Smith Mountain Lake Association Water Quality Monitoring Program

1995 Report

Carolyn L. Thomas and David M. Johnson
Ferrum College
Ferrum, Virginia 24088

In Cooperation with
The Smith Mountain Lake Association
Moneta, Virginia 24121
December 1995

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Rt. 2, Box 13B
Moneta, VA 24121
(540) 297-4146

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1. EXECUTIVE SUMMARY

The Smith Mountain Lake Water Quality Monitoring Program (SMLWQMP) is a water quality program initiated in 1987. The program is cooperatively administered by the Smith Mountain Lake Association (SMLA) and scientists from Ferrum College and is designed to monitor the trophic status of Smith Mountain Lake. On May 27, an organizing and training session was conducted by Ferrum College and the SMLA. Monitors collected samples weekly from the first week of June to the third week of August. This year the average total phosphorus concentration averaged 45.2 ppb, up considerably from the 1994 average of 28.6 ppb but similar to the 1993 average of 42.7 ppb. The reason for this increase is probably the heavy rains and flooding that occurred in June. The average chlorophyll-*a* concentration was 19.6 ppb, similar to the levels observed for the preceding two years. (Values for chlorophyll-*a* were calculated incorrectly. See Appendix Table A2a for corrected values. Corrected average value; CHA = 3.0 ppb.) The average Secchi depth declined slightly this year back to the 1992 average of 2.0 meters after averaging 2.3 meters in both 1993 and 1994. The Carlson Trophic State Index is calculated using the three parameters monitored and can range from 1 to 100, with values over 50 indicating eutrophic status. Values for the Combined Trophic Status Index (TSI) for Smith Mountain Lake are given below:

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

This year, the Carlson Trophic State Index was plotted against time and the regression line indicates an average increase of nearly a unit and a half (1.43) per year, a trend that cannot continue if the resource is to be sustained. When the average value of each water quality parameter is correlated with distance from the dam, the trends observed are the same as for past years and typical of a mountain reservoir; water clarity decreases while both nutrient concentration and algal biomass increase in the upper channels of the lake.

Phase II of the program began this year. The objectives of the new phase are to locate sampling locations in a manner that maximizes the information obtained from the monitoring program and to begin evaluating tributary loading to the lake. To begin evaluating tributary loading of nutrients to the lake twenty sampling sites were selected and technicians collected grab samples each week. The addition of tributary sites expanded the scope of the monitoring project and will provide information on the relative contribution of different tributaries to nutrient loading to the lake. The loading of phosphorus from tributaries is apparent with the tributary concentration (109.4 ppb) averaging nearly 250% higher than the lake average. After the week of heaviest precipitation the tributary concentration averaged slightly less than 300 ppb and was well over 1000 ppb in two of the Blackwater tributaries. Phosphorus levels in the lake reflect this loading with weekly averages doubling from the first week to the sixth week followed by a gradual decline during the dry summer that followed.

A study of fecal coliform bacteria at eight sites was also carried out with funding from the SMLA and the Smith Mountain Lake Policy Advisory Board. Although the study was limited in scale and scope, fecal coliform numbers were found to vary considerably with time and location. In this particular study it appears that coves with marinas have higher fecal coliform counts than coves without marinas, although this was not the case in every instance.

The introduction of GIS capabilities for displaying results and managing information adds a new dimension to the program and prepares us for the future. Using the developing tributary database and GIS-based modeling, it will be possible to evaluate soil loss in the lake watershed and identify areas of the watershed contributing disproportionately to nutrient and silt loading in the lake.

Water quality in Smith Mountain Lake is cause for concern. After last year's decline, phosphorus levels were higher than ever this year, average chlorophyll-*a* concentration remains high, and the average Secchi depth declined slightly. However, local agencies continue to increase their efforts and cooperation among local jurisdictions is growing. The Natural Resource Conservation Service (NRCS) Office in Franklin County is working with farmers to improve conservation practices and the Blue Ridge Soil and Water Conservation District has received funding for a second demonstration project in the Blackwater watershed. Comprehensive planning for Smith Mountain Lake has begun, involving officials from Franklin, Bedford, Pittsylvania, and Roanoke Counties. While nutrient enrichment in Smith Mountain Lake continues to be a problem, it is a problem now recognized and being addressed.

2. INTRODUCTION

The Smith Mountain Lake Water Quality Monitoring Program (SMLWQMP) is a program designed to monitor the water quality of Smith Mountain Lake located in Southwestern Virginia. Measuring total phosphorus, chlorophyll-*a* and Secchi depth is used to monitor the trophic status of the lake. Samples are collected once a week from Memorial Day to Labor Day. The program is cooperatively administered by scientists from Ferrum College and the Smith Mountain Lake Association (SMLA), a lake resident citizen's association. This document reports on the 1995 monitoring season, the ninth year of the program. The Virginia Environmental Endowment (VEE) provided primary funding for the project during the first three years and the report submitted to the VEE describes the development of the project from 1987-1990 (Johnson and Thomas, 1990). Monitoring results from 1990 to 1994 can be found in reports by Drs. Thomas and Johnson (December 1991, 1992, 1993, and 1994).

This year’s training session was held on May 27 and lead by the Ferrum College scientists and the SMLA Volunteer Monitoring Coordinator with assistance from the student technicians. Tracy Rakes returned this year as student manager and Casey Magruder and Maggie Murphy worked as technicians. The training session was held at the Bethlehem United Methodist Church in Moneta and was attended by 41 members including experienced monitors and many new volunteer monitors. The program included a review of the previous year's findings and planning the schedule for the upcoming year. Experienced monitors located sampling sites (some sites were new some were the same as the previous year) on the map of Smith Mountain Lake, received new supplies (sample bottles and filters), and had their monitoring equipment checked. New volunteer monitors were assigned sample sites, led through the sampling procedures and issued sampling equipment and supplies. Monitoring began the week of May 28 and the first samples were picked up on Tuesday, June 6. Samples were picked up and new supplies issued each Tuesday for twelve weeks until the third week of August.

Phase II of the program began this year. The objectives of the new phase are to locate sampling locations in a manner that maximizes the information obtained from the monitoring program and to begin evaluating tributary loading to the lake. The channel sampling sites have been separated from sampling sites in coves and the sites relabeled to reflect this separation. The new sample site identification labels are based on:

(1) The main tributary location of the site (i.e. Blackwater would have "B" in the site label)

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

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

An attempt was made to locate sampling sites 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. The sampling sites in the channels and main basin (that portion of Smith Mountain Lake between the dam and the confluence of the Roanoke and Blackwater Channels) will, as a group, be used to evaluate the overall trend in Smith Mountain Lake water quality. These sites were deliberately located away from the shoreline to avoid localized influences on water quality. The sites begin at the dam and extend to the Hardy Ford Bridge (Route 634) on the Roanoke channel and extend to the Route 834 Bridge on the Blackwater channel. The channel and basin sites, as a group, are referred to as the trend stations. The cove sampling sites are also important for trend analysis and help fulfill the role of "watchdogs". In this role, as much of the lake as possible is monitored for signs of localized deterioration of water quality associated with site-specific problems such as malfunctioning septic systems. To begin evaluating tributary loading of nutrients to the lake, twenty sampling sites were selected at locations where a road crosses a tributary and the technicians collected grab samples on their weekly trips to pick up samples.

Newsletters were written and distributed to monitors and SMLA officers 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 or tips on more efficient sample collection. Two newsletters were written in 1995. In September, Sue and Bob Halstead hosted the annual end-of-the-season meeting and social event. At these combination picnic/business meetings, the co-directors of the program from Ferrum College gave reports on the results of the sample collection and analyses and the monitoring program coordinator of SMLA made a presentation on the program and plans for the coming year.

Results of the 1995 monitoring season are discussed in the following sections.

3. METHODS

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

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

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

4. RESULTS

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

The three water quality parameters monitored on Smith Mountain Lake are water turbidity, total phosphorus and chlorophyll-*a*. In 1995 the average values for all lake samples were:

Total phosphorus	45.20 ± 26.00 ppb (50 sample sites)
Chlorophyll-*a*	19.63 ± 13.65 ppb (50 sample sites) (Corrected average value; CHA = 3.0 ppb, see App. Table A2a)
Secchi depth	2.03 ± 0.69 meters (85 sample sites)

When these three water quality parameters are evaluated based on the means for each station and correlated with miles to the dam, trends are exhibited which would be considered typical of a reservoir. The upper reaches of the tributaries are more riverine in water quality and the lower reaches closer to the Smith Mountain Lake Dam exhibit more lacustrine water quality**.**

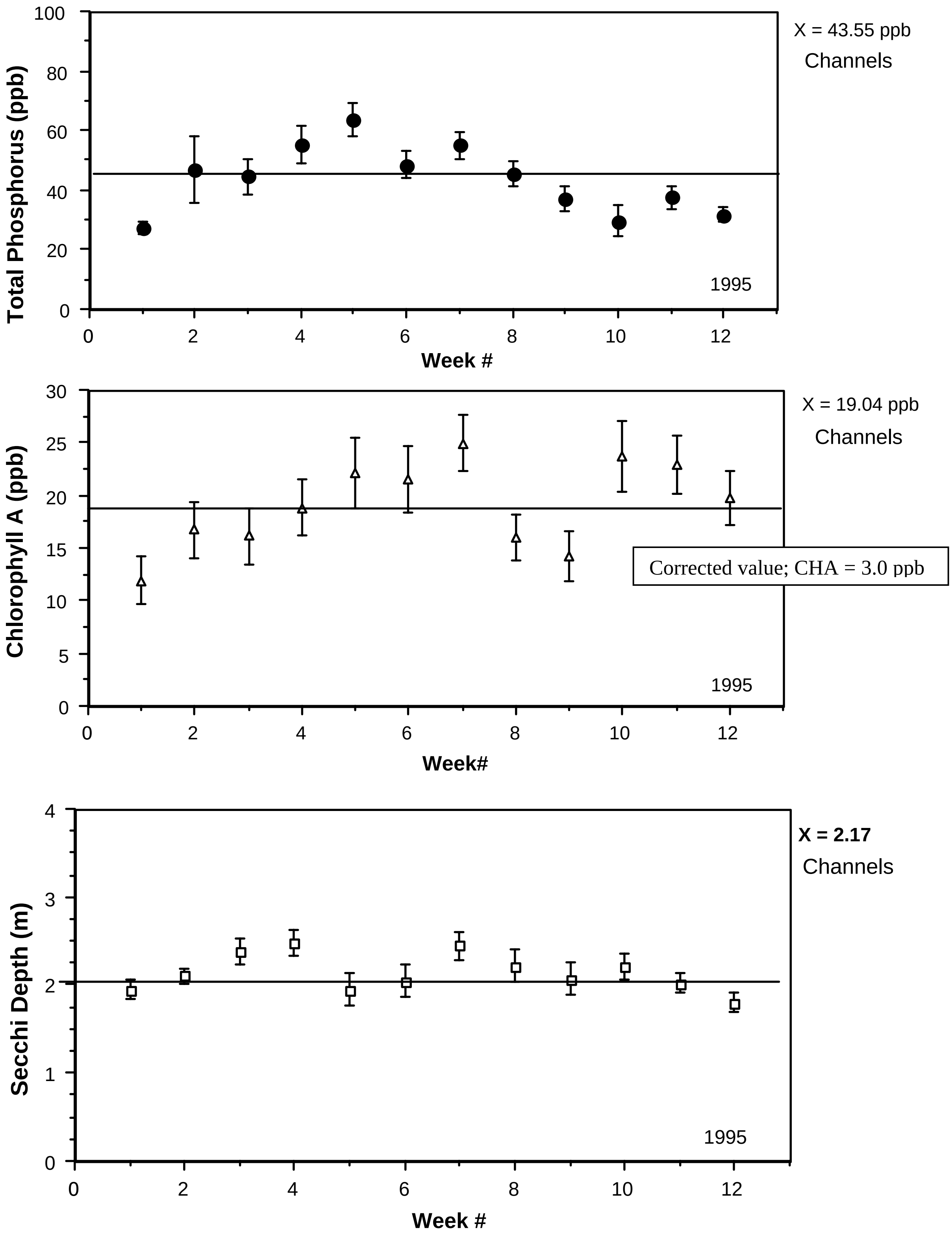
4.1 Results for Channel, Cove, and Tributary Site Samples

4.1.1 Channel Sites

Weekly averages for samples collected from the 30 channel sites in Smith Mountain Lake are shown in figure 1. The lowest total phosphorus concentrations occurred in Week 1 and Week 10 and the highest concentration occurred in Week 5**.** The average chlorophyll-*a* concentration for the channel sites exhibited the lowest algal population during Week 1 and the highest population in Week 7. Secchi depth values for the channel sample sites (85 sites) exhibited the highest mean during Week 4 and the lowest Secchi depth was observed in Week 12. Total phosphorus concentration (TP) in the channels decreased as miles to the dam decreased indicating less nutrient enriched water toward the main basin (Figure 2). The highest average total phosphorus concentration found in the channels of the lake (96.0 ppb) was measured at a station on the Blackwater Channel 22 miles from the dam and second highest in the lake (94.7 ppb) was at a station 31 miles from the dam up the Roanoke Channel of Smith Mountain Lake. The lowest total phosphorus value found at a channel site (TP = 17.86 ppb) was measured at a station approximately 1 mile from the dam. The decrease in the total phosphorus concentrations in the channels was significantly correlated with decreasing distance to the dam ($R^2 = 0.720$).

The chlorophyll-*a* concentration (CHA) in the channels decreased with distance to the dam indicating less algal growth as the larger expanse of water is approached (Figure 2). The highest average chlorophyll-*a* concentrations in the channels (40.97 ppb) were measured at a station approximately 22 river miles from the dam on the Blackwater Channel of the lake. The lowest average chlorophyll-*a* concentration in the channels (1.43 ppb) occurred at the station closest to the dam. The decrease in the chlorophyll-*a* concentrations in the channels was significantly correlated with the decreasing miles to the dam ($R^2 = 0.609$).

The Secchi depth values in the channels (Figure 2) increased as miles to the Dam decreased indicating better water clarity closer to the dam and in the larger expanse of water. The channel station averaging the lowest water clarity as measured by Secchi depth was located 22 river miles from the Dam in the Blackwater Channel of the lake (1.11 m), and 23 miles from the dam in the Roanoke Channel (1.33 m). The highest water clarity, indicated by average Secchi depth of occurred at a channel station 1 mile from the dam (3.25 m). All of the stations with mean Secchi depth readings greater than 3.0 m were within three miles of the Smith Mountain Lake Dam. The increase in the Secchi Depth was significantly correlated with the decreasing miles to the dam ($R^2 = 0.902$).



Corrected value; CHA = 3.0 ppb

Figure 1. **1995 Data for channel samples averaged by week.**
(x = average value)

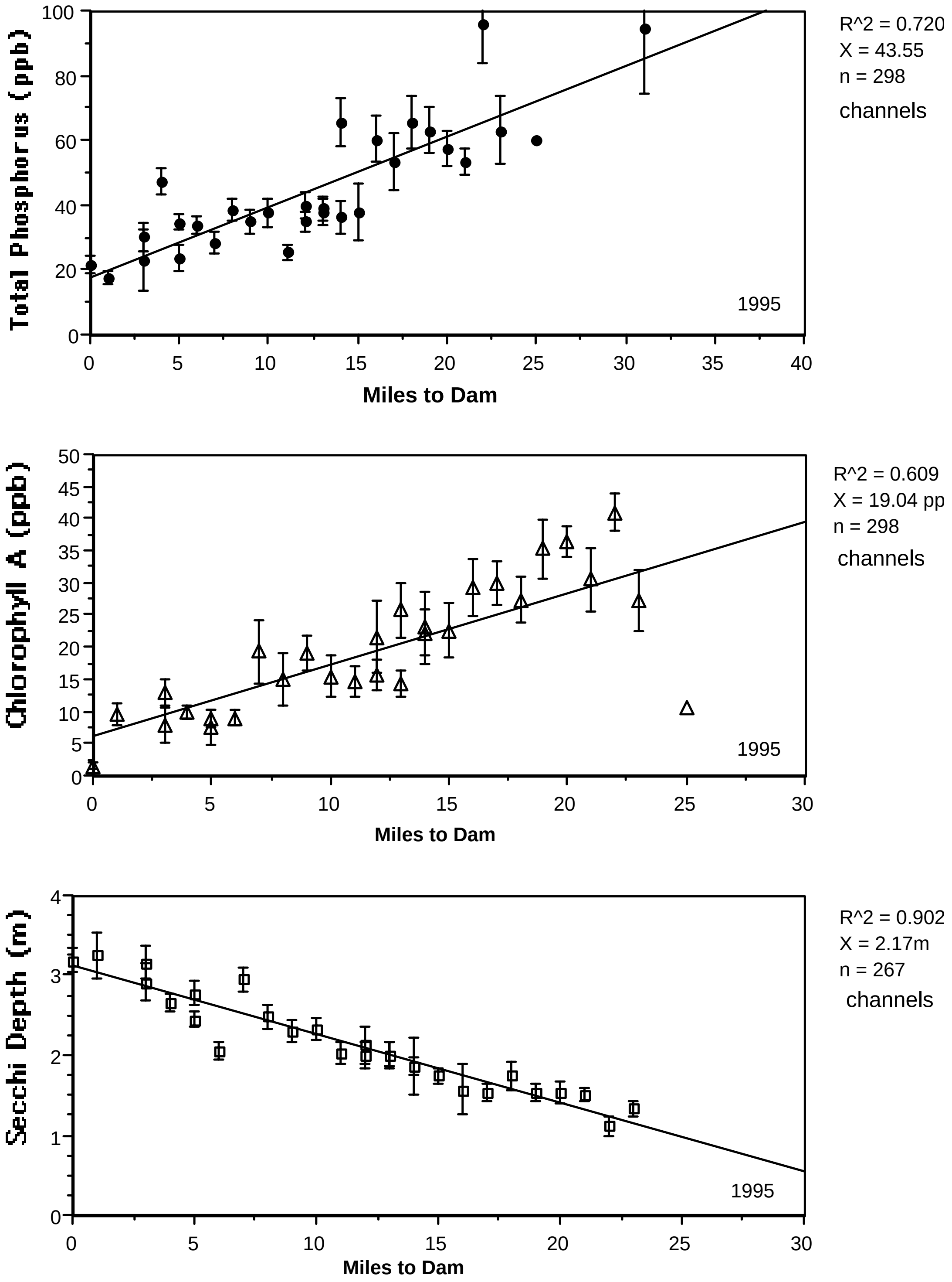


Figure 2. **1995 Channel sample site averages versus distance to the SML Dam.** (x = average value)

4.1.2 Cove Sites

The cove sample sites (20 sites) exhibited the lowest phosphorus concentration in Week 9, the week before the low value occurred in the channel, while exhibiting the highest concentration in Week 3, two weeks prior to the highest channel average (Figure 3). The cove sample sites exhibited the lowest algal population during Week 3 and the highest population during Week 10. Secchi depth averages in the cove sites were highest in Week 4 and the lowest in Week 6.

