Smith Mountain Lake Association Water Quality

Volunteer Monitoring Program

1993 Report

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FIGURES

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Smith Mountain Lake Association

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Moneta, VA 24121

703/297 - 4146

1993 OFFICERS

President - John Barr
Vice President - Jim Spitz
Secretary - F. Jean Beall
Treasurer - John Harkness
Past President - Robert C. Hawlk

1993 DIRECTORS

James Brown

Cy Cooley

James Cunningham

Ken Davis

Ben Henderson

Charles Hoover

Thomas Jobes

Karl Lerz

Paul Rundle

Wilma Schafer

Donald Ward

SMITH MOUNTAIN LAKE VOLUNTEER MONITORS

1993

Advanced Monitors

Howard & Katherine Chilton, Union Hall
Paul Rundle, Moneta
Richard Chamberlain, Moneta
Warren B. Melroy, Moneta
Ken Dugan, Moneta
Ed & Loretta Osika, Lynchburg
Carl Ostertag, Huddleston
Jim Murphy, Huddleston
Daphne Jamison, Wirtz
Andy & Ellie Anderson, Moneta
Janet & Richard Hill, Huddleston
Gary & Betty Hatfield, Union Hall
Gene McCullough, Huddleston
Mickey & Bob Hawlk, Union Hall
Ted Bogsrud, Hardy
Raymond Strachan, Huddleston
Louise & John Quinn, Pittsville
Ralph Bates, Moneta
Lynn Kastner, Moneta
Fred (Willie) Emrich, Moneta

Basic Monitors

Miriam & Dan Walthers, Hardy
Roger & Betty Ann Mueller, Moneta
Glenn Randa, Moneta
Jean Beall, Huddleston
Hazel & Charles Bray, Moneta
Becky Rowe, Wirtz
Maxwell Dyett, Moneta
Tom Holt, Moneta
Mary Ann & Joseph Spahr, Moneta
Bert & Marian Thurman, Wirtz
John & Shirley Barr, Hardy

1. EXECUTIVE SUMMARY

The Smith Mountain Lake Water Quality Volunteer Monitoring Program (SMLWQVMP) is a water quality program initiated in 1987 and designed to monitor the trophic status of Smith Mountain Lake, located in southwestern Virginia. In May, an organizing and training session was conducted by the two project directors from Ferrum College and the SMLA Volunteer Monitoring Coordinator with assistance from two student technicians. Samples were collected weekly from the first week of June to the last week of August. The parameters measured included water turbidity, observed with a Secchi disc; total phosphorus, measured spectrophotometrically after persulfate digestion; and chlorophyll-*a*, determined using the acetone extraction method with fluorimetric detection.

The 1993 results for each of the three parameters are as follows: the mean Secchi depth was 2.61 meter, the mean total phosphorus concentration was 42.7 ppb, and the mean chlorophyll-*a* concentration was 23.7 ppb. (Note: Values for chlorophyll-*a* were calculated incorrectly. Please see the Appendix Table A2a for corrected values. Corrected average: CHA = 3.6 ppb). The value for total phosphorus was 19% higher in 1993 than in 1992 and the value for chlorophyll-*a* was 331% higher in 1993 than in 1992. These parameters, evaluated on the weekly mean of all stations, followed a fluctuating pattern similar to the previous years. When these three water quality parameters are evaluated based on the means for each station and correlated with miles to the dam, trends are exhibited which would be considered typical of a reservoir. The upper reaches of the tributaries are more riverine in water quality, and the lower reaches (closer to the Smith Mountain Lake Dam) exhibit more lacustrine water quality. Water clarity is lower, and nutrient concentrations and algal biomass are higher, in the upstream areas of the lake.

Because the reported chlorophyll-*a* concentrations are much higher this year than in previous years, the results were closely examined. Some of the apparent increase may be due to having underestimated the chlorophyll-*a* concentration for the past several years, resulting from loss of sensitivity in the fluorimeter used to measure chlorophyll-*a*. Taking this possibility into consideration, the increase in chlorophyll-*a* is still large and the findings are corroborated by data from the Virginia Department of Environmental Quality.

In 1992, for the first time, the mean total phosphorus concentration in Smith Mountain Lake was higher than the average for southeastern lakes and reservoirs.

In 1993, the same is true for chlorophyll-*a*. These values indicate nutrient-enriched water in Smith Mountain Lake. The trophic status of a lake indicates the degree of nutrient enrichment and the resulting suitability of that lake for various uses. The Carlson Trophic State Index ranges from 1 to 100, with values over 50 indicating eutrophic status. The Combined Trophic Status Index (TSI) for Smith Mountain Lake for the past several years are: 1990, TSI = 48; 1991, TSI = 47; 1992, TSI = 51; 1993, TSI = 56.

Last year's results indicated a decline in water quality but, because of spring flooding, we were careful not to reach premature conclusions about a downward trend. This year, with another significant decline in water quality, we recommend that the lake community, acting through the Smith Mountain Lake Association and the Smith Mountain Lake Policy Advisory Board, take actions to prevent the continued decline of water quality in Smith Mountain Lake.

2. INTRODUCTION

The Smith Mountain Lake Water Quality Volunteer Monitoring Program (SMLWQVMP) is a program designed to monitor the water quality of Smith Mountain Lake, located in southwestern Virginia. The program is jointly coordinated by scientists from Ferrum College in Ferrum, Virginia and members of the Smith Mountain Lake Association (SMLA), a lake residents' citizen association. This document reports on the 1993 monitoring efforts of the SMLWQVMP, which is the seventh year of this ongoing program. The detailed data, data analysis, and conclusions for the first three years (1987, 1988 and 1989) can be found in the Final Report to the Virginia Environmental Endowment (VEE) by Johnson and Thomas (March, 1990). The VEE provided primary funding for the project during the first three years. Detailed reports on the 1990 and 1991 monitoring effort can be found in the *Smith Mountain Lake Association Water Quality Volunteer Monitoring Program 1990 - 1991 Report* and the *Smith Mountain Lake Association Water Quality Volunteer Monitoring Program 1992 Report*, both by Thomas and Johnson (December, 1991 and 1992).

In May, a training session was organized and taught by the Ferrum College scientists and the SMLA Volunteer Monitoring Coordinator with assistance from the student technicians. In 1993, the student technician was Teresa Mowry and the student volunteer Lab Aide was Craig Hogge. In 1993, the training session was held at the Smith Mountain Lake Visitor Center at Hales Ford Bridge. The 1993 session was well attended, including both experienced monitors and new volunteer monitors. The number of monitors participating was very consistent, with some experienced monitors leaving the program but new monitors joining the program each year. The program consisted of a review of the previous year's findings and the planned schedule for the upcoming year. Experienced monitors confirmed their sample site locations on the map of Smith Mountain Lake provided by the program directors, received new supplies (sample bottles and filters), and had their monitoring equipment checked. The program co-directors worked with the new volunteer monitors to assign sample site locations, explain the sampling procedures, and issue sampling equipment and supplies.

Sample collection began the first week of June and the first sample bottles and sample filters were picked up in the second week of June. The sample bottles and sample filters were picked up and new supplies issued each Tuesday. In 1993, samples were collected for twelve weeks until the last week in August. Newsletters were written and published by the program co-directors and student technician during the summer, reporting on activities of the program. Announcements were included in the newsletters in addition to advice or tips on more efficient sample collection. Two newsletters were written in 1993. At the end of the monitoring season, an end of the sampling year meeting and social event was held. At these combination picnic/business meetings, the co-directors of the program from Ferrum College gave reports on the results of the sample collection and analyses, and the monitoring program coordinator of SMLA made a presentation on the program and plans for the coming year.

The results of the data analyses, and conclusions and comparisons with the previous six years of data, will be discussed in the following sections.

3. METHODS

Detailed methods of sample collection, preservation and analyses, and quality control/quality assurance procedures can be found in the VEE Report (Johnson and Thomas, 1990).

The parameters measured included water turbidity, observed with a Secchi disc; total phosphorus, measured spectrophotometrically after persulfate digestion; and chlorophyll-*a*, determined using the acetone extraction method and fluorimetry.

The quality control and quality assurance procedures evaluated sample collection and storage by the volunteers as well as the laboratory procedures used for sample analysis.

4. 1993 RESULTS

The three water quality parameters monitored on Smith Mountain Lake are water turbidity, total phosphorus, and chlorophyll-*a*. In 1993, Secchi depth averaged 2.61 m, total phosphorus averaged 42.70 ppb, and chlorophyll-*a* averaged 23.70 ppb. (Note: Values for chlorophyll-*a* were calculated incorrectly. Please see the Appendix Table A2a for corrected values. Corrected average: CHA = 3.6 ppb).

In 1993 these parameters, evaluated on a weekly mean of all stations, followed a fluctuating pattern similar to the previous years (as illustrated in Figure 1). The Secchi depth exhibited the highest mean value in Week 4 and the lowest mean value during Week 1. The grand mean of Secchi depth values, including all 678 values for all stations and all 12 weeks, was 2.6 ± 0.3 m. Total phosphorus concentration exhibited the lowest mean value in Week 3 and the highest mean value in Week 10. The grand mean of all 489 samples was 42.7 ± 1.6 ppb. Chlorophyll-*a* concentrations exhibited the lowest mean value in Week 3 and the highest mean value during Week 10. The grand mean for 483 samples was 23.7 ± 1.3 ppb (Corrected average: CHA = 3.6 ppb).

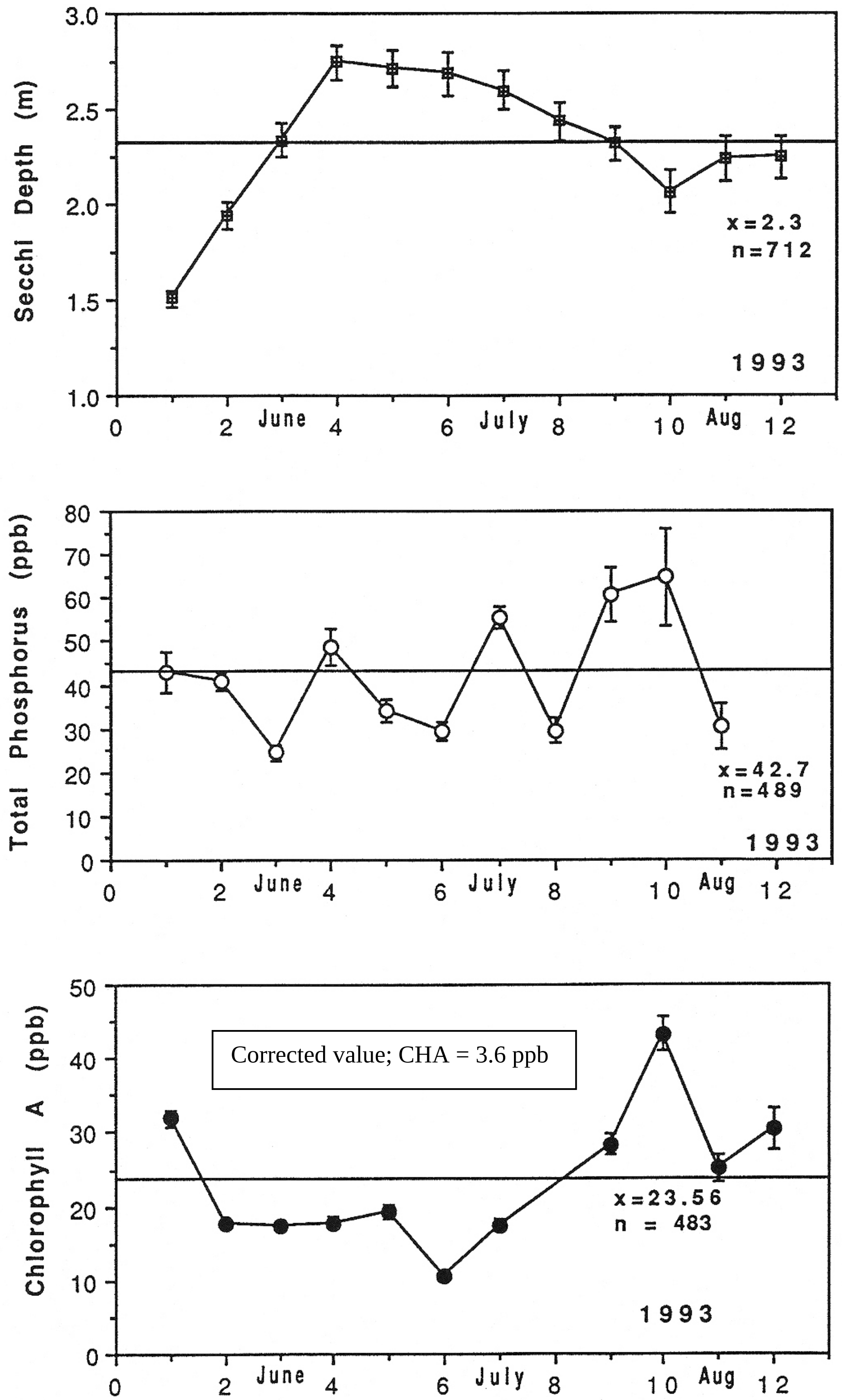

Figure 1. 1993 Smith Mountain Lake data averaged by sampling period.

