Smith Mountain Lake

Water Quality Monitoring Program

1999 Report

SMLA

Ferrum College

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Life Sciences Division

Ferrum College

Sponsored by

The Smith Mountain Lake Association

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1. EXECUTIVE SUMMARY

The Smith Mountain Lake Volunteer Water Quality Monitoring Program (SMLVWQMP) is a water quality data collection 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. In May 1999 Ferrum College and the SMLA conducted an organizing and training session. Monitors collected samples every other week from the first week of June through the third week of August in 1999.

The parameters measured each year to evaluate the trophic status of Smith Mountain Lake indicate a lower water quality in 1999 when compared to 1998 and/or 1997. The parameters monitored are those used to monitor trophic status and include total phosphorus, nitrate, chlorophyll-*a*, and Secchi depth. Total phosphorus and nitrate are plant nutrients that stimulate the growth of algae. Phosphate is the form of phosphorus most immediately available to algae and is the limiting nutrient in Smith Mountain Lake. Chlorophyll-*a* is extracted from algae and is a measure of the algal population. Secchi depth is a measure of water clarity that decreases as algal populations and siltation increase. This year the average total phosphorus concentration was 28.9 ppb, which is higher than the 1998 total phosphorus average. The average nitrate concentration was 296 ppb, and 1999 is the third year for nitrate measurement in the lake for our program and is higher than in 1998 and 1997. The average chlorophyll-*a* concentration was 3.9 ppb, which is slightly higher than reported recently in these annual reports. The average Secchi depth reading was 2.2 m, again somewhat lower than the 1998 value. In order to better understand the dynamics of the lake, the sample sites on the lake were grouped by zones based on their miles in 5 mile increments to the dam on Smith Mountain Lake as was done in 1997; Zone 1 being the closest to the dam (1-5 mi) and Zone 6 being the farthest away from the dam (25+mi). In all zones and for all three parameters (TP, CHA, & SD) measured for all thirteen years (1987-1999), no significant trend, either lower or higher water quality was noted. The significant trend in all parameters (TP, NO3, CHA, & SD) that was noted again this year, as in previous years, was decreasing water quality with distance from the dam

Tributaries (22) around Smith Mountain Lake were sampled again this year by Ferrum College personnel and analyzed for total phosphorus. The average total phosphorus concentration for all tributaries was 61.8 ppb (which is higher than the 1998 average) and was most likely affected by the lack of rainfall in July and August of 1999. The tributaries were also analyzed for nitrate concentration (NO3) in 1999 for the second time and the average was 621 ppb, again more than two times the average nitrate concentration in the lake, as was the total phosphorus in the tributaries.

The fifth year of studying fecal coliform bacteria populations in marina coves and non-marina coves involved 14 sites, including 7 marinas, five non-marinas, and 2 sites located in the headwaters of the Roanoke Channel and the Blackwater Channel. The fecal coliform average colony counts in 1999 were the some of the lowest seen. The marinas' average fecal coliform count was 17.7 $\pm$ 1.7 cfus and the non-marinas' average was 16.8 $\pm$ 2.4 cfus. In 1999 none of the samples collected by Ferrum College exceeded the state standards for swimmable/fishable waters. The purpose for these samples was to evaluate the effect of marinas and boats on the environmental health of Smith Mountain Lake. There were two additions to the program in the summer of 1999. The first was the rain event samples taken from July 12-16 in order to evaluate the fate of the fecal coliform and sediment as washed in the lake from runoff. These data showed a high fecal coliform count in the first 18 hours in the river and tributaries but a significant decrease in numbers when the fecal coliforms reached the lake. The second new project was the shoreline reconnaissance using dissolved oxygen, pH and oxidation-reduction potential (ORP) to attempt to find leaking drainfields or septic systems. These results were inconclusive this year.

The Trophic Status Index (TSI) for Smith Mountain Lake in 1999 ranged from a low of 35 (indicating oligotrophic conditions) in the main basin at site M1 to as high as 58 and 59 (indicating eutrophic conditions) in the upper reaches of the Roanoke and Blackwater Channels at sites R31 and B22. These significant differences give further support to the variation in water quality among the lake zones described above.

The overall lake quality is at least as good in 1999 as it has been in the past several years. The Smith Mountain lake Association and Ferrum College will continue to keep a watchful eye on the lake's water quality in order to respond to problems more quickly. Next year's (2000) plans include doing another event sample (rain) for fecal coliforms from the headwaters to the lake on the Roanoke Channel to evaluate the transport of fecal coliforms into the lake. In 2000, shoreline monitoring using a multiparameter probe will be attempted again to determine the feasibility of identifying possible drainfield and septic tank influences. Collaboration with the Franklin County and Bedford County Health Departments and the West Region of the Department of Environmental Quality will continue in 2000.

2. INTRODUCTION

The Smith Mountain Lake Water Quality Monitoring Program (SMLWQMP), now in its thirteenth year, is a program designed to monitor the water quality and the trophic status of Smith Mountain Lake, a large (25,000 acre) pump-storage reservoir located in South Western Virginia. Scientists from Ferrum College and designated members of the Smith Mountain Lake Association (SMLA) jointly manage the project. This report describes the 1999-monitoring season, the twelfth year of the program. Secchi depths were recorded and samples collected every other week from the first week of June to the third week of August.

The sampling season for the monitoring program runs roughly from Memorial Day to Labor Day. The samples are picked up at the homes of the monitors by Ferrum College interns and analyzed for total phosphorus, chlorophyll-*a* and nitrate concentrations. The monitoring network includes "trend stations" on the main channels and "watchdog stations" in coves off the main channels. One of two types of monitoring is carried out at each site; at "basic stations" water clarity is measured with a Secchi disk while, at "advanced stations", water clarity is measured and samples are collected for further analysis in the Water Quality Laboratory at Ferrum College. In 1999 there were 74 stations in the lake monitoring network (32 advanced channel stations, 20 advanced cove stations and an additional 22 basic stations, all but one located in coves).

Beginning in 1995, Ferrum College personnel began collecting 20 tributary samples each sampling period in order to begin assessing tributary inputs of nutrients to the lake. In 1996 a volunteer monitoring team began collecting samples in the upper Roanoke channel just below the confluence of Back Creek, 34 miles from the dam. This sample site has been designated T21 and is considered the headwater station for the Roanoke channel. Sample site T3 is the headwater station designated for the Blackwater channel and it is located at the Route 834 Bridge near Riverside Exxon. Both headwater stations are considered to be tributary stations, although there is minimal velocity at either site during base flow conditions. All other tributary stations are on flowing tributaries near their confluence with the lake except for the upper Gills Creek site. This site, T0, is several miles from the lake and a volunteer monitor collects samples there.

Collection of lake samples for fecal coliform enumeration also began in 1995 with samples collected at 8 sites on three occasions. In 1996 and 1997, the number of sampling sites was increased to 12 and, during 1998 and 1999 fecal coliform samples were collected at 14 sites on six occasions. Personnel from the SMLA and Ferrum College collected bacterial samples every other week, alternating with the weeks during which trophic samples were to be picked up from the volunteer monitors.

The 1999 training session was carried out in May by the Ferrum College scientists, Carolyn Thomas and David Johnson, and the SMLA Volunteer Monitoring Coordinator, John Singer, with assistance from the student technicians, Amy Hayes, Susanne Stoneman, Rea Prillaman, Jeff Hurst, Minh Nyguen, Scott Queen, Lisa Swain, and Lacey Biles. The training session was held at the Bethlehem United Methodist Church in Moneta. The program included a review of the previous year's findings and planning for the upcoming season. Experienced monitors reviewed their sample site locations and 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, practiced the sampling procedures, and issued sampling equipment and supplies. Sample collection began the week of May 30 through June 5 and the first sample bottles and sample filters were picked up Tuesday, June 8. Newsletters were written and published by the program co-directors and student technicians during the summer, reporting on activities of the program. Announcements were included in the newsletters in addition to advice and tips on sample collection. Two newsletters were written in 1999. In September, the annual end-of-the-season meeting and social event was held at the residence of Bonnie Johnson on the lake. At this combination picnic/business meeting, reports were made on the monitoring results and SMLA President, Jim Spitz, discussed the program and plans for the coming year.

The Virginia Environmental Endowment (VEE) provided primary funding for the project during the first three years and the final report to the VEE describes the development of the project during the period from 1987-1990 (Johnson and Thomas, 1990). Beginning in 1990, support for the project has come from the Commonwealth of Virginia (through the Smith Mountain Lake Policy Advisory Board), the SMLA and Ferrum College. Monitoring results from 1990 to 1998 can be found in the project annual reports.

This year's monitoring results, data analyses and conclusions, and comparisons with the previous eleven 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 water quality parameters measured include water clarity (turbidity), measured as Secchi disc depth; total phosphorus, measured spectrophotometrically (λ = 700 nm) after persulfate digestion; nitrate, also measured spectrophotometrically (λ = 540 nm) after cadmium reduction; and chlorophyll-*a*, determined using the acetone extraction method and measured fluorimetrically.

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

Sampling station codes contain information on the location of the site. The sample site codes are based on:

(1) The section of the lake in which the site is located ("C" for Craddock Creek, "B" for Blackwater, “M” for main basin, “R” for Roanoke, “G” for Gills Creek).

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

(3) Designation of the sampling station as a cove, main channel or a tributary (cove site codes start with "C", tributary sampling site codes begin with “T”, channel sampling site codes have no letter designation and begin with the letter of the channel as given in (1) above).

(4) Basic monitoring site codes begin with an "S" (for Secchi depth).

An example of a sampling site code would be "CB14" which would indicate a cove sample off of the Blackwater channel 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 2 miles beyond the Hardy Ford Bridge on the

Roanoke channel and to the Route 834 Bridge in Franklin County on the Blackwater channel. The cove sampling sites are also important for trend analysis and help fulfill the role of "watchdogs". In the "watchdog" mode, 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, interns collect grab samples (to fill a bottle with water) every other week at 19 tributary sites on their rounds to pick up lake water samples. Volunteer monitors collect two additional tributary samples, one in upper Gills Creek and another in the upper Roanoke Channel just downstream from the confluence of Back Creek.

4. RESULTS FROM TROPHIC STATUS MONITORING

In this section the parameters used to monitor trophic status are displayed. These parameters include total phosphorus, nitrate, chlorophyll-*a*, and Secchi depth. Total phosphorus and nitrate are plant nutrients that stimulate the growth of algae. Phosphate, the form of phosphorus most immediately available to algae, is the limiting nutrient in Smith Mountain Lake. Chlorophyll-*a* is extracted from algae and is a measure of the algal population. Secchi depth is a measure of water clarity that decreases as algal populations and siltation increase. The seasonal average for the lake stations for each parameter over the past three years is shown in Table 1. The average concentration of each nutrient was higher in 1999 than 1998 leading to a higher average concentration of chlorophyll-*a* and a lower average Secchi depth. It is reassuring to observe in reference to evaluation of quality control the high degree of internal consistency among the data in Table 1. A more complete discussion of water quality trends is presented in Section V of this report.

Table 1. Summary of trophic state data from 1997 to 1999.

	Nitrate (ppb)	***Total Phosphorus (ppb)***	***Chlorophyll-a (ppb)***	***Secchi Depth (m)***
1999	296	28.9	3.9	2.2
1998	257	24.4	3.8	2.3
1997	180	27.6	4.1	2.1

4.1 Lake Stations

4.1.1 Variation of Trophic Parameters over Time

The values for each parameter were averaged for each sampling period to indicate the variation of the parameters during the sampling season. The results are displayed in figures 1-4.

(a) Total Phosphorus: The Smith Mountain Lake stations (54 sites) exhibited the lowest average concentration of total phosphorus (TP = 23.8 ppb) during the fifth sampling period (August 25-

31) and the highest mean concentration (TP = 35.4 ppb) during the first sampling period (May 31-June 5).

(b) Nitrate: The lowest average concentration (54 sites) of nitrate (NO3 = 119.4 ppb) occurred during the sixth sampling period (August 8-14) and the highest average nitrate concentration (NO3 = 455.8 ppb) during the fourth sampling period (July 11-17).

(c) Chlorophyll-*a*: The sample set (54 sites) with the lowest average chlorophyll-*a* concentration (CHA = 1.6 ppb) was collected during the first sampling period (May 31-June5) and the set with the highest average chlorophyll-*a* concentration (CHA = 6.8 ppb) was collected during the fourth sampling period (July 11-17).

(d) Secchi Depth: The lake (81 sites) exhibited the highest average Secchi depth (SD = 2.8 m) (highest water clarity) during the second sampling period (June 13-June 19). The lowest average Secchi depth (SD = 2.04 m) occurred during the fourth sampling period (July 11-17).

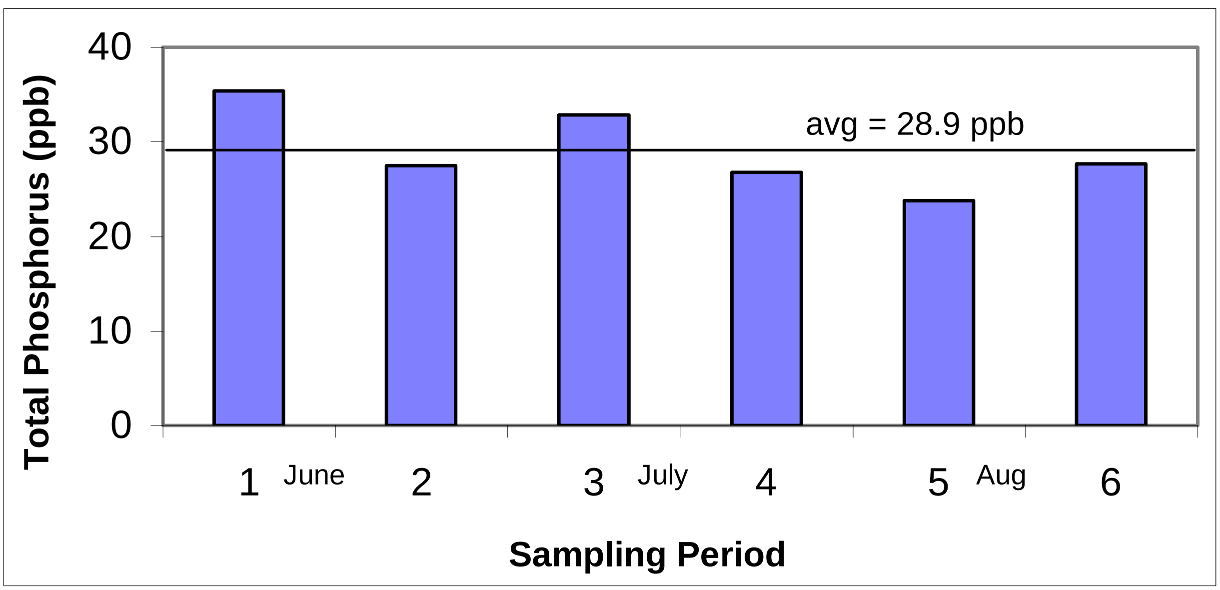


Figure 1. Average total phosphorus concentration for each sampling period in 1999.

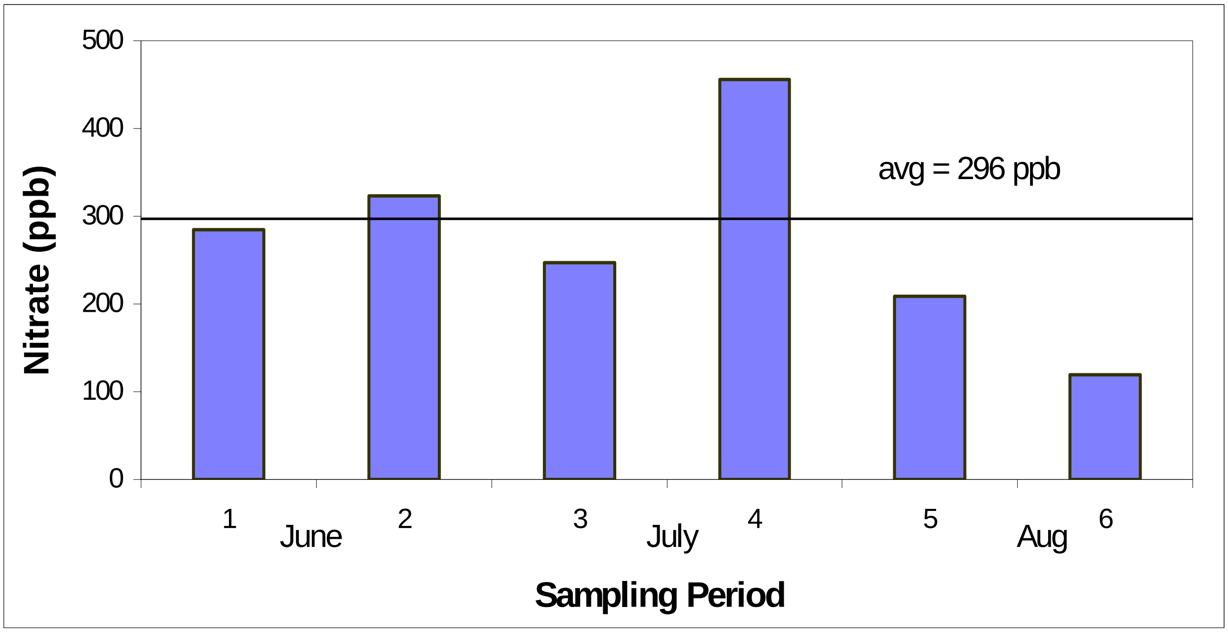


Figure 2. **Average nitrate concentration for each sampling period in 1999.**

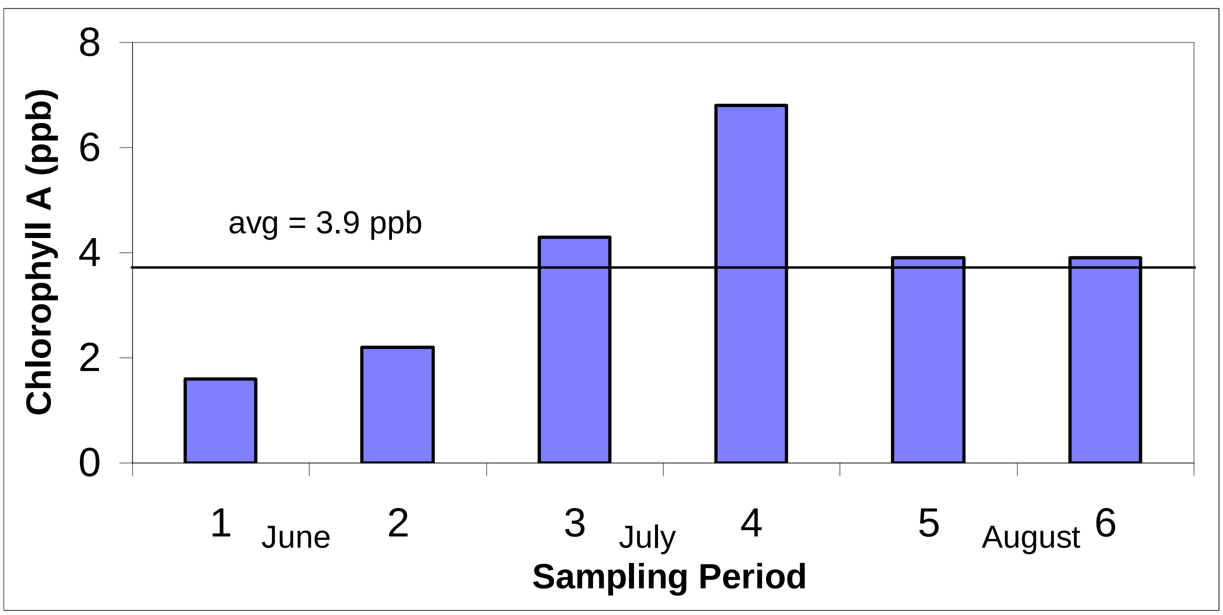


Figure 3. **Average chlorophyll–*a* concentration for each sampling period in 1999.**

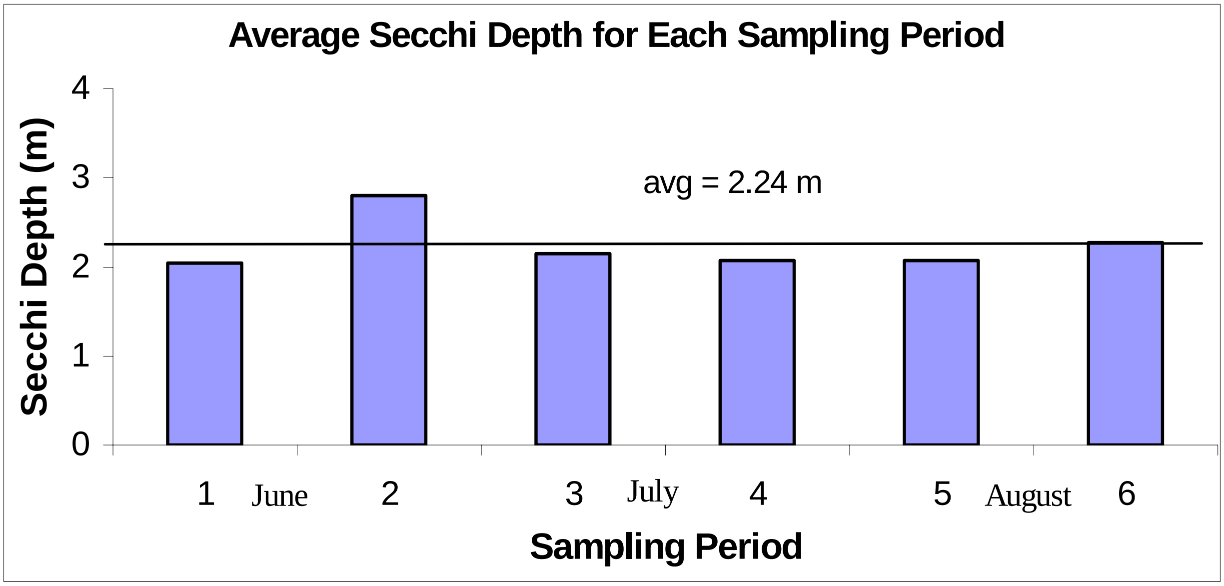


Figure 4. Average Secchi depth for each sampling period in 1999.

4.1.2 Variation of Trophic Parameters with Distance from the Dam

The parameters were averaged by station over the six sampling periods and the average values were graphed as a function of distance from the dam. The results are displayed in figures 5-8.

(a) Total Phosphorus: Total phosphorus levels in the lake increase as distance to the dam increases, but not as regularly as in the past. The correlation coefficient (R^2) is lower than usual and the cause is a group of stations in coves off the Roanoke Channel between 15 and 20 miles from the dam (Figure 5). The sampling site with the highest average total phosphorus concentration (TP = 60 ppb) was in one of these coves (CR17). The lowest average total phosphorus concentration (TP = 10.8 ppb) was at a site in the main basin of the lake (CM1). It would be interesting and perhaps useful to conduct a visual survey of the coves with the unusually high phosphorus levels to see if an apparent cause can be identified.

