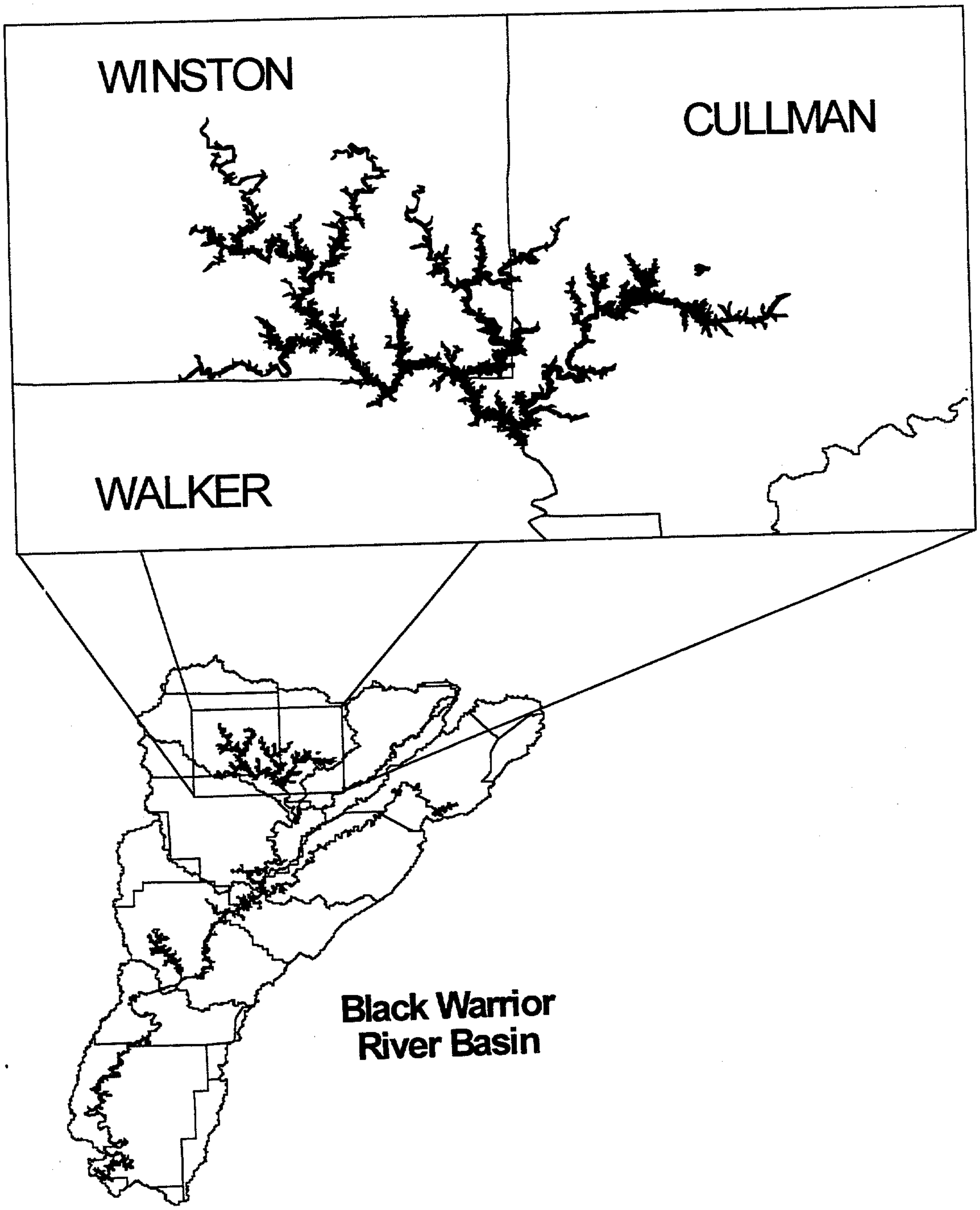
LEWIS SMITH LAKE
PHASE I DIAGNOSTIC/FEASIBILITY
FINAL REPORT



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LEWIS SMITH LAKE

Phase I Diagnostic/Feasibility Study

FINAL REPORT

June, 1998

Preface

A 70% federal and 30% state matching grant to the state of Alabama provided funding for this study. This grant was made available through the Clean Water Act Section 314 nationally competitive Clean Lakes Program. Federal funding was administered through the United States Environmental Protection Agency and Auburn University provided the matching funds through cooperative agreement with the Alabama Department of Environmental Management.

This report includes results from a comprehensive water quality study. Comments or questions related to the content of this report should be addressed to:

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LEWIS SMITH LAKE

PHASE I DIAGNOSTIC/FEASIBILITY STUDY

FINAL REPORT

1 November 1997

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EXECUTIVE SUMMARY

DIAGNOSTIC STUDY

Lewis Smith Lake is located in northwest Alabama in Cullman, Walker and Winston counties. The lake is an Alabama Power Company Reservoir constructed for power generation. The dam is located on the Sipsey Fork of the Mulberry Fork of the Black Warrior River approximately 19.3 km northeast of Jasper, Alabama. Operation began in 1961 and since that time the reservoir has been utilized for power development, flood control and recreational purposes. Nearest municipalities include Jasper and Cullman, Alabama. The Water Works and Sewer Board of the city of Birmingham, only 40 km to the SE, has a raw water intake located approximately one quarter mile (km) downstream of Smith Dam. This source is used for industrial and public water supply.

Normal pool is maintained at 155.5 m msl. Drawdown begins 1 July and is usually completed by 1 December. Drawdown results in a winter pool elevation of 151.2 m msl, an annual fluctuation of 4.3 m. Average depth at full pool is 19.9 m and during drawdown 20.1 m. Reservoir volume is 171,470.4 ha-m at full pool and 138,619.6 ha-m at drawdown. At full pool the lake is 8,580 ha and has a mean hydraulic retention time of 435 days. Water-use classification for the lake is Swimming/Fish and Wildlife throughout and Public Water Supply near the dam.

Although lacking significant point sources of pollution, Smith Lake received waters from watersheds with substantial amounts of nonpoint source pollution. Strip coal mining, agricultural and forestry operations and lakeshore residential development all influenced water quality of the lake (Bayne et al. 1987). Agricultural development in the lake basin has been particularly strong with poultry, beef cattle and hog rearing operations leading the way. By the mid-1980's, concern among local residents that water quality of Smith Lake was being degraded led to a special appropriation by the Alabama Legislature to fund an investigation of the lake. Auburn University's Department of Fisheries and Allied Aquacultures, working through a Cooperative Agreement with the Alabama Department of Environmental Management, undertook a one-year limnological study of Lewis Smith Lake beginning in

January 1986 (Bayne et al. 1987). The primary objective of the study was to characterize the existing water quality and biological condition of the lake so that future changes in lake conditions could be detected. Additionally, efforts were made to identify lake areas that showed any impact resulting from watershed activities.

Bayne et al. (1987) concluded that Smith Lake was a relatively healthy oligotrophic reservoir in 1986. Drought conditions that existed during that year may have limited nonpoint nutrient loading of the lake resulting in reduced algal biomass and primary productivity. Concern was expressed in regards to the poor buffering capacity (low total alkalinity) and acid waters of the lake with a warning that further acidification could harm lake biota. With limited prior limnological data available for comparison, water quality and trophic trends were undetectable, and further study of the lake was recommended.

From November 1994 through October 1995, as part of a Phase I, Clean Lakes, Diagnostic/ Feasibility Study, Lewis Smith Lake was examined to assess current limnological condition. The study was conducted by Auburn University (AU) under contract with the Alabama Department of Environmental Management (ADEM). Others providing data or information included in this lake assessment were: U.S. Environmental Protection Agency (EPA), Alabama Power Company, ADEM and the Alabama Public Health Department.

Meteorological conditions can affect water quantity and water quality of reservoirs. Drought conditions existed throughout Alabama during the mid-1980's resulting in above normal temperatures (+2.1°C) and below normal rainfall (-11.2 cm) in the vicinity of Smith Lake in 1986. Meteorological conditions were nearer normal in 1995 with mean annual temperatures just below normal (-0.2°C) and rainfall somewhat above normal (+2.7 cm). Mean daily inflow and outflow in 1986 averaged less than 50% of the inflow and outflow recorded in 1995. Drought conditions that existed in 1986 would be expected to reduce nonpoint source loading of sediment and nutrients to the lake while increasing the hydraulic retention time of the lake.

Smith Lake is a warm monomictic lake that in both 1986 and 1995 stratified thermally ($\Delta T =$ 1.0°C/m depth) prior to the April sampling trip both years and remained stratified through November 1986 and October 1995. Highest water temperatures were measured during the summer and lowest during winter (January) in both 1986 and 1995. In 1995, seasonal mean water temperatures were higher than 1986 values during winter, spring, and summer but were similar during the fall. Mean air temperatures and solar radiation were higher in 1986 than in 1995, so the warmer water of 1995 must have been caused by other conditions, perhaps higher densities of phytoplankton in 1995.

Chemical stratification accompanied thermal stratification of Smith Lake as was evidenced by dissolved oxygen (DO) profiles. DO concentrations declined with water depth and concentrations <1.0 mg/L were commonly encountered even during January 1995 when the lake was not thermally stratified. DO concentrations of 0.0 mg/L were measured on numerous sampling dates in deeper (>30 m) areas of the lake and occasionally at depths as shallow as 10 m.

Specific conductance, a measure of the ionic content of water, ranged from a low of 32.5 µmhos/cm in the Brushy Creek embayment in June 1995 to a high of 53.1 µmhos/cm in Ryan Creek embayment in January 1995. Specific conductance is a crude indicator of natural fertility since increases in ionic content are usually accompanied by increases in plant nutrients. Mainstem Alabama reservoirs were found to have specific conductance values ranging from about 23 µmhos/cm to 200 µmhos/cm (Bayne et al. 1989). Smith Lake ranked in the lower half of the Alabama range indicating that it was one of the less fertile lakes in the state. However, when annual mean specific conductance measured at 2 m was compared statistically for 1986 and 1995 using an analysis of variance (ANOVA) and Tukey's Studentized Range Test (Tukey's Test), conductance was higher ($P<0.05$) in 1995 at every sampling station. Lake fertility seems to have increased between 1986 and 1995. This may reflect a general trend of increasing fertility of the lake or it may have resulted from higher rainfall and watershed runoff that occurred in 1995. Likely both of these factors are responsible for the increase.

Total alkalinity, the concentration of bases in water (expressed as mg/L $CaCO_3$), primarily composed of bicarbonate (HCO_3^-) and carbonate ($CO_3^=$) ions, usually increases as basin soil fertility increases. In a recent study, total alkalinity of large mainstream impoundments of Alabama varied from a low of 7 mg/L to a high of 67 mg/L (Bayne et al. 1989). At the mainstem sampling stations in Smith Lake, total alkalinity varied from a low of 7.5 mg/L (as $CaCO_3$) during the spring of 1995 to a high of 20 mg/L in the summer of 1995. In the summer and fall of 1948 prior to impoundment of the Sipsey Fork, total alkalinity of the river near Double Springs, Alabama ranged between 8 mg/L and 16 mg/L as $CaCO_3$ (Alabama Water Improvement Advisory Commission 1949). This variable has changed little in 48 years and indicates that basin soils are relatively infertile and low in soluble forms of carbonates. Alkalinities of tributary embayments were similar to alkalinities measured at the nearest mainstem sampling station.

Total hardness is a measure of the divalent, alkaline earth metal content of water. Calcium (Ca^{++}) and magnesium (Mg^{++}) are normally the most abundant metals in soils of the eastern United States and are generally associated with carbonate minerals responsible for alkalinity of water. Seasonal means and ranges of total hardness at a given sampling station were quite similar to alkalinity means and ranges.

Carbonate minerals function as natural chemical buffers that prevent wide fluctuations in pH of lake water. The low alkalinity of Smith Lake waters resulted in a range of pH from 6.7 to 9.2 (<2 m depth) during 1986. In 1995 the pH range was from 6.5 to 9.0 (2 m depth). Increases in fertility and productivity of Smith lake could cause even more dramatic swings in pH that could be detrimental to biota.

Nitrogen and phosphorus are plant nutrients that are required in relatively high concentrations to support plant growth. Nitrogen concentrations normally exceed phosphorus concentrations by an order of magnitude or more (Wetzel 1983). Of the macronutrients, phosphorus is usually in shortest supply and therefore is the element most often limiting to plant growth in freshwater ecosystems. In some cases, phosphorus concentrations, relative to nitrogen, are high and nitrogen availability becomes limiting. This usually occurs at total nitrogen to total phosphorus ratios <16:1 (Porcella and Cleave 1981).

Nitrogen is available to plants as nitrates (NO_3^-) or as the ammonium ion (NH_4^+). Nitrogen concentrations were variable temporally and spatially in both 1986 and 1995. In general, total inorganic nitrogen (TIN = NH_3-N + NO_2-N + NO_3-N) concentrations were highest in winter and spring and declined during summer and fall in 1986 and 1995. The Ryan and Rock creek embayments frequently had the highest seasonal mean TIN concentrations. Smith Lake had relatively high concentrations of NO_3-N, comparable to levels reported in two of the more eutrophic reservoirs in Alabama (Bayne et al. 1993a, Bayne et al. 1995).

Phosphorus in water is routinely reported as total phosphorus (TP) (all forms of phosphorus expressed as P) and soluble reactive phosphorus (SRP) the major component of which is orthophosphate (PO_4^{3-} expressed as P), the most common and abundant form of phosphorus available to plants. Both TP and SRP were somewhat higher in 1986 than in 1995. In 1995, seasonal mean TP ranged between 0 μg/L and 16 μg/L on the mainstem of the lake and between 0 μg/L and 15 μg/L in the tributary embayments. SRP seasonal mean concentrations ranged from 0 μg/L to 2 μg/L throughout the lake. The relatively long hydraulic retention time of Smith Lake (435 days) and great depths results in rather rigid thermal and chemical stratification. During the growing season anaerobic conditions in deeper water were common and phosphorus mobilization from sediment may be a significant source of phosphorus loading in this lake. Destratification would be required to bring the phosphorus into the photic zone.

During the summer growing season of 1995 the ratio of total nitrogen (TN) to total phosphorus (TP) at mainstem sampling stations varied from 16 to 58. Tributary embayment ratios ranged from 18 to 65. Optimum TN to TP ratios for phytoplankton growth is in the range of 11 to 16 (Porcella and Cleave

1981). Phytoplankton growth in Smith Lake was phosphorus limited at all locations with the possible exception of the most upstream stations 9 and 7. The relatively high NO_3-N concentrations found at downstream locations on the mainstem (stations 1 and 5) and in embayments of Rock and Ryan creeks (stations 3 and 2) are responsible for some of the higher TN:TP ratios. Nonpoint sources of pollution are suspected of causing these elevated nitrogen levels. Any increase in bioavailable phosphorus to Smith Lake will likely increase, perhaps dramatically, the algal productivity of the lake.

In an effort to identify sources of contaminants entering Smith Lake, chlorides (Cl^-) were measured in composite, photic zone samples collected for water quality analysis. Elevated Cl^- levels are thought to indicate the presence of animal (particularly human) waste introduced from the watershed. Seasonal mean Cl^- concentrations were always highest at downstream stations 1, 2 and 3. These same stations usually had the highest seasonal mean NO_3-N concentrations. Stations 2 and 3 were embayments of Ryan and Rock creeks, respectively, and station 1 was the dam forebay. Intensive agricultural operations (e.g. poultry and beef cattle) on the watersheds of Ryan, Rock and Crooked creeks are known sources of animal waste (USDA 1991). The relatively high seasonal mean Cl^- and NO_3-N concentrations measured at mid reservoir station 5 may reflect the influence of housing development along the shoreline of the lake. Mainstem and tributary stations upstream of station 5 usually had Cl^- and NO_3-N concentrations lower than those measured at station 5. Septic systems of lakeshore homes are suspected of releasing domestic sewage or nutrients into the lake. Shallow soil depth to bedrock and steep slopes around the lake shore create problems for effective septic tank function (Personal Communication, J. Frutiger, Cullman Co. Health Dept.).

Concentrations of select metal ions were measured in photic zone composite samples collected 15 August 1995 at all sampling locations. The following metals (detection limit) were not present at concentrations higher than instrument detection limits: Iron (20 µg/L) and manganese (20 µg/L) were found at concentrations ranging from 31 to 76 μg/L and 22 to 102 μg/L, respectively. Highest concentrations of both metals were found in Brushy Creek embayment (station 8).

Phytoplankton densities in 1995 ranged from a low of 357 organisms/ml at station 1 during the spring 1995 to 2,294 organisms/ml at station 3 during the summer 1995. Highest densities occurred during the summer and fall and lowest densities during the spring. Seasonal mean densities were usually similar among stations within a season and mean embayment densities were similar to nearby mainstem station densities. In 1995, seasonal mean phytoplankton densities were about twice what they were at the same locations in 1986. On an annual basis, mean densities were significantly ($P < 0.05$) higher in 1995 at all locations except at mainstem at Duncan's Creek (station 5) and mainstem downstream from the confluence of Sipsey Fork and Brushy Creek (station 7).

Numerical dominance was shared by green algae (Division Chlorophyta) and diatoms (Division Chrysophyta) at mainstem sampling stations. Diatoms were generally more abundant in spring months and green algae more abundant in summer and fall months. The blue-green algae (Division Cyanobacteria) were the third most abundant algal Division. This pattern of algal dominance is common in Alabama lakes (Bayne et al. 1993a, 1993b, and 1995). Fifty-four algal taxa were identified from samples taken from Smith Lake. These taxa are generally common constituents of lake phytoplankton communities in this region (Taylor et al. 1979). Among the dominant phytoplankton genera, all occur with great frequency in reservoirs of the southeastern United States (Taylor et al. 1979).

Phaeophytin-corrected, chlorophyll a concentration is an indicator of phytoplankton biomass and is a variable often used to determine the trophic status of lakes in the absence of macrophytes (Carlson 1977 and EPA 1990). Corrected chlorophyll a concentrations from about 6.4 to 56 μg/L are indicative of eutrophic waters (Carlson 1977). Waters having concentrations > 56.0 μg/L are considered hypereutrophic and waters with concentrations of from 1.0 to <6.4 μg/L are classified as mesotrophic. Corrected chlorophyll a concentrations in Smith Lake in 1995 ranged from a low of 0.60 μg/L in the

Ryan Creek embayment (station 2) in the winter to a high of 4.54 μg/L in the Rock Creek embayment (station 3) in the summer. With the exception of the 0.60 μg/L concentration, the lake lies well within the mesotrophic range. Seasonal mean chlorophyll a concentrations were highest in summer and fall and lowest in winter and spring.

In 1986 chlorophyll a was not corrected for phaeopigments (Bayne et al. 1987). In order to compare the 1995 chlorophyll a data with the 1986 data uncorrected chlorophyll a concentrations were reported for both years. With one exception (station 2 in January) mean chlorophyll a concentrations were higher at every station during all seasons in 1995. Annual means for each sampling station were significantly ($P < 0.05$) higher in 1995 than in 1986. Water clarity, as measured by Secchi disk visibility, was also statistically ($P < 0.05$) greater in 1986 than in 1995. Clarity usually decreases as phytoplankton biomass increases.

Phytoplankton primary productivity integrates a number of environmental variables in addition to algal biomass into an expression of system productivity. Productivity rates have also been used to trophically categorize lakes. Lakes with productivities ranging from 250-1000 mgC/m^2•day are considered mesotrophic and values > 1000 mgC/m^2•day are considered eutrophic (Wetzel 1983).

Mean primary productivity measured during the growing seasons of 1986 and 1995 indicates that Smith Lake has remained in the mesotrophic (250-1000 mgC/m^2•day) range on most sampling occasions. However, a statistical analysis of the volumetric (mgC/m^3•hour) data for the 2 years revealed a significant ($P < 0.05$) increase in productivity from 1986 to 1995 at two (stations 5 and 7) of the three (1, 5 and 7) stations examined during the growing season (May through September) of both years. This is consonant with the significant ($P < 0.05$) changes reported in water clarity, phytoplankton densities, and chlorophyll a concentrations from 1986 to 1995.

The Algal Growth Potential Test (AGPT) determines the total quantity of algal biomass supportable by the test waters and provides a reliable estimate of the bioavailable and limiting nutrients

(Raschke and Schultz 1987). In Smith Lake it appears that more plant nutrients are entering the lake from the mid reservoir area downstream to the dam. Distributional patterns of chlorides and nitrates within the lake support this observation. Nonpoint source nutrient enrichment is likely responsible for the increases in nutrients in this area of the lake. Two suspected sources of nutrients are animal waste entering some of the tributary streams and human waste entering the lake from malfunctioning septic systems. In general, phosphorus relative to nitrogen seemed to be in shorter supply downstream and earlier in the growing season. Nitrogen was relatively more important upstream and later in the growing season. Internal phosphorus loading caused by the release of phosphorus from anaerobic sediments as the growing season progresses may be partly responsible for increase in influence of nitrogen later in the growing season. Additional plant nutrients, particularly phosphorus, could increase algal biomass in Smith Lake and continue the cultural eutrophication that has occurred in this lake over the past 10 years.

FEASIBILITY STUDY

Cultural Eutrophication

Lewis Smith Lake is not use-threatened or use-impaired (ADEM 1996) although water quality concerns have been expressed (Bayne et al. 1987 and ADEM 1996). One area of concern is cultural eutrophication that has resulted in increased phytoplankton biomass and decreased visibility within the water column.

There were relatively few permitted point-source dischargers in the Smith Lake basin. Nevertheless, cultural eutrophication of Smith Lake was evident when the 1986 study results were compared to 1995 data. Phytoplankton densities and biomass more than doubled during this 10 year period. In addition, algal primary productivity was higher and Secchi disk visibility (water clarity) was lower in 1995 than in 1986. Based on the Carlson Trophic State Index using the mean photic zone chlorophyll a concentration, Smith Lake was borderline oligotrophic/mesotrophic in 1986 and was borderline mesotrophic/eutrophic in 1995 (Carlson 1977). Perhaps some of the increased algal biomass present in 1995 was caused by greater rainfall and watershed runoff during that year than occurred in the drought year of 1986. Trophic state trend data for Smith Lake reveal a tendency for algal biomass to increase during years of higher rainfall (ADEM 1995 and ADEM 1996).

From 1991 through 1995 water quality was examined in the upstream embayments of Crooked, Rock and Ryan creeks (D. R. Bayne, unpublished data). Water samples were collected monthly during the growing season (April - October) and analyzed for chlorophyll a and Algal Growth Potential (maximum standing crop of algal biomass). Algal biomass was extremely variable in these waters apparently because nutrients needed to support algal growth were being supplied intermittently from nonpoint sources (mainly animal waste). Crooked and Rock creeks had growing season mean chlorophyll a concentrations in the eutrophic range and Ryan Creek was mesotrophic. Chlorophyll a concentrations in Crooked and Rock creeks were significantly ($P < 0.008$ and $P < 0.0003$, respectively) correlated with 7-day antecedent rainfall in the basins. Algal growth potential in these two creeks frequently exceeded levels considered likely to produce nuisance blooms. Management of animal waste (poultry and beef cattle) in these and other watersheds within the Smith Lake basin affects water quality in the lake.

The intensive animal rearing operations in the Ryan-Crooked-Rock Creeks Hydrologic Unit generate about 1 billion pounds of animal waste annually of which 185 million pounds enters streams and lakes (USDA 1991). This is roughly equivalent to the human waste generated by a city of 1.15 million people. An estimated 2,300 tons of dead poultry must be disposed of each year (USDA 1991).

Algal production in Smith Lake is predominately phosphorus limited. Any bioavailable phosphorus in animal waste that enters Smith Lake will likely result in increased algal growth. Poultry are produced in houses and the accumulated waste and litter in the houses is removed at intervals and spread on nearby pastures and agricultural crops. Waste from cattle is deposited directly on pastures and feed lots. Phosphorus in these wastes can enter surface waters in two ways. Rainfall runoff can cause soil erosion that moves sediment bound (sorbed) phosphorus or phosphorus can be dissolved in runoff and enter surface waters. Until recently, it was believed that phosphorus added to agricultural soils was tightly bound and unless the soil moved, phosphorus was virtually fixed (Sharpley 1997). Now, however, it is clear that the amount of dissolved phosphorus in runoff is dependent upon the amount of phosphorus added to the soil. In essence, soils that receive excessive amounts of phosphorus (animal waste) release increasing amounts of soluble phosphorus to surface and subsurface water even if soil erosion is adequately controlled (Sharpley 1997). Agricultural scientists at Auburn University have shown that the amount of phosphorus in animal waste produced in Winston and Cullman counties exceeds (101-200%) the phosphorus needs for crops grown in those counties (C. W. Wood, Jr., Personal Communication). If cultural eutrophication of Smith Lake is to be controlled, consideration should be given to balancing phosphorus (animal waste) added to croplands with phosphorus needs of those crops.

An additional source of nutrients to Smith Lake is septic tank drainage from lakeshore housing. The geology and soils of the region are not well suited for septic tank function. The most serious problem is the shallow depth from soil surface to bedrock and steep slopes around the lake shore (Personal Communication, J. Frutiger, Cullman Co. Health Dept.). Continued shoreline housing and commercial development around the lake will likely add to the problem.

This study documented a dramatic rise in algal biomass in Smith Lake between 1986 and 1995. Similar increases will likely occur in the future if actions are not taken to limit nutrient enrichment of the lake. Local public participation in an adequate forum should be encouraged and utilized to ensure that the historical multiple uses of Smith Lake are preserved and maintained. Once this input is received, management alternatives can be explored to limit further nutrient enrichment and algal growth in Smith Lake. One alternative might be the establishment of numerical water quality standards that address nutrient enrichment.

Control of nutrients entering Smith Lake from land-applied animal waste disposal will require that state and federal agencies work together to assure that best management practices are effectively utilized. In view of the quantity of manure being produced relative to crop needs, it may be necessary to transport excess manure out of the Smith Lake drainage basin or perhaps apply the manure to forest lands within the basin. The long term solution to the septic tank problem is community wastewater treatment for businesses and homes around the lake. Until this can be accomplished, existing septic tank systems near the lake should be inspected at regular intervals to assure proper function. Any new septic systems should be properly designed, constructed and maintained and placed as far away from the lake shore as possible.

Lake Acidification

Total alkalinity of water is a measure of the concentration of titratable bases and is expressed as equivalent calcium carbonate. Carbonate ($CO_3^=$) and bicarbonate (HCO_3^-) ions in water are responsible for most of the total alkalinity measured in waters of this region. These ions provide a source of carbon for aquatic photosynthesis and serve to raise the pH and chemically buffer the waters to prevent wide fluctuations in pH.

Total alkalinity of natural waters varies from <5.0 to several hundred mg/l as $CaCO_3$ (Boyd 1979). Smith Lake waters are low in alkalinity and therefore, relatively incapable of preventing pH changes should acidic or basic substances enter the lake. This acidic, poorly buffered condition is not a recent development. Measurements of pH and total alkalinity were taken in the Sipsey River and reported by the Alabama Water Improvement Advisory Commission (1949). Measurements of pH in the river during September and October 1948 ranged from 5.0 to 6.8. Alkalinities were reported from 0.0 mg/l to 15.0 mg/l as $CaCO_3$.

Surface waters with total alkalinity concentrations below 10 mg/L are considered highly sensitive to acid contamination (Mayer et al. 1984). Alkalinity of Smith Lake waters usually ranged between 10 and 15 mg/L as $CaCO_3$ but occasionally fell below 10 mg/L. Any acid contamination of Smith Lake will further reduce total alkalinity and pH will decrease. As pH declines below 6.5 fish growth rate slows, at a pH of about 5.0 reproduction ceases and below pH of about 4.0 fish die (Boyd 1979). Other aquatic organisms react in a similar way although some are not as tolerant as fish to low pH. Some valuable fish food organisms begin to disappear below pH 6.0 (Mayer et al. 1984). Indirectly, low pH can result in higher concentrations of heavy metals that become toxic to fish and wildlife. At higher hydrogen ion concentrations metals bound in soil and sediment are mobilized to the water where they can be accumulated by the biota (Mayer et al. 1984). In the 1986 Smith Lake study (Bayne et al. 1987) concentrations of chromium, copper, iron, manganese and zinc exceeded critical levels considered acceptable by the U. S. Environmental Protection Agency (EPA 1986).

Smith Lake usually met the pH criteria (6.0-8.5) for waters use-classified as fish and wildlife by the Alabama Department of Environmental Management. However, most of the water column pH values were <7.0 during 1986 and 1995 and values <6.0 were recorded on occasion. These relatively low pH values together with excessive heavy metal concentrations measured in 1986 dictate the following special precautions be taken in this acid sensitive lake:

1.01 all active and inactive mining sites within the Smith Lake Basin should be inventoried to identify sources of acid mine drainage;

1.02 pH of precipitation in the vicinity of Smith Lake should be monitored to determine if any changes in pH occur, and;

1.03 pH of Smith Lake waters should be measured throughout the water column (2 m intervals) at five mainstem and four tributary embayment stations at least once each growing season (April - October).

These actions will help identify any sources of acid contamination of Smith Lake and aid in preventing changes in pH that might be detrimental to fish and other aquatic organisms.

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PART I. DIAGNOSTIC STUDY

1.0 LAKE IDENTIFICATION

Lewis Smith Lake is located in northwest Alabama in Cullman, Walker and Winston counties. The lake is an Alabama Power Company Reservoir constructed for power generation. The dam is located on the Sipsey Fork of the Mulberry Fork of the Black Warrior River approximately 19.3 km northeast of Jasper, Alabama. Operation began in 1961 and since that time the reservoir has been utilized for power development, flood control and recreational purposes. Nearest municipalities include Jasper and Cullman, Alabama. The Water Works and Sewer Board of the city of Birmingham, only 40 km to the SE, has a raw water intake located approximately one quarter mile (km) downstream of Smith Dam. This source is used for industrial and public water supply.

Morphometric characteristics of Lewis Smith Lake appear in Table 1-1. Hydroelectric dam and turbine specifications appear in Table 1-2. The lake is composed of the mainstem and numerous tributary streams. Normal pool is maintained at 155.5 m msl. Drawdown begins 1 July and is usually completed by 1 December. Drawdown results in a winter pool elevation of 151.2 m msl, an annual fluctuation of 4.3 m. Average depth at full pool is 19.9 m and during drawdown 20.1 m. Reservoir volume is 171,470.4 ha-m at full pool and 138,619.6 ha-m at drawdown.

The Alabama Department of Environmental Management water-use classification for Lewis Smith Lake is as follows:

> From Lewis Smith Dam to three miles upstream from Lewis Smith Dam: Public Water Supply/Swimming/Fish and Wildlife.
>
> From three miles upstream from Lewis Smith Dam to reservoir limits: Swimming/Fish and Wildlife
>
> From Lewis Smith Lake limits to Sipsey Fork and tributary from Sandy Creek: Fish and Wildlife
>
> From Sipsey Fork and tributary from Sandy Creek to its source: Outstanding National Resource Water.

Table 1-1. Morphometric characteristics of Lewis Smith Lake.

Drainage area	2,445 km^2
Surface area	8,580 ha
Surface area at drawdown	6,886 ha
Shoreline length	805 km
Full reservoir length	56.3 km
Maximum depth at dam	80.5 m
Average depth at full pool	19.9 m
Normal pool elevation	155.5 m msl
Normal pool volume	1,714 x 10^6 m^3
Drawdown pool elevation	151.2 m msl
Drawdown pool volume	1,386 x 10^6 m^3
Average depth at drawdown	20.1 m
Hydraulic retention time	435 days

[1] mean sea level

Table 1-2. Lewis Smith Lake hydroelectric dam and turbine specifications.

Location	
Town	Near Jasper, Alabama
County	Cullman and Walker
River	Black Warrior
Construction started	November 25, 1957
In-service date	September 5, 1961
Dam	
Type	Rock fill
Maximum height	91.4 m
Spillway gates	Fixed crest spillway @ elevation 159.1 m msl
Hydraulic Turbines	
Number	2
Type	Francis type; 111,500 horsepower
Water discharge (ea.)	5,100 cfs

2.0 BASIN GEOLOGY AND DRAINAGE

Smith Lake lies in the Warrior Basin of the Cumberland Plateau section of the Appalachian Plateau physiographic province. The Warrior Basin is characterized by a synclinal submaturely to maturely dissected sandstone and shale plateau of moderate relief (Table 2-1). Hartsells, Wynnville and Albertville soils dominate the more level areas. They have loamy subsoils and fine sandy loam surface layers. Most slopes with these soils are less than 10 percent. More rugged portions of the Appalachian Plateau are dominated by Montevallo and Townley soils. These soils have either a channey loam, or a clayey subsoil and silt loam surface layers. The Basin is elliptical in shape and is approximately 55 kilometers measured from north to south. East to west the basin measures approximately 75 km. Altitude varies from about 152 meters in the south to 335 meters in the north, with a local relief of 183 meters (U. S. Army Corps of Engineers, 1981).

Table 2-1. Characteristics of soil associations surrounding Lewis Smith Lake and their suitability/limitations for selected uses.

			Characteristics		
Soil Association	Slope and Landscape	Soil Series	Depth	Bedrock	Drainage
Hartsells-Linker-Albertville	Nearly level and gently rolling cultivated fields with hardwood timber along the major drainages	Hartsells	Moderately deep	Sandstone	Well-drained
		Linker	Moderately deep	Sandstone	Well-drained
		Albertville	Deep	Shale	Well-drained
Hartsells-Wynnville-Albertville	Nearly level and gently rolling cultivated fields	Hartsells	Moderately deep	Sandstone	Well-drained
		Wynnville	Deep but has fragipans at about 25"		Moderately well-drained
		Albertville	Deep		Well-drained
Hector-Rockland Limestone-Allen	Steep and very steep wooded slopes and foot slope areas that are open pastureland. The steep slopes have many rock ledges, bluffs and boulders.	Hector	Shallow	Sandstone	Well-drained
		Allen	Deep		Well-drained
Montevallo-Townley Enders	Steep and very steep wooded mountainous slopes with Virginia Pine being dominant	Montevallo	Shallow	Shale	Well-drained
		Townley	Moderately deep	Shale	Well-drained
		Enders	Deep		Well-drained

U. S. Army Corps of Engineers. 1981.

Table 2-1 (Cont'd)

Soil Association	Surface Texture	Dominant Slope (%)	Suitability/Limitations					
			Cropland	Pasture	Woodland	Septic Tanks	Roads	Building
Hartsells-Linker-Albertville	Loamy Loamy Loamy	2-15	Good	Good	Good	Severe: depth to rock	Moderate: depth to rock	Moderate slope, depth to rock
Hartsells-Wynnville-Albertville	Loamy	0-15	Good	Good	Good	Severe: depth to rock	Moderate: depth to rock	Moderate: slope, depth to rock
Hector-Rockland Limestone-Allen	Gravely, loamy, loamy	25-40	Poor: slope, depth to rock	Poor: slope, droughty	Poor: depth to rock	Severe: depth to rock, slope	Severe: depth to rock, slope	Severe: slope, depth to rock
Montevallo-Townley Enders	Shaly, loamy loamy Gravely, loamy	6-40	Poor: slope, depth to rock	Poor: slope, droughty	Poor: depth to rock	Severe: depth to rock, slope	Severe: slope	Severe: slope

U. S. Army Corps of Engineers. 1981.

3.0 PUBLIC ACCESS

Lewis Smith Lake is a popular recreational lake. Public access is available through free public access areas (4) and user fee access areas (26). These areas include boat ramps, picnic areas, campgrounds and marinas. Many private homes located on the lake also have boat launches for lake access. Frequently utilized user fee access areas included Duncan Bridge Marina, Big Bridge Marina, Rock Creek Marina and Richard's Marina. Tailwater access is also possible at Alabama Power's Dam facility.

4.0 SIZE AND ECONOMIC STRUCTURE OF POTENTIAL USER POPULATION

Smith Lake is bordered by Winston, Cullman and Walker counties. Adjacent counties having potential lake users include Blount, Jefferson and Morgan. According to a recent survey, these counties contributed to the majority of visitors to Smith Lake from 28 July 1994 through 31 July 1995 (FIMS, 1996 draft). Table 4-1 includes population and income data for these counties in the vicinity of Smith Lake. Populations within these counties range from a high of 651,525 in Jefferson county to a low of 22,053 in Winston county. Jefferson county had the highest per capita income while Winston county, adjacent to the lake, had the lowest. Winston county also had the highest percentage of families with incomes below the poverty level.

Business and employment data from counties in the vicinity of Smith Lake are presented in Tables 4-2 and 4-3. Services and retail trade businesses comprised the largest number of business establishments in the area. Wholesale trade was also important. Construction and manufacturing businesses were significant in these counties, but not as high in total numbers. Manufacturing, services and retail trade employed the greatest numbers of people in this area.

Agricultural production data for each county in the vicinity of Smith Lake appear in Table 4-4. According to the Census of Agriculture, Alabama (1992), Cullman county had the highest number of farms and greatest total farm acreage of the counties in the vicinity of Smith Lake. Cullman, Blount and Morgan counties had the most acreage in cropland of the counties near the lake. Several of the counties near Smith Lake are important producers of broilers, cattle, corn and cotton. Cullman county is the leading producer of broilers in the state and ranks high nationally in broiler production.

Table 4-1. Total population and income characteristics of Alabama counties in the vicinity of Smith Lake.

State	County	Total Population (1990)	Per Capita Income (1989)	% Families with Income Below Poverty Level
Alabama				
	Blount	39,248	$10,168	6.6%
	Cullman	67,613	$10,447	15.3%
	Jefferson	651,525	$13,277	16.0%
	Morgan	100,043	$12,830	8.3%
	Walker	67,670	$10,105	5.8%
	Winston	22,053	$9,349	19.8%

U. S. Bureau of the Census. 1990.

Table 4-2. Number of business establishments of Alabama counties in the vicinity of Lewis Smith Lake.

State	County	Total	Agricultural, Forestry, Fishing	Mining	Construction	Manufacturing	Transportation, Public Utilities	Wholesale Trade	Retail Trade	Finance, Insurance, Real Estate	Services	Unclassified Establishments
Alabama												
	Blount	515	6	4	74	47	20	35	145	30	136	18
	Cullman	1,336	16	4	159	114	82	87	373	81	368	52
	Jefferson	17,565	149	62	1,415	907	574	1,758	4,287	1,748	6,057	608
	Morgan	2,439	27	4	216	204	80	190	660	192	767	99
	Walker	1,348	7	35	108	89	92	80	438	92	359	48
	Winston	481	4	2	23	112	32	48	126	26	95	13

U. S. Bureau of the Census. 1990.

Table 4-3. Number of employees for business establishments of Alabama counties in the vicinity of Lewis Smith Lake.

