2007 Warrior Reservoir Report

Rivers and Reservoirs Monitoring Program

Alabama Department of Environmental Management

Field Operations Division
Environmental Indicators Section
Aquatic Assessment Unit
May 2012

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Black Warrior River Basin

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LIST OF ACRONYMS

A&I	Agriculture and Industry water supply use classification
ADEM	Alabama Department of Environmental Management
AGPT	Algal Growth Potential Test
BW	Black Warrior
CHL *a*	Chlorophyll *a*
DO	Dissolved Oxygen
F&W	Fish and Wildlife
MAX	Maximum
MDL	Method Detection Limit
MIN	Minimum
MSC	Mean Standing Crop
NTU	Nephelometric Turbidity Units
OAW	Outstanding Alabama Waters
ONRW	Outstanding National Resource Water
PWS	Public Water Supply
QAPP	Quality Assurance Project Plan
RRMP	Rivers and Reservoirs Monitoring Program
S	Swimming and Other Whole Body Water-Contact Sports
SD	Standard Deviation
SOP	Standard Operating Procedures
TEMP	Temperature
TN	Total Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

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INTRODUCTION

Warrior Reservoir was established in 1962 by the US Army Corp of Engineers (COE) with the completion of Armistead Selden Lock and Dam. The reservoir stretches seventy-seven miles from Oliver Dam in Tuscaloosa to just south of Eutaw, Alabama and encompasses 7,800 acres of waterway. The construction of the dam replaced locks seven, eight, and nine of an old lock system that consisted of seventeen locks along the river's course. The locks were created by the US federal government beginning in the 1880's as a means of making the entire river navigable from Birmingham to Mobile. Warrior Reservoir, along with other impoundments in the chain, provides a significant amount of commerce and recreation to the State of Alabama.

The Alabama Department of Environmental Management (ADEM) monitored Warrior Reservoir as part of the 2007 assessment of the Black Warrior and Cahaba River (BWC) Basins under the Rivers and Reservoirs Monitoring Program (RRMP). Implemented in 1990, the objectives of this program are to provide data that can be used to assess current water quality conditions, identify trends in water quality conditions, and to develop Total Maximum Daily Loads (TMDLs) and water quality criteria. Descriptions of all RRMP monitoring activities are available in ADEM's 2012 Monitoring Strategy.

In 2004, the ADEM implemented a specific water quality criterion for nutrient management at the forebay of Warrior Reservoir, which has been intensively monitored by ADEM since 1998. This criterion represents the maximum growing season mean (Apr-Oct) chlorophyll *a* (chl *a*) concentration allowable while still fully supporting the reservoir's Fish & Wildlife (F&W) use classification.

The purpose of this report is to summarize data collected at seven stations in Warrior Reservoir during the 2007 growing season and to evaluate growing season trends in mean lake trophic status and nutrient concentrations using ADEM's nine-year dataset. Monthly and mean concentrations of nutrients [total nitrogen (TN); total phosphorus (TP)], algal biomass/productivity [chl *a*; algal growth potential testing (AGPT)], sediment [total suspended solids (TSS)], and trophic state [Carlson's trophic state index (TSI)] were compared to ADEM's historical data and established criteria.

METHODS

Sampling stations were selected using historical data and previous assessments (Fig. 1). Specific location information can be found in Table 1. Warrior Reservoir was sampled in the dam forebay along with three additional mainstem stations through mid and upper reservoir. Sampling locations were also established in the Big Brush Creek, Five Mile Creek, and Big Sandy Creek embayments.

Water quality assessments were conducted at monthly intervals, April-October. All samples were collected, preserved, stored, and transported according to procedures in the ADEM Field Operations Division Standard Operating Procedures (ADEM 2007), Surface Water Quality Assurance Project Plan (ADEM 2005), and Quality Management Plan (ADEM 2003).

Mean growing season TN, TP, chl *a*, and TSS were calculated to evaluate water quality conditions at each site. For mainstem stations, monthly concentrations of these parameters were graphed with the closest available USGS flow data and ADEM's previously collected data to help interpret the 2007 results.

Figure 1. Warrior Reservoir with 2007 sampling locations. A description of each sampling location is provided in Table 1.

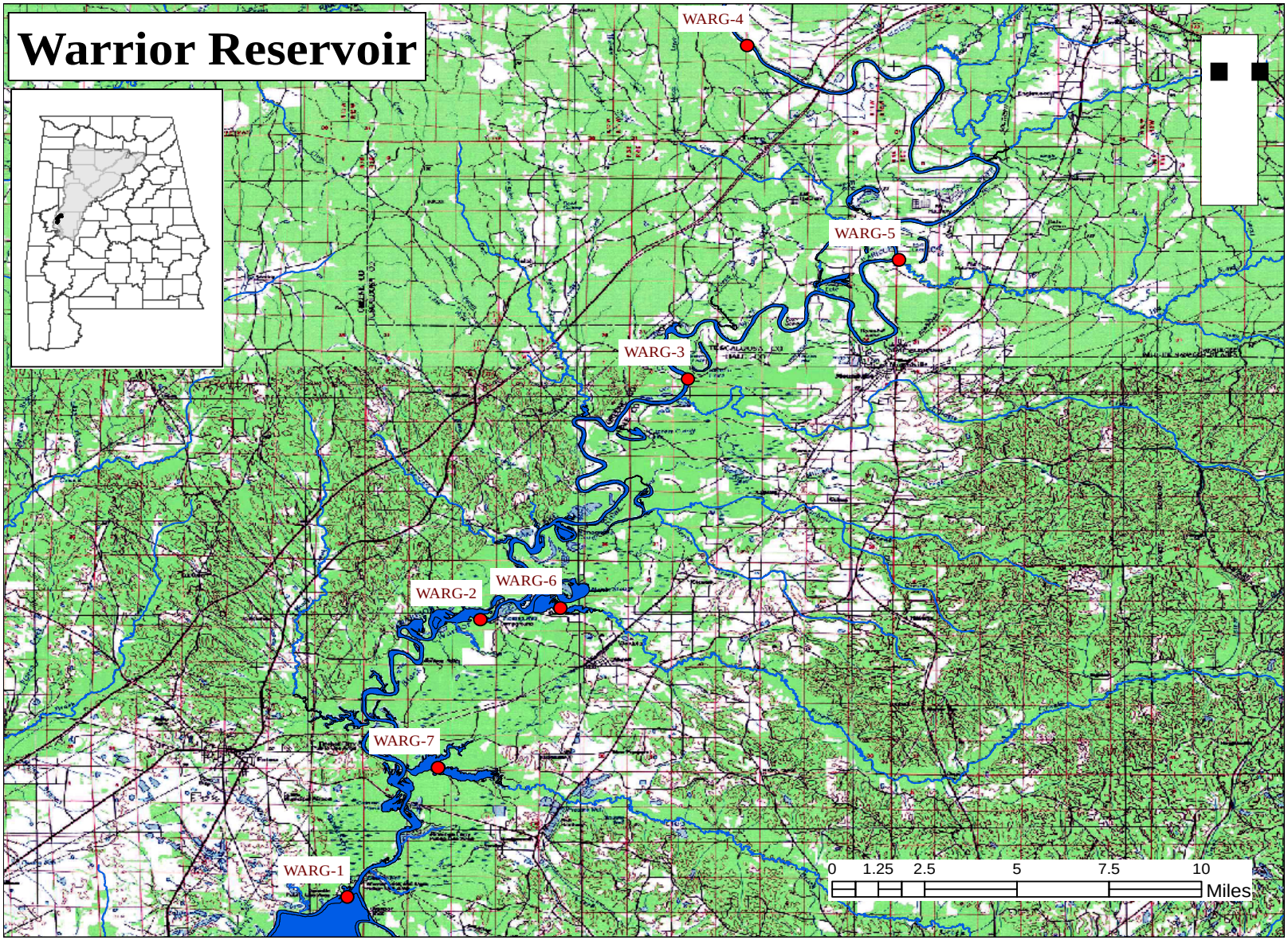


Table 1. Descriptions of the 2007 monitoring stations in Warrior Reservoir.

HUC	County	Station Number	Report Designation	Waterbody Name	Station Description	Chl *a* Criteria	Latitude	Longitude
Warrior Reservoir								
031601130607	Greene	*WARG-1	Lower	Black Warrior R	Deepest point, main river channel, dam forebay.	12 µg/l	32.77967	-87.83922
031601130607	Greene	WARG-2	Mid	Black Warrior R	Deepest point, main river channel, immed. downstream of Lock 8 Public Use Area.		32.89492	-87.78727
031601130602	Greene	WARG-3	Upper	Black Warrior R	Deepest point, main river channel, at Lock 9 Public Use Area.		32.99508	-87.70566
031601130204	Tuscaloosa	WARG-4	Above I-59	Black Warrior R	Deepest point, main river channel, approximately 3.5 miles upstream of I-59 crossing.		33.13381	-87.68262
031601130105	Tuscaloosa	WARG-5	Big Sandy Ck	Big Sandy Ck	Main creek channel, Big Sandy Creek 0.5 miles upstream of confluence with Black Warrior River.		33.04478	-87.62318
031601130402	Hale	WARG-6	Five Mile Ck	Five Mile Ck	Main creek channel, Five Mile Creek, 0.5 miles upstream of confluence with Black Warrior River.		32.89998	-87.75597
031601130507	Hale	WARG-7	Big Brush Ck	Big Brush Ck	Main creek channel, Big Brush Creek 0.5 miles upstream of confluence with Black Warrior River.		32.83340	-87.80384

*Growing season mean chl *a* criteria implemented at this station in 2004.