When these three water quality parameters are evaluated based on the means for each station and correlated with miles to the dam, trends are exhibited which would be considered typical of a reservoir. The upper reaches of the tributaries are more riverine in water quality and the lower reaches, closer to the Smith Mountain Lake Dam, exhibit more lacustrine water quality (as illustrated in Figure 2). The Secchi depth increased as miles to the dam decreased, indicating better water clarity closer to the dam in the larger expanse of water. The lowest water clarity as measured by Secchi depth (mean SD = 1.0 m) was measured at two stations approximately 14 miles from the dam, and the highest water clarity was measured at a station approximately 5-6 miles from the dam (mean SD = 3.66 m). The increase in Secchi mean depth was significantly correlated with decreasing miles to the dam (significance level of .001). The total phosphorus concentration (TP) decreased as miles to the dam decreased, indicating less nutrient-enriched water toward the main basin. The highest total phosphorus concentrations (TP = 97 ppb and 81.5 ppb) were measured at stations approximately 12.5 and 27.5 miles from the dam, and the lowest total phosphorus values (mean TP = 14.9 ppb and 18.7 ppb) were measured at stations approximately 8.75 and 8.25 miles from the dam. The correlation between decrease in total phosphorus concentration and decreasing miles to the dam was not as obvious in 1993 as it has been in previous years. The chlorophyll-*a* concentration (CHA) decreased as miles to the dam decreased. The highest chlorophyll-*a* concentrations (CHA = 90.2 ppb and 88.2 ppb) were sampled and measured at stations approximately 12.5 and 14 miles from the dam, and the lowest chlorophyll-*a* concentrations (CHA= 4.0 and 4.7 ppb) were observed at stations approximately 1.0 and 2.75 miles from the dam. The decrease in the chlorophyll-*a* concentrations was significantly correlated with the decreasing miles to the dam (significance level of 0.001).

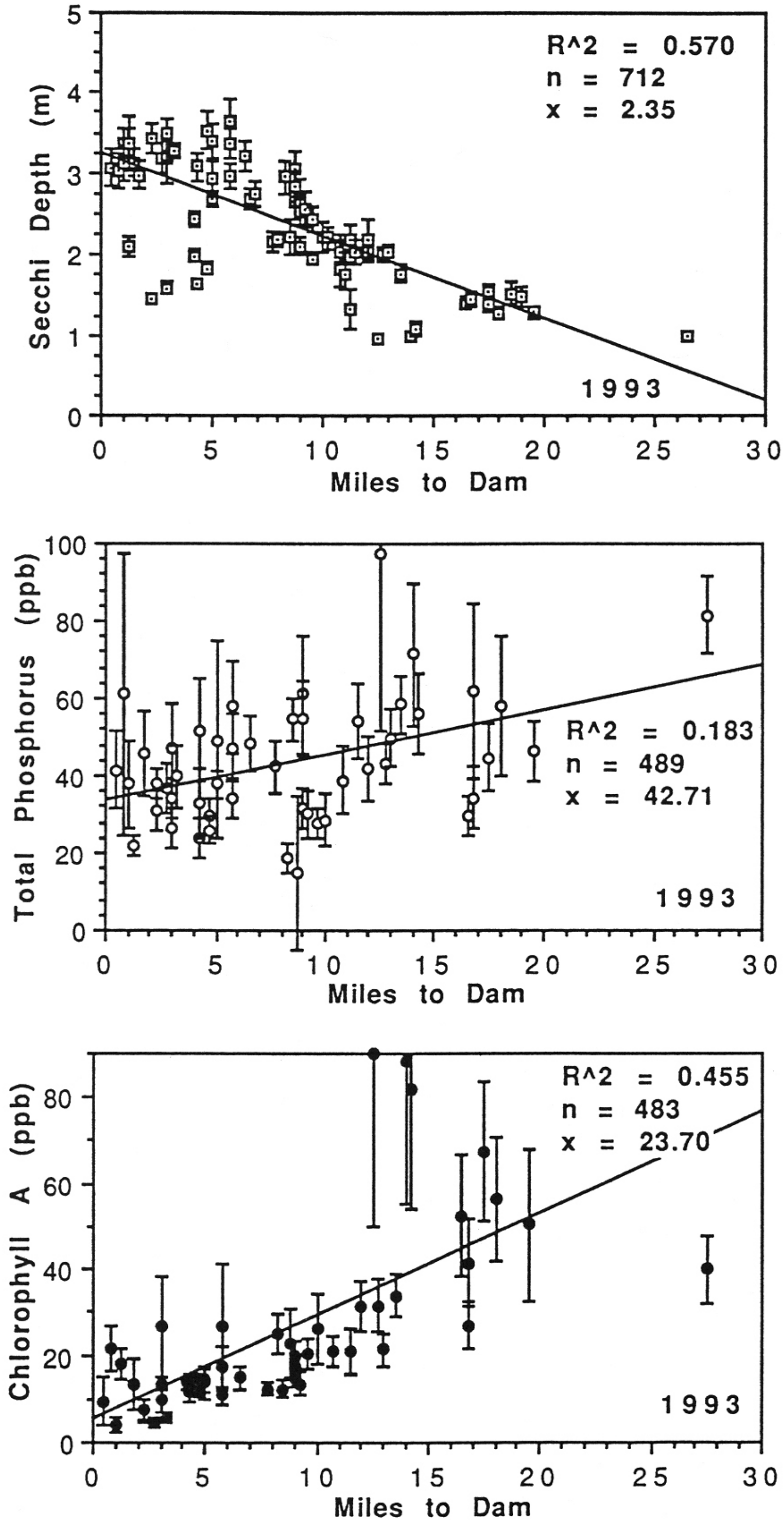

Figure 2. 1993 sample site average versus miles to the SML Dam.

4.1 Results for Leesville Lake

There is insufficient data on Leesville Lake for trend analysis but the results for 1992 and 1993 are summarized below. The raw data for Leesville Lake can be found in Appendix Table A4.

	1992			1993		
Station	**SEC(m)**	**TP(ppb)**	**CHA(ppb)**	**SEC(m)**	**TP(ppb)**	**CHA(ppb)**
100	1.5	58.6	4.9	1.8	73.1	38.7
101	1.6	44.3	5.3	1.8	43.5	21.7
102	1.6	41.9	6.4	1.8	58.9	27.4
103	0.7	76.6	3.7	0.8	54.6	12.2
104	0.5	185.3	2.4	0.8	65.2	9.5
105	1.6	29.4	3.1	3.0	48.5	10.1

Sampling Sites:

Site 100-102: Collected by the Quinns on east side of Leesville Lake

Site 103: Tolei's Bridge, Rt. 608

Site 104: Pigg River Bridge, Rt. 605

Site 105: Bridge below SML Visitor Center at dam

4.2 Discussion of Results

4.2.1 Total Phosphorus

The level of total phosphorus increased again this year, by about 20%. During the first five years of the monitoring program, average levels of total phosphorus remained nearly constant. Changes in the number and location of sampling stations made it difficult to determine if the small differences observed were due to fluctuating water quality or an artifact of sampling. Since 1991, our network of sampling stations has been well established and the average total phosphorus concentration has increased by over 60%. This large increase in phosphorus levels must be attributed to nutrient enrichment.

Determination of total phosphorus went smoothly this past summer and preliminary analyses indicated good precision and accuracy. Table 1 gives the slopes and intercepts which are similar to those from previous years. The last week of phosphorus data was discarded because power to the building was cut off at a critical point and the calibration data was unacceptable.

Table 1. Summary of calibration data for phosphate analysis.

week	slope	intercept	R^2
1	0.002	0.062	0.998
2	0.002	0.053	0.983
3	0.002	0.086	0.923
4	0.002	0.018	0.985
5	0.002	0.012	0.999
6	0.002	0.051	0.999
7	0.002	0.017	0.999
8	0.002	0.052	0.985
9	0.003	0.073	0.901
10	0.002	0.030	0.960
11	0.002	0.030	0.960
12	0.001	0.069	0.376

Figure 3 shows a composite calibration curve including all data (except for Week 12).

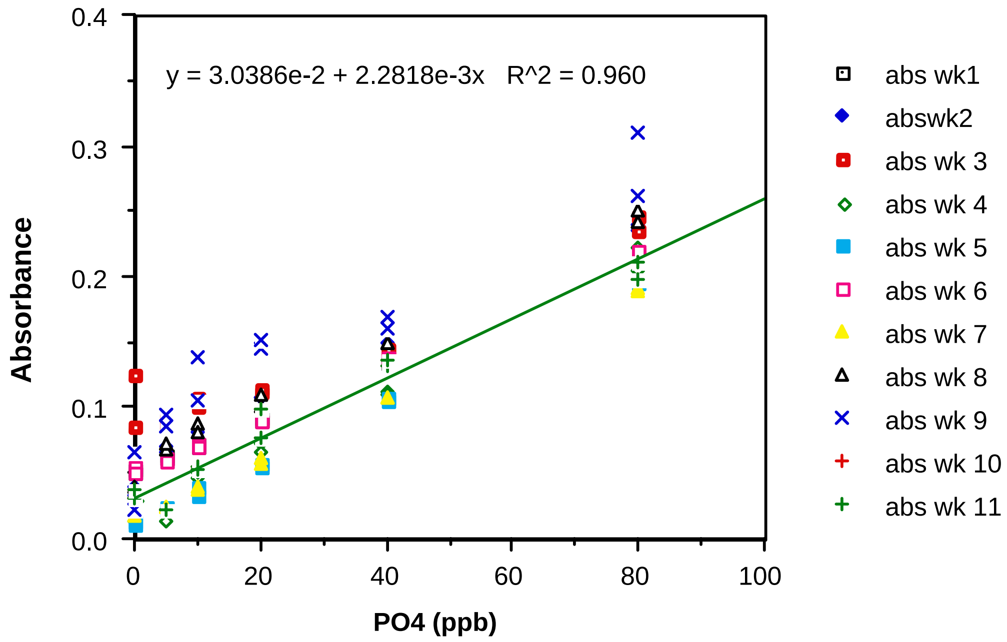

Figure 3. Composite calibration curve for phosphate analysis.

