stations. A twenty-eight mile (28 mi.) segment of Crooked Creek is included on the Alabama CWA §303(d) list of impaired waterbodies with a partial support status for excessive pathogens from intensive animal feeding operations. Percent land cover of the Lower Rock Creek sub-watershed was estimated as 40% deciduous forest, 13% evergreen forest, 20% mixed forest, 7% pasture/hay, and 7% row crop. Estimates by the local SWCDs were higher for urban (11%), mines (7%), and pasture (27%) and lower for forest (50%) and row crop (2%) land uses. Two (2) current construction/stormwater authorizations and two (2) CAFO registrations have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *moderate* (1.47 AU/Acre), with poultry-broiler and cattle being the dominant animals. Sedimentation estimates indicated a *low* potential for NPS impairment (2.8 tons/acre). The overall potential for impairment from nonpoint sources was estimated as *low*. Mean concentrations in Rock Creek for TN, TP, chlorophyll *a*, and TSS were among the lowest of the Black Warrior basin. Mean TN and TSS concentrations in Crooked Creek were the highest of any tributary of Smith Reservoir, but among the lowest of the basin. Mean chlorophyll *a* concentration was the second highest of the basin. DO concentrations, for both creeks remained above 6 mg/l April-October. Profiles for both creeks indicate stratified conditions and deoxygenated water in most months.

The Lower Ryan Creek sub-watershed drains approximately 97 mi^2 in Cullman and Walker Counties (ADEM 2004). Percent land cover of the Lower Ryan Creek sub-watershed was estimated as 36% deciduous forest, 16% evergreen forest, 20% mixed forest, 12% pasture/hay and 4% row crop. Estimates of land-use by the local SWCDs were higher for open water (13%) and pasture (6%), and lower for forest (52%) and row crop (1%) landuses. Six (6) current construction/stormwater authorizations, two (2) mining NPDES permits, one (1) semi-public/private NPDES permit, and two (2) CAFO registrations have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *high* (2.68 AU/Acre), with poultry-broiler being the dominant animal. Sedimentation estimates indicated a *low* potential for NPS impairment (1.5 tons/acre). The overall potential for impairment from nonpoint sources was estimated as *moderate*. However, Ryan Creek was found to have one of the lowest mean concentrations of chlorophyll *a* and TSS of any Black Warrior tributary. TN and TP concentration were also among the lowest. DO concentrations remained sufficient throughout the sampling season. Profiles indicate stratified conditions and deoxygenated condition in April, September, and October.

Figure 18. Tuscaloosa Reservoir with 2002 sampling locations.



Tuscaloosa Reservoir

Nitrogen.

Mainstem. Mean TN concentrations in Tuscaloosa Reservoir were among the lowest of the Black Warrior basin locations (Fig. 3). Within the reservoir, mean concentrations decreased from North River to mid reservoir locations. The Lower reservoir location concentration was slightly lower than the North River location, but higher than both the Mid and Upper locations. Graphs of mean TN data indicate that concentrations in Upper and the Lower reservoir stayed the same while Mid reservoir concentrations increased from 1998 compared to 2002 (Appendix Fig. 9).

Highest values for the North River, Upper, Mid, and Lower reservoir locations all occurred in May (Fig. 19). Lowest values occurred in June and August for the North River station and July and August for the Upper reservoir. Concentrations in the Mid and Lower reservoir locations were lowest in July.

Lake mean TN concentrations appeared to be related to discharge April-September (Fig. 19). Concentrations increased April-May along with increased discharge. When flow declined May-August, TN concentrations decreased. As flow increased in September, lake mean TN concentrations increased. In October concentrations decreased as flow increased.

Tributaries. The mean TN concentration in Binion Creek, a tributary to Tuscaloosa Reservoir, was the second lowest of any tributary in the Black Warrior basin (Fig. 7). The concentration was much lower than downstream Bankhead and Warrior tributaries.

Monthly TN concentrations in Binion Creek were similar to those found in the mainstem reservoir (Fig. 20). Low concentrations in April sharply increased to season highs in May, and then returned to low concentrations June-August. In September and October, concentrations increased.

Phosphorus.

Mainstem. Mean TP concentrations in Tuscaloosa Reservoir were above Upper Smith Reservoir and below Lower Bankhead Reservoir (Fig. 4). Values decreased from 0.049 mg/l at the North River reservoir location to 0.032 mg/l at the Lower station. Graphs of mean TP data indicate that concentrations in Upper, Mid and the Lower reservoir increased from 1998 - 2002 (Appendix Fig. 9).

Monthly TP concentrations were similar at all four reservoir locations April-June, reaching lowest values in April and May (Fig. 19). TP concentrations continued to increase in the North River station through July when highest values were recorded, then gradually decreased the remainder of the season. Upper reservoir location peaked in August while Mid and Lower reservoir continued to increase through September.

Lake mean TP concentrations slowly increased April-September as discharge fluctuated from high flows in May to low flows in August (Fig. 19). TP concentrations decreased September-October as discharge continued to increase.

Tributaries. The mean TP concentration in Binion Creek, a tributary to Tuscaloosa Reservoir, was similar to upstream Smith Reservoir tributaries, but lower than tributaries of Bankhead or Warrior (Fig. 7).

Monthly TP concentrations in Binion Creek varied April-October (Fig. 20). Concentrations increased April-May and decreased June-July to season lows. Highest concentrations occurred August-October.

Algal Growth Potential Tests.

Nitrogen was indicated as the limiting nutrient in the Mid location with nitrogen and phosphorus co-limiting in the Upper reservoir station (Table 4). In the Lower reservoir, phosphorus was indicated as the limiting factor. Mean MSC values for the Mid, Upper, and Lower reservoir locations (1.89, 1.80, and 1.82 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*.

Mainstem. The mean chlorophyll *a* concentrations in Tuscaloosa Reservoir were among the lowest of Black Warrior basin mainstem locations (Fig. 5). Mean concentrations declined from the North River reservoir location to the Lower reservoir location. Mean concentrations at the dam forebay location were the lowest of any Black Warrior basin location. Graphs of mean chlorophyll *a* data collected in 1998 and 2002 indicate that concentrations in Upper and Mid reservoir decreased from 1998 to 2002 (Appendix Fig. 9).

The North River reservoir location reached lowest monthly chlorophyll *a* values in April and June and highest values in September (Fig. 21). Concentrations for the Upper and Mid reservoir locations peaked in August. Lowest concentrations occurred in April and June for Upper reservoir and October for the Mid reservoir station. The Lower station had monthly concentrations lower than any other stations.

Lake mean chlorophyll *a* concentrations were low throughout the sampling season (Fig. 21). Discharge increased April-May and Aug-September along with a slight increase in chlorophyll *a* concentrations. Flow and chlorophyll *a* concentrations decreased May-June. For June-August, flow continued to decrease, but lake mean chlorophyll *a* concentrations increased.

Tributaries. The mean chlorophyll *a* concentration in Binion Creek, a tributary to Tuscaloosa Reservoir, was higher than those tributaries of Smith Reservoir with the exception of Crooked Creek and lower than most of the tributaries of Bankhead and Warrior Reservoirs (Fig. 8).

Monthly chlorophyll *a* concentrations in Binion Creek remained low April-September (Fig. 20). In October, concentrations increased over 3.5 times the next highest concentration.

Total Suspended Solids.

Mainstem. Mean TSS concentrations in Tuscaloosa Reservoir were similar to Smith, Holt and Oliver mainstem reservoir locations in the Black Warrior basin (Fig. 6). Within the reservoir, mean concentrations at the North River and Lower station were the similar and greater than those of both Upper and Mid reservoir locations. Mean concentrations of the Mid reservoir were the lowest of any Black Warrior location. Graphs of mean TSS data collected in 1998 and 2002 from comparable stations indicate that concentrations in Upper, Mid, and Lower reservoir increased (Appendix Fig. 9)

Monthly TSS concentrations at all four mainstem locations were similar April through August (Fig. 21). At Upper reservoir, TSS concentrations were highest in October and lowest in June. Concentrations peaked in May for North River and July for Mid reservoir stations. Lowest concentrations occurred in May and June. Monthly TSS concentrations in the Lower reservoir averaged 5 mg/l April-September then sharply increased to the high of 23 mg/l in October.

Lake mean TSS concentrations increased overall June-October (Fig. 21). Discharge increased April-May, decreased through August and increased August-October.

Tributaries. The mean TSS concentration in Binion Creek, a tributary to Tuscaloosa Reservoir was lower than those tributaries of Bankhead Reservoir (Fig. 8).

Monthly TSS concentrations in Binion Creek were highly variable April-October (Fig. 20). Concentrations were higher in April-May and September while lowest concentrations occurred in October.

Trophic State.

Monthly TSI values for the North River were in the mesotrophic range April, June, and July and in the eutrophic range in other months (Fig. 22). For Upper reservoir, TSI values were in the eutrophic range in May and August and in the mesotrophic range the other months. The Mid reservoir TSI values were in the mesotrophic range April-September, dropping to oligotrophic status in October. TSI values for the Lower reservoir increased from the oligotrophic range April-June to the mesotrophic range July-October.

Dissolved Oxygen/Temperature.

Mainstem. Dissolved oxygen concentrations at all reservoir locations changed little April-October (Fig. 22). 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 North River station indicated that strong thermoclines did not develop most months April-October (Fig. 23). Highest water column temperatures occurred July-August. A weak chemocline developed in June and continued through September. Deoxygenation of the hypolimnion occurred near the bottom June-September.

Depth profiles of temperature and DO from Upper Tuscaloosa Reservoir indicated that a weak thermocline existed near the bottom in April (Fig. 24). The thermocline and chemocline moved toward the surface and intensified May-September, with highest water column temperatures occurring June-August. From May-September, more than half the water column was deoxygenated. In October, both the thermocline and chemocline dissipated, leaving the water column mixed.

Depth profiles of temperature and DO from Mid Tuscaloosa Reservoir indicated that a developing thermocline existed in April (Fig. 25). The thermocline neared the surface and intensified May-August, with highest water column temperatures occurring July-August. The chemocline did not clearly develop until June-July, and then continued for the remainder of the sampling season. In July and August, the water column below 5 m was deoxygenated. In September-October, both the thermocline and chemocline dropped in the water column, increasing the depth of the hypolimnion and improving water column DO concentrations.

Depth profiles of temperature and DO from the Tuscaloosa dam forebay indicated that a strong thermocline existed May-October (Fig. 26). Highest water column temperatures occurred July-August. A weak chemocline began to develop in July and gradually intensified in the months following. Deoxygenation of the hypolimnion occurred for several meters immediately below the thermocline in October and at the bottom in May-June and August.

Tributaries. Monthly dissolved oxygen concentrations were well above the 5.0 mg/l recommended criterion limit (Fig. 20). These concentrations are similar to the well oxygenated water of the main reservoir.

Depth profiles of temperature and dissolved oxygen for Binion Creek show stratification in most months (Appendix Fig. 10). Distinct thermoclines were evident April-October. Highest temperature was reached in July. Essentially no chemocline existed April, May, August-October. Weak chemoclines in June and July create deoxygenated condition at the bottom.

Summary/Discussion.

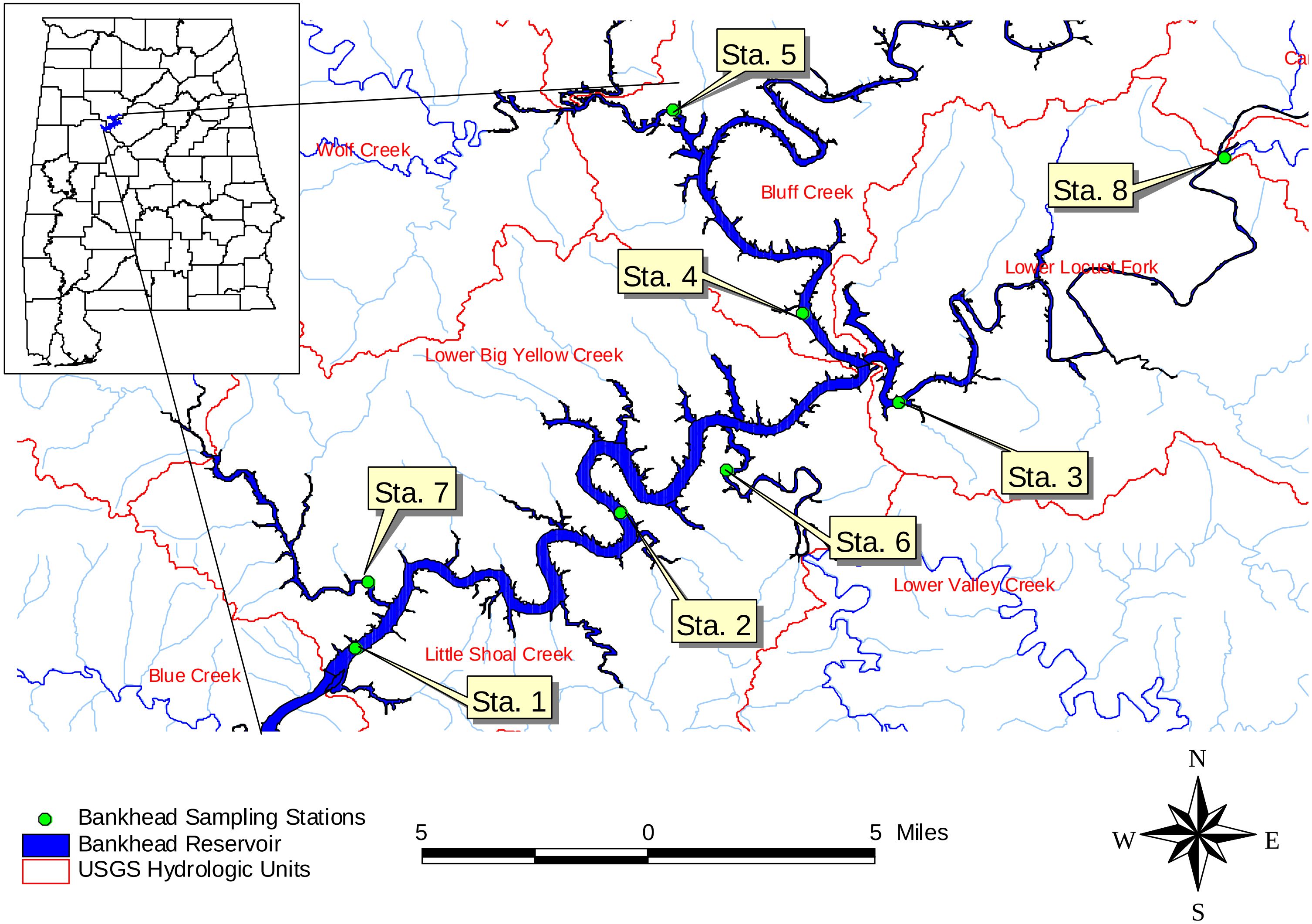
Water quality data from Tuscaloosa Reservoir indicated few water quality concerns. Mean TN and TP concentrations were among the lowest of all Warrior basin mainstem reservoir locations. Algal growth potential tests indicated that either nitrogen or phosphorus or both were the limiting nutrients at all reservoir locations, but mean MSC from these locations were well below the 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes. Mean TN concentrations from 1998 show similar values in 2002, however, mean TP concentrations increased. TP concentrations in 2002 were nearly double the concentrations in 1998. Further study is recommended to document future trends.

Mean chlorophyll *a* and TSS concentrations were also among the lowest of the basin. Data from 1998 show that mean chlorophyll *a* decreased or stayed the same at the Upper, Mid , and the Lower stations and TSI values remained in the oligotrophic to mesotrophic range. The mean TSS concentration at all three stations increased in 2002. Further monitoring is recommended to determine the source(s) of the increased TSS concentrations.

DO concentrations at 5 ft. remained above recommended limits on all months sampled, however, the majority of the water column in the Upper and Mid reservoir was essentially deoxygenated June-September. Continued monitoring is advised to determine water quality trends in this reservoir.

The Lower North River sub-watershed drains approximately 284 mi^2 in Fayette and Tuscaloosa Counties (ADEM 2004). The Lower North River sub-watershed includes the Binion Creek tributary embayment station. Percent land cover of the Lower North River sub-watershed was estimated as 3% transitional barren, 35% deciduous forest, 17% evergreen forest, 31% mixed forest, 6% pasture/hay, 6% row crop, and 3% open water. Estimates of land-use by the local SWCDs were essentially the same. Twenty-four (24) current construction/stormwater authorizations, one (1) mining/stormwater authorizations (non-coal <5acres), and four (4) NPDES permits, three mining and one semi-public/private, have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.06 AU/Acre). Sedimentation indicated a *low* potential for NPS impairment (4.0 tons/acre). The overall potential for impairment from nonpoint sources was estimated as *low*. The water quality assessment of Binion Creek is in agreement with this estimate. Concentrations of TN, TP, chlorophyll *a*, and TSS Creek were found to be among the lowest of the Warrior basin tributaries. DO concentrations were good April-October. Profiles show deoxygenation occurring only near the bottom in June and July.

Figure 27. Bankhead Reservoir with 2002 sampling locations.



Bankhead Reservoir

Nitrogen

Mainstem. Mean TN concentrations in Bankhead Reservoir were, overall, the highest of the upper Warrior basin mainstem locations (Fig.3). Within the reservoir, the mean concentration of Locust Fork was highest, followed by those of Mid reservoir, Lower reservoir, and Mulberry Fork, respectively. Graphs of mean TN data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mulberry Fork and Locust Fork were slightly lower and the Mid and Lower reservoir stations were higher (Appendix Fig. 11).

Monthly TN concentrations varied during the study period but were highest at both mainstem reservoir stations in October (Fig. 28). Mid and Lower reservoir locations increased April-June, decreased July-August and increased August-October. Lowest concentrations occurred in August for Mid reservoir and July and August for Lower reservoir.

To more clearly view the result of plotting nutrients vs. discharge at Bankhead locations, Locust Fork and Mulberry Fork, were graphed separately. In the graphs for Locust Fork and Mulberry Fork, discharge data was obtained from USGS gage stations located upstream of each embayment sampling location. In the Mid and Lower reservoir locations, discharge was measured through the Bankhead reservoir dam.

No obvious relationship appeared to exist between lake mean TN concentrations and mean lake discharge (Fig. 28). Lake mean TN concentrations (mean of Mid and Lower reservoir locations) were variable during the study period with mean discharge increasing April-May, then declining sharply May-June, then continuing a low level through October. Lowest TN concentrations occurred in August when lowest flows were reported.

In Mulberry Fork, no obvious relationship appeared to exist between monthly TN concentrations and mean lake discharge (Fig. 29). TN concentrations were low and similar during the study period with mean discharge decreasing sharply May-June, then declining slowly through August, and gradually increased through October. Highest TN concentrations occurred in October with lowest concentrations occurring in July.

In Locust Fork, monthly TN concentrations responded inversely to discharge April-September (Fig. 29). In October, TN concentrations increased as discharge continued to increase. Highest TN concentrations occurred during October with lowest concentrations occurring in July and September.

Tributaries. Mean TN concentrations of the tributaries of Bankhead Reservoir were generally higher than other tributaries of the Black Warrior basin (Fig. 7). Concentrations in Village and Valley Creeks were the highest and second highest of all tributaries, respectively. These concentrations were two to three times higher than any other tributary. Graphs of mean TN data collected in 1998 and 2002 from comparable stations indicate that the concentration in Lost Creek was slightly lower while the concentration at Valley Creek was higher in 2002 (Appendix Fig. 11).

To more clearly view the results of plotting nutrients, Bankhead Reservoir tributaries were divided into upper and lower sections. Each tributary will be discussed individually. When a USGS gage station was located near the sampling location, discharge data was obtained and concentrations vs. discharge were graphed.

Monthly TN concentrations in Lost Creek were similar April-October (Fig. 31). Lowest concentrations occurred in April, May and July. Highest concentrations occurred in June after a sharp drop in discharge.

Monthly TN concentrations in Village Creek were higher than any other Bankhead tributary (Fig. 31). Highest concentrations occurred in June and August with lows occurring in July. Discharge fluctuated monthly between 96 and 200 cfs. From April-September, concentrations responded inversely to flow.

Monthly TN concentrations in Valley Creek were higher than all other tributaries except for Village Creek (Fig. 32). Values were highest in April then declined to lows in August. Concentration followed discharge, generally decreasing from April-August, then increasing September-October.

Monthly TN concentrations in Big Yellow were variable April-June (Fig. 32). Concentrations decreased from June through August, then increased through October to season highs.

Phosphorus.

Mainstem. Mean TP concentrations were among the highest of all Black Warrior Reservoir mainstem locations (Fig. 4). Within the reservoir, concentrations were highest in

Locust Fork, followed by Mid reservoir. Mulberry Fork and Lower reservoir were the same and lower than the other two stations. Mean values for the Locust Fork reservoir location were the highest of any Black Warrior Reservoir location. Graphs of mean TP data collected in 1998 and 2002 from comparable stations indicate that concentrations at all four reservoir stations were much higher in 2002 (Appendix Fig. 11).

In the Mid reservoir location, lowest concentrations occurred in April and increased throughout the sampling season reaching highest concentrations in October (Fig. 28). In the Lower reservoir, TP was more variable. Highest concentrations occurred in September with lowest concentrations occurring in May.

To more clearly view the result of plotting nutrients vs. discharge at Bankhead locations, Locust Fork and Mulberry Fork, were graphed separately. In the graphs for Locust Fork and Mulberry Fork, discharge data was obtained from USGS gage stations located upstream of each embayment sampling location. In the Mid and Lower reservoir locations, discharge was measured through the Bankhead Reservoir dam.

Lake mean TP concentrations (mean of Mid and Lower reservoir locations) gradually increased through October (Fig. 28). Mean discharge was highest during May when lowest concentrations occurred.

In Mulberry Fork, TP values maintained a constant concentration April-July while discharge fluctuated from highest flows in May to low flows June-July (Fig. 29). Lowest TP concentrations in Mulberry Fork occurred in June and were highest in September. TP values increased in July-September as mean discharge increased August-October.

In the Locust Fork, TP values increased April-August apparently independent of mean lake discharge. From September-October, TP values increased overall as mean lake discharge increased (Fig. 30). Locust Fork TP concentrations were the highest of all Black Warrior reservoir stations, reaching highest values in October.

Tributaries. Mean TP concentrations for all Bankhead Reservoir tributaries were higher overall than any other Black Warrior tributary (Fig. 7). The two highest mean TP concentrations from a tributary were Village and Valley, respectively. Lost and Big Yellow Creeks were lower and more similar to other upstream tributaries. Graphs of mean TP data collected in 1998 and

2002 from comparable stations indicate that concentrations in Lost Creek and Valley Creek nearly doubled in 2002 (Appendix Fig. 11).

To more clearly view the results of plotting nutrients, Bankhead Reservoir tributaries were divided into upper and lower sections. Each tributary will be discussed individually. When a USGS gage station was located near the sampling location, discharge data was obtained and concentrations vs. discharge were graphed.

No obvious relationship existed between monthly TP concentrations and discharge in Lost Creek (Fig. 31). Concentrations increased April-July and decreased August-October. Discharge in Lost Creek increased sharply April-May, decreased through August and gradually increased through October.

No obvious relationship existed between monthly TP concentration and discharge in Village Creek (Fig. 31). Concentrations generally increased from April-August and decreased September-October. Highest concentrations occurred in August with lowest concentrations occurring in April. Discharge remained low and fairly constant throughout the months sampled.

Monthly TP concentrations in Valley Creek generally decreased from highs in April to lows in July (Fig. 32). Discharge fluctuated but generally decreased April-August. TP concentrations changed minimally despite a sharp increase in flow from August to September.

Monthly TP concentrations in Big Yellow Creek were consistently low throughout the study season (Fig. 32). High concentrations occurred in April and August-October.

Algal Growth Potential Tests.

Phosphorus was indicated as the limiting nutrient at the Mulberry Fork and Locust Fork locations of Bankhead Reservoir (Table 4). Nitrogen and phosphorus were co-limiting nutrients at the Mid and Lower reservoir. The mean MSC of Mulberry Fork, Locust Fork, and Mid reservoir (6.95, 15.91 and 9.61 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 Lower reservoir was 3.56 mg/l, below the maximum.

Chlorophyll *a*.

Mainstem. Mean chlorophyll *a* concentrations of Bankhead Reservoir were the highest of any of the Black Warrior basin locations (Fig. 5). Within the reservoir, concentrations decreased from Locust Fork to the dam forebay. The Locust Fork location was nearly twice that of the next highest location, Mid reservoir, with these two locations having the highest mean concentrations of any Warrior basin mainstem location. Mean values in the Mulberry Fork reservoir location were less than Locust Fork but higher than the Lower reservoir location. Graphs of mean chlorophyll *a* data collected in 1998 and 2002 from comparable stations indicate that concentrations all four reservoir stations were higher (Appendix Fig. 11).

Monthly chlorophyll *a* concentrations in the Lower and Mid reservoir locations decreased April-July, and increased through September followed by a decline in October (Fig. 33). Concentration lows occurred in May and/or June, and highest values were reported in August and September.

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

Lake mean chlorophyll *a* concentrations (mean of Mid and lower reservoir) increased May-September as mean lake discharge decreased (Fig. 33). Concentrations declined September-October as mean discharge continued to increase. Lowest concentrations occurred during highest flows.

In Mulberry Fork, chlorophyll *a* concentrations were similar for most of the sampling season, with the exception of a slight increase in September (Fig. 29). No obvious relationship appeared to exist between mean discharge and chlorophyll *a* concentrations.

In Locust Fork, chlorophyll *a* concentrations increased May-August, with a sharp increase July-August, as mean lake discharge decreased (Fig. 30). Mean concentrations decreased September-October as mean discharge increased. Concentrations were highest when discharge was lowest.

Tributaries. Mean chlorophyll *a* concentrations for tributaries of Bankhead Reservoir were variable (Fig. 8). Highest overall chlorophyll *a* concentration was found in Valley Creek and third highest concentration was in Lost Creek. The mean chlorophyll *a* concentration of Village Creek was low when compared to some tributaries of Smith Reservoir. Graphs of mean chlorophyll *a* data collected in 1998 and 2002 from comparable stations indicate that the concentration in Lost Creek was higher and Valley Creek was lower in 2002 (Appendix Fig. 11).

To more clearly view the results of plotting nutrients, Bankhead Reservoir tributaries were divided into upper and lower sections. Each tributary will be discussed individually. When a USGS gage station was located near the sampling location, discharge data was obtained and concentrations vs. discharge were graphed.

Monthly chlorophyll *a* concentrations in Lost Creek were generally low April-July and October (Fig. 31). The lowest concentration in May occurred during the highest recorded discharge. Lowest flow occurred in August when chlorophyll *a* concentration increased to highest levels.

No obvious relationship existed between monthly chlorophyll *a* concentrations and discharge in Village Creek (Fig. 31). Concentrations increased April-August during which flows remained low and consistent. Discharge was the same when the lowest concentration was measured in April and the highest concentration in August.

Monthly chlorophyll *a* concentrations for Valley Creek were variable April-October (Fig. 32). Peaks in concentration occurred in May, August, and September. Concentrations apparently fluctuated independently of flow as discharge fluctuated throughout the study. Higher flows occurred during September and October during which highest and lowest chlorophyll *a* concentrations occurred.

Monthly chlorophyll *a* concentrations in Big Yellow Creek were low April-October. Values fluctuated between 11-17 μg/l throughout the study.

Total Suspended Solids.

Mainstem. Mean TSS concentrations in Bankhead were higher than other upper Black Warrior Reservoir mainstem locations (Fig. 6). Within the reservoir, mean TSS concentrations were higher in Locust Fork, followed by Mulberry Fork, Mid reservoir, and the Lower reservoir, respectively. Graphs of mean TSS data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mulberry Fork and the Lower reservoir were higher and Locust Fork was lower (Appendix Fig. 11). The Mid reservoir station TSS concentration in 1998 was similar to the concentration in 2002.

Monthly TSS concentrations were highest during April and/or October at both mainstem Bankhead locations and varied similarly at the locations during the study period (Fig. 33). Concentrations generally decreased April-June then gradually increased through October. Lowest concentrations occurred in June and August for the Mid reservoir location and in September for the Lower reservoir location.

To more clearly view the result of plotting TSS vs. discharge at Bankhead locations, Locust Fork and Mulberry Fork, were graphed separately. In the graphs for Locust Fork and Mulberry Fork, discharge data was obtained from USGS gage stations located upstream of each embayment sampling location. In the Mid and Lower reservoir locations, discharge was measured through the Bankhead reservoir dam.

Changes in lake mean TSS concentrations (mean of Mid and lower reservoir) appeared to be related to mean discharge (Fig. 33). Concentrations decreased April-June remained relatively constant July-September, then increased in October. Discharge increased April-May, and sharply decreased in June. Low flows were recorded through September.

In Mulberry Fork, TSS concentrations followed a pattern similar to that of mean discharge, decreasing sharply April-June and changed very little through September (Fig. 29). Highest TSS concentrations in the Mulberry Fork occurred in April with high flows and lowest concentrations occurring in June with low flows.

In Locust Fork, TSS concentrations followed a pattern very similar to mean discharge (Fig. 30). TSS concentrations and mean discharge decreased April-June. From June-October, TSS concentrations increased and decreased in relation to discharge. Highest TSS concentrations in the Locust Fork occurred in October with lowest concentrations occurring in June.

Tributaries. Mean TSS concentrations of the tributaries of Bankhead Reservoir were higher than tributaries of Smith and Tuscaloosa Reservoirs (Fig. 8). Valley Creek had the third highest concentration of all tributaries. Graphs of mean TSS data collected in 1998 and 2002 from comparable stations indicate that concentrations in Lost Creek and Valley Creek were higher (Appendix Fig. 11).

To more clearly view the results of plotting nutrients, Bankhead Reservoir tributaries were divided into upper and lower sections. Each tributary will be discussed individually. When a USGS gage station was located near the sampling location, discharge data was obtained and concentrations vs. discharge were graphed.

Monthly TSS concentrations in Lost Creek followed the pattern of mean discharge in most months (Fig. 31). Concentrations and flow increased April-May, then sharply fell in June, increased in July, and continued declined August-September. Both TSS concentration and mean discharge increased in October.

Monthly TSS concentrations in Village Creek decreased from highest values in April to lowest values in June while mean discharge remained low and constant (Fig. 31). From July-October, concentrations fluctuated similarly to mean discharge.

No obvious relationship exists between TSS concentrations and mean discharge in Valley Creek (Fig. 32). Concentrations gradually increased from April through July, decreased in August, then increased to highest values in October. Mean discharge was similar during highest and lowest monthly TSS concentrations.

Monthly TSS concentrations in Big Yellow increased to highest concentrations in May then sharply dropped to lowest concentrations in June (Fig. 32). From June-October, concentrations gradually increased.

Trophic State. Monthly TSI values for the Lower reservoir, Mid reservoir, Locust Fork, and Mulberry Fork maintained eutrophic status for most of the sampling season (Figs. 34, 35, & 36). Mulberry Fork maintained constant TSI values in the eutrophic range throughout the months sampled. The trophic state of the Locust Fork reached hypereutrophic levels in August-September. At Mid and Lower locations, TSI values fluctuated within the lower half of the eutrophic range.

Dissolved Oxygen/Temperature.

Mainstem. DO concentrations at all four mainstem Bankhead locations followed a similar pattern during the study period, generally decreasing April-October (Figs. 34, 35 & 36). DO concentrations in the Lower reservoir were below the criterion limit September-October (4.53 and 3.69 mg/l, respectively). DO concentrations in the Mid reservoir were below the criterion limit in September and just above the limit in October (3.36 and 5.42 mg/l, respectively). In Mulberry Fork, DO concentrations were above the criterion limit in all months sampled though concentrations measured in September (5.61 mg/l) and October (5.61 mg/l) were near the limit. In Locust Fork, DO concentrations were above the criterion limit when sampled; though the concentration measured in September (5.52 mg/l) was near the limit.

Depth profiles of temperature and DO in the Mulberry Fork indicated that weak thermal and chemical stratification developed April-May (Fig. 37). Thermoclines and clemoclines became evident in June-September with essentially isothermal and isochemical conditions returning in October. Highest water column temperatures occurred in July with DO concentrations near zero occurring in June.

Depth profiles of temperature and DO in the Locust Fork indicated that the water column was essentially isothermal and isochemical in April-October (Fig. 38). Very weak chemical stratification developed May-August with isochemical conditions returning in September. Highest water column temperatures occurred in July and August, 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 Mid Bankhead Reservoir indicated that weak thermal and chemical stratification was evident in April (Fig. 39). The water column was isothermal and isochemical in May. Thermal stratification developed in June and July and became isothermal August to October. Chemical stratification developed in June and strengthened to August becoming isochemical in September-October. Highest water column temperatures occurred in June and August with deoxygenation occurring near the bottom in June and September.

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 and May (Fig. 40). Thermal stratification developed in June and strengthened July-August. Isothermal conditions returned September-October. Highest water column temperatures occurred in July and August. Chemical stratification developed in June in the lower portion of the water column. The anoxic portion of the water column increased July-August then decreased 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.

Tributaries. Monthly dissolved oxygen concentrations in both upper Bankhead Reservoir tributaries exhibited a similar pattern, a gradual decrease in concentrations April-September followed by a slight increase in October (Fig. 31). Lower Bankhead tributaries followed a slightly different pattern, generally increasing April-June, and then gradually decreasing July-October (Fig. 32). Concentrations for all Bankhead tributaries remained above the criterion limit of 5.0 mg/l on all dates sampled

Depth profiles of temperature and dissolved oxygen for Lost Creek show weak thermoclines and chemoclines in all months sampled (Appendix Fig. 12). Highest temperatures were reached in July. The hypolimnion began just a few meters beneath the surface and deoxygenated conditions existed for majority of the water column June-September.

Depth profiles of temperature and dissolved oxygen for Village Creek were essentially too shallow for the water column to be stratified (Appendix Fig. 13). DO concentrations were good throughout the water column with highest temperatures occurring in July.

Depth profiles of temperature and dissolved oxygen for Valley Creek showed weak thermoclines and distinct chemoclines in most months (Appendix Fig. 13). DO concentrations rapidly deteriorated causing deoxygenated conditions near the bottom June-August.

Depth profiles of temperature and dissolved oxygen for Big Yellow reveal stratified condition June-August (Appendix Fig. 14). Weak thermoclines are evident April and June-August. Chemoclines are evident in all months but October. Deoxygenation occurred June-August during highest temperatures.

Summary/Discussion.

Water quality concerns for Bankhead Reservoir are centered primarily in Locust Fork. The highest mean TN and TP concentrations measured in the basin occurred there. Monthly concentrations often increased with a decrease in discharge, suggesting that point sources may be an important contributor to elevated nutrient concentrations. Historic graphs show TN and TP concentrations to be generally increasing. Mean MSC values for Mulberry Fork, Locust Fork, and Mid reservoir locations 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 chlorophyll *a* concentrations of Locust Fork and Mid reservoir were the two highest of the Warrior basin. Historical graphs indicate that the chlorophyll *a* concentrations of all four stations were higher in 2002. TSI values indicate Mulberry Fork, Locust Fork, Mid, and Lower reservoir to be at least at the eutrophic level throughout the sampling season. Locust Fork reached hypereutrophic status in August and September. Additional nitrogen and phosphorus loading contributed to increased chlorophyll *a* concentrations and forced eutrophic to hypereutrophic conditions in the reservoir.

Mean TSS concentrations in Mulberry Fork and Locust Fork were among the higher values of the Warrior basin. Mulberry Fork was higher than in 1998 while Locust Fork remains nearly the same. Lower concentrations near the dam forebay show that much of the added load is settling in the upper portion of the reservoir.

DO concentrations remained > 2.0 mg/l for most of the water column April-October. Concentrations in the Mid and Lower reservoir were near or below the criteria limit of 5.0 mg/l in September and October.

The four tributary embayments on Bankhead monitored in 2002 include Lost, Valley, Big Yellow, and Village Creeks. The Baker Creek sub-watershed, which includes the Lost Creek tributary embayment station, drains approximately 58 mi^2 in Walker County (ADEM 2004). A thirty mile (30 mi.) segment of Lost Creek is included on the Alabama CWA §303(d) list of impaired waterbodies with a partial support status for siltation and other habitat alteration from abandoned surface mining sources. Percent land cover of the Baker sub-watershed was estimated as 7% open water, 43% deciduous forest, 21% evergreen forest, 29% mixed forest. Estimates of land-use by the local SWCD indicated a lower amount of forest (66%) and higher amount of mines (19%) and pasture (6%). Three (3) current construction/stormwater authorizations and ten (10) NPDES permits, nine mining and one industrial process wastewater-major, have been issued in the sub-watershed. The local Soil and Water Conservation District (SWCD) estimates of animal concentrations in the sub-watershed were *low* (0.01 AU/Acre). Sedimentation estimates indicated a *moderate* potential for NPS impairment (14.6 tons/acre) mostly from mined lands. The overall potential for impairment from nonpoint sources was estimated as *moderate*. Water quality analysis was in agreement with this assessment. TN, and TP were among the lowest of the basin. However, chlorophyll *a* and TSS were among the highest. During August and

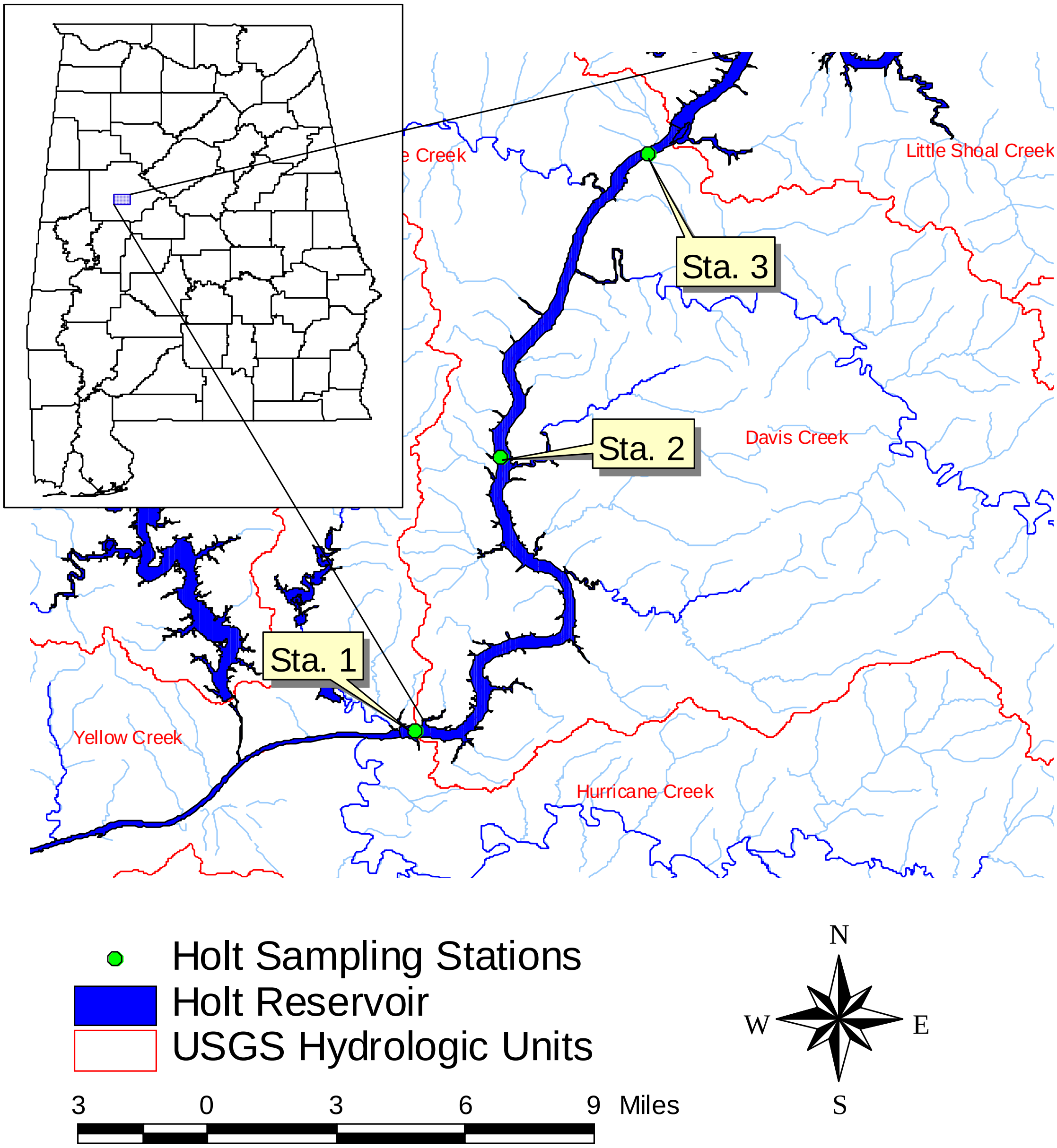
September chlorophyll *a* concentrations were more than three times higher than the other upper Bankhead tributary. DO concentrations remained above critical levels at the 5 ft. depth April-October, however, most of the water column was deoxygenated June-September.

The Little Shoal Creek sub-watershed, which includes the Valley Creek tributary embayment station, drains approximately 34 mi^2 in Cherokee County (ADEM 2004). Percent land cover of the Little Shoal Creek sub-watershed as determined by EPA, was estimated as 36% deciduous forest, 27% evergreen forest, 27% mixed forest, and 9% open water. Estimates of land-use by the local SWCD indicated a lower percent of open water (0%) land use and higher amount of mines (2%). Two (2) current mining NPDES permit have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.00 AU/Acre). Sedimentation estimates indicated a *moderate* potential for NPS impairment (8.5 tons/acre) from erosion of cropland. The overall potential for impairment from nonpoint sources was estimated as *low*. Highly elevated concentrations of TN and TP were reported, the second highest of the basin. Chlorophyll *a* and TSS concentrations were among the highest of the basin. DO concentrations were adequate in all months sampled.

The Lower Big Yellow Creek sub-watershed drains approximately 61 mi^2 in Tuscaloosa and Walker Counties (ADEM 2004). A twenty-one mile (21 mi.) segment of Big Yellow Creek is included on the Alabama CWA §303(d) list of impaired waterbodies with a non-support status for metals from abandoned surface mining sources. Percent land cover of the Lower Big Yellow Creek sub-watershed was estimated as 53% deciduous forest, 20% evergreen forest, 20% mixed forest and 7% open water. Estimates of land-use by the local SWCDs were higher for mines (15%) and pasture (2%), and lower for forest (81%) and open water (<1%). One (1) current mining NPDES permit has been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.00 AU/Acre). Sedimentation estimates indicated a *high* potential for NPS impairment (30.6 tons/acre) mostly from mined lands and exposed gullies. The overall potential for impairment from nonpoint sources was estimated as *moderate*. However, water quality analysis indicates no high concentrations of TN or TP. Mean TN concentration was slightly elevated, but was similar to other tributaries. Mean chlorophyll *a* was elevated but lower than other tributaries in Bankhead. DO concentrations were below critical levels in September and October. Deoxygenated conditions existed June-September, which involved more of the water column each month.

The Village Creek sub-watershed drains approximately 95 mi^2 in Jefferson County (ADEM 2004). A thirteen mile (13 mi.) segment of Village Creek is included on the Alabama CWA §303(d) list of impaired waterbodies with a non-support status for siltation, metals and pH violations from industrial, municipal, and urban runoff/storm sewer sources, surface mining-abandoned, subsurface mining-abandoned, mill tailings-abandoned, and mine tailings-abandoned sources. Percent land cover of the Village Creek sub-watershed was estimated as 17% low intensity residential industrial, 4% high intensity industrial, 9% commercial/industrial/transport, 26% deciduous forest, 13% evergreen forest, 26% mixed forest, and 4% other grasses. Estimates of land-use by the local SWCDs were higher for urban (68%) and lower for forest (25%). Twenty-nine (29) current construction/stormwater authorizations and sixteen (16) NPDES permits, 7 mining, 1 municipal, 2 industrial process wastewater-major, 5 industrial process wastewater-minor and 1 SID stormwater, have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.00 AU/Acre). Sedimentation estimates indicated a *high* potential for NPS impairment (29.8 tons/acre) mostly from mined lands and exposed gullies. The overall potential for impairment from nonpoint sources was estimated as *low*. Evidence of possible nonpoint source and point source impairment was evident in the Chattooga River embayment. Concentrations of TN and TP in Village Creek were the highest of any Black Warrior basin tributaries. The mean Chlorophyll *a* concentration was among the lowest of the basin. Although the assessment indicated a high likelihood of sedimentation problems, no evidence of elevated TSS concentrations were found. Depth profiles reveal adequate DO concentrations in all months sampled and deoxygenated conditions did not occur. Continued monitoring is recommended to document water quality trends.