(b) Nitrate: Unlike the phosphorus measurements, nitrate concentrations do not increase as distance to the dam increases in the Blackwater Channel. They do follow the same pattern as phosphorus in the Roanoke Channel but only for the sampling sites beyond 15 miles from the dam. The sampling site with the highest average nitrate concentration (N03 = 1622.0 ppb) was in the Roanoke Channel (R30). The lowest average nitrate concentration (NO3 = 56.3 ppb) was also in the Roanoke section (R11). Figure 6 shows the annual average nitrate concentration by station as a function of distance from the dam and distinguishes between the Roanoke channel and other sections of the lake. The large variation in nitrate concentrations in the Roanoke section needs to be studied, as does the reason for the rapid decrease in concentration observed coming toward the dam. The decrease is exponential, as can be seen from the good fit of the data with a second order polynomial trend line ($R^2 = 0.9202$). It is also interesting that the nitrate levels increase again closer than 10 miles from the dam. The appearance, as was also the case last year, suggests that there is an upwelling of nitrate rich waters near the dam, perhaps as a result of the mixing that occurs at the confluence of the two main channels.

(c) Chlorophyll-*a*: Chlorophyll-*a* levels (CHA) decreased as samples were taken closer to the dam but, as with total phosphorus, the trend was less regular this year (Figure 7). Rather than the normal pattern of regularly increasing concentration with increasing distance the stations show a more bimodal distribution. The chlorophyll-*a* levels are rather uniform until about 20 miles from the dam and then rise rapidly to a higher level, with the level at station R29 out of line with the rest of the stations. The highest average total chlorophyll-*a* concentration (CHA = 23.8 ppb), was on the Roanoke Channel (R29). The lowest average chlorophyll-*a* concentrations (CHA = 0.4 ppb) were found at three sites in the main basin (M0, M1, M5). An average chlorophyll-*a* concentration of 23.8 ppb is the highest observed in several years and may be due to drought conditions. High silt levels in the water of the upper Roanoke Channel normally blocks light and interferes with photosynthesis and the lack of run-off may have reduced the interference.

(d) Secchi Depth: Secchi depth increased as miles to the dam decreased, indicating greater water clarity toward the main basin (Figure 8). The highest average Secchi depth (SD = 3.71 m) in the lake was measured at a station in the Craddock Creek section of the lake (C5). The lowest average Secchi depth (SD = 1.33 m) was observed at the same station as the highest average chlorophyll-*a* concentration (R29).

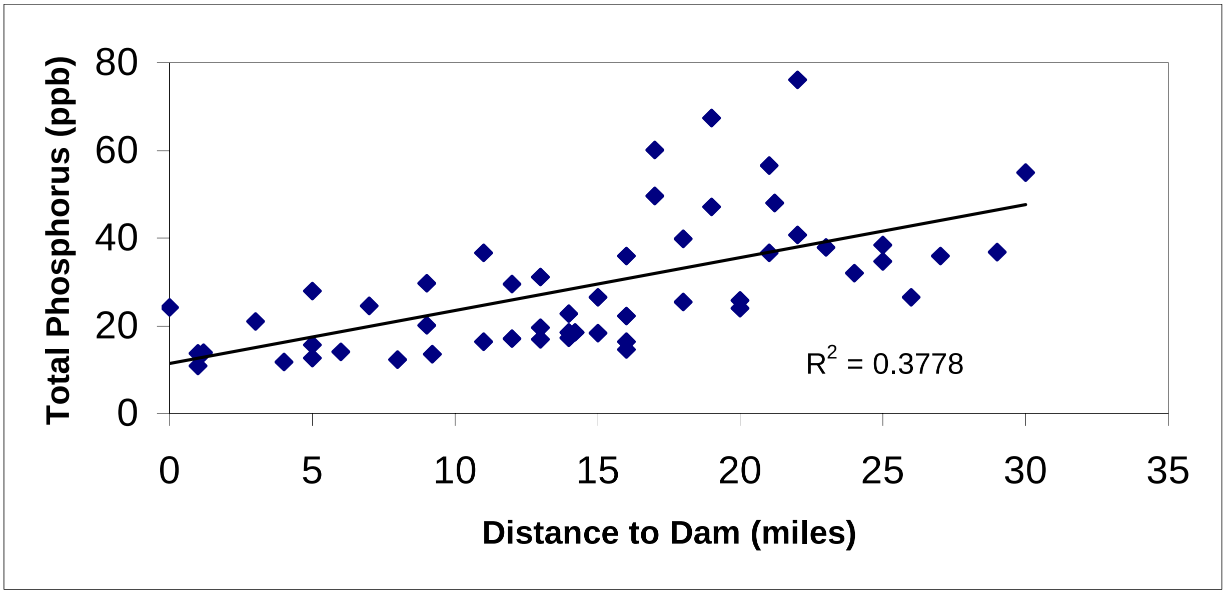


Figure 5. **Variation of total phosphorus concentration with distance from the dam.**

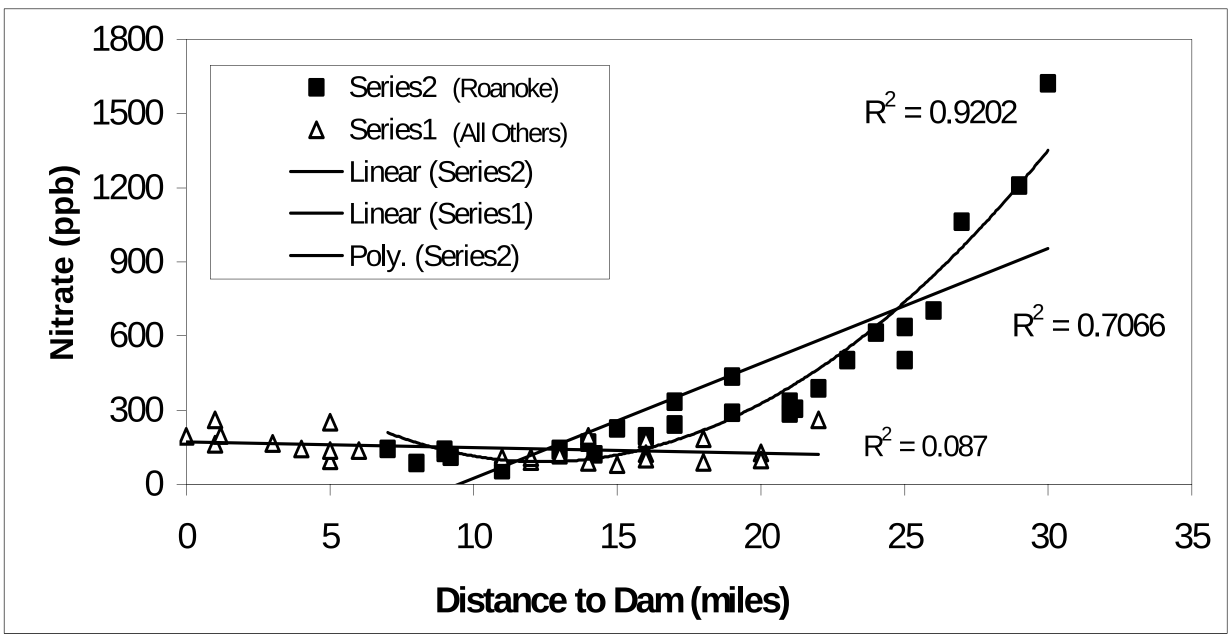


Figure 6. **Variation of nitrate concentration with distance from the dam.**

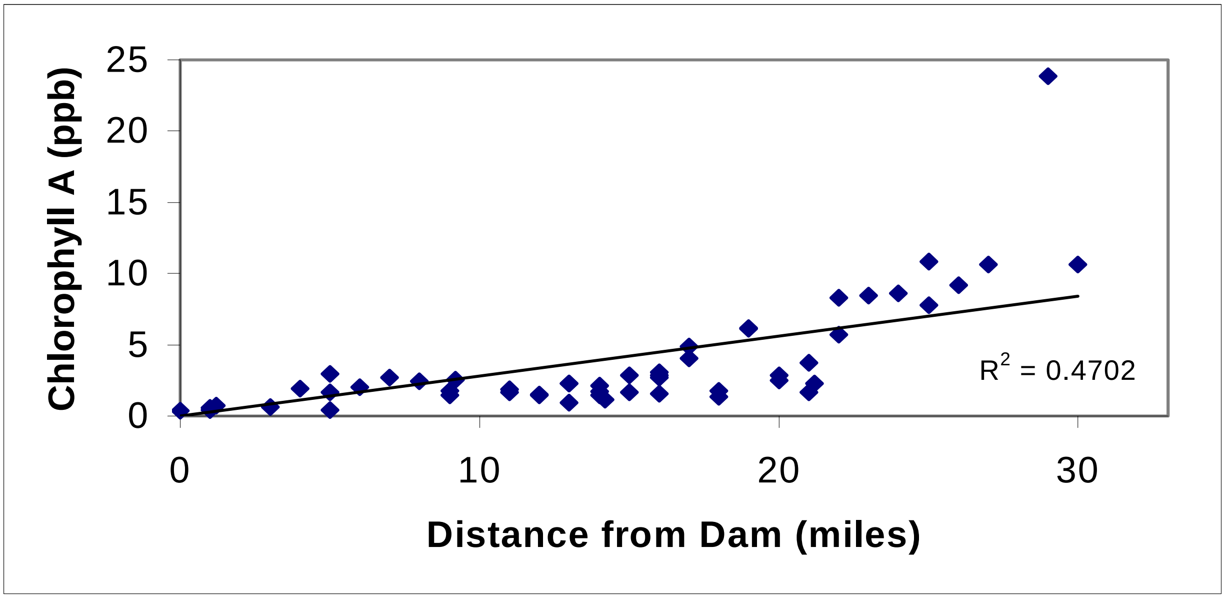


Figure 7. **Variation of chlorophyll-*a* concentration with distance from the dam.**

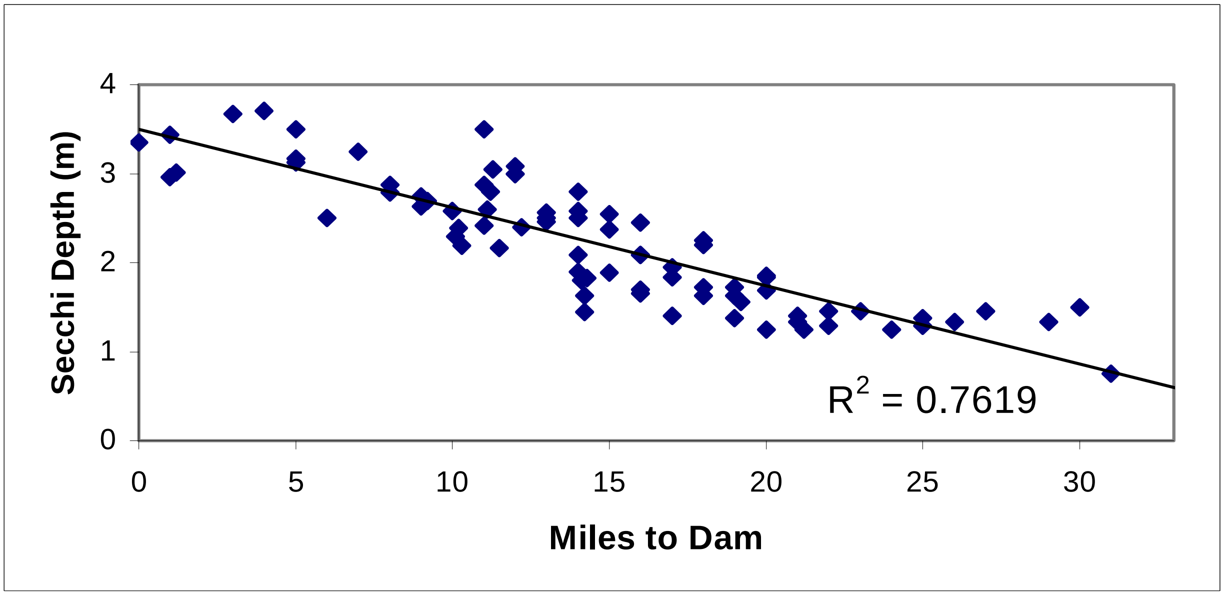


Figure 8. **Variation of Secchi depth with distance from the dam.**

4.2 Tributary Stations

4.2.1 Variation of Total Phosphorus and Nitrate during the Sampling Season

The values for each parameter were averaged for each sampling period to indicate their variation during the sampling season. The results are displayed in figures 9 and 10.

(a) Total Phosphorus: The tributaries (22 sites) exhibited the lowest average concentration of total phosphorus (TP = 49.1 ppb) in the fifth sampling period (July 25-31) and the highest mean concentration (TP = 71.9 ppb) in the third sampling period (June 27-July3).

(b) Nitrate: The lowest average concentration (22 sites) of nitrate ($NO3$ = 471 ppb) occurred during the second sampling period (June 13-19) and the highest average nitrate concentration ($NO3$ = 771.0 ppb) during the fourth sampling period (July 11-17).

For both phosphorus and nitrate the lowest average concentration was higher this year than last and the highest average concentration was lower this year than last. It would appear that both nutrients were more uniform in concentration in 1999 than in 1998 and is likely a result of the drought and lack of stormwater runoff that lead to large variations in concentration..

4.2.2 Average Tributary Concentration of Total Phosphorus and Nitrate by Year

Table 2 indicates that tributary phosphorus levels, after a trend of declining for four years, increased in 1999. Nitrate monitoring in tributaries was begun in 1998 and the average concentration was higher in 1999.

Table 2. **Average tributary concentrations of total phosphorus from 1995-1998.**

Year	*1995*	*1996*	*1997*	*1998*	*1999*
Average Tributary TP (ppb)	91.5	63.5	67.4	50.9	61.8
Average Tributary Nitrate (ppb)				568	621

4.2.3 Seasonal average nutrient concentrations for each tributary

In order to obtain information on relative impact on Smith Mountain Lake by each tributary, the average for each tributary has been calculated over the six sampling periods. The results are shown in figures 11 and 12, which also include the average tributary and lake concentrations of total phosphate and nitrate. To compare actual nutrient loading by tributary, the flow rate of each tributary must also be measured in the future. The tributary stations are identified below:

Tributary Station	Stream Name
T0	Upper Gills Creek
T1	Maggodee Creek
T2	Lower 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
T18	Lynville Creek
T19	Grimes Creek
T20	Indian Creek
T21	Roanoke Channel near Back Creek

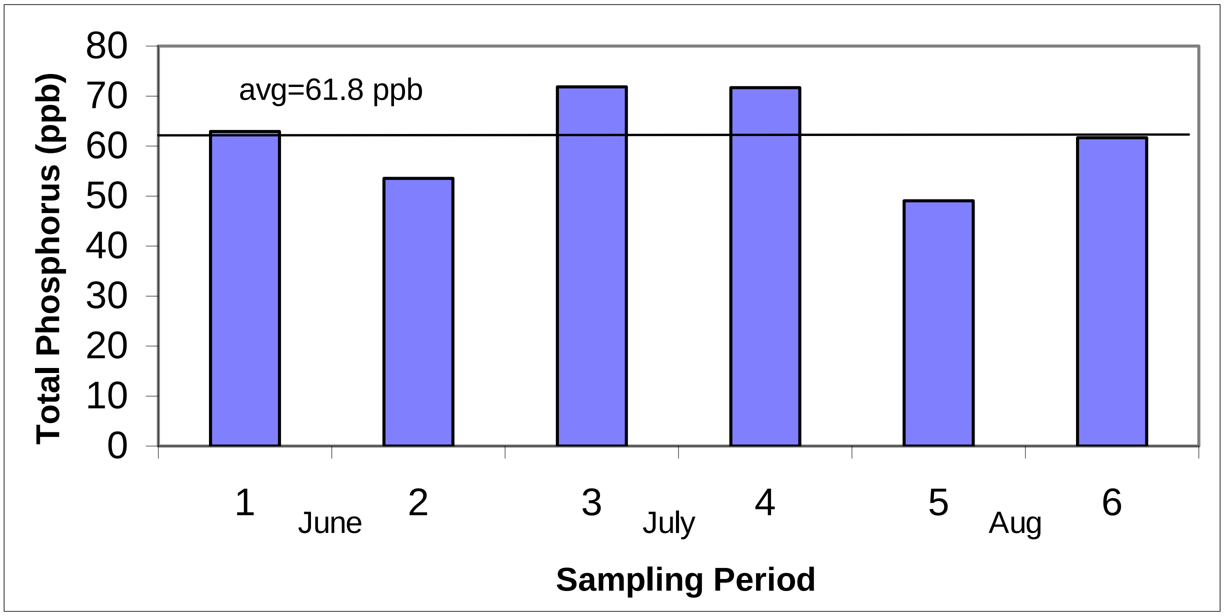


Figure 9. Average total phosphorus concentration at tributary stations for each sampling period.

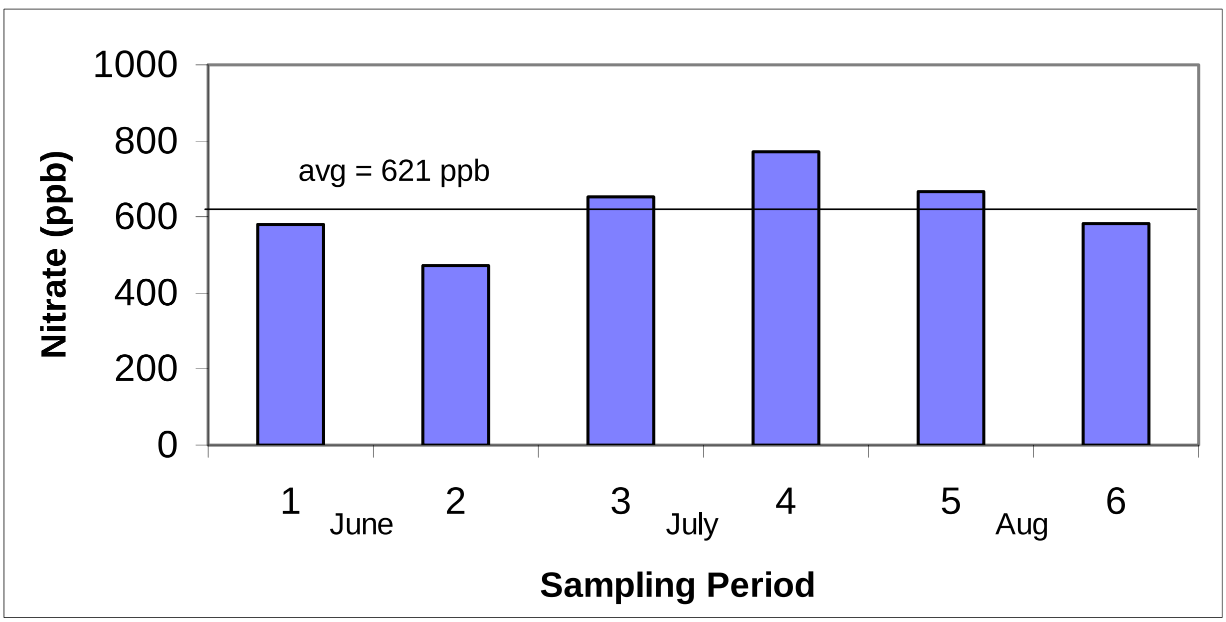


Figure 10. Average nitrate concentration at tributary stations for each sampling period.

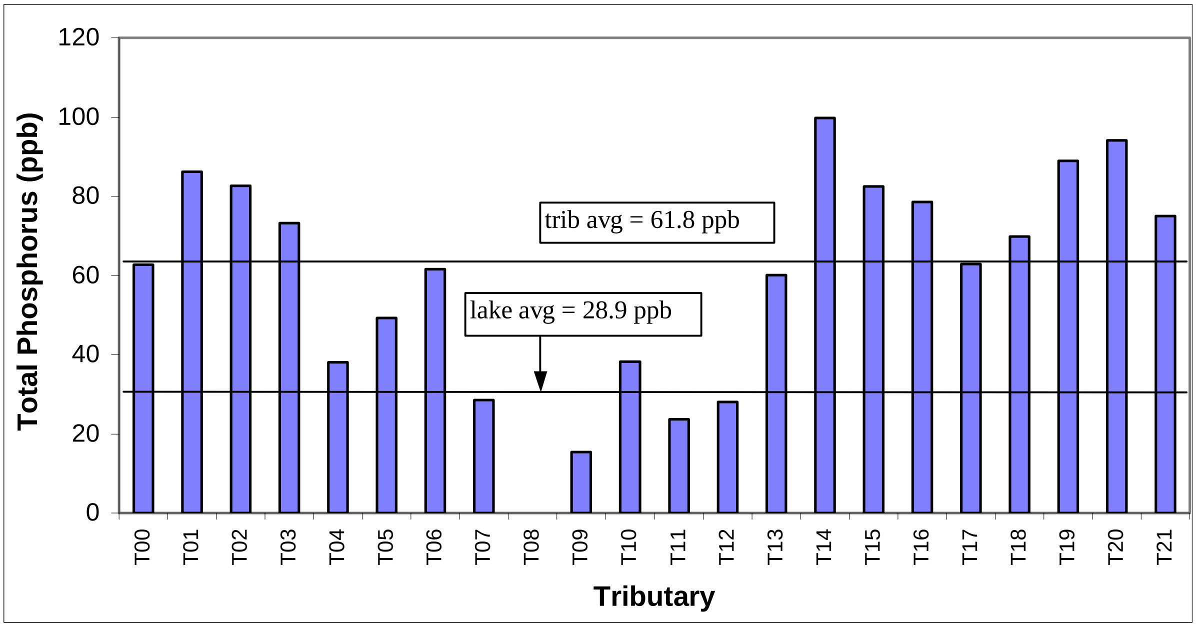


Figure 11. Seasonal average total phosphorus concentration for each tributary.

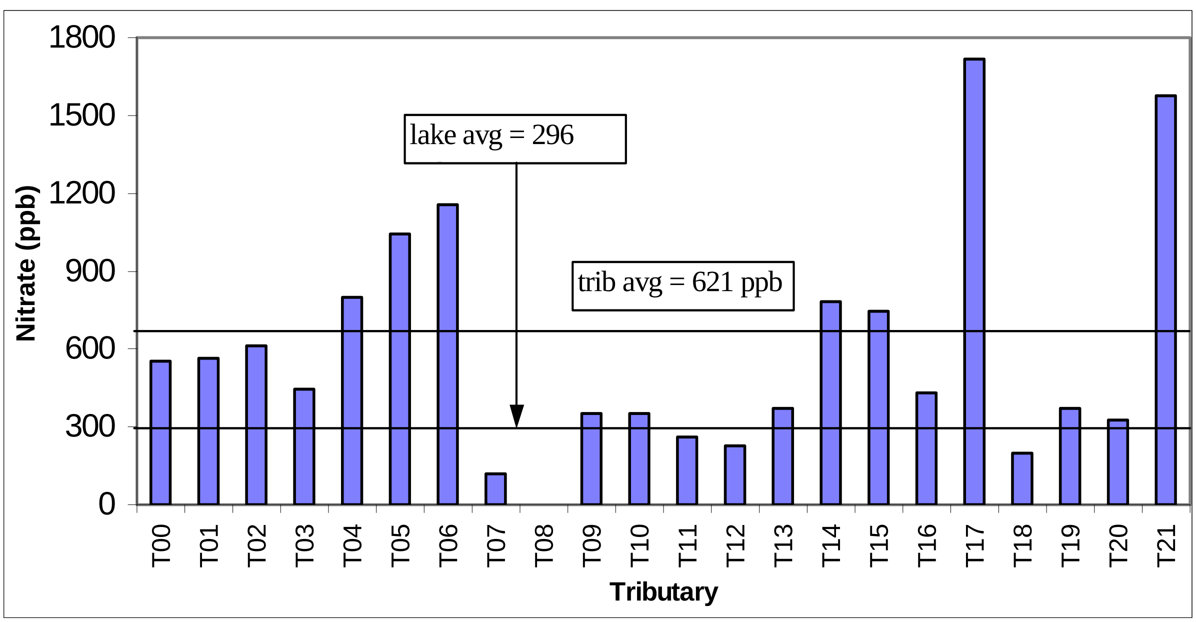


Figure 12. Seasonal average nitrate concentration for each tributary.
(Note: There is no data for tributary 8 because it went dry after the first sampling period.)

