Smith Mountain Lake
Water Quality Monitoring Program

1996 Report

Prepared by
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Sponsored by
The Smith Mountain Lake Association
Moneta, Virginia 24121

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FIGURES

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CO-PRINCIPAL INVESTIGATORS

Carolyn Thomas is a professor of Environmental Science Biology at Ferrum College where she has taught since 1979. She received a Bachelors degree in Biology and Mathematics from Florida Southern College, a Masters degree in Zoology /Ecology from University of Georgia, and a doctorate in Environmental Engineering from Virginia Tech (VPI). Since 1985 she has been involved in water quality research at Smith Mountain Lake especially emphasizing nutrient dynamics and enrichment. She is also actively involved in research on mountain streams and leaf decomposition in these streams.

David Johnson is professor of Chemistry and Environmental Science at Ferrum College where he has taught since 1979. He received bachelors in chemistry and his masters and doctorate in Environmental Chemistry, all from The University of Michigan. For the past 12 years he has been actively involved in water quality research at Smith Mountain Lake. He is currently on sabbatical leave working in restoration ecology and with Geographical Information Systems (GIS) and GIS-based models used for watershed management.
Student Technicians:

Jill Dorsch and **Mary Turner** were students at Ferrum College majoring in Environmental Science and completed their internships in this program.

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1. EXECUTIVE SUMMARY

The Smith Mountain Lake Water Quality Monitoring Program (SMLWQMP) is a water quality program initiated in 1987. The program is cooperatively administered by the Smith Mountain Lake Association (SMLA) and scientists from Ferrum College and is designed to monitor the trophic status of Smith Mountain Lake. On May 23, an organizing and training session was conducted by Ferrum College and the SMLA. Monitors collected samples weekly from the first week of June to the third week of August. The parameters measured include total phosphorus, measured spectrophotometrically after persulfate digestion; chlorophyll-*a*, determined using the acetone extraction method with fluorimetric detection; and water clarity, observed with a Secchi disc. The Carlson Trophic State Index is calculated from the three parameters monitored and can range from 1 to 100, with values over 50 indicating eutrophic status. Values for the Combined Trophic Status Index (TSI) for Smith Mountain Lake over the past ten years are given below:

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
TSI	46	45	48	48	47	51	56	54	56	54

When the average value of each water quality parameter is correlated with distance from the dam, the trends observed are the same as for past years and typical of a mountain reservoir; water clarity decreases while both nutrient concentration and algal biomass increase in the upper channels of the lake.

1996 was the tenth year of the Smith Mountain Lake Water Quality Monitoring Program and it was a good year. It was the second year of Phase II and it seems that we have adjusted to the changes in routine that came with the new phase. This is reflected in a much higher sampling efficiency. The average values for the three water quality parameters also look good. Compared to 1995, the average total phosphorus concentration is down 36%, average chlorophyll decreased by 17%, and average Secchi depth was unchanged. 1996 was a wet year, although there was no spring flooding as there had been in 1993 and 1995. The average total phosphorus concentration in the tributary stations decreased by 41%. The decline in phosphorus was observed lake wide, with lower concentrations in both the Roanoke and Blackwater channels. Although there is not yet data from a long enough period to correlate tributary concentrations to concentration in the lake, lower phosphorus concentrations in the tributaries will eventually result in lower lake concentrations. At this point the time lag between changing concentrations of phosphorus in tributaries and resulting changes in lake water concentration is not known. As in past years, the average Secchi depth has not followed the trends for average concentrations of total phosphorus and chlorophyll-*a*. A plausible explanation, also used in the past, is that turbidity in Smith Mountain Lake arises from two types of suspended particles, algae and clay. Secchi depth will correlate well with total phosphorus and chlorophyll-*a* only when algae is the primary cause of turbidity and this is not the case in most areas of Smith Mountain Lake.

The total phosphorus concentrations were slightly higher in the channels than in the coves, but for the chlorophyll-*a* concentrations the situation was reversed. This indicates higher algal populations in the coves that may have depleted phosphorus concentrations. The Secchi depth average was lower in the coves, indicative of shallow waters with more algae and silt.

The Roanoke and Blackwater sections of the lake are surprisingly similar in terms of water quality. The overall averages for the three water quality parameters are nearly the same; the weekly averages follow similar patterns, as does the variability of water quality with distance from the dam. However, there is considerable variation in water quality with distance from the dam. The combined TSI, calculated by station, is highly correlated with distance from the dam ($R^2 = 0.897$) and varies from a low of 41.5 (oligotrophic) at a station near the dam to a high of 63.5 (hypereutrophic) at the Blackwater station farthest from the dam.

The fecal coliform values for 1996 were lower than the 1995 fecal coliform values. The coliform population estimate for all marinas was higher than the coliform population estimates for non-marina sites. However, there were no fecal coliform values that exceeded Virginia's health standard for coliform in swimmable and fishable waters.

Local agencies continue their efforts and cooperation among local jurisdictions is growing. The Natural Resource Conservation Service (NRCS) Office in Franklin County is working with farmers to improve conservation practices and the Blue Ridge Soil and Water Conservation District is conducting two demonstration projects in the Blackwater basin. Work on a comprehensive plan for Smith Mountain Lake has begun, involving officials from Franklin, Bedford, Pittsylvania, and Roanoke Counties and coordinated by the Smith Mountain Policy Advisory Board. Protection of water quality in Smith Mountain Lake is at a critical stage and it is essential that the various constituencies in the lake community work together toward a shared vision.

2. INTRODUCTION

The Smith Mountain Lake Water Quality Monitoring Program (SMLWQMP) 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 report describes the 1996 monitoring season, the tenth year of the program. The Virginia Environmental Endowment (VEE) provided primary funding for the project during the first three years and the report to the VEE describes the development of the project during the period from 1987-1990 (Johnson and Thomas, 1990). Monitoring results from 1990 to 1995 can be found in annual reports (December 1991, 1992, 1993, 1994, and 1994).

On May 23 the 1996 training session carried out by the Ferrum College scientists, Carolyn Thomas and David Johnson, and the SMLA Volunteer Monitoring Coordinator, Bob Halstead with assistance from the student technicians, Jill Dorsch and Mary Turner. The training session was held at the Bethlehem United Methodist Church in Moneta. The number of monitors participating has been very consistent with some experienced monitors leaving the program as new monitors join. The program included a review of the previous year's findings and planning the schedule for the upcoming year. Experienced monitors learned their sample site locations on the map of Smith Mountain Lake provided by the program directors and their sample site identification numbers, 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 and sample site identification numbers, explain the sampling procedures and issue sampling equipment and supplies. Sample collection began the week of May 26 through June 1 and the first sample bottles and sample filters were picked up Tuesday, June 2. The sample bottles and sample filters were picked up and new supplies issued each Tuesday. Samples were collected for twelve weeks until August 17. 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 1996. In September, the annual end-of-the-season 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 1996 water quality monitoring program was the second year for Phase II of the program. The objectives of the new phase are to locate sampling locations in a manner that maximizes the information obtained from the monitoring program and to begin evaluating tributary loading to the lake. The channel sampling sites have been separated from sampling sites in coves and the sites related to reflect this separation. The new sample site labels are based on:

(1) The main tributary location of the site (*i.e.*, Blackwater would have "B" in the sample site name)

(2) The number of channel miles to the Smith Mountain Lake Dam (*i.e.*, 23 miles from the Dam would have a "23" in the sample site name.

(3) Whether it is a cove, main channel or a tributary sample (*i.e.*, a cove sample would have a "C" in the sample name). An example of a sample site identification number would be "CB14" which would indicate a cove sample on the Blackwater River 14 miles from Smith Mountain Lake Dam.

Sampling sites are located about every two miles on the Roanoke and Blackwater channels to monitor the movement of the silt and nutrient laden waters moving toward the main basin of the lake. These sites begin at the dam and extend to the Hardy Ford Bridge on the Roanoke channel and to the 834 bridges on the Blackwater channel. The cove sampling sites are also important for trend analysis and help fulfill the role of "watchdogs". In this role, as much of the lake as possible is monitored for signs of localized deterioration of water quality associated with site-specific problems such as malfunctioning septic systems. To evaluate tributary loading grab samples were collected at 20 sampling sites by the technicians on their weekly trips to pick up lake water samples collected by the volunteer monitors.

The results of the 1995 data analyses and conclusions and comparisons with the previous eight years' 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 include water turbidity, observed with a Secchi disc; total phosphorus, measured spectrophotometrically after persulfate digestion; and chlorophyll-*a*, determined using the acetone extraction method and measured using fluorimetry.

The quality control and quality assurance procedures evaluate sample collection and storage by the volunteers as well as laboratory procedures.

3.1 1996 Results

3.1.1 Introduction:

The results will be presented in two major sections. The first section will report on the comparison of the channel sites, cove sites and the tributary sites. The second section will report on the comparison of the Roanoke Channel and the Blackwater Channel of Smith Mountain Lake. The three parameters measured will be presented for all areas.

The three water quality parameters monitored on Smith Mountain Lake are water turbidity, total phosphorus and chlorophyll-*a*. In 1996 the average values for all lake samples were: total phosphorus, 29.0 ppb (46 sample sites); chlorophyll-*a*, 16.3 ppb (Corrected average value: CHA = 2.6 ppb, see App. Table A5a) (46 sample sites); and Secchi depth, 2.0 meters (74 sample sites).

The graphic presentation of these data shows the mean value where the point is on the scatter graphs or where the top of the column is on column graphs. The lines and bar ("T" like) around the mean value is a measure of the 95% confidence limits (alpha = 0.05) for that mean. Confidence limits are a measure of the spread of the values. In this report the confidence limits chosen would indicate that 95% of all values are within these limits.

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 discussed and illustrated in Figures 2, 4 and 6**.**

3.2 Comparison of Channel, Cove and Tributary Sites

3.2.1 Total Phosphorus

The channel (27 sites) stations in Smith Mountain Lake exhibited the lowest concentration of total phosphorus (TP = 18.4 ppb) in week 10 and the highest concentration (TP = 43.0 ppb) in Week 3 of the summer (See Figure 1 A). The cove sample sites (19 sites) exhibited the lowest total phosphorus concentration (TP = 16.9 3ppb) in Week 9 and the highest concentration of total phosphorus (TP = 32.34 ppb) in Week 3 (See Figure 1B).

Lake tributaries were also sampled each week and total phosphorus was analyzed for each of these 21 sample sites around the lake. Only total phosphorus was determined because it was thought to be the best of the three parameters available for providing the data necessary to begin identifying the nutrient sources in the lake's watershed (Figure 1 C).

The Roanoke Channel tributaries (9 sites) include the creek on Summit Drive, Snug Harbor Creek, Stoney Creek, Jumping Run Creek, Beaverdam Creek, Roanoke River at Bay Roc Marina, Lynville Creek, Grimes Creek, and Indian Creek. The Blackwater Channel tributaries (8 sites) include Maggodee Creek, Gills Creek, Blackwater River at SR 834, Poplar Camp Creek, Standiford Creek, Bull Run Creek, Cool Branch Creek, and the creek by Lumpkin's Marina. The other four sample sites listed under tributaries include a site just below the Smith Mountain Lake Dam (#105), a Leesville Lake site not far from the Smith Mountain Lake Dam (#103), a Pigg River site before it flows into Leesville Lake, and a site much farther up Gills creek before Gills Creek passes under US 122.

The tributaries exhibited the lowest concentration in Week 3 and the highest total phosphorus concentration in Week 11 as can be seen in Figure 1C**.** The tributaries (21 sites) influencing Smith Mountain Lake exhibited the lowest mean concentration of total phosphorus in Week 3

(TP = 37.9 ppb) and the highest concentration (TP = 96.7 ppb) in Week 11 of the summer sampling as can be seen in Figure 1C.

Total phosphorus concentration (TP) in the channels decreased as miles to the dam decreased indicating less nutrient enriched water toward the main basin where the two main tributaries converge (Figure 2A). The highest average total phosphorus concentration (TP = 78.7 ppb) in the channels was measured at a station on the Blackwater Channel at 22 miles from the dam, and in the Roanoke Channel at 19 miles an average of 65.2ppb was found. The lowest average total phosphorus concentration (TP = 17.5 ppb) was found at a main basin site 1 mile from the dam.

Total phosphorus concentration (TP) in the coves decreased as miles to the dam decreased in a similar trend (Figure 2B). The highest average total phosphorus concentration (TP = 52.4 ppb) in the coves was measured at a station on the Roanoke Channel at 21 miles from the dam. The lowest average total phosphorus concentration (TP = 12.1 ppb) was found in a cove off the main basin 4 miles from the dam. The decrease in the total phosphorus concentration is significantly correlated with decreasing miles to the dam for both the channels and the coves. (R^2 = 0.43 for the channels and R^2 = 0.72 for the coves.

The tributaries exhibited much higher total phosphorus concentration than the channel or cove stations with a few exceptions. The highest mean total phosphorus concentration (TP = 96.3 ppb) was found a Beaverdam Creek in Bedford County and flowing into the Roanoke Channel, followed closely be Indian Creek in Franklin County and also flowing into the Roanoke Channel (TP = 91.2 ppb) and Gills Creek in Franklin County and flowing into the Blackwater Channel (TP = 89.2 ppb). The lowest total phosphorus concentration (TP = 38.2 ppb) was found in Lumpkin's Marina Creek in Pittsylvania County and flowing into the main basin of the lake. Almost as low in total phosphorus concentration (TP = 30.5 ppb) was the Summit Drive Creek in Bedford County that flows into Craddock Creek (a tributary off the main basin).

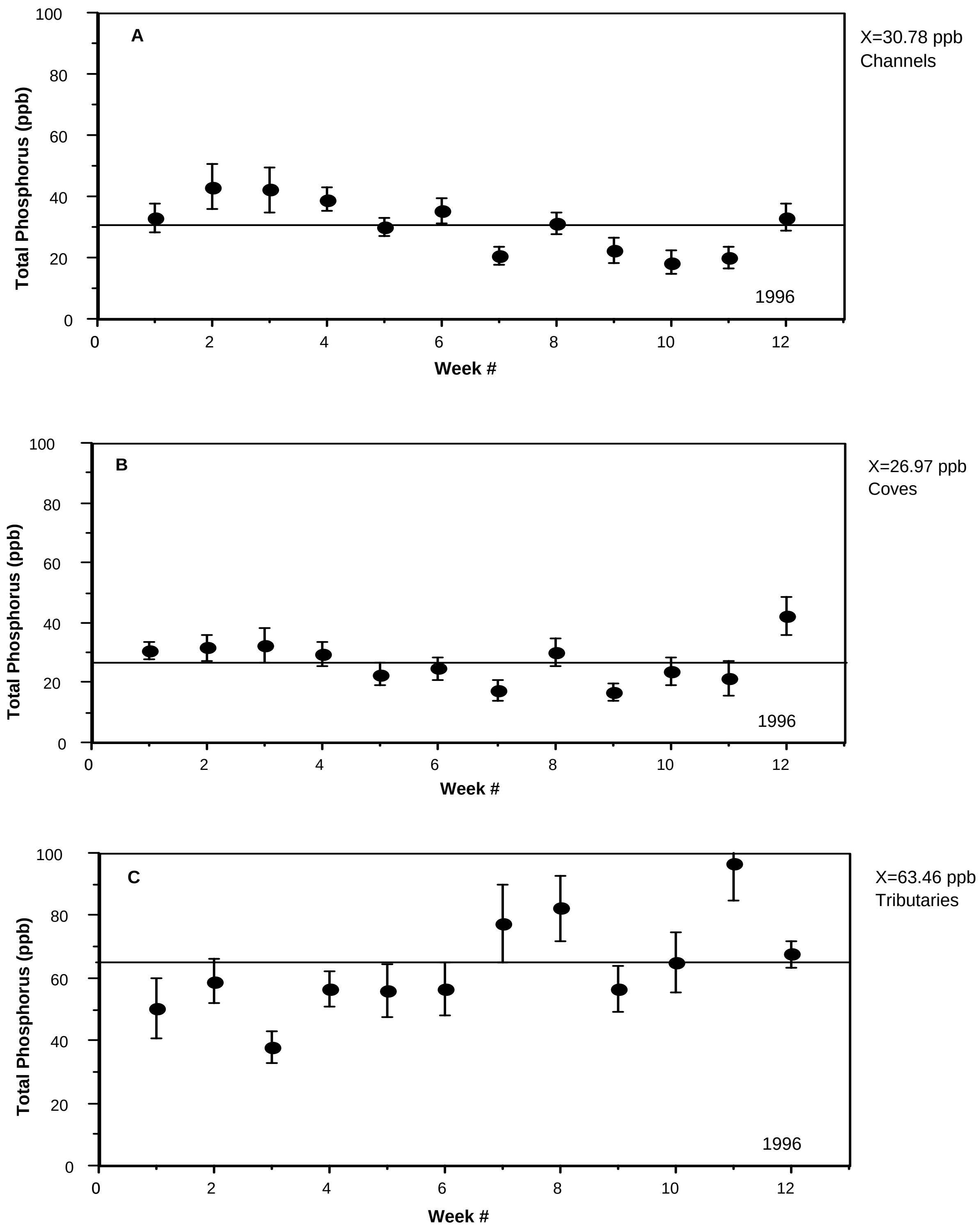


Figure 1. **Total phosphorus concentrations averaged by week.**
(x = average value)