Figure 41. Holt Reservoir with 2002 sampling locations.



Holt Reservoir

Nitrogen.

Mainstem. Mean TN concentrations in Holt Reservoir were similar to those of other lower Warrior Reservoir locations (Fig. 3). Within the reservoir, mean concentrations were similar throughout the reservoir. Graphs of mean TN data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mid and Lower Holt reservoir slightly increased (Appendix Fig. 15).

Monthly TN concentrations were similar at all three reservoir locations April-October (Fig. 42). Highest concentrations in the Upper and Mid reservoir occurred in July with lowest concentrations occurring in May. In the Lower reservoir, highest concentrations occurred in April with lowest concentrations occurring in May.

The lake mean TN concentration decreased April-May opposite of lake discharge then gradually increased through July as discharge declined (Fig. 42). TN concentrations decreased until September and increased in October. Mean lake discharge continued lower flows June-September.

Phosphorus.

Mainstem. Mean TP concentrations in Holt Reservoir were similar to Oliver and Warrior Reservoirs (Fig. 4). Within the reservoir, mean concentrations in the Upper reservoir were slightly higher than the Mid and Lower reservoir. Graphs of mean TP data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mid and Lower Holt reservoir were higher in 2002 (Appendix Fig. 15).

Monthly TP concentrations were variable April-October (Fig. 42). The Upper reservoir generally increased from lowest concentrations in May to highest concentrations in October. Lowest concentrations for the Mid reservoir occurred in July with highest concentrations occurring in September. In the Lower reservoir, monthly TP concentrations decreased April-August, peaked in September, and decreased in October.

Lake mean TP concentrations were variable April-July (Fig. 42). Concentrations increased July-September and then decreased in October. Mean discharge increased April-May, sharply declined in June and remained low the rest of the sampling season. Concentrations were similar in May during high flows and July during low flows.

Algal Growth Potential Tests.

Phosphorus was indicated as the limiting nutrient in all three reservoir stations of Holt Reservoir (Table 4). Mean MSC values for the Upper, Mid and Lower reservoir (3.76, 4.52, and 4.06 mg/l, respectively) were below the maximum 5.0 mg/l level suggested to assure protection from nuisance algal blooms and fish-kills in southeastern lakes.

Chlorophyll *a*.

Mainstem. Mean chlorophyll *a* concentrations in Holt Reservoir were below upstream Bankhead Reservoir and above downstream Oliver Reservoir (Fig. 5). Within the reservoir, mean concentrations in the Upper reservoir were lower than the Mid and Lower reservoir stations. Graphs of mean chlorophyll *a* data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mid and Lower reservoir were higher (Appendix Fig. 15).

Monthly chlorophyll *a* concentrations in the Upper reservoir had little variation from April-October with highest concentrations occurring June-September, and lowest concentrations occurring in May (Fig. 43). Mid reservoir dropped sharply from the highest concentration in April to the lowest concentration in May and remained around 15 μg/l from June to September. Concentrations in the lower reservoir generally decreased April-July and August-October. Highest values occurred in May with lowest values occurring in October.

Lake mean chlorophyll *a* concentrations generally decreased April-October with highest values occurring in April and August and lowest values occurring in October (Fig. 43). Mean lake discharge decreased April-October, with a sharp decrease May-June and a gradual decrease through October.

Total Suspended Solids.

Mainstem. Mean TSS concentrations in Holt Reservoir were similar to downstream Oliver Reservoir (Fig. 6). Within the reservoir, mean concentration in the Mid reservoir was greater than those of the Lower and Upper reservoir. Graphs of mean TSS data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mid and Lower reservoir were higher (Appendix Fig. 15).

Monthly TSS concentrations generally decreased April-July and increased August-October (Fig. 43). Highest concentrations for all locations occurred in October with lowest concentrations the Upper and Lower stations occurring in July. In the Mid reservoir, lowest concentrations occurred in July.

Lake mean TSS concentrations decreased along with mean discharge April-June (Fig. 43). Concentrations increased June-October to highest values. After the sharp decrease in June, mean discharge was low for the remainder of the sampling season.

Trophic State.

TSI values for all reservoir locations were within the eutrophic range for most of the sampling season (Fig. 44). In the Upper reservoir, TSI values decreased once into the mesotrophic range in May before returning into the eutrophic range for the remainder of the sampling season. Mid reservoir TSI values remained in the lower half of the eutrophic range for the entire sampling season. TSI values for the Lower reservoir also remained in the eutrophic range from April-September, but dropped to mesotrophic status in October.

Dissolved Oxygen/Temperature.

Mainstem. DO concentrations at all three Holt Reservoir locations followed a similar pattern April-October (Fig. 44). Concentrations in the Upper reservoir location were below criterion limit in July and August (4.87 and 4.92 mg/l, respectively) and near the limit in October (5.27 mg/l). DO concentrations in the Mid reservoir location declined June-September, nearing limits in September (5.02 mg/L), but remained above the criterion limit of 5.0 mg/l on all dates sampled. The Lower reservoir location fell below standards in September (4.62 mg/l) and near standards in October (5.39 mg/l).

Depth profiles of temperature and DO from the Upper Holt reservoir indicated little to no thermal stratification April-October. Highest water column temperatures occurred July-August (Figure 45). A weak chemocline existed in September with dissolved oxygen concentrations falling below 5.0 mg/l for the majority of the water column.

Depth profiles of temperature and DO from the Mid Holt reservoir station indicated that strong thermoclines and chemoclines did not develop during most months (Fig. 46). A weak thermocline occurred in June. All other months were isothermal. Highest water column temperatures occurred July and August. From June-August a chemocline developed and deoxygenation occurred near the bottom. A second chemocline developed near the surface in July and August.

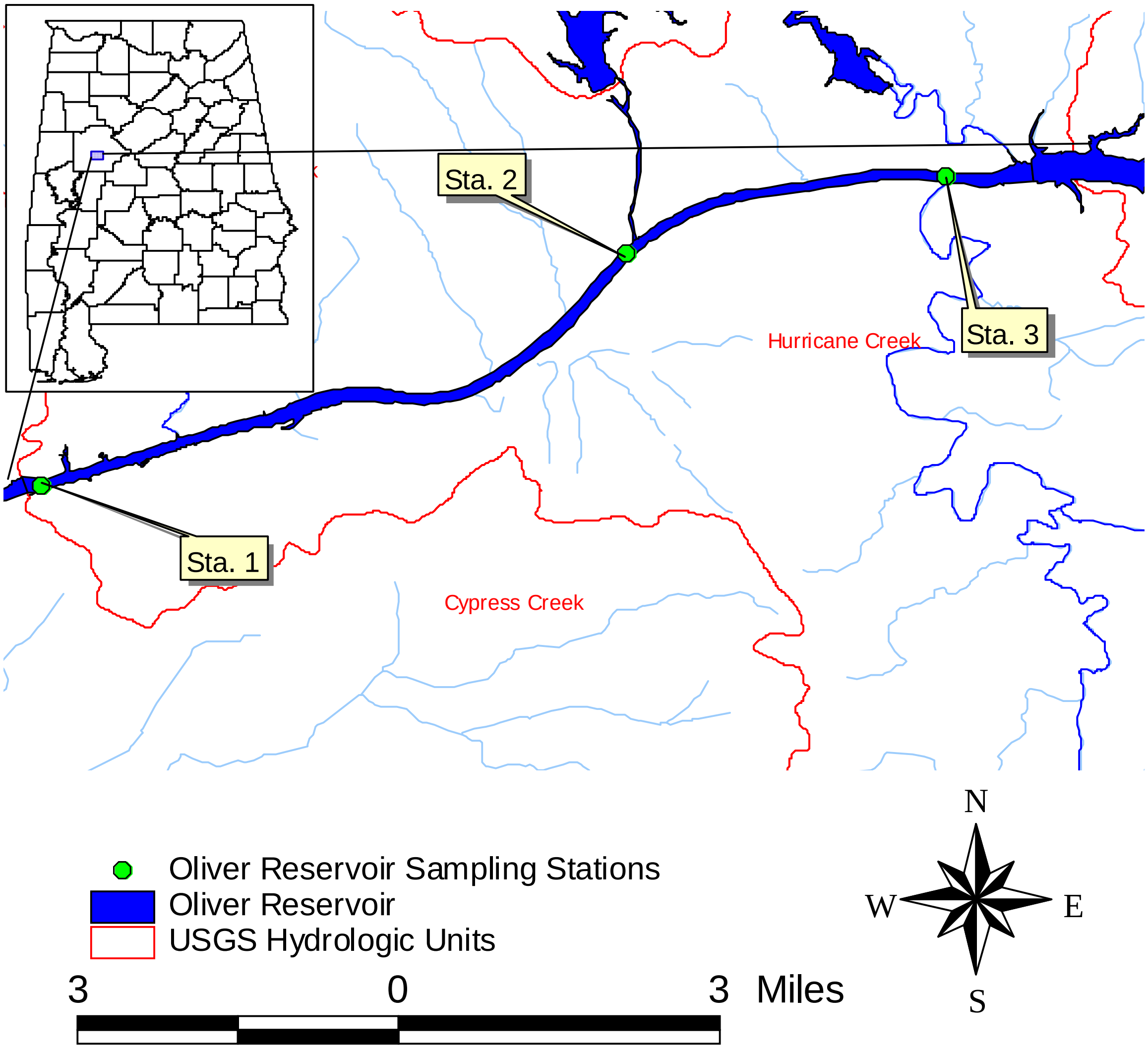
Depth profiles of temperature and DO from the Holt dam forebay indicated that no thermocline developed April-October, however, temperature decreased gradually with depth in June and July (Fig. 47). During June-July, a chemocline developed just below the surface and moved deeper into the water column in August. Deoxygenation occurred near the bottom in July and August. Highest water column temperatures occurred June-August. 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.

Summary/Discussion.

Data from Holt Reservoir indicate few water quality concerns. Mean TN data show concentrations similar to upstream and downstream reservoirs. Historic graphs from 1998 show the mean TN concentration to be slightly higher in 2002. Mean TP concentrations were elevated and also seem to be partly influenced by upstream Bankhead Reservoir. AGPT testing revealed phosphorus to be the limiting nutrient at all three reservoir locations in 2002. However, phosphorus levels nearly doubled in four years, likely causing the mean chlorophyll *a* concentrations to double from 1998 to 2002. Chlorophyll *a* concentrations were among the higher values of the basin and seemed to increase from upstream to the dam forebay.

Holt Reservoir was borderline eutrophic in 1998, but 2002 TSI values indicated eutrophic conditions for most of the sampling season (ADEM 1999). DO concentrations show further evidence of the eutrophication of Holt Reservoir. In 2002, two of the reservoir locations fell below the 5.0 mg/l criterion and the third came very close (5.02 mg/l). During 1998, DO concentrations remained well above the limit throughout the sampling season (ADEM 1999). Continued monitoring is advised to document increasing phosphorus concentrations and determine trophic state trends.

Figure 48. Oliver Reservoir with 2002 sampling locations.



Oliver Reservoir

Nitrogen.

Mainstem. Mean total nitrogen concentrations for Oliver Reservoir were similar to other lower Black Warrior reservoir locations (Fig. 3). Within the reservoir mean concentration increased from the Upper station to the Lower station. Graphs of mean TN data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mid and lower Oliver Reservoir increased (Appendix Fig. 16).

Monthly TN concentrations were similar at all three reservoir locations (Fig. 49). Highest concentrations occurred in July with lowest concentrations occurring in May and September.

Lake mean TN concentrations in Oliver Reservoir increased May-July and decreased August-September (Fig. 49). Lowest concentrations occurred in May with highest flows and highest concentrations occurring in July during lower flows. Mean discharge at Oliver Reservoir decreased sharply May-June, changed little through August, increased gradually August-October.

Phosphorus.

Mainstem. Mean TP concentrations in Oliver Reservoir were similar to other lower mainstem Warrior locations (Fig. 4). Within the reservoir, mean concentrations were similar across the reservoir. Graphs of mean TP data collected in 1998 and 2002 from comparable stations indicate that concentrations at both stations were higher (Appendix Fig. 16).

Monthly TP concentrations varied from April-October (Fig. 49). Concentrations generally increased from April-September when highest values were recorded. Lowest concentrations occurred in July for Upper reservoir and October for Mid reservoir. In the Lower reservoir, lowest concentrations occurred in May.

No obvious relationship appeared to exist between concentrations and mean lake discharge (Fig. 49). Concentrations varied only slightly April-July during which mean discharge dropped from highest to lowest flows. From July-September, concentrations increased and flow varied.

Algal Growth Potential Tests.

Phosphorus was indicated as the limiting nutrient at the Upper, Mid, and Lower stations of Oliver Reservoir (Table 4). Mean MSC values for the Upper, Mid, and lower reservoir (2.89, 3.15, and 3.19 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*.

Mainstem. Mean chlorophyll *a* concentrations in Oliver Reservoir were lowest of the lower Warrior reservoir locations (Fig. 5). Within the reservoir, the mean concentration decreased from the Upper reservoir to the Lower reservoir sampling locations. Graphs of mean chlorophyll *a* data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mid and Lower Oliver Reservoir slightly increased (Appendix Fig. 16).

Monthly chlorophyll *a* concentrations were variable through October with the Mid and Lower locations following similar patterns (Fig. 50). In the Upper reservoir, highest concentrations occurred in May, remained similar June-September, and decreased to lowest concentrations in October. Monthly chlorophyll *a* concentrations in the Mid and Lower reservoir reached highest values in May and August and lowest values in June, July and September.

Lake mean chlorophyll *a* concentrations increased April-May and June-August (Fig. 50). Concentrations seemed to increase or decrease with flow for all sampling dates except August. Mean discharge was lowest in August while the mean chlorophyll *a* concentration was one of the highest. Mean lake discharge decreased sharply May-June then remained low through October.

Total Suspended Solids.

Mainstem. Mean TSS concentrations in Oliver Reservoir were similar to upstream Holt reservoir locations and lower than downstream Warrior reservoir locations (Fig. 6). Mean concentrations across all three reservoir locations were similar. Graphs of mean TSS data collected in 1998 and 2002 from comparable stations indicate that concentrations in Mid and Lower Oliver Reservoir were much lower (Appendix Fig. 16).

Monthly TSS values varied April-October with lowest concentrations in the Upper and Mid reservoir locations occurring in July (Fig. 50). In the Upper reservoir, highest concentrations occurred in May. Mid reservoir reported highest monthly TSS values in October. Highest concentrations in the Lower reservoir occurred in April and October with lowest concentrations occurring in June.

Lake mean TSS concentrations followed a pattern similar to that of mean lake discharge (Fig. 50). Concentrations generally decreased April-July, then a gradually increased through

October. Higher concentrations were observed with increased flow, and concentrations were lower during lower flows.

Trophic State.

TSI values for at all three reservoir locations were within the mesotrophic range when sampled in April (Fig. 51). From May to October, the TSI for Oliver Reservoir was variable. In the Upper reservoir, TSI values were within the eutrophic range May-September and declined sharply into the mesotrophic range in October. TSI values in the Mid reservoir, cycled from mesotrophic levels June-July, to eutrophic levels in August, and back to mesotrophic September-October. In the lower reservoir, TSI values were variable June-October, alternating from oligotrophic to mesotrophic to eutrophic levels. TSI values declined to oligotrophic levels in June and September while reaching eutrophic status in between in August.

Dissolved Oxygen/Temperature.

Mainstem. DO concentrations at all three reservoir locations were similar April-October with concentrations of the Upper and Mid reservoir less than those of the lower reservoir May-October (Fig. 51). The Upper and Mid reservoir DO concentrations were very similar April-October. Concentrations in July and September were below the criterion limit of 5.0 mg/l at both the Upper (4.33 and 4.64 mg/l, respectively) and Mid stations (4.25 and 4.58 mg/l, respectively). DO concentrations in the both reservoir locations increased to levels just above the criterion limit in August and October. In the lower reservoir, DO concentrations neared criterion limits in July (5.13 mg/l), but remained above for the entire sampling season.

Depth profiles of temperature and DO indicate the water column in the Upper Oliver Reservoir was isothermal and isochemical for all months sampled (Fig. 52). Highest temperatures were recorded in July and August. Deoxygenation did not occur.

Depth profiles of temperature and dissolved oxygen indicated that the water column at the Mid reservoir location were isothermal and isochemical in April and May (Fig. 53). The thermocline began to develop in June. A well developed thermocline was clearly evident in July, August, and September. No clear chemocline developed throughout the sampling season, however, the DO slightly increased near the bottom June-October.

Depth profiles of temperature and dissolved oxygen indicate that the water column in the Oliver dam forebay was essentially isothermal and isochemical all months (Fig. 54). 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.

Summary/Discussion.

Water quality data from Oliver reservoir indicated concerns based on higher TN concentrations, higher TP concentrations, and lower mean chlorophyll *a*. Low DO concentrations occurred during several months which may also cause some concern; however, TSS concentrations from 2002 were lower than in 1998.

Higher mean TN concentrations were noted in upstream Holt and downstream Warrior Reservoirs. Concentrations were highest in July during lowest flow conditions and generally increased from the Upper reservoir to the dam forebay. Elevated levels in 2002 over those measured in 1998 may be cause for concern and should be monitored in the future.

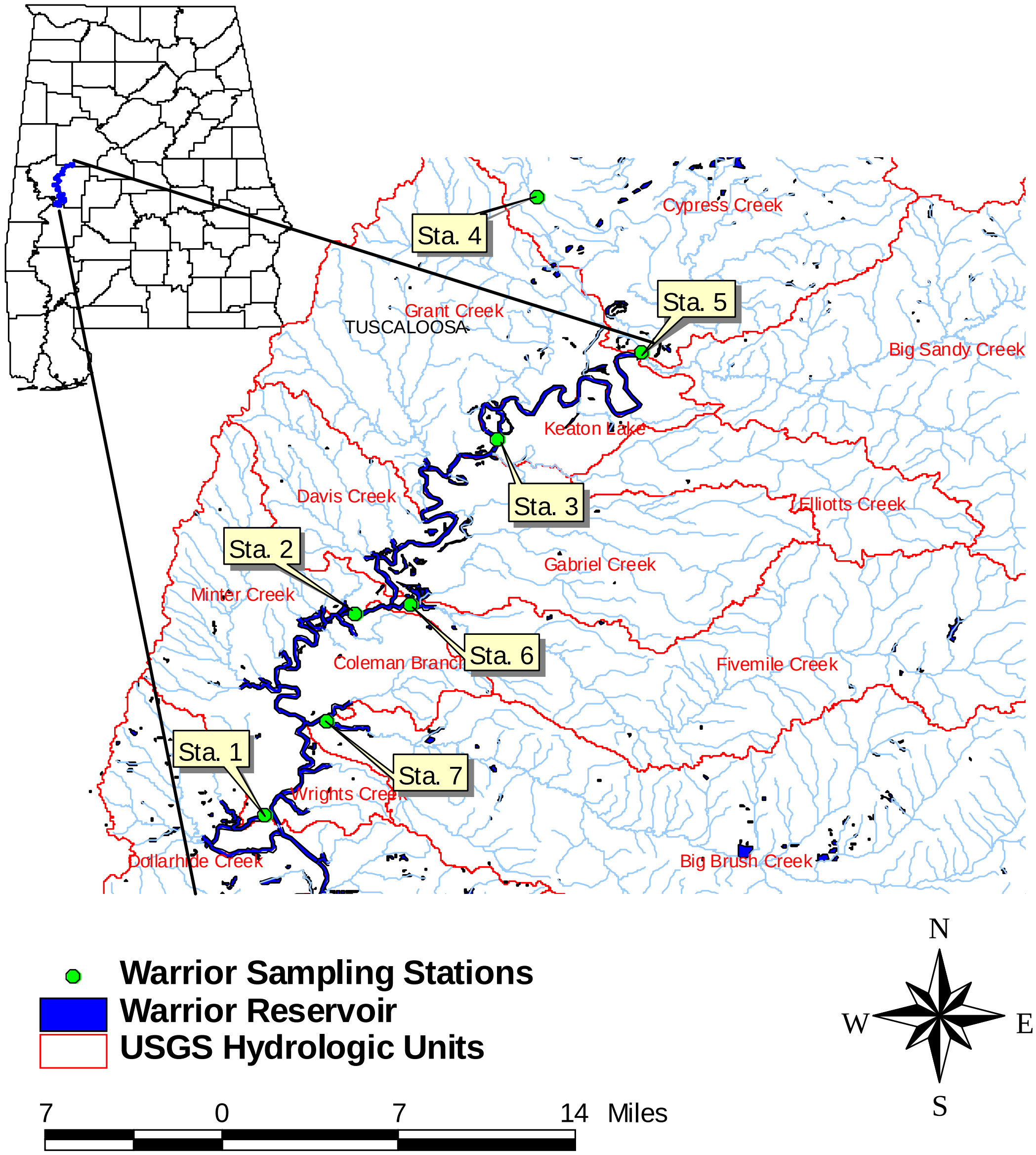
TP concentrations in Oliver Reservoir were high as compared to other Black Warrior Reservoirs. Concentrations were similar throughout the sampling season regardless of discharge and generally decreased overall from the Upper station to the dam forebay. Only a slight increase in mean TP concentration was observed from the 1998 to the 2002 data.

Chlorophyll *a* concentrations were lower than other nearby reservoirs and decreased from Upper to lower reservoir stations. Concentrations seemed to be related to discharge in all months but August. TSI values indicated eutrophic conditions at the Upper stations while the Mid and lower stations maintained mesotrophic or oligotrophic status for most months. Chlorophyll *a* concentrations were essentially the same in 1998 as in 2002.

Low DO concentrations were a concern for both the Upper and Mid stations July-October. During July and September, concentrations fell below criterion limits. Since the water column throughout the reservoir was destratified for almost the entire sampling season, low DO concentrations affect a larger portion of the reservoir.

TSS concentrations in Oliver Reservoir were similar to Holt and lower than Warrior Reservoirs. Graphs comparing the Mid and Lower station from 1998 to data collected in 2002 show a decrease in TSS concentrations.

Figure 55. Warrior Reservoir with 2002 sampling locations.



Warrior Reservoir

Nitrogen.

Mainstem. Mean TN concentrations in Warrior Reservoir were similar to those of other lower Warrior locations (Fig. 3). Within the reservoir, the mean concentration decreased from 0.945 mg/l in the Above I-59 station to 0.735 mg/l in the Lower reservoir. Graphs of mean TN data collected in 1998 and 2002 from comparable stations indicate that concentrations at Upper and Mid were higher (Appendix Fig. 17). The Lower reservoir slightly decreased mean TN concentrations from 1998 to 2002.

Monthly TN concentrations at all reservoir locations varied during the months sampled (Fig. 56). Highest concentrations for the Above I-59 and Mid reservoir stations occurred in April while the other stations occurred later in the sampling season, June for Upper reservoir and October for the Lower reservoir. Lowest concentrations at the Above I-59 and Upper occurred in September with lowest concentrations in the Mid and Lower stations occurring in July and April, respectively.

The lake mean TN concentration in Warrior Reservoir decreased April-May and July-September (Fig. 56). Lowest concentrations occurred in May and September while highest concentrations occurred in April and October. Discharge increased April-May then sharply declined May-June. Flow continued to remain low June-September. Concentrations were lowest during high and low flows.

Tributaries. Mean TN concentrations in the tributaries to Warrior Reservoir were slightly elevated as compared to other tributaries in the Black Warrior basin (Fig. 7). Concentrations were higher than upstream Smith and Tuscaloosa tributaries but lower than most Bankhead tributaries.

To more clearly view the results of plotting nutrients, Warrior Reservoir tributaries were separated from the main reservoir graph. Each tributary will be discussed individually. No USGS gage stations were located near sampling locations, so discharge data was unable to be obtained.

Monthly TN concentrations in Big Sandy Creek were similar to those found in the Upper station of the mainstem reservoir (Fig. 57). Concentrations decreased April-May, increased to season highs in August, and then sharply dropped to lowest concentrations in September. In October, monthly TN concentrations increased once again.

Monthly TN concentrations in Five Mile Creek were similar to Big Sandy Creek (Fig. 57). Concentrations decreased April-May and August-September. Values increased May-August and September-October. Highest concentrations occurred in August with lowest concentrations occurring in September.

Monthly TN concentrations in Big Brush Creek were variable April-October (Fig. 57). Concentrations fluctuated monthly reaching lowest concentrations in September and highest concentrations in October.

Phosphorus.

Mainstem. Mean TP concentrations were among the highest of the lower Black Warrior Reservoir locations (Fig. 4). Mean concentrations generally increased from the Above I-59 station to the Lower reservoir. Mean concentrations at the Lower reservoir and Upper station were among the highest of any main reservoir location. Graphs of mean TP data collected in 1998 and 2002 from comparable stations indicate that concentrations at Upper, Mid, and the Lower reservoir locations were higher (Appendix Fig. 17). The difference between the two data sets increased from Upper to Lower reservoir.

Monthly TP concentrations at all locations were similar April-June and August-October (Fig. 56). Above I-59 and Mid reservoir stations reached highest concentrations in September and lowest concentrations in July. In the Upper reservoir location, monthly TP concentration increased from lows in May to highs in August and September. Highest concentration in the Lower station occurred in July when other stations recorded lows.

No obvious relationship exists between lake mean concentrations and mean discharge (Fig. 56). Concentrations increased gradually May-September as discharge fluctuated from high flows in May to low flows in August.

Tributaries. Mean TP concentrations in the tributaries to Warrior Reservoir were similar across all three tributaries (Fig. 7). Highest concentration occurred in Five Mile, Big Brush, and then Big Sandy Creeks. Concentrations were only slightly higher than other tributaries in Smith and Tuscaloosa Reservoirs of the Black Warrior basin.

To more clearly view the results of plotting nutrients, Warrior Reservoir tributaries were separated from the main reservoir graph. Each tributary will be discussed individually. No USGS gage stations were located near sampling locations, so discharge data was unable to be obtained.

Monthly TP concentrations in Big Sandy Creek generally increased from April-October (Fig. 57). Concentrations dropped to lowest values in July and then increased to highest levels August-October.

Monthly TP concentrations in Five Mile Creek were generally higher than other Warrior tributaries in most months (Fig. 57). Concentrations decreased April-May to lowest values, sharply increased to season highs in July, and then decreased overall to lowest concentrations in October.

Monthly TP concentrations in Big Brush Creek generally increased April-Sept with the exception of slight decreases in May and July (Fig. 57). In October, monthly TP concentrations decreased to lowest concentrations.

Algal Growth Potential Tests.

Phosphorus was indicated as the limiting nutrient in all Warrior Reservoir locations (Table 4). Mean MSC values for the Above I-59 and Lower reservoir (2.35 and 3.69 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. Both the Upper and Mid stations(5.56 and 5.11 mg/l, respectively), had mean MSC values just above the suggested limit.

Chlorophyll *a*.

Mainstem. Mean chlorophyll *a* concentrations were the second highest overall of all Black Warrior basin locations (Fig. 5). Mean concentrations increased from the Above I-59 station to the Mid reservoir station. Mean chlorophyll *a* concentrations at the Lower reservoir location were the lowest of all four stations. Graphs of mean chlorophyll *a* data collected in 1998 and 2002 from comparable stations indicate that concentrations at Upper, Mid, and the Lower reservoir locations were higher (Appendix Fig. 17). The difference between the two data sets increased from upstream Upper to downstream Lower reservoir.

Monthly chlorophyll *a* concentrations were similar for all station in all months but May (Fig. 58). While the Above I-59, Upper, and Lower stations all increased to high concentrations in May, Mid station declined to the lowest concentration. A second peak in concentrations occurred in August for all stations followed by a decrease to lowest levels in October.

Lake mean chlorophyll *a* concentrations increased sharply April-May then decreased in June, concentrations once again increased July-August, followed by a decrease August-October (Fig. 58). Mean lake discharge was high April-May then sharply decreased in June, then remained low through September. Lake mean chlorophyll *a* concentrations were highest in May and August when discharge was highest and lowest.

Tributaries. Mean chlorophyll *a* concentrations in the tributaries to Warrior Reservoir were the second highest overall of the tributaries in the Black Warrior basin (Fig. 8). Big Sandy Creek had the lowest overall mean chlorophyll *a* concentration of any tributary.

To more clearly view the results of plotting nutrients, Warrior Reservoir tributaries were separated from the main reservoir graph. Each tributary will be discussed individually. No USGS gage stations were located near sampling locations, so discharge data was unable to be obtained.

Monthly chlorophyll *a* concentrations in Big Sandy Creek were very low and consistent through the sampling season (Fig. 57). Concentrations were similar reaching the highest concentration in October of 2.15 μg/l.

Monthly chlorophyll *a* concentrations in Five Mile Creek generally increased from lowest to highest levels April-September (Fig. 57). Concentrations sharply declined in October.

Monthly chlorophyll *a* concentrations in Big Brush Creek were higher than the other two Warrior Reservoir tributaries most months (Fig. 57). Concentrations sharply rose April-May, dropped in June, rose again July-August, and sharply declined September-October. Highest concentrations occurred in May and August with lowest concentrations occurring in October.

Total Suspended Solids.

Mainstem. Mean TSS concentrations in Mid Warrior Reservoir were among the highest of Black Warrior basin mainstem locations (Fig. 6). Mid, Upper, and Above I-59 reservoir locations were the three highest concentrations of Warrior basin locations. Graphs of mean TSS data collected in 1998 and 2002 from comparable stations indicate that concentrations at Upper, Mid, and the Lower reservoir location were Lower in 2002 than in 1998 (Appendix Fig. 17).

Monthly TSS concentrations varied at all locations during all months sampled (Fig. 58). Highest concentrations in the Above I-59 station occurred in April with lowest concentrations occurring in July. Highest concentrations in the Upper, Mid and Lower reservoir occurred in October. In the Upper reservoir, lowest concentrations occurred in May while lowest concentrations for the Mid and Lower reservoir locations occurred in July and/or September.

Lake mean TSS concentrations decreased and increased opposite of mean lake discharge April-September (Fig. 58). Mean lake discharge was high April-May, sharply decreased May-June, then remained low through September.

Tributaries. Mean TSS concentrations in the tributaries to Warrior Reservoir were the highest overall of the tributaries in the Black Warrior basin (Fig. 58). Concentrations in Big Sandy and Five Mile Creek were the two highest of any tributary.

To more clearly view the results of plotting nutrients, Warrior Reservoir tributaries were separated from the main reservoir graph. Each tributary will be discussed individually. No USGS gage stations were located near sampling locations, so discharge data was unable to be obtained.

Monthly TSS concentrations in Big Sandy Creek were higher than the other Warrior tributaries for most months (Fig. 57). Concentrations increased sharply in May then sharply decreased in June. From July-October concentrations were variable. Season highs occurred in May, while lowest concentrations occurred in June and September.

Monthly TSS concentrations in Five Mile Creek were similar throughout the sampling season (Fig. 57). Sampling began with highest concentrations in April, decreased in May, increased June-July, and then decreased to lowest concentrations in September.

Monthly TSS concentrations in Big Brush Creek were consistent April-October (Fig. 57). Concentrations varied monthly reaching lowest concentrations in September and highest concentrations in October.

Trophic State.

TSI values in the Above I-59 station decreased from eutrophic to mesotrophic levels April-July then remained within the eutrophic range through September (Fig. 59). In both the Upper and Mid reservoir stations, TSI values were stable, remaining in the lower eutrophic conditions April-October. In the Lower reservoir, TSI values decreased from eutrophic levels to mesotrophic levels April-June, steadily increased to eutrophic levels July-September, before returning to low mesotrophic levels in October.

Dissolved Oxygen/Temperature.

Mainstem. DO concentrations in the Lower reservoir were below all other Warrior mainstem reservoir locations April-October (Fig. 59). DO concentrations in the Lower reservoir decreased to levels just above criterion limits in September (5.51 mg/l). Concentrations at other mainstem Warrior Reservoir locations followed a similar pattern to that of the Lower reservoir but remained well above the criterion limit of 5.0 mg/l.

Depth profiles of temperature and DO from the Above I-59 Warrior reservoir indicated no thermal stratification April-October (Fig. 60). Highest water column temperatures occurred July-August. No chemoclines developed throughout the sampling season and dissolved oxygen concentrations remained above 5.0 mg/l throughout the water column for April-October.

Depth profiles of temperature and DO from both the Upper and Mid Warrior reservoir locations indicated very little to no thermal or chemical stratification April-October (Figs. 61 & 62). A slight thermocline and chemocline was detected near the surface May-August, however at no time did dissolved oxygen concentrations fall below 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. 63). Highest water column temperatures occurred in July and August with lowest DO concentrations occurring in September. DO concentrations in the dam forebay were never 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.

Tributaries. Monthly dissolved oxygen concentrations in Warrior Reservoir tributaries, Big Sandy and Big Brush Creek, were similar April-October (Fig. 57). Concentrations slightly decreased April-July followed by an increase August-October. Concentrations remained above the criterion limit of 5.0 mg/l on all dates sampled. Five Mile Creek was different, generally decreasing April-June and July-September, and increasing in June-July and September-October. Concentrations fell well below criterion limits on three occasions, June, August, and September (3.20, 4.83, and 3.14 mg/l, respectively).

Depth profiles of temperature and dissolved oxygen for Big Sandy Creek show isothermal and isochemical conditions throughout the sampling season (Appendix Fig. 18). Highest temperature occurred in July and August.

Depth profiles of temperature and dissolved oxygen for Five Mile Creek show variable conditions throughout the water column (Appendix Fig. 18). Highest temperatures were reached in July and August. DO concentrations were often below desirable concentrations.

Depth profiles of Big Brush Creek show essentially isothermal conditions and weak clemoclines (Appendix Fig. 19). Deoxygenation only occurred at the bottom July-September.

Summary/Discussion.

Water quality data from Warrior Reservoir indicated concerns based on mean TN concentrations, mean TP concentrations, and mean TSS concentrations that were among the highest of Warrior basin locations. Mean TN and mean TP were not only elevated in 2002 as compared to other Black Warrior mainstem stations, but historical graphs also indicate that concentrations were higher than in 1998 in all but one station. AGPT results indicate phosphorus as the limiting nutrient. The effects of elevated phosphorus levels are evident in the increase in 2002 mean chlorophyll *a* concentrations. Historical graphs also emulate trends for phosphorus and nitrogen. TSI remains in the lower eutrophic range for most stations in most months; however, if current trends continue and phosphorus continues to increase, TSI values will in turn increase as well. Further documentation is needed to document future trends and status of this reservoir.

Mean total suspended solids concentrations were among the highest of any mainstem Black Warrior reservoir location. Mean graphs which include historical data indicate lower concentrations in 2002. Current methods of sediment control may be limiting the sediment input into the system. Additional methods of control may be necessary, as mean concentrations are still among the highest of the basin.

Three tributary embayments were monitored on Warrior Reservoir. They included Big Sandy, Five Mile, and Big Brush Creeks. The Big Sandy Creek sub-watershed drains approximately 175 mi^2 in Bibb, Hale and Tuscaloosa Counties (ADEM 2004). Percent land cover of the Big Sandy Creek sub-watershed was estimated as 33% deciduous forest, 21% evergreen forest, 37% mixed forest, 2% pasture/hay, 2% row crop, and 2% forested wetland.

Estimates of land-use by the local SWCDs were similar to EPA data. Thirteen (13) current construction/stormwater authorizations and two (2) mining NPDES permits have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.02 AU/Acre). Sedimentation estimates indicated a *low* potential for NPS impairment (3.1 tons/acre). The overall potential for impairment from nonpoint sources was estimated as *low*. The water quality analysis largely agrees with this assessment. Mean TN, TP, and chlorophyll *a* concentrations were among the lowest of the tributaries of the Black Warrior basin. DO concentrations were well above any critical concentration level. Depth profiles of dissolved oxygen show well oxygenated water throughout the water column. Highest temperatures occurred in July and August. Mean total suspended solids was the highest of any tributary. Monthly total suspended solids concentrations at Big Sandy Creek were higher during most months. Concentrations appear to fluctuate independently of flow. Future monitoring is recommended to determine sources of sediment.

The Five Mile Creek sub-watershed drains approximately 110 mi^2 in Bibb, Hale and Perry Counties (ADEM 2004). Percent land cover of the Five Mile Creek sub-watershed was estimated as 4% transitional barren, 18% deciduous forest, 29% evergreen forest, 36% mixed forest, 4% pasture/hay, and 7% forested wetland. Estimates of land-use by the local SWCDs were higher for pastureland (9%) land use. Two (2) current construction/stormwater authorizations have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.00 AU/Acre). Sedimentation estimates indicated a *low* potential for NPS impairment (3.6 tons/acre). The overall potential for impairment from nonpoint sources was estimated as *low*. Mean concentrations of TP and TSS in Five Mile Creek were the second highest recorded of any tributary. Mean TN and chlorophyll *a* were both elevated as compared to other tributaries in the Black Warrior basin. DO was also of some concern as it fell well below criterion limits on three occasions, June, August, and September (3.20, 4.83, and 3.14 mg/l, respectively). The profiles clearly indicate that well-oxygenated water only occurred neared the surface. Further monitoring is recommended to investigate sources of nutrients and causes of low DO.

The Big Brush Creek sub-watershed drains approximately 201 mi^2 in Hale and Perry Counties (ADEM 2004). Percent land cover of the Big Brush Creek sub-watershed was estimated as 4% transitional barren, 16% deciduous forest, 29% evergreen forest, 33% mixed forest, 4% pasture/hay, 2% row crop, 10% wetland, and 2% open water. Estimates of land-use by the local SWCDs were higher for pasture (21%) and row crop (4%), and lower for forest (69%) and open water (<1%) land uses. Two (2) NPDES permits, one municipal and one SID stormwater, have been issued in the sub-watershed. The SWCD estimates of animal concentrations in the sub-watershed were *low* (0.01 AU/Acre). Sedimentation estimates indicated a *low* potential for NPS impairment (2.0 tons/acre). The overall potential for impairment from nonpoint sources was estimated as *low*. Only slightly elevated concentrations of TN, TP, chlorophyll *a*, and TSS in Big Brush Creek have been found. DO concentrations neared criterion limits in August. Depth profiles of temperature and dissolved oxygen show deoxygenation only occurred at the bottom June-September.

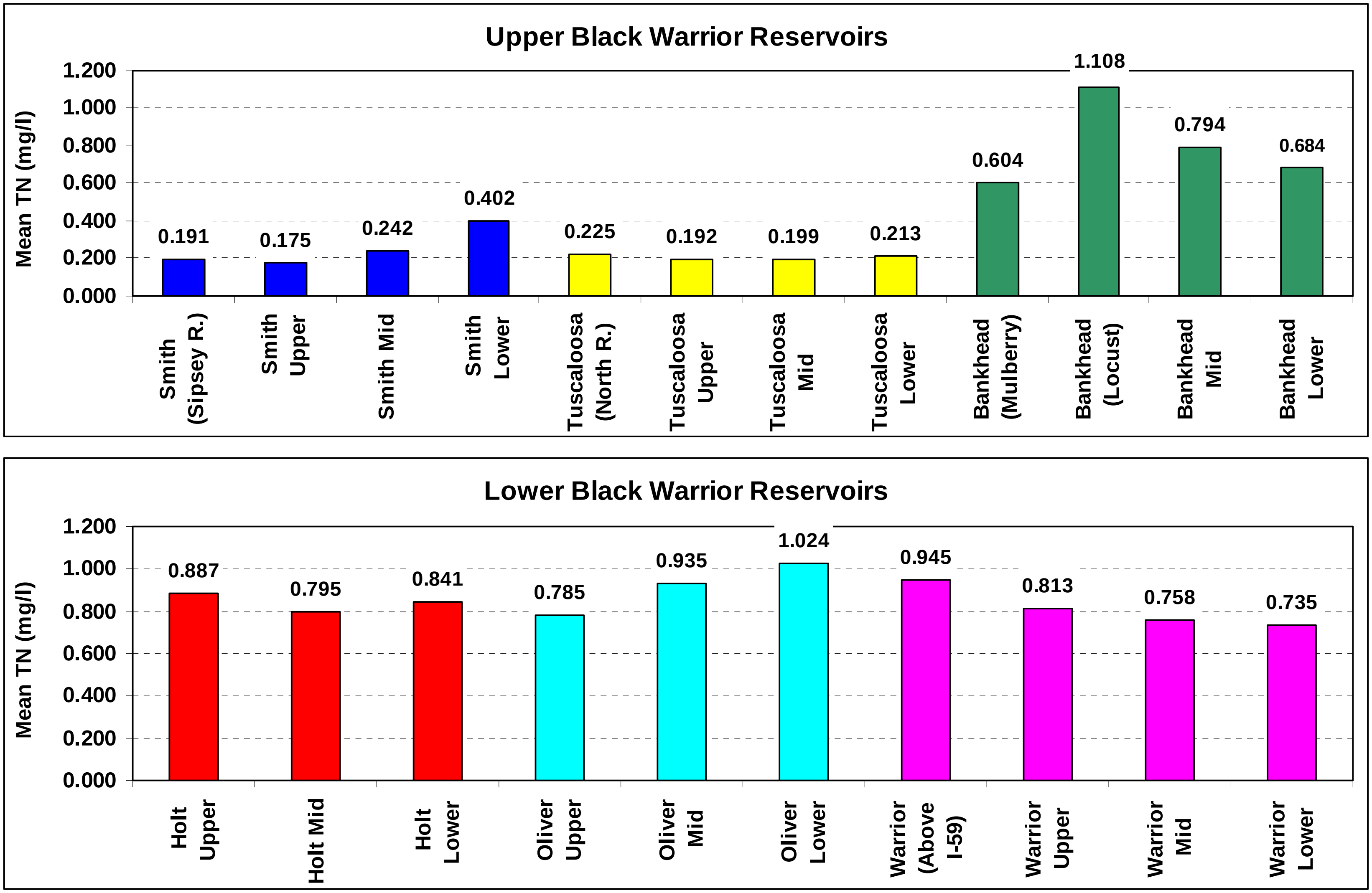


Figure 3. Mean total nitrogen (TN) concentrations of the Black Warrior Reservoir locations, April-October 2002.

