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Dynamics of Chemical and Physical Characteristics of Water, Bottom Muds, and Aquatic Life in a Large Impoundment on a River

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DYNAMICS OF CHEMICAL AND PHYSICAL CHARACTERISTICS OF WATER, BOTTOM MUDS, AND AQUATIC LIFE IN A LARGE IMPOUNDMENT ON A RIVER

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DYNAMICS OF CHEMICAL AND PHYSICAL CHARACTERISTICS OF WATER, BOTTOM MUDS AND AQUATIC LIFE IN A LARGE IMPOUNDMENT ON A RIVER

INTRODUCTION

Physical and chemical conditions existing in various river systems and in some impoundments on these rivers in the United States have been investigated periodically during the past 60 years. Generally, these studies have been conducted either to determine the amount of dissolved and suspended materials carried by the rivers, or to evaluate the habitat for propagation of fisheries. In more recent years the greater emphasis of such studies has been concerned with fisheries and public health aspects of these water areas.

Present day thinking of multi-uses of these water areas, primarily the impoundments, has created a pressing need for more complete understanding of physical and chemical conditions in all such areas if full utilization and enjoyment of these areas are to be obtained. In particular, here in the Southeastern United States, it is necessary that we understand the impact that these dynamic chemical-physical conditions have upon both the flora and fauna of our mainstream impoundments.

To obtain this understanding, one must have knowledge of the input-output relationships of salts and organic matter brought into the impoundment by creeks, streams, and rivers, their distribution in water, biota, and bottom muds within the impoundment, and the extent of their downstream movement through the tailwater. The salts and organic matter include that leached from the soils of the watershed, from domestic sewage, and from industrial wastes. This type information is the basis for evaluating the extent of eutrophication in any impoundment, and since complete river system impoundment is a rather recent event, it is imperative that such information be obtained as rapidly as possible.

With these problems in mind, the present study on Lake Eufaula[1], a mainstream impoundment on the Chattahoochee River, was begun. This research had as its objectives:

1. Locate the stratification and density currents in various regions of the reservoir during a 3-year period.
2. Determine the distribution of oxygenated waters (i.e. those water regions suitable for occupancy by fish) in various regions of the reservoir throughout each year.
3. Obtain information on the concentrations of plant nutrients, including minor elements and toxic cations in waters and bottom muds of tributary streams, various regions of the reservoir, and its tailwaters during various seasons of the year.
4. Determine concentrations of suspended organic, and inorganic materials present at various water depths in various parts of the reservoir and its tailwaters during various seasons of the year.
5. Determine the distribution, chemical composition, and pro-

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[1] Lake Eufaula is known as Walter F. George Reservoir by U.S. Army, Corps of Engineers, and as Lake Chattahoochee by Georgia residents.

duction of plankton in waters at various depths and regions of the reservoir during various seasons of the year.

6. Determine rate of development, distribution, and chemical composition of rooted aquatic plants at each region sampled in this reservoir.

7. Determine the condition of various species of fish in various portions of the reservoir at different seasons of the year.

8. Correlate data obtained in achieving the above objectives by computer data analyses, and develop prediction techniques for use in future monitoring of water, plant, and fish life in the reservoir.

In the Project Outline it was pointed out that these objectives would cover a sufficient period of time prior to the initiation of operation of a paper mill on this reservoir to give a basic pattern of preoperational data, and that it should continue for a sufficient period to accumulate data on any changes brought about by the effluent after the mill became operational. Since the mill did not become operational until early 1967, and since a Phase II study of the reservoir has been approved, this aspect of the research will be investigated as a part of that project.

Additional data on flow-dispersion patterns within this reservoir and in the downstream headwaters of Lake Seminole were obtained under a contract with the Federal Water Pollution Control Administration. Pertinent information from this research will be included and discussed under appropriate sections of this report.

Comparative data from one headwater impoundment, Bartlett's Ferry

Reservoir, and from a downstream impoundment, Lake Seminole were obtained at infrequent intervals, but are of sufficient importance to be incorporated into this report. Under the Phase II study plan these areas will be included in a regular sampling schedule.

Since the experiences of the Principal Investigator and his consulting collegues have been primarily on smaller impoundments (mainly farm ponds), some data, techniques, etc. were developed on these smaller bodies of water. Such information has proved invaluable in the establishment of certain chemical and physical parameters as well as providing leads on more complicated systems that appear operative in large as well as in small areas of impounded waters. It should be emphasized that fertilized or fed farm ponds offer an excellent opportunity to evaluate a variety of nutrient pollution effects upon the associated biological community. Thus, much more reliable information on the large impoundment was derived in a shorter time and at less expense.

Of necessity, this will be a preliminary summary-type report. Several factors dictate that such a report is the most logical way to summarize Phase I of this study. Firstly, since sufficient residue of funds were available to request an additional 6 months of research, much of the warm weather period was devoted to accumulation of additional data. Secondly, a considerable effort was made throughout the study period to modify, develop, or utilize new techniques to more accurately sample or analyze the materials gathered from the reservoir ; thus, a considerable portion of this report will deal with newer techniques. Thirdly, the time-span of completed study

(Phase I) has yielded much valuable but varied data that cannot be adequately evaluated until additional data are collected. The Phase II study will provide the time for accumulating those data needed to give a proper perspective for an analyses of these variables and how they may alter the conditions in an aquatic environment. Since this research was concerned with an elaborate and complicated system that involved weather, chemical, and biological interactions, a broader span in time is a vital factor in deriving reliable estimates of parameters under study. Thus the Phase II report will be utilized for summarizing the more complicated systems involved in this study.

DESCRIPTION OF LAKE EUFAULA AND ITS DRAINAGE AREA

The Chattahoochee River arises in the foothills of North Georgia. The uppermost impoundment on the river near Buford, Georgia forms Lake Sidney Lanier, which has a surface area of 38,000 acres at pool elevation of 1,070 feet. Its shoreline at this level is 540 miles. The drainage area for this impoundment is 1,040 square miles. The following series of impoundments starts at river 166 which is at Columbus, Georgia, and extends upstream to approximately river mile 196 near West Point, Georgia:

Reservoir name	Surface area, acres	Elevation feet	Drainage area square miles
Langdale	152	547.7	3,600
Riverview	75	530.5	3,600
Bartlett's Ferry	5,850	404.0	4,260
Goat Rock	940	337.0	4,670
Oliver	2,150	337.0	4,670
North Highland	200	266.4	4,670

Two additional small impoundments on the river within the city limits of Columbus, Georgia, have a total area of less than 300 acres. The headwater of Lake Eufaula is adjacent to the lower dam on the river at Columbus (Figure 1).

Lake Eufaula was created by a 2.5 mile long dam at mi 75 on

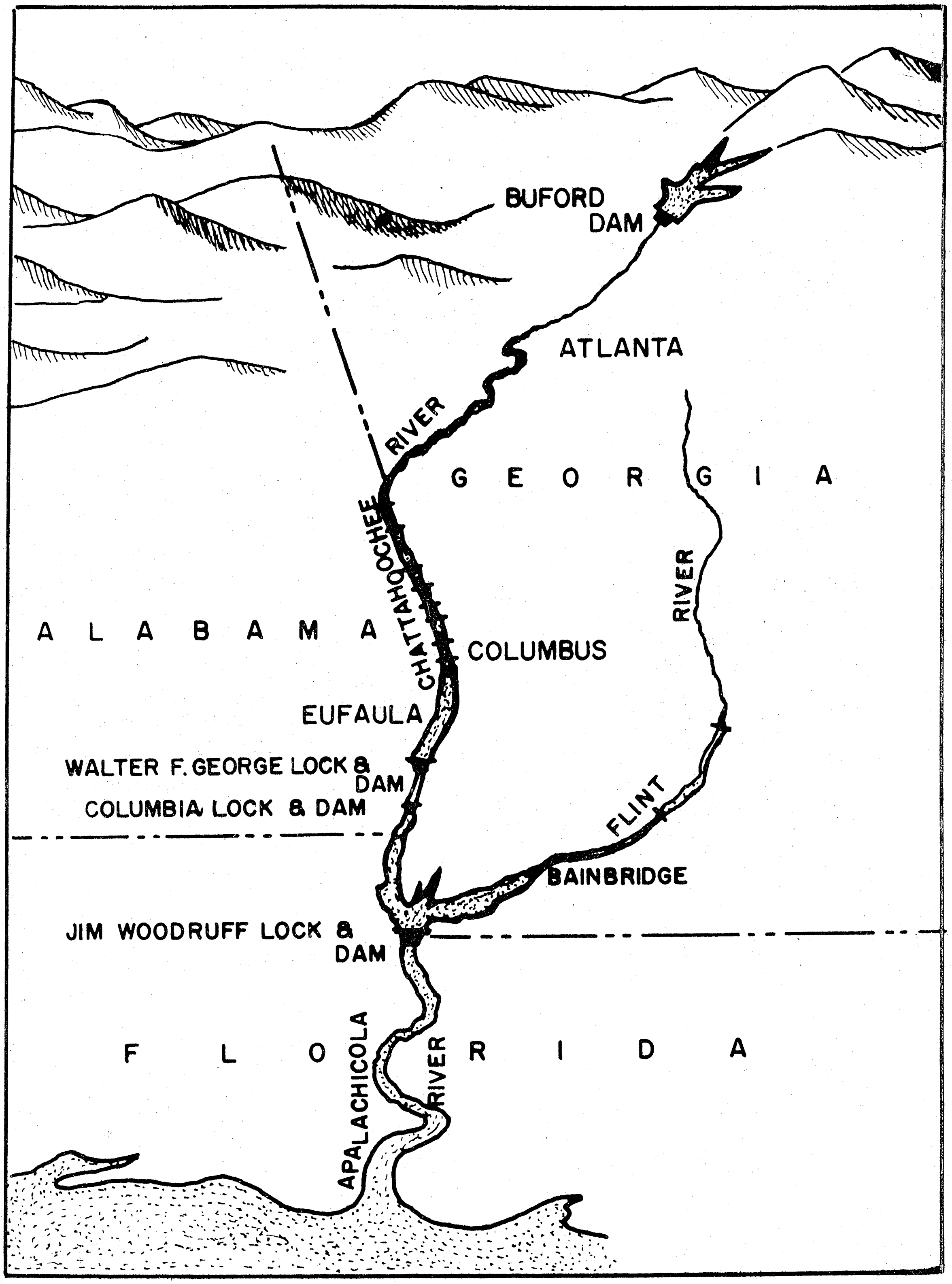


Figure 1. Water resources developments on Apalachicola, Chattahoochee, and Flint Rivers (from U.S. Army, Corps of Engineers).

Chattahoochee River near Ft. Gaines, Georgia, and is approximately 85 river miles in length; it has a surface area of 45,000 acres at an elevation of 190 feet and has a shoreline of 620 miles. The total drainage area for this impoundment is 7,460 square miles. Normal operation calls for a full pool on April 1, and it remains at this level until it is drawndown to an elevation of 185 feet in November. It is maintained at this elevation through following March.

The average depth of the area inundated by this impoundment is 20.4 feet, and maximum depth of water adjacent to the dam is about 90 feet. A cross section (Figure 2) of the reservoir approximately 6 miles above the dam shows that the old river channel forms a deep ditch through the impoundment and accounts for the greater depth at the dam. A drawdown of 5 feet exposes approximately 7,200 acres.

A unique feature of this mainstream impoundment is its partial separation at river mile 97, approximately 22 miles above the dam, by 2 parallel causeway-type bridges. At this location the reservoir is 1.25 miles in width and the causeway openings are bridge spans of approximately 800 feet length across the old river channel. To further complicate the situation, the river channel also parallels the upstream face of the causeway (Figure 3). Thus, these bridged spans operate as 70-foot deep sluice ways between the two sectors of the reservoir.

The drainage area for Lake Sidney Lanier is located entirely within the Appalachian foothills physiographic area. The portion of

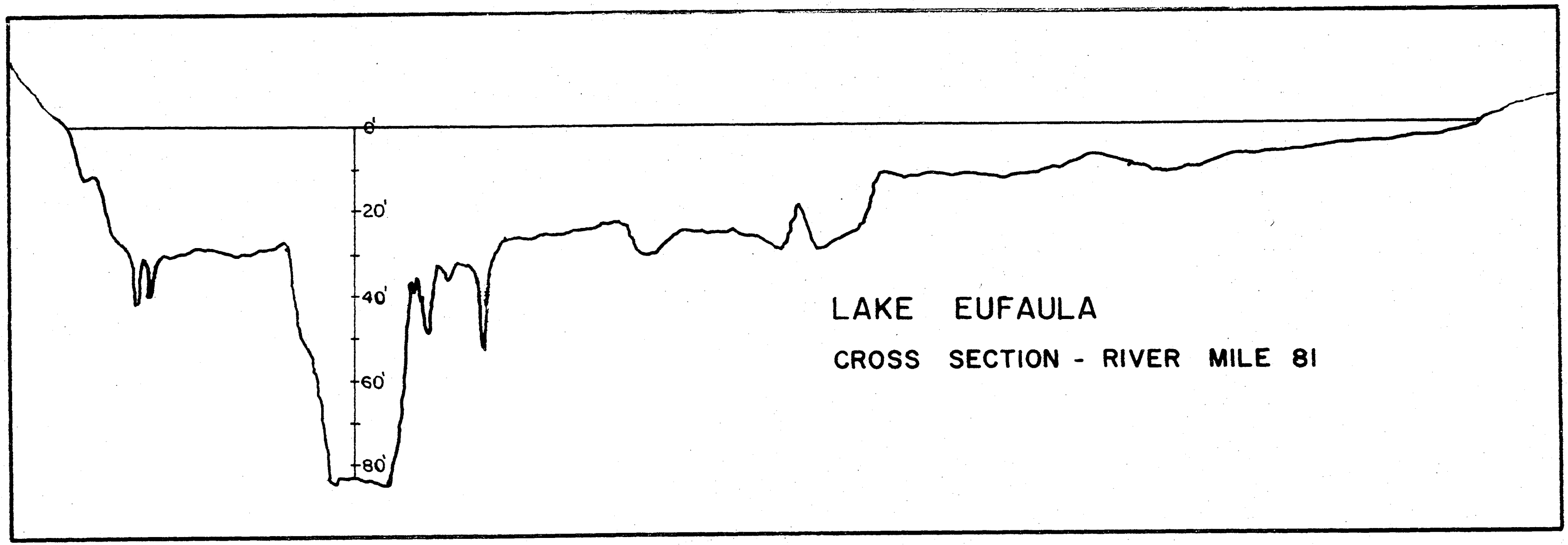


Figure 2. Typical configuration of bottom in mid and lower portions of Lake Eufaula.

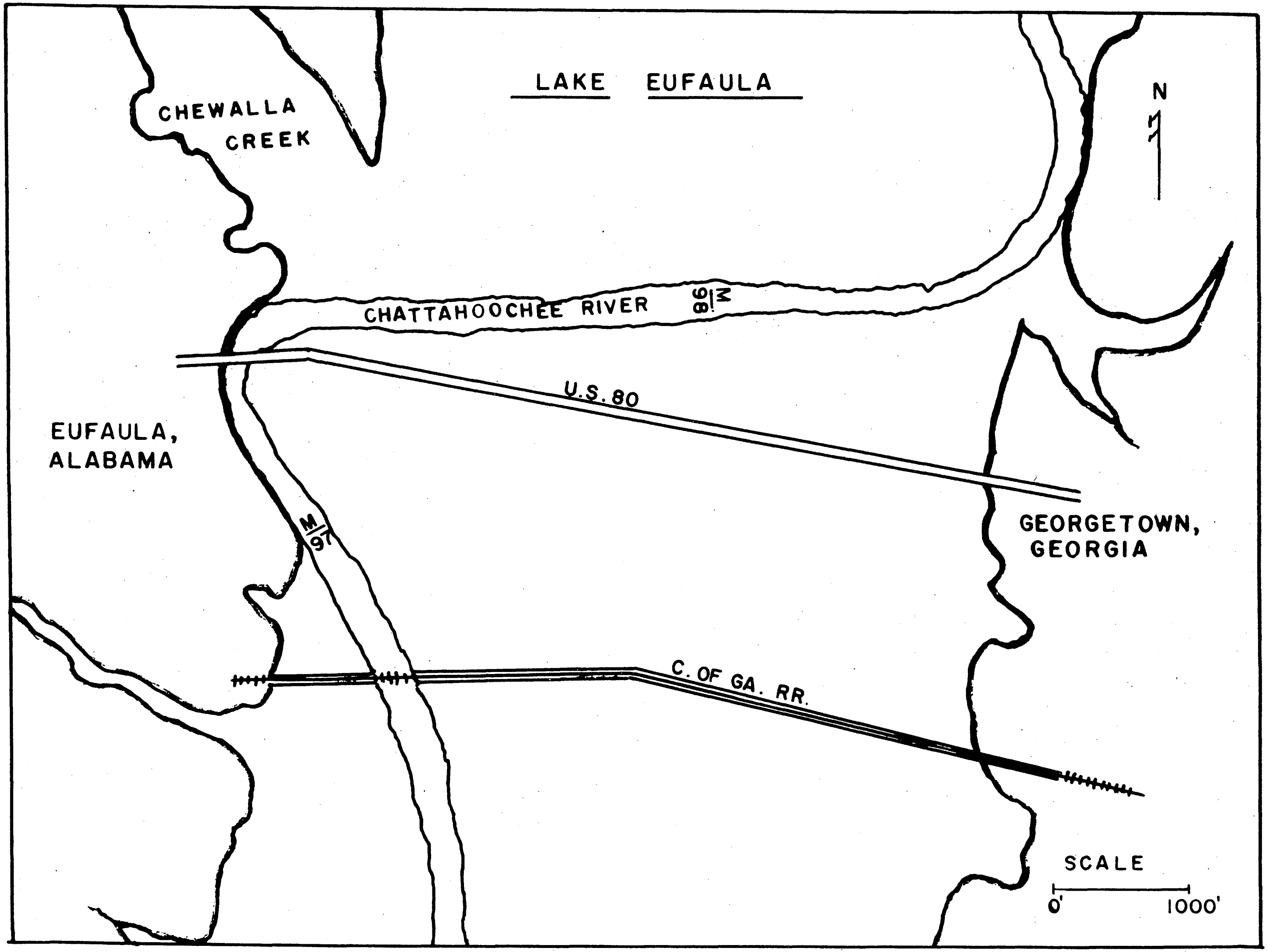


Figure 3. Dual bridge complex between river miles 96 and 98 on Lake Eufaula.

drainage area between Lake Sidney Lanier and Columbus, Georgia, is Piedmont Plateau. The drainage area immediately adjacent to Lake Eufaula is primarily Lower Coastal Plains, but a small portion of the drainage area on the western side of the reservoir is Black Belt soil. It is estimated that less than 20 percent of this entire drainage area is cultivated land.

Dispersed throughout this drainage area are numerous towns and cities that discharge both domestic and industrial wastes in varying degrees of stabilization into the Chattahoochee river. Thus, by the time the river reaches the upper end of Lake Eufaula, it has received the effluent from over 3/4 million people and their associated industrial wastes. During early stages (1965) of this research project the degree of sewage stabilization changed from none to complete secondary treatment for both Columbus and Phenix City areas. Also, textile mills located in area of West Point, Georgia, improved their waste treatment facilities when a new mill went into operation in early 1967.

A new paper mill, Alabama Kraft Company, located on the reservoir at river mile 120, approximately 40 miles above the dam, began operation in January, 1967. This mill had installed an elaborate waste stabilization plant that required several weeks to fill after the plant started operating. An unusual feature of this disposal system is that the opening for release of effluent is 40 feet below lake surface. This waste was released for about 2 weeks in March and the mill discontinued operation because of a strike and remained closed until mid-May. Thus, their effluent release was interrupted for approximately 8 weeks in this late spring period.

METHODS OF CHEMICAL AND PHYSICAL ANALYSES OF WATER AND EXTRACTS FROM SUSPENDED MATTER, SOILS, PLANTS, AND FISH

The wet chemical analytical procedures employed in the analyses of water are either those proposed by Standard Methods for Examination of Water and Waste Water, APHA, or modifications of these methods employing Hach chemicals and procedures as given in Hach model DR-EL manual, 3rd Edition (Hach Chemical Co., Ames, Iowa).

Initially it was proposed that a majority of the chemical analyses of water would be done by wet chemistry. However, as the project became operative,it was discovered that these procedures were too time-consuming as well as being subject to error to yield the volume and type of data needed for this study.

Thus, a considerable amount of effort was expended in devising methods and techniques for utilizing recently developed instruments to provide the required data to accomplish the objectives set forth for this project. Some techniques were simple and became operative early in the life of the project, others were more difficult to devise and only became operative in 1967. Other techniques are still in the developmental stages and were never operative during this project.

In the paragraphs that follow, the techniques used to obtain chemical and physical data on water, plants, fish, and soils from Lake Eufaula will be outlined. Adapted, new or developmental techniques will be discussed for the appropriate chemical or physical determination.

<u>Temperature of Water</u> - Measured to nearest 0.1°C (with YSI thermis-

tor-type thermometer) in-place to depths of 90 feet, or in sample bottle immediately after it came on-board boat.

Dissolved Oxygen in Water - Measured to nearest 0.1 ppm O_2 (with YSI model 51 oxygen meter employing silver-gold electrode - KCl electrolyte - 0.5 mil thick teflon membrane) in place to depths of 90 feet, or in sample bottle immediately after it came on-board boat. The O_2 measurements by YSI model 51 oxygen meter were checked periodically by Winkler method of analyses.

pH of Water and Soil - Measured to 0.1 pH value with glass electrode, Photovolt, solid state, battery operated meter. Measurements made in sample bottle immediately after it came on-board boat.

Resistivity of Water and Soil - Measured as ohms per cm^3 with Industrial Instruments resistivity meter employing a wheatstone bridge and a platinum coated probe with a factor of 0.1, or with a soil resistivity cup with a factor of 1;

$$\text{Conductivity} = 1/\text{resistivity}\,.$$

Turbidity of Water - Determined by refracted light technique, employing either a Hach turbidimeter or a Coleman nepho-colorimeter. Turbidimeter was standardized with a 47-JTU plastic bar. Nephlometer was standardized on distilled water that had been filtered through 0.45 μ Millipore filter.

Calculations for Total Solids:

$$\text{Mg/l dry wt.} = 1.32 + 1.1084\ \text{JTU}\,,$$

$$\text{Mg/l dry wt.} = 1.83 + 0.1534\ \text{nephlo value}\,.$$

Light Penetration into Water - Determined at surface and at 2.5-foot intervals of depth to point of extinction with sealed Weston selenium cells coupled to microampere meter. Surface light intensity measured simultaneously by Weston model 756 outdoor light meter with quartz-covered light cells.

Free Carbon Dioxide in Water - Determined by titration with 0.05 N NaOH to pH 8.3 to an accuracy of 0.001 ml with micrometer pipette (Method 3.3.1, Standard Methods, APHA, 1960).

Calculations:

$$\text{mg/l } CO_2 = \frac{\text{ml NaOH} \times 0.05\text{N} \times 44{,}000}{\text{ml sample}} ,$$

Sample size of 100 ml - factor = 22 .

Total Alkalinity of Water - Determined by titration with 0.05N HCl to pH 5.2 to an accuracy of 0.001 ml with micrometer pipette (Method 403, Standard Methods, APHA, 1960).

Calculations:

$$\text{Total alkalinity as mg/l } CaCO_3 = \frac{\text{ml std. acid} \times 0.05\text{N} \times 50{,}000}{\text{ml sample}} ,$$

Sample size of 100 ml - factor = 25 ,

Total carbonates = Total alkalinity (mg/l $CaCO_3$) x 0.6 .

Total Calcium + Magnesium Content or Total Hardness of Water - Determined by titration with EDTA (1 ml EDTA = 1 mg $CaCO_3$) using chrome black T as indicator to an accuracy (visually) of 0.01 ml with burette (Method B, Standard Methods, APHA, 1960).

Calculations:

$$\text{Mg/l } CaCO_3 = \frac{\text{ml EDTA} \times 1{,}000}{\text{ml sample}} ,$$

Sample size of 100 ml - factor = 10 .

Calcium Content of Water - Determined by titration with EDTA (1 ml EDTA = 1 mg $CaCO_3$) using murexide as indicator to an accuracy of 0.01 ml using a Photovolt Lumitron colorimeter (Method C, Standard Methods, APHA, 1960).

Calculations:

$$mg/l\ CaCO_3 = \frac{ml\ EDTA \times 1{,}000}{ml\ sample},$$

Sample size of 100 ml - factor = 10 ,

$$mg/l\ Ca = \frac{ml\ EDTA \times 400.4}{ml\ sample},$$

Sample size of 100 ml - factor = 4 .

Nitrogen as NH_4 in Water - Determined by distillation of raw water (treated with m/2 phosphate buffer) and collection of 100 ml of distillate in dilute boric acid. Color of Nesselerized distillate measured by spectrophotometry at 425 mu (Method B, Standard Methods, APHA, 1960).

Phosphorus Content of Water - Determined on water by molybdenum blue method - color developed by stannous chloride and measured by spectrophotometry at 690 mµ (Method B, Standard Methods, APHA, 1960).

Chlorides in Water - Determined by titration with $HgNO_3$ (0.0141 N) using diphynylcarbazone indicator to a visual accuracy of 0.01 ml (Hach Method).

Calculations:

Sample size of 100 ml - factor = 5 ,

$CaCO_3$ equivalent = ppm chlorides x 1.41 .

Sulfates in Water - Determination by barium sulfate turbidimeter method. Turbidity measurement made on nephlometer and compared with known standards (Hach method).

Iron Content of Water (Wet)- Determined colorimetrically with 1-10-phenanthroline. Color measured on colorimeter or on spectrophotometer at 500 mu (Hach Method).

Silicates in Water - Determined colorimetrically by Hach's amino acid method. Sample treated with ammonium molybdate and oxalic acid and color developed with amino acid (Hach Method).

Sodium Content of Water - Determined by flame photometry, using Coleman Model 21 flame photometer and sodium filter.

Potassium Content of Water - Determined by flame photometry, using Coleman Model 21 flame photometer and potassium filter.

Carbon in the Aquatic Environment - Carbon dioxide comprises 0.04% of normal air and is highly soluble in water. However, the source of CO_2 in water is seldom from the air phase, but results from CO_2 production by both aerobic and anaerobic decomposition of organic matter. The abundance of the carbon atom in nature(mainly organic matter) is due to its valence of 4 and the ability for these atoms to be linked together in a wide variety of ways. Research on this project was concerned with abundance of inorganic carbon compounds (CO_2, $HCO3$, and $CO3$) as well as assimulated carbon in organic matter.

Carbon dioxide and alkalinity relationships in natural waters are shown by following equations:

$$CO_2 + H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$
$$M(HCO_3)_2 \rightleftharpoons M^+ + 2\ HCO_3^-$$
$$HCO_3 \rightleftharpoons CO_3^- + H^+$$
$$CO_3^= + H_2O \rightleftharpoons HCO_3^- + OH^- .$$

A change in concentration of any one of these systems will alter the concentration of other ions and result in a change of pH. The relationships of carbon dioxide, alkalinity and pH in a water with 100 mg/l $CaCO_3$ total alkalinity are illustrated in Figure 4.

Carbon also exists in the aquatic environment in at least 3 organic forms - living organisms, organic detritus, and soluble organic carbon. Each of these forms can eventually contribute to the carbon dioxide content of natural waters.

Wet chemical methods for determination of CO_2 and alkalinity of water, by shifting of the pH, are available and widely used. In the case of CO_2, the standard base used to elevate the pH may be neutralizing other acid radicals in addition to the free CO_2. Thus, there is an urgent need for a more specific detection method for free CO_2 in water. Alkalinity on the other hand is determined by a depression of the pH with a standard acid. Here again, the acid may be neutralizing weak base or very weak acid radicals in addition to the carbonate and bicarbonate ions.

To date, instrumentation adapted to the direct measurement of CO_2 and alkalinity in water is unsatisfactory for routine use. It is possible, however, to check the total C as determined by wet chemistry for free CO_2 and total alkalinity by a special technique utilizing the Beckman carbonaceous analyzer. This technique also

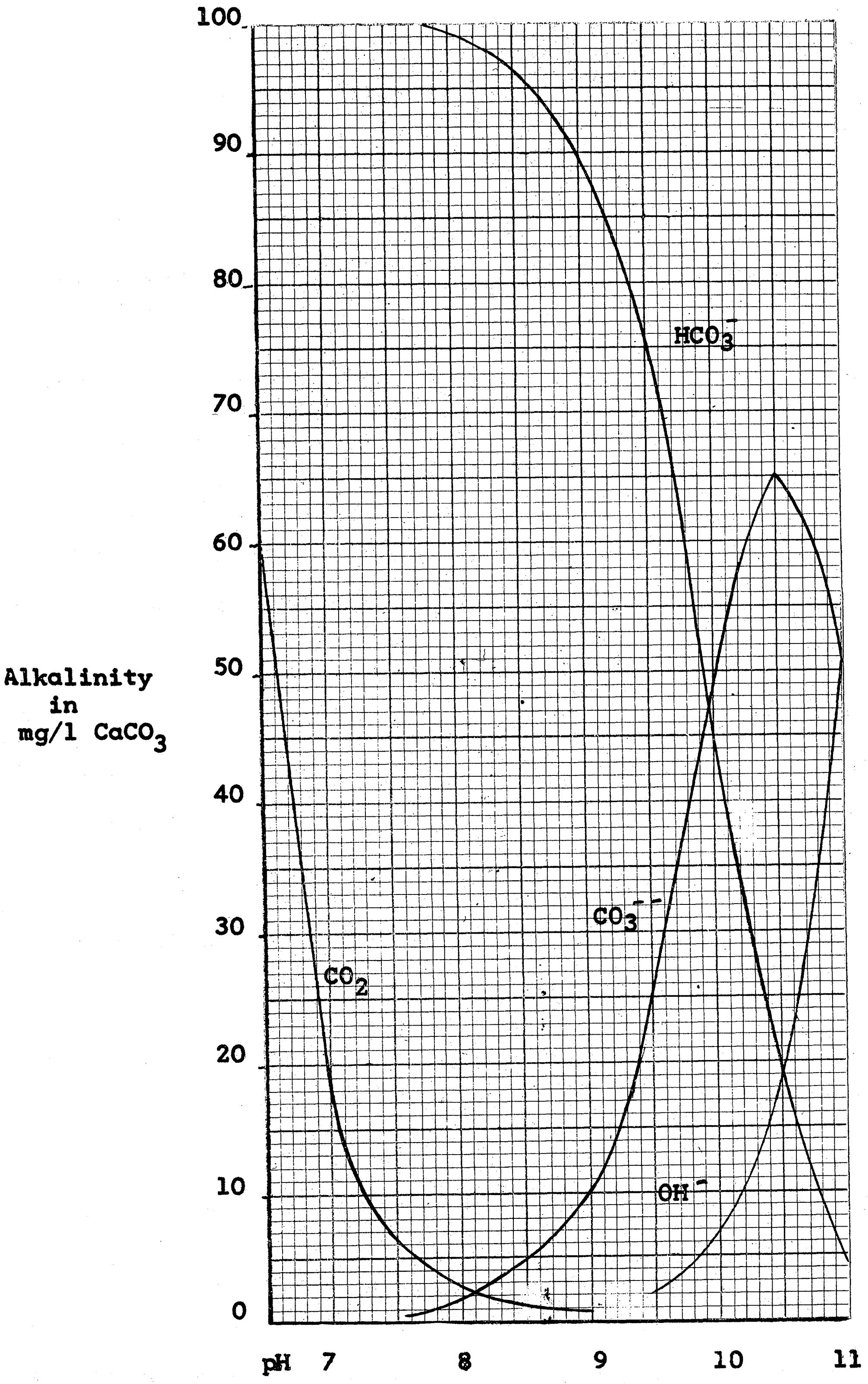


Figure 4 . Carbon dioxide, alkalinity, and pH relationships in a solution with total alkalinity of 100 mg/l $CaCO_3$.

permits the estimation of CO_2 by subtracting that portion of carbonaceous C contributed by total alkalinity from the total amount expelled by the special technique. This procedure is given in the following discussion of this carbonaceous analyzer.

The Beckman laboratory model carbonaceous analyzer is essentially an adapted, carbon train-electric furnace apparatus coupled with an infra red (CO_2 specific) analyzer and a recorder. The carrier gas for the system is oxygen , pressure and flow of which can be regulated at all times. The furnace operates at a temperature of 960°C, thus the injected sample of liquid is immediately burned within the Vycor carbon train and the resulting CO_2 is transported to the IR analyzer by the carrier gas. Sample size is usually 20 µl and sensitivity of detection is less than .5 ppm C.

For total carbon determination, the sample of raw water was homogenized with a tissue homogenizer, then 20 µl were withdrawn from well mixed sample and injected into the analyzer. Because of small sample size, particle size within sample must be less than 50 µ to pass freely through bore of injection syringe. The analyzer will complete the analysis for C and recover within 2 minutes. The relative quantity of C passing through the detector cell was recorded on a chart and the concentration was determined from a curve prepared by obtaining recorded values for known concentrations of C.

Three separations of the total C in a water sample are possible; i.e. soluble C, carbonaceous C, and volatile C. By applying appropriate relationship equations the particulate matter C and the free CO_2 may be calculated.

The determination of soluble C was accomplished by filtering the raw water sample through an 8 μ Millipore filter and analyzing the filtrate. To eliminate C contamination in the Millipore filter the pad was pre-washed with 10 ml 0.1 N HCl followed by a rinse of 10 ml of glass distilled water. The amount of C in particulate matter was then determined as follows:

Total C ppm - soluble C ppm = Particulate matter C ppm .

The determination of carbonaceous C was accomplished by addition of sufficient 1 N HCl to the raw water sample to reduce the pH to 3.0. This converted all of the bound ($CO_3^{=}$) and half-bound (HCO_3^{-}) CO_2 to free CO_2. The free CO_2 was then expelled from the water sample by bubbling with N_2 gas for 5 minutes. At the end of this aeration period the sample was analyzed for the remaining total C content. The carbonaceous C content was then determined as follows:

Total C ppm - CO_2-free total C ppm = Carbonaceous C ppm .

An estimate of C in free CO_2 in original water sample may be obtained by following calculation:

Carbonaceous C ppm - Total alkalinity C ppm = Carbon dioxide C ppm ,

Where total alkalinity C ppm = .12 x ppm $CaCO_3$ (total alkalinity) Thus, the free CO_2 content could be calculated as follows:

CO_2 = C ppm x 3.66 = free CO_2 ppm .

Total Hardness (water) - Hardness of water is a general term that describes the amount of soap required to produce a foam or lather, or the amount of scale produced in boilers pipes, or other units where the temperature is elevated materially.

Hardness is caused by divalent metallic and alkaline earth elements that are capable of reacting with soap to form precipitates, and with anions in water, which react with heat to form scale. The following are principal cations and associated anions that produce hardness.

Cation	Anion
Ca	HCO_3
Mg	SQ_4
Sr	Cl
Fe	NO_3
Mn	SiO_3

The hardness due to HCO_3^- is termed carbonate or non-permanent while the hardness produced by Cl and SO_4 is termed permanent (i.e. the hardness not destroyed by boiling).

Conversion factors from divalent ions to hardness as ppm $CaCO_3$ are given below:

Ca to $CaCO_3$ = ppm Ca x 2.497
Mg to $CaCO_3$ = ppm Mg x 4.116
Sr to $CaCO_3$ = ppm Sr x 1.142
Fe to $CaCO_3$ = ppm Fe x 1.792
Mn to $CaCO_3$ = ppm Mn x 1.822
Zn to $CaCO_3$ = ppm Zn x 1.531
Al to $CaCO_3$ = ppm Al x 3.701

It is readily evident that the term "hardness" is related to domestic and industrial uses of water and may or may not have the same undesirable effects biologically. It was the opinion of investigators on this project that the determination of abundance of the various divalent cations and their accompanying anions, within the various components of the aquatic environment would be more informative for the purposes of this investigation. However, since a majority of the prior research has relied upon total hardness determinations, this analytical technique was included on this project to determine how this information would compare with cation composition of water. Actually the EDTA total hardness determination used on this project estimated only that part due to Ca and Mg in solution in filtered water.

In future research it is anticipated that specific cation concentrations in water will be determined with modern instrumentation, such as the atomic absorption spectrophotometer.

Data on the divalent elements and associated anions obtained by this research will be given separately, and their overall relationship will be considered in the general discussion of results.

Elemental Analyzes with an Atomic Absorption Spectrograph - Some of the metallic and alkaline earth elements in water, plants, soil and fish samples were detected and their concentration determined using a Beckman DB-G spectrophotometer equipped with a laminar flow burner and atomic absorption accessory. Since this is a relatively new instrument for determination of elemental content of a solution, a brief outline of the technique used and a typical concentration-response curve for each selected element will be given in this section.

Working solutions, containing all elements under study and in the relative concentrations anticipated in a given set of samples, were prepared from stock concentrations within a few hours prior to actual analyses. Fresh mixtures were a necessity to minimize the absorption on glass of certain elements such as chrominum and cobalt, within these dilute mixtures. A typical mixture of elements for analyses of Chattahoochee river water was as follows:

Ca	10 ppm
Na	5
K	2
Fe	2
Mg	2
Mn	1
Cu	1
Zn	1
Sr	1

A typical mixture of elements used for analyses of diluted extracts of soil, plant, and fish samples was as follows:

Ca	25 ppm
Na	10
Mg	10
Mn	5
Fe	5
K	5
Sr	2
Zn	2
Cu	1
Pb	1

Cr	1 ppm
Ni	1
Co	1
Cd	1
Mo	1

The data obtained on Mg, Zn, Cu, and Fe in 1965 were determined by a Perkin-Elmer Model 303 atomic absorption spectrophotometer, which could be used to analyze only filtered water samples. Data obtained on these and other elements in 1966 and 1967 were determined on a Beckman Atomic Absorption Spectrophotometer equipped with a laminar flow burner that was capable of analyzing raw water samples.

Beckman provides two interchangable laminar flow burners for their atomic absorption spectrophotometer, an air-acetylene model and a nitrous oxide-acetylene model. The air-acetylene model is more economical on air and fuel consumption and is a good burner for the type analyses discussed in this report. The nitrous oxide-acetylene burner is a much hotter flame source and is used for detection of such elements as Al and Si. This latter burner model may be operated on air-acetylene and gives very satisfactory results, but the air consumption is 3 to 4 times greater than with the regular air-acetylene burner. This nitrous oxide-acetylene burner also has another fault that causes it to have a "memory" when operated in the cold mode. This contamination arises in the fore end of sprayer chamber which is completely sealed around the sample injector. This sealed space acts as a condensation cell for spray vapors and when a sufficient quantity accumulates it drains into the condenser and some of the vapors are swept along in the air stream to the burner head. This condensation may be corrected in air-acetylene operation by removing the rubber seal from around injector.

The laminar flow burner is designed to operate in either the cold or hot mode. In the cold mode the injected sample is transported to the burner as a cold spray mist, and the sensitivity of the AA unit is similar to a regular turbulent flow burner such as employed on P-E 303. When operating in the hot mode the injected sample is pre-heated in the spray chamber and transported through the condenser into the burner head as an aerosol mist. This technique increases the sensitivity of an AA unit approximately 10 times.

The principal of atomic absorption spectrophotometry is to provide an energy source that is specific for a given element in its most active ground state, and when a sample of that element is excited within a flame operating between the source and detector it absorbs energy from this source in proportion to its concentration. Thus when this source is operative on an AA unit the scale deflection is set to 100% transmittance. When a sample containing this element is introduced into the flame,its absorption results in a decrease in deflection of the needle toward 0%T in proportion to its concentration.

The relative detection ability of an atomic absorption spectrophotometer depends in a large measure upon the output of the hollow cathode source lamp. The amount of energy reaching the photo detection unit can be increased either by a higher micro-ampere input into lamp (which shortens the life of filament) or by increasing the slit width (which reduces the sensitivity of certain wave bands and gives more flame noise on the recorder) or by increasing the gain amplifier (which also results in excessive recorder noise). One way to overcome this low energy difficulty is to operate the AA unit on a half-scale deflection and 2X scale-expand the recorder. To utilize this procedure necessitates dilution of samples to the appropriate concentration that will allow full detection on a half-scale range.

It might be pointed out that on full scale deflection reliable results are obtained between 100 and 15% T, and on half-scale deflection between 50 and 15% T. The individual concentration curves for each element serve as a guide for establishing the optimum operational range for most reliable detection with an AA unit.

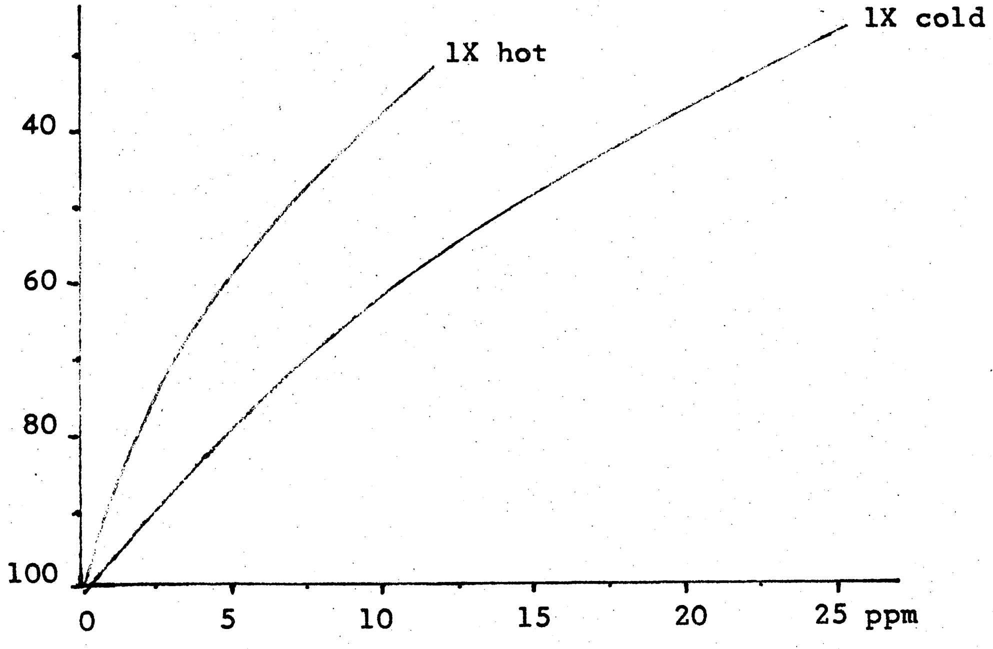
The major source of error with the Beckman atomic absorption spectrophotometer arose from contamination in the laminar flow burner. When analyzing plant, fish, and soil extracts there was a rather heavy deposit of metallic compounds within the heated sprayer chamber and in the condenser. The only satisfactory method for controlling this deposit accumulating and producing an instrument "memory" was to regularly flush the sprayer chamber with 70% ethanol, followed by scrubbing with a bottle brush and again flushing with ethanol and water. When sufficient deposits accumulated the condenser had to be dismantled and the interior flushed with ethanol, scrapped and scrubbed until practically no residue could be removed.

While the burner unit was dismantled the fuel injector was removed and thoroughly cleaned. To reduce clogging of tiny holes in injector used on air-acetylene laminar flow burner, a micro-nite filter was installed on the acetylene hose at its junction with the tank pressure.regulator.

Calcium - at. wt. 40.08. Standard prepared by dissolving 2.4973 g calcium carbonate (Iceland spar) in 10 ml concentrated HCl and then diluting to 1 liter with glass distilled water. Solution contains 1 mg Ca/ml. Working standards contained from .001 mg Ca/ml to .025 mg Ca/ml. Instrument settings were as follows:

Hollow cathode source	Ca; Ca-Mg-Al; Ba-Ca-Sr-Mg lamp
Wave length	432 mμ
Slit width	.2 mm
Current	10 ma
Fuel- acetylene	4 psi
Air	17 psi
Burner flame height	.3 in

With laminar flow burner operated in hot mode, the sensitivity was 0.01 ppm Ca with standard solution. However, with river or pond waters, the detection was poor, being in the range of 10 to 15 percent of the concentration indicated by EDTA titration. An addition of 0.1 ml of 5% LaO_2 to 10 ml of natural water increased the detection by AA to approximately the same amount indicated by EDTA titration.

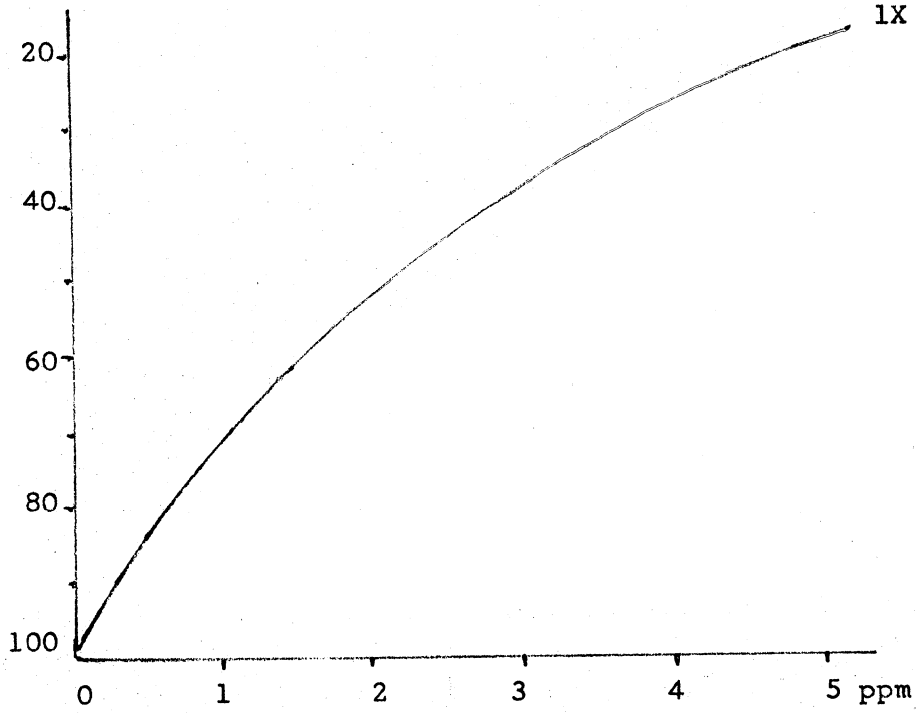


Typical Ca concentration - response curve.

