2012 Warrior Reservoir Report

Rivers and Reservoirs Monitoring Program

Alabama Department of Environmental Management

Field Operations Division
Environmental Indicators Section
Aquatic Assessment Unit
June 2015

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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 2012 assessment of the Black Warrior and Cahaba River Basins under the Rivers and Reservoirs Monitoring Program (RRMP). ADEM began monitoring lake water quality statewide in 1985, followed by a second statewide survey in 1989. In 1990, the Reservoir Water Quality Monitoring Program (now known as RRMP) was initiated by ADEM. The current 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 (ADEM 2012).

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 2012 growing season and to evaluate trends in mean lake trophic status and nutrient concentrations using ADEM's historic dataset. Monthly and mean concentrations of nutrients [total nitrogen (TN); total phosphorus (TP)], algal biomass/productivity [chlorophyll *a* (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 2012), Surface Water Quality Assurance Project Plan (ADEM 2013), and Quality Management Plan (ADEM 2012).

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 2012 results.

Figure 1. Warrior Reservoir with 2012 sampling locations. A description of each sampling location is provided in Table 1.

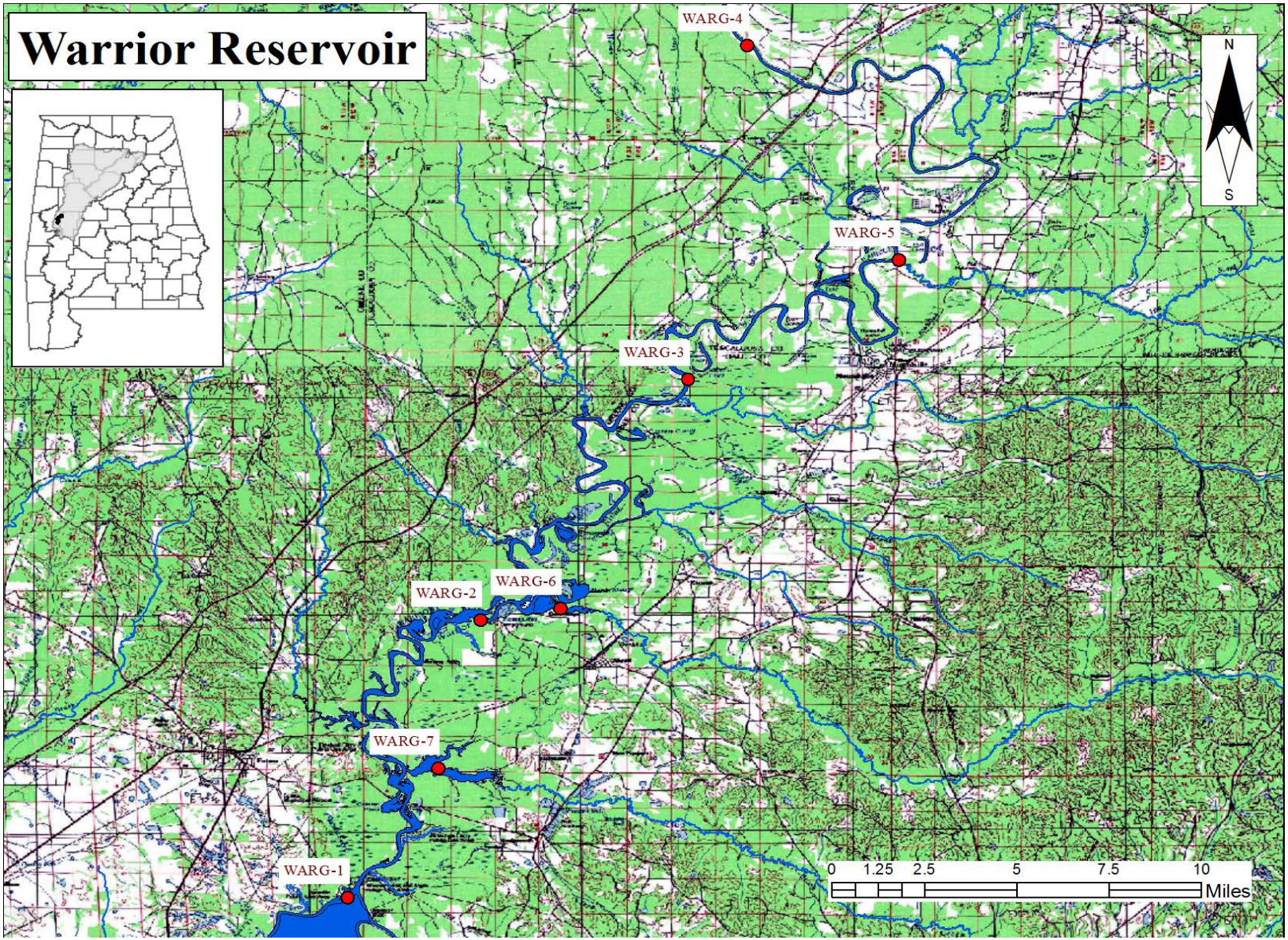


Table 1. Descriptions of the 2012 monitoring stations in Warrior Reservoir.

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 2012 are presented in Appendix Table 1. The table contains the minimum, maximum, median, mean, and standard deviation of each parameter analyzed.

Stations with the highest concentrations of nutrients, chlorophyll *a*, and TSS are noted in the paragraphs to follow. Though stations with lowest concentrations are not always mentioned, review of the graphs will indicate stations that may be potential candidates for reference waterbodies and watersheds.

In 2012, the highest mean growing season TN value was calculated for the upper station (Fig. 2). Mean growing season TN concentrations at each mainstem were variable since 1998, though 2012 concentrations were lower compared to 2011. Mean TN concentrations have decreased at the Big Sandy Ck and Big Brush Ck stations, 2007-2012, while values at the Five Mile Ck station increased. Monthly TN concentrations were below historic means in most months for all stations.

In 2012, the highest mean growing season TP value was calculated at three stations: upper, Five Mile Ck, and Big Brush Ck (Fig. 2). Mean growing season TP concentrations have decreased overall at each station 2002-2012. Monthly TP concentrations were below historic means most months at each station with one historic low measured at the lower station in July (Fig. 5).

In 2012, the highest growing season mean chl *a* value was calculated for the mid station (Fig. 3). Mean growing season chl *a* concentrations have increased at all mainstem stations from 2011-2012. Mean concentrations at all embayment stations have decreased since 2007. Although exceeding the criteria in 2007, mean chl *a* concentration at the lower station was below

the established criteria 2011-2012. The highest monthly chl *a* concentration was measured at the mid station in August which was also a historic high (Fig. 6). Monthly chl *a* concentrations were at or below historic means a majority of months sampled at the upper and lower stations. Historic low concentrations were measured in the upper and mid stations in June.

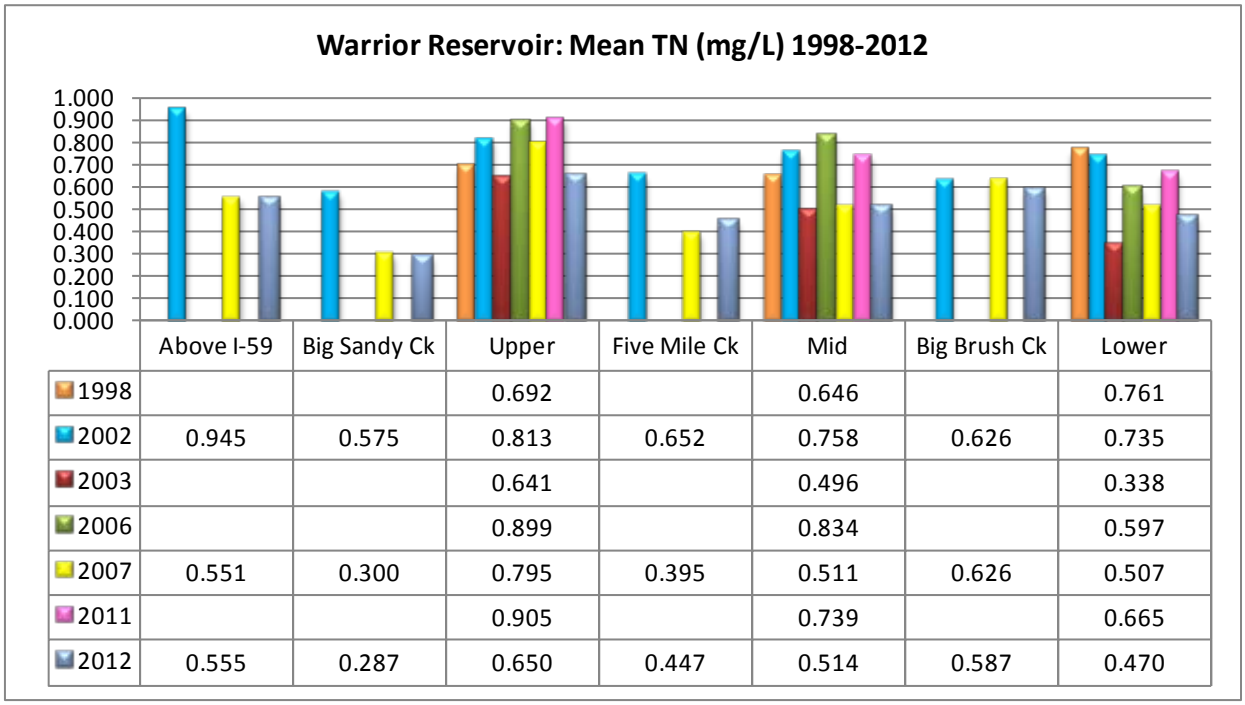
In 2012, the highest mean growing season TSS value was calculated for Big Sandy Creek (Fig. 3). Mean TSS have decreased overall at each mainstem since 1998 and at each tributary since 2002. Monthly TSS concentrations were below historic means a majority of months sampled at all stations (Fig. 7). Historic low concentrations were measured in June and October at the upper station and July and October at the mid station. Additional historic lows were measured in the lower station in April and October.