The total phosphorus concentration (TP) in the coves decreased as miles to the dam decreased indicating less nutrient enriched water toward the main basin (Figure 4). The highest total phosphorus concentration found in the coves of the lake (83.0 ppb) was measured at a cove station 23 miles from the dam at Smith Mountain Lake. The lowest total phosphorus value found at a cove site (24.0 ppb) was measured at a station approximately 1 mile from the dam. The decrease in the total phosphorus concentrations in the coves was significantly correlated with the decreasing miles to the dam ($R^2 = 0.853$).

The chlorophyll-*a* concentration (CHA) in the coves decreased as miles to the dam decreased indicating less algal growth as the larger expanse of water is approached (Figure 4). The highest average chlorophyll-*a* concentrations in the coves (35.2 ppb) were measured at two stations approximately 20 and 24 river miles from the dam. The lowest average chlorophyll-*a* concentration in the coves (2.3 ppb) occurred at the station closest to the dam. The decrease in the chlorophyll-*a* concentrations in the coves was significantly correlated with the decreasing miles to the dam ($R^2 = 0.875$).

The Secchi depth values in the coves (Figure 4) increased as miles to the dam decreased indicating better water clarity closer to the dam and in the larger expanse of water. The cove station with the lowest average water clarity as measured by Secchi depth was located 22 river miles from the dam (1.3 m). The highest water clarity occurred at a cove station 1 mile from the dam (3.20 m). All of the stations with mean Secchi depth readings greater than 3 meters were within three miles of the Smith Mountain Lake Dam. The increase in the Secchi depth was significantly correlated with the decreasing miles to the dam ($R^2 = 0.898$).

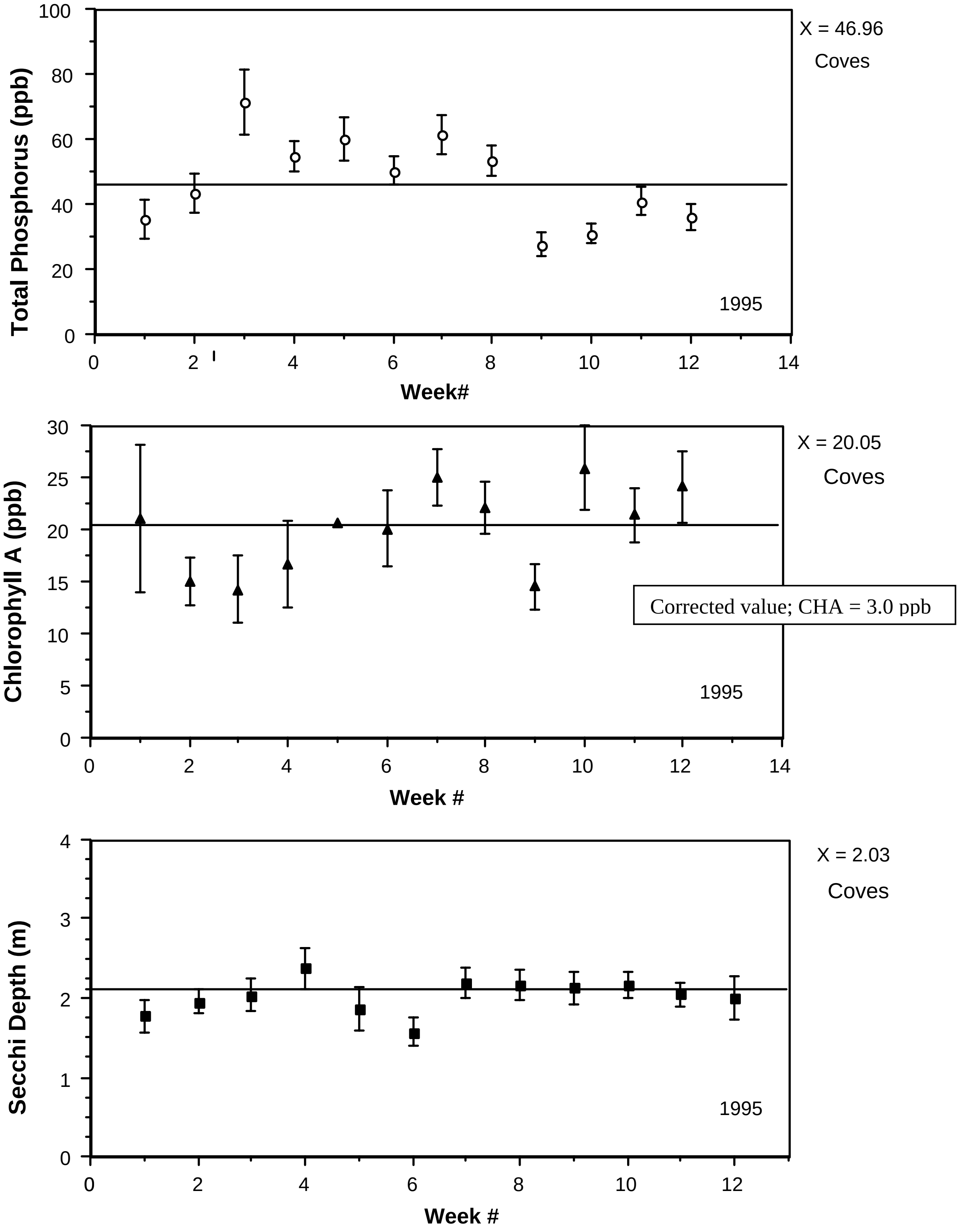


Figure 3. **1995 Data for cove sample sites averaged by week.**
(x = average value)

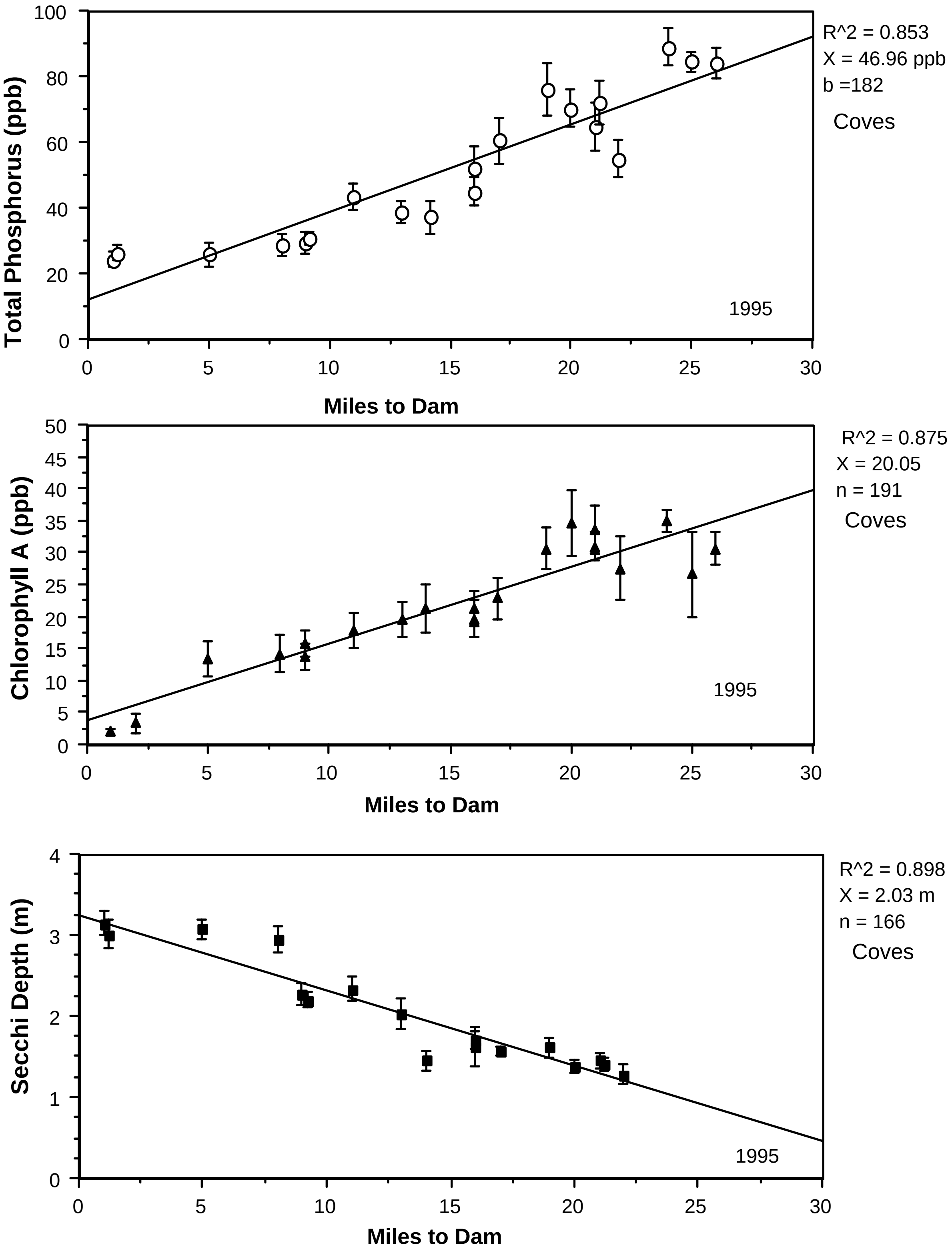


Figure 4. **1995 Cove sample averages vs. distance to the SML Dam.**
(x = average value)

4.1.3 Tributary Sites

Twenty lake tributaries were sampled each week and analyzed for total phosphorus. The tributary sample sites exhibited (Figure 5) the lowest average total phosphorus concentration in Week 9, which was the same week that the coves exhibited the lowest average total phosphorus concentration. The tributary sites exhibited the highest average total phosphorus concentration during the sixth week of the summer of 1995. The grand mean for total phosphorus in the 480 lake samples was 45.20 ± 26.00 ppb and the grand mean for total phosphorus in the 219 tributary samples was 109.31 ± 65.21 ppb.

The Roanoke Channel tributaries (9 sites) include the creek on Summit Drive, Snug Harbor Creek, Stoney Creek, Jumping Run Creek, Beaverdam Creek, Roanoke River at Bay Roc Marina, Lynville Creek, Grimes Creek, and Indian Creek. The Blackwater Channel tributaries (8 sites) include Maggodee Creek, Gills Creek, Blackwater River at SR 834, Poplar Camp Creek, Standiford Creek, Bull Run Creek, Cool Branch, and the creek at Lumpkin's Marina.

In the tributary sample sites Maggodee Creek exhibited the highest mean concentration of Total Phosphorus of all the tributaries (274.0 ppb) and Cool Branch Creek exhibited the lowest mean Total Phosphorus concentration (46.3 ppb) as shown in Figure 6. Both of these are tributaries of the Blackwater Channel of Smith Mountain Lake.

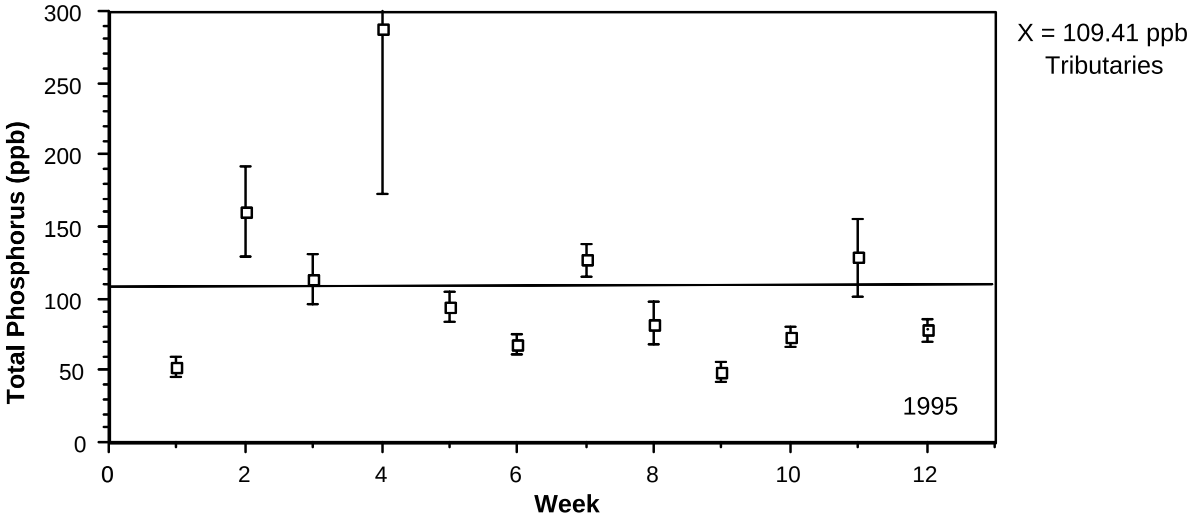


Figure 5. 1995 Data for tributary samples averaged by week.
(x = average value)

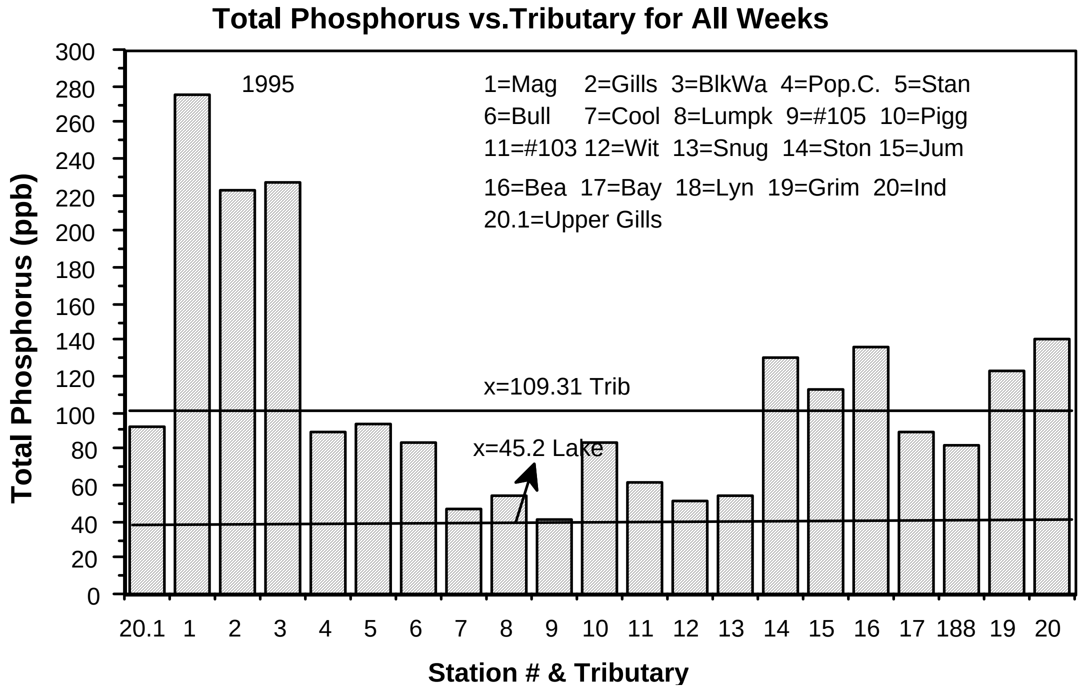


Figure 6. **1995 Average total phosphorus concentration for each tributary.** (x = average value)

4.2 Comparison of Roanoke Channel, Blackwater Channel, and Main Basin

The highest total phosphorus value in the Roanoke Channel tributaries was observed in Week 2, with the lowest mean values found in weeks 1 and 9. The mean value for all Roanoke tributaries for all weeks was 102.2 ± 34.1 ppb.