Magnesium - at. wt. 24.32. Standard prepared by dissolving 1.000 g magnesium metal in 10 ml concentrated HCl and diluting to 1 liter with glass distilled water. Solution contained 1 mg Mg/ml. Working solutions contained from .0001 mg Mg/ml to .005 mg Mg/ml. Instrument settings were as follows:

Hollow cathode source	Mg; Mg-Ca-Al; Mg-Ca-Sr-Ba lamp
Wave length	285 mμ
Slit width	.2 mm
Current	10 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner flame height	.3 in

With laminar flow burner operated in cold mode, the sensitivity was 0.01 ppm Mg with standard solution. With untreated river or lake water, the sensitivity was approximately 90 percent of that obtained when 0.1 ml of 5% LaO_2 was added to 10 ml sample.

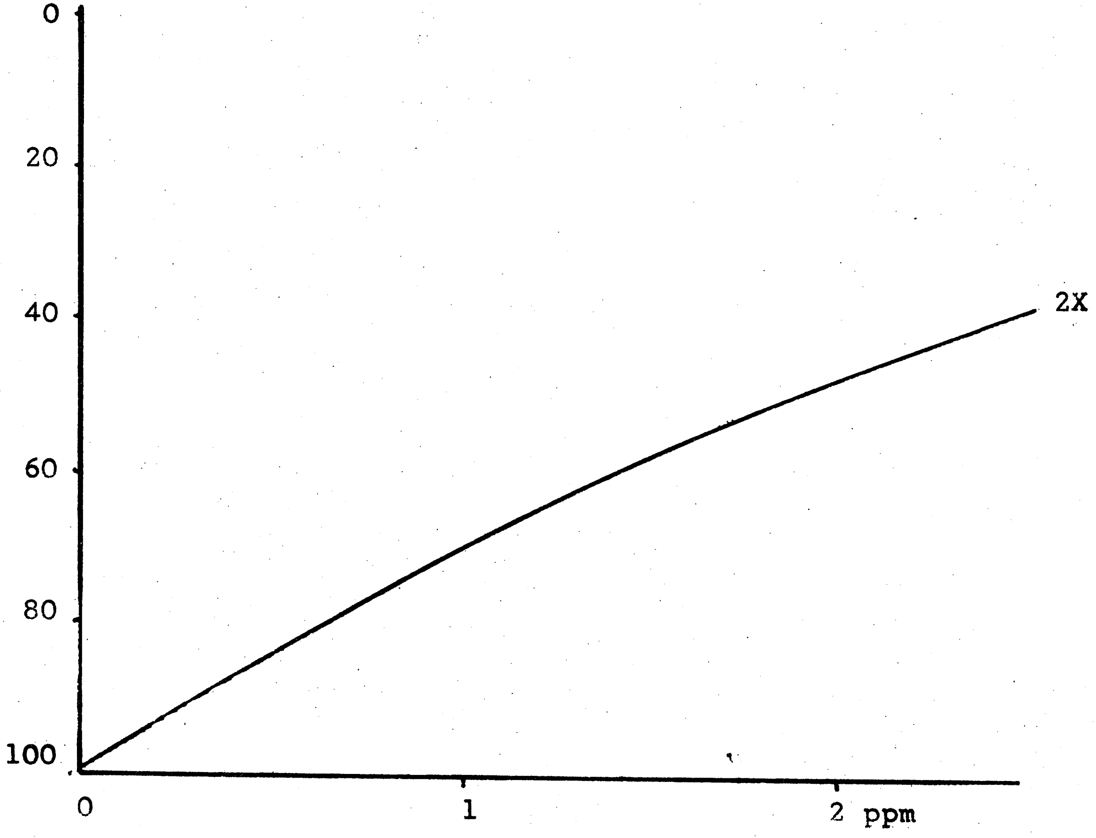


Typical Mg concentration - response curve for cold mode operation.

Strontium - at. wt. 87.63. Standard prepared by dissolving 1.6848 g Sr No_3 in glass distilled water and diluting to 1 liter. Solution contains 1 mg St/ml. Working solutions contained from .0002 mg Sr/ml to .002 mg Sr/ml. Instrument settings were as follows:

Hollow cathode source	Sr; Sr-Ca-Ba-Mg lamp
Wave length	460.8 mμ
Slit width	0.25 mm
Current	15 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner heigth	.3 in

With laminar flow burner operated in hot mode,the sensitivity was .01 ppm Sr with standard solution. With lake and river water,the sensitivity was equally good.

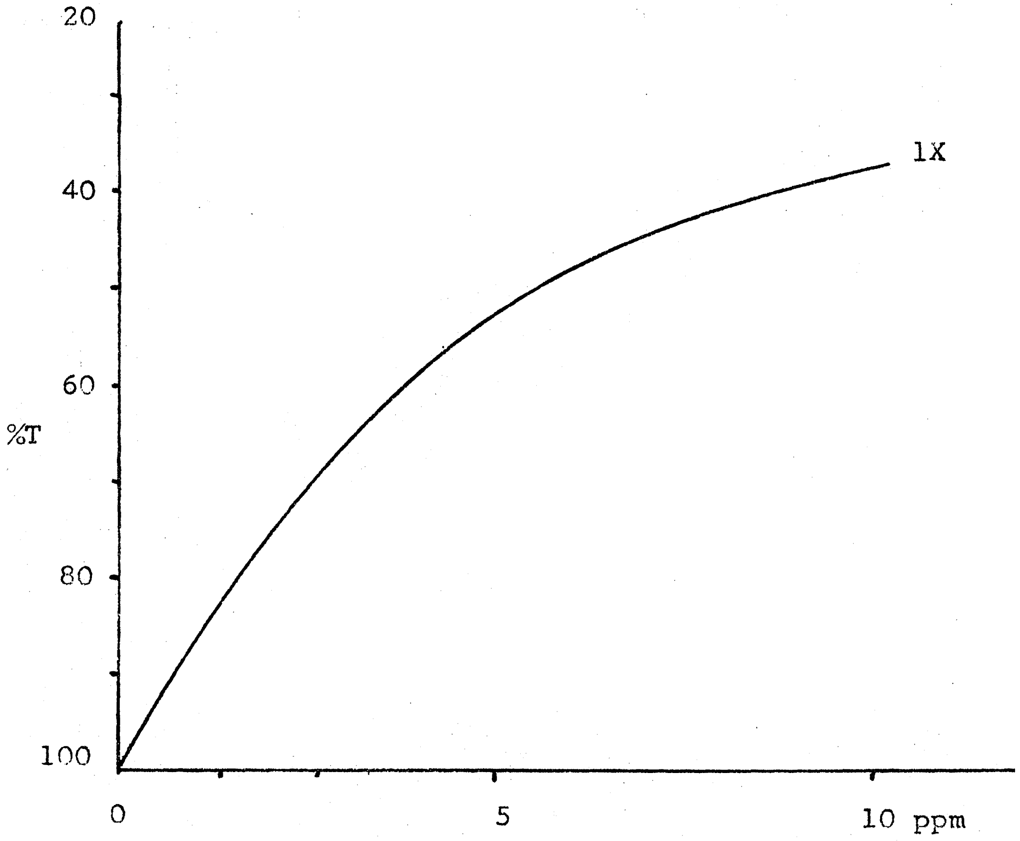


Typical Sr concentration - response curve for hot mode operation.

Sodium - at. wt. 22.99. Standard prepared by dissolving 2.5425 g of sodium chloride in 1 liter of glass distilled water. Solution contains 1 mg Na/ml. Working solutions contained from .0001 mg Na/ml to .025 mg Na/ml. Instrument settings were as follows:

Hollow cathode source	None (Mirror)
Wave length	589 mµ
Slit width	.2 mm
Current	Mirror
Fuel - acetylene	4 psi
Air	17 psi
Burner flame height	.3 in

Emission type determination using either cold or hot mode of laminar flow burner. Sensitivity $<$0.01 ppm using either mode.

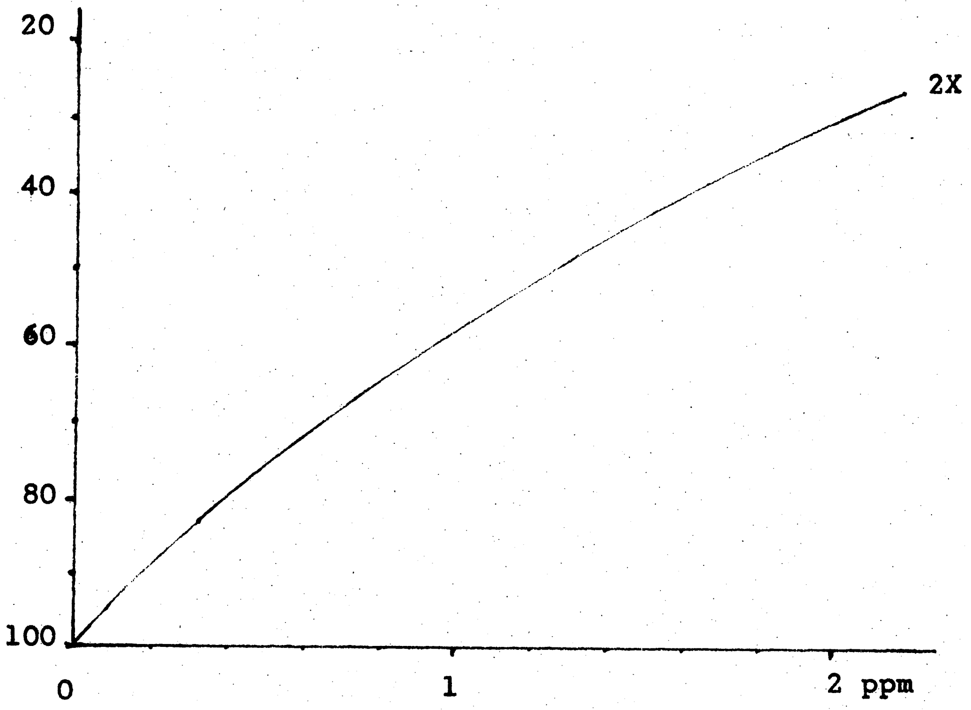


Typical Na concentration - response curve for cold mode operation.

Iron - at. wt. 55.84. Standard prepared by dissolving 1.000 g iron wire in 20 ml HCl and then diluting to 1 liter with glass distilled water. Solution contains 1 mg Fe/ml. Working solutions contained from .0001 mg Fe/ml to .005 mg Fe/ml. Instrument settings were as follows:

Hollow cathode source	Fe; Fe-Cu-Mn; Fe-Zn-Mn-Ni lamp
Wave length	248 mμ
Slit width	.20 mm
Current	20 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner height	.3 in

With laminar flow burner operated in hot mode the sensitivity was 0.01 ppm Fe with standard solution. With river and lake waters ,the sensitivity was equally good.

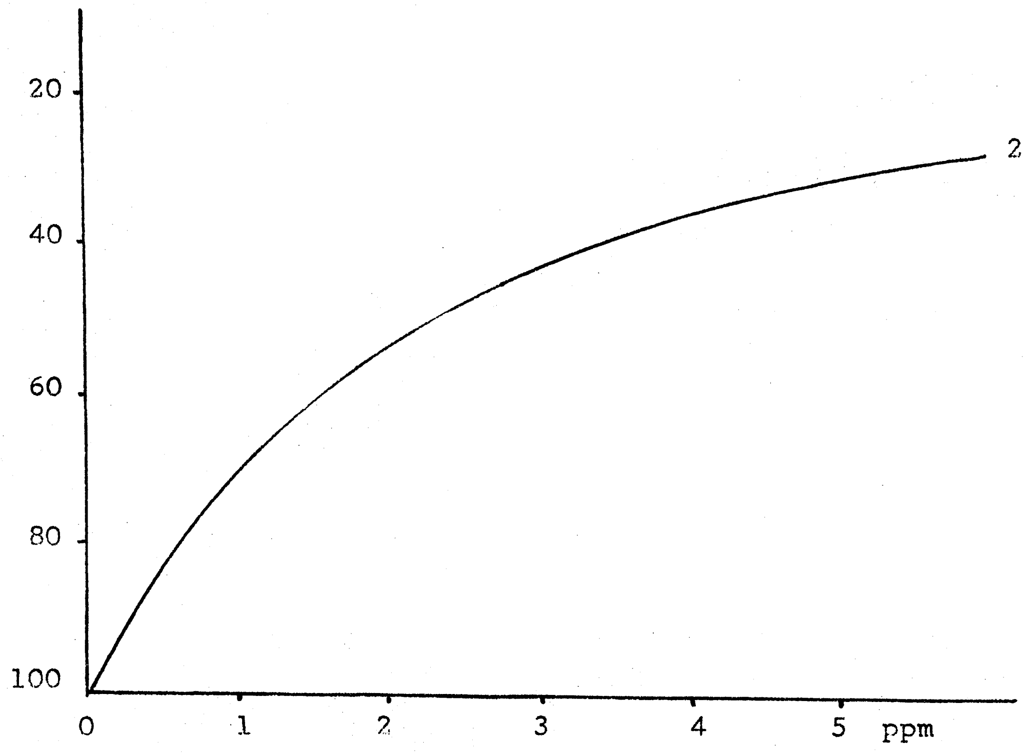


Typical Fe concentration - response curve for hot mode operation.

Manganese - at. wt. 54.93. Standard prepared by dissolving 1.000 g manganese metal in 10 m of HCl and then diluting to 1 liter with glass distilled water. Solution contained 1 mg Mn/ml. Working standards contained from .0001 mg Mn/ml to .002 mg Mn/ml. Instrument settings were as follows:

Hollow cathode source	Mn; Mn-Fe-Cu; Mn-Fe-Cr-Ni lamp
Wave length	279 mμ
Slit width	0.15 mm
Current	15 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner height	.3 in

With laminar flow burner operated in hot mode, the sensitivity was 1 ppb Mn with standard solution. With pond and river water, the sensitivity was equally good.

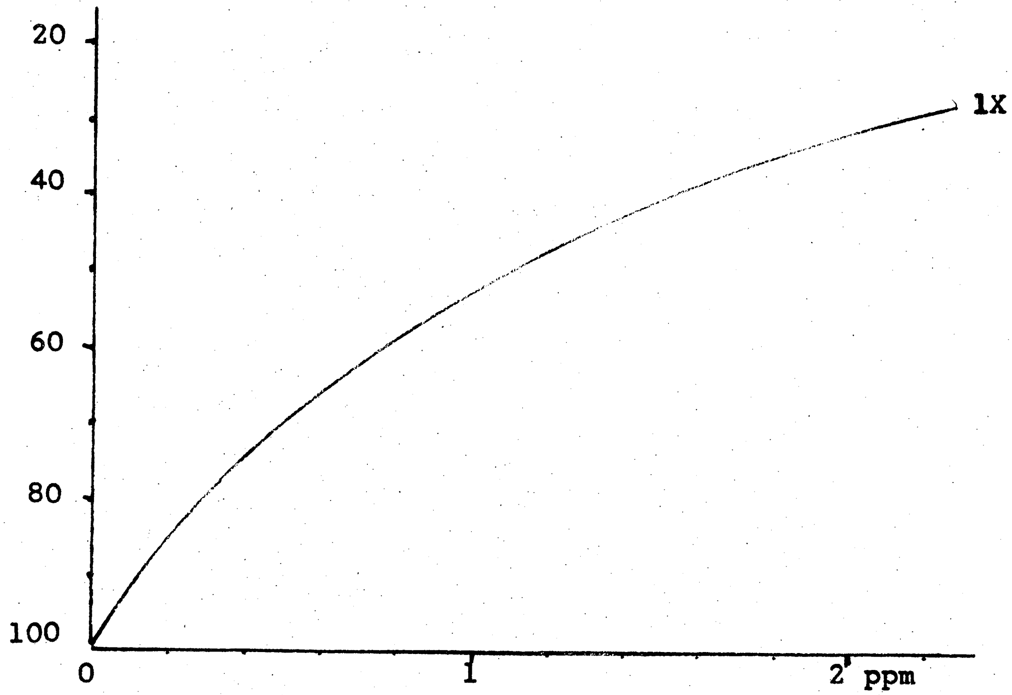


Typical Mn concentration - response curve for hot mode operation.

Zinc - at. wt. 65.37. Standard prepared by dissolving 1.000 g zinc metal in 10 ml HCl and then diluting to 1 liter with glass distilled water. Solution contains 1 mg Zn/ml. Working solutions contained from .0001 mg Zn/ml to .002 mg Zn/ml. Instrument settings were as follows:

Hollow cathode source	Zn; Zn-Cu-Pb-Sn lamp
Wave length	214 mμ
Slit width	.5 mm
Current	10 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner flame height	.3 in

With laminar flow burner operated in hot mode the sensitivity was 1 ppb Zn with standard solution. With lake or river waters, the sensitivity was equally good.

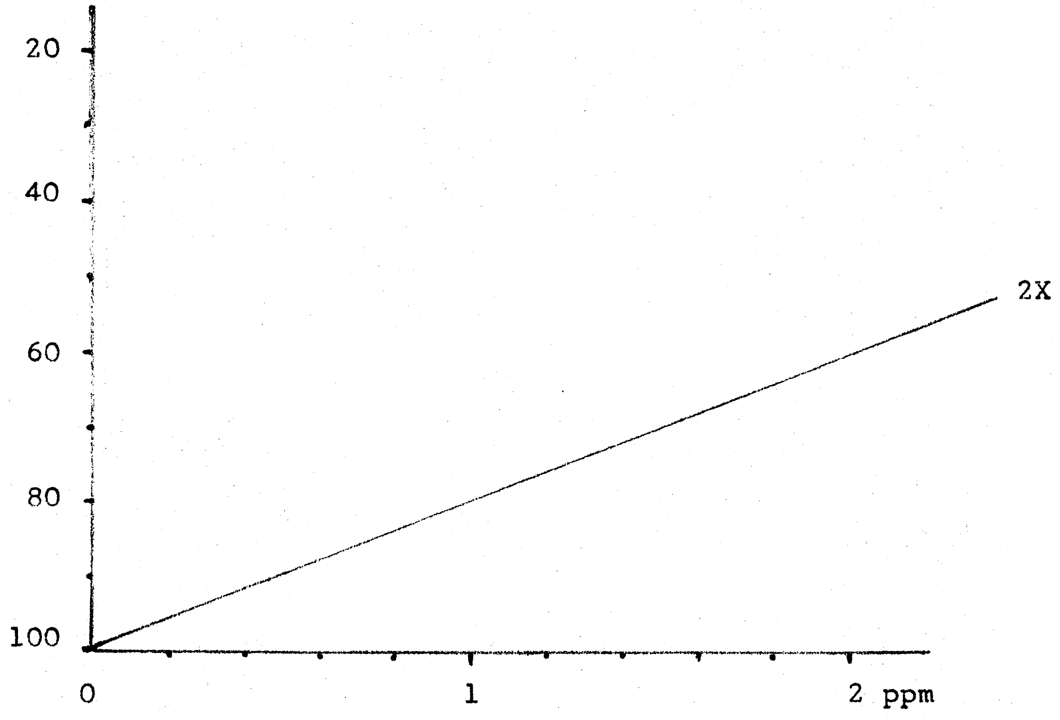


Typical Zn concentration - response curve for hot mode operation.

Copper - at. wt. 63.57. Standard prepared by dissolving 1.000 g copper foil in 10 ml HNO_3 and then diluting to 1 liter with glass distilled water. Solution contains 1 mg Cu/ml. Working solutions contained from .0001 mg Cu/ml to .002 mg Cu/ml. Instrument settings were as follows:

Hollow cathode source	Cu; Cu-Fe-Mn; Cu-Zn-Pb-Sn lamp
Wave length	324.7 mμ
Slit width	.2 mm
Current	10 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner height	.3 in.

With laminar flow burner operated in hot mode, the sensitivity was 10 ppb Cu with standard solution. With river and lake water, the sensitivity appeared to be about 0.1 ppm Cu.

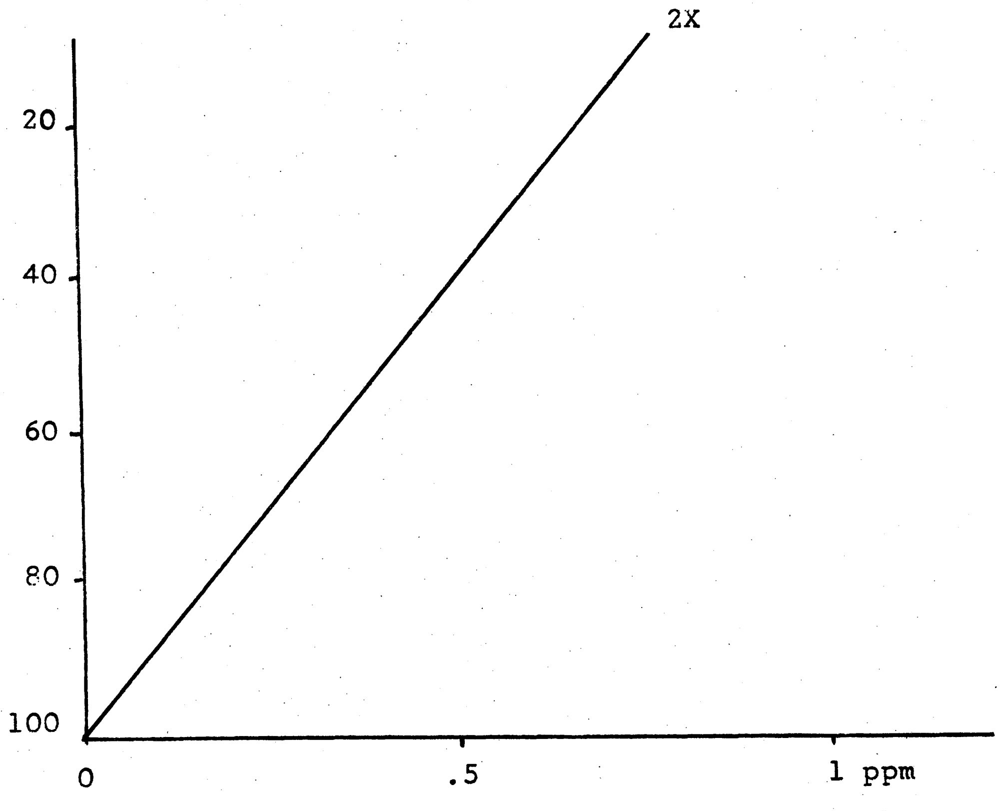


Typical Cu concentration - response curve for hot mode operation.

Cadmium - at. wt. 228.8. Standard prepared by dissolving 1.0 g cadmium metal in 10 ml HNO_3 and diluting to 1 liter with glass distilled water. Solution contained 1 mg Cd/ml. Working solutions contained from .0001 mg Cd/ml to .002 mg Cd/ml. Instrument settings were as follows:

Hollow cathode source	Cd lamp
Wave length	229 mμ
Slit width	.2 mm
Current	8 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner flame height	.3 in

With laminar flow burner operated in hot mode, the sensitivity was 1 ppb Cd with standard solution.

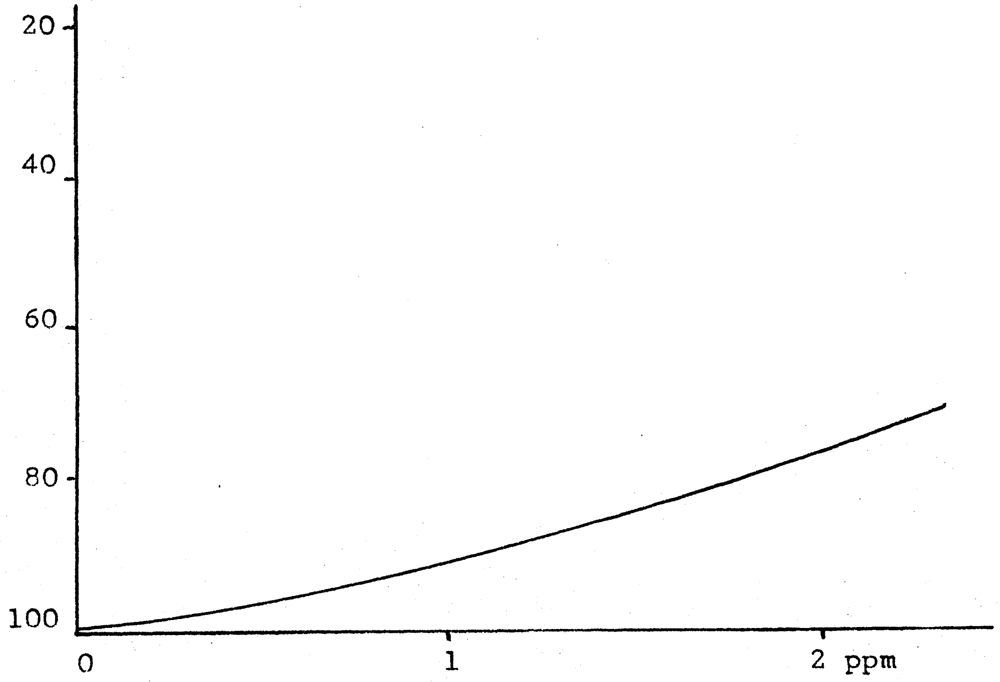


Typical Cd concentration - response curve for hot mode operation.

Molybdonum - at. wt. 95.95. Standard prepared by dissolving 1 g molybdomum metal in 10 ml HNO_3 and then diluting to 1 liter with glass distilled water. Solution contains 1 mg Mo/ml. Working solutions contained from .0001 mg Mo/ml to .002 mg Mo/ml. Instrument settings were as follows:

Hollow cathode source	Mo lamp
Wave length	313.0 mμ
Slit width	.2 mm
Current	15 ma
Fuel - acetylene	4-4.4 psi
Air	17 psi
Burner flame height	0.3 in

With laminar flow burner operated in hot mode, the sensitivity was .05 ppm Mo with standard solution. With river and lake water, sensitivity appeared equally good.

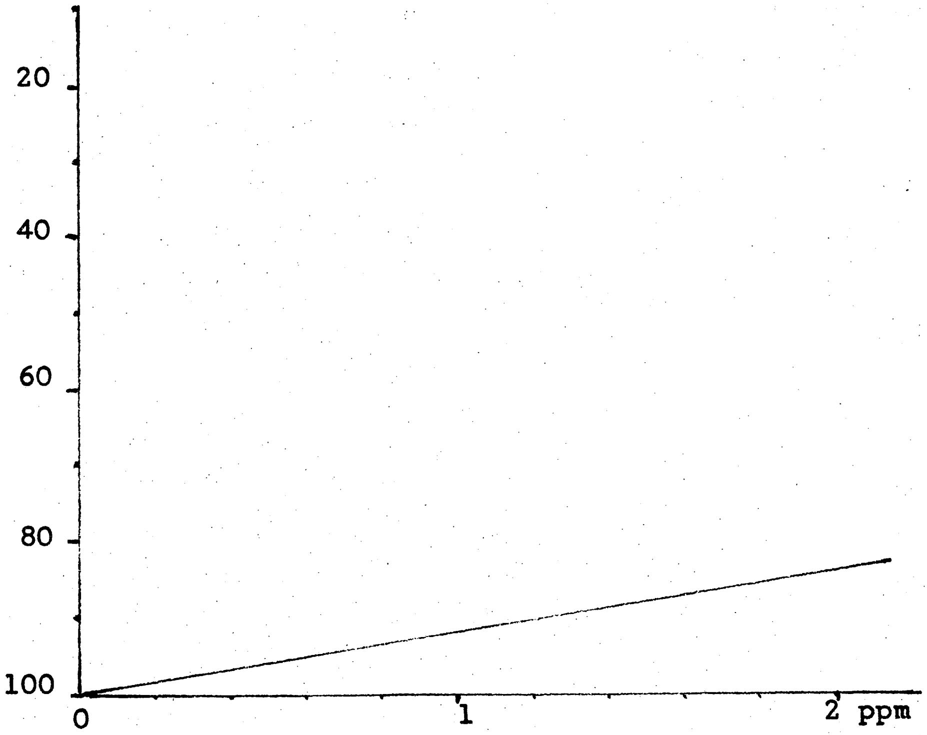


Typical Mo concentration - response curve for hot mode operation.

Lead - at. wt. 207.21. Standard prepared by dissolving 1.000 g lead metal in 10 ml HNO_3 and diluting to 1 liter with glass distilled water. Solution contains 1 mg Pb/ml. Working solution contained from .0001 mg Pb/ml to .002 Pb/ml. Instrument settings were as follows:

Hollow cathode source	Pb; Pb-Cu-Zn-Sn lamp
Wave length	283 mμ
Slit width	.2 mm
Current	15 Ma
Fuel - acetylene	4 psi
Air	17 psi
Burner flame height	.3 in.

With laminar flow burner operated in hot mode, the sensitivity was .05 ppm Pb with standard solution.

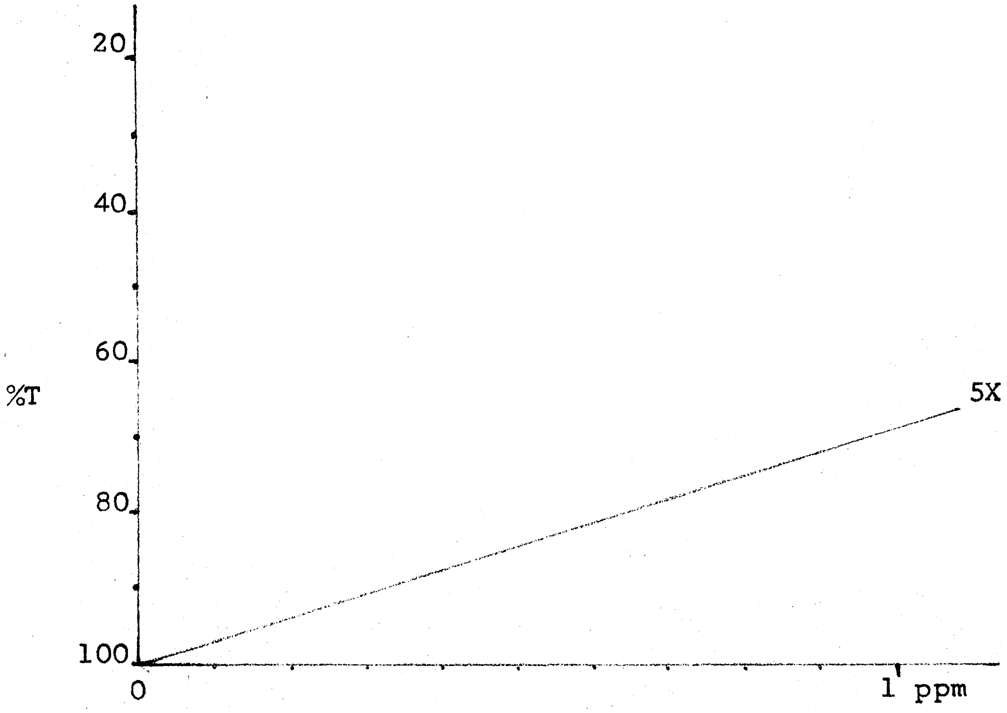


Typical Pb concentration - response curve for hot mode operation.

Chromium - at. wt. 52.01. Standard prepared by dissolving 1.000 g chromium metal in 10 ml HNO_3 and diluting to 1 liter with glass distilled water. Solution contained 1 mg Cr/ml. Working solutions contained from .0001 mg Cr/ml to .002 mg Cr/ml. Instrument settings were as follows:

Hollow cathode source	Cr; Fr-Fe-Mn-Zn lamp
Wave length	358 mμ
Slit width	.2 mm
Current	12 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner flame height	.3 in

With laminar flow burner operated in hot mode, the sensitivity was .01 ppm Cr with standard solution.

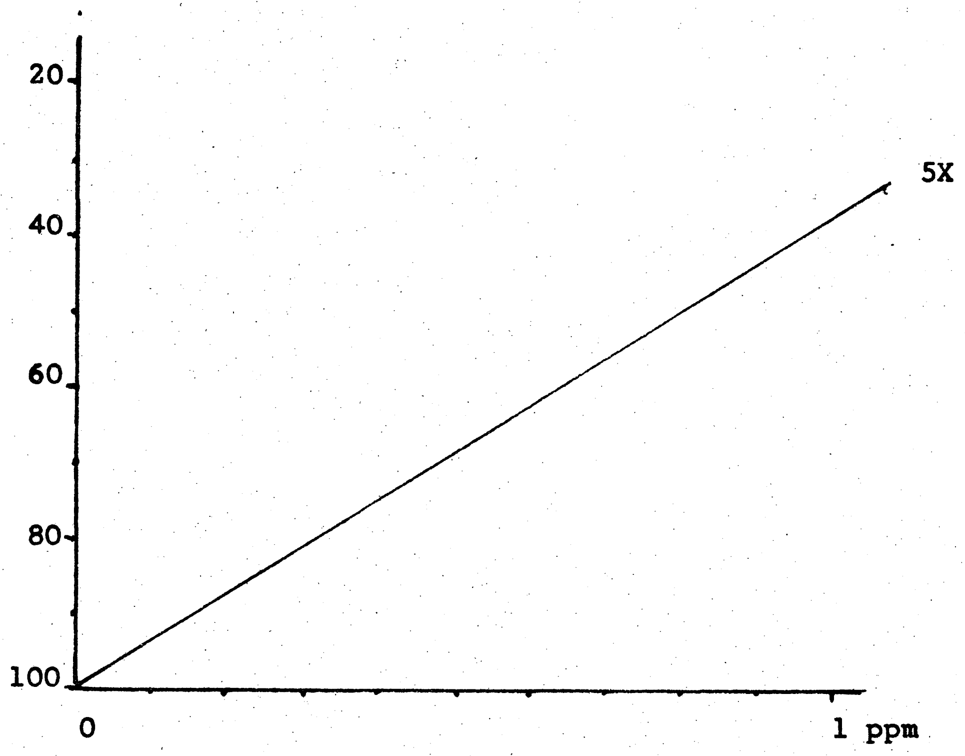


Typical Cr concentration - response curve for hot mode operation.

Cobalt - at. wt. 58.93. Standard prepared by dissolving 4.938 g of cobalt nitrate in 1 liter of glass distilled water. Solution contains 1 mg Co/ml. Working solutions contain from .0002 mg Co/ml to .002 mg/Co/ml. Instrument settings were as follows:

Hollow cathode source	Co lamp
Wave length	241 mμ
Slit width	.2 mm
Current	15 ma
Fuel- acetylene	4 psi
Air	17 psi
Burner flame height	.3 in

With laminar flow burner operated in hot mode, the sensitivity was .01 ppm Co with standard solution.

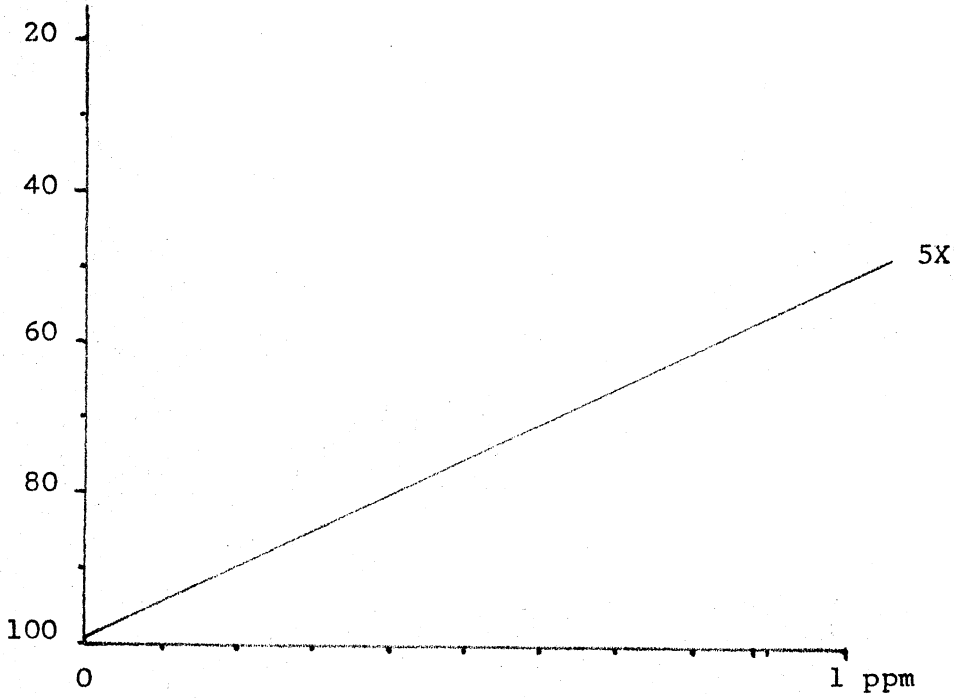


Typical Co concentration - response curve for hot mode operation.

Nickel - at. wt. 58.69. Standard prepared by dissolving 1.0 g of nickel metal in 10 ml HNO_3 and diluting to 1 liter with glass distilled water. Solution contained 1 mg Ni/ml. Working solutions contained from .0001 mg Ni/ml to .002 mg Ni/ml. Instrument settings were as follows:

Hollow cathode source	Ni; Ni-As; Ni-Fe-Cu-Zn lamp
Wave length	232 mμ
Slit width	.2 mm
Current	15 ma
Fuel - acetylene	4 psi
Air	17 psi
Burner flame height	.3 in

With laminar flow burner operated in hot mode, the sensitivity was .01 ppm Ni with standard solution.



Typical Ni concentration - response curve for hot mode operation.

SAMPLING EQUIPMENT AND PROCEDURES

A study of chemical and physical factors in any aquatic environment is no better than the sampling techniques used to obtain the data. As a first requirement, the procedure employed must obtain an adequate and representative sample of the particular factor under investigation. Secondly, the procedure must be reproducible by the developing investigator as well as by other investigators. Thirdly, the technique should be as simple to perform and as adaptable to all situations as possible. Lastly, the technique should be as portable and economical as possible. Considerable effort was expended on this study to select or devise techniques which fulfilled the above requirements. Those techniques employed for routine sampling are discussed in this section.

Since this study was concerned with sampling a reservoir and tailwater that was over 100 river miles in length it was necessary that all boat equipment be mobile overland as well as on water. Thus, the boat equipment had to be portable on a trailer. Another consideration on the size of boat was determined by the character of the wave action on the reservoir. The lower region of this reservoir is notorious for suddenly becoming rough almost daily throughout the summer. Therefore, a 20-foot fiberglass surf-fishing boat, equipped with twin outboard motors, was selected as the principal work boat for this study. Two additional boats and outboard motors utilized for aquatic weed control research, were also used on this study. All equipment was portable by trailer, and all boats and vehicles were equipped with 2-way radios so that boats and vehicles could be dispatched and coordinated to most efficiently accomplish the particular study underway.

Two of the boats were equipped with depth indicators,which saved considerable time in locating old stream and creek channels for water and soil sampling, as well as providing needed information for navigating over various portions of the reservoir. These sounders were also helpful in locating areas of suitable depth for the establishment of aquatic vegetation and for determining the type (sand or muck, clear or stumpy) of reservoir bottom. The recording sounder was used to map cross section profiles of the reservoir bottom.

The larger fiberglass boat was equipped with two 12-volt electric hoists including davits. The smaller fiberglass boat was also equipped with a similar type removeable hoist and davit. This equipment proved indespensible in the collection of water and soil samples throughout the entire study.

Two of the boats were equipped with voltage convertors, which permitted the use of 110-volt instruments on-board these boats. In addition, a small 1500 watt 110-volt a.c. and 12 volt d.c. alternator was also employed on long runs to provide additional currents for instruments, small motors, and to recharge batteries.

Specific instruments utilized in the field included Yellow Springs Instruments model 51 oxygen-temperature meters. In addition to the regular 10-foot lead on standard probes, one probe with an 100-foot lead was available on the large boat. This permitted in-place measurements of temperature and dissolved oxygen concentrations to water depths of 90 feet.

A Troxler Electronic Laboratories transistorized portable Scaler model 200 B, equipped with a Troxler pulse height analyzer, model E-200, and a Troxler Model 300 scintillation probe was used on-board boats to determine gamma radiation counts on collected water and soil samples.

An Industrial Instruments resistivity meter equipped with a regular platinum probe for measurements in water and a resistivity cup for measurements on soils was avaiable for use on the large boats.

A Weston Instruments model 756 daylight type light meter was on-board the boat to measure surface sunlight intensity, and a Weston microampere meter coupled to a triple-selenium-cell submersible light head was utilized to measure light intensity at different water depths. The sensitivity of cells in submersible head was sufficient to require a 1-ohm shunt when the unit was operative in the atmosphere.

A Photovolt portable pH - mv meter equipped with a glass electrode probe and a platinum electrode probe for measuring pH and redox potential in water and soil samples was also on-board the boats.

An American Instruments Company micro photofluorometer equipped to be operated as a portable unit was employed on the larger boat to detect fluorescent type dyes in flow-dispersion studies.

Sample collecting equipment regularly employed included 2 -liter capacity Hydro Products deep well water samplers. Since these bottles operated on a single rope, they were attached to the electric hoists on-board the boats at a great savings in time.

A Hydro Products Phleger core-type soil sampler with removable plastic-tube liners was employed primarily to collect samples of exposed bottom soils during drawdown periods.

An all-plastic sampler was developed by the principal investigator that was capable of collecting surface residue to a depth of 1/4 inch over approximately 0.5 square feet of lake bottom. The sample-collecting chamber was cocked on-board the boat, the sampler lowered to the bottom on a rope, and the collecting chamber activated by a messenger dropped along the rope. The sampler was then retrieved by the rope and the contents of the collecting chamber removed into a plastic pan or bag. Leakage of collected muck was nil as long as the sampler was underwater.

A Hach Chemical Company turbidity meter was operated on-board the large boat to determine the amount of suspended matter in water samples.

Procedure for Collection of Water Samples

Water samples for chemical and plankton analyses were collected with a Hydro Products deep well sampler at the surface and at intervals of 10 or 20 feet of depth - the interval and number of samples collected depending upon the location in the reservoir. As soon as the collected sample came on-board the boat, the top of sample bottle was opened, the oxygen-temperature probe was inserted, and these two parameters measured by the YSI meter. The resistivity and pH of the water sample were also measured by inserting these probes into the water bottle. The turbidity was also determined on each water sample on-board boat by Hach turbidometer. Water for chemical and plankton analyses was withdrawn from sample bottle with a siphon into a 1-quart nalgene plastic bottle that was filled to overflowing and then tightly capped. The sample was then stored in the shade on-board the boat.

Chemical and plankton analyses were performed within 24 hours after samples were collected.

Procedure for Collecting and Extracting Plankton And Other Suspended Matter Samples (This Technique was Developed in 1967)

A portion (usually 200 ml) of each water sample collected for chemical analyses was vacuum filtered and the suspended matter collected on an 8 u pore-size Millipore filter. The filter and its residue was placed in a 50 ml beaker and the residue removed by extracting with 4 ml of hot aqua regia. The extracted filter was washed with distilled water and removed from the beaker. The solution in the beaker was evaporated to dryness. The dried residue was then dissolved in 20 ml of hot 0.1 N HCl and stored in plastic beaker for analyses on atomic absorption spectrophotometer.

The filtrate was saved for determinations of its soluble element composition.

Procedure for Preserving, Collecting, and Extracting Soil Samples

Two techniques of soil sampling were employed in this study.

Profile soil samples were collected with a Hydro Products Phleger core sampler in shallow water and dewatered areas of the reservoir at various times of the year. In a majority of cases, the cutting tip was forced into the soil for a sufficient depth to collect a 4-to 6-inch profile in the plastic interliner of the sampler. The interliner was removed from the sampler with the soil sample intact and the ends of the liner were closed by stoppers. The liner was brought into the laboratory and the sample of soil was air dried, then separated into a top, and remaining lower portion, ground in a mortar to pass a 40-mesh screen, and stored for analyses.

Samples of the interface area adjacent to water and bottom mud were collected throughout the summer of 1967 by the all-plastic hydrosol sampler described earlier. An area of 0.5 or 1 square foot was included in each sample. Immediately after a sample came on-board, the pH, resistivity, gamma count, and redox potential were determined. The entire content of sampler was placed in a one-gallon plastic bottle and transported to the laboratory. The entire content was dried over infrared lamps, weighed, and ground to pass a 40-mesh screen. This dried sample was weighed and stored for analyses.

The cation-exchange procedure (Jackson, 1964) was utilized for extracting soil samples. Briefly the procedure was as follows:

A 5.0 or 10.0 g sample of dried soil was placed into a 125 ml Erlemmeyer flask and 20 ml NH_4O AC was added. Flask was stoppered and then agitated on a mechanical shaker for 15 minutes after which the solution and soil was allowed to stand and react for 24 hours. The soil solution was vacuum filtered through No. 42 filter paper on a Buchner funnel and the soil residue washed with additional 100 ml NH_4OAC. The filtrate was dried on water bath, and the dried residue was treated with 2 ml H_2O_2 + 4 ml 3 N HNO_3. Flask was covered with watch glass and allowed to stand 30 minutes after which sample was again dried on water bath. The resulting residue was dissolved in 5 ml 6N HCl and diluted to 100 ml with distilled water. This solution was filtered and the filtrate stored in plastic cups for phosphorus and cation analyses.

Jackson, M. L. Soil Chemical Analysis. Prentice-Hall, Inc., 498 pp. 1964.

