Smith Mountain Lake
Water Quality Monitoring Program

1998 Report

SMLA **Ferrum College**

Prepared by

Dr. David M. Johnson and Dr. Carolyn L. Thomas

Life Sciences Division

Ferrum College

Sponsored by

The Smith Mountain Lake Association

March, 1999

CONTENTS

FIGURES

TABLES

Smith Mountain Lake Association

Moneta, Virginia

1998 OFFICERS

President	James H. Spitz
Vice President	William D. Telford
Treasurer	John F. Imirie
Secretary	Bonnie Johnson

1998 DIRECTORS

Stanley T. Dubelle
Donald E. Fink
Ronn E. Hunt
Michael H. Knapp
Ilma Mowery
James M. Nielsen
Frank M. Oakes
Robert E. Ollweiler
George Realmuto
Susan Mele
John A. Singer
Tony W. Keffer
William Muldoon
Randy W. Agnew
Thomas L. Smith

Ferrum College

Ferrum, Virginia
"Educating with Confidence since 1913"

President	Dr. Jerry M. Boone
Vice President and Dean	Dr. Richard Sours
Chair, Life Sciences Division	Prof. Ronald T. Stephens

1998 SMITH MOUNTAIN LAKE VOLUNTEER MONITORS

Advanced Monitors

Daphne Jamison, Wirtz
Janet & Richard Hill, Huddleston
Robert & Joan Ollweiler, Moneta
Anne & Don Daly, Penhook
Paul Dooley, Moneta
Len & Donna Kastner, Moneta
Hazel & Charles Bray, Moneta
Ed Shirey, Union Hall
Ted Bogsrud, Hardy
D. Willis Hartman, Union Hall
Chuck Franz, Union Hall
Houston Snoddy, Burnt Chimney
Jim & Marilyn Bissinger, Huddleston
Bill & Helen Duffany, Huddleston
Walter & Hilde Hussa, Moneta
Allan Wandelt, Wirtz
Neil Dick, Wirtz
Eric and Melba Anderson, Moneta
Dennis Blevins, Goodview
Paul Gascoyne, Goodview
Bob Dooley, Hardy
Dan Holgreve, Hardy
Erich & Meg Faber, Hardy
Pat Moriarty, Huddleston
George Rice, Huddleston
Dewey Felton, Moneta

Basic Monitors

Betty & Roger Mueller, Moneta
Ron Holasek, Moneta
Glenn Randa, Moneta
Dan & Miriam Walthers, Hardy
Marian & Bert Thurman, Wirtz
Joseph & Mary Ann Spahr, Moneta
Jim & Patti Gerhart, Moneta

1. EXECUTIVE SUMMARY

The Smith Mountain Lake Water Quality Monitoring Program (SMLWQMP) 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 1998 an organizing and training session was conducted by Ferrum College and the SMLA. Monitors collected samples every other week from the first week of June through the third week of August in 1998. The parameters measured each year to evaluate the trophic status of Smith Mountain Lake indicate a slightly better water quality in 1998 when compared to 1997 and/or 1996. 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 24.4 ppb, which is slightly lower than the 1997 total phosphorus average. The average nitrate concentration was 257 ppb, and 1998 is the second year for nitrate measurement in the lake for our program and is better than in 1997. The average chlorophyll-*a* concentration was 3.8 ppb, which is lower than reported recently in these annual reports. The average Secchi depth reading was 2.3 m, again somewhat higher than the 1997 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, and SD) measured for all twelve years (1987-1998), no significant trend, either lower or higher water quality, was noted. The significant trend in all parameters (TP, NO3, CHA, and 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 50.9 ppb, which is lower than the 1997 average, and was most likely affected by the lack of rainfall in July and August of 1998. The tributaries were also analyzed for nitrate concentration (NO3) in 1998 for the first time and the average was 568 ppb, more than two times the average nitrate concentration in the lake.

The fourth year of studying fecal coliform bacteria populations in marina coves and non-marina coves involved 14 sites, including seven marinas, five non-marinas, and two sites located in the headwaters of the Roanoke Channel and the Blackwater Channel. The fecal coliform average colony counts in 1998 were higher than they were in 1997 or 1996. The marinas' average fecal coliform count was 26.7 ± 2.7 cfus and the non-marinas' average was 13.6 ± 1.0 cfus. In 1998 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.

The Trophic Status Index (TSI) for Smith Mountain Lake in 1998 ranged from a low of 35 (indicating oligotrophic conditions) in the main basin at site M1, to as high as 53 and 55 (indicating eutrophic conditions) in the upper reaches of the Roanoke and Blackwater Channels at sites R32 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 1998 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 (1999) plans include adding an event sample (rain) for fecal coliforms from the headwaters to the lake for a 24-hour period to evaluate the transport of fecal coliforms into the lake. In 1999, shoreline monitoring using a multiparameter probe will begin on a limited basis 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 on a more regular basis in 1999, and biweekly reports of findings will be made available to the public.

2. INTRODUCTION

The Smith Mountain Lake Water Quality Monitoring Program (SMLWQMP), now in its twelfth 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 southwestern Virginia. Scientists from Ferrum College and designated members of the Smith Mountain Lake Association (SMLA) jointly manage the project. This report describes the 1998 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 1998 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 flow 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 this past summer, 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 1998 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 and Rachel Pannell. 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 31 through June 6 and the first sample bottles and sample filters were picked up Tuesday, June 9. 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 1998. In September, the annual end-of-the-season meeting and social event was held at the picnic shelter at The Boardwalk, a residential development 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 1997 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, a 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 834 bridge in Franklin County on the Blackwater channel. The cove sampling sites are also important for trend analysis and help us fulfill the role of "watchdogs". In the "watchdog" mode, we monitor as much of the lake as possible 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 every other week at 20 tributary sites on their rounds to pick up lake water samples. Volunteer monitors collect two additional tributary samples.

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 is shown in Table 1. Although nitrate is higher in 1998 than in 1997 (the first year of nitrate monitoring), total phosphorus and chlorophyll-*a* have decreased slightly and the Secchi depth has increased for the first time in several years. A more complete discussion of water quality trends is presented in Section 5 of this report.

Table 1. Summary of trophic state data for 1997 and 1998.

	Nitrate	Total Phosphorus	Chlorophyll-A	Secchi Depth
1998	257 ppb	24.4 ppb	3.8 ppb	2.3 m
1997	180 ppb	27.6 ppb	4.1 ppb	2.1 m

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 (52 sites) exhibited the lowest average concentration of total phosphorus (TP = 14.0 ppb) in the first week of June and the highest mean concentration (TP = 31.2 ppb) in the third week of July (Figure 1).

(b) Nitrate: The lowest average concentration (52 sites) of nitrate ($NO3$ = 125.9 ppb) occurred during the second week of August and the highest average nitrate concentration ($NO3$ = 416.0 ppb) during the first week of June, the first sample week of 1998 (Figure 2).

(c) Chlorophyll-*a*: The sample set (52 sites) with the lowest average chlorophyll-*a* concentration (CHA = 3.0 ppb) was collected during the third week in July and the set with the highest average chlorophyll-*a* concentration (CHA = 6.5 ppb) was collected during the first week in August (Figure 3).

(d) Secchi Depth: The lake (74 sites) exhibited the highest average Secchi depth (SD = 2.35 m) (highest water clarity) during the third week of June. The lowest average Secchi depth (SD = 1.68 m) occurred two weeks earlier during the first sampling period, the first week of June (Figure 4).

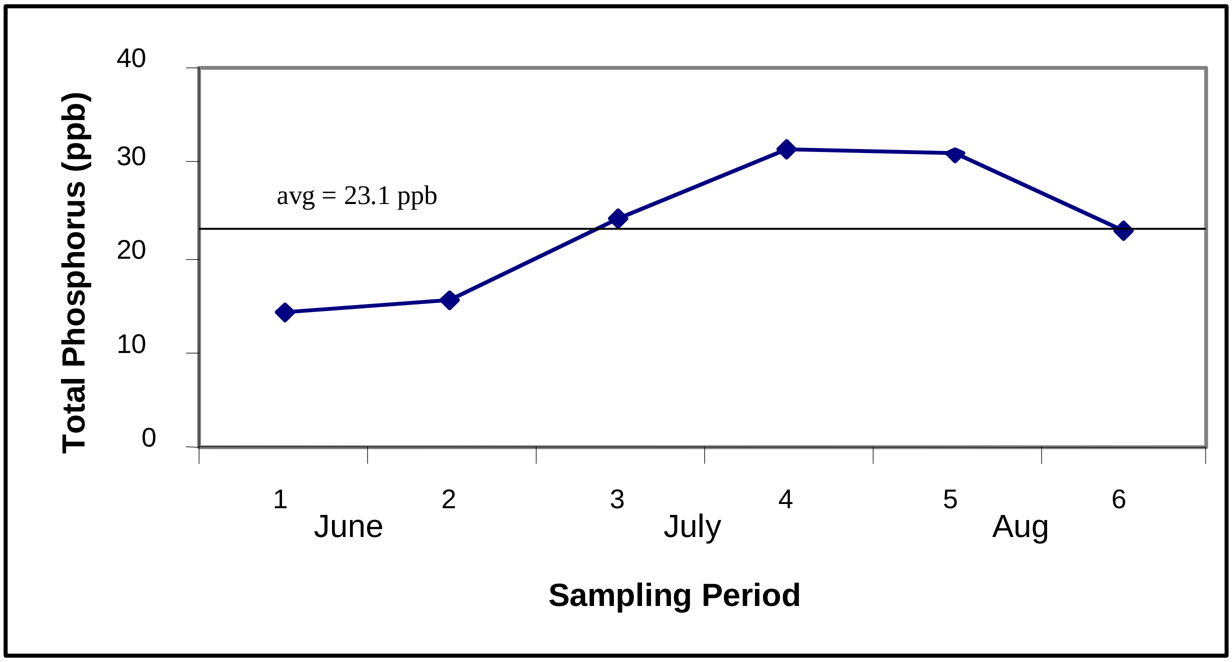


Figure 1. Average total phosphorus concentration for each sampling period in 1998.

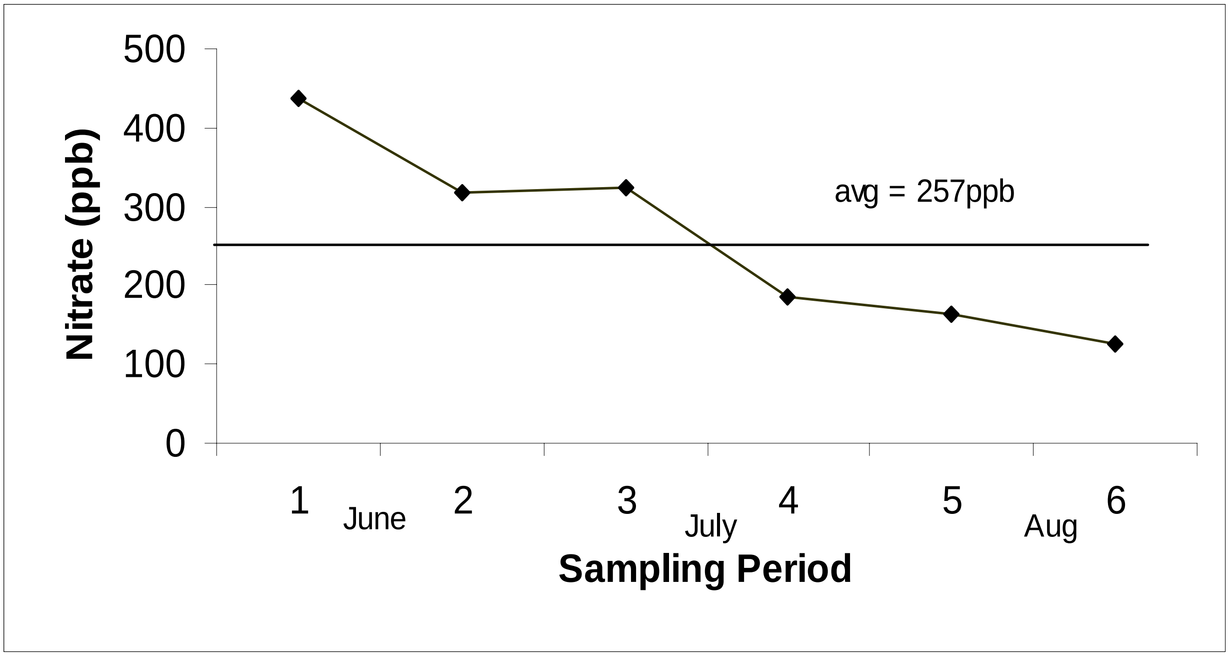


Figure 2. Average nitrate concentration for each sampling period in 1998.

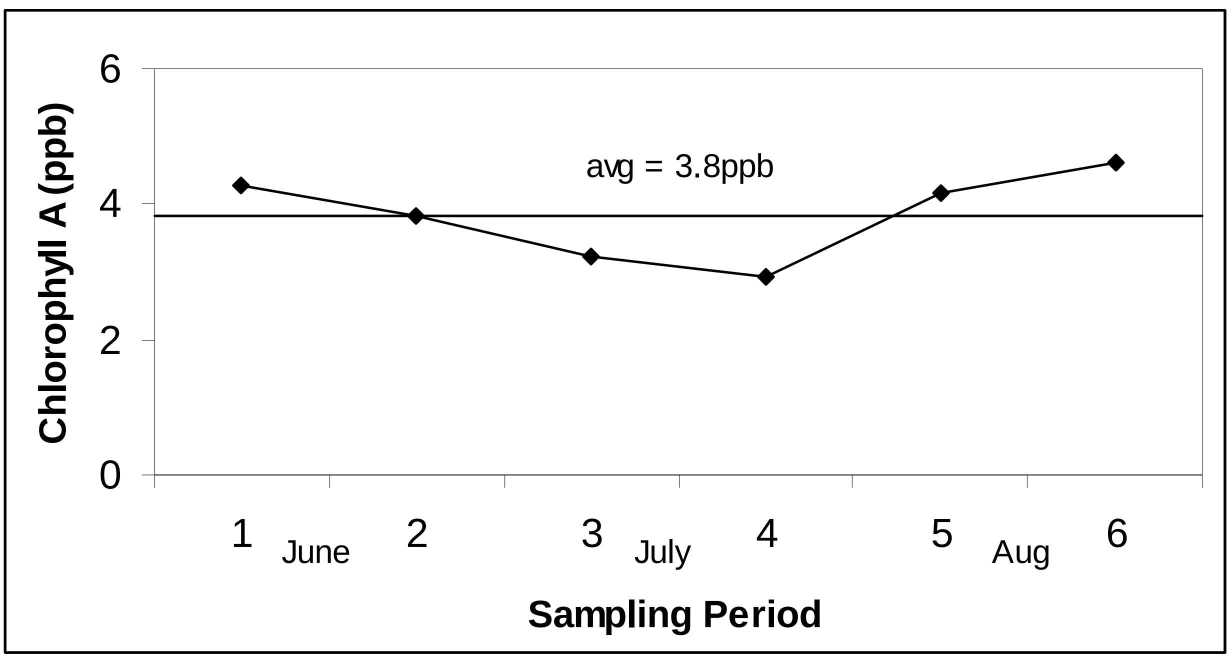


Figure 3. Average chlorophyll-*a* concentration for each sampling period in 1998.

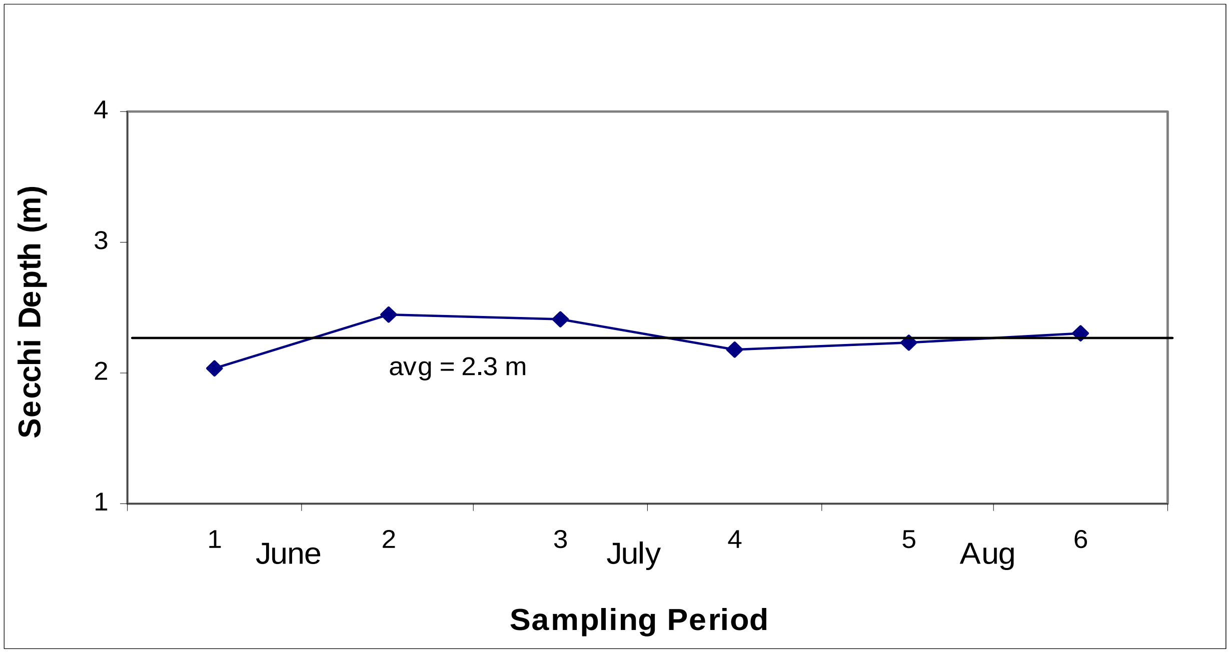


Figure 4. **Average Secchi depth for each sampling period in 1998.**

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 decrease as distance to the dam decreases, indicating water less nutrient-enriched toward the main basin where the two main channels converge (Figure 5). The sampling site with the highest average total phosphorus concentration (TP = 65.9 ppb) was in the Roanoke Channel, 32 miles from the dam. The lowest average total phosphorus concentration (TP = 6.9 ppb) was at a site in the Craddock Creek section of the lake, 6 miles from the dam.

