Smith Mountain Lake
Water Quality Monitoring Program

2000 Report

SMLA | Ferrum College

Prepared by

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Life Sciences Division

Ferrum College

Sponsored by

The Smith Mountain Lake Association

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1. EXECUTIVE SUMMARY

The Smith Mountain Lake Volunteer Water Quality Monitoring Program was initiated in 1987 and has functioned each year since. The Smith Mountain Lake Association and scientists from Ferrum College cooperatively administer the program. The mission of the program is to monitor the aging and health, or trophic status (in scientific terms) of Smith Mountain Lake.

As in earlier years, the program in 2000 began in late May with the training and organizational meeting. The volunteer monitors then collected water samples every other week until mid August. Students and staff of Ferrum College took tributary and fecal coliform samples, collected the samples from the volunteer monitors, analyzed the samples and organized the data under the supervision of Dr. Carolyn L. Thomas and Dr. David M. Johnson who then prepared and submitted this report.

The trophic status of SML was measured by four parameters: total phosphorus, nitrate, chlorophyll-*a,* and the degree of water clarity as determined by Secchi depth measurements. 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 probably 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, which decreases as the algal populations, and the suspended solids increase. In addition, the 2000 program included measurements of fecal coliform bacteria and four special studies.

1.1 Conclusions – Trophic Status

To better understand the data compiled over the years and the dynamics of the lake's trophic status, the sample sites on the lake have been grouped by zones. The zones are based on distance from the dam with Zone 1 being the closest to the dam (1-5 miles) and Zone 6 being the greatest distance from the dam (25+ miles). As in previous years, there is an inverse correlation between the distance from the dam and water quality. The water quality is best at the dam and diminishes as distance increases from the dam.

The primary conclusion from the data assembled in 2000 is that the trophic status of SML is virtually identical to the status fourteen years ago. There has been no significant positive or negative trend. Long-term trend lines of measures for total phosphorus, nitrate and chlorophyll-*a* are either absolutely flat (staying at the same level) or are slightly favorable. The long-term trend line for measurements of Secchi depth are quite favorable until the measurements are taken further from the dam, where the trend line is flat.

Although the long-term trends are neither favorable nor unfavorable, there are yearly variations that are significant and should be watched closely. For the past two years the concentrations of total phosphorus and chlorophyll-*a* have increased sharply. Total phosphorus increased from 24.4 ppb in 1998 to 28.9 in 1999 and 35.9 in 2000. Chlorophyll-*a* increased from 3.8 ppb in 1998 to 3.9 in 1999 to 14.6 in 2000. In most lakes in the United States phosphorus is considered the limiting nutrient and that is most likely true in SML. Therefore, the increased phosphorus in recent years may have led to the increased chlorophyll-*a* and, in turn, an increased algal population. We have no specific explanation for this change but a continuation of this short-term trend would be reason for serious concern.

1.2 Conclusions – Fecal Coliform Measurements

Fecal coliform bacteria populations in marina coves, non-marina coves and two headwaters sites were studied again for the sixth year. The sample sites included six marina coves, six non-marina coves and one each at the headwaters of the Roanoke Channel and the Blackwater Channel. The average fecal coliform counts for the summer were well below (favorable) the Virginia Department of Health standard for swimmable/fishable and potable waters. There were samples taken in five locations around the lake in the first sample period (the last week of May) that were in violation of the standard. Virtually all other samples taken throughout the summer were substantially below the standards. Mean colony counts throughout the summer of 2000 were higher than other recent years but the averages were so low that this is probably not a cause for alarm.

1.3 Conclusions – Special Studies

The Ferrum College staff conducted four special studies during the year 2000. The first was a shoreline reconnaissance attempting to detect near shore septic system effluent. The study consisted of slowly moving along near the shoreline while taking readings of conductivity, dissolved oxygen, pH and oxidation-reduction potential. A study of this nature was first attempted in 1999. As in 1999, no significant results were found and these shoreline reconnaissance measurements will be discontinued in future years.

The second special study conducted by the Ferrum College staff was an intense study of fecal coliform counts during a significant rain event. A similar study was made in 1999 in the Upper Blackwater arm of the lake. This year's study had to be postponed until very late November due to the drought conditions that existed during the summer and fall. The study was conducted in the Beaverdam Creek tributary of the Roanoke River. Water samples were taken at five sites in the creek throughout the rainstorm. As in 1999, the study showed the significant presence of fecal coliform from non-point source rain runoff (general sources rather than specific sources such as sewage treatment plants, industrial plants, etc.). Although high levels of fecal coliform enter the lake from non-point source runoff, they do not appear to survive for long in the lake.

A third special study of the high and seemingly random variability of fecal coliform counts were observed through depth, time and site in a intensive study in the Betty's Creek Cove in July 2000. As expected, the study confirmed the need for many samples at different depths, sites, and times of day.

The fourth, and final, special study was conducted to evaluate the effectiveness of using the antibiotic resistance assay (ARA) for bacterial source tracking of the fecal bacteria found in Beaverdam Creek and the Blackwater River. The small sample size makes the results inconclusive but appears to hold the promise of distinguishing between bacteria from human, domestic animals, and wild animal sources at a laboratory cost that is manageable. More intensive sampling must be done to confirm these results.

1.4 Summary

In conclusion, the overall lake water quality was at least as good in 2000 as it has been in the past, but we must watch for increasing levels of total phosphorus and chlorophyll-*a*. The Smith Mountain Lake Association and Ferrum College will continue to keep a watchful eye on the Smith Mountain Lake's water quality in 2001 in order to respond to problems identified by this water monitoring program.

2. INTRODUCTION

The Smith Mountain Lake Water Quality Monitoring Program (SMLWQMP), now in its fourteenth year, is a water quality 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 2000 monitoring season, the fourteenth year of the program. Secchi depths were recorded and water 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 2000 there were 86 stations in the lake monitoring network (34 advanced channel stations, 26 advanced cove stations, and an additional 26 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 headwaters station for the Roanoke channel. Sample site T3 is the headwaters station designated for the Blackwater channel, and it is located at the Route 834 bridge near Riverside Exxon. Both headwaters stations are considered to be tributary stations, although there is minimal velocity at either site during base flow conditions. All other tributary stations are on flowing tributaries near their confluence with the lake except for the upper Gills Creek site. This site, T0, is several miles from the lake, and a volunteer monitor collects samples there.

Collection of lake samples for fecal coliform enumeration also began in 1995 with samples collected at 8 sites on three occasions. In 1996 and 1997, the number of sampling sites was increased to 12. During 1998 – 2000, 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 2000 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, Erin Feamster, Patricia Moyer, Philip Davis, Jay Swain, Addison Dalton, Ainsley Worrell, Scott Queen, and Amy Hayes. 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 28 and continued through June 3. The first sample bottles and sample filters were picked up Tuesday, June 6. 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 2000. In November, the annual end-of-the-season meeting and social event was held at the residence of Bill and Ann Telford on the lake. At this combination picnic/business meeting, reports were made on the monitoring results, and SMLA President, Bill Telford, 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. 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 1999 can be found in the project annual reports.

This year’s monitoring results, data analyses and conclusions, and comparisons with the previous thirteen 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, measured spectrophotometrically (λ = 540 nm) after cadmium reduction; and chlorophyll-*a*, determined using the acetone extraction method and measured fluorimetrically.

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

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

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

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

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

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

An example of a sampling site code would be "CB14" which would indicate a cove sample off of the Blackwater channel 14 miles from Smith Mountain Lake Dam.

Sampling sites are located about every two miles on the Roanoke and Blackwater channels to monitor the movement of the silt and nutrient laden waters moving toward the main basin of the lake. These sites begin at the dam and extend 2 miles beyond the Hardy Ford Bridge on the Roanoke channel and to the Route 834 Bridge in Franklin County on the Blackwater channel.

The cove sampling sites are also important for trend analysis and help fulfill the role of "watchdogs". In the "watchdog" mode, as much of the lake as possible is monitored for signs of localized deterioration of water quality, which may be due to site-specific problems such as malfunctioning septic systems. To evaluate tributary loading, interns collect grab samples (to fill a bottle with water) every other week at 19 tributary sites on their rounds to pick up lake water samples. Volunteer monitors collect two additional tributary samples, one in upper Gills Creek and another in the upper Roanoke Channel just downstream from the confluence of Back Creek.

4. RESULTS FROM TROPHIC STATUS MONITORING

In this section the parameters used to monitor trophic status are displayed. These parameters include total phosphorus, nitrate, chlorophyll-*a*, and Secchi depth. Total phosphorus and nitrate are plant nutrients that stimulate the growth of algae. Phosphate, the form of phosphorus most immediately available to algae, is the limiting nutrient in Smith Mountain Lake. Chlorophyll-*a* is extracted from algae and is a measure of the algal population. Secchi depth is a measure of water clarity that decreases as algal populations and siltation increase. The seasonal average for the lake stations for each parameter over the past four years is shown in Table 1. The average concentration of phosphorus (a nutrient) was higher in 2000 than in 1997 – 1999, leading to a much higher average concentration of chlorophyll-*a* based on previous lake observations and what limnologists generally know about lakes and reservoirs. It is reassuring to observe in reference to evaluation of quality control the high degree of internal consistency among the data in Table 1. A more complete discussion of water quality trends is presented in Section 6 of this report.

Table 1. Summary of trophic state data from 1997 to 2000.

	Nitrate (ppb)	*Total Phosphorus (ppb)*	*Chlorophyll-a (ppb)*	*Secchi Depth (m)*
2000	129	35.9	14.6	2.2
1999	296	28.9	3.9	2.2
1998	257	24.4	3.8	2.3
1997	180	27.6	4.1	2.1

4.1 Lake Stations

4.1.1 Variation of Trophic Parameters over Time

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

(a) Total Phosphorus: The Smith Mountain Lake stations (44 sites) exhibited the lowest average concentration of total phosphorus (TP = 27.9 ppb) during the fifth sampling period (July 30-August 5) and the highest mean concentration (TP = 45.2 ppb) during the sixth sampling period (August 13-19).

(b) Nitrate: The lowest average concentration (44 sites) of nitrate (NO3 = 25.6 ppb) occurred during the sixth sampling period (August 13-19) and the highest average nitrate concentration (NO3 = 206.1 ppb) during the third sampling period (July 2-8).

(c) Chlorophyll-*a*: The sample set (44 sites) with the lowest average chlorophyll-*a* concentration (CHA = 3.1 ppb) was collected during the second sampling period (June 18-24), and the set with the highest average chlorophyll-*a* concentration (CHA = 29.2 ppb) was collected during the sixth sampling period (August 13-19).

(d) Secchi Depth: The lake (81 sites) exhibited the highest average Secchi depth (SD = 2.43 m) (highest water clarity) during the third sampling period (July 2-8). The lowest average Secchi depth (SD = 1.92 m) occurred during the sixth sampling period (August 13-19).

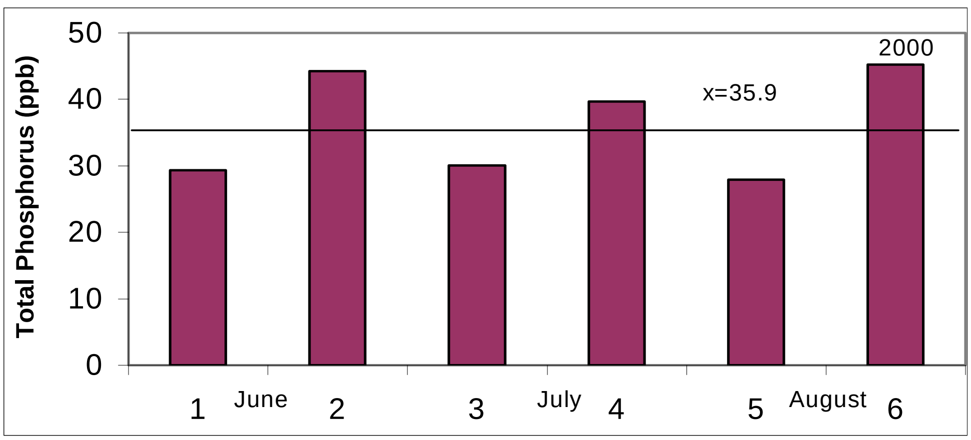


Figure 1. Average total phosphorus concentration for each sampling period in 2000.

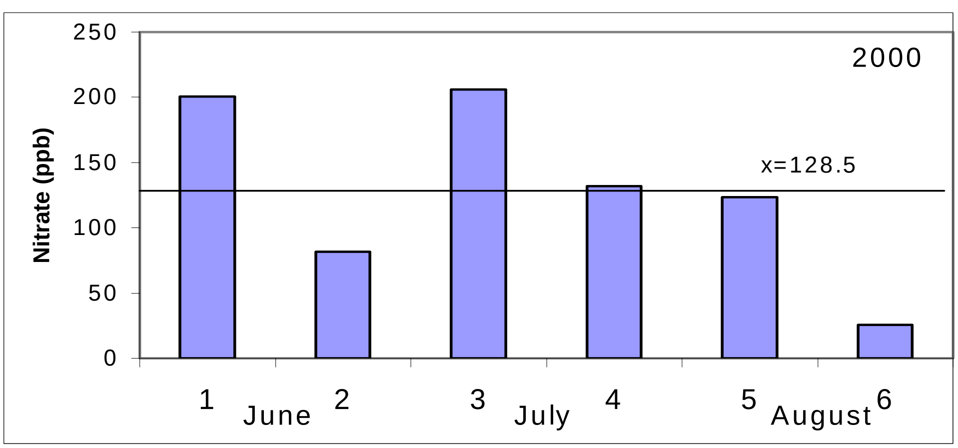


Figure 2. Average nitrate concentration for each sampling period in 2000.

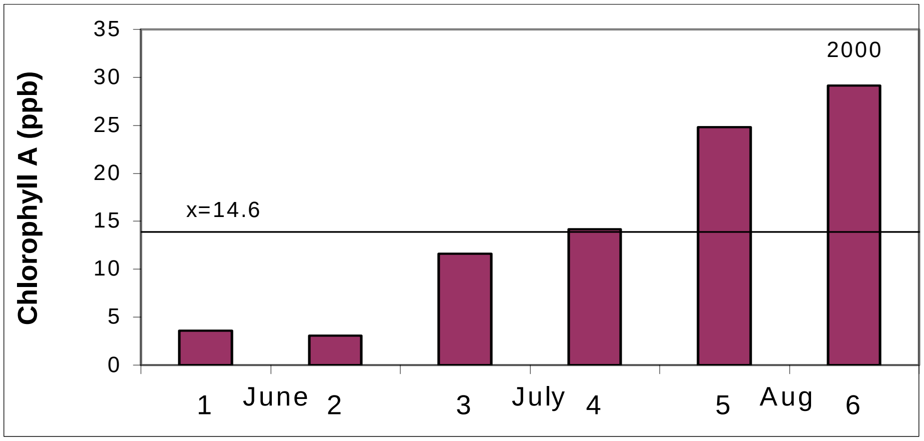


Figure 3. Average chlorophyll-*a* concentration for each sampling period in 2000.

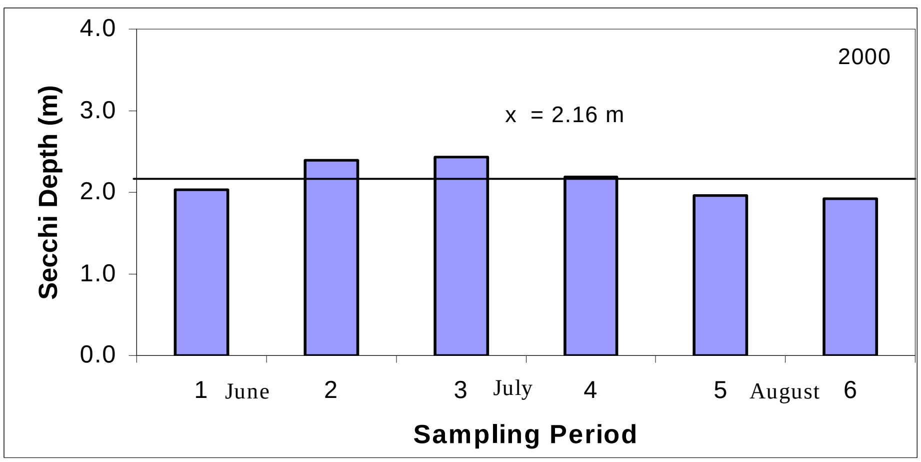


Figure 4. Average Secchi depth for each sampling period in 2000.

4.1.2 Variation of Trophic Parameters with Distance from the Dam

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

(a) Total Phosphorus: Total phosphorus levels in the lake increase as distance to the dam increases, but not as regularly as in the past. The correlation coefficient (R^2) is lower than usual and the cause is a group of stations in coves off the Roanoke Channel between 15 and 20 miles from the dam (Figure 5). The sampling site with the highest average total phosphorus concentration (TP = 101 ppb) was in the main Blackwater channel (B22). The lowest average total phosphorus concentration (TP = 9.4 ppb) was at a site close to the main basin of the lake (CR8). The trend line in Figure 5 is significant (α =0.01) with a sample size of 288.

(b) Nitrate: Unlike the phosphorus measurements, nitrate concentrations do not increase as distance to the dam increases. The sampling site with the highest average nitrate concentration (N03 = 1331.8 ppb) was in the Roanoke Channel (R29). The lowest average nitrate concentration (NO3 = 6.4 ppb) was also in the Roanoke section (CR13). Figure 6 shows the annual average nitrate concentration by station as a function of distance from the dam. It is also interesting that the nitrate levels increase again closer than 10 miles from the dam. This observation, as was also the case last year, suggests that there is an upwelling of nitrate-rich waters near the dam, perhaps as a result of the mixing that occurs at the confluence of the two main channels or of the water pumped back from Leesville Lake. The nitrate concentration at sites below the dam have been greater than 300 ppb over the last three years which could be the source of the observed higher nitrate concentration. The trend line in Figure 6 is significant (α = 0.05) with a sample size of 288.

(c) Chlorophyll-*a*: Chlorophyll-*a* levels (CHA) decreased as samples were taken closer to the dam, but, as with total phosphorus, the trend was less regular this year (Figure 7). Rather than the normal pattern of regularly increasing concentration with increasing distance the stations show a more bimodal distribution. The chlorophyll-*a* levels are rather uniform until about 20 miles from the dam and then rise rapidly to a higher level, with the level at station R29 out of line with the rest of the stations. The highest average total chlorophyll-*a* concentration (CHA = 85.6 ppb), was in a cove off the Roanoke Channel (CR26). The lowest average chlorophyll-*a* concentrations (CHA = 0.88 ppb) were found at a site in the main basin (CR9). The trend line in Figure 7 is significant (α =0.01) with a sample size of 288

(d) Secchi Depth: Secchi depth increased as miles to the dam decreased, indicating greater water clarity toward the main basin (Figure 8). The highest average Secchi depth (SD = 3.92 m) in the lake was measured at a station in the Craddock Creek section of the lake (C4). The lowest average Secchi depth (SD = 0.92 m) was at station B22.

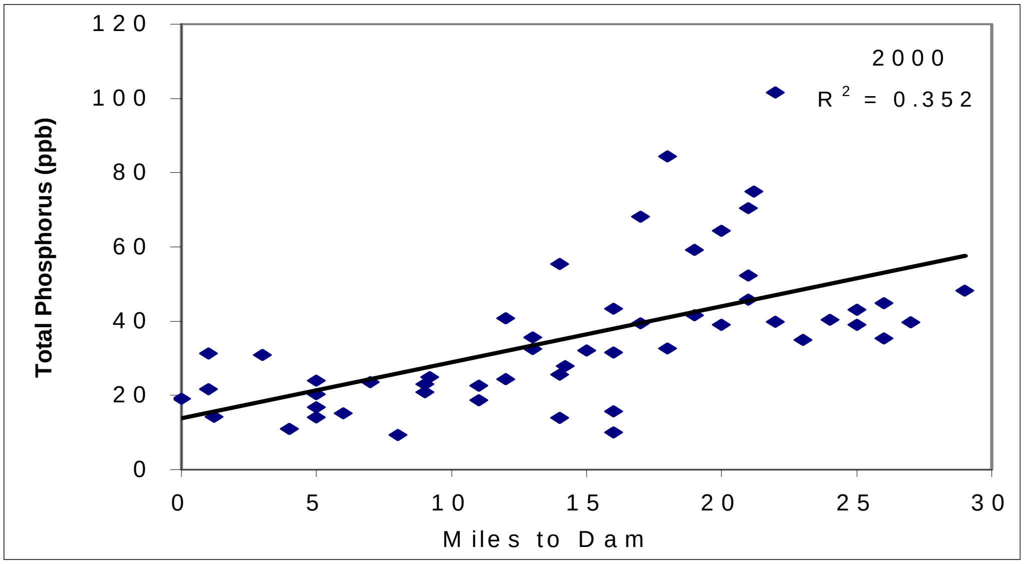


Figure 5. Variation of total phosphorus concentration with distance from the dam.