4.2.2 Chlorophyll-*a*

The reported chlorophyll-a concentrations are much higher this year than in previous years and the results need to be closely examined. (Note: Values for chlorophyll-a were calculated incorrectly. Please see the Appendix for corrected value.) We think that some of the apparent increase is due to having underestimated the chlorophyll-a concentration for the past several years. The fluorimeter used for measuring chlorophyll-*a* was serviced this spring and recalibrated. It was apparent that the instrument had lost sensitivity and this would lead to an underestimation of chlorophyll-*a* levels. The instrument was calibrated twice during this past summer and the results are shown in figures 4 and 5. On July 30, an EPA calibration standard was used and gave a calibration factor of 0.23. The August 13th calibration was performed using a standard prepared from pure chlorophyll-*a* obtained from Sigma Chemical Company, and gave a calibration factor of 0.36. A calibration factor of 0.30 was used for calculating this summer's chlorophyll-*a* concentrations. In past years, a factor of 0.10 was used.

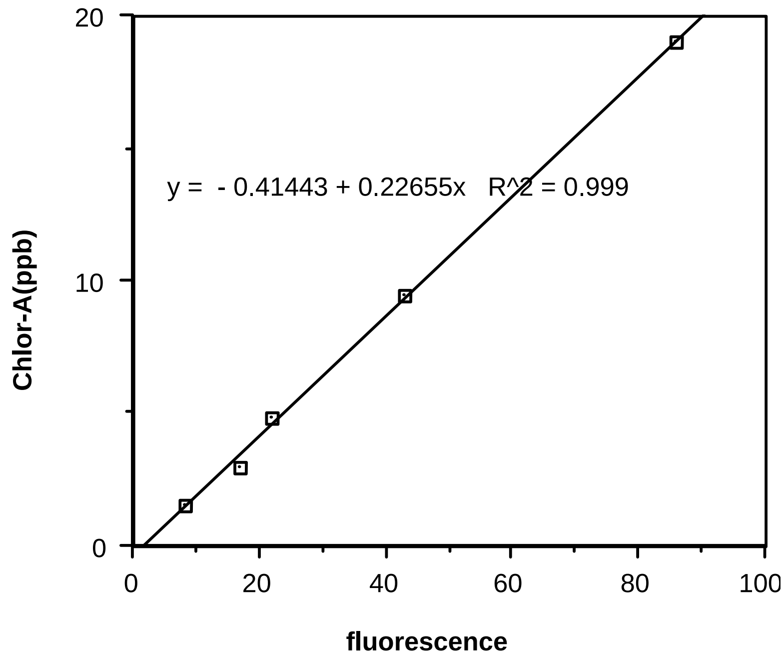

Figure 4. Calibration of fluorimeter with EPA standard on July 30, 1993.

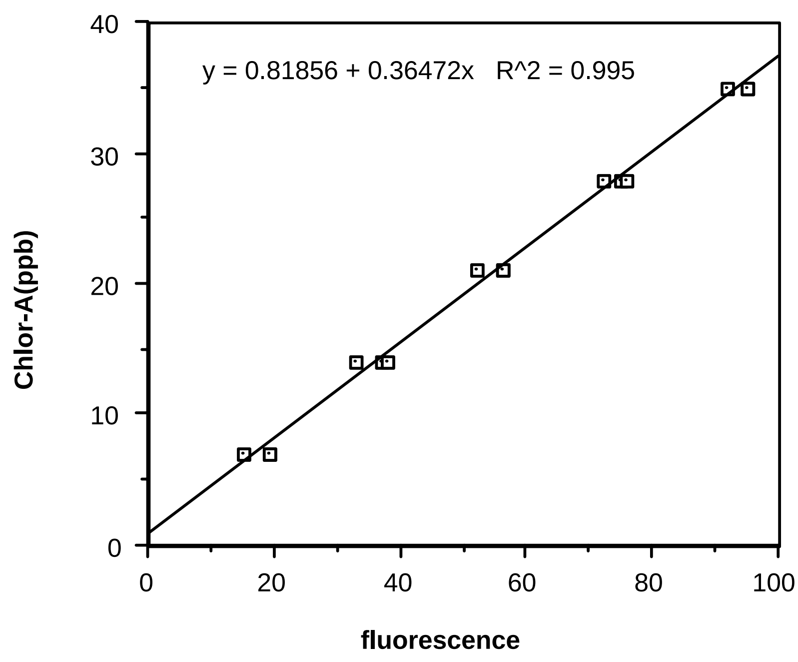

Figure 5. Calibration of fluorimeter with pure chlorophyll-*a* standard on August 13, 1993.

We do not know when the fluorimeter began losing sensitivity but, even if a calibration factor of 0.30 is applied to fluorescence readings from past years, there is still a large increase in this year's chlorophyll-*a* level. Figure 6 indicates the results of revising results from the three previous years, assuming a gradual loss of sensitivity. The revisions were calculated using the following calibration factors: 1987-89, Fx = 0.10; 1990, F_x = 0.15; 1991, F_x = 0.20; 1992, F_x = 0.25; 1993, F_x = 0.30.

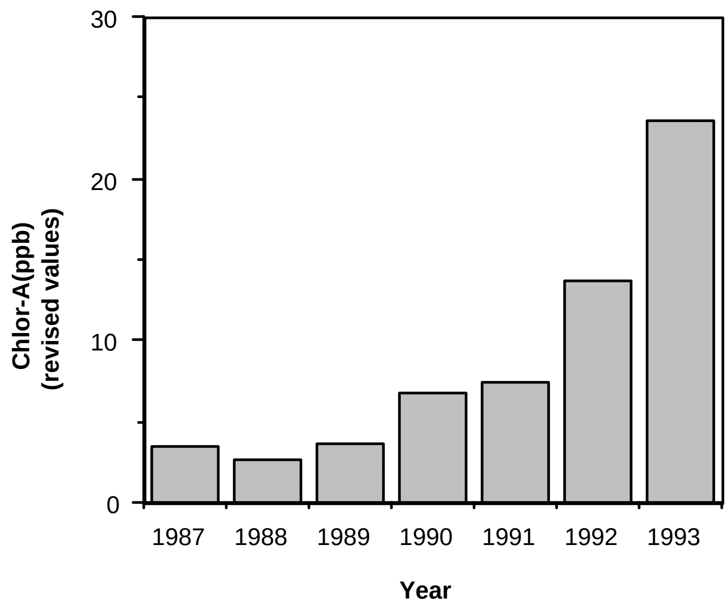

Figure 6. Revised average chlorophyll-*a* by year, assuming loss of fluorimeter sensitivity.

To corroborate these findings, we have obtained chlorophyll-*a* data from the Water Division of the Virginia Department of Environmental Quality (formerly the State Water Control Board). These results are given in Table 2. The Virginia DEQ data shows very good agreement with our results. Except for 1990, we have collected many more samples than DEQ and their concentrations show greater variability. In each year of the comparison, the DEQ results are higher than SMLA results, but this can be attributed to station locations. The SMLA network includes a greater proportion of stations in the central basin where chlorophyll-*a* levels are lower. However, the trends indicated by both sampling networks show the same trend and the overall agreement is surprisingly good given the inherent lack of precision in chlorophyll-*a* determinations. The comparison can be seen clearly in Figure 7.

Table 2. Chlorophyll-*a* data from Virginia Dept. of Environmental Quality.

1990-Apr	1990-Jun	1990-Aug	1990-Oct	1991	1992	1993
19.80	1.10	0.95	1.08	14.00	16.12	12.62
7.40	1.70	85.10	23.77	4.84	16.27	78.00
7.30	11.10	42.02	23.08	6.86	15.77	5.82
9.20	14.30	30.04	17.98	2.96	22.92	33.85
9.50	10.70	29.22	15.17	1.92	8.73	
2.10	1.70	8.51	6.68	4.26	7.00	
2.70	9.30	3.39	4.88	2.37	2.77	
2.30	2.10	4.39	4.60	14.74	25.04	
1.80	1.50	3.50	3.77		*79.42	
2.40	6.00	2.53	2.91		*82.41	
7.60	1.40	4.87	4.58		*149.99	
7.90	2.30	3.91	7.00		*104.5	
6.20	1.70	5.28	4.28		(*excluded)	
7.00	10.70	19.41	6.85			
2.40	2.80	2.86	2.01			
2.70	1.30	3.36	2.53			
Annual Avg					**Gr Avg = 14.5**	
6.14	4.98	15.58	8.20			

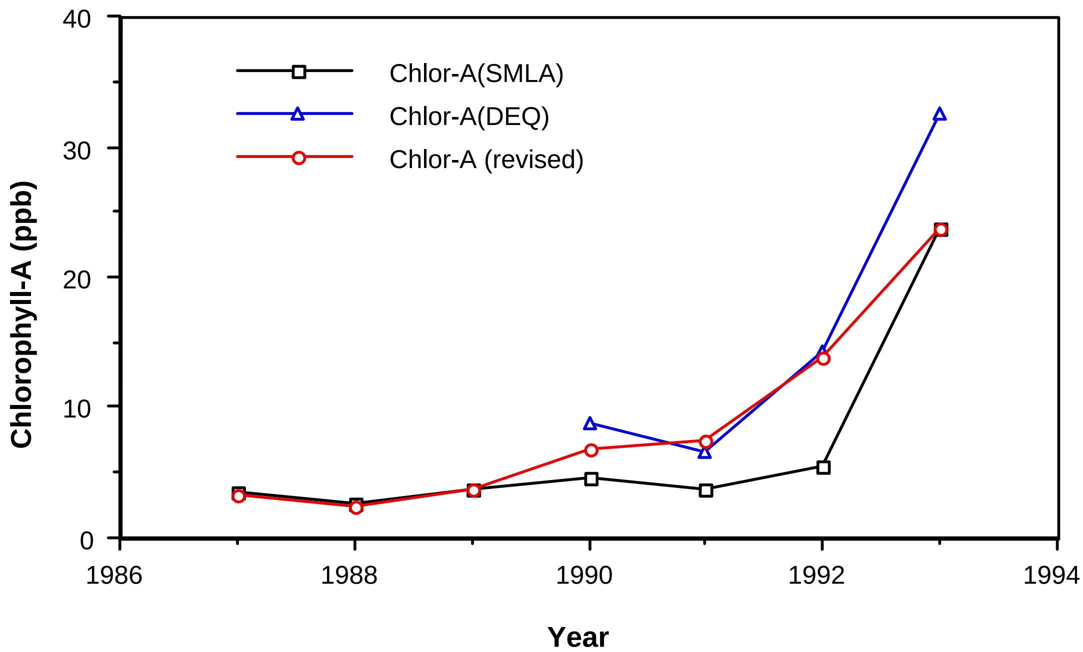

Figure 7. Comparison of chlorophyll-*a* data from SMLA and Virginia DEQ.

Chlorophyll-*a* is an important parameter in trophic state monitoring but it is difficult to determine reliably. The difficulties inherent in quantifying chlorophyll-*a* were discussed in detail in our final report to the Virginia Environmental Endowment (1990). The uncertainty associated with chlorophyll-*a* measurements is demonstrated by this year's preliminary determinations, as shown in Table 3. A gallon of water was collected from Smith Mountain Lake. While keeping the sample well mixed, twenty 100 mL portions were filtered and analyzed using the standard procedure. The fluorescence of the chlorophyll extracts is given in the column Rf, and the chlorophyll-*a* concentrations are in the next column to the right, Ca. The variability of different portions taken from the same sample is apparent and gives a standard deviation that is 51% of the mean value. This same procedure was repeated with a second one-gallon sample of SML water. This time, however, the fluorimeter readings were repeated twice on the same extracts to determine the variability of the instrumental response. Comparison of RF-1, RF-2, and RF-3 indicates very little variation in instrumental response. The absolute variability among portions of the water sample remains about the same, although the relative variation is smaller because of the higher mean value for the chlorophyll-*a* concentration in the second sample. Several extract blanks were prepared by treating an unused glass fiber filter in the same manner as a sample. In all cases the blank fluorescence reading was zero, indicating that light scattering by the glass fibers from the filters was not contributing to the fluorescence. The variability stems from the filtering and extraction processes.