(b) Nitrate: Nitrate concentrations (NO3), when averaged by station, also decreased toward the dam (Figure 6). The sampling site with the highest average nitrate concentration was in the Roanoke Channel, 29 miles from the dam (N03 = 921.4 ppb). The lowest average nitrate concentration was found at a station on Gills Creek (a tributary of the Blackwater channel) 15 miles from the dam (NO3 = 63.2 ppb). Figure 6 shows the annual average nitrate concentration by station as a function of distance from the dam and distinguishes among the Roanoke channel, the Blackwater channel, and other sections of the lake.

It is clear that the high nitrate levels in the Roanoke River will swamp out any local inputs along the Roanoke channel, unless the input is large. The reason for the rapid decrease in nitrate concentration isn't known but could be due to assimilation by organisms, dilution by lake water, or the cooler river water moving down under the warmer lake water. Nitrate will not be adsorbed to suspended silt and removed by sedimentation as is known to happen with phosphates. The pattern of nitrate levels is similar to that observed last year during the first year of monitoring. The nitrate levels are much higher in the upper reaches of the Roanoke channel than anywhere else in the lake and the lowest average levels were measured in the Gills Creek section. Also, unlike total phosphorus and chlorophyll-*a*, nitrate levels reach a minimum 10-15 miles from the dam and then increase slightly nearer the dam. Possible explanations include a more pronounced pumpback effect than for phosphorus, upwelling of nitrate-laden waters near the dam.

(c) Chlorophyll-*a*: As was the case with phosphorus and nitrate, chlorophyll-*a* levels (CHA) decreased closer to the dam, indicating less biotically (specifically algae) enriched water toward the main basin (Figure 7). The highest average total chlorophyll-*a* concentrations in the lake were measured at a station on the Roanoke Channel 25 miles from the dam (CHA = 16.3 ppb), and in the Blackwater Channel at 22 miles from the dam (CHA = 13.0 ppb). The lowest average chlorophyll-*a* concentrations were found at two sites in the Craddock Creek section of the lake at 1 mile and 1.2 miles from the dam (CHA = 0.6 ppb at both sites).

(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 = 4.13 m) in the lake was measured at a station in the Craddock Creek section of the lake, 4 miles from the dam. The lowest average Secchi depths were found 32 miles up the Roanoke Channel (SD = 1.05 m) and at 22 miles up the Blackwater Channel (SD = 1.6 m).

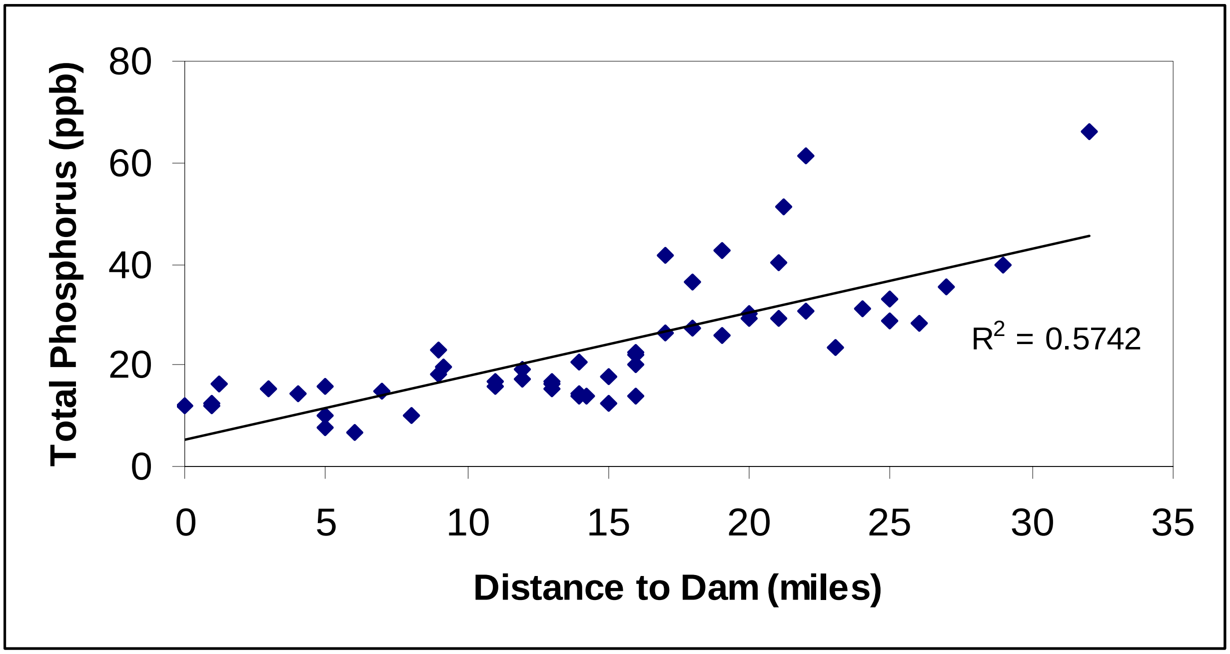


Figure 5. **Variation of total phosphorus concentration with distance from the dam.**

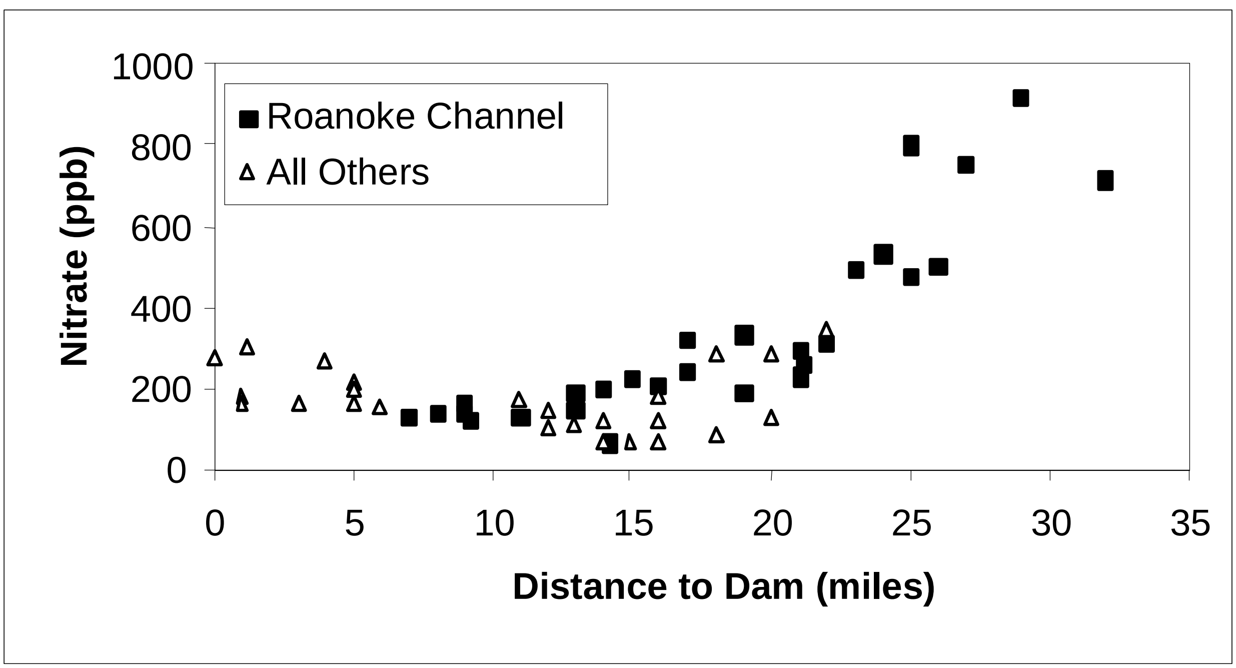


Figure 6. **Variation of nitrate concentration with distance from the dam.**

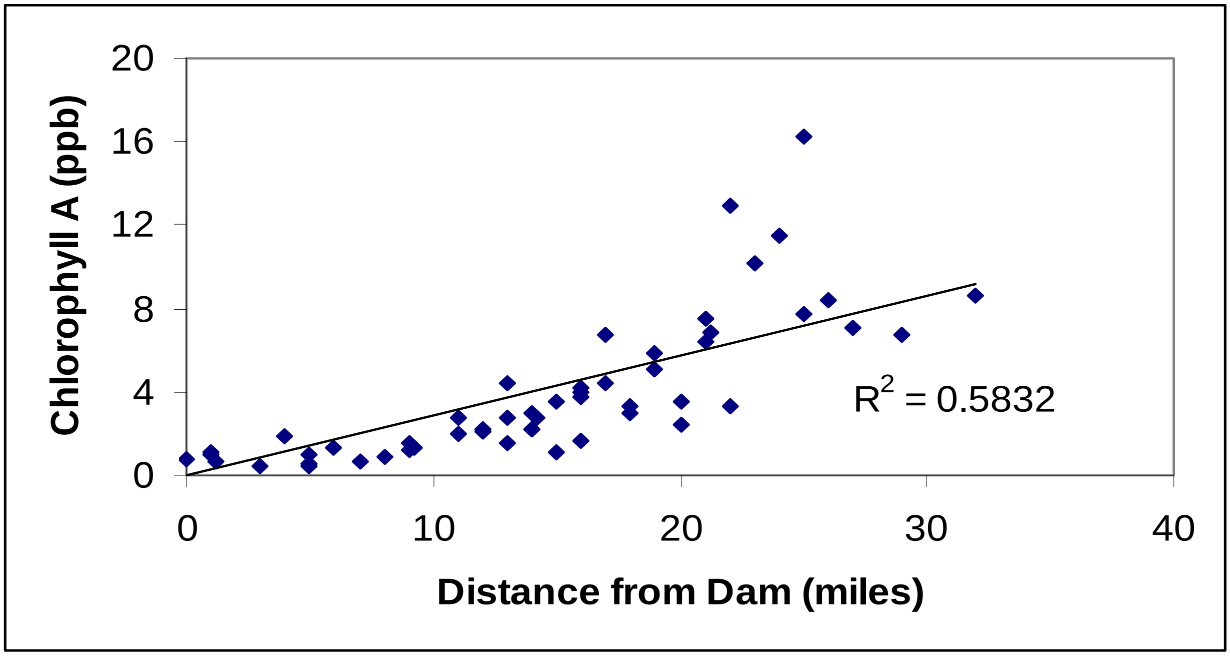


Figure 7. Variation of chlorophyll-*a* concentration with distance from the dam.

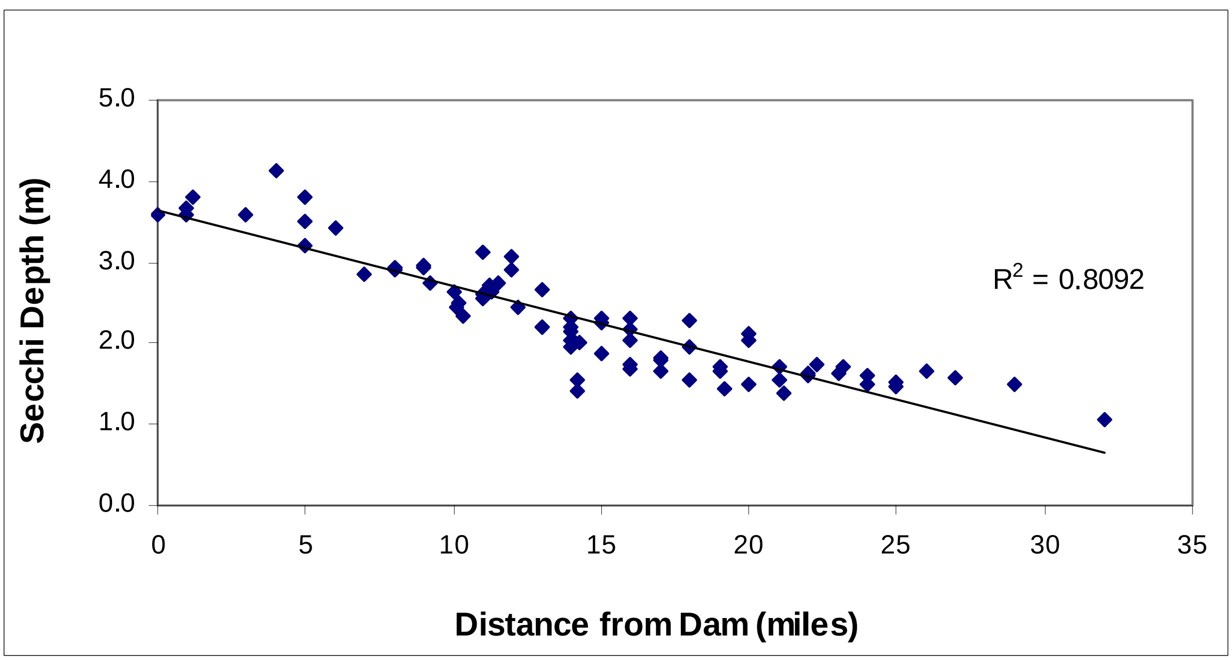


Figure 8. Variation of Secchi depth with distance from the dam.

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 = 21.2 ppb) in the first week of June and the highest mean concentration (TP = 74.1 ppb) in the second week of August (Figure 9).

(b) Nitrate: The lowest average concentration (22 sites) of nitrate (NO3 = 374 ppb) occurred during the fourth week in July and the highest average nitrate concentration (NO3 = 816.0 ppb) during the first week of July (Figure 10).

The two nutrients being monitored displayed opposite trends over time. Total phosphorus concentrations increased during the summer, while nitrate concentrations were decreasing.

4.2.2 Average Tributary Concentration of Total Phosphorus by Year

Table 2 indicates that tributary phosphorus levels have been declining over the four years of monitoring.

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

Year	1995	1996	1997	1998
Average Tributary TP (ppb)	91.5	63.5	67.4	50.9

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 considered. 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

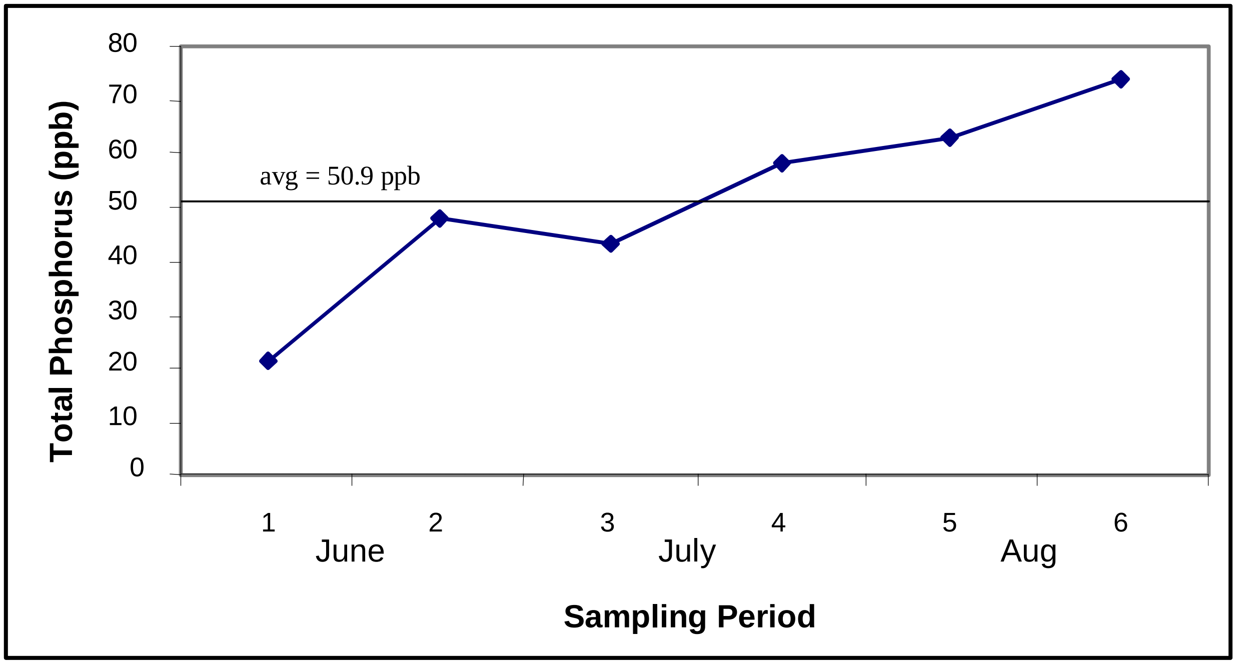


Figure 9. **Average total phosphorus concentration at tributary stations for each sampling period.**