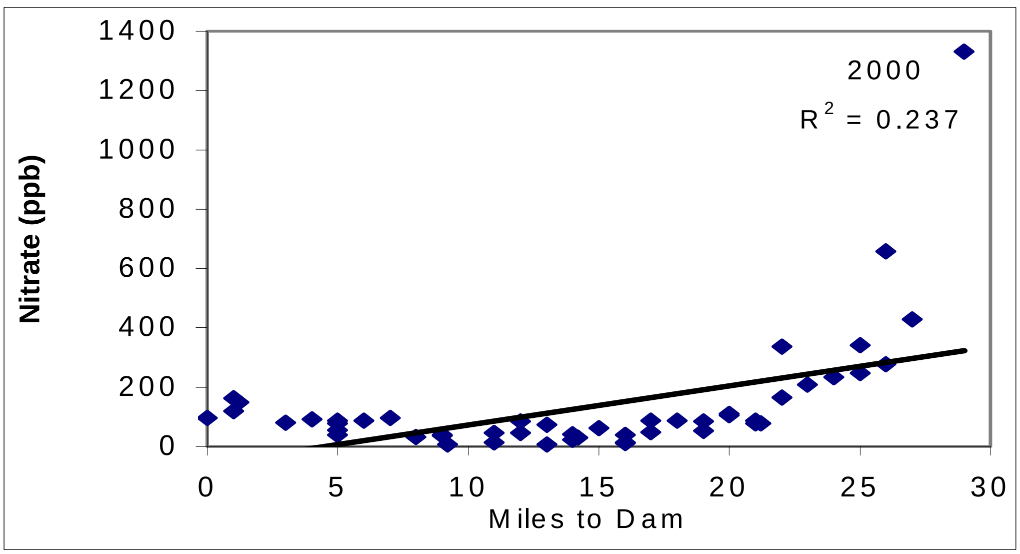


Figure 6. Variation of nitrate concentration with distance from the dam.

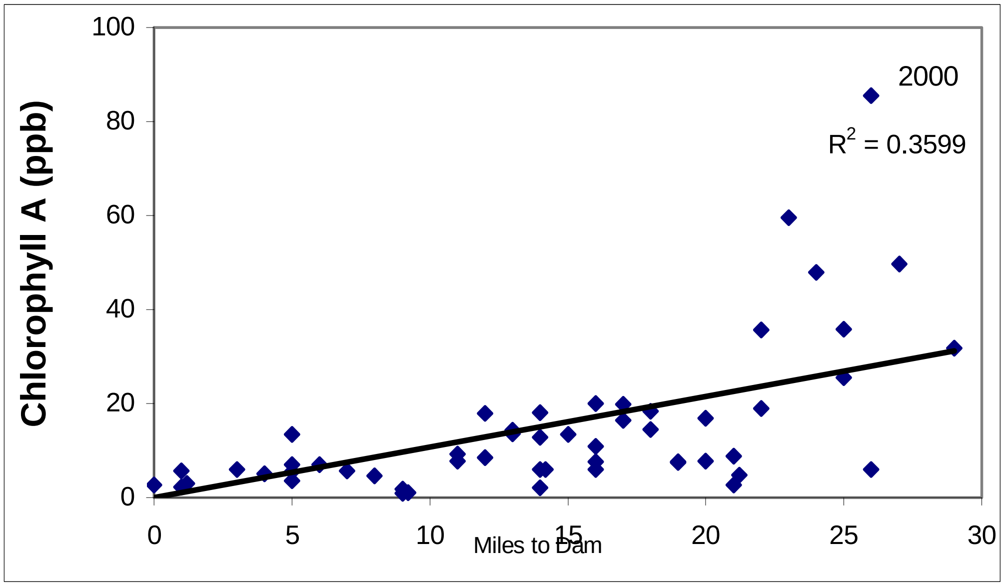


Figure 7. Variation of chlorophyll-*a* concentration with distance from the dam.

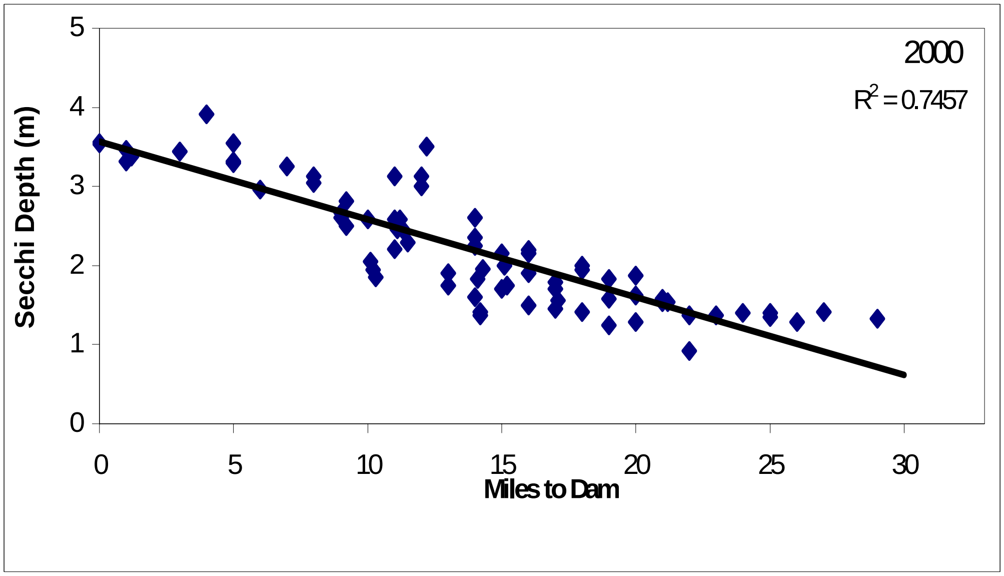


Figure 8. Variation of Secchi depth with distance from the dam.

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 = 59.4 ppb) in the fourth sampling period (July 16-27) and the highest mean concentration (TP = 96.1 ppb) in the second sampling period (June 18-24).

(b) Nitrate: The lowest average concentration (22 sites) of nitrate (NO3 = 400.2 ppb) occurred during the sixth sampling period (August 13-19), and the highest average nitrate concentration (NO3 = 679 ppb) occurred during the first (May 28 – June 3) and fourth (July16-22) sampling periods (NO3 = 679 ppb).

For phosphorus, both the highest and lowest average concentrations are higher than in 1999. However, for nitrate the lowest and the highest average concentration were both lower this year than last year.

4.2.2 Average Tributary Concentration of Total Phosphorus and Nitrate by Year

Table 2 indicates that tributary phosphorus levels, after a trend of declining for four years, increased in 1999 and increased significantly in 2000. Nitrate monitoring in tributaries was begun in 1998, and the average concentration was higher in 1999, but the 2000 mean was lower than the 1999 mean.

Table 2. Average tributary concentrations of total phosphorus from 1995-2000. TP is the total phosphorus concentration.

Year	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Average Tributary TP (ppb)	91.5	63.5	67.4	50.9	61.8	80.9
Average Tributary Nitrate (ppb)				568	621	570

4.2.3 Seasonal Average Nutrient Concentrations for each Tributary

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

Trib. Station	Stream Name	Trib. Station	Stream Name
T0	Upper Gills Creek	T11	Leesville Lake-Former Station 103
T1	Maggodee Creek	T12	Creek at Summit Drive
T2	Lower Gills Creek	T13	Creek at Snug Harbor
T3	Blackwater River	T14	Stoney Creek
T4	Poplar Camp Creek	T15	Jumping Run
T5	Standiford Creek	T16	Beaverdam Creek
T6	Bull Run	T17	Roanoke Channel at Bay Roc
T7	Cool Branch	T18	Lynville Creek
T8	Branch at Lumpkin's Marina	T19	Grimes Creek
T9	Below Dam - Former Station 105	T20	Indian Creek
T10	Pigg River - Former Station 104	T21	Roanoke Channel near Back Creek

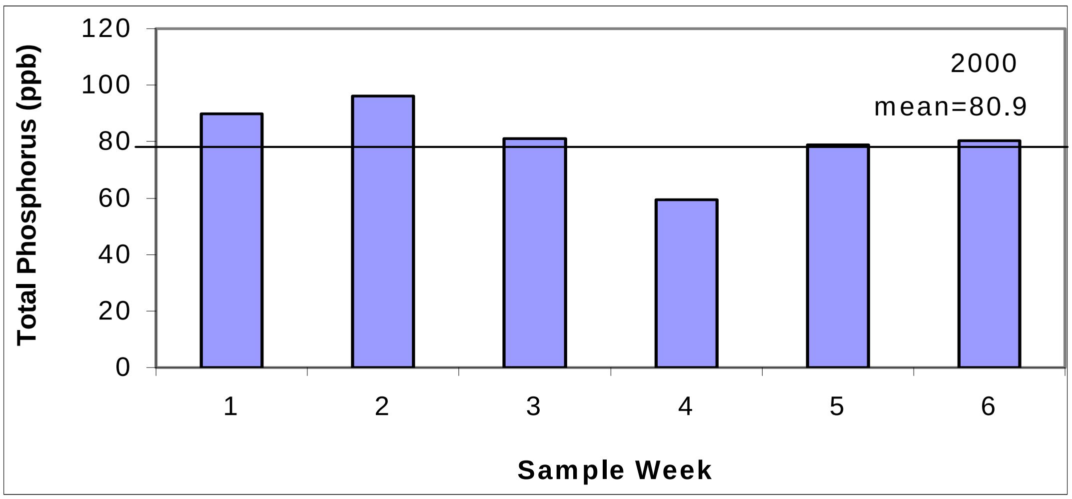


Figure 9. Average tributary total phosphorus concentration by sampling period.

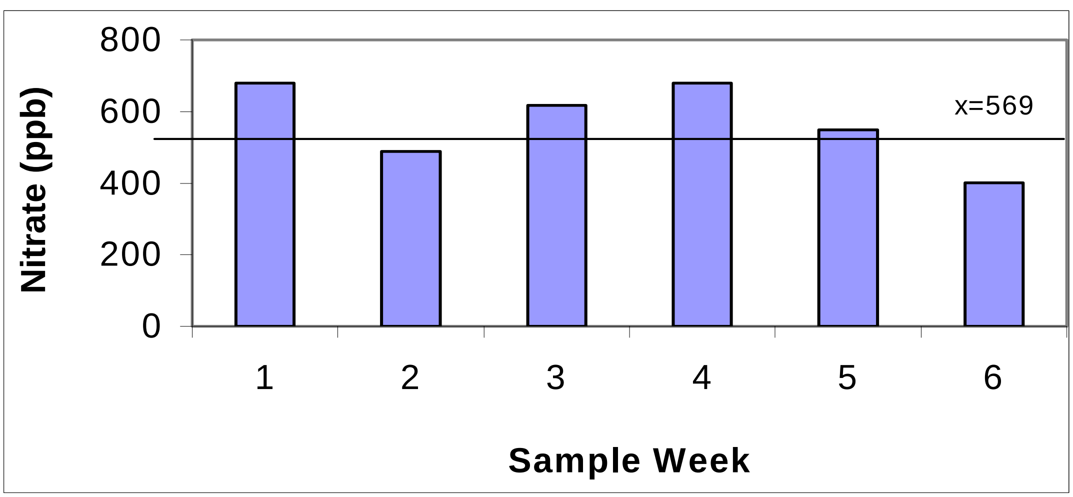


Figure 10. Average tributary nitrate concentration by sampling period.

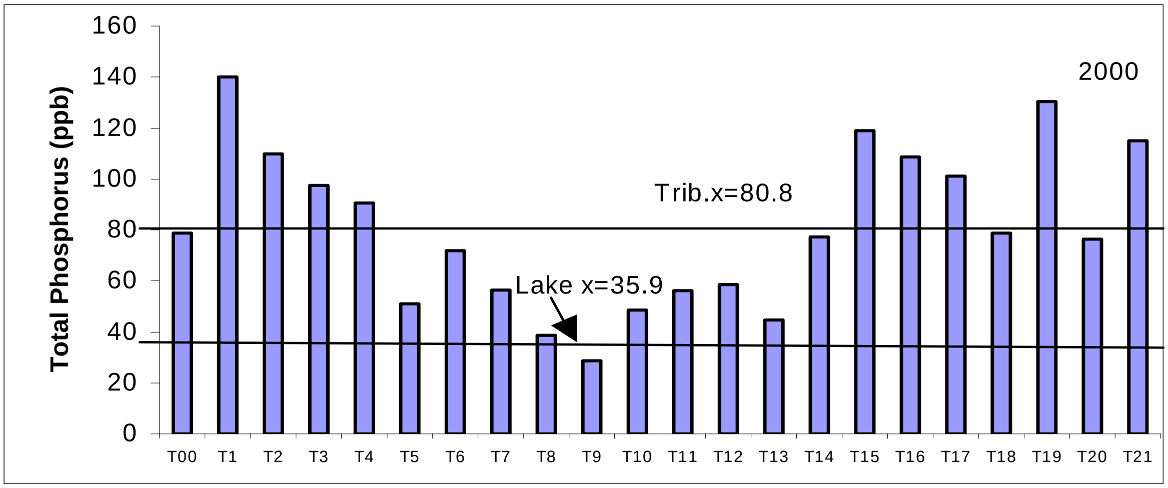


Figure 11. Seasonal average total phosphorus concentration for each tributary.

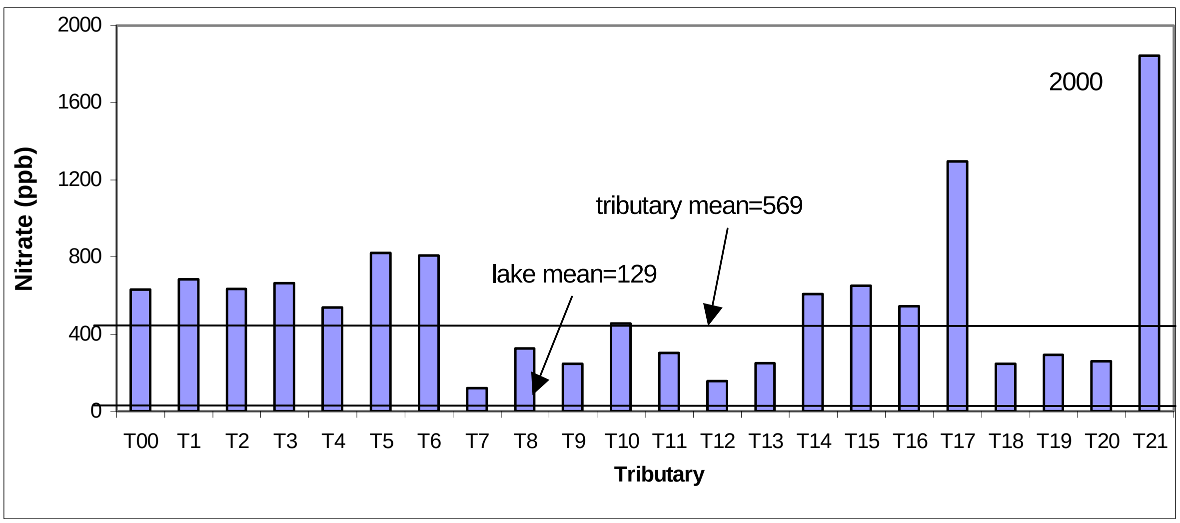


Figure 12. Seasonal average nitrate concentration for each tributary.

4.3 Results for Sample Sites Below the Dam

The interns collect grab samples from a bridge in the same manner as the tributary samples. The difference is that these samples are collected below the dam and are not tributaries flowing directly into the lake. Because of the pumpback system, water from these sites may end up in the lake. T9 is in the Roanoke River just below the dam at the AEP Visitor Center, T10 is in the Pigg River near its confluence with the Roanoke River, and T11 is in the Roanoke River after the confluence with the Pigg River and near where Leesville Lake begins. The results for 1993 through 2000 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 A.4. The average total phosphorus concentration in the Roanoke River below the dam generally decreased until this year, which may be only a one-year phenomenon and not a sign of decreasing water quality in the lake. The higher phosphorus concentration in the Pigg River (site T10) compared to the lake continues to elevate the phosphorus levels in the Roanoke River. There was a significant increase in phosphorus concentrations below the dam and in the Pigg River in 2000. The mean total phosphorus concentrations in the sites below the dam went from 15.3 ppb in 1999 to 44.5 ppb in 2000. This is consistent with the increased concentrations in the lake and other tributaries, which also showed higher phosphorus levels in 2000.

Table 3. Summary of results for TP at sites below the dam (1993 - 2000).

	Total Phosphorus (ppb)								
Site/Location	1993	1994	1995	1996	1997	1998	1999	2000	Avg
T9/ Roanoke R. below	48.5	25.6	40.5	38.3	19.7	11.4	11.5	28.8	28.0
T10/Pigg R. at Rt. 605	65.2	64.5	83.4	48.3	38.9	43.4	22.2	48.7	51.8
T11/Roanoke R. at Rt. 608	54.6	38.7	62.1	48.1	33.9	33.1	12.3	56.0	42.4
Average by year	56.1	42.9	62.0	44.9	30.8	29.3	15.3	44.50	40.7

Table 4 gives similar results for two years of nitrate monitoring at sites below the dam. As with total phosphorus, the nitrate levels below the dam, in the Pigg River, and at Rt. 608 were considerably higher in 2000 than in 1999, again an indication of increasing nutrient loads in the lake for this year.

Table 4. Summary of results for nitrate at sites below the dam (1998 to 2000).

	Nitrate (ppb)			
Site/Location	1998	1999	2000	Avg
T9/ Roanoke R. below dam	516	225	246	329
T10/Pigg R. at Rt. 605	447	200	454	367
T11/Roanoke R. at Rt. 608	427	182	302	304
Average by year	463	202	334	333

4.4 Shoreline Reconnaissance

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

After two summers of shoreline monitoring in many coves on the lake both in Franklin County, Bedford County and Pittsylvania County, no significant results were found. When one of the measurements would indicate a potential pollution source we could not repeat the observation by measuring again at the same place a few minutes later. We purposely chose coves we thought would show pollution influence and yet found nothing significant. Therefore, we are suggesting discontinuing the shoreline reconnaissance measurements. However the method could be employed on a need basis when there is a report of problems or obvious pollution sources.

4.5 Summary of Section

Overall, it would appear that water quality in Smith Mountain Lake declined significantly from 1999 to 2000. It is more accurate to say that the trophic level increased due to chlorophyll-*a* and phosphorus increases. The changes are small for phosphorus but significantly higher for chlorophyll-*a* (274%). Average total phosphorus levels increased in both lake and tributary samples, average NO_3 levels decreased in both lake and tributary samples and water clarity remained unchanged. The increase in chlorophyll-*a* levels in 2000 is of concern. The relative change in each parameter from 1998 to 2000 is shown in Table 5.

Table 5. Relative change (%) in water quality parameters from 1998-2000.

	TP - Lake	TP - Tribs	NO3 - Lake	NO3 - Lake	Chlorophyll-*a*	Secchi Depth
98-99	+18%	+21%	+15%	+9%	+3%	-4%
99-00	+24%	+31%	-56%	-8%	+274%	0%

Water circulation, nutrient interchange and biotic relationships connect the channels and the coves of Smith Mountain Lake. Tributaries provide nutrients to coves, especially phosphorus, as demonstrated with the data in this section. The average concentration of total phosphorus from the sampled tributaries was 80.8 ppb, substantially higher than the average concentration of 35.9 ppb for the lake. The situation with nitrate is not as clear. 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. The 56% decrease in nitrate levels may have been due to the increased algal production (up 274%) and increased uptake of nitrate by the algal cells. It is highly unlikely that the nitrate concentration limits the growth of algae in a sediment-rich habitat like Smith Mountain Lake.