Table 3. Data from preliminary chlorophyll-*a* analysis to show variability of replicate analyses.

Fx	Rf	Ca	RF-1	Ca	RF-2	Ca	RF-3	Ca
0.3	28	8.4	52	15.6	53	15.9	55	16.5
0.3	43	12.9	53	15.9	53	15.9	56	16.8
0.3	47	14.1	65	19.5	65	19.5	64	19.2
0.3	37	11.1	44	13.2	46	13.8	46	13.8
0.3	18	5.4	39	11.7	39	11.7	39	11.7
0.3	31	9.3	59	17.7	59	17.7	58	17.4
0.3	38	11.4	74	22.2	74	22.2	74	22.2
0.3	37	11.1	49	14.7	55	16.5	54	16.2
0.3	67	20.1	100	30	100	30	100	30
0.3	63	18.9	41	12.3	41	12.3	41	12.3
0.3	15	4.5	87	26.1	89	26.7	85	25.5
0.3	26	7.8	79	23.7	80	24	84	25.2
0.3	40	12	44	13.2	44	13.2	45	13.5
0.3	22	6.6	77	23.1	74	22.2	74	22.2
0.3	20	6	39	11.7	39	11.7	40	12
0.3	24	7.2	76	22.8	79	23.7	88	26.4
0.3	94	28.2	67	20.1	66	19.8	66	19.8
0.3	75	22.5	100	30	100	30	100	30
0.3	40	12	42	12.6	38	11.4	41	12.3
0.3	56	16.8	65	19.5	58	17.4	65	19.5
Avg		12.32		18.78		18.78		19.13
Stdev		6.24		5.88		5.93		5.94

4.2.3 Secchi Depth

The average Secchi depth was slightly greater this year than last, indicating slightly higher water clarity. This year's mean Secchi depth (2.35 m) was nearly identical to the average of all yearly mean values since 1987 (2.36 m). This might seem inconsistent with the results for phosphorus and chlorophyll, but is not necessarily so. From 1985-87, personnel from Ferrum College collected hundreds of suspended solids samples from Smith Mountain Lake and analyzed them for both volatile and nonvolatile content. The nonvolatile fraction was essentially suspended clay particles while the volatile fraction represented both algae and organic detritus. Taken as a whole, the samples indicated that about 60% of the suspended solids were nonvolatile. In many lakes and reservoirs algae is primarily responsible for turbidity, and Secchi depth correlates well with chlorophyll-*a* concentration. Smith Mountain Lake is surrounded by rugged terrain and its tributaries receive heavy runoff from agriculture. The counties surrounding the lake all display high rates of soil erosion. Thus, turbidity in Smith Mountain Lake may not correlate well with chlorophyll-*a* levels. This is especially true in the upper channels of the lake and in Leesville Lake. In these locations, phosphorus levels are very high and water clarity is very low, but chlorophyll-*a* concentration is relatively low. There is plenty of phosphorus to support heavy algal growth but the water is so "muddy" that photosynthesis is limited. This past summer was relatively dry, with few heavy downpours to wash soil into the lake and contribute to turbidity. This may well be the reason that water clarity did not decline to the extent of the other two water quality indicators. We can expect that, sooner or later, heavy rains will lead to high levels of inorganic turbidity and combine with high algal turbidity, greatly diminishing water clarity and the aesthetic appeal of Smith Mountain Lake.

5. WATER QUALITY TRENDS

The apparent changes in water quality have been discussed by parameter in the previous section. In this section, the water quality trends will be displayed in the manner we have used for the past several years. Figures 8 and 9 show the average yearly values for each parameter; Figure 8 as a bar graph and Figure 9 as a line graph. Table 4 compares water quality in Smith Mountain Lake with water quality in other southeastern lakes and reservoirs over a period of seven years. In 1993, for the first time, values for all three water quality parameters from Smith Mountain Lake are below the average for other southeastern lakes and reservoirs. These values, when compared to other southern lakes and reservoirs, indicate nutrient-enriched water in Smith Mountain Lake. This is also the first time that the nutrient enriched description has been used in the SMLWQVM Program.

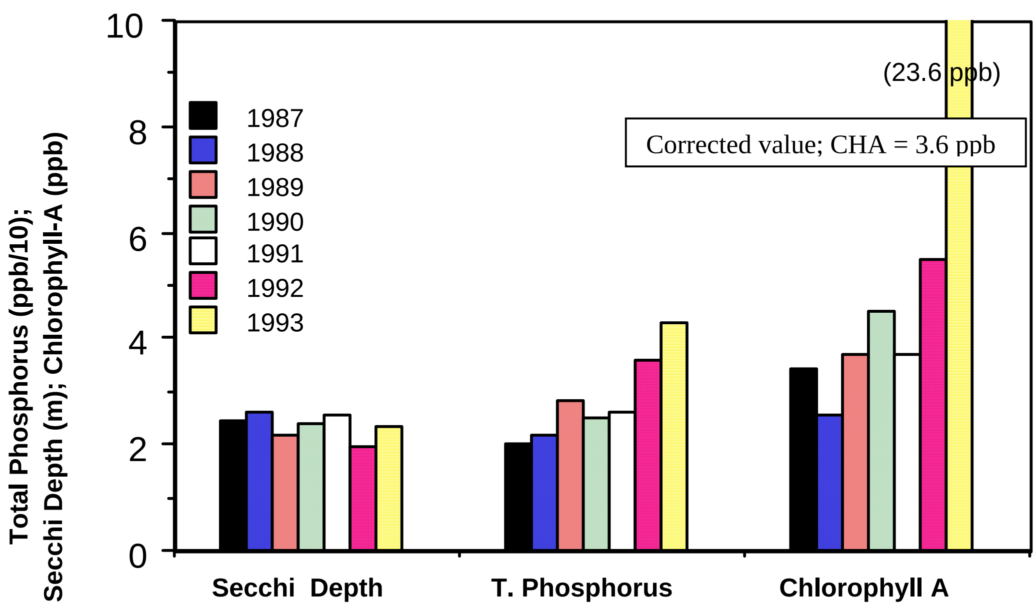

Figure 8. Bar graph comparison of water quality parameters by year.

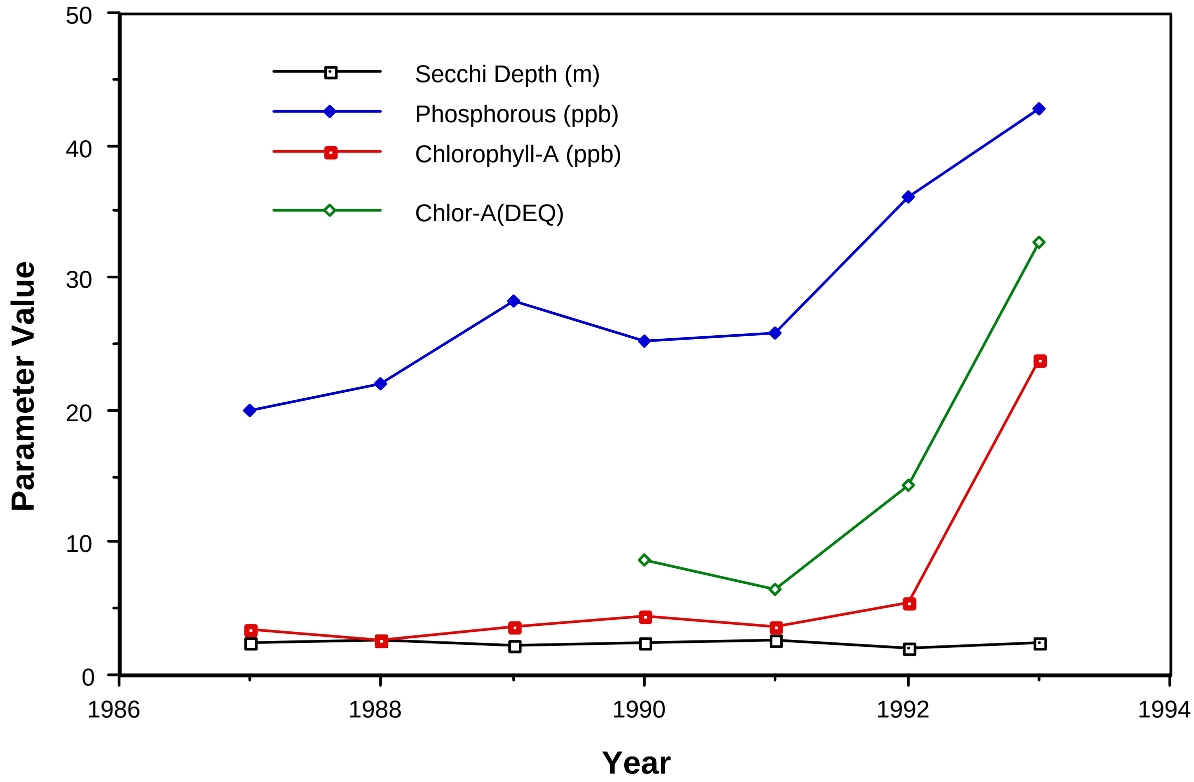

Figure 9. **Line graph comparison of water quality parameters by year.**

Table 4. **Comparison of water quality data from Smith Mountain Lake in 1987 – 1993 with data from other southeastern lakes and reservoirs. (*Reckhow, 1988).**

	Averages for Smith Mountain Lake							Average
Parameter	1987	1988	1989	1990	1991	1992	1993	S.E. Lakes*
Total Phosphorus (ppb)	19.7	20.9	27.8	25.2	25.9	36.0	42.7	33.0
Chlorophyll-*a* (ppb)	3.8	2.6	3.7	4.5	3.0	5.5	23.7(3.6)	8.1
Secchi Depth (m)	2.4	2.7	2.2	2.4	2.6	2.0	2.3	1.7

6. CARLSON'S TROPHIC STATE INDEX APPLIED TO SMITH MOUNTAIN LAKE

The trophic status of a lake indicates the degree of nutrient enrichment and the resulting suitability of that lake for various uses. The process of eutrophication is described at the beginning of the Training Manual for the monitoring program. Phosphorus is most often the nutrient that limits algal production and attempts have been made to relate the trophic status of a lake to concentration of phosphorus. Table 5 shows one such effort. (Note that the relationships are for northern temperate lakes and will not represent southeastern lakes as well.)

The algal growth resulting from inputs of phosphorus can also be used to evaluate the trophic status of a lake. This is done by extracting the green pigment, chlorophyll-*a*, from algae and determining its concentration. Table 6 shows the assignment of trophic status based on the concentration of chlorophyll-*a*. It also shows that the evaluation of trophic status is a matter of professional judgment, not a parameter to be exactly measured.

**Table 5. Proposed relationships among phosphorus concentration, trophic state, and lake use for northern temperate lakes.
(Reckhow and Chapra, 1983)**

TP (ppb)	Trophic State	Lake Use
< 10	Oligotrophic	Suitable for water-based recreation and cold water fisheries. Very high water clarity and aesthetically pleasing.
10-20	Mesotrophic	Suitable for recreation, often not for cold water fisheries. Clarity less than in oligotrophic lakes.
20-50	Eutrophic	Reduction in aesthetic properties reduces enjoyment from body contact recreation. Generally productive for warm water fish.
> 50	Hypereutrophic	A typical "old-aged" lake in advanced succession. Some fisheries, but high levels of sedimentation and algae or macrophyte growth diminish open water surface area.

Table 6. Trophic status related to chlorophyll-*a* concentration in different studies (Reckhow and Chapra, 1983).