RESULTS

Growing season mean graphs for TN, TP, chl *a*, TSS, and TSI are provided in this section (Figs. 2, 3, and 11). Monthly graphs for TN, TP, chl *a*, TSS and DO are also provided (Figs. 4-8). Mean monthly discharge is included in monthly graphs for TN, TP, chl *a*, and TSS as an indicator of flow and retention time in the months sampled. Algal growth potential test (AGPT results appears in Table 2. Depth profile graphs of temperature and DO appear in Figs. 9-10. Summary statistics of all data collected during 2007 are presented in Appendix Table 1. The table contains the minimum, maximum, median, mean, and standard deviation of each parameter analyzed.

According to the National Weather Service, during 2007 Alabama recorded its driest January through August period in the past 100 years. The drought was intensified by a drier than normal preceding winter and spring. Though difficult to quantify, drought of this magnitude will affect water quality in a number of ways and is a likely factor in many of these results.

Stations with the highest concentrations of nutrients, chlorophyll, and TSS are noted in the paragraphs to follow. Though stations with lowest concentrations are not mentioned, review of the graphs that follow will indicate these stations that may be potential candidates for reference waterbodies and watersheds. Highest mean TN concentrations at mainstem reservoir locations in 2007 occurred in the upper reservoir, with Big Brush Creek the highest of tributary locations (Fig. 2). Seasonal mean TN concentrations fluctuated 1998-2007 at the upper and mid mainstem stations and did not exhibit any clear long-term trends. The lower mainstem station showed a decrease overall in concentrations since 1998. The Above I-59 and all tributary stations were lower in 2007 than in 2002, with the exception of Big Brush Ck, which was similar in both years. Monthly TN concentrations at the lower and mid stations were at or below historic means for much of the sampling season (Fig. 4). The upper reservoir station was more variable, setting historic highs in April and July, and low in June.

Highest mean TP concentrations at mainstem reservoir locations in 2007 occurred in the upper reservoir, with Big Brush Creek and Five Mile Creek the highest of tributary locations (Fig. 2). Seasonal mean TP concentrations at the upper and lower stations were variable in each year sampled, however, the remaining stations showed a decreasing trend from 2002 to 2007

(Fig. 2). Monthly TP concentrations showed very little variation across the 2007 growing season and were at or below historic means in each month monitored (Fig. 5).

Highest mean chl *a* concentrations at mainstem reservoir locations in 2007 occurred in the upper reservoir, with Big Brush Creek the highest of tributary locations (Fig. 3). Seasonal mean chl *a* concentrations at the upper and mid stations have generally been increasing from 1998 to 2007 with the highest mean concentrations measured in 2007 (Fig. 3). Results showed a similar trend at the lower station with the highest concentration in 2007, which exceeded the chl *a* criteria of 12 µg/L (Fig. 3). In 2007, seasonal mean chl *a* values also increased at all three tributary stations and the above I-59 location (Fig. 3). Monthly chl *a* results for 2007 showed the lower station was above historic means in all months sampled and the mid station in all months except for May. Both stations were historically high in four of the seven months. The upper station was above historic means in four of the seven months, setting historical highs in April, June, and October (Fig. 6).

Highest mean TSS concentrations at mainstem reservoir locations in 2007 occurred above I-59, with Big Brush Creek and Five Mile Creek the highest of tributary locations (Fig. 3). Seasonal mean TSS concentrations have fluctuated at the three mainstem stations since 1998, but overall concentrations have generally decreased at the mid and lower stations with 2007 concentrations the lowest on record (Fig. 3). Big Brush Ck showed little change in mean TSS concentrations from 2002 to 2007 while the Above I-59 location showed an increase in concentration (Fig. 3). Big Sandy Ck and Five Mile Ck showed similar results as the mainstem stations with concentrations decreasing from 2002 to 2007 (Fig. 3). Monthly TSS concentrations were at or below historic mean values at the mainstem stations with the exception of the lower station during the July and September sampling events (Fig. 7). The lower station appeared to exhibit a relationship between TSS and discharge (Fig. 7).

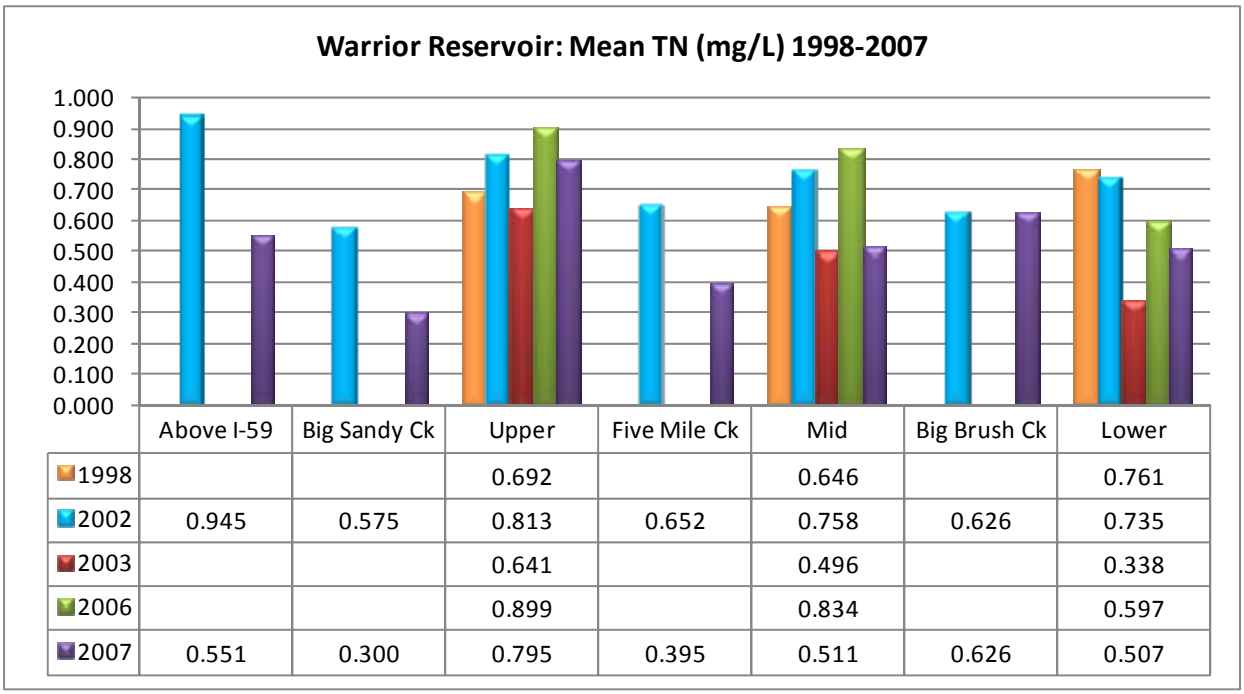
AGPT results for the lower Warrior Reservoir station indicated phosphorus limited conditions August 1998-August 2007 (Table 2). The mid and upper stations indicted phosphorus limited conditions August 1998- June 2007. In July 2007 the mid station was nitrogen limited and co-limited in August 2007. In July 2007 the upper station was co-limited, and then nitrogen limited in August 2007 (Table 2). The mean standing crop (MSC) value at the mid reservoir was

slightly above 5 mg/L in 2002 and June 2007. The upper station MSC value in 2002 was also slightly above 5 mg/L, the value that Raschke et al. (1996) defined as protective of reservoir and lake systems.

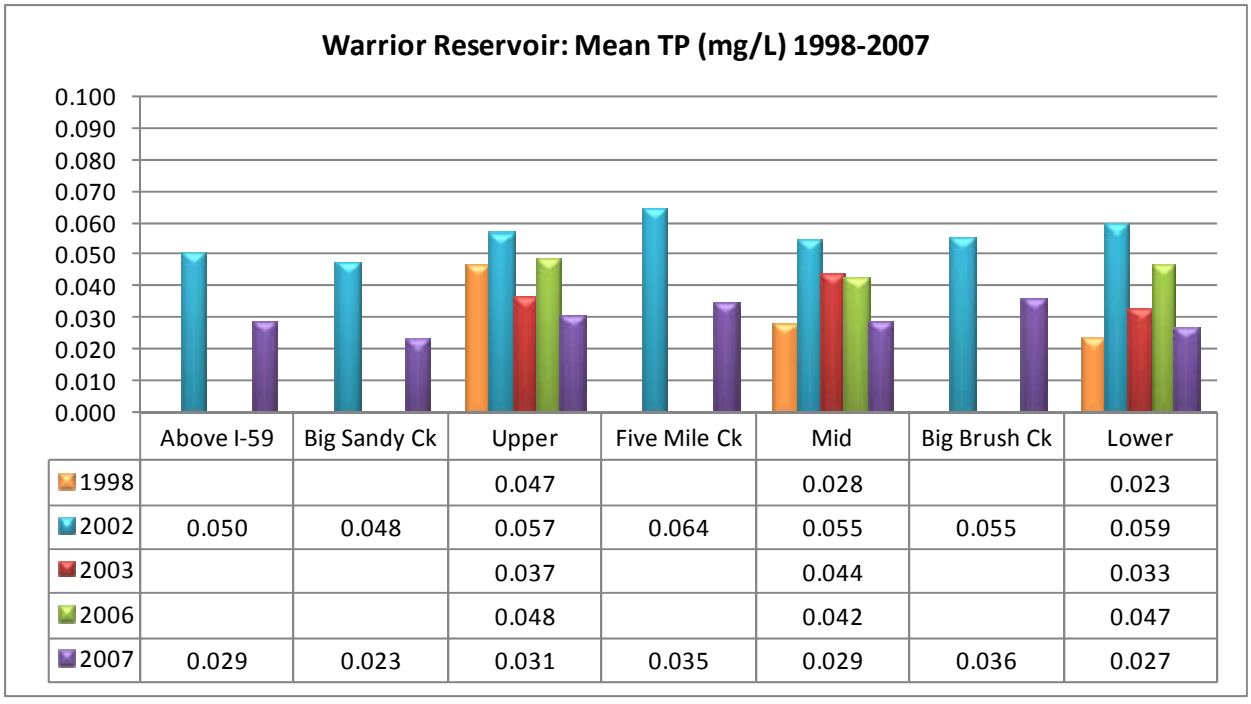
All measurements of dissolved oxygen concentrations in the mainstem stations met the ADEM Criteria (ADEM Admin. Code R. 335-6-10-.09) limit of 5.0 mg/L at 5.0 ft (1.5 m) (Fig. 8). The dissolved oxygen concentrations at the Five Mile Ck station were below ADEM criteria limits in July and August (Fig. 8). Profiles of temperature at the mainstem stations show highest temperatures were reached in August (Fig. 9, 10, & 11). The lower, mid and upper reservoir depth profiles show all three locations were fairly well mixed throughout the sampling season (Fig. 9, 10, & 11).