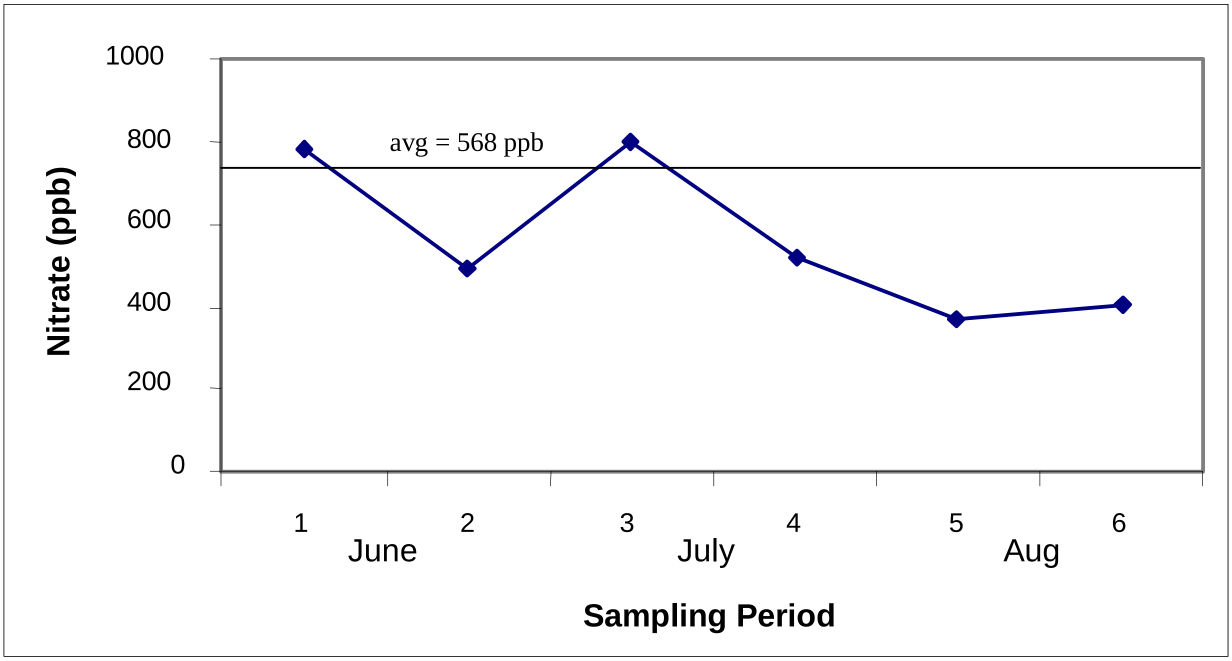


Figure 10. **Average nitrate concentration at tributary stations for each sampling period.**

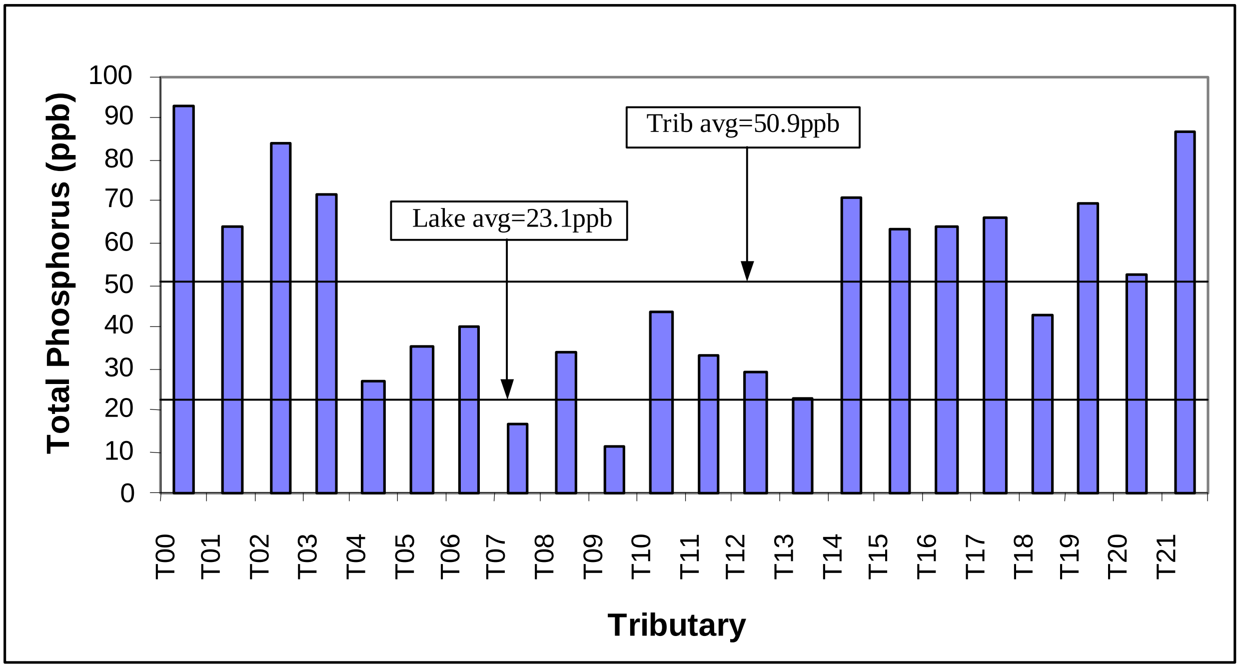


Figure 11. Seasonal average total phosphorus concentration for each tributary.

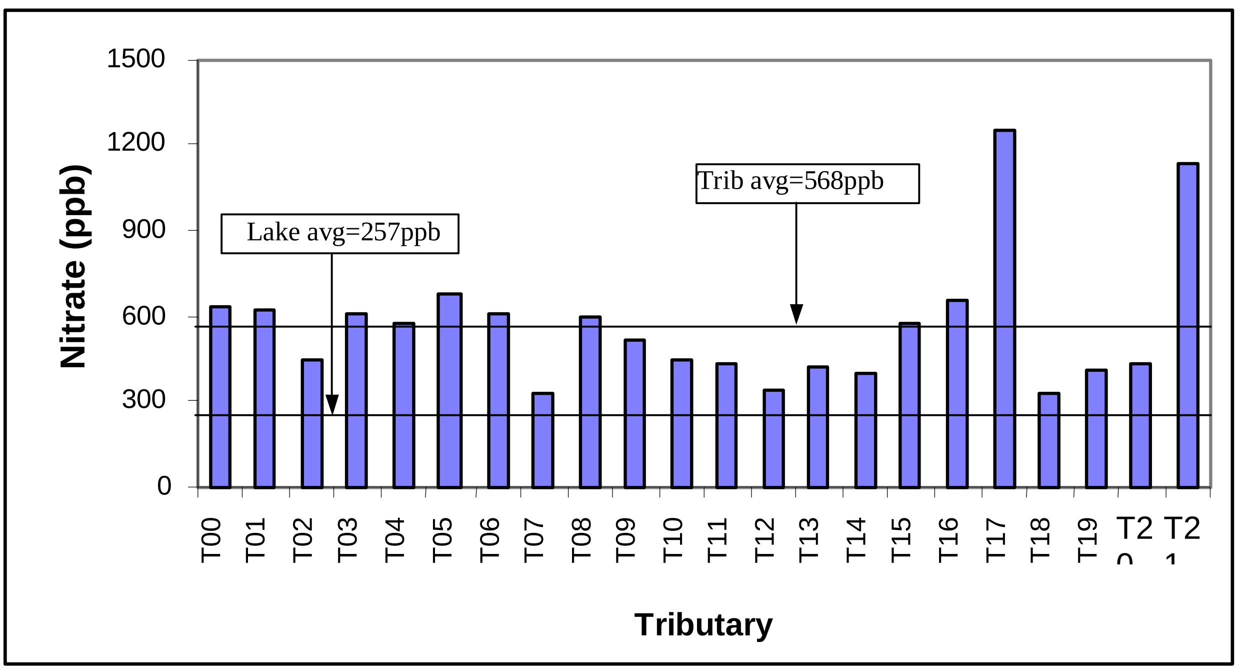


Figure 12. Seasonal average nitrate concentration for each tributary.

4.3 Results for Sample Sites Below the Dam

These samples are collected as grab samples from a bridge by the interns in the same manner as the tributary samples. While the samples collected below the dam are not tributaries flowing directly into the lake, water from these sites does end up in the lake because of the pumpback system. T9 is in the Roanoke River just below the dam at the APCO Visitor Center, T10 is in the Pigg River near its confluence with the Roanoke River, and T11 is in the Roanoke River after the confluence with the Pigg River and near where Leesville Lake begins. The results for 1993 through 1998 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 Table A4 and Table A6. 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. The significant decrease in Pigg River phosphorus concentrations since 1995 is encouraging.

Table 3. Summary of 1993 to 1998 results for total phosphorus at sites below the dam.

	Total Phosphorus (ppb)						
Site/Location	1993	1994	1995	1996	1997	1998	Site avg
T9/ Roanoke R. below dam	48.5	25.6	40.5	38.3	19.7	11.4	30.7
T10/Pigg R. at Rt. 605	65.2	64.5	83.4	48.3	38.9	43.4	57.2
T11/Roanoke R. at Rt. 608	54.6	38.7	62.1	48.1	33.9	33.1	45.1
Average by year	56.1	42.9	62.0	44.9	30.8	29.3	44.3

Table 4 gives similar results for the first year 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. This suggests that the nitrate-laden waters of the Roanoke Channel do move down below the surface and begin upwelling as they approach the dam.

Table 4. Summary of 1998 results for nitrate at sites below the dam.

Site/Location	Nitrate (ppb)
T9/ Roanoke R. below dam	516
T10/Pigg R. at Rt. 605	447
T11/Roanoke R. at Rt. 608	427
Average by year	463

4.4 Summary of Section

Overall, it would appear that water quality in Smith Mountain Lake was slightly better in 1998 than in 1997. It also appears that tributary phosphorus levels are, on the average, going down.

The channels and the coves of Smith Mountain Lake are dependent on each other for water circulation, nutrient interchange and biotic relationships. The tributaries provide much of the nutrients, especially phosphorus, as demonstrated with these data. The average concentration of total phosphorus from the sampled tributaries was 50.9 ppb, substantially higher than the average concentration of 23.1 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. 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.

5. FECAL COLIFORMS IN SMITH MOUNTAIN LAKE

5.1 Fecal Coliform Monitoring

Water samples were collected from 14 sites on Smith Mountain Lake on June 2, June 16, July 1, July 14, July 28, and August 14, 1998. 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, and 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 runoff 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. It 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 the following: (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 headwaters 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 headwaters 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 16 indicates the comparison of the sum of the ranks of each sample site. Figure 15 indicates the mean fecal coliform colony forming units (cfus), commonly called colony counts, for the six sample dates. Figure 17 shows a comparison of mean fecal coliform counts for the four sample years (1995-1998) for each site and the means for both combined marina fecal coliform counts and non-marina fecal coliform counts. The conclusions drawn from these data are:

1. The mean colony counts and variances for 1998 (marinas = 26.7 ± 2.7 cfus and non-marinas =13.6 ± 1.0 cfus) were higher than the mean colony counts and variances for 1997 (marinas =16 ± 15 cfus and non-marinas = 11.0 ±10.99 cfus).

2. Sample date was an important influence on the fecal coliform population estimates, with the mid-summer sample date July 15, 1998 exhibiting the highest mean number of colonies. In 1998 a significant trend ($\alpha = 0.5$) toward increasing number of fecal coliforms was observed as the summer passed (Figure 13). In the past there has been a proposed relationship with rain events and increased number of coliforms, but in the summer of 1998 there was no significant rainfall from July through August, therefore disputing that relationship.

3. The mean coliform population estimate for all marinas was higher (22.9 ± 25.0 cfus) than the mean coliform population counts for non-marina (13.6 ± 19.3 cfus). The three headwaters sites' mean fecal coliform population was in between the marinas and non-marinas in number (21.7 ± 18.1 cfus), as seen in Figure 14.

4. Four marina coves (Pelican Point, Indian Point, Smith Mountain Lake Yacht Club, and Foxport Marinas) had lower fecal coliform mean counts for the summer than one of the non-marina coves (Palmer's Trailer Park), as was true of the Pelican Point Marina in 1995, 1996 and 1997. The mean fecal coliform population for Pelican Point Marina for 1998 was 7.9 ± 7.3 cfus, 3.5 ± 1.9 cfus for Indian Point Marina, 37.6 ± 36.3 cfus for Smith Mountain Lake Yacht Club, 22.9 ± 25.0 cfus for Foxport Marina, and for Palmer's Trailer Park Cove the mean fecal coliform population was 47.2 ± 30.4 cfus (Figure 15).

5. The confluence of the two main tributaries and the Smith Mountain Lake Park Cove had the lowest fecal coliform counts on all six sample dates, which has not been the case in the past (Figure 15).

6. When all marina sites and non-marina sites are included, the mean fecal coliform population estimates for the marinas were not significantly higher than those for the non-marinas. However, three of the six marinas (Shoreline Marina, Smith Mountain Lake Dock and the Smith Mountain Lake Yacht Club) had consistently higher fecal coliform counts than the non-marina sites.

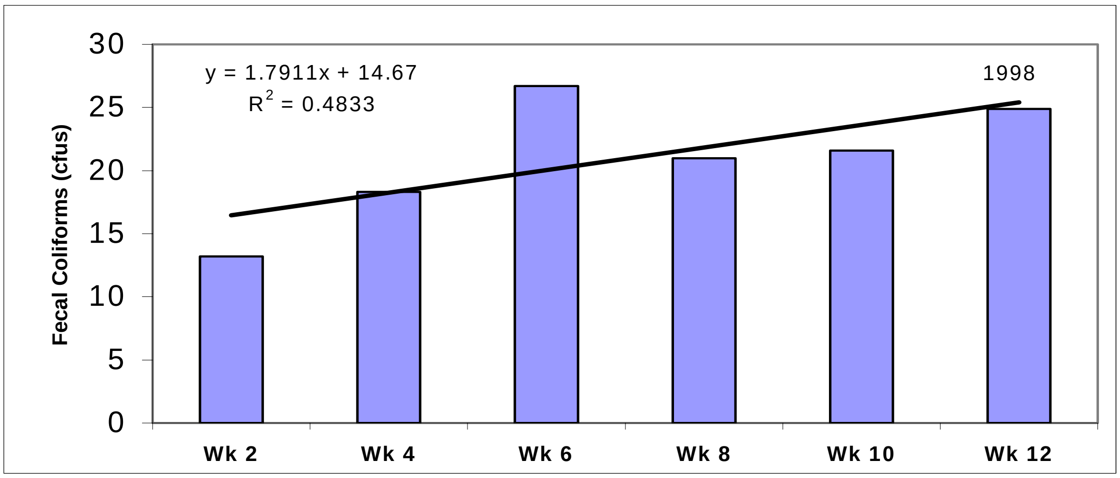


Figure 13. Fecal coliforms vs. week sampled on Smith Mountain Lake in 1998. (Each sample date included 14 sites with 2 samples per site and three replicate filters per sample, n =84.)

7. In a comparison of the sums of fecal coliform populations for sample dates and sites (Figure 16) in 1998, Smith Mountain Lake Dock, Shoreline Marina, Smith Mountain Lake Yacht Club (marina sites), Palmer's Trailer Park (non-marina site), and Hardy Ford Bridge (headwaters 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 1998. One of the marina sites, Shoreline Marina, had the highest fecal coliform count of the summer on the July 15th sample date (142 cfus) but exhibited lower counts on the other 5 sample dates (8, 24, 49, 55 & 21 cfus). This cove is on Becky's Creek and has been the center of controversial water quality measurements during the summer of 1998. Note that this highest measurement does not exceed Virginia's health standard for potable, swimmable or fishable waters.

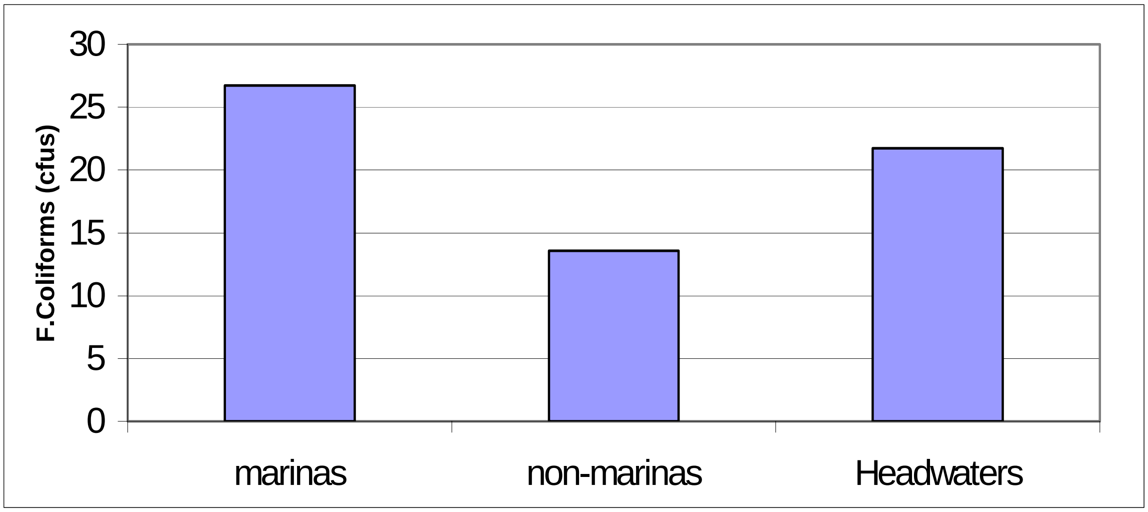


Figure 14. **Mean fecal coliform count vs. site type on Smith Mountain Lake 1998.** (There were 6 marina sites, 5 non-marina sites, and 2 headwaters sites.)

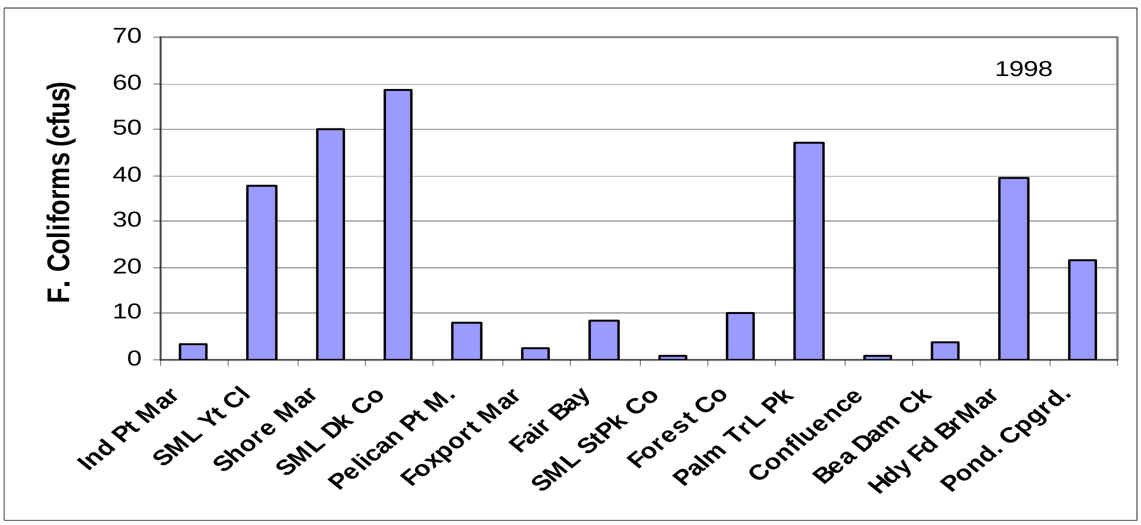


Figure 15. **Mean fecal coliform count vs. sample site on Smith Mountain Lake 1998.** (Each site has two stations sampled 6 times during the summer.)