State	County	Total	Agricultural, Forestry, Fishing	Mining	Construction	Manufacturing	Transportation, Public Utilities	Wholesale Trade	Retail Trade	Finance, Insurance, Real Estate	Services	Unclassified Establishments
Alabama												
	Blount	6,472	75	46	332	2,816	246	359	1,163	197	1,225	13
	Cullman	17,656	51	(100-249)	1,211	6,119	618	913	4,849	(500-999)	3,011	17
	Jefferson	332,538	1,024	4,285	35,541	42,727	30,962	27,860	58,630	30,153	100,558	798
	Morgan	36,955	82	(100-249)	2,749	13,747	1,419	2,007	7,030	1,705	8,028	(20-99)
	Walker	15,223	17	2,266	634	2,804	812	630	3,895	780	3,348	37
	Winston	7,958	9	(100-249)	317	5,128	269	409	998	(100-249)	469	2

U. S. Bureau of the Census. 1990.

Table 4-4. Agricultural production of Alabama counties in the vicinity of Lewis Smith Lake.

State	County	Total Farms	Farm Acreage	Total Cropland Acreage	Cattle Sold x 1000	Hogs Sold x 1000	Broilers Sold x 1000	Corn Bushels x 1000	Wheat Bushels x 1000	Soybeans Bushels x 1000	Cotton Bales
Alabama											
	Blount	1,121	137,426	72,311	16	19.8[1]	49,510	298	4.3	44.5	2,387
	Cullman	2,086	196,859	109,606	30.6	16.4	121,253	427	16.2	186	1,209
	Jefferson	387	35,748	18,657	3.4	2.3	647[1]	7	0	D[2]	0
	Morgan	1,129	155,914	93,305	18.5	5.5	23,077	314	110	289.5	5,836
	Walker	430	50,257	25,431	4.3	D[2]	14,741	12.7	0	D[2]	0
	Winston	559	56,680	27,398	7.1	7.9	24,231	29.5	0	D[2]	D[2]

---

[1] Data from 1987 Agricultural Census, all other data from 1992 Agricultural Census for Alabama.
[2] D indicates information withheld to avoid disclosing data for individual farms.

5.0 HISTORY OF LAKE USES

Alabama Power Company impounded Lewis Smith Lake in 1961 as a multipurpose storage project. It lists as uses of the reservoir the following: hydroelectric power generation, flood control, navigation flow augmentation and storage for power generation. The reservoir also provides water for industrial and municipal use, recreational opportunities for the public and habitat for fish and wildlife (FIMS Draft 1996).

There are many homes along the shoreline occupied by both permanent and semi-permanent residents. A recreational survey done by Fishery Information Management Systems (FIMS) indicated that the most popular activities on the lake included boating and boat fishing and related activities such as waterskiing, and family outings (FIMS Draft 1996). Bass tournaments are also a popular activity on the lake.

The tailwaters downstream from Smith Dam provide habitat for rainbow trout which are stocked through a cooperative agreement between Alabama Game and Fish and the U. S. Fish and Wildlife Service. This stocking program dates back to the 1970's and provides a unique fishery to the area (Personal Communication, Jerry Moss).

A commercial catfish fishery exists on Smith Lake. According to Game and Fish biologists this is a limited fishery utilizing primarily trotlines, but also slat boxes, gill and trammel nets. State biologists have observed an increase in the commercial fishery during the past several years (Moss et al. 1994).

6.0 USER POPULATION AFFECTED BY LAKE DEGRADATION

Lewis Smith Lake has been characterized as having "pristine" waters particularly in the upper reaches of the various creek arms. However, activities conducted within the lake basin such as coal surface mining, forestry, agricultural operations and lakeshore residential development threaten the water quality of this reservoir.

Reservoir monitoring conducted by ADEM since 1989 and a limited historical database indicated that Smith Lake is responding to increased nutrient inputs mainly in embayment arms which receive runoff from primarily agricultural operations. An increase in phytoplankton chlorophyll a concentrations with an increase in trophic status indicated that the nutrient inputs are being utilized primarily in algal production. Cultural eutrophication can impact historical water quality uses and affect most users of Smith Lake.

7.0 LAKE USE COMPARISON WITH NEARBY LAKES

Lake Guntersville is located northeast of Smith Lake on the Tennessee River. The lake was impounded by the Tennessee Valley Authority (TVA) in 1939 for hydroelectric power generation and flood control. The lake has a surface area of 27,114 hectares and serves as a public water supply and discharge point for several municipalities and industries. In a recent survey visitors to Smith Lake stated that Guntersville Lake was their next choice for recreational activities if they could not be on Smith Lake. It is a popular lake for fishing, boating, skiing, swimming, camping and other related activities (FIMS, 1996 draft).

Logan Martin Lake is another potential alternative reservoir for visitors to Smith Lake (FIMS 1996 draft). This reservoir is located southeast of Smith Lake on the Coosa River. The lake was impounded in 1964 by Alabama Power Company for power generation. It is about 6,176 hectares in surface area and has been heavily utilized by the public for recreation and permanent residences. It is one of the most popular lakes in the state having numerous private clubs, golf courses and marinas. There is a "no consumption" advisory on catfish and bass in the lake from Riverside to Logan Martin Dam and a "no consumption" advisory on crappie from the mouth of Choccolocco Creek and the Coosa River to the mouth of Clear Creek and the Coosa river due to PCB contamination (ADPH 1997).

8.0 POINT SOURCE POLLUTION INVENTORY

A point source pollution inventory of actual and permitted discharges was compiled for industrial, municipal and mining discharges in Alabama flowing into Lewis Smith Lake from November 1994 through October 1995 (Tables 8-1 and 8-2). Data were obtained from the Alabama Department of Environmental Management (ADEM). Annual point source loading estimates were calculated by expanding each monthly sampling value from a daily load to a monthly load by multiplying the sampling date daily loading estimate by the number of days in the month and summing the 12 monthly loading estimates.

A total of 53 permitted dischargers were identified; 41 industrial, ten municipal, two landfills and 14 mining discharges (Tables 8-1 and 8-2). All industrial and landfill facilities had stormwater discharge permits, and would not be considered point sources. Another landfill was located within the watershed, but it did not require a stormwater discharge permit (Figure 8-1). All landfills were for manufacturing and construction waste.

The total annual volume of wastewater effluent discharged into Lewis Smith Lake from the ten monitored municipal dischargers was 88 million gallons per year. The municipal discharge of the Good Hope Wastewater Treatment Plant (WWTP) contributed 42.0% and the West Point School contributed 15.5%. Eight dischargers produced the remaining 42.5% of the total wastewater effluent.

Annual point source biochemical oxygen demand (BOD) loading was 5,296 lb/year (2,402 kg/year). The largest contributors were the Hendrix Health Care Center in Double Spring (40.9%), the Good Hope WWTP (22.6%) and Double Springs HUD Housing (13.5%). Seven dischargers produced the remaining 23.0% of BOD loading.

Table 8-1. Actual point source loading of permitted municipal (M) and mining (Mn) dischargers of biochemical oxygen demand (BOD), total suspended solids (TSS) and ammonia nitrogen (NH_3-N) and nonpoint loading of permitted industrial (I) and landfill (L) discharges into Lewis Smith Lake, November 1994 - October 1995.

Facility	NPDES Number	FAC[1]	Receiving Stream	Actual Flow[2] (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (lb/yr)	NH3-N Loading (lb/yr)
				<u>Ryan Creek</u>				
Cold Spring School	AL0051080	M	Raccoon Creek	0.018	6.634	267	717	238
Good Hope WWTP	AL0058343	M	Bavar Creek	0.101	36.817	1194	1185	---
Southern Pines WWTP	AL0047767	M	UT to Price Creek	0.021	7.734	116	422	18
Brushy Pond Mine	AL0049417	Mn_3	Ryan Creek	---	---	---	---	---
Cold Springs Mine	AL0031461	Mn	UTs to Big Br	---	---	---	---	---
Cold Springs Mine #2	AL0049247	Mn	UTs to Lick Creek	---	---	---	---	---
Ryan Creek Mine	AL0049212	Mn_3	UTs to Ryan Creek	---	---	---	---	---
Ryan Creek Mine	AL0059153	Mn_3	UTs to Ryan Creek	---	---	---	---	---
Americold Compressor Co.	---	I	UT to Kilpatrick Creek	---	---	---	---	---
Buettner Bros. Lumber Co.	---	I	Ryan Creek	---	---	---	---	---
Garrison, R.E. Trucking	---	I	UT to Bullard Branch	---	---	---	---	---
Good Hope Const. Co. Inc.	---	I	UT to Bullard Branch	---	---	---	---	---

Table 8-1 (Continued)

Facility	NPDES Number	FAC[1]	Receiving Stream	Actual Flow[2] (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (lb/yr)	NH3-N Loading (lb/yr)
Inland Buildings	---	I	UT to Ryan Ck	---	---	---	---	---
Jeff's Auto Parts	---	I	UT to Vest Ck	---	---	---	---	---
Mid Central Carriers Inc.	---	I	Ryan Creek	---	---	---	---	---
Nicholson File	---	I	Little Ryan Ck	---	---	---	---	---
Peek Auto Parts	---	I	UT to Ryan Ck	---	---	---	---	---
Peerless Coating Inc.	---	I	Ryan Creek	---	---	---	---	---
Pennington Seed Inc.	---	I	UT to Ryan Ck	---	---	---	---	---
Professional Coatings	---	I	UT to Ryan Ck	---	---	---	---	---
Rehau Inc.	---	I	UT to Ryan Ck	---	---	---	---	---
Schaffer Concrete Products	---	I	UT to Ryan Ck	---	---	---	---	---
T&J Trucking Inc.	---	I	Chaney Branch	---	---	---	---	---
Tyson Foods Cullman	---	I	Ryan Creek	---	---	---	---	---
Webb Wheel Products Inc.	---	I	UT to Ryan Ck	---	---	---	---	---
Willingham Salvage	---	I	UT to Ryan Ck	---	---	---	---	---
Shaddix Septic Tanks	---	I	Chaney Branch	---	---	---	---	---

Table 8-1 (Continued)

Facility	NPDES Number	FAC[1]	Receiving Stream	Actual Flow[2] (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (lb/yr)	NH3-N Loading (lb/yr)
Transfer Press Exchange	---	I	Chaney Branch	---	---	---	---	---
SUBTOTALS				0.14	51.185	1577	2324	256
			Crooked Creek					
West Point School	AL0051136	M	Crooked Creek	0.037	13.602	178	1220	127
Auto Salvage	---	I	UT to Crooked Creek	---	---	---	---	---
SUBTOTALS				0.037	13.602	178	1220	127
			Rock Creek					
Addison High School	AL0051811	M	UT to Boone Creek	0.007	2.434	90	238	8
Ryan Creek Mine	AL0049212	Mn_3	UTs to Rock Creek		---	---	---	--- ---
Ryan Creek Mine	AL0059153	Mn_3	UTs to Rock Creek		---	---	---	--- ---
Wheat Mine	AL0062871	Mn	UTs to Rock Creek		---	---	---	--- ---
Hyche Landfill		L		---	---	---	---	---
Cavalier Homes of Al Plt3	---	I	UT to Rock Creek	---	---	---	---	---
Cavalier Homes of Al Inc.	---	I	Boone Creek	---	---	---	---	---

Table 8-1 (Continued)

Facility	NPDES Number	FAC[1]	Receiving Stream	Actual Flow[2] (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (lb/yr)	NH3-N Loading (lb/yr)
Bartlett Used Auto Parts	---	I	UT to White Oak Creek	---	---	---	---	---
SUBTOTALS				0.007	2.434	90	238	8
				Sipsey Fork				
Double Springs HUD Housing	AL0057177	M	Cane Creek	0.015	5.476	713	838	---
Hendrix Health Care Center	AL0057541	M	Curtis Mill Creek	0.020	7.157	2169	5723	30
Winston County High School	AL0051829	M	UT to Cane Creek	0.008	3.009	146	448	167
Big Bear Mine	AL0057860	Mn	Big Bear Br.	---	---	---	---	---
Pruitt, Bobby Landfill	---	L	UT to Cane Creek	---	---	---	---	---
Robins Lumber Co. Inc.	---	I	Sandy Creek	---	---	---	---	---
Ronnie's Lumber Co. Inc.	---	I	Rockhouse Creek	---	---	---	---	---
Lane Ready Mix	---	I	Small Creek	---	---	---	---	---
SUBTOTALS				0.043	15.642	3028	7009	197

Table 8-1 (Continued)

Facility	NPDES Number	FAC[1]	Receiving Stream	Actual Flow[2] (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (lb/yr)	NH3-N Loading (lb/yr)
				Clear Creek				
Double Springs Elementary Sch	AL0050458	M	UT to Clear Creek	0.006	2.129	314	325	120
Hickory Grove Mine	AL0052787	Mn	UTs to Clear Creek	---	---	---	---	---
Beech Grove Mine	AL0049981	Mn	Mineral Spring Br	---	---	---	---	---
Black Pond Mine #6	AL0050482	Mn	UTs to Clear Creek	---	---	---	---	---
Poplar Springs Mine #2	AL0051977	Mn	UTs to Clear Creek	---	---	---	---	---
Marshall Durbin Farms	---	I	Little Clear Creek	---	---	---	---	---
B&B Sawmill	---	I	Kidd Branch	---	---	---	---	---
Bama Textiles	---	I	Mineral Springs Branch	---	---	---	---	---
Nailfast	---	I	Mineral Springs Hollow	---	---	---	---	---
Trim Masters Inc.	---	I	UT to Mineral Springs Branch	---	---	---	---	---
Winston Furniture Co. Inc.	---	I	Mineral Springs Branch	---	---	---	---	---
SUBTOTALS				0.006	2.129	314	325	120

Table 8-1 (Continued)

Facility	NPDES Number	FAC[1]	Receiving Stream	Actual Flow[2] (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (lb/yr)	NH3-N Loading (lb/yr)
				Brushy Creek				
Lane Ready Mix	---	I	Brushy Creek	---	---	---	---	---
Grayson Lumber Co.	---	I	Collier Creek	---	---	---	---	
				Dismal Creek				
Meek High School	AL0051799	M	Dismal Creek	0.007	2.705	109	1490	46
Wilson Bend Mine	AL0029751	Mn	UTs to Dismal Creek	---	---	---	---	---
Piney Ridge Mine	AL0049964	Mn_3	UTs to Dismal Creek	---	---	---	---	---
Hearn's Salvage Co.	---	I	UT to Dismal Creek	---	---	---	---	---
Quality Dinettes, Inc.	---	I	UT to Dismal Creek	---	---	---	---	---
SUBTOTALS				0.007	2.705	109	1490	46
				Lewis Smith Lake				
Environmental Improvement Mine	AL0063894	Mn	Smith Lake	---	---	---	---	---
Brushy Pond Mine	AL0049417	Mn_3	UTs to Smith Lake	---	---	---	---	---
Piney Ridge Mine	AL0049964	Mn_3	UTs to Smith Lake	--	---	---	---	---
Huey's Marina	---	I	Smith Lake	---	---	---	---	---

Table 8-1 (Continued)

Facility	NPDES Number	FAC[1]	Receiving Stream	Actual Flow[2] (MGD)	Total Flow (MG/yr)	BOD Loading (lb/yr)	TSS Loading (lb/yr)	NH3-N Loading (lb/yr)
Speegle's Marina	---	I	Smith Lake	---	---	---	---	---
Duskin Point Marina	---	I	Smith Lake	---	---	---	---	---
Richards' Clearwater Mar	---	I	Smith Lake	---	---	---	---	---
TOTALS				0.24	87.697	5296	12606	754

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[1] All industrial permits are stormwater discharge permits
[2] Actual Flow (MGD) is the mean for the sampling period
[3] Facilities with permits to discharge into more than one subwatershed
---No information available

Table 8-2. Potential point source loading of permitted municipal (M) and mining (Mn) dischargers of biochemical oxygen demand (BOD), total suspended solids (TSS) and ammonia nitrogen (NH_3-N) into Lewis Smith Lake, November 1994 - October 1995.

Facility	NPDES Number	FAC	Permitted Flow (MGD)	Permitted BOD (mg/L)	Permitted BOD (lb/day)	Permitted BOD Load (lb/yr)	Permitted TSS (mg/L)	Permitted TSS (lb/day)	Permitted TSS Load (lb/yr)	Permitted NH3-N (mg/L)	Permitted NH3-N (lb/day)	Permitted NH3-N (lb/yr)
Ryan Creek												
Cold Spring School	AL0051080	M	0.025	20	4.2	1522	30	6.3	2283	8	1.7	609
Good Hope WWTP	AL0058343	M	0.175	10	14.6	5327	30	43.8	15982	1	1.5	533
Southern Pines WWTP	AL0047767	M	0.035	10	3.0	1095	30	8.8	3196	2	0.6	213
SUBTOTALS			0.235	40	21.8	7944	90	58.9	21461	11	3.8	1355
Crooked Creek												
West Point School	AL0051136	M	0.045	20	7.5	2740	30	11.3	4110	8	3.0	1096
Rock Creek												
Addison High School	AL0051811	M	0.016	20	2.7	974	30	4.0	1461	8	1.1	390
Sipsey Fork												
Double Springs HUD Housing	AL0057177	M	0.020	30	5.0	1826	---	---	---	---	---	---
Hendrix Healthcare	AL0057541	M	0.026	13	2.8	1029	---	---	---	4	0.9	317
Winston County High School	AL0051829	M	0.012	20	2.0	731	30	3.0	1096	8	0.8	292
SUBTOTALS			0.58	63	9.8	3586	30	3.0	1096	12	1.7	609

Table 8-2 (Continued)

Facility	NPDES Number	FAC	Permitted Flow (MGD)	Permitted BOD (mg/L)	Permitted BOD (lb/day)	Permitted BOD Load (lb/yr)	Permitted TSS (mg/L)	Permitted TSS (lb/day)	Permitted TSS Load (lb/yr)	Permitted NH3-N (mg/L)	Permitted NH3-N (lb/day)	Permitted NH3-N (lb/yr)
Clear Creek												
Double Springs Elementary Sch	AL0050458	M	0.020	30	5.0	1826	30	5.0	1826	1.2	0.2	73
Dismal Creek												
Meek High School	AL0051799	M	0.009	20	1.5	548	30	2.3	822	8	0.6	219
TOTAL			0.383	193	48.3	17618	240	84.3	30776	48.2	10.2	3741

--No information available

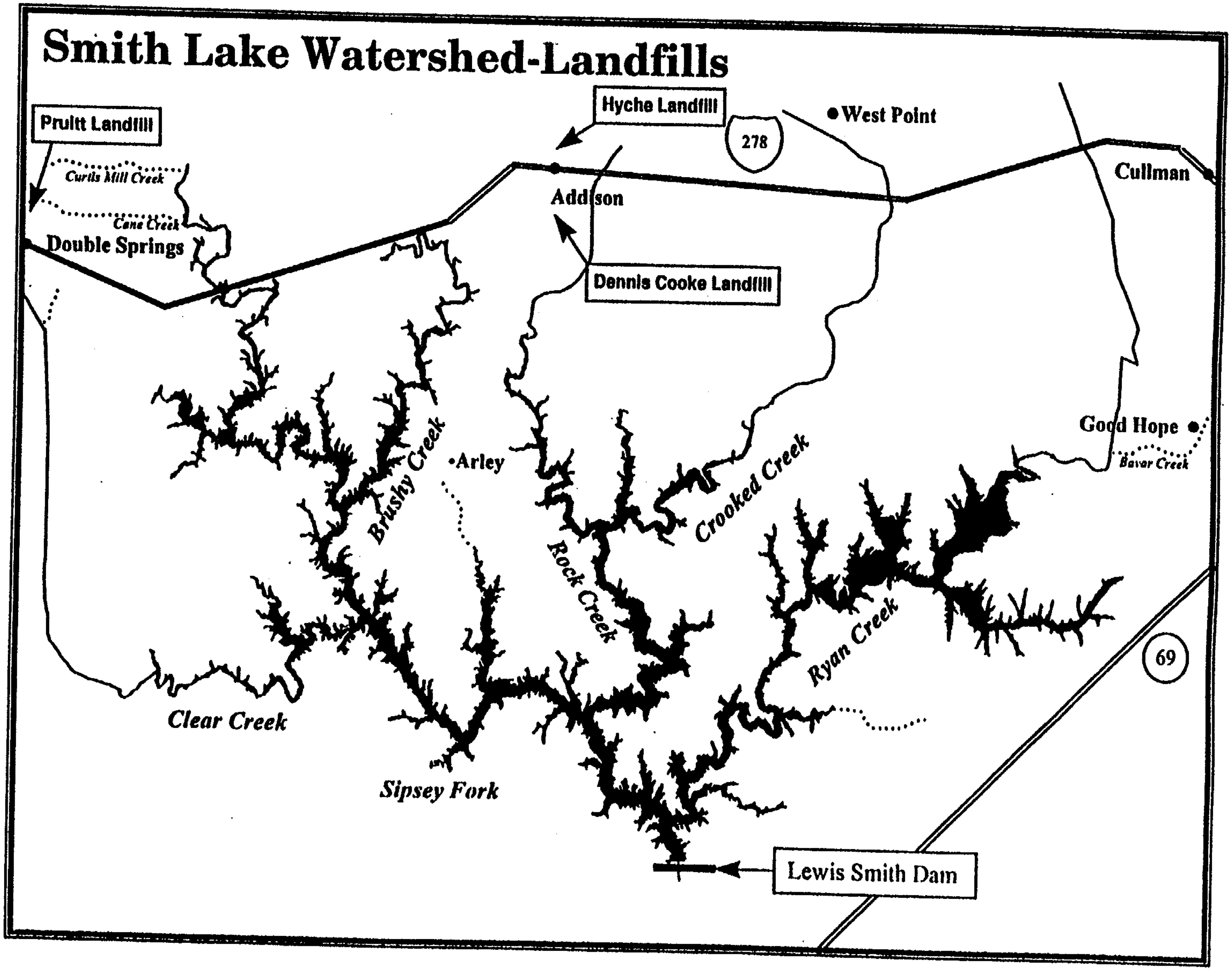


Figure 8-1. Location of permitted landfills in the Lewis Smith Lake watershed.

Annual point source total suspended solids (TSS) loading was 12,606 lb/year (5,717 kg/year). Hendrix Health Care Center contributed 45.4%, Meek High School 11.8%, West Point School 9.7% and Good Hope WWTP 9.4% of the TSS load. Seven discharges produced the remaining 23.7%.

Annual point source ammonia nitrogen (NH3-N) loading was estimated at 754 lb/year (342 kg/year). Cold Springs School contributed 31.5%, Winston County High School 22.2%, West Point School 16.9% and Double Springs Elementary School 15.7%. Four discharges produced the remaining 13.7%. Two discharges did not have NH3-N discharge limits and did not monitor for it.

Analysis of total phosphorus (TP) and total nitrogen (TN) was not required by any of the permits. For this reason annual point source loading of these two nutrients could not be determined.

Of the two major contributors of BOD and TSS to Lewis Smith Lake, the Hendrix Health Care Center discharged 211% of its permitted annual BOD load, and 75% of its permitted discharge. No TSS permit limit was found, but TSS's were monitored and the annual load was estimated at 5,723 lb/year (2,595 kg/year). The Good Hope WWTP only discharged 22.4% of its permitted annual BOD load, 7.4% of its permitted annual TSS load and 57.6% of its permitted discharge. Two facilities were found to discharge greater quantities of TSS and NH_3-N than were permitted. Meek High School, the only permitted discharge into Dismal Creek, discharged 181% of its permitted annual TSS load, 82% of its permitted discharge, 20% of its permitted annual BOD load, and 21% of its permitted annual NH_3-N load. Double Springs Elementary School, the only permitted discharge into Clear Creek, discharged 16.4% of its permitted annual NH_3-N load, 29% of the permitted discharge, 17% of its permitted annual BOD load, and 18% of its permitted annual TSS load.

Of the five subwatersheds monitored, the Ryan Creek and Sipsey Fork were the most impacted. Each had three point sources. The Ryan Creek subwatershed received 29.8% of the total annual BOD load, 18.4% of the total annual TSS load, 33.8% of the total annual NH3-N load, and 58.4% of the total annual discharge. Sipsey Fork subwatershed received 57.1% of the total annual BOD load, 55.6% of the total annual TSS load, 26.2% of the total annual NH3-N load, and 17.8% of the total annual discharge. The percent of the total annual NH3-N load is accounted for by only two of the permitted facilities as the Double Springs HUD Housing in the Sipsey Fork did not monitor NH3-N.

Since this study was conducted, two of the municipal dischargers into the Sipsey Fork no longer have permitted discharges. Hendrix Health Care Center and Double Springs HUD Housing were connected to the Double Springs WWTP which discharges into Clear Creek. Future plans are to also connect the Winston County School, which discharges to the Sipsey Fork, and the Double Springs Elementary, which discharges to Clear Creek, to the Double Springs WWTP. This will remove all permitted discharges from the Sipsey Fork subwatershed and move them to the Clear Creek subwatershed.

9.0 NUTRIENT AND TOTAL SUSPENDED SOLIDS LOADING

Five tributary streams (Table 9-1 and Figure 9-1) were sampled 18 times from November 1994 through October 1995. Stations were sampled once during the month of November, twice monthly from December through May, and then once monthly from June through October. Three of the sampling dates were after significant rainfall events (February 28, March 7 and April 24, 1995). Water samples were collected just below the water's surface directly into 2 L Nalgene bottles or, when water was too deep to wade, water was collected using a Van Dorn water sampler and then transferred into 2 L Nalgene bottles for transport to laboratory facilities at Auburn University. Water samples used to estimate the concentration of total suspended solids were collected with a depth-integrated, suspended-sediment sampler using methods described by Glysson and Edwards (1988) except at station 15 (tailwaters of the Alabama Power Company dam), where a near-surface grab was the only feasible alternative. Water samples were analyzed for total phosphorus, soluble reactive phosphorus (orthophosphate), nitrate-

Table 9-1. Location of tributary sampling stations for the assessment of nutrient loading into Lewis Smith Lake from November 1, 1994 through October 31, 1995.

Stream	Station Number	Station Description
Ryan Creek	10	East of Trimble, 1.3 miles on county road 18, upstream of bridge crossing T11S R4W S11
Crooked Creek	11	5.6 miles south of Jones Chapel on county road 31, 1.9 miles southeast on county road, upstream of bridge crossing, T10S R5W S34
Rock Creek	12	2.7 miles south of Addison on county road 41, 1.1 miles southeast on county road 66, upstream of bridge crossing T10S R6W S21
Sipsey Fork	13	West of Grayson, 3.8 miles southwest of county road 60 and state highway 33 intersection on county road 60, downstream of bridge crossing T9S R8W S8
Clear Creek	14	2.5 miles southwest of Double Springs on county road 25, upstream of bridge crossing T11S R9W S1
Tailwaters	15	Lewis Smith Dam, east on county road 43 T13S R5W S6

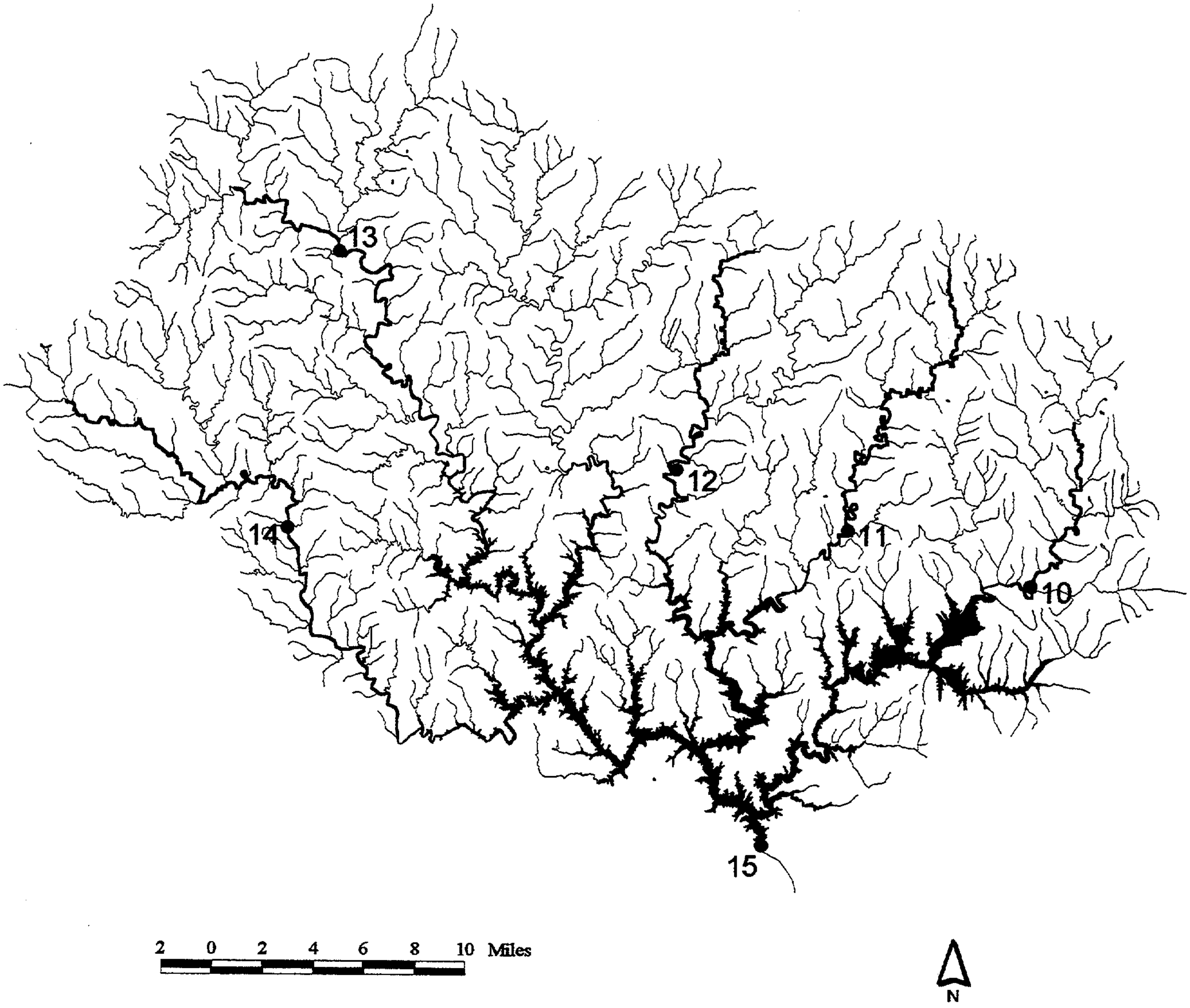


Figure 9-1. Location of tributary sampling stations 10 (Ryan Creek), 11 (Crooked Creek), 12 (Rock Creek), 13 (Sipsey Fork), 14 (Clear Creek) and 15 (Alabama Power dam tailwaters) for the diagnostic study of Lewis Smith Lake, November 1994 through October 1995

nitrogen, nitrite-nitrogen, total ammonia nitrogen, Kjeldahl nitrogen, alkalinity, specific conductance, turbidity and total suspended solids utilizing methods described in Table 10-3.

Stream discharge was measured in situ on each sampling date at all stations (10-14) except station 15 where mean daily discharge was furnished by the Alabama Power Company. Discharge was determined by measuring stream depth and mean current velocity using a Marsh-McBirney, model 201D portable water current meter. Mean current velocity was the velocity at a depth of 0.6 of the total depth from the surface. Depth and mean current velocity were measured for each 1-3 m wide cell along a transect at the sampling site. Total stream discharge was then calculated by summing the product of depth X mean velocity X width of each cell along the transect. Mean daily discharge in cubic feet per second (cfs) for Clear Creek and Sipsey Fork were obtained from United States Geological Survey (USGS) gage data.

The 18 measured and calculated discharges from the 18 sampling dates for stations 10-14 were regressed against 18 concurrent gaged discharge values of Clear Creek and Sipsey Fork. Regressions giving the best fit (highest R^2) were used to predict mean daily discharge for the sampling period of November 1994 to October 1995. The Clear Creek gage was used to regress Ryan Creek, Crooked Creek, and Clear Creek ($R^2 = 0.75$, 0.93 and 0.93, respectively). Sipsey Fork gage was used to regress Rock Creek and Sipsey Fork ($R^2 = 0.95$ and 0.97, respectively). Linear regressions ($y = a + bx$) were determined to estimate mean daily discharge for all stations. There were no significant differences ($P > 0.05$) between mean daily discharges calculated from linear regression or log-log linear regression at any station.

Annual mean daily discharge for the five tributary streams ranged from 69.6 cfs in Crooked Creek to 199.7 cfs for Clear Creek (Table 9-2). Total monthly discharge (m^3 X 10^6) was calculated and plotted from November 1994 through October 1995 for stations 11-15 (Figures 9-2, 9-3, 9-4, 9-5, 9-6, and 9-7). Ryan, Crooked and Clear Creeks had peak total monthly discharges in March and April. All

Table 9-2. Mean (range) daily discharge and mean (range) concentration of total phosphorus, total nitrogen and total suspended solids at Ryan Creek (10), Crooked Creek (11), Rock Creek (12), Sipsey Fork (13), Clear Creek (14) and the Alabama Power Dam tailwaters (15) during the diagnostic study of Lewis Smith Lake from November 1994 through October 1995.

	Mean Daily Discharge		Total Phosphorus		Total Nitrogen		Total Suspended Solids	
Stations	(cfs)	R^2 (p)	(μg/L)	R^2 (p)	(μg/L)	R^2 (p)	(mg/L)	R^2 (p)
10	100.7^a (0-2048)	0.75 (<0.01)	67 (20-251)	0.34 (0.01)	1616 (861-2987)	0.72 (<0.01)	12.11 (1.17-91.05)	0.52 (<0.01)
11	69.6^a (0-1422.9)	0.93 (<0.01)	50 (11-236)	0.48 (<0.01)	1204 (315-2600)	0.82 (<0.01)	9.68 (0.01-59.35)	0.64 (<0.01)
12	139.9^b (4.5-6020.3)	0.95 (<0.01)	69 (12-322)	0.08 (0.23)	1490 (440-2821)	0.45 (<0.01)	11.54 (0.95-89.15)	0.48 (<0.01)
13	195.6^b (0-8960.1)	0.97 (<0.01)	18 (6-68.5)	0.46 (<0.01)	185 (76.5-512)	0.13 (0.14)	6.34 (0.17-38.02)	0.75 (<0.01)
14	199.7^a (0-4299.2)	0.93 (<0.01)	46 (10-280)	0.62 (<0.01)	592 (331-1175)	0.54 (<0.01)	31.84 (0.91-259.9)	0.85 (<0.01)
15	1548.9^c (0-7449)	---	14.7 (5-42)	0.14 (0.16)	781.1 (463-1219)	0.006 (0.77)	2.54 (0.78-6.570)	0.02 (0.58)

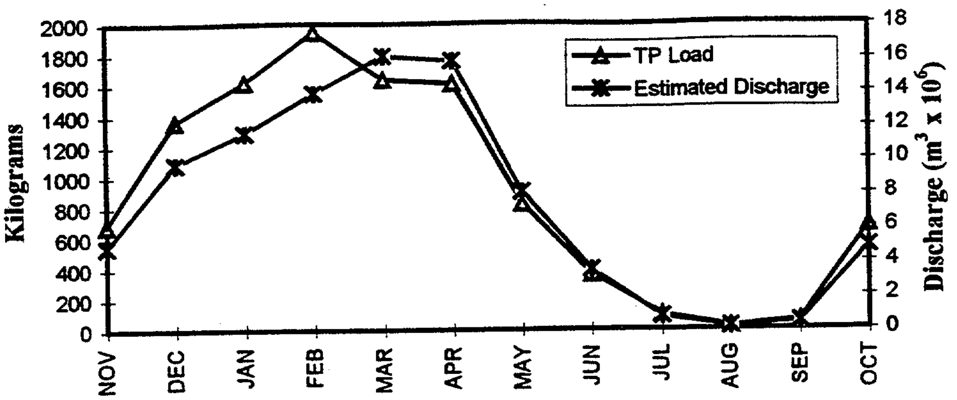
---

[a] Means estimated from mean daily discharge values estimated from regression based on USGS gaged discharge of Clear Creek at New Hope Church near Poplar Springs, AL.

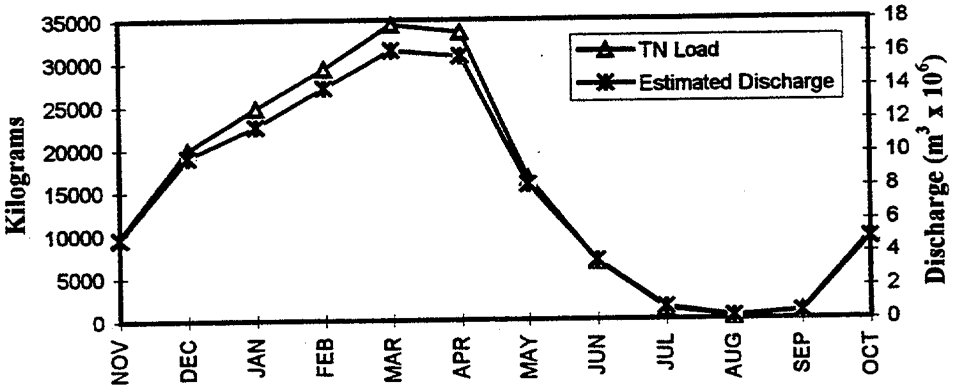
[b] Means estimated from mean daily discharge values estimated from regression based on USGS gaged discharge of Sipsey Fork near Grayson, AL.

[c] Means calculated from mean daily discharge data collected by Alabama Power Company.

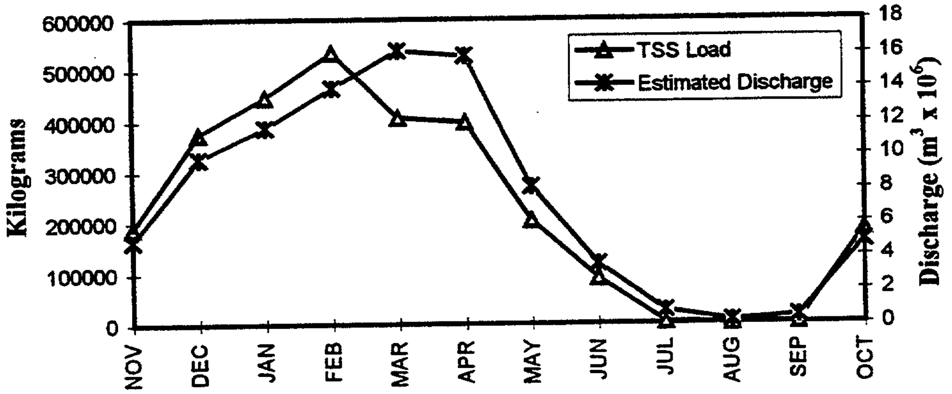
---No regression was necessary.