Mean growing season TSI values were calculated using season mean chl *a* concentrations and Carlson's Trophic State Index. TSI values for all mainstem locations indicate the reservoir is eutrophic. Since 2003 the mainstem stations show an increasing trend while mean annual discharge decreased (Fig. 12).

Figure 2. Seasonal mean TN and seasonal mean TP measured in Warrior Reservoir, April-October 1998-2007. Bar graphs consist of mainstem and embayment stations, illustrated from upstream to downstream as the graph is read from left to right.

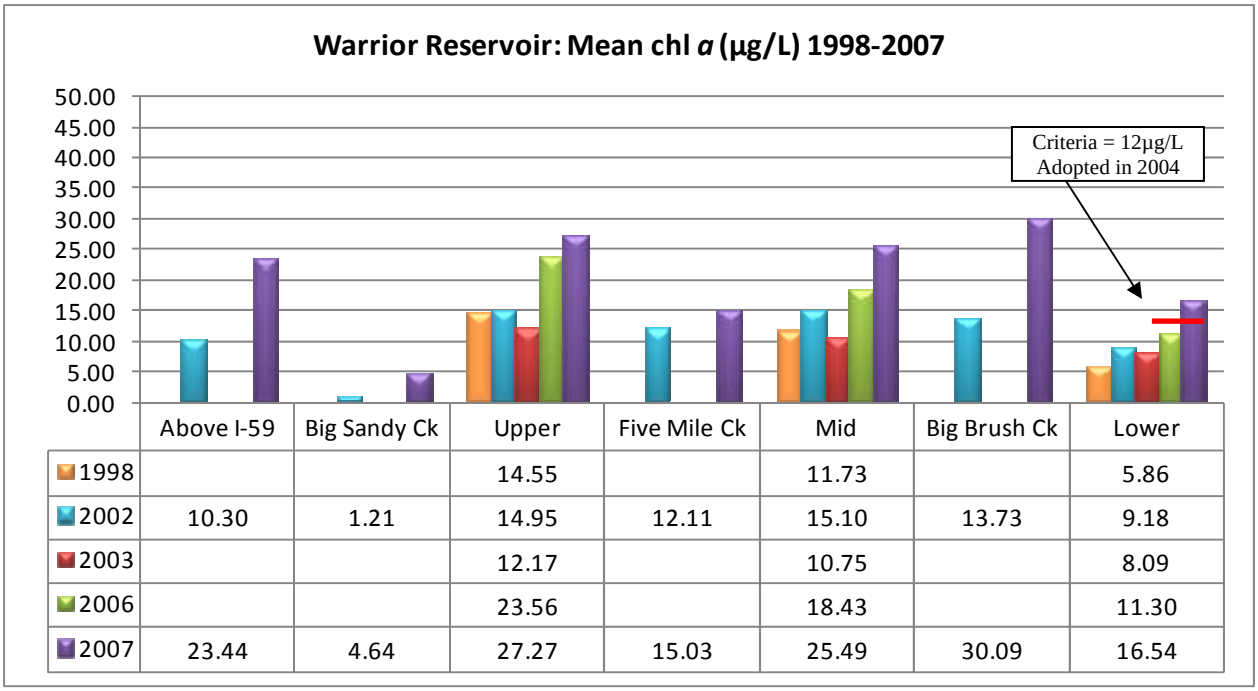


	Above I-59	Big Sandy Ck	Upper	Five Mile Ck	Mid	Big Brush Ck	Lower
1998			0.692		0.646		0.761
2002	0.945	0.575	0.813	0.652	0.758	0.626	0.735
2003			0.641		0.496		0.338
2006			0.899		0.834		0.597
2007	0.551	0.300	0.795	0.395	0.511	0.626	0.507

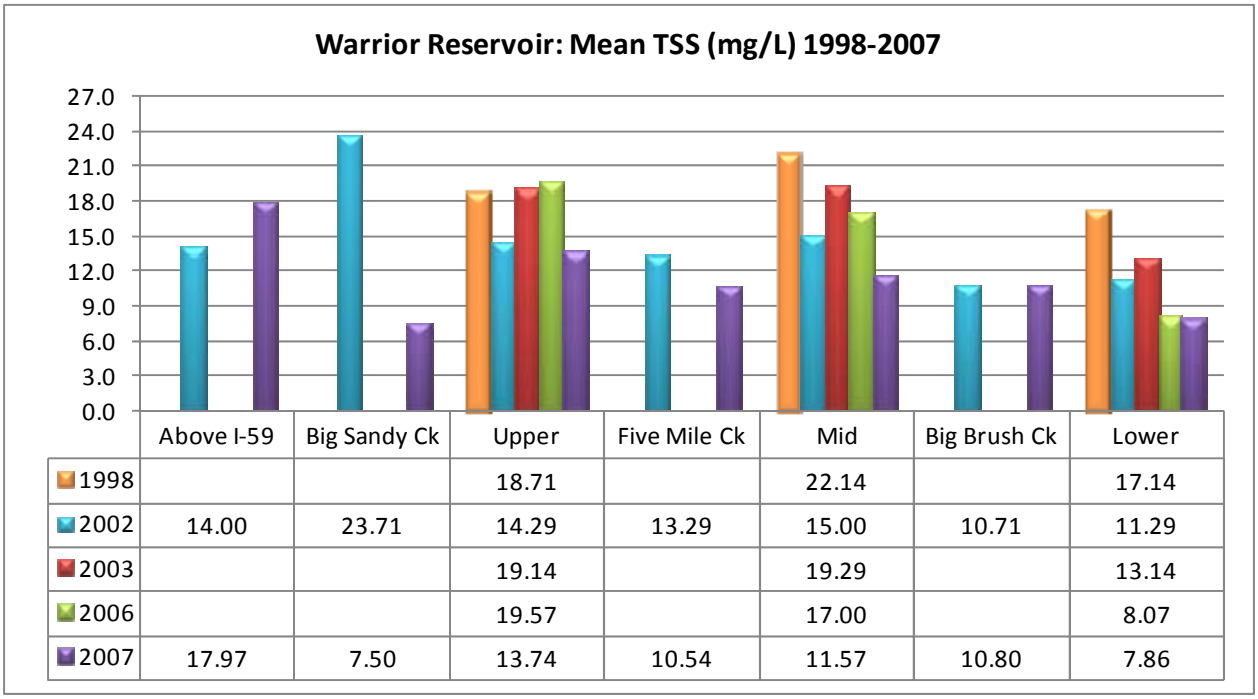


	Above I-59	Big Sandy Ck	Upper	Five Mile Ck	Mid	Big Brush Ck	Lower
1998			0.047		0.028		0.023
2002	0.050	0.048	0.057	0.064	0.055	0.055	0.059
2003			0.037		0.044		0.033
2006			0.048		0.042		0.047
2007	0.029	0.023	0.031	0.035	0.029	0.036	0.027

Figure 3. Seasonal mean chl *a* and seasonal mean TSS measured in Warrior Reservoir, April-October 1998-2007. Bar graphs consist of mainstem and embayment stations, illustrated from upstream to downstream as the graph is read from left to right. Chl *a* criteria applies to the growing season mean of the lower station only.



	Above I-59	Big Sandy Ck	Upper	Five Mile Ck	Mid	Big Brush Ck	Lower
1998			14.55		11.73		5.86
2002	10.30	1.21	14.95	12.11	15.10	13.73	9.18
2003			12.17		10.75		8.09
2006			23.56		18.43		11.30
2007	23.44	4.64	27.27	15.03	25.49	30.09	16.54



	Above I-59	Big Sandy Ck	Upper	Five Mile Ck	Mid	Big Brush Ck	Lower
1998			18.71		22.14		17.14
2002	14.00	23.71	14.29	13.29	15.00	10.71	11.29
2003			19.14		19.29		13.14
2006			19.57		17.00		8.07
2007	17.97	7.50	13.74	10.54	11.57	10.80	7.86

Figure 4. Monthly TN of the mainstem stations in Warrior Reservoir, April-October 2007. Each bar graph depicts monthly changes in each station. The historic mean (1992-2007) and min/max range are also displayed for comparison. The "n" value equals the number of data points included in the monthly historic calculations. TN was plotted vs. the closest discharge (USGS 02466030 Black Warrior River at Selden L & D near Eutaw, AL).