Procedure for Collecting and Storing Plant Samples(1)

Samples of selected species of rooted aquatic plants were collected at various times and places throughout study period. The intact plant sample was picked up with a digging fork, the soil rinsed from the roots and stems and the intact plant was placed in a plastic bag and stored in the shade. When the sample reached the laboratory the entire plant was washed with tap water to remove all soil and organic debris. The washed sample was then frozen until it could be placed on a freeze-drier. The dried sample was stored in a dessicator until it could be ground in a Wiley mill to pass a 40-mesh screen. The ground, dried sample was then stored in a plastic container for analyses.

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(1) Complete details of this procedure were given in the following thesis:
Denton, Jerry B.
Relationships between the chemical composition of aquatic plants and water quality. M.S. Thesis, Auburn University, 78 pp. 1966.

Procedures for Collecting and Storing Fish Samples (1)

Samples of selected species of fish were collected by various techniques at different times and places. Briefly the methods of collecting fish included seining, electric shocking, rotenoning, and dynamiting. Immediately following the picking up of the samples of live fish, they were placed in ice and kept there until they were brought into the laboratory where they were separated by species, and their individual total length, total depth, and weight was determined prior to the fish being frozen. The frozen fish were then dried on a freeze-drier and stored in dessicators until each sample reached a constant dry weight. The dried fish were ground in a Wiley mill to pass a 40-mesh screen. Each ground, dried fish sample was stored in a plastic container for analyses.

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(1) Complete details on collection procedures, etc. will be found in thesis (now in preparation) of Beverly Clement and Roland Reagan.

Methods of Analyses of Plant(1) and Fish Tissue

A 0.5-g sample of dried, ground tissue was incinerated at approximately 500°C for 24 hours. After the ash weight was determined, the ash was dissolved in the crucible with 4 ml of aqua regia. This solution was boiled to dryness and the residue was taken up in 50 ml 0.1N hot HCl. This solution was used for phosphorus and atomic absorption analyses.

Total nitrogen content of each dried tissue sample was determined by Coleman Model 29 Nitrogen Analyzer II. Total carbon content of dried tissue sample was determined by Coleman Carbon-Hydrogen Analyser.

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(1) A different procedure for preparation of plant samples for analyses is described in following thesis:
Denton, Jerry B.
Relationship between the chemical composition of aquatic plants and water quality. M.S. Thesis, Auburn University 78 pp. 1966.

RESULTS AND DISCUSSION

Studies concerned with chemical and physical characteristics of water in natural lakes have been carried on by limnologists for more than three quarters of a century. These scientists have developed a tremendous volume of data from which they have evolved some very complicated theories relating to the interacting systems operating within these bodies of water. Since an effort has been made to study only those bodies of water which are in as natural a condition as possible, the science of limnology has not concerned itself with those systems operative in man-made impoundments. In fact, data on rivers and their impoundments are largely, and purposely, excluded from the comprehensive reviews published by Hutchinson (1957 and 1967).

Complimenting the development of the science of limnology has been the evolvement of the science of waterworks and sewage technology. These researchers have been concerned primarily with the industrial and domestic needs and the public health aspects as related to waters of rivers and impoundments. Thus, this latter group was concerned mainly with use of rivers and impoundments as water sources and effluent disposal areas.

Each of these groups has produced a profound influence on the thinking and training of scientists and technicians. One group being oriented toward a condition where man's influence on the environment was excluded, the other where man utilized the water and ignored his influence on the environment. Thus, the dilemma of pollution today is largely a result of lack of understanding of dynamics of chemical-physical-biological interactions within streams and their impoundments. It must be remembered, however, that large impoundments in the United States have been created since World War I and that public utilization of these impoundments did not start until well after the end of World War II. Thus, the need for an understanding of these bodies of water is of rather recent orgin.

Most of the techniques and basic knowledge developed by the two aforementioned groups of scientists are applicable to the solution of many problems in these impoundments today. In other cases the available techniques are either so inaccurate or insensitive as to provide unreliable data for the solution of many biological problems. Aquatic biologists have generally accepted these techniques as providing the needed measurements of environmental parameters and have not been critical of the inadequate results that have been obtained. Instrumentation has been developed which has been or is capable of being adapted to the analytical needs of the aquatic biologists. Full utilization of these modern techniques must be adopted by biologists if they plan to keep abreast with knowledge to maintain and improve our surface water resources.

The data presented in the following sections of this report will be concerned with those parameters believed to be essential to our basic understanding of the environment within a large stream-multipurpose impoundment. Several parameters known to be important in such a study have not been adequately sampled or evaluated due to lack of sufficiently accurate and rapid detection techniques. Those areas needing technology developments will be pointed out in the text.

Chemical and Physical Characteristics of Water

Data collected on a number of physical and chemical characteristics of the waters from the various sections of Lake Eufaula during the periods May to November, 1965, March to November 1966, and January to October 1967 have been averaged by stations and depths for each year. Averaged data for each station and depth within the upper (river-run) region, within the middle (upper inundated) region, and within the lower (wider and deeper) region of reservoir are tabulated separately. Also shown in these tables are data from those creeks entering the reservoir within each of the regions. These detailed tables are included in the Appendix.

The dynamics of each of the parameters measured in these waters will be discussed in following sections.

Temperature and Dissolved Oxygen (D.O.) - Temperature and barometric pressure have direct effects upon the solubility of oxygen in water. Temperature and oxygen solubility vary inversely, whereas barometric pressure and oxygen solubility vary together. Under field conditions temperature is the most variable as well as being the most influential factor affecting oxygen solubility.

The presence or absence of D.O. in water also exerts an influence upon the solubility of other elements and compounds that may be present in suspended matter or adsorbed onto the surface of the lake bottom. Thus, the status of D. O. predetermines the concentration of many other chemicals within the body of water at any given time.

Information on water temperature and D. O. concentration characteristics in streams and impoundments is of prime importance to the fisheries biologists. These two water quality criteria are the primary considerations in setting the water quality standards by State and Federal Water Pollution Control panels.

In Lake Eufaula, individual determinations of temperature and D. O. varied widely from surface to bottom, from station to station, and from one sampling date to another. Since these are highly variable factors and since it is impossible to present each set of individual determinations, examples to illustrate these different conditions will be used. To facilitate utilization of data on temperature and D. O. in discussions, in later sections, they have been averaged by stations, depths and years for each lake portion (Appendix Tables 1A, 1B, 1C), and these data have been further summarized for comparative purpose in Table 1.

In the discussion of these two criteria for Lake Eufaula, an attempt will be made to illustrate the dynamic situation that can exist in a warm water, multi-purpose impoundment on a large stream.

During the colder months of the year there were sufficient water flows and mixing to give fairly uniform temperatures and dissolved oxygen concentrations in waters at all depths throughout the reservoir. As an example, there was a difference of less than 3° from surface

Table 1

Averaged temperature and dissolved oxygen concentrations of Lake Eufaula waters by regions and depths for 1965, 1966, and 1967.

			Average conditions at given depths				
Region	Yr.	Component	0'	20'	40'	60'	80'
Upper	65	°C	29.6	28.9	28.8		
		O_2 ppm	6.59	5.17	5.15		
	66	°C	25.5	23.0	25.7		
		O_2 ppm	6.77	6.27	4.97		
	67	°C	24.7	23.8	26.1		
		O_2 ppm	6.95	6.65	6.67		
Middle	65	°C	26.0	25.0	24.6	25.2	
		O_2 ppm	6.20	3.82	2.72	2.42	
	66	°C	28.7	26.7	26.4	26.1	
		O_2 ppm	6.69	4.26	3.34	2.41	
	67	°C	27.1	25.2	26.0	24.9	
		O_2 ppm	7.35	4.73	3.16	3.51	
Lower	65	°C	30.5	28.4	27.3	26.5	26.2
		O_2 ppm	7.63	3.44	1.61	.91	1.91
	66	°C	29.0	27.2	26.6	25.7	26.6
		O_2 ppm	6.84	4.66	3.28	2.50	1.16
	67	°C	27.3	25.2	24.4	23.8	24.5
		O_2 ppm	8.37*	4.65	2.18	1.32	1.12

* Super-saturated with D.O.

to 80-foot depth, and less than 3 ppm difference in D.O. concentration for the same location in mid-fall of each year of the study (Figures 5, 6).

With the onset of warm weather, water temperatures began to vary with depth and so did the D.O. concentration. Usually by late May surface water temperatures were exceeding 28°C and stratification of the deeper waters in lower region of the reservoir had occurred

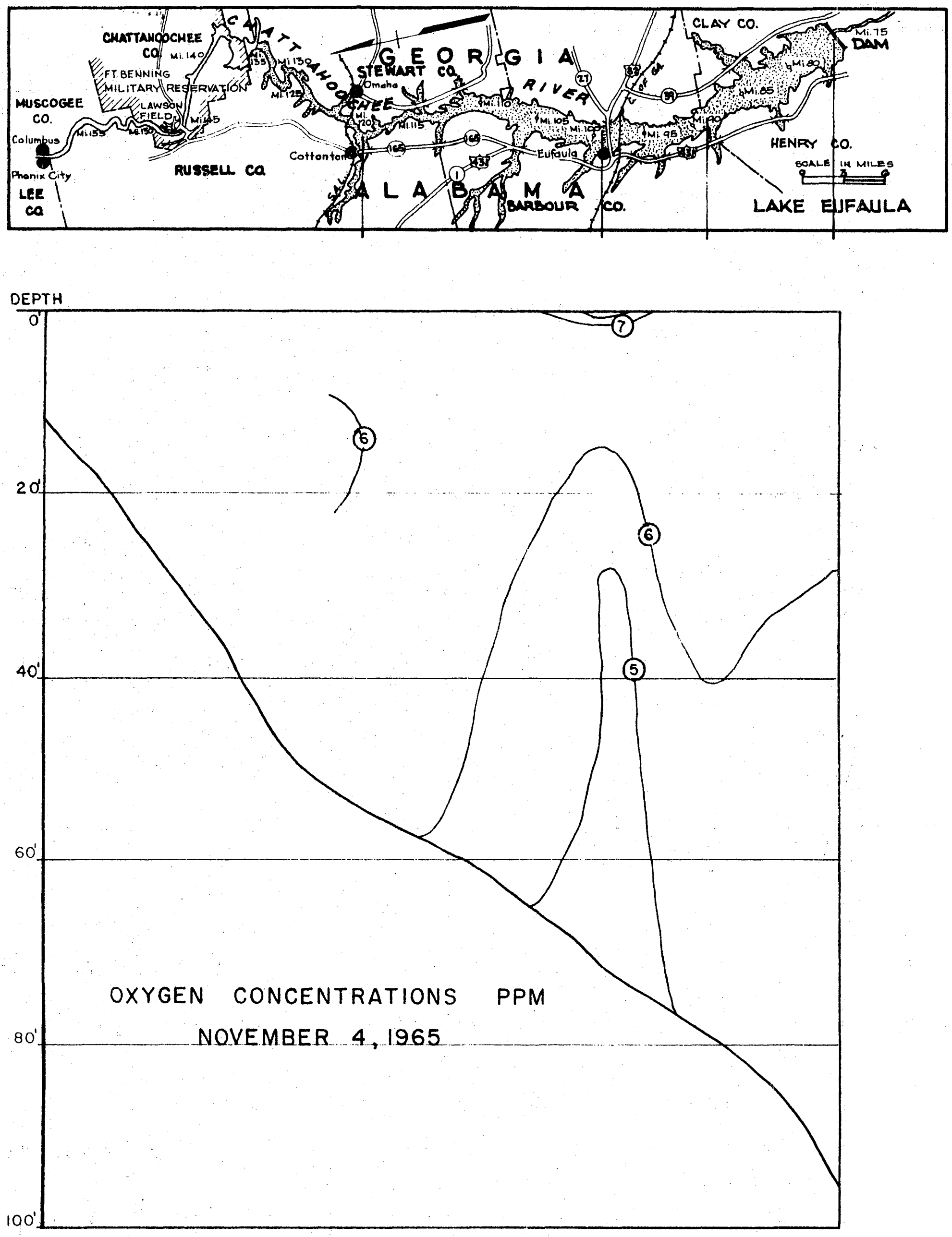

Figure 5. Dissolved oxygen concentration pattern in Lake Eufaula waters in early November.

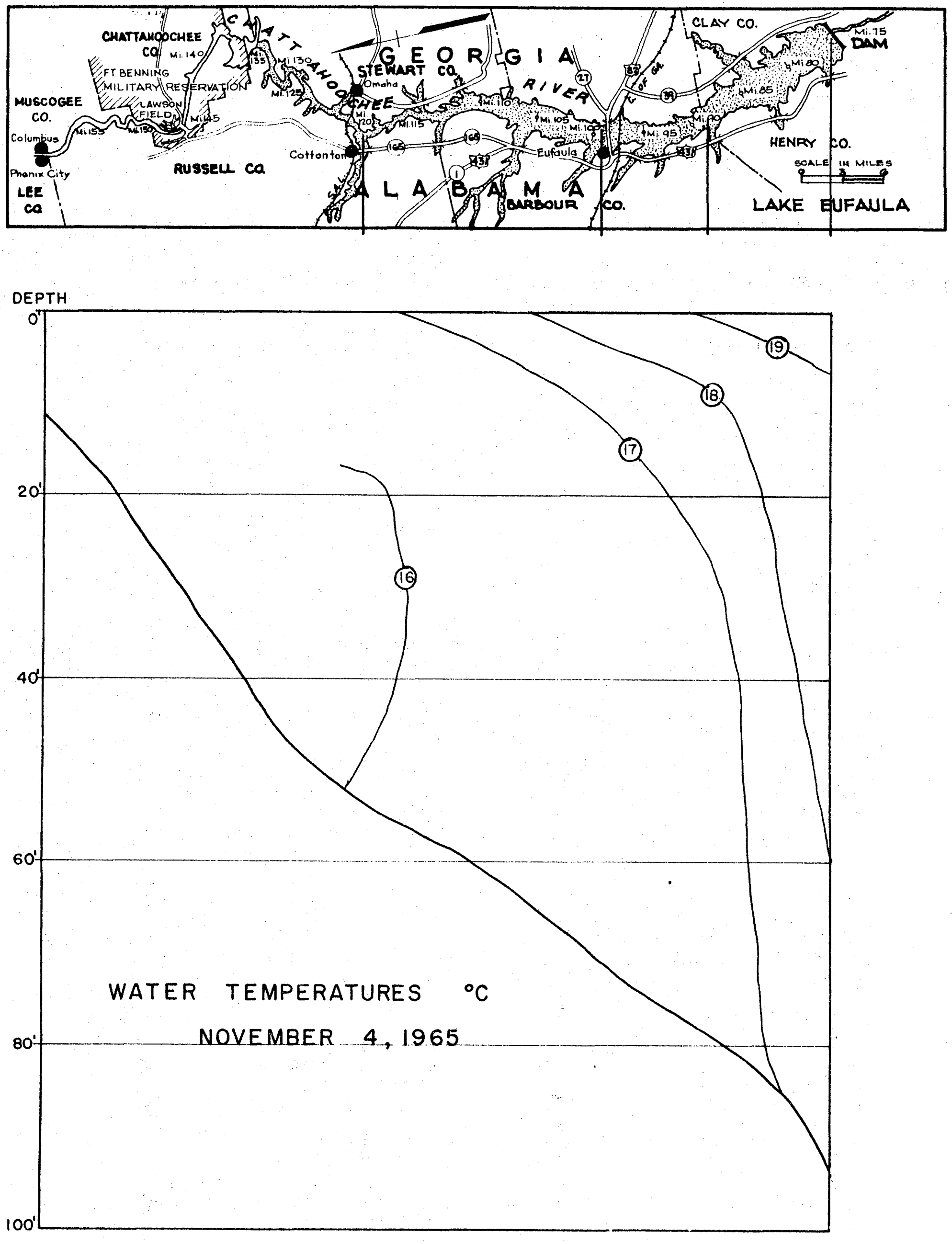

Figure 6. Water temperature pattern in Lake Eufaula in early November.

and moved upstream at a rather rapid rate so that by mid-June it reached areas with water depths of approximately 60 feet. Under hot weather conditions and normal river flows, stratification would proceed to its most upstream detectable point, approximately 45 river miles above the dam where water depths were 45 feet. Incidentally, this initial stratification point is in the vicinity of a paper mill effluent discharge outlet which is at the 40-foot depth level (bottom of river) of the reservoir.

During mid-summer stratification, D.O. concentrations of 1 ppm were found at depths less than 20 feet in mainstream sector of reservoir. Water temperatures under those severe hot weather conditions varied from 5° to 8°C from surface to 80-foot depths. Such conditions are illustrated in Figures 7 and 8 for August, 1965. The paucity of phytoplankton growths in surface waters probably accounts for these small differences in temperature in these deeper waters. In contrast, tributary streams with heavy phytoplankton growths had temperature differences as great as 5°C from surface to 15-foot depth; however, the D.O. concentration at this depth was significantly greater (2.5 ppm or more) than in the reservoir proper. It is significant to note that during warm weather mainstream surface water D.O. concentrations seldom approached and almost never exceeded saturation. This condition of sub-saturation of D.O. in surface waters in the main impoundment is not understood, but it is suspected to result from the interaction of current, wave-action, and turbidity upon phytoplankton production.

Changes in weather conditions during the summers of 1965 and

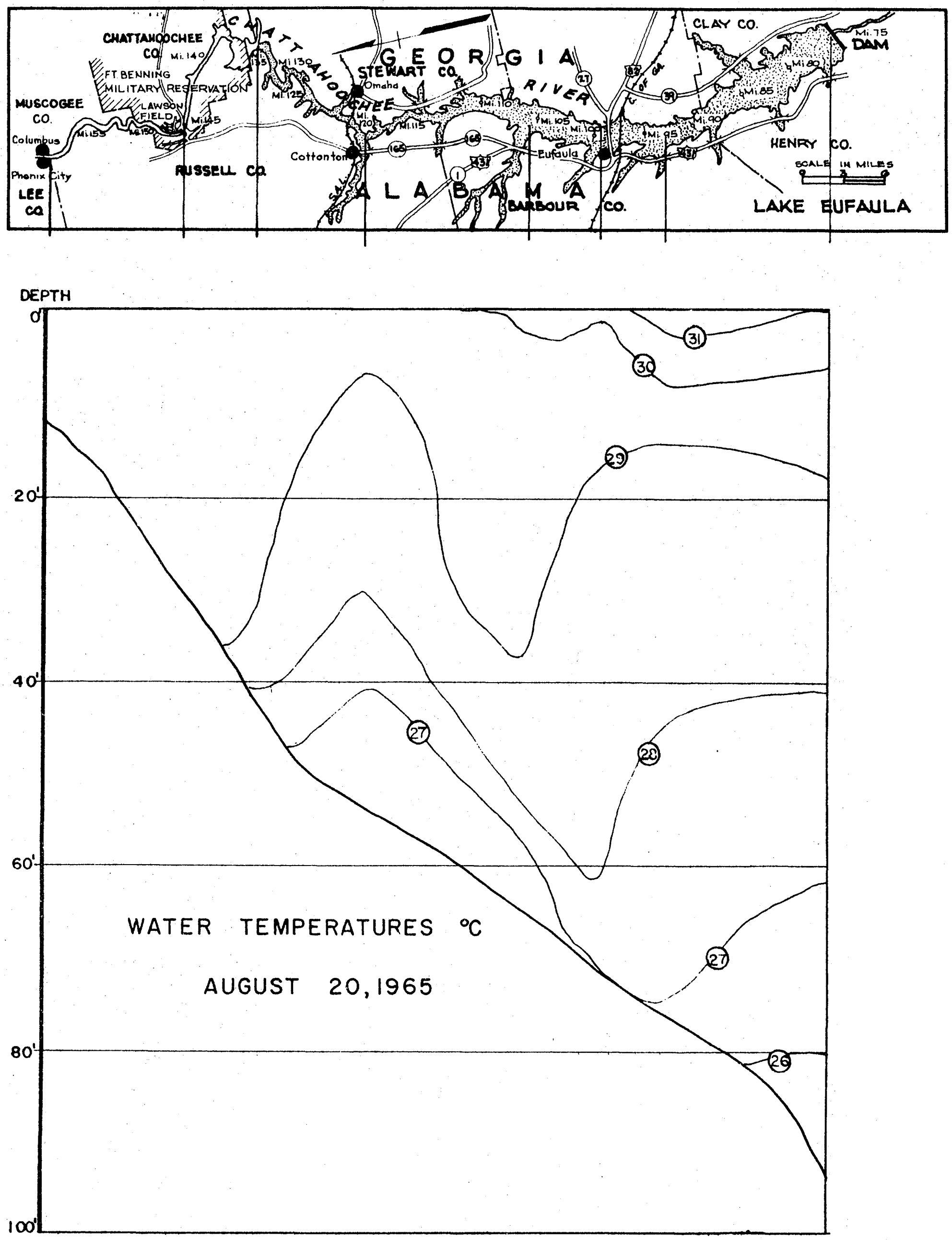

Figure 7. Water temperature pattern in Lake Eufaula in mid-August.

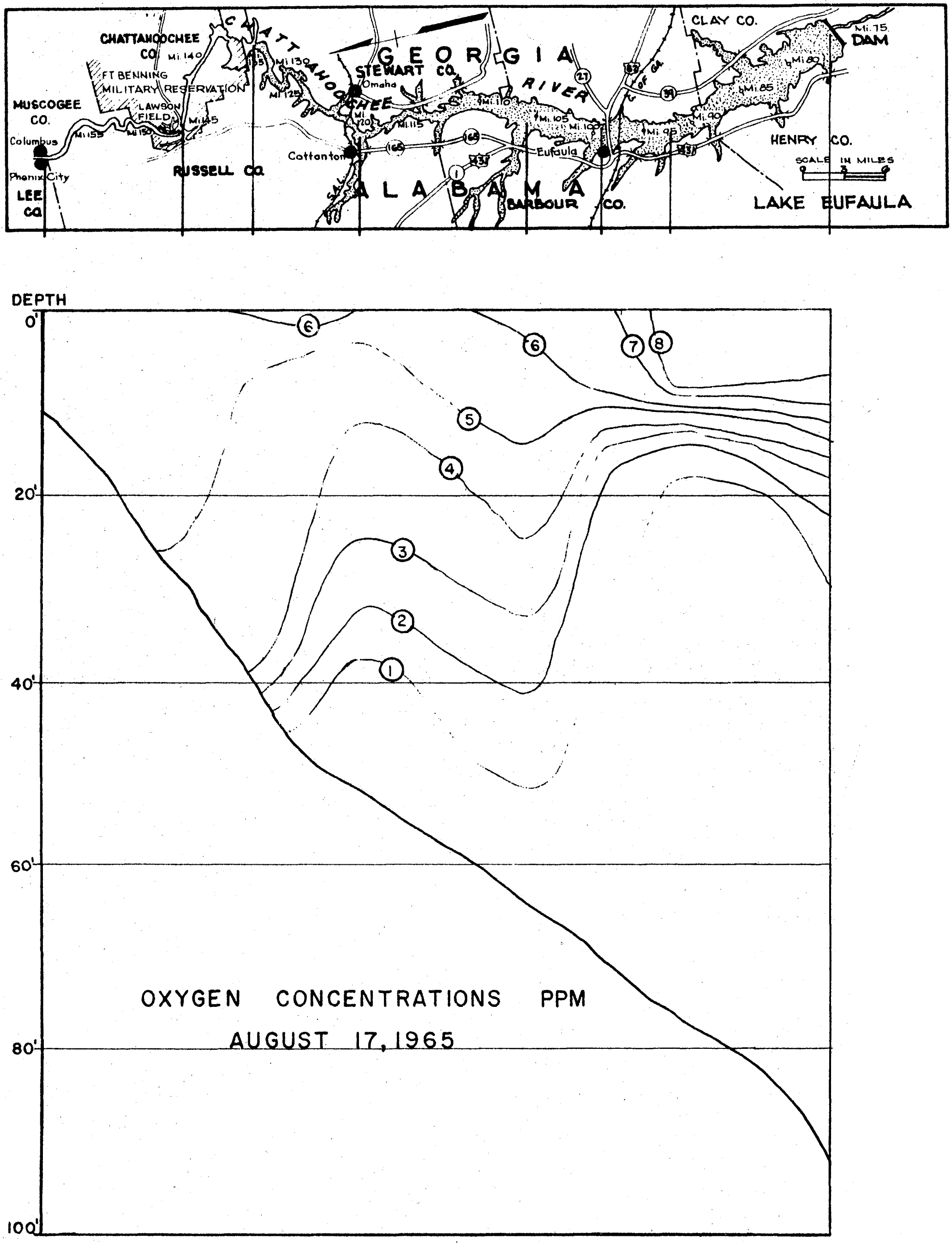

Figure 8. Dissolved oxygen concentration pattern in Lake Eufaula waters in mid-August.

1966 produced drastic changes in D.O. concentrations. On one occasion during mid-August surface waters contained 9 ppm D.O. and bottom waters at 40 feet contained 3.5 ppm D.O. Three days later, after a period of cloudy, rainy weather, the waters at this same location contained 3.5 ppm D.O. from surface to bottom of river. The causes of such reductions in D.O. concentration are not known. However, following such overturns, an uninterrupted period of 7 to 14 hot days would produce another stratified condition over most of lower 2/3 of reservoir.

In contrast to the drastic chemical changes that occurred throughout the summers of 1965 and 1966, the summer of 1967 did not produce hot weather of sufficient duration to cause complete D.O. depletion in any mainstream area of the reservoir.

During the first half of September of both 1965 and 1966, the entire reservoir overturned because of a cooling of the surface waters of approximately 2°C. Data on the pattern of the overturn in 1966 were obtained by chemical analyses and by fluorescent dye.

On September 6 a dye study was begun to determine the time-of-flow of water at 70+ foot depth in the lower portion of reservoir(1). The dye was pumped down by hose to a release point 6 feet above the river bottom at 3 locations (points A, B and C) as indicated in Figure 9. The movements of these clouds were followed

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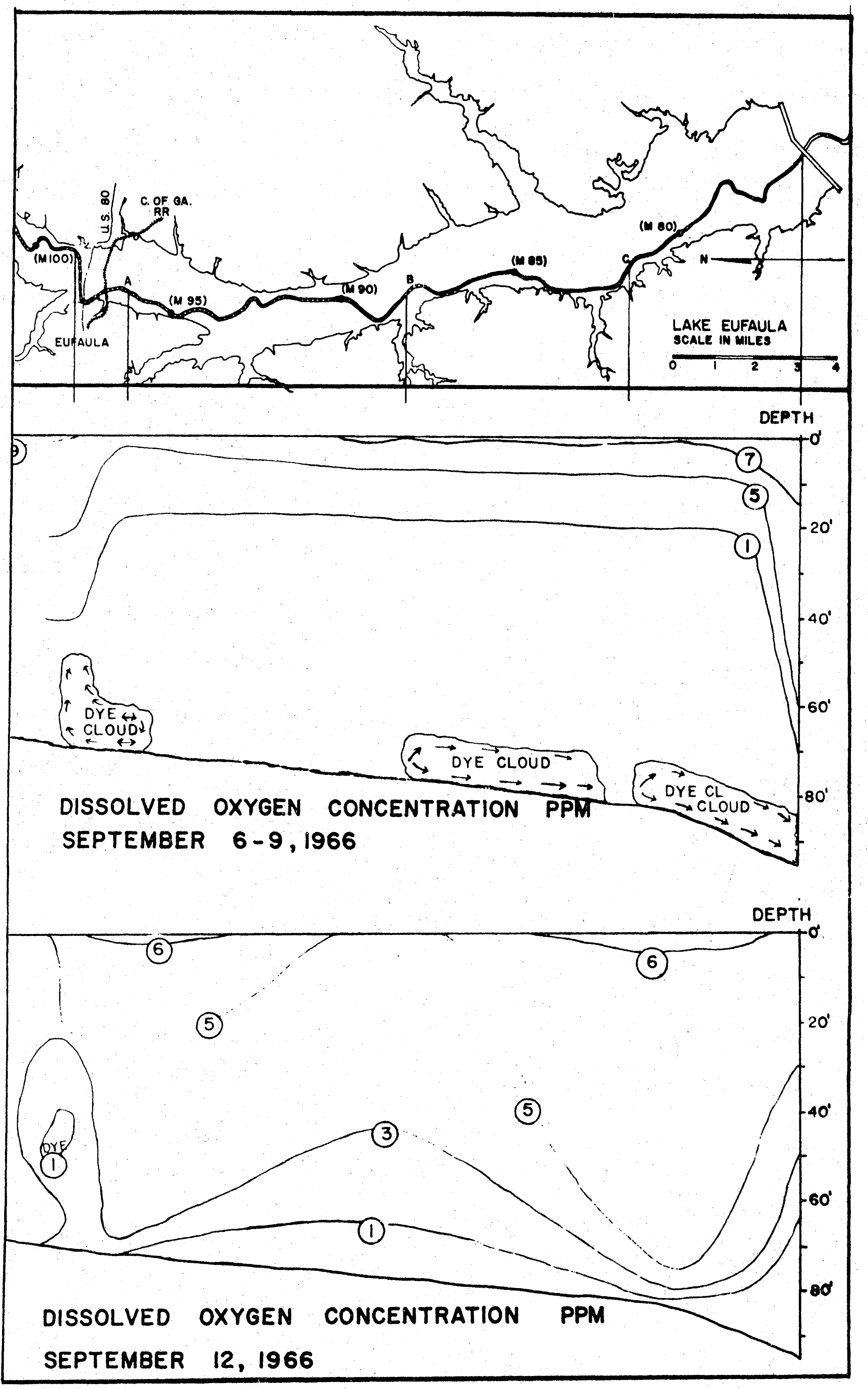
(1) Complete data were given in Report on Contract No. WA-66-10 U.S.D.I., FWPCA, Time-of-flow and dispersion studies on Walter F. George Reservoir.



DISSOLVED OXYGEN CONCENTRATION PPM
SEPTEMBER 6-9, 1966

DISSOLVED OXYGEN CONCENTRATION PPM
SEPTEMBER 12, 1966

Figure 9. Dissolved oxygen concentration patterns and dye patterns in lower portion of Lake Eufaula during period September 6-12, 1966.

for the next 7 days. During the 96 hours following application, each of the two lower clouds (B and C) moved downstream in a 10-foot thick cloud for a distance of approximately 6 miles. The upstream cloud (A) moved 0.25 mile downstream during 24 hours following injection. It then reversed its movement and traveled in an upstream direction for next 72 hours. On September 9 this dye cloud had progressed through two parallel bridges to a point 2.5 miles upstream from the point of injection. The thickness of this cloud was approximately 20 feet in contrast to the 10-foot thickness of the downstream clouds indicating that more turbulence occurred in this back current situation than occurred in normal downstream flow.

Data on water temperatures and D.O. concentrations existing on September 9 for this region of the reservoir are given in Figures 9 and 10. These data are representative of the conditions that existed throughout the first 4 days of this study. During the next 48 hours the moderate easterly wind, which had already plagued the research operations for 72 hours, intensified and became cooler. Thus, by September 12 the majority of the lake had already overturned or was in process of overturning as indicated by Figure 9. Monitoring of areas occurpied by 2 lower dye clouds indicated complete dissipation of the fluorescent dye. D. O. and temperature monitoring also indicated that bottom waters had mixed with upper waters.

Monitoring of the uppermost edge of the upstream cloud (A) with the fluorometer indicated that this cloud had moved toward the surface to the 45-foot letel, and that non-fluorescent waters had under-run the cloud. Dissolved oxygen monitoring of this area confirmed

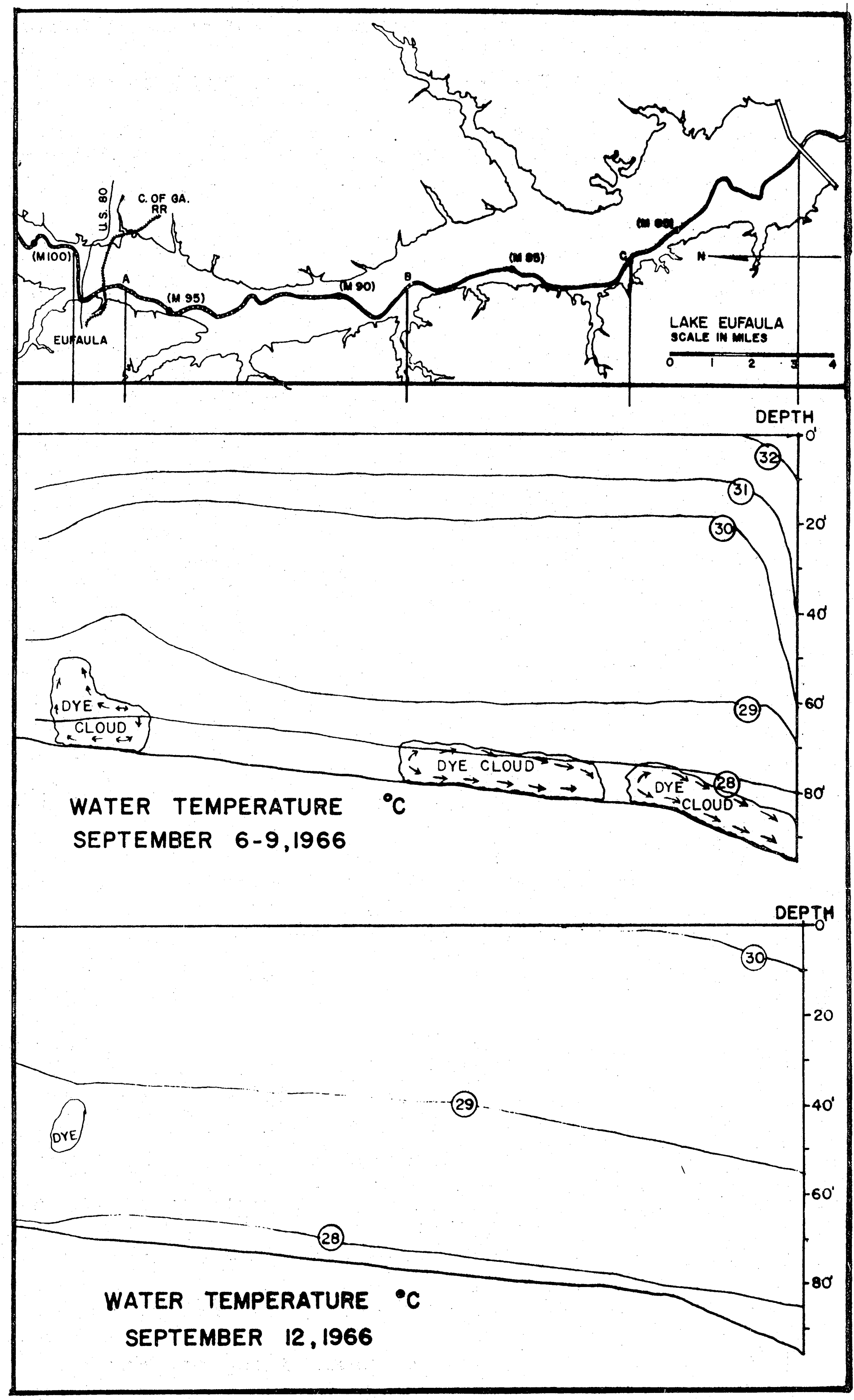


Figure 10. Water temperature patterns and dye patterns in lower portion of Lake Eufaula during period September 6-12, 1966.

the fluorometer findings for the area still occupied by dye had 0.5 ppm D.O. while waters below and above this 45-foot level had waters with 2 + ppm D.O. (see Figure 9).

In addition to confirming the findings of the YSI oxygen and temperature probe concerning stratification and overturn, this fluorescent dye also established that density currents do exist under stratified conditions in the deeper water areas of this reservoir. However, the most significant aspect of this deep water phase of dye research was the detection of upstream currents created by the 2 causeway type bridges on this reservoir.

Information on time-of-flow of the reaches of reservoir between river miles 141 and 110, and river miles 87.7 and 75.1 are given in Figure 11. Under relatively normal mid-summer weather and flowrates the average rate of flow in the river-run sector of the reservoir was 0.41 mile per hour. In the lower sector of the reservoir the deep water time-of-flow was approximately 0.08 mile per hour.

Based upon averaged inflow and outflow data for this reservoir (Appendix Table 6), and taking into consideration the loss by seepage and evaporation (Appendix Table 7), there would be a complete exchange of water volume (926,000 acre-feet) within approximately 80 days. This would have produced an averaged time-of-flow within the lower portion of approximately 1 mile per 24 hours, or 0.04 mile-per-hour. Comparing the observed with the calculated flow rate indicates that the water in lower depths of the river channel was traveling at twice the calculated rate. This appears to further indicate that a density current does exist in this reservoir under hot weather conditions.

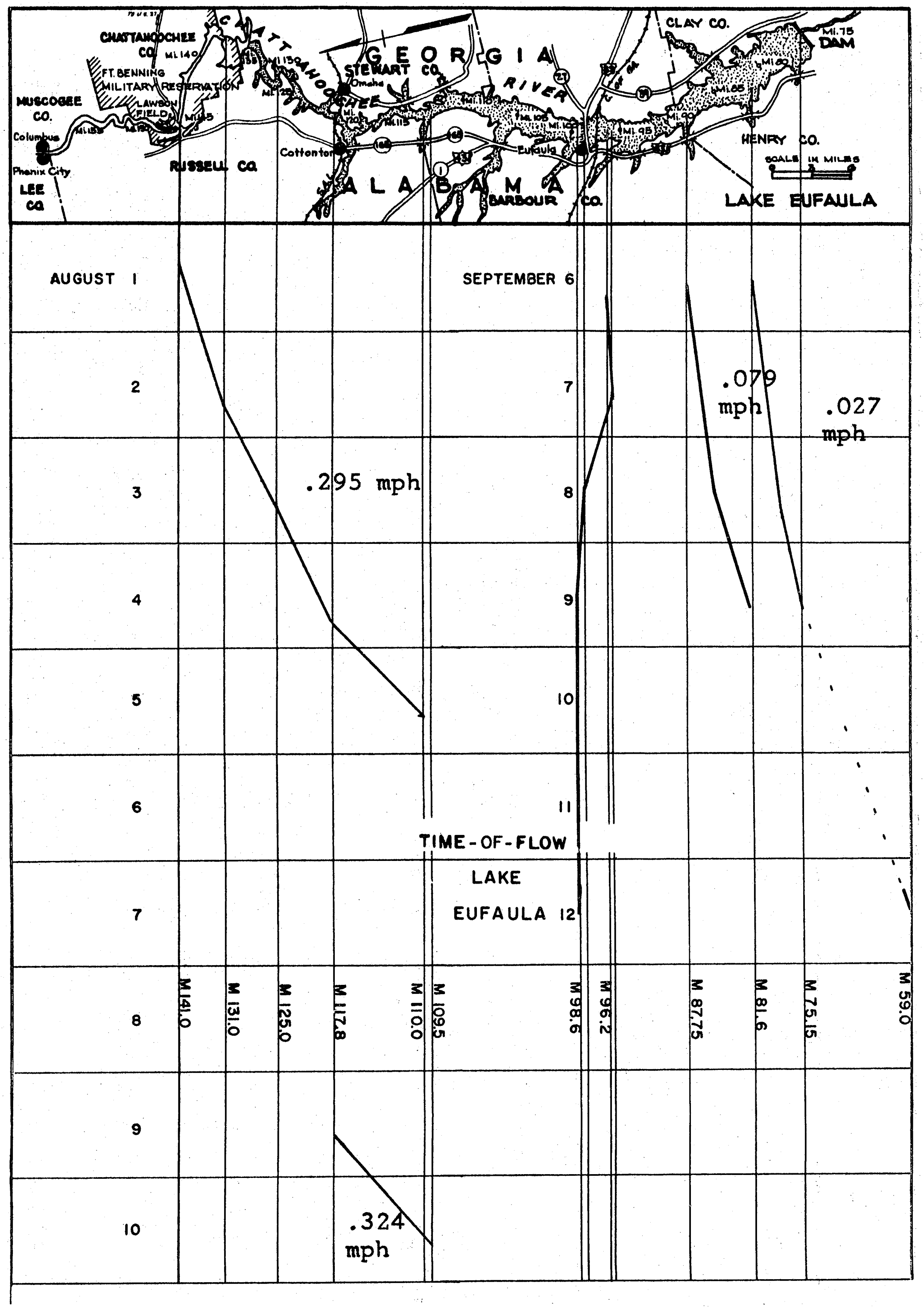


Figure 11. Time-of-flow for fluorescent dye in various portions of Lake Eufaula during August and September, 1966.

The time-of-flow in a downstream area below Columbia dam (see Figure 1), as determined by use of fluorescent dye, is given in Figure 12.

Resistivity (or Conductance) - Averaged data on resistivity of waters from different stations and depths within each lake portion are given in Appendix Tables 1-A, 1-B, 1-C. While these data are expressed as ohms/cm^3, they might readily be converted to conductance values by obtaining the reciprocal of each value.

The summarized resistivity data presented in Table 2 indicate two features of Lake Eufaula waters. First, these are very soft waters. Second, changes in resistivity values did not appear to be associated with any marked changes in composition of any one element, but apparently resulted from a change in concentration of several elements. Slight decreases in resistivity values for bottom waters within creeks (Table 3) could be associated with increased concentrations of Ca in these waters.

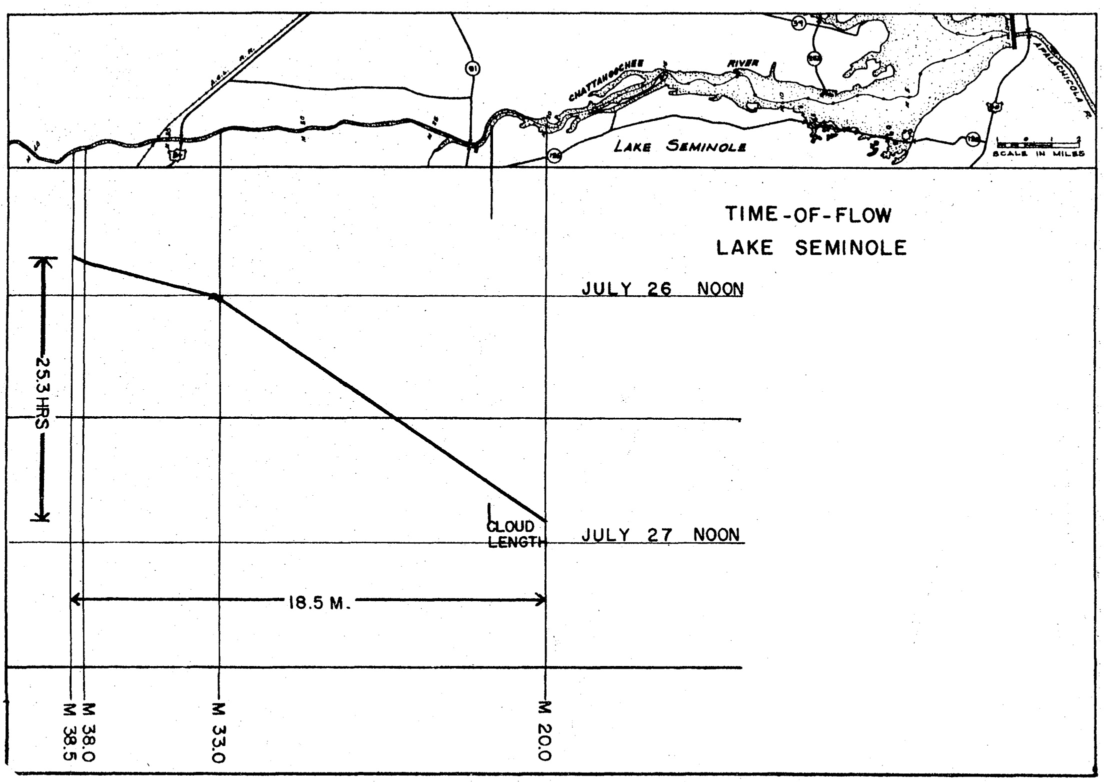


Figure 12. Time-of-flow of fluorescent dye in Chattahoochee river below the Columbia Dam.

Table 2

Averaged resistivity values of Lake Eufaula waters by regions and depths for 1965, 1966, and 1967

			Averaged ohms/cm^3 for given depths				
Region	Yr.	Component	0'	20'	40'	60'	80'
Upper	65	Resistivity	15153	14788	15843		
	66		17289	17281	18416		
	67		17699	17233	17150		
Middle	65		17185	17657	17483	16250	
	66		16716	17127	16446	15945	
	67		17441	17044	18055	16560	
Lower	65		16522	15700	16200	14633	17957
	66		17355	17891	17380	16657	16000
	67		16800	16700	16400	16900	15500

Table 3

Averaged resistivity values for waters at different depths in tributary creeks of various regions of Lake Eufaula in 1965, 1966, and 1967

			Averaged ohms/cm^3 for given depths	
Region			0'	Near bottom
Upper	65	Resistivity	18500	-
	66		17065	19450
	67		18608	16850
Middle	65		14450	13705
	66		16555	12395
	67		16482	14900
Lower	65		-	-
	66		18625	14050
	67		17750	18866

pH. - The averaged data on pH for each station and depth within each lake region for each year are given in Appendix Tables 1-A, 1-B, 1-C.

Surface water pH's were fairly constant for the entire length of main reservoir throughout the 3-year period as shown below. Of more importance was the fact that at no time did these pH values vary beyond the range from 5.5 to 9.0. Deeper water areas within the reservoir showed a slight decrease in pH values, but these were still within the safe and desirable range for aquatic life.

It should be noted that the pH range within creeks was no wider than for the main reservoir.

Region	Year	Averaged pH for given depths				
		0′	20′	40′	60′	80′
Upper	65	7.25	6.65	6.74		
	66	7.40	7.15	7.10		
	67	7.28	6.60	6.51		
Middle	65	7.26	6.72	6.78	6.75	
	66	7.67	7.18	7.08	7.03	
	67	7.44	7.09	6.79	6.85	
Lower	65	7.90	7.05	6.79	6.66	6.90
	66	8.00	7.52	7.27	7.20	7.19
	67	7.75	6.75	6.45	6.80	6.35

Potassium and Sodium - The data collected on the concentrations of K and Na in waters of Lake Eufaula and its tributaries throughout the 2 1/2-year study period are summarized in Appendix Tables 2A, 2B,and 2 C . While some variations in concentrations for each of these elements existed from station to station for each year, these variations are of such random nature as to indicate only changes that might be associated with river-flow-rates (dilution).