8. 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.

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 four sample years (1995-1998).

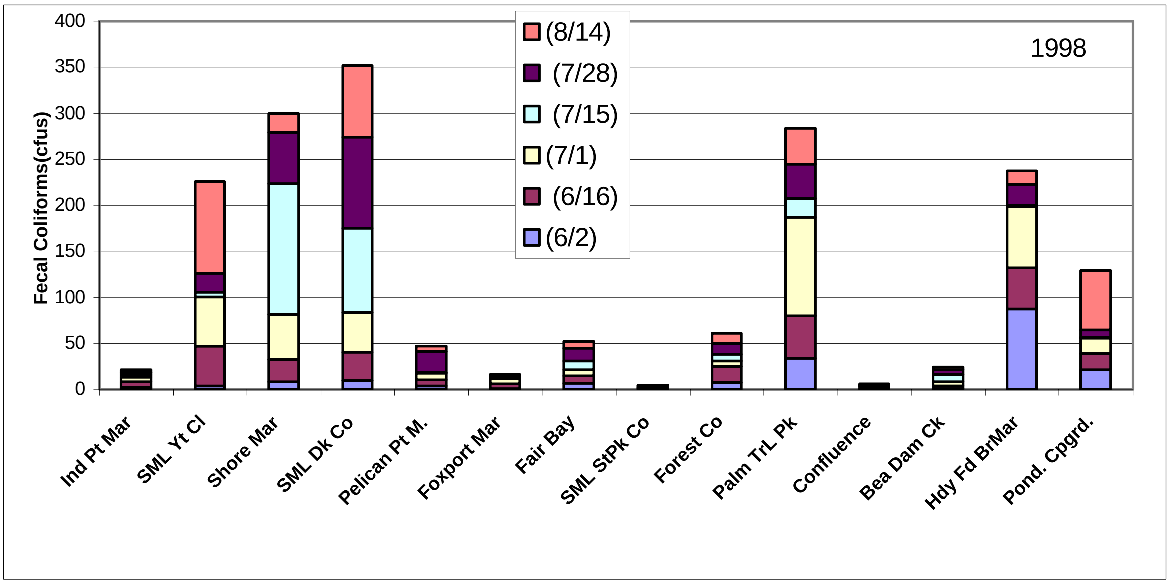


Figure 16. Sum of fecal coliforms counts for Smith Mountain Lake in 1998 at each site for all sample dates.
(Each site and date has two stations per site.)

In the comparison of four years of sampling fecal coliforms, the marinas have been consistently higher than the non-marinas. We also observed a very high fecal coliform population 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 headwaters sites, which presents a false impression of extremely high fecal coliform counts in the headwaters of the lake.

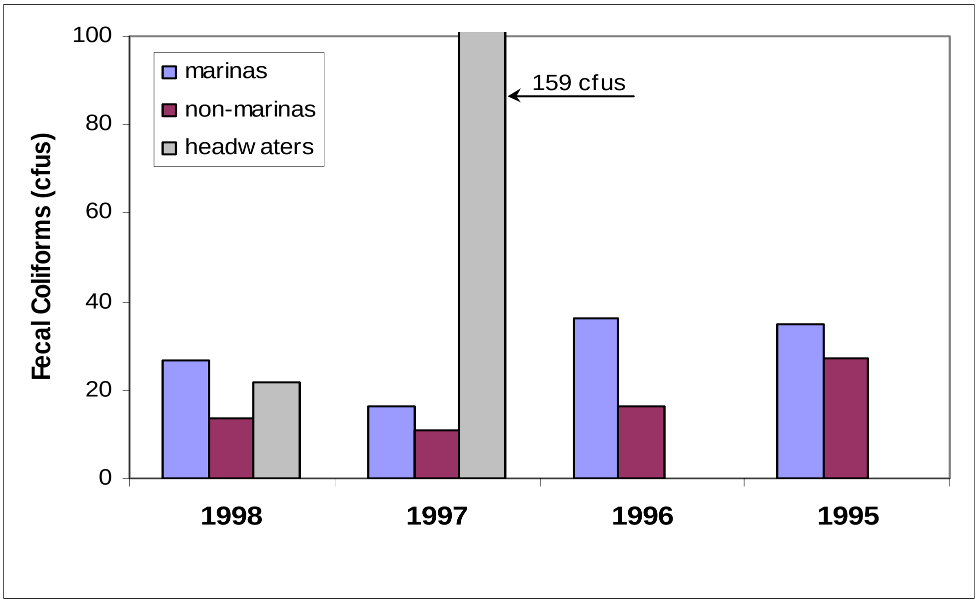


Figure 17. Mean fecal coliform counts per site type and year sampled for Smith Mountain Lake.

In 1997 and 1998 there has been 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. 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. The results of all three sampling groups were not always in agreement, but we feel that was to be expected with the knowledge that these sites were not at the identical sites or at the same times. The three agencies involved met in September to talk about our sampling regimes' similarities and differences. Plans were made at this time for more collaboration and coordination before the 1999 sampling season.

5.2 Fecal Coliforms and DNA Analysis

In addition to the analysis of the fecal coliform population numbers in the fourteen sites and comparison of the marinas and non-marina coves, an attempt to identify the potential animal source(s) of the fecal coliforms was made with the further analysis of fecal coliform colonies from the June sample date. The further analysis included species identification using standard biochemical tests and DNA fingerprint analysis using 41 of the *Escherichia coli* species colonies. Of the 128 fecal coliform colonies selected for further study, 82 colonies were identified as *E. coli*. The findings are listed below and the conclusions indicate that this was a useful analysis and should be continued.

In addition to the usefulness in identifying the source of the fecal coliforms, these analyses also provided quality control information to confirm that our laboratory procedures did indeed identify the fecal coliforms and that most of them (82/128) are of the *E. coli* species.

The following description of procedures is very technical and not expected to be understood completely by most of the readers but is necessarily included for those DNA and cell biology scientists who read the report in order to learn our methods. A discussion of the practical application of these findings will follow the technical section.

***Escherichia coli* DNA Analysis**

By: Ron Stephens, Ferrum College

March 9, 1999

Escherichia coli (*E. coli*) bacteria were isolated and identified from water samples collected from fourteen different sites on Smith Mountain Lake. Two water samples were collected at each site, and four bacterial colonies were isolated from each sample for a total of one hundred twenty eight bacterial isolates. From these isolates, eighty-two *E. coli* colonies were identified using bioMérieux Vitek API 20E typing system. In addition to *E. coli*, the following bacterial types were isolated: *Ent. cloacae, Klebsiella Gr., C. freundii, Klebsiella pneumoniae, Ser. plymuthica*.

Readable restriction endonuclease digestion profiles (REDP/DNA fingerprints) were obtained from forty-one of the *E. coli* isolates. The DNA fingerprints were determined using the Gene Path Strain Typing System and the *E. coli* restriction enzyme kit purchased from Bio-Rad Laboratories, Hercules, California. The REDP of each *E. coli* isolate was analyzed using Jandel Scientific Sigma Gel™ gel analysis software. The REDP's of the *E. coli* isolates from this study were then compared to REDP's of *E. coli* isolates collected from known animal sources and from unknown sources. The *E. coli* from the unknown sources was from surface water samples from

Smith Mountain Lake or from streams flowing into Smith Mountain Lake. TCL software was used to compare the REDP's of all *E. coli* isolates, which resulted in the following results:

1. Many of the REDP's of isolates from the same water sample matched. These results were expected.

2. Many of the REDP's of isolates from the same water sample were different. These results were also expected since a single water sample is likely to contain more than one strain of *E. coli*.

3. Some of the REDP's of isolates from a specific water sample match isolates from a second water sample collected at the same site.

   1-1-2 (Site 1, Sample 1, Isolate 2) matches 1-2-3

   3-2-1 matches 3-1-4

   The matching isolates could be from the same source or from a different source.

4. Some of the REDP's of isolates from a specific water sample match the REDP's of isolates collected at different sampling sites.

   4-2-2 matches 2-2-2

   2-2-3 matches 4-2-2 and 4-2-3

   These isolates also could be from the same or different sources.

5. One of the isolates, 12-2-2, matches an isolate from water samples that was collected in 1997. This sample was collected from surface water in the Glade Hill section of Franklin County near route 674. This match indicates that the source from this isolate still exists or that the bacterium is surviving in the lake.

6. One isolate, 3-1-4, matches an isolate from a cow that was collected in 1997. This cow isolate was collected in the Glade Hill section of Franklin County. Whether these matching isolates are from the same or a different source cannot be determined. This match does support the concept that DNA fingerprint technology can be used to determine the possible source of fecal coliform bacteria in aquatic systems.

Practical Application of Findings: the description of the technical procedure is to demonstrate that standard methods were followed for isolating and identifying the potential source of the DNA. The use of the Vitek API 20E typing system is very common is many bacterial identification labs including hospital laboratories and is primarily used to identify the species of the bacteria to help in diagnosing diseases or bacteria that is in the wrong place. We of course could describe coliform bacteria as being in the wrong place when it is in Smith

Mountain Lake. The digestion profiles methods described are standard methods when identifying DNA fingerprints. The DNA we are identifying or mapping are from the *E.coli* species of bacteria, which are considered a fecal coliform bacteria. All warm-blooded animals have fecal coliform bacteria in their digestive tract and when feces are excreted many of these bacteria are excreted and make up part of the feces mass. Most species of warm blooded animals are believed to have different strains of *E.coli* which differ primarily in the DNA composition and therefore would exhibit different distinctive DNA fingerprints. Through our study we were hoping to be able to identify the animal source of the *E.coli* by fingerprinting the DNA and comparing the fingerprint to previously sampled and identified *E.coli* sources. For example the DNA lab has fingerprinted *E.coli* from deer, horses, cows, and many other warm-blooded animals including humans. In the results listed above two such matching fingerprints were found. Conclusion #6 above indicates that in one of our water samples *E.coli* strains matches a sample taken from a cow in the Glade Hill section of the watershed in 1997. This indicates that the cow or a cow excreting the same strain of E. coli is still in the watershed and the contamination continues to make its way in to Smith Mountain Lake in 1998. Conclusion #5 indicates that the same *E.coli* strain that was found in a water sample in 1997 is still present in the water in 1998. The source or sources of this strain have not been identified but continue to contribute fecal coliform to Smith Mountain Lake. Both of those conclusions indicate that the DNA work was worthwhile and should be considered for future work in identifying the sources of fecal coliform populations in Smith Mountain Lake. There are other cellular biological methods of identifying animal sources of fecal coliforms and these methods will also be investigated in the future.

6. WATER QUALITY TRENDS

6.1 Water Quality Trends by Zone

The lake sites have been grouped into zones based on site 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

It should be noted that the later years' (especially 1995-1998) data is based on more sample sites and broader coverage of the lake. For Zones 5 and 6 (see Figures 18, 19, 20) there is no data in the earlier years.

In Figure 18, no significant trend in total phosphorus concentration appears during the 11-year period in any of the zones. All zones show a peak total phosphorus concentration in 1993. In each of the last 3 years the phosphorus concentrations have decreased in all zones, except for zone 2 where concentrations have remained about the same. The largest decreases are seen in the zones farthest up the channels from the dam.

Chlorophyll-*a* trends by zone are shown in Figure 19. As with total phosphorus, there are no significant trends for any zone over the 11 years that data has been collected. There has been a general decline in chlorophyll-*a* over the past three years in all zones but zone 5, where chlorophyll-*a* concentrations have increased in each of the past two years.

The average Secchi depth by zone is shown in Figure 20. Again, there are no significant trends over the period monitored for any zone. However, the trend toward increased water clarity can be seen in each zone over the last three years and that is a hopeful sign.

Figure 21 shows the strong correlation between water quality and distance from the dam. Moving away from the dam, there is a pronounced increase in phosphorus and chlorophyll-*a* and decreased Secchi depth, and the three trends are highly significant.

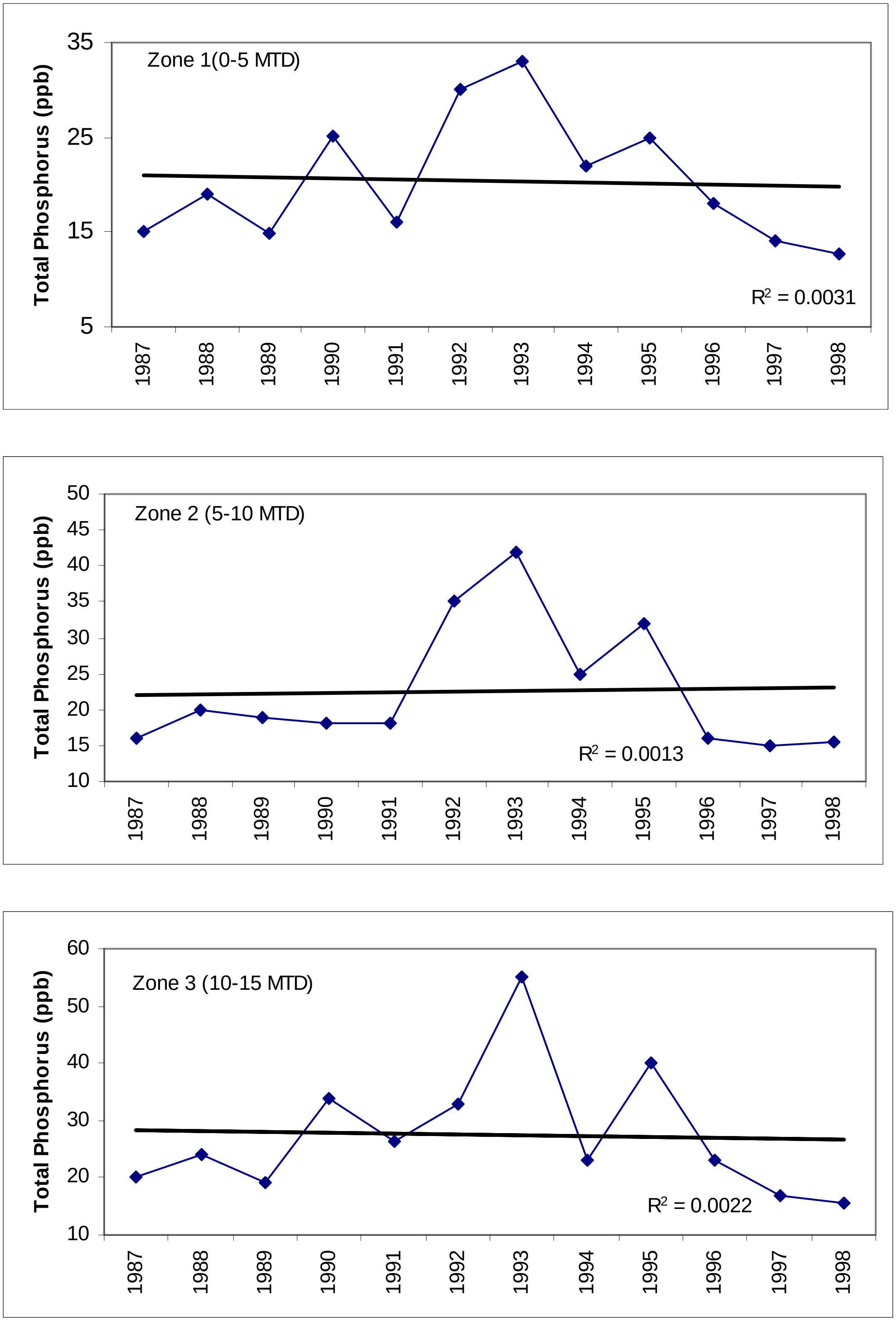
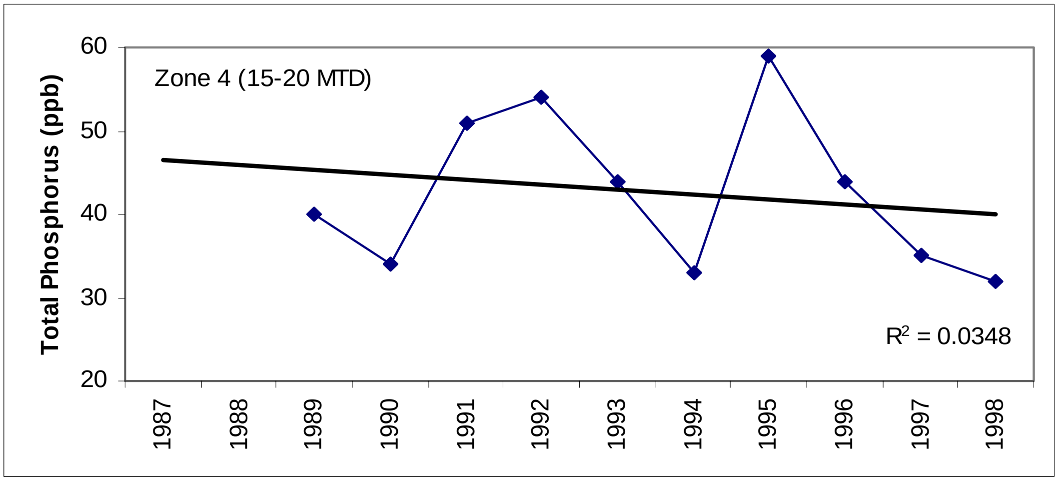
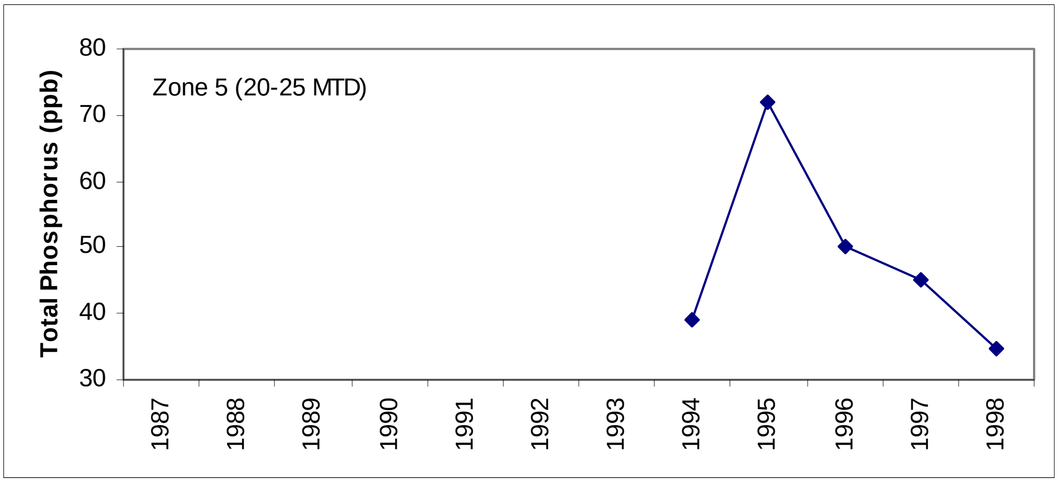


Figure 18. Average annual total phosphorus concentration by zone in Smith Mountain Lake.