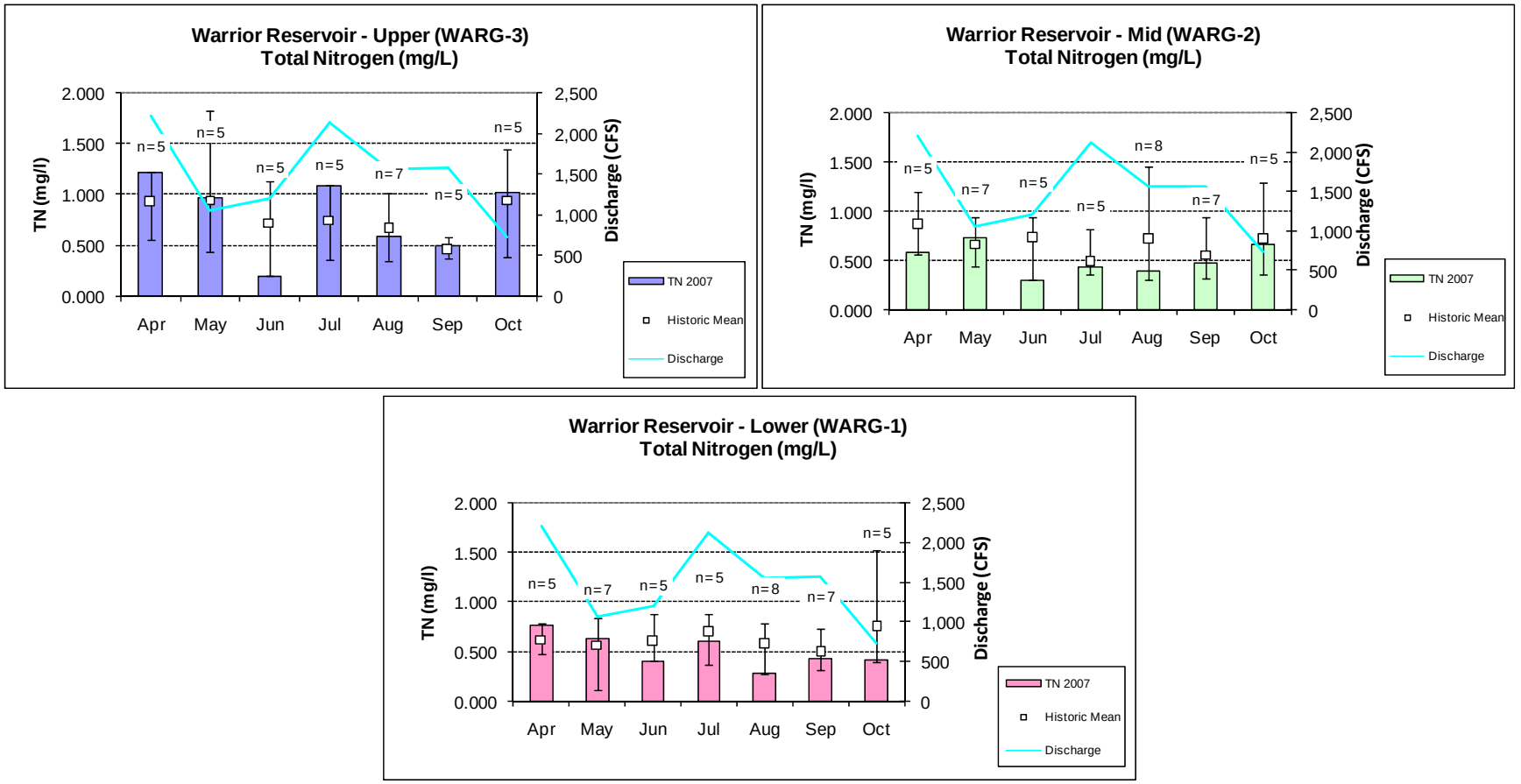
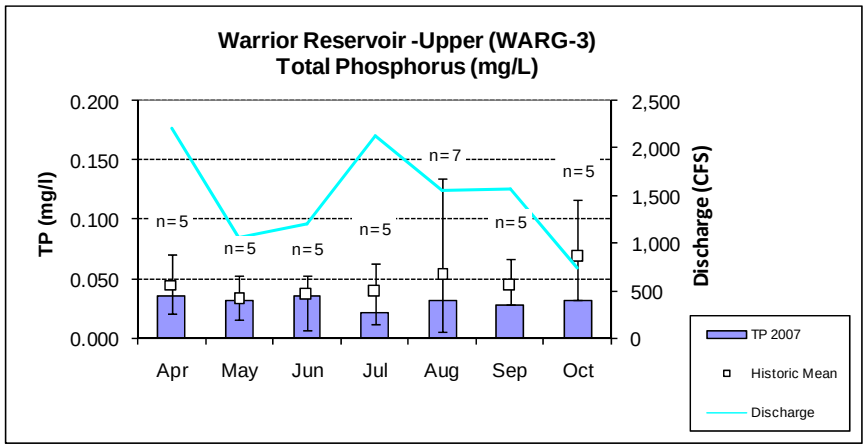
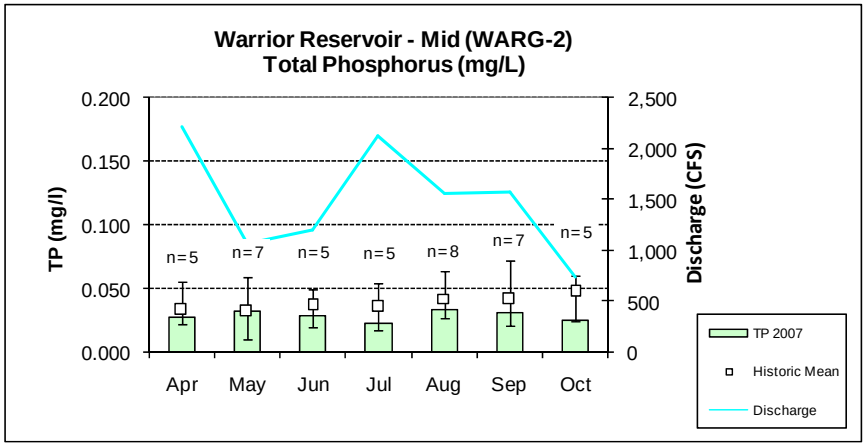


Figure 5. Monthly TP of the mainstem stations in Warrior Reservoir, April-October 2007. Each bar graph depicts monthly changes in each station. The historic mean (1992-2007) and min/max range are also displayed for comparison. The "n" value equals the number of data points included in the monthly historic calculations. TP was plotted vs. the closest discharge (USGS 02466030 Black Warrior River at Selden L & D near Eutaw, AL).





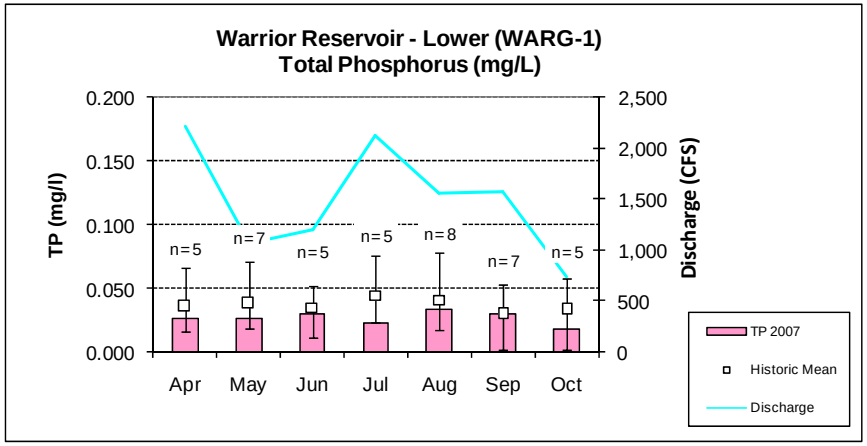


Figure 6. Monthly chl *a* of the mainstem stations in Warrior Reservoir, April-October 2007**.** Each bar graph depicts monthly changes in each station**.** The historic mean (1992-2007) and min/max range are also displayed for comparison. The "n" value equals the number of data points included in the monthly historic calculations. Chl *a* was plotted vs. the closest discharge (USGS 02466030 Black Warrior River at Selden L & D near Eutaw, AL).