As has been observed since the second year of the monitoring project, water quality improves significantly as it moves from the upper channels toward the dam. Eroded soil is carried to the lake by silt-laden streams but sedimentation begins in the quiescent lake water. Phosphorus, in the form of phosphate ions, strongly associates with soil particles and settles out during the sedimentation process. Total phosphorus, chlorophyll-*a* and Secchi depth all correlate significantly with distance from the dam. This is not the case for nitrate that is a labile ion, that is, it does not adsorb to silt particles. As a result they do not settle out of the water column and there is not a correlation between nitrate concentration and distance from the dam. It is also apparent from the lower correlation coefficients in Figures 5-8 that this relationship was less well defined in 2000 than in most other years. This may be due to the aging of the lake and the movement downstream of a sediment plume.

5. FECAL COLIFORM IN SMITH MOUNTAIN LAKE

5.1 Fecal Coliform Monitoring

Water samples were collected from fourteen sites on Smith Mountain Lake on May 25, June 14, June 28, July 6, July 25, and August 16, 2000. 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 on the Bedford County side of the lake.
3. Fairway Bay on the Franklin County side of the lake.
4. Palmer's Trailer Park Cove on the Franklin County side of the lake.
5. Smith Mountain Lake State Park Cove on the Bedford County side of the lake

Marina sites

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

Headwaters Sites

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

These sites were selected as representative coves around Smith Mountain Lake, to allow comparison between non-marina coves and marina coves and to allow evaluation of two headwaters 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 and is located off Little Bull Run, a tributary of the Blackwater Channel. (5) Smith Mountain Lake State Park Cove was sampled where it intersects the main channel.

The marina sites include: (6) Shoreline Marina which is up Becky's Creek, a tributary of the Roanoke Channel in Franklin County, and is a storage place for many houseboats and may have some people living aboard their boats. (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 13 indicates the comparison of the sum of the ranks of each sample site. Figure 14 indicates the mean fecal coliform colony forming units (cfus), commonly called colony counts, for the six sample dates. Figure 15 shows a comparison of mean fecal coliform counts for the six sample years (1995-2000) for each site and the means for both combined marina fecal coliform counts and non-marina fecal coliform counts.

Results:

1. All means of fecal coliform populations averaged over the whole summer were below the Virginia health standard for swimmable and fishable waters and the Virginia standard for potable waters.

2. Many values for fecal coliform populations on May 25 violate the Virginia health standards for swimmable and fishable waters in addition to violating the Virginia standard for potable waters. The following sites had at least one sample station above the 200 cfus limit on May 25th: Bay Roc Marina, Beaverdam Creek, Indian Point Marina, Smith Mountain Lake Yacht Club, Fairway Bay, Forest Cove, Smith Mountain Lake Dock, and Ponderosa Campground cove. On two other sample dates one of the sites had at least one station violate the standard, Smith Mountain Lake Yacht Club on July 25th and Foxport Marina on August 16th. This standard is 200 cfus per 100 mL sample (geometric mean of more than one sample) or 1000 cfus per 100 mL for one sample (Figure 16).

3. The mean colony counts and variances for marinas in 2000 (54.03 $\pm$ 88.22 cfus) were higher than the 1998 and 1999 counts, and the non-marinas' counts in 2000 (25.27 $\pm$ 40.98 cfus) were also higher than the mean colony counts and variances for 1998 and 1999. (1998 - marinas = 26.7 $\pm$ 2.7 and non-marinas = 13.6 $\pm$ 1.0 cfus; 1999 –marinas =17.65 $\pm$ 1.65 and non-marinas = 16.84 $\pm$ 2.43 cfus).

4. As in 1999 sample date was an important influence on the fecal coliform population estimates, with the early summer sample date May 25, 2000 exhibiting the highest mean number of colonies by far (159.75 cfus). In 2000 as in 1999, a significant trend ($\alpha = 0.05$) toward decreasing number of fecal coliforms was observed as the summer passed (Figure 13). Other scientists have observed a relationship with rain events and increased number of coliforms in streams. Consistent with this observation, in the summer of 2000 there was the heavier spring rainfall with less rainfall in the summer months probably causing lower fecal coliform population observed. In the rain event samples done in 1999 and 2000, rainfall resulting in runoff was the most significant influence on fecal coliform counts.

5. The mean coliform population estimate for all marinas was higher (54.03 ± 88.22 cfus) than the mean coliform population counts for non-marina sites (25.27 ± 40.98 cfus). The two headwaters sites' mean fecal coliform population was lower than the marinas and slightly higher than the non-marinas in number (41.45 ± 86.97 cfus) as seen in Figure 14.

6. All of the other marina coves, non-marina coves and the headwaters sample sites had lower fecal coliform mean counts for the summer than one of the marina coves (Smith Mountain Lake Yacht Club). Each sample time during the summer had a different site with the highest count, except the last two weeks in July in which the Yacht Club was highest two times in a row (Figure 15).

7. The confluence of the two main tributaries and the Smith Mountain Lake Park Cove had the lowest fecal coliform counts on five out of six sample dates, which was true in 1999 also. This year the other two sites that were consistently low were Pelican Point Marina and Foxport Marina (Figure 15)**.**

8. When all marina sites and non-marina sites are included, the mean fecal coliform population estimate for the marinas was higher than that for the non-marinas. Five of the seven marinas (Shoreline Marina, Smith Mountain Lake Dock, Bay Roc Marina, Indian Point Marina, and the Smith Mountain Lake Yacht Club) had consistently higher fecal coliform counts than the non-marina sites in 1999 and in 2000 (Figure 15). The source of these fecal coliforms is not known and should be investigated more thoroughly (see Antibiotic Resistance Assay section). The high variability of fecal coliform counts is shown by the large standard

deviations of each mean. In fact, the standard deviations are greater than the mean values and, therefore, it is not possible to show significant statistical differences among sites.

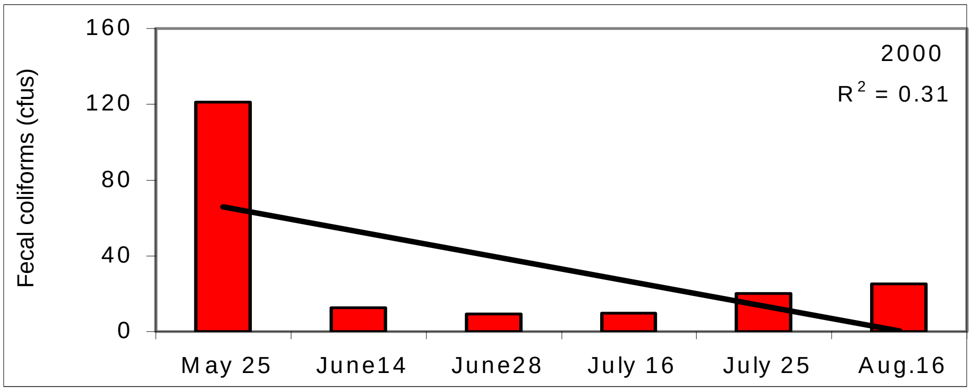


Figure 13. Fecal coliform vs. week sampled on Smith Mountain Lake in 2000. (Each sample date included 14 sites with 2 samples per site and three replicate filters per sample, n =84).

9. In a comparison of the sums of fecal coliform populations for sample dates and sites (see Figure 16) in 2000, Smith Mountain Lake Yacht Club, Bay Roc Marina, Smith Mountain Lake Dock, Shoreline Marina, and Indian Point Marina (all marina sites), and Ponderosa Campground (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 2000.

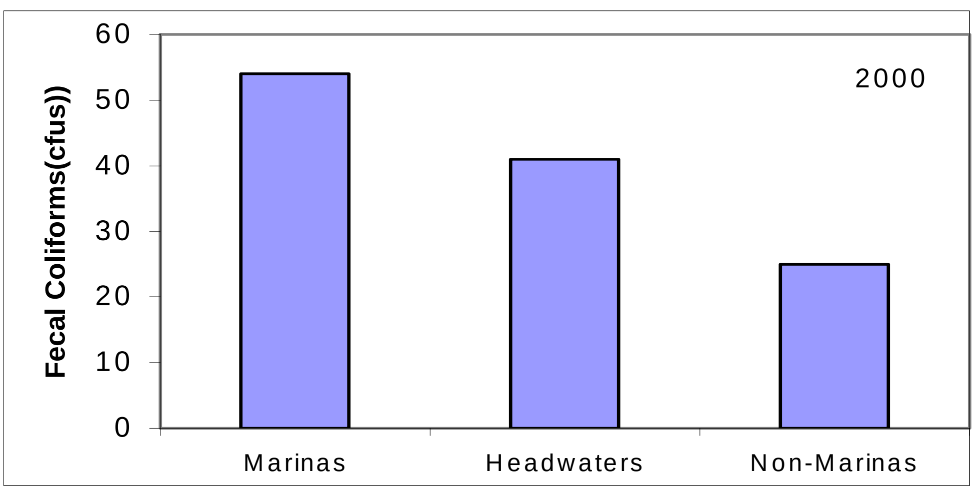


Figure 14. Mean fecal coliform count vs. site type on Smith Mountain Lake 2000. (There were 7 marina sites, 5 non-marina sites, and 2 headwaters sites.)

10. The mean fecal coliform count for marina sites has been greater than the mean fecal coliform counts for the non-marina sites for the five of the six sample years (1995-2000). The one exception was in 1999 when the values were almost equal, with the marinas' mean of 16 cfus vs. the non-marinas mean of 17 (Figure 17).

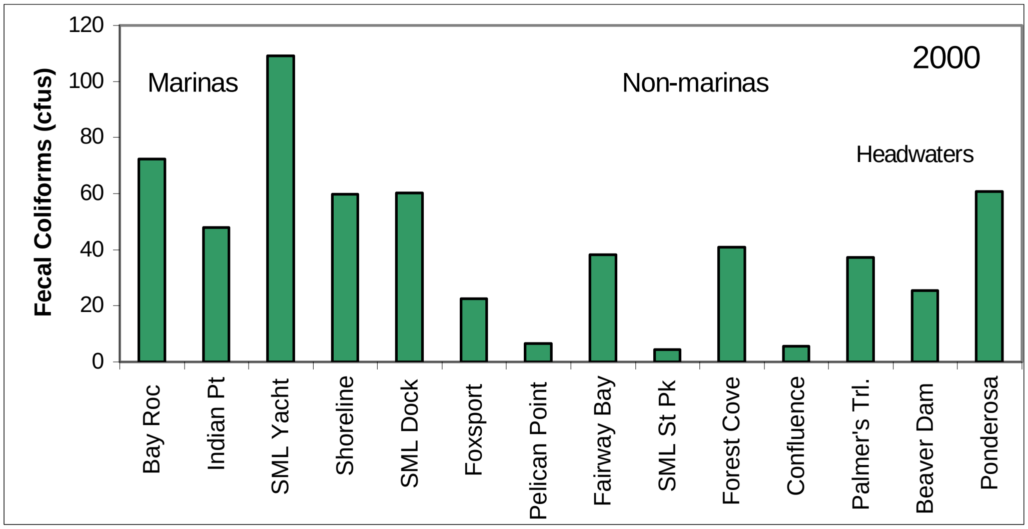


Figure 15. Mean fecal coliform count vs. sample site on Smith Mountain Lake, 2000. (Each site has two stations sampled 6 times during the summer.)

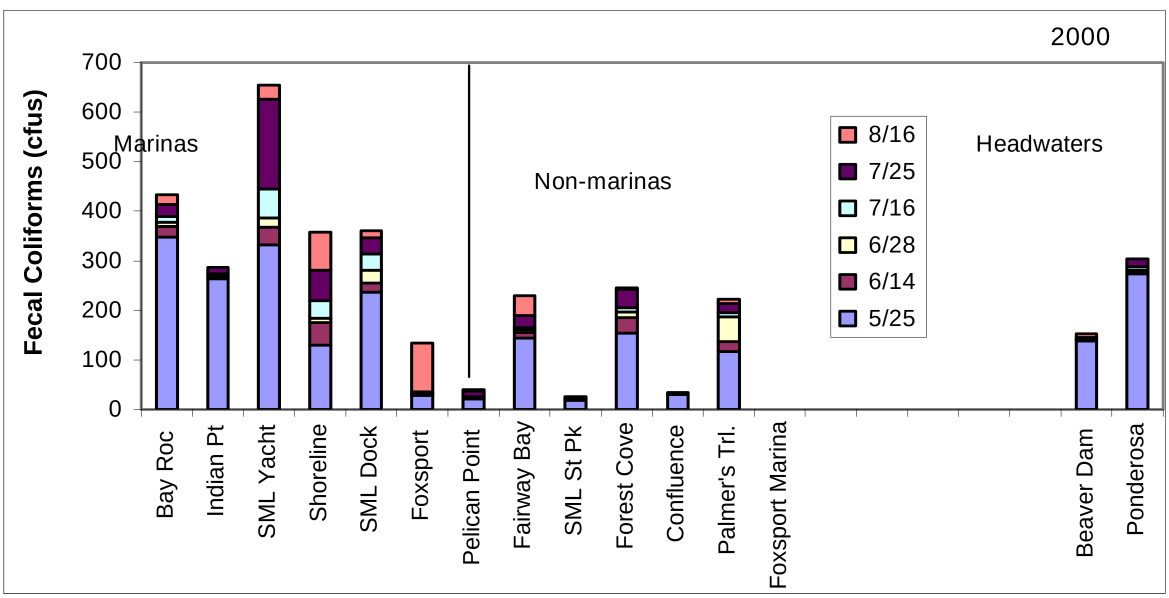


Figure 16. Sum of fecal coliform counts for Smith Mountain Lake in 2000 at each site for all sample dates.
(Each site and date has two stations per site)

11. In the comparison of six years of sampling fecal coliforms (1995-2000) 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 possible false impression of extremely high fecal coliform counts in the headwaters of the lake (Figure 17).

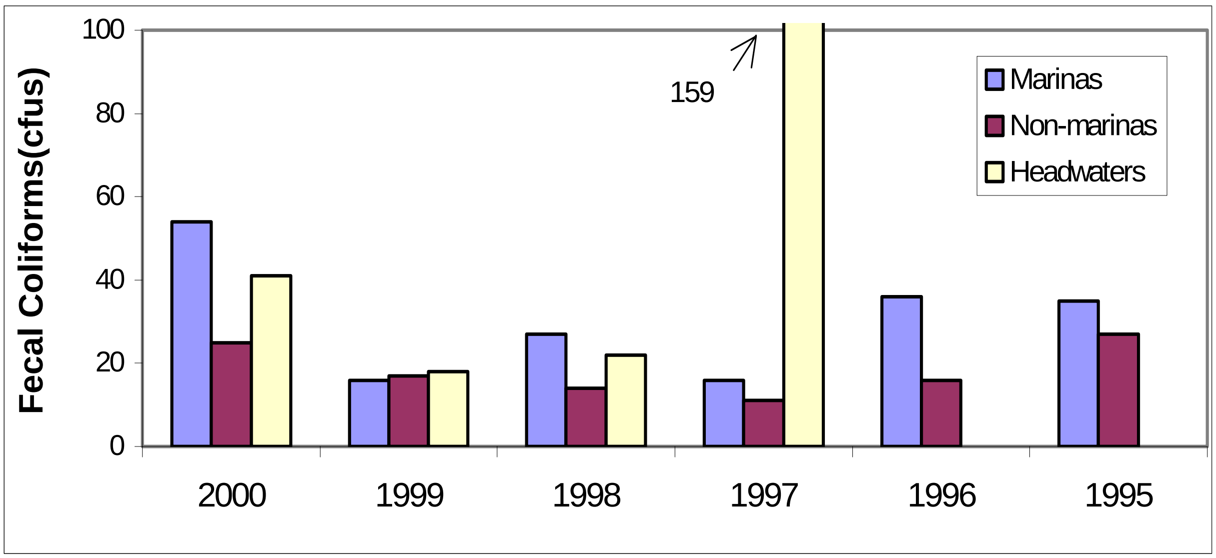


Figure 17. Mean fecal coliform counts per site type and year sampled for Smith Mountain Lake.

Note: In 1997 and 1998 there was considerable controversy about the fecal coliform populations in Smith Mountain Lake. The Virginia Department of Health, especially the Franklin and Bedford County offices, was sampling regularly around the shoreline of the lake in 1998 and found a few sites with unusually high fecal coliform counts. They continued to sample in 1999 and 2000 and identified no sites with high fecal coliform counts. The Virginia Department of Water Quality, especially the West Piedmont District, was also sampling occasionally at a number of open water sites around Smith Mountain Lake for fecal coliform population and identified no sites with high fecal coliform counts. The results of all three sampling groups were not always in agreement, but we feel that was to be expected with the knowledge that these sites were not the same nor were the sample times the same. Because of this potential for variability, in 2000 a study was done to determine the source and range of variability of fecal coliform counts. The results of this study are reported later in this report.

5.2 Fecal Coliform Rain Event Sample

As in 1999, a study was done to evaluate the fate of fecal coliforms and non-point source runoff in the Smith Mountain Lake watershed and the lake during a rainfall event. The timing of rainfall events and the rest of the project sample schedule made this study impossible to do during the summer. The sites were chosen, the contacts made, and the schedule planned in the summer with the samples being taken during the fall (November 29^{th} -December 1^{st}). The sites were chosen on the Beaverdam Creek tributary of the Roanoke River in Bedford County. Rain was falling lightly when the sampling began and continued for approximately 30 hours. The air temperatures were cold at approximately 10 degrees Celsius and the water temperature was slightly higher. Samples were also taken at the five sites one time on March 3, 2001 for comparative purposes (2160 hours elapsed). The weather was cold and clear and approximately the same temperature as the weather in November 2000.

5.2.1 Sample Sites

The five sites include watershed and lake sites.

1. Beaverdam Creek headwaters site: This site drains forested and agricultural land, including beef cattle pastures, in Bedford County. This site is on Spradlin Road off Rt. 757 by a one lane wooden bridge.

2. Fisherman’s Cove site: This site has a number of residences nearby and a metal salvage shop. This site is off Rt. 757 at Fisherman’s Cove Road and the one lane wooden bridge by the salvage shop and frequently exhibits stagnant water. This site is also one of our tributary sample sites that we measure total phosphorus and nitrate concentration at every other week during the summer sample season.

3. Hemlock Shores site: This site is a longtime residential community with a private boat launch. This site is reached by turning off Rt. 757 at Hemlock Shores, then left on East Beaverdam Court and right onto Sweetwater Court and sampled at the third dock from the boat launch. This site is on a bend of the creek and has many houses on both sides.

4. Beaverdam Marker 4 site: This site is a lake site and is a long-term residential community (Pleasure Point) on one site and forest on the other side. This site is reached by turning off Rt. 757, to Carroll Road, left on Navigation Road, right on Pleasure Point Drive, and right on Bluewater Court to the dock at the house at the end of the cul de sac.

5. Beaverdam Marker 1 site: This site is a lake site and is at the confluence of Beaverdam Creek and the Roanoke River. This site is reached from the end of Pleasure Point Drive at a dock right at the Beaverdam Creek Marker 1.

5.2.2 Methods

The water samples were taken at each site with a polyethylene bottle attached to a long pole and stretched out to the deepest flow of the water at that site. The bottle was rinsed with river water three times then filled, capped, and stored in ice until transported back to the lab (less than 6 hours). The samples were processed in the lab for fecal coliform enumeration using standard methods (APHA). The fecal coliform enumeration method used was the membrane filtration of 100 mL of sample water and using m-fecal coliform media incubated 44.5 degrees Celsius and the blue colonies counted after 18-24 hours.

5.2.3 Results

1. There was a decrease in fecal coliform populations at all sample times as the samples were taken further downstream. Site 1 in the headwaters was always the highest counts of fecal coliforms. These results are identical to the sites sampled in 1999 on then Blackwater tributaries (Figures 18 & 20.