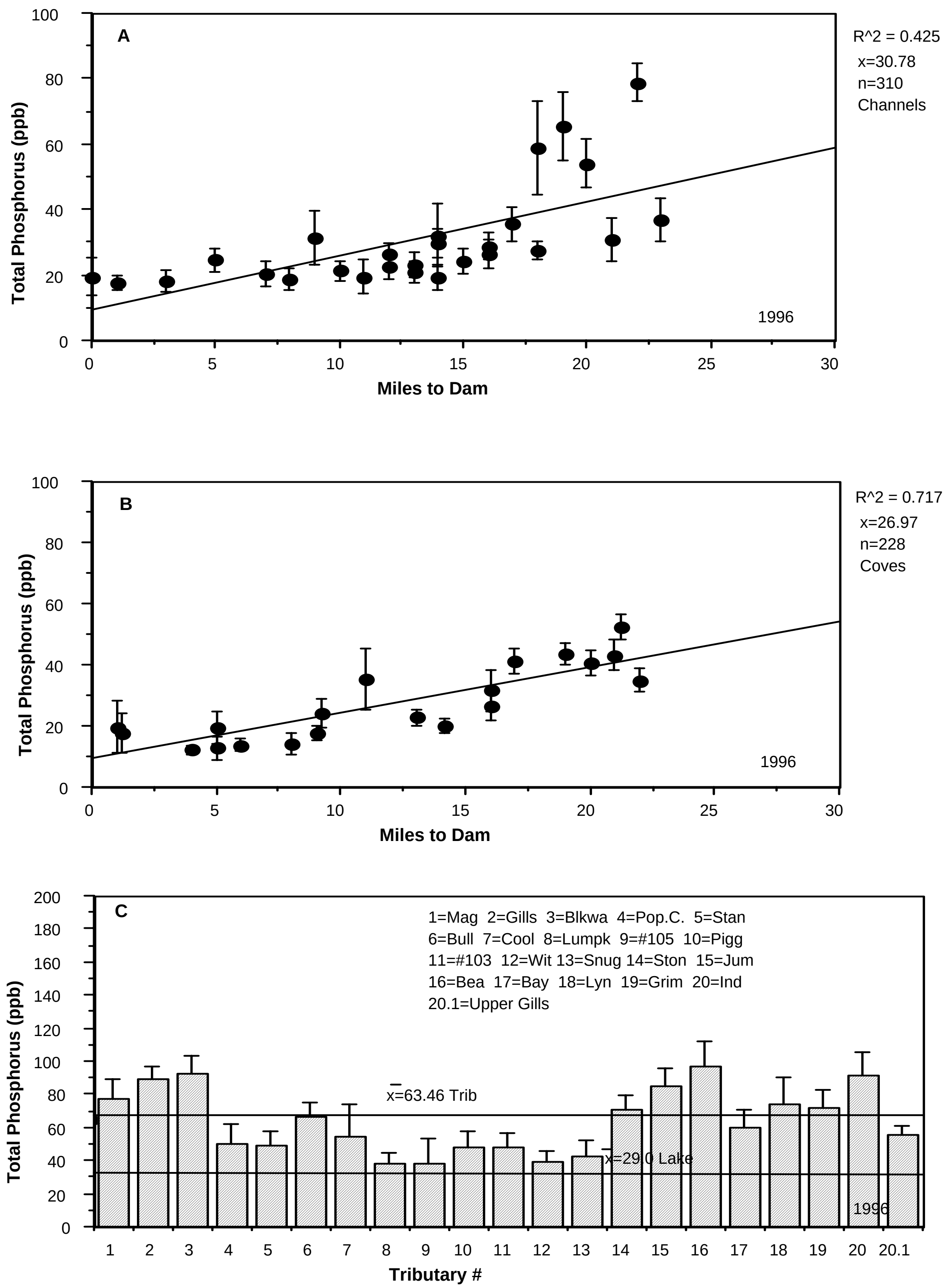


Figure 2. (A&B) Total phosphorus concentration averaged by site vs. miles to the SML Dam and (C) average TP for tributary stations.
(x = average value)

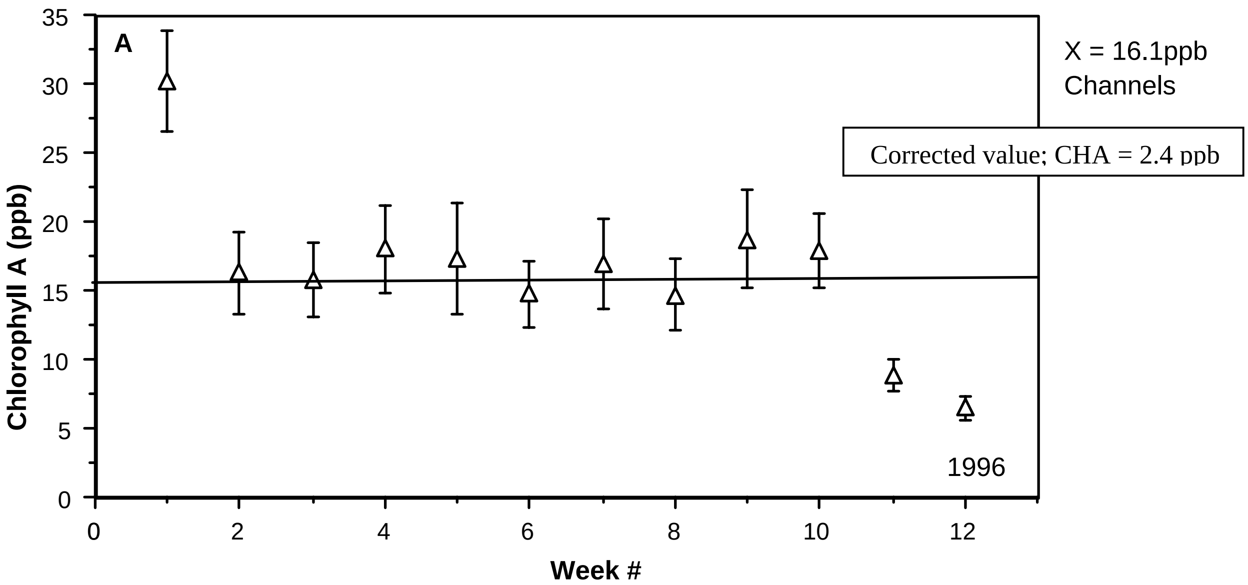
3.2.2 Chlorophyll-*a*

(Chlorophyll-*a* values were calculated incorrectly; see Appendix Table A5a for corrected values)

The channel (27 sites) and the cove (19 sites) sample sites in Smith Mountain Lake exhibited the lowest chlorophyll-*a* concentration in Week 12 (CHA = 6.5 ppb for channels and CHA = 7.7 ppb for coves) and the highest chlorophyll-*a* concentration in the first week of the summer (CHA = 30.2 ppb for channels and CHA = 22.4 ppb for coves), which was the same high and low chlorophyll-*a* concentrations as the values for the whole lake sample sites as can be seen in Figure 3A and 3B**.**

Chlorophyll-*a* concentration (CHA) in the channels decreased as miles to the dam decreased indicating less algal production toward the main basin where the two main tributaries converge (Figure 4A). The highest average total chlorophyll-*a* concentration (CHA = 35.5 ppb) in the channels was measured at a station on the Roanoke Channel at 23 miles from the dam, and in the Blackwater Channel at 22 miles an average of 30.5 ppb was found. The lowest average chlorophyll-*a* concentration (CHA = 1.4 ppb) was found at a main basin site 1 mile from the dam.

Chlorophyll-*a* concentration (CHA) in the coves decreased as miles to the dam decreased in a similar trend (Figure 4B). The highest average chlorophyll-*a* concentration (CHA = 33.0 ppb) in the coves was measured at a station on the Roanoke Channel at 21 miles from the dam. The lowest average chlorophyll-*a* concentration (CHA = 5.9 ppb) was found in a cove off the main basin 1 mile from the dam. The decrease in the chlorophyll-*a* concentration is significantly correlated with decreasing miles to the dam for both the channels and the coves (R^2 = 0.85 for the channels and R^2 = 0.76 for the coves).



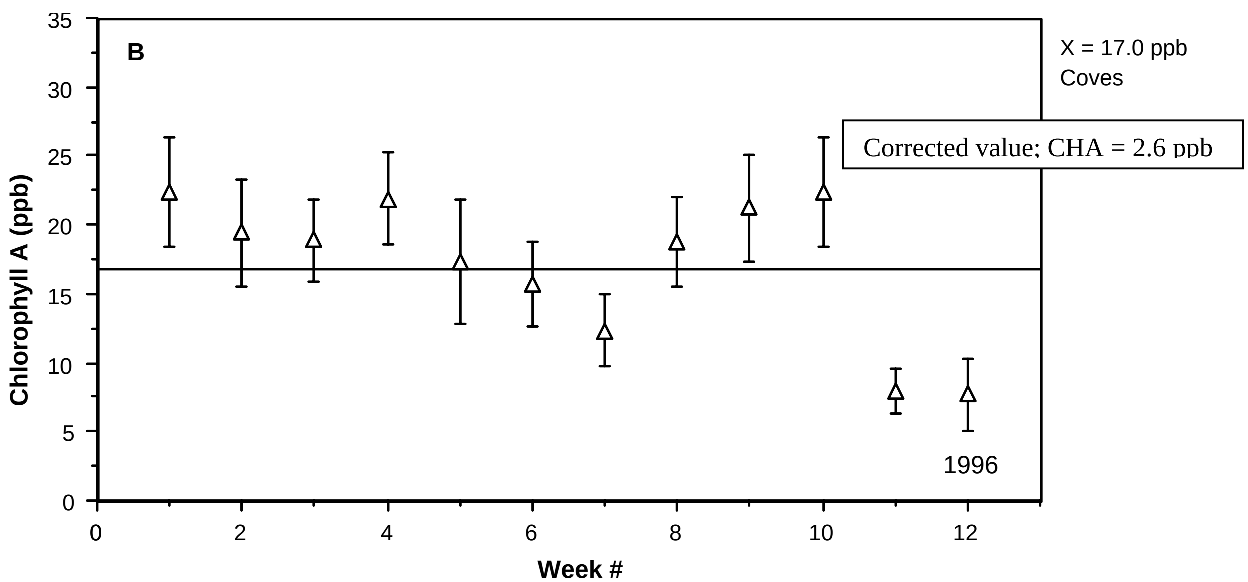


Figure 3. **A Comparison of average chlorophyll-*a* concentration for channel sites and cove sites by week.**
(x = average value)

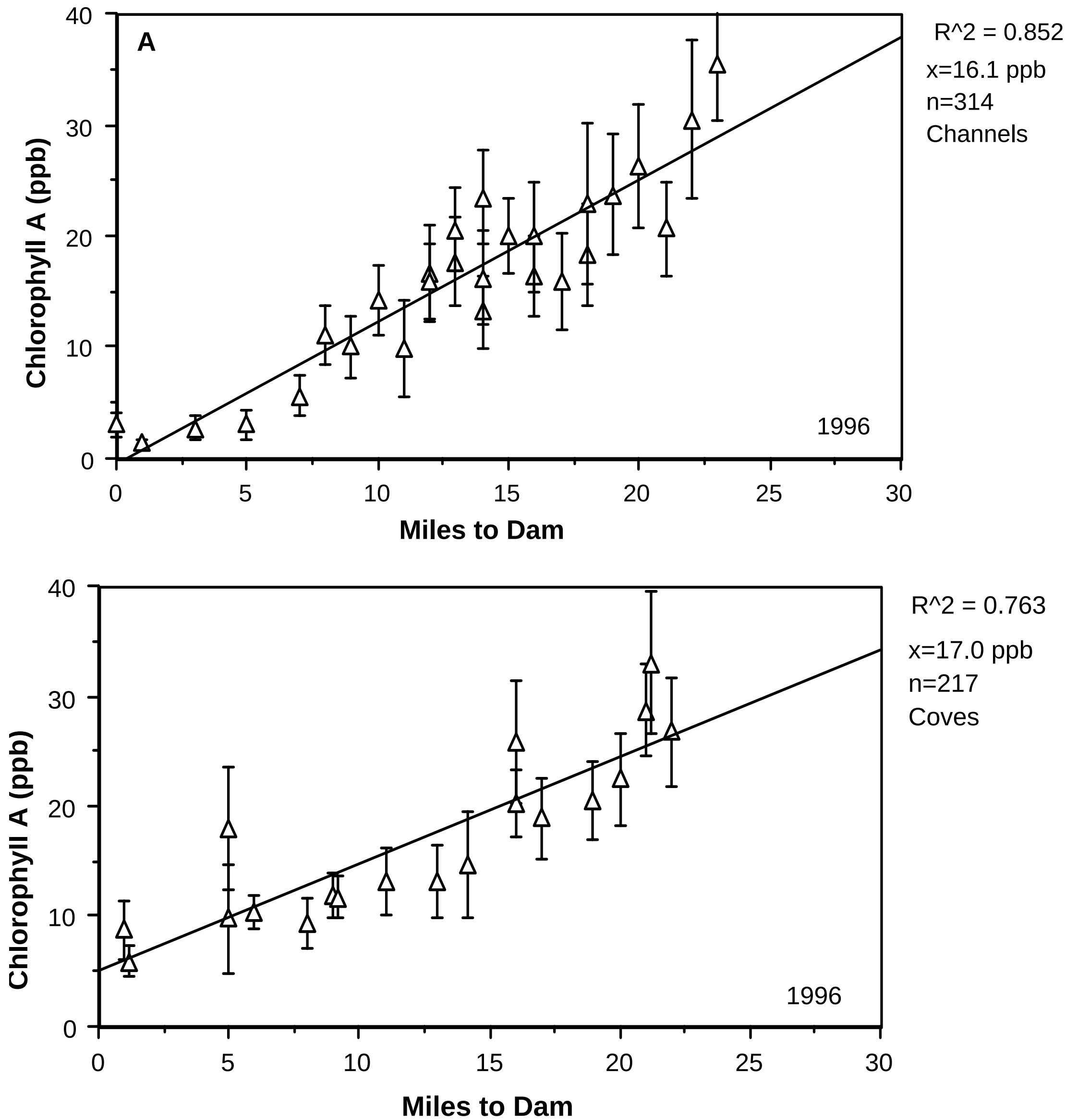


Figure 4. Average chlorophyll-*a* concentration for channel sites and cove sites vs. miles to the SML Dam.
(x = average value)

3.2.3 Secchi Depth

The channel (23 sites) sample sites exhibited the highest Secchi depth readings (SD = 2.27 m) in Week 11 and the cove (47 sites) sample sites in Smith Mountain Lake exhibited the highest Secchi depth (SD = 2.19 m) in Week 12 (See Figure 5A). The lowest Secchi depth reading in the channels and the coves which indicates the least water clarity (was found in the first week of the summer (SD = 1.69 m for channels and SD=1.58m for coves) as can be seen in Figure 5B**.**

Secchi depth measurements in the channels increased as miles to the dam decreased indicating greater water clarity toward the main basin where the two main tributaries converge (Figure 6A). The highest average Secchi depth reading (SD = 3.07 m) in the channels was measured at a station on the main basin within a mile of the dam, the lowest average Secchi depth readings were found at 22 miles up the Blackwater Channel (SD = 1.1 m) and at 19 miles up the Roanoke Channel (SD = 1.5 m). The water clarity is much lower in the upper reaches of the Roanoke and Blackwater Channels of Smith Mountain Lake where the depth of the water is much less also.

Secchi depth readings in the coves increased as miles to the dam decreased in a similar trend (Figure 6B). The highest average Secchi depth reading (SD=3.42m) in a cove off the main basin four miles from the dam. The lowest average Secchi depth reading was found in a cove off the Roanoke Channel 14 miles from the dam with the lowest Secchi depth reading (SD = 1.4 m) found on the Blackwater Channel at 20 miles from the dam. The increase in Secchi depth readings is significantly correlated with decreasing miles to the dam for both the channels and the coves (R^2 = 0.90 for the channels and R^2 = 0.72 for the coves).

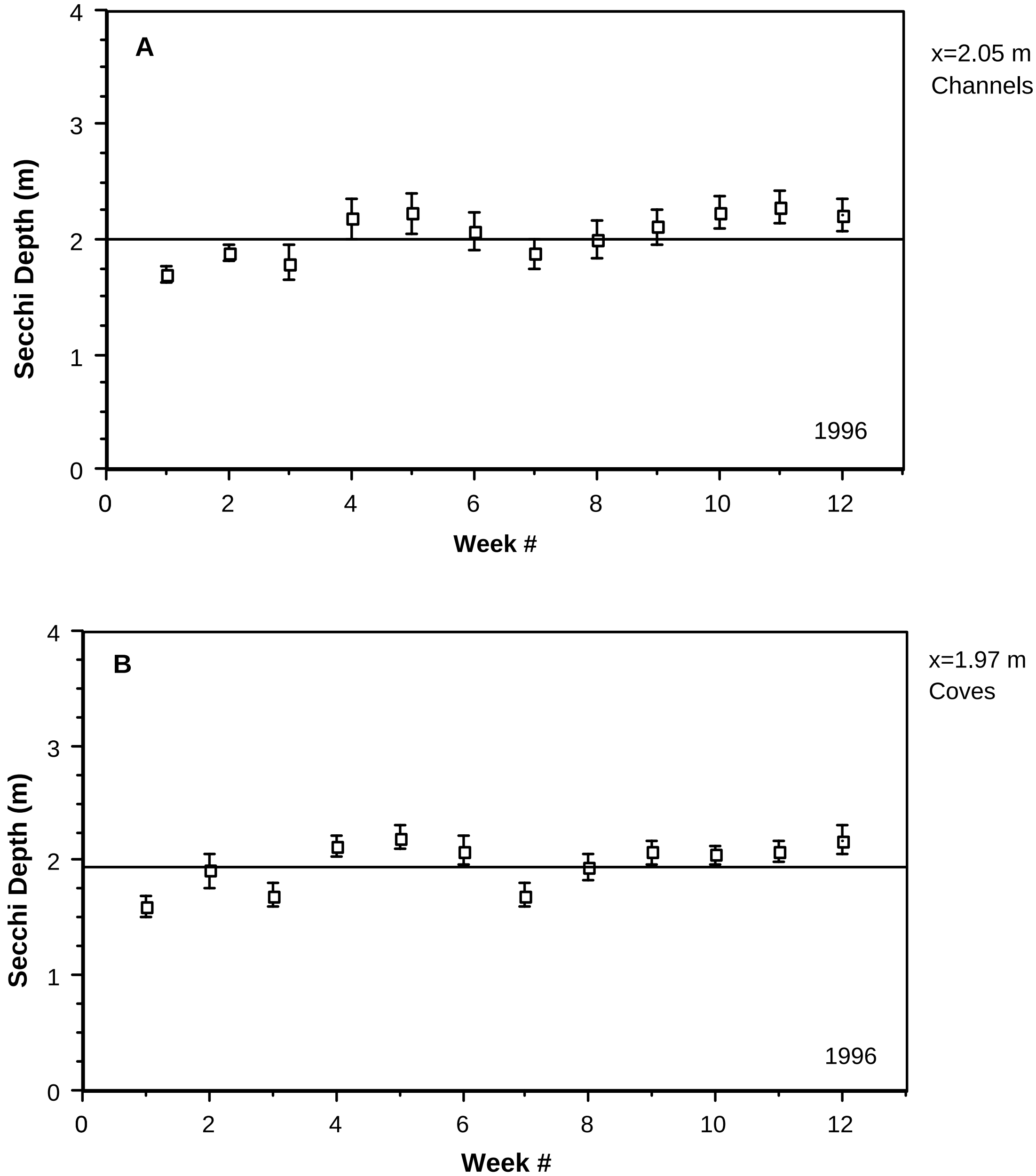
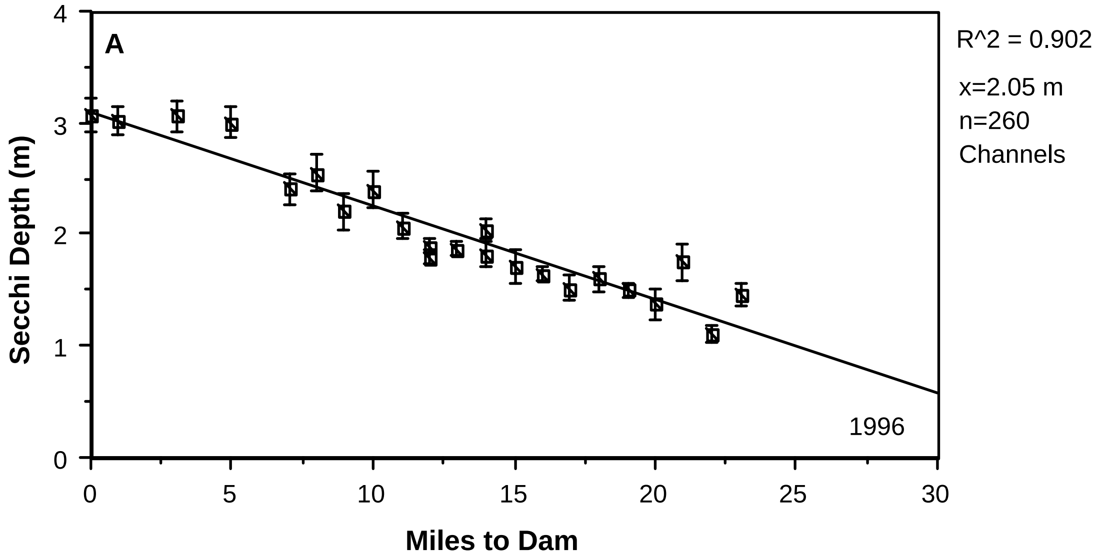