In 2012, AGPT results indicated co-limiting nutrients at the upper and lower stations and nitrogen limiting at the mid station (Table 2). The MSC values were below 5 mg/L, the value defined as protective of reservoir and lake systems (Rashke and Schultz 1987).

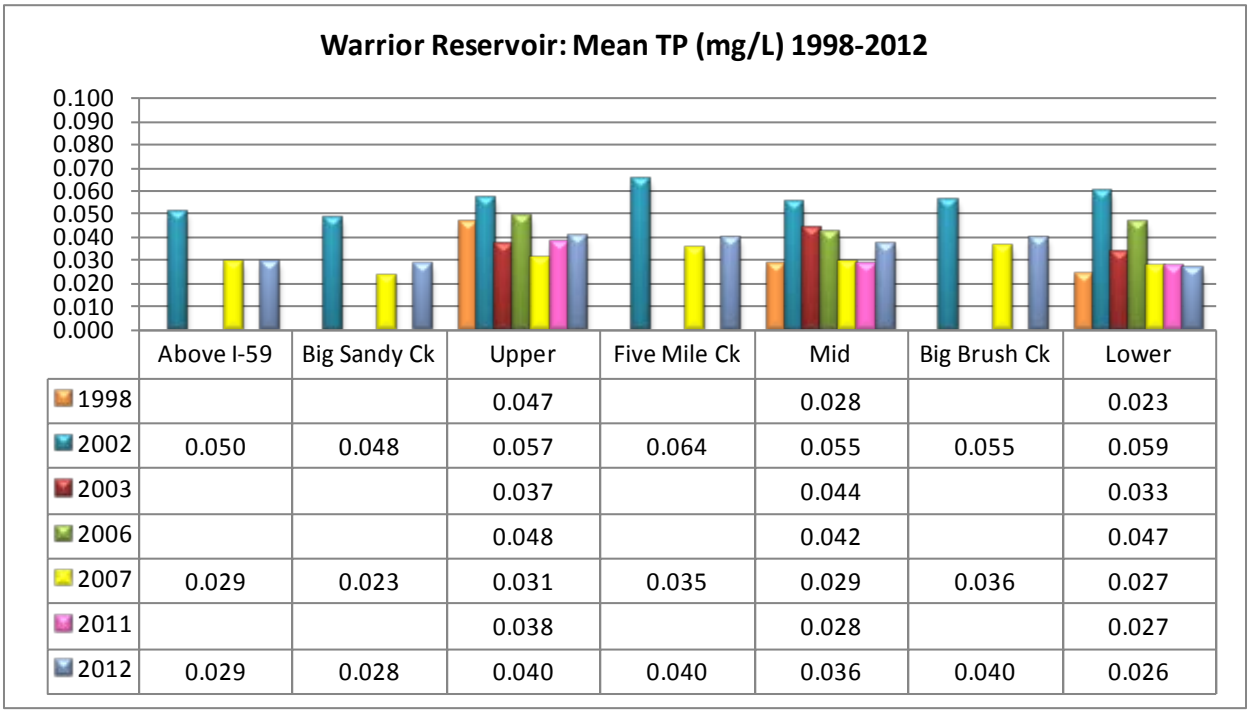
All measurements of dissolved oxygen concentrations for each station met the ADEM Criteria (ADEM Admin. Code R. 335-6-10-.09) limit of 5.0 mg/L at 5.0 ft (1.5 m) (Fig. 8). Profiles of DO show each mainstem station was mixed most months and remained above 5 mg/L top to bottom (Fig. 9, 10, & 11). Profiles of temperature at the mainstem stations show highest temperatures were reached in July and some thermal stratification occurred at each station June-August, between the surface and two meters.

TSI values were calculated using monthly chl *a* concentrations and Carlson's Trophic State Index. Mainstem stations were mostly eutrophic for a majority of the growing season (Fig. 12). Big Brush Ck and Five Mile Ck were eutrophic most months with the highest TSI tributary value calculated at the Five Mile Ck embayment in June. Values for Big Sandy Ck were mostly oligotrophic.

Figure 2. Mean growing season TN and TP measured in Warrior Reservoir, April-October, 1998-2012. Stations are illustrated from upstream to downstream as the graph is read from left to right.

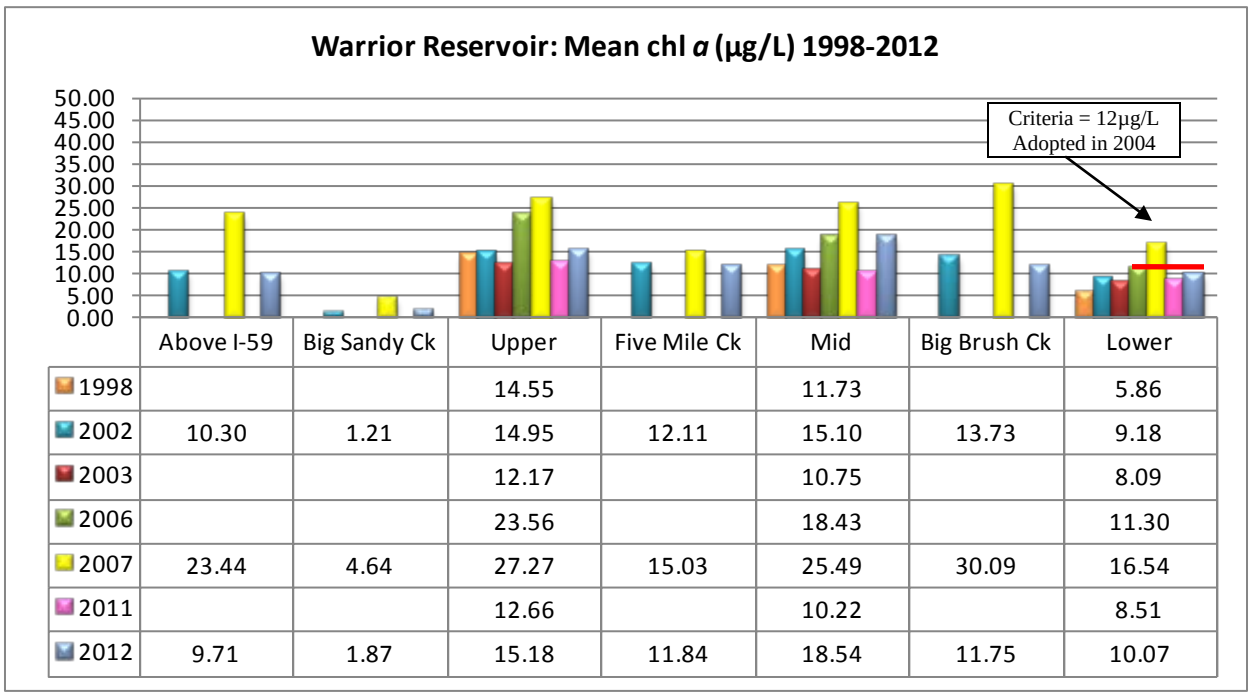


	Above I-59	Big Sandy Ck	Upper	Five Mile Ck	Mid	Big Brush Ck	Lower
1998			0.692		0.646		0.761
2002	0.945	0.575	0.813	0.652	0.758	0.626	0.735
2003			0.641		0.496		0.338
2006			0.899		0.834		0.597
2007	0.551	0.300	0.795	0.395	0.511	0.626	0.507
2011			0.905		0.739		0.665
2012	0.555	0.287	0.650	0.447	0.514	0.587	0.470