4.3 Results for Sample Sites Below the Dam

The interns collect grab samples from a bridge in the same manner as the tributary samples. The difference is that these samples are collected below the dam and are not tributaries flowing directly into the lake. Because of the pumpback system, water from these sites does end up in the lake. T9 is in the Roanoke River just below the dam at the AEP 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 near where Leesville Lake begins. The results for 1993 through 1999 are summarized in Table 3. The values given for each year are the annual averages. The raw data for Leesville Lake can be found in Appendix 3b. The average total phosphorus concentration in the Roanoke River below the dam continues to decrease, a sign of improving water quality in the lake. The higher phosphorus concentration in the Pigg River (site T10) continues to elevate the phosphorus levels in the Roanoke River. There was a significant decrease in phosphorus concentrations below the dam and in the Pigg River in 1999. This is in contrast to the lake and other tributaries, which showed higher phosphorus levels in 1999.

Table 3. Summary of results for total phosphorus at sites below the dam.

	Total Phosphorus (ppb)							
Site/Location	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**Avg**
T9/ Roanoke R. below dam	48.5	25.6	40.5	38.3	19.7	11.4	11.5	28.0
T10/Pigg R. at Rt 605	65.2	64.5	83.4	48.3	38.9	43.4	22.2	52.3
T11/Roanoke R. at Rt 608	54.6	38.7	62.1	48.1	33.9	33.1	12.3	40.4
Annual Average	56.1	42.9	62.0	44.9	30.8	29.3	15.3	40.2

Table 4 gives similar results for two years of nitrate monitoring at sites below the dam. The data for nitrate shows a pattern different than that displayed by phosphorus in that the nitrate levels are higher in the water released from the dam than in the Pigg River. As with total phosphorus, the nitrate levels below the dam and in the Pigg River were considerably lower in 1999 than in 1998, again an indication of improving water quality in the lake.

Table 4. **Summary of results for nitrate at sites below the dam (1998 to 1999).**

	Nitrate (ppb)		
Site/Location	**1998**	**1999**	**Avg**
T9/ Roanoke R. below dam	516	225	371
T10/Pigg R. at Rt 605	447	200	324
T11/Roanoke R. at Rt 608	427	182	305
Annual Average	463	202	333

4.4 Shoreline Reconnaissance

The shoreline reconnaissance study is part of an effort to detect near shore septic system effluent. It was undertaken because of the potential impact that septic systems have on water quality. The shoreline reconnaissance was carried out by trolling near the shoreline of selected coves while monitoring conductivity, oxidation-reduction potential (ORP), and pH using a multi-probe analyzer with data logger. It should be noted that the analyzer was obtained using funds from the Smith Mountain Lake Environmental Trust. These parameters were measured in coves with no septic systems in order to establish baseline conditions. Identification of malfunctioning septic systems was attempted by looking for parameter values that deviate from the typical range of background values. Compared to lake water, septic tank discharges and drainfield leachate have lower ORP, higher conductivity and higher nitrate concentrations. It was anticipated that one of the parameters could act as a signature for failing septic systems and that one or more of the other parameters could then be used to confirm the suspicion. The study was not intended as an additional monitoring effort but rather as a short-term research project to provide understanding about what needs to be done to protect the long-term quality of water in Smith Mountain Lake.

The first area trolled was located near Palmer’s Marina and based on the high conductivity readings potential hot spots were encountered. The background reading was 130-135 υmho/cm and the elevated readings were 180-185 υmho/cm. Occasionally a high conductivity reading couldn’t be detected again when a pass was repeated. There is a possibility that our propeller stirred up the water enough to obliterate the signal. In other locations along the cove the readings were constantly high, along a radius of at least 100 feet. In other places low readings

(110-120 υmho/cm) were found which might indicate a spring emerging in the lake. Unfortunately, the first attempt gave the only hopeful results obtained. Other areas were looked at further up in the Blackwater Channel at Crafts Ford, Poplar Camp and Shenandoah Shores; elevated values were not found there. On the Roanoke side, reconnaissance was carried out in coves at Bridgewater Plaza, The Water Wheel, Webster's Marine, Campers Paradise, and Stoney Creek. In coves off the Roanoke Channel no elevated values were detected because the background readings were both high and variable. For example, conductivity is in the range of 130-180 υmho/cm in the Blackwater Channel but ranges from 230 υmho/cm to over 300 υmho/cm on the Roanoke Channel. Within a given cove, away from shore, conductivity typically varied from 220-260 υmho/cm. Nitrate is as low as 50 ppb on the Blackwater side and goes up over 1000 ppb at stations on the Roanoke side. The high ambient levels in coves off the Roanoke Channel make it very difficult and perhaps impossible to detect signatures from failing septic systems with our present technology and database. The intent is to continue the investigation this coming summer on the Blackwater side of the lake, as well as investigate the source of high conductivity and nitrate levels in the Roanoke Channel.

4.5 Summary of Section

Overall, it would appear that water quality in Smith Mountain Lake declined slightly from 1998 to 1999. It is more accurate to say that the trophic level increased slightly. The changes are small but consistent among all parameters. Average total phosphorus and nitrate levels increased in both lake and tributary samples, average chlorophyll-*a* levels increased and water clarity deceased. The relative change in each parameter from 1998 to 1999 is shown in Table 5.

Table 5. **Relative change (%) in water quality parameters from 1998-1999.**

TP - Lake	TP - Tribs	NO3 - Lake	NO3 Tribs	Chlorophyll-*a*	Secchi Depth
+18%	+21%	+15%	+9%	+3%	-4%

Water circulation, nutrient interchange and biotic relationships connect the channels and the coves of Smith Mountain Lake. Tributaries provide nutrients to coves, especially phosphorus as demonstrated with the data in this section. The average concentration of total phosphorus from the sampled tributaries was 61.8 ppb, substantially higher than the average concentration of 28.9

ppb for the lake. The situation with nitrate is not as clear. The highest nitrate levels were observed in the lake, although the average tributary concentration of nitrate is higher than the average concentration in the lake. Hypothetically, it seems that the cooler, nitrate laden waters in the Roanoke Channel flow down under the surface of the lake and then begin upwelling near the dam. Because nitrate is not the limiting nutrient in Smith Mountain Lake, it is not easy to assess the impact that high nitrate levels have on water quality.

As has been observed since the second year of the monitoring project, water quality improves significantly as it moves from the upper channels toward the dam. Eroded soil is carried to the lake by silt-laden streams but sedimentation begins in the quiescent lake water. Phosphorus, in the form of phosphate ions, strongly associates with soil particles and settles out during the sedimentation process. Total phosphorus, chlorophyll-*a* and Secchi depth all correlate significantly with distance from the dam. This is not the case for nitrate that is a labile ion, that is, it does not adsorb to silt particles. As a result they do not settle out of the water column and there is not a correlation between nitrate concentration and distance from the dam. It is also apparent from the lower correlation coefficients in Figures 5-8 that this relationship was less well defined in 1999 than most other years. Presently, this difference is being attributed to the drought conditions and the changes in runoff and circulation patterns caused by the drought.

5. FECAL COLIFORMS IN SMITH MOUNTAIN LAKE

5.1 Fecal Coliform Monitoring

Water samples were collected from fourteen sites on Smith Mountain Lake on May 20, June 1, June 29, July 6, July 27, and August 12, 1999. These samples were collected and stored according to standard methods (APHA). Two sites were sampled at each station and three replicates at each site were filtered. A standard 100mL aliquot of sample was 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 22-24 hours of incubation at 45.5° C in an incubator.

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

Non-marina sites

1. Main basin at the 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.
5. Smith Mountain Lake State Park Cove on the Bedford County side of the lake

Marina sites

6. Shoreline Marina on the Franklin County side of the lake.
7. Pelican Point Marina on the Franklin County side of the lake.
8. Smith Mountain Lake Dock on the Pittsylvania County side of the lake.
9. Smith Mountain Lake Yacht Club on the Bedford County side of the lake.
10. Foxport Marina on the Franklin County side of the lake.
11. Indian Point Marina on the Franklin County side of the lake.
12. Bay Roc Marina at Hardy Ford Bridge on the Franklin County side of the lake.

Headwaters Sites

13. Ponderosa Campground on the Franklin County side of the lake.
14. Beaverdam Creek on the Bedford County side of the lake.

These sites were selected as representative coves around Smith Mountain Lake, to allow comparison between non-marina coves and marina coves and to allow evaluation of two headwater 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 pasture and is located after the confluence of the two main channels and in close proximity to Smith Mountain Lake Dam. (3) Fairway Bay (Franklin County) is surrounded by homes and multi-family residences and is 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, a tributary of the Blackwater Channel. (5) Smith Mountain Lake State Park Cove was sampled where it intersects the main channel.

The marina sites include: (6) Shoreline Marina which is up Becky's Creek, a tributary of the Roanoke Channel in Franklin County and is a storage place for many houseboats. (7) Pelican Point Marina is on the Blackwater Channel in Franklin County and is a storage place for many large sailboats and a few houseboats. (8) Smith Mountain Lake Dock Cove is a cove off the main basin in Pittsylvania County, in close proximity to Smith Mountain Lake Dam and is a storage place for many houseboats. (9) Smith Mountain Lake Yacht Club is in a cove off the Roanoke Channel in Bedford County and is a storage place for many houseboats. (10) Foxport Marina is on the channel of Gills Creek, a major tributary of the Blackwater River and has very few boats docked there. (11) Indian Point Marina is in a cove off the main channel of the Roanoke River, and is a recently developed marina with very few docked boats. (12) Bay Roc Marina at Hardy Ford Bridge is one of the oldest marinas and is on the Franklin County side of the lake located at the beginning of the lake.

There are two headwater sites which primarily indicate specific watershed influences and not within lake influences. Organic compounds and other nutrients in a body of water come from two possible sources, allochthonous inputs and autochthonous inputs. "Allochthonous" refers to input from outside the body of water in other words from the watershed, and "autochthonous" refers to input from within the body of water, for example the algal population photosynthesis. The two headwater sites reflect two of the allochthonous inputs to Smith Mountain Lake. (13) Ponderosa Campground Cove is located on a curve far upstream on the Blackwater River not far from the non-navigable portion of the river, and (14) Beaverdam Creek is a tributary of the Roanoke River on the Bedford side of the lake.

Figure 13 indicates the comparison of the sum of the ranks of each sample site. Figure 14 indicates the mean fecal coliform colony forming units (cfus) commonly called colony counts for the six sample dates. Figure 15 shows a comparison of mean fecal coliform counts for the five sample years 1995-1999 for each site and the means for both combined marina fecal coliform counts and non-marina fecal coliform counts.

Results:

1. All values for fecal coliform populations (all sites on all sample dates) meet Virginia health standards for swimmable and fishable waters in addition to meeting the Virginia standard for potable waters. This standard is 200 cfus per 100 mL sample (geometric mean of more than one sample) or 1000 cfus per 100 mL for one sample.(See Figure 16)

2. The mean colony counts and variances for 1999 marinas (17.65 $\pm$ 1.65 cfus) were lower than the 1998 counts, however the 1999 non-marinas counts (16.84 $\pm$ 2.43 cfus) were higher than the mean colony counts and variances for 1998. (marinas = 26.7 $\pm$ 2.7 and non-marinas = 13.6 $\pm$ 1.0 cfus).

3. Sample date was an important influence on the fecal coliform population estimates, with the early summer sample date June 1, 1999 exhibiting the highest mean number of colonies (37.9 cfus). In 1999 a significant trend ($\alpha = 0.05$) toward decreasing number of fecal coliforms was observed as the summer passed (See Figure 13). Other scientists have observed a relationship with rain events and increased number of coliforms in streams. Consistent with this observation, in the summer of 1999 there was only one significant rainfall from July through August sampling period and lower fecal coliform population were observed.

4. The mean coliform population estimate for all marinas was higher (20.93 $\pm$ 1.65 cfus) than the mean coliform population counts for non-marina sites (16.83 $\pm$ 2.43 cfus). The three headwater

sites mean fecal coliform population was lower than the marinas and non-marinas in number (14.35 $\pm$ 27.99 cfus) as seen in Figure 14. This lower count from the watershed samples again may indicate the low rainfall amounts and the influence of non point source runoff on these values.

5. All seven of the marina coves had lower fecal coliform mean counts for the summer than one of the non-marina coves (Palmer's Trailer Park), as was true at many of the marinas from 1995 – 1998 (Figure 15).

6. The confluence of the two main tributaries and the Smith Mountain Lake Park Cove had the lowest fecal coliform counts on five out of six sample dates, which has not been the case in the past (Figure 16).

7. When all marina sites and non-marina sites are included, the mean fecal coliform population estimates for the marinas was significantly higher than that for the non-marinas. Five of the seven marinas (Shoreline Marina, Smith Mountain Lake Dock, Bay Rock Marina, Indian Point Marina, and the Smith Mountain Lake Yacht Club) had consistently higher fecal coliform counts than the non-marina sites (Figure 16).

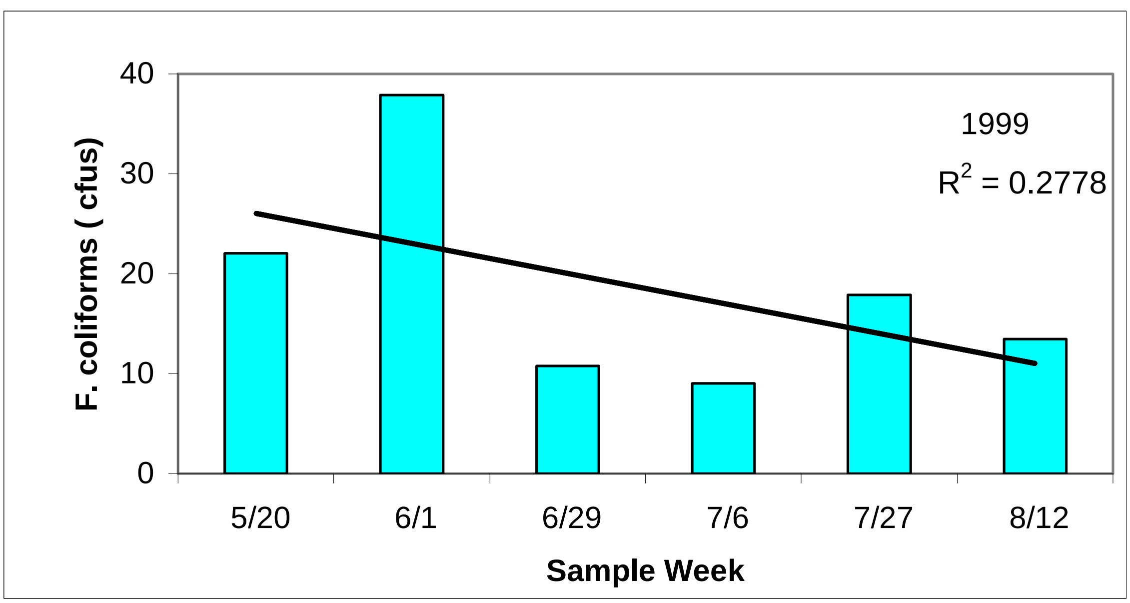


Figure 13. **Fecal coliforms vs. week sampled on Smith Mountain Lake in 1999.**

(Each sample date included 14 sites, with 2 samples per site and 3 replicate filters per sample)

8. In a comparison of the sums of fecal coliform populations for sample dates and sites (see Figure 16) in 1999, Smith Mountain Lake Dock, Shoreline Marina, Smith Mountain Lake Yacht Club, Bay Rock Marina (marina sites), Palmer's Trailer Park (non-marina site), and Ponderosa (head water site) have the highest sum of fecal coliform populations and the Confluence of the two channels and the Smith Mountain Lake State Park Cove (non-marina sites) had the lowest sum of fecal coliform populations for the summer of 1999. One of the non-marina sites, Palmer's Trailer Park had the highest fecal coliform count of the summer on the June 1st sample date (156 cfus). Trailers with drainfields and septic systems surround this cove. Note that this highest measurement does not exceed Virginia's health standard for potable, swimmable or fishable waters.

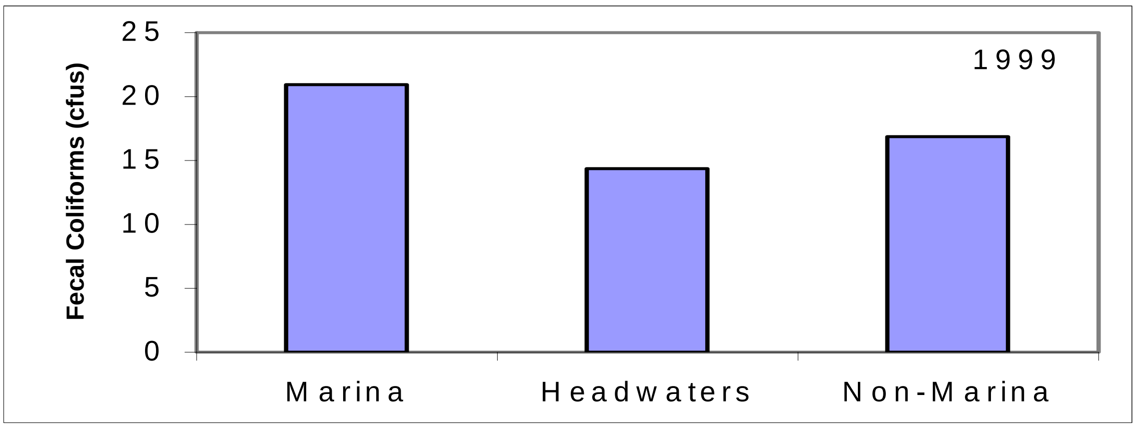


Figure 14. **Mean Fecal Coliform Count vs. site type on Smith Mountain Lake 1999.** (There were 7 marina sites, 5 non-marina sites, and 2 headwater sites)

9. The mean fecal coliform count for marina sites has been greater than the mean fecal coliform counts for the non-marina sites for the five sample years (1995-1999) (Figure 17).

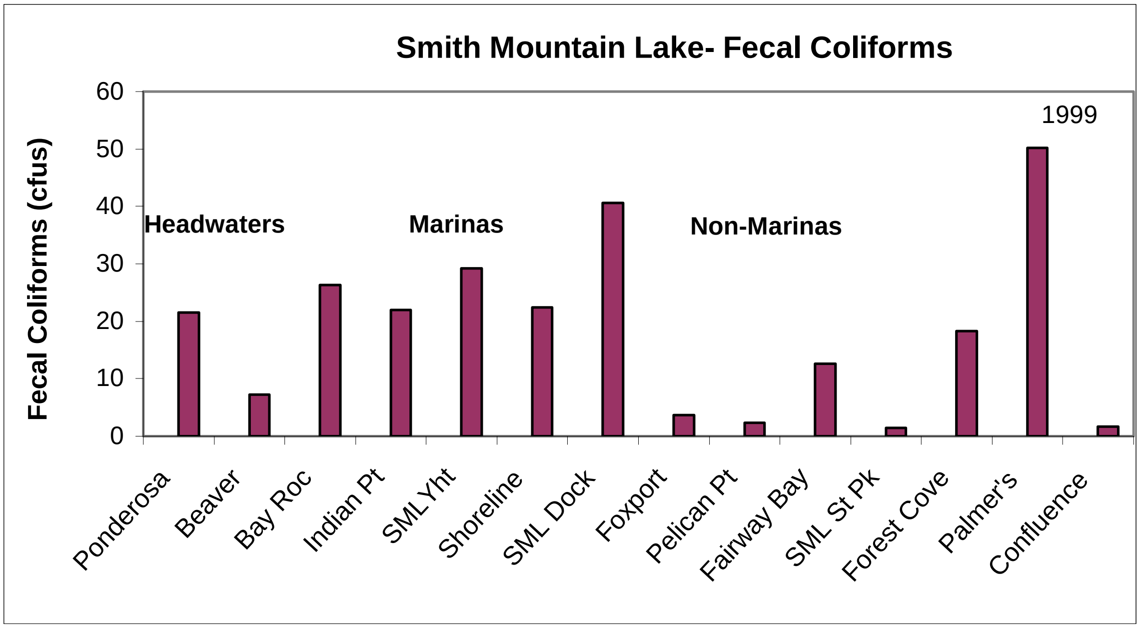


Figure 15. **Mean Fecal Coliform Count vs. sample site on Smith Mountain Lake 1999.**
(Each site has two stations sampled 6 times during the summer.)

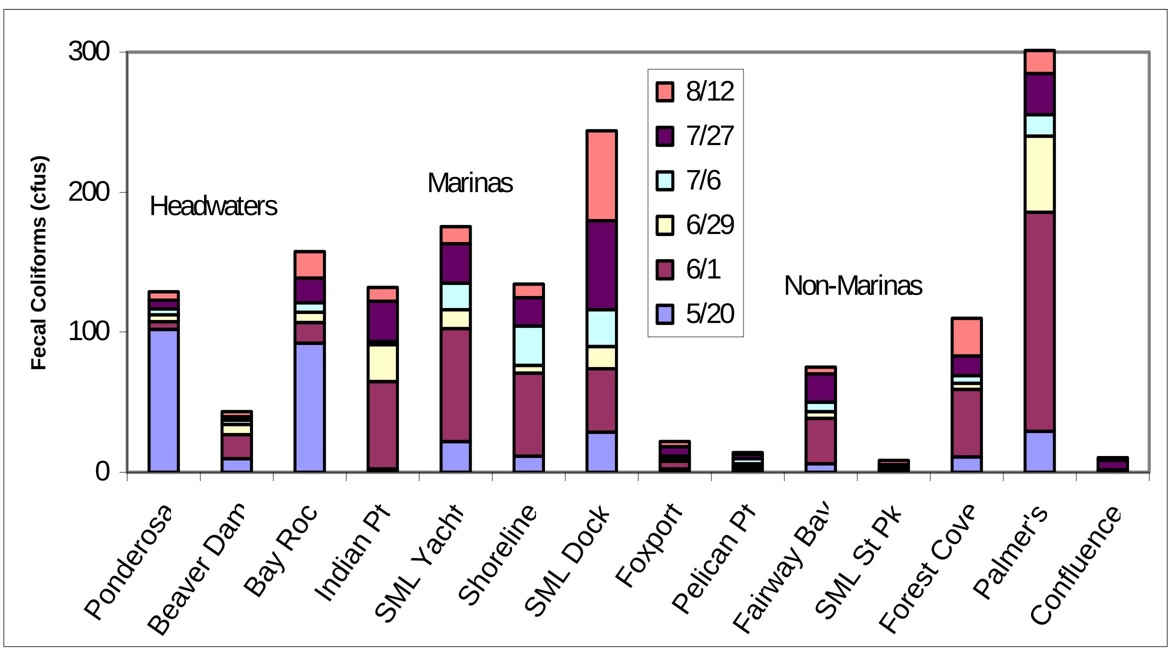


Figure 16. **Sum of Fecal Coliforms counts for Smith Mountain Lake in 1999 at each site for all sample dates.**
Each site and date has two stations per site.

10. In the comparison of five years of sampling fecal coliforms (1995-1999) the marinas have been consistently higher than the non-marinas. A very high fecal coliform population was observed at one of the headwaters sites in 1997. This high mean is a result of one sample date in which the fecal coliform count was unusually high at one of the two headwater sites which presents a possible false impression of extremely high fecal coliform counts in the headwaters of the lake (Figure 17).