Figure 5. **Secchi depths for channel sites and cove sites by averaged by week.** (x = average value)



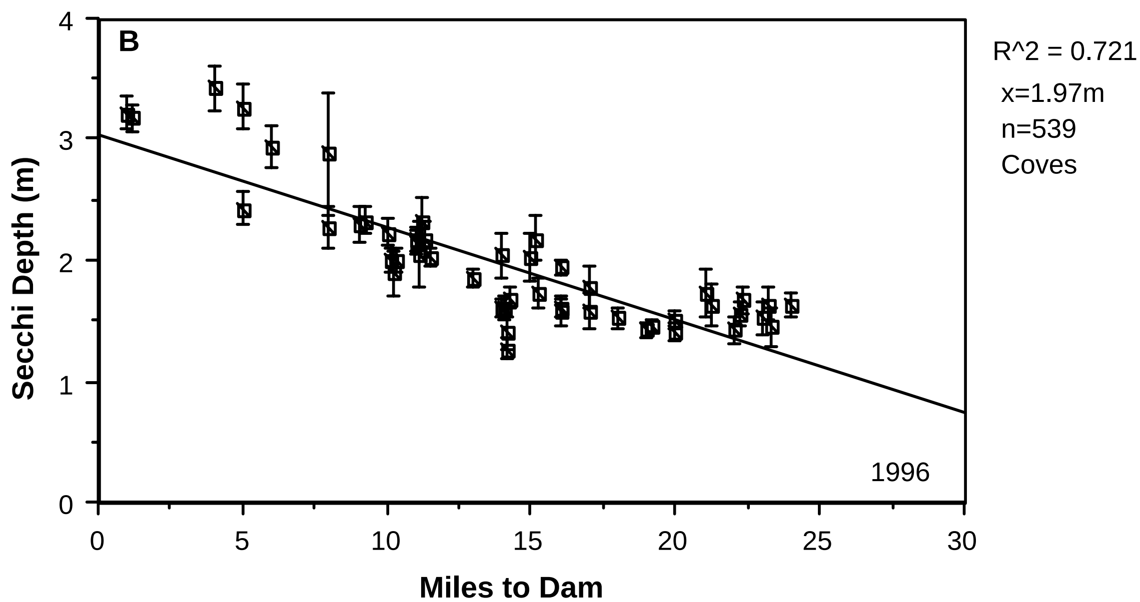


Figure 6. **Average Secchi depth versus miles to the SML Dam.**
(x = average value)

3.2.4 Summary of Section

The channels and the coves of Smith Mountain Lake are dependent on each other for water circulation, nutrient interchange and biotic relationships. The tributaries provide much of the nutrients especially phosphorus as demonstrated with these data. The mean phosphorus loading from the tributaries sampled was 63.46 ppb, substantially higher than the mean phosphorus concentration for the channels (30.78 ppb) and the coves (26.97 ppb). It is surprising, however that the phosphorus concentration in the coves was lower than in the channels. This difference is not statistically significant, and as expected the channel and cove weekly fluctuation in phosphorus were very similar. There did appear to be a correlation between the peak phosphorus concentration in the tributaries at Week 11 and the peak phosphorus concentration the following week (Week 12 in the coves). Both the channel and cove phosphorus concentrations were correlated with the distance from Smith Mountain Lake Dam with the coves being much more highly correlated with a coefficient of 0.72 (n = 228) in comparison to the channel coefficient of 0.43 (n = 310).

The tributaries mean phosphorus concentration (63.46 ppb) was significantly higher than the mean lake (includes channels and coves) phosphorus concentration (29.0 ppb). The Franklin County tributaries exhibited higher phosphorus concentrations (approximately 62 ppb) than the Bedford County tributaries (approximately 50 ppb). The tributary where the highest phosphorus concentrations were found was Beaverdam Creek that is in Bedford County and the tributary where the lowest phosphorus concentrations were found was Lumpkin's Marina Creek in Pittsylvania County.

The chlorophyll-*a* concentrations were almost identical between the channels and the coves showing the weekly fluctuations to be very similar and the mean chlorophyll-*a* concentration in the coves to be slightly higher (17.0 ppb) than the chlorophyll-*a* concentration in the channels (16.1 ppb). Both the channel and cove chlorophyll-*a* concentrations were strongly correlated with the distance from Smith Mountain Lake Dam with the coves' correlation coefficient of 0.76 (n = 228) and the channels' coefficient of 0.85 (n = 310).

The water clarity of the channels and coves was not significantly different, however the coves were slightly more turbid with a lower Secchi depth (1.97 m) than the channels' Secchi depth readings (2.05 m). The weekly fluctuations were very similar.

Both the channel and cove Secchi depth readings were strongly correlated with the distance from Smith Mountain Lake Dam with the coves' correlation coefficient of 0.72 (n = 539) and the channels' coefficient of 0.90 (n = 260).

A few differences were found in comparing channels' and coves' water quality parameters but the similarities found indicate a very actively circulating lake with the tributaries contributing significant phosphorus loading.

3.3 Comparison of Water Quality in the Three Major Sections of Smith Mountain Lake

Smith Mountain Lake has three major sections and for analyzing water quality trends it is useful to compare water quality in these three sections. For purposes of comparison the "Roanoke arm" refers to both cove and channel stations in the Roanoke section, the "Blackwater arm" refers to cove and channel stations in the Blackwater section, and the "main basin" refers to those stations below the confluence of the Roanoke and Blackwater channels. The Blackwater arm does not include Gills Creek stations and the main basin does not include Craddock Creek stations. The three water quality parameters will be compared for each principal section of the lake in two ways. First, weekly average values will be compared by section over the twelve weeks of the monitoring season. In the second comparison, station averages over all twelve weeks will be shown for each section as a function of distance to the dam.

3.3.1 Weekly Average Total Phosphorus Concentrations

Figure 7 shows weekly average total phosphorus concentrations for the three sections delineated above. The Roanoke stations (21 sites) exhibited the highest average value during Week 3 (41.6 ppb) and the lowest value during Week 11 (19.3 ppb) with an overall average total phosphorus concentration of 32.3 ppb. The weekly average for the Blackwater stations (11 sites) was also highest during Week 3 (55.6 ppb) and lowest during Week 9 (22.3 ppb) and the overall average total phosphorus concentration was 37.9 ppb. In the main basin (7 sites) the average concentration was highest during Week 2 (29.9 ppb) and lowest during Week 7 (8.1 ppb) with an overall average of 19.5 ppb.

3.3.2 Weekly Average Chlorophyll-*a* Concentrations

(Chlorophyll-*a* values were calculated incorrectly; see Appendix Table A5a for corrected values)

Figure 8 compares weekly average chlorophyll-*a* concentrations for the three sections. The Roanoke stations (21 sites) exhibited the highest average value during Week 1 (30.9 ppb) and the lowest value during Week 12 (8.1 ppb) with an overall average chlorophyll-*a* concentration of 19.0 ppb. The weekly average for the Blackwater stations (11 sites) was also highest during the first week (34.8 ppb) and lowest during the last (8.3 ppb) with an overall average chlorophyll-*a* concentration of 19.9 ppb. In the main basin (7 sites) the average concentration was highest during Week 4 (15.7 ppb) and lowest during Week 11 (1.3 ppb) with an overall average chlorophyll-*a* concentration of 4.9 ppb.

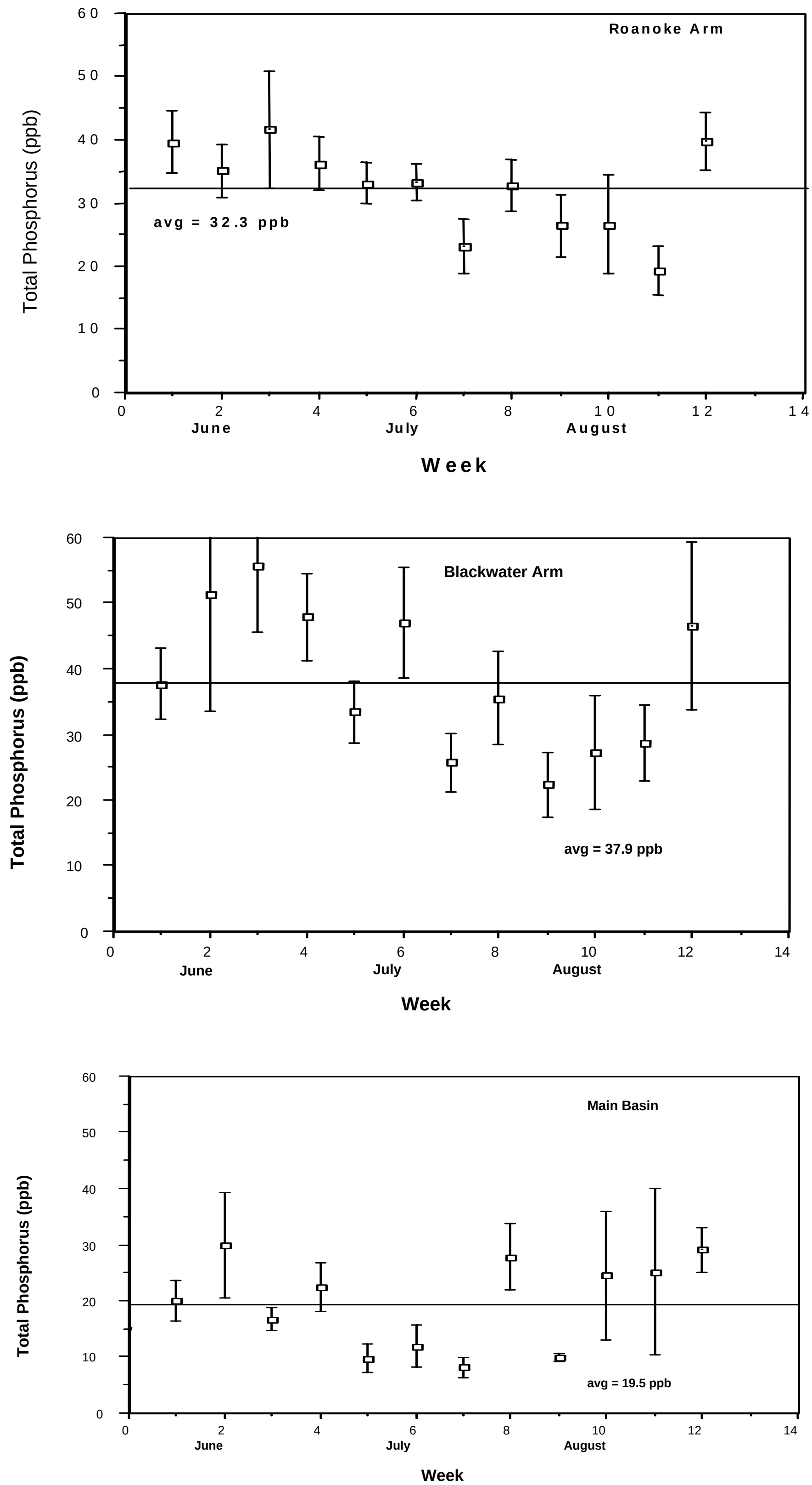


Figure 7. 1996 average weekly total phosphorus concentrations by section.

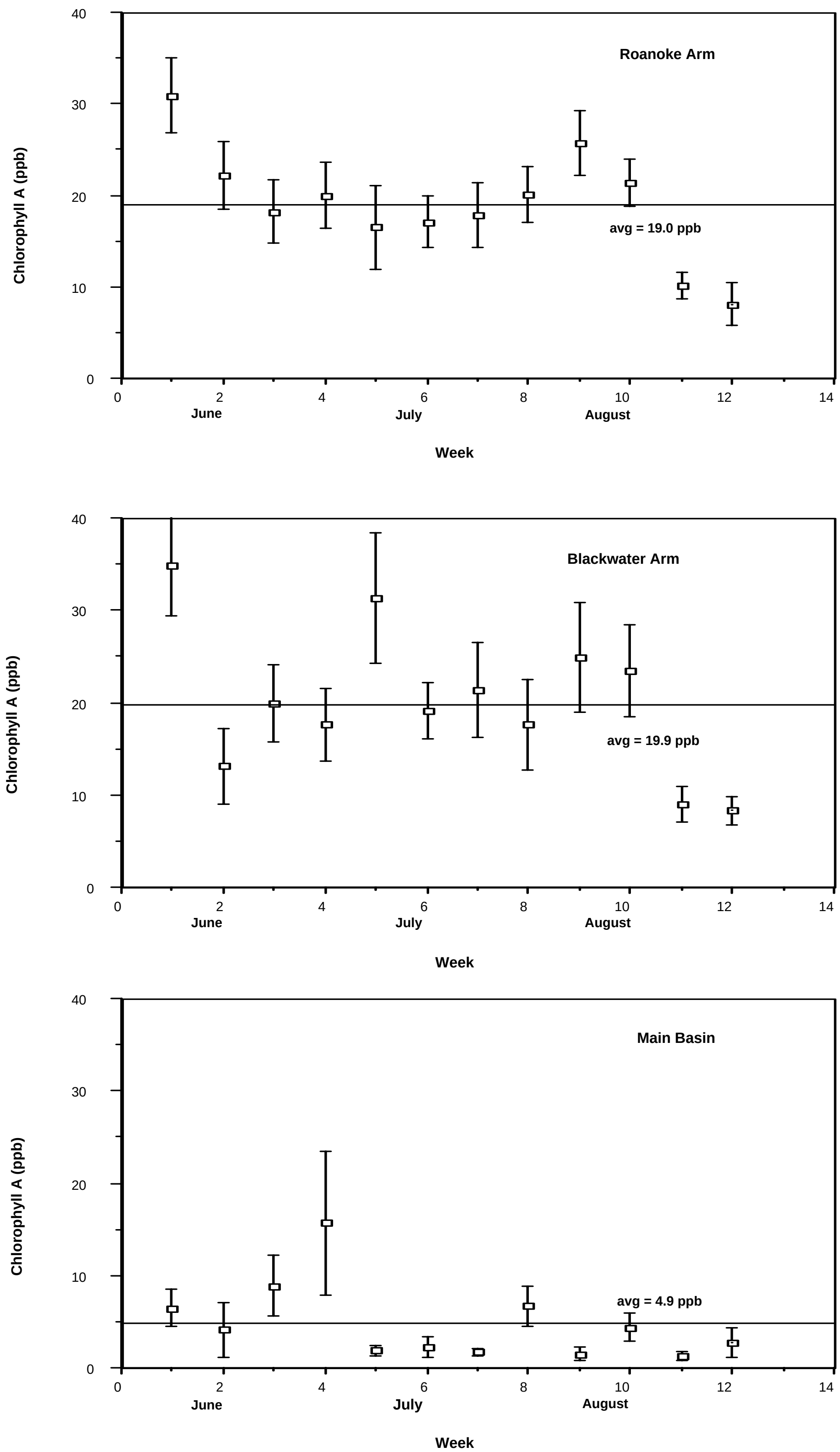


Figure 8. 1996 average weekly chlorophyll-*a* concentration by section.

3.3.3 Weekly Average Secchi Depth

Figure 9 compares weekly average Secchi depths for the three sections. The Roanoke stations (44 sites) exhibited the lowest average value during Week 1 (1.46 m) and the highest value during Week 12 (2.17 m) with an overall average Secchi depth of 1.78 m. The weekly average for the Blackwater stations (18 sites) was lowest during the seventh week (1.67 m) and highest during Week 11 (2.22 m) with an overall average Secchi depth of 1.90 m. In the main basin (7 sites) the average depth was lowest during Week 1 (2.06 m) and highest during Week 5 (3.36 m) with an overall average Secchi depth of 2.99 m.

3.3.4 Variation of Phosphorus Concentration with Distance from Dam

Figure 10 compares the variation of total phosphorus concentration with distance from dam in the three major sections of Smith Mountain Lake. The total phosphorus concentration (TP) in the Roanoke arm decreased as miles to the dam decreased indicating less nutrient enriched water toward the main basin. The decrease in the total phosphorus concentrations in the coves was significantly correlated with the decreasing miles to the dam (R^2 = 0.591). A similar trend occurs in the Blackwater arm with a higher correlation (R^2 = 0.693) and in the Main Basin, although with a lower correlation (R^2 = 0.343).

3.3.5 Variation of Chlorophyll-*a* Concentration with Distance from Dam

(Chlorophyll-*a* values were calculated incorrectly; see Appendix Table A5a for corrected values)

Figure 11 compares the variation of chlorophyll-*a* concentration with distance from dam in the three major sections of Smith Mountain Lake. The chlorophyll-*a* concentration (CHA) in the Roanoke Channel decreased as miles to the dam decreased indicating less alga growth as the larger expanse of water is approached. The correlation of chlorophyll-*a* concentration with distance from the dam is stronger than that for total phosphorus concentration in the Roanoke arm (R^2 = 0.823) and in the Blackwater arm (R^2 = 0.865). In the Main Basin, the correlation is not significant (R^2 = 0.053).

3.3.6 Variation of Secchi Depth with Distance from Dam

Figure 12 compares the variation of Secchi depth with distance from dam in the three major sections of Smith Mountain Lake. The Secchi depth values in the Roanoke Channel increased as miles to the Dam decreased indicating increased water clarity closer to the dam. The increase in the Secchi Depth was significantly correlated with the decreasing miles to the dam (R^2 = 0.580). As with the previous two parameters considered, the correlation was even stronger in the Blackwater arm (R^2 = 0.846). In the Main Basin there is a significant correlation but the correlation is weaker than in the other two sections (R^2 = 0.454).