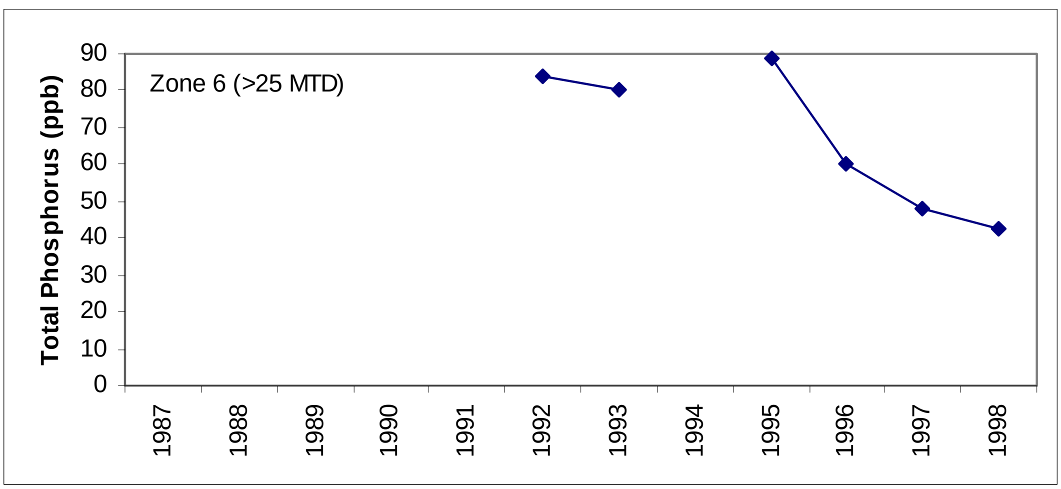


Figure 18. Average annual total phosphorus concentration by zone in Smith Mountain Lake. (cont.)

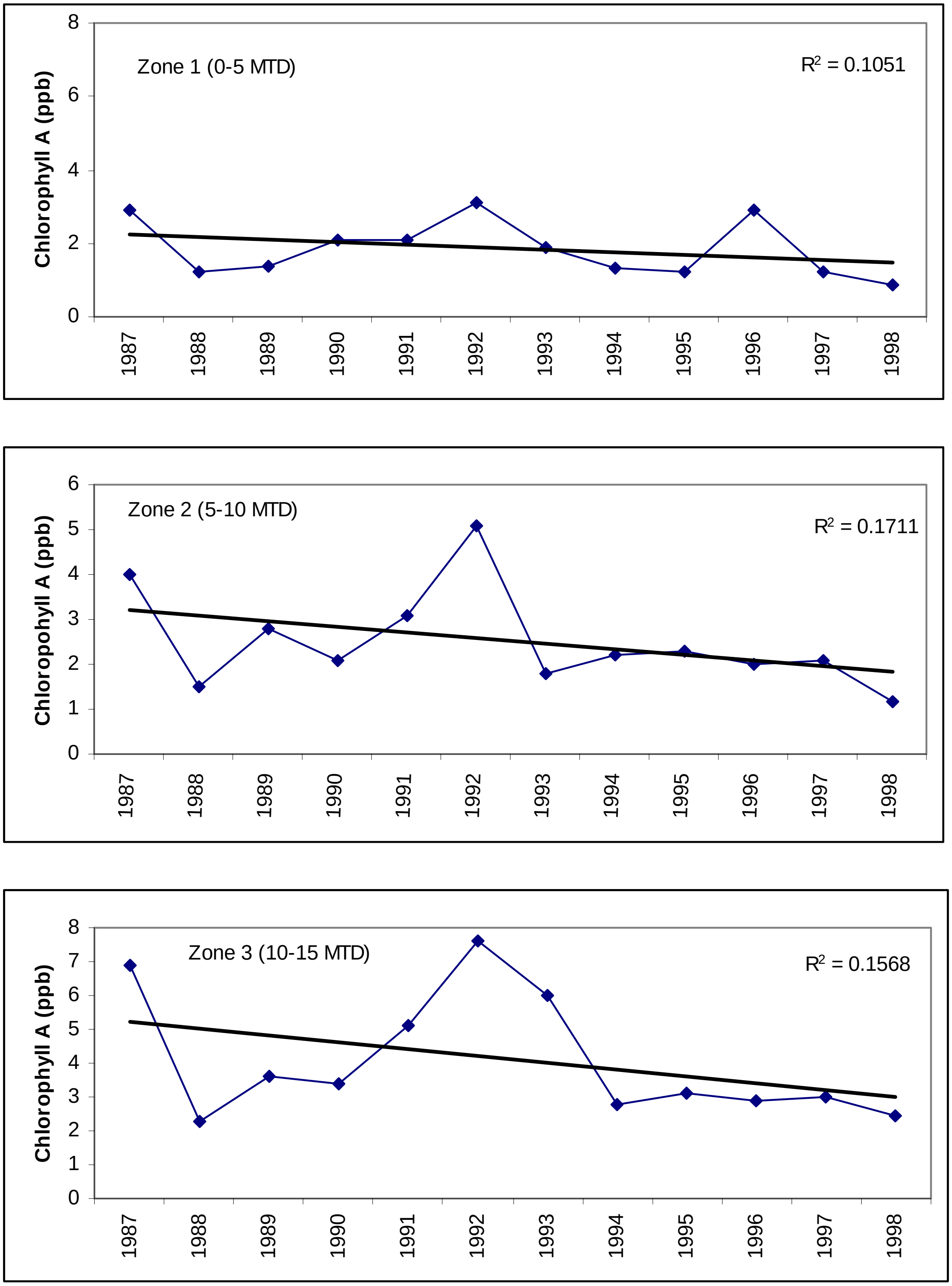


Figure 19. Average annual chlorophyll-*a* concentration by zone in Smith Mountain Lake.

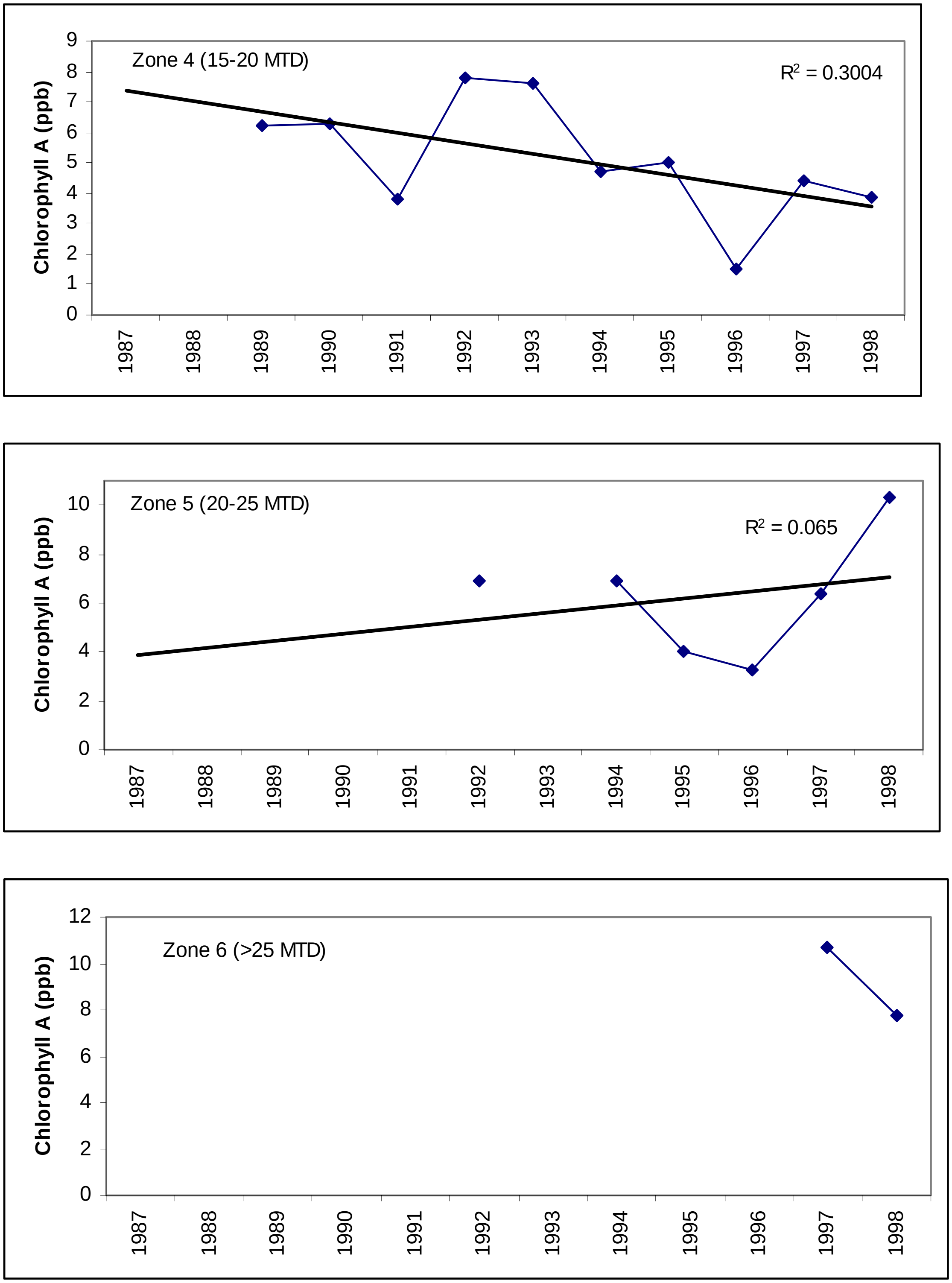


Figure 19. Average annual chlorophyll-*a* concentration by zone in Smith Mountain Lake. (cont.)

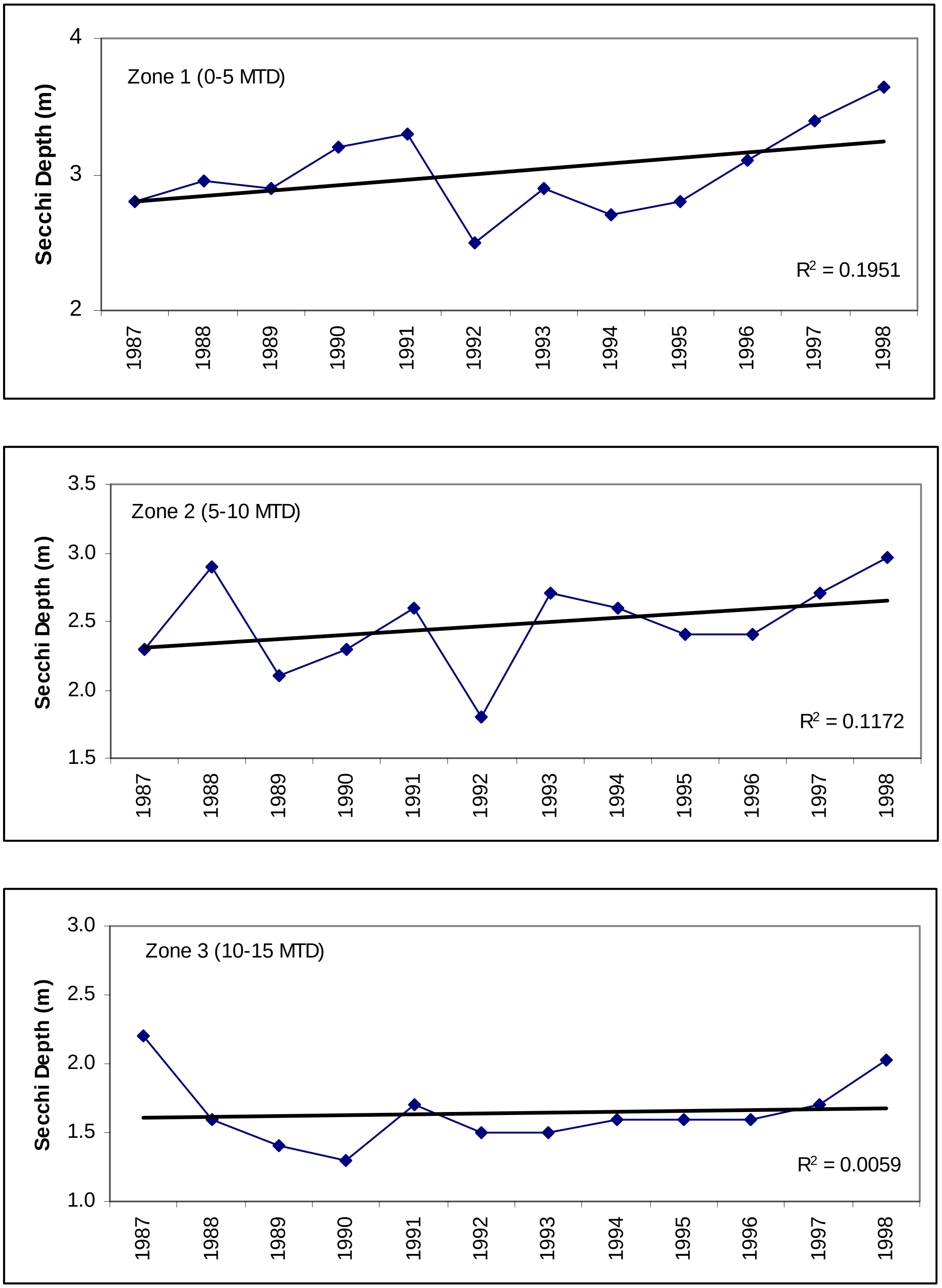
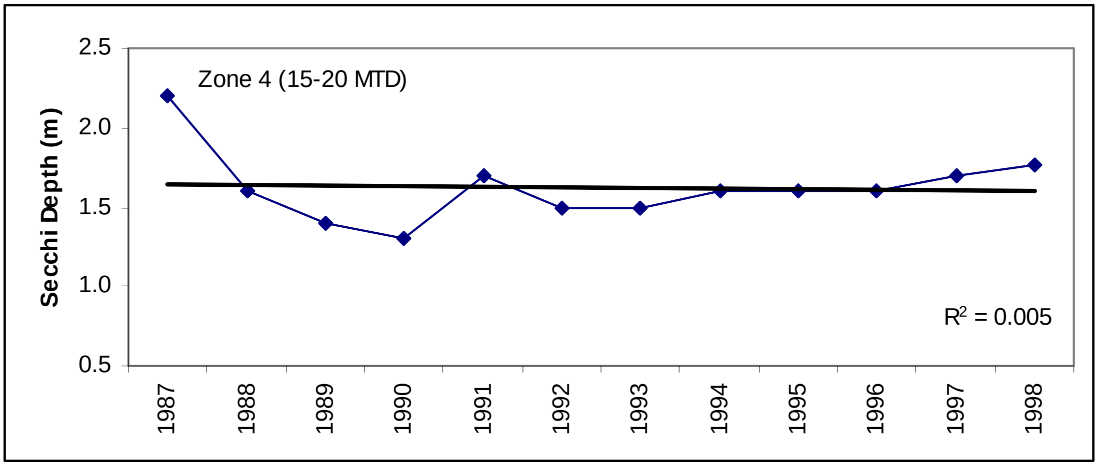
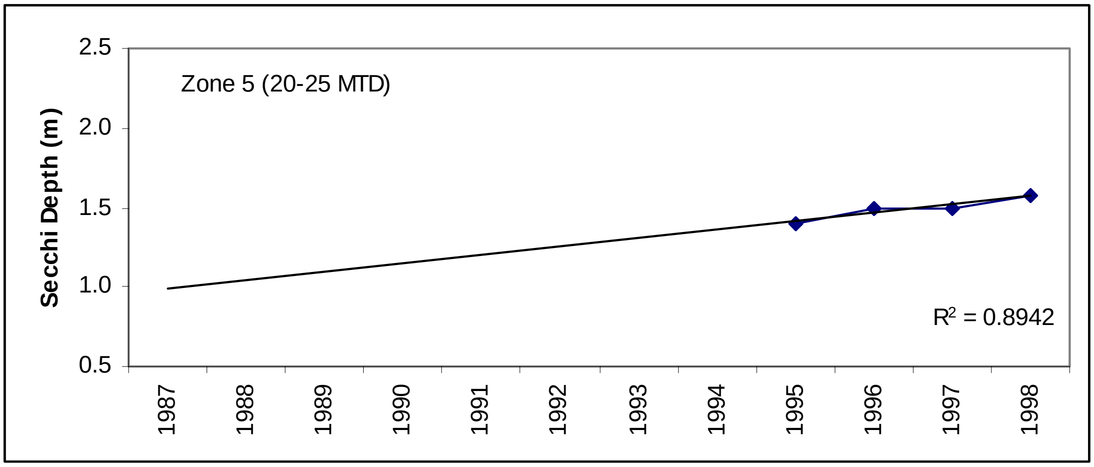


Figure 20. Annual average Secchi depth by zone in Smith Mountain Lake.