In the Blackwater Channel tributaries the highest total phosphorus was found in Week 4 (TP = 607.2 ± 713.2 ppb), with the lowest mean value observed in Weeks 1 and 9. The mean value for all Blackwater tributaries for all weeks was 95.8 ± 89.6 ppb.

4.2.1 Roanoke Channel

The weekly averages of total phosphorus for the Roanoke Channel stations (25 sites) are displayed in Figure 7. The highest values were exhibited during Week 5 (71.1 ppb) and the lowest total phosphorus concentration during Week 9 (29.5 ppb) with overall mean total phosphorus of 53.2 ppb for a total of 236 samples. The chlorophyll-*a* concentrations found in the Roanoke channel weekly exhibited similar fluctuations with the highest chlorophyll-*a* values in Week 10 (31.4 ppb) and the lowest value for chlorophyll-*a* in Week 9 (16 ppb). The overall mean of chlorophyll-*a* samples for the Roanoke Channel was 23.9 ppb for 236 total samples and 25 sample sites (Corrected value; CHA = 3.6 ppb). The Secchi depth observations indicated the best water clarity in Week 10 and the worst water clarity during Week 6. The overall mean of Secchi depth values for the Roanoke Channel was 1.8 m.

The total phosphorus concentration (TP) in the Roanoke Channel decreased as miles to the dam decreased indicating less nutrient enriched water toward the main basin (Figure 8). The highest total phosphorus concentration found in the Roanoke Channel of the lake (TP = 95.0 ppb) was measured at a Roanoke Channel station 31 miles from the dam at Smith Mountain Lake. The lowest total phosphorus value found at a Roanoke Channel site (TP = 24.0 ppb) was measured at a station approximately 11 miles from the dam. The decrease in the total phosphorus concentrations in the coves was significantly correlated with the decreasing miles to the dam ($R^2 = 0.840$).

The chlorophyll-*a* concentration (CHA) in the Roanoke Channel decreased with distance to the dam indicating less algal growth as the larger expanse of water is approached (Figure 8). The highest average chlorophyll-*a* concentration in the Roanoke Channel (35.2 ppb) was measured at a station approximately 19 river miles from the dam. The lowest average chlorophyll-*a* concentration in the Roanoke Channel (11.2 ppb) occurred at a station 9 miles to the dam.

The Secchi depth values in the Roanoke Channel (Figure 8) increased as miles to the dam decreased indicating better water clarity closer to the dam and in the larger expanse of water. The Roanoke Channel station averaging the lowest water clarity as measured by Secchi depth (1.1 m) was located 14 river miles from the Dam The highest water clarity, indicated by an average Secchi depth of 3.0 m, occurred at two Roanoke Channel stations 6 and 7 miles from the dam. The increase in the Secchi Depth was significantly correlated with the decreasing miles to the dam ($R^2 = 0.784$).

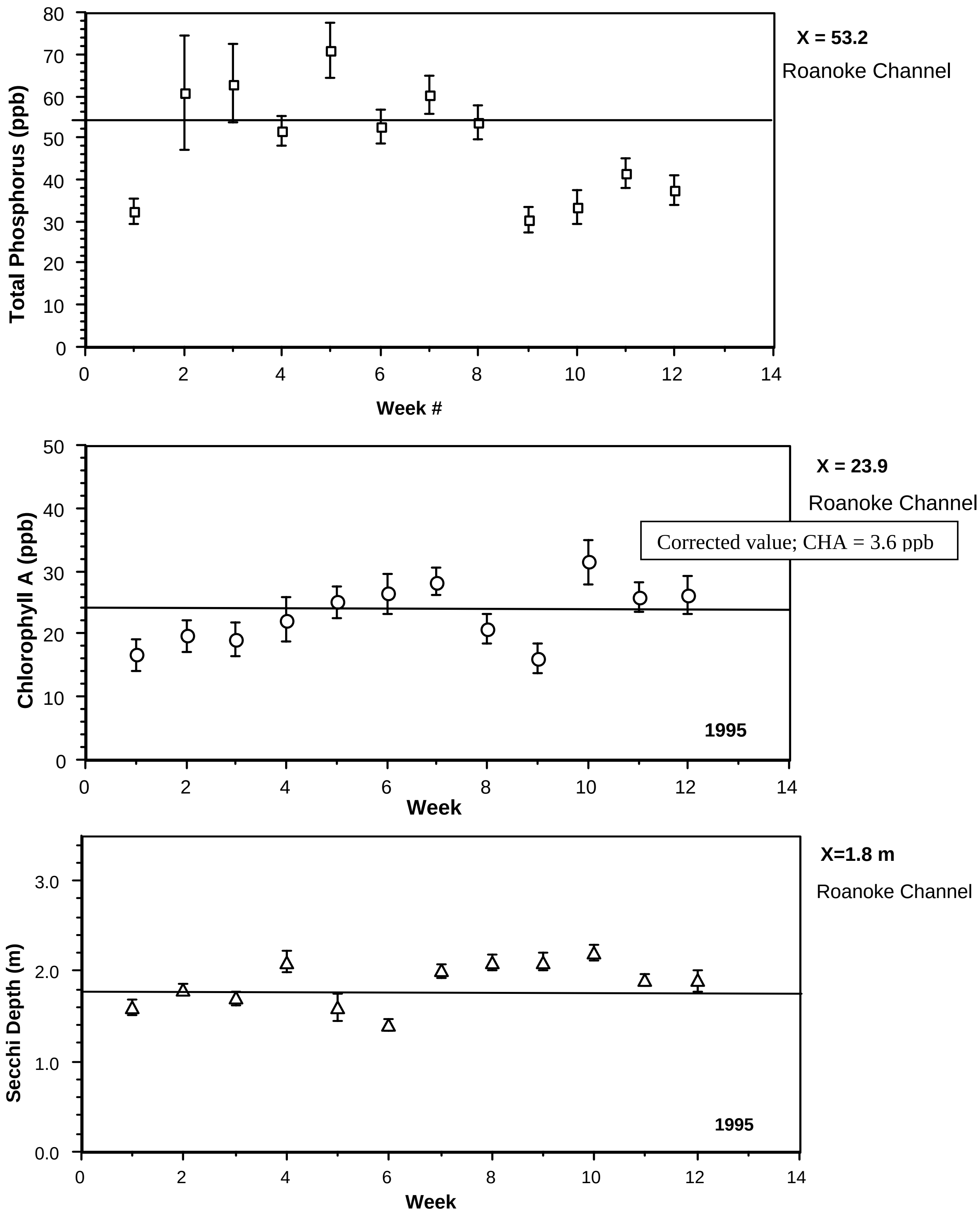


Figure 7. **1995 Data for Roanoke Channel sample sites averaged by week.**
(x = average value)

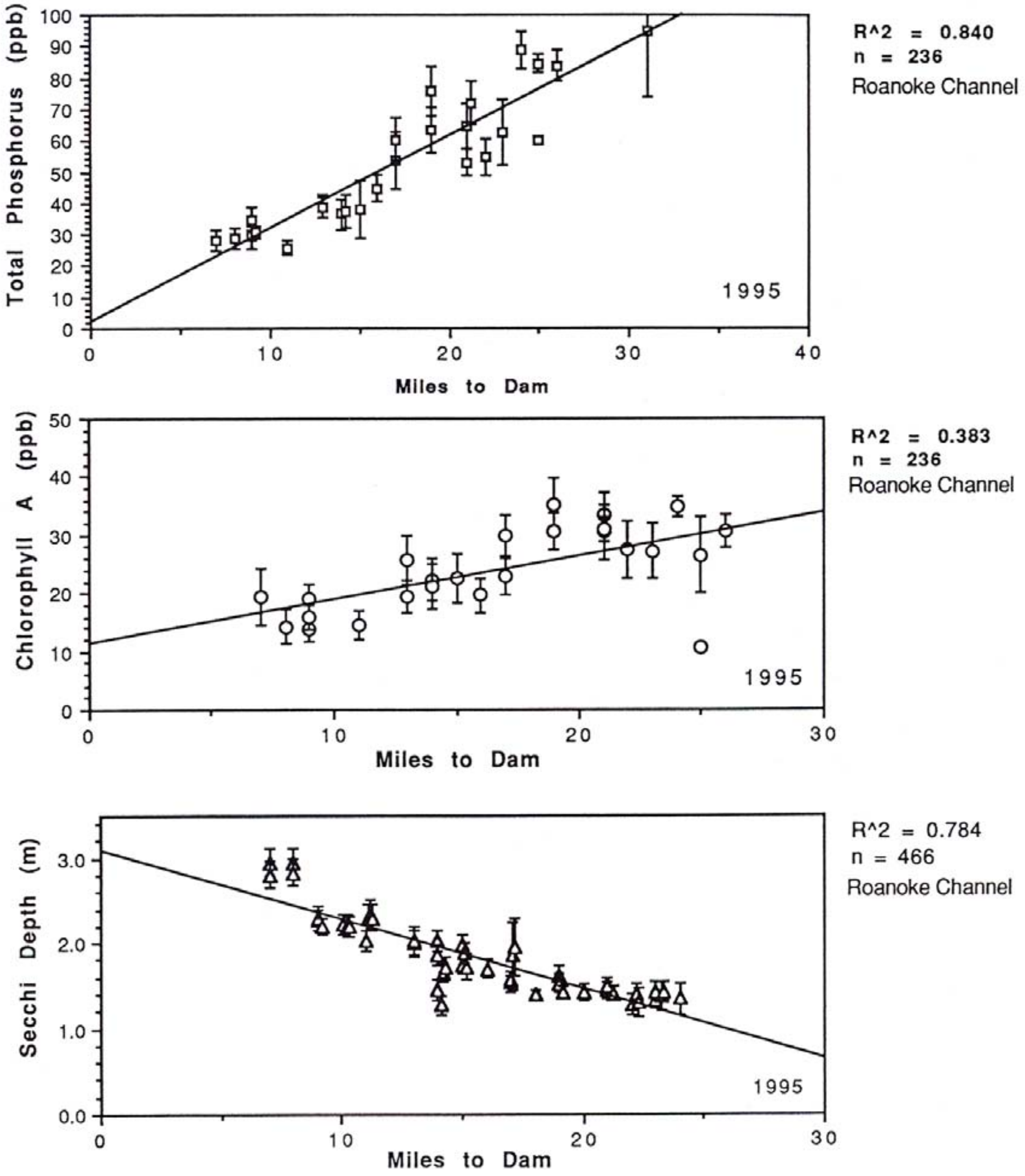


Figure 8. **Roanoke Channel sample site averages versus miles to SML Dam.**

4.2.2 Blackwater Channel

The weekly average for total phosphorus in the Blackwater Channel stations (11 sites) exhibited the highest values during Week 5 (71.1 ppb) and the lowest total phosphorus concentration during Week 12 (35.0 ppb) with overall mean total phosphorus of 56.5 ppb for a total of 113 samples (Figure 9). The chlorophyll-*a* concentrations found in the Blackwater Channel weekly exhibited similar fluctuations with the highest chlorophyll-*a* values in Week 7 (38.4 ppb) and the lowest value for chlorophyll-*a* in Week 3 (20.0 ppb). The overall mean of chlorophyll-*a* samples for the Blackwater Channel was 26.2 ppb for 113 total samples and 11 sample sites (Corrected value; CHA = 3.9 ppb). The Secchi depth observations indicated the best water clarity in Week 3 and the worst water clarity during Week 6. The overall mean of Secchi depth values for the Blackwater Channel was 1.9 m.

The total phosphorus (TP) concentration in the Blackwater Channel decreased as miles to the dam decreased indicating less nutrient enriched water toward the main basin (Figure 10). The highest total phosphorus concentration found in the Blackwater channel of the lake (98.0 ppb) was measured at a Blackwater Channel station 22 miles from the dam at Smith Mountain Lake. The lowest total phosphorus value found at a Blackwater Channel site (33.3 ppb) was measured at a station approximately 11 miles from the dam. The decrease in the total phosphorus concentrations in the coves was significantly correlated with the decreasing miles to the dam ($R^2 = 0.724$).

The chlorophyll-*a* concentration (CHA) in the Blackwater Channel decreased as miles to the dam decreased indicating less alga growth as the larger expanse of water is approached (Figure 10). The highest average chlorophyll-*a* concentrations in the Blackwater Channel (40.3 ppb) were measured at a station approximately 22 river miles from the dam. The lowest average chlorophyll-*a* concentration in the Blackwater Channel (14.1 ppb) occurred at a station 9 miles from the dam.

The Secchi depth values in the Blackwater Channel (Figure 10) increased as miles to the dam decreased indicating better water clarity closer to the dam and in the larger expanse of water. The Blackwater Channel station averaging the lowest water clarity as measured by Secchi depth (1.1 m) was located 22 river miles from the dam. The highest water clarity occurred at a Blackwater Channel station 7 miles from the dam (2.4). The increase in the Secchi depth was significantly correlated with the decreasing miles to the dam ($R^2 = 0.907$).

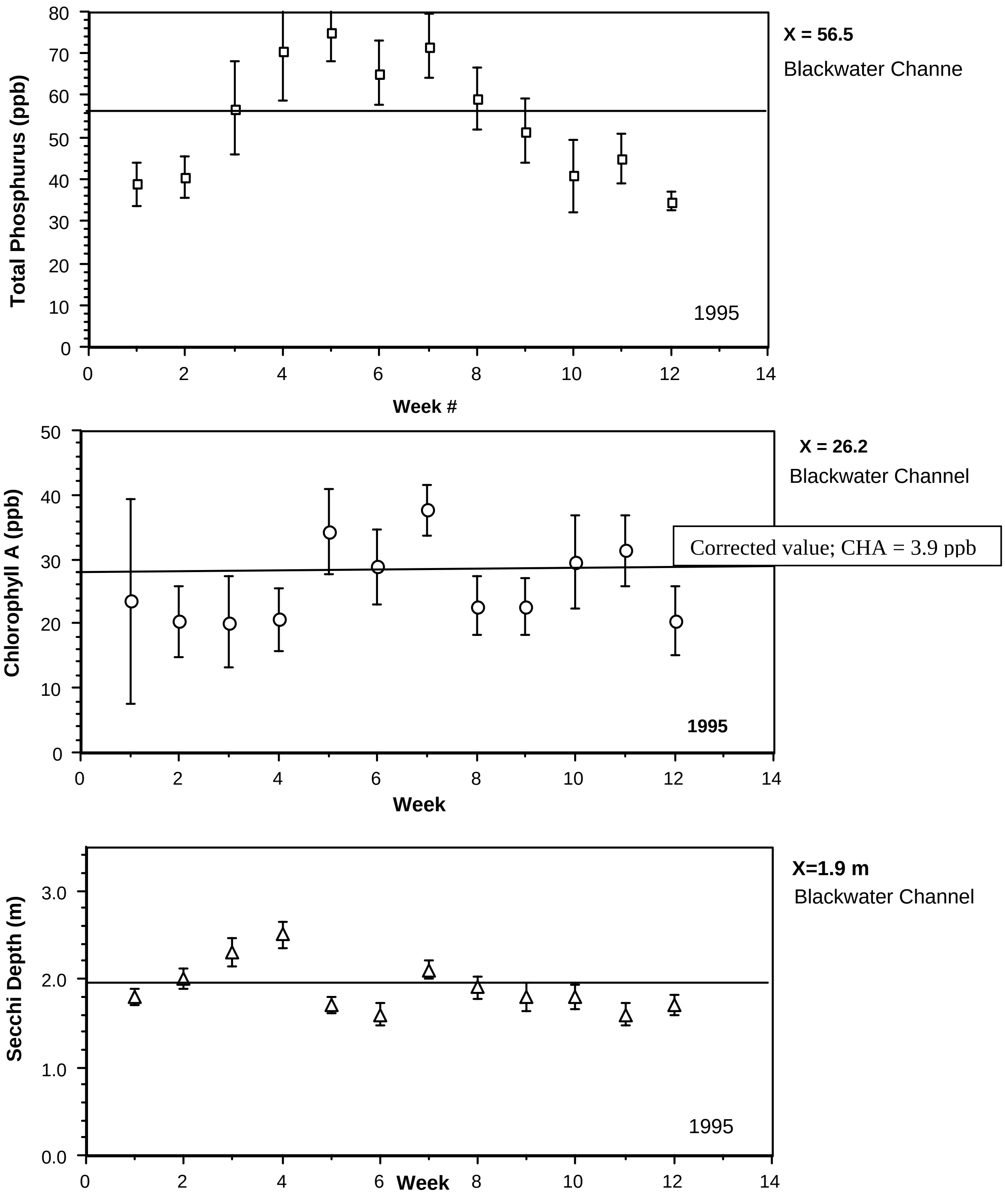


Figure 9. 1995 Data for Blackwater Channel sample sites averaged by week.
(x = average value)