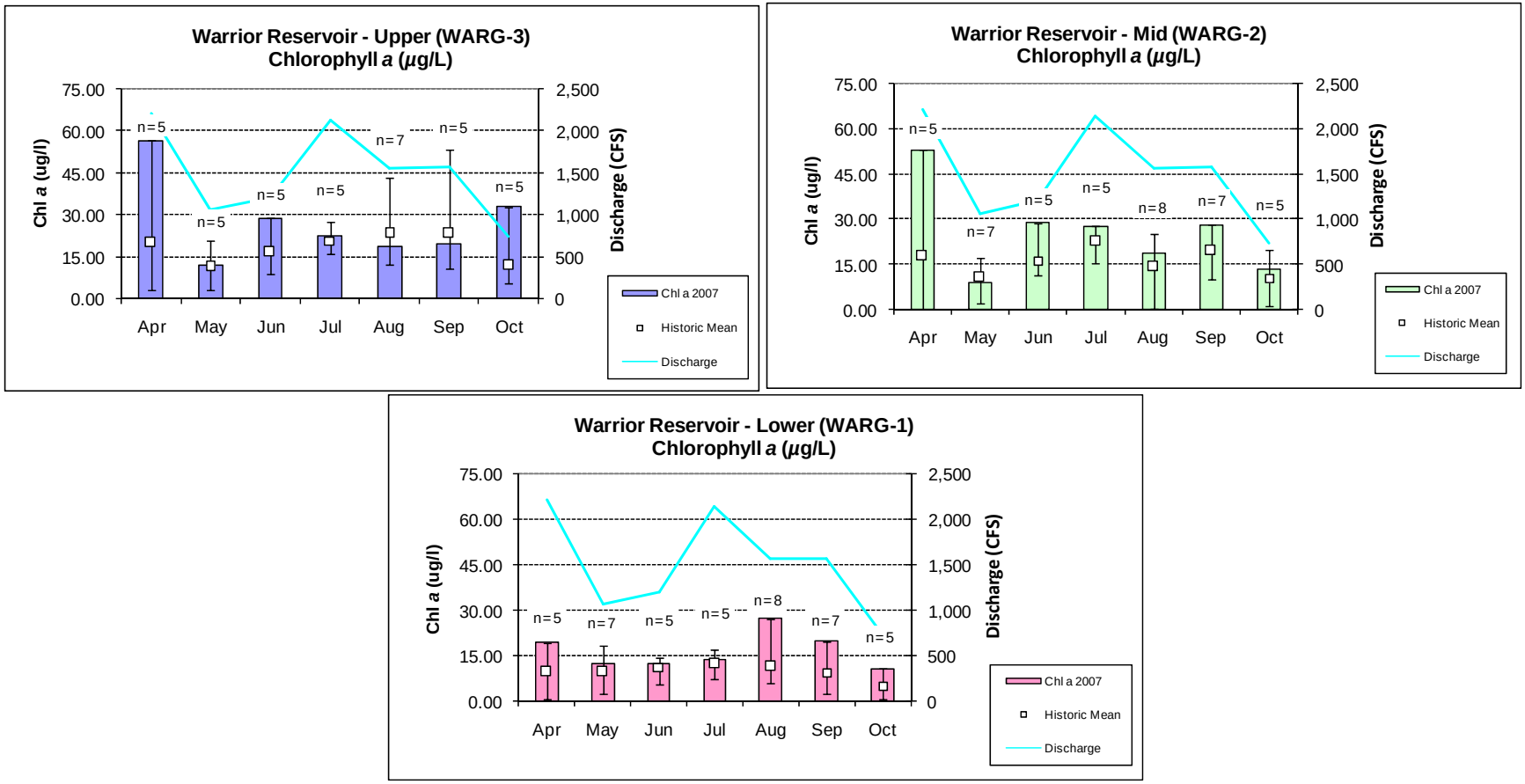
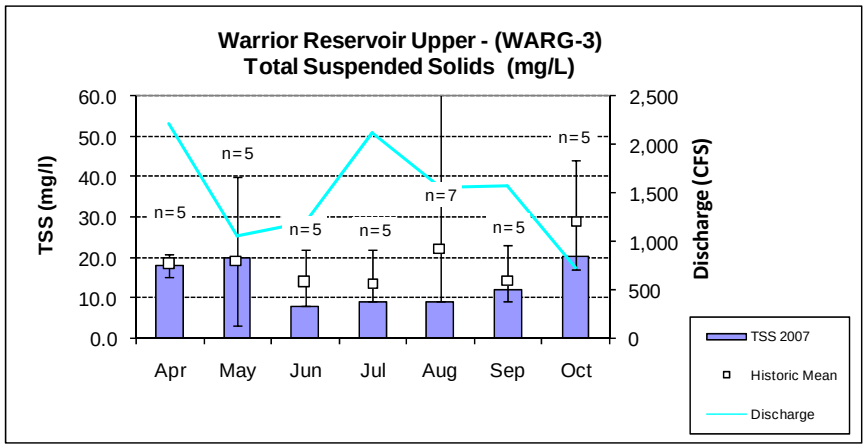
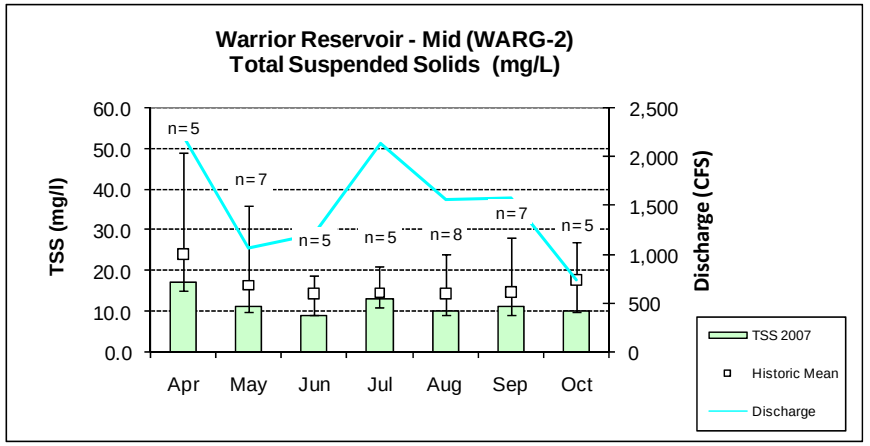


Figure 7. Monthly TSS of the mainstem stations in Warrior Reservoir, April-October 2007. Each bar graph depicts monthly changes in each station. The historic mean (1992-2007) and min/max range are also displayed for comparison. The "n" value equals the number of data points included in the monthly historic calculations. TSS was plotted vs. the closest discharge (USGS 02466030 Black Warrior River at Selden L & D near Eutaw, AL).





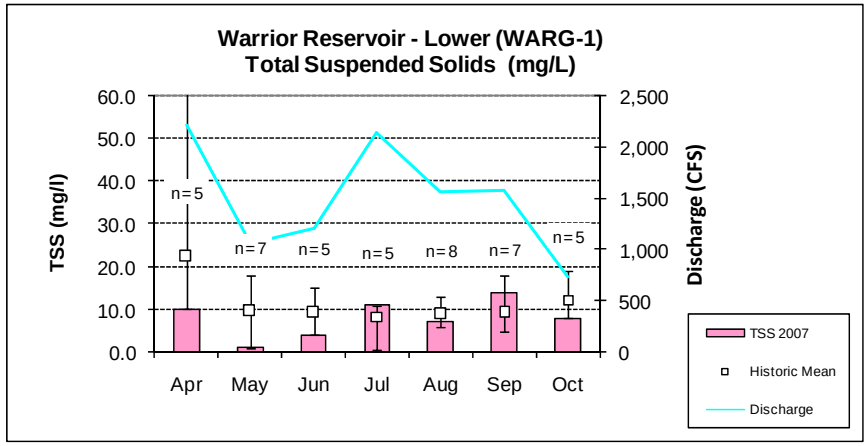


Table 2. Algal growth potential test results (expressed as mean Maximum Standing Crop (MSC) dry weights of *Selenastrum capricornutum* in mg/L) and limiting nutrient status. MSC values below 5 mg/L are considered to be protective in reservoirs and lakes; values below 20 mg/L MSC are considered protective of flowing streams and rivers. (Raschke and Schultz 1987).

Station	Upper		Mid		Lower	
	MSC	Limiting Nutrient	MSC	Limiting Nutrient	MSC	Limiting Nutrient
August 1998	3.12	Phosphorus	3.57	Phosphorus	2.90	Phosphorus
August 2002	5.56	Phosphorus	5.11	Phosphorus	3.69	Phosphorus
June 2007	4.93	Phosphorus	5.09	Phosphorus	3.77	Phosphorus
July 2007	2.18	Co-limiting	2.36	Nitrogen	3.23	Phosphorus
August 2007	2.62	Nitrogen	2.87	Co-limiting	4.30	Phosphorus

Figure 8. Monthly DO concentrations at 1.5 m (5 ft) for Warrior Reservoir stations collected April-October 2007. ADEM Water Quality Criteria pertaining to reservoir waters require a DO concentration of 5.0 mg/L at this depth (ADEM 2005). In tributaries, when total depth was less than 3 m, criteria apply to the mid-depth reading.