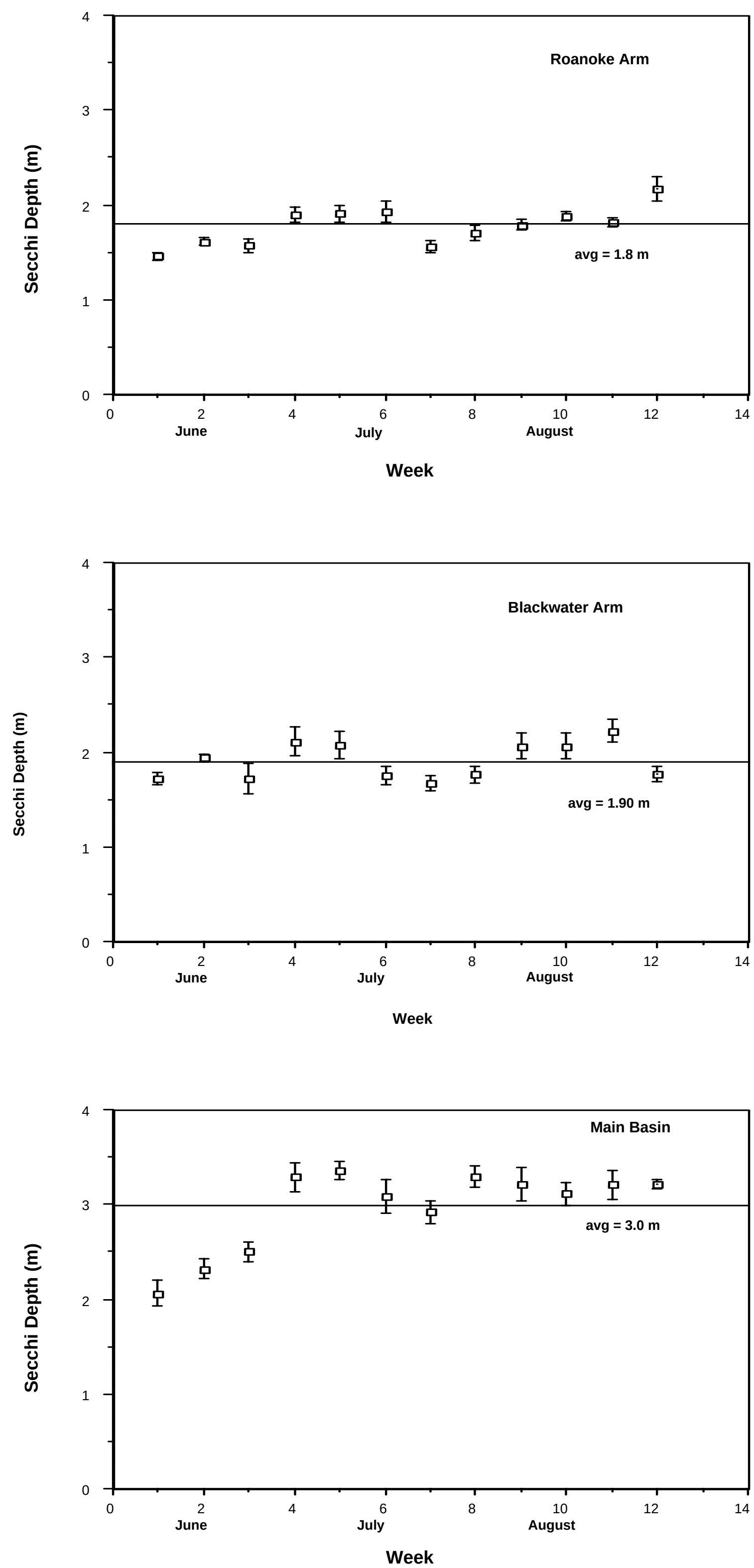


Figure 9. 1996 average weekly Secchi depth by section.

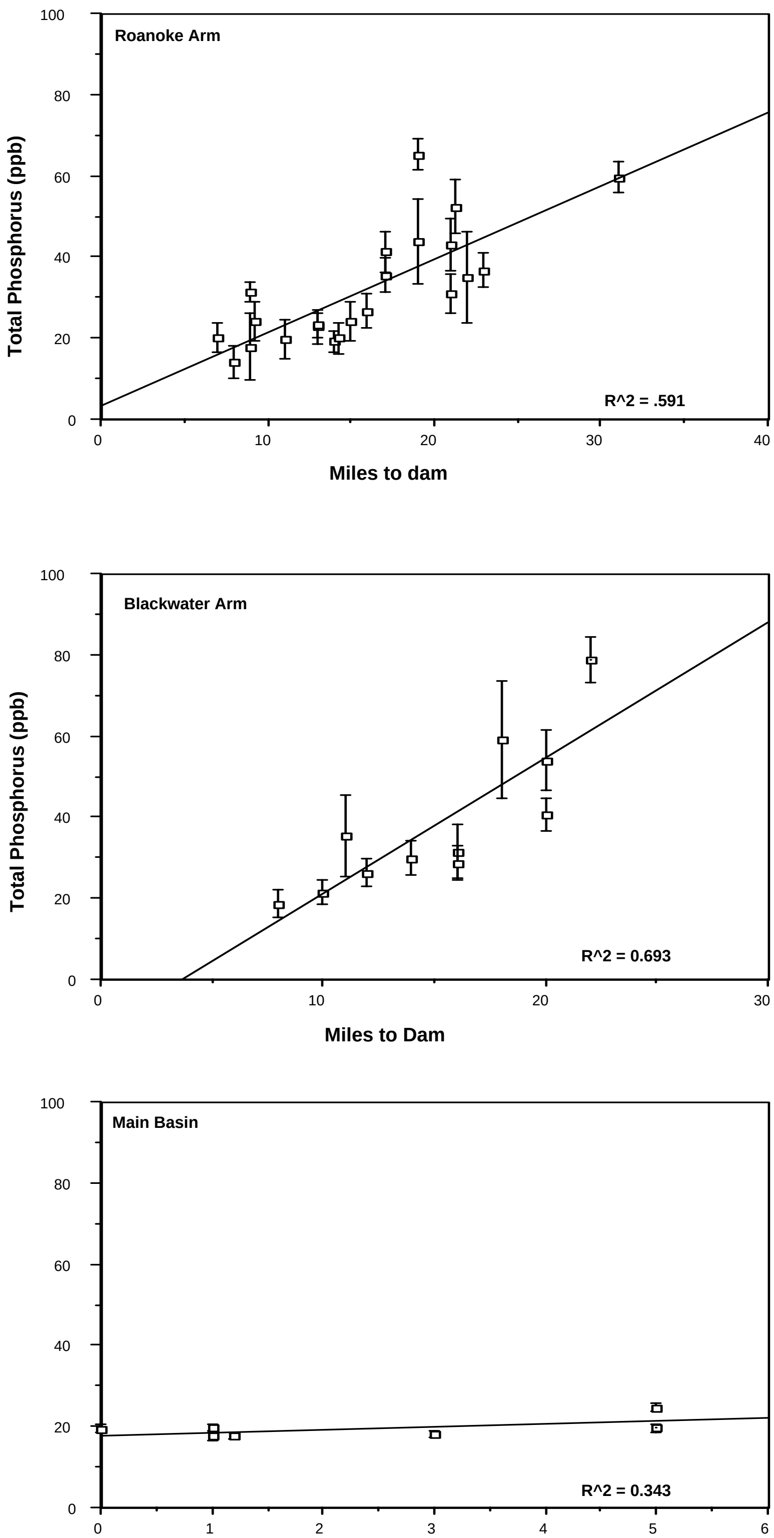


Figure 10. 1996 total phosphorus concentration versus distance from dam.

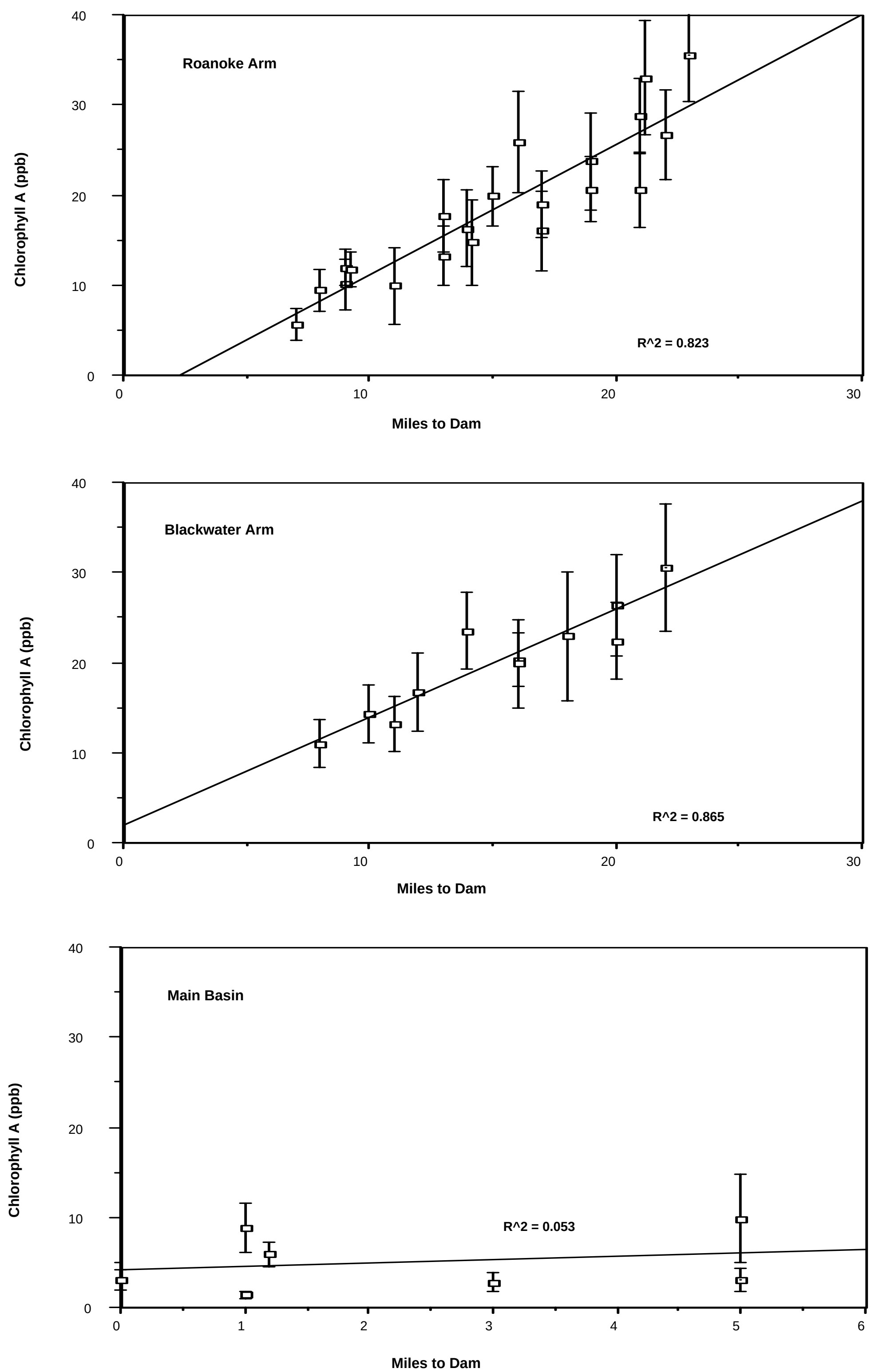


Figure 11. 1996 Chlorophyll-*a* concentration versus distance from dam.

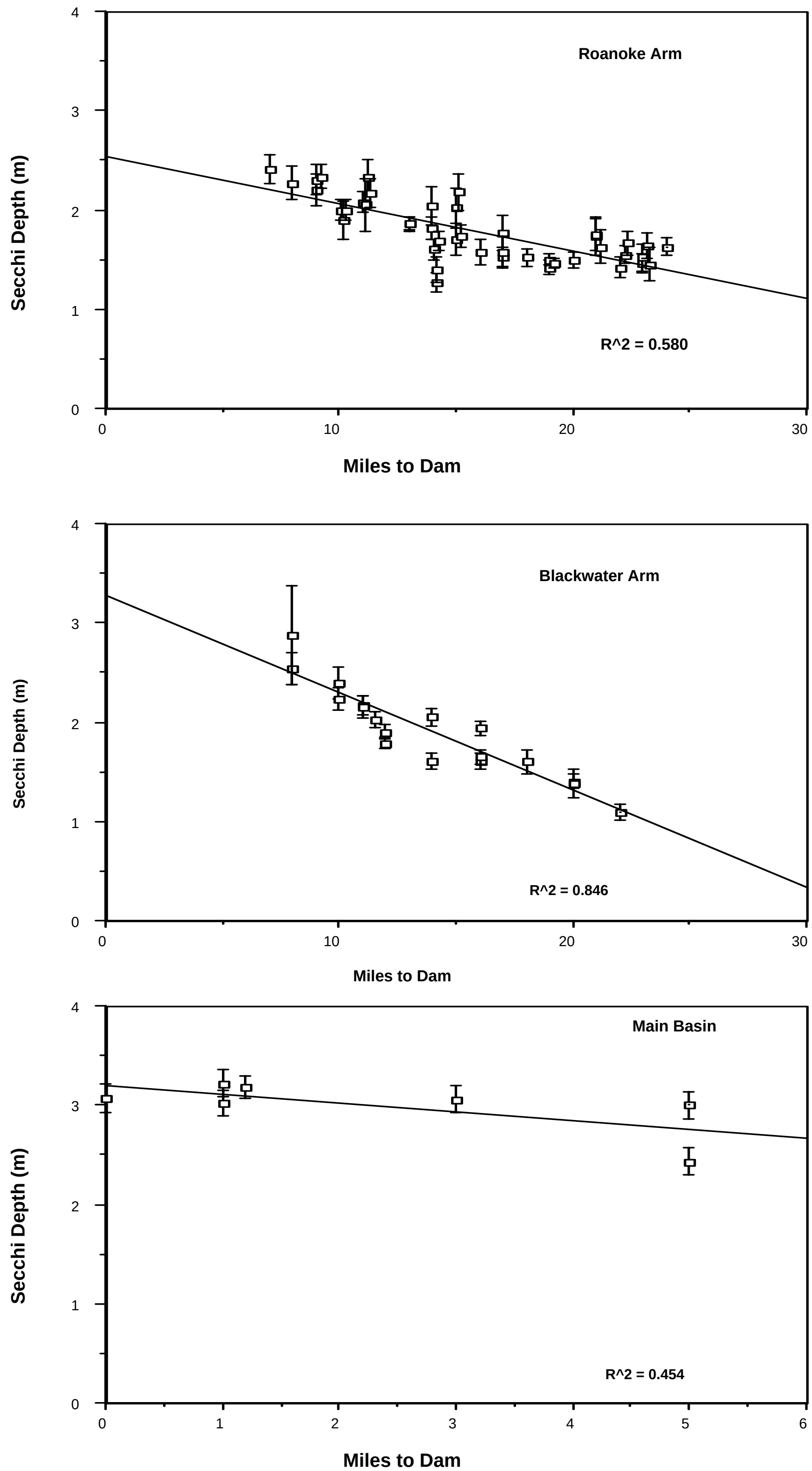


Figure 12. 1996 Secchi depth versus distance from dam.

3.3.7 Summary of Section

The similarity of the Roanoke and Blackwater sections of the lake is surprisingly close. The overall averages for the three water quality parameters are nearly the same. The weekly averages follow similar patterns, as does the variability of water quality with distance from the dam. Table 1 below summarizes the comparison of the three major sections of the lake. In the last column the combined Carlson Trophic State Index is given. The index value is calculated from the average value of the three water quality parameters and a discussion of the trophic state index can be found in Chapter 7 of this report.

Table 1. Average value of water quality parameters by section of lake.

	TP (ppb)	CHA (ppb)	SD (m)	TSI-C
Roanoke Arm	32.3	19.0	1.8	54.2
Blackwater Arm	37.9	19.9	1.9	55.6
Main Basin	19.5	4.9	3.0	45.2

Water quality in the main basin is clearly different than the two channels leading to it. The major nutrient input to the lake is nonpoint source pollution from the watershed. The most common forms of phosphorus adsorb strongly to clay particles and are carried into the upper reaches of the lake by the major tributaries. A large portion of the clay particles, along with the absorbed phosphorus, settles as the water moves toward the dam. This conclusion was written in the first report and this year’s data adds further confirmation. In Figure 13 the combined Carlson’s Trophic State Index (see Chapter 7) has been calculated for each advanced monitoring station and plotted as a function of distance from the dam. The high correlation ($R^2 = 0.897$) indicates a strong, consistent trend of improving water quality moving toward the dam.

To end this section on variation of water quality with location, the average parameter values and TSI for each station are shown in Table 2. The stations have been sorted in ascending order by TSI and the large difference in water quality by location is apparent.

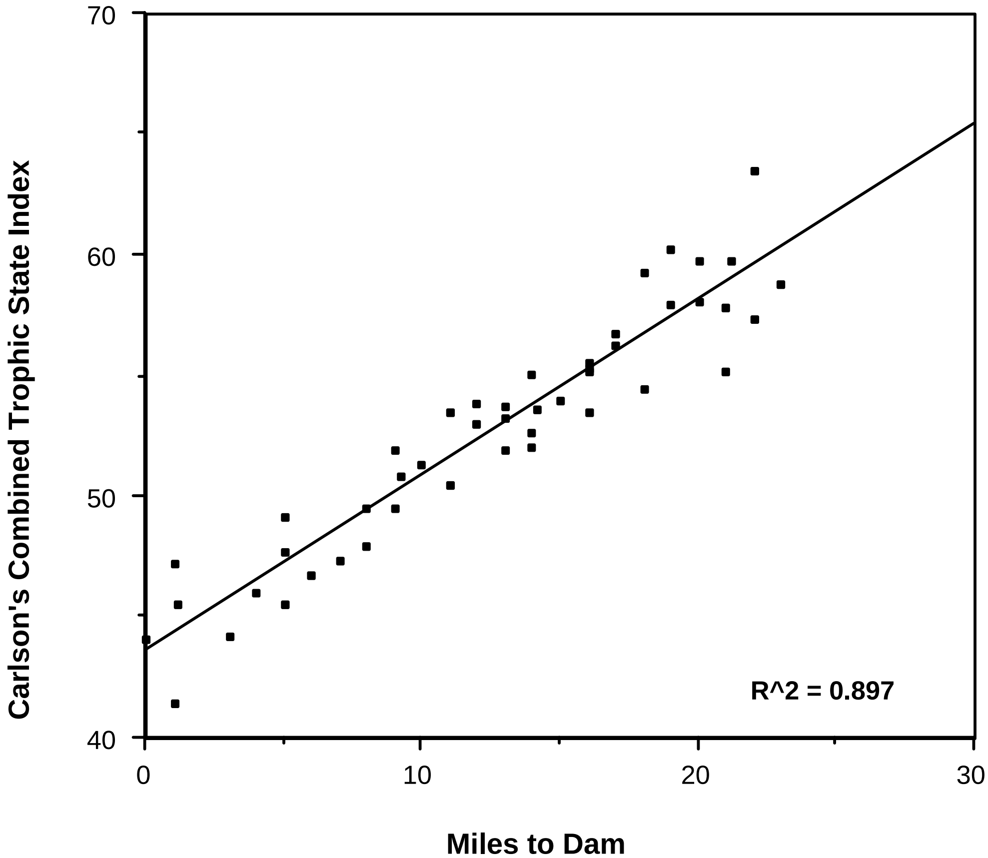


Figure 13. The combined trophic state index for each station versus distance from dam.

Table 2. Average value for each water quality parameter and resulting combined trophic state index (TSI) for each station.