Total Phosphorus

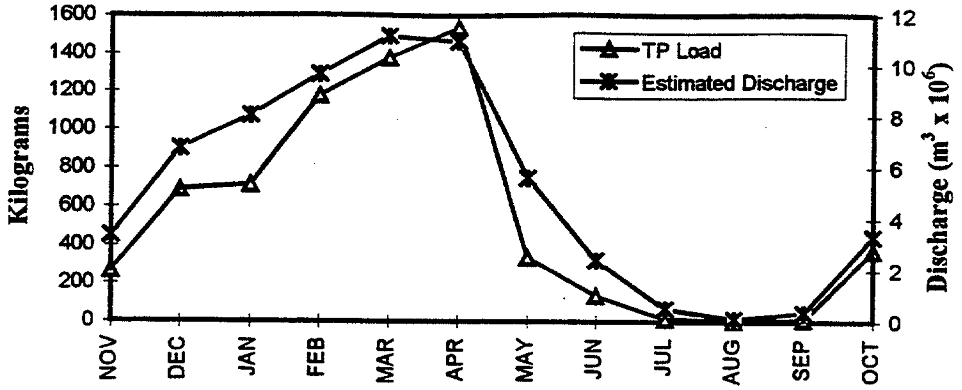


Total Nitrogen

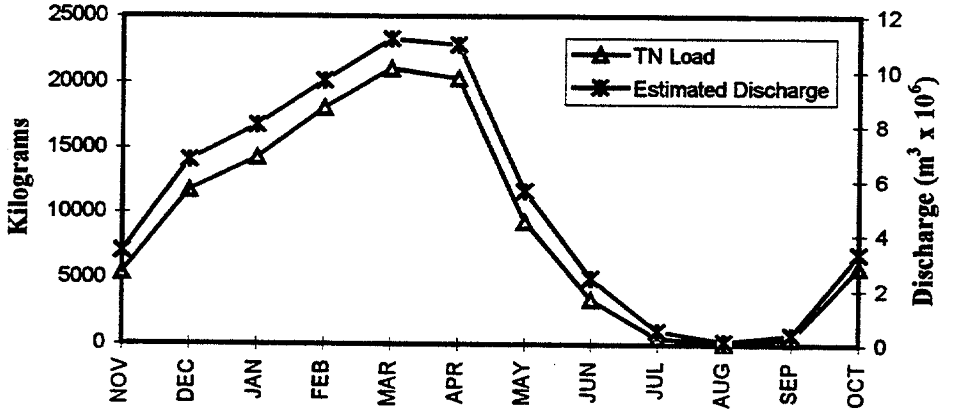


Total Suspended Solids

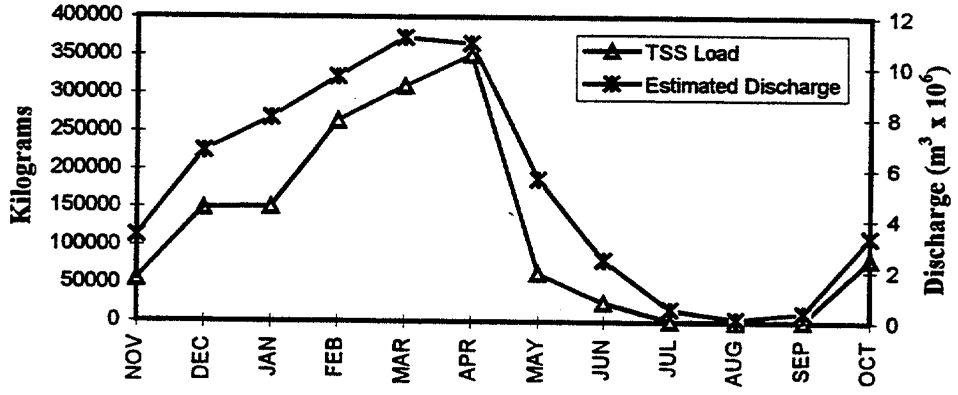
Figure 9-2. Total monthly loading (point and nonpoint source) at station 10, Ryan Creek, for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS) as determined by FLUX, plotted with estimates of total monthly discharge during the diagnostic study of Lewis Smith Lake, November 1994 through October 1995



Total Phosphorus

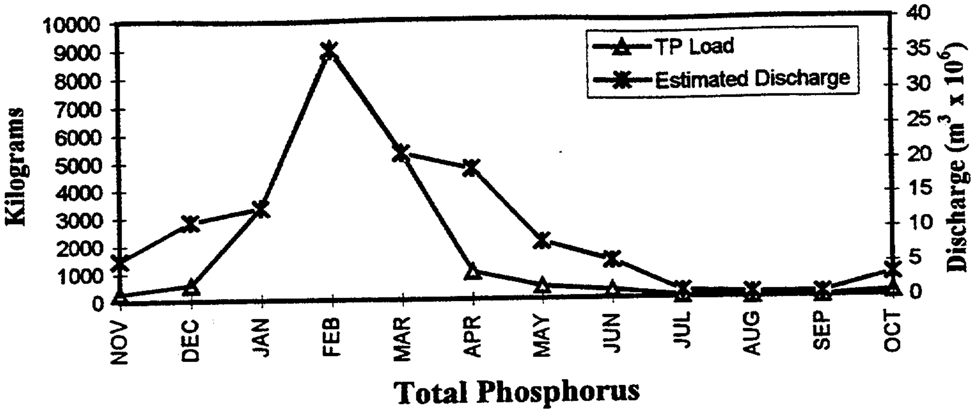


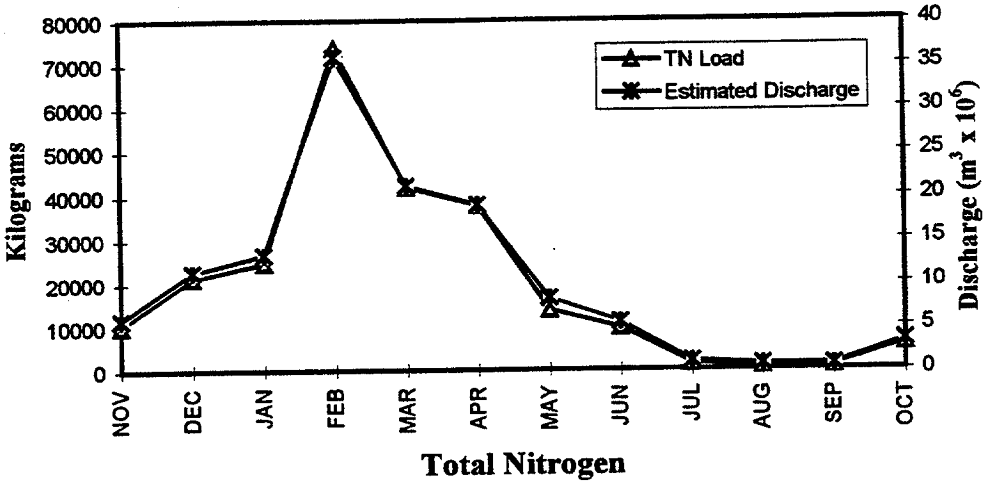
Total Nitrogen



Total Suspended Solids

Figure 9-3. Total monthly loading (point and nonpoint source) at station 11, Crooked Creek, for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS) as determined by FLUX, plotted with estimates of total monthly discharge during the diagnostic study of Lewis Smith Lake, November 1994 through October 1995





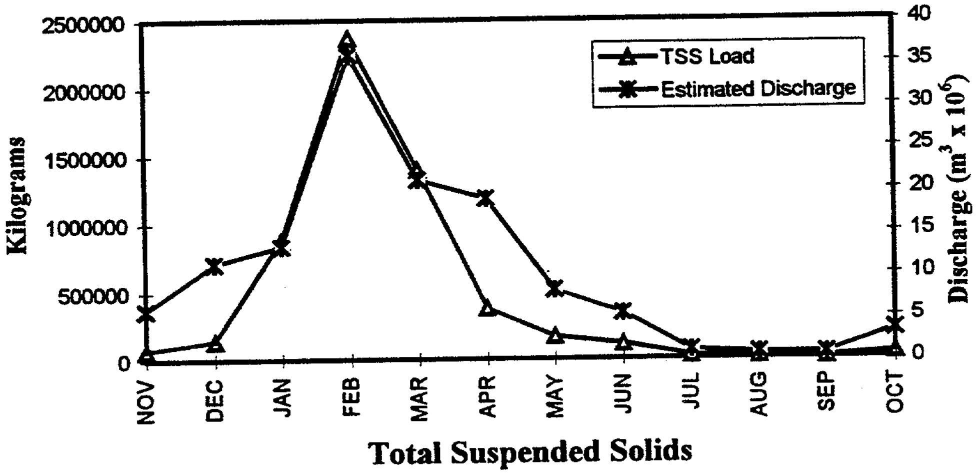
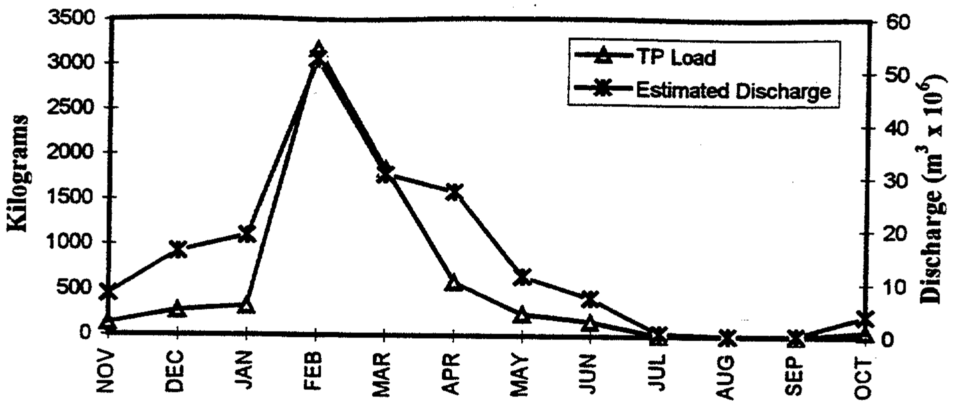
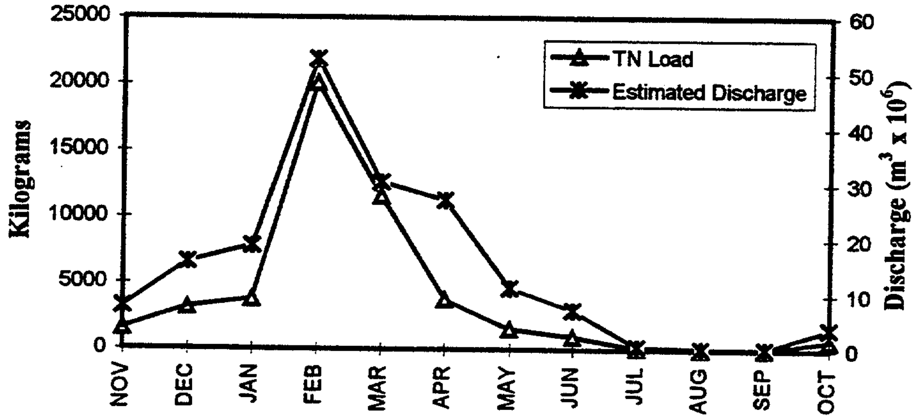


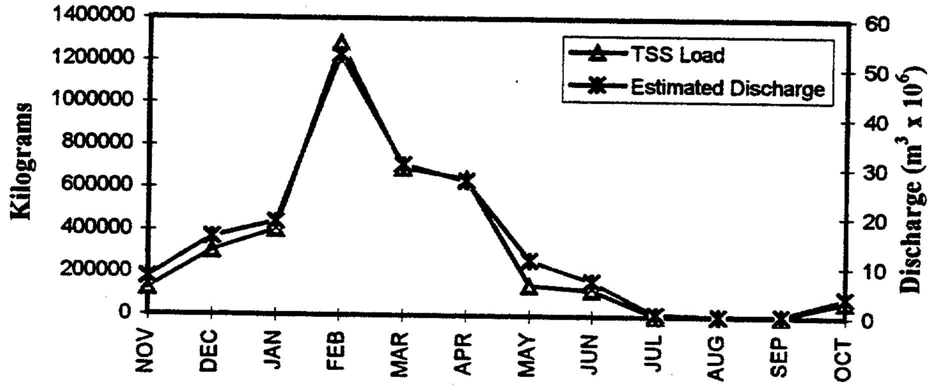
Figure 9-4 Total monthly loading (point and nonpoint source) at station 12, Rock Creek, for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS) as determined by FLUX, plotted with estimates of total monthly discharge during the diagnostic study of Lewis Smith Lake, November 1994 through October 1995



Total Phosphorus

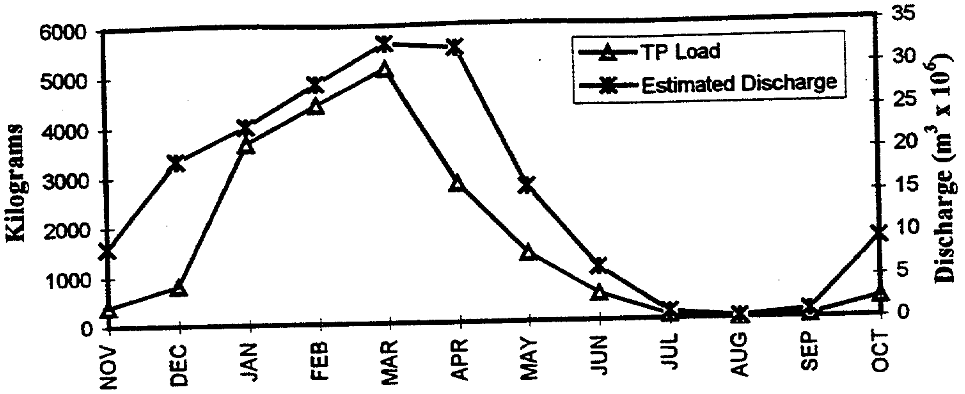


Total Nitrogen

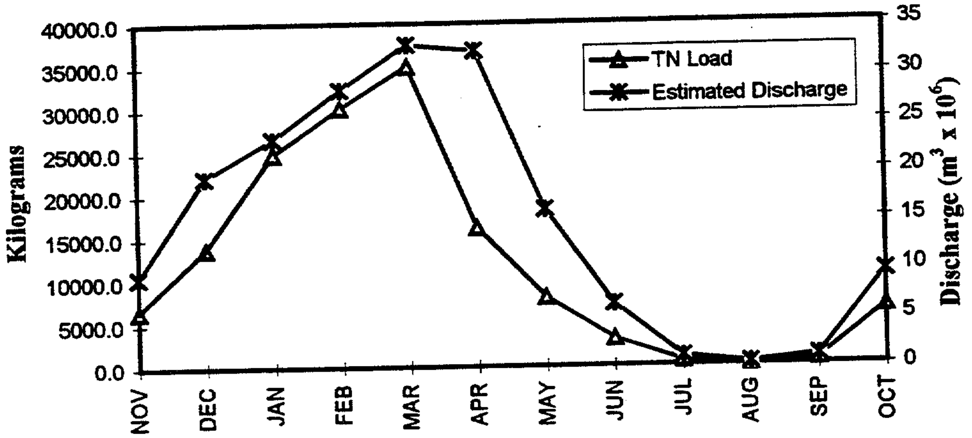


Total Suspended Solids

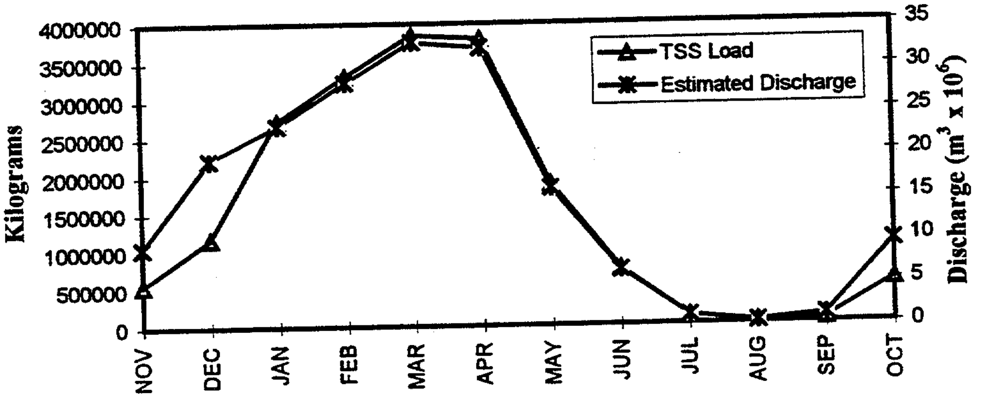
Figure 9-5. Total monthly loading (point and nonpoint source) at station 13, Sipsey Fork, for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS) as determined by FLUX, plotted with estimates of total monthly discharge during the diagnostic study of Lewis Smith Lake, November 1994 through October 1995



Total Phosphorus

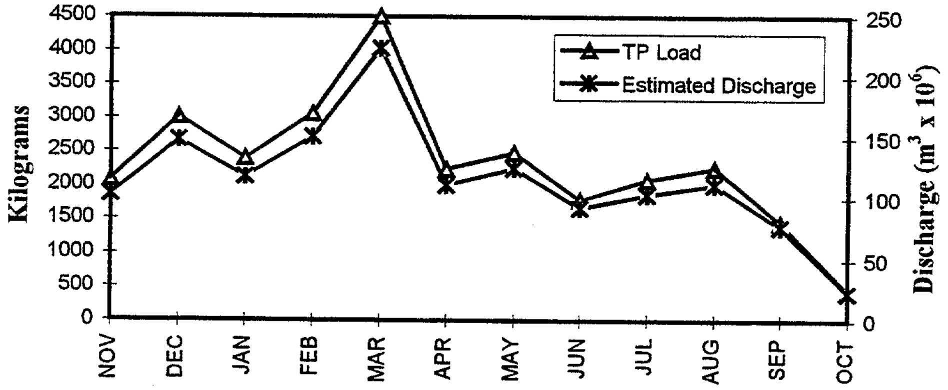


Total Nitrogen

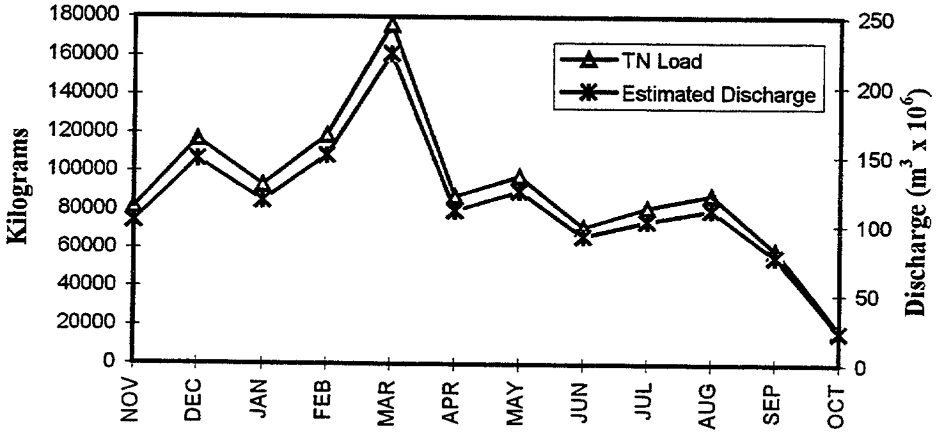


Total Suspended Solids

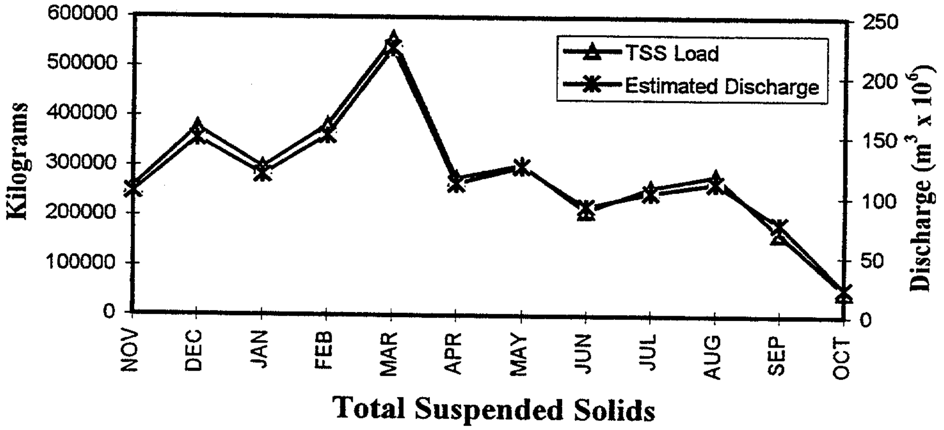
Figure 9-6. Total monthly loading (point and nonpoint source) at station 14, Clear Creek, for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS) as determined by FLUX, plotted with estimates of total monthly discharge during the diagnostic study of Lewis Smith Lake, November 1994 through October 1995



Total Phosphorus



Total Nitrogen



Total Suspended Solids

Figure 9-7. Total monthly loading (point and nonpoint source) at station 15, Alabama Power Company dam for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS), as determined by FLUX, plotted with estimates of total monthly discharge during the diagnostic study of Lewis Smith Lake, November 1994 through October 1995.

three creeks demonstrated similar discharge patterns with an increase in discharge from October until March and then a gradual decline until July. Rock Creek and Sipsey Fork had peak total monthly discharges in February. Both creeks had similar discharge patterns with a gradual increase from October until January, then a sharp increase through February and a steep decline from February until March, a plateau through April and a gradual decline until July. All five streams were at base flow from July through September.

Annual mean concentrations of water quality variables were estimated for all stations from the 18 samples collected from November 1994 until October 1995 (Table 9-2). SAS was used to perform regressions between stream discharge and concentrations of total phosphorus, total nitrogen and total suspended solids to determine R^2 and probabilities (p) (SAS 1990).

Mean annual TP concentrations ranged from 15 μg/L to 69 μg/L. TP varied significantly ($p = 0.014$) between sampling sites (Table 9-2). TP concentrations were highly positively correlated ($p < 0.01$) with instantaneous stream discharge in Crooked Creek, Sipsey Fork and Clear Creek ($R^2 =$ 0.48, 0.46 and 0.62, respectively), and strongly correlated ($p = 0.01$) in the Ryan Creek ($R^2 = 0.34$). There was no significant correlation ($p = 0.23$) between TP concentration and instantaneous stream discharge in Rock Creek ($R^2 = 0.08$). As expected there was also no correlation ($p = 0.16$) between TP concentration and instantaneous stream discharge at the tailwaters site ($R^2 = 0.14$).

Mean annual TN concentrations ranged from 185 to 1,616 μg/L (Table 9-2). TN concentrations varied significantly ($p < 0.01$) between the sampling sites. TN concentrations were highly positively correlated ($p < 0.01$) to instantaneous stream flow in Ryan, Crooked, Rock and Clear Creeks (R^2 0.72, 0.82, 0.45 and 0.54, respectively) and not significantly correlated ($p = 0.14$ and 0.77) to instantaneous stream flow in either the Sipsey Fork or the tailwaters site ($R^2 = 0.13$ and 0.01, respectively).

Mean annual TSS concentrations ranged from 2.54 to 31.84 mg/L (Table 9-2). TSS concentrations did not vary significantly ($p > 0.05$) between sampling sites. TSS concentrations were

Table 9-3. Estimated total loading (point and nonpoint) using FLUX for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS) from tributary streams and the lake outlet at the Alabama Power Dam during the diagnostic study of Lewis Smith Lake from November 1994 through October 1995.

Stream	Station Number	Watershed Area (miles^2)	Mean Daily Discharge (cfs)	TP Loading (mt/yr[f])	TN Loading (mt/yr[f])	TSS Loading (mt/yr[f])
Ryan Creek	10	49[ab]	100.7[c]	11	187	2825
Crooked Creek	11	46 [ab]	69.6[c]	7	110	1448
Rock Creek	12	79[ab]	139.9[d]	20	241	5561
Sipsey Fork	13	89[ab]	195.6[d]	7	47	3785
Clear Creek	14	90[ab]	199.7[c]	20	145	18709
Tailwaters at Alabama Power Dam	15	944[ab]	1548.9[e]	28	1086	3410
Total Stream Load (from stations 10-14)				65	730	32328

[a] Watershed area in square miles above the point of sampling.

[b] Watershed area determined by digitizing 1:24000 topographic maps.

[c] Means estimated from mean daily discharge values estimated from regression based on USGS gaged discharge of Clear Creek at New Hope Church near Poplar Springs, AL.

[d] Means estimated from mean daily discharge values estimated from regression based on USGS gaged discharge of Sipsey Fork near Grayson, AL.

[e] Means calculated from mean daily discharge data collected by Alabama Power Company.

[f] mt/yr = metric tons/year.

highly positively correlated ($p < 0.01$) to instantaneous stream flow in all creeks, but was not significantly correlated ($p = 0.58$) at the tailwaters site.

Total loading (point and nonpoint source) for TP, TN and TSS from the five tributary streams (stations 10-14) and the tailwaters (station 15) was estimated using FLUX for the period of 1 November, 1994 through 31 October, 1995 (Table 9-3). FLUX is an interactive data reduction program for estimating nutrient loading from grab sample nutrient concentration data, with associated instantaneous flow measurements, and continuous flow (mean daily discharge) data (Walker 1996). Continuous flow records were obtained from USGS for Sipsey Fork (station 13) and Clear Creek (station 14) and from the Alabama Power Company for the tailwaters (stations 15). Continuous flow was estimated for stations 10-14 as mentioned previously. Water quality data for stations 10-14 were from the 18 sampling dates from November 1994 through October 1995. Water quality data for station 15 were from 17 sampling dates December 1994 through October 1995, except TP which only had 16 sampling dates. Only one sample date was collected in December 1994.

In the five tributary streams (stations 10-14) total loading of TP, TN and TSS generally increased with increasing tributary discharge except for Sipsey Fork which had one of the highest discharge rates but the lowest loadings. Based on TSS loading, nonpoint source loading was evidently the predominant contributor, since the point source loading contributed less than 1% at all stations.

Total loading of TP, TN and TSS from all five tributary streams (stations 10-14) into Lewis Smith Lake was 65 metric tons, 730 metric tons and 32,328 metric tons, respectively. Of these total amounts, the Sipsey Fork and Crooked Creek contributed the least (Figures 9-8 and 9-9). Sipsey Fork accounted for 10.5% of the TP, 6.4% of the TN and 11.7% of the TSS. Crooked Creek accounted for 10.3% of the TP, 15.1% of the TN and 4.4% of the TSS. Clear Creek contributed the major portions of the TSS load (57.9%). Rock and Clear Creeks contributed a significant portion of the TP loading

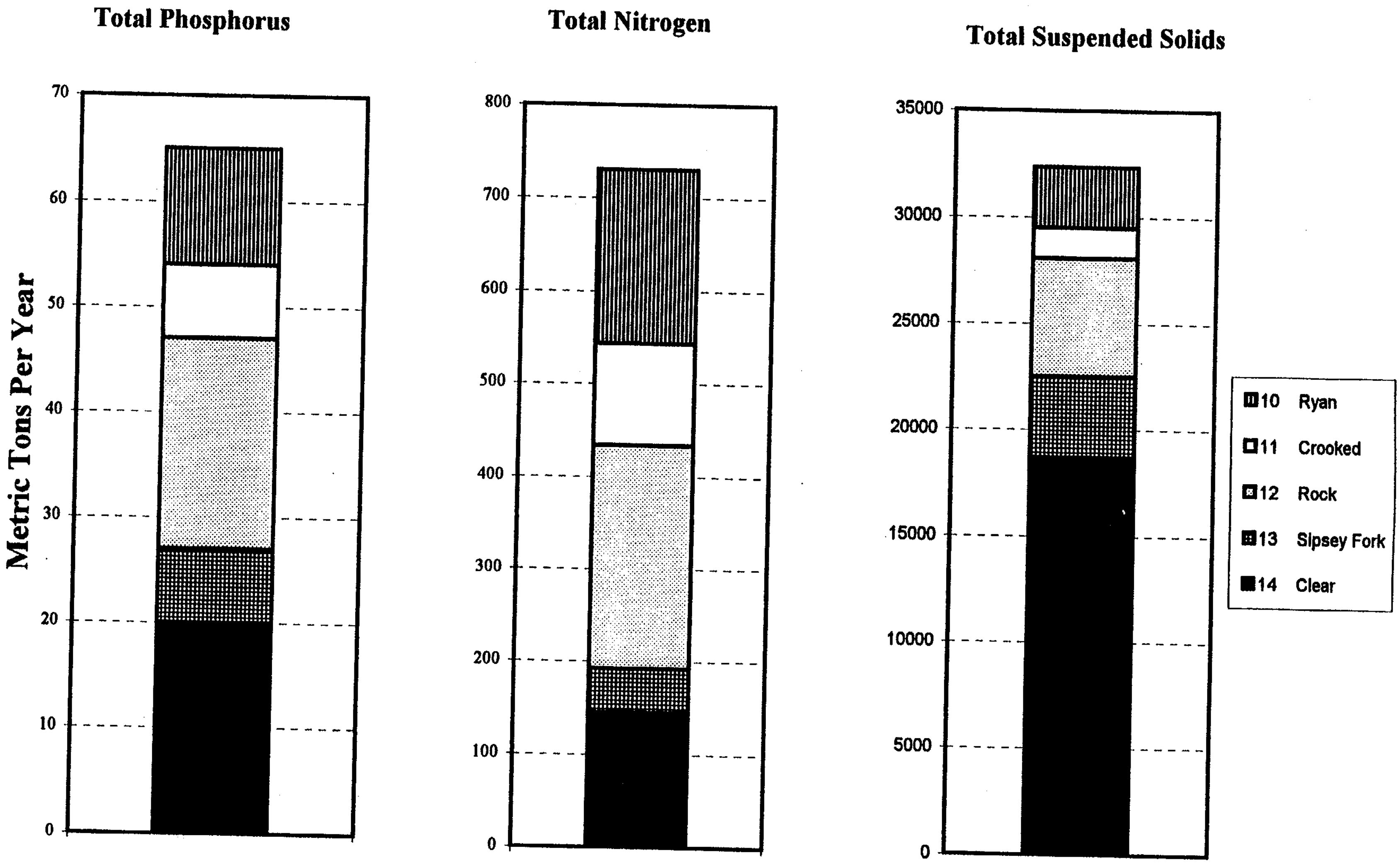


Figure 9-8. Total annual loading (point and nonpoint source) of total phosphorus, total nitrogen and total suspended solids from each tributary, as determined by FLUX, during the diagnostic study of Lewis Smith Lake, November 1994 through October 1995

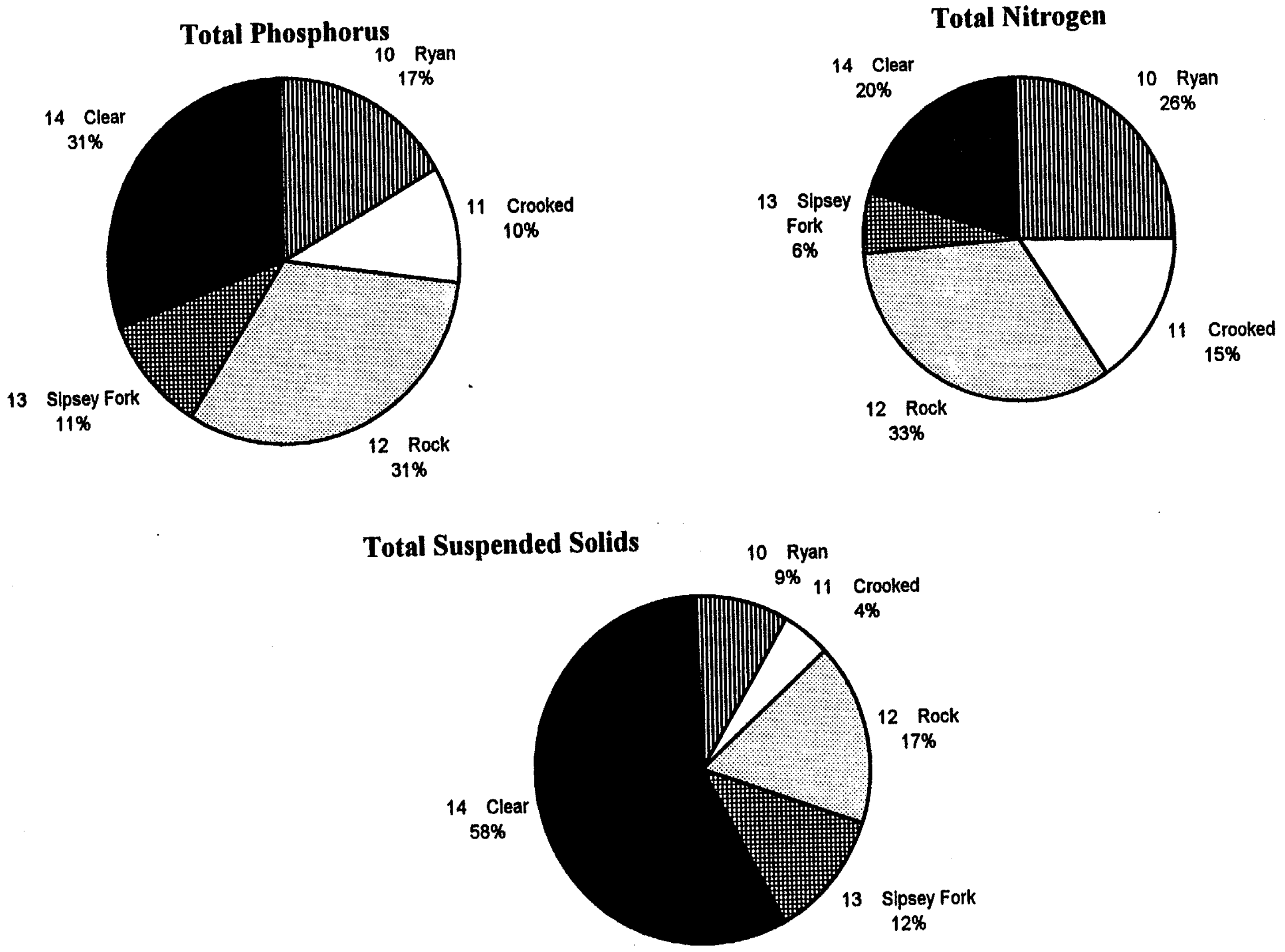


Figure 9-9. Total annual loading (point and nonpoint source) of total phosphorus, total nitrogen and total suspended solids from each tributary, as determined by FLUX, during the diagnostic study of Lewis Smith Lake, November 1994 through October 1995

(31.4% and 30.5%, respectively). Rock and Ryan Creeks contributed a significant portion of the TN load (33.0% and 25.6%, respectively).

Total monthly loading of TP, TN and TSS was also estimated using FLUX (Figures 9-2, 9-3, 9-4, 9-5, 9-6 and 9-7). Loading estimate patterns for all variables were similar to total monthly discharge patterns for Rock Creek and Sipsey Fork. TP, TN and TSS were highest in February at these stations. Estimated loading patterns at the other three creeks were more variable. Total monthly loading of TP in Ryan Creek preceded the total monthly discharge by peaking in February, while total monthly discharge peaked in March and April. At Crooked Creek, total monthly TP loading and total monthly discharge were similar, with the highest values in March and April. At Clear Creek total monthly TP peaked in March and declined rapidly in April, while total monthly discharge peaked and remained fairly constant during March and April. Total monthly TN loading was highest in March and April at Crooked and Ryan creeks as were the total monthly discharges. In Clear Creek total monthly TN peaked in March and then declined in April, while total monthly discharge peaked and remained fairly constant during March and April. Total monthly TSS loading peak at Ryan Creek preceded the total monthly discharge by peaking in February, while total monthly discharge peaked in March and April. At Crooked Creek, total monthly TSS loading increased through March and peaked in April, while total monthly discharge peaked in March and held constant during April. Total monthly TSS loading and total monthly discharge patterns were similar at Clear Creek. Both peaked during March and April.

10.0 LEWIS SMITH LAKE LIMNOLOGY

10.1 Lewis Smith Lake Limnological History

Lewis Smith Lake was created when the Alabama Power Company (APCO) completed construction of a dam across the Sipsey Fork of the Black Warrior River in 1961. There were no large towns or industries located in the drainage basin and therefore point sources of pollution were not a problem. As a result, Smith Lake has been one of the more pristine reservoirs in the state of Alabama, and because of this, relatively little attention had been given to the water quality of the lake until the mid-1980's.

One of the earliest records of water quality in the Sipsey Fork prior to impoundment of Smith Lake appears in a report on stream pollution prepared by the Alabama Water Improvement Commission soon after its formation in 1947 (Alabama Water Improvement Advisory Commission 1949). In September and October 1948 at a point on the Sipsey Fork 10 miles upstream of the confluence with Mulberry Fork there was little evidence of organic enrichment of the river. Percent saturation of dissolved oxygen ranged between 81 and 93, BOD_5 varied from 0.0 mg/L to 1.5 mg/L and the most probable number of coliform bacteria ranged between 0.9 colonies/ml to 75.0 colonies/ml. Sipsey Fork waters were also low in hardness (26-48 mg/L as $CaCO_3$) and alkalinity (0-15 mg/L as $CaCO_3$) and had an acid pH (5.0-6.8).

Alabama Power Company has collected water quality data in Smith Lake and its tailwaters at intervals since impoundment but these data are not readily available. APCO did provide some water quality data for 1977 and 1982 for comparison with more recent data gathered and reported by Bayne et al. (1987).

In 1985, the paucity of information on water quality and trophic condition of Alabama reservoirs prompted ADEM, in a joint effort with the EPA, Region IV, to survey most of the public reservoirs in Alabama. A total of 31 lakes were sampled once in September 1985. Limited baseline water quality data were reported for Smith Lake and the trophic status was borderline oligotrophic/mesotrophic with a mean corrected chlorophyll a concentration of 2.61 μg/L (Raschke 1985).

Although lacking significant point sources of pollution, Smith Lake received waters from watersheds with increasing amounts of nonpoint source pollution. Strip coal mining, agricultural and forestry operations and lakeshore residential development were beginning to influence water quality of the lake (Bayne et al. 1987). Agricultural development in the lake basin has been particularly strong with poultry, beef cattle and hog rearing operations leading the way. By the mid-1980's, concern among local residents that water quality of Smith Lake was being degraded led to a special appropriation by the Alabama Legislature to fund an investigation of the lake. Auburn University's Department of Fisheries and Allied Aquacultures, working through a Cooperative Agreement with the Alabama Department of Environmental Management, undertook a one-year limnological study of Lewis Smith Lake beginning in January 1986 (Bayne et al. 1987). The primary objective of the study was to characterize the existing water quality and biological condition of the lake so that future changes in lake conditions could be detected. Additionally, efforts were made to identify lake areas that showed any impact resulting from watershed activities.

Water quality was measured at all locations in January and monthly April through November, 1986. In situ measurements of temperature, dissolved oxygen, pH and conductivity were made throughout the water column at each sampling location. Other variables measured included plant nutrients, total suspended solids and heavy metals. The phytoplankton and macroinvertebrate communities were also examined. Severe drought conditions existed during the spring and summer of 1986.