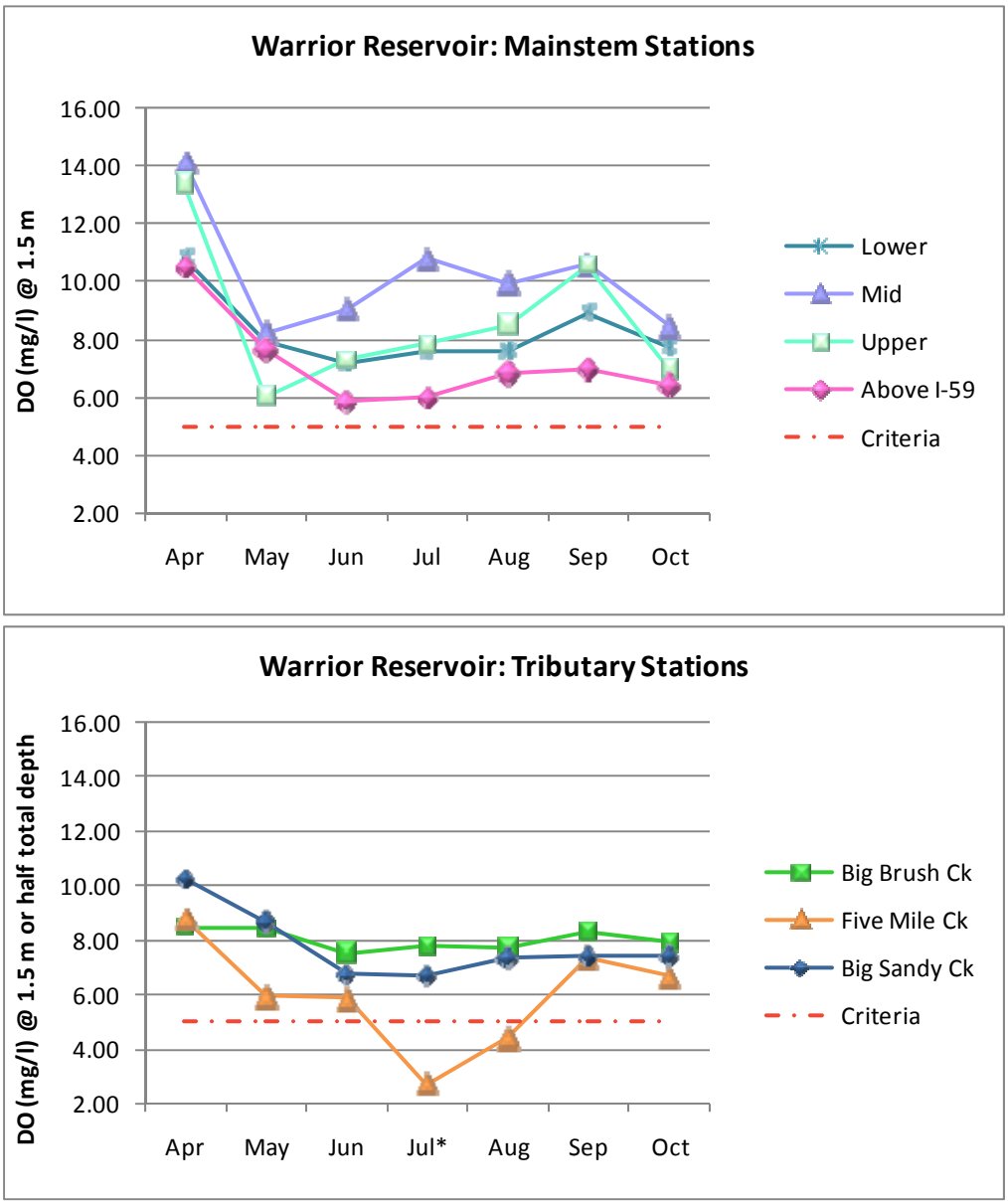


Figure 9. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C) and conductivity (µmhos) in lower Warrior Reservoir, April-October 2007.

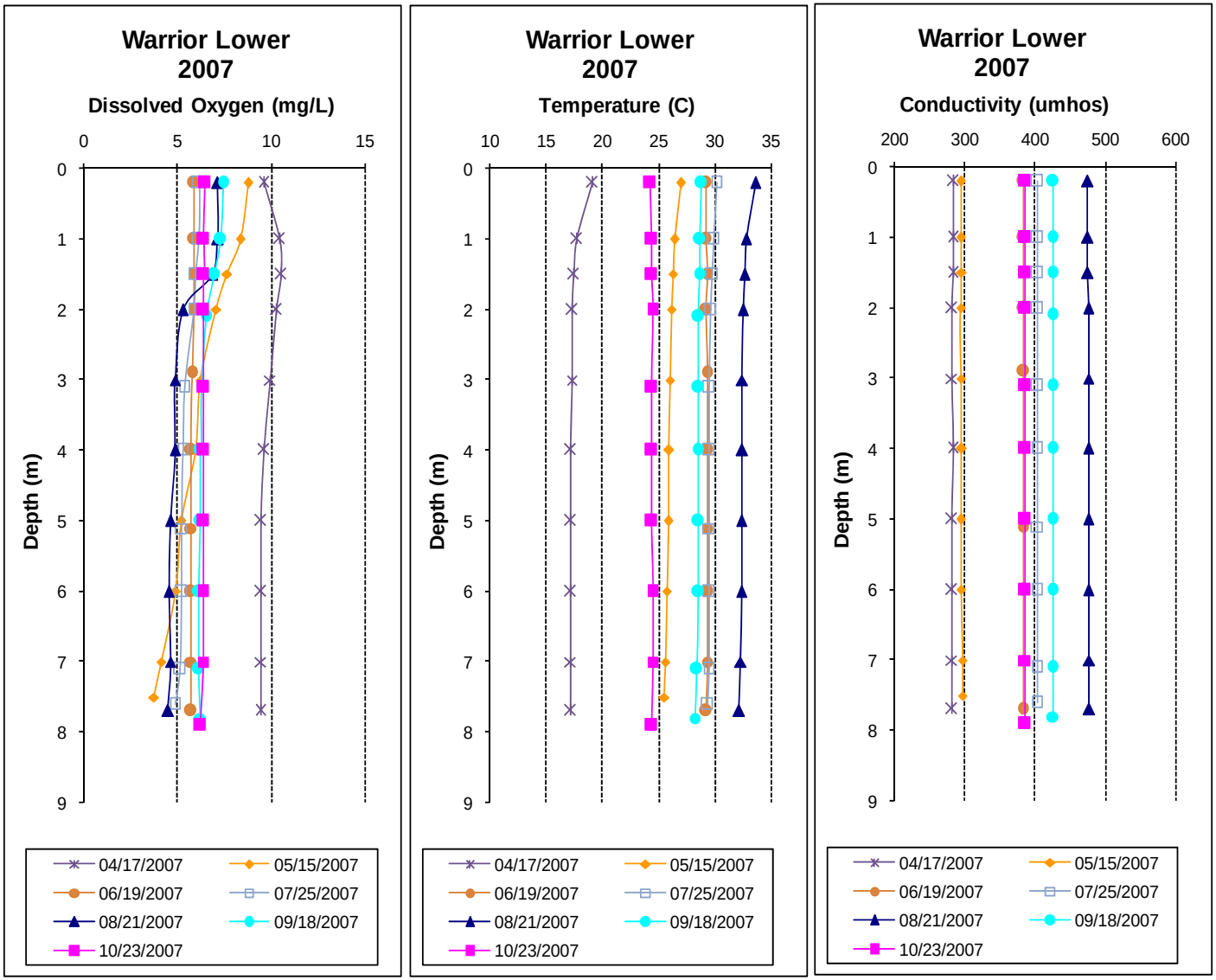


Figure 10. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C) and conductivity (µmhos) in mid Warrior Reservoir, April-October 2007.

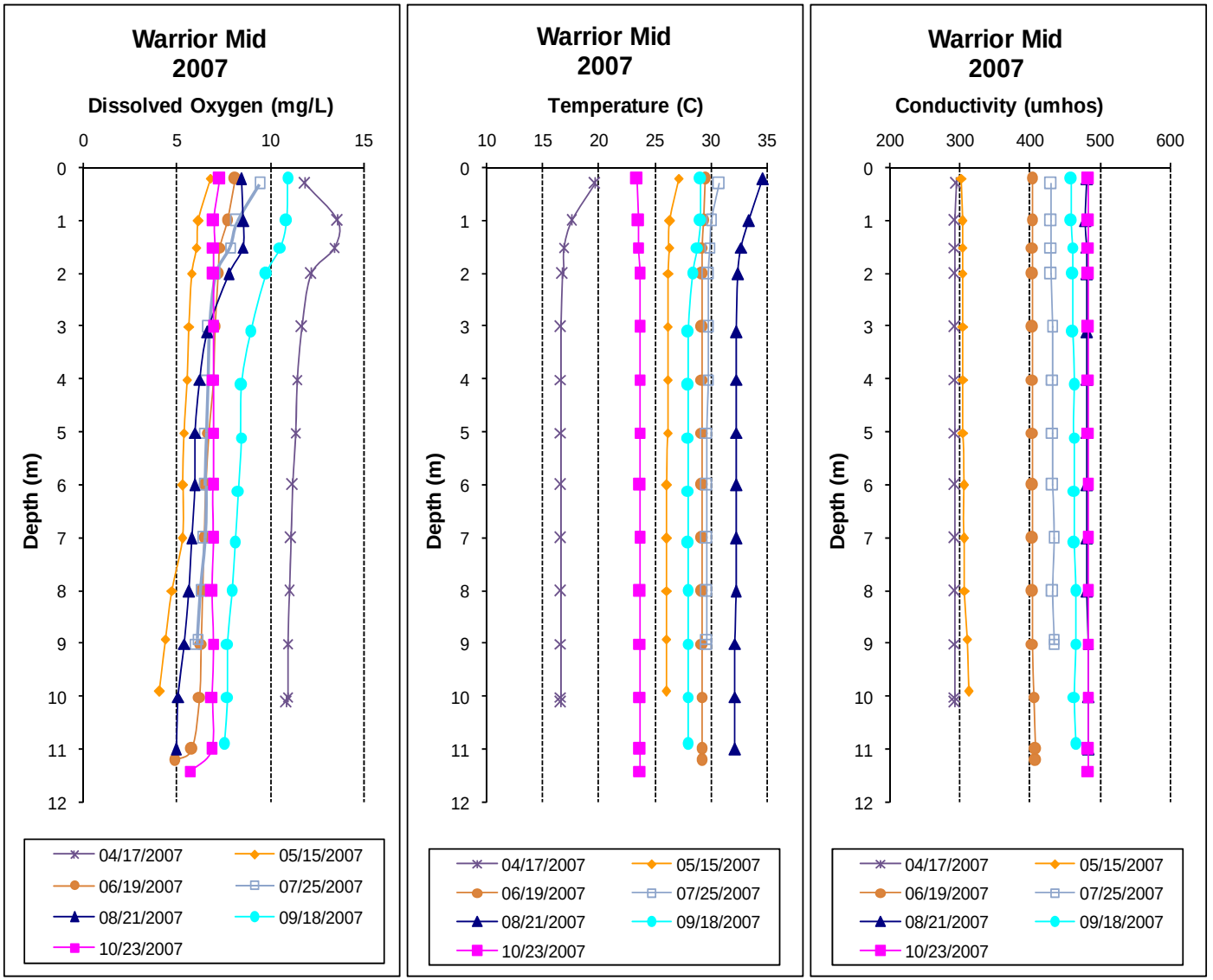


Figure 11. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C) and conductivity (µmhos) in upper Warrior Reservoir, April-October 2007.