2. The highest counts were found at 21 hours, which apparently means the rainfall was not significant enough to cause much in the way of non-point source effects (Figures 18 &19.)

3. The maximum count for each site came at different times (Figure 18), such as:
   Site 1 Headwaters of Beaverdam Creek at 21 hours, a count of 193 cfus
   Site 2 Fisherman's Cove at 0 hours, a count of 99 cfus
   Site 3 Hemlock Shores at 7 hours, a count of 53 cfus

Site 4 Beaverdam Marker #4 at 21 hours, a count of 43 cfus

Site 5 Beaverdam Marker #1 at 21 hours, a count of 31 cfus

4. No lag time of the fecal coliforms moving down the river is evident at this sample time. This may be due to the influence low temperatures and heavy rain.

5. The decrease in the fecal coliform counts moving down from the headwaters of Beaverdam Creek to the lake sites (sites 3-5) may indicate a dilution effect and a failure to thrive (Figures 18 & 19). The ambient physical and chemical properties of the lake are low carbon concentration and lower mean temperature than shallower streams. These conditions are not optimal for the growth of bacteria like fecal coliforms that live in the intestinal tract of mammals.

6. The counts of fecal coliforms at all sites do not exceed the Department of Health standards for potable water throughout the sample time (Figure 18).

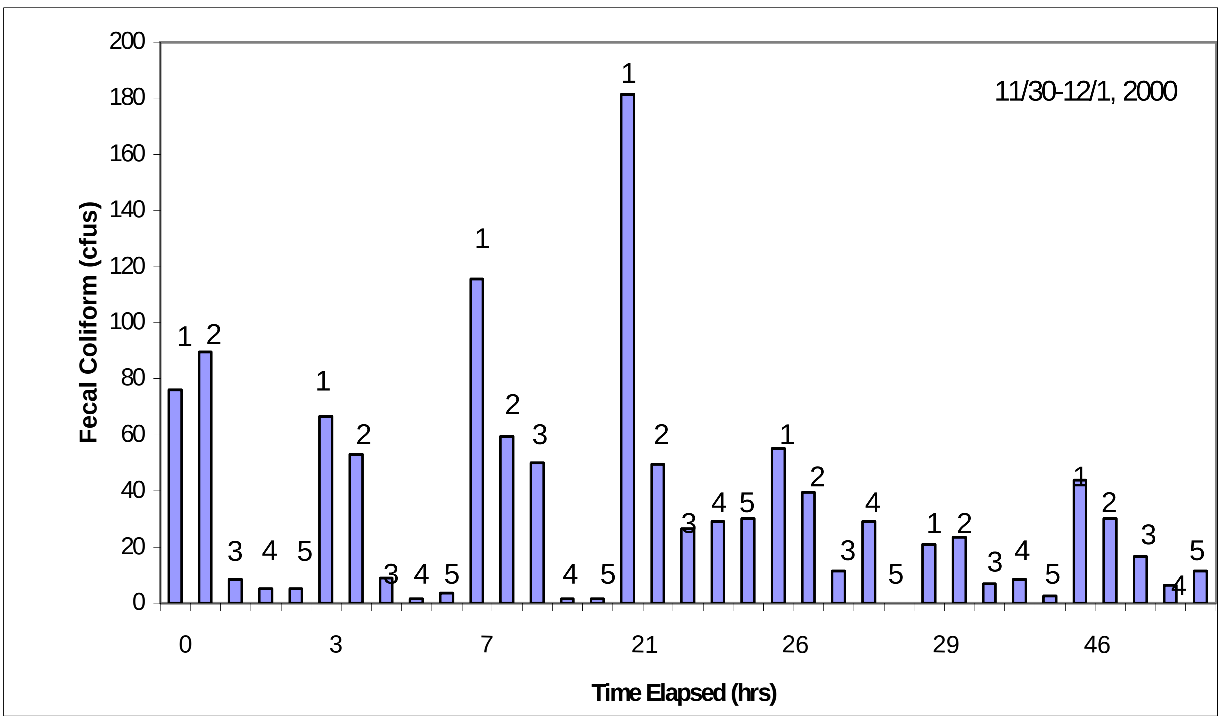


Figure 18. Fecal coliform counts (cfus) at five stations on Beaverdam Creek sampled from Nov. 29-Dec. 1, 2000 in the Smith Mountain Lake watershed after a rain event began.
(Site 1 is near the headwaters, sites 2-5 follow downstream with site 5 at the confluence with the Roanoke River.)

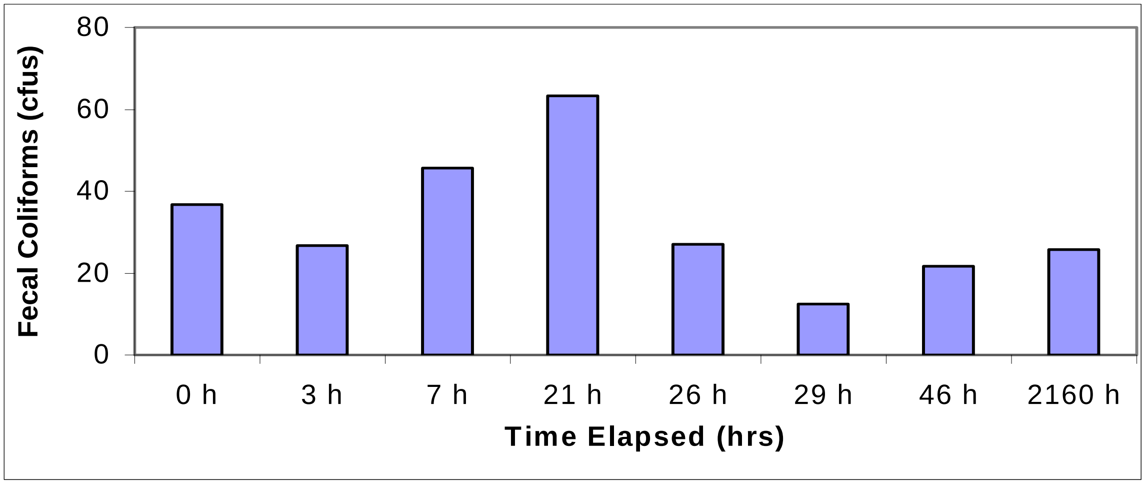


Figure 19. Fecal coliform counts (cfus) versus hours elapsed.

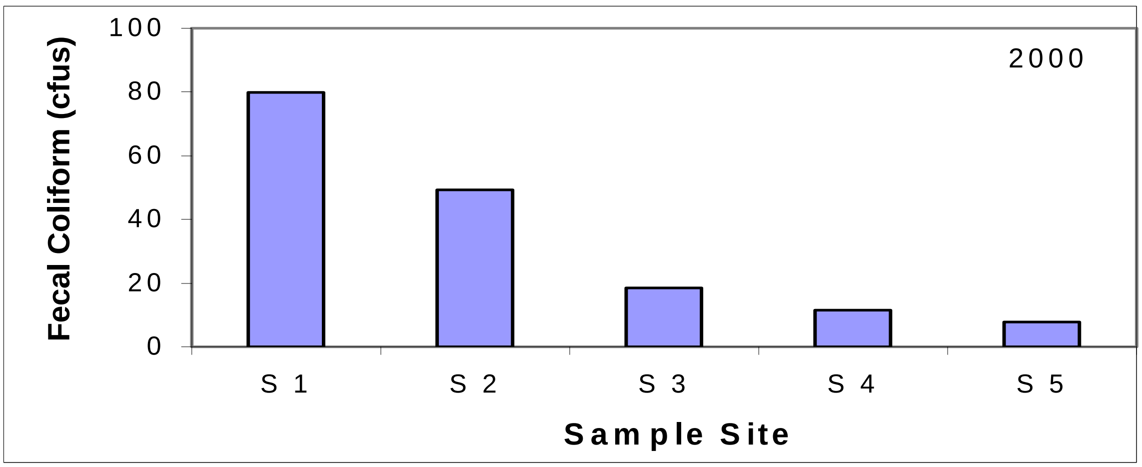


Figure 20. Smith Mountain Lake rainfall event samples, Nov. 29 - Dec. 1, 2000 at five sites in the watershed and lake for 46 hours after the rainfall began. (Site 1 is near the headwaters, Site 2 is at Fisherman's Cove bridge, Site 3 is at Hemlock Shores dock, Site 4 is at Beaverdam marker 4, Site 5 is at Beaverdam marker 1.

5.3 Intensive Cove Study

In 2000 a study was done to evaluate the sources of variance in fecal coliform measurements. Bacterial counts have always exhibited a high variance, which makes interpretation of significant differences difficult. Samples were taken at the Shoreline Marina Cove because of the willingness of the marina owner to assist in water quality studies. Seven sites throughout the cove, 8 different depths, and 42 hours worth of samples were taken for this study.

5.3.1 Methods

The water samples were taken at each site with a polyethylene bottle filled at the surface and with a Kemmerer water sampler used at each depth at that site. Each site was sampled at each sample time for each depth. The bottle was rinsed with lake water three times then filled, capped and stored in ice until transported back to the lab (less than 6 hours). The samples were processed in the lab for fecal coliform enumeration using standard methods (APHA). The fecal coliform enumeration method used was the membrane filtration of 100 mL of sample water and using m-fecal coliform media incubated 44.5 degrees Celsius and the blue colonies counted after 18-24 hours.

5.3.2 Results

1. Each variable of depth, site and time showed variance (standard deviations) almost as great or as great as the mean values of the fecal coliform counts (Figures 21-23).

2. Site 4 had the highest mean fecal coliform counts and the highest standard deviation. This site was the site farthest into the cove and the shallowest site (Figure 21).

3. A depth of 1 meter had the highest mean fecal coliform counts and the highest standard deviation. The variable of depth showed the most significant differences with the 1-meter depth exhibiting significantly higher fecal coliform counts (Figure 22).

4. The mean fecal coliform counts for each time of day showed very little difference among different times of day. Samples were taken for 46 hours approximately every 2 hours, during the daylight and at night and during bright sun, cloudy skies, and a thunderstorm. No significant difference was discovered among all of these differences (Figure 23).

5. Therefore, the number of replicate samples and sites must be great enough to be accurately representative of the lake.

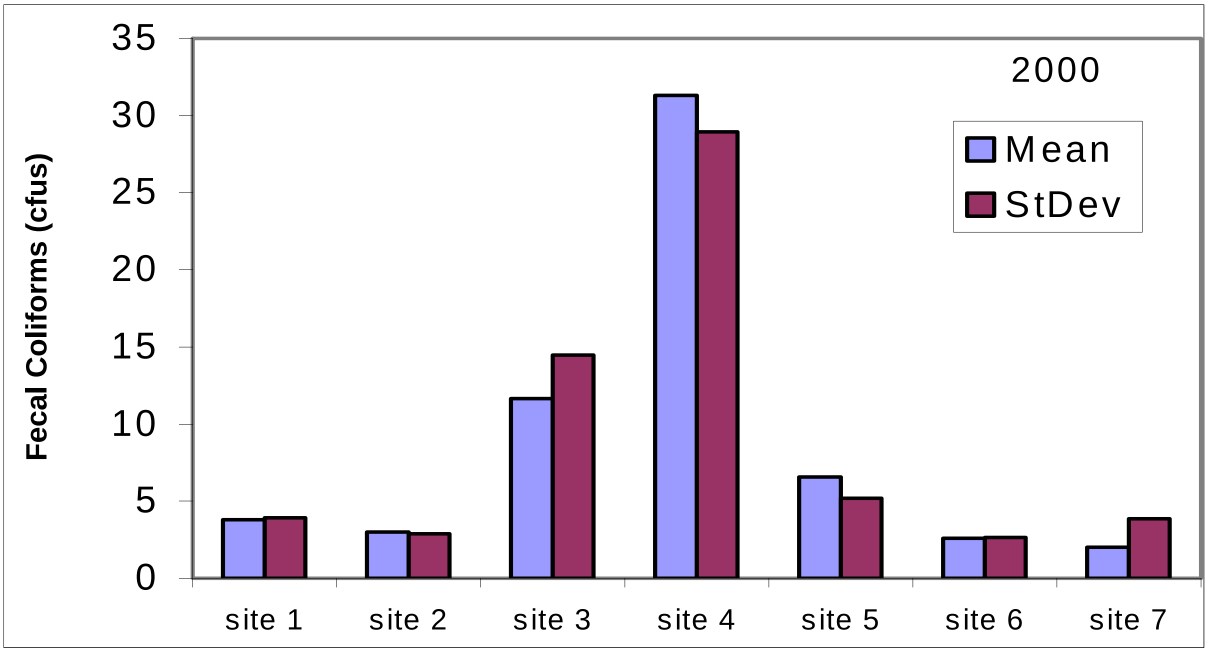


Figure 21. Intensive study of fecal coliform populations; variation with location.

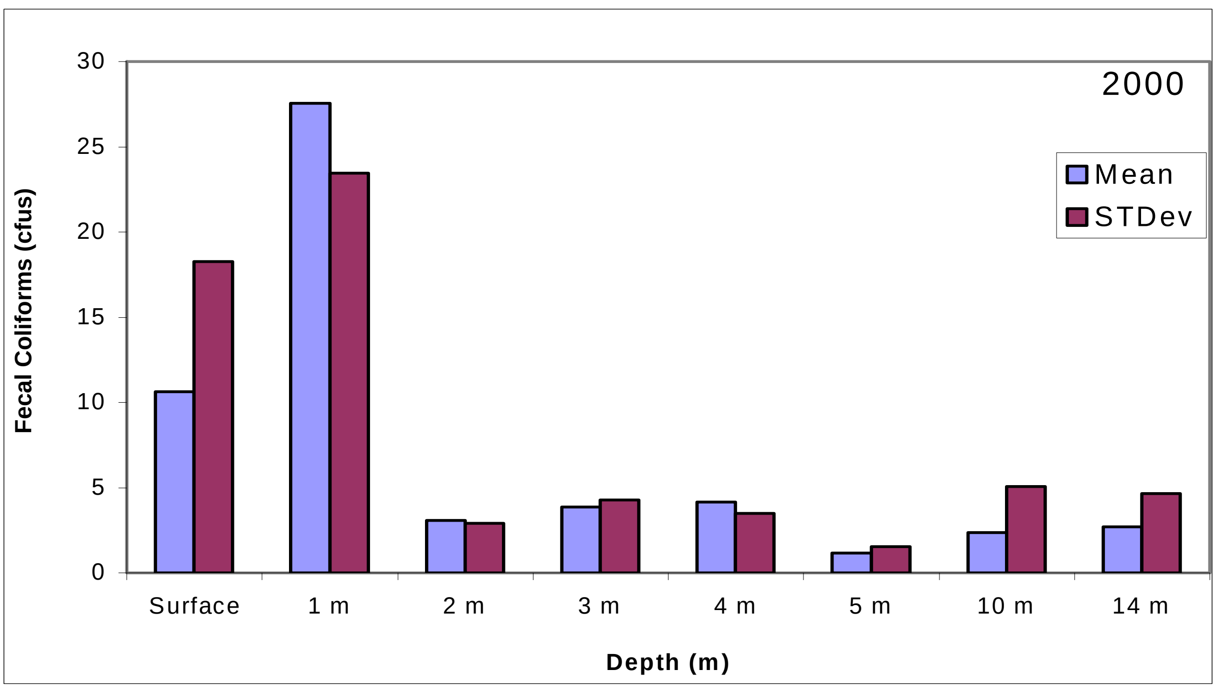


Figure 22. Intensive study of fecal coliform populations; variation with depth.

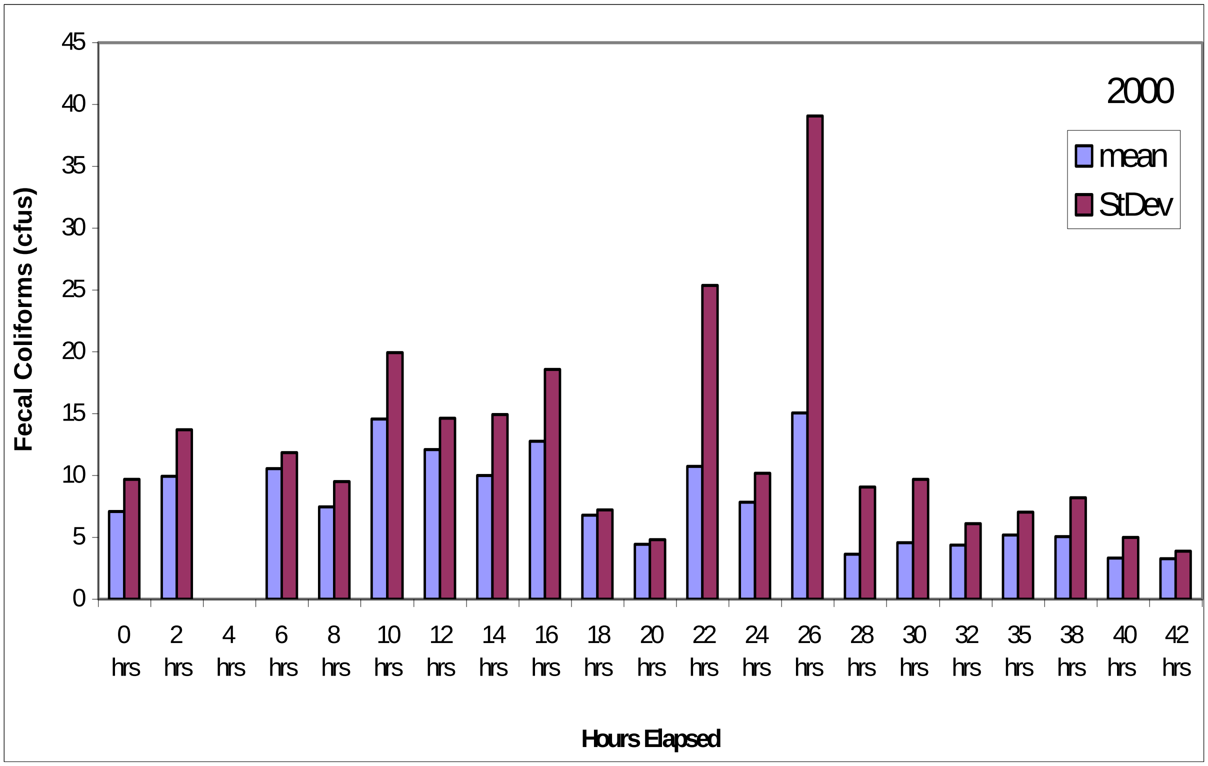


Figure 23. Intensive study of fecal coliform populations; variation with time.

5.4 Antibiotic Resistance/Bacterial Source Tracking of Fecal Streptococci

5.4.1 Introduction

Ferrum College scientists Dr. Carolyn L. Thomas and Dr. David M. Johnson have been studying water quality at Smith Mountain Lake since 1985. For the last 6 years (1995-2000) fecal coliform population has been assessed by comparing 14 marina and non-marina sites. For most of these samples the numbers have been below the Virginia standards for fecal coliform counts. Because this is a very important and controversial water quality parameter, we have decided that knowing the source of these fecal coliforms would be valuable in attempting to decrease the fecal coliform numbers and therefore improving the water quality of Smith Mountain Lake.

With this in mind, two years ago we did a preliminary study of bacterial sources using the DNA fingerprinting method developed by Dr. George Simmons at Virginia Tech. We worked with Mr. Ron Stephens, an associate of Dr. Simmons and a professor at Ferrum College. Although interesting results were found (we were able to trace some fecal coliforms back to a specific farm) they were too time consuming and expensive for the information we had learned.

Antibiotic Resistance Analysis became a more common research method at this time and Dr. Hagedorn and his associates shared the information with us about this method and its' successes. The method is explained in Harwood et al. (2000).

Last summer (July 2000), Dr. Hagedorn and his graduate student Amy Bowman demonstrated (for faculty and students from Ferrum College's Water Quality Lab) the method in their lab at Virginia Tech. Since that time, in discussions with Dr. Hagedorn, it was decided to try the method at Ferrum College.