	Chlorophyll-*a* Concentration (ppb)			
Trophic Status	**Sakamoto**	**NAS**	**Dobson**	**EPA-NES**
Oligotrophic	0.3-2.5	0-4	0-4.3	<7
Mesotrophic	1-15	4-10	4.3-8.8	7-12
Eutrophic	5-140	>10	>8.8	>12

Trophic status can also be evaluated from Secchi disk measurements since algal growth decreases water clarity. Researchers have also attempted to relate water quality parameters such as conductivity and total organic nitrogen to trophic status. Regardless of how trophic status is evaluated, a particular status is used to summarize the water quality in a lake with respect to certain uses. The particular summary term, such as mesotrophic, is assigned to a lake based on a summary statistic, such as the average total phosphorus concentration. Further, researchers have devised water quality indices based on one or more summary statistics to better communicate water quality information to the general public. Using an index, water quality can be placed on a scale from 1 to 100, with 1 being the best. An index can be derived from any summary statistic by means of a mathematical transformation and provides a way of directly comparing various parameters that are measured in very different units. For example, without indexing, most people would have a hard time comparing the significance of 14 ppb total phosphorus concentration with a 3.5 meter Secchi depth.

The State of Virginia makes use of one of the best-known trophic state indices (TSI), called the Carlson Trophic State Index after the researcher who developed it. We will also use this index to help interpret the water quality data collected on Smith Mountain Lake. Carlson's TSI may be calculated from any of the parameters we monitor: total phosphorus concentration (TP), chlorophyll-*a* concentration (CA), or Secchi disk depth (SD). The index obtained from each of these parameters can be averaged to give a combined TSI. This is important because any of the individual parameters can be misleading in some situations. Secchi disk readings are a misleading indicator of trophic status in lakes with non-algal turbidity caused by soil erosion, such as in the upper river channels and near shore areas of Smith Mountain Lake. Phosphorus will not be a good indicator in lakes where algal growth is not limited by availability of phosphorus (we are confident that algal growth in Smith Mountain Lake is phosphorus limited). Chlorophyll-*a* may be the best indicator during the growing season and the worst at other times. By examining the TSI derived from each of the three parameters and the combined TSI, the most reliable evaluation of trophic status can be made.

The following equations are used for the calculation of TSIs:

$$TSI(TP) = 14.42 \ln TP + 4.15$$

$$TSI(CA) = 9.81 \ln CA + 30.6$$

$$TSI(SD) = 60 - 14.41 \ln SD$$

$$TSI(combined) = [TSI(TP)+TSI(CA)+TSI(SD)]/3$$

Tables 7 and 8 show the input data for calculating the trophic state index, the calculated values of the trophic state index, and data to help interpret the water quality data from Smith Mt. Lake.

Table 7. Input data for calculation of the Trophic State Index.

	SD (m)	TP (µg/L)	CA (µg/L)
Smith Mt Lake 1987	2.5	20	3.4
1988	2.6	22	2.6
1989	2.2	28	3.7
1990	2.4	25	4.5
1991	2.6	26	4.2
1992	2.0	36	5.5
1993	2.4	43	23.6 (3.6)
main basin	3.5	35	10.0
upper arm	1.5	50	40.0
oligotrophic*	3.7	10	7.0
eutrophic*	2.0	20	12.0
avg. SE lake**	1.7	33	8.1

*EPA-NES (1974)
**Reckhow, WRB (1988)

Table 8. Calculated values for Carlson's Trophic State Index.

Year	Trophic Status			
	TSI-SD	TSI-TP	TSI-CA	Combined
1987	47	47	43	46
1988	46	49	40	45
1989	49	52	43	48
1990	47	51	45	48
1991	47	51	45	47
1992	50	56	47	51
1993	48	58	62	56
main basin	42	55	53	50
upper arm	54	61	67	61
oligotrophic*	41	37	50	43
eutrophic*	50	47	55	51
avg. SE lake**	52	55	51	53

*EPA-NES (1974)
**Reckhow, WRB (1988)

TSIs are given for each year of the Smith Mt. Lake Volunteer Water Quality Monitoring Program in Figure 10 (a-d).

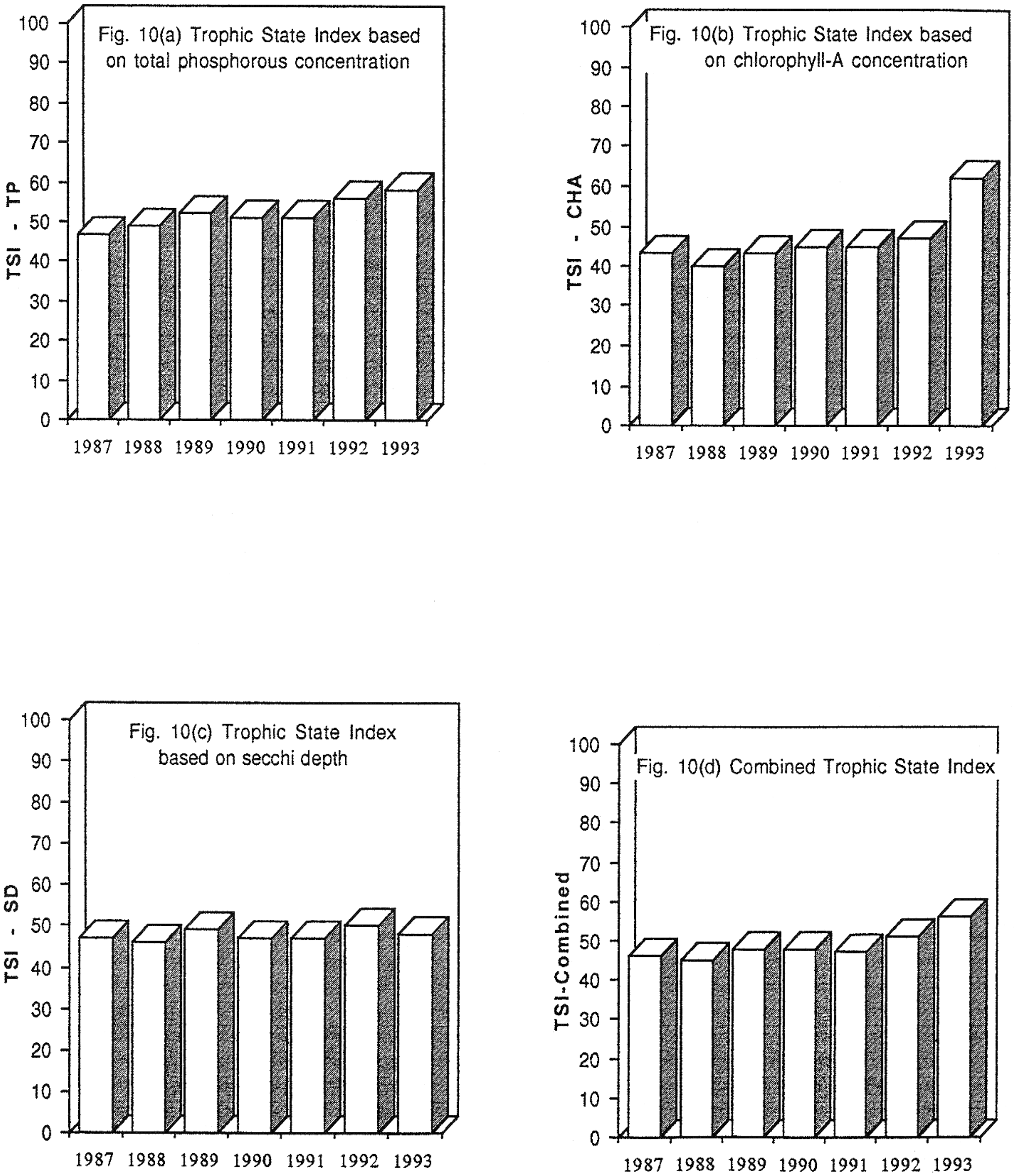

Figure 10. Carlson's Trophic State Index for Smith Mountain Lake.

7. SAMPLING EFFICIENCY

The monitoring program depends on volunteers for sample collection and one measure of success for the program is the consistency with which these volunteers attend to their stations. Table 9 presents the collection efficiencies for 1991, 1992, and 1993. The figures show that the volunteer monitors are very conscientious about sample collection. Advanced monitors collected 90% of the samples possible in 1993 but, in spite of the fact that the percentage efficiency is lower than in 1991 and 1992, this sampling efficiency is still remarkably high for volunteer sampling programs. Their sampling efficiency is as good or better than that of professionals in agencies responsible for environmental sampling. This degree of commitment no doubt carries over to the care with which samples are collected, and is evidence of their dedication to the program.

Table 9. Comparison of sampling efficiencies for 1991, 1992, and 1993.

	Sampling Efficiencies		
	1991	**1992**	**1993**
Secchi Disk Measurements	86%	90%	80%
Total Phosphorus Samples	96%	93%	90%
Chlorophyll-*a* Samples	95%	93%	90%

8. CONCLUSIONS AND SUMMARY

Last year the results from our monitoring program indicated a decline in water quality. We did not interpret this as a trend because heavy precipitation during the spring resulted in flooding and a large nutrient input at the beginning of the monitoring season. Although the average values for all three water quality parameters indicated declining water quality, the water quality showed signs of recovery during the summer. As the following excerpt from last year's press release shows, we were careful not to reach premature conclusions:

> *"The average total phosphorus and chlorophyll-A concentrations were at the highest levels measured to date by the monitoring program while water clarity was at the lowest. The apparent decline in water quality is not seen as a trend at this point, but rather the result of unusually high rainfall and flooding during the late spring. Heavy runoff carried large amounts of nutrient rich silt into the primary tributaries of the lake and led to the lowest water clarity yet to be measured in the upper channels of the lake. While water clarity was extremely low during the first month of sampling, improvement was seen during July and August. The results, while not a cause for alarm, do indicate the urgency for watershed protection."*

This year's results show another sharp increase in total phosphorus and a very large increase in the level of chlorophyll-*a*, in agreement with results from the Virginia Department of Environmental Quality. Water clarity did not show a dramatic decline, but this may well be due to the relatively dry summer and lower input of soil-derived inorganic particulate matter (in contrast to the summer of 1992). We are confident that these results are valid and that they support the 1992 decision made by the Virginia DEQ to designate Smith Mountain Lake and all its tributaries as "nutrient enriched waters". This designation is statutory and carries with it regulatory consequences. We recommend that the lake community, acting through the Smith Mountain Lake Association and the Smith Mountain Lake Policy Advisory Board, take actions to prevent the continued decline of water quality in Smith Mountain Lake. Positive steps might include:

1. Finding out about the regulatory implications of the "nutrient enriched" designation and supporting the DEQ in their effort to protect water quality in Smith Mountain Lake.

2. Encouraging lake residents to use lawn and garden chemicals conservatively and maintain optimal functioning of septic tanks.

3. Closely following the progress and results from the Blackwater Demonstration Project and other efforts being made by the Blue Ridge Soil and Water Conservation District to prevent soil loss from the SML watershed.

4. Insisting on effective erosion control at all construction sites in the SML watershed and supporting enforcement efforts by the counties surrounding the lake.

5. Actively seeking funds at the local, state and national level to develop a dynamic model of water quality in Smith Mountain Lake, beginning with existing resource information from GIS and satellite imagery.

6. Exploring the feasibility of engineering approaches to sediment trapping in the upper channels.

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We would like to acknowledge the hard work of our student technicians **Teresa Mowry** and **Craig Hogge** this summer. They were responsible for making the long trek around the lake collecting the volunteers' samples every week, and for doing the weekly analyses for total phosphorus and chlorophyll-*a*. It should be noted that this was made more difficult this year because of the renovation of the building housing the Life Science Division and the Smith Mountain Lake Lab. We would like to thank **Brenda Berg** for tabulating the Secchi disk depth data weekly and sending the data to Ferrum College. We greatly appreciate **Walt Berg** for taking over the position of Smith Mountain Lake Association Coordinator of the volunteer monitoring program, and **Chuck Hoover** for taking over as chairman of the Lake Committee of the SMLA especially on such short notice in the Spring in response to Paul Rundle's illness. We would also like to acknowledge the hard work and unfailing support of **John Barr** as Acting President of the SMLA after the unfortunate illness and death of Joe Wagoner. We appreciate greatly the help provided by **Kip Foster** of the Virginia Department of Environmental Quality in Roanoke by providing us with the state's chlorophyll-*a* data measured on Smith Mountain Lake and other information he provided us.