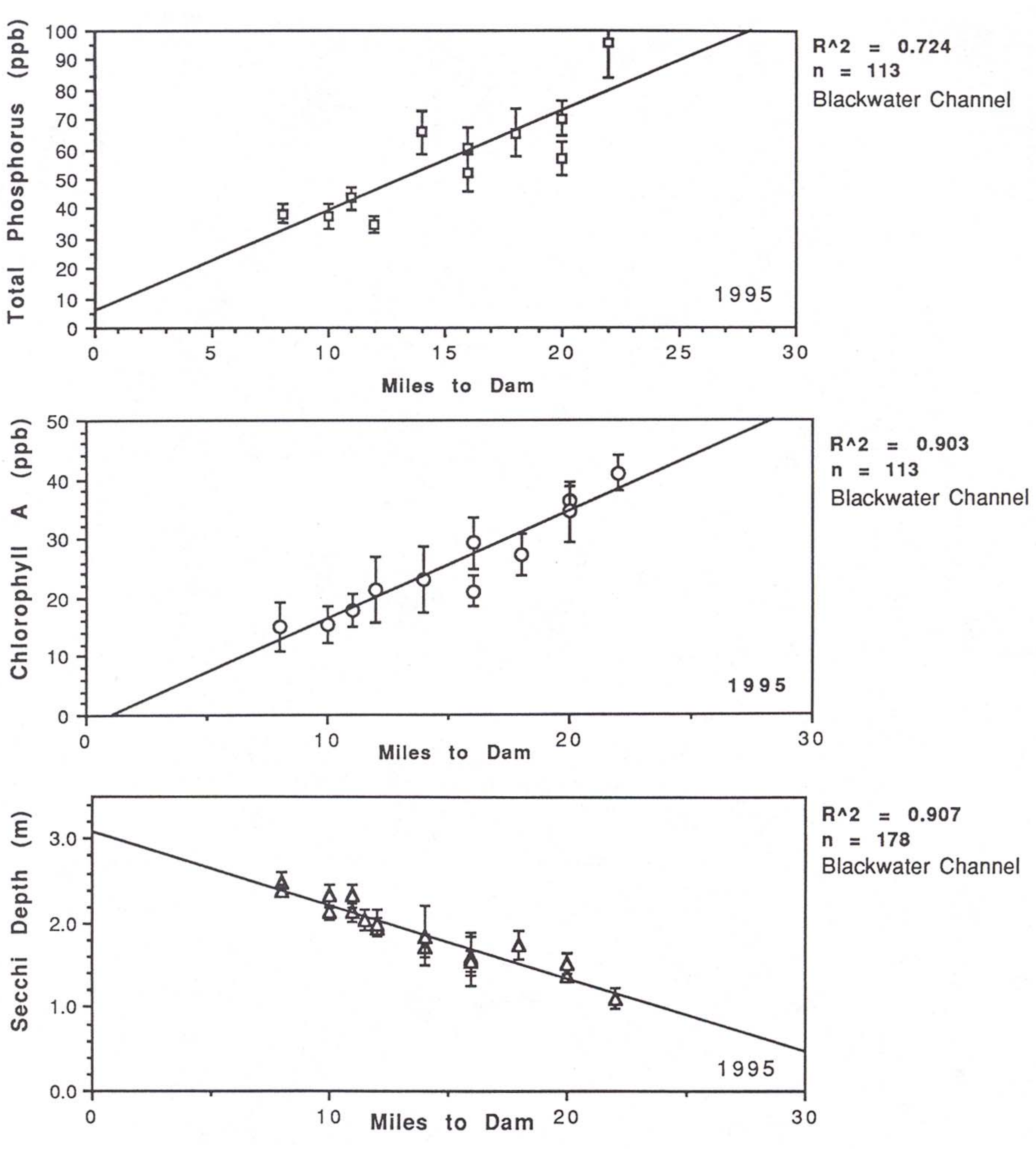


Figure 10. **1995 Blackwater Channel sample site averages versus miles to SML Dam.**

4.2.3 Main Basin

The weekly averages of total phosphorus for the main basin stations (5 sites) exhibited the highest values during Week 4 (58.1 ppb) and the lowest total phosphorus concentration during Week 10 (10.0 ppb) with an overall mean total phosphorus of 23.3 ppb for a total of 54 samples (Figure 11). The chlorophyll-*a* concentrations found in the main basin weekly exhibited similar fluctuations with the highest chlorophyll-*a* values in Week 7 (14.3 ppb) and the lowest values for chlorophyll-*a* in Week 3 and 4 (not detectable). The overall mean of chlorophyll-*a* samples for the Main Basin was 7.9 ppb for 46 total samples collected at 5 sample sites (Corrected value; CHA = 1.2 ppb). The Secchi depth observations indicated the best water clarity in Week 7 and the worst water clarity during weeks 1 and 2. The overall mean of Secchi depth values for the main basin was 3.0 m.

The total phosphorus concentration (TP) in the main basin decreased slightly as miles to the dam decreased indicating less nutrient-enriched water closer to the dam (Figure 12). The highest total phosphorus concentration found in the main basin of the lake (30.0 ppb) was measured at a main basin station 3 miles from the dam. The lowest total phosphorus value found at a main basin site (18.6 ppb) was measured at a station approximately 1 mile from the Dam.

The chlorophyll-*a* concentration (CHA) in the main basin decreased slightly as miles to the dam decreased indicating less algae growth closer to the dam (Figure 12). The highest average chlorophyll-*a* concentrations in the main basin (14.2 ppb) were measured at a station approximately 5 miles from the dam. The lowest average chlorophyll-*a* concentration in the main basin (6.0 ppb) occurred at a station 5 miles from the dam.

The Secchi depth values in the main basin (Figure 12) increased slightly as miles to the dam decreased indicating better water clarity closer to the dam. The main basin station averaging the lowest water clarity as measured by Secchi depth (2.9 m) was located 5 miles from the dam. The highest water clarity, indicated by an average Secchi depth of 3.4 m, occurred at a main basin station 1 mile from the dam.

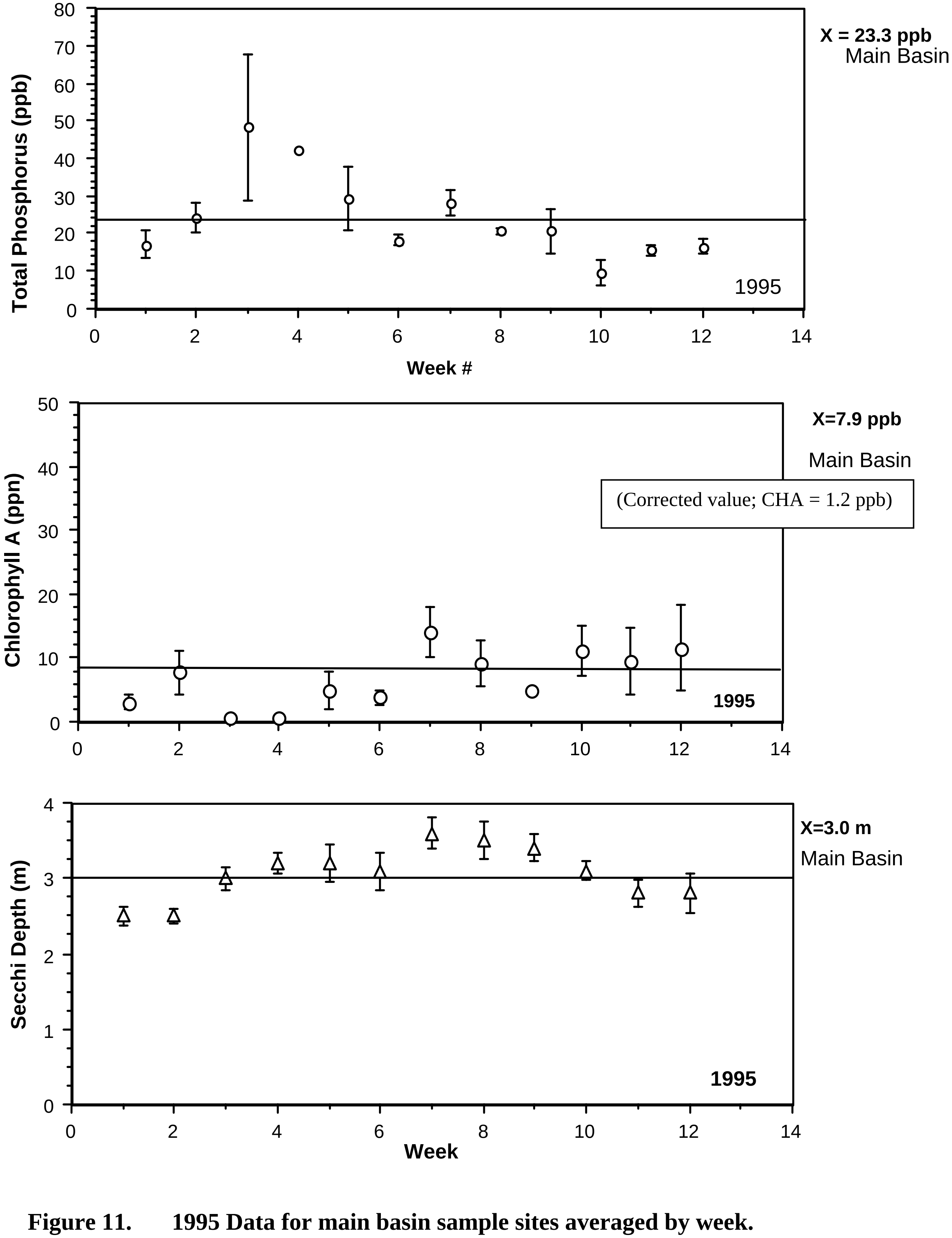


Figure 11. **1995 Data for main basin sample sites averaged by week.**
(x = average value)

In both of these channels there is a closer fit to the regression lines as indicated by larger R-values than when all data is combined or when compared to the main basin. The greater the R-value, the more highly correlated the two parameters (miles to the dam and TP, CHA, or SD). In Figure 12, the main basin data shows a much lower correlation between each of the three parameters (TP, CHA, SD) and miles to the dam. This is reflective of the riverine nature of the channels compared to the more completely mixed main basin. In the channels of the Roanoke and Blackwater there is a greater current velocity in a constant direction downstream which would cause the gradient observed in the parameters in the tributaries. In the main basin the volume of water is greater therefore the current velocity is decreased and does not occur in only one direction. This results in greater mixing and a greater homogeneity of parameter values which decreases the correlation between miles-to-dam and parameter value.

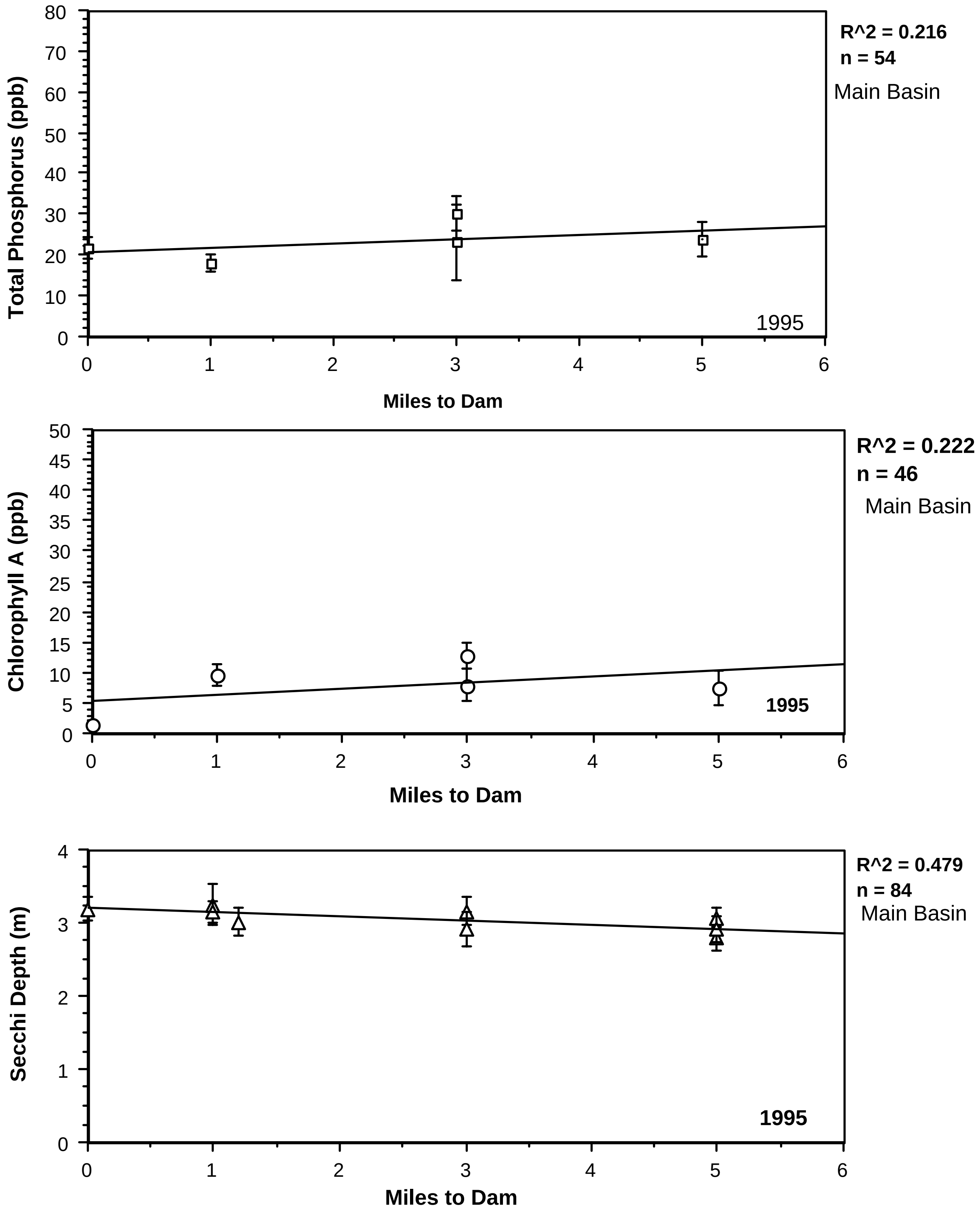


Figure 12. 1995 Main Basin sample site averages versus miles to SML Dam.

4.3 Results for Leesville Lake

The Leesville Lake samples are collected by the student technicians as grab samples from a bridge in the same manner as the tributary samples. The difference between these samples and the other tributary samples is that these samples represent water quality downstream from the dam. The results for 1993 through 1995 are summarized in Table 1. Note that the values given for each year are the yearly averages. Thus the column and row designated as average are the average value of the yearly averages. The raw data for Leesville Lake can be found in appendix 4. The Roanoke River samples are collected before (site 105) and after (site 103) the confluence with the Pigg River. Total phosphorus in the Roanoke River samples follows the pattern for the lake with 1994 values being lower than in 1993 and 1995. The Pigg River samples do not follow this pattern. Phosphorus concentrations in the Pigg River are similar in 1993 and 1994 and considerably higher in 1995. The higher phosphorus levels in the Pigg River increase the phosphorus concentration in the Roanoke River. In 1995, the increased phosphorus concentration in the Pigg River is reflected in the Roanoke River below the Pigg River. Also, since the phosphorus levels are higher in the Roanoke River just below the dam than they are at lake stations near the dam, it appears that phosphorus from the Pigg River is being pumped back toward the dam. This would explain the slightly higher phosphorus concentration at station M1 (see Figure 12).

Table 1. Summary of 1993 to 1995 results for sites below the dam.

Location (former site number)	**Total phosphorus (ppb)**			
	1993	1994	1995	Average by site
Roanoke, below dam (105)	48.5	25.6	40.5	38.2
Pigg River, Rt. 605 (104)	65.2	64.5	83.4	71.0
Roanoke, Rt. 608 (103)	54.6	38.7	62.1	51.8
Average by year	56.1	42.9	62.0	

5. DISCUSSION OF RESULTS

Because sample site locations were changed this year, some care must be taken when comparing this year's results with results from previous years. Coverage and distribution of sites have not changed dramatically from previous years so that comparisons can certainly be made but some change may be attributed to alterations in the monitoring sites.

5.1 Total Phosphorus

Phosphorus concentrations increased markedly this year over the concentrations observed in 1994 and were very similar to those measured in 1993. The reason is probably the heavy rains and flooding that occurred in June. The loading of phosphorus from tributaries is apparent with the tributary concentration (109.4 ppb) averaging nearly 250% higher than the lake average (45.2 ppb). After the week of heaviest rain the tributary concentration averaged nearly 300 ppb and exceeded 1000 ppb in three of the Blackwater tributaries (see Appendix 3). Phosphorus levels in the lake reflect this loading, both at channel sites and cove sites. The weekly summaries (figure 5A) for these sites show a doubling of phosphorus levels from the first week to the sixth week followed by a gradual decline during the dry summer that followed.