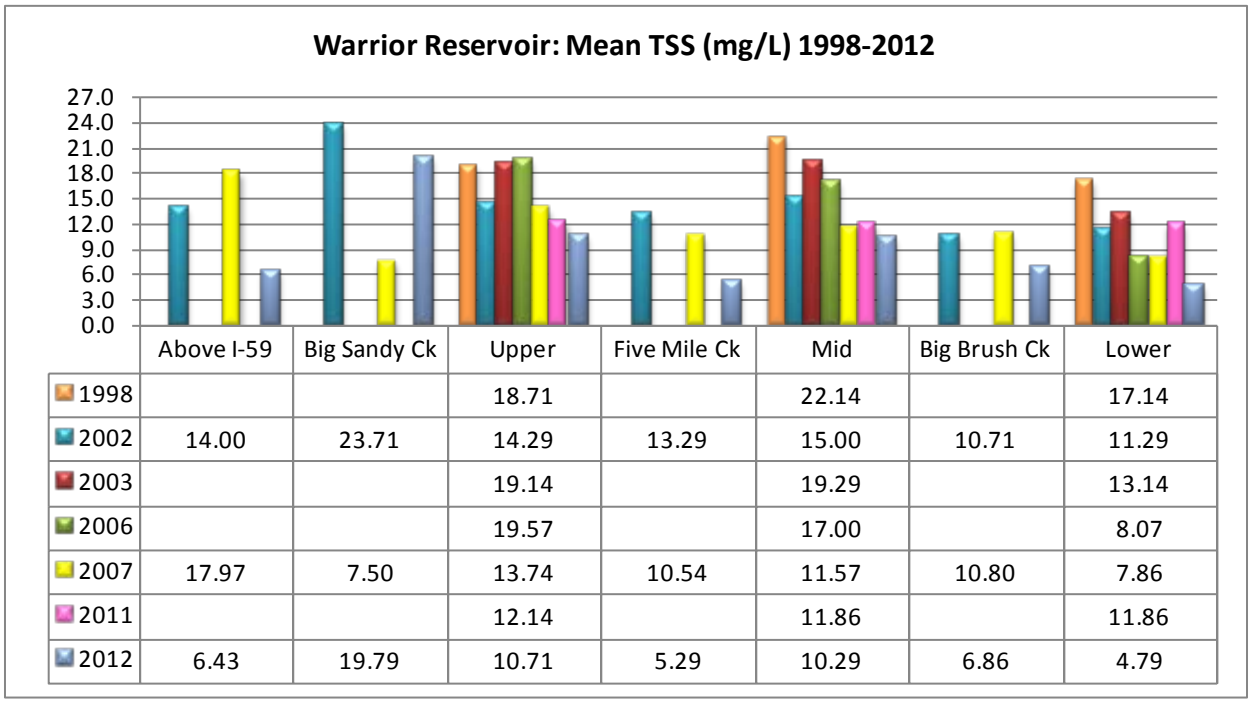


	Above I-59	Big Sandy Ck	Upper	Five Mile Ck	Mid	Big Brush Ck	Lower
1998			0.047		0.028		0.023
2002	0.050	0.048	0.057	0.064	0.055	0.055	0.059
2003			0.037		0.044		0.033
2006			0.048		0.042		0.047
2007	0.029	0.023	0.031	0.035	0.029	0.036	0.027
2011			0.038		0.028		0.027
2012	0.029	0.028	0.040	0.040	0.036	0.040	0.026

Figure 3. Mean growing season chl *a* and TSS measured in Warrior Reservoir, April-October, 1998-2012. Stations are 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
2011			12.66		10.22		8.51
2012	9.71	1.87	15.18	11.84	18.54	11.75	10.07



	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
2011			12.14		11.86		11.86
2012	6.43	19.79	10.71	5.29	10.29	6.86	4.79

Figure 4. Monthly TN concentrations measured in Warrior Reservoir, April-October, 2012, vs. average monthly discharge. Each bar graph depicts monthly changes in each station. The historic mean (1992-2012) and min/max ranges 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).

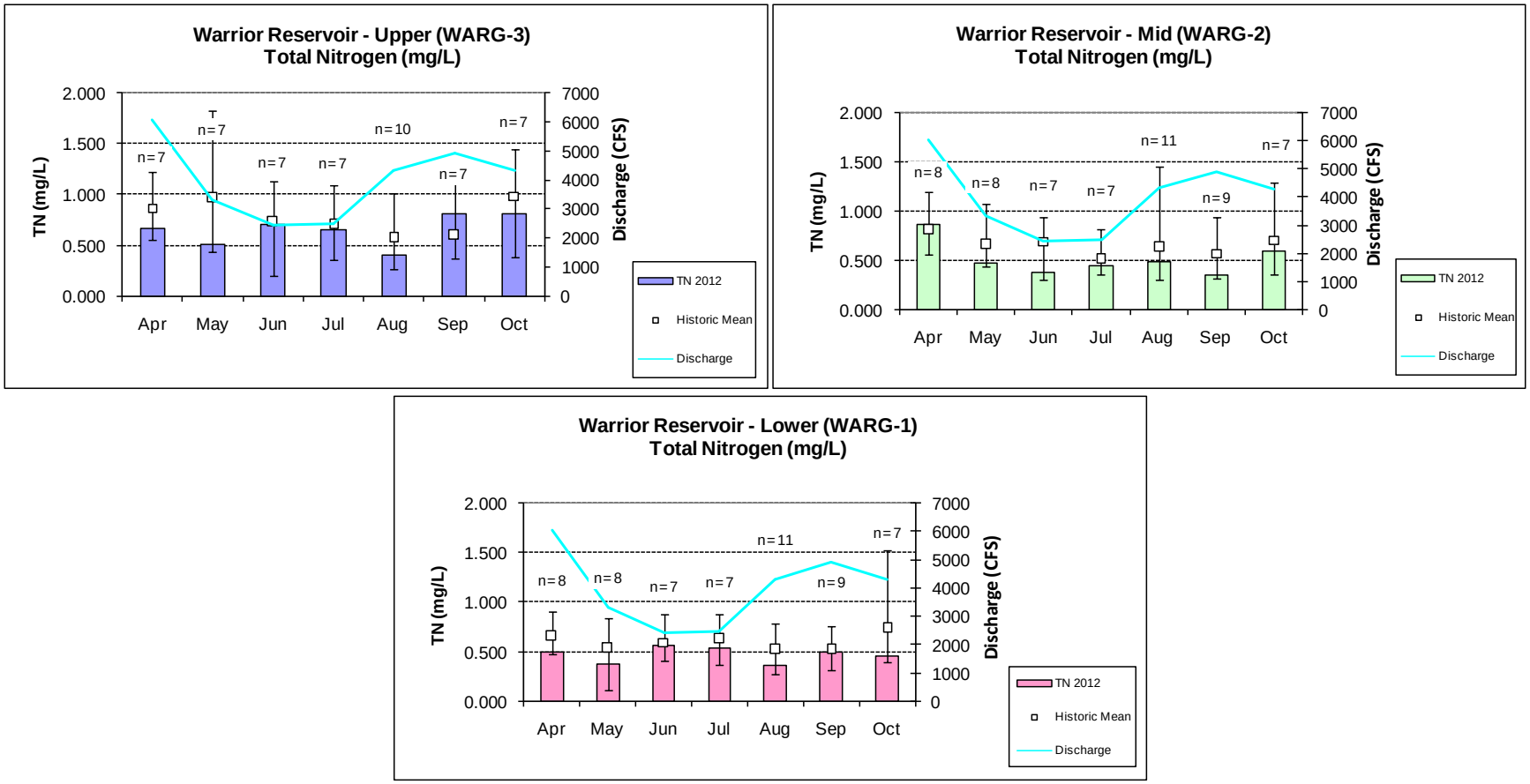


Figure 5. Monthly TP concentrations measured in Warrior Reservoir, April-October, 2012, vs. average monthly discharge. Each bar graph depicts monthly changes in each station. The historic mean (1992-2012) and min/max ranges are also displayed for comparison. The "n" value equals the number of data points 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).