Station	PO4 (ppb)	CHA (ppb)	SD (m)	TSI-C
M1	17.5	1.4	3.0	41.5
M0	19.4	3.1	3.1	44.1
M3	18.1	2.8	3.1	44.2
CM1.2	17.6	5.9	3.2	45.5
M5	24.6	3.0	3.0	45.6
C04	12.1	10.6	3.4	46.0
C06	13.7	10.4	2.9	46.8
CM1	19.7	8.8	3.2	47.2
R07	20.2	5.6	2.4	47.4
C05	12.7	18.0	3.3	47.7
CR08	13.9	9.4	2.3	47.9
CM5	19.5	9.8	2.4	49.2
CR09	17.7	11.9	2.3	49.5
B08	18.6	11.0	2.5	49.5
R11	19.5	9.9	2.1	50.5
CR09.2	24.1	11.7	2.3	50.9
B10	21.3	14.3	2.4	51.3
R09	31.3	10.1	2.2	51.9
CR13	22.7	13.2	1.9	51.9
R14	19.1	16.3	1.8	52.1
G14	32.0	13.2	1.9	52.7
G12	22.6	15.9	1.9	53.0
G13	21.1	20.6	1.9	53.2
G16	26.4	16.4	1.9	53.5
CB11	35.2	13.2	2.1	53.5
AVG	29.0	16.9	2.1	53.5
CR14.2	20.0	14.7	1.4	53.6
R13	23.1	17.7	1.9	53.7
B12	26.3	16.7	1.9	53.8
R15	24.2	19.9	1.7	54.0
G18	27.4	18.3	1.8	54.4
B14	29.8	23.5	2.0	55.1
R21	30.9	20.6	1.8	55.2
CB16	31.5	20.3	1.9	55.2
B16	28.7	19.9	1.6	55.3
CR16	26.7	25.9	1.6	55.6
R17	35.5	16.0	1.5	56.3
CR17	41.3	18.9	1.6	56.8
CR22	34.9	26.7	1.4	57.3
CR21	43.0	28.7	1.7	57.8
CR19	43.6	20.6	1.4	58.0
CB20	40.6	22.4	1.4	58.1
R23	36.7	35.5	1.5	58.8
B18	58.9	22.9	1.6	59.3
B20	54.0	26.3	1.4	59.7
CR21.2	52.4	33.0	1.6	59.8
R19	65.2	23.7	1.5	60.2
B22	78.7	30.5	1.1	63.5

3.4 Results for Leesville Lake

The Leesville Lake samples are collected by the student technicians as grab samples from a bridge in the same manner as the tributary samples. The difference is that these samples are collected below the dam. T9 is in the Roanoke River just below the dam at the APCO Visitor Center, T10 is in the Pigg River near its confluence with the Roanoke River, and T11 is in the Roanoke River after the confluence with the Pigg River and about where Leesville Lake begins. The results for 1993 through 1996 are summarized in Table 3. The values given for each year are the annual averages. Thus the column and row designated as average are the average value of annual averages. The raw data for Leesville Lake can be found in the Appendix, Table A.3b. Total phosphorus in these samples follow the pattern for the lake with 1996 averages being lower than in 1995, although the average phosphorus concentration in the Roanoke River below the dam is just slightly lower than in 1995. The average phosphorus concentration in the Pigg River is considerably lower than last year and so its effect on the concentration in the Roanoke River is much less pronounced than in the previous years.

Table 3. Summary of 1993 to 1995 results for sites below the SML Dam.

	Total Phosphorus (ppb)				
Location (original site number)	**1993**	**1994**	**1995**	**1996**	**Average by site**
T9, Roanoke, below dam (105)	48.5	25.6	40.5	38.3	38.2
T10, Pigg River, Rt. 605 (104)	65.2	64.5	83.4	48.3	65.4
T11, Roanoke, Rt. 608 (103)	54.6	38.7	62.1	48.1	50.9
Average by year	56.1	42.9	62.0	44.9	

4. FECAL COLIFORMS IN SMITH MOUNTAIN LAKE

Water was collected from eight sites on Smith Mountain Lake on May 20, July 8, and August 14, 1996. These samples were collected and stored according to standard methods of bacterial sampling (APHA). The 100mL of the samples were filtered immediately upon return to the laboratory. The membrane filtration method for bacterial analyses was used with DIFCO m-Fecal Coliform media prepared with rosolic acid, as prescribed in standard methods (APHA). Characteristic blue fecal coliform colonies were counted and recorded after 24 hours of incubation at 45.5 C in a water bath.

The sites on Smith Mountain Lake that were sampled included the following:

<u>Non-marina sites</u>

1. Main basin of Smith Mountain Lake at confluence of the Blackwater and Roanoke Channels.
2. Forest Cove of the Bedford County side of the lake.
3. Fairway Bay on the Franklin County side of the lake.
4. Palmer's Trailer Park Cove on the Franklin County side of the lake.

<u>Marina sites</u>

5. Shoreline Marina on the Franklin County side of the lake.
6. Pelican Point Marina on the Franklin County side of the lake.
7. Smith Mountain Lake Dock on the Pittsylvania County side of the lake.
8. Smith Mountain Lake Yacht Club on the Bedford County side of the lake.

These sites were selected were selected to representative coves around Smith Mountain Lake, and to allow comparison between non-marina coves and marina coves. (1) The main basin site at the confluence of the Blackwater and Roanoke Channels was selected to provide samples not influenced by run off from nearby shoreline. (2) Forest Cove (Bedford County) is surrounded by a residential area of low density, includes a horse pasture and is located after the confluence of the two main channels in close proximity to Smith Mountain lake Dam. (3) Fairway Bay (Franklin County) is surrounded by homes and multi-family residences and is not far from Hales Ford Bridge on the Roanoke Channel. (4) Palmer's Trailer Park Cove is surrounded by trailers that have been there for a long time each with a septic tank and drain field and is located off

Little Bull Run off the Blackwater Channel. (5) Shoreline Marina is up Becky's Creek that is a tributary of the Roanoke Channel near the Hales Ford Bridge in Franklin County and is a storage place for many houseboats. (6) Pelican Point Marina is on the Blackwater Channel in Franklin County and is a storage place for many large sailboats and a few houseboats. (7) Smith Mountain Lake Dock is a cove off the main basin in Pittsylvania County and in close proximity to Smith Mountain Lake Dam and is a storage place for many houseboats. (8) Smith Mountain lake Yacht Club is in a cove off the Roanoke Channel in Bedford County and not far from Hales Ford Bridge and is a storage place for many houseboats.

Figure 14 compares of the sum of the ranks of each sample sites shown in Figure 15. Indicates the mean fecal coliform colony forming units (cfus) commonly called colony counts for the three sample dates. The conclusions drawn from these data are:

1. The mean colony counts and variances for 1996 (marinas mean = 16.1±10.7 cfus and non-marinas = 4.9±7.3 cfus) were lower than the mean colony counts and variances for 1995 (marinas mean = 36±24 cfus and non-marinas = 27±36 cfus).

2. Sample date was an important influence on the fecal coliform population estimates, with the last sample date August 14, 1996 exhibiting the highest mean number of colonies (10.5±6.5cfus). In 1995 the July 3rd sample exhibited the highest colony counts (approximately 68 cfus).

3. The mean coliform population estimate was for all marinas was higher (16.1±10.7 cfus) than the mean coliform population counts for non-marina sites (4.9±7.3 cfus).

4. One marina cove (Pelican Point Marina) had lower fecal coliform counts than one of the non-marina coves (Palmer's Trailer Park) on all three sample dates, as was true in 1995. The mean colony counts for Pelican Point Marina for 1996 were 3.0±2.4 cfus and the mean colony counts for Palmer's Trailer Park Cove was 15.9±4.1 cfus.

5. The confluence of the two main tributaries had higher fecal coliform counts than Forest Cove on all three sample dates and higher fecal coliform counts than Fairway Bay on last sample date (August 14, 1996).

6. Although the mean fecal coliform population estimates for the marinas were not significantly higher than the same for the non-marinas when all marina sites and non-marina sites are include, three of the marinas (Shoreline Marina, Smith Mountain Lake Dock and the Smith Mountain Lake Yacht Club) had consistently higher fecal coliform counts than three of the non-marina sites (confluence of rivers, Fairway Bay, and Forest Cove). Mean colony counts for the three marina sites were 20.5±7.6 cfus and the mean colony counts for the three non-marina sites was 1.5±0.6 cfus. These three marina sites exhibited a significantly higher fecal coliform population estimate than the three non-marina sites.

7. In a comparison of the ranks of the sample sites where the lowest fecal coliform population estimates were ranked as 1st and the highest fecal coliform population estimate was ranked as 8th and the ranks of each site are added, Shoreline Marina (marina site) has the highest sum of ranks and Forest Cove (non-marina site) has the lowest sum of ranks. With the exception of Palmer's Trailer Park Cove (non-marina site) all of the non-marina sites had lower sum of ranks than all of the marina sites (Figure 14).

8. All values for fecal coliform populations meet Virginia health standards for swimmable and fishable waters in addition to meeting the standard for potable waters.

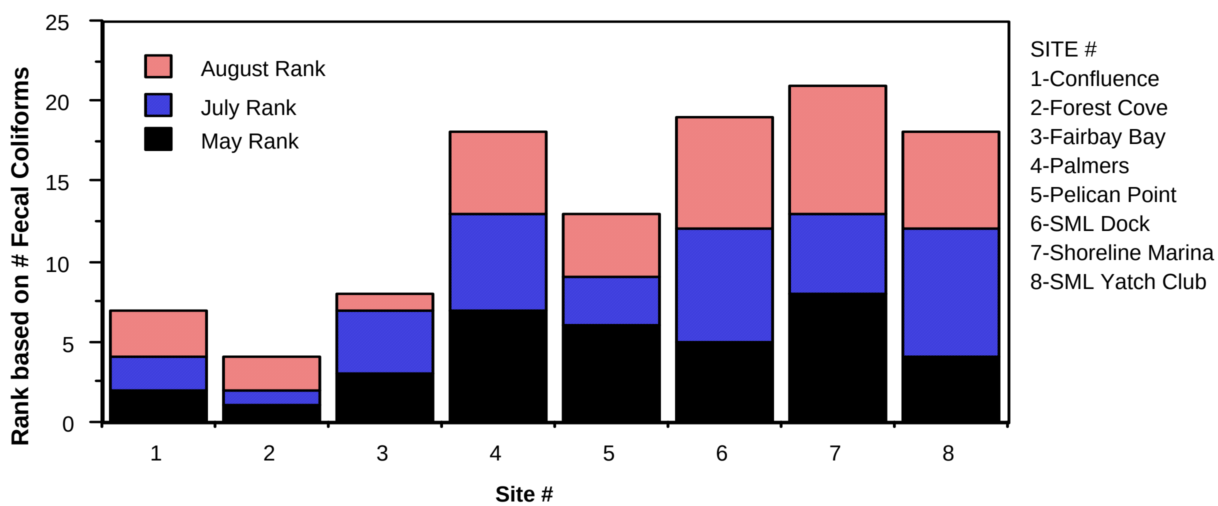


Figure 14. Fecal Coliform counts by sample site for 1996 on Smith Mountain Lake.

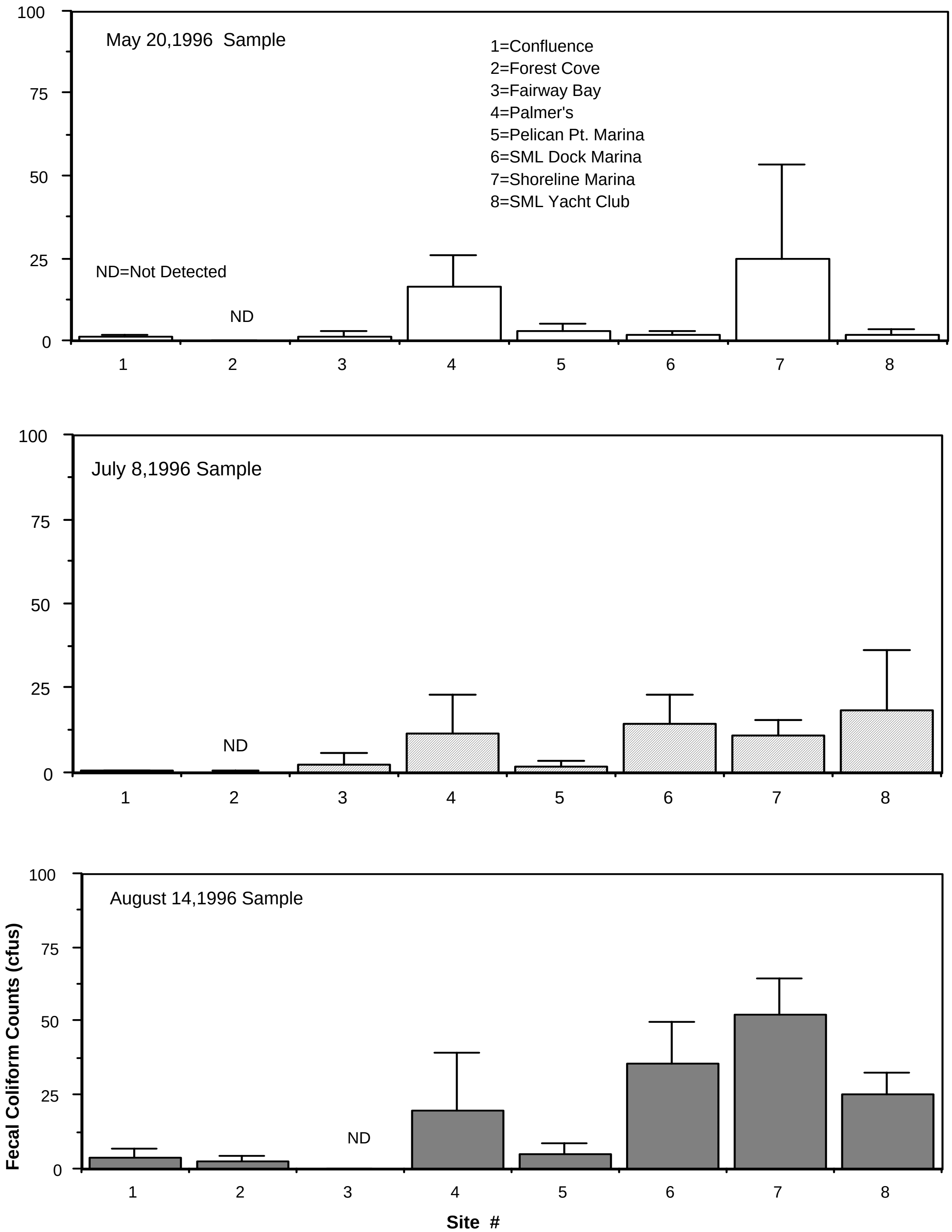


Figure 15. Smith Mountain Lake F. coliform counts by date.
(Samples were taken on the three dates May 20th, July 8th, and August 14th at 8 sites. Sites 1-4 are non-marina sites and sites 5-8 are marina sites.)

5. QUALITY CONTROL/QUALITY ASSURANCE

The full QA/QC program for the monitoring program is described in detail in the 1990 Final Report to the VEE. The results of this year's QA/QC program follow.

5.1 QA/QC for Total Phosphorus

Each week a set of standards is prepared so that a calibration curve can be constructed showing the relationship between phosphorus concentration in a sample and its absorption of light with a wavelength of 700nm. Table 4 summarizes the calibration data. The slope indicates the relationship between concentration and absorption and was very consistent from week to week. This gives confidence that the spectrophotometer used to measure absorbance was stable and that the standards were prepared in a consistent manner. The intercept is the absorbance of the reagent blank and indicates the extent to which the standards are contaminated with phosphorus during the analytical process. This background is subtracted from each sample to compensate. The contamination is due almost entirely to sample digestion. During digestion four reagents are added which contain small amounts of phosphorus that, along with the extra handling and manipulation, led to some inevitable contamination. The correlation coefficient (R^2) is a measure of how well the calibration line fits the data points with values ranging from 0 (no fit) to 1 (perfect fit). Averaging over 0.99, the correlation coefficient indicates excellent precision and shows both the care with which standard were prepared and the stability of the instrument.

Table 4. Summary of 1996 calibration data for total phosphorus.

Week	Slope	Intercept	R^2
1	0.0028	0.038	0.995
2	0.0028	-0.006	0.989
3	0.0025	0.027	0.985
4	0.0024	0.025	0.997
5	0.0025	0.022	0.996
6	0.0026	0.023	0.995
7	0.0025	0.006	0.993
8	0.0024	0.025	0.998
9	0.0026	-0.003	0.998
10	0.0025	0.028	0.994
11	0.0022	0.010	0.961
12	0.0026	0.004	0.992
Avg	0.0025	0.017	0.991
Stdev	0.0002	0.014	0.010

In Table 5, data for lab standards, field blanks, and surrogate samples are summarized. The lab standards are aliquots of the standards prepared to calibrate the instrument that have been placed in test tubes and then analyzed along with the other samples. Results from analyzing the lab standards indicate how sample manipulation in the lab affects phosphorus concentration. Assuming reasonable care has been taken in transferring samples and adding chemical reagents, the results of this testing indicates whether or not the test tubes are being cleaned sufficiently between runs. The field blanks and surrogate samples are also prepared in the same manner as blanks and standard solutions used in the laboratory for calibration. However, they are poured into sample bottles and given to volunteer monitors to carry out in the field and then stored in the same manner as the lake water samples. This allows examination of the effects of sample collection, storage and sample bottle on the results of phosphorus determinations. Insufficiently cleaned containers generally add phosphorus but a very clean container may actually reduce the phosphorus concentration in a sample by adsorption of phosphate to container walls. To avoid container effects a sample must be stored in a container that has been previously equilibrated with a solution of similar phosphate concentration. In practice this is impossible because the phosphorus concentrations are not known before they have been analyzed. This source of contamination is minimized by designating a particular sample bottle for each site and reusing that bottle each week. The average percent error is about 5.5% and the overall QA/QC results for total phosphorus are very good.

Table 5. Summary of phosphorus data for field blanks, surrogate samples, and lab standards.

QC/QA Sample	n	Target (ppb)	avg	std dev	error	% error
lab blank	12	0.0	1.4	1.7	1.4	*
lab std 1	11	10.0	10.4	5.0	0.4	4.4
lab std 2	12	20.0	20.6	11.5	0.6	3.2
lab std 3	11	40.0	40.9	4.3	0.9	2.3
lab std 4	11	80.0	87.8	14.2	7.8	9.8
lab std 5	10	160.0	169.5	17.3	9.5	6.0
field blank	14	0.0	0.9	2.8	0.9	*
surrogate 1	14	10.0	11.3	5.3	1.3	13.0
surrogate 2	14	20.0	19.6	7.0	-0.4	-2.2
surrogate 3	11	40.0	42.2	9.1	2.2	5.5
surrogate 4	14	80.0	77.1	16.6	-2.9	-3.6
surrogate 5	13	160.0	167.4	19.1	7.4	4.6

5.2 QA/QC for Chlorophyll-a

Calibration of the fluorimeter used to determine chlorophyll continues to be difficult. The fluorimeter continues to give very consistent readings from day to day and week-to-week for a given standard and the instrument is quite reliable. However, the instrument does slowly lose sensitivity as the source and detector deteriorate with age. The problem is that chlorophyll standards are unstable and a stock standard must be prepared each year. EPA standards and standards prepared from commercially available chlorophyll-*a* have both been employed with rather mixed results. The problems inherent in the analysis of chlorophyll-*a* have been described in several past reports and obtaining reliable standards for calibration may limit the accuracy of results. In 1993 and 1994 we used a calibration factor of 0.75, based on an average of several calibrations. 1995 calibration results gave a value of 0.625, although there was reason to believe that the instrument had not lost sensitivity. This past summer the standard solution of chlorophyll-*a* gave a result that was not reasonable. The fluorescence reading of the new standard was much less than the fluorescence of the standard from the previous year that would have undergone at least some decomposition. The two standards were poured into clear containers and the solution colors were different, both in intensity and in shade. In discussing the situation with the company supplying the chlorophyll-*a* we were told that there were significant differences in chlorophyll-*a* extracts from batch to batch. The supplier sent a second vial of chlorophyll-*a* to insure that the problem was not specific to the material in the first container, overheating during delivery for example. However, the chlorophyll-*a* in both vials was from the same batch and gave the same results. Next year an attempt will be made to find a company that specifically prepares chlorophyll-*a* standards with QA/QC data from interlab comparisons. For this year’s data, a calibration factor of 0.625 was used.