The correlation between phosphorus concentration and miles to the dam is very similar for cove sites and channel sites and there is no significant difference in average phosphorus concentrations. This strongly supports a conclusion reached in earlier studies (Johnson and Leffler, 1987; Johnson and Thomas, 1990) in which no differences in water quality were detected among coves with very different shoreline land uses. Coves are not sufficiently isolated (hydrologically) to develop distinctive water quality characteristics. As the lake level rises and falls the coves are flushed and the effective mixing rapidly destroys evidence of local land use impacts. This will make the detection of local deterioration difficult in all but severe cases. Differences in water quality in Smith Mountain Lake result primarily from proximity to tributary loadings. At this time water quality seems to depend on tributary loading more than shoreline land use. As the population along the shoreline increases this could change but it will be hard to detect because of mixing. Rather than localized deterioration that could act as a warning, there may be a gradual and generalized decline in water quality that will be more difficult to detect.

5.2 Chlorophyll-a

Chlorophyll-*a* concentrations in 1995 were similar to those observed the past two years. The average value in 1995 (19.6 ppb) is lower than in 1994 (23.4 ppb) or 1993 (23.7 ppb) but the difference is not statistically significant (Values for chlorophyll-*a* were calculated incorrectly. See Appendix Table A2a for corrected values. Corrected average value; CHA = 3.0 ppb). If the calibration factor had not been adjusted, based on the fluorescence of this year's chlorophyll-*a* standard, the average would have been 23 ppb (see the discussion of chlorophyll-*a* in the next section, "Quality Control/Quality Assurance").

5.3 Secchi Depth

The average Secchi depth declined slightly this year back to the 1992 average of 2.0 meters after averaging 2.3 meters in 1993 and 1994. In the earlier study of near shore water quality (Johnson and Thomas, 1990), about 40% (by mass) of the total suspended solids were found to be volatile. While it is not an exact measure, the portion of suspended particulate matter that is volatile gives an estimate of the algal turbidity, while the non-volatile fraction gives an estimate of the clay particle contribution to turbidity. At stations further from shore volatile particulate matter contributes a larger fraction of the total. It would be useful to collect similar data for different sections of the lake so that the relative contribution of algae growing in the lake can be distinguished from the contribution made by soil being carried into the lake.

5.4 Variation of Water Quality with Location

Water quality varies considerably with location in Smith Mountain Lake. At the stations nearest the dam, oligotrophic conditions still prevail while the upper reaches of both the Blackwater and Roanoke Channels are highly eutrophic. The average value for each parameter in three sections of the lake is shown in Table 2.

Table 2. Average value of water quality parameter at different locations.
(Corrected CHA values given in parentheses)

	Total Phosphorus (ppb)	Chlorophyll-*a* (ppb)	Secchi Depth (m)
Main Basin	23	8 (1.2)	3.0
Roanoke Channel	53	24 (3.6)	1.8
Blackwater Channel	56	26 (3.9)	1.9

6. FECAL COLIFORMS IN SMITH MOUNTAIN LAKE

Water Samples were collected from eight sites on Smith Mountain Lake on May 20, July 3, and July 24, 1995. These samples were collected and stored according to standard methods of bacterial sampling (APHA). The 100 mL of the samples were filtered immediately upon return to the laboratory. The membrane filtration method for bacterial analyses was used with DIFCO m-Fecal Coliform media prepared with rosolic acid, as prescribed in standard methods (APHA). Characteristic blue fecal coliform colonies were counted and recorded after 24 hours at 45.5ºC.

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

Non-marina sites

1. Main basin of Smith Mountain Lake at 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.

Marina Sites

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

These sites were selected to represent the characteristic coves around Smith Mountain Lake, and to allow a comparison between non-marina coves and marina coves. (1) The main basin site at the confluence of the Blackwater and Roanoke Channels was selected to provide samples not influenced by runoff from nearby shoreline. (2) Forest Cove (Bedford County) is surrounded by residential area of low density, includes a cleared horse pasture, and is located after the confluence of the two main channels in close proximity to Smith Mountain Lake Dam. (3) Fairway Bay (Franklin County) is surrounded by homes and multi-family residences and is not far from Hales Ford Bridge on the Roanoke Channel. (4) Palmer's Trailer Park Cove is surrounded by trailers that have been there for a long time, each with a septic tank and drain field, and is located off Little Bull Run off the Blackwater Channel. (5) Shoreline Marina (Franklin County) is up Becky's Creek, which is a tributary of the Roanoke Channel near Hales Ford Bridge and is a storage place for many houseboats. (6) Pelican Point Marina (Franklin County) is on the Blackwater Channel and is a storage place for many large sailboats and a few houseboats. (7) Smith Mountain Lake Dock (Pittsylvania County) is in a cove off the main basin and in close proximity to the Smith Mountain Lake Dam: it is a storage place for many houseboats. 8) Smith Mountain Lake Yacht Club (Bedford County) is in a cove off the Roanoke Channel not far from Hales Ford Bridge, and is the storage place for many houseboats.

Figure 13 indicates the mean Fecal Coliform colony forming units (cfus) commonly called colony counts for the three sample dates. The conclusions drawn from these data are:

1. Sample date was the most important influence on the fecal coliform population estimates, with July 3rd samples exhibiting the highest number of colonies at every sample site.

2. The mean coliform population estimates for all marinas was slightly higher (36 ± 24 cfus) than the mean coliform population estimates for the non-marina sites (27 ± 36 cfus). This was not a significant difference however because the 95% confidence limits overlap.

3. One marina cove (Pelican Point Marina in Franklin County) had lower fecal coliform counts than one of the non-marina coves (Palmer's Trailer Park Cove) on all three sample dates.

4. The confluence of the two main tributaries had higher fecal coliform counts than the Forest Cove site on the last two sample dates (7/3 and 7/24/95) and higher fecal coliform counts than Fairway Bay, Palmer's Trailer Park Cove, Pelican Point Cove and Shoreline Marina Cove on the last sample date (7/24/95).

5. Although the mean fecal coliform population estimates were not significantly higher when all of the marina sites are included than they were at the non-marina sites when all of the non-marina sites are included, three of the marinas (Shoreline Marina, Smith Mountain Lake Dock and Smith Mountain Lake Yacht Club) had consistently higher fecal coliform counts than three of the non-marina sites (Confluence of channels, Fairway Bay and Forest Cove). The mean fecal coliform counts at the three marina sites mentioned above was 45 ± 13 cfus and the mean fecal coliform counts at the three non marina sires mentioned above was 6 ± 3 cfus. Shoreline Marina, Smith Mountain Lake Dock and Smith Mountain Lake Yacht Club had significantly higher fecal coliform population estimates than the confluence of channels, Fairway Bay and Forest Cove.

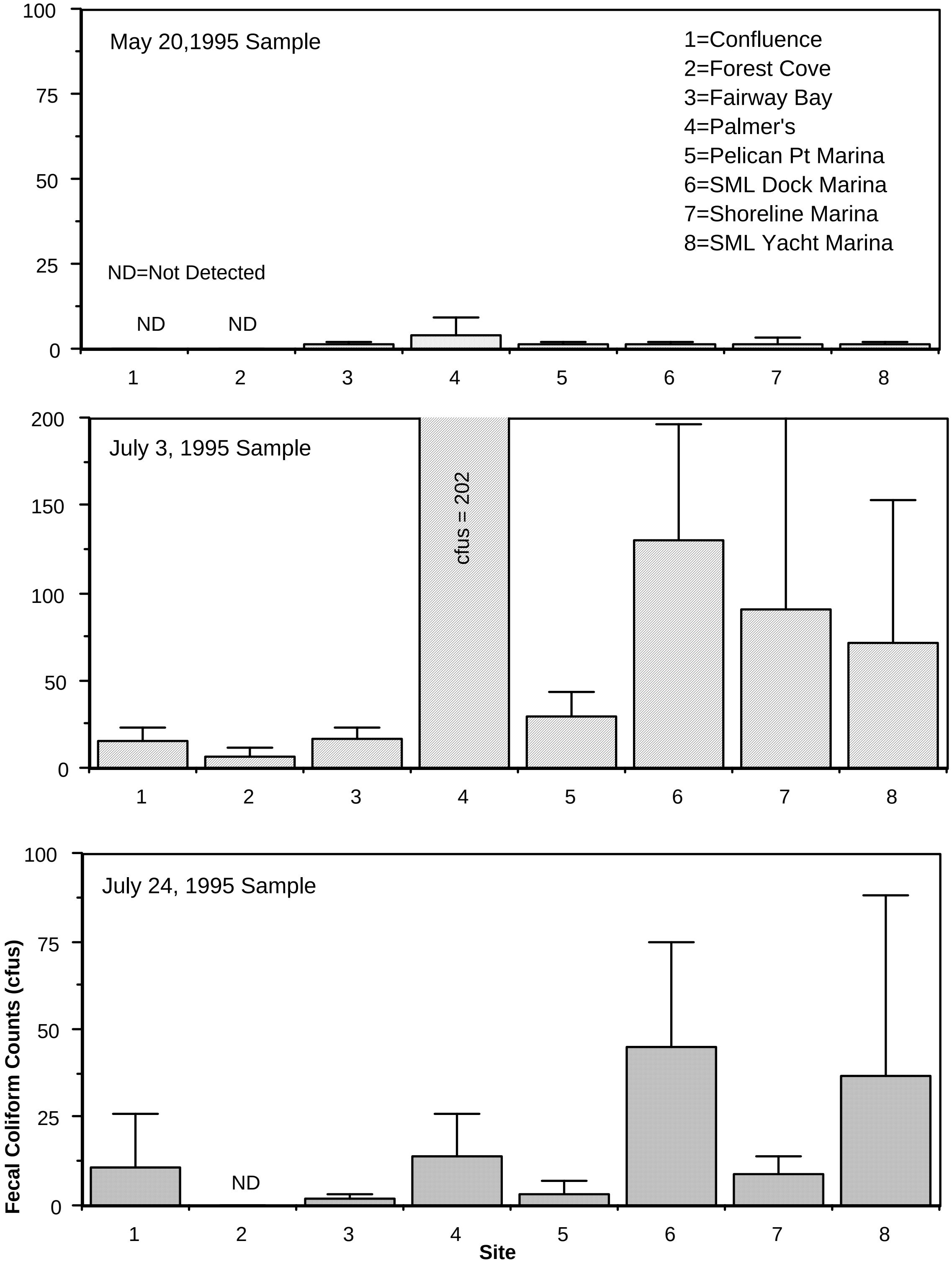


Figure 13. Smith Mountain Lake fecal coliform data for 1995.
Note: Samples were taken on the three dates at 8 sites. Sites 1-4 are non-marina sites and sites 5-8 are marina sites. Graph B has a different scale than graphs A and C.

7. QUALITY CONTROL/QUALITY ASSURANCE

7.1 Total Phosphorus

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

Each week a set of standards is prepared so that a calibration curve can be constructed showing the relationship between phosphorus concentration in a sample and its absorption of light with a wavelength of 700 nm. Table 3 summarizes the calibration data. The slope indicates the relationship between concentration and absorption and is completely consistent from week to week. This results in confidence that the spectrophotometer used to measure absorbance had a stable sensitivity and that the standards were prepared in a consistent manner. The intercept indicates the extent to which the standards are contaminated with phosphorus during the analytical process. This background, averaging 7 ppb, is then subtracted from each sample to compensate. This degree of contamination is low relative to the levels determined in the lake and is due almost entirely to sample digestion. During digestion four reagents are added which contain small amounts of phosphorus and the extra handling and manipulation lead to some unavoidable contamination. The correlation coefficient (R^2) is a measure of how well the calibration line fits the data points with values ranging from 0 (no fit) to 1 (perfect fit). Averaging over 0.99, the correlation coefficient indicates excellent precision and shows both the care with which standards were prepared and the stability of the instrument used to make the measurements.

In Table 4, data for field blanks and surrogate samples are summarized. Average values are 7 to 10 ppb higher than the target concentrations and precision is much lower than for the standard solutions in the previous table. However, because the standard deviations are higher, there is not a statistically significant difference between the target concentrations and the average values. The field blanks and surrogate samples are prepared and in the same manner as blanks and standard solutions used in the laboratory for calibration. Thus the difference in results must be due to sample handling and/or storage. The field blanks and surrogate samples are put in used sample bottles that have been rinsed once with distilled water and the bottles are apparently contaminating the contents. Being aware of the possibility, this source of contamination has been minimized by designating a particular sample bottle for each site and reusing that bottle each week. The field blanks and surrogate samples are placed into used bottles randomly selected, which is the worst-case scenario. Next summer bottles designated for a given concentration will be used to develop a most probable scenario for the contamination of samples due to handling, sample container, and storage.

Table 3. Summary of calibration data.

Week	Slope	Intercept	R^2
1	0.002	0.000	0.968
2	0.002	0.021	0.993
3	0.002	0.012	0.980
4	0.002	0.022	0.991
5	0.002	0.013	0.998
6	0.002	0.020	0.996
7	0.002	0.018	0.998
8	0.002	0.015	0.997
9	0.002	0.015	0.988
10	0.002	0.008	0.998
11	0.002	0.009	0.996
12	0.002	0.015	0.999
Avg	0.002	0.014	0.992
Stdev	0.000	0.007	0.009

Table 4. Summary of data for field blanks and surrogate samples.

Target Concentration	Replicates	Average	Std Dev
0 ppb	11	7.8	7.7
20 ppb	11	30.5	17.2
40 ppb	8	47.1	21.0

7.2 Chlorophyll-a

Calibration of the fluorimeter used to determine chlorophyll continues to be a frustration. The instrument continues to give very consistent readings from day to day and week-to-week for a given standard, indicating that the instrument is quite reliable. However, the instrument does slowly lose sensitivity as the source and detector deteriorate with age. The problem is that chlorophyll standards are unstable and a stock standard must be prepared each year. EPA standards and standards prepared from commercially available chlorophyll-*a* have both been employed with rather mixed results. The problems inherent in the analysis of chlorophyll-*a* have been described in several past reports and obtaining reliable standards for calibration probably limits the accuracy of the results. For the past two years we have used a calibration factor of 0.75, based on an average of several calibrations. This year results indicate a value of 0.65, even though we have reason to believe that the instrument has not lost sensitivity. As a result the mean value for chlorophyll-*a* this year shows a slight decrease. If a calibration factor of 0.75 is used, the mean value for chlorophyll-*a* is the same as last year (23 ppb) (Values for chlorophyll-*a* were calculated incorrectly. See Appendix Table A2a for corrected values. Corrected average value; CHA = 3.0 ppb). Because of these uncertainties we discourage concluding that there was any actual decrease in chlorophyll-*a* this past summer.

7.3 Site Comparison

This year two monitors sampled at approximately the same location (site M3), although not necessarily on the same day of the week. This allows for a comparison of results that fully integrates the analytical process. The results are summarized below in Table 5.

Table 5. Summary of data for site comparison.

Site	**Total Phosphorus (ppb) Average (Std Dev)**	**Chlorophyll-*a* (ppb) Average (Std Dev)**	**Secchi Depth (m) Average (Std Dev)**	**Combined TSI**
M3 (Murphy)	23.1(30.0)	5.8(2.1)	3.2(0.6)	47
M3 (Schafer)	30.1(12.7)	6.6(2.7)	2.9(0.6)	49

The average values for each of the water quality parameters are similar. The differences in the average values are less than half the standard deviations and there is no statistical difference between the samples collected by the two monitors. It is interesting that results from the samples collected by the Murphys indicate somewhat better quality for all three parameters and therefore give a slightly lower value for the combined trophic state index.

8. WATER QUALITY TRENDS

Results of each water quality parameter measured have been discussed in the previous section. In this section the water quality trends will be displayed in the manner we have used for the past several years. Table 6 and Figure 14 compare water quality in Smith Mountain Lake over the nine-year period of the monitoring program.