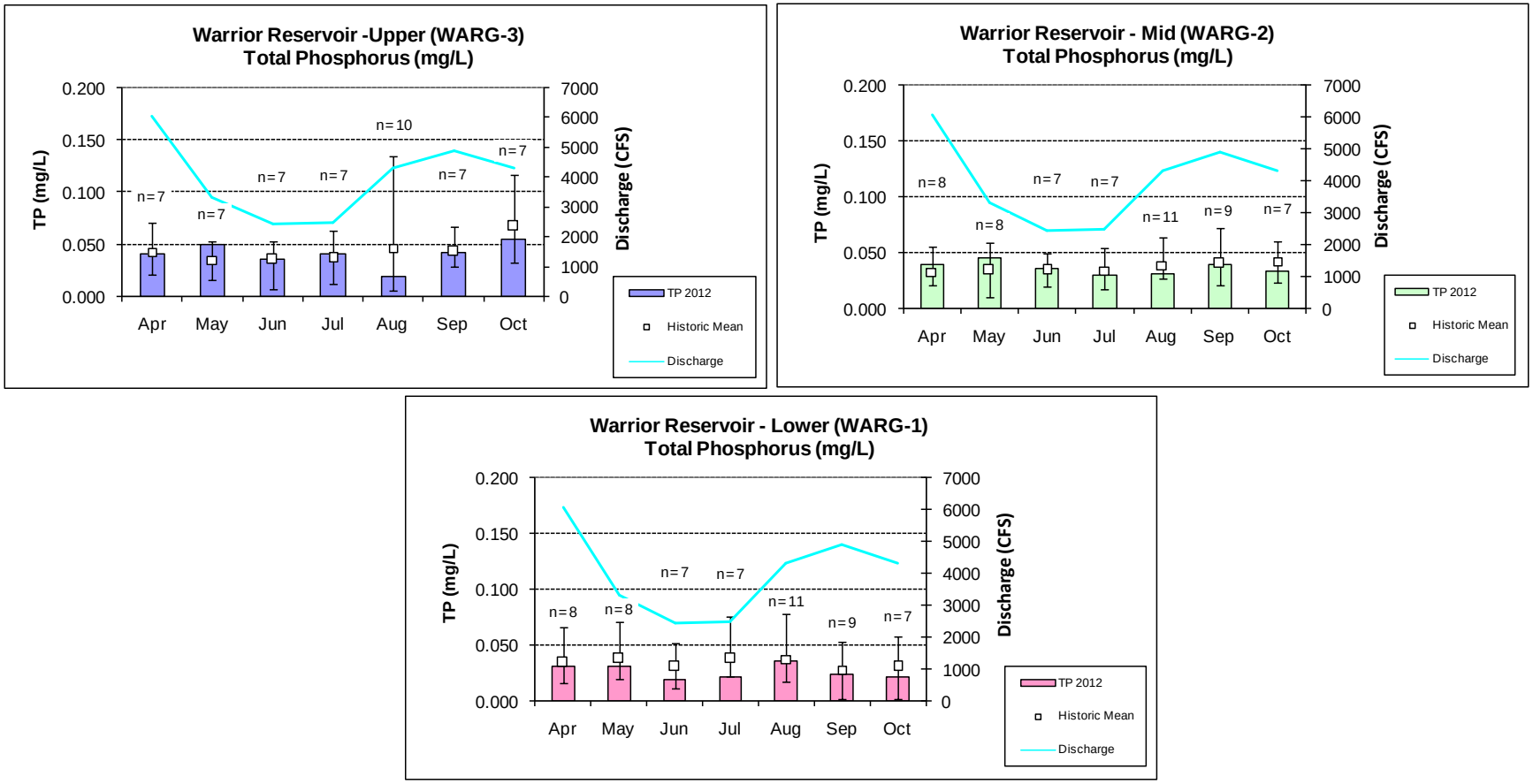


Figure 6. Monthly chl *a* concentrations measured in Warrior Reservoir, April-October, 2012, vs. average monthly discharge. Each bar graph depicts monthly changes in each station**.** The historic mean (1992-2012) and min/max ranges are also displayed for comparison. The "n" value equals the number of 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).

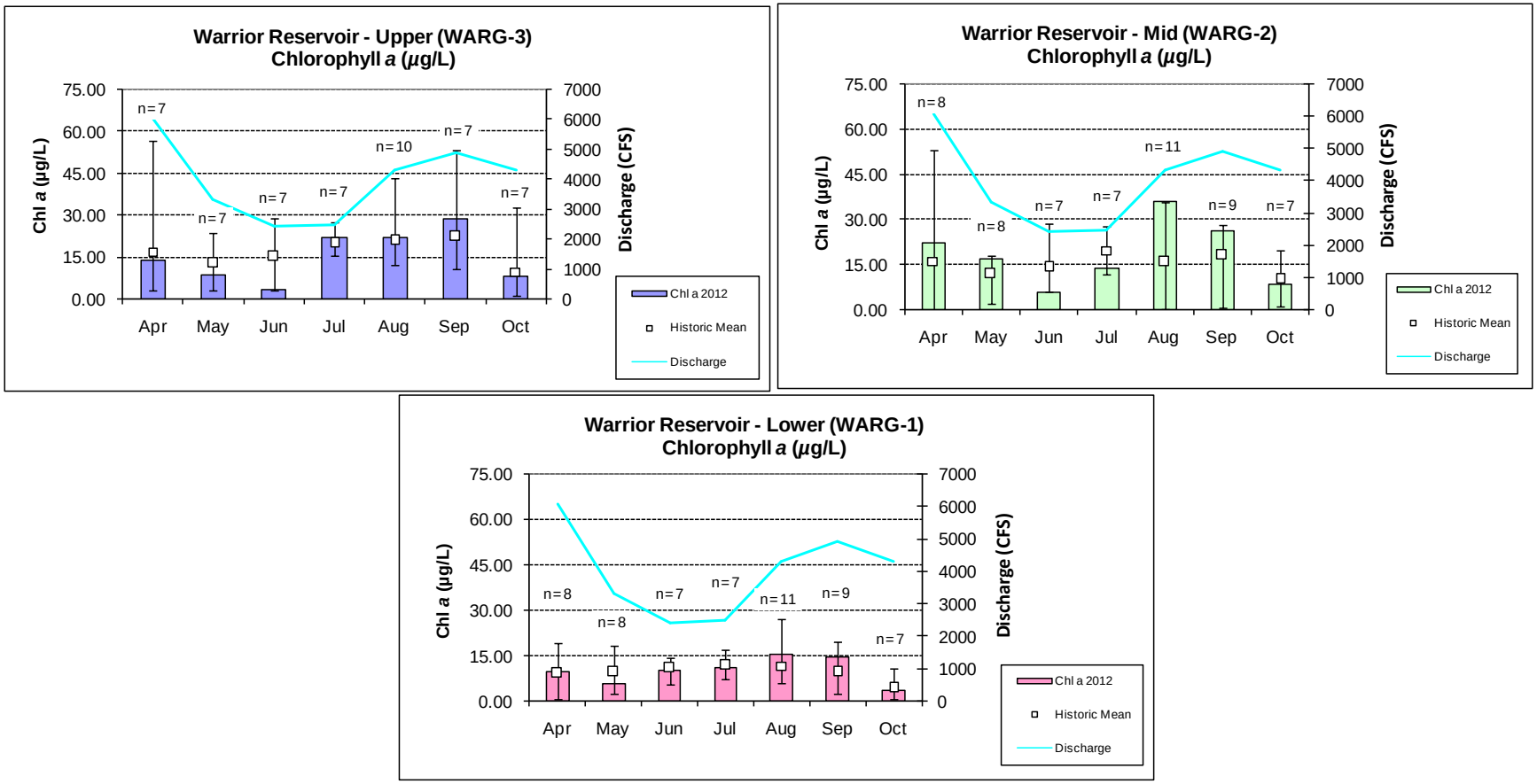


Figure 7. Monthly TSS concentrations measured in Warrior Reservoir, April-October, 2012, vs. average monthly discharge. Each bar graph depicts monthly changes in each station. The historic mean (1992-2012) and min/max ranges are also displayed for comparison. The "n" value equals the number of data points 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).

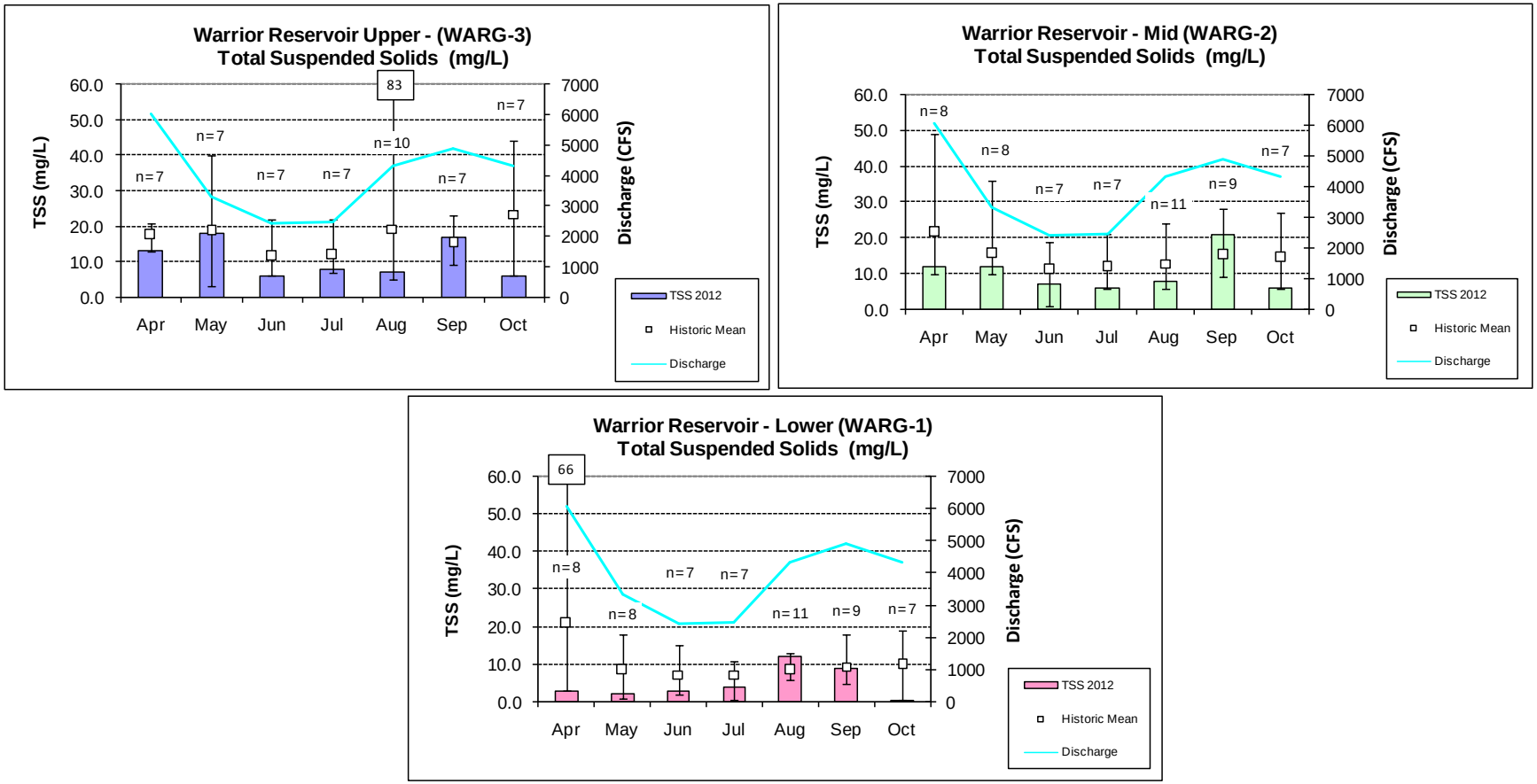
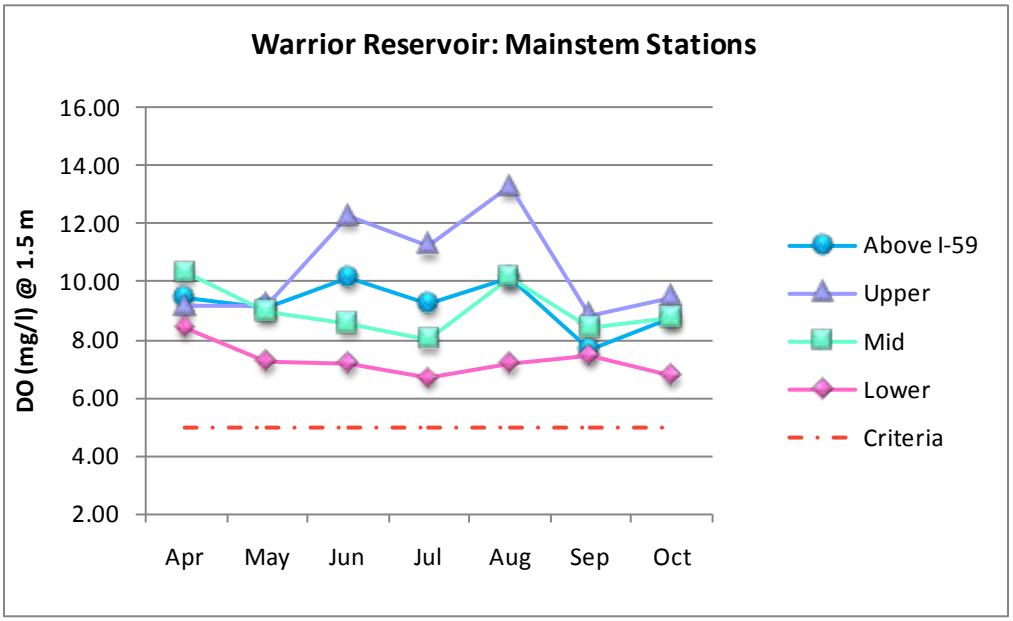