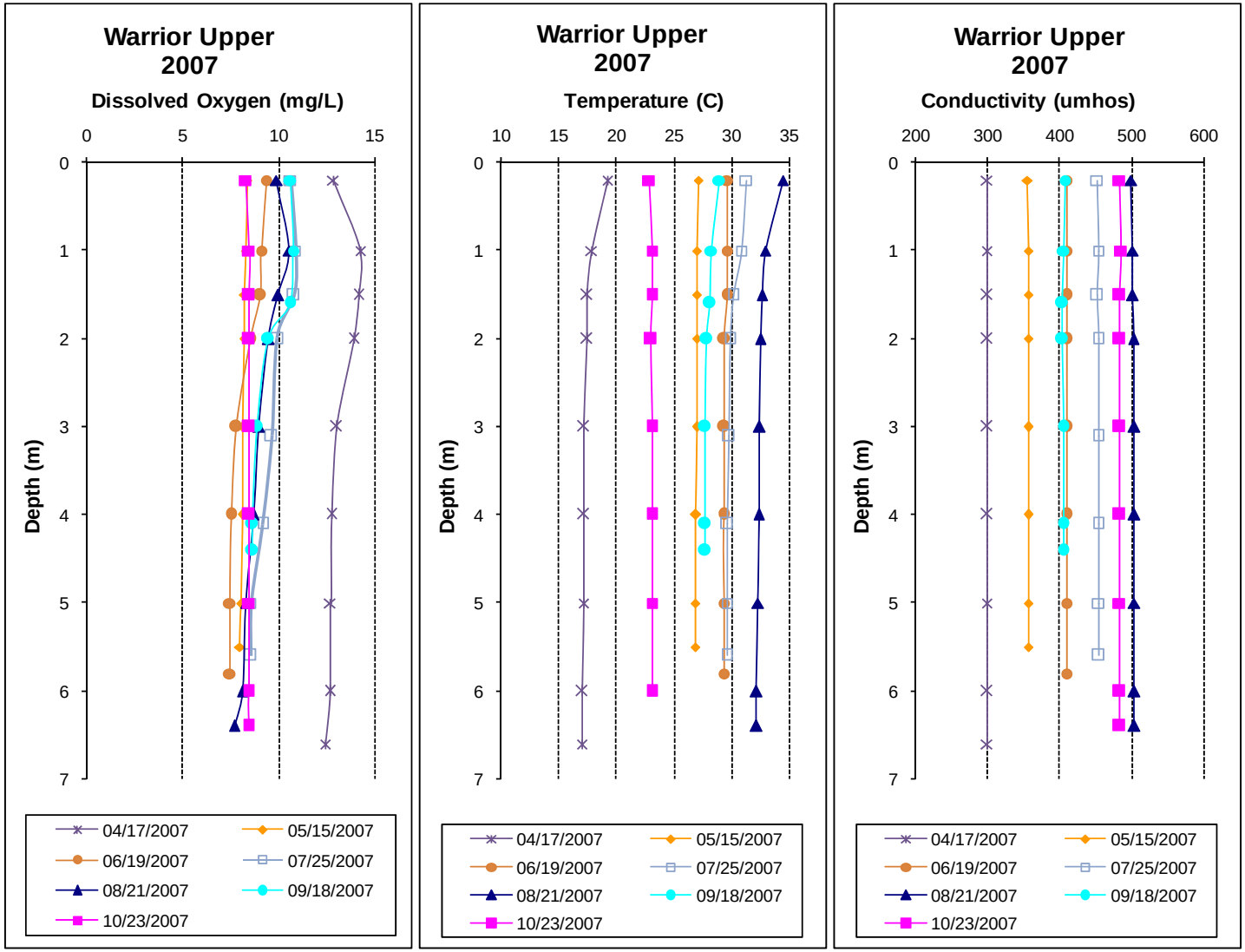
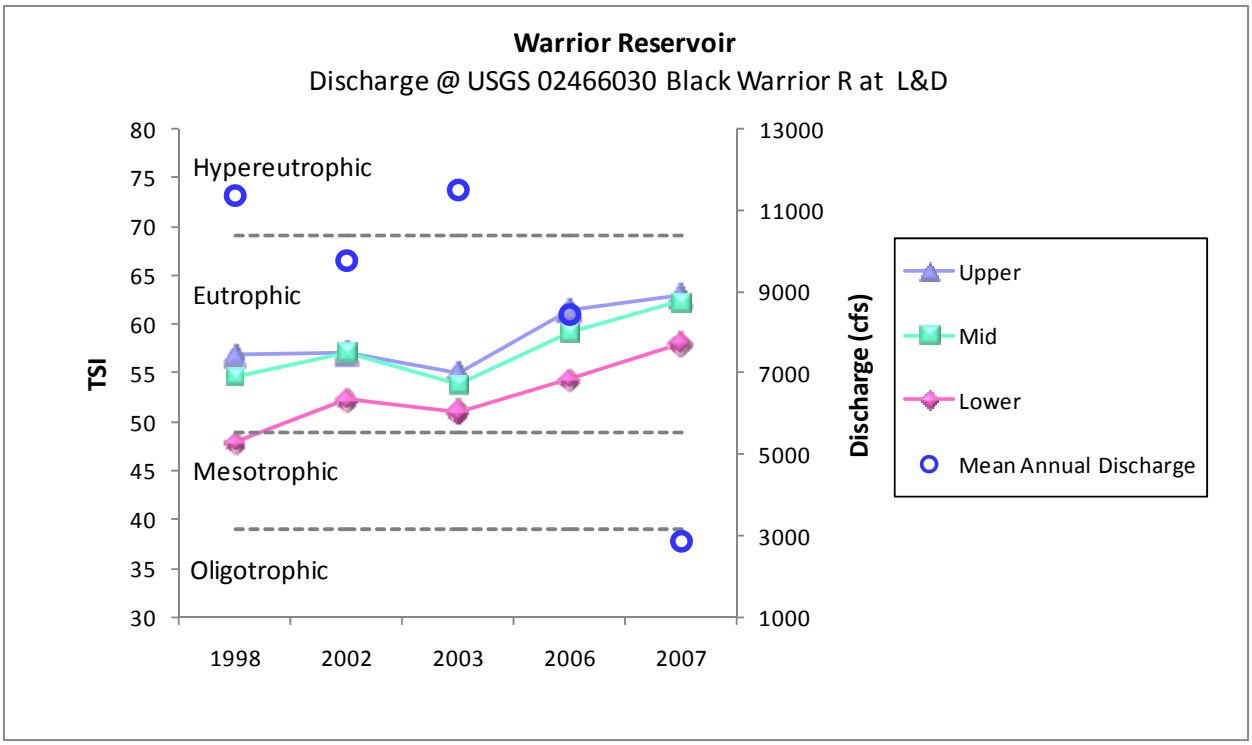


Figure 12. Seasonal mean growing season TSI values 1998-2007 for Warrior Resrvoir mainstem stations using chl *a* concentrations and Carlson's Trophic State Index calculation.



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APPENDIX

Appendix Table 1. Summary of Warrior Reservoir water quality data collected April-October, 2007. Minimum (min) and maximum (max) values calculated using minimum detection limits when results were less than this value. Median (med), mean, and standard deviation (SD) values were calculated by multiplying the MDL by 0.5 when results were less than this value.