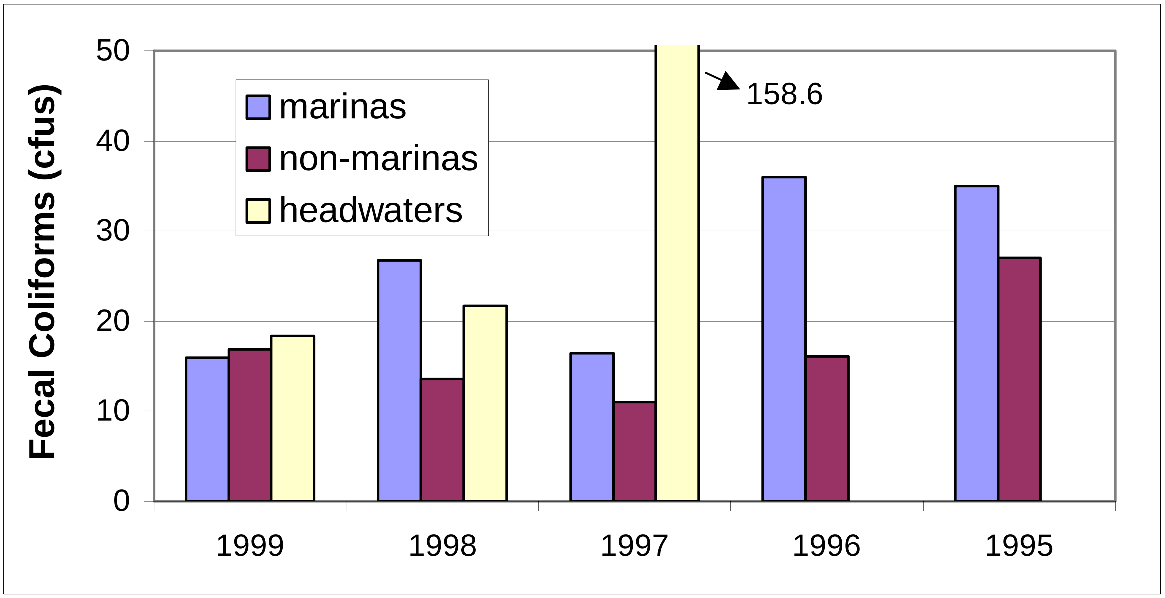


Figure 17. **Mean fecal coliform counts per site type and year sampled for Smith Mountain Lake.**

Note: In 1997 and 1998 there was considerable controversy about the fecal coliform populations in Smith Mountain Lake. The Virginia Department of Health, especially the Franklin and Bedford County offices were sampling regularly around the shoreline of the lake in 1998 and found a few sites with unusually high fecal coliform counts. They continued to sample in 1999 and identified no sites with high fecal coliform counts. The Virginia Department of Water Quality, especially the West Piedmont District, was also sampling occasionally at a number of open water sites around Smith Mountain Lake for fecal coliform population and identified no sites with high fecal coliform counts. The results of all three sampling groups were not always in agreement, but that was to be expected given that these sites and sampling dates were different. The Department of Environmental Quality (West Piedmont District) and the Franklin

County Department of Health collaborated last fall (1998) and this summer (1999) in sampling methods and sample sites. The results of this collaboration are not yet known.

5.2 Fecal Coliform Event Sample

In order to evaluate the fate of fecal coliform in the Smith Mountain Lake watershed and the lake, a rainfall event sample was planned and accomplished on July 12th-16th, 1999. Sampling began on the morning of July 12th about 2 hours after the rainfall started and continued for 96 hours at regular intervals at six different sites.

Sample Sites: The six sites include watershed sites and lake sites.

1. Maggoddee Creek Site: a tributary of the Blackwater River primarily drains forested and agricultural land including dairy cattle pastures in Franklin County. The site was not far from the US 122 bridge crossing of Maggoddee Creek and less than 1/4 mile from the Blackwater River.

2. Blackwater River Crossing Site: a road crossing through water of the Blackwater River less than a mile from the Maggoddee Creek tributary. The Blackwater River primarily drains forested and agricultural land in Franklin County.

3. Blackwater River Bridge Site: at the SR 834 bridge over the Blackwater River near the Riverside Exxon station in Franklin County.

4. Ponderosa Campground Cove Site: at the campground cove which is on a bend of the Blackwater River where debris collects when rain and overland flow pushes the debris into to the river. This would be considered a lake site in Franklin County Blackwater Channel.

5. 4 H Center Site 1: a lake site on the Blackwater Channel at the site of the dock and the gazebo on the 4H Center lakefront in Franklin County.

6. 4H Center Site 2: a lake site down the Blackwater Channel from the 4H Center Site 1.

Methods: The water samples were taken at each site with a polyethylene bottle attached to a long pole and stretched out to the deepest flow of the water at that site. The bottle was rinsed with river water three times then filled, capped and stored in ice until transported back to the lab (less than 6 hours). For the first 6 hours (0-6 hours) samples were taken every hour, then every 2 hours for the next 6 hours (6-12 hours), every 4-5 hours for the next 36 hours (12-48 hours) and every 24 hours for the next 48 hours (48-96 hours). The samples were processed in the lab for fecal coliform enumeration and total suspended particulates using standard methods (APHA).

The fecal coliform enumeration method used was the membrane filtration of 100 mL of sample water and using m-fecal coliform media incubated 44.5 degrees Celsius and the blue colonies counted after 18-24 hours. Total suspended particulate matter (TSP) was determined by filtering 100mL of sample water though a glass fiber filter, drying and weighing the filter before and after filtration.

Results:

1. The watershed sample sites (sites 1-3) showed significantly greater fecal coliform counts than the lake sample sites (sites 4-6) throughout the 96-hour sample period (Figure 18).

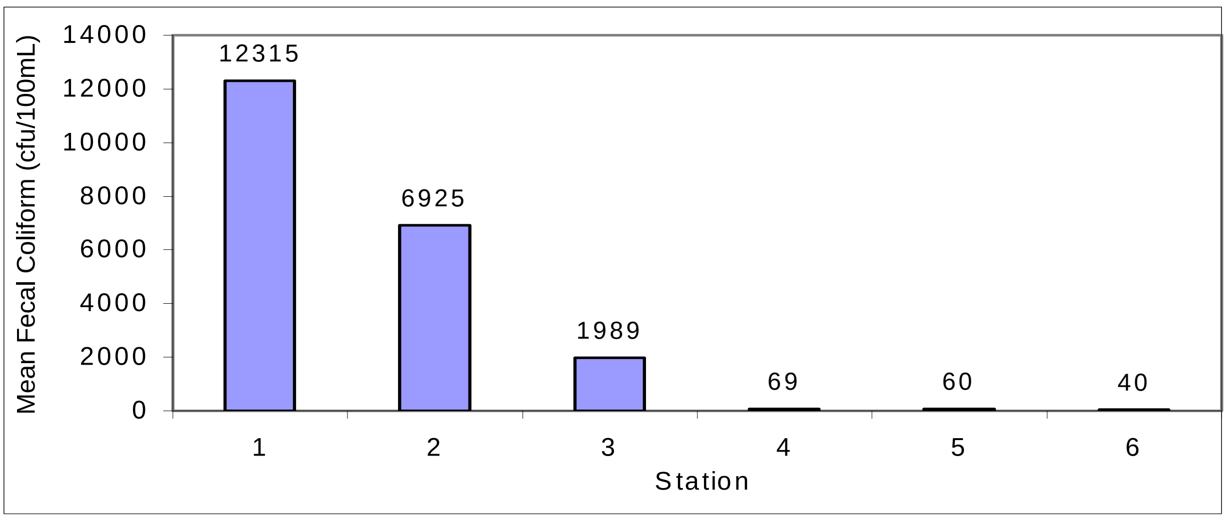


Figure 18. Smith Mountain Lake rainfall event samples, July 12-16, 1999 at six sites in the watershed and lake for 96 hours after the rainfall began.
(Site 1 is Maggoddee Creek, Site 2 is Blackwater River crossing, Site 3 is Blackwater River Bridge, Site 4 is Ponderosa Campground cove, Site 5 is 4H Center Gazebo, and Site 6 is 4H Center at picnic shelter.)

2. The maximum count for each site came at different times, such as: (See Figures19 A-F)

Site 1 Maggoddee Creek at 18 hours, a count of 57,100 cfus

Site 2 Blackwater Crossing at 19 hours, a count of 38,400 cfus

Site 3 Blackwater Bridge at 27 hours, a count of 4,900 cfus

Site 4 Ponderosa Cove at 15 hours, a count of 720 cfus

Site 5 4H Site 1 at 15 hours, a count of 262 cfus

Site 6 4H Site 2 at 1 hour and 35 hours, counts of 168 and 160 cfus, respectively

3. The lag time of the fecal coliforms moving down the river is evident in the first three sample sites, but is not obvious in the lake sample sites. This may be due to the influence of other inflows, such as overland flow, to the lake sites from the rainfall. (See Figures 19 A, B, &C)

4. The decrease in the fecal coliform counts moving down from the tributary of Maggoddee Creek to the 4H center sites indicates a dilution effect and a failure to thrive. (See Figures 19A-F) The ambient physical and chemical properties of the lake are low carbon concentration and lower mean temperature than shallower streams. These conditions are not optimal for the growth of bacteria like fecal coliforms that live in the intestinal tract of mammals.

5. The high numbers of counts of fecal coliforms in Sites 1-3 do exceed the Department of Health standards for potable water throughout the sample time (Figure 19 A, B & C).

6. Ponderosa Campground and the 4-H Site 1 samples exceeded the Department of Health Standard only once at the peak count at the 15 hours sample time (720 and 262 cfus), but were below the standard the rest of the sample period.

7. The 4-H Site 2 never exceeded the Department of Health standard.

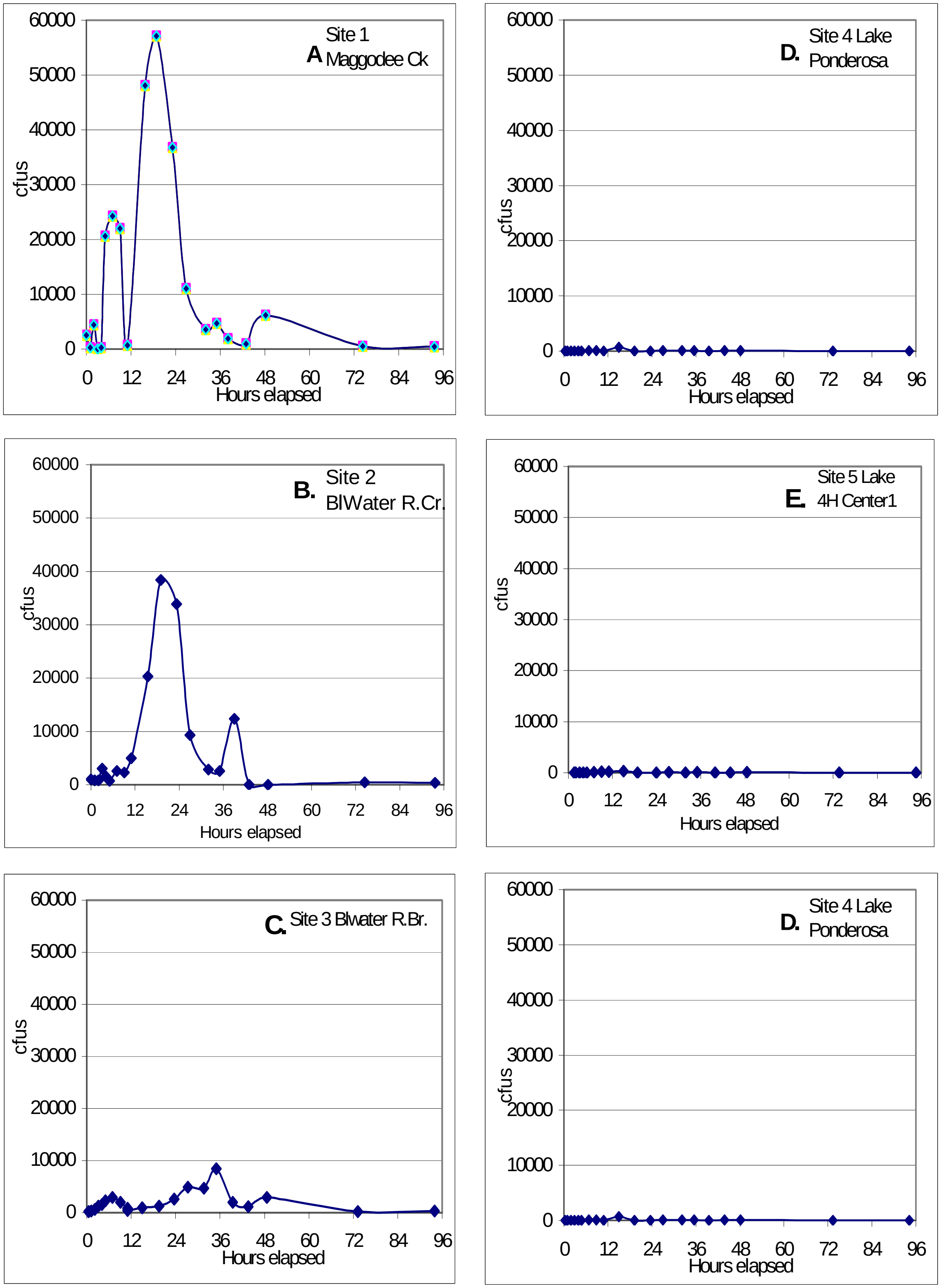


Figure 19. Fecal coliform counts (cfus) at six stations sampled from July 12-16, 1999 in the Smith Mountain Lake watershed after a rain event began.

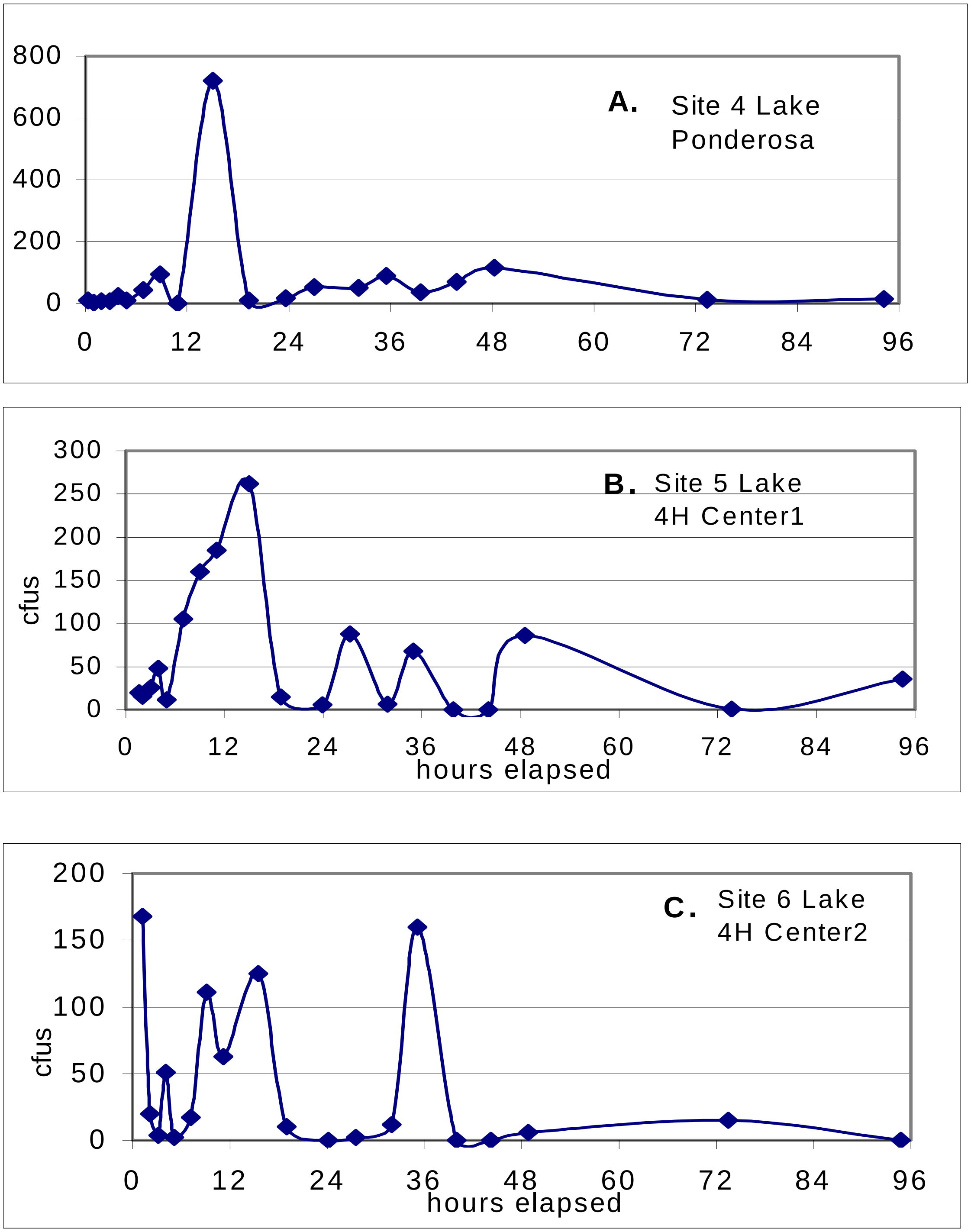


Figure 20. **Expanded scale graphs for Sites 4-6 on Smith Mountain Lake for the rain event sample on July 12-16, 1999.**
Note the different scales on each figure.

8. Fecal coliform counts and total suspended particulates (TSP) showed a significant correlation (R^2= 0.62, α=0.05) at the sample sites sampled during the rain fall event sample July 12-16, 1999. This may suggest that the fecal coliforms are being carried into the water on the soil particles (Figure 21).

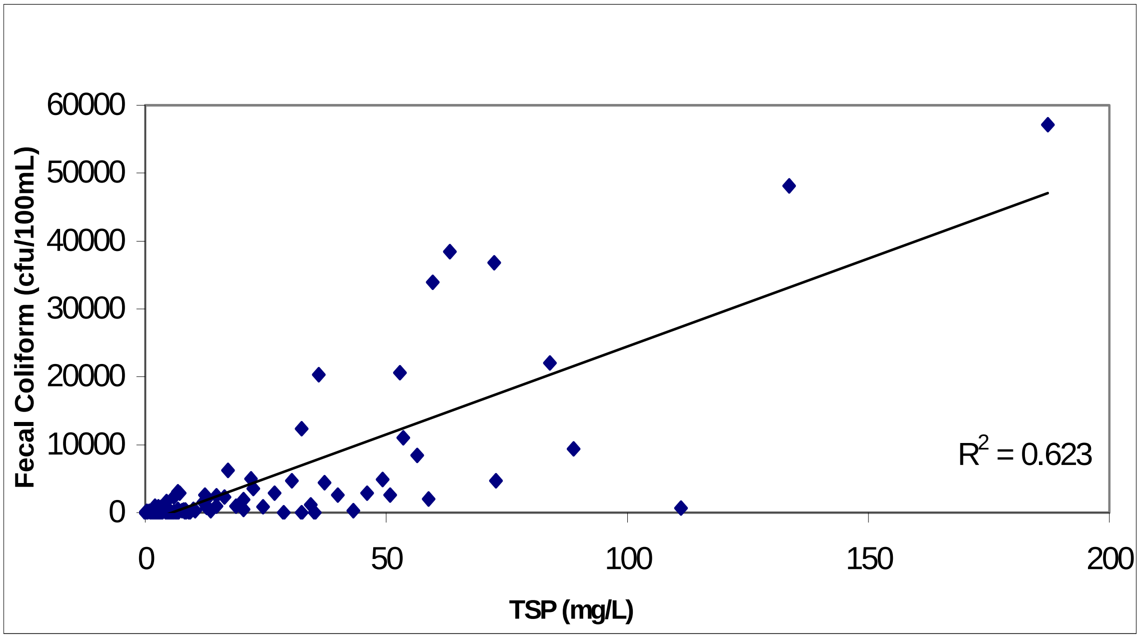


Figure 21. **Fecal coliforms versus total suspended particulates from samples collected in the rain event sample in the Smith Mountain Lake watershed on July 12-16, 1999.**

6. WATER QUALITY TRENDS

6.1 Water Quality Trends by Zone

In studying Smith Mountain Lake over the last thirteen years, attempts to describe the lake as a single unit have been stymied because of the broad differences between the upper reaches of the lake and the lower reaches nearer the dam. As a result, water quality is now being assessed in zones based on the distance to the dam. The evaluation of water quality based on zones provides some interesting suggestions about multiple uses of the lake. For example fishing would be best in those zones that have greater nutrient enrichment and water used for potable water to produce drinking water would be better in those zones with lower nutrient enrichment.

The lake sample sites are divided into zones based on the site's distance from the dam:

Zone 1 = 0-5 miles	Zone 4 = 15-20 miles
Zone 2 = 5-10 miles	Zone 5 = 20-25 miles
Zone 3 = 10-15 miles	Zone 6 = 25 + miles

The data do not show much in the way of trends in a comparison of the thirteen years' worth of data that has been collected. It should be noted that Zone 5 has only five to seven years' worth of data and Zone 6 only has three to seven years' worth of data.

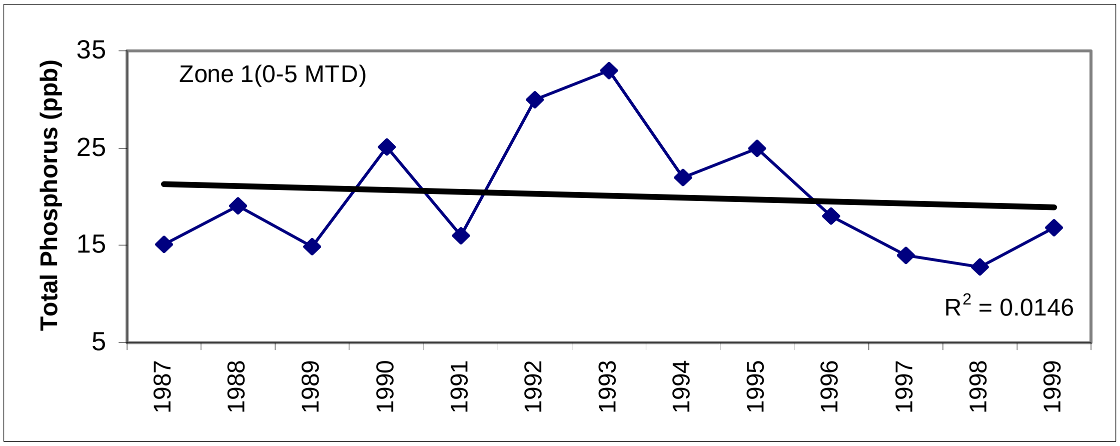
In Figure 22 no significant trend in total phosphorus concentration over the thirteen-year period in any zone is noted. However, in 1992 in Zone 4 (15-20mi) a high concentration of total phosphorus was found, which appears to show up the next year (1993) in Zones 1, 2 and 3 perhaps indicating a movement of phosphorus downstream. All zones show a high total phosphorus concentration in 1995. All zones except for six show a higher total phosphorus concentration in 1999 than in 1998, which high level is unexpected because of the low rainfall and therefore low runoff in 1999.