Table 2. Algal growth potential test results, Warrior Reservoir, 1998-2012, (expressed as mean Maximum Standing Crop (MSC) dry weights of *Selenastrum capricornutum* in mg/L) and limiting nutrient status. MSC values below 5 mg/L are considered to be protective in reservoirs and lakes; values below 20 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
August 2012	4.27	Co-limiting	4.26	Nitrogen	4.18	Co-limiting

Figure 8. Monthly DO concentrations at 1.5 m (5 ft) for Warrior Reservoir stations collected April-October, 2012. 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, the criterion applies to the mid-depth reading.



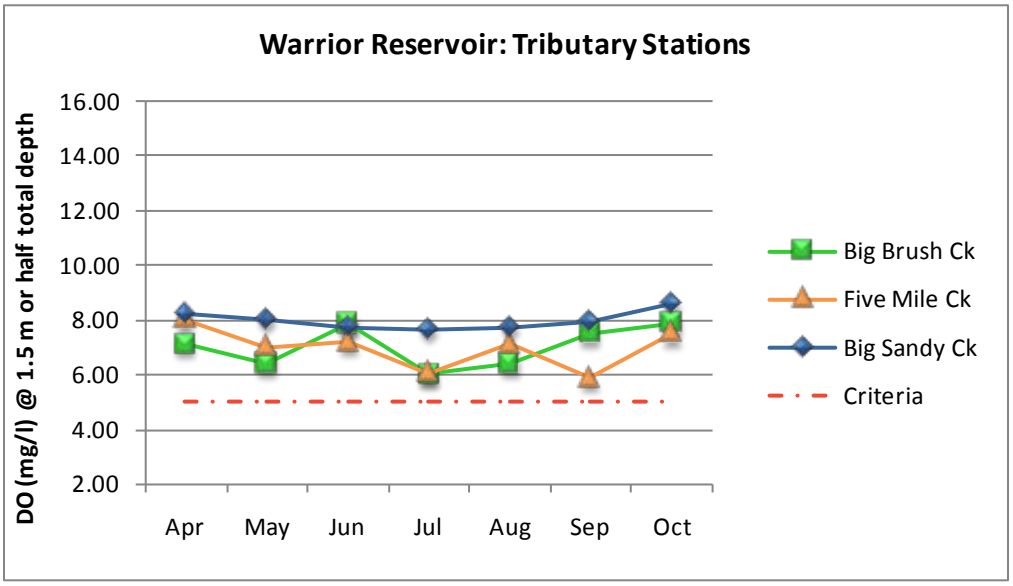


Figure 9. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C) and conductivity (µmhos) in lower Warrior Reservoir, April-October, 2012.

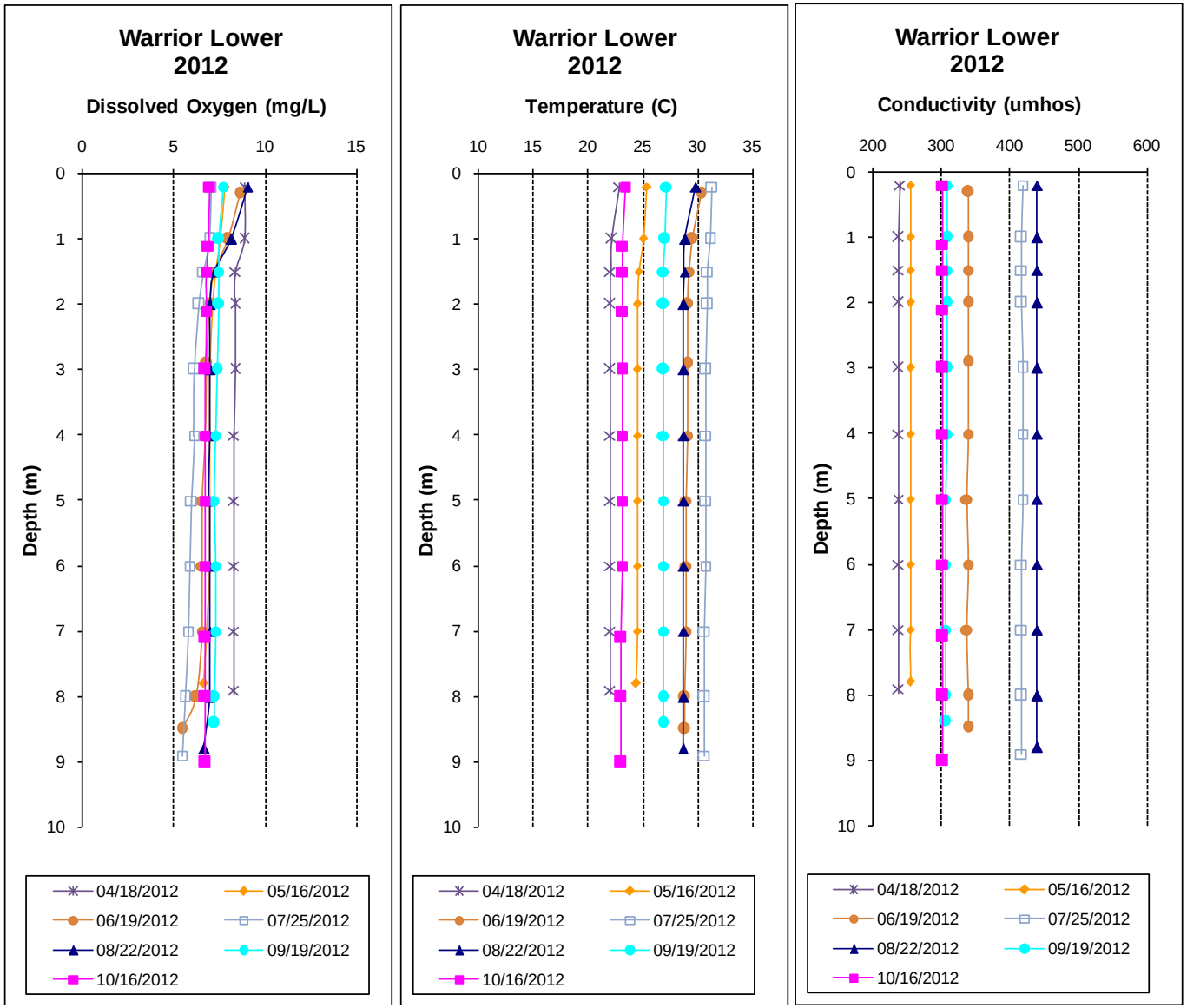


Figure 10. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C) and conductivity (µmhos) in mid Warrior Reservoir, April-October, 2012.