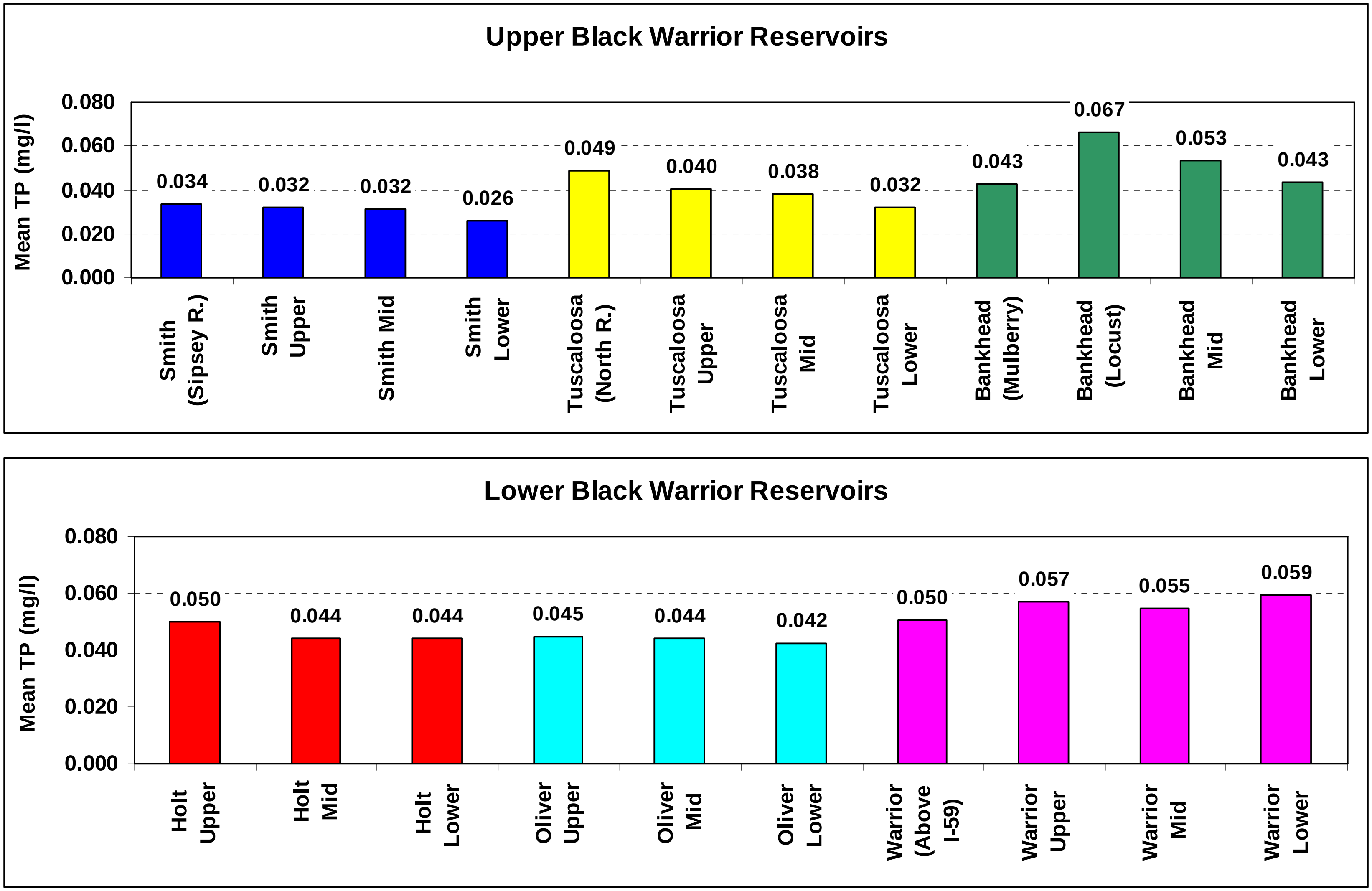


Figure 4. Mean total phosphorus (TP) concentrations of Black Warrior Reservoir locations April-October 2002.

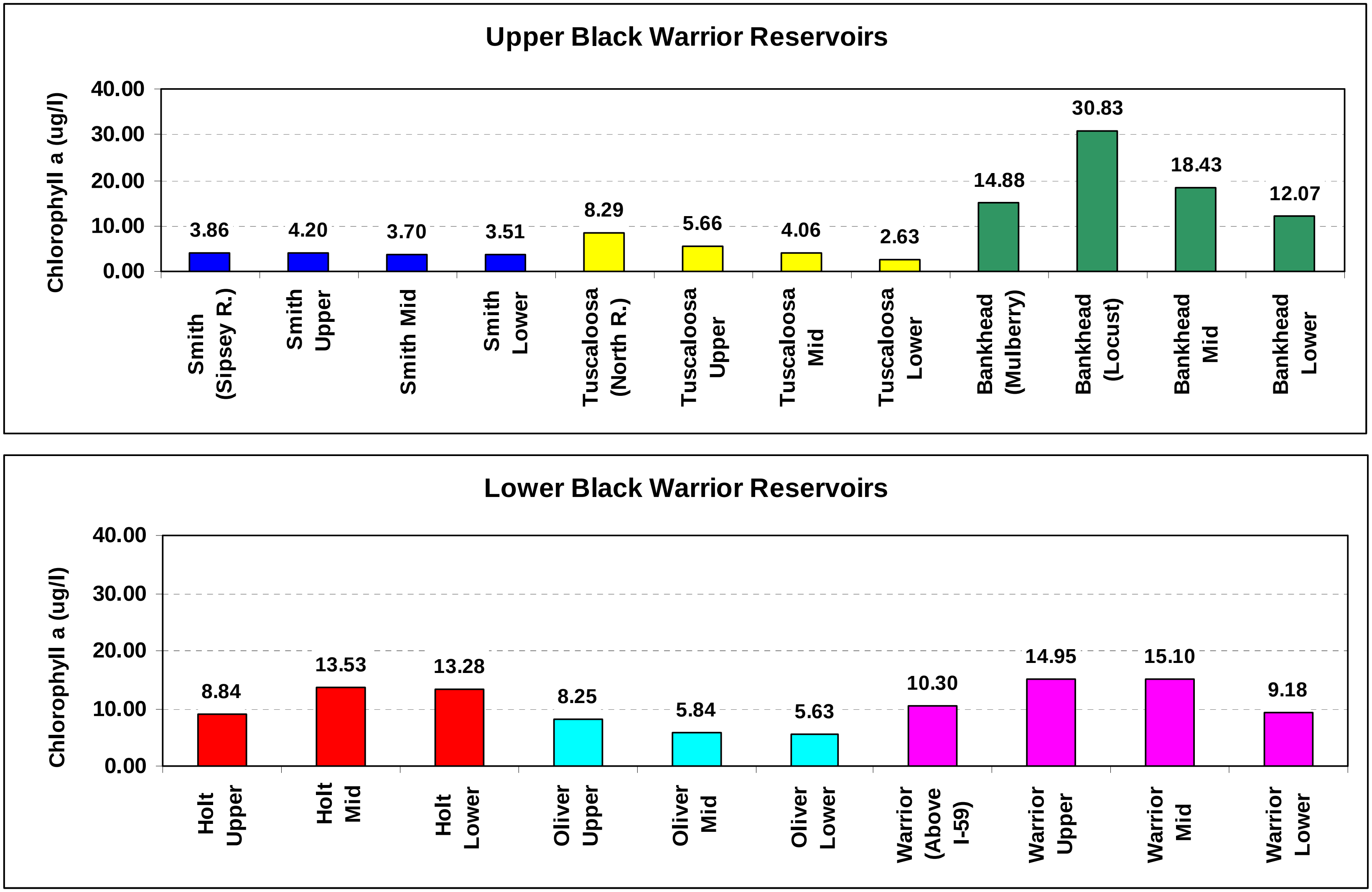
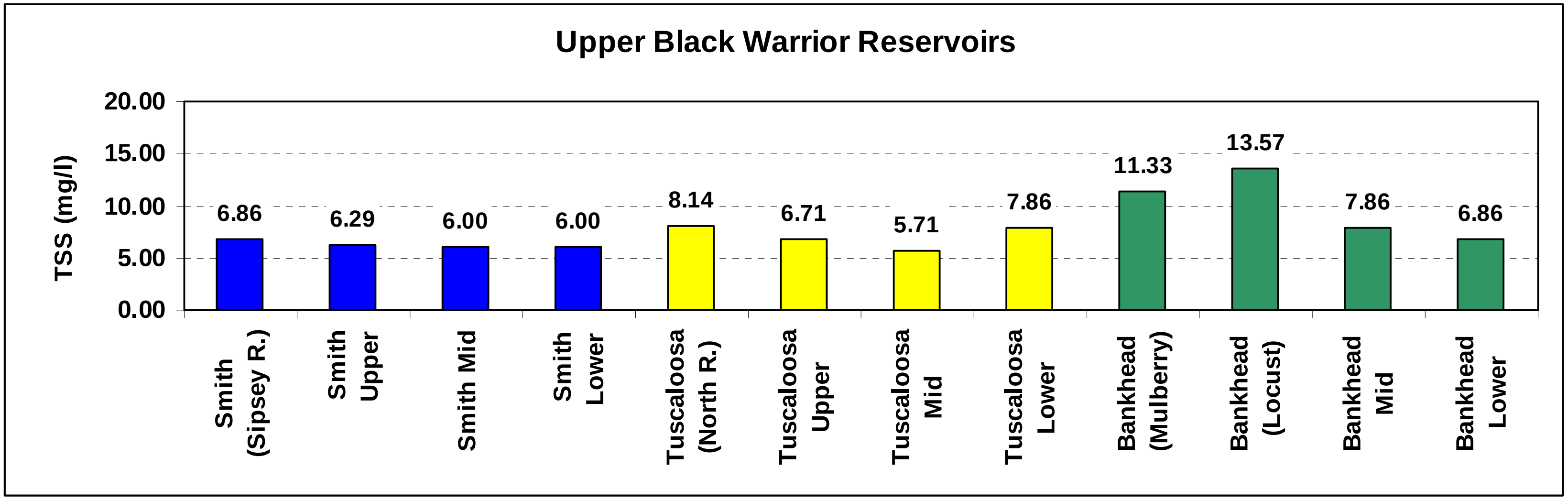


Figure 5. Mean chlorophyll *a* concentrations of Black Warrior Reservoir locations April-October 2002.



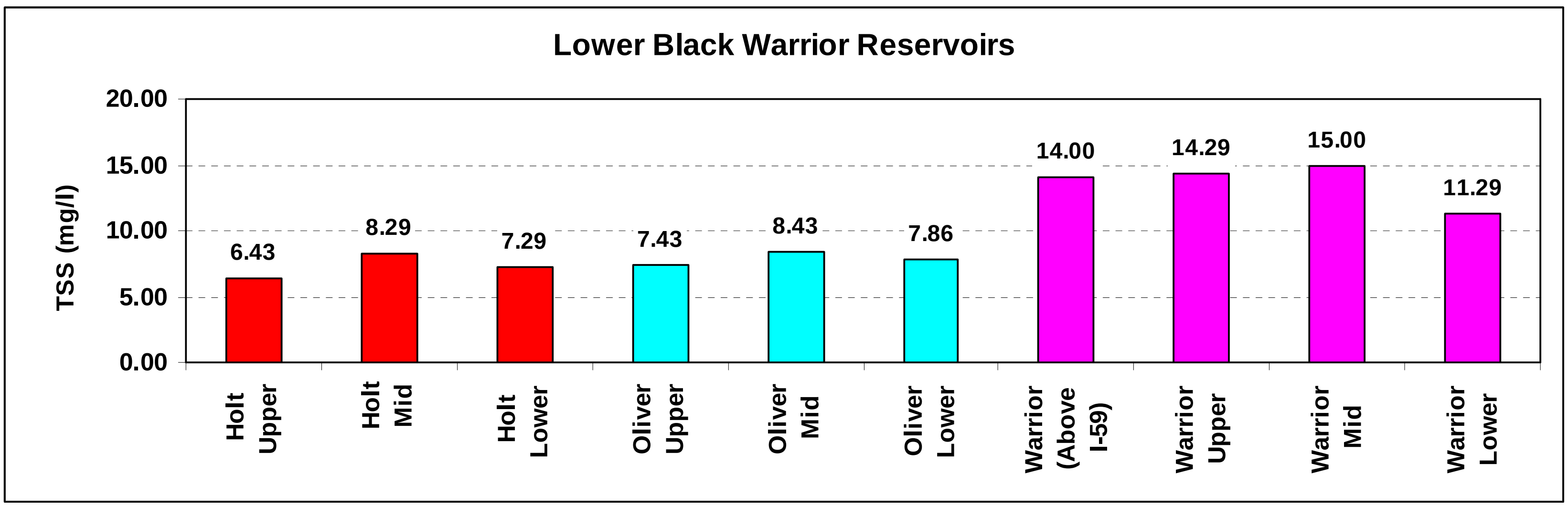


Figure 6. Mean total suspended solids (TSS) concentrations of Black Warrior Reservoir locations April-October 2002.

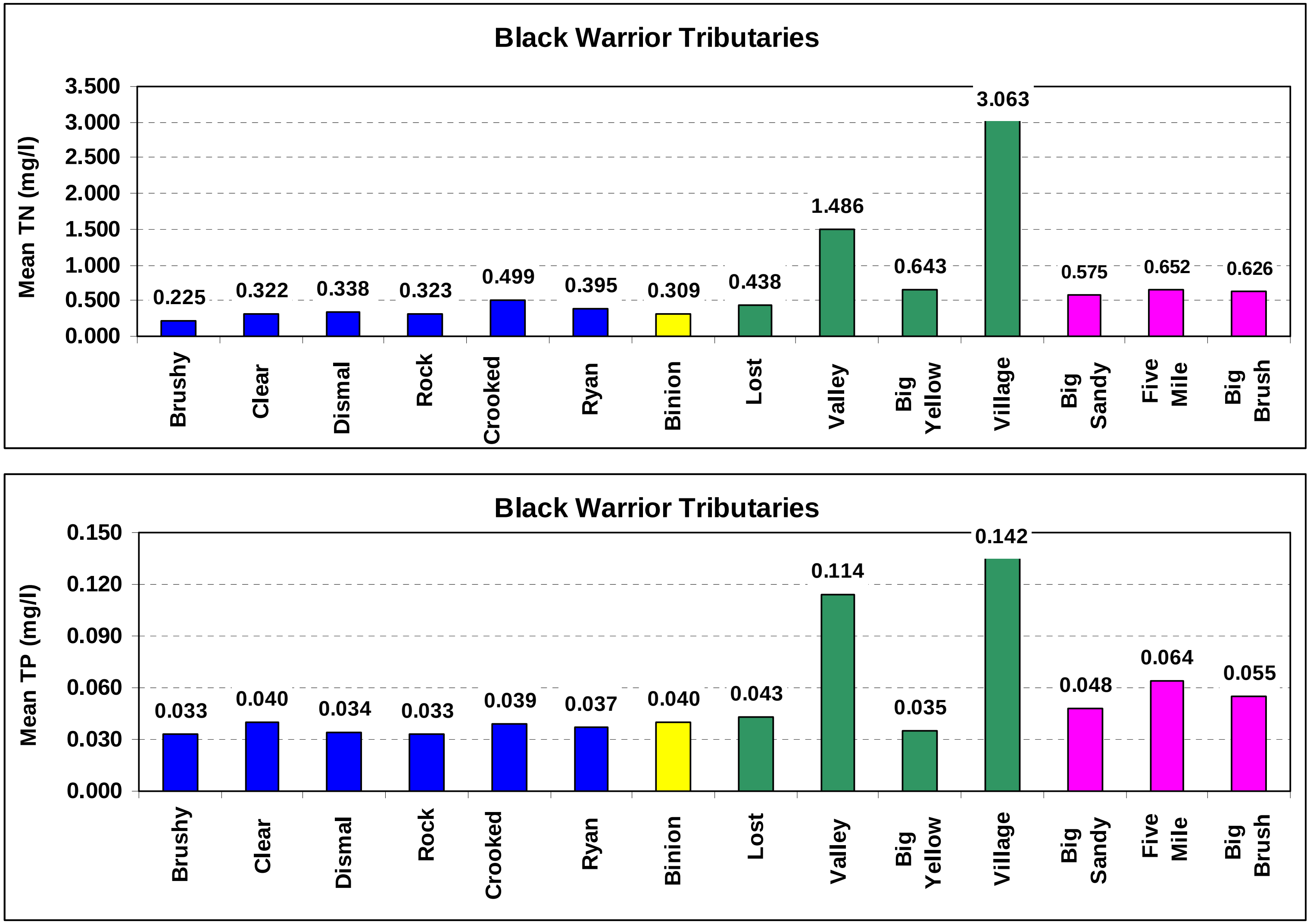


Figure 7. Mean total nitrogen (TN) and mean total phosphorus (TP) concentrations of Black Warrior Tributary locations, April-October 2002.

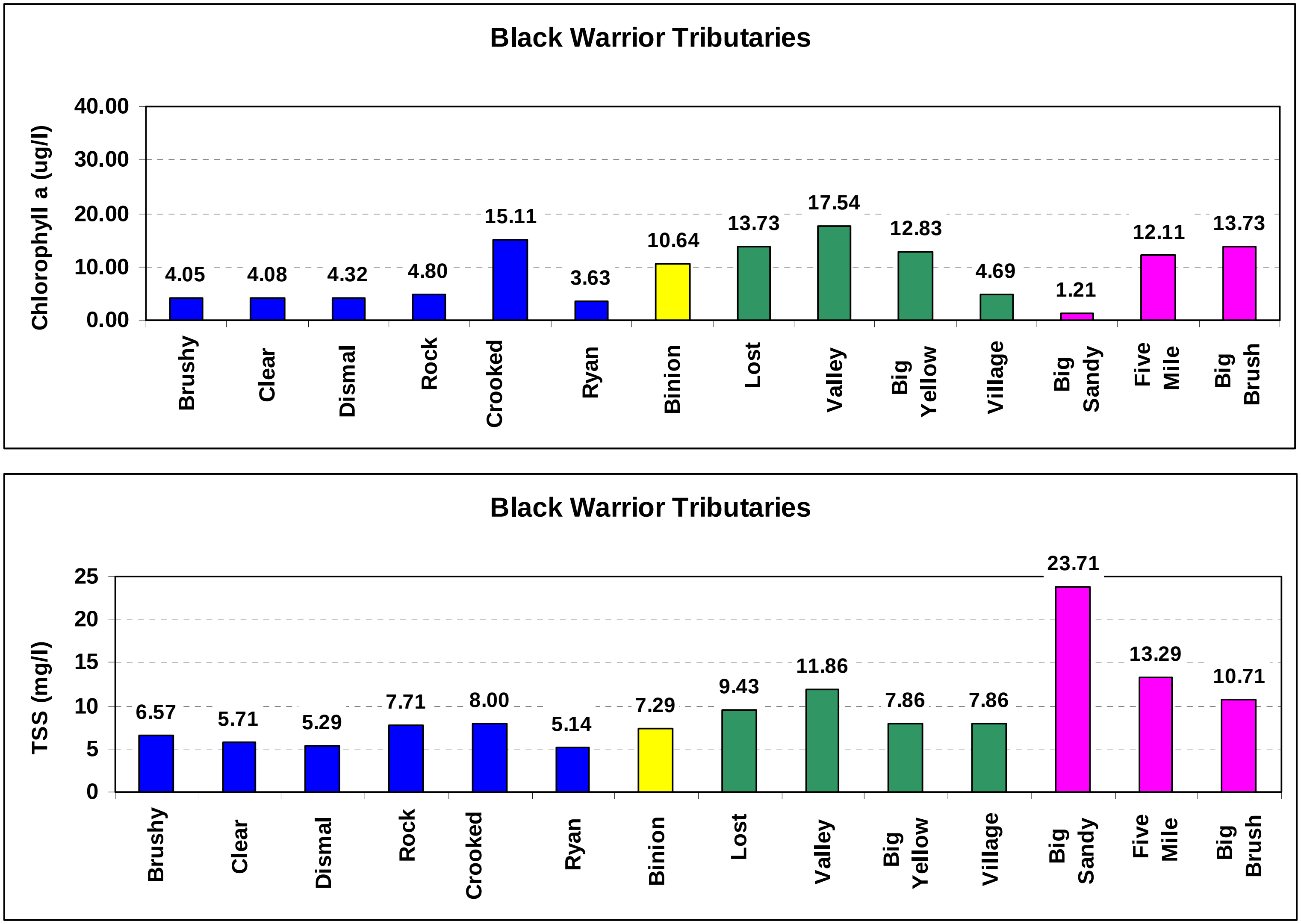


Figure 8. Mean chlorophyll *a* concentrations and mean total suspended solids (TSS) of Black Warrior Tributary locations, April-October 2002.

Table 4. Algal growth potential testing (AGPT) of Black Warrior River Reservoirs, August 2002

Reservoir	Station	Collection Date	Mean MSC (mg/l) C	C+N	C+P	Limiting Nutrient
Smith	Upper	8/22/2002	1.69	1.88	1.92	Co-limiting
	Mid	8/21/2002	1.41	1.5	**2.2**	Phosphorus
	Lower	8/21/2002	1.44	1.41	**2.38**	Phosphorus
Tuscaloosa	Upper	8/20/2002	1.8	**2.88**	**2.1**	Co-limiting
	Mid	8/20/2002	1.89	**2.64**	2.17	Nitrogen
	Lower	8/20/2002	1.82	1.98	**2.74**	Phosphorus
Bankhead	Mulberry	8/21/2002	6.95	6.81	**13.63**	Phosphorus
	Locust	8/21/2002	15.91	14.75	**17.99**	Phosphorus
	Mid	8/21/2002	9.61	**11.45**	**11.72**	Co-limiting
	Lower	8/21/2002	3.56	**5.16**	**13.99**	Co-limiting
Holt	Upper	8/21/2002	3.76	3.29	**16.68**	Phosphorus
	Mid	8/21/2002	4.52	4.23	**14.51**	Phosphorus
	Lower	8/21/2002	4.06	3.74	**12.08**	Phosphorus
Oliver	Upper	8/21/2002	2.89	2.57	**19.29**	Phosphorus
	Mid	8/21/2002	3.15	2.96	**21.08**	Phosphorus
	Lower	8/21/2002	3.19	2.99	**20.91**	Phosphorus
Warrior	Above I-59	8/21/2002	2.35	2.31	**20.29**	Phosphorus
	Upper	8/20/2002	5.56	5.18	**14.49**	Phosphorus
	Mid	8/20/2002	5.11	4.87	**14.12**	Phosphorus
	Lower	8/20/2002	3.69	2.95	**13.77**	Phosphorus

MSC = Maximum Standing Crop

C = Control; C+N = Control + Nitrogen; C+P = Control + Phosphorus

Values in **bold** print are significantly different from control.

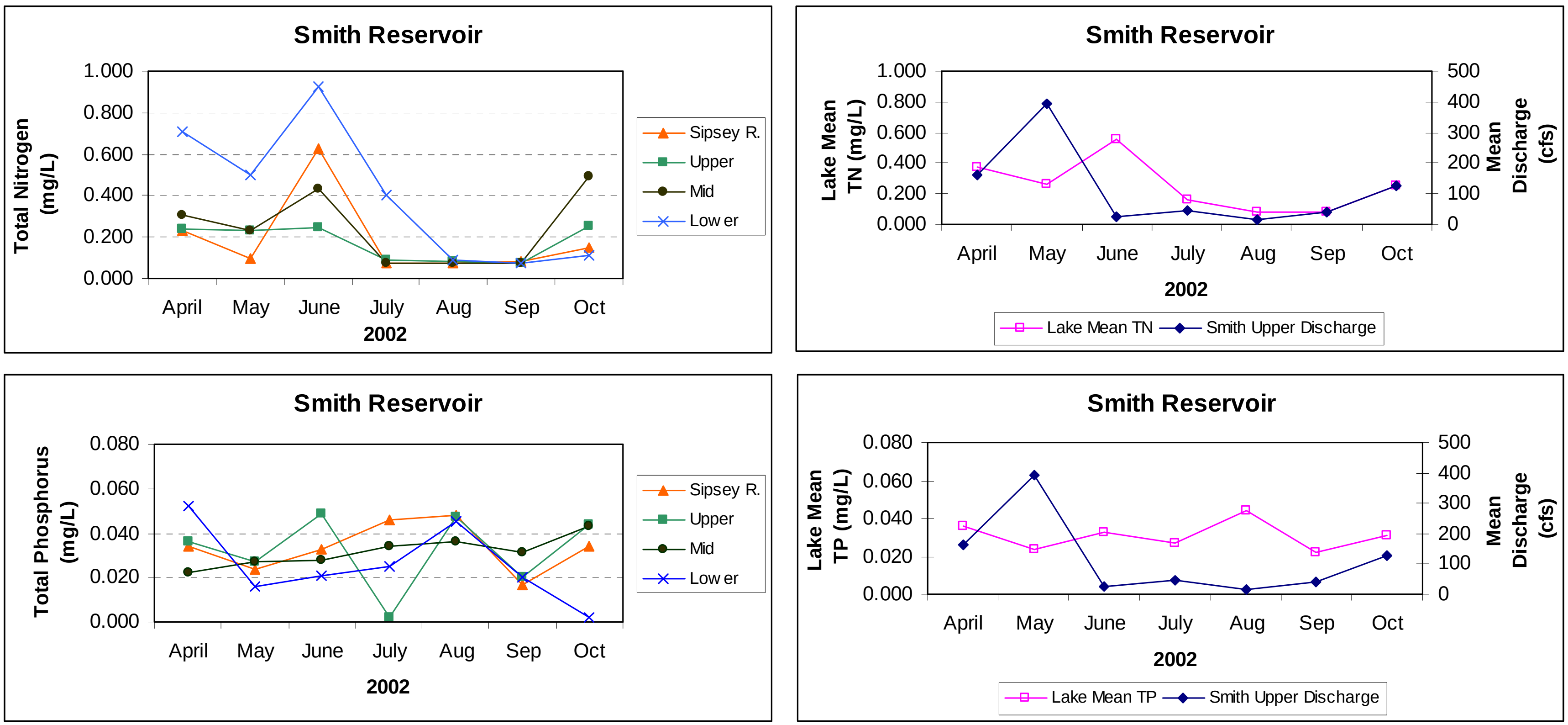


Figure 9. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Smith Reservoir, April-October 2002.

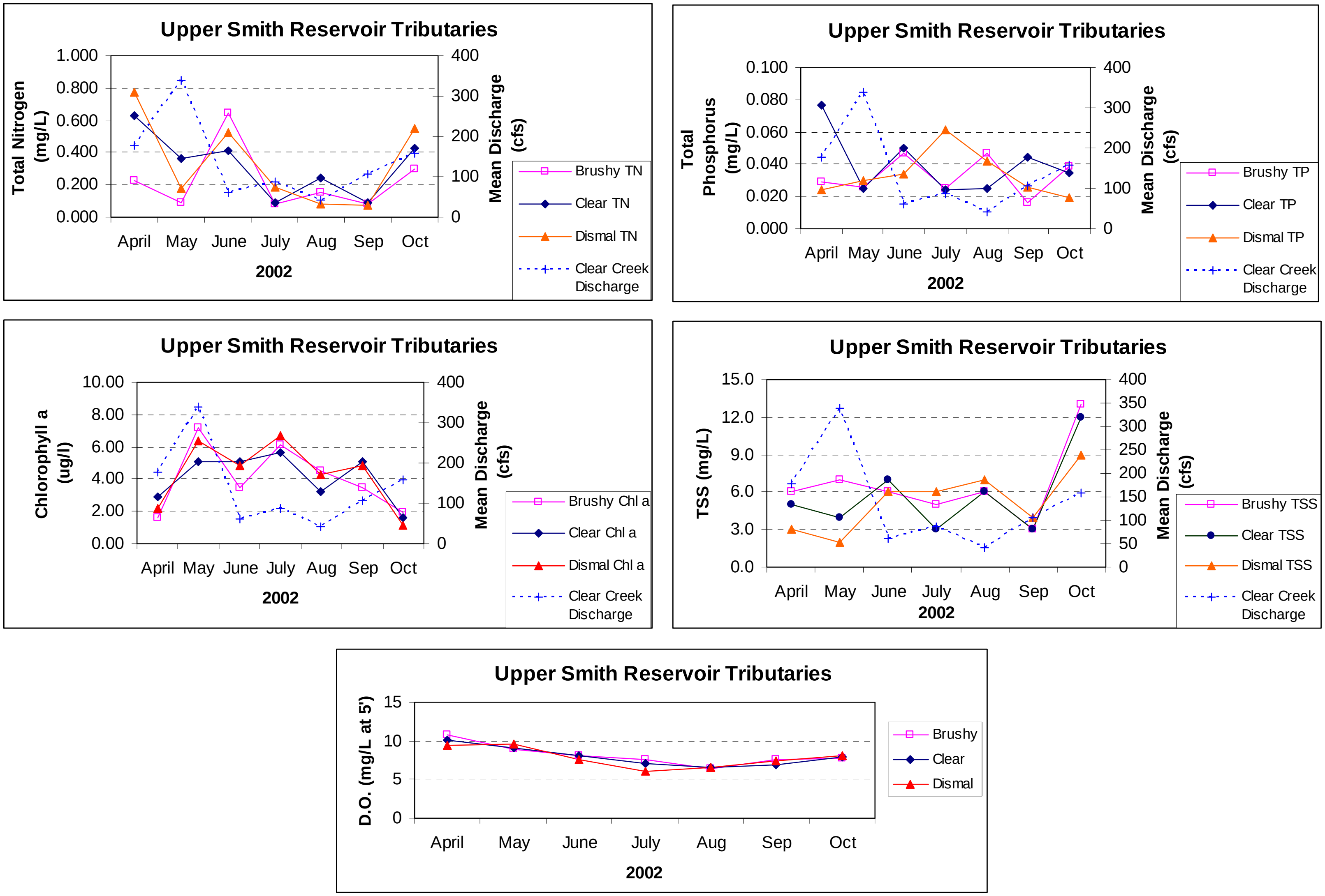


Figure 10. Total nitrogen (TN), total phosphorus (TP), chlorophyll *a*, total suspended solids (TSS), and dissolved oxygen (DO) in Upper Smith Reservoir Tributaries, April-October 2002.

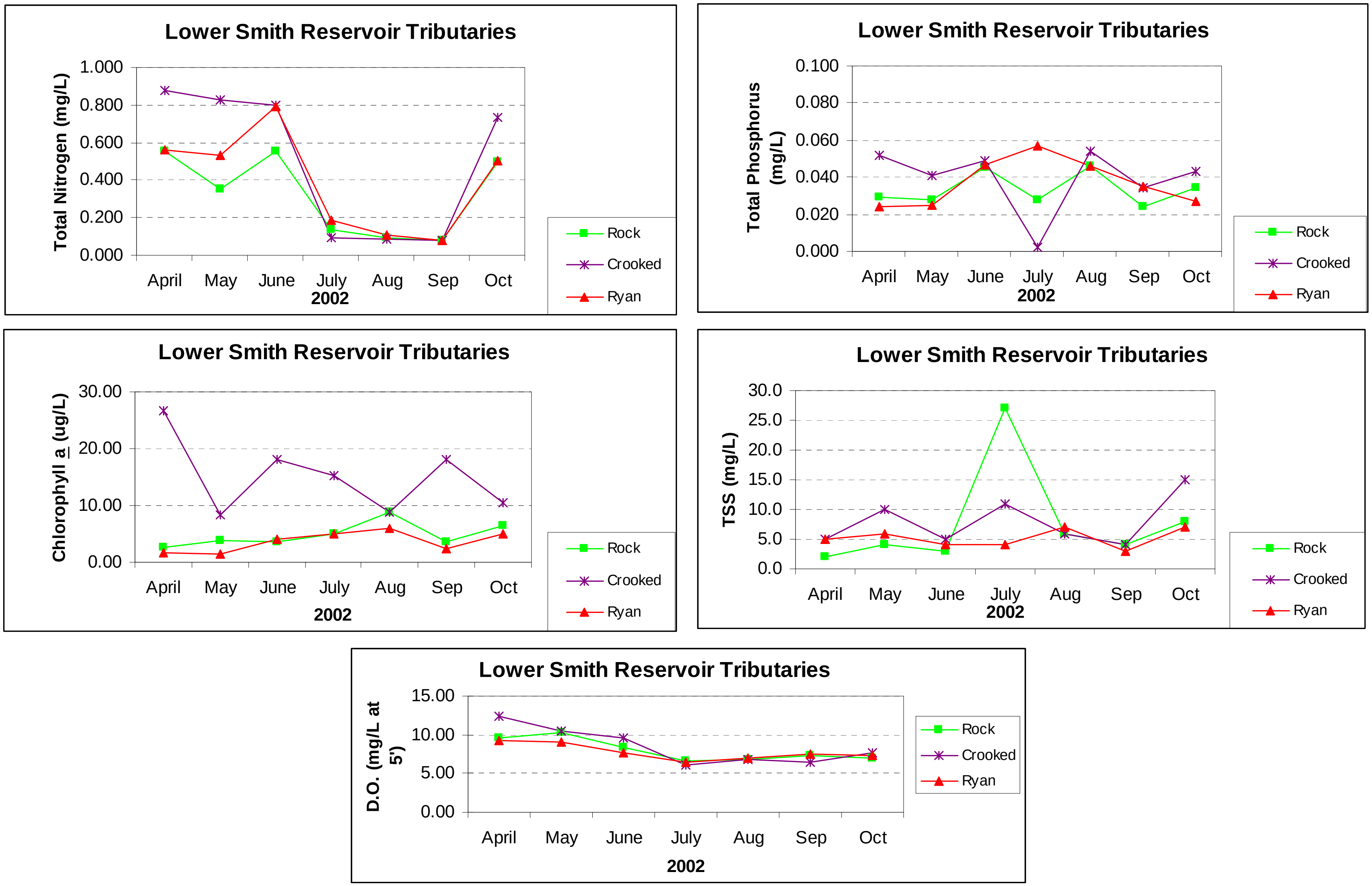


Figure 11. Total nitrogen (TN), total phosphorus (TP), chlorophyll *a*, total suspended solids (TSS), and dissolved oxygen (DO) in Lower Smith Reservoir Tributaries, April-October 2002.

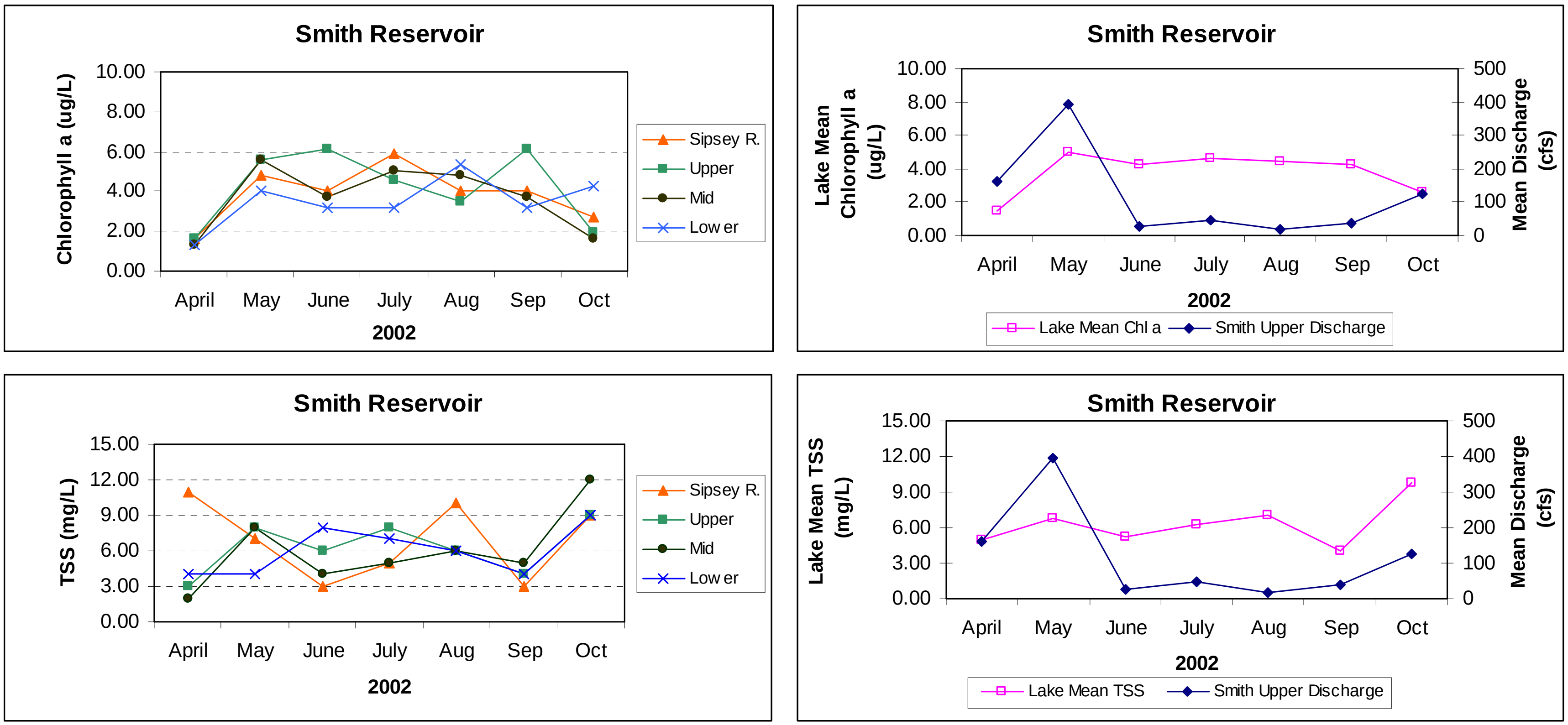


Figure 12. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS), lake mean TSS vs. discharge of Smith Reservoir, April-October 2002.

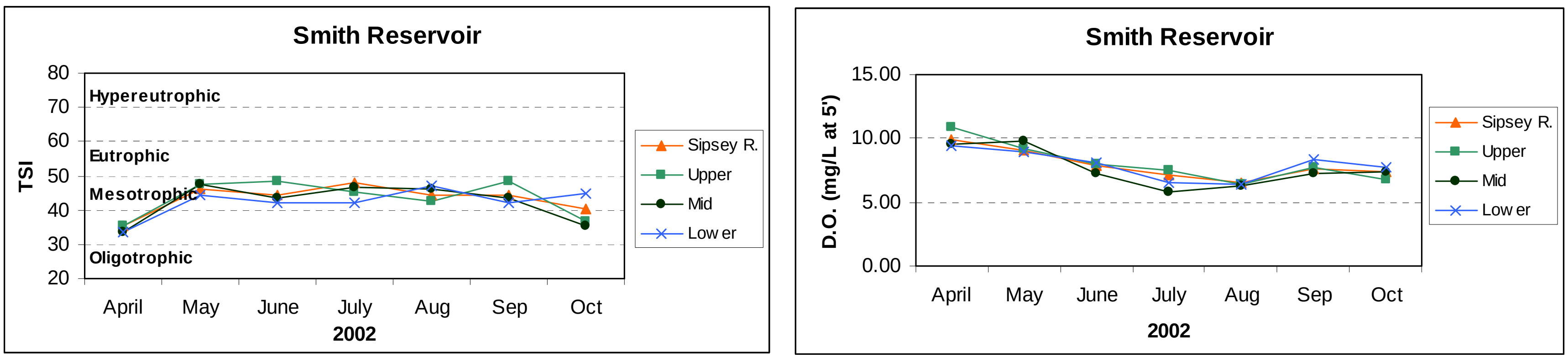


Figure 13. Trophic state index (TSI) and dissolved oxygen (DO) for Smith Reservoir, April-October 2002.

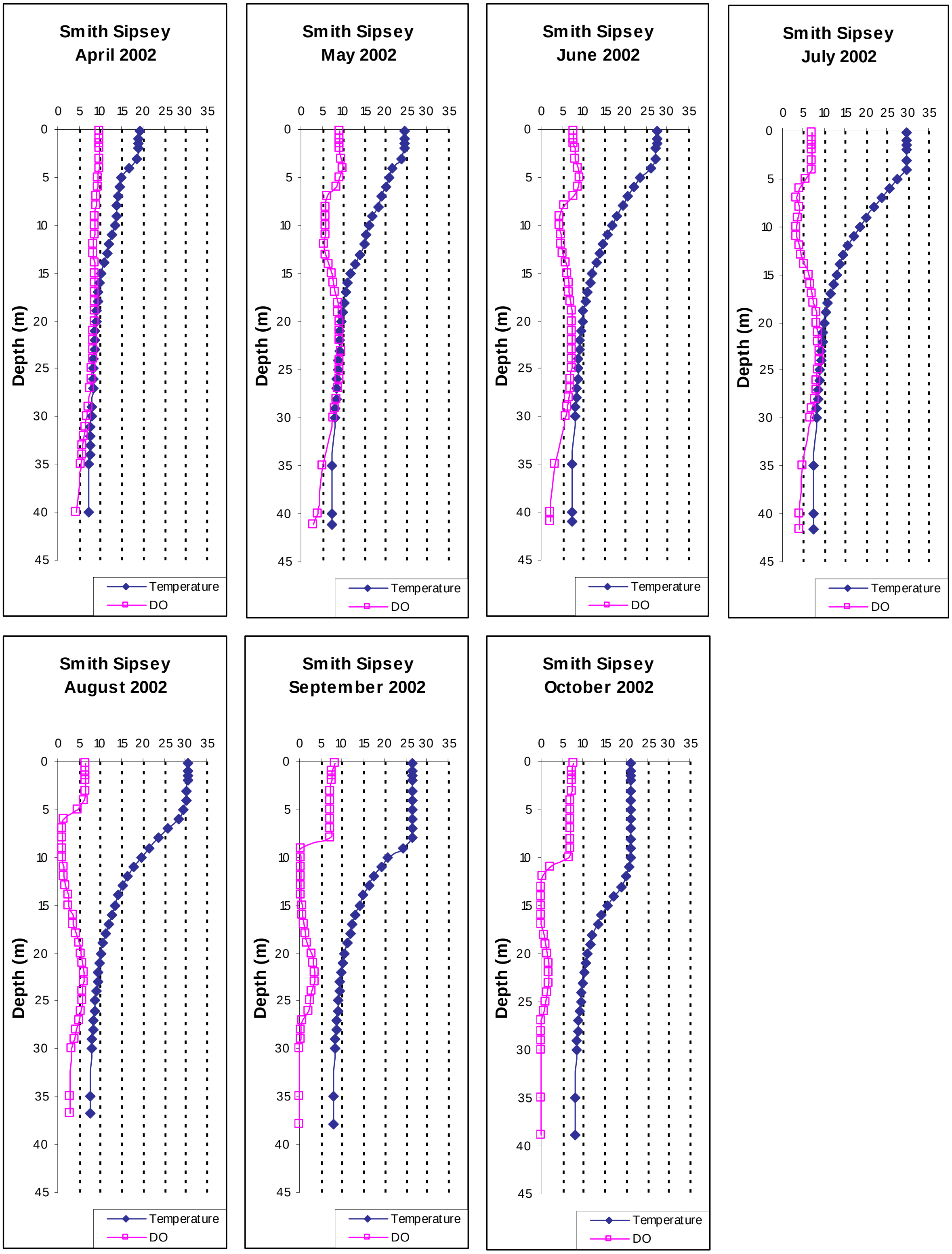


Figure 14. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Sipsey River in upper Smith Reservoir, April-October 2002.

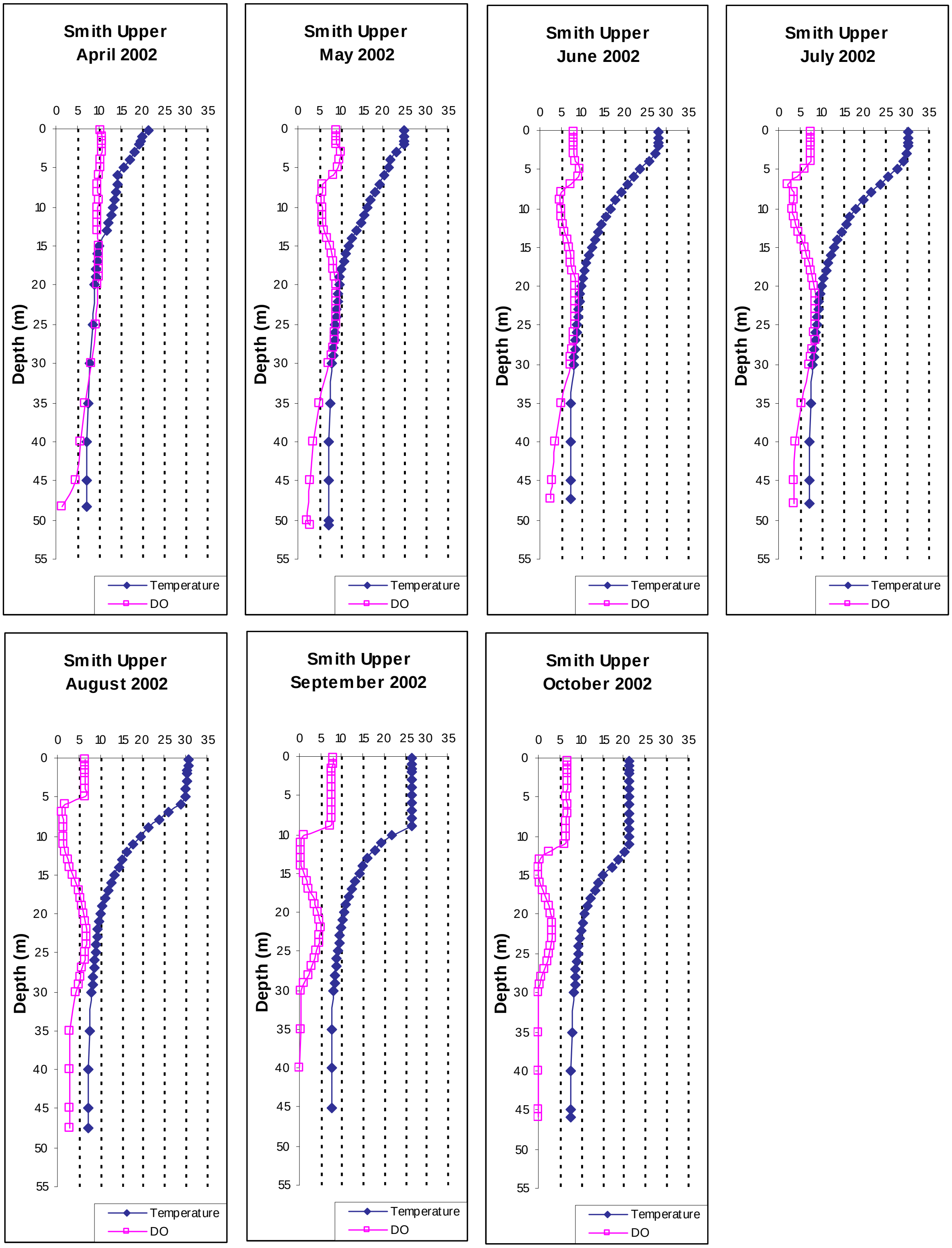


Figure 15. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Upper Smith Reservoir downstream of Brushy Creek confluence, April-October 2002.