The averaged K concentrations, as ppm, by depths for each region and year were as follows:

Region	Year	K ppm				
		0'	20'	40'	60'	80'
Upper	65	1.82	2.07	1.75		
	66	1.93	1.85	2.07		
	67	1.74	1.15	2.28		
Middle	65	1.65	1.74	1.81	1.88	
	66	1.92	1.94	2.00	1.98	
	67	1.43	1.35	1.45	1.46	
Lower	65	1.60	1.63	1.62	1.68	1.55
	66	1.81	1.95	1.75	1.97	1.54
	67	1.40	1.42	1.43	1.05	2.00

The average K concentrations, as ppm, by depths for tributary streams within each region and year were as follows:

Region	Year	K ppm	
		0'	near bottom
Upper	65	1.00	-
	66	2.58	1.81
	67	1.36	1.44
Middle	65	2.10	1.99
	66	1.63	1.69
	67	1.30	1.36
Lower	66	1.63	1.61
	67	1.15	.95

Limited data on seasonal trends of K concentrations for 1967 indicated there was a slightly greater concentration of this element during summer period than for the spring period as shown below:

	Spring	Summer			
	0' - 40'	0'	20'	40'	60'+
K ppm	1.33	1.74	1.64	1.99	1.53

These differences might also have been due to dilution as mentioned previously.

The averaged Na concentrations as ppm by depths for each region and year were as follows:

		Na ppm				
Region	Year	0'	20'	40'	60'	80'
Upper	65	6.49	6.50	5.80		
	66	5.10	4.40	4.49		
	67	5.38	4.90	5.36		
Middle	65	4.00	3.96	4.08	4.12	
	66	4.91	4.91	4.91	4.29	
	67	5.34	5.10	5.22	5.32	
Lower	65	7.04	7.86	7.54	4.12	5.88
	66	4.49	4.10	4.20	4.55	3.52
	67	5.33	5.31	5.00	4.19	5.25

The averaged Na concentrations as ppm by depths for tributary streams within each region and for each year were as follows:

		Na ppm	
Region	Year	0'	Near bottom
Upper	65	2.00	
	66	5.96	4.29
	67	3.83	4.03
Middle	65	6.00	6.68
	66	3.46	3.28
	67	4.88	4.28
Lower	66	3.31	2.60
	67	5.26	3.09

Comparative spring and summer concentrations of Na in Lake Eufaula are given below:

	Spring		Summer			
	0'	40'	0'	20'	40'	60'+
Na ppm	4.50		5.73	5.35	5.35	4.89

Dilution again is suspected in causing these differences in Na concentrations.

With both elements, differences in solubility constants associated with temperature might help account for the decreased concentrations in cooler weather.

Calcium, Magnesium and Total Hardness - Data collected on calcium and magnesium contents in waters from Lake Eufaula and its tributaries during 1965, 1966 and 1967 indicated some degree of variation between depths and stations but there were no drastic changes in yearly averages (Appendix Tables 2-A, 2-B, 2-C and 3-A, 3-B, and 3-C.

During both 1965 and 1966 the total hardness of these river waters was determined by the EDTA compleximeteric method (Table 4) and then calculated from the Ca and Mg contents of these waters. These averaged data on total hardness of waters throughout the reservoir for each year and for each method of determination are shown graphically in Figures 13 and 14.

The variations between EDTA and calculated (from Ca + Mg content) total hardness for any given location are not so great as might be expected at first glance. Suffice it to say that these lake waters are in the very soft category; that portion of calculated total hardness attributed to Mg was consistently between 4.25 and 5.5 ppm $CaCO_3$ equivalent, while the portion attributable to Ca was responsible for the evident variation. The causes of the disagreement in the two methods of determination are not known, but it is suspected that certain naturally occurring constitutents of water in some way interferred with color changes associated with the compleximeteric EDTA method. Since total hardness was of little value in this biological study, its determination by EDTA titration was limited in 1967.

Table 4

Averaged Calcium, Magnesium, and total hardness concentrations of Lake Eufaula waters by regions and depths for 1965, 1966 and 1967

			Averaged concentrations in ppm for given depth(1)				
Region	Year		0'	20'	40'	60'	80'
Upper	65	Ca	3.95	6.42	3.78		
		Mg	1.25	1.23	1.33		
		EDTA	16.73	15.20	15.40		
	66	Ca	4.57	4.77	4.72		
		Mg	1.10	1.15	1.17		
		EDTA	14.73	13.82	14.59		
	67	Ca	2.97	3.52	2.72		
		Mg	1.12	1.14	1.06		
		EDTA	13.11	14.12	13.62		
Middle	65	Ca	3.67	3.88	4.36	4.48	
		Mg	1.42	1.38	1.30	1.50	
		EDTA	15.79	15.82	15.57	17.25	
	66	Ca	4.46	4.48	4.64	5.01	
		Mg	1.22	1.20	1.17	1.16	
		EDTA	14.52	14.63	17.28	17.73	
	67	Ca	3.44	3.41	3.66	2.97	
		Mg	1.14	1.16	1.41	1.16	
		EDTA	13.18	13.58	13.25	13.61	
Lower	65	Ca	4.25	4.34	4.63	4.92	5.34
		Mg	1.39	1.44	1.40	1.35	1.28
		EDTA	15.77	16.13	17.25	18.53	21.56
	66	Ca	4.41	4.85	4.57	4.85	5.33
		Mg	1.18	1.16	1.19	1.19	1.12
		EDTA	15.20	15.57	15.22	16.61	17.90
	67	Ca	3.62	3.70	3.53	4.32	3.82
		Mg	1.22	1.24	1.29	1.10	1.26
		EDTA	14.75	14.25	15.00	17.50	16.50

(1) EDTA = total hardness, expressed as ppm $CaCO_3$

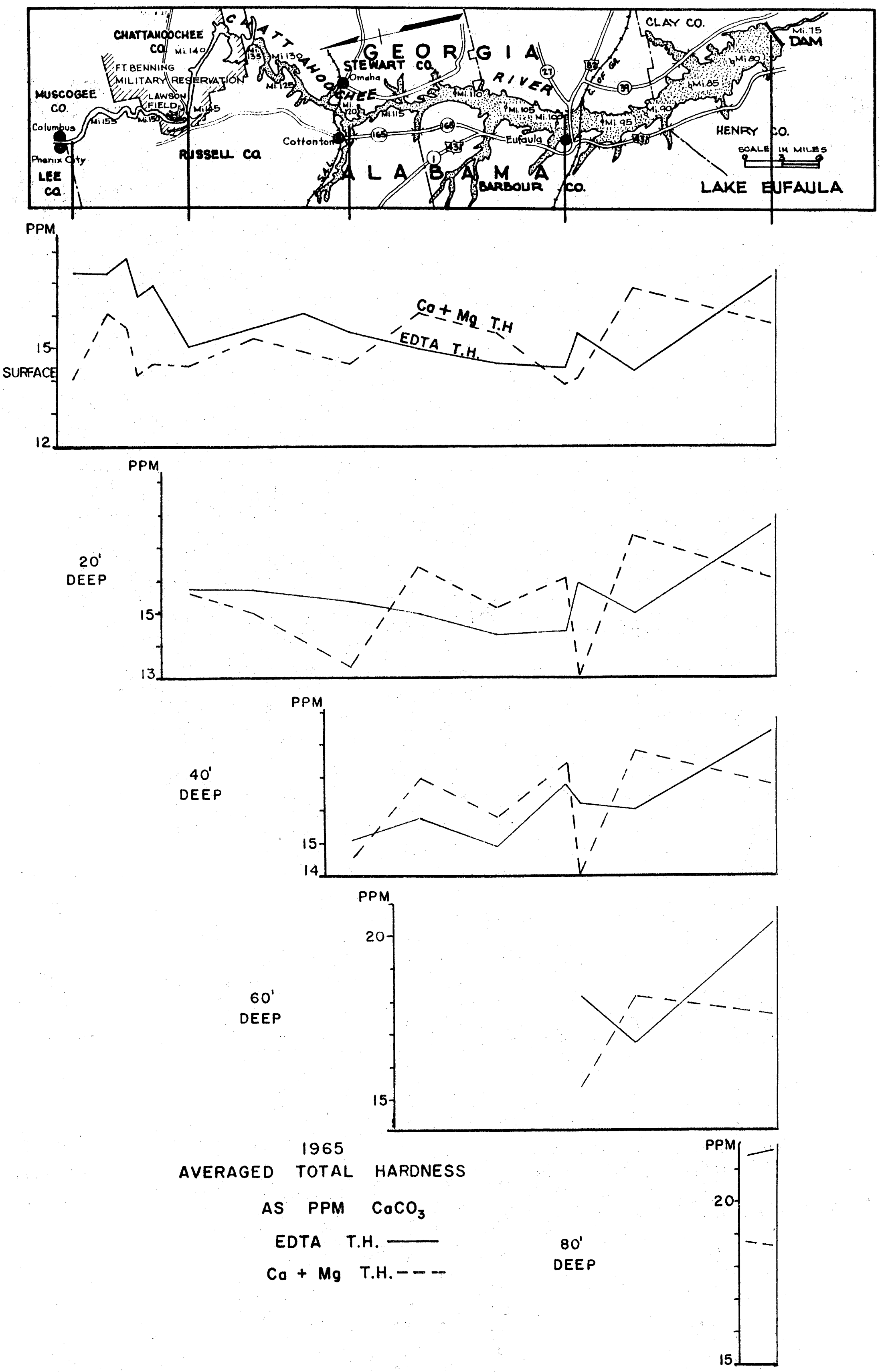


Figure 13. Averaged total hardness of Lake Eufaula waters in 1965 as determined by EDTA titration and calculated from calcium and magnesium content.

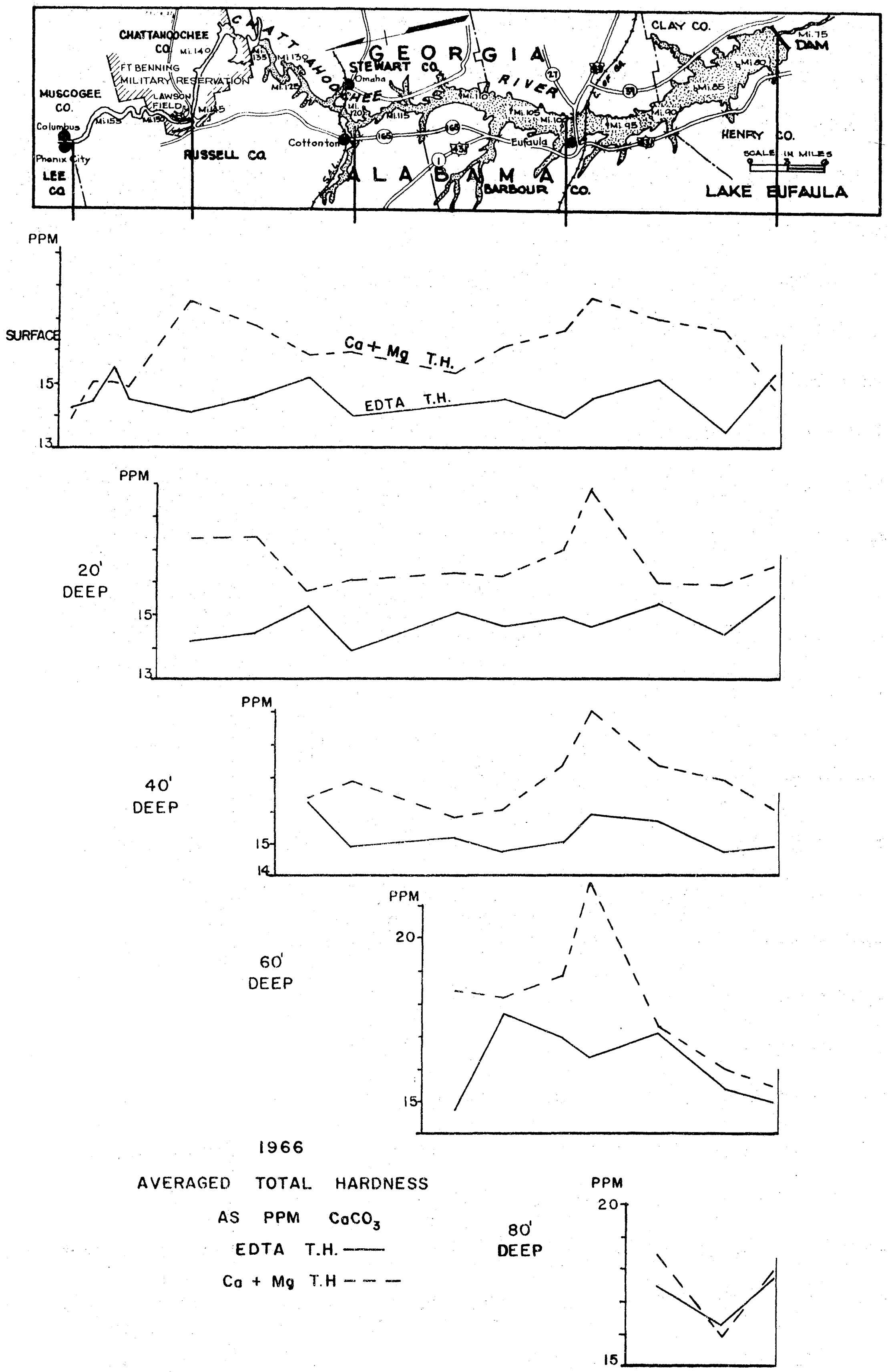


Figure 14. Averaged total hardness of Lake Eufaula waters in 1966 as determined by EDTA titration and calculated from calcium and magnesium content.

One other interesting feature in each of these figures is the change in total hardness concentrations associated with each area in the vicinity of bridges located at mile 98, at mile 120, and at mile 145. These variations apparently resulted from current turbulence created by bridge piers located at various points across the river. However, the mouths of major tributary creeks are also located in these areas, and they may have contributed to these changes in concentrations (Table 5).

Data collected during 1967 and shown below indicated that there was an approximate 40 percent decrease in Ca concentration in waters during summer than was present during the early spring.

	Spring	Summer			
	0 - 40'	0'	20'	40'	60'
Ca ppm	4.04	2.55	2.61	3.04	3.59
Mg ppm	1.18	1.11	1.16	1.12	1.19
EDTA, ppm $CaCO_3$	15.30	13.65	13.80	13.95	15.52

Previous research in plastic pools had indicated that such a condition could occur. However, further collection of data on Ca and Mg contents of these waters on a year around basis is needed to verify this cycle and define its characteristics.

Comparative data on the Ca and Mg concentrations in the Chattahoochee river arm of Lake Seminole are given in Tables 6, 7, and 8 . These data indicate an increase in Ca concentration in water as the river proceeds through the limestone sink areas near the Alabama, Florida, and Georgia state lines. The Mg on the other hand does not increase indicating that these lime sinks are practically pure $CaCO_3$

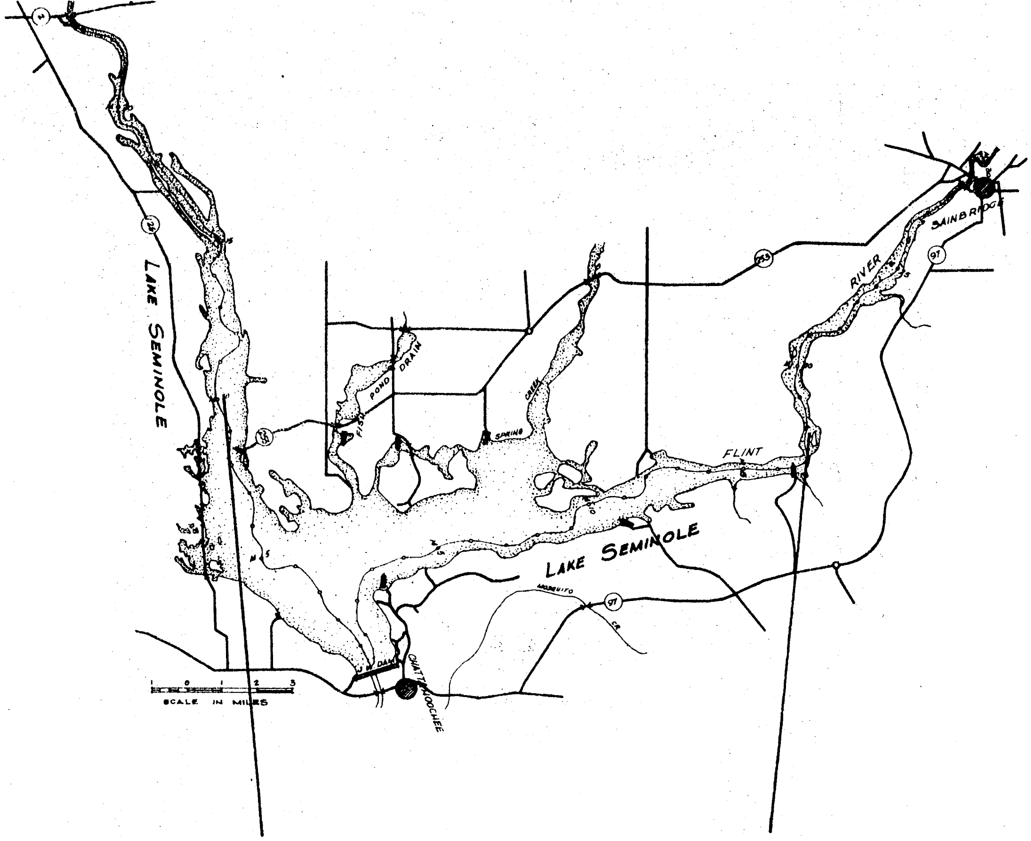
Table 5

Averaged calcium, magnesium and total hardness concentrations of waters at different depths in tributary creeks of various regions of Lake Eufaula in 1965, 1966, and 1967

Region	Year	Component	Averaged concentrations in ppm at given depth	
			0'	Near bottom
Upper	65	Ca	4.92	-
		Mg	1.55	-
		EDTA	20.50	-
	66	Ca	4.45	5.00
		Mg	1.25	1.20
		EDTA	14.85	14.33
	67	Ca	4.50	4.57
		Mg	1.07	1.07
		EDTA	13.00	13.00
Middle	65	Ca	4.14	6.19
		Mg	1.35	1.29
		EDTA	21.15	22.61
	66	Ca	7.40	9.82
		Mg	1.05	1.17
		EDTA	18.28	24.31
	67	Ca	4.16	5.90
		Mg	1.11	1.11
		EDTA	14.75	19.20
Lower	65	Ca	-	-
		Mg	-	-
		EDTA	-	-
	66	Ca	4.27	9.65
		Mg	1.07	1.10
		EDTA	16.00	34.95
	67	Ca	3.00	4.60
		Mg	1.06	.86
		EDTA	15.00	18.25

Table 6

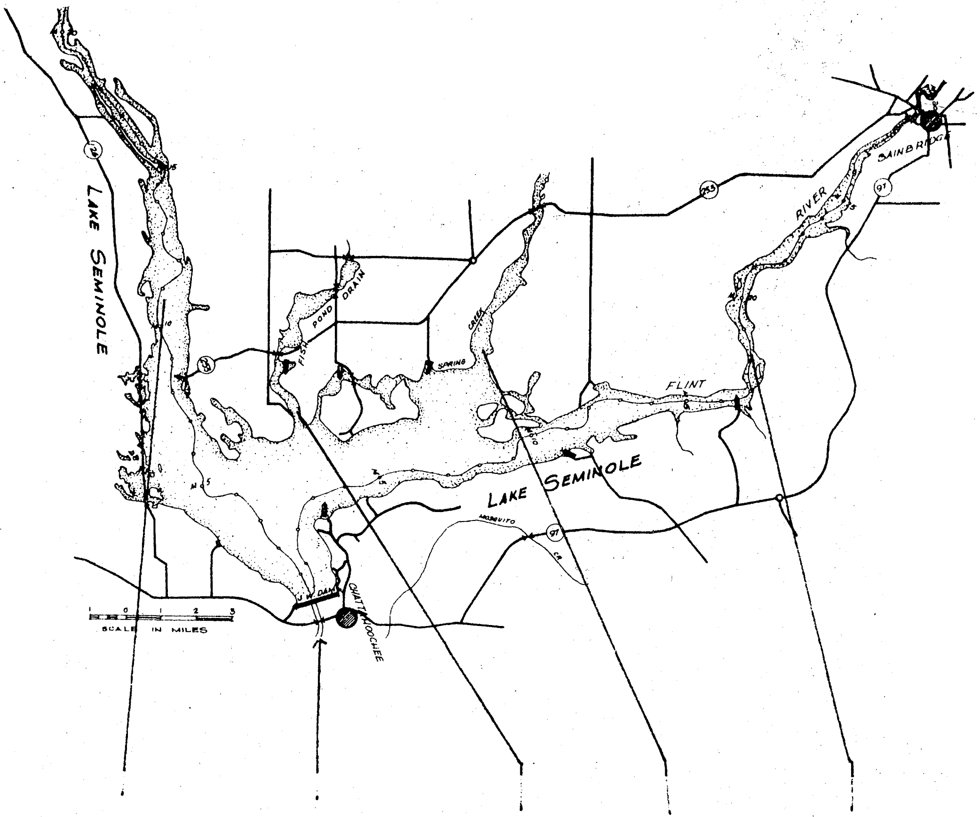
Averaged composition of waters from various regions of Lake Seminole in 1965



Depth, feet	0-30	0-20
pH	7.30	6.84
Total alk, ppm $CaCO_3$	28.26	58.1
Resistivity, ohms/cm	14052	7911
Total hard, ppm $CaCO_3$	26.37	56.6
Ca, ppm $CaCO_3$	7.59	19.8
Mg, ppm	1.18	1.13
Na, ppm	7.36	7.6
K, ppm	1.58	.89
Zn, ppm	.058	.013
Cu, ppm	.024	.039
Fe, ppm	.24	.444
Mn, ppm	.023	.022
N, as ppm NH_3	.319	.194
P, ppm	.020	.044
Total C, ppm	14.08	17.09
Total chlorides, ppm	5.85	5.43
Total Sulfates, ppm	6.47	2.78
Turbidity, nephlos	26.5	24.4

Table 7

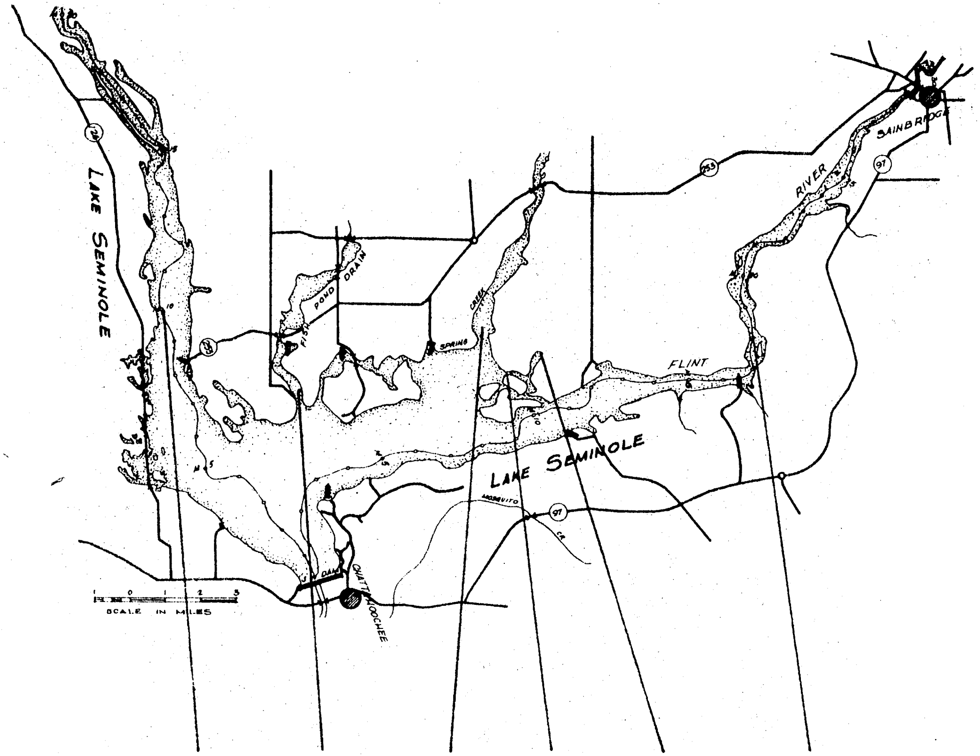
Averaged composition of waters from various regions of Lake Seminole in 1966



Depth, feet	0-30	0-10	0-10	0-20	0-30
pH	7.43	7.64	7.73	8.14	7.66
Total alk, ppm $CaCO_3$	23.62	46.43	39.84	82.2	33.75
Resistivity, ohms/cm	16418	8512	11900	6718	11194
Total hard, ppm CaCO3	20.37	45.2	37.10	80.63	34.2
Ca, ppm $CaCO_3$	7.19	14.6	18.95	37.68	12.82
Mg, ppm	1.09	1.23	.91	.77	.94
Na, ppm	5.04	2.89	1.78	2.28	2.74
K, ppm	1.60	.73	.48	.62	1.22
Zn, ppm	.033	.023	.001	.011	.166
Cu, ppm	.006	.004	-	.003	.013
Fe, ppm	.72	.38	.055	.083	2.09
Mn, ppm	.038	.019	.045	.07	.043
N, as ppm NH_3	.209	.251	.11	.29	.104
P, ppm	.008	.01	-	.001	.028
Total C, ppm	14.43	-	16.88	25.0	16.9
Soluble C,ppm	8.66	-	-	10.44	9.4
Particulate C, ppm	3.97	-	-	-	7.36
Total chlorides, ppm	4.08	4.02	-	3.67	4.22
Total Sulfates, ppm	8.44	3.5	3.5	2.35	5.94
Turbidity - JTU	17.0	4.4	2.0	4.1	22.6

Table 8

Averaged composition of waters from various regions of Lake Seminole in 1967



Depth, feet	0-25	0-15	0-25	0	0	0-20
pH	7.28	7.05	7.38	7.59	-	6.98
Total alk, ppm $CaCO_3$	25.0	54.04	81.06	56.53	48.33	44.50
Resistivity, ohms/cm	13492	8435	7243	9323	10700	9680
EDTA hard, ppm $CaCO_3$	-	52.25	83.27	50.87	-	49.25
Ca, ppm	4.4	17.55	23.60	18.77	15.47	10.44
Mg, ppm	1.25	.93	.49	.91	1.55	.78
Na, ppm	5.67	2.52	2.15	2.53	2.31	3.12
K, ppm	2.21	.43	.30	.49	.39	.60
Zn, ppm	.161	.013	.019	.075	.022	.020
Cu, ppm	.015	.007	.007	.024	.042	.004
Fe, ppm	.185	.055	.140	.072	.060	.230
Mn, ppm	.034	.022	.014	.026	.017	.013
N, as ppm NH_3	.188	.215	.165	.225	-	.190
P, ppm	.103	.068	.037	.032	-	.046
C_T, ppm	12.58	18.44	26.62	18.42	23.00	14.90
C_{-CO_2}, ppm	10.38	9.20	12.00	12.44	17.30	6.60
C_S, ppm	8.21	16.90	20.48	13.80	9.50	12.55
Total chlorides, ppm	6.85	5.47	5.45	5.47	-	5.65
Total Sulfates, ppm	6.00	3.10	2.62	2.75	-	3.60
Turbidity - JTU	5.16	1.34	1.74	1.40	1.87	5.20
Sr, ppm	.007	.012	.015	.025	.012	.013
Pb, ppm	-	.180	.032	.014	.071	-

in composition.

Additional data on the Ca and Mg concentration in the Flint River and Spring creek arms of Lake Seminole are also given in Tables 6, 7, and 8 . These data are presented for later comparative use in regards to aquatic plant chemical composition from various regions of both reservoirs.

Data on ranges of concentrations of Ca and Mg in Bartlett's Ferry Reservoir are given in Table 9. These data indicate the same general trends in Ca and Mg contents of Chattahoochee river waters as has been presented for Lake Eufaula.

Table 9

Ranges in composition of waters from Bartlett's Ferry Reservoir during 1967

Depth, feet	0	25
JTU	10-72	11-85
pH	7.8-10.2	6.8-7.9
Alk. ppm $CaCO_3$	15.0-17.5	13.75-16.25
$Ohms/cm^3$	17100-21000	17500-18500
EDTA hard. ppm $CaCO_3$	14.5-15.0	15.0-16.5
Ca ppm	3.2-6.2	2.9-5.0
Mg	.81-1.2	1.07-1.15
Na	5.6-6.8	6.0-7.2
K	1.12-1.42	1.2-1.3
Zn	.17-1.83	.2-1.75
Cu	.18-.20	.19-.20
Fe	.15-1.50	.10-1.70
Mn	.01-.10	.03-.21
N as NH_4	.14-.26	.07-.40
P	.005-.36	.005-.19
C_T	7.0-11.2	9.0-10.6
Pb	.05-.10	.05-.18
Sr	.005-.015	.012-.016

Alkalinity - The averaged data on alkalinity, expressed as ppm $CaCO_3$, for each station and depth within each lake region are presented in Appendix Tables 3-A, 3-B, and 3-C.

Alkalinity, showed a decline in concentrations throughout the study period. The most drastic change occurred between 1965 and 1966 as indicated in Table 10. This decline in alkalinity is believed to have resulted from a reduction in decomposition of flooded vegetation.

Table 10

Averaged total alkalinity, as ppm $CaCO_3$, concentrations of Lake Eufaula waters by regions and depths for 1965, 1966, and 1967

Region	Year	Averaged alkalinity, ppm, for given depths[1] 0'	20'	40'	60'	80'
Upper	65	24.50	26.70	23.03		
	66	18.58	17.07	17.13		
	67	18.70	16.67	17.58		
Middle	65	20.86	21.44	23.12	27.85	
	66	18.05	17.11	17.74	17.42	
	67	17.83	18.33	18.75	18.12	
Lower	65	25.62	20.73	23.44	23.28	29.42
	66	18.93	17.96	19.07	20.27	23.50
	67	19.06	19.06	19.06	20.00	18.75

(1) Alkalinity = Total alkalinity, titrated to pH 5.2 and expressed as ppm $CaCO_3$.

Turbidity - The averaged measurements on concentrations of suspended matter in lake waters, expressed as nephlo units for 1965 and as Jackson turbidity units (JTU) for 1966 and 1967, are given in Appendix Tables 3-A, 3-B, 3-C.

To better understand the changes in turbidity associated with portions and depths of this reservoir, these averaged data are summarized below:

			Depth			
Region		Year	0'	20'	40'	60'+
Upper	Nephlo	65	20.8	29.7	25.0	
	JTU	66	13.3	20.4	30.7	
	JTU	67	14.8	16.3	20.7	
Middle	Nephlo	65	36.9	43.7	57.1	51.0
	JTU	66	11.6	20.2	19.2	21.3
	JTU	67	10.6	12.8	11.9	15.8
Lower	Nephlo	65	11.5	18.4	23.2	40.0
	JTU	66	4.7	6.2	7.2	8.9
	JTU	67	3.6	4.7	6.7	8.7

From these data it is readily evident that the suspended matter in upper and middle regions was much greater in waters at all depths than in lower region. The values for the upper and middle regions of the reservoir might have been slightly higher or lower depending upon the suspended matter content on a particular sampling date.

Based upon these data it would appear that turbidity has decreased over the 3-year period of this study. The decrease may also be a chance occurrence, but it is a fact that during the early 1930's the waters in upper region often approached 400 JTU's. Thus, there has been a great stabilization of soils in this drainage area in recent years as evidenced by these 3-year data.

All related data plus visual observations on lower region of Lake Eufaula throughout this study period indicate that surface water turbidity was due to microscopic plant growths, but at lower depths a major portion of the turbidity resulted from colloidal materials, such as iron, and decomposing plant materials with a smaller amount being due to soil colloids and other particles.

Averaged data on turbidity of surface and near-bottom waters of tributary streams within each portion of reservoir during 1965, 1966, and 1967 are given below.

Region	Year		Averaged turbidity for given depths	
			0'	near bottom
Upper	65	Nephlos	33.0	
	66	JTU	16.0	20.0
	67	JTU	9.2	20.0
Middle	65	Nephlos	14.5	21.9
	66	JTU	8.4	15.2
	67	JTU	8.1	21.4
Lower	65			
	66	JTU	5.7	21.2
	67	JTU	6.2	27.1

Iron (Fe) and Manganese (Mn) - Data collected on Fe and Mn concentrations in waters of Lake Eufaula during 1965, 1966, and 1967 varied for different depths and stations as indicated by the averages given in Appendix Tables 4-A, 4-B, 4-C. At times there were even greater variations between sampling data which is not readily evident from data in these tables.

The data given for 1965 were obtained from samples filtered through No. 42 filter paper while those data for 1966 and 1967 are for unfiltered waters (Table 11). However, during 1966 and 1967 determinations of Fe were made on unfiltered and filtered (through 8 u millipore filter) waters. The differences in these Fe contents for 1966-67 are shown in Table 12. They appear to be of the same general order as the differences between the 1965 and 1966-67 data (Table 11).

The higher concentrations of Fe indicated for the upper and middle regions of the reservoir (in 1966-67) were due primarily to iron carried by mud particles. This provides support for the theory

Table 11

Averaged iron and manganese concentrations of Lake Eufaula waters by regions and depths for 1965, 1966, and 1967

			Depth				
Region	Year	Component	0'	20'	40'	60'	80'
Upper	65	Fe ppm	.125	.110	.117		
		Mn	.030	.038	.021		
	66	Fe	.556	.850	.780		
		Mn	.079	.102	.152		
	67	Fe	.496	.477	.740		
		Mn	.023	.038	.040		
Middle	65	Fe	.132	.155	.160	.357	
		Mn	.012	.024	.022	.174	
	66	Fe	.587	.870	.983	1.173	
		Mn	.073	.063	.305	.323	
	67	Fe	.471	.373	.476	.692	
		Mn	.016	.031	.064	.081	
Lower	65	Fe	.070	.120	.141	.061	.260
		Mn	.045	.033	.038	.135	.067
	66	Fe	.187	.200	.345	.562	1.290
		Mn	.050	.080	.145	.225	.950
	67	Fe	.107	.033	.205	.400	.175
		Mn	.011	.018	.048	.105	.050

Table 12

Averaged percentages of removable Fe and Mn from waters of Lake Eufaula as determined from concentrations determined for raw and filtered waters

Region	Year	ppm Fe raw water	ppm Fe filtered water	% removable Fe
Upper	'66	.816	.461	43.5
	'67	.885	.231	73.9
Middle	'66	.670	.346	48.4
	'67	.619	.167	73.0
Lower	'66	.573	.316	44.9
	'67	.187	.061	67.4
Creeks	'67 (0')	.415	.152	63.4
	(bottom)	1.403	.308	78.1

Region	Year	ppm Mn raw water	ppm Mn filtered water	% removable Mn
Upper	'66	.121	.019	84.3
	'67	.036	.005	86.1
Middle	'66	.085	.050	41.2
	'67	.056	.016	71.4
Lower	'66	.186	.076	59.3
	'67	.034	.012	64.7
Creeks	'67 (0')	.031	.005	83.9
	(bottom)	.079	.052	34.2

that the portion of reservoir above mile 98 functions as a settling basin and that the portion between miles 98 and 75 is a clearer water area.

It will be noted that at 20 + foot depths the data indicate a relatively greater concentration of Fe than was detected in surface waters. Some portion of this increased Fe content was due to underrunning of muddy waters in the lower half of the reservoir. However, much of this increased concentration is believed to have resulted from suspension of colloidal forms of iron. This situation seemingly was enhanced by D.O. deficiency which converted the precipitated ferric (Fe^{+++}) form on the bottom to soluble ferrous (Fe^{++}) forms, allowing more Fe to be in solution, then when an aerobic condition occurred the ferrous iron was converted to colloidal ferric iron which remained in suspension for indefinite periods.

Manganese did not occur in either the concentrations or in the same general trend as was evidenced for iron. There was no conclusive evidence that manganese content of water was associated with muddiness. In fact, the data seemingly indicates that in surface waters muddiness decreased the Mn content, and that increased concentrations of Mn were associated with growths of phytoplankton.

In deeper water areas, D.O. deficiency apparently brought about the conversion of precipitated manganic (Mn^{+++}) form to the soluble manganous (Mn^{++}) form, but only in limited amounts when compared with iron under the same conditions (Table 12). Unlike the iron, when the stratified area became aerobic, the manganous form again precipitated on the hydrosol.

The following are averaged ratios of Fe to Mn in Lake Eufaula waters for 1965, 1966, and 1967:

1965	3.35 to 1.0
1966	4.12 to 1.0
1967	11.54 to 1.0

These ratios indicate that stratification was much more evident in 1965 and 1966 than it was in 1967.

Zinc and Copper - The averaged concentrations data on Zn and Cu are summarized for each year in Appendix Tables 4-A, 4-B, 4-C. While the total concentrations are generally in the ppb range, the variations are often many-fold different between years for same station and between stations for a given year.

The data for 1965 were all obtained on waters that had been passed through No. 42 filter paper, thus accounting for generally lower values of Zn reported in the tabular data particularly those for the river-run areas of the reservoir. In 1966 and 1967 the data shown in aforementioned tables are for Zn concentrations in raw river waters. In each of these years the waters were passed through 8 u millipore filter and the concentration of Zn in the filtrate was obtained. In order to more fully understand the data on filterable Zn from those river waters, the averaged removal of Zn for the upper, middle, and lower regions of reservoir are given below:

Region	Year	ppm Zn raw water	ppm Zn filtered water	% removable Zn
Upper	'66	.062	.024	61.3
	'67	.040	.022	45.0
Middle	'66	.070	.026	62.9
	'67	.749	.434	42.1
Lower	'66	.027	.011	59.3
	'67	.426	.227	46.7
Creeks	'67 0'	.038	.012	68.4
	Bottom	.052	.016	69.2

It is most interesting to note that Zn concentrations increased in the middle portion of reservoir in 1967 and that this increase carried over into lower portion. The suspect source of this Zn was from condenser, and other piping of a new paper mill located at the extreme upper end of middle portion. This concentration will be expected to decrease with time since the amount of soluble Zn in tubing, etc., should decrease after several months flushing with water.

The averaged Cu content of raw and filtered lake waters and percent of removable Cu by filtration are shown below:

Region	Year	ppm Cu raw water	ppm Cu filtered water	% removable Cu
Upper	'66	.019	.014	24.3
	'67	.024	.017	29.2
Middle	'66	.025	.015	40.0
	'67	.011	.009	18.2
Lower	'66	.024	.010	58.3
	'67	.028	.015	46.4
Creeks	'67 0'	.017	.015	11.8
	Bottom	.016	.013	18.7

These data indicate only a random variation associated with overall lake conditions during these 2 years.

Nitrogen and Phosphorus - The data collected on N as ammonia (NH_4) and P as orthophosphates in waters of Lake Eufaula are summarized in Appendix Tables 5-A, 5-B, 5-C. It is obvious from the analytical methods used that these data did not account for the total N or P content in these raw waters. That considerable variation existed between analyses for each element is evident in each table.

The averaged concentrations of N as NH_4 during cool months was slightly less than for the summer months as indicated by the averaged data for 1967:

	Cool months	Summer months			
	0' to 40'	0'	20'	40'	60'+
N ppm	.219	.237	.213	.435	.332

Comparative averaged N as NH_4 concentrations by depths for each year were as follows:

	0'	20'	40'	60'+
1965 N ppm	.2077	.2463	.2777	.3250
1966 N ppm	.2094	.2171	.2728	.3285
1967 N ppm	.2365	.2189	.4351	.3132

The increased NH_4 concentration associated with water depth is a normal phenomenon, however, these marked increases at lower depths are also associated with a part of the middle portion and the lower portion of reservoir. The highest value, 0.4351 ppm N as NH_4 at the 40-foot depth in 1967, is believed to have resulted from drainage from a large hog-farm operation on the Georgia bank in middle portion of reservoir. Similar high data on total N have been obtained for this same area in 1966 by Alabama Kraft Company personnel.

Comparative data on concentrations of N as NH_4 in tributary creeks on Lake Eufaula were as follows:

	0'	near bottom
1965 N ppm	.135	.229
1966 N ppm	.193	.214
1967 N ppm	.327	.343

The increased N content of surface waters in main reservoir and in tributary creeks in 1967 can only be attributed to the continuous mixing of these surfaces and lower waters resulting from the cooler weather and lack of stratification.

The averaged concentrations of orthophosphates during cool months was several fold less than those existing in summer months of 1967 as indicated by following data:

	Cool months		Summer months		
	0' to 40'	0'	20'	40'	60'+
P ppm	.015	.092	.097	.092	.083

Comparative averaged P as orthophosphate concentrations by depths for each year in main reservoir were as follows:

	0'	20'	40'	60'+
1965 P ppm	.024	.043	.029	.034
1966 P ppm	.011	.011	.009	.018
1967 P ppm	.067	.070	.063	.082

The explanation of decreased P content of waters during cool weather is unknown, but could have been an interaction between cool water temperatures, excessive clay colloid content of these waters, and increased flow.

Averaged data on P as orthophosphate content of surface and near bottom waters from tributary creeks were as follows:

		0'	Near bottom
1965	P ppm	.037	.039
1966	P ppm	.006	.011
1967	P ppm	.049	.069

No logical causes for the decreased P content in main reservoir and in tributary streams in 1966 are known.

Total carbon and CO_2- free carbon - The data collected on the total carbon content of raw waters from Lake Eufaula during period from July 1965 through September 1967 are summarized by stations and depths in Appendix Tables 5-A, 5-B, 5-C. Data collected in 1967 on CO_2-free carbon content of raw waters are also summarized in the same tables.

Trends in total carbon contents of lake waters in 1965 and 1966 are shown in Figure 15. The decrease in total carbon content in river waters above mile 120 in 1966 was assumed to have resulted from the improved sewage treatment facilities put into operation by Columbus, Georgia and Phenix City, Alabama in late 1965. Data on remaining portions of reservoir are practically the same for 1965 and 1966 and are only slightly higher than those obtained for 1967 as shown below:

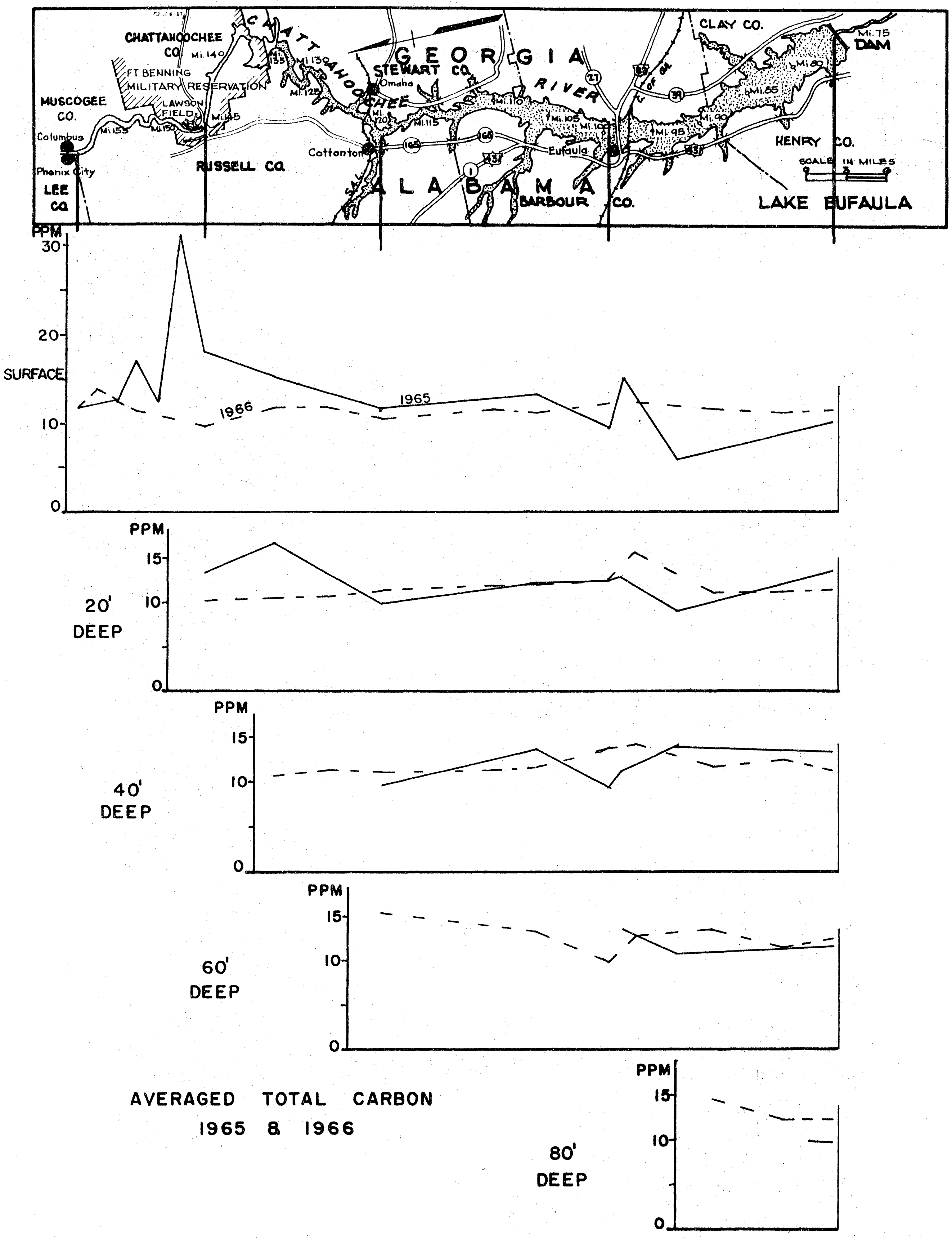


Figure 15. Averaged total carbon contents of waters at various depths for entire length of Lake Eufaula for 1965 and 1966.