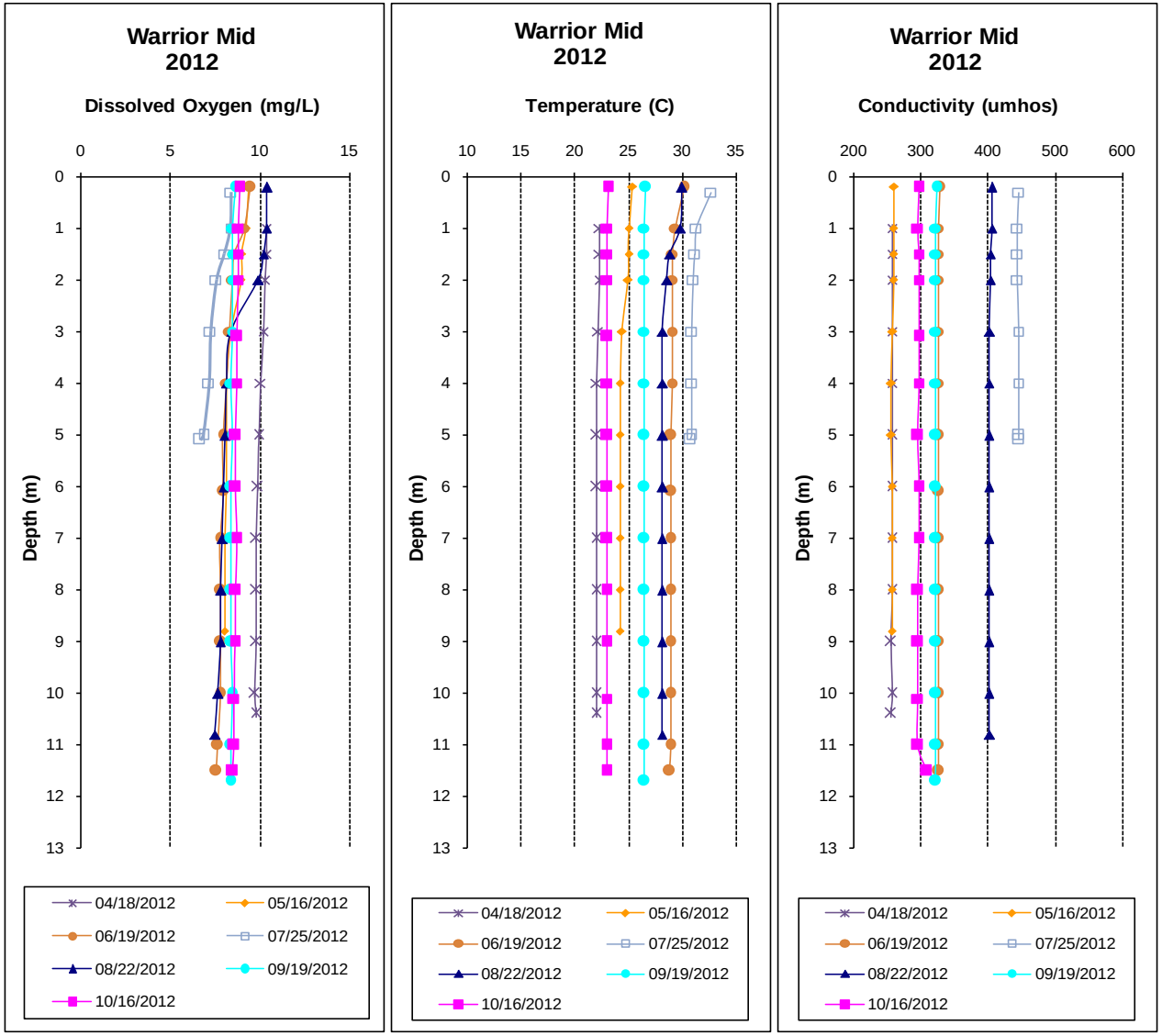


Figure 11. Monthly depth profiles of dissolved oxygen (mg/L), temperature (C) and conductivity (µmhos) in upper Warrior Reservoir, April-October, 2012.

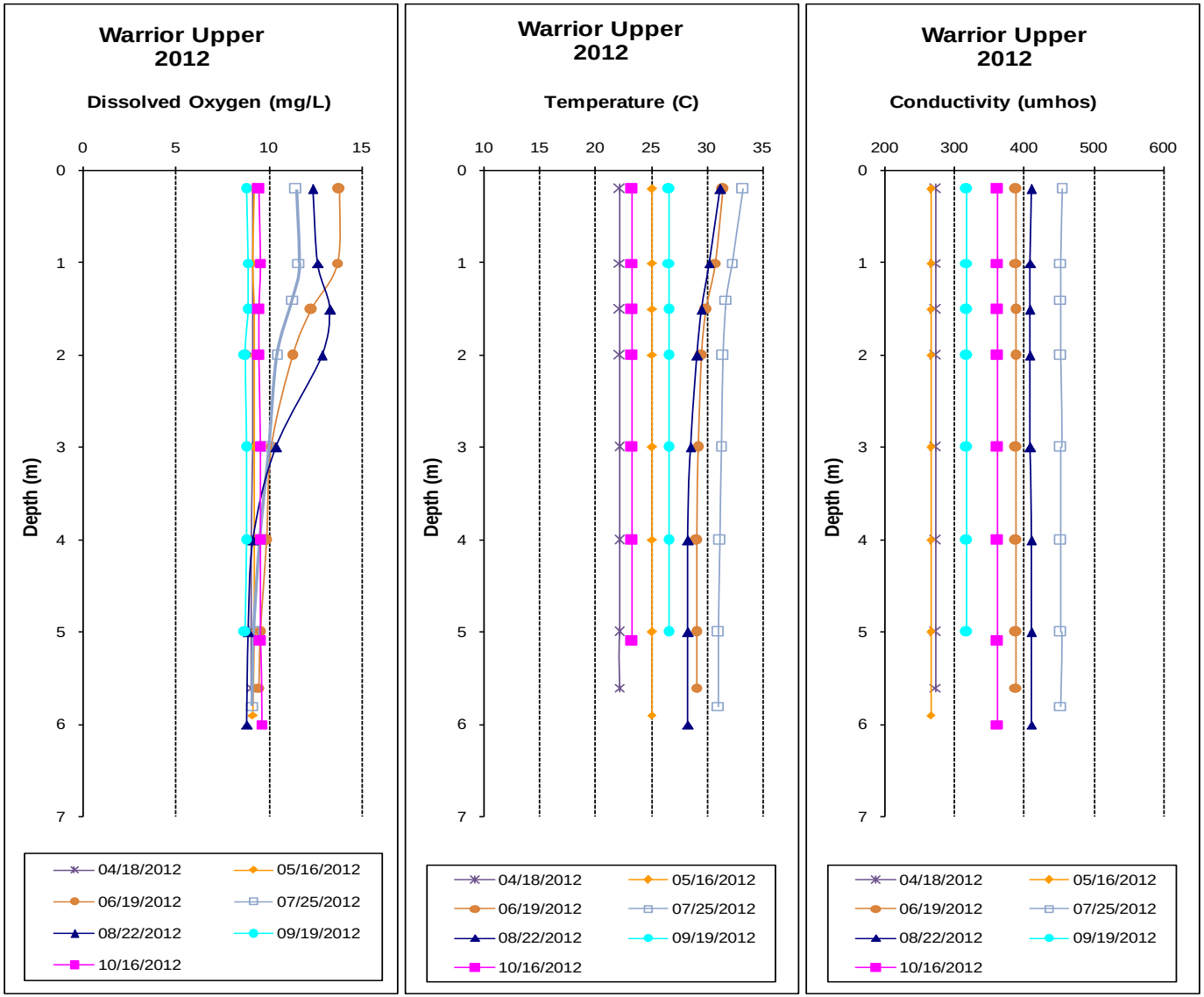
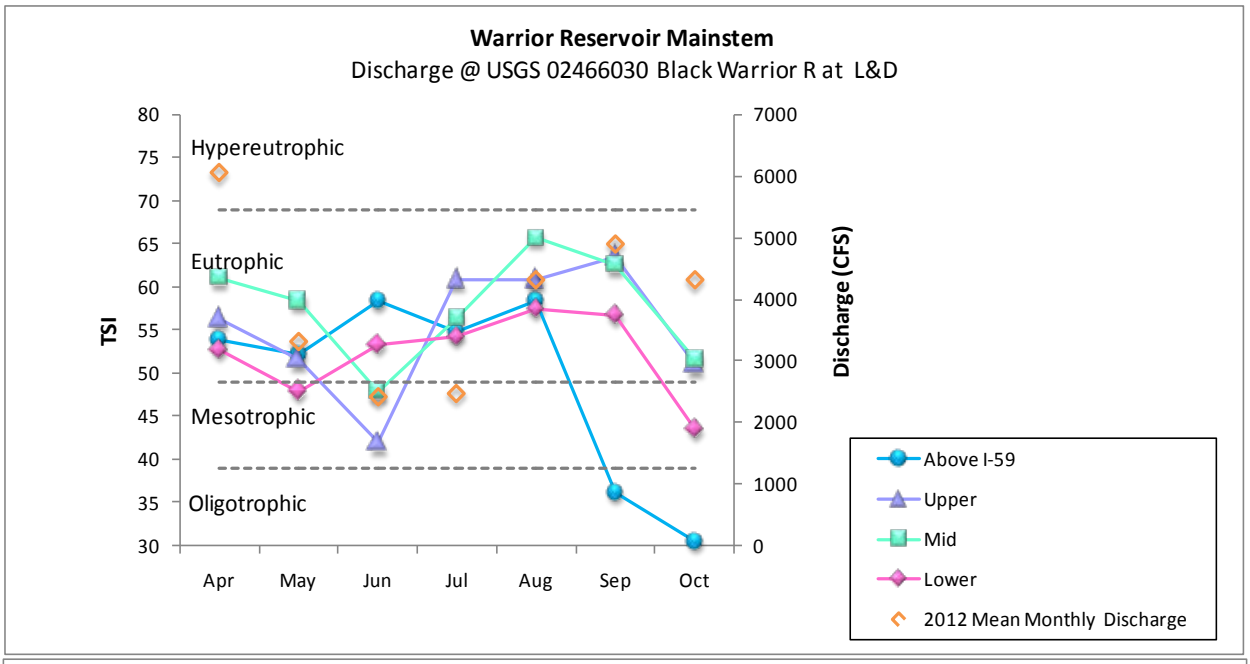
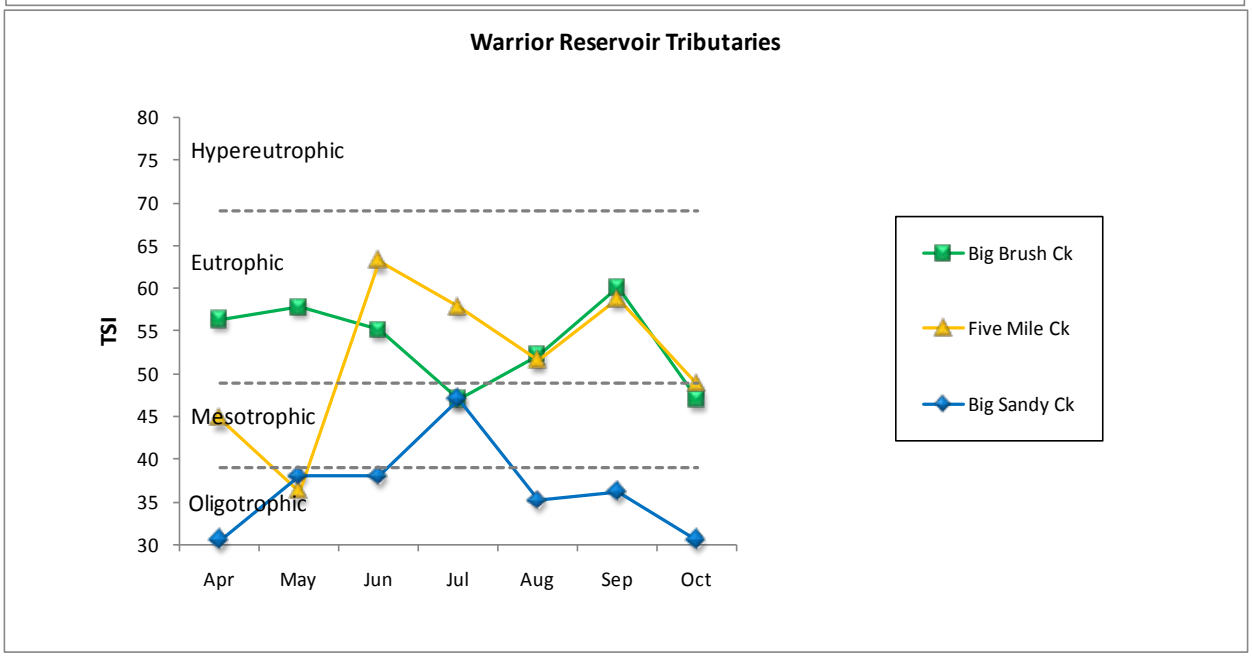