Waters of Smith Lake thermally and chemically stratified April through November 1986 and anaerobic conditions were encountered in deeper (30 + m) areas. The lake was exceptionally clear for an Alabama reservoir with a mean Secchi disk visibility in excess of 4.0 m and relatively low turbidity and total suspended solids. Conductivity (19-23 μmhos/cm) and total alkalinity (11-13 mg/L as $CaCO_3$) were low for Alabama waters and daytime pH was usually <7.0. Raschke (1985) reported phosphorus to be the limiting plant nutrient in Smith Lake. In 1986 mean total phosphorus concentrations (25-38 μg/L) were similar throughout the lake. NO_3-N concentrations (115-267 μg/L), however, were significantly ($P<0.05$) higher in the Rock Creek and Ryan Creek embayments, two tributaries draining watersheds with intensive agricultural activities.

Of the eleven heavy metal ions measured in the photic zone of Smith Lake, aluminum, arsenic, cadmium, mercury, nickel and selenium never exceeded critical concentrations considered acceptable by the U.S. Environmental Protection Agency. Concentrations of chromium, copper, iron, manganese and zinc did exceed recommended criteria on occasion. Because some heavy metals toxic to aquatic life are more soluble in waters of lower pH and alkalinity, Bayne et al. (1987) warned of the consequences of increased acidification of the lake.

Algal plankton biomass as well as macroinvertebrate abundance were relatively low when compared to most other Alabama reservoirs. Mean phytoplankton chlorophyll a (uncorrected for phaeopigments) concentration for the lake was 1.9 μg/L. Phytoplankton primary productivity was only 3.0 mg C m^{-3} hr^{-1}.

Bayne et al. (1987) concluded that Smith Lake was a relatively healthy oligotrophic reservoir in 1986. Drought conditions that existed during that year may have limited nonpoint nutrient loading of the lake resulting in reduced algal biomass and primary productivity. Concern was expressed in regards to the poor buffering capacity (low total alkalinity) and acid waters of the lake with a warning that further acidification could harm lake biota. With limited prior limnological data available for comparison, water quality and trophic trends were undetectable, and further study of the lake was recommended.

A second, more intensive assessment of Alabama public lakes was conducted in 1989. Auburn University working through a Cooperative Agreement with ADEM visited 34 public lakes twice (spring and summer) during the 1989 growing season (Bayne et al. 1989). Corrected chlorophyll a concentration (8.0 µg/L) measured in the dam forebay 1 August 1989 was 2 to 3 times higher than values previously reported for the lake (Raschke 1985 and Bayne et al. 1987). Rainfall during the 1989 growing season was unusually high particularly during June and July and likely resulted in increased nutrient loading from nonpoint sources in the basin.

The Reservoir Water Quality Monitoring Program was begun in 1990 by ADEM with funding in part provided by the EPA Clean Lakes grants. Under this program all public lakes are monitored every 2 years and certain use-impaired lakes are monitored yearly. Results of these studies are routinely published in biennial departmental reports and 305(b) reports submitted by ADEM to EPA (ADEM 1992 and 1994). Trophic status of Smith Lake has been variable during the 1990's probably reflecting rainfall\runoff conditions prior to sampling. While the lake continues to support all designated uses, ADEM (1994) expressed concern over the effects of mine drainage and heavy metals.

In 1991 a coalition of state and federal agencies led by the USDA, Soil Conservation Service designated the Ryan-Crooked-Rock Creeks Hydrologic Unit Area (HUA) as a priority watershed in terms of adverse effects caused by animal waste (USDA 1991). This HUA of about 250,000 acres makes up a major portion of the drainage area of Smith Lake. Cullman County, one of the two counties in the HUA, led the nation in broiler production and Alabama in cattle numbers in 1988. The amount of animal waste produced in the HUA was estimated to be near 1.0 billion pounds annually with 185 million pounds of this waste entering streams and lakes. This is equivalent to the waste generated by a human population of 1.15 million. In addition, over 2,300 tons of dead poultry from normal mortality is disposed of each year (USDA 1991).

The impact of animal rearing operations within this HUA was documented in the late 1980's. ADEM, in their Nonpoint Source Assessment Report and in the 1988 305(b) Water Quality Report to Congress, stated that water quality standards in about 55 miles of streams within the unit were frequently violated. They received numerous complaints of stream pollution caused by animal waste discharge in the HUA (USDA 1991). In 1988 and 1989 Auburn University's Department of Fisheries and Allied Aquacultures working through a Cooperative Agreement with the USDA, Soil Conservation Service, conducted water quality and biological studies of select streams within the HUA (Deutsch et al. 1990). Crooked Creek and especially Ryan Creek (Rock Creek was not studied) were negatively influenced by agricultural activities on the watersheds. Sampling conducted during a significant rainfall revealed dramatic effects on water quality of receiving streams.

A $2.9 million cooperative project involving nine federal, state and local agencies was begun in 1991 to correct water quality problems in the Ryan-Crooked-Rock Creeks hydrologic unit (USDA 1991). The plan involved installation of animal waste control facilities, dead poultry and swine disposal systems, livestock exclusion from streams, alternative water supplies, land treatment in conjunction with waste utilization and continued stream and lake monitoring and evaluation. The Extension Service, with technical assistance from SCS staff located in Cullman County, were to install practices over a 5-year period. At completion, a 53% reduction in waste load to receiving streams in the HUA was expected. Auburn University, working through a series of Cooperative Agreements with SCS, continued to examine water quality and biotic communities of select HUA streams from 1991 through 1995. Streams included in the study were Ryan, Crooked, Rock and Blevins and nearby reference streams Inman, Rush and Marriot. Algal communities of the Ryan, Crooked, Rock and Sipsey embayments of Smith Lake were also examined during the 5 years. A final report on the results of these studies was being prepared at the time of this writing.

10.2 Current Limnological Condition

From November 1994 through October 1995, as part of a Phase I, Clean Lakes, Diagnostic/ Feasibility Study, Lewis Smith Lake was examined to assess current limnological condition. The study was conducted by Auburn University (AU) under contract with the Alabama Department of Environmental Management (ADEM). Others providing data or information included in this lake assessment were: U.S. Environmental Protection Agency (EPA), Alabama Power Company, ADEM and the Alabama Public Health Department.

10.2.1 Lake Water Quality

Water quality variables were measured in Smith Lake in January and monthly from April through October of 1995 (Table 10-1). Three mainstem locations and six tributary embayments were sampled during the study (Table 10-2 and Fig. 10-1). At each sampling station, in situ measurements of temperature, pH, dissolved oxygen (DO) and specific conductance were made throughout the water column with a Hydrolab® Surveyor II and Surveyor III (Table 10-3). Sampling was usually conducted between 0700 and 1300 hours. Secchi disk visibility was measured and the 1% incident light depth was determined with a submarine photometer at each sampling station.

A composite water sample was collected from the photic zone of the water column at each sampling station for additional water quality analyses. The photic zone depth was defined as four times the Secchi disk visibility depth (Taylor 1971). This estimate usually exceeded the 1% incident light depth. A submersible electric pump and hose apparatus was raised and lowered throughout the photic zone and the water was collected in a plastic container onboard the boat. Aliquots of this composite

Table 10-1. Schedule of activities for the diagnostic study of Smith Lake in 1994 and 1995.

	1994			1995									
Task	Month	N	D	J	F	M	A	M	J	J	A	S	O
Water Quality				X			X	X	X	X	X	X	X
Metals											X		
Chlorophyll a				X			X	X	X	X	X	X	X
Phytoplankton				X			X	X	X	X	X	X	X
Primary Productivity								X	X	X	X	X	
Algal Growth Potential Test								X	X	X	X	X	

Table 10-2. Smith Lake sampling locations and activities during the diagnostic study conducted in 1994 and 1995.

Sampling Stations #	Description	Water Quality	Chlorophyll	Phytoplankton	Primary Productivity	AGPT
1	Dam forebay	X	X	X	X	X
2	Ryan Creek embayment	X	X	X		
3	Rock Creek embayment	X	X	X		
4	Dismal Creek embayment	X	X	X		
5	Mainstem at Duncan Creek	X	X	X	X	X
6	Clear Creek embayment	X	X	X		
7	Mainstem downstream of Sipsey/Brushy Creek confluence	X	X	X	X	X
8	Brushy Creek embayment	X	X	X		
9	Sipsey River embayment	X	X	X		X

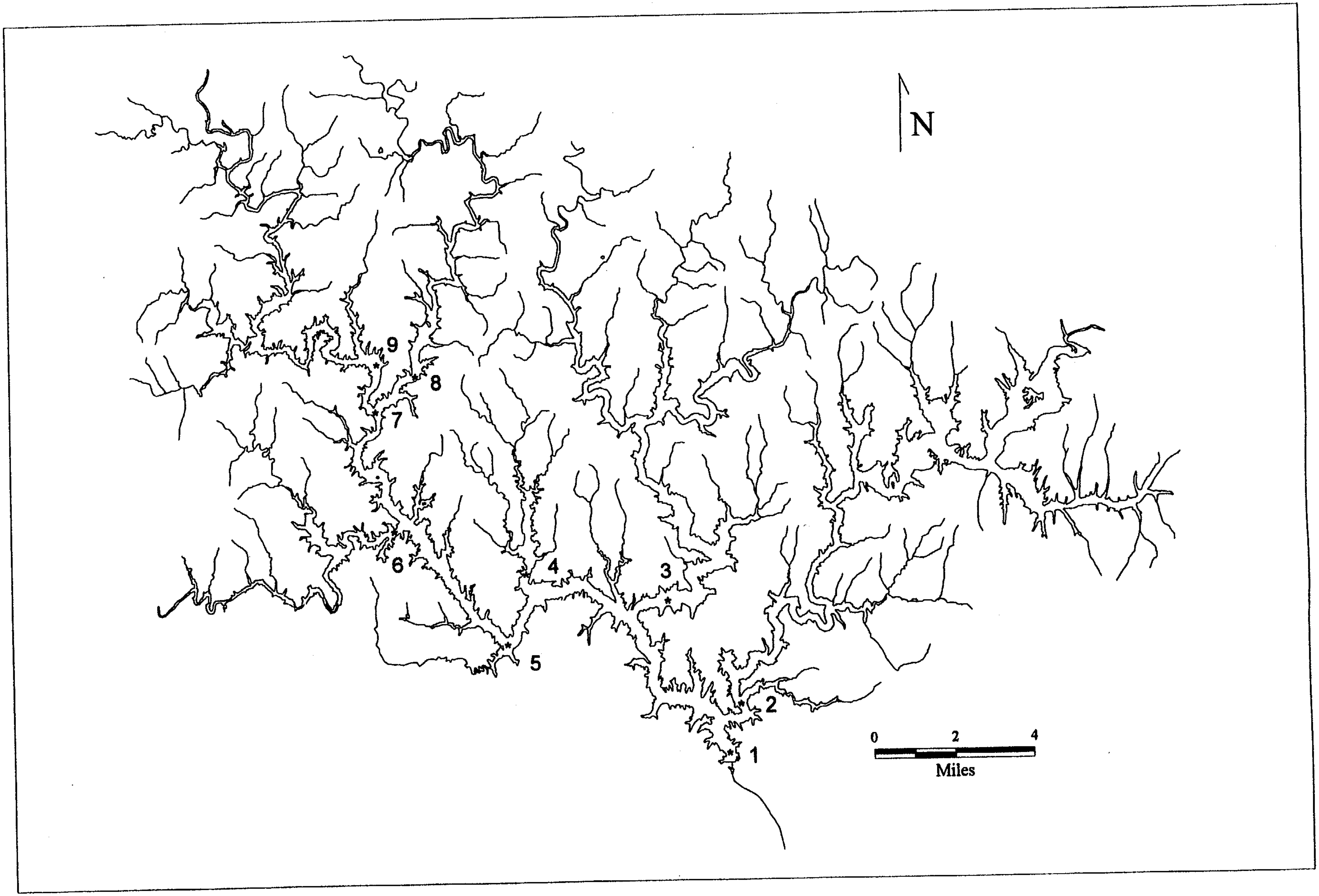


Figure 10-1. Map of Lewis Smith Lake showing lake sampling locations for the diagnostic study conducted during 1994 and 1995.

Table 10-3. Analytical methods used in measuring water quality in Smith Lake, 1994 and 1995.

Variable	Method	Reference
In Situ		
Temperature	Thermistor	APHA 1992
Dissolved oxygen	Membrane electrode	APHA 1992
pH	Glass electrode	APHA 1992
Specific conductance	Conductivity cell	APHA 1992
Visibility	Secchi disk	Lind 1985
Photic zone determination	Submarine photometer	Lind 1985
Laboratory Analyses		
Total suspended solids	Vacuum filtration	APHA 1992
Turbidity	HACH turbidimeter	APHA 1992
Alkalinity	Potentiometric titration	APHA 1992
Hardness	EDTA titrimetric	Boyd 1979
Chlorides	Mercuric nitrate	APHA 1992
Total ammonia (NH_3-N)	Phenate method	APHA 1992
Nitrite (NO_2-N)	Diazotizing method	APHA 1992
Nitrate (NO_3-N)	Cadmium reduction	APHA 1992
Kjeldahl nitrogen	Macro Kjeldahl	APHA 1992
Total phosphorus	Persulfate digestion, ascorbic acid	APHA 1992
Soluble reactive phosphorus	Ascorbic acid	APHA 1992
Metals		ADEM Lab

sample were poured into Nalgene® containers and stored on ice during transport to laboratory facilities at Auburn University. Samples to be held for later analysis (total phosphorus and Kjeldahl nitrogen) were preserved in the field (APHA et al. 1992). All analyses were conducted within recommended holding times (APHA et al. 1992). Samples were collected at mid-channel locations between 0700 and 1300 hours. Methods used to analyze water appear in Table 10-3.

When practical, limnological conditions existing in Smith Lake in 1995 were compared to conditions existing in 1986 based on results of a similar study conducted at that time (Bayne et al. 1987). Such a comparison assisted in determining if significant changes had occurred in the lake during the previous decade.

Meteorological conditions can affect water quantity and water quality of reservoirs. Drought conditions existed throughout Alabama during the mid-1980's resulting in above normal temperatures (+2.1°C) and below normal rainfall (-11.2 cm) in the vicinity of Smith Lake in 1986 (Table 10-4). Meteorological conditions were nearer normal in 1995 with mean annual temperatures just below normal (-0.2°C) and rainfall somewhat above normal (+2.7 cm). Mean daily inflow and outflow in 1986 averaged less than 50% of the inflow and outflow recorded in 1995 (Table 10-4). Drought conditions that existed in 1986 would be expected to reduce nonpoint source loading of sediment and nutrients to the lake while increasing the hydraulic retention time of the lake.

To minimize water quality variations caused by seasonal changes in meteorological conditions, water quality data were grouped and examined by season. The seasons were defined as follows: winter (January), spring (April and May), summer (June, July and August) and fall (September and October).

Smith Lake is the deepest ($Z = 20$ m) and one of the most voluminous (171,432 ha-m) reservoirs in Alabama. During periods of average discharge (394 ha-m per day) the hydraulic retention time is 435 days. Under reduced flows of 1986 the mean annual retention time was 992 days and under more normal

Table 10-4. Meteorological conditions, Sipsey River inflow and lake outflow measured during the limnological study of Lewis Smith Lake, 1986 and 1995.

Year	Month	Temp[1] °C	DFN[2]	Rainfall[1] (cm)	DFN[2] (cm)	Mean Daily Solar Radiation[3] (Langleys)	Mean Daily Inflow[4] (CFS)	Mean Daily Outflow[5] (CFS)
1986	Jan	4.6	0.6	1.1	-4.6	250	29	620
	Feb	8.7	3.1	3.4	-1.9	266	145	416
	Mar	11.8	1.7	3.4	-3.6	433	139	230
	Apr	16.8	1.0	0.4	-5.3	522	26	1
	May	20.8	0.9	8.3	3.5	479	97	70
	Jun	24.9	1.1	2.8	-1.1	525	99	1,257
	Jul	27.1	1.6	2.5	-2.2	536	16	1,240
	Aug	24.9	-0.3	5.0	1.4	506	5	886
	Sept	23.3	1.1	3.6	-1.2	413	4	1,250
	Oct	16.4	0.8	6.2	3.0	296	18	467
	Nov	12.3	2.6	7.0	2.5	173	124	18
	Dec	5.2	-0.3	4.3	-1.7	144	180	2,044
	Annual	16.4	1.2	48.0	-11.2	379	74	708
1995	Jan	5.0	1.4	5.2	-0.4	175	214	1,554
	Feb	5.7	-0.2	6.6	1.2	262	648	2,197
	Mar	12.3	1.4	4.8	-1.9	363	342	2,951
	Apr	15.6	-0.1	6.6	1.0	477	317	1,505
	May	20.3	0.5	4.3	-1.1	478	130	1,641
	Jun	22.6	-1.1	5.1	0.9	529	88	1,249
	Jul	25.9	0.6	5.5	0.6	463	12	1,358
	Aug	27.2	2.3	3.2	-0.5	456	6	1,463
	Sept	21.0	-0.9	3.8	-1.0	397	5	1,048
	Oct	15.3	-0.4	6.7	3.2	332	50	301
	Nov	6.6	-3.5	6.3	1.5	203	133	2,248
	Dec	4.4	-1.2	5.2	-0.9	191	224	2,165
	Annual	15.2	-0.1	63.2	2.7	360	177	1,640

[1] Temperature and rainfall data from Haleyville and St. Bernard, AL, 1986 and 1995.
[2] DFN = deviation from normal
[3] Solar radiation from Winfield, AL
[4] United States Geological Survey, Sipsey Fork, Black Warrior River
[5] Alabama Power Company

flows encountered in 1995, 428 days. These retention times are much higher than values reported for other Alabama reservoirs.

Smith Lake is a warm monomictic lake that in both 1986 and 1995 stratified thermally ($\Delta T =$ 1.0°C/m depth) prior to the April sampling trip both years and remained stratified through November 1986 and October 1995 (Fig. 10-2). Highest water temperatures were measured during the summer and lowest during winter (January) in both 1986 and 1995 (Tables 10-5, 10-6, 10-7 and 10-8). In 1995, seasonal mean water temperatures were higher than 1986 values during winter, spring, and summer (Tables 10-5, 10-6 and 10-7) but were similar during the fall (Table 10-8). Mean air temperatures and solar radiation were higher in 1986 than in 1995 (Table 10-4), so the warmer water of 1995 must have been caused by other conditions, perhaps higher densities of phytoplankton in 1995.

Chemical stratification accompanied thermal stratification of Smith Lake as was evidenced by dissolved oxygen (DO) profiles (Fig. 10-2). DO concentrations declined with water depth and concentrations <1.0 mg/L were commonly encountered even during January 1995 when the lake was not thermally stratified (see electronic data). DO concentrations of 0.0 mg/L were measured on numerous sampling dates in deeper (>30 m) areas of the lake and occasionally at depths as shallow as 10 m.

Seasonal mean DO concentrations measured in the upper water column (0.3 m-2.0 m) were similar in 1986 and 1995 (Tables 10-5, 10-6, 10-7, and 10-8). The lowest DO concentration measured at 2 m depth in 1995 was 6.5 mg/L.

Beginning in June 1986 a pattern of DO distribution in the water column was noted at most of the sampling stations. Maximum DO concentrations were measured in the epilimnion but declined in the metalimnion and rose again in the hypolimnion before declining further (Bayne et al. 1987). In 1995 the same phenomenon occurred beginning at most sampling locations in May and persisting through October (Fig. 10-3). Bayne et al. (1987) attributed these DO distribution patterns to either organic matter decomposition in the metalimnion or the concentration of zooplankton in the metalimnion. Organic

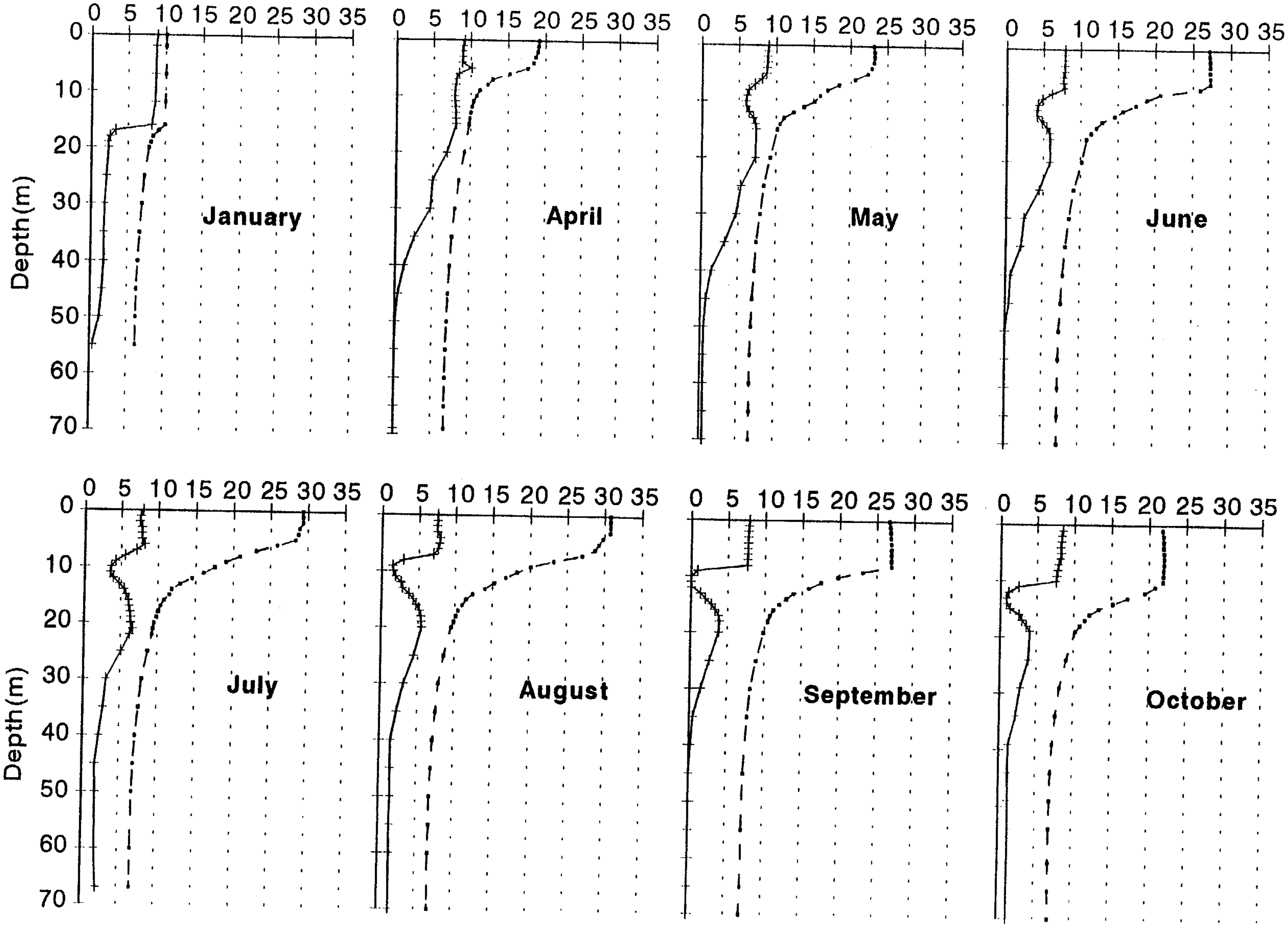


Figure 10-2. Dissolved oxygen (mg/l) (—+—) and temperature (C°) (– ▪ –) profiles at station 1 (dam forebay) on Smith Lake, January 1995 through October 1995.

Table 10-5. Temperature, dissolved oxygen and conductivity measured at each Smith Lake sampling station during the winter (January) of 1986 and 1995. Values are reported for the 2 m depth in 1995 and 0.3 m depth in 1986.

Mainstem station	Temperature (°C)		Dissolved oxygen mg/L		Conductivity μmhos/cm	
	1986	1995	1986	1995	1986	1995
1	8.3	10.1	9.7	8.8	15.5	44.7
5	7.7	10.2	10.1	10.1	9.5	43.6
7	7.0	9.6	9.1	9.5	10.0	40.8
Embayment Stations						
2	8.3	10.2	9.0	8.3	28.5	53.1
3	8.3	10.4	9.2	8.5	15.0	43.8
4	7.6	10.3	10.0	9.3	10.0	41.7
6	7.1	10.2	9.6	10.3	8.5	42.8
8	-	9.9	-	9.8	-	39.6
9	-	9.6	-	10.3	-	44.4

Table 10-6. Mean (range) temperature, dissolved oxygen and conductivity measured at each Smith Lake sampling station during the spring (April and May) of 1986 and 1995. Values are reported for the 2 m depth in 1995 and either 2 m or 0.3 m depth for 1986.

Mainstem station	Temperature (°C)		Dissolved oxygen mg/L		Conductivity µmhos/cm	
	1986	1995	1986	1995	1986	1995
1	18.6 (17.0-20.1)	21.1 (19.0-23.2)	9.8 (9.8-9.9)	8.9 (8.9-8.9)	23.3 (23.0-24.0)	45.9 (44.8-47.0)
5	18.7 (16.6-20.9)	21.2 (18.8-23.5)	9.7 (9.5-10.0)	9.2 (8.8-9.6)	20.5 (20.0-21.0)	39.5 (39.2-39.7)
7	19.3 (16.6-22.1)	21.9 (20.0-23.8)	9.5 (9.3-9.7)	9.1 (9.0-9.2)	20.5 (20.0-21.0)	34.3 (34.0-34.5)
Embayment Stations						
2	19.2 (16.9-21.6)	21.6 (19.7-23.5)	9.3 (8.6-9.9)	9.0 (8.8-9.1)	29.0 (26.0-33.0)	47.1 (44.8-49.4)
3	18.9 (17.1-21.0)	21.9 (20.2-23.7)	9.5 (8.8-9.9)	9.1 (8.6-9.7)	24.3 (23.0-26.0)	45.2 (44.8-45.6)
4	18.5 (17.1-20.0)	21.9 (20.2-23.5)	9.4 (9.0-9.7)	9.0 (8.6-9.4)	22.3 (21.0-24.0)	42.7 (42.4-43.0)
6	18.4 (16.2-20.6)	22.1 (20.2-24.0)	9.7 (9.6-9.8)	9.0 (8.7-9.3)	18.8 (18.0-20.0)	37.1 (36.6-37.6)
8	-	22.1 (20.3-23.8)	-	9.0 (8.7-9.2)	-	33.2 (33.1-33.3)
9	-	22.0 (20.0-24.0)	-	9.2 (8.9-9.4)	-	34.4 (34.3-34.5)

Table 10-7. Mean (range) temperature, dissolved oxygen and conductivity measured at each Smith Lake sampling station during the summer (June, July and August) of 1986 and 1995. Values are reported for the 2 m depth in 1995 and either 2 m or 0.3 m depth for 1986.

Mainstem station	Temperature (°C) 1986	Temperature (°C) 1995	Dissolved oxygen mg/L 1986	Dissolved oxygen mg/L 1995	Conductivity µmhos/cm 1986	Conductivity µmhos/cm 1995
1	27.8 (27.1-28.6)	29.1 (27.2-30.8)	8.5 (7.7-9.8)	7.6 (7.5-7.9)	29.8 (25.0-35.0)	47.7 (44.6-51.4)
5	28.0 (27.2-28.5)	28.8 (26.6-30.6)	8.3 (7.8-9.1)	8.0 (7.5-8.3)	25.7 (23.0-28.0)	41.4 (37.2-45.2)
7	26.8 (23.7-28.5)	29.1 (27.1-30.7)	9.3 (7.2-11.7)	7.6 (7.1-7.9)	25.8 (23.0-29.0)	37.4 (33.5-41.3)
Embayment Stations						
2	27.5 (24.4-30.1)	28.9 (27.1-30.7)	8.8 (7.8-9.6)	8.0 (7.9-8.1)	35.7 (31.0-43.0)	48.1 (44.2-52.2)
3	27.6 (25.0-29.4)	28.9 (27.2-30.5)	9.2 (8.0-10.6)	8.2 (7.7-8.7)	28.7 (25.0-32.0)	47.1 (45.6-49.6)
4	27.5 (24.4-29.2)	28.7 (26.5-30.6)	9.5 (7.8-11.1)	7.9 (7.6-8.2)	27.0 (25.0-29.0)	44.5 (41.8-48.2)
6	28.2 (27.5-29.2)	28.9 (26.8-30.9)	6.0 (3.0-8.4)	7.9 (7.4-8.2)	24.8 (23.0-28.0)	40.1 (35.9-44.7)
8	-	29.1 (27.1-30.7)	-	7.7 (7.2-8.0)	-	36.7 (32.5-40.9)
9	-	29.0 (27.1-30.7)	-	7.7 (7.1-8.1)	-	37.6 (34.1-41.5)

Table 10-8. Mean (range) temperature, dissolved oxygen and conductivity measured at each Smith Lake sampling station during the fall (September and October) of 1986 and 1995. Values are reported for the 2 m depth in 1995 and either 2 m or 0.3 m depth for 1986.

Mainstem station	Temperature (°C)		Dissolved oxygen mg/L		Conductivity µmhos/cm	
	1986	1995	1986	1995	1986	1995
1	24.2 (22.8-25.5)	24.3 (21.9-26.8)	8.0 (7.7-8.5)	8.0 (7.7-8.3)	28.0 (27.0-29.0)	50.2 (50.0-50.4)
5	24.2 (22.7-25.8)	24.3 (21.7-26.8)	7.6 (7.0-8.0)	7.7 (7.2-8.2)	27.3 (27.0-28.0)	44.6 (44.3-44.9)
7	24.4 (22.9-26.0)	24.0 (21.4-26.6)	7.2 (6.7-7.9)	7.3 (6.8-7.7)	27.5 (27.0-28.0)	40.9 (40.4-41.4)
Embayment Stations						
2	24.6 (23.0-26.2)	24.3 (21.8-26.7)	8.1 (7.8-8.3)	8.1 (7.7-8.5)	36.0 (34.0-39.0)	51.7 (51.6-51.8)
3	24.3 (22.8-25.8)	24.1 (21.4-26.8)	8.0 (7.6-8.4)	8.2 (7.6-8.7)	26.8 (25.0-28.0)	47.7 (46.8-48.6)
4	24.2 (22.8-25.7)	24.0 (21.4-26.6)	7.5 (7.0-8.1)	8.0 (7.3-8.6)	26.8 (26.0-28.0)	46.9 (45.6-48.2)
6	24.0 (22.4-25.7)	23.9 (21.4-26.5)	7.9 (6.9-9.6)	7.1 (6.5-7.7)	26.3 (26.0-27.0)	45.2 (44.7-45.6)
8	-	23.9 (21.3-26.5)	-	7.3 (6.7-7.9)	-	40.3 (39.5-41.0)
9	-	23.9 (21.3-26.6)	-	7.3 (6.5-8.1)	-	40.9 (39.9-41.8)

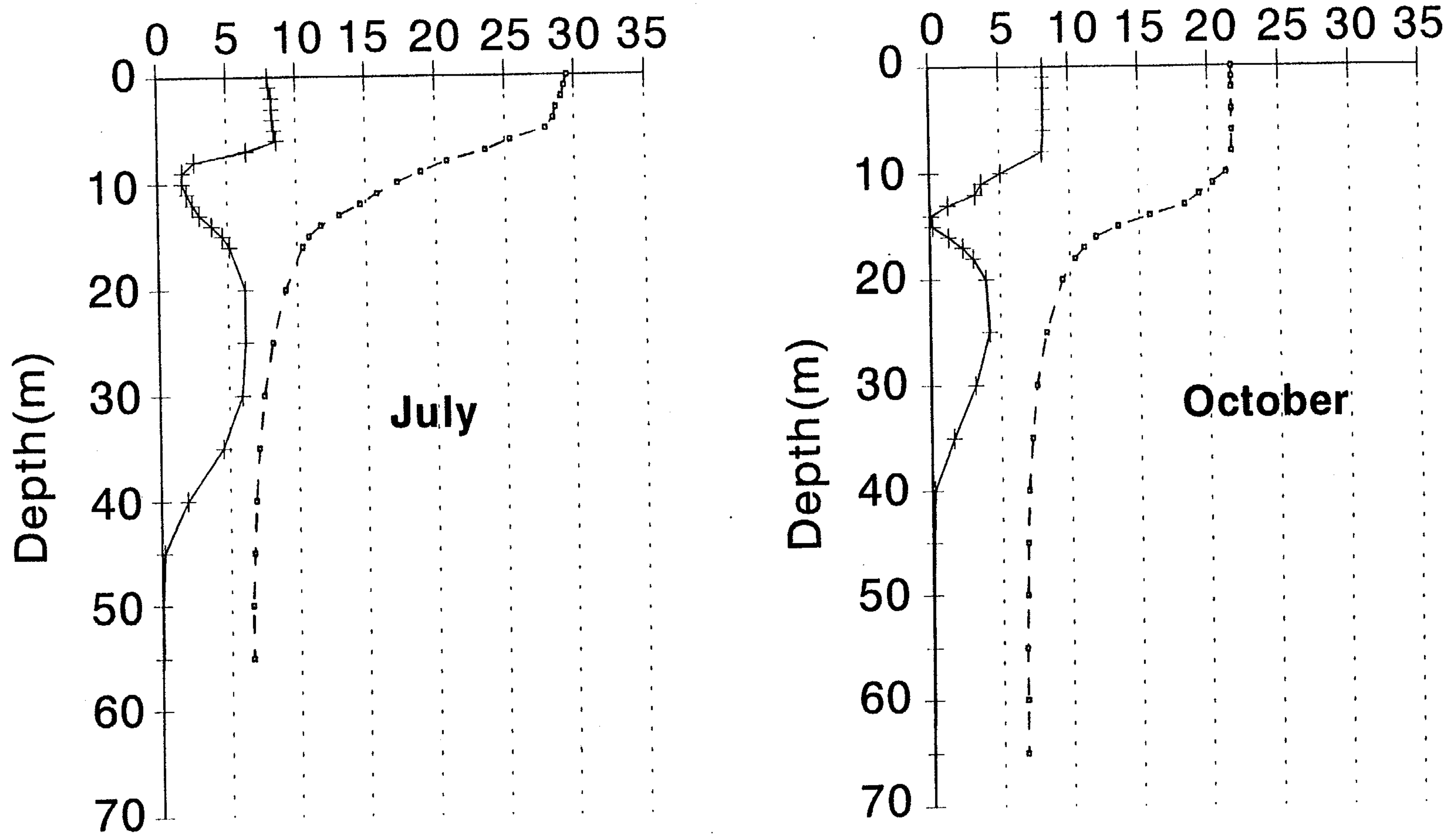


Figure 10-3. Dissolved oxygen (mg/l) (—+—) and temperature (C°) (—■—) profiles at station 5 on Smith Lake during July and October 1995.

matter (plankton) produced in the epilimnion dies and sinks toward the bottom. The colder more dense water of the thermocline (metalimnion) slows the descent of the material allowing decomposition to occur at this level. The decomposition process uses available oxygen and creates the oxygen slump. This oxygen slump can be accentuated by large numbers of zooplankton living and respiring in the metalimnion. Cox (1984) reported similar occurrences in metalimnia of some of the TVA tributary reservoirs.

Specific conductance, a measure of the ionic content of water, ranged from a low of 32.5 µmhos/cm in the Brushy Creek embayment in June 1995 to a high of 53.1 µmhos/cm in Ryan Creek embayment in January 1995 (Tables 10-5, 10-6, 10-7 and 10-8). Specific conductance is a crude indicator of natural fertility since increases in ionic content are usually accompanied by increases in plant nutrients. Mainstem Alabama reservoirs were found to have specific conductance values ranging from about 23 µmhos/cm to 200 µmhos/cm (Bayne et al. 1989). Smith Lake ranked in the lower half of the Alabama range indicating that it was one of the less fertile lakes in the state. However, when annual mean specific conductance measured at 2 m was compared statistically for 1986 and 1995 using an analysis of variance (ANOVA) and Tukey's Studentized Range Test (Tukey's Test), conductance was higher ($P<0.05$) in 1995 at every sampling station (Fig. 10-4). Lake fertility seems to have increased between 1986 and 1995. This may reflect a general trend of increasing fertility of the lake or it may have resulted from higher rainfall and watershed runoff that occurred in 1995 (Table 10-4). Likely both of these factors are responsible for the increase.

Specific conductance of tributary embayments was similar to nearby mainstem locations, however, seasonal mean conductance was consistently highest in Ryan Creek (station 2) when compared to all other sampling stations in both 1986 and 1995 (Tables 10-5, 10-6, 10-7 and 10-8, Fig. 10-5). Clear Creek embayment in 1986 and Brushy Creek embayment in 1995 had the lowest mean specific conductance when compared to other sampling stations.

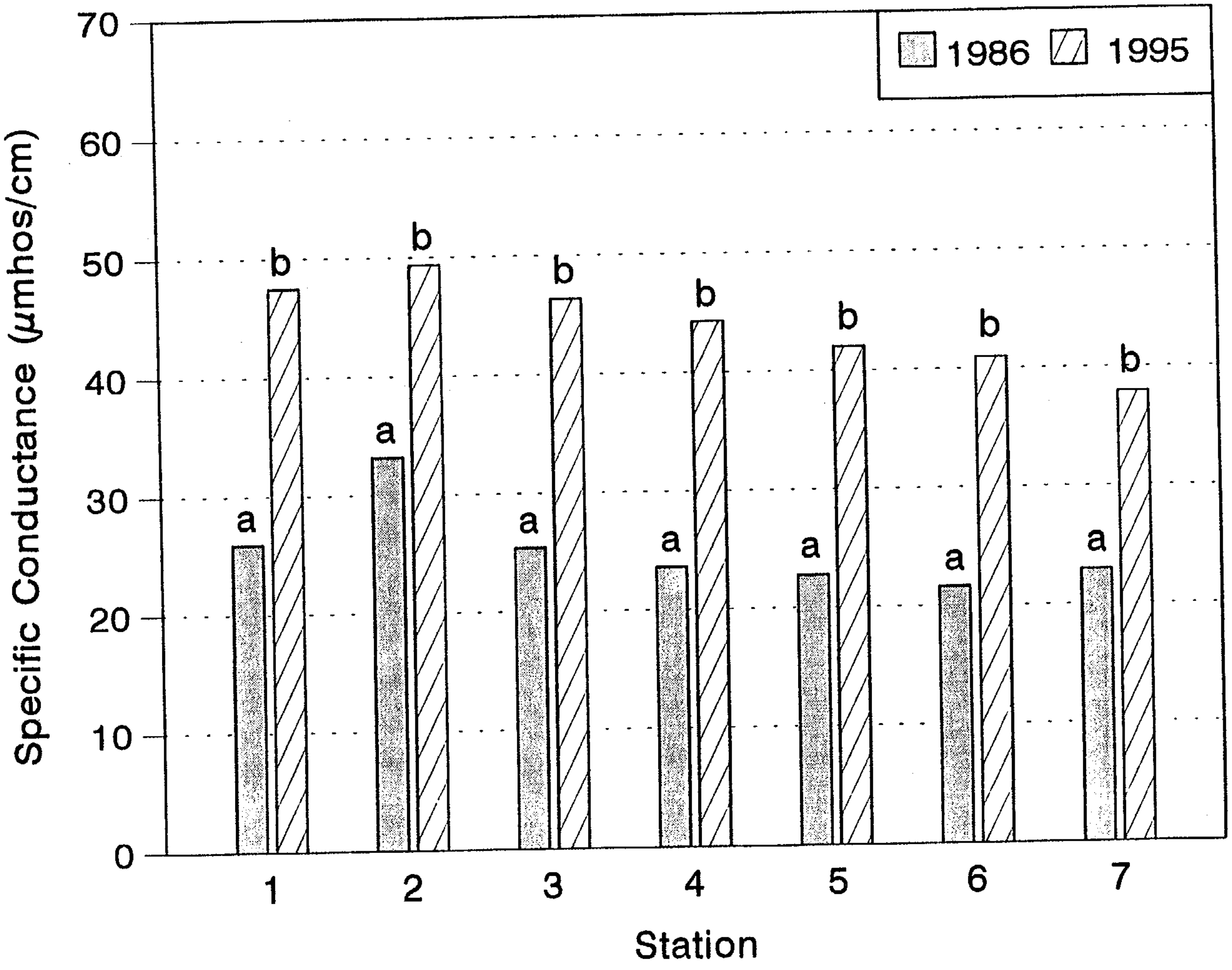


Figure 10-4. Annual mean specific conductance at a depth of 2m at stations 1-7 during 1986 and 1995. Within a station, bars with different letters represent significantly different means ($P<0.05$).