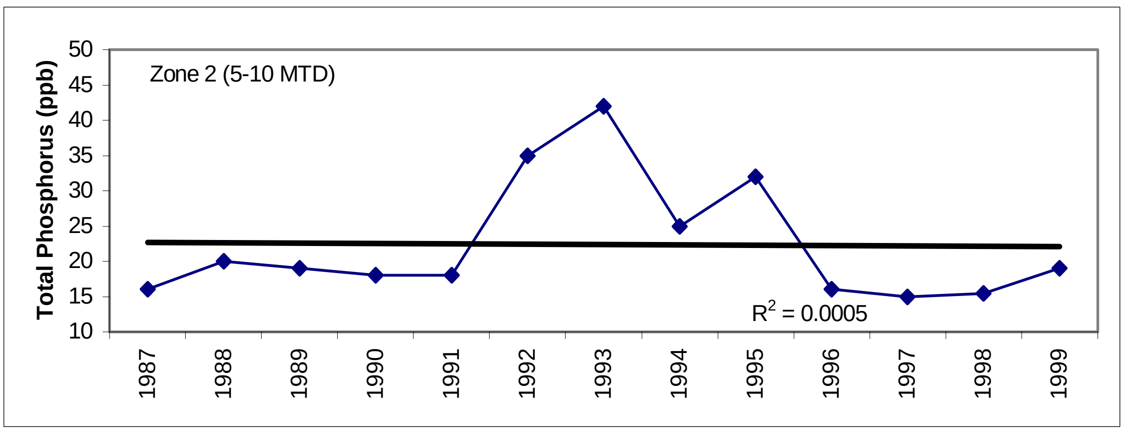
In Figure 23 chlorophyll-*a* shows no significant change in concentration from Zones 1, 2, 3 and 5 over the thirteen years of data collection. Zone 4 shows a slightly significant decrease over the years with a significant low chlorophyll-*a* concentration 1n 1996. Zones 1, 2, 3 and 4 show a high concentration in 1992, while Zone 4 also shows a high concentration in 1993. Zone 5 shows the highest concentration in 1998. An interesting point in 1996 is that in Zone 1 (0-5mi) chlorophyll-*a* is at a high point while Zone 4 shows a lower concentration in chlorophyll-*a* than in most other years. Zones 2 & 6 show a higher concentration of chlorophyll-*a* in 1999 while the other zones show a lower concentration in 1999.

The Secchi depth (Figure 24) means in all zones show no significant trend of increasing or decreasing over the thirteen years; however, zones 1, 2 and 3 (10-15mi) show a slight increase in water clarity over the thirteen years. In 1999 the Secchi depth went down in zones 1, 2, 5 and 6 and up in zones 3 and 4.

It should be noted that the later years' (especially 1995-1999) data is based on more sample sites and broader coverage of the lake. Some of these trends may reflect the sample size difference (number of sites) and improved coverage of the lake.

When comparing all three parameters' trends (Figure 25) by zone, a significant increase in total phosphorus and chlorophyll-*a* concentrations and a significant decrease in Secchi depth is seen, all indicating lower water quality in the upper main channels of Smith Mountain Lake. This finding has been reported in many previous reports as all three parameters were plotted versus "Miles to the Dam". This finding gives further credence to the division into zones of the lake for water quality evaluations.





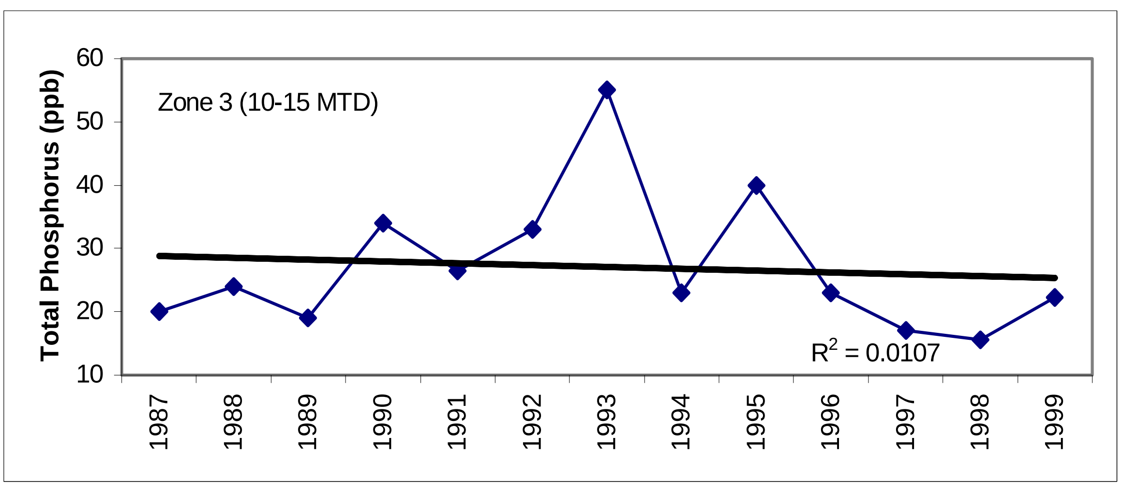


Figure 22. **Average annual total phosphorus concentration by zone in Smith Mountain Lake.**

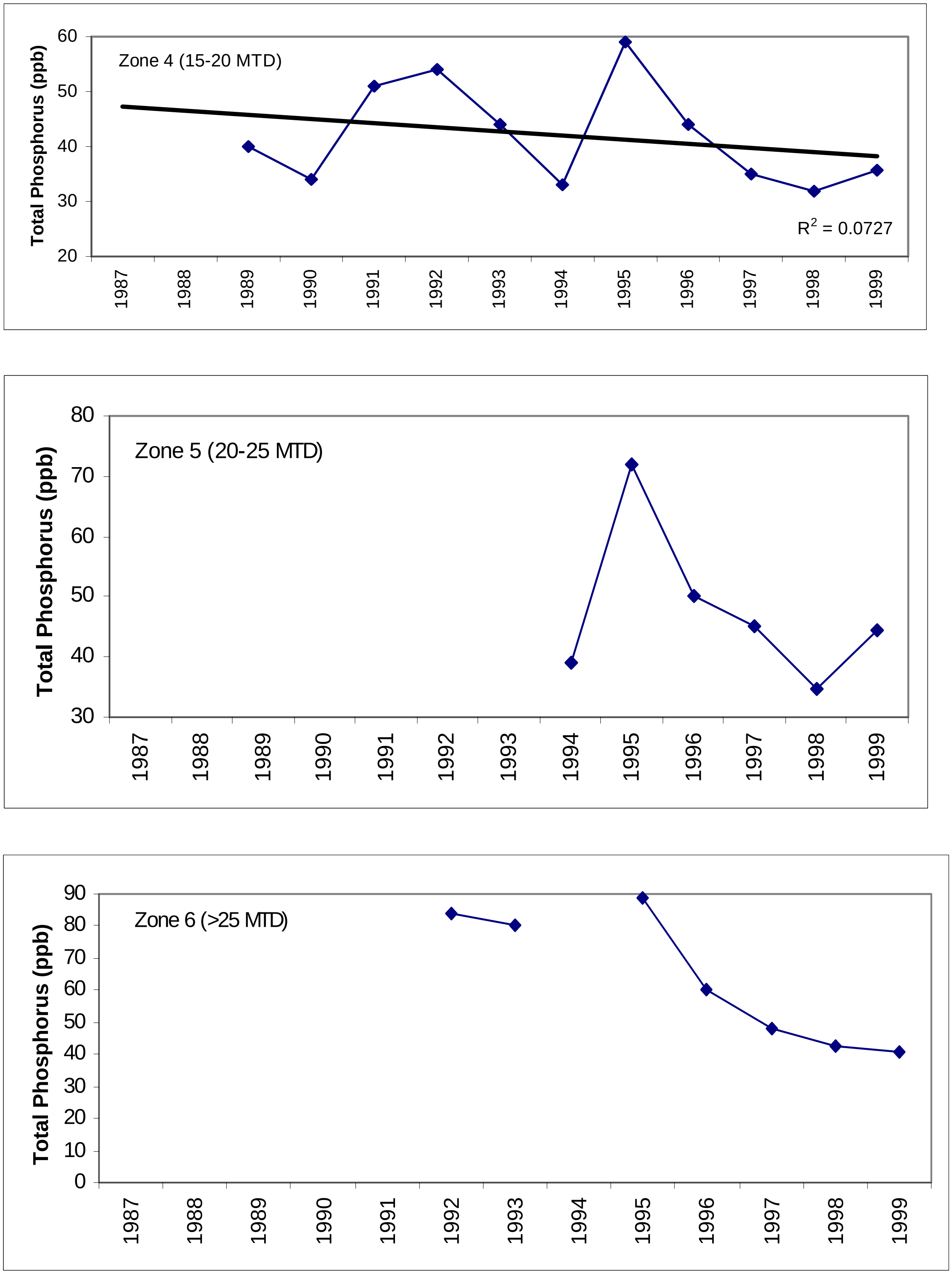


Figure 22. **Average annual total phosphorus concentration by zone in Smith Mountain Lake. (cont.)**

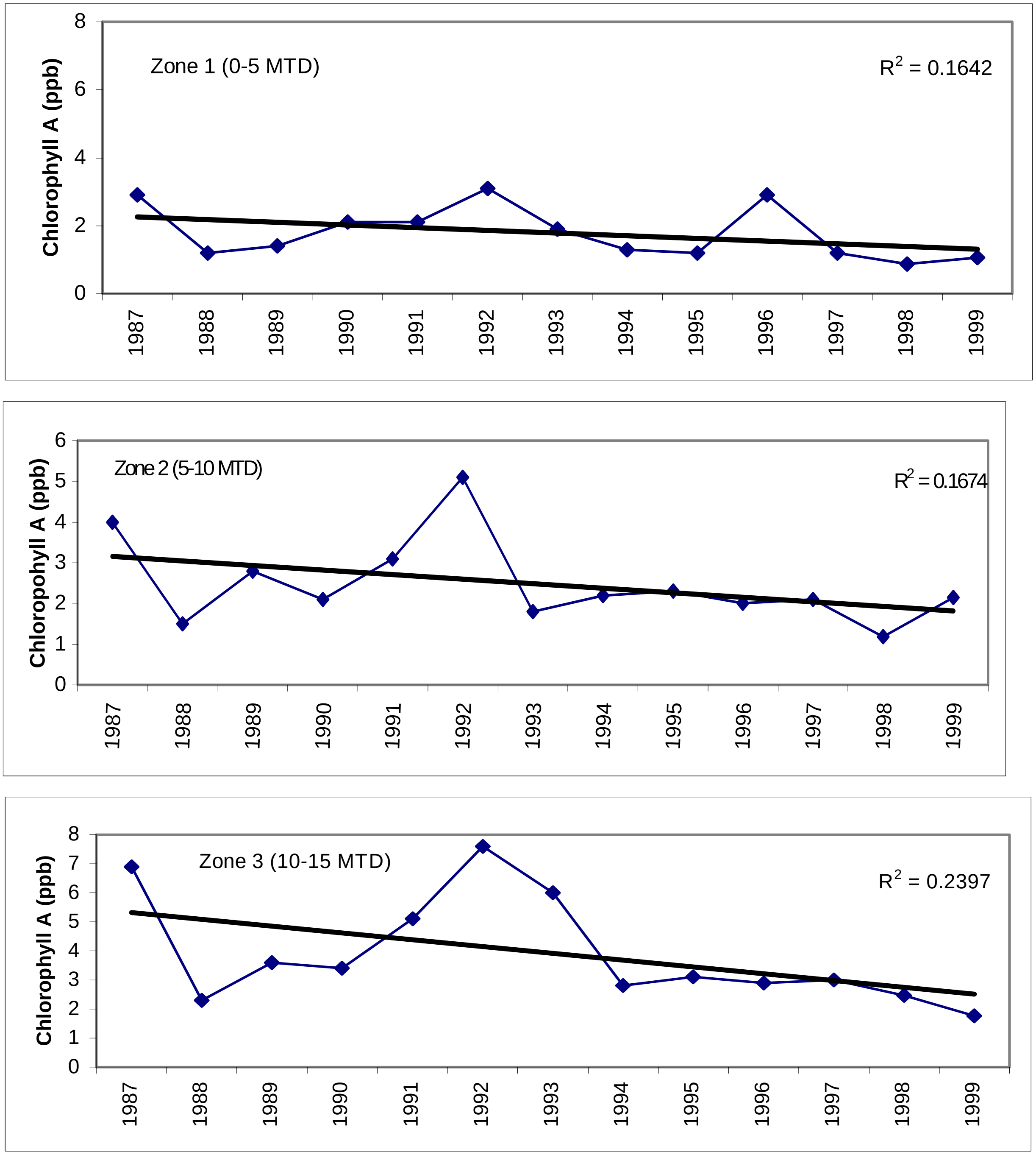
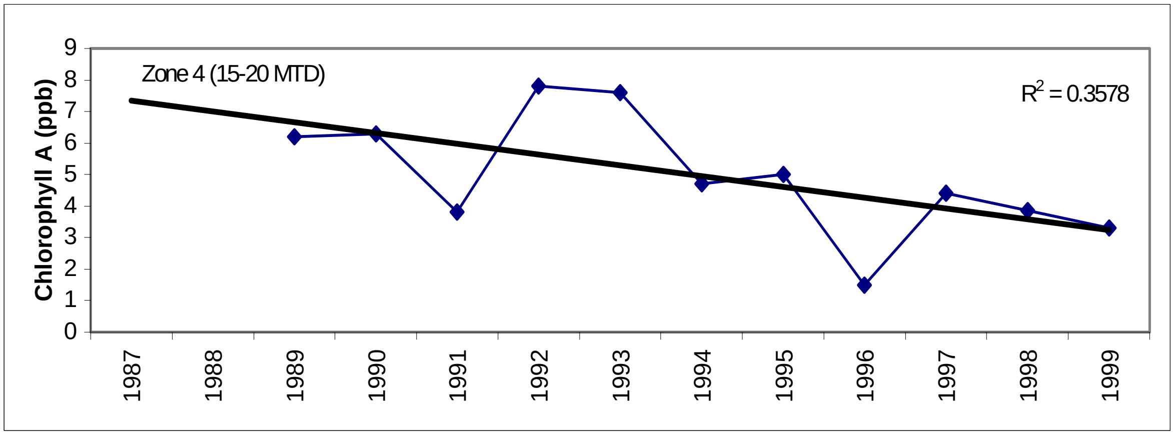
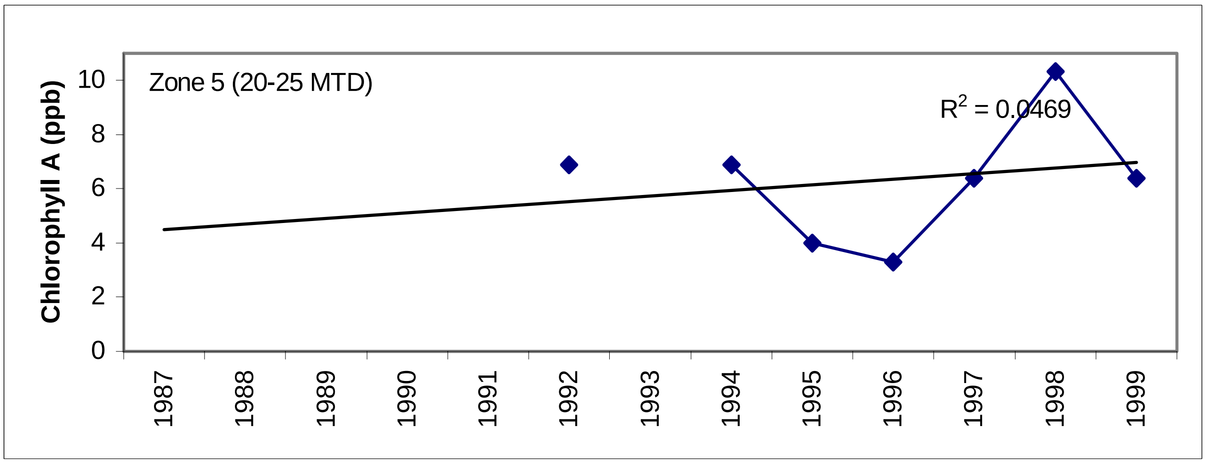


Figure 23. Average annual chlorophyll-*a* concentration by zone in Smith Mountain Lake.





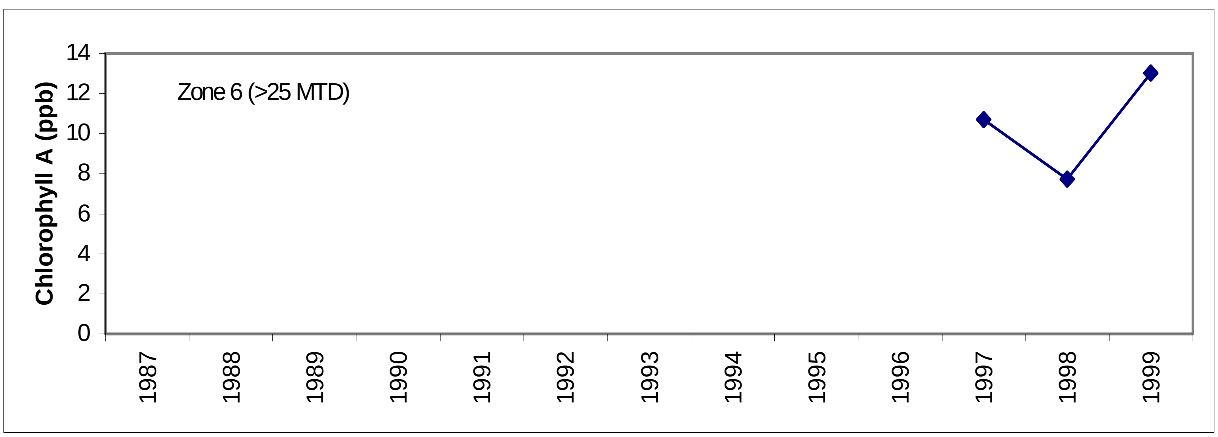
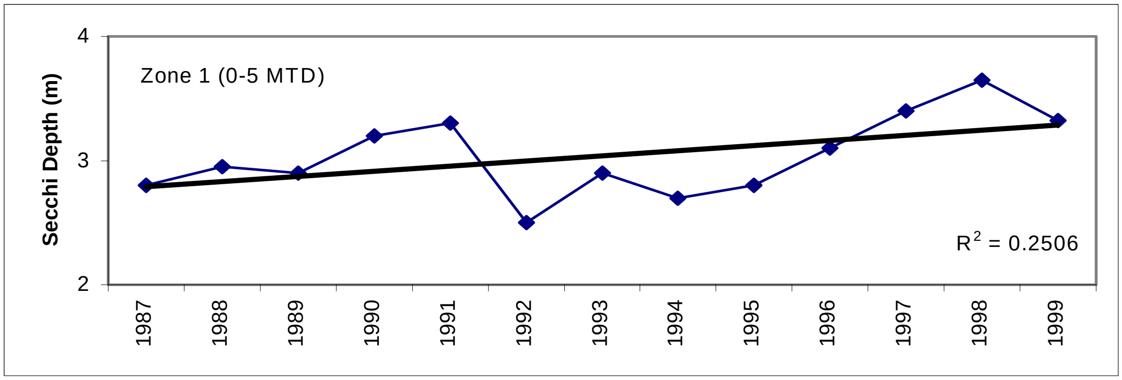
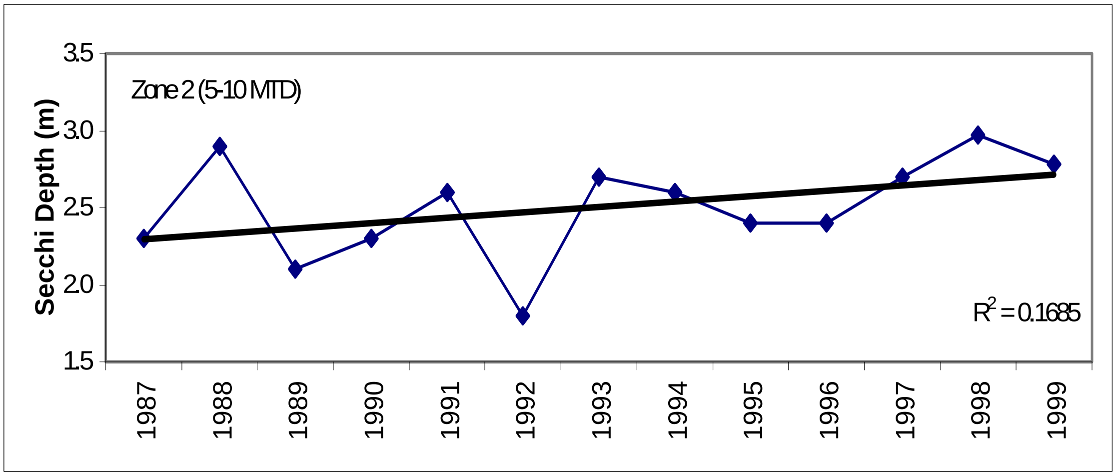


Figure 23. Average annual chlorophyll-*a* concentration by zone in Smith Mountain Lake. (cont.)





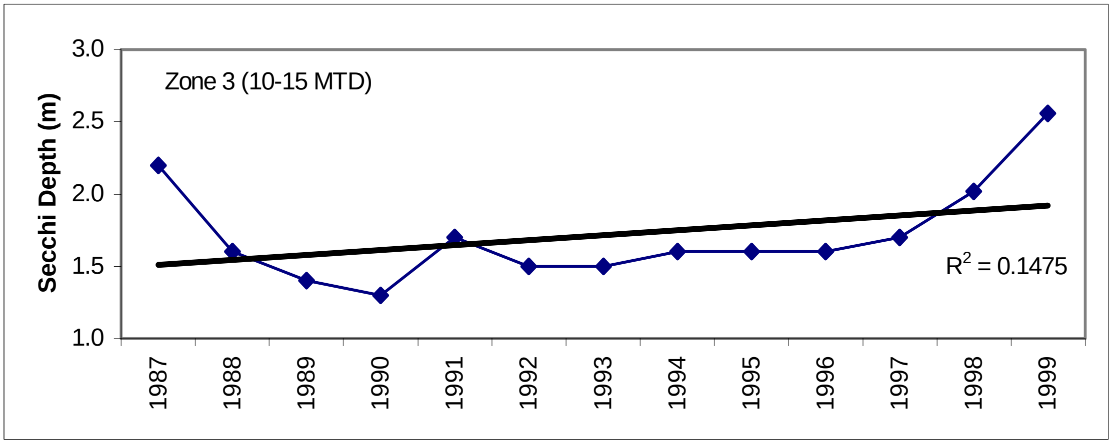
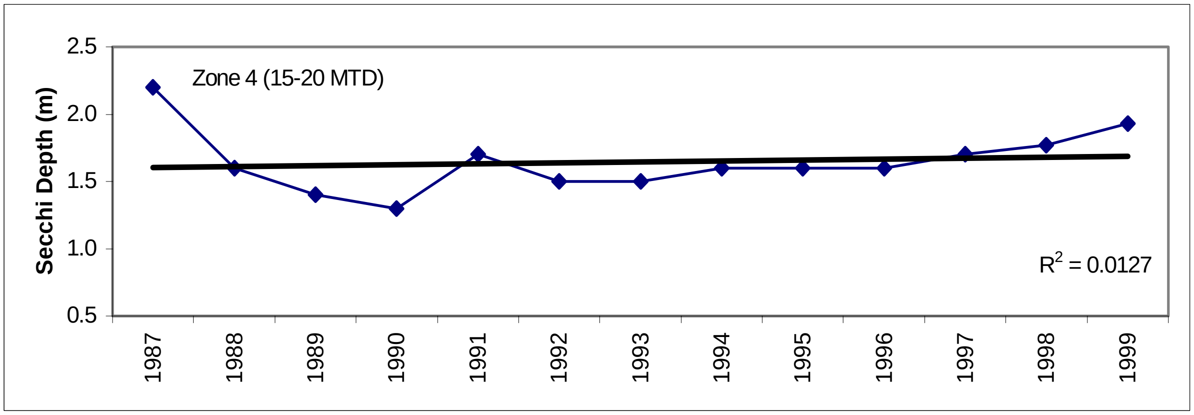
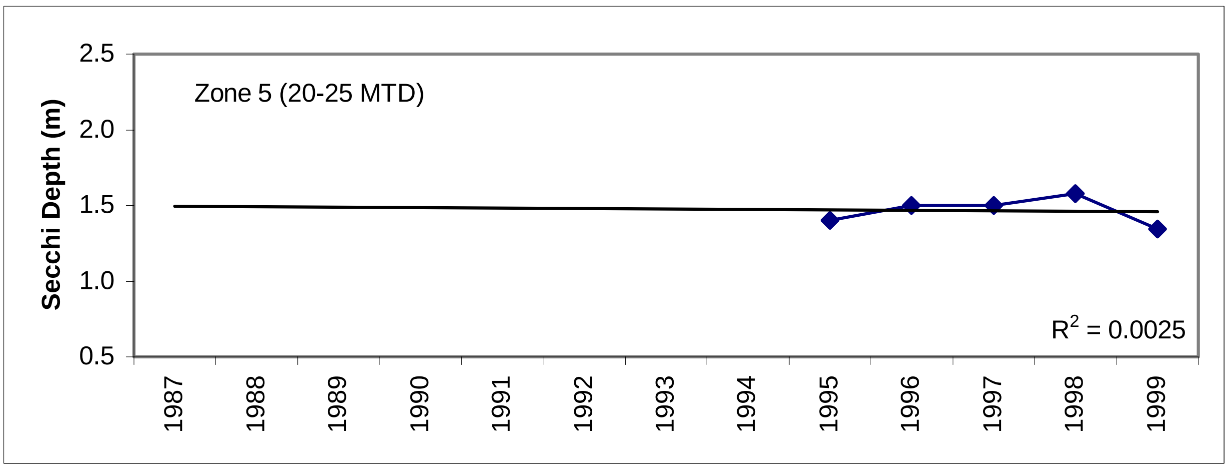


Figure 24. Average annual Secchi depth for zones in Smith Mountain Lake.