5.3 Secchi Disk Depth

The training received by the volunteer monitors, the simplicity of the technique, and the fact that Secchi depth is recorded to the nearest quarter meter gives inherent reliability to this measurement.

6. WATER QUALITY TRENDS

Results of each water quality parameter measured have been discussed in the previous section. In this section, the water quality trends are displayed in the manner that has been used for the past several years. Table 6 and Figure 16 compare water quality in Smith Mountain Lake over the ten-year period of the monitoring program.

Compared to last year, the average Secchi depth is the same but the chlorophyll-*a* concentration is a little lower and the average total phosphorus concentration is considerably lower than last year.

Table 6. Water quality data from Smith Mountain Lake 1987-1996.

Parameter	Average Smith Mountain Lake									
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
TP (ppb)	19.7	20.9	27.8	25.2	25.9	36.0	42.7	28.6	45.2	29.0
CHA (ppb)	3.8	2.6	3.7	4.5	3.0	5.5	23.7	23.4	19.6	16.3
SD (m)	2.4	2.7	2.2	2.4	2.6	2.0	2.3	2.3	2.0	2.0

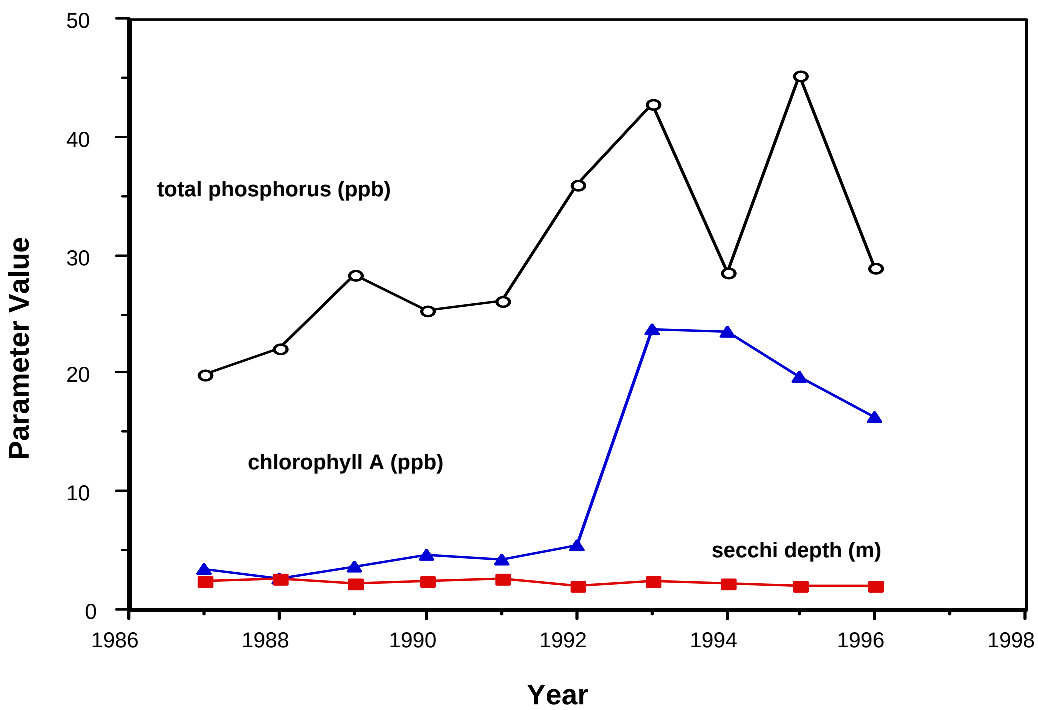


Figure 16. Graphical comparison of water quality parameters by year.

7. CARLSON'S TROPHIC STATE INDEX

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 7 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 apparent concentration. Table 8 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 7. Proposed relationships among phosphorus concentration, trophic state, and lake use for northern temperate lakes.

(Reckhow and Chapra, 1983)

Phosphorus Concentration (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 8. 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, trophic status can be placed on a scale from 1 to 100, with 1 being the least eutrophic. 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 water quality significance of a 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. This index will also be used to help interpret the water quality data collected on Smith Mountain Lake. Carlson's TSI may be calculated from any of the parameters being monitored: 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 (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.

The following equations are used for the calculation of TSIs:

$$TSI(TP) = 14.42 \ln TP + 4.15$$
$$TSI(CA) = 9.81 \ln CA + 30.6$$
$$TSI(SD) = 60 - 14.41 \ln SD$$
$$TSI(C) = [TSI(TP) + TSI(CA) + TSI(SD)]/3$$

TSIs are given for each year of the Smith Mountain Lake Volunteer Water Quality Monitoring Program in Table 9 and Figure 17.

Table 9. Trophic state index in Smith Mountain Lake by year.

	TSI-SD	TSI-TP	TSI-CA	Combined
1987	47	47	43	45.7
1988	46	49	40	44.9
1989	49	52	43	48.1
1990	47	51	45	47.8
1991	47	51	45	47.5
1992	50	56	47	51.2
1993	48	58	62	55.9
1994	48	53	62	54.0
1995	50	59	60	56.3
1996	50	53	58	53.6
main basin	42	55	53	50.2
upper arm	54	61	67	60.5
oligotrophic*	41	37	50	42.7
eutrophic*	50	47	55	50.8
avg. SE lake**	52	55	51	52.7

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

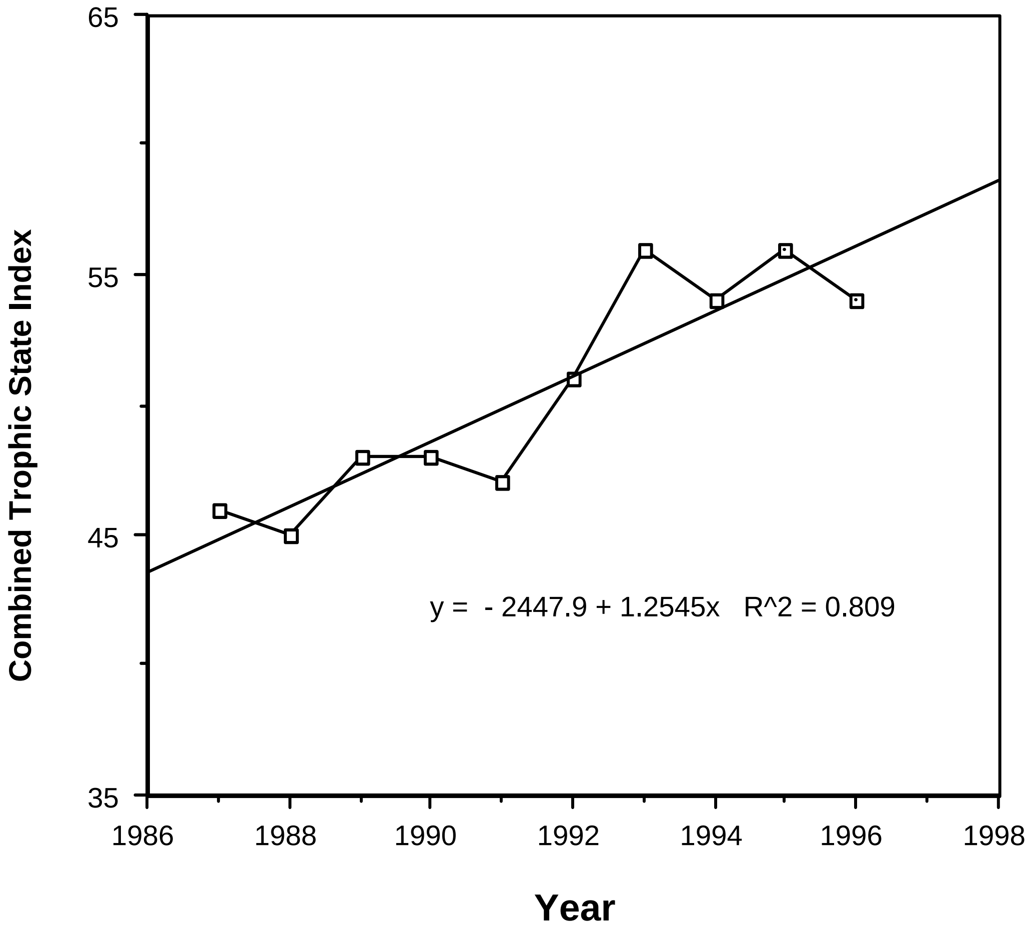


Figure 17. Trend in the combined trophic state index over time.

Figure 17 also displays the least squares plot of the combined trophic state index over time. This year's combined TSI (53.6) is slightly less than last year's value (56.3) and similar to the value for 1994 (54.0). This is reflected in the regression line of Figure 17. The lower TSI value for this year is contrary to the overall trend of increasing TSI and gives a slightly lower correlation coefficient of 0.809, down from last year's value of 0.839 but still highly significant. The slope has also decreased and the average increase in TSI is now 1.25 units per year compared to nearly 1.5 units per year indicated in 1995. While a one year decrease in TSI does not signify a trend, it is still good news because the change is in the right direction.

8. 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 10 presents the collection efficiencies for 1991 through 1996. The figures show that the volunteer monitors are very conscientious about sample collection. Advanced monitors collected 96% of the samples possible in 1996 and 92% of the samples possible for basic monitors. This sampling efficiency is remarkably high for volunteer sampling programs. In 1995 a decrease in efficiencies was attributed to the implementation of Phase 2 of the Water Quality Monitoring Program and the change in sample sites to better cover the lake and to provide cove sites to match the tributary sites. In 1996 the sampling efficiencies are back up to the levels they were previously. The volunteers' sampling efficiency is as good as 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 the volunteer's dedication to the program.

Table 10. Comparison of sampling efficiencies for 1991-1996.

	Sampling Efficiencies					
	1991	**1992**	**1993**	**1994**	**1995**	**1996**
Secchi Disk Measurements	86%	90%	80%	93%	75%	92%
Total Phosphorus Samples	96%	93%	90%	99%	80%	96%
Chlorophyll-*a* Samples	95%	93%	90%	98%	80%	96%

9. CONCLUSIONS AND SUMMARY

1996 was the tenth year of the Smith Mountain Lake Water Quality Monitoring Program and it was a good year. It was the second year of Phase II and it seems that we all have adjusted to the changes in routine that came with the new phase. This is reflected especially in sampling efficiency that had dropped off last year (see Table 10). Monitoring results are also cause for optimism with the combined TSI as low as it has been since 1992. Compared to 1995, the average total phosphorus concentration is down 36%, average chlorophyll has decreased by 17%, while average Secchi depth remained constant. This is especially good news since 1996 was a wet year, although there was no spring flooding as there had been in 1993 and 1995. The average total phosphorus concentration in the tributary stations decreased by 41%. The decline in phosphorus was observed lake wide, with lower concentrations in both the Roanoke and Blackwater channels. Although we do not yet have data from a long enough period to correlate tributary concentrations to concentration in the lake, it would make sense that lower phosphorus concentrations in the tributaries would result in lower lake concentrations. At this point what we don't know is the time lag between changing concentrations of phosphorus in tributaries and resulting changes in lake water concentration. As in past years, the average Secchi depth has not followed the trends for average concentrations of total phosphorus and chlorophyll-*a*. A plausible explanation, also used in the past, is that turbidity in Smith Mountain Lake arises from two types of suspended particles, algae and clay. Secchi depth will correlate well with total phosphorus and chlorophyll-*a* only when algae are the primary cause of turbidity.

The Roanoke and Blackwater sections of the lake are surprisingly similar in terms of water quality. The overall averages for the three water quality parameters are nearly the same; the weekly averages follow similar patterns, as does the variability of water quality with distance from the dam. However, there is considerable variation in water quality with distance from the dam. The combined TSI, calculated by station, is highly correlated with distance from the dam (R^2=0.897) and varies from a low of 41.5 (oligotrophic) at a station near the dam to a high of 63.5 (hypereutrophic) at the Blackwater station farthest from the dam.

10. ACKNOWLEDGEMENTS

Jill Dorsch and Mary Turner were the student technicians this past summer and they did a terrific job. Their professionalism and conscientiousness and ability to work well together made for a summer of smooth sailing and everyone enjoyed their positive, friendly attitude. We would also like to acknowledge the support of Karl Lerz as President of the SMLA and offer special thanks to Bob Halstead for his hard work and the enthusiasm and leadership he brings to the program. The heart of any volunteer monitoring program is the volunteer and ours are not only dedicated but a lot of fun to work with. Finally we wish to thank the Smith Mountain Policy Advisory Board and Ferrum College for their support.

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APPENDIX

Table A1. 1996 Lake monitoring stations with monitor names and station locations.

Station	Monitor	Latitude	Longitude	Site Number
B10	Hartman	79.643	37.050	87
B12	Loos	79.666	37.043	45
B14	Jamison	79.676	37.035	85
B16	Jamison	79.704	37.040	50
B18	Shirey	79.720	37.035	52
B20	Shirey	79.728	37.033	53
B22	Franz	79.743	37.063	55
B8	Hartman	79.616	37.036	15
C4	Hill	79.572	37.056	8
C5	Hill	79.565	37.066	7
C6	Hill	79.568	37.082	6
CB11	Loos	79.654	37.040	41
CB16	Jamison	79.703	37.045	49
CB20	Franz	79.737	37.036	54
CM1	McKee	79.539	37.055	2
CM1.2	McKee	79.535	37.063	1
CM5	Bissinger	79.587	37.047	9
CR13	Kastner	79.642	37.099	28
CR14.2	Dooley	79.682	37.119	97
CR16	Ollweiler	79.663	37.145	57
CR17	Ollweiler	79.667	37.150	58
CR19	Hussa	79.692	37.159	64
CR21	Bray	79.706	37.150	68
CR21.2	Bray	79.708	37.148	69
CR22	Bogsrud	79.712	37.167	71
CR8	Bissinger	79.593	37.065	33
CR9	Daly	79.606	37.077	21
CR9.2	Daly	79.617	37.070	20
G 14	Wandelt/Dick	79.673	37.055	47
G12	Loos	79.666	37.047	43
G13	Hartman	79.674	37.049	84
G16	Wandelt/Dick	79.688	37.062	48
G18	Wandelt/Dick	79.682	37.072	59
M0	McKee	79.538	37.043	3
M1	Duffany	79.547	37.047	4
M3	Duffany	79.564	37.041	5
M5	Duffany	79.588	37.042	10
R11	Dooley	79.612	37.089	22
R13	Kastner	79.642	37.103	29
R14	Dooley	79.647	37.113	31
R15	Ollweiler	79.657	37.131	35
R17	Hussa	79.676	37.152	60
R19	Hussa	79.697	37.161	66

Table A1. 1996 Lake monitoring stations with monitor names and station locations. (cont.)

Station	Monitor	Latitude	Longitude	Site Number
R21	Bray	79.707	37.155	70
R23	Bogsrud	79.717	37.180	74
R31	Bay Rock	79.797	37.218	86
R7	Bissinger	79.595	37.052	12
R9	Daly	79.617	37.073	19
SB12	Thurman	79.664	37.040	42
SCB 10	Randa	79.639	37.023	40
SCB 11	Randa	79.632	37.017	24
SCB 11.5	Randa	79.644	37.062	13
SCB 8	Randa	79.599	37.026	38
SCB14	Thurman	79.683	37.031	51
SCB16	Thurman	79.693	37.034	46
SCM5	Ballengee	79.588	37.048	32
SCR 19	Anderson	79.690	37.164	65
SCR 25.5	Devlin	79.740	37.207	36
SCR10.1	Holasek	79.629	37.073	18
SCR10.2	Holasek	79.628	37.076	17
SCR10.3	Holasek	79.635	37.080	16
SCR11.1	Mueller	79.604	37.103	25
SCR11.2	Mueller	79.616	37.105	26
SCR11.3	Mueller	79.631	37.106	27
SCR14	Gerhardt	79.642	37.112	30
SCR14.1	Spahr	79.665	37.109	34
SCR14.2	Spahr	79.679	37.105	91
SCR14.3	Spahr	79.659	37.113	92
SCR15	Gerhardt	79.646	37.120	93
SCR15.1	Casey	79.656	37.120	39
SCR15.2	Casey	79.672	37.116	37
SCR17	Gerhardt	79.670	37.157	95
SCR17.1	Taylor	79.677	37.158	61
SCR18	Anderson	79.690	37.148	44
SCR20	Anderson	79.704	37.161	67
SCR22.2	Barr	79.705	37.170	72
SCR22.3	Walthers	79.707	37.171	73
SCR23	Barr	79.717	37.181	76
SCR23.2	Walthers	79.721	37.183	77
SCR23.3	Barr	79.725	37.183	14
SCR24	Walthers	79.724	37.197	78
SCR7	Ballengee	79.585	37.061	11
SCR8	Ballengee	79.588	37.068	23

Table A2. 1996 Tributary stations.