Ms. Carol Love (Lab Coordinator for Ferrum College Life Sciences Division) has been responsible for most of the work on this project, including planning and ordering supplies, setting up the lab space, doing the antibiotic preparation, screening of colonies, and writing part of this progress report. Dr. Carolyn Thomas took the samples, and the 14 students in the BIO 303 General Microbiology class filtered and counted the samples for fecal streptococci colonies. Amy Bowman compared our results to her computer archives and reported the predicted sources of the fecal streptococci found at our sample sites. The results are presented below in section 5.4.4.

5.4.2 Progress Report:

The following tasks were completed as a result a grant received from the Virginia Water Resources Center at the end of October of 2000.

During August 2000, a budget (~ $2000) was developed to test approximately 25 water samples using the Antibiotic Resistance Analysis (ARA) procedure developed by Dr. Chuck Hagedorn at Virginia Tech. The budget included supplies, equipment, and labor, and was submitted to the Virginia Water Resources Office in September. Funds were received in October and equipment and supplies were ordered. A small lab room in Garber Hall was dedicated to this pilot project.

Water samples were collected on November 29 and five of them were filtered for ARA testing. This was considered a "test run" of the procedure and the first test was a good learning experience and some data was obtained. The data was sent to Amy Bowman at Virginia Tech for analysis and that data analysis is included here.

After having gained procedural experience on the test run, samples were collected for additional ARA testing in early March on Beaverdam Creek and the Blackwater River

5.4.3 Sample Sites

The isolates came from Beaverdam Creek in Bedford County, which empties into the Roanoke River channel of Smith Mountain Lake. Five sites along the creek (two sites) and its cove (three sites) were sampled:

- Site BD1 is high on the creek at the bridge across Spradlin Road,
- Site BD2 is at the bridge at Fisherman's Cove Road,
- Site BD3 is off of Sweetwater Court,
- BD4 is off of Bluewater Court, and
- BD5 is off of Pleasure Point Drive at channel marker BE2.

5.4.4 Preliminary Analyses

Bacterial counts at each site for the November sample collection are shown in Table 6.

Table 6. Bacterial count by site for November samples

Site	cfu/100mL
BD-1	27
BD-2	96
BD-3	13
BD-4	1
BD-5	5

Probable sources have been identified for the November samples (from Ms. Amy Bowman in Dr. Hagedorn's lab), however the number of samples is too small to be conclusive. The March 2001 samples have not yet been typed.

6. WATER QUALITY TRENDS

6.1 Water Quality Trends by Zone

In studying Smith Mountain Lake over the last fourteen years we have found that lake cannot be described as a single, homogeneous waterbody because of the broad differences between the upper reaches of the lake and the lower reaches nearer the dam. As a result we have attempted to describe the lake by zones based on the distance to the dam. As can be seen in the remainder of this section, the evaluation of water quality based on zones provides some interesting suggestions regarding multiple uses of the lake. For example, fishing would be best in those zones that have greater nutrient enrichment, and water used for potable water to produce drinking water would be better in those zones with lower nutrient enrichment.

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

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

The data do not show much in the way of trends over the fourteen years of data that have been collected. It should be noted that Zone 5 has only five to eight years of data and Zone 6 has only three to eight years of data.

In Figure 22 no significant trend in total phosphorus concentration over the fourteen-year period in any zone is noted. However, in 1992 in Zone 4 (15-20mi) a high concentration of total phosphorus was found, which appears to show up the next year (1993) in Zones 1, 2 and 3 perhaps indicating a movement of phosphorus downstream. All zones show a high total phosphorus concentration in 1995 but not the movement of phosphorus downstream. All zones show a higher total phosphorus concentration in 2000 than in 1999, which was also true between 1998 and 1999. This represents a 38% increase over all zones in two years with the highest increase in Zone 5 of 59.7% and the lowest increase in Zone 6 with 3%.

In Figure 23, chlorophyll-*a* shows a very significant increase in concentration in all zones in 2000. For all zones except Zone 2, the 2000 data point is the highest concentration over the fourteen years of data collection. From 1998 to 2000 there was a 298% increase in chlorophyll-*a* over all zones. The percent increase in each zone was as follows: Zone 6 = 537%, Zone 5 = 132%, Zone 4 = 227%, Zone 3 = 357%, Zone 2 = 184%, and Zone 1 = 426%. The highest percent increases were in Zone 6 and Zone 1. This increase causes concern and requires further investigation of potential causes.

The Secchi depth (Figure 24) means in all zones show no significant trend of increasing or decreasing over the fourteen years, except in Zone 1 and Zone 3 where the increasing trend is significant (α =0.05). An increasing trend indicates better water quality. In 2000 Zones 2, 3 and 4 (5-20mi) show decreases, however in water clarity from 1999 to 2000. Secchi disc depth is influenced by many factors including algal populations and silt from soil erosion, therefore distinguishing the causes of significant trends is difficult.

It should be noted that the later years' (especially 1995-2000) data is based on more sample sites and broader coverage of the lake. Some of these trends may reflect the sample size difference (number of sites) and improved coverage of the lake.

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

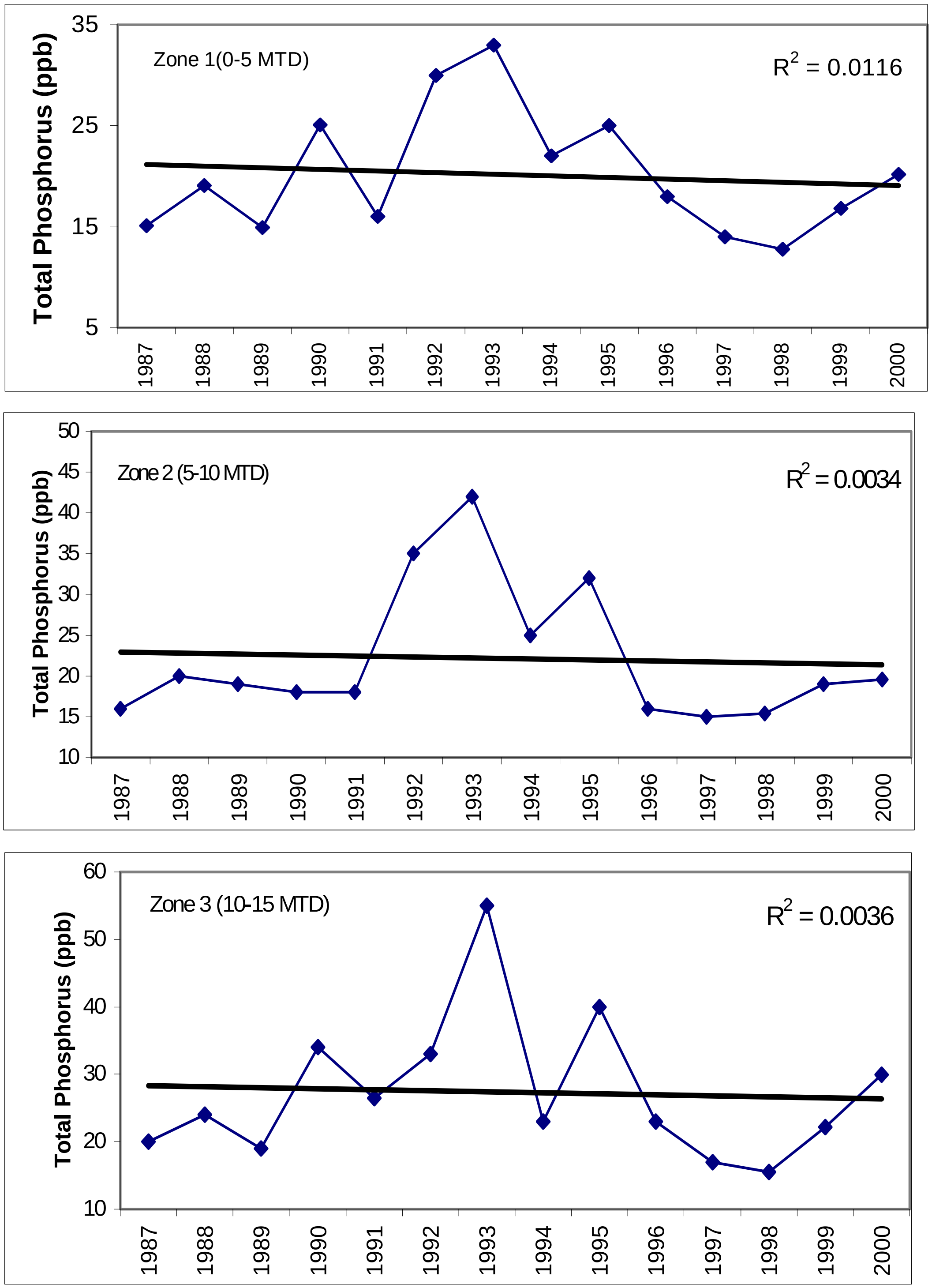


Figure 24. **Average annual total phosphorus concentration by zone in Smith Mountain Lake.**

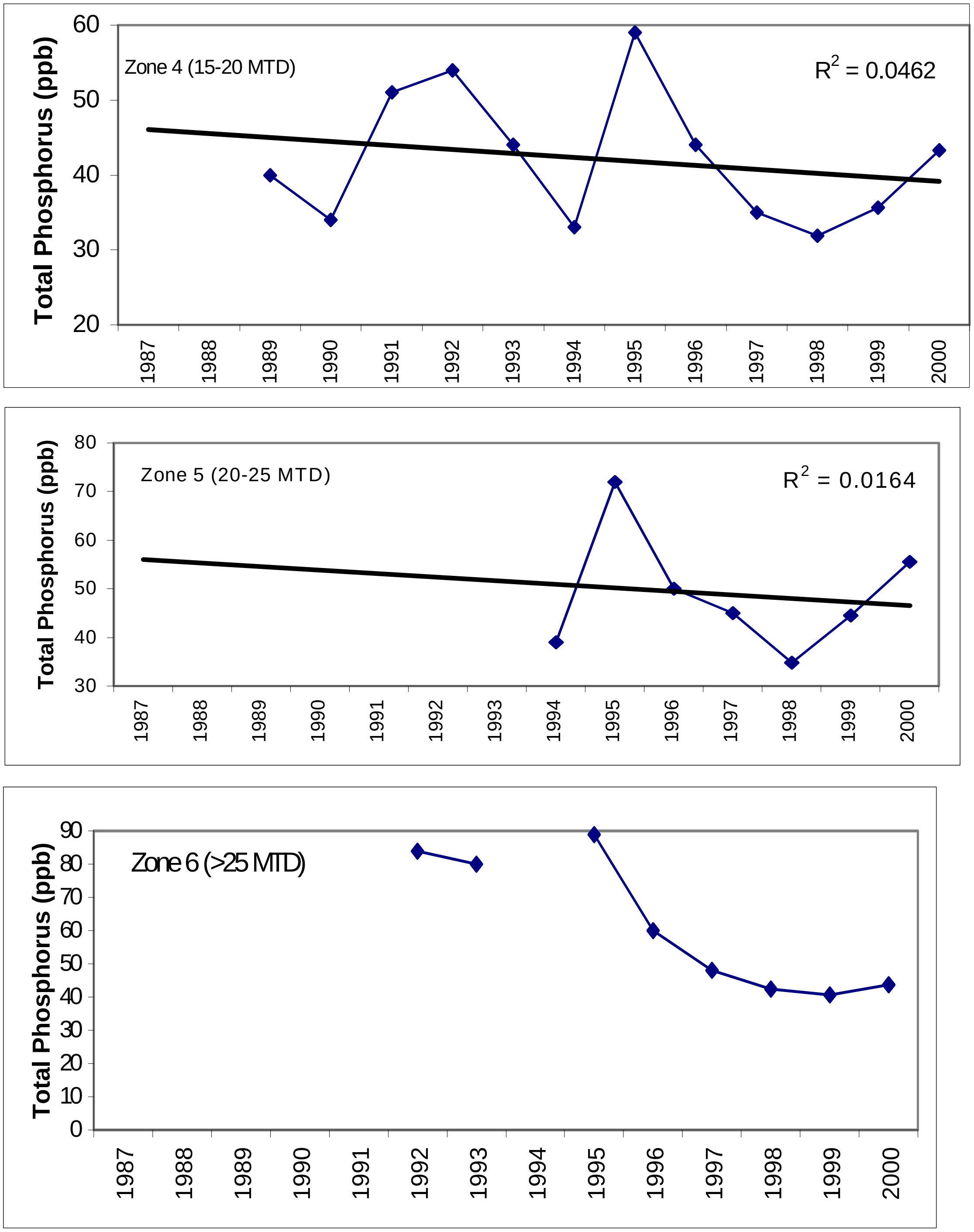


Figure 24. Average annual total phosphorus concentration by zone in Smith Mountain Lake (cont.).

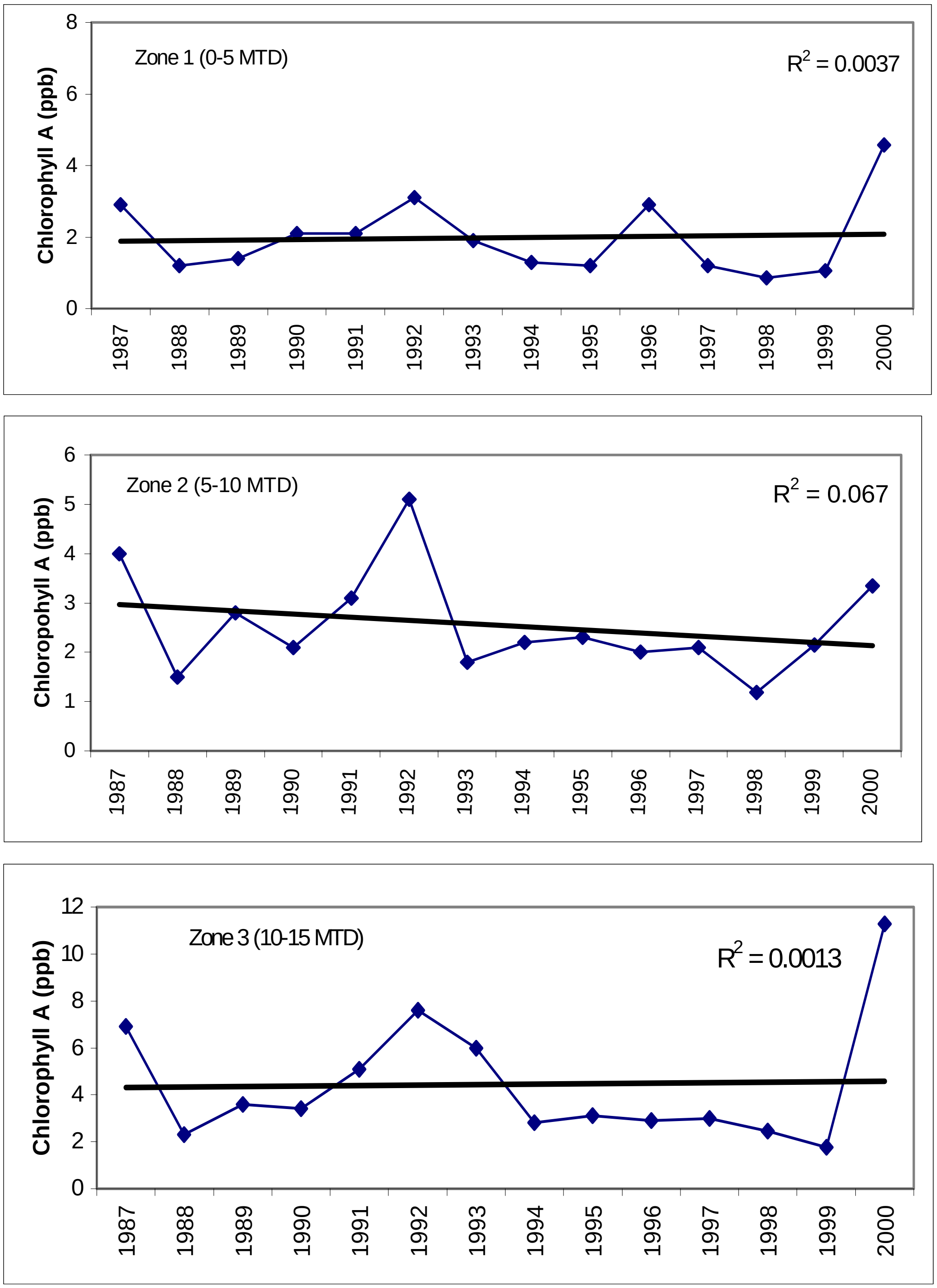


Figure 25. Average annual chlorophyll-*a* concentration by zone in Smith Mountain Lake.

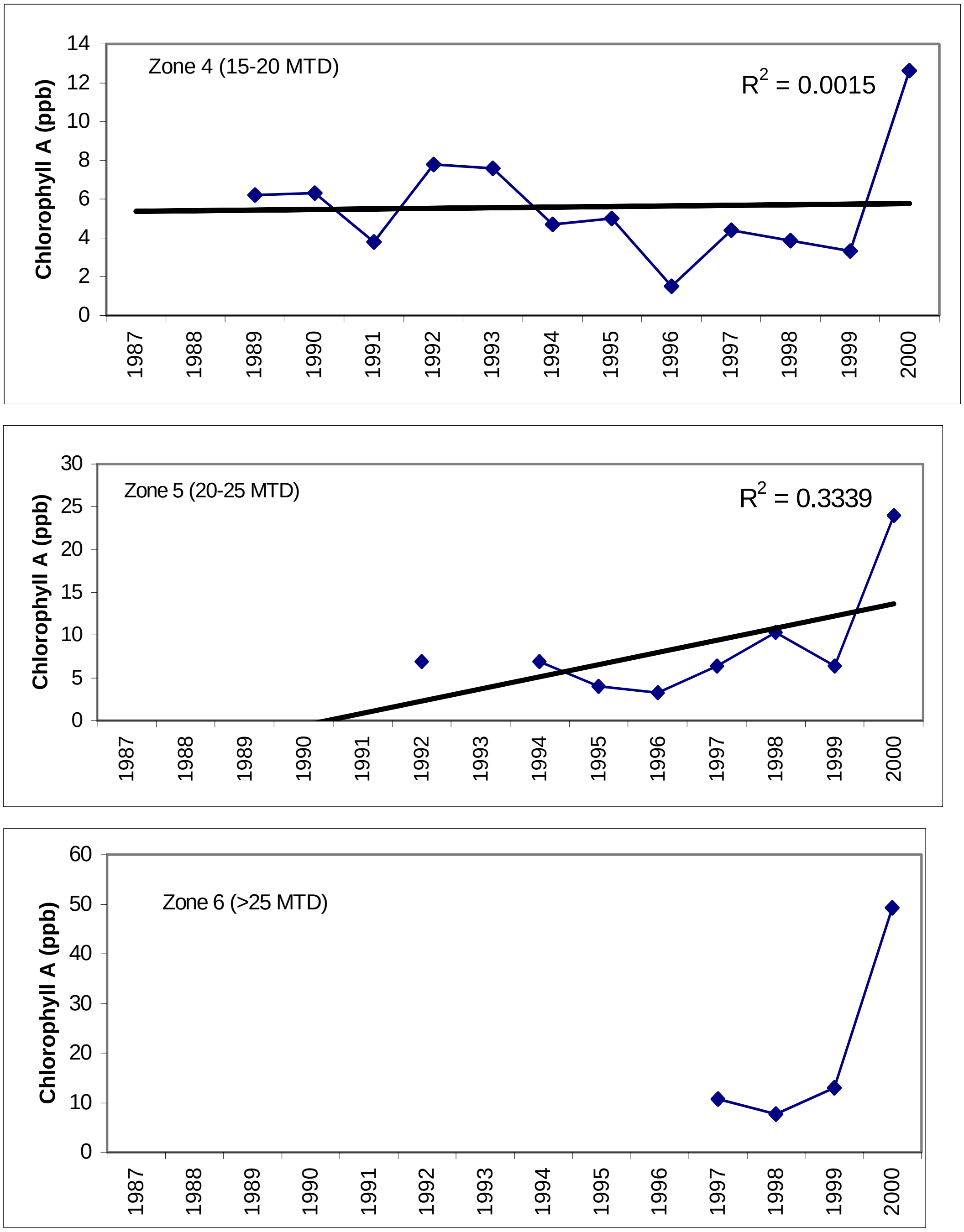


Figure 25. Average annual chlorophyll-*a* concentration by zone in Smith Mountain Lake (cont.).