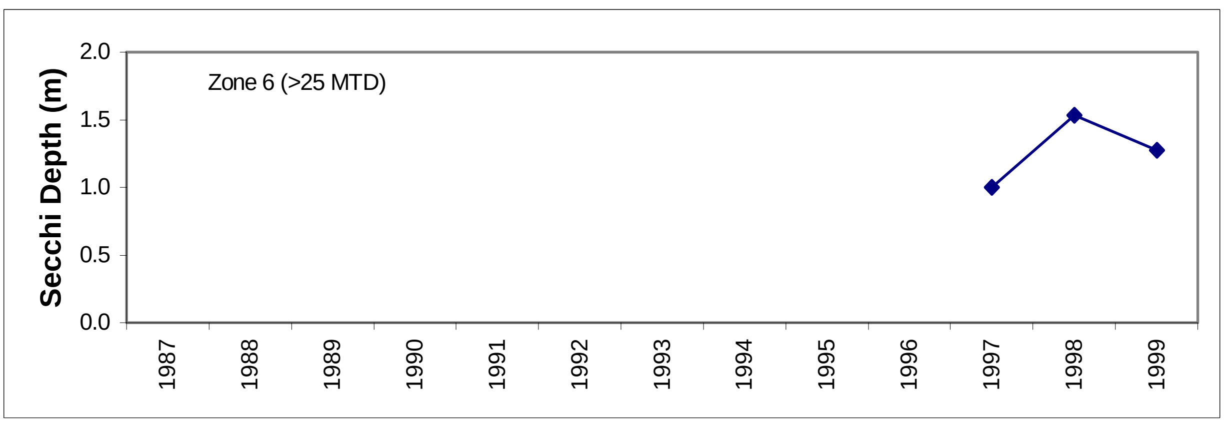


Figure 24. Average annual Secchi depth for zones in Smith Mountain Lake. (cont.)

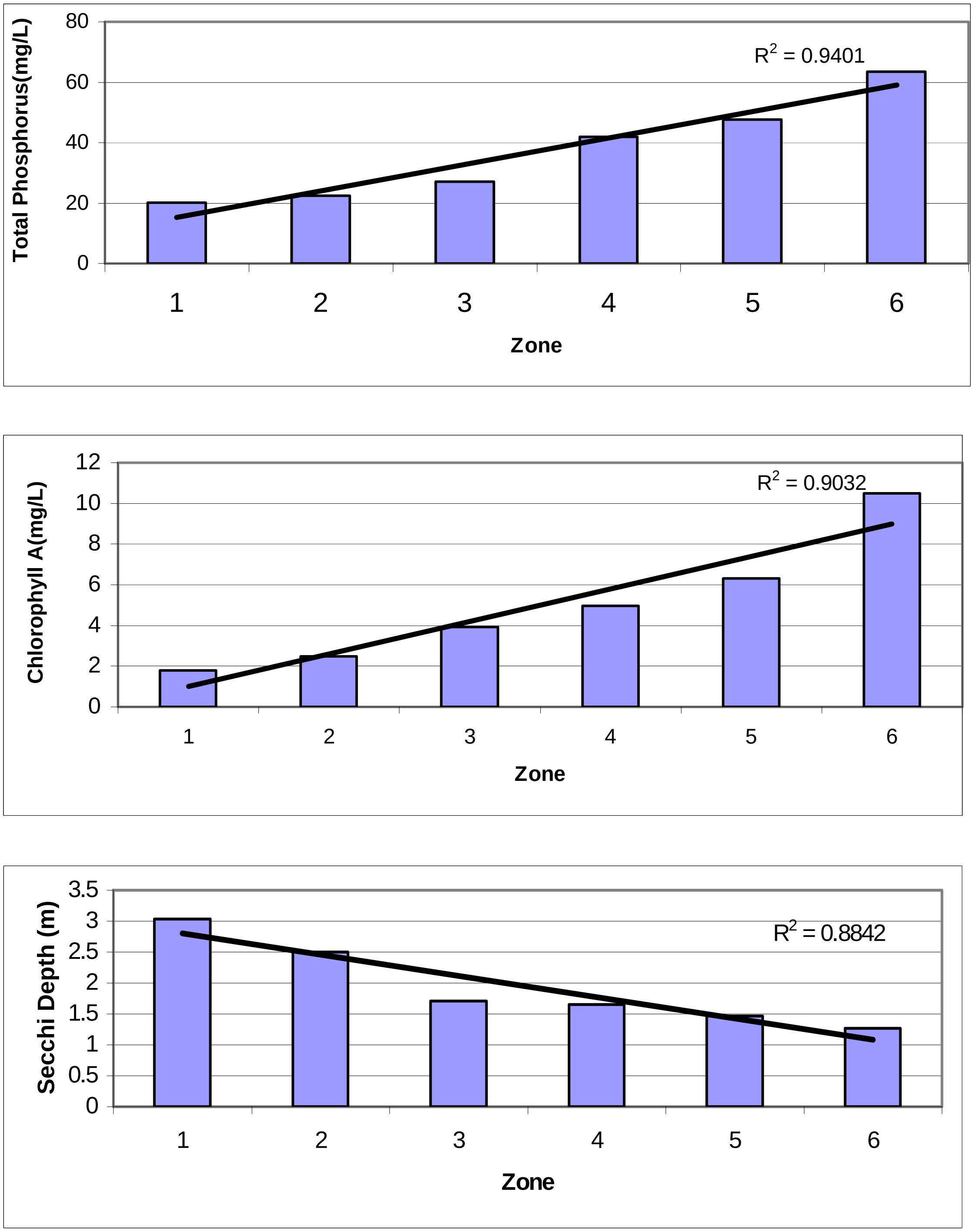


Figure 25. **Average parameter value by zone summed over years 1987-1999.**

6.2 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 volunteer 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 6 shows one such effort (Note that the relationships are for northern temperate lakes and will not represent southeastern lakes as well).

Table 6. 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 diminishes open water surface area.

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 filtered from lake water samples and measuring its concentration. Table 7 shows the trophic status delineation 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.

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, which 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.

Table 7. **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

One of the best-known trophic state indices is the Carlson Trophic State Index, TSI, after the researcher who developed it. This index is used to help interpret the water quality data collected on Smith Mountain Lake. The Carlson TSI may be calculated from total phosphorus concentration (TP), chlorophyll-*a* concentration (CHA), or Secchi disk depth (SEC). 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:

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

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

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

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

Another useful aspect of the trophic state index is in comparing the stations being monitored. In Figure 26, the combined trophic state index for each station has been plotted as a function of its distance from the dam and the result demonstrates again the trend toward improved water quality near the dam.

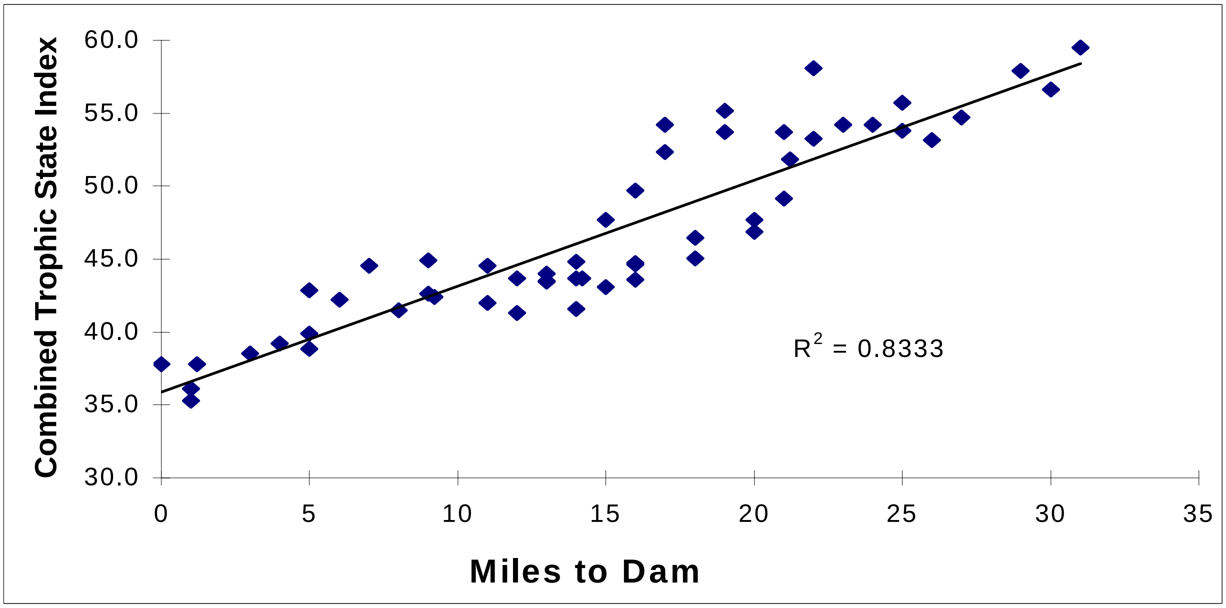


Figure 26. Combined Trophic State Index as a function of distance from dam.

Table 8 gives summary information from the TSI for the past three years. In 1999, the average TSI along with minimum and maximum values increased very slightly while the correlation coefficient decreased slightly. It is also interesting to note that, while the correlation coefficient decreased for each parameter plotted as average station value versus distance from the dam, the correlation coefficient for the combined TSI continued to give a highly significant correlation.

Table 8. **Combined Trophic State Index summary for 1997 - 1999.**

Year	**Avg Combined TSI**	**TSI Range**	**R^2 (TSI vs MTD)**
1997	47.0	36.7 - 56.3	0.867
1998	45.6	35.1 - 56.3	0.885
1999	46.7	35.3 - 59.5	0.833

Table 9 gives the monitoring stations ordered according to the combined TSI. For each station, especially those with high TSI-C values, it is useful to look at TSIs calculated on the basis of total phosphorus, chlorophyll-*a* or Secchi depth to see which parameter(s) is most affecting the value of the combined trophic state index.

Table 9. **Monitoring stations arranged in order of Combined Trophic State Index.**

station	miles to dar	TP	CHA (ppb)	SD (m)	miles to dar	TSI-C
M1	1	13.7	0.4	3.4	1	35.3
CM1	1	10.8	0.6	3.0	1	36.1
M0	0	24.3	0.4	3.3	0	37.8
CM1.2	1.2	13.8	0.7	3.0	1.2	37.8
M3	3	21.0	0.6	3.7	3	38.5
M5	5	27.9	0.4	3.5	5	38.8
C4	4	11.7	1.9	3.7	4	39.2
C5	5	12.7	1.7	3.2	5	39.9
B12	12	17.1	1.5	3.0	12	41.3
CR8	8	12.3	2.4	2.9	8	41.5
G14	14	17.2	1.5	2.8	14	41.6
R11	11	16.4	1.9	2.9	11	42.0
C6	6	14.0	2.0	2.5	6	42.2
CR9.2	9.2	13.6	2.5	2.7	9.2	42.4
CR9	9	20.1	1.5	2.6	9	42.6
CM5	5	15.6	2.9	3.1	5	42.8
G15	15	18.3	1.7	2.4	15	43.1
G13	13	31.1	0.9	2.5	13	43.4
CR13	13	16.8	2.3	2.5	13	43.5
G16	16	22.1	1.6	2.5	16	43.6
B14	14	18.5	2.1	2.5	14	43.7
G12	12	29.6	1.5	3.1	12	43.7
CR14.2	14.2	18.4	1.1	1.6	14.2	43.7
R13	13	19.5	2.3	2.6	13	44.0
CB11	11	36.7	1.7	3.5	11	44.5
R7	7	24.5	2.7	3.3	7	44.6
CB16	16	14.6	3.1	2.1	16	44.6
B16	16	16.3	2.7	2.1	16	44.7
R14	14	22.7	1.7	2.1	14	44.8
R9	9	29.6	1.8	2.7	9	44.9
G18	18	25.4	1.7	2.3	18	45.0
B18	18	39.8	1.3	2.2	18	46.5
B20	20	24.0	2.5	1.9	20	46.9
R15	15	26.4	2.8	1.9	15	47.7
CB20	20	25.7	2.8	1.8	20	47.7
CR21	21	36.6	1.7	1.3	21	49.1
CR16	16	36.0	2.8	1.7	16	49.7
CR21.2	21.2	48.0	2.3	1.3	21.2	51.8
R17	17	49.6	4.9	2.0	17	52.3
CR26	26	26.4	9.2	1.3	26	53.2
CR22	22	40.7	5.7	1.5	22	53.3
R21	21	56.5	3.8	1.4	21	53.7
CR19	19	47.2	6.1	1.6	19	53.7
R25	25	34.7	7.8	1.4	25	53.8
CR24	24	32.0	8.6	1.3	24	54.2
CR17	17	60.0	4.0	1.4	17	54.2
R23	23	37.9	8.4	1.5	23	54.2
R27	27	36.0	10.6	1.5	27	54.7

7. 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.

7.1 Calibration Data for Total Phosphorus and Nitrate

7.1.1 Total Phosphorus

Each week a set of standards is prepared so that a calibration curve can be constructed to determine the relationship between total phosphorus concentration in a sample and its absorption of light at 700nm. Table 10 summarizes the calibration data. The slope indicates the relationship between concentration and absorption and was very consistent from week to week. This gives us 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, which, along with the extra handling and manipulation, lead 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 standards were prepared and the stability of the instrument.

Table 10. **Summary of 1999 calibration data for total phosphorus.**

Sampling Period	Slope	Intercept	R^2
1	0.0026	0.083	0.9962
2	0.0024	0.016	0.9991
3	0.0024	0.014	0.9994
4	0.0021	0.011	0.9923
5	0.0023	0.001	0.9807
6	0.0018	0.022	0.9755
Avg	0.0023	0.0250	0.9910

7.1.2 Nitrate

This was the second season in which volunteer monitor samples were analyzed for nitrate. The calibration data for nitrate is displayed in Table 11 in the same manner that calibration data was displayed for total phosphorus in Table 10. The correlation coefficient for nitrate is not as high as for total phosphorus and that is inherent to the method. The reduction of nitrate to nitrite is accomplished by shaking the samples with powdered cadmium and the conversion efficiency limits the precision of the method. The average correlation coefficient is still well above 0.9.

Table 11. **Summary of 1999 calibration data for nitrate.**

Sampling Period	Slope	Intercept	R^2
1	0.0008	0.1936	0.9571
2	0.0009	0.1945	0.9387
3	0.0007	0.1245	0.8996
4	0.0006	0.0516	0.8689
5	0.0011	0.0237	0.9764
6	0.0011	0.0972	0.9877
Avg	0.0009	0.1140	0.9377

7.2 Field Blanks and Surrogate Samples for Total Phosphorus and Nitrate

The QA/QC plan for the project is also to include field blanks and surrogate samples. The field blanks and surrogate samples are 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 lakewater samples. This is to examine the effect 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 absorption of phosphate on 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 if phosphorus concentrations are not known before they have been analyzed. Designating a particular sample bottle for each site and reusing that bottle each week has minimized this source of contamination. At the beginning of this season a sheet was prepared giving the concentrations for surrogate samples in order to assure a full range of concentrations were included. Unfortunately, there was a miscommunication and, although the surrogates may have been made correctly, the concentrations were never recorded in the lab notebook and the differences between measured concentrations and target concentrations could not be determined. This was a serious oversight that should have been identified early on, but it was not. It is regrettable that this important information is not available but it does not invalidate the results because the data on lab blanks and calibration standards to validate the laboratory procedures is available and it compares favorably with past years. The surrogates and field blanks, as described above, are to insure that sample collection, storage and handling do not add or remove phosphorus to the collected samples. These procedures have been checked annually for more than 10 years with acceptable results and there is no reason to think that the situation has changed this past summer. On the other hand, we do realize that this is a serious problem and are taking steps to assure that it does not happen again.

*7.3 QA/QC for Chlorophyll-*a

Calibration of the fluorimeter used to determine chlorophyll continues to be difficult but the procedure developed last year seems to give good results. The fluorimeter gives very consistent readings from day to day and week-to-week for a given standard and it is believed that the instrument is quite reliable. Chlorophyll-*a* standards are unstable and a stock standard must be prepared each year. Pure chlorophyll-*a* was obtained from Sigma Chemical and a stock standard prepared and diluted to approximately 200 ppb. The absorption measured three times at 664 nm.

The literature value (APHA, 1995) for absorbency (ε_{664} = 87.67 L/g$*$cm) was used to calculate the concentration using Beer's Law:

Absorbance = adsorptivity x pathlength x concentration

The actual concentration of the chlorophyll-*a* standard was found to be 174 ppb and this standard was diluted by a factor of 10 to give the working standards used to calibrate the fluorimeter. The fluorescence of the standard was measured three times and the average was 18.5 fluorescence units. The calibration factor used to convert fluorescence reading to chlorophyll-*a* concentration is derived from the relationship:

Ca = CHA(ppb)/R

Where: Ca is the calibration factor,
CHA is the concentration determined spectrophotometrically,
R is the fluorescence reading.

The calibration factor was determined to be 0.94 and this factor is modified by multiplying by the ratio, 15/100, which is the dilution factor that accounts for the chlorophyll-*a* in 100 mL of lake water being extracted into 15 mL of 95% acetone. This gives a final value of 0.14 and is the same as that determined in 1998.

7.4 QA/QC for 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.

7.5 QA/QC for Fecal Coliforms

Three different quality control procedures were followed in 1998 to evaluate the quality of our fecal coliform analysis in 1998. The most basic was the inclusion of uninoculated plates (controls) with the same m-Fecal coliform media, filters and absorbent pads in each sample processing. These plates were incubated with the Smith Mountain Lake water sample filters, media and absorbent pads at 44.5 ^{o}C. All uninoculated controls for all sample dates counted 20-24hours later were found to have zero colony forming units (0 cfus).

A second quality control procedure followed was the inoculation of a known bacterial culture of *Escherichia coli* received from Carolina Biological Supply in a sterile tap water solution, and subsequent filtration of this *Escherichia coli* and water solution on the August 15th sample date, following the identical procedures used with the Smith Mountain Lake water samples. The results indicated convincingly that the blue colonies that were counted on the m-Fecal coliform media plates were fecal coliforms.

The third procedure used in 1998 was the further species identification of a number of our counted characteristically blue colonies on our first sample date June 2nd, 1998. These 121 different colonies of gram-negative rod shaped bacteria were identified to species and strain using the API 20E system provided by Analytab Products (Plainview, NJ). All 121 colonies were species of fecal coliforms, and 112 of these colonies were identified as *Escherichia coli*.

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 12 indicates the sampling efficiency data for 1999 and Table 13 presents the collection efficiencies from 1992 through 1999. The figures show that the volunteer monitors are very conscientious about sample collection. Advanced monitors collected 95% of the samples possible in 1999 and 89% of the samples possible for basic monitors. This sampling efficiency is remarkably high for any monitoring program, voluntary or otherwise. 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 and in 1997 the sampling efficiencies were back up to the levels that they had been 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 12. Sampling efficiency data for 1999.

sample type	monitoring stations	possible samples	samples collected	%effeciency
CHA/NO3/PO	54	324	309	95%
secchi	76	456	405	89%

Table 13. Comparison of sampling efficiencies for 1992-1999.

Sampling Efficiency (%)

	1992	1993	1994	1995	1996	1997	1998	1999
Secchi Depth	90	80	93	75	92	95	96	89
Total Phosphorus	93	90	99	80	96	96	96	95
Chlorophyll-*a*	93	90	98	80	96	97	96	95
Nitrate	NA	NA	NA	NA	NA	99	96	95

9. CONCLUSIONS

1999 was another very busy year for the monitoring program and other activities related to water quality at Smith Mountain Lake. Nine students worked on water quality projects at Ferrum College over the summer. Two student interns took primary responsibility for the monitoring program and a third acted as the liaison with the Claytor Lake Program. Four students worked on the Marina Education Program, sponsored by the Virginia Department of Health and another worked on the Blackwater Riparian NPS Pollution Reduction Project sponsored by the Virginia Water Quality fund. The last student worked primarily for the Life Sciences Division but worked in several capacities in the Water Quality Lab.

The water quality parameters measured in Smith Mountain Lake indicate a slight decrease in water quality and a slight increase in nutrient enrichment. This would be expected in the natural aging of lakes and is not necessarily anthropomorphic in cause. The evaluation using mileage zones in the lake again provides much more useful information about the lake than the lake-wide measures. The zones further away from the dam are more eutrophic than the zones near the dam.

The fecal coliform observations in the lake were lower this year than in previous years, however the rain event sample indicated the significant influence of non point source run off on fecal coliform populations. However, the high input of fecal coliforms to the lake from non-point source runoff does not appear to greatly increase populations nor do they thrive in the lake.

In 2000 similar studies will continue, including the basic monitoring of nutrients and fecal coliform in the lake and nutrients in the tributaries. Another rain event sample will be conducted, this time in the Roanoke Channel of the lake and the shoreline reconnaissance project will be continued as a possible means of detecting water quality impacts from failing septic systems. A non-rain event intensive sampling will be taken on a busy cove of the lake at different times in an 8 hour period, at different sites and depths to evaluate the variation of fecal coliforms with time and space.