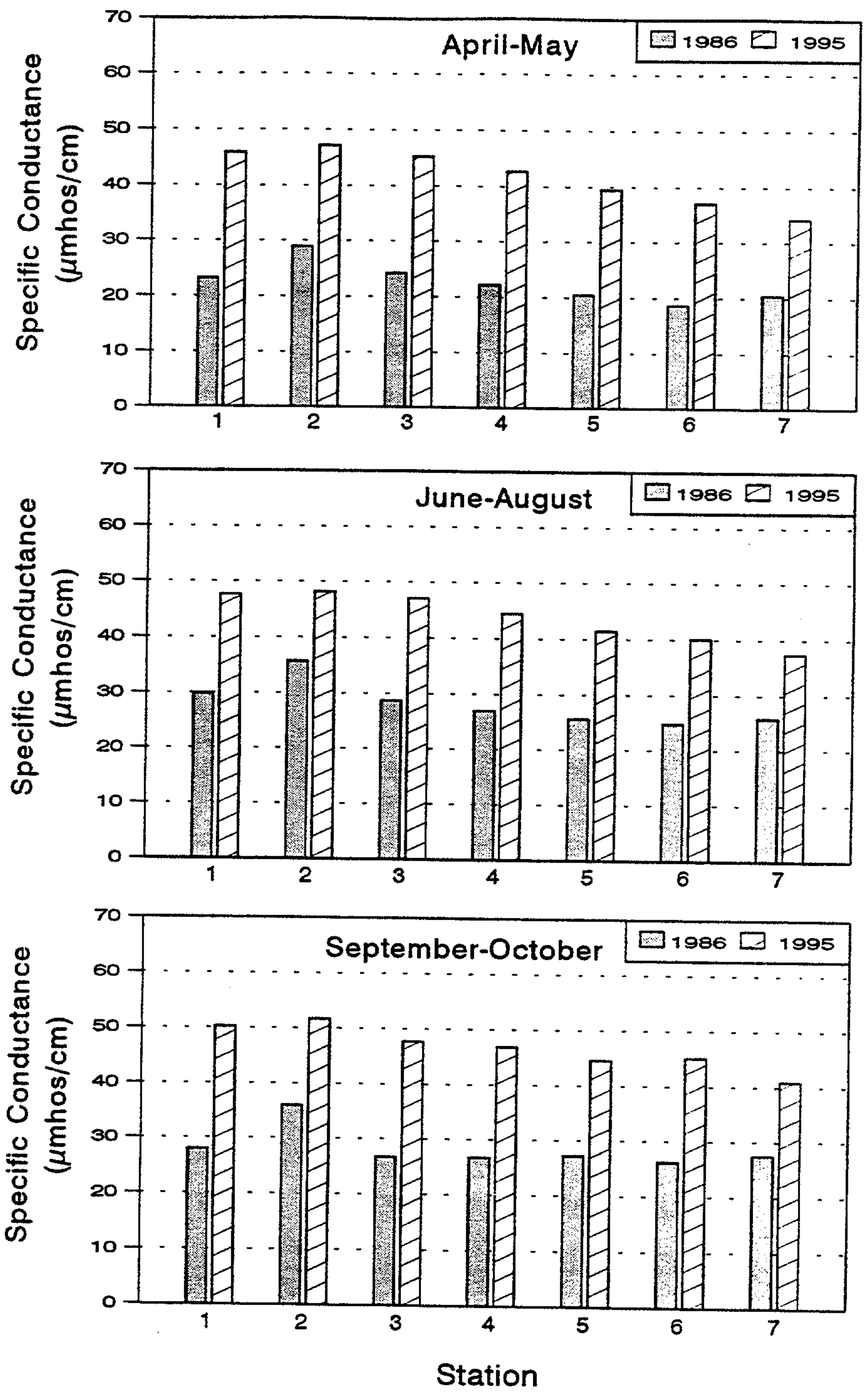


Figure 10-5. Seasonal mean specific conductance at a depth of 2m at stations 1-7 during the spring, summer and fall of 1986 and 1995.

Examination of temperature, DO and specific conductance data at the mainstem stations (1, 5 and 7) in January 1995 revealed that the lake may not have mixed thoroughly prior to that date (see electronic data). Relatively low DO concentrations and high specific conductance at greater depths suggest persistent chemical stratification. The similarity of water column conditions existing at the dam forebay (station 1) and the Duncan Creek mainstem station 5 between January and April 1995 (no sampling in February and March) raises the possibility that deeper areas of Smith Lake may not completely mix each year (see electronic data).

Turbidity and total suspended solids (TSS) were consistently higher at all stations during winter (January) of 1986 than in winter 1995 (Table 10-9). Seasonal mean turbidity and TSS during spring, summer and fall seasons were usually similar at comparable sampling stations in 1986 and 1995 (Tables 10-10, 10-11 and 10-12). Increased rainfall and runoff that occurred in 1995 (Table 10-4) did not result in higher concentrations of suspended solids in the upper water column of Smith Lake.

Light penetration as measured by Secchi disk visibility was greater in 1986 than in 1995. On all but one occasion, Clear Creek (station 6) in the spring (Table 10-14), seasonal mean visibilities were greater in 1986 (Tables 10-13, 10-14, 10-15 and 10-16, Fig. 10-6). When annual mean visibilities were tested statistically using an ANOVA and Tukey's Test, 1986 visibilities were significantly ($P<0.05$) greater at most sampling stations (Fig. 10-7). Maximum visibility measured in 1986 was 9.0 m in Ryan Creek embayment (station 2) and in 1995 the maximum was 6.7 m in the dam forebay (station 1). The lower limit of the photic zone was usually two to three times the Secchi visibility depth. As is typical of mainstream reservoirs, upstream (stations 7, 8 and 9) locations frequently had higher turbidity and lower visibility than downstream (stations 5 and 1) locations (Thornton et al. 1990).

Total alkalinity, the concentration of bases in water (expressed as mg/L $CaCO_3$), primarily composed of bicarbonate (HCO_3^-) and carbonate ($CO_3^=$) ions, usually increases as basin soil fertility increases. In a recent study, total alkalinity of large mainstream impoundments of Alabama varied from

Table 10-9. Turbidity and total suspended solids measured at each Smith Lake sampling station during the winter (January) of 1986 and 1995. Photic zone composite samples were analyzed. 1 JTU = about 2 NTU's.

	Turbidity		Total Suspended Solids (mg/L)	
Mainstem Station	(JTU's) 1986	(NTU's) 1995	1986	1995
1	4.0	1.2	4.50	0.16
5	3.5	1.7	4.00	0.57
7	7.0	2.7	2.00	0.86
Embayment Stations				
2	3.0	1.2	8.00	0.39
3	3.5	1.1	7.00	0.03
4	3.5	1.9	5.50	0.73
6	4.5	2.4	4.50	0.70
8	-	2.5	-	0.65
9	-	2.6	-	0.83

Table 10-10. Mean (range) turbidity and total suspended solids measured at each Smith Lake sampling station during the spring (April and May) of 1986 and 1995. Photic zone composite samples were analyzed. 1 JTU = <u>about</u> 2 NTU's.

	Turbidity		Total Suspended Solids (mg/L)	
Mainstem Station	(JTU's) 1986	(NTU's) 1995	1986	1995
1	1.8 (0-5)	1.9 (1.7-2.1)	3.00 (1.0-6.0)	0.45 (0.26-0.65)
5	1.5 (0-3)	4.2 (3.1-5.2)	1.50 (1.0-2.0)	2.00 (1.50-2.50)
7	1.5 (0-3)	4.0 (3.4-4.5)	2.25 (1.0-5.0)	1.71 (1.12-2.30)
Embayment Stations				
2	1.0 (0-2)	1.9 (1.7-2.0)	0.75 (0.0-1.0)	0.28 (0.09-0.47)
3	1.0 (0-2)	2.0 (1.9-2.0)	0.75 (0.0-1.0)	0.83 (0.79-0.87)
4	1.3 (0-3)	3.0 (2.6-3.3)	1.50 (1.0-3.0)	1.56 (1.31-1.80)
6	3.0 (0-6)	6.4 (4.7-8.1)	1.50 (0.0-2.0)	3.23 (3.00-3.46)
8	-	4.1 (3.4-4.8)	-	1.39 (0.17-2.60)
9	-	4.1 (3.4-4.8)	-	1.55 (0.70-2.40)

Table 10-11. Mean (range) turbidity and total suspended solids measured at each Smith Lake sampling station during the summer (June, July and August) of 1986 and 1995. Photic zone composite samples were analyzed. 1 JTU = <u>about</u> 2 NTU's.

Mainstem Station	Turbidity (JTU's) 1986	Turbidity (NTU's) 1995	Total Suspended Solids (mg/L) 1986	Total Suspended Solids (mg/L) 1995
1	1.8 (0-5)	1.8 (1.2-2.5)	1.00 (1.0-1.0)	1.5 (1.0-1.9)
5	2.2 (1-6)	1.6 (1.3-2.2)	1.00 (1.0-1.0)	1.3 (0.8-2.2)
7	4.5 (1-15)	1.9 (1.5-2.1)	1.33 (1.0-2.0)	1.2 (1.2-1.2)
Embayment Stations				
2	1.7 (0-5)	1.5 (0.9-2.1)	1.33 (1.0-3.0)	1.1 (0.9-1.4)
3	1.5 (1-3)	1.3 (1.0-1.5)	1.00 (1.0-1.0)	1.0 (0.8-1.4)
4	1.7 (1-3)	1.8 (1.3-2.2)	1.50 (1.0-4.0)	1.4 (1.1-1.9)
6	5.7 (0-17)	3.9 (3.4-4.6)	2.33 (1.0-4.0)	2.8 (2.7-3.0)
8	-	2.5 (2.4-2.7)	-	2.0 (1.6-2.4)
9	-	2.1 (2.0-2.3)	-	1.6 (1.4-1.7)

Table 10-12. Mean (range) turbidity and total suspended solids measured at each Smith Lake sampling station during the fall (September and October) of 1986 and 1995. Photic zone composite samples were analyzed. 1 JTU = about 2 NTU's.

	Turbidity		Total Suspended Solids (mg/L)	
Mainstem Station	(JTU's) 1986	(NTU's) 1995	1986	1995
1	1.0 (0-2)	1.8 (1.7-1.8)	1.25 (1.0-2.0)	1.3 (1.1-1.5)
5	1.3 (0-3)	3.7 (2.7-4.6)	2.25 (1.0-5.0)	2.3 (2.1-2.6)
7	2.6 (0-5)	3.6 (2.8-4.4)	2.25 (1.0-4.0)	2.1 (1.9-2.2)
Embayment Stations				
2	0.5 (0-1)	1.6 (1.5-1.6)	2.25 (1.0-5.0)	1.2 (1.0-1.3)
3	1.0 (0-2)	1.5 (1.2-1.8)	2.25 (1.0-5.0)	1.1 (1.1-1.1)
4	1.5 (0-3)	2.3 (2.0-2.6)	2.50 (1.0-4.0)	1.6 (1.1-2.1)
6	4.8 (1-9)	4.7 (3.4-6.0)	4.75 (3.0-8.0)	3.2 (2.2-4.2)
8	-	3.7 (3.2-4.2)	-	2.6 (2.2-3.0)
9	-	4.4 (3.7-5.1)	-	2.5 (2.5-2.5)

Table 10-13. Secchi disk visibility and the 1% incident light depth at each Smith Lake sampling station during the winter (January) of 1986 and 1995.

Mainstem Station	Secchi Visibility (cm)		1% Incident Light (cm)	
	1986	1995	1986	1995
1	-	438	-	830
5	-	343	-	745
7	-	284	-	687
Embayment Stations				
2	-	631	-	1,430
3	-	412	-	796
4	-	322	-	698
6	-	296	-	620
8	-	297	-	712
9	-	299	-	707

Table 10-14. Mean (range) Secchi disk visibility and 1% incident light depth at each Smith Lake sampling station during the spring (April and May) of 1986 and 1995.

Mainstem Station	Secchi Visibility (cm) 1986	Secchi Visibility (cm) 1995	1% Incident Light (cm) 1986	1% Incident Light (cm) 1995
1	614 (602-625)	524 (373-674)	-	923 (902-944)
5	447 (275-618)	339 (328-349)	-	750 (740-760)
7	342 (219-465)	307 (293-321)	-	724 (715-733)
Embayment Stations				
2	868 (836-900)	427 (366-488)	-	1,076 (992-1,160)
3	691 (591-790)	402 (346-458)	-	912 (896-928)
4	467 (333-600)	300 (261-338)	-	783 (763-802)
6	257 (221-292)	297 (249-344)	-	604 (575-633)
8	-	305 (282-328)	-	709 (687-730)
9	-	320 (309-331)	-	729 (695-763)

Table 10-15. Mean (range) Secchi disk visibility and 1% incident light depth at each Smith Lake sampling station during the summer (June, July and August) of 1986 and 1995.

Mainstem Station	Secchi Visibility (cm) 1986	Secchi Visibility (cm) 1995	1% Incident Light (cm) 1986	1% Incident Light (cm) 1995
1	334 (240-456)	273 (235-332)	-	856 (778-916)
5	330 (290-386)	324 (240-395)	-	987 (702-1,376)
7	343 (282-425)	296 (249-328)	-	779 (673-866)
Embayment Stations				
2	477 (395-615)	296 (259-338)	-	896 (864-931)
3	380 (276-529)	345 (268-398)	-	896 (775-960)
4	359 (319-420)	305 (235-364)	-	848 (739-910)
6	317 (240-400)	228 (189-271)	-	653 (595-705)
8	-	273 (226-324)	-	746 (691-832)
9	-	271 (239-307)	-	804 (727-867)

Table 10-16. Mean (range) Secchi disk visibility and 1% incident light depth at each Smith Lake sampling station during the fall (September and October) of 1986 and 1995.

Mainstem Station	Secchi Visibility (cm) 1986	Secchi Visibility (cm) 1995	1% Incident Light (cm) 1986	1% Incident Light (cm) 1995
1	421 (416-425)	290 (272-307)	-	897 (879-915)
5	373 (370-375)	322 (307-336)	-	770 (770-770)
7	322 (310-334)	302 (290-314)	-	628 (612-644)
Embayment Stations				
2	539 (490-588)	280 (266-293)	-	867 (831-903)
3	430 (420-440)	300 (293-307)	-	816 (704-927)
4	340 (330-350)	251 (232-270)	-	739 (736-742)
6	260 (200-319)	200 (175-224)	-	445 (445-445)
8	-	266 (234-297)	-	643 (627-658)
9	-	288 (251-324)	-	617 (609-624)

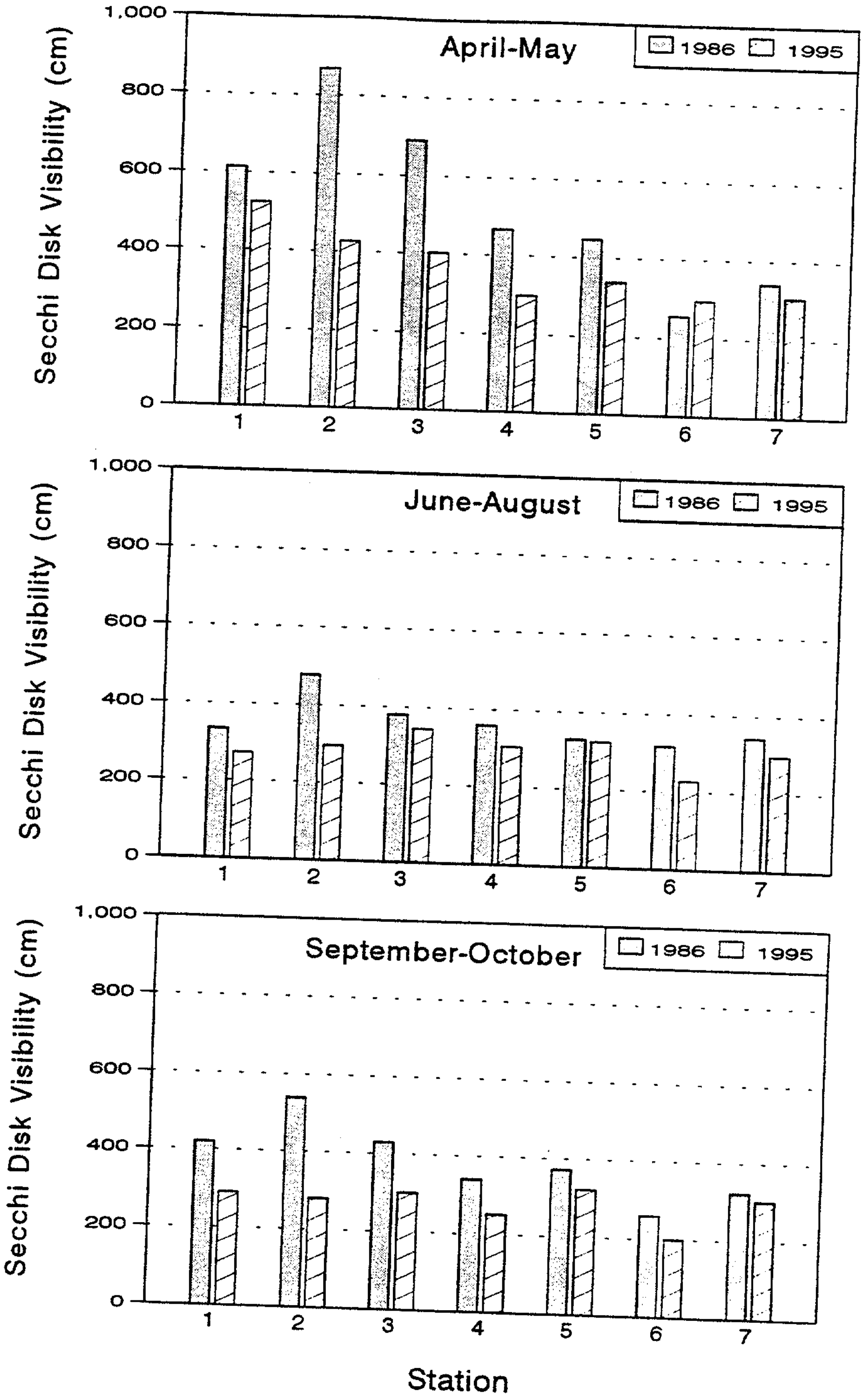


Figure 10-6. Seasonal mean Secchi disk visibility at stations 1-7 during the spring, summer and fall of 1986 and 1995.

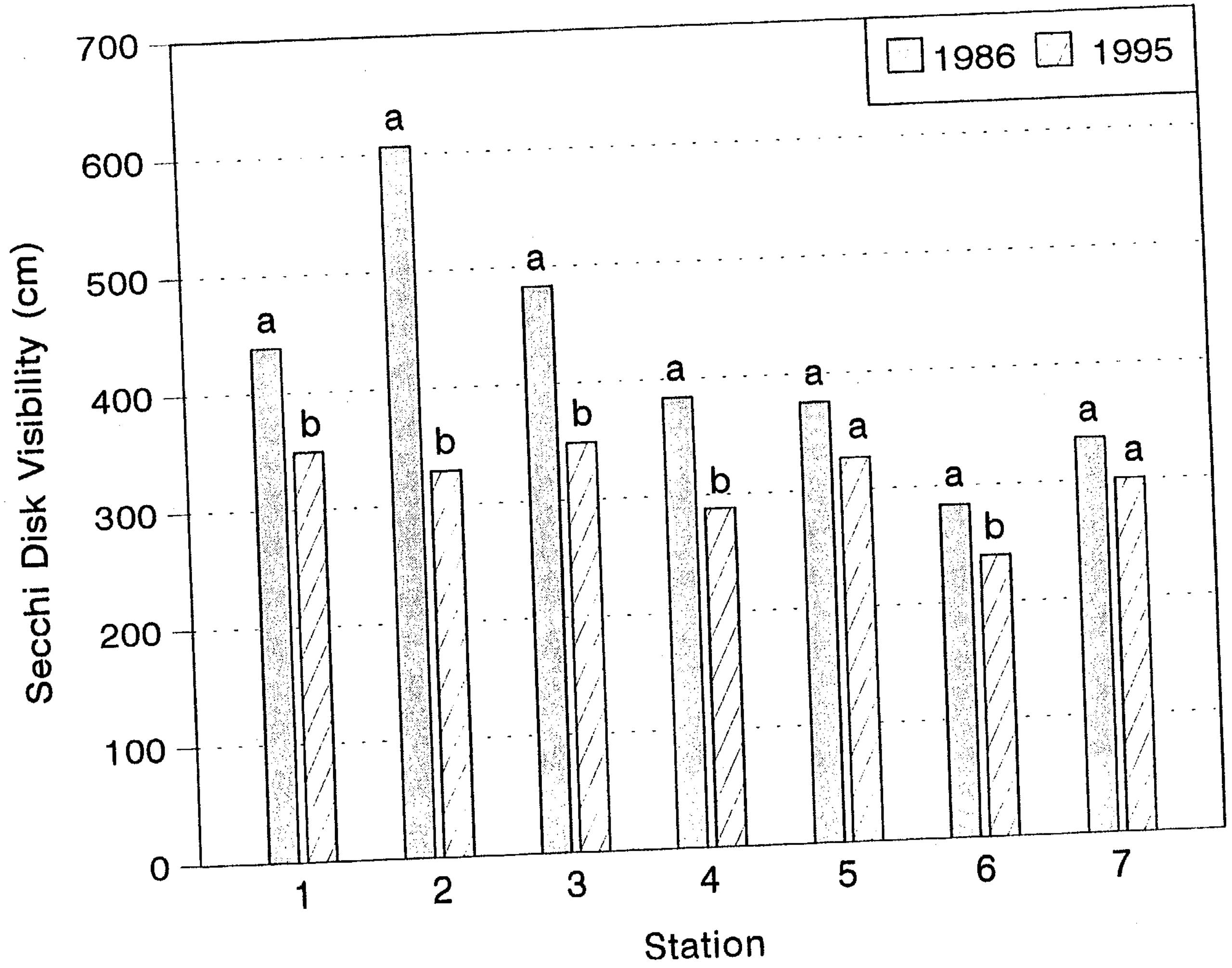


Figure 10-7. Annual mean Secchi disk visibility at stations 1-7 during 1986 and 1995. Within a station, bars with different letters represent significantly different means ($P<0.05$).

a low of 7 mg/L to a high of 67 mg/L (Bayne et al. 1989). At the mainstem sampling stations in Smith Lake, total alkalinity varied from a low of 7.5 mg/L (as $CaCO_3$) during the spring of 1995 to a high of 20 mg/L in the summer of 1995 (Tables 10-17, 10-18, 10-19 and 10-20). In the summer and fall of 1948 prior to impoundment of the Sipsey Fork, total alkalinity of the river near Double Springs, Alabama ranged between 8 mg/L and 16 mg/L as $CaCO_3$ (Alabama Water Improvement Advisory Commission 1949). This variable has changed little in 48 years and indicates that basin soils are relatively infertile and low in soluble forms of carbonates. Alkalinities of tributary embayments were similar to alkalinities measured at the nearest mainstem sampling station.

Total hardness is a measure of the divalent, alkaline earth metal content of water. Calcium (Ca^{++}) and magnesium (Mg^{++}) are normally the most abundant metals in soils of the eastern United States and are generally associated with carbonate minerals responsible for alkalinity of water. Therefore, total alkalinity (expressed as mg/L $CaCO_3$) and total hardness (as mg/L $CaCO_3$) concentrations in water are usually similar and tend to vary together. Such was the case in Smith Lake (Tables 10-17, 10-18, 10-19 and 10-20). Seasonal means and ranges of total hardness at a given sampling station were quite similar to alkalinity means and ranges. In the 1948 pollution study, water hardness measured in the Sipsey Fork near Double Springs, Alabama ranged from 26 mg/L to 44 mg/L (Alabama Water Improvement Advisory Commission 1949).

Carbonate minerals function as natural chemical buffers that prevent wide fluctuations in pH of lake water. The low alkalinity of Smith Lake waters resulted in a range of pH from 6.7 to 9.2 (<2 m depth) during 1986 (Tables 10-17, 10-18, 10-19 and 10-20). In 1995 the pH range was from 6.5 to 9.0 (2 m depth). Increases in fertility and productivity of Smith lake could cause even more dramatic swings in pH that could be detrimental to biota.

Nitrogen and phosphorus are plant nutrients that are required in relatively high concentrations to support plant growth. Nitrogen concentrations normally exceed phosphorus concentrations by an order

Table 10-17. Total alkalinity, hardness and pH measured at each Smith Lake sampling station during the winter (January) of 1986 and 1995. The pH was measured in situ at 0.3 m in 1986 and 2.0 m in 1995. Alkalinity and hardness were measured in photic zone composite samples.

Mainstem station	pH (SU)		Total Alkalinity (mg/L as $CaCO_3$)		Hardness (mg/L as $CaCO_3$)	
	1986	1995	1986	1995	1986	1995
1	6.8	6.5	-	11.8	-	16.8
5	6.8	6.8	-	12.8	-	20.7
7	6.9	6.6	-	12.8	-	16.8
Embayment Stations						
2	6.8	6.9	-	15.5	-	22.9
3	6.6	6.7	-	11.0	-	18.1
4	6.8	6.8	-	12.8	-	17.0
6	6.7	6.7	-	12.8	-	16.9
8	-	6.5	-	12.3	-	16.6
9	-	6.7	-	15.8	-	19.3

Table 10-18. Mean (range) pH, total alkalinity and hardness measured at each Smith Lake sampling station during the spring (April and May) of 1986 and 1995. The pH was measured in situ at 2.0 m in 1995 and at either 0.3 m or 2.0 m in 1986. Alkalinity and hardness were measured in photic zone composite samples.

Mainstem station	pH (SU) 1986	pH (SU) 1995	Total Alkalinity (mg/L as $CaCO_3$) 1986	Total Alkalinity (mg/L as $CaCO_3$) 1995	Hardness (mg/L as $CaCO_3$) 1986	Hardness (mg/L as $CaCO_3$) 1995
1	7.6 (7.4-8.0)	7.1 (7.0-7.2)	-	12.1 (12.0-12.3)	-	15.4 (14.3-16.5)
5	7.5 (7.2-8.4)	7.0 (6.9-7.2)	-	9.5 (9.3-9.8)	-	13.4 (12.6-14.1)
7	7.3 (7.1-8.0)	7.1 (7.0-7.2)	-	11.3 (10.5-12.0)	-	14.1 (13.0-15.2)
Embayment Stations						
2	7.6 (7.4-7.7)	7.2 (7.2-7.3)	-	12.0 (11.8-12.3)	-	15.9 (15.9-15.9)
3	7.4 (7.3-7.6)	7.5 (7.5-7.5)	-	11.6 (10.0-13.3)	-	14.3 (14.3-14.3)
4	7.4 (7.3-7.9)	7.3 (7.3-7.4)	-	10.3 (9.5-11.0)	-	13.9 (13.4-14.5)
6	7.3 (7.0-7.7)	7.1 (7.1-7.2)	-	9.3 (9.3-9.3)	-	13.7 (13.0-14.3)
8	-	7.2 (7.1-7.2)	-	8.4 (7.5-9.3)	-	12.6 (11.0-14.2)
9	-	7.1 (6.9-7.2)	-	12.0 (11.3-12.8)	-	14.4 (13.5-15.3)

Table 10-19. Mean (range) pH, total alkalinity and hardness measured at each Smith Lake sampling station during the summer (June, July and August) of 1986 and 1995. The pH was measured in situ at 2.0 m in 1995 and at either 0.3 m or 2.0 m in 1986. Alkalinity and hardness were measured in photic zone composite samples.

Mainstem station	pH (SU)		Total Alkalinity (mg/L as $CaCO_3$)		Hardness (mg/L as $CaCO_3$)	
	1986	1995	1986	1995	1986	1995
1	7.8 (7.3-8.6)	7.3 (7.2-7.4)	-	15.8 (15.0-16.3)	-	15.9 (15.4-16.6)
5	7.3 (6.9-7.7)	7.4 (7.3-7.6)	-	14.8 (13.3-16.3)	-	14.8 (14.5-15.4)
7	7.2 (6.9-9.2)	7.3 (7.3-7.3)	-	15.8 (15.0-17.5)	-	15.5 (14.6-16.1)
Embayment Stations						
2	8.2 (8.0-8.3)	7.7 (7.4-7.9)	-	16.6 (13.8-20.0)	-	16.3 (15.5-16.9)
3	8.3 (8.0-8.8)	7.9 (7.5-9.0)	-	15.2 (13.8-16.8)	-	15.1 (14.7-15.4)
4	7.9 (7.3-9.1)	7.7 (7.4-7.9)	-	16.5 (14.5-17.5)	-	15.1 (14.2-16.3)
6	6.7 (6.4-8.1)	7.3 (7.2-7.4)	-	15.0 (13.8-16.3)	-	16.1 (15.1-16.7)
8	-	7.3 (7.2-7.4)	-	16.1 (14.5-18.8)	-	14.8 (14.0-15.4)
9	-	7.2 (7.1-7.2)	-	16.6 (16.0-17.5)	-	16.5 (15.8-17.4)

Table 10-20. Mean (range) pH, total alkalinity and hardness measured at each Smith Lake sampling station during the fall (September and October) 1986 and 1995. The pH was measured in situ at 2.0 m in 1995 and at either 0.3 m or 2.0 m in 1986. Alkalinity and hardness were measured in photic zone composite samples.

Mainstem station	pH (SU)		Total Alkalinity (mg/L as $CaCO_3$)		Hardness (mg/L as $CaCO_3$)	
	1986	1995	1986	1995	1986	1995
1	7.0 (6.9-7.1)	7.1 (7.0-7.2)	-	15.6 (14.5-16.8)	-	17.6 (17.2-18.0)
5	6.9 (6.8-7.1)	7.2 (7.1-7.4)	-	14.0 (11.8-16.3)	-	16.9 (16.7-17.2)
7	6.8 (6.7-6.9)	6.9 (6.9-6.9)	-	16.8 (14.5-19.0)	-	16.7 (15.1-18.2)
Embayment Stations						
2	7.1 (7.0-7.5)	7.1 (7.1-7.2)	-	15.4 (13.8-17.0)	-	18.9 (18.9-19.0)
3	7.1 (6.8-7.6)	7.1 (7.0-7.1)	-	14.4 (14.0-14.8)	-	16.7 (16.7-16.8)
4	6.9 (6.8-7.1)	6.9 (6.9-6.9)	-	14.8 (13.8-15.8)	-	17.2 (16.6-17.9)
6	6.9 (6.8-7.0)	6.9 (6.8-7.0)	-	14.6 (12.8-16.5)	-	17.2 (17.0-17.5)
8	-	7.0 (6.9-7.2)	-	13.4 (11.5-15.3)	-	14.5 (13.9-15.1)
9	-	6.9 (6.8-7.1)	-	14.8 (13.5-16.0)	-	16.5 (16.0-17.0)

of magnitude or more (Wetzel 1983). Of the macronutrients, phosphorus is usually in shortest supply and therefore is the element most often limiting to plant growth in freshwater ecosystems. In some cases, phosphorus concentrations, relative to nitrogen, are high and nitrogen availability becomes limiting. This usually occurs at total nitrogen to total phosphorus ratios <16:1 (Porcella and Cleave 1981).

Nitrogen is available to plants as nitrates (NO_3^-) or as the ammonium ion (NH_4^+). Nitrogen concentrations were variable temporally and spatially in both 1986 and 1995 (Tables 10-21, 10-22, 10-23 and 10-24). In general, total inorganic nitrogen (TIN = NH_3-N + NO_2-N + NO_3-N) concentrations were highest in winter and spring and declined during summer and fall in 1986 and 1995. The Ryan and Rock creek embayments frequently had the highest seasonal mean TIN concentrations that were usually higher than nearby mainstem station TIN levels. Brushy Creek and Sipsey Fork TIN concentrations were usually among the lowest measured and were similar to mainstem station 7 (upstream). Apparently Rock (which includes Rock Creek and Crooked Creek) and Ryan creeks are contributing TIN to the mainstem of Smith Lake. TIN concentrations were not consistently higher in 1995 than in 1986. In fact, during the summer and fall seasons, TIN levels were much higher in 1986 than in 1995 (Tables 10-23 and 10-24). This is somewhat surprising considering that 1986 was a drought year (Table 10-4). Since inorganic nitrogen compounds are quite soluble, increases in rainfall and runoff can result in higher concentrations of nitrogen in lake waters. Nevertheless, Smith Lake had relatively high concentrations of NO_3-N, comparable to levels reported in two of the more eutrophic reservoirs in Alabama (Bayne et al. 1993a, Bayne et al. 1995).

Total Kjeldahl nitrogen (TKN) is the sum of the organic nitrogen and ammonia. In unpolluted lakes, density of plankton communities determines, to a large extent, the amount of organic matter present in surface waters. In Smith Lake, TKN increased progressively from winter through fall of 1995

Table 10-21. Ammonia, nitrite, nitrate and total Kjeldahl nitrogen concentrations measured at each Smith Lake sampling station during the winter (January) of 1986 and 1995. Photic zone composite samples were analyzed.

Mainstem Station	NH_3-NH_4-N ($\mu g/L$)		NO_2-N ($\mu g/L$)		NO_3-N ($\mu g/L$)		TKN ($\mu g/L$)	
	1986	1995	1986	1995	1986	1995	1986	1995
1	-	19	-	3	-	222	-	154
5	-	22	-	1	-	105	-	219
7	200	74	-	2	-	125	-	163
Embayment Stations								
2	200	7	-	2	-	281	-	148
3	-	14	-	9	-	324	-	190
4	-	41	-	3	-	125	-	151
6	200	45	-	1	-	110	-	190
8	-	54	-	2	-	125	-	178
9	-	49	-	1	-	106	-	172

Table 10-22. Mean (range) ammonia, nitrite, nitrate and total Kjeldahl nitrogen concentrations measured at each Smith Lake sampling station during the spring (April and May) of 1986 and 1995. Photic zone composite samples were analyzed.

	NH_3-NH_4-N (μg/L)		NO_2-N (μg/L)		NO_3-N (μg/L)		TKN (μg/L)	
Mainstem Station	1986	1995	1986	1995	1986	1995	1986	1995
1	0	26 (10-14)	0	2 (2-2)	225 (150-300)	312 (235-388)	-	166 (154-178)
5	0	34 (28-40)	0	2 (1-2)	282 (140-510)	211 (152-269)	-	208 (163-252)
7	0	34 (27-40)	0	2 (1-2)	180 (10-340)	135 (100-170)	-	202 (193-210)
Embayment Stations								
2	0	24 (17-30)	0	2 (2-2)	203 (110-280)	308 (245-370)	-	163 (133-193)
3	0	22 (16-28)	0	4 (3-4)	275 (200-350)	391 (307-474)	-	225 (207-243)
4	0	21 (14-28)	0	2 (2-2)	238 (150-321)	228 (150-305)	-	182 (154-210)
6	0	39 (24-54)	1 (0-3)	1 (1-1)	205 (120-320)	182 (158-206)	-	213 (207-219)
8	-	49 (43-54)	-	2 (1-2)	-	149 (93-204)	-	168 (166-169)
9	-	31 (24-37)	-	2 (1-2)	-	132 (98-165)	-	269 (261-276)

Table 10-23. Mean (range) ammonia, nitrite, nitrate and total Kjeldahl nitrogen concentrations measured at each Smith Lake sampling station during the summer (June, July and August) of 1986 and 1995. Photic zone composite samples were analyzed.

Mainstem Station	NH_3-NH_4-N (μg/L)		NO_2-N (μg/L)		NO_3-N (μg/L)		TKN (μg/L)	
	1986	1995	1986	1995	1986	1995	1986	1995
1	0	7 (0-15)	0	1 (0-3)	216 (140-340)	112 (24-174)	-	235 (222-258)
5	0	11 (8-16)	0	1 (0-1)	161 (130-220)	105 (59-138)	-	214 (145-299)
7	0	13 (3-23)	1 (0-5)	0	168 (100-240)	58 (55-65)	-	192 (166-231)
Embayment Stations								
2	0	5 (0-9)	0	1 (0-3)	393 (220-915)	122 (57-157)	-	216 (204-225)
3	0	7 (1-14)	0	1 (0-3)	269 (190-380)	206 (149-269)	-	249 (219-284)
4	17 (0-100)	8 (0-20)	0	1 (0-2)	254 (180-420)	84 (60-121)	-	196 (187-216)
6	0	30 (28-33)	1 (0-7)	1 (0-1)	142 (0-320)	54 (10-78)	-	218 (175-255)
8	-	12 (10-14)	-	0	-	37 (23-49)	-	245 (187-284)
9	-	13 (2-24)	-	0	-	38 (18-69)	-	201 (139-273)

Table 10-24. Mean (range) ammonia, nitrite, nitrate and total Kjeldahl nitrogen concentrations measured at each Smith Lake sampling station during the fall (September and October) of 1986 and 1995. Photic zone composite samples were analyzed.