Table 6. **Water quality data from Smith Mountain Lake 1987-1995.**

Parameter	**Annual average for Smith Mountain Lake**								
	1987	1988	1989	1990	1991	1992	1993	1994	1995
Total Phosphorus (ppb)	19.7	20.9	27.8	25.2	25.9	36.0	42.7	28.6	45.2
Chlorophyll-*a* (ppb)	3.8	2.6	3.7	4.5	3.0	5.5	23.7	23.4	19.6
				(Corrected values)			(3.6)	(3.5)	(3.0)
Secchi Disk Depth (m)	2.4	2.7	2.2	2.4	2.6	2.0	2.3	2.3	2.0

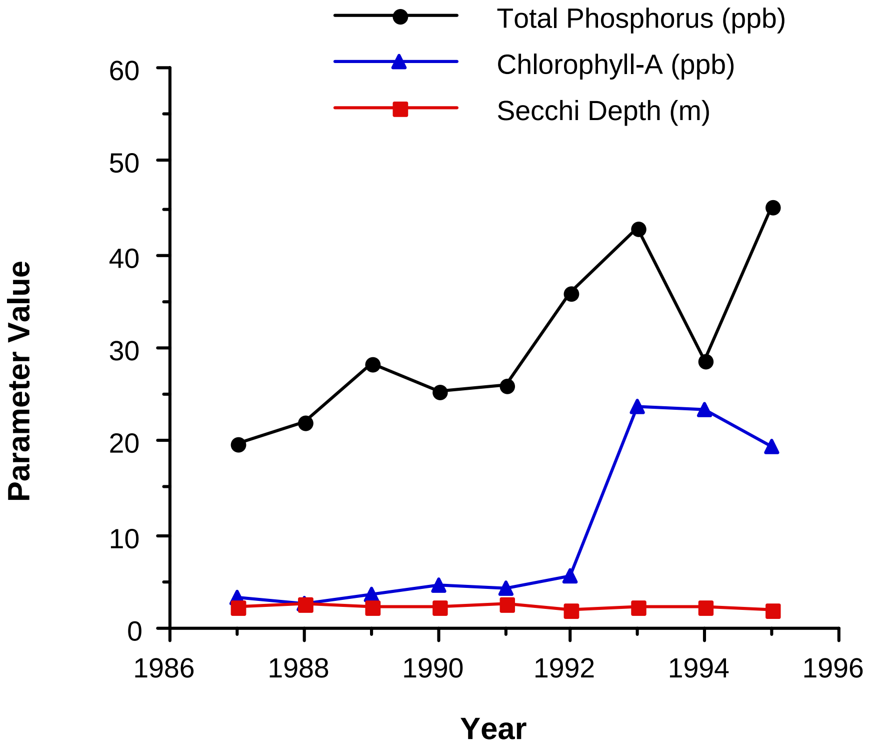


Figure 14. **Graphical comparison of water quality parameters by year.**

9. CARLSON'S TROPHIC STATE INDEX

The trophic status of a lake indicates the degree of nutrient enrichment and the resulting suitability of that lake for various uses. The process of eutrophication is described at the beginning of the Training Manual for the monitoring program. Phosphorus is most often the nutrient that limits algal production and attempts have been made to relate the trophic status of a lake to concentration of phosphorus. Table 7 shows one such effort (note that the relationships are for northern temperate lakes and will not represent southeastern lakes as well).

Table 7. Proposed relationships among phosphorus concentration, trophic state, and lake use for northern temperate lakes.
(Reckhow and Chapra, 1983)

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

The algal growth resulting from inputs of phosphorus can also be used to evaluate the trophic status of a lake. This is done by extracting the green pigment, chlorophyll-*a*, from algae and determining its apparent concentration. Table 8 shows the assignment of trophic status based on the concentration of chlorophyll-*a*. It also shows that the evaluation of trophic status is a matter of professional judgment, not a parameter to be exactly measured.

Table 8. **Trophic Status related to chlorophyll-*a* concentration in different studies.** (Reckhow and Chapra, 1983).

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

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

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

The following equations are used for the calculation of TSIs:

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

TSIs are given for each year of the Smith Mountain Lake Water Quality Monitoring Program in Table 9 and Figure 15. Also shown in Table 9 are TSIs for the three major sections of Smith Mountain Lake and some general figures for use as a point of reference.

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

	Trophic Status Index (TSI)			
	TSI-SD	TSI-TP	TSI-CA	Combined
1987	47	47	43	46
1988	46	49	40	45
1989	49	52	43	48
1990	47	51	45	48
1991	47	51	45	47
1992	50	56	47	51
1993	48	58	62	56
1994	48	53	62	54
1995	50	59	60	56
main basin	44	49	51	48
Roanoke Channel	52	61	62	58
Blackwater Channel	51	62	63	59
oligotrophic*	41	37	50	43
eutrophic*	50	47	55	51
avg. SE lake**	52	55	51	53

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

The combined TSI varies considerably with location in Smith Mountain Lake. At the station nearest the dam (TSIs for individual stations are not shown in this report) the combined TSI indicates oligotrophic conditions while the upper reaches of both the Blackwater and Roanoke Channels are highly eutrophic. The main basin has a combined TSI indicating mesotrophic conditions.

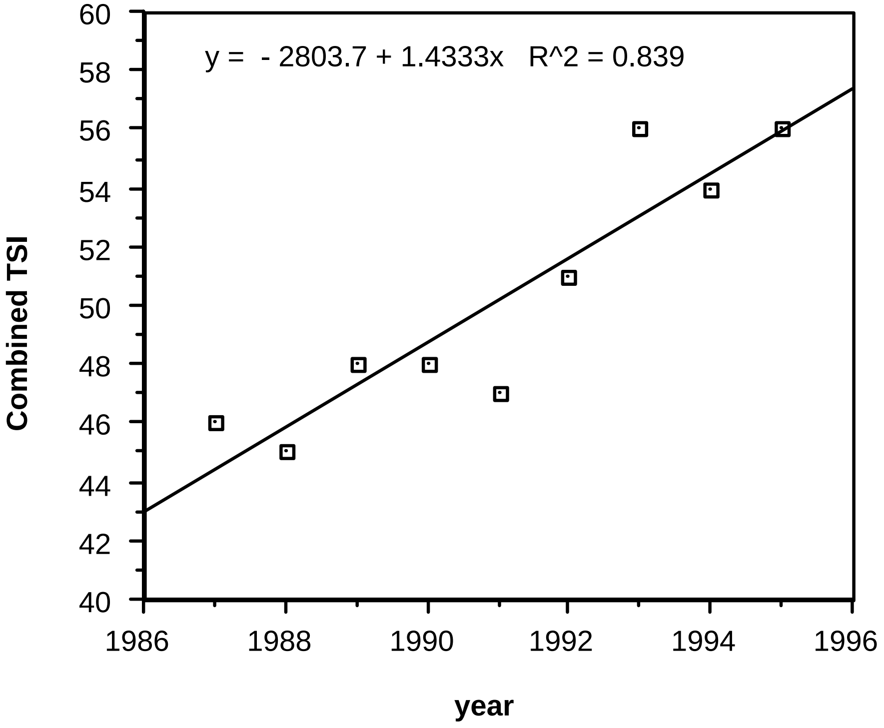


Figure 15. Regression showing increased combined trophic state index over time.

Figure 15 is the least squares plot of the combined trophic state index versus time. The coefficient of 0.839 indicates a close correlation of the TSI with time. The TSI is increasing nearly 1.5 units per year (Slope = 1.4333), indicating a rapid increase in the trophic status of the lake. The TSI is a logarithmic function and an increase in TSI from 40 to 50 or 55 is generally associated with the transition from an oligotrophic to a eutrophic state. A survey of 88 southeastern US lakes and reservoirs by Ken Reckhow published in 1988 showed an average TSI of 53. It is clear that we must reverse this trend if we want to continue enjoying Smith Mountain Lake. At this time the TSI appears to be increasing as much each year as we would like to see in a generation.

10. SAMPLING EFFICIENCY

The monitoring program depends on volunteers for sample collection and one measure of success for the program is the consistency with which these volunteers attend to their stations. Table 10 presents the collection efficiencies for 1991, 1992, 1993, 1994 and 1995. The figures show that the volunteer monitors are very conscientious about sample collection. Advanced monitors collected 80% of the samples possible in 1995 and 75% of the samples possible for basic monitors. These sampling efficiencies are a little lower than in previous years, but this sampling efficiency is still remarkably high for volunteer sampling programs. The decrease in efficiencies is attributed to the implementation of Phase II 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 addition to sample site changes the sample site identification numbers have all been changed which caused some delay in sample collection and in issuing of sampling supplies. 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 their dedication to the program.

Table 10. Comparison of sampling efficiencies for 1991-1995.

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

11. GIS WORK ON THE SMITH MOUNTAIN LAKE WATERSHED

In December 1993, Johnson applied for a Burroughs-Wellcome Fellowship through the Appalachian College Association, proposing to apply GIS (Geological Information System) and GIS-based modeling as a tool for managing water quality in Smith Mountain Lake. The 1993 Annual Report of the SML Water Quality had just been completed and the results indicated a significant deterioration in water quality. Investigators from Ferrum College and the SMLA concluded that Smith Mountain Lake must be protected from siltation and the associated nutrient inputs arising from soil loss throughout the watershed to prevent the continued deterioration of water quality. This can be partially accomplished by instituting Best Management Practices (BMPs) in areas of the watershed where nonpoint source (NPS) agricultural pollution is high. Johnson proposed using GIS procedures to identify areas of high non point source potential to help maximize the return on investment in BMPs. The work was to be done at Virginia Tech's Information System Support Lab (ISSL) with Dr. Vern Shanholtz acting as his mentor.

Johnson received the fellowship and was able to expand the project to include the following:

- Ferrum College purchased several computers with 486DX/66 Mhz processors and 340 Mb hard drives. Johnson received one of the machines so that some of the GIS work could be done at Ferrum College.

- Application was made for professional development funds administered by the Dean's Office and Johnson received $1500 to help pay for GIS software along with training and support in the use of the software.

- The Life Sciences Division agreed to commit $1000 toward the purchase of a Calcomp digitizing tablet and Fellowship funds supplied the remaining $1500. With the computer, software and digitizing tablet we will have full GIS capability at Ferrum College as soon as we can obtain a large format printer or plotter to produce maps. A CalComp plotter has been obtained from government surplus and we are attempting to get it on line.

- The Smith Mountain Lake Association provided a $2000 grant to help pay for obtaining data for GIS modeling and for the cost of printing maps.

- GIS is being used in a demonstration and assessment project located in the Smith Mountain Lake Watershed. The Blue Ridge Soil and Water Conservation District, chaired by Daphne Jamison (one of the volunteer monitors), received federal and state funds for a project providing alternative sources of water for beef cattle and dairy cows. In five cost-shared installations, solar powered pumps, ram pumps and sling pumps will be used to provide water to the animals away from streams so that vegetative buffer strips can be maintained along stream banks to decrease siltation in the streams. Another of the volunteer monitors, Houston Snoddy, is participating in the project. The project includes water quality monitoring of streams flowing into Smith Mountain Lake that integrates that project with the ongoing water quality monitoring in the lake. In addition, it provides for a very detailed GIS-based model to be developed for two subsheds (Gills Creek and Maggodee Creek) in the Smith Mountain Lake watershed.

We now have a well-integrated group working to provide the database and information needed for more effective watershed management. The effort includes personnel and support from the Blue Ridge Soil and Water Conservation District, Ferrum College, the Smith Mountain Lake Association, Virginia Tech, and federal, state, regional, and local agencies. The State of Virginia considers the effort a model and has provided funding to develop a display. The display was on view at the 1995 National Watershed Conference in Charleston, West Virginia in June and at the monitors' picnic in September.

Work on a GIS-based model for the Smith Mountain Lake Watershed is progressing, but rather slowly.

- A Memorandum of Agreement with the State of Virginia (Division of Soil and Water Conservation, Department of Conservation and Recreation) has been obtained to receive and use data from the VirGis database. Although the database was developed at ISSL, the Division has the intellectual property rights. Work agreements with MapTech have been signed to take the data from magnetic tape stored at the Tech Computing Center and convert it to a format compatible with a personal computer. Most of the work has been accomplished.

- Because data retrieval and post processing is expensive, all of the data required for the watershed model cannot be obtained directly. The SML Watershed includes parts of seven counties. A VirGis database exists for six of the counties (Bedford, Botetourt, Campbell, Montgomery, Pittsylvania, and Roanoke). There is no VirGIS database for Franklin County, which contributes the largest area to the Smith Mountain Lake watershed. To obtain the six data layers (watershed boundaries, soils, hydrology, elevations, land use and transportation) necessary to run the model for the six counties would cost over $8,000. To map the landuse in Franklin County would cost $30,000-$45,000. To save funds, portions of the transportation layer for each of the counties will be digitized by faculty and students at Ferrum College, saving $2100. Soil slope ranges will be used instead of DEMs (digitized elevation models) that will save about $2000. County boundaries can be extracted from the watershed boundaries and save $630. At present Johnson has obtained two data layers for Franklin County (watershed boundaries and streams) and four data layers (soils, landuse, watershed boundaries, and streams) for the other six counties at a cost of $2550. The landuse data layer for Franklin County is more problematic. If resources to complete this map layer are not obtained, the map of erosion potential for the Smith Mountain Lake Watershed will not contain information on Franklin County, the county with the largest area in the watershed.

- The soil layer is fundamental to watershed modeling because it contains the information on soil type and erodibility. And, although state funds may become available for landuse mapping, it is not generally done until the county soil map is complete. Franklin County is the only county in the SML watershed without a completed soil map. Dean Rector, with the NRCS in Richmond, reports that 65% of the 450,000 acres of soil in Franklin County have been mapped to date. About 160,000 acres are left to map at a rate of 40,000 acres per year. This gives a completion time of about four years to complete fieldwork. Additional time will then be required to compile data and digitize the maps. The Virginia Soil and Water Conservation Division has given those areas of Franklin County in the SML Watershed priority and the areas will be completed ahead of schedule. To speed up the process another soil scientist has been transferred to the Franklin County Office to work on soil mapping.

GIS is already being used to support the water quality monitoring program. It is being used to organize and access information on monitoring sites and to help visualize and interpret water quality data.

12. CONCLUSIONS AND SUMMARY

Expansion of the program, a study of coliform bacteria, and the beginning of a new phase in the monitoring program made this a challenging year. Realignment of monitoring sites and the use of new site identification labels caused some confusion in the beginning weeks and this is reflected in the lower than usual sampling efficiency. The volunteer monitors did a truly fine job of adapting to the new system and we congratulate and thank them for their extra efforts and patience. The new system is already paying off in terms of information and the program is stronger than ever. The use of designated trend and watchdog stations will allow more reliable analysis of water quality trends without diminishing our role as lookouts for localized water quality problems. The addition of tributary sites expanded the scope of the monitoring project and will provide information on the relative contribution of different tributaries to nutrient loading to the lake. The introduction of GIS capabilities for displaying and managing information adds a new dimension to the program and prepares us for the future. Using the developing tributary database and GIS-based modeling, we can evaluate different areas of the lake watershed and identify areas of the watershed contributing disproportionately to nutrient and silt loading in the lake.

Water quality in Smith Mountain Lake continues to be a cause for concern. After a one-year decrease in average phosphorus concentration, the level was higher than ever this year, average chlorophyll-*a* concentration remains high, and the average Secchi depth declined slightly. Water quality varies considerably with location in Smith Mountain Lake. Near the dam the combined trophic state index indicates oligotrophic conditions while the upper reaches of both the Blackwater and Roanoke Channels are highly eutrophic. The regression lines of water quality parameter versus miles-to-dam indicate a generally constant change in water quality with distance from the dam. The Carlson Trophic State Index for the entire lake was plotted against time and the regression line indicates an average decrease of nearly a unit and a half (1.43) per year, a trend that cannot continue if the resource is to be preserved for future generations. On the other hand, not all the news is negative. Local agencies continue to increase their efforts and cooperation among local jurisdictions is improving. The Natural Resource Conservation Service (NRCS) Office in Franklin County is working with farmers to improve conservation practices and the Blue Ridge Soil and Water Conservation District has received funding for a second demonstration project in the Blackwater watershed (Gills and Maggodee Creek). Planning for a comprehensive plan for Smith Mountain Lake has begun which involves officials from Franklin, Bedford, Pittsylvania, and Roanoke Counties.

13. ACKNOWLEDGEMENTS

We would like to acknowledge the hard work and effectiveness of our student technicians Tracy Rakes, Casey Magruder and Maggie Murphy this past summer. They were responsible for making the long trek around the lake collecting the volunteers' samples every week and for doing the weekly analyses for total phosphorus and chlorophyll-a. They also took on the task of sampling the tributaries that was quite an adventure with muddy roads, washed out bridges, and all sorts of unwanted animal life. Tracy Rakes was the organizing influence as lab coordinator, and Casey Magruder and Maggie Murphy were environmental science interns. We would also like to acknowledge the support of Karl Lerz as President of the SMLA. We would like to especially thank Bob Halstead for his hard work and enthusiasm. His efficient and effective leadership has made our job easier, and his expertise in soil conservation has been valuable to the program.

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APPENDIX

Table A1. 1995 Monitors' last name and station identification number.

S=Secchi only, C=cove station, R=Roanoke Channel, B=Blackwater Channel, G=Gills Creek, M=Main basin, # refers to miles to dam.

Monitor	Station	Monitor	Station	Monitor	Station
Anderson	SCR18	Franz	B22	Schafer	M5
Anderson	SCR19.2	Franz	CB20	Shirey	B18
Anderson	SCR20	Hartman	B8	Shirey	B20
Ballengee	SCM5	Hartman	B10	Spahr	SCR14.1
Ballengee	SCR7	Hartman	G13	Spahr	SCR14.2
Ballengee	SCR8	Hatfield	B12	Spahr	SCR14.3
Barr	SCR22.2	Hatfield	G12	Taylor	SCR17.1
Barr	SCR23	Hatfield	CB11	Taylor	SCR17.2
Barr	SCR23.3	Hill	R7	Thurman	SB12
Bay Rock Site	R31	Hill	CR8	Thurman	SCB14
Bogsrud	R23	Holasek	SCR10.1	Thurman	SCB16
Bogsrud	CR22	Holasek	SCR10.2	Walthers	SCR22.3
Bray	R21	Holasek	SCR10.3	Walthers	SCR23.2
Bray	CR21	Jamison	B14	Walthers	SCR24
Bray	CR21.2	Jamison	B16		
Casey	SCR15.2	Jamison	CB16		
Casey	SCR15.1	Kastner	R13		
Coleman	R25	Kastner	CR13		
Coleman	CR24	McCullough	M0		
Coleman	CR25	McCullough	CM1		
Coleman	CR26	McCullough	CM1.2		
Daly	R9	Mueller	SCR11.1		
Daly	CR9	Mueller	SCR11.2		
Daly	CR9.2	Mueller	SCR11.3		
Dooley	R11	Murphy	M1		
Dooley	R14	Murphy	M3		
Dooley	CR14	Ollweiler	R15		
Dugan	R17	Ollweiler	CR16		
Dugan	R19	Ollweiler	CR17		
Dugan	CR19	Ostertag	C4		
Dyett	SCR14	Ostertag	C5		
Dyett	SCR15	Ostertag	C6		
Dyett	SCR17	Schafer	M3		

Table A2. 1992 Total phosphorus data.