	0'	20'	40'	60'+
1965 C ppm	12.26	12.46	13.17	11.21
1966 C ppm	11.56	11.17	12.61	13.42
1967 C ppm	10.09	10.11	9.95	10.43

These data all indicate that the domestic, agricultural, and industrial effluents entering this reservoir are relatively devoid of organic matter, and more importantly, the condition has improved each year.

The CO_2-free carbon contents of these lake waters for 1967 were the following percentages of total carbon contents of raw lake waters:

upper region	46%
middle region	37%
lower region	55%

The remaining averaged soluble + particulate carbon (CO_2-free carbon) contents of these waters were as follows:

upper region	5.54 ppm C
middle region	6.11 ppm C
lower region	4.80 ppm C

Based upon CO_2-free carbon - C.O.D. relationship established by Dr. G. N. Greene of the Farm Ponds Project, Auburn University, these waters had such a low C.O.D. value that they gave a calculated negative value. Further support of this condition was obtained by Alabama Kraft Company Water Quality Laboratory on B.O.D. The average of bi-weekly 5-day B.O.D. tests for the upper and middle regions of reservoir for 1967 was approximately 2 ppm O_2. Thus, only 0.6

ppm of this CO_2-free carbon was decomposable into CO_2.

Based upon total CO_2-free carbon contents of fertilized ponds these lake waters are very devoid of microscopic plant growth. This condition had already been indicated by presence of relatively large concentrations of soluble NH_4 and P in these lake waters. The tributary streams were also generally low in total CO_2-free carbon content as indicated by Table 13.

Chemical Composition of Suspended Matter in Water - As previously mentioned, the technique for separation and analyses of suspended matter in lake water was developed in mid-summer of 1967 and only a limited amount of these data are available for inclusion in this report. These averaged data are presented in Tables 14, 15, 16 and 17. It is to be noted that these data are in ppm for each element as it occurred in the sample of water. Therefore, these values can be compared directly with raw water and filtered water chemical content.

A number of interesting relationships are evident in these data. Since the data are limited, these relationships will have to be considered only as possibilities. Yet, they do indicate that these selected elements vary considerably in the suspended matter of water over distance as well as time in Lake Eufaula.

Calcium concentrations in suspended matter decreased throughout main reservoir during August and then increased during September. Similar analyses of phytoplankton removed from ponds during August indicated an even greater decline in Ca content, and only a slight recovery in September.

Table 13

Averaged total carbon content at surface and near bottom in tributary streams of 3 regions of Lake Eufaula during 1965, 1966, and 1967

Region	Year	Component	Averaged concentration in ppm at given depths	
			0′	near bottom
Upper	65	C_T	-	-
	66	C_T	10.9	10.9
	67	C_T	9.5	9.6
		C_{-co2}	4.91	4.45
Middle	65	C_T	21.0	19.7
	66	C_T	12.7	17.0
	67	C_T	10.5	13.9
		C_{-co2}	6.71	8.32
Lower	65	C_T	-	-
	66	C_T	11.0	15.8
	67	C_T	11.7	17.7
		C_{-co2}	6.97	9.07

Table 14

Averaged chemical element composition of suspended matter collected on August 3, August 9, and August 16, 1967 between river miles 120 and 98

	August 3		August 9			August 16	
Depth	0'	40'	0'	20'	40'	0'	40'
Ca ppm	.318	.386	.225	.167	.335	.093	.092
Mg ppm	.093	.147	.090	.072	.171	.043	.039
Na ppm	.093	.085	.071	.057	.080	.222	.131
K ppm	.340	.400	.245	.210	.330	.390	.372
Zn ppm	.132	.104	.043	.046	.049	.129	.098
Mn ppm	.125	.129	.110	.100	.164	.057	.087
Fe ppm	.835	.941	.787	.627	.950	.574	.526
Cu ppm	.202	.194	.119	.100	.122	.140	.123
Pb ppm	.015	.023	.016	.014	.015	-	-
JTU	13.3	19.0	12.5	16.5	20.0	8.6	10.9
Mg/l dry wt.	16.06	22.38	15.17	19.61	23.49	10.85	13.40
Sr ppm	.0013	.0016	.0025	.0009	.003	-	-

Table 15

Averaged chemical element composition of suspended matter collected August 9 and September 20, 1967 between Columbus, Georgia and river mile 120

	August 9			Sept. 20
Depth	0'	20'	40'	0'
Ca ppm	.292	.306	.319	1.221
Mg ppm	.116	.138	.170	.068
Na ppm	.075	.088	.077	.224
K ppm	.283	.337	.405	.415
Zn ppm	.076	.080	.024	.134
Mn ppm	.133	.140	.159	.029
Fe ppm	.788	.763	.950	.573
Cu ppm	.130	.136	.095	.052
Pb ppm	.018	.017	.012	.016
Cr ppm	-	-	-	.032
Ni ppm	-	-	-	.006
Co ppm	-	-	-	.0009
Cd ppm	-	-	-	.0009
JTU	13.0	16.1	19.0	7.5
Mg/l dry wt.	15.73	19.16	22.38	9.63
Sr ppm	.0014	.0017	.0021	.0013

Table 16

Averaged chemical element composition of suspended matter collected on August 29, 1967 between river mile 98 and Walter F. George Dam

Depth	0'	20'	40'	60'
Ca ppm	.195	.197	.213	.205
Mg ppm	.014	.014	.020	.019
Na ppm	.079	.083	.085	.081
K ppm	.226	.236	.220	.185
Zn ppm	.120	.126	.105	.097
Mn ppm	.020	.035	.074	.185
Fe ppm	.337	.225	.316	.443
Cu ppm	.146	.150	.159	.146
Pb ppm	.0016	.0018	.001	.002
Cr ppm	.0077	.0025	.004	.0095
Co ppm	.0001	.0003	.0017	.0005
JTU	7.33	9.0	10.7	11.75
Mg/l dry wt.	9.44	11.30	13.18	14.34
Sr ppm	.0001	.0001	.0001	.0001

Table 17

Averaged chemical element composition of suspended matter collected on August 16 and 29, 1967 from tributary creeks on Lake Eufaula

	August 16		August 29	
Depth	0'	25'	0'	25'
Ca ppm	.080	.098	.177	.306
Mg ppm	.026	.036	.014	.043
Na ppm	.168	.128	.092	.087
K ppm	.257	.300	.273	.253
Zn ppm	.124	.149	.092	.103
Mn ppm	.036	.057	.018	.134
Fe ppm	.349	.601	.130	1.390
Cu ppm	.161	.105	.159	.140
Pb ppm			.003	.005
Cr ppm			.022	.028
Co ppm			.0005	.0001
JTU	7.5	15.3	4.2	28.0
Mg/l dry wt.	9.63	18.28	5.98	32.35
Sr ppm	-	-	.0002	.0001

In addition to the reduction in Ca content, there was a comparable decrease in Mg and Fe content and a lesser decrease in Mn and K content in August. All of these elements varied concurrently in an apparrently related manner.

In contrast, the Cu content remained fairly consistent both in time and in location within the suspended matter from main reservoir. Zinc concentrations increased with time and in location. It is not understood exactly what is the source or, more importantly, the significance of what appears to be a relatively high concentration of Cu and Zn in the suspended matter from this reservoir.

An examination of elemental content of suspended matter from tributary creeks indicates a greater degree of chemical variation between samples of surface and bottom waters than was evident in main reservoir during 1967. This difference was attributed to more stratified condition within creeks in 1967 than was evidenced in main reservoir.

In all of these suspended matter samples there was a detectable amount (generally above 10 ppb) of Pb and Cr. In those samples from main reservoir the Pb content appeared to be greater, whereas in the tributary creeks the Cr content was higher. Neither the source nor significance of these two elements are understood.

While the discussion of these data has been limited, this is an area of research that has here-to-fore been ignored but is a most important aspect of reservoir water chemistry. Needless to say, much effort will be expended during next two years to develop and refine techniques and to accumulate sufficient data to gain some insight into the role of these chemicals in the suspended matter and particularly in attempting to separate the colloidal, dead and living suspended matter.

Light penetration , which is a physical factor dependent upon the degree of water turbidity, was measured at irregular intervals but under sufficiently different water conditions to give an understanding of the variations of light intensities within these surface waters. These data are presented as foot-candles of surface illumination, and as foot-candles and percentage of surface illumination for the various water depths, in Table 18.

Table 18

Foot-candles of illumination at surface and at various water depths in Lake Eufaula, with corresponding percentage values of surface light concentrations at the given depths, and including turbidity values, in parenthesis, under appropriate water depths for specific locations and dates indicated

Location river mile	Date	Turbidity (1)	Foot-candles light/percent surface illumination at various depths					
			0'	1'	2.5'	5'	7.5'	10'
138	7-20-65	(N)	8400 (19)		2239/26.6	46/0.5		2/.002 (53)
129	7-20-65	(N)	10000 (40)		5577/55.8	236/2.4		43/.4 (36)
117	8-3-65		10200		4293/42.1	1431/14.0	751/7.4	107/1.0
117	11-4-65	(N)	7400 (14)		3065/41.4	634/8.6	148/2.0	5/0.7 (11)
116	7-20-65	(N)	9200 (33)		4963/53.9	2057/22.3		460/5.0 (35)
112	7-20-65	(N)	10600 (34)		5643/53.2	275/2.6		22/.2 (31)
112	8-3-65		9800		6149/62.7	1537/15.7	154/1.6	61/.6
96	8-3-65		9150		3176/34.7	508/5.6		57.6
90	7-23-65	(N)	5200 (16)		2696/51.8	866/16.6	385/7.4	(15)
96	10-4-66	(JTU)	5900 (8)	3747/63.5	1648/27.9	607/10.3		34/16
75	8-23-66		2000 (7)	1666/83.8	666/33.3	267/13.3		27/1.3
75	10-4-66		2000	1866/62.2		733/24.4		53/1.8
130	6-15-67	(JTU)	6800 (14)	4482/65.9	2627/38.6	309/4.5		
119(Cr.)	6-15-67	(JTU)	9150 (7)	5363/58.6	4732/51.7	1262/13.8	883/9.7	
116(Cr.)	6-15-67	(JTU)	5700 (9)	1350/23.7	600/10.5	144/2.5	24/.4	
111(Cr.)	4-19-67		8200		3360/41.0	1210/14.8	457/5.6	168/2.0
108	4-19-67		6750		2825/41.9	1614/23.9	461/6.8	184/2.7
107(Cr.)	4-19-67		6800		3920/57.6	2248/33.1	761/11.2	323/4.7
102	4-19-67		5800		2213/38.2	843/14.5	242/4.2	74/1.3
95(Cr.)	3-29-67		6000		1789/29.8	488/8.1	455/7.6	
95(Cr.)	8-29-67	(JTU)	3100 (5)	1500/48.4	391/12.6	195/6.3	49/1.6	
96	8-29-67	(JTU)	5300 (16)	2650/50.0	434/8.2	72/1.4		
86	8-29-67	(JTU)	6700 (4)	4982/74.4	3092/46.1	1546/23.1	481/7.2	69/1.0

1. (N) = Nephlo values for turbidity

Discussion of Water Composition Data

It is evident from previous sections that during the course of this research considerable effort has been exerted to obtain more reliable estimates of the parameters under study by improving old techniques and by developing or by utilizing new techniques. As a result it is believed that the estimates obtained for each successive year are more nearly representative than those for preceeding years.

On a drainage area as large and complex as the one for Lake Eufaula, many factors contributed to the quality of the impounded waters. Some were man-made factors, such as domestic and industrial pollution; others were combinations of man's activities coupled with natures, such as soil erosion; and others were natural factors, such as seasons, temperature, and rainfall. When all of these became interactive, a wide variety of water quality conditions could and did exist. It would be impossible to completely catergorize causes and effects on water quality conditions. Rather, an attempt will be made to show the interdependence of measured water quality conditions during this study period.

Turbidity, which is a relative measure of the quantity of suspended matter in water, has been measured on Chattahoochee river at various points in Georgia, since early 1900's. In the early 30's these waters often contained over 400 ppm (JTU) of suspended soil particles and colloids.(1)

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(1) Albert, Frank A., and Albert H. Spector. 1955. A new song on the muddy Chattahoochee. Water, The Yearbook of Agriculture, USDA, U.S. Government Printing Office, pp. 205-210.

This was largely the result of row-crop farming of the hilly redland portions of this drainage area. During the course of this present study, waters collected from this general region on the Chattahoochee river never exceeded 67 ppm (JTU). This reduction has occurred largely as a result of farm land being taken out of cultivation and used as permanant pastures or planted in pine trees.

Within the lake itself the upper third is mainly a deep river-run area and the middle third is the shallower (upper) inundated area. These two regions of the reservoir serve primarily as the settling basin allowing the lower third of lake to remain clear a majority of the year. Under clear water conditions the turbidity generally ranged from 4 JTU's near the dam to 16 JTU's in river at Columbus. Most of this suspended matter was a mixture of living and dead phytoplankton plus other organic debris.

Since the higher turbidity values (20+ JTU's) resulted largely from suspended soil particles transported by surface runoff, the quantity of suspended matter was dependent upon season of the year and duration and intensity of rainfall (locally it might also have been dependent upon construction and mining operations on the watershed). While these muddy waters (20-60 JTU's) contained considerable detectable Fe (.5 to 1 ppm), a more moderate amount of turbidity (15 to 20 JTU's) likewise had an equivalent Fe content. It is suspected that much of this moderate turbidity resulted from suspended Fe colloids. Under these same conditions, the detectable concentrations of Mn was lower in muddy waters and higher in the moderately turbid waters.

Turbidity may also be used to measure the quantity of organic matter in form of phytoplankton in clear lake waters. The removal and analyses of the suspended matter would provide an approximate estimate of its chemical composition. Likewise, an analysis of the filtrate (water) would shed light upon those elements which were in such small particles as to pass an 8 u filter or were in solution. While data on suspended matter are limited, they offer some trends in composition which will be pointed out below.

Generally, in Lake Eufaula waters, turbidity assumed to have been associated with phytoplankton growths never exceeded 16 JTU's and in a majority of cases had a value of 10 JTU's or less. This in itself indicates a low order of microscopic plant growth since fertilized ponds may often exceed 16 JTU's of turbidity in their surface phytoplankton growths. The averaged chemical composition of surface water samples of phytoplankton, and associated suspended matter, and filtrates from these samples from each region of the reservoir, and from a farm pond and from plastic pools are given in Table 19.

A comparison of the JTU values from each location indicates some degree of difference in quantities of suspended matter present in each area, but when a comparison is made of the chemical composition of suspended matter and filtrate there is not an obvious correlation between the two sets of data. These date, which are probably the most comprehensive sets of information on this particular phase of reservoir water chemistry available to-date, pose more questions than answers at present.

Table 19

Comparative chemical compositions of suspended matter and filtrate water of samples collected from various portions of Lake Eufaula and a fertilized fish pond

Region	L. Eufaula mid portion		L. Eufaula lower portion		L. Eufaula upper portion		S-6		L. Eufaula Creeks		L. Eufaula Creeks	
Date	August		August		September		September		August 16		August 29	
Sample	s.m.	f.H_2O	s.m.	f.H_2O	s.m.	f.H_2O	s.m.	f.H_2O	s.m.	f.H_2O	s.m.	f.H_2O
JTU	8.6		3.0		7.5		3.9		7.4		4.2	
Ca	.093	2.990	.187	3.000	1.223	2.500	.085	3.000	.083	3.22	.177	2.900
Mg	.043	1.242	.008	1.175	.057	.850	.020	1.970	.029	1.09	.014	1.130
Fe	.574	.015	.265	.050	.448	.087	.060	.100	.354	.144	.130	.243
Mn	.057	.006	.016	.012	.022	.001	.039	.015	.035	.006	.018	.005
Cu	.140	.007	.135	.030	.048	.010	.036	.015	.155	.010	.159	.006
Zn	.129	.017	.130	.037	.127	.016	.040	.035	.124	.011	.092	-
Na	.221	6.120	.078	4.975	.215	10.775	.053	1.400	.172	4.220	.092	5.810
K	.390	1.550	.230	1.375	.457	1.200	.300	.800	.271	1.380	.272	1.360
Pb	-	.001	.002	-	.016	-	.002	.070			.003	
Cr			.010		.030							
Co			.0001		.001		.001	.015				

It has been known for a long time that species of phytoplankton have pulses of growth, as far as population numbers and ages of individual cells are concerned, but the chemical composition of these pulses are unknown. From more extensive sampling of phytoplankton growths in fed fish ponds, data have been obtained which indicate some degree of chemical element cycling in ponds, but also suggest that the quantities of such elements may decrease with advancement of season while population numbers may increase (Figures 16 and 17). This same phenomenon was also indicated by a decline in chemical element composition of suspended matter collected from Lake Eufaula waters on 4 successive sampling dates in August 1967 (Figure 17).

Thus, our present state of understanding can be summarized by saying that the technique devised to study suspended matter in surface waters has yielded variable data that suggest seasonal trends. However, until more sophisticated equipment is available to separate living and dead phytoplankton and suspended colloids in these residue samples, a complete understanding of even the cyclic nature of these data will be impossible.

An interesting feature of all data on residue and filtrate chemical composition has been that the Ca and Mg contents in raw waters have consistently been less than the total quantities calculated from residue + filtrate content. In the case of metallic elements, the accountability of raw water content to residue + filtrate content has been rather good.

Light penetration data indicated a sufficient quantity of light within the upper 7 feet of water to support plant life. From prior

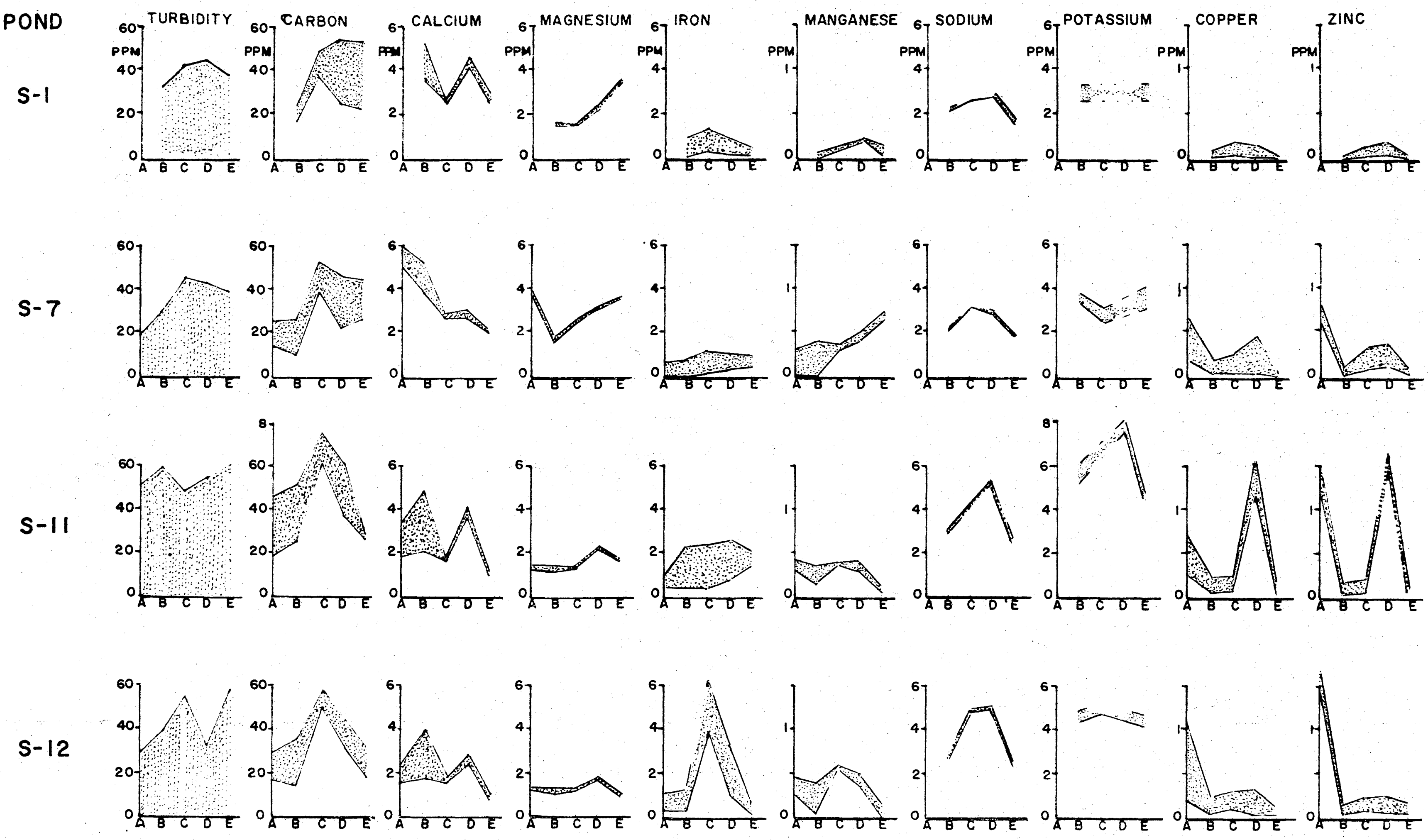

Figure 16. Relative abundance and chemical composition of suspended matter (shaded area) and filtered water (clear area under shaded area), expressed as ppm concentrations in original surface water samples collected from 4 ponds (which received regular applications of organic fish feed) on June 28 (A), July 25 (B), August 21 (C), September 1 (D), and October 3 (E).

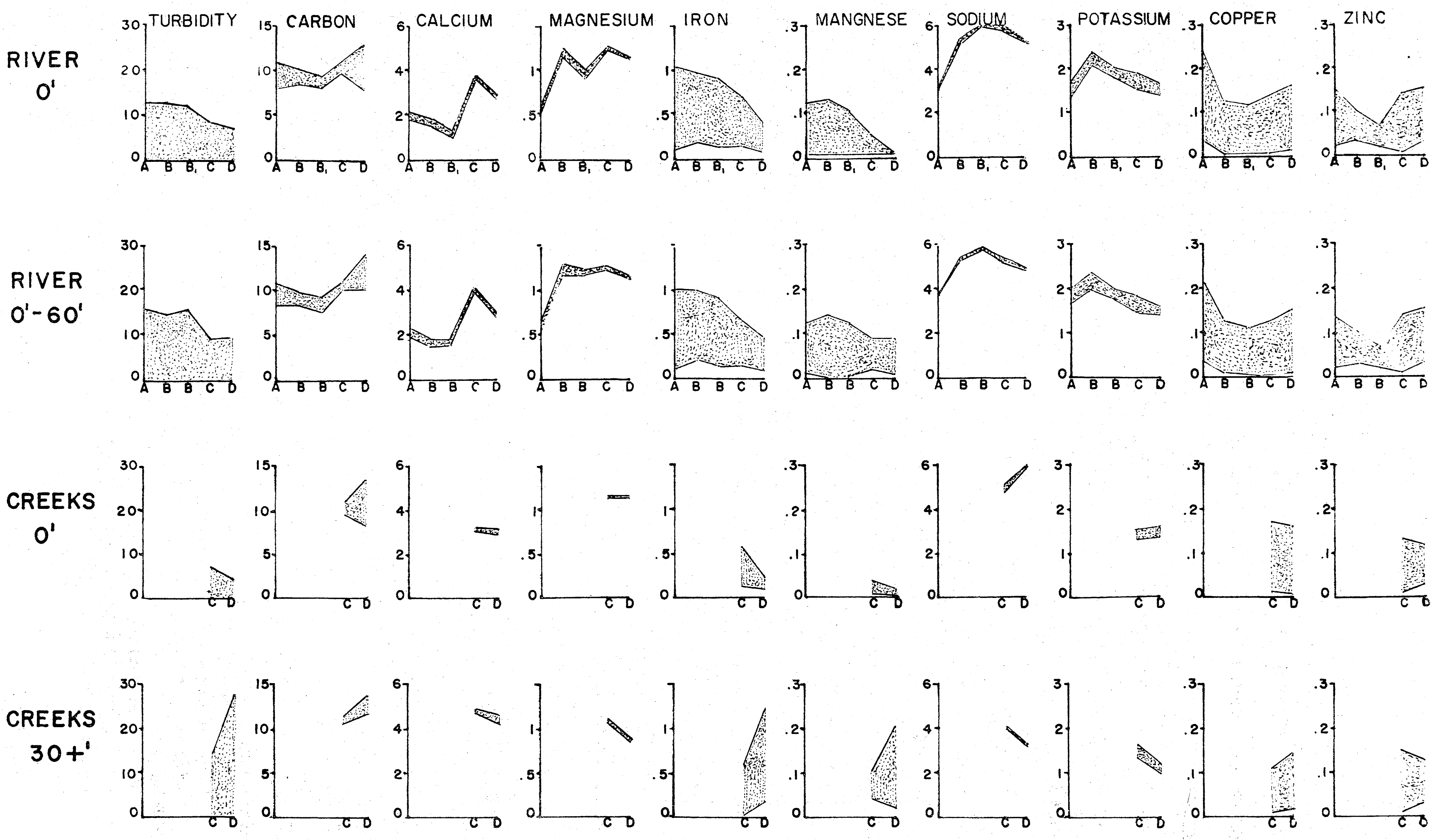

Figure 17. Relative abundance and chemical composition of suspended matter (shaded area) and filtered water (clear area under shaded area), expressed as ppm concentrations in original water samples collected at specified locations and depths of Lake Eufaula on August 3 (A), August 9- region 1 (B), August 9- region 2 (C), August 16 (D), and August 29 (E).

research by Blackburn[1] at this Station, it was determined that certain submersed rooted plants thrived on light intensities as low as 10 foot-candles. Other data obtained here by Beasley[2] on light penetration into a heavy growth of *Microcystis* sp. indicated that photosynthetic action occurred at approximately 5 foot-candles of light intensity.

In water, a 50% higher concentration of Ca was present in samples collected in early spring than was evident in those collected in summer and fall. On the otherhand, Na, K, Cu, Zn, and P concentrations in these same water samples was lower during spring period than in summer and fall periods.

The Ca-Mg pattern within Lake Eufaula during the course of this study can be summarized by stating that the averaged relationship varied from 2.43:1 to 4.44:1.

The Fe-Mn patterns in Lake Eufaula waters during period of stratification and immediately following an overturn are illustrated by following data.

Condition	Element	concentration	ppm
Stratified		raw H_2O	filtered H_2O
D.O.>1	Fe	.046	.016
	Mn	.017	.003
D.O.<1	Fe	1.145	.621
	Mn	.452	.108

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[1] Blackburn, R.D.
The effects of various light intensities and light sources on the growth of Elodea densa (Planch) Caspary and *Heteranthera* dubia (Jacquin) Macmillian. M.S. Thesis, Auburn Univ, 83 pp. 1959.

[2] Beasley, P. G.
The penetration of light and the concentration of dissolved oxygen in fertilized pond waters infested with *Microcystis*. M.S. Thesis, Auburn Univ., 70 pp. 1962.

Condition	Element	concentration	ppm
following overturn		raw H_2O	filtered H_2O
D.O.>1	Fe	.119	.017
	Mn	.137	.004
D.O.<1	Fe	.926	.600
	Mn	.537	.557

A curious feature of these data is concerned with percentage-remaining-after-filtration ratios between Fe and Mn in stratified waters (ratio approximately 2:1) and in overturned waters (ratio approximately 1:2). This is a partial explanation of why the Fe-Mn ratios for 1965 and 1966, when there were numerous periods of stratification with complete D.O. depletion, were lower than in 1967 when D.O. was present even in the deeper waters throughout the reservoir.

Occurrences of minor element constituents in Lake Eufaula waters during early spring months were detected by condensation of river water, dissolving the suspended matter and analyzing the entire resulting solution. Averaged concentrations of those elements checked were as follows:

Sr	0.0011 ppm
Ni	0.0136
Cr	0.0517
Cd	0.0007
Co	0.0010
Pb	0.0079

Averaged concentrations of same minor element constituents in raw waters from Lake Eufaula during summer months were as follows:

		range
Sr	0.0082 ppm	.001-.03
Ni	0.0210	.01 -.03
Cr	0.0146	.001-.03
Cd	-	-
Co	0.0036	.001-.005
Pb	0.0070	.001-.04

The concentrations of these same minor elements in tributary creek waters of Lake Eufaula were the same as given above for all elements except Sr which was 0.0181 ppm.

The dynamics of physical characteristics of the waters in Lake Eufaula throughout this 2-1/2 year study period can be further emphasized by presenting the averages for inflowing and outflowing waters and minimum and maximum values obtained on each characteristic that was measured within the lake. These data are presented in Table 20.

In Table 21 the chemical composition data have been applied to averaged inflow and outflow data and the approximate quantities of each element entering upper region of Lake Eufaula, the quantities passing through lower region, and the quantities leaving the reservoir in tailwaters for each 24 hour period are given. The gain or loss column gives some indication of those elements which are retained in bottom muds and those which are flushed from the reservoir. In the case of calcium, it has been observed that concentrations in tailwaters were often higher than in bottom waters of reservoir immediately above dam. River banks and relief wells (both high in Ca) immediately below turbine flumes possibly account for this slight increase in Ca concentrations in tailwaters.

The most significant contribution derived from these gain and loss

Table 20

Averaged inflow and outflow composition of Lake Eufaula waters including 3-year range in lake water composition

	Inflow water	Range in lake	Outflow water
pH	6.96	5.5-9.0	7.13
Ohms/cm^3	16761	11,700-22,000	16171
Turbidity, JTU's	18.25	1.7-68.0	11.37
Alkalinity, ppm $CaCO_3$	20.00	6.6-49.7	22.07
EDTA hard. ppm $CaCO_3$	14.62	11.5-40.0	19.5
Ca ppm	4.16	.51-14.0	5.22
Mg	1.17	.50-2.07	1.19
Na	5.37	1.5-12.5	3.89
K	1.45	.01-3.5	1.40
Zn	.043	.001-1.19	.031
Cu	.015	.001-.63	.012
Fe	.472	.001-1.25	.478
Mn	.058	.001-.05	.040
N	.208	.01-1.92	.133
P	.044	.001-.21	.029
C_T	11.73	3.6-23.5	10.08
C_{-co2}	5.43	2.5-12.0	6.92
gamma counts/min.(1)		273-486	
Cl_2		1.0-15.0	5.05
SO_4		3.5-10.0	5.50

(1) Background gamma counts ranged from 549-980 counts per min.

Table 21

Calculated average pounds per day for 3 year period of elements entering upper region, passing through lower region, and eliminated through tailwater, with indicated gain to or loss from reservoir each day

Flow CFS	Inflow Upper Region 10,935	Lower Region 10,900	Outflow Tailwater 10,870	Gain or loss (-) within reservoir Inflow-outflow
	lbs/day	lbs/day	lbs/day	lbs/day
Ca	243,576	257,628	303,203	- 59,627
Mg	68,505	73,190	69,121	- 616
Na	314,424	305,641	225,950	88,474
K	108,321	95,439	81,319	27,002
Zn	2,517	4,508	1,800	717
Cu	878	2,166	697	181
Fe	27,636	16,218	27,764	128
Mn	3,396	7,787	2,323	1,073
N	12,178	14,403	7,725	4,453
P	2,576	1,873	1,684	892
C_T	686,815	695,012	585,496	101,319
C_{-CO_2}	317,937	275,779	401,948	-84,011
				17,038
C^2			293,329	
SO_4			319,467	
1 ppm =	58,552		58,085	

data is the increased confidence which can be placed on the analytical data on which these computations are based.

During the early 1900's some chemical analyses of waters collected from the Chattahoochee river near West Point, Georgia were made and reported by U.S. Geological Survey. These data are summarized in Table 22.

In summarizing the chemical composition of rivers of the eastern and gulf region of the United States, Clarke (1924) states (p. 79) ---"All are low in salinity and relatively high in silica and alkalies. In several of the analyses the alkaline radicals are in excess of calcium. River waters, in short, seem to exhibit distinct regional peculiarities, which, in most cases, if not in all, are due to the geology of the region transversed. These waters with one or two exceptions, flow from areas of crystalline schists, and owe little to sedimentary environments." This statement is in agreement with data accumulated by this study.

A more recent (1959) analyses of waters from the same river system was made by this same agency, and these results are summarized in Table 23.

In concluding this discussion on water composition in Lake Eufaula, it is evident that urbanization and industrial development on this river during the past half-century have had a limited influence on many of its chemical constituents.

Table 22

Averaged analyses of 34 composited water samples collected from Chattahoochee river at West Point, Georgia between October, 1906 and October, 1907[1]

CO_3	21.32 ppm
SO_4	8.49 ppm
Cl	3.96 ppm
NO_3	1.32 ppm
Ca	9.06 ppm
Mg	1.51 ppm
Na	12.08 ppm
K	3.40 ppm
SiO_2	37.73 ppm
Fe_2O_3	1.13 ppm
Salinity	52.00 ppm

(1) Source:
Clarke, Frank W.
The data of geochemistry. USGS Bul. 770, 5th Ed. 1924, pp. 78-79.

Table 23

Minimum and maximum concentrations of elements, as determined by spectrographic analyses, in Apalachicola river waters collected at Blountstown, Florida.(1)

Element	Range ppb
Ag	.058 - .11
Al	73. - 2550
B	5 - 11
Ba	21 - 42
Be	.058
Co	.75
Cr	2.2 - 7.8
Cu	2.1 - 51.
Fe	96 - 1220
Li	.075 - .12
Mn	4 - 25
Mo	0 - .62
Ni	2.6 - 34
P	0 - 58
Pb	2.1 - 6.2
Rb	.75 - 2.1
Sn	1.3
Sr	7.5 - 34.
Ti	.8 - 99
V	0 - 2.2

(1) See Appendix Table 8

From: Durum, W. H.

Chemical Characteristics of Bottom Soils

The soils covering the bottom of Lake Eufaula are sedimentary types since the area inundated was river flood plains. The physical composition of these bottom soils varied from almost pure deposits of sand, to sandy loams, to varying colloidal mixtures of clay and organic matter. The location, thickness, and area covered by each of these deposits appeared to be almost completely dependent upon conditions existing prior to flooding of the area. For example, in the main river channel, large sand bars were still in existence in 1967 throughout the entire length of the impoundment. Whether or not these sand bars are shifting is unknown, but sampling of these areas revealed an absence of silt deposits on their surface. A somewhat similar condition existed on sand bars located in shallower water areas. In these cases, the sand bars apparently formed slight ridges on the lake bottom and silt deposits were apparently collecting in the troughs between these sand ridges. Such a situation is believed to be the result of silt shifting by bottom water currents.

When bottom soil sampling was initiated in 1965, the existence of the extensive sand bars in the old river channel restricted core sampling to those shallower flooded areas where sufficient clay existed to permit a core sampler to be withdrawm from the lake bottom. Consequently, much time and effort was expended in bottom soil sampling. However, a series of representative samples from various areas in the upper and middle portion of the lake were obtained, and data on their chemical composition are given in Table 24.

Table 24

Quantities (average and range) of chemical elements recovered from neutral cation exchange extractions of 1965 cored soil samples from 10 to 20-foot depths in Lake Eufaula

	Average	Range
Ca ppm(1)	1354.04	216 - 2088
Mg ppm	153.63	50 - 301
Na ppm	23.037	4 - 60
K ppm	69.921	28 - 116
Sr ppm	5.331	2.4 - 11
Zn ppm	8.216	2 - 17.2
Mn ppm	111.26	40 - 224
Fe ppm	6.126	4.2 - 11.2
Cu ppm	2.80	1.9 - 3.2
Pb ppm	3.858	2.0 - 9.4
Cr ppm	1.316	0.01 - 2.5
Ni ppm	.384	0.1 - 0.8
Mo ppm	.679	0.1 - 3.0
Co ppm	.421	0.2 - 0.5
Cd ppm	.073	0.05 - 0.12
N %	.0758	0.031 - 0.102
C %	1.255	0.96 - 1.75
P ppm	1.015	0.4 - 2.4

(1) PPM = µg/g dry weight of soil.

During 1966 the same core sampling technique was employed. While much time and effort had to be expended to obtain these samples, a greater degree of successful sampling was possible through the use of a depth indicator to locate the more silt-laden bottom areas. As a result, core samples of sufficient thickness were available to permit their separation into an A (top 1" of core) and B (lower 4+" section of core) horizon. Prior to separation into the 2 horizons, these core samples were allowed to air-dry within the original sample tube. Thus, the associated water collected with the core was allowed to evaporate and the soluble contents were retained in the soil sample. The data on the chemical composition of horizons A and B of soil samples collected in 1966 are summarized in Table 25.

During the winter draw-down period from January to March, 1967 an extensive series of soil core samples was collected from the dewatered bottom at an elevation of 4' to 5' below normal pool level. This was an important series of samples since they were taken within that bottom area which is the potential habitat for rooted submersed and emersed aquatic weeds. The thickness of this series of core samples was uniformly between 3" and 4", thus no attempt was made to divide these samples into an A and B horizon. This decision was also influenced by the fact that this sampling area was a region subject to current as well as surface erosion and no surface silt deposits were evident when the samples were collected. Data on the chemical composition of this series of soil samples are given in Table 26.

As a result of the difficulties encountered in using the soil

Table 25

Quantities (averages and ranges) of chemical elements recovered from neutral exchange extractions of 1966 cored soil samples from 2- to 20-foot depths in Lake Eufaula

Horizon	A		B	
	Average	Range	Average	Range
Ca ppm	528.6	88.0 - 869.0	701.09	133 - 1353
Mg ppm	102.29	18.7 - 196.9	130.24	58.5 - 220
Na ppm	18.93	9.3 - 36.3	19.39	6.9 - 37.3
K ppm	54.81	8.4 - 90.0	65.77	18.0 - 132.0
Sr ppm	3.96	1.0 - 5.28	3.68	0.9 - 12.3
Zn ppm	16.236	2.7 - 153.0	24.464	2.4 - 180.0
Mn ppm	122.81	17.7 - 379.5	131.11	27.5 - 220.0
Fe ppm	19.63	4.7 - 30.0	9.22	5.0 - 14.0
Cu ppm	2.73	1.1 - 8.3	4.09	1.4 - 10.5
Pb ppm	4.14	.8 - 9.5	2.74	.4 - 12.0
Cr ppm	.663	.3 - 1.1	.904	.45 - 1.5
Ni ppm	1.263	.3 - 4.5	1.10	.3 - 2.5
Mo ppm	2.587	.3 - 12.0	2.782	.3 - 8.4
Co ppm	.557	.2 - 1.10	.518	.10 - .90
Cd ppm	.233	.06 - .85	.331	.15 - .74
N %	.0533	.011 - .095	.0563	.031 - .077
C %	1.128	.41 - 2.07	1.120	.52 - 1.77
P ppm	2.175	.99 - 3.15	2.515	1.21 - 6.30

(1) PPM = µg/g dry weight of soil.

Table 26

Quantities (average and range) of chemical elements recovered from neutral cation exchange extractions of 1967 cored soil samples from dewater edge (4- to 5-foot depths) of Lake Eufaula

	Average	Range
Ca ppm	652.5	45 - 2560
Mg ppm	102.06	9.0 - 195.9
Na ppm	13.075	4.8 - 28.6
K ppm	43.896	6.0 - 160.0
Sr ppm	2.525	.25 - 9.68
Zn ppm	14.663	1.5 - 132.0
Mn ppm	83.742	2.0 - 440.0
Fe ppm	10.715	3.5 - 45.0
Cu ppm	5.233	1.4 - 15.5
Pb ppm	2.725	.2 - 20.0
Cr ppm	.872	.05 - 2.8
Ni ppm	1.113	.4 - 23.0
Mo ppm	1.690	.1 - 9.2
Co ppm	.535	.1 - 3.0
Cd ppm	.446	.1 - 1.3
N %	.0606	.003 - .260
C %	.891	.12 - 3.03
P ppm	1.925	.99 - 3.75

(1) PPM = µg/g dry weight of soil.

core sampling apparatus, a new bottom soil (hydrosol) sampler was designed and built by the Project Leader in 1967. This sampler has already been described in the section SAMPLING EQUIPMENT AND PROCEDURES of this Report. A sampler that would consistently collect representative samples of bottom materials existing within the so-called interface area between water and bottom soil has long been needed. It has been suspected that this area is a rich reservoir of precipitated organic and inorganic matter that may, under certain conditions, be in constant exchange with the water. Other types of bottom samplers capable of collecting such a sample have been so small in cross section that they disturbed and dissipated the hydrosol to such an extent that an inaccurate sample was entrapped in the sampler. After the sample was entrapped, all substrate conditions had to be specific, otherwise the sample could not be retrieved by the sampling apparatus.

The hydrosol sampler has many advantages. Firstly, it was light in weight and could be operated by hand if necessary. Secondly, it could be operated at any water depths and would retrieve the hydrosol sample with equal effectiveness from any depth. Thirdly, it would collect the fluid fraction over any type of bottom substrata, but was more effective over a muck bottom. Forthly, samples collected by this sampler have contained a much greater concentration of exchangable elements than have those collected with other devises. This last statement is illustrated by the data in Tables 27 and 28 on chemical composition of hydrosols collected from main reservoir

Table 27

Quantities (average and range) of chemical elements recovered from neutral cation exchange extractions of 1967 hydrosol samples from 3- to 80-foot depths in Lake Eufaula

	Average	Range
Ca ppm	1641.1	775-3250
Mg ppm	378.2	190-2150
Na ppm	379.4	38-1950
K ppm	182.7	50-730
Sr ppm	4.73	.75-20
Zn ppm	28.31	6.5-90
Mn ppm	539.4	80-1330
Fe ppm	322.4	11-3950
Cu ppm	8.17	.2-30
Pb ppm	3.58	.3-18
Cr ppm	3.29	.2-45
Ni ppm	1.98	.35-7.5
Mo ppm		
Co ppm	2.67	.1-45
Cd ppm	.79	.14-10
N %	.1965	.0735-.552
C %	2.343	.780-3.322
P ppm	48.91	2.1-360

(1) PPM = μg/g dry weight of soil.

Table 28

Quantities (average and range) of chemical elements recovered from neutral cation exchange extractions of 1967 hydrosol samples from 8- to 50-foot depths in tributary creeks of Lake Eufaula

	Average	Range
Ca ppm	1628.5	370-2880
Mg ppm	266.85	50-555
Na ppm	188.15	30-540
K ppm	154.0	60-240
Sr ppm	3.815	1-10
Zn ppm	19.05	4.3-48
Mn ppm	321.85	105-545
Fe ppm	167.15	8-1000
Cu ppm	8.83	.5-17
Pb ppm	6.00	.3-16
Cr ppm	2.145	.5-10
Ni ppm	1.720	.4-8.6
Mo ppm	-	-
Co ppm	1.356	.18 - 4.3
Cd ppm	.3895	.07-.86
N %	.1949	.0112-.3421
C %	2.556	.683-4.153
P ppm	89.98	2.1-240

(1) PPM = µg/g dry weight of soil.

and tributary creeks of Lake Eufaula in 1967.

Comparative data on extractable elements in core and hydrosol samples collected from various areas of Lake Seminole during this same period are summarized in Table 29. Additional data on hydrosol in an upstream impoundment, Bartlett's Ferry Reservoir, are summarized in Table 30.

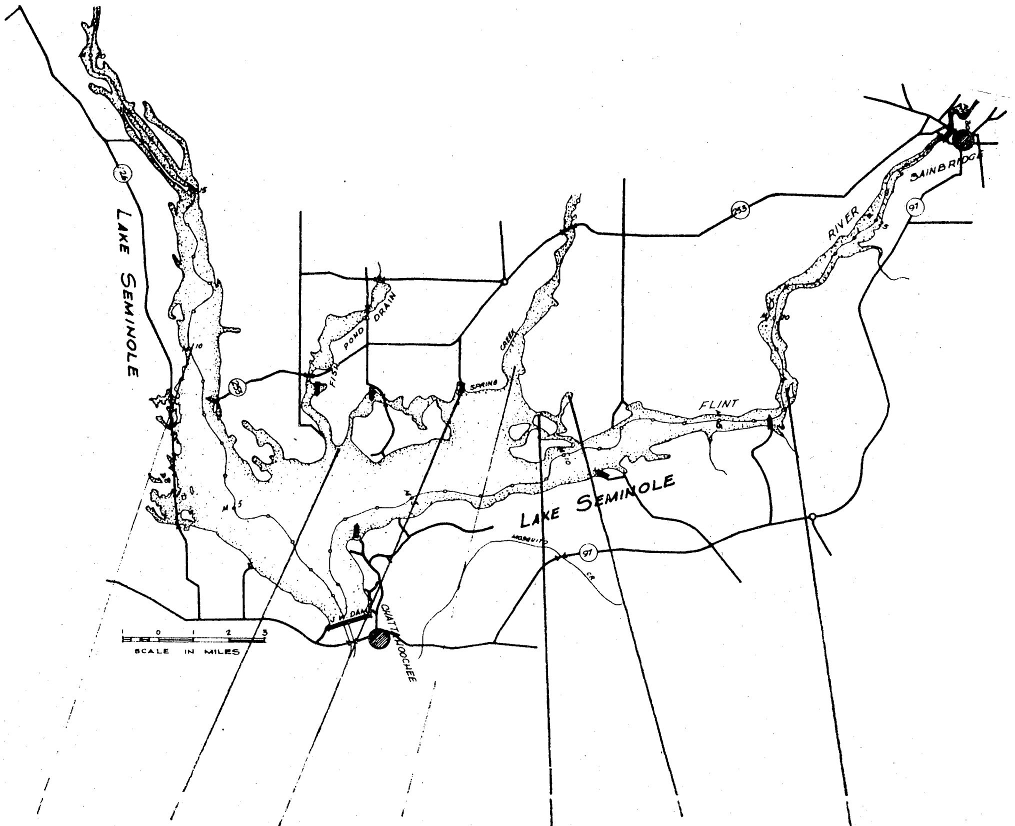
The chemical composition data on bottom soils presented in each of preceeding Tables represent those quantities of elements which can be removed or replaced on the soil colloid by a neutral cation exchange reaction. These data do not represent the chemical composition of these soils. Rather, this is the best technique available to estimate those quantities of elements which might become available for use by various forms of aquatic plants.