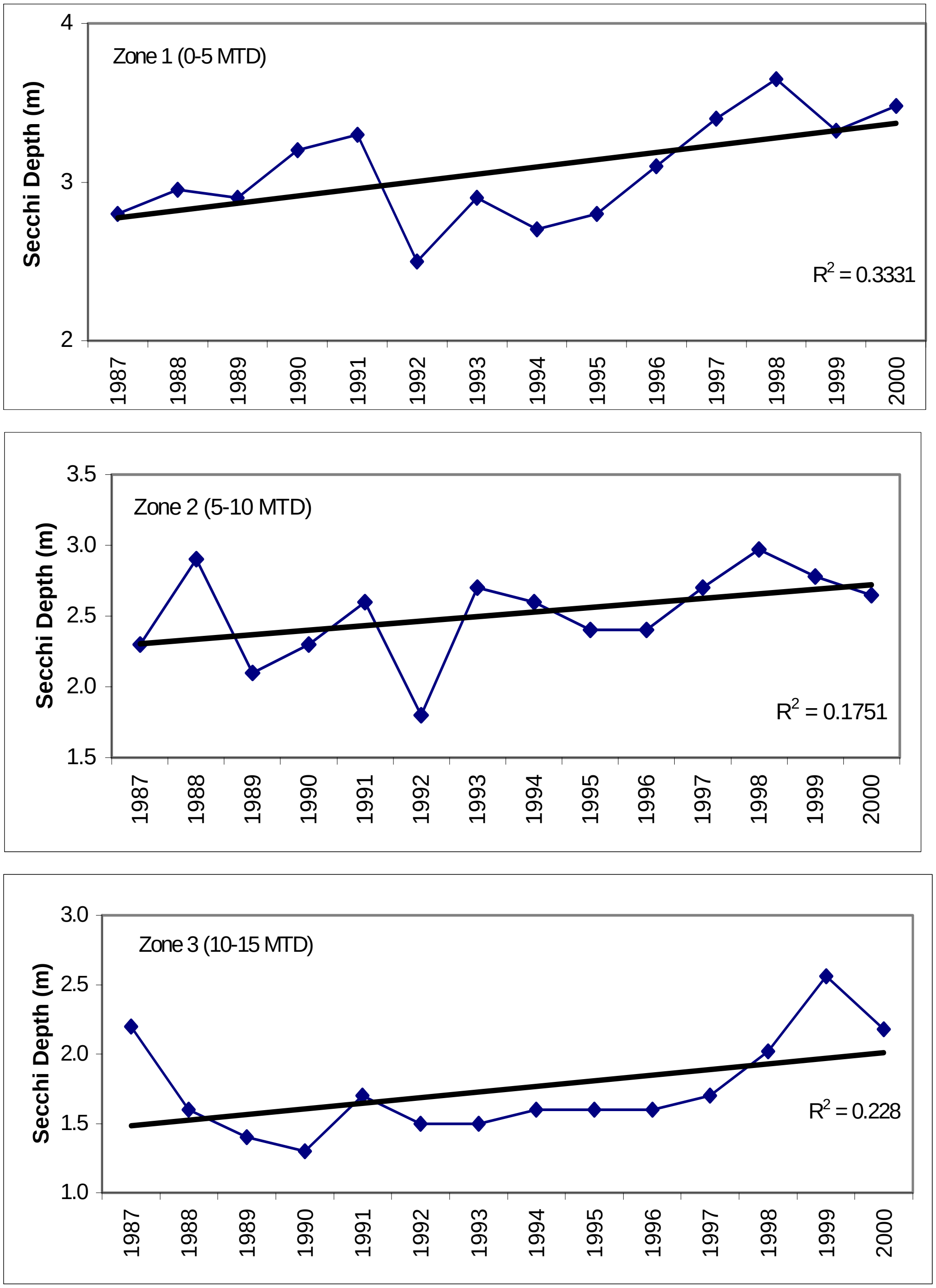
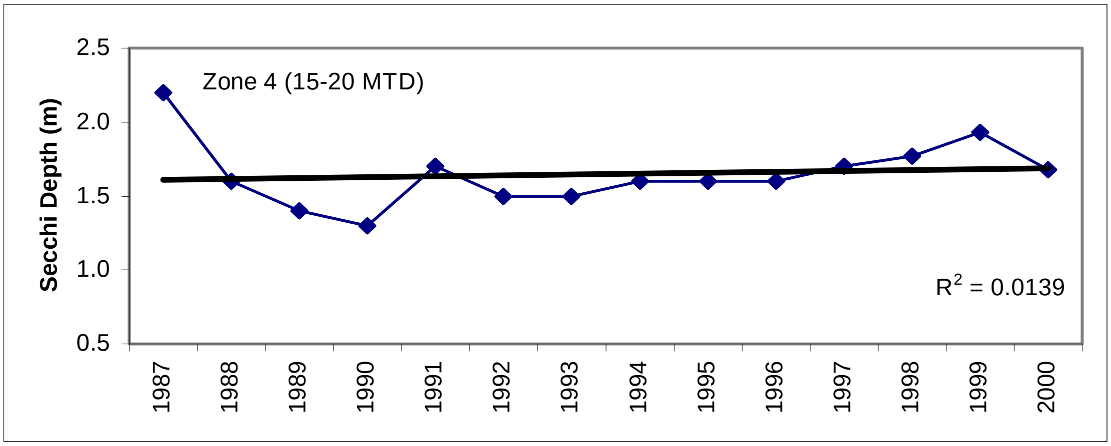


Figure 26. Average annual Secchi depth for zones in Smith Mountain Lake.



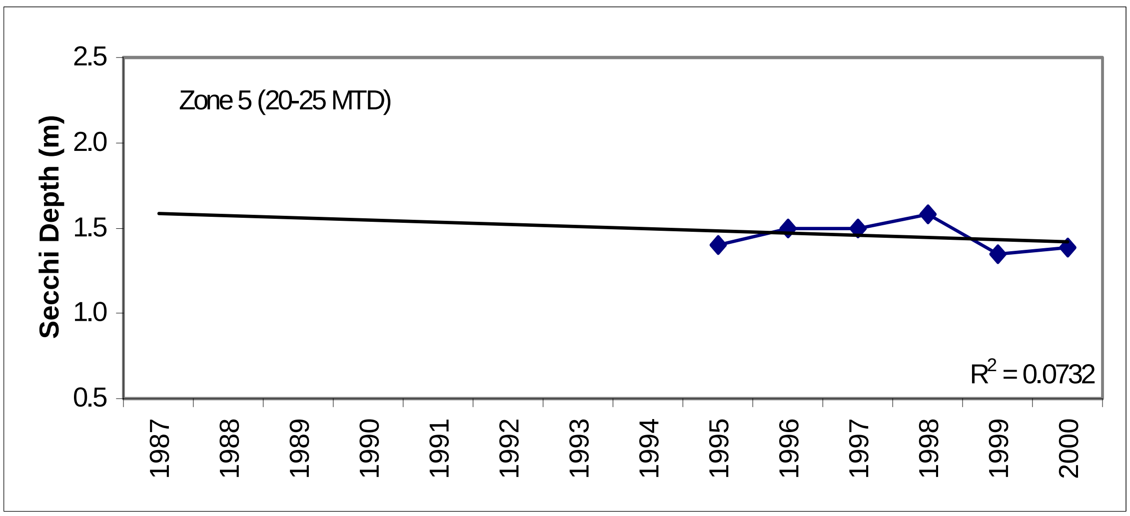


Figure 26. Average annual Secchi depth for zones in Smith Mountain Lake (cont.).

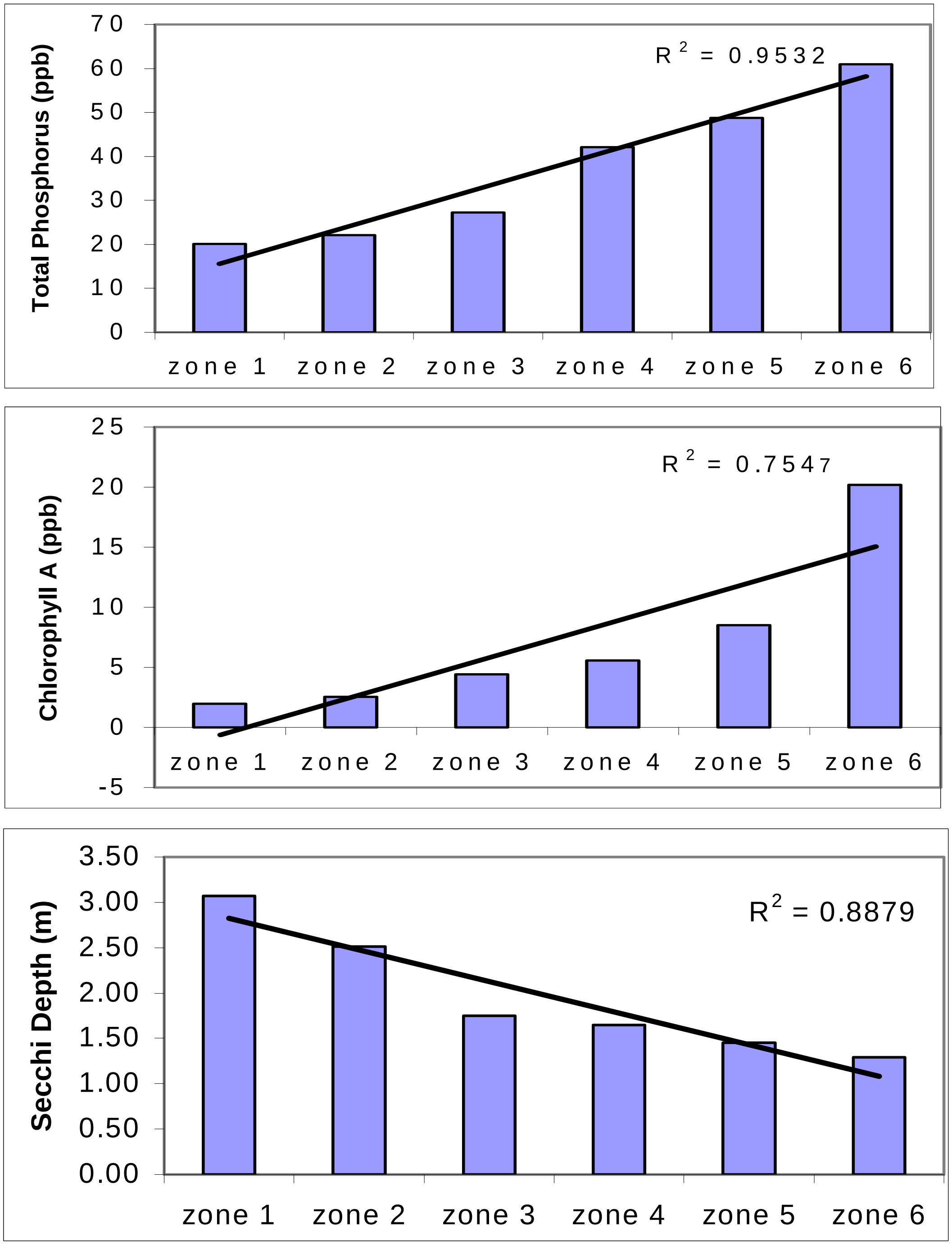


Figure 27. Average parameter value by zone summed over years 1987-1999.

6.2 Carlson's Trophic State Index

The Trophic State index was not calculated this year.

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 and will be reported in another publication in 2001.

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 13 indicates the sampling efficiency data for 2000 and Table 14 presents the collection efficiencies from 1992 through 2000. The figures show that the volunteer monitors are very conscientious about sample collection. Advanced monitors collected from 81-86% of the samples possible in 2000 and 89% of the samples possible for basic monitors. This sampling efficiency is remarkably high for any monitoring program, voluntary or otherwise. In 1995 a decrease in efficiencies was attributed to the implementation of Phase 2 of the Water Quality Monitoring Program and the change in sample sites to better cover the lake and to provide cove sites to match the tributary sites. In 1996 and in 1997 the sampling efficiencies were back up to the levels that they had been previously. In 2000 the advanced monitors' efficiency was lower than it has been in 5 years, however the basic monitors were the same efficiency as last year. 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 volunteers' dedication to the program.

Table 7. Sampling efficiency data for 2000.

Sample Type	Monitoring Stations	Possible Samples	Samples Collected	% Efficiency
CHA/NO3/PO	52	312	270	87%
Secchi	84	504	450	89%

Table 8. Comparison of sampling efficiencies for 1992-2000.

Sampling Efficiency (%)

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Secchi Depth	90	80	93	75	92	95	96	89	89
Total Phosphorus	93	90	99	80	96	96	96	95	83
Chlorophyll-*a*	93	90	98	80	96	97	96	95	81
Nitrate	NA	NA	NA	NA	NA	99	96	95	86

9. CONCLUSIONS

In 2000 the Smith Mountain Lake Water Quality Program accomplished a number of special studies concerning the influences on water quality. Ten students worked on water quality projects at Ferrum College over the summer. Two student technicians took primary responsibility for the monitoring program and a third acted as the liaison with the Claytor Lake Program. Six students worked on the Marina Education Program, sponsored by the Virginia Department of Health. The last student worked primarily for the Life Sciences Division but worked in several capacities in the Water Quality Lab.

The water quality parameters measured in Smith Mountain Lake indicate a decrease in water quality and an increase in nutrient enrichment, especially in the increase in the algal population. This would be expected in the natural aging of lakes and is not necessarily caused by anthropogenic activities, however the 274% increase in chlorophyll-*a* in 2000 is cause for concern (CHA = 14.6 ppb). This is too great an increase to be natural variation. No other obvious explanation is known except for the simple explanation of increased nutrient enrichment. The total phosphorus concentration increased by 39% lake wide (TP = 35.9 ppb) however the nitrate decreased by 56% (NO3 = 129 ppb). In most lakes in the United States phosphorus is considered the limiting nutrient and that is most likely true in Smith Mountain Lake. Therefore the increased phosphorus in previous years may have led to the increased algal population. The evaluation using mileage zones in the lake again provides much more useful information about the lake than the lake-wide measures. The zones further away from the dam show a greater decrease in water quality than the zones nearer the dam.

The fecal coliform observations in the lake were higher in 2000 than in previous years in all categories, including marina coves, non-marina coves, and headwaters coves. The marinas' average fecal coliform counts (54 $\pm$ 88 cfus) were twice as high as the non-marinas' fecal coliform counts (25 $\pm$ 41 cfus). It will not be known if waste discharge from boats cause these higher values until bacterial source tracking can be carried out. Once again, the average fecal coliform counts in 2000 were below the Virginia Department of Health standard. The rain event sample on Beaverdam Creek on the Roanoke Channel of the lake showed the significant influence on fecal coliform populations on non-point source runoff. The high input of fecal coliforms with non-point source runoff, however, does not appear to survive or thrive in the lake.

The high and seemingly random variability of fecal coliform counts was observed through depth, time, and site, therefore confirming the need for many samples and the need to sample at different depths, sites, and times of day.

A preliminary study was done to evaluate the effectiveness of using the Antibiotic Resistance Assay (ARA) for bacterial source tracking of the fecal bacteria found in Beaverdam Creek and the Blackwater River. The small sample size makes the results inconclusive but some of the fecal bacteria were found to come from human sources. More intensive sampling must be done to confirm these results.

The shoreline reconnaissance study done on Smith Mountain Lake was deemed ineffective and will not be continued next year.

In 2001 similar programs will continue, including the basic monitoring of nutrients in the lake and in the tributaries, and the continued monitoring of fecal coliforms around the lake. A more intensive sample is planned in Beaverdam Creek and the Blackwater River to further evaluate the sources of the fecal bacteria found there. Another rain event sample may be conducted on another tributary of the lake if the weather allows the conditions for such a study to occur.

10. ACKNOWLEDGEMENTS

Thanks go out to all of our volunteer monitors who once again made this program possible with their dedication and support. The Smith Mountain Lake Association again provided the much needed political and financial support. Patricia Moyer, Erin Feamster and Philip Davis were the student technicians this past summer, and they did a fine job. Amy Hayes worked for a short time this summer preparing the *Smith Mountain Lake Water Quality Program Methods Manual.* Their conscientiousness and hard work kept the monitoring program running smoothly, and everyone enjoyed their positive, friendly attitude. Assisting the student technicians when possible were Scott Queen, Jay Swain, Emily Halsey, Ainsley Worrell, Addison Dalton and Philip Davis, who had other duties assigned but assisted the Smith Mountain Lake Project when their other duties allowed. The intensive cove study had much appreciated help from Dr. Bob Pohlad and Tim Pohlad-Thomas. The rain event study had help from Dr. Carolyn Thomas' fall 2000 Microbiology Class who filtered the samples and counted the colonies. We would also like to acknowledge the support and time of Mr. John Singer, the liaison with the SMLA, and offer him special thanks again this year for his boat and time used for fecal coliform sampling. His enthusiasm and the leadership he brings to the program are wonderful. SMLA President Bill Telford for the second year has done a fine job of maintaining and building support for the program. We would also like to thank Shoreline Marina for their assistance and allowing us to dock at their marina while doing the intensive cove study. Finally, we wish to thank the Smith Mountain Policy Advisory Board (now known as the Tri County Lake Advisory Commission), Hilde Hussa (Executive Director) for providing political support, and Ferrum College for making space and equipment available at no cost to the project as a community service.

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APPENDIX

Table A1. 2000 SML stations with monitor names and station locations.

Station	Monitor	Longitude	Latitude	Site Number
B8	*no monitor 2000*			
B10	*no monitor 2000*			
B12	Chilton			
B14	Jamison	79.676	37.035	85
B16	Jamison	79.704	37.040	50
B18	Shirey	79.720	37.035	52
B20	Shirey	79.728	37.033	53
B22	Franz	79.743	37.063	55
C4	Hill	79.572	37.056	8
C5	Hill	79.565	37.066	7
C6	Hill	79.568	37.082	6
CB11	Chilton			
CB16	Jamison	79.703	37.045	49
CB20	Franz	79.737	37.036	54
CM1	Rice	79.539	37.055	2
CM1.2	Rice	79.535	37.063	1
CM5	E. Anderson	79.587	37.047	9
CR8	E. Anderson	79.593	37.065	33
CR9	Hunt	79.606	37.077	21
CR9.2	Hunt	79.617	37.070	20
CR13	Kastner	79.642	37.099	28
CR14.2	P. Dooley	79.682	37.119	97
CR16	Ollweiler	79.663	37.145	57
CR17	Ollweiler	79.667	37.150	58
CR19	Smith	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	Gascoyne/Louk			
CR25	Gascoyne/Louk			
CR26	B. Dooley/Holgreve			
G12	Chilton			
G13		79.674	37.049	84
G 14	Wandelt/Dick	79.673	37.055	47
G15				
G16	Wandelt/Dick	79.688	37.062	48
G18	Wandelt/Dick	79.682	37.072	59
M0	Rice	79.538	37.043	3
M1	Overman	79.547	37.047	4
M3	Overman	79.564	37.041	5
M5	Overman	79.588	37.042	10
R7	E. Anderson	79.595	37.052	12
R9	Hunt	79.617	37.073	19
R11	E. Anderson	79.612	37.089	22
R13	Kastner	79.642	37.103	29
R14	P. Dooley	79.647	37.113	31
R15	Ollweiler	79.657	37.131	35
R17	Smith/Lorent	79.676	37.152	60
R19	Smith/Lorent	79.697	37.161	66
R21	Bray	79.707	37.155	70

Table A1. 2000 SML stations with monitor names and station locations (cont.).