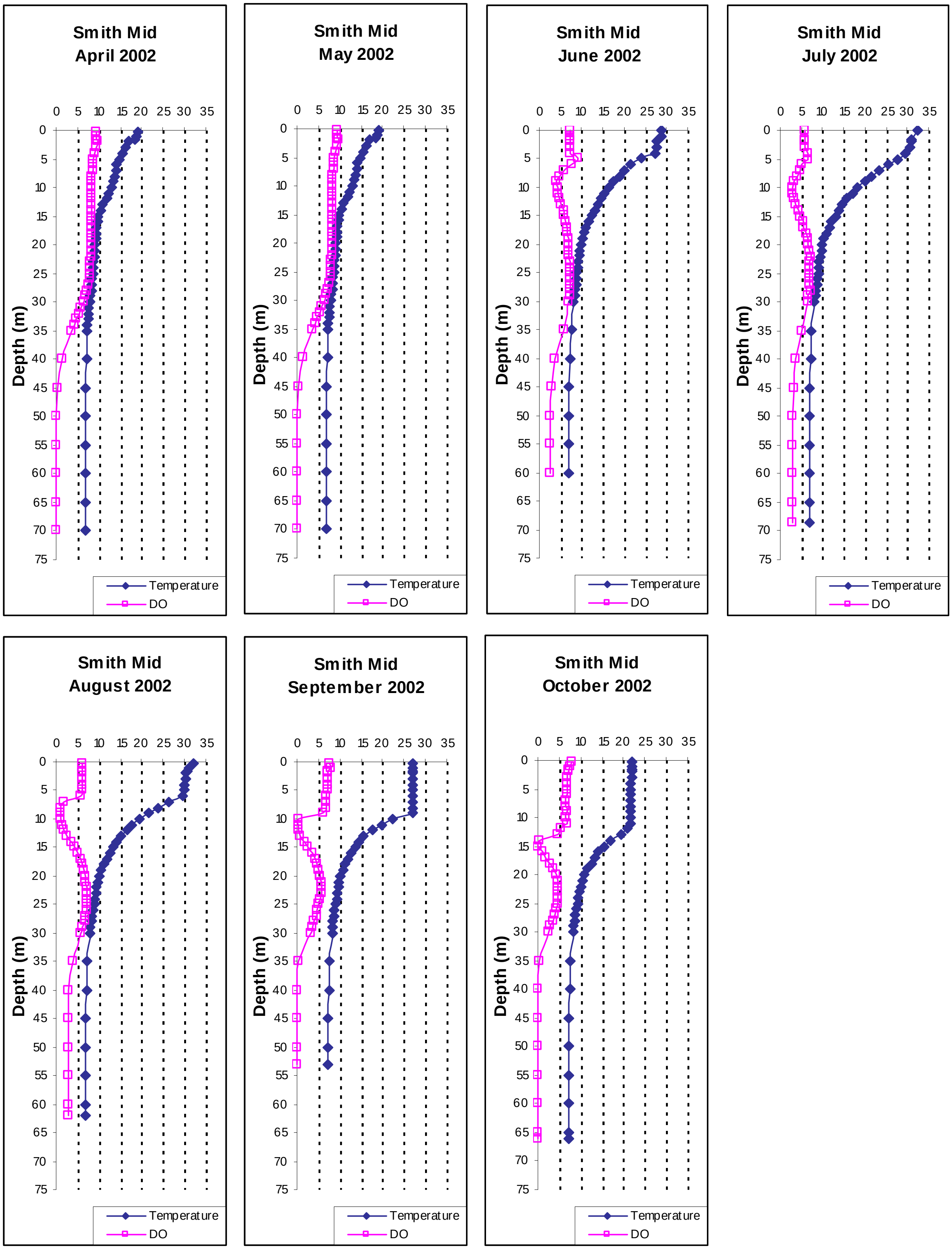


Figure 16. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Mid Smith Reservoir at the Duncan Cr/Sipsey River confluence, April-October 2002.

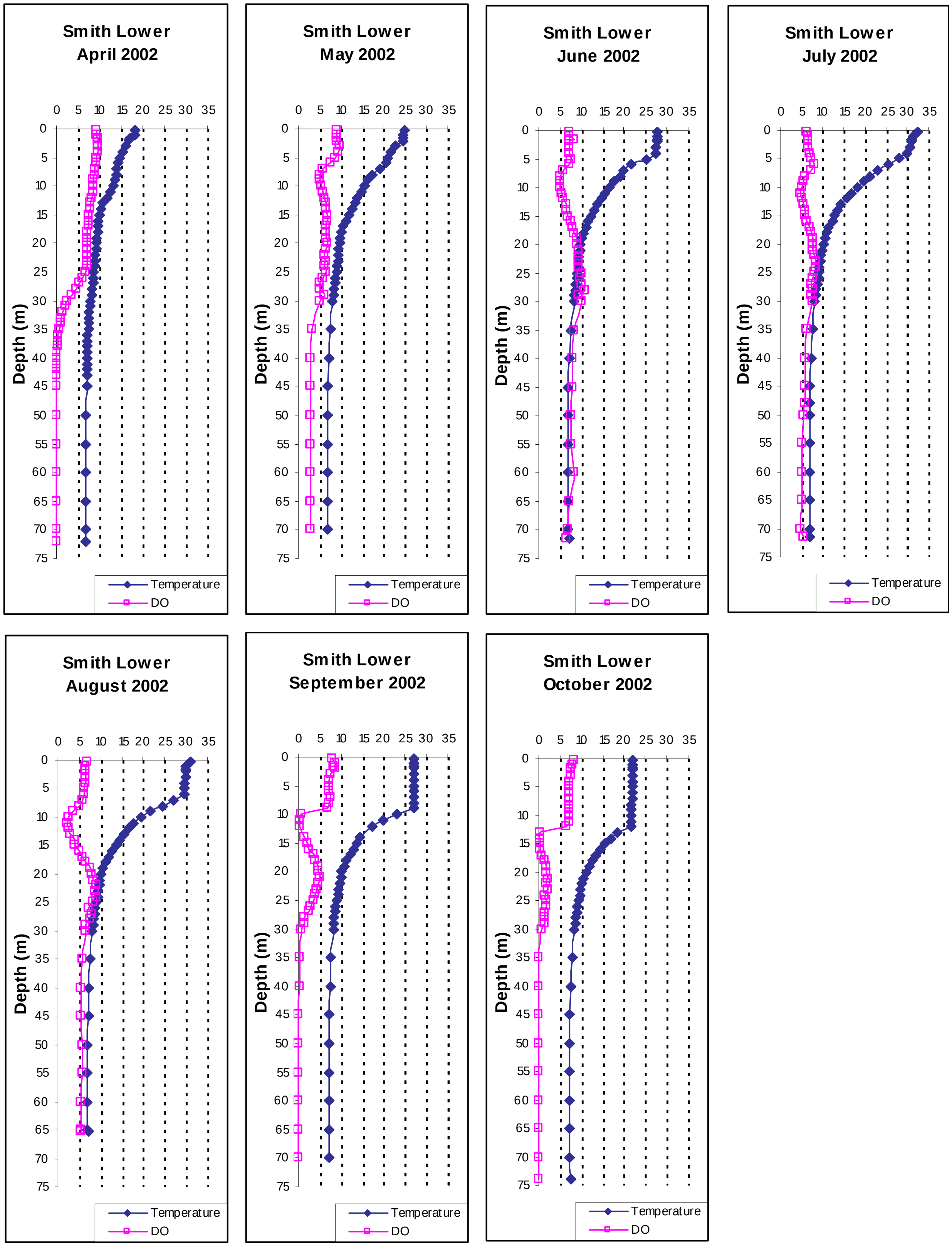


Figure 17. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Smith Reservoir, April-October 2002.

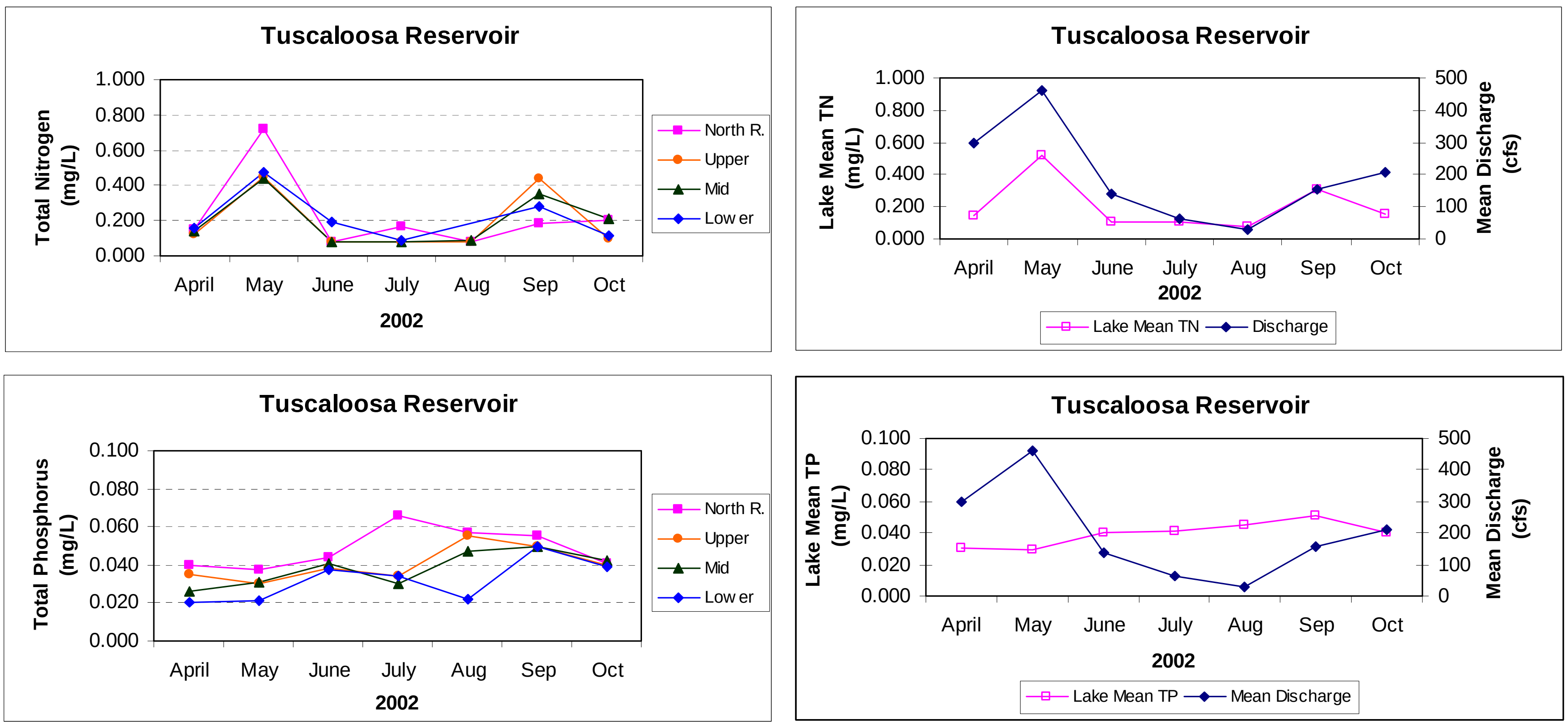


Figure 19. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge for Tuscaloosa Reservoir, April-October 2002.

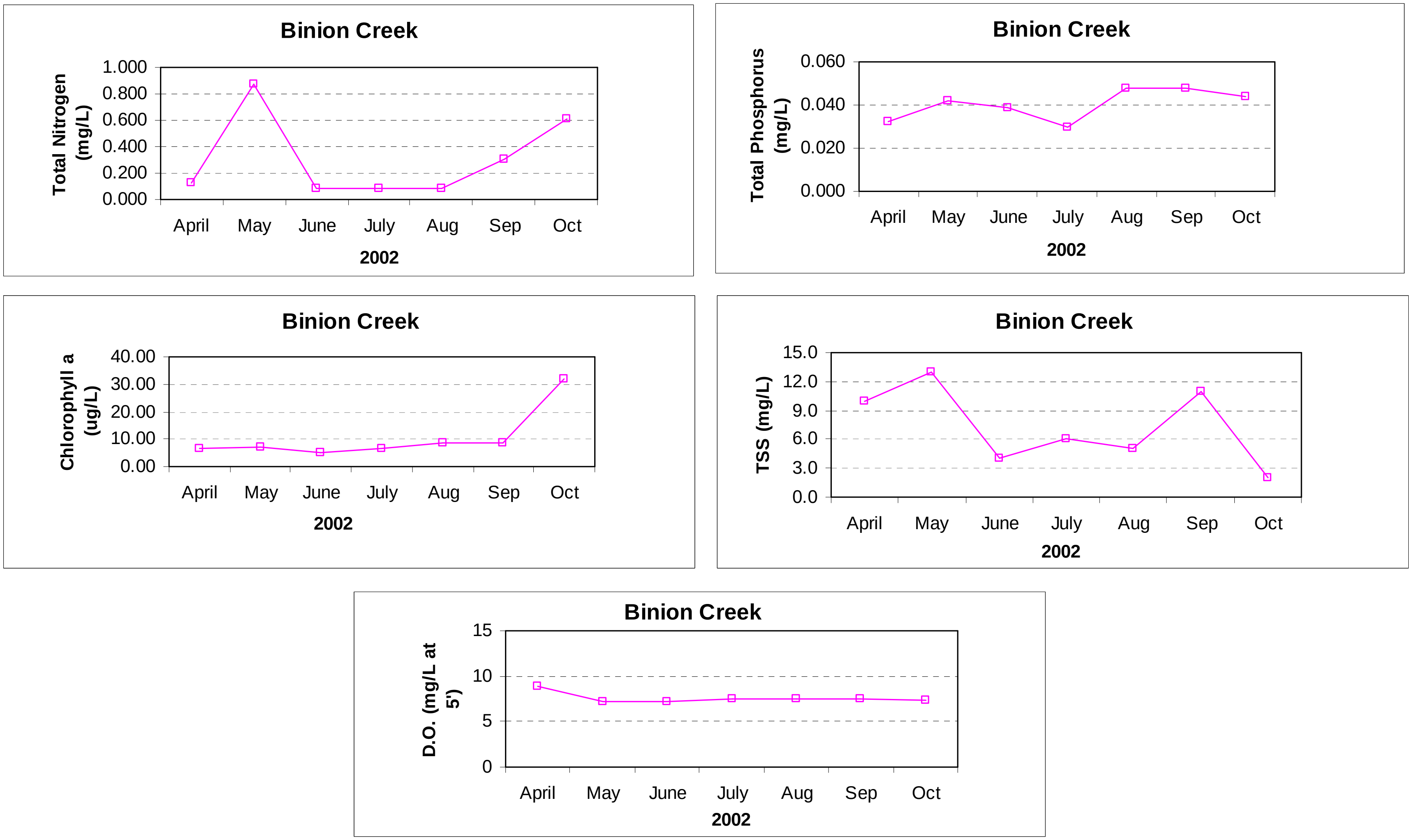


Figure 20. Total nitrogen (TN), total phosphorus (TP) Chlorophyll *a*, total suspended solids (TSS), and dissolved oxygen (DO) for Binion Creek, a tributary of Tuscaloosa Reservoir, April-October 2002.

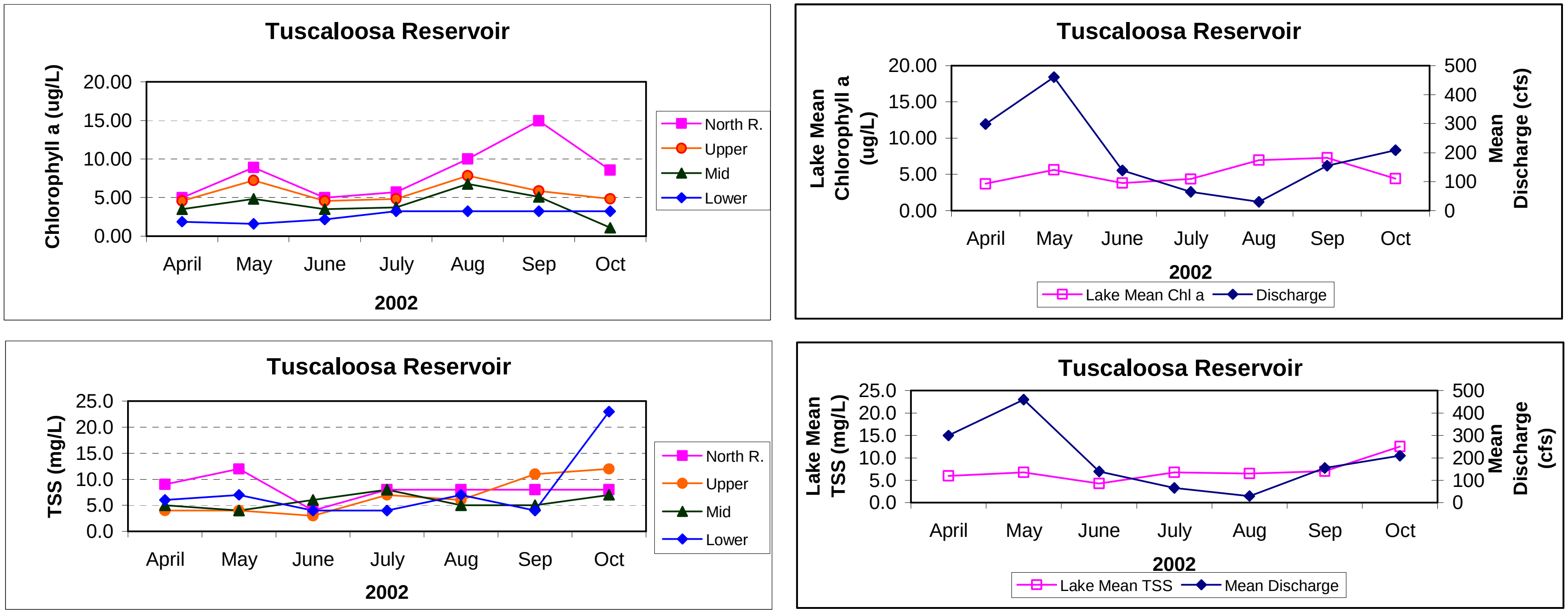


Figure 21. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS), lake mean TSS vs. discharge for Tuscaloosa Reservoir, April-October 2002.

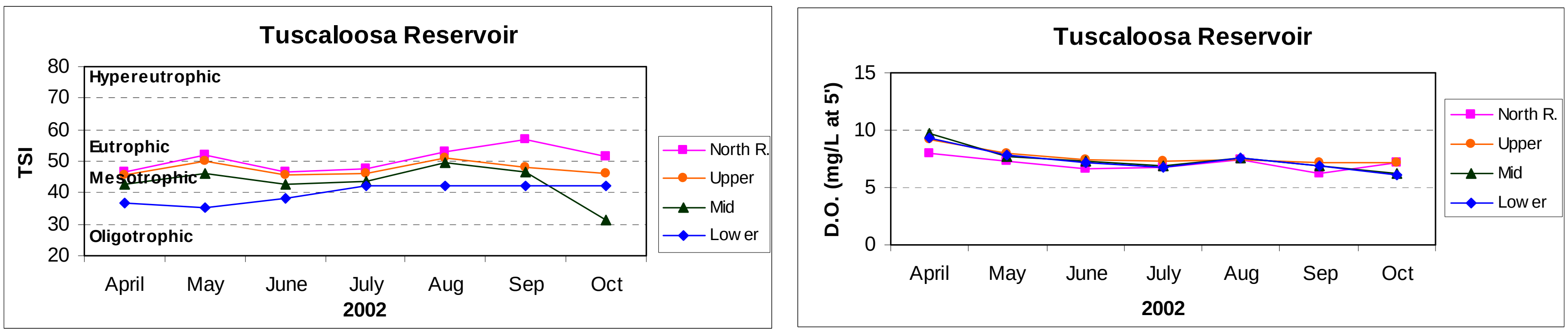


Figure 22. Trophic state index (TSI) and dissolved oxygen (DO) for Tuscaloosa Reservoir, April-October 2002.

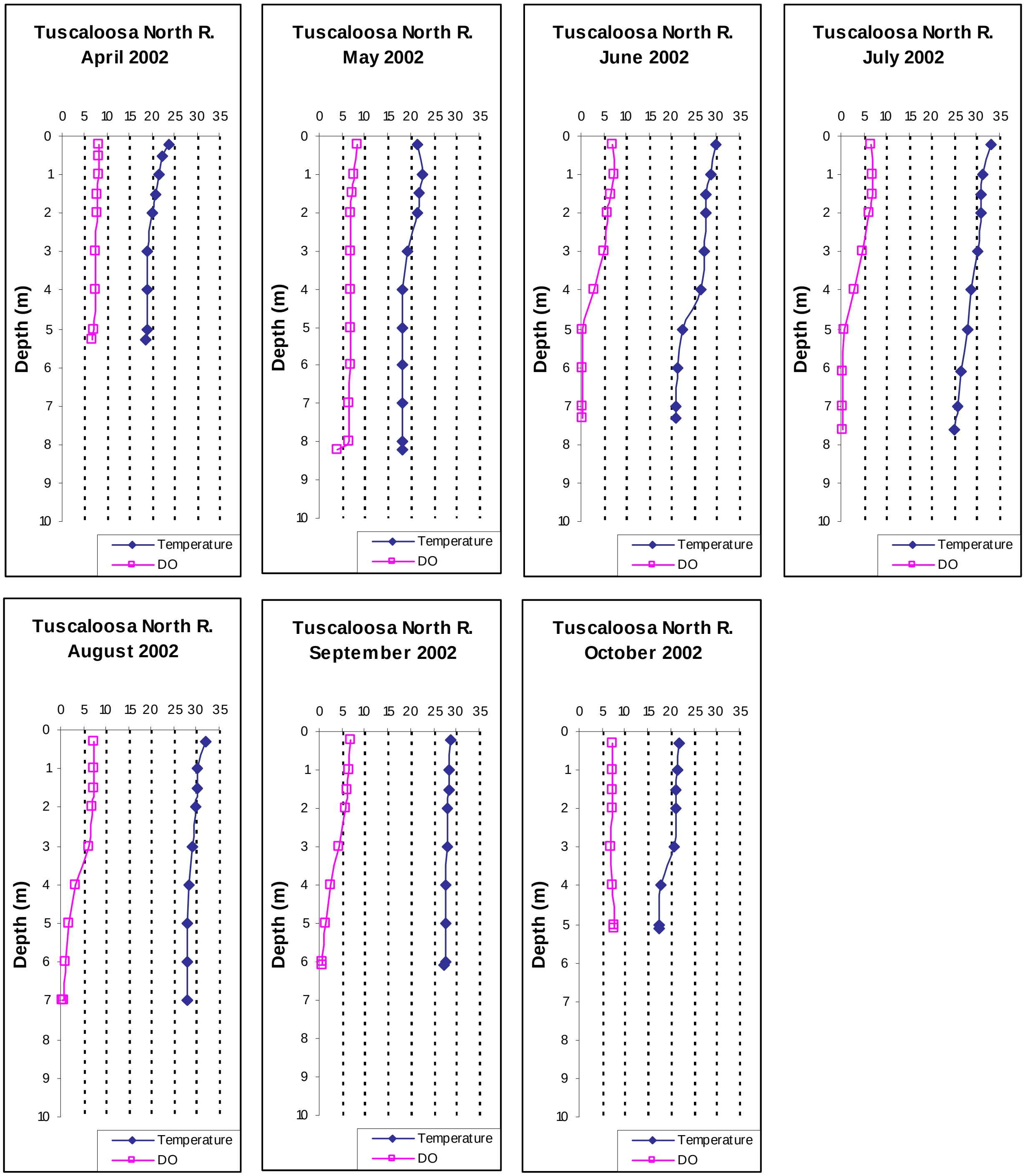


Figure 23. Depth profiles of dissolved oxygen (DO) and temperature (Temp) of North River in upper Tuscaloosa Reservoir, April-October 2002.

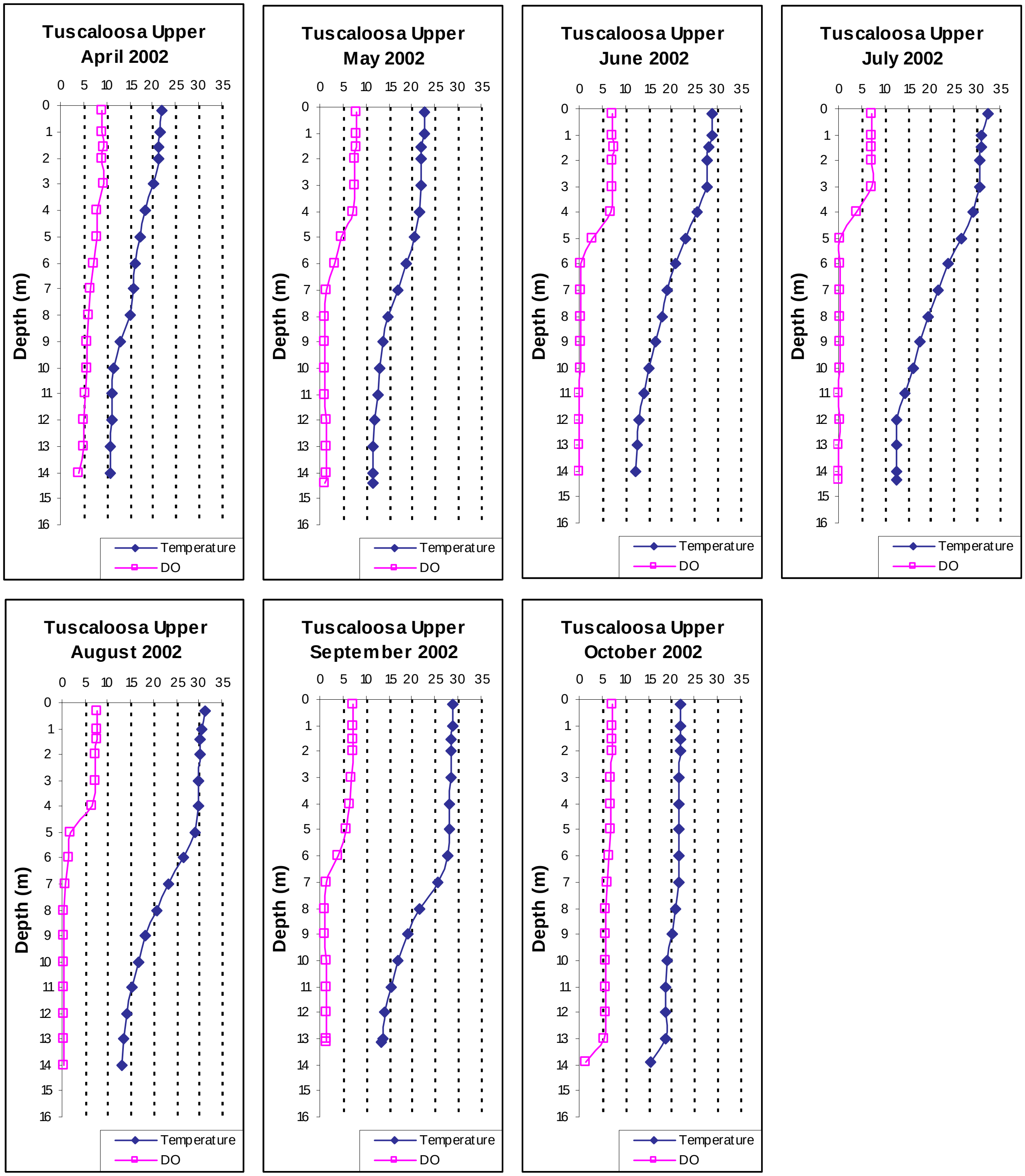


Figure 24. Depth profiles of dissolved oxygen (DO) and temperature (Temp) of Upper Tuscaloosa Reservoir, April-October 2002.

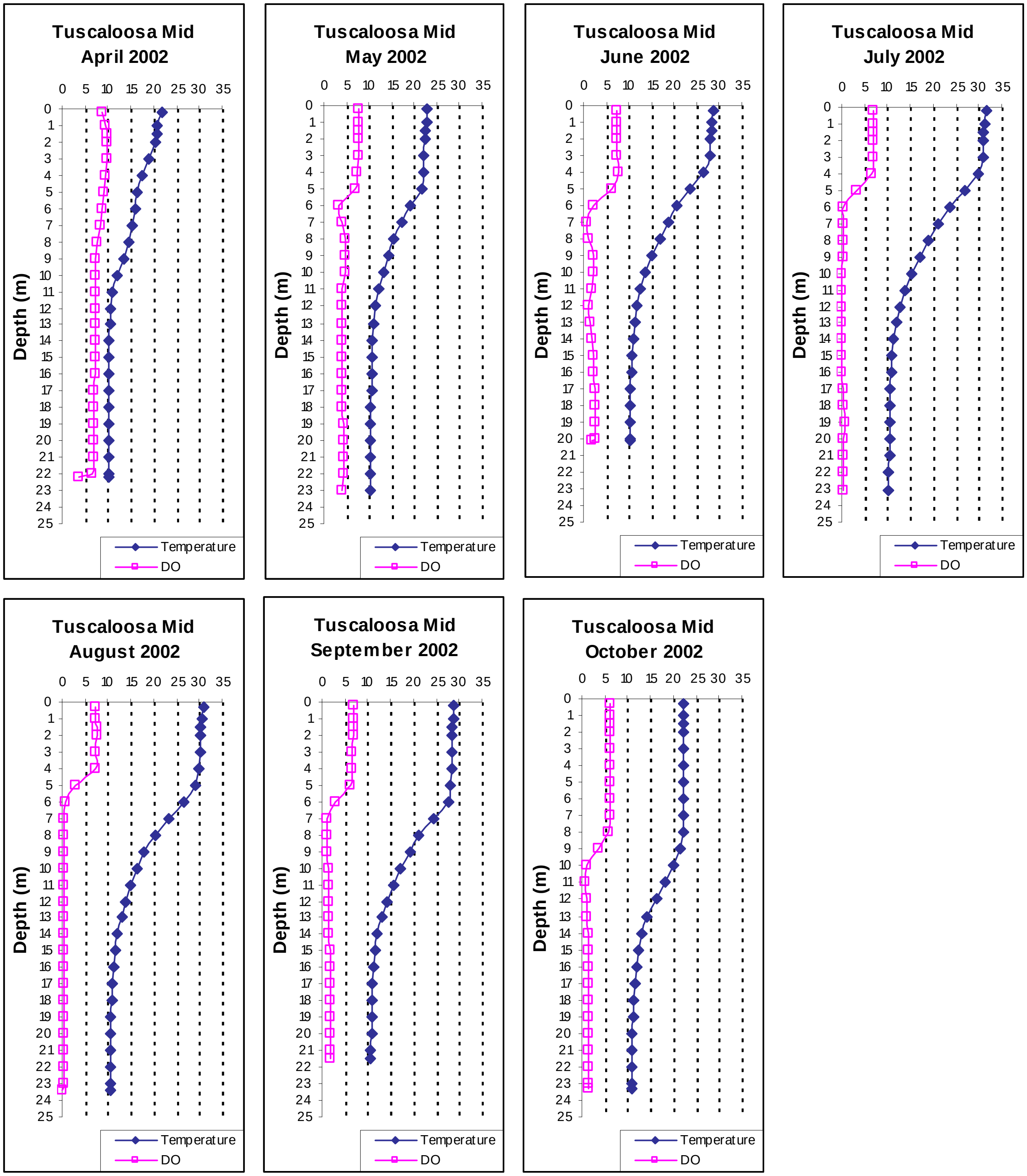


Figure 25. Depth profiles of dissolved oxygen (DO) and temperature (Temp) of Mid Tuscaloosa Reservoir, April-October 2002.

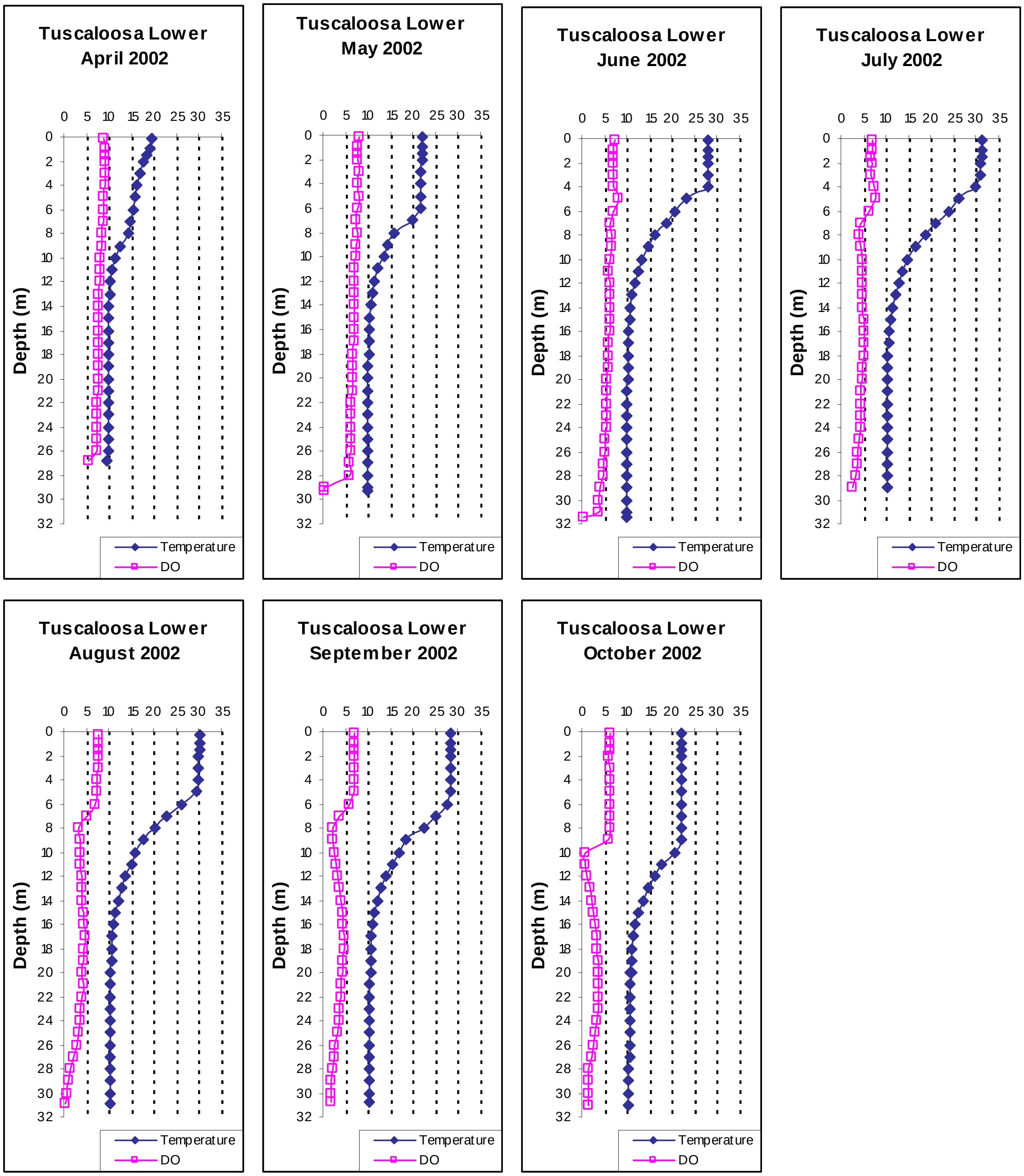


Figure 26. Depth profiles of dissolved oxygen (DO) and temperature (Temp) of the dam forebay of Tuscaloosa Reservoir, April-October 2002.

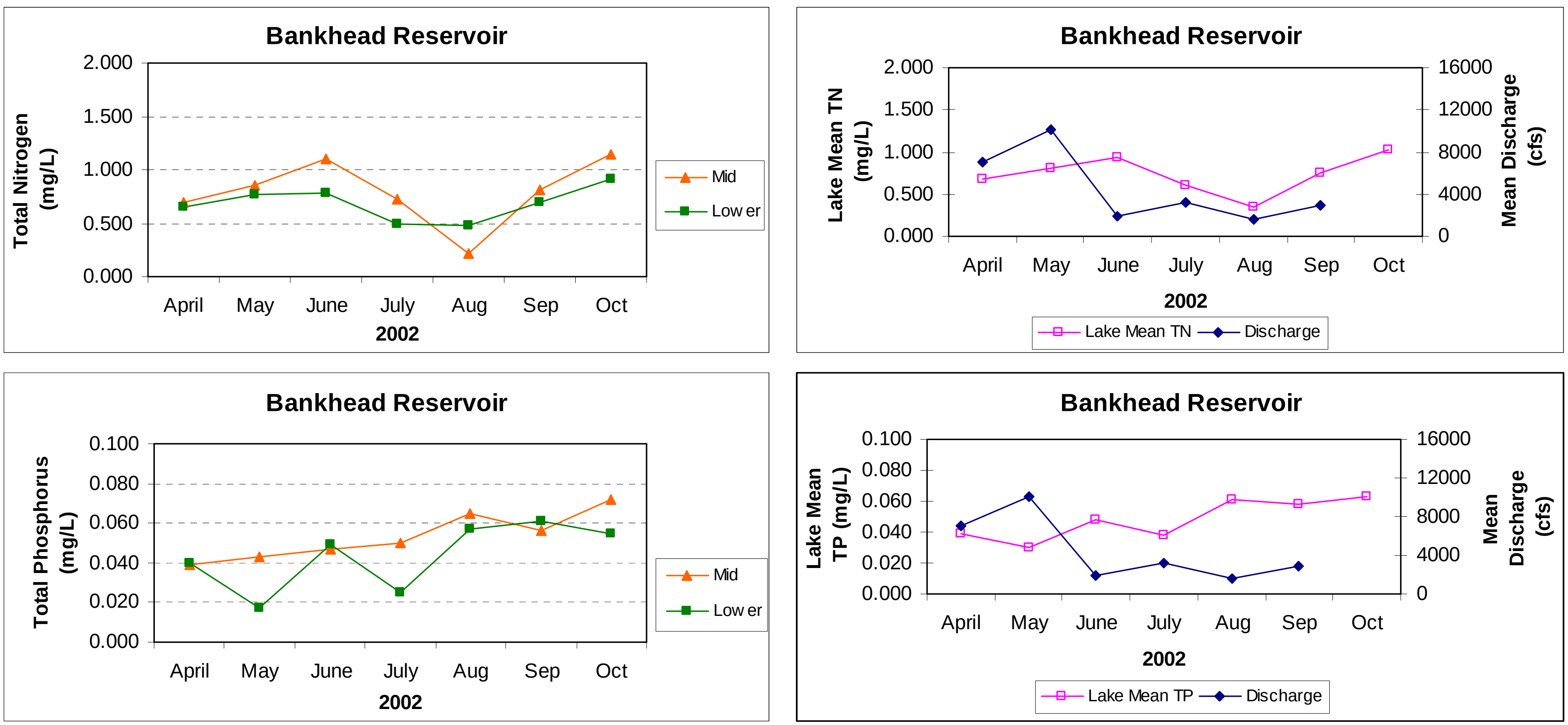


Figure 28. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Bankhead Reservoir, April-October 2002.

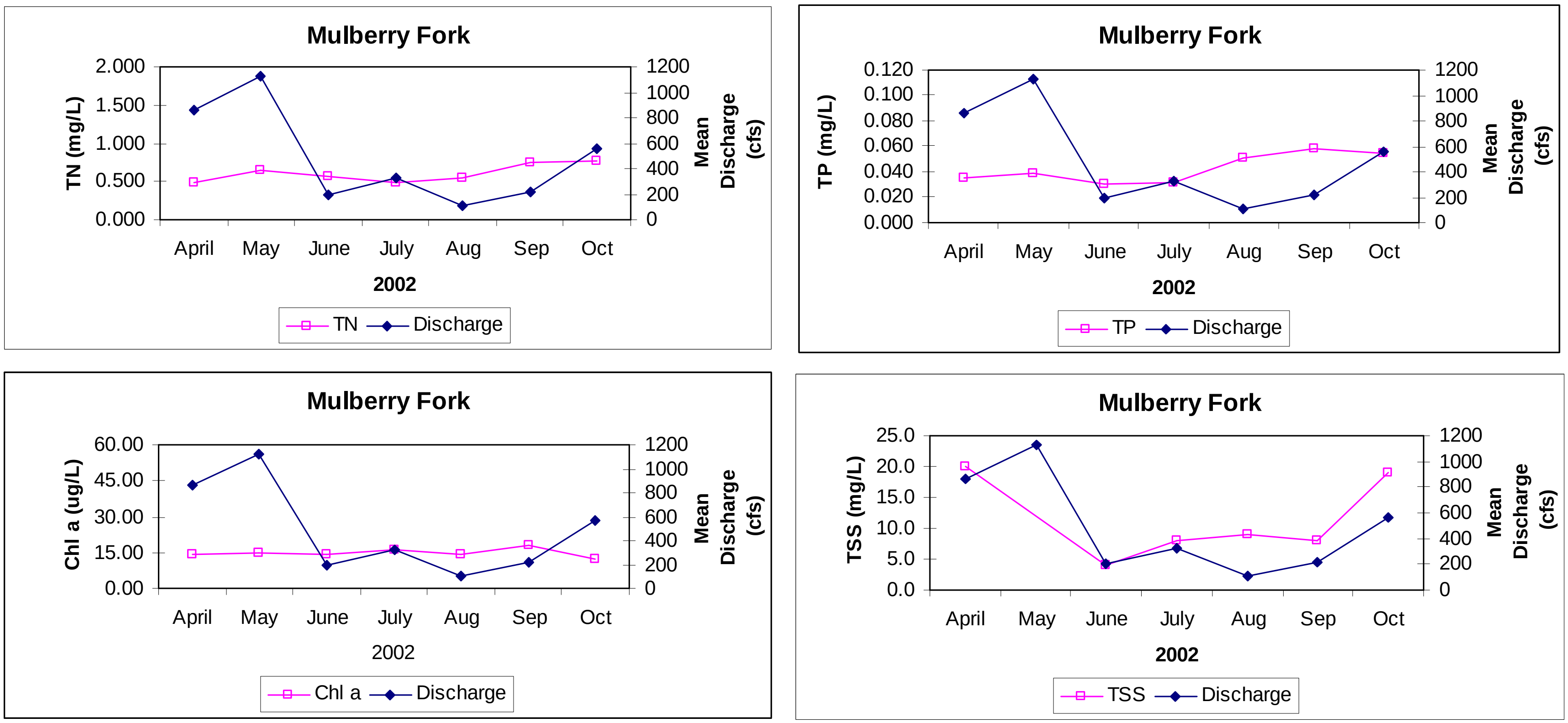


Figure 29. Total nitrogen (TN), total phosphorous (TP), chlorophyll a, and total suspended solids (TSS) of Mulberry Fork of Bankhead Reservoir, April-October 2002.