Station	Monitor	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Sta Avg	Stdev
B8	Hartman	42.5	34.5	46.5	48.5	56.5	35.5	48.0	40.0	33.0	19.0	28.5	29.5	38.5	10.5
B10	Hartman	28.0	25.0	31.0	41.0	57.0	34.0	46.0	39.5	69.5	19.5	25.5	36.5	37.7	14.3
B12	Hatfield	27.5	27.5	27.5	42.0	42.0	42.5	51.5	41.5		23.0	31.5	27.5	34.9	9.2
B14	Jamison				61.0	87.0	96.5	78.0	61.0	46.0		49.5	46.5	65.6	19.3
B16	Jamison				47.0	78.5	66.5	66.5	51.5	91.0		48.0	34.0	60.3	18.7
B18	Shirey		44.5	50.0	89.5	112.0	62.5	100.0	57.5	39.5	79.5	47.0	38.5	65.5	25.7
B20	Shirey		42.0	56.5	76.0	81.0	71.0	67.5	77.5	40.0	43.0	40.5	35.5	57.3	17.6
B22	Franz	47.5	43.0	102.5	170.5	106.0	109.5	125.0	121.5	69.5	65.5	95.5		96.0	37.6
C4	Ostertag	26.0	34.0	47.0	48.5	51.0	36.0	52.5	49.0	65.5			63.5	47.3	12.5
C5	Ostertag	26.5	25.5	30.5	42.0	46.0	34.0	42.5	37.5	27.5			34.5	34.6	7.2
C6	Ostertag	28.0	24.0	34.5	36.0	51.0	34.5	39.0	33.5	33.0			24.5	33.8	7.8
G12	Hatfield			49.5	39.5	48.5	49.5	53.5	41.5		21.5	34.5	22.0	40.0	11.9
G13	Hartman				43.5	48.0	41.0	60.0	37.5	23.0	24.0	30.5	32.0	37.7	11.9
M0	McCullough	16.5	25.5	34.5	42.0	17.5	15.5	26.0	20.0	21.0	8.5	18.0	17.5	21.9	9.0
M1	Murphy	24.0	23.5	19.5		17.5	15.5	26.0	23.0	17.0	3.5	14.5	12.5	17.9	6.5
M3	Murphy	8.5	14.0	111.5		17.0	21.5	24.5	18.5	10.0	2.0	14.5	11.5	23.0	30.0
M3	Schafer	24.5	36.5	56.0		41.0	18.5	24.0	22.5	40.0	17.5		20.5	30.1	12.6
M5	Schafer	12.0	21.0	19.5		53.0	20.0	40.0	19.5	15.0	16.0		21.0	23.7	12.7
R7	Hill	21.0			40.0		43.5		31.5	24.0	18.5	24.5	23.0	28.2	9.2
R9	Daly	19.5	26.5	45.0	41.5	61.5	37.5	40.5	36.0	36.5	19.5	30.5	25.5	35.0	11.9
R11	Dooley	21.5	27.0	17.0	34.0		30.5	37.0	30.0	18.0	14.0	28.5	24.0	25.5	7.3
R13	Kastner	34.5	46.5	51.5	42.0	52.5	45.5	45.5	48.0	29.5	19.0	27.0	25.5	38.9	11.3
R14	Dooley	26.0	31.0	43.0	40.0	80.0	40.5	44.0	39.5	16.5	18.0	32.0	26.0	36.3	16.6
R15	Ollweiler		39.0	0.1	49.5	114.0	41.0	31.5	28.0	23.5	26.0	36.0	29.5	38.0	28.1
R17	Dugan					88.0	69.0	64.5	53.5		28.0	38.5	34.0	53.6	21.6
R19	Dugan					93.0	63.0	71.0	71.5		56.5	47.0	40.5	63.2	17.5
R21	Bray	43.0	54.5	62.5	67.0		65.5	75.0	56.0	41.5	38.5	46.5	35.5	53.2	13.1
R23	Bogsrud	26.5	146.0		71.5	91.0	64.0	68.0	60.5	50.5	35.0	40.5	39.5	63.0	33.3
R25	Coleman							60.0						60.0	0.0
R31	Bay Rock	43.5	240.5	74.5	82.0	67.0	103.5	84.5	79.5	44.5	98.5	77.0	81.5	89.7	50.8
Ch Avg		27.3	46.9	45.9	56.2	63.7	48.5	54.9	45.7	37.0	29.7	37.7	31.8	**Ch Avg**	**44.2**
Ch Stdev		10.4	50.5	26.1	29.4	27.6	25.0	23.3	22.2	20.0	23.6	18.2	14.4	**Stdev**	**27.4**
CM1	McCullough		16.0	24.0	34.5	32.0	27.5	34.5	29.0	8.0	18.5	22.0	22.0	24.3	8.2
CM1.2	McCullough	12.5	14.0	32.0	38.0	34.0	31.5	32.0	33.0	23.0	18.5	25.0	23.0	26.3	8.3
CM5	Hill						37.5		31.5	13.5	19.0	28.5	24.5	25.7	8.7
CR8	Hill				45.0	25.5	35.0		31.0	24.5	19.0	24.5	25.0	28.6	8.1
CR9	Daly	19.0	19.5	51.0	44.5	37.5	32.5	37.0	33.0	11.5	16.5	26.5	24.0	29.3	12.0
CR9.2	Daly		20.5	39.0	38.5	36.0	31.0	34.5	33.5	33.5	20.5	24.5	27.5	30.8	6.7
CR13	Kastner	42.0	34.5	52.5	44.0	56.5	44.0	41.0	43.5	17.0	28.0	32.5	27.0	38.5	11.2
CR14.2	Dooley		41.0	65.5	39.0		48.0	45.0	41.0	12.5	21.0	33.0	26.5	37.2	15.0
CR16	Ollweiler		57.5	76.5	49.5	46.0	49.5	32.0	38.5	26.0	39.0	44.0	34.5	44.8	13.8
CR17	Ollweiler		51.5	117.0	66.0	60.5	55.0	44.0	45.0	37.0	53.5	80.0	56.0	60.5	22.0
CR19	Dugan			116.0		91.5	65.5	72.5	68.0		42.5	74.0	77.0	75.8	21.2
CR21	Bray	34.0	74.0	93.5	62.0	89.0	48.0	112.5	75.5	45.0	46.5	49.5	46.0	64.6	24.2
CR21.2	Bray	52.5	75.0	115.5	84.5	99.0	79.0	89.0	68.5	52.0	40.0	57.5	53.5	72.1	22.3
CR22	Bogsrud	38.0	51.5		72.5	87.0	67.5	65.5	69.0	34.0	35.5	42.5	42.0	55.0	18.0
CR24	Coleman							85.0	93.0					89.0	5.7
CR25	Coleman							82.5	86.5					84.5	2.8
CR26	Coleman							87.5	80.5					84.0	4.9
CB11	Hatfield		42.0	39.0	52.5	49.5	50.5	65.0	45.5		27.0	35.5	28.5	43.5	11.6
CB16	Jamison				62.0	68.5	73.5	60.5	52.0	25.5		39.0	37.0	52.2	16.9
CB20	Franz	48.5	67.5	103.0	87.0	88.5	77.0	82.0	64.5	50.5	51.0	54.0		70.3	18.5
Cv Avg		35.2	43.4	71.1	54.6	60.0	50.1	61.2	53.1	27.5	31.0	40.7	35.8	**Cv Avg**	**47.5**
Cv Stdev		13.9	52.7	35.0	17.1	26.9	19.3	22.9	20.0	13.9	18.1	16.8	16.4	**Stdev**	**23.5**
Lake Avg		28.6	45.7	54.2	54.9	61.6	48.6	56.5	48.1	33.2	30.0	38.4	32.8	**Gr Avg**	**45.4**
Stdev		12.0	40.6	31.0	24.6	26.5	22.0	23.8	21.6	18.1	19.4	17.6	14.7	**Stdev**	**26.0**

Table A3. 1995 Chlorophyll-*a* data.

(Corrected values on next page.)

Station	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Sta Avg	Stdev
B8	10.6	9.4	9.4	8.8	6.3	7.5	26.3	7.5	12.5	16.9	50.0		15.0	12.9
B10	10.6	6.3	5.6	7.5	14.4	13.8	40.6	20.0	17.5	11.9	21.9		15.5	9.9
B12		6.3	7.5	9.4	26.9	19.4	56.9	20.0		19.4	42.5	6.3	21.4	16.8
B14		5.6	10.6	16.9	48.8	40.6	38.8	13.8	10.0			22.5	23.1	15.7
B16		33.1	11.3	29.4	52.5	41.3	26.9	20.0	31.3			17.5	29.2	12.5
B18		30.0	19.4	22.5	50.0	20.6	29.4	20.6	21.3	46.9	20.0	20.0	27.3	11.1
B20		36.3	41.3	44.4	37.5	50.0	41.3	31.9	25.0	33.1	25.6	35.6	36.5	7.6
B22	49.4	36.3	56.3	26.9	38.1	37.5	40.6	47.5	40.6	50.0	27.5		41.0	9.2
C4	14.4	10.6	13.8	11.3	4.4	5.6	6.9	10.6	5.6	11.3	13.1	11.3	9.9	3.4
C5	13.1	6.3	8.8	6.3	5.6	3.1	8.8	8.8	8.1	8.1	9.4	20.6	8.9	4.4
C6	13.1	6.3	10.6	6.9	8.8	6.9	5.0	12.5	5.0	4.4	15.6	13.1	9.0	3.8
G12	6.9	0.0	6.9	14.4	14.4	28.1	20.0	0.0	0.0	12.5	21.9	15.0	11.7	9.2
G13	6.9		6.9	11.9	11.9	20.6	20.6	11.3	11.3	21.3	20.0		14.3	5.8
TG 20	6.9	8.3	4.4	3.1	5.6	5.0	19.4			5.6	3.8		6.9	4.9
M0	0.0	4.0	0.6	0.6	0.0	0.6	0.6	0.6	4.4	1.9	3.1	0.6	1.4	1.5
M1	5.0	12.0			6.9	5.0	17.5	3.8	5.6	15.0	7.5	16.3	9.5	5.2
M3	4.4	18.0			7.5	6.3	15.0	15.0	5.6	21.3	17.5	17.5	12.8	6.2
M3	1.9	2.0				3.8	15.0	17.5	3.8	11.3			7.9	6.6
M5	4.4	3.0				3.1	21.9	8.8	5.0	6.3			7.5	6.6
R7	10.6		8.1	12.5	12.5	9.4		10.0	10.0	50.6	34.4	34.4	19.3	14.9
R9	15.6	25.0	15.0	20.0	20.0	7.5	25.0	8.8	8.8	18.1	32.5	32.5	19.1	8.6
R11	13.1	21.0	6.9			17.5	25.0	8.1	8.1	25.6	10.0	10.0	14.5	7.2
R13	8.1	13.0	20.6	29.4	29.4	43.1	44.4	14.4	14.4	47.5	11.3	33.8	25.8	14.1
R14	28.8	46.0	18.8				25.0	20.0	20.0	11.3	19.4	11.3	22.3	10.5
R15	21.9	35.0	14.4	15.0	15.0	43.1	23.8	10.6	10.6	19.4	52.5	10.0	22.6	13.8
R17			25.0	32.5	32.5	41.3	36.9			37.5	18.8	15.6	30.0	9.3
R19			33.8	30.0	30.0	40.0	36.9			60.6	30.6	20.0	35.2	11.8
R21	8.8	14.0	31.3	40.6	40.6	42.5	1.3	43.8	43.8	51.9	28.8	18.8	30.5	16.2
R23	8.1	13.0		33.1	33.1	38.1	43.1	13.1	13.1	16.9	33.8	53.1	27.1	0.0
R25							10.6						10.6	0.0
Ch Avg	11.9	16.7	16.1	18.8	22.1	21.5	24.9	16.0	14.2	23.6	22.9	19.8	**Ch Avg**	**19.1**
Ch Stdev	10.5	12.9	13.1	12.3	16.1	16.7	14.2	11.0	11.1	17.2	13.2	11.8	**stdev**	**14.0**
CM1	3.1	3.1	1.3	1.3	0.0	0.6	2.5	0.0	3.1	1.9	1.3	5.6	2.0	1.6
CM1.2	1.9	0.6	0.6	1.3	0.0	1.3	5.0	18.8	2.5	2.5	1.3	4.4	3.3	5.1
CM5			3.8	9.4	10.0	6.9	7.5	22.5	7.5	30.0	17.5	18.1	13.3	8.4
CR8	9.4	13.1	6.9	9.4	10.0	6.9		12.5	8.8	36.3	13.8	29.4	14.2	9.6
CR9	11.3	11.3	8.1	8.1	17.5	6.9	22.5	26.9	10.0	8.1	13.8	19.4	13.6	6.5
CR9.2		14.4	7.5	5.0	18.1	13.8	21.3	20.0	8.8	15.6	24.4	25.0	15.8	6.7
CR13	18.1	10.0	9.4	4.4	29.4	19.4	21.9	19.4	19.4	39.4	22.5	20.0	19.4	9.2
CR14		15.0	21.9	10.0		36.9	35.6	16.9	10.6	31.3		12.5	21.2	10.8
CR16		28.8	25.6	9.4	11.9	22.5	32.5	9.4	16.3	6.3	31.3	22.5	19.7	9.5
CR17		27.5	9.4	13.8	18.8	15.6	45.0	15.0	22.5	30.0	30.0	23.1	22.8	10.0
CR19			15.0		40.0	33.8	25.0	41.3		33.1	32.5	24.4	30.6	8.7
CR21	34.4	19.4	41.9	30.6	33.8	31.9	31.3	22.5	17.5	58.8	29.4	51.3	33.5	12.2
CR21.2	31.3	19.4	41.3	39.4	39.4	33.8	32.5	28.8	31.3	26.9	19.4	28.1	30.9	7.1
CR22	15.0	9.4		58.1	20.6	23.8	16.3	27.5	15.6	33.8	27.5	55.0	27.5	16.0
CR24							36.3	33.8					35.0	1.8
CR25							31.3	21.9					26.6	6.6
CR26							28.8	32.5					30.6	2.7
CB11		9.4	8.1	6.9	19.4	10.6	27.5	28.1		17.5	22.5	28.1	17.8	8.6
CB16		19.4	15.0	31.3	23.8	21.9	30.0	3.8	28.1		18.8	19.4	21.1	8.1
CB20	65.0	25.0	11.9	28.1	38.1	55.6	21.9	39.4	16.3	42.5	36.3		34.5	16.2
Cv Avg	21.0	15.0	14.2	16.6	20.7	20.1	25.0	22.0	14.5	25.9	21.4	24.1	**Cv Avg**	**20.2**
Cv Stdev	16.5	8.4	12.1	15.1	12.1	15.1	11.7	11.3	9.9	16.5	11.3	13.5	**Stdev**	**13.2**
Per Avg	14.6	15.7	15.4	17.9	21.5	21.0	24.9	18.2	14.0	24.4	22.3	21.6	**Gr Avg**	**19.6**
Stdev	14.2	11.4	12.8	13.9	14.7	15.8	12.9	11.4	10.2	16.6	12.0	12.6	**Stdev**	**13.7**

Table A3a. 1995 Chlorophyll-*a* data (CORRECTED).