Mainstem Station	NH_3-NH_4-N ($\mu g/L$)		NO_2-N ($\mu g/L$)		NO_3-N ($\mu g/L$)		TKN ($\mu g/L$)	
	1986	1995	1986	1995	1986	1995	1986	1995
1	71 (0-280)	0	0	1 (1-1)	128 (0-280)	36 (28-44)	-	236 (228-236)
5	75 (0-200)	8 (0-15)	0	1 (1-1)	128 (40-240)	59 (21-96)	-	259 (233-284)
7	0	5 (0-9)	0	1 (0-1)	60 (20-120)	57 (1-113)	-	248 (243-253)
Embayment Stations								
2	51 (0-200)	2 (0-3)	2 (0-6)	1 (1-1)	170 (120-260)	26 (23-29)	-	214 (201-227)
3	25 (0-100)	6 (0-11)	0	2 (1-2)	213 (110-260)	81 (51-111)	-	253 (230-276)
4	26 (0-100)	5 (4-5)	0	1 (1-1)	110 (10-240)	34 (1-67)	-	263 (221-305)
6	50 (0-200)	21 (9-32)	2 (0-6)	1 (0-1)	28 (0-80)	22 (4-39)	-	219 (175-262)
8	-	18 (14-22)	-	1 (1-1)	-	63 (1-124)	-	211 (210-212)
9	-	3 (0-6)	-	1 (1-1)	-	69 (1-137)	-	241 (233-249)

in concert with changes in algal biomass. In general, embayment TKN concentrations were similar to the nearest mainstem sampling location (Tables 10-21, 10-22, 10-23 and 10-24).

Phosphorus in water is routinely reported as total phosphorus (TP) (all forms of phosphorus expressed as P) and soluble reactive phosphorus (SRP) the major component of which is orthophosphate (PO_4^{3-} expressed as P), the most common and abundant form of phosphorus available to plants. Both TP and SRP were somewhat higher in 1986 than in 1995 (Tables 10-25, 10-26, 10-27 and 10-28). In 1995, seasonal mean TP ranged between 0 µg/L and 16 µg/L on the mainstem of the lake and between 0 µg/L and 15 µg/L in the tributary embayments. SRP seasonal mean concentrations ranged from 0 µg/L to 2 µg/L throughout the lake. Upstream embayments (Sipsey Fork, Clear Creek and Dismal Creek) usually had higher TP concentrations than mainstem locations but the Ryan and Rock creek embayments had concentrations similar to or lower than mainstem locations. Ryan and Rock creeks appear to be contributing relatively large quantities of total inorganic nitrogen to the lake, but not SRP and TP. EPA (1986) suggested a limit of 50 µg/L TP at the point where a stream enters a lake or reservoir to avoid excessive nutrient loading. Upstream TP concentrations in Smith Lake never exceeded 31 µg/L in 1995.

In reservoirs, phosphorus associated with suspended particles tends to sink if water movement subsides sufficiently in lentic areas of the lake. The phosphorus is deposited in bottom sediments and may remain there indefinitely. Mainstream reservoirs are known to trap large quantities of incoming phosphorus. Lawrence (1970) reported losses of 61% and 75% in Lakes Seminole and Walter F. George, respectively, two lakes located on the Chattahoochee River on the border between Alabama and Georgia. Under certain circumstances some of the accumulated phosphorus can reenter the water column and reach the photic zone, a process known as internal loading of phosphorus. Lakes with anaerobic hypolimnia are more prone to internal loading since reducing conditions mobilize phosphorus in the sediments and release soluble phosphorus to the overlying water column. The relatively long hydraulic retention time of Smith Lake (435 days) and great depths results in rather rigid thermal and chemical

Table 10-25. Orthophosphate and total phosphorus concentrations measured at each Smith Lake sampling station during the winter (January) of 1986 and 1995. Photic zone composite samples were analyzed.

Mainstem Station	PO_4-P ($\mu g/L$) 1986	PO_4-P ($\mu g/L$) 1995	TP ($\mu g/L$) 1986	TP ($\mu g/L$) 1995
1	10	0	15	0
5	25	0	50	0
7	35	0	60	0
Embayment Stations				
2	10	0	15	1
3	20	0	35	0
4	15	0	50	0
6	20	0	50	0
8	-	0	-	0
9	-	0	-	1

Table 10-26. Mean (range) orthophosphate and total phosphorus concentrations measured at each Smith Lake sampling station during the spring (April and May) of 1986 and 1995. Photic zone composite samples were analyzed.

Mainstem Station	PO_4-P (μg/L) 1986	PO_4-P (μg/L) 1995	TP (μg/L) 1986	TP (μg/L) 1995
1	38 (13-54)	2 (1-2)	48 (20-60)	12 (7-16)
5	30 (0-62)	2 (1-2)	40 (16-60)	10 (9-10)
7	38 (0-67)	1 (0-2)	51 (20-100)	10 (10-10)
Embayment Stations				
2	46 (5-60)	1 (1-1)	51 (22-70)	7 (6-7)
3	13 (13-13)	1 (1-1)	44 (17-70)	8 (8-8)
4	40 (0-59)	2 (1-2)	46 (18-70)	11 (10-11)
6	34 (0-70)	1 (0-2)	47 (15-80)	15 (13-16)
8	-	1 (0-2)	-	13 (10-15)
9	-	2 (2-2)	-	13 (11-14)

Table 10-27. Mean (range) orthophosphate and total phosphorus concentrations measured at each Smith Lake sampling station during the summer (June, July and August) of 1986 and 1995. Photic zone composite samples were analyzed.

Mainstem Station	PO_4-P (μg/L)		TP (μg/L)	
	1986	1995	1986	1995
1	5 (0-8)	1 (1-2)	45 (20-120)	6 (2-8)
5	5 (0-15)	1 (1-2)	22 (7-40)	6 (3-11)
7	7 (0-18)	1 (0-1)	45 (10-100)	16 (6-31)
Embayment Stations				
2	13 (0-30)	1 (1-2)	25 (10-40)	7 (0-12)
3	20 (4-40)	2 (1-2)	15 (10-20)	7 (1-10)
4	5 (0-20)	1 (1-2)	10 (5-15)	8 (1-13)
6	2 (0-3)	2 (0-3)	30 (10-40)	10 (8-13)
8	-	1 (0-1)	-	6 (1-9)
9	-	1 (0-1)	-	13 (8-22)

Table 10-28. Mean (range) orthophosphate and total phosphorus concentrations measured at each Smith Lake sampling station during the fall (September and October) of 1986 and 1995. Photic zone composite samples were analyzed.

Mainstem Station	PO_4-P (μg/L) 1986	PO_4-P (μg/L) 1995	TP (μg/L) 1986	TP (μg/L) 1995
1	6 (0-12)	1 (0-1)	13 (4-30)	11 (7-14)
5	5 (0-6)	1 (0-1)	24 (0-50)	12 (10-14)
7	9 (0-18)	1 (0-1)	21 (7-40)	12 (11-12)
Embayment Stations				
2	0	0	16 (0-50)	8 (8-8)
3	9 (0-20)	2 (0-4)	14 (0-30)	10 (8-11)
4	0	1 (0-1)	20 (0-50)	14 (11-16)
6	6 (0-14)	1 (0-1)	20 (10-30)	10 (8-12)
8	-	0	-	11 (10-11)
9	-	1 (0-1)	-	14 (13-14)

stratification (Fig. 10-2). During the growing season anaerobic conditions in deeper water were common and phosphorus mobilization from sediment may be a significant source of phosphorus loading in this lake. Destratification would be required to bring the phosphorus into the photic zone.

During the summer growing season of 1995 the ratio of total nitrogen (TN) to total phosphorus (TP) at mainstem sampling stations varied from 16 to 58 (Table 10-29). Tributary embayment ratios ranged from 18 to 65. Optimum TN to TP ratios for phytoplankton growth is in the range of 11 to 16 (Porcella and Cleave 1981). Phytoplankton growth in Smith Lake was phosphorus limited at all locations with the possible exception of the most upstream stations 9 and 7. The relatively high NO_3-N concentrations found at downstream locations on the mainstem (stations 1 and 5) and in embayments of Rock and Ryan creeks (stations 3 and 2) are responsible for some of the higher TN:TP ratios. Nonpoint sources of pollution are suspected of causing these elevated nitrogen levels. Any increase in bioavailable phosphorus to Smith Lake will likely increase, perhaps dramatically, the algal productivity of the lake.

In an effort to identify sources of contaminants entering Smith Lake, chlorides (Cl^-) were measured in composite, photic zone samples collected for water quality analysis (Tables 10-1 and 10-3). Chlorides pass through the digestive systems of animals unchanged (APHA et al. 1992). Because humans consume relatively large quantities of salt (NaCl) (about 6 g of Cl^- per person per day) the amount of Cl^- in municipal sewage is about 15 mg/L higher than the carriage water (Sawyer 1960). Elevated Cl^- levels might indicate the presence of animal (particularly human) waste introduced from the watershed. Seasonal mean Cl^- concentrations were always highest at downstream stations 1, 2 and 3 (Tables 10-30, 10-31, 10-32 and 10-33). These same stations usually had the highest seasonal mean NO_3-N concentrations (Tables 10-21, 10-22, 10-23 and 10-24). Stations 2 and 3 were embayments of Ryan and Rock creeks, respectively, and station 1 was the dam forebay (Fig. 10-1). Intensive agricultural operations (e.g. poultry and beef cattle) on the watersheds of Ryan, Rock and Crooked creeks are known sources of animal waste (USDA 1991). In 1988, Cullman County led the nation in

Table 10-29 . Summer mean total nitrogen (μg/L TN), total phosphorus (μg/L TP) and the TN:TP ratio at all mainstem and tributary embayment stations in Smith Lake, 1995.

Mainstem Stations	TN	TP	TN:TP
1	348	6	58
5	320	6	53
7	250	16	16
Embayment Stations			
2	339	7	48
3	456	7	65
4	281	8	35
6	273	10	27
8	282	6	47
9	239	13	18

Table 10-30. Chloride, total organic carbon and phaeophytin-corrected chlorophyll a concentration measured at each Smith Lake sampling station during the winter (January) of 1995.

Mainstem Station	Chlorides (mg/L)	Total Organic Carbon (mg/L)	Chlorophyll a (μg/L)
1	3.65	2.85	1.40
5	2.05	2.38	1.40
7	2.05	2.61	1.67
Embayment Stations			
2	3.15	2.94	0.60
3	3.15	2.79	1.54
4	2.50	2.48	1.87
6	1.95	2.53	2.00
8	2.00	2.57	1.67
9	1.20	2.78	1.94

Table 10-31. Mean (range) chloride, total organic carbon and phaeophytin-corrected chlorophyll a concentration measured at each Smith Lake sampling station during the spring (April and May) of 1995.

Mainstem Station	Chlorides (mg/L)	Total Organic Carbon (mg/L)	Chlorophyll a (μg/L)
1	2.05 (1.65-2.45)	3.14 (2.64-3.64)	1.42 (0.67-2.18)
5	1.57 (1.40-1.75)	2.58 (2.38-2.77)	2.46 (1.94-2.98)
7	1.28 (1.15-1.40)	3.02 (2.84-3.20)	2.50 (2.07-2.94)
Embayment Stations			
2	2.12 (1.95-2.30)	2.59 (2.46-2.71)	1.41 (1.00-1.82)
3	1.97 (1.60-2.35)	3.22 (2.94-3.49)	1.65 (1.60-1.69)
4	1.60 (1.55-1.65)	3.07 (2.88-3.26)	2.60 (2.07-3.14)
6	1.45 (1.45-1.45)	2.67 (2.56-2.79)	2.67 (2.40-2.94)
8	1.45 (1.30-1.60)	2.48 (2.43-2.54)	2.25 (1.60-2.89)
9	1.43 (1.35-1.50)	2.70 (2.54-2.86)	2.30 (1.60-3.00)

Table 10-32. Mean (range) chloride, total organic carbon and phaeophytin-corrected chlorophyll a concentration measured at each Smith Lake sampling station during the summer (June - August) of 1995.

Mainstem Station	Chlorides (mg/L)	Total Organic Carbon (mg/L)	Chlorophyll a (μg/L)
1	1.67 (1.50-1.92)	3.48 (2.92-4.46)	2.49 (2.00-3.34)
5	1.55 (1.50-1.60)	3.32 (2.99-3.78)	2.58 (2.34-2.87)
7	1.27 (1.15-1.35)	3.24 (3.04-3.52)	2.76 (1.67-3.80)
Embayment Stations			
2	1.76 (1.48-1.90)	3.15 (2.92-3.45)	2.74 (2.20-3.67)
3	1.82 (1.65-1.92)	3.63 (3.41-4.05)	3.45 (2.80-4.54)
4	1.53 (1.45-1.65)	3.53 (2.93-4.40)	2.98 (2.60-3.27)
6	1.45 (1.30-1.60)	3.45 (3.06-3.71)	2.56 (2.00-3.40)
8	1.25 (1.10-1.35)	2.93 (2.68-3.16)	2.96 (2.27-4.14)
9	1.35 (1.10-1.50)	2.91 (2.50-3.27)	2.51 (2.00-3.14)

Table 10-33. Mean (range) chloride, total organic carbon and phaeophytin-corrected chlorophyll a concentration measured at each Smith Lake sampling station during the fall (September - October) of 1995.

Mainstem Station	Chlorides (mg/L)	Total Organic Carbon (mg/L)	Chlorophyll a (μg/L)
1	1.97 (1.80-2.15)	3.60 (3.36-3.85)	3.90 (3.67-4.14)
5	1.53 (1.50-1.55)	3.42 (3.04-3.80)	2.94 (2.54-3.34)
7	1.45 (1.35-1.55)	4.25 (3.47-5.03)	3.00 (2.80-3.20)
Embayment Stations			
2	2.02 (1.95-2.10)	3.49 (3.34-3.63)	3.67 (3.60-3.74)
3	2.02 (2.00-2.05)	3.42 (3.30-3.54)	3.50 (3.14-3.87)
4	1.67 (1.65-1.70)	3.40 (3.16-3.64)	3.77 (3.47-4.07)
6	1.57 (1.50-1.65)	3.58 (3.24-3.93)	3.14 (2.67-3.60)
8	1.40 (1.35-1.45)	4.24 (3.25-5.22)	3.30 (3.00-3.60)
9	1.38 (1.30-1.45)	4.30 (3.52-5.09)	2.50 (2.20-2.80)

poultry production and was Alabama's leading beef cattle producer (USDA 1991). An estimated 94,000 tons of animal waste enters tributaries to Smith Lake each year; equivalent to the direct waste discharge of 1.15 million people (USDA 1991). Intensive studies of flowing portions of Ryan and Crooked creeks revealed excessive nutrient enrichment and biological degradation resulting from poor waste management on these watersheds (Deutsch et al. 1990).

The elevated Cl^- and NO_3-N concentrations in these embayments (stations 2 and 3) are likely related to animal waste produced on these watersheds. Station 1, the dam forebay, is downstream from these tributaries (Fig. 10-1) and is no doubt influenced by flows from these two streams as well as from mainstem contributions. The relatively high seasonal mean Cl^- and NO_3-N concentrations measured at mid reservoir station 5 (Fig. 10-1) may reflect the influence of housing development along the shoreline of the lake. Mainstem and tributary stations upstream of station 5 usually had Cl^- and NO_3-N concentrations lower than those measured at station 5. Septic systems of lakeshore homes are suspected of releasing domestic sewage or nutrients into the lake. Shallow soil depth to bedrock and steep slopes around the lake shore create problems for effective septic tank function (Personal Communication, J. Frutiger, Cullman Co. Health Dept.). Continued housing development around the lake in the absence of community sewage treatment facilities could hasten the cultural eutrophication of Smith Lake.

Concentrations of select metal ions were measured in photic zone composite samples collected 15 August 1995 at all sampling locations (Table 10-3 and Fig. 10-1). The following metals (detection limit) were not present at concentrations higher than instrument detection limits: aluminum (200 μg/L), arsenic (10 μg/L), cadmium (3 μg/L), chromium (15 μg/L), copper (20 μg/L), mercury (0.5 μg/L), nickel (20 μg/L), selenium (10 μg/L) and zinc (30 μg/L). Iron (20 μg/L) and manganese (20 μg/L) were found at concentrations ranging from 31 to 76 μg/L and 22 to 102 μg/L, respectively. Highest concentrations of both metals were found in Brushy Creek embayment (station 8).

In August 1986, iron and manganese concentrations in Clear Creek embayment were 700 µg/L and 400 µg/L, respectively (Bayne et al. 1987). In fact these metals were frequently found at concentrations exceeding detection limits (100 µg/L for iron and 50 µg/L for manganese) used in 1986 when sampling was done monthly for 9 months. During that study iron, manganese, copper, chromium and zinc concentrations did exceed, on at least one occasion, levels considered acceptable by the Environmental Protection Agency (1986). Even though metal ion concentrations appear lower in 1995 than in 1986 based on limited 1995 sampling, the pH and alkalinity of Smith Lake remain low (Tables 10-17, 10-18, 10-19 and 10-20). Heavy metals toxic to aquatic life are more soluble in acid waters and therefore any acidic substances (e.g. acid precipitation or acid mine waste) entering this poorly buffered (low alkalinity) lake may threaten the aquatic biota.

10.2.2 Phytoplankton

The photic zone composite water sample collected at each sampling station (Table 10-2) was the source of water used for analysis of phytoplankton related variables. Aliquots of the composite sample were separated for total organic carbon (TOC) analyses, phytoplankton identification and enumeration, chlorophyll a analyses and Algal Growth Potential Tests (AGPT) (Table 10-34). Phytoplankton enumeration, chlorophyll a analysis and TOC analysis were conducted in January and monthly April through October 1995 (Table 10-1). Phytoplankton primary productivity was measured May through September of 1995 at mainstem stations 1, 5 and 7 (Table 10-2 and Figure 10-1). The carbon-14 method of estimating net productivity was used (Table 10-34). Duplicate light and dark bottles were incubated for 3 h at midday at each of three depths within the photic zone: the lower limit of the photic zone, midway between the lower limit and the surface and about 0.3 m below the surface. The lower limit of the photic zone was determined by multiplying the Secchi disk visibility by a factor of four (Taylor

Table 10-34. Analytical methods used in measuring carbon and microbiological variables in Smith Lake during the diagnostic study, 1995.

Variable	Method	Reference
Total Organic Carbon	Persulfate digestion with Dohrmann DC-80	APHA, 1992
Chlorophyll a	Spectrophotometric	APHA, 1992
Algal Growth Potential Test	U.S.E.P.A. methodology	Athens, GA lab
Phytoplankton Enumeration	Sedimentation chamber	APHA, 1992
Phytoplankton Primary Productivity	Carbon 14 method	APHA, 1992

1971). Productivity measured during the 3 h exposure was expanded to mean daily productivity (mgC/ m^2•day) using solar radiation data obtained at the site during the exposure and total daily radiation measured in Winfield, Alabama by a cooperative observer for the National Oceanic and Atmospheric Administrations (NOAA) (Table 10-4).

Phytoplankton densities in 1995 ranged from a low of 357 organisms/ml at station 1 during the spring 1995 (Table 10-36) to 2,294 organisms/ml at station 3 during the summer 1995 (Table 10-37). Highest densities occurred during the summer and fall and lowest densities during the spring. Seasonal mean densities were usually similar among stations within a season and mean embayment densities were similar to nearby mainstem station densities (Tables 10-35, 10-36, 10-37 and 10-38, Fig. 10-8). In 1995, seasonal mean phytoplankton densities were about twice what they were at the same locations in 1986. On an annual basis, mean densities were significantly ($P < 0.05$) higher in 1995 at all locations except at mainstem at Duncan's Creek (station 5) and mainstem downstream from the confluence of Sipsey Fork and Brushy Creek (station 7) (Fig. 10-9).

Numerical dominance was shared by green algae (Division Chlorophyta) and diatoms (Division Chrysophyta) at mainstem sampling stations (Fig. 10-10). Diatoms were generally more abundant in spring months and green algae more abundant in summer and fall months. The blue-green algae (Division Cyanobacteria) were the third most abundant algal Division. Euglenoids (Division Euglenophyta) and dinoflagellates (Division Pyrrhophyta) were combined into an "others" category. In 1986, green algae made up a larger proportion of the plankton community than they did in 1995. The diatoms increased in relative abundance in 1995 and seemed to dominate further into the summer and fall seasons than they did in 1986 (Fig. 10-10). This pattern of algal dominance is common in Alabama lakes (Bayne et al. 1993a, 1993b, and 1995).

Table 10-35. Mean (range) phytoplankton density and uncorrected chlorophyll a concentration at each Smith Lake sampling station during the winter (January) of 1986 and 1995.

Mainstem Station	Phytoplankton Density (organisms/ml) 1986	Phytoplankton Density (organisms/ml) 1995*	Chlorophyll a (μg/L) 1986	Chlorophyll a (μg/L) 1995*
1	100 (67-132)	1,329	0.9 (0.8-1.0)	2.5
5	72 (64-81)	1,400	1.1 (0.8-1.3)	2.7
7	68 (43-94)	820	1.0 (0.8-1.1)	3.9
Embayment Stations				
2	42 (39-46)	932	2.2 (1.3-3.1)	1.2
3	42 (31-53)	1,214	1.3 (1.1-1.5)	3.2
4	162 (148-175)	1,140	0.6 (0.3-0.9)	3.9
6	88 (83-93)	1,048	1.8 (1.0-2.6)	3.7
8	-	878	-	3.5
9	-	952	-	3.9

*Only one sample collected at each station in January 1995.

Table 10-36. Mean (range) phytoplankton density and uncorrected chlorophyll a concentration at each Smith Lake sampling station during the spring (April and May) of 1986 and 1995.

Mainstem Station	Phytoplankton Density (organisms/ml)		Chlorophyll a (μg/L)	
	1986	1995	1986	1995
1	77 (31-109)	453 (357-548)	0.7 (0.0-1.4)	2.5 (1.0-4.0)
5	206 (100-321)	871 (673-1,068)	0.7 (0.3-1.3)	4.3 (3.2-5.5)
7	248 (171-331)	675 (595-754)	0.7 (0.0-1.9)	4.7 (3.7-5.7)
Embayment Stations				
2	55 (39-85)	564 (385-742)	1.1 (0.7-1.5)	2.5 (1.6-3.3)
3	67 (37-104)	681 (661-701)	1.0 (0.0-2.5)	3.0 (2.7-3.3)
4	161 (57-249)	772 (741-802)	1.2 (0.0-3.1)	4.9 (3.8-6.0)
6	245 (224-275)	758 (735-781)	0.5 (0.0-1.1)	4.9 (4.3-5.4)
8	-	873 (628-1,117)	-	4.4 (3.3-5.4)
9	-	838 (835-841)	-	4.4 (3.0-5.9)

Table 10-37. Mean (range) phytoplankton density and uncorrected chlorophyll a concentration at each Smith Lake sampling station during the summer (June - August) of 1986 and 1995.

Mainstem Station	Phytoplankton Density (organisms/ml)		Chlorophyll a (μg/L)	
	1986	1995	1986	1995
1	499 (83-1,053)	867 (709-988)	1.8 (0.0-3.8)	4.4 (3.2-5.9)
5	760 (177-1,969)	824 (756-901)	2.6 (1.2-3.5)	4.9 (4.4-5.3)
7	415 (122-746)	978 (805-1,192)	2.0 (0.3-3.5)	5.1 (3.7-6.2)
Embayment Stations				
2	400 (58-872)	831 (784-891)	1.9 (0.0-4.6)	4.8 (3.7-6.4)
3	853 (120-2,331)	1,533 (780-2,294)	2.5 (0.8-4.1)	6.1 (5.1-7.8)
4	495 (212-842)	1,038 (856-1,194)	2.8 (1.2-3.6)	5.3 (4.2-6.1)
6	497 (123-1,066)	852 (652-1,075)	2.0 (0.0-4.1)	4.9 (4.1-6.4)
8	-	1,103 (954-1,362)	-	5.6 (4.0-7.6)
9	-	930 (700-1,218)	-	5.0 (3.6-6.7)

Table 10-38. Mean (range) phytoplankton density and uncorrected chlorophyll a concentration at each Smith Lake sampling station during the fall (September and October) of 1986 and 1995.

Mainstem Station	Phytoplankton Density (organisms/ml) 1986	Phytoplankton Density (organisms/ml) 1995	Chlorophyll a (μg/L) 1986	Chlorophyll a (μg/L) 1995
1	440 (343-537)	1,129 (928-1,329)	1.9 (0.6-3.8)	6.5 (5.7-7.3)
5	596 (309-929)	752 (645-859)	2.4 (1.6-2.9)	5.3 (4.4-6.2)
7	1,018 (350-2,623)	1,059 (872-1,245)	3.1 (1.8-4.1)	5.5 (5.2-5.9)
Embayment Stations				
2	185 (135-279)	1,307 (1,071-1,543)	2.1 (0.6-3.5)	6.4 (6.1-6.7)
3	398 (287-521)	957 (757-1,157)	1.9 (1.2-2.7)	7.2 (6.5-7.8)
4	673 (382-1,081)	1,092 (928-1,255)	2.2 (1.5-2.8)	7.1 (5.6-8.7)
6	644 (446-818)	939 (697-1,180)	2.5 (1.8-3.1)	5.7 (5.0-6.3)
8	-	931 (912-949)	-	5.7 (5.2-6.2)
9	-	871 (813-930)	-	4.9 (4.5-5.3)

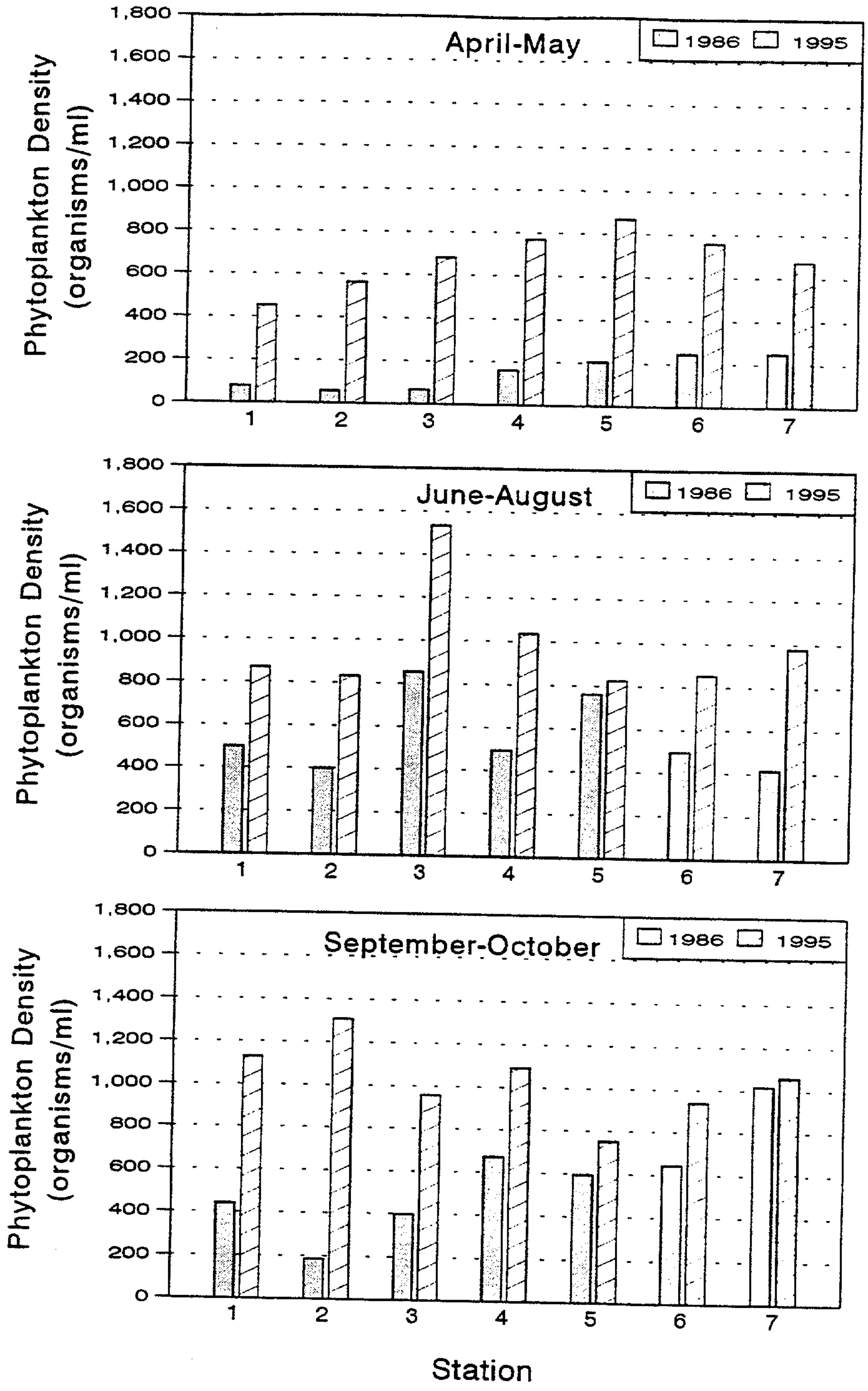


Figure 10-8. Seasonal mean phytoplankton density at stations 1-7 during the spring, summer and fall of 1986 and 1995.

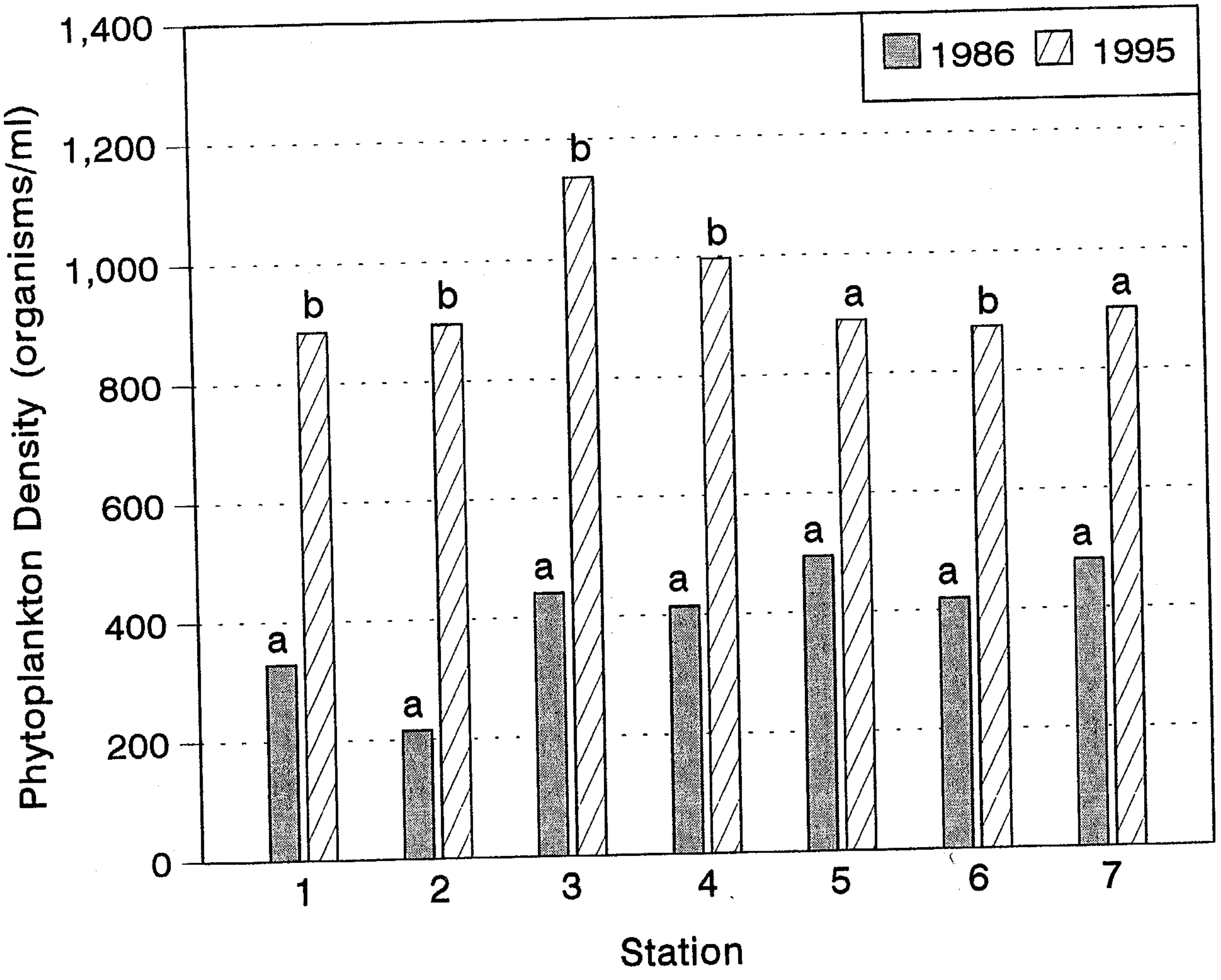
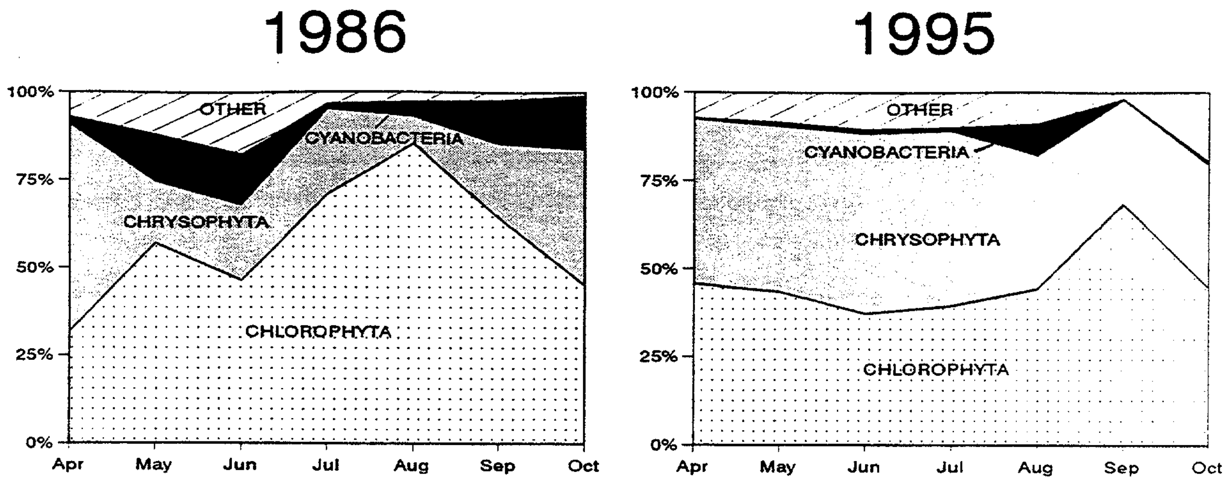
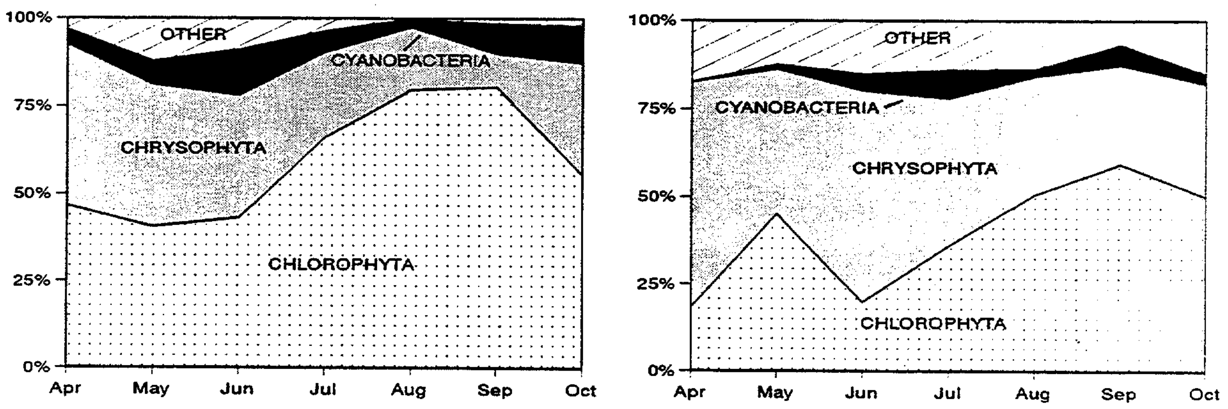


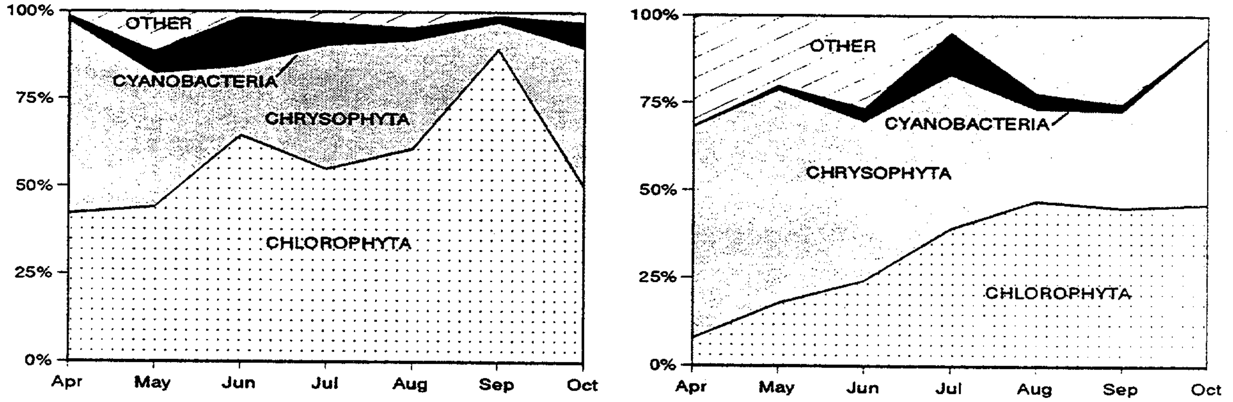
Figure 10-9. Annual mean phytoplankton density at stations 1-7 during 1986 and 1995. Within a station, bars with different letters represent significantly different means ($P<0.05$).



Station 1



Station 5



Station 7

Figure 10-10. Percent composition of phytoplankton cummunities by algal Division in Smith Lake at stations 1 (dam forebay), 5 and 7 during the 1986 and 1995 growing seasons.

Fifty-four algal taxa were identified from samples taken from Smith Lake (Table 10-39). These taxa are generally common constituents of lake phytoplankton communities in this region (Taylor et al. 1979). Green algal taxa were most numerous although diatoms were not always identified to genus.

Pennate and centric diatoms were common and abundant throughout the reservoir and, in aggregate, were numerically dominant on most sampling occasions (Table 10-40). The most commonly encountered pennate diatoms that could be identified without special preparation were Fragilaria spp. and Asterionella spp. The centric diatoms, Melosira distans and M. granulata were common and abundant. M. distans was frequently the dominant alga (Table 10-40). Dinobryon sp. is another chrysophyte that was common and occasionally dominant. Dominant green algae included Chlamydomonas spp., Ankistrodesmus convolutus, Cosmarium spp. and Staurastrum spp.