Tributary Station Number	Stream Name
T1	Maggodee Creek
T2	Gills Creek
T3	Blackwater River
T4	Poplar Camp Creek
T5	Standiford Creek
T6	Bull Run
T7	Cool Branch
T8	Branch at Lumpkin's Marina
T9	Below Dam – Former Station 105
T10	Pigg River – Former Station 104
T11	Leesville Lake – Former Station 103
T12	Creek at Summit Drive
T13	Creek at Snug Harbor
T14	Stoney Creek
T15	Jumping Run
T16	Beaverdam Creek
T17	Roanoke Channel at Bay Roc Marina
T18	Lynville Creek
T19	Grimes Creek
T20	Indian Creek

Table A3. 1996 Total phosphorus data for lake stations

station	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	avg	stdev
B08	27.3	22.6	20.5	39.6	20.4	20.0	15.1	0.0	4.6	10.9	28.7	13.9	18.6	10.8
B10	32.4	24.4	9.2	36.2	35.9	22.7	15.1	26.3	17.5	12.1	13.4	10.0	21.3	9.9
B12	27.3	24.7	39.4	35.8	42.3	36.7	25.3	28.0	12.4	5.7	13.0	24.4	26.3	11.4
B14	36.7		55.8	44.7	27.2	43.3	9.9	28.4	21.0	18.1	16.6	25.6	29.8	13.9
B16	24.7	34.3	36.2	32.0	18.4	28.6	19.6	27.2	14.8	15.3	67.4	26.4	28.7	14.1
B18		171.7	106.8	80.0	38.3	52.7	24.9	52.4	19.5	29.4	32.8	39.7	58.9	45.4
B20		63.5	87.6	60.7	53.9	102.1	34.2	42.7	35.1	43.0	22.0	49.1	54.0	23.7
B22	74.6		74.7	90.2	61.9	90.4	63.4	84.3	56.7	101.5	57.5	110.5	78.7	18.2
C04	13.8	22.2	11.9	17.7	13.2	6.0	7.4	7.8	9.7	8.5	7.1	19.3	12.1	5.3
C05	20.0	46.1	15.0	11.0	8.8	4.4	0.6	9.9	7.7	6.9	3.5	18.6	12.7	12.0
C06	13.5	21.9	18.2	12.7	8.0	13.4	16.4	9.1	8.1	7.7	5.8	30.3	13.7	7.1
CB11	32.7	38.6	35.4	27.4	30.4	38.7	24.5	18.8	8.9	15.7	15.2	135.6	35.2	33.1
CB16	44.4	31.5	96.2	30.3	22.0	26.2	24.1	26.3	15.9	11.7	21.1	28.0	31.5	22.0
CB20	38.9		49.9	49.7	17.2	55.4	26.5	56.6	39.0	35.8	28.3	48.7	40.6	12.8
CM1	12.4	14.0	16.6	10.5	0.0	5.6	7.0	18.3	11.6	12.1	104.7	23.7	19.7	27.5
CM1.2	12.7	15.5	7.6	14.8	7.2	2.9	7.4	14.6	8.1	85.9	11.6	22.5	17.6	22.1
CM5	32.4	32.9	22.5	17.7	7.6	6.0	10.3	59.1	8.9	15.3	2.2		19.5	16.6
CR08	40.7	25.8	13.1	16.0	12.4	7.9	3.4	14.1	5.8	13.7	0.0		13.9	11.3
CR09	21.8	24.0	12.3	14.3	7.2	29.3		21.3	10.8	12.1		24.0	17.7	7.3
CR09.2	26.9	30.1	55.4	19.0	18.8	18.1		13.3	14.0	6.5		39.3	24.1	14.4
CR13	27.6	27.6	21.7	16.9	20.0	29.3	24.9	13.7	8.9	33.0	8.9	39.7	22.7	9.5
CR14.2	21.5	34.7		21.5	24.0	13.8	14.7	22.5	12.0	7.7	18.8	29.1	20.0	7.8
CR16	33.1	5.5	53.5	31.6	37.9	31.3	3.8	33.5	18.7	15.7	9.8	45.6	26.7	15.9
CR17	36.0	8.3	26.4	55.6	42.3	42.2	50.8	52.8	53.1	40.6	35.0	52.2	41.3	13.7
CR19	56.7	51.4	42.5	54.4	47.9	49.6	32.6	57.0	18.7	43.4	25.1	43.6	43.6	12.3
CR21	37.1	54.6		57.3	41.1	40.6		62.1	23.4	24.1	29.2	60.8	43.0	14.9
CR21.2	48.7	79.2		52.2	57.1	41.8		57.0	33.9	49.0	43.6	61.6	52.4	12.5
CR22	39.6	36.1	51.5	61.1	30.8	30.5	26.5	37.3	21.4	25.7	19.3	38.5	34.9	12.1
G12	25.5	21.5	32.3	51.4	19.2	23.5	18.0	27.6	16.3	2.9	6.2	26.4	22.6	12.4
G13	19.6	45.0	16.2	28.7	16.0	22.7	20.0	33.9	11.6	10.9	4.9	23.7	21.1	10.9
G14	10.6	119.0	15.4	43.4	22.0	17.3	14.7	30.9		14.1	35.0	29.1	32.0	30.6
G16	15.3	7.3	53.1	30.3	20.8	37.9	19.2	30.5		13.3	21.5	40.9	26.4	13.6
G18	21.1	28.6	42.1	14.8	31.6	23.9	27.7	40.2		14.5	22.4	34.2	27.4	9.2
M0	12.4	76.3	15.8	15.6	12.8	14.2	5.4	24.6	12.8	11.3	0.0	31.9	19.4	19.7
M1	16.4	7.6	22.5	28.7	14.0	10.7	15.6	25.9	9.7	12.5	22.9	23.7	17.5	7.0
M3	21.8	29.7	15.4	40.0	7.6	13.0	1.8	22.5	8.9	4.9	24.2	26.8	18.1	11.4
M5	32.0	32.9	16.6	30.3	18.8	30.9	9.5	29.7	8.5	29.8	10.3	46.0	24.6	11.7
R07	34.6	35.4	18.2	15.6	8.8	39.8	5.0	16.2	26.5	20.1	2.2		20.2	12.6
R09	85.1	44.3	13.1	16.0	26.4	58.9		20.4	12.0	6.5		30.3	31.3	24.8
R11	19.6	28.6		19.0	33.2	56.6	13.1	15.4	15.9	0.0	13.4	0.0	19.5	15.8
R13	37.5	35.4	29.2	19.0	49.5	16.9	9.1	25.5	5.4	9.3	13.4	27.6	23.1	13.4
R14	18.2	26.9		24.9	19.6	14.2	9.1	18.3	41.0	5.7	0.0	32.7	19.1	11.9
R15	18.2	9.8	44.1	39.2	35.2	28.2	16.4	40.6	15.9	14.5	1.3	26.8	24.2	13.6
R17	41.8	34.7	33.9	75.4	31.2	30.9	54.1	41.5	20.2	16.5	14.3	31.9	35.5	16.8
R19	106.6	52.8	155.4	39.6	57.1	53.8	41.1	63.7	39.0	41.0	50.8	81.2	65.2	34.6
R21	34.2	69.9		50.1	42.7	27.8		2.4	16.3	15.3	18.4	31.9	30.9	19.7
R23	29.8	27.9	59.4	48.9	39.5	35.2	24.5	42.3	90.7	16.5	9.8	16.2	36.7	22.2
R31	55.3	28.3	35.8	48.0	45.1	33.2	39.9	51.1	76.2	168.1	53.0	81.2	59.6	37.7
avg	32.4	37.8	38.1	35.2	27.2	30.8	19.8	31.2	21.1	23.6	21.4	37.8		
std dev	19.1	29.5	30.3	19.3	15.6	20.4	14.3	18.2	18.3	28.8	20.4	24.7		
											grand	mean	**29.7**	
												stdev	**22.9**	

Table A4. 1996 Total phosphorus data for tributaries.

station	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12		avg	std dev
T01	71.6	76.7	65.2	85.9	61.5	57.7	192.4	41.5	75.1	60.6	52.6	82.7		77.0	38.5
T02		61.4	65.2	96.1	72.2	114.9	65.8	81.4	78.6	104.3	135.8	105.1		89.2	23.9
T03	60.4	116.5	55.0	99.8	50.3	47.6	136.4	113.8	94.6	86.7	172.7	73.0		92.2	38.2
T04	56.4	20.8	18.6	34.1	30.0	23.9	33.4	94.8	24.9	88.3	141.2	38.1		50.4	38.2
T05	20.4	124.7	26.8	57.3	43.5	36.7	68.7	47.3	34.7	28.1	31.4	65.9		48.8	28.5
T06	29.1	45.0	97.0	91.0	54.7	47.2	52.9	104.5	57.8	39.8	110.1	66.3		66.3	27.3
T07	9.5	22.2	1.3	68.7	10.0	13.8	28.9	168.4	18.3	62.6	199.2	46.7		54.1	64.5
T08	16.4	55.7	23.7	29.5	44.3	27.0	36.6	29.3	19.1	95.1	30.1	52.2		38.2	21.7
T09	6.9	23.7	16.6	22.8	43.9	24.3	192.8	43.1	11.2	22.1	1.3	50.7		38.3	50.9
T10	21.8	85.6	14.3	47.6	29.2	39.4	50.4	33.5	51.6	23.3	123.2	60.0		48.3	30.6
T11	27.6	71.7	31.1	37.9	22.0	37.1	9.1	39.8	33.2	93.5	76.4	98.4		48.1	29.2
T12	16.4	53.9	28.8	36.2	30.0	74.8	64.6	25.9	15.5	25.7	62.9	39.3		39.5	19.9
T13	13.5	37.5	31.1	31.6	25.6	26.2	23.7	91.1	126.4	18.5	43.6	38.9		42.3	33.0
T14	57.8	48.9	34.3	64.9	88.2	62.4	76.0	94.4	109.5	13.3	98.9	93.3		70.2	28.7
T15	105.5	51.4	32.3	67.0	77.8	93.1	88.5	78.0	59.4	152.4	140.3	73.4		84.9	34.7
T16	165.5	60.7	37.4	106.2	75.0	68.2	198.8	78.9	44.1	58.2	172.2	90.2		96.3	53.6
T17	55.3	28.3	35.8	48.0	45.1	33.2	39.9	51.1	76.2	168.1	53.0	81.2		59.6	37.7
T18	129.8	78.5	18.6	43.0	35.2	20.4	72.7	198.7	40.6	55.0	133.5	57.7		73.6	54.3
T19	40.0	40.0	58.6	42.1	167.5	100.5	51.2	94.0	76.2	40.2	75.1	69.8		71.3	36.9
T20	72.0	109.1	28.0	23.6	137.2	172.1	72.7	151.6	87.6	68.2	101.1	73.0		91.4	45.6
TG20	28.7	26.1	76.2	51.8	33.2	65.5	73.1	68.4	54.3	59.4	70.6	62.8		55.8	17.6
avg	50.2	59.0	37.9	56.4	56.0	56.5	77.6	82.4	56.6	64.9	96.4	67.6			
std dev	42.4	30.8	23.4	26.2	38.1	38.4	55.8	46.7	32.2	42.0	53.3	19.6			
											grand	mean		**63.5**	
												std dev		**41.0**	

Table A5. 1996 Chlorophyll-*a* data for Smith Mountain Lake.

station	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12	avg	stdev
B08	23.8	3.8	14.4	22.5	0.0	13.8	10.0	2.5	1.3	19.4	17.5	3.8	11.0	8.6
B10	33.8	6.3	20.6	28.8	0.0	13.1	7.5	10.6	19.4	21.9	5.6	3.8	14.3	10.6
B12	33.1	8.8	53.1	12.5	6.9	8.8	26.3	13.1	9.4	19.4	3.1	6.3	16.7	14.4
B14	46.9	15.0	7.5	20.0	44.4	31.9	30.6	7.5	25.0	32.5	17.5	3.1	23.5	14.3
B16	27.5	11.9	6.9	6.9	60.0	32.5	33.8	21.9	12.5	6.3	9.4	9.4	19.9	16.2
B18		10.6	24.4	1.3	50.6	15.0	61.3	6.9	59.4	6.9	5.6	10.0	22.9	22.9
B20		42.5	23.1	3.1	52.5	13.1	12.5	15.0	33.1	57.5	17.5	18.8	26.3	17.7
B22	61.3		21.9	6.3	50.0	6.3	11.9	56.3	54.4	43.1	10.0	13.8	30.5	22.4
C04	28.1	2.5	6.3	13.1	6.9	8.8	20.0	5.0	13.1	11.3	10.0	2.5	10.6	7.4
C05	26.3	16.3	25.0	16.3	5.0	7.5	14.4	3.1	18.8	71.9	9.4	2.5	18.0	18.7
C06	18.1	12.5	16.3	13.8	16.3	2.5	10.0	12.5	6.3	7.5	4.4	4.4	10.4	5.3
CB11	7.5	7.5	25.0	33.1	16.9	18.1	5.0	6.3	4.4	25.6	2.5	6.3	13.2	10.2
CB16	42.5	11.9	15.0	21.9	26.3	28.1	18.1	21.9	27.5	16.9	7.5	6.3	20.3	10.1
CB20	36.9		7.5	37.5	37.5	29.4	16.9	31.3	28.1	9.4	2.5	10.0	22.4	13.4
CM1	4.4		23.1	25.6	4.4	3.1	3.1	14.4	4.4	10.6	1.9	1.3	8.8	8.7
CM1.2	3.8		13.1	10.0	1.3	7.5	0.6	11.3	3.8	8.8	3.8	1.3	5.9	4.4
CM5	16.3	11.9	9.4	54.4	2.5	3.8	1.9	1.3	1.3	4.4	0.6		9.8	15.6
CR08	17.5	8.1	13.1	23.1	4.4	3.1	0.6	10.0	4.4	15.6	3.1		9.4	7.2
CR09		13.8	15.0	14.4	13.1	3.1		15.0	9.4	20.0		3.8	11.9	5.5
CR09.2		9.4	20.6	10.6	13.8	3.1		16.3	13.8	12.5		5.0	11.7	5.4
CR13	1.9	6.9	11.9	23.1	24.4	3.8	4.4	15.6	36.3	20.6	7.5	1.9	13.2	10.9
CR14.2	44.4	21.3	0.0	1.3	0.0	28.1	11.3	7.5	7.5	5.6	6.3	43.8	14.7	16.0
CR16	31.3	21.9	0.0	41.9	57.5	25.0	15.0	33.1	53.1	21.9	7.5	3.1	25.9	18.5
CR17	18.8	6.3	27.5	2.5	2.5	25.0	19.4	30.6	38.1	31.9	17.5	6.9	18.9	12.2
CR19	25.0	20.6	25.0	37.5	0.0	26.9	10.6	29.4	31.9	26.9	5.6	7.5	20.6	11.8
CR21	28.8	50.0	18.8	25.0	37.5	41.9	41.9	10.6	37.5	30.6	18.1	3.8	28.7	13.9
CR21.2	55.6	50.6	51.9	1.3	61.3	10.0	24.4	30.0	38.1	50.6	17.5	4.4	33.0	21.3
CR22	1.9	41.3	41.9	22.5	4.4	28.1	11.9	56.9	38.8	35.0	18.8	19.4	26.7	16.6
G12	41.3	3.8	0.0	21.9	23.1	11.9	15.6	15.6	25.0	13.1	10.0	9.4	15.9	10.9
G13	33.1	15.0	21.9	40.6	0.0	15.0	26.9	10.0	32.5	29.4	15.0	7.5	20.6	12.1
G14	4.4	37.5	20.0	23.1	20.0	3.1	4.4	11.3	0.0	15.0	13.8	5.6	13.2	10.8
G16	32.5	26.3	22.5	14.4	11.9	37.5	3.1	4.4	0.0	25.6	13.1	5.6	16.4	12.3
G18	34.4	12.5	13.8	48.1	13.1	34.4	8.8	33.1	0.0	10.6	7.5	3.8	18.3	15.1
M0	3.1		11.9	1.9	2.5	0.6	1.3	6.9	0.6	1.9	1.3	1.9	3.1	3.4
M1	4.4	1.9	1.9	2.5	0.6	0.6	0.6	0.6	0.0	1.3	0.6	1.3	1.4	1.2
M3	9.4	1.3	1.3	1.3	1.3	0.0	1.3	3.1	0.6	3.1	0.6	10.0	2.8	3.4
M5	4.4	1.3	1.9	14.4	0.6	0.0	3.1	9.4	0.0	0.6	0.0	0.6	3.0	4.5
R07		6.3	9.4	18.8	3.1	1.9	3.1	1.3	2.5	8.8	1.3		5.6	5.5
R09			17.5	16.9	3.1	2.5		8.1	5.0	21.3		6.3	10.1	7.3
R11	49.4	25.0	0.0	6.9	0.0	4.4	3.8	11.9	5.0	7.5	1.9	3.1	9.9	14.2
R13	53.1	8.1	23.8	14.4	11.3	11.9	8.1	13.1	31.9	12.5	15.6	8.1	17.7	13.2
R14	27.5	23.8	0.0	38.8	0.0	13.1	15.6	22.5	37.5	2.5	8.1	5.6	16.3	13.8
R15	18.8	9.4	25.0	21.3	41.9	29.4	13.1	20.0	31.9	16.9	10.0	1.9	19.9	11.0
R17	35.0	5.6	0.0	20.6	0.0	21.9	13.1	15.0	48.1	18.8	11.3	2.5	16.0	14.4
R19	29.4	21.3	25.0	68.8	0.0	16.9	36.3	14.4	30.6	26.9	10.6	4.4	23.7	17.9
R21	36.9	42.5	6.9	6.9	23.1	21.3	35.6	13.1	20.0	33.1	3.8	4.4	20.6	13.9
R23	50.6	51.3	50.0	3.8	46.3	38.8	53.1	48.8	19.4	28.8	17.5	17.5	35.5	17.2
TG20	10.6	11.3	6.3	12.5	1.9	4.4	0.6	2.5	1.3	0.6	3.1	0.6	4.6	4.5
avg	26.5	17.0	16.6	19.3	16.7	14.8	14.9	15.8	19.2	19.2	8.3	6.7		
stdev	16.5	14.4	13.2	15.1	19.6	12.2	14.2	13.3	17.1	15.1	5.9	7.2		
											grand	**mean**	**16.3**	
												stdev	**14.8**	

Table A5a. 1996 Chlorophyll-*a* Data for Smith Mountain Lake (Corrected values).