Station	Parameter	N	Min	Max	Med	Mean	SD
WARG-1	**Physical**						
	Turbidity (NTU)	7	4.6	8.1	6.9	6.4	1.4
	Total Dissolved Solids (mg/L)	7	167.0	271.0	192.0	200.9	37.1
	Total Suspended Solids (mg/L)	7	1.0	14.0	8.0	7.9	4.4
	Hardness (mg/L)	4	52.4	74.0	67.8	65.5	9.5
	Alkalinity (mg/L)	7	44.0	81.5	68.8	64.1	14.5
	Photic Zone (m)	7	2.75	4.35	3.48	3.44	0.58
	Secchi (m)	7	0.83	1.31	1.15	1.10	0.19
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.015	0.015	0.008	0.008	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	0.012	0.395	0.109	0.156	0.137
	Total Kjeldahl Nitrogen (mg/L)	7	0.200	0.501	0.369	0.351	0.104
	Total Nitrogen (mg/L)[J]	7	0.282	0.764	0.429	0.507	0.167
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.004	0.009	0.005	0.006	0.003
	Total Phosphorus (mg/L)[J]	7	0.018	0.034	0.026	0.027	0.005
	CBOD-5 (mg/L)	7	< 1.0	3.9	1.3	1.4	1.2
	Chlorides (mg/L)[J]	7	23.0	42.9	36.1	34.3	7.4
	Biological						
	Chlorophyll a (ug/L)[J]	7	10.68	27.23	13.88	16.54	5.87
	Fecal Coliform (col/100 mL)[J]	1				5	
WARG-2	**Physical**						
	Turbidity (NTU)	7	7.1	11.2	9.3	9.5	1.4
	Total Dissolved Solids (mg/L)	7	170.0	273.0	222.0	220.9	37.9
	Total Suspended Solids (mg/L)	7	9.0	17.0	11.0	11.6	2.7
	Hardness (mg/L)	4	54.5	106.0	70.8	75.6	22.5
	Alkalinity (mg/L)	7	46.9	84.6	71.7	66.6	13.9
	Photic Zone (m)	7	2.37	2.93	2.49	2.56	0.20
	Secchi (m)	7	0.56	1.03	0.82	0.82	0.16
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.015	0.042	0.008	0.012	0.013
	Nitrate+Nitrite Nitrogen (mg/L)	7	< 0.002	0.296	0.019	0.098	0.136
	Total Kjeldahl Nitrogen (mg/L)	7	0.225	0.637	0.430	0.412	0.134
	Total Nitrogen (mg/L)	7	< 0.301	0.732	0.478	0.510	0.152
	Dissolved Reactive Phosphorus (mg/L)[J]	7	0.004	0.009	0.007	0.007	0.002
	Total Phosphorus (mg/L)	7	0.023	0.034	0.029	0.029	0.004
	CBOD-5 (mg/L)	7	< 1.0	2.1	0.5	0.8	0.6
	Chlorides (mg/L)[J]	7	3.9	59.5	40.6	34.6	17.9
	Biological						
	Chlorophyll a (ug/L)[J]	7	9.08	52.87	27.59	25.49	14.34
	Fecal Coliform (col/100 mL)[J]	1				<1	

Station	Parameter	N	Min	Max	Med	Mean	SD
WARG-3	**Physical**						
	Turbidity (NTU)	7	6.1	17.0	9.2	10.6	4.0
	Total Dissolved Solids (mg/L)	7	192.0	281.0	230.0	227.1	30.7
	Total Suspended Solids (mg/L)	7	8.0	20.2	12.0	13.7	5.5
	Hardness (mg/L)	4	57.3	106.0	74.4	78.0	22.1
	Alkalinity (mg/L)	7	49.6	84.6	70.8	68.6	13.0
	Photic Zone (m)	7	1.77	3.30	2.35	2.50	0.49
	Secchi (m)	7	0.62	0.84	0.78	0.76	0.08
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.015	0.021	0.008	0.009	0.005
	Nitrate+Nitrite Nitrogen (mg/L)	7	< 0.002	0.430	0.016	0.134	0.185
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.150	1.083	0.587	0.661	0.348
	Total Nitrogen (mg/L)	7	< 0.198	1.220	0.961	0.795	0.372
	Dissolved Reactive Phosphorus (mg/L)[J]	7	0.005	0.009	0.006	0.007	0.002
	Total Phosphorus (mg/L)	7	0.021	0.035	0.032	0.031	0.005
	CBOD-5 (mg/L)	7	< 1.0	3.9	0.5	1.1	1.3
	Chlorides (mg/L)[J]	7	20.9	63.6	37.4	40.2	13.2
	Biological						
	Chlorophyll a (ug/L)[J]	7	11.75	56.60	22.43	27.27	14.65
	Fecal Coliform (col/100 mL)[J]	1				<1	
WARG-4	**Physical**						
	Turbidity (NTU)	7	8.0	32.8	11.1	13.6	8.6
	Total Dissolved Solids (mg/L)	7	163.0	230.0	218.0	207.0	23.0
	Total Suspended Solids (mg/L)	7	9.0	55.0	12.0	18.0	16.5
	Hardness (mg/L)	4	60.2	103.0	76.4	79.0	20.5
	Alkalinity (mg/L)	7	51.4	85.6	72.0	71.0	13.4
	Photic Zone (m)	7	1.12	3.04	2.75	2.51	0.65
	Secchi (m)	7	0.56	1.15	0.81	0.88	0.22
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.015	0.062	0.008	0.015	0.021
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.003	0.413	0.048	0.150	0.180
	Total Kjeldahl Nitrogen (mg/L)	7	0.180	0.587	0.385	0.401	0.172
	Total Nitrogen (mg/L)[J]	7	< 0.252	0.957	0.560	0.551	0.264
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.004	0.009	0.006	0.006	0.002
	Total Phosphorus (mg/L)	7	0.021	0.044	0.027	0.029	0.008
	CBOD-5 (mg/L)	7	< 1.0	4.4	0.5	1.8	1.7
	Chlorides (mg/L)[J]	7	20.9	72.9	40.8	44.6	19.7
	Biological						
	Chlorophyll a (ug/L)[J]	7	15.26	51.80	16.55	23.44	13.24
	Fecal Coliform (col/100 mL)[J]	1				10	

Station	Parameter	N	Min	Max	Med	Mean	SD
WARG-5	**Physical**						
	Turbidity (NTU)	6	3.7	38.7	7.6	12.1	13.2
	Total Dissolved Solids (mg/L)	7	76.0	154.0	137.0	124.9	28.0
	Total Suspended Solids (mg/L)	7	3.0	24.5	5.0	7.5	7.7
	Hardness (mg/L)	4	40.8	50.2	47.1	46.3	4.6
	Alkalinity (mg/L)	7	40.5	61.0	52.5	50.5	7.3
	Photic Zone (m)	1				0.80	
	Secchi (m)	1				0.80	
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.015	0.017	0.008	0.009	0.004
	Nitrate+Nitrite Nitrogen (mg/L)	7	0.066	0.133	0.119	0.111	0.023
	Total Kjeldahl Nitrogen (mg/L)	7	< 0.150	0.582	0.075	0.188	0.187
	Total Nitrogen (mg/L)	7	< 0.173	0.648	0.208	0.300	0.169
	Dissolved Reactive Phosphorus (mg/L)[J]	7	0.007	0.020	0.012	0.013	0.004
	Total Phosphorus (mg/L)	7	0.017	0.026	0.024	0.023	0.003
	CBOD-5 (mg/L)	7	< 1.0	3.6	0.5	1.3	1.2
	Chlorides (mg/L)[J]	7	39.9	48.2	46.5	45.1	3.0
	Biological						
	Chlorophyll a (ug/L)[J]	7	< 0.10	19.22	2.14	4.64	6.57
	Fecal Coliform (col/100 mL)[J]	1				110	
WARG-6	**Physical**						
	Turbidity (NTU)	7	9.9	15.5	11.0	12.1	2.4
	Total Dissolved Solids (mg/L)	7	46.0	123.0	68.0	79.6	28.9
	Total Suspended Solids (mg/L)	7	4.0	19.0	10.0	10.5	4.9
	Hardness (mg/L)	4	12.0	38.0	26.9	26.0	10.7
	Alkalinity (mg/L)	7	7.9	38.5	25.9	24.9	11.0
	Photic Zone (m)	7	1.38	2.10	1.80	1.80	0.26
	Secchi (m)	7	0.63	1.03	0.73	0.80	0.18
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.015	0.015	0.008	0.008	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.002	0.049	0.003	0.014	0.020
	Total Kjeldahl Nitrogen (mg/L)	7	0.212	0.595	0.350	0.381	0.146
	Total Nitrogen (mg/L)[J]	7	< 0.214	0.598	0.399	0.395	0.153
	Dissolved Reactive Phosphorus (mg/L)[J]	7	0.006	0.015	0.015	0.012	0.004
	Total Phosphorus (mg/L)	7	0.028	0.051	0.034	0.035	0.008
	CBOD-5 (mg/L)	7	< 1.0	2.2	0.5	1.0	0.7
	Chlorides (mg/L)[J]	7	3.9	23.2	15.3	13.7	6.8
	Biological						
	Chlorophyll a (ug/L)[J]	7	4.45	26.54	13.88	15.03	6.64
	Fecal Coliform (col/100 mL)[J]	1				2	

Station	Parameter	N	Min	Max	Med	Mean	SD
WARG-7	**Physical**						
	Turbidity (NTU)	7	7.4	13.2	9.5	9.8	2.3
	Total Dissolved Solids (mg/L)	7	107.0	247.0	152.0	167.6	46.2
	Total Suspended Solids (mg/L)	7	6.0	18.0	9.0	10.8	4.0
	Hardness (mg/L)	4	41.0	93.8	52.2	59.8	23.7
	Alkalinity (mg/L)	7	28.2	73.9	51.1	54.0	17.3
	Photic Zone (m)	7	1.96	3.00	2.03	2.22	0.40
	Secchi (m)	7	0.48	0.97	0.79	0.78	0.17
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.015	0.015	0.008	0.008	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	< 0.002	0.103	0.022	0.030	0.036
	Total Kjeldahl Nitrogen (mg/L)	7	0.355	0.856	0.618	0.597	0.171
	Total Nitrogen (mg/L)[J]	7	< 0.356	0.859	0.660	0.626	0.184
	Dissolved Reactive Phosphorus (mg/L)[J]	7	0.006	0.012	0.009	0.009	0.002
	Total Phosphorus (mg/L)	7	0.024	0.071	0.030	0.036	0.017
	CBOD-5 (mg/L)	7	< 1.0	4.6	1.7	1.9	1.6
	Chlorides (mg/L)[J]	7	17	40	36	33	9
	Biological						
	Chlorophyll a (ug/L)[J]	7	20.29	46.53	30.51	30.09	9.30
	Fecal Coliform (col/100 mL)[J]	1				<1	

J=one or more of the values provided are estimated; < = Actual value is less than the detection limit