In each of these tables (Lake Eufaula data) the averaged quantity of each element exchanged from the soil samples are given followed by the minimum and maximum quantities removed from samples in each series. It will be noted that most averages are approximate mid-value of the ranges given, indicating that sampling was of a rather random nature and that no particular evidence of biased values is present. Thus, we can assume that these values are representative of exchangable chemical quantities in the soils from those areas of Lake Eufaula that are represented in these sampling data.

In evaluating these data on exchangable elements from bottom soils of Lake Eufaula it is evident that sampling technique was a major factor in determining the quantity of an element or elements that could be recovered from a particular sample. In most cases

Table 29

Averaged composition of bottom soils, collected by 2 methods, in various areas of Lake Seminole during 1965, 1966, and 1967



	Hydrosol	Hydrosol	Hydrosol	Hydrosol	Core	Hydrosol	Core	Core	Core	Hydrosol
Ca ppm	1900	3350	2781	4786	455	2804	532	562	595	910
Mg ppm	250	113	45.3	51.9	15.8	64	6.6	31.1	30	28
Na	135	508	109	78	9	237	9.3	35.7	8.1	100
K	150	153	66.7	140	46.2	86.7	45.7	92.5	20.2	40
Sr	2.5	1.7	1.1	1.52	.61	1.72	.6	-	.97	.5
Zn	25	10.6	21.8	19.6	3.2	16.3	2.25	.7	2.85	4
Mn	644	232	423	254	57.7	658	127.5	37.3	74	237
Fe	14	59.5	60.3	107.3	10	128	9.35	72.8	8	40
Cu	6.5	13.8	5.3	9.13	4.54	6.78	4.9	.37	5.75	14
Pb	.6	11.6	.47	3.13	.64	1.6	.8		1	1.2
Cr	2	2.75	1.67	1.53	1.18	1.08	.4		1.5	.5
Ni	.3	1.2	.58	1.13	.8	1.67	.6		.8	.2
Mo		2.2			1.56		1.8		.65	
Co	3	.95	2.28	2.09	.3	.56	.2		.65	.25
Cd	.57	.80	.41	.35	.67	.37	.2		.37	1.0
N%	.233	.268	.283	.3557	.268	.345		.339	.091	.373
C%	3.06	9.882	2.60	5.756	7.18	6.09		.923	1.09	5.59
P ppm	6.9	12.77	27.10	32.2	1.68	30.9	1.26	7.62	2.20	4.20

Table 30

Quantities (average and range) of chemical elements recovered from neutral cation exchange extractions of 1967 hydrosol samples from 10- 40-foot depths in Bartlett's Ferry Reservoir

	Average	Range
Ca ppm	964.0	780-1340
Mg ppm	195.2	125-240
Na ppm	176.6	155-230
K ppm	182.0	120-280
Sr ppm	2.79	1.4-4.0
Zn ppm	14.10	8.0-22.0
Mn ppm	305.6	210-470
Fe ppm	251.5	28-830
Cu ppm	12.0	1.5-18.0
Pb ppm	1.40	.25-2.00
Cr ppm	2.54	.10-8.5
Ni ppm	1.52	.50-4.0
Mo ppm		
Co ppm	1.11	.65-2.0
Cd ppm	.734	.40-1.0
N %	.278	.163-.550
C %	2.146	1.92-2.41
P ppm	5.84	4.2-10.0

(1) PPM = µg/g dry weight of soil.

the averaged quantity of an element recovered from any hydrosol sample exceeded the maximum quantity of that element recovered from any core sample. However, this does not indicate that all necessary data on soil composition studies in a reservoir could or should be obtained with a hydrosol sampler. For example, the marginal sampling can only be accomplished with a core sampler if one is to obtain reliable data on elements available to plants whose roots extend several inches beneath the soil surface. Likewise, one should use the hydrosol sampler to determine those exchangable elements that could be utilized by various forms of algae and floating plants.

Since the specific applications of these data on exchangable element from soil to growth of aquatic plants is unknown at present, it will suffice to summarize this discussion at this point in the report with 2 statements. First, with a few exceptions the quantities of each exchangable element recovered was 2 or more times greater in hydrosol samples than in core samples.

Other comparative data on quantities of exchangable elements in rich and poor aquatic soils are given in Tables 31 and 32 and 33. It is quite evident from these data that the geological formations associated with a particular drainage basin have a profound influence on quantities of exchangable elements present in inundated aquatic habitats. Enhancement of these quantities by man's activities within a given basin is also evident.

Table 31

Averaged quantities of chemical elements recovered by neutral cation exchange extraction of bottom soil samples from Wapanocca Refuge Lake in Arkansas

Ca ppm	8275.4
Mg ppm	578.5
Na ppm	18.289
K ppm	191.51
Sr ppm	13.67
Zn ppm	26.27
Mn ppm	429.5
Fe ppm	59.67
Cu ppm	6.175
Pb ppm	48.68
Cr ppm	3.466
Ni ppm	.705
Mo ppm	.532
Co ppm	.599
N %	.424
C %	4.260
P ppm	3.034

(1) PPM = µg/g dry weight of soil.

Table 32

Averaged quantities of chemical elements recovered by cation exchange extraction of samples collected from surface of soils in 'W' series plastic pools (1965), by core sampling in numbered series (1966), by hydrosol sampling of same numbered pools[1] in 1967

	1965	1966	1967
Ca ppm	417.33	1940.	271.57
Mg ppm	107.48	287.5	59.94
Na ppm	24.93	332.5	48.65
K ppm	84.05	170.0	76.214
Sr ppm	3.756	2.52	3.014
Zn ppm	23.39	18.37	70.98
Mn ppm	130.71	401.0	49.71
Fe ppm	11.025	184.0	14.657
Cu ppm	2.508	14.0	6.742
Pb ppm	4.566	1.42	7.500
Cr ppm	.740	.72	.571
Ni ppm	1.025	1.47	.928
Mo ppm	2.383		3.028
Co ppm	.550	1.137	.550
Cd ppm	.143	.955	.100
N %	.2054	1.053	
C %	7.625		
P ppm	6.560	5.43	2.196

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(1) Pool Nos. 18, 23, 37, 38.

Table 33

Averaged quantities of chemical elements recovered by neutral cation exchange extractions from soils in numbered[1] and lettered[2] plastic pools in 1965

	Numbered series	Letter series
Ca ppm	470.0	355.0
Mg ppm	47.25	29.5
Na ppm	58.50	48.0
K ppm	145.0	130.0
Sr ppm		
Zn ppm	1.7	7.4
Mn ppm	83.12	5.65
Fe ppm	76.25	20.40
Cu ppm	.51	1.04
N %	.053	.100
C %	.693	1.108
P ppm	5.25	7.75
Om %	4.029	3.675

(1) Pool Nos. 13, 25, 27, 28, 29, 30, 33, 37, 38

(2) Pool Nos. C-8, C-10, E-4, E-11, F-10, F-11, G-12.

Chemical Composition of Aquatic Plants

The public demand for clean waters must take into account the fact that surface water areas are like land areas in that some type of vegetation is going to occupy any suitable habitat. Thus, the more abundant the nutrient supply the more dense the vegetation. In an aquatic habitat this vegetation may take the form of bacteria, phytoplankton, filamentous algae, submersed weeds, emersed weeds, floating weeds, and marginal weeds.

To understand the chemical complexities of the aquatic habitat of Lake Eufaula requires a knowledge of the chemical composition of the aquatic plants that occur within this environment. To more adequately understand the water, soil, aquatic plant relationship, data on chemical composition of plants from other aquatic environments are included for a comparative purpose.

At this time it should be pointed out that aquatic weed infestations in Lake Eufaula have been limited. The cause of this lack of rooted plant growth is unknown, but could possibly have been influenced by the yearly winter draw-down period exposing most of suitable habitat to several weeks of freezing weather. Thus, sampling of plant species from similar environments was resorted to in an effort to more fully understand what was occurring in the shallow edge of Lake Eufaula.

The diversity of chemical composition of two troublesome aquatic plant species, water hyacinth (*Eichhornia crassipes*) and alligatorweed (*Alternanthera philoxeroides*) from different environments are illustrated in Figures 18 and 19.

Collection Site	C	Ash	Ca	Mg	Fe	Mn	P	N	K	Na
			Chemical composition as percent of dry weight							
0-0-0 ponds	30.8	33.4	.44	.80	1.43	.20	.073	.936	1.23	.08
0-8-0 ponds	37.1	16.7	.515	1.03	.43	.069	.195	.771	1.60	.621
8-8-0 ponds	35.3	15.2	.55	1.14	.30	.061	.145	.861	1.71	.709
P. Pools	41.5	15.3	1.60	.97	.23	.14	.161	1.115	2.147	.632
Lake Seminole '65	39.8	17.9	1.74	.49	.23	.27	.162	2.239	3.562	.223
Lake Seminole '67	34.8	16.5	1.04	.42	.29	.068	.205	1.491	2.480	.270

Figure 18. Comparative chemical composition of entire water hyacinth plants from several habitats.

Collection Site	C	Ash	Ca	Mg	Fe	Mn	P	N	K	Na
			Chemical composition as percent of dry weight							
P. pools '65	42.9	6.1	1.18	.336	.25	.032	.106	.848	1.39	.508
P. pools '66	40.5	8.0	1.04	.471	.164	.072	.049	1.08	1.21	.561
P. pools '67		5.3	.30	.505	.061	.033	.090	.779	.36	.091
Lake Seminole '65	39.5	18.4	1.43	.307	.072	.044	.170	3.04	4.56	.37
Lake Seminole '66-'67	35.3	13.9	1.35	.328	.120	.022	.107	2.26	2.50	.35
Lake Eufaula '67	36.3	21.0	.716	.598	.157	.053	.185	3.00	3.98	.52

Figure 19. Comparative chemical composition of entire alligatorweed plants from several habitats.

Samples of water hyacinths were collected from Auburn University experimental ponds where no inorganic fertilization was practiced; where 80 lb. P_2O_5 was added per acre during summer months; and where 80 lb. P_2O_5 plus 80 lb. N was added per acre during summer months. Another set of water hyacinth samples was collected from Auburn University plastic pool series where only $CaCO_3$ was added to precipitate suspended clay colloids in water. The final illustrated samples of hyacinths were collected from the Faceville landing area on the Flint river arm of Lake Seminole in 1965 and 1967. No sample of this plant from Lake Eufaula was included in this illustration because this species has never invaded this reservoir.

Samples of alligatorweeds were collected from some Auburn University plastic pool series in 1965, in 1966, and in 1967. When this series was established in early 1965, each pool received the same amount of homogenous field soil and equal amounts of $CaCO_3$ to precipitate suspended clay colloids. Other samples were collected from Faceville area on Flint river arm of Lake Seminole in 1965 and in 1967. The final illustrated samples of alligatorweed were collected from upper portion of Lake Eufaula in 1967.

An examination of these two illustrations shows the great diversity of chemical composition which can occur within a plant species grown under different environmental conditions. Apparently these two species are able to partially substitute one element, such as Mg, for another element, such as Ca.

It is also apparent that alligatorweed was able to accumulate an apparent luxury supply of K and possibly N in proportion to that quantity made available to the plant by the water and soil of its habitat. This last factor of nutrient consumption in relation to its availability in the environment is shown by alligatorweed composition from same series of plastic pools over a 3-year period (Table 34). These pools had no replinishment of nutrient supply other than from rain water, and their water overflow loss was approximately 50% each year.

Comparisons of chemical composition of these two plants species in Lakes Eufaula and Seminole with experimental ponds and pools illustrates that these plants were able to accumulate vast quantities of elements from the continuously replinished supply available in river waters.

Data on the averaged chemical element composition of the following plant species from several localities are given in indicated tables.

Alligatorweed - *Alternanthera philoxeroides*	Table 34
Water hyacinth - *Eichhornia crassipes*	Table 35, 36
Waterwillow - *Justicia americana*	Table 37
Smartweeds - *Polygonum* spp.	Table 38
Parrotfeather - *Myriophyllum brasiliense*	Table 39
Eurasian milfoil - *Myriophyllum spicatum*	Table 40
Grass - *Paspalum fluitans*	Table 41
Buttonbush - *Cephalanthus occidentalis*	Table 42
Giant cutgrass - *Zizaniopsis miliaceae*	Table 43

Needlerush - *Eleocharis acicularis*	Table 44
Eelgrass - *Vallisnera americana*	Table 45
Curly leaf pondweed - *Potamogeton crispus*	Table 46
- *Bacopa* sp.	Table 47
White waterlily - *Nymphaea tuberosa*	Table 49
Banana waterlily - *Nymphaea mexicana*	Table 48
- *Hydrocotyle* sp.	Table 47
Algae - *Lyngbya* sp.	Table 49
Chara sp.	Table 50
Nitella sp.	Table 50

Included in the above listing of plants are certain species that have previously been reported in the thesis of Jerry B. Denton. Certain data from this thesis have been incorporated into the various tables on plant composition. These data were useful indicators of changes in plant composition with time and with changes in sampling sites within the same general area of a given habitat.

Also included in the tabular presentation are averaged compositions of the following species of algae as presented in the dissertation of Claude E. Boyd (Table 51).

Filamentous forms	Planktonic forms
Chara sp.	*Microcystis* sp.
Pithophora sp.	*Aphanizomenon* sp.
Cladophora sp.	*Anabaena* sp.
Spirogyra spp.	*Euglena* sp.
Giant *Spirogyra* sp.	
Rhizoclonium sp.	

Filamentous forms

Hydrodictyon sp.

Oedogonium sp.

Mougeotia sp.

Lyngbya sp.

Nitella sp.

These data of Boyd's have been particularly useful in comparative studies of differences in composition of algae samples obtained by separation with No. 25 bolting silk (Boyd) and separation by use of 8 µ Millipore filter. This has emphasized that composition is varied within size groups of a species of alga and that other constituents besides the alga cells may have been retained by the Millipore filter.

Table 34

Averaged chemical element composition of alligatorweed collected from plastic pools and from Lakes Eufaula and Seminole during period 1965-1967

Area	Plastic pool	Plastic pool	Plastic pool	Lake Seminole		Lake Eufaula
Year	'65	'66	'67	'65	'66-67	'66-67
Ash %	6.108	8.04	5.31	18.39	13.90	20.97
Ca ppm	11760.0	10450.0	3000.0	14300.0	13478.0	7155.0
Mg ppm	3360.0	4710.0	5050.0	3070.0	3282.0	5979.0
Na ppm	5080.0	5610.0	915.0	3700.0	3505.0	5200.0
K ppm	13900.0	12100.0	3600.0	45600.0	25006.0	39844.0
Sr ppm		9.0	9.0		4.98	6.64
Zn ppm	160.0	88.5	255.0	90.0	90.57	135.64
Mn ppm	320.0	720.0	328.0	440.0	224.3	528.4
Fe ppm	250.0	1640.0	610.0	720.0	1196.0	1574.2
Cu ppm	38.0	43.0	27.5	15.0	112.4	80.46
Pb ppm		14.5	9.0		8.78	17.55
Cr ppm		21.0	29.0		24.08	42.99
Ni ppm		12.5	10.0		7.86	10.52
Mo ppm		8.5	-		7.95	10.03
Co ppm		6.5	1.1		6.09	5.92
Cd ppm		1.25	1.5		3.88	1.95
N %	.848	1.001	.799	3.045	2.260	3.003
C %	42.969	40.48		39.515	35.34	36.34
P ppm	1060.0	492.5	900.0	1700.00	1076.00	1852.00

(1) ppm = µg/g dry weight of plant.

Table 35

Averaged chemical element composition of water hyacinth collected from Auburn University experimental ponds in 1967.

Area 0.1 acre earthen ponds

Treatment	0-0-0		0-8-0		8-8-0	
Collection Site	Edge	Center	Edge	Center	Edge	Center
% Moist.	93.85	86.81	92.45	94.03	92.48	93.98
Ash %	37.04	33.06	17.63	15.89	17.19	13.25
Ca ppm	3750	5120	4850	4950	5617	5450
Mg ppm	8350	7700	11050	9600	10650	12200
Na ppm	783	817	5800	6633	5987	8200
K ppm	12467	12067	20333	11733	18933	15200
Sr ppm	4.3	3.0	6.0	5.7	5.7	9.3
Zn ppm	540.0	573.3	320.0	163.3	285.0	175.0
Mn ppm	2067	1933	797	580	683	543
Fe ppm	15250	13300	4600	4100	4380	1600
Cu ppm	177	157	177	217	167	170
Pb ppm	8.0	5.3	2.7	10.7	8.7	4.0
Cr ppm	167	176	82	71.3	86.7	78.0
Ni ppm	30.7	33.3	20	14	14.7	24.7
Co ppm	2.8	6.47	1.00	1.67	1.4	1.2
Cd ppm	1.07	1.13	.80	.67	.4	1.0
N %	1.092	.781	.663	.880	1.012	.710
C %	32.35	30.86	36.89	37.13	37.44	33.24
P ppm	767	695	2140	1773	1553	1350

(1) PPM = µg/g dry weight of plant.

Table 36

Averaged chemical element composition of water hyacinth collected from plastic pools in 1965 and from Lake Seminole during period 1966-67

Area	Plastic Pools		Lake Seminole		
Year	'65		'65		'66-67
Plant Part	Shoot	Root	Shoot	Root	Whole
Ash %	14.557	16.113	15.930	20.00	16.48
Ca ppm	19480.0	12570.0	19910.0	14830.0	10400.0
Mg ppm	10020.0	9360.0	4000.0	5810.0	4200.0
Na ppm	5020.0	7630.0	1050.0	3410.0	2700.0
K ppm	20870.0	22070.0	41650.0	29600.0	24800.0
Zn ppm	140.0	450.0	50.0	160.0	155.0
Mn ppm	890.0	1810.0	3940.0	1590.0	680.0
Fe ppm	120.0	2280.0	250.0	2840.0	2900.0
Cu ppm	21.0	41.0	11.0	15.0	90.0
Pb ppm					16.0
Cr ppm					80.0
Ni ppm					12.0
Mo ppm					6.0
Co ppm					.4
N %	1.371	.860	2.	1.868	1.491
C %	41.23	41.936	40.721	38.960	34.81
P ppm	1920.0	1310.0	1770.0	1470.0	2050.0

(1) PPM = µg/g dry weight of plant.

Table 37

Averaged chemical element composition of waterwillow collected from plastic pools, from Bartlett's Ferry Reservoir and from Lake Seminole during period 1965-67

Area	Plastic Pools	Bartlett's Ferry	Lake Seminole	
Year	'67	'67	'65	'66-67
Ash %	10.14	12.39	12.60	14.98
Ca ppm	7200.0	16920.0	17640.0	13560.0
Mg ppm	11000.0	8490.0	2990.0	4691.0
Na ppm	800.0	1730.0	1590.0	2292.0
K ppm	11200.0	27067.0	26520.0	26460.00
Sr ppm	23.0	12.0	-	6.2
Zn ppm	190.0	254.0	20.0	108.4
Mn ppm	300.0	780.0	830.0	733.6
Fe ppm	660.0	820.0	1920.0	2536.0
Cu ppm	44.0	564.0	9.0	142.0
Pb ppm	2.0	6.4	-	8.0
Cr ppm	16.0	35.6	-	58.0
Ni ppm	10.0	8.4	-	18.8
Mo ppm	-	-	-	12.0
Co ppm	0.6	13.6	-	5.12
Cd ppm	2.2	10.4	-	2.5
N %	1	2.782	3.951	2.553
C %	41.71	42.65	41.629	38.39
P ppm	2300.0	2133.0	2410.0	1767.0

(1) PPM = µg/g dry weight of plant.

Table 38

Averaged chemical element composition of smartweeds collected from Lake Eufaula during 1966-67

Area	Lake Eufaula
Year	'66-67
Ash %	15.24
Ca ppm	8150.0
Mg ppm	4550.0
Na ppm	1352.0
K ppm	19163.0
Sr ppm	20.2
Zn ppm	142.2
Mn ppm	599.4
Fe ppm	2074.0
Cu ppm	64.9
Pb ppm	12.0
Cr ppm	64.9
Ni ppm	18.9
Mo ppm	10.14
Co ppm	7.66
Cd ppm	4.28
N %	1.529
C %	29.57
P ppm	1488.0

(1) PPM = μg/g dry weight of plant.

Table 39

Averaged chemical element composition of parrotfeather collected from plastic pools and from Lake Seminole during 1966-67

Area	Plastic Pool	Lake Seminole	
Year	'65	'65	'66-67
Ash %	9.47	10.82	27.62
Ca ppm	21490.0	22600.0	34100.0
Mg ppm	7780.0	1850.0	731.0
Na ppm	5270.0	2660.0	2640.0
K ppm	15370.0	16800.0	3135.0
Sr ppm			7.5
Zn ppm	170.0	40.0	32.0
Mn ppm	700.0	1320.0	965.0
Fe ppm	360.0	690.0	202.5
Cu ppm	22.0	7.0	12.5
Pb ppm			9.5
Cr ppm			4.5
Ni ppm			4.0
Mo ppm			19.0
Co ppm			19.0
Cd ppm			2.7
N %	1.347	1.580	1.145
C %	43.253	42.798	44.96
P ppm	1730.0	960.0	780.0

(1) PPM = µg/g dry weight of plant.

Table 40

Averaged chemical element composition of Eurasian milfoil collected from plastic pools and from Lake Seminole during period 1965-67

Area Year	Plastic Pools '65	Plastic Pools '66	Lake Seminole '66-67
Ash %	13.88	6.68	24.97
Ca ppm	19030.0	6105.0	25960.0
Mg ppm	3490.0	3723.0	1503.0
Na ppm	12800.0	4207.0	3719.0
K ppm	18000.0	7700.0	8671.0
Sr ppm		7.5	5.59
Zn ppm	280.0	186.5	120.4
Mn ppm	1730.0	950.0	1185.0
Fe ppm	2120.0	4100.0	2991.0
Cu ppm	25.0	78.5	107.5
Pb ppm		49.5	13.45
Cr ppm		90.0	163.5
Ni ppm		16.0	26.61
Mo ppm		9.0	12.25
Co ppm		13.5	9.33
Cd ppm		6.5	2.61
N %	2.490	1.917	2.280
C %	42.93	27.82	34.02
P ppm	2930.0	600.0	1365.00

(1) PPM = µg/g dry weight of plant.

Table 41

Averaged chemical element composition of Paspalum fluitans collected from Lake Eufaula during period 1965-67

Area	Lake Eufaula	
Year	'65	'66-67
Ash %	12.71	18.91
Ca ppm	2600.0	1500.0
Mg ppm	2170.0	3133.0
Na ppm	2200.0	1740.0
K ppm	25400.0	22453.0
Sr ppm	-	1.33
Zn ppm	40.0	198.7
Mn ppm	240.0	1076.0
Fe ppm	980.0	896.7
Cu ppm	20.0	32.7
Pb ppm		4.53
Cr ppm		107.3
Ni ppm		20.0
Co ppm		5.67
Cd ppm		2.60
N %	1.907	2.122
C %	48.84	34.95
P ppm	2020 0	870.0

(1) PPM = µg/g dry weight of plant.

Table 42

Averaged chemical element composition of buttonbush collected from Lake Eufaula

Area	Lake Eufaula
Year	'66
Ash %	8.02
Ca ppm	1100.0
Mg ppm	2035.0
K ppm	12320.0
Sr ppm	2.0
Zn ppm	60.0
Mn ppm	140.0
Fe ppm	160.0
Cu ppm	105.0
Pb ppm	32.0
Cr ppm	1.0
Ni ppm	3.0
Mo ppm	5.0
Co ppm	8.0
Cd ppm	2.0
N %	1.970
C %	10.6
P ppm	2365.0

(1) PPM = µg/g dry weight of plant.

Table 43

Averaged chemical element composition of giant cutgrass collected from Lakes Eufaula and Seminole during 1966-67

Area	Lake Eufaula	Lake Seminole
Year	'66-67	'66-67
Ash %	14.03	10.20
Ca ppm	1483.0	4217.0
Mg ppm	1662.0	972.0
Na ppm	1800.0	1512.0
K ppm	30900.0	19332.0
Sr ppm	1.3	1.5
Zn ppm	176.7	134.2
Mn ppm	361.3	495.5
Fe ppm	1993.0	2022.0
Cu ppm	38.3	105.0
Pb ppm	7.3	10.25
Cr ppm	90.7	67.0
Ni ppm	19.0	17.0
Mo ppm	9.0	10.0
Co ppm	3.3	4.85
Cd ppm	1.5	.93
N %	1.789	1.527
C %	41.59	43.87
P ppm	1957.0	1020.0

(1) PPM = µg/g dry weight of plant.

Table 44

Averaged chemical element composition of needlerush collected from plastic pools during period 1965-1967

Area	Plastic Pools	Plastic Pools
Year	'65	'66-67
Ash %	8.423	5.44
Ca ppm	5170.0	1430.0
Mg ppm	2640.0	682.0
Na ppm	5420.0	2750.0
K ppm	37950.0	8745.0
Sr ppm	-	4.75
Zn ppm	400.0	120.0
Mn ppm	1170.0	190.0
Fe ppm	1880.0	190.0
Cu ppm	22.0	13.5
Pb ppm	-	8.0
Cr ppm	-	17.0
Ni ppm	-	14.0
Mo ppm	-	9.0
Co ppm	-	10.0
Cd ppm	-	.85
N %	1.496	1.50
C %	44.09	44.84
P ppm	1850.0	1162.0

(1) PPM = µg/g dry weight of plant.

Table 45

Averaged chemical element composition of eelgrass collected from plastic pools during period 1965-1967

Area	Plastic Pools		Plastic Pools
Year	'65		'66-67
Plant part	Shoot	Root	Whole
Ash %	20.62	21.91	25.80
Ca ppm	7870.0	6440.0	4212.0
Mg ppm	8730.0	1980.0	6395.0
Na ppm	10670.0	7680.0	7566.0
K ppm	42400.0	14700.0	15772.0
Sr ppm	-	-	4.5
Zn ppm	80.0	180.0	233.0
Mn ppm	2920.0	1890.0	1615.0
Fe ppm	490.0	5770.0	6400.0
Cu ppm	16.0	61.0	85.0
Pb ppm	-	-	12.7
Cr ppm	-	-	237.7
Ni ppm	-	-	45.7
Mo ppm	-	-	-
Co ppm	-	-	10.0
Cd ppm	-	-	7.25
N %	1.887	1.413	1.555
C %	39.77	36.56	
P ppm	2120.0	1760.0	1001.0

(1) PPM = µg/g dry weight of plant.

Table 46

Averaged chemical element composition of <u>Potamogeton</u> <u>crispus</u> collected from Lake Seminole during 1965-67

Area	Lake Seminole	
Year	'65	'66-67
Ash %	26.49	20.27
Ca ppm	27600.0	28579.0
Mg ppm	840.0	770.0
Na ppm	1860.0	3302.0
K ppm	26600.0	15899.0
Sr ppm	-	7.25
Zn ppm	60.0	153.4
Mn ppm	1170.0	1762.0
Fe ppm	370.0	1711.0
Cu ppm	1.0	109.1
Pb ppm	-	7.0
Cr ppm	-	74.1
Ni ppm	-	22.37
Mo ppm	-	10.3
Co ppm	-	8.73
Cd ppm	-	4.45
N %	3.433	1.999
C %	42.63	36.81
P ppm	1240.0	1649.0

(1) PPM = µg/g dry weight of plant.

Table 47

Averaged chemical element composition of <u>Bacopa</u> sp. and <u>Hydrocotyl</u> sp. collected from Lake Seminole in 1967

Area	Lake Seminole	
Year	'67	
Species	<u>Bacopa</u> sp.	<u>Hydrocotyl</u> sp.
Ash %	21.53	20.78
Ca ppm	44600.0	9000
Mg ppm	800.0	3300
Na ppm	15000.0	2700
K ppm	8400.0	31600
Sr ppm	5.0	4.0
Zn ppm	150.0	200
Mn ppm	10700.0	80
Fe ppm	4300.0	4360
Cu ppm	370.0	100
Pb ppm	2.0	20
Cr ppm	84.0	90
Ni ppm	20.0	22
Co ppm	14.0	2.0
Cd ppm	10.0	0.4
N %	2.155	3.148
C %	34.75	35.94
P ppm	1450.0	1900

(1) PPM = µg/g dry weight of plant.

Table 48

Averaged chemical element composition of white waterlily and banana waterlily from Lake Seminole in 1967

Area	Lake Seminole	
Year	'67	
Species	White waterlily	Banana waterlily
Ash %	7.01	6.66
Ca ppm	8500.0	5200
Mg ppm	12400.0	1160
Na ppm	12400.0	7700
K ppm	8000.0	1400
Sr ppm	1.0	2.4
Zn ppm	130.0	100
Mn ppm	80.0	980
Fe ppm	200.0	700
Cu ppm	430.0	122
Pb ppm	2.0	2.0
Cr ppm	6.0	52
Ni ppm	6.0	8.0
Co ppm	10.0	0.4
Cd ppm	10.0	0.2
N %	3.650	1.070
C %	42.22	41.34
P ppm	1630.0	860.0

(1) PPM = µg/g dry weight of plant.

Table 49

Averaged chemical element composition of Lyngba spp. collected from Auburn University experimental ponds in 1965 and from Lake Eufaula in 1967

Area	Exp. ponds	Lake Eufaula
Year	'65	'67
Ash %	72,11	17.20
Ca ppm	1900	4500.0
Mg ppm	2000	1400.0
Na ppm	700	600.0
K ppm	15000	4200.0
Sr ppm	0.4	
Zn ppm	430	
Mn ppm	1180	
Fe ppm	16400	
Cu ppm	400	
Pb ppm	70	
Cr ppm	700	
Ni ppm	40	
Co ppm	18	
Cd ppm	24	
N %	.886	5.01
C %	11.36	40.23
P ppm	1800	310.0

(1) PPM = µg/g dry weight of plant.

Table 50

Averaged chemical element composition of *Chara* spp. and *Nitella* spp. collected from Auburn University experimental ponds in 1965 and from Lake Seminole in 1967

Area	Exp. Ponds	Lake Seminole	Exp. Ponds	Lake Seminole
Year	'65	'67	'65	'67
	Chara		Nitella	
Ash %	43.41	58.09	19.11	22.27
Ca ppm	80300.0	5830.0	18,900	19,508.0
Mg ppm	9200.0	1930.0	9500.0	2596.0
Na ppm	1300.0	3075.0	2800.0	4858.0
K ppm	23500.0	2100.0	37,300.0	4179.0
Sr ppm		3.5		5.42
Zn ppm	89.0	395.0		33.99
Mn ppm	2926.0	2360.0		560.3
Fe ppm	2520.0	9100.0		4396.0
Cu ppm	19.0	650.0		30.74
Pb ppm		28.0		12.0
Cr ppm		395.0		28.6
Ni ppm		41.0		6.21
Mo ppm				4.29
Co ppm		16.0		4.03
Cd ppm		11.0		1.51
N %	2.46	1.765	2.70	2.337
C %	29.28	15.20	38.43	34.84
P ppm	2500.0	1900.0	2300.0	954.0

(1) PPM = µg/g dry weight of plant.

Table 51

Chemical composition of some algae from ponds and lakes in Southeastern United States

Analysis	Chara	Pithophora	Cladophora	Spirogyra	Giant Spirogyra	Rhizoclonium	Hydrodictyon	Oedogonium
	Averaged composition as percent dry weight for given species.							
Ash	43.4	27.77	23.38	13.06	13.86	17.36	17.94	12.69
C	29.3	35.38	35.27	42.40	41.16	39.10	39.96	40.84
N	2.46	2.57	2.30	3.01	2.35	3.46	3.87	2.64
P	.25	.30	.56	.20	.23	.43	.24	.08
S	.55	1.42	1.58	.27	.24	.27	1.41	.15
Ca	8.03	3.82	1.69	.57	.84	.52	.69	.44
Mg	.92	.20	.23	.45	.30	.21	.17	.16
K	2.35	3.06	6.08	.92	.99	1.90	4.21	3.03
Na	.13	.07	.18	1.42	1.43	.09	.38	.06
	Averaged composition as ppm dry weight for given species							
Fe	2520	2836	1040	1368	1793	1820	1373	1645
Mn	2926	829	2300	1641	1658	1687	1963	1729
Zn	89	29	10	72	46	89	129	119
Cu	19	23	190	47	34	75	114	75
B	6.7	65	84.6	4.2	4.3	1.8		8.1

Analysis	Mougeotia	Lyngbya	Nitella	Microcystis	Aphanizomenon	Anabaena	Euglena
	Averaged composition as percent dry weight for given species						
Ash	14.54	17.20	19.11	6.2	7.21	5.19	4.12
C	40.74	40.23	38.43	46.46	47.65	49.70	48.14
N	1.77	5.01	2.70	8.08	8.57	9.43	5.14
P	.25	.31	.23	.68	1.17	.77	.67
S	.36	.28	.34	.27	1.18	.53	.19
Ca	1.68	.45	1.89	.53	.73	.36	.05
Mg	.57	.14	.95	.17	.21	.42	.07
K	1.20	.42	3.73	.79	.68	1.20	.34
Na	.49	.04	.28	.04	.19	.18	.02
	Averaged composition as ppm dry weight for given species						
Fe	60	5230	2388	2751	167	80	240
Mn	1080	3866	2180	322	833	800	1545
Zn	520	171	240	48	120	0	73
Cu	143	101	39	37	187	70	290
B	8	112	9.8	3.6	-	0	3.8

Chemical Composition of Freshwater Fish

Fishing success in Lake Eufaula has been phenomonal for years 1964, 1965, 1966, and 1967. The major catches have been largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigro-maculatus*) and white crappie (*Pomoxis annularis*). While the fishermen have concentrated their efforts on the 3 species listed above, other edible species are abundant in the reservoir as shown in Table 52 furnished by Fisheries Division, Alabama Department of Conservation. However, in accounting for the chemical composition of the aquatic environment within Lake Eufaula, it is necessary that the composition of as many of these species as possible be determined.

A limited amount of comparative chemical composition data on freshwater fishes from Lake Eufaula, Lake Seminole and Auburn University experimental ponds will be presented in this report. More detailed and complete analyses of the entire body of several species of fish will be presented in theses now in preparation by Beverly Clement and by Roland Reagan.

It was imperative in developing these analytical techniques to sample fish from different types of habitats, and it was equally important that each analysis be representative of the content of the entire fish. The importance of these two requirements can be illustrated by data on chemical composition of channel catfish (*Ictalurus punctatus*) from ponds receiving no fertilization, from ponds receiving P only fertilization (Table 53), and on the chemical composition of head portion, middle portion, and tail portion as shown in Table 54.

Table 52

FISH POPULATION SAMPLE SUMMARY

LAKE EUFAULA

AUGUST 11-12, 1966

Two acre, block-net shoreline sample, east bank, 1 mile below Hatchechubee Creek Landing.

Species	Number Collected	Weight (Pounds)
1. Largemouth Bass	315	21.09
2. Spotted Bass	1	.16
3. Coosa Bass	1	.20
4. White Bass	37	.53
5. Chain Pickerel	4	3.92
6. Channel Catfish	163	9.26
7. White Catfish	192	3.50
8. Brown Bullhead	21	5.96
9. Snail Catfish	11	1.56
10. Flat Bullhead	13	.54
11. Bluegill	1,395	25.68
12. Redear	75	7.51
13. Redbreast	75	5.40
14. Longear	14	.55
15. Green Sunfish	29	.62
16. Warmouth	118	2.43
17. Black Crappie	255	6.40
18. White Crappie	11	1.29
19. Yellow Perch	2	.04
20. Gizzard Shad	19,505	240.30
21. Threadfin Shad	5,351	29.41
22. Carp	38	17.69
23. Golden Shiner	66	3.65
24. Blacktail Shiner	3	.07
25. Taillight Shiner	322	.58
26. Brook Silversides	12	.03
27. Gambusia	1	T
28. Pugnose Minnow	7	T
29. Tadpole Madtom	19	.05
Totals	28,056	388.42

Table 53

Averaged chemical element composition of channel catfish randomly selected at draining time from Auburn University experimental ponds, 1966

Treatment	8-8-0	0-0-0	8-8-2
% Ash	26.10	22.71	19.15
Ca ppm (1)	42716	34349	37080
Mg ppm	2163.7	2132.3	2148
Na ppm	5419.7	5448.3	5915.3
K ppm	6037.7	6382.3	6616
Sr ppm	5.0	4.0	4.67
Zn ppm	148.3	93.7	155.7
Mn ppm	37.0	35.7	47.0
Fe ppm	271.0	168.0	149.3
Cu ppm	42.0	58.3	31.7
Pb ppm	18.0	16.0	15.33
Cr ppm	12.0	18.0	8.33
Ni ppm	5.27	7.67	7.0
Mo ppm	8.27	5.67	7.33
Co ppm	4.27	2.80	2.67
Cd ppm	2.80	2.47	2.67
N %	10.415	11.778	11.331
P ppm	46427	38124	40830

(1) ppm = µg/g dry weight of fish.

Table 54

Averaged chemical element composition(1) of head, middle, and tail portions of channel catfish collected at draining time from Auburn University experimental ponds, 1966

	Whole fish	Body portions		
		Head	Middle	Tail
Ca ppm	37381	50373	34153	29284
Mg ppm	2116	2534	2023	1887
Na ppm	5521	6942	5323	4517
K ppm	6220	4779	6756	7501
Sr ppm	4.5	6.9	4.0	3.17
Zn ppm	131	140	90	167.7
Mn ppm	39.3	54.3	32	33.3
Fe ppm	191.6	181	223.3	184.0
Cu ppm	42.55	19	66	46.0
Pb ppm	16.1	17	16.6	15.7
Cr ppm	12.66	17.6	10.6	10.0
Ni ppm	6.55	7	5.6	7.27
Mo ppm	7.00	9.6	6.0	5.6
Co ppm	3.15	4.3	2.1	3.33
Cd ppm	2.60	2.66	2.66	2.60
N %	11.174	8.283	12.179	13.060
P ppm	41119	62746	34494	28140

(1) 1 ppm = 1 µg/g dry weight of fish

Data on channel catfish collected from Lakes Eufaula and Seminole are summarized in Table 55.

Other species of freshwater fish for which chemical composition data will be presented include the following:

Largemouth bass (*Micropterus salmoides*) Table 56
Bluegill bream (*Lepomis macrochirus*) Table 57
Green sunfish (*Lepomis cyanellus*) Table 58
Redbreast sunfish (*Lepomis auritias*) Table 58
Redear sunfish (*Lepomis microlophus*) Table 58
Black crappie (*Pomoxis nigro-maculatus*) Table 59
White crappie (*Pomoxis annularis*) Table 59
Warmouth (*Chaenobryttus coronarius*) Table 60
Yellow bullhead catfish (*Ameiurus natalis*) Table 61
Gizzard shad (*Dorosoma cepedianum*) Table 62
Golden shiner (*Notemigonus crysoleucas*) Table 62
Fathead (*Pimephales promelas*) Table 63

It will be noted that composition data on these species are reported by inch-group of total length of the fish. The sizes of largemouth bass reported in Table 56 indicate that certain elements, such as Ca, show slight increases in content with length, whereas other elements such as Zn, Cu, and Fe show some decrease in content with total length.

Bluegill data indicate a marked increase in Ca and Mg content through 6 inch groups and then a decrease in inch groups 7 and 8 (Figure 20). Other elements in the bluegill analyses show similar trends.

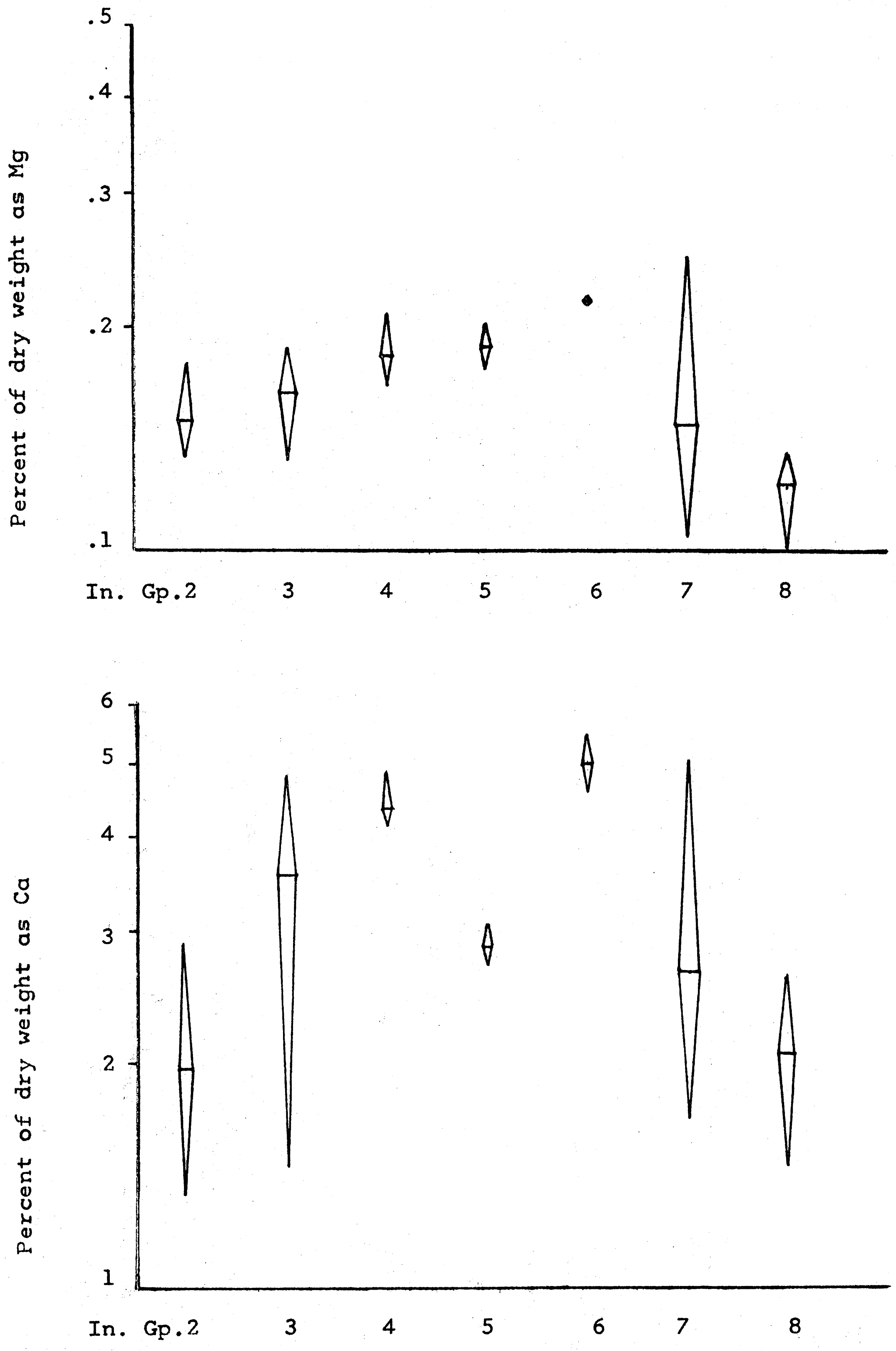


Figure 20. Averages and ranges of calcium and magnesium concentrations in various inch groups of bluegills collected from ponds and reservoirs in Alabama and Georgia.

These two species were chosen to illustrate total length-chemical composition trends because more different lengths have been analyzed. However, the numbers of individuals included in each inch-group were too small to firmly establish any definite pattern. Available data on other species are too meager to make any such comparisons at present. These and other unusual features of chemical composition trends in several species of freshwater fish will be explored in the two theses now in preparation.

As pointed out earlier in this Section, the data given in the tables are averaged analyses of fish collected from various environments. Of particular interest are those data on metallic element composition which appear to be high values for animals. Comparative metallic element composition data of four species collected from experimental ponds are given below.