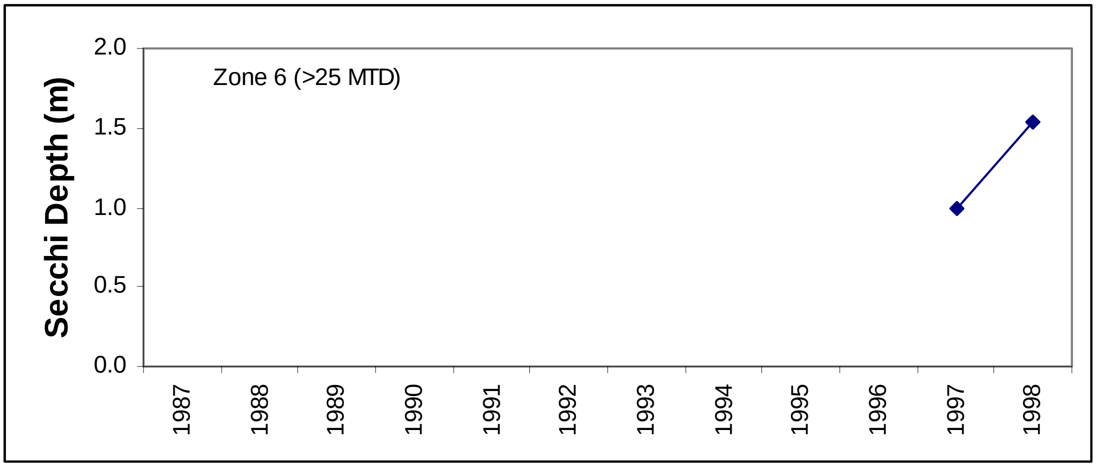


Figure 20. Annual average Secchi depth by zone in Smith Mountain Lake. (cont.)

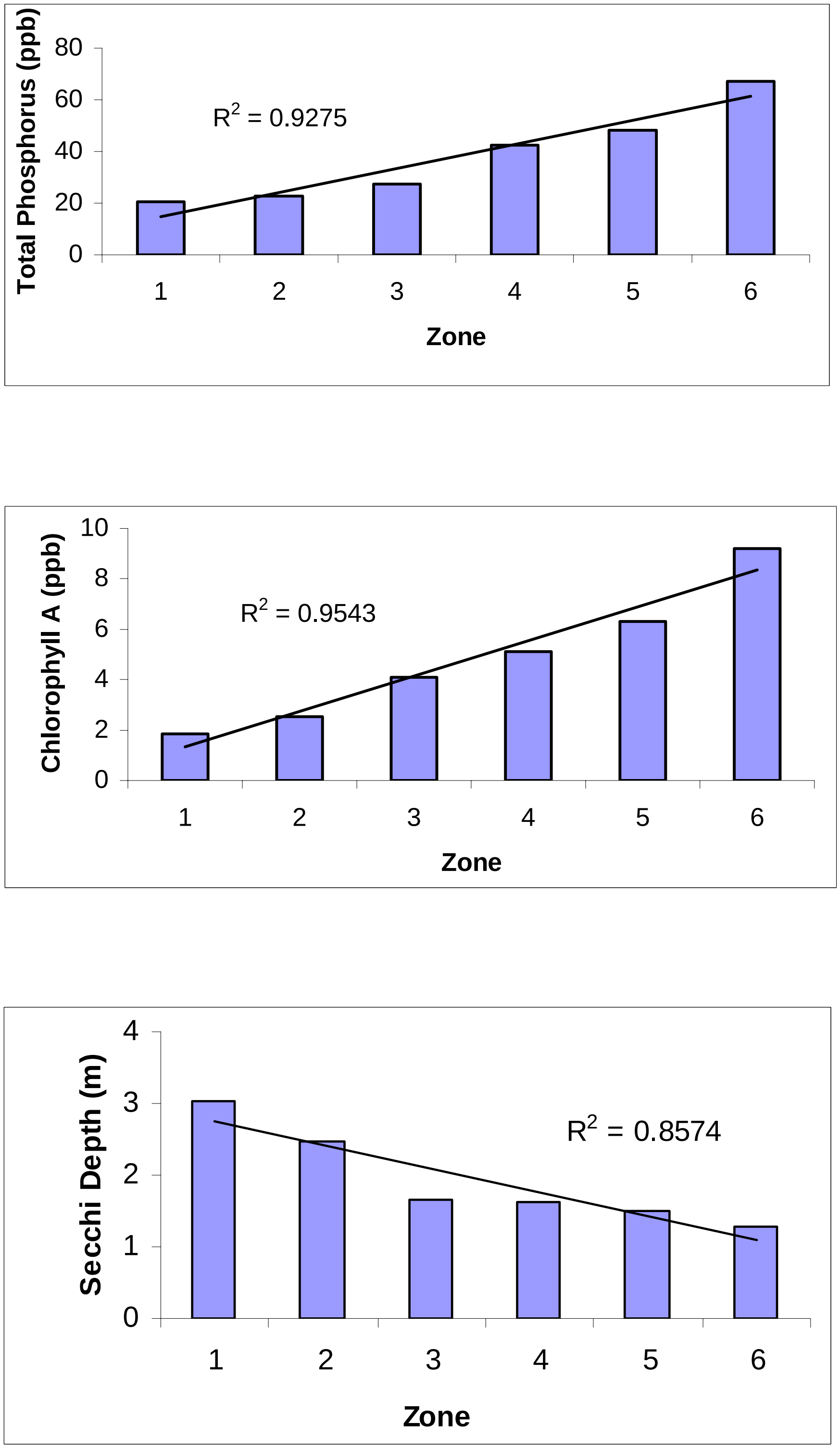


Figure 21. Average parameter value by zone (1987-1998).

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 phosphorous. Table 5 shows one such effort. (Note that the relationships are for northern temperate lakes and will not represent southeastern lakes as well.)

Table 5. 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 6 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. Furthermore, 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 6. Trophic status related to chlorophyll-a concentration in different studies.
(Reckhow and Chapra, 1983)

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

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 phosphorous 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 22, 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.

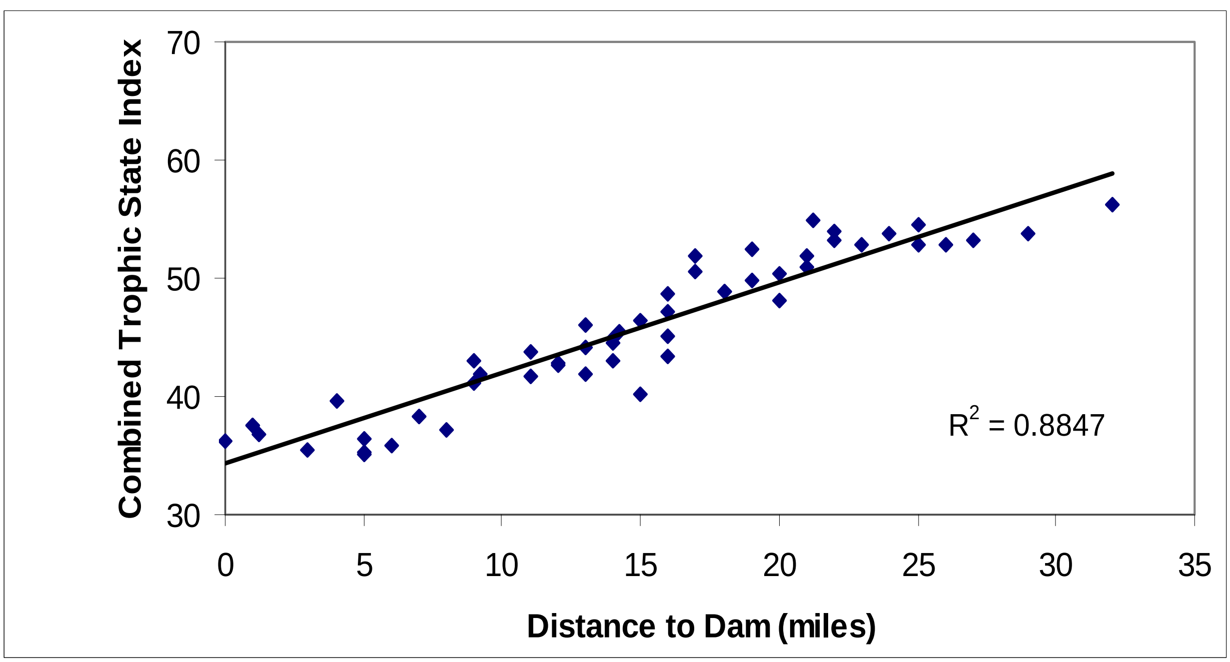


Figure 22. Combined Trophic State Index as a function of distance from dam.

Table 7 gives summary information from the TSI for the past two years. Station R34 was converted to a headwaters tributary station in 1998 and was therefore removed from the TSI analysis for 1997. In 1998, the average TSI and minimum TSI declined slightly, the maximum value remained the same, and the correlation coefficient increased slightly.

Table 7. Combined Trophic State Index summary for 1997 and 1998.

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

Table 8 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 8. Monitoring stations arranged in order of Combined Trophic State Index.

station	miles to dam	TP(ppb)	CHA (ppb)	SD (m)	TSI-C
C05	5.0	7.8	1.0	3.8	35.1
CM5	5.0	9.9	0.6	3.2	35.3
M3	3.0	15.1	0.4	3.6	35.5
C06	6.0	6.9	1.3	3.4	35.8
M0	0.0	12.0	0.7	3.6	36.2
M5	5.0	15.6	0.5	3.5	36.5
CM1.2	1.2	16.1	0.6	3.8	36.9
CR08	8.0	9.9	0.9	2.9	37.1
CM1	1.0	11.8	1.1	3.7	37.5
M1	1.0	12.4	1.0	3.6	37.6
R07	7.0	14.9	0.7	2.9	38.4
C04	4.0	14.2	1.9	4.1	39.6
G15	15.0	12.7	1.1	2.3	40.2
CR09	9.0	18.3	1.3	3.0	41.2
CB11	11.0	16.0	2.0	3.1	41.7
G13	13.0	16.9	1.5	2.7	41.8
CR09.2	9.2	19.6	1.3	2.8	41.9
B12	12.0	17.2	2.2	2.9	42.7
G12	12.0	19.3	2.1	3.1	42.8
R09	9.0	23.0	1.6	2.9	43.0
G14	14.0	14.6	2.2	2.3	43.0
G16	16.0	20.0	1.6	2.3	43.5
R11	11.0	16.8	2.7	2.6	43.8
CR13	13.0	15.2	2.7	2.2	44.1
R14	14.0	13.8	3.0	2.0	44.6
B14	14.0	20.8	2.2	2.2	44.9
B16	16.0	13.9	3.7	2.0	45.1
CR14.2	14.2	13.8	2.8	1.5	45.5
R13	13.0	16.1	4.4	2.2	46.0
R15	15.0	17.6	3.5	1.9	46.5
CB16	16.0	21.8	4.0	2.2	47.2
B20	20.0	29.0	2.4	1.7	48.1
CR16	16.0	22.6	4.2	1.7	48.8
B18	18.0	36.5	3.3	2.3	48.8
G18	18.0	27.1	2.9	1.6	48.8
CR19	19.0	25.7	5.9	2.0	49.8
CB20	20.0	30.3	3.5	1.5	50.3
R17	17.0	26.3	6.7	1.8	50.6
R21	21.0	29.4	7.5	2.1	51.0
CR21	21.0	40.4	6.4	2.1	51.8
CR17	17.0	41.8	4.4	1.7	51.9
R19	19.0	42.8	5.1	1.7	52.5
CR25	25.0	33.1	7.7	1.6	52.7
CR26	26.0	28.5	8.4	1.5	52.8
R23	23.0	23.7	10.2	1.4	52.9
R27	27.0	35.5	7.1	1.5	53.1
B22	22.0	61.3	3.3	1.5	53.2
R29	29.0	40.0	6.8	1.5	53.7
CR24	24.0	31.0	11.5	1.6	53.8
CR22	22.0	30.9	13.0	1.7	53.9
R25	25.0	28.6	16.3	1.6	54.5
CR21.2	21.2	51.5	6.9	1.5	54.9
R32	32.0	65.9	8.6	1.7	56.3

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 QA/QC for 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 9 summarizes the calibration data. The slope indicates the relationship between concentration and absorption and was very consistent from week to week. This gives confidence that the spectrophotometer used to measure absorbance was stable and that the standards were prepared in a consistent manner. The intercept is the absorbance of the reagent blank and indicates the extent to which the standards are contaminated with phosphorus during the analytical process. This background is subtracted from each sample to compensate. The contamination is due almost entirely to sample digestion. During digestion four reagents are added which contain small amounts of phosphorus that, along with the extra handling and manipulation, 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 9. Summary of 1998 calibration data for total phosphorus.

sampling period	slope	intercept	R^2
1	0.0032	0.0160	0.9936
2	0.0024	0.0289	0.9924
3	0.0033	0.0027	0.9812
4	0.0023	0.0098	0.9869
5	0.0022	0.0286	0.9958
6	0.0022	0.0040	0.9953
Avg	0.0026	0.0150	0.9909

In Table 10, data for surrogate samples are summarized. The 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 lake water 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 adsorption 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 since we don't know phosphorus concentrations before they have been analyzed. We minimize this source of contamination by designating a particular sample bottle for each site and reusing that bottle each week. The average percent error is low and the overall QA/QC results for total phosphorus are good.

Table 10. Summary of data for surrogate samples for total phosphorus.

QA/QC Sample	Period	n	Avg	Stdev	% Error
40 ppb	3	6	40.0	4.2	0.0
20 ppb	4	6	21.7	7.4	8.4

7.2 QA/QC for Nitrate

This was the second season in which volunteer monitor samples were analyzed for nitrate. Field blanks and surrogate samples were not prepared this season because of a miscommunication, but the method is straightforward and the procedure is well established. The calibration data is displayed in Table 11. The correlation coefficient for nitrate is not as high as for total phosphorus, which is typical. The reduction of nitrate to nitrite is accomplished by shaking the samples with powdered cadmium and the conversion efficiency is not very exact from one sample run to the next. The lower slopes in sampling periods 2 and 4 are a cause for concern that will be addressed next season.

Table 11. Summary of 1998 calibration data for nitrate.

Sampling Period	Slope	Intercept	R^2
1	0.0011	0.0951	0.9703
2	0.0005	0.0319	0.9089
3	0.0010	0.0305	0.9527
4	0.0006	0.0530	0.9559
5	0.0010	0.0024	0.8776
6	0.0011	0.0280	0.9829
Avg	0.0009	0.0402	0.9414

*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 fluorometer gives very consistent readings from day to day and week-to-week for a given standard and we feel 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 path length 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 1997.

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.

7.4 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 20-24 hours 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 being counted on the m-Fecal coliform media plates were fecal coliforms.

The third procedure used in 1998 was species identification of a number of the characteristically blue colonies counted on the first sample date (June 2nd). 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 1998 and Table 13 presents the collection efficiencies from 1991 through 1998. The figures show that the volunteer monitors are very conscientious about sample collection. Advanced monitors collected 97.5% of the samples possible in 1998 and 95% of the samples possible for basic monitors. This sampling efficiency is remarkably high for volunteer sampling programs. In 1995 a decrease in efficiencies was attributed to the implementation of Phase 2 of the Water Quality Monitoring Program and the change in sample sites to better cover the lake and to provide cove sites to match the tributary sites. In 1996 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 1998.

sample type	monitoring stations	possible samples	samples collected	%effeciency
CHA/NO3/PO4	52	312	300	96%
secchi	74	444	428	96%

Table 13. Comparison of sampling efficiencies for 1991-1998.

Sampling Efficiency (%)

	1991	1992	1993	1994	1995	1996	1997	1998
Secchi Depth	86	90	80	93	75	92	95	96
Total Phosphorus	96	93	90	99	80	96	96	96
Chlorophyll-*a*	95	93	90	98	80	96	97	96
Nitrate	NA	NA	NA	NA	NA	NA	99	96

9. CONCLUSIONS

1998 was one of the busiest, most productive years to date for the monitoring program and other activities related to water quality at Smith Mountain Lake. In all, seven students worked on water quality projects at Ferrum College. Two student interns took primary responsibility for the monitoring program and a third acted as the liaison with the Claytor Lake Program. Two more 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 news is mostly good. Average nitrate concentration was up slightly from the past year but the trend analysis by zone shows declining phosphorus and chlorophyll-*a* concentrations and increasing water clarity for each of the past three years. It is still not clear if these are long-term trends in water quality or result from drier weather during the spring. The high phosphorus levels observed in the 1993-1996 period seem to have been associated with spring flooding. There is a need to analyze the correlation of water quality parameters with spring precipitation patterns.

Fecal coliform counts were similar to previous years. With rare exceptions, the counts are very low, and there was not a single sample collected in our program that violated the standard for fishable-swimmable water.

10. ACKNOWLEDGEMENTS

As always, first thanks go to the many monitors who volunteer their time so willingly. We were fortunate this year to have had excellent help from the student technicians and great support from the Smith Mountain Lake Association. Amy Hayes and Rachel Pannell were given primary responsibility for the monitoring at Smith Mountain Lake and did a fine job, with excellent help from Minh Nguyen and Leon Reyes. John Singer, liaison from the SMLA, not only did a fine job of coordinating activities between the SMLA and Ferrum College but also used his boat to go out with us every two weeks to collect fecal coliform samples. Jim Spitz, SMLA President, also has done a great job of maintaining and building support for the program. The tremendous amount of work that needs to be done to protect water quality in Smith Mountain Lake will require a well-integrated, cooperative effort and we have been privileged to work with many fine people in the volunteer monitoring program.