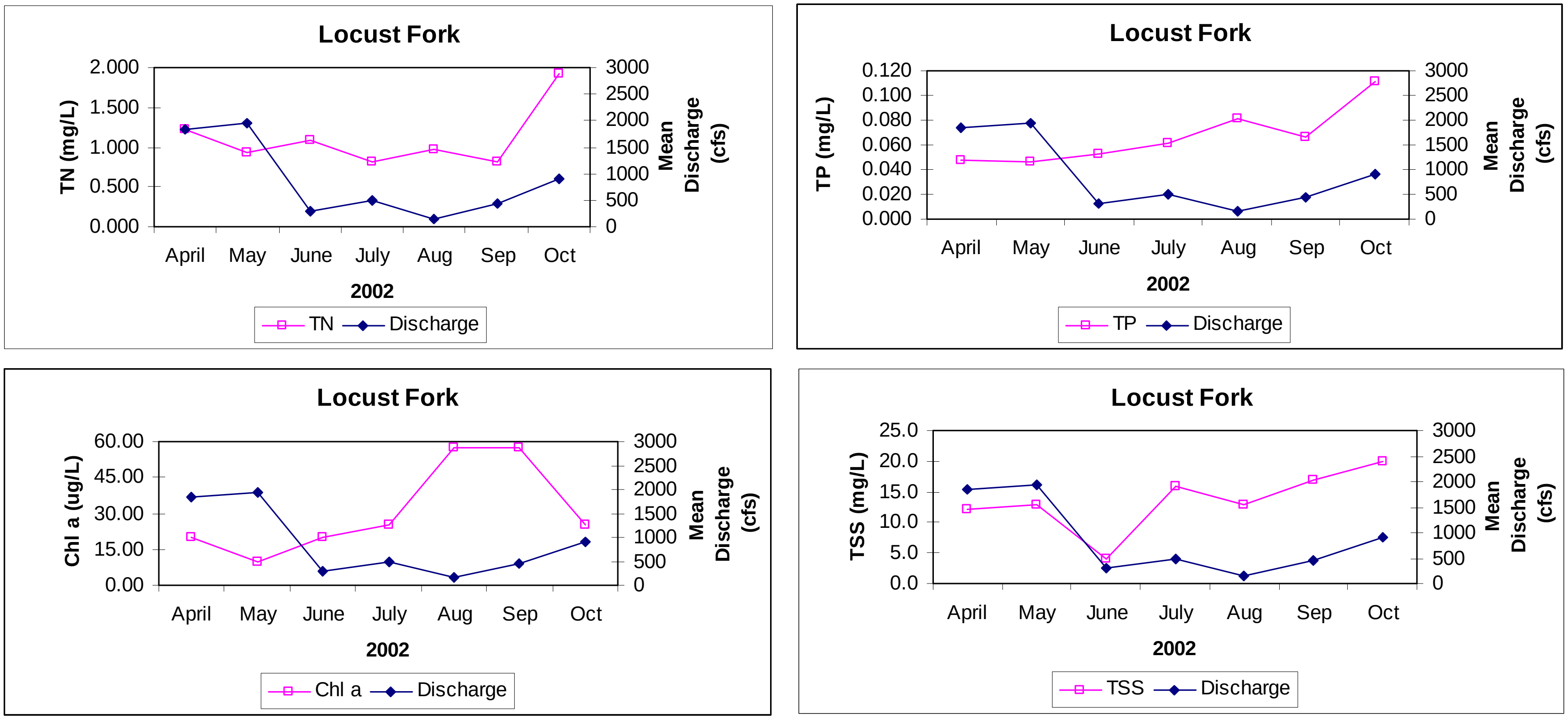


Figure 30. Total nitrogen (TN), total phosphorus (TP), chlorophyll a, and total suspended solids (TSS) in the Locust Fork of Bankhead Reservoir, April-October 2002.

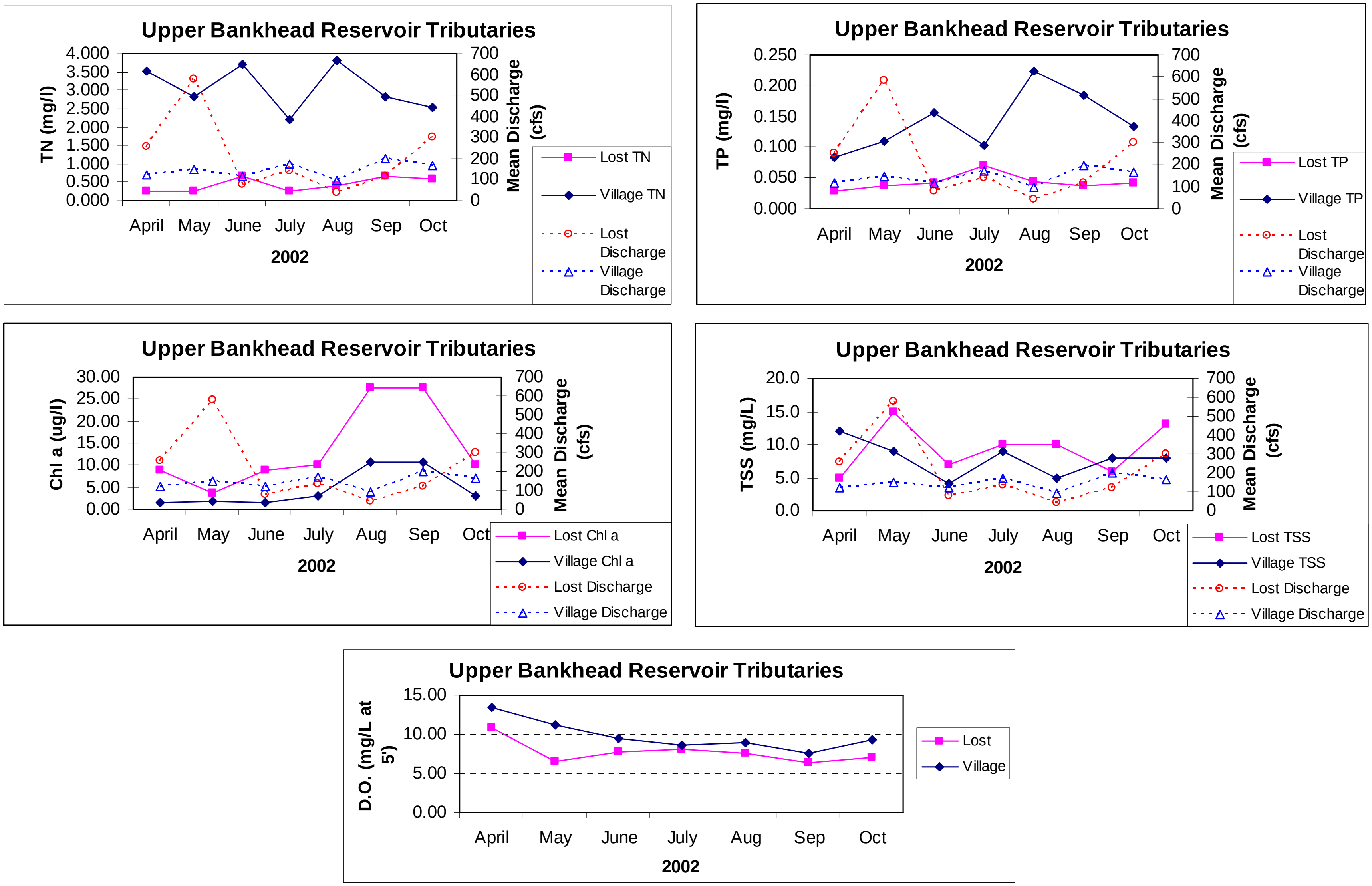


Figure 31. Total nitrogen (TN), total phosphorus (TP), mean chlorophyll *a*, total suspended solids (TSS), and dissolved oxygen (DO) of Upper Bankhead Reservoir Tributaries, April-October 2002.

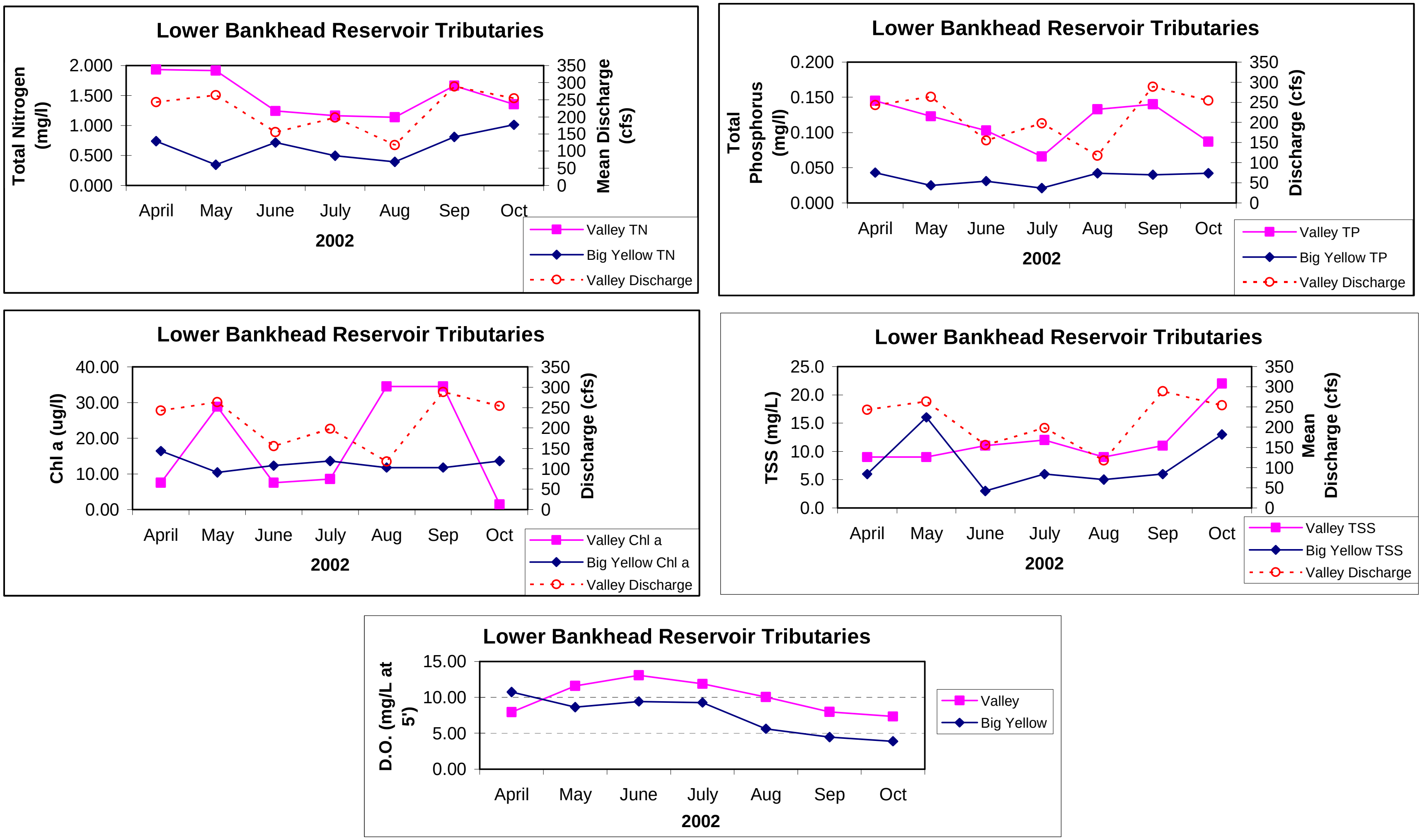


Figure 32. Total nitrogen (TN), total phosphorus (TP), mean chlorophyll *a*, total suspended solids (TSS), and dissolved oxygen (DO) of Lower Bankhead Reservoir Tributaries, April-October 2002.

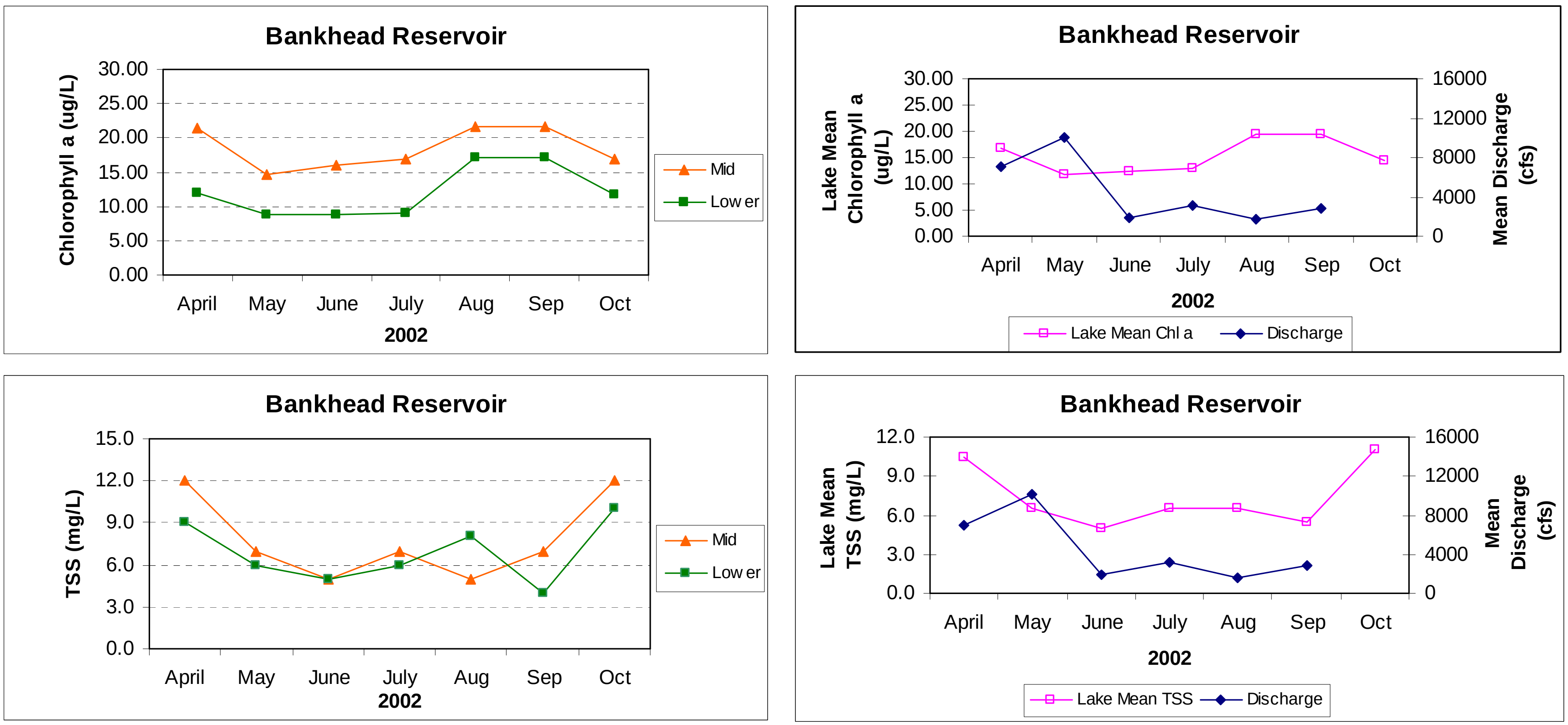


Figure 33. Chlorophyll a, lake mean chlorophyll a vs. discharge, total suspended solids (TSS), lake mean TSS vs. discharge of Bankhead Reservoir, April-October 2002.

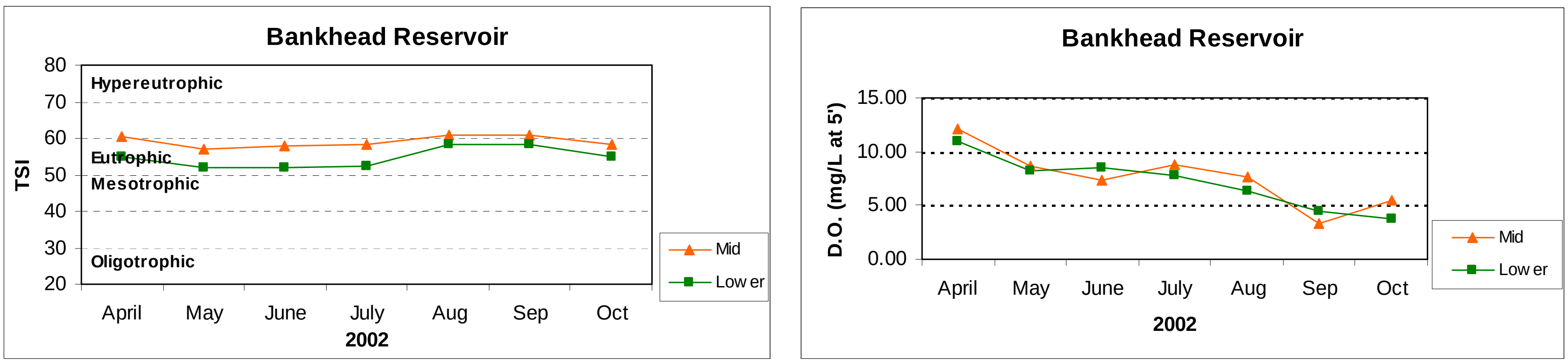


Figure 34. Trophic state index (TSI) and dissolved oxygen (DO) for Bankhead Reservoir, April-October 2002.

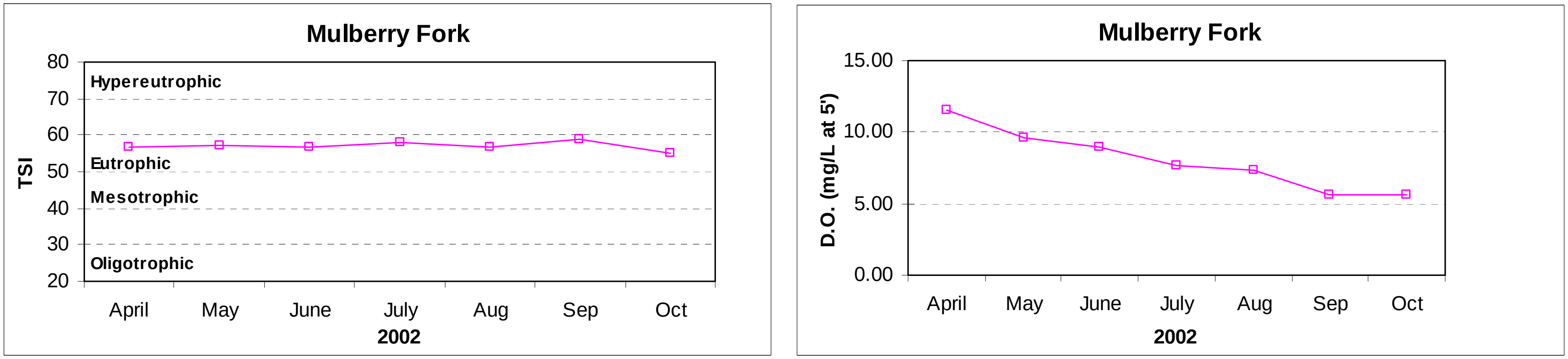


Figure 35. Trophic state index (TSI) and dissolved oxygen (DO) of Mulberry Fork of Bankhead Reservoir, April-October 2002.

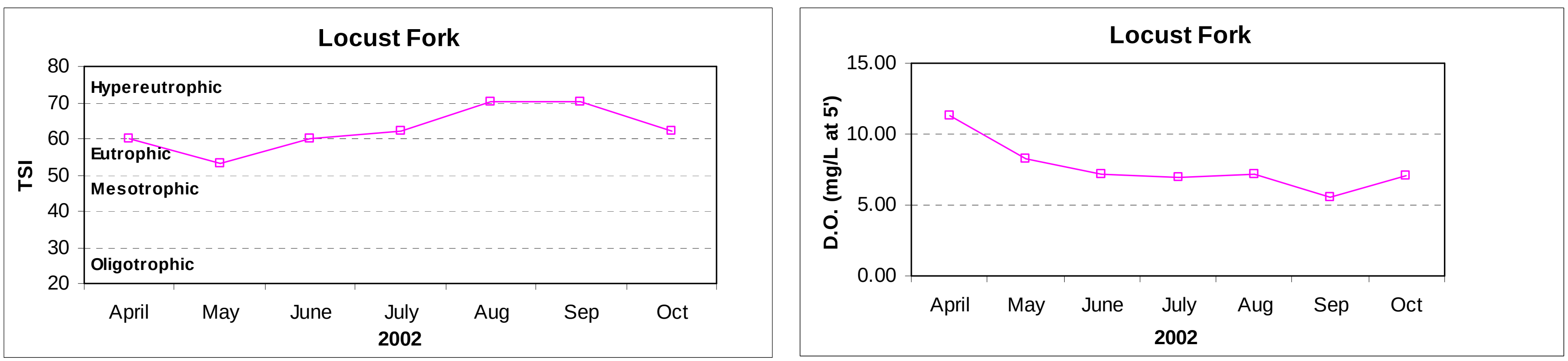


Figure 36. Trophic state index (TSI) and dissolved oxygen (DO) of Locust Fork of Bankhead Reservoir, April-October 2002.

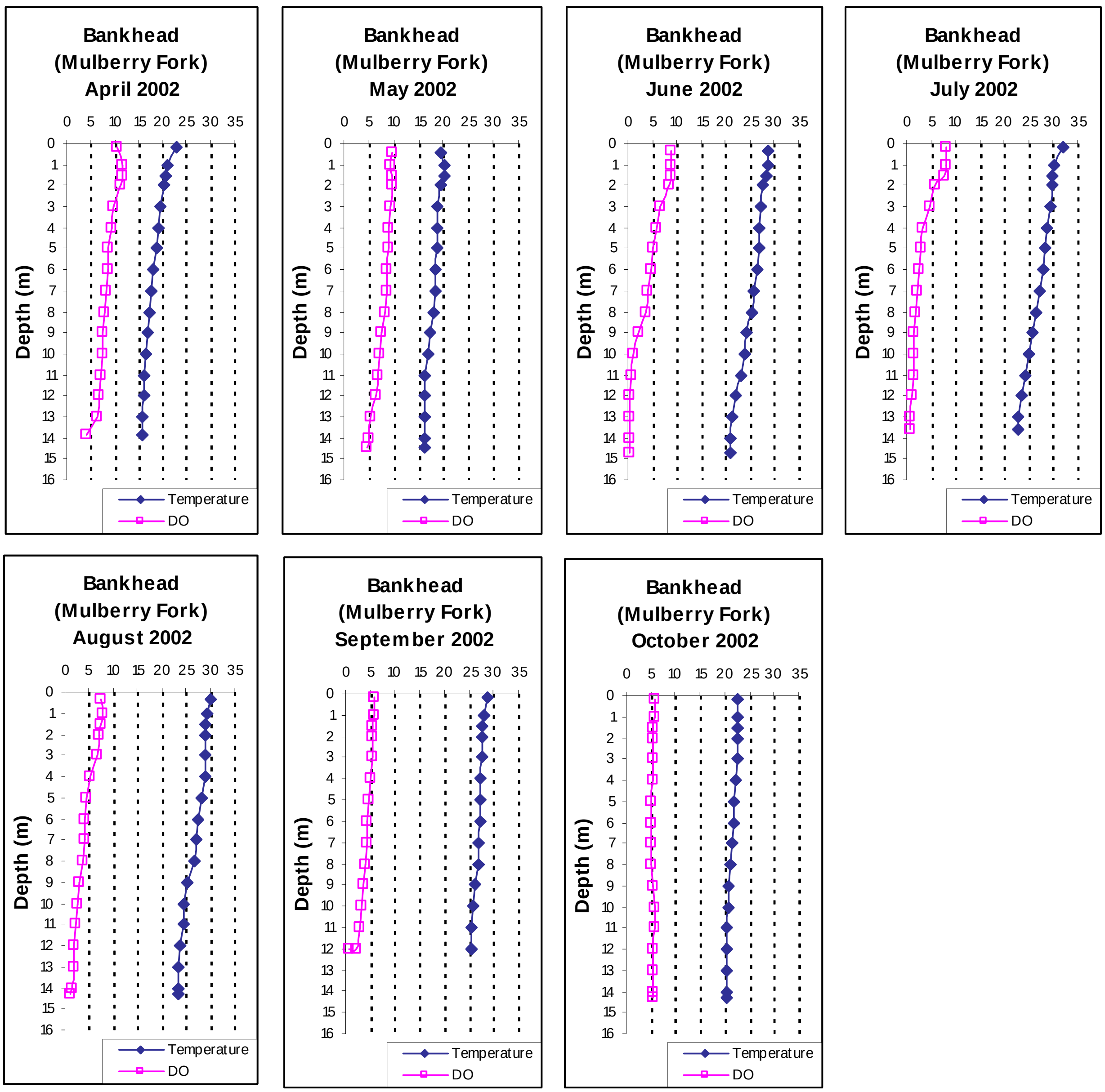


Figure 37. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Upper (Mulberry) Bankhead Reservoir, April-October 2002.

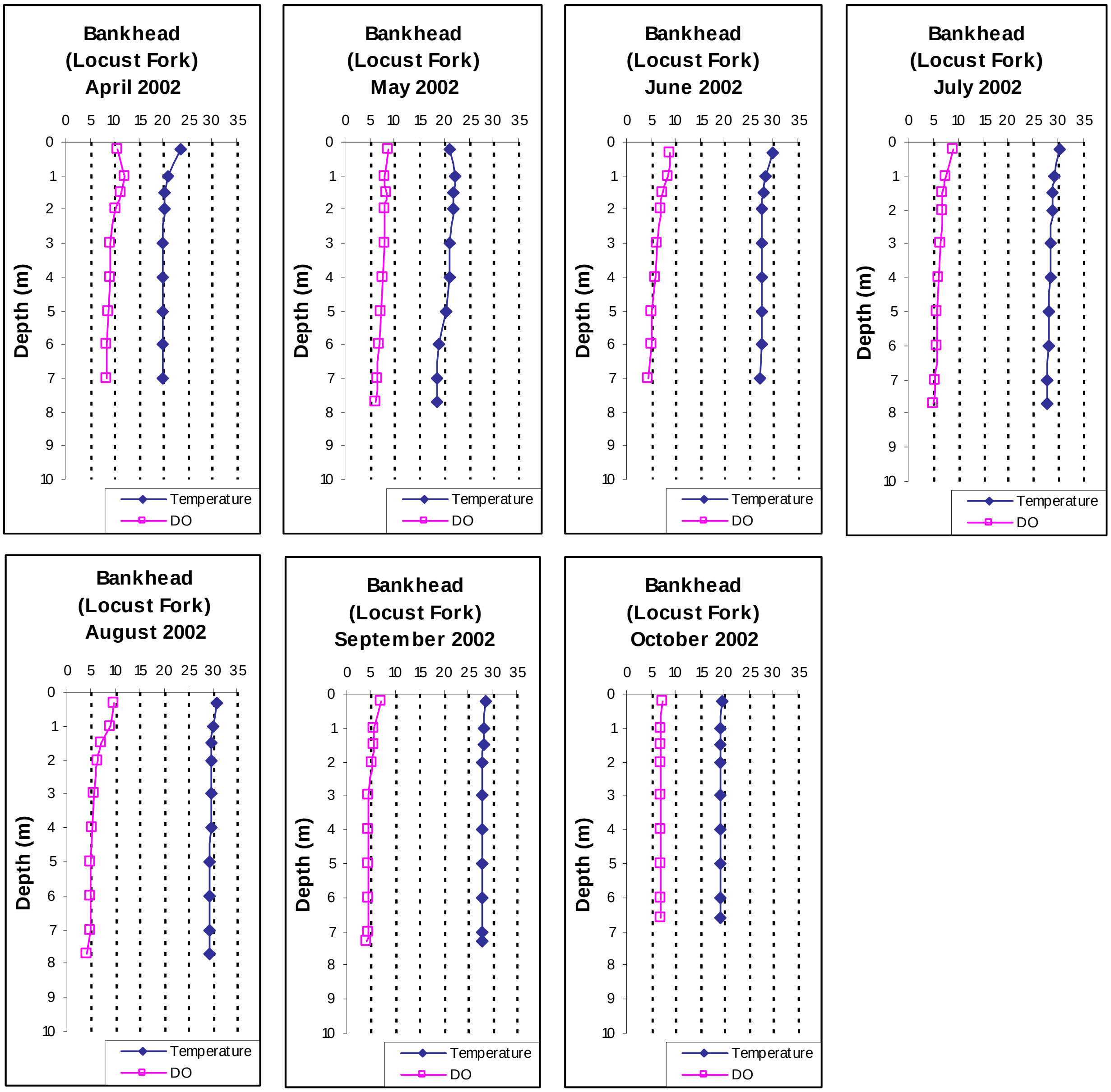


Figure 38. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Upper (Locust) Bankhead Reservoir, April-October 2002.

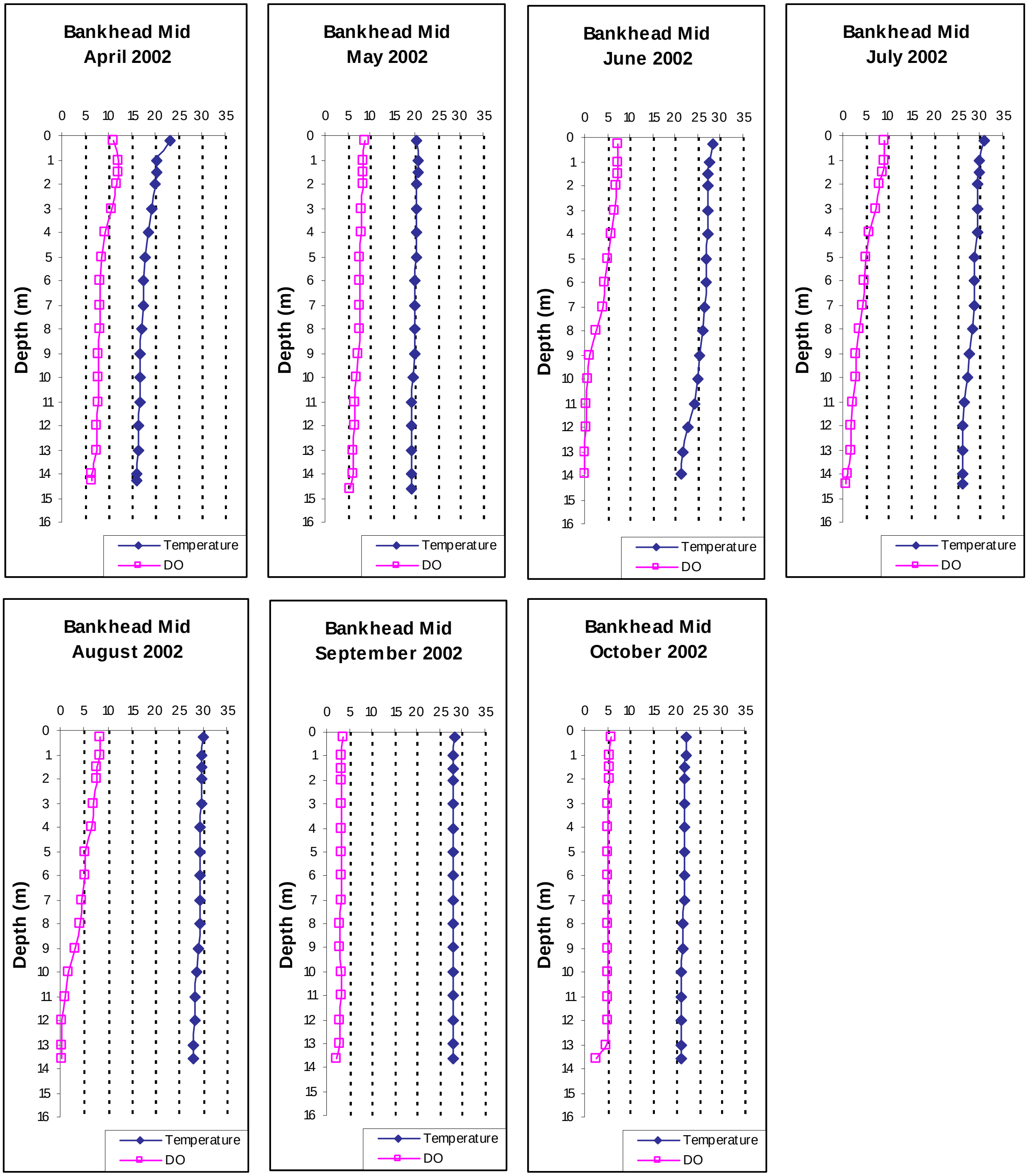


Figure 39. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Mid Bankhead Reservoir, April-October 2002.

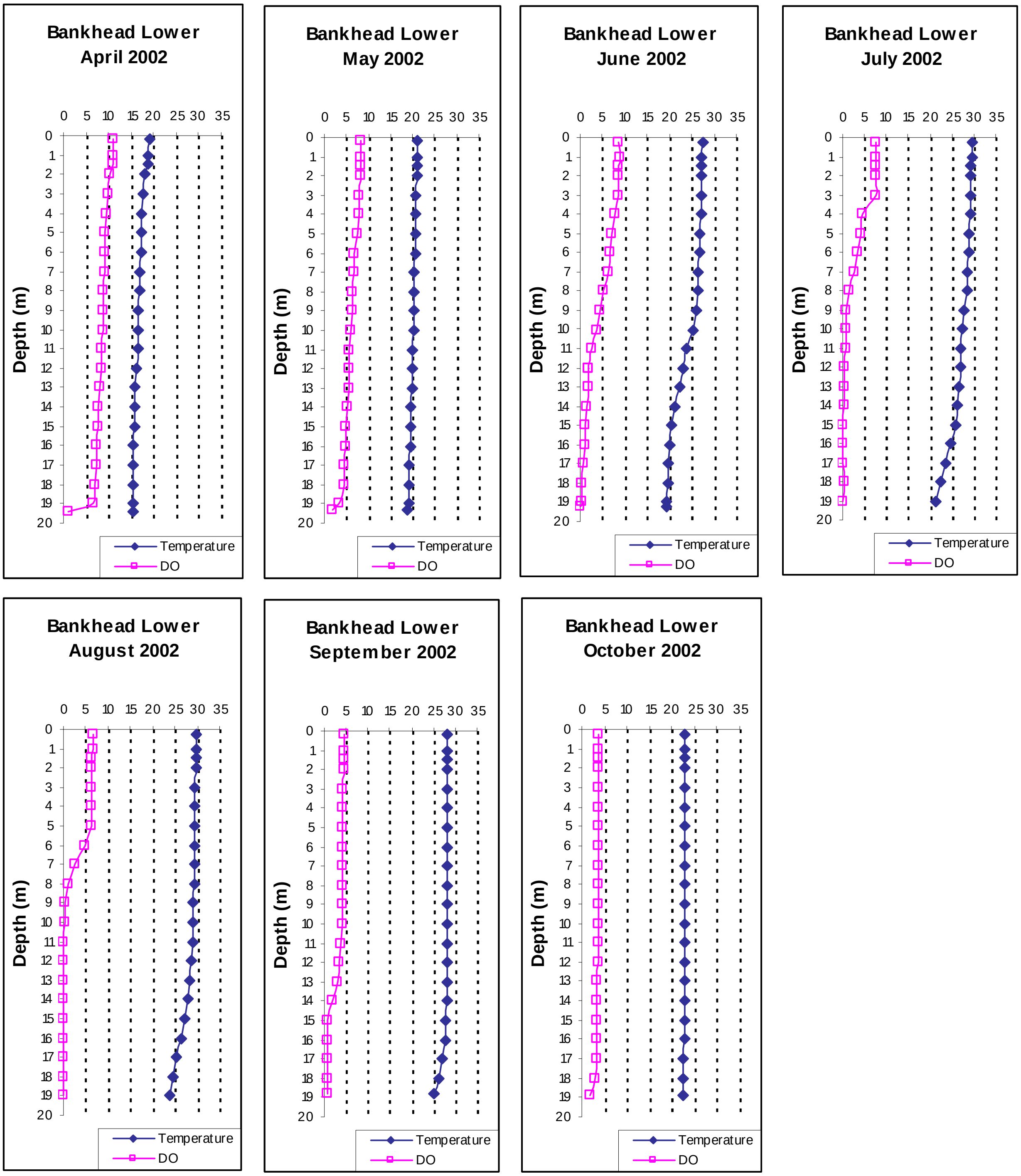


Figure 40. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Bankhead Reservoir, April-October 2002.

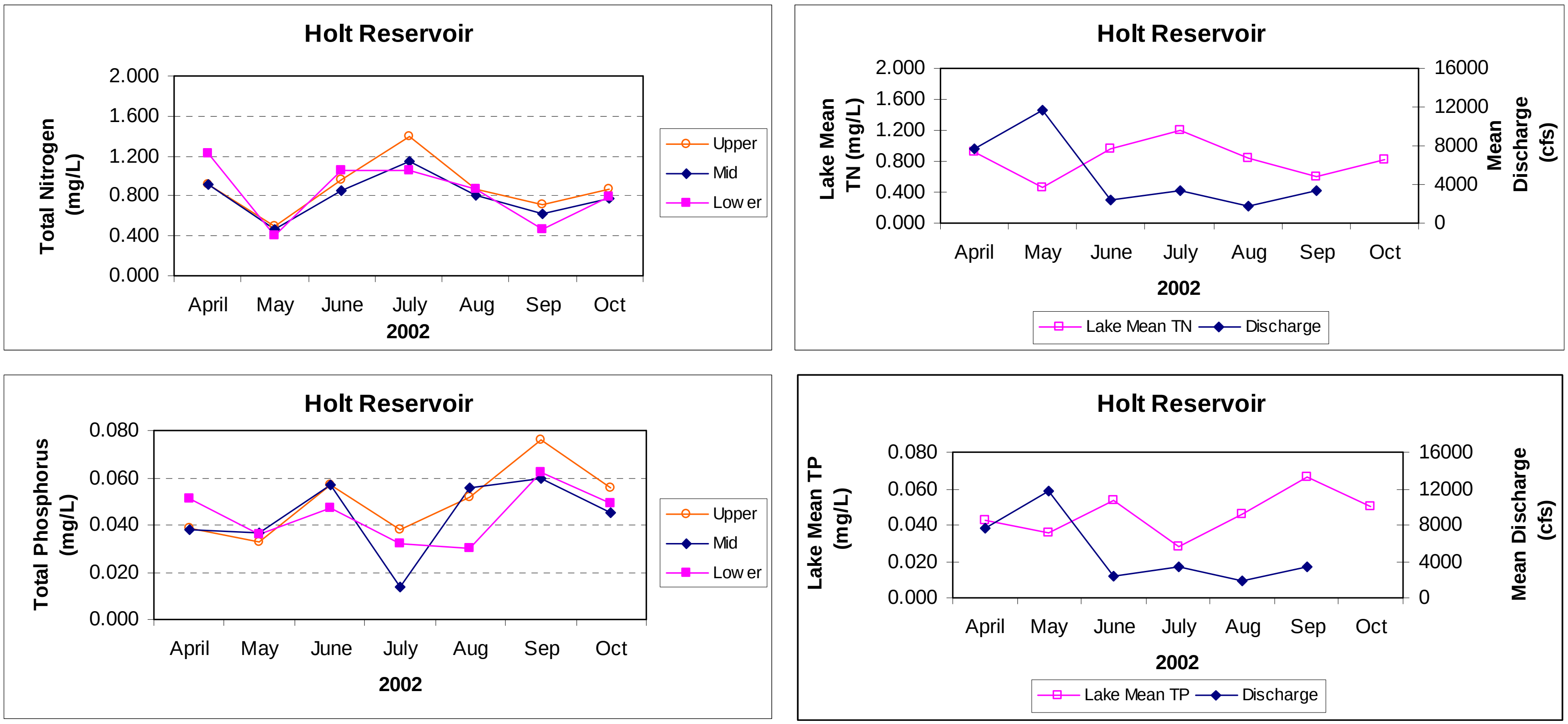


Figure 42. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Holt Reservoir, April – October 2002.

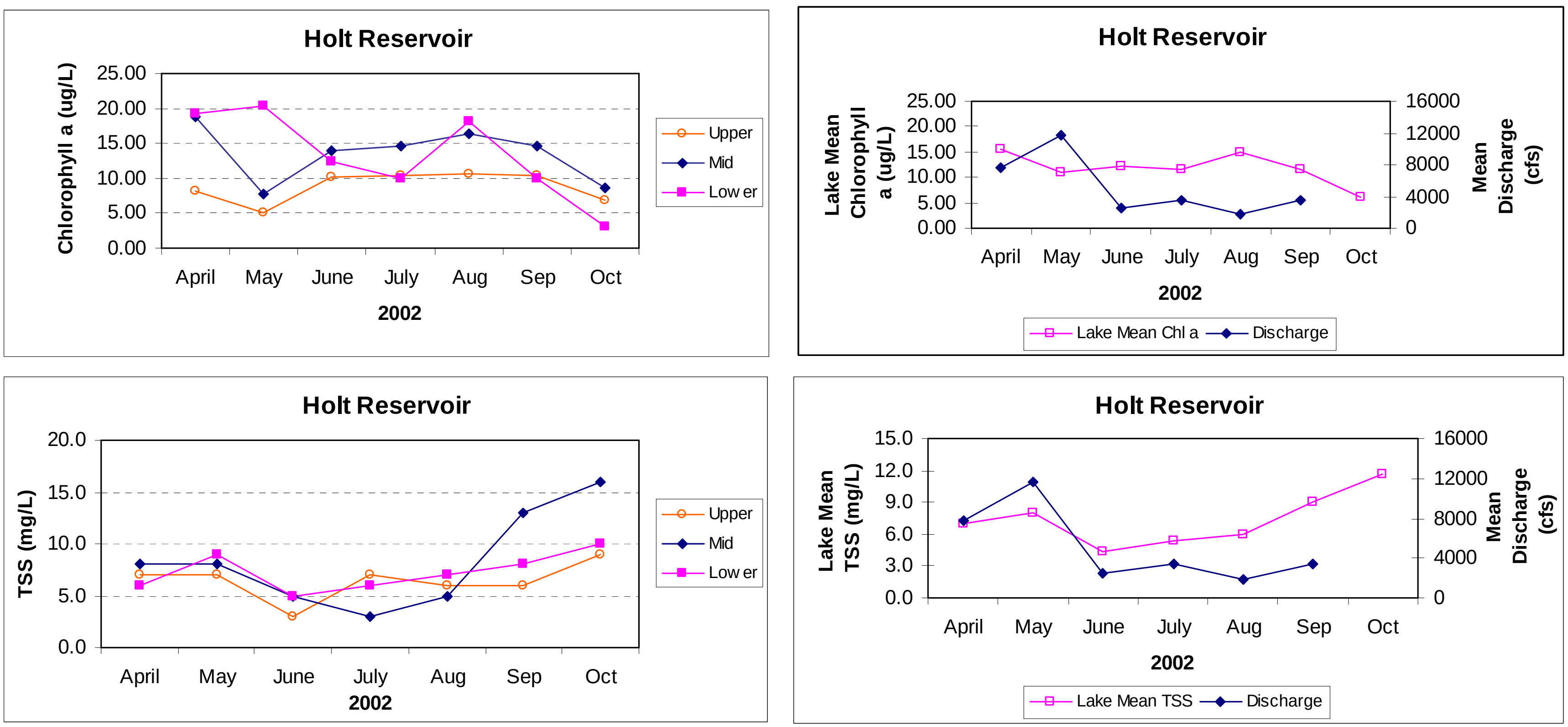


Figure 43. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS) and lake mean TSS vs. discharge of Holt Reservoir, April-October 2002.