Among the dominant phytoplankton genera, all occur with great frequency in reservoirs of the southeastern United States (Taylor et al. 1979). Palmer (1969) listed Ankistrodesmus, Chlamydomonas and Melosira as genera of algae tolerant of organic pollution. A euglenophyte, Trachelomonas spp. was abundant and sometimes dominant in the winter and spring. Dinobryon spp., a genus usually associated with cool, clear, well-oxygenated waters was abundant during the spring in Smith Lake.

Phaeophytin-corrected, chlorophyll a concentration is an indicator of phytoplankton biomass and is a variable often used to determine the trophic status of lakes in the absence of macrophytes (Carlson 1977 and EPA 1990). It is a variable that integrates the physical, chemical and biological environmental components into one expression of biotic response and is, therefore, superior to simple physical (water transparency) or chemical (nutrients) variables used to characterize trophic status (Hern et al. 1981). Corrected chlorophyll a concentrations from about 6.4 to 56 μg/L are indicative of eutrophic waters (Carlson 1977). Waters having concentrations > 56.0 μg/L are considered hypereutrophic and waters with concentrations of from 1.0 to <6.4 μg/L are classified as mesotrophic. Corrected chlorophyll a concentrations in Smith Lake in 1995 ranged from a low of 0.60 μg/L in the Ryan Creek embayment

Table 10-39. Phytoplankton taxa by major group indicating occurrence at selected stations in Smith Lake during the 1995 diagnostic study.

Division	Algal Taxa	Station 1	2	3	4	5	6	7	8	9
CHLOROPHYTA	Acanthosphaera				X					
	Actinastrum sp.	X	X	X	X	X	X	X	X	X
	Ankistrodesmus convolutus	X	X	X	X	X	X	X	X	X
	Ankistrodesmus falcatus	X	X	X	X	X	X	X	X	X
	Ankistrodesmus fusiformis				X	X	X		X	X
	Ankistrodesmus nannoselene	X	X	X	X	X	X	X	X	X
	Arthrodesmus sp.	X	X	X	X	X	X	X	X	X
	Chlamydomonas sp.	X	X	X	X	X	X	X	X	X
	Chodatella sp.		X		X					
	Closteriopsis sp.	X	X	X	X	X	X	X	X	X
	Closterium sp.	X	X	X	X	X	X	X	X	
	Coelastrum sp.	X	X	X						X
	Cosmarium sp.	X	X	X	X	X	X	X	X	X
	Crucigenia sp.	X	X	X	X	X	X	X	X	X

Table 10-39. (Cont.)

Division	Algal Taxa	Station								
		1	2	3	4	5	6	7	8	9
CHLOROPHYTA	Desmidium sp.	X								
	Dictyosphaerium sp.		X							X
	Elakatothrix sp.					X	X			X
	Euastrum sp.							X		
	Gloeocystis sp.	X	X	X	X	X	X	X	X	X
	Golenkinia sp.	X	X	X	X	X	X	X	X	X
	Micrasterias sp.				X					X
	Oocystis sp.	X	X	X	X	X	X	X	X	X
	Pandorina sp.			X	X					
	Pediastrum sp.				X					
	Scenedesmus abundans								X	
	Scenedesmus acuminatus	X	X	X					X	X
	Scenedesmus quadricauda			X	X				X	X
	Scenedesmus sp.	X	X	X	X	X	X	X	X	X

Table 10-39. (Cont.)

Division	Algal Taxa	Station								
		1	2	3	4	5	6	7	8	9
CHLOROPHYTA	Schroederia sp.		X	X						
	Selenastrum sp.				X	X				X
	Sphaerocystis sp.				X	X		X	X	
	Staurastrum sp.	X	X	X	X	X	X	X	X	X
	Tetraedron minimum	X	X	X	X	X	X	X	X	X
	Tetraedron sp.	X	X	X	X	X	X	X	X	X
	Treubaria sp.	X	X	X	X			X		
CHRYSOPHYTA	Asterionella sp.	X	X	X	X	X	X	X	X	X
	Dinobryon sp.	X	X	X	X	X	X	X	X	X
	Fragillaria sp.	X	X	X	X	X	X	X	X	X
	Melosira distans	X	X	X	X	X	X	X	X	X
	Melosira granulata	X	X	X	X	X	X	X	X	X
	Tabellaria sp.							X	X	X
	Centric diatom	X	X	X	X	X	X	X	X	X

Table 10-39. (Cont.)

Division	Algal Taxa	Station								
		1	2	3	4	5	6	7	8	9
CHRYSOPHYTA	Pennate diatom	X	X	X	X	X	X	X	X	X
CYANOBACTERIA	Anabaena sp.								X	
	Aphanocapsa sp.				X	X	X	X	X	X
	Gomphosphaeria sp.	X	X	X	X	X	X	X	X	X
	Merismopedia sp.	X	X	X	X	X	X	X	X	X
	Raphidiopsis sp.		X		X	X	X	X	X	
	B-G Filament				X			X		
EUGLENOPHYTA	Euglena sp.	X		X					X	X
	Trachelomonas sp.	X	X	X	X	X	X	X	X	X
PYRRHOPHYTA	Ceratium hirundinella		X						X	
	Ceratium		X	X	X	X	X	X	X	X
	Peridinium sp.	X	X	X	X	X	X	X	X	X

Table 10-40. Dominant algal taxa collected at sampling stations on Smith Lake during the diagnostic study, 1995.

Station→	Stations				
Season Year↓	1	2	3	4	5
WINTER 1995					
	1. Melosira distans	1. Pennate diatoms	1. Pennate diatoms	1. Melosira distans	1. Pennate diatoms
	2. Pennate diatoms	2. Chlamydomonas sp.	2. Chlamydomonas sp.	2. Pennate diatoms	2. Melosira distans
	3. Chlamydomonas sp.	3. Melosira granulata	3. Melosira distans	3. Chlamydomonas sp.	3. Trachelomonas sp.
SPRING 1995					
	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms
	2. Chlamydomonas sp.	2. Chlamydomonas sp.	2. Chlamydomonas sp.	2. Trachelomonas sp.	2. Trachelomonus sp.
	3. Gloeocystis sp.	3. Gloeocystis sp.	3. Fragilaria sp.	3. Chlamydomonas sp.	3. Melosira distans
SUMMER 1995					
	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms
	2. Chlamydomonas sp.	2. Chlamydomonas sp.	2. Gloeocystis sp.	2. Chlamydomonas sp.	2. Peridinium sp.
	3. Melosira distans	3. Cosmarium sp.	3. Chlamydomonas sp.	3. Cosmarium sp.	3. Chlamydomonas sp.
FALL 1995					
	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms
	2. Ankistrodesmus convolutus	2. Ankistrodesmus convolutus	2. Ankistrodesmus convolutus	2. Ankistrodesmus convolutus	2. Starvastrum sp.
	3. Cosmarium sp.	3. Cosmarium sp.	3. Cosmarium sp.	3. Chlamydomonas sp.	3. Chlamydomonas sp.

Table 10-40. (Continued)

	Stations			
Station→ Season Year↓	6	7	8	9
WINTER 1995				
	1. Pennate diatoms	1. Melosira distans	1. Melosira distans	1. Pennate diatoms
	2. Melosira distans	2. Pennate diatoms	2. Pennate diatoms	2. Melosira distans
	3. Chlamydomonas sp.	3. Chlamydomonas sp.	3. Chlamydomonas sp.	3. Trachelomonas sp.
SPRING 1995				
	1. Trachelomonas sp.	1. Trachelomonas sp.	1. Pennate diatoms	1. Trachelomonas sp.
	2. Dinobryon sp.	2. Pennate diatoms	2. Melosira distans	2. Pennate diatoms
	3. Pennate diatoms	3. Melosira distans	3. Chlamydomonas sp.	3. Dinobryon sp.
SUMMER 1995				
	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms
	2. Chlamydomonas sp.	2. Trachelomonas sp.	2. Chlamydomonas sp.	2. Chlamydomonas sp.
	3. Peridinium sp.	3. Melosira distans	3. Melosira distans	3. Melosira distans
FALL 1995				
	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms	1. Pennate diatoms
	2. Staurastrum sp.	2. Trachelomonas sp.	2. Staurastrum sp.	2. Comarium sp.
	3. Chlamydomonas sp.	3. Chlamydomonas sp.	3. Chlamydomonas sp.	3. Chlamydomonas sp.

(station 2) in the winter to a high of 4.54 μg/L in the Rock Creek embayment (station 3) in the summer (Tables 10-30, 10-31, 10-32 and 10-33). With the exception of the 0.60 μg/L concentration, the lake lies well within the mesotrophic range. Seasonal mean chlorophyll a concentrations were highest in summer and fall and lowest in winter and spring (Figure 10-11). Within a season, station means were quite similar with embayments and nearby mainstem locations having similar concentrations.

In 1986 chlorophyll a was not corrected for phaeopigments (Bayne et al. 1987). In order to compare the 1995 chlorophyll a data with the 1986 data uncorrected chlorophyll a concentrations were reported for both years (Tables 10-35, 10-36, 10-37 and 10-38). With one exception (station 2 in January) mean chlorophyll a concentrations were higher at every station during all seasons in 1995. Annual means for each sampling station were significantly ($P < 0.05$) higher in 1995 than in 1986 (Fig. 10-12).

Phytoplankton primary productivity is the rate of formation of organic matter over a specified time period (Wetzel 1983). The C-14 method of measuring productivity approximates net productivity, which is the gross accumulation of new organic matter minus any losses (e.g. respiration) that occur during the specified time interval. Phytoplankton biomass is an important variable influencing primary productivity although the efficiency with which a unit of phytoplankton biomass produces a unit of organic matter (photosynthetic efficiency) is quite variable (Fogg 1965). Efficiency can be affected by such physicochemical variables as light, temperature, degree of turbulence and nutrients. Species composition, size structure of the plankton algae and predation are examples of biotic influences on efficiency. Bayne et al. (1990) reported photosynthetic efficiencies (mgC fixed per mg chlorophyll a•hour) of West Point Lake phytoplankton communities ranging from 0.2 to 4.9. Phytoplankton primary productivity integrates a number of environmental variables in addition to algal biomass into an expression of system productivity. Productivity rates have also been used to trophically categorize lakes.

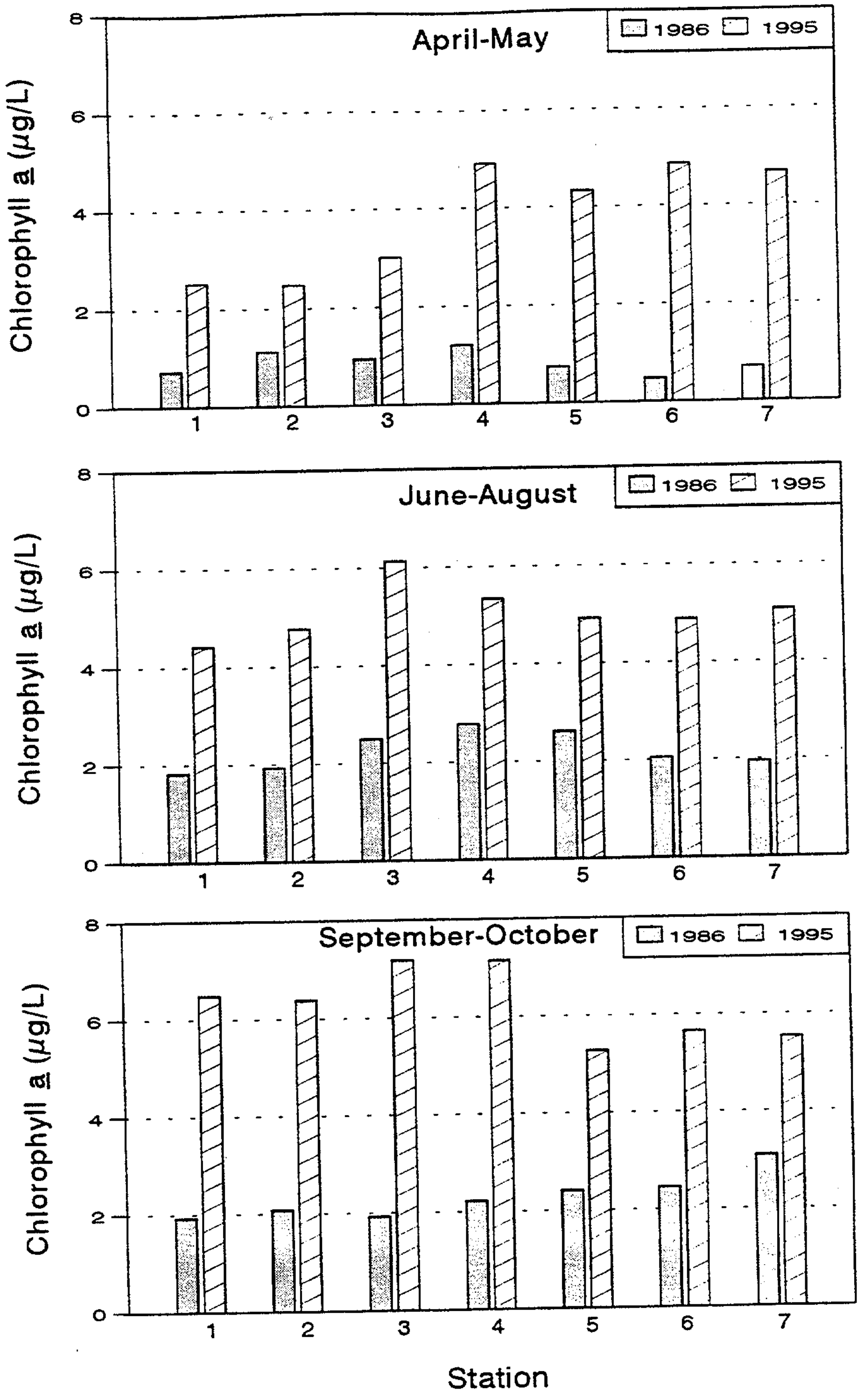


Figure 10-11. Seasonal mean concentration of chlorophyll a at stations 1-7 during the spring, summer and fall of 1986 and 1995.

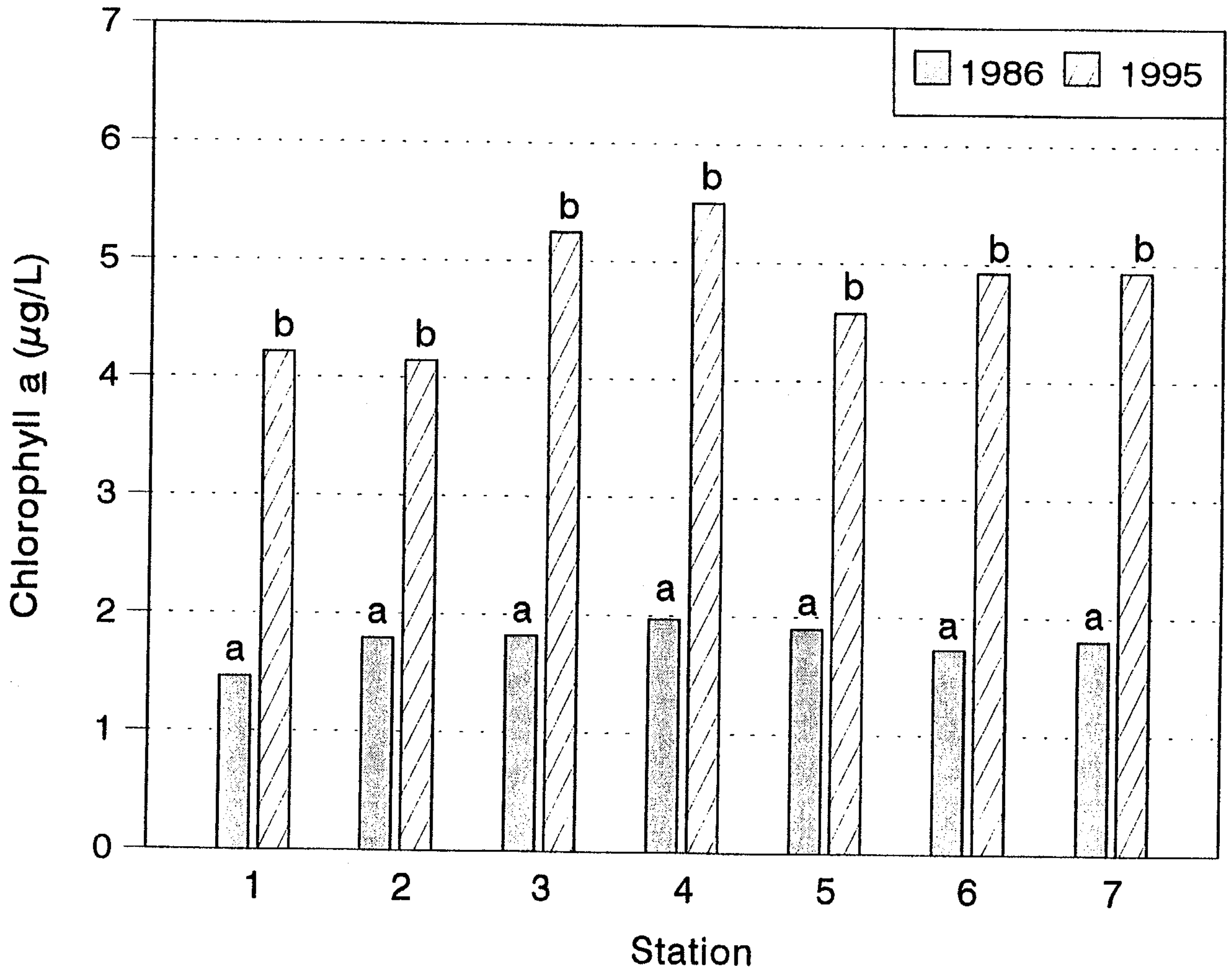


Figure 10-12. Annual mean concentration of chlorophyll a at stations 1-7 during 1986 and 1995. Within a station, bars with different letters represent significantly different means ($P<0.05$).

Lakes with productivities ranging from 250-1000 mgC/m^2•day are considered mesotrophic and values > 1000 mgC/m^2•day are considered eutrophic (Wetzel 1983).

Mean primary productivity measured during the growing seasons of 1986 and 1995 indicates that Smith Lake has remained in the mesotrophic (250-1000 mgC/m^2•day) range on most sampling occasions (Table 10-41). However, a statistical analysis of the volumetric (mgC/m^3•hour) data for the 2 years revealed a significant ($P < 0.05$) increase in productivity from 1986 to 1995 at two (stations 5 and 7) of the three (1, 5 and 7) stations examined during the growing season (May through September) of both years. This is consonant with the significant ($P < 0.05$) increases reported for phytoplankton densities and chlorophyll a concentrations from 1986 to 1995.

There were no consistent patterns in seasonal mean primary productivity measured at the three mainstem stations (Table 10-41). The absence of a longitudinal productivity gradient (upstream to downstream) is noteworthy and is in agreement with the rather even distribution of chlorophyll a among sampling stations (Tables 10-30, 10-31, 10-32 and 10-33). This probably reflects the absence of any dominating point sources of nutrients entering Smith Lake.

The Algal Growth Potential Test (AGPT) determines the total quantity of algal biomass supportable by the test waters and provides a reliable estimate of the bioavailable and limiting nutrients (Raschke and Schultz 1987). Maximum algal dry weights below 5.0 mg/L are thought to assure protection from nuisance phytoplankton blooms and fish-kills in southeastern lakes, excluding Florida (Raschke and Schultz 1987). Mean maximum dry weights above 10.0 mg/L indicate highly productive waters that may be subjected to nuisance blooms. Growing season mean dry weights on the mainstem of Smith Lake in 1995 were all below 5.0 mg/L except for mid reservoir station 5 in July (Table 10-42). Values over 4.0 mg/L were measured in the dam forebay (station 1) in July and at station 5 in June. Growing season mean dry weights were higher downstream at stations 1 and 5 than upstream at stations

Table 10-41. Mean (range) phytoplankton primary productivity measured at select sampling stations in Smith Lake during the growing seasons of 1986 and 1995. Productivity reported on a volumetric (mgC m^{-3} hr^{-1}) and areal (mgC m^{-2} day^{-1}) basis.

Month	Station	mgC m^{-3} hr^{-1}		mgC m^{-2} day^{-1}	
		1986	1995	1986	1995
5	1	1.56 (1.54-1.58)	1.71 (1.55-1.86)	794.5	161.6
	5	0.42 (0.38-0.47)	3.76 (3.75-3.76)	125.4	405.9
	7	2.28 (1.84-2.71)	3.23 (2.96-3.49)	630.6	241.2
6	1	-	5.22 (4.67-5.77)	-	830.2
	5	-	4.87 (4.62-5.12)	-	511.8
	7	-	4.49 (4.39-4.60)	-	887.4
7	1	7.01 (6.95-7.07)	3.36 (3.17-3.55)	1052.9	238.7
	5	5.35 (5.02-5.68)	7.38 (7.30-7.45)	875.5	780.2
	7	2.28 (2.18-2.39)	7.27 (7.04-7.50)	314.7	743.2
8	1	-	6.17 (5.17-6.97)	-	636.4
	5	-	9.89 (8.66-11.12)	-	1,049.3
	7	-	4.23 (2.89-5.62)	-	535.2

Table 10-41. (Continued)

Month	Station	mgC m^{-3} hr^{-1} 1986	mgC m^{-3} hr^{-1} 1995	mgC m^{-2} day^{-1} 1986	mgC m^{-2} day^{-1} 1995
9	1	1.49 (1.30-1.68)	4.53 (4.30-4.78)	486.3	344.9
	5	4.02 (3.77-4.26)	1.51 (1.35-1.67)	634.1	124.1
	7	2.64 (2.47-2.82)	2.16 (2.10-2.23)	187.4	231.0

Table 10-42. Mean maximum dry weight (mg/l) of Selenastrum capricornutum cultured in Smith Lake waters in 1995[1]. The growing season mean weight for each station is also presented.

Mainstem Station	Month					Seasonal Mean
	May	June	July	August	September	
1	1.14	2.71	4.20	1.55	1.43	2.20
5	2.11	4.95	5.13	1.46	1.63	3.05
7	1.01	1.66	3.18	1.66	0.78	1.66
9	2.44	2.61	1.75	1.66	1.04	1.90

[1] Results of Algal Growth Potential Tests conducted by the Ecological Support Branch, U. S. Environmental Protection Agency, Region IV.

7 and 9 (Table 10-42). Frequently, highest algal growth potential occurs at the most upstream riverine sampling station having relatively high nutrient content (Bayne et al. 1993a, Bayne et al. 1993b and Bayne et al. 1993c). In Smith Lake it appears that more plant nutrients are entering the lake from the mid reservoir area downstream to the dam. Distributional patterns of chlorides (Tables 10-30, 10-31, 10-32 and 10-33) and nitrates (Tables 10-21, 10-22, 10-23 and 10-24) within the lake support this observation. Nonpoint source nutrient enrichment is likely responsible for the increases in nutrients in this area of the lake. Two suspected sources of nutrients are animal waste entering some of the tributary streams and human waste entering the lake from malfunctioning septic systems.

In most freshwater lakes, phosphorus is the essential plant nutrient that limits growth and productivity of plankton algae (Wetzel 1983). Nitrogen usually becomes the limiting nutrient when bioavailable phosphorus increases relative to nitrogen, as in the case of waters receiving quantities of treated municipal waste (Raschke and Schultz 1987). The AGPT is helpful in identifying these common growth limiting nutrients. In Smith Lake, phosphorus was the limiting or co-limiting nutrient on all sampling occasions except at station 9 (Sipsey Fork) in July (Table 10-43). In general, phosphorus relative to nitrogen seemed to be in shorter supply downstream and earlier in the growing season. Nitrogen was relatively more important upstream and later in the growing season. Internal phosphorus loading caused by the release of phosphorus from anaerobic sediments as the growing season progresses may be partly responsible for increase in influence of nitrogen later in the growing season. The same spatial trend was observed when TN:TP ratios were compared using summer water chemistry data (Table 10-29). Phosphorus limitation was strongest from mid-lake (station 5) to the dam (station 1). Additional plant nutrients, particularly phosphorus, could increase algal biomass in Smith Lake and continue the cultural eutrophication that has occurred in this lake over the past 10 years.

Total organic carbon (TOC) concentrations are composed of dissolved and particulate fractions and the ratio of dissolved to particulate ranges from 6:1 to 10:1 in most unpolluted lakes (Wetzel 1983).

Table 10-43. Temporal and spatial variation in nutrient limitation based on results of Algal Growth Potential Tests[1] conducted during the 1995 growing season at Smith Lake.

Date	Mainstem Station			
	1	5	7	9
May 1995	P[2]	P	P	P
June 1995	P	P	N + P	N + P
July 1995	P	P	N + P	N
August 1995	N[3] + P	P	P	N + P
September 1995	N + P	N + P	N + P	N + P

[1] AGPT conducted by the Ecological Support Branch, U. S. Environmental Protection Agency, Region IV.

[2] P = Phosphorus limitation.

[3] N = Nitrogen limitation.

Most of the particulate fraction is composed of dead organic matter with living plankton contributing a small amount to the total (Wetzel 1983). The overwhelming influence of dissolved organic carbon, most of which is contributed from the watershed, tends to stabilize TOC concentrations and prevents wide fluctuations in concentration both spatially and temporally (Tables 10-30 through 10-33). TOC concentrations in Smith Lake ranged from a low of 2.38 mg/L in winter and spring at station 5 to a high of 5.22 mg/L at station 8 in the fall. There was little variation in seasonal mean TOC concentrations among stations during any season. Embayment concentrations were usually similar to nearby mainstem sampling areas. Seasonal mean TOC concentrations increased throughout the growing season (spring through fall) in concert with similar changes in chlorophyll a (algal biomass) (Tables 10-30, 10-31, 10-32 and 10-33). Smith Lake TOC concentrations were generally well below TOC concentrations measured in some eutrophic Alabama lakes. For example, seasonal mean TOC concentrations measured in Lake Neely Henry ranged from a low of 3.4 mg/L in the spring of 1993 to a high of 9.7 mg/L during the summer of 1994 (Bayne et al. 1995).

11.0 BIOLOGICAL RESOURCES

11.1 Fishery

Smith Lake is known for its excellent spotted bass fishery and more recently a trophy striped bass fishery. Continuing public interest and concern has resulted in reservoir sampling by Alabama Game and Fish during 1987, 1988 and 1990-1993 as part of their Reservoir Management Program. Fisheries data from the most recent (1993) management report are presented in Tables 11-1 through 11-2. Electrofishing, gillnetting and seining were all utilized to determine the composition and condition of the sportfish and other species in the lake. Electrofishing involved 30 minutes of sampling (pedal-down time) at each of 10 randomly selected sites. Results from the 1994-1995 Bass Anglers Information Team (B.A.I.T.) annual report are presented in Tables 11-3 and 11-4. The B.A.I.T. program was designed to compliment the Alabama Reservoir Management Program and provides angling results related to only the black bass fishery. A list of fish species collected from Smith Lake and the surrounding watershed appears in Table 11-5.

While bass tournaments on the lake declined in number since 1993, the bass populations showed improvement in number of bass caught per day in 1995. The establishment of a slot limit of 13-16 in. in 1995 could have produced this effect. The goal of this slot limit was to protect 3 and 4 year old fish and improve bass size structure within the lake. However, the establishment of this slot limit probably contributed to the overall low ranking received by Smith Lake in the B.A.I.T. report based on quality indicators by anglers (Table 11-4). Spotted bass are the dominant Micropterus species in Smith Lake due to favorable habitat. Results from both the 1993 reservoir sampling and 1995 angling indicate that spotted bass continue to exhibit modest growth.

The state has stocked Gulf Coast striped bass and Florida largemouth bass in Smith Lake since 1980 (Table 11-6). Controversy and support of the striped bass stocking program continues around the lake. Some fishermen are concerned that the striped bass are consuming large numbers of crappie in the lake. However, the stocking of striped bass has created a popular fishery in the lake and, according to research done by Alabama Game and Fish personnel, do not adversely affect native predator populations within the lake (Personal Communication, Steve Smith, Alabama Game and Fish).

The state has also stocked rainbow trout in the tailwaters below Smith Lake as a put and take fishery since the 1970's. Approximately 3,000-3,300, 7-11 inch trout have been stocked six times each year in a cooperative effort by Alabama Game and Fish and the U. S. Fish and Wildlife Service (Personal Communication, Jerry Moss, Alabama Game and Fish).

Table 11-1. Total number, catch per unit effort (CPE) and percent of sample of target species collected by electrofishing in Smith Lake, 1993. RSD-S = relative stock density (stock size), RSD-Q = relative stock density (quality size), RSD-P = relative stock density (preferred size), RSD-M = relative stock density (memorable size).

Species	Gear[1]	No. of Samples	Total[2] Effort	Substock			RSD-S				RSD-Q				RSD-P				RSD-M				TOTAL	
				No.	CPE	SSR	No.	CPE	PCT.	Wr	No.	CPE	PCT.	Wr	No.	CPE	PCT.	Wr	No.	CPE	PCT.	Wr	No.	CPE
Largemouth Bass	EF	10	5.21	13	2.5	13	56	10.8	57.1	82	13	2.5	13.3	83	20	3.8	20.4	81	9	1.7	9	84	111	21.3
Spotted Bass	EF	10	5.21	69	13.3	33	112	21.5	53.3	87	89	17.1	42.4	89	7	1.3	3.3	95	2	0.3	1	92	279	53.6
Bluegill	EF	4	2.10	3	1.4	2	137	65.2	91.9	83	12	5.7	8.05	80									152	72.4
Gizzard Shad	EF	10	5.21				29	5.6	49.2	82	30	5.8	50.8	85									59	11.3
Threadfin Shad	EF	6	2.40				212	88.3	45.8		251	104.6	54.2										463	192.9
Striped Bass	GN	10	10.00	17	1.7	100	9	0.9	52.9	106	6	0.6	35.3	101	2	0.2	11.8	114					34	3.4

[1] EF denotes electrofishing and GN denotes gill netting

[2] Effort is in hours when gear is EL and in net-nights when gear is GN

Table 11-2. Number of species collected by gear type from Smith Lake, 1993.

	Gear Type					
	Electrofishing			Gill Netting		
Species	No.	CPH	Effort (Hours)	No.	CPE	Effort (Net-Nights)
Largemouth Bass	111	21.3	5.21			
Spotted Bass	279	53.6	5.21	20	2.0	10.00
Striped Bass				34	3.4	10.00
Bluegill Sunfish	152	72.4	2.10			
Gizzard Shad	59	11.3	5.21	17	1.7	10.00
Threadfin Shad	463	192.9	2.40			
White Crappie	7	4.2	1.67			
Black Crappie	1	0.6	1.67			
Redear Sunfish	1	0.6	1.67			
Longear Sunfish	1	0.6	1.67			
Green Sunfish	3	1.8	1.67			
Warmouth	2	1.2	1.67			
Channel Catfish	4	2.4	1.67	23	2.3	10.00
Common Carp				4	0.4	10.00
Spotted Sucker	12	7.2	1.67	12	1.2	10.00
Blacktail Redhorse	18	10.8	1.67	7	0.7	10.00
Golden Redhorse	1	0.6	1.67			
Longnose Gar				7	0.7	10.00
Logperch	1	0.6	1.67			
Spottail Shiner	19	11.4	1.67			
Brook Silverside	27	16.2	1.67			

Table 11-3. Ranking by quality indicators for all reservoirs with five or more tournament reports in the 1994 B.A.I.T. program.

Rank	Percent Success	Average Weight	Bass per Man-day	Pounds per Man-day	Hours per Bass>5LB	Overall	Value
1	Martin	Eufaula	Martin	Jordan	Wheeler	Jordan	112
2	Weiss	Guntersville	Jones Bluff	Jones Bluff	Wilson	Gainesville	98
3	Harding	Wilson	Jordan	Lay	Eufaula	Logan Martin	98
4	Jones Bluff	West Point	Logan Martin	Logan Martin	Cedar Creek	Jones Bluff	96
5	Logan Martin	Pickwick	Millers Ferry	Millers Ferry	Aliceville	Wheeler	96
6	Jordan	Jordan	Gainesville	Gainesville	Gainesville	Lay	94
7	Neely Henry	Lay	Lay	Martin	Pickwick	Millers Ferry	92
8	Aliceville	Wheeler	Demopolis	Wheeler	Guntersville	Weiss	89
9	Mobile Delta	Weiss	Neely Henry	Neely Henry	Harding	Aliceville	86
10	Lay	Jones Bluff	Harding	Mitchell	Holt	Neely Henry	85
11	Millers Ferry	Mitchell	Aliceville	Wilson	Weiss	Martin	84
12	Gainesville	Gainesville	Mitchell	Demopolis	Jordan	Harding	79
13	Warrior	Logan Martin	Wheeler	Weiss	Millers Ferry	Wilson	77
14	Wheeler	Millers Ferry	Holt	Aliceville	Warrior	Pickwick	71
15	Tuscaloosa	Neely Henry	Little Bear	Holt	Neely Henry	Eufaula	67
16	Holt	Aliceville	Weiss	Harding	Logan Martin	Holt	66
17	Demopolis	Harris	Tuscaloosa	Pickwick	Tuscaloosa	Demopolis	63
18	Little Bear	Demopolis	Mobile Delta	Little Bear	Harris	Mitchell	58
19	Smith	Holt	Warrior	Eufaula	Lay	Guntersville	51
20	Pickwick	Mobile Delta	Pickwick	Tuscaloosa	West Point	Tuscaloosa	50
21	Harris	Tuscaloosa	Cedar Creek	Mobile Delta	Martin	Warrior	48
22	Cedar Creek	Little Bear	Smith	Warrior	Demopolis	Mobile Delta	45
23	Wilson	Harding	Harris	Harris	Little Bear	Little Bear	44
24	Mitchell	Warrior	Wilson	Smith	Smith	Cedar Creek	41
25	Eufaula	Smith	Eufaula	Cedar Creek	Mitchell	Harris	38
26	West Point	Martin	Guntersville	Guntersville	Jones Bluff	West Point	36
27	Guntersville	Cedar Creek	West Point	West Point	Mobile Delta	Smith	26

Table 11-4. Ranking by quality indicators for all reservoirs with five or more tournament reports in the 1995 B.A.I.T. program.

Rank	Percent Success	Average Weight	Bass per Man-day	Pounds per Man-day	Hours per Bass>5LB	Overall	Value
1	Martin	Eufaula	Martin	Jones Bluff	Guntersville	Jones Bluff	115
2	Holt	Wilson	Jones Bluff	Jordan	Aliceville	Jordan	104
3	Weiss	Guntersville	Weiss	Martin	Jones Bluff	Holt	96
4	Harding	Pickwick	Jordan	Lay	Eufaula	Weiss	94
5	Mobile Delta	Jones Bluff	Holt	Weiss	Holt	Martin	93
6	Jordan	West Point	Mobile Delta	Neely Henry	Wilson	Lay	90
7	Cedar Creek	Aliceville	Cedar Creek	Harding	Cedar Creek	Harding	87
8	Neely Henry	Lay	Harding	Holt	Wheeler	Neely Henry	78
9	Jones Bluff	Jordan	Neely Henry	Mitchell	Pickwick	Cedar Creek	76
10	Demopolis	Mitchell	Lay	Demopolis	Jordan	Guntersville	72
11	Mitchell	Logan Martin	Little Bear	Logan Martin	Lay	Demopolis	71
12	Lay	Millers Ferry	Mitchell	Wheeler	Weiss	Mitchell	71
13	Millers Ferry	Demopolis	Demopolis	Millers Ferry	Harding	Wheeler	68
14	Gainesville	Neely Henry	Wheeler	Guntersville	West Point	Logan Martin	67
15	Logan Martin	Wheeler	Gainesville	Gainesville	Logan Martin	Pickwick	66
16	Harris	Harding	Logan Martin	Cedar Creek	Gainesville	Aliceville	62
17	Little Bear	Gainesville	Millers Ferry	Pickwick	Martin	Eufaula	62
18	Wheeler	Weiss	**Smith**	Little Bear	Demopolis	Wilson	60
19	Pickwick	Holt	Harris	Mobile Delta	Harris	Gainesville	58
20	Aliceville	Martin	Pickwick	Wilson	Neely Henry	Millers Ferry	56
21	Eufaula	Coffeeville	Coffeeville	Eufaula	Little Bear	Mobile Delta	55
22	Guntersville	Cedar Creek	Aliceville	Aliceville	Mitchell	Little Bear	44
23	Wilson	Harris	Guntersville	**Smith**	Coffeeville	West Point	39
24	**Smith**	Little Bear	Wilson	Harris	Millers Ferry	Harris	34
25	West Point	Mobile Delta	West Point	Coffeeville	Mobile Delta	Coffeeville	19
26	Coffeeville	**Smith**	Eufaula	West Point	**Smith**	**Smith**	18

Table 11-5. Checklist of fish species collected from Smith Lake and the surrounding watershed.

Scientific Name	Common Name
Petromyzontidae	
Ichthyomyzon castaneus	chestnut lamprey
Ichthyomyzon gagii	southern brook lamprey
Lepisosteidae	
Lepisosteus occulatus	spotted gar
Lepisosteus osseus	longnose gar
Clupeidae	
Dorosoma cepedianum	gizzard shad
Dorosoma petenense	threadfin shad
Cyprinidae	
Campostoma oligolepis	largescale stoneroller
Cyprinella callistia	Alabama shiner
Cyprinella venusta	blacktail shiner
Cyprinella whipplei	steelcolor shiner
Cyprinus carpio	carp
Hybopsis winchelli	clear chub
Luxilis chrysocephalus	striped shiner
Lythrurus bellus	pretty shiner
Nocomis leptocephalus	bluehead chub
Notemigonus crysoleucas	golden shiner
Notropis asperfrons	burrhead shiner
Notropis atherinoides	emerald shiner
Notropis baileyi	rough shiner
Notropis stilbius	silverstripe shiner
Notropis volucellus	mimic shiner
Opsopoeodus emiliae	pugnose minnow
Phenacobius catostomus	riffle minnow
Pimephales notatus	bluntnose minnow
Pimephales vigilax	bullhead minnow
Rhinichthys atratulus	blacknose dace
Semotilus atromaculatus	chreek chub
Semotilus thoreauianus	dixie chub
Catastomidae	
Erimyzon oblongus	creek chubsucker
Hypentelium etowanum	Alabama hogsucker
Minytrema melanops	spotted sucker

Table 11-5 (Continued)

Scientific Name	Common Name
Catastomidae	
Moxostoma duquesnei	black redhorse
Moxostoma erythrurum	golden redhorse
Moxostoma poecilurum	blacktail redhorse
Ictaluridae	
Ameiurus melas	black bullhead
Ameiurus natalis	yellow bullhead
Ictalurus punctatus	channel catfish
Noturus leptacanthus	frecklebelly madtom
Noturus nocturnus	freckled madtom
Pylodictis olivaris	flathead catfish
Esocidae	
Esox niger	chain pickerel
Salmonidae	
Oncorhynchus mykiss	rainbow trout
Fundulidae	
Fundulus olivaceus	blackspotted topminnow
Poeciliidae	
Gambusia sp.	mosquitofish
Atherinidae	
Labidesthes sicculus	brook silverside
Moronidae	
Morone chrysops	white bass
Morone saxatilis	striped bass
Centrarchidae	
Ambloplites ariommus	shadow bass
Lepomis auritus	redbreast sunfish
Lepomis cyanellus	green sunfish
Lepomis gulosus	warmouth
Lepomis macrochirus	bluegill
Lepomis marginatus	dollar sunfish
Lepomis megalotis	longear sunfish

Table 11-5 (Continued)

Scientific Name	Common Name
Centrarchidae	
Lepomis microlophus	redear sunfish
Lepomis miniatus	red spotted sunfish
Micropterus coosae	redeye bass
Micropterus punctulatus	spotted bass
Micropterus salmoides	largemouth bass
Pomoxis annularis	white crappie
Pomoxis nigromaculatus	black crappie
Percidae	
Etheostoma bellator	warrior darter
Etheostoma douglasi	tuskaloosa darter
Etheostoma parvipinne	goldstripe darter
Etheostoma rupestre	rock darter
Etheostoma stigmaeum	speckled darter
Etheostoma whipplei	redfin darter
Etheostoma zonistium	bandfin darter
Percina maculata	blackside darter
Percina nigrofasciata	blackbanded darter
Percina sciera	dusky darter
Percina shumardi	river darter
Percina sp.	mobile logperch

Table 11-6. Fish stockings in Lewis Smith Reservoir, 1980-1993.