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 and 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 Phosphorous 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. 1998 Smith Mt. Lake monitoring stations with monitor names and station locations.

Station	Monitor	Latitude	Longitude	Site Number
B12	Hatfield			
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	Hatfield			
CB16	Jamison	79.703	37.045	49
CB20	Franz	79.737	37.036	54
CM1	Moriarty/Rice	79.539	37.055	2
CM1.2	Moriarty/Rice	79.535	37.063	1
CM5	Bissinger	79.587	37.047	9
CR8	Bissinger	79.593	37.065	33
CR9	Daly	79.606	37.077	21
CR9.2	Daly	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			
G12	Hatfield			
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	Moriarty/Rice	79.538	37.043	3
M1	Duffany	79.547	37.047	4
M3	Duffany	79.564	37.041	5
M5	Duffany	79.588	37.042	10
R7	Bissinger	79.595	37.052	12

Table A1. **1998 Smith Mt. Lake monitoring stations with monitor names and station locations. (cont.)**

Station	Monitor	Latitude	Longitude	Site Number
R9	Daly	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
R23	Bogsrud	79.717	37.180	74
R25	Blevins			
R27	B. Dooley			
R29	B. Dooley	79.797	37.218	86
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	Ballengee	79.588	37.048	32
SCR10.1	Holasek	79.629	37.073	18
SCR10.2	Holasek	79.628	37.076	17
SCR10.3	Holasek	79.635	37.080	16
SCR11.1	Mueller	79.604	37.103	25
SCR11.2	Mueller	79.616	37.105	26
SCR11.3	Mueller	79.631	37.106	27
SCR14	Gerhardt	79.642	37.112	30
SCR14.1	Spahr	79.665	37.109	34
SCR14.2	Spahr	79.679	37.105	91
SCR14.3	Spahr	79.659	37.113	92
SCR15	Gerhardt	79.646	37.120	93
SCR17	Gerhardt	79.670	37.157	95
SCR17.1	Taylor	79.677	37.158	61
SCR22.3	Walthers	79.707	37.171	73
SCR23.2	Walthers	79.721	37.183	77
SCR24	Walthers	79.724	37.197	78
SCR7	Ballengee	79.585	37.061	11
SCR8	Ballengee	79.588	37.068	23
T0(Gills)	Snoddy			

Table A2. 1998 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. 1998 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	8.4	3.4	16.5	35.3	31.1	8.6	17.2	12.0
B14	7.8		27.1	13.6	34.7		20.8	10.7
B16	5.9		14.0	18.3	17.5		13.9	4.9
B18	30.9	30.9	33.1	47.5	42.5	34.1	36.5	6.3
B20	19.7	27.1	32.2	36.2	28.4	30.5	29.0	5.1
B22	19.7		51.6	96.6	72.0	66.4	61.3	25.3
C04	5.6	10.5	8.6	14.0	25.6	20.9	14.2	7.0
C05	4.4	0.0	15.8	4.9	12.5	9.5	7.8	5.3
C06	2.2	13.4	14.6	4.0	6.5	0.5	6.9	5.4
CB11	10.3	5.5	17.1	30.5	22.5	10.5	16.0	8.4
CB16	11.6		14.9	30.5	30.2		21.8	8.6
CB20	11.6	43.4	25.8	47.9	27.5	25.9	30.3	12.1
CM1	11.6	3.8	24.9	13.1	11.1	6.4	11.8	6.7
CM1.2	4.7	19.2	14.9	29.7	14.7	13.6	16.1	7.4
CM5	5.3	0.0	12.8	20.5		10.9	9.9	6.9
CR08	10.9	0.0	19.2	11.4		8.2	9.9	6.2
CR09	10.9		26.5	26.6	20.2	7.3	18.3	7.9
CR09.2	10.9		34.0	22.3	14.7	15.9	19.6	8.1
CR13	10.3	21.3	26.2	16.2	8.8	8.2	15.2	6.7
CR14.2	8.8	6.7	27.1	14.0		12.3	13.8	7.1
CR16	10.9	10.5	23.1	30.1	39.3	21.8	22.6	10.2
CR17	21.9	20.0	36.2	65.3	53.8	53.6	41.8	17.0
CR19	26.3	26.7	23.4	29.7	35.6	12.3	25.7	7.1
CR21	20.3	56.7	32.2	61.0	38.8	33.2	40.4	14.2
CR21.2	26.6	53.0	40.4	81.8	65.2	41.8	51.5	18.0
CR22	24.1	18.8	19.8	48.3	46.1	28.2	30.9	12.0
CR24	16.6	39.6	35.5	32.3	31.5	30.5	31.0	7.1
CR25	23.1	37.5	35.2	27.9	41.5	33.2	33.1	6.1
CR26	15.3	14.6	25.2	42.7	39.7	33.2	28.5	11.0
G12	13.4	3.0	19.5	28.8	22.9	28.2	19.3	9.0
G13	16.6	1.7	21.0	23.1	22.0		16.9	7.9
G14	10.0	0.0	16.8	18.3	17.9	24.5	14.6	7.8
G15	8.1	0.0	18.3	24.4	12.5		12.7	8.4
G16	10.9	3.0	29.2	25.3	17.5	34.1	20.0	10.7
G18	16.6	6.3	26.8	30.1	34.3	48.6	27.1	13.3
M0	5.6	8.0	27.1	5.3	6.1	20.0	12.0	8.4
M1	2.8	5.5	24.3	14.4	21.5	5.9	12.4	8.3
M3	12.8	2.5	18.6	19.7	24.7	12.3	15.1	7.0
M5	12.5	0.0	16.2	27.9	19.3	17.7	15.6	8.4
R07	13.1	3.0	10.7	29.2		18.6	14.9	8.7
R09	13.1		24.9	29.7	36.5	10.9	23.0	9.7
R11	11.9	0.0	19.5		32.5	20.0	16.8	10.7
R13	10.6	0.5	16.2	25.3	27.9	15.9	16.1	9.1
R14	4.4	3.0	12.5	31.4		17.7	13.8	10.3
R15	16.9	2.5	18.0	20.5	27.0	20.9	17.6	7.5
R17	13.1	21.3	23.1	45.7	50.6	3.6	26.3	16.8
R19	29.4	36.3	44.3	50.5	72.5	24.1	42.8	15.9
R21	20.3	30.9	31.9	34.9	28.4	30.0	29.4	4.5
R23	21.3	8.0	16.5	36.6	34.7	25.0	23.7	10.0
R25	15.9	39.2	24.3	35.3	34.7	22.3	28.6	8.3
R27	18.8	21.3	40.4	35.7	35.2	61.8	35.5	14.1
R29	33.4	39.6	32.2	45.7	50.2	38.6	40.0	6.4
period avg	14.0	15.5	24.2	31.2	30.7	22.9	**grand avg**	**23.1**
stdev	7.4	16.0	9.1	17.9	15.6	14.7	**grand stdev**	**15.3**

Table A4. 1998 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	22.2	209.2	51.6	78.8	79.7	117.7	93.2	65.1
T01	30.0	58.4	58.3	66.2	83.4	87.7	64.0	20.8
T02	33.4	78.4	58.9	96.2	92.9	144.1	84.0	37.6
T03	25.6	65.0	52.2	78.8	62.5	143.6	71.3	39.6
T04	14.1	16.3	33.7	26.6	31.5	39.1	26.9	9.9
T05	17.2	43.0	37.1	46.2	27.9	41.8	35.5	11.0
T06	27.5	38.4	48.6	42.7	44.7	39.1	40.2	7.2
T07	0.0	0.0	12.5	17.5	24.3	45.0	16.5	16.9
T08	14.1	13.4	39.8	66.6			33.5	25.3
T09	10.6	3.0	15.2	9.7	25.6	4.5	11.4	8.2
T10	20.3	45.5	31.6	48.3	45.2	69.5	43.4	16.7
T11	9.4	35.9	43.4	36.6	56.5	16.8	33.1	17.3
T12	10.9	9.2	30.4	37.5	32.9	52.3	28.9	16.4
T13	10.0	10.9	28.3	23.1	39.3	25.0	22.8	11.1
T14	42.5	64.2	66.8	77.5	91.5	82.7	70.9	17.2
T15	29.7	65.0	59.2	75.3	80.6	70.9	63.5	18.2
T16	29.7	44.6	52.2	80.1	85.6	90.0	63.7	24.9
T17	24.1	44.6	40.4	91.0	64.3	130.9	65.9	39.3
T18	19.4	25.0	65.5	47.0	42.5	55.5	42.5	17.7
T19	34.4	53.4	44.3		144.3		69.1	50.7
T20	21.3	88.4	30.1	71.4	84.7	19.5	52.6	32.4
T21	20.6	40.9	58.0	108.3	87.5	205.9	86.9	66.3
period avg	21.2	47.8	43.5	58.3	63.2	74.1	**grand avg**	**50.9**
stdev	10.3	25.0	15.4	27.8	31.0	52.4	**grand stdev**	**36.3**

Table A5. 1998 nitrate data for Smith Mountain Lake.

station	period 1	period 2	period 3	period 4	period 5	period 6	station avg	station stdev
B12	192.2		208.2	95.0	119.6	87.3	140.5	50.2
B14	202.2		220.2	0.0	46.6		117.3	95.6
B16	382.2		258.2	0.0	61.6		175.5	152.8
B18	524.2	524.2	344.2	120.0	75.6	83.6	278.6	195.5
B20	646.2	520.2	346.2	50.0	76.6	69.1	284.7	236.2
B22		990.2	434.2	121.7	63.6	114.5	344.8	348.3
C04	336.2	498.2	200.2	171.7	185.6	173.6	260.9	120.4
C05	172.2	474.2	148.2	193.3	144.6	152.7	214.2	117.5
C06	140.2	312.2	120.2	125.0	124.6	114.5	156.1	70.2
CB11	170.2	400.2	150.2	106.7	97.6	90.9	169.3	107.2
CB16	272.2		152.2	6.7	47.6		119.7	102.8
CB20			340.2	51.7	28.6	88.2	127.2	124.8
CM1	138.2	270.2	278.2	121.7	154.6	133.6	182.8	65.4
CM1.2	452.2	230.2	540.2	178.3	184.6	211.8	299.6	142.4
CM5	282.2	328.2	136.2	41.7		0.0	157.7	129.1
CR08	138.2	364.2	150.2	26.7		0.0	135.9	128.6
CR09			176.2	121.7	116.6	140.0	138.6	23.4
CR09.2			146.2	123.3	109.6	105.5	121.1	15.9
CR13	212.2	286.2		98.3	60.6	80.0	147.5	87.1
CR14.2	100.2	0.0	130.2	76.7			76.8	48.2
CR16	162.2	382.2	352.2	108.3	120.6	120.9	207.7	114.3
CR17	146.2	504.2	358.2	136.7	146.6	142.7	239.1	142.3
CR19	184.2	416.2	262.2	58.3	97.6	120.0	189.8	120.5
CR21	196.2	576.2	316.2	123.3	75.6	74.5	227.0	176.9
CR21.2	202.2	564.2	204.2	411.7	49.6	100.9	255.5	178.6
CR22	676.2	230.2	560.2	156.7	132.6	84.5	306.7	226.9
CR24	1110.2			636.7	280.6	90.9	529.6	388.3
CR25	842.2			730.0	263.6	69.1	476.2	319.9
CR26	1290.2	64.2	920.2	246.7	377.6	127.3	504.4	448.9
G12	258.2	8.2	128.2	86.7	57.6	61.8	100.1	79.2
G13	386.2	2.2	52.2	83.3	24.6		109.7	140.9
G14	220.2	0.0	98.2	0.0	12.6	84.5	69.3	78.2
G15	138.2	0.0	82.2	20.0	75.6		63.2	49.0
G16	138.2	8.2	112.2	26.7	72.6	65.5	70.6	45.0
G18	136.2	24.2	104.2	83.3	80.6	72.7	83.5	33.8
M0	618.2	32.2	324.2	195.0	189.6	277.3	272.7	179.3
M1	284.2	20.2	196.2	0.0	238.6	215.5	159.1	108.9
M3	192.2	6.2	180.2	223.3	217.6	149.1	161.4	73.6
M5	246.2	0.0	256.2	238.3	234.6	193.6	194.8	89.3
R07	128.2	8.2	266.2	65.0		165.5	126.6	88.1
R09			256.2	221.7	71.6	124.5	168.5	73.9
R11	112.2	0.0	280.2		150.6	83.6	125.3	91.9
R13	232.2	408.2	244.2	73.3	93.6	63.6	185.9	123.2
R14	186.2	342.2	302.2	98.3		80.9	202.0	105.2
R15	198.2	494.2	376.2	91.7	112.6	77.3	225.0	157.2
R17	490.2	658.2	416.2	115.0	135.6	96.4	318.6	215.5
R19	384.2	586.2	612.2	158.3	149.6	109.1	333.3	207.8
R21	478.2	216.2	522.2	305.0	142.6	100.9	294.2	159.4
R23	1290.2	444.2		325.0	285.6	120.9	493.2	411.7
R25	1346.2		1012.2	870.0	549.6	219.1	799.4	386.9
R27	1364.2	918.2		628.3	621.6	239.1	754.3	373.6
R29	1530.2	1082.2	846.2	920.0	681.6	468.2	921.4	332.9
R32	1490.2	190.2	1422.2	428.3	368.6	396.4	716.0	529.2
period avg	437.9	318.7	323.8	186.4	162.7	128.5	**grand avg**	**257.9**
stdev	416.0	284.6	264.4	213.7	145.6	85.6	**grand stdev**	**277.1**

Table A6. 1998 nitrate samples for Smith Mountain Lake tributaries.

Station	week 1	week 2	week 3	week 4	week 5	week 6	sta avg	sta stdev
T00	1006.2	336.2	1292.2	428.3	368.6	396.4	638.0	407.3
T01	862.2	414.2	800.2	493.3	385.6	782.7	623.0	214.9
T02	544.2	454.2	626.2	336.7	295.6	410.9	444.6	124.9
T03	1036.2	430.2	786.2	510.0	267.6	637.3	611.2	273.1
T04	902.2	442.2	866.2	543.3	389.6	291.8	572.6	255.0
T05	728.2	712.2	1012.2	836.7	463.6	311.8	677.4	253.2
T06	552.2	608.2	976.2	571.7	575.6	370.0	609.0	198.8
T07	1072.2	48.2	292.2	153.3	218.6	148.2	322.1	376.3
T08	522.2	558.2	770.2	561.7			603.1	112.8
T09	650.2	442.2	786.2	566.7	360.6	290.0	516.0	186.7
T10	646.2	310.2	578.2	550.0	265.6	331.8	447.0	162.7
T11	598.2	292.2	600.2	455.0	322.6	298.2	427.7	145.4
T12	596.2	172.2	304.2	286.7	155.6	505.5	336.7	178.5
T13	506.2	368.2	548.2	428.3	393.6	295.5	423.3	92.5
T14	780.2	312.2	440.2	420.0	188.6	266.4	401.3	208.2
T15	340.2	640.2	912.2	823.3	330.6	415.5	577.0	252.9
T16	932.2	638.2	994.2	636.7	322.6	411.8	655.9	269.1
T17	1748.2	932.2	1718.2	1323.3	1020.6	798.2	1256.8	407.5
T18	488.2	558.2	338.2	200.0	167.6	163.6	319.3	171.7
T19	566.2	380.2	472.2		247.6		416.6	135.8
T20	708.2	338.2	602.2	491.7	212.6	242.7	432.6	200.8
T21	1530.2	1454.2	1846.2	343.3	908.6	750.9	1138.9	563.8
period avg	787.1	492.8	798.3	521.9	374.4	406.0	**grand avg**	**567.7**
stdev	340.1	287.0	407.5	249.8	221.4	194.1	**grand stdev**	**329.8**