Station	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Sta Avg	Stdev
B8	1.6	1.4	1.4	1.3	0.9	1.1	3.9	1.1	1.9	2.5	7.5		2.3	1.9
B10	1.6	0.9	0.8	1.1	2.2	2.1	6.1	3.0	2.6	1.8	3.3		2.3	1.5
B12		0.9	1.1	1.4	4.0	2.9	8.5	3.0		2.9	6.4	0.9	3.2	2.5
B14		0.8	1.6	2.5	7.3	6.1	5.8	2.1	1.5			3.4	3.5	2.4
B16		5.0	1.7	4.4	7.9	6.2	4.0	3.0	4.7			2.6	4.4	1.9
B18		4.5	2.9	3.4	7.5	3.1	4.4	3.1	3.2	7.0	3.0	3.0	4.1	1.7
B20		5.4	6.2	6.7	5.6	7.5	6.2	4.8	3.8	5.0	3.8	5.3	5.5	1.1
B22	7.4	5.4	8.4	4.0	5.7	5.6	6.1	7.1	6.1	7.5	4.1		6.1	1.4
C4	2.2	1.6	2.1	1.7	0.7	0.8	1.0	1.6	0.8	1.7	2.0	1.7	1.5	0.5
C5	2.0	0.9	1.3	0.9	0.8	0.5	1.3	1.3	1.2	1.2	1.4	3.1	1.3	0.7
C6	2.0	0.9	1.6	1.0	1.3	1.0	0.8	1.9	0.8	0.7	2.3	2.0	1.4	0.6
G12	1.0		1.0	2.2	2.2	4.2	3.0			1.9	3.3	2.3	2.3	1.0
G13	1.0		1.0	1.8	1.8	3.1	3.1	1.7	1.7	3.2	3.0		2.1	0.9
TG 20	1.0	1.2	0.7	0.5	0.8	0.8	2.9			0.8	0.6		1.0	0.7
M0	0.0	0.6	0.1	0.1	0.0	0.1	0.1	0.1	0.7	0.3	0.5	0.1	0.2	0.2
M1	0.8	1.8			1.0	0.8	2.6	0.6	0.8	2.3	1.1	2.4	1.4	0.8
M3	0.7	2.7			1.1	0.9	2.3	2.3	0.8	3.2	2.6	2.6	1.9	0.9
M3	0.3	0.3				0.6	2.3	2.6	0.6	1.7			1.2	1.0
M5	0.7	0.5				0.5	3.3	1.3	0.8	0.9			1.1	1.0
R7	1.6		1.2	1.9	1.9	1.4		1.5	1.5	7.6	5.2	5.2	2.9	2.2
R9	2.3	3.8	2.3	3.0	3.0	1.1	3.8	1.3	1.3	2.7	4.9	4.9	2.9	1.3
R11	2.0	3.2	1.0			2.6	3.8	1.2	1.2	3.8	1.5	1.5	2.2	1.1
R13	1.2	2.0	3.1	4.4	4.4	6.5	6.7	2.2	2.2	7.1	1.7	5.1	3.9	2.1
R14	4.3	6.9	2.8				3.8	3.0	3.0	1.7	2.9	1.7	3.3	1.6
R15	3.3	5.3	2.2	2.3	2.3	6.5	3.6	1.6	1.6	2.9	7.9	1.5	3.4	2.1
R17			3.8	4.9	4.9	6.2	5.5			5.6	2.8	2.3	4.5	1.4
R19			5.1	4.5	4.5	6.0	5.5			9.1	4.6	3.0	5.3	1.8
R21	1.3	2.1	4.7	6.1	6.1	6.4	0.2	6.6	6.6	7.8	4.3	2.8	4.6	2.4
R23	1.2	2.0		5.0	5.0	5.7	6.5	2.0	2.0	2.5	5.1	8.0	4.1	0.0
R25							1.6						1.6	0.0
Ch Avg	1.8	2.5	2.4	2.8	3.3	3.2	3.7	2.4	2.1	3.5	3.4	3.0	**Ch Avg**	**2.9**
Ch Stdev	1.6	1.9	2.0	1.8	2.4	2.5	2.1	1.7	1.7	2.6	2.0	1.8	**stdev**	**2.1**
CM1	0.5	0.5	0.2	0.2	0.0	0.1	0.4	0.0	0.5	0.3	0.2	0.8	0.3	0.2
CM1.2	0.3	0.1	0.1	0.2	0.0	0.2	0.8	2.8	0.4	0.4	0.2	0.7	0.5	0.8
CM5			0.6	1.4	1.5	1.0	1.1	3.4	1.1	4.5	2.6	2.7	2.0	1.3
CR8	1.4	2.0	1.0	1.4	1.5	1.0		1.9	1.3	5.4	2.1	4.4	2.1	1.4
CR9	1.7	1.7	1.2	1.2	2.6	1.0	3.4	4.0	1.5	1.2	2.1	2.9	2.0	1.0
CR9.2		2.2	1.1	0.8	2.7	2.1	3.2	3.0	1.3	2.3	3.7	3.8	2.4	1.0
CR13	2.7	1.5	1.4	0.7	4.4	2.9	3.3	2.9	2.9	5.9	3.4	3.0	2.9	1.4
CR14		2.3	3.3	1.5		5.5	5.3	2.5	1.6	4.7		1.9	3.2	1.6
CR16		4.3	3.8	1.4	1.8	3.4	4.9	1.4	2.4	0.9	4.7	3.4	2.9	1.4
CR17		4.1	1.4	2.1	2.8	2.3	6.8	2.3	3.4	4.5	4.5	3.5	3.4	1.5
CR19			2.3		6.0	5.1	3.8	6.2		5.0	4.9	3.7	4.6	1.3
CR21	5.2	2.9	6.3	4.6	5.1	4.8	4.7	3.4	2.6	8.8	4.4	7.7	5.0	1.8
CR21.2	4.7	2.9	6.2	5.9	5.9	5.1	4.9	4.3	4.7	4.0	2.9	4.2	4.6	1.1
CR22	2.3	1.4		8.7	3.1	3.6	2.4	4.1	2.3	5.1	4.1	8.3	4.1	2.4
CR24							5.4	5.1					5.3	0.3
CR25							4.7	3.3					4.0	1.0
CR26							4.3	4.9					4.6	0.4
CB11		1.4	1.2	1.0	2.9	1.6	4.1	4.2		2.6	3.4	4.2	2.7	1.3
CB16		2.9	2.3	4.7	3.6	3.3	4.5	0.6	4.2		2.8	2.9	3.2	1.2
CB20	9.8	3.8	1.8	4.2	5.7	8.3	3.3	5.9	2.4	6.4	5.4		5.2	2.4
Cv Avg	3.2	2.3	2.1	2.5	3.1	3.0	3.7	3.3	2.2	3.9	3.2	3.6	**Cv Avg**	**3.0**
Cv Stdev	2.5	1.3	1.8	2.3	1.8	2.3	1.8	1.7	1.5	2.5	1.7	2.0	**Stdev**	**1.9**
Per Avg	2.2	2.4	2.3	2.7	3.2	3.1	3.7	2.8	2.2	3.7	3.3	3.2	**Gr Avg**	**2.9**
Stdev	2.1	1.7	1.9	2.1	2.2	2.4	1.9	1.7	1.5	2.5	1.8	1.9	**Stdev**	**2.0**

Table A4. 1995 Secchi data.

Station	Monitor	wk1	wk2	wk3	wk4	wk5	wk6	wk7	wk8	wk9	wk10	wk11	wk12	Sta Avg	Stdev
B8	Hartman	2.00	2.50	3.00	3.00	2.00	2.50	2.50	2.50	3.00	3.00	2.50	2.00	2.54	0.40
B10	Hartman	2.00	2.50	3.00	3.00	1.50	2.00	2.50	2.00	2.50	2.50	2.50	2.00	2.33	0.44
B12	Hatfield	2.00	2.50	3.00	1.50	2.00	2.50	2.00	1.50	2.00	1.50	2.00	2.25	2.06	0.45
B14	Jamison			3.00	3.50		1.25	2.00	2.50	1.75	1.50	1.25	1.50	2.03	0.80
B16	Jamison			2.50	3.00		0.75	1.00	2.00	1.50	1.00	1.00	1.25	1.56	0.78
B18	Shirey			2.25	2.25	1.50	1.25	1.25	1.75	1.50	1.50	1.00	1.75	1.60	0.41
B20	Shirey			2.00	1.75	1.75	1.25	1.75		1.25	1.25	1.00	1.50	1.50	0.33
B22	Franz	1.25	1.50	1.00	1.00	0.75	0.75	1.75	1.00	0.75	1.00			1.08	0.33
C4	Ostertag	2.25	2.50	2.75	2.75	2.00	3.00	3.00	2.50	2.75	3.00	2.50	2.50	2.63	0.31
C5	Ostertag	2.25	2.25	2.50	2.50	1.75	2.75	2.50	2.50	2.50	2.75	2.75	2.75	2.48	0.29
C6	Ostertag	2.00	2.25	2.50	2.00	1.50	2.25	2.25	2.00	1.75	1.75	2.25	2.75	2.10	0.34
G12	Hatfield	2.50	3.00	3.00	3.00	2.00	2.50	2.00	1.50	1.50	1.75	2.00	2.00	2.23	0.56
G13	Hartman		2.00	3.50	3.00	1.50	1.50	2.00	1.50	1.50	2.00	2.00	2.00	2.05	0.65
M0	McCullough		2.50	3.70	3.10	3.10	3.50	3.80	3.50	3.50	3.20	2.80	3.10	3.25	0.39
M1	Murphy	2.50	2.25	3.00		2.50	4.25	5.00	3.50	3.50	3.50	2.50	3.75	3.30	0.85
M3	Murphy	2.50	2.25	3.00		2.75	3.35	4.00	4.00	3.50	3.50	2.75	3.25	3.17	0.58
M3	Schafer		2.50	2.50	3.00	3.00	2.00	3.75		3.50	2.75	2.50	2.00	2.75	0.58
M5	Schafer		2.50	2.50	3.00	3.00	2.00	3.00			2.50	2.25	2.25	2.56	0.37
R7	Hill	2.25	2.50	2.75	3.50	3.75	2.75	3.25	3.00	3.25	3.25	2.25	3.00	2.96	0.47
R9	Daly	2.00	2.25	2.25	3.00	1.25	2.00	2.75	2.50	2.50	2.75	2.25	2.00	2.29	0.46
R11	Dooley	1.50	1.75	2.00	2.50		1.50	2.00	2.50	2.00	2.50	2.00	2.50	2.07	0.39
R13	Kastner	2.00	2.00	1.60	2.20	1.10	1.70	2.25	2.60	2.40	2.40	2.00	1.80	2.00	0.41
R14	Dooley	1.50	1.75	1.50	2.50		1.50	2.00	2.00	2.00	2.00	2.00	2.25	1.91	0.32
R15	Ollweiler		1.50	1.75	2.25	1.75	1.25	1.80	1.80	1.50	2.00	1.75	1.50	1.71	0.27
R17	Dugan			1.50	1.20	1.10	1.40		2.00	1.70	1.60	1.90	1.80	1.58	0.31
R19	Dugan			1.50	1.20	1.00	1.20		1.80	1.70	1.60	1.80	1.70	1.50	0.30
R21	Bray	1.25	1.50	1.25	1.25		1.25	1.75	1.50	1.75	2.00	1.75	1.50	1.52	0.26
R23	Bogsrud		1.00	1.50		1.50	0.75	1.50	1.50	1.25	1.50	1.50	1.50	1.35	0.27
R31	Bay Rock														
Ch Per Avg		1.98	2.15	2.37	2.44	1.92	1.95	2.44	2.22	2.16	2.20	2.03	2.15	**Ch Avg**	**2.17**
Stdev		0.41	0.47	0.71	0.75	0.77	0.89	0.92	0.72	0.80	0.75	0.53	0.62	**Stdev**	**0.73**
CM1	McCullough		2.70	3.50	3.00	3.20	2.50	3.00	3.50	3.10	3.50	3.20	3.00	3.11	0.32
CM1.2	McCullough		2.20	3.10	3.20	3.80	2.50	3.20	3.20	3.10	3.10	3.30	2.70	3.04	0.43
CM5	Hill	2.75	3.00	2.75	3.50	3.50	3.00	3.50	3.50	3.00	3.00	2.25	2.75	3.04	0.40
CR8	Hill	2.25	2.75	2.50	3.50	3.50	2.75	3.00	3.25	3.50	3.25	2.25	3.00	2.96	0.46
CR9	Daly	2.00	2.00	2.25	3.00	1.75	1.75	2.50	2.50	2.50	3.00	2.00	2.00	2.27	0.43
CR9.2	Daly	2.25	2.00	2.50	2.50	1.75	1.75		2.50	2.50	2.50	2.00	2.00	2.20	0.31
CR13	Kastner	1.80	1.80	1.80	3.00	1.00	1.60	2.10	2.50	2.50	2.20	2.00	1.60	1.99	0.52
CR14	Dooley	1.00	1.50	1.25	1.75		0.75	1.50	1.75	1.75	1.50	1.75	2.00	1.50	0.37
CR16	Ollweiler		1.75	1.75	1.75	1.50	1.00	1.80	1.70	1.75	2.25	1.75	1.50	1.68	0.30
CR17	Ollweiler		1.50	1.75	1.75	1.50	1.25	1.50	1.60	1.50	1.50	1.75	1.50	1.55	0.15
CR19	Dugan			1.30	1.10	1.00	1.50	2.00	2.00	1.70	1.90	2.00	1.60	1.61	0.38
CR21	Bray	1.25	1.50	1.25	1.00	1.00	1.50	1.75	1.75	1.75	2.00	1.75	1.50	1.50	0.32
CR21.2	Bray	1.25	1.50	1.25	1.00	1.00	1.50	1.50	1.50	1.50	1.75	1.75	1.50	1.42	0.25
CR22	Bogsrud		1.00	1.50		1.00	0.75	1.50	1.50	1.50	1.50	1.50	1.50	1.33	0.29
CB11	Hatfield	2.50	3.00	3.00	2.00	2.00	2.50	2.50	2.00	2.00	1.75	2.50	2.50	2.35	0.41
CB16	Jamison			3.00	2.75		1.00	1.50	2.00	1.50	1.25	1.25	1.50	1.75	0.70
CB20	Franz	1.75	1.25	1.50	1.25	1.00	1.25	1.50	1.50	1.50	1.25			1.38	0.21
Cv Per Avg		1.73	1.80	1.94	2.05	1.74	1.56	2.04	2.07	1.98	2.04	1.92	1.87	**Cv Avg**	**2.06**
Stdev		0.66	0.68	0.74	0.90	0.95	0.66	0.69	0.71	0.67	0.71	0.57	0.58	**Stdev**	**0.73**

Table A5. 1995 Bacteria (fecal coliform) data.

Site	Site	May 20	July 3	July 24	Avg
Palmer's	11	6	0	4	3.3
	11	6	221	23	83.3
	11	15	176	14	68.3
	Avg	9	132	14	
	12	2	246	31	93.0
	12	4	267	31	100.7
	12	6	234	4	81.3
	Avg	4	249	22	
	13	0	258	13	90.3
	13	0	172	6	59.3
	13	0	240	2	80.7
	Avg	0	223	7	
Pelican Point	21	3	42	11	18.7
	21	0	26	6	10.7
	21	0	15	2	5.7
	Avg	1	28	6	
	22	2	27	2	10.3
	22	1	50	0	17.0
	22	1	31	0	10.7
	Avg	1	36	1	
	23	0	29	1	10.0
	23	0	36	1	12.3
	23	0	2	0	0.7
	Avg	0	22	1	
SML Dock	31	1	195	88	94.7
	31	0	202	35	79.0
	31	0	156	22	59.3
	Avg	0	184	48	
	32	1	42	13	18.7
	32	1	64	57	40.7
	32	0	52	42	31.3
	Avg	1	53	37	
	33	4	174	54	77.3
	33	1	186	3	63.3
	33	0	96	89	61.7
	Avg	2	152	49	
Confluence	41	0	6	2	2.7
	41	0	7	3	3.3
	41	0	20	38	19.3
	Avg	0	11	14	
	42	0	8	2	3.3
	42	0	21	1	7.3
	42	0	31	0	10.3
	Avg	0	20	1	
	43	0	17	13	10.0
	43	0	9	34	14.3
	43	0	20	6	8.7
	Avg	0	15	18	

Site	Site	May 20	July 3	July 24	Avg
Forest Cove	51	0	6	0	2.0
	51	0	12	1	4.3
	51	0	8	0	2.7
	Avg	0	9	0	
	52	0	8	0	2.7
	52	0	4	0	1.3
	52	0	2	0	0.7
	Avg	0	5	0	
	53	0	2	1	1.0
	53	0	18	0	6.0
	53	0	5	0	1.7
	Avg	0	8	0	
Fairway Bay	61	2	15	2	6.3
	61	2	13	2	5.7
	61	0	12	1	4.3
	Avg	1	13	2	
	62	0	8	1	3.0
	62	0	21	2	7.7
	62	0	23	5	9.3
	Avg	0	17	3	
	63	0	29	1	10.0
	63	2	8	0	3.3
	63	0	19	2	7.0
	Avg	1	19	1	
Shoreline	71	5	81	9	31.7
	71	2	5	2	3.0
	71	2	388	0	130.0
	Avg	3	158	4	
	72	0	24	14	12.7
	72	2	84	14	33.3
	72	1	17	16	11.3
	Avg	1	42	15	
	73	0	0	10	3.3
	73	0	177	9	62.0
	73	0	46	6	17.3
	Avg	0	74	8	
SML Yacht Club	81	2	17	31	16.7
	81	3	12	152	55.7
	81	1	4	116	40.3
	Avg	2	11	100	
	82	1	108	16	41.7
	82	0	78	18	32.0
	82	0	5	23	9.3
	Avg	0	64	19	
	83	0	7	178	61.7
	83	0	48	125	57.7
	83	0	24	168	64.0