R23	Bogsrud	79.717	37.180	74
R25	Gascoyne/Louk			
R27	B. Dooley/Holgreve			
R29	B. Dooley/Holgreve	79.797	37.218	86
R30				
R31				
SCB8	Randa	79.599	37.026	38
SCB10	Randa	79.639	37.023	40
SCB11	Randa	79.632	37.017	24
SCB11.5	Randa	79.644	37.062	13
SB12	Thurman	79.664	37.040	42
SCB14	Thurman	79.683	37.031	51
SCB16	Thurman	79.693	37.034	46
SCM5	*no monitor 2000*	79.588	37.048	32
SCR7	*no monitor 2000*	79.585	37.061	11
SCR8	*no monitor 2000*	79.588	37.068	23
SCR10.1	Gore	79.629	37.073	18
SCR10.2	Gore	79.628	37.076	17
SCR10.3	Gore	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	Hach	79.665	37.109	34
SCR14.2	Hach	79.679	37.105	91
SCR14.3	Hach	79.659	37.113	92
SCR15	Gerhardt	79.646	37.120	93
SCR 15.1	Holasek			
SCR 15.2	Holasek			
SCR17	Gerhardt/Holasek	79.670	37.157	95
SCR17.1	*no monitor 2000*	79.677	37.158	61
SCR18	A. Anderson			
SCR19	A. Anderson			
SCR20	A. Anderson			
SCR22.2		79.707	37.171	73
SCR 22.3				
SCR 23				
SCR 23.2				
SCR23.3		79.721	37.183	77
SCR24		79.724	37.197	78
T0(Gills)	Snoddy			
T21(Roanoke)	Faber			

Table A2. 2000 SML tributary stations and other down stream 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. 2000 Total Phosphorus data from SML sample stations.

Station	May28-Jun3	Jun 11-17	Jun26-Jul 1	July 9-15	July 23-29	Aug 6-12	station avg	station stdev
B12	23.1	20.1	39.0	22.0	22.3	20.1	24.4	7.2
B14	0.0	0.0	27.5	25.1	17.1		13.9	13.3
B16	14.2	36.2	0.0	0.0	0.0		10.1	15.8
B18			54.5	43.5		0.0	32.7	28.8
B20			30.4	59.7		102.7	64.3	36.3
B22	130.0	103.3	87.9	87.4	113.8	87.1	101.6	17.7
C4	7.7		21.6	19.3	2.7	3.4	10.9	8.9
C5	15.8	27.3	16.0	23.9	16.8	22.3	20.3	4.8
C6	17.3	19.0	17.5	12.4	13.1	11.6	15.1	3.2
CB11	11.5	28.3	25.6	12.8	14.9	18.6	18.6	6.9
CB16	13.8	23.3	20.1	19.3	2.3		15.8	8.3
CB20	29.2	48.7	41.2	41.2	27.5	46.0	39.0	8.7
CM1	8.1		59.3	12.8	6.4	21.9	21.7	21.9
CM1.2	11.2	11.2	19.0	16.2	8.6	19.0	14.2	4.4
CM5	26.5	48.7	19.0	15.8	11.2	22.3	23.9	13.2
CR5			14.1				14.1	
CR8	3.1	18.0		0.8		15.6	9.4	8.7
CR9	41.9	18.3	14.5	20.8	8.6	20.8	20.8	11.3
CR9.2	25.0	56.9	11.9	19.7	11.6	24.1	24.9	16.7
CR13			27.1			44.1	35.6	12.0
CR14.2	21.9	30.5	9.0	50.1	26.0	30.1	27.9	13.4
CR16	35.0		24.1	57.8	61.6	38.2	43.3	15.9
CR17	45.0	75.1	62.3	85.8	87.1	53.0	68.1	17.4
CR19	40.8	53.3	43.0	0.8	53.1	58.2	41.5	21.0
CR21	48.5	60.1	59.0	115.5	63.4	76.4	70.5	23.8
CR21.2	49.2	69.4	67.9	105.5	70.5	87.1	74.9	19.2
CR22	46.2	47.6	29.3	27.0		49.0	39.8	10.7
CR24	31.5	48.7	40.4	24.3	37.1	60.4	40.4	12.8
CR25	29.6	55.5	30.1	49.3	22.0	71.9	43.1	19.1
CR26			32.3	50.5	27.1	69.3	44.8	19.2
G12	41.9	65.1	54.1	27.4	22.3	33.8	40.8	16.4
G14	19.6	34.8	27.1	23.2	23.4		25.6	5.8
G16	22.3	42.6	26.4	27.4	39.0		31.5	8.8
G18	24.2	169.4	39.3	104.7			84.4	66.6
M0	29.6	43.0	10.4	15.8	-4.0	20.1	19.2	16.1
M1			31.2	43.2	6.8	43.8	31.2	17.3
M3			18.6		37.1	36.7	30.8	10.6
M5			27.5	18.2	-1.0	22.7	16.8	12.5
R7	19.6	26.2	14.9	14.3		42.7	23.5	11.7
R9	14.2	33.3	11.9	18.2	25.7	34.5	23.0	9.7
R11	21.2	26.2	19.7	10.5		35.3	22.6	9.1
R13			18.2	40.1	20.5	51.2	32.5	15.9

Table A3. 2000 Total phosphorus data from SML sample stations (cont.).

R14	18.1	31.2	22.3	222.0	7.5	31.6	55.4	82.1
R15	19.6	34.0	26.4	35.5	29.4	47.9	32.1	9.6
R17	26.5	34.0	40.1	52.8	39.7	43.0	39.4	8.8
R19	45.0		52.7	72.0	62.0	64.5	59.2	10.5
R21	50.4		33.8	31.6	29.0	84.1	45.8	23.0
R21				20.5		84.1	52.3	45.0
R23	38.8		-3.6	38.9		65.6	34.9	28.6
R25	38.8	40.1	29.7	33.2	25.3	67.1	39.0	14.8
R26	35.4						35.4	
R27	33.8	49.4	29.0	33.2	25.3	67.1	39.6	15.8
R29	38.1	63.3	31.9	41.2	29.7	85.3	48.3	21.7
Week avg	29.4	44.2	30.1	39.7	27.9	45.2	Grand avg	35.9
stdev	20.5	29.5	17.8	37.9	24.8	25.4	Grand stde	27.5

Table A4. 2000 Total phosphorus data for SML tributaries.

Tributary	May28-Jun3	Jun 11-17	Jun26-Jul 1	July 9-15	July 23-29	Aug 6-12	station avg	station stdev
T00	120.0	108.7	47.1	48.2	48.6	99.3	78.7	34.2
T1	170.4	162.6	124.9	111.2	140.5	131.6	140.2	22.6
T2	115.0	106.9	101.2	88.9	158.3	89.3	109.9	25.7
T3	82.7	141.2	100.4	70.1	114.9	74.9	97.4	27.2
T4	98.1	105.8	102.7	2.8	137.5	96.4	90.5	45.6
T5	93.5		42.3	34.3	29.0	55.6	50.9	25.8
T6	95.0	113.3	87.5	64.7	4.2	66.7	71.9	37.8
T7	16.5	31.2	79.0	67.0	53.8	90.4	56.3	28.3
T8	28.1	68.3	19.7				38.7	26.0
T9	18.1	13.0	76.7	20.8	9.0	35.3	28.8	25.1
T10	98.5	98.7	29.7	20.8	9.0	35.3	48.7	39.7
T11	31.2	66.2	70.4	10.5	52.3	105.6	56.0	33.1
T12	96.2	54.4	41.6	64.3	29.4	64.9	58.4	23.0
T13	43.1	53.0	31.2	40.5	49.4	51.2	44.7	8.2
T14	108.1	176.9	63.4	31.6	33.8	50.1	77.3	56.2
T15	114.2	113.0	138.2	108.5	148.3	92.3	119.1	20.5
T16	166.2	141.2	99.0	71.6	87.5	86.4	108.6	36.8
T17	88.8	83.7	104.5	73.5	144.6	110.8	101.0	25.3
T18	116.5	70.1	64.9	70.5	93.4	57.1	78.8	22.1
T19			183.8	90.8		116.7	130.5	48.0
T20	78.8	102.6	93.4	66.2	50.9	66.4	76.4	19.2
T21	108.8	112.3	84.1	92.0	182.7	110.8	115.1	35.0
Week avg	89.9	96.1	81.2	59.5	78.9	80.3	Trib avg	80.9
Week stdev	41.5	40.9	38.1	30.3	55.3	26.8	Trib stdev	41.5

Table A5. 2000 Nitrate data for SML.

Station	May28-Jun3	Jun 11-17	Jun26-Jul 1	July 9-15	July 23-29	Aug 6-12	station avg	station stdev
B12	59.3	-87.8		116.1	72.2	71.4	46.2	78.0
B14	-105.8	-92.8	57.8	48.3	-62.2		-30.9	78.4
B16	-69.5	-75.8	84.4	32.8	4.4		-4.7	68.4
B18			140.0	60.6		57.7	86.1	46.7
B20			148.9	91.7		76.8	105.8	38.1
B22	869.3	284.2	207.8	185.0	134.4	343.2	337.3	270.9
C4	51.8	-30.8	156.7	92.8	122.2	155.0	91.3	71.8
C5	86.8	38.2	147.8	113.9	32.2	110.5	88.2	45.5
C6	41.8	8.2	217.8	36.1	42.2	179.5	87.6	87.8
CB11	170.5	-59.8		19.4	14.4	85.0	45.9	86.5
CB16	-8.2	-93.8	50.0	119.4	5.6		14.6	78.4
CB20	190.5	96.2	122.2	92.8	46.7	107.7	109.3	47.2
CM1	175.5	108.2	161.1	177.2	182.2	174.1	163.1	27.8
CM1.2	209.3	23.2	204.4	182.8	170.0	97.7	147.9	73.1
CM5	108.0	-26.8	78.9		37.8	-7.7	38.0	56.7
CR5			77.8				77.8	
CR8	136.8	23.2			-5.6	-24.1	32.6	72.1
CR9	44.3	29.2	106.7	49.4	17.8	-34.1	35.5	45.9
CR9.2	44.3	-37.8	65.6	27.2	-4.4	-49.5	7.5	46.0
CR13		-17.8	43.3		36.7	-36.8	6.3	39.7
CR14.2	125.5	-54.8	84.4	38.3	31.1	-47.7	29.5	71.3
CR16	-57.0	49.2	0.0	77.2	0.0	0.0	11.6	46.5
CR17	166.8	0.0	177.8	95.0	34.4	46.8	86.8	73.0
CR19	63.0	64.2	92.2	87.2	33.3	-24.1	52.6	43.0
CR21	221.8	70.2	86.7	121.7	36.7	-15.0	87.0	80.7
CR21.2	180.5	42.2	91.1	100.6	54.4	-4.1	77.5	62.9
CR22	394.3	223.2	85.6		147.8	-21.4	165.9	155.9
CR24	449.3	291.2	135.6	145.0	410.0	-25.0	234.3	181.8
CR25	699.3	367.2	181.1	147.2	101.1	-15.0	246.8	254.2
CR26		439.2	303.3	307.2	354.4	-13.2	278.2	171.8
G12	288.0	112.2		33.9	42.2	-46.8	85.9	126.3
G14	70.5	-27.8	53.3	68.3	36.7		40.2	40.4
G16	4.3	20.2	95.6	81.7	-7.8		38.8	46.8
G18	-88.3	-119.8	60.0	97.2			-12.7	107.3
M0	-77.0	140.2	114.4	181.7	150.0	68.6	96.3	93.0
M1			168.9	143.9	121.1	43.2	119.3	54.3
M3			105.6	116.1	81.1	18.6	80.4	43.7
M5			123.3	78.3	21.1	-1.4	55.4	56.4
R7	374.3	21.2	56.7		22.2	8.6	96.6	156.2
R9	50.5	-68.8	61.1	137.2	57.8	-1.4	39.4	69.1
R11	-48.3	-8.8	127.8		15.6	-12.3	14.8	67.1
R13		22.2	127.8	90.6	100.0	30.5	74.2	45.9
R14	-22.0	48.2	48.9	98.3	14.4	-55.0	22.1	55.1
R15	-119.5	85.2	265.6	92.8	68.9	-15.9	62.8	128.0
R17	-59.5	32.2	166.7	101.7	78.9	-28.6	48.5	84.4
R19	51.8	10.2	136.7	152.8	182.2	-21.4	85.4	83.3
R21	16.8	31.2	76.7	116.1	222.2	0.5	77.2	82.7
R23	183.0	312.2	72.2		516.7	-36.8	209.5	215.1

Table A5. 2000 nitrate data for SML (cont.).

R25	578.0	409.2	170.0	365.0	543.3	-12.3	342.2	226.4
R26	656.8						656.8	
R27	1163.0	429.2	510.0	492.8	-13.3	-5.9	429.3	432.2
R29	1353.0	640.2	3836.7	662.8	1492.2	5.9	1331.8	1340.5
Week avg	200.5	139.7	162.8	155.4	148.7	128.5	**Grand avg**	**128.5**
Week stdev	325.9	263.0	385.7	341.0	322.5	300.0	**Grand stdev**	**300.0**

Table A6. 2000 nitrate samples for SML tributaries.

Tributary	May28-Jun3	Jun 11-17	Jun26-Jul 1	July 9-15	July 23-29	Aug 6-12	station avg	station stdev
T00	749.3	777.2	676.7	767.2	266.7	545.0	630.3	198.1
T1	1023.0	634.2	656.7	582.8	827.8	377.7	683.7	220.4
T2	898.0	660.2	743.3	602.8	716.7	177.7	633.1	244.3
T3	1048.0	589.2	756.7	385.0	1027.8	174.1	663.5	349.8
T4	589.3	396.2	482.2	689.4	702.2	377.7	539.5	142.4
T5	660.5	744.2	1282.2	871.7	678.9	682.3	820.0	239.3
T6	816.8	647.2	991.1	820.6	497.8	1076.8	808.4	213.6
T7	5.5	2.2	160.0	247.2	144.4	156.8	119.4	96.7
T8	311.8	164.2	505.6				327.2	171.2
T9	338.0	118.2	288.9	342.8	187.8	201.4	246.2	91.0
T10	798.0	449.2	458.9	357.2	437.8	225.0	454.3	190.0
T11	414.3	378.2	253.3	260.6	332.2	175.9	302.4	88.7
T12	166.8	140.2	161.1	232.8	126.7	104.1	155.3	44.4
T13	184.3	91.2	336.7	371.7	247.8	271.4	250.5	102.3
T14	603.0	499.2	1027.8	711.7	505.6	296.8	607.3	247.4
T15	703.0	844.2	900.0	619.4	514.4	326.8	651.3	213.0
T16	874.3	597.2	501.1	522.8	552.2	219.5	544.5	209.5
T17	1766.8	875.2	943.3	1939.4	1344.4	900.5	1294.9	468.2
T18	386.8	116.2	252.2	266.1	303.3	149.5	245.7	99.7
T19	408.0	208.2	243.3	330.6		265.9	291.2	79.1
T20	331.8	91.2	365.6	271.7	284.4	200.5	257.5	99.0
T21	1864.3	1732.2	1592.2	3085.0	1288.9	1499.5	1843.7	639.2
Week avg	679.1	488.9	617.2	679.9	549.4	400.2	**GR mean**	**569.9**
Week Stdev	465.1	391.9	382.3	667.2	355.0	358.6	**GR stdev**	**452.7**

Table A7. 2000 Chlorophyll-*a* data for Smith Mountain Lake.

Station	May28-Jun3	Jun 11-17	Jun26-Jul 1	July 9-15	July 23-29	Aug 6-12	station avg	station stdev
B12	2.55	4.95	4.8	15	6	18	8.550	6.331
B14	3.75	2.25	6.75	10.05	7.2		6.000	3.063
B16	2.1	2.85	11.25	10.8	10.8		7.560	4.653
B18			30	9.45		4.2	14.550	13.635
B20			9.9	19.5		21	16.800	6.022
B22	12.6	12.3	13.35	14.7	48	12.6	18.925	14.270
C4	1.2	0.9	4.95	6.6	9.75	6.75	5.025	3.448
C5	1.5	2.4	10.2	5.1	14.85	8.4	7.075	5.076
C6	1.8	1.2	14.55	3.45	10.35	10.35	6.950	5.527
CB11	1.95	3.15	13.65	10.95	4.95	21	9.275	7.339
CB16	4.8	1.65	19.5	7.8	21		10.950	8.780
CB20	6.3	5.1	4.05	11.55	10.05	9.6	7.775	3.032
CM1	0.9	0.45	1.05	4.05	2.7	3.9	2.175	1.590
CM1.2	1.05	1.5	6.9	2.85	3.3	2.7	3.050	2.071
CM5	1.65	2.4	0.9		3.45	9.6	3.600	3.484
CR5			13.5				13.500	
CR8	2.25	1.8			8.85	5.4	4.575	3.269
CR9	0.6	0.6	0.75	0.6	1.35	1.35	0.875	0.372
CR9.2	0.6	0.15	0.6	0.45	1.95	2.4	1.025	0.917
CR13			5.55		21	14.1	13.550	7.740
R14			2.1				2.100	
CR14.2	1.8	1.05	5.7	7.2	11.25	8.4	5.900	3.923
CR16	14.7	1.2	9.9	8.4	58.5	27	19.950	20.733
CR17	9.15	4.65	9.6	11.55	52.5	31.5	19.825	18.554
CR19	0.6	5.85	1.2	8.25	8.4	21	7.550	7.398
CR21	1.35	0.75	2.1	4.5	6.6	0.9	2.700	2.353
CR21.2	6.45	6.9	0.9	9.9	3.9	0.9	4.825	3.588
CR22	8.85	6.3	24		66	73.5	35.730	31.895
CR24	4.35	5.85	13.5	40.5	73.5	150	47.950	56.538
CR25	3.15	5.25	9.3	37.5	0	97.5	25.450	37.816
CR26			114	15	63	150	85.500	59.017
G12	1.8	1.8	7.05	7.95	81	7.65	17.875	31.054
G13								
G14	1.2	2.4	3.9	73.65	9.45		18.120	31.202
G15								
G16	1.05	3.3	3	14.4	8.25		6.000	5.395
G18	2.4	5.1	31.5	36	16.5		18.300	15.148
M0	1.05	0.9	2.25	5.25	3.6	2.85	2.650	1.642
M1			3.9	8.7	5.85	4.35	5.700	2.167
M3			4.5	7.2	7.5	4.65	5.963	1.608
M5			2.1	8.4	4.65	6.75	5.475	2.724
R7	2.25	1.8	4.95		9.3	10.35	5.730	3.945
R9	0.15	0.6	1.2	0	4.8	3.6	1.725	1.998
R11	1.95	1.95	7.95		18	9.15	7.800	6.602
R13			6.3	4.35	27	19.5	14.288	10.822
R14	1.35	1.05		12	30	19.5	12.780	12.354
R15	4.65	3.45	5.4	9	39	19.5	13.500	13.794
R17	0.45	3.15	1.05	7.95	40.5	45	16.350	20.668
R19	9.6	3.6	1.05	10.5	10.2	9.9	7.475	4.081

Table A7. 2000 Chlorophyll-*a* data for Smith Mountain Lake (cont.).

R21	1.05	1.05	12.15	13.5	0	25.5	8.875	10.097
R23	6	3.45	70.5		88.5	129	59.490	54.305
R25	2.4	5.7	15	51	67.5	73.5	35.850	31.973
R26	6						6.000	
R27	4.95	4.05	14.85	15	109.5	150	49.725	63.468
R29	9.9	5.25	16.5	49.5	79.5	30	31.775	28.321
mean/date	3.586	3.096	11.592	14.187	24.788	29.155	**Grand avg**	**14.617**
std/date	3.476	2.380	18.638	15.197	28.384	42.180	**Grand stdev**	**23.706**

Table A8. 2000 Secchi data for Smith Mountain Lake.