	µg/g dry weight			
Element	Fathead	C. Catfish	Largemouth bass	Bluegill
Zn	173	131	107	85
Cu	52	42	15	45
Pb	12	16	5	2
Cr	11	12	8	18
Ni	5	6	4	6
Cd	2	2	1	1

Table 55

Averaged chemical element composition(1) of channel catfish randomly collected by rotenone and electricity from Lakes Eufaula and Seminole in 1966-67

% Moist	81.78
% Ash	21.14
Ca ppm	37360
Mg	1883.3
Na	4016.3
K	7067
Sr	4.5
Zn	87.3
Mn	76.0
Fe	449.3
Cu	35.0
Pb	14.67
Cr	46.7
Ni	9.33
Mo	4.0
Co	2.17
Cd	1.53
N %	10.751
C %	36.82
P ppm	32366

(1) 1 ppm = 1 µg/g dry weight of fish

Table 56

Averaged chemical element composition(1) of various inch-groups of largemouth bass randomly collected by rotenone, dynamite, and electricity from Lakes Eufaula and Seminole during 1966 and 1967

In. gp.	3	4	7	8	9	10
% Moist.	75.88	77.82			74.96	74.88
% Ash.	18.42	15.85	19.68	18.77	20.14	19.21
Ca ppm	33390	24895	36239	20540	41750	44750
Mg ppm	1906.7	1768	2101	1872	2050	1825
Na ppm	2855	1598	3736	1390	4450	4200
K ppm	13920	14300	6378	11700	12700	11800
Sr ppm	20.13	6.85	2.5	4.0	25.0	32.5
Zn ppm	188.0	82.5	77.0	108.0	12.5	7.5
Mn ppm	35.33	14.0	6.0	22.0	4.5	4.0
Fe ppm	185.2	77.5	63.0	23.0	125.0	80.0
Cu ppm	292.2	15.0	20.0	24.0	177.5	220.0
Pb ppm	5.17	2.5	22.0	12.0	5.5	6.5
Cr ppm	20.33	12.5	1.0	35.0	16.0	13.5
Ni ppm	49.7	3.25	8.0	4.5	12.5	10.0
Mo ppm			3.0			
Co ppm	10.5	7.5	1.5	20.0	6.5	7.5
Cd ppm	.9	.75	2.3	1.0	.5	.55
N %	10.62	11.53	9.90	10.18	9.40	10.33
C %	41.15	44.55	43.92	42.70	35.05	41.02
P ppm	30626	29835	37827		40400	38500

(1) 1 ppm = 1 µg/g dry weight of fish

Table 57

Averaged chemical element composition(1) of different inch-groups of bluegills randomly collected by rotenone, dynamite, and electricity from Lakes Eufaula and Seminole during 1966 and 1967

Inch Gp.	2	3	4	5	6	7	8
% Moist.	76.83	76.33	75.75	72.91	74.55	68.17	79.63
% Ash	14.96	18.90	20.76	22.99	22.58	18.25	15.13
Ca ppm	19557	35772	43820	28600	49000	26400	20605
Mg ppm	1499	1624	1824	1872	2140	1461	1209
Na ppm	1665	2035	2700	1807	4175	2398	1520
K ppm	12057	11360	12200	9270	12500	7532	7433
Sr ppm	7.5	16.25	30.0	6.5	25.0	7.88	5.5
Zn ppm	113.0	227.0	458.0	125.5	40.0	88.3	73.3
Mn ppm	71.0	76.5	55.6	107.5	52.5	54.1	39.7
Fe ppm	188.1	219.5	1084.0	43.5	345.4	111.4	147.2
Cu ppm	153.5	38.25	208.4	29.5	142.5	75.8	14.67
Pb ppm	3.43	3.80	5.20	9.0	3.5	6.79	3.0
Cr ppm	20.9	20.5	29.0	22.5	25.0	13.57	12.17
Ni ppm	10.57	88.25	136.6	7.0	54.0	7.64	3.17
Mo ppm						4.0	
Co ppm	11.0	12.75	6.4	24.0	6.5	13.77	11.5
Cd ppm	.84	.85	.20	1.0	.60	1.56	.68
N %	10.42	9.25	9.70	8.65	9.98	8.87	8.29
C %	44.35	43.57	40.86	42.65	38.08	45.27	47.54
P ppm	24846	28420	33800	31850	40400	29283	24960

(1) 1 ppm = 1 μg/g dry weight of fish

Table 58

Averaged chemical element composition of[(1)] various species of sunfish family collected by rotenone, dynamite, and electricity from Lakes Eufaula and Seminole in 1965 and 1966.

Species	Green Sunfish	Redbreast	Redear
In. Gp.	4	5	5
% Moist.	81.08	79.77	79.58
% Ash	22.67	29.80	22.25
Ca ppm	39415	49502	42015
Mg ppm	2475	2569	1955
Na ppm	4110	4670	3758
K ppm	5884	5744	9372
Sr ppm	4.0	4.5	10.0
Zn ppm	132.0	99.0	58.5
Mn ppm	42.0	36.0	41.0
Fe ppm	130.0	80.0	225.0
Cu ppm	44.0	14.0	53.0
Pb ppm	15.0	25.0	13.5
Cr ppm	4.0	5.0	9.5
Ni ppm	10.0	9.0	36.0
Mo ppm	3.0	4.0	2.0
Co ppm	1.5	1.0	4.5
Cd ppm	2.2	3.3	2.25
N %	9.240	10.285	9.35
C %	34.30	33.69	41.16
P ppm	46700	53238	31733

(1) 1 ppm = 1 μg/g dry weight of fish

Table 59

Averaged chemical element composition(1) of two species of crappie collected by rotenone, dynamite, and electricity from Lakes Eufaula and Seminole in 1965 and 1966

Species	White crappie		Black crappie
In. Gp.	8	9	7
% Moist.	89.27	77.65	81.24
% Ash	19.26	24.59	27.97
Ca ppm	35492	38500	50436
Mg ppm	1821	2035	2382
Na ppm	2802		4577
K ppm	5477		6071
Sr ppm	3.5	1.0	6.0
Zn ppm	62.0	195.0	61
Mn ppm	17.0	30.0	21
Fe ppm	113.0	260.0	70
Cu ppm	48.0	30.0	23
Pb ppm	16.0	20.0	20
Cr ppm	1.0	14.0	8
Ni ppm	7.0	9.0	7
Mo ppm	4.0	18.0	2
Co ppm	1.2	12.0	1.5
Cd ppm	3.0	3.0	2.0
N %	9.480	11.220	10.927
C %	40.47	38.26	36.63
P ppm	35726	47520	51837

(1) 1 ppm = 1 μg/g dry weight of fish

Table 60

Averaged chemical element composition(1) of warmouth collected by rotenone, dynamite, and electricity in Lakes Eufaula and Seminole in 1966 and 1967

In. Gp.	4	5
% Moist.	75.93	74.82
% Ash	19.78	26.93
Ca ppm	41500	43618
Mg ppm	1770	2270
Na ppm	4200	4016
K ppm	11400	5511
Sr ppm	50.0	-
Zn ppm	100.0	87.0
Mn ppm	55.0	55.0
Fe ppm	320.0	210.0
Cu ppm	100.0	55.0
Pb ppm	8.0	20.0
Cr ppm	13.0	14.0
Ni ppm	55.0	9.0
Mo ppm	-	6.0
Co ppm	10.0	1.5
Cd ppm	1.1	2.0
N %	10.57	10.765
C %	41.57	40.58
P ppm	39600	40629

(1) 1 ppm=1 µg/g dry weight of fish

Table 61

Averaged chemical element composition(1) of various inch groups of yellow bullhead catfish collected by rotenone, dynamite and electricity from Lakes Eufaula and Seminole in 1966 and 1967

Location	Lake Eufaula	L. Seminole	L. Seminole
In. Gp.	6	6	7
% Moist.	81.20	80.06	78.32
% Ash	16.72	22.48	24.37
Ca ppm	36500	40162	39508
Mg ppm	1750	1821	1961
Na ppm	3300	4390	5137
K ppm	15600	6725	5791
Sr ppm	25.0	-	-
Zn ppm	50.0	50.0	63.0
Mn ppm	56.0	65.0	115.0
Fe ppm	480.0	650.0	700.0
Cu ppm	100.0	40.0	46.0
Pb ppm	4.0	15.0	17.0
Cr ppm	35.0	8.0	11.0
Ni ppm	96.0	9.0	6.0
Mo ppm	-	6.0	6.0
Co ppm	3.0	1.5	2.0
Cd ppm	1.8	3.0	1.8
N %	12.14	9.448	10.750
C %	41.34	43.76	39.87
P ppm	27400	39228	31523

(1) 1 ppm = 1 µg/g dry weight of fish

Table 62

Averaged chemical element composition(1) of gizzard shad and golden shiners collected by rotenone from Lake Eufaula in 1965 and 1966

Species	Gizzard shad	Shiners
% Moist.	79.41	80.76
% Ash	20.43	20.41
Ca ppm	39229	45750
Mg ppm	1723	2025
Na ppm	3893	3223
K ppm	9560	9590
Sr ppm	12.33	35.0
Zn ppm	101.75	56.6
Mn ppm	64.75	38.0
Fe ppm	876.25	360.0
Cu ppm	92.75	115.6
Pb ppm	8.25	9.0
Cr ppm	23.5	14.33
Ni ppm	67.5	57.3
Mo ppm	7.0	9.0
Co ppm	4.37	5.0
Cd ppm	2.35	1.4
N $	10.41	9.92
C %	39.76	40.49
P ppm	26519	30443

(1) 1 ppm = µg/g dry weight of fish

Table 63

Averaged chemical element composition of fathead minnow collected by rotenone from Auburn University experimental ponds in 1966

In. Gp.	2	3	4
Ca ppm	37360	30754	34052
Mg ppm	2615	1417	2016
Na ppm	5136	1650	3742
K ppm	5800	10660	7744
Sr ppm	4.85	5.0	4.92
Zn ppm	195.0	140.0	173.0
Mn ppm	140.3	62.0	109.0
Fe ppm	1293.3	287.5	790.0
Cu ppm	37.7	74.0	52.2
Pb ppm	17.3	3.75	11.9
Cr ppm	9.66	14.0	11.4
Ni ppm	6.33	4.0	5.4
Mo ppm	5.33	-	-
Co ppm	2.83	6.25	4.2
Cd ppm	2.93	1.20	2.24
N %	6.873	9.56	7.96
C %	39.196	47.2	42.40
P ppm	34324	24830	30526

1 ppm = 1 µg/g dry weight of fish

SUMMARY

The determination of chemical and physical characteristics in water, bottom muds, and aquatic life within Lake Eufaula and its Chattahoochee river headwaters and tailwaters started in May, 1965 and continued through November, 1967.

Lake Eufaula, which is the 10th downstream impoundment on Chattahoochee river, is a multipurpose, run-of-river, reservoir, with surface area of 45,000 acres, an average depth of 20 feet, and a drainage area of 7,460 square miles. The averaged rate-of-flow since its impoundment in 1963 has been 10,800 cfs.

During 1930's this river was known as the "muddy Chattahoochee" and often had a silt load in excess of 400 ppm. The turbidity during the course of this study has ranged from 3 to 68 ppm indicating the influence of upstream impoundments as sediment basins, but more importantly it domonstrates the change from row crop farming to pasture lands and wood lots.

Early emphasis in this study was on water chemistry and was concerned with temperature, dissolved oxygen, and stratification relationships. During summers of 1965 and 1966 surface water temperatures often approached and occasionally exceeded 30°C, while bottom waters at depths of 75+ feet were 6° to 8° cooler. Dissolved oxygen concentrations in surface waters often approached, but rarely exceeded saturation. During hot, dry periods dissolved oxygen concentrations were depleted at less than 20-foot depths. These stratified conditions were broken at least 4 times during each of these two summers as a result of severe rain-wind storms. During first half of September of each of these years, a drop of approximately 2° C in surface water temperatures has produced an overturn in the entire lake with a complete mixing of adequate dissolved oxygen for fish life at all depths. Even though many regions of the lake were unsuitable for occupancy by fish during these hot, stratified periods, sufficient areas of aerated waters (approximately 600,000 acre-feet) were available for fish habitation.

Throughout 1967 the weather was abnormally cool and surface water temperatures seldom exceeded 28°C and bottom waters at 75+ foot depths were approximately 5° cooler. While the dissolved oxygen concentrations in surface waters never exceeded saturation even under these cooler conditions, the dissolved oxygen concentrations even at 85-foot depths was never completely depleted. These semi-stratified conditions were disrupted at 10-to 14-day intervals by cool, rainy weather conditions.

Throughout the three summers this lake has been under observation, water temperatures and dissolved oxygen concentrations have been in a constant state of change both in relation to time and to location within the reservoir.

In a series of dye studies conducted during mid-summer of 1966 it was demonstrated that even under hot weather conditions the waters in upper portions (region of impoundment contained within old river channel) were completely mixed even in areas with water depths of 40 feet. In deep water (70+-foot depths) areas under extreme stratified conditions, a dye injection into the 10-foot strata of bottom waters in old river channel moved at a rate of 0.08 mph over a 12-mile stretch of river channel and did not mix with overlying waters throughout this area.

One deep-water dye injection into the river channel in an area immediately downstream from a dual bridge installation at Eufaula, Alabama, moved downstream in a 10-foot strata for 24 hours, but then reversed its movements and during the next 96 hours moved for a distance of 2.5 miles upstream. This demonstrated that partial obstruction within a reservoir may produce peculiar flow patterns that could enhance nuisance conditions produced by various pollutants. In fact it could simulate the piston-type currents characteristic of estuaries that are subjected to tidal action. This condition should be recognized and considered in designing bridges and jetties for new reservoirs.

A total of 15 elements in raw lake waters were routinely determined. These are all in the essential element category for plant growth. The principal nutrient elements nitrogen, phosphorus, and potassium were each present in sufficient quantities (3 year averages, ppm N = .242, P = .037, K = 1.73) to have supported an abundant growth of phytoplankton. However, production of such a growth was never attained throughout the 3 year period of this research. This fact is verified by an averaged total carbon content in raw waters of 11.6 ppm and it never exceeded 23.5 ppm even in an area where inadequately treated domestic sewage was present. Thus, the production of undesirable blooms of phytoplankton on Lake Eufaula involves other factors in addition to an adequate, available supply of nitrogen, phosphorus, and potassium.

In the case of total carbon content (11.6 ppm), the carbonate carbon ($=CO_3$), as estimated by total alkalinity determinations, accounted for an averaged 2.43 ppm carbon. Of the remaining 9.2 ppm of carbon, that portion which could be readily degraded into CO_2 as determined by 5-day B.O.D. tests never exceeded 1.0 ppm carbon. Thus, Lake Eufaula with all of its multi-sources of agricultural, domestic, and industrial pollution did not have an organic carbon pollution problem during this 3-year period.

The soluble calcium content of this reservoir averaged 4.2 ppm over the 3-year period. The calcium content in 1965 and 1966 averaged 4.6 ppm but in 1967 it dropped to 3.4 ppm. The cause of this drop is unknown, but all data indicate that these waters were calcium poor to the extent that the lack of this element might be a limiting factor in aquatic life development in this reservoir. The soluble magnesium, on the otherhand, remained fairly constant around the average of 1.2 ppm over the 3-year period. This quantity of magnesium appears sufficient to adequately support aquatic life.

The soluble sodium content averaged 5.1 ppm, and varied slightly around this value for the 3-year period.

The total iron and manganese concentrations in raw waters, averaged .428 and .097 ppm respectively. Concentrations of each element varied considerably from these values depending upon turbidity, stratification, and phytoplankton production. Values for iron concentrations were increased by turbidity and stratification (dissolved oxygen depletion). Values for manganese were decreased by turbidity, and increased by stratification and phytoplankton production.

The copper concentrations in raw waters ranged from .001 to .63 ppm and the zinc concentrations in same water ranged from .001 to 1.25 ppm. Neither the source nor cause of this wide range of these two elements are known. Their presence in such large amounts in waters of Lake Eufaula and other impounded waters in its vicinity has caused concern in regards to their possible detrimental influence on aquatic life in these habitats.

Ranges in concentrations of other minor elements in water samples were as follows:

Strontium	.001 to .03 ppm.
Nickel	.01 to .03 ppm.
Chronium	.001 to .03 ppm.
Cobalt	.001 to .005 ppm.
Lead	.001 to .04 ppm.

In the case of each of the metallic elements, it was possible to remove as much as 2/3 of the indicated concentrations in raw waters by filtering the samples through an 8 µ millipore filter. This indicates that a major portion of each of these metals was a constituent of either colloids or particles that were of sufficient size to be retained by this 8 µ filter.

Studies on composition of suspended matter in reservoir waters were confined to 1967 since a usable technique for separation of the suspended matter from raw waters had to be devised. The technique adopted for these studies employed an 8 µ pore-size Millipore filter, an aqua-regia extraction procedure, and analyses by an atomic absorption spectrophotometer.

Comparative data on suspended matter in commercial catfish ponds and in reservoir and tributary creek waters were collected during summer of 1967. In each of these habitats the quantity of suspended matter, that was composed of microscopic plant material, increased as the summer progressed. The total carbon content of these suspended matter samples also increased, but not in direct proportion to quantity of suspended matter in all cases. This discrepancy in quantity of suspended matter and total carbon content is believed to have been due to increased bacterial populations which were not retained by the 8 µ pore-size filter and thus were not present in carbon analyses.

The mineral contents of these suspended matter samples were higher in the early summer and generally decreased as the summer progressed. The rate of decrease of such elements as calcium, magnesium and sodium appeared to be closely associated with phytoplankton pulses, i.e. new plant growths. In the case of iron, manganese, copper, zinc, and potassium the changes in content of suspended matter seemed to be associated with depletion of dissolved oxygen in bottom waters. Thus, it is suspected that most of these elements might have been present as suspended colloids and were retained as such by the filters. More sophisticated equipment and techniques will have to be employed to answer this question.

From all data accumulated on composition of suspended matter it appears that phytoplankton can assimulate large amounts of certain metals in their normal metabolism, and that as the summer progresses these phytoplankton tend to change their chemical composition and acquire a composition characteristic of an aging terrestial plant. However, until a method of separating organic and colloidal suspended matter is devised, the above statements must be considered as a conjecture on what actually happens.

These data on suspended matter compositions are extremely valuable since they represent that portion of raw surface waters which have here-to-fore been disregarded in routine laboratory analyses of filtered water samples. If the chemical content of natural surface waters are to be utilized in the establishment of water quality criteria by State and Federal agencies these chemical contents of suspended matter must be considered as a portion of surface water composition.

Sampling of bottom soils in Lake Eufaula was initiated in 1965, and was continued through 1966 and 1967. During 1965 and 1966 deep water samples were collected with a core sampler. In 1967 only the dewatered edge of lake was sampled with this apparatus.

A new bottom sampler was designed and built by Project Leader in 1967. This sampler collects that portion of the bottom sediment that lies between the solid bottom soil and the overlying water. This has commonly been described as the interface area or zone. Since the materials which this sampler collects are semi-fluid in nature, they have been called hydrosol. This sampler was used to collect all underwater bottom samples during 1967. It was also used to collect soil samples for herbicide residue analyses in aquatic weed control research. Residue analyses of soils collected by this sampler and those obtained by diving were identical. Thus, this sampler is collecting the soil surface area which has here-to-fore been unavailable to surface operated samplers.

All soil samples were dried and then extracted with a neutral cation exchange solution. Chemical analyses were made of the extracted (exchanged) elements in this solution.

In evaluating these data on exchangeable elements from bottom soils it is evident that sampling technique was a major factor in determining the quantity of an element or elements that could be recovered from a particular sample. In many cases the averaged quantity of an element recovered in the hydrosol samples exceeded the maximum quantity of that element recovered from any core sample. This does not indicate, however, that all necessary data on soil composition studies in a reservoir could or should be obtained with a hydrosol sampler, for example, the marginal sampling can only be accomplished with a core sampler if one is to obtain reliable data on elements available to plants whose roots extend several inches beneath the soil surface. Likewise, one should use the hydrosol sampler to determine those exchangeable elements that are currently being depositied or that could be used by various submersed plants, algae and floating plants.

To understand the chemical complexities of any aquatic habitat requires a knowledge of the chemical composition of aquatic plants that occur in the environment. Since aquatic plant development on Lake Eufaula has been limited, sampling of other occupied areas, i.e.

Lake Seminole and various experimental ponds and pools, was carried out in an attempt to find the explanation for this lack of aquatic plant development.

Only four aquatic plant species of any immediate concern were growing in Lake Eufaula during this study period. These plants were alligatorweed, giant cutgrass, smartweeds, and *Paspalum fluitans*. Of these four, only the first two were found in the other habitats under observation. Another aquatic species, waterwillow, was growing in Bartlett's Ferry Reservoir, which is immediately above, and in Lake Seminole, which is below, but none was found within Lake Eufaula.

Chemical composition of alligatorweed from various environments indicated a wide range in composition of such elements as calcium, magnesium, iron, manganese, sodium, and phosphorus in apparently normal plants, but lush growth of this species seemingly was associated with an abundant supply of nitrogen and potassium. It was also apparent from a study of the habitat, as well as the composition of the plant, that the nitrogen and potassium had to be supplied to the water roots and that the maintenance of an adequate concentration in the water medium was essential for lush growth.

In Lake Eufaula it has been observed that alligatorweed was apparently seriously retarded each winter by the 5-foot draw-down, and that it required the first half of each summer for surviving plants to become reestablished to the extent that they were able to effectively absorb nutrients from the flowing waters. However, during latter part of July and through August and September these reinfestations produced plant growths that indicated a luxury supply of nutrients.

Chemical data on waterhyacinths from habitats with different nutrient levels indicated that this species possibly has a wide composition tolerance for such elements as calcium, magnesium, iron, manganese, phosphorus, and sodium, but to produce healthy plants, the available nutrient level must be higher than for all alligatorweed. Since this is a floating species, its nutrient requirements must be met by an ample concentration of all elements in the water.

Eurasian milfoil is a newcomer to this section of United States. However, from the vast area it now occupies in certain sections of the Southeast, it is evident that certain habitats are suitable for its propagation. Data on chemical composition of plants from 2 infected areas and one from plastic pool provides evidence that this species has a high calcium requirement. In Lake Seminole, the only area presently infested with this species has a high calcium content in its waters (20+ ppm) and even though living propagules are floating into other areas of the lake, the plant has not become established any place where the calcium content is less than 20 ppm in the water.

Since most aquatic plants are capable of absorbing large amounts of major and minor plant nutrients from the surrounding waters, they have a potential use as collectors or absorbers of various types of nutrient pollutants. Their use in this role only awaits an economical method of harvesting and utilizing such nutrient collectors.

Rotenone sampling in 1965, 1966, and 1967 of the fish population in Lake Eufaula indicates that at least 29 species are present, but that less than 5 percent (approximately 20 lb. per acre) of the total weight per acre could be classed as harvestable sizes and species for the sport fishermen. This population composition is typical of reservoirs in the southeastern region of United States. Fishing success, however, has been phenomenal for largemouth bass, and black and white crappie, and, sport fishermen have not complained of any decline in catch over this 3-year period. This is a bit unusual since catches by sport fishermen have generally started declining by the 4th year after impoundment (1967) in most reservoirs in this region.

Since the principal interest of this study was to compare chemical composition of various life forms in this reservoir environment, samples of 21 different species of fish were randomly collected by use of rotenone, electricity, and seining from Lakes Eufaula and Seminole and from various fish ponds within the vicinity of these lakes. Each fish used for analyses was measured and weighed, freeze-dried, ground, a sample ashed, the residue dissolved in a weak acid solution, and this solution analyzed by atomic absorption spectrophotometer.

Comparative chemical composition data on two species, largemouth bass, and bluegill, from both Lakes Eufaula and Seminole and from experimental ponds have indicated an increase in calcium content of whole fish from the 2-inch group through the juvenile sizes (for each species) and then a decrease in calcium content in the adult sizes. It was also found that copper and zinc content within these

2 species was from 5 to 20 fold greater in reservoir fish than in experimental pond fish. Incidentally these pond fish were from habitats where copper sulfate had been applied for algae control, and indicates that the use of this algacide will not result in as much residue in fish as may be found in specimens from streams and reservoirs. Other heavy metals such as chromimum and lead were also more abundant in stream fish than in those removed from ponds. Some evidence on possible sources of some of these heavy metals is available, but further sampling of all species is needed to firmly establish these sources.

Based upon the data accumulated thus far on this study of Lake Eufaula, the approximate relative abundance of some selected elements in water, suspended matter, hydrosol (soil), plants, and fish were as follows:

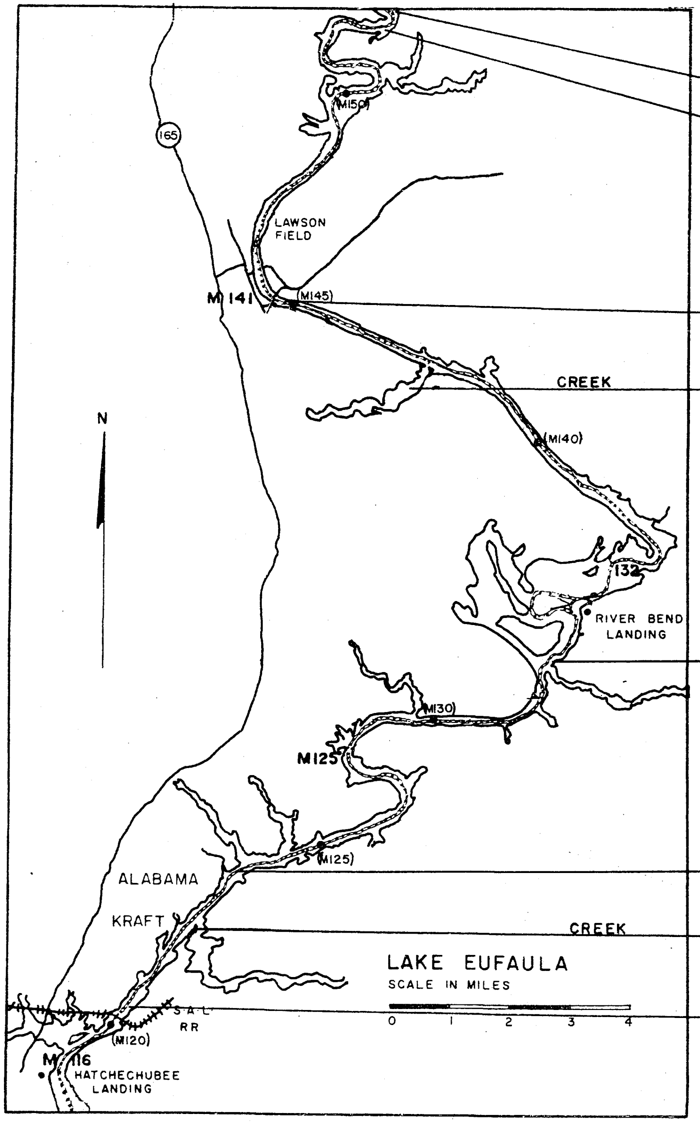
Element	Water (raw)	Suspended matter	Hydrosol (dry wt.)	Plants (dry wt.)	Fish (dry wt.)
Calcium	4.2	.13	1640	7100	35,000
Magnesium	1.2	.03	380	6000	2,000
Iron ppm	.4	.40	320	1575	150
Manganese ppm	.1	.03	540	530	35
Sodium ppm	5.1	.17	380	5200	2,500
Potassium ppm	1.7	.33	180	40000	7,000
Phosphorus ppm	.04	-	50	1850	38,000
Copper ppm	.03	.107	8	80	105
Zinc ppm	.06	.128	28	135	131
Nitrogen ppm	.242	-	1965	30,000	98,000
Carbon ppm	11.6	2.4	23,430	363,000	412,000

In most cases the maximum concentration for any element listed above was 2 or more fold the given approximate quantity. Thus, more extensive sampling is needed to establish a better average and range of composition of these and other elements in the various portions of the aquatic environment in Lake Eufaula and its associated head and tail-waters.

APPENDIX TABLES

Appendix Table 1-A

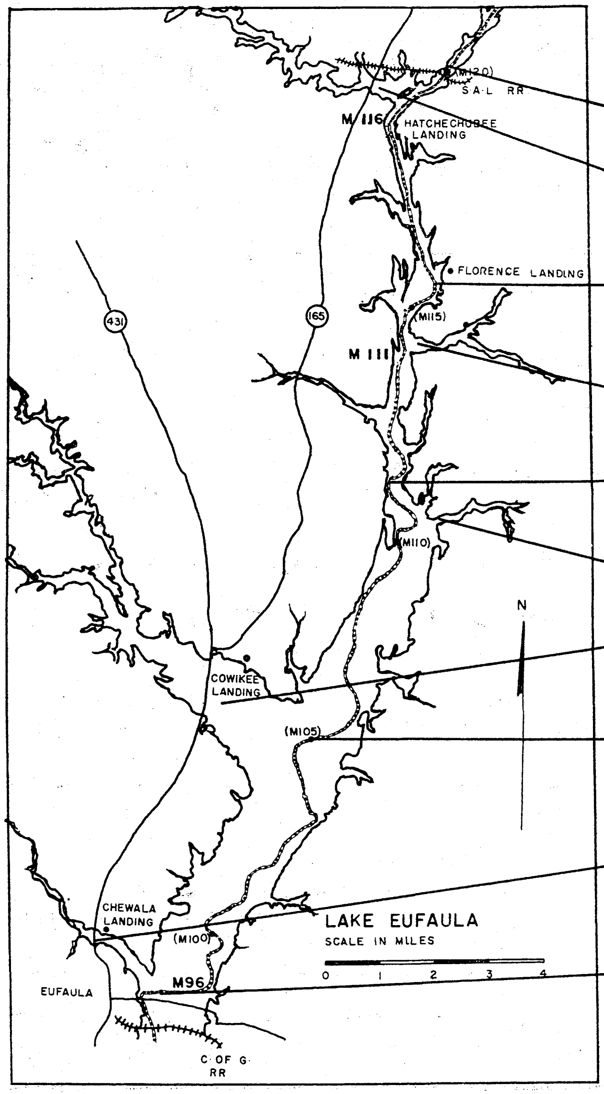
Averaged temperature, dissolved oxygen concentration, pH, and resistivity of water at indicated locations and depths in upper region of Lake Eufaula for 1965, 1966, and 1967



	TEMP. °C			OXYGEN PPM			pH			OHMS/CM^3		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	29.00	25.12	27.52	6.40	6.25	6.78	7.54	8.02	7.77	15280	16125	17844
0'	29.60	23.88	23.80	5.83	6.26	6.60	7.34	7.33	7.43	13300	19475	16617
0'	29.00	21.74	23.35	6.73	6.98	6.51	6.80	7.26	7.21	15400	17075	17583
20'	28.95	21.92	23.80	5.27	6.90	6.40	6.53	7.28	7.20	13825	17433	17067
0'		30.5	23.0		6.5	7.95	6.4	7.4	7.2	18500	14630	22350
0'	30.10	26.99	25.5	7.00	6.63	8.10	7.10	7.22	7.2	15467	17050	17200
30'	29.03	24.78	29.45	5.00	5.40	6.45	6.93	7.21	7.2	15067	17832	18325
0'	30.00	28.80	23.75	6.50	7.82	6.70	7.90	7.39	6.91	15300	16955	18628
40'		28.05	26.00		4.46	5.63		7.08	7.18		16440	17083
0'		23.5	25.3		8.0	7.00		7.6	8.00		19500	14867
30'		21.25	25.0		5.37	2.75		7.4	6.75		19450	16850
0'	30.10	26.25	25.14	7.10	6.72	[illegible]	6.83	7.21	7.18	16175	17054	18323
20'	28.83	23.99	23.88	5.07	5.64	6.9	6.50	7.01	6.0	15750	17130	17400
40'	28.60	24.20	25.10	5.30	5.13	6.9	6.55	6.98	5.15	16620	19000	15975

Appendix Table 1-B

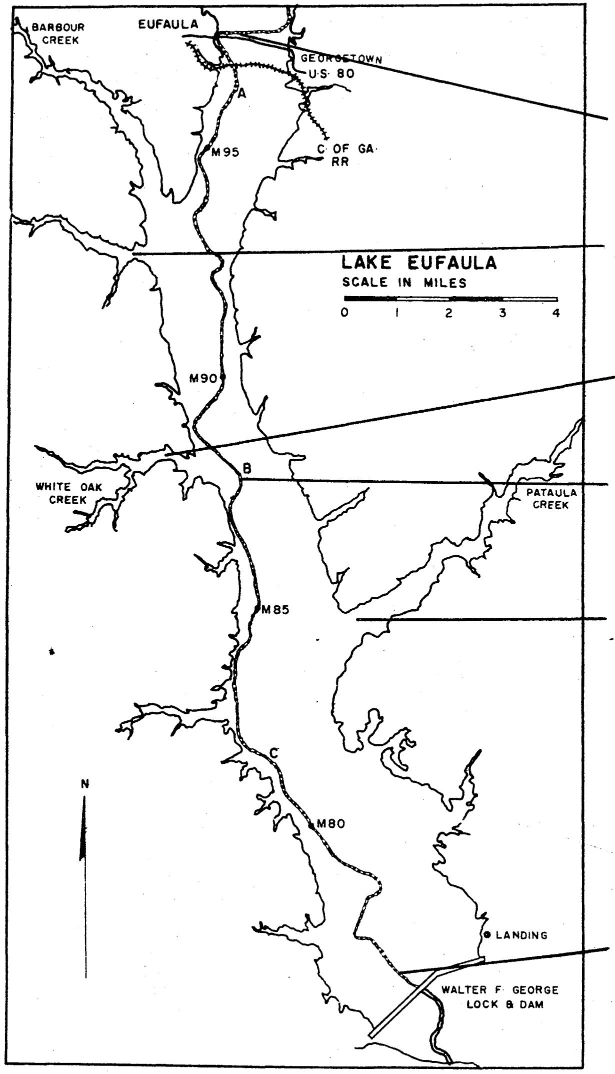
Averaged temperature, dissolved oxygen concentration, pH, and resistivity of water at indicated locations and depths in middle region of Lake Eufaula for 1965, 1966, and 1967



	TEMP. °C			OXYGEN PPM			pH			OHMS / CM³		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	30.10	26.25	25.14	7.10	6.72	7.00	6.83	7.21	7.18	16175	17054	18323
20'	28.83	23.99	23.88	5.07	5.64	6.90	6.50	7.01	6.00	15750	17130	17400
40'	28.60	24.20	25.10	5.30	5.13	6.90	6.55	6.98	5.15	16620	19000	15975
0'		28.43	27.00		8.71	8.65	6.7	7.86	7.85	13900	19989	16150
20'		24.90	25.60		2.05	4.10	6.43	7.03	6.90	14366	12740	16050
0'			28.0			8.40			7.85			19200
20'												
40'			27.9						6.80			22000
0'			25.00			9.00			8.90			17400
30'			22.00			1.50			7.30			16000
0'		29.06	27.17		5.92	6.83		7.61	7.71		15914	16633
20'		27.90	25.40		3.85	4.40		7.12	7.45		16325	16700
40'		27.61			3.65			7.08			15414	
60'		27.66	25.96		2.33	4.13		6.80	7.30		15566	16400
0'			26.58			9.5			8.25			17933
30'			24.58			3.62			6.70			16900
0'		28.00	26.50		6.07	8.00	7.3	7.80	7.15	14500	13600	15950
20'		26.67	24.50		1.77	2.50	6.5	7.22	6.75	13600	12640	15050
40'		26.17	26.00		1.42	2.90	6.4	7.20	6.3		11600	11900
0'	26.00	29.37	26.60	6.35	7.34	6.38	7.15	7.58	7.05	18700	17185	17100
20'	25.00	25.48	24.75	4.35	4.63	3.50	7.00	7.16	7.03	18900	17866	17166
40'	24.57	25.09	24.72	2.90	3.91	2.25	7.05	7.12	7.05	18500	17633	15100
60'	25.90	25.50	23.75	2.30	3.10	3.56	7.07	7.18	6.87	16900	16128	16616
0'	31.50	27.75	25.90	6.0	7.42	7.95	7.25	8.08	7.30	15250	16075	16430
30'	28.90	26.00	20.35	.45	1.67	3.00	5.70	7.25	6.35	13150	12600	13500
0'	26.02	27.62	26.50	6.06	6.81	7.80	7.37	7.82	7.16	15671	17050	16833
20'	24.95	26.80	25.50	3.30	4.32	6.30	6.44	7.27	6.80	16414	17192	17266
40'	24.55	26.58	25.43	2.55	2.46	4.07	6.52	7.05	6.53	16467	16292	17066
60'	24.40	25.17	25.10	2.54	1.82	2.86	6.42	7.13	6.40	15600	16142	16666

Appendix Table 1-C

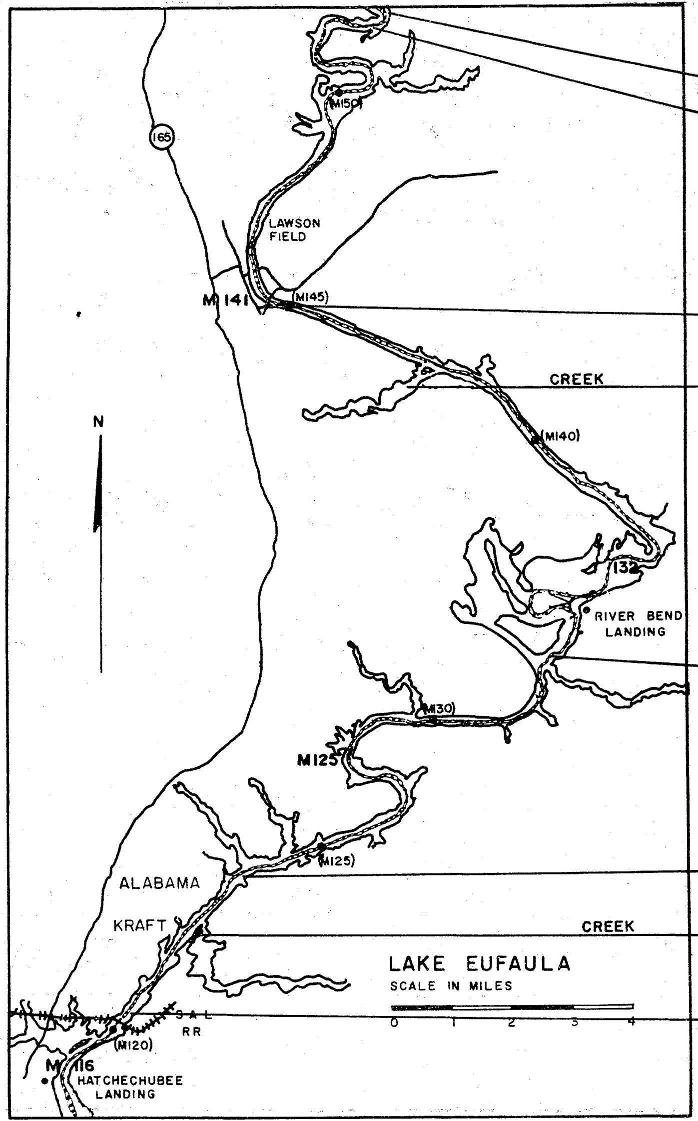
Averaged temperature, dissolved oxygen concentration, pH, and resistivity of water at indicated locations and depths in lower region of Lake Eufaula for 1965, 1966, and 1967



	TEMP. °C			OXYGEN PPM			pH			OHMS / CM³		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	26.02	27.62	26.50	6.06	6.81	7.80	7.37	7.82	7.16	15671	17050	16833
20'	24.95	26.80	25.50	3.30	4.32	6.30	6.44	7.27	6.80	16414	17192	17266
40'	24.55	26.58	25.43	2.55	2.46	4.07	6.52	7.05	6.53	16467	16292	17066
60'	24.40	25.17	25.10	2.54	1.82	2.86	6.42	7.13	6.40	15600	16142	16666
0'		27.0	29.5		6.5	8.0		8.2	7.2		18750	17300
40'		28.0	27.0		3.0	2.5		7.1	6.5		20800	19700
0'		25.00	28.00		7.0	6.5		8.7	8.5		18500	16900
40'		24.50	27.00		2.6	1.5		7.2	6.5		7300	15500
0'	31.5	28.61	26.85	8.15	6.58	8.60	7.95	7.82	8.35	16900	16855	16400
20'	28.35	26.27	24.75	1.95	3.45	2.97	7.00	7.22	6.55	15600	17138	16150
40'	27.75	25.97	24.35	.42	2.55	1.57	6.80	7.11	6.50	15800	16570	15700
60'	27.20	25.62	23.75	.20	1.88	1.32	6.85	7.10	6.80	15300	15500	16900
0'			27.40			6.37			6.50			19050
40'			25.75			4.50			6.55			21400
0'	29.44	29.31	27.75	7.12	7.11	8.15	7.84	8.18	7.15	16144	17855	17200
20'	28.35	28.12	25.60	4.94	5.87	6.32	7.11	7.82	6.95	15800	18644	17250
40'	26.90	27.30	24.5	2.80	4.02	2.80	6.78	7.43	6.40	16600	18189	17100
60'	25.88	25.78		1.62	3.12		6.47	7.31		13966	17814	
80'	26.17	26.59	24.5	1.91	1.16	1.12	6.60	7.19	6.35	17957	16000	15500

Appendix Table 2-A

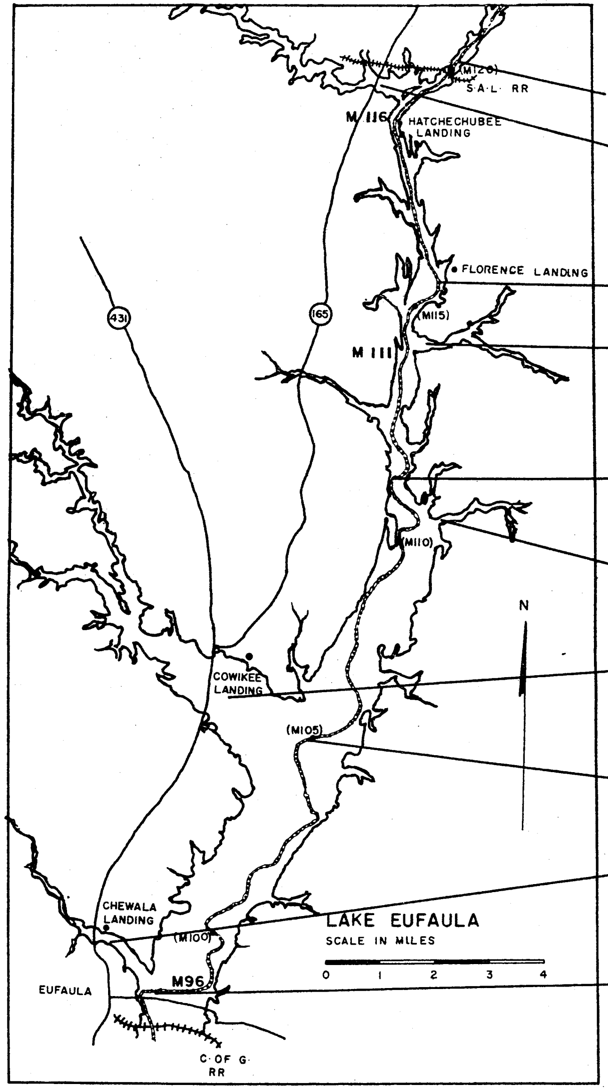
Averaged calcium, magnesium, potassium, and sodium concentrations in water at indicated locations and depths in upper region of Lake Eufaula for 1965, 1966, and 1967



	CALCIUM PPM			MAGNESIUM PPM			POTASSIUM PPM			SODIUM PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	4.46	4.40	3.42	1.21	.99	1.22	1.90	2.28	1.64	6.68	5.8	5.11
0'	4.32	4.40	3.08	1.18	.95	1.17	1.95	1.69	1.79	8.00	4.78	5.33
0'	3.49	5.0	2.91	1.23	1.22	1.13	1.69	1.94	1.53	6.33	4.86	6.32
20'	9.18	4.98	2.69	1.26	1.19	1.13	2.18	1.76	1.75	7.26	4.43	5.05
0'	4.92	4.80	6.0	1.55	1.41	1.01	1.0	3.2	1.22	2.0	8.22	2.18
0'	4.03	4 57	2.76	1.28	1.17	1.13	1.76	1.96	1.61	6.53	5.63	6.54
30'	3.89	4.97	1.00	1.34	1.21	1.20	1.73	2.04	1.85	6.22	4.98	5.60
0'	3.78	4.50	2.62	1.34	1.17	1.16	1.74	1.65	1.79	5.5	5.17	5.05
40'	-	4.45	3.71	-	1.13	1.17	-	1.89	1.80	-	5.06	5.28
0'	-	4.10	3.00	-	1.09	1.13	-	1.96	1.51	-	3.70	5.48
30'	-	5.0	4.57	-	1.20	1.07	-	1.81	1.44	-	4.29	4.03
0'	3.64	4.54	3.03	1.27	1.13	.93	1.91	2.07	2.07	5.9	4.4	3.95
20'	3.66	4.56	4.35	1.20	1.11	1.16	1.96	1.95	.54	5.74	4.36	4.75
40'	3.67	4.73	3.45	1.32	1.13	.80	1.77	2.10	2.71	5.37	4.49	5.12

Appendix Table 2-B

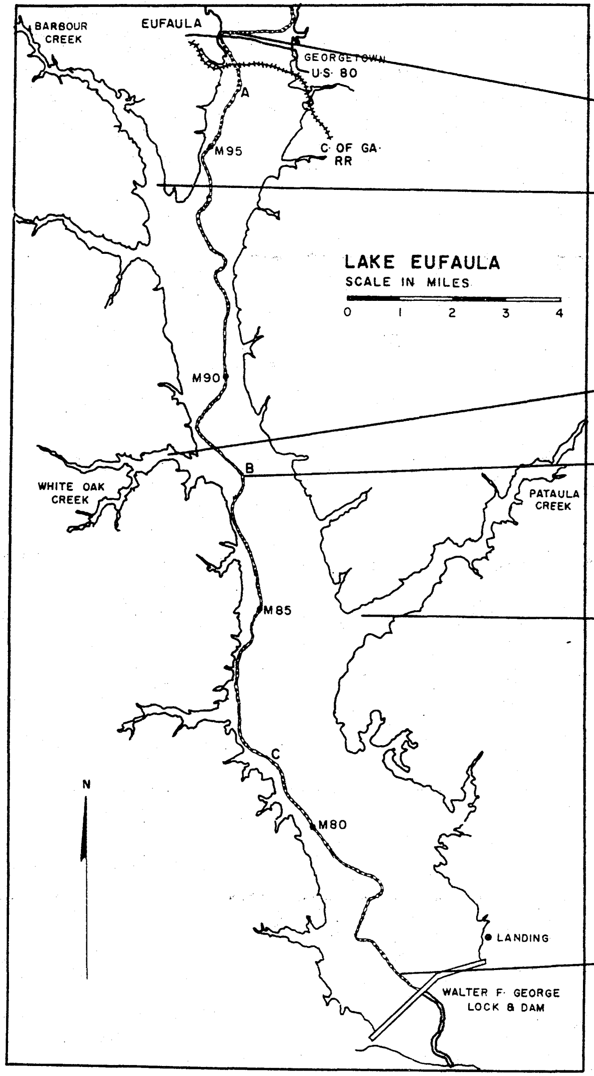
Averaged calcium, magnesium, potassium, and sodium concentrations in water at indicated locations and depths in middle region of Lake Eufaula for 1965, 1966, and 1967