10. ACKNOWLEDGEMENTS

Thanks go out to all our volunteer monitors who once again made this program possible with their dedication and support. The Smith Mountain Lake Association again provided the much needed political and financial support. Suzanne Stoneman, Amy Hayes and Rea Prillaman were the student technicians this past summer, and they did a fine job. Their conscientiousness and hard work kept the monitoring program running smoothly, and everyone enjoyed their positive, friendly attitude. Assisting the student technicians were Jeff Hurst, Minh Nyguen, Scott Queen, Lisa Swain, and Lacey Biles who assisted the Smith Mountain Lake project when their other duties allowed. The rain event sample had much appreciated help from Dr. Bob Pohlad and Tim Pohlad-Thomas. We would also like to acknowledge the support and time of Mr. John Singer, the liaison with the SMLA, and offer him special thanks again this year for his boat and time used for fecal coliform sampling. The enthusiasm and leadership he brings to the program are wonderful. SMLA President Bill Telford and Past-President Jim Spitz have done a fine job of maintaining and building support for the program. Finally, we wish to thank the Smith Mountain Policy Advisory Board, Hilde Hussa (SMLPAB Executive Director), and Ferrum College for making space and equipment available at no cost to the project as a community service.

REFERENCES

American Public health Association. 1995 *Standard Methods for Examination of Water and Wastewater*,16th edition. Washington

Carlson, R.E. 1977. "A Trophic State Index for Lakes", *Limnol. Oceanog.* 22(2):361-369.

Downie, N.M. and R.W. Heath. 1974. *Basic Statistical Methods* p.314, Harper and Row, Publishers, New York, NY.

Johnson, David M. and Carolyn L. Thomas. 1993 & 1995. *Smith Mountain Lake Water Quality Volunteer Monitoring Program: 1993 and 1995 Annual Reports* published by Ferrum College

Johnson, David M. and Carolyn L. Thomas. 1990. *Smith Mountain Lake Water Quality Monitoring and Public Education Program.* Final Report to Virginia Environmental Endowment, Grant # 86-27 and 88-20. 123pp.

Johnson, David M. and John W. Leffler. 1987. *An Assessment of the Effects of Shoreline Landuse on the Water Quality of Smith Mountain Lake, Virginia* Final Report to Virginia Environmental Endowment, Grant 85-03. 39pp.

Ney, John. 1996. “Oligotrophication and Its Discontents: Effects of Reduced Nutrient Loading on Reservoir Fisheries”, *American Fisheries Society Symposium* 16:285-295.

Reckhow, K.H. and S.C. Chapra. 1983. *Engineering Approaches to Lake Management, Vol. 1: Data Analysis and Empirical Modeling*, pp 189-193, Ann Arbor Science Book Publishers, Ann Arbor, MI.

Thomas, Carolyn L. and David M. Johnson. 1992a,b &1994. *Smith Mountain Lake Water Quality Volunteer Monitoring Program: 1990-91, 1992, 1994 Report.* Published by Ferrum College.

Thomas, Carolyn L. and David M. Johnson. 1988, 1992. *Training Manual for Smith Mountain Lake Lay Monitoring Program.* Published by Ferrum College, Ferrum, VA.

U.S. Environmental Protection Agency. 1974. "The Relationships of Phosphorus and Nitrogen to the Trophic State of Northeast and North-Central Lakes and Reservoirs", *National Eutrophication Paper No. 23*, U.S. EPA, Corvallis, Oregon.

APPENDIX

Table A1. 1999 Smith Mt. Lake monitoring stations with monitor names and station locations.

Station	Monitor	Latitude	Longitude	Site Number
B8	*no monitor 1999*			
B10	*no monitor 1999*			
B12	Chilton			
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
C4	Hill	79.572	37.056	8
C5	Hill	79.565	37.066	7
C6	Hill	79.568	37.082	6
CB11	Chilton			
CB16	Jamison	79.703	37.045	49
CB20	Franz	79.737	37.036	54
CM1	Rice	79.539	37.055	2
CM1.2	Rice	79.535	37.063	1
CM5	E. Anderson	79.587	37.047	9
CR8	E. Anderson	79.593	37.065	33
CR9	Hunt	79.606	37.077	21
CR9.2	Hunt	79.617	37.070	20
CR13	Kastner	79.642	37.099	28
CR14.2	P. 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
CR24	Blevins			
CR25	Blevins			
CR26	B. Dooley/Holgrave			
G12	Chilton			
G13	Felton	79.674	37.049	84
G 14	Wandelt/Dick	79.673	37.055	47
G15	Felton			
G16	Wandelt/Dick	79.688	37.062	48
G18	Wandelt/Dick	79.682	37.072	59
M0	Rice	79.538	37.043	3
M1	Rice	79.547	37.047	4
M3	Rice	79.564	37.041	5
M5	Rice	79.588	37.042	10
R7	E. Anderson	79.595	37.052	12
R9	Hunt	79.617	37.073	19
R11	E. Anderson	79.612	37.089	22
R13	Kastner	79.642	37.103	29
R14	P. 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
R21	Bray	79.707	37.155	70

Table A1. 1999 Smith Mt. Lake monitoring stations with monitor names and station locations. (cont.)

R23	Bogsrud	79.717	37.180	74
R25	Blevins			
R27	B. Dooley/Holgrave			
R29	B. Dooley/Holgrave	79.797	37.218	86
R30	Cundiff			
R31	Cundiff			
SCB8	Randa	79.599	37.026	38
SCB10	Randa	79.639	37.023	40
SCB11	Randa	79.632	37.017	24
SCB11.5	Randa	79.644	37.062	13
SB12	Thurman	79.664	37.040	42
SCB14	Thurman	79.683	37.031	51
SCB16	Thurman	79.693	37.034	46
SCM5	*no monitor 1999*	79.588	37.048	32
SCR7	*no monitor 1999*	79.585	37.061	11
SCR8	*no monitor 1999*	79.588	37.068	23
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	Hack	79.665	37.109	34
SCR14.2	Hack	79.679	37.105	91
SCR14.3	Hack	79.659	37.113	92
SCR15	Gerhardt	79.646	37.120	93
SCR17	Gerhardt	79.670	37.157	95
SCR17.1	*no monitor 1999*	79.677	37.158	61
SCR18	A. Anderson			
SCR19	A. Anderson			
SCR20	A. Anderson			
SCR22.3	*no monitor 1999*	79.707	37.171	73
SCR23.2	*no monitor 1999*	79.721	37.183	77
SCR24	*no monitor 1999*	79.724	37.197	78
T0(Gills)	Snoddy			
T21(Roanoke)	Faber			

Table A2. 1999 tributary stations.

Tributary Station Number	Stream Name
T0	Upper Gills Creek
T1	Maggodee Creek
T2	Lower 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
T21	Roanoke Channel below Back Creek

Table A3. 1999 total phosphorus data for Smith Mountain Lake.

station	period 1	period 2	period 3	period 4	period 5	period 6	station avg	station stdev
B12	28.8	14.0	23.3	4.3	17.6	14.4	17.1	7.7
B14	0.0	32.8	26.2	0.0	8.5	43.3	18.5	16.7
B16	2.3	17.8	27.9	6.2	21.5	22.2	16.3	9.1
B18	1.5	60.7	36.6	31.0	36.3	72.8	39.8	22.7
B20		32.8	32.9	23.3	31.1	0.0	24.0	12.5
B22	82.7	46.1	75.8	73.3	108.9	70.0	76.1	18.6
C4	16.2	19.0	16.2	7.6	11.1	0.0	11.7	6.4
C5	12.7	16.9	17.5	14.8	4.1	10.0	12.7	4.6
C6	18.5	16.9	23.3	6.2	7.2	12.2	14.0	6.1
CB11	141.2	18.2	17.5	11.9	10.2	21.1	36.7	46.9
CB16		18.2	25.8	9.0	11.5	8.3	14.6	6.6
CB20	37.3	29.0	34.5	27.1	26.3	0.0	25.7	12.2
CM1	15.8	18.6	13.3	2.9	5.4	8.9	10.8	5.6
CM1.2	21.2	14.0	27.5	1.9	9.3	8.9	13.8	8.4
CM5	14.2	14.8	1.2	2.9	8.9	51.7	15.6	16.9
CR8	28.1	13.6	13.7	5.2	5.9	7.2	12.3	7.8
CR9	27.7	12.5	16.6	11.0	11.1	41.7	20.1	11.2
CR9.2		11.1	21.6	10.0	12.8	12.2	13.6	4.2
CR13	25.8	19.0	27.0	19.5	8.0	1.7	16.8	9.2
CR14.2	24.2	20.3	18.3	19.0	3.7	25.0	18.4	7.0
CR16	31.9	36.5	27.9	43.8	25.9	50.0	36.0	8.6
CR17	41.5	51.5	44.1	47.6	92.0	83.3	60.0	19.9
CR19	33.5	39.0	30.8	61.4	71.1		47.2	16.1
CR21	38.8	50.3	48.3	45.7		0.0	36.6	18.7
CR21.2	46.2	62.3	48.3	55.7	68.0	7.2	48.0	19.7
CR22	76.2	36.5	41.6	40.5	31.5	17.8	40.7	17.7
CR24	48.5	32.3	48.7	32.9	24.6	5.0	32.0	14.9
CR25	55.4	31.9	35.8	42.9	45.9	18.9	38.5	11.5
CR26	50.0	28.6	24.1	33.8	22.0	0.0	26.4	14.9
G12	31.5	19.0	27.9	38.6	43.3	17.2	29.6	9.5
G13	71.5	24.8	16.2	23.3	29.3	21.1	31.1	18.5
G14	18.5	19.8	15.8	23.3	8.5	17.2	17.2	4.5
G15	29.6	21.1	19.1	21.0	8.5	10.6	18.3	7.1
G16	21.9	23.2	32.9	30.5	21.1	3.3	22.1	9.5
G18	27.7	19.8	13.7	37.1	22.0	32.2	25.4	7.8
M0	11.9	18.2	19.1	18.1	5.4	72.8	24.3	22.2
M1		14.8	18.3	18.1	11.1	6.1	13.7	4.6
M3		16.9	24.5	17.1	4.1	42.2	21.0	12.5
M5		21.1	56.6	27.1	21.5	13.3	27.9	15.0
R7	23.5	21.5	55.4	25.7	5.4	15.6	24.5	15.3
R9	23.8	21.1	54.5	17.6	4.6	56.1	29.6	19.2
R11	21.9	17.8	26.6	14.8	17.2	0.0	16.4	8.3
R13	25.0	25.3	19.1	24.8	10.2	12.8	19.5	6.1
R14	16.2	35.7	28.7	7.6	8.5	39.4	22.7	12.6
R15	29.6	31.5	42.0	16.7	18.0	20.6	26.4	8.9
R17	92.7	38.6	39.1	28.1			49.6	25.3
R19	64.2	61.9	103.3	40.0			67.4	22.8
R21	49.6	39.8	42.9	69.0	28.9	108.9	56.5	26.4
R23		31.1	41.6	33.8	29.8	53.3	37.9	8.7
R25	33.5	24.8	37.9	53.3	32.8	26.1	34.7	9.4
R27	32.7	32.3	46.6	41.0	27.2	36.1	36.0	6.3
R29	37.3	32.8	36.6	45.7	32.4	36.1	36.8	4.4
R30	33.1		51.2	59.5	51.1	80.0	55.0	15.2
R31	49.6		57.0	24.3	34.6	79.4	49.0	19.0
period avg	35.4	27.5	32.8	26.8	23.8	27.7	**grand avg**	**28.9**
stdev	25.6	13.0	17.5	18.2	22.1	26.7	**grand stdev**	**21.1**

Table A4. 1999 total phosphorus data for Smith Mountain Lake tributaries.

station	period 1	period 2	period 3	period 4	period 5	period 6	station avg	station stdev
T00	44.6	60.3	95.8	68.6	73.7	32.8	62.6	22.3
T01	81.5	41.9	117.9	161.9	106.7	6.7	86.1	55.6
T02	107.7	81.1	99.5	121.9	81.1	3.9	82.5	41.6
T03	67.7	62.3	81.2	86.2	83.7	57.8	73.1	12.1
T04	52.7	45.3	10.4	54.8	27.6		38.1	18.8
T05	70.0	48.6	76.2	51.9	26.3	22.2	49.2	22.0
T06	55.4	54.0	67.0	63.8	73.3	55.6	61.5	7.8
T07	18.5	14.0	59.5	21.4	2.4	55.6	28.6	23.4
T08								
T09	13.1	20.3	27.9	26.7	4.6	0.0	15.4	11.5
T10	38.5	45.7	50.4	55.2	45.0	-5.6	38.2	22.2
T11	19.6	21.5	26.6	44.8	6.7	22.8	23.7	12.3
T12	26.2	26.5	41.2	25.7	8.9	40.0	28.1	11.8
T13	27.7	35.7	79.5	121.0	45.9	51.1	60.1	34.7
T14	95.0	82.3	129.1	83.8	93.3	115.0	99.8	18.5
T15	83.1	76.5	79.5	59.0	64.6	131.7	82.4	25.8
T16	84.6	63.2	71.6	90.0	56.7	105.6	78.6	18.2
T17	73.1	51.9	63.7	68.6	32.8	87.2	62.9	18.7
T18	83.5	61.5	70.4	71.4	27.2	105.0	69.8	25.7
T19	127.7	73.6	90.8	62.9	89.3		88.9	24.6
T20	64.2	58.6	100.8	93.8	40.2	207.2	94.1	59.8
T21	87.3	101.1	70.4	72.4	41.1	77.8	75.0	20.1
period avg	62.9	53.6	71.9	71.7	49.1	61.7	**grand avg**	**61.8**
stdev	31.9	23.0	29.9	34.7	32.0	55.3	**grand stdev**	**35.2**

Table A5. 1999 nitrate data for Smith Mountain Lake.

station	period 1	period 2	period 3	period 4	period 5	period 6	station avg	station stdev
B12	0.0	103.9	0.0	262.3	89.4	88.9	90.7	87.6
B14	19.3	580.6	167.9	265.7	85.7	39.8	193.1	192.0
B16	68.0	543.9	155.0	202.3	113.9	0.7	180.6	174.4
B18	166.8	552.8	96.4	145.7	146.6	0.0	184.7	173.5
B20		176.1	149.3	179.0	118.5	14.4	127.4	60.6
B22	296.8	225.0	229.3	500.7	262.1	59.8	262.3	130.1
C4	4.3	272.8	122.1	235.7	133.9	94.4	143.9	89.0
C5	0.0	109.4	82.1	270.7	97.5	20.7	96.8	87.3
C6	13.0	147.2	180.7	259.0	157.5	61.6	136.5	80.0
CB11	0.0	47.2	179.3	227.3	84.8	117.1	109.3	76.7
CB16		83.9	205.0	279.0	55.7	0.0	124.7	102.2
CB20	174.3	47.2	110.7	167.3	84.8	0.0	97.4	62.1
CM1	3.0	93.9	282.1	355.7	159.4	71.6	160.9	122.5
CM1.2	0.0	157.2	202.1	584.0	160.3	73.5	196.2	185.6
CM5	0.0	87.2	252.1	289.0	113.9	82.5	137.5	100.9
CR8	0.0	78.3	110.7	224.0	82.1	15.3	85.1	73.2
CR9	0.0	109.4	246.4	385.7	51.2	48.9	140.3	134.4
CR9.2		48.3	115.0	320.7	43.9	21.6	109.9	109.9
CR13	4.3	110.6	322.1	357.3	33.0	0.0	137.9	147.6
CR14.2	44.3	151.7	229.3	234.0	58.5	6.2	120.6	89.8
CR16	0.0	357.2	73.6	535.7	192.1	0.0	193.1	197.1
CR17	85.5	339.4	216.4	579.0	183.0	53.5	242.8	176.7
CR19	199.3	321.7	167.9	632.3	120.3		288.3	184.5
CR21	315.5	469.4	522.1	322.3		37.1	333.3	168.7
CR21.2	566.8	420.6	245.0	417.3	181.2	1.6	305.4	185.0
CR22	645.5	526.1	422.1	505.7	236.6	0.0	389.3	213.6
CR24	974.3	1038.3	469.3	635.7	531.2	35.3	614.0	334.9
CR25	790.5	671.7	482.1	882.3	194.8	0.0	503.6	317.1
CR26	1071.8	1058.3	657.9	829.0	327.5	277.1	703.6	316.9
G12	34.3	143.9	63.6	329.0	79.4	0.0	108.3	108.0
G13	43.0	103.9	135.0	382.3	50.3	0.0	119.1	125.5
G14	0.0	19.4	137.9	322.3	59.4	0.0	89.8	114.3
G15	0.0	0.0	26.4	424.0	30.3	0.0	80.1	154.3
G16	0.0	39.4	183.6	260.7	135.7	0.0	103.2	98.0
G18	0.0	0.0	119.3	344.0	43.0	37.1	90.6	120.1
M0	165.5	90.6	136.4	520.7	159.4	91.6	194.0	149.0
M1		141.7	309.3	517.3	206.6	130.7	261.1	143.0
M3		83.9	186.4	272.3	178.5	104.4	165.1	67.0
M5		159.4	300.7	560.7	181.2	48.9	250.2	174.6
R7	50.5	45.0	136.4	402.3	141.2	91.6	144.5	121.2
R9	84.3	161.7	106.4	354.0	60.3	0.0	127.8	112.2
R11	0.0	55.0	97.9	79.0	105.7	0.0	56.3	42.9
R13	148.0	183.9	103.6	369.0	51.2	1.6	142.9	117.4
R14	39.3	121.7	125.0	472.3	245.7	0.0	167.3	156.8
R15	195.5	243.9	213.6	432.3	277.5	0.0	227.1	127.6
R17	178.0	430.6	202.1	524.0			333.7	147.6
R19	264.3	717.2	290.7	474.0			436.5	181.1
R21	474.3	525.0	155.0	320.7	244.8	7.1	287.8	178.1
R23		975.0	243.6	789.0	499.4	0.0	501.4	353.5
R25	1114.3	938.3	323.6	617.3	816.6	0.0	635.0	377.5
R27	1678.0	1269.4	683.6	1159.0	805.7	771.6	1061.2	347.6
R29	1511.8	1425.0	933.6	1560.7	631.2	1186.2	1208.1	334.7
R30	1679.3		1195.0	1585.7	1374.8	2275.3	1622.0	367.4
R31	1661.8		1579.3	1942.3	2323.9	291.6	1559.8	685.4
period avg	284.8	323.1	247.2	455.8	209.5	119.4	**grand avg**	**295.8**
stdev	462.3	347.8	217.6	299.9	245.1	368.6	**grand stdev**	**387.8**

Table A6. 1999 nitrate samples for Smith Mountain Lake tributaries.

Station	period 1	period 2	period 3	period 4	period 5	period 6	sta avg	sta stdev
T00	445.5	630.6	419.3	620.7	867.5	338.9	553.7	192.2
T01	885.5	357.2	489.3	585.7	810.3	250.7	563.1	249.4
T02	854.3	402.8	537.9	967.3	548.5	359.8	611.7	245.7
T03	453.0	422.8	460.7	670.7	480.3	186.2	445.6	154.9
T04	1283.0	432.8	666.4	885.7	729.4		799.4	315.6
T05	946.8	379.4	1280.7	944.0	1296.6	1403.5	1041.8	376.9
T06	855.5	442.8	890.7	927.3	2580.3	1239.8	1156.1	742.6
T07	0.0	39.4	192.1	292.3	159.4	36.2	119.9	113.5
T08								
T09	265.5	216.1	442.1	737.3	354.8	88.0	350.7	224.6
T10	389.3	340.6	320.7	629.0	419.4	11.6	351.8	199.8
T11	203.0	165.0	165.0	549.0	419.4	69.8	261.9	182.4
T12	38.0	148.3	275.0	562.3	258.5	73.5	225.9	190.4
T13	300.5	269.4	443.6	572.3	447.5	194.4	371.3	140.1
T14	375.5	259.4	1562.1	1185.7	803.9	512.5	783.2	506.5
T15	788.0	442.8	715.0	957.3	1049.4	518.0	745.1	238.0
T16	345.5	309.4	347.9	735.7	415.7		430.8	174.7
T17	1230.5	2053.9	1795.0	1364.0	1348.5	2516.2	1718.0	501.1
T18	168.0	176.1	193.6	485.7	165.7	8.9	199.7	155.5
T19	134.3	346.1	362.1	674.0	339.4		371.2	193.4
T20	449.3	190.6	312.1	567.3	291.2	151.6	327.0	157.2
T21	1775.5	1861.7	1816.4	1284.0	200.3	2515.3	1575.5	779.7
period avg	580.3	470.8	651.8	771.3	666.0	581.9	**grand avg**	**621.3**
stdev	462.1	512.6	518.1	274.8	560.1	805.2	**grand stdev**	**521.6**

Table A7. 1999 chlorophyll-*a* data for Smith Mountain Lake.

station	period 1	period 2	period 3	period 4	period 5	period 6	station avg	station stdev
B12	2.38	0.42	0.7	1.82	1.12	2.66	1.5	0.9
B14		0.42	0.98	2.38	4.06	2.8	2.1	1.5
B16		1.26	2.1	4.34	3.36	2.38	2.7	1.2
B18		0.84	0.98	1.4	0.28	3.22	1.3	1.1
B20		0.84	3.36	1.26	3.78	3.08	2.5	1.3
B22	1.54	0.56	4.62	10.64	16.80	15.54	8.3	7.1
C4	0.35	1.96	0.7	1.96	2.66	3.78	1.9	1.3
C5	0.42	0.98	0.84	1.12	4.76	1.82	1.7	1.6
C6	0.42	0.84		0.84	5.74	2.38	2.0	2.2
CB11	0.28	0.42	1.82	2.66	1.96	2.8	1.7	1.1
CB16		1.82	2.52	5.04	2.52	3.5	3.1	1.2
CB20	0.42	0.42	0.98	2.24	10.36	2.66	2.8	3.8
CM1	0.35	0.28	0.98	0.28	0.70	0.98	0.6	0.3
CM1.2	0.21	0.14	1.12	0.56	1.54	0.7	0.7	0.5
CM5	0.70	1.68	5.04	2.24	3.78	4.2	2.9	1.7
CR8		0.7	3.08	2.66	2.24	3.5	2.4	1.1
CR9	0.98	0.42	1.96	2.1	0.84	2.52	1.5	0.8
CR9.2		0.56	3.22	4.06	0.70	4.2	2.5	1.8
CR13	1.26	0.98	2.94	2.94	2.10	3.36	2.3	1.0
CR14.2	0.70	0.7	1.82	1.54	1.26	0.84	1.1	0.5
CR16	1.12	2.52	4.2	3.22	3.08	2.94	2.8	1.0
CR17	1.26	1.47	3.78	5.6	8.40	3.78	4.0	2.7
CR19	5.04	8.68	7.28	8.82	0.84		6.1	3.3
CR21	0.70	1.26	2.66	2.1		1.54	1.7	0.8
CR21.2	0.70	1.12	4.34	5.46	1.26	0.84	2.3	2.1
CR22	1.54	3.08	14	10.08	1.68	3.78	5.7	5.1
CR24	1.75	8.96	10.64	8.96	10.36	10.92	8.6	3.5
CR25	2.52	15.4	4.34	26.6	3.64	12.6	10.9	9.3
CR26	2.17	5.6	3.64	12.74	16.80	14	9.2	6.1
G12	0.42	0.21	0.56	2.1	1.54	3.92	1.5	1.4
G13	0.63	1.12	0.98	1.12	0.98	0.7	0.9	0.2
G14	0.28	1.68	1.54	0.7	2.10	2.52	1.5	0.8
G15	0.70	1.68	3.64	2.24	0.84	0.98	1.7	1.1
G16	0.42	1.75	2.1	0.84	2.94	1.26	1.6	0.9
G18	0.70	0.91	2.52	3.36	0.84	2.1	1.7	1.1
M0	0.21	0.28	0.42	0.42	0.42	0.42	0.4	0.1
M1		0.63	0.28	0.42	0.42	0.28	0.4	0.1
M3		0.952	0.28	0.42	0.84	0.7	0.6	0.3
M5		0.07	0.56	0.56	0.42	0.56	0.4	0.2
R7	1.12	0.7	6.3	4.48	1.54	2.1	2.7	2.2
R9	0.42	0.42	3.64	2.38	0.70	3.08	1.8	1.4
R11	0.70	2.03	1.82	2.1	1.68	2.94	1.9	0.7
R13	0.84	2.1	1.68	2.52	3.64	2.8	2.3	1.0
R14	1.12	1.75	1.96	3.64	0.84	0.98	1.7	1.0
R15	1.12	1.75	3.36	4.62	3.08	3.08	2.8	1.2
R17	3.08	6.02	4.76	5.74			4.9	1.3
R19	6.16	5.18	5.6	7.7			6.2	1.1
R21	1.12	2.24	6.16	4.06	2.38	6.58	3.8	2.2
R23	6.44	3.08	25.2	4.48	6.58	4.9	8.4	8.3
R25	2.10	4.48	12.46	3.08	9.10	15.54	7.8	5.5
R27	9.10	4.34	15.4	11.2	15.40	8.4	10.6	4.3
R29	3.92	6.16	22.4	85.4	14.00	11.2	23.8	30.8
R30	0.21		4.2	39.2	6.30	3.22	10.6	16.1
R31	0.70		4.06	40.6	6.16	2.94	10.9	16.7
Period Avg	1.6	2.2	4.3	6.8	3.9	3.9	**grand avg**	**3.9**
stdev	1.9	2.8	5.2	13.9	4.4	3.9	**grand stdev**	**6.8**

Table A8. 1999 Secchi data for Smith Mountain Lake.