Species	Date	Rate	Size Group (in)	Total
Fla.LMB[1]	11/80	.005	7	100
Fla.LMB	04/81	.94	1	19,980
Gulf Coast STB[2]	06/83	2.31	2	49,000
Gulf Coast STB	04/84	.004	7-11	92
Gulf Coast STB	05/84	1.41	2	30,000
Fla.LMB	05/85	.94	2	20,000
Fla.LMB	08/85	.17	3-4	3,500
Gulf Coast STB	12/85	.05	8	1,078
Gulf Coast STB	05/86	1.18	2	25,000
Gulf Coast STB	05/86	3.77	2	80,000
Fla.LMB	05/86	2.06	1	43,700
Fla.LMB	06/87	.77	2	16,400
Gulf Coast STB	06/88	2.00	1-2	42,400
Gulf Coast STB	06/89	2.00	1-2	42,400
Gulf Coast STB	05/90	.85	1	18,000
Gulf Coast STB	05/90	.69	2	14,700
Gulf Coast STB	06/90	.47	2	10,000
Fla.LMB	05/90	1.00	1-2	21,200
Fla.LMB	05/91	1.99	1-2	42,156
Gulf Coast STB	05/91	3.00	2	63,604
Fla.LMB	05/92	2.00	1-2	42,400
Gulf Coast STB	06/92	3.14	1-2	66,500
Fla.LMB	05/93	2.00	2	42,400
Gulf Coast STB	06/93	3.44	1-2	72,952

[1] LMB = Largemouth bass

[2] STB = Striped bass

11.2 WILDLIFE

A checklist of birds, amphibians and reptiles expected in the Smith Lake watershed appears in Table 11-7. Though much of the watershed is forested, the counties within the watershed are known for poultry, cattle and other agricultural production. Development of lakeside property has also increased in recent years. These activities on the watershed affect wildlife habitat. The Sipsey Wilderness Area within the Bankhead National Forest provides unique habitat for several species found only in this area of the state. Table 11-8 lists three rare and endangered species found within the Smith Lake watershed.

Table 11-7. Checklist of birds, amphibians and reptiles expected in and around Smith Lake and its surrounding watershed.

Family Scientific Name	Common name
BIRDS	
Gaviidae	
Gavia immer	common loon
Podicipedidae	
Podiceps auritus	horned grebe
Podiceps nigricollis	eared grebe
Podilymbus podiceps	pied-billed grebe
Pelecanidae	
Pelecanus erythrorhynchos	white pelican
Phalacrocoracidae	
Phalacrocorax auritus	double-crested cormorant
Anhingidae	
Anhinga anhinga	anhinga
Ardeidae	
Ardea herodias	great blue heron
Butorides virescens	green heron
Florida caerula	little blue heron
Bubulcus ibis	cattle egret
Casmerodius albus	great egret
Egretta thula	snowy egret
Hydranassa tricolor	Louisiana heron
Nycticorax hycticorax	black-crowned night heron
Nyctanassa violacea	yellow-crowned night heron
Ixobrychus exilis	least bittern
Botaurus lentiginosus	American bittern
Ciconiidae	
Mycteria americana	wood stork
Threskiornithidae	
Plegadis falcinellus	glossy ibis
Eudocimus albus	white ibis
Anatidae	
Olor columbianus	whistling swan
Branta canadensis	Canada goose
Anser albifrons	white-fronted goose
Chen caerulescens	snow goose

Table 11-7 (Continued)

Family	Scientific Name	Common name
Anatidae		
	Dendrocygna bicolor	fulvous tree duck
	Anas platyrhynchos	mallard
	Anas rubripes	black duck
	Anas strepera	gadwall
	Anas acuta	pintail
	Anas crecca	green-winged teal
	Anas discors	blue-winged teal
	Anas americana	American wigeon
	Anas cylpeata	northern shoveler
	Aix sponsa	wood duck
	Aythya americana	redhead
	Aythya collaris	ring-necked duck
	Aythya valisineria	canvas back
	Aythya marila	greater scaup
	Aythya affinis	lesser scaup
	Bucephala clangula	common goldeneye
	Bucephala albeola	bufflehead
	Clangula hyemalis	oldsquaw
	Melanitta delglandi	white-winged scoter
	Melanitta perspicillata	surf scoter
	Oxyura jamaicensis	ruddy duck
	Lophodytes cucullatus	hooded merganser
	Mergus merganser	common merganser
	Mergus serrator	red-breasted merganser
Cathartidae		
	Cathartes aura	turkey vulture
	Coragyps atratus	black vulture
Accipitridae		
	Elanoides forficatus	swallow-tailed kite
	Ictinia misisippiensis	Mississippi kite
	Accipter striatus	sharp-shinned hawk
	Accipter cooperii	Cooper's hawk
	Buteo jamaicensis	red-tailed hawk
	Buteo lineatus	red-shouldered hawk
	Buteo platypterus	broad-winged hawk
	Buteo swainsoni	Swainson's hawk
	Buteo lagopus	rough-legged hawk
	Aquila chrysaetos	golden eagle
	Haliaeetus leucocephalus	bald eagle
	Circus cyaneus	marsh hawk
Pandionidae		
	Pandion haliaetus	osprey

Table 11-7 (Continued)

Family Scientific Name	Common name
Falconidae	
Falco perigrinus	peregrin falcon
Falco columbarius	merlin
Falco sparverius	American kestrel
Tetraonidae	
Bonasa umbellus	ruffed grouse
Phasianidae	
Colinus virginianus	bobwhite
Meleagrididae	
Meleagris gallopavo	turkey
Gruidae	
Grus canadensis	sandhill crane
Rallidae	
Rallus elegans	kingrail
Rallus limicola	Virginia rail
Porzana carolina	sora
Porphyrula martinica	purple gallinule
Gallinula chloropus	common gallinule
Fulica americana	American coot
Charadriidae	
Charadrius semipalmatus	semipalmated plover
Charadrius melodus	piping plover
Charadrius vociferus	killdeer
Pluvialus dominica	American golden plover
Pluvialus squatarola	black-bellied plover
Scolopacidae	
Arenaria interpres	ruddy turnstone
Philohela minor	American woodcock
Capella gallinago	common snipe
Numenius phaeopus	whimbrel
Bartramia longicauda	upland sandpiper
Actitis macularia	spotted sandpiper
Tringa solitaria	solitary sandpiper
Tringa melanoleuca	greater yellow legs
Tringa flavipes	lesser yellow legs
Catoptraphorus semipalmatus	willet
Calidris melanotus	pectoral sandpiper
Calidris fuscicollis	white-rumped sandpiper
Calidris bairdii	Baird's sandpiper
Calidris minutilla	least sandpiper
Calidris alpina	dulin
Calidris pusilla	semipalmated sandpiper
Calidris mauri	western sandpiper

Table 11-7 (Continued)

Family Scientific Name	Common name
Scolopacidae	
Calidris alba	sanderling
Limnodromus griseus	short-billed dowitcher
Limnodromus scolopaceus	land-billed dowitcher
Micropalama himantopus	stilt sandpiper
Tryngites subruficollis	buff-breasted sandpiper
Limosa fedoa	marbled godwit
Recurvirostridae	
Recurvirostra americama	American avocet
Phalaropodidae	
Phalaropus fulicarius	red phalarope
Steganopus tricolor	Wilson's phalarope
Lobipes lobatus	northern phalarope
Laridae	
Larus argentatus	herring gull
Larus delawarensis	ring-billed gull
Larus artricilla	laughing gull
Larus philadelphia	Bonaparte's gull
Sterna forsteri	Forster's tern
Sterna hirundo	common tern
Sterna albifrons	least tern
Thalasseus maximus*	royal tern
Hydroprogne caspia	caspian tern
Chlidonias niger	black tern
Columbidae	
Columba livia	rock dove
Zenaida macroura	mourning dove
Columbina passerina	ground dove
Cuculidae	
Cocoyzus americanus	yellow-billed cuckoo
Cocoyzus erythropthalmus	black-billed cuckoo
Tytonidae	
Tyto alba	barn owl
Otus asio	screech owl
Bubo virginianus	great horned owl
Strix varia	barred owl
Asio flammeus	short-eared owl
Aegolius acadicus	saw-whet owl

Table 11-7 (Continued)

Family Scientific Name	Common name
Caprimulgidae	
Caprimulgus carolinensis	Chuck-Will's-widow
Caprimulgus vociferus	whip-poor-will
Chordeiles minor	common nighthawk
Apodidae	
Chaetura pelagica	chimney swift
Trochilidae	
Archilochus colubris	ruby-throated hummingbird
Alcedinidae	
Megacerle alcyon	belted kingfisher
Picidae	
Colaptes auratus	common flicker
Dryocopus pileatus	pileated woodpecker
Centurus carolinus	red-bellied woodpecker
Melanerpea erythrocephalus	red-headed woodpecker
Sphyrapicus varius	yellow-bellied sapsucker
Dendrocopos villosus	hairy woodpecker
Dendrocopos pubescens	downy woodpecker
Picoides borealis	red-cockaded woodpecker
Tyrannidae	
Tyrannus tyrannus	eastern kingbird
Tyrannus verticalis	western kingbird
Muscivora forficata	scissor-tailed flycatcher
Myiarchus crinitus	great creasted flycatcher
Sayornis phoebe	eastern phoebe
Empidonax flaviventris	yellow-bellied flycatcher
Empidonax virescens	acadian flycatcher
Empidonax traillii	willow flycatcher
Empidonax alnorum	alder flycatcher
Empidonax minimus	least flycatcher
Contopus virens	eastern wood pewee
Nuttallornis borealis	olive-sided flycatcher
Alaudidae	
Eremophila alpestris	horned lark
Hirundinidae	
Iridoprocne bicolor	tree swallow
Riparia riparia	bank swallow
Stelgidopteryx ruficollis	rough-winged swallow
Hirundo rustica	barn swallow

Table 11-7 (Continued)

Family Scientific Name	Common name
Hirundinidae	
Petrochelidon pyrrhonota	cliff swallow
Progne subis	purple martin
Corvidae	
Cyanocitta cristata	blue jay
Corvus brachyrhynchos	common crow
Paridae	
Parus carolinensis	carolina chickadee
Parus bicolor	tufted titmouse
Sittidae	
Sitta carolinensis	white-breasted nuthatch
Sitta canadensis	red-breasted nuthatch
Sitta pusilla	brown-headed nuthatch
Certhidae	
Certhia familiaris	brown creeper
Troglodytidae	
Troglodytes aedon	house wren
Troglodytes troglodytes	winter wren
Thryomanes bewickii	Bewick's wren
Thryothorus ludovicianus	carolina wren
Telmatodytes palustris	long-billed marsh wren
Cistothorus platensis	short-billed marsh wren
Mimidae	
Mimus polyglottos	mocking bird
Dumetella carolinensis	gray catbird
Toxostoma rufum	brown thrasher
Turdidae	
Turdus migratorius	american robin
Hylocichla mustelina	wood thrush
Catharus guttatus	hermit thrush
Catharus ustulatus	Swainson's thrush
Catharus minimus	gray-cheeked thrush
Catharus fuscescens	veery
Sialia sialis	eastern bluebird

Table 11-7 (Continued)

Family Scientific Name	Common name
Sylviidae	
Polioptila caerula	blue-gray gnatcatcher
Regulus satrapa	golden-crowned kinglet
Regulus calendula	ruby-crowned kinglet
Motacillidae	
Anthus spinoletta	water pipit
Anthus spragueii	Sprague's pipit
Bombycillidae	
Bombycilla cedrorum	cedar waxwing
Laniidae	
Lanius ludovicianus	loggerhead shrike
Sturnidae	
Sturnus vulgaris	starling
Vireonidae	
Vireo griseus	white-eyed vireo
Vireo bellii	Bell's vireo
Vireo flavifrons	yellow-throated vireo
Vireo solitarius	solitary vireo
Vireo olivaceus	red-eyed vireo
Vireo philadelphicus	Philadelphia vireo
Vireo gilvus	warbling vireo
Parulidae	
Mniotilta varia	black-and-white warbler
Protonotaria citrea	prothonotary warbler
Limnothlypis swainsonii	Swainson's warbler
Helmitheros vermivorus	worm-eating warbler
Vermivora chrysoptera	golden-winged warbler
Vermivora pinus	blue-winged warbler
Vermivora bachmanii	Bachman's warbler
Vermivora peregrina	Tennessee warbler
Vermivora celata	orange-crowned warbler
Vermivora ruficapilla	Nashville warbler
Parula americana	northern parula
Dendroica petechia	yellow warbler
Dendroica magnolia	magnolia warbler
Dendroica tigrina	cape may warbler
Dendroica caerulescens	black-throated blue warbler
Dendroica coronata	yellow-rumped warbler
Dendroica virens	black-throated green warbler

Table 11-7 (Continued)

Family Scientific Name	Common name
Parulidae	
<u>Dendroica</u> <u>cerulea</u>	cerulean warbler
<u>Dendroica</u> <u>fusca</u>	blackburnian warbler
<u>Dendroica</u> <u>dominica</u>	yellow-throated warbler
<u>Dendroica</u> <u>pensylvanica</u>	chestnut-sided warbler
<u>Dendroica</u> <u>castanea</u>	bay-breasted warbler
<u>Dendroica</u> <u>striata</u>	blackpoll warbler
<u>Dendroica</u> <u>pinus</u>	pine warbler
<u>Dendroica</u> <u>kirtlandii</u>	Kirtland's warbler
<u>Dendroica</u> <u>discolor</u>	prairie warbler
<u>Dendroica</u> <u>palmarum</u>	palm warbler
<u>Seiurus</u> <u>aurocapillus</u>	ovenbird
<u>Seiurus</u> <u>noveboracensis</u>	northern waterthrush
<u>Seiurus</u> <u>motacilla</u>	Louisiana waterthrush
<u>Oporornis</u> <u>formosus</u>	Kentucky warbler
<u>Oporornis</u> <u>agilis</u>	Connecticut warbler
<u>Oporornis</u> <u>philadelphia</u>	mourning warbler
<u>Geothypis</u> <u>trichas</u>	common yellowthroat
<u>Icteria</u> <u>virens</u>	yellow-breasted chat
<u>Wilsonia</u> <u>citrina</u>	hooded warbler
<u>Wilsonia</u> <u>pusilla</u>	Wilson's warbler
<u>Wilsonia</u> <u>canadensis</u>	Canada warbler
<u>Setophaga</u> <u>ruticilla</u>	american redstart
Ploceidae	
<u>Passer</u> <u>domesticus</u>	house sparrow
Icteridae	
<u>Dolichonyx</u> <u>oryzivorus</u>	bobolink
<u>Sturnella</u> <u>magna</u>	eastern meadowlark
<u>Sturnella</u> <u>neglecta</u>	western meadowlark
<u>Agelaius</u> <u>phoeniceus</u>	red-winged blackbird
<u>Icterus</u> <u>spurius</u>	orchard oriole
<u>Icterus</u> <u>galbula</u>	northern oriole
<u>Euphagus</u> <u>carolinus</u>	rusty blackbird
<u>Euphagus</u> <u>cyanocephalus</u>	Brewer's blackbird
<u>Quiscalus</u> <u>quiscula</u>	common crackle
<u>Molothrus</u> <u>ater</u>	brown-headed cowbird
Thraupinae	
<u>Piranga</u> <u>olivacea</u>	scarlet tanager
<u>Piranga</u> <u>rubra</u>	summer tanager

Table 11-7 (Continued)

Family Scientific Name	Common name
Fringillidae	
Cardinalis cardinalis	cardinal
Pheucticus ludovicianus	rose-breasted grosbeak
Pheucticus melanocephalus	black-headed grosbeak
Guiraca caerulea	blue grosbeak
Passerina cyanea	indigo bunting
Passerina ciris	painted bunting
Spiza americana	dickcissel
Hesperiphona vespertina	evening grosbeak
Carpodacus purpureus	purple finch
Spinus pinus	pink siskin
Spinus tristis	american goldfinch
Loxia curvirostra	red crossbill
Piplio erythrophthalmus	rufous-sided towhee
Passerculus sandwichensis	Savannah sparrow
Ammondramus savannarum	grasshopper sparrow
Ammondramus henslowii	Henslow's sparrow
Ammospiza leconteii	Le Conte's sparrow
Ammospiza caudacuta	sharp-tailed sparrow
Chondestes grammacus	lark sparrow
Pooecetes gramineus	vesper sparrow
Aimophila aestivalis	Bachman's sparrow
Junco hyemalis	dark-eyed junco
Spizella passerina	chipping sparrow
Spizella pallida	clay-colored sparrow
Spizella pusilla	field sparrow
Zonotrichia querula	Harris' sparrow
Zonotrichia leucophrys	white-crowned sparrow
Zonotrichia albicollis	white-throated sparrow
Passerella iliaca	fox sparrow
Melospiza lincolnii	Lincoln's sparrow
Melospiza georgiana	swamp sparrow
Melsopiza melodi	song sparrow
Calcarius lapponicus	lapland longspur
Calcarius pictus	Smith's longspur
AMPHIBIANS	
Bufonidae	
Bufo americanus americanus	american toad
Bufo quercicus	oak toad
Bufo terrestris	southern toad
Bufo woodhousei	Fowler's toad

Table 11-7 (Continued)

Family Scientific Name	Common name
Hylidae	
Acris crepitans crepitans	northern cricket frog
Acris gryllus gryllus	southern cricket frog
Hyla avivoca	bird-voiced treefrog
Hyla cinerea	green treefrog
Hyla crucifer crucifer	northern spring peeper
Hyla femoralis	pine woods treefrog
Hyla gratiosa	barking treefrog
Hyla squirella	squirrel treefrog
Hyla versicolor	gray treefrog
Pseudacris brachyphona	mountain chorus frog
Pseudacris nigrita nigrita	southern chorus frog
Pseudacris ornata	ornate chorus frog
Pseudacris triseriata feriarum	upland chorus frog
Microrhylidae	
Gastrophyryne carolinensis	eastern narrow-mouthed toad
Pelobatidae	
Scaphiopus holbrooki holbrooki	eastern spadefoot toad
Ranidae	
Rana catesbeiana	bullfrog
Rana clamitans melaneta	green frog
Rana palustris	pickerel frog
Rana pipiens sphenocephala	southern leopard frog
Ambystomatidae	
Ambystoma maculatum	spotted salamander
Ambystoma opacum	marbled salamander
Ambystoma talpoideum	mole salamander
Ambystoma texanum	small-mouthed salamander
Ambystoma tigrinum tigrinum	eastern tiger salamander
Cryptobranchidae	
Cryptobranchus alleganiensis	hellbender
Amphiumidae	
Amphiuma means	two-toed amphiuma
Amphiuma tridactylum	three-toed amphiuma
Plethodontidae	
Aneides aeneus	green salamander
Desmognathus aeneus	seepage salamander

Table 11-7 (Continued)

Family Scientific Name	Common name
Plethodontidae	
Desmognathus fuscus fuscus	northern dusky salamander
Desmognathus fuscus auriculatus	southern dusky salamander
Desmognathus monticola spp.	seal salamander
Desmognathus ochrohaeus	mountain dusky salamander
Eurycea bislineata	two-lined salamander
Eurycea longicauda longicauda	long-tailed salamander
Eurycea longicauda guttolineata	three-lined salamander
Eurycea lucifuga	cave salamander
Gryinophilus palleucus palleucus	Tennessee cave salamander
Gryinophilus palleucus necturoides	no common name
Gryinophilus porphyriticus porphyriticus	northern spring salamander
Gryinophilus porphyriticus dunni	carolina spring salamander
Gryinophilus porphyriticus duryi	Kentucky spring salamander
Hemidactylium scutatum	four-toed salamander
Manculus quadridigitatus	dwarf salamander
Plethodon dorsalis dorsalis	zigzag salamander
Plethodon glutinosus glutinosus	slimy salamander
Pseudotriton montanus flavissumus	gulf coast mud salamander
Pseudotriton ruber ruber	northern red salamander
Pseudotriton ruber vioscai	southern red salamander
Proteidae	
Necturus beyeri	Beyer's waterdog
Necturus maculosus	mudpuppy
Salamandridae	
Notopthalmus viridescens viridenscens	red-spotted newt
Notopthalmus viridescens louisianensis	central newt
Sirenidae	
Siren intermedia intermedia	eastern lesser siren
Siren intermedia nettingi	western lesser siren
REPTILES	
Alligatoridae	
Alligator mississippensis	american alligator
Anguidae	
Ophisaurus attenuatus longicaudus	eastern slender glass lizard
Ophisaurus ventralis	eastern glass lizard

Table 11-7 (Continued)

Family Scientific Name	Common name
Iguanidae	
Anolis carolinensis carolinensis	green anole
Sceloporus undulatus undulatus	southern fence lizard
Sceloporus undulatus hyacinthus	northern fence lizard
Scincidae	
Eumeces anthracinus anthracinus	northern coal skink
Eumeces anthracinus pluvialis	southern coal skink
Eumeces egregius similis	northern mole skink
Eumeces fasciatus	five-lined skink
Eumeces inexpectatus	southeastern five-lined skink
Eumeces laticeps	broad-headed skink
Spincella laterale	ground skink
Teidae	
Cnemidophorus sexlineatus sexlineatus	eastern six-lined racerunner
Colubridae	
Carphophis amoenus amoenus	eastern worm snake
Carphophis amoenus helenae	midwest worm snake
Cemophora coccinea copei	northern scarlet snake
Coluber constrictor constrictor	northern black racer
Coluber constrictor priapus	southern black racer
Diadophis punctatus punctatus	southern ringneck snake
Diadophis punctatus edwardsi	northern ringneck snake
Diadophis punctatus stictogenys	Mississippi ringneck snake
Elaphe guttata guttata	corn snake
Elaphe obsoleta obsoleta	black rat snake
Elaphe obsoleta spiloides	gray rat snake
Farancia abacura abacura	eastern mud snake
Farancia abacura reinwardti	western mud snake
Farancia erytrogramma erytrogramma	rainbow snake
Heterodon platyrhinos	eastern hognose snake
Heterodon simus	southern hognose snake
Lampropeltis calligaster rhombomaculata	mole snake
Lampropeltis getulus getulus	eastern kingsnake
Lampropeltis getulus holbrooki	speckled kingsnake
Lampropeltis getulus niger	black kingsnake
Lampropeltis triangulum triangulum	eastern milksnake
Lampropeltis triangulum elapsoides	scarlet kingsnake
Lampropeltis triangulum syspila	red milk snake
Masticophis flagellum flagellum	eastern coachwhip
Nerodia erythrogaster erythrogaster	red-bellied water snake
Nerodia erythrogaster flavigaster	yellow-bellied water snake
Nerodia rigida sinicola	Gulf glossy water snake

Table 11-7 (Continued)

Family Scientific Name	Common name
Colubridae	
Nerodia septemvittata	queen snake
Nerodia sipedon pleuralis	midland water snake
Nerodia taxispilota	brown water snake
Opheodrys aestivus	rough green snake
Pituophis melanoleucus melanoleucus	northern pine snake
Storeria dekayi dekayi	northern brown snake
Storeria wrightorum	midland brown snake
Storeria occipitomaculata occipitomaculata	northern red-bellied snake
Tantilla coronata	southeastern crowned snake
Thamnophis sauritus sauritus	eastern ribbon snake
Thamnophis sauritus sirtalis	eastern garter snake
Virginia striatula	rough earth snake
Virginia valeriae valeriae	eastern smooth earth snake
Elapidae	
Micrurus fulvius fulvius	eastern coral snake
Viperidae	
Agkistrodon contortrix contortrix	southern copperhead
Agkistrodon contortrix mokeson	northern copperhead
Agkistrodon piscivorus piscivorus	eastern cottonmouth
Crotalus horridus	timber rattlesnake
Sistrurus miliarius miliarius	carolina pigmy rattlesnake
Sistrurus miliarius barbouri	dusky pigmy rattlesnake
Sistrurus miliarius streckeri	western pigmy rattlesnake
Chelydridae	
Chelydra serpentina serpentina	common snapping turtle
Macroclemys temmincki	alligator snapping turtle
Emydidae	
Chrysemys picta dorsalis	southern painted turtle
Chrysemys picta marginata	midland painted turtle
Deirochelys reticularia reticularis	eastern chicken turtle
Graptemys barbouri	Barbour's map turtle
Graptemys geographica	map turtle
Graptemys nigrinoda nigrinoda	northern black-knobbed sawback
Graptemys pseudogeographica ouachitensis	ouachita map turtle
Graptemys pulchra	Alabama map turtle
Pseudemys concinna concinna	river cooter
Pseudemys scripta scripta	yellow-bellied pond slider
Pseudemys scripta elegans	red-eared pond slider
Terrapene carolina carolina	eastern box turtle
Terrapene carolina triungis	three-toed box turtle

Table 11-7 (Continued)

Family Scientific Name	Common name
Kinosternidae	
Kinosternon subrubrum subrubrum	eastern mud turtle
Sternotherus minor depressus	flattened mud turtle
Sternotherus minor peltifer	stripe-necked musk turtle
Sternotherus odoratus	common musk turtle
Testudinidae	
Gopherus polyphemus	gopher tortoise
Trionychidae	
Trionyx muticus muticus	midland smooth softshell
Trionyx muticus calvatus	Gulf Coast smooth softshell
Trionyx spiniferus spiniferus	eastern spiny softshell
Trionyx spiniferus asper	gulf coast spiny softshell

*=accidental

Table 11-8. Rare and endangered species from Smith Lake watershed.

	Common name
Amphibians	
Necturus sp.	black warrior waterdog
Birds	
Picoides borealis	red cockaded woodpecker
Mussels	
Villosa lienosa	little spectaclecase

PART II. FEASIBILITY STUDY

LAKE RESTORATION ALTERNATIVES

PROBLEM: Cultural Eutrophication

PRIMARY CAUSES:

Nonpoint-source discharge of animal (mainly poultry and beef cattle) waste from farms within the basin

Nutrient enrichment caused by nonpoint source septic drainage from lakeshore homes

Lewis Smith Lake is not use-threatened or use-impaired (ADEM 1996) although water quality concerns have been expressed (Bayne et al. 1987 and ADEM 1996). One area of concern is cultural eutrophication that has resulted in increased phytoplankton biomass and decreased visibility within the water column. Of the larger (> 5,000-acres) impoundments in Alabama, Lewis Smith Lake, Lake Martin and Lake Tuscaloosa are unique in having relatively clear waters with limited algal growth caused by low to moderate nutrient enrichment. These three lakes are also relatively deep and have more rocky substrate. When compared to the other 21 large river impoundments in the state, these lakes are quite unusual. The clear waters are appealing to swimmers, skiers, boaters and lake home owners for obvious reasons. Surprisingly these lakes are popular among sport fishermen even though total fish biomass and trophy bass production are lower in these clear water lakes (Bayne et al. 1994b). These lakes support a higher ratio of spotted bass (Micropterus punctulatus) to largemouth bass (M. salmoides) than is found in the more eutrophic Alabama lakes and this provides the bass angler with an additional target species. Lewis Smith Lake produced the world record spotted bass in 1972. Fishing in relatively clear, deeper lakes instead of the more turbid, shallower lakes (most eutrophic lakes) presents challenges that most skilled anglers welcome.

There were relatively few permitted point-source dischargers in the Smith Lake basin. The volumn of municipal wastewater reaching Smith Lake during the study was an estimated 0.24 million gallons/day (MGD). By contrast, West Point Lake located on the Chattahoochee River downstream from Atlanta, Georgia received an average of 240.32 MGD during a comparable time period in 1990-1991 (Bayne et al. 1994a). Point-source organic loading of Smith Lake was only a fraction of the loading that occurred in some other, recently examined river impoundments. For example, Weiss Lake and Lake Neely Henry had annual BOD_5 loads of 3.7 and 1.1 million pounds, respectively, while Smith Lake received an estimated 0.005 million pounds during the study year (Bayne et al. 1993b and Bayne et al. 1995). In addition, the volumn of Smith Lake is an order of magnitude greater than any of the three lakes used in these comparisons.

Nevertheless, cultural eutrophication of Smith Lake was evident when the 1986 study results were compared to 1995 data. Phytoplankton densities and biomass more than doubled during this 10 year period. In addition, algal primary productivity was higher and Secchi disk visibility (water clarity) was lower in 1995 than in 1986. Based on the Carlson Trophic State Index using the mean photic zone chlorophyll a concentration, Smith Lake was borderline oligotrophic/mesotrophic in 1986 and was borderline mesotrophic/eutrophic in 1995 (Carlson 1977). Perhaps some of the increased algal biomass present in 1995 was caused by greater rainfall and watershed runoff during that year than occurred in the drought year of 1986. Trophic state trend data for Smith Lake reveal a tendency for algal biomass to increase during years of higher rainfall (ADEM 1995 and ADEM 1996).

From 1991 through 1995 water quality was examined in the upstream embayments of Crooked, Rock and Ryan creeks (D. R. Bayne, unpublished data). Water samples were collected monthly during the growing season (April - October) and analyzed for chlorophyll a and Algal Growth Potential (maximum standing crop of algal biomass). Algal biomass was extremely variable in these waters apparently because nutrients needed to support algal growth were being supplied intermittently from nonpoint sources (mainly animal waste). Crooked and Rock creeks had growing season mean chlorophyll a concentrations in the eutrophic range and Ryan Creek was mesotrophic. Chlorophyll a concentrations in Crooked and Rock creeks were significantly ($P < 0.008$ and $P < 0.0003$, respectively) correlated with 7-day antecedent rainfall in the basins. Algal growth potential in these two creeks frequently exceeded levels considered likely to produce nuisance blooms. Management of animal waste (poultry and beef cattle) in these and other watersheds within the Smith Lake basin affects water quality in the lake.

The intensive animal rearing operations in the Ryan-Crooked-Rock Creeks Hydrologic Unit generate about 1 billion pounds of animal waste annually of which 185 million pounds enters streams and lakes (USDA 1991). This is roughly equivalent to the human waste generated by a city of 1.15 million people. An estimated 2,300 tons of dead poultry must be disposed of each year (USDA 1991).

Algal production in Smith Lake is predominately phosphorus limited. Any bioavailable phosphorus in animal waste that enters Smith Lake will likely result in increased algal growth. Poultry are produced in houses and the accumulated waste and litter in the houses is removed at intervals and spread on nearby pastures and agricultural crops. Waste from cattle is deposited directly on pastures and feed lots. Phosphorus in these wastes can enter surface waters in two ways. Rainfall runoff can cause soil erosion that moves sediment bound (sorbed) phosphorus or phosphorus can be dissolved in runoff and enter surface waters. Until recently, it was believed that phosphorus added to agricultural soils was tightly bound and unless the soil moved, phosphorus was virtually fixed (Sharpley 1997). Now, however, it is clear that the amount of dissolved phosphorus in runoff is dependent upon the amount of phosphorus added to the soil. In essence, soils that receive excessive amounts of phosphorus (animal waste) release increasing amounts of soluble phosphorus to surface and subsurface water even if soil erosion is adequately controlled (Sharpley 1997). Agricultural scientists at Auburn University have shown that the amount of phosphorus in animal waste produced in Winston and Cullman counties exceeds (101-200%) the phosphorus needs for crops grown in those counties (C. W. Wood, Jr., Personal Communication). If cultural eutrophication of Smith Lake is to be controlled, consideration should be given to balancing phosphorus (animal waste) added to croplands with phosphorus needs of those crops.

An additional source of nutrients to Smith Lake is septic tank drainage from lakeshore housing. The geology and soils of the region are not well suited for septic tank function. The most serious problem is the shallow depth from soil surface to bedrock and steep slopes around the lake shore (Personal Communication, J. Frutiger, Cullman Co. Health Dept.). Continued shoreline housing and commercial development around the lake will likely add to the problem.

RECOMMENDATIONS

This study documented a dramatic rise in algal biomass in Smith Lake between 1986 and 1995. Similar increases will likely occur in the future if actions are not taken to limit nutrient enrichment of the lake. Local public participation in an adequate forum should be encouraged and utilized to ensure that the historical multiple uses of Smith Lake are preserved and maintained. Once this input is received, management alternatives can be explored to limit further nutrient enrichment and algal growth in Smith Lake. One alternative might be the establishment of numerical water quality standards that address nutrient enrichment.

Control of nutrients entering Smith Lake from land-applied animal waste disposal will require that state and federal agencies work together to assure that best management practices are effectively utilized. In view of the quantity of manure being produced relative to crop needs, it may be necessary to transport excess manure out of the Smith Lake drainage basin or perhaps apply the manure to forest lands within the basin. The long term solution to the septic tank problem is community wastewater treatment for businesses and homes around the lake. Until this can be accomplished, existing septic tank systems near the lake should be inspected at regular intervals to assure proper function. Any new septic systems should be properly designed, constructed and maintained and placed as far away from the lake shore as possible.

PROBLEM: Lake Acidification

PRIMARY CAUSES:

Low chemical buffering capacity of Smith Lake waters

Mining activities within the basin

Acid precipitation

Total alkalinity of water is a measure of the concentration of titratable bases and is expressed as equivalent calcium carbonate. Carbonate ($CO_3^{=}$) and bicarbonate (HCO_3^-) ions in water are responsible for most of the total alkalinity measured in waters of this region. These ions provide a source of carbon for aquatic photosynthesis and serve to raise the pH and chemically buffer the waters to prevent wide fluctuations in pH.

Total alkalinity of natural waters varies from <5.0 to several hundred mg/1 as $CaCO_3$ (Boyd 1979). Smith Lake waters are low in alkalinity and therefore, relatively incapable of preventing pH changes should acidic or basic substances enter the lake. This acidic, poorly buffered condition is not a recent development. Measurements of pH and total alkalinity were taken in the Sipsey River and reported by the Alabama Water Improvement Advisory Commission (1949). Measurements of pH in the river during September and October 1948 ranged from 5.0 to 6.8. Alkalinities were reported from 0.0 mg/l to 15.0 mg/l as $CaCO_3$.

Surface waters with total alkalinity concentrations below 10 mg/L are considered highly sensitive to acid contamination (Mayer et al. 1984). Alkalinity of Smith Lake waters usually ranged between 10 and 15 mg/L as $CaCO_3$ but occasionally fell below 10 mg/L. Any acid contamination of Smith Lake will further reduce total alkalinity and pH will decrease. As pH declines below 6.5 fish growth rate slows, at a pH of about 5.0 reproduction ceases and below pH of about 4.0 fish die (Boyd 1979). Other aquatic organisms react in a similar way although some are not as tolerant as fish to low pH. Some valuable fish food organisms begin to disappear below pH 6.0 (Mayer et al. 1984).

Indirectly, low pH can result in higher concentrations of heavy metals that become toxic to fish and wildlife. At higher hydrogen ion concentrations metals bound in soil and sediment are mobilized to the water where they can be accumulated by the biota (Mayer et al. 1984). In the 1986 Smith Lake study (Bayne et al. 1987) concentrations of chromium, copper, iron, manganese and zinc exceeded critical levels considered acceptable by the U. S. Environmental Protection Agency (EPA 1986).

RECOMMENDATIONS

Smith Lake usually met the pH criteria (6.0-8.5) for waters use-classified as fish and wildlife by the Alabama Department of Environmental Management. However, most of the water column pH values were <7.0 during 1986 and 1995 and values <6.0 were recorded on occasion. These relatively low pH values together with excessive heavy metal concentrations measured in 1986 dictate the following special precautions be taken in this acid sensitive lake:

1) all active and inactive mining sites within the Smith Lake Basin should be inventoried to identify sources of acid mine drainage;
2) pH of precipitation in the vicinity of Smith Lake should be monitored to determine if any changes in pH occur, and;
3) pH of Smith Lake waters should be measured throughout the water column (2 m intervals) at five mainstem and four tributary embayment stations at least once each growing season (April - October).

These actions will help identify any sources of acid contamination of Smith Lake and aid in preventing changes in pH that might be detrimental to fish and other aquatic organisms.

ENVIRONMENTAL EVALUATION

The following questions and answers pertain to suggested restoration activities to address water quality problems identified in the Phase I Diagnostic/Feasibility Study of Lewis Smith Lake.

1. Will the proposed projects displace any people? NO
2. Will the proposed projects deface existing residences or residential areas? NO
3. Will the proposed projects be likely to lead to a change in established land use patterns such as increased development pressure near the lake? NO
4. Will the proposed projects adversely affect a significant amount of prime agricultural land or agricultural operations on such land? NO
5. Will the proposed projects result in a significant adverse effect on parkland, other public land or lands of recognized scenic value? NO
6. Will the proposed projects result in a significant adverse effect on lands or structures of historic, architectural, archaeological or cultural value? NO
7. Will the proposed projects lead to a significant long-range increase in energy demands? NO
8. Will the proposed projects result in significant and long range adverse changes in ambient air quality or noise levels? NO
9. Do the proposed projects involve use of in-lake chemical treatment? NO
10. Will the proposed projects involve construction of structures in a floodplain? NO
11. Will dredging be employed as part of the restoration procedures, and if so, where will the dredge material be deposited? NO
12. Will the proposed projects have a significant adverse effect on fish and wildlife, or on wetlands or any other wildlife habitat, especially those of endangered species? NO

13. Are there additional feasible alternatives to the proposed restoration projects, and why were they not chosen? Feasible alternatives for restoration will be evaluated on a case by case basis.

14. Are there additional adverse environmental impacts from the proposed restoration projects that were not addressed in the previous questions? NO

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