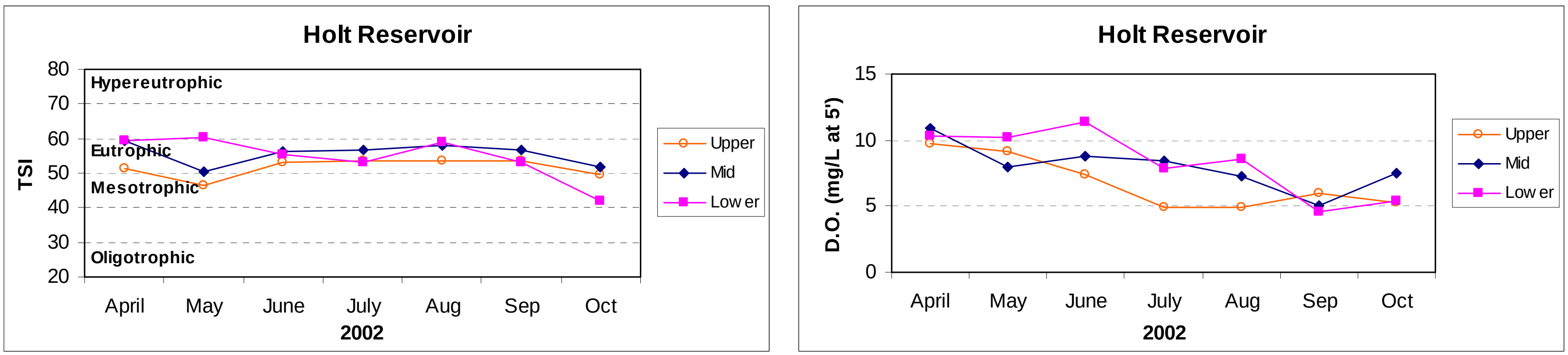


Figure 44. Trophic state index (TSI) and dissolved oxygen (DO) of Holt Reservoir, April – October 2002.

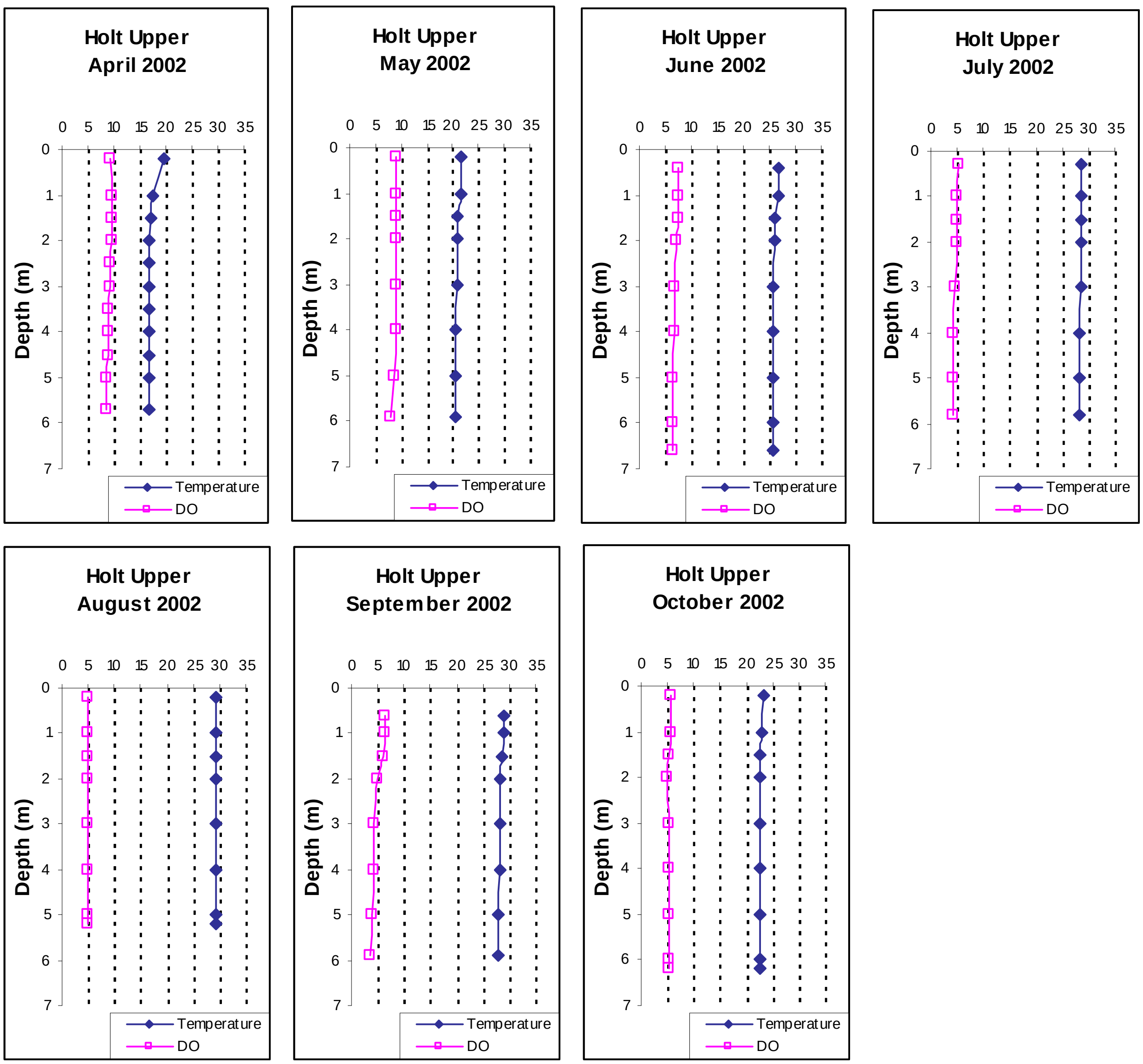


Figure 45. Depth profiles of dissolved oxygen (DO) and temperature (Temp) of Upper Holt Reservoir, April-October 2002.

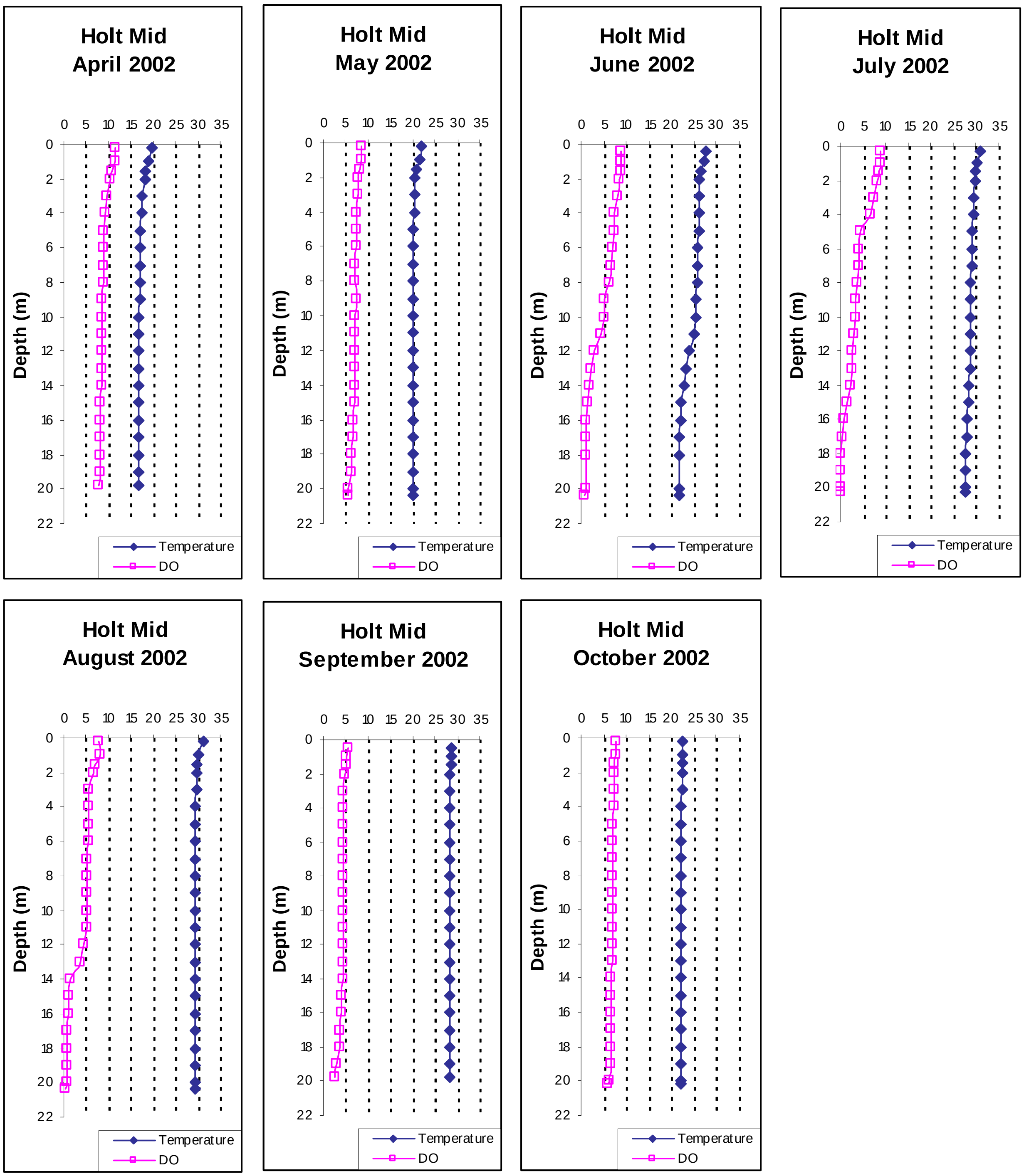


Figure 46. Depth profiles of dissolved oxygen (DO) and temperature (Temp) of Mid Holt Reservoir, April-October 2002.

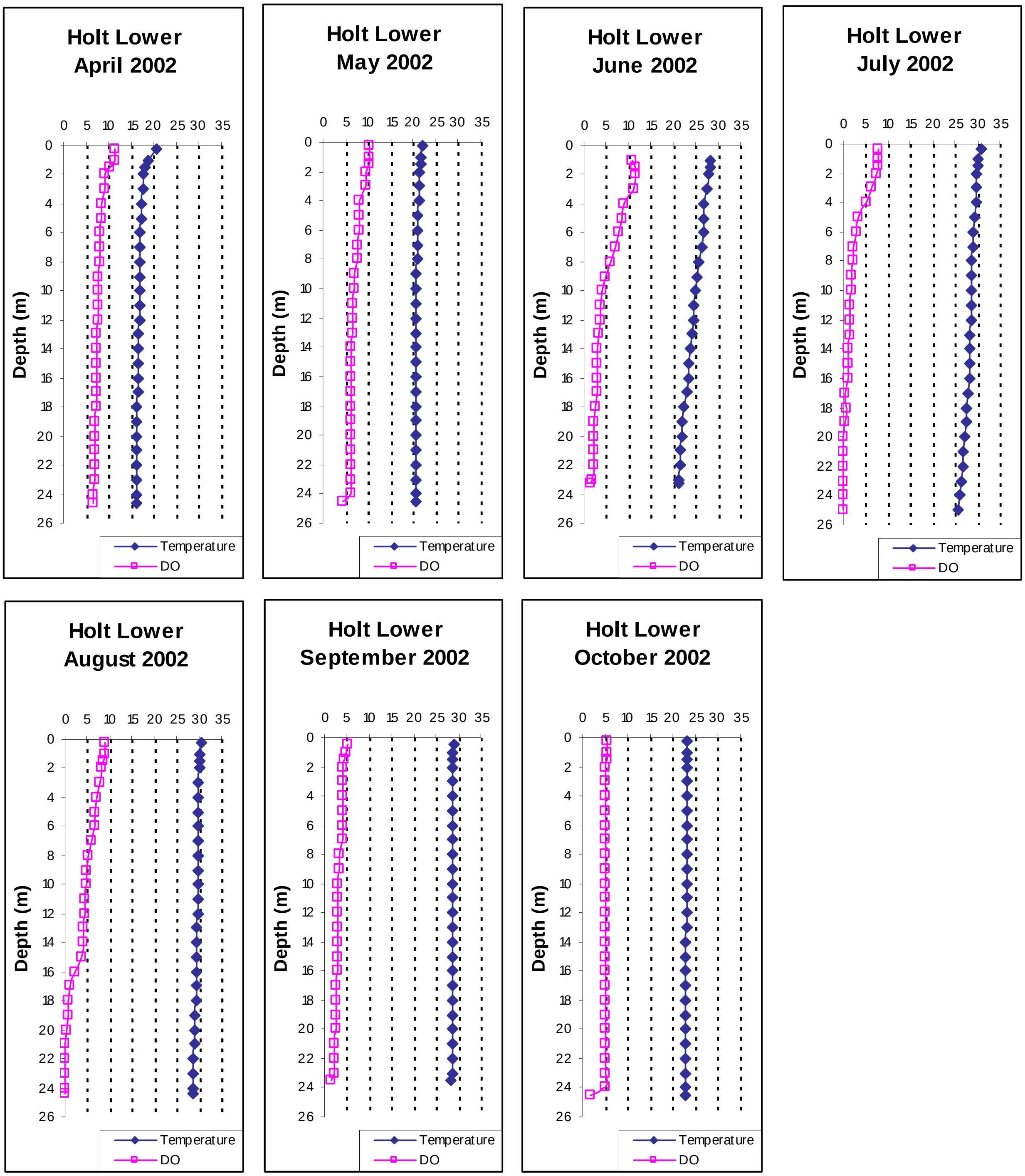


Figure 47. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Holt Reservoir, April-October 2002.

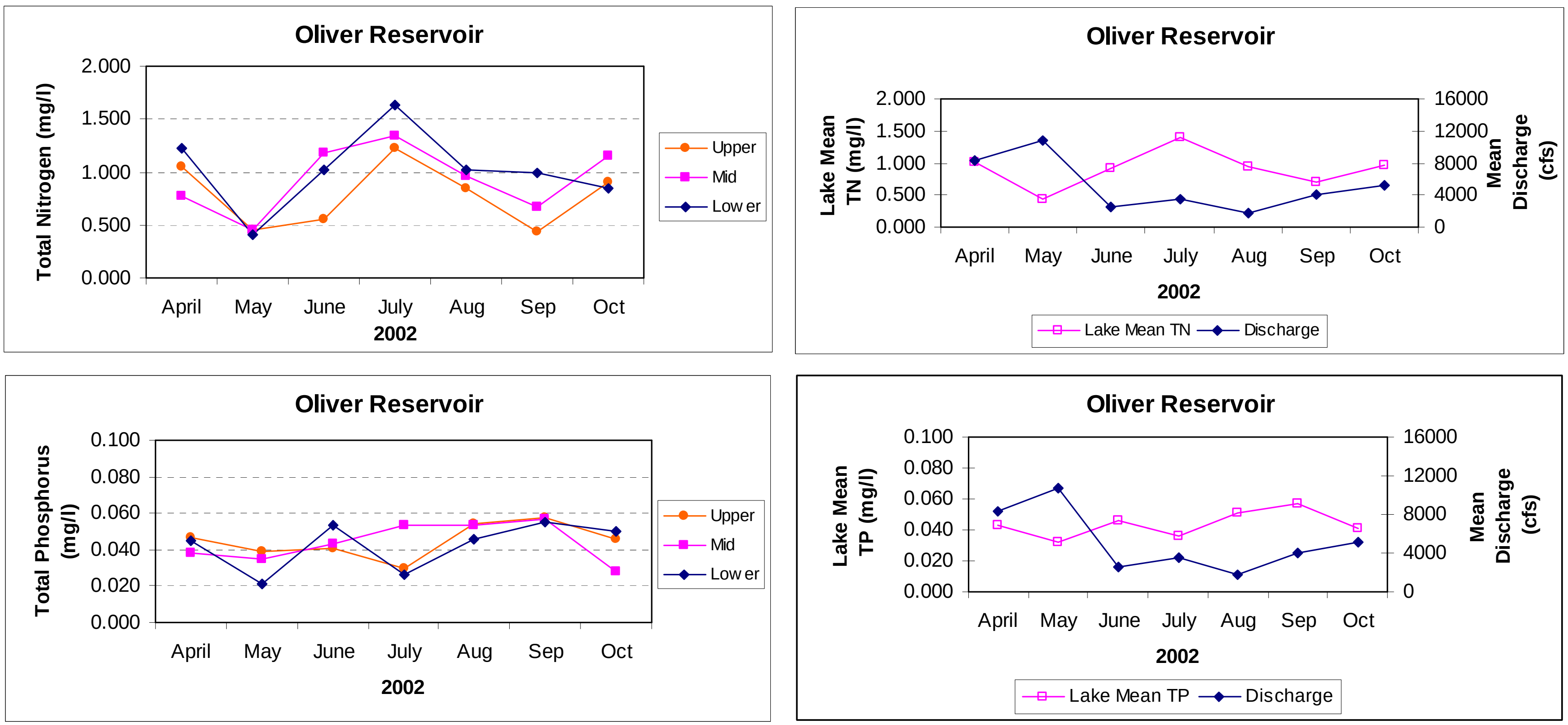


Figure 49. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Oliver Reservoir, April-October 2002.

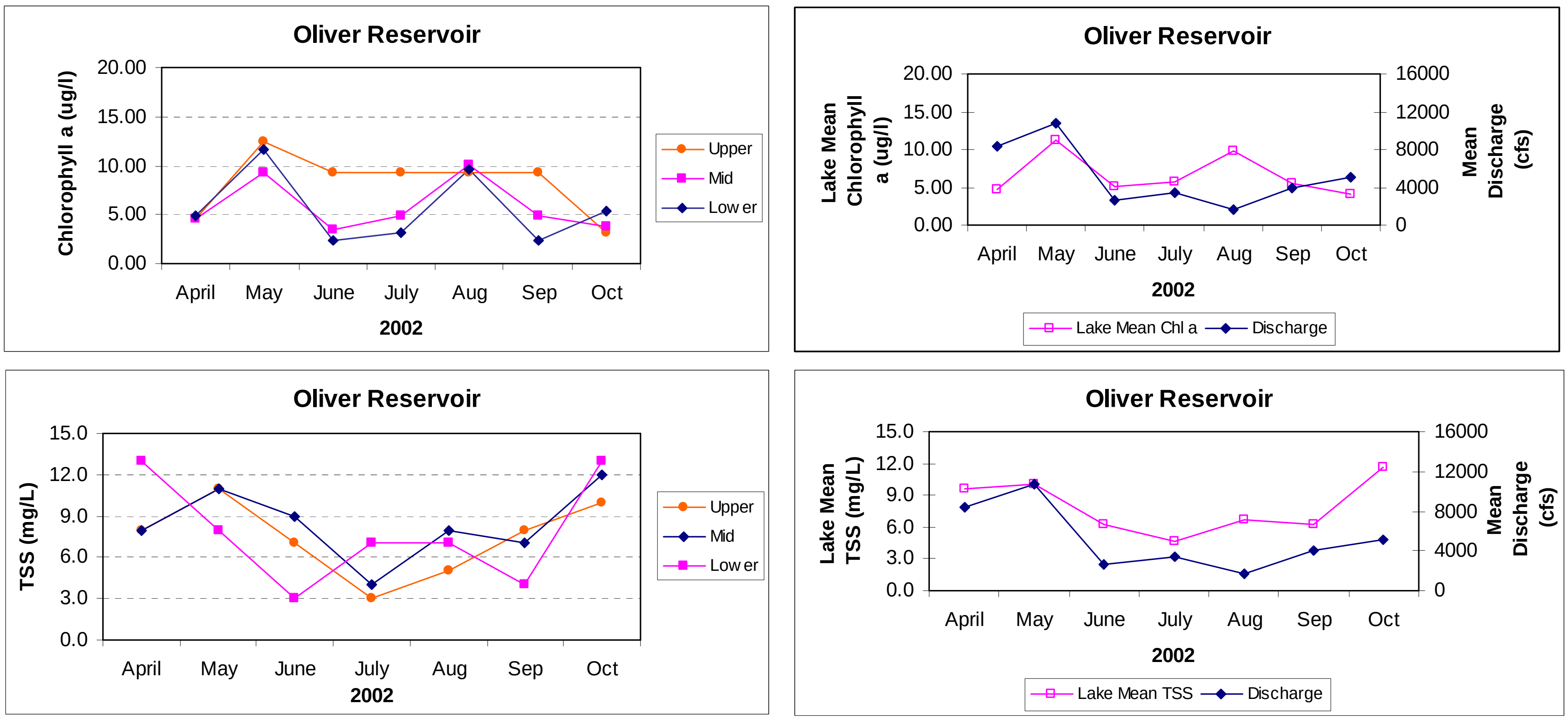


Figure 50. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS) and lake mean TSS vs. discharge of Oliver Reservoir, April-October 2002.

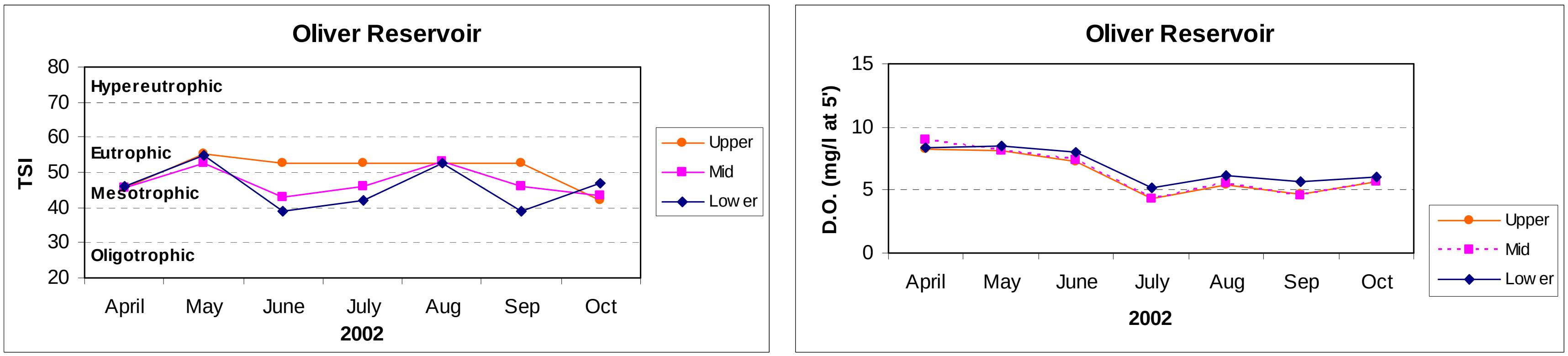


Figure 51. Trophic state index (TSI) and dissolved oxygen (DO) of Oliver Reservoir, April-October 2002.

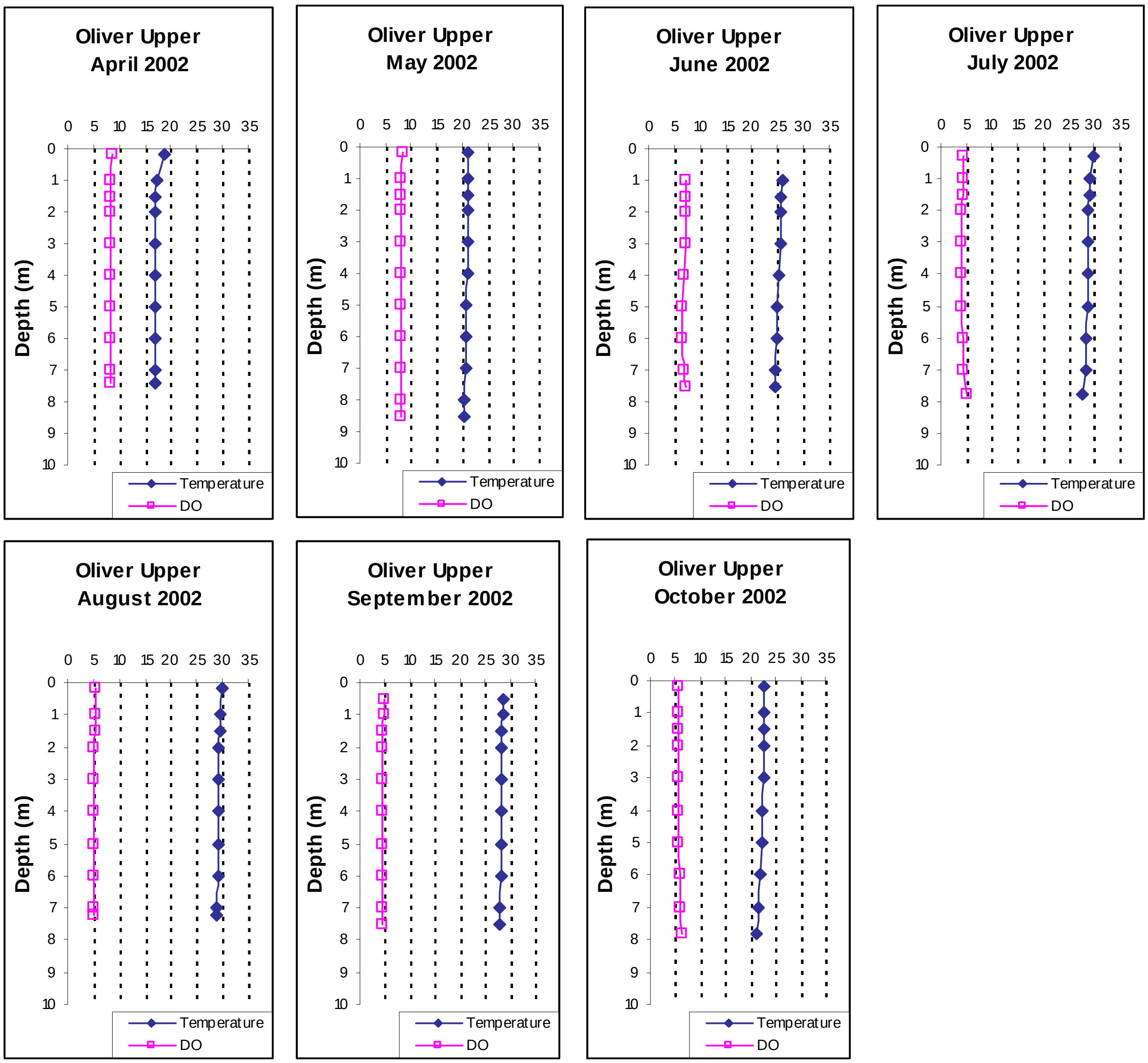


Figure 52. Depth profiles of dissolved oxygen (DO) and temperature (Temp) of Upper Oliver Reservoir, April-October 2002.

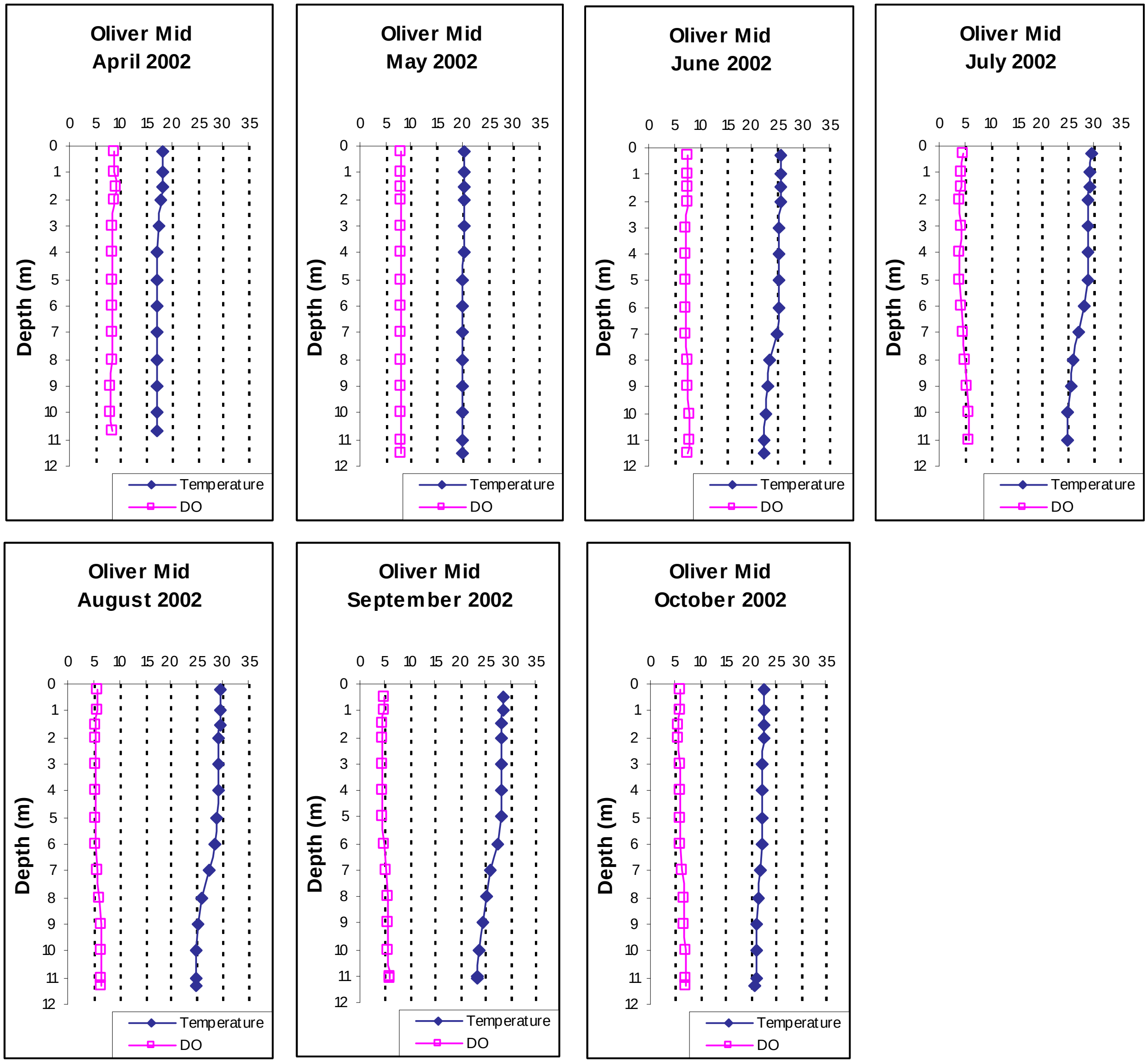


Figure 53. Depth profiles of dissolved oxygen (DO) and temperature (Temp) of Mid Oliver Reservoir, April-October 2002.

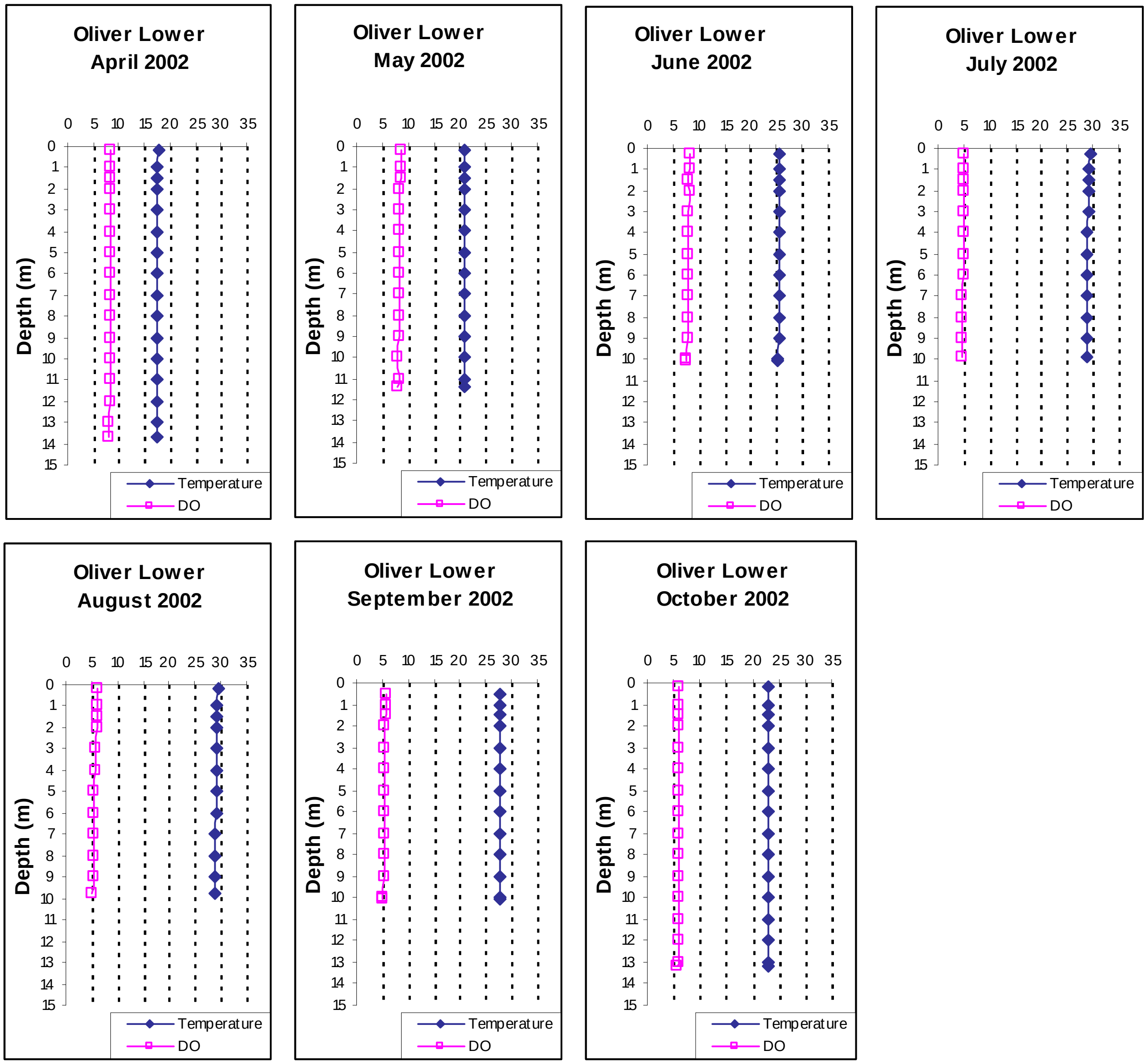


Figure 54. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Oliver Reservoir, April-October 2002.

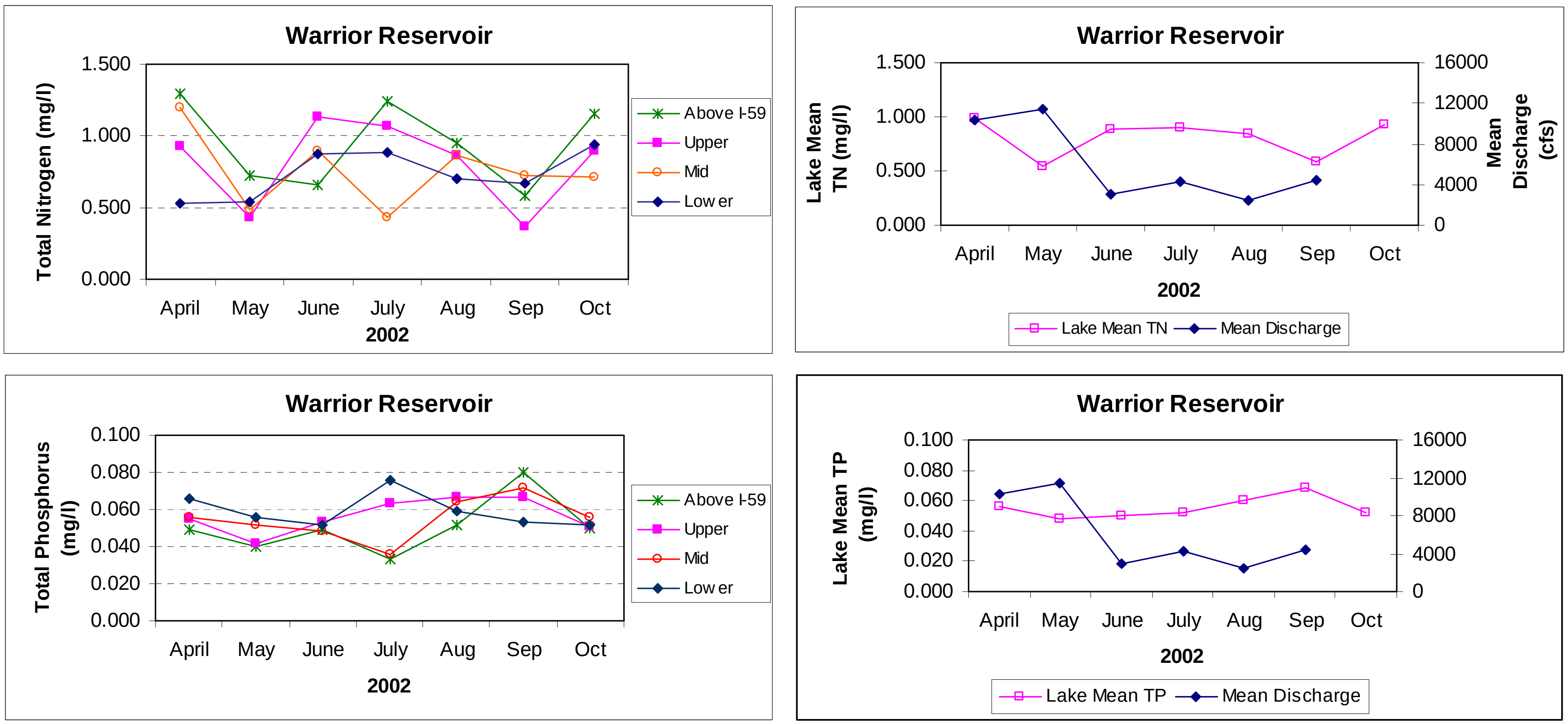


Figure 56. Total nitrogen (TN), lake mean TN vs. discharge, total phosphorus (TP), and lake mean TP vs. discharge of Warrior Reservoir, April-October 2002.

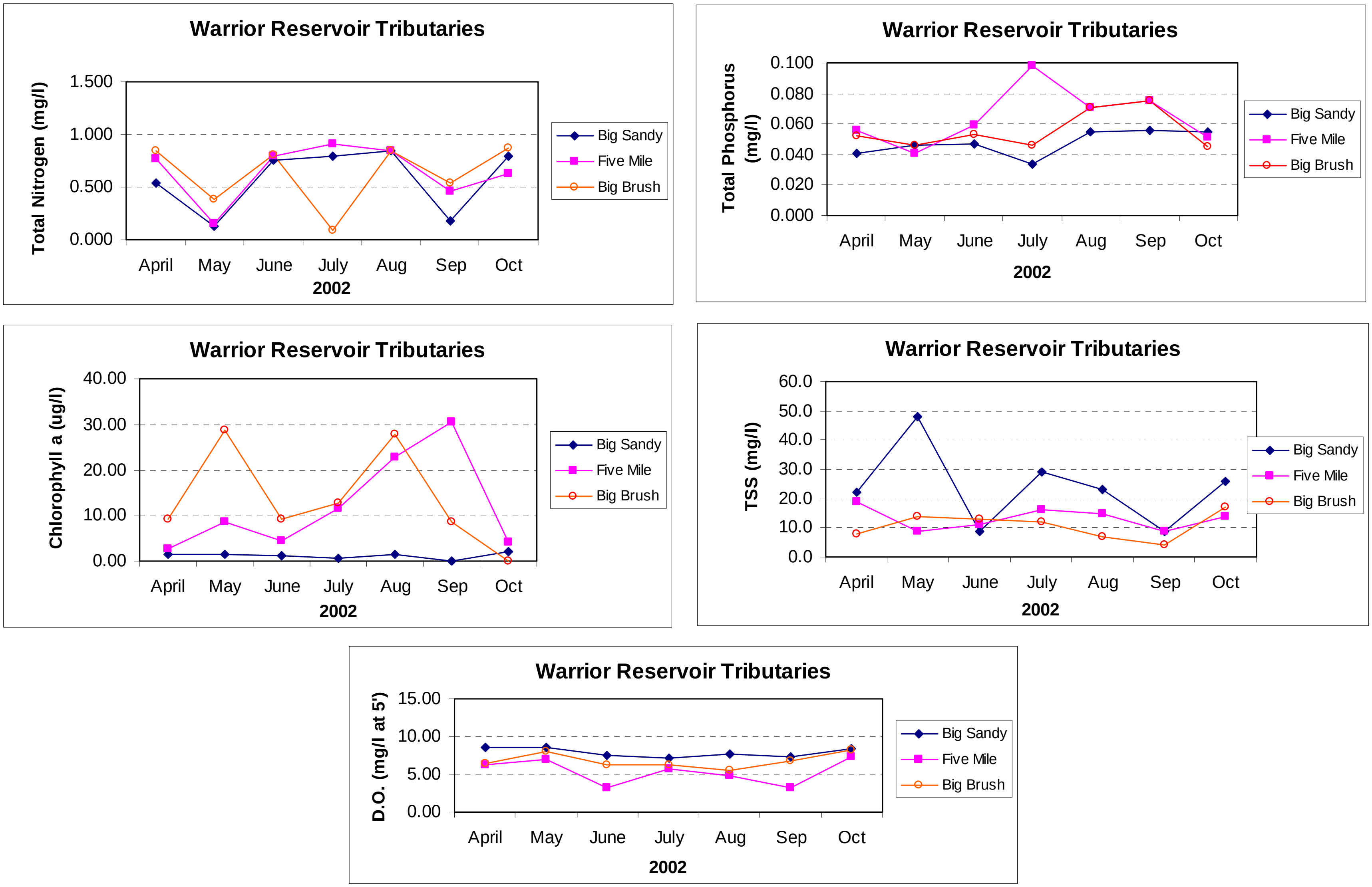


Figure 57. Total nitrogen (TN), total phosphorus (TP), chlorophyll *a*, total suspended solids (TSS), and dissolved oxygen (DO) of Warrior Reservoir Tributaries, April-October 2002.

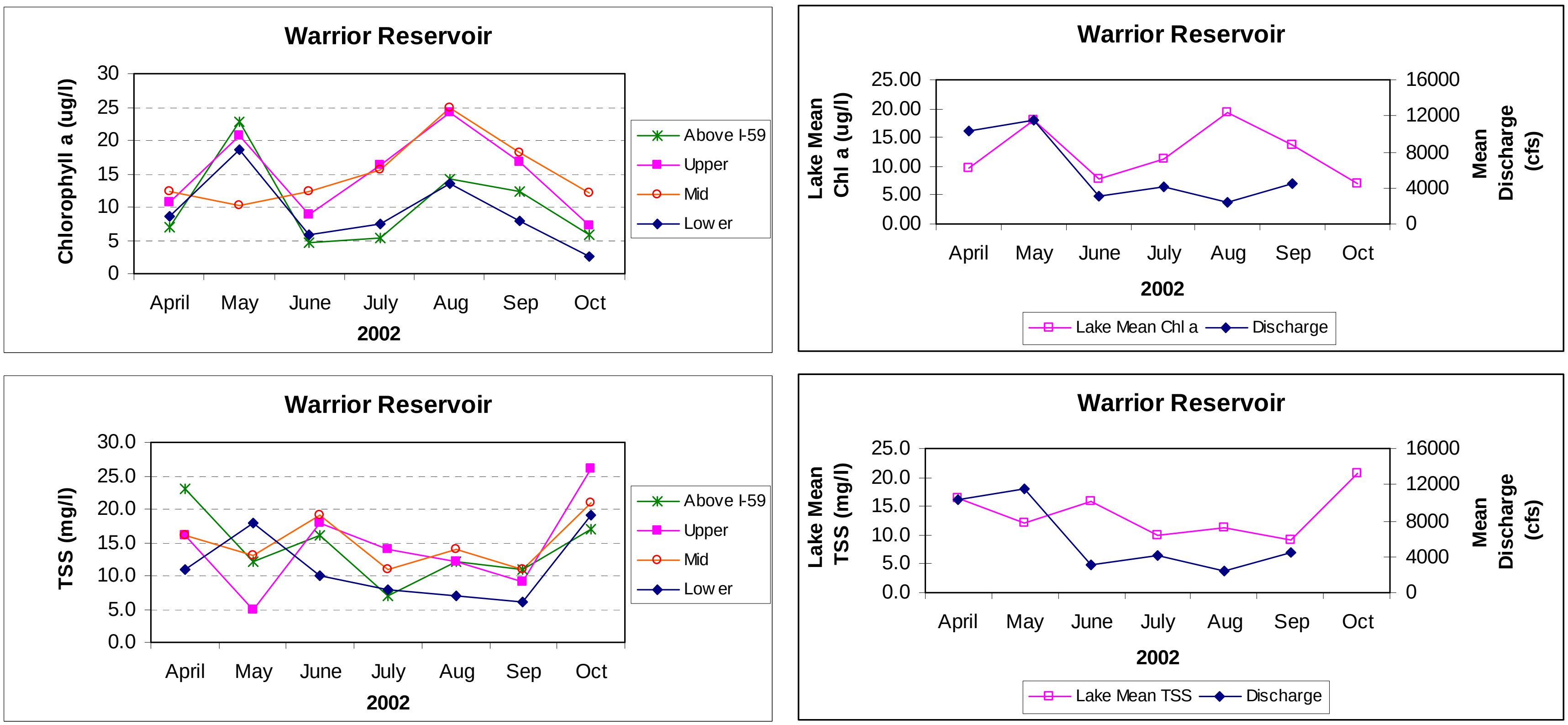


Figure 58. Chlorophyll *a*, lake mean chlorophyll *a* vs. discharge, total suspended solids (TSS) and lake mean total suspended solids (TSS) vs. discharge of Warrior Reservoir, April-October 2002.