Station	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12	Sta Avg	Stdev
B08	3.6	0.6	2.2	3.4		2.1	1.5	0.4	0.2	2.9	2.6	0.6	1.8	1.2
B10	5.1	0.9	3.1	4.3		2.0	1.1	1.6	2.9	3.3	0.8	0.6	2.3	1.5
B12	5.0	1.3	8.0	1.9	1.0	1.3	3.9	2.0	1.4	2.9	0.5	0.9	2.5	2.2
B14	7.0	2.3	1.1	3.0	6.7	4.8	4.6	1.1	3.8	4.9	2.6	0.5	3.5	2.1
B16	4.1	1.8	1.0	1.0	9.0	4.9	5.1	3.3	1.9	0.9	1.4	1.4	3.0	2.4
B18		1.6	3.7	0.2	7.6	2.3	9.2	1.0	8.9	1.0	0.8	1.5	3.4	3.4
B20		6.4	3.5	0.5	7.9	2.0	1.9	2.3	5.0	8.6	2.6	2.8	3.9	2.7
B22	9.2		3.3	0.9	7.5	0.9	1.8	8.4	8.2	6.5	1.5	2.1	4.6	3.4
C04	4.2	0.4	0.9	2.0	1.0	1.3	3.0	0.8	2.0	1.7	1.5	0.4	1.6	1.1
C05	3.9	2.4	3.8	2.4	0.8	1.1	2.2	0.5	2.8	10.8	1.4	0.4	2.7	2.8
C06	2.7	1.9	2.4	2.1	2.4	0.4	1.5	1.9	0.9	1.1	0.7	0.7	1.6	0.8
CB11	1.1	1.1	3.8	5.0	2.5	2.7	0.8	0.9	0.7	3.8	0.4	0.9	2.0	1.5
CB16	6.4	1.8	2.3	3.3	3.9	4.2	2.7	3.3	4.1	2.5	1.1	0.9	3.0	1.5
CB20	5.5		1.1	5.6	5.6	4.4	2.5	4.7	4.2	1.4	0.4	1.5	3.4	2.0
CM1	0.7		3.5	3.8	0.7	0.5	0.5	2.2	0.7	1.6	0.3	0.2	1.3	1.3
CM1.2	0.6		2.0	1.5	0.2	1.1	0.1	1.7	0.6	1.3	0.6	0.2	0.9	0.7
CM5	2.4	1.8	1.4	8.2	0.4	0.6	0.3	0.2	0.2	0.7	0.1		1.5	2.3
CR08	2.6	1.2	2.0	3.5	0.7	0.5	0.1	1.5	0.7	2.3	0.5		1.4	1.1
CR09		2.1	2.3	2.2	2.0	0.5		2.3	1.4	3.0		0.6	1.8	0.8
CR09.2		1.4	3.1	1.6	2.1	0.5		2.4	2.1	1.9		0.8	1.8	0.8
CR13	0.3	1.0	1.8	3.5	3.7	0.6	0.7	2.3	5.4	3.1	1.1	0.3	2.0	1.6
CR14.2	6.7	3.2		0.2		4.2	1.7	1.1	1.1	0.8	0.9	6.6	2.7	2.4
CR16	4.7	3.3		6.3	8.6	3.8	2.3	5.0	8.0	3.3	1.1	0.5	4.2	2.6
CR17	2.8	0.9	4.1	0.4	0.4	3.8	2.9	4.6	5.7	4.8	2.6	1.0	2.8	1.8
CR19	3.8	3.1	3.8	5.6	0.0	4.0	1.6	4.4	4.8	4.0	0.8	1.1	3.1	1.8
CR21	4.3	7.5	2.8	3.8	5.6	6.3	6.3	1.6	5.6	4.6	2.7	0.6	4.3	2.1
CR21.2	8.3	7.6	7.8	0.2	9.2	1.5	3.7	4.5	5.7	7.6	2.6	0.7	4.9	3.2
CR22	0.3	6.2	6.3	3.4	0.7	4.2	1.8	8.5	5.8	5.3	2.8	2.9	4.0	2.5
G12	6.2	0.6		3.3	3.5	1.8	2.3	2.3	3.8	2.0	1.5	1.4	2.6	1.5
G13	5.0	2.3	3.3	6.1		2.3	4.0	1.5	4.9	4.4	2.3	1.1	3.4	1.6
G14	0.7	5.6	3.0	3.5	3.0	0.5	0.7	1.7		2.3	2.1	0.8	2.2	1.6
G16	4.9	3.9	3.4	2.2	1.8	5.6	0.5	0.7		3.8	2.0	0.8	2.7	1.8
G18	5.2	1.9	2.1	7.2	2.0	5.2	1.3	5.0		1.6	1.1	0.6	3.0	2.2
M0	0.5		1.8	0.3	0.4	0.1	0.2	1.0	0.1	0.3	0.2	0.3	0.5	0.5
M1	0.7	0.3	0.3	0.4	0.1	0.1	0.1	0.1		0.2	0.1	0.2	0.2	0.2
M3	1.4	0.2	0.2	0.2	0.2		0.2	0.5	0.1	0.5	0.1	1.5	0.5	0.5
M5	0.7	0.2	0.3	2.2	0.1		0.5	1.4		0.1		0.1	0.6	0.7
R07		0.9	1.4	2.8	0.5	0.3	0.5	0.2	0.4	1.3	0.2		0.8	0.8
R09			2.6	2.5	0.5	0.4		1.2	0.8	3.2	0.0	0.9	1.3	1.1
R11	7.4	3.8		1.0		0.7	0.6	1.8	0.8	1.1	0.3	0.5	1.8	2.2
R13	8.0	1.2	3.6	2.2	1.7	1.8	1.2	2.0	4.8	1.9	2.3	1.2	2.6	2.0
R14	4.1	3.6		5.8		2.0	2.3	3.4	5.6	0.4	1.2	0.8	2.9	1.9
R15	2.8	1.4	3.8	3.2	6.3	4.4	2.0	3.0	4.8	2.5	1.5	0.3	3.0	1.7
R17	5.3	0.8		3.1		3.3	2.0	2.3	7.2	2.8	1.7	0.4	2.9	2.0
R19	4.4	3.2	3.8	10.3		2.5	5.4	2.2	4.6	4.0	1.6	0.7	3.9	2.6
R21	5.5	6.4	1.0	1.0	3.5	3.2	5.3	2.0	3.0	5.0	0.6	0.7	3.1	2.1
R23	7.6	7.7	7.5	0.6	6.9	5.8	8.0	7.3	2.9	4.3	2.6	2.6	5.3	2.6
Per Avg	4.0	2.6	2.9	2.9	3.1	2.4	2.3	2.4	3.3	2.9	1.3	1.0	**Gr Avg**	**2.6**
Stdev	2.5	2.2	1.9	2.3	3.0	1.8	2.1	2.0	2.5	2.2	0.9	1.1	**Stdev**	**2.2**

Table A6. 1996 Secchi depth data for Smith Mountain Lake.

Station	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12	avg	std dev
B08	2.00	2.00	2.50	3.00	3.50	2.50	2.00	2.00	3.00	3.00	3.00	2.00	2.54	0.54
B10	2.00	2.00	2.50	3.00	3.00	2.00	2.00	1.50	2.75	3.00	3.00	2.00	2.40	0.54
B12	2.00	2.00	2.00	1.75	2.00	1.50	1.50	1.75	2.00	2.25	2.00	2.00	1.90	0.23
B14	2.00		2.50	2.25	2.00	2.00	1.50	2.00	2.00	2.25	2.25	1.75	2.05	0.27
B16	1.50	2.00	1.50	2.00	1.50	1.50	1.50	1.50	1.50	1.75	2.00	1.50	1.65	0.23
B18			0.75	2.00	1.50	1.75	1.50	1.75	1.75	1.50	2.00	1.50	1.60	0.36
B20			0.25	1.25	1.50	1.50	1.50	1.50	1.50	1.25	1.75	1.75	1.38	0.43
B22	1.25		0.75	0.75	1.25	1.00	1.50	1.00	1.00	1.25		1.25	1.10	0.24
C04	2.50	2.75	2.75	3.25	4.25	4.25	3.25	3.50	4.00	3.50	3.75	3.25	3.42	0.58
C05	2.50	2.50	2.50	3.00	4.00	4.25	3.00	3.75	3.50	3.50	3.75	3.00	3.27	0.61
C06	2.50	2.50	1.75	3.00	3.50	4.00	2.50	3.25	3.00	3.00	3.25	3.00	2.94	0.58
CB11	2.00	2.00	2.00	2.50	2.25	1.50	1.75	2.00	2.50	2.75	2.50	2.00	2.15	0.36
CB16	2.00	2.25	2.00	2.00	2.00	2.00	1.50	2.00	2.00	2.00	2.00	1.50	1.94	0.22
CB20	1.50		1.00	1.25	1.50	1.25	1.75	1.50	1.25	1.50		1.50	1.40	0.21
CM1		2.50	2.75	3.50	3.50			3.50	3.50	3.00	3.50	3.25	3.22	0.38
CM1.2		2.50	2.75	3.00	3.50	3.00	3.25	3.50	3.50	3.25	3.50	3.25	3.18	0.34
CM5	1.75	1.75	2.00	3.00	3.00	2.75	2.50	2.75	2.25	2.50	2.50		2.43	0.45
CR08	1.25	1.50	2.00	2.75	2.75	3.00	2.25	2.50	2.50	2.25	2.25		2.27	0.53
CR09	1.50	2.00	2.00	2.50	2.75	3.00		2.25	2.50	2.50		2.00	2.30	0.44
CR09.2	2.00	1.75	2.50	3.00	2.50	2.50		2.25	2.25	2.50		2.00	2.33	0.35
CR13	1.50	1.75	2.00	2.25	2.00	1.50	1.75	1.75	2.00	2.00	2.00		1.86	0.23
CR14.2	1.00		1.25		2.00	2.00	1.50	1.25	1.50	1.50	1.25	0.75	1.40	0.39
CR16	1.25	1.50	1.25	1.75	1.75	1.25	1.25	1.25	1.50	1.75	1.75	2.75	1.58	0.43
CR17	1.25	1.50	1.25	1.50	1.75	1.25	1.25	1.25	1.50	1.75	1.75	3.00	1.58	0.49
CR19	1.25	1.25	1.25	1.25	1.25	1.25	1.50	1.50	1.50	1.50	1.50	2.00	1.42	0.22
CR21	1.25	1.25		1.50	1.75	1.50	1.50		1.50	1.75	2.00	3.25	1.73	0.58
CR21.2	1.25	1.25		1.50	1.50	1.50	1.50		1.50	1.50	1.75	3.00	1.63	0.50
CR22	1.75	1.50	1.00	1.50	1.25	1.00	1.00	1.00	1.50	1.75	2.00	1.75	1.42	0.36
G12	1.75	2.00	2.00	1.75	2.00	1.50	1.75	2.00	2.50	2.50	2.00	1.50	1.94	0.32
G13	2.00	2.00	2.00	2.25	2.00	1.50	1.50	1.50	2.00	2.50			1.93	0.33
G14	1.75	2.25	1.75	2.25	1.75	1.50	1.50	2.00		1.75	2.50	2.25	1.93	0.34
G16	1.75	2.50	1.75	2.25	1.50	1.50	1.50	1.75		2.25	2.50	1.75	1.91	0.39
G18	1.75	2.00	1.50	2.00	1.25	1.50	1.75	1.75		2.50	2.75	1.50	1.84	0.45
M0		2.50	2.50	4.00	3.00	2.50	3.00	3.50	3.50	3.25	3.00	3.00	3.07	0.48
M1	2.25	2.50	2.50	3.00	3.50	3.50	2.75	3.25	3.25	3.25	3.25	3.25	3.02	0.42
M3	2.25	2.25	2.50	3.25	3.50	3.50	3.00	3.25	3.25	3.25	3.50	3.25	3.06	0.47
M5	2.00	2.25	2.50	3.25	3.50	3.25	3.00	3.25	3.25	3.25	3.25	3.25	3.00	0.48
R07	1.75	1.75	2.00	2.75	3.00	3.00	2.50	2.75	2.25	2.25	2.50		2.41	0.45
R09	1.50	1.75	2.25	2.00	3.00	3.00		2.25	2.00	2.75	1.75	2.00	2.20	0.51
R11	1.50	1.75	2.00		2.50	2.50	2.25	2.00	2.00	2.25		2.00	2.08	0.31
R13	1.50	1.75	1.75	2.00	2.25	1.75	1.75	1.75	2.00	2.00	2.00		1.86	0.21
R14	1.25	1.75	1.75		2.00	2.50	1.75	1.50	2.00	2.00	1.50	2.00	1.82	0.34
R15	1.25	1.50	1.50	1.75	1.75	1.25	1.50	1.50	1.50	2.00	1.75	3.25	1.71	0.53
R17	1.25	1.50	1.25	1.25	1.25	1.25	1.50	1.50	1.50	1.75	1.75	2.50	1.52	0.36
R19	1.50	1.50	1.25	1.50	1.25	1.25	1.50	1.50	1.50	1.75	1.50	2.00	1.50	0.21
R21	1.50	1.50		1.50	1.50	1.50	1.50		1.50	2.00	2.00	3.00	1.75	0.49
R23	1.75	1.75	1.00	1.50	1.25	1.25	1.00	1.25	1.50	1.75	2.00	1.50	1.46	0.32

Table A6. 1996 Secchi depth data for Smith Mountain Lake. (cont.)

SB 12	1.75	1.75	2.00	2.00	1.75	1.75	1.25	1.75	2.00	1.75	2.00	1.75	1.79	0.21
SCB 10	1.50	2.00	2.00	2.50	2.75	2.00	2.25	2.25	2.75	2.50	2.25	2.00	2.23	0.36
SCB 11	1.50	2.00	2.00	2.50	2.50	1.75	2.00	2.25	2.50	2.50	2.50	2.00	2.17	0.34
SCB 11.5	1.75	1.75	2.00	2.50	2.00	1.75	1.75	2.00	2.50	2.00	2.25	2.00	2.02	0.27
SCB 14	1.50	1.75	1.75	2.00	1.75	1.75	1.00	1.50	1.75	1.50	1.50	1.50	1.60	0.25
SCB 16	1.50	1.75	1.50	2.00	2.00	1.75	1.50	1.25	1.50	1.75	1.50	1.25	1.60	0.25
SCB 8	1.75	8.00	2.00	2.75	2.50	2.25	2.25	2.25	2.75	2.50	3.00	2.50	2.88	1.65
SCR 10.1	1.25	1.75	2.00	2.25	2.50	2.25	2.00	2.00	2.25	2.00	2.00	1.75	2.00	0.32
SCR 10.2	1.25	1.75	2.00	2.25	0.25	2.50	2.00	2.50	2.00	2.00	2.25	2.00	1.90	0.62
SCR 10.3	1.25	1.75	2.00	2.25	2.25	2.50	2.00	2.00	2.25	2.00	2.00	1.75	2.00	0.32
SCR 11.1	1.50	1.75		2.75	2.25	3.25	0.25	2.25	2.50		2.00	2.00	2.05	0.81
SCR 11.2	1.75	1.75		2.75	2.75	3.25		2.50	2.25		2.00	2.00	2.33	0.52
SCR 11.3	1.50	1.50		2.50	2.25	2.75		2.25	2.50		2.00	2.25	2.17	0.43
SCR 14	1.50	2.00	2.00	2.00	2.00	1.75	1.75	1.75	1.75	2.00	2.00	4.00	2.04	0.64
SCR 14.1	1.00	1.75	1.50	2.00	2.25	1.75	1.75	1.50	1.50	1.50	1.50	1.25	1.60	0.33
SCR 14.2	1.00	1.25	1.00	1.50	2.00	1.25	1.50	1.25	1.00	1.25	1.25	1.00	1.27	0.29
SCR 14.3	1.00	1.75	1.75	2.00	2.25	1.75	1.50	1.50	1.50	1.50	1.75	2.00	1.69	0.32
SCR 15	1.50	2.00	2.00	2.00	2.00	1.75	1.75	1.50	1.75	2.00	2.00	4.00	2.02	0.65
SCR 15.1		1.75	2.00	2.25	2.25	2.50	1.75	1.75	2.00	2.00	2.00	3.75	2.18	0.57
SCR 15.2		1.50	1.50	2.00	1.75	2.25	1.50	1.50	1.50	1.50	1.50	2.50	1.73	0.36
SCR 17	1.50	1.25	1.25	1.75	1.75	1.75	1.50	1.75	1.50	1.75	2.00	3.50	1.77	0.59
SCR 18	1.25	1.25	1.50	1.75	1.50	1.25	1.25	1.50	1.50	1.50	1.75	2.25	1.52	0.29
SCR 19.2	1.50	1.25	1.50	1.50	1.50	1.25	1.25	1.25	1.50	1.50	1.75	1.75	1.46	0.18
SCR 20	1.75	1.25	1.50	1.50	1.50	1.25	1.00	1.50		1.75	1.75	1.75	1.50	0.25
SCR 22.2	2.00	1.50	1.00		1.50	1.75	1.75	1.25	1.50	1.75	1.75	1.25	1.55	0.29
SCR 22.3	1.75		1.25	1.75						1.75	2.00	1.50	1.67	0.26
SCR 23	2.00	2.00	1.00	0.75	1.50	1.75	1.50	1.00	1.25	2.25	1.75	1.50	1.52	0.46
SCR 23.2	2.00		1.25	2.00		1.50				1.75	1.75	1.25	1.64	0.32
SCR 23.3	1.50	2.00	1.00	0.75	1.50		1.25	1.00	2.25	2.25	1.00	1.50	1.45	0.52
SCR 24	1.75		1.25	1.75						1.75	1.75	1.50	1.63	0.21
AVG	1.63	1.92	1.75	2.14	2.16	2.04	1.77	1.95	2.09	2.13	2.15	2.17		
STD DEV	0.36	0.83	0.55	0.67	0.77	0.79	0.58	0.70	0.68	0.58	0.62	0.76		
										grand	mean	**1.99**		
											st dev	**0.69**		

Table A7. 1996 Bacterial (F. coliform) data for Smith Mountain Lake.

			May 20		July 8		August 14	
Site	**Site**	**Replicate**	**Count**	**SD**	**Count**	**SD**	**Count**	**SD**
Palmer's	11	111	25	2.00	23	2.00	4	1.50
	11	112	21		27		4	
	11	113	21		27		0	
	12	121	24	1.25	0	1.25	0	1.75
	12	122	18		0		16	
	12	123	26		0		24	
	13	131	8	2.00	7	1.75	42	2.00
	13	132	2		11		53	
	13	133	4		10		33	
Pelican Point	21	211	8	2.50	4	2.00	12	2.50
	21	212	2		3		7	
	21	213	4		3		7	
	22	221	2	2.75	3	2.25	7	3.00
	22	222	2		1		1	
	22	223	2		0		3	
	23	231	1	2.25	0	2.25	4	3.00
	23	232	1		0		1	
	23	233	2		1		1	
SML Dock	31	311	0	2.50	20	2.00	13	1.50
	31	312	2		14		40	
	31	313	2		14		33	
	32	321	1	2.50	7	2.25	40	1.50
	32	322	0		3		43	
	32	323	0		2		32	
	33	331	3	2.50	21	2.25	20	1.50
	33	332	2		26		41	
	33	333	4		23		60	
Confluence	41	411	2	2.00	1	2.00	1	2.50
	41	412	2		1		2	
	41	413	0		0		2	
	42	421	0	2.25	0	2.00	7	2.75
	42	422	1		1		7	
	42	423	2		0		8	
	43	431	1	2.50	0	2.50	2	2.25
	43	432	0		0		3	
	43	433	1		0		3	

Table A7. 1996 Bacterial (F. coliform) data for Smith Mountain Lake. (cont.)

			May 20		July 8		August 14	
Site	Site	Replicate	Count	SD	Count	SD	Count	SD
Forest Cove	51	511	0	2.00	0	3.00	3	2.50
	51	512	0		0		3	
	51	513	0		0		2	
	52	521	0	2.25	0	2.75	0	2.75
	52	522	0		0		4	
	52	523	0		0		2	
	53	531	0	2.50	0	2.75	6	2.75
	53	532	0		0		0	
	53	533	0		1		1	
Fairway Bay	61	611	1	1.25	0	1.75	0	2.00
	61	612	0		0		0	
	61	613	2		0		0	
	62	621	4	1.25	1	2.00	0	2.00
	62	622	1		1		0	
	62	623	0		3		0	
	63	631	1	1.25	1	2.00	0	2.00
	63	632	2		3		0	
	63	633	1		11		0	
Shoreline Marina	71	711	68	1.00	19	1.50	47	1.00
	71	712	56		5		40	
	71	713	63		13		60	
	72	721	4	1.00	9	1.25	66	1.00
	72	722	3		12		33	
	72	723	11		3		62	
	73	731	10	1.00	13	1.50	67	1.00
	73	732	2		12		40	
	73	733	6		12		52	
SML Yacht Club	81	811	3	1.00	25	1.25	31	1.00
	81	812	2		45		30	
	81	813	5		33		32	
	82	821	0	1.00	42	1.50	23	1.25
	82	822	0		5		27	
	82	823	0		5		30	
	83	831	1	1.00	10	1.75	20	1.25
	83	832	1		0		27	
	83	833	1		0		9	