APPENDIX

Table A1. 1993 Total Phosphorus data.

STA/WK	93/1	93/2	93/3	93/4	93/5	93/6	93/7	93/8	93/9	93/10	93/11	Sta Avg	Stdev
ST 1	60.5	60.4		49.0	71.7	31.6	49.5	33.8	87.6	45.0	56.5	53.9	17.8
ST 2	73.8	29.5		42.5	42.6	32.5	51.0	28.0	79.5	21.5	24.5	39.1	18.0
ST 3	30.0	38.6		47.0	80.4	42.6	63.0	48.5	121.4	49.5	27.0	57.6	28.3
ST 4		28.9	18.1	52.0	29.1	66.5	92.0	33.0	63.8	19.5	18.5	42.1	25.2
ST 5		28.9	53.3	50.5	19.1	35.4	58.5	69.5	115.2	82.5	28.0	54.1	29.3
ST 6		18.9	19.2	93.5	17.4	28.7	50.0	74.5	39.5	31.5	15.5	38.9	26.5
ST 7	31.0	30.4		52.0	21.3	37.8	39.0	39.5	52.9	47.5	27.0	38.6	11.0
ST 8	101.4	101.9		43.0	50.4	27.8	73.5	23.5	27.6	111.0	18.0	53.0	34.7
ST 9	47.1	46.9		44.5	20.0	27.8	61.5	27.5	8.6	32.0	24.0	32.5	16.0
ST 16	74.8	72.5	23.1	45.5	30.0	31.6	92.0	22.0	50.5	66.0	40.5	47.4	23.1
ST 17	70.0	39.1	53.8	50.0	68.3	27.3	75.5	44.5	86.2	102.0	25.5	57.2	25.3
ST 18	46.2	30.9	39.6	47.5	41.3	26.3	60.5	30.0	78.6	53.5	23.5	43.2	17.3
ST 19	66.2	29.0	27.5	37.5	27.8	16.7	89.0	18.0	54.3	60.5	10.0	37.0	24.3
ST 20	31.0	32.4	23.6	40.0	30.9	21.1	50.5	22.0	65.7	75.5	12.0	37.4	20.6
ST 21	29.0	27.5	19.8	31.5	28.7	22.5	56.0	14.5	34.8	65.5	10.0	31.1	17.5
ST 37	33.3	31.9	20.9	43.0	34.3	23.9	47.0	26.0	24.3	0.0	22.0	27.3	13.1
ST 38	41.9	35.3	15.4	40.5	23.0	22.5	65.5	22.0	49.0	10.0	21.0	30.4	17.1
ST 39	16.2	35.7	10.4	25.0	17.4	19.6	41.0	12.5	21.0	0.0	6.5	18.9	12.6
ST 40	15.7	27.1	13.2	28.0	19.6	12.0	32.0	5.5	47.6	55.5	8.0	24.9	16.7
ST 41	20.5	44.9	14.8	29.5	23.5	14.8	42.5	9.5	33.3	36.5	17.5	26.7	12.5
ST 42	20.0	33.8	17.6	30.5	23.5	18.2	33.0	8.5	38.1	115.0	24.5	34.3	29.7
ST 43	26.2	36.2	22.0	24.5	22.2	33.5	46.0	4.5	49.0	17.5	46.0	30.1	14.5
ST 44	30.0	45.9	19.8	23.5	25.7	28.7	66.0	6.0	38.6	51.5	40.5	34.6	17.4
ST 45	22.9	28.0	14.3	19.5	23.9	23.0	46.5		34.3	265.0	15.0	52.2	80.4
ST 49		32.8		49.0		26.8	76.5	24.5	0.0	0.0		29.9	27.0
ST 50		32.2		46.5		33.5	43.0	9.0	10.0	37.0		30.2	15.0
ST 51		25.0		39.9		23.5	43.7	23.5	0.0	45.0		28.7	15.9
ST 55	27.1	47.8	22.1	55.9	44.1	22.1	71.8	44.1	51.2	270.0	25.4	65.5	73.6
ST 56	20.5	50.2	24.9	1.4	42.7	17.4	40.4		91.1	21.0	35.2	36.0	25.5
ST 57	18.1	43.5	21.1	17.8	32.4	28.2	50.2	3.3	59.2	20.0	34.7	31.0	16.7
ST 64	50.5	35.3	12.7	22.5	19.7	2.8	60.6	16.9	28.6	16.0	27.2	24.2	15.7
ST 65	22.9	32.4	17.8	29.1	22.5	5.2	30.5	23.0	23.5	8.0	27.2	21.9	9.2
ST 66	21.0	57.0	18.3	30.0	25.4	14.1	25.4	17.4	45.1	406.0	10.8	65.0	120.7
ST67							35.7	23.0	135.7	240.0	51.6	97.2	91.2
ST 68							39.4	.	122.1	71.0	52.6	71.3	36.3
ST69							29.1	68.5	82.2	43.0	58.2	56.2	20.9
ST 70	48.1	53.6	29.1	44.6	34.3	22.1	41.3	28.2	122.1	29.0	38.5	44.3	28.9
ST 71	36.8	52.2	26.4	38.7	33.0	24.1	57.5	23.1	80.7	40.6	223.6	60.0	60.2
ST 72	70.3	47.8	21.7	86.3	11.3	29.2	68.4	69.3	42.0	30.2	33.5	44.0	23.9
ST 76		36.2		131.3	31.6	45.3	46.2	60.8	50.0	11.8		51.7	35.3
ST 77		33.8		103.3	26.9	50.5	86.8	23.1	15.1	35.4		46.9	31.8
ST 78		53.1		42.9	30.2	37.7	48.1	23.1	39.2	30.7		38.1	9.9
ST 79	30.7	38.2	25.5	108.5	21.7	23.1	96.2	22.6	54.2	25.0	11.3	42.6	33.6
ST 80	31.6	42.5	20.3	60.8	24.1	27.4	48.6	27.8	129.7	0.0	3.8	38.5	37.1
ST 81	50.9	40.1	25.5	33.5	25.9	21.2	71.7	23.1	130.2	75.5	5.7	45.2	37.1
ST 82	25.9	39.6	26.9	108.5	58.5	50.0	53.8	25.5	177.8	89.6	16.5	64.7	49.0
ST 83	24.1	39.6	23.6	60.8	59.9	64.6	52.8	60.8	43.9	90.1	12.3	50.8	22.2
ST 84	56.1	43.5	25.9	33.5	55.2	27.4	62.3	17.0	104.7	78.8	16.0	46.4	28.9
ST 97	160.8	69.1	59.0	108.5	69.3	67.0	50.0	73.1	84.0	92.9	63.2	73.6	17.2
Avg	42.8	40.9	24.3	48.8	34.0	29.0	55.3	29.4	61.7	65.7	30.4	**Gr Avg**	**42.9**
Stdev	28.5	14.6	11.3	27.5	16.7	13.9	17.5	19.4	39.9	77.6	33.7	**Stdev**	**36.1**

Table A2. 1993 Chlorophyll-*a* data.

(see next page for corrected values)

STA/WK	93/1	93/2	93/3	93/4	93/5	93/6	93/7	93/9	93/10	93/11	93/12	Sta Avg	Stdev
ST 1	16.8	7.8	3.3	10.8		10.2	24.0	16.5	17.7	9.9	6.6	12.4	6.2
ST 2	13.8	9.6	5.1	14.1		6.9	22.8	14.4	15.3	12.6	10.2	12.5	5.0
ST 3	12.6	15.3	5.1	16.5		9.0	27.3	13.8	15.6	17.4	14.7	14.7	5.8
ST 4	48.0	9.9	21.6	36.0	54.0	7.2	18.0	57.0	39.0	23.7		31.4	18.0
ST 5	9.9	15.3	21.9	21.9	21.6	4.2	10.5	60.0	29.4	14.4		20.9	15.6
ST 6	48.0	21.9	12.3	24.9	17.1	7.5	19.8	24.9	14.1	18.6		20.9	11.0
ST 7	39.0		2.7	15.3	0.1	3.0	20.7	12.3	21.0	5.4	17.4	13.7	11.8
ST 8	51.0		11.4	13.2	0.1	11.7	9.6	11.1	26.7	9.6	29.7	17.4	14.6
ST 9	5.7		16.8	9.9	0.1	7.8	7.5	12.6	21.9	11.7	13.5	10.8	6.1
ST 16	36.0	16.8	33.0	20.4	15.0	5.7	8.1	9.9	42.0	25.2	21.3	21.2	11.9
ST 17	45.0	42.0	17.4	28.5	20.7	21.3	33.0	66.0	54.0	20.4	25.2	34.0	15.9
ST 18	51.0	39.0	14.4	28.8	27.0	8.4	54.0	29.7	66.0	17.7	11.4	31.6	18.9
ST 19	13.5	10.5	2.1	3.0	3.0	3.6	6.0	6.6	6.3	2.7	3.6	5.5	3.6
ST 20	3.3	12.3	3.9	5.4	3.3	2.7	2.4	10.5	0.3	4.2	3.6	4.7	3.6
ST 21	5.4	9.0	5.4	6.9	5.1	3.9	28.8	4.8	5.4	4.2	6.0	7.7	7.1
ST 37	15.3	21.9	22.2	18.9	3.3	42.0	4.5	27.0	27.3	25.5	18.0	20.5	10.8
ST 38	45.0	7.8	24.3	8.4	15.3	12.6	22.2	23.7	16.8	12.0	28.5	19.7	10.8
ST 39	26.7	33.0	16.2	11.7	17.4	13.2	21.0	63.0	21.6	28.5	22.5	25.0	14.2
ST 40	11.1	21.3	11.4	18.6	13.2	8.4	6.0	13.5	18.9	9.0	19.5	13.7	5.1
ST 41	19.2	9.0	23.4	10.8	11.4	10.5	7.5	12.0	11.7	7.2	11.4	12.2	4.9
ST 42	16.2	24.9	8.7	12.6	11.4	11.1	15.0	12.0	17.1	16.5	6.9	13.9	4.9
ST 43	20.7	14.4	13.2	10.2	17.4	7.8	13.2	17.1	19.5	10.5	15.3	14.5	4.0
ST 44	24.6	9.9	12.9	9.9	18.0	12.9	8.1	12.0	16.2	11.7	12.0	13.5	4.6
ST 45	13.5	10.5	16.8	13.8	13.2	15.0	3.6	12.3	36.0	10.2	12.0	14.3	8.0
ST 49		17.7		11.4		12.0	6.3	45.0	45.0			22.9	17.5
ST 50		9.9		9.3		9.3	11.1	19.8	22.2			13.6	5.8
ST 51		15.0		15.3		12.3	15.6	45.0	54.0			26.2	18.3
ST 55	48.0	21.3	39.0	16.5	36.0	7.8	18.3	26.4	60.0	9.9	13.2	26.9	16.8
ST 56	87.0	36.0	20.7	13.2	27.0	8.1	27.3	54.0	105.0	63.0	15.3	41.5	31.9
ST 57	99.0	39.0	45.0	42.0	48.0	16.5	7.8	63.0	165.0	36.0	14.7	52.4	45.0
ST 64	25.2	28.8	24.0	14.4	5.7	6.3	12.0	17.1	135.0	11.7	15.0	26.8	36.6
ST 65	25.2	17.4	13.5	16.2	7.8	4.8	7.2	13.5	18.9	45.0	29.4	18.1	11.6
ST 66	24.6	22.5	13.5	22.5	63.0		15.6	13.5	14.7	9.0	14.1	21.3	15.5
ST67							21.9	120.0	96.0	6.3	207.0	90.2	81.0
ST 68							14.7	135.0	18.3	126.0	147.0	88.2	65.9
ST69							63.0	63.0	168.0	96.0	19.2	81.8	55.4
ST 70	51.0	33.0	27.0	54.0	60.0	27.3	54.0	15.0	96.0	168.0	156.0	67.4	51.6
ST 71	90.0	19.5	39.0	66.0	84.0	51.0	33.0	11.4	171.0	26.7	25.5	56.1	46.1
ST 72	78.0	15.9		69.0	15.6	13.5	10.2	13.5	183.0	45.0	60.0	50.4	53.3
ST 76		10.2		4.5	15.6	7.2	17.4	1.5	19.5		16.5	11.6	6.7
ST 77		8.7		10.8	9.6	4.2	5.4	1.2	27.3		11.4	9.8	7.9
ST 78		10.2		9.3	1.5	7.8	2.7	3.6	21.6		1.5	7.3	6.8
ST 79	3.0	2.7	1.5	2.1	1.5	2.1	1.5	29.7	2.4	54.0	4.5	9.5	16.9
ST 80	4.5	3.0	1.2	2.7	0.9	3.0	1.8	19.5	4.2	1.8	1.8	4.0	5.3
ST 81	4.8	2.4	4.2	2.7	14.4	3.6	63.0	19.2	5.4	3.9	23.7	13.4	18.0
ST 82	21.0	23.7	20.7	13.2	18.6	13.8	15.3		23.4	2.4	23.1	17.5	6.6
ST 83	29.1	6.6	16.2	15.0	3.6	8.7	13.8		18.3	13.5	24.6	14.9	7.8
ST 84	19.8	15.3	12.0	12.6	12.6	6.6	5.4		16.5	15.3	150.0	26.6	43.6
ST 97	72.0	39.0	75.0	27.0	54.0	4.5	19.8	33.0	72.0	16.5	24.9	39.8	24.8
Avg	31.8	17.7	17.4	17.8	19.2	10.6	17.5	28.4	43.3	25.1	30.4	**Gr Avg**	**23.7**
Stdev	25.5	10.7	14.3	14.7	19.9	9.3	14.9	28.2	47.9	33.1	45.4	**Stdev**	**28.7**