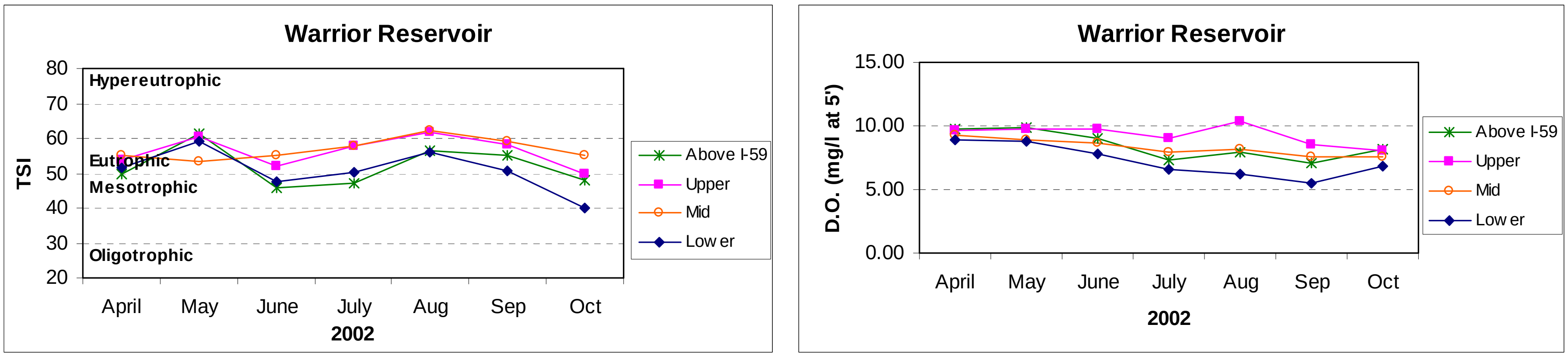


Figure 59. Trophic state index (TSI) and dissolved oxygen (DO) of Warrior Reservoir, April-October 2002.

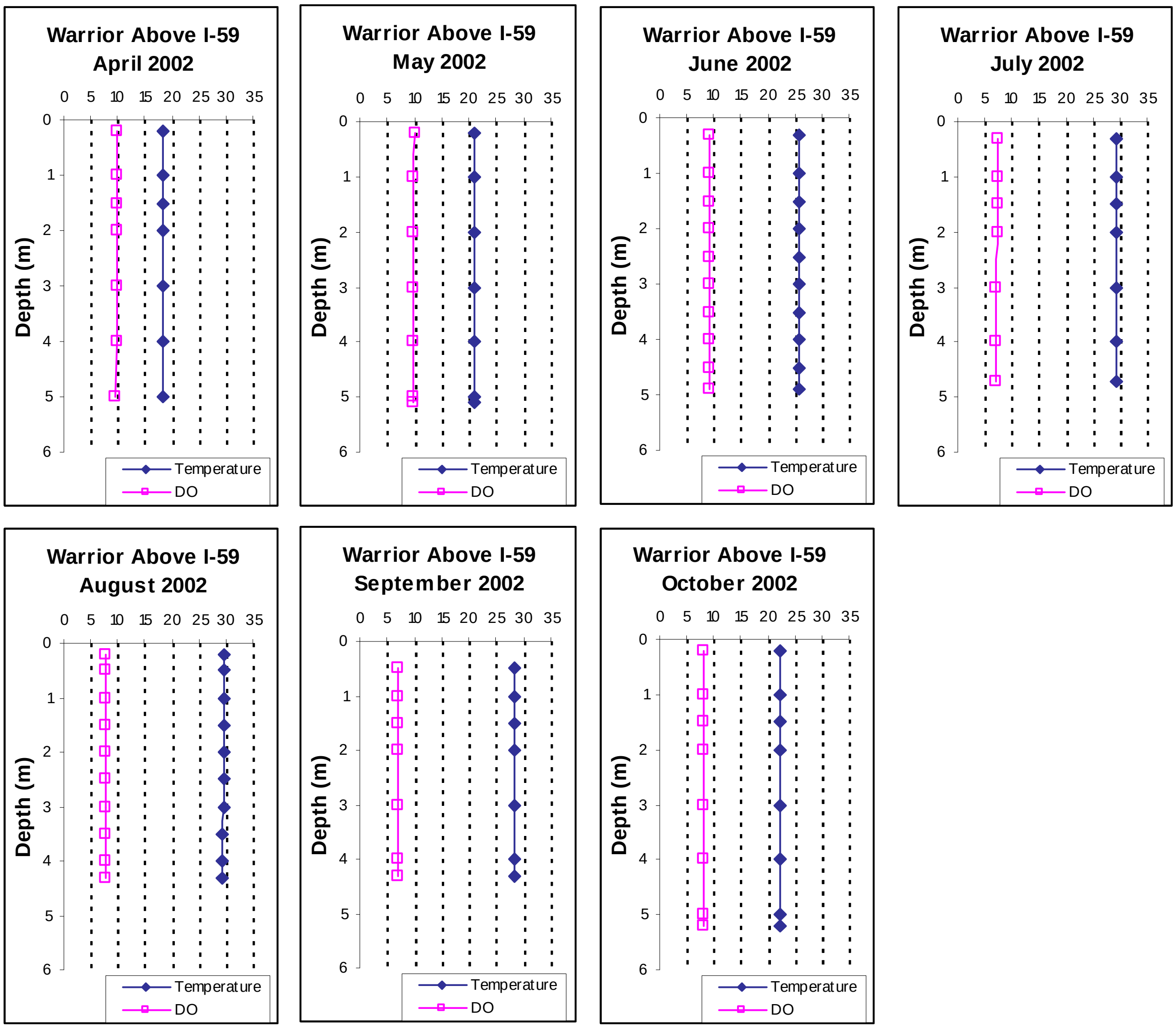


Figure 60. Depth profiles of dissolved oxygen (DO) and temperature (Temp) above I-59 in upper Warrior Reservoir, April-October 2002.

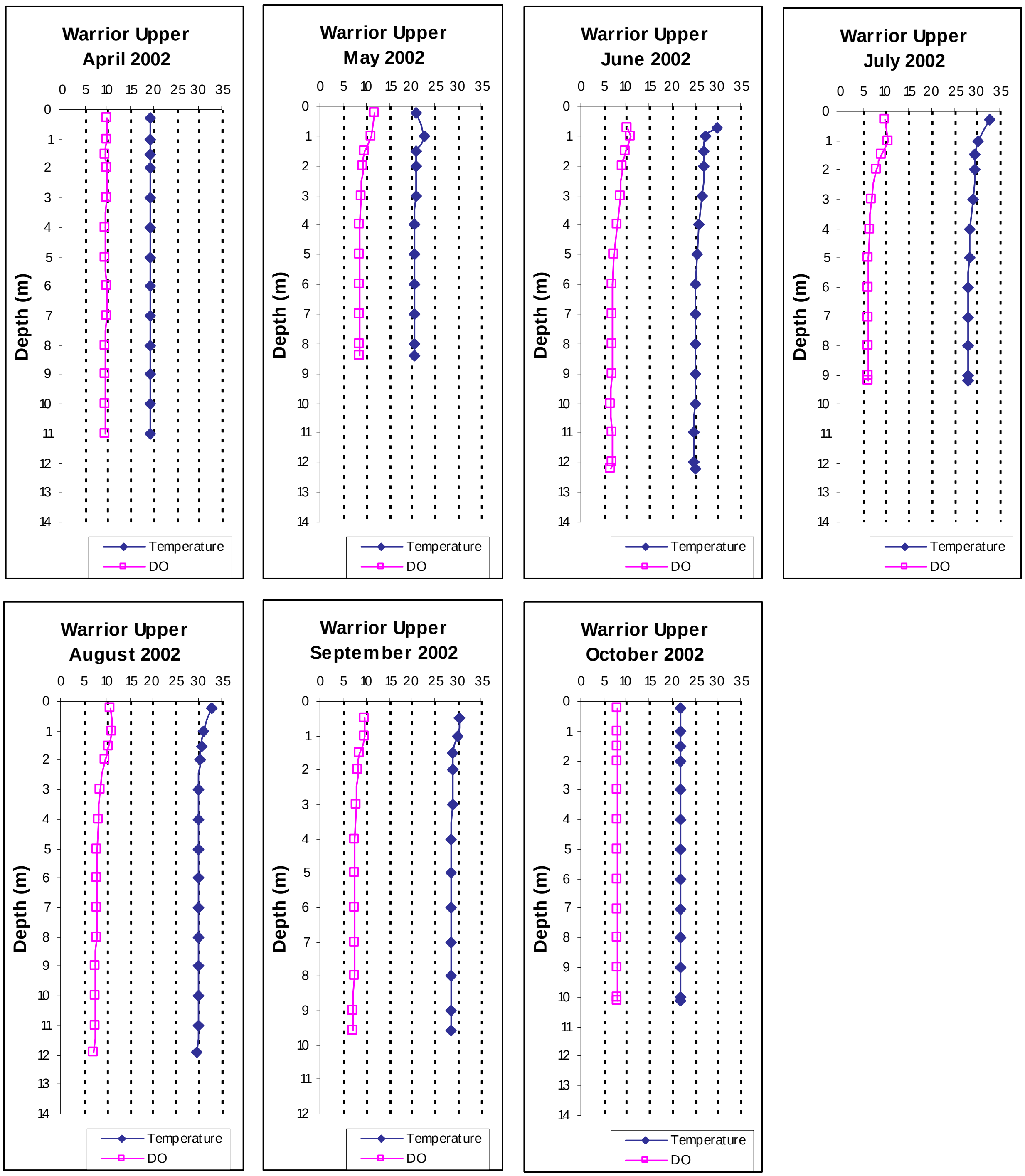


Figure 61. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Upper Warrior Reservoir, April-October 2002.

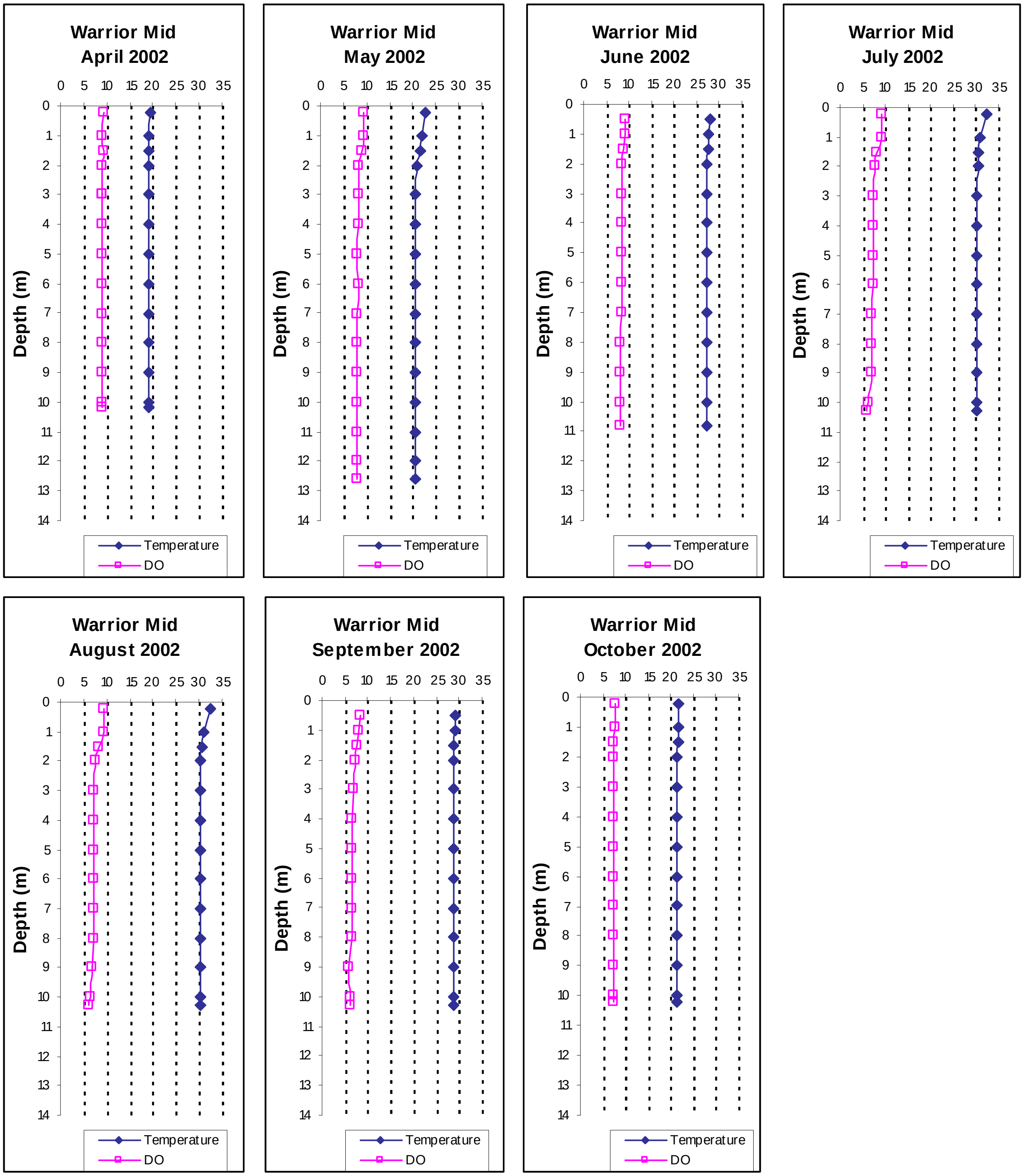


Figure 62. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Mid Warrior Reservoir, April-October 2002.

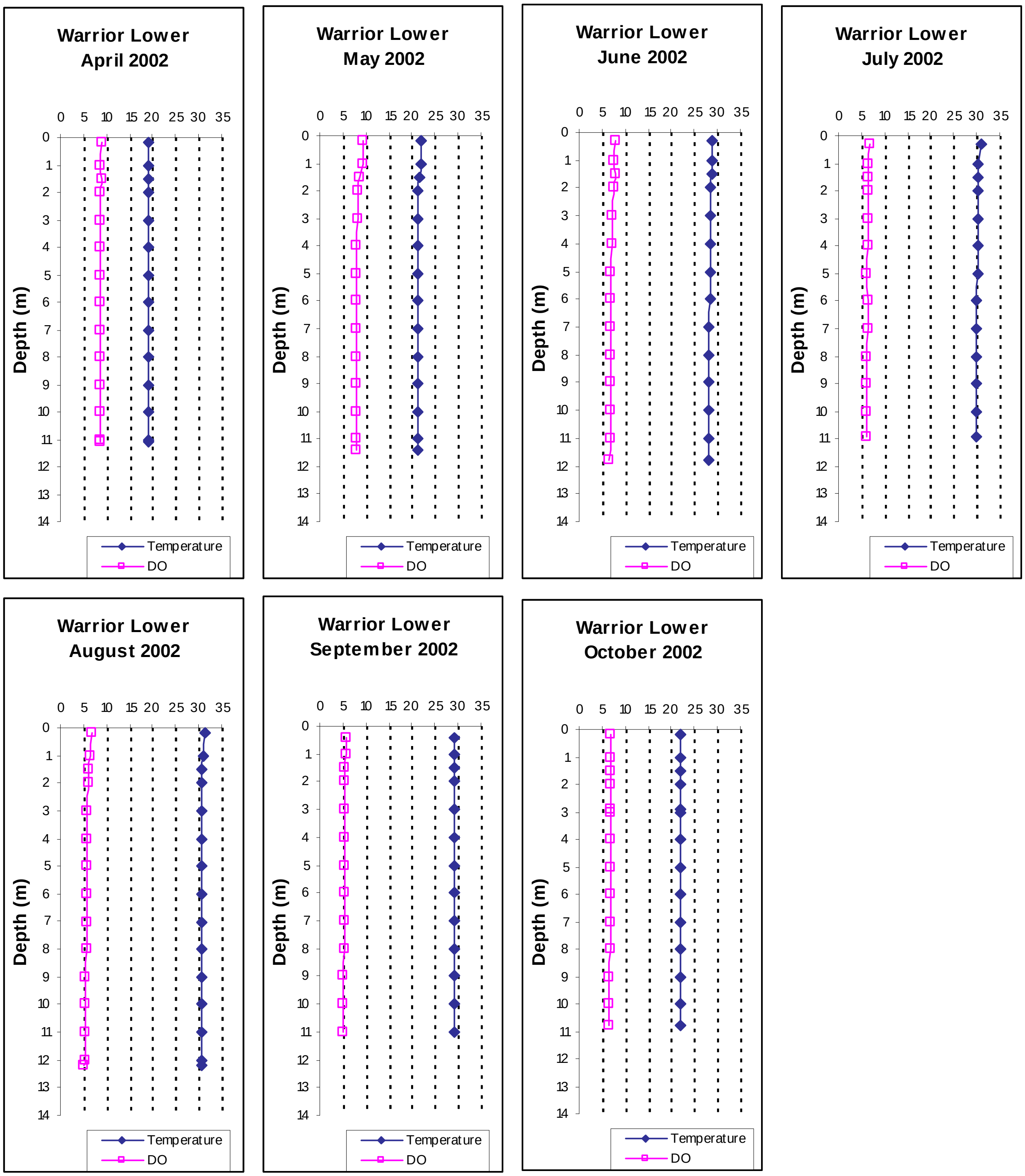


Figure 63. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in the dam forebay of Warrior Reservoir, April-October 2002.

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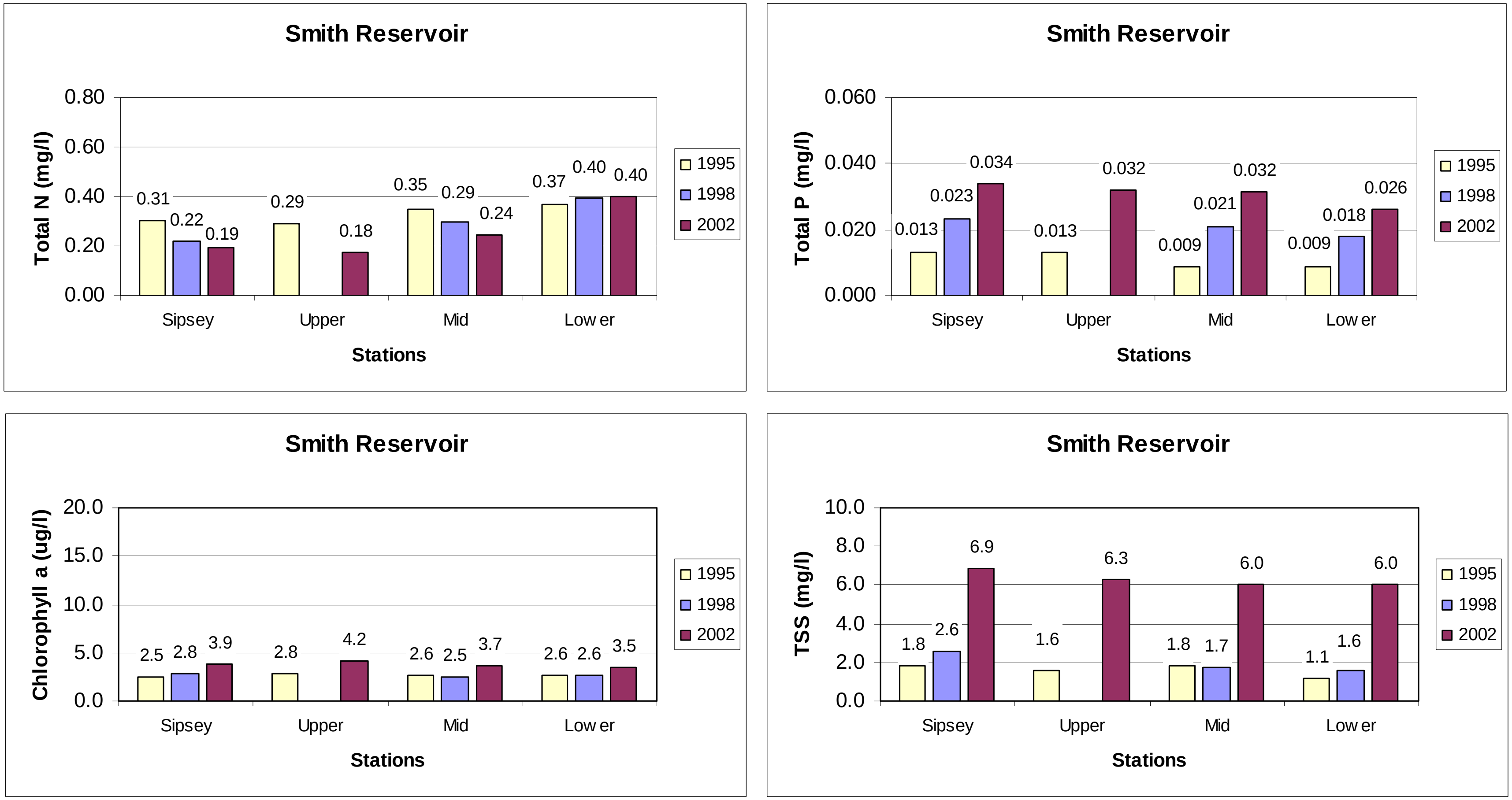
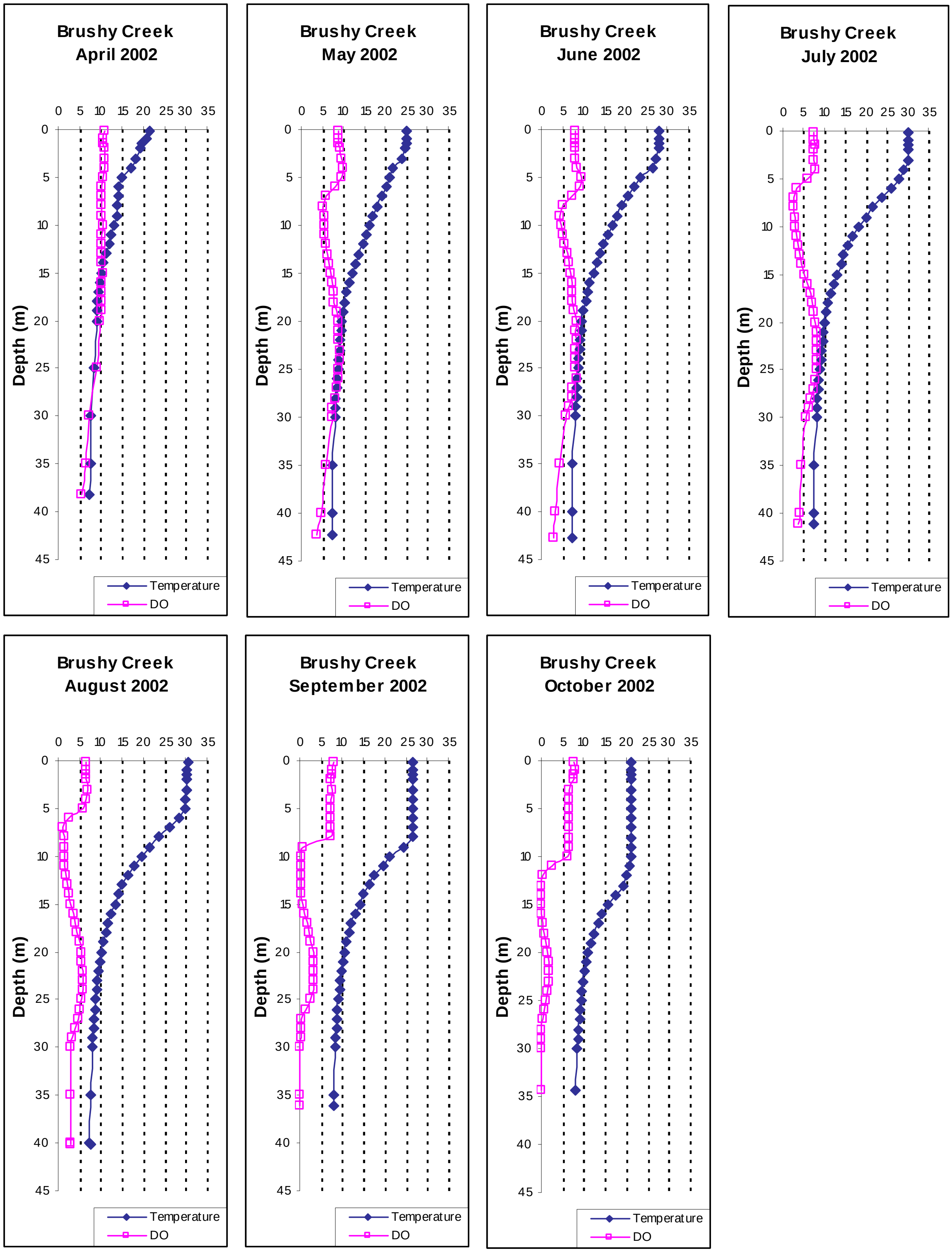
APPENDIX

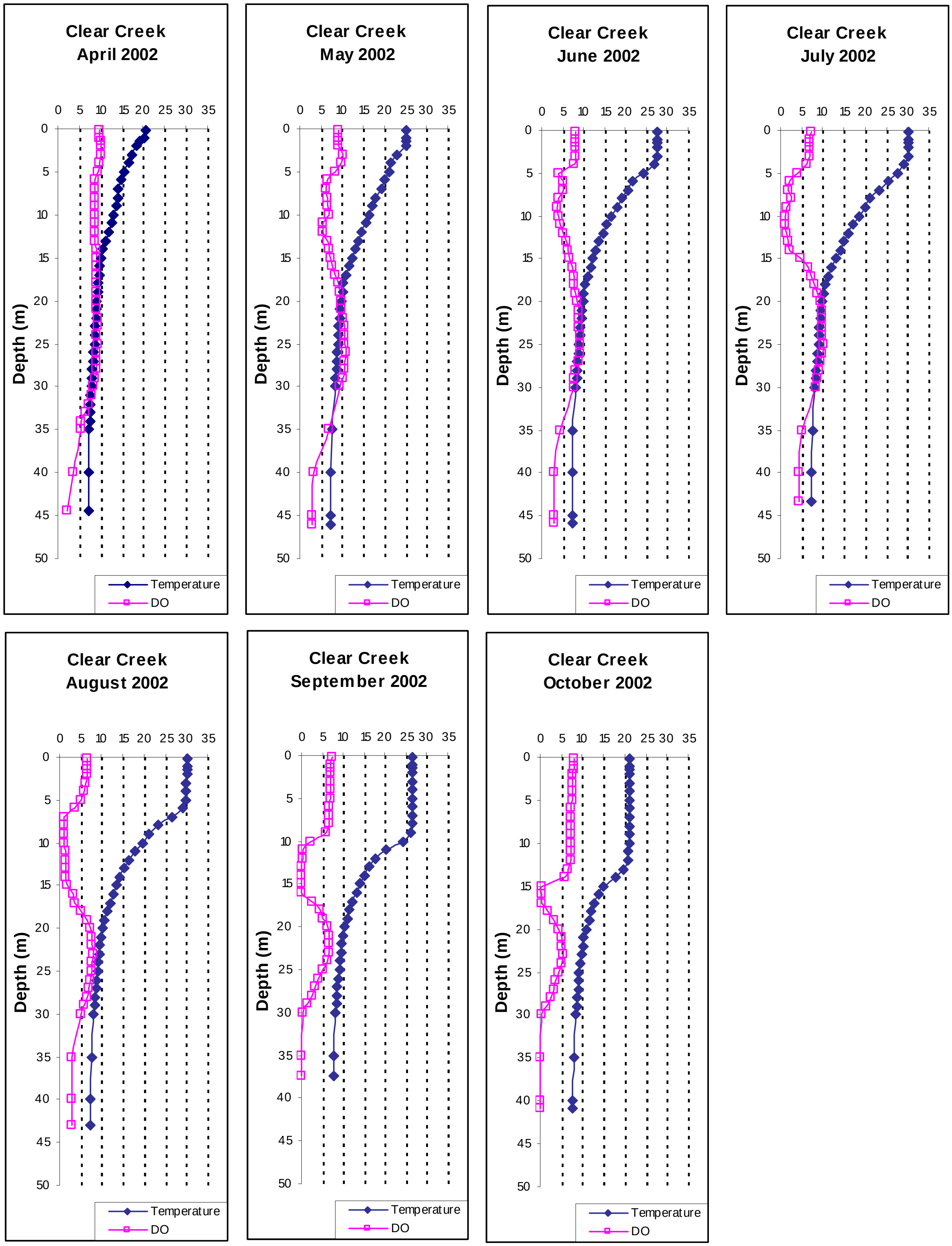


Appendix Figure 1. Mean TN, TP, chlorophyll a, and TSS concentrations from Smith Reservoir, 1995, 1998, and 2002.

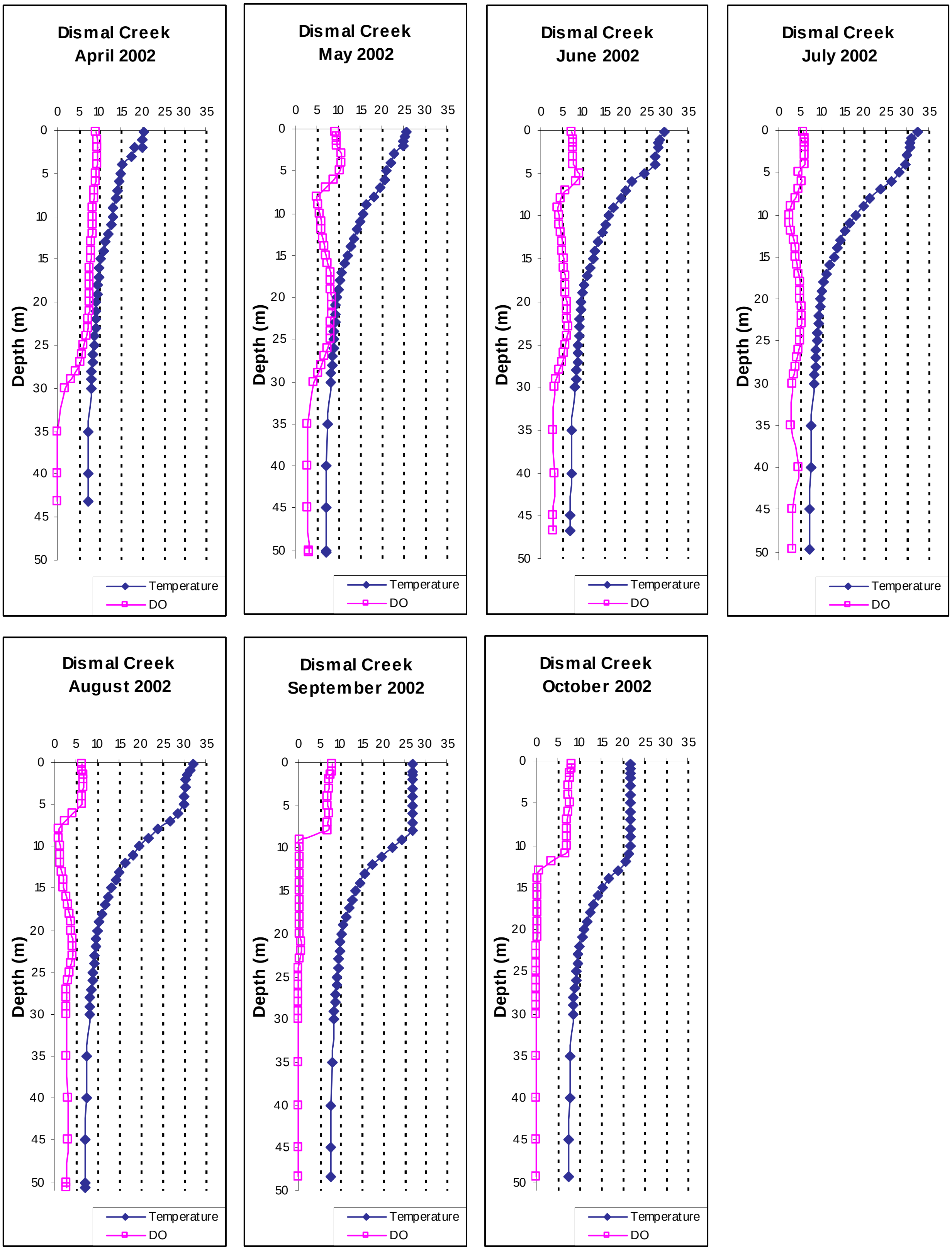
Appendix Figure 2. Mean TN, TP, chlorophyll a, and TSS concentrations from Smith Reservoir Tributaries, 1995, 1998, and 2002.



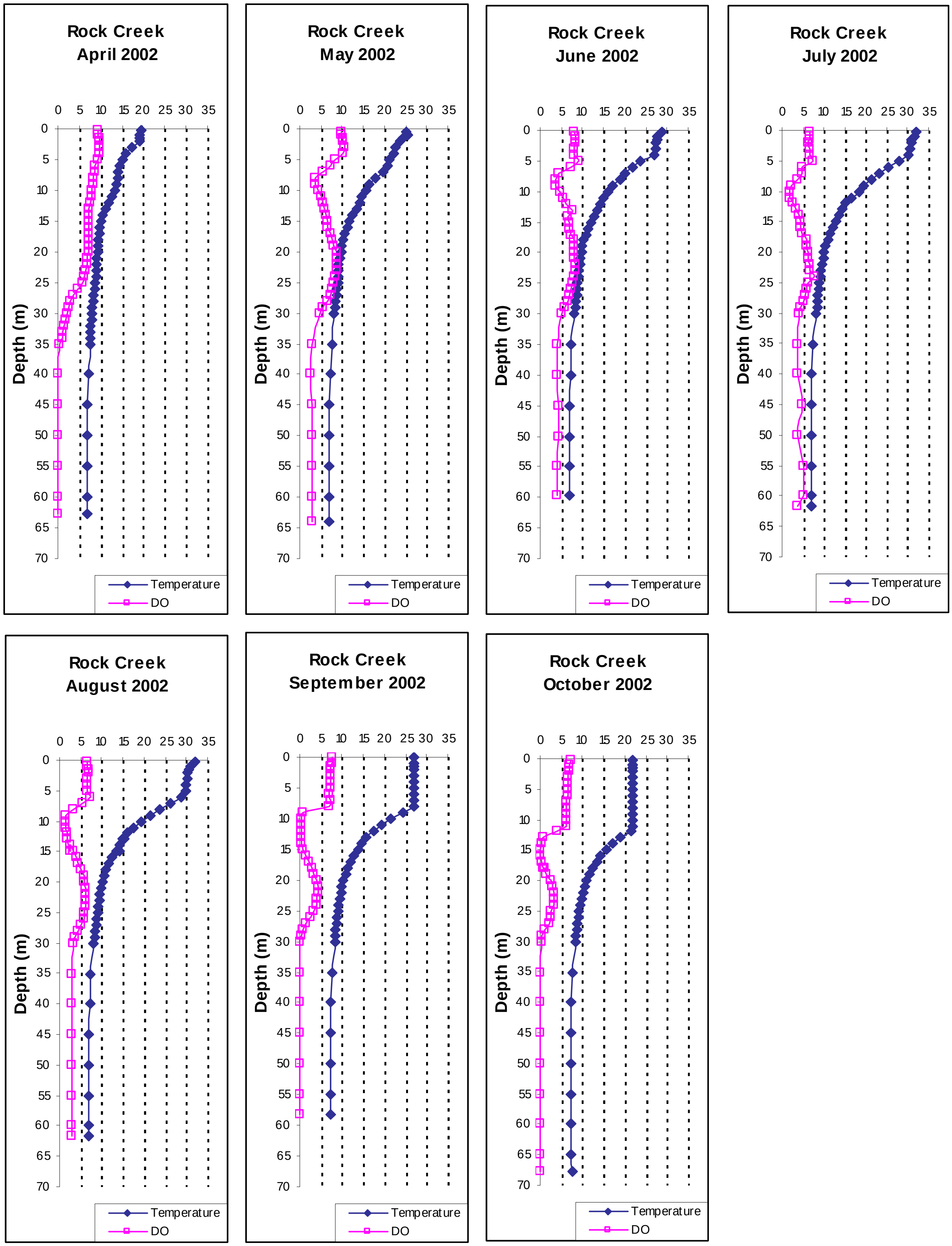
Appendix Figure 3. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Brushy Creek, Smith Reservoir tributary embayment, April-October 2002.



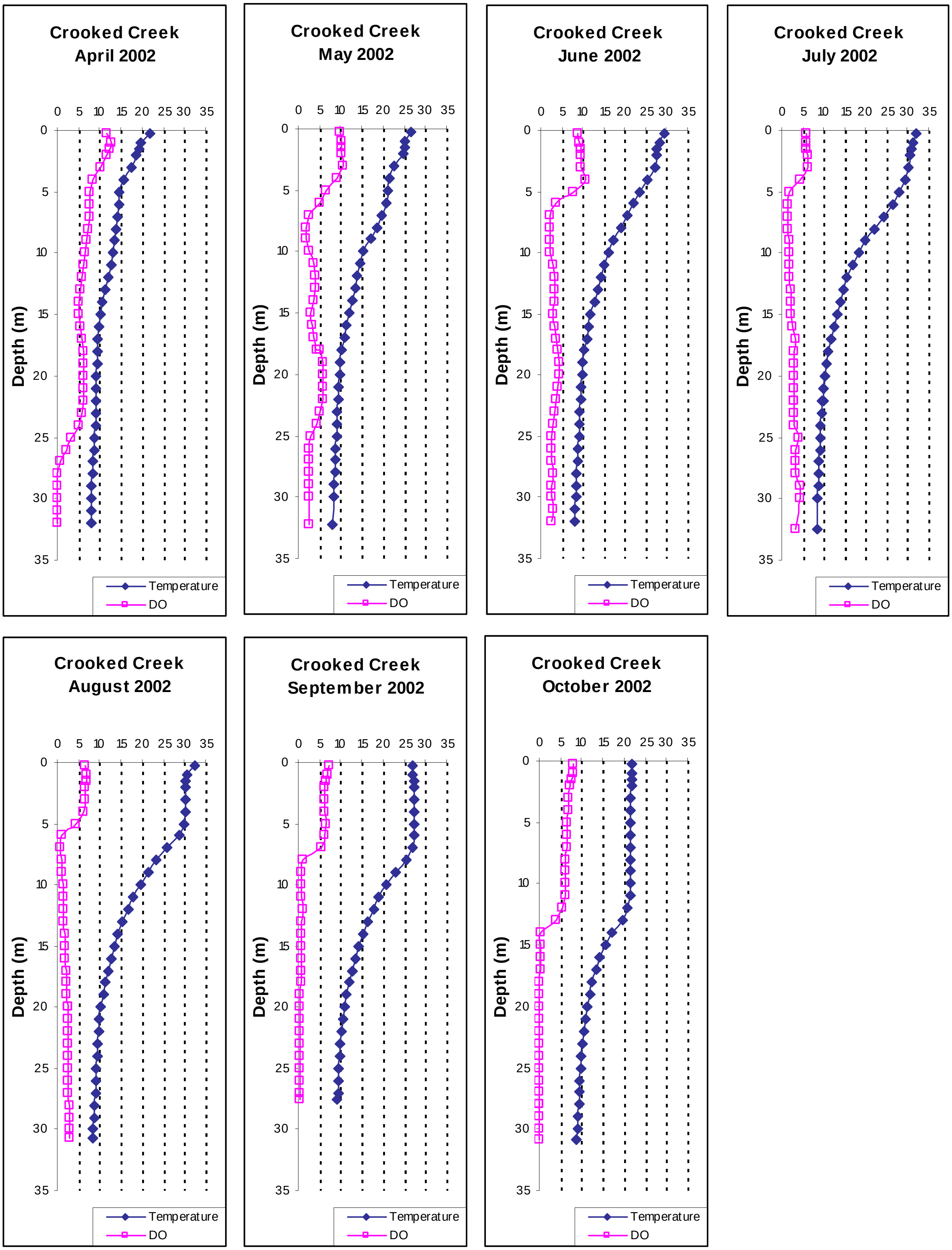
Appendix Figure 4. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Clear Creek, Smith Reservoir tributary embayment, April-October 2002.



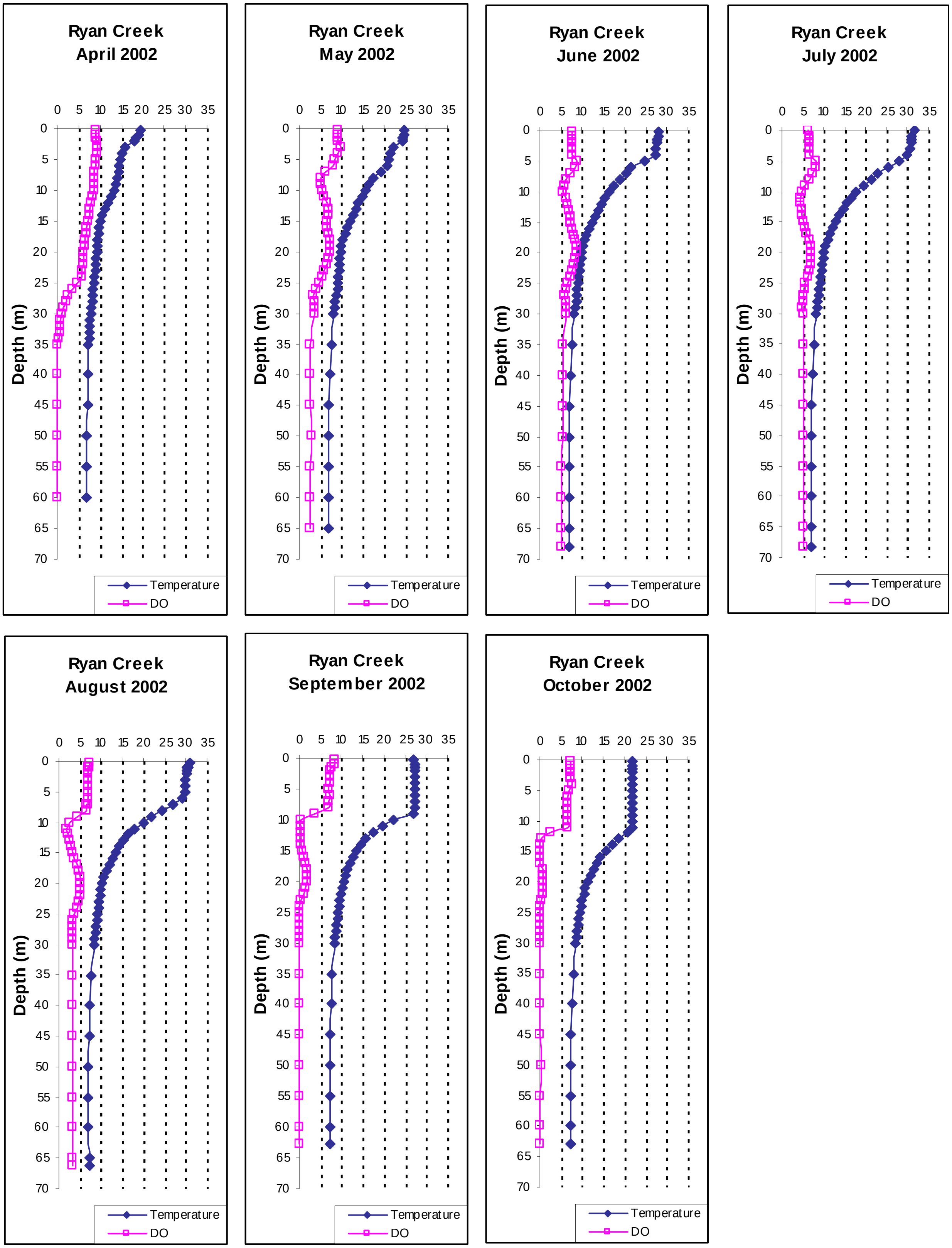
Appendix Figure 5. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Dismal Creek, Smith Reservoir tributary embayment, April-October 2002.