Figure 12. Monthly TSI values calculated for mainstem and tributary Warrior Resrvoir stations, April-October, 2012, using chl *a* concentrations and Carlson's Trophic State Index calculation. Monthly TSI was plotted vs. the closest mean monthly discharge (USGS 02466030 Black Warrior River at Selden L&D near Eutaw, AL).





REFERENCES

ADEM. 2012. Quality Management Plan (QMP) For The Alabama Department Of Environmental, Alabama Department of Environmental Management (ADEM), Montgomery, AL. 58 pp.

ADEM. 2012 (as amended). Standard Operating Procedures #2041 *In Situ* Surface Water Quality Field Measurements-Temperature, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2044 *In Situ* Surface Water Quality Field Measurements–Turbidity, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2046 Photic Zone Measurement and Visibility Determination, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2047 *In Situ* Surface Water Quality Field Measurements–By Datasonde, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2061 General Surface Water Sample Collection, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012 (as amended). Standard Operating Procedures #2062 Dissolved Reactive Phosphorus (DRP) Surface Water Sample Collection and Field Processing, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM 2012 (as amended). Standard Operating Procedures #2063 Water Column Chlorophyll *a* Sample Collection and Field Processing, Alabama Department of Environmental Management (ADEM), Montgomery, AL.

ADEM. 2012. State of Alabama Water Quality Monitoring Strategy June 19, 2012. Alabama Department of Environmental Management (ADEM), Montgomery, AL. 88 pp. http://www.adem.alabama.gov/programs/water/wqsurvey/2012WQMonitoringStrategy

ADEM. 2013. Quality Assurance Project Plan (QAPP) for Surface Water Quality Monitoring in Alabama. Alabama Department of Environmental Management (ADEM), Montgomery, AL. 78 pp.

Alabama Department of Environmental Management Water Division (ADEM Admin. Code R. 335-6-10-.09). 2010. Specific Water Quality Criteria. Water Quality Program. Chapter 10. Volume 1. Division 335-6.

Alabama Department of Environmental Management Water Division (ADEM Admin. Code R. 335-6-10-.11). 2010. Water Quality Criteria Applicable to Specific Lakes. Water Quality Program. Chapter 10. Volume 1. Division 335-6.

American Public Health Association, American Water Works Association and Water Pollution Control Federation. 1998. Standard methods for the examination of water and wastewater. 20th edition. APHA, Washington, D.C.

Carlson, R.E. 1977. A trophic state index. Limnology and Oceanography. 22(2):361-369.

Lind, O.T. 1979. Handbook of common methods in limnology. The C.V. Mosby Co., St. Louis, Missouri. 199 pp.

Raschke, R.L. and D.A. Schultz. 1987. The use of the algal growth potential test for data assessment. Journal of Water Pollution Control Federation 59(4):222-227.

Raschke, R. L., H. S. Howard, J. R. Maudsley, and R. J. Lewis. 1996. The Ecological Condition of Small Streams in the Savannah River Basin: A REMAP Progress Report. EPA Region 4, Science and Ecosystem Support Division, Ecological Assessment Branch, Athens, GA.

U.S. Environmental Protection Agency. 1990. The lake and reservoir restoration guidance manual. 2nd edition. EPA-440/4-90-006. U.S.E.P.A. Office of Water. Washington, D.C. 326 pp.

Welch, E.B. 1992. Ecological Effects of Wastewater. 2nd edition. Chapman and Hall Publishers. London, England. 425 pp.

Wetzel, R.G. 1983. Limnology. 2nd edition. Saunders College Publishing. Philadelphia, Pennsylvania. 858 pp.

APPENDIX

Appendix Table 1. Summary of Warrior Reservoir water quality data collected April-October, 2012. 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	6.6	12.6	10.1	9.6	2.0
	Total Dissolved Solids (mg/L)[J]	7	164.0	350.0	180.0	217.7	69.3
	Total Suspended Solids (mg/L)	7	< 1.0	12.0	3.0	4.8	4.1
	Hardness (mg/L)	4	69.5	116.0	86.4	89.6	19.4
	Alkalinity (mg/L)	7	44.0	94.6	62.6	62.5	17.8
	Photic Zone (m)	7	2.72	3.33	2.98	3.01	0.25
	Secchi (m)	7	0.82	1.35	0.94	1.01	0.21
	Chemical						
	Ammonia Nitrogen (mg/L) [J]	7	< 0.008	0.037	0.012	0.013	0.012
	Nitrate+Nitrite Nitrogen (mg/L)	7	< 0.005	0.287	0.070	0.143	0.131
	Total Kjeldahl Nitrogen (mg/L)[J]	7	0.092	0.515	0.360	0.327	0.167
	Total Nitrogen (mg/L)[J]	7	< 0.362	0.567	0.498	0.470	0.078
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.005	0.006	0.002	0.003	0.002
	Total Phosphorus (mg/L)	7	0.019	0.036	0.024	0.026	0.006
	CBOD-5 (mg/L)[J]	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	13.6	28.7	15.5	18.7	6.0
	Biological						
	Chlorophyll a (ug/L)	7	3.74	15.49	10.15	10.07	4.23
	E. coli (col/100mL) [J]	3	< 1	3	2	2	1
WARG-2	**Physical**						
	Turbidity (NTU)	7	10.7	19.0	14.5	14.5	2.9
	Total Dissolved Solids (mg/L)	7	170.0	262.0	194.0	204.3	37.5
	Total Suspended Solids (mg/L) [J]	7	6.0	21.0	8.0	10.3	5.4
	Hardness (mg/L)	4	33.8	86.6	76.7	68.4	24.0
	Alkalinity (mg/L)	7	44.3	85.9	60.0	62.9	15.2
	Photic Zone (m)	7	2.02	2.76	2.36	2.37	0.28
	Secchi (m)	7	0.46	0.92	0.83	0.76	0.18
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.036	0.004	0.008	0.012
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.005	0.255	0.051	0.108	0.113
	Total Kjeldahl Nitrogen (mg/L)	7	0.219	0.639	0.403	0.406	0.135
	Total Nitrogen (mg/L)[J]	7	< 0.346	0.867	0.474	0.514	0.175
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.005	0.006	0.002	0.004	0.002
	Total Phosphorus (mg/L)	7	0.030	0.045	0.036	0.036	0.005
	CBOD-5 (mg/L)[J]	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	14.2	26.0	18.5	19.4	3.9
	Biological						
	Chlorophyll a (ug/L)	7	5.87	35.78	17.09	18.54	10.45
	E. coli (col/100mL) [J]	3	< 1	13	9	8	6