Station	May28-Jun3	Jun 11-17	Jun26-Jul 1	July 9-15	July 23-29	Aug 6-12	station avg	station stdev
B12	3.00	3.50		3.00	3.00		3.13	0.25
B12.2				3.50			3.50	
B14	2.50	3.00	3.00	2.00	2.50		2.60	0.42
B16	2.00	2.00	2.00	1.50	2.00		1.90	0.22
B18			2.00	2.00			2.00	0.00
B20			1.75	2.00			1.88	0.18
B22	0.75	1.00	0.75	1.00	1.00	1.00	0.92	0.13
C4	4.25	4.00	4.25	3.00	3.75	4.25	3.92	0.49
C5	3.50	4.00	4.25	3.00	3.00	3.50	3.54	0.51
C6	2.75	2.75	3.50	3.00	2.50	3.25	2.96	0.37
CB11	3.00	3.50		3.00	3.00		3.13	0.25
CB16	2.00	2.50	2.50	2.00	2.00		2.20	0.27
CB20	2.00	1.50	1.75	1.75	1.50	1.25	1.63	0.26
CM1	3.25	3.50	3.50	3.50	3.50	3.50	3.46	0.10
CM1.2	2.50	3.25	3.50	3.50	4.00	3.50	3.38	0.49
CM5	3.75	3.75	3.25	3.00	3.00	3.00	3.29	0.37
CR8	3.00	3.50	3.50	2.75	2.75	2.75	3.04	0.37
CR9	2.50	3.00	3.00	2.50	2.50	2.50	2.67	0.26
CR9.2		3.00	4.00		2.25	2.00	2.81	0.90
CR13		2.00	2.00	1.75	1.75	2.00	1.90	0.14
CR14.2	1.25	1.50	1.00	1.50	1.50	1.50	1.38	0.21
CR16	1.25	2.00	2.00	1.50	1.25	1.00	1.50	0.42
CR17	1.75	1.75	2.00	1.50	0.50	1.25	1.46	0.53
CR19	1.5	2.50	1.50	1.50	1.50	1.00	1.58	0.49
CR21	1.50	1.75	1.75	1.5	1.25	1.50	1.54	0.19
CR21.2	1.50	1.50	1.75	1.75	1.25	1.50	1.54	0.19
CR22	1.50	1.75	1.50	1.25	1.25	1.00	1.38	0.26
CR24	1.75	1.50	1.75		1.00	1.00	1.40	0.38
CR25	2.00	1.50	1.50		1.00	0.75	1.35	0.49
CR26	1.50	1.50	1.50	1.50	1.00	0.75	1.29	0.33
G12	2.50	3.00		3.00	3.50		3.00	0.41
G14	2.50	2.00	2.75	2.25	2.25		2.35	0.29
G16	2.00	2.25	2.50	2.00	2.00		2.15	0.22
G18	2.00	2.75	2.00	1.50	1.50		1.95	0.51
M0	2.25	4.00	4.00	3.75	3.25	4.00	3.54	0.70
M1			3.00	3.00	3.50	3.75	3.31	0.38
M3			3.50	3.00	3.25	4.00	3.44	0.43
M5			3.00	3.00	3.25	4.00	3.31	0.47
R7	2.75	3.75	3.75	3.75	2.50	3.00	3.25	0.57
R9	2.60	2.50	4.00	2.50	2.00	2.00	2.60	0.73
R 9.2	2.50			2.50			2.50	0.00
R11	2.00	2.50	2.75	2.50	1.75	1.75	2.21	0.43
R13		2.00	2.00	1.75	1.50	1.50	1.75	0.25
R14	1.25	1.75	1.75		1.50	1.75	1.60	0.22
R15	1.50	1.50	2.75	1.75	1.25	1.50	1.71	0.53
R17	2.00	3.00	1.50	1.75	1.00	1.50	1.79	0.68

Table A8. 2000 Secchi data for Smith Mountain Lake (cont.).

R19	2.00	3.00	2.00	1.50	1.00	1.50	1.83	0.68
R21	1.75	1.75	1.75	1.75	1.25	1.25	1.58	0.26
R23	1.50	1.75	1.50	1.25	1.25	1.00	1.38	0.26
R25	2.00	1.50	1.50		1.00	1.00	1.40	0.42
R27	2.00	1.25	1.50	1.50	1.50	0.75	1.42	0.41
R29	1.50	1.50	1.50	1.50	1.25	0.75	1.33	0.30
R34(T21)	1.50	1.25					1.38	0.18
SCB 8	3.00	3.00	3.50	2.75	3.00	3.50	3.13	0.31
SCB10	2.25	3.00	3.00	2.50	2.25	2.50	2.58	0.34
SCB11	2.25	2.50	3.25	2.75	2.00	2.75	2.58	0.44
SCB11.5	2.50	2.50	1.75	2.25	2.50	2.25	2.29	0.29
SCR10.1	2.25	2.25		2.25	2.00	1.50	2.05	0.33
SCR10.2	2.00	2.25		2.25	1.75	1.50	1.95	0.33
SCR10.3	2.00	1.75		2.25	1.50	1.75	1.85	0.29
SCR11.1	1.25	4.00	3.00	2.25	2.50	1.75	2.46	0.97
SCR11.2	1.75	3.50	3.50	2.75	2.50	1.50	2.58	0.85
SCR11.3	1.25	3.00	3.75	2.50	2.25	2.00	2.46	0.86
SCR14	1.75	2.50	3.25	2.25		1.50	2.25	0.68
SCR14.1	1.25	2.00	2.25	2.25	1.50	1.75	1.83	0.41
SCR14.2	1.00	1.50	1.50	1.75	1.25	1.50	1.42	0.26
SCR14.3	1.25	2.25	2.25	2.50	1.75	1.75	1.96	0.46
SCR15	1.75	2.50	3.00	2.00		1.50	2.15	0.60
SCR 15.1			2.75	1.75	1.75	1.75	2.00	0.50
SCR 15.2			2.25	1.50	1.75	1.50	1.75	0.35
SCR17	1.75	1.75	2.25	1.50		1.25	1.70	0.37
SCR17.1			2.00	1.50	1.50	1.25	1.56	0.31
SCR18	1.50	2.00	1.25	1.50	1.00	1.25	1.42	0.34
SCR19	1.25	1.50	1.00	1.50	1.00	1.25	1.25	0.22
SCR20	1.50	1.50	1.25	1.25	1.00	1.25	1.29	0.19
T 21					0.25		0.25	
Week avg	2.03	2.39	2.43	2.19	1.96	1.92	**Grand avg**	**2.16**
Week stdev	0.69	0.82	0.91	0.69	0.84	0.96	**Grand Stdev**	**0.84**

Table A9. 2000 Fecal coliform data (cfus) from Smith Mountain Lake.

Site	Site#,Rep#	May 30	June 13	June 27	July 5	July 24	Aug15	Site avg
Bay Roc Marina	1-1-1	303	11	20	14	14	12	
	1-1-2	257	42	16	11	20	20	
	1-1-3	387	21	12	12	20	27	
	1-2-1	405	19	1	16	42	22	
	1-2-2	327	18	3	6	40	22	
	1-2-3	408	19	0	8	5	22	
Avg /site/date		348	22	9	11	24	21	72
Beaver Dam Creek	2-1-1	198	2	2	0	0	20	
	2-1-2	37	1	3	1	5	7	
	2-1-3	289	2	0	1	5	5	
	2-2-1	117	3	1	2	0	9	
	2-2-2	124	4	0	1	3	1	
	2-2-3	61	3	0	3	2	0	
Avg /site/date		138	3	1	1	3	7	25
Indian Point Marina	3-1-1	211	0	1	7	14	1	
	3-1-2	313	3	6	8	20	0	
	3-1-3	414	4	3	7	12	2	
	3-2-1	260	0	5	2	10	1	
	3-2-2	254	0	7	2	10	1	
	3-2-3	127	3	9	0	4	0	
Avg /site/date		263	2	5	4	12	1	48
SML Yacht Club	4-1-1	552	25	36	72	86	0	
	4-1-2	395	33	32	72	380	48	
	4-1-3	220	53	35	71	236	48	
	4-2-1	271	40	6	51	140	25	
	4-2-2	273	32	7	39	142	28	
	4-2-3	282	27	3	42	100	28	
Avg /site/date		332	35	20	58	181	30	109
Shoreline Marina	5-1-1	69	23	14	18	34	30	
	5-1-2	93	12	14	30	140	12	
	5-1-3	81	31	16	29	36	12	
	5-2-1	62	71	2	47	60	16	
	5-2-2	167	64	4	22	45	206	
	5-2-3	309	66	2	73	53	186	
Avg /site/date		130	45	9	37	61	77	60
Fairway Bay	6-1-1	254	15	3	6	26	217	
	6-1-2	180	7	0	7	20	8	
	6-1-3	110	13	5	7	18	3	
	6-2-1	114	6	9	1	16	8	
	6-2-2	106	12	11	2	28	2	
	6-2-3	100	13	5	3	42	2	
Avg /site/date		144	11	6	4	25	40	38
SML State Pk. Cove	7-1-1	14	6	0	1	4	2	
	7-1-2	22	1	1	1	2	0	
	7-1-3	37	3	0	0	0	1	
	7-2-1	19	2	0	5	6	2	
	7-2-2	13	0	0	2	0	1	
	7-2-3	10	1	0	0	0	0	
Avg /site/date		19	2	0	2	2	1	4

Table A9. 2000 Fecal coliform data (cfus) from Smith Mountain Lake (cont.).

Forest Cove	8-1-1	156	46	23	3	72	1	
	8-1-2	211	67	26	3	65	4	
	8-1-3	211	55	20	7	74	3	
	8-2-1	119	7	2	9	4	4	
	8-2-2	125	6	2	12	4	1	
	8-2-3	101	7	0	13	7	4	
Avg /site/date		154	31	12	8	38	3	41
SML Dock Cove	9-1-1	171	28	37	43	38	3	
	9-1-2	130	31	38	49	50	17	
	9-1-3	445	33	36	44	24	24	
	9-2-1	189	5	15	14	24	38	
	9-2-2	230	8	17	19	30	3	
	9-2-3	259	6	9	22	34	5	
Avg /site/date		237	19	25	32	33	15	60
Confluence	10-1-1	46	0	0	0	0	10	
	10-1-2	44	0	0	0	2	0	
	10-1-3	40	0	0	1	0	0	
	10-2-1	16	1	0	0	0	0	
	10-2-2	25	0	0	0	2	0	
	10-2-3	12	2	0	0	1	1	
Avg /site/date		31	1	0	0	1	2	6
Palmer's Trailer Pk.	11-1-1	117	15	46	8	14	0	
	11-1-2	89	22	48	7	18	8	
	11-1-3	109	13	47	4	22	12	
	11-2-1	137	14	57	10	26	11	
	11-2-2	119	32	58	9	20	12	
	11-2-3	134	22	40	14	16	7	
Avg /site/date		118	20	49	9	19	8	37
Pelican Point M.	12-1-1	34	2	0	3	9	6	
	12-1-2	16	2	0	4	16	5	
	12-1-3	12	5	0	5	17	4	
	12-2-1	22	0	1	1	5	0	
	12-2-2	27	2	1	3	7	1	
	12-2-3	14	0	0	4	10	0	
Avg /site/date		21	2	0	3	11	3	7
Foxport Marina	13-1-1	10	1	0	2	3	2	
	13-1-2	15	0	0	4	2	183	
	13-1-3	13	3	0	0	7	196	
	13-2-1	39	2	1	1	2	208	
	13-2-2	50	5	0	1	7	1	
	13-2-3	42	0	2	0	2	3	
Avg /site/date		28	2	1	1	4	99	22
Ponderosa Campgrd	14-1-1	341	3	2	30	10	1	
	14-1-2	212	5	2	15	40	n/a	
	14-1-3	235	2	3	0	10	n/a	
	14-2-1	531	8	0	4	14	n/a	
	14-2-2	305	3	2	3	10	n/a	
	14-2-3	88	5	0	15	8	n/a	
Avg /site/date		274	5	1	7	16		61
Avg per date		161	13	10	13	30	25	

Table A10. Fecal coliforms in Beaverdam Creek, November 2000.

Date	Sample Location	Bottle #	Time Elapsed	Time	(# colonies) cfu/100mL	Mean (cfus)
11/29/00	1	1	0.0 hrs	11:20AM	74	
11/29/00	1		0.0 hrs	11:20AM	78	76.00
11/29/00	1		0.0 hrs	11:20AM		
11/29/00	2	2	0.33 hrs	11:42AM	80	
11/29/00	2		0.33 hrs	11:42AM	99	89.50
11/29/00	2		0.33 hrs	11:42AM		
11/29/00	3	3	0.66 hrs	11:57AM	9	
11/29/00	3		0.66 hrs	11:57AM	8	8.50
11/29/00	3		0.66 hrs	11:57AM		
11/29/00	4	4	0.75 hrs	12:05PM	0	
11/29/00	4		0.75 hrs	12:05PM	10	5.00
11/29/00	4		0.75 hrs	12:05PM		
11/29/00	5	5	1.0 hrs	12:18PM	8	
11/29/00	5		1.0 hrs	12:18PM	2	5.00
11/29/00	5		1.0 hrs	12:18PM		
11/29/00	1	6	3.25 hrs	2:34PM	79	
11/29/00	1		3.25 hrs	2:34PM	54	66.50
11/29/00	1		3.25 hrs	2:34PM		
11/29/00	2	7	3.33 hrs	2:44PM	65	
11/29/00	2		3.33 hrs	2:44PM	41	53.00
11/29/00	2		3.33 hrs	2:44PM		
11/29/00	3	8	3.5 hrs	2:55PM	11	
11/29/00	3		3.5 hrs	2:55PM	7	9.00
11/29/00	3		3.5 hrs	2:55PM		
11/29/00	4	9	3.75 hrs	3:07PM	2	
11/29/00	4		3.75 hrs	3:07PM	1	1.50
11/29/00	4		3.75 hrs	3:07PM		
11/29/00	5	10	4.0 hrs	3:15PM	2	
11/29/00	5		4.0 hrs	3:15PM	5	3.50
11/29/00	5		4.0 hrs	3:15PM		
11/29/00	1	11	6:75 hrs	6:00PM	115	
11/29/00	1		6:75 hrs	6:00PM	116	115.50
11/29/00	1		6:75 hrs	6:00PM		
11/29/00	2	12	7.0 hrs	6:19PM	54	
11/29/00	2		7.0 hrs	6:19PM	65	59.50
11/29/00	2		7.0 hrs	6:19PM		
11/29/00	3	13	7.16 hrs	6:30PM	47	
11/29/00	3		7.16 hrs	6:30PM	53	
11/29/00	3		7.16 hrs	6:30PM		50.00
11/29/00	4	14	7.33 hrs	6:48PM	2	
11/29/00	4		7.33 hrs	6:48PM	1	
11/29/00	4		7.33 hrs	6:48PM		1.50
11/29/00	5	15	7.5 hrs	6:56PM	2	
11/29/00	5		7.5 hrs	6:56PM	1	
11/29/00	5		7.5 hrs	6:56PM		1.50

Table A10. Fecal coliforms in Beaverdam Creek, November 2000. (cont.).

11/30/00	1	16	21.0 hrs	8:19AM	193	
11/30/00	1		21.0 hrs	8:19AM	170	
11/30/00	1		21.0 hrs	8:19AM		181.50
11/30/00	2	17	21.16 hrs	8:29AM	62	
11/30/00	2		21.16 hrs	8:29AM	37	
11/30/00	2		21.16 hrs	8:29AM		49.50
11/30/00	3	18	21.33 hrs	8:41AM	35	
11/30/00	3		21.33 hrs	8:41AM	18	
11/30/00	3		21.33 hrs	8:41AM		26.50
11/30/00	4	19	21.5 hrs	8:52AM	15	
11/30/00	4		21.5 hrs	8:52AM	43	
11/30/00	4		21.5 hrs	8:52AM		29.00
11/30/00	5	20	21.66 hrs	9:02AM	31	
11/30/00	5		21.66 hrs	9:02AM	29	
11/30/00	5		21.66 hrs	9:02AM		30.00
11/30/00	1	21	26.66 hrs	1:58PM	55	
11/30/00	1		26.66 hrs	1:58PM	55	
11/30/00	1		26.66 hrs	1:58PM		55.00
11/30/00	2	22	26.83 hrs	2:10PM	39	
11/30/00	2		26.83 hrs	2:10PM	40	
11/30/00	2		26.83 hrs	2:10PM		39.50
11/30/00	3	23	27.0 hrs	2:22PM	9	
11/30/00	3		27.0 hrs	2:22PM	14	
11/30/00	3		27.0 hrs	2:22PM		11.50
11/30/00	4	24	27.25 hrs	2:35PM	21	
11/30/00	4		27.25 hrs	2:35PM	37	
11/30/00	4		27.25 hrs	2:35PM		29.00
11/30/00	5	25	27.33 hrs	2:41PM	0	
11/30/00	5		27.33 hrs	2:41PM	0	
11/30/00	5		27.33 hrs	2:41PM		0.00
11/30/00	1	26	29.16 hrs	4:30PM	19	
11/30/00	1		29.16 hrs	4:30PM	23	
11/30/00	1		29.16 hrs	4:30PM		21.00
11/30/00	2	27	29:33 hrs	4:38PM	26	
11/30/00	2		29:33 hrs	4:38PM	21	
11/30/00	2		29:33 hrs	4:38PM		23.50
11/30/00	3	28	29:50 hrs	4:47PM	8	
11/30/00	3		29:50 hrs	4:47PM	6	
11/30/00	3		29:50 hrs	4:47PM		7.00
11/30/00	4	29	29:66 hrs	5:01PM	3	
11/30/00	4		29:66 hrs	5:01PM	14	
11/30/00	4		29:66 hrs	5:01PM		8.50
11/30/00	5	30	29:83 hrs	5:08PM	4	
11/30/00	5		29:83 hrs	5:08PM	1	

Table A10. Fecal coliforms in Beaverdam Creek, November 2000.

11/30/00	5		29:83 hrs	5:08PM		2.50
12/1/00	1	31	46.16 hrs	9:30AM	23	
12/1/00	1		46.16 hrs	9:30AM	65	
12/1/00	1		46.16 hrs	9:30AM		44.00
12/1/00	2	32	46:33 hrs	9:41AM	46	
12/1/00	2		46:33 hrs	9:41AM	14	
12/1/00	2		46:33 hrs	9:41AM		30.00
12/1/00	3	33	46.5 hrs	9:48AM	20	
12/1/00	3		46.5 hrs	9:48AM	13	
12/1/00	3		46.5 hrs	9:48AM		16.50
12/1/00	4	34	46.66 hrs	10:01AM	8	
12/1/00	4		46.66 hrs	10:01AM	5	
12/1/00	4		46.66 hrs	10:01AM		6.50
12/1/00	5	35	46.83 hrs	10:07AM	11	
12/1/00	5		46.83 hrs	10:07AM	12	
12/1/00	5		46.83 hrs	10:07AM		11.50

3/3/01	1			90 days	54	
3/3/01	1			90 days	48	
3/3/01	1			90 days	50	50.67
3/3/01	2			90 days	67	
3/3/01	2			90 days	76	
3/3/01	2			90 days	71	71.33
3/3/01	3			90 days	3	
3/3/01	3			90 days	5	
3/3/01	3			90 days	9	5.67
3/3/01	4			90 days	1	
3/3/01	4			90 days	0	
3/3/01	4			90 days	1	0.67
3/3/01	5			90 days	0	
3/3/01	5			90 days	1	
3/3/01	5			90 days	0	0.33

Table A11. Intensive cove fecal coliform sample means, 2000.

Hrs elapsed	mean	StDev	#samples
0	7	10	48
2	10	14	48
4			
6	11	12	36
8	8	10	48
10	15	20	48
12	12	15	48
14	10	15	48
16	13	19	48
18	7	7	48
20	4	5	48
22	11	25	48
24	8	10	48
26	15	39	48
28	4	9	48
30	5	10	48
32	4	6	48
35	5	7	48
38	5	8	48
40	3	5	48
42	3	4	48

site	#samples	site	Mean	StDev
site 1	126	site 1	3.809524	3.943023
site 2	120	site 2	2.983333	2.907491
site 3	120	site 3	11.625	14.47168
site 4	120	site 4	31.30833	28.96036
site 5	120	site 5	6.575	5.18184
site 6	121	site 6	2.575	2.639326

Depth	Mean	STDev	# samples
Surface	10.6338	18.25769	426
1 m	27.53333	23.42566	60
2 m	3.078431	2.890281	51
3 m	3.85	4.291187	120
4 m	4.166667	3.49124	84
5 m	1.162162	1.552362	111
10 m	2.35	5.065085	60
14 m	2.716667	4.647185	60