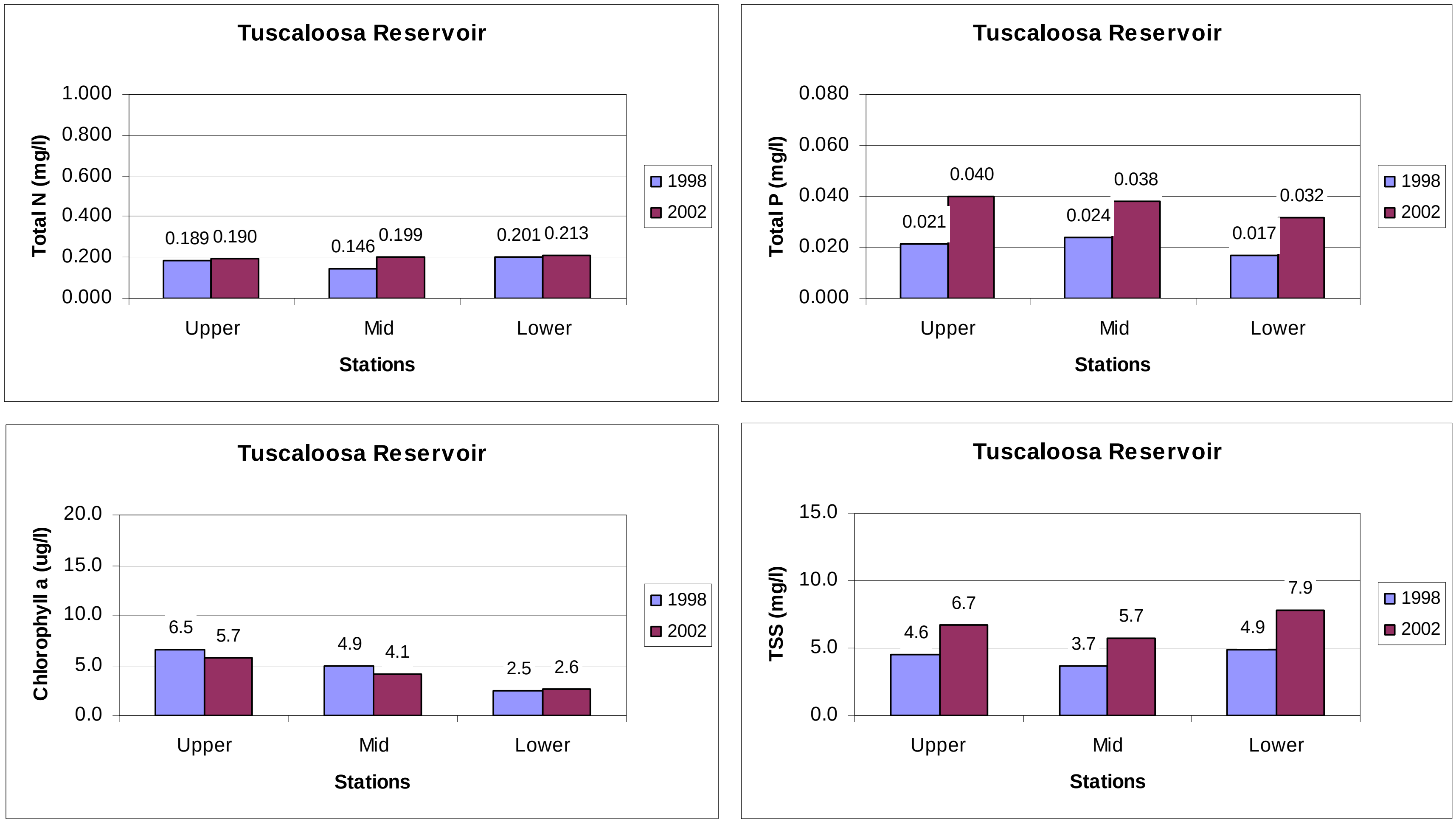
Appendix Figure 6. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Rock Creek, Smith Reservoir tributary embayment, April-October 2002.



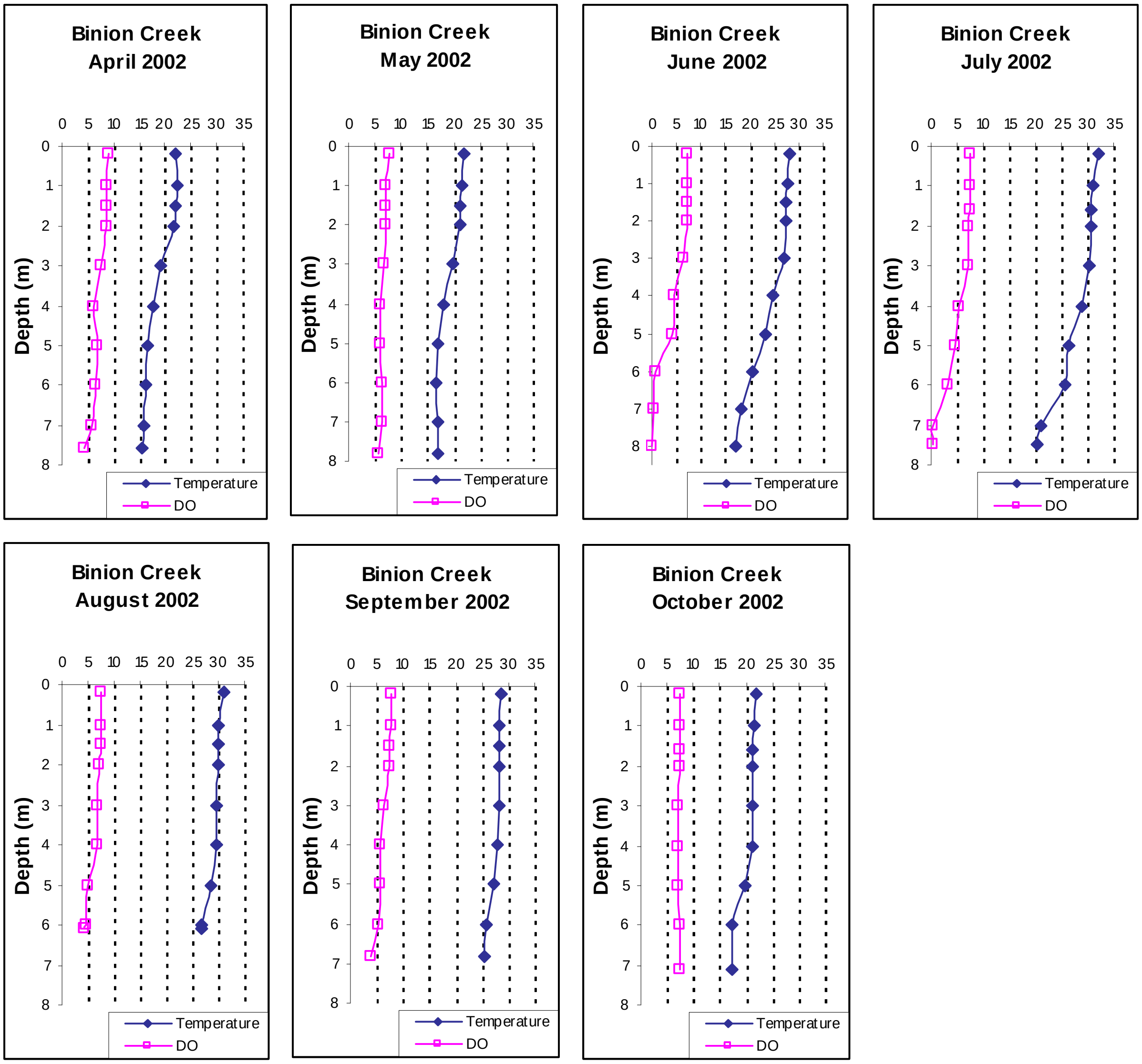
Appendix Figure 7. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Crooked Creek, Smith Reservoir tributary embayment, April-October 2002.



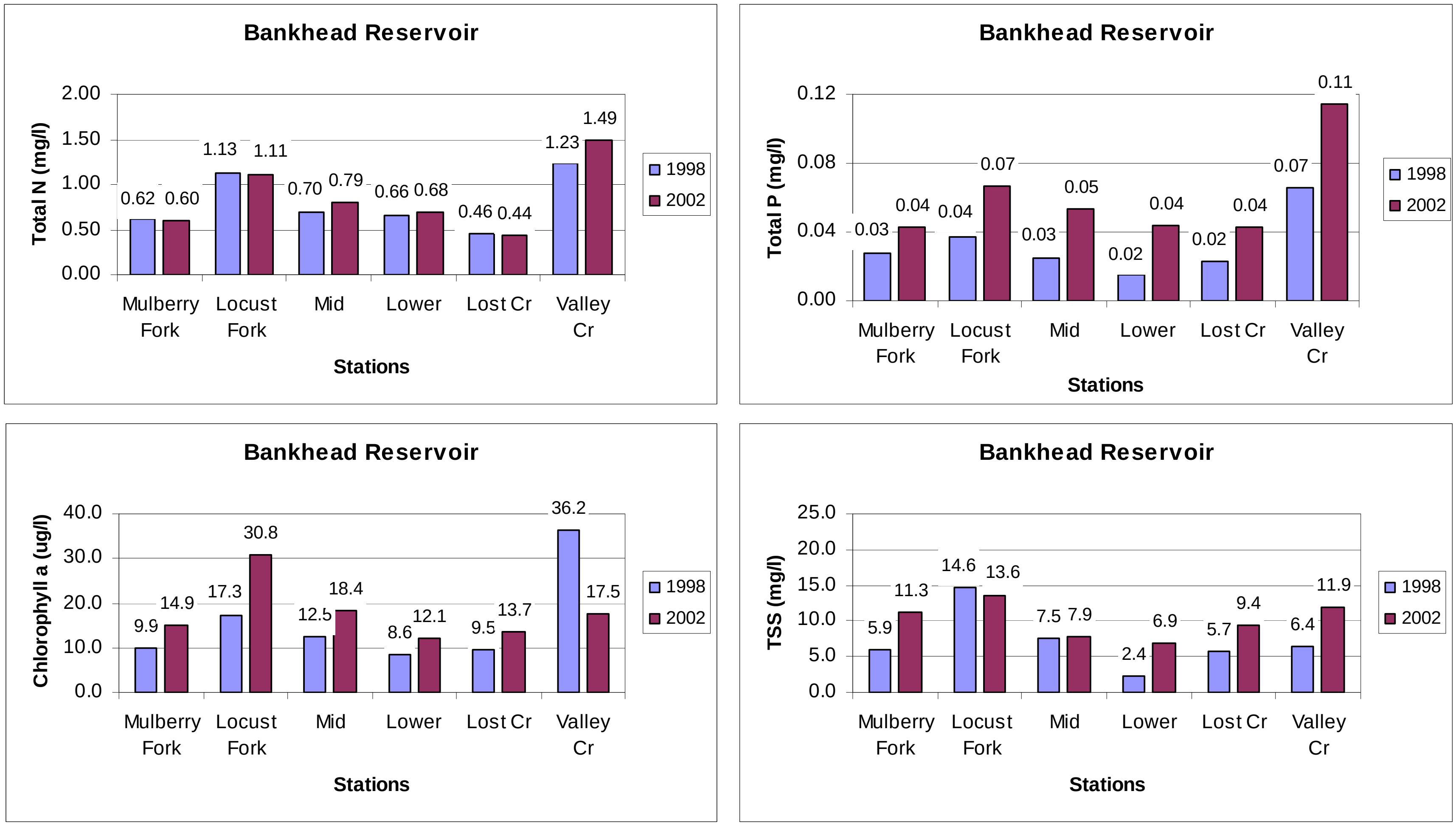
Appendix Figure 8. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Ryan Creek, Smith Reservoir tributary embayment, April-October 2002.



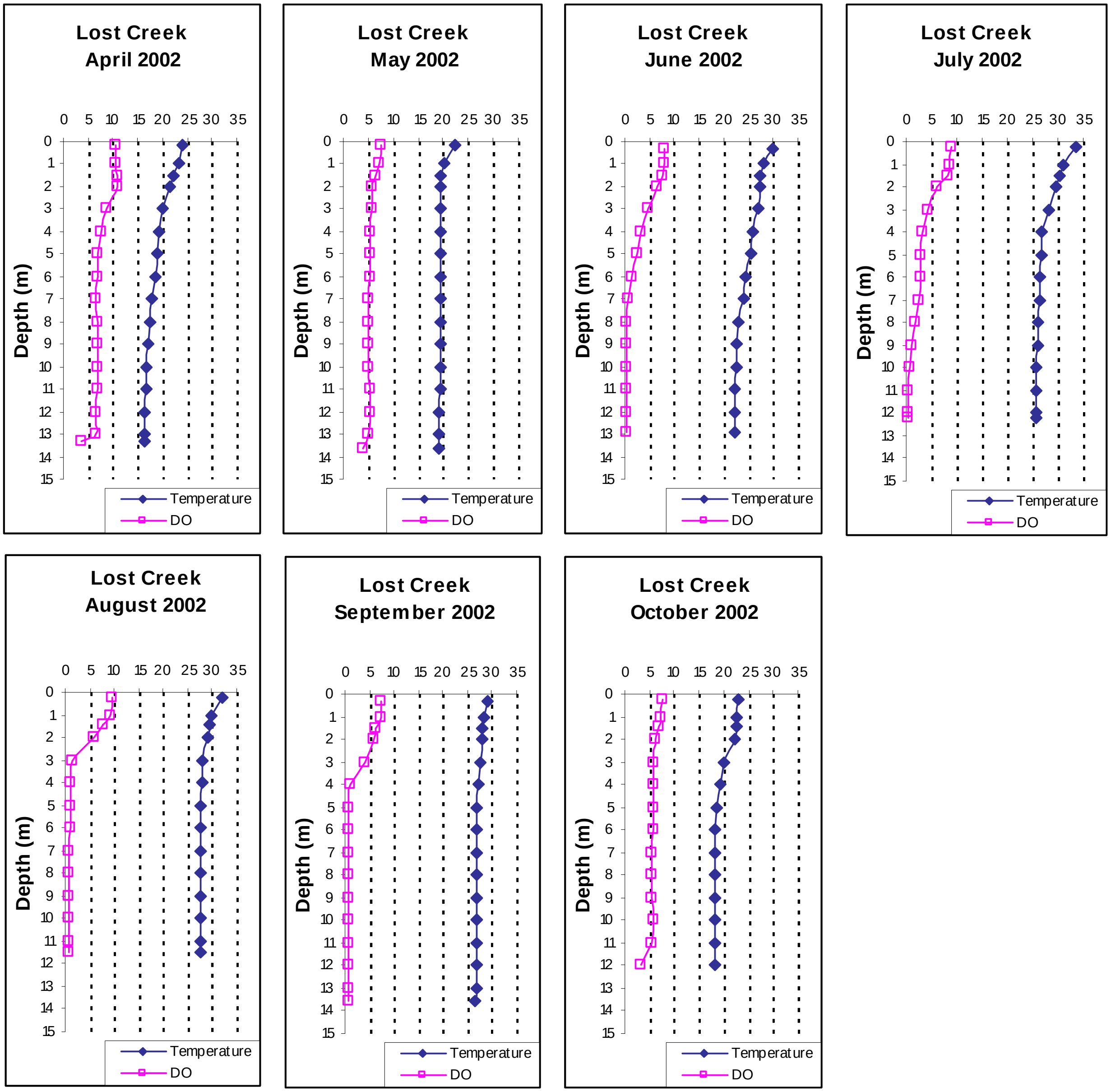
Appendix Figure 9. Mean TN, TP, chlorophyll a, and TSS concentrations from Tuscaloosa Reservoir, 1998 and 2002.



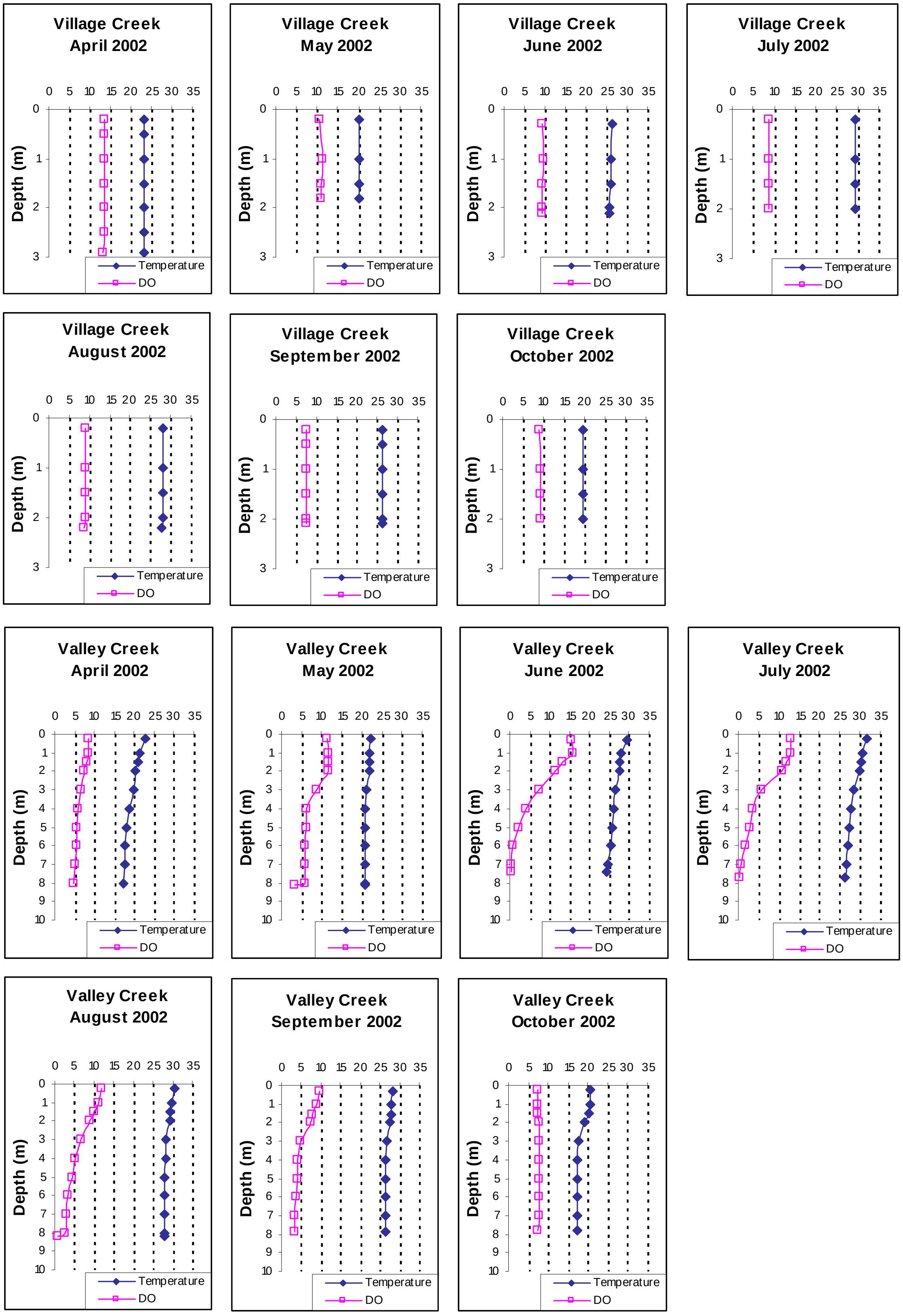
Appendix Figure 10. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Binion Creek, Tuscaloosa Reservoir tributary embayment, April-October 2002.



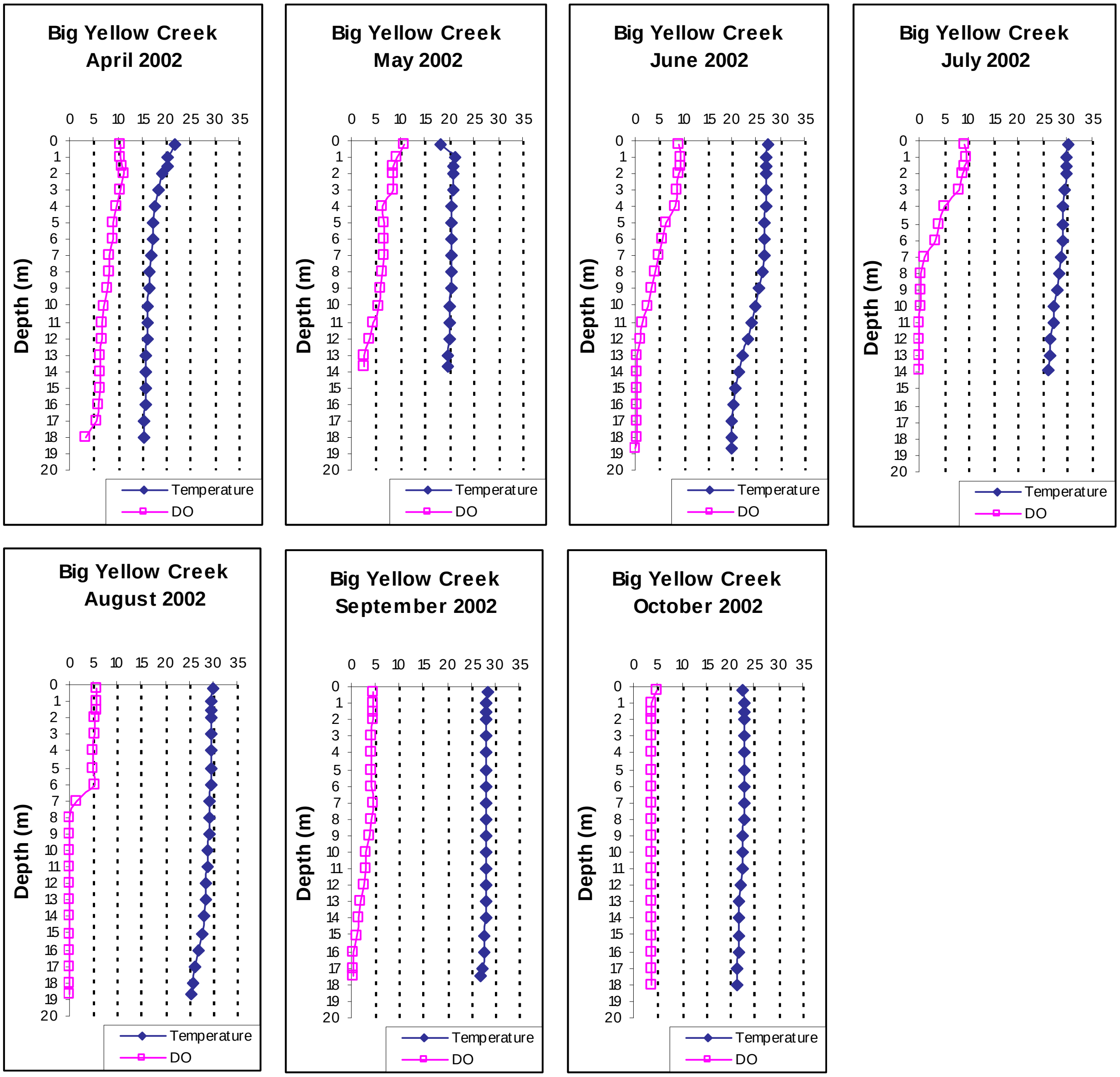
Appendix Figure 11. Mean TN, TP, chlorophyll a, and TSS concentrations from Bankhead Reservoir, 1998 and 2002.



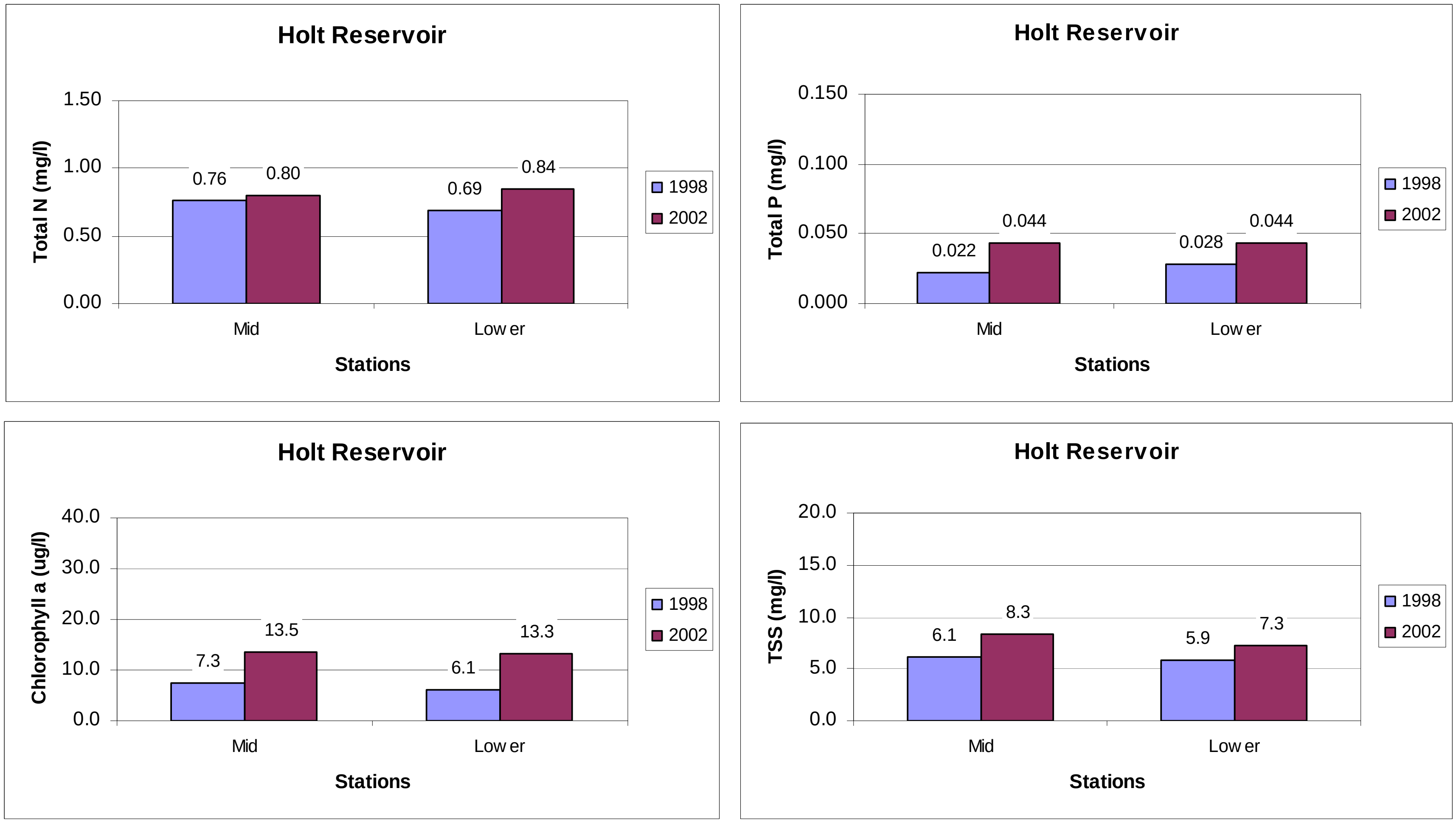
Appendix Figure 12. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Lost Creek, Bankhead Reservoir tributary embayment, April-October 2002.



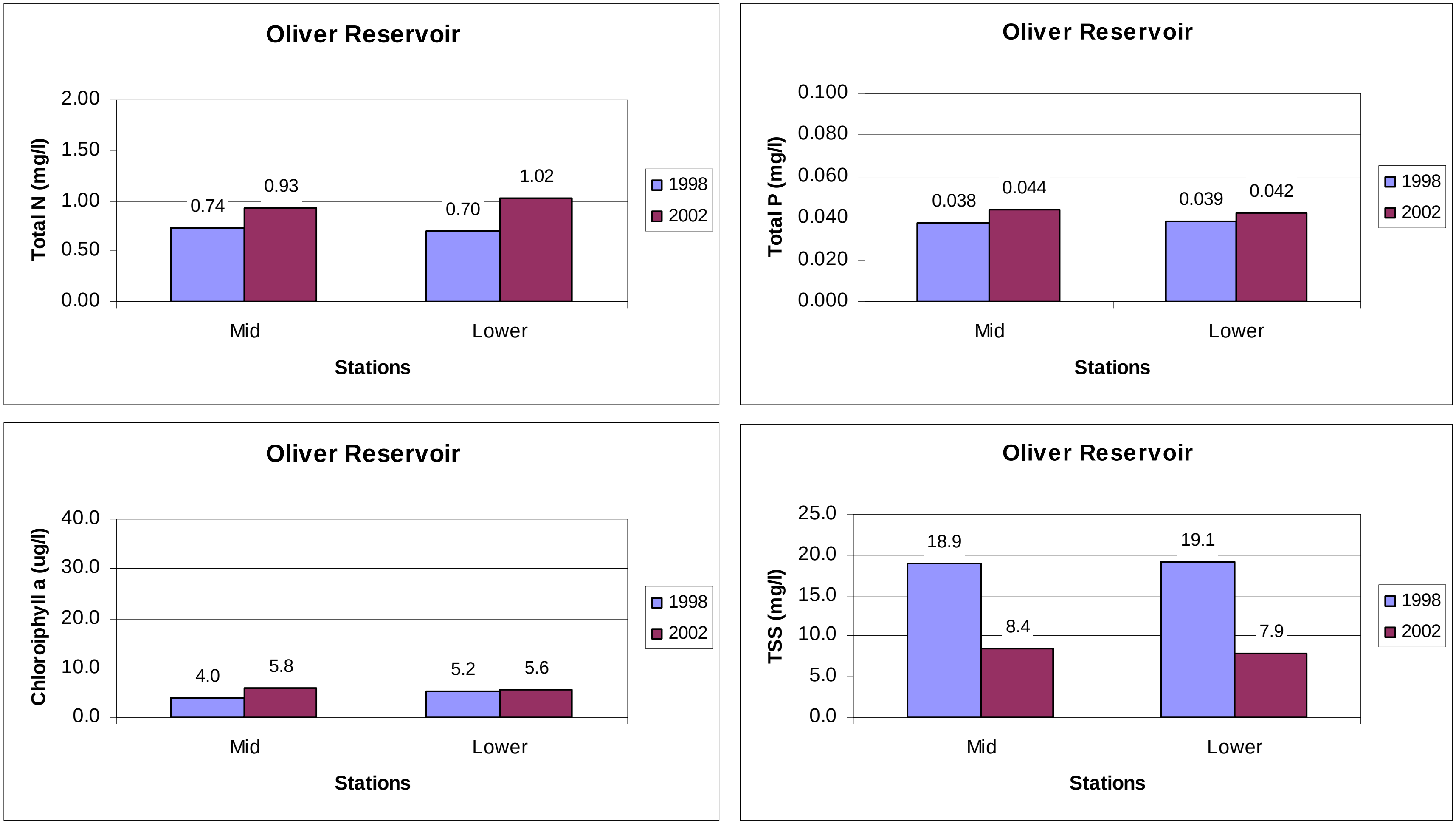
Appendix Figure 13. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Village and Valley Creeks, Bankhead Reservoir tributary embayments, April-October 2002.



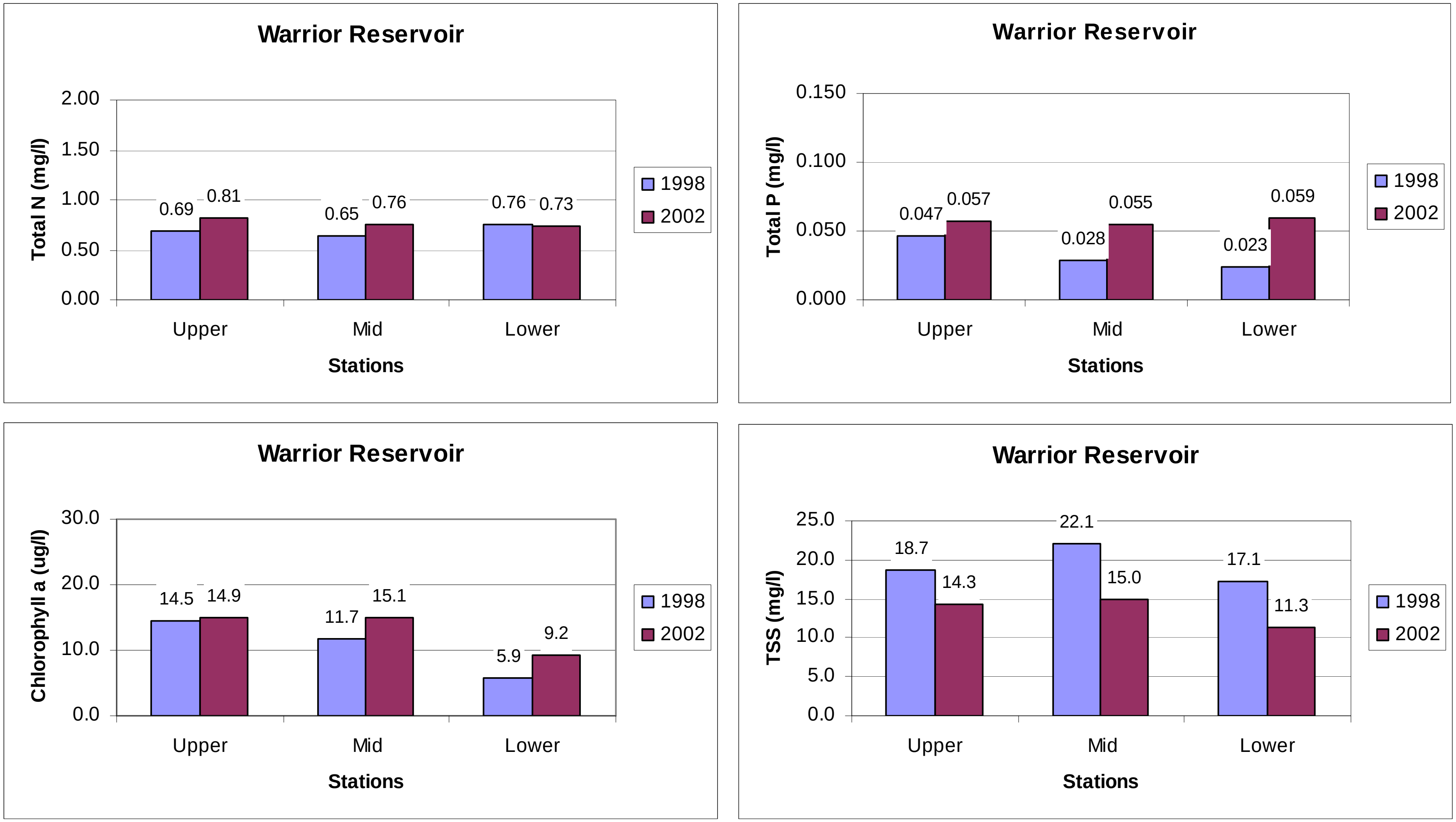
Appendix Figure 14. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Big Yellow Creek, Bankhead Reservoir tributary embayment, April-October 2002.



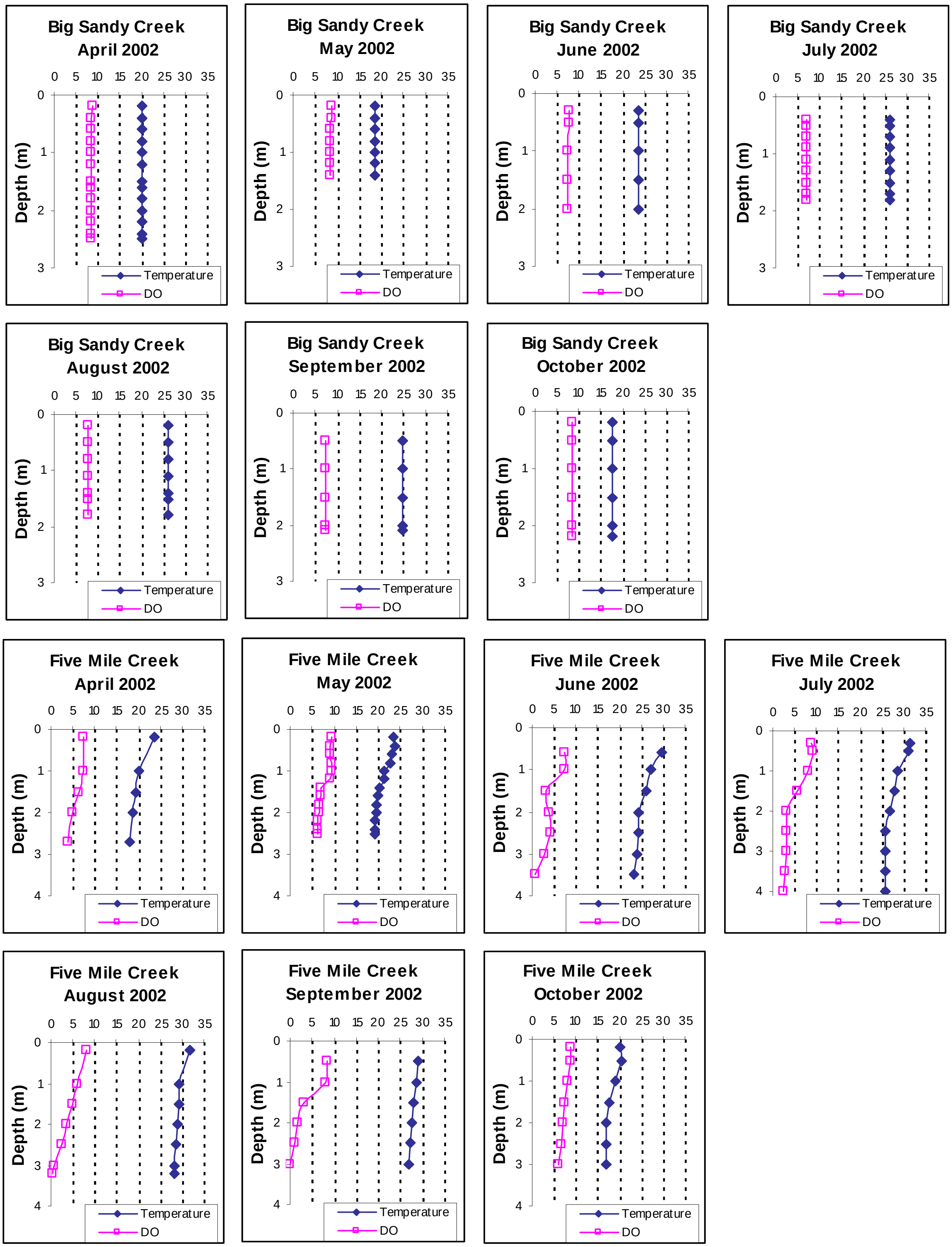
Appendix Figure 15. Mean TN, TP, chlorophyll a, and TSS concentrations from Holt Reservoir, 1998 and 2002.



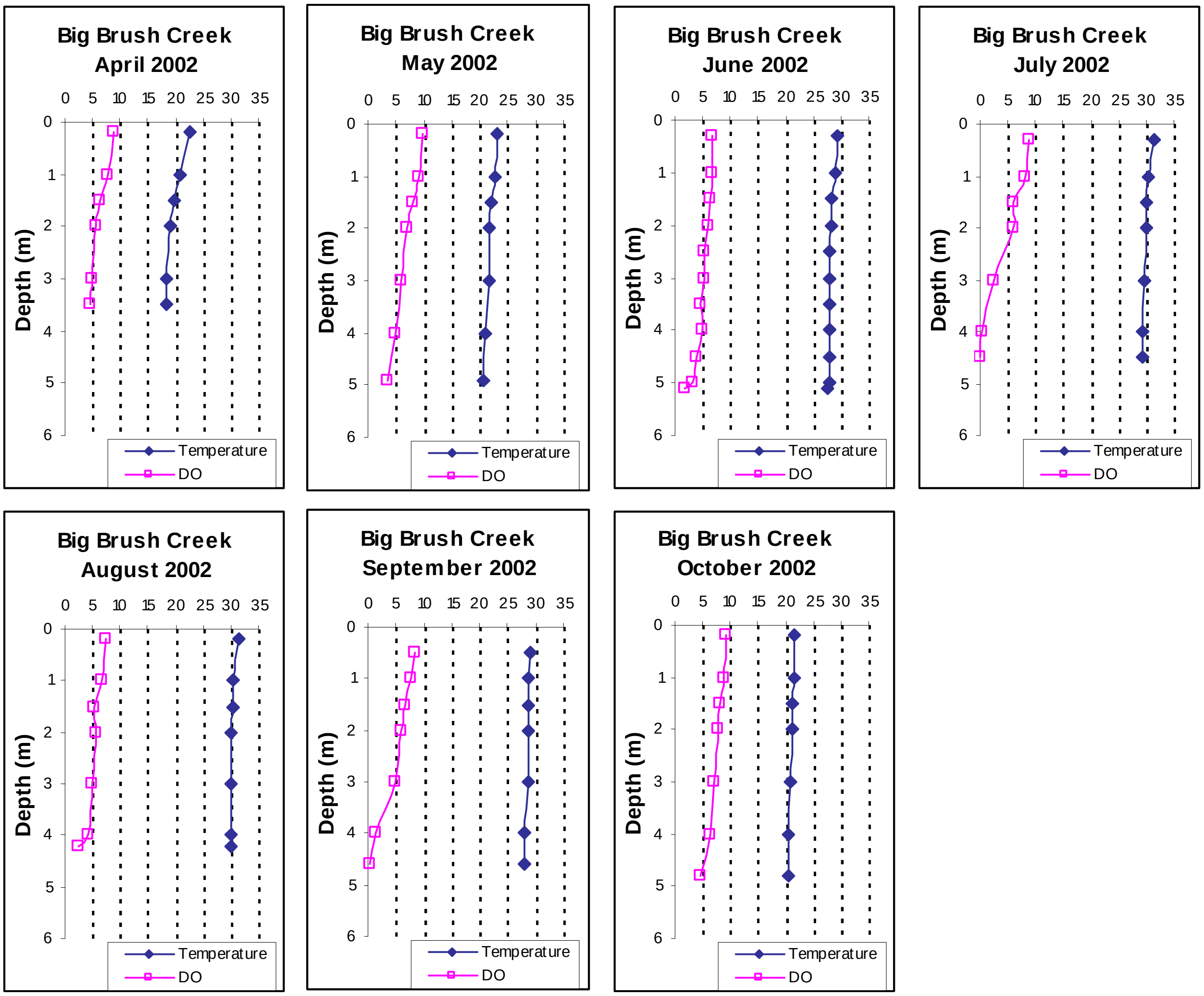
Appendix Figure 16. Mean TN, TP, chlorophyll a, and TSS concentrations from Oliver Reservoir, 1998 and 2002.



Appendix Figure 17. Mean TN, TP, chlorophyll a, and TSS concentrations from Warrior Reservoir, 1998 and 2002.



Appendix Figure 18. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Big Sandy and Five Mile Creeks, Warrior Reservoir tributary embayment, April-October 2002.



Appendix Figure 19. Depth profiles of dissolved oxygen (DO) and temperature (Temp) in Big Brush Creek, Warrior Reservoir tributary embayment, April-October 2002.