Station	period 1	period 2	Period 3	period 4	period 5	period 6	station avg	stdev
B12	2.00	5.50	3.00	2.50	2.00	3.00	3.00	1.30
B12.2	2.00	3.00	2.25		2.50	2.25	2.40	0.38
B14	3.00	3.00	2.00	2.50	2.25	2.25	2.50	0.42
B16	2.50	3.00	1.50	2.00	1.50	2.00	2.08	0.58
B18		3.00	1.75	2.00	2.25	2.00	2.20	0.48
B20		2.50	1.50	1.75	1.75	1.75	1.85	0.38
B22	1.50	1.50	1.25	1.00	1.00	1.50	1.29	0.25
C4	2.50	4.00	3.00	4.00	4.00	4.75	3.71	0.81
C5	2.25	3.25	2.75	3.25	4.00	3.50	3.17	0.61
C6	1.75	3.00	2.00	2.25	3.00	3.00	2.50	0.57
CB11	2.50	5.50	3.50	3.00	3.00	3.50	3.50	1.05
CB16	2.50	2.50	1.50	2.25	1.75	2.00	2.08	0.41
CB20	2.25	2.00	1.75	1.50	1.75	1.75	1.83	0.26
CM1	2.50	3.00	3.00	3.50	2.75	3.00	2.96	0.33
CM1.2	2.25	3.25	3.00	3.67	2.67	3.25	3.01	0.50
CM5	2.75	3.50	2.75	2.75	3.00	4.00	3.13	0.52
CR13	2.75	3.00	2.70	2.10	2.00	2.20	2.46	0.41
CR14.2	1.75	1.50	1.50	2.00	1.50	1.50	1.63	0.21
CR16	1.50	2.00	1.75	1.90	1.33		1.70	0.28
CR17	1.50	1.62	1.40	1.25	1.25		1.40	0.16
CR18	1.75	1.88	1.75			1.50	1.72	0.16
CR19	1.60	1.80	1.80	1.30			1.63	0.24
CR19.2	1.50	1.75	1.50			1.50	1.56	0.13
CR20	1.75	1.75	1.75			1.50	1.69	0.13
CR21	1.50	1.50	1.25	1.25	1.25	1.25	1.33	0.13
CR21.2	1.25	1.25	1.25	1.25	1.25	1.25	1.25	0.00
CR22	1.50	1.50	1.50	1.50	1.50	1.25	1.46	0.10
CR24	1.25	1.50	1.25	1.00	1.50	1.00	1.25	0.22
CR25	1.75	1.50	1.25	1.00	1.25	1.00	1.29	0.29
CR26	1.25	2.00	1.25	1.00	1.50	1.00	1.33	0.38
CR8	2.50	3.25	3.25	2.50	2.75	3.00	2.88	0.34
CR9	3.00	3.40	2.30	2.40	2.20	2.50	2.63	0.47
CR9.2	2.50	3.25	2.50	2.40	2.50	3.00	2.69	0.35
G12	2.50	5.00	3.00	2.50	2.00	3.50	3.08	1.07
G13	2.00	3.50	2.50	2.00			2.50	0.71
G14	2.50	4.25	2.75	2.50	2.00		2.80	0.86
G15	1.75	3.25	2.25	2.25			2.38	0.63
G16	2.25	3.00	2.50	2.25	2.25		2.45	0.33
G18	2.25	2.50	2.25	2.00	2.25		2.25	0.18
M0	3.00	3.75	3.50	3.33	3.00	3.50	3.35	0.30
M1		3.50	3.50	3.67	3.00	3.50	3.43	0.25
M3		4.25	3.00	3.33	3.75	4.00	3.67	0.50
M5		3.25	3.25	3.50	3.75	3.75	3.50	0.25
R7	2.75	3.00	3.50	3.00	3.50	3.75	3.25	0.39
R9	3.25	3.50	2.50	2.30	2.00	2.90	2.74	0.58
R11	2.75	3.75	3.00	2.75	2.50	2.50	2.88	0.47
R13	2.70	3.40	2.70	2.30	1.80	2.50	2.57	0.53
R14	2.00	2.50	2.00	2.00	2.00	2.00	2.08	0.20
R15	1.75	2.25	2.10	1.60	1.75		1.89	0.27
R17	2.00	2.10	2.30	1.40			1.95	0.39
R19	1.60	1.90	2.00	1.40			1.73	0.28
R21	1.50	1.50	1.25	1.50		1.25	1.40	0.14
R23	1.50	1.50	1.50	1.50	1.50	1.25	1.46	0.10
R25	2.00	1.75	1.25	1.00	1.25	1.00	1.38	0.41
R27	1.25	2.00	1.24	1.25	1.50	1.50	1.46	0.29
R29	1.50	1.50	1.25	1.25	1.25	1.25	1.33	0.13
R30				1.50			1.50	
R31(BRM)				0.75			0.75	
R34(T21)	1.00	1.25	1.00	1.00	0.50	0.75	0.92	0.26

Table A8. 1999 Secchi data for Smith Mountain Lake. (cont.)

Station	period 1	period 2	Period 3	period 4	period 5	period 6	station avg	stdev
SB12		3.00					3.00	
SCB10	2.50	3.00	2.75	2.50	2.25	2.50	2.58	0.26
SCB11	2.50	3.00	2.75	2.00	2.00	2.25	2.42	0.41
SCB11.5	1.75	2.75	2.50	2.00	2.00	2.00	2.17	0.38
SCB14	1.75	2.25	1.50		2.00	2.00	1.90	0.29
SCB16	1.75	2.00	1.25		1.50	1.75	1.65	0.29
SCB8	2.25	4.00	2.50	2.50	2.50	3.00	2.79	0.64
SCR10.1	2.25	3.00	2.00	2.25	2.25	2.00	2.29	0.37
SCR10.2	2.25	2.75	2.25	2.50	2.50	2.10	2.39	0.24
SCR10.3	2.00	2.75	2.00	2.25	2.25	1.90	2.19	0.31
SCR11.1	2.00	3.50	2.50	2.75		2.25	2.60	0.58
SCR11.2	2.25	4.50	2.50	2.50		2.25	2.80	0.96
SCR11.3	2.50	5.25	3.00	2.50		2.00	3.05	1.28
SCR14	2.50	3.75	2.50	2.25	2.00	2.50	2.58	0.61
SCR14.1	1.25	2.50	1.75	1.75	1.75		1.80	0.45
SCR14.2	1.25	1.75	1.50	1.50	1.25		1.45	0.21
SCR14.3	1.35	2.50	1.75	1.75	1.80		1.83	0.42
SCR15	2.50	3.75	2.25	2.25	2.00	2.50	2.54	0.62
SCR17	1.75	2.75	1.50	1.75	1.50	1.75	1.83	0.47
SCR18				1.50	1.75		1.63	0.18
SCR19				1.25	1.50		1.38	0.18
SCR20				1.25	1.25		1.25	0.00
samp avg	2.04	2.80	2.15	2.08	2.07	2.27	**Grand avg**	**2.24**
stdev	0.53	1.01	0.69	0.75	0.74	0.91	**Grand Stdev**	**0.83**

Table A9. 1999 Fecal coliform and Secchi disc depth data from Smith Mountain Lake.

SITE	Sample #	REP #	Ct (5/20)	SD (5/20)	Ct (6/1)	SD(6/1)	Ct (6/29)	SD (6/29)
Hardy Ford Bridge	1,1	1	88	1	33	1	6	0.5
	1,1	2	42		16		6	
	1,1	3	138		16		10	
	1,2	1	108	0.5	9	0.5	11	0.75
	1,2	2	86		0		6	
	1.2	3	90		14		8	
Beaver Dam Creek	2,1	1	2	2.5	40	1	4	1
	2,1	2	10		15		10	
	2,1	3	10		6		5	
	2,2	1	12	1.5	28	1.5	7	1
	2,2	2	16		5		10	
	2,2	3	9		9		9	
Indian Point Marina	3,1	1	0	1.25	88	1	57	1
	3,1	2	0		52		39	
	3,1	3	2		27		56	
	3,2	1	6	1.5	73	1	1	1.25
	3,2	2	3		55		0	
	3,2	3	2		82		3	
SML Yacht Club	4,1	1	20	0.5	40	1	24	1
	4,1	2	63		249		22	
	4,1	3	15		48		23	
	4,2	1	13	1	44	1.5	8	1.5
	4,2	2	8		28		6	
	4,2	3	11		34		8	
Shoreline Marina	5,1	1	7	1	62	1	5	1.75
	5,1	2	15		46		7	
	5,1	3	15		78		3	
	5,2	1	4	1.5	68	1.5	6	1.5
	5,2	2	16		52		5	
	5,2	3	11		53		5	
Fairway Bay	6,1	1	10	1.25	55	1.5	3	2
	6,1	2	8		49		7	
	6,1	3	12		72		6	
	6,2	1	0	1.75	3	1.5	3	2
	6,2	2	5		8		6	
	6,2	3	1		8		4	
SML State Park Cove	7,1	1	1	2	1	1.5	1	2.25
	7,1	2	1		1		0	
	7,1	3	1		1		0	
	7,2	1	0	2	1	2	0	2.5
	7,2	2	0		3		1	
	7,2	3	0		0		0	
Forest Cove	8,1	1	19	2.75	71	1	8	1
	8,1	2	29		81		10	
	8,1	3	18		101		4	
	8,2	1	0	3.25	18	1.25	2	1.75

Table A9. 1999 Fecal coliform and Secchi disc depth data from Smith Mountain Lake. (cont.)

SITE	Sample	REP #	Ct (5/20)	SD (5/20)	Ct (6/1)	SD(6/1)	Ct (6/29)	SD (6/29)
SML Dock Cove	9,1	1	24	2.25	49	2	28	2.5
	9,1	2	35		84		21	
	9,1	3	44		91		25	
	9,2	1	26	3	17	1.75	6	2.5
	9,2	2	16		13		8	
	9,2	3	27		18		8	
Confluence	10,1	1	0	3.25	0	1.75	0	2.5
	10,1	2	0		0		1	
	10,1	3	2		2		0	
	10,2	1	0	4	1	1.5	0	2.5
	10,2	2	0		1		0	
	10,2	3	0		1		0	
Palmer's Trailer Pk	11,1	1	28	2	178	1.25	20	1.5
	11,1	2	21		157		15	
	11,1	3	41		159		14	
	11,2	1	29	2	159	1.5	99	2
	11,2	2	26		143		86	
	11,2	3	32		142		91	
Pelican Point M.	12,1	1	2	3	3	1.75	0	3
	12,1	2	0		2		1	
	12,1	3	0		3		1	
	12,2	1	8	3	0	1.25	2	3.25
	12,2	2	2		3		0	
	12,2	3	1		1		6	
Foxport Marina	13,1	1	1	3.25	3	1.25	4	2.5
	13,1	2	0		4		5	
	13,2	1	4	3	8	1.25	1	2.25
	13,2	2	1		9		1	
	13,2	3	8		4		1	
Ponderosa Campgrd.	14,1	1	93	1	0	1	0	1
	14,1	2	80		2		5	
	14,1	3	89		9		13	
	14,2	1	119	0.75	8	1	2	0.75
	14,2	2	124		8		7	
	14,2	3	109		5		3	

Table A9. 1999 Fecal coliform and Secchi disc depth data from Smith Mountain Lake. (cont.)

SITE	Ct (7/5)	SD (7/5)	Ct (7/27)	SD (7/27)	Ct (8/10)	SD (8/10)
Hardy Ford Bridge	8	0.5	29	0.75	13	0.5
	5		0		7	
	12		18		9	
	2	0.5	12	0.5	20	0.75
	0		29		22	
	11		19		44	
Beaver Dam Creek	3	1	1	1.5	4	1
	2		1		6	
	2		1		5	
	1	1	2	1.25	3	1
	3		2		0	
	5		10		1	
Indian Point Marina	5	1	58	1	13	1
	2		88		11	
	3		9		16	
	3	1	7	1.25	15	1
	1		5		3	
	1		4		2	
SML Yacht Club	28	0.75	13	0.5	12	1
	22		35		13	
	19		56		14	
	11	1.25	20	1	3	1.5
	26		32		14	
	18		1		16	
Shoreline Marina	31	1	7	1	11	1
	32		2		10	
	26		12		15	
	46	1.25	32	1.25	3	1.25
	16		26		14	
	18		42		5	
Fairway Bay	8	1.25	19	1.5	11	1.5
	2		64		9	
	0		13		3	
	13	1.25	10	1.5	3	1.5
	7		12		3	
	11		4		0	
SML State Park Cove	1	1.75	6	1.75	0	3.5
	0		5		0	
	0		0			
	2	2	0	2.25		2.5
	1		0			
	6		0		9	
Forest Cove	3	1.25	4	1.5	16	1.75
	7		5		60	
	2		1		2	
	7	1	1	2.5	3	2.25
	6		2		3	
	7		74		76	

Table A9. 1999 Fecal coliform and Secchi disc depth data from Smith Mountain Lake. (cont.)

SITE	Ct (7/5)	SD (7/5)	Ct (7/27)	SD (7/27)	Ct (8/10)	SD (8/10)
SML Dock Cove	28	1.75	60	1.75	91	2
	29		61		74	
	6		81		86	
	27	1.75	100	2.5	71	2.25
	34		80		61	
	32		0		0	
Confluence	0	2.5	0	2	0	3.5
	0		1		2	
	0		0		0	
	0	2	1	2	0	4
	3		0		0	
	0		37		10	
Palmer's Trailer Pk	18	1	34	1.5	7	1.5
	27		33		17	
	25		34		55	
	5	1.5	31	1.5	6	2
	10		38		14	
	9		3		0	
Pelican Point M.	5	1.75	2	2	2	3
	11		2		2	
	4		4		0	
	2	2.5	1	2	2	3
	2		4		0	
	1		4		0	
Foxport Marina	2	1.5	8	2.25	5	2
	4		10		1	
	1		4		2	
	0	1.5	1	2	4	2.5
	3		3		0	
	0		13		10	
Ponderosa Campgrd.	3	0.5	0	0.5	4	0.75
	5		7		2	
	10		6		10	
	2	0.5	12	0.75	3	0.75
	0		4		12	
	6					

Table A10. 1999 Fecal coliform event sampling.

Date	Site	Actual Time	Time Elapsed	CFU/100mL	TSP (mg/L)
7/12/1999	1	12:00PM	0:00	2500	14.8
7/12/1999	1	1:00PM	1:00	290	13.6
7/12/1999	1	2:00PM	2:00	4400	37.2
7/12/1999	1	3:00PM	3:00	14	32.4
7/12/1999	1	4:00PM	4:00	250	43.2
7/12/1999	1	5:00PM	5:00	20600	52.8
7/12/1999	1	7:00PM	7:00	24300	
7/12/1999	1	9:00PM	9:00	22000	84
7/12/1999	1	11:00PM	11:00	710	111.2
7/13/1999	1	3:45AM	15:45	48100	133.6
7/13/1999	1	6:50AM	18:50	57100	187.2
7/13/1999	1	11:12AM	23:12	36800	72.4
7/13/1999	1	2:52PM	26:52:00	11030	53.6
7/13/1999	1	8:09PM	32:09:00	3570	22.4
7/13/1999	1	11:00PM	35:00:00	4710	30.4
7/14/1999	1	2:52AM	38:52:00	1885	20.4
7/14/1999	1	6:58AM	42:58:00	940	18.8
7/14/1999	1	12:10PM	48:10:00	6190	17.2
7/15/1999	1	2:20PM	74:20:00	480	10
7/16/1999	1	11:33AM	93:33:00	440	6.8
7/12/1999	2	12:00PM	0:00	1000	2
7/12/1999	2	1:00PM	1:00	835	2.8
7/12/1999	2	2:00PM	2:00	850	4.4
7/12/1999	2	3:00PM	3:00	3045	6.8
7/12/1999	2	4:00PM	4:00	1535	12
7/12/1999	2	5:00PM	5:00	770	12.8
7/12/1999	2	7:00PM	7:00	2600	12.4
7/12/1999	2	9:00PM	9:00	2295	16.4
7/12/1999	2	11:00PM	11:00	5000	22
7/13/1999	2	3:30AM	15:30	20300	36
7/13/1999	2	7:00AM	19:00	38400	63.2
7/13/1999	2	11:18AM	23:18	33900	59.6
7/13/1999	2	2:58PM	26:58:00	9350	88.8
7/13/1999	2	8:00PM	32:00:00	2850	46
7/13/1999	2	11:00PM	35:00:00	2600	40
7/14/1999	2	3:00AM	39:00:00	12360	32.4
7/14/1999	2	7:05AM	43:05:00	0	35.2
7/14/1999	2	12:15PM	48:15:00	0	28.8
7/15/1999	2	2:27PM	74:27:00	425	8.4
7/16/1999	2	11:40AM	93:40:00	380	8
7/12/1999	3	12:30PM	0:30	170	1.2
7/12/1999	3	1:12PM	1:12	310	2.4
7/12/1999	3	2:06PM	2:06	605	3.6
7/12/1999	3	3:06PM	3:06	1210	4
7/12/1999	3	4:05PM	4:05	1600	4.4
7/12/1999	3	5:00PM	5:00	2310	6
7/12/1999	3	7:00PM	7:00	2865	7.2
7/12/1999	3	9:06PM	9:06	1980	12.8
7/12/1999	3	11:00PM	11:00	820	24.4
7/12/1999	3	11:02PM	11:02	455	20.4
7/13/1999	3	3:00AM	15:00	925	14.8
7/13/1999	3	7:30AM	19:30	1300	
7/13/1999	3	11:35AM	23:35	2630	50.8
7/13/1999	3	3:18PM	27:18:00	4900	49.2
7/13/1999	3	7:40PM	31:40:00	4710	72.8
7/13/1999	3	11:00PM	35:00:00	8440	56.4
7/14/1999	3	3:25AM	39:25:00	2005	58.8
7/14/1999	3	7:38AM	43:38:00	1135	34.4
7/14/1999	3	12:39PM	48:39:00	2880	26.8
7/15/1999	3	1:15PM	73:15:00	240	10.4
7/16/1999	3	12:01PM	94:01:00	275	7.6

Table A10. 1999 Fecal coliform event sampling. (cont.)

Date	Site	Actual Time	Time Elapsed	CFU/100mL	TSP (mg/L)
7/12/1999	4	12:18PM	0:18	9	2.8
7/12/1999	4	1:00PM	1:00	2	4.4
7/12/1999	4	1:54PM	1:54	7	4.4
7/12/1999	4	2:54PM	2:54	8	4.4
7/12/1999	4	3:54PM	3:54	25	5.6
7/12/1999	4	4:50PM	4:50	10	6.8
7/12/1999	4	6:50PM	6:50	43	6.4
7/12/1999	4	8:50PM	8:50	93	6
7/12/1999	4	10:50PM	10:50	0	4.8
7/13/1999	4	3:00AM	15:00	720	3.2
7/13/1999	4	7:15AM	19:15	10	3.2
7/13/1999	4	11:36AM	23:36	17	2.8
7/13/1999	4	3:00PM	27:00:00	53	5.2
7/13/1999	4	8:15PM	32:15:00	50	3.6
7/13/1999	4	11:28PM	35:28:00	89	1.6
7/14/1999	4	3:33AM	39:33:00	35	
7/14/1999	4	7:48AM	43:48:00	70	
7/14/1999	4	12:12PM	48:12:00	115	5.2
7/15/1999	4	1:23PM	73:23:00	11	8.4
7/16/1999	4	12:13PM	94:13:00	15	9.2
7/12/1999	5	1:38PM	1:38	20	1.6
7/12/1999	5	2:00PM	2:00	16	2
7/12/1999	5	3:00PM	3:00	26	4.4
7/12/1999	5	4:00PM	4:00	48	1.6
7/12/1999	5	5:00PM	5:00	12	2
7/12/1999	5	7:00PM	7:00	105	3.2
7/12/1999	5	9:00PM	9:00	160	0.4
7/12/1999	5	11:00PM	11:00	185	0.8
7/13/1999	5	3:00AM	15:00	262	
7/13/1999	5	6:50AM	18:50	15	0.4
7/13/1999	5	11:57AM	23:57	6	0.4
7/13/1999	5	3:17PM	27:17:00	88	2.4
7/13/1999	5	7:49PM	31:49:00	7	
7/13/1999	5	11:00PM	35:00:00	68	1.2
7/14/1999	5	3:53AM	39:53:00	0	
7/14/1999	5	8:05AM	44:05:00	0	2
7/14/1999	5	12:36PM	48:36:00	86	0.4
7/15/1999	5	1:40PM	73:40:00	1	2
7/16/1999	5	12:32PM	94:32:00	36	1.6
7/12/1999	6	1:15PM	1:15	168	
7/12/1999	6	2:08PM	2:08	20	
7/12/1999	6	3:10PM	3:10	4	
7/12/1999	6	4:09PM	4:09	51	2
7/12/1999	6	5:11PM	5:11	2	
7/12/1999	6	7:10PM	7:10	17	
7/12/1999	6	9:08PM	9:08	111	
7/12/1999	6	11:10PM	11:10	63	
7/13/1999	6	3:30AM	15:30	125	
7/13/1999	6	7:00AM	19:00	10	
7/13/1999	6	12:07PM	24:07:00	0	
7/13/1999	6	3:30PM	27:30:00	2	
7/13/1999	6	8:00PM	32:00:00	12	
7/13/1999	6	11:10PM	35:10:00	160	
7/14/1999	6	4:02AM	40:02:00	0	
7/14/1999	6	8:13AM	44:13:00	0	1.2
7/14/1999	6	12:47PM	48:47:00	6	0
7/15/1999	6	1:50PM	73:50:00	15	2.8
7/16/1999	6	12:47PM	94:47:00	0	2.8