Table A2a. 1993 Chlorophyll-*a* data (CORRECTED).

STA/WK	93/1	93/2	93/3	93/4	93/5	93/6	93/7	93/9	93/10	93/11	93/12	Sta Avg	Stdev
ST 1	2.5	1.2	0.5	1.6		1.5	3.6	2.5	2.7	1.5	1.0	1.9	0.9
ST 2	2.1	1.4	0.8	2.1		1.0	3.4	2.2	2.3	1.9	1.5	1.9	0.7
ST 3	1.9	2.3	0.8	2.5		1.4	4.1	2.1	2.3	2.6	2.2	2.2	0.9
ST 4	7.2	1.5	3.2	5.4	8.1	1.1	2.7	8.6	5.9	3.6		4.7	2.7
ST 5	1.5	2.3	3.3	3.3	3.2	0.6	1.6	9.0	4.4	2.2		3.1	2.3
ST 6	7.2	3.3	1.8	3.7	2.6	1.1	3.0	3.7	2.1	2.8		3.1	1.6
ST 7	5.9		0.4	2.3	0.0	0.5	3.1	1.8	3.2	0.8	2.6	2.1	1.8
ST 8	7.7		1.7	2.0	0.0	1.8	1.4	1.7	4.0	1.4	4.5	2.6	2.2
ST 9	0.9		2.5	1.5	0.0	1.2	1.1	1.9	3.3	1.8	2.0	1.6	0.9
ST 16	5.4	2.5	5.0	3.1	2.3	0.9	1.2	1.5	6.3	3.8	3.2	3.2	1.8
ST 17	6.8	6.3	2.6	4.3	3.1	3.2	5.0	9.9	8.1	3.1	3.8	5.1	2.4
ST 18	7.7	5.9	2.2	4.3	4.1	1.3	8.1	4.5	9.9	2.7	1.7	4.7	2.8
ST 19	2.0	1.6	0.3	0.5	0.5	0.5	0.9	1.0	0.9	0.4	0.5	0.8	0.5
ST 20	0.5	1.8	0.6	0.8	0.5	0.4	0.4	1.6	0.0	0.6	0.5	0.7	0.5
ST 21	0.8	1.4	0.8	1.0	0.8	0.6	4.3	0.7	0.8	0.6	0.9	1.2	1.1
ST 37	2.3	3.3	3.3	2.8	0.5	6.3	0.7	4.1	4.1	3.8	2.7	3.1	1.6
ST 38	6.8	1.2	3.6	1.3	2.3	1.9	3.3	3.6	2.5	1.8	4.3	3.0	1.6
ST 39	4.0	5.0	2.4	1.8	2.6	2.0	3.2	9.5	3.2	4.3	3.4	3.7	2.1
ST 40	1.7	3.2	1.7	2.8	2.0	1.3	0.9	2.0	2.8	1.4	2.9	2.1	0.8
ST 41	2.9	1.4	3.5	1.6	1.7	1.6	1.1	1.8	1.8	1.1	1.7	1.8	0.7
ST 42	2.4	3.7	1.3	1.9	1.7	1.7	2.3	1.8	2.6	2.5	1.0	2.1	0.7
ST 43	3.1	2.2	2.0	1.5	2.6	1.2	2.0	2.6	2.9	1.6	2.3	2.2	0.6
ST 44	3.7	1.5	1.9	1.5	2.7	1.9	1.2	1.8	2.4	1.8	1.8	2.0	0.7
ST 45	2.0	1.6	2.5	2.1	2.0	2.3	0.5	1.8	5.4	1.5	1.8	2.1	1.2
ST 49		2.7		1.7	0.0	1.8	0.9	6.8	6.8			2.9	2.7
ST 50		1.5		1.4	0.0	1.4	1.7	3.0	3.3			1.7	1.1
ST 51		2.3		2.3	0.0	1.8	2.3	6.8	8.1			3.4	2.9
ST 55	7.2	3.2	5.9	2.5	5.4	1.2	2.7	4.0	9.0	1.5	2.0	4.0	2.5
ST 56	13.1	5.4	3.1	2.0	4.1	1.2	4.1	8.1	15.8	9.5	2.3	6.2	4.8
ST 57	14.9	5.9	6.8	6.3	7.2	2.5	1.2	9.5	24.8	5.4	2.2	7.9	6.8
ST 64	3.8	4.3	3.6	2.2	0.9	0.9	1.8	2.6	20.3	1.8	2.3	4.0	5.5
ST 65	3.8	2.6	2.0	2.4	1.2	0.7	1.1	2.0	2.8	6.8	4.4	2.7	1.7
ST 66	3.7	3.4	2.0	3.4	9.5		2.3	2.0	2.2	1.4	2.1	3.2	2.3
ST67							3.3	18.0	14.4	0.9	31.1	13.5	12.2
ST 68							2.2	20.3	2.7	18.9	22.1	13.2	9.9
ST69							9.5	9.5	25.2	14.4	2.9	12.3	8.3
ST 70	7.7	5.0	4.1	8.1	9.0	4.1	8.1	2.3	14.4	25.2	23.4	10.1	7.7
ST 71	13.5	2.9	5.9	9.9	12.6	7.7	5.0	1.7	25.7	4.0	3.8	8.4	6.9
ST 72	11.7	2.4		10.4	2.3	2.0	1.5	2.0	27.5	6.8	9.0	7.6	8.0
ST 76		1.5		0.7	2.3	1.1	2.6	0.2	2.9		2.5	1.7	1.0
ST 77		1.3		1.6	1.4	0.6	0.8	0.2	4.1		1.7	1.5	1.2
ST 78		1.5		1.4	0.2	1.2	0.4	0.5	3.2		0.2	1.1	1.0
ST 79	0.5	0.4	0.2	0.3	0.2	0.3	0.2	4.5	0.4	8.1	0.7	1.4	2.5
ST 80	0.7	0.5	0.2	0.4	0.1	0.5	0.3	2.9	0.6	0.3	0.3	0.6	0.8
ST 81	0.7	0.4	0.6	0.4	2.2	0.5	9.5	2.9	0.8	0.6	3.6	2.0	2.7
ST 82	3.2	3.6	3.1	2.0	2.8	2.1	2.3		3.5	0.4	3.5	2.6	1.0
ST 83	4.4	1.0	2.4	2.3	0.5	1.3	2.1		2.7	2.0	3.7	2.2	1.2
ST 84	3.0	2.3	1.8	1.9	1.9	1.0	0.8		2.5	2.3	22.5	4.0	6.5
ST 97	10.8	5.9	11.3	4.1	8.1	0.7	3.0	5.0	10.8	2.5	3.7	6.0	3.7
Avg	4.8	2.7	2.6	2.7	2.7	1.6	2.6	4.3	6.5	3.8	4.6	**Gr Avg**	**3.5**
Stdev	3.8	1.6	2.2	2.2	3.0	1.4	2.2	4.2	7.2	5.0	6.8	**Gr Stdev**	**4.3**

Table A3. 1993 Secchi depth data.