Station	Parameter	N	Min	Max	Med	Mean	SD
WARG-3	**Physical**						
	Turbidity (NTU)	7	8.4	22.5	11.8	13.4	4.8
	Total Dissolved Solids (mg/L)[J]	7	188.0	260.0	208.0	220.3	29.6
	Total Suspended Solids (mg/L)[J]	7	6.0	18.0	8.0	10.7	5.2
	Hardness (mg/L)	4	24.6	94.6	79.9	69.8	31.0
	Alkalinity (mg/L)	7	45.7	89.3	62.1	64.3	16.6
	Photic Zone (m)	7	2.04	2.96	2.61	2.54	0.34
	Secchi (m)	7	0.58	0.98	0.91	0.80	0.18
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)	7	< 0.002	0.448	0.211	0.193	0.184
	Total Kjeldahl Nitrogen (mg/L)	7	0.220	0.664	0.403	0.458	0.180
	Total Nitrogen (mg/L)	7	< 0.406	0.816	0.662	0.650	0.152
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.005	0.023	0.006	0.007	0.007
	Total Phosphorus (mg/L)	7	0.019	0.055	0.040	0.040	0.012
	CBOD-5 (mg/L)[J]	7	< 2.0	2.5	1.0	1.2	0.6
	Chlorides (mg/L)	7	14.3	28.8	18.4	19.6	5.4
	Biological						
	Chlorophyll a (ug/L)	7	3.20	28.84	13.88	15.18	9.29
	E. coli (col/100mL)[J]	3	< 1	16	14	10	8
WARG-4	**Physical**						
	Turbidity (NTU)	7	8.1	14.2	9.9	10.6	2.2
	Total Dissolved Solids (mg/L)	7	178.0	296.0	196.0	217.7	49.4
	Total Suspended Solids (mg/L)	7	< 1.0	15.0	5.0	6.4	5.5
	Hardness (mg/L)	4	81.8	117.0	94.2	96.8	16.7
	Alkalinity (mg/L)	7	47.8	90.1	65.6	67.3	17.5
	Photic Zone (m)	7	2.00	3.46	2.71	2.73	0.43
	Secchi (m)	7	0.64	1.04	0.74	0.82	0.16
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.007	0.008	0.004	0.004	0.000
	Nitrate+Nitrite Nitrogen (mg/L)[J]	7	0.006	0.413	0.286	0.212	0.160
	Total Kjeldahl Nitrogen (mg/L)	7	0.189	0.526	0.334	0.343	0.127
	Total Nitrogen (mg/L)[J]	7	0.262	0.708	0.593	0.555	0.151
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.005	0.015	0.002	0.005	0.005
	Total Phosphorus (mg/L)	7	0.021	0.036	0.029	0.029	0.007
	CBOD-5 (mg/L)[J]	7	< 2.0	2.1	1.0	1.2	0.4
	Chlorides (mg/L)	7	11.7	26.4	14.1	16.2	5.2
	Biological						
	Chlorophyll a (ug/L)	7	0.53	17.09	10.68	9.71	6.60
	E. coli (col/100mL)[J]	1	1	23	9	11	11

Station	Parameter	N	Min	Max	Med	Mean	SD
WARG-5	**Physical**						
	Turbidity (NTU)	7	9.6	57.1	25.7	25.8	16.9
	Total Dissolved Solids (mg/L)	7	70.0	158.0	132.0	118.3	31.7
	Total Suspended Solids (mg/L) [J]	7	< 1.0	50.0	14.0	19.8	18.3
	Hardness (mg/L)	4	44.2	78.2	58.6	59.9	16.7
	Alkalinity (mg/L)	7	7.8	61.7	36.1	37.8	19.0
	Photic Zone (m)	7	1.00	1.66	1.40	1.39	0.22
	Secchi (m)	7	0.31	1.10	0.71	0.71	0.30
	Chemical						
	Ammonia Nitrogen (mg/L) [J]	7	< 0.008	0.019	0.004	0.006	0.006
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	0.037	0.108	0.094	0.084	0.028
	Total Kjeldahl Nitrogen (mg/L) [J]	7	< 0.041	0.346	0.223	0.203	0.112
	Total Nitrogen (mg/L) [J]	7	< 0.058	0.440	0.290	0.286	0.132
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.005	0.007	0.005	0.005	0.001
	Total Phosphorus (mg/L)	7	0.015	0.045	0.027	0.028	0.012
	CBOD-5 (mg/L)	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	6.8	61.8	37.8	35.3	16.4
	Biological						
	Chlorophyll a (ug/L)	7	< 0.10	5.34	1.78	1.87	1.77
	E. coli (col/100mL) [J]	3	71	727	75	291	377
WARG-6	**Physical**						
	Turbidity (NTU)	7	11.0	33.8	13.8	16.6	7.8
	Total Dissolved Solids (mg/L)	7	44.0	88.0	70.0	68.6	18.4
	Total Suspended Solids (mg/L)	7	< 1.0	11.0	6.0	5.3	4.1
	Hardness (mg/L)	4	15.5	124.0	26.0	47.8	51.0
	Alkalinity (mg/L)	7	2.8	30.1	21.4	19.7	9.7
	Photic Zone (m)	7	1.40	2.20	1.79	1.77	0.30
	Secchi (m)	7	0.42	0.96	0.77	0.77	0.18
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.008	0.033	0.004	0.008	0.011
	Nitrate+Nitrite Nitrogen (mg/L) [J]	7	< 0.002	0.061	0.002	0.015	0.022
	Total Kjeldahl Nitrogen (mg/L) [J]	7	0.110	0.760	0.399	0.432	0.226
	Total Nitrogen (mg/L) [J]	7	< 0.121	0.761	0.402	0.447	0.215
	Dissolved Reactive Phosphorus (mg/L) [J]	7	< 0.005	0.008	0.005	0.005	0.002
	Total Phosphorus (mg/L)	7	0.027	0.051	0.043	0.040	0.009
	CBOD-5 (mg/L) [J]	7	< 2.0	2.0	1.0	1.1	0.4
	Chlorides (mg/L)	7	1.5	11.6	6.0	6.5	3.1
	Biological						
	Chlorophyll a (ug/L)	7	1.78	28.04	8.54	11.84	9.26
	E. coli (col/100mL) [J]	3	5	50	17	24	24

Station	Parameter	N	Min	Max	Med	Mean	SD
WARG-7	**Physical**						
	Turbidity (NTU)	7	8.2	17.0	12.1	12.4	3.6
	Total Dissolved Solids (mg/L)	7	100.0	200.0	140.0	142.0	39.5
	Total Suspended Solids (mg/L)	7	2.0	15.0	4.0	6.9	5.3
	Hardness (mg/L)	4	25.5	129.0	67.6	72.4	42.7
	Alkalinity (mg/L)	7	20.0	60.4	43.3	41.2	16.5
	Photic Zone (m)	7	1.81	2.60	2.16	2.21	0.35
	Secchi (m)	7	0.46	1.05	0.89	0.84	0.22
	Chemical						
	Ammonia Nitrogen (mg/L)	7	< 0.008	0.027	0.004	0.007	0.009
	Nitrate+Nitrite Nitrogen (mg/L)	7	< 0.002	0.069	0.002	0.019	0.026
	Total Kjeldahl Nitrogen (mg/L)	7	0.354	0.882	0.522	0.567	0.181
	Total Nitrogen (mg/L)	7	< 0.415	0.912	0.524	0.587	0.181
	Dissolved Reactive Phosphorus (mg/L)[J]	7	< 0.005	0.008	0.002	0.004	0.002
	Total Phosphorus (mg/L)	7	0.020	0.062	0.034	0.040	0.017
	CBOD-5 (mg/L)[J]	7	< 2.0	2.0	1.0	1.0	0.0
	Chlorides (mg/L)	7	10.0	33.4	14.3	19.3	10.2
	Biological						
	Chlorophyll a (ug/L)	7	5.34	20.29	12.28	11.75	5.56
	E. coli (col/100mL)[J]	3	1	14	9	8	6

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