	CALCIUM PPM			MAGNESIUM PPM			POTASSIUM PPM			SODIUM PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	3.64	4.54	3.03	1.27	1.13	.93	1.91	2.07	2.07	5.9	4.4	3.95
20'	3.66	4.56	4.35	1.20	1.11	1.16	1.96	1.95	.54	5.74	4.36	4.75
40'	3.67	4.73	3.45	1.32	1.13	.80	1.77	2.10	2.71	5.37	4.49	5.12
0'	4.80	7.54	3.52	1.18	.96	1.18	2.65	1.67	1.45	6.5	3.32	5.40
30'	5.22	8.54	2.80	1.17	1.03	1.14	2.15	1.60	1.52	6.66	3.19	5.55
0'	4.24		3.80	1.43		1.17			1.75			4.50
20'	4.48			1.30								
40'	4.92		2.80	1.15		1.25			1.70			5.70
0'			3.35			1.10			.95			4.48
30'			4.15			1.13			1.02			4.48
0'		4.29	3.21		1.30	1.06		1.73	1.25		4.99	5.87
20'		3.92	3.50		1.23	1.06		1.71	1.15		4.81	5.37
40'		4.32			1.25			1.85			5.39	
60'		4.06	2.70		1.11	1.08		1.86	1.28		4.04	5.83
0'			4.02			1.05			1.04			5.80
30'			3.51			1.16			1.01			4.11
0'	2.60	10.36	4.48	1.25	1.20	1.04	2.00	1.66	1.41	6.0	3.68	4.07
20'	6.20	11.20	5.70	1.18	1.17	1.00	2.10	1.78	.91	5.75	3.34	4.77
40'	6.80	12.23	7.60	1.18	1.20	1.05	1.90	1.53	2.02	5.50	3.15	2.40
0'	3.84	4.42	2.76	1.45	1.15	1.15	1.80	2.02	1.31	4.0	4.83	5.53
20'	3.55	4.68	3.05	1.40	1.18	1.28	1.88	2.13	1.50	3.92	5.04	4.47
40'	3.93	4.62	4.35	1.35	1.08	1.67	1.73	2.10	1.11	4.16	4.50	4.72
60'	3.95	5.45	2.62	1.55	1.11	1.22	1.86	2.01	1.56	4.25	4.34	4.96
0'	5.03	4.3	4.62	1.62	1.015	1.18	1.65	1.56	1.68	7.5	3.37	4.68
30'	6.55	7.52	11.62	1.62	1.29	1.20	1.80	1.85	1.67	8.8	3.46	4.36
0'	2.94	4.68	3.97	1.40	1.20	1.17	1.50	2.02	1.40	4.0	4.91	5.46
20'	3.60	4.85	3.68	1.43	1.19	1.15	1.60	1.97	1.41	4.0	4.88	5.48
40'	4.24	4.98	3.83	1.40	1.20	1.30	1.90	2.06	1.56	4.0	4.84	5.26
60'	5.04	5.54	3.60	1.45	1.22	1.20	1.90	2.06	1.53	4.0	4.50	5.17

Appendix Table 2-C

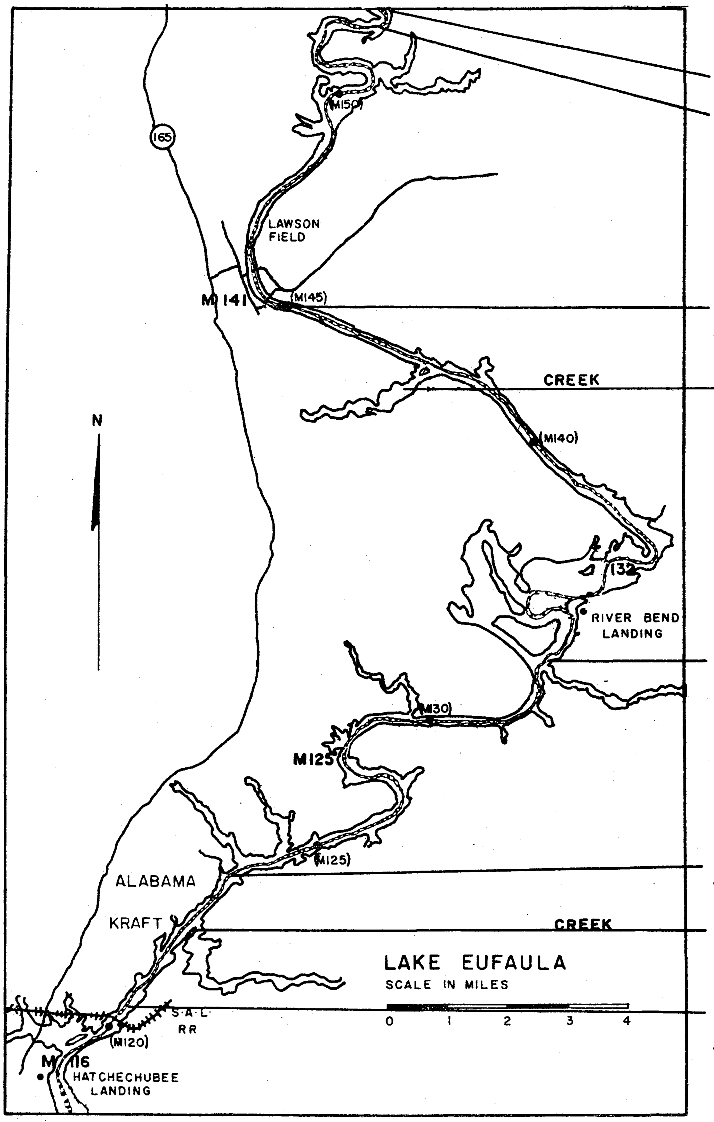
Averaged calcium, magnesium, potassium, and sodium concentrations in water at indicated locations and depths in lower region of Lake Eufaula for 1965, 1966, and 1967



	CALCIUM PPM			MAGNESIUM PPM			POTASSIUM PPM			SODIUM PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	2.94	4.68	3.97	1.40	1.20	1.17	1.8	2.02	1.40	4.0	4.91	5.46
20'	3.60	4.85	3.68	1.43	1.19	1.15	1.8	1.97	1.41	4.0	4.88	5.40
40'	4.24	4.98	3.83	1.40	1.20	1.30	1.75	1.98	1.56	4.0	4.84	5.26
60'	5.04	5.54	3.60	1.45	1.22	1.21	1.60	2.06	1.53	4.0	4.50	5.17
0'		3.95	2.6		1.17	1.13		1.34	1.40		3.64	7.0
40'		6.63	4.6		1.25	.82		1.35	1.05		3.01	3.2
0'		4.5	3.4		.98	1.18		1.93	1.30		2.98	6.0
40'		12.67	4.6		.945	1.10		1.87	1.30		2.18	4.65
0'	4.28	4.74	3.40	1.50	1.25	1.28	1.63	1.90	1.45	7.5	4.62	5.95
20'	4.40	4.94	3.77	1.56	1.22	1.31	1.57	2.18	1.55	7.5	4.28	5.95
40'	4.67	4.57	3.72	1.50	1.27	1.40	1.67	1.79	1.47	7.0	4.46	5.49
60'	4.80	5.00	4.32	1.50	1.25	1.10	1.55	2.16	1.05	6.5	4.90	4.19
0'			4.77			.87			.77			2.78
40'			4.45			.68			.50			1.42
0'	4.22	4.08	3.85	1.28	1.12	1.17	1.57	1.72	1.34	6.59	4.36	4.72
20'	4.28	4.77	3.63	1.32	1.10	1.17	1.69	1.72	1.30	8.23	3.93	4.68
40'	4.60	4.57	3.35	1.31	1.12	1.18	1.56	1.70	1.40	8.09	3.93	4.50
60'	5.04	4.71		1.21	1.13		1.82	1.78		1.77	4.21	
80'	5.34	5.33	3.82	1.28	1.12	1.26	1.55	1.54	2.0	5.88	3.52	5.25

Appendix Table 3-A

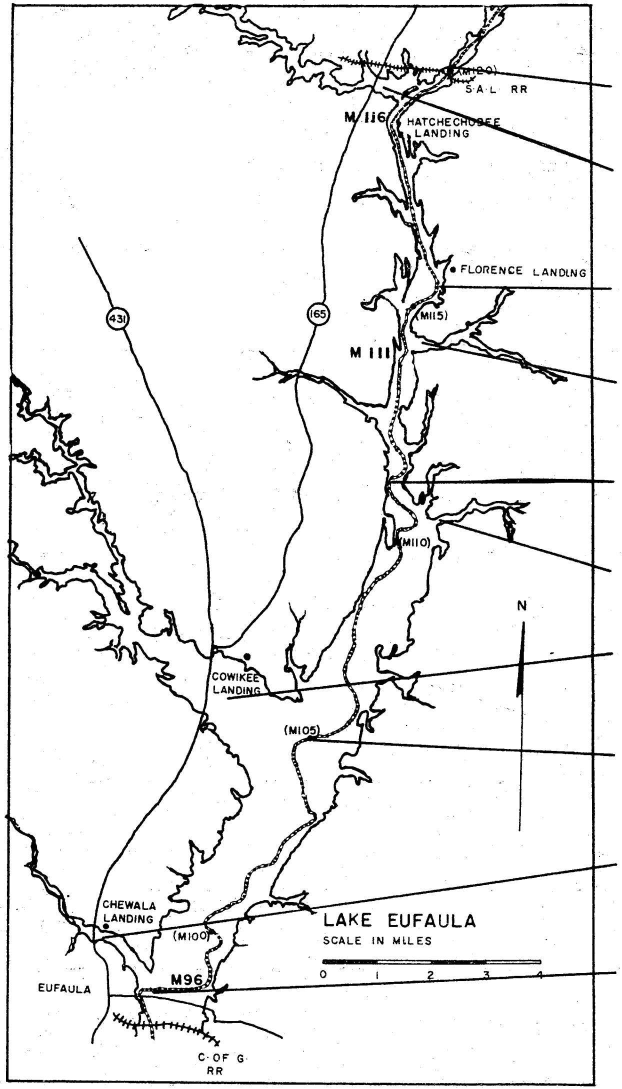
Averaged turbidity, alkalinity, and EDTA hardness concentrations in water at indicated locations and depths in upper region of Lake Eufaula for 1965, 1966, and 1967



	TURBIDITY JTU			ALKALINITY PPM C CO_3			EDTA HARD. PPM C CO_3		
	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	24.6	9.07	16.33	28.5	21.0	17.98	17.3	14.41	13.0
0'	10.	10.84	16.6	32.02	17.9	22.61	20.56	14.80	13.25
0'	13.5	14.57	13.95	16.02	18.78	18.12	15.4	14.56	12.75
20'	32.75	20.18	16.83	29.51	18.02	15.83	15.29	13.88	13.00
0'	33.0	24.0	11.50	24.8	23.7	15.0	20.5	14.7	
0'	27.3	15.86	9.83	23.87	17.5	16.67	15.8	14.75	13.0
30'	34.2	20.07	16.50	23.17	17.3	16.87	15.66	14.50	13.25
0'	22.5	8.43	15.96	24.50	18.33	19.16	16.1	15.35	13.10
40'		13.26	15.45		17.29	16.43		15.58	13.62
0'		8.0	7.0		20.0	24.58		15.0	13.0
30'		20.0	21.0		15.83	16.88		14.33	13.0
0'	27.0	20.85	16.0	22.12	18.0	17.70	15.23	14.55	13.6
20'	22.25		28.11	23.89	16.13	17.50	15.71	13.77	15.25
40'	25.0	30.68	20.75	24.26	16.81	19.44	15.14	14.68	14.0

Appendix Table 3-B

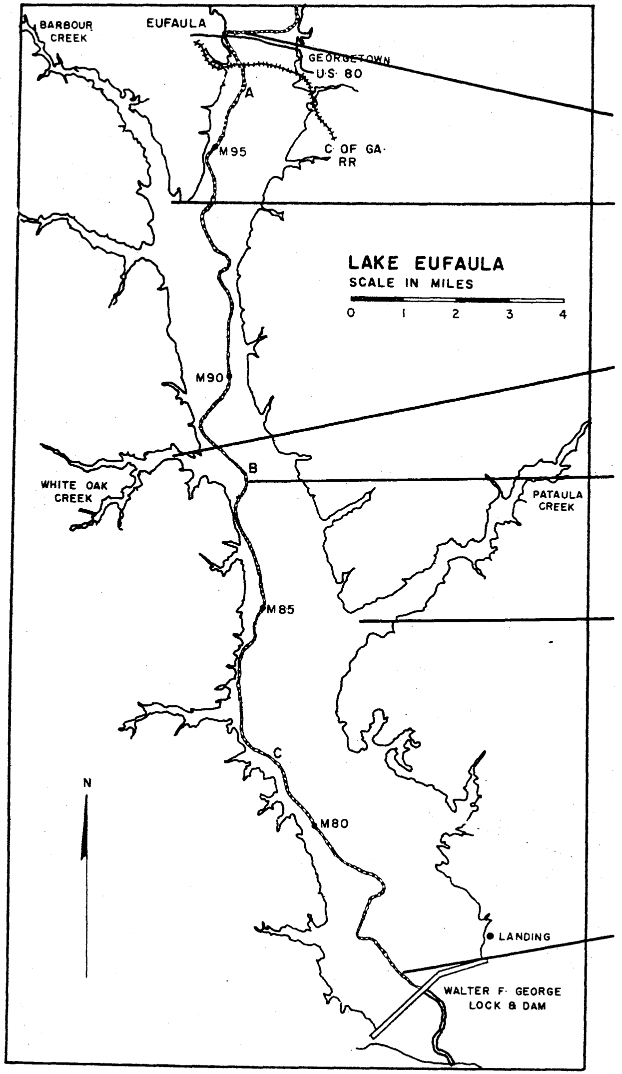
Averaged turbidity, alkalinity, and EDTA hardness concentrations in water at indicated locations and depths in middle region of Lake Eufaula for 1965, 1966, and 1967



	TURBIDITY JTU			ALKALINITY PPM C CO$_3$			EDTA HARDNESS PPM C CO$_3$		
	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	27.0	20.85	16.0	22.12	18.0	17.70	15.23	14.55	13.6
20'	22.25	28.11		23.89	16.13	17.50	15.71	13.77	15.25
40'	25.0	30.68	20.75	24.26	16.81	19.44	15.14	14.68	14.0
0'	10.0	12.06	7.5	29.70	19.98	24.37	20.00	17.0	13.0
20'	16.3	22.10	17.0	28.10	24.05	16.87	20.06	20.6	12.0
0'				21.5			15.0		
20'				21.33			15.0		
40'				22.05			15.75		
0'			6.4			16.25			
30'			12.0			22.5			
0'		14.25	8.0		17.50	17.08		14.94	13.0
20'		23.33	10.75		17.27	18.75		14.45	13.0
40'		22.81			18.13			15.13	
60'		22.75	13.33		16.56	18.75		18.38	12.75
0'			9.3			16.25			12.0
30'			23.3			18.25			12.5
0'	11.	5.67	12.15	30.4	23.7	20.25	19.7	22.6	20.0
20'	12.	15.0	8.3	28.2	27.74	20.0	21.6	28.6	16.0
40'	27.	19.2	27.5	30.7	30.6		21.0	32.8	33.5
0'	53.5	13.33	12.4	23.02	17.92	18.5	18.0	14.68	13.3
20'	60.0	26.41	15.33	21.55	16.16	18.33	17.97	14.53	14.75
40'	81.0	22.10	10.50	25.90	17.00	20.0	14.47	14.74	
60'	71.0	25.33	20.33	30.60	15.15	18.75	17.50	17.66	14.33
0'	22.5	7.5	5.16	33.75	16.56	18.75	23.75	15.25	14.0
30'	32.4	46.0	40.5	31.00	23.13	25.0	27.8	15.25	22.0
0'	20.3	7.25	11.33	18.08	18.75	17.91	14.38	13.95	13.25
20'	27.50	10.83	12.33	21.46	17.91	17.91	14.50	14.92	13.00
40'	33.25	12.81	13.33	21.40	18.11	17.50	16.50	21.98	13.25
60'	31.0	15.95	13.66	25.10	20.55	17.50	17.0	17.16	13.75

Appendix Table 3-C

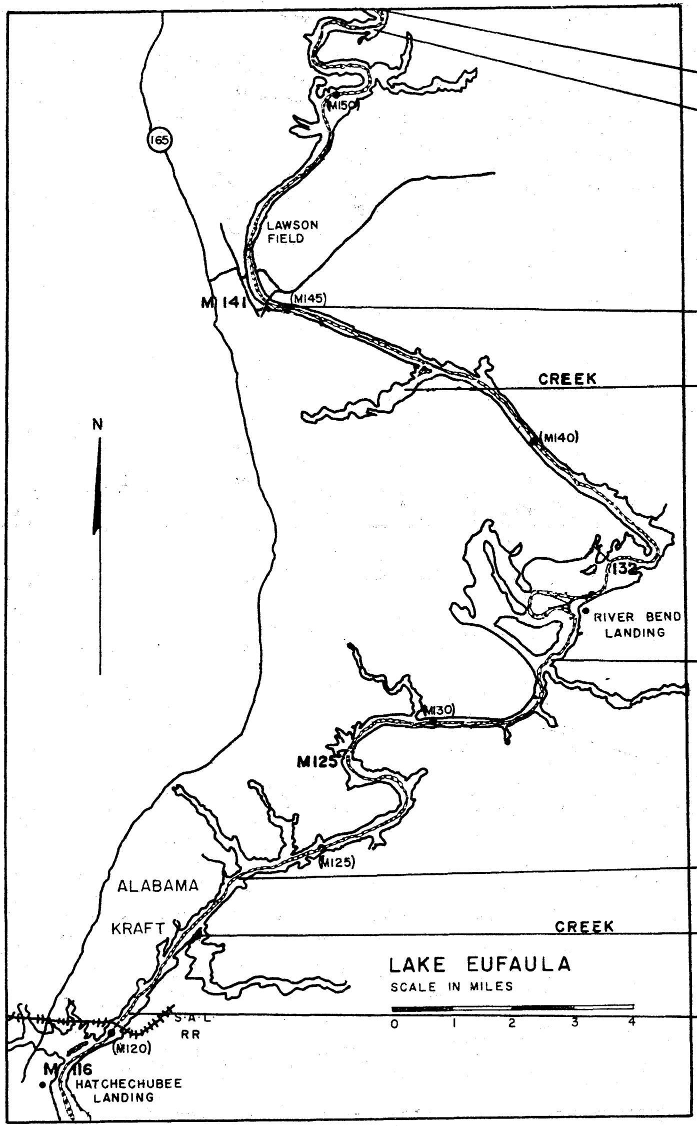
Averaged turbidity, alkalinity, and EDTA hardness concentrations in water at indicated locations and depths in lower region of Lake Eufaula for 1965, 1966, and 1967



	TURBIDITY JTU			ALKALINITY PPM C CO_3			EDTA HARDNESS PPM C CO_3		
	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	20.3	7.25	11.33	18.08	18.75	17.91	14.38	13.95	13.25
20'	27.5	10.83	12.33	21.46	17.91	17.91	14.50	14.92	13.00
40'	33.25	12.81	13.33	21.40	18.11	17.50	16.50	21.98	13.25
60'	31.0	15.95	13.66	25.10	20.55	17.50	17.00	17.16	13.75
0'		5.5	5.0		17.5	17.5		15.0	14.0
40'		32.7	50.0		19.16	16.25		21.66	18.0
0'		6.0	4.0		17.5	17.5		17.0	15.0
40'		9.75	6.0		44.37	21.25		48.25	20.0
0'	13.5	4.95	5.25	29.06	18.87	18.75	14.33	15.11	15.0
20'	26.0	8.73	7.25	19.53	18.27	19.37	15.06	15.59	14.5
40'	35.0	10.32	8.50	21.43	19.03	19.37	16.06	15.50	15.0
60'	44.0	10.22	11.25	20.87	21.25	20.0	16.70	17.28	17.5
0'			9.75			18.41			16.0
40'			25.5			16.87			16.75
0'	9.45	4.5	1.85	22.18	19.00	19.37	17.21	15.30	14.5
20'	10.8	3.64	2.25	21.93	17.66	18.75	17.21	15.56	14.0
40'	11.5	4.03	5.0	25.46	19.11	18.75	18.43	14.93	15.0
60'	27.1	6.25		25.70	19.29		20.37	15.94	
80'	49.1	10.38	6.0	29.42	23.50	18.75	21.56	17.90	16.5

Appendix Table 4-A

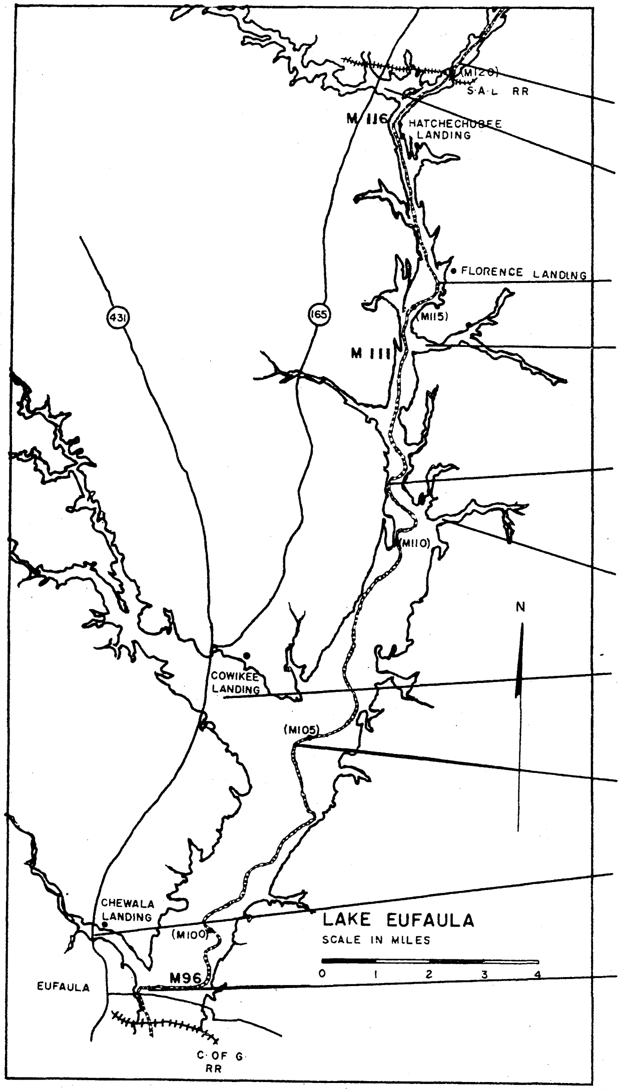
Averaged iron, manganese, zinc, and copper concentrations in water at indicated locations and depths in upper region of Lake Eufaula for 1965, 1966, and 1967



	IRON PPM			MANGANESE PPM			ZINC PPM			COPPER PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	.13	.366	.532	.036	.030	.009	.006	.085	.044	.004	.005	.012
0'	.122	.453	.540	.061	.130	.045	.002	.138	.042	.007	.006	.015
0'	.18	.69	.44	.025	.075	.021	.005	.044	.036	.002	.022	.019
20'	.10	.72	.873	.038	.095	.052	.007	.066	.039	.007	.022	.019
0'	.37	.43	.73	.058	.023	.006	.002	.081	.012	.006	.001	.005
0'	.09	.62	.236	.030	.140	.012	.011	.065	.02	.009	.003	.006
30'	.083	.73	.86	.022	.141	.040	.015	.043	.062	.047	.011	.002
0'	.10	.44	.623	.005	.030	.032	.065	.035	.032	.005	.004	.018
40'	-	.73	.750	-	.056	.043	-	.061	.035	-	.003	.006
0'	-	.062	.316	-	.022	.021	-	.015	.116	-	-	.243
30'	-	.523	.777	-	.027	.009	-	.018	.031	-	-	.020
0'	.129	.79	.607	.020	.07	.022	.011	.063	.067	.017	.006	.110
20'	.120	.98	.08	.038	.11	.024	.007	.070	.050	.016	.006	.010
40'	.151	.88	.612	.021	.26	.039	.007	.073	.034	.010	.009	.035

Appendix Table 4-B

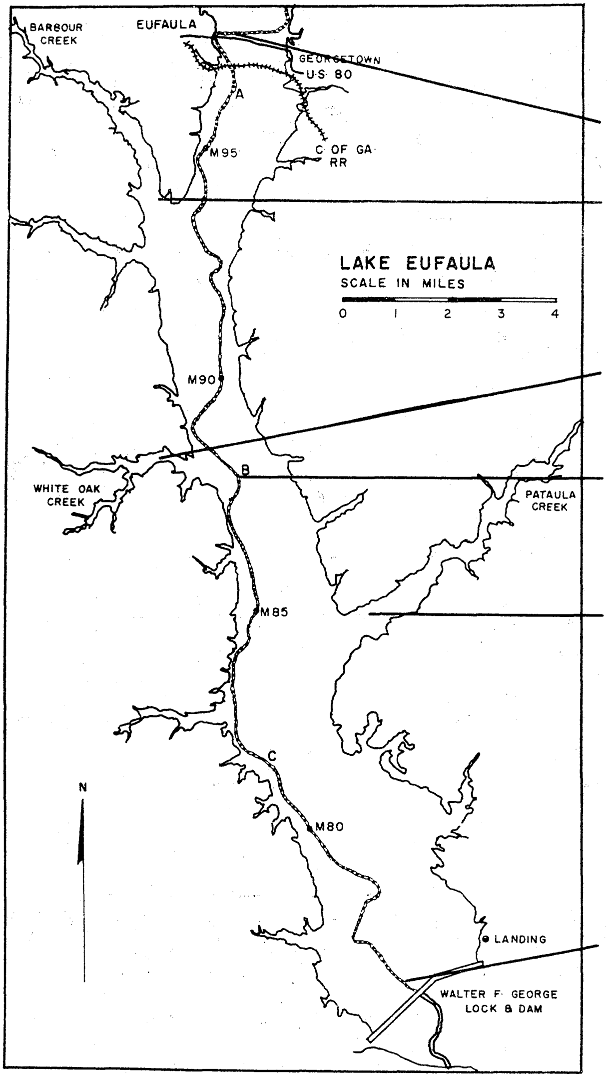
Averaged iron, manganese, zinc, and copper concentrations in water at indicated locations and depths in middle region of Lake Eufaula for 1965, 1966, and 1967



	IRON PPM			MANGANESE PPM			ZINC PPM			COPPER PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	.129	.79	.607	.020	.07	.022	.011	.063	.067	.017	.006	.110
20'	.120	.98	.08	.038	.11	.024	.008	.070	.050	.025	.006	.010
40'	.151	.88	.612	.021	.26	.039	.007	.073	.034	.015	.009	.035
0'	.07	1.128	.16	.05	.025	.012	.018	.051	.033	.006	.003	.033
30'	.09	2.41	.955	.07	.154	.034	.012	.324	.055	.006	.006	.032
0'	.005	-	.83	.005	-	.005	-	-	.02	-	-	.013
20'	.005	-		.005								
40'	.016			.027								
0'			.09			.020			.043			.016
30'			.24			.013			.045			.010
0'		.64	.313		.07	.020		.071	.049		.005	.013
20'		1.04	.280		.04	.023		.102	.050		.004	.016
40'		1.01	.500		.75	.040		.129	.030		.001	.009
60'		1.17			.09			.086			.007	
0'			.161			.015			.090			.083
30'			.485			.043			.137			.079
0'	.130	.372	.355	.073	.021	.028	.018	.067	.045	.008	.009	.017
20'	.127	1.632	.400	.070	.043	.047	.014	.132	.033	.009	.013	.013
40'	.127	2.128	2.200	.070	.049	.132	.014	.010	.055	.009	.005	.018
0'	.177	.79	.338	.025	.10	.014	.029	.027	.050		.007	.132
20'	.285	.98	.396	.008	.05	.049	.038	.021	.066		.007	.251
40'	.315	1.25	.365	.007	.265	.107	.020	.150	.100		.010	.280
60'	.528	1.38	.750	.008	.25	.091	.055	.019	.083		.007	.015
0'	.270	.73	.198	.001	.013	.015	.048	.687	.072	.005	.009	.028
30'	.320	1.91	.956	.103	4.705	.036	.020	.062	.075	.004	.001	.020
0'	.214	.33	.403	.005	.05	.026	.015	.033	.060	.008	.007	.036
20'	.175	.59	.443	.060	.10	.023	.053	.028	.068	.012	.005	.041
40'	.150	.69	.563	.032	.20	.046	.141	.050	.080	.010	.005	.084
60'	.187	.97	.633	.340	.63	.072	.085	.046	.106	.009	.006	.066

Appendix Table 4-C

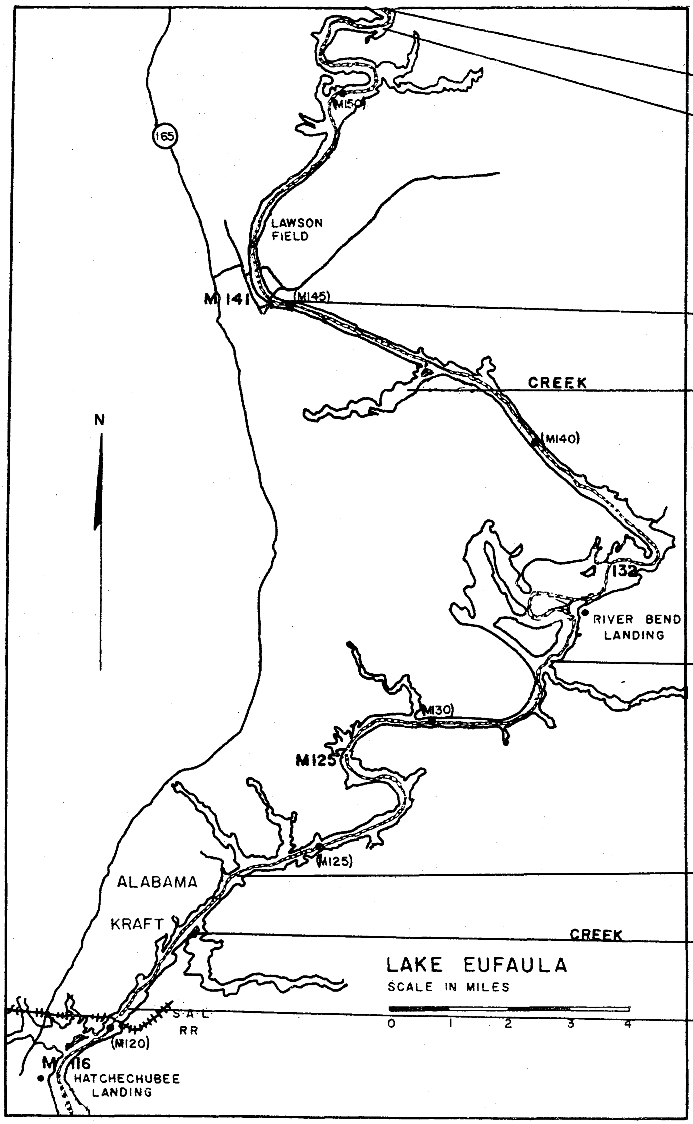
Averaged iron, manganese, zinc, and copper concentrations in water at indicated locations and depths in lower region of Lake Eufaula for 1965, 1966, and 1967



	IRON PPM			MANGANESE PPM			ZINC PPM			COPPER PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	.214	.33	.403	.005	.05	.026	.015	.033	.060	.008	.007	.036
20'	.175	.59	.443	.060	.10	.023	.053	.078	.068	.012	.005	.041
40'	.150	.69	.563	.032	.20	.046	.141	.050	.080	.010	.005	.084
60'	.187	.97	.633	.340	.63	.072	.085	.046	.106	.009	.006	.066
0'		.37	.20		1.002	.020		.37	.022		.005	.015
40'		1.653	3.45		.233	.040		.111	.030		.004	.015
0'		.30	.05		.04	.01		.185	.03		.010	.012
40'		.725	.15		.007	.02		.132	.03		.010	.010
0'	.05	.32	.165	.03	.08	.010	.040	.046	.641	.002	.003	.062
20'	.16	.23	.20	.02	.05	.025	.028	.024	.122		.004	.052
40'	.162	.52	.30	.02	.23	.06	.037	.064	.113	.005	.003	.061
60'	.097	.57	.40	.03	.22	.105	.022	.025	.061	.002	.006	.081
0'			.857			.057			.041			.007
40'			2.40			.150			.037			.011
0'	.07	.055	.05	.06	.02	.012	.033	.016	.15	.009	.001	.122
20'	.08	.17	.045	.045	.11	.011	.027	.027	.233	.005	.001	.262
40'	.12	.17	.111	.057	.06	.038	.014	.031	.099	.058	.001	.111
60'	.29	.555		.240	.23		.028	.028		.007	.001	-
80'	.26	1.290	.175	.067	.95	.05	.012	.026	.127	.007	.001	.085

Appendix Table 5-A

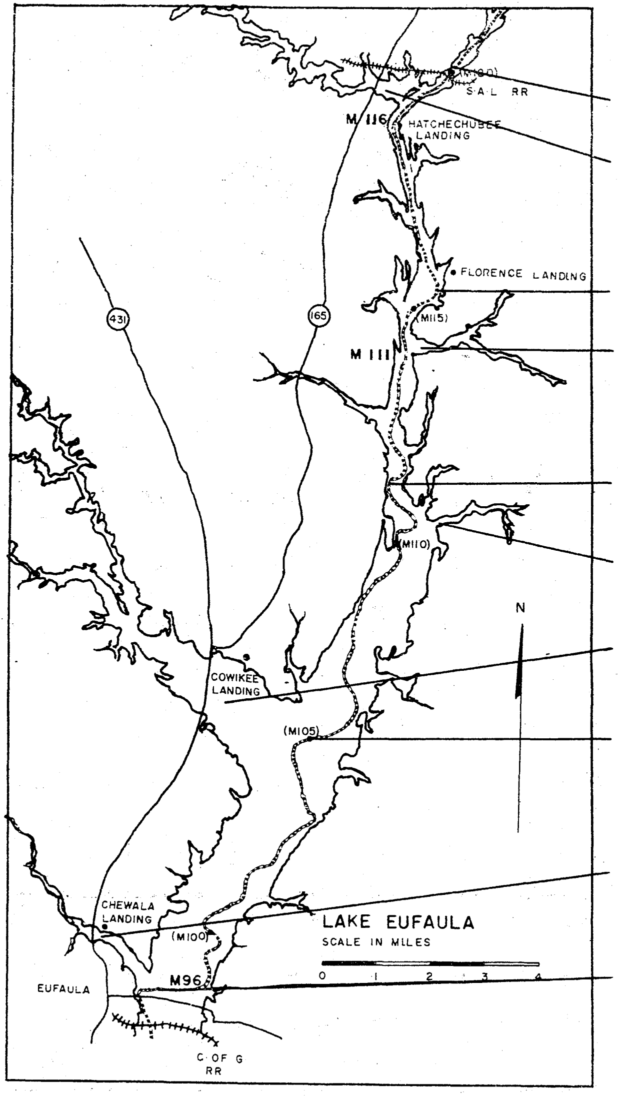
Averaged nitrogen, phosphorus, total carbon, and carbon dioxide-free carbon concentrations in water at indicated locations and depths in upper region of Lake Eufaula for 1965, 1966, and 1967



	NITROGEN PPM			PHOSPHORUS PPM			TOTAL CARBON PPM			CO -FREE CARBON PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	.205	.16	.25	.025	.002	.06	11.8	13.95	10.05	-	-	5.3
0'	.485	.31	.15	.050	.013	.066	17.0	11.4	8.54	-	-	4.42
0'	.22	.177	.21	.020	.050	.098	18.0	9.83	10.0	-	-	4.48
20'	.306	.165	.145	.033	.032	.050	13.25	9.75	10.95	-	-	4.03
0'	.22	-	-	.030	.001	.017	-	9.30	8.5	-		5.0
0'	.090	.213	.17	.022	.010	.069	15.32	11.78	9.05	-	-	4.65
30'	.186	.145	.15	.077	.006	.117	16.6	10.75	9.40	-	-	5.50
0'	.060	.100	.45	.013	.016	.076	-	11.88	11.46	-	-	6.32
40'	-	.195	.265	-	.025	.111	-	11.24	10.02	-	-	4.45
0'		.170	.666		.007	.046		12.5	10.53			4.83
30'		.40	.265		.011	.057		10.93	9.6			4.45
0'	.24	.165	.179	.01	.013	.077	11.6	10.17	9.77	-	-	5.93
20'	.31	.189	.055	.054	.023	-	9.91	11.07	12.0	-	-	7.2
40'	.395	.201	.131	.014	.028	.067	9.75	15.50	12.0	-	-	6.5

Appendix Table 5-B

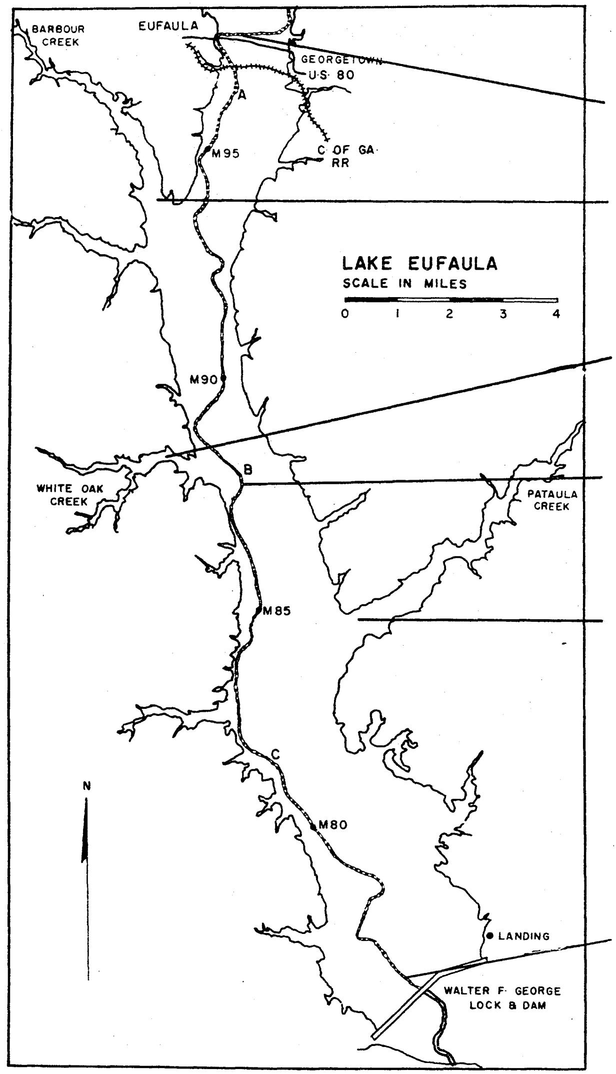
Averaged nitrogen, phosphorus, total carbon, and carbon dioxide-free carbon concentrations in water at indicated locations and depths in middle region of Lake Eufaula for 1965, 1966, and 1967



	NITROGEN PPM			PHOSPHORUS PPM			TOTAL CARBON PPM			CO FREE CARBON PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'	.240	.165	.179	.010	.013	.077	11.6	10.17	9.77			5.93
20'	.310	.189	.055	.054	.023		9.91	11.07	12.00			7.20
40'	.395	.201	.131	.014	.028	.067	9.75	15.50	12.00			6.50
0'	.120	.118	.235	.020	.007	.166		11.90	10.80			4.90
30'	.370	.140	.320	.033	.004	.099		15.65	11.55			4.15
0'									9.00			5.50
20'												
40'			.210									
0'			.360			.029			9.90			5.50
30'			.190			.026			10.85			5.60
0'		.217	.283		.010	.060			9.60			6.00
20'		.209	.360		.011	.056			9.30			4.90
40'		.342			.011							
60'		.138	.236		.005	.072			10.80			6.27
0'			.315			.036			10.15			8.50
30'			.273			.057			10.80			6.50
0'	.140	.352	.240	.030	.004	.028		15.13	10.55			6.65
20'	.180	.398	.450	.030	.004	.047		18.58	11.75			7.85
40'	.220	.138	.680	.030	.011	.135		19.30	23.70			14.80
0'	.08	.173	.357	.002	.005	.080	11.0	11.18	9.60			5.60
20'	.17	.226	.325	.025	.010	.111	12.5	11.57	10.20			5.75
40'	.24	.189	1.560	.022	.009	.052	15.15	11.72	10.30			5.83
60'		.279	.465	.020	.014	.123	10.0	13.22	11.30			7.63
0'	.136	.096	.283	.070	.010	.046	21.0	11.07	11.05			8.00
30'	.146	.136	.340	.066	.003	.081	19.67	14.60	15.00			11.00
0'		.287	.366	.01	.008	.060	9.5	12.42	9.80			6.66
20'		.292	.376	.01	.005	.068	12.3	12.03	9.56			6.06
40'		.370	.330		.006	.08	13.53	12.76	7.06			6.06
60'		.394	.350		.065	.106	13.36	13.60	9.93			5.26

Appendix Table 5-C

Averaged nitrogen, phosphorus, total carbon, and carbon dioxide-free carbon concentrations in water at indicated locations and depths in lower region of Lake Eufaula for 1965, 1966, and 1967



	NITROGEN PPM			PHOSPHORUS PPM			TOTAL CARBON PPM			CO2 FREE CARBON PPM		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
0'		.287	.366	.01	.008	.06	9.5	12.42	9.8			6.66
20'		.292	.376	.01	.005	.068	12.3	12.03	9.56			6.06
40'		.370	.330		.006	.08	13.53	12.76	7.06			6.06
60'		.394	.350		.065	.106	13.36	13.60	9.93			5.26
0'		.468	.190		.001	.041		11.0	11.8			8.1
40'		.125	.200		.001	.090		11.65	19.0			13.8
0'		.048	.250		.01	.041		11.0	11.7			7.0
40'		.178	.420		.05	.041		20.0	16.3			7.0
0'	.136	.223	.260	.05	.005	.046	6.0	12.0	15.00			5.75
20'	.159	.278	.190	.06	.003	.052	9.0	11.55	9.75			4.2
40'	.112	.290	.190	.05	.003	.072	14.0	11.97	9.90			3.8
60'	.118	.401	.305	.05	.005	.064	11.0	13.50	10.00			4.15
0'			.315			.045			11.75			5.82
40'			.225			.057			14.00			6.45
0'	.206	.169	.140	.032	.001	.057	10.15	11.35	9.50			5.25
20'	.347	.233	.150	.042	.001	.041	13.65	11.51	9.70			5.25
40'	.364	.245	.190	.032	.001	.048	13.45	11.11	10.50			5.53
60'	.448	.380		.035	.001		11.86	13.14				
80'	.409	.379	.210	.033	.002	.049	9.85	13.64	10.50			4.5

Appendix Table 6

Averaged monthly inflow and outflow, in cfs, for Lake Eufaula during period April 1963-November 1967. Courtesy: U.S. Army Corps of Engineers District, Mobile

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	In-flow
						Inflow							
1963				8325	11959	7581	8845	5655	3704	3606	4811	8939	7077
1964	19493	18026	29120	42125	21748	6969	10222	10056	5682	15710	9192	17164	17140
1965	14465	19456	19219	12258	6320	8369	6130	5010	4116	6404	3856	5415	9251
1966	14785	27050	27648	9998	14452	7316	4930	6257	4592	7218	9157	9057	11872
1967	16748	13186	9363	5533	7565	8333	9003	9296	8787	5660	9231		9337
						Outflow							
1963				10791	11397	7738	6552	5281	3857	3297	4355	8775	6894
1964	19120	18211	28768	39471	22265	6145	10215	10379	5989	16554	9969	18182	17105
1965	13925	19533	18665	14290	5637	8618	4874	3290	4699	6445	5325	6316	9300
1966	14155	26086	28432	8607	12845	7817	5300	6933	4976	5677	10895	8702	11702
1967	18272	13336	9357	5057	5566	7736	9915	8138	9835	6652	8948		9346

Appendix Table 7

Pond Seepage and Pond Evaporation Losses in the Piedmont [1]

Month	Seepage per acre pond Acre-Inches	Evaporation Loss Inches	Combined Loss
January	6.7	1.4	8.1
February	5.9	1.9	7.8
March	6.6	2.7	9.3
April	6.6	4.1	10.7
May	7.0	5.9	12.9
June	7.2	6.5	13.7
July	7.7	5.9	13.6
August	8.5	5.9	14.4
September	10.5	4.7	15.2
October	11.7	3.7	15.4
November	10.0	2.4	12.4
December	7.1	1.3	8.4
Total	95.5	46.4	141.9

1. Calculated from "Hydrology of a small area near Auburn, Alabama", by D.A. Parsons, U.S.D.A. Soil Conservation Service and Alabama Agricultural Experiment Station Coop. S.C.S.-TP-85, 40 pp. (Records for 1947)

Appendix Table 8

Spectrographic Analyses, expressed as ppb concentrations, of Apalachicola river waters, collected at Blountstown, Florida[1]

Element	Collection dates			
	12/17/58	3/30/59	8/24/59	9/29/59
Ag	.11	.058	.098	.071
Al	73	2550	173	135
B	5	11	5.5	5.6
Ba	42	21	29	26
Be		.058		
Co			.75	
Cr	2.2	2.2	6.9	7.8
Cs				
Cu	2.1	7.0	51	6.2
Fe	96	1220		
Ge				
Li	.096	.70	.075	.12
Mn	5	25	20	4
Mo	0	.17	.46	.62
Ni	4.6	2.6	23	34
P	0	58	0	0
Pb	6.2	2.1	3.6	2.7
Rb	1.0	2.1	.75	2.1
Si				
Sn				1.3
Sr	34	7.5	28	25
Ti	.8	99	8.3	6.9
V		2.2	0	0
Zn	0	0	0	0
Zr				
CFS	11000	54000	11900	9030

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1. Source:

Durum, W. H.
Occurrence of trace elements in water.
Proc. Conf. on Physiological Aspects of Water Quality.
U.S. Public Health Service, Wash., D. C. pp. 51-66.

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