YR/WK	93/1	93/2	93/3	93/4	93/5	93/6	93/7	93/8	93/9	93/10	93/11	93/12	St Avg	Stdev
ST 1	1.00	2.00			3.00		3.00	2.50	2.00	2.50	2.00	2.00	2.22	0.62
ST 2	1.50	2.00			2.50		2.50	2.50	2.00	2.50	2.00	2.00	2.17	0.35
ST 3	1.50	2.00			2.50		2.50	2.50	2.00	2.00	2.00	2.00	2.11	0.33
ST 4	1.50	2.00	2.50	2.50	2.50	2.00	2.50	2.00		1.50	1.50	2.00	2.05	0.42
ST 5	1.50	2.50	2.50	2.50	2.50	2.50	2.00	2.00		1.50	1.50	1.50	2.05	0.47
ST 6	1.50	2.50	2.50	2.50	2.50	2.50	2.00	2.00		1.50	2.00	2.00	2.14	0.39
ST 7					3.00	2.75	3.00	2.75	2.25	2.50	2.50	2.75	2.69	0.26
ST 8					3.00	3.00	3.50	3.00	2.50	2.50	2.75	3.50	2.97	0.39
ST 9					3.00	3.00	3.25	2.75	2.25	2.50	2.75	3.00	2.81	0.32
ST 10				3.00	3.50	3.00	3.75	2.50	2.25	2.00	2.00	2.50	2.72	0.63
ST 11				2.50	3.25	3.25	3.75	3.00	2.25	2.25	2.50	2.75	2.83	0.52
ST 12				2.50	3.25	3.25	3.75	3.50	2.25	2.50	2.75	3.75	3.06	0.57
ST 13	1.25	2.00	2.25	2.50	2.50	2.75	2.75	2.25	2.75	1.75	1.75	2.00	2.21	0.47
ST 14	1.25	2.00	2.25	2.50	2.25	2.50	2.50	2.00	1.75	1.75	1.75	2.00	2.04	0.38
ST 15	1.25		2.25	2.50	2.25	2.50	2.50	2.00	2.00	1.75	1.75	2.00	2.07	0.39
ST 16		1.50	2.00	2.00	2.00	2.00	2.75	2.00	2.00	1.50	2.50	2.00	2.02	0.36
ST 17		1.25	1.50	2.25	2.00	1.75	2.00	1.75	1.50	1.50	2.00	2.00	1.77	0.31
ST 18		2.00	2.00	2.00	2.00	2.00	2.50	2.00	2.00	1.50	2.50	1.50	2.00	0.32
ST 19		3.50		3.25	3.50	3.00	3.00	3.50	3.25				3.29	0.22
ST 20		2.75		3.50	3.75	3.00	3.25	2.50	3.50				3.18	0.45
ST 21		3.00		3.75	4.00	3.50	3.00	3.00	3.75				3.43	0.43
ST 28				3.25	3.50								3.38	0.18
ST 29				3.50	3.25								3.38	0.18
ST 30				3.25	3.00								3.13	0.18
ST 34		1.75	2.25	2.25	2.25		2.00						2.10	0.22
ST 35		2.00	2.00	2.25	2.75		2.00						2.20	0.33
ST 36		2.00	2.00	2.25	3.00		1.75						2.20	0.48
ST 37	2.00	2.00	2.00	3.00	3.00	2.50	3.25	3.00	2.00	2.00	2.00	2.50	2.44	0.50
ST 38	2.00	2.50	2.50	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.50	3.00	2.63	0.43
ST 39	1.50	3.00	3.00	3.50	3.50	3.50	3.50	3.00	2.50	2.00	3.00	3.50	2.96	0.66
ST 40	1.50	2.00	2.00	2.25	2.00	2.00	2.00	1.50	2.25	2.00	2.25	2.00	1.98	0.25
ST 41	1.50	2.00	1.75	2.00	1.50	2.00	2.00	2.00	2.00	1.75	2.00	1.50	1.83	0.22
ST 42	1.75	2.50	2.25	2.50	2.50	2.50	2.50	2.75	3.00	2.25	2.75	2.00	2.44	0.34
ST 43	1.50	2.75	3.75	3.50	4.25	3.75	4.25	4.00	3.50	3.25	4.00	3.75	3.52	0.76
ST 44	1.75	2.75	3.25	3.25	3.75	4.00	4.25	4.00	3.50	3.50	4.00	3.75	3.48	0.69
ST 45	1.50	2.50	3.50	3.75	4.00	3.75	4.00	3.75	3.50	3.50	4.00	3.00	3.40	0.74
ST 49	2.00	2.00		3.50	3.50	3.25	3.00	2.50	2.25	2.00			2.67	0.65
ST 50	2.00	2.00		3.50	3.50	3.00	2.50	2.50	2.00	2.00			2.56	0.63
ST 51	1.50	2.00		3.00	2.75	2.75	2.25	2.00	2.00	1.75			2.22	0.51
ST 52		1.75	1.75	1.75			1.75	1.75	1.50	1.25	1.50	1.75	1.64	0.18
ST 53		1.50	1.50	1.75			1.50	1.75	1.50	1.25	1.50	2.00	1.58	0.22
ST 54		1.25	1.50	1.50			1.50	1.50	1.25	1.25	1.50	1.75	1.44	0.17
ST 55	1.50	1.50	1.75		1.25		1.75	1.50	1.50	1.50	1.00	1.25	1.45	0.23
ST 56	1.50	1.50	1.75		1.25		2.00	1.50	1.50	1.25	1.00	1.25	1.45	0.28
ST 57	1.50	1.50	1.75		1.25		1.50	1.50	1.50	1.25	1.00	1.25	1.40	0.21
ST 58	1.75	2.25	2.75	2.50	2.50	2.50	3.25	3.25	3.00	2.75	3.00	2.75	2.69	0.43
ST 59	1.75	2.00	2.75	3.00	2.00	3.50	3.00	3.00	3.00	3.00	3.00	3.00	2.75	0.53

(Secchi data continued on next page)

Table A3 1993 Secchi depth data (cont'd)..

YR/WK	93/1	93/2	93/3	93/4	93/5	93/6	93/7	93/8	93/9	93/10	93/11	93/12	St Avg	Stdev
ST 60	1.50	2.25	2.75	3.00	2.00	3.50	3.50	3.00	3.25	3.25	3.75	3.50	2.94	0.69
ST 61								1.75	1.75	1.50	1.50	1.50	1.60	0.14
ST 62								1.75	1.50	1.75	1.50	1.50	1.60	0.14
ST 63								1.75	1.50	1.50	1.50	1.50	1.55	0.11
St 64	1.75	1.75	3.00		4.00		3.50	3.50	3.50	4.00	3.50		3.17	0.86
ST 65	1.50	2.00	3.00		4.00		4.25	4.00	3.50	4.00	4.00		3.36	0.99
ST 66	1.75	2.25	3.00		3.50		3.50	3.25	3.00	3.50	3.50		3.03	0.63
ST 67							1.00	0.75		1.00	1.00	1.00	0.95	0.11
ST 68							1.00	1.00		1.00	1.00	1.00	1.00	0.00
ST 69							1.00	1.50	1.00	1.00	1.00	1.00	1.08	0.20
ST 70		1.00	1.50	1.75	1.75	1.25	1.50	1.50	1.50	1.00	1.00	1.50	1.39	0.28
ST 71		1.00	1.25	1.75	1.50	1.00	1.25	1.50	1.50	1.00	1.00	1.25	1.27	0.26
ST 72		1.00	1.50	1.75	1.25	1.25	1.25	1.50	1.50	1.00	1.00	1.25	1.30	0.25
ST 73	1.50	1.00	1.75		1.75	1.75	1.75	1.50	1.50	1.25	1.25	2.00	1.55	0.29
ST 74	1.25	0.75	1.75		1.75	2.00	1.75	2.00	1.50	1.25	1.00	1.75	1.52	0.41
ST 75	1.00	0.75	1.75		1.75	2.00	1.75	2.00	1.50	1.25	1.00	1.50	1.48	0.43
ST 76			2.50	3.50	3.00	3.50	3.50	3.00	2.50				3.07	0.45
ST 77			3.00	4.00	3.00	3.75	3.50	3.00	3.00				3.32	0.43
ST 78			3.00	4.00	3.50	4.00	3.25	3.25	3.00				3.43	0.43
ST 79		2.00	3.00	2.50	3.50	2.75	4.00	2.00	3.00	4.00	3.00	4.00	3.07	0.74
ST 80		2.00	3.00	3.00	3.25	2.00	3.00	4.00	3.00	4.00	3.00	4.00	3.11	0.70
ST 81		2.00	3.00	3.00	3.00	2.00	3.00	3.25	3.00	3.50	3.00	4.00	2.98	0.58
ST 82		2.00	3.00	3.25	3.00	3.25	2.50	2.50	2.50	2.00	2.00	2.00	2.55	0.51
ST 83		2.00	3.00	3.25	3.50	4.00	3.00	4.00	3.50	3.00	3.00	3.00	3.20	0.56
ST 84		2.00	3.00	3.50	3.50	4.00	4.00	4.00	3.50	3.00	3.00	3.50	3.36	0.60
ST 91		2.00	2.00	2.50	2.25	2.00	2.00	1.50	2.00	1.50	2.00	2.00	1.98	0.28
ST 92		1.75	2.00	1.75	2.25	2.25	2.25	1.75	2.00	1.75	2.00	1.75	1.95	0.22
ST 93		2.00	2.00	2.00	2.50	2.75	2.00	2.00	2.50	2.00	2.00	2.25	2.18	0.28
ST 94	1.00	1.00				0.50	2.00	1.50	1.00	1.00	3.00	1.00	1.33	0.75
ST 95	1.20	2.00			1.25		2.00	1.50	1.50	1.50	3.00	2.00	1.77	0.56
ST 96	1.10	2.00			2.00		2.00	2.00	1.50	1.25	3.00	1.50	1.82	0.57
ST 97			1.00										1.00	0.00
Avg	1.51	1.94	2.31	2.75	2.72	2.69	2.60	2.41	2.28	2.04	2.21	2.21	**Gr Avg**	**2.33**
Stdev	0.27	0.56	0.63	0.66	0.80	0.82	0.86	0.82	0.75	0.86	0.89	0.87	**Stdev**	**0.83**

Table A4. Water quality data for Leesville Lake.

YR/WK	93/1	93/2	93/3	93/4	93/5	93/6	93/7	93/8	93/9	93/10	93/11	93/12	St Avg	Stdev
	Leesville Lake Total Phosphorus													
LS ST100	235.4		40.1	60.8	42.5	44.8	55.7	42.9	103.3	74.5	31.1		73.1	60.7
LS ST 101	29.2		34.0	33.5	24.1	17.5	59.4	17.0	75.9	121.2	23.1		43.5	33.2
LS ST 102	31.1		40.1	43.4	25.9	26.9	85.8	23.1	163.7	136.8	11.8		58.9	52.4
LS ST 103	25.0	54.6	52.4	57.5		42.0	43.4	41.0	91.0	84.9			54.6	21.2
LS ST 104	47.2	87.9	50.9	75.0		54.2	42.5	69.3	117.5	42.5			65.2	25.1
LS ST 105	23.1	41.4	18.9	54.2		42.0	68.9	60.8	86.8	40.6			48.5	21.6
Per Avg	65.2	61.3	39.4	54.1	30.8	37.9	59.3	42.4	106.4	83.4	22.0		**Gr Avg**	57.4
Stdev	83.8	24.0	12.3	14.4	10.1	13.3	16.4	20.4	31.5	39.7	9.7		**Stdev**	39.2
	Leesville Lake Chlorophyll-*a*													
LS ST100	17.7		15.3	15.3	68.4	33.0	24.0		23.4	15.9	147.0	26.7	38.7	41.2
LS ST 101	39.0		11.4	13.8	11.1	28.2	23.7		6.0	27.3	28.2	28.2	21.7	10.5
LS ST 102	22.2		15.3	9.0	12.6	9.0	18.3		66.0	69.0	24.9	29.1	27.5	22.1
LS ST 103	7.5	3.6	5.7	8.4		9.3	9.9		29.4	10.5		25.8	12.2	9.0
LS ST 104	6.3	16.2	2.7	2.1		5.4	25.5		12.0	11.1		4.2	9.5	7.6
LS ST 105	5.7	16.5	4.5	2.7		12.0			9.9	14.7		14.4	10.1	5.2
Per Avg	16.4	12.1	9.2	8.6	30.7	16.2	20.3		24.5	24.8	66.7	21.4	**Gr Avg**	20.6
Stdev	13.0	7.4	5.6	5.5	32.7	11.5	6.4		22.2	22.5	69.6	10.0	**Stdev**	22.7
	Leesville Lake Chlorophyll-*a* (Corrected)													
LS ST100	2.7		2.3	2.3	10.3	5.0	3.6		3.5	2.4	22.1	4.0	5.8	6.2
LS ST 101	5.9		1.7	2.1	1.7	4.2	3.6		0.9	4.1	4.2	4.2	3.3	1.6
LS ST 102	3.3		2.3	1.4	1.9	1.4	2.7		9.9	10.4	3.7	4.4	4.1	3.3
LS ST 103	1.1	0.5	0.9	1.3		1.4	1.5		4.4	1.6		3.9	1.8	1.4
LS ST 104	0.9	2.4	0.4	0.3		0.8	3.8		1.8	1.7		0.6	1.4	1.1
LS ST 105	0.9	2.5	0.7	0.4		1.8			1.5	2.2		2.2	1.5	0.8
Per Avg	2.5	1.8	1.4	1.3	4.6	2.4	3.0		3.7	3.7	10.0	3.2	**Gr Avg**	3.1
Stdev	1.9	1.1	0.8	0.8	4.9	1.7	1.0		3.3	3.4	10.4	1.5	**Stdev**	3.4
	Leesville Lake Secchi Depth													
LS ST100							2.00	1.25	1.25	2.00	2.00	2.25	1.79	0.43
LS ST 101							2.00	1.00	1.25	2.00	2.00	2.25	1.75	0.50
LS ST 102							2.00	1.00	1.75	2.00	2.00	2.00	1.79	0.40
LS ST 103			0.75										0.75	
LS ST 104			0.75										0.75	
LS ST 105			3.00										3.00	
Per Avg			1.5				2.0	1.1	1.4	2.0	2.0	2.2	**Gr Avg**	1.7
Stdev			1.3				0.0	0.1	0.3	0.0	0.0	0.1	**Stdev**	0.6