Table A7. 1998 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	3.29	4.62	1.26	0.42	0.84	2.94	2.2	1.6
B14	3.22		1.68	2.8	1.26		2.2	0.9
B16	2.94		3.22	3.78	5.04		3.7	0.9
B18	6.44	1.89	2.66	4.97	2.87	1.19	3.3	2.0
B20	4.97	0.49	4.34	4.06	0.42	0.28	2.4	2.2
B22		2.1	4.48	6.79	2.38	0.84	3.3	2.3
C04	2.40	1.26	4.55	1.4	0.98	0.84	1.9	1.4
C05	0.91	0.91	1.12	1.19	0.91	0.7	1.0	0.2
C06	0.84	1.54	1.4	1.4	1.33	1.4	1.3	0.2
CB11	3.50	2.03	1.26	2.24	2.66	0.28	2.0	1.1
CB16	4.55		2.1	5.32	4.06		4.0	1.4
CB20		12.32	0.21	2.66	0.56	1.82	3.5	5.0
CM1	0.49	4.97	0.35	0.28	0.35	0.14	1.1	1.9
CM1.2	0.70	2.1	0.21	0	0.14	0.56	0.6	0.8
CM5	0.35	0.84	0.63	0.14		0.91	0.6	0.3
CR08	1.26	0.63	1.12	0.7		0.63	0.9	0.3
CR09			0.7	0.56	1.82	1.96	1.3	0.7
CR09.2			0.91	2.31	0.77	1.26	1.3	0.7
CR13	5.18	5.32	0.35	3.22	1.12	1.12	2.7	2.2
CR14.2	3.92	2.94	0.35	2.03	4.34	3.22	2.8	1.4
CR16	4.34	4.34	3.5	1.61	3.92	7.77	4.2	2.0
CR17	2.10	7	2.24	1.54	11.62	1.82	4.4	4.1
CR19	7.49	8.19	6.65	3.57	8.05	1.47	5.9	2.8
CR21	2.24	9.8	10.08	3.78		6.16	6.4	3.5
CR21.2	6.86	5.04	7.91	7.56	11.06	2.968	6.9	2.7
CR22	14.00	13.51	5.46	7.21	10.92	26.6	13.0	7.5
CR24	6.37			4.76	14.00	21	11.5	7.5
CR25	8.12			7.7		7.28	7.7	0.4
CR26	14.00	5.81	1.82	6.3	4.06	18.2	8.4	6.3
G12	3.08	1.12		1.96	2.66	1.68	2.1	0.8
G13	1.75	0.63	1.05	0.63	3.57		1.5	1.2
G14	0.91	0	0.98	0.28	3.92	7.14	2.2	2.8
G15	0.98	0.7	0.84	0.35	2.45		1.1	0.8
G16	1.26	1.61	3.08	1.75	1.12	1.05	1.6	0.8
G18	3.22	2.03	1.26	1.54	2.87	6.65	2.9	2.0
M0	0.14	1.05	0.28	0.14	1.05	1.68	0.7	0.6
M1	1.82	3.08	0.07	0	0.35	0.42	1.0	1.2
M3	0.49	1.82	0.07	0	0.00	0.14	0.4	0.7
M5	0.84	0.91	0	0.84	0.00	0.14	0.5	0.5
R07	1.05	1.12	0.42	0.21		0.63	0.7	0.4
R09			1.96	0.7	0.28	3.29	1.6	1.4
R11	3.36	1.89	1.47		3.36	3.64	2.7	1.0
R13	5.46	10.78	0.98	3.57	2.24	3.43	4.4	3.5
R14	6.86	2.73	1.54	1.89		1.89	3.0	2.2
R15	6.58	3.92	1.54	2.52	3.36	3.22	3.5	1.7
R17	7.84	9.38	9.24	0.21	8.26	5.39	6.7	3.5
R19	0.49	5.81	11.2	1.47	6.02	5.74	5.1	3.8
R21	10.78	2.17	8.82	13.16	4.90	5.11	7.5	4.1
R23		9.1	9.87	4.9	21.00	6.09	10.2	6.4
R25	7.49			10.01	21.00	26.6	16.3	9.0
R27	14.00	2.66	5.6	7.91	4.20	8.26	7.1	4.0
R29	11.06	6.23	4.76	4.48	3.64	10.5	6.8	3.2
R34	1.12	2.31	22.4				8.6	12.0
Period Avg	4.3	3.8	3.2	2.9	4.2	4.6	**grand avg**	**3.8**
stdev	3.8	3.4	4.1	2.9	4.9	6.3	**grand stdev**	**0.6**

Table A8. 1998 Secchi data for Smith Mountain Lake.

station	period 1	period 2	period 3	period 4	period 5	period 6	station avg	station stdev
B12	2.25	3.50	3.50	2.75	2.50	3.00	2.92	0.52
B14	2.25	3.25	2.00	2.00	1.75		2.25	0.59
B16	2.25	3.00	1.75	1.50	1.75		2.05	0.60
B18	2.50	2.50	2.00	2.00	2.00	2.75	2.29	0.33
B20	2.00	2.25	2.25	1.75	2.25	2.25	2.13	0.21
B22		1.75	1.50	1.66	1.60	1.50	1.60	0.11
C04	3.50	4.25	4.00	4.00	4.25	4.75	4.13	0.41
C05	3.00	4.00	4.00	3.50	4.00	4.25	3.79	0.46
C06	3.50	3.50	3.25	3.00	3.50	3.75	3.42	0.26
CB11	2.75	4.00	2.75	3.00	3.25	3.00	3.13	0.47
CB16	2.25	3.25	2.00	1.75	1.75		2.20	0.62
CB20		2.75	1.75	1.75	2.00	2.00	2.05	0.41
CM1	4.00	4.00	3.00	4.00	3.50	3.50	3.67	0.41
CM1.2	3.75	4.00	3.00	4.00	4.00	4.00	3.79	0.40
CM5	3.00	3.25	3.00	3.00		3.75	3.20	0.33
CR08	2.50	2.50	3.50	2.50		3.50	2.90	0.55
CR09			3.00	2.85	3.00	3.00	2.96	0.08
CR09.2			3.00	2.50	3.00	2.50	2.75	0.29
CR13	1.60	2.00	3.50	2.10	2.00	2.00	2.20	0.66
CR14.2	1.25	1.50	2.00	1.50	1.50	1.50	1.54	0.25
CR16	1.25	1.70	2.20	1.90	1.30		1.67	0.40
CR17	1.25	1.70	1.90	1.65	1.75		1.65	0.24
CR18		1.50	1.75	1.50	1.50	1.50	1.55	0.11
CR19	1.50	1.50	1.60	1.70	1.70	2.00	1.67	0.19
CR19.2		1.50	1.75	1.25	1.25	1.50	1.45	0.21
CR20		1.50	1.75	1.50	1.25	1.50	1.50	0.18
CR21	1.25	1.75	1.50	1.50	1.75	1.50	1.54	0.19
CR21.2	1.25	1.50	1.25	1.25	1.50	1.50	1.38	0.14
CR22	1.50	2.00	1.75	1.50	1.50	1.50	1.63	0.21
CR24	1.75	2.00	1.60	1.30	1.25	1.00	1.48	0.37
CR25	1.75	2.00	1.60	1.30	1.50	1.00	1.53	0.35
CR26	1.75	2.25	2.00	1.50	1.50	1.00	1.67	0.44
G12	2.50	4.00	2.75	3.00	2.75	3.50	3.08	0.56
G13	3.00	3.00	2.00	2.75	2.50		2.65	0.42
G14		3.25	2.25	2.00	1.50	2.50	2.30	0.65
G15	2.50	2.50	2.00	2.25	2.00		2.25	0.25
G16		2.75	2.60	2.00	2.00	2.25	2.32	0.34
G18		2.50	1.75	1.50	2.00	2.00	1.95	0.37
M0	3.75	3.75	3.50	4.00	4.00	2.50	3.58	0.56
M1	3.50	4.00	3.50	3.50	3.50	3.50	3.58	0.20
M3	3.50	3.50	3.50	3.50	3.50	4.00	3.58	0.20
M5	2.50	3.50	3.50	3.50	4.00	4.00	3.50	0.55
R07	2.00	3.00	3.00	2.75		3.50	2.85	0.55
R09			3.00	3.00	3.00	2.75	2.94	0.13
R11	1.75	2.25	3.50		2.75	2.75	2.60	0.65
R13	1.50	1.90	2.80	2.10	2.40	2.50	2.20	0.46
R14	1.50	1.75	2.50	2.00	2.00	2.00	1.96	0.33
R15	1.38	1.85	2.00	2.10	1.95		1.86	0.28
R17	1.40	1.80	1.70	2.00	2.10	2.00	1.83	0.26
R19	1.30	1.50	1.70	1.90	1.80	2.00	1.70	0.26
R21	1.50	2.25	1.50	1.50	1.75	1.75	1.71	0.29
R23	1.50	2.00	1.75	1.50	1.50	1.50	1.63	0.21
R25	2.00	2.00	1.25	1.30	1.25	1.00	1.47	0.43
R27	1.50	2.25	1.75	1.50	1.50	1.00	1.58	0.41
R29	1.50	1.75	1.75	1.50	1.50	1.00	1.50	0.27
R34	0.50	1.00	1.00	1.25	1.50		1.05	0.37

Table A8. 1998 Secchi data for Smith Mountain Lake. (cont.)

station	period 1	period 2	period 3	period 4	period 5	period 6	station avg	station stdev
SB12.2	3.00	3.00	2.25	2.25	2.25		2.55	0.41
SCB8		3.00	3.00	3.00	2.75		2.94	0.13
SCB 10		3.00	2.75	2.25	2.50		2.63	0.32
SCB 11		2.50	2.50	2.50	2.75		2.56	0.13
SCB 11.5		3.00		2.50			2.75	0.35
SCB 14	2.00	2.75	2.00	1.75	1.75		2.05	0.41
SCB 16	1.75	2.00	2.00	1.50	1.50		1.75	0.25
SCR 10.1	1.75	2.25	3.00	2.25	3.00		2.45	0.54
SCR 10.2	1.75	2.25	3.00	2.50	3.00		2.50	0.53
SCR 10.3	1.75	2.00	2.75	2.50	2.75		2.35	0.45
SCR 11.1	1.75	2.25	4.00	2.75	2.50	2.25	2.58	0.77
SCR 11.2	1.50	2.25	4.25	2.50	3.25	2.50	2.71	0.94
SCR 11.3	1.50	2.25	4.00	2.50	3.00	2.50	2.63	0.83
SCR 14		2.25	2.75	2.25	2.25	2.25	2.35	0.22
SCR 14.1	1.50	1.90	2.50	1.75	2.25		1.98	0.40
SCR 14.2	1.25	1.25	1.90	1.00	1.50		1.38	0.34
SCR 14.3	1.50	1.80	2.75	1.80	2.25		2.02	0.49
SCR 15		2.25	2.50	2.25	2.25	2.25	2.30	0.11
SCR 17		1.75	1.75	1.75	1.75	2.00	1.80	0.11
SCR 22.3	1.75	2.00	1.75	1.75	1.50		1.75	0.18
SCR 23.2	1.75	1.75	1.75	1.75	1.50		1.70	0.11
SCR 24	1.75	1.75	1.75	1.50	1.33		1.62	0.19
period avg	2.04	2.45	2.43	2.18	2.24	2.39	**grand avg**	**2.29**
stdev	0.78	0.80	0.78	0.75	0.80	0.97	**grand stdev**	**0.82**

Table A9. 1998 fecal coliform (cfu/100mL) data for Smith Mountain Lake.

SITE	Samp#	Replicate#	Ct (6/2)	SD(6/2)	Ct (6/16)	SD(6/16)	Ct(7/1)	SD(7/1)
Ind Pt Mar	3,1	1	0		6		10	
	3,1	2	0	1.25	5	1.25	5	1.5
	3,1	3	0		8		6	
	3,2	1	4		6		2	
	3,2	2	6	1.50	6	1.5	8	1.5
	3,2	3	1		6		2	
SML Yt Cl	4,1	1	8		122		59	
	4,1	2	5	1.25	120	0.75	122	1.5
	4,1	3	5		5*		38	
	4,2	1	1		15		36	
	4,2	2	4	1.25	8	1.25	38	2.25
	4,2	3						
	4,2	3	4		30		33	
Shore Mar	5,1	1	9		27		47	
	5,1	2	7	1	21	1.00	64	1.25
	5,2	1	12		20		33	
	5,2	2	3	1.00	25	1.25	37	2.25
	5,2	3	10		3*		49	
SML Dk Co	9,1	1	20		23		46	
	9,1	2	6	2	11	3	36	3
	9,1	3	6		59		43	
	9,2	1	3		5		45	
	9,2	2	11	2	45	3.50	54	3
	9,2	3	10		43		36	
Pelican Pt M.	12,1	1	4		6		11	
	12,1	2	3	2.00	9	3.75	8	3
	12,1	3	2		8		9	
	12,2	1	0		4		5	
	12,2	2	10	1.75	2	3.5	7	3
	12,2	3	5		9		4	
Foxport Mar	13,1	1	0		0			
	13,1	2	2	2.00	0	4.25	4	2
	13,1	3	0		3		12	
	13,2	1	0		13		6	
	13,2	2	3	2	6	3.25	7	2
	13,2	3	0		6		3	
Fair Bay	6,1	1	4		2		4	
	6,1	2	3	1.50	0	1.25	7	2.5
	6,1	3	6		24		4	
	6,2	1	13		8		9	
	6,2	2	4	1.50	12	1.50	6	2.25
	6,2	3	9		4		10	

Table A9. 1998 fecal coliform (cfu/100mL) data for Smith Mountain Lake. (cont.)

SITE	Samp#	Replicate#	Ct (7/15)	SD(7/15)	Ct (7/28)	SD(7/28)	Ct(8/14)	SD(8/14)
Ind Pt Mar	3,1	1	2		5		1	
	3,1	2	2	1.25	1	1.25	2	1.00
	3,1	3	0		5		1	
	3,2	1	2		2		3	
	3,2	2	2	1.25	4	1.25	7	1.00
	3,2	3	2		2		3	
SML Yt Cl	4,1	1	190		27		1	
	4,1	2	0	1.25	29	1.25	64	1.00
	4,1	3	0		40		393	
	4,2	1	4		23		16	
	4,2	2	17	1.75	1	1.5	21	1.00
	4,2	3						
	4,2	3	5		9		3	
Shore Mar	5,1	1	185		37		53	
	5,1	2	143	1.00	55	1.00	12	0.75
	5,2	1	228		61		42	
	5,2	2	77	1.50	61	1.00	17	1.50
	5,2	3	221		89		0	
SML Dk Co	9,1	1	13		101		85	
	9,1	2	114	2.50	84	2.25	108	1.75
	9,1	3	29		40		86	
	9,2	1	108		324		88	
	9,2	2	282	2.50	40	2.75	80	2.25
	9,2	3	1		7		17	
Pelican Pt M.	12,1	1	1		20		0	
	12,1	2	0	3	45	2.25	25	2.25
	12,1	3	0		32		10	
	12,2	1	3		3		0	
	12,2	2	1	3.50	1	3.00	3	2.25
	12,2	3	1		31		1	
Foxport Mar	13,1	1	2		2		2	
	13,1	2	0	2.5	1	3	0	2.75
	13,1	3	0		2		1	
	13,2	1	2		1		1	
	13,2	2	3	2.50	3	2.50	1	2.25
	13,2	3	4		0		2	
Fair Bay	6,1	1	4		34		1	
	6,1	2	20	1.75	12	1.5	4	1.50
	6,1	3	3		6		2	
	6,2	1	24		10		0	
	6,2	2	1	1.75	11	1.50	23	1.50
	6,2	3	3		10		16	

Table A9. 1998 fecal coliform (cfu/100mL) data for Smith Mountain Lake. (cont)

Site	Samp#	Replicate#	Ct (6/2)	SD(6/2)	Ct (6/16)	SD(6/16)	Ct(7/1)	SD(7/1)
SML StPk Co	7,1	1	0		1		2	
	7,1	2	0	1.75	0	2.00	0	3.5
	7,1	3	0		0		0	
	7,2	1	0		3		0	
	7,2	2	0	1.75	2	2	1	3
	7,2	3	0		0		2	
Forest Co	8,1	1	13		19		8	
	8,1	2	21	1.75	22	2.50	4	2.5
	8,1	3	10		25		6	
	8,2	1	1		13		3	
	8,2	2	1	2.50	15	3.5	7	2.5
	8,2	3	0		8		9	
Palm TrL Pk	11,1	1	27		25		113	
	11,1	2	28	1.75	22	2.00	110	1.5
	11,1	3	22		30		100	
	11,2	1	45		67		100	
	11,2	2	32	1.75	69	2.00	159	1.5
	11,2	3	47		64		59	
Confluence	10,1	1	1		3		0	
	10,1	2	1	2.00	2	3.25	1	2.75
	10,1	3	1		1		1	
	10,2	1	0		5		1	
	10,2	2	0	1.75	3	3.25	0	3
	10,2	3	0		2		0	
Bea Dam Ck	2,1	1	1		4		2	
	2,1	2	0	1.50	6	2.00	2	2
	2,1	3	0		3		1	
	2,2	1	0		3		5	
	2,2	2	0	1.50	1	1.75	6	2.25
	2,2	3	2		4		7	
Hdy Fd BrMar	1,1	1	76		50		18	
	1,1	2	81	0.50	57	0.5	15	0.75
	1,1	3	85		62		24	
	1,2	1	100		16		128	
	1,2	2	90	0.50	60	0.5	129	0.75
	1.2	3	90		23		87	
Pond. Cpgrd.	14,1	1	22		16		11	
	14,1	2	12	0.25	26	0.75	12	1
	14,1	3	11		17		7	
	14,2	1	22		12		19	
	14,2	2	23	0.5	15	0.75	38	0.75
	14,2	3	36		19		14	

Table A9. 1998 fecal coliform (cfu/100mL) data for Smith Mountain Lake. (cont.)

SITE	Samp#	Replicate#	Ct (7/15)	SD(7/15)	Ct (7/28)	SD(7/28)	Ct(8/14)	SD(8/14)
SML StPk Co	7,1	1	6		0		6	
	7,1	2	1	1.75	0	2.25	0	2.50
	7,1	3	0		0		0	
	7,2	1	0		1		0	
	7,2	2	0	1.75	1	2.25	0	2.5
	7,2	3	2		0		0	
Forest Co	8,1	1	9		15		45	
	8,1	2	6	2.00	18	2.25	12	1.75
	8,1	3	10		30		1	
	8,2	1	10		4		0	
	8,2	2	0	2.00	1	3.00	1	2.75
	8,2	3	10		3		3	
Palm TrL Pk	11,1	1	12		34		32	
	11,1	2	15	2	49	2	29	1.25
	11,1	3	12		35		15	
	11,2	1	30		33		48	
	11,2	2	27	2.00	33	2.00	64	2.00
	11,2	3	29		41		42	
Confluence	10,1	1	1		0		2	
	10,1	2	0	2.5	2	3.5	0	2.50
	10,1	3	1		1		0	
	10,2	1	0		1		0	
	10,2	2	1	3	0	3.5	2	3.50
	10,2	3	1		1		1	
Bea Dam Ck	2,1	1	29		14		3	
	2,1	2	0	1.25	1	1.25	9	1.00
	2,1	3	18		1		3	
	2,2	1	0		7		1	
	2,2	2	1	1.25	3	1.00	0	1.00
	2,2	3	3		2		2	
Hdy Fd BrMa	1,1	1	1		19		9	
	1,1	2	1	0.75	12	0.75	39	0.50
	1,1	3	1		17		12	
	1,2	1	0		35		14	
	1,2	2	3	0.75	40	0.75	13	0.50
	1.2	3	3		15		1	
Pond. Cpgrd.	14,1	1	2		3		169	
	14,1	2	0	1	13	1	54	0.75
	14,1	3	1		0		54	
	14,2	1	1		7		61	
	14,2	2	1	1.00	13	1.25	22	0.50
	14,2	3	1		15		26	